European Commission

Ocean-Climate Nexus

Understanding
the changes, responding
to the challenges

Horizon 2020
Research Framework Programme

Research and Innovation

Ocean-Climate Nexus – Understanding the changes, responding to the challenges
Horizon 2020 - Research Framework Programme

European Commission
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EUROPEAN COMMISSION

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Directorate-General for Research and Innovation
Horizon 2020

2022

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EXECUTIVE SUMMARY

Strengthening the nexus between the ocean and climate change is a priority for the EU.

The research and innovation framework programme, Horizon 2020, has funded scientific research on the ocean and climate nexus which reinforces the European and global scientific capacity to better understand drivers of change in the ocean and tackle emerging threats, as well as bringing forth solutions and innovations, and supporting decision-making in climate change mitigation and adaptation policies, as well as in policies aimed at preserving a healthy state of the ocean and seas. The research carried out supports the transformative European Green Deal agenda with transparent, comprehensive and balanced scientific evidence and innovative solutions. It promotes high-quality research that is essential for policy-making and it contributes significantly to global scientific assessments.

The portfolio is made up of over 350 projects, with a budget of approx. €1BL that feature achievements in having strengthened the scientific knowledge on global climate change and biosphere integrity, and having brought forth key understanding for tackling environmental and climate change in the most vulnerable ecosystems, such as the ocean and Polar Regions, that are test beds for climate change impacts and sustainable development. The portfolio has also identified and deployed innovative and sustainable solutions that are based on win-win strategies that are biodiversity positive with climate mitigation and adaptation co-benefits, including nature-based solutions that ensure integrity of the Polar Regions and of the ocean. In addition, the portfolio has contributed to evidenced-informed policy-making and implementation, and has supported key international processes under the UNFCCC, as well as leading in EU-science diplomacy.

The publication is intended to contribute to raising awareness of the crucial role of the ocean-climate nexus for climate change processes, as well as bringing the ocean health on a path to recovery as a priority for the EU. The research is supportive in addressing the ocean-climate-biodiversity-pollution challenges in a holistic manner by reinforcing the understanding of the interrelationship between the ocean and climate change and incorporating them in their interlinked nature into policies.

INTRODUCTION

Our ocean, our future, our responsibility[1]

In a historic move, on 26 July 2022, the UN declares **healthy environment as a human right!**[2] The General Assembly said climate change and environmental degradation were some of the most pressing threats to humanity's future. It called on states to step up efforts to ensure their people have access to a "clean, healthy and sustainable environment."

In the **G7 Ocean Deal** from May 2022[3], the G7 governments declared that *we will also continue to advance our knowledge of the* ***ocean-climate nexus***. *Clean, healthy and productive ocean with resilient marine ecosystems is essential for all life on Earth*. *We highlight our commitment … to advance the collective work on ocean science, ocean observation, assessment of ocean status and ocean action throughout this critical decade. Building on G7 Leaders' commitment under the G7 2030 Nature Compact to further our sustainable relationship with the ocean, we will also continue to advance our knowledge of the ocean-climate nexus*.

The draft **G20 Environment Communiqué on Marine litter, Oceans and Sustainable finance summer 2022** states that *Ocean science underpins effective conservation, restoration and sustainable use of the ocean and its ecosystems services, including through Nature-based Solutions and Ecosystem-based Approaches. We therefore commit to scaling-up the collaboration during the UN Decade of Ocean Science for Sustainable Development by progressing robust and transformational ocean science actionable into win-win strategies and solutions for both climate and biodiversity addressing consistently and jointly the intertwined crisis of pollution, climate change impacts and biodiversity loss*.

Climate change, biodiversity loss and pollution are driven by human activities and are mutually reinforcing. The **ocean** is the largest storage system for the planetary reservoirs of climate-regulating factors such as heat, water and carbon, providing the major distribution mechanisms of those same elements. The ocean plays a fundamental role in the physics of the Earth climate and its biological components carry the single greatest capacity on the planet with respect to carbon sequestration, an indispensable action to maintain our climate stable. The **ocean** is being largely impacted by industry-scale human activities. Since the industrial revolution, the mobilisation and utilisation of fossil carbon has generated an excess of greenhouse gases and heat content in the atmosphere. Promptly taken up by the ocean, these elements have altered its temperature, alkalinity, patterns of currents, mixing intensity and water volume. The un-natural built up or otherwise alteration of the physical oceanic compartments, which have a clear role in the regulation of the planetary temperature, intensity of meteorological events, distribution of water, and functioning of the biological systems, have affected the action of the ocean on the earth's climate, fuelling its transformation.

Research and innovation play an essential role in enabling the global society to reach the vision of a sustainable planet, including reaching the climate goals and other UN Sustainable Development Goals. European research and innovation is driving, navigating and accelerating the transformative Green Deal agenda through transparent, comprehensive and balanced scientific evidence and innovative solutions. Regarding the **ocean-climate-biodiversity nexus**, the EU funds research that addresses the climate, biodiversity and pollution crises and underlines the need for convergence between the different policies and actions, applying a systems and synergistic approach that considers social and environmental impacts.

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[1] Excerpt from UNOC political declaration 2022

[2] https://digitallibrary.un.org/record/3982508?ln=en A/76/L.75

[3] 2022-05-27-2-g7-ocean-deal-data.pdf (g7germany.de)

1 The ocean-climate nexus

The ocean and the climate are intimately and inextricably linked.

The **ocean** represents over 70% of the Earth's surface and contains 97% of all water on Earth. Its physical and biological processes play a key role in the water cycle, the carbon cycle, and climate variability.

The **ocean-climate nexus** is based on the profound interconnection at the level of the various elements that regulate our planetary climate, including physical factors (heat, water, carbon) and biological systems (i.e. biological carbon-pump or oxygen production).

The **ocean** is key to regulating the Earth's climate and is the reason why it is stable and life sustaining. The extent to which the climate changes largely depends on the capacity of the ocean to absorb heat and carbon emissions associated with human activities. Its biological components carry the single greatest capacity on the planet with respect to carbon sequestration. Rates of climate change on decadal to centennial time scales ultimately depend on oceanic processes.

Thus, the **ocean** plays a fundamental role in **mitigating climate change** by serving as a major heat and carbon sink. Ocean-based mitigation and adaptation solutions have the potential of contributing 21-25% of the annual greenhouse gases emissions reductions needed by 2050[4]. The ocean has absorbed a significant portion (some 30%) of the carbon dioxide pollution caused by human activities, and as a result is becoming more acidic. Ocean acidification affects the ability of some ocean organisms to create carbonate-based shells and skeletons, and the potential impacts on the oceanic food web is enormous, from the poles to the tropics.

The ocean has absorbed over 90% of anthropogenic heat to date[5], affecting the **Polar Regions** and the ocean in different ways. The **Arctic** could be warming up four times[6] as fast as the rest of the world. Greenland is now releasing hundreds of gigatonnes of melted ice into the ocean each year[7]. Changes in the **Antarctic** are primarily focused on two regions: West Antarctica and the Antarctic Peninsula, where more gigatonnes of ice is being dumped into the ocean. East Antarctica, however, is also beginning to respond to the rising temperatures. At the same time, ocean warming has already resulted in observed deoxygenation, stratification (interrupting circulation and mixing), species shifts, marine heatwaves, or coral bleaching at various scales. Such changes will affect the EU - and the rest of the planet – through rising sea levels, changing weather patterns, a higher incidence of extreme weather events, permafrost thawing with release of greenhouse gases and various pathogens, etc.

As concerns about climate change increase, the interrelationship between the ocean and climate change must be recognized, understood, and incorporated into governmental policies. Raising awareness of the crucial role of the ocean-climate nexus for climate change processes, as well as bringing the ocean health on a path to recovery is **a priority for the EU**[8].

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[4] Turning the Tide: Ocean-Based Solutions Could Close Emission Gap by 21% | World Resources Institute (wri.org) and https://www.wri.org/news/release-ocean-based-climate-action-could-deliver-fifth-emissions-cuts-needed-limit-temperature and https://www.frontiersin.org/articles/10.3389/fmars.2018.00337/full and Blue carbon: The potential of coastal and oceanic climate action | McKinsey and Frontiers | The Potential for Ocean-Based Climate Action: Negative Emissions Technologies and Beyond (frontiersin.org)

[5] https://www.ncei.noaa.gov/news/ocean-heat-content-rises

[6] https://www.breakthroughonline.org.au/climatedominoes and https://www.theguardian.com/environment/2022/jun/15/new-data-reveals-extraordinary-global-heating-in-the-arctic

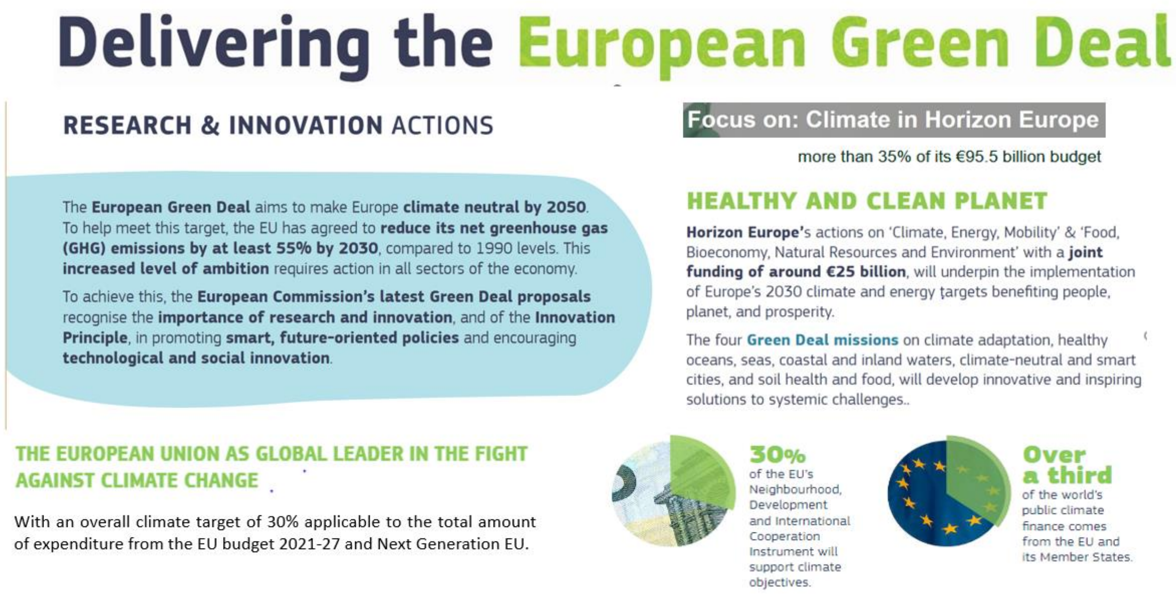
[7] https://phys.org/news/2022-07-greenland-unusually-extensive-ice-sheet.html

[8] The **European Council conclusions on oceans and seas** (Nov 2019) underline the importance of protecting the **Arctic** and the **outermost regions and OCTs**, given their specific vulnerability to climate

2 The Global and EU policy context

The European Union (EU) is a major investor in ocean and polar research, contributing to several policies and priorities:

- **European Green Deal**[9]



The European Green Deal (EGD) provides an action plan to boost the efficient use of resources by moving to a clean, circular economy, and to restore biodiversity and cut pollution. The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition to a climate neutral EU by 2050. Acknowledging the key role played by the ocean in mitigating and adapting to climate change, the EGD Communication commits to analyse the findings of the IPCC SROCC and to propose measures in the maritime area. More specifically, it states that lasting solutions to climate change require greater attention to nature-based solutions, including healthy and resilient ocean and seas.

Climate Action and the European Green Deal[10]

The European Green Deal aims to make Europe **climate neutral by 2050**. To make this objective legally binding, the Union approved the European Climate Law, which

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change, ensuring healthy and resilient oceans, protecting the biodiversity of vulnerable marine and coastal ecosystems and **strengthening research and ocean science**. (https://www.consilium.europa.eu/en/press/press-releases/2019/11/19/oceans-and-seas-threatened-by-climate-change-council-adopts-conclusions/). In March 2020, the **Croatian Presidency** stated that: '**strengthening the nexus between the ocean and climate change is a priority for the EU**'[8] and that 'there is growing political awareness of the **importance of ocean as an integral part of the Earth's climate system** and of the need to ensure **integrity of ocean and costal ecosystems in the context of climate change** ('ocean and climate nexus').' 'The ocean was identified as a priority of the Presidency at COP25, and it forms an important part of the **COP25** outcome.' The submission by Croatia (Croatian Presidency of the Council of the European Union) and the European Commission on behalf of the European Union and its Member States to the UNFCCC on 8 June 2020 informing the dialogue on the ocean and climate change to consider how to strengthen mitigation and adaptation action in this context highlighted that 'The dialogue is an excellent occasion to build on the political momentum gained at COP25 on the ocean and climate change nexus based on the **best available science**. The EU highlighted that the dialogue should be guided by **latest available science on the climate and the ocean nexus**, and particularly by the IPCC's SROCC'.

[9] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[10] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/climate-action-and-green-deal_en

also sets a new, more ambitious net greenhouse gas emissions reduction target of at least **-55% by 2030**, compared to 1990 levels.

In order to achieve our decarbonisation objectives, emissions must be reduced **in all sectors**, from industry and energy, to transport and farming. Climate change is a global threat and can only be addressed by a **global response**. That is why the EU actively engages and supports its international partners on climate action, in particular through the UN Framework Convention of Climate Change (UNFCCC) and its **Paris Agreement**. In parallel to mitigation actions, the EU is taking action on **climate adaptation**, to face the unavoidable impacts of climate change.

PROTECTING THE ENVIRONMENT AND THE OCEAN WITH THE GREEN DEAL[11]

Europe's ocean, seas, and environment are a source of natural and economic wealth for Europe. We must preserve and protect them to ensure that they continue sustaining us in the future.

European Green Deal priorities include protecting our biodiversity and ecosystems, reducing air, water and soil pollution, moving towards a circular economy, improving waste management and ensuring the sustainability of our blue economy and fisheries sectors. By working on these key areas, the EU will improve the health and quality of life of citizens, address environmental problems and reduce greenhouse gas emissions.

The Marine Strategy Framework Directive and the Commission Decision on Good Environmental Status, as well as the Annex III of the Directive aim to protect more effectively the marine environment across Europe and better link ecosystem components, anthropogenic pressures and impacts on the marine environment with the MSFD's 11 descriptors and with the new Decision on Good Environmental Status.

With the proposal for the new Nature Restoration Law, the European Commission approved the first continent-wide, comprehensive law of its kind. The proposal aims to restore ecosystems, habitats and species across the EU's land and sea areas to enable the long-term and sustained recovery of biodiverse and resilient nature, contribute to achieving the EU's climate mitigation and climate adaptation objectives and meet international commitments. Among the targets of the Nature Restoration Law are **marine ecosystems**, with the aim of restoring marine habitats such as seagrass beds or sediment bottoms that deliver significant benefits, including for climate change mitigation, and restoring the habitats of iconic marine species such as dolphins and porpoises, sharks and seabirds.

EU Arctic policy[12]

The EU has an important role to play in supporting successful Arctic cooperation and helping to meet the challenges now facing the region. Through regional and multilateral cooperation, it helps in effectively addressing climate change, international cooperation and sustainable development. Understanding the science of climate change[13], helping to develop strategies to mitigate and adapt to climate change, and safeguarding the Arctic environment are part of the EU's wider efforts in relation to the Arctic. A safe, stable, sustainable and prosperous Arctic[14] is important not just for the region itself, but for the EU and the rest of the world. The EU is

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[11] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/protecting-environment-and-oceans-green-deal_en
[12] https://eeas.europa.eu/headquarters/headquarters-homepage/20956/arctic-short-introduction_en_en
[13] https://eeas.europa.eu/headquarters/headquarters-homepage/20955/climate-change-and-arctic-environment_en
[14] https://eeas.europa.eu/headquarters/headquarters-homepage/20952/sustainable-development-arctic_en

committed to contributing to sustainable development in a balanced and integrated manner. The EU offers a wide range of funding opportunities in the Arctic regions for businesses, entrepreneurs, researchers, local and regional authorities, young people and Indigenous peoples' groups.

Internationally, the ocean-climate research nexus is addressed by:

- **United Nations 2030 Agenda and its Sustainable Development Goals** in generating scientific knowledge, developing research capacity and finding innovative solutions and technologies, including nature-based, to the imbalance generated by the human activities on the ocean-climate nexus (UN SDGs 13 - Climate Action and 14 - Life below water).

[15]

UN Sustainable Development Goals that are directly related (red line) or indirectly related (blue line) to the world's ocean.[16]

- **UN Decade of Ocean Science for Sustainable Development (2021-2030)**[17] to support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide behind a common framework. This will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the Ocean.
- **UN Decade on Ecosystem Restoration**[18] aiming to prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean.

3 The European Union Research and Innovation Policy

The **European Union research and innovation policy (R&I)** drives, navigates and accelerates the transformative Green Deal agenda through transparent, comprehensive and balanced scientific evidence and innovative solutions. It promotes high-quality research that is essential from the perspective of other EU policies. It also contributes to global scientific assessments like IPCC, IPBES, WOA, etc.

The European research policy seeks to reinforce the scientific capacity to better understand drivers of change in the ocean and tackle emerging threats, bring forth solutions and innovations, and support decision-making in climate change mitigation and adaptation policies, as well as in policies that aim at preserving a healthy state of the ocean and seas.

The EU's research and innovation framework programmes advance the **ocean-climate nexus science** in an endeavour to better understand the role of seas and ocean, including the Earth's icecaps, in climate change and help secure the long-term provision of ecosystem services, such as climate change adaptation and mitigation and carbon sequestration (both on land and sea). The **Polar and Ocean Research on the EUROPA page**[19] contains details of specific policies, partnerships and documents related to the ocean-climate nexus research and innovation science. Sustained R&I cooperation within the **Arctic and in the Antarctic** is increasingly important for understanding the rapid changes taking place in the region and to predict their regional and global impacts, and contribute to the implementation of the climate and environmental goals of the European Green Deal.

[15] Download : Download high-res image (588KB)
[16] https://www.sciencedirect.com/science/article/pii/S0308597X20302050?via%3Dihub
[17] https://en.unesco.org/ocean-decade
[18] https://www.decadeonrestoration.org/
[19] https://ec.europa.eu/info/research-and-innovation/research-area/environment/climate-action/polar-research_en

The **EU R&I framework programme** supports excellent science that:

- strengthens scientific knowledge on global climate change and biosphere integrity,
- tackles environmental and climate change in the most vulnerable ecosystems such as the ocean and polar regions as a test bed for climate change impacts and sustainable development,
- identifies and deploys innovative and sustainable solutions based on win-win strategies that are biodiversity positive with climate mitigation and adaptation co-benefits, including NBSs to ensure integrity of the polar regions and the ocean,
- contributes to better, evidenced-based policymaking and implementation,
- supports international processes (UNFCCC, CBD, IPCC, IPBES, etc.) and
- enables leading in EU-science diplomacy.

Horizon 2020

Under Horizon 2020, the European Commission has funded **over 350 projects in the ocean-climate nexus thematic research areas, with a budget of approx. €1BL**. The funding comes mainly from Societal Challenge 2 (Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy) and Societal Challenge 5 (Climate Action, Environment, Resource Efficiency and Raw Materials). Marine related research has also been funded under all other societal challenges and under the Excellent Science and the Industrial Leadership pillars. The funded projects investigate mainly the bio-ecological, biogeochemical and physical aspects of the ocean-climate nexus and several contributed significantly to the state of the art science presented through the IPCC process.

Also of relevance are the projects funded under the joint programming initiatives JPI Oceans[20] and JPI Climate[21], that are pan-European intergovernmental initiatives gathering European countries to jointly coordinate climate, marine and maritime research and fund new transnational research initiatives that provide useful knowledge and services. The European Commission's Joint Research Centre also conducts research in support of European policies with independent evidence (EU Science Hub: Environment, resource scarcity, climate change & sustainability).

Horizon Europe

The research and innovation activities to be undertaken in Horizon Europe for the ocean-climate nexus are part of Cluster 6 – Food, Bioeconomy, Natural Resources, Agriculture and Environment, Intervention Area 4 – Seas, ocean and in-land waters and Clusters 5 – Climate, Energy and Mobility – Destination 1 - climate science. Under Cluster 6, there is a dedicated R&I roadmap for the ocean-climate nexus research.

In addition, the brand new policy tools under Horizon Europe of missions and partnerships will help further the policy agenda for the ocean-climate nexus. The two **Horizon Europe Missions on Healthy Ocean and Seas and Climate change adaptation** will help bring forth innovative solutions and breakthrough advancements for tackling the challenges that the climate-ocean nexus faces.

HE Mission: "Adaptation to climate change including societal transformation" [22] has been identified as the mission area aimed at delivering solutions to the climate challenge. It is focused on the improvement of our knowledge on the climate-earth system, as well as the mitigation and adaptations options available, allowing for a systematic and comprehensive picture of challenges and climate-responsible opportunities for the EU's economy and society.

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[20] https://www.jpi-oceans.eu/
[21] http://www.jpi-climate.eu/home
[22] https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme/mission-area-adaptation-climate-change-including-societal-transformation_en

HE Mission: EU Mission Restore our Ocean and Waters[23] will help achieve the marine and freshwater targets of the European Green Deal, such as protecting 30% of the EU's sea area and restoring marine eco-systems and 25 000km of free-flowing rivers. As one of its objectives, the Mission will prevent and eliminate pollution by, for example, reducing plastic litter at sea, nutrient losses and use of chemical pesticides by 50% and it will also contribute to make the blue economy climate-neutral and circular with net-zero maritime emissions. Crosscutting enabling actions will support these objectives, in particular broad public mobilisation and engagement and a digital ocean and water knowledge system, known as Digital Twin Ocean. The Atlantic and Arctic basin lighthouse that will be rolled out under the mission will deliver transformative solutions for protecting and restoring marine habitats and will help Atlantic and Arctic communities better understand, prepare for and manage climate risks and opportunities, in particular by adapting to extreme weather events in coastal areas and sea level rise and other climate change impacts. The H2020 ocean-climate nexus portfolio contributes significantly to the mission objectives, in particular the biodiversity and pollution objectives and the digital enabler. In particular, it supports the Atlantic and Arctic basin lighthouse with the scientific advancements in the ocean-climate-biodiversity thematic area at the sea-basin level (observations, understanding, modelling, projecting, predicting, responding with solutions, connecting science with society, international coordination of research efforts, ocean literacy and societal transformation), and the digital enabler with all the observations.

4 The H2020 ocean-climate nexus portfolio and the research results

The current publication presents below the **outcome of the research conducted under Horizon 2020**[24], 2014-2020. All projects funded are disseminated on the **Community Research and Development Information Service (CORDIS)**[25], the European Commission's primary source of results from the projects funded by the EU's framework programmes for research and innovation (FP1 to Horizon Europe). To highlight are the extensive dissemination products such as Results in Brief, CORDIS Results Packs[26], and the Projects & Results repository contain all public project information, and results. In addition, on the **Horizon Results Platform**[27] you can discover the wealth of EU-funded research results and get in contact with their creators. Especially if you are a policy-maker, an investor, an entrepreneur, a researcher, an innovation, legal, business development or financing expert, or any interested citizen and are interested in **making their results matter!**

The outcomes are grouped along the following subchapters:

- Observing, understanding, modelling, projecting and predicting
- Responding with solutions
- Connecting Science with Society, international coordination of research efforts, ocean literacy and societal transformation

Next, key impacts and exploitable results are highlighted for the most impactful projects.

The annexes contain an analysis and visualisation of the portfolio using the in-house visualisation tool (annex 1), highlighted ocean-climate nexus projects with detailed information (CORDIS project factsheet, reporting, results, news; Horizon Results Platform link to Key Exploitable Results; contribution to international assessments and policy; etc.) (annex 2), full listing of the ocean-climate nexus portfolio as extracted using the in-house text mining tool (annex 3), a historical overview and milestones of the ocean-

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[23] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters_en
[24] https://ec.europa.eu/programmes/horizon2020/en/home
[25] https://cordis.europa.eu/en
[26] multilingual collections of up-to-date project portfolios that focus on a specific theme, bringing you the latest thematic research https://cordis.europa.eu/results-packs/en
[27] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/30662;keyword=climate%20services

climate-biodiversity agenda (annex 4), and an overview of the ocean-climate research findings, as extracted from recent global assessments such as the IPCC, IPCC-IPBES, WOA, etc. (annex 5).

4.1 Observing, understanding, modelling, projecting and predicting

To be able to deliver **ocean forecasts and early warnings, climate projections and assessments and protect ocean health and its benefits**, it is vital to measure Essential Ocean Variables (EOVs). The majority of EOVs are also Essential Climate Variables (ECVs)[28] defined by the Global Climate Observing System. ECVs cover atmospheric, oceanic, and terrestrial domains. A number of OCG networks measure atmospheric and oceanic ECVs. EOV specification sheets are identified by the **GOOS expert panel.**

Physics	Biochemistry	Biology and Ecosystems
• Sea state • Ocean surface stress • Sea ice • Sea surface height • Sea surface temperature • Subsurface temperature • Surface currents • Subsurface currents • Sea surface salinity • Subsurface salinity • Ocean surface heat flux	• Oxygen • Nutrients • Inorganic carbon • Transient tracers • Particulate matter • Nitrus oxide • Stable carbon isotopes • Dissolved organic carbon	• Phytoplankton biomass and diversity • Zooplankton biomass and diversity • Fish abundance and distribution • Marine turtles, birds, mammals abundance and distribution • Hard coral cover and composition • Seagrass cover and composition • Macroalgal canopy cover and composition • Mangrove cover and composition • Microbe biomass and diversity (*emerging) • Invertebrate abundance and distribution (*emerging)
Cross-disciplinary (including human impact)		
	• Ocean colour • Marine debris (*emerging)	• Ocean sound

Climate models have significantly improved and EU funded projects have been crucial for supporting a strong European contribution to the 6th IPCC assessment cycle. The resulting Coupled Models Intercomparison Project (CMIP6) models have been used for policy-relevant climate projections. A new generation of high-resolution simulations offer new and considerably more accurate insights into the nature of climate and weather extremes and their change under future climate scenarios. Attribution of climate events (e.g. extreme events) is becoming feasible, including the role of aerosols as short-lived radiative forcers.

[28] https://www.goosocean.org/index.php?option=com_content&view=article&id=283&Itemid=441

Decadal climate predictions are now regularly available; they are skilful and offer a unique opportunity to address climate-related aspects of the Horizon Europe Green Deal objectives and Horizon Europe Missions. Based also on new standards for user uptake, the information provided by decadal climate predictions becomes more and more relevant to the citizens and European climate action policies.

The importance of **observing climate**, and characterising the processes that shape it, are critical to evaluating climate models. For example, improved observations (in-situ) of key ocean currents, such as Atlantic Meridional Overturning Circulation (AMOC) and Southern Ocean overturning, are necessary to improve the predictive skill, to inform scenarios (IPCC). Another example: emergent observational constraints and related statistical tools are being developed to narrow uncertainties in regional climate change projections at all time scales and require suitable observational datasets.

Projects such as **Blue-Action** and **SO-CHIC** have been key in improving our knowledge, by combining observational and modelling approaches over the Atlantic and, respectively, the Arctic and Southern Oceans. The climate is changing more rapidly in the Arctic than in any other regions. There is now evidence that these changes strongly affect ecosystems, people and communities well beyond the Arctic. Together with its American and Canadian partners, Blue-Action evaluated the impact of Arctic warming on the Northern Hemisphere, developed new techniques to improve forecast accuracy at sub-seasonal to decadal scales, projected arctic sea-ice decline, established Arctic-extratropical teleconnections linked to El Nino-Southern Oscillation and led to a better understanding of connection between the Atlantic meridional overturning circulation and Greenland melting. These allowed Blue-Action to also develop forecasting fish distribution and abundance, with the potential to improve the way that fisheries are performed and the quality of fisheries management systems by facilitating better planning and reducing uncertainty associated with estimates of fish abundance, productivity, and fish stock dynamics. "Extreme weather risks in the Arctic: A web based tool for risk assessment"[29], is a tool developed by Blue-Action to drive public consensus to existing and emerging weather-related risks and Arctic impacts on shipping, coastal infrastructures, local communities, fisheries, port operations, and search and rescue missions.

The project **APPLICATE** was instrumental in developing and promoting international collaborations like the polar amplification model intercomparison projects (PAMIP)[30], while advancing innovative approaches and datasets using numerical weather prediction and climate models. The project's many contributions include the coordination of model intercomparison experiments (e.g., PAMIP, SIMIP) provision of novel datasets (e.g., YOPP and ECMWF datasets), the development of evaluation software with a clear polar focus (e.g., ESMvalTool), all highlighting the high profile of APPLICATE's work and representing a stepping stone in improving knowledge about climate change in support of the Intergovernmental Panel on Climate Change. The project has shed new light on the strength of the link between Arctic and mid-latitude weather and climate. Its work contributes to more accurate forecasts, including of extreme weather events. The project was featured in the RESEARCH EU MAGAZINE, in the Special Feature: Squaring the Arctic Circle: Protecting and preserving Earth's Far North.

In the *Climate Science2Policy workshop* organised on 17-18 November 2020, the cluster of selected Horizon 2020 climate and Earth system modelling projects **PRIMAVERA, CONSTRAIN, APPLICATE, TiPES, CRESCENDO, FORCeS, Blue-Action, COMFORT, EUCP, 4C, PROTECT, TiPACCs, ClimateEurope, VERIFY, SO-CHIC** and **NUNATARYUK** have informed the Commission services of the state-of-the-art on findings and advances of the physical science of climate change, as emerged from the ongoing projects, key policy messages and research needs in climate science around the

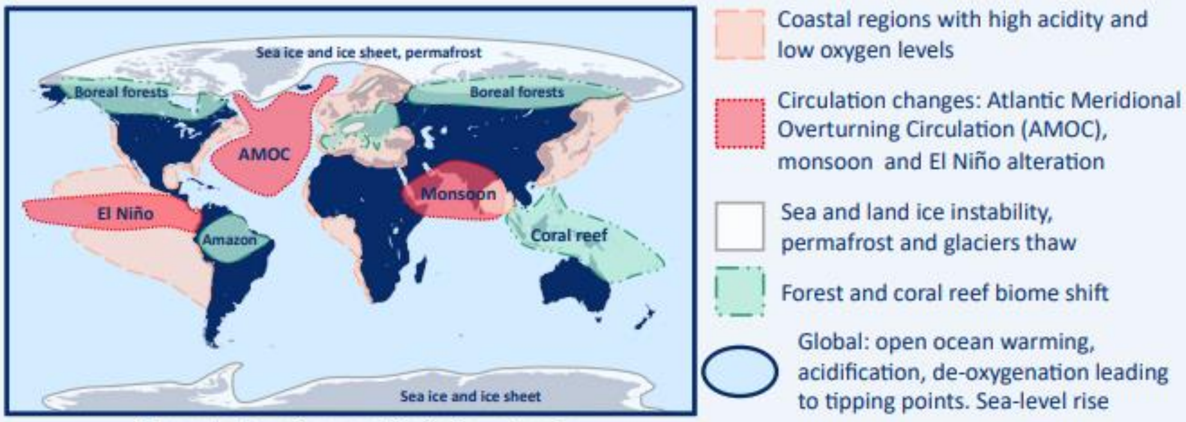
[29] https://maps.dnvgl.com/labs/blueaction/
[30] https://www.wcrp-climate.org/modelling-wgcm-mip-catalogue/cmip6-endorsed-mips-article/1303-modelling-cmip6-pamip

themes: evaluations of climate models, climate projections, and predictions, and extreme events, carbon budgets, clouds and aerosols, ocean and polar processes, tipping points.

Another policy brief, *Atlantic Pole to Pole: Climate Science to Policy*[31] has been prepared by the **Blue-Action, MISSION ATLANTIC, SO-CHIC,** and **TRIATLAS** highlighting the importance of connected, interdisciplinary long-term science and ocean monitoring to understand global physical systems, make predictions and inform future policy.

There is a threat of imminent abrupt and irreversible transitions in the Earth system. This must be tackled urgently through political, economic, and societal action. Taking advantage of ground-breaking research and having science and policy working collaboratively is the only way to prevent the destabilization of major Earth system tipping elements and avoiding the critical thresholds known as tipping points. Three EU-funded projects under the Horizon 2020 programme, **Tipping Points in the Earth System** (TiPES), **Our Common Future Ocean in the Earth System** (COMFORT), and **Tipping Points in Antarctic Climate Components** (TiPACCs) have worked together towards developing a policy brief that presents the key findings to date from these projects. On that basis, they jointly formulated persisting knowledge gaps as well as policy recommendations[32].

Figure 2. Candidates for tipping elements



Please note that regions are only indicative, not precise.
Figure modified from Heinze et al., PNAS 2021. Licence: 4.0 (CC BY)

In the climate system, many different large-scale components have been identified as tipping elements, i.e., sub-systems that may undergo abrupt transitions, with a potentially large impact on environment, economy and society. Individual tipping elements have been studied in varying level of detail in the past, while in particular thresholds for tipping remain uncertain for most tipping elements. Moreover, these climate subsystems do not stand on their own but are dynamically coupled to other parts of the climate system, potentially leading to tipping cascades with modified thresholds and impacts. In this workshop, the potential for tipping cascades in the climate system and other dynamical systems were discussed, with a review of how such cascades can be treated theoretically. Project **TiPES** has organised the workshop *Cascading tipping in the Earth system*[33], presenting the research conducted under the project.

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[31] Blue-Action, MISSION ATLANTIC, SO-CHIC, and TRIATLAS (2021), Atlantic Pole to Pole: Climate Science 2 Policy. What kind of research priorities should be taken into account in establishing a framework for international collaboration in the next decades? DOI: https://www.zenodo.org/record/4889819

[32] Policy Brief: Key findings and recommendations from three H2020 Projects on Tipping Points: TiPES, COMFORT, and TiPACCs | Zenodo and Science-to-policy talk on "Tipping points in the Earth's Climate" (europa.eu)

[33] https://indico.nbi.ku.dk/event/1696/

Focusing on the Southern Ocean, the policy brief *The Southern Ocean on Europe's shores - climate impacts, sea level rise, and the marine environment*[34] presented in February 2022 by the project **SO-CHIC** focused on issues such as climate, sea level rise, disaster risk reduction and the changing marine environment, and the critical influence the Southern Ocean has on these in Europe.

Zooming in on the **oceanic carbon cycle**, the following projects are highlighted:

<u>Phytoplankton Carbon (PC)</u>

CAP ICE - CArbon Production of under-ICE phytoplankton blooms in a changing Arctic Ocean
ODEON – Online DEposition over OceaNs: Modelling the effect of air pollution on ocean bio-geochemistry in an Earth System Model

<u>Dissolved Organic Carbon (DOC)</u>

NUNATARYUK – Permafrost thaw and the changing arctic coast: science for socio-economic adaptation
SponGES – Deep-sea Sponge Grounds Ecosystems of the North Atlantic: an integrated approach towards their preservation and sustainable exploitation
CHROME - Linking Chemical diversity and Reactivity of Arctic dissolved Organic Matter for its integration in Earth system models
CarbEx – Tracing carbon exchanges/fluxes between Arctic and Atlantic basins
COMFORT – Our common future ocean in the Earth system – quantifying coupled cycles of carbon, oxygen, and nutrients for determining and achieving safe operating spaces with respect to tipping points
AtlantOS – Optimizing and Enhancing the Integrated Atlantic Ocean Observing System
POSEIDOMM – Photochemistry at the Ocean's Surface: Effects and Interactions of Dissolved Organic Matter with Microplastics
CRESCENDO - Coordinated Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach
MicroPEAT – Microbial communities of Temperate, Artic and Tropical peatlands and their role in the response of carbon storage function to global change

<u>Inorganic Carbon and fluxes at the ocean interfaces (IC)</u>

4C – Climate-Carbon Interactions in the Current Century - new observation-based data products on ocean surface pCO2, ocean interior inorganic carbon
C-CASCADES – Carbon Cascades from Land to Ocean in the Anthropocene
SEACELLS – Marine phytoplankton as biogeochemical drivers: Scaling from membranes and single cells to populations
SO-CUP - Southern Ocean Carbon Uptake - identify and quantify the processes that control the amount of inorganic carbon that is subducted with the SAMW/AAIW
SONAR-CO2 - Southern Ocean Nanoplankton Response to CO2

<u>Particulate Organic Carbon (POC)</u>

GOCART – Gauging Ocean organic Carbon fluxes u sing Autonomous Robotic Technologies
MYCO-CARB – Revealing the mechanistic basis of the roles of mycoplankton in the marine carbon cycle
CAPTURE - Carbon pathways in the Southern Ocean
CarbOcean – An integrative approach to unravel the ocean's biological carbon pump – autonomous robotic ocean profiler to simultaneously observe fluxes of particulate organic carbon (POC) and particulate inorganic carbon (PIC), together with physico-chemical ocean parameters

[34] https://www.youtube.com/watch?v=D9623IC10UM and http://www.sochic-h2020.eu/news/

THAWSOME - THAWing permafrost: the fate of Soil Organic Matter in the aquatic Environment – For the first time, this project measured degradation rates of particulate organic carbon in large Arctic rivers
NOCEANIC - Key factors driving particulate organic matter fluxes and related nitrogen losses in the main anoxic oxygen minimum zones of the world ocean
Ocean artUp - Ocean Artificial Upwelling –assess the effects of forced upwelling on the biological carbon pump, from carbon uptake through primary production, the consumption of primary produced organic matter in the pelagic food web, to the sinking of particulate organic carbon and its remineralisation on the way to depth.
QSIPP – Exploring bacterial Quorum Sensing Infochemicals and hydrolytic Proteins linked to marine Particle degradation
HADES - Benthic diagenesis and microbiology of hadal trenches - first detailed, combined analysis of benthic diagenesis and microbial ecology of some of the deepest oceanic trenches on Earth
CWCC-Dynamics - Cold-Water Coral Community Dynamics- incorporate management plans and policies that take into account particulate organic carbon fluxes that shape deep-sea benthic communities.

Marine Primary Production (PP)

MECODIHR - MEchanisms of Coupling of Ocean Dynamics and Intermediate trophic levels: High Resolution study
CoastObs - Commercial service platform for user-relevant coastal water monitoring services based on Earth observation - will develop innovative EO-based products: monitoring of seagrass and macro-algae, phytoplankton size classes, primary production, and harmful algae as well as higher-level products such as indicators and integration with predictive models.
AtlantOS - Optimizing and Enhancing the Integrated Atlantic Ocean Observing System
NeTNPPAO - Near-term predictability of net primary production in the Atlantic Ocean
DUSTCO - Effects of atmospheric DUST deposition on COccolithophore production
IRONCOMM - Investigating the role of bacteria-produced siderophores in satisfying diatom Fe requirements
ODEON - Online DEposition over OceaNs: Modeling the effect of air pollution on ocean bio-geochemistry in an Earth System Model
NannoChem - Using Nannofossil Chemistry to constrain the cellular response of marine phytoplankton to changing carbon dioxide concentrations in the surface ocean
NITROX- Nitrogen regeneration under changing oxygen conditions - characterize and quantify factors controlling N2-fixation and primary productivity
CAP ICE - CArbon Production of under-ICE phytoplankton blooms in a changing Arctic Ocean
TROPHY - The consequences of temperature-resource interactions for the future of marine phytoplankton communities
INGENE – Integrating Nutrient economy in phytoplankton GENomics and Evolution
GrIS-Melt - Impacts of Greenland Ice Sheet melt on primary productivity and carbon cycling in Greenland coastal ecosystems
BULLE - Biological Understanding of the CO2 and O2 LeveL in the ocEan
EQUIP - Elemental quota in marine phytoplankton for effective carbon sequestration, clean energy and biogeochemical modelling

Blue Carbon (BC)

RHODOCAR - Global and local impacts on Atlantic RHODOlith beds: Implications for estimates of blue CARbon ecosystem services
GLOMAC - GLObal-scale interactions between MAngrove forests and Climate
SEAMET - Multi-driver climate change effects on SEAgrass METabolism: ecosystem implications
MarshFlux - The effect of future global climate and land-use change on greenhouse gas fluxes and microbial processes in salt marshes

Extreme Events (EE)

CRESCENDO - Coordinated Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach
COMFORT - Our common future ocean in the Earth system – quantifying coupled cycles of carbon, oxygen, and nutrients for determining and achieving safe operating spaces with respect to tipping points
TiPES - Tipping Points in the Earth System
TRIATLAS - Tropical and South Atlantic climate-based marine ecosystem predictions for sustainable management

Carbon Budget Closure (CBC)

C-CASCADES - Carbon Cascades from Land to Ocean in the Anthropocene
SO-CHIC - Southern Ocean Carbon and Heat Impact on Climate
HYADES - Hydrostatic pressure and prokaryotic activity in the deep sea
CONSTRAIN - Constraining uncertainty of multi decadal climate projections
VERIFY - Observation-based system for monitoring and verification of greenhouse gases

Observing the environment from space, from the ground and from mobile platforms provides a constant and consistent flow of information about the health of the planet, the changing climate and the human activities and their impacts. By supporting the GEO initiative and the Copernicus programme, and by funding related research activities in Horizon 2020, the EU is actively contributing to worldwide efforts to build a global observation network. The *CORDIS Result Pack on* Environmental Observations for informing citizens and supporting policymaking through innovative applications[35] showcases the results of several Horizon 2020-funded projects, which have been building on these assets to develop commercial applications, create benefits for citizens and support better policymaking.

Zooming in on the **Copernicus Marine Environment Monitoring Service (CMEMS)** to note the provision of regular and systematic reference information on the physical and biogeochemical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas via:

- daily production of ocean carbon products (operational, quality controlled) on: Dissolved organic carbon (DIC), fugacity of CO2 (FCO2), surface flux of CO2 (FGCO2), surface partial pressure of CO2 (SPCO2)
- complementary products on biogeochemistry : phytoplankton, Phytoplankton Sizes Class Types, Phytoplankton Functional Types, primary production
- all available based on in-situ, satellite and models, observation and 10 day forecast, reanalysis on global scale and per EU sea basin
- Global Ocean Surface Carbon: https://www.copernicus.eu/en/access-data/copernicus-services-catalogue/global-ocean-surface-carbon
- Monthly ocean monitoring indicator on global yearly ocean CO2 sink, pH, global ocean primary production trend
- CARBOOCEAN (FP6) https://www.copernicus.eu/en/marine-carbon-sources-and-sinks-assessment
- Understanding carbon cycle and ocean carbon conundrum with Sentinel-3A https://www.copernicus.eu/en/understanding-carbon-cycle-and-ocean-carbon-conundrum-sentinel-3a
- COPERNICUS marine services: Global Ocean- in-situ Near real time observations of ocean surface currents https://www.copernicus.eu/en/access-data/copernicus-services-catalogue/global-ocean-situ-near-real-time-observations-ocean

[35] https://cordis.europa.eu/article/id/421641-environmental-observations-informing-citizens-and-supporting-policymaking-through-innov

The Horizon 2020 ocean-climate nexus project portfolio has been analysed by an external expert[36] who carried out a series of gap analysis, articulated in Strengths, Weaknesses, Opportunities and Threats (SWOT). These are presented in the different sections below and provide valuable insights into the Horizon 2020 research carried out, remaining research gaps and recommendations towards Horizon Europe.

Observations

Strengths	**Weaknesses (GAPS and barriers)**
○ European scientists are involved in on-going programmes of observations, including EU-wide efforts, with connectedness to global initiatives of observation, with the production of excellent science. ○ A strong reference community exists in investigating Earth's climate, also in its oceanic dimension. An ontology exists, a shared vocabulary, which allows this community to build with vastly shared standards, such as the ECVs. ○ Europe directive "MFSD" has created accountability for the status of the marine ecosystems in the EU Member States, which need to regularly monitor their seas, creating relevant observation baselines. ○ Improved understanding and quantification of ocean's carbon cycle through an integrated approach which combines remote sensing and in situ optical measurements from innovative oceanographic technologies (Biogeochemical Argo float) for the study of CC in the ocean (WhiteShift).	○ Globally integrated observing system is needed (ATLANTOS). ○ Coverage and Connectedness of observation infrastructures. ○ Some peripheral areas are not well observed and lacking both infrastructure and the networks, i.e.: Antarctica (Nunataryuk). ○ The number of population-genetics studies on the deep seas (<200m depth), one of the largest ecosystems on Earth, is minuscule"[37] (ATLAS). ○ Integration across disciplines and holistic approaches are required.
Opportunities	**Threats**
○ Prioritised climate services (BlueAction). ○ RIs for observations. ○ Holistic Observations. ○ Integration with international programmes. ○ New Networks in remote areas such Arctic/Antarctic (Nunataryuk). ○ NEW sensor development. ○ 'Framework of Ocean Observing' (FOO): a strategy for the future to foster progress in sustained ocean observing considering the recognition that more integration across disciplines is needed to best respond to user needs and societal drivers (ATLANTOS). ○ Early-warning systems based on observations. ○ Development of the global ocean data product "GLODAPv2" (AtlantOS). ○ Analysis of the impact of CC on phytoplankton using remote sensing to estimate biological carbon export and sequestration (WhiteShift).	○ Acceleration of change by unknown mechanisms and synergistic effects. ○ Data lost today is lost forever. ○ Unprepared to predict/ mitigate/ adapt to CC impact.[38]

[36] EC Expert contract n. CT-EX2018D321960-102, Dr. Ilaria Nardello
[37] M. L. Taylor, C. N. Roterman. (2017). Invertebrate population genetics across Earth's largest habitat: The deep-sea floor. Molecular Ecology. https://doi.org/10.1111/mec.14237
[38] EC Expert contract n. CT-EX2018D321960-102 by Dr. Ilaria Nardello.

Predictions

Strengths	Weaknesses (GAPS and barriers)
○ Relevance of predictive efforts established. ○ Synergy among scientists in place. ○ State-of-the-art of weather forecasting systems progressively improving (IMPREX). ○ New climate analysis framework based on compound events to enhance projections of climate extremes (IMPREX)[39]. ○ Improved understanding of the role of atmospheric variables on sea-ice-dynamics forecast (APPLICATE). ○ Enhancement of the Arctic climate research community of the EU Arctic Cluster to provide policy-relevant information and supporting the EU in implementing its integrated policy for the Arctic (APPLICATE). ○ In line with the strategy for EU international cooperation in research and innovation (COM (2012)497), International cooperation between countries with different climate prediction capacity is effectively taking place (EUCP).	○ The time resolution of climate change predictions at the decennial scale is needed (ATLAS, EUCP)[40&41] ○ Spatial resolution at the regional level is still required and essential to empower local communities and their resilience with the tools to adequately forecast their ecosystem conditions and plan accordingly. ○ Biological components are still neglected in modelling efforts. ○ Model Initialisation problems. ○ Post processing. ○ Forecast quality and reliability (STERCP). ○ Need to strengthen the link with ocean-climate models (IMPREX). ○ Low resolution of Global Climate Models for some geographic areas (i.e. tropics) still remains a weakness in climate predictions (PRIMAVERA). ○ Reliability of the climate models for the areas at the boundary of two climate zones affected by different weather system (PRIMAVERA). ○ Time-lag between data availability and publication (PRIMAVERA). ○ State-of-the-art climate models still largely disagree on reproducing Arctic sea-ice changes (PRIMAVERA)[42].
Opportunities	**Threats**
○ Add contribution of bottom topography to refine modelling of oceanic conditions, such as currents, nutrient transportation and sea-level *(GlobalMass: ATLAS)* ○ Add Ice Sheet dynamics to hindcast models to improve future scenario predictions (CONCLIMA) ○ Functional biogeography (CLIMAFISH) can help us understand and prepare for the shift in ecosystem productivity and functioning ○ Solve the global sea level budget for the first time, thanks to novel combination of	○ Unpreparedness to mitigate or adapt to CC impact, especially at the regional level, in peripheral areas and in communities at the margins ○ Inability to capture and model the synergic effects of additional (man-made) stressors on CC Impact ○ The combined and cumulative effect of different hazards matters most of the European stakeholders (PRIMAVERA) ○ Unreliable model predictions over

[39] Zscheischler, J., Westra, S., Van Den Hurk, B. J., Seneviratne, S. I., Ward, P. J., Pitman, A., ... & Zhang, X. (2018). Future climate risk from compound events. Nature Climate Change, 8(6), 469-477.
[40] Atlas project, D7.2. Thought-leadership papers on priorities from expert assessment of Atlantic VMEs and EBSAs.
[41] EUCP, Deliverable D6.4 Scientific knowledge gaps and best practices.
[42] Massonnet, F., Vancoppenolle, M., Goosse, H., Docquier, D., Fichefet, T., & Blanchard-Wrigglesworth, E. (2018). Arctic sea-ice change tied to its mean state through thermodynamic processes. Nature Climate Change, 8(7), 599-603.

observation data as well as computational and statistical tech (GLOBALMASS) ○ Informing management tools to evaluate priorities for effective management of marine areas, including vulnerable ecosystems or MPAs (SIM4NEXUS) ○ Climate information prepared according to stakeholders' needs (IMPREX)[43] ○ Water-specific applications and case study examples to support flood and drought risk management and water resource adaptation planning, not only at regional but also at national and European level (IMPREX) ○ Identification of the European regions most affected by the occurrence of eventual extremes through the production of impact maps at much higher resolutions (~25-60km) (PRIMAVERA) ○ Reduce errors in climate model predictions through a climate-model-combination approach (STERCP) ○ New tools to forecast sea-ice dynamics on "weather time scale" to help stakeholders in tactical decision-making process (APPLICATE)[44] ○ Design of the future Arctic observing system (APPLICATE) ○ Near-Term Climate Predictions to bridge the gap between seasonal predictions and long-term climate projections, providing to remove the inequality and heterogeneity that underpin the current differences in country-to-country adaptation capability, stimulate a market for climate services, improve the social and economic well-being of Europe and its citizens, improve the Copernicus Climate Change service (EUCP)	the dynamics of fundamental OCN processes, such as the Atlantic Meridional Overturning Circulation (AMOC), would have a profound impact on human socio-economic systems (STERCP)[45] ○ The degree of warming observed in the Arctic is much faster than that observed in the rest of the world, in both observations and model simulations, phenomenon known as the Arctic Amplification (APPLICATE) [46&47]

4.2 Responding with solutions

Ocean science underpins effective conservation, restoration and sustainable use of the ocean and its ecosystems services, including through Nature-based Solutions and Ecosystem-based Approaches[48]. H2020 projects delivers robust and transformational ocean science actionable into win-win strategies and solutions for both climate and biodiversity, **addressing consistently and jointly the intertwined crisis of climate change, biodiversity loss** and **pollution**. H2020 endeavours on bringing **win-win strategies and solutions for climate and biodiversity.**

[43] IMPREX, Position Paper: Towards more action-oriented research and climate services.
[44] Mohammadi-Aragh, M., Goessling, H. F., Losch, M., Hutter, N., & Jung, T. (2018). Predictability of Arctic sea ice on weather time scales. Scientific reports, 8(1), 1-7.
[45] Selten, F. M., Schevenhoven, F. J., & Duane, G. S. (2017). Simulating climate with a synchronization-based supermodel. Chaos: An Interdisciplinary Journal of Nonlinear Science, 27(12), 126903.
[46] Cowtan, K., & Way, R. G. (2014). Coverage bias in the HadCRUT4 temperature series and its impact on recent temperature trends. Quarterly Journal of the Royal Meteorological Society, 140(683), 1935– 1944. https://doi.org/10.1002/qj.2297.
[47] EC Expert contract n. CT-EX2018D321960-102 by Dr. Ilaria Nardello.
[48] https://ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en

Climate services: *CORDIS Result Pack on* How climate services can help decision taking in a changing climate: Stories from Horizon 2020 projects[49]

Nature-based solutions (NBS): *CORDIS Result Pack on* NATURE-BASED SOLUTIONS: TRANSFORMING CITIES, ENHANCING WELL-BEING[50]; Project MERCES focuses on the marine environment and how ecosystem restoration of degraded marine environments in Europe can be restored through efficient and effective NBS.

Project **FutureMARES** provides socially and economically viable nature-based solutions (NBS) for climate change (CC) adaptation and mitigation to safeguard the marine and transitional ecosystems' natural capital, biodiversity and services. The project will develop three, climate-ready NBS:

- restoration of habitat-forming species acting as 'climate rescuers' buffering coastal habitats from negative CC effects, improving seawater quality, and sequestering carbon,

- conservation actions explicitly considering the range of impacts of CC and other hazards on habitat suitability for biota to preserve the integrity of food webs (e.g. marine protected areas) and protect endangered species (e.g. charismatic megafauna), and

- sustainable, ecosystem-based harvesting (capture and culture) of seafood.

MaCoBioS's objective is to ensure efficient and integrated management and conservation strategies for European Marine Coastal Ecosystems (MCE) to face climate change. The project evaluates the effectiveness of nature-based solutions and protection measures at enhancing the resilience capacity of MCE and the delivery of services, with the end goal of providing long-term solutions to climate change threats.

In the Arctic environment, project **FACE-IT** aims at enabling adaptive co-management of social-ecological fjord systems in the Arctic in the face of rapid cryosphere and biodiversity changes. The project will identify ways to manage the impacts of climate change on the cryosphere and marine biodiversity, and the interaction with other drivers of change (nature-based tourism).

REIS platform, developed by the **SOCLIMPACT** project, proposes solutions to the European island territories in order to give answers to problems arising from climate change. The website has an interactive tool that shows climate forecasts and recommendations to increase the resilience of 12 insular regions (Azores, Balearic Islands, Canary Islands, Corsica, Crete, Cyprus, Fehmarn, Madeira, Malta, Sardinia, Sicily and the French Antilles).

Project **AquapHOx** has developed a new technology, a new flexible optical sensor platform for ocean and coastal monitoring of O2, pH and temperature. It is the first high-performance, all-in-one optical sensor technology to monitor the health of our ocean.

[49] https://cordis.europa.eu/article/id/422577-climate-services
[50] https://cordis.europa.eu/article/id/421853-nature-based-solutions

Solutions – climate change mitigation

Strengths	Weaknesses (GAPS and barriers)
○ Ocean fertilization is an established technique to improve primary production rates, in Iron-deficient areas of the ocean, e.g. the Southern Ocean. ○ Phytoplankton productivity is now investigated also with optical sensors allowing for faster and broader ocean-monitoring (Whiteshift). ○ Sharing of knowledge, ideas and other information on climate issues between Climate innovators, researchers and end-users (BRIGAID). ○ Improved innovation capacity to support EU policy in Climate adaptation and disaster risk resilience, flood protection and drought management (BRIGAID).	○ Uncertain effects of food-web repercussions with ocean fertilization. ○ Ocean technology still hardly enduring the oceanic harsh, corrosive and fouling conditions.
Opportunities	**Threats**
○ Improve design and commercial fitness of the ocean energy devices, e.g. turbines for tidal energy (D2T2). ○ Technology and methodology for the controlled enhancement of the biological pump (Appels, OceanLines, MESOPP and IcyLab). ○ Novel routes for greening shipping due to ice sheet melting in the Arctic. ○ Blue Carbon (DENOCS, MARSHFLUX). ○ Linking the Climate Innovation Window (CIW), a portal created to facilitate the market uptake of climatic resilience innovations[51], to other relevant climate platforms, such as the European Climate Adaptation Platform (ClimateADAPT)[52] and the European Innovation Partnerships EIP-Water (BRIGAID). ○ Reduce life-losses from natural hazards, in line with the Sendai Framework for Disaster Risk Reduction over the period 2015−2030 (BRIGAID)[53]. ○ To provide biological datasets for climate forecasting models to perform future projections of marine life (DPaTh-To-Adapt). ○ Understand the role of microbial loops, especially in oxygen- depleted water conditions, on primary production (phytoplankton and algae growth) and secondary biological production (fisheries) (NITROX, DENOCS).	○ Repeat in the ocean the mistakes of industrial agriculture ○ Inability to abandon the fossil-fuel energy production ○ Ocean Acidification/De-alkalinisation ○ Hypoxia ○ Toxicity[54]

[51] BRIGAID, Stocktaking Report WP2-4 Deliverable 2.4: Stocktaking report of 3th InnovationCycle including the selections for WP2, WP3 and WP4.
[52] https://climate-adapt.eea.europa.eu/.
[53] UNISDR, 2015 Sendai Framework for Disaster Risk Reduction 2015–2030 (Geneva: United Nations Office for Disaster Risk Reduction).
[54] [54] Portfolio analysis carried out under EC Expert contract n. CT-EX2018D321960-102 by Dr. Ilaria Nardello.

Biological resources, Biodiversity, Habitat integrity, Ecosystem Functioning, MPAs

Strengths	Weaknesses (GAPS and barriers)
o AORA initiative for the Marine Microbiome Roadmap: "Environment and Climate" pillar. o MPAs are growing. o Development of an interdisciplinary conceptual framework to improve the understanding of the sensitivity of marine organisms to CC (DPaTh-To-Adapt). o Improved knowledge on the distribution and the genomic resources of inaccessible organisms like deep-sea sponges (SponGES). o The mechanisms which could make one coral species more adapt to deoxygenated waters upon ocean warming are highlighted[55] (DENOCS).	o Consideration of the feedback effects of biodiversity redistribution (due to CC) on climate itself is critical yet lacking in most mitigation and adaptation strategies (INTAROS)[56] o Essential Biodiversity Variables appear poorly adopted potentially resulting in an under-representation of this research dimension. o Governance of the High Seas and Areas Beyond National Jurisdiction (ABNJs). o Lack of adequate instruments, such as high-resolution climate change predictions for the next 2 to 5 decades, will hinder the evaluation of priorities for Area-Based-Management-Tools (ABMTs) in Areas Beyond National Jurisdiction (ABNJs) (ATLAS).[57] o Lack of studies of how the observed shifts in species composition are affecting marine ecosystem-functioning at a biogeographic scale. o Warming does not present a homogeneous pattern within any given biological community; species may respond differently to ongoing changes to the local climate regime (DPaTh-To-Adapt).
Opportunities	**Threats**
o Blue carbon o Assisted evolution (EVOLMArine) o Integrated LMMAs and MPAs for increased resilience to CC impact (ATLAS) o Marine microbial biotechnology for environmental remediation and carbon capture (SPONGES, NITROX) o Ocean fertilization: research is required to understand the limits of this technological opportunity. o Serious Games (SIM4NEXUS). o Functional biogeographic studies to predict ecosystem shifts based on changing biodiversity composition. o Knowledge-based solutions for the European fisheries and aquaculture sectors [58], based on PESTLE scenarios, i.e. considering Political, Environmental, Social, Technological,	o Perpetration of erroneous perception of limitlessness of our planetary resources and lack of consideration for the ocean's role. o Over-exploitation of resources/habitats. o Economic system failure. o Biogeographic Migrations, at the various trophic levels, from zooplankton to commercial fish species, and all the way up to human populations (CLIMEFISH, DPaTh-To-Adapt). o Harmful Algal Blooms (HABs) are considered to have increased in frequency and impact around the world in recent decades with global risks to health and economies [55] (CERES). o Loss of marine biodiversity linked to ocean CC (DPaTh-To-Adapt).[60]

[55] https://cordis.europa.eu/article/id/411745-a-better-understanding-of-stress-responses-in-coral-bleaching

[56] Gretta T. Pecl, et al.(2017). *Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science*, vol. 355, Issue 6332, eaai9214. DOI: 10.1126/science.aai9214

[57] Atlas project, D7.2. Thought-leadership papers on priorities from expert assessment of Atlantic VMEs and EBSAs

[58] CERES, (2016) Exploratory socio-political scenarios for the fishery and aquaculture sectors in Europe. (Eds.Pinnegar J.K., Engelhard G.H.) Deliverable D1.1 - Glossy 'report card' aimed at stakeholders. Centre for Environment, Fisheries & Aquaculture Science (Cefas), Lowestoft, 8pp.

Legal and Economic conditions (CERES). ○ Curb the impact of Harmful Algal Blooms (HABs)[59] (CERES). ○ New chemistry algorithms could improve the robustness of ecosystem-climate models (SponGES). ○ Investigation of the microbiome associated with deep-sea sponges could provide novel bioactives for exploitation in pharmaceutical and industrial marine chemical sectors and other blue-biotechnology applications (SponGES). ○ Improved culturing of sponge cell lines could support biotechnology applications (SponGES). ○ Provide options for blue carbon solutions, such as restoration of coral reefs (DENOCS).	

Governance, Management and Spatial Planning

Strengths	Weaknesses
Nature is recognised as part of the solution to CC mitigation efforts. ○ Global initiatives as drivers. ○ "Blue Carbon" concept being introduced. ○ Management tools are available to support marine spatial planning. ○ Use of most advanced technologies to improve future ecosystem benefits for humankind (ECOPOTENTIAL). ○ Co-designed and co-developed activities with the staff of Protected Areas working on local and concrete issues (ECOPOTENTIAL). ○ Increase the interdisciplinary work between economists, policy makers, ecologists, fisheries experts and business stakeholders for the sustainable management of aquatic ecosystems61 (AQUACROSS). ○ A strong focus on training, with a mobility programme facilitating inter-disciplinary learning (MARmaED). The Nexus approach allows to create interrelations between different sectors towards an integrated management of resources, being demonstrated its potential to unleash synergies and minimise trade-offs (SIM4NEXUS)[62].	○ ABNJ are regulated but lacking management tools ○ Carbon neutrality is a primary goal of EU policy (A clean planet for all, EU Green Deal) however reversing the effect of other man-made stressors shall be included in our R&I efforts, such as remediation from pollution. ○ Marine Spatial Planning is required for a non-conflictual use of our marine system. The concept of ecosystem services is not always compatible with the practical conservation issues of MPAs managers (ECOPOTENTIAL)[63].

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[60] Portfolio analysis carried out under EC Expert contract n. CT-EX2018D321960-102 by Dr. Ilaria Nardello.
[59] Townhill, B. L., Tinker, J., Jones, M., Pitois, S., Creach, V., Simpson, S. D., & Pinnegar, J. K. (2018). Harmful algal blooms and climate change: exploring future distribution changes. ICES Journal of Marine Science, 75(6), 1882-1893.
[61] AQUACROSS, Managing aquatic biodiversity: from local to global – an EU perspective.
[62] Hülsmann, S., Sušnik, J., Rinke, K., Langan, S., van Wijk, D., Janssen, A. B., &Mooij, W. M. (2019). Integrated modelling and management of water resources: the ecosystem perspective on the nexus approach. Current Opinion in Environmental Sustainability, 40, 14-20.
[63] ECOPOTENTIAL, (2018) Science-Policy Brief meeting "Science for post 2020 Environmental targets: Insights from Earth Observation of Protected Areas".

Opportunities	Threats
○ Decision Support systems and other Management tools informed by regionalised earth system models to evaluate priorities for effective planning and management of marine areas, including vulnerable ecosystems or MPAs, over the decennial time scale. ○ Ocean economy growing sustainably, starting from the local level (AQUACROSS). ○ Use of social sciences and serious-gaming tools to create social transformation (SIM4NEXUS) and facilitate strategic Planning (BRIGAId). ○ Biological and Ecological Essential Ocean Variables (EOVs) give a major contribution in comprehending the effects of CC on marine organisms and ecosystems (ECOPOTENTIAL). ○ Provision of useful dataset for the analysis of MSFD descriptors to monitor ecosystem functions, processes and services, and the pressures they face (ECOPOTENTIAL). ○ Reduction of ecological model uncertainties (ECOPOTENTIAL). ○ Development of practical tools for policy and environmental managers to support the local ecosystem-based management (EBM) for the protection of biodiversity in aquatic ecosystems (AQUACROSS). ○ Novel standards in the training of a new generation of multi-disciplinarily skilled and creative marine scientists fit to address Europe's future challenges64 (MARmaED). ○ Consolidation of the experimental hydraulic and hydrodynamic research community network throughout Europe and sharing of knowledge and data with stakeholders, including industry and government agencies (HYDRALAB+). New method to evaluate the policy coherence between different policy domains at national and regional levels, helping the identification of gaps and barriers towards the sustainable and efficient management of resources (SIM4NEXUS).	Over-exploitation of resources/ habitats. ○ Unpreparedness to predict/ mitigate/ adapt to changes. Anthropogenic pressures cause severe threats to ecosystem integrity, functions and processes, potentially leading to the loss of biodiversity and ecosystem services (ECOPOTENTIAL, AQUACROSS[65]).[66]

[64] https://cordis.europa.eu/project/id/675997/.
[65] AQUACROSS, Deliverable 3.1 the AQUACROSS Innovative Concept.
[66] Portfolio analysis carried out under EC Expert contract n. CT-EX2018D321960-102 by Dr. Ilaria Nardello.

4.3 Connecting Science with Society, international coordination of research efforts, ocean literacy and societal transformation

On **science diplomacy**, the **All-Atlantic Ocean Research and Innovation Alliance (AAORIA)**[67] is a shared commitment by the European Union, Argentina, Brazil, Canada, Cabo Verde, Morocco, South Africa and the United States. It aims at advancing marine research and innovation, on shared priorities such as increasing our understanding of the relationship between the ocean and climate, and to develop outcome-oriented science for mitigating and adapting to its consequences of enhancing marine research and innovation cooperation along and across the Atlantic Ocean.

EU-PolarNet[68] provides a coordination platform to co-develop strategies to advance the European Polar Research action and its contribution to the policy-making processes.

The polar research projects funded by the European Union have started a collaboration initiative, the **EU Polar Cluster**[69], which merges a broad spectrum of research and coordination activities. They range from the most up-to-date findings on permafrost and sea ice, enhancing observation to improving predictions, networking research stations to coordinating access to icebreakers.

The **EDU-ARCTIC** project looks at innovative educational program attracting young people to natural sciences through Arctic research.

Ocean literacy, scientists of tomorrow, and support for communities at the margins

Strengths	Weaknesses
Global initiatives as drivers: ○ UN-IOC 's Decade of Ocean Science declared (2020-2029) ○ UN SDGs ○ Many OCNP projects contain an element of education and training and by their own nature support societal transformation ○ ERCs and MSCA are HR-capacity building programmes and many of them are included in the OCNP, providing evidence that this action is being strongly considered by the Commission and largely implemented.	○ An EU policy framework to support the up-skilling of students and young career scientists and entrepreneurs is missing ○ Projects strictly referring to ocean literacy were absent from the OCNP ○ Lack of entrepreneurial skill within the biology sphere ○ Lack of bioinformaticians
Opportunities	**Threats**
○ Blue Growth. ○ Bioinformatic disciplines. ○ Computer serious game for simulating the land-food-energy-water-climate nexus to make better decision (SIM4Nexus). ○ Training event for the scientists of tomorrow (APPLICATE). ○ Societal transformation. ○ Local community engagement and cohesion. ○ Use of social sciences to create community engagement and cohesion.	○ Lack of grip by the policies on the citizenship if not educated. ○ Perpetration of erroneous perception of limitlessness of our planetary resources and lack of consideration for the ocean's role. ○ Over-exploitation of resources/ habitats. ○ Unprepared to predict/mitigate/ adapt to changes. ○ Biogeographic shifts in natural populations, including humans.[70]

[67] https://www.allatlanticocean.org/whoweare
[68] http://www.eu-polarnet.eu/
[69] https://www.polarcluster.eu/
[70] portfolio analysis carried out under EC Expert contract n. CT-EX2018D321960-102 by Dr. Ilaria Nardello

4.4 Key exploitable results (KER)

The **Horizon Results Platform (HRP)**[71] is a searchable repository of **Key Exploitable Results (KER)** of EU-funded research and innovation projects. These are the main and prioritised results, selected by the project partners, with a high potential value to be "exploited". This means being usable and derive benefits downstream the value chain of a product, process or solution, or act as an **important input to policy**, further research, or education. A result can be any tangible or intangible output of the action, such as data, knowledge, and information whatever their form or nature.

The Key Exploitable Results (KER) for the ocean-climate nexus portfolio, as showcased in the word cloud below, is strongly connected to and supporting the implementation of the climate and biodiversity objectives of the Union: 'policy', preparedness, adaptation, mitigation, ecosystem, arctic, climate services, societal transformation, etc.

Acronym	Key Exploitable Results (KER)
APPLICATE[72]	**KER 1: Preparedness** **APPLICATE** is making substantial progress in the development of the next generation of sea ice models, coupling them with climate models so to allow long-term high-resolutions simulations. The project provides important contributions to the Year of Polar Prediction and IPCC scientific assessments, as well as to the Copernicus Climate Change services. It is also providing a deep insight into the knowledge of Polar Amplification through the Polar Amplification Model Intercomparison Project (PAMIP), with important implications for the future OCN policy, leading to greater adaptation capacity (3).

[71] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform

[72] 1)https://cordis.europa.eu/project/id/727862/; 2) https://applicate.eu/; 3) Smith, D. M., Screen, J. A., Deser, C., Cohen, J., Fyfe, J. C., García-Serrano, J., ... &Peings, Y. (2019). The Polar Amplification Model Intercomparison Project (PAMIP) contribution to CMIP6: investigating the causes and consequences of polar amplification.

KER 2: Preparedness, modelling

Atmosphere-Ocean Single Column Model - A tool to help improve coupled models in the Arctic – Scientific or Technological R&D Result including ICT Hardware

KER 3: Mitigation and Adaptation – extreme weather risk planning and management

Risk management case study 1: Is Svalbard prepared for extreme rainfall?

Risk management case study 2: Is Alaska prepared for extreme wildfires?

KER 4: Preparedness, prediction, Mitigation and Adaptation – climate services

Energy case study 1: How does Arctic Sea Ice affect energy production in mid-latitudes?

Energy case study 2: How did Arctic sea ice affect energy production in Europe in 2018?

KER 5: Preparedness, prediction

Impact of sea ice thickness initialisation for Arctic seasonal sea ice prediction - Using satellite sea ice thickness observations within operational analysis systems can considerable increase the skill of seasonal Arctic sea ice forecasts – Scientific or Technological R&D Result including ICT Hardware

KER 6: Preparedness, prediction

Recommendation of an optimal sampling strategy for monitoring and predicting the Arctic sea ice volume at interannual timeframe - Sampling in situ data, such as sea ice thickness, in only a few well-placed locations allows a fair reconstruction of the pan-Arctic sea ice volume by means of a newly developed statistical empirical model – Scientific or Technological R&D Result including ICT Hardware

KER 7: Preparedness, model evaluation

CRISTO Framework for model evaluation - Numerical models aren't perfect and are constantly evaluated to assess their performance. But what criteria should good metrics fulfill?

KER 8: Preparedness, prediction

Need for improving the uptake of existing microwave and infrared satellite observations over snow and sea-ice – The Arctic region has a relatively sparse coverage of in-situ atmospheric observations but the best coverage of Low Earth Orbit satellite temperature and humidity sounding observations of anywhere in the globe, as shown in the image. Through comprehensive observing system experiments with a state-of-the-art numerical weather prediction system, it was demonstrated that the use of these observations in regions with snow and sea-ice should be improved in order to further improve the initial conditions of the weather forecasts, and thereby enhance forecast skill in Polar Regions. Improvements to numerical weather prediction systems targeted at enhancing the uptake of microwave and infrared satellite observations over snow and sea-ice would translate in forecast skill gains in polar regions - Scientific or Technological R&D Result including ICT Hardware

	KER 9: Preparedness, in-situ monitoring - Policy Related Result **Policy brief: In-situ monitoring of Arctic sea ice –** Strategic placement of in-situ sampling sites to monitor Arctic sea ice
AQUACROSS[73]	**KER 1: Governance** The application of the analytical Drivers, Pressures, States, Impacts, Responses (DPSIR) framework) enabled the **assessment of the EU policy effectiveness in reducing six known human pressures** (nitrogen pollution, species extraction, invasive alien species, water abstraction, alterations to morphology, and plastic waste) on aquatic biodiversity. The results show that a greater coherence is between the environmental and sectoral EU policies, to prevent biodiversity loss and ensure the provision of multiple services from aquatic ecosystems (2). **KER 2: Governance** Three interlinked and freely available tools were developed to support the adoption of the **ecosystem-based management (EBM) in aquatic ecosystems**: the AQUACROSS Linkage Framework, the **AquaLinks Tool and the AQUACROSS Information Platform**. These tools were applied to eight case studies, in support of environmental managers to effectively **manage threats to different types of aquatic ecosystems and their biodiversity** (3), and exploring the potential of EBM as a climate change adaptive instrument for the realisation of blue-carbon reservoirs.
AtlantOS[74]	**KER 1 – Observations Networks** The project's **models of observation-coordination and data-management systems, as well as the articulation of joint principle and goals for developing data-products of societal use, are exportable for other basin scale initiatives** (Mediterranean, Arctic, etc.). The project contributed to the **development of the global ocean data product "GLODAPv2",** composed of data from 724 scientific cruises covering the global ocean, where data have been adjusted to be internally consistent to better than 0.005 in salinity, 1 % in oxygen, 2 % in nitrate, 2 % in silicate, 2 % in phosphate, 4 $\mu mol\,kg^{-1}$ in dissolved inorganic carbon, 6 $\mu mol\,kg^{-1}$ in total alkalinity, 0.005 in pH, and 5 % for the halogenated transient tracers.[2] GLODAPv2 products, including the mapped climatology, are openly available at CDIAC (http://cdiac.ornl.gov/oceans/ GLODAPv2/).

[73] 1) AQUACROSS, Deliverable 3.1 the AQUACROSS Innovative Concept. 2) Rouillard, J., Lago, M., Abhold, K., Roeschel, L., Kafyeke, T., Klimmek, H., &Mattheiß, V. (2018). Protecting and Restoring Biodiversity across the Freshwater, Coastal and Marine Realms: Is the existing EU policy framework fit for purpose? Environmental Policy and Governance, 28(2), 114-128.; 3) Rouillard, J., Lago, M., Abhold, K., Roeschel, L., Kafyeke, T., Klimmek, H., &Mattheiß, V. (2018). Protecting and Restoring Biodiversity across the Freshwater, Coastal and Marine Realms: Is the existing EU policy framework fit for purpose? Environmental Policy and Governance, 28(2), 114-128.

[74] Source : 1) Visbeck, M. Ocean science research is key for a sustainable future.NatCommun 9, 690 (2018). https://doi.org/10.1038/s41467-018-03158-3; 2) Olsen, A., Key, R. M., van Heuven, S., Lauvset, S. K., Velo, A., Lin, X., Schirnick, C., Kozyr, A., Tanhua, T., Hoppema, M., Jutterström, S., Steinfeldt, R., Jeansson, E., Ishii, M., Pérez, F. F., and Suzuki, T.: The Global Ocean Data Analysis Project version 2 (GLODAPv2) – an internally consistent data product for the world ocean, Earth Syst. Sci. Data, 8, 297–323, https://doi.org/10.5194/essd-8-297-2016, 2016.

KER 2 – Preparedness, observation

New Era of Carbonate System Measurements – Marine carbon observations are of utmost interest to understand the uptake, transport and storage of anthropogenic CO2 in the ocean. Total alkalinity (TA) is one of four key parameters characterizing the marine carbon system. High-quality TA measurements are essential for reliable ocean carbon and acidification observations. Well-established titration methods meet the requirements, but have several drawbacks (e.g. non-autonomous, need of bottled, poisoned seawater samples, long measurement time). The **automated underway analyzer CONTROS HydroFIA® TA** overcomes these disadvantages and enables high quality, high-resolution measurements. Under laboratory conditions the analyzer featured a precision of ±1.5 μmol kg−1 (±1.1 μmol kg−1) and an accuracy of ±1.0 μmol kg−1 (−0.3±2.8 μmol kg−1). This performance meets fundamental requirements of the ocean carbon and acidification observation community. Further, the spatio-temporal measuring resolution can be increased compared to traditional methodology. Thus, the HydroFIA® is suitable for autonomous long-term measurements for e.g. carbonate system studies - Scientific or Technological R&D Result including ICT Hardware
The CONTROS HydroFIA® TA analyzer heralds a new era in unattended ocean carbon observations. It enables high-quality total alkalinity (TA) measurements with minimal instrumental and personnel effort in comparison to traditional methods. It supports discrete sample and quasi-continuous measurements, enabling observations at high temporal resolution and the acquisition of long-term data sets. Increasing the temporal and spatial measuring resolution of TA gives new insights into biogeochemical processes in the aquatic environment that were not possible before. The target audience are operators for this kind of instruments or monitoring platforms in general such as scientists from research institutions and universities or entities following a legal mandate for regular monitoring of chemical parameters. CONTROS HydroFIA® TA analyzer are available at -4H-Jena engineering GmbH.

KER 3 – Mitigation and Adaptation

Re**duction of carbon footprint of shipping via ocean currents and waves** - The project made an Atlantic Ocean-wide assessment of achievable reduction of carbon intensity through ship route optimization. It employed model reconstructions of ocean surface gravity waves and currents during 2017 and computed more 2,500 optimal and safe tracks between main harbours of the Atlantic. It found carbon intensity savings in excess of 5% (annual averages) and 10% (monthly averages), with a variable contribution of ocean currents, depending on geographic location and season. ICT Software Digital solution.

KER 4 – Societal transformation

Refined IAOOS requirements Report - Refined description from AtlantOS work of the societal imperatives for sustained Atlantic Ocean observations, the phenomena to observe, EOVs, and contributing observing networks.

ATLAS[75]	**KER 1- MPAs/Marine Spatial Planning/Governance** "Other effective area-based conservation measures" (OECMs), such as Sectoral/local conservation measures, can complement MPAs and contribute to ecologically representative and effectively-managed marine protected areas systems, integrated into broader governance systems such as marine spatial planning. Local Marine Managed Areas (LMMAs), for example, can respond to short-term fishers' needs and targeted biodiversity conservation, and contribute to the achievement of specific SDGs on food security, poverty elimination and resilient ecosystems if properly supported by long-term investments, strong institutions and integrated ocean management. The project demonstrates a local "Topographically enhanced carbon pump", from the interaction between tidal currents and Cold-Water Coral (CWC) mounds, inducing downwelling events of surface water that brings organic matter to 600m-deep CWCs. This positive feedback between CWC growth on carbonate mounds and enhanced food supply is essential for their sustenance in the deep sea and represents an example of ecosystem engineering of unparalleled magnitude. **KER 2 – Observation (Assessment tools)** 1) "Despite the deep sea being the largest habitat on Earth, there are just 77 population genetic studies of invertebrates (115 species) inhabiting non-chemosynthetic ecosystems on the deep-sea floor (below 200 m depth). We review and synthesize the results of these papers. Studies reveal levels of genetic diversity comparable to shallow-water species. Generally, populations at similar depths were well connected over 100s–1,000s km, but studies that sampled across depth ranges reveal population structure at much smaller scales (100s–1,000s m) consistent with isolation by adaptation across environmental gradients, or the existence of physical barriers to connectivity with depth. Few studies were ocean-wide (under 4%), and 48% were Atlantic-focused. There is strong emphasis on megafauna and commercial species, with research into meiofauna, "ecosystem engineers" and other ecologically important species lacking. Only nine papers account for ~50% of the planet's surface (depths below 3,500 m). Just two species were studied below 5,000 m, a quarter of Earth's seafloor. The number of population genetics studies to date is miniscule in relation to the size of the deep sea." **KER 3 – Governance, Biodiversity, Policy Related Result** ATLAS adopted an indicator-based approach to evaluate Good Environmental Status (GES) in the deep sea. They applied the **Nested Environmental status Assessment Tool (NEAT)** for assessing the GES of the European areas of the deep sea, in the ATLAS case study. After a careful and comprehensive review of the existing information, a selection of existing indicators was conducted and new indicators were proposed considering the specific constraints of working in the deep sea and the main characteristics of these ecosystems. The Nested Environmental status Assessment Tool (NEAT) developed within the European DEVOTES project, was evaluated as an

[75] Source: 1) Daniela Diz, David Johnson, Michael Riddell, Sian Rees, Jessica Battle, Kristina Gjerde, Sebastian Hennige, J. Murray Roberts. Mainstreaming marine biodiversity into the SDGs: The role of other effective area-based conservation measures (SDG 14.5). (2018). Marine Policy, Volume 93, 2018, Pages 251-261, ISSN 0308-597X. https://doi.org/10.1016/j.marpol.2017.08.019.; 2) ATLAS project, D7.2. Thought-leadership papers on priorities from expert assessment of Atlantic VMEs and EBSAs.; 3) Thornalley David JR, Oppo Delia W, et al. (2018) Anomalously weak Labrador Sea convection and Atlantic overturning during the past 150 years. Nature 556, 227-230. https://doi.org/10.1038/s41586-018-0007-4.; 4) M. L. Taylor, C. N. Roterman. (2017). Invertebrate population genetics across Earth's largest habitat: The deep-sea floor. Molecular Ecology. https://doi.org/10.1111/mec.14237.; 5) Vad J, Orejas C, Moreno-Navas J, Findlay HS, Roberts JM. 2017. Assessing the living and dead proportions of cold-water coral colonies: implications for deep-water Marine Protected Area monitoring in a changing ocean. https://doi.org/10.7717/peerj.3705.; 6) ATLAS Project - Deliverable 3.1 Good Ecological Status and Biodiversity Assessments

appropriate tool to assess the environmental status of the deep sea. NEAT was applied to nine European deep-sea case study areas in order to identify indicators which are suitable for the deep sea. Additional indicators, not included in the NEAT tool, were added to include the EC's Marine Strategy Framework Directive descriptors. An extensive literature review was conducted to facilitate the selection of threshold values for each GES indicator. The results highlighted the scarcity of deep-sea data currently available, even in 'well-studied' case study areas and that the selection of indicators, thresholds and spatial scale, habitats and ecosystem components, can have a significant impact on the NEAT results. The results also highlight the need for easier access to vessel monitoring system data and technological equipment (e.g. towed cameras, autonomous underwater vehicles) including artificial intelligence for data processing, monitoring data at appropriate spatial and temporal scales and intersectoral collaborations and online data archiving.

KER 4 – Governance, Biodiversity

In one of their publications, they also refer of a **novel methodology to assess the proportion of living vs dead coral, in large colonies, based on the visual contrast between white/pale living and grey/dark dead portions of the colonies.** This optical method could provide a new way by which coral colonies can be visually monitored over time, with the use of marine autonomous survey vehicles, which offer an important new platform from which such a surveying technique could be applied, to monitor deep-water marine protected areas in the future. TRL is unclear.

KER 5 – Societal transformation

Effective Knowledge Transfer (KT) is a core-crosscutting dimension to the ATLAS project and is being achieved through the adoption of a broad range of targeted Knowledge Transfer tools and channels, ensuring engagement and exchange so that research outputs are transferred effectively to relevant end-users. ATLAS partners have carried out many Knowledge Transfer activities addressing policy, industry, science and public stakeholders, during the first 24 months of the project.

KER 6 – Societal transformation, educational outreach

Atlantic Adventures with ATLAS - The ATLAS Educational Outreach Portfolio - The ATLAS Educational Outreach Portfolio is new unique and dynamic portfolio of educational tools and resources based on ATLAS research in the deep sea. The portfolio includes an educational programme and workshop with a range of activities and packs created for educators, researchers and the general public to use and learn about ATLAS. All the resources are free to download from the ATLAS project website and are available in several languages. The ATLAS educational programme comprises of a suite of resources highlighting the importance of the ocean; ocean acidification; pressure in the deep; how ROVs work; technology used in the deep-sea exploration and hydrothermal vents. A 'reef survey' image is available to download which can be printed and laid out to allow exploration of cold-water coral reefs. Augmented reality colouring sheets were developed to bring three of the ATLAS research areas to life through the Spectacular app by Quiver Vision. All of the resources are freely available to download, and selected resources are also available in: French, German, Portuguese and Spanish.

KER 7 – Societal transformation, ocean literacy

ATLAS GeoNode marine data visualisation tool - An open source geospatial content management system that allows users to visualise and download ATLAS project data and other relevant data layers. It focuses on users and facilitates collaborative use of geospatial data and maps. It will also be used to transfer ATLAS data and scientific outputs to wider stakeholders in industry, policy. The GeoNode is designed around the 12 ATLAS project case studies. It provides an online platform for enhanced exchange of information amongst ATLAS partners on data produced across the project, and it facilitates project development of area-based management plans. The ATLAS GeoNode is embedded in an Atlantic ATLAS community page, hosted on the EMODnet central portal. This promotes the ATLAS project to a wide range and number of stakeholders already visiting the EMODnet web services. It also ensures the long-term visibility and impact of ATLAS data beyond the duration of the project. The ATLAS GeoNode page acts as central hub for the project partners and external stakeholders to discover, visualize and download ATLAS geospatial data through a dedicated online GIS platform. The GeoNode offers open access data from the 12 ATLAS case studies. Currently, it features 46 geospatial data layers (in standard formats), 9 visualization maps and accompanying metadata and associated documents with many more on the way. ICT Software Digital solution.

KER 8 – Mitigation and Adaptation, Biodiversity, MPA – Policy Relevant result

ATLAS Policy Brief on MPA network design – Marine Protected Areas are effective in protecting deep-sea ecosystems however 'connectivity', one of the criteria for designing MPA networks, responds to climate change and thus key physical drivers need to be considered to ensure truly effective MPA networks. Climate change is predicted to have broad-scale effects on ocean circulation patterns, seawater chemistry and, consequently, the location and suitability of habitats for species. Present-day conservation measures in the North Atlantic Ocean rely heavily on identifying and protecting areas of known importance for the survival of populations of interesting species. It is now feared that with the disruption of environmental cues and conditions brought about by climate change, many of the areas currently under some form of environmental protection will not be fit for purpose, in the longer term, as they will no longer accommodate the conditions that are favourable to the species they are intended to protect. Based on ATLAS scientific results & data, the policy brief puts forwards recommendations and considerations in a format that is tailored for policy makers, to improve current ocean planning, management & conservation tools.

KER 9 – Preparedness – modelling and prediction; Mitigation and Adaptation, Ecosystem functioning

New approach to identify the key environmental parameters that control cold-water coral ecosystem performance. In the course of the last major global warming event, the transition from the last glacial period to the present warm phase between 18,000 and 8,000 years ago, cold-water coral ecosystems vanished in some parts of the North Atlantic and re-occurred in others. Marine-geological investigations revealed that these turnovers are mostly linked to changes in either food supply or bottom water oxygenation. In terms of food supply, the lateral food supply controlled by bottom water hydrodynamics appears to be much more important than vertical food supply controlled by surface ocean productivity. Interestingly, temperature as well as salinity changes associated with this warming event seem to have had only a rather limited impact on the performance of the cold-water corals. Consequently, to estimate the future fate of cold-water corals in times of global change, a key parameter to be considered in modelling approaches is bottom water hydrodynamics. This knowledge has great capacity to improve the modelling/prediction of the fate of cold-water corals and their ecosystem functions under future global change. Scientific or Technological R&D Result including ICT Hardware.

KER 10 –Mitigation and Adaptation, ecosystem functioning, Area Based management Tool - Policy Related Result

Current deep-sea Area Based Management Tools are unprepared for Climate Change - We have used a Pressure-State-Response (PSR) framework to; (i) identify and characterise pressures on Area Based Management Tools (ABMTs); (ii) characterise the ecological / biological state of ABMTs and predict shifts in response to pressures and; (iii) to identify potential responses and measures to fill gaps identified. Three ABMTs were assessed: 1) OSPAR Marine Protected Areas, 2) Convention on Biological Diversity (CBD) Ecologically or Biologically Significant Areas, and 3) Regional Fisheries Management Organisations' (RFMO's) closures to protect Vulnerable Marine Ecosystems (VMEs). They were assessed for a 20-50-year time-frame, using a step-wise methodology based on five key variables based on available technical and scientific information. Our work shows the need for more complete impact assessments, and further research including the impact of additional variables and more precise and reliable spatial and temporal models. Conservation targets for highly mobile species can likely be met by relocating ABMTs, and for sessile/low mobility species, there are a few mitigation options to support short-term conservation efforts.

KER 11 – Mitigation and Adaptation, Ecosystem Functioning, Marine Spatial Planning - Policy Related Result

An expert assessment of risks posed by climate change and anthropogenic activities to ecosystem services in the deep-sea - Our study shows the importance of considering deep-sea ecosystem services for future blue growth, and marine spatial planning in the deep sea, and should also be considered to inform intergovernmental science-policy decisions.

The European Commission, under its Blue Growth Strategy, has been seeking to support sustainable growth in the North Atlantic across five sectors known as Blue Economy: aquaculture, maritime & coastal tourism, blue biotechnology, ocean energy, & seabed mining. However, the balance between societal needs & environmental sustainability required for sustainable Blue Growth poses challenges to economic & policy agendas. We have used the 'Delphi Approach' to consider this delicate equilibrium & assess the potential impacts or risks posed by different human activities on deep-sea ecosystem services. The interactive expert-based survey assesses risks to deep-sea ecosystem services in the North Atlantic Ocean from climate change, pollution, the blue economy, & their cumulative effects. Our results show pollution & temperature change pose a high risk to more than 28% of deep-sea ecosystem services, while over 19% are at high risk from ocean acidification & fisheries. Services considered to be most at risk of being impacted by anthropogenic activities were biodiversity & habitat as supporting services, biodiversity as a cultural service, & fish & shellfish as provisioning services. Our study shows the importance of considering deep-sea ecosystem services for future blue growth, and marine spatial planning in the deep sea, and should also be considered to inform intergovernmental science-policy decisions.

KER 12 – Mitigation and Adaptation, Ecosystem Functioning, Marine Spatial Planning; Ocean Governance - Policy Related Result

New evidence to support the protection of the Tropic Seamount - Our study provides the first biological study to ground-truth the occurrence of potential Vulnerable Marine Ecosystems (VMEs) on the Tropic Seamount in the subtropical North Atlantic Ocean. By combining with predictive models, our work also increases spatial coverage beyond the scope of Remotely Operated Vehicles and Autonomous Underwater Vehicles in the area. Our work contributes new knowledge on the distribution of the hexactinellid sponge *Poliopogon amadou* and their preferred conditions (water depth and current speed), toward the improved understanding of the environmental drivers and biogeography of VME species and sponges in the Atlantic. Our results have implications for spatial management and describing VMEs. A case has been presented toward designating the Tropic Seamount as an Ecologically or Biologically Significant marine Area (EBSA) as a contribution to address biodiversity conservation in Areas Beyond National Jurisdiction (ABNJ).

We have discovered extensive monospecific grounds of *P. amadou* at the Tropic Seamount, located in an ABNJ in the subtropical North Atlantic Ocean. We have produced an ensemble habitat suitability map for *P. amadou* distribution using three different modelling techniques; Maximum Entropy (Maxent), General Additive Models (GAMs), and Random Forest (RF), for the purpose of management applications. These models, and the maps produced, can fill knowledge gaps and provide some guidance, rather than none, on the distribution of VME indicator species and inform on-going high seas management efforts such as maritime spatial planning, environmental impact assessments and the conservation of biogeographically unique provinces. They could also contribute to UN negotiations of a new treaty to protect biodiversity beyond national jurisdiction (BBNJ). Our results improve the understanding of marine VME biogeography that will hopefully lead to better ocean governance and spatial planning in marine exploitation. Our work is particularly important for the International Seabed Authority (ISA) as the regulatory body for seabed activity in Areas Beyond National Jurisdiction and the development of policy tools on the exploitation of minerals.

KER 13 – Preparedness, observing

Low-cost imaging systems to observe the deep sea - Two custom-made underwater camera systems (live-view drift camera and a stereo-baited remote video) have been developed by **ATLAS** partners (IMAR-UAz), in collaboration with the MapGES and iAtlantic projects, allowing greater data collection and spatial coverage at a reduced cost. The design and development of both systems will improve capacity to monitor and explore the deep-sea bed and commercially important fish populations. Scientific or Technological R&D Result including ICT Hardware

KER 14 – Preparedness, predicting; Mitigation and Adaptation, Ecosystem Functioning – Policy Related Result

Predictive maps for future habitat suitability - ATLAS partners have modelled and developed predictive maps of habitat suitability for six cold-water coral and six deep-sea fish species under current conditions and forecast changes under future projected high-emission climate conditions for the whole North Atlantic Ocean. The results forecasted that over 50% of cold-water coral habitat could be at risk, and suitable habitats for commercially important deep-sea fish could shift by up to 100 km northwards. Environmental niche modelling is a valuable tool for forecasting changes in habitat suitability. This approach can help to integrate climate change considerations as part of area-based management decisions or conservation and sustainable use of biodiversity in international areas.

KER 15 – Mitigation and Adaptation, Ecosystem Functioning, Marine Spatial Planning; Ocean Governance - Policy Related Result

Novel Marine Spatial Planning decision support protocol - A novel workflow required to facilitate application to test Blue Growth scenarios in deep-sea areas has been developed by ATLAS partners NUI Galway (Ireland) and the Department of Fisheries and Oceans (Canada), with the MaREI (Observation and Operations Spoke, (Ireland)), in order to inform adaptive management. The workflow supports the implementation of the EU Framework Programme 7 'Monitoring and Evaluation of Spatially Managed Areas' (MESMA) generic planning framework. The workflow enables greater connectivity and interoperability of marine data, increasing the use and exploitation of available data while also identifying gaps that can be filled by novel modelling approaches. The workflow will assist marine spatial planning and the delivery of ecosystem-based management as well as highlighting lacunae and issues to be addressed by ocean governance. ICT Software Digital solution.

KER 16 – Preparedness, observing

Cold-water coral and sponge physiology database - An extensive literature review of 94 papers (31 general publications; 47 specific to ecophysiology of scleractinian CWCs; 4 papers refer to physiological research with other cnidarians species; 13 dealing with DWS) has been conducted by ATLAS researchers. All existing publications on this topic have been compiled into an excel inventory, and data (533 entries) from the publications have been standardised and stored in databases, transforming the vast knowledge into a more user-friendly format. Data on the following processes, standardized to the units indicated in brackets have been included:

1. Food capture and ingestion (mmol C g DW^{-1} d^{-1})
2. Respiration (mmol C g DW^{-1} d^{-1})
3. DOC mucus excretion (mmol C g DW^{-1} d^{-1})
4. POC mucus excretion (mmol C g DW^{-1} d^{-1})
5. Calcification rate/growth rate (mmol C g DW-1 d-1)

This is the **first coherent and standardised database of its kind**. It has been used to develop physiological models of sponges and cold-water corals as a function of food availability and to inform physiological experiments conducted in the ATLAS project. Scientific or Technological R&D Result including ICT Hardware.

KER 17 – Preparedness, observing; Mitigation and Adaptation, Ecosystem Functioning, Marine Spatial Planning

Using eDNA and quantitative PCR to assess biodiversity in the open ocean - ATLAS partners, UCD, have developed a sensitive detection method, a species-specific eDNA assay, to assess biodiversity hotspots for conservation. This was accomplished through the development of a species-specific probe-based qPCR assay for the Chilean devil ray, followed by pilot study to evaluate the capability of this method to determine the presence of this transient pelagic animal in the field based on seawater samples. The Chilean devil ray is IUCN Red Listed as Vulnerable and is difficult to observe in the wild, and difficult to sample without restraining and potentially injuring or killing individuals. The results show that eDNA can be used as a non-invasive, sensitive detection method for monitoring transient pelagic species in the open ocean. This study has important implications for future studies inferring species presence in open ocean environments, including rare or invasive species, and for identifying areas for conservation. Scientific or Technological R&D Result including ICT Hardware.

KER 18 – Preparedness, observing

Quantification of oxygen uptake by cold water coral communities using the non-invasive aquatic eddy covariance approach - ATLAS researchers have developed a new non-invasive method that estimates current velocity and dissolved oxygen concentration to quantify oxygen uptake rates of CWC gardens. Estimates of in-situ oxygen uptake by complex benthic communities at two cold-water coral (CWC) reef mounds at Rockall Bank and, mixed coral garden communities at Condor Seamount, Azores, have been collected using the non-invasive aquatic eddy covariance technique. These estimates provide important insights into local cycling of organic matter, i.e., rates and driving factors, and the carbon requirements of cold-water coral reefs and gardens communities. This method can be used to assess the implications of climate-driven shifts in carbon supply for the local and regional functioning of CWC communities. The **state-of-the-art aquatic eddy covariance (AEC) technique** enables the non-invasive acquisition of high-resolution current velocity and dissolved oxygen time series that are used to quantify benthic oxygen fluxes under the of local hydrodynamic regime. The AEC technique, published in >70 peer-reviewed articles, including 6 within the framework of the ATLAS project, was applied here to CWC communities. Estimates of oxygen uptake rates of mixed coral garden communities, in the Azores, were estimated for the very first time and used to investigate benthic metabolism at the site. The results from this study clearly identified CWC mound communities at the Rockall Bank as habitats of enhanced carbon cycling, when compared to plain deep-sea habitats at analogous depths.

This work provides additional information to help assess the implications of climate-driven shifts in carbon supply for deep-sea ecosystems. Scientific or Technological R&D Result including ICT Hardware

KER 19 – Preparedness, observing

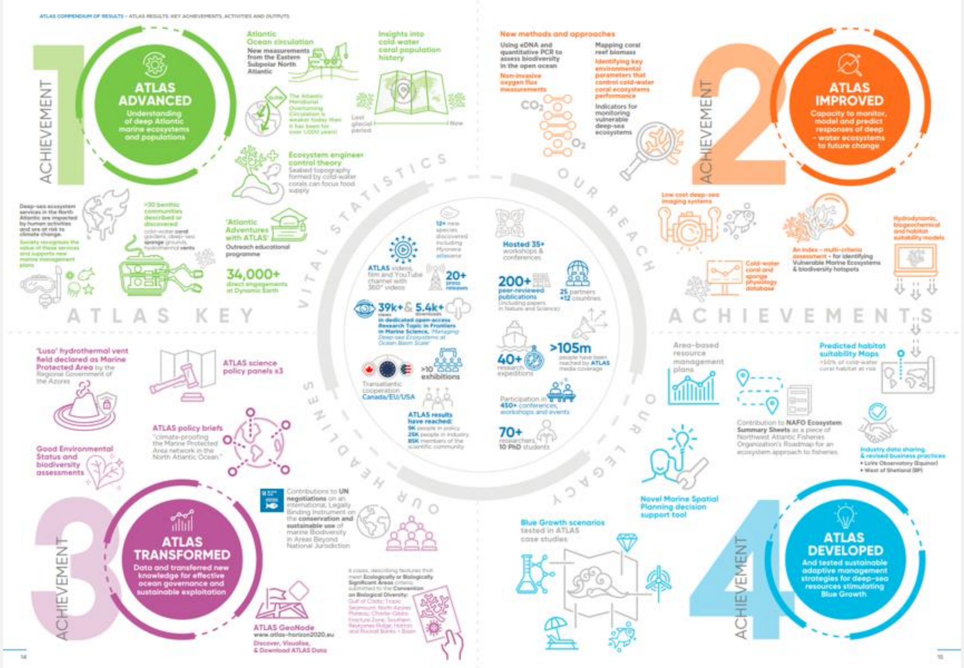
New approach to map coral reef biomass and its usefulness to derive ecosystem functions - ATLAS partners, UEDIN, have developed a new approach to estimate the biomass of important cold-water coral reef species and their contribution to key ecosystem processes such as the carbon cycle. Using High Definition video data, environmental variables extracted from multibeam data and respiration data from literature, the project has mapped the spatial variation of biomass of sponges and coral at the Mingulay reef (Scotland, UK). This study shows that predictive maps can provide valuable insight on the contribution of dominant fauna to carbon turn over at an ecosystem scale & that the Mingulay reef overturns five times more organic carbon as compared to soft-sediment at a similar depth. The methodology has the potential to be applied to other under-water habitats, improving our capacity to measure, monitor and predict changes in the ocean. Scientific or Technological R&D Result including ICT Hardware.

KER 20 – Preparedness, observing

New deep-sea species discovered and described by the EU ATLAS project - Within the framework of the ATLAS project (2016 - 2020), more than 40 research cruises have been conducted leading to the discovery of more than 30 benthic communities, the identification of at least 35 new records of species in areas where they were previously unknown, and 12 new or putative new species to science, including the discovery of a bivalve, *Myonera atlasiana* (dedicated to the ATLAS project). ATLAS partners discovered more than 30 benthic communities, including cold-water coral reefs and gardens, deep-sea sponge aggregations and hydrothermal vents in the North Atlantic Ocean, including the Luso hydrothermal vent field in the Azores. The team has contributed to the identification of at least 12 new or putative new species to science and have found approximately 35 new records of species at the Gulf of Cádiz, Strait of Gibraltar, Alborán Sea, Azores and Davis Strait, Eastern Arctic. Analysis of samples collected during the MEDWAVES expedition led by IEO has highlighted the importance of geomorphological features as biodiversity hotspots, the description of several new species of molluscs, bryozoans and echinoderms, and new records of polychaetes and peracarid crustaceans at mud volcanoes of the Gulf of Cádiz and seamounts in the Alboran Sea. While increasing our understanding of biodiversity in the deep North Atlantic, these discoveries have also had a direct impact on policy and national and international level. For example, the site of the Luso hydrothermal vent has been designated as a Marine Protected Area by the Regional Government of the Azores. Scientific or Technological R&D Result including ICT Hardware

KER 21 – Societal transformation, ocean literacy, Policy Related Result

ATLAS Compendium of Results - summaries the key achievements of the four-year European Union Horizon 2020 ATLAS project: A trans-Atlantic assessment and deep-sea ecosystem-based spatial management plan for Europe (2016 – 2020). This booklet describes the team’s key outputs and activities and outlines the next steps needed to ensure ATLAS’ legacy and long-term impact.



BIGSEA[76]

KER 1 – Governance/Societal Transformation

OPERATIONAL GOVERNANCE TOOLS could be developed from the results of their methodology application, which creates maps of the use of the marine biological resources (fishing) in the High Seas.

KER 2 – Preparedness, modelling, Policy Related result

Well-managed fisheries can provide a buffer against food crises

A new global bioeconomic fisheries model shows that wild-caught fish could serve as a lifesaving resource during a global food emergency – but only if marine ecosystems are in a healthy state to start with. This demonstrates a previously overlooked benefit of good fisheries management: it automatically builds a large backup supply of food in the sea, at no additional cost.

Blue-Action[77]

KER 1 – Societal Transformation

Prioritised climate services may have economic impact if exploited to deliver a societal-service provision, either commercial or not. Although it is too early to see how far would the project take this development, the bases are laid for an **exploitable idea of service provision** to either the citizen as well as businesses that rely on improved forecasting capacity for strengthening their competitiveness. A feasibility study to market-size this kind of application would be required, as a first follow-up, but also the

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[76] Source: 1) Galbraith, E. D., Carozza, D. A., & Bianchi, D. (2017). A coupled human-Earth model perspective on long-term trends in the global marine fishery. Nature communications, 8(1), 1-7.10.5194/gmd-11-1421-2018; 2) Claret, M., Galbraith, E. D., 3) Palter, J. B., Bianchi, D., Fennel, K., Gilbert, D., & Dunne, J. P. (2018). Rapid coastal deoxygenation due to ocean circulation shift in the northwest Atlantic. Nature climate change, 8(10), 868-872; 4) Bryndum-Buchholz, A., Tittensor, D. P., Blanchard, J. L., Cheung, W. W., Coll, M., Galbraith, E. D., & Lotze, H. K. (2019). Twenty-first-century climate change impacts on marine animal biomass and ecosystem structure across ocean basins. Global change biology, 25(2), 459-472.

[77] Source: 1) Blue-Action, Deliverable D5.16 (2017); 2) Payne, M. R., Hobday, A. J., MacKenzie, B. R., Tommasi, D., Dempsey, D. P., Fässler, S. M., ... & Matei, D. (2017). Lessons from the first generation of marine ecological forecast products. Frontiers in Marine Science, 4, 289.10.1038/s41558-018-0105-1; 3) Sgubin, G., Swingedouw, D., Drijfhout, S., Mary, Y., & Bennabi, A. (2017). Abrupt cooling over the North Atlantic in modern climate models. Nature communications, 8, 14375. 4) Årthun, M., Eldevik, T., Viste, E., Drange, H., & Furevik, T. co-authors. 2017. Skillful prediction of northern climate provided by the ocean. Nat. Commun, 8, 15875; Horizon Results Platform.

feasibility should concern the technical aspects of each proposed service development. **Instruments for social engagement, which the project has developed, could be useful for societal transformation purposes.**

KER 2 – Mitigation and Adaptation, foresight scenarios

Use of Strategic Foresight scenarios for regional adaptation: The case of the Yamal region in Arctic Russia – The scenarios for regional adaptation were developed through the 'Strategic Foresight', a specific co-design **methodology** with the goal of supporting regional stakeholders of the Yamal region in Western Siberia, Russia. Yamal is a gas producing region faced with uncertainty regarding future social, political, economic, climate and environmental change. The project's objective was to provide tools to respond to the situation of general uncertainty and to better understand the risks and opportunities associated with future transformations in the Arctic. The **scenarios** encompass climate predictions as well as possible environmental, social and cultural concerns, economic opportunities, and political and legal developments. Project findings can be taken up by stakeholders located in other European and non-European regions, which are facing complex and uncertain situations. The outcomes of the project in forms of scenarios for the Yamal region in Arctic Russia have proven to be useful not only to those stakeholders who participated in scenario workshops, but also for other Yamal stakeholders and can also be relevant for people from other parts of Russia dependent on oil and gas extraction. In terms of societal readiness level, the scenarios provide a socio-technical assemblage acceptable to users, re-tested in their relevant environment and proved to be a good **roadmap for adaptation**.

KER 3 – Preparedness, Mitigation and Adaptation, extreme weather risks (assessment tool)

Extreme weather risks in the Arctic: A web based tool for risk assessment – Prototype of an interactive web map for assessing the risk of polar lows in the Arctic. The demo application is freely available online on a trial basis: https://maps.dnvgl.com/labs/blueaction/. The application is also a tool for driving public consensus to existing and emerging weather-related risks and Arctic impact: extreme weather including polar lows can have severe and lasting impact not only on shipping, but also on coastal infrastructures, local communities, fisheries, port operations, and search and rescue missions.

KER 4 – Mitigation and Adaptation, Ecosystem Functioning, forecasting, climate services

Forecasting fish distribution and abundance in the Atlantic Ocean – The project has worked on the co-development of the first suite of **marine ecological climate services** for Europe for the following fish species**:** Sandeel recruitment, Blue Whiting, Bluefin Tuna, Makrel (Lystfiskeri), and Hornfisk (Garfish). The project's work has focussed **on forecasting fisheries up to a decade into the future**. In some areas (e.g. the North East Atlantic), the project is increasingly able to predict ocean characteristics such as sea surface temperature five years or more into the future. These ocean characteristics play an important role in the timing of migration, spawning, and population dynamics of many economically important fish species.

KER 5 – Preparedness, Policy Related Result – Climate Action – prediction

Key messages for decision-makers: Climate Prediction in the Atlantic-Arctic sector is reaching useful skill levels, and research indicates that there is great potential to further enhance prediction skill. The EU researchers are leading the field, and EU funded projects have contributed to this by helping unite European research. Improving prediction skill requires improved understanding of key processes and development of new more resolved numerical models. Critical to this are sustained long-term observations of the ocean and new observations for validating the new models. Climate modellers need to provide feedback to the observational community on required data, through workshops and by working together in projects. Massive investments are required to develop these new models, as developments in computing infrastructure now outpace development of numerical climate models. To cope with these new challenges the climate researchers need to adopt community models, developed by large-teams, with simulations analysed by the wider scientific community. Climate services based on seasonal to decadal prediction are demanded by stakeholders. The development of useful climate services requires strong interaction between climate researchers and stakeholder partners. Greater awareness among stakeholders of the potential benefits of climate services is required to further accelerate the field.

KER 6 – Preparedness, observation and predictions, Policy Related Result

Key messages for decision-makers: How we can use ocean observations and predictions to respond to the climate emergency – Results emerging from climate models give us the ability to predict changes in the ocean and global climate, and their associated impacts on our society. Blue-Action has shown that these predictions are possible on seasonal to decadal time-scales, which are relevant for businesses, policymakers and communities to plan for the future and address the impacts of the climate emergency. Cutting-edge research by Blue-Action researchers on ocean observations and model projections demonstrates how these results can lead to robust predictions of the physical characteristics and productivity of the ocean and climate up to a decade in advance. These findings can be translated into climate services, providing vital relevant information for diverse industries including conservation, fisheries and transport. These results come from new large-scale ocean observation networks that can quantify changes in the North Atlantic Ocean circulation and the subsequent impact on climate. These sustained observations feed into climate models that show skill in predicting the ocean conditions on a seasonal to decadal timescale. These predictions are a powerful tool for climate adaptation in sectors and regions affected by strong natural climate variability. One such sector is fisheries, where combining biological and oceanographic models allow us to predict fish abundance and distributions years into the future. These results demonstrate the potential to make robust decadal predictions that can be translated into climate services. These can be valuable inputs to decision-making for climate adaptation by policy-makers.

KER 7 – Preparedness, predictions, weather forecasts – Policy Related Result

Prediction of temperature-attributable mortality in Europe using weather forecasts with lead times up to 15 days – Implementing adequate health preventing measures, which have a positive impact on reducing temperature-attributable mortality (TAM), is essential in public health decision making, particularly in a context of climate change and rising temperatures. Yet, these systems have room for improvement. We identified some of the key aspects that could be refined. Stakeholders emphasised the need of a unified and flexible Pan-European service that provides relevant information. They also highlighted the need to include mortality data to model the real impact of weather. Lastly, end-users demanded that the system was able to produce warnings for multiple lead times beyond the traditionally used 1 to 2 days. Hence, to design prototypes of European weather early warning systems that address these needs, our objective was to study the predictability of temperature-attributable mortality in Europe at the regional scale using weather forecasts with lead times of up to 15 days. The project's main finding is that **temperature predictability can be transformed into TAM predictability**. Due to the differences in the temperature-mortality associations, significant differences in the TAM predictability are found across the regions. These differences would not be identified if only temperature forecasts were considered. We have seen better predictability in summer for regions associated with a high risk of mortality for summer temperatures. While for winter, better skill is found in regions with a different temperature-mortality association. Although it depends on the region and season, in general

	TAM can be predicted on weather time scales, as lead times with useful skill are comparable after the transformation of temperature into TAM. In addition, there is a relationship between temperature predictability and TAM predictability, so the project presumes that future improvement in the weather forecasting will directly lead to improvements in TAM forecasting. More detail can be found on the website heathealth.eu. These results are relevant for decision-making, but it is also vital to raise awareness about the risks of ambient temperatures for public health. We specially need collaboration of scientists and meteorological agencies that might be interested in turning the prototype into operational mode. The current prototype can be upgraded for research purposes, or strengthened with real-time forecasts from an eventual future operational version driven by weather and subseasonal-to-seasonal climate forecasts. **KER 8 – Preparedness, predictions, Policy Related Result** **Key messages for decision-makers: what we know and potential impacts of the slowing Gulf Stream –** The Gulf Stream is an ocean current that forms part of the Atlantic Meridional Overturning Circulation (AMOC). It transports heat northwards from the tropics, and is largely responsible for the relatively mild climate of Western Europe. A reduction in overturning circulation could lead to lower temperatures in the North Atlantic Ocean, which would affect the climate in Europe. Understanding the links between the climate and the Gulf Stream, and the implications of any slowing which may occur, is vital for businesses, communities and policy-makers to be able to plan for the future. Research led by Blue-Action suggests that warmer summers in the sub-polar North Atlantic could be contributing to changes in overturning circulation. To progress further in understanding overturning circulation and how it influences Europe’s weather and climate, we need to combine long-term, comprehensive observational programmes with cutting-edge model development. Oceanographers are able to predict the surface temperatures of the North Atlantic Ocean up to a decade in advance, though crucially depending on adequate ocean observations. This suggests that by understanding how the North Atlantic Ocean temperatures influence the climate of Europe, we could extend our prediction horizon to up to a decade in the future. At even longer timescales, a better understanding of physical processes of the North Atlantic Ocean through observational programmes and model development will enable us to anticipate potential abrupt changes to ocean circulation and consequences for the climate in Europe.
BLUE CLOUD[78]	**KER 1: Preparedness, big data, EOV products and virtual reality services and laboratories** **Zoo and Phytoplankton EOV products - Demonstrator 1** The Zoo and Phytoplankton EOV demonstrator provides a description of the current state of the plankton communities and forecasts their evolution, representing valuable information for the modelling, assessment and management of the marine ecosystem. This demonstrator results are presented in three parts: 1. The Phytoplankton EOVs delivers a workflow that allows the development of vertical distribution of chlorophyll-a concentrations - as a proxy for total phytoplankton biomass - using Machine Learning-based methods. 2. The Zooplankton EOVs delivers a workflow that allows the development of interpolated maps of zooplankton abundances in a region encompassing the North East Atlantic, using a DIVAnd software tool. 3. The Scientific Validation delivers a workflow with near real-time data to quantify the relative contributions of drivers in phytoplankton dynamics. Scientific or Technological R&D Result including ICT Hardware.

[78] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/search;keyword=Blue%20cloud

	KER 2: Preparedness, big data **Blue Cloud VRE & Labs** The Blue Cloud VRE is a cyber-platform bringing together and providing access to multidisciplinary data from observations and models, analytical tools, and computing facilities essential to support research aiming to understand better and manage the many aspects of ocean sustainability. Its services include the Enabling Framework, the Collaborative framework, the Analytics Framework and the Publishing Framework. Those services have been exploited to deploy and activate the following VLabs that are specifically conceived to support the developments of the Blue-Cloud Demonstrators. The BlueCloudLab virtual laboratory (TRL 8) provides an open and free access working environment to experiment with Blue-Cloud facilities. **Blue-Cloud Virtual Research Environments** (VRE) to provide computing platforms and analytical services facilitating the collaboration between researchers. Each Blue-Cloud VRE includes services that facilitate collaboration between users, services supporting the execution of analytical tasks embedded in a distributed computing infrastructure, as well as services enabling the co-creation of entire **Virtual Laboratories**, aimed at realising open science-friendly working environments. Thanks to Blue-Cloud, scientists and practitioners are able not only to easily access different sets of marine data but also to process and experiment with them via the analytical and visual tools made available by each demonstrator.
BRIGAID[79]	**KER 1: Preparedness** With the aim to address the need to find innovative solutions as mitigation and adaptation measures to CC, BRIGAID project has led to the realization of a "**Test and Implementation Framework (TIF)**", designed to bring existing innovations to the market, from a Technological Readiness Level (TRL) of 4 (the first complete innovation prototype has undergone basic functional tests to evaluate its performance). A total number of 125 innovations after three stocktaking cycles were evaluated according to their ability to reduce risks from floods, droughts, or extremes, and finally uploaded in the **Climate Innovation Window** (CIW), **a portal created to facilitate the market uptake of climatic resilience innovations** (2). **KER 2: Preparedness** About the impacts of global coastal storm surge events, BRIGAID demonstrates that the adoption of **CC-risk-reducing measures**, including flood protection and forecasting, early warning and evacuation, has led to a steady decline in mortality from storm surges since 1960s,as observed from a compiled record of major global storm surges caused by windstorms for the period 1900–2015 (3).

[79] 1) https://brigaid.eu/; 2) BRIGAID, Stocktaking Report WP2-4 Deliverable 2.4: Stocktaking report of 3th Innovation Cycle including the selections for WP2, WP3 and WP4. 3) Bouwer, L. M., &Jonkman, S. N. (2018). Global mortality from storm surges is decreasing. Environmental Research Letters, 13(1), 014008.

CERES[80]	**KER 1: Preparedness** The approach used within CERES started from the provision of spatially and temporally resolved estimates of climate-driven changes in key physical and biogeochemical parameters in European Seas (NE Atlantic, North, Baltic, Mediterranean and Barents Seas), based on IPCC AR5 scenarios and regionally downscaled climate models (3). The output of the physics models were integrated with the resulting changes in productivity, biology and ecology of key shellfish and fish species, allowing the estimate of climate-related economic losses/gains for both fisheries and aquaculture (i.e. typical farm approach), with the use of bio-economic models. The framework created by CERES conducted to the development of PESTLE (Political, Environmental, Social, Technological, Legal and Economic) scenarios, which provide stakeholders with **possible solutions to increase their adaptation capacity to CC**, representing an important tool to support Blue Growth across Europe (4). **KER 2: Ecosystem Functioning** CERES has investigated the effects of CC on the occurrence of Harmful algal blooms (HABs), which cause toxic effects to higher trophic level species, including fish, shellfish, marine mammals, and humans, with critical consequences for food security and safety. In particular, species distribution modelling results has shown that HABs are likely to occur further north on average around north-west Europe in the coming century, with some species' habitat shifting faster and further than others do. This result has important implications for aquaculture, recreation, and ecosystems of the identified area, suggesting the need to implement specific surveillance and mitigation measures (5)
ClimeFish[81]	**KER 1: Governance** Sustainable Fisheries management must include predicted environmental change in their integrated ecosystem models in order to gain an insight in what the available stocks will be in the near future and thus prepare for the sustainable management of fisheries in a rapidly changing scenario. The science basis is summarised above, while their **prototype Decision Supporting Framework** is already available, as an interim project results, on line.
CONCLIMA[82]	**KER 1: Preparedness** The project has found that the ocean is an active forcing on ice-sheet expansion/retreat. **It should become standard practice to include the ocean as a forcing in paleo-ice-sheet modelling.**

[80] 1) https://ceresproject.eu/; 2)https://cordis.europa.eu/project/id/678193/results; 3) CERES, Deliverable D1.3 Projections of physical and biogeochemical parameters and habitat indicators for European seas, including synthesis of Sea Level Rise and storminess.; 4) CERES, (2016) Exploratory socio-political scenarios for the fishery and aquaculture sectors in Europe. (Eds. Pinnegar J.K., Engelhard G.H.) Deliverable D1.1 - Glossy 'report card' aimed at stakeholders. Centre for Environment, Fisheries & Aquaculture Science (Cefas), Lowestoft, 8pp.; 5) Townhill, B. L., Tinker, J., Jones, M., Pitois, S., Creach, V., Simpson, S. D., ... &Pinnegar, J. K. (2018). Harmful algal blooms and climate change: exploring future distribution changes. ICES Journal of Marine Science, 75(6), 1882-1893.

[81] 1) Serpetti, N., Baudron, A. R., Burrows, M. T., Payne, B. L., Helaouet, P., Fernandes, P. G., & Heymans, J. J. (2017). Impact of ocean warming on sustainable fisheries management informs the Ecosystem Approach to Fisheries. Scientific reports, 7(1), 1-15.; 2) Parmesan, C., &Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. Nature, 421(6918), 37-42.

[82] 1) Caesar, L., Rahmstorf, S., Robinson, A., Feulner, G., & Saba, V. (2018). Observed fingerprint of a weakening Atlantic Ocean overturning circulation. Nature, 556(7700), 191-196.

CRESCENDO[83]	**KER 1: Mitigation and Adaptation** The project shows that the scale of time for new rapid-growth plantations deployment to actually curb CO2 emissions, at the desired level, may compete with other sustainability goals, because of the envisaged requirements for land use. They conclude that protection of existing plantations and natural afforestation may be better options. These lessons could be used also for approaching the **CCS options in the marine environment.**
DENOCS[84]	**KER 1: Mitigation and Adaptation** Novel quantitative laboratory techniques based on bioimaging and micro-environmental sensing (1) were developed to investigate the dynamics and impact sites of NO and H2O2 in corals, coral tissue culture, and isolated photosymbionts subjected to experimental treatments that mimic global change-induced environmental stress scenarios. These studies allowed to demonstrate that under environmental stress the symbiosis between the animal host and the microalgae living within their tissues, responsible of the peculiar colour of corals, breaks down, leading to the bleaching and subsequent dead of the coral itself. In particular, it has been found that the environmental stress generates low levels of oxygen that could stimulate the production of harmful cellular radicals such as NO, affecting the survival of microalgal symbiont (2).
DPath-To-Adapt[85]	**KER 1: Ecosystem Functioning** The study of thermal tolerance of marine macrophytes reported in this project showed that *Posidoniaoceanica*is the most vulnerable species to rising marine temperatures. Although the thermally resilient genotypes of *P. oceanica*were identified in Cyprus, where summer temperatures already exceed the upper thermal limit for western Mediterranean populations, to protect *P.oceanica*from CC impacts specific adaptation solutions are needed to reduce their loss in the Mediterranean region. On the other hands, polar and sub-polar seaweed populations, at Arctic and sub-Arctic latitudes showed broad thermal tolerance, highlighting the potential positive feedback of warming in the region on their growth (1). **KER 2: Ecosystem Functioning, Governance** The study of the response of kelp ecosystems to climate stress, cited by IPCC, pointed out the role of genetic diversity in *underpinning species*

[83] Source: 1) Henson, S. A., Beaulieu, C., Ilyina, T., John, J. G., Long, M., Séférian, R., & Sarmiento, J. L. (2017). Rapid emergence of climate change in environmental drivers of marine ecosystems. Nature Communications, 8(1), 1-9.10.1111/gcb.13680; 2) Bopp, L., Resplandy, L., Untersee, A., Le Mezo, P., & Kageyama, M. (2017). Ocean (de) oxygenation from the Last Glacial Maximum to the twenty-first century: insights from Earth System models. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 375(2102); 3) Burke, E. J., Ekici, A., Huang, Y., Chadburn, S. E., Huntingford, C., Ciais, P., & Krinner, G. (2017). Quantifying uncertainties of permafrost carbon–climate feedbacks. Biogeosciences, 14(12), 3051-3066.; 4) Kwiatkowski, L., & Orr, J. C. (2018). Diverging seasonal extremes for ocean acidification during the twenty-first century. Nature Climate Change, 8(2), 141-145.; 5) O'Neill, B. C., Tebaldi, C., Van Vuuren, D. P., Eyring, V., Friedlingstein, P., Hurtt, G., & Meehl, G. A. (2016). The scenario model intercomparison project (ScenarioMIP) for CMIP6.

[84] 1) Moßhammer, M., Schrameyer, V., Jensen, P. Ø., Koren, K., &Kühl, M. (2018). Extracellular hydrogen peroxide measurements using a flow injection system in combination with microdialysis probes–Potential and challenges. Free Radical Biology and Medicine, 128, 111-123.; 2)https://cordis.europa.eu/article/id/411745-a-better-understanding-of-stress-responses-in-coral-bleaching.

[85] 1)https://cordis.europa.eu/project/id/659246/reporting.; 2) Wernberg, T., Coleman, M. A., Bennett, S., Thomsen, M. S., Tuya, F., &Kelaher, B. P. (2018). Genetic diversity and kelp forest vulnerability to climatic stress. Scientific Reports, 8(1), 1-8.

	performance and ecosystem vulnerability to successfully mitigate impacts of pressures, such as global warming (2). The experimental results showed that genetic diversity consistently outperformed other explanatory variables in contributing to the response of kelp forests to the marine heatwaves provoked by extreme climatic perturbations, *with the heatwave extirpating forests with low genetic diversity*. The "**Community Vulnerability Index"** (CVI) developed within DPaTh-To-Adapt allows the identification of several global hot-spots and safe-spots of climate change vulnerability in shallow ocean systems, highlighting the importance of local adaptation of marine species whose populations of different regions display starkly different climate change vulnerabilities.
ECOPOTENTIAL[86]	**KER 1: Governance** ECOPOTENTIAL has given a fundamental contribution to the implementation of conservation strategies and policies providing innovative and more effective **management and monitoring tools for stakeholders and** policymakers. Particular relevance in CC issues assumes the identification of the biological and ecological Essential Ocean Variables (EOVs) from Earth Observation (EO) and in situ **monitoring** data *to globally assess marine life in a changing ocean (2)* and to *prioritize* ***data collection*** *efforts needed for operational and policy-relevant conservation monitoring systems* (3). To achieve this challenge a bottom-up approach was built, starting from the collection of the existing available data for a series of targeted European and Extra-European Protected Areas, including coastal and marine ecosystems. This activity led to the development of the **Dynamic Ecological Information (DEIM) web-service, a globally comprehensive site catalogue that enables the open access to standardised information for science, politics, citizens and other stakeholders (4).** The open and interoperable access to environmental data is nowadays one of the most powerful tool for knowledge sharing as well as to improve sustainable policies and practices, assured within the project with the development of the GEO Ecosystem Virtual Laboratory Platform (VLab), in compliance with GEOSS (5). To answer to the *Open Science paradigm,* ***VLabis a virtual environment supporting the activities of the ecosystem community-of-practice.*** **Through data brokering and dedicated software technologies, it provides useful information, data, maps, models for supporting evidence-based decision-making in protected areas as well as by end-users in ecological studies.**
EUCP[87]	**KER 1: Preparedness** Although at its early stage, **EUCP** is producing important results for the implementation of the World Climate Research Programme (WCRP), through the launching of **decadal near-term (NT) climate predictions**, every year, providing an important step towards the capacity of anticipating rapid CC scenarios. As shown in their publication (2), NT predictions of temperature and precipitation attained comparable results to those obtained with operational seasonal forecasting. EUCP activities also identify a list of CC

[86] 1) https://www.ecopotential-project.eu/; 2) Miloslavich, P., Bax, N. J., Simmons, S. E., Klein, E., Appeltans, W., Aburto-Oropeza, O., & Chiba, S. (2018). Essential ocean variables for global sustained observations of biodiversity and ecosystem changes. Global change biology, 24(6), 2416-2433.; 3) ECOPOTENTIAL, (2017) Deliverable 2.2 EO-driven Essential Variables.; 4) ECOPOTENTIAL, (2016) Deliverable No: 5.1 Final list of data delivered by PAs. 5) ECOPOTENTIAL, (2016) Deliverable No: D10.1 Design of the ECOPOTENTIAL Virtual Laboratory.

[87] 1)https://www.eucp-project.eu/the-project/; 2) Kushnir, Y., Scaife, A. A., Arritt, R., Balsamo, G., Boer, G., Doblas-Reyes, F., ... &Matei, D. (2019). Towards operational predictions of the near-term climate. Nature Climate Change, 9(2), 94-101.; 3) EUCP, Deliverable D4.1 + MS15 Review of user needs and list of impact indicators.

	indicators as a basis to identify new potential climate products (i.e. the number of heat days compared to the seasonal mean temperature) for different sectors and end-users (i.e. tourism, agriculture) (3).
EVOLMarine[88]	**KER 1: Adaptation and Mitigation** Studies on a marine worm in controlled conditions and ocean warming conditions showed that it was able to retain high levels of adaptive within-generational plasticity, despite being exposed to highly selective, constant global change scenarios over multiple generations. These findings lend support to the feasibility of conservation approaches that employ an evolutionary perspective. This **"Assisted Evolution"** technique has been championed as one potential means of conserving Earth's biodiversity in the face of the ongoing global change. **Thermal Habitat Suitability Index** for common and rare species may serve to guide biodiversity conservation strategies. From the project's experiments, it emerges that rare species are less likely to adapt and can be severely threatened by change, especially considering that escape routes to suitable environmental conditions may also be blocked by geographical barriers (e.g.: closed or semi-enclosed basins).
GlobalMass[89]	**KER 1 - Preparedness** While the potential contributions of ice sheets to SLR remain the largest source of uncertainty in projecting future SLR, authors recommend planners and governors to account for a SLR of 2m, for the 21st Century.
HYDRALAB+[90]	**KER 1: Mitigation and Adaptation** **HYDRALAB+** gave access to a large number of researchers to hydraulic and hydrodynamic experimental facilities, allowing to establish design criteria and performance limits of new solutions specifically addressed to CC adaptation. An interactive tool that provides access to online inventories was developed to easily examine the available facilities and instruments (1). Among them, those particularly useful to analyse **coastal processes**, ice, fluvial, and coasts and vegetation within CC scenarios were identified (2). **Innovative measurement techniques and methodological protocols were tested to incorporate the biological component into physical models** (3). Scaled modelling studies were performed to capture the bio-geomorphological response of systems exposed to climate change impact, over decadal timescale, which is adequate to investigate CC-adaptation measures (4). Lastly, Large-scale experiments allowed investigating the mechanisms of iceberg-tsunamis calving, which represent a potential risk for human being and coastal infrastructures (5).

[88] 1) Gonzalez, A., & Bell, G. (2013). Evolutionary rescue and adaptation to abrupt environmental change depends upon the history of stress. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1610), 20120079.

[89] 1) Bamber, J. L., Oppenheimer, M., Kopp, R. E., Aspinall, W. P., & Cooke, R. M. (2019). Ice sheet contributions to future sea-level rise from structured expert judgment. Proceedings of the National Academy of Sciences, 116(23), 11195-11200.

[90] 1) HYDRALAB+, Deliverable 6.2 Foresight study: experimental facilities for study of climate change and adaptation.; 2) HYDRALAB+, Deliverable 3 - D3-V Knowledge platform providing access to the online Inventories.; 3) HYDRALAB+, Deliverable 8.Critical review of challenges for representing climate change in physical models Numerical modelling of bio geomorphological interactions in the context of climate adaptation; 4) HYDRALAB+, Deliverable D5-XIII - Minutes of the 3rd Advanced Workshop JRA1 - Scaling morphodynamics in time.; 5) Heller, V., Chen, F., Brühl, M., Gabl, R., Chen, X., Wolters, G., & Fuchs, H. (2019). Large-scale experiments into the tsunamigenic potential of different iceberg calving mechanisms. Scientific reports, 9(1), 1-10.

IMPREX[91] [92]	**KER 1: Preparedness, Governance** The efforts made within this project in high resolution modelling provide significant advances towards a more effective **water risk management and adaptation planning capacity to face the occurrence of extremes in Europe, through the analysis of compound events, defined as the combination of multiple climate drivers and hazards**. Moreover, the strong synergy with strategic stakeholder sectors has ensured a better calibration of the climate information according to their needs. However, the methods and tools developed within the project have not been applied to marine regions thus their linkage with ocean climate models could help improve predictions. **KER 2: Preparedness** The improvement of weather forecasts is fundamental for the development of future climate scenarios at regional scale. The efforts made within this project in high resolution modelling provide significant advances towards a more effective water risk management and adaptation planning capacity to face the occurrence of extremes in Europe, through the analysis of compound events, defined as the combination of multiple climate drivers and hazards (3). Moreover, the strong synergy with strategic stakeholder sectors has ensured a better calibration of the climate information according to their needs. However, the methods and tools developed within the project have not been applied to marine regions thus their linkage with ocean climate models could help improve predictions.
INTAROS[93]	**KER 1 – Governance/Societal Transformation** The "**Pan Arctic Observing Forum**" is an instrument for local community engagement and societal transformation, at the regional level.
MARmaED[94]	**KER 1: Preparedness** Significant advances have been obtained in **forecasting the extreme ocean warming events**, known as marine heat waves (MHW), in the Mediterranean Sea, considered as a Hotspot region for CC. The work, cited by SROCC IPCC Report, showed a worrying increase in intensity and frequency of MHWs in the near future. Looking at the 2100, RCP8.5 projections indicated *the occurrence of long-lasting MHW every year to affect the entire basin, up to three months longer from June-October, about 4 times more intense and 42 times more severe than present-day events* (2). The project

[91] 1) Zscheischler, J., Westra, S., Van Den Hurk, B. J., Seneviratne, S. I., Ward, P. J., Pitman, A., ... & Zhang, X. (2018). Future climate risk from compound events. Nature Climate Change, 8(6), 469-477.

[92] 1) https://www.imprex.eu; 2) IMPREX, Final Technical Report.; 3) Zscheischler, J., Westra, S., Van Den Hurk, B. J., Seneviratne, S. I., Ward, P. J., Pitman, A., ... & Zhang, X. (2018). Future climate risk from compound events. Nature Climate Change, 8(6), 469-477.

[93] Source: 1) Kohnert, K., Serafimovich, A., Metzger, S., Hartmann, J., & Sachs, T. (2017). Strong geologic methane emissions from discontinuous terrestrial permafrost in the Mackenzie Delta, Canada. Scientific reports, 7(1), 1-6; 2)) Sejr, M. K., Stedmon, C. A., Bendtsen, J., Abermann, J., Juul-Pedersen, T., Mortensen, J., & Rysgaard, S. (2017). Evidence of local and regional freshening of Northeast Greenland coastal waters, Sci. Rep.-UK, 7, 13183.; 3)) Pecl, G. T., Araújo, M. B., Bell, J. D., Blanchard, J., Bonebrake, T. C., Chen, I. C., ... & Falconi, L. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science, 355(6332), eaai9214.

[94] 1)https://cordis.europa.eu/project/id/675997/; 2) Darmaraki, S., Somot, S., Sevault, F., Nabat, P., Narvaez, W. D. C., Cavicchia, L., ... & Sein, D. V. (2019). Future evolution of marine heatwaves in the Mediterranean Sea. Climate Dynamics, 53(3-4), 1371-1392.; 3) Pershing, A. J., Record, N. R., Franklin, B. S., Kennedy, B. T., McClenachan, L., Mills, K. E., ... & Wolff, N. H. (2019). Challenges to natural and human communities from surprising ocean temperatures. Proceedings of the National Academy of Sciences, 116(37), 18378-18383.; 4) MARmaED, Trait-based indicators of fish community composition and change. 5) MARmaED, Deliverable D1.6 Trait-based indicators of fish community composition and change.

	also analysed the potential of human and ocean systems to adapt to such changes, suggesting that the *"forward-looking strategies"* will increase probability of success for humans, while a homogenization can be expected for the marine species mix, with specialists being replaced by generalist for marine ecosystems can (3). **KER 2: Mitigation and Adaptation** A new methodology for the **assessment of vulnerability in fish species due to CC**, identifying the most important drivers of their community-trait composition (4). The application of the ***traits-based approach***, which describes species and communities basing on their functional traits(size, growth and reproduction), on the Atlantic cod evidenced that increasing temperatures and higher fishing pressure could lead to reduce this species resilience, with higher probability of a catastrophic collapse for the majority of the cod stocks in the Baltic Sea (5).
MELOA[95]	**KER 1: Preparedness, observation drifters** **WAVY Ocean drifters reveal unusually strong surface currents as response to the onset of a storm; WAVY Ocean drifters open the way to effectively track oil slicks and plastic debris** Seven WAVY Ocean drifters were deployed in the Balaric Sea and successfully recovered during the Calypso22 exercise coordinated by the NATO CMRE, La Spezia, Italy. After two weeks of calm seas (wave height 0.5-1.5m) and eddy dominated dynamics, an easterly storm raised the wave height to 3-4m and forced surface currents of up to 0.8m/s, occasionally appearing to exceed 1m/s. Such high current values occurred in the upper 14cm of the Ocean, the surface sub-layer tracked by the WAVY Ocean, where the (wave-induced) Stokes drift and even the wave breaking effect add to the wind-induced surface current. Were there any plastic debris or oil slicks at the surface and they would also be displaced at similar velocities which 1-5m drifters would have failed to detect. Scientific or Technological R&D Result including ICT Hardware **KER 2: Preparedness, observation drifters** The **WAVY Operation software** is an integrated platform for collection, management, processing, annotation, curation and visualization of the georeferenced data collected by the WAVY drifters in the context of scientific campaigns. Among other features, WAVY Operation Software includes Organization and User authorization management, Campaign and deployments planning and operation, Visualization of near-real time and historical datasets, Model processing, Datasets curation with outliers annotation, and datasets sharing. **KER 3: Preparedness, observation drifters** The **MELOA Geoportal** (https://geoportal.ec-meloa.eu) is an online, map based, data visualization tool for the public data stored in the WAVY's online Catalogue. The main purpose of the MELOA Geoportal is to enable end-users the exploration and visualization of WAVYs data in an easy-to-use way, targeting diverse audiences: From marine scientists to citizens and general public. The usability and user experience have been one of the main objectives to be addressed, bringing user experience research methods to the design process to provide a user-centred perspective during software development.

[95] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/search;keyword=MELOA

	KER 4: Preparedness, observation drifters **Cost effective, multi-purpose surface drifter for open ocean deployments.** **WAVY Ocean** is equipped with satellite communications, GPS/GNSS, IMU and payload sensors capable of measuring the temperature (sea-surface and near surface gradient), the wave height and direction and the air pressure. WAVY Ocean as a battery lifetime of 140 days (wave data every 3 hours) or 77 days (wave data every hour). The data is processed on-board and transmitted via satellite to the web-based WAVY Operation Software and Data Catalog. The solar panel is used to harvest energy allowing to recover the units even when the battery is empty.
MERCES[96]	**KER 1: Societal Transformation, ocean literacy, Ecosystem Functioning – Policy Related Result** **MERCES dissemination and communication: when science engages society at different levels - MERCES has provided two typologies of newsletter to stimulate the** interest for the ecological restoration to different target audience: one for citizen science and academia, one dedicated to private/public industrial stakeholders and regulating authorities who wish to put their business at the heart of the Restoration Agenda (and linked to the MERCES' Business Club). Through the newsletters, MERCES disseminates 1) results of scientific research and field studies, 2) how citizens can have an active role in restoring marine ecosystems, 3) awareness for the need to restore marine habitats and 4) know-how on best practices and tools for a "marine ecosystem restoration business". MERCES newsletters engage society at different levels presenting different aspects of the ecological restoration. Newsletters inform on the ongoing pilot studies of restoration in different marine ecosystems: from the seagrass meadows and macroalgal forests, to the coralligenous habitats and the deep sea. Newsletters aim also to stimulate the interest of industries (i.e., flood defence, coastal management, carbon trading, oil and gas, ports and harbours, mining) and regulating authorities, belonging to the sectors identified in the EU's Blue Growth strategy, to extend business opportunities in marine restoration. Some case studies of active restoration projects show the positive effects on restoration when scientific research and business groups work together. This strict collaboration drives innovation and address the challenge of the Blue Growth. Citizen science is important to improve the awareness of experts and no-experts on the recovery and conservation of the marine ecosystems. A MERCES newsletter reports the fruitful collaboration between researchers and SCUBA divers to save an iconic seascape in the Medes Islands (Spain) and in the Gallinara Island (Italy). **KER 2: Ecosystem Functioning – Policy Related Result** **Multi-disciplinary implications of marine ecosystem restoration in changing European Seas -** MERCES has been designed to assess the outcomes of different solutions for marine restoration; determine the degree of their effectiveness along with socio-economic cost-benefit analyses; and define legal, policy and governance frameworks of restoration action. MERCES has developed approaches and guidelines to restore marine ecosystems from shallow soft and hard bottom to the most remote parts of European seas, the deep sea, which is increasingly impacted by human activities. The high number of case studies has allowed to test different restoration protocols in different environmental and governance conditions, identifying gaps of knowledge and the best and successful practices in terms of ecosystem service recovery. MERCES has contributed to enhance social awareness about the

[96] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/search;keyword=merces

	societal need of marine restoration also in terms of natural capital. The ecological restoration is an useful tool for achieving the Good Environmental Status in different marine ecosystems according to the MSFD, contrasting biodiversity loss as in the EU Biodiversity strategy, protecting the health, natural capital and services of European seas, and enhancing their resilience to global change, providing new business opportunities. The legal and governance support is a priority to allow the identification of the best policies to facilitate the restoration actions at different levels of governance along the EU seas. Before to start any restoration we have to identify the best practice to apply in relation to the environmental/social characteristics of the region and the cause/pressure that can limit the success and effectiveness of the restoration. Along with the recovery of the natural capital, the identification of the good, services return, and their implications for society are priorities. Restoring marine habitats is potentially difficult and costly, and knowledge about what makes restoration a success and why and when it fails is important in order to enhance conservation capacity and economic sustainability of the ecological restoration. **KER 3: Governance, Ecosystem Functioning – Policy Related Result** **MERCES project: putting business at the hearth of the restoration agenda -** The webinar series of the MERCES Business Club brings together businesses, policy makers, decision takers and scientists with an interest in marine ecosystem restoration from the coastal zone to the deep sea. The webinars have featured @Getting Better Value from Our Coasts', 'Private Finance in Marine Ecosystem Restoration', 'Ecosystem Restoration in Deep Water' and 'Building a Business Case for Marine Ecosystem Restoration'. Recent developments have seen the growth of private sources of finance for restoration and conservation of biodiversity in marine ecosystems. The Northern coast of Norway is the example of the initiative from private industry to make commercial use of sea urchins to restore kelp forest in the region. The decommissioning of the obsolete oil and gas platforms from the ocean are to be paid for through taxation, and therefore there are significant societal interests in the process, especially in relation to fisheries and planning of marine space. Deep-sea mining is expected to increase in the near future and a priority is to address restoration actions early during the exploration phases of mining. The MERCES Business Club aims to stimulate greater appreciation of best practice in marine restoration between businesses, policy makers and scientists. The Business Club includes a more than 350 private and public major industries, such as civil and coastal engineering companies, offshore oil and gas, ports and harbours and renewable energy providers, and government contacts with responsibilities in coastal and marine environmental management around Europe. The MERCES Webinar series has provided a cost effective method for communicating with European businesses, and especially SMEs, saving cost and time for travelling to meetings. MERCES has featured best practice of marine restoration in the business-focused newsletters. MERCES has demonstrated that marine ecological restoration is possible and feasible, and should be encouraged in terms of policies, economic implementation and new job opportunities.
MESOPP[97]	**KER 1: Preparedness** The project uses acoustic data, in collaboration with Australian Institute to come up with a standardised methodology. The methodology needs further development to overcome barriers and, if successful, could **strengthen the predictive capacity of biomass distribution models at the global level, based on regional-base assumptions of biomass communities**.

[97] 1) Proud, R., Cox, M. J., & Brierley, A. S. (2017). Biogeography of the global ocean's mesopelagic zone. Current Biology, 27(1), 113-119.

NITROX[98]	**KER 1:Mitigation and Adaptation Measures** "Perhaps our most important finding was a feedback regulation between N2 fixation, primary production by algae and cyanobacteria, and their degradation after they die and sink out of the surface water," Dr Löscher explains. "This means that oxygen-poor conditions favour N2 fixation, in turn allowing algae to grow and resulting in deoxygenation." This process would, in principle, cause oxygen-poor waters to continuously expand. But it's not the case" NITROX demonstrates that the extreme anoxia due to hydrogen sulfide being produced in deoxygenated waters actually stops N2 fixation. As a result, no more organic material is produced and exported, and oxygen consumption in deeper waters decreases. "This is the first evidence of a feedback cycle driven by bacteria, which can counteract one of the consequences of climate change – namely ocean deoxygenation."
NUNATARYUK[99]	**KER 1: Societal transformation** The project is preparing a map of the vulnerabilities of the local socio-economic pillars, including water quality (relevance for GES), human and animal health, and, last but not least, infrastructures.
OceanLINES[100]	**KER 1: Ecosystem Functioning** Although the experimental work did not allow to address the initial aim of the proposal of developing a new methodology to apply satellite fluorescence data to the study of phytoplankton nutrient limitation, significant advances have been achieved in understanding processes of nutrient limitation, ocean fertilisation and their influence on climate predictions. In particular, the work conducted in the tropical North Atlantic has revealed the role of iron in controlling the coupling between oceanic nitrogen and phosphorus cycles, having important consequences in predicting the future phytoplankton responses to the anthropogenic input of these nutrients (2).
OSeaIce[101]	**KER 1: Preparedness, observation, modelling** **Observation-based selection of climate models projects Arctic ice-free summers around 2035** Arctic sea ice has been retreating at an accelerating pace over the past decades. Model projections show that the Arctic Ocean could be almost ice free in summer by the middle of this century. However, the uncertainties related to these projections are relatively large. Here the project uses 33

[98] 1) Grundle, D. S., Löscher, C. R., Krahmann, G., Altabet, M. A., Bange, H. W., Karstensen, J., ... & Fiedler, B. (2017). Low oxygen eddies in the eastern tropical North Atlantic: Implications for N 2 O cycling. Scientific reports, 7(1), 1-10.

[99] 1) Biskaborn, B. K., Smith, S. L., Noetzli, J., Matthes, H., Vieira, G., Streletskiy, D. A., ... & Allard, M. (2019). Permafrost is warming at a global scale. Nature communications, 10(1), 264.

[100] 1)https://cordis.europa.eu/project/id/658035/; 2) Browning, T. J., Achterberg, E. P., Yong, J. C., Rapp, I., Utermann, C., Engel, A., & Moore, C. M. (2017). Iron limitation of microbial phosphorus acquisition in the tropical North Atlantic. Nature communications, 8(1), 1-7.

[101] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/search;keyword=OSeaIce

	global climate models from the Coupled Model Intercomparison Project 6 (CMIP6) and select models that best capture the observed Arctic sea-ice area and volume and northward ocean heat transport to refine model projections of Arctic sea ice. This model selection leads to lower Arctic sea-ice area and volume relative to the multi-model mean without model selection and summer ice-free conditions could occur as early as around 2035. These results highlight a potential underestimation of future Arctic sea-ice loss when including all CMIP6 models. Scientific or Technological R&D Result including ICT Hardware. **KER 2: Preparedness, observation, modelling** **Impact of ocean heat transport on the Arctic sea-ice decline** The project used the EC-Earth global climate model to carry out model simulations in which the ocean heat transport was increased compared to a control run, resulting in a loss of Arctic sea-ice area and volume. It found that for a same amount of ocean heat transport increase, the loss of Arctic sea-ice volume was stronger if the sea-surface temperature was raised in the North Pacific Ocean compared to the North Atlantic Ocean. The recent increase in Atlantic and Pacific ocean heat transports has led to a decrease in Arctic sea-ice area and volume. The project uses the EC-Earth3 coupled global climate model and perform different sensitivity experiments to gain insights into the relationships between ocean heat transport and Arctic sea ice. We show that the wider the domain in which the sea-surface temperature is increased and the larger the level of warming, the larger the increase in ocean heat transport and the stronger the decrease in Arctic sea-ice area and volume. The project also finds that for a same amount of ocean heat transport increase, the reductions in Arctic sea-ice area and volume are stronger when the sea-surface temperature increase is imposed in the North Pacific, compared to the North Atlantic. This is explained by the lower-salinity water at the Bering Strait and atmospheric warming of the North Atlantic Ocean in the Pacific experiments. Finally, the project finds that the sea-ice loss is mainly driven by reduced basal growth along the sea-ice edge and enhanced basal melt in the Central Arctic. Scientific or Technological R&D Result including ICT Hardware.
PRIMAVERA [102]	**KER 1: Preparedness, modelling** The project's results provide significant benefits to the reduction of inter-model spread for the production of more robust high-resolution projections, constituting the European contribution to a CMIP6 High-resolution Model Inter-comparison project (HIRESMIP). This is being used to improve understanding of the drivers of variability and change in European climate, including high impact events, since such regional changes continue to be characterised by high uncertainty. The project also gives a valuable insight into the adaptation of climate data/information to the needs of specific sectors such as energy, transport, insurance, water, agriculture and health ones through the analysis of ad hoc climate projection case studies. The outcome of this advance in climate research is to allow for better planning, improved deployment of resources and strengthen their risk management decisions.

[102] 1) Massonnet, F., Vancop penolle, M., Goosse, H., Docquier, D., Fichefet, T., & Blanchard-Wrigglesworth, E. (2018). Arctic sea-ice change tied to its mean state through thermodynamic processes. Nature Climate Change, 8(7), 599-603.; 2) Goosse, H., Kay, J. E., Armour, K. C., Bodas-Salcedo, A., Chepfer, H., Docquier, D.& Park, H. S. (2018). Quantifying climate feedbacks in Polar Regions. Nature communications, 9(1), 1-13.

	KER 2: Preparedness, modelling **PRIMAVERA** has produced important advances in understanding Arctic sea-ice change. The application of a process-oriented approach has highlighted the major role played by thermodynamic processes in sea-ice dynamics, suggesting that the recent and projected reductions in sea-ice thickness induce a transition of the Arctic towards a state with enhanced volume seasonality but reduced interannual volume variability and persistence, before summer ice-free conditions eventually occur (1). Moreover, the quantification of feedbacks on polar climate by considering the interactions between the different components of the polar systems (atmosphere, sea ice, ice sheets, land surfaces and ocean) provides a powerful tool for the reduction of the uncertainties of future climate projections (2). The results obtained in this field open up new opportunities for improving our understanding of OCN dynamics and to identify the relative contribution of various processes to observed CC.
SOCLIMPACT [103]	The SOCLIMPACT project aims at developing an innovative interdisciplinary methodology to deal with the economic impacts of climate change (CC) on the main Blue Economy sectors of European islands. **KER 1: Mitigation and Adaptation (adaptation to SLR) – Policy Related Result** **The impact of Sea Level Rise on ports' disruption costs: Evidence from European Islands** – The costs have been calculated with reference to 1meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of all port infrastructures in the islands, which also depend on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, the project has assumed that a 1 m increase in port height is required to cope with the SLR under the RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality. The rising sea levels will affect the maritime transport sector, thus new investments will be needed to keep ports' operability in the future. Under the high emissions scenario (business as usual), the costs of inaction could increase by 16 million euros per year, by the end of the century. The starting point was the identification of the principal ports in each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1-meter elevation). Thus, the costs of 1-meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports areas of the entire area should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all ports' infrastructures' in the island for 125 years time horizon. No discount rate has been applied. **KER 2: Mitigation and Adaptation (energy demand) – Policy Related Result** **Climate change effects on energy demand for cooling buildings and desalinate sea water: Evidence from European islands** - Results show that the impact of climate change is considerable, especially the one associated to an increase in demand for desalination energy due to change in precipitation and temperatures. Changes range from moderate in Cyprus (from

[103] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/search;keyword=soclimpact

3% to 8.9%) to very high in the Canary Islands (from 60.2% in RCP2.6, near future to 103.3% in RCP8.5, distant future). The increase in demand due to change in cooling degree days is less important, as it is partially outbalanced by a decrease in demand for heating degree days. Change in energy demand goes from about 4% to 6% in the two different time horizons of RCP2.6, and from 8.2% (Malta, near future) to 38.3% (Canary Islands, distant future) for RCP8.5.

KER 3: Mitigation and Adaptation, socio-economic aspects – Policy Related Result

Socio-economic implications of climate change: Application of GINFORS- GEM-3-ISL models to European Islands – Changes in the mean temperature, sea levels and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. These impact-chains, examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2ºC by the end of the century, and RCP8.5, a high-emission scenario, have been used as inputs in the macro-economic models. The effects on 14 sectors of economic activity, GDP, consumption, investment and employment of nine European Islands are analysed. The **GEM-E3-ISL model** also provides an endogenous representation of labour market and trade flows.

In total 18 scenarios have been quantified for Madeira, Cyprus, Crete, Malta, Sardinia, Sicily, Azores, Balearic and Canary Islands. The scenarios can be classified in the following categories:

1. Tourism scenarios: examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of the marine environment, increased risk of forest fires and beach reduction.
2. Energy scenarios: examine the impacts of increased electricity consumption for cooling purposes and for water desalination.
3. Infrastructure scenarios: examine the impacts of port infrastructure damages.
4. Aggregate scenarios: examine the total impact of the previous-described changes in the economy.

The assessment suggests that islands should intensify their efforts for economic diversification, promoting local products and small manufacturers. The exercise shows the importance of modelling all Islands individually, because the reactions to climate change and the damages in the respective sectors differ widely across islands and from the main countries.

KER 4: Mitigation and Adaptation (aquaculture) – Policy Related Result

The impact of increased sea surface temperatures caused by climate change on aquaculture production - The effects were calculated using a lethal temperature threshold by specie and considering the production share of each region. It was utilised the forecast of the water temperature increase in four IPCC scenarios (RCP2.6 near, RCP2.6 distant, RCP8.5 near, RCP8.5 distant), which correspond to four water temperature increases in every region. We assume that the biomass in each species is regulated by a thermal function, and that the monthly production depends on the monthly water temperature in every region. Overall, the great heterogeneity of results among islands, scenarios and time horizons highlights the importance of downscaling climate projections and of adapting them to the different economic characteristics of the islands. In this respect, it is also important to underline that economic projections also substantially differ between islands of the same region (Mediterranean Sea; Atlantic Ocean), once more calling for specific in-depth investigation of each territory. The islands that show negative impacts is due to the representative proportions of the production of tuna and mussels, which are the most affected species.

	KER 5: Preparedness, hazards – Policy Related Result **Climate Change Outlook: Projected changes on hazard indicators for 12 EU islands until 2100 -** Soclimpact project provides downscaled information on the impacts of climate change on the blue economy of 12 EU islands. Also, it addresses the problem of an evident lack of high-resolution wave simulations comprising the Atlantic islands, by the expansion of the Med-Cordex database and the size of atmosphere-ocean coupled simulations, not published as of today. The decreased uncertainty about CC impacts on the Blue Economy and about the costs of adaptation will increase the potential for innovation and knowledge of the sea behaviour in the coming years. It is important to note that Atlantic islands lie in very critical areas where global models might be inaccurate in predicting the large scale patterns (regional models are not available), and resolution is so coarse that in fact many islands don't even exist in model orography. The new CMIP6 simulations might shed more light on this issue; the project suggests that results should be updated as they become available. Stakeholders should be made aware that uncertainty is an inherent characteristic of climate data, and that any future planning must cope with it. Users can check climate hazards projections for 12 EU islands and outermost regions, with relevance to four blue economy sectors (tourism, aquaculture, energy and maritime transport). Physical changes and their evolution have been projected under RCP2.6 and RCP 8.5 scenarios and for two periods (2046-2065) and (2081-2100). **KER 6: Mitigation and Adaptation (tourism) – Policy Related Result** **Assessing tourists' response to Climate Change impacts on EU islands -** Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictability of the effect that certain adaptation policies and risk management strategies can have at island destinations, and develop their plans accordingly, thus leading to an increased empowerment of the behavioural theory to raise the effectiveness of climate and environmental policies. In order to illustrate the results, the project has designed a set of infographics for each island. **Estimated tourism revenues for implementing Adaptation Policies at European islands** – The project analysed tourists' willingness to pay for the potential adaptation and mitigation policies that could be implemented at islands destinations to overcome Climate Change impacts occurring at these locations. A total of 2528 tourists were surveyed at 10 European island destinations (Azores, Madeira, Canary Islands, Balearic Islands, Malta, Sicily, Baltic Islands (Fehmarn), Antilles (Martinique and Guadeloupe), Cyprus and Crete). The results from the surveys, combined with the total number of tourists visiting all these islands, represent the amount of extra tourism revenues the European islands could obtain in the case of implementing the studied policies.
SIM4NEXUS [104]	**KER 1: Preparedness** To address the goal of securing an efficient and sustainable use of resources, a Serious Game has been set up, tested in 12 case studies, involving practitioners from policy, business, civil society and research. Important results have been obtained in the multi-disciplinary analysis of future CC scenarios through a model to track the roadmaps towards a zero carbon economy (2). A model ensemble assessment of the combined effects of CC and climate mitigation efforts on food showed that by 2050, stringent climate

[104] 1) https://www.sim4nexus.eu/; 2) SIM4NEXUS, D1: Review of thematic models and their capacity to address the nexus and policy domains. 3) Hasegawa, T., Fujimori, S., Havlík, P., Valin, H., Bodirsky, B. L., Doelman, J. C., & Mason-D'Croz, D. (2018). Risk of increased food insecurity under stringent global climate change mitigation policy. Nature Climate Change, 8(8), 699-703.

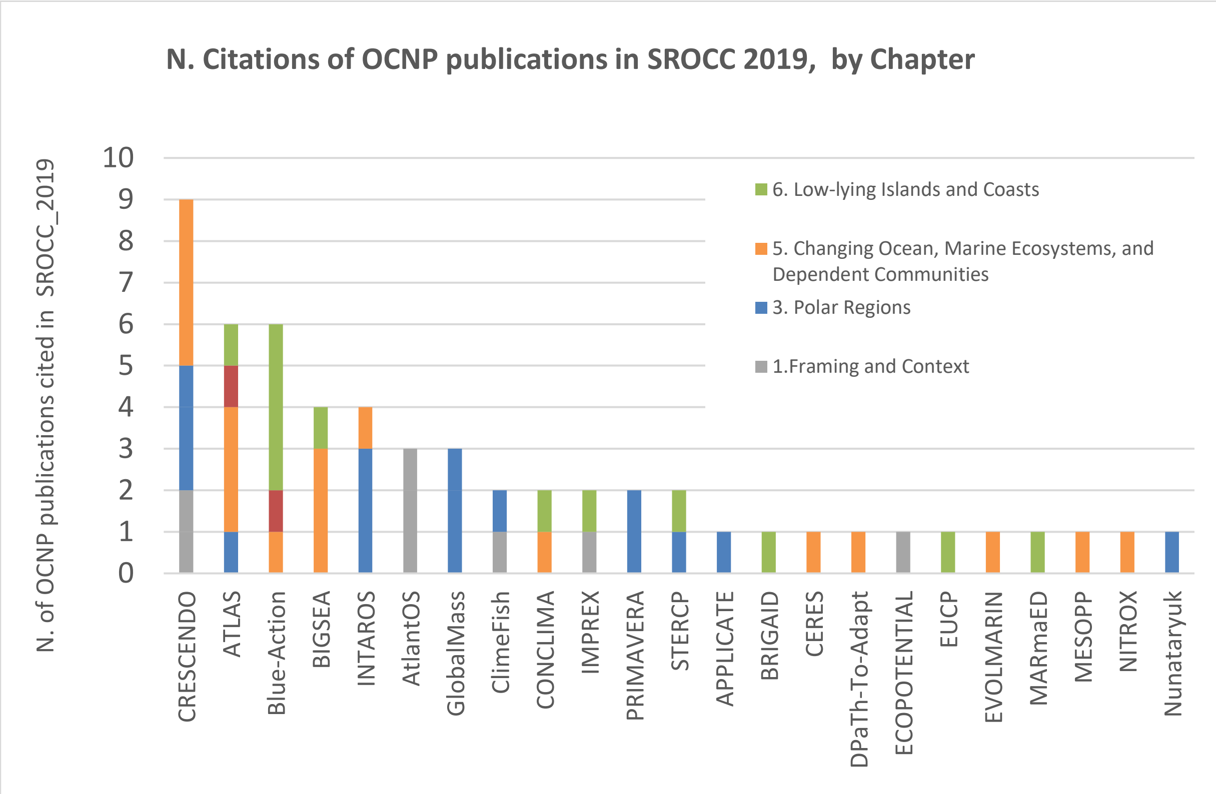
	mitigation policy would have a greater negative impact on global hunger and food consumption than the direct impacts of CC (3).
SponGES[105]	**KER 1: Ecosystem Functioning, Governance** **SponGES** results contribute to provide biodiversity data, freely available through the SponGIS data portal (2), compliant with international standards, to be used for the implementation of the MSFD, the EU Maritime Strategy for the Atlantic Ocean Area, the Galway Statement on Atlantic Ocean Cooperation, as well as the international agreements established to conserve **Vulnerable Marine Ecosystems** (VMEs) and Ecologically or Biologically Sensitive Areas (EBSAs). In particular, **a new Multi-Criteria Assessment (MCA) method was developed for the identification of VMEs in the NE Atlantic that integrates the VME database compiled by the International Council for the Exploration of the Sea (ICES)** (3). **Key Exploitable Result 2: Biological Resources** In the last years, marine sponges have been identified as an important source of thousands of novel chemicals with pharmaceutically relevant properties. The investigation of new optimized culture media for sponges cell lines represents a breakthrough for marine biotechnology, enabling for the first time their increase in the rate and number of cell divisions in laboratory (4). Three promising compounds for their anti-fouling activities were extracted from sponges: the barettin, the barrettides and the ianthelline, particularly active against human pathogenic bacterial strains (4). Moreover, a deep insight in the study of the genomic resources of sponges as well as the assessment of their **microbiome** allowed to answer **some ecological questions on marine food web and nutrient recycling** (5).
STERCP[106]	**KER 1: Preparedness** **STERCP** applied a "supermodel" approach, based on advanced machine learning algorithms, to climate research. With the aim to improve climate predictions, the project combined climate models dynamically, largely reducing the error that have persisted across generations of climate models (1). The application of the CMIP3 and CMIP5 model combination, applied to the Atlantic Meridional Overturning Circulation (AMOC), indicate a weakening of AMOC of approximately 25% by the end of the 21st century, having a meaningful impact on the European climate (2).
WhiteShift[107]	**KER 1: Preparedness** **WhiteShift** demonstrates Biogeochemical Argo floats as well as satellite ocean colour potential for the improvement of estimates of carbon budgets,

[105] 1) https://cordis.europa.eu/project/id/679849/; 2) https://spongis.org/; 3) Morato, T., Pham, C. K., Pinto, C., Golding, N., Ardron, J. A., Durán Muñoz, P., & Neat, F. (2018). A multi criteria assessment method for identifying Vulnerable Marine Ecosystems in the North-East Atlantic. Frontiers in Marine Science, 5, 460. 4) Conkling, M., Hesp, K., Munroe, S., Sandoval, K., Martens, D. E., Sipkema, D., &Pomponi, S. A. (2019). Breakthrough in Marine invertebrate cell culture: Sponge cells Divide Rapidly in improved nutrient Medium. Scientific reports, 9(1), 1-10.; 5) SponGES, Deliverable 5.1 Sponge grounds bioactive compounds (a list of 3 bioactive compounds).; 6) Rooks, C., Fang, J. K. H., Mørkved, P. T., Zhao, R., Rapp, H. T., Xavier, J. R., & Hoffmann, F. (2020). Deep-sea sponge grounds as nutrient sinks: denitrification is common in boreo-Arctic sponges. Biogeosciences, 17(5), 1231-1245.

[106] 1) Selten, F. M., Schevenhoven, F. J., & Duane, G. S. (2017). Simulating climate with a synchronization-based supermodel. Chaos: An Interdisciplinary Journal of Nonlinear Science, 27(12), 126903. 2) Reintges, A., Martin, T., Latif, M., &Keenlyside, N. S. (2016). Uncertainty in 21st Century Projections of the Atlantic Meridional Overturning Circulation.

[107] 1)https://cordis.europa.eu/project/id/749949/; 2) Neukermans, G., & Fournier, G. (2018). Optical modeling of spectral backscattering and remote sensing reflectance from Emiliania huxleyi blooms. Frontiers in Marine Science, 5, 146.

	facilitating predictions of climate models at space and time scales useful to decision-making. In particular, the development of an analytical model for spectral backscattering and ocean colour remote sensing of *Hemilianahuxleyi* blooms provides important new insights into the OCN through the analysis of the polar ward shift of this calcifying species attributed to CC (2).



4.5 Highlighted Policy Implementation Support

The Horizon 2020 funded ocean-climate nexus portfolio is especially represented by projects dealing with bioecological, biogeochemical and physical investigations. Preparedness and solutions to climate change impacts is one of the main topics covered by the portfolio, which is a proxy for SDG13 – Climate Action targets; followed by the concerns for a Healthy and Resilient Ocean, identifiable with the SDG14 Life Below Water targets; as well as the Marine Strategy Framework Directive objective for a better understanding of the pressures and impacts of climate change, biodiversity loss and pollution and anthropogenic activities in the ocean, and their implications for marine biodiversity, their habitats, and the ecosystems they sustain. The Marine Strategy Framework Directive in particular clearly emerges as a very relevant theme for research and innovation purposes. The targets of the Clean Planet for All and Adaptation to Climate Change are also well represented in the portfolio, as well as activities supporting the implementation of the Arctic policy.

The portfolio gravitates around the ocean-climate-biodiversity nexus and underlines the need for convergence between the different policies and actions, applying a nexus approach, with win-win strategies and approach that are inclusive of social and environmental impacts. Lasting solutions to climate change require greater attention to nature-based solutions, including healthy and resilient ocean and seas.

The portfolio has contributed largely to its societal remit, with a relevant number of peer-reviewed publications, also within top level journals. An impressive 20% of the projects were represented through their publications in the IPCC's SROCC 2019 report and marked this result as a policy impact, given the relevance that IPCC actions have on policy shaping.

4.6 Looking forward to Horizon Europe

Based on the Horizon 2020 ocean-climate nexus portfolio analysis and the European and global policy context, the following research priorities could be addressed in the Horizon Europe Research and Innovation Framework Programme (2020-2027):

Observations

- *Multidisciplinary investigation* to tackle the complexity of the ocean-climate nexus;
- *Novel sensing techniques* which are fast-tracking and can operate autonomously, either remotely or in-situ, are required to improve monitoring efforts for Good Environmental Status (GES) and early warning system for climate change impact;
- *Vulnerable Marine Ecosystems,* such as the Polar Regions, must be observed and monitored as a priority for climate change impacts; the Antarctic networks for Permafrost Observations is far less developed than the Arctic one and provides statistically insignificant data trends; reinforcing the observation system for Antarctic Permafrost should be a research policy priority given its potential to affect the global climate system; observation and monitoring programmes for Good Environmental Status (GES) should be extended to these areas;
- *Improved indicators and novel observation sensors for Good Environmental Status (GES) assessment*: faster, wider, autonomous and holistic (integrated) monitoring indicators for GES should be implemented, including molecular investigation and optical sensing technologies;
- *Integrated EU programmes with Global Networks*: the ocean has no boundaries and a vast part is beyond national jurisdiction; only globally connected initiatives can safeguard the ecosystem services that the open ocean provides.

Predictions

- *Temporal and spatial scales* of climate change predictions are crucial; impacts will be felt within the next 20 years at a rate likely more rapid than many species can adapt to and beyond the resilience thresholds; to evaluate priorities for area-based management tools (ABMTs) in Areas Beyond National Jurisdiction (ABNJ), high resolution climate change predictions for the next 2 to 5 decades are needed (link to ATLAS project);
- A *refined parametrisation* of the Ice-Sheet dynamics is relevant to reconstruct our climatic history and anticipate the changes, under foreseeable scenarios, ahead of us;
- *Sea-level budgets* need to account for oceanic bottom deformation under ocean mass increase (GlobalMass) and, at the same time, consider the increased mass change due to greater ice sheet melting induced by a minor magnitude of the regional cloud coverage, in the Arctic area;
- The application of a *climate-model-combination approach*, or “super-modelling” approach, based on advanced machine-learning algorithms could enhance seasonal-to-decadal predictions in ecological and economic systems (STERCP).

Mitigation and Adaptation solutions to Climate Change Impact

Considering the Paris Agreement approach, Nature-Based Solutions potentially represent 30 per cent of the actions to mitigate climate change effects.

Major sinks of greenhouse gases are in the ocean, and R&I efforts are required to keep and sometimes bring back the marine ecosystem into a functional equilibrium and functional ecosystem service delivery.

The recommendation is to PROTECT the vulnerable ecosystems from climate change effects; and ENHANCE, CREATE or REGENERATE blue carbon ecosystems, leading to additional carbon sequestration.

- *MSFD – GES* is the basis for mitigation solutions such as *Blue Carbon*; continued action is recommended, also with the implementation of novel devices and methodologies, to account for a holistic approach to monitoring for conservation, including advanced biological technologies (optical and biomolecular) and fast-tracking, as well as autonomous technologies (gliders, ROVs, and satellites);
- Investigate and pilot potential methodologies for conserving Earth's biodiversity in the face of the ongoing global change. For example: *assisted-evolution programs* have already been successfully implemented in aquaculture, and are gaining momentum in coral reef restoration initiatives [EVOLMARINE project];
- Use *Marine Spatial Planning and marine areas management systems* to create resilient coastal ecosystems which will provide services for the years to come:
    - Use science to support effective governance and management systems which can evaluate the cumulative pressure of stressors, also balancing Blue Growth against long-term sustainability;
    - Achieve temporal stability of management measures to ensure sustainability (ATLAS project);
    - Consider that connectivity of MPAs is vulnerable to atmospheric-driven changes in ocean circulation over short time. The issue even takes a geopolitical interest when MPAs are in High Seas or Areas Beyond National Jurisdiction (ABNJ).
- *Ecosystem engineering:* an example of natural ecosystem engineering is in "Topographically enhanced carbon pump": interaction between tidal currents and Cold-Water Coral (CWC) mounds induces downwelling events of surface water that brings organic matter to 600-m deep CWCs;
- *Greener Shipping* options should become available in Arctic Ice-Sheet melting scenarios. *Predicting these opportunities* will bring some economic outcome, in terms of increased commerce, but also in lessening fuel consumption for maritime transportation;
- Investigate the *enhanced carbon pump* options and their repercussions along the food-web and water conditions, such as with the addition of growth-limiting elements; Whereas it may be unsuitable to spray vast areas of the ocean with fertilising elements (as we did on land), it could be beneficial to understand how a nature-based solution could help ocean farming and climate change solutions.

Marine Bioresources, biodiversity, Habitat integrity and Ecosystem Functioning

- To improve our knowledge on *genetic diversity* as well as on the eco-physiological response of marine organisms to climatic stress could optimize the assessment of the vulnerability of marine ecosystems, ensuring successful conservation and management strategies (DPaTh-To-Adapt);
- The "Canary in the Coal Mine" for climate change – related risks, a most vulnerable ecosystem to climatic change threats, because of the extreme adaptations required to thrive in it; And: a prime location for potential economic development, under growing economic interest; The *Arctic ecosystem* transformation in the short-medium term under sustained climate change conditions could provide important services, such as: faster transcontinental shipping routes; novel and rather productive fishing grounds, where boreal (and commercially relevant) species could colonise the Arctic niche. It appears imperative to ensure that we can maintain a Good Environmental Status (GES) for the Arctic and other vulnerable ecosystems, providing the knowledge basis to adaptively inform the necessary "decision support

frameworks", for a sustainable and peaceful ocean governance of these areas (WhiteShift, Nunataryuk);

- Adaptation is required to account for the assessed borealisation of Arctic fish communities (CLIMEFISH). *Functional-biogeography* tools can support gaining insight in this kind of ecosystem transformation in the face of CC impact.
- *Biodiversity*: investigate and introduce the feedback of *biodiversity redistribution* (due to CC) on climate itself, which is a critical yet lacking parametrisation, in most mitigation and adaptation strategies (INTAROS project);
- *Microbiome*: Marine microorganisms affect the rate at which the ocean absorbs CO_2 and have therefore a major role in climate regulation, over the long term. Communities of microorganisms also act at the interface between any living marine organism and its surroundings, playing a key role in the well-being of marine bioresources. *Marine microbiota has also proven effective in reducing pollution and promoting marine environment restoration.* Yet, this part of the ecosystem is still poorly known, including their community-regulation mechanisms. Implementing Research and Innovation Actions in the marine microbiome realm, along specific policy objectives, is very likely to produce relevant output;
- *Understanding the potential of the microbial community involved in N2 fixation* to respond to and to possibly mitigate the ongoing ocean deoxygenation could be important in evaluating nature-based solutions to Climate Change impact (OceanLINES, DENOCS, NITROX);
- Working on the definition of relevant *variables and indicators that can be measured by Remote Sensing* and have a great potential to optimize the way of managing the environment (ECOPOTENTIAL);
- New interventions are still needed for a *global coral conservation strategy* to protect reefs from CC impacts (IMPREX);
- The application of the *traits-based approach to the modelling* of species-specific vulnerability to environmental conditions, based on their functional traits (size, growth and reproduction), appears as a promising way to characterise and predict functional community changes in response to CC (MARmaED);
- Define operational frameworks for *data brokering and dedicated software technologies* to provides useful information, data, maps, models for supporting evidence-based decision-making in protected areas as well as by end-users in ecological studies;
- "More efforts to share experiences internationally would greatly benefit the process of refining both the international environmental *accounting guidelines and marine ecosystem service classifications.* Solutions include: improved tracking of users (both scientific and operational), the mapping of value chains, and improvements to methodologies through the development of international standards or guidelines for the valuation of ocean observations. Innovation in many areas, and combinations of innovations may have the capacity to foster both economic development and ocean sustainability";
- *Carbon Capture and Storage solutions (CCS):* enhancement of the biological pump could artificially cause a carbon sink and bring down the planet temperature. Research is required to understand the limits of this technological opportunity (Appels, OceanLines, IcyLab and Mesopp).

Governance, Management and Spatial Planning

- Particularly challenging, in terms of governance, is the 64% of the ocean that lies in Areas Beyond National Jurisdiction (ABNJ): Globally Integrated Observation Networks and the use of combined approaches could help.

- The existing MPAs network is vulnerable to atmospheric-driven changes in ocean circulation. It would be beneficial to *integrate MPAs within a connected network of managed areas.*
- Use of *Locally Managed Marine Areas* (LMMAs) tools could be adapted to respond to short-term local-community needs, while contributing to biodiversity conservation targets, and ultimately for the achievement of specific SDGs on food security, poverty elimination and resilient ecosystems, if properly supported by long-term investments, strong institutions and integrated oceans management (ATLAS).
- *"Other effective area-based conservation measures"* OECMs can complement MPAs and contribute to ecologically representative and effectively managed MPA systems integrated into broader governance systems, such as Marine Spatial Planning (ATLAS project).
- Testing/validation/adoption of *novel instrumentation* (e.g. optical and molecular) for environmental and biological sensing and monitoring, either remotely or in-situ, could improve our ability to maintain the GES of our ecosystems (ATLAS and ECOPOTENTIAL) and support governance efforts.
- Increased spatial and temporal resolution models for societal/policy Decision Support Systems (DDS): Temporal and spatial scales of CC predictions are crucial. Impacts will be felt within the next 20 years at a rate likely more rapid than many species can adapt and beyond resilience thresholds. To evaluate priorities for ABMTs in ABNJ high resolution climate change predictions for the next 2 to 5 decades are needed (ATLAS project).
- *Decision Support Systems shall be informed by increased spatial resolution modelling to improve planning and monitoring actions.*
- The recommendation is to use the scenarios deriving from the *Functional Biogeography* approach (ClimeFish) when planning for use of space, including fishery grounds and MPAs.
- Sustainable fisheries management must include predicted environmental changes in their *integrated ecosystem models* in order to gain an insight into what the available stocks will be in the near future and, thus, prepare for the sustainable management of fisheries to a rapidly changing scenario.
- The *Nexus approach is crucial* in identifying the links and integrating the impacts of different policy areas, in cross-sectoral, cross-scale and cross-regional pathways. The Nexus approach exploits synergies and addresses unwanted trade-offs between policy domains, building up a knowledge-base framework to assess long-term society-wide impacts in response to CC (Sim4Nexus). A broad assessment of *policy coherence between policy domains* could help the monitoring of effective progress towards the achievement of climate policy targets (Sim4Nexus).
- Innovative and sustainable solutions that are based on *win-win strategies* that are biodiversity positive with climate mitigation and adaptation co-benefits, including nature-based solutions to ensure integrity of the Polar Regions and the ocean.
- Initiatives and tools to improve our *understanding of the value of the oceanic ecosystem services* and equip humanity, especially communities more exposed to the climate change related impact, with the necessary knowledge about the ocean and its relations with the climate system and human well-being.
- *Research Infrastructures*: RIs may play a role beyond research, for example for education and related public societal services.
- The use of *social sciences* can be very relevant in local societal transformation (BIGSEA).
- Developing an *integrated approach that links economic, social and environmental goals within the ecosystem-based management (EBM)* is a crucial step for the EU to reach its biodiversity conservation targets (AQUACROSS).

- Continuation and refinement of the *MSFD action*, which poses the strongest foundation to a healthy and resilient ecosystem, of some blue carbon value.
- *Sustained and integrated efforts* of both the *ocean observing communities and the Earth system modelling communities*.
- *Advanced biological investigation technologies*, such as molecular tools, to further our understanding of the ecosystem functioning, including the microbial level, and unlock the potential of nature itself to bring solutions for our societal issues.
- Improve our knowledge on *genetic diversity* as well as on the *eco-physiological response of marine organisms to climatic stress* to optimize the assessment of the vulnerability of marine ecosystems, ensuring successful conservation and management strategies.
- *Planning and governance schemes* are essential for our sustained benefitting of the ocean's ecosystem services, and that solid and refined scientific knowledge must be at the basis of such regulatory plans.
- *Ocean literacy* actions could become more relevant, also with the identification of some champions, examples of which could be found among the ESFRI Research Infrastructures, and a dedicated stream of funding under the MSCA programmes.
- The *innovation aspect of research* in these fields should be incentivised with the possibility to access a feasibility-study call, to bring any relevant discovery from H2020 projects, into a higher TRL, to reach at least 3-6, keeping the consortium composition to the essential number of participants and always including at least one industry and one public research or Research Infrastructure partner.
- The use of *social sciences* could be enhanced for an additional dimension, which will be especially useful in bringing forward and communicating the necessary societal transformation, which will be required to maintain a cohesive society in times of climate change impact.

5 Conclusion

The **Research and Innovation framework programmes** have a sustained track record of funding the thematic research that is addressed by this publication.

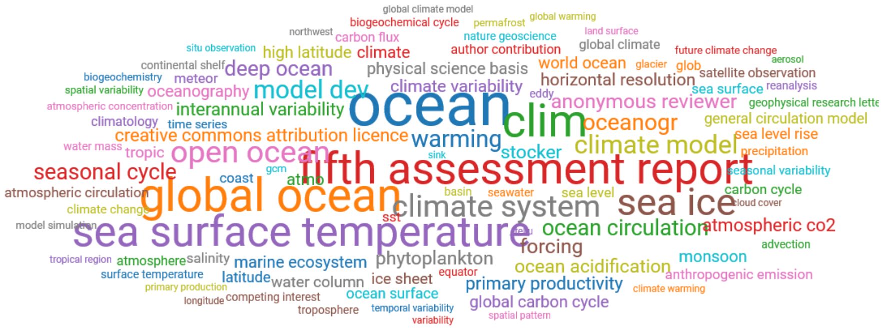
The **H2020 ocean-climate nexus portfolio** of projects is well equipped to inform the Commission priorities and policies, and society in general, about humanity's current challenges, under a +1.5° C climate-warming scenario, as well as on preparedness, mitigation and adaptation measures. A greater impact of policy measures will eventually take hold only with a society empowered to gauge the complexity and the relevance of the threats of climate change impact. Efforts to contribute to societal transformation and to reach out to the most vulnerable communities will largely support the achievement of the described policy objectives, in the long term.

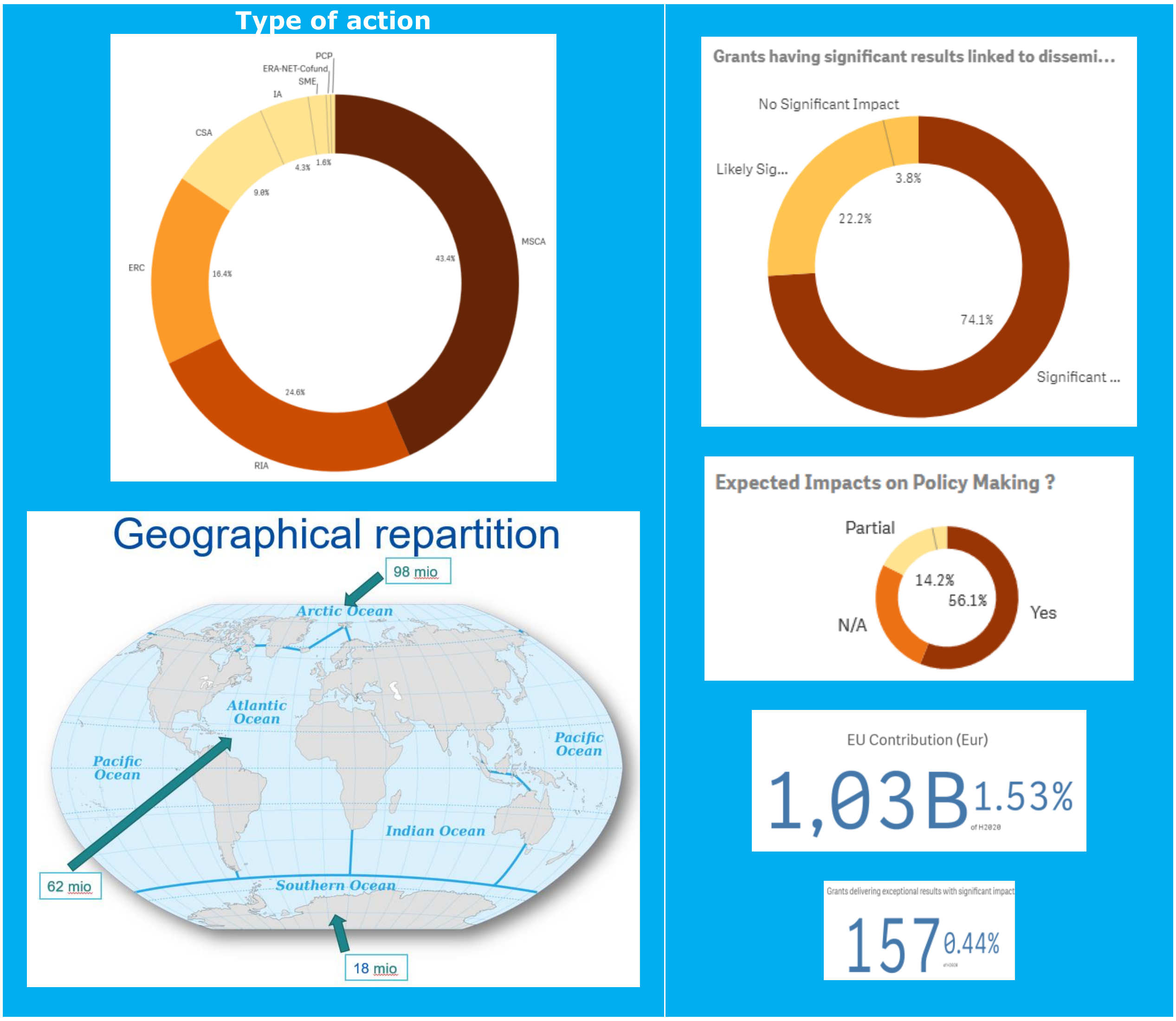
With the **new framework programme, Horizon Europe**, the dedicated funding will continue, especially under Cluster 6 - Food, Bioeconomy, Natural Resources, Agriculture and Environment[108] and Cluster 5 – Climate, Energy and Mobility[109], as well as the bottom-up programmes (ERC, MSCA, etc.), and the new policy tools: the Horizon Missions, notably Mission Restore our Ocean and Waters by 2030 and Mission on Climate Adaptation to Climate Change, including Societal Adaptation. The funded projects are continuously and with a short delay made available on the CORDIS webpage, for an effective dissemination.

[108] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/cluster-6-food-bioeconomy-natural-resources-agriculture-and-environment_en
[109] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/cluster-5-climate-energy-and-mobility_en

ANNEX 1: H2020: HORIZON DASHBOARD AND CORTEX ANALYSIS

Using the European Commission text mining tool supporting policy decisions with data-driven insights about the implementation of the EU policies (CORTEX) and the data analysis and visualisation tool (Horizon Dashboard[110]), the key information for the H2020[111] ocean-climate nexus research and innovation projects – 2014-2020[112] is presented below.





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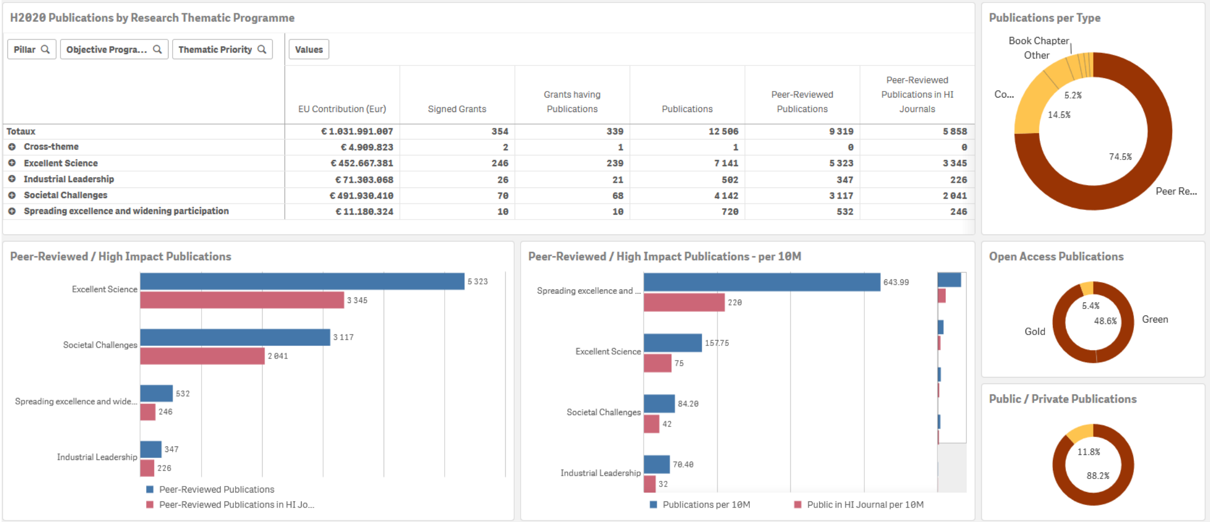
[110] https://www.youtube.com/watch?v=Pl0Hv96MRVs

[111] Horizon 2020 Resarch Framework Programme https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en

[112] HORIZON DASHBOARD https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-dashboard and CORTEX https://webgate.ec.europa.eu/funding/pages/viewpage.action?spaceKey=iknowplus&title=CORTEX


H2020 Publications by Research Thematic Programme
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Cross-theme € 4.909.823 2 1 1 0 0
Excellent Science € 452.667.381 246 239 7 141 5 323 3 345
Industrial Leadership € 71.303.068 26 21 502 347 226
Societal Challenges € 491.930.410 70 68 4 142 3 117 2 041
Spreading excellence and widening participation € 11.180.324 10 10 720 532 246
Publications per Type
Book Chapter
Other
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Peer-Reviewed / High Impact Publications
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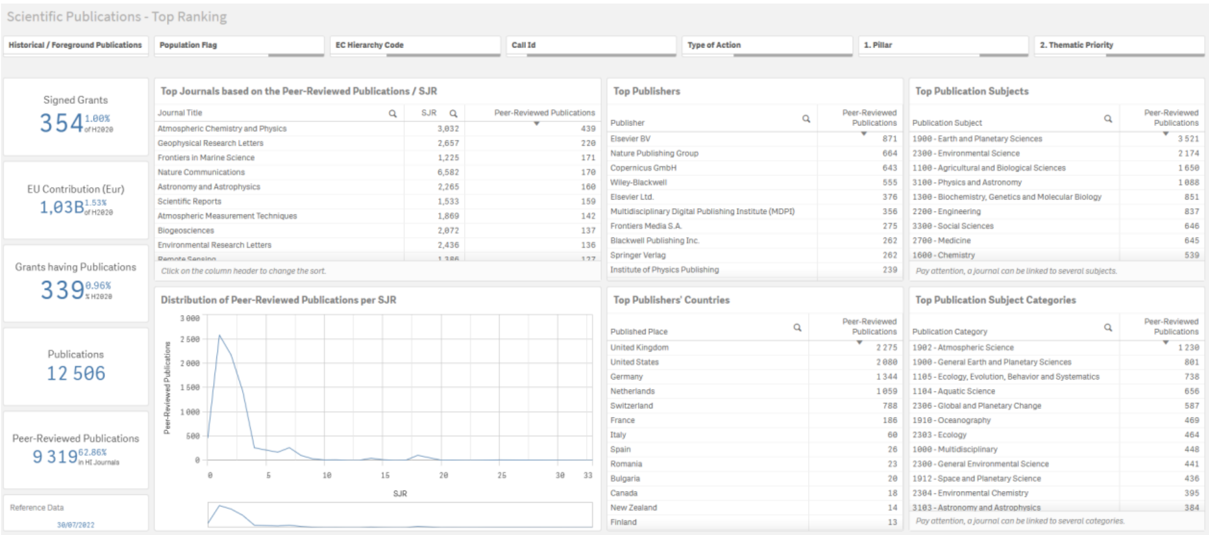
Scientific Publications - Top Ranking
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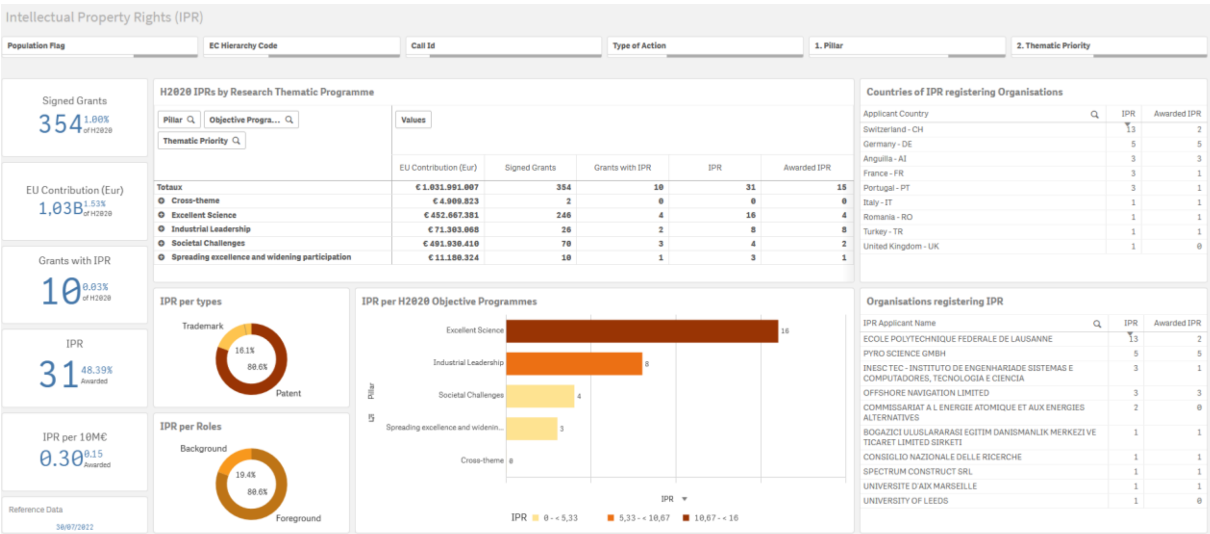
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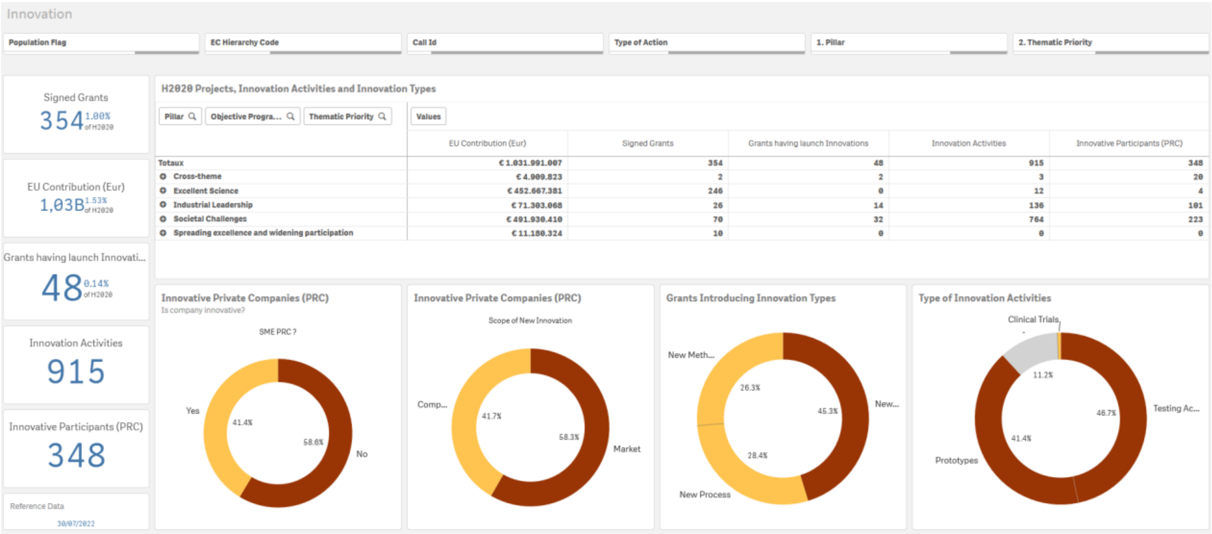
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915
Innovative Participants (PRC)
348
Reference Data
30/07/2022
H2020 Projects, Innovation Activities and Innovation Types
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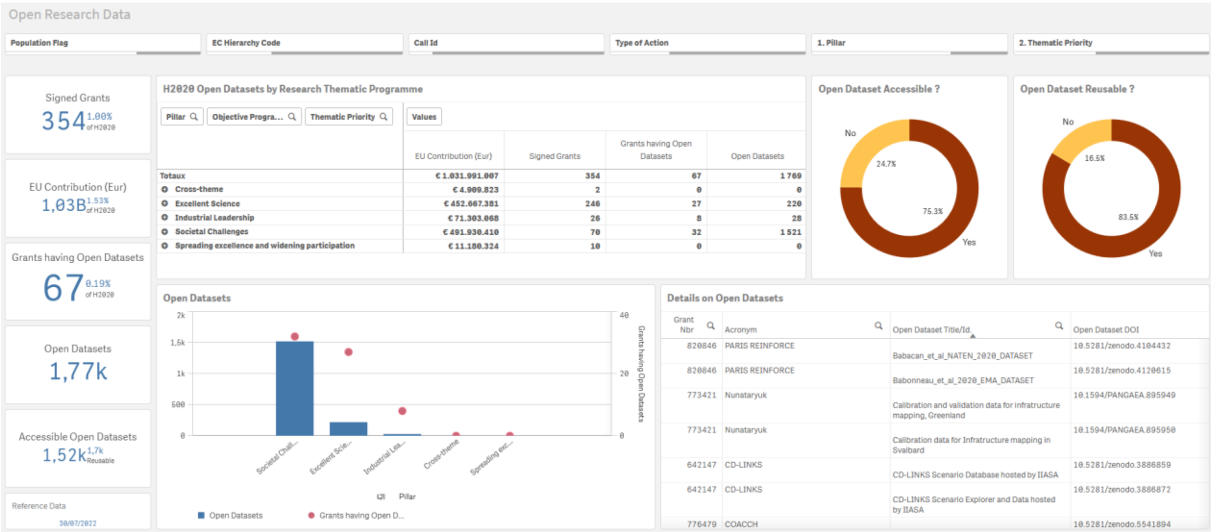
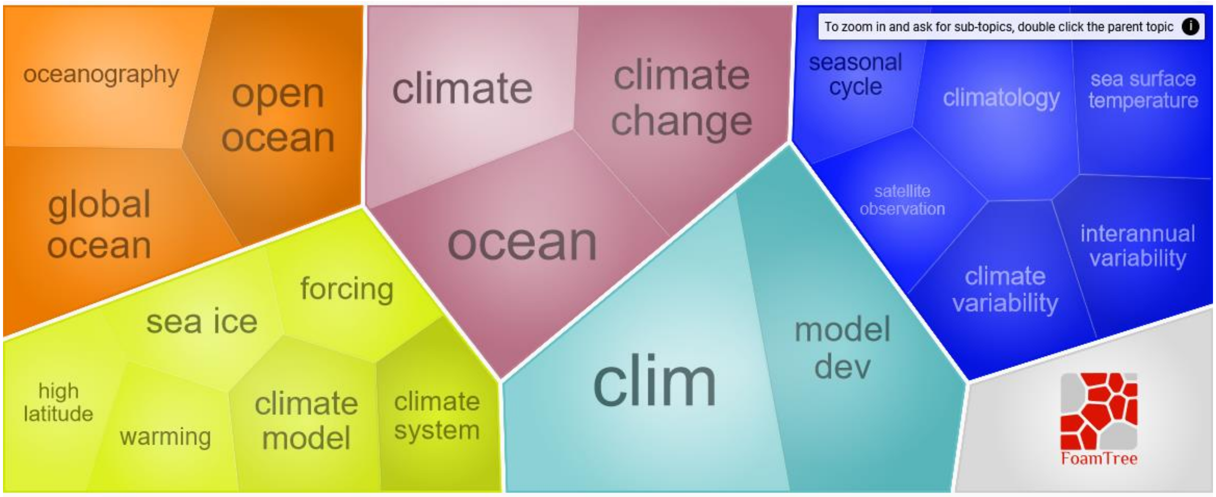
Totaux | € 1.031.991.007 | 354 | 48 | 915 | 348
Cross-theme | € 4.909.823 | 2 | 2 | 3 | 20
Excellent Science | € 452.667.381 | 246 | 0 | 12 | 4
Industrial Leadership | € 71.303.068 | 26 | 14 | 136 | 101
Societal Challenges | € 491.930.410 | 70 | 32 | 764 | 223
Spreading excellence and widening participation | € 11.180.324 | 10 | 0 | 0 | 0
Innovative Private Companies (PRC)
Is company innovative?
SME PRC ?
Yes
41.4%
58.6%
No
Innovative Private Companies (PRC)
Scope of New Innovation
Comp...
41.7%
58.3%
Market
Grants Introducing Innovation Types
New Meth...
26.3%
45.3%
New...
28.4%
New Process
Type of Innovation Activities
Clinical Trials
11.2%
46.7%
Testing Ac...
41.4%
Prototypes


Open Research Data
Population Flag
EC Hierarchy Code
Call Id
Type of Action
1. Pillar
2. Thematic Priority
Signed Grants
354 1.00% of H2020
EU Contribution (Eur)
1,03B 1.53% of H2020
Grants having Open Datasets
67 0.19% of H2020
Open Datasets
1,77k
Accessible Open Datasets
1,52k 1,7k Reusable
Reference Data
30/07/2022
H2020 Open Datasets by Research Thematic Programme
Pillar
Objective Progra...
Thematic Priority
Values
EU Contribution (Eur) | Signed Grants | Grants having Open Datasets | Open Datasets
Totaux | € 1.031.991.007 | 354 | 67 | 1 769
Cross-theme | € 4.909.823 | 2 | 0 | 0
Excellent Science | € 452.667.381 | 246 | 27 | 220
Industrial Leadership | € 71.303.068 | 26 | 8 | 28
Societal Challenges | € 491.930.410 | 70 | 32 | 1 521
Spreading excellence and widening participation | € 11.180.324 | 10 | 0 | 0
Open Dataset Accessible ?
No
24.7%
75.3%
Yes
Open Dataset Reusable ?
No
16.5%
83.5%
Yes
Open Datasets
2k
1.5k
1k
500
0
40
20
0
Grants having Open Datasets
Societal Chall...
Excellent Scie...
Industrial Lea...
Cross-theme
Spreading exc...
Pillar
Open Datasets
Grants having Open D...
Details on Open Datasets
Grant Nbr | Acronym | Open Dataset Title/Id | Open Dataset DOI
820846 | PARIS REINFORCE | Babacan_et_al_NATEN_2020_DATASET | 10.5281/zenodo.4104432
820846 | PARIS REINFORCE | Babonneau_et_al_2020_EMA_DATASET | 10.5281/zenodo.4120615
773421 | Nunataryuk | Calibration and validation data for infratructure mapping, Greenland | 10.1594/PANGAEA.895949
773421 | Nunataryuk | Calibration data for Infratructure mapping in Svalbard | 10.1594/PANGAEA.895950
642147 | CD-LINKS | CD-LINKS Scenario Database hosted by IIASA | 10.5281/zenodo.3886859
642147 | CD-LINKS | CD-LINKS Scenario Explorer and Data hosted by IIASA | 10.5281/zenodo.3886872
776479 | COACCH | | 10.5281/zenodo.5541894


oceanography
open ocean
global ocean
climate
climate change
ocean
To zoom in and ask for sub-topics, double click the parent topic
seasonal cycle
climatology
sea surface temperature
satellite observation
interannual variability
climate variability
forcing
sea ice
high latitude
warming
climate model
climate system
clim
model dev
FoamTree

ANNEX 2: H2020: HIGHLIGHTED OCEAN-CLIMATE NEXUS PROJECTS

Information on the project and the link to its website can be obtained by entering the project number in the **CORDIS EU research results** search at: http://cordis.europa.eu/projects/home_en.html. Information on the **Key Exploitable Results (KER)** can be obtained by entering the project acronym in the search function of the **Horizon Results Platform** at: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/search.

Horizon 2020 topic	Acronym	Title	Project nr. & CORDIS link	Project Website	Key Exploitable Results & Contributions	EU Contribution	Keywords
LC-CLA-08-2018 - Addressing knowledge gaps in climate science, in support of IPCC reports	**4C**	CLIMATE-CARBON INTERACTIONS IN THE CURRENT CENTURY	821003	https://4c-carbon.eu/	Scientific advancement, IPCC AR6, COP26	€ 7 784 750	OCN, ocean carbon sink, ocean salinity 2000m deep, satellite observation
BG-08-2018-2019 - All Atlantic Ocean Research Alliance Flagship	**AANChOR**	ALL ATLANTIC COOPERATION FOR OCEAN RESEARCH AND INNOVATION	818395	https://allatlanticocean.org/	Policy support, RTD publication	€ 3 995 892	OCN, AAORA, scientific diplomacy, MHW,
MSCA-IF-2020 - Individual Fellowships	**AcidICC**	UNDERSTANDING OCEAN ACIDIFICATION IMPACTS ON CHEMICAL COMMUNICATION IN MARINE SPECIES	101026010	N.A.	N.A.	€ 212 933	OCN, OA, marine communities
ERC-2019-COG - ERC Consolidator Grant	**ANTSIE**	ANTARCTIC SEA ICE EVOLUTION FROM A NOVEL BIOLOGICAL ARCHIVE	864637	N.A.	N.A.	€ 1 999 928	OCN, Antarctic, sea ice, climate science, geochemical
ERC-CoG-2015 - ERC Consolidator Grant	**APPELS**	A Probe of the Periodic Elements for Life in the Sea	681746	https://www.earth.ox.ac.uk/research-groups/ocean-biogeochemistry/research-projects/	Results	€ 2 000 000	OCN, marine metallome/metalloproteome, phytoplankton, ocean biogeochemistry
BG-10-2016 - Impact of Arctic changes on the weather and climate of the	**APPLICATE**	Advanced Prediction in Polar regions and beyond: Modelling, observing system design and LInkages associated	727862	https://applicate-h2020.eu/about/	IPCC SROCC, IPCC AR6, KER, EU Polar Cluster, EU Polar Science Week, AAORIA,	€ 7 999 591	Arctic, Polar, OCN, climate science, ocean observation, ice, weather and climate predictions

Northern Hemisphere		with ArctiC ClimATE change			HORIZON MAGAZINE, feedback to policy		
INFRAIA-01-2016-2017 - Integrating Activities for Advanced Communities	**AQUACOSM**	NETWORK OF LEADING EUROPEAN AQUATIC MESOCOSM FACILITIES CONNECTING MOUNTAINS TO OCEANS FROM THE ARCTIC TO THE MEDITERRANEAN	731065	https://www.aquacosm.eu/	Demonstrators, pilots, prototypes, educational material	€ 9 999 804	OCN, aquatic experimentation in mesocosm, RI, pelagic marine systems (irst by expanding it to 10 freshwater (rivers and lakes), 2 brackish and 2 benthic marine facilities), integrated freshwater and marine research infrastructure network
EIC-SMEInst-2018-2020 - SME instrument	**AquapHOx**	THE FIRST HIGH-PERFORMANCE, ALL-IN-ONE OPTICAL SENSOR TECHNOLOGY TO MONITOR THE HEALTH OF OUR OCEANS	829640	https://www.pyroscience.com/en/	Results in brief	€ 1 746 410	OCN, ocean health, novel sensor technology, ocean acidification, optical sensor, O2 monitoring, pH measurement, seawater temperature, underwater platform
MSCA-IF-2014-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)	**ARCGATE**	ARCGATE: MAXIMIZING THE POTENTIAL OF ARCTIC OCEAN GATEWAY ARRAY	652757	https://asof.awi.de/index.php	N.A.	€ 171 460	OCN, Arctic, physical and biogeochemical budgets for the Arctic Ocean, observation
LC-SPACE-18-EO-2020 - Copernicus evolution: Research activities in support of the evolution of the Copernicus services	**ARCOS**	Arctic Observatory for Copernicus SEA Service	101004372	ARCOS (Arctic Observatory for Copernicus SEA) (arcos-project.eu)		€ 1 498 061	OCN, ocean observation, Arctic, polar, adaptation, EWS, climate services, Geospatial Intelligence Products, automatic early-warning system, ice
SEC-21-GM-2016-2017 - Pan European Networks of practitioners and other actors in the field of security	**ARCSAR**	Arctic and the North Atlantic Security and Emergency Preparedness Network	786571	https://arcsar.eu/	EU Polar Cluster	€ 3 492 021	Arctic, security, emergency response, protection
LC-CLA-20-2020 - Supporting the	**Arctic PASSION**	Pan-Arctic Observing System of Systems:	101003472	https://arcticpa	EU Polar Cluster	€ 14 998 301	Arctic, observing system

implementation of GEOSS in the Arctic in collaboration with Copernicus		Implementing Obsevations for Societal Needs		ssion.eu/			
LC-CLA-07-2019 - The changing cryosphere: uncertainties, risks and opportunities	**ArcticHubs**	Global drivers, local consequences: Tools for global change adaptation and sustainable development of industrial and cultural Arctic "hubs"	869580	https://projects.luke.fi/arctichubs/	EU Polar Cluster	€ 5 956 083	Arctic, sustainability, resilience
INFRAIA-02-2017 - Integrating Activities for Starting Communities	**ARICE**	Arctic Research Icebreaker Consortium: A strategy for meeting the needs for marine-based research in the Arctic	730965	https://arice-h2020.eu/	EU Polar Cluster	€ 5 996 563	Arctic, R&I capacity
BG-08-2018-2019 - All Atlantic Ocean Research Alliance Flagship	**AtlantECO**	ATLANTIC ECOSYSTEMS ASSESSMENT, FORECASTING & SUSTAINABILITY	862923	https://www.atlanteco.eu/	N.A.	€ 10 925 660	OCN, Atlantic, ecosystems, ecosystem services, climate science, biodiversity
BG-08-2014 - Developing in-situ Atlantic Ocean Observations for a better management and sustainable exploitation of the maritime resources	**AtlantOS**	Optimizing and Enhancing the Integrated Atlantic Ocean Observing System	633211	AtlantOS | Optimising and Enhancing the Integrated Atlantic Ocean Observing Systems (atlantos-h2020.eu)	KERs	€ 20 652 921	Atlantic, ocean observation, OCN, climate science
BG-01-2015 - Improving the preservation and sustainable exploitation of Atlantic marine ecosystems	**ATLAS**	A Trans-AtLantic Assessment and deep-water ecosystem-based Spatial management plan for Europe	678760	Home - atlas - a transatlantic assessment and deep-water ecosystem-based spatial management plan for Europe (eu-atlas.org)	KERs, scientific discoveries, scientific advances	€ 9 100 316	Atlantic, OCN, climate science, ecosystem functioning, blue carbon

LC-CLA-08-2018 - Addressing knowledge gaps in climate science, in support of IPCC reports	**Beyond EPICA**	Beyond EPICA Oldest Ice Core: 1,5 Myr of greenhouse gas – climate feedbacks	815384	https://www.beyondepica.eu/en/	EU Polar Cluster	€ 10 999 942	Antarctic, OCN, climate science, carbon, ice
ERC-CoG-2015 - ERC Consolidator Grant	**BIGSEA**	BIOGEOCHEMICAL AND ECOSYSTEM INTERACTIONS WITH SOCIO-ECONOMIC ACTIVITY IN THE GLOBAL OCEAN	682602	https://earthsystemdynamics.org/iesd/bigsea/	KER, feedback to policy	€ 1 600 000	OCN, marine ecosystems, fisheries, human-ocean system
MSCA-IF-2018 - Individual Fellowships	**BioSIGNAL**	BIOLOGICAL PUMP SENSITIVITY AND CLIMATE CHANGE: INTERROGATING PAST ENVIRONMENTAL PERTURBATIONS	838373	https://alexpohl.github.io/BioSIGNAL/	N.A.	€ 257 619	OCN, biological pump, climate science, sensitivity of the biological pump, ecological model, representation of marine biogeochemical cycles
BG-07-2019-2020 - The Future of Seas and Oceans Flagship Initiative	**Blue Cloud**	BLUE-CLOUD: PILOTING INNOVATIVE SERVICES FOR MARINE RESEARCH & THE BLUE ECONOMY	862409	https://blue-cloud.org/	Policy feedback and new products and technologies, KERs,	€ 5 999 520	OCN, cloud-based open science
BG-10-2016 - Impact of Arctic changes on the weather and climate of the Northern Hemisphere	**Blue-Action**	Arctic Impact on Weather and Climate	727852	https://blue-action.eu/	IPCC SROCC, IPCC AR6, COP26, KER, EU Polar Cluster, Scientific Advances, AAORIA, policy briefing with European Parliament	€ 7 500 000	Arctic, Northern Hemisphere, OCN, climate science, climate services, ice, oceanic circulation, AMOC, extreme weather
MSCA-IF-2019 - Individual Fellowships	**BULLE**	BIOLOGICAL UNDERSTANDING OF THE CO2 AND O2 LEVEL IN THE OCEAN	894264	N.A.	N.A.	€ 184 707	OCN, ‘respiratory quotient’ (RQ), et primary production and bacterial activities
LC-CLA-07-2019 - The changing cryosphere: uncertainties, risks and opportunities	**CAPARDUS**	Capacity-building in Arctic standardisation development	869673	https://capardus.nersc.no/	EU Polar Cluster	€ 2 003 009	Arctic

MSCA-IF-2016 - Individual Fellowships	**CAP-ICE**	CARBON PRODUCTION OF UNDER-ICE PHYTOPLANKTON BLOOMS IN A CHANGING ARCTIC OCEAN	746748	http://ocean.stanford.edu/ardyna/CAP-ICE.html	Results in brief	€ 264 668	OCN, Arctic Ocean, sea-ice, climate science, Arctic marine CO2 sequestration, under-ice phytoplankton blooms (UIBs), novel model adapted to under-ice environments will allow quantifying the contribution of UIBs to the Arctic carbon cycle, Bio-Argo floats, first assessment of UIB primary production and carbon export in AO
MSCA-IF-2018 - Individual Fellowships	**CarbEx**	Tracing carbon exchanges/fluxes betweenArctic and Atlantic basins	839311	https://orbit.dtu.dk/en/projects/tracing-carbon-exchangesfluxes-between-arctic-and-atlantic-basins-2	Results in Brief	€ 219 312	OCN, Arctic, Antarctic, climate science, carbon exchanges and fluxes, oceanic carbon, Arctic carbon cycle, observation, satellite, impacts, permafrost thaw, DOC, Farm Strait, algorithm for seasonal and annual fluctuations, carbon reservoir
MSCA-ITN-2014-ETN - Marie Skłodowska-Curie Innovative Training Networks (ITN-ETN)	**C-CASCADES**	CARBON CASCADES FROM LAND TO OCEAN IN THE ANTHROPOCENE	643052	https://c-cascades.ulb.ac.be/	N.A.	€ 3 112 980	OCN, climate science, carbon cycle, CO2 and CH4, land-to-ocean carbon cycle
EO-3-2016 - Evolution of Copernicus services	**CEASELESS**	Copernicus Evolution and Aplications with Sentinel Enhancements and Land Effluents for Shores and Seas	730030	https://ceaseless.barcelonatech-upc.eu/en	Results in brief	€ 1 999 332	OCN, observation, COPERNICUS services, CMEMS, coastal, Sentinel
LC-CLA-07-2019 - The changing cryosphere: uncertainties, risks and opportunities	**CHARTER**	Drivers and Feedbacks of Changes in Arctic Terrestrial Biodiversity	869471	https://www.charter-arctic.org/	EU Polar Cluster	€ 5 899 931	Arctic, terrestrial biodiversity, adaptation, climate science, biochemical soil carbon exchange, sea ice, albedo, ESM
LC-CLA-12-2020 - Advancing climate services	**CoCliCO**	COASTAL CLIMATE CORE SERVICES	101003598	https://coclicoservices.eu/	N.A.	€ 5 999 641	OCN, climate science, adaptation, coastal risk,

							climate services
LC-CLA-08-2018 - Addressing knowledge gaps in climate science, in support of IPCC reports	**COMFORT**	Our common future ocean in the Earth system – quantifying coupled cycles of carbon, oxygen, and nutrients for determining and achieving safe operating spaces with respect to tipping points	820989	https://comfort.w.uib.no/	IPCC AR6, feedback to policy	€ 8 191 663	OCN, climate science, carbon, tipping points, oxygen, ocean sustainability, marine ecosystems, nutrient cycles
ERC-StG-2015 - ERC Starting Grant	**CoupledIceClim**	COUPLED CLIMATE AND GREENLAND ICE SHEET EVOLUTION: PAST, PRESENT AND FUTURE	678145	https://www.fabiodisconzi.com/open-h2020/projects/204437/index.html	N.A.	€ 1 677 282	OCN, climate science, Greenland, ice sheet evolution
SC5-01-2014 - Advanced Earth-system models	**CRESCENDO**	Coordinated Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach	641816	https://ukesm.ac.uk/crescendo/	Feedback to policy, IPCC	€ 14 338 876	CIMIP6, WCRP, ESM, biogeochemical feedbacks
LC-CLA-17-2020 - Polar climate: understanding the polar processes in a global context in the Arctic and Antarctic Regions	**CRiceS**	Climate relevant interactions and feedbacks: the key role of sea ice and snow in the polar and global climate system	101003826	https://www.crices-h2020.eu/	EU Polar Cluster	€ 7 999 266	Polar, climate science, ice, OCN, biogeochemical
MSCA-IF-2019 - Individual Fellowships	**CYCLOCARB**	OCEANIC CARBON CYCLING RESPONSE TO GLOBAL TEMPERATURE CHANG	897046	https://www.cerege.fr/fr/post-doc-cartapanis/cyclocarb-introduction	N.A.	€ 277 061	OCN, oceanic carbon cycle
MSCA-IF-2016 - Individual Fellowships	**DENOCS**	THE DOUBLE EDGED ROLE OF NITRIC OXIDE AND HYDROGEN PEROXIDE IN A	747464	https://verenaschrameyer.com/	Results in brief	€ 212 194	OCN, coral bleaching, nitric oxide (NO) and hydrogen

		Coral Symbiosis					peroxide (H2O2)
ERC-2018-ADG - ERC Advanced Grant	**DEVOCEAN**	Impact of diatom evolution on the oceans	833454	https://www.fabiodisconzi.com/open-h2020/projects/223600/index.html	N.A.	€ 2 500 000	OCN, diatom, global biochemical cycle of silica, carbon and nutrients, ocean productivity
MSCA-IF-2017 - Individual Fellowships	**DOVuFRIS**	Detecting Ocean Variability under Filchner-Ronne Ice Shelf	790062	https://www.bas.ac.uk/project/dovufris/	Result in brief	€ 183 454	OCN, ice shelf melt, ocean variability, climate science
MSCA-IF-2014-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)	**DPaTh-To-Adapt**	Rethinking climate change vulnerability: Drivers patterns of thermal tolerance adaptation in the ocean	659246	https://imedea.uib-csic.es/	N.A.	€ 170 121	OCN, climate science, ocean warming, impacts on biota, sensitivity hotspots, adaptation of ecosystems, physiology, ecology, evolutionary biology, biogeography and physical oceanography into an interdisciplinary conceptual framework, blue carbon, kelp forests
MSCA-IF-2018 - Individual Fellowships	**DYNACLIM Ocean**	Ocean DYNAmics reconstruction using remotely sensed variables in two CLIMate hotspots	840374	https://www.fabiodisconzi.com/open-h2020/projects/224581/index.html	N.A.	€ 259 398	OCN, climate science, sea, dynamics, Mediterranean, Arctic, salinity, surface, navigation, satellite
MSCA-IF-2017 - Individual Fellowships	**DYNOS**	The coupled dynamics of Southern Ocean climate change	794766	N.A.	N.A.	€ 183 454	OCN, Southern Ocean, climate science, models, physical
LC-SPACE-18-EO-2020 - Copernicus evolution: Research activities in support of the evolution of the Copernicus services	**ECFAS**	A PROOF-OF-CONCEPT FOR THE IMPLEMENTATION OF A EUROPEAN COPERNICUS COASTAL FLOOD AWARENESS SYSTEM	101004211	Welcome to the European Coastal Flood Awareness System (ecfas.eu)	New products and technologies	€ 1 500 000	OCN, ocean observation, climate science, adaptation, climate risks, marine forcing forecasts, coastal flood maps, hazard and impact assessment, SLR, coast

SC5-16-2014 - Making Earth Observation and Monitoring Data usable for ecosystem modelling and services	**ECOPOTENTIAL**	ECOPOTENTIAL: IMPROVING FUTURE ECOSYSTEM BENEFITS THROUGH EARTH OBSERVATIONS	641762	http://www.ecopotential-project.eu/	Featured in Results Packs: Biodiversity and ecosystem services and environmental observation, scientific advances,	€ 14 874 340	OCN,MPAs, Adaptation, EBM, ice, ecosystems, EO, EOVs
LC-CLA-07-2019 - The changing cryosphere: uncertainties, risks and opportunities	**ECOTIP**	Arctic biodiversity change and its consequences: Assessing, monitoring and predicting the effects of ecosystem tipping cascades on marine ecosystem services and dependent human systems	869383	https://ecotip-arctic.eu/	EU Polar Cluster	€ 6 361 535	Arctic, ecological tipping cascades, adaptation, OCN, climate science, marine biodiversity, ecosystem services
MSCA-IF-2017 - Individual Fellowships	**EdgeStress**	ON THE EDGE: THE INFLUENCE OF MULTIPLE STRESSORS ON THERMAL TOLERANCE IN POLEWARD EDGE POPULATIONS IN A CLIMATE CHANGE ERA	797387	https://www.researchgate.net/project/On-the-edge-The-influence-of-multiple-stressors-on-thermal-tolerance-in-poleward-edge-populations-in-a-climate-change-era-EdgeStress	Results	€ 245 719	OCN, Arctic, climate science, OA, sea ice melting, multiple stressors, biodiversity, global warming, thermal stress, poleward migration and distribution edge
INFRAIA-02-2017 - Integrating Activities for Starting Communities	**EUMarineRobots**	MARINE ROBOTICS RESEARCH INFRASTRUCTURE NETWORK	731103	https://www.eumarinerobots.eu/	Results	€ 4 998 736	OCN, robots, exploration
BG-15-2014 - European polar research cooperation	**EU-PolarNet**	Connecting Science and Society	652641	https://eu-polarnet.eu/	EU Polar Cluster	€ 2 174 503	Polar research coordination

INFRADEV-03-2018-2019 - Individual support to ESFRI and other world-class research infrastructures	**Euro-Argo RISE**	Euro-Argo Research Infrastructure Sustainability and Enhancement	824131	https://www.euro-argo.eu/EU-Projects/Euro-Argo-RISE-2019-2022	Results	€ 3 953 406	OCN, temperature and salinity, profiling float, 2000m deep, climate science, biogeochemistry, essential ocean observations, Europe
BG-07-2019-2020 - The Future of Seas and Oceans Flagship Initiative	**EuroSea**	IMPROVING AND INTEGRATING EUROPEAN OCEAN OBSERVING AND FORECASTING SYSTEMS FOR SUSTAINABLE USE OF THE OCEANS	862626	https://eurosea.eu/	demonstrators	€ 12 253 891	OCN, observation, ocean health, climate science, biological and biogeochemical measurements, marine heatwaves
MSCA-IF-2014-GF - Marie Skłodowska-Curie Individual Fellowships (IF-GF)	**EVOLMarine**	RAPID EVOLUTION AND GEOGRAPHIC RANGES: PREDICTING MARINE SPECIES PERSISTENCE AND DISTRIBUTION IN A CHANGING OCEAN	659359	N.A.	Results in brief	€ 250 160	OCN, marine ectotherms, adaptation to ocean warming and acidification, species, ocean, biodiversity, global change, plasticity
LC-CLA-07-2019 - The changing cryosphere: uncertainties, risks and opportunities	**FACE-IT**	The future of Arctic coastal ecosystems - Identifying transitions in fjord systems and adjacent coastal areas	869154	https://www.face-it-project.eu/	IPCC AR6, EU Polar Cluster	€ 6 399 272	Arctic, fjords, social-ecological systems, Arctic coastal ecosystrems, adaptation
MSCA-IF-2017 - Individual Fellowships	**FlocDOM**	A BROAD ECOLOGICAL APPROACH TO STUDY THE BIOLOGICAL UPTAKE OF DISSOLVED ORGANIC MATTER (DOM) AND DOM-FLOCCULATES IN THE RAPIDLY CHANGING ARCTIC COASTAL ECOSYSTEMS	800371	N.A.	Results	€ 200 194	OCN, carbon sequestration, DOM, Arctic, flocculated DOM
LC-CLA-08-2018 - Addressing knowledge gaps in climate science, in support of IPCC reports	**FORCeS**	Constrained aerosol forcing for improved climate projections	821205	https://forces-project.eu/	EU Polar Cluster	€ 7 998 287	Polar, climate science, aerosol radiative forcing

MSCA-IF-2015-GF - Marie Skłodowska-Curie Individual Fellowships (IF-GF)	**Future4Oceans**	WINDOW TO THE FUTURE: UNDERSTANDING AND ASSESSING THE VULNERABILITY OF MARINE BIODIVERSITY TO OCEAN ACIDIFICATION	702628	https://www.fabiodisconzi.com/open-h2020/projects/202789/index.html	Result in brief	€ 244 269	OCN, OA, marine ecosystems, multi-stressors experimental FOCE systems, genomic studies of the adaptive capacity of marine species to OA
LC-CLA-06-2019 - Inter-relations between climate change, biodiversity and ecosystem services	**FutureMARES**	Climate Change and Future Marine Ecosystem Services and Biodiversity	869300	https://www.futuremares.eu/	COP26, Featured in Horizon Magazine	€ 8 555 905	NBS, marine conservation, climate science, OCN, CC adaptation and mitigation, coastal, blue carbon
ERC-ADG-2015 - ERC Advanced Grant	**GlobalMass**	GLOBAL LAND ICE, HYDROLOGY AND OCEAN MASS TRENDS	694188	https://www.globalmass.eu/	Key findings	€ 2 397 430	OCN, SLR, satellite and *in-situ* data related to different aspects of the sea level budget
MSCA-IF-2019 - Individual Fellowships	**GLOMAC**	GLOBAL-SCALE INTERACTIONS BETWEEN MANGROVE FORESTS AND CLIMATE	896888	https://explore.openaire.eu/search/project?projectId=corda__h2020::23cd122b03d9b4443646bc807efaf658	Results	€ 178 320	OCN, blue carbon, mangroves, carbon cycle, climate science
ERC-2016-COG - ERC Consolidator Grant	**GOCART**	GAUGING OCEAN ORGANIC CARBON FLUXES USING AUTONOMOUS ROBOTIC TECHNOLOGIES	724416	https://projects.noc.ac.uk/gocart/	Results	€ 1 999 110	OCN, ocean's biological carbon pump, gliders
BG-07-2015 - Response capacities to oil spills and marine pollutions	**GRACE**	Integrated oil spill response actions and environmental effects	679266	Integrated oil spill response actions and environmental effects	Special feature	€ 5 277 554	Ocean observation, OCN, Arctic, adaptation, coastal protection, ice, pollution, SST, oil spills, marine pollution
BG-08-2018-2019 - All Atlantic Ocean Research Alliance Flagship	**iAtlantic**	INTEGRATED ASSESSMENT OF ATLANTIC MARINE ECOSYSTEMS IN SPACE AND TIME	818123	https://www.iatlantic.eu/	scientific advances, COP26	€ 10 631 224	OCN, Atlantic, climate science, marine biodiversity, OA, ocean circulation
MSCA-IF-2016 - Individual Fellowships	**ICEDNA**	INVESTIGATING CHANGES IN ANTARCTIC MARINE	749851	https://sites.google.com/view/i	Result	€ 200 194	OCN, polar, environmental

		ECOSYSTEMS USING ENVIRONMENTAL DNA		cedna/home			DNA (eDNA) analysis
MSCA-IF-2017 - Individual Fellowships	**IceDynamO**	THE DYNAMICS OF SEA ICE VARIABILITY – ROLE OF THE OCEANS	792639	https://geo.au.dk/en/research/research-areas/department-groups/paleoceanography-and-paleoclimate-group/research/teodora-pados-the-dynamics-of-sea-ice-variability-role-of-the-oceans	Results in brief	€ 212 194	OCN, Arctic, sea-ice variability, climate science, sediment core extraction, Greenland, micro-palaeontological and geochemical analyses, high-resolution, multi-proxy reconstruction of the dynamics and variability of the East Greenland Current and the sea-ice cover off north-east Greenland at centennial resolution throughout the Holocene, foraminifer
ICT-26-2016 - System abilities, development and pilot installations	**ILIAD**	INTRA-LOGISTICS WITH INTEGRATED AUTOMATIC DEPLOYMENT: SAFE AND SCALABLE FLEETS IN SHARED SPACES	732737	https://iliad-project.eu/	Scientific advances, demonstrators, pilots, prototypes	€ 6 987 71	Robots, fleet management
MSCA-IF-2020 - Individual Fellowships	**IMOS**	IMAGING OCEAN SINKERS FOR EVALUATING CARBON EXPORT FLUXES	101032903	N.A.	N.A.	€ 245 732	OCN, ocean carbon export fluxes, particle imaging
MSCA-IF-2017 - Individual Fellowships	**INADEC**	IMPACTS OF THE NORTH ATLANTIC DECADAL VARIABILITY ON EUROPEAN CLIMATE: MECHANISMS AND PREDICTABILITY	800154	https://www.bsc.es/research-development/research-areas/climate-prediction/atlantic-variability-and-predictability	Results in brief	€ 170 121	OCN, climate science, Atlantic, SST, AMV, teleconnections between the AMV and European climate
BG-09-2016 - An integrated Arctic observation system	**INTAROS**	Integrated Arctic observation system	727890	https://intaros.nersc.no/	EU Polar Cluster, Research EU Magazine	€ 15 490 066	Arctic, observation, OCN

MSCA-IF-2018 - Individual Fellowships	**IRONBIND**	THE INFLUENCE OF OCEAN ACIDIFICATION ON PHYTOTRANSFERRIN-MEDIATED IRON UPTAKE RATES IN PHYTOPLANKTON	844733	https://twitter.com/jmcquaid	N.A.	€ 87 403	OCN, OA, marine phytoplankton, climate science
INFRAIA-1-2014-2015 - Integrating and opening existing national and regional research infrastructures of European interest	**JERICO-NEXT**	JOINT EUROPEAN RESEARCH INFRASTRUCTURE NETWORK FOR COASTAL OBSERVATORY – NOVEL EUROPEAN EXPERTISE FOR COASTAL OBSERVATORIES	654410	https://www.jerico-ri.eu/	Results	€ 9 998 876	OCN, coastal observation, infrastructure
LC-CLA-07-2019 - The changing cryosphere: uncertainties, risks and opportunities	**JUSTNORTH**	Toward Just, Ethical and Sustainable Arctic Economies, Environments and Societies	869327	https://justnorth.eu/	EU Polar Cluster	€ 5 999 994	Arctic, sustainability, economic activities
LC-SPACE-02-EO-2018 - Copernicus evolution – Mission exploitation concepts	**KEPLER**	Key Environmental monitoring for Polar Latitudes and European Readiness	821984	https://kepler-polar.eu/	EU Polar Cluster	€ 2 899 156	Polar, ice services, COPERNICUS
BG-09-2014 - Acoustic and imaging technologies	**LAkHsMI**	Sensors for LArge scale HydrodynaMic Imaging of ocean floor	635568	Lakhsmi project		€ 3 040 221	OCN, ocean observation, environmental monitoring, SST
MSCA-IF-2015-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)	**LAWINE**	LINKS BETWEEN WARMING ARCTIC AND CLIMATE EXTREMES IN NORTHERN EURASIA	707262	https://orcid.org/0000-0002-2939-7561	Results in brief	€ 191 325	OCN, Arctic, climate science, extreme events, teleconnection, Eurasia, warming, amplification
LC-CLA-06-2019 - Inter-relations between climate change, biodiversity and ecosystem services	**MaCoBioS**	MARINE COASTAL ECOSYSTEMS BIODIVERSITY AND SERVICES IN A CHANGING WORLD	869710	https://macobios.eu/	N.A.	€ 6 980 657	OCN, coastal, biodiversity and ecosystems, CC-biodiversity-ecosystem services, MCEs, NBS, BC
H2020-MSCA-IF-2020	**MARINEGLYCAN**	Marine chemical glycobiology: a molecular understanding of the carbon cycle and	101029842	N.A.	KER	€ 162 806	OCN, marine carbon cycle, marine microalgae

		bioactive sulfated marine glycans					
MSCA-ITN-2015-ETN - Marie Skłodowska-Curie Innovative Training Networks (ITN-ETN)	**MARmaED**	MARine MAnagement and Ecosystem Dynamics under climate change	675997	https://www.marmaed.uio.no/	N.A.	€ 4 073 903	OCN, food webs, climate change
SC5-18-2017 - Novel in-situ observation systems	**MELOA**	Multi-purpose/Multi-sensor Extra Light Oceanography Apparatus	776825	https://www.ec-meloa.eu/	KER	€ 4 694 844	OCN, observation, wavy drifter device, monitor surface currents and surface dynamic, SST
SC5-07-2015 - More effective ecosystem restoration in the EU	**MERCES**	Marine Ecosystem Restoration in Changing European Seas	689518	Welcome to Merces | Merces (merces-project.eu)	KERs, featured in results pack, scientific advances	€ 6 651 117	OCN, adaptation, marine ecosystems restoration, conservation, ecosystem services, NBS
BG-08-2018-2019 - All Atlantic Ocean Research Alliance Flagship	**MISSION ATLANTIC**	TOWARDS THE SUSTAINABLE DEVELOPMENT OF THE ATLANTIC OCEAN: MAPPING AND ASSESSING THE PRESENT AND FUTURE STATUS OF ATLANTIC MARINE ECOSYSTEMS UNDER THE INFLUENCE OF CLIMATE CHANGE AND EXPLOITATION	862428	https://missionatlantic.eu/	Scientific advances	€ 11 501 717	OCN, Atlantic, climate change, marine ecosystems
MSCA-IF-2015-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)	**NITROX**	NITROX- NITROGEN REGENERATION UNDER CHANGING OXYGEN CONDITIONS	704272	N.A.	Results in brief	€ 212 194	OCN, deoxygenation, N, Baltic Sea, primary productivity
BG-11-2017 - The effect of climate change on Arctic permafrost and its socio-economic impact, with a focus on coastal areas	**NUNATARYUK**	Permafrost thaw and the changing arctic coast: science for socio-economic adaptation	773421	https://nunataryuk.org/	IPCC AR6, EU Polar Cluster, scientific advances	€ 11 467 317	Arctic, adaptation, permafrost thaw, methane emissions
ERC-2019-ADG - ERC Advanced Grant	**OCEAN DEOXYFISH**	OCEAN DEOXYGENATION EFFECTS ON THREATENED TOP PREDATORS: NEW	883583	https://www.mare-centre.pt/en/sh	Results	€ 3 110 111	OCN, deoxygenation, impact of sharks and tuna, permanent oxygen minimum

		UNDERSTANDING AND PREDICTIONS FROM NOVEL BIO-LOGGING INSTRUMENTS AND DATA		arks-under-pressure-deoxygenating-deep-sea-drives-sharks-to-the-surface				zones (OMZ)
ERC-2018-STG - ERC Starting Grant	**OceaNice**	PALEOCEANOGRAPHY OF THE ICE-PROXIMAL SOUTHERN OCEAN DURING PAST WARM CLIMATES	802835	https://www.uu.nl/staff/pkbijl	N.A.		€ 1 500 000	OCN, Antarctic, ice sheets, SO warming, palaeoceanography
MSCA-IF-2014-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)	**OceanIS**	OCEAN INTERACTION WITH ANTARCTIC ICE SHELVES	661015	N.A.	N.A.		€ 195 454	OCN, Antarctic, ice shelves
MSCA-IF-2014-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)	**OceanLiNES**	OCEAN LIMITING NUTRIENTS – EXAMINATION FROM SPACE	658035	http://oceanlinesproject.blogspot.com/p/about.html	N.A.		€ 159 460	OCN, marine phytoplankton, fluorescence, energy and carbon, climate science, satellite, oceanic nutrient stress status
MSCA-IF-2016 - Individual Fellowships	**OceanModes**	BASIN MODES OF THE OCEAN: THEIR ROLE IN THE INTERANNUAL TO INTERDECADAL CLIMATE VARIABILITY	749924	https://www.umr-lops.fr/Le-Laboratoire/Contacts/Pages-perso/Antoine-Hochet	N.A.		€ 264 668	OCN, climate science, ocean variability, ocean-atmosphere system, stochastic variability
LC-CLA-02-2019 - Negative emissions and land-use based mitigation assessment	**OceanNETs**	Ocean-based Negative Emission Technologies - analyzing the feasibility, risks, and cobenefits of ocean-based negative emission technologies for stabilizing the climate	869357	https://www.oceannets.eu/	COP26		€ 7 192 894	Ocean NETs/CDR, OCN, climate science, carbon, sequestration, blue carbon, governance
MSCA-IF-2015-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)	**ODEON**	ONLINE DEPOSITION OVER OCEANS: MODELING THE EFFECT OF AIR POLLUTION ON OCEAN BIO-GEOCHEMISTRYIN AN EARTH SYSTEM MODEL	705652	https://www.uu.nl/en/research/institute-for-marine-and-atmospheric-research-imau	Result in Brief		€ 177 598	OCN, biogeochemistry, climate science, ESM, primary productivity, Fe deposition, oceanic carbon cycle

MSCA-IF-2018 - Individual Fellowships	**OSeaIce**	TWO-WAY INTERACTIONS BETWEEN OCEAN HEAT TRANSPORT AND ARCTIC SEA ICE	834493	https://sites.google.com/view/daviddocquier/home	KER, Results in brief	€ 101 926	OCN, climate science, Arctic, sea ice, observation, ocean heat transport
MSCA-IF-2019 - Individual Fellowships	**P4 Plight**	PLIGHT OF PELAGIC PRIMARY PRODUCERS IN A CHANGING MARINE ENVIRONMENT	885498	N.A.	N.A.	€ 224 933	OCN, coccolithophores, marine pelagic ecosystem, impact of past climate extremes
LC-CLA-17-2020 - Polar climate: understanding the polar processes in a global context in the Arctic and Antarctic Regions	**PolarRES**	Polar Regions in the Earth System	101003590	https://polarres.eu/	EU Polar Cluster	€ 7 996 321	Polar, climate science, ice, ocean observation, OCN, chemical, circulation
SC5-01-2014 - Advanced Earth-system models	**PRIMAVERA**	PRocess-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment	641727	Home | PRIMAVERA (primavera-h2020.eu)	featured, results in brief	€ 14 967 969	OCN, climate science, CMIP6
LC-CLA-07-2019 - The changing cryosphere: uncertainties, risks and opportunities	**PROTECT**	PROjecTing sEa-level rise : from iCe sheets to local implicaTions	869304	https://protect-slr.eu/	IPCC AR6, EU Polar Cluster, scientific advances	€ 9 996 661	Polar, climate services, adaptation, ice, SLR, OCN, climate science, cryosphere, Greenland
MSCA-IF-2018 - Individual Fellowships	**RHODOCAR**	GLOBAL AND LOCAL IMPACTS ON ATLANTIC RHODOLITH BEDS: IMPLICATIONS FOR ESTIMATES OF BLUE CARBON ECOSYSTEM SERVICES	844703	https://www.ccmar.ualg.pt/project/global-and-local-impacts-atlantic-rhodolith-beds-implications-estimates-blue-carbon	Results	€ 147 815	OCN, blue carbon ecosystem services, rhodolith beds
INFRAIA-01-2016-2017 - Integrating Activities for Advanced Communities	**SeaDataCloud**	SEADATACLOUD - FURTHER DEVELOPING THE PAN-EUROPEAN INFRASTRUCTURE FOR MARINE AND OCEAN	730960	https://www.seadatanet.org/	Results in brief,	€ 9 999 737	OCN, data, infrastructure, marine, interoperability, Common Data Index, coastal, maritime data infrastructure, ODV, temperature, salinity,

		DATA MANAGEMENT						SLR by sea basins) and climatology (regional gridded field products based on the aggregated datasets) for all the European sea basins
INFRAIA-01-2016-2017 - Integrating Activities for Advanced Communities	**SeaDataCloud**	SEADATACLOUD - FURTHER DEVELOPING THE PAN-EUROPEAN INFRASTRUCTURE FOR MARINE AND OCEAN DATA MANAGEMENT	730960	https://www.seadatanet.org/About-us/SeaDataCloud	Results in brief	€ 9 999 737	OCN, observation, marine and ocean data management
MSCA-IF-2016 - Individual Fellowships	**SEAMET**	MULTI-DRIVER CLIMATE CHANGE EFFECTS ON SEAGRASS METABOLISM: ECOSYSTEM IMPLICATIONS	752250	https://www.researchgate.net/project/SEAMET-Multi-driver-climate-change-effects-on-seagrass-metabolism-ecosystem-implications	Results in brief	€ 183 454	OCN, blue carbon, seagrass, climate science, physiological tolerance, metabolic adjustments and plasticity limits of marine benthic photoautotrophs to different Global Climate Change drivers (e.g. ocean acidification, temperature and hypoxia), acclimation and adaptation to CC, ecosystem functioning
MG-3.3-2016 - Safer waterborne transport and maritime operations	**SEDNA**	Safe maritime operations under extreme conditions: the Arctic case	723526	https://www.sedna-project.eu/	Results in brief, prototypes	€ 6 498 752	OCN, Arctic, safe maritime operations, CC adaptation, resilience, sea safety
MSCA-IF-2019 - Individual Fellowships	**SedTraceFlux**	The critical role of sedimentary trace element fluxes in ocean biogeochemistry	891489	N.A.	Results	€ 191 149	OCN, ocean biogeochemistry, climate science, Trace elements and isotopes (TEIs)
LC-CLA-08-2018 - Addressing knowledge gaps in climate science, in support of IPCC reports	**SO-CHIC**	Southern Ocean Carbon and Heat Impact on Climate	821001	http://www.sochic-h2020.eu/	IPCC AR6, EU Polar Cluster, EU Polar Science Week, science to policy	€ 7 989 925	Antarctic, Atlantic, OCN, climate science, ice, carbon cycle, heat, SLR

SC5-06-2016-2017 - Pathways towards the decarbonisation and resilience of the European economy in the timeframe 2030-2050 and beyond	**SOCLIMPACT**	DownScaling CLImate imPACTs and decarbonisation pathways in EU islands, and enhancing socioeconomic and non-market evaluation of Climate Change for Europe, for 2050 and beyond.	776661	Soclimpact - Project to fight against Climate Change in EU islands	KERs, Advancements-climate services	€ 4 481 340	Climate services, blue economy, OCN, adaptation, coastal, islands, SLR, socio-economic impacts of CC, SST, hazards
MSCA-IF-2016 - Individual Fellowships	**SONAR-CO2**	SOUTHERN OCEAN NANOPLANKTON RESPONSE TO CO2	748690	https://sites.google.com/usal.es/sonar-co2/home	Results	€ 158 121	OCN, oceanic carbon pump, OA, Southern Ocean, cocolithophores, chemical and physical variables, PIC, Subantarctic Zone
EO-1-2014 - New ideas for Earth-relevant space applications	**SPICES**	SPACE-BORNE OBSERVATIONS FOR DETECTING AND FORECASTING SEA ICE COVER EXTREMES	640161	N.A.	Results in brief	€ 2 995 678	OCN, climate science, sea ice cover, hazards, observation, Arctic, MYI
LCE-15-2015 - Enabling decarbonisation of the fossil fuel-based power sector and energy intensive industry through CCS	**STEMM-CCS**	STRATEGIES FOR ENVIRONMENTAL MONITORING OF MARINE CARBON CAPTURE AND STORAGE	654462	https://www.stemm-ccs.eu/	Results in brief, scientific advances, award	€ 15 918 369	OCN, climate science, marine carbon capture, offshore marine carbon storage, sub-seabed, CO2 leaks, environmental monitoring
ERC-CoG-2014 - ERC Consolidator Grant	**STERCP**	Synchronisation to enhance reliability of climate predictions	648982	https://stercpproject.w.uib.no/	Results	€ 1 999 388	OCN, AMOC, CMIP models, ocean-atmosphere coupled models, methods to reduce the systematic error of models, predictability of the supermodel, inter-annual, decadal and climate variability.
ERC-StG-2014 - ERC Starting Grant	**SUSTAINABLEOCEAN**	ACCOMMODATING NEW INTERESTS AT SEA: LEGAL TOOLS FOR SUSTAINABLE OCEAN GOVERNANCE	639070	https://www.uu.nl/en/research/sustainable-ocean	Results in brief	€ 1 051 500	OCN, ocean governance, offshore sector, threat to marine ecosystems

BG-07-2019-2020 - The Future of Seas and Oceans Flagship Initiative	**TechOceanS**	Technologies for Ocean Sensing	101000858	https://techoceans.eu/	Scientific advances, results	€ 8 975 662	OCN, new remote ocean sensing technology to support ocean conservation and monitoring.
MSCA-IF-2015-EF - Marie Skłodowska-Curie Individual Fellowships (IF-EF)	**TERMS-Ocean**	TRANSGENERATIONAL ECOPHYSIOLOGICAL RESPONSES TO MULTIPLE STRESSORS IN A CHANGING OCEAN	704895	https://biosciences.exeter.ac.uk/	Results in brief	€ 195 454	OCN, climate science, transgenerational phenotypic plasticity (TPP) in the response of a keystone marine invertebrate to the combined impacts of climate change and OA
LC-CLA-08-2018 - Addressing knowledge gaps in climate science, in support of IPCC reports	**TIPACCs**	Tipping Points in Antarctic Climate Components	820575	https://www.tipaccs.eu/	science to policy, EU Polar Cluster, EU Polar Science Week	€ 4 602 897	Antarctic, polar, OCN, climate science, tipping points, ice, SLR, ocean circulation, EWS, adaptation
LC-CLA-08-2018 - Addressing knowledge gaps in climate science, in support of IPCC reports	**TiPES**	Tipping Points in Earth System	820970	https://www.tipes.dk/about/	IPCC AR6, science to policy, scientific advances and project of the month	€ 8 561 238	OCN, climate science, tipping points, ocean system, adaptation
ERC-2020-COG - ERC CONSOLIDATOR GRANTS	**TITANICA**	A new era of transient tracers in the Arctic and Atlantic oceans	101001451	https://explore.openaire.eu/search/project?projectId=corda__h2020::bce3c12ab4c901ee208dcad6e22810e3	N.A.	€ 2 642 578	OCN, Arctic, Antarctic, AMOC, transient radionuclide tracers (129I, 236U, 39Ar and 14C), oceanographic processes on timescales from years to millennia
BG-08-2018-2019 - All Atlantic Ocean Research Alliance Flagship	**TRIATLAS**	TROPICAL AND SOUTH ATLANTIC CLIMATE-BASED MARINE ECOSYSTEM PREDICTIONS FOR SUSTAINABLE MANAGEMENT	817578	http://www.triatlas.eu/	Scientific advancement	€ 11 000 000	OCN, Atlantic, climate science, ecosystems, pollution, CC
ERC-2017-ADG - ERC Advanced Grant	**UltraPal**	ULTIMATE PALEO-OCEAN RECORDS FROM BIOGENIC	788752	https://www.epfl.ch/labs/lgb/	N.A.	€ 2 435 000	OCN, biogenic calcites, paleo-ocean reconstruction

		CALCITES					
ERC-2018-STG - ERC Starting Grant	**WAAXT**	WAVE-MODULATED ARCTIC AIR-SEA EXCHANGES AND TURBULENCE	805186	N.A.	Results	€ 2 000 000	OCN, Arctic, wave, sea ice, ocean boundary layer processes in a changing Arctic Ocean
ERC-StG-2014 - ERC Starting Grant	**WAPITI**	WATER-MASS TRANSFORMATION AND PATHWAYS IN THE WEDDELL SEA: UNCOVERING THE DYNAMICS OF A GLOBAL CLIMATE CHOKEPOINT FROM IN-SITU MEASUREMENTS	637770	N.A.	N.A.	€ 1 998 125	OCN, Antarctic, shelf circulation, global ocean overturning circulation, Weddell Sea, SLR
MSCA-IF-2020 - Individual Fellowships	**WARMM**	WARMING OCEAN AND RESPONSES OF ARCTIC MARINE MAMMALS	101025534	N.A.	N.A.	€ 286 921	OCN, warming, Arctic, marine mammals
MSCA-IF-2016 - Individual Fellowships	**WhiteShift**	A CALCIFYING PHYTOPLANKTER'S RESPONSE TO CLIMATE CHANGE AND ITS ROLE IN SINKING CARBON IN THE SUBARCTIC OCEAN USING SPACEBORNE AND IN SITU OBSERVATIONS AND ECOLOGICAL MODELLING	749949	https://grietneukermans.weebly.com/	N.A.	€ 173 076	OCN, subarctic, marine calcifying phytoplankton, observations, in-situ modelling, climate science

ANNEX 3: H2020: CORTEX OCEAN-CLIMATE NEXUS PROJECTS (COMPLETE)

Call Id	Grant Nbr	Grant Acronym	EU Contribution (Eur)	PMON - Overall Assessment	Peer-Reviewed Publications	Peer-Reviewed Publications in HI Journals	Open Datasets	IPR	PMON - Significant Impact Results	PMON - Expected Impacts on Policy Making ?	PMON - Expected Innovation Capacity ?
H2020-WIDESPREAD-2014-2	668981	EnvMetaGen	2.228.000	Most Objectives Achieved	37	14	0	0	Significant Impact	Yes	Yes
H2020-WIDESPREAD-05-2017-Twinning	810176	Clim4Vitis	999.989	All Objectives Achieved	41	13	0	0	Significant Impact	Yes	Yes
H2020-WIDESPREAD-05-2017-Twinning	809988	RENATURE	995.885	Most Objectives Achieved	25	10	0	0	Significant Impact	Yes	Yes
H2020-WATER-2015-two-stage	689150	SIM4NEXUS	7.895.658	All Objectives Achieved	37	19	586	0	Significant Impact	Yes	Yes
H2020-WATER-2014-two-stage	641811	IMPREX	7.996.848	Most Objectives Achieved	58	35	9	0	Significant Impact	Partial	Partial
H2020-TWINN-2015	692419	BLUEandGREEN	996.688	All Objectives Achieved	281	146	0	0	Significant Impact	Yes	Partial
H2020-TWINN-2015	692014	ECARS	1.000.000	All Objectives Achieved	31	15	0	0	Significant Impact	Partial	Partial
H2020-TWINN-2015	692413	EDGE	1.031.250	Most Objectives Achieved	13	3	0	0	Significant Impact	Yes	Yes
H2020-TWINN-2015	692331	NitroPortugal	999.938	All Objectives Achieved	15	11	0	0	Significant Impact	Yes	Partial
H2020-TWINN-2015	691998	SERBIA FOR EXCELL	931.745	All Objectives Achieved	14	0	0	0	Significant Impact	Yes	Yes
H2020-TWINN-2015	692427	STRONGMAR	999.204	Most Objectives Achieved	16	4	0	3	Significant Impact	Yes	Yes
H2020-SMEInst-2018-2020-2	829640	AquapHOx	1.222.487	All Objectives Achieved	0	0	0	5	Significant Impact	Yes	Yes
H2020-SFS-2017-2	773713	PANDORA	5.598.389	Most Objectives Achieved	41	26	0	0	Significant Impact	Yes	Yes
H2020-SFS-2015-2	678396	TAPAS	6.918.513	All Objectives Achieved	18	11	0	0	Significant Impact	Yes	Yes
H2020-SFS-2014-2	633680	DiscardLess	5.000.000	Most Objectives Achieved	33	23	0	0	Significant Impact	Yes	Yes
H2020-SFS-2014-2	634495	MINOUW	5.904.030	All Objectives Achieved	55	24	0	0	Significant Impact	Yes	Yes
H2020-SC5-2017-TwoStage	776866	RECONECT	13.520.690	Some Objectives	18	7	0	0	Significant Impact	Partial	Partial

				Achieved							
H2020-SC5-2017-OneStageB	776479	COACCH	4.999.844	All Objectives Achieved	33	22	21	0	Significant Impact	Yes	Yes
H2020-SC5-2017-OneStageB	776613	EUCP	12.999.515	Most Objectives Achieved	106	84	9	0	Significant Impact	Yes	Yes
H2020-SC5-2017-OneStageB	776825	MELOA	4.694.845	All Objectives Achieved	3	1	0	0	Significant Impact	Yes	Yes
H2020-SC5-2017-OneStageB	776787	S2S4E	4.771.289	All Objectives Achieved	17	10	0	0	Significant Impact	Yes	Yes
H2020-SC5-2017-OneStageB	776661	SOCLIMPACT	4.481.340	Most Objectives Achieved	18	5	7	0	Significant Impact	Yes	Yes
H2020-SC5-2017-OneStageB	776810	VERIFY	9.998.964	Most Objectives Achieved	53	47	0	0	Significant Impact	Yes	Yes
H2020-SC5-2016-TwoStage	730004	Climate-fit.City	2.936.601	All Objectives Achieved	10	3	2	0	Significant Impact	Yes	Yes
H2020-SC5-2015-two-stage	689518	MERCES	6.651.118	All Objectives Achieved	0	0	30	0	Significant Impact	Partial	Yes
H2020-SC5-2014-two-stage	641918	AfricanBioServices	9.891.769	Most Objectives Achieved	28	14	0	0	Significant Impact	Yes	Yes
H2020-SC5-2014-two-stage	642147	CD-LINKS	5.037.963	All Objectives Achieved	54	47	3	0	Significant Impact	Yes	Yes
H2020-SC5-2014-two-stage	641816	CRESCENDO	14.338.876	Most Objectives Achieved	345	256	16	0	Significant Impact	Yes	Yes
H2020-SC5-2014-two-stage	641762	ECOPOTENTIAL	14.874.340	All Objectives Achieved	163	119	117	0	Significant Impact	Yes	Yes
H2020-SC5-2014-two-stage	641727	PRIMAVERA	14.967.970	All Objectives Achieved	82	58	21	0	Significant Impact	Yes	N/A
H2020-REFLECTIVE-SOCIETY-2014	649307	HERA JRP UP	5.000.000	All Objectives Achieved	17	4	0	0	Significant Impact	Yes	Partial
H2020-MSCA-RISE-2015	690958	MARSU	1.080.000	Most Objectives Achieved	18	13	6	0	Significant Impact	N/A	Yes
H2020-MSCA-RISE-2014	643712	GreenBubbles	1.611.000	All Objectives Achieved	14	6	0	1	Significant Impact	Yes	Yes
H2020-MSCA-NIGHT-2020bis	101036063	SCICLI	147.363	All Objectives Achieved	0	0	0	0	Significant Impact	N/A	N/A
H2020-MSCA-ITN-2017	764991	CLOUD-MOTION	3.919.734	All Objectives Achieved	18	14	0	0	Significant Impact	Yes	Yes
H2020-MSCA-ITN-2017	766327	MixITiN	2.882.899	Most Objectives Achieved	25	14	35	0	Significant Impact	Yes	Yes
H2020-MSCA-ITN-2015	675153	AdaptEconII	3.200.532	All Objectives Achieved	15	7	0	0	Significant Impact	Yes	Yes
H2020-MSCA-ITN-2015	675997	MARmaED	4.073.903	Most Objectives Achieved	21	19	0	0	Significant Impact	Yes	Yes
H2020-MSCA-ITN-2014	642575	ALFF	3.710.595	Most Objectives Achieved	22	13	0	0	Significant Impact	N/A	Yes

H2020-MSCA-ITN-2014	643084	BASE-LiNE Earth	3.749.331	All Objectives Achieved	16	12	0	0	Significant Impact	Yes	Yes
H2020-MSCA-ITN-2014	643052	C-CASCADES	3.112.981	All Objectives Achieved	26	20	0	0	Significant Impact	Yes	Yes
H2020-MSCA-ITN-2014	642153	MarineUAS	3.851.103	Most Objectives Achieved	8	1	0	0	Significant Impact	Partial	Yes
H2020-MSCA-ITN-2014	642973	PRIDE	3.784.089	All Objectives Achieved	12	8	0	0	Significant Impact	Yes	Partial
H2020-MSCA-IF-2018	832738	ESCAPE	191.149	Most Objectives Achieved	15	4	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2018	834493	OSeaIce	101.926	All Objectives Achieved	7	6	3	0	Significant Impact	Yes	N/A
H2020-MSCA-IF-2018	844891	VESYNECH	160.932	All Objectives Achieved	0	0	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2017	792370	DURCWAVE	170.122	Most Objectives Achieved	15	6	2	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2017	796802	DUSTCO	148.636	Most Objectives Achieved	2	2	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2017	795722	EnvironMetal	175.420	Most Objectives Achieved	2	2	1	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2017	797236	FESTIVAL	158.122	All Objectives Achieved	3	2	2	0	Significant Impact	Yes	N/A
H2020-MSCA-IF-2017	795315	FOREPAST	170.122	Most Objectives Achieved	6	3	4	0	Significant Impact	Partial	Yes
H2020-MSCA-IF-2017	792639	IceDynamO	212.195	All Objectives Achieved	0	0	0	0	Significant Impact	Yes	Yes
H2020-MSCA-IF-2017	800154	INADEC	170.122	All Objectives Achieved	3	1	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2017	797007	MAPAPAIMA	185.076	Most Objectives Achieved	1	0	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2017	797961	PROTECT	158.122	All Objectives Achieved	3	2	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2017	798365	SABIR	200.195	All Objectives Achieved	2	1	0	0	Significant Impact	Partial	N/A
H2020-MSCA-IF-2016	737480	ACCLIM	158.122	All Objectives Achieved	7	4	0	0	Significant Impact	N/A	Partial
H2020-MSCA-IF-2016	750937	ADAPTOMICS	195.455	All Objectives Achieved	3	3	0	0	Significant Impact	No	Yes
H2020-MSCA-IF-2016	746748	CAP-ICE	264.668	Most Objectives Achieved	4	4	2	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	749461	DUST-GLASS	164.653	Most Objectives Achieved	3	2	0	0	Significant Impact	N/A	Partial
H2020-MSCA-IF-2016	746033	ELEMIN	166.157	All Objectives Achieved	8	7	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	753937	eSEAS	208.400	Most Objectives	3	3	0	0	Significant Impact	Yes	N/A

				Achieved							
H2020-MSCA-IF-2016	747637	EVOMA	158.122	Most Objectives Achieved	4	4	0	0	Significant Impact	Yes	Yes
H2020-MSCA-IF-2016	752325	GrIS-Melt	200.195	Most Objectives Achieved	1	1	0	0	Significant Impact	Yes	N/A
H2020-MSCA-IF-2016	746186	POSEIDoN	177.599	All Objectives Achieved	3	2	2	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	743547	REHIPRE	170.122	All Objectives Achieved	3	2	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	752250	SEAMET	183.455	Most Objectives Achieved	1	1	0	0	Significant Impact	Yes	Yes
H2020-MSCA-IF-2016	753021	TransTurb	123.138	Most Objectives Achieved	2	1	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	747102	TRIM	195.455	Most Objectives Achieved	3	3	0	0	Significant Impact	No	No
H2020-MSCA-IF-2016	749380	UCYN2PLAST	246.668	All Objectives Achieved	5	4	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	749699	WACO	173.076	Most Objectives Achieved	1	1	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2016	749949	WhiteShift	173.076	All Objectives Achieved	2	2	0	0	Significant Impact	Yes	Yes
H2020-MSCA-IF-2015	703251	CONCLIMA	164.653	Most Objectives Achieved	3	2	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2015	701478	DryMIN	183.455	Most Objectives Achieved	3	2	0	0	Significant Impact	Partial	Partial
H2020-MSCA-IF-2015	701329	FIBER	158.122	Most Objectives Achieved	7	6	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2015	707818	FIMAF	200.195	Most Objectives Achieved	0	0	0	0	Significant Impact	Yes	Yes
H2020-MSCA-IF-2015	706318	FREYA	212.195	Most Objectives Achieved	5	5	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2015	702628	Future4Oceans	244.269	Most Objectives Achieved	1	1	0	0	Significant Impact	Yes	N/A
H2020-MSCA-IF-2015	707968	IDEA	212.195	Most Objectives Achieved	5	5	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2015	700952	ISLANDPALECO	251.276	Most Objectives Achieved	1	0	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2015	704951	ISOMET	165.211	Most Objectives Achieved	4	3	0	0	Significant Impact	Yes	N/A
H2020-MSCA-IF-2015	706428	Ko-Tsah-To	177.599	Most Objectives Achieved	3	1	0	0	Significant Impact	Yes	N/A
H2020-MSCA-IF-2015	707262	LAWINE	191.326	All Objectives Achieved	5	4	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2015	703880	MSCCC	159.461	Most Objectives Achieved	3	3	0	0	Significant Impact	Yes	N/A

H2020-MSCA-IF-2015	706303	MultiSens	170.122	All Objectives Achieved	3	1	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2015	704272	NITROX	212.195	All Objectives Achieved	6	6	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2015	705652	ODEON	177.599	All Objectives Achieved	3	1	0	0	Significant Impact	Partial	Yes
H2020-MSCA-IF-2015	702747	POSEIDOMM	180.277	All Objectives Achieved	6	5	3	0	Significant Impact	Yes	N/A
H2020-MSCA-IF-2015	704585	PROCEED	177.599	All Objectives Achieved	3	2	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2015	702916	SOUTHERNCHA NGE	195.455	Most Objectives Achieved	0	0	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2015	704895	TERMS-Ocean	195.455	Most Objectives Achieved	1	1	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2014	659398	ACE_GFAT	158.122	All Objectives Achieved	4	2	0	0	Significant Impact	Partial	N/A
H2020-MSCA-IF-2014	657473	BioFrost	171.461	Most Objectives Achieved	2	2	0	0	Significant Impact	N/A	No
H2020-MSCA-IF-2014	655661	DeepTrees	251.858	All Objectives Achieved	19	9	0	0	Significant Impact	No	N/A
H2020-MSCA-IF-2014	659359	EVOLMARIN	250.160	All Objectives Achieved	3	3	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2014	661342	NEARCONTROL	203.200	All Objectives Achieved	3	2	0	0	Significant Impact	Yes	Yes
H2020-MSCA-IF-2014	660893	OCTANT	159.461	Most Objectives Achieved	1	0	0	0	Significant Impact	N/A	Yes
H2020-MSCA-IF-2014	656821	SEAGAS	238.410	All Objectives Achieved	13	10	0	0	Significant Impact	N/A	N/A
H2020-MSCA-IF-2014	653223	USIFlux	173.076	Most Objectives Achieved	4	4	0	0	Significant Impact	Yes	N/A
H2020-MSCA-COFUND-2015	713750	DOC2AMU	2.354.400	All Objectives Achieved	56	35	0	1	Significant Impact	N/A	N/A
H2020-MSCA-COFUND-2015	701647	PSI-FELLOW-II-3i	4.248.000	All Objectives Achieved	171	105	0	0	Significant Impact	Yes	N/A
H2020-MSCA-COFUND-2015	713730	TLRH-VRF COFUND	318.600	All Objectives Achieved	3	0	0	0	Significant Impact	N/A	N/A
H2020-MSCA-COFUND-2014	665667	EPFL Fellows	3.398.400	All Objectives Achieved	150	131	0	13	Significant Impact	Yes	N/A
H2020-MSCA-COFUND-2014	665778	POLONEZ	5.841.000	Most Objectives Achieved	410	207	0	0	Significant Impact	Partial	N/A
H2020-MG-2017-Two-Stages	769255	SAFEWAY	4.521.100	Most Objectives Achieved	42	19	0	0	Significant Impact	Yes	Yes
H2020-MG-2016-SingleStage-INEA	723986	EUNADICS-AV	7.441.814	All Objectives Achieved	12	9	0	0	Significant Impact	Yes	Yes
H2020-MG-2016-	723989	SKILLFUL	2.991.672	All Objectives	3	0	0	0	Significant Impact	Yes	Yes

SingleStage-INEA				Achieved							
H2020-MG-2015_TwoStages	690770	SHIPLYS	6.144.150	All Objectives Achieved	5	4	0	0	Significant Impact	Yes	Yes
H2020-LEIT-BIO-2015-1	686070	DD-DeCaF	6.250.636	All Objectives Achieved	47	39	0	0	Significant Impact	Yes	Yes
H2020-LC-SC3-2018-Joint-Actions-3	826033	ETIP OCEAN 2	975.260	All Objectives Achieved	0	0	0	0	Significant Impact	Yes	N/A
H2020-LCE-2017-RES-CCS-RIA	764760	CarbFix2	2.200.318	All Objectives Achieved	21	9	0	0	Significant Impact	Yes	Yes
H2020-LCE-2015-1-two-stage	654010	MacroFuels	5.999.893	Most Objectives Achieved	9	5	0	0	Significant Impact	Yes	Yes
H2020-LCE-2015-1-two-stage	654462	STEMM-CCS	15.918.369	All Objectives Achieved	91	63	0	0	Significant Impact	Yes	Yes
H2020-LCE-2014-3	646529	TILOS	11.008.623	All Objectives Achieved	36	9	0	2	Significant Impact	Yes	Yes
H2020-LCE-2014-2	657982	Cheap-GSHPs	4.844.652	All Objectives Achieved	12	2	0	0	Significant Impact	Yes	Yes
H2020-LC-CLA-2018-2	821003	4C	7.784.750	All Objectives Achieved	99	79	10	0	Significant Impact	Yes	Yes
H2020-LC-CLA-2018-2	820989	COMFORT	8.191.664	Most Objectives Achieved	75	63	1	0	Significant Impact	Yes	Yes
H2020-LC-CLA-2018-2	820829	CONSTRAIN	7.999.804	Most Objectives Achieved	106	83	29	0	Significant Impact	Yes	Partial
H2020-LC-CLA-2018-2	821205	FORCeS	7.998.287	All Objectives Achieved	71	51	8	0	Significant Impact	Yes	Yes
H2020-LC-CLA-2018-2	820846	PARIS REINFORCE	6.950.549	Most Objectives Achieved	33	19	21	0	Significant Impact	Yes	Yes
H2020-LC-CLA-2018-2	820970	TiPES	8.561.239	Most Objectives Achieved	118	78	47	0	Significant Impact	Yes	N/A
H2020-INT-SOCIETY-2015	693642	SMART	2.491.210	All Objectives Achieved	44	5	0	0	Significant Impact	Yes	Yes
H2020-INFRAIA-2019-1	871120	INTERACT	10.000.000	Most Objectives Achieved	12	2	0	0	Significant Impact	Yes	Yes
H2020-INFRAIA-2017-1-two-stage	731103	EUMarineRobot s	4.998.737	Most Objectives Achieved	45	21	2	0	Significant Impact	Yes	Yes
H2020-INFRAIA-2016-1	731060	INFRAVEC2	9.998.845	All Objectives Achieved	88	63	0	0	Significant Impact	Yes	Yes
H2020-INFRAIA-2016-1	730938	INTERACT	10.000.000	Most Objectives Achieved	23	15	0	0	Significant Impact	Yes	Yes
H2020-INFRAIA-2016-1	730960	SeaDataCloud	9.999.738	All Objectives Achieved	10	6	35	0	Significant Impact	Yes	Yes
H2020-INFRAIA-2014-2015	654109	ACTRIS-2	9.541.195	All Objectives Achieved	374	240	14	0	Significant Impact	Yes	Yes
H2020-INFRAIA-2014-2015	654110	HYDRALAB-PLUS	9.979.376	All Objectives Achieved	21	6	28	0	Significant Impact	Yes	Yes

H2020-INFRAIA-2014-2015	654410	JERICO-NEXT	9.998.876	Most Objectives Achieved	62	37	0	0	Significant Impact	Yes	Yes
H2020-INFRADEV-2016-2	739562	DANUBIUS-PP	3.996.405	All Objectives Achieved	5	0	0	0	Significant Impact	Yes	Yes
H2020-INFRADEV-2016-1	730944	RINGO	4.719.680	Most Objectives Achieved	22	18	36	0	Significant Impact	Yes	Yes
H2020-INFRADEV-1-2015-1	676555	EMSODEV	4.298.602	All Objectives Achieved	4	3	9	0	Significant Impact	Yes	Yes
H2020-INFRADEV-1-2014-1	654182	ENVRI PLUS	14.683.534	Most Objectives Achieved	14	5	0	0	Significant Impact	Yes	Yes
H2020-EO-2017	776361	AirQast	1.876.956	Most Objectives Achieved	2	2	0	0	Significant Impact	Partial	Yes
H2020-EO-2017	776186	CHE	3.765.190	All Objectives Achieved	18	16	9	0	Significant Impact	Yes	Yes
H2020-EO-2016	730030	CEASELESS	1.999.333	Most Objectives Achieved	11	5	1	0	Significant Impact	Yes	Yes
H2020-EO-2016	730066	EOMORES	2.005.862	All Objectives Achieved	13	6	0	0	Significant Impact	Yes	Yes
H2020-EO-2016	730098	MARINE-EO	4.378.584	All Objectives Achieved	0	0	0	0	Significant Impact	Yes	Yes
H2020-EO-2014	640176	BACI	2.997.859	All Objectives Achieved	80	64	1	0	Significant Impact	Yes	Yes
H2020-EO-2014	640171	EUSTACE	2.694.969	Most Objectives Achieved	20	15	6	0	Significant Impact	Partial	Yes
H2020-EO-2014	638822	FIDUCEO	5.497.799	Most Objectives Achieved	11	9	0	0	Significant Impact	Yes	Yes
H2020-EINFRA-2017	777413	DARE	2.957.500	Most Objectives Achieved	2	1	0	0	Significant Impact	Yes	Partial
H2020-EINFRA-2015-1	675680	BlueBRIDGE	5.295.754	All Objectives Achieved	10	2	1	0	Significant Impact	Yes	Yes
H2020-EINFRA-2015-1	675191	ESiWACE	4.951.049	All Objectives Achieved	23	12	0	0	Significant Impact	Partial	Yes
H2020-EINFRA-2015-1	675121	VI-SEEM	3.300.000	Most Objectives Achieved	52	4	14	0	Significant Impact	Yes	Yes
H2020-DRS-2015	700099	ANYWHERE	11.973.368	Most Objectives Achieved	48	29	0	0	Significant Impact	Yes	Yes
H2020-DRS-2015	700174	RESCCUE	6.896.992	Most Objectives Achieved	25	0	0	0	Significant Impact	Partial	Partial
H2020-COMPET-2014	633127	UPWARDS	2.103.594	All Objectives Achieved	42	15	0	0	Significant Impact	Yes	Yes
H2020-BG-2017-1	774499	GoJelly	5.998.115	All Objectives Achieved	48	25	0	1	Significant Impact	Yes	Yes
H2020-BG-2016-1	727862	APPLICATE	7.999.591	All Objectives Achieved	47	34	5	0	Significant Impact	Partial	N/A
H2020-BG-2016-1	727852	Blue-Action	7.500.000	All Objectives	125	90	5	0	Significant Impact	Yes	Yes

				Achieved							
H2020-BG-2016-1	727890	INTAROS	15.490.067	Most Objectives Achieved	72	57	162	0	Significant Impact	Partial	Yes
H2020-BG-2015-2	678760	ATLAS	9.100.317	All Objectives Achieved	117	93	96	0	Significant Impact	Yes	Yes
H2020-BG-2015-2	678193	CERES	5.586.851	All Objectives Achieved	41	29	4	0	Significant Impact	Yes	Yes
H2020-BG-2015-2	677039	ClimeFish	5.000.000	All Objectives Achieved	46	31	22	0	Significant Impact	Yes	Yes
H2020-BG-2015-2	679849	SponGES	9.994.303	Most Objectives Achieved	87	66	98	0	Significant Impact	Partial	Yes
H2020-SPACE-2018	821934	HiSea	1.941.662	Failed Critical Objectives	4	3	0	0	No Significant Impact	No	Partial
H2020-MSCA-RISE-2015	691053	ODYSSEA	1.705.500	Most Objectives Achieved	44	26	0	0	No Significant Impact	N/A	N/A
H2020-MSCA-RISE-2015	691037	QUEST	144.000	Most Objectives Achieved	16	14	0	0	No Significant Impact	N/A	Yes
H2020-MSCA-IF-2018	838535	TEMPO	196.708	Most Objectives Achieved	2	2	1	0	No Significant Impact	N/A	N/A
H2020-MSCA-IF-2017	787344	WAVREP	165.599	Most Objectives Achieved	3	1	5	0	No Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	746312	ACOSA	200.195	Most Objectives Achieved	3	1	0	0	No Significant Impact	Partial	N/A
H2020-MSCA-IF-2015	708063	NeTNPPAO	170.122	Some Objectives Achieved	0	0	0	0	No Significant Impact	N/A	N/A
H2020-MSCA-IF-2014	656381	SHARP	267.147	Most Objectives Achieved	2	2	0	0	No Significant Impact	No	N/A
H2020-WIDESPREAD-05-2017-Twinning	810139	PORTWIMS	997.626	Some Objectives Achieved	59	30	0	0	Likely Significant Impact	Partial	Partial
H2020-SC5-2015-one-stage	690133	GEO-CRADLE	2.910.800	Most Objectives Achieved	8	5	1	0	Likely Significant Impact	Yes	Yes
H2020-SC5-2014-two-stage	642018	GREEN-WIN	3.624.763	Most Objectives Achieved	16	13	2	0	Likely Significant Impact	Yes	Yes
H2020-SC5-2014-two-stage	642260	TRANSrisk	7.454.018	Most Objectives Achieved	22	12	4	0	Likely Significant Impact	No	Partial
H2020-RUR-2017-2	773782	COASTAL	4.999.944	Some Objectives Achieved	12	5	52	0	Likely Significant Impact	Partial	Partial
H2020-MSCA-RISE-2017	777998	CONCHA	778.500	Most Objectives Achieved	7	0	0	0	Likely Significant Impact	Yes	Yes
H2020-MSCA-RISE-2017	778349	GRASP-ACE	877.500	Most Objectives Achieved	3	1	0	0	Likely Significant Impact	Yes	Yes
H2020-MSCA-RISE-2015	691135	RISEN	1.057.500	Most Objectives Achieved	156	51	4	0	Likely Significant Impact	N/A	Yes
H2020-MSCA-ITN-2015	674911	IMPACT	2.538.628	Most Objectives Achieved	20	9	0	0	Likely Significant Impact	Partial	Yes

H2020-MSCA-ITN-2014	643073	CRITICS	3.896.688	Most Objectives Achieved	16	7	0	0	Likely Significant Impact	Yes	Yes
H2020-MSCA-IF-2018	839311	CarbEx	219.312	Most Objectives Achieved	3	2	2	0	Likely Significant Impact	No	Partial
H2020-MSCA-IF-2018	839039	INDITOL	184.708	Most Objectives Achieved	1	0	0	0	Likely Significant Impact	Partial	N/A
H2020-MSCA-IF-2017	795053	EPISODE	175.420	All Objectives Achieved	0	0	0	0	Likely Significant Impact	Partial	N/A
H2020-MSCA-IF-2017	796025	Mesophotic	269.635	Most Objectives Achieved	17	15	0	0	Likely Significant Impact	Yes	Yes
H2020-MSCA-IF-2017	794264	TROPHY	212.195	Most Objectives Achieved	4	4	0	0	Likely Significant Impact	Partial	N/A
H2020-MSCA-IF-2016	747877	D BIOME	183.455	Most Objectives Achieved	9	6	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	751782	GLEC-LAW	183.455	All Objectives Achieved	10	0	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	752813	GlobChangeBeh av	196.400	Most Objectives Achieved	0	0	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2016	747120	ISEBI	263.943	Most Objectives Achieved	4	3	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2015	703813	C-LEAK	183.455	Most Objectives Achieved	6	2	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2015	709185	CLIMCONFLICT	187.866	All Objectives Achieved	1	1	0	0	Likely Significant Impact	Yes	N/A
H2020-MSCA-IF-2015	708119	DUSC3	173.076	Most Objectives Achieved	1	0	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2015	708407	SOSiC	187.420	Most Objectives Achieved	5	4	0	0	Likely Significant Impact	N/A	Yes
H2020-MSCA-IF-2014	654091	CO2NOR	151.649	All Objectives Achieved	1	1	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2014	658602	COCLIMAT	196.400	Most Objectives Achieved	4	0	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2014	656810	DENDRONUTRI ENT	170.122	Most Objectives Achieved	8	4	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-IF-2014	659246	DPaTh-To-Adapt	170.122	Most Objectives Achieved	2	2	0	0	Likely Significant Impact	Yes	Yes
H2020-MSCA-IF-2014	660630	ICE-OTOPE	183.455	Most Objectives Achieved	1	1	0	0	Likely Significant Impact	Yes	N/A
H2020-MSCA-IF-2014	656896	MAIDEN-SPRUCE	173.076	All Objectives Achieved	3	1	0	0	Likely Significant Impact	N/A	N/A
H2020-MSCA-COFUND-2016	754433	STARS	1.416.000	Most Objectives Achieved	3	1	0	0	Likely Significant Impact	N/A	N/A
H2020-MG-2018-SingleStage-INEA	824348	ENDURUNS	7.908.265	Some Objectives Achieved	8	1	0	0	Likely Significant Impact	Yes	Yes
H2020-LC-CLA-2018-2	820575	TiPACCs	4.602.898	All Objectives	15	13	5	0	Likely Significant	Partial	Partial

				Achieved					Impact		
H2020-INFRAIA-2016-1	730997	EUROCHAMP-2020	8.941.290	Most Objectives Achieved	116	91	0	0	Likely Significant Impact	Partial	Yes
H2020-INFRAEOSC-2018-2	824068	ENVRI-FAIR	18.997.879	Most Objectives Achieved	17	9	0	0	Likely Significant Impact	Yes	Partial
H2020-INFRADEV-1-2014-1	653980	ARISE2	2.985.250	Most Objectives Achieved	77	36	0	0	Likely Significant Impact	Partial	Yes
H2020-ICT-2015	687809	POWER	3.747.938	Most Objectives Achieved	12	3	1	0	Likely Significant Impact	Yes	Yes
H2020-ICT-2014-1	643990	POINT	3.494.888	Most Objectives Achieved	5	1	1	0	Likely Significant Impact	Yes	Yes
H2020-FTIPilot-2016-1	730628	OCEAN_2G	1.909.823	All Objectives Achieved	0	0	0	0	Likely Significant Impact	Yes	Yes
H2020-FETHPC-2017	800925	VECMA	3.999.478	All Objectives Achieved	34	21	0	0	Likely Significant Impact	Yes	Yes
H2020-EO-2017	776348	CoastObs	1.968.614	All Objectives Achieved	8	5	2	0	Likely Significant Impact	Yes	Yes
H2020-EIC-FTI-2018-2020	831041	W2EW	3.000.000	Most Objectives Achieved	0	0	0	0	Likely Significant Impact	Yes	Yes
H2020-EeB-2015	680555	TESSe2b	4.311.700	Most Objectives Achieved	9	2	0	0	Likely Significant Impact	N/A	Yes
H2020-DRS-2015	700699	BRIGAID	7.739.806	Most Objectives Achieved	22	11	0	1	Likely Significant Impact	Partial	Yes
H2020-BG-2018-1	818395	AANChOR	3.995.893	Most Objectives Achieved	0	0	0	0	Likely Significant Impact	Partial	Partial
H2020-BG-2017-1	773421	Nunataryuk	11.467.318	Most Objectives Achieved	74	55	5	0	Likely Significant Impact	Yes	Yes
H2020-BG-2016-2	727277	ODYSSEA	8.398.716	Most Objectives Achieved	8	5	0	0	Likely Significant Impact	Yes	Yes
H2020-BG-2014-2	633211	AtlantOS	20.652.921	Most Objectives Achieved	86	60	81	0	Likely Significant Impact	Yes	Yes
H2020-SMEInst-2018-2020-1	877470	EcoFLEXY	50.000	-	0	0	0	0	-	-	-
H2020-SMEInst-2018-2020-1	877659	myPAL-NET	50.000	-	0	0	0	0	-	-	-
H2020-SMEInst-2018-2020-1	867793	Wave Scale	50.000	-	0	0	0	0	-	-	-
H2020-SC5-2016-OneStageB	730258	BE-OI	2.223.000	-	9	7	0	0	-	-	-
H2020-SC5-2014-one-stage	642007	ESMERALDA	3.002.166	-	37	6	0	0	-	-	-
H2020-SC1-2016-RTD-Zika	734857	ZIKAction	6.916.081	-	29	18	0	0	-	-	-
H2020-PHC-2015-two-stage	668786	HEAT-SHIELD	5.777.543	-	73	22	0	0	-	-	-
H2020-PHC-2014-two-stage	634402	METASPACE	2.998.944	-	20	16	0	0	-	-	-
H2020-MSCA-IF-2015	706781	REOPTIMIZE	195.455	-	3	1	0	0	-	-	-
H2020-MSCA-IF-2014	656774	Behaviour-Connect	195.455	-	4	2	0	0	-	-	-

H2020-MSCA-IF-2014	656625	CHOCOLATE	185.076	-	1	0	0	0	-	-	-
H2020-MSCA-IF-2014	661163	Coastal Hypoxia	177.599	-	4	3	0	0	-	-	-
H2020-MSCA-IF-2014	654942	COGNAC	173.076	-	5	4	0	0	-	-	-
H2020-MSCA-IF-2014	658025	CRISIS	195.455	-	1	1	0	0	-	-	-
H2020-MSCA-IF-2014	655339	DPETNA	158.122	-	8	8	0	0	-	-	-
H2020-MSCA-IF-2014	658072	FISHARC	183.455	-	1	0	0	0	-	-	-
H2020-MSCA-IF-2014	657195	MEROXRE	173.076	-	1	1	0	0	-	-	-
H2020-MSCA-IF-2014	660814	PLIOTRANS	183.455	-	3	3	0	0	-	-	-
H2020-MSCA-IF-2014	658120	SEADOG	183.455	-	3	3	0	0	-	-	-
H2020-MSCA-IF-2014	657355	tRRACES	195.455	-	3	3	0	0	-	-	-
H2020-MSCA-IF-2014	654492	UACSURF	195.455	-	2	2	0	0	-	-	-
H2020-LEIT-BIO-2014-1	635536	EmPowerPutida	6.020.825	-	23	18	0	0	-	-	-
H2020-INT-INCO-2015	692173	MESOPP	1.061.690	-	1	1	42	0	-	-	-
H2020-INNOSUP-2019-02	861841	WoRShIP	128.750	-	0	0	0	0	-	-	-
H2020-INFRASUPP-2016-1	730995	SEACRIFOG	1.999.890	-	8	4	0	0	-	-	-
H2020-FETHPC-2014	671564	ComPat	3.942.885	-	33	14	0	0	-	-	-
H2020-FETHPC-2014	671627	ESCAPE	3.977.953	-	9	5	0	0	-	-	-
H2020-EURO-SOCIETY-2014	649186	ISIGrowth	2.498.610	-	48	19	0	0	-	-	-
H2020-EUB-2015	689772	HPC4E	1.998.176	-	12	3	0	0	-	-	-
H2020-EO-2015	687537	EONav	1.999.794	-	0	0	0	3	-	-	-
H2020-EO-2014	637010	EGSIEM	1.752.050	-	6	1	0	0	-	-	-
H2020-EO-2014	640276	GAIA-CLIM	5.999.726	-	11	8	0	0	-	-	-
H2020-EO-2014	640161	SPICES	2.995.678	-	13	11	7	0	-	-	-
H2020-EINFRA-2014-2	654367	EarthServer-2	2.839.743	-	4	1	2	0	-	-	-
H2020-DRS-2014	653522	RESIN	7.466.005	-	5	4	0	0	-	-	-
H2020-BG-2016-1	727453	BLUEMED	2.998.000	-	0	0	0	0	-	-	-
H2020-BG-2014-1	652643	Respon-SEA-ble	3.696.644	-	1	1	0	0	-	-	-
H2020-BG-2014-1	652644	SeaChange	3.494.876	-	1	0	0	0	-	-	-
ERC-2018-STG	804599	MARIPOLDATA	1.391.932	-	6	5	0	0	-	-	-
ERC-2018-ADG	835067	DIATOMIC	2.495.753	-	37	27	0	0	-	-	-
ERC-2017-STG	759457	FAIRFISH	1.493.605	-	6	6	0	0	-	-	-
ERC-2017-STG	758005	MC2	1.500.000	-	14	9	0	0	-	-	-
ERC-2017-COG	770765	highECS	1.998.654	-	22	19	0	0	-	-	-
ERC-2017-COG	771056	LICCI	1.999.999	-	14	8	0	0	-	-	-
ERC-2017-COG	772751	RAVEN	2.000.000	-	12	12	0	0	-	-	-
ERC-2017-COG	771369	Sea2Cloud	1.999.329	-	5	3	0	0	-	-	-

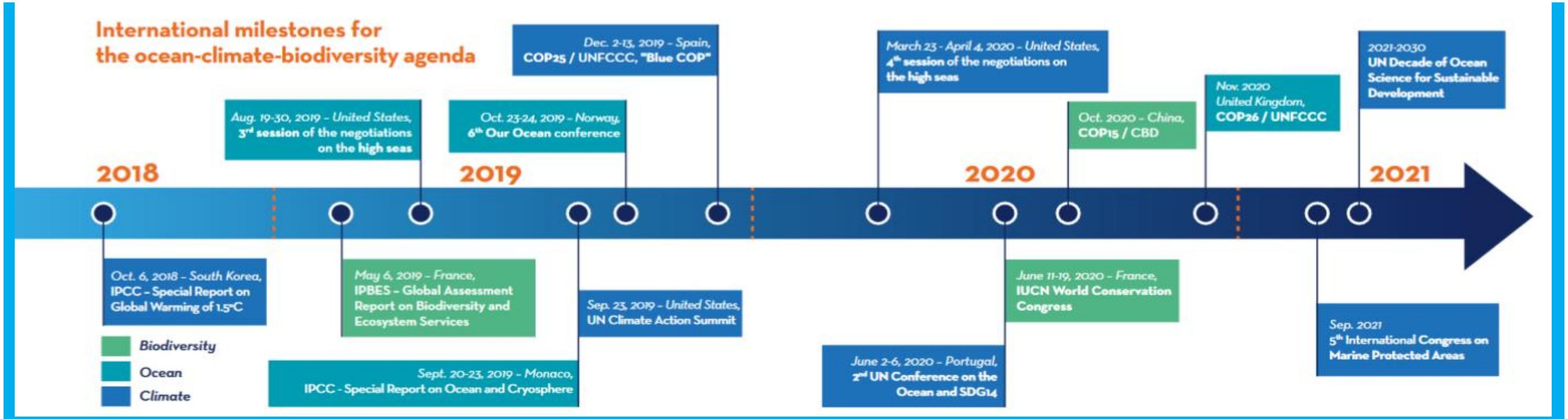
ERC-2017-ADG	786427	Couplet	2.127.711	-	8	7	0	0	-	-	-
ERC-2017-ADG	787652	INTEXseas	2.500.000	-	17	4	0	0	-	-	-
ERC-2017-ADG	787574	PALAEO-RA	2.499.975	-	24	22	1	0	-	-	-
ERC-2017-ADG	787904	PLAST-EVOL	2.499.986	-	9	8	0	0	-	-	-
ERC-2017-ADG	787304	SOS	1.830.070	-	14	7	0	0	-	-	-
ERC-2017-ADG	787516	SPHERE	2.500.000	-	8	3	0	0	-	-	-
ERC-2016-STG	714062	C2Phase	1.499.549	-	10	7	2	0	-	-	-
ERC-2016-STG	714918	CloudBrake	1.867.120	-	1	0	0	0	-	-	-
ERC-2016-STG	715254	DRY-2-DRY	1.465.000	-	55	38	0	0	-	-	-
ERC-2016-STG	714087	So2Sat	1.496.500	-	60	48	0	0	-	-	-
ERC-2016-STG	716092	SPACE	1.499.082	-	9	8	0	0	-	-	-
ERC-2016-STG	715513	SPONGE ENGINE	1.465.097	-	16	16	0	0	-	-	-
ERC-2016-STG	717022	SURFACE	1.499.626	-	37	24	0	0	-	-	-
ERC-2016-STG	715386	TOPIOS	1.484.760	-	39	20	0	0	-	-	-
ERC-2016-STG	715028	VOLATILIS	1.396.300	-	13	8	0	0	-	-	-
ERC-2016-STG	714617	WeThaw	1.999.985	-	15	14	0	0	-	-	-
ERC-2016-PoC	727440	BioCHANGE	149.428	-	9	7	0	0	-	-	-
ERC-2016-COG	724289	BYONIC	1.668.418	-	7	7	0	0	-	-	-
ERC-2016-COG	726349	CLIMAHAL	1.979.112	-	38	33	0	0	-	-	-
ERC-2016-COG	725698	D-TECT	1.968.000	-	27	20	0	0	-	-	-
ERC-2016-COG	724427	FOUR ACES	1.999.475	-	120	12	0	0	-	-	-
ERC-2016-COG	726176	FRAGCLIM	1.998.802	-	12	8	0	0	-	-	-
ERC-2016-COG	724416	GOCART	1.999.110	-	18	15	0	0	-	-	-
ERC-2016-COG	725546	METLAKE	2.000.000	-	34	26	0	0	-	-	-
ERC-2016-COG	726165	PyroTRACH	1.999.832	-	34	30	0	0	-	-	-
ERC-2016-COG	724602	RECAP	2.225.713	-	55	42	0	0	-	-	-
ERC-2016-COG	724046	SUCCESS	1.993.811	-	47	33	0	0	-	-	-
ERC-2016-ADG	742206	ATM-GTP	2.500.000	-	88	63	0	0	-	-	-
ERC-2016-ADG	741120	COMPASS	3.499.270	-	7	4	0	0	-	-	-
ERC-2016-ADG	742798	COS-OCS	2.462.135	-	8	5	1	0	-	-	-
ERC-2016-ADG	742067	DeAge	2.456.250	-	17	14	0	0	-	-	-
ERC-2016-ADG	742472	ECCLES	2.249.834	-	23	20	0	0	-	-	-
ERC-2016-ADG	743080	ERA	2.492.834	-	29	12	0	0	-	-	-
ERC-2016-ADG	740963	EXOCONDENSE	2.492.565	-	37	25	0	0	-	-	-
ERC-2016-ADG	741413	HOPE	2.278.884	-	18	14	3	0	-	-	-

ERC-2016-ADG	741112	ITHACA	2.494.117	-	11	10	0	0	-	-	-
ERC-2016-ADG	742312	MATURATION	2.500.000	-	16	11	0	0	-	-	-
ERC-2016-ADG	742224	WACSWAIN	2.817.554	-	5	3	0	0	-	-	-
ERC-2015-STG	679812	CLOCK	1.184.931	-	13	11	0	0	-	-	-
ERC-2015-STG	679651	ConFooBio	1.497.151	-	17	12	0	0	-	-	-
ERC-2015-STG	678145	CoupledIceClim	1.677.282	-	9	7	0	0	-	-	-
ERC-2015-STG	677756	FORECASToneM ONTH	1.808.000	-	33	27	0	0	-	-	-
ERC-2015-STG	678371	ICY-LAB	1.999.885	-	24	21	0	0	-	-	-
ERC-2015-STG	679873	MONASS	1.497.212	-	12	2	0	0	-	-	-
ERC-2015-STG	678812	OXYGEN	1.767.455	-	21	12	0	0	-	-	-
ERC-2015-STG	678779	ROC-CO2	1.499.696	-	16	11	0	0	-	-	-
ERC-2015-STG	678799	SILCI	1.198.136	-	19	17	0	0	-	-	-
ERC-2015-STG	676982	THAWSOME	1.500.000	-	2	1	0	0	-	-	-
ERC-2015-STG	679030	WHIPLASH	1.480.421	-	45	10	0	0	-	-	-
ERC-2015-CoG	681447	AROMA-CFD	1.656.579	-	59	28	0	0	-	-	-
ERC-2015-CoG	682602	BIGSEA	1.600.000	-	19	15	0	0	-	-	-
ERC-2015-CoG	682760	CONTROLPAST CO2	2.000.000	-	29	27	0	0	-	-	-
ERC-2015-CoG	682172	NETS	1.587.602	-	12	8	0	0	-	-	-
ERC-2015-CoG	683043	RESPONDER	2.443.800	-	17	10	0	0	-	-	-
ERC-2015-CoG	683237	TIMED	2.400.000	-	13	12	0	0	-	-	-
ERC-2015-CoG	681715	Virocellsphere	2.749.901	-	13	12	0	0	-	-	-
ERC-2015-AdG	695331	CC-TOP	2.499.756	-	21	18	0	0	-	-	-
ERC-2015-AdG	694509	CUNDA	2.597.754	-	27	16	0	0	-	-	-
ERC-2015-AdG	694561	EntangleGen	2.390.000	-	28	17	0	0	-	-	-
ERC-2015-AdG	695446	EnvJustice	1.910.811	-	57	43	0	0	-	-	-
ERC-2015-AdG	694768	EUREC4A	3.013.334	-	44	40	0	0	-	-	-
ERC-2015-AdG	694481	GC2.0	2.497.563	-	39	27	0	0	-	-	-
ERC-2015-AdG	694188	GlobalMass	2.397.430	-	18	13	0	0	-	-	-
ERC-2015-AdG	694578	IsoMet	2.494.693	-	15	5	0	0	-	-	-
ERC-2015-AdG	694569	MICROLIPIDS	2.499.426	-	50	32	0	0	-	-	-
ERC-2014-STG	640458	A-LIFE	1.987.980	-	41	33	0	0	-	-	-
ERC-2014-STG	637776	ALKENoNE	940.883	-	9	4	0	0	-	-	-
ERC-2014-STG	638467	C4T	1.877.209	-	8	7	0	0	-	-	-
ERC-2014-STG	639828	CALI	1.482.844	-	20	11	0	0	-	-	-
ERC-2014-STG	638703	COALA	1.892.221	-	46	40	0	0	-	-	-

ERC-2014-STG	637462	DecentLivingEnergy	869.722	-	16	14	0	0	-	-	-
ERC-2014-STG	639003	DEEP TIME	1.438.846	-	14	12	0	0	-	-	-
ERC-2014-STG	638665	EURO-LAB	1.827.855	-	25	21	0	0	-	-	-
ERC-2014-STG	640422	GREENT	1.500.000	-	25	22	0	0	-	-	-
ERC-2014-STG	636746	HUCO	1.500.000	-	12	7	0	0	-	-	-
ERC-2014-STG	640004	PHYSFISH	1.499.880	-	26	20	0	0	-	-	-
ERC-2014-STG	639070	SUSTAINABLEOCEAN	1.051.500	-	5	0	0	0	-	-	-
ERC-2014-STG	637770	WAPITI	1.998.125	-	24	12	0	0	-	-	-
ERC-2014-CoG	649087	ASICA	2.269.689	-	13	10	0	0	-	-	-
ERC-2014-CoG	646857	ECLAIR	1.999.511	-	9	4	0	0	-	-	-
ERC-2014-CoG	647570	ESTUARIES	2.000.000	-	2	2	0	0	-	-	-
ERC-2014-CoG	646612	Eurasia3angle	2.000.000	-	32	11	0	0	-	-	-
ERC-2014-CoG	649081	MAGIC	1.999.999	-	36	32	0	0	-	-	-
ERC-2014-CoG	648661	MarineIce	2.681.881	-	43	32	0	1	-	-	-
ERC-2014-CoG	647204	QUINCY	2.000.000	-	39	31	0	0	-	-	-
ERC-2014-CoG	647423	SEDAL	1.716.954	-	76	60	0	0	-	-	-
ERC-2014-CoG	647224	SIZE	1.670.406	-	20	16	0	0	-	-	-
ERC-2014-CoG	647383	SPIRE	1.839.634	-	89	15	0	0	-	-	-
ERC-2014-CoG	647035	STEEPclim	1.847.546	-	7	5	0	0	-	-	-
ERC-2014-CoG	648982	STERCP	1.999.389	-	31	21	0	0	-	-	-
ERC-2014-CoG	648609	TWORAINS	1.999.439	-	36	28	0	0	-	-	-
ERC-2014-ADG	666971	BIOSTASES	2.092.644	-	42	33	0	0	-	-	-
ERC-2014-ADG	669947	HADES	3.185.000	-	49	34	0	0	-	-	-
ERC-2014-ADG	662770	Local State	2.469.285	-	32	9	0	0	-	-	-
ERC-2014-ADG	669830	MicrobioS	2.184.433	-	32	29	0	0	-	-	-
ERC-2014-ADG	670390	SEACELLS	2.704.190	-	14	13	0	0	-	-	-
Totaux			**1.031.991.007**		**9 319**	**5 858**	**1 769**	**31**			

ANNEX 4: INTERNATIONAL MILESTONES OF THE OCEAN- CLIMATE-BIODIVERSITY AGENDA

In the last three decades, the ocean's pivotal role has become widely recognized in climate regulation and sustaining planetary life, as well as its fragility to the growing anthropogenic pressure. Largely driven by the consensual scientific knowledge gathered by the independent **Intergovernmental Panel on Climate Change** (IPCC, 1988), which dedicated one of its reports to the **ocean-climate nexus (Scientific Report on the Oceans and Cryosphere in a Changing Climate, "SROCC", 2019)**, a series of policy actions have taken place, towards a global climate strategy and finally recognising the role of nature in being part of the solution. The **Blue COP25** has brought for the very first time the ocean on the bright spot of the UN climate change conference, highlighting the close links between the health of the climate and the health of the ocean. **COP26** follows on with the announcement of an **annual Ocean-Climate Dialogue**, which marks a huge step forward in the global recognition of the crucial role played by the ocean in tackling climate change, strengthening the role of the ocean and ocean-based climate action in the **UNFCCC process**.



[113]

[113] International milestones for the ocean-climate-biodiversity agenda[113]

[114]

[114] https://wordpress.vermontlaw.edu/vlscop25/files/2019/08/Ocean-History-Timeline-Infographic.pdf

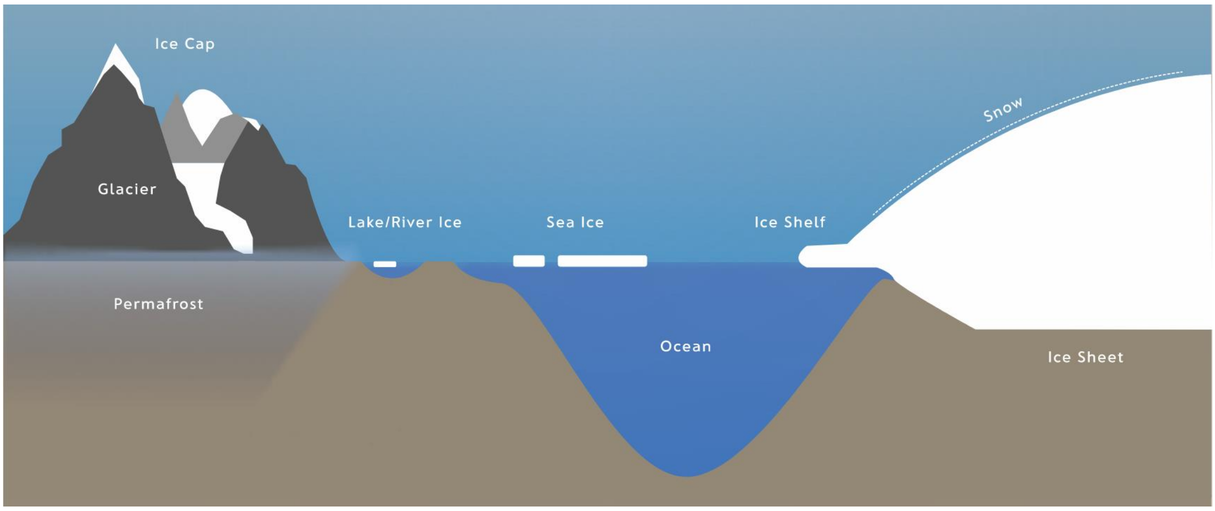
ANNEX 5: OVERVIEW OF OCEAN-CLIMATE RESEARCH FINDINGS -

GLOBAL ASSESSMENTS

The **IPCC SROCC** 2019[115] stresses that:

- Over the 21st century, the ocean is projected to *transition to unprecedented conditions* with increased temperatures, greater upper ocean stratification, further acidification, oxygen decline, and altered net primary production. There is much *uncertainty about the extent of these physical changes* and about the subsequent reactions of marine ecosystems;
- *Global mean sea-level rise* will cause the frequency of extreme sea level events to increase;
- *Global-scale glacier mass loss, permafrost thaw, and decline in snow cover and Arctic sea ice extent* are projected to continue in the first half of this century with unavoidable consequences for river runoff and local hazards;
- *Marine heatwaves and extreme El Niño and La Niña events* are projected to become more frequent;
- The *Atlantic Meridional Overturning Circulation (AMOC)* is projected to weaken with any substantial weakening of the AMOC producing changes in addition to those caused by the global warming, such as decrease in marine productivity in the North Atlantic, more storms in Northern Europe, and less Sahelian and South Asian summer rainfall.
- Global warming induced changes to the Ocean and Cryosphere are projected to affect *Polar marine ecosystems* through direct and indirect effects on habitats, populations and their viability, and to harm habitat-forming cold-water corals, which support high biodiversity.
- The report shows that climate-resilient and sustainable development is only possible with immediate, drastic, coordinated and sustained *mitigation measures to preserve the vital functions of the ocean*.

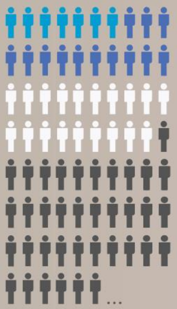
Highlighted excerpts from the Infographic[116] prepared by the Energy & Climate Intelligence Unit explaining the IPCC Special Report on the Ocean and the Cryosphere in a Changing Climate:



[115] https://www.ipcc.ch/srocc/ and the factsheet https://www.ipcc.ch/site/assets/uploads/2019/09/SROCC-factsheet.pdf
[116] INFOGRAPHIC: SPECIAL REPORT ON THE OCEAN AND CRYOSPHERE HTTPS://ECIU.NET/ANALYSIS/INFOGRAPHICS/IPCC-SROCC

MUCH OF THE DAMAGE CAUSED BY **CLIMATE CHANGE** IS **IRREVERSIBLE** ON TIMESCALES RELEVANT TO HUMAN SOCIETIES.

OF THE WORLD'S 7.6 BILLION PEOPLE ...

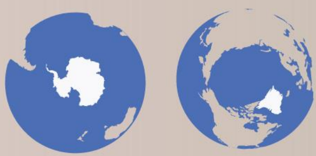


- Live in low-lying coastal zones
- Live on coasts
- Rely on the the water that flows from the Hindu Kush Himalayan glaciers for drinking, agriculture, energy, or other purposes.
- = 100 million

Ocean covers most of Earth's surface. Since 1970, the ocean has absorbed over 90% of the extra heat caused by human-caused global warming.

680 MILLION PEOPLE LIVE IN LOW-LYING COASTAL AREAS

66% OF HINDU KUSH HIMALAYAN GLACIERS MAY BE LOST BY 2100



Ice sheets and glaciers cover 10% of Earth's surface.

The massive white spaces of the cryosphere perform a vital service in regulating the planet's temperature by reflecting the sun's heat back into space. Any loss of ice accelerates climate change.

EARTH'S ICE IS IN MELTDOWN.

"ICE SHEETS AND GLACIERS WORLDWIDE ARE LOSING MASS."

35
BILLION DOUBLE DECKER BUSES

... worth of ice mass was lost from the West Antarctic and Greenland ice sheets every year from 2006-2015.

ARCTIC AIR SURFACE TEMPERATURE HAS INCREASED BY ...

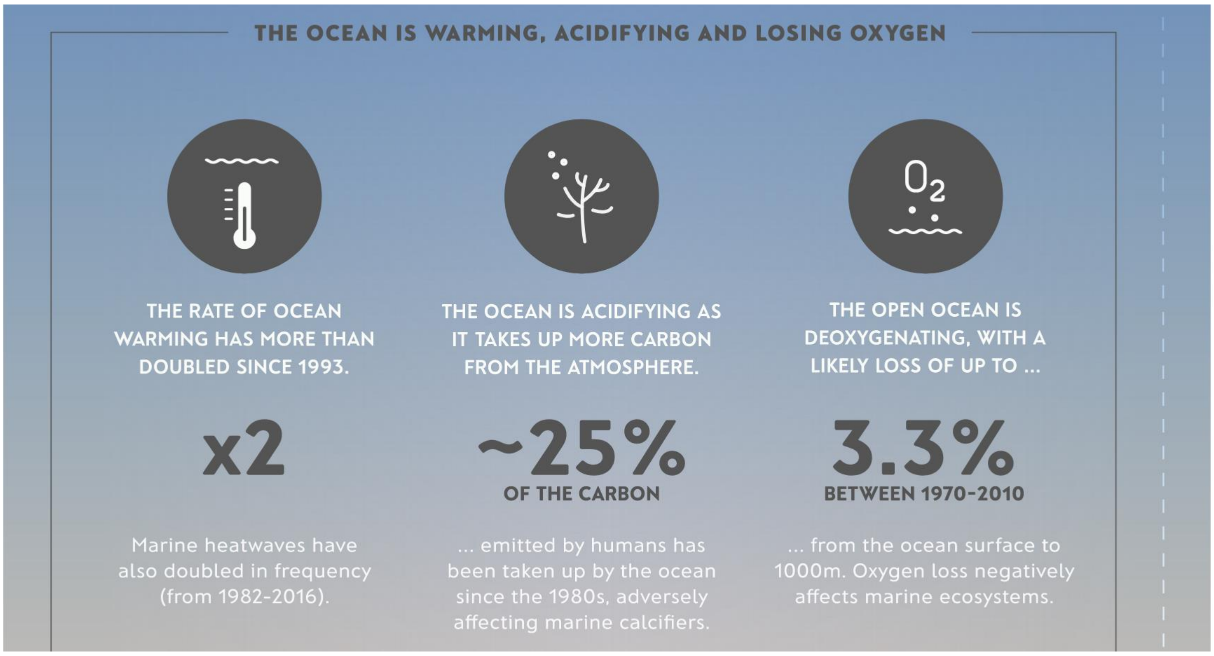
x2
(DOUBLE)

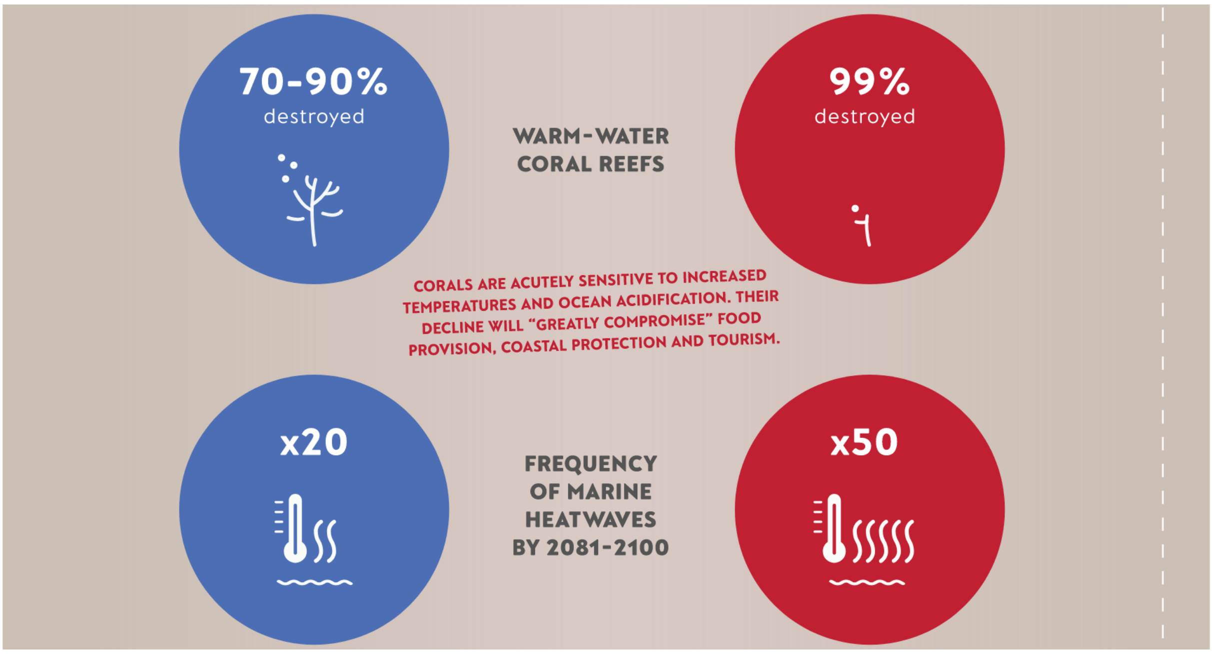
... the global average over the last two decades. Arctic sea ice is declining in all months of the year.

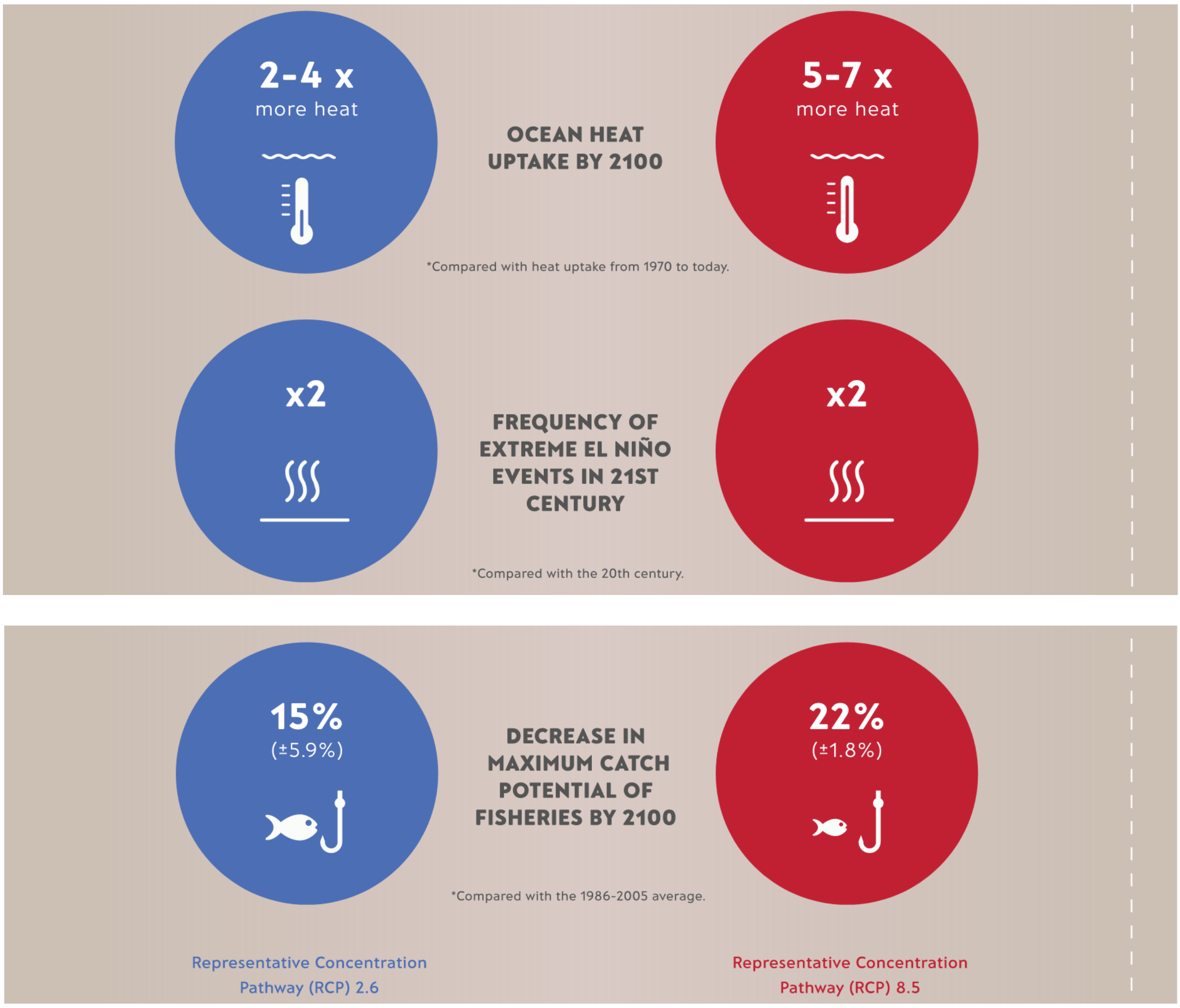
PERMAFROST TEMPERATURES HAVE INCREASED TO RECORD HIGH LEVELS.

1500
BILLION TONNES OF CARBON

... is contained under the permafrost. For an idea of how much this is, the total mass of carbon in the atmosphere today is about 870 billion tonnes.

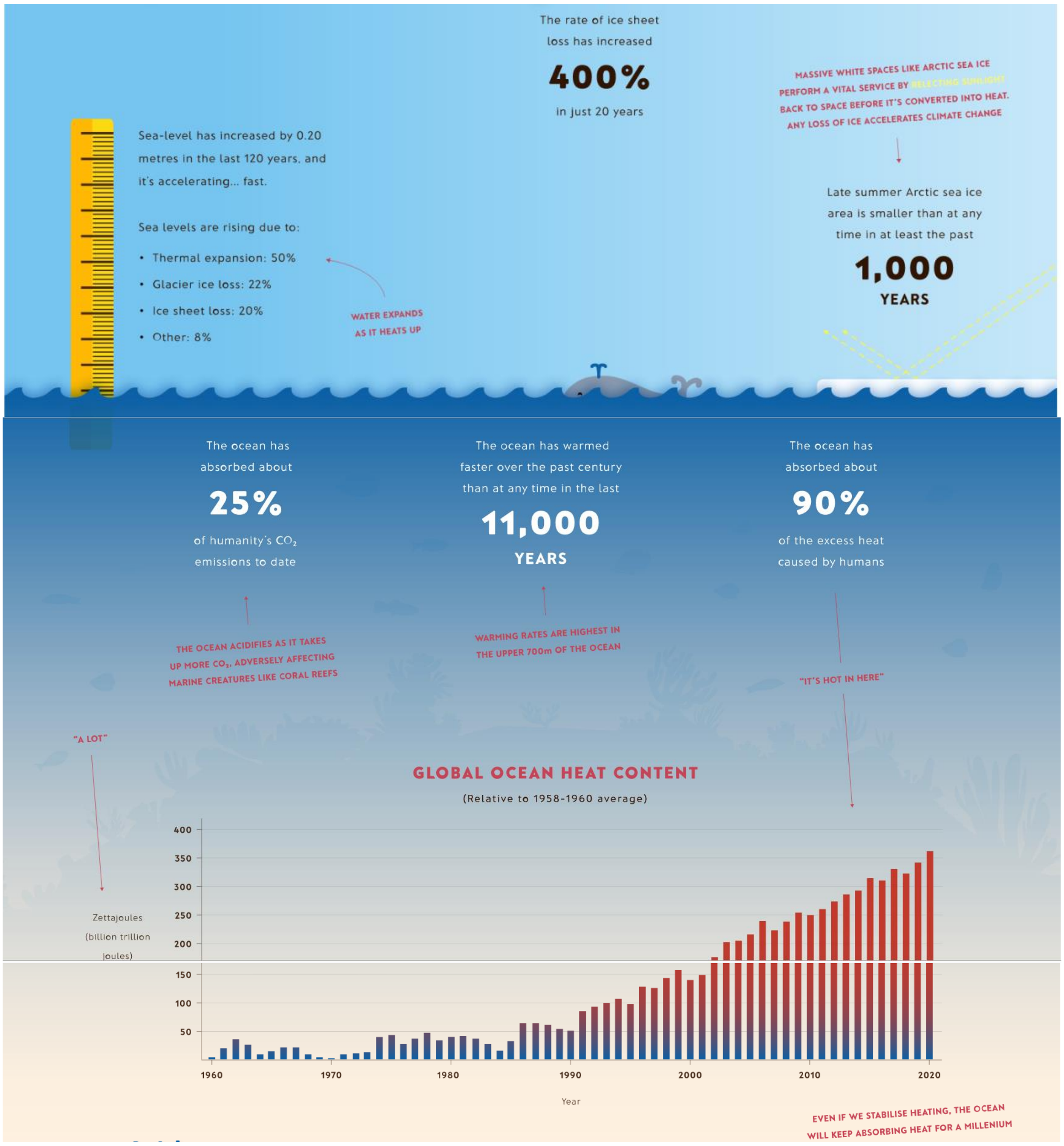

THE OCEAN IS WARMING, ACIDIFYING AND LOSING OXYGEN
THE RATE OF OCEAN WARMING HAS MORE THAN DOUBLED SINCE 1993.
x2
Marine heatwaves have also doubled in frequency (from 1982-2016).
THE OCEAN IS ACIDIFYING AS IT TAKES UP MORE CARBON FROM THE ATMOSPHERE.
~25%
OF THE CARBON
... emitted by humans has been taken up by the ocean since the 1980s, adversely affecting marine calcifiers.
O2
THE OPEN OCEAN IS DEOXYGENATING, WITH A LIKELY LOSS OF UP TO ...
3.3%
BETWEEN 1970-2010
... from the ocean surface to 1000m. Oxygen loss negatively affects marine ecosystems.


70-90%
destroyed
WARM-WATER
CORAL REEFS
99%
destroyed
CORALS ARE ACUTELY SENSITIVE TO INCREASED TEMPERATURES AND OCEAN ACIDIFICATION. THEIR DECLINE WILL "GREATLY COMPROMISE" FOOD PROVISION, COASTAL PROTECTION AND TOURISM.
x20
FREQUENCY
OF MARINE
HEATWAVES
BY 2081-2100
x50


2-4 x
more heat
OCEAN HEAT
UPTAKE BY 2100
5-7 x
more heat
*Compared with heat uptake from 1970 to today.
x2
FREQUENCY OF
EXTREME EL NIÑO
EVENTS IN 21ST
CENTURY
x2
*Compared with the 20th century.
15%
(±5.9%)
DECREASE IN
MAXIMUM CATCH
POTENTIAL OF
FISHERIES BY 2100
22%
(±1.8%)
*Compared with the 1986-2005 average.
Representative Concentration
Pathway (RCP) 2.6
Representative Concentration
Pathway (RCP) 8.5

The **IPCC SIXTH ASSESSMENT**

Highlighted excerpts from the Infographic[117] prepared by the Energy & Climate Intelligence Unit explaining the IPCC AR6:



[117] Infographic: IPCC Explainer: The Science of Climate Change https://eciu.net/analysis/infographics/ipcc-science-of-climate-change

Temperatures will continue to increase until mid-century under all scenarios. In the absence of deep reductions in CO_2 emissions, 1.5°C and 2°C will be exceeded this century. Many changes are baked in for thousands of years. Changes to global sea level, the ocean and ice sheets are "irreversible" on timescales relevant to human societies.

SEA-LEVEL

Over the next 2,000 years, mean sea-level will eventually rise:

- At 5°C: 19-22 metres
- At 2°C: 2-6 metres
- At 1.5°C: 2-3 metres

"It will remain elevated for thousands of years"

DUE TO CONTINUING DEEP-OCEAN WARMING AND ICE-SHEET MELT

OCEAN

"Changes are irreversible on centennial to millennial time scales in global ocean temperature, ocean acidification and deoxygenation"

GLACIERS

Under a best case scenario, glaciers will lose 18% of their current mass by 2100

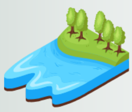
ICE SHEETS

At sustained levels of heating between 3°C and 5°C, "ice sheets will be lost irreversibly over multiple millennia":

- West Antarctic Ice Sheet: complete loss
- Greenland Ice Sheet: near-complete loss

The IPCC used five illustrative scenarios – **'Shared Socioeconomic Pathways' or SSPs** – to investigate how emissions and heating may increase. In all of them, CO_2 increases out to about 2040. What happens after that depends on choices we make now.

PROJECTIONS (GHG EMISSIONS)	VERY LOW	LOW	INTERMEDIATE	HIGH	VERY HIGH
	A BEST CASE SCENARIO: NET ZERO CO_2 BY 2055		ROUGHLY IN LINE WITH CURRENT NATIONAL PLEDGES UNDER THE PARIS AGREEMENT		REVERSAL OF CLIMATE POLICIES
SSPs:	SSP 1-1.9	SSP 2-2.6	SSP 2-4.5	SSP 3-7.0	SSP 5-8.5
CO_2 EMISSSIONS TAKEN UP BY LAND + OCEAN SINKS	70%	65%	54%	44%	38%
SEA-LEVEL RISE BY 2150	37 - 86cm	46 - 99cm	0.66 - 1.33m	–	0.98 - 1.88m (SEA LEVEL RISE OF 5 METRES BY 2150 "CANNOT BE RULED OUT")



Overall, the carbon cycle is expected to "weaken" as a result of increasing temperatures, leading to more CO_2 emissions remaining in the atmosphere and less being absorbed by the land and ocean. That's not good news because without the land and ocean doing its thing (generously absorbing about half of the CO_2 we emit today) climate change would already be around twice as bad as it is now.

While the VERY HIGH scenario is unlikely as the rate of annual CO_2 emissions slows down — as we transition away from fossil fuels and decouple emissions from economic growth — the CO_2 levels it contains "cannot be ruled out". This is because as we heat up, there's an increasing risk we open a Pandora's Box of climate feedbacks...

1. **WGI - Climate Change 2021: The Physical Science Basis**[118] stresses that:

- Large-scale indicators of climate change in the atmosphere, ocean, and cryosphere are *reaching levels, and changing at rates, unseen in centuries to many thousands of years*;
- Many consequences of ongoing climate change are *irreversible on centennial to millennial time scales*, *especially for changes in the ocean, ice sheets and global sea level*;
- Past emissions have led to unavoidable future changes in *ocean temperature* and *sea level rise* from ocean *thermal expansion*, which are *irreversible on centennial to millennial time scales*. Over the rest of the 21st century, projected *ocean warming* ranges from *double to 4 –8 times the observed change during 1971 –2018*. *Ocean stratification, acidification and deoxygenation* will continue to increase in the 21st century, *at a rate depending on the future emission scenario;*
- Human influence likely contributed to increases in atmospheric moisture and extremely likely contributed to changes in *ocean salinity*;
- It is virtually certain that the *global ocean has warmed* over the past five decades and extremely likely that human influence is the main driver of this warming. It is virtually certain that CO_2 emissions are the main driver of *global ocean acidification*. There is high confidence that *oxygen* levels have dropped in many ocean regions since the mid-20th century and that the geographic range of many marine organisms has changed over the last two decades;
- *Global mean sea level* increased by 0.20m between 1901 and 2018. Human activity was very likely the main driver of observed global mean sea level rise since at least 1970;
- During the last decade, annual *Arctic sea ice* coverage reached its lowest level since at least 1850, and late summer coverage was less than anytime during at least the past 1000 years. Recent *global glacier retreat* is *unprecedented* in at least the last 2000 years. The rate of *global mean sea level rise* beginning around 1900 has risen faster than over any preceding century in at least the last thousand years. The *rate of ocean heat content gain* was greater over the past century than at any time since the ending of the last ice age. *Acidification of the open surface ocean* is greater now, and has been increasing faster, than anytime in at least thousand years;
- *Greenland and Antarctic Ice Sheet mass loss* was four times larger during 2010 –2019 than 1992 –1999;
- Additional warming will lead to *permafrost thawing, loss of seasonal snow cover, and melting of sea ice*, the *Greenland Ice Sheet and glaciers*. The *Arctic Ocean* will become practically *sea ice-free in late summer* by the end of the 21st century under all but the lowest two CO_2 emissions scenarios. There is low confidence in the projected decrease of *Antarctic sea ice*;
- *Glaciers* will continue to *lose mass* for at least several decades even if global temperature is stabilized. Both *Greenland and Antarctic Ice Sheets* will continue to *lose mass* throughout this century. *Poorly understood ice-sheet destabilization processes* could contribute *more than one additional meter of sea level increase* by 2100 in addition to the likely projected *global mean sea level rise*;
- *Global mean sea level* will continue to rise over the 21st century. Over the 21st century, the majority of coastal locations have a median projected regional sea -level rise within ±20% of the projected global mean sea level increase. The *frequency of extreme sea level events* will increase in the 21st century, so that once-per -century extreme sea level events will occur annually in 2100. Beyond 2100, *sea level will continue to rise for centuries to millennia* due to continuing *deep ocean heat uptake* and *mass loss from ice sheets*, and will remain elevated for thousands of years;

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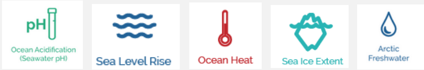
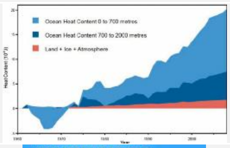
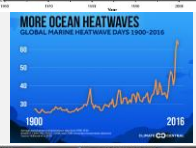
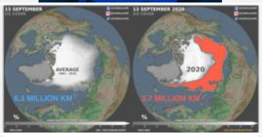
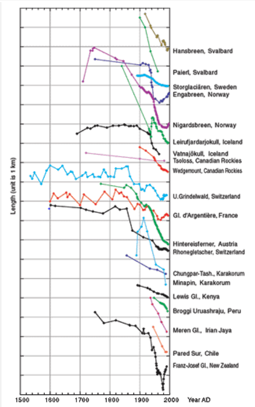
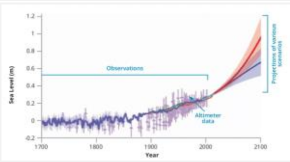
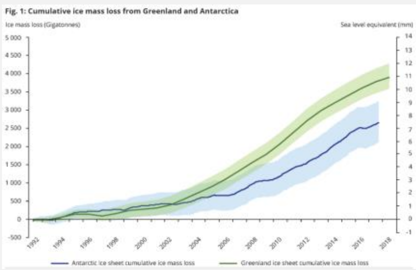
[118] https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/ and the following FactSheets:
1. Ocean - https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Ocean.pdf
2. Europe - https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Europe.pdf
3. Polar Regions - https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Polar_regions.pdf
4. Small Islands -https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Small_Islands.pdf

- At sustained warming levels between 3°C and 5°C, *near-complete loss of the Greenland Ice Sheet and complete loss of the West Antarctic Ice Sheet* is projected to *occur irreversibly over multiple millennia* (medium confidence); with *substantial parts or all of Wilkes Subglacial Basin in East Antarctica lost over multiple millennia* (low confidence);
- There is deep uncertainty regarding the *Antarctic contribution to global mean sea level rise* beyond 2100 linked to *potential destabilization of the West Antarctic Ice Sheet*;
- All future warming scenarios show committed *sea-level rise of several metres* after two millennia, with *ice sheets the dominant uncertainty on century timescales;*
- On multi decadal-to-centennial timescales there is *deep uncertainty in sea-level projections* associated with the response of the *ice sheets*;
- Under high CO_2 emission scenarios, the *ocean* and land *carbon sinks* are projected to become less effective at slowing the growth rate of atmospheric CO_2. Land and *ocean CO_2 sinks* have removed on average 56% of all anthropogenic CO_2 emissions over the past six decades. Projections show that these sinks will take up a larger amount of CO_2 under high compared to low CO_2 emission scenarios. However, the fraction of emissions removed from the atmosphere by land and oceans will decrease with higher cumulative CO_2 emissions, resulting in a higher proportion of remaining CO_2 in the atmosphere.
- The *ocean* remains a *sink* of CO_2 *for centuries* after emissions become net negative; There is low confidence in the *timing of the sink -to -source transition* and the *magnitude of the CO_2 source*; Carbon dioxide removal could reverse some aspects climate change if CO_2 emissions become net negative, but *some changes would continue in their current direction for decades to millennia*, for instance, *sea level rise due to ocean thermal expansion* would not reverse for several centuries to millennia;
- Understanding of *multi -decadal reversibility* (i.e., the system returns to the previous climate state within multiple decades after the radiative forcing is removed) has improved since AR5 for many atmospheric, land surface and sea ice climate metrics following sea surface temperature recovery; Some processes suspected of having *tipping points*, such as the *Atlantic Meridional Overturning Circulation (AMOC),* have been found to *often undergo recovery after temperature stabilization with a time delay* (low confidence). However, *substantial irreversibility* is further substantiated for some cryosphere changes, *ocean warming, sea level rise, and ocean acidification;*
- *Potential abrupt changes in the ocean and cryosphere* include an *AMOC collapse* or a *destabilization of Greenland and Antarctic ice sheets*. Although it is unlikely that an abrupt collapse of the AMOC will occur during the 21st century, such a collapse cannot be ruled out after 2100 (low confidence);
- The *effects of CDR on the carbon cycle and climate* - ocean-based CDR methods have the potential to sequester CO_2 from the atmosphere. However, a given amount of CO_2 sequestered by CDR results in a smaller amount of CO_2 reduction in the atmosphere due to the redistribution of CO_2 between carbon pools (e.g., degassing from the ocean) and Earth system feedbacks. The *sequestration potential* of many land- and *ocean-based CDR methods* is *weakened by associated Earth system feedbacks* by decreasing either the land or ocean carbon uptake or through effects on climate. CDR methods can have *positive or negative biogeochemical* and *biophysical side-effects* and *other side-effects related to water, food and biodiversity.* The level of confidence in the *direction and magnitude of multiple side effects* of CDR methods varies from low to medium and is often *project and region specific;*
- *Ocean fertilisation* with iron speeds up the growth of phytoplankton and thus uptake of CO_2, some of which would sink into the deep ocean as carbon when the organisms die. So, there is some potential in attempting to boost productivity through intentional nutrients enrichment. Another proposal is for nutrient and micronutrient enrichment for fish stock enhancement. Iron fertilization is the best studied to date, but *knowledge so far is still inadequate to predict global consequences.*

	Current state	Prediction
	Indicators reaching levels, and changing at rates, unseen in centuries to many thousands of years Consequences of climate change are irreversible on centennial to millennial time scales, especially for the ocean, ice sheets and global sea level	Ocean stratification, acidification and deoxygenation will continue to increase Substantial irreversibility for some cryosphere changes, ocean warming, sea level rise, and ocean acidification Upper ocean stratification, ocean acidification and ocean deoxygenation will continue to increase in the 21st century, at rates dependent on future emissions. Changes are irreversible on centennial to millennial time scales in global ocean temperature, deep ocean acidification and deoxygenation.
	Ocean acidification at highest level of last 26000 years and increasing faster, than anytime in at least 1000 years Oxygen levels have dropped in many ocean regions and the geographic range of many marine organisms has changed over the last two decades	
	Rate of ocean heat content gain greater than at any time since the ending of the last ice age	Predicted ocean warming ranges from double to 4 – 8 times; additional warming will lead to permafrost thawing, loss of seasonal snow cover, and melting of sea ice, the Greenland Ice Sheet and glaciers
	Marine heatwaves much more frequent	Frequency and severity of marine heat waves are projected to increase
	Annual Arctic sea ice coverage at its lowest since at least 1850; Summer Arctic ice coverage less than anytime during at least the past 1000 years	The Arctic Ocean will become practically sea ice-free in late summer
	Glacier retreat unprecedented in at least the last 2000 years	Glaciers will continue to lose mass for at least several decades even if global temperature is stabilized
	Sea level rise faster than any prior century for 3000 years	Global mean sea level will continue to rise for centuries to millennia The frequency of extreme sea level events will increase
	Greenland and Antarctic Ice Sheet mass loss four times larger	Near-complete loss of the Greenland Ice Sheet and complete loss of the West Antarctic Ice Sheet to occur irreversibly over multiple millennia Potential abrupt changes in the ocean and cryosphere include an AMOC collapse or a destabilization of Greenland and Antarctic ice sheets Chance of exceeding tipping points, such as sea level rise due to collapsing ice sheets or ocean circulation changes

- *Regional fact sheet – Ocean:*
  - *Marine heatwaves* have become more frequent over the 20th century (high confidence) and are also projected to i*ncrease around the globe over the 21st century* (high confidence).
  - The largest changes in the frequency of *marine heatwaves* are projected to occur in the *Arctic Ocean* (medium confidence).
  - The surface *Southern Ocean* has *warmed* more slowly than the global average or slightly cooled (very high confidence)
  - The *Southern Ocean* has very likely *freshened*. The projected *salinity* pattern is similar (medium confidence).
  - The surface *North Atlantic Ocean* has *warmed more slowly* than the global average or slightly cooled (very high confidence).
  - It is very likely that *Atlantic* has become *more saline*. The projected pattern is similar (medium confidence).
  - Anthropogenic warming is very likely to further decrease *ocean oxygen* concentrations, and this *deoxygenation* is projected to *persist for thousands of years* (medium confidence).
  - It is virtually certain that *global mean sea level* will continue to rise over the 21st century in response to continued warming of the climate system, and this rise will *continue to rise for centuries to millennia due to continuing deep ocean heat uptake and mass loss from ice sheets* (high confidence).
  - Over the 21st century, the majority of *coastal locations* have a median projected regional *sea level rise* within ± 20% of the projected global mean sea level change (medium confidence).
  - With the rising atmospheric CO2 concentration, the *ocean acidification* has increased globally over the past four decades (virtually certain).
  - In the open ocean, *acidification*, changes in *sea ice*, and *deoxygenation* are detectable in many areas (high confidence).
- *Regional fact sheet – Polar Regions:*
  - There is high confidence that *glaciers have lost mass in all polar regions* since 2000 and will *continue to lose mass* at least for several decades, even if global temperature is stabilized.
  - Both *major ice sheets – Greenland and Antarctica – have been losing mass* since at least 1990, with the highest loss rate during 2010–2019 (high confidence), and they are projected to *continue to lose mass*.
  - Arctic:
    - It is very likely that the Arctic has *warmed* at more than twice the global rate over the past 50 years, and it is virtually certain that surface warming in the Arctic will continue to be more pronounced than the global average warming over the 21st century.
    - *Extreme heat events* have increased around the Arctic since 1979, and minimum temperatures have increased at about *three times the global rate*
    - *Permafrost warming and thawing* have been widespread in the Arctic since the 1980s, and there is high confidence in *future permafrost warming, decreasing permafrost extent with increased risk of hazardous impacts, including carbon release.*
    - Reductions in *spring snow cover extent* have occurred across the Northern Hemisphere since at least 1978 (very high confidence), and it is virtually certain that this *reduction will continue with further warming*, despite a likely increase in winter snow amount in the far northern continental regions and central Arctic.
    - The observed increase in relative *sea level rise* is *virtually certain to continue* in Arctic (other than Northeastern Canada and west coast of Greenland) contributing to more frequent and severe coastal flooding and shoreline retreat along sandy coasts
    - Current Arctic *sea ice cover* (both annual and late summer) is *at its lowest level since at least 1850* (high confidence) and is projected *to reach practically ice-free conditions at its summer minimum at least once before 2050 under all scenarios.*
  - Antarctic:
    - Observations show a widespread, strong *warming* trend starting in the 1950s in the Antarctic Peninsula. Significant warming trends are observed in other West Antarctic regions and at selected stations in East Antarctica (medium confidence).

- The Antarctic Peninsula, West Antarctica and some East Antarctic regions are projected to continue to *warm* in the 21st century at a rate greater than global.
- Antarctic *snowfall* and net snow accumulation have increased over the 20th century (medium confidence).
- Mass *losses from West Antarctic outlet glaciers*, mainly induced by *ice shelf basal melt*, outpace mass gain from increased snow accumulation on the continent.
- At sustained warming levels between *2°C and 3°C, the West Antarctic Ice Sheet will be lost almost completely and irreversibly over multiple millennia*; both the *probability of complete loss and the rate of mass loss increases with higher surface temperatures*.
- For *Antarctic sea ice*, there is no significant trend in satellite-observed sea ice area from 1979 to 2020 in both winter and summer, due to regionally opposing trends and large internal variability.

2. **WGII - Climate Change 2022: Impacts, Adaptation and Vulnerability**[119] stresses that:

- *Crosscutting fact sheet – Biodiversity:*
  - Climate change has *altered marine*, terrestrial and freshwater *ecosystems* all around the world (very high confidence). Climate change has *caused local species losses*, increases in disease (high confidence), and *mass mortality events* of plants and animals (very high confidence), resulting in the *first climate driven extinctions* (medium confidence), *ecosystem restructuring*, increases in areas burned by wildfire (high confidence), and *declines in key ecosystem services* (high confidence). *Climate-driven impacts on ecosystems* have caused measurable economic and livelihood losses and altered cultural practices and recreational activities around the world (high confidence).
  - *Extreme climate events* comprising conditions beyond which many species are adapted are occurring on all continents, with severe impacts (very high confidence). The most severe impacts are occurring in the *most climate-sensitive species and ecosystems*, characterized by traits that limit their abilities to regenerate between events or to adapt, and those *most exposed to climate hazards* (high confidence).
  - *Threats to species and ecosystems in oceans, coastal regions*, and on land, particularly in *biodiversity hotspots*, present a *global risk that will increase with every additional tenth of a degree of warming* (high confidence). The transformation of terrestrial and *ocean/coastal ecosystems and loss of biodiversity, exacerbated by pollution, habitat fragmentation and land-use changes, will threaten livelihoods and food security* (high confidence).
  - Without *urgent and deep emissions reductions*, *some species and ecosystems, especially those in polar and already-warm areas*, *face temperatures beyond their historical experience in the next decades* (e.g., >20% of species on some *tropical landscapes and coastlines at 1.5°C global warming*). *Unique and threatened ecosystems* are expected to be *at high risk in the very near term at 1.2°C global warming levels* (very high confidence) due to mass tree mortality, *coral reef bleaching, large declines in sea-ice dependent species, and <u>mass mortality events from heatwaves.</u>*
  - *At warming levels beyond 2°C by 2100, risks of extirpation, extinction and ecosystem collapse escalate rapidly* (high confidence). *Climate impacts on ocean and coastal ecosystems will be exacerbated by increases in intensity, reoccurrence and duration of marine heatwaves* (high confidence), in some cases, leading to *<u>species extirpation, habitat collapse or surpassing ecological tipping points</u>* (very high confidence).
  - The *risk of species extinction* increases with warming in all climate change projections for *native species studied in hotspots* (high confidence), being about *ten-times greater for endemic species* from 1.5°C to 3°C above pre-industrial levels (medium confidence). *Very high extinction risk in biodiversity hotspots* due to climate change is more common for *endemic species* than other native species

[119] https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/ and Fact Sheets: Biodiversity - https://www.ipcc.ch/report/ar6/wg2/downloads/outreach/IPCC_AR6_WGII_FactSheet_Biodiversity.pdf
Sea Level Rise *Coming soon,* Cities and Settlements by the Sea *Coming soon*

(high confidence). For these endemic species, considering all scenarios and time periods evaluated, *~100% on islands*, ~84% on mountains, ~12% on continents (high confidence) and *~54% in the ocean (notably the Mediterranean)* (low confidence) are *projected to be threatened with* *extinction due to climate change*.

- Risks from *sea level rise for coastal ecosystems and people* are very likely to *increase tenfold well before 2100* without adaptation and mitigation action as agreed by Parties to the Paris Agreement (very high confidence). Sea level rise under emission scenarios that do not limit warming to 1.5°C will increase the risk of coastal erosion and submergence of coastal land (high confidence), *loss of coastal habitat and ecosystems* (high confidence) and worsen salinisation of groundwater (high confidence), *compromising coastal ecosystems and livelihoods* (high confidence). The *ability to adapt* to current coastal impacts, cope with future coastal risks and prevent further acceleration of sea level rise beyond 2050 *depends on immediate implementation of mitigation and adaptation actions* (very high confidence).
- *Marine heatwaves*, including well-documented events along the west coast of North America (2013–2016) and east coast of Australia (2015– 2016, 2016–2017 and 2020), drive *abrupt shifts in community composition* that may *persist for years* (very high confidence), with *associated biodiversity loss* (very high confidence), *collapse of regional fisheries and aquaculture* (high confidence) and *reduced capacity of habitat-forming species to protect shorelines* (high confidence). Some *habitat-forming coastal ecosystems* including many coral reefs, kelp forests and seagrass meadows, will undergo *irreversible phase shifts due to marine heatwaves* with *global warming levels >1.5°C and are at high risk this century even in <1.5°C scenarios* that include periods of *temperature overshoot beyond 1.5°C* (high confidence). Under SSP1- 2.6, *coral reefs are at risk of widespread decline, loss of structural integrity and transitioning to net erosion by mid-century* due to *increasing intensity and frequency of marine heatwaves* (very high confidence).
- *All biodiversity hotspots are impacted, to differing degrees, by human activities* (very high confidence). Climate change impacts are *compounded* by other *anthropogenic impacts*, including *habitat loss and fragmentation*, hunting, *fishing and its bycatch, over-exploitation*, water abstraction, *nutrient enrichment, pollution, human introduction of invasive species*, pests and diseases, all of which *reduce climate resilience* (very high confidence).
- *Increasing the resilience of biodiversity and ecosystem services to climate change* includes *minimising additional stresses or disturbances*, reducing fragmentation, increasing natural habitat extent, connectivity and heterogeneity, maintaining taxonomic, phylogenetic and functional diversity and redundancy and protecting small-scale refugia where microclimate conditions can allow species to persist (high confidence).
- *Ecosystem protection and restoration* can build resilience of ecosystems and generate opportunities to restore ecosystem services with substantial co-benefits (high confidence).
  - Potential benefits and avoidance of harm are maximized when *Nature-based Solutions with safeguards* are deplo*yed in the right places and with the right approaches for that area, with inclusive governance* (high confidence). Taking account of *interdisciplinary scientific information*, *Indigenous knowledge and local knowledge and practical expertise is essential to* *effective Ecosystem-based Adaptation* (high confidence).
- *Maintaining planetary health* is essential for human and societal health and a pre-condition for climate resilient development (high confidence). *Effective ecosystem conservation on approximately 30% to 50% of Earth's land, freshwater and ocean areas*, including all remaining areas with a high degree of naturalness and ecosystem integrity, will *help protect biodiversity, build ecosystem resilience and ensure essential ecosystem services* (high confidence). In addition to this protection, *sustainable management* of the rest of the planet is also important.
- Available *adaptation options* can *reduce risks to ecosystems and the services* they provide *but they cannot prevent all changes and* *should not be regarded as a substitute for reductions in greenhouse gas emissions* (high confidence). *Ambitious and swift global mitigation offers more adaptation options and pathways to sustain ecosystems and their services* (high confidence).

3. **WGIII - Climate Change 2022: Mitigation of Climate Change**[120] stresses that:

- *Total net anthropogenic GHG emissions* have *continued to rise* during the period 2010–2019, *as have cumulative net CO2 emissions* since 1850. *Average annual GHG emissions during 2010–2019 were higher than in any previous decade*, but the rate of growth between 2010 and 2019 was lower than that between 2000 and 2009. (high confidence)
- *Projected cumulative future CO2 emissions* over the lifetime of existing and currently planned fossil fuel infrastructure without additional *abatement exceed the total cumulative net CO2 emissions in pathways that limit warming to 1.5°C (>50%) with no or limited overshoot*. They are *approximately equal to total cumulative net CO2 emissions in pathways that limit warming to 2°C (>67%).* (high confidence)
- *Global GHG emissions are projected to peak between 2020 and at the latest before 2025* in global modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot and in those that limit warming to 2°C (>67%) and assume immediate action. In both types of modelled pathways, *rapid and deep GHG emissions reductions follow throughout 2030, 2040 and 2050* (high confidence). *Without a strengthening of policies beyond those that are implemented by the end of 2020, GHG emissions are projected to rise beyond 2025, leading to a median* ***global warming of 3.2*** *[2.2 to 3.5] °C by 2100* (medium confidence).
- *Global net zero CO2 emissions* are *reached in the early 2050s* in modelled pathways that *limit warming to 1.5°C (>50%) with no or limited overshoot*, and *around the early 2070s in modelled pathways that limit warming to 2°C (>67%).* Many of these pathways continue to net negative CO 2 emissions after the point of net zero. These pathways also include deep reductions in other GHG emissions. The level of peak warming depends on cumulative CO 2 emissions until the time of net zero CO 2 and the change in non-CO 2 climate forcers by the time of peaking. Deep GHG emissions reductions by 2030 and 2040, particularly reductions of methane emissions, lower peak warming, reduce the likelihood of overshooting warming limits and lead to less reliance on net negative CO 2 emissions that reverse warming in the latter half of the century. *Reaching and sustaining global net zero GHG emissions results in a gradual decline in warming*. (high confidence)
- *All global modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot, and those that limit warming to 2°C (>67%), involve rapid and deep and in most cases immediate GHG emission reductions in all sectors*. Modelled mitigation strategies to achieve these reductions include transitioning from fossil fuels without CCS to very low- or zero-carbon energy sources, such as renewables or fossil fuels with CCS, demand side measures and improving efficiency, reducing non-CO2 emissions, and *deploying carbon dioxide removal (CDR) methods to counterbalance residual GHG emissions*. (high confidence)
- *All mitigation strategies face implementation challenges, including technology risks, scaling, and costs.* Many challenges, such as dependence on CDR, *pressure on* land and *biodiversity* (e.g., bioenergy) and reliance on technologies with high upfront investments (e.g., nuclear), are significantly reduced in modelled pathways that assume using resources more efficiently (e.g., IMP-LD) or that shift global development towards sustainability (e.g., IMP-SP). (high confidence)
- The deployment of *carbon dioxide removal (CDR) to counterbalance hard-to-abate residual emissions is unavoidable if net zero CO2 or GHG emissions are to be achieved.* The *scale and timing of deployment* will depend on the trajectories of gross emission reductions in different sectors. Upscaling the deployment of CDR depends on developing effective approaches to address *feasibility* and *sustainability constraints especially at large scales*. (high confidence)
- *CDR* refers to *anthropogenic activities that remove CO2 from the atmosphere and store it durably in* geological, terrestrial, or *ocean reservoirs*, or in products. CDR methods vary in terms of their *maturity, removal process, time scale of carbon storage, storage medium, mitigation potential, cost, co-benefits, impacts and risks, and governance requirements* (high confidence). Specifically, maturity ranges from

[120] https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/ and Fact Sheets coming soon

lower maturity (e.g., ocean alkalinisation) to higher maturity (e.g., reforestation); *removaland storage potential ranges from lower potential (<1 GtCO 2 yr–1, e.g., blue carbon management)* to higher potential (>3 GtCO2 yr–1, e.g., agroforestry); costs range from lower cost (e.g., USD-45–100 per tCO 2 for soil carbon sequestration) to higher cost (e.g., USD100–300 per tCO 2 for DACCS) (medium confidence). *Estimated storage time scales* vary from decades to centuries for methods that store carbon in vegetation and through soil carbon management, to *10,000 years or more for methods that store carbon in geological formations* (high confidence). The processes by which CO2 is removed from the atmosphere are categorised as biological, geochemical or chemical. Afforestation, reforestation, improved forest management, agroforestry and soil carbon sequestration are currently the only widely practiced CDR methods (high confidence).

- The *impacts, risks and co-benefits of CDR deployment for ecosystems, biodiversity* and people will be highly variable depending on the method, site-specific context, implementation and scale (high confidence). Reforestation, improved forest management, soil carbon sequestration, peatland restoration and *blue carbon management are examples of methods that can enhance biodiversity and ecosystem functions, employment and local livelihoods, depending on context* (high confidence). In contrast, afforestation or production of biomass crops for BECCS or biochar, when poorly implemented, can have adverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and on the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure (high confidence). *Ocean fertilisation, if implemented, could lead to nutrient redistribution, restructuring of ecosystems, enhanced oxygen consumption and acidification in deeper waters (medium confidence).*

- The *removal and storage of CO2 through vegetation* and soil management *can be reversed by human or natural disturbances*; it is also *prone to climate change impacts.* In comparison, *CO2 stored in geological and ocean reservoirs* (via BECCS, DACCS, *ocean alkalinisation*) and as carbon in biochar is less prone to reversal (high confidence).

- In addition to deep, rapid, and sustained emission reductions, CDR can fulfil three different complementary roles globally or at country level: lowering net CO 2 or net GHG emissions in the near term; counterbalancing 'hard-to-abate' residual emissions (e.g., emissions from agriculture, aviation, *shipping*, industrial processes) in order to help reach net zero CO2 or net zero GHG emissions in the mid-term; and achieving net negative CO2 or GHG emissions in the long term if deployed at levels exceeding annual residual emissions (high confidence).

- Rapid emission reductions in all sectors interact with future scale of deployment of CDR methods, and their associated risks, impacts and co-benefits. *Upscaling the deployment of CDR methods depends on developing effective approaches to address sustainability and feasibility constraints, potential impacts, co-benefits and risks.* Enablers of CDR include ***accelerated research***, development and demonstration, improved tools for risk assessment and management, targeted incentives and development of agreed methods for measurement, reporting and verification of carbon flows (high confidence).

- ***Accelerated and equitable climate action in mitigating, and adapting to climate change impacts is critical to sustainable development.*** Climate change actions can also result in some *trade-offs.* The trade-offs of individual options could be managed through policy design. The *Sustainable Development Goals (SDGs)* adopted under the UN 2030 Agenda for Sustainable Development can be used as a *basis for evaluating climate action in the context of sustainable development* (high confidence).

- There is a *strong link between sustainable development, vulnerability and climate risks.* Limited economic, social and institutional resources often result in high vulnerability and low adaptive capacity, especially in developing countries (medium confidence). Several response options deliver both mitigation and adaptation outcomes, especially in human settlements, land management, and in relation to ecosystems. However, land and *aquatic ecosystems can be adversely affected by some mitigation actions, depending on their implementation* (medium confidence).

<u>Coordinated cross-sectoral policies and planning can maximise synergies and avoid or reduce trade-offs between mitigation and adaptation</u> (high confidence).

- There are *mitigation options which are feasible to deploy at scale in the near term*. Feasibility differs across sectors and regions, and according to capacities and the speed and scale of implementation. Barriers to feasibility would need to be reduced or removed, and enabling conditions strengthened to deploy mitigation options at scale. These *barriers and enablers* include geophysical, *<u>environmental-ecological</u>*, technological, and economic factors, and especially institutional and socio-cultural factors. Strengthened near-term action beyond the NDCs (announced prior to UNFCCC COP26) can reduce and/or avoid long-term feasibility challenges of global modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot (high confidence).

The **IPBES-IPCC joint report 2021**[121] stresses that:

- The ambitious implementation of ocean-based actions to protect, sustainably manage and restore ecosystems have co-benefits for climate mitigation, climate adaptation and biodiversity objectives and can help to contain temperature rise within the limits envisaged by the Paris Agreement, provided that such actions support, and are not in lieu of, ambitious reductions of emissions from fossil fuels and land use change;
- The adaptive capacity of most ecosystems and social-ecological systems will be exceeded by unabated anthropogenic climate change, and significant adaptive capacity will be required to cope with residual climate change even under ambitious emissions reduction;
- Actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges such as climate mitigation and adaptation are often referred to as nature-based solutions. Nature-based solutions (NbS) can play an important role in climate mitigation, but the extent is debated, and they can only be effective with ambitious reductions in all human-caused greenhouse gas emissions. Nature-based solutions can be most effective when planned for longevity and not narrowly focussed on rapid carbon sequestration. Estimates of potential contributions of nature-based solutions to climate mitigation vary widely and some proposed actions such as large-scale afforestation or bioenergy plantations may violate an important tenet of nature-based solutions – namely that they should simultaneously provide human well-being and biodiversity benefits. Ecosystems can aid climate change mitigation over time, but only when complementing rapid emissions reductions in energy production, transportation, agriculture, building and industrial sectors to meet the Paris Agreement’s commitment to keeping climate change well below 2°C. In addition, failing to substantially reduce emissions from these sectors is projected to increase the climate-related risks for natural systems and reduce or limit their ability to contribute to climate change mitigation via nature-based solutions.
- Restoring carbon- and species-rich ecosystems on land and in the ocean is also highly effective for both climate change mitigation and biodiversity, with large adaptation co-benefits. Ecosystem restoration provides opportunities for co-benefits for climate change mitigation and biodiversity conservation, which are maximized if restoration occurs in priority areas for both goals. Restoration is among the cheapest and rapidly implemented nature-based climate mitigation measures. Ecosystem restoration also enhances resilience of biodiversity in the face of climate change and provides multiple nature´s contributions to people such as regulating floods, enhancing water quality, reducing soil erosion and ensuring pollination. Ecosystem restoration can also provide multiple social benefits such as creation of jobs and income, especially if implemented taking into consideration the needs and access rights of indigenous peoples and local communities. Restoration with a variety of native species ensures ecosystem resilience in the face of climate change and has benefits for biodiversity, but also relies on novel species assemblages to match future climatic conditions.

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[121] https://ipbes.net/events/ipbes-ipcc-co-sponsored-workshop-report-biodiversity-and-climate-change

- Globally, disturbance of previously undisturbed marine sediment carbon through trawling was estimated to release the equivalent of 15 to 20% of atmospheric CO_2 absorbed annually by the ocean. Such order of magnitude indicates a knowledge gap on ocean carbon storage capacity to be closed by further research.
- Avoiding and reversing the loss and degradation of carbon- and species-rich ecosystems in the ocean is of highest importance for combined biodiversity protection and climate change mitigation actions with large adaptation co-benefits. Significant reductions in the destruction and degradation of non-forest terrestrial ecosystems such as wetlands and peatlands, grasslands and savannas; and coastal ecosystems such as mangroves, salt marshes, kelp forests, seagrass meadows and deep water and polar blue carbon habitats can reduce greenhouse gas emissions from land- and sea-use change and maintain large carbon sinks if properly managed. For example, mangroves may sequester four times more carbon than rainforest per unit area. Destruction and degradation are also the most important drivers of biodiversity loss freshwater ecosystems and the second most important drivers of biodiversity loss in marine ecosystems. Substantial co-benefits with biodiversity are realizable by reversing destruction and degradation of natural ecosystems – building on ambitious reductions in fossil fuel emissions as a precondition – with adaptive co-benefits to people. For example, coastal wetlands and coral reefs provide coastal protection from storm surges and rising sea level, while wetlands help reduce flooding.

The **UN WOA II** 2021[122] stresses that:

- Many pressures from human activities continue to degrade the ocean; pressures include those associated with climate change; unsustainable fishing, including illegal, unreported and unregulated fishing; the introduction of invasive species; atmospheric pollution causing acidification and eutrophication; excessive inputs of nutrients and hazardous substances, including plastics, microplastics and nanoplastics; increasing amounts of anthropogenic noise; and ill-managed coastal development and extraction of natural resources. There continues to be a lack of quantification of the impacts of pressures and their cumulative effects;
- Thermal expansion from a warming ocean and land ice melt are the main causes of the accelerating global rise in the mean sea level;
- Global warming is also affecting many circulation systems. The Atlantic Meridional Overturning Circulation has already weakened and will most likely continue to do so in the future. The impacts of ocean circulation changes include a regional rise in sea levels, changes in the nutrient distribution and carbon uptake of the ocean and feedbacks with the atmosphere, such as altering the distribution of precipitation;
- More than 90 per cent of the heat from global warming is stored in the global ocean. Oceans have exhibited robust warming since the 1950s from the surface to a depth of 2,000 m. The proportion of ocean heat content has more than doubled since the 1990s compared with long-term trends. Ocean warming can be seen in most of the global ocean, with a few regions exhibiting long-term cooling;
- The ocean shows a marked pattern of salinity changes in multidecadal observations, with surface and subsurface patterns providing clear evidence of a water cycle amplification over the ocean. That is manifested in enhanced salinities in the near-surface, high-salinity subtropical regions and freshening in the low-salinity regions such as the West Pacific Warm Pool and the poles;
- An increase in atmospheric CO_2 levels, and a subsequent increase in carbon in the oceans, has changed the chemistry of the oceans to include changes to pH and aragonite saturation. A more carbon-enriched marine environment, especially when coupled with other environmental stressors, has been demonstrated through field studies and experiments to have negative impacts on a wide range of organisms, in particular those that form calcium carbonate shells, and alter biodiversity and ecosystem structure;

[122] https://www.un.org/regularprocess/woa2launch

- Decades of oxygen observations allow for robust trend analyses. Long-term measurements have shown decreases in dissolved oxygen concentrations for most ocean regions and the expansion of oxygen-depleted zones. A temperature-driven solubility decrease is responsible for most near-surface oxygen loss, though oxygen decrease is not limited to the upper ocean and is present throughout the water column in many areas;
- Total sea ice extent has been declining rapidly in the Arctic, but trends are insignificant in the Antarctic. In the Arctic, the summer trends are most striking in the Pacific sector of the Arctic Ocean, while, in the Antarctic, the summer trends show increases in the Weddell Sea and decreases in the West Antarctic sector of the Southern Ocean. Variations in sea ice extent result from changes in wind and ocean currents;
- The complex interactions of temperature and salinity with nutrients and chemical cycles of the ocean imply that variations in those variables owing to climate change and anthropogenic impact thus affect marine ecosystems, population, coastal communities and the related economy. Ocean warming is causing significant damage to marine ecosystems, and species are losing their habitats, forcing them to adapt or relocate to new temperatures or look for new feeding, spawning or nursery areas. Ocean acidity and the availability of sufficient oxygen both underpin the provision of marine ecosystem services to human society. Rapid changes in ocean acidity and falling oxygen levels caused by climate change and anthropogenic $CO2$ emissions are, however, now being observed, which is changing marine habitats and ecosystems worldwide. Warming is causing oxygen levels to fall, and acidification is rapidly changing the carbonate chemistry of surface ocean waters, which together are reducing the growth and survival of many organisms and degrading ecosystem resilience. Closing knowledge gaps in ocean science by supporting capacity-building efforts that increase the understanding of how the ocean and its ecosystems are responding to changes in ocean physical and chemical properties is an important pathway to reducing the impacts of such changes and achieving Sustainable Development Goal 14;
- Concern has been expressed about the climatic risks resulting from the sudden release of large amounts of methane from marine hydrates (mainly methane hydrates).

The **UNFCCC Climate Dialogues. Ocean and Climate Change Dialogue[123] Dec 2020** and the **Informal summary report by the Chair of the Subsidiary Body for Scientific and Technological Advice report 21 April 2021 stresses** that:

- Science provides the basis for understanding the action needed and must be strengthened in parallel with action moving forward.
- The ocean provides multiple untapped and powerful opportunities to mitigate and adapt to climate change, provided environmental and social safeguards are met.
- Address gaps and needs in relation to ocean and climate knowledge and action under the UNFCCC process
- Support mainstreaming of coherent action across biodiversity, ocean and climate change agendas
- Invest in ocean science and monitoring
- The ocean is our planet's largest ecosystem. It stabilizes the climate, stores carbon, nurtures unimaginable biodiversity and directly supports human well-being through food and energy resources, as well as by providing cultural and recreational services.
- The ocean sits at the *crossroads of all the major challenges* we face today: climate change, biodiversity loss, food security, energy transition and threats to human

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[123] https://unfccc.int/event/ocean-and-climate-change-dialogue-to-consider-how-to-strengthen-adaptation-and-mitigation-action and https://unfccc.int/sites/default/files/resource/SBSTA_Ocean_Dialogue_SummaryReport.pdf

health. The ocean is not just a global climate regulator or a victim of climate change, but also a place to implement science-based mitigation and adaptation action.

- *Ocean science* has played the primary role to date in strengthening understanding of climate change impacts and the action needed under the UNFCCC, the Paris Agreement and the 2030 Agenda for Sustainable Development. Ocean science tells us that climate change and ocean health are inseparable. However, as indicated in the World Ocean Assessment of 2016, humankind is running out of time to start managing the ocean sustainably.
- *The science we need to strengthen action on adaptation and mitigation:*
    - More scientific evidence is needed in diagnosing and explaining the impacts and risks of climate change on the ocean and cryosphere. It is not possible to manage what we cannot measure. Despite advancements in ocean observations (mostly in terms of physical measurements such as those obtained through the Argo network), *long-term, sustained and increased observations are needed, particularly in the fields of ocean biochemistry, ecology and biology. Further research is also needed on physical climate changes, such as the significant changes happening in the carbon balance of the ocean, as well as impacts on ecosystems.*
    - Moving forward, research must focus on *integrating society, economy, climate and biodiversity* in order to provide *science for solutions that leave no one behind*.
    - The *Global Ocean Science Report 2020*[124] indicates that *ocean research is limited and underfunded, particularly in Africa.* Moving forward, more observation and research is needed, particularly to increase support for *ocean science in Africa, the LDCs and SIDS* so that everyone can benefit.
- Critical gaps remain in scientific observation and research on areas like *blue carbon*, *ocean acidification* and *deoxygenation*, seagrass, macroalgae and carbon in the sea floor, in order to manage the whole ocean.
- Long-term and sustainable funding is needed in ocean observation and research is needed to help evaluate the *impacts of climate change on the ocean and ocean ecosystems*, address the needs of the most vulnerable countries, and help assess options and opportunities for adaptation and mitigation action. Examples of needs raised in the discussion group include:

  (a) Evaluating and quantifying the broad range of benefits provided by coastal and marine ecosystems in order to strengthen the ability to account for them in NDCs and NAPs and in efforts to leverage financial support;
  (b) Increasing observation and research of the impact of climate change on ecosystems and marine areas involved in mitigation and adaptation, including the effects of pollution;
  (c) Increasing observation and understanding of sea level rise.

- Actions to support development and strengthen national policies include:

  (a) Assessing the risks to coastal and marine resources, ecosystems and economies caused by ocean warming, acidification and loss of oxygen, including an analysis of all human activities in marine areas and land–ocean interactions, in order to create policies and an integrated plan;
  (b) Considering all adaptation and mitigation options available (such as those described by the IPCC and the Ocean Panel). A vital consideration for countries is marine spatial planning and/or integrated coastal zone management as a means to consider how to set the targets needed to ensure the deployment of renewable energy, food security, and protection of the environment, lives and livelihoods;
  (c) Mainstreaming ocean, climate and biodiversity action;
  (d) Building synergies and strengthening understanding between different sectors, for example between the fisheries, tourism and energy sectors to enable them to coexist in a supportive manner, protect biodiversity and manage its various uses

[124] IOC-UNESCO 2020. Global ocean science report 2020: charting capacity for ocean sustainability https://en.unesco.org/gosr

through joint decision-making and opportunities for empowerment between stakeholders;

(e) Integrating gender-responsive, and rights-and ecosystem-based action that takes into account vulnerable coastal and marine communities and the behaviour change needed for sustainable change;

(f) Identifying entry points to coordinate the inclusion of the private sector in sustainable action, such as robust data collection and incorporating the private tourism sector.

The **UNFCCC Ocean and Climate Change Dialogue June 2022**[125]

The 2nd Ocean and Climate Dialogue to strengthen ocean-based action evoked the following key topics: blue carbon ecosystems (including carbon offsetting), Nature-Based Solutions (NBS) as win-win scenarios that help pursue synergies across sectors, Marine Protected Areas (MPAs), protection, restoration and conservation of coastal and marine ecosystems, rapid, deep decarbonization of global economies, reduce GHG emissions from the shipping sector, Marine Renewable Energies (MREs), adaptation objectives, innovative approaches to build coastal resilience that integrate both technological and Nature-based Solutions, adaptation solutions to climate impacts on fisheries, technology, capacity-building, science and partnerships for ocean-climate action, overcome knowledge gaps, creative thinking and innovative solutions for financing. The integration of ocean related issues in Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) under the Paris Agreement was also mentioned. As a Party to the UNFCCC, the EU recalled the importance of the ocean and climate nexus for the EU and its MS as an integral part of their policies from a mitigation and adaptation perspective. The need for ambitious action was underlined with concrete examples on mitigation (carbon neutrality goal, decarbonisation of the shipping and fisheries sectors, offshore renewable energy, nature-based solutions) and adaptation (nature based solutions, marine protected areas). The EU underlined the importance of science notably the IPCC report and its observation (Copernicus) and innovation and research (Horizon Europe) programmes. As finance and capacity building is key for developing countries, the EU flagged its various commitments in this respect. This Dialogue was the opportunity for the EU to link various ocean negotiations and processes notably BBNJ, CBD and the 30x30 goal, CCAMLR and UNOC.

Next steps are: the SBSTA Chair will prepare an informal summary report to be presented at COP27 plenary session with the expectation to find some reflection in its outcome; address a specific set of solutions and challenges to address the climate-ocean nexus where relevant across the UNFCCC agenda; as such, the Ocean and Climate Dialogue series could be informed by a 3-year roadmap that identifies a set of topics for each annual dialogue to progressively cover a range of solutions, allowing for more in-depth discussions on topics; the “world café” format (i.e., an informal setting for participants to explore topics across the scope of the Global Stocktake, in a larger room with several small tables) could facilitate interactive exchanges and in-depth discussions; Reflect one ongoing assessments of the ocean’s capacity to sustain climate benefits currently provided, and forward looking assessments, research and data needs to verify the mitigation potential of carbon-rich habitats and species beyond those already recognized in the IPCC Wetlands supplement. These efforts would be complementary rather than duplicative of the Research and Systematic Observation work streams and discussions; Exchange updates across international policy processes relating to ocean-climate action, including the Convention on Biological Diversity (CBD) and related post-2020 Global Biodiversity Framework and the International Maritime Organisation (IMO). Reflect on how to fill the gaps, including in science, technology, finance and capacity building; Provide more clarity on financial mechanisms, and briefing on financial flows for

[125] https://unfccc.int/event/ocean-and-climate-change-dialogue-2022 and https://ocean-climate.org/wp-content/uploads/2022/06/Synthesis-Report_SBSTA56_Ocean-and-Climate-Dialogue_15_06_22.pdf and https://unfccc.int/topics/ocean

ocean-climate action, including an annual determination of finance needs and recommendations for strengthening support across constituted bodies.

The **High Level Ocean Panel**[126] stresses that:

- Cautioned that *carbon storage in the seabed*, warranted more research and development to better understand its *environmental impacts and long-term efficacy*[127]
- Identifies adaptation solutions and, in this regard, highlights the importance of fully protected MPAs. MPAs enhance the resilience of ecosystems in the face of environmental and climate changes. Currently, MPAs that are fully or highly protected cover only 2.6% of the global ocean[128]
- As part of adaptation and mitigation responses, the importance of *precaution in the face of scientific uncertainty* was noted. Action must be undertaken recognizing the *need for appropriate environmental and social safeguards*, ensuring the inclusion of traditional knowledge in understanding the locality-specific risks and the co-design of associated responses; and
- Nature is a fundamental part of *ocean resilience to climate change*. Protecting and restoring nature is critical to human well-being, ocean health and climate change. Nature-based solutions include preserving and restoring blue carbon ecosystems, establishing and maintaining climate-smart MPAs, supporting climate-smart fisheries and small-scale fisheries, ecosystem-based adaptation, sustainable natural resource management, and *protecting and restoring coastal ecosystems*.[129]

[126] https://oceanpanel.org/
[127] The Ocean as a Solution to Climate Change: Five Opportunities for Action
[128] Ocean Solutions That Benefit People, Nature and the Economy
[129] Transformations for a Sustainable Ocean Economy: A Vision for Protection, Production and Prosperity

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This publication outlines key aspects of the Horizon 2020 EU-funded ocean-climate nexus research and innovation portfolio and its support to the implementation of the European Green Deal and in particular its climate, biodiversity objectives.

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