THE OCEAN CLIMATE NEXUS

THE CRITICAL ROLE OF OCEAN SCIENCE IN RESPONDING TO CLIMATE CHANGE

A call from the ocean research community

On 30 November 2015 the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) will get underway in Paris. COP21 represents a momentous opportunity for governments to make serious commitments to address climate change and its implications for humankind and the health of our planet. The role of the ocean in the climate system must be an integral part of these discussions. The earth's climate and the ocean are fundamentally linked in ways we still do not fully understand. The ocean plays a key role as a climate regulator and in buffering the damaging effects of climate change. But the human activities that cause climate change, predominantly greenhouse gas emissions, are also affecting the health of the ocean, making it increasingly warmer and causing ocean acidification. We are damaging the very system that is fundamental to our wellbeing.

Ocean scientists are at the front line in the quest for knowledge to understand the role of the ocean in the earth and climate systems, and the implications of changing oceans for our environment and wellbeing. Hence, ocean research must be at the heart of our global response to climate change. For this reason, the ocean science communities of Europe and the North America, through the combined voices of the European Marine Board and the Consortium for Ocean Leadership, are issuing this joint call for action.

To the COP21:

We call on the Parties to the United Nations Framework Convention on Climate Change to:

- Recognize the fundamental role of the ocean in the climate system in reaching a post-2020 climate agreement;
- Deliver a strong agreement with ambitious mitigation targets to reduce harmful greenhouse gas emissions and curb damage to the ocean and its ecosystems;
- Understand and promote the role of ocean and climate research as a fundamental tool in the societal response to climate change and provide impetus to improve the knowledge base for climate action.

To Research Funders:

Our research communities stand ready to work across borders and disciplines towards a greater understanding of the ocean-climate nexus, and to communicate scientific knowledge to support ocean stewardship and measures to understand, mitigate and adapt to global change.

We call on the funders of research to support major and, where necessary, long-term ocean-climate research and observation programmes with a level of investment that matches the gravity of the impacts of a changing ocean and the importance of the ecosystem services it provides. To achieve the scale of research required, international collaboration will be essential.

In this short statement, we summarize the role of the ocean in the earth and climate systems. We set out some of the key challenges for unravelling the links between ocean and climate and the most important research priorities that can help provide answers and support an evidence-based societal response to climate change.

The ocean: our planetary life support system

Covering 71% of the earth's surface, the ocean plays a critical role in our climate system. The ocean stores, transports and exchanges with the atmosphere huge amounts of heat, water and greenhouse gases such as carbon dioxide. The ocean harbours an enormous and largely undiscovered biodiversity and provides a large fraction of the animal protein consumed by the world population. Ocean phytoplankton are responsible for approximately half the global biospheric net primary production. The ocean is so systemically important within the earth system that it has been called the planet's life support system.

Human activities, including the release of greenhouse gases to the atmosphere, are already strongly affecting the ocean and these effects are projected to increase in the future. Since the industrial revolution, the ocean has stored more than 25% of the human emissions of carbon dioxide and 90% of the additional heat resulting from the greenhouse gas effect. In doing so, the ocean acts as a buffer to reduce the global effects of climate change, but not without consequences.

The ocean is warming, sea level is rising and sea ice is rapidly shrinking. In addition, ocean acidification is happening in large areas of the global ocean because of carbon-dioxide uptake, while reduced ventilation is leading to lower oxygen levels in parts of the ocean. Other human activities including different types of pollution, nutrient loading, unsustainable fishing, and resource exploitation, are adding to the pressure on the ocean. Without drastic action to reduce the causes of climate change, these growing pressures and changes will have unforeseeable consequences for marine life, for ocean health, and for human wellbeing.

The ocean-climate nexus: a grand challenge of our time

In recent decades, international collaborative research has led to an improved understanding of ocean-climate interactions and the influence of human activities on these systems. The challenge now is to enhance our understanding of fundamental processes and to develop observational and modelling frameworks that will allow an integrated assessment of the interconnected ocean-climate-human system. Meeting this challenge will enable much more reliable projections of possible future change. Combined with a deeper understanding of the social and economic drivers, such a knowledge base can underpin effective ocean management at local, regional, and global scales.

The changing state of the ocean

Research has sought to investigate the role of the ocean in climate change. Variability of sea-surface temperatures on interannual to decadal timescales has been linked to changes in regional and local climate. For example, warmer sea-surface temperatures in the North Atlantic Ocean influence Atlantic hurricane activity, summer climate over Europe and North America, and rainfall over the African Sahel, India and Brazil. Climate change has the potential to disrupt ocean currents and thus the oceanic redistribution of heat, which may impact on regional climates. A warmer ocean also has consequences for the formation, extent and persistence of sea ice in polar and continental margin regions. For example, increased inflow of warm Atlantic waters into high latitudes has been linked to the decline of Arctic sea ice and mass loss from the Greenland ice sheet, both of which have feedbacks to the climate system.

The uptake and storage of heat and carbon by the ocean, and its transport and exchange with the atmosphere, varies among regions and over annual to multi-decadal timescales. Research is currently underway to understand such spatial and temporal variations because the projections of the earth's future climate, which include projections of sea level, the continental water cycle, hurricane activity, sea ice, and ocean acidification, depends on this understanding. Hence, knowledge of the complex processes underlying the ocean's variability is critical for an assessment of the interactions within the ocean-climate-human nexus.

The importance of marine biodiversity

Changes in ocean physics and chemistry (e.g. warming, deoxygenation, acidification), along with pollution, are known to influence marine ecosystem productivity and services through effects on the physiology, life cycle and the distribution of many marine organisms. For humans, this can have obvious implications, for example, when commercial fish stocks are affected. However, the impacts of these changes on biodiversity and the functioning of marine food webs are highly complex and still poorly understood. It is now accepted that marine biodiversity is key to maintaining stable and productive marine ecosystems and the services they provide. Biodiversity enhances the ability of ecosystems to respond to change by allowing greater scope for development of alternative food web structures with changing environmental conditions. Conversely, loss of biodiversity may reduce the resilience of marine ecosystems, that is, the capacity to adjust to both gradual changes and rapid fluctuations.

The marine biosphere also provides important feedbacks to the climate system, one of which is through the "biological pump", which exports carbon from the surface ocean to the deep ocean. The strength of the biological pump and its long-term evolution depends upon many complex processes such as ocean circulation, supply of nutrients, primary production and marine food-web processes. Thus, the study of changing ocean physics and chemistry, and more generally of climate, is inextricably linked to the study of the marine biosphere and its evolution.

Observing the ocean: an imperative for both research and management

Multidisciplinary and multidimensional synchronous observing of the global ocean is key to understanding oceanic processes. A primary goal is to improve our capability to make much more reliable projections of future states of marine systems and, in turn, to link these to climate. To achieve this at a wide range of spatial (global, regional, local) and temporal (seasonal to multi-decadal) scales requires a fundamental leap in our understanding of physical, chemical and biological processes in the ocean and their interactions. For this we need data and advanced models.

Ocean Observing

Our global ocean observing capabilities have steadily improved in the last decades. Investments in observing infrastructure (including both *in situ* and remote observing hardware and e-infrastructures), coupled with new sensor and platform technologies, allow for greater spatial and temporal coverage and the measurement of an increasing array of parameters. However, there are still major gaps in our observing capacity and in the type of variables that can be measured.

Addressing Parameter Gaps

There is a need to complete and sustain the initial global physical and carbon ocean observing systems designed more than 10 years ago, extend these to include a larger suite of essential biogeochemical, biodiversity and ecosystem variables, and build more integrated systems which combine information from satellites, *in situ* observations, process modelling, and integrated models.

Long-term time series

Long-term observations of the ocean are needed to understand its role in the global oceanic heat and carbon budget. Improved understanding of the physical and biological dynamics of the ocean is vital for assessing how much, and how fast, the earth will warm due to increased greenhouse-gas concentrations and for enhancing the quality of projections for the next decades.

Projecting the future by understanding the past

Historical ocean observations and natural archives (e.g. sediment cores) when coupled with current high-quality observations, form a basis for developing estimates of previous ocean states. These provide powerful constraints and verification for modelling systems developed for making projections of climate states. However, many of the historical data sets require data rescue and data reprocessing activities.

Combining advanced models with observations

Advanced modelling frameworks that link the ocean, climate, and human systems, using the comprehensive data sets outlined above, can provide essential tools for planning and responding to climate change. Estimates of current state are pivotal to the development of predictions. The best possible analysis of present conditions can only be achieved by combining information from model results and observations. This requires stronger interactions between relevant research communities, projects and infrastructures.

e-Infrastructures and data access

The use for research and management of ocean observations will only progress if underpinned by advanced e-infrastructures, supporting data exchange, management, archival and making data openly available for research and downstream products and services.

International cooperation

Because most of the ocean lies beyond the jurisdiction of individual nations, and because of the high cost of building and operating observing infrastructures, coordinated international collaborations are essential for developing and operating ocean observing systems and their integration into modelling activities.

The time to act is now

The above is not just a wish list from a research community seeking new funding sources; it sets out the most important building blocks for providing the knowledge base needed to tackle the impacts of climate change. By committing the appropriate scale of international investments to ocean observation and research, a significant leap is possible towards understanding the patterns of change. This is crucial to inform political decisions on approaches for mitigation and adaption to climate change. In the context of COP21 and a new climate agreement, that's a goal to which, we hope, all parties can subscribe.

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European MARINE BOARD Advancing Seas & Ocean Science

The European Marine Board provides a platform for its member organizations to develop common priorities, to advance marine research and to bridge the gap between science and policy, in order to meet future marine science challenges and opportunities.

CONSORTIUM FOR Ocean Leadership

A Washington, DC-based non-profit organization that represents the leading public and private ocean research and education institutions, aquaria, and industry; working to advance research, education, and sound ocean policy.