DOSI
DEEP-OCEAN STEWARDSHIP INITIATIVE

POLICY BRIEF
November 2024

Deep-ocean knowledge gaps in the IPCC Assessment Reports: identification, implications, and critical research needs

This policy brief urges policymakers to prioritise deep-ocean research to address knowledge gaps identified from the IPCC's Sixth Assessment Report (AR6). This will enhance scientific understanding for effective, evidence-based climate policies and regulations.

Key messages

- The deep ocean is integral to Earth's climate system and serves as a vast reservoir for biodiversity and other natural resources.
- Significant and concerning deep-ocean changes are underway, yet large uncertainties hinder the creation of evidence-based policies and regulations.
- Additional emerging anthropogenic stressors highlight the urgent need to address deep-ocean science gaps to support effective management and mitigate harm.
- A meta-analysis of the IPCC AR6 reports identified major deep-ocean science gaps that inform seven key areas for research priority: (1) meridional overturning circulation, (2) ocean deoxygenation and acidification, (3) primary production, (4) ocean carbon cycle, (5) ocean ecosystems, (6) fisheries, and (7) ocean-based climate interventions.

The importance of the deep ocean

Vast storage capacities and residence times underpin the ability of the deep ocean (the region below 200 m depth) to regulate Earth's climate. This region serves as the **largest carbon reservoir on the planet**, absorbing 30% of anthropogenic CO_2 from the atmosphere to date. The deep ocean has also **absorbed 90% of excess heat** resulting from anthropogenic changes in atmospheric composition, significantly slowing transient global warming on land. It accounts for **95% of Earth's habitable space**, supporting numerous unique ecosystems and potentially important nutritional assets for tackling increasing threats to food security. Despite this initial known importance, the deep sea remains largely unexplored and uncertainty surrounds our understanding of its fundamental physical, chemical, and biological properties, including baseline state and variability, processes, and sensitivities.

Underrepresentation of the deep ocean in IPCC Reports

The reports of the Intergovernmental Panel on Climate Change (**IPCC**) provide the most comprehensive assessment of past, present and future climate change, its causes, potential impacts and response options. A defining aspect of the IPCC assessment reports is a formal uncertainty language framework that intends to aid identification of key knowns and major knowledge gaps. Current IPCC reporting protocol, however, leads to:

- **Skewed focus on *high certainty* findings**, which is further exacerbated in the Executive Summaries and Summaries for Policy Makers (Figure 1).
- **Chronic omission of understudied climate system components in policy considerations**, including the deep ocean, which is beset by uncertainty due to challenges hindering observation.
- **Missing communication of critical research needs** for investigating and better understanding deep-ocean vulnerabilities and risks.

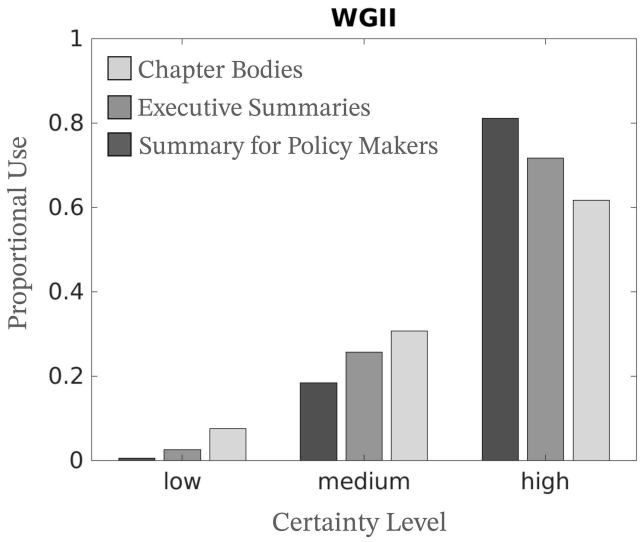


Figure 1: Proportional use of low, medium and high certainty expressions in the IPCC AR6 Working Group II report. A similar pattern is seen for all other AR6 reports, highlighting a skewed focus on high certainty findings.

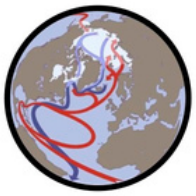
Identifying critical deep-ocean science gaps

To address this issue, a large team of **DOSI** and **DOOS** members reviewed 3,000 pages across six ocean-relevant AR6 and interim reports to identify where coordinated effort within the science community could improve confidence in deep-ocean systems for the next assessment report (AR7). The study identified **219 major science gaps related to the deep ocean** as (1) those expressed using *very low* and *low confidence* statements and (2) those included in dedicated 'Knowledge Gaps' sections, representing major structural deficiencies in climate research.

Major sources of deep-ocean uncertainty

Almost **50% of the identified science gaps are associated with uncertain consequences for biological ocean systems**, primarily regarding the future of deep-ocean ecosystems and fisheries. These arise largely as a result of uncertainties in changing ocean temperature and heat content, highlighting a **critical need to further investigate these interactions**.

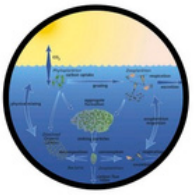
Seven priority areas for coordinated deep-ocean research



Meridional overturning circulation (MOC): sparse transport estimates (especially in the Southern Ocean) and large model spread lead to low confidence in MOC changes and their potential reversibility. Whilst ensemble projections indicate the likelihood of future Atlantic MOC weakening, there is significant uncertainty in the expected timing and magnitude.

Ocean deoxygenation and acidification: current observational gaps limit the ability to sufficiently monitor ocean deoxygenation and acidification, track mechanisms impacting ocean carbon, and constrain models. Major knowledge gaps surround the evolutionary adaptability and potential vulnerability of numerous species to ongoing ocean deoxygenation and acidification, with uncertain ramifications for seafood supply.

Primary production: observational gaps and limited understanding of dominant drivers prevent identification and attribution of ongoing changes in timing, distribution, and composition of algal blooms, and net production. Uncertainty in regional net primary production has increased from AR5 to AR6, undermining confidence in projections of all higher trophic levels.



Ocean carbon cycle: observational gaps, particularly in the Southern Ocean, prevent rigorous detection and attribution of change. Models disagree on the anticipated response of regional ocean CO_2 sinks to projected wind and freshwater forcings, with significant uncertainty surrounding the expected sign of physical and biochemical changes impacting the biological carbon pump.

Ocean ecosystems: lack of present-day baselines for biodiversity, biomass, and food-web structure limits capacity to quantify change, assess vulnerability and adaptability of different species, and identify extinction risks. These gaps also prevent reliable simulation of biological processes and interactions in climate models.

Fisheries: large uncertainty surrounds anticipated changes in fish biomass and habitat range in response to climate change (e.g., warming, deoxygenation, acidification), changes in primary production and food supply, and fisheries activity. Major knowledge gaps also surround the interaction of these stressors and the net impact to anticipate on fishery productivity and food security.

Ocean-based climate interventions: Marine carbon dioxide removal (mCDR) has not been comprehensively analysed in integrated assessments, and interactions between different methods have not been evaluated. The deep sea is the carbon repository for many mCDR technologies, but impacts on deep environments, processes and ecosystems have yet to be assessed. mCDR technologies are neither ready to be deployed at scale nor regulated in the absence of the necessary frameworks.

A new era of extensive collaboration

Many policy and regulatory decisions are under development that will determine the fate of the deep ocean and its ecosystems for generations to come. The major gaps identified here expose where science-based decision making is on unsteady ground. They largely surround interactions of multiple biological, physical, and biogeochemical stressors, culminating in potentially major impacts on deep-ocean ecosystems (and their services) and the ongoing regulatory capacity of the deep ocean in the Earth's climate system.

This highlights the **urgent need for a new era of extensive collaboration** to (1) exchange information and tools across research disciplines, (2) coordinate activities across networks, (3) co-design and implement an effective deep-ocean observing system that serves the needs of diverse stakeholders, and (4) develop skilful numerical models for trustworthy predictions informing mitigation and management efforts.

Recommended actions for future reporting

The science gaps presented here demonstrate that **low confidence surrounds many acutely important and policy-relevant issues in the deep sea**. The current IPCC reporting protocol, however, fails to highlight vulnerability and risk for the deep ocean and other areas where research is largely absent. This policy brief presents the following **calls for action**, to avoid omitting low confidence-high risk issues in future IPCC reporting:

- **Introduce inverse assessment reports** to expose where policy cannot be supported by an adequate evidence base.
- **Include a mandatory 'Knowledge Gaps' section** for each AR7 chapter to highlight where research needs are most profound, providing valuable direction for researchers and funding agencies.
- **Diversify IPCC authorship** by engaging scholars from Low-Middle Income Countries, social scientists, and indigenous knowledge holders to expand framing beyond natural sciences and identify reporting blind spots.

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About DOSI and DOOS

The Deep-Ocean Stewardship Initiative is a global network of experts that integrate science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdiction.

The Deep Ocean Observing Strategy (DOOS) is a community-driven, international initiative working to strategically align the deep-ocean research community toward collective solution-based science and accelerate the generation and use of deep-ocean data for science and societal needs.

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Key reference

This policy brief is based on a research paper titled Future directions for deep ocean climate science and evidence-based decision making by Pillar et al. (2024).

Further reading

Hetherington et al. (2024) Deepening the Decade: Collaborative Action for Advancing Deep-Ocean Science and Policy in the United Nations Decade of Ocean Science for Sustainable Development.

Levin (2021) IPCC and the deep sea: a case for deeper knowledge.

Levin et al. (2022) Designing, generating, and translating deep-ocean observations for and with international policy makers.

Smith et al. (2022) The Deep Ocean Observing Strategy: Addressing Global Challenges in the Deep Sea Through Collaboration.

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