Responses to reviewers comments:

Veitch et al., A description of Ocean Forecasting Applications around the Globe

On behalf of the co-authors, I would like to thank both reviewers for their comments that have been well received and acted upon. Please see, in blue, our responses to each comment that have significantly improved this manuscript.

RC 1

This article introduces all aspects of the global ocean forecast applications, which is very comprehensive and detailed.

1. Firstly, the overall structure of the article could be classified according to application scenarios rather than regions. Examples can be given to illustrate what applications there are in those regions.
   Thank you for this suggestion, and we can understand how it would make the review more cohesive. However, in this manuscript we are specifically calling on the nine separate regions of the Oceans Prediction DCC to provide the landscape of their region, with respect to Downstream Applications, through some examples. It is related to a manuscript on the landscape of forecast systems, that follows the same structure. In the revised version of the manuscript, we hope to have made the chapter more cohesive by grouping the specific applications into a number of broad categories that include: Extremes, Hazards and Safety; Natural Resources and Energy; Shipping, Ports and Navigation and Climate Adaptation.

2. In 2 The West Pacific and Marginal Seas of South and East Asia and 3 Indian Seas, there are also applications like storm surge, climate change, ship routing, water quality, Coastal tourism, Coastal Engineering and so on. Moreover, there's no detailed operational forecasting systems and its applications in China, which is suggested to be included in.

   Thank you for highlighting these omissions. In the West Pacific and Marginal Seas of Sea and East Asia, information has been included on the MOANA system in Australia, CSIRO and BOM in Australia, the OCEANUS and COAST systems in China that uses the Global Forecast system of FIO. For the Indian Seas section, more information has been added on their Marine Heat Wave, fishing (including small vessel advisories), coral bleaching and coral bleaching tools. Please refer to the revised sections to see the inclusions, which are extensive.

3. Both titles 2.4 and 2.5 refer to natural resources and energy. They should be merged.
   Done

4. In 6 North-East Atlantic section, titles 6.1 to 6.5 have the word "sector", but there are no "sector"in other parts. Please keep the consistence in the whole article.
   The subsections of each region have been redefined by broadly grouping them into the same subsections: Extremes, Hazards and Safety; Natural Resources and Energy; Shipping, Ports and Navigation and Climate Adaptation.

5. The Format of 8 North America is different with other sections. There are no subset serial numberin 8.
   The North American section has been completely revised and follows the same numbering and format as the other sections.

RC 2

This paper gives an example-based overview of downstream applications of ocean forecasting systems around the world, broken down into eight regions dealt with in turn. It is successful in conveying a sense of the range of applications that exist, with many interesting examples provided. Where I feel it misses an opportunity though, is collating that information into a coherent summary of the global status of ocean forecasting applications.

We have restructured the paper by reorganizing each section into the following broad categories of downstream applications: Extremes, Hazards and Safety; Natural Resources and Energy; Shipping, Ports and Navigation and Climate Adaptation. Each category is explained in the new methodology chapter in the introductory section. In addition, a summary section has been added that ties the manuscript together, as has a general section on various engagement strategies. We believe that these changes has made for a much more cohesive manuscript.

General comments:

The paper would benefit greatly from a **summary section** at the end that discusses, in the context of the regional overviews and examples provided, the overall status of ocean forecasting applications globally. What commonalities are there between regions? Where do regions differ? Which applications are well served? Which are not being addressed as well as they should? What lessons can be learned from the examples provided? Where are the major gaps?

We agree that the manuscript would benefit from a summary section. We have included the the following (l1070-l1089):

11. Summary

Operational oceanography supports the Blue Economy, providing the knowledge and tools for us to sustainably use our oceans for economic growth, better livelihoods, and job creation. Around the world, scientists and forecasters are developing cutting-edge tools that transform raw ocean data into practical solutions for a variety of challenges. These tools help us understand and protect our marine environments, manage resources, and ensure safety at sea.

This report has provided some examples of Downstream Applications, based on operational forecast systems, for eight of the nine regional teams, identified by the OP DCC. a It is by no means a comprehensive review, but it does provide an indication of the needs and services in each region as well as the relative maturity level of downstream applications. The regions with the most established and most numerous operational forecast systems (e.g. the Mediterranean and Black Sea; North East Atlantic; North America; parts of the Western Pacific and Asia and to some extent the Arctic) tend to also have the most mature downstream applications. The forecasting systems of the Indian Seas, South America and Africa can be thought of as 'emerging' and by this we mean: new, rapidly growing and often under- or less-resourced. Despite this, the INCOIS system developed for the Indian Seas is a sophisticated system that incorporates real time observations and provides mature tools for stakeholders that support various offshore activities. Part of their success is related to their close engagement with their stakeholders. The African region is one of the least developed in terms of regionally optimized forecast systems, with only a few developed in various parts of the continent. However, they do have two fairly mature user-support platforms that are based primarily on earth observations and whose tools are co-designed with stakeholders. These dissemination platforms are ready to ingest tools based on regionally optimized forecasts.

In this review, a sample of various downstream applications around the Globe reveals that while established and reliable forecast systems are a key factor in their abundance, a good relationship with stakeholders is critical for their uptake.

The **methodology** could be better described. This could either be done by expanding the end of the Introduction section, or by adding a short new section following the introduction. Things I'd like to see clarified include:

- How were the examples chosen? From some kind of survey or search? Through the DCC Regional Teams? Just through the authors' personal knowledge?
- Most of the focus seems to be on use of large public sector forecasting systems. Is this an accurate reflection of the state of ocean forecasting applications, or a result of smaller-scale entities and applications not having visibility on the international stage? I don't know the answer, but if the authors have any insights these would be worth noting.
- The subsection headings (e.g. Oil Spill, Marine Litter), have some commonality between regions, but aren't consistent. Please clarify whether there was an attempt to categorise examples under certain headings for each region (in which case the absence of it for a region could be taken to imply there are no mature examples), or if for each region a subset of examples was chosen independently.

The lack of more detail on the methodology was an oversight on our part, we have added the following paragraph (l.62-79) in the Introduction section in response:

The distribution of the regions is based on both the UNEP (United Nations Environmental Programme) as well as the GOOS Regional Alliances, with some clustering.

The regional sections have been prepared by each of the regional teams of the OceanPrediction DCC (https://www.unoceanprediction.org/en/about/community) and, though not comprehensive, each provide a flavour of the needs in each region as well as some of the downstream application services developed to meet them and their maturity levels. The downstream applications have been broadly grouped as follows: Extremes, Hazards and Safety; Natural Resources and Energy; Shipping, Ports and Navigation and Climate Adaptation and specific contributions for each grouping may differ per region. Extremes, Hazards and Safety refers to all extreme events, both offshore (such as marine heat waves) and coastal (such as storm surges), marine pollution (that includes water quality and oil spills) and search and rescue operations. Natural Resources and Energy refers to all downstream applications associated with the sustainable exploitation of marine resources (we include aquaculture), renewable energy, tourism and recreation as well as conservation efforts. Shipping, Ports and Navigation includes operational support for research activities (including cruise-track optimization as well as deploying equipment) and Climate Adaptation focuses on longer time-scale tools that are provided to support coastal and ecosystem resilience. The examples provided are primarily based on public sector forecasting systems and services, with a few exceptions. The OceanPrediction DCC Atlas of Services, https://www.unoceanprediction.org/, will contain a more complete list of downstream services in each of the regions.

The initial overview for each region could helpfully be expanded in a lot of cases. The African Seas overview gives a good concise summary of the general status of ocean forecasting applications around Africa. In contrast, the Indian Seas

overview is rather generic. In all cases though, I'd encourage the authors to review these overview sections to ensure they meaningfully summarise the specific situation in each region, while minimising generic statements that could apply to all or most regions.

An effort has been made to make each of the introductory sections more equitable.

There is an inconsistency in the length of the different sections. For instance, the Indian Seas section is less than a page, whereas the North America section takes up 11 pages (a third of the manuscript) despite largely focussing on a single country. Some discrepancy in section length is reasonable, but this feels excessive, and the authors should ensure a fair amount of focus is given to each region. The balance between comprehensiveness and conciseness isn't always as well achieved as it could be. Some sections need expanding on, others need tightening up to avoid the paper being excessively long.

One option could be to include, as part of a new section following the Introduction, an overview of common applications (e.g. oil spill, ship routing, search and rescue, etc) which deals with generic (non-region-specific) aspects. The specific regional examples in the following sections could then be streamlined, which may aid with ensuring the manuscript works as a clear coherent whole.

We agree and this has been addressed be reorganizing and trimming each of the regional contributions and avoiding generic statements. The length of the sections is now between 2.5 to 4.5 pages. To help achieve this, we have grouped the various application examples into the following broad categories: Extremes, Hazards and Safety; Natural Resources and Energy; Shipping, Ports and Navigation and Climate Adaptation

The manuscript is mostly well written, but I'd recommend a thorough read through the entire manuscript to check both for typos/grammar and tightness of language (e.g. L42: "both … as well as").

Specific comments:

L32: "Also emphasized is the important role of ocean literacy and citizen science to increase awareness and education in these critical topics". Ocean literacy and citizen science receive only limited mention in the manuscript. Given it's highlighted in the abstract, it would be good to bring this out a bit more in the text.

Agreed. We have decided to include a separate section (l1018 to l1069), entitled: 'Education, stakeholder engagement and ocean literacy' in which we talk about these issues in a general way with some specific examples, in various regions, of the various types of interventions: 'Technical Workshops, Ocean Literacy, Stakeholder Engagement and Co-Design, Citizen Science'. See text added below:

10. Education, stakeholder engagement and ocean literacy

Educati*on, stakeholder engagement and ocean literacy activities are essential components in supporting the full value chain from data production (operational forecast systems) to the provision of useful downstream applications. These activities are carried out in all regions and at various different stages along the value chain: from education outreach activities with learners, technical workshops, to community engagement and co-design workshops with stakeholder groups. They help to ensure that the downstream applications produced have real value and are measurably impactful. Below we provide some examples of the types of education and engagement activities that take place.*

Technical Workshops

The Sub-Commision of the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization for the Western Pacific and adjacent seas (WESTPAC) develops and strengthens regional and Member States' capacity for ocean model development, data assimilation, model validation, and development of Ocean Forecasting System, through a series of national and regional trainings, scientific workshops, and professional exchanges among partner institutions (https://ioc-westpac.org/ofs/capacities/). The Regional Training and Research Center on Ocean Dynamics and Climate (RTRC-ODC) was officially established at the 8th WESTPAC Intergovernmental Session in 2010. The First Institute of Oceanography, State Oceanic Administration of China, organized the lecture series on ocean models (2011), ocean dynamics (2012), air-sea interaction and modeling (2013), climate models (2014), climate change (2015), ocean dynamics and multi-scales interaction (2016), development of coupled regional ocean models (2017), ocean forecast system (2018) and climate dynamics and air-sea interactions (2019). In the evaluation period of 2015-2019, 191 young scientists from 36 countries joined the lectures (https://ioc-westpac.org/rtrc/odc/).

Ocean Literacy

With ongoing Arctic Sea ice decline, scientific results from the region are more frequently appearing in national news and the general public are more aware of the Arctic environment and how it is changing. The freely accessible forecast maps from most services, with an interface that can select given variables and watch as they run forward in time, provide a useful tool to demonstrate how changeable, for example, the ice edge is in response to forcing even on the short term, which can be used to engage with wider audiences and educate about the Arctic as a dynamic system. For

example, Coursera, a website offering a number of free online courses for studying in evenings, has a course entitled "Frozen in the Ice: Exploring the Arctic", based out of the University of Boulder, Colorado (https://www.coursera.org/learn/frozen-in-the-ice); the course allows participants to act as virtual participants on the MOSAiC Arctic research campaign, and one of the six modules is based around Arctic forecasting. Activities such as this allow the public to get closer to polar research, and many large research campaigns now include outreach as part of their programs.

Stakeholder Engagement and Co-Design

With NOAAs Office of Response and Restoration, the Emergency Response Division (ERD) develops tools, guidelines, and small, field-oriented job aids to assist preparedness for response communities. In addition, NOAA provides standard techniques for observing oil, assessing shoreline impact, and evaluating and selecting cleanup technologies that have been widely accepted by response agencies.

South Africa's National Oceans and Coastal Information Management System (OCIMS) holds annual stakeholder engagement workshops that facilitates the co-design of the decision support tools. Between the workshops, dialogue between stakeholders and developers is maintained through active whattsapp groups.

While INCOIS provides extensive training to users for efficient utilization of their forecast products, they have noticed that NGOs, Universities, local government departments and localized user community networks are found to be very effective in ensuring that the information reaches the user in time. User-uptake is supported by their good relationship with local fishing communities who are involved with the safe-keeping of their observation platforms in exchange for timely warnings of maritime hazards. This relationship builds awareness as well as trust with coastal communities.

Citizen Science

New Zealand's Moana Project innovatively incorporates citizen science by partnering with commercial fishers to gather essential oceanographic data. Fishing vessels are equipped with the "Mangōpare" sensor system, which automatically collects and transmits subsurface temperature measurements in near real-time as the vessels go about their normal fishing activities. This transforms the fishing fleet into a vast, mobile observation network, expanding data coverage across a wider spatial range than traditional research methods. This mutually beneficial partnership provides scientists with valuable data, while fishers gain access to information that can enhance their own operations. By empowering local communities and increasing data accessibility, Moana fosters collaboration and contributes to a deeper understanding of the marine environment, ultimately supporting sustainable fisheries management and scientific research.

L34: "with emphasis given on their level of maturity." This is a good aim, but hasn't been achieved as well as it could be. I suggest a review of each section's text with this aim in mind.

This has been addressed in the summary section (l1077 – l1087):

It is by no means a comprehensive review, but it does provide an indication of the needs and services in each region as well as the relative maturity level of downstream applications. The regions with the most established and most numerous operational forecast systems (e.g. the Mediterranean and Black Sea; North East Atlantic; North America; parts of the Western Pacific and Asia and to some extent the Arctic) tend to also have the most mature downstream applications. The forecasting systems of the Indian Seas, South America and Africa can be thought of as 'emerging' and by this we mean: new, rapidly growing and often under- or less-resourced. Despite this, the INCOIS system developed for the Indian Seas is a sophisticated system that incorporates real time observations and provides mature tools for stakeholders that support various offshore activities. Part of their success is related to their close engagement with their stakeholders. The African region is one of the least developed in terms of regionally optimized forecast systems, with only a few developed in various parts of the continent. However, they do have two fairly mature user-support platforms that are based primarily on earth observations and whose tools are co-designed with stakeholders. These dissemination platforms are ready to ingest tools based on regionally optimized forecasts.

L54: "eight of the nine regions." To help this be read as a standalone paper, please specify with a reference the context in which these regions were defined.

This has been included in the methodology paragraph in the introductory section (l62-l64):

'The distribution of the regions is based on both the UNEP (United Nations Environmental Programme) as well as the GOOS Regional Alliances, with some clustering. '

L57: "The OceanPrediction DCC Atlas of Services, a web portal that will be launched soon." I believe this is already launched (https://www.unoceanprediction.org/en/atlas) though remains a work in progress. The text could be updated to reflect its status.

This has been modified (l78)

The OceanPrediction DCC Atlas of Services, https://www.unoceanprediction.org/, will contain a more complete list of downstream services in each of the regions.

L61-63: “in several countries including Australia, China, Japan, and Korea in 2000s and Indonesia in 2010s. There are no significant endogenous research and development activities targeting operational forecast systems in other countries.” From a language point-of-view, “in several … including” implies the list of countries is non-exhaustive, but the next sentence implies it is exhaustive. Also, while it may not be on the scale of efforts in the countries listed, activities in New Zealand (https://www.metocean.co.nz/, https://www.moanaproject.org/) may merit mention. Furthermore, “no significant endogenous” implies that there might be significant exogenous examples in other countries – is this the case?

This statement has been changed as follows (l 83):

‘*..related to meteorology, hydrography, and oceanography in several countries including Australia, China, Japan, Korea, Indonesia and New Zealand....*’

Section title 2.5 Natural resources & energy repeats that of Section 2.4, and I suspect should be something different.

This has been corrected.

L137: “'Boast Safety Index' (BSI)”. Should “Boast” be “Boat”?

Corrected

L215-216: “In South Africa and Mozambique the met services and a local municipality have developed downscaled storm surge models (Section 3.1.4).” There is no Section 3.1.4, and there is no apparent extant section in this manuscript this might be referring to.

The correct reference (Cirano et al., 2025) has been included here

Section 8 subsections lack numbering.

L571-575: This is a good example of generic information about an application type which could be dealt with in an overview section.

L578-611: The description of NOAA and other US agencies’ role in oil spill response is genuinely interesting, but an excessive level of detail for this particular paper. It is also in danger at times of reading like an advert for NOAA (e.g. “NOAA brings scientific expertise to the table to help answer these questions.” – which an internet search tells me is taken directly from https://oceanservice.noaa.gov/hazards/spills/).

L627-636: This text appears to be copy/pasted verbatim from https://www.sarsat.noaa.gov/about-sarsat/, now-broken hyperlinks included.

The above three comments could be applied to much of the North America section, which I suggest is revised accordingly. At the moment it mostly appears to be a collection of text taken from various NOAA websites, rather than a truly representative overview of the continent’s ocean forecasting applications.

Table 1: On the one hand, using a table like this can neatly summarise a large amount of diverse information, and part of me thinks the technique should be used more widely in the article. On the other hand, Table 1 is more a list of systems than applications (the latter being the focus of the paper), more than a dozen of which are run by a single agency. On balance, I suggest removing Table 1 and incorporating the most pertinent information and references from it into the revised North America text.

Thank you for these important comments (all six of the above). The North American section has been completely revised, with generic statements removed, and is now only 4.5 pages long and includes more detail on Canadian services.

L804-805: “As detailed in Section 3.1.9, there are a number of short-term (up to 10 day) forecasting systems available in the Arctic.” Another reference to a non-existent section and information that doesn’t seem to exist in the manuscript.

This reference has been changed to Cirano et al., 2025

L817: “NWS” – presumably National Weather Service, but worth expanding and clarifying that it and NOAA are US agencies.

These have been included in parentheses.

9.2 Fisheries: This is an interesting paragraph, but it is unclear whether there are any existing applications (known to the authors) or just an emerging need. This should be clarified. Similarly, for Section 9.4.

Included here (in the Natural Resources and Energy subsection, l924-926):

While no specific operational downstream applications have been identified in this category for the Arctic, in the sections below are described the growing needs specific to the region.