

Working Group 4 report

WG number : 4

Targeted Societal Outcome : Predicted Ocean

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Ocean Decade Definition of the Outcome :

The vast volume of the ocean is neither adequately mapped nor observed, nor is it fully understood. Exploration and understanding of key elements of the changing ocean including its physical, chemical and biological components and interactions with the atmosphere and cryosphere are essential, particularly under a changing climate. Such knowledge is required from the land-sea interface along the world's coasts to the open ocean and from the surface to the deep ocean seabed. It needs to include past, current and future ocean conditions. More relevant and integrated understanding and accurate prediction of ocean ecosystems and their responses and interactions will underpin the implementation of ocean management that is dynamic and adaptive to a changing environment and changing uses of the ocean.

Identify regional challenges that need to be overcome to achieve Southern Ocean priorities ([cfr report](#)) over the next 10 years in the context of your appointed Societal Outcome.

Research Challenges (purely scientific)

Challenge R1: Better estimates of sea ice thickness

- Accurate estimates of the volume (ie thickness, as area is well constrained) of sea ice is crucial for understanding the thermodynamics and energy balance of the system
- Measuring changes to sea ice volume is impossible without accurate measurements of current state
- Current practice is to measure sea ice thickness using *in situ* observations, although techniques are in development for estimating using satellite observations
- Just as important as sea ice thickness is the snow-ice ratio and consequently the mean density and freeboard of sea ice
- Sea ice models are often calibrated against data collected in the Arctic region. We know that Antarctic sea ice has significantly different characteristics to Arctic sea ice, and so the parameterisation of these models can be improved

Challenge R2: Observing across trophic levels

- Currently observe the environment (ocean and sea ice) and have observational programs in place for several top predators.
- There is a yawning gap in observations between the environment and top predators.
- Primary production mostly only observed using ocean colour estimates, although bio-Argo is changing this and providing observations through the water column.
- Very limited observations of secondary trophic levels (zooplankton and small fish)

- Mesopelagic fish rarely observed, and only by *in situ* trawl surveys
- Observations of larger fish based on catch records from industrial exploitation
- Need to characterise year-round behaviour of species. Significant deficit of observations in autumn and winter.

Logistical and Technical Challenges (funding, infrastructure, data accessibility, etc.)

Challenge LT1: Improving spatial and temporal coverage of observations

- We need to observe year round and have better coverage of a larger proportion of the Southern Ocean (particularly under the sea ice)
- Need an appropriate network that is capable of detecting regional and seasonal variation/variability
- Any *in situ* observations on the shelf are lacking. This includes measurements of bathymetry but also flow on/off the shelf. This is crucial for detecting change in circulation and water formation
- Vertical movement of water is poorly understood. This limits our understanding of vertical flux of tracers such as carbon, oxygen and other nutrients.
- There is nowhere in the Southern Ocean where we can confidently say we can properly characterise a complete annual cycle of many variables (e.g. sea ice, mixed layer depth, circumpolar deepwater intrusion on to the shelf, but also almost all biological variables) to the extent that we can provide quantitative measurements (such as those that are needed to parameterise or evaluate a model)
- The characterisation of annual and seasonal cycles is critical to improving our understanding of the region
- A better understanding of more regions is necessary. We have good spatial coverage of regions such as the West Antarctic Peninsula or the Ross Sea, but marginal coverage of large regions such as the Southern Indian or Pacific Ocean regions.

Challenge LT2: Improving regional environmental models

- Many model parameters are based on observations from outside the Southern Ocean (biogeochemistry is a good example). These parameters are appropriate for global models, but are often not appropriate in the Southern Ocean
- Carbon cycling through the environment is poorly understood and poorly represented in ocean (and ocean-sea ice) models
- Three dimensional fluxes are largely un-bounded in current models (due to lack of observations for comparison)
- Incorporating wave models into ocean-sea ice interactions is critical to properly understand the marginal ice zone
- Global models will always make compromises: these may be due to regional variation, limitation in computing resources or time available.
- High resolution regional models are needed for the Southern Ocean (and sub-regions).
- Biological responses are strongly non-linear and so models that get timing and magnitude of environmental variability right are crucial.
- Even high resolution ocean models largely have simplistic biogeochemical components. Improved regional ocean and sea ice biogeochemistry is critical to understand the Southern Ocean ecosystem.

- Impact of changes in ice sheet volume and melt rate is poorly understood
- Freshwater input from snow, rain or ice sheet melting is poorly understood
- Fast ice representation is crucial for many systems, but missing in almost all regional models
- The effects of teleconnections on the Southern Ocean needs to be understood and predicting the future trends/impacts of teleconnections is essential for the Southern Ocean in coming decades?

Identify tangible actions that would be able to address these challenges. Delineate the scope of suggested actions (leading organisation, involved stakeholders, funding, timeline, implementation).

Action 1

Name of Action	Improve estimates of sea ice thickness
Related challenge	R1
Short description	Estimates of sea ice thickness are poorly constrained. Improvements can be made through the following actions <ol style="list-style-type: none"> 1. Improve capability for under ice upward looking measurements of sea ice thickness 2. Develop Antarctic-specific parameters for sea ice models 3. Improve estimates of sea ice volume from satellite observations (which in turn requires validation against <i>in situ</i> observations) 4. More widespread <i>in situ</i> measurements of physical properties, particularly density and snow/ice ratio
Key stakeholders to consider	National Antarctic programs, sea ice modelling community, managers of national facilities
Timeline	SO Decade
Potential resources	Large scale observational campaigns
Other comments	

Action 2

Name of Action	Increased observing program across trophic levels
Related challenge	R2
Short description	We currently have observational programs for the environment (ocean and sea ice) and a number of top predators, however a significant gap exists in observing between these ends of the

	<p>trophic ecosystem. We need more observations of the trophic levels between these extremes. This could include</p> <ol style="list-style-type: none"> 1. Targeted sampling programs across trophic levels 2. Closing the gap between statistical and dynamical/mechanistic models of biology (statistical models are empirically derived from observations, whereas dynamical and mechanistic models require understanding of key, driving processes) 3. Improve our understanding and estimates of mid-trophic levels 4. Increase observations of predators in winter 5. Improve battery technology and decrease weight of animal borne tags (to allow tagging of more species) 6. Improve autonomous vehicles to allow them to observe biology
Key stakeholders to consider	National Antarctic programs, long term monitoring programs, ecosystem management bodies (CCAMLR, IWC etc)
Timeline	SO Decade
Potential resources	
Other comments	

Action 3

Name of Action	Improved spatial (circumpolar) and temporal (across seasons) observations
Related challenge	LT2
Short description	<p>Much of the Southern Ocean is under observed. A number of actions can be undertaken to address this, including:</p> <ol style="list-style-type: none"> 1. Ice-capable Argo needs to be expanded, along with ice-capable bio-Argo and gliders. We need circumpolar coverage and improved deployment techniques. 2. Development of a coordinated global effort that delivers circumpolar observations with effort more evenly distributed in space and across seasons. 3. Develop observing programs that monitor the carbon cycle in a manner that allows easy comparison across voyages or observing programs. 4. Increase the use of fishing vessels (and other ships of opportunity) as observing platforms. Investigate

	<p>possibilities to use such platforms for sampling (which is critical).</p> <ol style="list-style-type: none"> 5. Firming up and expansion of animal-borne sensor network 6. New technologies that allow better and more measurements (such as ΔO^{18} sampling) 7. Development of paleo records to allow long-term assessment of stability of models. This is especially so in the abyssal ocean.
Key stakeholders to consider	National Antarctic programs, managers of national facilities
Timeline	SO Decade
Potential resources	Large scale observational campaigns, universities and organisations developing new technologies
Other comments	

Action 4

Name of Action	Improved regional and targeted observations to infill currently under-observed regions
Related challenge	LT2
Short description	<p>Hard to access regions of the Southern Ocean, such as ice covered regions and on the continental shelf , need special attention to improve observations. Specifically:</p> <ol style="list-style-type: none"> 1. More observations on the continental shelf through collaboration by multiple ships or countries . 2. Increase <i>in situ</i> observations under the ice. Can be done through Autonomous profilers, AUVs, ROVs or other systems. 3. Regional observing programs that can detect regional change (and across seasons) 4. More sea ice attachment type observations: e.g. ice-tethered profiler (ITP) and IMB (Ice mass-balance buoy).
Key stakeholders to consider	National Antarctic programs, managers of national facilities
Timeline	SO Decade
Potential resources	Universities and organisations developing new technologies,those with a vested interest in a specific region
Other comments	

Action 5

Name of Action	Improved performance of regional environmental models
Related challenge	LT2
Short description	<p>Global models are an important tool for understanding important processes, variability and change in the Southern Ocean, however regional models are essential for understanding regionally specific and small-scale processes and change. The development of a suite of regional, high resolution (time and space) ocean-sea ice models is an important task for the SO Decade. These models should aim to include:</p> <ol style="list-style-type: none"> 1. Improved flow of carbon through the system, and improved observations to allow proper evaluation of carbon cycling. 2. Data assimilation needs to be common. Data assimilation of biological tracers must be developed 3. Development of regionally-appropriate parameters for physical and biogeochemical models 4. Development and incorporation of more complex regional biogeochemical models that properly represent the range of phytoplankton and zooplankton species in the region. 5. A focus on accurate representation of fast ice in regional models 6. Develop ocean-sea ice-ice sheet regional models that have resolution and capacity to model dynamic changes in ice sheet (such as changes in geometry) 7. Closing the gap between forecast models (short term) and decadal time scales in order to inform decisions made at policy-relevant intermediate timescales
Key stakeholders to consider	Large modelling centres that currently have global models, universities and other organisations that focus on development of regional models
Timeline	SO Decade
Potential resources	
Other comments	

Describe already-existing activities and stakeholders who are presently working towards resolving these challenges.

Name of Action	
Related challenge	ex: R1, U2, ... (see above)
Short description	
Leading organisation	
Key stakeholders	
Timeline	
Resources	
Other comments	

Rank suggested actions in order of priority while taking into account feasibility and timeline. The highest ranking actions will be included in the Southern Ocean Action Plan and will most likely require additional notes.

Order of priority	Action number & name
1	Action 3: Improved spatial (circumpolar) and temporal (across seasons) observations
2	Action 5: Improved performance of regional environmental models
3	Action 4: Improved regional and targeted observations to infill currently under-observed regions
4	Action 1: Improve estimates of sea ice thickness
5	Action 2: Increased observing program across trophic levels

If you have any further comments/suggestions, please describe them below.

***** Don't forget to have a look and comment on the reports of other Working Groups. *****