

Southern Ocean community comment on the Year of Polar Prediction Implementation Plan

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1) Introduction

The Year of Polar Prediction (YOPP)'s central objective is to "enable a significant improvement in environmental prediction capabilities for the polar regions and beyond, by coordinating a period of intensive observing, modelling, prediction, verification, user-engagement and education activities".

Such an improvement cannot be conceived without considering the critical role of the Southern Ocean in regional and global climate variability. This historically undersampled ocean is subject to the strongest, most persistent westerlies of the globe and highly energetic katabatic easterly winds close to the Antarctic continent, hosts a sea ice region of enormous seasonal extent, and is a significant contributor to the thinning of Antarctic ice shelves which buttress the grounded inland ice sheet. These factors make it both challenging and critically important to characterize the processes governing Southern Ocean dynamics and variability. The role of the Southern Ocean in prediction of many aspects of the global climate system on timescales of days to years is becoming even more apparent as connections to the tropical and Northern Hemisphere climate modes are progressively unveiled.

For these reasons and many others, the Southern Ocean region has become a research priority for climate science. Major transformations in terms of observing and model-data synthesis capabilities have taken place in recent years. The Southern Ocean Observing System (SOOS) has been a central contributor in the coordination of these transformations. SOOS is an international initiative, co-sponsored by the Scientific Committee on Antarctic Research (SCAR) and the Scientific Committee on Oceanic Research (SCOR) and endorsed by the World Climate Research Program (WCRP) projects CliC (Climate and Cryosphere) and CLIVAR (Climate and Ocean: Variability, Predictability and Change) as well as the Partnership for Observation of the Global Oceans (POGO). The SOOS mission is to facilitate the collection and delivery of essential observations on dynamics and change of Southern Ocean systems to all international stakeholders, through the design, advocacy, and implementation of cost-effective observing and data delivery systems.

SOOS specifically includes components that are vital to realizing the YOPP goals. SOOS is coordinating projects that are working to:

- Provide information that can enhance near real-time data capabilities, e.g. by improving understanding of satellite measurements
- Provide guidance on how to optimize an observing system
- Lead to a better understanding of air-ice-ocean interactions
- Improve data assimilation software for improved Southern Ocean reanalysis and state estimation
- Improve understanding of model, data, and forecast errors.

The Southern Ocean Region Panel (SORP) is a forum for the discussion and communication of scientific advances in the understanding of climate variability and change in the Southern Ocean. SORP is co-sponsored by CLIVAR, CliC and SCAR and has a role to advise CLIVAR, CliC, and SCAR on progress, achievements,

new opportunities and impediments in internationally-coordinated Southern Ocean research.

Together, SOOS and SORP form a strong representation of the Southern Ocean observational and modelling communities.

The Year of Polar Prediction (YOPP) is an exciting initiative with the potential to greatly enhance our prediction capabilities in both Poles. Many aspects of the YOPP Implementation Plan align directly with SOOS and SORP objectives. For this reason, efforts are warranted on all fronts to leverage each contribution towards the common goal.

This Working Paper is designed to highlight key Southern Ocean field and modelling capabilities of relevance to YOPP, identify key areas for collaborative efforts, and raise the imperative of the Southern Ocean's role in prediction capabilities.

Timetable for near-term SOOS and SORP planning activities relevant to YOPP:

1. SOOS Air-sea flux workshop, Frascati, Italy, September 21-23, 2015. <http://www.soos.aq/calendar?view=event&cid=82>
Registration is open NOW. Formal abstract deadline has passed, but email to Sarah Gille (sgille@ucsd.edu) and indicate interest/send abstract.
2. CLIVAR/CliC/SCAR Southern Ocean Region Panel meeting, Frascati, Italy, Sept. 24-25, 2015. Co-chairs: Lynne Talley (ltalley@ucsd.edu), John Fyfe (john.fyfe@ec.gc.ca)
3. Southern Ocean Satellite Needs Community Report: Currently available for review, comments due end of July. <http://soos.aq/science/satellite-data>
4. SOOS Regional Working Groups are being developed, and proposals for Capability Working Groups by the community will be open in August 2015. Contact: Anna Wahlin (anna.wahlin@gu.se), Oscar Schofield (oscar@marine.rutgers.edu), Louise Newman (newman@soos.aq)

2) Importance of the Southern Ocean in climate predictability

The predictability of the climate system is limited by model errors, the inherent chaotic nature of the atmosphere and ocean, limited ability to characterize the system's past and present state, and uncertainties regarding future forcing (volcanic eruptions, anthropogenic emissions among others). The atmosphere alone is largely unpredictable beyond a month, but owing to the longer decorrelation timescales of "slower" components, predictability of certain aspects of the climate system can extend to a season and perhaps up to a decade (Doblas-Reyes et al., 2013; Meehl et al., 2014; Bellucci et al., 2015;

Gopalakrishnan et al., 2013). Due to their relatively large mass and specific heat, the world oceans are the memory of our climate system. The ability to predict climate at seasonal time scales and beyond thus largely rests on a correct knowledge of the oceanic state.

The surface waters that interact directly with the atmosphere, i.e. the ocean “mixed layer” (~upper 100 m), exert a control on the overlying atmospheric flow on short time scales. The deeper the mixed layers, the stronger the potential control on the atmosphere, as adjustment between the air-sea system will not be quickly achieved. The Southern Ocean is home to very deep mixed layers (>400 m in some regions), and thus it can partially govern atmospheric evolution. Because of this, air-sea exchanges in the Southern Ocean are capable of releasing or sequestering massive amounts of heat and CO₂.

Knowledge of the sea-ice state is also vital to seasonal predictability. In the most southern part of the Southern Ocean cold atmospheric temperatures and strong winds that flow off the Antarctic Ice Sheet leads to the formation of both sea ice and salty dense water that can cascade thousands of meters from the continental shelf to the abyssal sea floor to ventilate the abyssal ocean. Polynyas are particularly important regions where massive amounts of ocean heat are fluxed to the atmosphere and some of the strongest vertical mixing rates can occur. By affecting the depth and heat content of the mixed layer, sea ice formation can thus modulate air-sea interactions.

The strong air-sea exchanges combined with large subduction regions within and north of the Antarctic Circumpolar Current, as well as upwelling regions to the south give the Southern Ocean a significant capacity to store and release heat, fresh water, carbon dioxide, and other gases, on various time scales, and thus attributing a key role to this part of the world ocean in inter-annual climate predictability. The rate of heat and CO₂ uptake into the Southern Ocean greatly exceeds that of any other ocean and the expectation is that it will continue to be the region of largest uptake of heat and CO₂ into the future (IPCC, 2013). Mass loss of parts of the Antarctic ice sheet has been accelerating over the past two decades (e.g., Hanna et al., 2013; Paolo et al., 2015). Extensive warming of the Antarctic Peninsula stands out compared with cooling of the main regions of Antarctica and a slight overall sea ice expansion (e.g., Parkinson and Cavalieri, 2012). Warming in West Antarctica and increase in circulation of warmer Antarctic Circumpolar Deep Waters (CDW) into the Antarctic continental margin are critical for changes in ice sheet mass balance. Warm subsurface waters from the Antarctic Circumpolar Current reach the continental margin in the Amundsen-Bellingshausen Sea sectors, where in recent years an increased volume of CDW has intruded into cavities of the floating ice shelves, and has been implicated in the accelerated ice sheet mass loss, which has a critical impact on barostatic contributions to global sea level rise.

Our ability to predict seasonal climate anomalies requires knowledge of the sea-ice cover and the ocean mixed layer properties such as heat content, salinity, thickness, and underlying stratification. On longer time-scales the entire ocean state must be characterized. The Southern Ocean has a major influence on

regional and global climate due the fact that it connects and transforms the global water masses. Furthermore, the Southern Ocean dynamics is prone to numerous feedbacks, particularly because of the presence of sea ice.

Knowledge of the Southern Ocean atmosphere/sea ice coverage and ocean mixed layers is rapidly evolving, thanks largely to the augmentation of satellite observations with the Argo array. Challenges still exist, however, in modelling and predicting the evolution of sea ice and the mixed layer. This is exacerbated by the fact that knowledge of air-sea and air-ice-ocean fluxes in this region, particularly in the sea ice zone and over the Antarctic continental shelf seas, is critically sparse. Most *in situ* observations of flux-related variables measure basic meteorological quantities such as temperature and wind speed, and turbulent fluxes are determined from bulk formulae that have (with few exceptions) not been tested extensively in high-latitude, high-wind regimes, especially during harsh winter months.

Given the sparseness of the observations, it is perhaps not surprising that gridded flux products from data syntheses and reanalyses differ substantially from each other, in some cases with net heat fluxes differing by 20 W m^{-2} or more in the annual mean (Stephenson et al., 2012). Similar issues exist with respect to precipitation changes over the Southern Ocean and Antarctica (e.g., Bromwich et al., 2011). The Antarctic sea-ice zone, seasonally waxing and waning to either cover or expose nearly half of the Southern Ocean south of 50°S , particularly affects air-sea interaction. This ice cover also governs the albedo, causing seasonal swings in the high-latitude radiation balance that are second only to the Northern Hemisphere snow-covered land. Yet, observed trends in ice cover are poorly understood due largely to uncertainties in knowledge of air-ice-ocean exchanges and pronounced interannual variability. While the observations in the open ocean can be characterised as sparse, in the sea-ice zone they are nearly non-existent.

3) SOOS Activities

A number of current SOOS activities and products are of relevance to YOPP:

SOOS Air-Sea Fluxes Task Team

Air-sea fluxes are a critical link for polar predictability and in the climate system because they play a key role in the transfer, movement and storage of heat, fresh water, momentum, carbon dioxide, oxygen, and other gases. This Task Team was developed to bring together the greater Southern Ocean air-sea flux community, related investigators and users, to identify priority needs, to clarify community vision, and to develop a coherent strategy for continuation and enhancement of existing efforts. To this end, a workshop will be held from the 21-23 September 2015, hosted by ESA at ESRIN, Frascati, Italy. This workshop is sponsored by SOOS, WCRP and ESA. Registration is currently open, but should be completed quickly.

Relevance to YOPP: This workshop is obviously a key topic of interest. In particular, plans for an internationally coordinated pilot field project and development of a strategy for enhancing air-sea flux observations will be discussed.

More Information: <http://soos.aq/calendar?view=event&cid=82>

Satellite Data Requirements for the Southern Ocean: review activity

In order to address growing disparities in Polar remote sensing, and in particular to articulate the satellite needs specific to the Southern Ocean, SOOS and CliC coordinated a community survey to canvas uses of remote sensing and define limitations and recommendations for improvement of Southern Ocean remote sensing. This report is now available for review at <http://soos.aq/science/satellite-data> (deadline: end of July 2015).

Relevance to YOPP: Satellite data is highlighted as a key data contributor to YOPP (section 4.1.4). This Community Report provides a focal point for YOPP to articulate Southern Ocean satellite data needs to the data providers.

Under Ice Observations

Many of the key scientific questions concerning the role of high latitude air-ice-ocean interactions in the climate system remain unanswered because of a paucity of observations, principally because of historical lack of access to the very large extent of seasonal sea ice. New technologies now allow such measurements to be made. The goal of this SOOS initiative was to develop a strategy for sustained observations of the Antarctic sea-ice zone and under ice shelves. The international strategy has now been published and is available for download at <http://www.soos.aq/science/under-ice>

Relevance to YOPP: Implementation of this strategy is a key focus for SOOS over the coming years, and a SOOS Capability Working Group is being proposed to drive it forward. Involvement of YOPP in the planning phases for field campaigns would ensure YOPP requirements are being met, and co-SOOS-YOPP endorsement of proposals would lend weight to funding applications.

Regional Working Groups

Regions of the Southern Ocean differ from each other—from the scientific priorities for observations and observing system requirements (variables, spatial and temporal sampling requirements), through to national capabilities and infrastructure for the implementation of field campaigns. SOOS will therefore be implemented regionally. SOOS is currently developing 5-6 Regional Working Groups that will assist the delivery of coordinated and, where possible, standardised observations of essential physical, chemical and biological variables across a specified region. At the centre of Regional Working Groups is the facilitation of coordinated and multidisciplinary field efforts, and communication of project plans. More information on the Working Groups will be available by September 2015 on the SOOS website.

Relevance to YOPP: SOOS Regional Working Groups will provide a mechanism for YOPP communication of requirements (e.g., priority gaps in observations, sharing of

resources and infrastructure) directly to the communities charged with making the observations.

SOOS Capability Working Groups

SOOS encourages proposals for Working Groups with targeted objectives to enhance observing capabilities—such as the development of new technologies, development of new standards and methodologies, coordination of a community towards a common goal. These Working Groups are designed to cut across and feed into the Regional Working Groups. A proposal template will be available on the SOOS website in the coming months.

Relevance to YOPP: Some aspects of YOPP may require community development prior to implementation. A SOOS Capability Working Group may provide the mechanism to bring the relevant community together towards production of a key product. Examples include algorithm development/testing, satellite validation efforts, ship observations...etc.

Southern Ocean Field Project Portal

Key to enhancing collaborative efforts, discovering data and sharing resources is knowledge of planned field campaigns. SOOS is in the process of developing a database for researchers, logistics personnel and others to enter metadata on planned and existing field activities, visualized with a dynamic online map.

Relevance to YOPP: This portal will provide YOPP information on existing and upcoming field activities, which will facilitate planning efforts, e.g., planning for satellite validation efforts, ship and station observations, surface buoys.

SOOS Data Management Activities

Southern Ocean observational data is dispersed across many national and thematic data centres, making data discovery difficult. The NASA GCMD is providing SOOS with a Metadata Portal and the SOOS Data Management Sub-Committee is working with them to populate the portal. As a starting point, priority will be given to pulling in metadata records of SOOS Essential Ocean Variables (recently defined and on SOOS website by September). NASA GCMD is currently updating a number of key services identified at the recent SOOS data meeting, and the portal will be online by the end of July at <http://gcmd.gsfc.nasa.gov/KeywordSearch/Home.do?Portal=soos-beta&MetadataType=0>.

Relevance to YOPP: The Metadata Portal can be used by YOPP to search all national, institutional and thematic data centres for YOPP-relevant data.

4) Southern Ocean Observation efforts of relevance to YOPP

Knowledge of all national and international field efforts planned for 2017-2019 is difficult, and development of the SOOS Field Project Portal will go a long way to providing an avenue to compile this information. At this early stage, and based on the requirements outlined in the YOPP Implementation Plan, we can identify

several initiatives that will take place during YOPP Phase 2 (2017-2019), and may, therefore, contribute to YOPP.

The following list is **incomplete**, but because of the imminent YOPP summit, it should be useful to articulate some of the major field campaigns that should be in place during YOPP. As stated in the YOPP Implementation Plan, how these projects can be extended for YOPP will require further discussion between Principal Investigators and YOPP. Given the time required for logistics and infrastructure planning, these discussions should be initiated quickly.

The field observations below are grouped roughly in two categories: (a) sustained international observation systems that are already considered contributions to the Global Ocean Observing System (GOOS), and (b) shorter term observational programs and nationally funded process experiments that may be of limited lifetime but may involve large resources.

a) Sustained International Observation Systems

Argo and Ice-Capable Argo (international)

Timeline: Ongoing

Point-of-contact: Susan Wijffels (Susan.Wijffels@csiro.au)

Overview: Argo floats profile for temperature and salinity to 2000 m every 10 days; real-time data are posted publicly, and quality controlled at least annually. The data are invaluable worldwide for nearly synoptic observations, and a large number of useful data products are posted routinely by numerous agencies in multiple countries. Argo data are essential for upper ocean property and mixed layer mapping. There is a very active Southern Ocean Argo community, and over 260,000 profiles have been collected from the Southern Ocean since 2000. Although previously restricted to waters north of 60°S, ice-capable Argo floats (e.g. Klatt et al., 2007) are now further enhancing collection of data from the sea-ice zone. Under-ice Argo floats also profile every 10 days; all under-ice profiles are reported shortly after the first surfacing of the float after sea ice melt with estimated locations (under ice tracking only in the Weddell Sea region). Argo profiles are useful for air-sea flux analysis through their incorporation in ocean state estimates, similar to atmospheric reanalysis; global analyses are made routinely; one specific state estimate focused on the Southern Ocean is a special focus of the SOCCOM Argo-equivalent program described below. The map below shows Argo deployments since 08/2011 (blue) and planned deployments for the coming season 2015/16 (green).

Information on deployments, profiles and plans are available at <http://www.jcommops.org/argo>

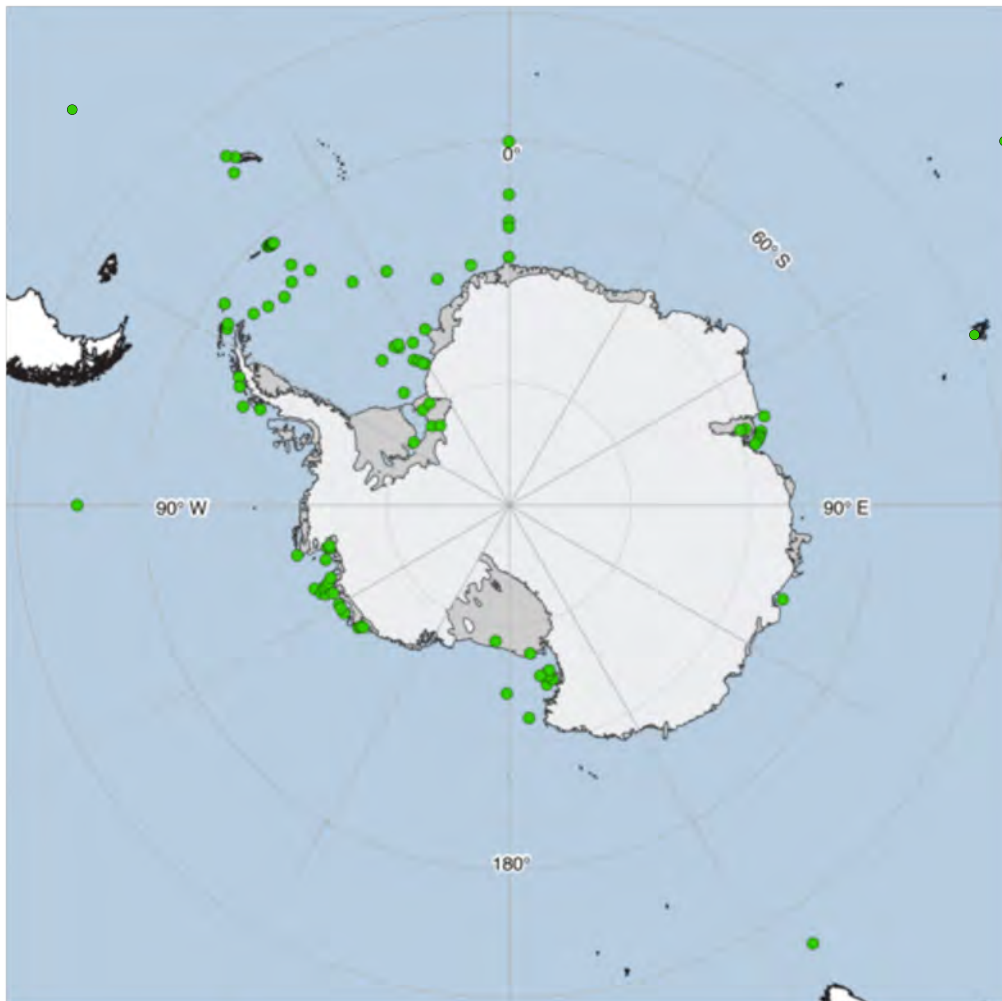


Southern Ocean Network of Moorings (international and national)

Timeline: Ongoing

Principal Investigator: Numerous national efforts, survey incomplete

Overview: Many mooring arrays and individual moorings are currently maintained in the Southern Ocean as part of national/multinational projects. Several of these are long-term observing system installations, including the German (AWI) moorings in the Weddell Sea and Greenwich meridian, and OceanSites moorings near Tasmania (Australia), west of Chile and east of Argentina (both USA), all with air-sea flux as well as in situ measurements. The Weddell Sea network includes RAFOS sound sources that permit tracking of under-ice floats and gliders in that region (Germany). Other longer term deployments with plans for continuation exist in the Ross Sea, in Prydz Bay, and in the Amundsen Sea. Many are short-term, with a deployment length less than two years. SOOS is currently working to compile information on the existing and planned (funded) network of moorings, and to enhance data discovery by working with OceanSITES towards a central repository for Southern Ocean mooring data. The map below, which is not yet comprehensive, indicates the approximate location of moorings currently deployed, as well as planned deployments for the 2015/16 season (contributing nations: China, Japan, Australia, New Zealand, Italy, Korea, Norway, Sweden, USA, UK, Germany, France, and India).



GO-SHIP hydrographic observations (international)

Timeline: Ongoing

Point-of-contact: Bernadette Sloyan (Bernadette.Sloyan@csiro.au), Martin Kramp (mkramp@jcommops.org)

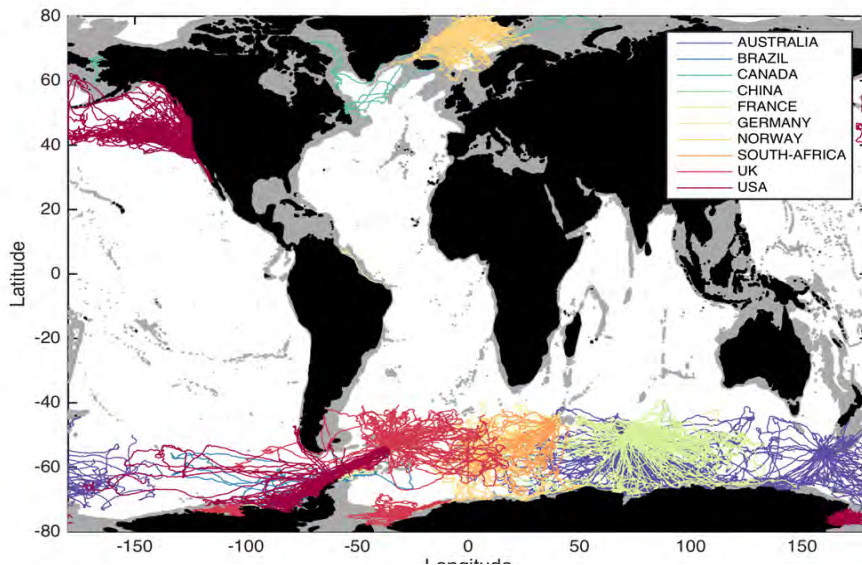
Status: Funded

Overview: GO-SHIP provides the reference standard measurements for physical and biogeochemical properties for global ocean observing. It is the only program that provides full water column measurements including components for the ocean carbon system. GO-SHIP collects underway meteorological and ocean surface data. Data management is well defined and routine, and data are publicly available through a network of data centers. The Argo profiling float network relies on GO-SHIP observations as a calibration standard, and takes advantage of GO-SHIP cruises for float deployments. For the purposes of YOPP, GO-SHIP also provides the opportunity to access regions of the Southern Ocean for observing, although activities that require substantial additional ship time should be discussed and planned at least one year in advance.

Information: <http://www.go-ship.org/>

Data: Available through network of data centers listed on the GO-SHIP website; routine water column data publicly available within 6 weeks of cruise; chemistry data publicly available within months of cruise.

MEOP-CTD dataset : 333395 profiles, 107 deployments, 789 tags



b) National/Multi-national Observational Activities

Indian Ocean Service of Observations (Océan Indien Service d'Observation, OISO) (France)

Timeline: Ongoing

Principal Investigator: Nicolas Metz (nicolas.metzl@locean-ipsl.upmc.fr)

Status: Funded

Overview: A yearly cruise in the Indian sector (Kerguelen area) taking a range of biogeochemical/physical measurements to monitor Carbon uptake and storage. The program has been going on for almost 20 years, and is funded for future years including 2017-2019. Cruises are usually in Jan-Feb of each year on the RRS Marion Dufresnes II

More information: <http://caraus.ipsl.jussieu.fr/oiso-campagnes.html>.

Chinese Activities

Timeline: 2016-2020

Principal Investigator: Varied – general contact Jiuxin Shi (shijiuxin@ouc.edu.cn)

Status: Funded

Overview: In the past 5 years, most Chinese observations in the polar region were supported by the Chinese Polar Environment Comprehensive Investigation and Assessment Programme (2011-2015). This programme will be extended 5 years (2016-2020) but the detailed field work plan is still pending. The likely observing activities during YOPP include:

- Hydrographic observation at transects in regions around Prydz Bay (February, 2017, 2019), South Shetland Islands (February, 2018), and possibly Ross Sea.
- Mooring deployment/recovery in Prydz Bay (February, 2017, 2018, 2019)
- Underway observations along ship track (Indian sector cruise: Fremantle - Prydz Bay - Ross Sea - Hobart/Christchurch, 2016/2017, 2018/2019; Circumpolar cruise: Fremantle - Prydz Bay - Ross Sea - South Shetland

Islands – Drake Passage – Ushuarua – Drake Passage - Prydz Bay – Fremantle, 2017/2018, 2019/2010): current in upper ocean (38kHz/300kHz ADCP), temperature, salinity and chemistry (CO₂, etc) of sea surface water, meteorology, sea ice (ASPeCt).

- Expendable probes (XBT/XCTD, radiosonde) observation at transects: Fremantle - Prydz Bay (2017-2019), Ross Sea - Hobart/Christchurch (2017-2019), Drake Passage (2018).
- Ice Mass Balance Buoy (IMB) on fast ice in Prydz Bay near Zhongshan Station in winter (2017-2019).
- Argo floats and surface drifting floats might be released in the ACC region and Prydz Bay respectively.
- Observation activities in the Scotia Sea, including the Southern Shetland Islands and the Orkney Islands utilising commercial fishing vessels. These activities focus on hydrographic observations and ecosystem survey along transects.

Data: All the data will be available from the Chinese National Arctic and Antarctic Data Center (www.chinare.org.cn) after a protection period (usually 2 years).

Research of Ocean-ice Boundary Interaction and Change around Antarctica (ROBOTICA)

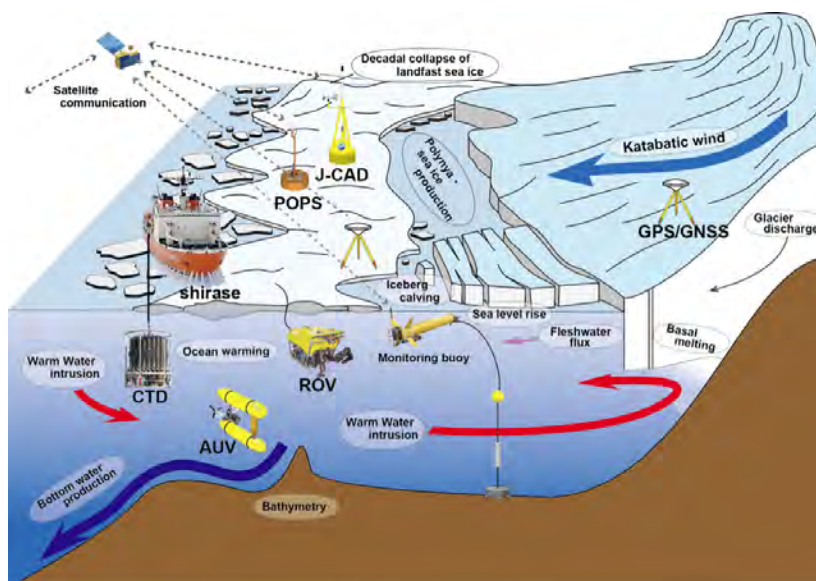
Timeline: 2016 - 2023

Principal Investigator: Shigeru Aoki (shigeru@lowtem.hokudai.ac.jp); Takeshi Tamura (tamura.takeshi@nipr.ac.jp)

Status: Funded

Overview: An integrated field project spanning 9 years including YOPP years, focusing on 3 East Antarctic Coastal regions:

- Ocean-Glacier-sea ice interaction in Totten/Vinceness Bay (2020/21)
- Decadal variability of ocean and land-fast sea ice in Lutzow-holm Bay (2016/17-21/22)
- Sea-ice production and dense water formation in the Cape Darnley Polynya (2016/17-20/21)



Data: Will be available through http://scidbase.nipr.ac.jp/?ml_lang=en
More Information: <http://www.lowtem.hokudai.ac.jp/en/groups/acros.html>

Measurements from the Polynyas and Ice Production in the Ross Sea (PIPERS)

Timeline: April-Dec 2017

Principal Investigator: Steve Ackley (Stephen.Ackley@utsa.edu)

Status: Funded

Overview: A two month cruise into the Ross Sea on the US Icebreaker NB Palmer will be conducting an atmosphere-ice-ocean interaction experiment in the polynyas and sea ice regions of the western Ross Sea.

Data Contribution: Measurements contributing directly to YOPP could be the GTS transmission of surface pressure and temperature from three drifting buoy arrays deployed during the cruise with expected lifetimes from April-Dec 2017.

YOPP Data Denial Experiment for Numerical Weather Analyses: Other measurements obtained on the cruise will include boundary layer measurements of heat, moisture and momentum, radiosonde measurements of atmospheric profiles (temperature and humidity), radiative fluxes and surface temperatures of sea ice. A lidar measuring cloud heights will also be continuously operating. As these measurements are part of an integrated research experiment, they will not be transmitted in near real time through the GTS. The accumulated data set will be used post cruise in comparison with analysed forecast fields for weather analyses during the same period. The comparison with this analysis, from probably the only winter measurements of these quantities from the Antarctic sea-ice zone during YOPP, will provide an important quantitative measure of the present skill of the numerical weather forecasts and analyses in the little studied winter atmosphere of the Antarctic sea-ice zone, and will enhance the development of polar predictability for this region.

KOPRI Amundsen Sea Project

Timeline: 2015/16; 2017/2018

Principal Investigator: SangHoon Lee (hooenator@icloud.com)

Status: Funding confirmed for 2015/16; Not yet confirmed for 2017/18

Overview: This is phase 3 of a project that began in 2010. The details of the 2017/18 plan is not yet finalized or funded. Observation efforts include moorings, sediment traps, gliders, drifters and a variety of biochemical process studies.

Data: This project involves many nations (Korea, Sweden, USA, UK, and France) and the data collected is submitted across the national data centres.

More Information: <http://soos.aq/news/current-news/188-kopriamundsenproject>

Water-mass transformation and Pathways in the Weddell Sea (WAPITI)

Timeline: 2017 - 2019

Principal Investigator: Jean-Baptiste Sallée

Status: Funded

Overview: This project builds on recent technological developments to push the boundary of Lagrangian observation networks towards the Antarctic slope and shelf. In addition, by combining these new observations with existing datasets (including seals, Argo, and ship-based datasets) and state-of-the-art numerical models, it aims to provide an original synthesis of the large-scale dynamics of the Weddell Sea.

More information: <http://wapiti.cedricmarcelly.com/>

Brazilian High Latitude Oceanography Group

Timeline: Feb 2017

Principal Investigator: Mauricio Mata (mauricio.m.mata@gmail.com)

Status: Funding not yet confirmed

Overview: A campaign to redeploy moorings in Bransfield Strait and re-visit hydrographic stations set (Bransfield Strait, Gerlache Strait and NW Weddell Sea (West SR04 Section). Measurements include full depth oceanographic stations, Moorings (T,S,O₂, velocity), and surface CO₂ fluxes.

Data: Brazilian National Oceanographic Data Centre

More Information: www.goal.furg.br

Southern Ocean and Climate (SO-CLIM)

Timeline: 2014 – Mar/Apr 2017

Principal Investigators: Stéphane Blain (stephane.blain@obs-banyuls.fr), Hervé Claustre, Sabrina Speich

Status: Funded

Overview: Improve the quantification of important climate relevant parameters such as air-sea fluxes of heat, freshwater and carbon in the Indian Ocean sector of the Southern Ocean.

Data: <http://soclim.com/find-data-en.php>

More information: <http://soclim.com/index.php>

Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM)

Timeline: 2014 - 2020

Principal Investigators: Jorge Sarmiento (jls@Princeton.EDU), Ken Johnson (johnson@mbari.org), Lynne Talley (ltalley@ucsd.edu), Joellen Russell (jrussell@email.arizona.edu), Steve Riser (riser@ocean.washington.edu), Heidi Cullen (hcullen@climatecentral.org), Matt Mazloff (mmazloff@ucsd.edu), Ariane Verdy (averdy@ucsd.edu), Sarah Gille (sgille@ucsd.edu), Igor Kamenkovich (ikamenkovich@rsmas.miami.edu), Laurie Juranek (ljuranek@coas.oregonstate.edu), Shari Bell (sbell@climatecentral.org); NOAA (GFDL, PMEL, AOML) investigators; many associate (unfunded) investigators

Status: Funded

Overview: This represents the deployment of ~200 ice-capable BGC-Argo floats throughout the Southern Ocean, contributing to the Argo program (see above). The floats provide 10-day measurements of temperature, salinity, nitrate, oxygen, pH, optical backscatter, and chlorophyll fluorescence. These observations are being assimilated in an ocean model, and used to improve coupled climate models. The Southern Ocean State Estimate, which

assimilates these data, provides high quality air-sea flux “reanalysis” specific to the Southern Ocean. This product should be of special relevance and use to YOPP.

Data: <http://socom.princeton.edu/socomviz.php>
<http://socom.princeton.edu/content/float-data-ftp-access>
More information: <http://socom.princeton.edu/>

Ocean Regulation of Climate through Heat and Carbon Sequestration and Transports (ORCHESTRA)

Timeline: April 2016 – March 2021

Principal Investigator: Michael Meredith (mmm@bas.ac.uk)

Status: Funding not yet confirmed

Overview: Key project deliverables include:

- Deployment of operational autonomous networks delivering real-time surface and interior heat and carbon data (2017-19)
- Major ship-based expeditions to quantify the interior fluxes of heat, carbon and other tracers through the Southern Ocean and northwards into the Atlantic overturning circulation (2017, 2018)
- Aircraft flights for determination of air-sea-ice heat and carbon fluxes in different sea ice conditions (2017,18,19)
- Improvements to UK climate/Earth System models, coded and made available to wider community (2018)
- Global air-sea fluxes climatology, optimized for the Southern Ocean, and available online (2020)
- Climate and ocean model runs demonstrating improved predictive skill, for inclusion in the IPCC process and policy development (2020).

Data: If funded, marine data will be submitted to BODC as required by funding agency. Metadata will be provided to SOOS GCMD.

Other relevant, ongoing (funded) observational campaigns for which more complete information should be provided to YOPP, principally national efforts:

- (a) Southern Ocean Carbon and Climate Observatory (CSIR, South Africa); Pedro Monteiro, Sandy Thomalla, Seb Swart, <http://socco.org.za>
- (b) Australian work in southern Indian and Pacific sectors (R/V Investigator, Aurora Australis)
- (c) Chilean work (U. Concepcion and other institutions) in the SE Pacific sector (ongoing, with emphasis on predictability)
- (d) German work (AWI) in the Weddell and between South Africa and Antarctica
- (e) Argentine work (U. Buenos Aires) on the Malvinas Plateau and South American western boundary

5) Southern Ocean modelling and reanalysis efforts of relevance to YOPP

With the focus of this SOOS contribution on observational programs, state estimation and reanalysis, which incorporate data sets, are described briefly.

Model-data synthesis (state estimation) efforts

Timeline: ongoing

State estimates for the Southern Ocean: ECCO and ECCO-related Southern Ocean State Estimate (SOSE)

Principal investigators, points of contact: Patrick Heimbach (ECCO); Matthew Mazloff (SOSE)

Status: Funded

Overview: Models and data are combined to create atmospheric reanalyses, which are usually the principal products used to provide optimal initial conditions of the atmospheric state globally several times per day for the purpose of numerical weather prediction. Because of lack of in situ data, these reanalyses are particularly poor in the Southern Ocean. Air-sea fluxes from these reanalyses are improved by optimizing them in solving for the ocean state. Ocean state estimation, although similar in some aspects to atmospheric reanalysis, is fundamentally different in the way it combines data and model. It does not adjust states sequentially which introduces artificial property sources/sinks, but rather it adjusts surface boundary conditions and independent model inputs to produce a time-evolving state that is consistent with the model dynamics at all times, free of artificial heat, freshwater, or momentum sources/sinks (e.g., Wunsch and Heimbach, 2013). In the process it thus adjusts the atmospheric reanalysis, demonstrably improves the estimated air-sea fluxes, and provides more credible basin-scale or global budgets. The ocean state indicates the temporally integrated air-sea exchanges. Thus by constraining ocean models to be consistent with the observed state on climate scales one can infer the atmospheric exchanges. This is currently underway using statistical models (Giglio and Roemmich, 2014) and with full general circulation models (Forget et al., 2015). Regional efforts focusing on the Southern Ocean have been produced (Mazloff et al., 2010) and continue to evolve. Products are publicly available.

Information and output:

ECCO: <http://www.ecco-group.org/>

SOSE: <http://sose.ucsd.edu>

Satellite-based surface turbulent fluxes.

Principal investigator: Jiping Liu (jiping.liu07@gmail.com)

Status: Funded

A new satellite-based surface turbulent fluxes (including heat and moisture fluxes) data set over Antarctic sea ice will be developed from a combination of in-progress satellite retrievals and a new method to compute surface turbulent fluxes over sea ice. The data will have a spatial resolution of 1 degree (or finer) lat/long and temporal resolution of daily (or 6-hourly). This new surface flux data set will be used to provide insight into air-sea ice-ocean interactions in the Southern Ocean and meaningful evaluation of coupled model simulations.

Sea Ice reanalysis efforts

Ocean-sea ice models are run in “data assimilation” mode to provide constraints on the modelled sea ice cover. Even the simple constraint of sea ice concentration can have positive effects on sea ice thickness (Massonnet et al., 2013).

Understanding variations in sea ice thickness over the past decades is a critical step to close the sea ice mass balance. This can help to understand the origins of the small, yet significant positive trend in total Antarctic sea ice extent as observed since 1979. More sea ice reanalyses produced with forced or coupled models are expected to come, and it becomes now technically feasible to constrain these models using sea ice thickness data too, e.g. from laser altimetry.

Model analysis efforts

Numerous unconstrained ocean models are run to analyze the Southern Ocean state. These models represent the observed ocean statistics and can be used to understand the predictability window of the region. SOOS is coordinating an effort to prioritize an observing system. As part of this effort, work is actively underway to determine the time-scales for which model errors or intrinsic ocean non-linearity degrade predictability for aspects of the state that need to be determined. Once these time-scales are diagnosed one can assess which observational platforms are most practical to constrain a model to achieve the required level of predictability.

"Data Denial Experiments" are a class of model experiments to improve predictability. By running perfect prediction experiments but disabling in turn initial information on sea ice thickness, ocean mixed layer, or sea surface salinity/temperature, it is possible to understand what factors control predictability at monthly to interannual time scales.

6) Collaborative Efforts between SOOS and YOPP

There is significant overlap in the data requirements of YOPP, and the data collection and delivery that SOOS facilitates. Joint YOPP-SOOS advocacy for the collection of these datasets will strengthen national funding bids and enhance international observing efforts—to the benefit of both SOOS and YOPP communities. SOOS has a process in place by which it can provide endorsement for projects and programmes seeking funding. There is potential to combine this effort for those projects wishing to contribute to both SOOS and YOPP.

There are large international efforts that exist that could contribute to both YOPP and SOOS, but which are facing substantial funding issues. Argo has greatly enhanced our understanding of the physical state of the Southern Ocean, with over 260,000 profiles collected south of 40°S since 2000. Argo is currently extending into the massive seasonal sea-ice zone, which is critical sampling for assimilation and prediction, and which has heretofore represented the largest data gap in the global ocean observing system. The community needs to ensure the imperative remains strongly vocalized for not only a continuation of current levels of funding, but this extension of the existing array into the sea-ice zone.

Data discovery and access is an ongoing issue. SOOS is working hard to enhance discovery but resources for this are limited. Where possible, YOPP should work to encourage meteorological, ice and ocean observations from all ships into GTS or other accessible data archives.

There are many programs and initiatives driving observational and modelling activities in the Southern Ocean. An efficient communication pathway between YOPP and these communities (including SOOS and SORP) would benefit all, as YOPP begins to formulate firm regional plans, to better articulate YOPP requirements, benefits and opportunities. Of the 20 world leading experts in Southern Ocean observations and modelling at the 2015 SOOS SSC meeting, only two were aware of YOPP, and neither had clear information on YOPP objectives/needs for the Southern Ocean. Given the lead-times required to gain funding for field initiatives and the start date of YOPP Phase 2, this connection should be made quickly. A possible avenue to assist communication between YOPP, SOOS and SORP would be identification of a liaison or contact for each group.

Final thoughts:

SOOS is moving from its developmental phase into one of implementation, with the start of Regional and Capability Working Groups and a data management system. SOOS is an umbrella for a wide range of scientific efforts in the Southern Ocean. SOOS has not made facilitating seasonal prediction one of its missions. However, short-term efforts could be investigated in support of YOPP. These efforts could, for example, work towards improving near-real-time observation capabilities.

YOPP is also in a planning stage, with interests in regional process experiments, improvement of modelling and reanalysis.

It is clear that development of Southern Ocean initiatives within YOPP will benefit the SOOS observing and state estimation community, and that the resources already in place and that are planned in SOOS could greatly benefit YOPP.

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