SOOS Theme 4: The Future of Antarctic Sea Ice

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Introduction

The Antarctic sea ice cover dominates large regions of the Southern Ocean at maximum extent. The seasonal change in sea ice cover represents one of the largest earth-wide swings in, for example, surface albedo, exceeded only by the seasonal snow cover on land in the Northern Hemisphere. Some regions, particularly the Western Antarctic Peninsula are exposed to climate change, due to reduction in sea ice over the past 40 years, with significant impact on the temperatures, ice shelves and the environment, in particular, ice-dependent ecosystems. In the Ross Sea, however, sea ice extent has increased, and has balanced the WAP losses so that overall circumpolar extent has shown a slight increase over the same period. Changes in sea ice formation feeds into other SOOS themes including Heat and Salt Fluxes and Ice Shelves and Sea Level. Whether ice formation takes place on or off the continental shelf may be crucial in how Antarctic Bottom Water may be affected in the Ross Sea, Weddell Sea, Adelie Land Coast, and Prydz Bay. Sea ice effects on ecosystems in the Ross Sea are currently unknown and may be complicated by factors such as the recent rise in commercial toothfish fishing in the Ross Sea. In the Arctic, the global warming is at roughly twice the global average rate, with a dramatic reduction in summer sea ice extent as one of the clearest indicators of this trend. Physical and biological processes are being transformed across the entire region while climate feedback mechanisms change atmospheric and oceanic dynamics impacts at global scales.

Satellite observation of sea ice has been done for more than four decades and is one of the most important applications of Earth Observation data in climate change studies. Several sensors and retrieval methods have been developed and successfully utilized to measure sea ice area, concentration, drift, thickness and other sea ice variables. In climate change studies based on satellite data, it is a major challenge to construct homogeneous time series from a series of consecutive satellite sensors needed for detection of changes over several decades. At the same time there is an evolution in sensors and observation technology, which makes it possible to observe new sea ice parameters for future monitoring.

In addition to concentration and thickness estimates, other sea- ice parameters are important for climate research, such as motion, albedo, snow cover, surface temperature, duration of melt season, leads/polynyas and deformation features. Data on all these parameters are needed to quantify the dynamic and thermodynamic processes responsible for the regional, seasonal and interannual variability of the sea ice. The total mass and volume of sea ice, including motion and fluxes, can be retrieved from observations of three parameters: ice concentration, ice motion and ice thickness, provided there is sufficient data available. Data on the two former parameters are available for the last two-three decades, whereas ice thickness data are particularly scarce in the Antarctic. Estimation of total ice volume and fluxes can therefore mainly be based on global model simulations. However, global models show significant discrepancies in sea ice extent alone in the Southern Ocean and are not very consistent with observations. In particular, with regard to the sea ice thickness many global models lack the capability to provide a correct distribution. Furthermore, most of the IPCC model simulations (e.g. *Stroeve et al., 2007; Boe et al., 2009*) have failed to predict the increase in Antarctic sea ice extent, and have instead suggested extent and volume should have decreased. The disagreement between models and observations could indicate a substantial natural variability component to the observed increase or an underestimation of the sea ice sensitivity in the models, or lack of knowledge on Southern Ocean sea ice properties and processes, or discrepancies in the forcing data for sea ice from the atmosphere and ocean. One of the goals in sea ice climate research is to better understand the natural variability of sea ice versus possible anthropogenic effects, but the insufficiency of models to even get the sign of change correct in the Southern Ocean, suggests this can only be achieved through better understanding of processes and eventual monitoring by a large-scale Southern Ocean Observing System in the sea ice zone.

The European Space Agency (ESA) has sponsored the Sea Ice Climate Change Initiative (SICCI) and has produced a User Requirement Document (Sandven 2013). Table 1, produced from surveys of the sea ice community, has defined the Essential Variables for sea ice cover that need to be observed. Since satellite observations are the only potential source of continuous information about sea ice extent, type, thickness, and drift, these are the main points of interest in the development of the SOOS observing network for sea ice. However, process experiments and Calibration/Validation of the satellite products are an important component in the stage of development of these observations to the level that they can be monitored. These experiments and observations are therefore important and relevant to SOOS, and will require regional sea ice studies, ship and autonomous vehicle deployments and ancillary use of ships of opportunity to refine the satellite observations.

The role of the sea ice cover in important problems (relevant to SOOS) related to Ecosystems, Carbon Fate and others are also probably indeterminate from these variables alone and will require direct sampling of the ice cover for biology and biogeochemistry, time series experiments using drifting buoys and long-term drift station occupations. In addition, important parameters related to sea ice and its long-term climatic prediction and the Heat and Salt Fluxes theme will further require measurement of air-sea fluxes of sensible and latent heat, momentum, and gas exchange (e.g. CO2, DMS and Bromine) and these currently (and probably in future) will require surface-based measurements of e.g. sea ice topography, ocean heat flux, winds, air pressure and temperature, radiation and snow properties of depth, surface flooding, density, moisture. Studies for these problems are being developed in the upcoming 10-year plan for the SCAR/CLiC project, Antarctic Sea Ice Processes and Climate (ASPeCt) and some of these will be summarized below.

Sea Ice Essential Climate Variables

Sea Ice ECVs measurable by satellite observations on a circumpolar basis. Table 1. (Sandven, 2013)

Variable	Application	Unit	Accuracy			Spatial resolution (km)			Observation cycle (hr)			Bias			Delay (hr)		Stability	Priority	Comments
			Thresh	Break	Obj	Thresh	Break	Obj	Thresh	Break	Obj	Thresh	Break	Obj	Thresh	Obj	(Decade)	1=high 4=low	
Sea ice cover	Climate	%*	5	3	2	50	30	15	72	48	24	12.5	5	1	168	24	4	1	
Sea ice thickness	Climate	cm	100	50	20	250	50	5	168	48	24	?	?	?	168	24	?	1	
Sea ice drift	Climate	cm/s	20	10	5	20	10	5	120	24	24	?	?	?	120	6	?	1	
Ice surface temp	Climate	K	2	1	0.5	500	100	25	24	12	6	?	?	?	48	24	?	1	
Sea ice cover	NWP global	%	20	10	5	100	15	5	120	24	24	Na	Na	Na	120	3	Na	2	
Sea ice thickness	NWP global	cm	50	30	10	100	50	20	720	60	48	Na	Na	Na	120	24	Na	3	
Sea ice type	NWP global	%	20	10	5	100	25	10	120	24	24	Na	Na	Na	120	3	Na	2	FY+MY+new
Ice surface temp	NWP global	K	4	1	0.5	250	15	5	12	3	1	Na	Na	Na	4	1	Na	2	
Sea ice cover	NWP regional	%	20	5	2	50	10	1	24	6	3	Na	Na	Na	1	0.5	Na	2	
Sea ice thickness	NWP regional	cm	50	30	10	100	50	10	720	60	48	Na	Na	Na	120	24	Na	3	
Sea ice type	NWP regional	%	20	10	2	50	25	5	120	24	24	Na	Na	Na	120	3	Na	2	FY+MY+new
Sea ice drift	NWP regional	cm/s	10	5	2	10	5	1	120	24	6	Na	Na	Na	60	3	Na	3	
Ice surface temp	NWP regional	K	2	?	0.5	100	?	5	2	?	0.5	Na	Na	Na	4	1	Na	3	
Sea ice cover	Ocean global	%	10	5	2	20	10	5	120	24	24	Na	Na	Na	120	3	Na	1	
Sea ice thickness	Ocean global	cm	50	30	10	100	50	15	720	60	48	Na	Na	Na	120	12	Na	1	
Sea ice type	Ocean global	%	20	10	5	50	10	5	120	24	24	Na	Na	Na	120	3	Na	1	FY+MY+new
Sea ice drift	Ocean global	cm/s	20	10	5	20	10	5	120	24	24	Na	Na	Na	120	6	Na	1	
Snow depth on ice	Ocean global	cm	20	10	5	200	100	50	240	120	72	Na	Na	Na	120	12	Na	1	
Sea ice cover	Ocean coastal	%	10	3	2	10	5	1	120	12	6	Na	Na	Na	120	3	Na	1	
Sea ice thickness	Ocean coastal	cm	30	20	5	100	20	1	720	48	12	Na	Na	Na	60	3	Na	1	
Sea ice type	Ocean coastal	%	20	10	5	10	5	2	120	12	6	Na	Na	Na	120	3	Na	1	FY+MY+new
Sea ice drift	Ocean coastal	cm/s	10	5	2	10	5	1	120	24	6	Na	Na	Na	60	3	Na	1	
Snow depth on ice	Ocean coastal	cm	20	10	5	50	30	10	120	72	48	Na	Na	Na	120	12	Na	1	
Iceberg drift	Ocean coastal	Km/h	0.2		0.1	1.0	0.2	0.1	24		6	Na	Na	Na	?	?	Na	3	

Three performance levels in the Table are defined as follows:

- **Threshold** is the limit below which the observation becomes ineffectual and is of no use for the targeted application
- **Breakthrough** level represents the level beyond which a significant improvement in the target application is achieved.
- **Objective** = maximum performance limit for the observation, beyond which no significant improvement in the targeted application is achieved

The Sea Ice ECV's relevant to SOOS are shown in the last sets of rows, Ocean global and Ocean coastal in Table 1.

Description of the main sea ice variables

Sea ice coverage and concentration

Sea ice coverage and concentration is required for monitoring the mass balance of sea ice particularly in view of recent climate change and global warming. Changes in sea ice cover and concentration can significantly affect both global ocean and atmospheric circulation through global energy balance changes, with subsequent impacts on weather and climate. As a result, sea ice coverage observations are important for forcing ocean models and for boundary conditions in NWP. In addition, operational services for shipping and safety at sea rely on sea ice concentration information at high latitudes.

State of readiness as an ECV

Since 1979, passive microwave satellites have provided near daily coverage of the polar sea ice covers and have estimated ice concentration. Currently, there are concerns about the algorithms to convert passive microwave emissions into measurements of sea ice concentration. The use of shipbased observations (ASPeCt) in Antarctica has recently been discussed by Beitch et al (Feb 2013). Figures 1 and 2 shows the comparison of ice concentration estimated from the ship visually with that seen from the satellite using four different passive microwave algorithms.

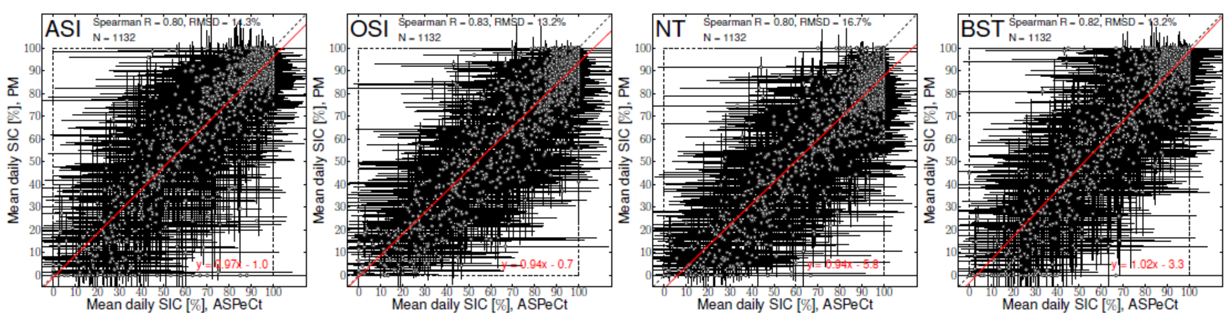


Figure 1. Comparison of satellite estimates of ice concentration with the mean daily ship-based (ASPeCt) using four different algorithms (e.g. NT is NASA Team algorithm).

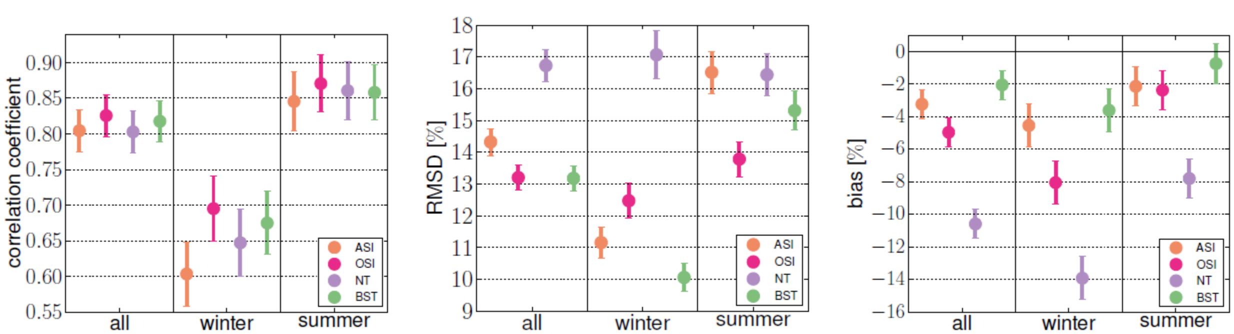


Figure 2 Correlation Coefficient, Root Mean Square Difference(RMSD) and Bias for the various algorithms identified in Figure 1, compared to surface observations as a function of season.

From Table 1, the Threshold value for ice concentration as an ECV is given as 10%, so currently with an RMSD varying from 10 to 17% (middle, Fig.2), the current level of satellite measurement of ice concentration is not at the level of an ECV.

The importance of the ASPeCt observations in providing the widespread statistical comparison of the algorithms has been highly important, providing at least an estimate of the errors involved in using passive microwave data. For SOOS and ASPeCt, the necessity of continuing this observational record and better quantifying the ship-based estimate of ice concentration using digital cameras, and Unmanned Airborne System (UAS) photography appears to be a critical component of better refining the use of satellite observations of ice concentration as an ECV.

Sea ice thickness

Sea ice thickness is required for monitoring the mass balance and horizontal freshwater transports and is unarguably both the least known and most important parameter to provide for knowledge of the Future of Antarctic Sea Ice. Knowledge of ice thickness is also important for navigation purposes in sea ice infested regions where safe passage is only possible in areas where the ice is thin. Measuring ice thickness from satellites requires auxiliary information, including the geoid, the ocean circulation, ocean tides, surface pressure, etc. The occurrence of snow on sea ice introduces a major source of uncertainty. Its depth and density influence the freeboard and surface topography of the sea ice and therefore impact the calculation of ice mass from surface area and freeboard, or ice surface topography measurements. There is thus a requirement to measure the thickness of the snow, and its density, when it occurs on floating sea ice.

State of readiness as an ECV

Two types of altimeter, laser and radar, have been designed and used to estimate sea ice thickness. The laser altimeter on ICESat returned data from 2003-2009 but was not in continuous operation throughout the year. Radar altimetry is now being returned from CryoSAT. It is projected that ICESat 2 will be launched in 2016. In the gap between ICESat 1 and ICESat 2, several airborne lidar systems are being flown from aircraft, the most available system is NASA's IceBridge flights, flown over the Bellingshausen, Amundsen and Ross Seas. Helicopter lidar flights have been used by the Australian programme on two expeditions into the East Antarctic sea ice zone, SIPEX 1 and 2 in 2007 and 2012.

As mentioned above, the use of lidar altimetry (or radar) is a complex problem and so sea ice thickness is currently in the Pilot or Process stage of development as an ECV. Field studies such as on SIMBA and SIPEX provided great insight into algorithm development to convert surface elevation from altimetry into ice thickness and currently about five papers have been published on the ice thickness estimated from ICESat. Their estimates however, differ widely (analogous to the passive microwave estimates from different algorithms), so the application of laser altimetry to estimating sea ice thickness is still under development. Radar altimetry from CryoSat 2 has not been examined as yet, and with the ambiguity in reflection of the radar signal from either the snow surface, or the snow-ice interface or something in between, its utility to provide useful estimates of sea ice thickness is currently unknown.

SOOS has several important roles in the determination of sea ice thickness in future. One is in providing the endorsement (two this year) of sea ice process and remote sensing experiments that will provide Calibration/Validation of the airborne lidar systems currently being flown, experiments that will correlate topside sea ice elevation measured by terrestrial lidar with ice draft over the same area measured with uplooking swath bathymetry from an AUV. Regional studies that provide long-range AUV measurements of under-ice topography are also important to support, coupled with the regional efforts discussed under other themes.

Sea ice types

The ability to distinguish between new ice (usually smooth and thin), first year ice and multi-year ice is particularly important for monitoring sea ice development, subsequent salinity changes and their combined effect on ocean circulation. An important issue for Antarctic sea ice is the formation of ice in wave fields at the outer ice edge as sea ice advances seasonally. The pushing together of ice to form pancake ice has the potential for increasing ice thickness at higher rates than the growth of ice at the bottom of an existing ice sheet, so salt and heat fluxes can be higher as well. In other areas, the snow overburden can push the top ice surface below sea level and, if the ice is warm enough, seawater can percolate into the interface forming a surface slush layer. The refreezing of the slush layer forms snow ice, with a higher proportion of freshwater from snow than surface sea water, so heat and salt flux per unit volume will be less than an equivalent of that volume of sea ice formed from seawater alone. Another ice type, platelet ice, forms at the base of ice shelves from the rising of buoyant waters formed by the melting of ice shelves and can redeposit at the base of the ice shelves or beneath an adjacent fast ice cover. The water mass formed in this way, Ice Shelf Water, can further mix with adjacent waters and be a constituent of Antarctic Bottom Water in some areas.

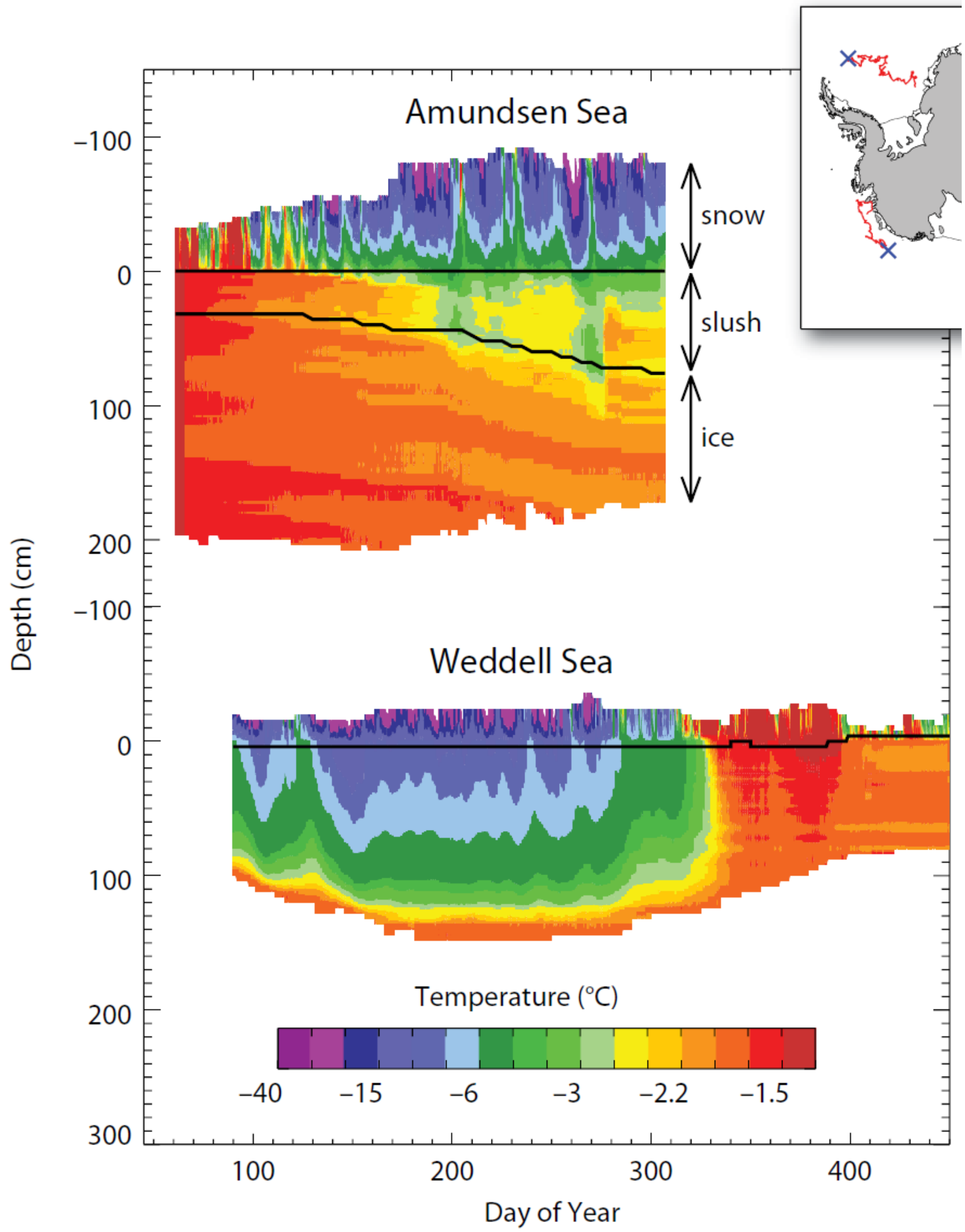
State of readiness as an ECV

The possibility of distinguishing ice types from satellite observations alone and, therefore, becoming an ECV on a widespread basis is restricted to its detection by active or passive microwave satellites. Passive microwave sensors are further limited by horizontal resolution scales of several to 10s of kms, so openings in the pack ice of order a few to a few hundred meters will be apparent as an ice concentration signal, rapidly disappearing as thin ice forms. Over larger areas, like the larger coastal polynyas, thin ice algorithms using passive microwave have been used to estimate sea ice production. As with the algorithms for ice concentration, there is disagreement between the algorithms in the amount detected so the distinguishing of thin sea ice and measuring sea ice production from space in polynyas is at the level of a Pilot or Process stage of development as an ECV. Direct ship-based measurements of sea ice production in winter coastal polynyas, currently proposed and endorsed by SOOS, will provide an opportunity for refinement of these algorithms and can potentially lead to the monitoring of new ice as an ECV.

The monitoring of pancake ice formation as an ECV is not feasible at this time. The formation process itself is ill-understood and needs coupled wave-ice experiments at the level of scientific Process experiments. The ASPeCt program will be including ice-edge and wave-ice interaction in its plans for Antarctic sea ice field studies. The eventual determination of pancake ice formation ice may result when ice forecast models are coupled with wave forecast models, and have appropriate parameterizations for formation rates developed from these field studies.

The monitoring of snow ice formation as an ECV is also not feasible at this time. The development of snow ice has, however, been measured by Ice Mass Balance Buoys remotely and also from measurements at the drifting ice stations, Ice Station Weddell (ISW), SIMBA's Ice Station Belgica (ISB),and Ice Station Polarstern (ISPOL) and has some potential for estimations on the regional scale with large-scale buoy deplolments. Figure 3 (Maksym et al 2012), from two Ice Mass Balance buoys

Figure 3. Ice Mass Balance buoys for the Amundsen Sea (top) and the Weddell Sea (bottom).



Deployed in the Amundsen and Weddell Seas shows the development of surface slush for the IMB for the Amundsen Sea (top of Figure 3) in contrast to no surface slush for the Weddell Sea pack ice (bottom of Figure 3). A SOOS observation system could therefore include repeated and/or widespread deployments of Ice Mass Balance Buoys to determine the potential for surface flooding and snow ice formation. The ASPeCt program also will be incorporating a buoy program of this type for process studies for snow ice formation and other uses. IMBs also provide the direct measurements of air-ice-ocean fluxes through the ice cover and can be coupled with radiation, wind sensors in the atmosphere and CTD, radiometer and oxygen sensors for dual use with other components of SOOS. With the use of IMB data to develop sea ice and coupled model parameterizations, and provide validation for model simulations, an eventual outcome may be simpler buoys deployed less frequently for monitoring as tie points for model prediction.

Platelet ice formation is part of the Ice Shelves interaction and as with other parameters for under ice shelves is primarily a candidate for study from through ice shelf moorings and from autonomous vehicles sent under the ice shelves.

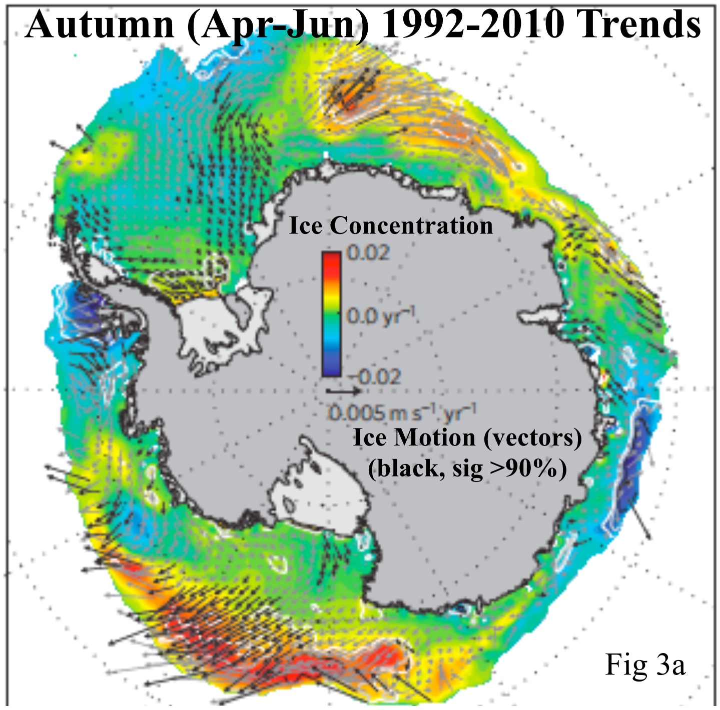
Sea Ice Drift

Sea ice drift has important influence upon regional freshwater and heat budgets because ice transports and redistributes buoyant freshwater and latent heat energy. The redistribution of sea ice from its location of formation, to other areas by ocean currents and wind, causes freshwater to be discharged from the higher latitudes to lower ones. The drift of sea ice is therefore important in the heat and freshwater budgets of the regional climate. Image tracking of drifting sea ice can also be used to deduce information on the underlying ocean currents.

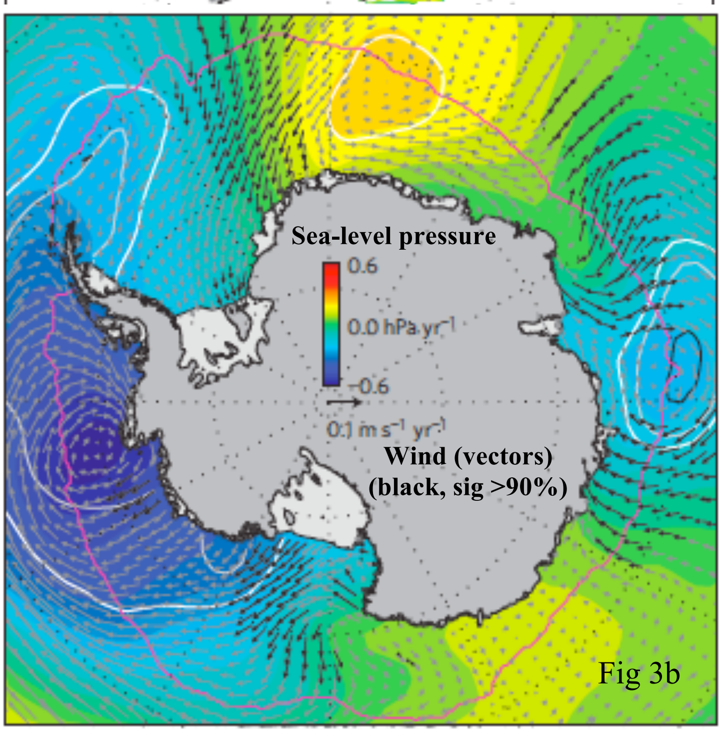
State of readiness as an ECV

Sea ice drift has been derived from three sources to date: time series of buoy locations; passive microwave by correlation/coherence of signal received over short time intervals; and active microwave (radar) feature tracking using repeated passes. Long time series have recently been analyzed of circumpolar drift records by Holland and Kwok (2013, Nature Geoscience) and their principal results are shown in Figure 4.

Figure 4. Top is Ice Motion vectors (change) superimposed on ice concentration trends from 1992-20120. Bottom shows wind vectors (black change>90% sig) superimposed on atmospheric pressure trends for the same period.



to



Drift increases or changes occurred over the period and were, in most sectors linked to trends in winds and sea level pressure. The correlation was primarily in the Atlantic and Pacific sectors, while the coastal current seemed to dominate in East Antarctica.

While the results from this study are highly important and verify the utility of the passive microwave data sets for long-term ice motion, the use of higher resolution radar imagery for ice tracking is preferred. Studies are currently underway to develop drift vectors for the high-resolution data and future use will depend on the launch of new radar satellites, as data from Envisat, for example, is no longer available.

In terms of satisfying the criteria for an ECV, comparisons with buoy data using positioning have shown some caveats in the usage of radar and passive microwave data for sea ice drift. For passive microwave drift vectors for the given regions of study where buoy data is available, high drift rates on short time scales from buoys are shown to be underestimated by passive microwave. For some regions where tidal or inertial effects drive, particularly, ice deformation (e.g. the western Weddell Sea), radar drift vectors obtained at even daily intervals (past have been at 3 day intervals) will not capture the cycles in ice deformation, necessary for computing the mass balance from the opening of leads and closing in the next half of the tidal cycle (~12 hrs) that has caused thin ice formed to be deformed into ridges on these sub-daily scales.

Drift vectors from satellite, either passive or active microwave, are therefore in the Pilot study characterization of an ECV. Detailed comparisons with those drift and deformation products from arrays of GPS equipped buoys are still warranted with buoy arrays distributed in several sea ice regions, probably in combination with other SOOS regional studies undertaken.

Snow Depth on Sea Ice

Snow on sea ice relates to many climate and ocean problems, from determining albedo on the upper surface, controlling the fluxes between ice and the atmosphere, to contributing to the formation of the sea ice itself through surface flooding (Figure 3). It also impacts on any type of remote sensing of ice cover properties i.e. passive microwave emission and radar backscatter as well as being the critical parameter in determining the elevation of the sea ice cover from altimetry and its relation to ice thickness.

State of readiness as an ECV

Recent attempts have been made to determine snow depth from passive microwave emissions and to use these in for example, determining snow depth on sea ice for application to laser altimetry. Difficulties on the application to Antarctic sea ice, however, have proven to be nearly intractable in its application as an ECV. These difficulties have included the inability of passive microwave to determine snow depths greater than 50cm while field data from SIMBA has shown mean snow depths over several hundred meters averaging 70cm. The low spatial resolution (12.5km) has also diminished its value in application to laser altimetry since spot size from ICESat 1 is only 70m. Recent data using an airborne snow radar on IceBridge has shown some promise determining snow depth but is in need of ship-based Calibration/Validation against surface measurements. Snow depth monitoring as an ECV currently remains therefore in the realm of a Process study, at least until snow radar is shown, through one or several surface-based Cal/Val studies, to be a reliable airborne estimate.

Antarctic Sea Ice Processes and Climate (ASPeCt) and its integration with SOOS

A first step and probably a relatively straightforward one is the integration of the ASPeCt data collections to become part of the SOOS data archive. Data management for both SOOS and ASPeCt currently reside in the Australian Antarctic Data Center so the existing ASPeCt data: ship observations, ice thickness profiles from drilling sections and the ice core data bases can be integrated into SOOS "relatively seamlessly" (from a non-data manager's perspective!).

The ASPeCt Science and Implementation Plan for the next ten years is currently under development with expected publication in 2014. Several topics of relevance to SOOS themes have been outlined here in relation to sea ice ECVs and further specifics, as well as additional plans summarized below.

Sea Ice Ship Observations Data Base.

New software is planned with integration with the Ice Watch system developed for Arctic use on vessels recently. A further development is the use of digital camera technologies that have been trialed on several cruises in both the Antarctic and Arctic. Image processing of digital images is used to quantify elements such as ice concentration which are estimated visually along with other relevant parameters such as ice roughness, floe size and even animal counts for example. Use of more quantitative measures may assist for example in the validation of the ice concentration algorithms for passive microwave and further that product toward an ECV. The expectation is that ship observations of sea ice in a few years will be able to be obtained as part of the icebreaker's underway data, similar to met observations, SST, pCO2, that are part of any science cruise.

Further development of underway instrumentation that will add to the suite of specialized sea ice cruises will include regular deployment of medium range AUVs and UAS, use of underway EMI profilers to measure ice thickness, and Marine Lidar mounted on the vessel to obtain elevations of the ice cover while underway.

Antarctic Fast Ice Network (AFIN)

Several stations have been established on the land-fast ice near manned bases, providing information on fast ice thickness and air-ice-ocean fluxes. Both establishing more stations and providing long time series information will serve a data base for monitoring the circumpolar fast ice and its response to climatic changes, compatible with SOOS interests. In conjunction with AFIN long-term measurements, high-resolution fast ice experiments are proposed using airborne EMI as a potential mapper of platelet ice under fast ice, sea ice coring for properties and ice shelf oceanography with moorings on adjacent fast ice.

Polynya Process Experiments

As described above, polynyas in winter are major sources of sea ice production. However, the characterization by satellite alone is insufficient without direct measurement of sea ice production and associated air-ice-ocean fluxes. A recent proposal (PIPERS) has been made to NSF (April 2013) to conduct a combined ship-based study of Ross Sea and Terra Nova Bay Polynyas and adjacent sea ice areas. Buoy arrays of Ice Mass Balance and position buoys will measure evolution of the ice cover over time and airborne lidar flights (using algorithms developed on the ship field campaign with AUV swath bathymetry and terrestrial surface lidar) will provide estimates of the ice flux off the continental shelf to determine how water masses are transformed from on-shelf sea ice production.

Ice Edge Process Experiments

Ship cruises measuring waves, wave-ice interaction and associated ice formation of pancake ice need to be done to characterize the development of pancake ice types, and their effects on ice formation rates, fluxes and associated biological and biogeochemical processes in sea ice.

Sea Ice Drift Stations

The three previous sea ice drift stations on Antarctic sea ice, ISW, ISB and ISPOL have provided essential time series information on both sea ice processes and air-ice-ocean interaction. Autonomous vehicles and Ice Mass Balance buoys with more sophisticated instrumentation can now be used, as they were on SIMBA for example, to extend the range of measurements and elsewhere for up to year-long periods (Figure 3). Two sea ice drift stations are under consideration, one in the Weddell Sea and one in the Amundsen Sea that would provide the essential sea ice component and should be done in conjunction with other SOOS based studies.