
Invited paper

The integrated Arctic Ocean Observing System (iAOOS): an AOSB-CLiC Observing Plan for the International Polar Year

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Abstract

The debate on the climatic impact of Arctic change is currently focused on the fate of the perennial sea-ice and the climatic and social effects of its disappearance. Developments in our observing techniques mean that we are in prospect of being technically able to describe the ocean-atmosphere-cryosphere system of high northern latitudes *operating as a complete system* for the first time. Understanding this system and improving its predictability in models seems to be our most direct way of extending the ability of society to mitigate for or adapt to its changes, including global change. The **integrated Arctic Ocean Observing System (iAOOS)**, described here, is a means of piecing together the available PIs, gear, ships and funding on the pan-Arctic scale that seems necessary to making the attempt, and the International Polar Year (2007–2009) provides the necessary stimulus for doing so.

Rationale and background: To many investigators, the polar reservoirs of ice and freshwater (including the ice-mass of Greenland) represent the key to the polar role in climate. And the climatic impact of Arctic change is still centred on the fate of the Arctic sea-ice and the climatic and social effects of its disappearance. Many state-of-the-art climate models predict that the perennial sea-ice of the Arctic Ocean will disappear in late

The complete text of the paper is available at <http://www.iopan.gda.pl/oceanologia/>

summer within a few decades or less. Important questions remain as to whether this expectation is justified, and if so when this change will take place and what effect it will have on climate on a regional-to-global scale. Such a dramatic physical affront to the ocean-atmosphere-cryosphere system in high northern latitudes, corresponding to a change in surface albedo from more than 0.8 to less than 0.3 over a surface larger than Europe, is bound to have radical effects on human activities with immediate impacts on the indigenous inhabitants of the circum-Arctic region and the ecosystem on which they depend, and with widespread effects on socio-economic activity on a hemispheric scale.

Since the mid 1990s, observational programs such as EC-VEINS and the pan-Arctic ASOF and US-SEARCH programs have shown clearly enough that large-scale coherent changes have been passing through northern seas on a time scale of decades. Though patchy in both space and time, these studies from the Arctic Ocean and subarctic seas have by now provided records of sufficient length and scope to show that a whole complex of inter-related changes are involved, to glimpse the regional drivers of these variations at annual-to-decadal scales and to hint at their climatic importance. At the same time, new and vital observing techniques have been emerging so that for the first time we are in prospect of being technically able to measure almost any of the key variables, at almost any place and time, that we need to describe the ocean-atmosphere-cryosphere system of high latitudes. So it now seems feasible that by filling gaps in our spatial coverage and extending the available series in time, we may be able to view the ocean-atmosphere-cryosphere system of high northern latitudes *operating as a complete system* for the first time. And improving our understanding of that system and testing its predictability does seem to be a most direct way of extending the ability of society to mitigate for or adapt to its changes. That at any rate is the rationale behind the integrated Arctic Ocean Observing System (iAOOS), and the upcoming International Polar Year (IPY) provides the necessary stimulus for piecing together the available PIs, gear, ships and funding on the pan-Arctic scale that seems necessary to making the attempt.

Purpose: In the IPY planning process, there is both a general and a specific purpose to this iAOOS project submission. Following its review of the > 1150 ‘expressions of interest’ (EoI) submitted to the IPY Project Office, the ICSU-WMO Joint Committee for the IPY undertook the task of identifying certain Coordination Proposals which were thought to have sufficient scope to act as ‘clustering projects’ for a range of other submissions. By August 2005, the Joint Committee had tentatively endorsed a total of 135 of these Coordination Proposals, 110 in science and

25 in outreach and education, with iAOOS as one of the former (#14); and the AOSB and CliC Boards were accordingly invited to develop their submission into a project for the IPY that might coordinate, or form the focus for, a range of studies dealing very generally with the circulation of Northern Seas and its role in climate. The business of integrating the broadest possible range of EoIs into an effective and manageable study centred on the fate of the Arctic ice has been going on ever since; the up-to-date listing of EoIs associated with iAOOS can be viewed at <http://www.ipy.org/development/eoi/proposal-details-print.php?id=14>. It will be clear, however, that such an exercise will provide only *a* scheme for iAOOS rather than *the* scheme for iAOOS, and the iAOOS plan is put forward in this light – to illustrate to interested parties (funding agencies and PIs mainly) what sort of intensive pan-Arctic observing effort might be possible if the available resources of funding, shiptime, gear and PIs are brought to bear. The extent to which this iAOOS plan may come to resemble any *actual* future international observing effort will not of course be known until the decisions of national and international funding agencies for IPY funding are individually determined and disclosed.

IAOOS Project Description: Any attempt to describe the full complexity of an observing system as comprehensive in its intended goals as iAOOS is liable to become choked with detail. Very few types of measurement will be *unimportant* and it will always be possible to slice the observing plan in a number of different ways in order to describe its elements. Here, we attempt to describe both a vertical and a horizontal ‘transect’ through iAOOS, hopefully without too much redundancy. The ‘vertical transect’ we describe is for the High Arctic, where the iAOOS primary focus on the fate of the perennial sea-ice necessarily involves a vertical stack of observations from satellite to seabed; this section will also serve to make the point that iAOOS is not just an ‘ocean’ program. The ‘horizontal transect’ through iAOOS that follows *will* largely be concerned with the ocean but in spanning the Arctic and subarctic seas, will make the equally valid point that iAOOS cannot just concern the Arctic. As the US-SEARCH and ASOF programs have clearly demonstrated, change may certainly be imposed on the Arctic Ocean from subarctic seas, and the signal of Arctic change is expected to have major climatic impact by reaching south through subarctic seas to modulate the Atlantic thermohaline circulation.

Transect 1. Observing the Arctic Ocean from satellites to seabed

There is a primary need to improve the observations and modelling of the Arctic atmosphere; on a global scale, the role of the atmosphere and sea ice in the interaction between regional and hemispheric to global

changes is not well understood. Thus current climate models, global as well as regional, are more unreliable in the Arctic than in most other regions, and the inter-model spread in scenarios for future climate is larger in the Arctic than elsewhere. There are many reasons for this. Some stem from the inability of models to handle mesoscale synoptic disturbances (even the present-day observational network is incapable of detecting all mesoscale cyclones). Some are related to an insufficient understanding of the several important local feedback mechanisms that appear to be special to the Arctic. Some of these processes are sub-grid scale in climate models and need to be parameterised; many deal directly with the energy transfer at the surface, and are therefore directly relevant for the melting of the sea ice.

In iAOOS, soundings of the atmosphere, sea ice, ocean surface, and terrestrial snow cover involving satellites, surface ships, manned ice camps, autonomous ice-tethered platforms (ITP) and IABP/ICEX buoys (Fig. 1) will together provide a new and coordinated way of studying the role of the Arctic in European and global climate. Data assimilation and modelling will provide the integration required to develop our understanding of the key processes and mechanisms and to support the development of improved weather forecasts and climate models.

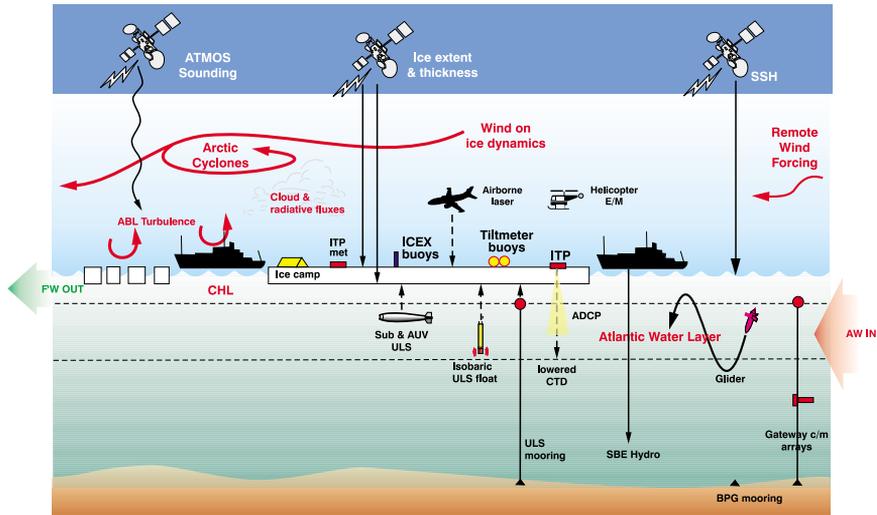


Fig. 1. Schematic of the vertical stack of observations from satellites to seabed that would be necessary to inform an iAOOS study focused on the present state and future fate of the Arctic perennial sea-ice

In summary, the ‘atmospheric’ objectives of iAOOS will enable us to better detect Arctic cyclones; to improve modelling of their interaction with sea ice; to quantify the contribution of the cyclones to the transport

of heat and moisture; to understand and model boundary-layer processes over the Arctic Ocean; to develop improved parameterisations of turbulent fluxes in the atmospheric boundary layer (ABL) over the Arctic Ocean; to understand and model the formation and life cycle of Arctic clouds; and to understand and model radiative transfers through the Arctic atmosphere and their interaction with the snow/ice surface albedo.

Observing the sea-ice itself forms the second fundamental component of iAOOS. Recently we have seen strong indications of radical changes in the Arctic sea ice (e.g. Comiso 2002, Rothrock et al. 2003, Serreze 2003), including the thinning of the Arctic ice-pack from more than 3 m on average to less than 2 m over a large part of the central basin of the Arctic Ocean, and among the most disturbing modelling results are those predicting the disappearance of the Arctic perennial ice during this century. However, the processes are far from clear. The iAOOS strategy is to address these knowledge gaps by large-scale, long-term observations at high resolution, aiming to achieve a sufficiently synoptic coverage of the Arctic Ocean to detect time- and space-scales in the variability of sea ice thickness, extent, concentration, type and drift, while measuring also the essential climate parameters that control these variables. Ultimately, the intention is to form a new and more dependable picture of the future of the Arctic by establishing a more rational basis for predicting the reduction to disappearance of its perennial sea-ice.

This program element will of necessity be one of the most innovative in iAOOS (see Fig. 1). Our ability to map the changes in sea-ice cover on a pan-Arctic scale has already benefited from the arrival of passive AMSR multi-channel reconstructions at 5–85 GHz. The satellite radar altimetry which has been used to provide estimates of ice thickness from direct measurements of ice freeboard (Laxon et al. 2003), sea surface height (SSH) and potentially other retrievals even in these ice covered regions (Peacock & Laxon 2004) has so far suffered from two drawbacks. First, its geographical coverage has hitherto been limited to latitudes south of 81.5°N leaving a large part of the central Arctic without cover; this situation will not be fully remedied until the re-launch of CRYOSAT (expected March 2009) which will extend cover to 88°N . A lack of ground truth has posed a second, more fundamental problem for the validation of ice-thickness and SSH estimates alike. That can now change, using a broad range of new techniques. Deployed across the ice-surface, a network of a dozen or so tiltmeter buoys (Figs 1, 2c), developed by Wadhams and co-workers under the EU's SITHOS and GreenICE projects, will measure the power spectrum of flexural-gravity waves propagating through the ice to provide their own new and independent measures of ice thickness; processing will be accomplished

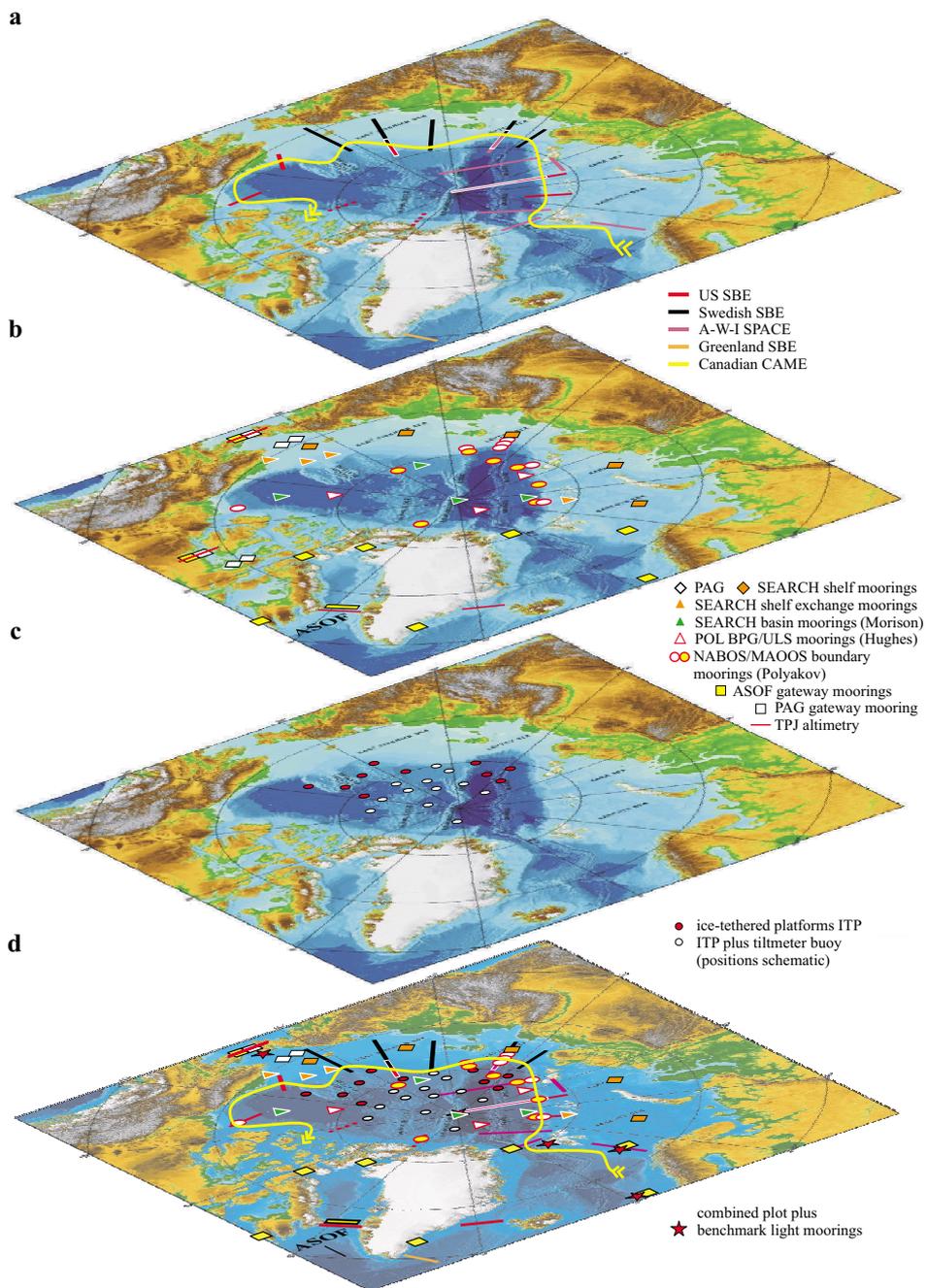


Fig. 2. The elements of an integrated Arctic Ocean Observing System showing the ship-based Shelf Basin Exchange transects (a), the proposed mooring system for Shelf, Slope, Basin and Gateways (b), grids of Ice-Tethered Platform and Tiltmeter Buoys (positions figurative) (c), and the full combined deployment (d)

on board with transmission of spectra or raw data by low-orbit satellite (Iridium), and as the network moves around the Arctic, the distribution of modal sea ice thickness is mapped in time and space. Above the ice, airborne laser and helicopter electromagnetic sensors will provide accurate local calibration and validation of satellite-derived ice-freeboard measurements. Beneath the ice, autonomous underwater vehicles (AUV) and floats operating accurately at constant pressure will carry Upward Looking Sonar (ULS) to further validate satellite estimates of ice-thickness, while a small scatter of bottom pressure gauges (BPGs) moored across the Arctic deep basins (Fig. 2b) will provide the necessary ground truth to derive estimates of the Arctic Ocean circulation from remotely sensed measurements of sea surface height. Though all these systems are new, all exist or are in immediate prospect, and by their use, for the first time, direct measurements or validated estimates of the circulation, stratification and ice-volume of the Arctic Ocean will be possible with monthly-to-seasonal resolution.

Transect 2: Observing change in the circulation and properties of Arctic and subarctic seas

In describing the ocean observing effort in iAOOS, it is convenient to switch to the horizontal ‘plane’, since the appropriate boundaries for ocean observing must spread far beyond the Arctic Ocean itself to include the subarctic seas. It is now demonstrable that a substantial component of Arctic variability originates in Nordic Seas, and is further altered in crossing the circumarctic shelves before being introduced along the Arctic Ocean boundary. In turn, we would expect the major climatic and societal impacts of Arctic change to take effect via ocean transfers south through the Canadian Arctic Archipelago and western Nordic Seas. The ocean programme of iAOOS is defined by all of these elements (inputs, shelves, boundary, deep-basins and outputs) and together they define its domain. The remainder of this submission takes the form of a brief tour through this domain, with the dual purpose of summarising the component tasks and of illustrating further the technical developments that could make iAOOS possible. We begin with the Arctic Ocean itself as the central ‘hub’ of the programme before describing the observational elements that are designed to cover its exchanges to and from subarctic seas.

Arctic Ocean circulation

As just mentioned, the perennial ice-cover of the Arctic Ocean and its fate forms a primary focus of iAOOS. The central Arctic Ocean is also where the inflows from Atlantic and Pacific and the products of the shelves merge and are redistributed. Here, the fresh surface layer of Arctic river runoff

(10% of global total runoff) and its associated cold halocline layer (CHL) normally act to isolate the sea-ice cover from the warm Atlantic-derived layer below (see Fig. 1), though a change in the location of freshwater storage in the Arctic Ocean coupled with a more extensive spread of Atlantic water has recently (1990s) allowed contact between this warm sub-layer and the surface.

Thus year-round monitoring of the surface water properties *and* the Arctic circulation are both needed to identify their roles in the development of the Arctic ice-cover. In turn, changes in freshwater distribution and atmospheric circulation jointly control the ‘switchgear’ (Steele et al. 1996, 2004) that determines the amount and preferred path of the freshwater flux southwards to the Atlantic thermohaline ‘conveyor’ (see below). Under the EC-DAMOCLES component of iAOOS, an extensive integrated scheme of floats and gliders (Fig. 3) will make subsurface profiles throughout the upper water column of the Arctic Ocean (emphasis on the upper 800 m but with excursions to 2 km depth), thus exploring and describing both the variable

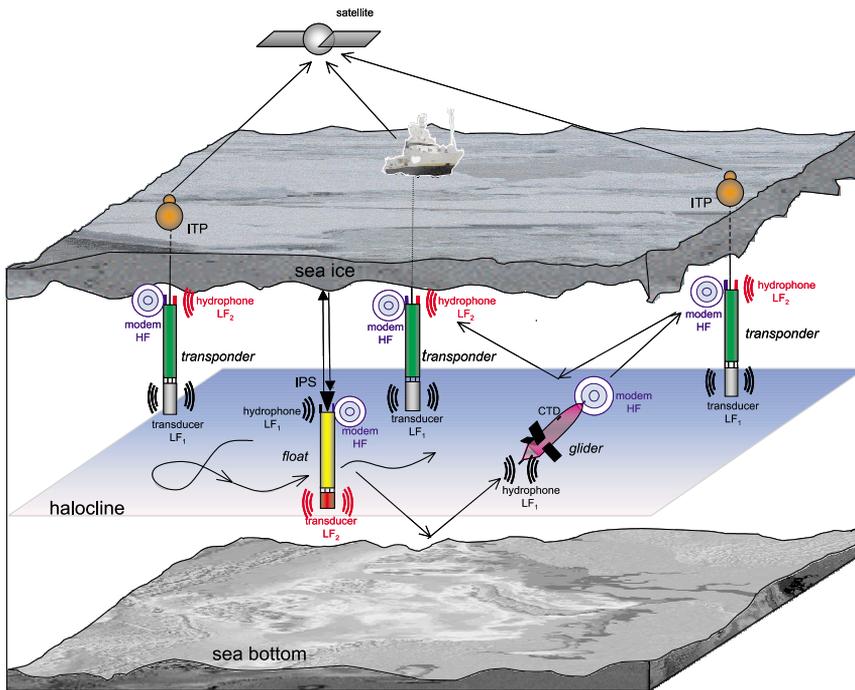


Fig. 3. The ocean observing scheme proposed for the Arctic Ocean by the DAMOCLES Integrated Project of EC-FP6. The proposed network of tiltmeter buoys for ice-thickness measurement is not separately shown but would be laid in close proximity to the ITPs. A combined ULS and bottom pressure programme by US-SEARCH and EC-DAMOCLES would complete the system

CHL and the variable Atlantic-derived sublayer, communicating their data to satellites and receiving measurement-control and navigation information via a net of ice-tethered platforms (ITPs; Fig. 2c).

The ITPs themselves (proposed variously by EC-DAMOCLES, US-SEARCH, NOAA, and WHOI) will deploy profiling CTDs through the upper water column and will monitor the vertical structure of ocean currents using ADCPs, while also fulfilling their conventional role of collecting meteorological data at the ice surface. Because of the limitations of sound propagation in shallow waters, the DAMOCLES float and glider programme will be confined to the Arctic deep basins, but the exchanges between Arctic shelves and the deep basins will be addressed by the addition of dedicated hydrological sections—extensions of selected Shelf Basin Exchange (SBE) transects (see below and Fig. 2a) – with a heavy reliance on tracers such as ^{129}I , ^{18}O , barium etc. Individually or in combination, these tracers will allow us to calculate the precise advective time-scales of all tracer-laden water masses.

Inputs from subarctic seas

The northward flux of heat by the ocean, estimated at 260TW where it crosses the Greenland-Scotland Ridge to enter the Nordic Seas (Hansen & Østerhus 2000, revised 2004, and pers. comm.) is of major importance to the climate of Europe. In recent decades we have been aware that the flow of Atlantic water northwards to the Barents Sea and into the Arctic Ocean has become warmer, stronger and probably narrower (e.g. Quadfasel et al. 1991, Morison et al. 1998, Polyakov et al. 2004, 2005). Only recently, however, have we learned that the spread of warmth to the Barents Sea and Arctic might be attributable to a mix of both local and remote forcing (Orvik & Skagseth 2003) conveying the possibility of prediction. An ability to predict the warmth of the main inflows to the Arctic is so central to the aims of iAOOS as to justify maintaining the three main ocean flux arrays concerned – Faroe-Shetland Channel or Svinoy, Barents Sea Opening and Fram Strait (yellow squares in Figs 2b and 2d) – as iAOOS ‘observatories’, using them to test and develop our predictive skills, and where these predictions fail, to determine which factors (e.g. diversions or short-circuits of flow and their drivers) have caused them to fail. To partner these arrays, an expanded suite of observations appropriate to the IPY should be developed and maintained at OWS Mike, reflecting not only its importance as our principal 50-year benchmark of change in the Norwegian Sea but also its vital location, conveniently straddling the important but unmeasured offshore branch of the Atlantic Current. Thus this objective envisages maintaining and expanding the present ASOF arrays, but for the

new purpose of identifying and predicting the mix of local and remote forcing that controls the flux of warmth and salt to the Arctic Ocean. Continuation of the long-established gateway moorings in the Bering Strait, maintained by the University of Washington (UW), Seattle, since 1990 (yellow square Fig. 2b), will supply the corresponding coverage of the variable Pacific inflow to the Arctic Ocean, perhaps reinforced in the western Strait by the additional moorings proposed for the IPY by the Pacific Arctic Group (white square labelled PAG in Fig. 2b).

New cutting-edge observing techniques will complement the conventional moored arrays in both the Atlantic and Pacific gateways. In the EC-DAMOCLES component of iAOOS, a Norwegian NERSC initiative for monitoring the transports of heat and mass through Fram Strait by acoustic tomography will cover the highly variable flows in the deepest part of the Strait as well as the important fluxes along either boundary by installing two transmitters either side of the Strait with a single receiver in mid-Strait. A simplified Yo-Yo system attached to the top of the receiver mooring will surface every other day to transmit the data to satellite in close to real time. A system of SeaGliders is under consideration both for primary data collection and backup data retrieval. While in open water in the eastern Strait, mission control might be achieved by Iridium communication via satellite; in the ice-covered west, RAFOS beacons would be used for glider navigation and data recovery. In the case of the Bering Strait, Topex-Poseidon-Jason altimetry support (1992–2012 expected) would add to the existing UW in situ observations of Bering Strait throughflow, providing east-west gradients in sea level every 1.5 days in the ice-free season (June–November; see Cherniawsky proposal, IOS Sidney, Canada).

Shelf-Basin Interactions

In crossing the broad circumarctic shelves, the saline Atlantic-water streams are separated into fresh water and brine-enriched end members by the freeze/melt cycle (Midttun 1985), and the drainage of these brines plays an important role in the ventilation and renewal of the deep and intermediate waters of the Arctic Ocean. Recent results (Skogseth et al. 2005) confirm that annual estimates of total brine rejection can be made from model-assisted interpolation of satellite and in situ data, that the variability can be linked to atmospheric forcing and source-water salinity, and that the dominant mixing and entrainment processes occurring on the way to the shelf break can be understood. Using these techniques, interannual variability and trends in the export of brine-enriched shelf waters would be studied through the IPY.

More generally, the transformations and mixing of the various source water masses as they cross the broad circumarctic shelves and enter the circumarctic boundary current contribute substantially to the modification of water masses throughout the whole Arctic water column. In iAOOS, it is proposed to study this sensitive zone and its highly non-linear processes of water mass transformation using a mix of observational and modelling techniques: (i) A scatter of shelf moorings and shelf-exchange moorings to be set by US-SEARCH in a broad arc from the Barents Sea to Alaska (Fig. 2b; positions defined in the SEARCH Science Plan), supplemented by shelf moorings of the Pacific Arctic Group immediately to the north of Bering Strait and by Canadian shelf-basin exchange moorings across the Beaufort Sea shelf. (ii) Complete circumarctic coverage of the Arctic Ocean Boundary Current through the enhancement of the present NABOS array into an international Mooring-based Arctic Ocean Observational System (MAOOS; Fig. 2b) coordinated by IARC Fairbanks. (iii) Standardised icebreaker-based hydrographic transects across the shelf-basin boundary and into the central basins to distinguish temporal from spatial changes and deduce local interactions with the shelves along the flow-path of the boundary current. As shown in Fig. 2a, these transects would form an internationally-coordinated circumarctic ‘Snapshot’ of Shelf-Basin Exchange (SBE) processes during the IPY, with a US-led Shelf-Basin Exchange (SBE) study, supplemented by Canadian icebreaker-based hydro sections in the summers of 2007 and 2008, contributing around 8 icebreaker- or aircraft-based transects, and EC-DAMOCLES contributing a further 6 to 9 icebreaker transects made up from the Swedish SBE lines plus the A-W-I Synoptic Pan-Arctic Climate and Environment (SPACE) study. At intervals, these would be tied to the MAOOS mooring network where they cross the boundary current (see Fig. 2d) and each of the radiating SBE lines would be connected in azimuth by the circumarctic hydrography of the Canadian Arctic Margin Experiment (CAME), now partnered by the newly-funded Arctic Synoptic Basin-wide Oceanography (ASBO) Project of UK-NERC, and the Pan-Arctic ocean Circulation Experiment (PACE). (iv) Ocean circulation models combined with detailed process models will cover the atmosphere-ice-ocean system with high temporal and spatial resolution.

The combination of these approaches will permit four results of global importance: the provision of a regional heat and freshwater budget, the provision of physical and biogeochemical boundary conditions for basin-wide studies of the Arctic Ocean, an understanding of how ocean-climate signals propagate around and into the Arctic deep basins, and a ‘benchmark’ synoptic assessment of a rapidly-changing and climatically-important system.

Output to impacts

The final element of the iAOOS ocean programme addresses the time-varying processes by which the signals of Arctic change are transferred through subarctic seas to lower latitudes, where they are anticipated to have their main societal or climatic impact.

The first main objective of this sub-task addresses the issue of how much fresh water passes south from the Arctic to the N Atlantic, what might control the changing balance of flow either side of Greenland, and (in a little more detail) what might promote the episodes of diffuence of freshwater from the E Greenland Current (EGC) back into the Nordic Seas. State-of-the-art freshwater flux arrays (yellow squares on Fig. 2b) have already been established under the ASOF Programme in Lancaster Sound (BIO Canada), in the Kennedy Channel (OSU and IOS Sidney) and in Hudson Strait (WHOI), and coverage west of Greenland has now been completed by the establishment of a UW SeaGlider-based monitoring program for the Davis Strait (see Fig. 2b) following their first successful use in operational survey there by Eriksen and Rhines (UW). The continuation of these technically-advanced arrays and systems into iAOOS has yet to be negotiated. East of Greenland, it is planned to maintain and augment the existing ice and freshwater flux arrays in the western Fram Strait (seven moorings maintained by NPI Tromsø), midway along the E Greenland shelf at 74°N (University of Hamburg SFB 520), and south of Denmark Strait (ASOF-EC) to provide for the first time a continuing measure of the gross and net freshwater flux for comparison with changes in the regional windfield and ocean circulation. Here, the A-W-I NAOSIM model will be employed as the main interpretative tool. The fact that this model has been able to simulate the remarkable events of 1994–5, when the largest volume flux of ice yet measured through Fram Strait (e.g. Widell et al. 2003) was substantially redirected eastwards into the Greenland Sea (Karcher & Gerdes, pers. comm. 2003), justifies our reliance on this technique. Newly developed autonomous moored water samplers coupled with hydrographic analysis (Mauritzen 1996, Rudels et al. 2002, Jonsson & Valdimarsson 2004), will provide the tracer data necessary to identify the source and continuity of these flows, while moored profilers and other techniques will study their influence on the processes of vertical exchange in the adjacent Greenland Sea.

The second objective of this task addresses the fundamental question of whether the influence of ocean fluxes on the MOC is likely to take effect through processes of local (overflow), regional (‘hosing’ the NW Atlantic) or global (worldwide salinity redistribution) scale, individually or in combination. The DAMOCLES component of iAOOS intends to

address this by setting up an interactive two-way linkage with the UK-NERC ‘RAPID’ project led by Keith Haines of Reading University to assimilate all N Atlantic datasets for the past 40 years, including those from high latitudes, into a high-quality ocean circulation model with the aim of expanding our view of the space-time evolution of major ocean-climate anomalies on a larger scale than can be tackled in iAOOS or DAMOCLES alone. Since this part of iAOOS directly addresses the efficiency with which the Arctic communicates with the Ocean’s thermohaline ‘conveyor’, it may yet prove to be the component of greatest importance to the Earth’s changing climate system¹.

The iAOOS ‘legacy phase’ and the longer term observational context

iAOOS will take place under the aegis of the AOSB and the Climate and Cryosphere programme (CliC) of WCRP, drawing its research science partly from an enhanced subset of US-SEARCH, partly from the DAMOCLES Integrated Project of EC Framework Programme 6, currently getting underway, and partly from the Chinese, Korean and Japanese scientists of the Pacific Arctic Group. None of these efforts is small. DAMOCLES, for example contributes the integrated efforts of 47 European research institutions including 10 Small and Medium Enterprises (SMEs) distributed among 12 European countries. If the funding round permits anything like the scale of scientific effort proposed here, it will certainly be the largest and most intense collaborative research effort ever devoted to the Arctic Ocean and to the variability of its physical environment.

Even so, this level of effort hardly seems excessive for the tasks of (1) observing the ocean-atmosphere-cryosphere system of high northern latitudes *operating as a complete system* for the first time, (2) from that, identifying and understanding the changes occurring in the perennial sea-ice of the Arctic Ocean and in the whole gamut of atmospheric, riverine and oceanic processes across the Arctic/subarctic domain that are collectively responsible for forcing these changes, (3) using that understanding to improve the realism by which these changes are simulated in models, thus extending the lead-time prior to the onset of extreme climate events, and (4) determining appropriate adaptation strategies for a range of anticipated socio-economic impacts following the disappearance of the perennial sea-ice.

¹As a linked activity in the IPY, sediment coring at key Arctic sites with relatively high sediment accumulation rates will set our short modern records into the longer-term context of Arctic change (Mikkelsen, pers. comm. 2005).

Though this intense focus on the science of the polar regions and on the human dimension of polar change seems appropriate to these tasks and is of a scale appropriate to the importance and potentialities of a 4th International Polar Year (IPY), it could not be sustained at such high intensity and complexity beyond the four-year study envisaged here. The paradox is of course that the climatically-important changes underway in the Arctic Ocean and in its sea-ice are expected to work themselves through on decade-to-century time-scales. The solution must lie in setting iAOOS into the context of the much longer-term research efforts that are currently getting underway in the Arctic, which share many of the goals of iAOOS. Figure 4 attempts to do this. Supplementing the existing full US Study of Environmental Arctic Change (SEARCH; blue bar) with a correspondingly large and complete major international effort (yellow bar), the new International Study of Arctic Change (ISAC) will coordinate a multi-decadal and multi-disciplinary pan-Arctic effort to understand, explain and identify the socio-economic impacts of change at high northern latitudes; ISAC will be organised under the aegis of the non-governmental Arctic Ocean Sciences Board (AOSB) and International Arctic Science Committee (IASC). ArcticNet will have similar stamina in the Canadian Arctic, and it is probable that other large component parts of iAOOS such as DAMOCLES will develop a ‘legacy phase’ of their own in due course. Further details of the AOSB-ClC Plan for the IPY can be accessed at <http://asof.npolar.no>, while the corresponding Plan for the Southern Ocean by Steve Rintoul of CSIRO Marine Laboratories, Hobart, Tasmania is at <http://clivar.org/organisation/southern/documents/SOIPY.doc>.

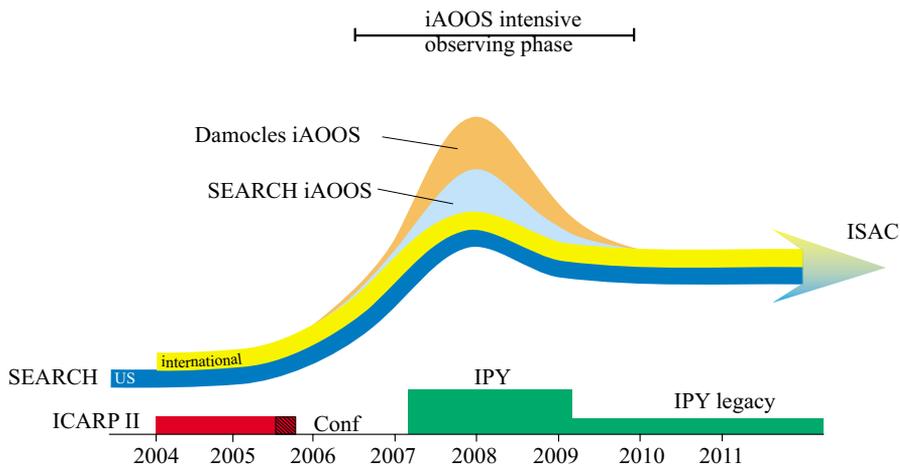


Fig. 4. The integrated Arctic Ocean Observing System (iAOOS) in relation to ICARP, IPY, and the multidecadal SEARCH and ISAC studies of Arctic change

Abbreviations and Acronyms

ABL	Atmospheric Boundary Layer
ADCP	Acoustic Doppler Current Profiler
ArcticNet	Arctic Network of Centres of Excellence of Canada
ASBO	Arctic Synoptic Basin-wide Oceanography Project
ASOF	Arctic-Subarctic Ocean Fluxes study
AOSB	Arctic Ocean Sciences Board
AUV	Autonomous Underwater Vehicle
A-W-I	Alfred Wegener Institute for Polar and Marine Research
BPG	Bottom Pressure Gauge
CAME	Canadian Arctic Margin Experiment
CHL	Cold Halocline Layer
CliC	Climate and Cryosphere program of WCRP
CSIRO	Australian Commonwealth Scientific and Research Organisation
CTD	Conductivity-Temperature-Depth probe
DAMOCLES	Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies
EC-FP6	Framework Programme Six of EC
EGC	East Greenland Current
GreenICE	Greenlandic Arctic Shelf Ice and Climate Experiment
IABP	International Arctic Buoy Program
IAOOS	integrated Arctic Ocean Observing System
IARC	International Arctic Research Center, Fairbanks
IASC	International Arctic Science Committee
ICSU	International Council for Science
IOS	Institute of Ocean Sciences
IPY	International Polar Year
ISAC	International Study of Arctic Change
ITP	Ice Tethered Platform
JASON	First follow-on mission to TOPEX/Poseidon [http://topex-www.jpl.nasa.gov/glossary.html#topexposeidon]
MAOOS	Mooring-based Arctic Ocean Observational System
MOC	Meridional Overturning Circulation of the North Atlantic
NERC	UK-Natural Environment Research Council
NERSC	Nansen Environmental and Remote Sensing Center
OSU	Oregon State University
OWS	Ocean Weather Ship
PACE	Pan-Arctic ocean Circulation Experiment
PAG	Pacific Arctic Group
RAFOS	Sonar Fixing and Ranging, spelled backwards

SBE	Shelf-Basin Exchange
SEARCH	Study of Environmental Arctic Change
SITHOS	Sea Ice Thickness Observation System
SPACE	Synoptic Pan-Arctic Climate and Environment study
TOPEX	TOPography EXperiment for Ocean Circulation [http://topex-www.jpl.nasa.gov/glossary.html#oceancirculation];
TOPEX-POSEIDON	Joint US-French orbital mission, launched in 1992 to track changes in sea-level height with radar altimeters.
TW	Terawatt (10^{12} watts)
ULS	Upward Looking Sonar
VEINS	Variability of Exchanges in Northern Seas
WCRP	World Climate Research program
WHOI	Woods Hole Oceanographic Institution

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