Arctic/Subarctic Ocean Fluxes (ASOF)

Report of Workshop

22-24 September 2000

Norsk Polarinstitutt
Tromsø, Norway

Table of Contents

1 Introduction ... 2

2 Working Group Reports ... 3

2.1 Ocean Fluxes ... 3

2.2 Shelf-Basin Interactions ... 4

2.3 Deep Sea Processes ... 5

2.4 Sea Ice ... 7

2.5 Palaeoclimatology ... 8

3 Measurement Methods and Platforms ... 9

3.1 New Technologies ... 9

3.2 Satellite Measurements ... 10

3.3 Ships for Arctic research ... 11

4 General issues ... 12

5 The Way Forward ... 13

6 Terms of Reference of the International Science Steering Committee for ASOF ... 15

7 List of presentations ... 16

8 Participants ... 18

Editors: Olav Orheim (Chair), Leif Anderson, Goran Bjork, JoLynn Carroll, Chad Dick, Bob Dickson, Mark Johnson, Peter Jones, Nalan Koc, Seymour Laxon, Wieslaw Maslowski, Jens Meincke, Jamie Morison and Jim Overland.

1 Introduction

Palaeoclimate records indicate that in the past, rapid changes may have occurred in thermohaline circulation (THC) leading to major climate shifts over periods as short as a few decades. Coupled models suggest that greenhouse warming may lead to dramatic weakening of the Atlantic THC, and potentially to a rapid climate cooling of NW Europe. Thus, in 1999, UK and Norway developed a joint effort to investigate whether such changes in the North Atlantic Current could occur in response to changes in the circulation of the Arctic and Subarctic seas. A meeting on Arctic/Subarctic Ocean Fluxes (ASOF) was held in April 2000 in Cambridge, UK with 50 participants to discuss the role of high-latitude oceans in decadal climate variability, based on a 'Strawman I' document compiled by Bob Dickson. Following this meeting an informal group of participants agreed to establish a planning group, led by Olav Orheim, to further develop ASOF. This group agreed to hold a workshop at Norsk Polarinstitutt to discuss ASOF as a programme for achieving co-ordinated flux measurements across the main gateways to and from the Arctic Ocean.

This workshop, which immediately followed the H.U. Sverdrup Symposium to commemorate the 75th anniversary of the Maud expedition, was given the task of identifying the relevant scientific challenges related to water fluxes and the Arctic Ocean, focusing on what to implement, and when and how to implement it. Leading scientists, programme managers and ship operators met to take a step forward in developing plans that can form a realistic basis for implementing national programmes and international initiatives.

The workshop was structured to begin with scientific presentations, using the Sverdrup Symposium. Participants then split into working groups to address specific topics and returned to plenary sessions to report results and allow wider discussion. The 70 participants gave altogether 44 presentations, including oral papers and posters. In addition Bob Dickson provided a 'Strawman II' document. Initial working groups addressed the topics of 1) Ocean fluxes, 2) Shelf-Basin interactions, 3) Deep sea processes, 4) Sea ice, and 5) Palaeoclimate. Additional groups examined methods and platforms for measurements, including 1) New technologies 2) Satellites, and 3) Available ice going vessels. Ways of achieving international funding cooperation were also discussed.

This workshop report contains the summary results from these various groups and plenary discussions, including an initial plan for the way forward. It should be read in conjunction with the Strawman II document (see below).

Acknowledgement
This Workshop was supported by International Arctic Science Committee (IASC), the Forum of Arctic Research Operators (FARO), the European Polar Board (EPB), Norwegian (NFR) and United Kingdom (NERC) Research Councils, National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), Office of Naval Research (ONR), the Fram Foundation, the International ACSYS/CliC Project Office and the Norwegian Ministry of the Environment.

2 Working Group Reports

2.1 Ocean Fluxes

Wide ranging discussions covered three main issues:

a) The further development of the Strawman II document,
b) The budget for the proposed programme, and
c) The relationship between ASOF and the US Study of Environmental Arctic Change (SEARCH).

Strawman II document

It is intended that within 1 month the Strawman II document will be amended and modified in the light of discussions at the Workshop. It will also be supplemented with a list of questions that are seen to be important to the design of the ASOF programme and its equipment. This is therefore seen as a necessary bridge between the 'Strawman' stage and the production of an ASOF Science Plan. The following are the types of question that are envisaged, but many more were raised and further questions are sought from the ASOF community for inclusion in the modified 'Strawman'.

1. How do we optimally merge the requirements of SEARCH and ASOF for ocean flux observing sites and systems? (See also below.)
2. Can Modeling studies be used to determine what we would expect to observe as a result of continuing changes in Arctic and Sub-Arctic fluxes? For example, if the freshening of both overflows continued at 0.01 psu per decade what would we expect to observe in the deep and abyssal Labrador Sea?
3. What is the most cost-effective mix of moored profiling – CTD section, standard ship-borne hydrography and sea-gliders to study changes in the critical fluxes?
4. Which of the new cheap profiling CTD-systems is best for our sub-ice hydrography? Can this be determined by comparative trials?

Budget

It was concluded that it was not appropriate or possible to establish budgets at this time. However, those budgets that have been estimated are unrealistic, and there is a need to explore methods of reducing costs. A number of suggestions were made. For example:

- Use bottom pressure gauges in place of some current meters to monitor e.g. Fram Strait.
- The new generation of autonomous gliders may be used to complement ship-based hydrography and moorings.

It was also noted that some instrumentation already exists and some parts of the programme are already being carried out and that this would further reduce the estimated cost of the new programme elements.

The possible benefits of Modeling activity to aid in the design of the observation programme were also noted. Modeling studies should be used where possible to optimise the observational network, and to examine the time scales necessary to answer the questions of scientific interest.

The Relationship of ASOF to SEARCH

The aim of ASOF is to track and understand the changes in the fluxes in and out of the Arctic Ocean and the Nordic and Labrador seas. It has the particular emphasis of using this knowledge to understand the changes in the thermohaline circulation.

The aim of SEARCH is to understand the complex of interrelated, pan-arctic changes that have been occurring in recent decades. These changes in the atmosphere, the oceans, and on land have been given the collective name 'Onami', which is Inuit for tomorrow. A key SEARCH hypothesis is that the changes are related to decadal trends in the atmospheric circulation of the Northern Hemisphere typified by the Arctic Oscillation (AO). This hypothesis is qualitatively demonstrated by the increase in temperature of the Atlantic water inflow that is arguably due to the advection of warm air into the Greenland and Norwegian seas under positive phases of AO (and its more localised equivalent, the North Atlantic Oscillation (NAO)). It is also illustrated by the decreasing salinity of the Arctic Ocean outflow through Fram Strait. This freshening is due both to cyclonic transport of river water around the Arctic Basin and enhanced summer melting of sea ice associated with the cyclonic atmospheric forcing of the Arctic Ocean under positive AO conditions. This reduction in salinity has the effect of weakening the thermohaline convection in the Nordic and Labrador seas and may be one of the most critical ties between Onami and global climate.

It was concluded that the aims of SEARCH and ASOF are the same with respect to ocean fluxes into and out of the Arctic Ocean and with respect to factors affecting thermohaline circulation in the Nordic and Labrador seas. ASOF will take responsibility for measuring these factors as an allied component of SEARCH, while SEARCH will provide the Arctic Basin context for ASOF.

2.2 Shelf-Basin Interactions

The Arctic Ocean is the most land-dominated of the world's major oceans with a land:ocean ratio of 1.2; remaining oceans show ratios from 0.55 to 0.13 (Vörösmarty et al., 2000; Global Biogeochemical Cycles 14:599-621). Shelf-basin interactions including the transport of water masses and biogeochemical fluxes are therefore crucial to our understanding of the deep Arctic Basin. Arctic shelves in particular are expected to play a disproportionately large role in moderating the responses of the Arctic Ocean to sustained shifts in climate. The working group on Shelf-Basin Interactions addressed two key issues:

a) What are the relevant processes occurring on shelves that influence the fluxes into and through the deep basin, and where are the critical areas in which these processes take place?
b) How can investigations be implemented to characterise these processes?

Relevant processes

Three sets of relevant processes were identified.

i) Ventilation

- The transformation of water masses transported across the shelves before entering the Arctic Basin.
- Nearshore and alongshore processes where freshwater from land and seawater are first mixed resulting in transformations in hydrographic, chemical, biological and sedimentological properties of these waters.
- Brine production, which transforms the hydrographic properties of water masses and in particular, allows the development of dense plumes of salty water.

All these processes are particularly important for water of Atlantic origin entering through the Barents and Kara Seas and especially the critical area of the Santa Anna Trough.

ii) Freshwater Input
River supplies of freshwater onto continental shelves, development of glacial ice and the subsequent melting of sea ice influence the distribution of temperature and salinity of Arctic water masses. Important drivers of these processes are the timing and extent of extreme events such as large fluxes of freshwater from rivers, intermittent formation of brine and the transport of these dense plumes to the Arctic Basin.

Critical areas for these processes are the Siberian shelves, the Bering Strait, and the Beaufort Sea.

iii) Air-Sea Exchange of Bioactive Gases
A central and yet, unresolved question in climate change theory is how changes in water fluxes will affect the air-sea exchange of the key greenhouse and bioactive gases.

Key areas for study are the Bering and Chukchi Seas and the Barents Sea.

Implementation
The implementation of field investigations to address the above issues must be considered within the context of other international investigations that are either currently underway or in the final stages of implementation (of which some are noted below). It was concluded that the Barents region should be the focus of the next program of investigation for Arctic shelf processes as this is a region of importance for the ASOF topics and lacks a coordinated research strategy.

i) Bering/Chukchi Sea
The USA has taken a lead in investigating this region of the Arctic and in particular will launch a large-scale field program in 2002-2006 as part of the U.S. Western Shelf-Basin Interactions Program (SBI). The program addresses physical as well as biogeochemical transformations focusing on the Beaufort Shelf and Chukchi Shelf.

ii) Beaufort Sea
Canada is sponsoring a number of initiatives in this region.

iii) Siberian Run-off
There are on-going national and joint Russian-German investigations to maintain a network of sampling for the main rivers in the Russian Arctic.

iv) Barents Sea
- More detailed long-term investigation is needed of the processes underlying the transformation of Atlantic water as it transits across the shelf.
- Brine production and transport processes need to be investigated with particular emphasis on capturing how these dense, salty plumes transit the shelf and enter the deep basin. This information will help to improve the current generation of numerical models for brine production and transport.
- Process studies of the air-sea exchange of greenhouse gases are a necessary precursor to the development of improved predictive models of global climate change.

2.3 Deep Sea Processes

Monitoring input and output fluxes at the main gateways to the Arctic Ocean alone will not provide the understanding or ability to predict flux variations. Using the measured inputs and outputs to develop a predictive capability requires additional focused effort to understand the processes that occur within the Arctic Ocean itself. Coupled ice-ocean models of the Arctic/Sub-Arctic region are necessary for predicting effects of climate change on the Arctic Ocean and on the flow out of it. Existing model results indicate variability in large-scale circulation within the central Arctic Ocean that will greatly influence exchanges between the Arctic and Sub-Arctic on interannual to decadal time scales. Verification of model results requires direct measurements within the Arctic Ocean.

Processes

Since the large scale circulation in the Arctic Ocean is determined by boundary currents along the perimeters of the deep basins, a limited set of repeat measurements will allow the identification of significant processes and will capture their variability. This in turn will provide information that will form the basis for model verification.
Particular points to address are:

1. Circulation and residence times of Atlantic water, Pacific water, and freshwater within the central Arctic Ocean;
2. Upward heat fluxes between the Atlantic layer and the Polar Mixed Layer influencing stratification and ice cover, which in turn affects the export of ice and freshwater out of the Arctic.

Shelf-slope plumes also represent a significant process by providing a mechanism for communication between the shelves and deep basins, and, for example, by cooling the Atlantic layer. They are generated as a result of ice formation and brine production on the shelves. The brine forms dense water that subsequently leaves the shelves to drain into deeper water in plumes that entrain intervening water as they sink. They are very difficult to measure and to model, but monitoring ice production on the shelves may be a means to predict and assess changes in this process.

Measurements

Repeat sections in a few carefully selected regions of the Arctic Ocean will allow investigation of the above processes. All sections should include a CTD survey, and, whenever possible, other hydrographic tracers should also be measured.

The importance of measurements to estimate the budgets of ice and freshwater was also recognised. These would require other measuring techniques and cannot be addressed by repeat sections.

Five potential key sections were proposed, following the boundary current to quantify changes in processes and in flow. These are:

- Section 1. West of St. Anna Trough to measure the inflowing Fram Strait branch.
- Section 2. East of the Voronin Trough to measure the Barents Sea branch and the combined Fram Strait and Barents Sea branch.
- Section 3. Canada Basin-Beaufort Sea to capture the Atlantic water as modified in its transit around the Canadian Basin and to evaluate the input from Bering Strait.
- Section 4. Alert-North Pole to capture the outflow from the Canadian Basin past the Canadian Archipelago on its way to Fram Strait.
- Section 5. East of the Lomonosov Ridge to measure the changes in the flow of Atlantic water into the Canadian Basin.

It was noted that Section 4 is the SEARCH section, which is to be carried out with aircraft. It is intended to do the other sections using ships, with the possibility of placing current moorings in some sections. Sections 1 and 2 would benefit from being extended to the North Pole to capture recirculation in the Eurasian Basin. The extensions would be done using aircraft in a program similar to SEARCH. While recognising that Section 5 is located in a logistically difficult region, it was felt that it would be valuable in order to obtain an early indication of changes in the flow of Atlantic water into the Canadian Basin.

2.4 Sea Ice

Consideration was given to the Strawman II document with regard to sea ice processes and variability. Discussion mainly centred on the related topics of measurement techniques and areas of particular interest.

Measurement techniques

The main measurements are with upward looking sonar to obtain ice thickness distribution and acoustic Doppler profilers, which provide estimates of ice velocities. Four systems were proposed for the East Greenland current. Similar systems have provided valuable information and experience has shown that this spatial coverage is adequate.

A second important system is Lagrangian measurements from drifting buoys. These would provide information on the evolution of the ocean layer directly below the ice as it transits the system. One concern is the vertical orientation of the ADCP system to measure the velocity profile. The question arose as to how the ADCP will remain vertical on a drifting wire under all conditions. It was also considered desirable to have information on how the ice floe itself varies with time. This can be accomplished with a vertical string of thermistors frozen in the ice that continues above and below the ice.

It was also noted that it is important to provide atmospheric data to the operational weather analysis centres to provide accurate forcing of sea ice models. These data require measurements from both drifting buoys and coastal stations.

Areas of particular interest

Monitoring and understanding sea ice processes in the region of Greenland Sea convection was considered to be important. A major goal of the proposed ASOF programme is to determine whether convection in this region may be shut down. Hence, direct measurements in the Greenland Sea are appropriate in addition to those in Fram and Denmark Strait.

Processes that occur in the Arctic Basin condition the ice coming through Fram Strait. If there were more heat in the upper ocean layers within the Arctic Basin, this would cause more melting and would provide an increase of liquid fresh water flux rather than ice flux. It was noted that the use of SAR ice motion data would provide information on characteristics of ice entering Fram Strait. (It was also noted that it was important that ASOF be coordinated with other programs such as SEARCH, particularly in the central Arctic region.)

The Barents Sea is a particularly important region in the context of climate change. Positive phases of the North Atlantic Oscillation correlate with less ice cover in the Barents Sea, which allows for increased heat transfer from the ocean to the atmosphere. Thus additional heat can eventually reach the central Arctic. It was noted that retrospective data sets are available to study variability in this region.

2.5 Palaeoclimatology

This research discipline had sparse representation at the workshop making it difficult to initiate effective discussion. As a consequence, additional input was sought after the workshop. It was noted that a number of parameters can be estimated using palaeo-records from marine sediment cores and that these were important to provide a context for both the current environmental conditions in the Arctic and Sub-Arctic, and the changes that are taking place in the climate of the region.

Palaeodata

During the 1999 IMAGES cruise of the RV *Marion Dufresne* exceptionally high resolution (2.5cm/10 yrs) sediment cores were retrieved from the northern Iceland shelf and the East Greenland Margin north of the Denmark Strait. These cores were taken in a position that yields information on the past SST variability of both the East Greenland Current (EGC) and the Irminger Current. Fossil diatom assemblages, which have proven to be a very good proxy for past SST, will be used for this reconstruction. Combining results from these cores with the proposed cores to be taken from the Eirik Drift as described in the Strawman II document, will provide a N-S transect along the EGC. This will enable reconstruction of past heat fluxes through the Denmark Strait.

It was noted that since the cores are already available from the northern Iceland shelf there would not initially be any cruise-related expenses, thereby reducing the cost of this type of study.

3 Measurement Methods and Platforms

3.1 New Technologies

A number of new technologies are becoming available for hydrographic measurements, and a number of these could make important contributions to the implementation of ASOF. Some of these are listed in Table 1 below, but it should be noted that the list is not complete and alternative contacts or suppliers may also be available.

Table 1: New technologies that may be available to assist in the implementation of ASOF field measurements.

Technique	Comments	Contact
SEAGLIDER, gliding PALACE float	Temperature, salinity, oxygen, and fluorometry sensors. Cost is US$65K with US$10K for redeployment. 30cm/sec speed, 1 year duration, 10,000km range. Limited to 2000m depth.	Contact: Charlie Eriksen (charlie@ocean.washington.edu)
Acoustic thermometry and tomography.	Measures integral temperature between endpoints using sound. Trans-arctic measurements planned. Franz Josef Land to Lincoln Sea data collected from 1998 to 2000 completed.	Contact: Peter Mikhalevsky, Mark Johnson, Alexander Gavrilov.
Autosub	Autonomous CTD and under-ice profiling system.	Contact: Steve Ackley sackley@pol.net Jon Copley jtc@mail.soc.soton.ac.uk
Profiling RAFOS floats.	Hydrographic properties.	Contact Russ Davis, Scripps.
Autonomous Underwater Vehicles (AUVs)	Temperature and Salinity sensors. No under-ice capability yet.	Contact: Jim Bellingham.
Moored profilers	CTDs and ADCPs.	Contact: John Toole
Automated water samplers	Tracer measurements on moorings.	Contact: Bill Smethie, Kelly Falkner (kfalkner@oce.orst.edu)
Watson Compass	For moorings near magnetic pole. Field tested in Canadian Archipelago.	Contact: Simon Prinsenberg
ICYCYLER	Vertical profiler with CTD type sensors. Senses overhead ice to avoid fouling.	Contact: Simon Prinsenberg

3.2 Satellite Measurements

Satellite measurements will be very important to the implementation of ASOF. Several platforms are already in operation, and other new satellites, with new sensors, are planned for the near future. The type of measurement and the parameters being measured are shown in Table 2, while the characteristics of operational and planned missions and sensors are shown in Table 3.

It should be noted that some types of measurement allow all weather capability:

Radar Altimeter (RA), Gravimeter (Grav), Synthetic Aperture Radar/Scatterometer (SAR/SCATT), and Passive Microwave (PM).

Others are limited by the presence of clouds:

Infra-red radiometer (IR), Laser Altimeter (LA).

Table 2. Parameters measured by satellite sensors. X indicates the region of coverage.

Measurements	**Arctic**	**Sub-Arctic**	**RA**	**LA**	**Grav**	**IR**	**PM**	**SAR/ SCATT**
Ocean Temperature		X				0.1K	1K	
Sea Surface Topography	X	X		2cm	2cm			
Ocean salinity		X					0.1 psu	
Winds		X					3 m s^{-1}	1 m s^{-1}
Sea Ice Concentration	X						10%	
Ice Motion	X						0.1 m s^{-1}	0.05 m s^{-1}
Ice Thickness			0.5 m	0.5 m				
Land Ice Topography	X		1m	0.1 m				

Table 3. Current and future satellite missions of interest to ASOF.

Mission	**From**	**Latitude**	**Instruments (Resolution/Accuracy)**
SSM/I	1987	88	PM (25km)
ERS	1991	82	RA(10km),IR(1km),SAR(100m)
RadarSat	1995	90	SAR (100m)
QuickScatt	1999	90	SCATT
EOS-PM	2000	90	PM (12km)
Envisat	2001	82	RA(10km),IR(1km),SAR(12m)
GRACE	2001	88	Grav.(1000km/2mm)
IceSat	2001	86	LA (80m)
CryoSat	2003	88	RA(1km)
SMOS Ocean sal.	2004	80	PM(200km)
GOCE	2004	88	Grav.(100km/2cm)

3.3 Ships for Arctic research

ASOF will involve both ice going vessels and research ships that only operate in blue water. The latter are numerous and no attempt was made to describe all these. However, the meeting was made aware of developments in research vessels aimed at ice infested waters, as follows:

Canada:
The icebreaker CCGS *Louis S. St-Laurent* is capable of expeditions in the central Arctic Ocean. It has ample laboratory space, and can accommodate about 40 researchers. Escorting shipping and other duties may determine its availability for research. However, at present there is no budget committed to supporting the ship for scientific purposes.

Germany:
Information was provided on two ships: 1) A medium size ice going vessel is under construction. 2) Plans have recently been presented by AWI for a joint European icebreaker which should be 130 m long and have deep drilling capability.

Norway:
Norsk Polarinstitutt's *Lance* is available for work in the ice margin zone. Univ. of Tromsø, Norwegian Institute of Fisheries and NP have proposed that Norway should build a new ice going vessel, but the government has not yet acted on that proposal.

Sweden:
The icebreaker *Oden* will conduct Arctic research for at least a total of 180 days over the next 3-5 years. There may be openings for new programmes from 2003.

UK:
James Clark Ross operated by the British Antarctic Survey is available for work in the ice margin zone. The larger *Shackleton* could theoretically also be available for the Arctic, but only based on a multi-year commitment.

USA:
The USCGC *Healy* has completed trials and will soon be operational. It is initially expected to work in even years in western (N. American) Arctic, and in odd years in Eastern Arctic, the latter with the first full season in 2003.

4 General Issues

While it is important to maintain momentum, we have to agree on a realistic timing for the field effort. For programmes or pieces of programmes not already funded, it was suggested that 2003 is realistic. Meanwhile, we have many challenges including the organization of international collaboration agreements, preparation of a science plan, submission of proposals (e.g., equipment development or testing) and modeling efforts that might better define our observational strategy.

SEARCH is the main forum for NSF in this connection, but is not yet finalised. There is a need also for coupling to the SBI project, which deals with shelf / basin interactions on the N. American side.

Canadian scientists hope to have in place a new programme for an enhanced Arctic research programme that would include support for icebreakers dedicated to research for up to three months per year.

The European Polar and Marine Boards may jointly promote part of ASOF.

International umbrella agreements are important for Russian cooperation, especially when working within Russian regions. The PAME project, related to marine pollution, may be one such umbrella for oceanographic research on the East Siberian continental shelf by coupling to transport processes for pollution from land into the Arctic Ocean. IASC is another important umbrella organization for assisting with the development of multinational projects in the Russian region.

A programme such as ASOF needs also to consider recruitment, and include for example funds for doctoral students and postdoctoral participation, with emphasis also on international exchanges.

5 The Way Forward

The meeting agreed that it was critical to maintain momentum for developing the plan and international cooperation for ASOF. It was also recognised that participation by individual nations depends on acceptance within their ordinary national planning or proposal processes. Thus any coherent international action is not likely to materialise before 2003.

Based on these factors, the following interim plan of action was agreed. This will be amended as appropriate as the ASOF programme is developed.

For year 2000

1. The report from this first ASOF workshop shall be produced and made available to all participants within one month.
2. In parallel with production of this report, Bob Dickson will, within a month, develop version 2.1 of the Strawman document, including where appropriate results from the workshop. This final version of the Strawman document will include a presentation of outstanding issues that need to be clarified in the development of the ASOF science plan. Such issues that national programmes might wish to address as soon as possible include validation of new technology and specific Modeling efforts to test whether proposed ASOF field programmes can meet the ASOF objectives.
3. Norsk Polarinstitutt (NP) will develop an ASOF web page before the end of the year. This page will present all ASOF documents, and have a section for news, and will allow comments on these items and group discussions. The page should have a mutual link with the SEARCH programme and also have links to programmes such as ACSYS/CliC and CLIVAR. This web page and NP will function as an information centre for the ASOF activity until ASOF or other bodies develop a "secretariat" or programme office.
4. An International Scientific Steering Committee (ISSC) will be established with terms of reference and interim members as listed below. This steering committee should establish its work and select a chairman by e-mail, and thereafter lead preparation for ASOF activities listed below.
5. NSF will explore possibilities of joint US/EC cooperation to further the development of ASOF.
6. France, Iceland, Japan, Poland and other nations with potential interest in ASOF will be approached to clarify their interests in ASOF and in designating a person for the interim ISSC. NP will coordinate these approaches.

For year 2001

1. An ASOF meeting should be held during first half of the year in USA. Time, place and agenda for this meeting will be decided by the ISSC. It was agreed that such a meeting should not repeat the present workshop's science presentations and discussions. However, it seemed likely that the planned meeting could fruitfully examine a) the outstanding issues identified in this workshop report and in the revised Strawman Version 2.1, b) progress on developing the science plan, and c) progress in international cooperation.
2. The Arctic Science Summit Week in Iqaluit, Canada, from 23 to 27 April should be used to clarify ASOF links to IASC, European Polar Board, Forum of Arctic Research Operators, Arctic Ocean Sciences Board, and possibly other international organisations dealing with Arctic research. This will also be a good venue for clarifying interests of other "Arctic science" nations in ASOF.

3. The ISSC should complete an ASOF science plan.
4. Programme managers in countries with interest in ASOF should informally explore how to develop joint thinking, and how to dovetail funding so that ASOF releases value-added results by integrating individual national efforts to achieve the ASOF objectives.
5. The European Polar Board and the European Marine Board should develop proposals for a joint Eurocore initiative (to be spelled out) and a joint Euroconference (an international conference sponsored by ESF aimed at discussing basic research on a major scientific question), as appropriate.

For year 2002

Plans for that year can only be tentative, but it seems likely that the following should be included:

1. National proposals to allow a major start of field activities in 2003.
2. An Euroconference.

6 Terms of Reference of the International Science Steering Committee for ASOF

Purpose

Co-ordinate the planning and implementation of studies relevant to the aims of the Arctic and Subarctic Ocean Fluxes programme.

Terms of Reference

- Complete a science plan for the programme and promote this to appropriate funding agencies.
- Interface with funding agencies and logistics providers to identify resource requirements.
- Co-ordinate the development of national ASOF implementation plans, identifying gaps and seeking to fill them.
- Review and revise strategies in the light of emerging results, and advise national programmes accordingly.
- Liase with other international bodies with research interests in the Arctic and Subarctic as appropriate.

Membership

Each country participating in ASOF will be entitled to representation on the ASOF ISSC. The ISSC should choose its chairperson from amongst its members. The following interim members of the ISSC were agreed: Leif Anderson (Sweden), Peter Haugan (Norway), Peter Jones (Canada), Jochem Marotzke (UK), Jens Meincke (Germany), Jamie Morison (USA), Sergey Priamikov (Russia).

7 Presentations at H.U. Sverdrup Symposium, 22-24 September 2000

Alekseev, G.V., Korablev, A.A., Ivanov, V.V.,Johannessen, O.M., Kovalevsky, D.V.,	Interannual Variability of Water Mass in the Greenland Sea and the Adjacent Areas
Anderson, L.	Carbon Fluxes in the Arctic Ocean – Potential Impact by Climate Change
Bjork, G., Gustafsson, B.G., Stigebrandt, A.	Upper Layer Circulation of the Nordic Seas as Inferred from the Spatial Distributions of Heat and Freshwater Content and Potential Energy
Bruemmer, B., Mueller, G., Affeld, B.	Atmospheric Cyclones an Ice Drift in the Fram Strait
Carroll, J., Carroll, M., Highsmith, R.B. Konar, Protushinsky, A., Sirenko, B., Denisenko, S.	Trajectories of Marine Ecosystem Response to Arctic Climate Change: A Barents-Bering Sea Comparison
Dickson, B.	Arctic Change and Ocean Fluxes
Fahrbach, E., Schauer, U., Osterhus, S.	Direct Measurements of Heat and Mass Transports Through Fram Strait
Falck, E.	Contribution of Waters of Atlantic and Pacific Origin in the Northeast Water Polynya
Haarpaintner, J., Kergomard, C., Gascard, J-C., Haugan, P.M.	Sea Ice Dynamics and Classification by Remote Sensing (ERS-2 SAR and ARGOS Buoys) In Isfjorden, Svalbard
Haarpaintner, J., Haugan, P.M., Gascard, J-C.	Interannual variability of the Storfjorden Ice Cover and Ice Production Observed by ERS-2 SAR
Hansen, B., Jonsson, S., Lundberg, P., Turell, W., Osterhus, S.	North Atlantic – Nordic Seas Exchanges
Hansen, E., Nøst, O.A.	The Western Barents Sea Polar Front Zone
Haugan, P.	The New Norwegian Marine Climate Initiative, NOClim
Ingvaldsen, R., Asplin, L.,Loeng, H.	Transport of Atlantic Water Through The Barents Sea
Jones, I., Mobbs, S.	Modelling Turbulent Fluxes over Regions of Broken Sea-ice
Johnson, M.	The Use of Acoustic Methods (ACOUS) to Measure Ocean Temp and Salinity via Sound Speed Across the Arctic Ocean Basin
Johnson, M.	New Observational current meter moorings along the shelf break between Svalbard and Lomonosov ridge
Jones, P.	Return Flow of Freshwater from the Pacific Ocean to the North Atlantic Ocean via the Arctic Ocean
Jones, P.	Circulation in the Arctic Ocean
Karcher, M., Gerdes, R., Kauker, F., Koeberle, C.	Arctic Warming – Evolution and Spreading of the 1990 Warm Event in the Nordic Seas and the Arctic Ocean
Kasajima, Y., Marchenko, A.	On the Excitation of double Kelvin Waves in the Barents Sea by the Interaction of the K1 diurnal Tide with Bottom Irregularities
Kasajima, Y., Svendsen, H., Slagstad, D.	The Generation of Topographic Waves with K1 Tidal Frequency at the Western Boundary of the Barents Sea
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8 Participants at H.U. Sverdrup Symposium, 22-24 September 2000

Name	*Institution*	*Country*	*E-mail address*
Alekseev, Genrikh	Arctic and Antarctic Research Institute	Russia	alexgv@aari.nw.ru
Anderson, Leif	Göteborg University	Sweden	leif@amc.chalmers.se
Bjørk, Göran	Göteborg University	Sweden	gobj@oce.gu.se
Brown, Louis B	Directorate for Geosciences, NSF	U.S.A	lbrown@nsf.gov
Brümmer, Burghard	University of Hamburg	Germany	bruemmer@dkrz.de
Budgell, Paul	Institute of Marine Research, Bergen	Norway	Paul.Budgell@imr.no
Calder, John	NOAA, Arctic Research Office	U.S.A.	john.calder@noaa.gov
Carroll, JoLynn	Akvaplan-niva, Tromsø	Norway	jolynn.carroll@akvaplan.niva.no
Carroll, Michael	Akvaplan-niva, Tromsø	Norway	michael.carroll@akvaplan.niva.no
Cerza, Martin	Office of Naval Research, London	UK	cerza@nadn.navy.mil
Colony, Roger	International Arctic Research Centre, Fairbanks	U.S.A	rcolony@iarc.uaf.edu
Dick, Chad	ACSYS/CLIC, Tromsø	Norway	chad.dick@npolar.no
Dickson, Robert	Centre for Environment, Fisheries and Aquaculture Science	UK	r.r.dickson@cefas.co.uk
Dudeney, John	British Antarctic Survey	UK	jrdu@pcmail.nerc-bas.ac.uk
Fahrbach, Eberhard	Alfred Wegener Institute	Germany	efahrbach@awi-bremerhaven.de
Falck, Eva	Göteborg University	Sweden	eva@amc.chalmers.se
Gavrilov, Alexander	Russian Academy of Science	Russia	gans@gans.msk.ru
Hansen, Bogi	Faroese Fisheries Laboratory	Faroe Island	bogihan@frs.fo
Hansen, Edmond	Norwegian Polar Institute	Norway	edmond.hansen@npolar.no
Harms, Ingo	University of Hamburg	Germany	harms@ifm.uni-hamburg.de
Hátun, Hjálmar	Faroese Fisheries Laboratory	Faroe Island	hjalmarh@frs.fo
Haugan, Peter M.	University of Bergen	Norway	Peter.Haugan@gfi.uib.no
Haakstad, Magne	Høgskolen i Bodø	Norway	magne.haakstad@hibo.no
Haarpaintner, Jörg	Norwegian Polar Institute	Norway	jorg@npolar.no
Isachsen, Pål Erik	Norwegian Polar Institute	Norway	pal.isachsen@npolar.no
Johnson, Mark	University of Alaska, Fairbanks	U.S.A	johnson@ims.uaf.edu
Jones, Ian	University of Leeds	UK	ian@env.leeds.ac.uk
Jones, Peter	Bedford Institute of Oceanography	Canada	jonesp@mar.dfo-mpo.gc.ca
Karcher, Michael J	Alfred Wegener Institute	Germany	mkarcher@awi-bremerhaven.de
Kasajima, Yoshie	Norwegian Polar Institute	Norway	yoshie@npolar.no
Koc, Nalan	Norwegian Polar Institute	Norway	nalan.koc@npolar.no
Kovalevsky, Dmitry	NIERSC, St. Petersburg	Russia	dmitry.kovalevsky@niersc.spb.ru
Laxon, Seymour	Dept. of Space and Climate Physics, University College London	UK	swl@mssl.ucl.ac.uk
Ledbetter, Michael	Arctic System Science Program, NSF	U.S.A	mledbett@nsf.gov

Name	*Institution*	*Country*	*E-mail address*
Loeng, Harald	Institute of Marine Research, Bergen	Norway	harald.loeng@imr.no
Lonnroth, Nadja	University of Helsinki	Finland	nlonnrot@cc.helsinki.fi
Løyning, Terje Brinck	Norwegian Polar Institute	Norway	loyning@npolar.no
Makshtas, Alexander	University of Alaska, Fairbanks	USA	makshtas@iarc.uaf.edu
Marotzke, Jochem	Southampton Oceanography Centre	UK	Jochem.Marotzke@soc.soton.ac.uk
Maslowski, Wieslaw	Dept. Oceanogr., Naval Postgrad. School	U.S.A	maslowsk@meeker.ucar.edu
Mauritzen, Cecilie	Woods Hole Oceanographic Institution	U.S.A	cmauritzen@whoi.edu
Meincke, Jens	University of Hamburg	Germany	meincke@ifm.uni-hamburg.de
Morison, James	University of Washington, Polar Science Center	U.S.A	morison@apl.washington.edu
Mørland, Terje	The Research Council of Norway	Norway	tmo@forskningsradet.no
Newton, Philip	Natural Environment Research Council	UK	p.newton@nerc.ac.uk
Nicholls, Keith	British Antarctic Survey	UK	kwni@bas.ac.uk
Nisancioglu, Kerim Hestnes	MIT Program in Atmospheres, Ocean & Climate	U.S.A	kerim@mit.edu
Nøst, Ole Anders	Norwegian Polar Institute	Norway	nost@npolar.no
O'Brien, James	The Florida State University	U.S.A	obrien@coaps.fsu.edu
O'Dwyer, Jane	Norwegian Polar Institute	Norway	jane@npolar.no
Orheim, Olav	Norwegian Polar Institute	Norway	orheim@npolar.no
Overland, James	Pacific Marine Env. Lab, NOAA, Seattle	U.S.A	overland@pmel.noaa.gov
Pavlov, Vladimir	Norwegian Polar Institute	Norway	Pavlov@npolar.no
Piechura, Jan	Institute of Oceanology, Polish Acad. Sciences	Poland	piechura@iopan.gda.pl
Pisarev, Sergey	Russian Academy of Science	Russia	sergey@pisarev.msk.ru
Pryamikov, Sergey	Arctic and Antarctic Research Institute, St. Petersburg	Russia	priamiks@aari.nw.ru
Pyle, Tom	National Science Foundation	U.S.A	tpyle@nsf.gov
Rhines, Peter	University of Washington	U.S.A	rhines@ocean.washington.edu
Rudels, Bert	Finnish Institute of Marine Research	Finland	bert.rudels@fimr.fi
Sakshaug, Egil	Biologisk Stasjon, Univ. Trondheim	Norway	egil.sakshaug@vm.ntnu.no
Saloranta, Tuomo Mikael	University of Bergen	Norway	tuomo@gfi.uib.no
Smethie Jr., William M.	Lamont-Doherty Earth Observatory	U.S.A	bsmeth@ldeo.columbia.edu
Svendsen, Harald	University of Bergen, Geophys. Inst.	Norway	harald.svendsen@gfi.uib.no
Söderkvist, Johan	Göteborg University	Sweden	joso@oce.gu.se
Wadhams, Peter	University of Cambridge	UK	pw11@cam.ac.uk
Wassmann, Paul	University of Tromsø	Norway	paulw@nfh.uit.no
Winther, Jan-Gunnar	Norwegian Polar Institute	Norway	winther@npolar.no