Report of 9th ASOF ISSG Meeting

November 8-9, 2011,

Bergen, Norway

Compiled by Thomas Haine (Johns Hopkins University) and Lilian Schubert (AWI)

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Introduction

The goals of the 9th meeting of the ASOF ISSG were to provide an:

1. Update on the status and plans for ASOF-relevant programs.
2. Discussion of the ASOF Database and synthesis of observations from moorings during the IPY.
3. Discussion of the 2011 iAOOS report and implementation.
4. Collaboration with the THOR program on "*Observed North Atlantic/Arctic Ocean climate variability and its predictability.*"

This report comprises of summaries of the science presentations at the workshop and the subsequent discussions. The workshop agenda and list of participants appears in Appendix A. The agenda and participants for the joint ASOF/THOR workshop are in Appendix B.

ASOF activities since the last ISSG meeting.
Tom Haine, ASOF chairperson, said that the revamped ASOF website is now live at: http://www.asof.awi.de/en/home/. Thanks are due to Lilian Schubert for managing the new site, and to AWI for hosting it. Tom asked that everyone provide brief summaries of their ASOF activities for the website, including links as necessary. Relevant publications (pdfs) are also needed (copyright permitting).

Two joint workshops with ESSAS biologists were held at the ESSAS Open Science Meeting in Seattle in May 2011. First, Tom and Ken Drinkwater convened a successful one day meeting on *"Arctic-Subarctic Interactions.*" This workshop brought together several disperse groups studying ocean fluxes and their biophysical effects. They included: ESSAS researchers who concentrate on the subarctic and the effects on the marine biota, especially fish; those working on the benthic-pelagic coupling and the biogeochemistry in the Barents and the Greenland shelves; those looking at the interaction between the Chukchi Sea and the western Bering Sea; and, scientists who during the IPY studied the effects of the Bering Sea on the Western Arctic. The object was to identify the gaps in our knowledge and to highlight what research can be carried out over the next few years to fill some of these gaps in our understanding of the effects of the interactions between the Arctic and subarctic and to coordinate the research on these issues. Areas of interest included physical, biogeochemical, and food web studies. Ken and Tom are convening a special session at the 2012 Ocean Sciences meeting in Salt Lake City with the same title.

A second one-day meeting on "*North West Atlantic Ecosystems*" was led by Chuck Greene. This mainly biological group has a clear need for physical variables, such as water mass analysis, and trajectory pathways/transit times in the subpolar North Atlantic. They are interested in the impacts of salinity anomalies being exported from the Arctic, plus NAO variability, and hence the impact on, for example, the Gulf of Maine primary productivity. Collaborating with Chuck and this group is a good opportunity for ASOF.

Case for an ASOF focus on Arctic Freshwater Export: Prospects, Impacts, and Challenges.
Tom briefly summarised the 2011 iAOOS report, partly based on discussions at the 8th ASOF ISSG meeting in Woods Hole, in October 2010. Much is relevant to ASOF science. In particular, climate model projections suggest that: sea ice will continue to decline while liquid freshwater supply to Arctic will increase. Moreover, it's likely that sea ice export will decrease and freshwater export will increase from the Arctic. It seems that the western route will be increasingly important rather than East of Greenland. Available observations confirm aspects of these projections, especially that Arctic sea ice is decreasing and freshwater storage is increasing. Liquid freshwater is accumulating in the Beaufort Gyre in particular, with an anomaly between 1000 and 8500 km^3 relative to climatology. Seemingly, another Great Salinity Anomaly is poised to be released. There are many uncertainties, however, including the timing, pathways, rates, and impacts of such an enhanced freshwater export.

Furthermore, there are known to be warm Atlantic Water anomalies present in the Norwegian Current. Observations appear to reveal propagation of these anomalies through the Nordic Seas and into the Arctic Ocean. Modeling studies suggest that they will circulate through the Arctic in the Atlantic Water layer and ultimately be exported south via the Greenland-Scotland overflows. There appears to be potential for the anomalies to impact the overflow transport and properties. Again, many questions arise, including the timing, pathways, rates, and impacts of these anomalies.

In this context, Tom proposed that ASOF should focus on Arctic export anomalies, their prospects, impacts, and challenges. Specifically, he suggested that ASOF should write a high-profile article that summarises the present knowledge on this topic, and outlines plausible, and suitably qualified, predictions for how they may unfold. This would be a good springboard for a concerted effort to raise funding and enthusiasm to observe the anomalies as they pass through the system. ASOF is particularly well placed to address these questions. To this end, Tom suggested that the next ASOF ISSG meeting involve a special workshop on "*Arctic Freshwater Export: Prospects, Impacts, and Challenges,*" with invited experts to guide the discussion. The outcome of this workshop could be the high-profile article mentioned above. Tentatively, this meeting will be held in October 2012 in Lerici, Italy, hosted by Marcello

Magaldi and Stefano Aliani. During the Bergen meeting Tom appealed for comments on these proposals. The discussions led by Laura de Steur and Michael Karcher, reported below, are especially germane.

Presentation Summaries

Atlantic Water in the Nordic Seas: Time series from IOPAS

Waldemar Walczowski (Institute of Oceanology Polish Academy of Sciences, Poland).

In the 2011 summer season, IOPAS carried out an oceanographic investigation in the Nordic Seas and Fram Strait region. During the cruise of the institute's vessel S/Y "Oceania" 151 CTD and LADCP profiles along 11 sections were performed (see **Fig. 1**). Continuous VMADCP measurements were carried out as well. The works were conducted as part of the Polish-Norwegian project AWAKE. In comparison to summer 2010, in summer 2011 the Atlantic Water (AW) temperature in the southern part of the investigated area (south of the Bear Island) increased, while in the northern part and Fram Strait, the AW temperature lowered. In both parts AW salinity increased. Apart from the hydrographic survey, in collaboration with the ACOBAR project, IOPAS recovered and redeployed a McLane Moored Profiler (MMP). The mooring is located in the core of the West Spitsbergen Current, west of Spitsbergen.

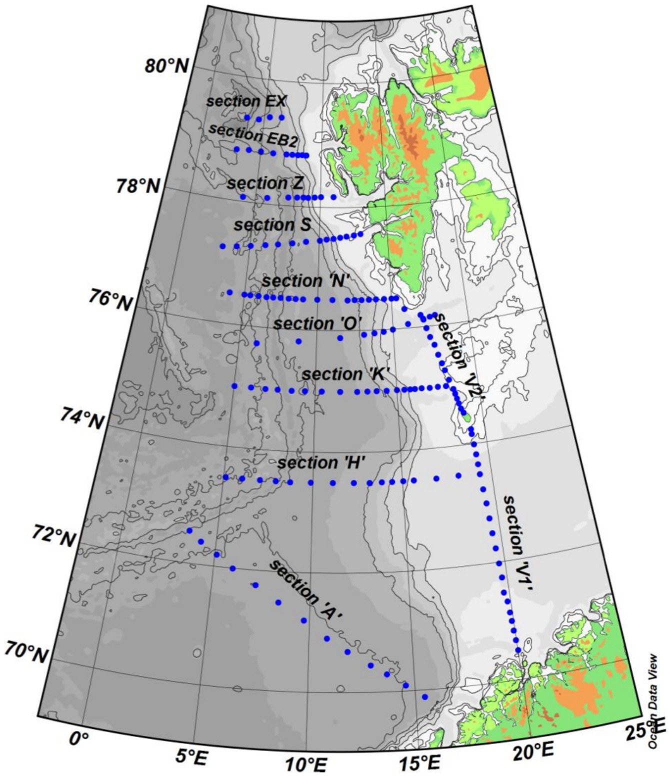

Fig. 1. Arex 2011 hydrographic stations taken by the S/Y "Oceania" as part of the AWAKE program.

Since 2000, annual time series collected by IOPAS reveal significant variability in the properties of the Atlantic Water carried by the West Spitsbergen Current. Periods of intensive northward, towards the Fram Strait, or eastward, towards the Barents Sea AW transport were observed. During the northward flow intensification, AW temperature in Fram Strait increased. In 2006 a record-high temperature of AW west of Svalbard was observed. The heat content of the AW layer in the Nordic Seas was also at a record-high. Changes of the ocean climate influence the Arctic ocean winter temperature and sea ice extent. Increasing AW salinity in the last two years, and increased temperature in the southern part in 2011, suggest that in summer 2012 AW in Fram Strait will be warmer.

Eddies in the Beaufort Sea and their Ecosystem Impacts

Takashi Kikuchi (JAMSTEC, Japan).

Recent results on unusual Beaufort Sea eddies.

Pacific Summer Water (PSW) is one of the dominant sources of heat, freshwater, and nutrients in the Arctic Ocean, especially for the Beaufort Sea/Canada Basin. Surface-intensified warm-core eddies play important roles to transport PSW from the Chukchi continental shelf into the Canada basin. Two interesting papers about eddies in the Beaufort Sea are published this year. Nishino et al. (2011) presented observational evidence of an unusually large warm-core eddy in the southern Canada Basin in early fall 2010 (see **Fig. 2**). The diameter of the eddy was about 100 km and the core temperature reached more than 5°C. This warm-core eddy contained high-ammonium shelf water and could supply ammonium to the euphotic zone in the southwestern Canada Basin. It may sustain ~30% higher biomass of pico-phytoplankton (<2 μm) than that in the surrounding water in the basin. Watanabe (2011) examined meso-scale eddies and shelf-basin exchange of PSW using satellite data sets and an eddy-resolving coupled sea ice–ocean model. Meso-scale eddies primarily induce shelf-basin transport under weak or westerly wind conditions during summer, while wind-driven Ekman transport is a major driver in the easterly wind regime. The model results suggested that year 2003 (2007) was the former (latter) case.

References:

Nishino et al., 2011; http://www.agu.org/journals/gl/gl1116/2011GL047885/
Watanabe, 2011; http://www.agu.org/journals/jc/jc1108/2010JC006259/

Preliminary XCTD results from the UNCLOS 2011 cruise

In August-September 2011, CCGS "Louis S. St-Laurent" had a cruise from the Canadian Arctic coast toward the Lomonosov Ridge in tandem with USCGC Healy (the UNCLOS 2011 cruise). During this expedition, 78 hydrographic profiles were collected by eXpendable Conductivity, Temperature, and Depth instruments (XCTD). Using these data, we examined the distribution, characteristics, and mixing processes of water masses in order to better understand the circulation scheme of the Arctic Ocean. One interesting finding is that Pacific-origin water masses were found to the north of the Chukchi Rise in September 2011, although no signal of these water masses was there in 2008 and 2009. According to previous publications, the Beaufort Gyre circulation was intensified in a recent couple of years. However, the XCTD data in 2011 might suggest a relaxation of the intensified circulation and a change of water mass distributions around the Mendeleyev Ridge and the north-western Canada Basin. Inter-annual variability is discussed in the context of changes in atmospheric circulation pattern and recent sea ice reduction.

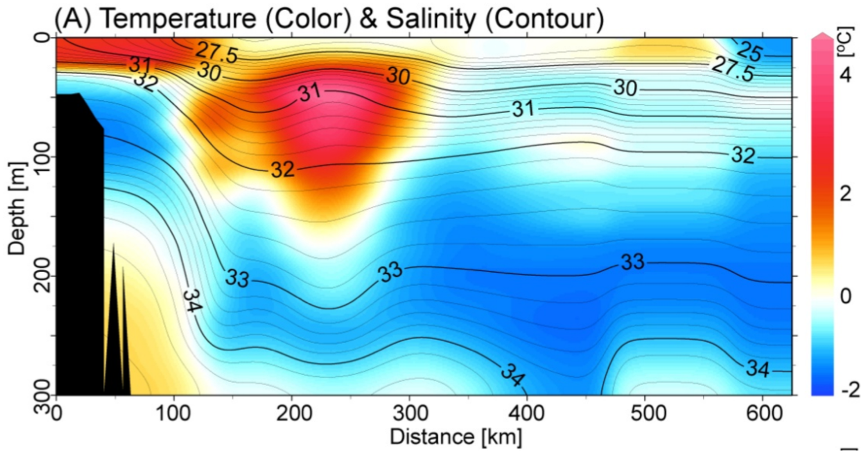

Fig. 2. Section from the 2010 R/V Mirai cruise along 155-160°W north of Point Barrow in 2010. See Nishino *et al.* (2011).

The Observed Variability in 12-years of the Volume Transports through Lancaster Sound and its Dependence on the Far-Field Wind in the Beaufort and Greenland Seas

Simon Prinsenberg (Bedford Institute of Oceanography, Dartmouth, Canada), Ingrid Peterson, Jim Hamilton, and Roger Pettipas.

Mooring arrays have been in place in Lancaster Sound since August 1998, monitoring the ocean volume, heat and freshwater transports. The volume, freshwater and heat fluxes exhibit large seasonal and inter-annual variabilities with small fluxes in the fall and winter and large fluxes in late summer (**Fig. 3**). Estimates of the seasonal volume flux range from a low of -0.01 Sverdrup (Sv) in the fall of 1998 to a high of 1.3 Sv in the summer of 2000. It has a 12-year annual mean of 0.65 Sv ranging from a summer high in August of 0.8 Sv to and early winter low in Nov-Dec of 0.2 Sv. There is a high coherence between the volume flux and freshwater flux estimates.

Estimates from 2006 to 2010 confirm the relationship between surface wind and volume transport derived from data collected between 1998 and 2006. Volume transport through Barrow Strait along the Northwest Passage is significantly correlated with northeastward winds in the Beaufort Sea, parallel to the western side of the Canadian Arctic Archipelago, at monthly to interannual time scales (**Fig. 4**). The optimum location and wind direction are consistent with the flow being driven by a sea level difference between the Canadian Basin and Baffin Bay, and the difference being determined by setup caused by alongshore winds in the Beaufort Sea. Examination of the residuals showed that northwestward winds east of Greenland account for an additional 8% of the variance, which suggests that a large-scale cyclonic atmospheric pressure pattern over the Arctic has a lesser role in determining the volume transport.

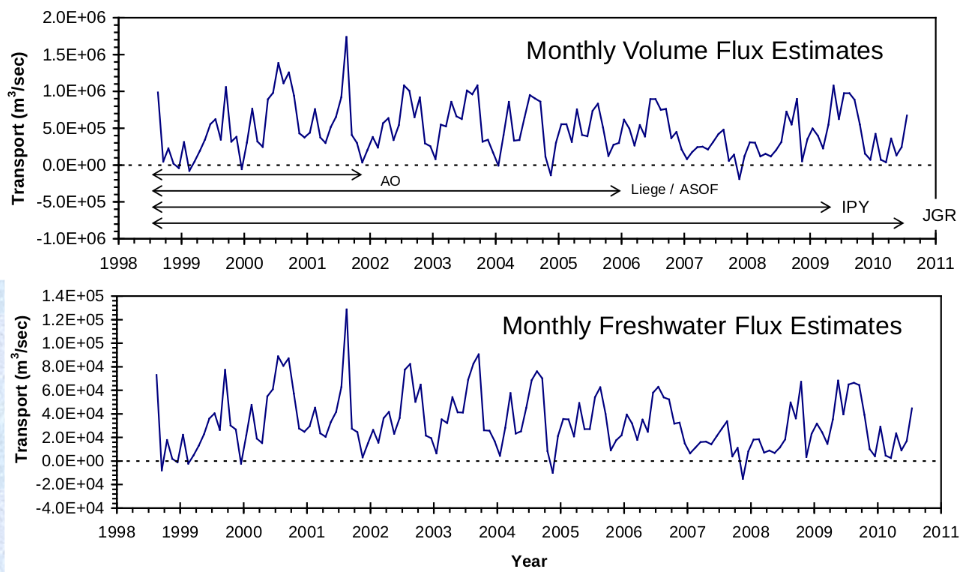

Fig. 3. Monthly volume (upper) and freshwater (lower) fluxes through western Lancaster Sound. The arrows in the upper panel indicate publications on the flux records from Simon Prinsenburg's group. The latest article is being submitted to *J. Geophys. Res.*

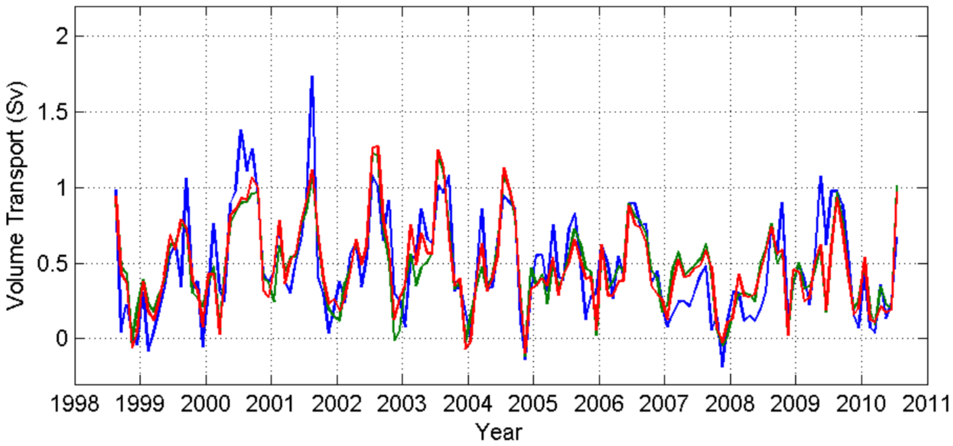

Fig. 4. Comparison of wind regression transport estimates and observed transport estimates for western Lancaster Sound. Blue is observed, Green is annual regression estimate using Beaufort Sea winds (r=0.81), and Red is annual regression estimate using Beaufort Sea and Greenland winds (r=0.84).

The ARKXXVI-3 Cruise with RV Polarstern to the Arctic Ocean: Some Preliminary Observations and Remarks

Bert Rudels (Finnish Meteorological Institute & University of Helsinki, Helsinki, Finland), S. Pisarev, B. Rabe, U. Schauer, and A. Wisotzki.

The objectives of the Polarstern XXVI-3 cruise to the Arctic Ocean in summer 2011 were: 1) To obtain a synopotic view of a large part of the Arctic Ocean–The Nansen, Amundsen and Makarov basins and across the Alpha Ridge into the Canada Basin. 2) To detect temporal changes between 2007 (ARKXXII) and 2011. 3) To deploy ice tethered platforms (2 POPS, 4 Profilers). 4) To deploy 5 mooring around the Gakkel Ridge (3 in the Amundsen Basin and 2 in the Nansen Basin) equipped with current meters and profilers as well as sediment traps. 4) To recover 3 NABOS moorings (Successful). 5) To run a CTD programme, water sampling (carbon system and nutrients, biology, tracers, launching of XCTDs and the test of a new mobile CTD from ice floes (helicopter transports). 6) To conduct ice studies and measure gas exchange under ice. The main goals for the hydrographic observations were to monitor the changes in the freshwater content of the upper water column and to study the relative importance of the two Atlantic inflow branches, the Fram Strait branch and the Barents Sea branch.

The inflow from the Norwegian Sea to the Arctic Ocean over the Barents Sea has, in spite of being of almost equal magnitude as the inflow through Fram Strait, received considerably less attention. Observations on recent expeditions with RV Polarstern in 2007 and now in 2011 as well as data from older icebreaker cruises indicate the strong presence and variability of the Barents Sea inflow. The largest inflow occurs in the St. Anna Trough. It mixes laterally with the thermocline and with the Atlantic and intermediate layers of the Fram Strait branch, creating strong temperature and salinity inversions and interleaving layers. The temperature and salinity of the Fram Strait branch is reduced and the presence of the Barents Sea branch in the boundary current increases downstream. The Barents Sea branch dominates the intermediate waters in the Amundsen Basin, indicating a flow from the Laptev Sea slope toward Fram Strait, and crosses the Lomonosov Ridge into the Makarov Basin. The Atlantic layer becomes more akin to that observed in the Barents Sea branch, while the warmer, more saline Fram Strait branch characteristics are only found in the Nansen Basin. This situation varies between the years, but an extreme interpretation is that the Barents Sea branch is the one that usually renews the Atlantic and intermediate waters in the Arctic Ocean beyond the Nansen Basin, while the Fram Strait branch returns towards Fram Strait in the Nansen Basin and over the Gakkel Ridge and only occasionally penetrates to the Lomonosov Ridge and into the Amerasian Basin (**Fig. 5**).

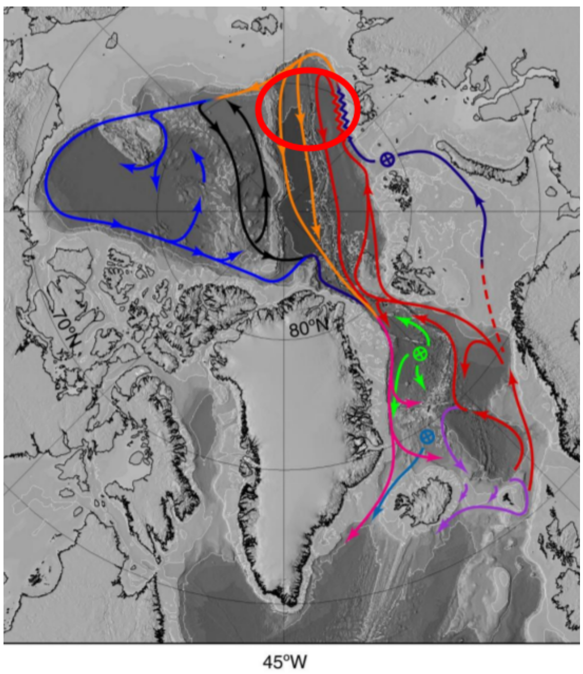

Fig. 5. The Fram Strait Arctic inflow branch (red) becomes squeezed between the Barents Sea inflow branch (dark blue) at the continental slope and the part that returns toward Fram Strait. This leads to a lowering of temperature and salinity and a large fraction of the Fram Strait branch is likely forced to return to Fram Strait in the Nansen Basin. The area north of the Laptev Sea slope (orange circle) is thus crucial for the distribution of heat in the Arctic Ocean.

Some Effects of Topography and Wind Stress on the Nordic Seas Overflow

Jiayan Yang (Woods Hole Oceanographic Institution, Woods Hole, USA) and Lawrence J. Pratt.

The overflow of the dense water mass across the Greenland-Scotland Ridge (GSR) from the Nordic Seas is a primary driver of the Atlantic Meridional Overturning Circulation (AMOC). So the stabilities of the AMOC and the overflow transport are intimately tied. In this study, we examine some effects of topography and wind stress on the Nordic Seas outflow of dense water over the Greenland-Scotland Ridge (GSR). Our approach is a nonlinear and two-layer model with both idealized and realistic topography.

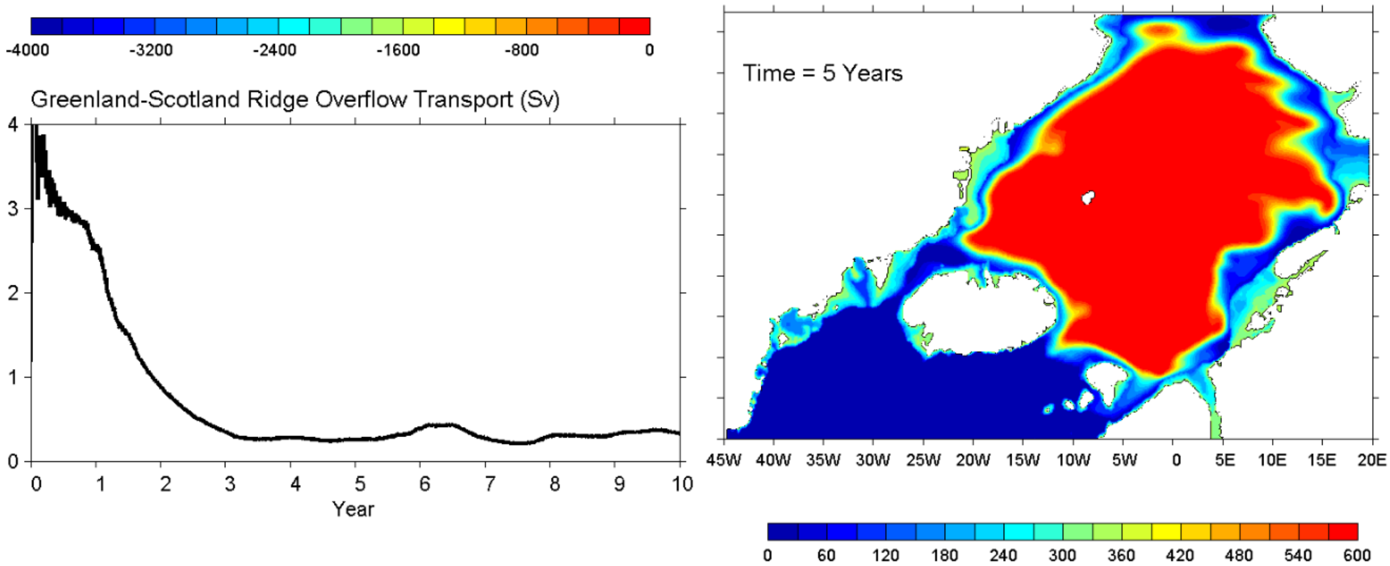

Fig. 6. In a two-layer, 1/12° wind-driven model the effective reservoir volume of the Nordic Seas to supply the Greenland-Scotland overflow is small. The majority of the dense Nordic Seas water is trapped inside closed geostrophic contours and is not easily available to overflow. The overflow decays over a few years.

First we have investigated the Nordic Seas' reservoir capacity to supply the overflow. The volume of the dense water in the upper layer above the GSR sill depth in the Nordic Seas, according to previous estimates, is sufficient to supply decades of overflow transport. This large capacity buffers the overflow responses to atmospheric variations and prevents an abrupt shutdown of the dense-water transport to the Atlantic Ocean. In this study, we use a numerical and an analytic model to show that the effective reservoir capacity of the Nordic Seas is actually much smaller than what was estimated previously. The basin-scale oceanic circulation is nearly geostrophic and its streamlines are basically along isobaths. The vast majority of the dense water is stored inside closed geostrophic contours in the deep basin and thus is not freely available to the overflow. The positive wind-stress curl in the Nordic Seas forces a convergence of the dense water toward the deep basin and makes the interior water even more removed from the overflow-feeding boundary current. Eddies generated by baroclinic instability help transport the interior water mass to the boundary current. But in the absence of a robust renewal of deep water, the boundary current weakens rapidly and the eddy-generation mechanism becomes less effective. Our study indicates that the Nordic Seas has a relatively small capacity as a dense water reservoir and thus the overflow transport is sensitive to climate changes (**Fig. 6**).

Second, we have examined the upstream pathways that lead to the overflow over the GSR sill. We are particularly interested in a branch for the Denmark Strait overflow along the coast of Iceland–the North Icelandic Jet. The existence of this branch is very robust. It is always present regardless of where and how the dense water is formed in the upstream Nordic Seas. The existence of this branch is supported by two dynamical constraints. The potential vorticity is not conserved along streamlines as shown in previous studies. A positive frictional torque is required in order to "permit" an outflow over the sill. So the dense water is more likely to approach the sill as an anti-cyclonic boundary current from the deep basin, i.e., to approach the Denmark Strait sill from the Iceland side instead of from the Greenland side. Another constraint is the momentum integral around a closed isobath. For a marginal sea that has two deep outlets, i.e., the Denmark Strait and Faroe Bank Channel, one can find a closed isobath that connects both passages. The integral constraint requires that the circulation can not be unidirectional around this closed path. So there must a westward flow along the northern slope of the Iceland as long as there is an outflow through the Faroe Bank Channel. These two constraints are tested by model experiments.

Quantifying the Influence of Atlantic Heat on Barents-Sea Sea-Ice Variability and Retreat

Tor Eldevik (University of Bergen, Norway).

The recent Arctic winter sea ice retreat is most pronounced in the Barents Sea. Using available observations of the Atlantic inflow to the Barents Sea and results from a regional ice-ocean model we assess and quantify the role of inflowing heat anomalies on sea-ice variability. The interannual variability and longer term decrease in sea ice area reflect the variability of the Atlantic inflow, both in observations and model simulations. During the last decade (1998-2008) the reduction in annual (July-June) sea ice area was 218×10^3 km^2, or close to 50%. This reduction has occurred concurrent with an increase in observed Atlantic heat transport, due to both strengthening and warming of the inflow. Modeled interannual variations in sea ice area between 1948 and 2007 are associated with anomalous heat transport ($r = -0.63$) with a 70×10^3 km^2 decrease per 10 TW input of heat. Based on the simulated ocean heat budget we find that the heat transport into the western Barents Sea sets the boundary of the ice-free Atlantic domain and, hence, the sea ice extent. The regional heat content and heat loss to the atmosphere scale with the area of open ocean as a consequence. Recent sea ice loss is thus largely caused by an increasing "Atlantification" of the Barents Sea. This study is under consideration at *J. Climate* (Årthun *et al.*).

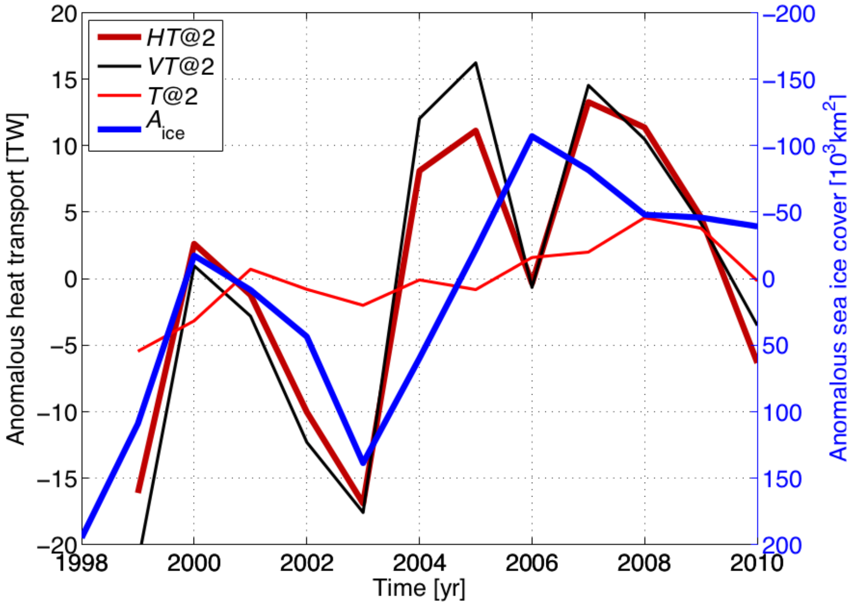

Fig. 7. Observations of annual Barents-Sea Opening (BSO) heat flux anomalies (thick red line) and Barents-Sea sea-ice cover anomalies (blue). The BSO heat fluxes lead the sea ice anomalies by two years and are decomposed into volume (thin black line) and temperature (thin red line) anomalies.

Hydrostatic and Non-Hydrostatic Simulations of the East Greenland Spill Jet

Marcello Magaldi (ISMAR, Lerici, Italy), Tom Haine, Robert S. Pickart, Wilken-Jon von Appen, Alex Brearley, Ben E. Harden, and Inga M. Koszalka .

The cascade of dense waters off the East Greenland shelf during Summer 2003 is investigated with two very high-resolution (~0.5 km) numerical simulations. The first simulation is non-hydrostatic but computationally expensive (wall-clock time of about three months on 145 processors). The second simulation is hydrostatic and about 3.75 times less expensive (wall-clock time of about 24 days on 145 processors). Both simulations are compared to a previous 2-km hydrostatic run (wall-clock time of about one week using 60 processors) which covers a wider area.

All runs compare well with observations and confirm the persistence and the causes of the East Greenland Spill Jet (EGSJ): in some cases, a local perturbation results in dense waters descending over the shelfbreak into the Irminger

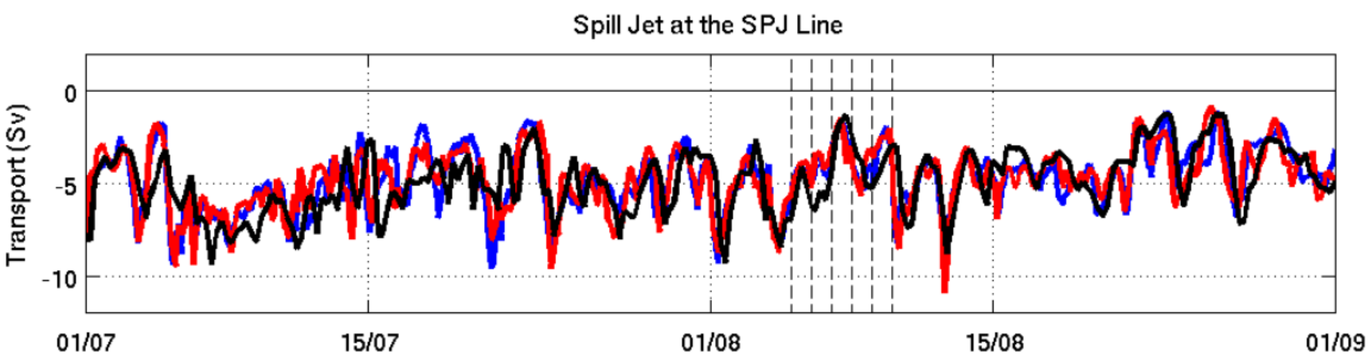

Fig. 8. East-Greenland spill jet transport timeseries from the high-resolution simulations by Marcello Magaldi. The 2 km run is black, the 0.5 km hydrostatic run is red, and the 0.5 km non-hydrostatic run is blue.

Basin (Type I). In other cases, surface cyclones associated with Denmark Strait Overflow (DSO) deep domes initiate the spilling process (Type II).

Differences among runs are quantified in terms of surface kinetic energy spectra, Okubo-Weiss parameter (measuring the importance of straining and vortical circulation), DSO and EGSJ transports. The non-hydrostatic surface kinetic energy spectrum is thicker in the sub-mesoscale range (scales of O(1) km). The Okubo-Weiss “hyperbolicity” is ten times larger for the 500m calculation compared to the the 2km run, indicating much stronger small-scale horizontal velocity gradients. However, the DSO and EGSJ transports do not significantly change with resolution or when non-hydrostatic dynamics are included (**Fig. 8**).

Denmark Strait Overflow Water Float Diagnostics

Inga Koszalka (Johns Hopkins University, Baltimore, USA) and Tom Haine.

In this talk I will present preliminary results from a numerical float study using a MITgcm simulation of the Irminger Basin during Summer 2003. This simulation is hydrostatic, features 2 km horizontal resolution and 97 layers in the vertical and is described in more detail in Magaldi *et al.*, 2011 (see also the talk of M. Magaldi during this session).

The float study concerns the fates of the Denmark Strait Overflow Waters, the origin of dense waters spilling off the shelf and their contribution to the overflow, and the mixing and transformation processes the dense waters undergo while transiting southward through the Irminger Basin. I will show the results from the set of 81 floats released in the overflow waters in the Denmark Strait in July 2003. The floats exhibit large vertical excursions owing to O(1000 m/day) model vertical velocities at the sill and along the East Greenland shelf break. I will mention possible causes for these intense vertical motions. Higher-resolution model experiments are planned to better resolve the underlying dynamics.

References:

M. G. Magaldi, T. W. N. Haine and R. S. Pickart, 2011, On the nature and variability of the East Greenland Spill Jet: A case study in summer 2003, J. Phys. Oceanogr, 41, 2307-2327, 10.1175/JPO-D-10-05004.1. http://journals.ametsoc.org/doi/abs/10.1175/JPO-D-10-05004.1

The ASOF Model Validation Database

Michael Karcher (AWI/OASYS, Germany).

Michael reported on the current status of the long-standing idea to establish a model validation database based on ASOF observational experience and data in conjunction with model expertise from AOMIP and other modeling groups. The aim of the model validation database is to provide a set of benchmark time series from key gateways connecting the Arctic and subarctic Oceans. These data sets will exploit the knowledge of researchers active in the investigation of the respective gateways to best determine the key timescales and spatial-averaging procedures relevant to large-scale models. The database will be configured in close interaction with modeling teams to ensure that it is useful and easy to access and handle for modelers. By this procedure ASOF hopes to establish a series of accessible benchmark data sets which facilitate model validation efforts.

This initiative needs dedicated time and thus funding support. To demonstrate the feasibility and usefulness of the idea, three teams of volunteers have agreed to perform pilot studies. These teams comprise of observers and modelers and are as follows (see **Fig. 9**):

- Canadian Archipelago (Observations: BIO (Prinsenberg), Model: BIO (Lu, Hannah), AWI (Wang, Wekerle))
- Davis Strait (Observations: UW (Lee, Curry), Model: UW (Zhang), Model:LANL (Hunke))
- Fram Strait (Observations: AWI (Beszczynska), Model: AWI (Gerdes, Karcher), Model: NOC (Aksenov))

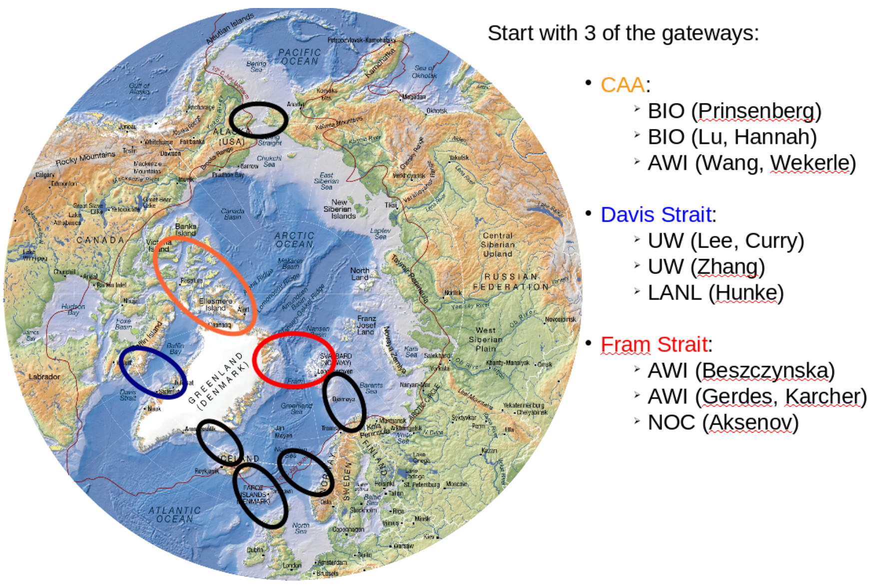

Fig. 9. Plans for the pilot phase of the ASOF Model Validation Database.

First results are expected by the 2012 ASOF meeting.

Synthesis of Observations from Oceanographic Moorings during the International Polar Years

Humfrey Melling (Fisheries and Oceans, Canada).

The international Arctic Ocean Observing System (iAOOS) supported many new observational initiatives in the Arctic Ocean during the International Polar Years. The Marine Working Group of the International Arctic Science Committee envisions bringing together the technical capacity, human resources and good will to compile Arctic Ocean data acquired during the IPY, and to complete its standardization, synthesis and timely migration from project archives to a single internally-consistent public resource. The starting point is a modest demonstration project focusing on observations from moored instruments.

IPY observations are presently dispersed among dozens of organizations, not universally accessible, and stored in a multitude of formats. The promise of the IPY and iAOOS for a better understanding of the Artic Ocean can best be realized if observations are shared and easily accessible for integration within comprehensive analyses. The immediate objective of this project is to collect and integrate the Arctic mooring-data acquisitions of all nations during the IPY. Success will be predicated on in-kind contributions from cooperating sources. The cash budget will be modest.

Following an overview of the initiative, I will solicit frank discussion: Is the concept appropriate? What are the perceived benefits? Is it worth somebody’s effort? Along more personal lines, I would like to know if you personally would share your data on a timely schedule, whether the outcome might justify some in-kind contribution from you and how we might find the ingredients–funds, human resources, infrastructure.

Freshwater Fluxes around Greenland: Can we Trace Freshwater Anomalies, when and where do they go?

Laura de Steur (Royal Netherlands Institute for Sea Research NIOZ, Netherlands).

The freshwater (FW) content in the Arctic Ocean had shown a considerable increase in 2006-2008 relative to the 1990s. The increase of FW in the central Arctic and specifically the Lincoln Sea, just north of Greenland, continued into 2009 and 2010. The question is whether this FW anomaly exits the Arctic through either the CAA or Fram Strait. Updated results from Lancaster sound, where FW flux correlates strongly with total volume transport, has not shown any significant change in FW flux towards the end of the 2000s. The FW flux in Fram Strait was maximum in 2008 due to a combination of large southward flow and low salinities but declined to the long-term mean value in 2009 due to small southward surface velocities in the East Greenland Current. In addition, sea ice is observed to have thinned significantly in Fram Strait relative to the 1990s (Hansen *et al.*, manuscript in preparation). The above observations confirm some main results from an Arctic Ocean Model Intercomparison study as presented in the AOSB/iAOOS report with respect to possible future changes in freshwater fluxes around Greenland. Observations of FW flux through these Arctic gateways should be continued in order to identify long-term changes and understand the relative importance of the pathways east and west of Greenland.

Discussion on Anomaly Propagation: Predicting Timing, Pathways, and Impacts

Michael Karcher (AWI/OASYS, Germany).

The topics for the Discussion were set as follows:

The Atlantic derived sublayer: Observing, modeling and, predicting transient signals connecting the Nordic Seas inflows, the Arctic, and the overflows.
The Beaufort Sea anomalies: Observing, modeling, and predicting the discharge of Beaufort Sea freshwater through the CAA, Baffin Bay, and into the North Atlantic.

- Where are the greatest uncertainties?
- What are the plausible scenarios for anomalies to flush through the system?
- What are the plausible impacts on MOC (overflows, LSW production) and ecosystems?
- Can we write a high-profile outlook paper on what we forsee will happen?
- What numerical experiments must we perform to clarify the range of plausible scenarios?
- What should we observe where and when to follow these anomalies?

The Atlantic derived sublayer

Observations and model results point to a sequence of large warm and low density anomalies which have entered the Arctic Ocean in the 1990s and 2000s. These anomalies are on a decades-long passage through the Arctic Ocean at the depth of the Atlantic derived intermediate layer. Model results indicate a long potential survival of these anomalies due to the protection from exchange with the mixed layer by the Arctic halocline. The return of these anomalies to Fram Strait and subsequent arrival at the overflows can be expected. The density anomalies are associated with depth anomalies of the isopycnals and consequently have an adverse effect on the overflow volume driven by hydraulic effects. Despite the impossibility to make concrete predictions on travel time (because they depend on local Arctic Ocean dynamics) and potential interaction with locally induced modifications in the Nordic Seas, a general potential for a reduction of the overflows due to the arrival of the anomalies can be expected.

Future research is need to better understand the coupling of mid-depth layer flow and the surface circulation in the Arctic. Regarding observations the monitoring of passing signals as well as mapping of the density structure in the Amerasian Basin could help identifying the anomalies and allow the evaluation of the associated predictive potential.

The Beaufort Sea anomalies/Arctic Ocean Freshwater content

The changes observed (and simulated) in the Arctic Ocean freshwater content are not confined to the area of the Beaufort Gyre. On the contrary, in the 1990s and 2000s large changes took place in the Makarov and the Eurasian Basin. These were a consequence of changes in the atmospheric forcing patterns (shifts in the Arctic Oscillation) and the response of the Arctic Ocean hydrography. In recent years a number of drivers for the freshwater content and its storage and release could be identified, such as large scale atmospheric patterns (AO/NAO), local Ekman Pumping, sources and “sinks” (ice growth and melt, runoff, precipitation). Freshwater exports are responding to the interior conditions in the Arctic as well as being subject to independent driving forces.

Open issues are a clear separation of these driving forces and an investigation of the long term behavior of the freshwater content in the Arctic. It remains open if there are thresholds for freshwater content in the system. A full understanding of the driving processes are specifically important because the results of IPCC-class model results for the 21st century show very different projections for freshwater content and export. With respect to observations, the message is that the full Arctic Ocean needs to be considered and limiting observations to the Beaufort Gyre is undesirable. A huge challenge is a reliable estimate of export, i.e. the timing and amplitude of freshwater anomaly propagation. Here large gaps remains including observational budgets even for the volume fluxes, let alone the freshwater fluxes.

Appendix A

9th ASOF ISSG Meeting
Helland-Hansen Room, Geophysical Institute,
Bergen, Norway
8th November 2011
In Association with the THOR Annual Meeting

PURPOSE
This year's ASOF ISSG meeting has the following purposes:

1. Update on status and plans for ASOF-relevant programs.
2. Discussion of the ASOF Database and synthesis of observations from moorings during the IPY.
3. Discussion of 2011 iAOOS report (available at: http://www.asof.awi.de/fileadmin/user_upload/Reports/iAOOS_Report_final-1.pdf) and implementation.
4. Collaboration with the THOR program (http://www.eu-thor.eu/) on "Observed North Atlantic/Arctic Ocean climate variability and its predictability." See the separate agenda and schedule for this workshop, which will be held on Wednesday 9th November.

LOGISTICS
35 single rooms have been reserved at the Rica Hotel Bergen (http://www.rica.no/Hoteller/Rica-Hotel-Bergen/). The rates are NOK 830 (€107) per night for single room including breakfast. Please make reservation with the hotel directly. rica.hotel.bergen@rica.no) or by fax: +47-55 36 2901. Please make sure to mention the code: 10268205.

Travel instructions to the Hotel Rica are available at: https://t3projects.zmaw.de/Project-NEWS.505.0.html

Travel and hotel accommodations are expected to be paid by participants directly.

Wireless will be available.

The meeting will be at the Geophysical Institute, Allégaten 70 5007 Bergen. Directions from the Rica to the Institute will follow.

AGENDA

8:00	Tom Haine (JHU)	Report on action items from 8th ISSG meeting and plan for the day. Website, ESSAS cooperation, AOMIP cooperation, iAOOS report.

Reports on status, progress, and plans:

8:20	W. Walczowski (IOPAN)	Update on Atlantic Water in the West Spitzbergen Current– interannual variability, transformation and importance.
8:40	Takashi Kikuchi (JAMSTEC)	Eddies in the Beaufort Sea and its impact to ecosystem
9:00	Simon Prinsenberg (BIO)	Using the 12yr mooring array data from Lancaster Sound in validating the Arctic-CAA 6km grid model and in the development of the real-time ice-ocean observation station in Lancaster Sound
9:20	Bert Rudels (FMI)	Summer 2011 Polarstern Arctic cruise.
9:40	Jiayan Yang (WHOI)	The effect of topography and wind stress on the Nordic Seas overflow
10:00	**Coffee**	
10:30	Tor Eldevik (U. Bergen)	Quantifying the influence of Atlantic heat on Barents Sea ice variability and retreat
10:50	Marcello Magaldi (ISMAR)	Hydrostatic and non-hydrostatic simulations of the East Greenland Spill Jet.
11:10	Inga Koszalka (JHU)	Denmark Strait Overflow Water float diagnostics.
11:30	Bob Pickart (WHOI)	Fate of dense water exiting Denmark Strait
11:50	Bob Pickart (WHOI)	New fieldwork investigating the sources of Denmark Strait Overflow Water
12:10	**Lunch**	

Reports on status, progress, and plans continued:

13:10	Craig Lee (UW APL: given by Tom Haine)	Update on Davis Strait
13:25	Simon Prinsenberg (BIO)	Summary of AOMIP meeting
13:40	M. Karcher (AWI/OASYS)	Update on ACCESS.
13:50	Bert Rudels (FMI)	ACSNet.

Discussion of data analysis and synthesis:

14:00	M. Karcher (AWI/OASYS)	Progress and plans for the ASOF Database: Preliminary results
14:20	Humfrey Melling (IOSBC)	Proposed IASC synthesis of observations from oceanographic moorings during the IPY

Anomaly Propagation: Predicting Timing, Pathways, and Impacts

15:10 Tom Haine (JHU), Michael Karcher(AWI, OASYS), Laura de Steur (NIOZ)

The Atlantic derived sublayer: Observing, modeling and predicting transient signals connecting the Nordic Seas inflows, the Arctic, and the overflows.

The Beaufort Sea anomalies: Observing, modeling and predicting the discharge of Beaufort Sea freshwater through the CAA, Baffin Bay, and into the North Atlantic.

Where are the greatest uncertainties?
What are the plausible scenarios for anomalies to flush through the system?
What are the plausible impacts on MOC (overflows, LSW production) and ecosystems?

Can we write a high-profile outlook paper on what we forsee will happen?
What numerical experiments must we perform to clarify the range of plausible scenarios?
What should we observe where and when to follow these anomalies?

16:00-19:00 Close and **visit to Aanderaa Data Instruments (AADI)**

ISSG attendees:	Invited Guests:
Confirmed: Agnieszka Beszczynska-Moeller (AWI: ASOF/THOR workshop only) Jean-Claude Gascard (LODYC) Tom Haine (JHU) Bogi Hansen (FRS) Hjalmar Hjatun (FRS) Michael Karcher (AWI/OASYS) Takashi Kikuchi (JAMSTEC) (ISSG meeting only) Harald Loeng (IMR) Humfrey Melling (IOSBC) Svein Østerhus (U. Bergen) Bob Pickart (WHOI) Simon Prinsenberg (BIO) Bert Rudels (FIMR) Øystein Skagseth (IMR) Waldemar Walczowski (IOPAN) *To be confirmed:* Sirpa Hakkinen (NASA GSFC) Rebecca Woodgate (UW APL)	*Confirmed:* Ken Drinkwater (IMR) Tor Eldevik (U. Bergen), Ruediger Gerdes (AWI) Mirjam Glessmer (U. Bergen) Rolf Käse (ZMAW) Inga Koszalka (JHU) Karin Larsen (FRS) Marcello Magaldi (ISM, Lerrici) Paul Myers (U. Alberta) Steffen Olsen (DMI) Mike Spall (WHOI) Laura de Steur (NIOZ)) Kjetil Våge (U. Bergen) Jiayan Yang (WHOI)
Apologies from: Craig Lee (UW APL) Fiamma Straneo (WHOI) Peter Rhines (UW) Lilian Schubert (AWI) Peili Wu (UKMO) Igor Yashayaev (BIO)	**Additional Input Requested from:**

Appendix B

Observed North Atlantic/Arctic Ocean climate variability and its predictability
A joint ASOF/THOR workshop, Rica Hotel Bergen, Wednesday Nov 9 2011

Programme:

0900 **Welcome and introduction** – Tom Haine, Detlef Quadfasel, and Tor Eldevik

0910 *Keynote talk*
Hazeleger, Wilco: Decadal predictions of the subpolar North Atlantic

0940 3 x 15min presentations + discussions
Langehaug, Helene et al.: Mechanisms for decadal scale variability in the North Atlantic Ocean circulation in the Bergen Climate Model
Cunningham, Stuart A. et al.: An Index of Interannual variability for the Atlantic Meridional Overturning Circulation
Dunstone, Nick: Impact of observations on MOC predictions

1040 **Coffee break**

1100 *Keynote talk*
Skagseth, Øystein: Observed North Atlantic/Arctic Ocean climate variability of predictive potential

1130 3 x 15min + discussions
Larsen, Karin et al.: Atlantic water hydrography in the Faroe area – sources and variability
Lohmann, Katja: Relation between Iceland-Scotland-Overflow strength and AMO in the millennium simulations
Hawkins, Ed et al.: Arctic Predictability in HadCM3 and the APPOSITE project

1230 **Lunch**

1330 *Keynote talk*
Gascard, Jean Claude: TBA

1400 3 x 15min presentations + discussions
Spall, Mike: Precipitation and the shutdown of deep convection in marginal seas
Myers, Paul: Freshwater Pathways from the Arctic to the sub-polar North Atlantic from modelling and data
Glessmer, Mirjam et al.: Nordic Seas freshwater anomalies tracked back to Atlantic inflow?

1500 **Coffee break**

1515 *Keynote talk*
Palmer, Matt: Anthropogenic controls on the meridional overturning circulation over the 20th Century

1545 3 x 15 min presentations + discussions
Mecking, Jenny et al.: Origins of Atlantic Decadal Varibaility
Frankignoul, Claude: The response of the atmospheric circulation to the variability of the Atlantic meridional overturning circulation
Keenlyside, Noel: Atmospheric response to North Atlantic Decadal variability

1645 **Coffee break**

1700 Concluding discussion
E.g., *Where do we stand concerning actual climate prediction – in general, and for the North Atlantic/Arctic region in particular? Where should/could we be heading?*

1800 **End of workshop (the latest)**

1930 **Joint ASOF/THOR dinner**

Alphabetic lists of contributors:

ASOF

1. Glessmer, M. et al.: Nordic Seas freshwater anomalies tracked back to Atlantic inflow?
2. Koszalka, Inga: (something on float diagnostics for EGC)
3. Magaldi, Marcello: (something on Spill Jet)
4. Myers, Paul: Freshwater Pathways from the Arctic to the sub-polar North Atlantic from modelling and data
5. Pickart, Bob: TBA
6. Spall, Mike: Precipitation and the shutdown of deep convection in marginal seas

THOR

7. Berens, Eric et al.: The impact of eddy processes on the freshwater distribution and AMOC in Greenland melting scenarios
8. Berx, Barbara et al.: Variability of volume, heat and salt transport in the Faroe Shetland Channel on seasonal and inter-annual time scales
9. Cunningham, S.A. et al.: An Index of Interannual variability for the Atlantic Meridional Overturning Circulation
10. Drijfhout, S.: Transitory cooling after a thermohaline circulation collapse
11. Dunstone, Nick: Impact of observations on MOC predictions
12. Frankignoul, C.: The response of the atmospheric circulation to the variability of the Atlantic meridional overturning circulation
13. Hansen, B. et al.: Mixing of the Faroe Bank Channel overflow by convective events
14. Hawkins, Ed et al.: Arctic Predictability in HadCM3 and the APPOSITE project
15. Jonsson, S. and H. Valdimarsson: Variability and forcing of the flow of water masses on the north Icelandic shelf
16. Keenlyside, N.: Atmospheric response to North Atlantic Decadal variability
17. Langehaug, Helene et al.: Mechanisms for decadal scale variability in the North Atlantic Ocean circulation in the Bergen Climate Model
18. Larsen, Karin et al.: Atlantic water hydrography in the Faroe area – sources and variability
19. Latif, M. and W. Park: Internal and External Variability: Kiel Climate Model versus Data
20. Lohmann, Katja: Relation between Iceland-Scotland-Overflow strength and AMO in the millennium simulations
21. Marini, C. and C. Frankignoul: The Atlantic Multidecadal Oscillation in a simulation of the last millennium with the IPSLCM4 climate model
22. McCarthy, G. et al.: Interannual variability in the Atlantic meridional overturning circulation at 26.5°N
23. Mecking, J.: Origins of Atlantic Decadal Varibaility
24. Mjell, T.L., et al.: Variability in ISOW Vigor Over the Last two Millennia and its Relationship to Climate
25. Paka, V.: Preparation for the final microstructure measurements in the Denmark Strait overflow
26. Park, W. and M. Latif: Atlantic Meridional Overturning Circulation response to idealized external forcing
27. Swingedouw, D. et al.: Decadal fingerprints of fresh water discharge around Greenland in a multi-models ensemble
28. Wouters, Bert: North Atlantic interdecadal Meridional Overturning Circulation variability in the EC-EARTH coupled model