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Special IPY Edition

Planning for the International Polar Year 2007-08

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Momentum for holding an International Polar Year in 2007-2008 continues to build. After receiving strong endorsements from the AOSB, the International Arctic Science Committee, and the European Polar Board at Arctic Science Summit week in Kiruna, Sweden, in April 2003, organizers have continued to build support for the concept. Other endorsements and input have been received from the US Polar Research Board, the Scientific Committee on Antarctic Research, the World Meteorological Organization and, most recently, the Antarctic Treaty nations.

At this stage in the planning, the focus is on establishing an underlying international structure to guide development of a coherent IPY strategy. Planning to date has been ad hoc, but leadership is being conveyed to the International Council for Science (ICSU). In May 2003, the ICSU Executive Committee took its first steps to form an IPY Planning Group and selection of core members is underway. This group will hold its first meeting later this summer to begin gathering information and formulating a draft science plan. This group is expected to call on those nations wishing to be involved to form a national committee to facilitate communication and planning; some nations have already begun the process in anticipation of the request. The IPY Planning Group will devise ways for all interested groups to describe their ideas and then move forward in selecting the science themes. Efforts are also underway to inform relevant agencies and decision-makers of IPY planning to ensure that funding can be made available for IPY activities.

IPY 2007-2008 is envisioned to be an intense, international campaign of coordinated polar observations and analysis: it will be bipolar in focus, multidisciplinary in scope, and truly international in participation. It is likely to contain a select number of scientific elements, incorporating elements of exploration, study of polar processes, and activities to monitor

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and understand change and its human dimensions. Its goals would include galvanizing new and innovative observations and research, building on and enhancing existing programs and initiatives, attracting and developing the next generation of polar scientists, and creating an exciting range of education and outreach activities that engage the public.

Why an International Polar Year? Most polar scientists know that the history of exploration of the polar regions is intimately intertwined with the history of polar science (see Box). The years 2007-2008 will mark the 125th anniversary of the First International Polar Year (1882/3), the 75th anniversary of the Second Polar Year (1932/3), and the 50th anniversary of the International Geophysical Year (1957/8). The IPYs and IGY were major initiatives, which resulted in significant new insights into global processes, and led to decades of invaluable polar research. The IGY resulted directly in the establishment of the Antarctic Treaty System. But in spite of the substantial investment of effort in polar exploration and research over the years, both by individual nations and through international programs, the relative inaccessibility and challenging environment of these regions have left them less well explored and studied than other key regions of the planet. This is despite the pivotal place of the Arctic and Antarctic in the Earth system and their many significant connections to questions of global climate, sea level, biogeochemical cycles, and marine and terrestrial ecosystems.

A QUICK IPY HISTORY

The First International Polar Year was inspired By Karl Weyprecht, an officer with the Austro-Hungarian navy. Weyprecht argued that polar expeditions should include teams of scientists who could make important discoveries by making observations on aurora, geomagnetism, and meteorological conditions. This was the first major international science collaboration and planning took seven years. Although he died before commencement of the First International Polar Year, 11 countries participated in 15 Polar expeditions (12 to the Arctic and 3 to the Antarctic), fulfilling Weyprecht's dream and heralding a new age of scientific discovery.

The Second International Polar Year was proposed in 1928 at an international conference of meteorological service directors. Forty nations participated in Arctic research from 1932 - 1933 (the 25th anniversary of the first IPY), largely in the fields of meteorology, magnetism, aurora, and radio science. However, due to the worldwide depression, the second IPY was smaller than originally envisioned.

What began as the Third International Polar Year (1957 - 1958) was expanded and then renamed the International Geophysical Year. It was proposed in 1952 by the International Council of Scientific Unions, following a suggestion by NAS member Lloyd Berkner. The IGY included significant work in the Antarctic and some in the Arctic, as well as geophysical work around the globe. Sixty-seven nations conducted research during the IGY, including 12 nations that established and maintained 65 stations in Antarctica.

Given this history, there is some debate whether IPY 2007-2008 is the third or fourth such effort. But regardless of name, the underlying premise is clear: the polar regions are unique and offer incredible opportunities for improving our understanding of the Earth system.

Contribution by the Arctic Ocean Sciences Board (AOSB) to the planning of an International Polar Year in 2007-08

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Summary: The Arctic Ocean Sciences Board warmly and strongly endorses the plans for a fourth International Polar Year in 2007-08, and commends three special studies as part of that initiative:

- A multi-platform Intensive Observing Period to focus on the Arctic Ocean itself, its physics, biogeochemistry, variability and the climatic drivers of that variability.
- An integrative circum-arctic assessment of the physical, biogeochemical, ecological and socio-economic importance of the Arctic shelves
- A study of the role of the High-latitude Oceans in the Global Water Cycle.

These studies are of very different scale, ranging from the regional scale required for the intensive system study of the Arctic Ocean, increasing to include much of the Arctic-subarctic seas in the integrative study of Arctic shelves in order to cover the exchanges of water to and from these shelves including associated fluxes of chemical constituents, and finally increasing to the global scale on which the Earth's Water and Carbon Cycles operate.

Rationale: the case for a new IPY is commended by the following facts:

(i) The Arctic Ocean is likely to be very different in 2007-8 from that revealed in our past observational record. There seems little doubt that the Earth is warming. Including 2002, all ten of the warmest years since records began in 1861 have occurred since 1990 (Jones and Moberg, 2003), the 4 warmest years of all being grouped in the last six (1998, 2002, 2001 and 1997 in descending order). Because of these recent extremes, the pace at which average global temperatures have been rising, which amounted to ≈+0.6 °C over the past century (IPCC, 2001), accelerated in the past two decades to a rate of +0.2 °C per decade. To quote the Third Assessment Report of the IPCC (IPCC TAR, *Impacts, Adaptation and Vulnerability*, Section 5.7 p 59) *"Climate change in the polar region is expected to be among the greatest of any region on Earth. Twentieth century data for the Arctic show a warming trend of as much as 5 °C over extensive land areas."* and on p60, *"The Arctic is extremely vulnerable to climate change and major physical, ecological and economic impacts are expected to appear rapidly"*. Preliminary reports from the Arctic Climate Impact Assessment (ACIA: reported in Arctic Bull., March 2003, p10) *"….suggest that mean annual temperatures could continue to increase by 2 to 5 °C and that UV-B radiation ….could increase by 20-90% in April in much of the Arctic by 2010-2020".* These facts in themselves commend the further intensive study of the Arctic *system* in IPY-4. This is reinforced by the fact that the recent amplification of the NAO—the dominant recurrent atmospheric forcing mode in the Arctic sector—may be unique in 600 years (Jones 2003).

(ii) Change in the Arctic is likely to have global climatic impacts. Two main changes of global scale and importance are expected. First, it has long been recognized that the Atlantic Meridional Overturning Circulation (MOC) is potentially sensitive to greenhouse gas- and other climate forcing, and that changes in the MOC have the potential to cause abrupt climate change. Most (but not all) projections of greenhouse gas induced climate change anticipate a

weakening of the MOC in the North Atlantic in response to increased freshening and warming in Arctic and subarctic seas (Rahmstorf and Ganopolski, 1999; Delworth and Dixon, 2000; IPCC, 2001) and the supposition is that the signal of Arctic change will be transferred south in the ocean circulation to influence the MOC—in the shallow outflows of fresh water which pass from the Arctic to the Atlantic either side of Greenland, and in the two main dense overflows which pass south through sills in the Greenland-Scotland Ridge to ventilate the deep Atlantic. More specifically, deep waters formed within the Arctic Ocean contribute about 30% to the dense water which overflows from the Nordic seas to 'drive' the abyssal limb of the Global thermohaline 'conveyor'. And three changeable components of Arctic origin contribute to the flux of freshwater to the North Atlantic that has been implicated (in models) with slowing-down the MOC. These are: relatively fresh waters of Pacific origin (see Jones et al 2003), the discharge of the rivers which flow into the Arctic Ocean, and sea ice (in solid form and as meltwater). The paleo temperature record for Central Greenland (e.g. Alley, 2000) is our best indication that these outflows from northern seas have the potential to affect the MOC and hence our climate. That record shows specifically that rapid irruptions of freshwater to the northwest Atlantic associated with intermittent iceberg surges (Heinrich 1988; Alley and MacAyeal, 1994; Ganopolski and Rahmstorf, 2001) and lake-bursts (Alley et al, 2002; Teller in press) have been a cause of drastic and rapid cooling events in the past, presumably in response to a slowdown in the MOC.

As a second major change, we can expect the Earth's water cycle to accelerate with global warming, simply because of the exponential increase of water vapour pressure with temperature; this change should be evident in the changing distribution and structure of salinity in the upper ocean and may eventually itself be the cause of change in the MOC.

The studies: An International Polar Year opens a unique opportunity for coordinated multi-disciplinary international studies of the Arctic Ocean. The AOSB commend the following three special studies for IPY-4:

(i) An Intensive Observing Period for the Arctic Ocean System.

As Swift pointed out in the 2002 ARCSS All-Hands Workshop, *"Reference-quality sections of CTD, hydrographic, and tracer data obtained from the Nordic Seas and Arctic Ocean during the 1980s and 1990s have become our primary window to the structure and circulation of the subsurface water masses there, and have played a formative role in the transformation of oceanographic thinking about the region and its relationship to the global thermohaline circulation. Where reference-quality Arctic Ocean profile data from the mid-1980s and late-1990s overlap, there are clear signals of change: not only the well-known 'warming' signal is seen but there is also a signature of a late-1980s Arctic Ocean ventilation event …."*

This statement reflects the fact that much of our knowledge regarding processes relevant to Arctic water mass formation and circulation and its variability has been gained stepwise through episodes of intensive field activity. Though our early knowledge was based on data from the many early ice camps, largely supported by the Soviet Union, our recent advances have largely been performed by icebreaking research vessels and submarines (noteably SCICEX) during the last 10-20 years. Essential supporting activities have been the provision of a gridded oceanographic data-set in the form of the Gore-Cherdomyrdin atlas, which provided a climatology against which more modern data could be compared, and the ACSYS Arctic Drifting Buoy Program which for decades has provided data on the changing large-scale flow patterns of sea-ice across the Arctic Ocean.

These modern field activities have mostly been single studies of different specific regions and processes (the first Arctic transect was not provided until the U.S./Canada Arctic Ocean Section of 1994) and considering all of the variability that has been deduced from these investigations there is a clear need for a larger synoptic study of the most critical regions of the Arctic Ocean, together with process-related investigations. Swift in fact proposed to ARCSS that a decadal reoccupation of a trans-Arctic CTD/hydrographic section should be made across the Chukchi

Borderland, Makarov Basin, Lomonosov Ridge, Amundsen Basin, and western Nansen Basin, coupled with a decadal survey across the key basins of the Nordic Seas to cover changes in the characteristics and supply of certain source waters external to the Arctic Ocean itself.

The prospect of an International Polar Year however opens a unique opportunity for a coordinated multi-disciplinary international study of the entire Arctic Ocean. This could be implemented by utilizing the resources of ships from the many nations (~10) at present performing investigations in the Arctic, aircraft to support ice camps, and moorings/buoys and other high technology instrumentation for collecting time series data. With a truly international planning effort, such a coordinated investigation using the right platforms for the right work would result in major advances in our understanding of this climatically significant region, of its variability at interannual and longer time scales, and of the way in which the variability in its various source regions becomes imprinted on the Arctic Ocean system.

One of the most striking aspects regarding the large scale variability of the Arctic Ocean during the recent past, concerns the Sea-Ice cover at the end of the summer (melting) season, which serves as a background for the further development of the multiyear ice during the following winter season. Actually there is a strong discrepancy between (1) observations from space, (2) in situ observations and (3) models, in dealing with this critical issue and it is still quite uncertain how to interpret the observed large-scale changes of the Arctic perennial ice.

Based on a new set of observations and validated models, we propose a dedicated study of arctic sea-ice during an entire seasonal cycle (2007-2008) in order to re-examine the recently-observed changes of the perennial ice in terms of trend versus variability. We propose to operate new lagrangian ULS drifters (prototype under development) measuring ice draft in a number of places restricted to the deep part of the Arctic Ocean, as well as the near-surface currents and the depth of the arctic cold halocline. This original data set will be complemented by (a) surface data concerning the air-sea-ice interface, in addition to a large set of remotely sensed parameters, (b) deep currents and water masses observations made by floats drifting under ice and (c) in situ data collected from ships and platforms operating in the Arctic Ocean. The domain of investigation will be the deep Arctic Ocean basin (not including Arctic shelves in this study) for several reasons : (1) most of the perennial Arctic Sea-Ice is located over the deep basin (2) the circulation of Atlantic Water is concentrated along the continental margin (3) lagrangian ULS drifters can only be acoustically operated in deep waters due to the limited range of acoustic propagation in shallow waters. This new data set will be used to constrain models of various kinds in order to provide the most accurate answers regarding Pan-Arctic perennial sea-ice, and its large-scale and long-term variability.

The preceding example makes the point that new and prospective observing techniques will be an essential element of an Intensive Survey of the Arctic Ocean during IPY-4 and are in fact part of the rationale for recommending one. Because the region is data-poor and so hard to access, the time is ripe for concerted multi-platform, multi-sensor studies that rely more on automated and autonomous systems such as floats, gliders, drifters, AUVs and long-term moorings to determine both natural variability and long-term changes. Many of these will rely on standard oceanographic techniques, modified to avoid or take advantage of the Arctic's persistent ice cover. Progress is being made on ice-tethered buoys with two-way communications capability, under-ice navigation of drifters and on ice-strengthened or ice-avoiding moored profilers. Plans are being made for linked systems such as PLUTO (Polar Links to Undersea Telecommunications and Observatories) that would combine acoustic tomography, cabled observatories, moorings, drifters and gliders and AUVs to provide coordinated, synoptic Arctic datasets. Many of these developments should have matured and be ready for deployment during the IPY. As described in Section 4 below, the International Study of Environmental Arctic Change (Inter-SEARCH) will also be developed in time to lead the scientific planning and coordination required for such a study during IPY-4, and has the pan-Arctic scope to do so.

(ii) An integrative circum-arctic assessment of the physical, ecological and socioeconomic importance of the Arctic shelves.

Most simulations of the future extent of Arctic sea-ice anticipate retraction. In Figure 1, we illustrate the projection of sea-ice extent and thickness at the time of IPY4 (2008), from work by the Climate Modelling Group, School of Ocean and Earth Sciences, University of Victoria, Canada. (http://wikyonos.seos.uvic.ca/movies/ice_annual.html). It makes the key point that the impact of a retracting ice cover will be felt first and greatest around the circum-arctic shelves, which is also the site of greatest socio-economic activity. These two facts commend the present study. Following on from current regional studies such as SBI and CASES, it is the AOSB view that there will, by the expected date of IPY-4, be compelling reasons to provide an integrated assessment of the physical, biogeochemical, ecological and socioeconomic impacts of change throughout the entire circum-arctic span of the shallow continental shelves—nearly 30% of the area of the Arctic Basin. Their further significance and the reason for including the sea-areas upstream and downstream from these shelves will be plain in the following varied examples.

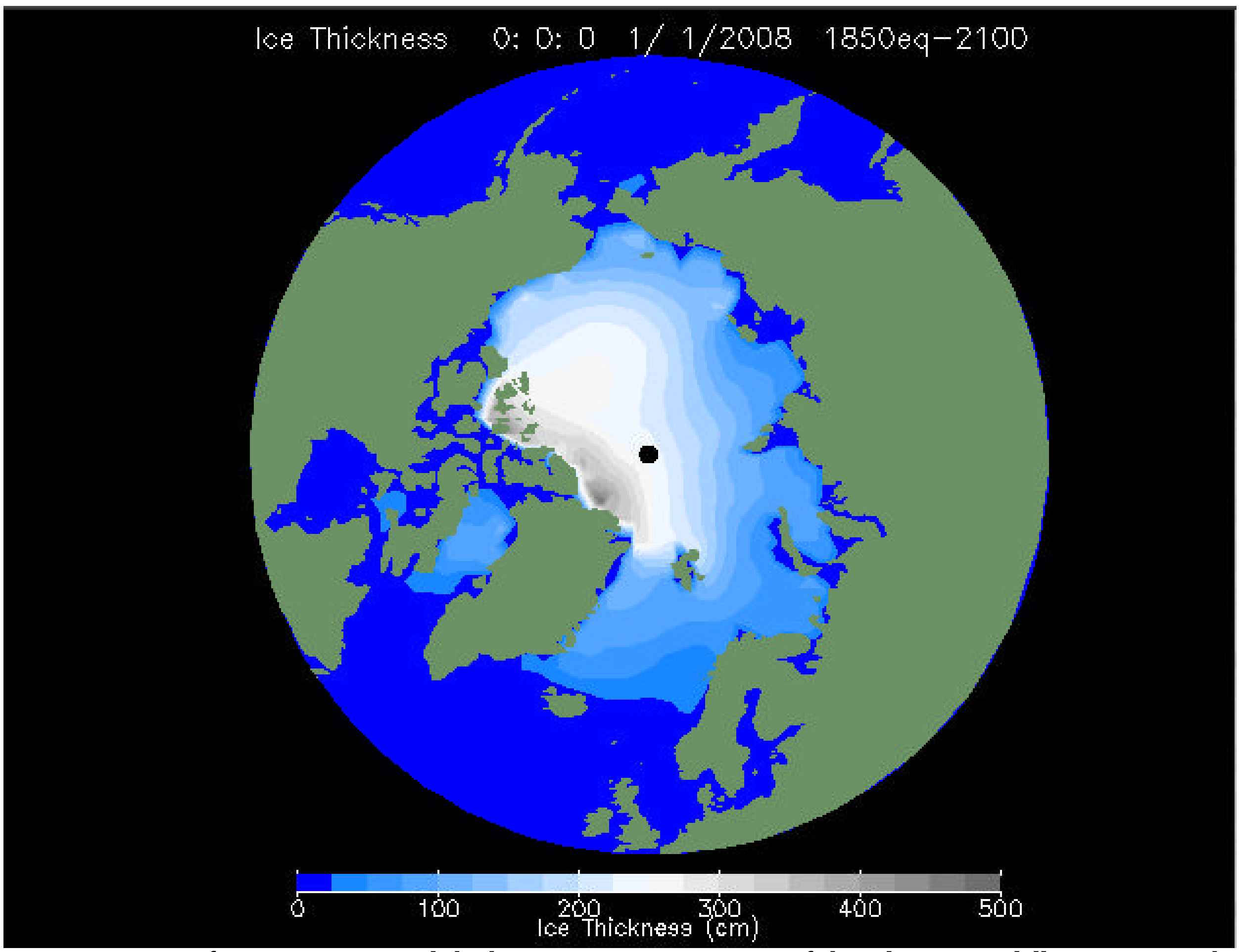

Figure 1: Projection of sea-ice extent and thickness in 2008. Courtesy of the Climate Modelling Group, School of Ocean and Earth Sciences, University of Victoria, Canada

- The water which inflows to the Arctic across the Barents Sea shelf—subsequently transformed into upper Polar Deep Water (uPDW)—actually forms the bulk of the contribution which the Arctic Ocean makes to Denmark Strait Overflow and hence to the deep limb of the MOC. Eurasian Basin Deep Water (EBDW) will always be too dense to contribute to overflow through Denmark Strait, and Canada Basin Deep Water

(CBDW) is currently too dense to do so; (Rudels et al., 2002). However, any deep ventilation within the Arctic Ocean and the Nordic Seas will contribute to an overflow by "pushing out" overlying waters.

- The circulation, nutrients, sea-ice dynamics, stratification and light climate of the circum-arctic shelves currently support high levels of biological production. These processes favor an enhanced flux of carbon dioxide from the atmosphere into the surface water; assessing the role of the circum-arctic shelves in driving change in the global carbon cycle is a priority goal for this study. Much of the projected climate change has a major impact on primary production through alteration of the nutrient input and light regime (stratification).

- The Arctic shelves form the conduit for contaminant inputs to the Arctic Ocean. The AMAP Report released in late 2002 suggests that long term climate variability and change is likely to affect the transport of contaminants to and within the Arctic, such as the Atlantic waters carrying radionuclides from European reprocessing plants. The large amount of river runoff entering the Siberian shelf seas, mainly the Kara and Laptev Seas, also brings particulate matter, nutrients, dissolved inorganic and organic carbon, as well as dissolved metals and a range of pollutants onto the shelves. A proportion of these materials are buried in the sediments while other parts enter the deep central Arctic Ocean.

- The formation of high-density water on certain Arctic shelves through brine rejection during freezing (eg Barents Sea; Nansen, 1909, Midttun, 1985) and its subsequent down-slope drainage is a major contributor to the ventilation of the Arctic Ocean as well as facilitating air – sea gas transport. With more open water in the fall (less sea-ice cover) there is a potential to form more sea ice during the winter season, increasing the brine production, which will add to both ventilation of deeper waters and to the uptake of atmospheric carbon dioxide.

- The various chemical signatures stemming from the shelf seas are useful tools to trace water masses in the central Arctic Ocean at all depths from the surface down to the bottom. They provide major insights into formation processes, circulation patterns, and residence times. Retraction of the sea-ice cover from the shelf edge may also cause altered vertical exchange, extended residence times and altered spreading pathways for contaminant inputs from the shelves. It would be a priority in this study to study the boundary current all around the Arctic Ocean, deducing the local interactions with the shelves from the change in the properties of this current along its flow path.

- Within the Arctic shelf sediments large pools of methane hydrates and methane gas pockets are present. The fate of these methane pools, with their potential to significantly add to the greenhouse gases in the atmosphere, is unknown but could be significant for climate change. Mapping the distribution of methane concentration in the Arctic shelf seas may permit us to deduce possible leakages from the underlying sediment.

- There is the strong potential for the invasion of nuisance bloom species to Arctic shelves as ice-retraction opens new sea-routes to commercial shipping. As Showstack (2001) reports: "*The IMO estimates that 10 billion tonnes of ballast water are transferred globally each year, and that 3000 species of animals and plants may be transferred daily around the world.*"

- The rapidity and extent of climate change in recent decades has left indigenous residents of the Arctic & subarctic shelves unable (in certain cases) to plan their activities (ACIA Report 2003). It will be necessary in IPY-4 to assess the prediction of the complex of changes on these shelves from the perspective of these indigenous residents, not merely from the perspective of science.

(iii) A study of the role of the High Latitude Oceans in the Global Water Cycle.

In view of the exponential increase of water vapour pressure with temperature, it is to be expected that the present extreme warmth of the Earth should be accompanied by an acceleration of the global water cycle yet this has been difficult to demonstrate from terrestrial pan-evaporation data (Roderick and Farquhar, 2002; Ohmura and Wild, 2002). However, much of the global water cycle is acted out over the oceans (which experience, for example, 86% of planetary evaporation and receive 78% of planetary precipitation), and there is increasing evidence (Curry, Dickson and Yashayaev 2003), that the Ocean is already registering an acceleration of the water cycle in the large-scale changes in ocean salinity that have been observed over recent decades.

For example, when we examine salinity changes along a long meridional transect through the South and North Atlantic from 50S to 60N, we find evidence of long term freshening over much of the watercolumn towards both poleward limits of the section between the late 1950s–early 60s and the 1990s, while in the intervening tropics and subtropics, the upper ocean became more saline. Averaged over the watercolumn, these observed changes in salinity are of a considerable amplitude and scale, amounting to –0.03 north of 40N and +0.02 between 40N and 25S. This sense of change in the large-scale salinity field does not seem be confined to the Atlantic. The salinification of low latitude surface oceans is also reported to be a feature of the Pacific (Wong et al, 1999; 2001) between the 1960s and the WOCE measurements of 1985-94. And over the same time period that the low latitude oceans were growing more saline, the water masses originating *globally* at high latitudes have become increasingly fresh. As in the north and South Atlantic, the intermediate waters of the Pacific, ventilated at higher latitudes in both hemispheres, have also become significantly fresher (Wong et al op cit)—by 0.001 per year over 25 years in the Antarctic Intermediate Waters of the South Pacific—and Bindoff and McDougall (2000) report similar findings for the Indian Ocean in comparing measurements made in 1962 with data from 1987.

If these observations prove representative, the simplest explanation for an apparently-symmetric freshening of intermediate waters at high latitudes of the North and South Pacific, Indian Ocean, and North and South Atlantic, and the parallel salinification of the upper watercolumn at low latitudes is an intensification of the global hydrologic cycle over recent decades. Seen in this light, the major increase in the freshwater outflow from the Arctic and subarctic to the North Atlantic over the past 40 years [reflected in a ≈ 20% increase in the southgoing flux of fresh waters of the shelf and upper-slope around the margins of the Labrador Sea since the mid-1960s (Dickson et al 2003), a broadscale freshening of the upper 1-1.5 km of the Nordic Seas over the past 4-5 decades (Blindheim et al 2000), and a remarkably rapid, persistent and uniform freshening of the entire system of overflow and entrainment that ventilates the deep North Atlantic by about 0.010 - 0.015 per decade over the past 4 decades (Dickson et al 2002)] may not be a N. Atlantic event merely, but the strong local expression of a global change.

Much remains to be done to confirm these preliminary findings—investigating the hydrographic record more globally to confirm whether these changes in the Ocean's salinity record are general, estimating E-P rates where the ocean data is good enough, attempting to assess from rawindsonde data what inter-ocean transfers of water vapour are involved in the problem, and trying to partition the high latitude freshening/ low latitude salinification down to its component parts.

Time remains for these tasks to be pursued and completed before the start of IPY-4 in 2007-8. If the hypothesis stands up to that further scrutiny, then we suggest that this theme—the role of the polar oceans in the Global Water Cycle—is of the appropriate scale and importance to drive a global investigation in IPY-4 with the broadest possible range of involvement by the scientific community. In the case of the Arctic alone, its study will involve changes in the windfield, in the storm climate, in circum-arctic precipitation and riverflow, in the horizontal and vertical ocean circulation, in the atmospheric moisture flux, in sea-ice extent, thickness and distribution, in the factors controlling the melt-season, in oceanic exchanges with subarctic seas, in the ice and freshwater flux to the N. Atlantic and hence in influences on the MOC. However this theme will require a truly bi-polar effort. Though Arctic and Antarctic Seas have characteristics and processes in common, their ventilation, circulation, deep-water formation and mode of influence on the global conveyor are quite different. And although annular modes dominate atmospheric variability around both poles (Thompson and Wallace 2000; Thompson et al 2000), the time dependence of the Arctic Oscillation (AO) and Southern Annular Mode (SAM) are in fact quite uncorrelated (Visbeck, pers comm). Thus scientific involvement in the proposed theme is likely to be both broadly-based and bi-polar, while the socio-economic importance of a change in the Water Cycle could scarcely be higher.

The International context: Polar science seems well suited to the development of the suggested tasks in the run-up period to IPY4. The following list, far from complete, will serve to support the point.

- The changes already evident in the Arctic, such as the cyclonic shift in the distribution of Atlantic/Pacific waters, atmospheric pressure and winds, as well as evidence for the thinning and retreat of the sea-ice, among others were the stimulus which led the community of Arctic researchers to formulate plans for an International Study of Environmental Arctic Change (Inter-SEARCH). While Inter-SEARCH plans to study the Arctic climate system as a whole (ocean-ice-atmosphere-rivers-biota-people), its oceanographic aspects are of great interest to the AOSB. The current state of planning for Inter-SEARCH, several years in the making, will be further refined at an Open Science Meeting (Seattle, US) in October 2003. Following publication of the Arctic Climate Impact Assessment (ACIA) in 2004, these plans will be adjusted appropriately and coordinated internationally at the second Int'l. Conference on Arctic Research Planning (ICARP-II) in 2005. Thus, the long, convoluted process of scientific planning and coordination required for IPY should be complete well before 2007-2008. Since the WCRP CLIVAR program stops short of the high Arctic, such a strong international coordinating body will be necessary to a successful IPY program in the north.

- The draft Second Call for EC Framework Programme 6, due for release in July 2003, is anticipated to include a call for Specific Support Actions that might be used to develop the themes proposed above: *"European contribution to climate related polar research: Actions towards international co-operation within climatic aspects of polar research with special emphasis on research related to climate change and its impacts on the Arctic with a view to providing a pan-European contribution to setting up of the International Polar Year"*

- The draft submission by the Climate and Cryosphere (CliC) Project of WCRP to the planning of IPY-4 currently contains a recommendation for a Joint Ocean Expeditionary Year in respect of the Southern Ocean, which might usefully complement the Intensive Observing Period for the Arctic proposed above.

- The Surface Ocean Lower Atmosphere Study (SOLAS) of IGBP and SCOR supports studies of processes pertinent to the exchange of climate-related gases between the ocean and atmosphere, highly relevant in the Arctic Ocean with its pristine environment.

- The novel techniques of ocean observation that will be necessary to address the suggested tasks are already under development. These include, hybrid glider-RAHFOS systems for sub-ice survey, ice tethered buoys to provide acoustic links to sub-ice gliders, Polar Links to Undersea Telecommunications and Observations (PLUTO), active and passive satellite systems capable of measuring sea-ice extent, deformation, freeboard, velocity and shear with high resolution, low cost profiling systems (eg the HOMER system of UK-SAMS) capable of making hydro-profiles to the ice-base affordably at the high spatial resolution necessary in Northern Seas.

- An evolving sequence of intensive national & international studies are already underway that will flesh-out the topics proposed in the interim before IPY-4: examples: ALIAS, ARCUS, ASOF, CASES, CHAMP, IAPP, IMPACS, JWACS, NoCLIM/ProCLIM & RAPID.

- New tracers of the Arctic and subarctic ocean circulation are coming into use, 129-I, SF6 etc.

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Glossary:

ACIA: Arctic Climate Impact Assessment
ACSYS: Arctic Climate System Study of the World Climate Research Program
ALIAS: Arctic Logistics Information and Support of the Arctic Research Consortium of the US (ARCUS)
AMAP: Arctic Marine Animal Program
ARCSS: Arctic System Science Program at NSF
AOSF: Arctic-Subarctic Ocean Fluxes program
CASES: Canadian Arctic Shelf Exchange Study
CHAMP: Arctic Community-wide Hydrologic Analysis and Monitoring
IAPP: International Arctic Polynya Program of the AOSB
ICSU: International Council for Science
IMPACS: International Monitoring Program of the Arctic Canadian Seas
IPCC: Intergovernmental Panel on Climate Change
JWACS: Joint Western Arctic Climate Study
NoCLIM/ProClim: Norwegian Ocean and Climate and Project and the Polar Ocean Climate Processes Project
RAPID: Rapid Climate Change Project
SCICEX: Submarine Arctic Science Cruise Exercise of the U.S. Navy

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