OCEANOGRAPHIC AND MARINE METEOROLOGICAL OBSERVATIONS IN THE POLAR REGIONS

A Report to the Joint WMO/IOC Technical Commission on Oceanography and Marine Meteorology

WMO/TD-No. 1032

2000

JCOMM Technical Report No. 8

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)

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N O T E

C O N T E N T S

FOREWORD

The following report consists of information gleaned from documents, from electronic sites, from organizations and from experts and managers in the interested organizations. I am grateful to all the sources, especially those who reviewed and commented on the original draft.

The task proved a bigger one than I had originally supposed. There is obviously a great deal of fragmentation and overlap between the national and international research and observational programmes at the same time as an existence of serious data and knowledge gaps. The information on many of the national programmes was obtained electronically and the currency of such information varied widely. The first draft included an Annex on the national programmes in the polar regions, but this was found to vary so much in content and currency that it has been dropped from the final report. Such a collection of information and references will however be useful and I recommend to JCOMM that the Member States of WMO and IOC be tasked with putting such a document together and keeping it up to date.

I have incorporated commentary and views when I thought that such comments would be helpful to JCOMM. Some of these were my own, but many were those I received from the experts. I have included very few references as I had to paraphrase the original text in most instances and will take personal responsibility for what is recorded in the text.

G.L. Holland

BACKGROUND

In Geneva, December 6-8, 1999, a meeting of experts was held to discuss a JCOMM/GOOS Polar Region Strategy. The meeting was part of a series of meetings to implement the decision of the WMO and IOC Governing Bodies to establish the JCOMM. The meeting agreed on the importance of JCOMM having available a mechanism to review, coordinate and advise on appropriate matters relating to polar seas and other areas affected by sea ice. It therefore recommended that the Joint Technical Commission establish a mechanism for dealing with polar seas and other sea ice regions. The meeting noted the importance of this mechanism coordinating and interacting closely with other bodies active in polar oceans and other sea ice areas. These included the Baltic Sea Ice Meeting, the International Ice Charting Working Group, relevant SCAR working groups, the Antarctic Treaty Consultative Meeting, the WMO Executive Council Working Group on Antarctic Meteorology, IODE and a range of other international committees and bodies.

The meeting also agreed on the importance of developing an integrated Polar Region Strategy Document for JCOMM. Such a document would serve as primary guidance for the work of the JCOMM working group proposed above, and should also prove useful to GOOS in developing its work related to polar regions. The meeting further agreed on the procedures and timetable for completion of the document.

The first step in the development of a strategy document was to request the preparation of a report on oceanographic and marine meteorological observations in the polar regions that is the present document.

1. INTRODUCTION

By far the most comprehensive observation system in the polar regions relates to the sea ice services provided by national authorities to the shipping industry, particularly in the north (e.g. the Arctic Ocean and adjacent seas, the Baltic Sea, Sea of Okhotsk, Beaufort Sea, the Greenland waters and the Gulf of St. Lawrence). These systems are routine systems that have evolved with technological advances over many decades of use. Although marine transportation has been the prime user of operational data in these regions, other operational uses for ice data exist (Such as the impact of ice on coastal and offshore structures, ice edge information for fisheries, ice cover for seal population reproduction etc.). Operational information for northern communities also involves routine requirements for marine atmospheric and ocean data as they relate to weather prediction, extreme weather warnings, search and rescue etc.

The polar regions have always been special regions for those dealing with the ocean and atmospheric environments. The extreme temperatures, the presence of permafrost, glaciers and sea-ice, the lack of vegetation and the strong seasonal fluctuations in radiation all make for a unique and hostile environment. The remoteness and mystery of these frozen outposts of the world have attracted much exploration and scientific endeavour over the years, but recently the polar regions have come under even more intense scientific scrutiny. Observations in the past have shown, and global climate models have predicted that the polar regions will undergo relatively more rapid and greater changes than other regions of the world and therefore climatologists are looking at the poles with renewed interest. It has also been recognized that the polar regions play a major role themselves in the global ocean and atmospheric processes and contribute to global climates in a significant way.

In addition to the need for knowledge of the polar regions in order to understand planetary changes in climate, there are many shorter and urgent reasons of high social and economic value that should lead governments to address the needs for monitoring the Arctic and Antarctic. One of the more alarming hypothesis is that changes in the Arctic outflow may lead to a drastic alteration, over a matter of decades, in the North Atlantic ocean circulation, which is responsible for the temperate climate of Western Europe.

The Antarctic resources and environment are protected under an international agreement but the changes in the land and sea ice cover are still the subject of much attention in terms of global climate change and navigation in the southern polar seas.

For the Polar Regions, there are many environmental issues to consider. There has been much concern expressed recently in the way that persistent chemicals are migrating to and impacting on the polar ecology and indeed on the northern indigenous populations. Environmental threats are likely to increase, more particularly in the north, as the search for resources and developments in science and engineering overcome some of the previous obstacles for arctic resource exploitation. The decreasing ice cover in the Arctic ocean has also prompted renewed interest in northern marine shipping routes. Tourism is on the increase in both polar hemispheres.

Despite increased scientific attention and a demand for better predictive capabilities, the number of operational observations in the polar regions has been falling. Government agencies have been hard pressed to find the significant funds required to continue polar networks. Nevertheless there exists a bewildering number of individual programmes, institutions, organizations and individuals engaged in a variety of ways in the collection and analysis of polar data.

2. USER REQUIREMENTS SUMMARY

The polar regions obviously have a unique family of users, and some care must be paid to the identification of the users before building up the set of requirements (Table 1). The first major difference is that the polar population is relatively sparse. Population translates into an electorate and an electorate translates into political will. Therefore the priority for normal day to day meteorological and ocean services can be expected to be rather low. This is a general statement and applies equally to a user in any sparsely populated region of the globe. It is an important consideration, because it recognizes that many user requirement priorities will be determined on more discrete needs, which must be investigated and serviced as appropriate. Priorities are seen to be determined by:

a) The need for observations from the polar regions of phenomena that threaten or are important to the well-being of the population majorities (such as climate and ozone depletion)

b) The need to protect and maximize the economic investments of nations (resource exploration and development, shipping etc.)

c) The need to obtain information from the polar regions that is critical to the accuracy of meteorological and ocean predictions for non-polar regions.

d) The need for strategic military information for national security considerations.

e) The need to protect the northern peoples, their culture and both polar environments. In contrast to the low priority likely to be accorded polar weather services, with the exception of the polar environment and its peoples have a relatively high priority in both the public and political spheres.

The following sections attempt to outline, for polar observational needs, what organizational mechanisms exist, what systems are in place and what national and international programmes are addressing the various polar issues. This is a preliminary step in assessing what additional actions are needed, if any, to ensure a sufficient distribution and flow of observational polar data, on an operational basis, to enable the routine application and forecasting of required parameters in the future.

2.1 Services (met/ocean/ice)

From the above arguments it can be seen that a complete coverage of general weather services and forecasts are unlikely to be required for the polar regions. The extreme polar conditions however make local services even more critical. Therefore, the meteorological services must maintain sufficient observations in the polar regions to enable effective local forecasts to be made. The fundamental requirements will be for limited public services and severe weather watches and warnings, and at least some capability of support for emergency response situations over the entire region. Local communities, airports, mining and hydrocarbon development sites, tourist operations research stations, etc. will all require specific local forecasts and services. In Europe the northern population density is higher and the requirements for such services will be correspondingly greater.

Tidal information is important for the operation of ports and in many polar regions the possibility of damage of shoreline structures by sea ice is another factor. In areas and times where open water exists the need for wave information is also important.

At present, the major operational users of ice and ocean data services are the shipping and fishing industries, and these are covered in the following sections. However, as resources are developed there will be additional needs for routine offshore ice, ocean and atmospheric services in support of such activities.

Table 2 gives the normal forecasting requirements for *in situ* measurements. In the polar regions, the absence of manned stations, lack of visibility, extreme operating conditions for personnel and equipment, combine to create requirements for special consideration for polar networks. In particular, instrument design for survival and reporting in sub-normal conditions, automated stations to compensate for lack of operators, communications, and an increased reliance on remote sensors and modelling capability.

2.2 Safe and efficient marine operations

User requirements can be categorized into two broad areas.

a) Tactical data and information: forecasts and predictions, including knowledge and warnings of extreme events, that are needed for daily operations, short-term planning and the safety of life, property and the environment.

b) Climatology, trends and longer range forecasts: these are necessary for strategic planning, risk assessment, cost/benefit and design purposes.

In operational conditions timely data is essential. Time delays are caused by transmission, handling, processing and communication of the observed data. Automated stations, and technical developments in observation and communication equipment, improvements in signal processing, direct links to users and faster models will help to reduce delays.

Many of the raw data needed will be observed by automated stations because of the cost. When lives and resources are at stake the question of redundancy must be faced in terms of maintaining a sufficiency of information and for the integrity of the whole system. Certainly for any link in the chain, from observation to communicated operational product, that is critical to successful forecasts, duplication and redundancy will be necessary.

Table 1 Existing and future users and their requirements for data on polar and sea ice regions

	Users		Requirements
1.	Shipping operators, route planners, shipping services	1.	In addition to information and forecasts needed for safe and efficient operation in temperate seas. Sea ice occurrence, extent, thickness, nature, movement, coherence, iceberg location, seasonal forecasts, break-up, freezing, icing conditions, wind forces and ice pressure predictions. For designated protected areas. environmentally sensitive areas (breeding, spawning, feeding, habitats etc.)
2.	Non-renewable resource exploration and development companies	2.	Meteorological, hydrological and ocean information to ensure safe efficient and environmentally acceptable operations, too site specific to be elaborated here, but likely to be supplied by the company based on local measurements and the wider regional information more generally available.
3.	Renewable resource managers	3.	Stock assessment, environmental conditions, monitoring of health and pollution parameters.
4.	Northern indigenous groups	4.	Predictions of extreme events, trends and climatic changes that are not part of traditional knowledge and that will impact on the culture and way of life, areas and pattern of use by indigenous people. Weather services. Environmental monitoring of contaminants in food air, water and marine environment.
5.	Designers - ships, ports, equipment, buildings etc.	5.	Ice, sea and atmospheric data, extreme events, climatology and trends. Geology topography, hydrology and cartography.
6.	Standards specification - building, operating codes etc.	6.	Climatology, extreme events for all parameters effecting safety of buildings, equipment etc.
7.	Weather and marine forecasters	7.	Pressure fields, upper air observations, humidity, precipitation, temperatures, snow and ice cover, sea level, sea state, cloud cover etc.
8.	Ice forecasters	8.	Range of characteristics observable and replicable for ice predictions, timing and duration of sea ice, snow cover, thickness, salinity and chemical profile, sea level and cartography, ridges and pressure fields, leads, polynyas, surface wind fields and upper ocean currents, differential movement of ice types, shore leads, land-fast areas, ice pressure.
9.	Climate modellers	9.	Climatology of temperature, snow and ice cover, radiation, precipitation, radiation characteristics etc. Paleontology information of all kinds.
10.	The military	10.	Strategic and operational conditions of atmospheric, terrestrial and marine environments.
11.	Researchers	11.	Accurate and reliable measurements in all areas and in all disciplines and covering all spatial and time scales according to the subject and nature of the research topic. The understanding obtained will be applied to operational requirements in all fields from climate prediction to management.
12.	Maritime lawyers	12.	Environmental, geological, topographical and cartographical data for boundary delimitation and disputes, jurisdictional zones, international treaties etc.
13.	Hydrographers and cartographers	13.	Geological, hydrographical and topographical data, sea level and meta-data.
14.	Tourism	14.	Location and abundance of biota, archeological sites, operational data for safe operation of eco-tourist trade.
15.	Conservation managers	15.	Contamination and pollution data, environmental changes and trends, extreme events, habitats, physiology, stock abundance location and trends, feeding, nesting, spawning and breeding areas, migration routes, stream and river input; estuaries, ice.
16.	Insurance companies	16.	Climatology, trends and extreme event predictions in all relevant parameters, to enable assessment of risk.
17.	Municipal and coastal area managers	17.	Snow, freezing rain, frost, wind, fog, precipitation and other warnings. Coastal developments and natural changes, erosion, sediment delivery and dispersal, contaminant and pollution data, environmental and ecological data, land and sea uses, resource information.
18.	Air transportation	18.	Accurate meteorological and ground condition data are critical for flying and airport operations.

The provision of ice services is a specialized and difficult service, although great advances have been made in recent years. In many countries sea-ice monitoring is well developed and well established. Requirements have to be derived from a thorough analysis of end-to-end systems and may differ from region to region due to different categories of sea ice and to different principles of operation in these regions. Thus, for example, the difference in sea ice conditions and in shipping characteristics in the Baltic Sea, on the Northern Sea Route, in the North West Passage and in the Antarctic, can lead to differing requirements.

It seems as if the existing well-designed ice monitoring systems largely satisfy present requirements for major shipping routes, with the possible exception of ice thickness. ‘Users’ may be served with interpreted observations as well as short-term predictions of ice conditions. Many captains however, prefer to receive real observational data and use their own judgement.

Rapid changes are still a problem. Even with today's satellites a revisit time of one day is not generally satisfied. With a system like RADARSAT in the ScanSAR wide mode (500 km swath) daily coverage can in principle be accomplished at latitudes above 70° and nearly so at 60-70°- latitudes, whereas the Gulf of St. Lawrence area, for example is only observed once every three days. To fulfil a daily coverage requirement, at all essential (subpolar) latitudes, two or three properly phased satellites would be required to be in orbit simultaneously.

In addition to information and forecasts needed for safe and efficient operation of marine transport in all seas, including the polar regions, the additional presence of superstructure icing conditions, sea ice and ice bergs create a special challenge for polar sea navigation. Most national governments operating ships in ice covered seas have developed national ice services. In some areas these services overlap and captains can take advantage of the benefits from different systems.

Some services such as the prediction of icing conditions (of great importance for smaller vessels), fog, ice pressure, the development of leads, etc. may inevitably be derived from models and not directly from observations. Direct observations will be needed to issue ice products such as those dealing with sea ice occurrence, extent, thickness, nature, characteristics and coherence.

As maritime traffic in the polar regions increases, additional environmental information is likely to be demanded to protect the environment and ecology. Designated protected areas will be assigned given times and locations to be avoided for sensitive habitats. Restrictions on speed and some routine operations may also be applied in given areas for specific times. As such restrictions have economic consequences, it will likely be more effective and probably more acceptable environmentally to have specific and timely information directly available to the operator, rather than to have general large restrictive areas and periods set in advance.

2.3 Global climate monitoring/prediction

All indications are that the Polar regions are of critical importance to studies of climatic change; the largest and earliest signals should occur there. Polar amplification and feedback are recurrent themes in numerical climate modeling, however we have hitherto lacked many of the ocean time-series to demonstrate these. The overwhelming need for Polar observations in the next decade is to increase our understanding of the interlinks in climatic variability and achieve some predictive capability.

The view of experts is that the present climate of the polar regions has not yet been sufficiently defined and would be a necessary first step before working towards documenting variability and trends. Lacking detailed knowledge of the causes and amplitude of changes, coupled ocean-atmosphere models provide the only available statements and predictions of the future climatic state. These however need to be complemented with an integrated long-term observational programme enabling continued monitoring of changes in the polar regions, in particular the Arctic interior.

The high latitude oceans form an important component of the total climate system, not least because the polar and sub polar seas of both hemispheres are the formation regions for the deep water of the world's oceans and thereby play a key role in the global ocean thermohaline circulation. The buoyancy of the upper ocean layers is a crucial factor in the ocean circulation and is influenced by atmospheric exchanges of heat and freshwater at the ocean surface, advection of relatively saline water from the south by the Atlantic Ocean circulation in the northern hemisphere, ice shelf processes in the southern hemisphere and the role and influence of the high latitude hydrological cycle. Unique high latitude processes involved in this context include sea ice formation and melt, iceberg discharge, and river input in the northern hemisphere.

Due to the contribution of heat to North Western Europe from the ocean and a perceived susceptibility of the North Atlantic circulation patterns to changes in the Arctic outflow, it has been postulated that a changing Arctic freshwater flux may cause a relatively rapid cooling of that region within a time scale of decades. Records obtained from glacial cores have indicated that sudden climatic changes do indeed occur, and this hypothesis is one deserving attention because, if true, the economic consequences could be tremendous. In this regard, the importance of monitoring the catchment area of rivers draining into the Arctic Ocean must remain a priority.

From the climate impacts viewpoint, there is a need to look at current observations on many aspects such as ice thickness, glacier extent, permafrost, forests, terrestrial and marine ecology, etc.

2.4 Climate research

Climate research is undertaken mostly by institutions funded by governments, who are also responsible for maintaining monitoring systems for many purposes. It is doubtful whether the national agencies funding research and those funding data observation systems coordinate their activities to the best advantage. This leads to inefficient use of scarce resources.

Many of the measurement needs for climate research have been identified in a number of national and international programmes, which have addressed the important unknowns in identifying how variability in the polar regions influences lower latitudes and contributes to global change. These organizations and programmes include the Arctic Ocean Sciences Board, the International Arctic Science Committee, the WRCP Arctic Climate System Study (ACSYS), the Japanese Frontier Research System for Global Change, the US-NOAA Global Change Research Program, the US-NSF Arctic System Science Study, the European Framework-V Key Action on "Global change, Climate and Biodiversity", and for the Antarctic, the International Antarctic Zone programme (iAnZone), the Scientific Committee for Antarctic Research (SCAR), the SCAR Global Change and the Antarctic (GLOCHANT) and the Antarctic Sea-Ice Processes and Climate Programme (ASPeCt). All express the need to link polar ocean variability with climate change and its societal impacts in the adjacent subpolar regions.

Climate scientists require long-term and continuously repeated observations. The recent political trend to privatise many government activities has led to a consequential increase in the cost of data. Although, some data sets are still made available to researchers at reduced cost, some institutions and organizations have been forced to charge relatively large sums for the retrieval of data, that are not compensated for in the funding of research by research grants.

Due to the latitudinal variation in the sun's incoming radiation, there is a net evaporation of fresh water from the surface in equatorial regions and a net precipitation in polar regions. In the Northern hemisphere, this produces an overall southward flow of freshwater. The freshwater circulation and local mixing are influenced by processes driven by weather, topography, sea-ice growth/decay etc., and by climate changes. Changes in the freshwater flow from the Arctic ocean have very significant consequences. The combined effects of large river runoff, advection of meteoric water, low evaporation rates and distillation by freezing, contribute to the formation of a strong halocline in the upper Arctic ocean, which limits thermal communication between the sea ice and the warmer waters of Atlantic origin below. Sea ice and freshened surface waters are transported by winds and currents, ultimately exiting the Arctic Ocean, primarily through Fram and Davis Straits. Variations in the freshwater outflow from these regions effect the density structure of the Arctic Ocean itself and the density profile of the water column in the adjacent seas, where convection takes place, mixing surface waters downwards. In descending, these waters remove carbon dioxide (and pollutants) from the surface and thus variations in the local exchange of surface with deeper waters play a role in both climate change and environmental quality. On a larger scale this downward convection motion produces dense deep waters that flow outwards from these two centres and influence the Atlantic ocean current patterns. Research into these processes and their variability are severely limited by the lack of adequate data on the freshwater input cycles.

Satellite data requirements are sure to increase. Large-scale investigations at moderate spatial resolution (100 meter to 1 km, and even 15 km) are of importance and coverage of large areas is required. Presently, many scientists are showing interest in fine-resolution data, like the 5-meter resolution that may be obtained from the recently launched ICONOS satellite and even with the 1-meter spatial resolution obtained over the SHEBA site from a U.S. National Reconnaissance system. However for large-scale investigations like climate studies these data are of limited use because the revisit time becomes long and the amount of data become overwhelming. Also very important is the coverage in time. Time series are necessary, with repeated coverage of important areas over decades. A sampling strategy has to be defined with the scientists but this requires careful considerations if the satellite resources and/or computer capacities are not sufficient.

In line with the requirements to establish the present climatology, data archeology programmes are still necessary. One AOSB programme is attempting to assemble data relevant to the significant warming period that occurred in the Arctic between 1922 -1958. The magnitude of this event seems at least as great and more extensive than the present warming in the last decade, but does not seem to be correlated to the same forcing processes. The geographical region involved extends from the Bering Sea, throughout the Arctic Ocean and marginal seas and into the Nordic Seas. The International Arctic Research Center, University of Alaska, has already begun the task of assembling the relevant past data sets.

In the study of climate trends, paleoclimatic information of all types, from glacial cores to traditional knowledge, are valuable. It is not possible to identify all such data sets or even to establish a priority for a particular area. Obviously those yielding accurate, extended and continuous time-series will be the most important.

2.5 Other research

If all the operational aspects of meteorological and ocean observations are taken into account, including impacts and other related social and environmental consequences to climatic variability and trends, then the area becomes almost all inclusive. Therefore the examples for data requirement included in this section are not, and are not intended to be comprehensive, but an indication of research more directly related to the two disciplines under discussion. Some of the other aspects have however been covered in the following sections.

One related global issue is the research into, and monitoring of, the extent of the ozone depletion over both polar regions. Scientists recently made more measurements than ever before of polar stratospheric clouds (PSCs) that trigger ozone loss in the stratosphere. The research was part of the largest ozone field experiment to date (SOLVE) that began in November 1999 to assess the state of the stratospheric ozone layer over the Arctic. More than 350 researchers are taking part in the field campaign that is slated to continue until March 2000.

Another current research issue is the influence of leads on the heat budget of the Arctic Ocean, for instance. In this context, fine-resolution, polarimetric SAR data are used for classification of thin ice as it develops in leads during winter conditions. But to do this on a large scale requires advanced methods and software and these are still being evaluated. Software which has been developed by Jet Propulsion Laboratory for the Alaska SAR Facility (ASF) for ice dynamic studies - including leads and the re-freezing - is important but needs validation.

New research into the combined heat and freshwater budgets for the total arctic ocean-ice-snow system, differs from previous efforts that have addressed either the heat or freshwater separately. Results are expected to identify sources of greatest uncertainty and be of use to operational agencies in determining the sources responsible for maintaining, or changing, the present state. For example it has been recognized that the magnitude of fluctuating winds (for sensible and latent -evaporation and sublimation - heat fluxes) is important. Also the critical role of variable snow cover on sea ice (neglected by many climate models), pointing to need to observe snow properties as well as variable cover and their influence on aspects of radiation, both short-wave and long-wave.

An OOPC/ AOPC subgroup is looking at the differences in the Operational SST analyses near the ice edge. It is not clear what the differences are caused by, but the scarcity of data is certainly an issue.

2.6 Living marine resources (e.g. conservation, protection)

The southern oceans as a whole and some areas of the Arctic are regions of high productivity. Changes in environmental conditions and fishing practices will impact on the abundance of species. For most of the Arctic, the fishing grounds are under national jurisdiction. The international waters in the southern hemisphere are protected, at least south of 60 degrees latitude, by the Environmental Protocol to the Antarctic Treaty which came into force in 1998. Stock assessment and other related environmental information is essential for management purposes. In the present situation of over capacity in the fishing industry and the related collapse of many traditional fishing stocks, the search for new sources of protein from the sea is vigorous and not always preceded by adequate research and knowledge. It is known, for example, that massive populations of krill exist in the southern ocean. If these populations were extensively fished without research into the impact of such removal on the higher trophic levels, the results may be serious and far reaching.

2.7 Environment

One of the most contentious issues for the polar regions, especially for the northern hemisphere is the occurrence of Persistent Organic Pollutants (POPs) in the polar ecosystem. These chemicals, such as pesticides and herbicides are not generated in the high latitudes, but are transported there by atmosphere and ocean, losing their volatility and settling in the colder environments. The indigenous species bio-accumulate these contaminants in their fatty tissues, and the resulting concentrations can be many times those of comparable species in more temperate regions. An international protocol is being negotiated, however monitoring requirements must be put in place, in order to monitor the effectiveness of, and compliance with, the agreement.

Environmental monitoring takes place under programmes of the Antarctic Treaty in the southern hemisphere and until recently, under a somewhat fragmented mixture of national activities in the northern hemisphere.

One of the most active environmental programmes in the Arctic followed the adoption, in 1991, of the Arctic Environmental Protection Strategy (AEPS) by the countries of the Arctic Council. The objectives are to protect the Arctic ecosystems, to provide for the protection and sustainable utilization of natural resources, accommodate traditional and cultural needs, to review regularly the state of the Arctic environment and to identify and reduce pollution.

Four programmes were established under the AEPS:

- Arctic Monitoring and Assessment Programme (AMAP) with responsibilities to monitor the levels of, and assess the effects of, anthropogenic pollutants in all compartments of the Arctic environment, including humans.

- Conservation of Arctic Flora and Fauna (CAFF) with responsibilities to facilitate the exchange of information and coordination of research on species and habitats of Arctic flora and fauna. CAFF has a biodiversity monitoring programme.

- Emergency Prevention, Preparedness and Response (EPPR) with responsibilities to provide a framework for future cooperation in responding to the threat of Arctic environmental emergencies.

- Protection of the Arctic Marine Environment (PAME) with responsibilities to take preventative and other measures, directly or through competent international organizations, regarding marine pollution in the Arctic, irrespective of origin.

AMAP is currently working to produce update assessments according to the the following schedule:

Assessment Item	Year of Reporting (Progress, Interim, Main)			
	Adopted		Tentative	
	2000	2002	2004	2006
Human Health	P(I)	M	I	M
POPs	P	M	I	M
Hg and other heavy metals	P	M	I	M
Radioactivity	P	M	I	M
Acidification	P	P	P	M
Oil and PAHs	P	P	M	P
TBT	P	P	M	P
Climate change effects	I	M	P	M
UV effects	I	M	P	M
Combined effects	P	P	M	P

The possibility of an increased maritime presence, again in the arctic, has been mentioned above and the requirement for operational environmental data to manage sensitive zones and periods to avoid unnecessary damage to the ecosystem.

2.8 Global numerical weather prediction

One of the most interesting findings recently has been the work on the so called Arctic Oscillation on the secular changes in the Arctic that link the pressure system over the poles with the dynamic Icelandic and Aluetian "lows". These features also occur in the Antarctic. The ocean, ice, atmosphere and stratosphere seem to be much more coupled in the polar regions than in mid latitudes, which has obvious implications for how we observe the Arctic. For example, observation requirements would include ice thickness, measurements of temperature, currents etc. in the ocean up to the ice edge and then over the ice pack (puddling of melt water), atmospheric profiles over the arctic basin, stratospheric measurements (and UV) of temperature and ozone.

Of importance to weather prediction are mid-latitude changes, such as deviations in the jet stream, initiated from changes in the polar regions.

3. OBSERVING SYSTEMS

There must be an examination of the various instrument packages existing and required for monitoring in the extreme polar conditions. It is likely to be found that a mix of existing proven instruments and new developments will be needed for the near to mid-term. New technology is always a priority to replace inadequate or inaccurate systems and to increase efficiency and effectiveness. For example, a significant effort is required to improve the instruments used to obtain meteorological and river run off data. Pragmatic choices must always be made. Researchers will tend to demand the most advanced systems available, but this should not be allowed to lead to overstated requirements that are not actually needed for operational applications.

Satellite observations will become of increasing importance. Planning cycles, however, take years and a generous overlap period must be allowed for calibration purposes and continuity of time series.

Included in the many effective systems presently in use are the surface buoys in the International Arctic and Antarctic Buoy Programmes, ocean moorings, including Upward Looking Sonars for ice draft, national airborne visual and radar patrols, supplemented by satellites with active and passive microwave sensors and optical scanners and sounding instruments.

Again, as a matter of balance, efforts must include improving the flow and availability of present data, from military facilities of all types, ships, icebreakers, submarines, aircraft and satellites, in addition to exploring new sources of data. Whereas the meteorological and oceanographic data is poor, much of the basic environmental data is non-existent.

Clearly the economic constraints, especially over Siberia are having an significant effect on the availability of Arctic data of all kinds.

The observing systems are categorized into *in situ* and remote sensing instrumentation with sea level treated as a special category.

3.1 In situ

The polar *in situ* surface observing systems are made up of a sparse network of manned stations maintained in communities, industrial and military establishments and research outposts. These are supplemented by observations from automated stations on land and at the sea/ice surface, together with a number of transient commercial and research vessels and icebreakers. Additionally, for ocean measurements, there are sea-bed and water column moorings, subsurface buoys, submersibles (automated and manned). The latter cannot be considered to yield publically available operational data, because of military restrictions on timely data release on the one hand and the small numbers of research submarine cruises and available under-ice automated submersibles on the other.

Considering the remoteness of the Antarctic continent, it is surprising to note that there are 78 manned stations, of which the majority (45) are occupied year round. Presumably meteorological measurements are made routinely at these stations. However, it is unclear how many readings are available for exchange in real or near-real time. As would be expected, most of the locations are found on or near the coast, although two permanent stations and a few summer camps are located within the continent. According to the WMO, the Antarctic Basic Synoptic Network (ABSN) comprises 31 staffed stations, including 13 upper air stations and in addition 50 automatic weather stations. The total number of stations (81) is close to the number of research stations, although the assumption that every research station is a part of the network may be erroneous.

The WMO established an Executive Council Working Group on Antarctic Meteorology as far back as 1964 to coordinate the implementation of the WWW basic components in this area. In 1999 the WMO Congress noted that, despite the difficult conditions the number of reports received from the Antarctic network was above the global average.

However there are still concerns over the quantity and coverage of atmospheric stations. For example, the number of upper air stations has fallen from 19 in 1993, with only one remaining in the interior of the continent. It is hoped that automated weather stations can be used to offset the lack of weather and climate data, with an objective of an eventual network with a 500 Km. spacing. The need for automated weather stations on Voluntary Observing Ships transiting the area is also emphasized as is the usefulness of using modern satellite observing techniques.

The WMO Secretariat is compiling, with the assistance of interested countries, an electronic and printed catalogue of Antarctic Climate data.

The data acquired by drifting and ice surface buoys has proved to be extremely valuable. It is an almost real-time system with transmission of surface data via satellite communications. The International Arctic Buoy Programme (IAPB) is an excellent example of a long-term undertaking that should have much larger support and be extended in both numbers and capability. The numbers of operating buoys however had fallen to 22 in 1999. Likely to be of greater importance in the future are sub-surface drifting buoys in ice-covered waters. Such advances will be even more useful when real-time or near real time acoustic communication links with such buoys is developed. The same acoustic techniques, once developed, could also be used to communicate with moored instrumentation. A corresponding Antarctic network called the International Programme for Antarctic Buoys (IPAB), made up of 18 agencies and institutions, is seeking to develop a similar operational network of buoys south of 55 degrees.

Apart from the buoy programme, which is operational, the majority of ocean data is derived form research initiatives. In fact, during the 1990s there was a major increase in the ship-based ocean-observing effort, contributed both by surface ships. (Polarstern and Oden in 1987 and 1991, the first US/Canadian Trans-Arctic Section in the summer of 1994 aboard Polar Sea and Louis St Laurent, and three further Polarstern cruises in 1993, '95 and '96 were highlights), and by the almost-annual submarine surveys of the US SCICEX Program (1993-99), which involved dedicated use of a U.S Sturgeon-class nuclear submarine for unclassified research in the Arctic ocean, including oceanographic and sea ice research.

For the crucial Arctic hydrological data, time series of river data exist for many of the major rivers, however the accuracy and continuity of such data is suspect and the coverage of many of the minor inflows, non-existent.

Obviously national and international research programmes in both the Arctic and Antarctic are too varied and numerous to cover comprehensively. They will all contribute in some way to our understanding of the polar processes and climatology. Those programmes with the longest continuous data sets will be extremely valuable in this regard. For example, the SHEBA experiment in the Beaufort Sea, 1997-1998 rendered site specific and extremely accurate and comprehensive atmospheric and ocean data for a whole annual cycle.

A joint Canada/USA AOcean Climate Station" was maintained in the Canada Basin (72deg30min N: 144deg W) from 1990 to 1995. This station allowed measurements of ice thickness, water properties and currents. The methodology proved successful; no equipment was lost and data return was above 90%. This was and remains the only station of its kind in the central Arctic Ocean. Given recent international concern over the disappearance of arctic ice, it seems reasonable to suggest re-instating this programme as an operational activity.

The North East Water (NEW) and Northwater (NOW) programmes, under the AOSB, have investigated the processes and events surrounding polynya formation over several cycles, these and many other research programmes provide most of the available ocean data and a significant portion of atmospheric data.

Finally among the *in situ* observations, must be mentioned the observations taken on contaminants of the air and water and on direct observation of the abundance and behaviour of arctic, animal, bird and marine populations. These are usually taken on an opportunity basis except for research expeditions that may have a particular environmental observational programme in mind.

An important factor for GOOS is that many of the established data-gathering or monitoring systems are either terrestrial or marine; they stop at the coastline and do not give integrated or compatible information on coastal or shore-line characteristics or processes. But the coastal zone and adjacent near-shore region is a critically important and distinctive area in the coastal zone of polar regions, socio-economically, politically, and scientifically. The Coastal module is a part of the GOOS and adequate attention should be paid to its requirements.

3.2 Remote sensing (satellite, aircraft, ship- and shore-based radar, acoustic, etc.)

Large streams of meteorological data are provided by environmental observation satellites. The space-based portion of the Global Observing System (GOS) comprises near-polar orbiting satellites, the geostationary satellites are of limited use for the polar regions. Polar orbiting satellite coverage is provided by the Russian METEOR 2 and METEOR 3 systems and the USA Tiros series, NOAA-12 operational morning satellite and NOAA-15 operational afternoon satellite. It is planned that EUMETSAT Meteorological Operational Satellite (METOP) will take over from NOAA-12 in 2003.

Satellite observations have the potential to fill in some of the gaps in the surface observing network=s coverage of certain parameters. Though forecasters currently use visible and infrared imagery to track cloud motion and system development, relatively little use has been made of the other data that may be derived from satellite observations. Even the current numerical models are not yet fully exploiting this potential, presumably waiting until advanced data assimilation schemes (3-D and 4-D variational methods) are implemented.

Technical developments of new and improved instruments require overlap transition periods to maintain time series validity. This must be built into planning cycles as with the transfer from SMMR to SSM/I microwave radiometers where a six-month overlap period was obtained. A transition period was similarly planned for going from ERS1 to ERS2 and is expected to be organized when going from ERS to ENVISAT. It is noted that the Europe and USA authorities have been cooperating on the development of a coherent polar satellite programme.

Table 2

Parameters normally required by forecasters from a surface-based in-situ observational network*

1. Parameters to be Measured Hourly	2. Parameters to be Measured every 3 Hours
	cloud amount,
air temperature,	snow depth,
dew point,	snow cover,
pressure,	ice cover,
precipitation occurrence,	soil temperature,
precipitation type,	soil moisture,
precipitation amount,	grass min. temperature,
visibility,	wave height and period,
sunshine,	water temperature,
cloud type,	seiche height and period,
cumuliform cloud,	lightning data,
wind speed and direction,	freezing spray,
precipitation rate,	UV,
pressure tendency,	tidal data.

* Taken from the National Public Weather Network Study - Canada, 1998

250-km horizontal resolution is sufficient for routine forecasts, however a denser observational network with 100-km horizontal resolution is essential for warnings.

Present monitoring systems exploit all available satellite observations: NOAA, AVHRR, SSM/I and SAR, with spatial resolutions ranging from 30 km to 30 m. In this way one compensates for deficiencies inherent with the different systems as to coverage - area and revisit time - and to light and cloud conditions. Data are generally received by remote ground stations whereby a time delay of data dissemination of one to three days at best is introduced. The infrastructure to receive, process, analyze and distribute satellite imagery in near real-time for sea ice monitoring has been developed in many regions. In several cases satellite observation are complemented with visual and radar observations from aircraft. Automated algorithms to classify and track sea ice are being developed and tested using time-sequential images to extract ice motion information.

Algorithms that use multi-spectral data from the geostationary satellites to extrapolate radar precipitation rate estimates to regions outside of radar coverage have been available for years. RAINSAT is the Canadian version of this technique.

Algorithm development research has also continued for snow cover, using SSM/I passive microwave satellite data for the determination of snow-water equivalent, snow extent and snow state (wet/dry) for different landscape regions (e.g. prairie, boreal forest, tundra). A new thrust is the use of ground-based and airborne microwave radiometers to conduct special investigations in support of snow cover algorithm development with a focus on the influence of snowpack properties and structure on microwave emission and seasonal variability.

Variational data assimilation schemes are essential to the effective incorporation of these non-traditional observations. For example, a 3-D variational scheme allows satellite data to be assimilated directly, avoiding the necessity of inverting satellite radiances into model variables. The 3-D scheme has been used in the global and regional assimilation cycles since 1997. A 4-D scheme, under development, will allow the continuous assimilation of observations in time and should be an improvement on the 3-D scheme.

A study was undertaken by the European Space Agency into a possible real-time and interactive satellite system with a Synthetic Aperture Radar (SAR). The analyses carried out show that a system like the RADARSAT system with a wide swath of 500 km and a spatial resolution of about 100 m would be suitable if designed with additional units for automatic interaction with the users. This system performance is dictated by the maximum size of a receiver station that may be installed on a ship, like an HRTP station for AVHRR data.

Data received from a satellite ground station are processed at dedicated centres and transmitted to ships, for instance, by various communication means dependent upon the geographical area: HF over long distances, UHF (cellular communications) over short, line-of-sight distances and via satellite communications, to so-called V-Sat stations. The latter is by way of geostationary satellites so that services beyond about 80°N is not possible.

In Europe, preference is made for systems that require a great deal of user involvement in the definition and the development phases and receive a substantial economic contribution. Although not of relevance for EUMETSAT the requirement as to one-day revisit time, for instance, may be stressed to a lesser degree when the user community is going to pay.

Requirements for the suite of observational systems must be seen in the context of the overall use including access to observation, meteorology and forecast processes and the means of communications from satellite ground stations to ice centres and from the centres to the >users=. The capabilities of complementary sensors on different platforms should also be considered as part of the whole system when determining the requirements for individual parts.

In addition to these system considerations, the technical requirements of the observation systems should also be considered. With SAR, for instance, the question of choice of frequency and polarization is an important one. New advances in remote sensing technology (such as polarimetric and multi-frequency SAR) are under study and the relative advantages of these new technologies to the user community, must be weighed against the increased cost and complexity.

3.3 Sea level

Sea level observations are provided from both in-situ measurements by tide gauges and from remote sensing by satellite altimetry. There is concern at the lack of polar tide gauges in both hemispheres. In 1998 the GLOSS manual lists a total of 27 polar tide gauges, 10 on Antarctica and 17 around the Arctic coasts. However only 5 of the former and 7 of the latter are described as fully operational and similar numbers, 4 and 6 respectively, were listed as out of operation.

In some areas, such as northern Canada and Greenland, tide gauges have been closed as a consequence of a lack of clearly voiced national and international interest in the importance of these sea level observations. In other areas, such as Siberia, a lack of resources has led to degradation or total failure of the equipment. In total, the loss of tide gauges has led to a plea for the IOC to encourage its Member States to support these activities on a continuos basis.

A particular problem is the data release for Russian Arctic tide gauges. For example, at the Sixth Session of the GLOSS Group of Experts, the Russian representative gave information on several time series from Arctic tide gauges, covering periods up to fifty years, whose existence was previously unknown. These time series data sets are not expected to be made available in the near future, moreover, the quality of such data sets has not been examined and may be doubtful. To improve the in-situ observations of sea-level in the Arctic, the scientific value of these data, particularly for ocean circulation and climate studies, needs to be emphasized through international programmes. The IOC Global Sea Level Observing System (GLOSS) has been reformulated as a Scientific Steering Group under JCOMM. One of the jobs for the new GLOSS SSG will be to study the need of gauges, including those in the polar regions, for ocean circulation studies. GOOS also has a role to play in emphasizing the critical requirement for observations of polar sea level.

The Australian National Tidal Facility operates a Southern Ocean Sea Level Centre for IOC/GLOSS, but sea level recording in the Antarctic is mainly through efforts by UK, France and Australia, with a couple of gauges from the US and Japan.

The ACCLAIM (Antarctic Circumpolar Current Levels by Altimetry and Island Measurements) programme in the South Atlantic and Southern Oceans consists of measurements from coastal tide gauges and bottom pressure stations, together with an ongoing research programme in satellite altimetry, one of its objectives is the study of variations of the Antarctic Circumpolar Current. Earlier measurements at coastal tide gauge sites took the form of sub-surface pressure measurements rather than sea level.

It is absolutely essential that any user of ACCLAIM data realizes which data type (either SSP or sea level) is being analyzed. For some data sets, the original data have been filtered to give one-hour sampling. Common to all records is an uncertainty connected with potential offset biases and drifts in the pressure sensors, however at some sites extensive tide pole data are also available and biases and long term drifts in the sensor data may eventually be rectified.

From 1993, many gauges have been replaced by gauges which record sea surface temperature, air pressure and sea level. All present coastal data will contain ancillary information on air pressures and sea temperatures.

Related to sea level is bottom pressure measurement, which the Proudman Oceanographic Laboratory (POL) has used extensively during the World Ocean Circulation Experiment (WOCE), especially at the Drake Passage.

Sea level observations are important for the estimation of tides, which have some influence on the ice dynamics in certain regions of the Arctic oceans. There is a strong semi-diurnal component in the upper part of Baffin Bay that may be of importance for the conditions in the Northwater Polynya (NOW) and in Nares Strait and tidal effects have been observed over the Yermak Plateau and in the Greenland Sea. Tide gauges are also desirable across areas where flow estimates are critical and where direct measurement is difficult.

4. DATA MANAGEMENT

The coordination of Arctic and Antarctic data sets has been a problem over the years and is still not adequately resolved. Data are archived in many national and international institutions, in many disciplines, as data sets for discrete programmes, in differing formats and of varying quality.

Sea Ice data represent the most comprehensive set of polar information and data holdings are consolidated at the Global Digital Sea Ice Data Bank (GDSIDB) under the World Meteorological Organization (WMO), which was developed in response to the WCRP and WCP requirements. The GDSIDB is now operational in two centres, at the Arctic and Antarctic Research Institute in St. Petersburg, Russia and the National Snow and Ice Data Center in Boulder, USA. A certain amount of metadata are included with the data sets held, which go back over fifty years in some cases. A future joint USA-Russian AArctic Sea Ice Atlas≅ on CD-Rom is planned based on these data holdings.

Ocean data is generally exchanged and archived under the auspices of the International Oceanographic Data and Information Exchange (IODE) mechanism of the IOC. However there is not a Responsible National Oceanographic Data Centre designated to manage a data set from the Arctic region. These data are treated as part of the global data set.

The Arctic Ocean Sciences Board has initiated discussions on arctic ocean data over the past five years, but with little progress. Members are considering the possibility of forming an inventory of Arctic data, which then could be made available as part of a distributed data set, held in a network of national and international centres.

Observations from the International Arctic Data Buoy Programme are archived as a data set. Other specialist data sets are available in various national data centres, for example for snow and ice and glacier data. However no comprehensive centre exists for any complete set of Arctic ocean and meteorological data.

In the Antarctic, SCAR and COMNAP have established a Joint Committee on Antarctic Data Management to advise on the management of Antarctic data. One of its key roles is to advise on the development of the Antarctic Data Management System including the recruitment of National Antarctic Data Centres (NADCs) and the encouragement of scientists to submit metadata to NADCs. The Committee is also examining national approaches to addressing freedom of access to scientific information. The Manager of the JCADM site has affirmed that it is up to date. This initiative is still rather new, however fourteen countries have already identified national centres.

The Antarctic Master Directory (AMD) is a central directory system containing all Antarctic data set descriptions gathered by National Antarctic Data Centres. A decision was made at the meeting of the Steering Committee in Lima in 1999 to move the AMD from the International Centre for Antarctic Information and Research (ICAIR) to the Global Change Master Directory (GCMD) of the IDN to minimise duplication of resources and metadata. This will be the totality of GCMD holdings, filtered for Antarctic locations. It is nearing completion and, when completed, it is planned to be updated every six months, until the systems upgrades to a distributed system with MD-8. A more complete description of the principles and objectives of these initiatives is given in Annex 2.

Research scientists often have some reservations about accepting human observation and anecdotal environmental information as part of a scientifically useful data set. It must be recognized, however, that such data often represents important records of changes that are unavailable by other means and can be obtained in no other way. Human observations are part of the Traditional Environmental Knowledge (TEK) that can assess or analyze subtle changes difficult to arrive at by instrumental observations. A comprehensive data system should have a place to accept or record this kind of information if it is useful.

The comment has been made that many individual data sets (buoys, moorings, satellite systems) are well managed and that an attempt to integrate the total information into one system would be counterproductive. However polar data directories showing the content and location of distributed data sets would be useful, and coordination amongst observing systems to satisfy operational needs would be welcome.

4.1 Data collection and information management and exchange

Before dealing with the specific aspects of data management, it would do well to emphasize a point that is sometimes overlooked when dealing with data. It is easy to be preoccupied with data management as an end to itself and to neglect the potential importance of data management as an important tool in the coordination process. Years ago, at the onset of IGOSS, it became clear that the ability to track and follow near-real time data gave an efficient and effective view of what programmes were underway. This observation has been echoed by the manager of JCADM who notes ΑOne of the main reasons for JCADM under the Antarctic Treaty, and National Antarctic Data Centres as an operational aspect of JCADM is to encourage greater efficiency in research. There is much duplication amongst the many national programmes in Antarctica and homing in on scientific publications is a poor way of picking up the inefficiencies. When one looks at data (observations), you get a far clearer picture. This is something that we are very focused on (nationally and internationally). The efficiency aspect certainly appeals to COMNAP. Given the increasingly multinational - multidisciplinary approach to Antarctic research, it can only increase in importance.≅

As has been mentioned before, much attention has paid by governments to sea ice observations, because of its importance to shipping and maritime trade considerations. It follows that the collection and exchange of sea ice data are more advanced than for most other parameters. That is not to say however, that all the national services operate completely compatible systems or that all data is exchanged. The former CMM WG/SG on Sea Ice was a international forum where problems of data exchange could be addressed.

4.1.1 Real time

Meteorological synoptic data from the polar regions are operationally exchanged through the Global Telecommunication System (GTS). In view of the sparse coverage of land-based stations, all vessels operating in or near polar regions should be reporting weather and sea surface information in real time to facilitate the rapid exchange of data. In the thinly populated and extreme conditions of the polar regions, available observations are likely to have a relatively large proportion of automated and remotely sensed data.

Again, sea ice services are routine. National and international systems collect, analyse and deliver operational products in real time to ship operators, using both *in situ* and satellite instruments.

For ocean data, few, if any, systems are presently considered real time. Operational sub-surface data could become important in the future for particular operations and activities.

Research uses are sometimes in need of real time data, when crucial data are linked to specific events, such as storms. Even some ecological studies of migration and social behaviour patterns with signals transmitted from tagged animals will need to use real time data transmission.

It is certain that the many new satellites and instruments planned to be flown in the next 10-15 year period and the wealth of data that will be acquired will enhance the real time coverage of the polar regions enormously. Among these are a number that may serve climate studies by supplying global, medium and coarse resolution data. In situ measurements for continuity, correlation and ground truthing must form an essential part of this transition.

4.1.2 Delayed mode

For operational purposes the value of data to a predictive capability will depend upon the time scale of the processes involved. This is why for many oceanographic purposes, data are exchanged operationally even though the data is thirty days old. However, some data are delayed for political, administrative or logistic reasons. For example restrictions placed upon release for military and security purposes, confidentiality for commercial applications and even some researchers will wish to guard their data from peer competition. Logistically some data will be delayed through lack of direct communication and others by the need for analysis and interpretation. Hopefully all such data will eventually be available for archival.

4.1.3 Historic

Recently data archeology programmes have been very successful in rescuing past data sets. Bringing together these data sets should have a high priority. As was mentioned above, one such programme is aimed at identifying the causes of the arctic warming event in the mid-twentieth century.

4.1.4 The Global Digital Sea Ice Data Bank (GDSIDB)

The GDSIDB was established as a WMO project in support of climate research programmes and specialized services. Two data centres of this bank in Boulder (USA) WDC-A for Glaciology and in St. Petersburg (Russia) AARI, established the feasibility of merging digitized sea ice data from various sources and countries into a single data bank, and developed archival and exchange formats and procedures.

Recently, the USA and Russia cooperated, in a bilateral programme, to produce a CD ROM of Arctic data including previously unavailable military data. This initiative could be extended to include data from other countries. For example, other important military data sets exist (ice draft from submarines (US, Russian)). Countries have anecdotal data covering a 400-year time series of ice edge, time-series of sea level gauge readings, and ocean chemistry observations, that could be collected into more comprehensive data sets.

4.2 Quality control

In any data system, quality control is essential, and perhaps even more so for polar data which is made up of so many individual programmes and pieces. Guidelines for the collection and storage of data and the associated metadata must be made available. There is a great need for some standardization and/or inter-comparison of data collection methods, sensors etc.

For sea ice the nomenclatures, terms, symbols etc. have been prepared by the former CMM Working Group on Sea Ice, and published by the WMO, since the 1950s. This will be a function to be continued under JCOMM.

4.3 Archival

Obviously, for climate studies long-term archives are important. To be useful long periods of data are needed in order to be able to estimate trends. Cost and volume are competing priorities, although with the continuing development of large-capacity filing systems there is almost no limit as to the amount of data that may be stored and the cost, per unit data point stored, is also falling as time passes by.

The problem of arranging for the eventual archival of data is a communal problem that would benefit from a common solution. It would seem that distributed data sets are the most acceptable for many countries, institutions and programmes, however it would provide insurance if there existed some comprehensive archive that can replenish lost data sets in the event of an accident or for any other reason. An alternative would be to have some shared distributed system that would see data holdings being duplicated amongst cooperating centres.

As has been already mentioned, sea ice collection and exchange is one of the most developed areas of polar data. The digital achival of data at the GDSIDB and similar work carried out at its Data Centres are examples of the activity being undertaken by this community of observers and users.

As data sets grow larger with time, the cost and worry of maintenance renewal grows. Governments and institutes accepting responsibility for archives must be prepared to deal with this problem. If data is eventually to be purged because of space or cost problems, the international community must agree on the guidelines to be followed, because in a distributed system any individual action could affect the integrity of the total data archive.

Cataloguing is also important. For remotely sensed data, as for other data, international standards and formats worked out by the international community should be followed. The catalogues should be accessible to any user, preferably using electronic means, such as the Internet.

Satellite data from past decades ago, originally taken for synoptic uses, can be useful for climatologies. Before such data are destroyed consideration should be given to their value to longer term studies. Of course, the metadata, explaining how they were taken and interpreted must also be available. For satellite data inventories, there is value in having browse images available to ascertain whether the data is of potential value before deciding on access.

5. MODELING, PRODUCTS, SERVICES

Accurate models capable of reproducing the processes involved and able to assimilate available data will eventually be available to overcome many of the present problems of data scarcity and to satisfy predictive needs, trend forecasting and strategic requirements. Unfortunately, the knowledge required to develop and prove these models is still missing and the observational needs still unanswered. Short-term models are of course being put to good use and are invaluable in such areas as weather and ice forecasting. It is the models for longer time changes and those involving complex interactions that need more research and data.

The data required for the process research that precedes model development is often more specific and detailed than the data input required for model input. In order to find out which parameters are important and how processes interact with each other, researchers need to study radiation, heat, energy and hydrological budgets. Therefore measurements of parameters not usually obtained operationally, but possibly essential for the development of operational systems, need to be allowed for in the planning of observations in the polar atmosphere and ocean.

For example, in snow and ice research, observations may include:

- sea ice total concentration, ice extent and thickness, ice characteristics
- surface roughness and orientation of roughness patterns of floe surfaces, pressure ridges, floe edges, etc.,together with surface winds, to provide parameters for equations of the air-ice frictional coupling to predict atmospheric driving forces in sea ice movement;
- ice-bottom roughness and topography, dimensions, nature, and pattern of pressure ridge keels, etc. to provide parameters for equations and calculations of water-ice stresses to predict sea ice movement in relation to ocean surface currents and atmospheric conditions;
- temperature and chemical profiles of surface snow, of the ice floes of different ages, of pressure ridges, and of upper layers of the water, to provide info for energetic calculations of ice melt, bottom freezing, pockets and movement of low-salinity water,etc., needed for predictions of changes in the nature, extent, and duration of ice cover in a variety of scales;
- the presence, growth, and biological nature of sub-ice algae and their attendant copeopod populations, for predictions of the pattern and timing of the local food chains.

A type of information that is regularly obtained, but not systematically analysed, is the the variation of net albedo of polar ocean and particularly of broken ice-water mixtures at different scales and their effects on surface heating and wind and eddy generation in the atmospheric boundary layer, for prediction of local weather, sea ice stress, wave generation at the ice edge, etc.

Infrastructures to receive, process, analyse and distribute RADARSAT imagery in near real-time for sea ice monitoring have been developed. For example, at the Canadian Ice Service, which includes: a Data Transfer Network (DTN) to transmit data from the Canadian receiving stations to the data processing facility and on to the Canadian Ice Service headquarters; the Ice Services Integrated System (ISIS) which provides image processing, analysis and product preparation, the Climatological Ice Data Archiving System (CIDAS) which distributes image, chart and other products and well as archiving them; and, an image and chart reception, display and analysis system (IceVu) used on board icebreakers and in ice offices.

6. INFORMATION EXCHANGE AND COMMUNICATION

Anyone attempting to collate the output of the national and international polar programmes finds themselves faced with a bewildering collection of fragmented information. There are many organizations that coordinate activities in discrete programmes, by separate disciplines, for a given operational use or even from a national standpoint. There does not seem however to be any attempt to coordinate the coordinators. It would be a mammoth but worthwhile task to prepare an inventory of past, present and future plans for polar observations.

6.1 Catalogues, guides, manuals, etc.

This type of information is invaluable for the coordination of programmes and activities. It includes inventories of data, programmes, instrumentation and personnel, guides and manuals for the standardization of observation and methodology, use of equipment, formats for data archival and exchange.

Over the years intergovernmental groups such as the WMO activities under the WWW and the CMM, such as the IOC activities under IODE and GLOSS and such as the joint activities under IGOSS have published many guides, manuals and similar documents, some of which focus on or relate to polar observations. The JCOMM may wish to review the availability and status of these documents at an early stage.

6.2 Technical documents

The grey literature is often overlooked as a source of knowledge, however technical documents describing techniques for overcoming difficult conditions, the performance of instruments and a hundred and one other details that do not usually find their way into peer reviewed papers, but are invaluable for operational activities.

As in the previous section, the WMO and IOC have published documents over the years that are relevant to JCOMM work. However, technical documents are only as useful as their availability and currency and again a review will be required.

6.3 Web sites, newsletter, brochures, etc.

The exchange of news on national programmes, available software, advances in the field, status of programmes etc. all are a part of coordination and will lead to greater efficiency.

7. CAPACITY BUILDING

In the polar regions, the phrase capacity building takes on a different context to the one in which is usually found. One could interpret it widely as the need to bring the collective capacity, of all countries interested in the polar regions, up to a point where the necessary polar observations can be taken operationally and in full. One of the challenges here is to develop the capacity to integrate and correlate a variety of quite different kinds of information on many different scales and collected for quite different uses. The above is not to say that some countries will not be in a position where they should assume leadership and others in a less favourable position that require assistance, however there should be a tendency towards a more mutual cooperative effort than one of pure financial and/or technical aid.

7.1 Technology development and transfer

There is a need to develop improved instrumentation for polar observations and this can more effectively be done collectively than through a variety of competing efforts. At present it is even impossible to measure adequately, important aspects of the polar marine environment (e.g. freshwater fluxes through straits).

7.2 Software exchange

The same rationale for a collective effort in the development of instrumentation applies equally to the development of models and the exchange of computer software.

7.3 Specialized training

Many of the countries engaged, or wishing to be engaged in polar research or observation, do not possess any national territories within the polar or sub-polar region. Such countries should be able to find the necessary training through a partnership with an Arctic country or one already involved in Antarctic research. In this way such countries can either become accustomed to the environment and its challenges before venturing on an individual programme or find a willing partner to share the cost and benefits of a mutual programme.

8. IMPLEMENTATION MECHANISMS

8.1 JCOMM

The new WMO/IOC Joint Technical Commission for Oceanography and Marine Meteorology is the parent for future sea ice work. It will be defining and refining this role over the next several years. As a Joint Technical Commission, JCOMM will be able to recommend and influence decisions at the governing bodies of both the WMO and IOC. Member States will be able to follow and support accepted polar programmes.

8.2 GOOS

The responsibilities of GOOS encompass the polar regions and include ocean applications of coastal management, health of the oceans, living resources and climate in addition to routine ocean services. The GOOS organization has the IOC and WMO as its major sponsors, and is directed by the GOOS Project Office housed in the IOC. The Global Ocean Observing System, is one of the major clients of JCOMM. It will be looking to JCOMM to improve its access to and relationship with the operationally strong meteorological community, whilst bringing some of the much needed ocean weather and climate related data to the table. In addition to the climate module, GOOS also has a coastal module, a living resources module and a Health of the Ocean module. These latter three modules fit less well into the JCOMM partnership but should also benefit from the communication and operational competence of WMO. In assisting in the solution of social issues in these other, mainly non-meteorological fields, the WMO will increase its visibility and influence.

8.3 GCOS

GCOS also includes the IOC and WMO in its sponsors and is one of the clients of JCOMM. GCOS will be closely associated with the polar regions as far as the climate observations are concerned. GCOS is an implementing organization and, in the sense that it has a requirement for continuous observations over long periods of time, it is an operational programme. The programme office is situated within the WMO.

8.4 IOCSOC

The IOC Regional Committee for the Southern Oceans is a long-standing regional intergovernmental committee. It has not been very active over the past decade and its terms of Reference are being reviewed at the IOC Executive Council in June. It does not directly duplicate the work of JCOMM but the two mandates should be complementary. IOCSOC is an intergovernmental committee and therefore should be playing a role in the implementation of plans developed by expert groups. Countries interested in the southern polar region may prefer to organize and implement their activities through the Antarctic Treaty, however IOCSOC does have its mandate in the international waters of the Southern Ocean and may yet be a valuable tool.

8.5 WMO-EC WG/AM

The WMO EC Working Group on Antarctic Meteorology has been in existence for many years and should be a source of information. Its mandate is for the synoptic network of meteorological stations, however these will include the observations from Voluntary Observing ships and this will be an overlapping interest with JCOMM. The Group does not appear to have an implementation role except through its influence at the WMO.

9. SCIENTIFIC ADVICE

In the South the Scientific Committee on Antarctic Research (SCAR) is widely recognized as the leading expert group for scientific advice. In the north the International Arctic Science Committee (IASC) and the Scientific Council on Oceanic Research (SCOR) may be prominent, although the latter has global ocean responsibilities. The Arctic Ocean Sciences Board does not consider itself an advisory body, but one concerned with the coordination of international arctic science programmes.

Internationally, within the organizations of IOC and WMO there are many specific expert groups that would be called on for advice as necessary. The international research programmes under the World Climate Research Programme (WCRP) includes many programmes with a direct polar interest, such as ACSYS and others such as CLIVAR and WOCE with less direct but nonetheless very pertinent connections. All these programmes have scientific advisory groups. Those programmes and organizations mentioned here are not all inclusive. There are many more.

It may be that the priority to address polar issues becomes high enough to warrant an international programme of research and observation. If this is the case, groups and sub-groups of observational scientists, supported by modellers, will be required to plan the details for the field operations. A major programme must be managed through an international effort, supported by the funds and facilities of national agencies. The international planning effort and agreed objectives must take precedence over the interests of individual scientists or nations.

9.1 IASC

Arctic countries consisting of Canada, Denmark/Greenland, Finland, Iceland, Norway, Sweden, USA and USSR. (now C.I.S.) established the International Arctic Science Committee (IASC) on August 28, 1990. IASC is a non-governmental organization to facilitate international consultation and cooperation and to promote research activities on Arctic science comprising natural, social and cultural sciences. IASC is open for accession by non-Arctic countries. Japan, France, Germany, Netherlands, Poland and the United Kingdom, acceded to IASC on January 21, 1991, as members of the Committee on the basis of past and ongoing significant research in the Arctic region.

9.2 SCAR

The Scientific Committee on Antarctic Research is a non-governmental scientific organization under the ICSU (International Council for Science), established to facilitate the cooperation and coordination of significant and effective scientific research in the Antarctic. SCAR has provided expertise on many problems such as protection of the Antarctic environment in response to requests from the Antarctic Treaty Consultative Meeting in cooperation with COMNAP (Council of Managers of National Antarctic Programmes), as well as scientific advice. It establishes Standing Working Groups and ad hoc groups of specialists as necessary.

9.3 SCOR

The Scientific Committee on Oceanic Research is a non-governmental scientific organization of ICSU. It is an advisory body of the IOC and has cooperated in many joint activities with them. SCOR has a President and a permanent Executive Secretary. Decisions on the work programme are made at the SCOR annual meetings and the activities are usually carried out through ad hoc working groups that are established for the specific task and are then disbanded. The Arctic and Southern Oceans would be under the global mandate of SCOR. Scientific advice can be requested directly through the IOC or through the ICSU sponsorship in climate research and other programmes.

9.4 AOSB

The Arctic Ocean Sciences Board was established in May, 1984, to fill a recognized need to coordinate the priorities and programmes of countries and institutions engaged in research in the Arctic Ocean and adjacent seas. The long-term mission of the AOSB is to facilitate Arctic Ocean research by the support of multinational and multidisciplinary natural science and engineering programmes by encouraging and supporting science-led international programmes; through exchange of information, initiating and maintaining observations and data exchange and through promoting cooperative events.

The AOSB is a non-governmental body that includes members and participants from research and governmental institutions in Canada, Denmark, Germany, Finland, France, Iceland, Japan, The Netherlands, Norway, Poland, Russia, Sweden, Switzerland, the United Kingdom and the United States of America. Membership is open to all nations participating in research in the Arctic Ocean and adjacent seas.

The Secretariat of the AOSB is presently provided by the National Research Foundation in Washington, D.C., at the address given below. Funds are provided by Members and participating institutions of the Board for participation in meetings and in the scientific programmes of the Board in which they participate.

9.5 OOPC and other GOOS and GCOS Panels

The whole gamut of specialized expert panels operating under JCOMM and its associated committees, such as GCOS and GOOS, and through the other incorporated programmes, such as IGOSS, GLOSS, IDBP, can all be accessed for advice on specific polar observation issues as and when necessary.

9.6 WCRP

WCRP activities address outstanding issues of scientific uncertainty in the Earth's climate system including transport and storage of heat by the ocean, the global energy and hydrological cycle, the formation of clouds and their effects on radiative transfer, and the role of the cryosphere in climate. These activities match the scientific priorities identified by the Intergovernmental Panel on Climate Change (IPCC), and provide the basis for responding to issues raised in the UN Framework on Climate Change (UNFCCC). WCRP also lays the scientific foundation for meeting the research challenges posed in Agenda 21. Together with the International Geosphere-Biosphere Programme (IGBP) and the International Human

Dimensions of Global Environmental Change Programme (IHDP), WCRP provides the international framework for scientific cooperation in the study of global change.

In addition, WCRP organizes and/or sponsors ad hoc meetings to consider scientific or planning issues and participants as appropriate in the planning of the ICSU/WMO/IOC/UNEP Global Observing System (GCOS). WCRP also co-sponsors with GCOS and the Global Ocean Observing System (GOOS) the Ocean Observation Panel for Climate (OOPC) overseeing the implementation of an ocean observation system for GCOS (or, equivalently, the climate component for GOOS) and, with GCOS the Atmospheric Observation Panel for Climate (AOPC), and to collaborate with IGBP and IHDP in the development of the System for Analysis, Research and Training (START).

Oversight Scientific guidance for the programme is provided by a Joint Scientific Committee (JSC), consisting of 18 scientists selected by mutual agreement between the three sponsoring organizations and representing climate-related disciplines in atmospheric, oceanic, hydrological and polar sciences. Implementation of the programme takes place through the Joint Planning Staff (JPS) in Geneva and the International Project Offices (IPOs).

Scientific advice on climate matters could be addressed to the WCRP through its WMO and IOC sponsors.

9.7 IGBP

Other international research programmes that would be expected to have an interest in polar programmes are managed by non governmental organizations such as the International Geosphere Biosphere Programme that is repsonsible for such programmes as JGOFS and GLOBEC. Of course much of the effort in these programmes comes from the support of governmental institutions.

10. INTERACTIONS

JCOMM can have interactions with any organization that has interests, activities or programmes in the polar regions. The list cannot be comprehensive and, with the large number of national and international bodies involved, there will certainly be some confusion with JCOMM=s attempts to coordinate polar observations. The best approach would seem to be to interact with the appropriate high level contact in the national and international hierarchy dealing with polar issues and hopefully, by so doing, incorporate the majority of minor organizations and players.

10.1 The Antarctic Treaty

It would be difficult to attempt any coopertive programme in the southern polar region without involving the Antarctic Treaty and its related organizations. Some of these appear below or are referred to in other parts of the text.

10.2 The Arctic Council

The Arctic Council is composed of the eight Arctic rim countries having national jurisdiction in the Arctic. Although the Council does not deal directly with the intergovernmental programmes of the UN, it nevertheless undertakes multilateral programmes and discusses regional issues of joint concern to its members.

10.3 The Baltic

The Baltic is a sub-Arctic region that, by nature of its geography has achieved a high degree of coordination amongst the Baltic States. This is demonstrated by the Helsinki Commission (HELCOM), one of the most successful and active of the Regional Seas Programmes, the Baltic Sea Ice Meeting (BSIM) and the close cooperation amongst the national regional ice-services and lately the Baltic GOOS which is just being established.

Although a sub-polar region, the experiences of cooperation amongst the Baltic countries in many aspects of northern ocean studies and marine meteorology would be of value to JCOMM in the implementation of plans for the wider polar region.

10.4 CCAMLAR

The Convention on the Conservation of Antarctic Marine Living Resources came into force in 1982, as part of the Antarctic Treaty System. It was established mainly in response to concerns that an increase in krill catches in the Southern Ocean could have a serious effect on populations of krill and other marine life; particularly on birds, seals and fish which mainly depend on krill for food.

The aim of the Convention is to conserve marine life. This does not exclude harvesting as long as such harvesting is carried out in a rational manner.

The Convention defines a Commission and a Scientific Committee to work together to manage marine living resources in the Southern Ocean. The resources specifically exclude seals and whales, as these are covered by other conventions. However, there is full cooperation with the operating bodies of these other conventions.

10.5 COMNAP

The Council of Managers of National Antarctic Programmes was established in 1988 to bring together those managers of national agencies responsible for the conduct of Antarctic operations in support of science.

The objectives of COMNAP are to review operational matters and to facilitate regular exchanges of information; to seek solutions to operational problems and to provide a forum for discussion on international collaboration in operations and logistics.

COMNAP meets annually and holds biennial symposia on Antarctic and logistics and operations. It also has working groups assigned to particular issues and organizes technical workshops on topics of interest to member agencies. COMNAP currently has 29 member countries.

10.6 IABP

The International Arctic Buoy Programme (IABP) is funded and managed by its participants. Representing eight countries, participants include operational and research agencies, meteorological and oceanographic institutes, and non-governmental organizations. Participant contributions include equipment, services, and programme coordination as well as funding.

The IABP maintains a network of automatic data buoys in the Arctic Basin which monitor synoptic-scale fields of pressure, temperature, and ice motion to support real-time operations and meteorological and oceanographic research. As of August 1999, there were 23 buoys operational, although 5 of these were giving position only. The failure rate is high, 25 buoys ceasing to function in the previous year against 16 deployed.

10.7 IHO

The International Hydrographic Organization has members representing the world hydrographic agencies and accepts responsibilitiy for the coordination of the charting and mapping of the world=s oceans. It is presently cooperating with the IOC in producing an updated chart for the Arctic Ocean. It also cooperates with WMO in the provision of marine safety services (including in polar waters) and in the preparation of various publications relating to sea ice.

10.8 IMO

IMO met for the first time in 1958. The adoption of maritime legislation remains the most recognized responsibility of the organization. Around 40 conventions and protocols have been adopted and maintained up-to-date. The enormous strides made in communications technology have made it possible for IMO to introduce major improvements into the maritime distress system, but although safety remains IMO's most important responsibility, pollution has also emerged as a priority.

IMO has a technical co-operation programme which is designed to assist Governments which lack the technical knowledge and resources needed to operate a shipping industry successfully. The emphasis of this programme is very much on training.

IMO has 157 Member States, but with a staff of 300 people, it is one of the smallest of the United Nations agencies, although achieving considerable success in its aim of "safer shipping and cleaner oceans." The challenge now facing IMO and its is how to maintain this success at a time when shipping is changing more rapidly than ever before.

The shipping industry is an important client for operational services in polar regions and with its responsibilties for ship safety and the environment, the IMO will be concerned about the availability of data from the point of view of both design and operation of vessels. Design needs imply an interest in climatological changes. The environmental regulations that will be required for increased shipping activities in polar regions have been already elaborated.

10.9 IPAB

There is a corresponding Antarctic network called the International Programme for Antarctic Buoys (IPAB), made up of 18 agencies and institutions, seeking to develop an operational network of buoys south of 55 degrees. Presently, the majority of deployments are made for research applications. There were 13 buoys operating in 1999.

11. CONCLUSIONS

The above report has shown that an effort to coordinate polar observations under JCOMM is certainly needed. It has also demonstrated however the difficulty of such a task. It would not be a service to the global community to embark on a programme that merely added one more organizational brick to the pile that already exists. Any strategy developed and adopted through JCOMM must endeavour to work with the existing organizations.

The most fruitful area of concentration will be by means of the operational data management networks, which provide information on past endeavours and on current activities. They are the source of information for research, for modelling and for operational applications.

JCOMM must examine the mandates of the committees and working groups that it is planning to replace. Many of these committees have been performing important operational and observational responsibilities that could easily be missed when being amalgamated into a single entity.

The efficiency of polar observations is a matter that should be included in a polar strategy study. The lack of co-ordination and cooperation is a major problem in this regard, which should be addressed. This lack of co-ordination extends, not only in the funding of observational systems aimed at the range of activities from research to operational monitoring, but also in the planning of systems that could benefit from the huge synergies in multi-use and multi-parameter observations that could be carried out using common logistics and at mutually advantageous sites.

Of potentially high importance is the integrity of the archival system for polar data. Operational systems may not aware of the potential usefulness of their data for longer-time strategic use and therefore may have policies that destroy these data when they appear to have reached the end of their operational usefulness. The breadth of the JCOMM mandate is such that all data should be considered as potentially important for archival and attention must be paid to adopting a policy that protects all polar data sets.

As was mentioned in the Foreword, the available information on national polar programmes was found to vary so much in content and currency that it has been decided to leave it out of the current document. Such a collection of information and references will however be extremely useful, especially in arriving at a strategy for polar observations. JCOMM should undertake a compilation of such data, charging Member States of the WMO and IOC to contribute national activities to a technical document, or electronic database, that can be regularly updated. The Annex from the original draft of this document and other WMO and IOC documents, such as WMO - 574 publication on ASea Ice Services in the World≅ could be used as starting points.

The JCOMM may wish to review, at an early stage of its work, the availability and status of previous WMO and IOC manuals, guides and technical documents relating to polar observations and data exchange.

Finally, it is recognized that the sea-ice observation systems are by far the most extensive and operational systems in the polar regions and it will be a challenge to bring this potential into a comprehensive system that addresses a broader range of parameters and users. Care must be taken to build on these extensive networks in a way that is seen to be beneficial and not competitive.

Annex 1

LIST OF ACRONYMS AND OTHER ABBREVIATIONS

AARI	Arctic and Antarctic Research Institute (Russia)
ABSN	Antarctic Basic Synoptic Network (WMO)
ACCLAIM	Antarctic Circumpolar Current Levels by Altimetry and Island Measurements
ACSYS	Arctic Climate System Study (WCRP)
AEPS	Arctic Environment Protection Strategy
AMAP	Arctic Monitoring and Assessment Programme
AMD	Antarctic Master Directory
AOPC	Atmospheric Observation Panel for Climate
AOSB	Arctic Ocean Sciences Board
ASAP	Automated Shipboard Aerological Programme (WMO)
ASF	Alaska SAR Facility
ASPeCT	Antarctic Sea-Ice Processes and Climate Programme
ATCM	Antarctic Treaty Consultative Meeting
BOOS	Baltic GOOS
BSIM	Baltic Sea Ice Meeting
CAFF	Conservation of Arctic Flora and Fauna
CBS	Commission for Basic Systems (WMO)
CCAMLAR	Commission for the Conservation of Antarctic Marine Living Resources
CEOS	Committee on Earth Observation Satellites
CIS	Canadian Ice Service
CLIC	Climate and Cryosphere project (WCRP)
CMM	Commission for Marine Meteorology (WMO)
COMNAP	Council of Managers of National Antarctic Programmes
COP	Conference of the Parties to FCCC
DBCP	Data Buoy Cooperation Panel (WMO/IOC)
DMI	Danish Meteorological Institute
EC	Executive Council
EGOS	European Group on Ocean Stations
EPPR	Emergency Prevention, Preparedness and Response
EOSS	European Sea Level Observing System
ESLS	European Sea Level Service
FCCC	Framework Convention on Climate Change
GCMD	Global Change Master Directory
GCOS	Global Climate Observing System
GDSIDB	Global Digital Sea Ice Data Bank
GLOCHANT	Global Change and the Antarctic (SCAR)
GLOSS	Global Sea-Level Observing System (IOC)
GOOS	Global Ocean Observing System
GOSSP	Global Observing Systems Space Panel
GPS	Global Positioning System
GSC	GOOS Steering Committee
GTS	Global Telecommunication System (WMO)
GTSPP	Global Temperature Salinity Profile Programme (IOC/WMO)
HELCOM	Helsinki Commission (Baltic)
IABP	International Arctic Buoy Programme
IASC	International Arctic Science Committee
ICAIR	International Centre for Antarctic Information and Research
ICEX	Ice and Climate Experiment (NASA)

IGBP	International Geosphere-Biosphere Programme
IGOSS	Integrated Global Ocean Services System (IOC/WMO)
IGS	International GPS Service
IHDP	International Human Dimensions Programme
IHO	International Hydrographic Organization
IICWG	International Ice Charting Working Group
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IOCSOC	IOC Southern Oceans Committee
IODE	International Oceanographic Data and Information Exchange (IOC)
IPAB	International Programme for Antarctic Buoys
ISABP	International South Atlantic Buoy Programme
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
JGOFS	Joint Global Ocean Flux Study
JPL	Jet Propulsion Laboratory (USA)
LUT	Local User Terminal
MEDS	Marine Environmental Data Service (Canada)
METOP	Meteorological Operational Satellite
NADC	National Antarctic Data Centres
NEW	North East Water Polynya (Greenland)
NOAA	National Oceanographic and Atmospheric Administration (USA)
NOW	Northwater Polynya (Northern Davis Strait)
NSIDC	National Snow and Ice Center (USA)
OOPC	Ocean Observations Panel for Climate
PAME	Protection of Arctic Marine Environment
POL	Proudman Oceanographic Laboratory (UK)
POPs	Persistent Organic Pollutants
POSSIR	Polar Seas and Other Sea Ice Regions (JCOMM Working Group)
PSMSL	Permanent Service for Mean Sea-Level
QC	Quality Control
RNODS	Responsible National Oceanographic Data Centre (of IODE)
SAR	Synthetic Aperture Radar
SCAR	Scientific Committee on Antarctic Research (ICSU)
SCOR	Scientific Committee on Oceanic Research (ICSU)
SIGRID	Format for the archival and exchange of sea-ice data-digital form
SMN	Argentina National Meteorological Service
SOC	Specialized Oceanographic Data Centre
SOOP	Ship-of-Opportunity Programme (IOC/WMO)
SST	Sea Surface Temperature
START	System for Analysis, Research and Training
TEK	Traditional Environmental Knowledge
UNEP	United Nations Environment Programme
VOS	Voluntary Observing Ship (WMO)
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WMO-EC WG/AM	WMO-EC Working Group on Antarctic Meteorology
WOCE	World Ocean Circulation Experiment
WWW	World Weather Watch (WMO)
XBT	Expendable Bathythermograph

JOINT COMMITTEE ON ANTARCTIC DATA MANAGEMENT

This Committee is a joint committee of SCAR and the Council of Managers of National Antarctic Programmes (COMNAP). Its purpose is to advise SCAR and COMNAP on the management of Antarctic data. One of its key roles is to advise on the development of the Antarctic Data Management System including the recruitment of National Antarctic Data Centres (NADCs) and the encouragement of scientists to submit metadata to NADCs. The issue of NADC recruitment is being addressed by developing a communications network and running regional "capacity-building" workshops. The Committee is also examining national approaches to addressing freedom of access to scientific information.

The Antarctic Data Directory System (ADDS)

The ADDS is regarded as the most appropriate starting point for overall Antarctic data management, as it will directly address the problems of awareness and access to relevant data. The development of a comprehensive integrated directory of Antarctic data is not however a trivial task. It requires the commitment and participation of all SCAR member countries, and significant ongoing resources. Failure to provide this commitment and support will inevitably lead to unnecessary duplication of expenditure, lost opportunities for cooperation, and a lower return on investment from Antarctic science.

Principles

- It is a directory containing data descriptions - it is not intended to develop a central database containing the actual data.
- All Antarctic scientific data will be described - including historical data, environmental monitoring data, and data for which access restrictions may apply.
- Conditions of access to the actual data will be the responsibility of data custodians - such as the funding or managing agencies and institutions.
- There will be no restrictions on access to the directory - availability of the directory and associated products will be widely promoted.
- The directory entries (metadata) will use the Directory Interchange Format (DIF) of the International Directory Network.
- The production and maintenance of Antarctic directory entries is recognised as a critical activity to Antarctic science - not merely an administrative overhead.

Benefits

- Creation of national data directories as part of the ADDS will provide a useful tool for Antarctic science and operators. To collect data set descriptions is not an easy task; even on a national scale, it requires a full-time person. On-going support from the managers of national Antarctic programmes is therefore required. The effort however will be repaid by the benefits that access to the AMD can provide to national programmes. Among these are:
- Facilitate access to data;

- Facilitate interdisciplinary research;
- Maximize the usage of data;
- Disseminate knowledge about Antarctic scientific programmes;
- Address Antarctic science strategy and planning by avoiding duplication of research and data collection;
- Improve the efficiency of Antarctic scientific data management;
- Facilitate new research through access to existing Antarctic scientific data;
- Provide a tool for support and decision making for Antarctic operators and scientists;
- Improve cooperation and interoperability between disciplines and Treaty nations;
- Allow better oversight of national programmes;
- National Antarctic Data Centres (NADCs).

SCAR countries may choose to establish National Antarctic Data Centres (NADCs), or to designate an existing institution as their NADC, as part of the ADDS implementation process. A NADC would be responsible for coordinating Antarctic data management within the country, and would provide the national focal point for the ADDS.

There are currently fourteen operational National Antarctic Data Centres. A number of other countries are expected to attain >>operational status== within two years. Recruitment of National Antarctic Data Centres is a joint responsibility of SCAR, COMNAP and JCADM.

The Antarctic Master Directory (AMD)

The AMD is a central directory system containing all Antarctic data set descriptions gathered by NADCs. A decision was made at the meeting of the Steering Committee in Lima in 1999 to move the AMD from the International Centre for Antarctic Information and Research (ICAIR) to the Global Change Master Directory (GCMD) of the IDN to minimise duplication of resources and metadata. This transfer is nearing completion.

Repositories and Directories

The ICSU World Data Centre system and groups such as the World Meteorological Organization are data repositories. Collectively, they contain a subset of the data collected as a result of Antarctic research, but the status of data management varies considerably depending on discipline and local factors. The ADDS is a data index providing a unique, consistent and uniform source of information about all Antarctic data (multi-disciplinary and multi-national), no matter where they are located.

The IDN, implemented by the national space agencies of the United States, Europe, and Japan under the auspices of the Committee on Earth Observation by Satellites (CEOS), provide universal access to data located in different countries and relating to different disciplines. The ADDS is a logical extension of the IDN addressing a void in Antarctic scientific data. Within the IDN, the Global Change Master Directory (GCMD) is the agency responsible for the development of DIF, supporting software and technical support.

Current Status

Twelve NADC have been designated B Australia, Canada, Chile, China, Germany, Japan, Netherlands, New Zealand, Norway, Spain, UK, and the USA Argentina, Brazil, Ecuador, Italy and Uruguay are active within JCADM and nearing NADC establishment. To November 1999, 5084 metadata records have been collected by NADCs. Active NADCs are also starting to address other multidisciplinary and multinational issues. For example, the provision of repositories for different types of cryospheric data, where one NADC might take responsibility for data sets on ice velocity and another for ice thickness data. Another example is the development of on-line, Antarctic-wide flora and fauna databases. This type of activity can be seen as some of the positive emergent properties of the NADC network.

JCADM and the >>Steering Committee== have identified actions required for the effective development of the ADDS:

- Transfer of the AMD from the International Centre for Antarctic Information and Research (ICAIR) to the GCMD. This move is designed to simplify the management of the ADDS. This transfer should be completed by the end of 1999. The next release of GCMD software (MD-8) due late 2000, will take the ADDS to a fully distributed system; metadata will not be transferred from NADCs but all metadata will be searchable from any Web browser.

- A stable point of contact to provide metadata expertise and associated technical support to NADCs including documenting DIF management. Lack of this support function was identified as a major limitation to NADC functionality.

- A link between JCADM and the IDN, especially acting as the Antarctic >>champion== and as a technical representative to/from the IDN. The ADDS and the IDN represent different communities that would both benefit from having someone fulfilling this linking role.

- Assist the GCMD in the development of software suitable for use by the Antarctic community. Current software requires simplification for effective use in the more diverse Antarctic community.

- Other than national support for the emerging NADCs, there is no funding for the ADDS. The estimated cost of this support is US$80,000 to cover the salary and travel for one full-time person. This is US$120,000 less than the original recommendation for ADDS support from the *ad hoc* Planning Group on Antarctic Data Management in 1992. The tasks readily identify the GCMD as the most effective location to place this support. The GCMD has been performing some of these functions for more than a year with no financial support from the Antarctic community.