

EC-PHORS Services Task Team

Services Requirements Paper

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Executive Summary

At the 16th World Meteorological Congress in June 2011 (Cg-XVI), Congress adopted Resolution 57¹ to embark on a multi-year initiative to develop a **Global Integrated Polar Prediction System (GIPPS)** as a legacy of the International Polar Year (IPY) and capable of providing information to meet user needs for decision making on timescales from hourly, monthly to decadal. Congress further decided to continue this decadal endeavor at Cg-XVII in May 2015 with the approval of Resolution 48.² The global benefits of such a system are envisioned in terms of enabling service delivery and developing observing strategies in Polar Regions, and in addressing key uncertainties in weather, climate, water and related environmental variability and change, thereby improving global prediction. This initiative would contribute to all WMO high priorities, in particular Disaster Risk Reduction and the Global Framework for Climate Services (GFCS)³.

The word ‘Global’ in GIPPS reflects that it would be an international effort and that the poles, including the *Third Pole*⁴, affect systems (weather, climate, hydrological, oceanographic, biological, chemical, etc) globally; ‘Integrated’ reflects the interconnections between all these systems, and also because the System itself will be based on the principles of operational services, observations, and research related to this that are integrated and aligned⁵. For polar areas, GIPPS is seen as becoming a foundation of delivering the WMO’s substantial contribution to, “...*the protection of life and property against natural disasters, to safeguarding the areas such as food security, water resources and transportation*”⁶.

The WMO Executive Council Panel of Experts on Polar Observations, Research and Services (EC-PORS) formulated the vision of the GIPPS through its first meetings in Ottawa, Canada in 2009 and Hobart, Australia in 2010 to be a foundation for delivering the WMO’s substantial contribution to “...*the protection of life and property against natural disasters, to*

¹ftp://ftp.wmo.int/Documents/PublicWeb/mainweb/meetings/cbodies/governance/congress_reports/english/pdf/1077_en.pdf

² http://library.wmo.int/pmb_ged/wmo_1157_en.pdf

³ Paragraph 11.9.5, Annex to Paragraph 11.9.5, and Resolution 11.9/3 from General Summary of Congress XVI, Agenda Item 11.9, “Other Cross-Cutting Matters – WMO Polar Activities”

⁴ Himalaya and Tibetan Plateau region

⁵ See Section 6.4 at http://www.wmo.int/pages/prog/www/WIGOS_6_EC_PORS/Final_Report2010.pdf

⁶ http://www.wmo.int/pages/about/index_en.html

safeguarding the environment and to enhancing the economic and social well-being of all sectors of society in areas such as food security, water resources, and transportation.” A Concept Paper⁷ was developed by EC-PORS members to articulate the scope and objectives of the GIPPS for the consideration of the WMO Congress. It was determined the development of a GIPPS must be service-driven and meet the vision and objectives of the WMO Strategic Plan. The objectives of the GIPPS are to:

- Meet ‘user requirements’ for high northern and southern latitudes, as well as for the Third Pole
- Accurately predict the future state of the atmosphere; sea ice; (upper) ocean; and hydrosphere/cryosphere, particularly where prediction systems that are tuned for lower latitudes are less robust; and
- Be supported by appropriate observational systems and enabling scientific research and development.

Also at the 16th Congress Session, the WMO Strategy for Service Delivery was approved. Service delivery is the highest priority strategic thrust in the WMO Strategic Plan (2012-15). While some WMO Members have achieved great success in service delivery, it was recognized that a strategy for service delivery was required to provide a more uniform and structured approach for WMO on service development and delivery applicable to all weather, climate, and water products. The strategy was designed to serve as high-level guidance for developing more detailed methods and tools for better integrating users into the service delivery process.

In 2014, WMO released a Strategy for Service Delivery and its Implementation Plan to guide National Meteorological and Hydrological Services (NMHSs) in the assessment of their current service delivery performance and to assist in the development of plans to improve service delivery in line with their strategic objectives. Improving levels of service delivery will provide direct benefits to service users, and, as a consequence, stronger community support for the institutions of the NMHSs. In the short-term (two years), a milestone of the Implementation Plan is for WMO to conduct an assessment of service delivery development in the NMHSs. The information contained in the assessment reports will be used by the Executive Council Working Group on Service Delivery (EC-WGSD) to track the implementation of the Strategy. For the

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http://www.wmo.int/pages/prog/arep/wwrp/new/documents/Doc3_3.pdf

implementation of the Strategy to be a success, exchange of knowledge and information among NMHS will be crucial.

The purpose of this paper, as a continuation of EC-PORS work on the GIPPS, is to define and validate the needs and opportunities for improving weather, ice, water, and climate services in the Polar Regions; relate these to the GIPPS concept; and ensure the concept of a GIPPS is responsive to user requirements. The WMO Service Delivery Progress Model is used to assess the level of development of the NMHSs in each polar region and to outline potential action plans for improving services delivery.

Introduction

Weather, snow, and ice play a central role in daily operations and life in the Polar Regions, and the climate is an ever-present influence. To appreciate the perspectives of users of weather, water, and climate services in the Polar Regions, it is important to gain an understanding of the polar environment and its relative challenges.

The Polar Regions experience daily incremental changes in daylight hours leading to the extremes of twenty-four hours of daylight in summer and complete darkness at mid-winter. These are the coldest parts of the earth, covered most or all of the year by ice and snow. The large amount of ice and snow also reflects a large part of what little sunlight the Polar Regions receive, contributing to extremely cold temperatures in winter. Glaciers are present wherever there is sufficient precipitation to form permanent ice. The polar ice packs significantly change their size during seasonal changes of the year. Sea ice cover (extent and character) has major implications for industry (shipping, commercial fishing, resource extraction), the lives and livelihoods of the residents, and the culture and infrastructure of the communities. The winter freeze-up and spring melt cycles are important drivers of transportation, subsistence, and even recreational activities.

The weather and climate of the Polar Regions are influenced by the polar ice caps and adjacent oceans. The Arctic Ocean and the Southern Ocean (the ocean around Antarctica) have different characteristics to each other and to the rest of the world's oceans. These differences, particularly with regard to circulation, ice cover, productivity, and biologic diversity have a profound impact on the people and other living things inhabiting the Polar Regions.

Regional Drivers

Arctic

There are many settlements in the northern polar region, including within the United States (Alaska), Canada, Denmark (Greenland), Iceland, Norway, Sweden, Finland and the Russian Federation. Arctic circumpolar populations share common challenges and influences but are extremely diverse communities with unique cultural interests. The Arctic region is home to almost four million people⁸, including an increasing majority of non-indigenous settlers. Economically, the region depends largely on natural resources, ranging from oil, gas, and metal ores to fish, reindeer and birds. Recently, the tourism sector has also grown in many parts of the Arctic.

Populations are commonly distributed along or are dependent on coastal waterways and river systems for transportation, access to goods and services, and subsistence activities such as fishing and hunting. River communities depend on accurate hydrology, river, and ice forecasts to assess flood vulnerability and freeze/thaw impacts. These river systems also provide critical habitats for species important to indigenous populations and commercial interests. Coastal communities depend on accurate knowledge of ice edge e.g., for subsistence activities. Coastal freshwater discharge and upwelling play an extremely important role in marine ecosystems, as they affect fish and wildlife, glacial retreat, and ultimately sea level rise. Ocean storms pose complex weather and oceanographic hazards that threaten ships and infrastructure offshore as well as coastal communities. Frequent ocean storms over ice-free areas have a compounding effect on coastal erosion problems and can disrupt traditional subsistence activities for indigenous peoples.

While the provision of weather and oceanographic services is inherently challenging in the Polar Regions where observational data is sparse and the climate is particularly harsh, this work is further complicated by climate change. Numerous reports have highlighted the extent and rapidity of climate changes at high latitudes. There is now widespread evidence of overall change in the Arctic region.

- Atmosphere – The Arctic continues to warm at more than twice the rate of lower latitudes.

⁸ AMAP, 1997. Arctic Pollution Issues: A State of the Arctic Environment Report. Arctic monitoring and Assessment Programme (AMAP), Oslo, Norway. xii+188 pp.

For winter 2014 (December, January, February), extreme monthly temperature anomalies in excess of +5°C over the central Arctic spread south over Europe and Alaska.⁹

- Sea Ice – Sea ice extent continues to see decreasing trends in all months and virtually all regions with ice losses of -2.6% and -13.3% per decade in March and September, respectively. While multiyear ice in March 2014 increased from the previous year, there is still much less of the oldest ice in 2014 compared to, for example, 1988.¹⁰
- Ocean – The Arctic Ocean ecosystems are shifting due to a combination of Arctic warming, large natural variability, and sensitivity to changing sea ice conditions.¹¹

Led by a team of more than 100 international scientists from 14 countries, the annual Arctic Report Card¹² continues to highlight the effects of a persistent warming trend that began over 30 years ago. Higher temperatures in the Arctic and unusually lower temperatures in some low latitude regions are linked to global shifts in atmospheric wind patterns. A shift in the Arctic Ocean system since 2007 is indicated by the decline in ice age and summer extent, and the warmer, fresher upper ocean. Continued dramatic loss of ice sheet and glacier mass, reduced snow extent and duration, and increasing permafrost temperatures are linked to higher Arctic air temperatures. Since 1998, biological productivity at the base of the food chain has increased by 20%. Polar bears and walrus continue to lose habitat in Alaskan waters. Increased “greenness” of tundra vegetation in Eurasia and North America are linked to an increase in open water and warmer land temperatures in coastal regions. All have repercussions and consequences to those who work, live, and play in the Arctic region.

The Arctic ecosystem is changing in terms of permafrost degradation, increasing winter runoff, coastal erosion, and reduced ice thickness, and there is increasing concern about how people and industries will adapt. Changes in water regimes, their intensity and flood frequency have direct consequences for the transfer of pollutants into the Arctic Ocean. Sea ice cover (extent, thickness, and character) in the Arctic has major implications for industry, the lives and livelihoods of the residents, and the culture and infrastructure of the communities. Polar sea ice has been diminishing in recent years and economic sectors such as shipping, tourism, fishing,

⁹ http://www.arctic.noaa.gov/reportcard/air_temperature.html

¹⁰ http://www.arctic.noaa.gov/reportcard/sea_ice.html

¹¹ <http://www.pewtrusts.org/en/projects/protecting-life-in-the-arctic/life-in-the-arctic/arctic-ecology>

¹² <http://www.arctic.noaa.gov/reportcard/>

mining, and energy development stand to gain from increased access to the regions.

Changes in Arctic climate have local to global implications. Several Arctic nations have published “national strategies” to outline the pursuit of high level objectives responsive to challenges and emerging opportunities arising from significant increases in Arctic activity, for example due to the diminishment of sea ice and the emergence of a new Arctic environment.

Finland’s Strategy for the Arctic Region¹³ defines a number of objectives for Finland’s Arctic policy and explores ways of promoting them. The strategy addresses local residents, education, research, the economy, infrastructure, the environment, stability and international cooperation in the Arctic. It is organized around priorities for sustainable development, continued proactive interest in the Arctic, expertise in maritime industry and shipping, environmental stewardship, stability and security, and foreign policy.

The Kingdom of Denmark (Greenland and the Faroe Islands) has adopted an Arctic Strategy for 2011-2020¹⁴ focused on development that benefits the inhabitants of the Arctic, involving common interests relating to for example international agreements, and regional and global issues. The strategy promotes these tenets: a peaceful, secure, and safe Arctic; self-sustaining growth and social sustainability in respect of the Arctic’s fragile climate; development with respect for the Arctic’s fragile climate, environment, and nature; and close cooperation with international partners.

Norway has also adopted an Arctic Strategy -- the “High North Strategy,¹⁵” through which it identifies the Arctic as the most important strategic priority in the coming years. It outlines several areas of focus: exercising credible and consistent authority in the High North, leading in the development knowledge in and about the High North, stewardship of the environment and natural resources, providing a suitable framework for further petroleum development in the Barent’s Sea, safeguarding the livelihoods, traditions and cultures of indigenous peoples, and strengthening international cooperation particularly with Russia.

¹³ <http://vnk.fi/julkaisukansio/2013/j-14-arktinen-15-arktiska-16-arctic-17-saame/PDF/en.pdf>

¹⁴ http://um.dk/en/~media/UM/English-site/Documents/Politics-and-diplomacy/Arktis_Rapport_UK_210x270_Final_Web.ashx

¹⁵ <http://www.regjeringen.no/upload/UD/Vedlegg/strategien.pdf>

Sweden's Strategy for the Arctic Region¹⁶ presents Sweden's relationship with the Arctic, together with the current priorities and future outlook for Sweden's Arctic policy, proceeding from an international perspective. The strategy specifies Sweden's top priorities in terms of three thematic areas: climate and the environment, economic development, and the human dimension.

The State Policy of the Russian Federation in the Arctic identifies four national interests: use of the Arctic zone of the Russian Federation as a strategic resource base of the Russian Federation providing a solution for problems of social and economic development of the country; maintenance of the Arctic as a zone of peace and cooperation; preservation of the unique ecological systems of the Arctic; and use of the Northern Sea Route as a national single transportation route of the Russian Federation in the Arctic (further – the Northern Sea Route).¹⁷

The United States' Strategy for the Arctic Region¹⁸ defines U.S. interests in the Arctic region and identifies prioritized lines of effort, building upon existing initiatives and focusing efforts where opportunities exist and action is needed. The strategy is built on three lines of effort: advance U.S. security interests, pursue responsible Arctic Region stewardship, and strengthen international cooperation.

Threaded throughout these national strategies are priorities placed upon stewardship of the Arctic Region, responsible resource development, and international collaboration. The formalizing of the national strategies will lead to action plans and initiatives to address these priorities, and they will undoubtedly touch on requirements for improvements in weather, water, and climate predictions and information services. For example, the United States has released an implementation plan for its National Strategy for the Arctic Region, and it calls specifically for improvements in weather and sea ice forecasts, sea ice research, observations, and stronger foundational scientific research. The GIPPS is a likely cross-cutting solution for these national strategies in the years ahead.

A major focus area for GIPPS requirements is the maritime environment, given that continued sea ice reductions will likely lengthen the navigation season in all regions and increase marine access to the Arctic's natural resources. In 2009, The Arctic Marine Shipping Assessment,

¹⁶ <http://www.government.se/content/1/c6/16/78/59/3baa039d.pdf>

¹⁷ <http://www.arctis-search.com/Russian+Federation+Policy+for+the+Arctic+to+2020>

¹⁸ http://www.whitehouse.gov/sites/default/files/docs/nat_arctic_strategy.pdf

or the AMSA 2009 Report, was approved at the Arctic Council Ministerial meeting in Tromsø. This report strongly outlines the reasons for improved research, observations, and services in the Arctic maritime environment. Six years after its original publication, the AMSA Report continues to resonate as both a comprehensive and an authoritative analysis on the subject of Arctic shipping.

From the AMSA 2009 Report: *“Arctic natural resource development (hydrocarbons, hard minerals and fisheries) and regional trade are the key drivers of future Arctic marine activity. Future Arctic marine activity will include many non-Arctic stakeholders, multiple users in Arctic waterways and potential overlap of new operations with indigenous uses. Arctic voyages through 2020 will be overwhelmingly destinational, not trans-Arctic. A lack of major ports, except for those in northern Norway and northwest Russia, and other critical infrastructure will be significant limitations for future Arctic marine operations. Offshore hydrocarbon developments may lead to increased marine traffic in the Bering Strait region. For the Canadian Arctic, the Northwest Passage is not expected to become a viable trans-Arctic route through 2020, but destinational shipping is anticipated to increase. Marine transportation of oil from the Pechora Sea to Europe is considered technically and economically feasible; the volume of oil and gas may be as high as 40 million tons per year by 2020 on the western Northern Sea Route.”*¹⁹

Antarctic

The southern polar region has no permanent human habitation. There are, however, a number of permanent research stations. In 2014, there were 29 nations carrying out substantial scientific programs in the Antarctic at approximately 40 stations operating year round, such as McMurdo Station, Palmer Station and Amundsen-Scott South Pole Station (United States), Troll Research Station (Norway), Esperanza Base and Marambio Base (Argentina), Scott Base (New Zealand), SANAE (South Africa), and Vostok Station (Russia), and another 60 seasonal field camps. It is estimated that the total station population ranges between 5,000 people in the summer and 1,000 over the winter. And there are tourists and fishermen.

However, observation stations are depleting rapidly in the Antarctic due to the fact that they are mostly sponsored by the research community, and the expansion and maintenance of these

¹⁹ <http://www.pame.is/amsa-2009-report>

systems is becoming a risk. While WMO Members have been requested to seriously consider expanding and maintaining these stations, the continued depletion of these stations will likely, at some stage, have a significant impact on services as verification of services will always remain a crucial part of science.

Human activities on the continent are regulated, administered, and managed by the Antarctic Treaty and related agreements, which are collectively known as the Antarctic Treaty System (ATS),²⁰ which is different than the individual national strategies for the Arctic region as described above. The Antarctic Treaty covers the area south of the 60th parallel. The ATS designates Antarctica as a “natural reserve, devoted to peace and science.” The original Antarctic Treaty was signed in 1959 by the 12 countries that were active in Antarctica during the International Geophysical Year of 1957-58. In 2015, there were 50 countries signatory to the treaty, 29 of which were entitled to participate in the consultative meetings by virtue of their substantial research activities in Antarctica. Seven nations maintain official land claims: Chile, Argentina, Australia, New Zealand, Norway, France, and Great Britain. Sovereignty claims are a motivating factor for many Antarctic campaigns.

The Council of Managers of National Antarctic Programs (COMNAP) is the international association, formed in 1988, which brings together representatives of the National Antarctic Programs of the 29 consultative parties to the Antarctic Treaty.²¹ COMNAP’s purpose is to “develop and promote best practice in managing the support of scientific research in Antarctica.” National Antarctic Program activities include the running of permanent stations and remote field camps and ancillary infrastructure; marine travel ranging from ice-breaking ships to small boats; overland transport from tractor convoys to quad bikes to skis; and air transport ranging from helicopters to fixed wing propeller or jet aircraft through to intercontinental commercial jets. Their concern for effective and environmentally responsible running of Antarctic research activities spans the full time frame of the GIPPS -- from tactical decision making within the hour to new station building plans and transport solutions like icebreakers that require decadal forward planning. COMNAP would, therefore, be a primary beneficiary of a GIPPS.

The Scientific Committee on Antarctic Research (SCAR) is an inter-disciplinary

²⁰ <http://www.ats.aq/e/ats.htm>

²¹ <https://www.comnap.aq/SitePages/Home.aspx>

committee of the International Council for Science (ICSU). SCAR is charged with initiating, developing and coordinating high quality international scientific research in the Antarctic region (including the Southern Ocean). SCAR also provides objective and independent scientific advice to the Antarctic Treaty Consultative Meetings and other organizations such as the UN Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) on issues of science and conservation affecting the management of Antarctica and the Southern Ocean and on the role of the Antarctic region in the Earth system. SCAR has made numerous recommendations on a variety of matters, many of which have been incorporated into Antarctic Treaty instruments. Foremost amongst these have been the advice provided for the many international agreements which provide protection for the ecology and environment of the Antarctic.

While there are no indigenous human cultures, there is a complex ecosystem, especially along Antarctica's coastal zones. In terms of the wider Antarctic region, sea ice grows out over the southern oceans to 60°S in some places. Hence the broader southern oceans and the region poleward of 60°S or at least poleward of the Antarctic Circle should be considered in terms of the GIPPS. There is significant marine activity across the southern oceans and there is a clear need for accurate and timely forecast information.

The Southern Ocean is rich in marine life, including species of interest to the fishing industry. Fisheries are regulated by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), which entered into force in 1982 and has a Commission today with 25 Members.²² CCAMLR was established with the objective of conserving Antarctic marine life. This was in response to increasing commercial interest in Antarctic krill resources, a keystone component of the Antarctic ecosystem and a history of over-exploitation of several other marine resources in the Southern Ocean. The Convention provides for the conservation and rational use of krill, fin fish, and other marine living resources within the Convention area. An important feature of CCAMLR is the ecosystem approach to conservation, requiring that the effects on the ecosystem must be taken into account in managing the harvesting of marine resources.

The Southern Ocean, however, experiences less fishing activity than many other parts of the world mainly due to the dangerous weather conditions, high operational costs, and large

²² <https://www.ccamlr.org/>

distances from markets. The Marginal Ice Zone (MIZ), or the outer edge of the sea ice pack, is an area of high productivity and fishing vessels often operate along its outer margin. Given the particular climatic conditions that fishing vessel operators are exposed to within the Convention area and the resulting possible implications for safety of life, coupled with the significant impact that accidents can have on the environment, it was expressed at the thirty-third meeting of CCAMLR²³ (2014) that safety standards for fishing vessels, in particular ice-strengthening requirements, should be enhanced in order to better protect crew members on the one hand and marine living resources on the other.

The Antarctic has become a very attractive tourism destination with a significant increase in cruise ships especially from South America. The total number of tourists visiting Antarctica during the 2014/15 season was around 37,000, including around 27,000 landed passengers. The majority of tourism voyages operated within the Antarctic Peninsula region during the five-month Austral summer season (from November to March), departing from Ushuaia, Argentina, and to a lesser extent from other ports north of the Antarctic Treaty Area. Four operators conducted deep-field tourism activities during the 2014-15 season, which was supported by advanced transport logistics, such as tractor transverses and aircraft operations. The premier representative body for Antarctic tourism is the International Association of Antarctica Tour Operators (IAATO), which includes over 100 member companies from the southern polar region, Europe, and North America.²⁴ IAATO was founded in 1991 to advocate and promote the practice of safe and environmentally responsible private-sector travel to the Antarctic. In fact, in January 2015, IAATO appointed a full time Environmental and Operations Manager who will focus, primarily, on safe field operations. Clearly, IAATO would be another beneficiary of GIPPS.

The focus for Antarctic tourism is the continental experience. The overwhelming desire of the tourist is to "set foot" on the continent. However, tourist access to Antarctica is particularly hampered by sea ice. Reductions in sea ice are predicted for the future, which will reduce 'natural' barriers to shipping access in the high latitudes and open up otherwise difficult areas for tourist access. With these activities comes an increased threat to life and property due to increasing melting of ice caps and the floating of ice bergs as some countries do not have the capability of providing sea ice warning services and or track the movement of ice bergs and rely on other

²³ <https://www.ccamlr.org/en/system/files/e-cc-xxxiii.pdf>, p8

²⁴ <http://iaato.org/home>

organizations/institutions for this. Every effort should be made possible to provide these countries with these capabilities.

The bulk of the Antarctic population, thus, consists of scientists, those offering the logistics for science to be conducted, tourists, and fishermen. The ATS (including CCAMLR) places the region in a unique framework of international collaboration with a systems approach to management and a focus on scientific research that blends well with the borderless nature of atmospheric and ocean processes and the cooperative delivery of weather and ocean services, concepts from which the GIPPS extends.

From a weather perspective, the higher latitudes of the Southern Hemisphere experience considerable levels of internal or natural variability in the atmospheric circulation, with the storm tracks dominating the weather and climate over the southern oceans. However, tropical influences are very important for modulating the circulation at high southern latitudes, especially over the Pacific sector which is exposed to energy propagation from the tropical Pacific. There is growing evidence that teleconnections between the Antarctic and the low latitudes as well as across the hemisphere are occurring and can be transmitted in both directions (that is both from and towards Antarctica). Teleconnections can take place via the atmosphere and/or the ocean, although the timescales are usually different. The most rapid teleconnections generally occur via the atmosphere, with storm track changes occurring on the scale of days or weeks.

Improved predictions of the Southern Annular Mode (SAM, describing variability in the southern ocean storm track and associated jet stream) on weekly to monthly time scales, and the influence of tropical variability on intra-seasonal time scales would be a major boost to forecast skill over the southern oceans. Moreover, SAM variability and tropical teleconnections modulate regional sea ice extent and Antarctic coastal weather and climate, especially across the West Antarctic coast and have important implications for operations in these regions.

The global ocean currently absorbs one-quarter of the anthropogenic CO₂ added to the atmosphere each year. Of the anthropogenic CO₂ emissions absorbed by the world's oceans, the Southern Ocean absorbs over 40%. Polar pH is changing at twice the rate of tropical waters. There is increasing concern that ocean acidification could affect the functioning of whole marine ecosystems, and particularly polar ecosystems. However, the mechanisms by which population

impacts will occur have not been identified. The best analogues we have for high-CO₂ ocean environments are natural marine ecosystems near volcanic vents. These ecosystems point the way toward dramatically different ecosystems once pH drops below 7.8. This may have potentially serious impacts within the 21st century, for the sustainability and management of many marine and coastal ecosystems.

The interconnectedness and sum value of the ocean, continental ice, sea ice, atmosphere and biota are fundamental drivers for the development of an integrated Polar Prediction system such as the GIPPS.

Third Pole/High Mountain

The Third Pole region is drawing increased attention among the international academic community. It is centered on the Tibetan Plateau, stretching from the Pamir Plateau and Hindu-Kush on the west to the Hengduan Mountains on the east, and from the Kunlun and Qilian Mountains on the north to the Himalayas on the south.

There are more than 50,000 glaciers in this region with total area of about 127,000 km² and ice volume of 15,000 km³ (Wang and Su, 2003). The total discharge from meltwater amounts to 150 km³, with about half outflows towards oceans and another half supplies the interior dry basins. The overall area of permafrost is larger than 1.5×10^6 km². Snow covers an area of up to 2.5×10^6 km² of this upland Asia region in extreme winter/spring climate.

The Third Pole region exerts a direct influence on social and economic development in the surrounding regions of China, India, Nepal, Tajikistan, Pakistan, Uzbekistan, Afghanistan, Bhutan, and Mongolia. It is a region with unique interactions among the atmosphere, cryosphere, hydrosphere and biosphere. In particular, the special atmospheric processes and active hydrological processes formed by glaciers, permafrost and persistent snow are especially influential, as are the ecosystem processes acting at multiple scales.

The Third Pole region is highly relevant to regional weather/climate and is a critical source for water availability; thus, it is extremely important in sustainable development in this most populated region of the world (Barnett *et al.*, 2005; Ding and Qin, 2009; Immerzeet *et al.*, 2010).

Approximately eight large rivers originate from the high Asian cryosphere. The Yangtze

and Yellow Rivers flow into the Pacific; the Ganges, Indus, Yarlung Zangbo/Brahmaputra and Lancang/Meikong Rivers flow into the Indian Ocean; while the Ob and Yenisei rivers flow into the Arctic. Interior rivers originating from high altitudes feed large oases in the lower deserted areas of the hinterland of Asian continent. The largest basin, Tarim River Basin, has a large population (about 20 million people), along with the Hexi Corridor (five million people). Life would not exist in these dry basins without snow/ice in the high mountains. Cryospheric changes in high Asia directly impacts sustainable development in local and adjacent regions, along with potential socio-economic impacts on downstream regions.

Existing Services

Arctic/Antarctic

National Meteorological and Hydrological Services observe weather, ice and water conditions around the world, providing a steady flow of data which are then transmitted worldwide for forecasts and planning purposes (WMO World Weather Watch). Forecasts and warnings are generally provided for surface, marine, and aviation weather interests, with emphasis when possible on high-impact events such as extra-tropical storms and polar lows, storm surge and other coastal hazards, heavy precipitation, floods, droughts, volcanic ash, and space weather. Services are delivered through a number of media from the Internet to high frequency (HF) radio broadcasts.

Meteorological and oceanographic services provided by various governments across the world, and indeed within the Polar Regions, vary in terms of content, presentation, and time scales covered. General forecast services, designed for land areas with permanent populations, are typically more robust than those for the coastal marine and offshore/high seas environments. “Public” weather forecast information is generally available on an hourly to daily basis for five to ten days in advance, containing routine information about temperatures, winds, and precipitation and warnings or alerts for extreme weather. Marine forecasts are generally less detailed – provided for broad areas – and do not extend as far into the future. Forecasts of wind, sea, and weather conditions are generally provided for 24 hours up to 72 hours in some locations with more general outlooks out through five days. In marine forecasts, hazards such as strong winds, freezing spray (ice accretion), fog, and heavy seas are emphasized. Marine and oceanographic services are also provided by the private (commercial) sector, primarily to provide greater detail in

forecasts and analysis to support commercial ship routing, oil and gas development, etc.

Sea ice services are handled and distributed both by various national institutes and commercial companies. The provision of ice charts and basic forecasts are usually governmental responsibility for the safety at sea. Current sea ice services are largely concentrated on the production of near-real-time ice information (analyses). Ice products are created by combining data from satellites, limited aerial and shipboard observations, and in-situ sensors, using models and expert analysis. Detailed ice information is required by a wide spectrum of users operating in ice-affected regions e.g. native hunters, cruise ships, commercial ships, supply ship, ice breakers.

In the Antarctic, routing advice is typically provided directly to ship operators and not made publicly available. For the Antarctic, National meteorological or oceanographic agencies provide tailor-made advice to their respective operational program. At times this results in multiple overlap of service and partly inconsistent service levels. Since 2013, The Australian Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) has provided routing advice towards certain locations of Antarctica (e.g., approaches to coastal stations) through the sea-ice zone through annotated imagery with an explanatory narrative.

Most National Antarctic weather services are built from small dedicated groups operating at the periphery of their homeland National Weather Service. Where such dedicated services exist, they generally comprise one or two dedicated personnel augmented by a yearly recruitment of forecasters and observers from within their agency to deploy on expedition. Weather observers are generally deployed for one year (i.e., overwinter), whereas forecasters are mostly deployed for the busy operational summer season only.

The Australian, British, American, Italian and German services, for example, maintain forecast briefing offices at their respective Antarctic bases during the busy summer operational season, particularly to support air transport operations. Other than the McMurdo summer forecast office, all other Antarctic briefing offices are insufficiently staffed to provide a continuous 24 hour, 7-days-a-week service. Weather watch is not always provided by many National programs, even when flying operations are underway. Consequently, issued forecasts are not necessarily amended or updated as appropriate under ICAO aviation or WMO public weather service

amendment criteria. In some programs, it is the aircraft pilots who will review the current surface and satellite observations to assess the validity of the last forecast issued.

Many national Antarctic programs only deploy trained observers to their stations, who then extend their meteorological skills into forecast service provision based on internet products. In addition to observers working as surrogate forecasters, some National meteorological services have forecasters with limited or no Antarctic specific training issuing their Antarctic forecasts. The high fraction of Antarctic personnel with expert science knowledge also sees Antarctic researchers with non-forecasting backgrounds filling the gap in weather service provision. Quality management systems for both Antarctic forecaster training and competency assessment as well as for the service delivery process are in 2015 largely under-developed.

Slow communications (i.e., low bandwidth) limits weather information retrieval. For those with internet connections, the Antarctic Mesoscale Prediction System version of the Weather and Research Forecasting model offers a high quality suite of maps and time series. Most vessels (including National Antarctic program vessels) as well as tourist operators on land make use of free and low-bandwidth friendly raw forecast data provided through email services. These services allow the operator to designate the domain of interest, model fields, time steps and email frequency. As a test to new production systems for a low-bandwidth friendly service, the Australian Bureau of Meteorology in 2014 provided more elaborate and free forecast charts and satellite imagery on request to vessels operating in Australian Antarctic waters through automated emails <100Kb. The service was found to be very useful by the half dozen vessels in the trial. Commercial services that include forecaster interpretation are also available from the Australian Bureau of Meteorology.

National hydrological services measure and monitor hydrologic variables and issue predictions for effective water resources management and flood management. The WMO promotes water-resources assessment and provides the forecasts needed to plan water storage, agricultural activities and urban development (Hydrology and Water Resources Programme). Like meteorological information, hydrologic services vary in terms of content, presentation, and time scales covered. Services are generally designed to ensure forecasts and warnings of hazardous events such as floods and droughts, as well as provide information necessary for important resource management activities. In many countries, the hydrological services are a separate entity

from the meteorological services and, often, belong to different ministries with very different missions. As with meteorological and oceanographic products and services, the private (commercial) sector provides more focused hydrological information to meet the needs of their customer base, i.e., dam operators, reservoirs, etc..

Climate services take several forms, from statistical information based upon historical records to predictions based upon computerized general circulation models to consensus-driven outlooks developed through regional forums (Regional Climate Outlook Forums). Like weather and oceanographic services, climate services are delivered both by government organizations and private companies. The WMO Climate Information and Prediction Service (CLIPS) project focuses on the promotion of operational climate prediction services, particularly on seasonal to inter-annual scales in a user-targeted manner. There is currently no consolidated or unified Regional Climate Center for the Arctic or Antarctic, though many climate analyses and forecasts are being produced from various centers.

Third Pole/High Mountain

Snow storms are forecast by most regional and national weather services for the Tibetan Plateau and Himalayas. Thermal conditions, such as snow cover, soil moisture, and heat flux, over these areas have been found to seriously impact the East Asian monsoon activity. Recognizing that this is a key factor for seasonal prediction of climate, this is a high priority of emphasis by the Beijing Climate Center (BCC).

Long-term prediction of water availability from changes in glacier meltwater is operational. However, the tipping point for continued decreasing meltwater in small glacier catchments is predicted to appear around the 2030s to 2040s.

Monitoring networks of permafrost exist along Tibetan highways and railways, with some initial predictions of permafrost thawing and preventive measures being made.

For ecology protection and pasture maintenance, some basic research is carried out in the headwater of rivers such as Yellow, Yangdz, and Meikong, including in situ measurements of ecology and hydrology.

User Needs

Arctic

From the AMSA 2009 report: *“As more ships venture into the Arctic, the demand for ice information, as well as other ocean data, products and services, will continue to increase and the resources available to meet this increased demand will be stretched. The ice parameters needed in the future will not change significantly but will be required over larger geographic areas and longer periods of the year. Operators will still need to know where the ice is and is not; where it is going to be, how closely packed it is and how thick and strong it is; generally, how difficult it will be to go around or, when necessary, go through. These parameters will be needed on a variety of space and time scales - from the hemispheric to the local, from months and weeks to daily or even hourly - to support tactical and strategic route planning for ships, scientific study and the development of policy and regulations to ensure safe marine practices.”*

Seasonal predictions, particularly the period of open water that defines an extended operations and shipping season, are increasingly in demand. Multi-decadal sea ice projections are also required for infrastructure planning, ecosystem stewardship under rapidly changing conditions, and projection of global climate impacts forced by changes first occurring in the Arctic²⁵.

On a decadal scale, sea ice loss is a major index of global climate change and represents an important time horizon for community, industrial, and environmental management. Unfortunately, current models appear to be too slow in future projections of sea ice loss, relative to what is actually occurring. A major difficulty for long-term modeling is diverse model results and lack of good physical data regarding winds and clouds.

People that live and work in the Polar Regions also have a great need for climate information, as expressed in the many reports documenting the impacts of climate change. Socio-economic decisions can benefit substantially from better knowledge of climate conditions at a scale useful for planning, mitigating and adapting. Researchers are interested in long time series of weather and ocean data.

²⁵ NOAA's Arctic Vision and Strategy http://www.arctic.noaa.gov/docs/NOAAArctic_V_S_2011.pdf

According to the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP), the rapidly-changing Arctic presents a challenge to those working on adaptation actions at the local, regional, or global level. The inherent uncertainty of long-range climate forecasts makes it important to provide Arctic communities with a broad suite of tools to help them respond to a changing ecological and social environment. This includes higher-resolution regional models, which are needed for climate prediction at a scale useful for planning, mitigating, and adapting.)

The following are but a few examples of specific user requirements for weather, water, sea ice, and climate information in the Arctic.

Natural Resource Development: Energy and mineral extraction and development are currently underway in the Arctic region. As ice continues to melt more each year, interest in deep water energy drilling has increased. As an example, a probability-based forecast for the timing of the formation/freeze up of sea ice was needed by a U.S government agency in 2012 to evaluate an industry request to extend the drilling season in the Chukchi Sea. This was groundbreaking work that pushed the limits of current forecast techniques and model performance in the U.S. The most critical information for operations planning in the Arctic is the length of the open-water season. Some years may have too short of an open-water season to expend resources; others may have long open-water season to maximize resources spent. Industry users need better information on sea-ice melt out in the summer and freeze up in the fall.

Transportation: In addition to an increase in resource development, a reduction in sea ice is opening shipping routes through the region. However, with the loss of sea ice and its damping effect, mariners will face a new sea state. In an ice-free Arctic, wave height conditions of 25-feet or greater could be the new normal that mariners may have to design and plan for. In addition, the increased marine traffic results in increased emissions of black carbon as well as the potential for increased emergency search-and-rescue and/or oil-spill response capabilities.

Community Resilience and Adaptation Planning: Resilience is a property of social-ecological systems that relates to the capacity of the system to cope with disturbance and recover in such a way as to maintain its core function and identity, while also maintaining the ability to learn from and adapt to changing conditions, and when necessary to transform. A resilient Arctic

system is thus better able to absorb disruptions in the form of both abrupt disturbance events as well as more gradual forces of change²⁶.

The result of climate change, resource development, increased transportation, and more have caused drastic and unprecedented changes to the way of life for the people living in the Arctic. Access to food resources is often related to travel access and safety. Warmer springs have led to faster snowmelt and river break-up that makes it difficult for communities to use snowmobiles to access their hunting and fishing camps. Late freeze-up of sea ice leaves many coastal communities vulnerable to fall storms that result in coastal erosion and are requiring some villages to consider relocating further inland. Such changes require enhanced weather, water, and climate information that will help these communities become more resilient and make informed decisions.

One special group with specific weather and climate outlooks is the reindeer herders in Euro-Russian Arctic. During the International Polar Year, a project named EALÁT concentrated on the effects on the life and work for this group of indigenous people. “Climate change is not currently a threat to reindeer husbandry. However, trends that are already being experienced (increased climate variability) may lead to further insecurity for herders as pastures are iced over, preventing reindeer from feeding. Tundra fires, which are expected to intensify in Siberia are already challenge for reindeer herders there as fire suppression in remote areas has been halted. As pastures are encroached, reindeer herders flexibility is reduced which limits their responses to future climate variability.”²⁷ This is an example of a group that will need specific services for weekly, seasonal, and long-time weather and climate outlooks.

Infrastructure Protection and Hazard Mitigation: Erosion and flooding are responsible for millions of dollars of property damage each year. Coastal erosion is impacting the Arctic’s coastlines as sea ice diminishes and permafrost melts. Analyzing over half a century of shoreline change data, most of the northern Alaska coast, for example, is retreating at rates of more than 1 meter a year²⁸. A number of communities are threatened with increased rates of coastal erosion

²⁶ Arctic Resilience Interim Report 2013 published by Stockholm Environmental Institute and the Stockholm Resilience Center, <http://www.sei-international.org/>

²⁷ <http://reindeerherding.org/challenges/climate-change/>

²⁸ National Assessment of Shoreline Change: Historical Shoreline Change Along the North Coast of Alaska, U.S. – Canadian Border to Icy Cape <http://pubs.usgs.gov/of/2015/1048/>

and flooding. Water level measurements are needed to support predictions (e.g., tides and river stages) and ultimately warnings about how high the water will get during flooding events. Most communities and villages are located along either the coast or a river system, and rely on them as a source of food, travel, and re-supply. They cannot make effective evacuation plans or decisions without this information. The ability to better predict and understand the effects of phenomena such as widespread thawing of permafrost will help communities prepare for considerable maintenance issues on existing roads, airports, buildings, and pipelines. Just as importantly, it will aid engineers when it comes to properly siting, designing, and constructing new infrastructure capable of withstanding future changes in their specific environments²⁹.

Ecological Changes: Changes in sea ice, higher sea-surface temperatures, warmer summers, reduced snow cover, etc. are causing a cascade of ecological impacts throughout the region.³⁰ Shrinking sea ice is causing walrus to move farther north each year, making it more difficult for indigenous hunters to access this important food source. Thawing permafrost results in the release of carbon dioxide and methane into the atmosphere. An increase of carbon dioxide in the atmosphere contributes to an increasing acidification of the world's ocean. Freshwater runoff from rivers flowing into the Arctic contributes to ocean acidification because river water from North America and Eurasia usually contains large amounts of organic matter. All these factors have consequences for marine organisms such as shellfish, which require a less acidic environment. Populations of these species will drop, and the species that depend on these shellfish and other marine organisms in the ecosystem as a food source will also be impacted. Long-term observations are needed in order to be able to identify trends in how marine organisms are reacting to the changing chemistry of the oceans they live in.³¹

Improved sea ice and marine weather forecasting would assist the energy, maritime shipping and transportation industries, as well as infrastructure planning, economic development, and ecosystem stewardship. An enhanced and integrated set of environmental observations is required to track changes to the Arctic across the land, in the atmosphere, and in the ocean, including physical indicators, biological responses, and social and economic impacts. Rapid

²⁹ Preliminary Report to the Alaska State Legislature, Alaska Arctic Policy Commission, January 30, 2014, <http://www.akarctic.com/>

³⁰ http://oceanservice.noaa.gov/education/pd/climate/teachingclimate/ecological_impacts_of_climate_change.pdf

³¹ <http://www.sciencepoles.org/interview/explaining-ocean-acidification-and-consequences-for-arctic-marine-ecosystem>

integration, interpretation, and dissemination of this information in near-real time are required to support decision-making.

Antarctic

There are generally two types of Antarctic weather service users: the operational community and the research community. The operational community seeks weather knowledge for natural resource exploitation and management, disaster mitigation, safe and efficient transportation, safe and efficient running of operations, infrastructure protection and long range infrastructure investment planning. The research community wishes to easily access authoritative, useful, comprehensive and up-to-date advice and information to assist in the conduct of their science.

It is well recognized that timely, accurate, and fit-for-purpose weather services underpin the safe and efficient running of Antarctic operations; however, quality weather and sea ice information is not consistently made available to all Antarctic operators. For example, some National Antarctic programs are supported with tailor-made products on an expedition specific-basis by affiliated national meteorological or research agencies, while Antarctic tourist, cargo, and fishing vessels are not similarly supported.

High seas forecasts issued from responsible Southern Ocean METAREA nations (i.e., Chile, Argentina, South Africa, Australia and New Zealand) are deemed inadequate by most tourist and National program vessels operating in Antarctic waters and it is uncertain whether fishing vessels routinely use them or not. Iceberg details are rarely included and there is no consistently agreed method for designating the sea ice edge location. There is also concern that Northern Hemisphere derived algorithms for observing and designating the sea ice edge are inappropriate for Antarctic ice due to flooding of the ice in the Marginal Ice Zone (MIZ) from open water waves. Ice accretion is another key forecast element that is not reliably included across all designated METAREAs.

For Antarctica, the need for a concerted effort to provide an integrated and consistent operational sea ice information service has recently been acknowledged by the concerned community of shipping operators and (potential) service providers. This has manifested in special attention to Antarctic issues during three international meeting, namely:

- The 4th Ice Analyst Workshop (in Helsinki, Finland in 2014)
- The first IICWG meeting held in the Southern Hemisphere (Punta Arenas, Chile in 2014) with a special focus on Antarctic sea ice
- A dedicated Sea Ice Challenges Workshop organized by COMNAP in Hobart, Australia in 2015.

At the COMNAP sea ice challenges meeting (2015), the Australian Bureau of Meteorology proposed that COMNAP members consider co-investing in the development and maintenance of a Southern Hemisphere sea ice service, on the basis that this community will be the prime beneficiary of such a service while promoting advances in the integrated science of sea ice prediction. The development of multiple national ice agencies is on the whole a much more inefficient alternative given the staff and infrastructure required to run a state of the art service in the style of the WMO service delivery model.

Most Antarctic operators and forecasters are still working from single deterministic solutions, despite the current state of the art being in the use of ensemble prediction systems. The Australian program is one of the few that places strong emphasis on ensemble products. They routinely inform operators with probabilities of exceeding key thresholds to assist in the planning and decision making process. For example, a crane operator may only wish to work in winds below 15 knots; a small boat driver below 20 knots, while a ship's master refuelling a station from ship-to-shore may be concerned with the probability of shifting winds that may cause the ship to swing on anchor etc.. These events can be placed in the context of risk assessment by providing information on the likelihood of certain hazard occurring. This area of emphasis on communication of forecast probabilities and decision support services is under development and fairly robust within the Australian program, for example.

Lack of observations has long been a problem for scientists working in the Antarctic. The early expeditions were mainly carried out during the brief Antarctic summer, and there is still a bias towards summer observations in some fields – for instance many of the research vessels investigating oceanographic conditions in the Southern Ocean are not equipped to work in the ice-strewn seas of the Austral winter, and 24-hour darkness restricts work on land at that time. Designing and implementing observation comprehensive, robust and uninterrupted observation programs is a key service for the research community that is currently in need of development.

At the latest Antarctic Meteorological Observations, Modelling and Forecasting Workshop (Cambridge, 2015), the Australian Bureau of Meteorology suggested that current service-providing organisations collaborate to define best practice in the science and implement quality management principles in both their training and product delivery systems, so as to ensure that the highest-quality service can be offered to all Antarctic operators. Further, service capacity could be built up at the National and International level through co-investment, commercial development and improved coordination to minimise duplication of effort and maximise on skill and resource sharing. This is an expanded concept of the funding and service delivery model, which was suggested to COMNAP at their sea ice challenges workshop in May 2015 (Hobart).

The World Meteorological Organisation, associated agencies and the Antarctic Treaty system provide an unparalleled framework for coordinating such international collaboration in Antarctic weather service development, whilst the GIPPS provides the complete model to realise an integrated weather, ocean, ice forecast and climate service.

Marine Survey

As an outcome of the Second Session of EC-PORS in Hobart, Australia, October, 2010, a small team of EC-PORS members agreed to facilitate the conducting of a survey to capture the service requirements of the marine community in the Polar Regions. To get the most out of a survey, the team made use of already existing projects with similar tasks of ascertaining user requirements. The survey methodology and results are summarized in a separate document. The survey was conducted in the Arctic first in 2011 and followed by the Antarctic in 2014. The findings as they relate to service requirements in the Arctic and Antarctic are presented here.

The survey found that weather, ocean and ice forecasts are important on both short and long time scales for marine users to accomplish their mission. Forecasts on shorter time scale (hours up to 2 weeks) are used for tactical decisions (navigation), on longer time scales for operational planning (30-days, seasonal to inter-annual) or even longer (years, decades) for strategic planning e.g. development of new logistics and investments. High spatial resolution (less than 10 km) is not critical as too much detail can be counterproductive and, therefore confusing and hard to interpret. Frequent updates of the shorter forecasts are valuable. Ice berg information was only requested by the “marine safety” user segment and occurrence, size, drift and shape were all valuable information. The U.S. Coast guard *Healy* and Swedish Ice breaker *Atle* were the only

marine users indicating that they found satellite imagery of ice useful. Snow cover and water on ice are more important for users within the “marine and coastal environment” and “climate and seasonal forecasting” user segment.

For Antarctic users, the survey was issued to the CONMAP members in 2015. The respondents reported wind, horizontal visibility, precipitation, temperature, sea state and sea ice as the main forecast elements that are imperative for reducing cost and risk to their activities. Around 80% of the respondents reported that these forecasts are imperative for tactical decision making (i.e., < 5 days). Daily to sub-daily updates and high resolution weather products are reported as most desired. Included in the mix of routinely accessed weather products are cutting edge but often non-validated products such as sea ice motion and thickness analyses and forecasts. Weather information becomes less critical for operational and strategic planning as opposed to shorter time-scale tactical decision making, though a requirement for seasonal to decadal atmospheric and oceanographic outlooks is still noted as useful by >50% of respondents, with a particular emphasis on sea ice outlooks. Only one respondent answered that their service requirement for seasonal to decadal atmospheric and oceanographic outlooks is currently being met.

The marine survey facilitated by the STT can be considered one example of linking service development and delivery to user needs as called for within WMO’s Service Strategy.

Third Pole/High Mountain

In 2011, in order to encourage regional cooperation for policy development through the advancement of relevant knowledge on the environmental changes occurring at the Third Pole, UNESCO, the Scientific Committee on Problems of the Environment (SCOPE), and the Chinese Academy of Sciences (CAS) launched an international scientific program called “The Third Pole Environment (TPE).” The TPE has identified six key science questions in this region: (1) Environmental and ecological changes having occurred on different time scales in the past, and driving mechanisms; (2) Characteristics of water and energy cycles, their main components, and relationship to the Indian monsoon and westerlies; (3) Responses of ecosystems changes to global warming, especially at high elevations; (4) The glacial status of the Third Pole, and the response of glacial retreat and mass balance changes to the water and energy cycle and its components, in addition to their environmental impacts; (5) The impact of anthropogenic activities; (6) The more appropriate way to adapt to global change and more efficient way to sustain future environment

sustainability in the Third Pole region.

Under the umbrella of the above questions, there are many aspects of user needs. The most prominent needs can be summarized as the following.

Seasonal climate prediction: Because of high elevation of rough topography of the Third Pole region, thermal state of the plateau determines largely of onset and northward progress of Indian monsoon and East Asia monsoon. In this respect, snow cover on the Third Pole region was listed as key variables for predict seasonal climate of surrounding regions. In situ snow cover data over the Third Pole region still needs to be integrated with satellite data. Reliable reanalysis data are very scarce. Existing reanalysis data sets are almost useless in the region. Regional climate models need to be improved in this domain so as to meet the requirements of various services as listed above.

Water availability prediction: This includes both seasonal and long-term prediction. Temperature and precipitation changes over the high mountains largely determine the meltwater availability in warm seasons. Seasonal distribution of meltwater to the downstream low lands is very important to agriculture and industry, and people's daily life. Also, the tipping point that overall meltwater change from "increasing" to "decreasing" in the next decades are also critical for the planning of the structure of socio-economy in these region. Because of rapid development of these countries in recent three decades, oasis and industry have rapidly growing yet the size of cities, human populations and areas for agriculture depends on water availability nowadays and in the future. Seasonal prediction and long-term projection of meltwater from high mountains is urgently needed for such services. Reliable hydrological models need to be coupled with climate models to stimulate seasonal river runoff and make projections of long-term changes. Long-term meltwater projections should be merged into the adaptation strategy of socio-economic development of lower basins in the future.

Hazards prevention: Many hazards are related to the changes of high mountain hydrometeorological conditions. For examples, spring floods in some catchments lead to big losses; glacier lake outburst floods in Himalayas, Tianshan, and Pamir regions destroy infrastructures and human lives; blizzards and strong snow storms kill many livestock like sheep and horses. These hazards need to be warned early and prevention based on observational data and

good models for accurate forecast and prediction. For catchment scale hydrology, coupling of weather models with ice melt models (e.g., degree-day model) need to be improved to predict spring floods and provide early warning services. Both in situ and satellites monitoring of high-risk glacier lake outburst floods should be operated for these regions where such floods may have high impacts. Blizzards warning systems should be based on regional climate models.

Infrastructural protection: Highways and railways on the high plateau and mountainous regions are destroyed because of heave and settling of frozen ground. Thawing of permafrost increases this hazardous situation, both today and in the future. Monitoring and predicting the changes of the thermal and ice state of permafrost is key to ensure the stability and maintenance of these transportation projects. There are similarly high needs for improved science and technology for other infrastructure projects, too, such as for buildings, bridges, etc.. Monitoring of borehole temperatures and ice content along the major linear projections over the Third Pole region should be intensified so that a more robust and precise prediction capability can be made.

Ecology protection and pasture maintenance: Large areas of pastures over the plateau and mountain regions are basic sources for millions of livestock of the region. However, these pastures are predicted to undergo significant changes with climate and cryospheric changes impacting the region. In recent years, on some regions of the plateau, increasing surface water flooded large areas of pastures, which led to negative impacts to the local people and economy. Scientific understanding of the interactions between frozen ground and ecology over the plateau is quite poor. This is mostly based on the right description of the water balance in the interface between cryosphere, atmosphere, and biosphere over the region. At present, there has only been some testing sites over the hinterland of the plateau.

Service Delivery Progress Model Assessment

This paper, as a continuation of EC-PHORS³² work on the GIPPS, is intended to define and validate the needs and opportunities for improving weather, ice, water, and climate services in the Polar Regions; relate these to the GIPPS concept; and ensure the concept of a GIPPS is responsive to user requirements. Accordingly, the WMO Service Delivery Progress Model is used

³²EC-PORS (Polar Observations, Research and Services) was changed to EC-PHORS (Polar and High Mountain Observations, Research and Services) by the 67th Session of Executive Council in June 2015; thus, references to the Expert Panel in 2015 and beyond will contain the new title.

to assess the level of development of the NMHSs in each polar region and to outline potential best practices and action plans for improving services delivery through the EC-PHORS collaboration.

The WMO Strategy for Service Delivery, which is aligned with the WMO Strategic Plan, was approved by Cg-XVI. Four years later, Cg-XVII agreed on the concept of a holistic approach to service provision.³³ The Strategy defines the four stages of a continuous, cyclic process for developing and delivering services and describes practices to strengthen service delivery across the entire WMO. The stages are: user engagement and developing partnerships; service design and development; service delivery; and evaluation and improvement. These four stages are further refined into six elements, which detail the activities required for high quality service delivery:

1. Evaluate user needs and decisions.
2. Link service development and delivery to user needs.
3. Evaluate and monitor service performance and outcomes.
4. Sustain improved service delivery.
5. Develop skills needed to sustain service delivery.
6. Share best practices and knowledge.

Through the Service Delivery Progress Model (SDPM), this framework provides a consistent method to evaluate whether organizations (e.g., NMHSs) have the components necessary to be positioned to meet emerging service requirements – such as in the polar and high mountain regions. The Services Task Team used the SDPM to generally evaluate the capacity for improving weather, ice, water, and climate services in the polar and high mountain regions through inputs from the task team membership. The following section of this white paper highlights potential areas where improvements should be focused as well as best practices identified through this process. The entire EC-PHORS membership should next be consulted for acceptance of this assessment, and an action plan or implementation plan could then be developed as a roadmap toward GIPPS.

Arctic

While there are some differences in how NMHS organizations in Arctic countries provide their services, in general, the NHMS operate with similar functions, capabilities, and

³³http://library.wmo.int/pmb_ged/wmo_1157_en.pdf, page 213.

responsibilities. Forecasts, warnings, and alerts for safety of life and property and to support the efforts to reduce the impacts of weather, water, climate, and related environmental hazards are provided. Essential data and information necessary for supporting the various critical economic sectors (e.g., water resources, transportation, agriculture, etc.) are provided. Observing system networks, telecommunication networks, data processing and forecasting systems, and other necessary investments are made to advance science and technology related to the provision of these services.

When reviewed in the context of the SDPM, weather service delivery across the Arctic can be considered advanced. The users of the products and services are known and there are processes for engaging with users on their requirements in most areas. Verification of forecast accuracy, quality, and effectiveness is conducted and serves as a source of required improvements, and science and technology improvements also drive service improvements. There are training mechanisms in place to develop/maintain skill in weather forecasting and best practices are shared toward improving service delivery.

In considering sea ice service delivery, some of the aforementioned components of the SDPM are under development but cannot be considered “advanced.” For example, sea ice forecasts are not consistently verified for accuracy, quality, and effectiveness. And while some developments in science and technology are being utilized to improve sea ice service delivery, there are significant observational and research investments that are not well connected to the operational environments in the NMHSs. This “research to operations” gap will be further described in a subsequent section of this paper.

Antarctic

Service delivery for the Antarctic is at a considerably lower level than that in the Arctic, because of the sparse habitation of the region poleward of 60°S. Relevant NMHSs (e.g., New Zealand, Australia, South Africa, Chile, Argentina) provide routine forecasts for sectors of the southern oceans, the Antarctic sea ice regions, and parts of the Antarctic coast in support of fisheries, tourism and scientific activities. In terms of the WMO Strategy for Service Delivery and the SDPM, Antarctic service delivery is at an intermediate level. Forecast operations and dissemination match the international state of the art, though verifying observations are sparse and liaison with user communities is not at an advanced stage.

Research to Operations (R2O) Considerations

Service delivery for weather, water, ice, and climate information has improved considerably over recent years owing to investments in modeling and observations (including satellites), and these investments were made effective by targeted research and development activities to make the data sets useful to the NMHSs. Ostensibly, the requirements for these investments were founded in user-based service needs.

With new or increased demands on the forecasting community when it comes to services in the polar regions and high mountain areas, this issue of ensuring relevant research is tightly coupled to operational efforts is very important. To improve the R2O process, strong interaction between the research and operational communities must exist. Verification of forecast skill and ongoing dialogue about performance should guide certain research investments toward improvement. Observations, modeling and prediction, and information dissemination to users should be tightly linked, and the financial support of the operational system and transitioning new technologies and capabilities into operations requires long-term commitment. This requires a robust infrastructure for transitioning research – such as the use of test beds or proving grounds within the NMHS structure so as not to draw resources away from the operational systems.

As an example, much research has been directed at climate change and estimating future states of climate variability, but this information is not often transitioned as a service or decision-tool to inform climate adaptation plans, risk management activities, advanced warning systems, etc.

There are specific R2O requirements, beyond the timeliness and longevity aspects, for operational observational data. Guidance around climate data management from various sources and metadata is needed, including on standards for preservation, archiving, management and information services.

Existing and Emerging International, Intergovernmental Opportunities and Partnerships

Over the last several years, interest in the Polar Regions, particularly the Arctic, has increased considerably in concert with broader discussions regarding climate change, environmental stewardship, and resource management. However, the practicalities and expense involved in getting scientists to these remote and harsh places means that Polar Regions will

remain under-sampled for years to come, constraining what can be achieved in the way of both understanding and forecasts. This reality places particular emphasis on the need to gain efficiency through partnerships.

The WMO provides leadership and guidance for a number of activities emphasizing attention and focus on polar matters, and the International Polar Year (IPY) provided additional focus and momentum. The UNESCO Intergovernmental Oceanographic Commission (IOC), in its resolution XXV-14, recognized the important role that polar ocean processes play in the global climate system and decided to strengthen the collaboration of IOC with Polar organizations. Both WMO and IOC are considering the International Polar Decade as a lasting legacy of the IPY.

EC-PHORS:

The 67th session of the WMO Executive Council (EC-67) in June 2015 re-established the Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS) with an updated Terms of Reference (ToR) taking into account the decisions of Cg-17 with regard to specifically the WMO Polar and High Mountain Activities, the Global Integrated Polar Prediction System (GIPPS), the Global Cryosphere Watch (GCW), and the International Polar Partnership Initiative (IPPI).

The EC-PHORS membership now includes 38 members and experts from 25 countries. The Panel is co-chaired by the Permanent Representatives of Australia and Canada with WMO. The Panel established task teams to address WMO Polar issues, especially to: (a) conduct its Antarctic responsibilities; (b) build a framework for its work in observations, research and services; (c) oversee development of the GCW; (d) provide leadership for development of a GIPPS; (e) advance the concept for a potential International Polar Decade; and (f) build partnerships.

Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM):

WMO and the IOC created a partnership in 1999 to promote the coordination of oceanographic and marine meteorological observing, data management, and services. JCOMM combines the expertise, technologies, and capacity building capabilities of the meteorological and oceanographic communities. Within its Services and Forecast Systems Program Area (SFSPA), the Expert Team on Sea Ice (ETSI) has been the focal point for promoting and coordinating

international cooperation in the acquisition, exchange, archival, and dissemination of sea-ice information.

The rapid retreat of the Arctic ice sheet in summer led to the establishment of new shipping routes in this region, with an associated requirement for enhanced maritime safety services. Icebergs will be a continued threat in the high arctic. JCOMM has consequently established, in coordination with the International Maritime Organization (IMO) and the International Hydrographic Organization (IHO), new Arctic “METAREAs” under the Global Maritime Distress and Safety System (GMDSS), which came into effect in 2011.³⁴ This expands to provision of weather and sea ice safety information services into Arctic waters, with Canada, the Russian Federation, and Norway acting as meteorological Issuing Services for the five new METAREAs. Canada has asked the U.S. to be a dissemination service for its two METAREAs.

Global Cryosphere Watch (GCW):

At Cg-16, a resolution was agreed upon to establish GCW, in collaboration with international partners, and in 2015, Cg-17 approved Resolution 43 in order to mainstream and implement GCW in WMO Programmes as a cross-cutting activity.³⁵ GCW will provide data, information, and products that will help Members and the wider user community reduce the loss of life and property from natural and human-induced disasters, improve management of energy and water resources, contribute to a better understanding of environmental factors affecting human health and well-being, understand, assess, predict, mitigate and adapt to climate variability and change, improve weather forecasts and hazard warnings, aid in management and protection of terrestrial, coastal and marine ecosystems, and support sustainable agriculture. GCW will provide information for informed decision making and policy development related to climate, water and weather, for use in real time, for climate change adaptation and mitigation, and for risk management.

GCW has made tremendous progress since its inception four years ago. It now has a steering group and three working groups. The Information and Services Working Group is responsible for the ongoing development and operation of the GCW portal and its data catalogue, cryospheric metadata and terminology, the GCW website, and outreach activities. The Group

³⁴ http://weather.gmdss.org/General_Arctic_Announcement_final-advance_notice.pdf

³⁵ http://library.wmo.int/pmb_ged/wmo_1157_en.pdf, page 505.

manages linkages to data contributors, works with national focal points, and develops documentation for outside use. It works through interoperability issues with data centres and other programmes. The Observations Working Group addresses capabilities and needs for surface-based and satellite observations. In addition to the establishment and coordination of operations of the GCW surface-based observational network, this Working Group assesses user needs and periodically reviews and updates observing system requirements and capabilities. The Integrated Products Working Group focuses on data homogeneity, interoperability, and compatibility of GCW observing and monitoring systems and derived cryospheric products. The U.S. Co-Chair of the STT is a member of the GCW Steering Group which will ensure that the WMO Strategy for Service Delivery is taken into account as the GCW continues in its effort to provide the framework for reliable, comprehensive, and sustained observing of the cryosphere.

WMO World Climate Programme (WCP) Climate Information and Prediction Services (CLIPS):

The WCP/CLIPS project was established in 1995 based on the vision that socio-economic decisions can benefit substantially from better knowledge of both contemporary and near-future climate conditions. The CLIPS project was conceived as an implementation arm of the World Climate Applications and Services Programme (WCASP), to build on the ongoing research advances and evolving operational networks, particularly on the regional and national scales. Among CLIPS activities which would contribute to service improvements to meet the interests for the Polar region are: the promotion of operational climate prediction services, particularly on seasonal to inter-annual scales; the provision of an active interface between the research and operational communities; and the development of operational frameworks linking global, regional and national level long range forecasts.

WMO has formally sought to define and establish Regional Climate Centers (RCCs) and Regional Climate Outlook Forums (RCOFs) since the 13th session of Congress (Cg-XIII) in May 1999³⁶ as these facilitate the development of “consensus” forecasts at a regional level as well as enhance regional networking by the NMHSs themselves and interaction with users at a regional level. And, in fact, such has been the topic by the WMO WCP CLIPS, which has stated that, post IPY, now would be a good opportunity to develop a collaborative mechanism for generating sustained, practical, and operational products and services to meet user needs for climate risk

³⁶<http://193.7.160.230/web/neacc/GuidanceEstablishmentDesignationWMORCCs.pdf>, Annex 1.

management in Polar Regions.

At the 2nd meeting of EC-PORS in Hobart, Australia, in October 2010, the group agreed to a stepwise approach in establishing Arctic and Antarctic PCOFs and Polar Regional Climate Centers (PRCC). Formal encouragement was provided by Cg-XVI to develop PCOFs and PRCCs. As suggested by the EC-PORS members in Hobart, a good next step, therefore, is for the NMHSs in the Arctic and Antarctic regions to begin to identify linkages within their centers dealing with global climate monitoring and global climate prediction as well as linkages between operational, research, and user communities dealing with polar climate and begin to develop an integrated, seamless suite of products to address the needs of the users/customers in both poles.

A PRCC Scoping Workshop is being planned for 17-19 November 2015 in Geneva, and the WMO Secretariat and the Services Task Team (STT) and Arctic members of EC-PHORS are working together to identify appropriate subject matter experts to be invited. The Scoping Workshop will initially focus on the Arctic with the expectation that the PRCC concept will take the form of an RCC-Network of nodes (similar to the RAVI RCC network). The workshop will include the engagement of the user, research, and operational communities, in line with the WMO Strategy for Service Delivery and its Implementation Plan.

Polar Prediction Project (PPP) and Year of Polar Prediction (YOPP):

In July 2012, the WMO Executive Council approved the establishment of the Polar Prediction Project (PPP), which is a new post-THORPEX legacy project initiated to serve the growing demand for skillful and reliable predictions in polar regions and beyond. The project's mission is to "Promote cooperative international research enabling the development of improved weather and environmental prediction services for the Polar Regions, on time scales from hours to seasonal." The PPP constitutes the hours-to-seasonal research component of the GIPPS. In December 2012, as part of its Implementation and Science Plans, the PPP Steering Group proposed an intensive observation and modeling period, called the Year of Polar Prediction (YOPP), which is scheduled to take place from mid-2017 to mid-2019. YOPP will be more focused on the prediction problem on daily to seasonal time scales, and it will engage forecast-stakeholder interaction.

As part of the "preparation phase," a YOPP Summit took place in Geneva from 13-15 July

2015. Again, in alignment with the WMO Strategy for Service Delivery and its Implementation Plan, the agenda included a Session on “User Relevant Aspects.” This session included presentations from Arctic shipping interests, Antarctic tour operators, and other users. One of the main objectives for YOPP is to promote a service delivery and capacity building framework that will help to improve the understanding of the benefits of using existing prediction information and services in the Polar Regions, differentiated across the spectrum of user types and benefit areas. The outcome from this session will undoubtedly further inform the development of this White Paper.

Arctic Council:

In 1996, the Arctic Council was established as a high level intergovernmental forum to provide a means for promoting cooperation, coordination, and interaction among the eight Arctic States (Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States), with the involvement of the Arctic Indigenous communities and other Arctic inhabitants on common Arctic issues, in particular issues of sustainable development and environmental protection in the Arctic. The scientific work of the Arctic Council is carried out in six expert working groups focusing on such issues as monitoring, assessing, and preventing pollution in the Arctic; climate change; biodiversity conservation and sustainable use; emergency preparedness and prevention; and living conditions of the Arctic residents. The development of GIPPS would benefit from engagement by one or more of these Working Groups, some of which are identified here.

For instance, in May 2011, the first binding agreement was negotiated under the auspices of the Arctic Council. The Agreement on Cooperation in Aeronautical and Maritime Search and Rescue (SAR) in the Arctic is an international treaty concluded among the member states of the Arctic Council. The treaty coordinates international SAR coverage and response in the Arctic and establishes the area of SAR responsibility of each state party. The treaty reflects the Arctic region's growing economic importance as a result of its improved accessibility due to global warming. It entered into force on 19 January 2013 after it had been ratified by each of the eight signatory states. The emerging melting of ice and opening of new land and sea in the High North will bring increasing numbers of tourists and industry to the area. Every year, 40 – 50 cruise ships sail among icebergs in cold waters where the temperature ranges from 0 – 5 degrees. These areas are also remote and far from dedicated rescue resources. In addition, maritime SAR operations

occur often in harsh weather conditions. The maritime rescue coordination centers need reliable and up-to-date information about the weather and sea state to be able to conduct safe operations without risking the rescue assets. Knowledge of the prevailing conditions can first be used to choose the optimal rescue assets for a task and then to optimize their routing. Detailed knowledge of wind and drift conditions at the distress site provide the foundation for faster search operations when the potential area of the victim can be estimated more precisely.

Under the auspices of the Protection of the Arctic Marine Environment (PAME), Canada, Finland, and the United States led the development of the Arctic Marine Shipping Assessment (AMSA). The AMSA considered a set of scenarios, or plausible futures, for Arctic marine navigation and developed recommendations in the interest of marine safety and marine environmental protection. Among the recommendations made in the 2009 Report are calls for increased linkages with international organizations, such as the WMO, to advance the safety of Arctic marine shipping, and investments in hydrographic, meteorological, and oceanographic data to support safe navigation and voyage planning in Arctic waters. Systems are needed to support real-time acquisition, analysis and transfer of meteorological, oceanographic, sea ice, and iceberg information. Progress reports are made every two years identifying how the Arctic Member states are addressing the recommendations. While the 2013 Status Report does indicate progress being made on improved nautical charts needed for the Arctic region, there does not appear to be any progress toward the development of an integrated real-time acquisition and dissemination of needed meteorological or oceanographic information. This presents a great opportunity to demonstrate the utility of a GIPPS capability in fulfillment of the AMSA recommendations.

International Ice Charting Working Group:

In 1999, the International Ice Charting Working Group (IICWG) was created by the world's ice centers. The main reasons for the creation of this group was the recognition of the ongoing interest of the nations influenced by ice covered seas in the use and protection of these seas as well as the recognition of the value and economics of cooperative activities in operational ice services supporting maritime navigation. The IICWG provides a forum for coordination of ice matters, including icebergs, and acts as an advisory body for the relevant international sea-ice organizations and programs, in particular, WMO/IOC JCOMM, CLiC, GCOS and the International Hydrographic Organization (IHO), and offers non-binding recommendations to

senior management as appropriate. The working group meets annually, and has two standing committees. The Data, Information, and Customer Support Committee, encompasses data and product exchange; terminology, data, and mapping standards; training, operations, and customer support. The Applied Science and Research Committee focuses on technology for analysis and forecasting; and applied science, research and development. A charter for the IICWG was signed by 12 nations.

Group on Earth Observation (GEO) Cold Region:

The Group on Earth Observations (GEO) was launched in response to calls for action by the 2002 World Summit on Sustainable Development and by the G8 (Group of Eight) leading industrialized countries. These high-level meetings recognized that international collaboration is essential for exploiting the growing potential of Earth Observations to support decision making in an increasingly complex and environmentally stressed world. The GEO is actively pursuing a Cold Regions Initiative, which addresses issues related to water, ecosystem, biodiversity, health, energy, disaster, climate, weather, and agriculture. GEO first started to engage with this issue by launching its water-related component – WA-01-C3: Information Services for Cold Regions. GEO Cold Regions built a cooperating framework, which is progressively involving the scientific and technical community, the space community, and countries willing to implement data infrastructure systems for the cold regions. Of particular relevance to EC-PHORS and the Services Task Team, especially, is that the GEO Cold Regions initiative will endeavor to provide a proactive framework for the development of information-related services for the “Future Earth” research initiative and strengthen partnerships with policy makers, stakeholders, and funders over the cold-region ecological and engineering fields. Thus, ensuring an active dialogue between the EC-PHORS and the GEO Cold Regions initiative will provide an additional opportunity to contribute in the development of the GIPPS.

European Commission:

Horizon 2020 is the biggest European Union (EU) Research and Innovation program ever with nearly €80 billion of funding available over seven years (2014 to 2020) – in addition to the private investment that this money will attract.³⁷ It promises more breakthroughs, discoveries and

³⁷ <http://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020>

world-firsts by taking great ideas from the lab to the market. It is a continuation of the EU's 7th Framework Program. The Horizon 2020 programme is divided into several sectors, with several initiatives that apply to the Polar Regions; e.g. Environment & Climate Action, Space, Transport, Social Sciences & Humanities.³⁸

Council of Managers of National Antarctic Programs (COMNAP):

The Council of Managers of National Antarctic Programs³⁹ is the international association, formed in 1988, which brings together representatives of the National Antarctic Programs of the 29 consultative parties to the Antarctic Treaty.

National Antarctic Programs are those organizations that have responsibility for delivering and supporting scientific research in the Antarctic Treaty Area on behalf of their respective governments and in the spirit of the Antarctic Treaty. As such, they collectively have the greatest first-hand experience of living and working in the Antarctic. Many of the National Antarctic Programs have operated in the Antarctic since the International Geophysical Year (IGY) of 1957/58.

COMNAP's purpose is to "...develop and promote best practice in managing the support of scientific research in Antarctica." As such, COMNAP endeavors to serve as a forum to develop practices that improve effectiveness of activities in an environmentally responsible manner; facilitating and promoting international partnerships; providing opportunities and systems for information exchange; and providing the Antarctic Treaty System with objective and practical, technical and non-political advice drawn from the National Antarctic Programs' pool of expertise.

COMNAP activities in Antarctica include the running of permanent stations and remote field camps and ancillary infrastructure; marine travel from ships to small boats; overland transport from tractor convoys to quad bikes to skis; and aviation transport ranging from helicopters to small fixed wing propeller or jet aircraft through to commercial jets. COMNAP, thus, collectively maintains the largest investment in Antarctica and, being the primary enablers of science logistics, would derive the greatest benefit from a GIPPS.

³⁸ <http://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020>

³⁹ <https://www.comnap.aq/SitePages/Home.aspx>

Scientific Committee on Antarctic Research (SCAR):

The Scientific Committee on Antarctic Research (SCAR) is an inter-disciplinary committee of the International Council for Science (ICSU). SCAR is charged with initiating, developing and coordinating high quality international scientific research in the Antarctic region (including the Southern Ocean), and on the role of the Antarctic region in the Earth system. The scientific business of SCAR is conducted by its Standing Scientific Groups which represent the scientific disciplines active in Antarctic research and report to SCAR.

In addition to carrying out its primary scientific role, SCAR also provides objective and independent scientific advice to the Antarctic Treaty Consultative Meetings and other organizations such as the UNFCCC and IPCC on issues of science and conservation affecting the management of Antarctica and the Southern Ocean and on the role of the Antarctic region in the Earth system. SCAR has made numerous recommendations on a variety of matters, many of which have been incorporated into Antarctic Treaty instruments. Foremost amongst these have been the advice provided for the many international agreements which provide protection for the ecology and environment of the Antarctic.

Sea Ice Prediction Network (Arctic and Antarctica):

The Sea Ice Prediction Network (SIPN), launched in fall 2013, is a collaborative network of scientists and stakeholders that seek to advance research on sea ice prediction and communicate sea ice knowledge and tools. An Antarctic equivalent branded “SIPN South” is being developed in 2015 for the Antarctic. The aims of SIPN include: (1) provide a focal point for seasonal outlooks for Antarctic sea ice; (2) stimulate discussion of seasonal forecasting of Antarctic sea ice; (3) be a source of information relevant to Antarctic sea ice; (4) through discussion and evaluation, help improve seasonal forecasting efforts of Antarctic sea ice; and (5) establish difference (if they exist) between models’ performance in the Arctic versus the Antarctic. In the absence of regional Polar Climate Centres, such research community efforts will partly fill the gap in seasonal ice prediction service.

International Association of Antarctica Tour Operators (IAATO):

Founded by seven private tour operators in 1991, the International Association of

Antarctica Tour Operators has grown to become the premier representative body for Antarctic tourism and now includes over 100 member companies from Argentina, Australia, Belgium, Canada, Chile, France, Germany, Italy, Japan, The Netherlands, New Zealand, Sweden, United Kingdom, and United States.

AATO's Membership incorporates the majority of private-sector tour operators. All commercial SOLAS passenger ship operators conducting tourism activities in the Antarctic Treaty Area are currently members of IAATO. Most tourist operators active in the Antarctic belong to the International Association of Antarctica Tour Operators (IAATO), which also participates in the ATCM as an invited expert organization. IAATO is dedicated to facilitating appropriate, safe and environmentally sound private-sector travel to the Antarctic. IAATO members have expressed a need for improvements in sea-ice and weather services to assist with the safe and efficient running of their operations.