# WORLD METEOROLOGICAL ORGANIZATION

## ARCTIC POLAR REGIONAL CLIMATE CENTRE NETWORK

## IMPLEMENTATION PLAN

**Version 3.1, 07 March 2018**

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# EXECUTIVE SUMMARY

Under the leadership of the World Meteorological Organization (WMO) Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS) Services Task Team (STT), and with the authority of the WMO Members, considerable progress has been made towards implementation of an Arctic Polar Regional Climate Centre (PRCC) Network. It is expected that a demonstration phase of the ArcRCC-Network will be initiated by the end of 2017.

The concept of PRCCs is a legacy of WMO's involvement in the 2007-2008 International Polar Year. With the (then) Executive Council Panel of Experts on Polar Observations, Research and Services (EC-PORS) taking up oversight on PRCC development (EC-65, 2013), further evolution of the concept proceeded briskly. In 2013, the Government of Canada funded a 'Programme of Implementing the Global Framework for Climate Services (GFCS) on Regional and National Scales' and in 2014 at the 5th session of EC-PORS, its Services Task Team (STT) began consultations on an implementation strategy for PRCCs. A survey to gauge needs for and capability to support an ArcRCC was conducted in 2015 and, based on the interest shown by Members, a scoping workshop was held in November 2015. Members identified potential contributions to the ArcRCC in early 2016, which encouraged the development of a concrete plan to launch a demonstration phase of an ArcRCC-Network. A meeting held in November 2016 facilitated the discussions and decisions that underpin this present implementation Plan.

The ArcRCC-Network will be unique in the current set of RCCs and RCC-Networks either in operation or being established around the world. Firstly, the domain of the Arctic RCC-Network falls across three of the WMO Regional Associations (for Asia, Europe and North America), requiring extensive cooperation at that level in addition to that needed between countries. Secondly, the structure for the ArcRCC-Network will be on two levels: there will be three sub-regional geographic domains, each of which will be guided by a Node that will perform all mandatory functions for the countries in its domain, and exceptionally, each node will undertake a significant cross-node mandatory function for the entire pan-Arctic domain. Specifically:

- Canada will lead the North American Node (with Canada and USA as members of consortium); Norway will lead the Northern Europe and Greenland Node (with Denmark, Finland, Iceland, Norway, Sweden and possibly other interested European countries as members of consortium); and the Russian Federation will lead the Eurasian Node; and

- Canada will lead development of Long-Range Forecasts (LRF); the Russian Federation will lead the Climate Monitoring; and Norway will lead operational Data Services based on WMO Information System (WIS) requirements.

The contributing countries to the ArcRCC-Network have further agreed that:

- the PRCC-Network operational entities will adhere to WMO Resolution 60 (Cg-17), WMO Policy for the International Exchange of Climate Data and Products to Support the Implementation of the GFCS;

- the first priority in the demonstration phase will be to set up the necessary cooperation and technical processes to ensure that all mandatory functions are fully operational, in order to attain WMO designation as an RCC-Network;

- important shared interests and objectives that exist between the PRCC-Network, the Global Cryosphere Watch (GCW) and the International Ice Charting Working Group (IICWG) will be fostered (all three will embed the intent to cooperate in their respective Terms of Reference and Implementation Plans);

- the PRCC will seek to address hazard identification and risk reduction requirements, and to provide relevant information to the NMHSs of its member countries to support their provision of services to high priority sectors including the marine, hydrological, natural resources and tourism communities. This would require development of products based on elements in addition to Temperature and Precipitation, many of which will be Essential Climate Variables (ECVs) and priority elements important to WMO and international bodies such as JCOMM, CHy, IICWG, GCW;

- Canada is hosting the first Polar Regional Climate Outlook Forum (PARCOF) in May 2018, in conjunction with representatives from the Year of Polar Prediction (YOPP) initiative, which aligns well with EC-PHORS priorities for polar regions;

- the proposed ArcRCC-Network will, to the extent feasible, consider the Arctic Council Ottawa Traditional Knowledge Principles.

The countries in the domain have offered extensive data, products and services in support of the ArcRCC-Network, and collectively offer a high level of experience and capability to perform the required functions of an RCC. That said, there will be challenges. Even though the contributing countries have well-supported NMHSs, the costs of operating at high latitudes is very high. Sustaining existing and implementing new activities such as observations or user interaction, or development of new products (such as LRF products with polar projection) to meet current and future requirements is expensive and will need the sustained support of the Members in the region. There will be a need for coordination, not only with the 'usual' neighboring countries, but with neighbors on other continents and in different language groups. It may take extensive effort to merge data, products and methods to produce harmonized pan-Arctic services. Not least, as climate research efforts develop and deliver new models, methods and tools, the participating countries will need to respond and incorporate them.

It will be important to look beyond the technical requirements and functions of the PRCC-Network, to the reasons why the Members have chosen to initiate it. The Arctic is experiencing changes in its climate and environment, and the people who live and work in the Arctic region are concerned with the impacts on their health and safety, on their economy, on the northern infrastructure and on traditional ways of life. Many of the social and economic opportunities for the people of the North are in climate-sensitive sectors. There is a strong need for reliable, consistent, balanced, seamless and authoritative information to help decision makers in the pan-Arctic region to reduce uncertainty, vulnerability and risk, and to improve resilience to climate variability and change. To understand the climate-relevant vulnerabilities, to identify the needs for climate information and for the PRCC to increasingly address those requirements will be critical to the long-term success of the ArcRCC-Network.

This Implementation Plan is developed by the domain Members, with the support of the WMO Secretariat, and under the guidance of the EC-PHORS STT and will be a living document, adjusted and updated as needed during the evolution of the Network. It is expected that the demonstration phase will begin in the spring of 2018, following presentation of the plan that was accepted by WMO Executive Council at its 69$^{th}$ Session in June 2017.

A successful implementation of the ArcRCC-Network is expected to lead next, with the continued guidance of EC-PHORS, to the launch of a Polar RCC or RCC-Network for the Antarctic region and, potentially, the Third Pole region.

# 1. Introduction

Indigenous peoples and others who live and work at high latitudes are increasingly challenged by a wide range and variations of weather and climate. Records of sea-ice extent and thickness, permafrost, glaciers, hydrology and temperature all evidence warming conditions in the Arctic in recent decades. Over the past century temperatures in the Arctic have been assessed to have increased at almost twice the rate of the rest of the world.

Traditional ways of life and existing infrastructure are seriously affected by these rapid changes, and there are distinct concerns on the extent to which human and natural systems can adapt to them. Some indigenous groups are highly vulnerable to climate variability and change not only because of their critical dependence on the environment for food, but also because of changes in storms and extreme weather events, and the climate-related risks of living close to shorelines along rivers, lakes and the ocean.

> 'Since 1875, the Arctic north of 60°N latitude has warmed at a rate of 1.36°C per century, approximately twice as fast as the global average (Bekryaev et al., 2010), and since 1979, Arctic land surface has warmed at an even higher rate of 0.5°C per decade (e.g., Climatic Research Unit (CRU) Gridded Dataset of Global Historical Near-Surface Air TEMperature Anomalies Over Land version 4 (CRUTEM4), Jones et al., 2012; Hadley Centre/CRU gridded surface temperature data set version 4 (HadCRUT4), Morice et al., 2012)'
>
> Source: Box 5.1, Polar Amplification, Chapter 5, and as per Section 2.4 'Changes in temperature' of the IPCC AR5, 2014, WG1 'The Physical Science Basis.

IPCC AR5 (2014) WG11: Chapter 28, Polar Regions:

'Changes in the physical and chemical environments of the polar regions are detailed in the WG1 contribution to the AR5. There is evidence that Arctic land surface temperatures have warmed substantially since the mid-20th century, and the future rate of warming is expected to exceed the global rate. Sea ice extent at the summer minimum has decreased significantly in recent decades, and the Arctic Ocean is projected to become nearly ice free in summer within this century. The duration of snow cover extent and snow depth are decreasing in North America while increasing in Eurasia. Since the late 1970s, permafrost temperatures have increased between 0.5°C and 2°C.' (see **ANNEX 1)**

AR5 WG1 FAQs: Polar regions illustrate the complexity of processes involved in regional climate change. Arctic warming is projected to increase more than the global mean, mostly because the melting of ice and snow produces a regional feedback by allowing more heat from the Sun to be absorbed. This gives rise to further warming, which encourages more melting of ice and snow.

Climate-sensitive socio-economic changes such as increased marine transportation, increasing tourism and increased exploitation of natural resources in the region (e.g. exploration for and extraction of minerals, oil and gas) bring both benefits and risks, but certainly add to the issues that need to be managed. All in all, there is a growing need for useful and targeted climate information to support effective decisions and to help mitigate risks to people, governments, businesses and the environment.

An effective solution to this growing need is to undertake a regionalized approach toward the development of improved climate products, information and services to support the service delivery activities of the Members of the World Meteorological Organization (WMO). This approach would aggregate skills and investments at the national level as well as provide a mechanism to share, coordinate, enhance and in some cases, harmonize products and services requested by relevant stakeholders.

WMO Members have developed and implemented Regional Climate Centres (RCCs) and RCC-Networks around the world, and have been increasingly sharing climate information and products through newsletters, websites and portals, and in Climate Outlook Forums (COFs) (face-to-face sessions between climate scientists and user communities) at regional, national and sub-national scales. Implementing RCCs and COFs has not so far been attempted at high latitudes for several reasons including that data are sparse, and the available prediction models have had limited skill at seasonal to interannual scales. That said, the Arctic climate is harsh, vulnerability to climate variability and change is high, and rate of climate and climate-related change facing the region warrants improved climate services.

***An Arctic Polar Regional Climate Centre Network – Goal and Benefits:***

Through a survey conducted by the WMO Secretariat in 2015, WMO Members expressed an interest in the Polar Regions and willingness to ascertain the activities, services and products they would consider being mandatory and/or highly recommended functions of a potential new Polar Regional Climate Centre. The survey revealed that Members have the capacities to meet the requirements for performing mandatory functions, and strong interests to implement an RCC-Network for the Arctic Polar Region. Subsequently, WMO Members have decided to put in place an Arctic Polar Regional Climate Centre Network (ArcRCC-Network), with the goal that it will help them to provide effective, user-relevant, decision-support climate information needed by people, governments, businesses and other users at high northern latitudes.

The expected benefits to Members of the ArcRCC-Network include:

- Strengthened collaboration among NMHSs on polar matters including on operational and longer term issues related to observations, data, forecasting, products and services to support climate risk management and adaptation to climate change;
- A more effective and coordinated approach on climate with stakeholders such as the Arctic Council and United Nations agencies with polar interests;
- Climate products and services that seamlessly cross national and regional boundaries (e.g. for marine transportation);
- Specific regional products such as sub-seasonal forecasts (because seasonal prediction skill may be currently low in the Polar Regions);
- Pan-Arctic forecast and climate monitoring products with polar stereographic projection;
- Improved imagery products (e.g., satellite);
- Improved observations of the cryosphere and associated products based on cryosphere information;
- Increasingly interoperable datasets for land, ocean, atmosphere for the Arctic;
- Strengthened cooperation with the research and development community on improving prediction models and for developing an increasing range of new climate products targeted at Arctic user requirements;
- Development of sector-specific products for the pan-Arctic region (e.g. for health, tourism, transportation, hydrology, etc.);
- Strengthened networking with stakeholders to improve two-way communications with indigenous peoples on climate information;
- Activities for user engagement such as regional or national climate outlook forums, during which users of PRCC products can learn more about the products and their potential use in decision making processes;
- Reduction of vulnerability and risk – improved community resilience;
- and others of relevance to the Members and stakeholders.

***Overview of the ArcRCC-Network Implementation Plan:***

This document briefly describes the background and principal functions of RCCs in general, lays out the approach to implementing the ArcRCC-Network (from concept to full

operations), identifies contributions to and deliverables of the Network, and specifies issues and challenges to be addressed.

Over the period 2008 to early 2017, considerable work has been accomplished to explore the issues, benefits and challenges associated with improving climate services at high latitudes. In this pre-implementation period, major decisions have been made regarding feasibility, governance, partners, stakeholders, domain, structure, priorities and deliverables of the proposed ArcRCC-Network. As of the acceptance of this present Implementation Plan by the relevant Members and WMO constituent bodies, the contributing countries and partners will be ready to implement the Network, in three phases: Phase 1: Demonstration (2018-2019); Phase 2: Designation (2019-2020); and Phase 3: Operational ArcRCC-Network (2020- ).

The primary focus of the present Plan is to prepare for and launch a demonstration phase whereby the ArcRCC-Network will begin to function (initially addressing the WMO Mandatory Functions as the highest priority) and will develop to the point of meeting all requirements for formal designation by WMO (Phases 1 and 2). This version of the plan addresses in general terms only what activities the Members might initiate in Phase 3, after the ArcRCC-Network has been formally designated. It is expected that this Implementation Plan will be a living document that will be updated by the contributing countries regularly as significant milestones are met, and as services are proposed and added to meet evolving requirements.

# 2. WMO Regional Climate Centres

## 2.1 The RCC concept

The basic infrastructure of the World Meteorological Organization (WMO) includes the National Meteorological and Hydrological Services (NMHSs) of its Members, and includes regional and global centres with capabilities in operationally generating and delivering up-to-date climate information and prediction products for climate services, especially in support of climate adaptation and risk management. WMO-designated Global Producing Centres for Long-Range Forecasts (GPCs or GPCLRFs) have been established to provide a range of global long-range forecasting products, and WMO-designated Regional Climate Centres (RCCs) are being implemented to generate and deliver more regionally-focused high-resolution data and products as well as training and capacity building. The GPCLRFs and the RCCs constitute integral components of WMO's Global Data Processing and Forecasting System (GDPFS) underpinning the generation of climate information products by the NMHSs. This implementation plan focuses on the RCC component. Further information on GPCs can be found in **ANNEX 2**.

The concept and rules and regulations associated with RCCs (for designation, criteria for Mandatory Functions, etc.) are embedded in WMO’s technical regulations, within the Manual on the Global Data Processing and Forecasting System, Volume 1: Global Aspects (WMO No. 485). Adherence to WMO’s technical regulations ensures that RCCs shall follow respective standard practices and procedures, which results in adequate uniformity and standardization in their practices and procedures.

Fundamentally, WMO RCCs are centres of excellence that operationally generate regional climate products including climate monitoring and prediction in support of regional and national climate activities and thereby strengthen the capacity of WMO Members in a given region to deliver better climate services to national users. While all WMO RCCs are required to fulfill certain mandatory functions, the RCC concept includes flexibility to accommodate specific regional needs, capabilities and limitations. The concept also provides options to implement a single multi-functional entity or a distributed-function RCC-Network collaboratively implemented by a number of interested hosts (see RCC definitions in **ANNEX 3**).

Within the RCC concept, service delivery to national clients remains in the purview of national institutions, and the RCC is essentially designed to assist with their mandate. In other words, RCCs are complementary to and supportive of NMHSs, who will deliver all warnings and national-scale products, and the primary recipients of RCC products and services (RCC Users) are the NMHSs, other RCCs and international institutions recognized by the Regional Association(s). In accordance with Resolution 60 (Cg-17) , the GFCS relevant data and products from the WMO RCCs and RCOFs should be made accessible among Members, in particular through the GFCS CSIS, on a free and unrestricted basis. Members are encouraged, as well, to share more data than some Members do today.

## 2.2 RCC functions

In the performance of their duties, and as centres of excellence, all WMO RCCs and RCC-Networks must follow guidance published by the WMO Commission for Climatology (CCl) on technical, climate-related matters, and by the WMO Commission on Basic Systems (CBS) on operational issues. RCC operations are expected to be consistent with the standards of the WMO Information System (WIS) and WMO RCCs may become WMO WIS Data Collection or Production Systems (DCPCs).

WMO RCC services span a set of Mandatory and Highly Recommended Functions as presented in the Manual on the GDPFS, but may include other functions developed to meet the requirements for climate information, products and services of the region.

***Mandatory Functions***: All WMO RCCs and RCC-Networks must fulfil all Mandatory Functions, the detailed criteria and products for which are defined in Appendix II-11 of the Manual on the GDPFS, and are also presented in this Plan in **ANNEX 4**. Briefly, these are:

- operational activities for long-range forecasting (LRF);
- operational activities for climate monitoring;
- operational data services to support operational LRF and climate monitoring; and
- training in the use of operational RCC products and services.

***Highly Recommended Functions***: WMO RCCs and RCC-Networks are encouraged to undertake as many 'Highly Recommended' Functions as possible, based on the requirements of user communities in the region. These are described in the Manual on the GDPFS in Attachment II-10, and presented here in **ANNEX 5.** Briefly, they include:

- climate prediction and climate projection;
- non-operational data services;
- coordination functions;
- training and capacity development; and
- research and development.

## 2.3 Designation by WMO of an RCC or RCC-Network

In order for a centre or a group of centres in a cooperative effort to be designated as an RCC or RCC-Network, it shall perform (at least) a minimum set of functions, the above noted 'Mandatory Functions', performance of which will be assessed against detailed criteria (presented in **ANNEX 4)**. The typical process for formal designation by WMO is described in the document 'How to establish and run a WMO Regional Climate Centre (RCC)' (WMO/TD-No. 1534), excerpts of which are presented in **ANNEX 6**. The step-by step process for designation of the ArcRCC-Network, a slightly modified approach because this is a trans-regional RCC-network, is described in section 6 of this Plan. The approach is rigorous and consistent across all WMO RCCs, and is overseen principally by the Regional Associations (through their Presidents and relevant subsidiary bodies); the

WMO Commission for Climatology (CCl), the WMO Commission for Basic Systems (CBS), the joint CCl/CBS Expert Team on RCCs, and either the WMO Executive Council (EC), or the World Meteorological Congress (Cg).

## 2.4 RCC implementation globally

The status, as of November 2016, of implementation of WMO RCC-Networks and of RCCs around the world is presented in **ANNEX 7**, and **ANNEX 8**, respectively.

# 3. Pre-Implementation (2008-2017)

## 3.1 Scoping and Planning

WMO's Climate Information and Prediction Services (CLIPS) project, implemented over the period 1995-2015, was instrumental in the development of the concept of Regional Climate Centres (RCCs) and their formal establishment on a global scale, and in development of the Regional Climate Outlook Forums (RCOFs) that now serve as platforms for generating consensus-based seasonal climate outlooks (See **ANNEX 9** for additional information on RCOFs). WMO Members, at the Sixteenth of the World Meteorological Congress, endorsed incorporating all CLIPS activities into the Global Framework for Climate Services (GFCS), and concluding CLIPS as a project by 2015.

The agreement between WMO and partnering agencies to create the GFCS, with its pillars addressing Observations and Monitoring; Research Modeling and Prediction; the Climate Services Information System (in which RCCs are a core component); Capacity Development and the critically important User Interface Platform, has solidified interest in ensuring effective climate services, focused on user requirements, everywhere in the world including at high latitudes.

The International Polar Year 2007-2008 (IPY) was sponsored by the International Council for Science (ICSU) and the World Meteorological Organization (WMO). The successful implementation of IPY 2007-2008 led WMO to develop a legacy project that would bring together WMO's climate data, operations, applications and research communities, and user communities, with the aim to provide climate products and services that addressed the needs of the highly vulnerable populations in Polar Regions. One early goal, explored by WMO and the World Climate Research Programme (WCRP) through the WMO-WCRP IPY Workshop on CLIPS in Polar Regions (2008, St. Petersburg, Russian Federation) was to consider extending the concept of RCOFs to high latitudes, and creating a Polar Climate Outlook Forum, or PCOF.

Over time, the successful implementation of Regional Climate Centres (RCCs) and RCC-Networks around the world led to the goal of developing Regional Climate Centres and RCC-Networks for the Polar Regions, and possibly also the Third Pole Region. At its 65th session in 2013, WMO's Executive Council agreed that, through its Panel of Experts on Polar Observations, Research and Services (EC-PORS[1]), the Global Cryosphere Watch (GCW), the Commission for Climatology (CCl), the Commission for Basic Systems (CBS) and the concerned Regional Associations should work in close cooperation to develop Polar RCCs (PRCCs) for both the Arctic and Antarctic regions, and to be engaged with the relevant priority projects of the Global Framework for Climate Services (GFCS) Implementation Plan.

In February-March 2015, a survey was conducted amongst Members on the needs and capacities for RCC Services for Polar Regions. Results showed a clear indication by Members on requirements and the available capacities for, and strong interests to perform Mandatory and also some Highly Recommended Functions, and to run an ArcRCC-Network. In quick succession, under the guidance of EC-PHORS, there followed a

1 EC-PORS became the Executive Council Panel of Experts on Polar and High-mountain Observations, Research and Services (EC-PHORS) at Cg-17, 2015.

Scoping Workshop on Climate Services for Polar Regions (17-19 November, 2015, Geneva, Switzerland); provision by Members in January-February 2016 of detailed information on potential contributions to the operations of the envisaged ArcRCC-Network; and the Arctic Polar Regional Climate Centre (PRCC) Network Implementation Planning Meeting (7-9 November 2016, Geneva, Switzerland).

At the Implementation Planning meeting, experts agreed upon key aspects of the ArcRCC-Network, presented below in section 4, and set up a plan of activity that will ensure presentation of the Implementation Plan to the 69th session of WMO's Executive Council (EC-69, 2017), launch a demonstration phase, and achieve formal designation by WMO (captured in sections 5 and 6 below). Their suggestions for the evolution of the Network following designation, are presented in section 7 and known gaps that need to be addressed during the demonstration phase are identified in section 8 below.

WMO and its Members have thus taken significant steps towards the implementing the vision of Polar Regional Climate Centres. A timeline of these initiatives with details, links and references is presented in **ANNEX 10**.

## 3.2 Needs and requirements

In 2015, the EC-PHORS Services Task Team (STT) developed a White Paper on 'The known requirements for Arctic Climate Services[2]' the purpose of which is to define and validate the needs and opportunities for improving weather, ice, water, and climate services in the Polar Regions. The focus is on regional drivers, existing services and research needs for Arctic, Antarctic and the Third Pole/High Mountains Regions. The STT used the WMO Service Delivery Progress Model to identify potential best practices and actions to improve service delivery among the NMHSs, drawing attention on how this complements the WMO RCC model and particularly those functions that are mandatory for RCC designation. The RCC concept was identified as a best practice. A Polar or Pan-Arctic RCC would represent advancement in service delivery for this region.

A goal of the STT through this White Paper is to help design the Polar RCC framework to meet user needs, align with the WMO Strategic Plan, and advance on the holistic vision of the Global Integrated Polar Prediction System (GIPPS). In this context, the potential support from the International Ice Charting Working Group (IICWG) and the Global Cryosphere Watch (GCW) to PRCC operations was highlighted. See Section 4.4 below and Annex 11 for additional information on GCW, IICWG and GIPPS.

The STT stressed the importance of understanding the critical needs for specific products (e.g., September minimum coverage), noting that for indigenous communities, the near-shore and fast ice may be more important than ice in the Arctic Ocean. As a general approach, it is important to be clear on the communities to be targeted.

In the Plenary discussions at the EC-PHORS 6th session in 2015, it was noted that a more thorough analysis of users and their needs would be necessary in order to have a solid base for planning of ArcRCC-Network functions and services. The STT did not have methods or capacities to do this, but the plan is to engage experts and users at the PARCOF in May 2018 to help understanding better the user needs. A contact with the IPP SERA Group on the Societal needs for data is established; the group will be represented at the PARCOF in May 2018.

In the White Paper, it is noted that the economy of the Arctic region, home to almost four million people, is heavily dependent on natural resources (in particular: oil, gas, metal ores, fish, reindeer and birds), and that the needs of the tourism industry and settlements (for services related to hydrology, river ice and sea ice, storms, ocean currents, freshwater discharge, etc.) were increasing.

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While the provision of weather, climate 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, causing e.g.: permafrost degradation; increasing winter runoff; coastal erosion; reduced sea ice thickness and extent; and changes in water regimes.

Particularly at weather scales but to some extent for seasonal to longer time scales, Member countries provide a range of services including forecasts and warnings 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. Across the pan-Arctic area, these services vary in terms of content, presentation, and time scales covered.

The Arctic Council Arctic Marine Shipping Assessment (AMSA) report[3] (2009) indicated that ocean operators 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'.

***At climate scales, known requirements include (but are not limited to)**:*

- seasonal predictions, particularly the period of open water that defines an extended operations and shipping season;
- multi-decadal sea ice projections for infrastructure planning, ecosystem stewardship, and projection of global climate impacts forced by changes first occurring in the Arctic;
- decadal predictions of sea ice loss - needed but problematic (long-term modeling gives diverse model results + lack of good physical data regarding winds and clouds + current models are too slow in future projections of sea ice loss);
- climate information in general; and long time series of weather and ocean data, to support research.

***Specific, known user needs include (but are not limited to):***

- Natural Resource Development (energy and mineral extraction and development): length of open water season, sea ice melting/freezing;
- Transportation, insurance, Search and Rescue, oil spill combatting: length of open water season, ice movements, sea ice melting/freezing, wave height, sea currents…;
- Community Resilience and Adaptation Planning: weekly – seasonal – long-time weather and climate outlooks needed for understanding, adapting and transforming to known and/or predicted changes;
- Infrastructure Protection and Hazard Mitigation (information of e.g. erosion, flooding, permafrost thawing);
- Versatile Ecological Changes caused by changes in e.g. sea ice, higher sea-surface temperatures, warmer summers, reduced snow cover, etc.

***Conclusions of the White Paper include that:***

- Improved sea ice and marine weather forecasting would assist the energy, maritime shipping, insurance 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 integration, interpretation, and dissemination of this information in near-real time are required to support decision-making.

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Several discussions have taken place on the matter of including sea ice and marine data sets as Mandatory Functions. During EC-PHORS 7, an advice was to stick to the 4 Mandatory Functions and include sea ice and marine data sets as Highly Recommended Functions. The WMO Secretariat is considering how to handle this in close collaboration with the PRCC-Network.

# 4. Overview of the ArcRCC-Network

## 4.1 Contributing countries

WMO Member countries that have agreed to contribute to the activities of the ArcRCC-Network include Canada, Denmark (and Greenland), Finland, France, Germany, Iceland, the Netherlands, Norway, the Russian Federation, Sweden, the UK and the USA.

These countries will interact with each other, for PRCC-Network activities, largely through their National Meteorological and Hydrological Services (NMHSs) and selected technical agencies (e.g. National Ice Services). Each country would benefit as well from developing national networks across government, academia and the private sector that can assist with such matters as understanding the requirements of, and provision of tailored services to priority national user communities, as well potentially with development of products, for data management, for training, and so on.

## 4.2 Structure

The Services Task Team (STT) in EC-PHORS has been an important body in the planning and establishing of the ArcRCC-Network. In the present phase of implementing, the STT will overlook and give advice to the Nodes and the entire Network, and be an important link between EC-PHORS and the PRCC-Network. The overall coordinator, the Node leaders and the other contributing countries will have the responsibility for the implementation.

For the ArcRCC-Network, a mixed-model approach has been agreed. There will be three multi-functional Nodes with geographic specialization (one of which will serve as the PRCC-Network leading institution), and several relevant cross-node activities. Using a geographical approach is expected to foster a more detailed coverage in each sub-region, but the risk would be lack of attention to boundary issues within the overall domain. It was recognized that a mixed model design like this requires effective coordination (most likely more than for distributed function models) of the RCC operations, products, services access and delivery, so that the entire Arctic Polar Region is covered in a seamless manner.

Each of the three sub-regional Nodes shall:

- undertake to perform ***all*** the Mandatory Functions (and to the extent possible, additional Highly Recommended Functions) for the countries in its domain (of course, with the support and inputs of the countries in its domain and from the pan-Arctic cross-node activities);
- undertake one or more cross-node activities for the whole pan-Arctic domain; and
- take a turn, in rotation, in serving as the lead for the ArcRCC-Network (noting the need for stability throughout the demonstration phase and designation process);
- adhere to WMO Resolution 60 (Cg-17), WMO Policy for the International Exchange of Climate Data and Products to Support the Implementation of the GFCS.

The agreed structural and activity elements for the ArcRCC-Network include:

i) **Lead Agency** for the PRCC Network:
   - **Norway** has taken the responsibility for the overall coordination of the PRCC Network – for the 3 first years.

ii) **Northern Europe and Greenland Node:**

- **Norway** will serve as the lead and the **Norwegian Meteorological Institute** (NMI) will coordinate all PRCC functions for the Node's domain (the Nordic countries could consider rotation of the Node lead if it suits the sub-region to do so, e.g. to strengthen collaboration and commitment).
- Members of the Node (the Consortium) are Denmark, Finland, Iceland, Norway and Sweden.
- Institutions in these countries that will support and contribute to the Node include, inter alia:
    - Denmark: the Danish Meteorological Institute (DMI); the Geological Survey of Denmark and Greenland (GEUS); the Polar Portal[4] (Monitoring ice and climate in the Arctic);
    - Finland: the Finnish Meteorological Institute (FMI);
    - Iceland: the Icelandic Meteorological Office (IMO);
    - Norway: the Norwegian Meteorological Institute (NMI);
    - Sweden: the Swedish Meteorological and Hydrological Institute (SMHI).
- France, Germany, the Netherlands and the UK, in their capacity as RA VI Nodes and GPCs will support the activities of the Northern Europe and Greenland Node.

iii) **Eurasia Node:**

- **The Russian Federation** (the only country in this Node) will serve as the lead and the **Arctic and Antarctic Research Institute (AARI)** will coordinate all PRCC functions for the Node's domain**.**
- Institutions supporting the PRCC work for Eurasia include:
    - the Arctic and Antarctic Research Institute (AARI) St. Petersburg;
    - the Main Geophysical Observatory (MGO), St. Petersburg;
    - the Russian Institute for Hydrometeorological information – World Data Center (RIHMI-WDC), Obninsk; and
    - the Hydrometeorological Centre of the Russian Federation (RHMC).
- The Russian Federation will also support many 'Highly Recommended' Functions, including seasonal forecasting, climate diagnostics and monitoring, data services, etc. for sea-ice, for the whole Arctic Ocean.

iv) **North America Node:**

- **Canada** will serve as lead, and **Environment and Climate Change Canada** (ECCC) will coordinate all PRCC functions for the Node's domain.
- Members of the Node (the Consortium) are Canada and the USA.
- Institutions in these countries that will support and contribute to the Node include, inter alia:
    - Canada: the ECCC Meteorological Service of Canada which includes the Canadian Ice Service; and possibly additional agencies including Polar Knowledge Canada;
    - USA: the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) and NWS/Alaska; NOAA's National Centers for Environmental Prediction (NCEP) and NCEP's Climate Prediction Center (CPC); the National Environmental Satellite, Data, and Information Service (NESDIS) of the National Centers for Environmental Information (NCEI) and the NESDIS Center for Satellite Applications and Research (STAR); and the US National Ice Center.

v) **Cross-node LRF services:**

- **Canada (ECCC)** will lead production of long-range forecasts. The LRF product(s) will be pan-Arctic, large scale, with appropriate projection. Each

4. Denmark/Greenland has an interest in supporting provision of data services through its polar portal, which could be a pan-Arctic contribution to the PRCC.

Node will be responsible to downscale and provide more tailored products for their sub-regions.
- Roshydromet has indicated willingness to support Canada in this work.
- Canada will seek collaboration with the WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME), jointly coordinated by the Korean Meteorological Agency and the Climate Prediction Centre of NOAA, in particular to add new polar projection maps to their existing map set.
- A host for the web-site/portal for the PRCC-Network LRF products is not yet assigned. Normally Canada would provide this but initially is not able to commit to it.

vi) **Cross-node Climate Monitoring:**
- **Russian Federation** (AARI) will coordinate development of all pan-Arctic Mandatory Climate Monitoring products. Development of the pan-Arctic Climate Bulletins will be done using the bulletin products from the three Nodes and a template approach. The pan-Arctic Climate Watch will be carried out in accordance with the WMO Guidance on Climate Watch Systems.

vii) **Cross-node provision of operational data services:**
- **Norway** (NMI) will host operational data services for the PRCC-Network domain, subject to all relevant data having the appropriate WIS-designed metadata, noting that no data would be archived in Norway, and that all datasets would be discoverable where housed.

## 4.3 Domain

There is no single, agreed, definition of the 'Arctic'. For Arctic activities, a domain is often established for specific scientific, political or social purposes. Existing descriptions of the Arctic include, inter alia, the area within the Arctic Circle (66°34'N. Latitude); the area North of the 10°C July temperature isotherm (i.e. the region where the average temperature for the warmest month, July, is below 10°C); the area north of the tree line; the area north of the southern limit of discontinuous permafrost; the area covered by language/family groups of indigenous peoples; and so on. In its 5$^{th}$ Assessment Report, the IPCC Working Group II (Impacts, Adaptation and Vulnerability) used the conventional IPCC definitions as a basis (i.e. defining the Arctic as the area within the Arctic Circle), while incorporating a degree of flexibility when describing the polar regions in relation to particular subjects.

Considering this, the geographical domain for contributions to and for the products and services of an ArcRCC-Network has been loosely defined, allowing some flexibility for domain variation for different services, if needed. The domain needed to support Arctic hydrological services, covering drainage basins of rivers flowing to the Arctic Ocean, for example, may be larger and more irregular than one suitable for pan-Arctic LRF products.

Noting that the PRCC-Network domain does not constitute a definition of the Arctic, is intended for operational purposes, and may vary for different activities, it covers up to 90°N Latitude at its northern extent and varies at its southern extent based on the requirements of the countries in the Network's sub-regional domains.

The southern extent will be 60°N Latitude (generally) for the Northern Europe and Greenland Node and the Eurasia Node, but outside of that as needed for development of products and services needed for the region (e.g. for Arctic watershed products and services). For the North America Node, all of Alaska and the Aleutian Islands will be included for the USA, and for Canada, the southern extent will include the Yukon Territory, the Northwest Territories, Nunavut, Nunavik and likely a portion of the Labrador coast (Nunatsiavut).

## 4.4 Partners and technical assets/contributors

The core WMO components contributing to the ArcRCC-Network will be the National Meteorological and Hydrological Services (NMHSs), along with the WMO system of RCCs, RCC-Networks, and Global Producing Centres of Long Range Forecasts (GPCLRFs) including the WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME) and the WMO Lead Center for Standard Verification System of Long-Range Forecasts (LC-SVSLRF). The PRCC-Network may also access and use major datasets through the World Data Centres, and through specialized centres such as the Global Precipitation Climatology Centre (GPCC), the Global Runoff Data Centre (GRDC), the National Snow and Ice Data Center (NSIDC), and others.

To ensure the efficient operation of the proposed ArcRCC-Network, it is important that these entities liaise with and build strong partnership with various international communities either beyond the WMO scope or WMO initiatives with significant non-NMHS participation. In terms of PRCC-relevant climate data, products and services, prediction capabilities, science guidance on the Mandatory and Highly Recommended Functions, etc., potential contributors and partners will include (but are not limited to):

- the Global Cryosphere Watch (GCW),
- the International Ice Charting Working Group (IICWG), and
- the Global Integrated Polar Prediction System (GIPPS) including:
    - its Polar Prediction Project (PPP) under the World Weather Research Programme (WWRP), with the Year of Polar Prediction community initiative and
    - the Polar Climate Predictability Initiative (PCPI) under the World Climate Research Programme (WCRP).

Background information on these partners is presented in **ANNEX 11**. Potential contributions to the ArcRCC-Network are identified as follows:

### *4.4.1 Global Cryosphere Watch (GCW)*

***The cryosphere:***

a component of the Earth System that includes solid precipitation, snow cover, sea ice, lake and river ice, glaciers, ice caps, ice sheets, permafrost, and seasonally frozen ground.

The GCW provides authoritative, clear, and useable data, information, and analyses on the past, current and future state of the cryosphere to meet the needs of WMO Members and partners in delivering services to users, the media, public, decision and policy makers. GCW aims to ensure a comprehensive, coordinated, and sustainable system of observations and information to allow for a more complete understanding of the cryosphere and to contribute to improved observations, research and services.

As decided at the ArcRCC-Network Implementation Planning meeting in November 2016, the GCW and ArcRCC-Network Implementation Plans will each refer to the synergy and common interests between them, and indicate the intent to collaborate as needed and as possible. In terms of contribution to the implementation and operations of the ArcRCC-Network and of benefits to GCW of the collaboration:

- Measurements from the GCW surface network (the core component of which is CryoNet) could support the RCC Mandatory and Highly Recommended Functions and would be useful for product validation.
- GCW products such as snow trackers (which portray seasonal variations against climatology), snow watch intercomparisons and snow assessments, inter alia, could all contribute to and benefit from collaboration with the ArcRCC-Network.
- The GCW metadata archive could be linked to the PRCC-Network metadata archive. Norway houses the WIS compliant GCW data portal, and will likely also

house the WIS compliant PRCC data portal. Norway has plans to have the relevant data host become a WIS Data Collection and Production Centre (DCPC). There is important synergy and shared interests to build on.

- GCW could serve as an excellent resource for technical expertise in matters related to the cryosphere, in support of common goals with the ArcRCC-Network.
- GCW would be able/willing to help review and assess PRCC products relevant to the cryosphere including LRF and other model output. For example, GCW can provide advice and information on forecast verification and on initial conditions, and can assist on interpretation of long range forecasting products for Polar Climate Outlook Forums.
- PRCC and GCW have mutual interests in research and development.
- New products related to cryosphere could be co-developed.
- GCW can facilitate contact with providers and users of cryosphere information and services for the PRCC.
- GCW would benefit from having PRCC and associated WMO Regional Associations promote improved exchange of snow data, or other cryospheric data elements. The breakdown of total precipitation to rainfall and snowfall is very important in areas where solid precipitation occurs.

### *4.1.2 International Ice Charting Working Group (IICWG)*

The International Ice Charting Working Group (IICWG) was formed in 1999 as an ad-hoc working group of northern hemisphere national ice services, to promote cooperation on all matters concerning sea ice and icebergs. While the ice services are primarily focused on providing operational ice information in support of maritime activities, they have a great interest in climate data and products related to ice information. All of the services, to one degree or another, use and/or produce climate products and long range forecasts for sea ice and icebergs.

***Satellite providers:***

Both IICWG and GCW have excellent collaboration with satellite providers, managed through the WMO Space Programme and EC-PHORS, which could support product development opportunities for PRCC. Collaboration between PRCC, GCW and IICWG could potentially influence space missions, and provide new data and products to meet user's needs.

The IICWG has expressed its unanimous support for the establishment of PRCCs covering both Polar Regions. As decided at the ArcRCC-Network Implementation Planning meeting in November 2016, the Terms of Reference of the IICWG and the ArcRCC-Network Implementation Plan will each refer to the synergy and common interests between them, and indicate the intent to collaborate as needed and as possible. In terms of contribution to the implementation and operations of the ArcRCC-Network and of benefits to the IICWG of the collaboration:

- IICWG could serve as an excellent resource for technical expertise in matters related to operational marine meteorology and climatology, in support of common goals with the ArcRCC-Network.
- IICWG could facilitate contact with marine users of climate information and services for the ArcRCC-Network.
- Activities that would be benefit both the IICWG and the PRCC include extending analysis of multispectral satellite information for multiple cold regions variables, and improving assimilation of observations and remotely sensed products, numerical modelling, downscaling and coupling the models.
- IICWG will assist in identification of research priorities for nowcasting, short-term and seasonal forecasting of sea ice, polar atmosphere, etc.; and will support cooperative verification and validation processes and in transitioning research advances to operations.

- IICWG will support assessment of quality and applicability of sea ice products and services – from analysis and nowcasting to long-range forecasts, including those produced by the PRCC.

### *4.1.3 GIPPS: PPP/YOPP and PCPI*

The Global Integrated Polar Prediction System (GIPPS) is a ten-year effort (2013-2022) that aggregates the efforts of the world's NMHSs and research institutions to map weather, water and climate in these regions and provide an invaluable resource to be drawn upon by decision-makers. GIPPS is comprised of two inter-related initiatives, the Polar Prediction Project (PPP) under the World Weather Research Programme (WWRP) and the Polar Climate Predictability Initiative under the World Climate Research Programme (WCRP). The WCRP PCPI is addressing the seasonal to multi-decadal component of the GIPPS while the WWRP PPP is addressing the shorter time scales.

The PPP mission is to "promote cooperative international research enabling development of improved weather and environmental prediction services for the polar regions, on time scales from hours to seasonal". The Year of Polar Prediction (YOPP) is a flagship initiative under the auspices of the WMO/WWRP PPP, with a focused field campaign scheduled for the period 2017-2019 to include Intensive Observation Periods (IOPs). The PPP-Social and Economic Research and Applications (SERA) sub-group conducts, coordinates and reviews social and interdisciplinary scientific research in collaboration with different user groups, and thus could contribute by helping to gauge the level of interest in ArcRCC activities and informing on users' needs.

The PCPI has a focus on polar regions and their role in the global climate system, and aims to improve predictability of the climate system on all time scales by improving our understanding of the underlying physical mechanisms and their representation in climate models.

In terms of contribution to the implementation and operations of the ArcRCC-Network:

- The PPP-SERA subgroup could liaise with the EC-PHORS STT and could support the national efforts of the ArcRCC-Network countries, through its work on outreach, communications and stakeholder engagement.
- On sub-seasonal to seasonal timescales, PRCC can build on YOPP outcomes (e.g. improved observations, data assimilation, verification etc.) and serve as a legacy of YOPP (PRCC and YOPP experts can collaborate on operationalizing experimental/research advances).
- YOPP can support getting user feedback on PRCC products and services, including through Polar Regional Climate Forums, and can assist in validating PRCC products.
- Improved scientific knowledge of the climate system and better representation of all physical mechanisms in climate models will, in time, improve predictability at high latitudes (and at lower latitudes as well), thus improving the PRCC outcomes and underpinning improved services and enhanced climate risk management in the Arctic.

## 4.5 Stakeholders

In addition to the climate science and technical aspects of understanding and predicting climate at high latitudes, substantial work has been done to identify, understand and respond to the impact of climate variability and change in these regions as well. This will contribute to the work of the ArcRCC-Network and the EC-PHORS STT in shaping the suite climate products and services that will meet the priority needs of the region.

The Intergovernmental Panel on Climate Change (IPCC) Working Group II (2014) noted in Chapter 28 on Polar Regions that several recent climate impact assessments on polar regions have been undertaken, including the synthesis report on Snow, Water, Ice and Permafrost in the Arctic (AMAP, 2011a), the State of the Arctic Coast 2010 (2011) reports, the Antarctic Climate and the Environment (Turner et al., 2009, 2013), Arctic Resilience Interim Report 2013 (2013), and the findings of the International Polar Year (IPY; Krupnick et al., 2011). These reports draw a consistent pattern of climate-driven environmental, societal, and economic changes in the polar regions in recent decades.

The products and services to be produced by the ArcRCC-Network will be used by the NMHSs to serve their national clients, and increasingly across the pan-Arctic area, products and services will also be needed to meet the needs of users whose activities are international in scope. To meet those needs, and to ensure that the ArcRCC-Network is relevant to and becomes a trusted source for the information needs of the user communities, it would be extremely helpful to draw upon the knowledge, experience and systems established for user interaction by partners such as the IICWG and GCW, UN bodies such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the World Health Organization (WHO), the World Tourism Organization (UNWTO) inter alia; major projects with a user focus such as COPERNICUS and EUPORIAS; and in particular, the Arctic Council along with its subsidiary bodies including the Arctic Monitoring and Assessment Programme (AMAP). Through its contributing countries, the ArcRCC-Network should interact closely with the Arctic Council and relevant bodies of UN Agencies with Arctic interests, to learn what findings and ongoing work they have that are relevant to the work of the PRCC-Network, to develop synergy and avoid duplication of effort, and to leverage political and financial support to the extent possible.

In addition, mechanisms such as Regional and National Climate Outlook Forums will serve, to some extent, in bringing climate information providers and user communities together for dialogue and information sharing. Considering the vast territory covered by the ArcRCC-Network, however, as well as the infrequency of holding COFs, using this method alone to assess user needs would be slow and most likely would provide incomplete results. Identification of user needs is a national responsibility and optimally each contributing country will take the steps necessary, in a systematic way, to collect this information, and to prioritize the requirements as needed for PRCC operations. A continued effort of the STT to define user requirements (through its White Paper) would be helpful, as will the work of SERA. In this way, the PRCC-Network will develop and issue climate products and services that the NMHSs can tailor to meet their domestic users' most urgent needs for decision making and risk reduction.

### *Indigenous people and Traditional Knowledge*

Indigenous people have permanent representation in the Arctic Council. Having settled down in places convenient for their accessibility, they are now in many cases highly vulnerable to impacts of climate variability and change through, inter alia, loss of hunting culture, declining food security, human health concerns, disrupted land transport, and increased marine shipping and resource development initiatives.

The Arctic Council defines Traditional Knowledge (TK) as a systematic way of thinking and knowing that is elaborated and applied to phenomena across biological, physical, cultural and linguistic systems, and endeavours to take TK into account in its work. TK is collected through millennia, and it is important to keep in mind that including TK in projects may need additional resources, both financial and human. Potential areas of contribution from TK to the ArcRCC-Network is still to be determined considering the local nature of TK. Areas for further consideration include weather/climate forecasting and community-based monitoring.

It is important to recognize and engage the groups representing indigenous people in the PRCC activities from the very beginning, recognizing that meeting the climate-relevant needs of indigenous users might require additional weather/climate information, products and services to those NMHSs and RCCs typically offer. It is important to work with TK networks and projects already in place in the Arctic, and to respect Guidance from the Arctic Council on engagement (e.g. the Ottawa Traditional Knowledge Principles). The Arctic-PRCC will need to consider the decisions of the Arctic Science Cooperation Task Force while addressing the Arctic's unique environment and community service needs and the Council's governance framework.

Background information on Stakeholders can be found in **ANNEX 12**.

## 4.6 Guidance on Roles and responsibilities

To support the PRCC network countries in launching their demonstration phase, and in putting in place the human, institutional and financial resources needed for performing the technical and administrative activities of the new ArcRCC-Network, some suggestions (non-binding) for roles and responsibilities for the Lead agency, the Node leads and for Consortium Members were developed (see **ANNEX 13**).

This guidance could be useful for scoping the level of work with national contributing agencies, and further developed to better cover the final set of mandatory and other agreed functions that will be undertaken.

## 4.7 Governance and oversight

The participating countries in the ArcRCC-Network will be responsible for establishing, operating and sustaining the Network; for ensuring that the work and outputs of the Network meet WMO rules and regulations, particularly with respect to the quality and formats of the mandatory products; for ensuring that the Network's outputs are aligned with the national, sub-regional and regional user requirements for the Arctic; and to align PRCC activities and expectations with those of the WMO Regional Associations for Asia, Europe and North America. The countries also will be required to assign and sustain adequate resources (human and financial) to conduct the work and support the future evolution of the ArcRCC-Network in line with changing regional requirements and any new requirements expected by WMO and its Members of the entire RCC system globally.

The role of WMO Members and constituent bodies and their related sub-groups in the formal designation process is laid out in section 6 below. Thus, governance and oversight on the development and implementation of the ArcRCC-Network as well as the designation process will involve:

- The WMO Member countries: Canada, Denmark (and Greenland), Finland, Iceland, Norway, the Russian Federation, Sweden, and the USA, some of which will have roles as Node leads, and one of which will be overall lead for the Network. In the case of governance as Node or overall Lead, regional cooperation will be coordinated with the national interests of all participating countries in the functioning of the Network. France, Germany, the Netherlands, the UK may contribute, largely in their roles as RA VI RCC-Network Nodes and/or as GPCs.
- The Regional Associations for Asia, North America and Asia (RA II, IV and VI, respectively) including their respective subsidiary bodies on RCC matters: (i) RA II Working Group on Climate Services; (ii) RA IV Task Team on GFCS; and (iii) RA VI Working Group on Climate and Hydrology.
- The WMO Technical Commissions; especially The Commission for Climatology (CCl) and the Commission for Basic Systems (CBS), but also the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) and others as required.

- The WMO CCl/CBS Expert Team on RCCs (ET-RCCs) which coordinates and guides the establishment and operation of RCCs worldwide.
- The WMO Secretariat including the WMO Secretary-General.
- WMO Executive Council (EC) and the World Meteorological Congress (Cg).
- The WMO Executive Council Panel of Experts on Polar and High-mountain Observations, Research and Services (EC-PHORS) and its Services Task Team (STT).

Subsequent to its formal designation by WMO, the ArcRCC-Network will continue to liaise with the above-noted bodies, as needed, on scientific, technical and operational matters related to fulfilling its goals, maintaining standards, and on the evolution of the responsibilities of the Network.

As noted elsewhere in this Implementation Plan, cooperation with relevant agencies will be vital to the successful operation of the ArcRCC-Network. While these efforts do not constitute oversight for the Network per se, the PRCC must be able to respond to and incorporate changes and advances in systems including:

- other RCCs and RCC-networks, the WMO global system of GPCs, and with technical partners including GCW and IICWG;

- the GIPPS communities (especially with respect to incorporating advancements in polar knowledge, models and prediction systems, and take part in (to the extent possible) translating research advances into operational practice;

- key stakeholders (such as the Arctic Council and its subsidiary bodies; UN agencies with interests in the Arctic; etc.) who's work could influence the types and nature of products and services requested of the Network.

## 4.8 Contributions

In 2016, the countries that have agreed to contribute to the ArcRCC-Network identified, through their Permanent Representatives, the data, products and services they plan to make available to support the work of the Network. These potential contributions are arranged in two sets of tables, APPENDICES I and II, on Mandatory Functions and 'Highly Recommended' Functions respectively.

The tables for Mandatory Functions for LRF, Climate Monitoring (CM), data services (DS) and training (T) (**APPENDIX I**) contain those data, products and services that are based solely on, or include at a minimum $T_{mean}$ and total Precipitation for LRF and $T_{max}$, $T_{min}$, $T_{mean}$ and total Precipitation for CM and DS (the basic, minimum requirements for RCC designation), as per the first priority for the implementation of the Network. The data, products and services that fall within the 'Highly Recommended' category (climate prediction and projection, non-operational data services, coordination functions, training and capacity building, research and development and other) are presented in **APPENDIX II**. As noted in section 2.2 above, the Mandatory Functions with criteria are identified in **ANNEX 4**, and the 'Highly Recommended' functions are spelled out in **ANNEX 5.**

In the contributions proposed by Members, there were many products and services offered that fit the profiles for mandatory LRF, Climate monitoring and operational data services, but were based on variables such as sea-ice, snow, hydrology parameters, etc., many of which are ECVs and could (eventually) be considered as mandatory for the region in question. At present, at the wishes of the participating experts, these contributions have been distributed within 'Highly Recommended' functions, some as special seasonal forecasts, some as non-operational data sets, some as 'other' climate monitoring products, etc.

As was highlighted at the Scoping Workshop (Nov 2015) and reiterated at the Planning meeting (Nov 2016), provision of the basic, minimum set of RCC Mandatory Functions may not be adequate to meet the needs of polar stakeholders. These meetings also highlighted that the Members supporting the ArcRCC-Network have the capacities to deliver beyond the defined mandatory RCC products. Therefore, the portfolio of the ArcRCC-Network could (eventually) be expanded, at the discretion of the contributing countries, to include a range of additional products/services to meet the requirements of the major regional users, stakeholders and partners in Polar Regions. The possibility of optimizing the use of remote sensing, satellite data and products including animations in observation-sparse areas will also be considered.

A number of strengths are revealed in the tables of contributions for the mandatory functions:

**LRF:** the Arctic polar region benefits from GPCs around the world, including in contributing countries Canada, USA, France and the UK and strong modeling and prediction capability at seasonal scale. There are established and experienced RCCs and RCC-Networks in Europe and the Russian Federation for collaboration and guidance. Most countries supporting the ArcRCC, at a minimum use and distribute, and many generate, seasonal scale prediction products for their countries. Canada has offered to lead production of LRF for the network.

**CM:** All ArcRCC-Network contributors have well established databases and analysis capabilities (means, anomalies, extremes, indices, mapping, time series etc.), essential to diagnostics and establishment of the reference climatologies. Some issue climate bulletins. The European countries and Russian Federation are experienced with regional climate watch, and Canada-USA are now piloting a similar service as well. The RCCs in Europe and Asia produce climate monitoring products covering part of (or contiguous to) the ArcRCC-Network domain, which will be useful for coordination across the northern hemisphere. The Russian Federation will ensure the pan-Arctic climate Monitoring functions are achieved.

**DS:** All countries in the domain have extensive and well-managed databases (with all appropriate QA/QC applied. Some work on data homogeneity, and some datasets are in gridded formats. Although not a mandatory function, it should be noted that most PRCC contributors have achieved, or are working towards WIS compliance. The Russian Federation and the USA host World Data Centres and manage regional or global datasets. Norway will provide the operational data services for the network.

**T:** Most countries in the PRCC domain have experience with training in general (if not RCC-specific type of training), and many develop guidance and information on products and methods for their existing products. This experience can be built upon.

## 4.9 Language

Coordination activities and communications between the technical experts of the contributing countries will generally be in English.

The ArcRCC-Network products and services for the pan-Arctic region will be in English. Translations of some of the products and information to national languages may be available through the sub-regional Nodes. The Russian Federation, for example, will offer the pan-Arctic climate monitoring products in both Russian and English through the Eurasian Node.

# 5. Implementation Phase 1: Demonstration (2017-2019)

The launch of the demonstration phase will shortly follow presentation to and acceptance of the Implementation Plan by WMO EC-69 in 2017. The primary focus for Phase 1, by decision of the contributing countries (at the Nov 2016 meeting), will be to ensure conduct of the Mandatory Functions, to the standards set out in the WMO Technical Regulations (as per the Manual on the GDPFS).

During Phase 1, the contributing countries have agreed to do the following:

i) Following presentation to and acceptance of the Implementation Plan to WMO members at EC-69, if not already done, the ArcRCC-Network Lead agency will announce the start date for the demonstration phase to the WMO Secretary-General (with copies to the Presidents of the WMO Regional Associations II, IV and VI, the Presidents of CCl and CBS, PRs of the contributing countries to the Network, and the co-chairs of EC-PHORS).

ii) Establish a coordination mechanism for the Network (such as a steering committee of experts from the contributing countries) to address and make decisions on technical, scientific, coordination, planning, oversight and other issues. Terms of Reference to guide this effort will be developed. Inter alia, this mechanism would consider products and services to be offered through the Network (in addition to the ones WMO requires as mandatory) in terms of quality, sustainability, representativeness, etc.; advise on projects to develop new products; and provide oversight on all pan-Arctic cross node activities.

iii) Establish a communications and coordination processes with relevant other RCCs and GPCs/GPCLRFs for routinely sharing information and products and for feedback.

iv) Launch a Polar Regional Climate Outlook Forum (potentially in autumn of 2017 or spring 2018, and potentially in conjunction with the launch of the demonstration phase): Canada will host and will include a focus on YOPP.

v) After approximately one year, tentatively hold a coordination meeting to review progress (potentially Autumn 2018), host not yet identified.

vi) After approximately one more year (potentially autumn 2019), evaluate the state of readiness to apply to WMO for formal designation. Lead centre and steering committee to coordinate the evaluation.

vii) When the contributing countries feel ready, begin the process to apply to WMO for formal designation as an RCC-Network. The Lead Centre will coordinate the application (see section 6 below).

Specific challenges related to coordination and carrying out the Mandatory Functions have been identified (during the meeting on Implementation planning, Nov 2016) and should be addressed during the conduct of the demonstration phase (see section 8 below).

During the demonstration phase, at the discretion of the contributing countries and under the advisement of the steering committee, the ArcRCC-Network could consider and begin to implement services for LRF, Climate Monitoring and supporting Data Services for variables other than T and P, noting that based on agreement by the Network contributors, any of the ECVs could be considered mandatory (WMO-No. 1534). In addition, the Network could implement any ‘Highly Recommended’ functions that would help the NMHSs meet the priority needs of users in their countries.

***A parallel process: Further identification of user requirements:***

To better understand the requirements of different user communities interested in specific products, there is a need to approach these communities to identify their needs. While ultimately a national responsibility, the continued engagement of the EC-PHORS

STT and their work on user requirements, as well as the effort and results of SERA (PPP) would provide insights on user requirements that will be very useful in this light.

# 6. Implementation Phase 2: Designation (2019-2020)

The typical WMO process for designation of an RCC or RCC-Network is described in in the document 'How to establish and run a WMO Regional Climate Centre (RCC)' (WMO/TD-No. 1534), excerpts of which are presented in **ANNEX 6**. In the case of an RCC for the Arctic, a somewhat modified process is proposed due to the unique situation in that the ArcRCC-Network will be trans-regional, involving three WMO Regional Associations (RA II, Asia; RA IV, North America; and RA VI, Europe).

The following steps recognize that there will need to be interaction between the respective Regional Associations, and (as per Decision 52, EC-68) a role for the WMO Executive Council Panel of Experts on Polar and High-mountain Observations, Research and Services (EC-PHORS) and its Services Task Team (STT), both of which have undertaken substantial activities in scoping the PRCC and in launching the ArcRCC-network demonstration phase.

It is assumed that, prior to the launch of the demonstration phase, the appropriate bodies (as identified under governance/oversight in section 4.7) will all have been informed of the intent of the countries to initiate the ArcRCC-Network and to soon thereafter, seek formal designation by WMO.

It is further assumed that before or during the demonstration phase:

- the Regional Associations and their respective subsidiary bodies will have established a coordination mechanism through which to provide their collective inputs to the designation procedures as well as evolution of the implementation plan and the conduct of the demonstration phase; and that
- the contributing countries, the Nodes and the lead agency for the ArcRCC-Network will have established and are maintaining communication, as needed, on technical and operational matters with the governance/oversight bodies (as per section 4.7).

***Process for designation of the ArcRCC-Network:***

All these preparatory efforts being in place, the remaining steps to be taken to apply for and attain formal WMO designation are as follows:

- At the appropriate time, when the contributing countries, the Nodes and the Lead Agency are confident that the ArcRCC-Network is performing all the Mandatory Functions to meet the detailed criteria (as presented in **ANNEX 3**), the Lead Agency will inform the RA Presidents and other relevant bodies of the status of their performance and request their assessment.

- Given that the ArcRCC-Network will have Nodes for three specific geographical sub-regions, each of which is expected to perform all Mandatory Functions for its domain, the WMO RAs (with the help of their respective subsidiary bodies on RCC matters) and the other relevant oversight bodies will evaluate compliance with the WMO Technical Regulations of each Node, and of the whole Network.

- When the Regional Associations are satisfied of compliance, they will jointly contact the WMO Secretary-General (SG), provide documentation on the process followed and their assessment of the candidate's capability to meet the requirements of the designation criteria, and request formal designation of the candidate as an RCC-Network.

- The WMO SG will arrange for an evaluation of both the request of the candidate and the assessment by the Regional Associations of the candidate's compliance by the CCl, the joint CCl/CBS Expert Team on RCCs (ET-RCCs), and the EC-PHORS and its Services Task Team (STT). If needed, the WMO SG will take up any concerns with the Presidents of the RAs, and the candidate will take the recommended steps to address the issues – this process repeats until all oversight bodies feel the candidate is fully compliant with the criteria.

- When advised by the President of CCl of satisfactory compliance with the designation criteria, the WMO SG will forward the request for formal designation to the President of CBS for further action (copies to the President of CCl, the Presidents of the RAs and to the Co-Chairs of EC-PHORS for information).

- WMO's CBS, through its relevant bodies, will review the submission and will discuss any concerns with the RAs and with CCl through the WMO Secretariat. If needed, the proposal might need to be resubmitted with all clarifications addressed.

- If successful up to this point, the candidate will be invited by CBS to present the proposal (in the form of an amendment to the Manual on the GDPFS) at one of its sessions for decision (the next CBS session(s) will be some combination of autumn 2018, autumn 2020 and autumn 2022). The presentation of the proposal shall be complimented by the respective demonstration of capabilities, through documentation and an oral presentation. The WMO Secretariat will assist in the development of the proposed amendment to the Manual on the GDPFS.

- With the approval of Members of CBS, the amendment to the Manual will be put up to either WMO Congress or WMO Executive Council for approval.

- With this final WMO approval, the Manual on the GDPFS will be revised, and the RAs and the candidate (in this case through the Lead Agency for the ArcRCC-Network) will be advised in writing on the designation of the respective WMO RCC or RCC-Network (with copies to the contributing countries and to EC-PHORS).

# 7. Implementation Phase 3: Operational ArcRCC-Network (2020- )

Once designated, the ArcRCC-Network will continue to perform all Mandatory Functions in a sustained manner. The contributing countries may by this time have established a more complete set of user requirements at national and sub-regional scales, and established a network of partners in each country for two-way feedback on RCC-relevant climate matters. The contributing countries should review, prioritize and make plans to address as many user needs as feasible. As well, the research and development communities will at some point be able to provide new methods and tools for product generation, and even improved prediction models for sub-seasonal and long-range forecasting.

In light of these expected advances, the contributing countries are strongly encouraged to create a development plan (a forward plan) for the ArcRCC-Network, laying out goals and timelines for network improvements, including proposals for resource mobilization, perhaps with the assistance of the WMO resource mobilization office. Items to consider for this forward plan include:

- As improved and new methods for product generation and tools (e.g. forecast models), are made available by the research and development communities, the PRCC-Network will need to update their procedures and apply the new models. Training may be required.

- The Members should identify a range of elements (beyond temperature ($T_{min}$, $T_{max}$, $T_{mean}$) and total Precipitation) for which additional effort will be made to support/promote observations and strengthen partnerships (e.g. with GCW, IICWG, etc.), in particular any of the Essential Climate Variables (ECVs) and those variables deemed high priority by GCW and IICWG.
- The Members will need to build relationships to further identify and to address requirements of key socio-economic sectors in the region (e.g. marine transportation, tourism, natural resources exploitation, aviation, hydrology, etc.). Surveys, meetings, and sector-specific Climate Outlook Forums could be considered.
- Set up processes whereby dialogue with indigenous peoples is promoted (e.g. through COFs), and to the extent possible, discuss/consider Traditional Knowledge on RCC-relevant climate matters.
- Establish a Help-desk approach supporting dissemination of RCC products to address questions and to capture/address user feedback, for overall network enhancement over time.
- Look for initiatives with which to develop synergy and work with proponents of new initiatives to try to avoid duplications, saving resources and time.
- Work towards having the host for the operational data services becoming a WMO-designated WIS Data Collection and Processing Centre (DCPC).
- Interact increasingly with the working groups of the Arctic Council on climate matters.

# 8. Addressing the Gaps/Challenges/Issues

A number of key decisions are pending at the time of development of this Implementation Plan. High priority issues to be addressed during the Demonstration Phase include the following, related to the structure, governance and coordination of the Network, and to the full implementation of the Mandatory Functions:

- **Leading institution for the PRCC-Network:** TBD. Norway is exploring the feasibility, with its appropriate decision bodies, of this being assigned to the Nordic Node for the first 2-3 years, to guide PRCC implementation through the demonstration phase. Should this not prove feasible, all other countries in the PRCC domain will be asked to explore the option with their governments.
- **Single web portal for the ArcRCC:** TBD. Normally the lead agency for the entire Network would host the ArcRCC-Network web portal (which could be a basic web page with links to the other ArcRCC-Network Nodes and to the web pages for pan-Arctic products for content).
- **Web portal, North America Node:** TBD. Canada is seeking options for initial assistance with this.
- ***Operational Activities for LRF:***
  - ***Web portal, pan-Arctic LRF:*** TBD. Canada is seeking options for initial assistance with this. Norway will internally consult on legal and other considerations for Norway to host the LRF website.
  - ***Consensus statement on regional or sub-regional forecasts:*** TBD. A process for development of the consensus has not yet been established.
  - ***LRF products with polar projection:*** Canada will collaborate with WMO LC-LRFMME to develop such products.
  - ***User feedback:*** TBD. A process will need to be established to collect user feedback, and to address it, for the improvement of PRCC products and services over time.
- ***Operational Activities for Climate Monitoring***
  - **Cross-node Climate Watch:** The Climate Watch, to be carried out in accordance with the WMO Guidance on Climate Watch Systems, will be developed by the Russian Federation. As happened in RA VI RCC Network

implementation, there may be a need for a workshop on the WMO process, to assist the members of the consortium.

- ***Historical reference climatology:*** This will be developed by Russian Federation. In most cases, national reference datasets exist, but it is not known to what extent these are interoperable. A process to collect and integrate all data required for a regional historical reference climatology for the PRCC domain needs to be considered. The temporal resolution for the reference climatology is identified as 'monthly at a minimum', but countries are urged to plan for daily resolution for better product options.
- ***Consistency in Methods and Procedures:*** TBD. While there are many climate monitoring products available at national levels, no process has yet been established to determine common methodologies (including algorithms, models, normal, formats, projections, etc.) that could help merge national and sub-regional products into seamless pan-arctic products with polar projections.
- ***ECVs and other high priority variables:*** TBD. A process to consider development of climate monitoring (or forecast) products and services based on elements other than Temperature and total Precipitation for PRCC implementation is required, to meet expectations of partners and known user requirements.

- ***Operational Data Services to support operational LRF and climate monitoring***
  - ***Quality controlled regional climate datasets:*** TBD. So far it is agreed that national datasets will continue to be housed by their hosts, and made discoverable through sharing WIS metadata. The requirement to establish an Arctic regional dataset, possibly gridded, has yet not been addressed. Capability across all PRCC contributors to share the WIS metadata needed for all products and datasets is not yet known.
- ***Training in the use of operational RCC products and services***
  - ***Manuals, Guidance on ArcRCC-Network products:*** TBD. There is no process for development of guidance materials specific to PRCC mandatory products and on their use, but possibly those developed for other RCCs could be applicable and revised and reused for PRCC.
  - ***Training for RCC users:*** TBD. There is no process to develop training for users in the interpretation and use of mandatory RCC products, but some PRCC contributors have training capabilities that could be built on.

The participating countries are encouraged to consider the Implementation Plan as a living document and to set up within it the tasks and milestones for addressing these and other high priority requirements as they become known.

***To consider:***

A number issues and activities have been identified that, if addressed would improve the functionality and effectiveness of the ArcRCC-Network, and would enhance its visibility to decision-makers at all levels. Addressing these is not required during the demonstration phase, but could be considered as requirements evolve and resources are available. The issues include:

- Setting up a communications and outreach initiative, to promote the ArcRCC-Network to decision makers, stakeholders and partners, to alert them to available products and services, and to encourage feedback (considering newsletters, e-mail distribution lists, and other mechanisms).

- Promoting and undertaking national and regional efforts to identify user requirements for climate products and services; liaising with the EC-PHORS STT, IICWG, GCW, YOPP/SERA experts and others on their continuing efforts to identify and address user requirements; building on these relationships through COFs and possibly interdisciplinary workshops to enhance synergy and reduce duplication of

effort. Note that it is possible that certain specialized or tailored climate services developed by individual countries could be provided on a cost-recovery or commercial basis to clients in those countries.

- Taking into account, to the extent feasible, Traditional Knowledge in the work of the ArcRCC-Network.
- Maintaining contact with the Research and Development communities, in particular for operationalizing advances in prediction capabilities, and in development of tools and methods for generating new products to meet the pan-Arctic – to - national needs for the PRCC domain.
- Working with IICWG, GCW and stakeholders to identify priority variables for LRF, Climate Monitoring and associated Data Services to expand beyond the minimum requirements of T- and P-based products and services.
- Developing effective interaction and information exchange with the Arctic Council and UN agencies with Arctic interests and with their relevant subsidiary bodies, to develop synergy, minimize duplication of effort, and to leverage political and financial support.
- Identifying priority activities in the categories of 'Highly Recommended Functions' to become standard to the work of the Network (e.g. to take advantage of currently available products such as the GCW snow trackers, or sea-ice forecasts).
- Setting up a 'Help Desk' or FAQs, to address questions raised by those that access and use PRCC information, and perhaps to provide examples of how to use the information in decision-making.
- Identifying, at Node and country level, the languages in which it is important to present RCC products and services, and ensuring the internal systems and resources are available to provide the translations as needed.

***Resources:***

Establishing and operating the ArcRCC-Network will largely be based on existing human and financial resources, but there will be new tools, additional web sites, training activities, and other new work that will require new resources. It is greatly appreciated that the contributing countries are committed to this initiative, and will see to it that the ArcRCC-Network is viable and sustained for the future.

# 9. Next steps

The timeline for the 'next steps', leading up to formal designation, is identified in section 5 above, but contains specifics for only the major milestones. As the Members assess processes, resources and timeframes to address the identified gaps (section 8 above), this timeline should be expanded accordingly, and become a living document aimed at meeting the goals and priorities.

# 10. Conclusions and recommendations

Planning for implementation of the ArcRCC-Network is well advanced, and the countries have enthusiastically agreed to support its work. The continuum of input and advice from the governance and oversight bodies will further guide the fledgling Network to formal designation by WMO, hopefully by 2020. Implementing a trans-regional RCC-Network has required new approaches to those typically applied to RCC launches and designation, and the work of the EC-PHORS and its STT have been invaluable. It is recommended that EC-

PHORS consider extending this process to the Antarctic and Third Pole regions as soon as feasible.

# Annex 1: IPCC AR5, WGII, Chapter28, Executive Summary

Reference:
Larsen, J.N., O.A. Anisimov, A. Constable, A.B. Hollowed, N. Maynard, P. Prestrud, T.D. Prowse, and J.M.R. Stone, 2014: **Polar regions. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change** [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1567-1612.

## Executive Summary

Additional and stronger scientific evidence has accumulated since the AR4 that reinforces key findings made in the Fourth Assessment Report (AR4).

**The impacts of climate change, and the adaptations to it, exhibit strong spatial heterogeneity in the polar regions because of the high diversity of social systems, biophysical regions, and associated drivers of change (*high confidence*). {28.2.2}** For example, the tree line has moved northward and upward in many, but not all, Arctic areas (high confidence) and significant increases in tall shrubs and grasses have been observed in many places (very high confidence). {28.2.3.1.2}

**Some marine species will shift their ranges in response to changing ocean and sea ice conditions in the polar regions (*medium confidence*).** The response rate and the spatial extent of the shifts will differ by species based on their vulnerability to change and their life history. {28.2.2, 28.3.2} Loss of sea ice in summer and increased ocean temperatures are expected to impact secondary pelagic production in some regions of the Arctic Ocean, with associated changes in the energy pathways within the marine ecosystem (medium confidence). These
changes are expected to alter the species composition of zooplankton in some regions, with associated impacts on some fish and shellfish populations (medium confidence). {28.2.2.1} Also, changes in sea ice and the physical environment to the west of the Antarctic Peninsula are altering phytoplankton stocks and productivity, and krill (high confidence). {28.2.2.2}

**Climate change is impacting terrestrial and freshwater ecosystems in some areas of Antarctica and the Arctic.** This is due to ecological effects resulting from reductions in the duration and extent of ice and snow cover and enhanced permafrost thaw (very high confidence), and through changes in the precipitation-evaporation balance (medium confidence). {28.2.1, 28.2.3}

**The primary concern for polar bears over the foreseeable future is the recent and projected loss of annual sea ice cover, decreased ice duration, and decreased ice thickness (*high confidence*).** Of the two subpopulations where data are adequate for assessing abundance effects, it is very likely that the recorded population declines are caused by reductions in sea ice extent. {28.2.2.1.2, 28.3.2.2.2}

**Rising temperatures, leading to the further thawing of permafrost, and changing precipitation patterns have the potential to affect infrastructure and related services in the Arctic (*high confidence*). {28.3.4.3}** Particular concerns are associated with damage to residential buildings resulting from thawing permafrost, including Arctic cities; small, rural settlements; and storage facilities for hazardous materials. {28.2.4-5}

In addition, there is new scientific evidence that has emerged since the AR4.
**The physical, biological, and socioeconomic impacts of climate change in the Arctic have to be seen in the context of often interconnected factors that include not only environmental changes caused by drivers other than climate change but also**

**demography, culture, and economic development.** Climate change has compounded some of the existing vulnerabilities caused by these other factors (high confidence). {28.2.4-5, 28.4} For example, food security for many Indigenous and rural residents in the Arctic is being impacted by climate change, and in combination with globalization and resource development food insecurity is projected to increase in the future (high confidence). {28.2.4}

**The rapid rate at which climate is changing in the polar regions will impact natural and social systems (*high confidence*) and may exceed the rate at which some of their components can successfully adapt (*low* to *medium confidence*). {28.2.4, 28.4}** The decline of Arctic sea ice in summer is occurring at a rate that exceeds most of the earlier generation model projections (high confidence), and evidence of similarly rapid rates of change is emerging in some regions of Antarctica. {WGI AR5 Chapters 4, 5, 9} In the future, trends in polar regions of populations of marine mammals, fish, and birds will be a complex response to multiple stressors and indirect effects (high confidence). {28.3.2} Already, accelerated rates of change in permafrost thaw, loss of coastal sea ice, sea level rise, and increased weather intensity are forcing relocation of some Indigenous communities in Alaska (high confidence). {28.2.4.2, 28.2.5, 28.3.4}

**Shifts in the timing and magnitude of seasonal biomass production could disrupt matched phenologies in the food webs, leading to decreased survival of dependent species (*medium confidence*).** If the timing of primary and secondary production is no longer matched to the timing of spawning or egg release, survival could be impacted, with cascading implications to higher trophic levels. This impact would be exacerbated if shifts in timing occur rapidly (medium confidence). {28.2.2, 28.3.2} Climate change will increase the vulnerability of terrestrial ecosystems to invasions by non-indigenous species, the majority likely to arrive through direct human assistance (high confidence).

**Ocean acidification has the potential to inhibit embryo development and shell formation of some zooplankton and krill in the polar regions, with potentially far-reaching consequences to food webs in these regions (*medium confidence*).** Embryos of Antarctic krill have been shown to be vulnerable to increased concentrations of carbon dioxide ($CO_2$) in the water (high confidence). As well, there is increasing evidence that pelagic molluscs (pteropods) are vulnerable to ocean acidification (medium confidence). {28.2.2, 28.3.2}

**There is increased evidence that climate change will have large effects on Arctic communities, especially where narrowly based economies leave a smaller range of adaptive choices. {28.2.6.1, 28.4}** Some commercial activities will become more profitable while others will face decline. Increased economic opportunities are expected with increased navigability in the Arctic Ocean and the expansion of some land- and freshwater-based transportation networks. {28.2.6.1.3, 28.3.4.3} The informal, subsistence-based economy will be impacted (high confidence). There is high confidence that changing sea ice conditions may result in more difficult access for hunting marine mammals. {28.2.6.1.6} Although Arctic residents have a history of adapting to change, the complex interlinkages among societal, economic, and political factors and climatic stresses represent unprecedented challenges for northern communities, particularly if the rate of change will be faster than the social systems can adapt (high confidence). {28.2.5, 28.4}

**Impacts on the health and well-being of Arctic residents from climate change are significant and projected to increase—especially for many Indigenous peoples (*high confidence*). {28.2.4}** These impacts are expected to vary among the diverse settlements, which range from small, remote, predominantly Indigenous communities to large cities and industrial settlements (high confidence), especially those in highly vulnerable locations along ocean and river shorelines. {28.2.4}

## Annex 2: Overview of WMO Global Producing Centres of Long-Range Forecasts

Information on WMO GPCs/GPCLRFs standard and requirements can be found at:

WMO designated GPCLRFs include the following:

- : China Meteorological Administration (CMA) / Bejing Climate Center (BCC)
- : Met Office, United Kingdom
- : Bureau of Meteorology (BOM), Australia
- : Meteorological Service of Canada (MSC)
- : Hydrometeorological Centre of Russia
- : South African Weather Services (SAWS)
- : Korea Meteorological Administration (KMA)
- : Japan Meteorological Agency (JMA) / Tokyo Climate Centre (TCC)
- : Météo-France
- : Climate Prediction Center (CPC) / National Oceanic and Atmospheric Administration (NOAA), United States of America

In addition to the institutions referenced above, WMO has also designated the following Lead Centres:

- jointly coordinated by KMA and CPC/NOAA
- jointly coordinated by BOM and MSC

**Other Major Centres Providing Global Seasonal Forecasts**

## Annex 3: RCC Definitions

RCC definitions include that:

- a WMO-RCC is a multifunctional centre that fulfils all the required functions of an RCC for the entire region, or for a sub-region to be defined by the regional association;
- a WMO RCC-Network is a group of centres performing climate-related activities that collectively fulfil all the required functions of an RCC; and that
- a WMO RCC-Network Node is a centre in a designated WMO RCC-Network. A Node will perform, for the region or sub-region defined by the regional association, one or several of the mandatory RCC activities (e.g. long-range forecasting (LRF), climate monitoring, climate data services, training).

# Annex 4: Detailed Criteria for Mandatory Functions of WMO RCCs/RCC Networks

*From the Manual on the GDPFS (WMO No. 485), Part II, new Appendix II-11*[5]

| Functions | Activities | Criteria |
|---|---|---|
| **Operational Activities for LRF** (both dynamical and statistical, within the range of 1 month to 2 year timescale, based on regional needs) | Interpret and assess relevant LRF products from Global Producing Centres (GPCs), distribute relevant information to RCC Users; and provide feedback to GPCs (see Attachment II-13) | ***Product:*** assessment of the reliability and outcomes of GPCs or LCs-LRFMME products including the reasoning (making use of LC SVSLRF), for the region of interest, in the form of texts, tables, figures, etc.<br>***Element:*** 2-m mean temperature, total precipitation<br>***Update frequency:*** monthly or at least quarterly |
| | Generate regional and sub-regional tailored products, relevant to RCC User needs, including seasonal outlooks etc. | ***Product:*** probabilities for tercile (or appropriate quantile) categories for the region or sub-region<br>***Element:*** 2-m mean temperature, total precipitation<br>***Output type:*** *rendered images (maps, charts), text, tables, digital data*<br>***Forecast period*:** one month up to 6 months<br>***Update frequency:*** 10 days to one month |
| | Generate consensus* statement on regional or sub-regional forecasts.<br><br>**NB: A collaborative process involves discussion with experts in the region (e.g. through Regional Climate Outlook Forums (RCOFs), teleconferencing, etc.).*<br><br>*Consensus is both the agreed process, and its joint conclusion, and can be that there is limited skill in the prediction for a region or sub-region* | ***Product:*** *consensus statement on regional or sub-regional forecast.*<br>***Element:*** *2-m mean temperature, total precipitation*<br>***Output type:*** *report*<br>F***orecast period*:** *a climatologically significant period (from one month to one year)*<br>***Update frequency:*** *at least once per year (to be defined by the region)* |
| | Perform verification of RCC quantitative LRF products, including the exchange of basic forecasts and hindcast data. | ***Products:*** verification datasets (e.g. SVS LRF scores, Brier Skill Score; ROC; Hit Rate Skill Score)<br>***Element:*** 2-m mean temperature, total precipitation |
| | Provide on-line access to RCC products/services to RCC Users. | ***Product:*** an on-line data/information portal |
| | Assess use of RCC products and services through feedback from RCC Users. | ***Product:*** analysis of feedback (which is made available using a template)<br>***Update frequency:*** annually, as part of a regular reporting of RCCs to WMO RAs |

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| | | |
|---|---|---|
| **Operational Activities for Climate Monitoring** | Perform climate diagnostics including analysis of climate variability and extremes, at regional and sub-regional scales | ***Products:*** climate diagnostics bulletin including tables, maps and related products<br>***Element:*** Mean, Max and Min temperatures, Total precipitation; other elements (esp. GCOS essential climate variables) to be determined by the region,<br>***Update frequency:*** monthly |
| | Establish an historical reference climatology for the region and/or sub-regions | ***Product:*** database of climatological means for various reference periods (e.g. 1931-60; 1951-80; 1961-90; 1971-2000; etc)<br>***Spatial resolution:*** *by station*<br>***Temporal resolution:*** *monthly at a minimum*<br>***Elements:*** Mean, Max and Min temperatures, Total precipitation; other elements (esp. GCOS essential climate variables) to be determined by the region,<br>***Update frequency:*** at least 30 years, preferably 10 years |
| | Implement a Regional Climate Watch | ***Products:*** climate advisories and information for RCC Users<br>***Update:*** whenever required, based on the forecast of significant regional climate anomalies. |
| **Operational Data Services, to support operational LRF and climate monitoring** | Develop quality controlled regional climate datasets, gridded where applicable | ***Products:*** regional, quality controlled climate datasets, gridded where applicable, following CCl guidance on QA/QC procedures<br>***Elements:*** Mean, Max and Min Temperature, and Precipitation, at a minimum<br>***Temporal resolution:*** *daily*<br>***Update:*** monthly |
| | Provide climate database and archiving services, at the request of NMHSs | ***Products:*** national databases with metadata, accessible to the NMHS in question (backup service, development site, etc).<br>***Elements:*** as determined by the NMHS<br>***Update:*** at the request of the NMHS |
| **Training in the use of operational RCC products and services** | Provide information on methodologies and product specifications for mandatory RCC products, and provide guidance on their use | ***Products:*** *Manuals, guidance documents and information notes*.<br>***Update frequency:*** when methods/products are revised or introduced or discontinued |
| | Coordinate training for RCC Users in interpretation and use of mandatory RCC products | ***Products:*** survey and analysis of regional training needs, and proposals for training activities. |

NOTE: an RCC is expected to perform certain functions (e.g. for homogeneity testing; database management; metadata management, statistical evaluation of climate data, etc.) using procedures proposed in the WMO Guide to Climatological Practices and in other official Commission for Climatology Guidance documents.

## Annex 5: RCC Highly Recommended Functions

RCC 'Highly Recommended' Functions (as per the Manual on the GDPFS (WMO No. 485), Attachment II-10) include:

- **Climate prediction and projection**
  - Assist RCC Users in the access and use of WCRP-CMIP climate model simulations
  - Perform downscaling of climate change scenarios
  - Provide information to RCC Users for use in development of climate adaptation strategies
  - Generate, along with warnings of caution on accuracy, seasonal forecasts for specific parameters where relevant, such as: onset, intensity and cessation of rainy season; tropical cyclone frequency and intensity
  - Perform verification on consensus statements for forecasts
  - Perform assessment of other GPC products such as SSTs, winds, etc.

- **Non-operational data services**
  - Keep abreast of activities and documentation related to WMO WIS, and work towards WIS compliance and DCPC designation
  - Assist NMHSs in the rescue of climate data from outmoded storage media
  - Assist NMHSs to develop and maintain historical climate datasets
  - Assist RCC Users in the development and maintenance of software modules for standard applications
  - Advise RCC Users on data quality management
  - Conduct data homogenization, and advise RCC Users on homogeneity assessment and development and use of homogeneous data sets
  - Develop and manage databases, and generate indices, of climate extremes
  - Perform Quality Assurance/Quality Control on national datasets, on request of an NMHS
  - Provide expertise on interpolation techniques
  - Facilitate data/metadata exchange amongst NMHSs, including on-line access, through an agreed regional mechanism
  - Perform Quality Assurance/Quality Control on regional datasets

- **Coordination functions**
  - Strengthen collaboration between NMHSs on related observing, communication and computing networks including data collection and exchange
  - Develop systems to facilitate harmonisation and assistance in the use of LRF products and other climate services
  - Assist NMHSs in user liaison, including the organisation of climate and of multidisciplinary workshops and other forums on user needs
  - Assist NMHSs in the development of a media and public awareness strategy on climate services

- **Training and capacity building**
  - Assist NMHSs in the training of users on the application and on implications of LRF products on users
  - Assist in the introduction of appropriate decision models for end-users, especially as related to probability forecasts
  - Promote technical capacity building on NMHS level (e.g. acquisition of hardware, software, etc.), as required for implementation of climate services

    - Assist in professional capacity building (training) of climate experts for generating user-targeted products

- **Research and development**
    - Develop a climate Research and Development agenda and coordinate it with other relevant RCCs
    - Promote studies of regional climate variability and change, predictability and impact in the Region
    - Develop consensus practices to handle divergent climate information for the Region
    - Develop and validate regional models, methods of downscaling and interpretation of global output products
    - Promote the use of proxy climate data in long-term analyses of climate variability and change
    - Promote application research, and assist in the specification and development of sector specific products
    - Promote studies of the economic value of climate information

## Annex 6: Typical RCC Designation process

Before applying for designation by WMO, a candidate RCC or RCC-Network requires clear mandates from its host country and from the relevant WMO Regional Association(s) to undertake and to sustain high quality, consistent climate activities for the benefit of the region. It also needs to have arranged for the appropriate resources to set up and run the centre in a sustained way, including for physical infrastructure, communications systems, and for administrative and human resources (Ref: WMO/TD-No1534).

The process for designation (based on WMO/TD-No1534), generally involves:

- conducting a survey of the Members on needs and capabilities;
- conducting a pilot, or demonstration of RCC functions;
- evaluation by the WMO Regional Association of compliance with the WMO Technical Regulations;
- formal application by the President of the Regional Association to WMO for designation, with appropriate information and documentation;
- evaluation by the WMO Commission for Climatology (CCl) and relevant others (e.g. experts from designated RCCs and GPCs, noting that the joint CCl/CBS Expert Team on RCCs now coordinates and guides the establishment and operation of RCCs worldwide in close liaison with the concerned Regional Association); and
- a review of the application by WMO's Commission for Basic Systems (CBS).
- If successful up to this point, the candidate will be invited by CBS to present the proposal (in the form of an amendment to the Manual on the GDPFS) along with documentation demonstrating capabilities, to include the candidate as a WMO designated RCC or RCC-Network.
- If approved by Members of CBS, the amendment to the Manual will be put up to either WMO Congress or WMO Executive Council for approval.
- With this WMO approval, the Manual on the GDPFS will be duly amended. The designation process is completed when the RA and the candidate are advised in writing by WMO of its successful designation.

# Annex 7: WMO RCC Networks (as of November 2016)

**Current:**

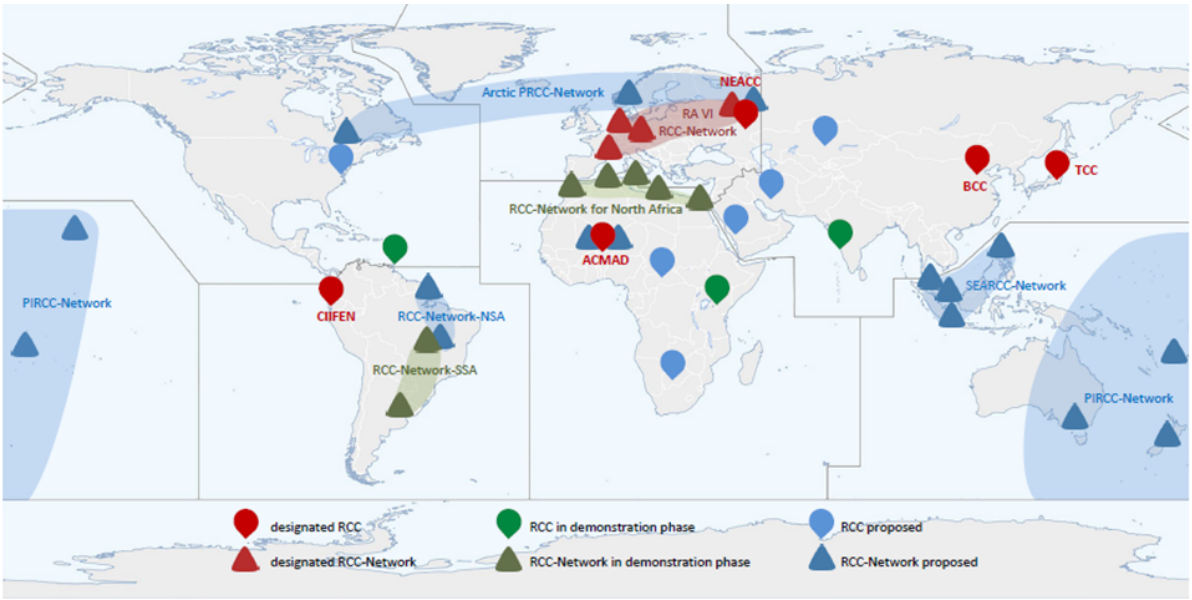
- The RA VI RCC network is designated and operational.
    - The RA VI RCC Network model is based on activity specialisation, with three Nodes (on climate data, on climate monitoring, and on long-range forecasting), with all three Nodes having integrated training activities. Together, these three Nodes meet all mandatory requirements for the RA VI RCC-Network.
    - There is one network coordinator, and also six consortium members that provide sub-regional or highly specialised RCC functions (both mandatory or highly-recommended). There is considerable cooperation and coordination amongst the contributing countries.
- The North Africa RCC-Network has completed its demonstration phase and is now applying for WMO designation.
    - The NA RCC-Network model is based on activity specialisation: Nodes on data services (lead: Algeria), climate monitoring (lead: Tunisia), LRF (lead: Morocco) and training (co-leads: Libya and Egypt), implemented in close collaboration with each Node being supported by all five countries.
- The Southern South America RCC-Network has completed its demonstration phase and is now applying for WMO designation.
        - The SSA RCC-Network model is co-led by Argentina (Buenos Aires Node) and Brazil (Brasilia Node) serving Southern South America (Argentina, Bolivia, Brazil, Chile, Paraguay, Uruguay), with seamlessly distributed responsibilities.

**Proposed:**

- the ECOWAS RCC-Network (West Africa);
- the Northern South America RCC-Network;
- the Pacific Islands RCC-Network (implementation meeting scheduled);
    - model of activity specialisation: Nodes on data services, climate monitoring, LRF, training and highly-recommended functions (Node leads and consortium members);
- the Southeast Asia RCC-Network (implementation meeting scheduled);
    - model of activity specialisation: Nodes on data services, climate monitoring and LRF (Node leads and consortium members);
- the Arctic Polar RCC-Network (implementation planning meeting was held 7-9 November 2016).

# Annex 8: Global RCC Implementation (as of November 2016)

- **RA I (Africa)**
  - 6 potential RCCs identified covering East, South, Central, West and North Africa (plus the continental scale),
  - ACMAD designated RCC-Africa in 2015,
  - East: ICPAC and North African RCC-Network - in demonstration phase - both candidates for designation
- **RA II (Asia)**
  - 3 RCCs designated; BCC and TCC in 2009, NEACC in 2013,
  - India started demonstration phase in 2013, - Candidate for designation
  - Iran, Saudi Arabia and Kazakhstan have formally expressed interest.
- **RA III (South America)**
  - 3 potential RCCs identified covering Western Coast of SA (WCSA), Northern SA, and Southern SA.
  - CIIFEN designated as RCC-WCSA in 2015
  - RCC-Network Southern SA in demonstration phase since 2014 – candidate for designation
- **RA IV (North America, Central America and the Caribbean)**
  - CIMH (Caribbean) started the demonstration phase in 2013 – candidate for designation
  - US RCC (USA and Central America) is in demonstration phase
- **RA V (Southwest Pacific)**
  - 2 RCC-Networks (South-East Asia and Pacific Island Countries) identified by RA V in 2014. Implementation consultations in progress
- **RA VI (Europe)**
  - RCC-Network designated in 2013 (3 Nodes: Data: De Bilt; Monitoring: Offenbach; LRF: Toulouse + Moscow)



# Annex 9: Regional Climate Outlook Forums

Background on WMO's Regional Climate Outlook Forums (RCOFs) can be found at:

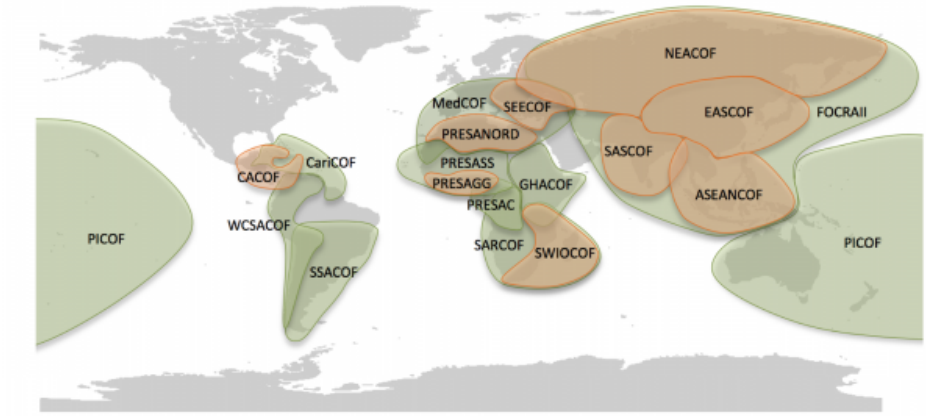
A WMO publication on RCOFs: Regional Climate Outlook Forums, WMO, 2016, in the form of a collection of fact sheets, can be found at: (enter 'Regional Climate Outlook Forums' in the search field). Extracts from this publication:

**'Concept:**
An RCOF is a platform that brings together national, regional and international climate experts and stakeholders' representatives from countries in a climatologically homogeneous area to provide consensus-based climate predictions based on input from NMHSs, regional institutions, WMO Regional Climate Centres (RCCs), Global Producing Centres for Long Range Forecasts (GPCLRFs) and other climate prediction centers. Through interaction with sectoral users, extension agencies and policymakers, RCOFs assess the likely implications of the outlooks on the most pertinent socio-economic sectors in a given region, and explore the ways in which use can be made of them.

RCOFs strengthen regional networking of the climate service providers and user-sector representatives. Participating countries recognize the potential of climate prediction and seasonal forecasting as a powerful development tool to help populations and decision-makers face the challenges posed by climatic variability and change. One of the important components of RCOFs is development of existing capacities of NMHSs in seasonal forecasting and communication of climate information to user community.'

**'Regional Climate Outlook Forums All Over the World:**
In different regions of the world, the RCOFs have evolved in different ways, based on specific needs and capabilities and tailored to meet the local conditions. Meanwhile, in all regions they constitute reliable and authentic sources of high-quality climate information, developed through a cooperative endeavour and on a sustainable basis.

In total, 19 RCOFs are regularly conducted in many parts of the world, serving mainly developing and least developed countries:




**ASEANCOF** Association of Southeast Asian Nations Climate Outlook Forum

**CACOF** Central American Climate Outlook Forum
**CariCOF** Caribbean Climate Outlook Forum
**EASCOF** East Asia winter Climate Outlook Forum
**FOCRAII** Forum on Regional Climate Monitoring, Assessment and Prediction for Regional Association II (Asia)
**GHACOF** Greater Horn of Africa Climate Outlook Forum
**MedCOF** Mediterranean Climate Outlook Forum
**NEACOF** North Eurasian Climate Outlook Forum
**PICOF** Pacific Islands Climate Outlook Forum
**ICU** Island Climate Update
**OCOF** Online Climate Outlook Forum
**Pacific ENSO Update** Pacific El Niño Southern Oscillation Update

**PRESAC** Prévisions Climatiques Saisonnières en Afrique Centrale
**PRESAGG** Prévisions Climatiques Saisonnières pour les pays du Golfe de Guinée
**PRESANORD** Prévisions Climatiques Saisonnières en Afrique du Nord
**PRESASS** Prévisions Climatiques Saisonnières en Afrique Soudano-Sahélienne
**SARCOF** Southern African Regional Climate Outlook Forum
**SASCOF** South Asian Climate Outlook Forum
**SEECOF** South-East European Climate Outlook Forum
**SSACOF** Southeast of South America Climate Outlook Forum
**SWIOCOF** South West Indian Ocean Climate Outlook Forum
**WCSACOF** Western Coast of South America Climate Outlook Forum’

# Annex 10: Timeline (2008-2017)

Significant events, activities and decisions relevant to implementation of an ArcRCC Network are identified in the following timeline:

**1995-2015**
**CLIPS (Climate Information and Prediction Services)**

Background on CLIPs can be found at:

Also see WMO Bulletin Vol. 64(1). 2015. Climate knowledge for climate action, pages 23-27: Climate Services - Transitioning from CLIPS to GFCS. G. Srinivasan et al., Available online at: (enter 'WMO Bulletin 2015 64(1) Climate knowledge for climate action' in the search field).

WMO's Climate Information and Prediction Services (CLIPS) project was implemented over 1995-2015. CLIPS was instrumental in the development of the concept of Regional Climate Centres (RCCs) and their formal establishment on a global scale. It also played a key role in the development of the Regional Climate Outlook Forums (RCOFs) that now serve as platforms for generating consensus-based seasonal climate outlooks. These initiatives, together with the CLIPS training workshops, have helped build capacities for climate services.

The present Global Framework for Climate Services (GFCS) with a vision "to enable society to better manage the risks and opportunities arising from climate variability and change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice" carries forward and builds on the solid foundation laid by CLIPS. So, while acknowledging the significant contributions made by CLIPS, the 2011 World Meteorological Congress endorsed closing CLIPS by 2015 and assimilating its activities into the emerging GFCS Climate Services Information System (CSIS), including relevant linkages with the GFCS User Interface Platform (UIP) component.

**2007-2008**
**International Polar Year (IPY)**

Krupnik, I., et al., Editors. 2011. Understanding Earth's Polar Challenges: International Polar Year 2007-2008. University of the Arctic, Rovaniemi, Finland/CCI Press (Printed version), Edmonton, Alberta, Canada and ICSU/WMO Joint Committee for International Polar Year 2007-2008.
ISBN 978-1-896445-55-7

Available online at: (under advanced search, enter 978-1-896445-55-7 in the search field for ISBN No.)

WMO was co-lead, along with ICSU; WMO decided to contribute to the IPY legacy.

**18-27 June 2008**
**Sixtieth session of WMO Executive Council (Geneva, Switzerland)**

WMO-No. 1032
Available online at: (enter 1032 in the search field)

The Executive Council noted that CCl and CBS experts were developing amendments to the CBS Manual on the Global Data-Processing and Forecasting System (WMO-No. 485), Volume 1 – Global Aspects, that would allow WMO

designation of Regional Climate Centres by the sixty-first session of the Executive Council in June 2009.

**8-11 September 2008**
**WMO-WCRP IPY Workshop on CLIPS in Polar Regions (St. Petersburg, Russian Federation)**

WMO-TD No. 1509
Available online at: (enter 1509 in the search field for WMO/TD No.)

Early initiatives to promote the CLIPS concept in Polar Regions, and to realize an opportunity for the NMHSs of its Members to contribute to the legacy of the ongoing IPY 2007-2008, were taken in 2008 at the WMO/WCRP/IPY Polar CLIPS Workshop. There, a Polar Climate Outlook Forum (PCOF), based on the successful Regional Climate Outlook Forum (RCOF) concept being promoted by WMO in many regions around the world, was identified as an effective mechanism to facilitate provision of climate information and sustained interaction between climate service providers and users/stakeholders within the Polar Regions, and to meet user needs for climate risk management in Polar Regions.

The scientific challenges of climate prediction in high latitude regions, and also the acute vulnerability of Polar Regions to climate variability and change, were recognized. The PCOF, would also be a contribution to the future WMO Global Cryosphere Watch (GCW).

**3-13 June 2009**
**Sixty-first session of the WMO Executive Council (Geneva, Switzerland)**
**WMO-No. 1042**

WMO-No. 1042
Available online at: (enter 1042 in the search field)

The Council noted the recent progress in the development of the amendments to the Manual on the Global Data-Processing and Forecasting System (GDPFS), Volume 1 (Global Aspects), thereby setting procedures for the establishment of WMO RCCs, and adopted Resolution 4 (EC-LXI) – Establishment of Regional Climate Centres.

This Resolution recognized the development of technical regulations, through the WMO CCl and CBS, and regional associations, to include a formal WMO mechanism for designation of Regional Climate Centres (RCCs) and decided that the establishment of RCCs and RCC networks shall be done in accordance with the Manual on the Global Data-Processing and Forecasting System, Volume 1 – Global Aspects. It requested the Secretary-General to publish procedures for establishment and designation of WMO Regional Climate Centres and RCC-Networks, and thus to lay down a well-defined process for the establishment and implementation of RCCs and RCC-Networks.

WMO-No. 485 is available online at: (enter 485 in the search field), or at:
WMO/TD-No. 1534 ('How to establish and run a WMO Regional Climate Centre (RCC)') is available online at: (enter 1534 in the search field for WMO/TD No.)

**31 August -4 September 2009**
**World Climate Conference-3 (WCC-3) (Geneva, Switzerland)**

Report of the World Climate Conference-3 - Better climate information for a better future: WMO/TD - No. 1048
Available online at: (enter 1048 in the search field)

The Conference Declaration noted the decision to establish a Global Framework for Climate Services (GFCS) to strengthen the production, availability, delivery and application of science-based climate prediction and services.

**2010-2011**

**High-level Taskforce towards the Global Framework for Climate Services (GFCS).**

**Climate knowledge for action.** Abu Zeid M.; Egeland J.; Chissano J.; et al. WMO-No. 1065. Available online at:  (enter 1065 in the search field)

The High-level Taskforce (HLT) on Global Framework for Climate Services (GFCS) began its work in January 2010. The HLT identified RCCs among the implementation priorities for the GFCS, and it recommended strengthening of existing RCCs and establishing new RCCs where there is a clear need. While RCCs are mostly designed to serve specific WMO Regional Associations (RAs), the HLT-GFCS also saw the need for RCCs straddling multiple RAs, and cited their potential coverage of Arctic and Antarctic regions as good examples.

**19-24 February 2010**

**Fifteenth session of the WMO Commission for Climatology (Antalya, Turkey)**

WMO-No. 1054.
Available online at:  (enter 1054 in the search field)

Members expressed an interest in working towards Regional Climate Centres (RCCs) for Polar Regions. Resolution 5 (CCl-XV) on 'Establishment and Operation of Regional Climate Centres worldwide' urged the WMO Secretary-General to promote a global coverage of RCCs/RCC Networks, and Regional Associations to make all possible efforts to accelerate their establishment.

On Monday 22 February 2010, in an informal session, experts from 15 countries discussed the concept of a Polar COF (a potential WMO contribution to the IPY Legacy). Challenges were identified including limited observations and limited skill in seasonal scale predictions at high latitudes.

**16 May to 3 June 2011**

**Sixteenth Session of the World Meteorological Congress (Geneva, Switzerland)**

WMO-No. 1077, Available online at:  (enter 1077 in the search field)

Congress adopted Resolution 17 (Cg-XVI) on implementing the Climate Services Information System (CSIS), in which it decided:

(1) To establish a Climate Services Information System with global, regional and national entities providing operational climate information, including data, monitoring and prediction products within the GFCS;
(2) To endorse the proposal made by the Commission for Climatology at its fifteenth session to effect the incorporation of CLIPS activities into the GFCS, and to conclude CLIPS as a project by 2015 at the latest;
(3) That CSIS operations shall adhere to the WMO Technical Regulations and should generate, as needed, new Technical Regulations pertinent to the advancement of operational climate services;
(4) That the implementation of CSIS should be guided by the Commission for Climatology;
(5) That the core operational CSIS products should be standardized in terms of production, presentation, delivery and verification;
(6) That CSIS will promote consensus-based approaches to facilitate common understanding and user appreciation of uncertainties through, inter alia, Climate Outlook Forums;

(7) That CSIS should be guided by the long-term vision of providing an authoritative source of climate information required for climate services at global, regional and national scales;

Members at Congress noted:

- the amendments to the Manual on the Global Data-processing and Forecasting System (GDPFS), Volume 1 (Global Aspects), as approved by EC-LXI, which established criteria for formal designation of WMO RCCs;
- the adoption of Resolution 4 (EC-LXI) on the Establishment of Regional Climate Centres, which provides further guidance on implementation and operation of RCCs, and the roles and responsibilities of the relevant entities;
- the document on "How to establish and run a WMO Regional Climate Centre (RCC)" (WCASP No. 80, WMO/TD-No. 1534, available in E/F/S), which clarifies the process for the establishment and implementation of RCCs and RCC-Networks, and the associated guidance for establishing and operating RCCs and RCC pilots:
- the need to establish standardized processes for development of RCC products including LRF, their presentation/style (appearance, formats, etc.), as well as delivery (including through web pages) to NMHSs and other relevant climate institutions in the region and their verification/assessment;
- that there are large areas cutting across the domains of regional associations with common climate information needs (e.g., Polar Regions, Mediterranean Region, Southeast Asia), and encouraged initiatives to develop such cross-regional RCCs;
- the recommendation of the EC Expert Panel on Polar Observations, Research and Services (EC-PORS) to define the scope of Arctic and Antarctic RCCs, noting their potential contribution to improve the quality, of climate products in these regions.

**6-8 June 2011**
**Sixty-third session of WMO Executive Council (Geneva, Switzerland)**

WMO-No. 1078,
Available online at: (enter 1078 in the search field)
Through Resolution 1 (EC-LXIII), a Task Team was set up to develop the draft GFCS Implementation Plan and suggest the governance structure.

**29-31 October 2012**
**Extraordinary Session of the World Meteorological Congress (Geneva, Switzerland)**

WMO-No. 1102.
Available online at: (enter 1102 in the search field)

In Resolution 2 (Cg-Ext.(2012)), Congress established the Intergovernmental Board on Climate Services (IBCS) and adopted the GFCS Implementation Plan. RCCs and RCOFs constitute key elements in the implementation of the GFCS, particularly in its Climate Services Information System (CSIS) pillar.

**15-23 May 2013**
**Sixty-fifth session of WMO Executive Council (Geneva, Switzerland)**

WMO-No. 1118.
Available online at: (enter 1118 in the search field)

EC agreed (item 4.3.23) that, through its Panel of Experts on Polar Observations, Research and Services (EC-PORS), the Global Cryosphere Watch (GCW), the Commission for Climatology (CCl), the Commission for Basic Systems (CBS) and the concerned Regional Associations should work in close cooperation to develop Polar RCCs (PRCCs) for both the Arctic and Antarctic regions, and to be engaged with the relevant priority projects of the Global Framework for Climate Services (GFCS) Implementation Plan.

**2013**

Environment and Climate Change Canada, Government of Canada funded a 'Programme of Implementation of Global Framework for Climate Services on Regional and National Scales', for the period 2013-2017. Key results include an improved climate service framework across the Arctic Polar Region, which will be achieved through the implementation of ArcRCC-Network.

**2013 – 2014**

The IPCC approved Climate Change 2013: The Physical Science Basis, the Working Group I contribution to AR5 in 2013. In 2014, the IPCC approved Climate Change 2014: Impacts Adaptation and Vulnerability and Climate Change 2014: Mitigation of Climate Change, the Working Group II and Working Group III contributions to AR5. The Fifth Assessment Report was completed in November 2014 with the Synthesis Report.

IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)].
Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.
Available at:

**IPCC**, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

**IPCC**, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 688 pp.
Available at:

Chapter 28 (Polar regions)
Larsen, J.N., O.A. Anisimov, A. Constable, A.B. Hollowed, N. Maynard, P. Prestrud, T.D. Prowse, and J.M.R. Stone, 2014: Polar regions. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1567-1612.

Available through:

**25-28 February 2014**
**Fifth session of EC-PORS (Wellington, New Zealand)**

Report is available at :

The Services Task Team (STT) took on responsibility for fostering the establishment of Polar RCCs for the Arctic, Antarctic and high mountain regions of the world and began consultations on an implementation strategy for PRCCs.

**3–8 July 2014**
**Sixteenth session of the WMO Commission for Climatology (Heidelberg, Germany)**

WMO-No. 1137.
Available online at:  (enter 1137 in the search field)

CCl Members noted (item 6.5) that a number of activities were initiated in the previous intersessional period to transition the Climate Information and Prediction Services (CLIPS) project into the GFCS, particularly with regard to Regional Climate Centres (RCCs) and Regional Climate Outlook Forums (RCOFs), and the associated national mechanisms. The Commission emphasized that several of these activities needed to be continued, including:
(a) Guidance on best operational practices in RCC implementation, seasonal prediction and consensus development approaches, particularly in RCOFs and national mechanisms to make optimal use of RCC and RCOF products;
(b) Standardized approaches to RCC/RCOF operations and expansion of the RCOF concept to new regions;
(c) Development of the Global Seasonal Climate Update (GSCU) for operational implementation and dissemination;
(d) Guidance on the implementation of the Climate Services Information System (CSIS) including the associated capacity development aspects and the development and dissemination of Climate Services Toolkit.

The Commission noted:

- the strengthened collaboration between CCl and CBS on operational climate prediction, through the joint CBS/CCl Expert Team on Operational Prediction on Sub-seasonal to Longer-time Scales (ET-OPSLS) and the CCl/CBS Expert Team on Regional Climate Centres (ET-RCCs).
- that the implementation of the GFCS Climate Services Information System (CSIS) offered excellent opportunities for transition of the CLIPS project activities (also work on climate watch and climate indices) into the GFCS as requested by Cg-XVI.

In conjunction with CCl-16, a Technical Conference on Climate Services – Building on CLIPS Legacy, was held from 30 June to 2 July 2014. The Conference agreed to address topical issues of direct relevance to climate risk management and adaptation, particularly to the GFCS, including several directly relevant to implementing an ArcRCC-Network:

- RCCs and RCOFs need to be further expanded and strengthened by introducing more systematic and objective procedures, including verification methods to enhance confidence. In view of the increasing demand for sub-seasonal information, the progress on seasonal to sub-seasonal prediction should be leveraged for operational services.
- Implement systems to channel recent research efforts enhancing the use of predictions at sub-seasonal and seasonal–to-interannual and decadal scales through operational systems put in place at global, regional and national levels for providing high quality climate services to stakeholders.

- In the process of developing products, stakeholders across the whole value chain need to be involved. This will make climate information valuable for decision- making by being specific and tailored.
- There is a need for more interdisciplinary work to better address specific needs in various sectors.

**February-March 2015**
**Survey of Members on needs and capacities for Polar RCC services**

As a part of the preparation for the Scoping Workshop (held in Nov 2015), a survey of Members on the needs and capacities for Polar RCC Services was initiated by the WMO Secretariat. The survey questionnaire was disseminated in February 2015 to the Permanent Representatives of 22 countries represented on the Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS), namely, Argentina, Australia, Canada Chile, China, Denmark, Finland, France, Germany, Iceland, India, Italy, Netherland, New Zealand, Norway, Republic of Korea, Russian Federation, South Africa, Switzerland, Sweden, United Kingdom of Great Britain, and the United States of America. Around 70% of surveyed (17 countries, including all the eight member states of the Arctic Council) provided responses, which shows the high interest of countries in regional polar activities.

The responses to this Survey provided a preliminary snapshot on the perspectives and expected contributions of the concerned countries, and prepared the ground for more specific discussions and negotiations around PRCC implementation. The following are the key outcomes of the survey, pertaining to the mandatory functions of WMO RCCs:

- More than three-quarters of the responding countries indicated their interest in contributing to the listed functions within the framework of a PRCC;
- More than two-thirds of the responding countries indicated that they require a PRCC to perform or coordinate the listed functions;
- More than two-thirds of the responding countries indicated that they provide services or carry out research to enable services addressing the listed functions for Polar regions.

Thus, the survey shows a clear indication by Members on requirements and the available capacities for, and strong interests to perform mandatory and also some of highly recommended functions, and to run an ArcRCC/Network.

**25 May to 12 June 2015**
**17th World Meteorological Congress (Geneva, Switzerland)**

WMO-No. 1157.
Available online at: (enter 1157 in the search field)

The Seventeenth World Meteorological Congress (Cg-17, 2015) agreed that Polar and High Mountain Regions become one of the seven WMO Priorities for the financial period 2016-2019, especially to “improve operational meteorological and hydrological monitoring, prediction and services in polar, high mountain regions and beyond”. Through the Resolution 40 (Cg-17), Congress decided that an integrated approach is needed to provide required services to users and advice to governments about adaptation and mitigation, based on an understanding of the global impact of changes in Polar and High Mountain Regions.

Under Resolution 60 (Cg-17) on the WMO Policy for the International Exchange of Climate Data and Products to Support the Implementation of the Global Framework for Climate Services, the World Meteorological Congress decided that 'the GFCS relevant data and products from the WMO WDCs, GPCLRFs, RCCs,

RCOFs and the ICSU WDS, as well as from the framework of the GCOS ECVs (Atmospheric, Oceanic and Terrestrial), will constitute an essential contribution to the Framework and therefore should be made accessible among Members, in particular through the GFCS CSIS, on a free and unrestricted basis'. The decision clarifies that “Free and unrestricted” means non-discriminatory and without charge, and that “Without charge”, in the context of Resolution 40 (Cg-XII) means at no more than the cost of reproduction and delivery, without charge for the data and products themselves.

**15-17 June 2015**
**Sixty-seventh session of WMO Executive Council (Geneva, Switzerland)**

WMO-No. 1158, Resolution 3 (EC-67)
Available online at: (enter 1158 in the search field)

In resolution 3 (EC-67) the WMO Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS) was re-established with an expanded responsibility, was charged with fostering the establishment of Polar Regional Climate Centres for the Arctic, Antarctic, and high mountain regions of the world. It was intended to adapt the WMO RCC and RCOF concepts to serve, for the first time, users at high latitudes. A polar RCC would be unique, in that it would cut across, and require cooperation at many levels involving, for example, three WMO Regional Associations (II, IV and VI, for Asia, North America and Europe, respectively) for the Arctic.

**17-19 November 2015**
**Scoping Workshop on Climate Services for Polar Regions (Geneva, Switzerland)**

There was a clear indication of interest and requirements for establishing an Arctic Polar RCC-Network; expression of national capabilities, expertise and commitment in producing relevant products and providing services; and initiation of potential mapping of national capabilities for populating the ArcRCC-Network.

**December 2015**

WMO requested detailed input from interested Members for proposed contributions to ArcRCC.

**Jan./Feb. 2016**

Members provided detailed information on potential contributions, using a template.

**June 2016**
**PRCC Concept Paper (v.2): "Development of a Polar Regional Climate Centre (PRCC): Towards an ArcRCC-Network"**

Available through:

Version 2 of the Concept Paper incorporated decisions from the Nov 2015 workshop.

**15-24 June 2016**
**Sixty-eighth session of WMO Executive Council (Geneva, Switzerland)**

WMO-No. 1168.
Available online at: (enter 1168 in the search field)

Having considered the recommendations of the Scoping Workshop on PRCCs, Members adopted Decision 52 (EC-68) on 'Polar Regional Climate Centres' in which EC:
**'Endorses** the ArcRCC Network as a joint initiative of Regional Associations II, IV and VI;
**Requests** EC-PHORS to review the technical details of potential contributions by Members to the ArcRCC Network vis-à-vis the designation requirements for Regional Climate Centres and guide the development of a draft implementation plan for the ArcRCC-Network in collaboration with CCl, CBS, and JCOMM as needed;
**Requests** the Secretary-General to facilitate a coordinated development of the draft implementation plan and to submit it to the Council for consideration at its sixty-ninth session, after endorsement of the stakeholders concerned;
**Requests** CCl to review and provide guidance for the demonstration phase of the ArcRCC-Network in close consultation with CBS, EC-PHORS and participating Members.'

**October 2016**

Member's potential contributions to ArcRCC were organized into contributions by function (for both mandatory and highly recommended functions).

**7-9 November 2016**
**Arctic Polar Regional Climate Centre (PRCC) Network Implementation Planning Meeting (Geneva, Switzerland)**

Progress towards defining ArcRCC structure and governance; technical and organizational arrangements; definition of initial products and services; and identification of next steps.

**November 2016 - January 2017**

Development (several iterations) of the Draft Implementation Plan for the ArcRCC-Network, including updated tables of contributions of the participating countries.

# Annex 11: Partners and technical assets

**Global Cryosphere Watch:**

The Global Cryosphere Watch (GCW) was initiated in 2007 with the mission to provide authoritative, understandable, and useable data, information, and analyses on the past, current and future state of the cryosphere to meet the needs of WMO Members and partners in delivering services to users, the media, public, decision and policy makers. Cg-17 decided to mainstream and implement GCW in WMO Programmes as a cross-cutting activity.

The cryosphere is a component of the Earth System that includes solid precipitation, snow cover, sea ice, lake and river ice, glaciers, ice caps, ice sheets, permafrost, and seasonally frozen ground. The cryosphere is global, existing not just in the Arctic, Antarctic and mountain regions, but at all latitudes and in approximately one hundred countries. The cryosphere provides some of the most useful indicators of climate change, yet is one the most under-sampled domains of the Earth System. Improved cryospheric monitoring and integration of that monitoring is essential to fully assess, predict, and adapt to climate variability and change.

There are at least 30 cryospheric properties that, ideally, would be measured. Many are measured at the surface, but spatial coverage is generally poor. Some have been measured for many years from space; the capability to measure others with satellites is developing. The major cryosphere elements and variables are:

- **Snow**: snow water equivalent (SWE), depth, extent, density, grain size, albedo
- **Solid Precipitation**: rate, snowfall amount
- **Lake and River Ice**: freezeup/breakup, thickness, snow on ice
- **Sea Ice**: extent, concentration, type (age), thickness, motion, temperature, snow on ice
- **Glaciers, Ice Caps, Ice sheets**: mass balance (accumulation/ablation), thickness, area, length (geometry), firn temperature, velocity, snowline/equilibrium line, icebergs, snow on ice
- **Frozen Ground/Permafrost**: soil temperature/thermal state, active layer thickness, borehole temperature, extent, snow cover

GCW is one of four components of WIGOS, and has three working groups (Observations, Integrated Products and Information and Services), each of which has teams working on various activities.

GCW is led by a Steering Group (GSG), which is comprised of experts – some are from EC-PHORS, relevant WMO Programmes, Technical Commissions and co-sponsored programmes, and some are from partners and contributors. EC-PHORS appoints the GSG chair and vice-chair and approves GSG membership. GCW works through EC-PHORS for making recommendations to WMO (for example, to propose amendments to the Technical Regulations).

GCW products, and the associated assessment of cryosphere products, would be a contribution to the PRCC effort.

**International Ice Charting Working Group (IICWG):** https://nsidc.org/noaa/iicwg

The International Ice Charting Working Group (IICWG) was founded in 1999 to promote cooperation between the world's ice centers on all matters concerning sea ice and icebergs. It is a technical forum of the national Ice Services with interests in both Northern and Southern hemispheres. Its work is described in a Charter (signed in 2007) (the charter can be found at:  ).

***Mission:***
The IICWG was formed as an ad-hoc working group of northern hemisphere national ice services primarily for the purpose of exchanging information and ideas to help one another better serve their clients. The preamble to the Terms of Reference adopted at the very first meeting in 1999 clearly and succinctly defines why the IICWG exists and what it does:

> “Recognizing the ongoing interest of the nations influenced by ice covered seas in the use and protection of these seas; and further recognizing the value and economics of cooperative activities in operational ice services supporting maritime
> navigation; the ice charting nations of the world hereby form the International Ice Charting Working Group.
>
> “The International Ice Charting Working Group provides a forum for coordination of ice matters, including icebergs, acts as an advisory body for the relevant international sea organizations and programs, in particular, WMO/IOC JCOMM, CLiC, GCOS and IHO, and offers non-binding recommendations to senior

management as appropriate …"

***Terms of Reference and structure:***
The IICWG Terms of Reference (Chapter 1 of the Charter) cover Data and Product Exchange; Terminology, Data, and Mapping Standards; Operations and Customer Support; Training; Technology for Analysis and Forecasting; and Applied Science, Research, and Development. The Group has 2 Standing Committees (on Data, Information, and Customer Support; and Applied Science and Research); and one sub-committee on Icebergs.

The IICWG works in collaboration with JCOMM, and reports to WMO bodies including EC-PHORS, GCW, and the ArcRCC-Network in development. It has strong linkages an feedback with satellite operators and customers at sea, both federal and commercial.

The IICWG meets annually in October (its 17th meeting was in Ottawa, 26-30/10/2016, hosted by the Canadian Ice Service).

The participating agencies of the IICWG can be found at:

Additional background can be found in 'The IICWG - An Historical Perspective After 13 Years' (PDF 1.1 MB, Oct. 2013), available at:

From that historical perspective: 'Of central importance in defining the IICWG's mission is the notion that it is concerned primarily with "operational ice services supporting maritime navigation". While research activities and climatological investigations are critical components of an ice service, they are not the main focus of the IICWG. The IICWG founders felt that these peripheral aspects were adequately addressed in other fora.'

**GIPPS:**

WMO Members, at the 15th World Meteorological Congress in 2011 (see para 11.9.5, WMO No. 1077), 'noted with interest the decadal initiative to develop a ***Global Integrated Polar Prediction System (GIPPS)***, capable of providing information to meet user needs for decision making on timescales from hours to centuries. It noted the global benefits of such a system in 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, contributing to all WMO high priorities, in particular Disaster Risk Reduction, and the Global Framework for Climate Services (GFCS). Congress agreed to embark on a multi-year endeavour towards GIPPS, as an IPY Legacy to benefit the global community. It also agreed that GIPPS shall engage regional associations, technical commissions, and relevant international organizations and academic research communities in the development of such a system. Noting the Concept Paper on GIPPS (see Annex XIII to the present report) and recognizing the importance of this initiative, Congress adopted Resolution 57 (Cg-XVI) – Global Integrated Polar Prediction System.'

As per the Concept Note: Members saw GIPPS as becoming a foundation of delivering the WMO's substantial contribution to "*the protection of life and property against natural disasters, to 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 transport*3", as being service driven (meeting user requirements), accurately predicting the future state of the atmosphere, ocean, and hydrosphere/cryosphere for high northern and southern latitudes, particularly where prediction systems that are tuned for lower

latitudes are less robust; and that it be supported by appropriate observational systems and enabling scientific research and development. Benefits that will flow from a polar prediction system include: Improved services to key users, including those involved in transportation, logistics and planning, biological and energy resource management, water resources, tourism, marine and aviation activities and Disaster Risk Reduction (DRR); Improved understanding of key physical process that drive the polar weather and climate system and to diagnose the benefits of particular observational technologies and approaches; and Providing input to global models to ensure that polar processes and teleconnections are effectively captured.

In addition to typical synoptic variables, a Polar Prediction System should focus on specialized variables, such as sea ice, permafrost, polar clouds, ice sheet mass balance, and snow cover.

The Concept Note stated that the proposed development of cross-regional Polar Regional Climate Centres (RCCs) and Polar Climate Outlook Forums (PCOFs) would be very useful for addressing services in the Polar Regions.

Congress (para 11.9.6) urged the Executive Council to develop a comprehensive description of the global community's polar service requirements and articulate the value to be delivered, and through mechanisms such as Polar Regional Climate Centres and Polar Climate Outlook Forums contribute to GFCS and the GIPPS. In Resolution 57 (Cg-XVI) on the GLOBAL INTEGRATED POLAR PREDICTION SYSTEM, members decided: (1) To embark on a decadal endeavour towards a Global Integrated Polar Prediction System (GIPPS), as an IPY Legacy to benefit the global community; (2) That GIPPS should provide information to meet user needs for decision-making on timescales from hours to centuries.

***GIPPS: Polar Prediction Project (PPP) and the Year of Polar Prediction (YOPP)***

Background on the PPP can be found at:  . Its mission is to "promote cooperative international research enabling development of improved weather and environmental prediction services for the polar regions, on time scales from hours to seasonal".

The PPP is described also in the WWRP Polar Prediction Project Implementation Plan for the Year of Polar Prediction (YOPP), WWRP/PPP No. 4 – 2016.  Its goal is to 'enable a significant improvement in environmental prediction capabilities for the polar regions and beyond, by coordinating a period of intensive observing, modelling, prediction, verification, user-engagement and education activities'.

With a focus on time scales from hours to a season, YOPP is a major initiative of the World Meteorological Organization's World Weather Research Programme (WWRP) and a key component of the Polar Prediction Project (PPP). YOPP is being planned and coordinated by the PPP Steering Group together with representatives from partners and other initiatives, including the World Climate Research Programme's Polar Climate Predictability Initiative (PCPI).

The objectives of YOPP are to:
1. Improve the existing **polar observing system** (enhanced coverage, higher-quality observations).
2. Gather **additional observations** through field programmes aimed at improving understanding of key polar processes.
3. Develop improved representation of **key polar processes** in (un)coupled models used for prediction.
4. Develop improved (coupled) **data assimilation systems** accounting for challenges in the polar regions such as sparseness of observational data.
5. Explore the **predictability** of the atmosphere-cryosphere-ocean system, with a focus on sea ice, on time scales from hours to a season.

6. Improve understanding of **linkages** between polar regions and lower latitudes, assess skill of models representing these linkages, and determine the impact of improved polar prediction on forecast skill in lower latitudes.
7. Improve **verification** of polar weather and environmental predictions to obtain better quantitative knowledge on model performance, and on the skill, especially for user relevant parameters.
8. Identify various stakeholders and establish their **decision making needs** with respect to weather, climate, ice, and related environmental services.
9. Assess the **costs and benefits** of using predictive information for a spectrum of users and services.
10. Provide **training opportunities** to generate a sound knowledge base (and its transfer across generations) on polar prediction related issues.

YOPP is implemented in three distinct phases. During the YOPP Preparation Phase (2013 through to mid-2017) this Implementation Plan was developed, which includes key outcomes of consultations with partners at the YOPP Summit in July 2015. Plans will be further developed and refined through focused international workshops. There will be engagement with stakeholders and arrangement of funding, coordination of observations and modelling activities, and preparatory research. During the YOPP Core Phase (mid-2017 to mid-2019), four elements will be staged: intensive observing periods for both hemispheres, a complementary intensive modelling and prediction period, a period of enhanced monitoring of forecast use in decision making including verification, and a special educational effort. Finally, during the YOPP Consolidation Phase (mid-2019 to 2022) the legacy of data, science and publications will be organized.

### *GIPPS: Polar Climate Predictability Initiative*

Background information on the Polar Climate Predictability Initiative (PCPI) can be found at: . The PCPI is an initiative of the World Climate Research Programme (WCRP), whose goal is to improve the understanding of the predictability of climate and the effect of human activities on climate. The PCPI has a focus on polar regions and their role in the global climate system, and aims to improve predictability of the climate system on all time scales by improving our understanding of the underlying physical mechanisms and their representation in climate models.

The PCPI will accomplish this task by co-ordinating the efforts of the international science community, bringing together the different elements of the WCRP, and working closely with other international agencies such as the World Weather Research Programme's Polar Prediction Project (WWRP - PPP). The focus here is not on prediction of the climate system, but instead on finding elements of the climate system that contribute to predictability, and how these processes may be improved in models.

The PCPI complements existing efforts by bringing together expertise on the modelling aspects of the climate. It is an initiative of the WCRP under the Grand Challenge "Cryosphere in a Changing Climate".

The PCPI is addressing the seasonal to multi-decadal component of the GIPPS (Globally Integrated Polar Prediction System) of the World Meteorological Organization, in close co-ordination with the WWRP PPP (World Weather Research Programme - Polar Prediction Project), which is addressing the shorter time scales. The unique role of the WCRP in polar climate science is to bring the global perspective and strength in global modelling.

# Annex 12: Stakeholders

***The Arctic Council and AMAP***

The Arctic Council is a high-level intergovernmental forum which promotes cooperation among Arctic States on common Arctic issues including the environment and sustainable development. The Arctic Council includes formal outreach mechanisms with nationally recognized indigenous groups beginning with the six Permanent Participants to the Arctic Council. The policy framework for the Arctic under the Arctic Council will influence the decisions on a PRCC that encompasses three WMO regions and has global reach. The ArcRCC-Network will need to consider the decisions of the Arctic Science Cooperation Task Force while addressing the Arctic's unique environment and community service needs and the Council's governance framework.

The Arctic Council's Arctic Monitoring and Assessment Programme (AMAP) provides reliable and sufficient information on the status of, and threats to, the Arctic environment, and provides scientific advice on actions to be taken in order to support Arctic governments in their efforts to take remedial and preventive actions relating to contaminants. The AMAP Working Group makes link between science and policy; it may also link with operational activities. AMAP has produced key assessment reports and have key working groups: see

***UNESCO:***

World Heritage and the Arctic:

***UNESCO. 2009.*** *Climate Change and Arctic Sustainable Development: scientific, social, cultural and educational challenges. UNESCO: Paris, 376 pp. ()*

*().*

***UNEP***

GRID Arendal's Polar and Cryosphere Division:

PROVIA reports including Research Priorities on Vulnerability, Impacts and Adaptation:

***WHO***

(TBD)

***UNWTO***

Tourism in the very north:

***COPERNICUS:*** Fostering the uptake of COPERNICUA and space applications:

***EUPORIAS:***

The GFCS Climate User Interface Platform developed by EUPORIAS:

# Annex 13: Technical and administrative roles and responsibilities

The following suggestions for the roles and responsibilities of the Lead Institution, the Node leads and the Consortium members are non-binding, and serve as guidance only.

Establishment of a steering committee (see section 5 of the IP) would provide additional guidance and support in the conduct of pan-Arctic and other responsibilities.

1. The **lead institution** would have the following responsibilities for the ArcRCC:
    a. Technical
        - The lead organization may have technical/operational roles and responsibilities, if it also undertakes to be a PRCC Node (see item 2 below);
        - Hosting the single point-of-entry website/portal through which RCC products and services will be made available;

    b. Administrative and coordination
        - Managing the relationship with WMO and relevant partners (e.g. GCW, IICWG, AC, etc.) and their constituent bodies (e.g. the RAs, CBS, CCl, etc.); handling correspondence, requests for updates and inputs, receiving and responding to requests from member countries and users, managing the feedback process;
        - Facilitating the relationship of PRCC with all GPCs and with the global set of RCCs and RCC-Networks;
        - Coordination across all Nodes and cross-node activities (e.g. pan-Arctic Climate Watch, LRF, etc.) to ensure development and delivery of seamless, reliable and high-quality products and services for the pan-Arctic region including provision of LRF using an MME approach with products of relevance for the whole Arctic (e.g., sea ice));
        - Organising meetings as needed on coordination and technical matters;
        - Ensuring the sharing of data and product across the geographical Nodes, to ensure development of pan-Arctic products as needed;
        - Promoting the establishment and sustained operation of regular RCOF activities and promoting national COFs (NB: hosting COFs is not mandatory for RCC designation, but COFs are very useful, e.g. for capacity development of scientists and for interaction with users);
        - Providing oversight and guidance on PRCC outreach efforts;
        - Promoting WIS compliance in all PRCC activities, and fostering the role of the geographical Nodes to become WIS DCPCs;
        - Providing oversight on adherence to WMO principles on the exchange of data and products;
        - Etc.

2. Each **Node** would have the following responsibilities for the ArcRCC:
    a. Technical
        - Each Node would undertake **all** mandatory RCC functions for its geographic domain and would undertake a number of highly recommended or other functions as required for the geographical domain of the Node (i.e. each Node would be, in effect, a multi-functional RCC for its sub-region). As many functions with pan-Arctic applicability as possible are encouraged. NB: It is not required that an RCC have the capability to develop/conduct LRF, but it must be able to interpret, assess LRF products and disseminate to and get feedback from its users.
        - Contributing data, methodology and expertise for development and provision of seamless pan-Arctic products and services.
        - Hosting a web site/portal pertinent to and in the language(s) of the geographic domain for RCC products.
    b. Administrative and coordination

- Managing the relationship with the lead PRCC agency in terms of responding to requests for input and services, providing and responding to feedback;
- Contributing to problem solving and coordination of the PRCC as a whole;
- Participating in and conducting meetings on cooperation, outreach, and on technical matters;
- Promoting regular RCOFs for the geographic domain and promoting national COFs;
- Establish a Climate Watch System for the geographic domain and participate in the pan-arctic climate watch system;
- Ensuring WIS compliance of the Node, and seeking the status of WIS DCPC;
- Adhering to WMO principles for the exchange of data and products;
- Arrange for/coordinate activities to establish the financial and human resources necessary to meet any PRCC requirements not otherwise covered through ongoing national or institutional mandates;
- Etc.

*3.* Each **Consortium Member** would have the following responsibilities for the ArcRCC:

a. Technical
   - Accessing, tailoring and applying the products developed through PRCC activities and ensuring their provision to national user communities through website and other means as required;
   - Contributing data, methodology and expertise for development and provision of seamless pan-Arctic products and services;

b. Administrative and coordination
   - Supporting the PRCC system as requested by the Nodes and lead centre (requests for input, feedback, data, product, expertise, etc);
   - Supporting implementation of national and sub-national COFs;
   - Adhering to WMO principles for the exchange of data and products;
   - Conduct national networking with potential contributors to the RCC activities (e.g. academic institutions, other government agencies, etc) to seek sources of data and products;
   - Conduct national networking with user communities to ensure effective dissemination of climate information and collection of (and response to) their feedback;
   - Dedicate the human and financial resources to any new work that would be required to fulfil the RCC responsibilities and to ensure the PRCC is effective and meets the WMO standards for designation.
   - Etc.

## Annex 14: Abbreviations and Acronyms

| | |
|---|---|
| AARI | Arctic and Antarctic Research Institute |
| AMAP | Arctic Monitoring and Assessment Programme |
| AR5 | The IPCC 5$^{th}$ Assessment Report |
| CBS | (WMO) Commission for Basic Systems |

| | |
|---|---|
| CCl | (WMO) Commission for Climatology |
| Cg | World Meteorological Congress |
| COF | Climate Outlook Forum |
| CLIPS | Climate Information and Prediction Services |
| CRU | Climatic Research Unit, University of East Anglia |
| DCPC | (WIS) Data Collection or Production Centre |
| DMI | Danish Meteorological Institute |
| EC | (WMO) Executive Council |
| ECCC | Environment and Climate Change Canada |
| EC-PHORS | (WMO) Executive Council Panel of Experts on Polar and High-mountain Observations, Research and Services |
| ECMWF | European Centre for Medium-range Weather Forecasts |
| ECV | Essential Climate Variable |
| FMI | Finnish Meteorological Institute |
| GCOS | Global Climate Observing System |
| GCW | Global Cryosphere Watch |
| GDPFS | (WMO) Global Data Processing and Forecasting System |
| GFCS | Global Framework for Climate Services |
| GIPPS | Global Integrated Polar Prediction System |
| GISC | (WIS) Global Information System Centre |
| GPC | (WMO) Global Producing Centre (of long-range forecasts) |
| GPCLRF | Global Producing Centre for Long-Range Forecasts |
| GPCC | Global Precipitation Climatology Centre |
| GRDC | Global Runoff Data Centre |
| ICSU | International Council for Science |
| IICWG | International Ice Charting Working Group |
| IMO | Icelandic Meteorological Office |
| IOC | International Oceanographic Commission (of UNESCO) |
| IPCC | Intergovernmental Panel on Climate Change |
| IPPI | International Polar Partnership Initiative |
| IPY | International Polar Year |
| JCOMM | Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology |
| LC-LRFMME | (WMO) Lead Centre for LRF Multi-Model Ensembles (associated with WMO GPCs) |
| LC-SVSLRF | (WMO) Lead Centre for WMO’s Standard Verification Scheme for LRF (Associated with WMO GPCs) |
| LRF | Long-range Forecast |
| MGO | Main Geophysical Observatory |
| NCEP | National Centers for Environmental Prediction |

| | |
|---|---|
| NESDIS | National Environmental Satellite, Data, and Information Service |
| NMHS | National Meteorological and Hydrological Service |
| NMI | Norwegian Meteorological Institute |
| NMS | National Meteorological Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NSIDC | National Snow and Ice Data Center |
| NWS | National Weather Service |
| P | Precipitation |
| P | President (e.g. of a WMO Regional Association, or a WMO Technical Commission) |
| PARCOF | Pan-ARctic Climate Outlook Forum |
| PPP | Polar Prediction Project |
| PR | Permanent Representative |
| PRCC | Polar Regional Climate Centre |
| QA/QC | Quality Assurance/Quality Control |
| RA | Regional Association |
| RCC | Regional Climate Centre |
| RCOF | Regional Climate Outlook Forum |
| RHMC | Hydrometeorological Centre of the Russian Federation |
| RIHMI-WDC | Russian Institute for Hydrometeorological information – World Data Center |
| SG | (WMO) Secretary-General |
| SMHI | Swedish Meteorological and Hydrological Institute |
| STT | Services Task Team (of EC-PHORS) |
| T | Temperature |
| TK | Traditional Knowledge |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNEP | United Nations Environment Programme |
| UNWTO | World Tourism Organization |
| WCRP | World Climate Research Programme |
| WDC | World Data Centre |
| WG | Working Group |
| WHO | World Health Organization |
| WIGOS | WMO Integrated Global Observing System |
| WIS | WMO Information System |
| WMO | World Meteorological Organization |
| WWRP | World Weather Research Programme |
| YOPP | Year of Polar Prediction |

## Annex 15: List of Contact Persons for ArcRCC-Network

**Canada:**

Mr John Parker
Marine and Ice Services Division / Canadian Ice Service
Environment and Climate Change Canada
Tel: +1 902 426 3256
Email: john.parker2@canada.ca

**Denmark:** **Mr Martin Stendel**
Danish Meteorological Institute
Tel: +45 3915 7500
Email: mas@dmi.dk

**Finland:** **(Ms Johanna Ekman /) Ms Andrea Vajda**
Finnish Meteorological Institute
Tel: +358 400 291 066
Email:

**France:** **Mr Jean-Michel Soubeyroux**
Direction de la Climatologie et des Services Climatique
Meteo France
Tel: +33 561 078 300;
Email:

**Germany:** **Mr Stefan Rösner**
Deutcher Wetterdienst
Tel: + 49 69 8062 4306
Email:

**Iceland:** **Mr Halldór Björnsson**
Icelandic Meteorological Office
Tel: +354-522-6000
Email: halldor@vedur.is

**Russian Federation:** **Mr Vasiliy Smolyaninsky**
Arctic and Antarctic Research Institute
Tel: +7 812 337 3149
Email:

**UK:** **Mr Richard Graham**
Met Office
Tel: +441 392 886 361
Email:

**The Netherlands:** **Mr Marion Borgers-Pettinga**
Royal Netherlands Meteorological Institute
Tel: +31 30 220 63 26
Email:

**Norway:** **Dr Eivind Støylen**
Norwegian Meteorological Institute
Tel: +47 402 43 404
Email:
Mr Helge Tangen (PRCC Coordinator)

Norwegian Meteorological Institute
Tel: +47 905 19 798
Email: helget@met.no

**Sweden:** **Mr Marcus Flarup**
Swedish Meteorological and Hydrological Institute
Tel: +46 11 495 8277
Email: marcus.flarup@smhi.se

**USA:** **Ms Shanna Pitter**
National Weather Service
International Affairs Office
Tel: +1 301 427 9066
Email:

**IICWG:** TBD

**GIPPS:** TBD

**Global Cryosphere Watch**: **Ms Rodica Nitu**
Project Manager (GCW)
Observing Systems Division
World Meteorological Organization
Tel: +41 22 730 8482
Email:

**WMO Secretariat:** **Mr Rupa Kumar Kolli**
Chief, World Climate Applications & Services Division
World Meteorological Organization
Tel: +41 22 730 8377
Email:

# Appendix 1: Potential Contributions of Data, Products and Services to the Arctic-PRCC-Network Mandatory Functions

1. **Operational Activities for Long Range Forecasts (LRF)**
   1.1 Overview of datasets, products, services offered
   1.2 Short dataset/product/service description
   1.3 Task descriptions

2. **Operational Activities for Climate Monitoring (CM)**
   2.1 Overview of datasets, products, services offered
   2.2 Short dataset/product/service description
   2.3 Task descriptions

3. **Operational Data Services (DS) to Support Operational LRF and CM**
   3.1 Overview of datasets, products, services offered
   3.2 Short dataset/product/service description
   3.3 Task descriptions

4. **Training (T) in the Use of Operational RCC Products and Services**
   4.1 Overview of datasets, products, services offered
   4.2 Short dataset/product/service description
   4.3 Task descriptions

# Appendix 2: Potential Contributions of Data, Products and Services to the Arctic-PRCC-Network Highly Recommended Functions

1. **Climate Prediction and Climate Projection**
   1.1 Overview of datasets, products, services offered
   1.2 Short dataset/product/service description
   1.3 Task descriptions

2. **Non-operational Data Services**
   2.1 Overview of datasets, products, services offered
   2.2 Short dataset/product/service description
   2.3 Task descriptions

3. **Coordination Functions**
   3.1 Overview of datasets, products, services offered
   3.2 Short dataset/product/service description
   3.3 Task descriptions

4. **Training and Capacity Building**
   4.1 Overview of datasets, products, services offered
   4.2 Short dataset/product/service description
   4.3 Task descriptions

5. **Research and Development**
   5.1 Overview of datasets, products, services offered
   5.2 Short dataset/product/service description
   5.3 Task descriptions

6. **Other**
   6.1 Overview of datasets, products, services offered
   6.2 Short dataset/product/service description
   6.3 Task descriptions