



# **Cryosphere and Climate The Arctic Challenge**

**Climate Change and Arctic Sustainable Development:  
scientific, social, cultural and educational challenges**

**UNESCO International Experts Meeting**

**Barry Goodison, Visiting Expert,  
World Meteorological Organization, Geneva**



The **cryosphere** collectively describes elements of the earth system containing **water in its frozen state** and includes:

**sea ice, lake and river ice, snow cover, solid precipitation, glaciers, ice caps, ice sheets, ice shelves, permafrost and seasonally frozen ground.**

The **cryosphere exists at all latitudes and in about one hundred countries.**



- is undergoing dramatic changes
- is one of the most under-sampled elements within the climate system

**GCW includes all components of the cryosphere, globally, regionally, nationally**



**Inuit say spring in the Arctic is becoming more dangerous**



# **Media and Policy Perspectives**

## **Socio-economic Impacts**

**Observing, Monitoring, Understanding, Prediction**



**No turning back on arctic warming**



**Warning for the North; Polar bears could face extinction as global climate change warms the Arctic**

**Melting Ice sheets, glaciers and global sea level rise**



**Thawing permafrost, GHG emission and coastal erosion**



**Farmers worried about absence of snow**

**Tourism at risk**



**Disappearing Glaciers Menace Water Supplies**



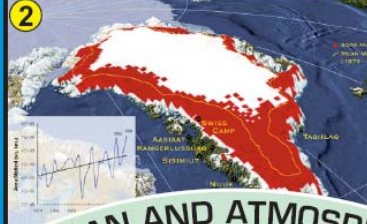
**Roof collapses, Basmany Market, Moscow**

**Floods feared as glaciers melt**

**SNOW COVER**  
Melting and retreating increases radiation absorption; a radiative feedback. Also large impacts on snow-based wildlife



**ICE SHEET**  
Melting of large ice sheets contributes to sea level rise and freshwater flux with potential effects on thermohaline circulation and global climate



**SEA ICE**  
Retreating sea ice contributes to increased radiative absorption and the loss of habitat for mammals such as polar bears and seals

**GLACIERS/ICE CAPS**  
Retreating glaciers initially increase runoff but lower flows eventually result as ice masses diminish. Impact example: reduced fish habitat and water supply



**RIVER ICE**  
Changes in magnitude/timing of snowmelt runoff and river-ice processes modify ice-jam flooding with related positive (e.g., aquatic recharge) and negative (infrastructure damage) impacts



**LAKE ICE**  
Shrinking ice cover produces numerous ecological impacts generally leading to greater productivity but can also affect surface transport



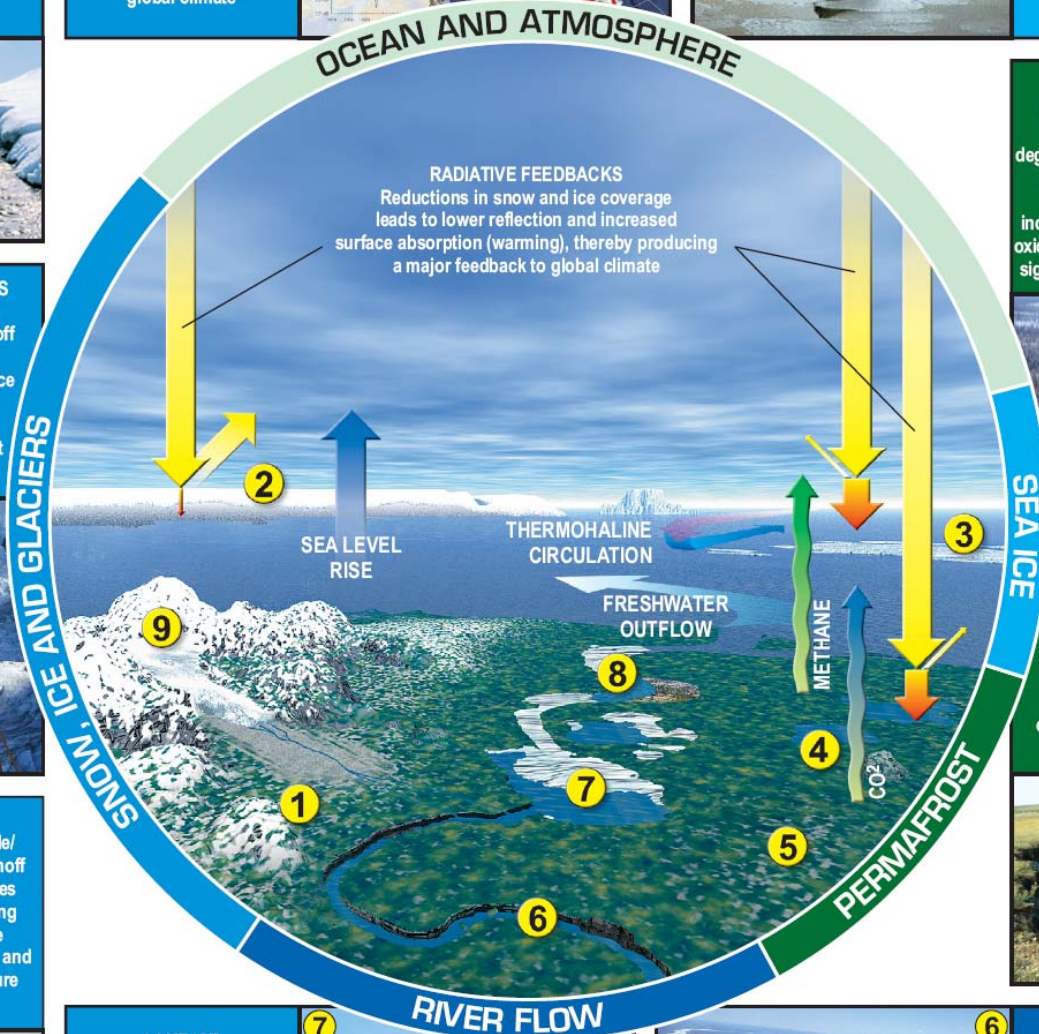
**TRACE GASES**  
With enhanced surface ponding as permafrost degrades, methane production increases. With wetland drying, CO<sub>2</sub> emissions increase as organic materials oxidize. Both processes can be significant climate feedbacks.



**PERMAFROST**  
Thawing permafrost changes geomorphic/geochemical processes and fluxes. Impact example: changes to flow systems and aquatic ecology



**RIVER FLOW**  
Increasing precipitation plus melting snow & ice increases arctic river flow although summer flows may decrease with enhanced evaporation. Changes in freshwater flux may affect thermohaline circulation and global climate



# Gaps in Cryospheric Knowledge: recent contributions

**Gaps in our knowledge** on cryosphere-climate interactions and the **impacts** of the changing cryosphere on physical and socio-economic systems have been identified in recent years through national and international initiatives.

- Science Plans or Assessments
  - WCRP's CliC Project,
  - Arctic Climate Impact Assessment (ACIA),
  - International Conference on Arctic Research Planning (ICARPII),
  - UNEP's Global Outlook for Snow and Ice,
  - IPCC WG1 chapter on Observations: Changes in Snow, Ice and Frozen Ground, and
  - Arctic Council's SWIPA initiative,
- **all articulate scientific gaps in knowledge and identify needed actions.**
- IGOS Cryosphere Theme and SAON focus on **observational gaps and needs**, complementing the reports noted above
- The most recent, ambitious collaborative initiative addressing many of the gaps in our knowledge has come through the **International Polar Year 2007-2008 (IPY)** projects.

**\*\*\*\*\**TIME FOR ONGOING ACTION*\*\*\*\*\***

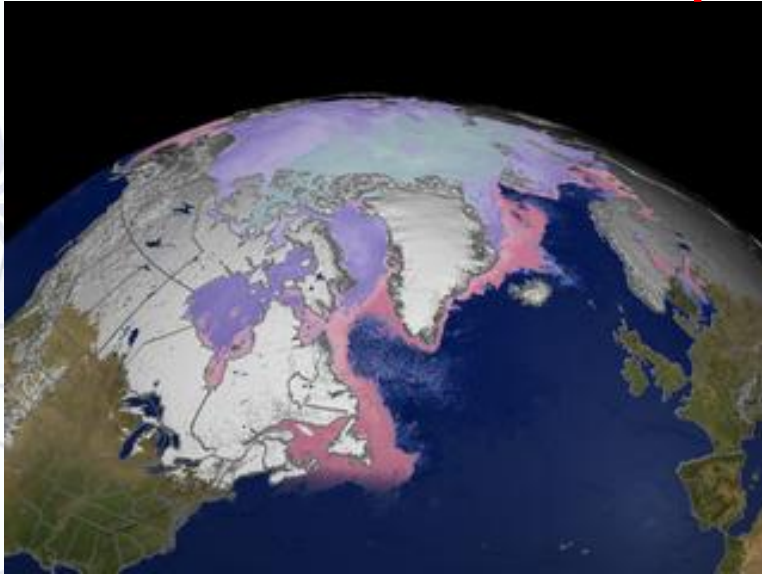
Sub-Committee on IPY Observations has developed a draft **roadmap towards IPY observing systems legacy**.

## Main observing initiatives contributing to the creation of an IPY Legacy

- Sustaining Arctic Observing Networks (**SAON**), with an Integrated Arctic Ocean Observing System (iAOOS), Arctic-HYCOS, and *Integrated AON*
- Pan-Antarctic Observing System (PAntOS), with a Southern Ocean Observing System (**SOOS**),
- The Global Cryosphere Watch (**GCW**),
- Polar Satellite Constellation (**PCS**),
- Polar Regional Climate Outlook Forum (**PCOF**)

# Global Cryosphere Watch- A WMO Initiative

research, observation, monitoring, assessment, product development and prediction



*“The 15th WMO Congress (May 2007) welcomed the proposal of Canada that WMO will create a **Global Cryosphere Watch** which would be an important component of the **IPY legacy**. Congress requested the WMO Inter-commission Task Group on IPY to establish an ad-hoc expert group to explore the possibility of creation of such global system and prepare recommendations for its development.”*

*A Legacy of CliC in the area of observations*

*A Component of the WMO Integrated Global Observing System*



# ***Global Cryosphere Watch: Confirmation of Concept***

- **GCW will contribute to WMO's integrated global observing and information systems WIGOS and WIS) and to the Global Climate Observing System (GCOS) network (as the Global Atmospheric Watch (GAW) does).**
- **There is strong community desire to establish a network of stations, CryoNET, working on a coherent agreed program monitoring changes in all components of the cryosphere, producing valuable long-term records, covering key areas of the globe with cryospheric observations.**
- **GCW will work with, and build on, existing programs** such as the GTN-G, GTN-P, GTN-H, and work with external partners such as space agencies and World Data Centers.
- **GCW will contribute to GEOSS** through the implementation of CryOS and as an IPY Legacy for observation, monitoring and provision of data and information.
- **GCW is not seen to be a data archive, but would link to associated data centres**
- **GCW will need a one-stop portal for authoritative up-to-date cryosphere data and products/information**, helping existing elements to be better integrated and contributing to a global data system.



# Moving GCW Forward: Some Basic Principles and Characteristics

To meet the need for a comprehensive, coordinated and sustainable global cryosphere observing system which integrates diverse space- and surface-based observing systems:

- GCW will be a focus for **implementing IGOS Cryosphere Theme (CryOS)** and will **build on the work already being done by the cryosphere community**. **Strong cooperation** is therefore needed among all partners to establish a functional Global Cryosphere Watch.
- The concept of GCW is based on the premise that **agreed-upon standards and recommended practices and procedures will apply to the cryospheric observing systems**. Where these do not currently exist, GCW would work with WMO and partners to develop appropriate best practices. This should include **homogeneity, interoperability, and compatibility of observations** from all GCW constituent observing and monitoring systems.
- **GCW will respect partnership, ownership and data-sharing policies** of all observing components and partner organizations
- **GCW should have** an organizational, programmatic, procedural and governance **structure** that will significantly improve the availability of, and access to, authoritative cryospheric information.
- **Targeted pilot and demonstration projects over the next two years are needed to demonstrate the feasibility of GCW.**

# Pilot and Demonstration Projects

Would:

- **show the range of information** that can be provided for the cryosphere components, both globally and regionally,
- **show how GCW can build on existing efforts** by the cryospheric community,
- **identify the time and resources required** to create a fully functional integrated cryosphere information system,
- **document standards, guidelines and best practices** being used in observing and product development, and
- **identify challenges/gaps/needs** that the GCW could address in a logical manner.

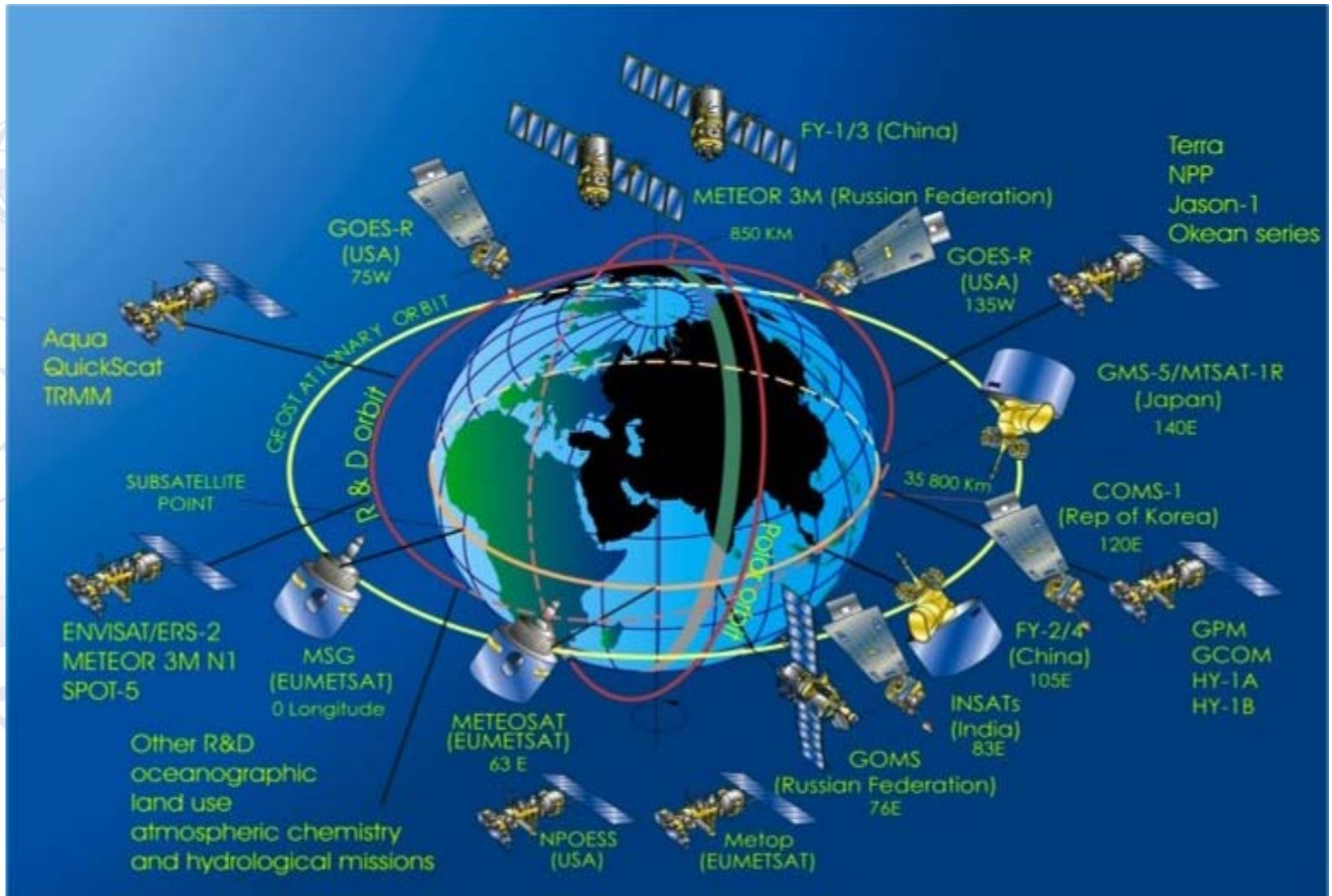
Pilot Projects would **focus on the components of the cryosphere**, identify how they would **contribute to implementing CryOS**, identify how they meet the **GCW principles and characteristics** noted above, and would contribute to **demonstrating integration of cryospheric data and information** from research to prediction.

Demonstration Projects would focus on **regional or national contributions as well as focus on specific tasks** to demonstrate standardization, integration and interoperability.

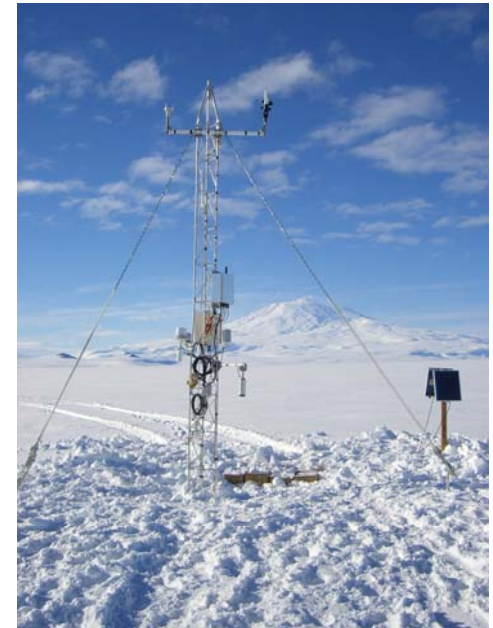
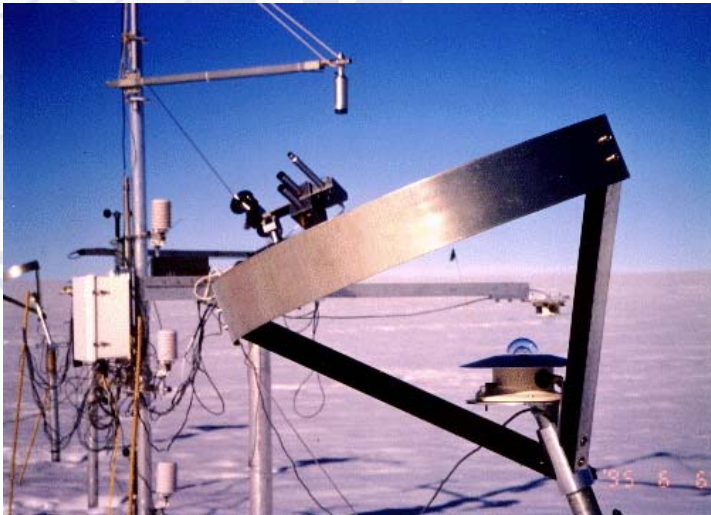
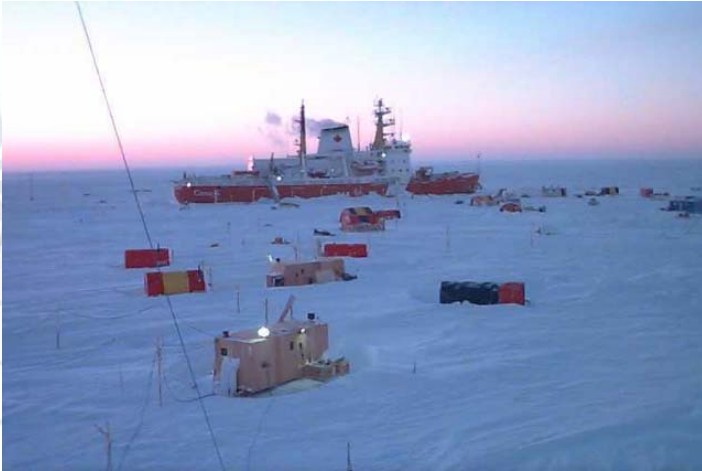
# Some Major Knowledge Gaps in Cryospheric Studies to be Addressed

- Determination of the *mass balance of ice sheets and glaciers* and their contribution to *sea-level* change through improved/enhanced observation and modeling
- Accurate determination of *sea ice extent and thickness* and improved representation of sea ice *in climate models* to improve future prediction of changes
- Improved *understanding and quantification* of the role of permafrost and frozen ground in the *carbon cycle* through a *coordinated measurement and modelling* framework for the northern high latitudes
- Significantly improved accuracy of observation and model prediction of *precipitation, especially snowfall*, over the Arctic land and ocean
- Determination of the present and future *freshwater balance of the Arctic* and assessment of the impact of changes on bio-geophysical and socio-economic systems
- Improved *prediction of the cryosphere* using regional climate models leading to improved prediction *on monthly to seasonal or longer time scales*
- *identification of climate and cryosphere information needs of people and groups living and working at high latitudes and provision of cryosphere products to users, along with information on their interpretation and use*

# The cryosphere observing system includes satellites...



..... and, of course, in situ, marine and aircraft measurements.





# In the Arctic alone...

There are

54 active networks

11 planned networks

31 observatories

25 Arctic data centers, archives, portals

17 Coordinating bodies



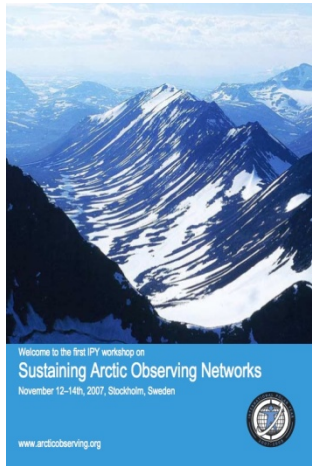
# ArcticObserving.org

## IPY Workshops on Sustaining Arctic Observing Networks



ARCTIC COUNCIL  
NORWEGIAN CHAIRMANSHIP  
2009-2008

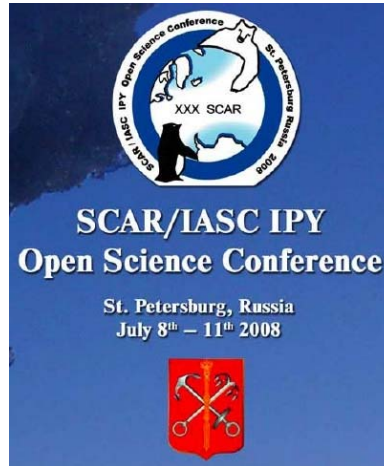
# SAON Workshops and Meetings



**Stockholm**  
(November 2007)



**Edmonton**  
(April 2008)



**St. Petersburg**  
(7 July)



**Seoul**  
(23 September)



**Helsinki**  
(15-17 October)



Final SAON report completed late 2008  
Terms of Reference of Arctic Forum in discussion

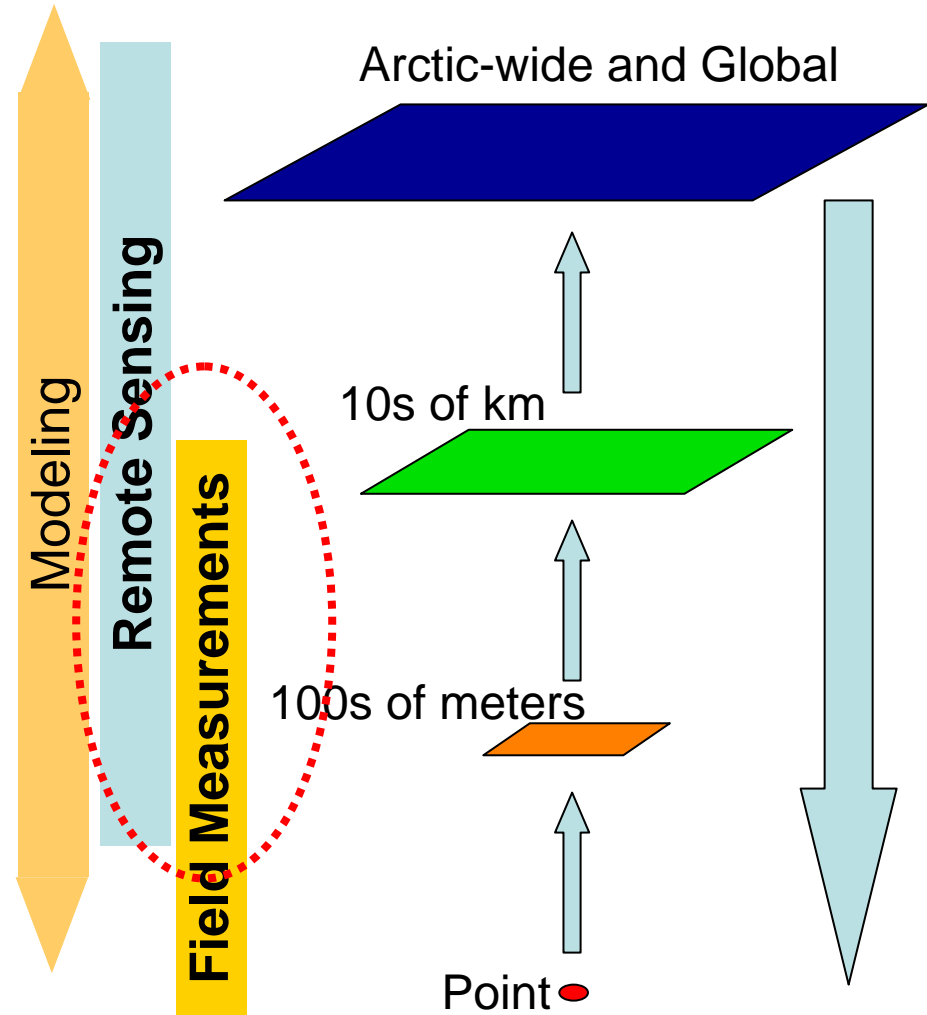
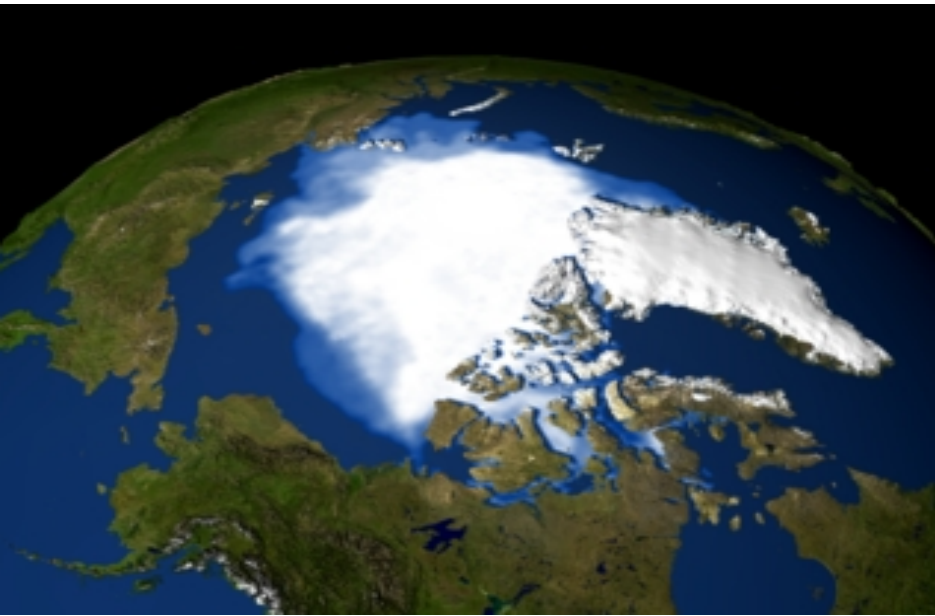
# **Recommendation: Sustaining Arctic Observing Networks (SAON)**

- *Recognizing that observing systems are essential for monitoring the current state and changes in the Arctic environment, and for validating and improving climate predictions over the Arctic;*
- *Recognizing that data and information for assessing climate variability and change and environmental sustainability are dependent on operational and research networks, on in-situ and satellite systems, and on effective data and information exchange;*
- *Considering that IPY provided an expansion of observations and stimulated international cooperation on data management and access; and*
- *Noting the Arctic Council/AMAP initiative, with other international organizations, on Sustaining Arctic Observing Networks (SAON), a process to further multinational engagement in developing sustained and co-ordinated pan-Arctic observing and data sharing systems and social, economic and cultural change; and, their recommendations for concerted action on sustaining Arctic observing systems;*

***It is recommended that a mechanism be established to facilitate international collaboration among operators, funding bodies and users of observational systems and data over the Arctic region.***



# Perspective and Scale



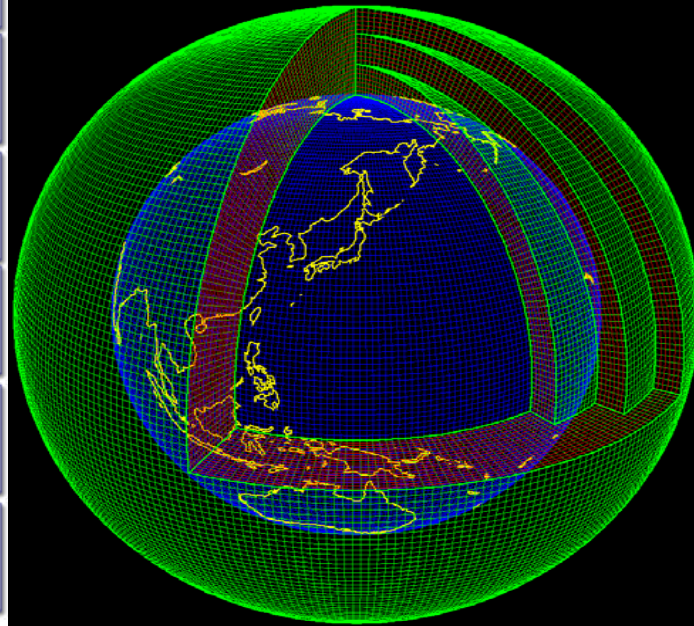
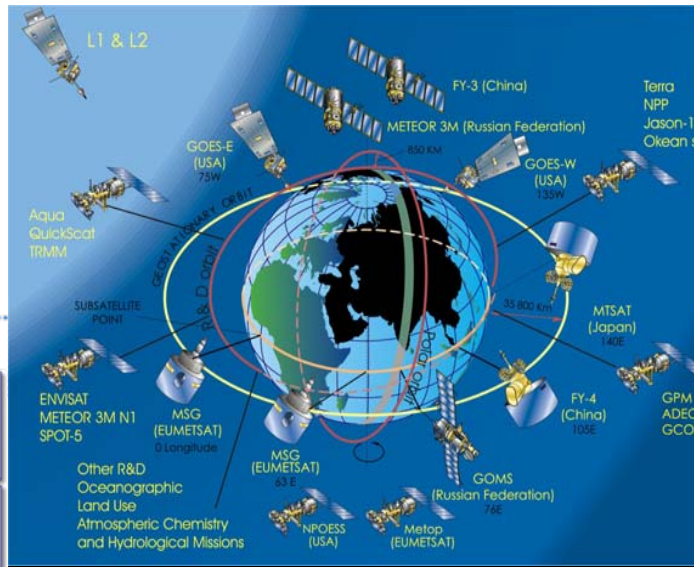
 = Calibration/Validation Scales

From Waleed Abdalati ICARPII

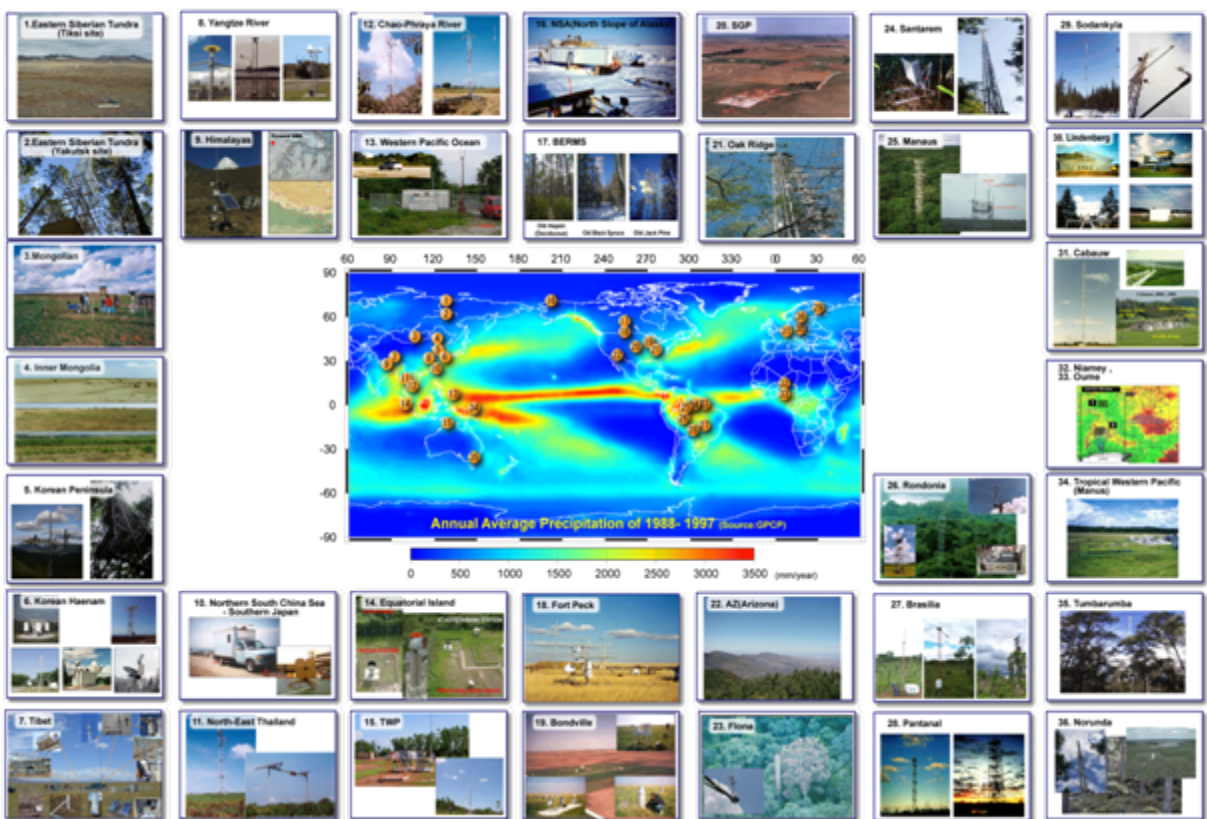


# Coordinated Enhanced Observing Period Three Unique Capabilities

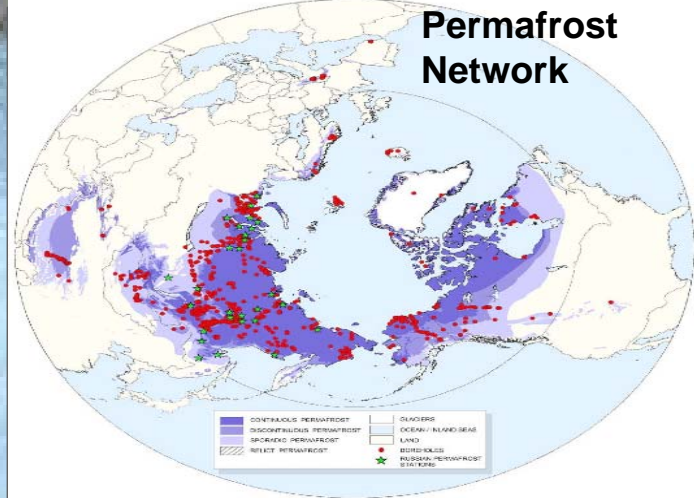
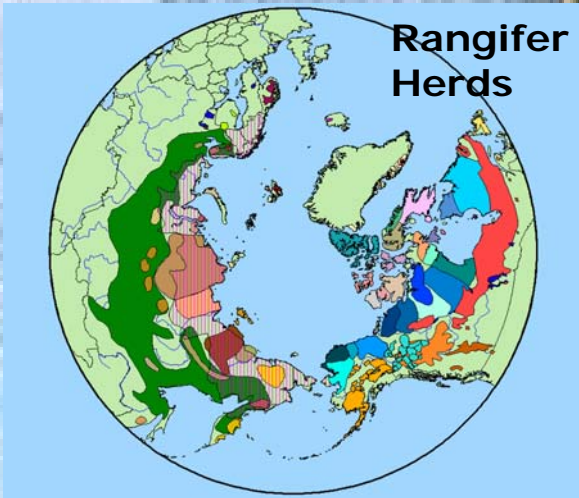
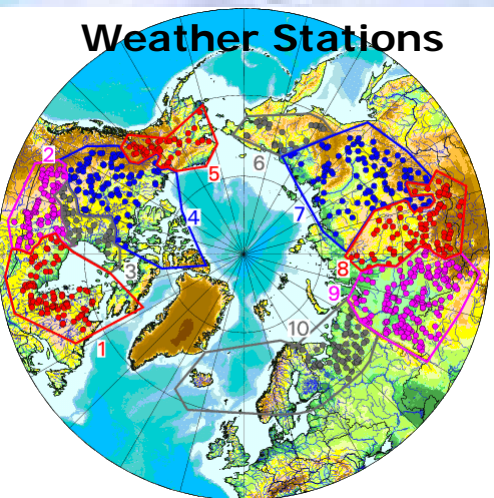
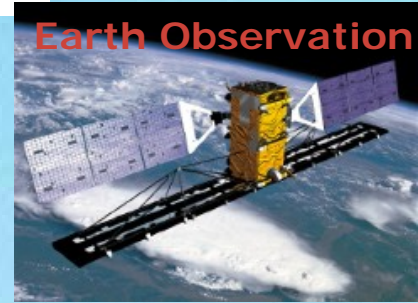
**A Prototype of the Global  
Water Cycle Observation  
System of Systems**



## International Cooperation for the Global Coverage



# Observation Networks

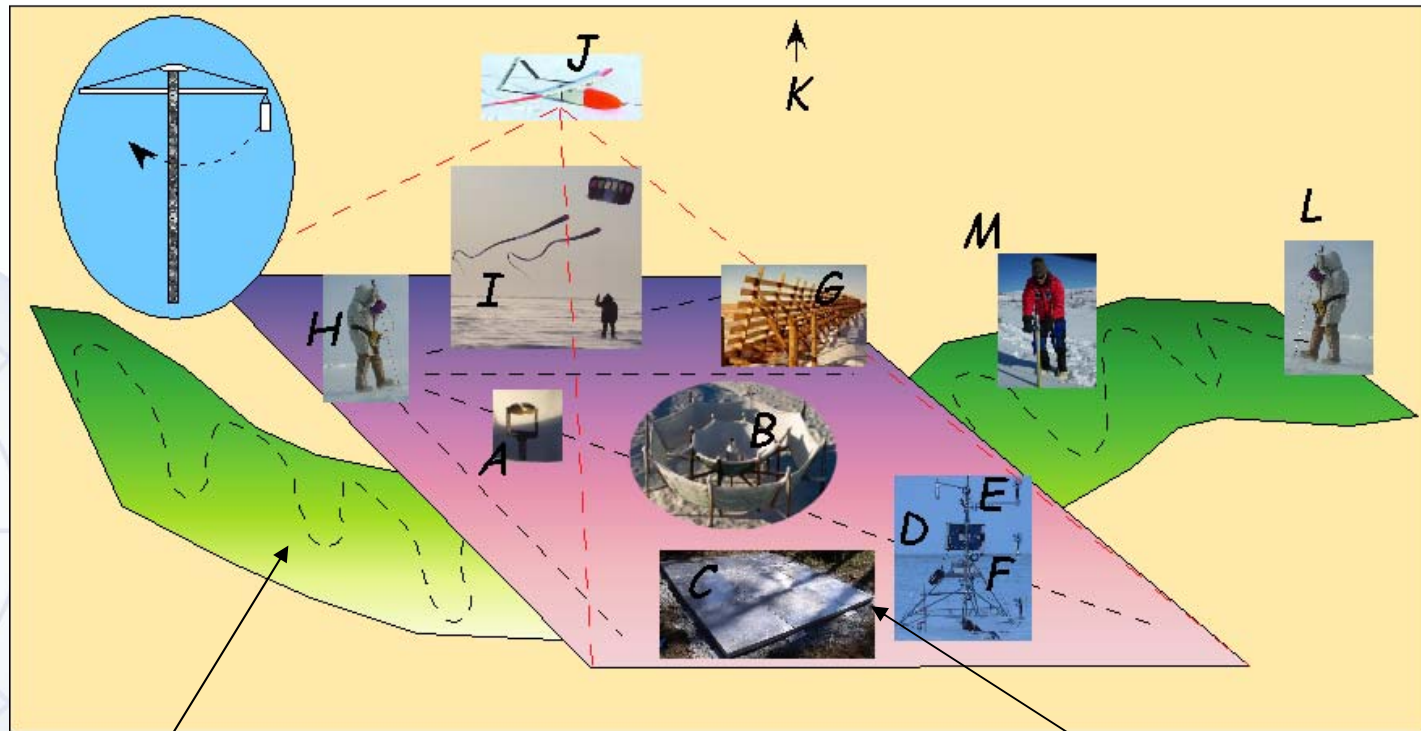


# Atmospheric Arctic Observing Sites

*A Basis for CryoNET?*



# A typical Snow-Net site



Small basin/watershed  
Surrounding the site

Area about 10 hectares  
immediately surrounding  
instrumentation

**...part of a Cryosphere Supersite – a contribution to CEOP**

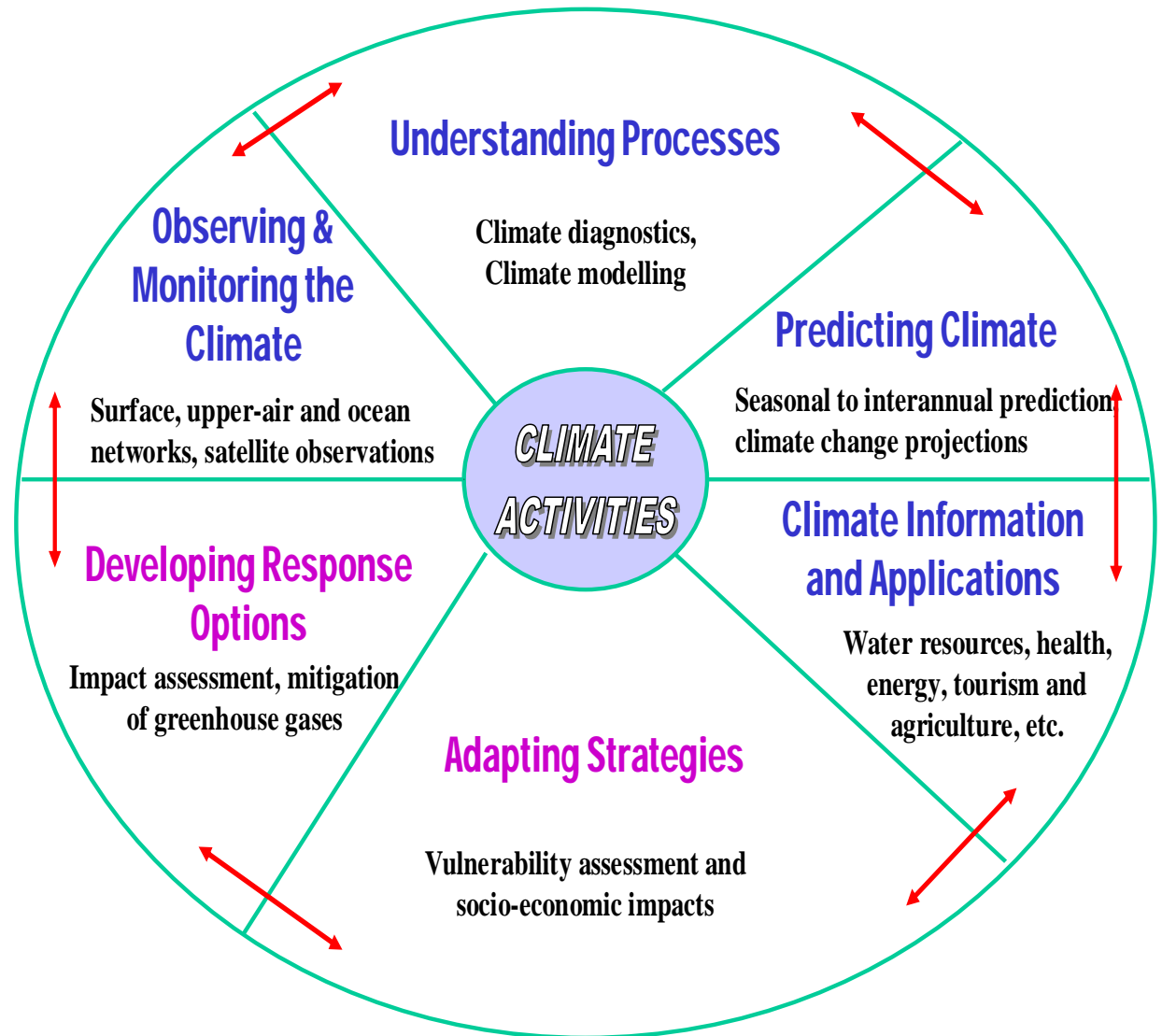
**....following observing standards, guidelines, best practices and with metadata**

# Recommendation: Integrated Monitoring

- *Considering the ICARPII recommendation that “an integrated observation and data management system, incorporating all relevant disciplines, scales and observing platforms, is paramount and will make use of polar reference stations, so called “supersites”;*
- *Noting the ICARPII recommendation that integrated observing plans require coordination of observations and modelling ensuring the same domains for modelling and observation work, thus leading to production of high-quality data sets representing the variability of essential parameters at dominant temporal and spatial scales;*
- *Noting the success of the approach of integrated observation by the WCRP Co-ordinated Enhanced Observing Period (CEOP) in creating a global reference network of observatories for water cycle studies, by collecting atmospheric and surface data from in-situ and satellite observations and output from atmospheric model over a reference area; and*
- *Noting the development of co-ordinated pan-Arctic observing through programs such as WMO’s Global Cryosphere Watch, IPY International Arctic Systems for Observing the Atmosphere (IASOA), and the Circumpolar Biodiversity Monitoring Program (CBMP):*

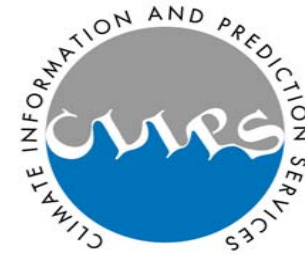
***It is recommended that an integrated polar reference observing network of “supersites” be established, building on existing infrastructure and facilities, where feasible, where in-situ, satellite and model data can provide long-term, multidisciplinary datasets suitable for environmental monitoring and prediction.***

# Integrated framework of WMO's climate activities





# CLIPS in Polar Regions



**There is a need for consistent, useful, operational climate information, products and services for high latitudes:**

Rapid change is affecting traditional way of life, health and safety; threatens land-based, freshwater and marine species



Industry including land and marine transportation, mining, oil and gas exploration and energy production must consider climate variability and change in planning and operations







# PolarCLIPS and PCOFs: IPY legacy, and GCW contribution

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- PolarCLIPS: the extension of the CLIPS concept to address the special needs of polar regions for
    - Climate and disaster risk management,
    - Adaptation to climate variability and change,
    - Socio-economic development (people, business, community)
  - PCOF: a Polar Climate Outlook Forum
    - Regular, international collaboration
    - Providers and users, interacting – building capacity together
    - Consensus approach
    - Science-based, user focused
-



# PolarCLIPS Workshop

## Recommendations (1)

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- Exploit climate data – especially new IPY datasets
  - Measure the ECVs; Promote polar ‘supersites’
  - Correct precipitation datasets for known biases
  - Improve remote sensing of rainfall and snowfall
  - Promote free/open exchange of climate information
  - Conduct research into downscaling and improving predictions – improve models for high latitude areas
  - Develop/share statistical tools (e.g. for extremes)
  - Provide climate monitoring products to users, with information on interpretation and use
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# PolarCLIPS Workshop

## Recommendations (2)

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- ID the climate vulnerability of users at high latitudes and needs for climate information to address these – surveys
  - Improve interdisciplinary collaboration and user liaison
  - Develop new info and operational products for decision-making
  - Develop the concept of PCOF as a viable operational mechanism to facilitate user services and feedback
  - Publish PCOF concept in peer-reviewed journal
  - Build capacity, including technical training for providers and joint efforts for providers and users together
-

# ***Recommendation: User Focussed Climate Services for Adaptation and Sustainable Development:***

- *Considering the importance of identifying the climate information needs of people and groups living and working at high latitudes;*
- *Recognizing the need to continue to improve the predictive skill of global and regional models for high-latitude areas, on all time scales;*
- *Noting the need to assist the users in interpretation and application of climate information and products in real life decision making;*
- *Given the need for capacity building, including technical training for climate scientists and product developers, and also for combined provider and user groups;*

***It is recommended to establish a viable operational mechanism to facilitate effective interactions between climate professionals and users/stakeholders, such as a Polar Climate Outlook Forum (PCOF), recognized by IPY as an WMO legacy project.***

# **Recommendation: International Polar Decade**

- *Noting that WMO and ICSU were the co-sponsors of IPY 2007-2008*
- *Considering the large investments of nations to IPY 2007-2008, the continuing and growing requirements for information on environmental change in Northern high latitudes by scientists, communities, northern peoples, decision and policy makers;*
- *Recognizing the need to build upon the surge of operational and research programmes conducted during IPY and the need to convert these into sustainable long-term research and monitoring capabilities;*
- *Noting the Declaration from Monaco Conference on “The Arctic: Observing the environmental changes and facing their challenges” on the need to “uphold the impetus launched by International Polar Year 2007-2008 and capitalize on the momentum created by consolidating and sustaining the mobilization of scientific research and monitoring initiatives”; and*
- *Noting that WMO Executive Council invited other international organizations to consider the launch of an International Polar Decade*

***It is recommended that, following WMO’s suggestion, ICSU and other international organizations consider the idea of an International Polar Decade as a long-term process of research and observations in Polar Regions to meet the requirements for climate change studies, assessments and prediction to benefit society.***