World Meteorological Organization
Working together in weather, climate and water

WMO Global Atmosphere Watch (GAW) and World Weather Research Programme (WWRP) research for the Arctic

Alexander Baklanov,
Atmospheric Research & Environment (ARE) Branch
Research Department (RES), WMO, Geneva
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Climate Change for Arctic Seas & Shipping
3rd CRAICC-PEEX workshop, 24-25 August 2015, DMI, Copenhagen, Denmark

Commission for Atmospheric Science

www.wmo.int

AREP GAW

World Meteorological Organization

Independent technical UN agency

191 Members
Secretariat in Geneva (staff 280)

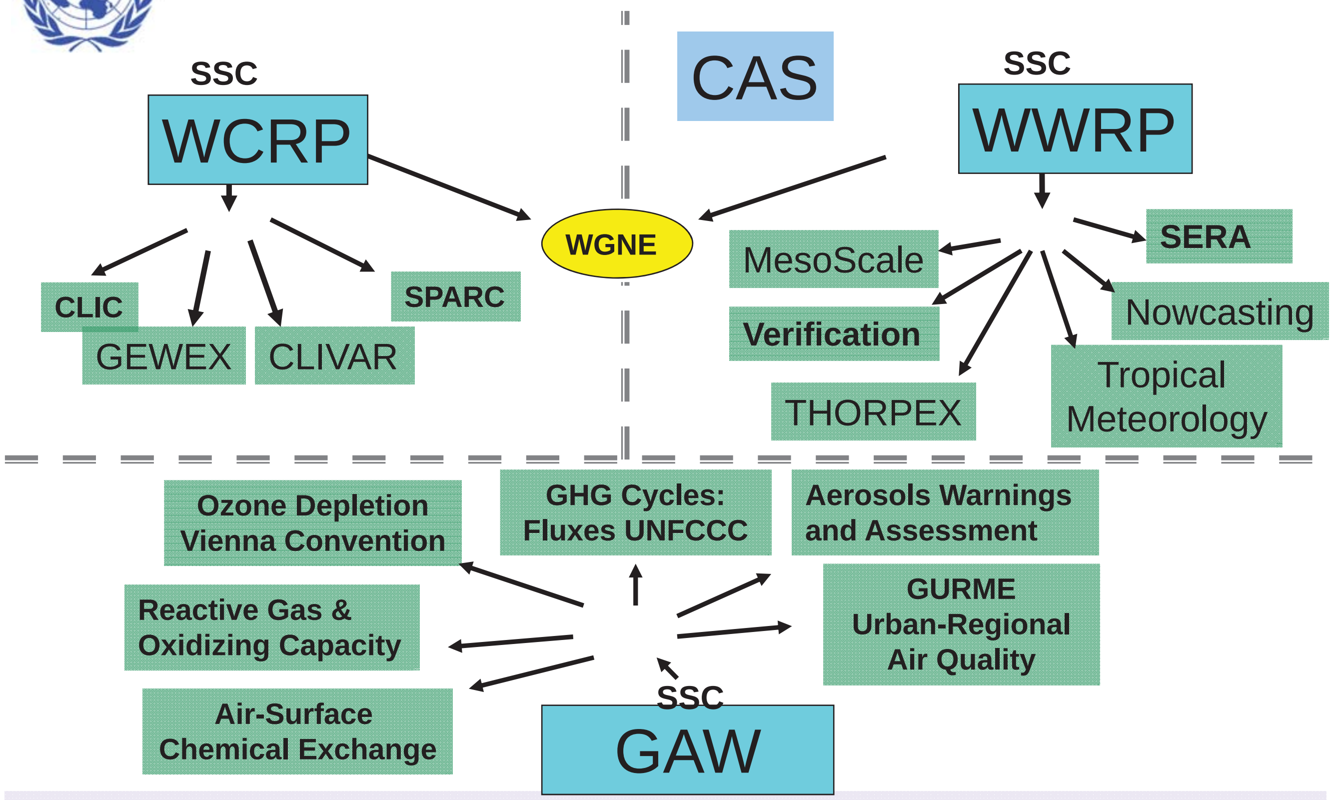
Technical Departments
Observing and Information Systems (OBS)
Climate and Water (CLW)
Weather and Disaster Risk Reduction Services (WDS)

Research Department (RES)
Atmospheric Research and Environment Branch (ARE)
- **World Weather Research Division (WWR)**
- **Atmospheric Environment Research Division (AER)**
  - *Global Atmosphere Watch (GAW) and GURME*

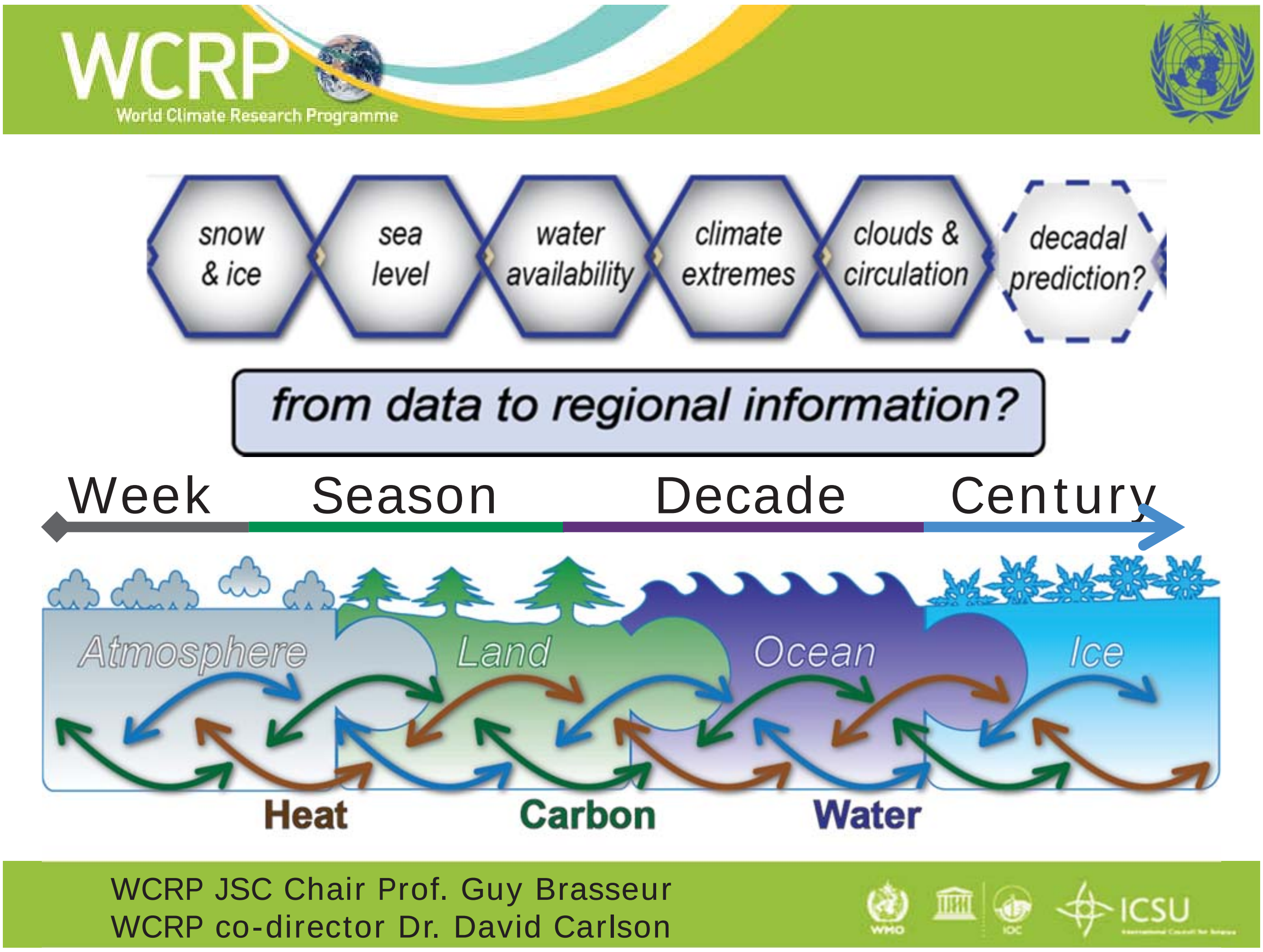
World Climate Research Program (WCRP)

WMO OMM

WMO Research Department



Weather, Climate and Environment Earth-System Research-Observations, Analysis and Prediction



RESEARCH PRIORITIES: 10-YEAR FUTURE VIEW

Commission for Atmospheric Science (CAS)

- High Impact Weather and its socio-economic effects in the context of global change
- Water: Modelling and predicting the water cycle for improved DRR and resource management
- Integrated GHG Information System: Serving society and supporting policy
- Aerosols: Impacts on air quality, weather and climate
- Urbanization: Research and services for megacities and large urban complexes
- Evolving Technologies: Their impact on science and its use

WMO

World Meteorological Organization

Working together in weather, climate and water

GAW

Commission for Atmospheric Science

Global Atmosphere Watch (GAW) program

Chair GAW SSC Prof. Greg Carmichael,
Chief AER division Dr. Oksana Tarasova

25 Years of GAW !!

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THE GAW MISSION

- Systematic long-term monitoring of atmospheric chemical and physical parameters globally
- Analysis and assessment
- Development of predictive capability

  (GURME, Sand and Dust Storm Warning System and new NRT Modelling Applications SAG)

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WMO/GAW Role

WMO Secretariat role is largely a catalyzer, facilitator, coordinator and advisor. The contribution of WMO Members to GAW is essential (dedicated institutions, individuals, finances, infrastructure).

GAW links, through collaboration, regions together (EMEP, EANET, ASEAN Haze agreement etc) enhancing observational capacity and provision of information.

WMO/GAW between operations, policy and research provides a global framework for interconnected local, regional and global issues. Research → demonstrated results of high societal relevance and value (GHG, ozone, UV, aerosols, reactive gases, precipitation chemistry, GURME) → operations.

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Overview of the Structure of GAW

- More than 100 countries have registered **more than 800 stations** with the GAW Station Information System (**GAWSIS**).
- Various **GAW expert groups and central facilities** exist under the oversight of the WMO Commission for Atmospheric Sciences (CAS) and its Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC).
- **7 Scientific Advisory Groups** (SAGs) to organise and co-ordinate GAW activities by parameter, and the Expert Teams on World Data Centres (ET-WDC) and Near-Real-Time Chemical Data Transfer (ET-NRT CDT).
- 4 Quality Assurance/Science Activity Centres (QA/SACs) perform network-wide **data quality and science-related functions**.
- 35 Central Calibration Laboratories (CCLs) and World and Regional **Calibration Centres** (WCCs, RCCs) maintain calibration standards and provide instrument calibrations and **training** to the stations.
- **6 World Data Centres** archive the observational data and metadata, which are integrated by the GAW Station Information System (GAWSIS).
- **GAW Training** (GAWTEC): More than 270 persons trained from 58 countries

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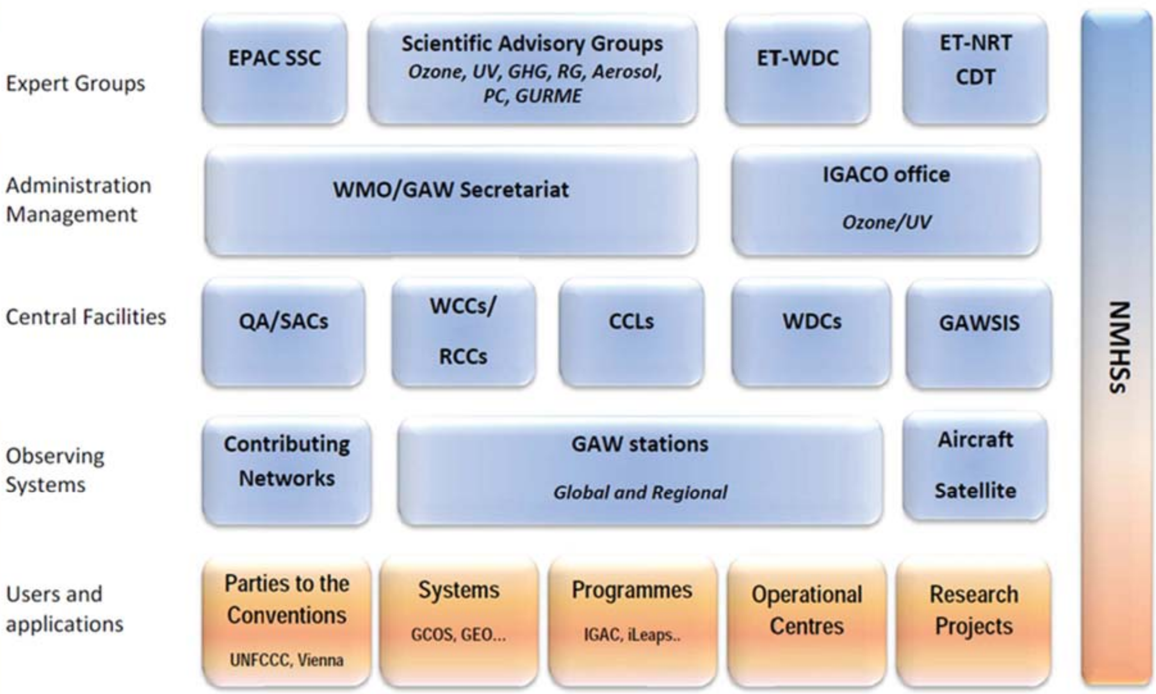
Structure of GAW



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GAW observations

- Stratospheric Ozone
- Tropospheric Ozone
- Greenhouse Gases (CO_2, CH_4, N_2O, CFCs)
- Reactive Gases (CO, VOC, NO_y, SO_2)
- Precipitation Chemistry => Total Deposition
- Aerosols (chemical, physical, AOD)
- UV Radiation
- (Natural Radionuclides, Rn^{222}, Be^{7}, ^{14}CO)

Meteorological measurements also needed

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WIGOS, GAW and Rolling Review of Requirements

- **WMO Congress: All WMO (and co-sponsored) observing systems shall use the RRR to design networks, plan evolution and assess performance.**
  - The RRR is the process used by WMO to collect, vet and record user requirements for all WMO application areas and match them against observational capabilities
  - Gap analysis results in *Statements of Guidance* (one per application area), that provides a narrative of how well a given application area is supported by WIGOS; to be supported by a quantitative gap analysis module (in development)
  - **GAW Task Team on Observational Requirements and Satellite Measurements as regards Atmospheric Composition and Related Physical Parameters**

GAW publications available from: http://www.wmo.int/pages/prog/arep/gaw/gaw-reports.html

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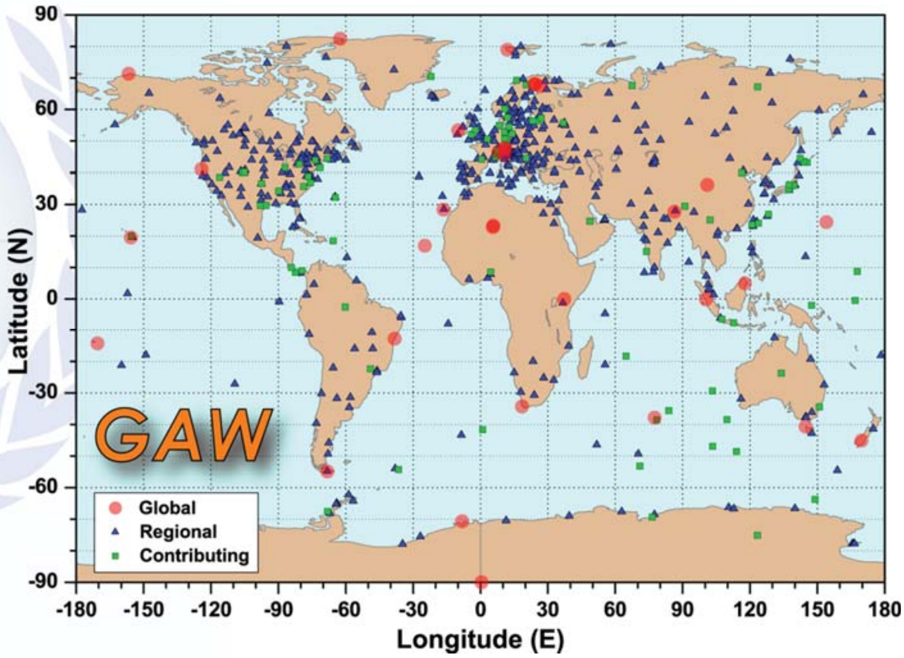
GAW stations network

Versatile station information is available through the GAW Station Information System GAWSIS (http://gaw.empa.ch/gawsis/).



Aircraft and satellite measurements also contribute to the observations

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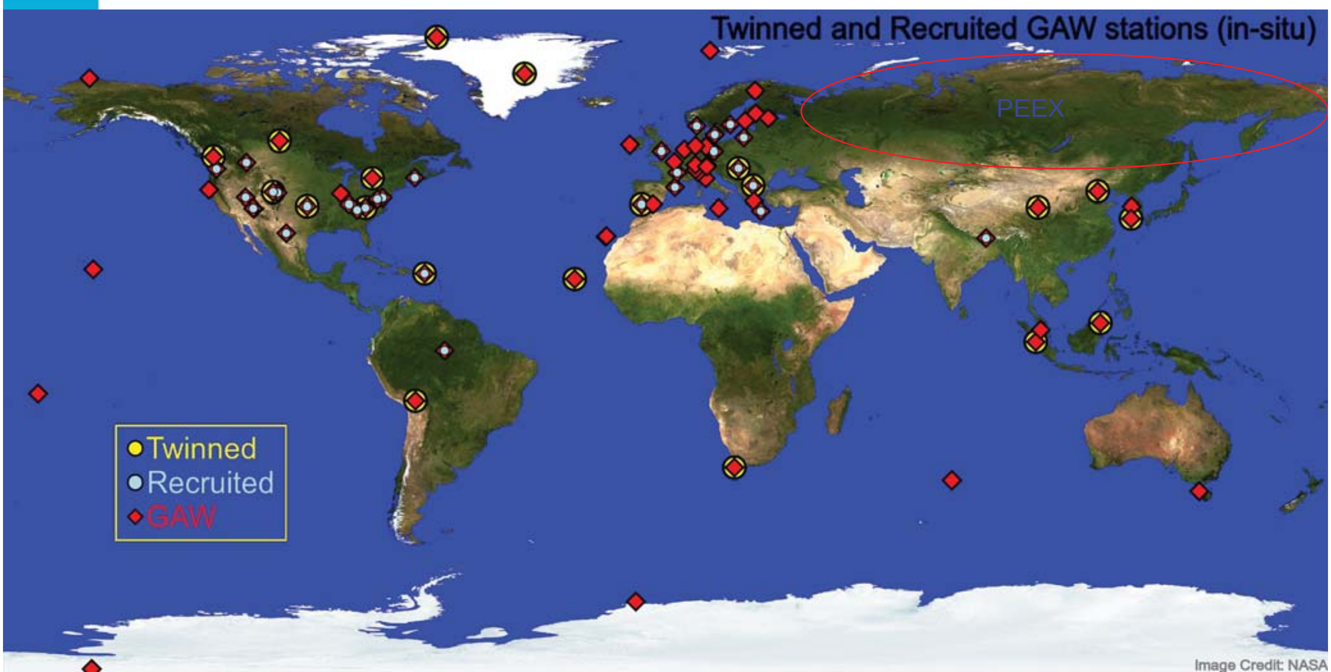
GAW In-situ Aerosol Network



Twinned: Operations supported by SAG members
Recruited: Joined GAW through efforts of SAG members

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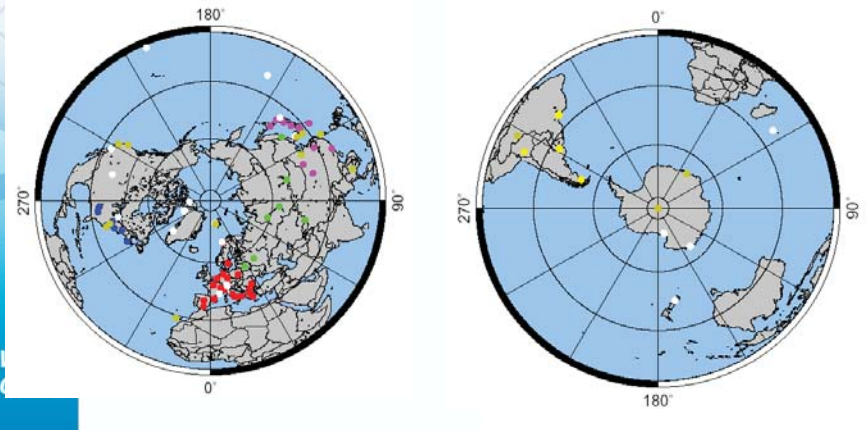
GAW Aerosol Lidar Observation Network

GALION is organized as a Network of Networks, coordinating

- American Lidar Network (ALINE), Latin America (●)
- Asian Dust and Aerosol Lidar Observation Network (AD-Net), East Asia (●)
- CIS-LINET, Commonwealth of Independent States (Belarus, Russia and Kyrgyz Republic) LIdar NETwork (●)
- Canadian Operational Research Aerosol Lidar Network (CORALNet), Canada (●)
- European Aerosol Research LIdar NETwork (EARLINET), Europe (●)
- Network for the Detection of Atmospheric Composition Change (NDACC), Global Stratosphere (○)
- CREST, Eastern North America (●)
- MicroPulse Lidar NETwork (MPLNET), Global (●)



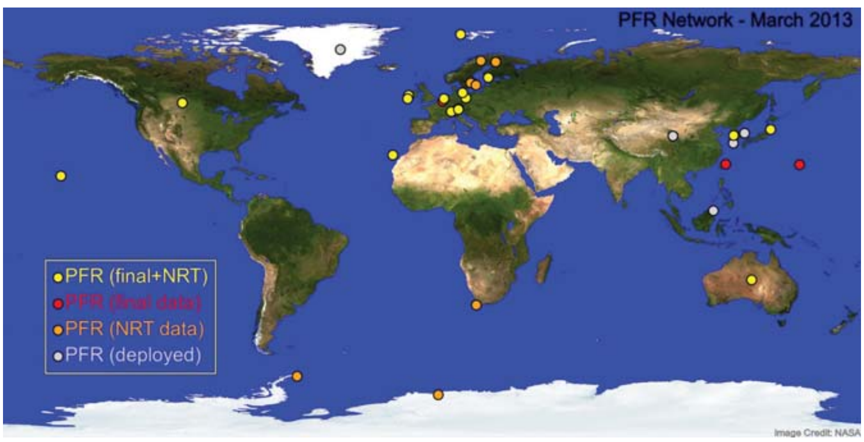
Applications

- Climate research and assessment
- Impact on radiation
- Air quality
- Plumes from special events
- Support for spaceborne observations

GAW-PFR Aerosol Optical Depth Network

Precision Filter Radiometer

- Manufactured and coordinated by World Optical Depth Research and Calibration Center
- Operated by GAW stations and national networks
- Suitable for use as a GCOS Reference Network
- Many stations submit both NRT and final data
- Some stations not yet submitting any data



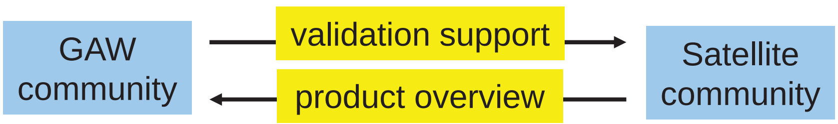
World Data Center for Remote Sensing of the Atmosphere

Satellite "one stop shop" for aerosols

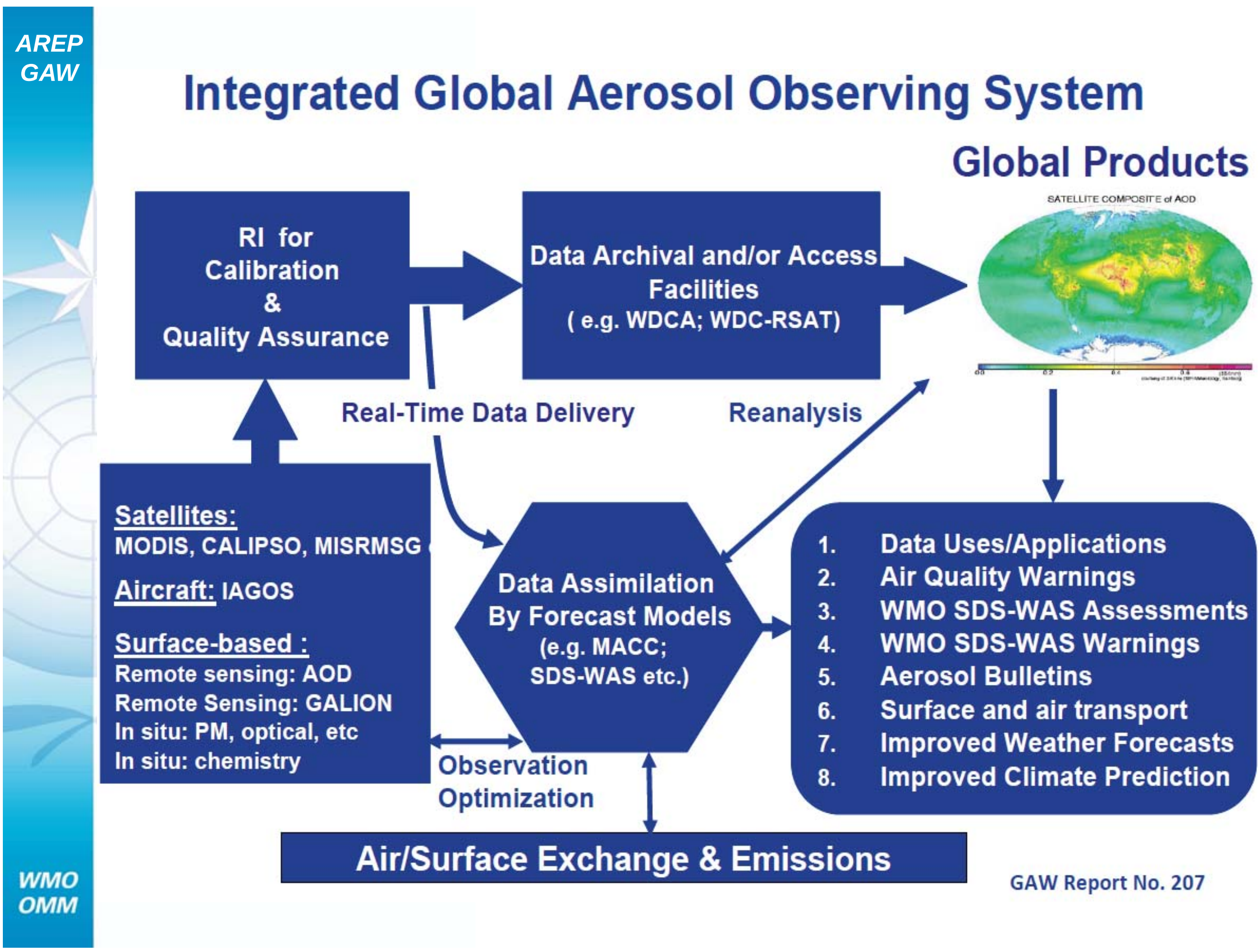
- Support easier access to satellite datasets by the GAW community
- Promote GAW datasets for satellite product validation

Support from WDC-RSAT for WMO-GAW

- Link different GAW-relevant data sets with each other and with models
- Cooperate with other international actors on interoperability (NASA, CNES)
- Assign 'Digital Object Identifiers' (DOI) to data sets
- Develop techniques to provide stations with satellite-based data and information products
- Develop computing-on-demand applications
- Develop and test strategies and techniques to validate satellite data sets

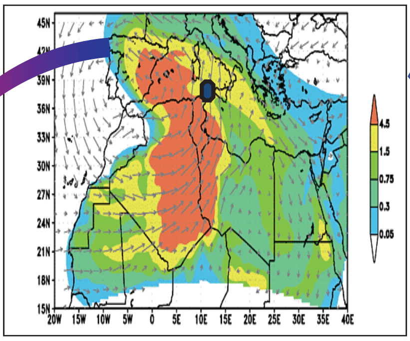


wdc for remote sensing of the atmosphere

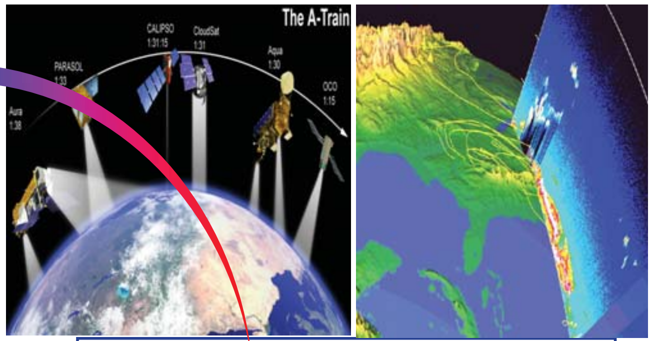


WMO Supported Aerosol and Weather Prediction Research

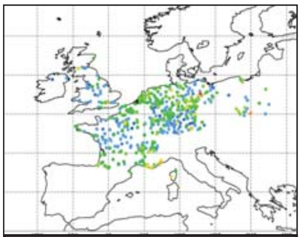
Forecast Models



18 UTC, 7 May 2002 30-hr forecast

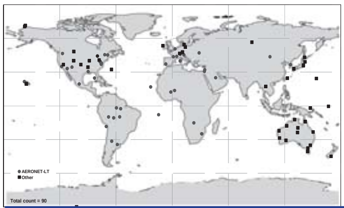


NASA A-Train MODIS CALIPSO
&
Geostationary Satellite IR Obs



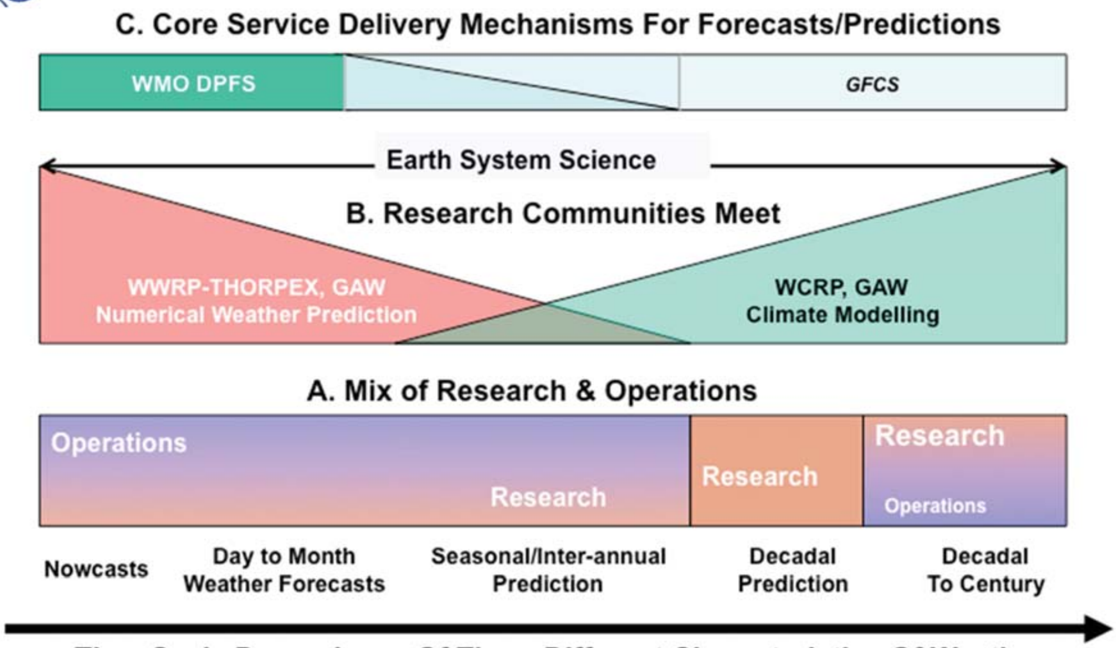
European PM10

GALION
Surface-based LIDAR



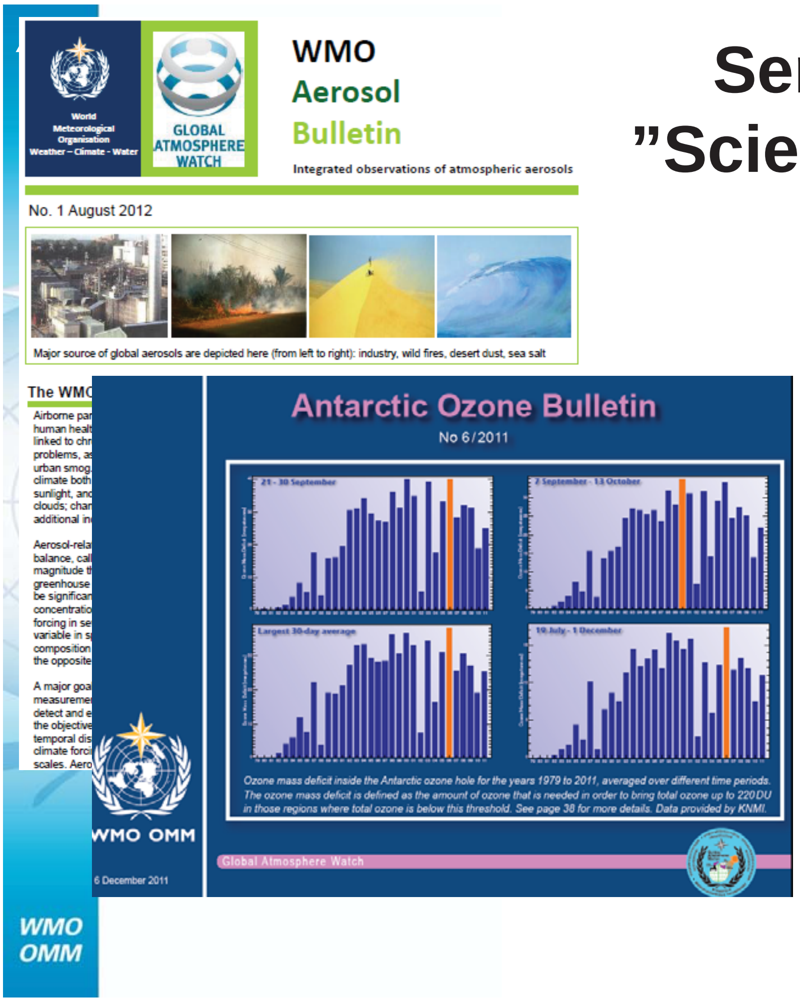
GAW/AERONET/SKYNET
Surface-based AOD

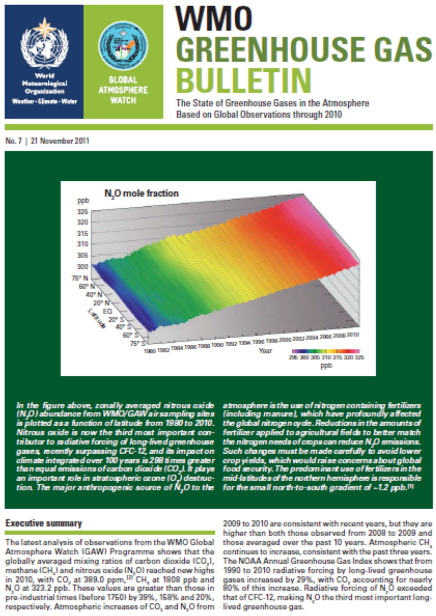
Seamless prediction



Time Scale Dependence Of Three Different Characteristics Of Weather, Climate, Water and Environmental Prediction Activities

Service delivery ”Science for service”





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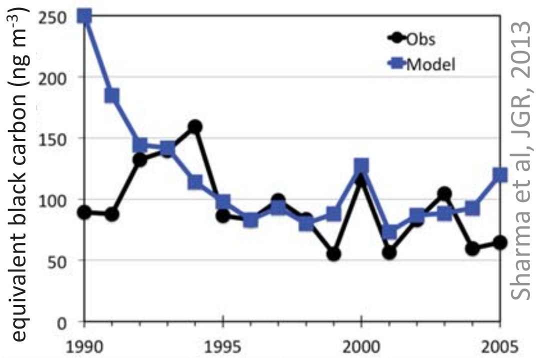
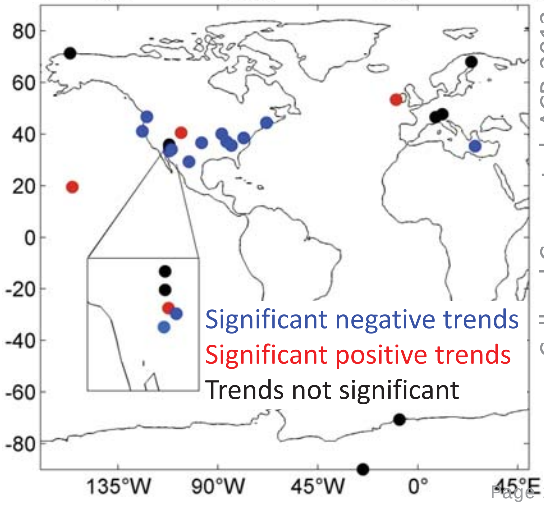
Aerosol Trends from GAW

- Trends in light absorption
  - Measurements interpreted as “equivalent” black carbon
  - NIES (Canada) model reproduces long-term, wintertime-average trend at Barrow
- Trends in light scattering
  - WMO/GAW and US/IMPROVE networks
  - Stations with at least 10 years of data submitted to World Data Center for Aerosols
  - 2-3 %/yr significant negative trend across US
- A rich data set for evaluating models





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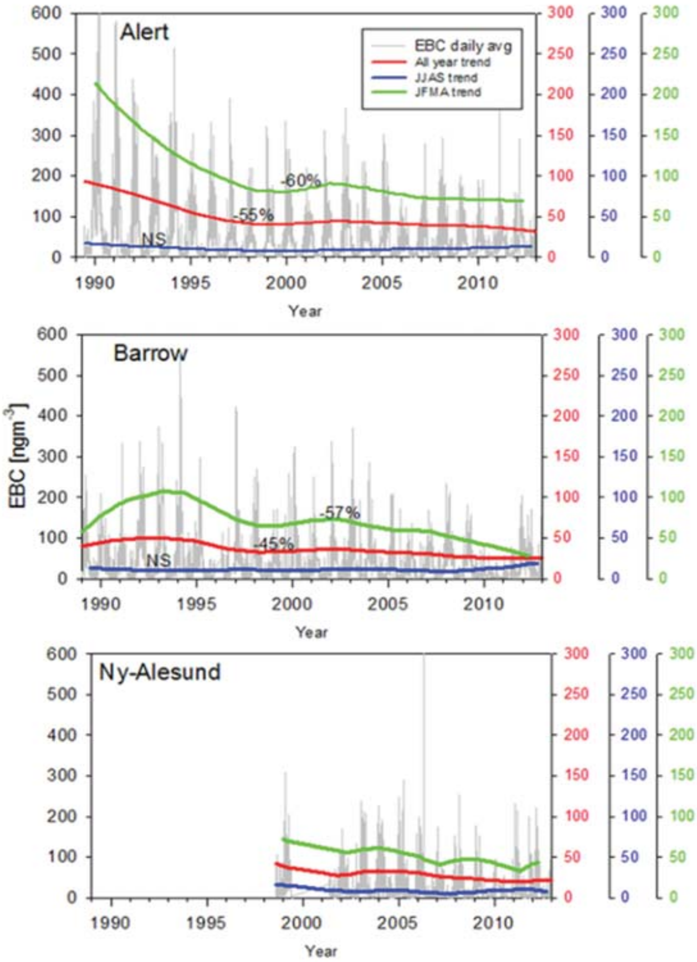
Observed BC trends

Equivalent BC has decreased at Arctic stations during the last decades

(from Sharma et al., 2013; Stohl et al., 2014)

Reflects mainly emission reductions in Europe and Russia in the 1990s.

All
Winter-spring (January to April)
Summer (June to September)



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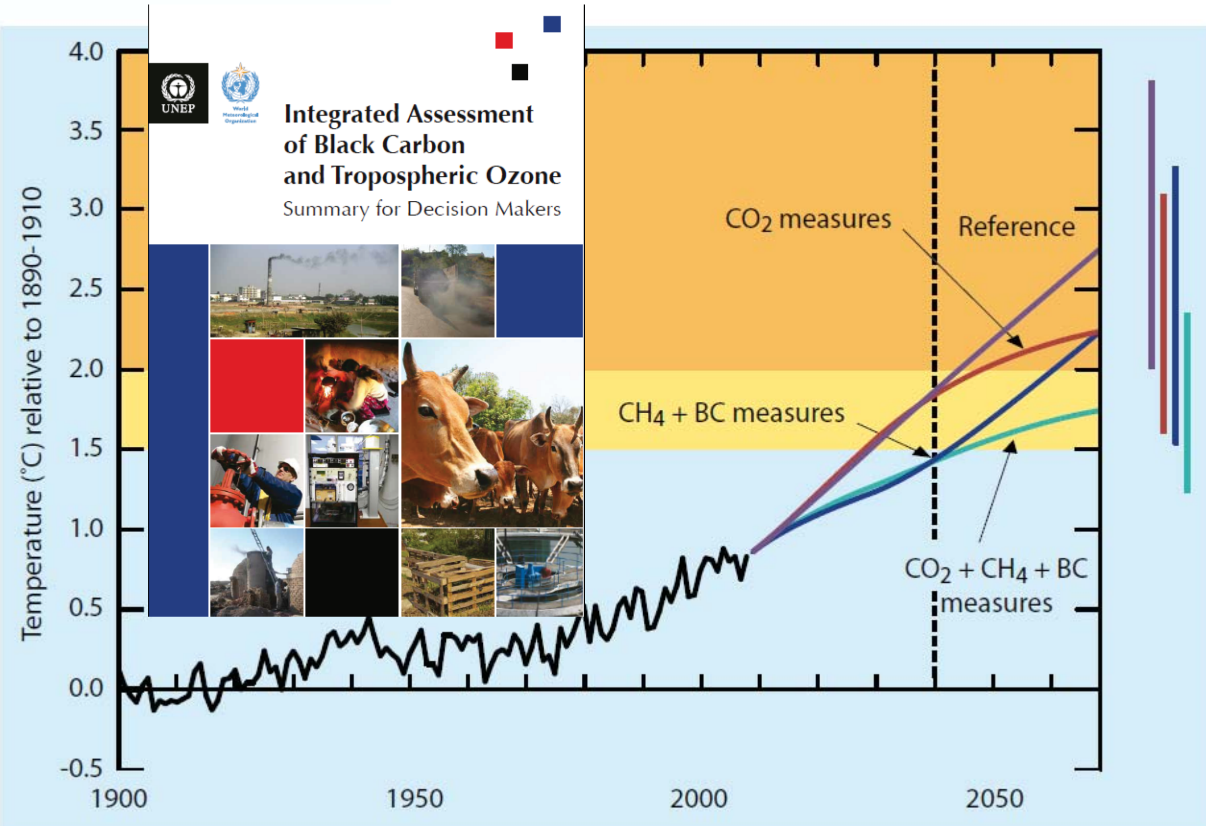
Result for Global Temperature Change (hybrid of results from GISS and ECHAM models informed by the literature) added to the historical record



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UNEP/WMO Integrated Assessment of Tropospheric Ozone and Black Carbon

http://www.wmo.int/pages/prog/arep/gaw/documents/BlackCarbon_SDM.pdf

- 16 identified measures, implemented by 2030, would reduce global warming by 0.5°C (0.2-0.7°C) in 2050 – half the warming projected by the Reference
- Near-term measures would improve the chance of not exceeding 2°C target, but only if CO_2 is also addressed, starting now
- A near-term strategy addressing SLCFs, is complementary to, and cannot be an alternative to dealing with long-lived GHGs, especially CO_2
- Substantial regional climate benefits: e.g. **in the Arctic (0.7 °C, range 0.2-1.3°C by 2040)**, for the Himalayas and South Asian monsoon
- Health and crop benefits are substantial – could avoid 2.4 million premature deaths (0.7-4.6 million) and loss of 52 million tonnes (30-140 million) of maize, rice, wheat and soybean, each year
- The identified measures are all currently in use in different regions around the world

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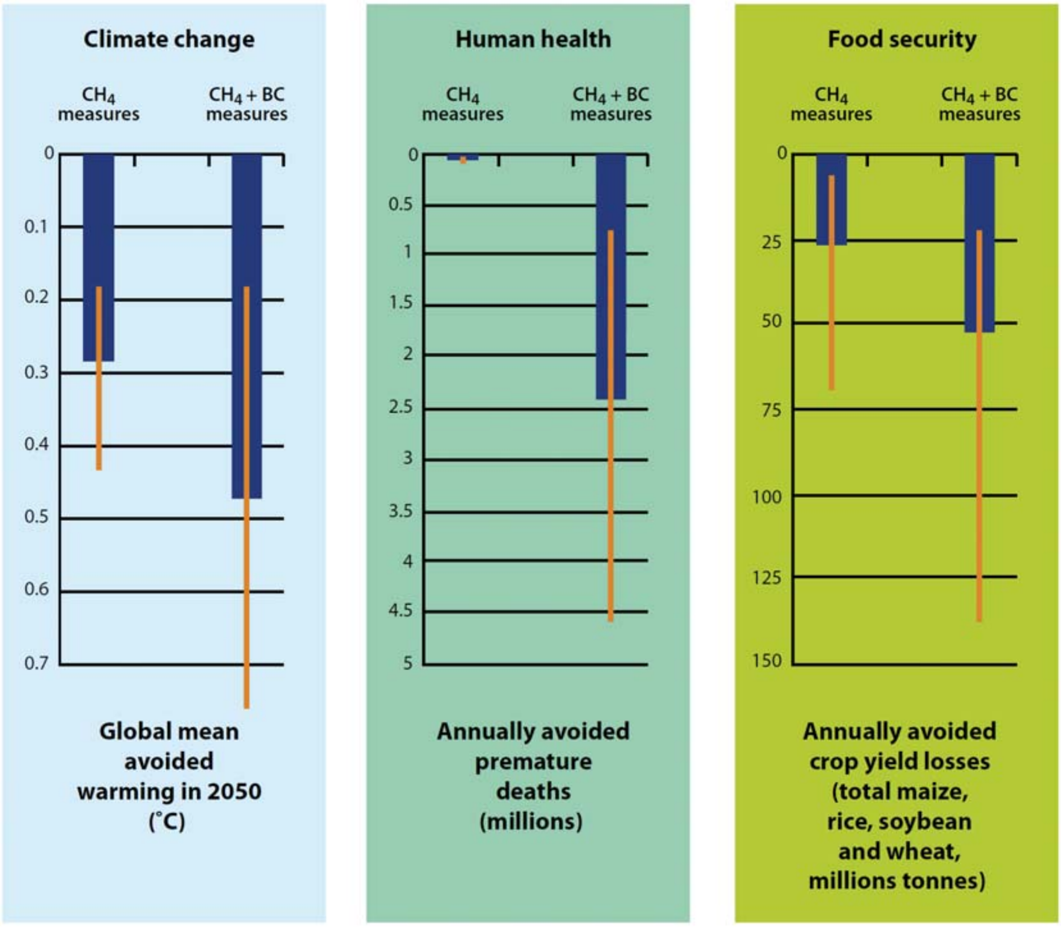
Impact of the Measures on Health, Crop yields and Climate



WMO OMM

World Meteorological Organization

Weather • Climate • Water

Commission for Atmospheric Science

World Weather Research Programme

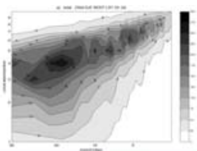
Sarah Jones, Chair WWRP SSC

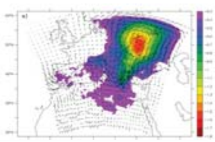
Paolo Ruti, Chief WWRD,WMO

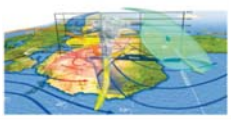
Christof Stache/AFP/Getty Images; Marina Shemesh /publicdomainpictures.net; Alexandros Vlachos/EPA; NOAA NWS; NOAA NWS

WWRP Mission

- WWRP advances society's resilience to high impact weather through research focused on improving the accuracy, lead time and utilization of weather prediction, and through engaging users & stakeholders to define research priorities and facilitate transition to applications
- WWRP promotes cooperative international & interdisciplinary research in the operational and academic communities and supports the development of early career scientists
- WWRP aims at Seamless Prediction of the Earth System from minutes to months using coupled systems – thus applying expertise in weather science to promote convergence between weather, climate and environmental communities







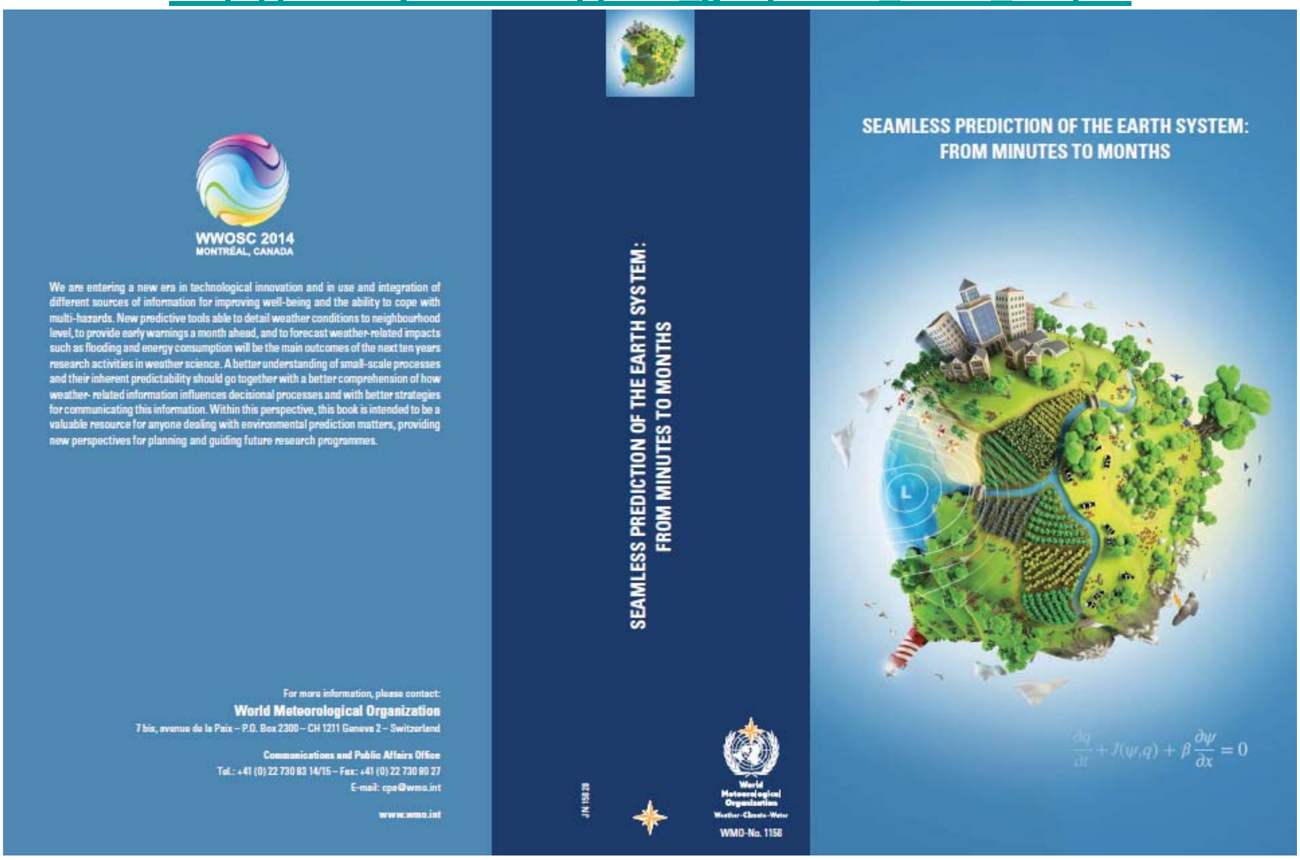
WWRP overarching goals

Commission for Atmospheric Science

Weather • Climate • Water

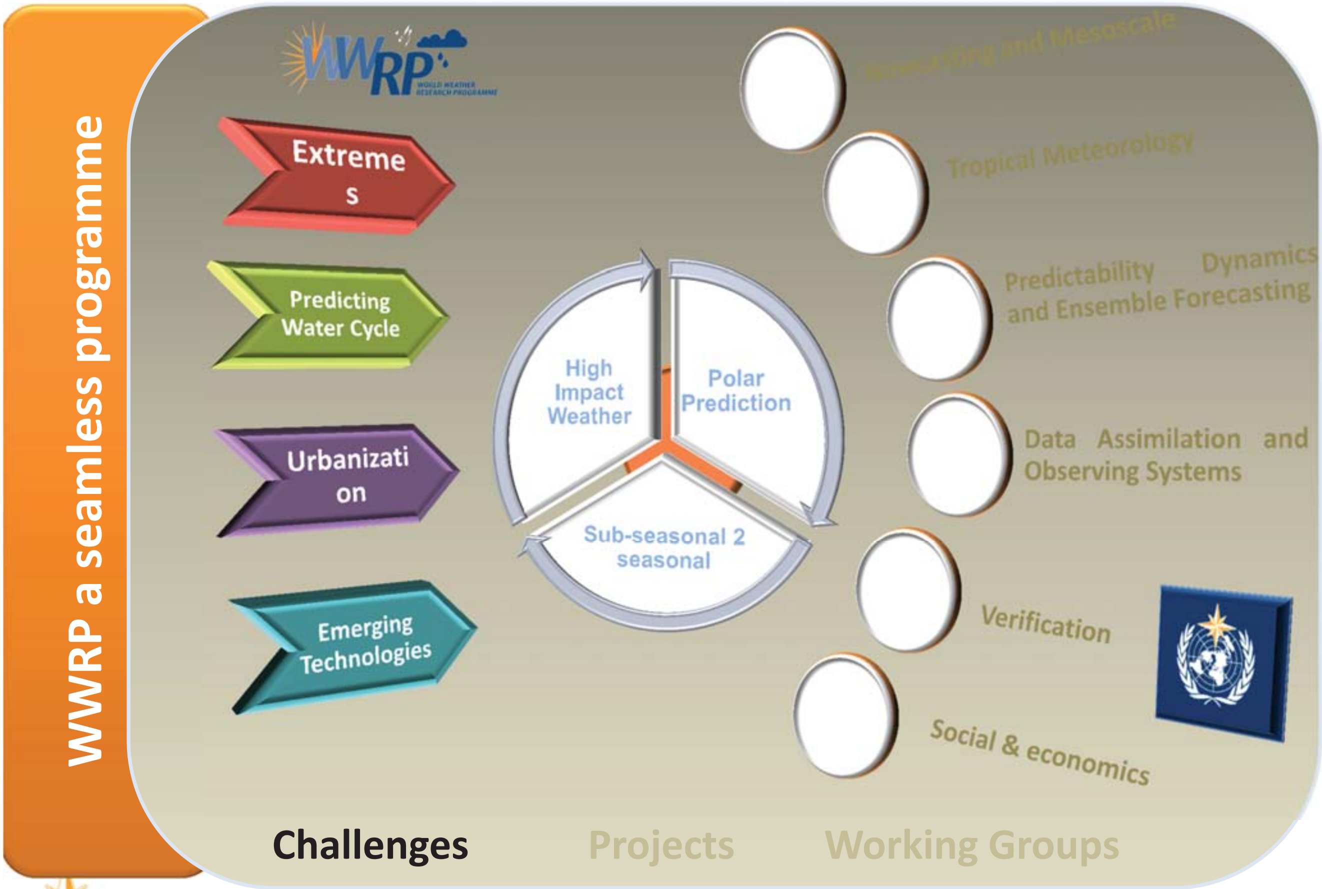
WWOSC 'Seamless Earth System Modelling' Book:

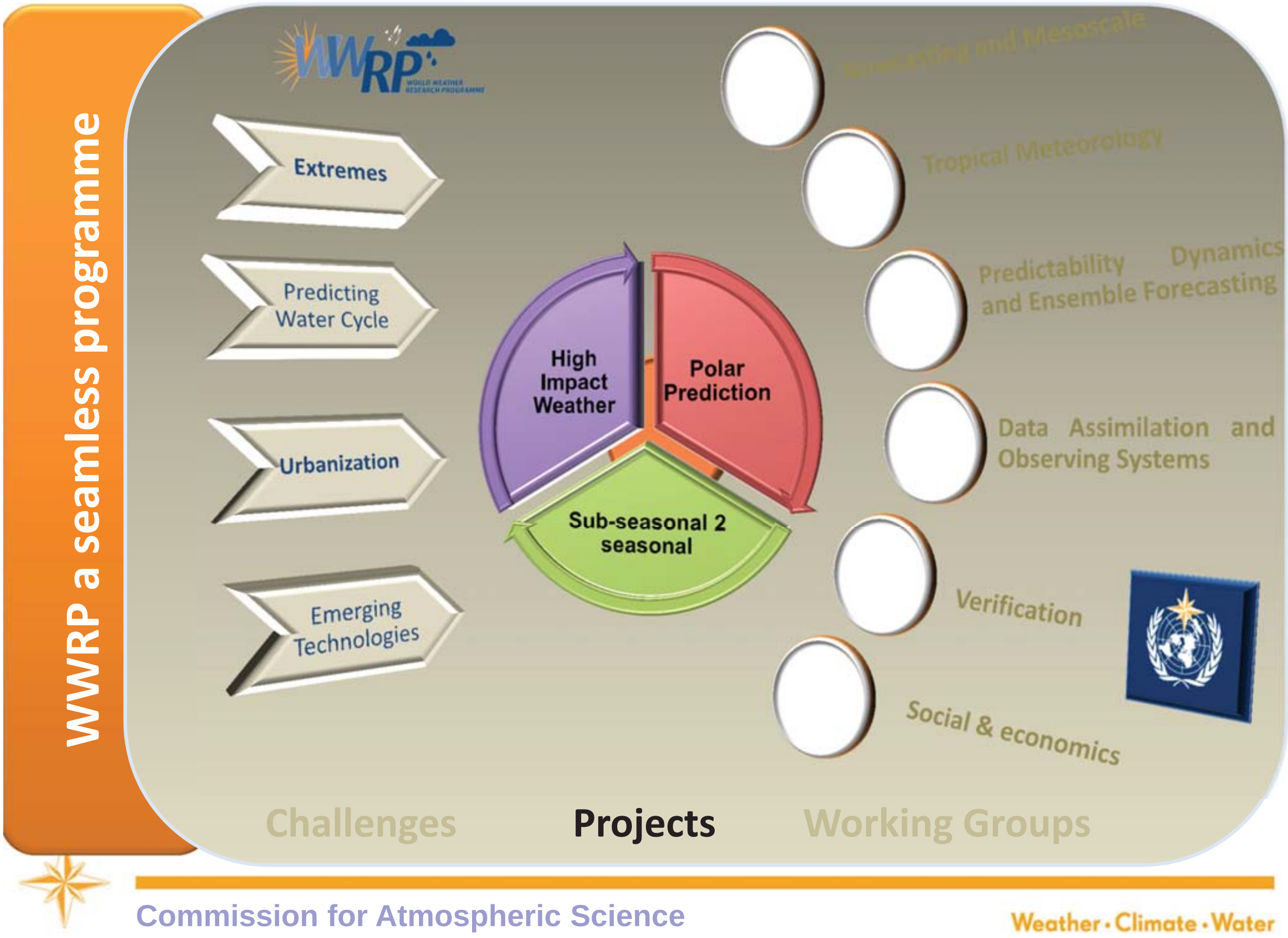
http://library.wmo.int/pmb_ged/wmo_1156_en.pdf

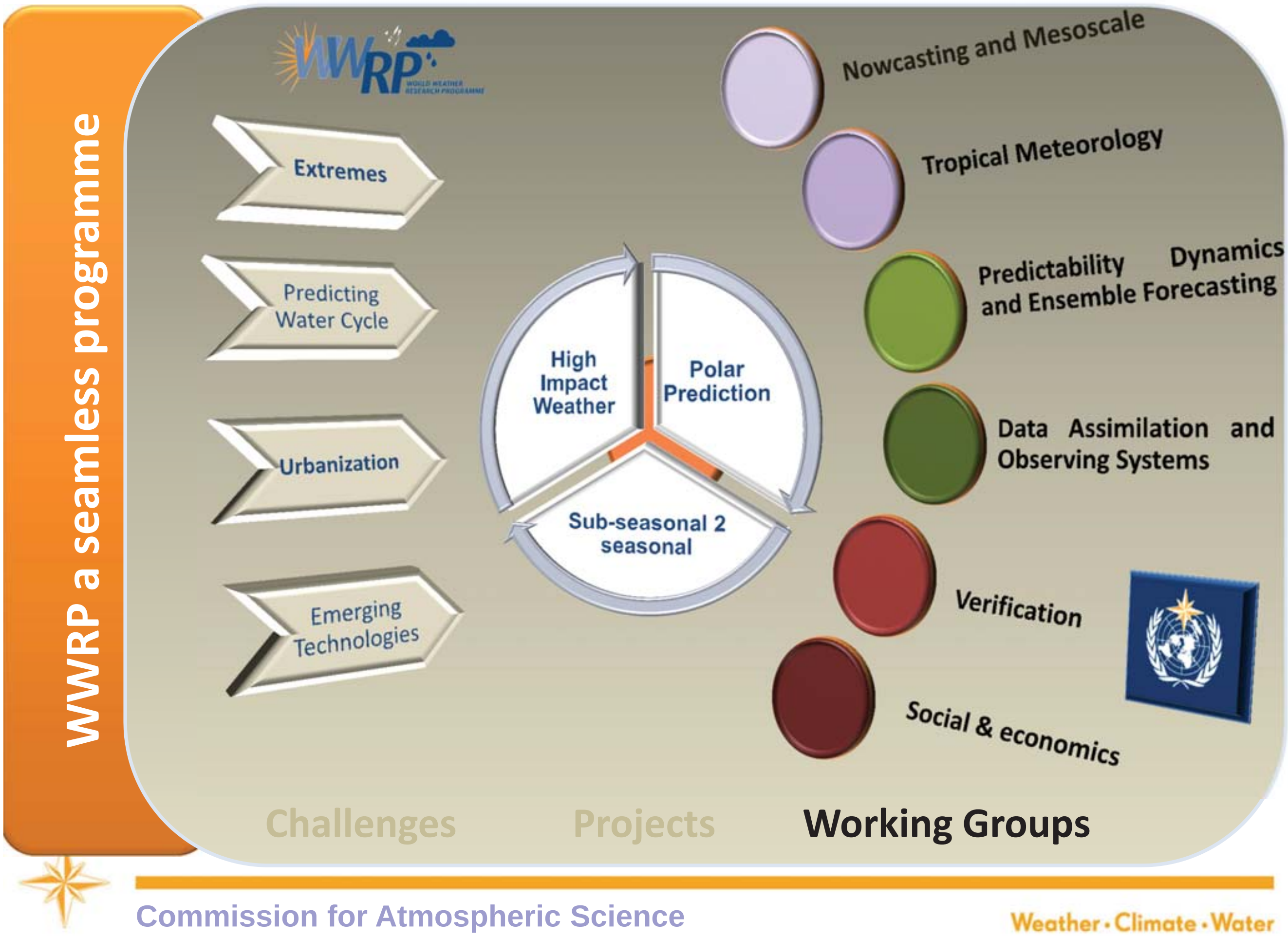


WWRP overarching goals

- Towards Environmental Prediction, integrating modeling components (hydrology, sea-ice, ocean, atmospheric composition, etc.) to better understand coupled processes and to improve forecasting methods.
- Towards a seamless predictive capability, developing a unified modeling approach to advance environmental prediction on the weekly to monthly time scale.
- Towards impacts forecasting, building community resilience in the face of increasing vulnerability to extreme weather events, through a better understanding of communication and decision-making processes.




WWRP a seamless programme
WWRP WORLD WEATHER RESEARCH PROGRAMME
Extremes
Predicting Water Cycle
Urbanization
Emerging Technologies
High Impact Weather
Polar Prediction
Sub-seasonal 2 seasonal
Nowcasting and Mesoscale
Tropical Meteorology
Predictability Dynamics and Ensemble Forecasting
Data Assimilation and Observing Systems
Verification
Social & economics
Challenges
Projects
Working Groups
Commission for Atmospheric Science
Weather • Climate • Water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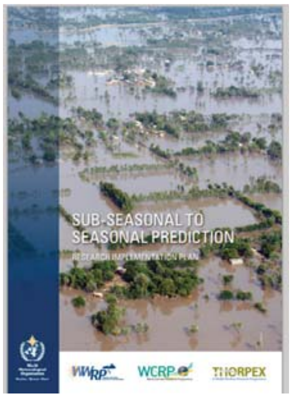
Sub-seasonal to seasonal

"Bridging the gap between weather and climate

Co-chairs: Frédéric Vitart (ECMWF), Andrew Robertson (IRI)

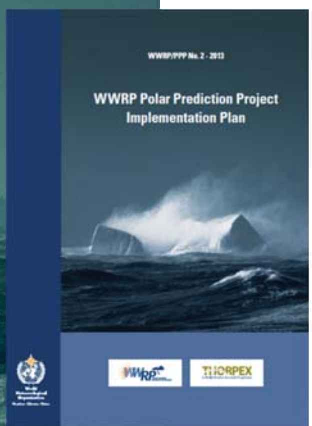


Project Office: KMA/NIMR

- Evaluate potential predictability of sub-seasonal events through a multi-model approach.
- Understand systematic errors and biases in the sub-seasonal to seasonal forecast range
- Focus on specific extreme event case studies increasing resilience and improving adapting capacity.

The Polar Prediction Project

Promote cooperative international research enabling development of improved weather and environmental prediction services for the polar regions, on time scales from hourly to seasonal

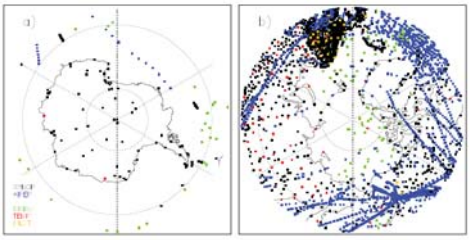


Chair: Thomas Jung, AWI

Project Office: Alfred Wegener Institute, Germany

WWRP: Polar Prediction Project (PPP)

The Science Plan and Implementation Plan are available!



Courtesy T. Jung, AWI

❑ **Objective:**
"Promote cooperative international research enabling development of improved weather and environmental prediction services for the polar regions, on time scales from hourly to seasonal" (contribution to WMO GIPPS)

❑ **Research components**:
- observations, modeling, data assimilation, ensemble forecasting
- predictability, diagnostics, teleconnections
- societal and economic research applications, verification

❑ **Implementation**: Year of Polar Prediction (YOPP) – period 2017-2018

❑ **Synergies** with the WCRP Polar Climate Predictability Initiative (PCPI)

❑ **International Coordination Office**: AWI, Germany

❑ **Trust fund**: from Canada, UK and USA so far, further contributions welcome

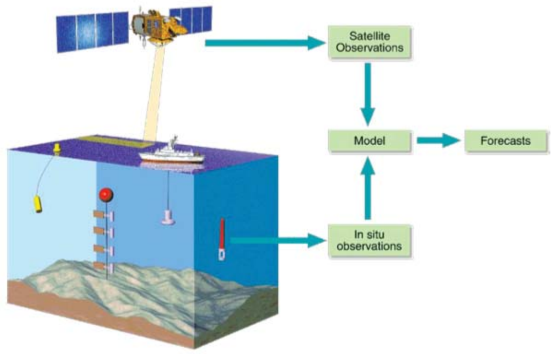
The Year of Polar Prediction

Preparation Phase 2013 to mid-2017	YOPP mid-2017 to mid-2019	Consolidation Phase mid-2019 to 2022
Community engagement	Intensive observing periods & satellite snapshot	Data denial experiments
Alignment with other planned activities	Dedicated model experiments	Model developments
Development of Implementation Plan	Coupled data assimilation	Dedicated reanalyses
Preparatory research	Research into use & value of forecasts	Operational implementation
Summer school Workshops	Intensive verification effort	YOPP publications
Fundraising & Resource mobilization	Summer school	YOPP conference

The Year of Polar Prediction

When: 13-15 July 2015
Where: WMO, Geneva, Switzerland
Attendance: ≈ 180 people

- give an overview of the present level of planning,
- identify stakeholder expectations and requirements,
- develop priorities,
- define intensive observing periods,
- agree on the YOPP data legacy,
- coordinate planned activities, and
- gather formal committments from parties interest in YOPP



High Impact Weather Project

- Increasing resilience to Urban Flood, Wildfire, Urban Heat and Air Pollution in Megacities, Localised extreme wind, Disruptive winter weather through improving forecasts for timescales of minutes to two weeks and enhancing their communication and utility in social, economic and environmental applications
- Implementation Plan (2015-2024) approved by WWRP SSC
- Links to WCRP through quantifying vulnerability and risk assessment, and for response to High Impact Weather in a changing climate.

Chair: Brian Golding, MetOffice

Christof Stache/AFP/Getty Images; Marina Shemesh /publicdomainpictures.net; Alexandros Vlachos/EPA; NOAA NWS; NOAA NWS

Scope defined by a set of hazards

Urban Flood: Reducing mortality, morbidity, damage and disruption from flood inundation by intense rain.

Disruptive Winter Weather: Reducing mortality, morbidity, damage and disruption from snow, ice and fog to transport, power & communications infrastructure.

Wildfire: Reducing mortality, morbidity, damage and disruption from wildfires & their smoke.

Urban Heat Waves & Air Pollution: Reducing mortality, morbidity and disruption from extreme heat & pollution in the megacities of the developing and newly developed world.

Extreme Local Wind: Reducing mortality, morbidity, damage and disruption from wind & wind blown debris in tropical & extra-tropical cyclones, downslope windstorms & convective storms, including tornadoes.

WMO 2016-2019 strategy

Disaster risk reduction: Improve the accuracy and effectiveness of impact-based forecasts and multi-hazard early warnings

Global Framework for Climate Services: Implement climate services under the GFCS particularly for countries that lack them → Sub-seasonal to seasonal

Aviation meteorological services: to provide sustainable high quality services in support of safety, efficiency and regularity of the air transport worldwide

Polar and high mountain regions: Improve operational meteorological and hydrological monitoring, prediction and services in polar and high mountain regions

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World Meteorological Organization

A United Nations Specialized Agency
Working together in Weather, Climate and Water

Thank you for your attention

GAW and WWRP publications available from:
http://www.wmo.int/pages/prog/arep/gaw/gaw-reports.html
and
http://www.wmo.int/pages/prog/arep/wwrp/new/wwrp_new_en.html

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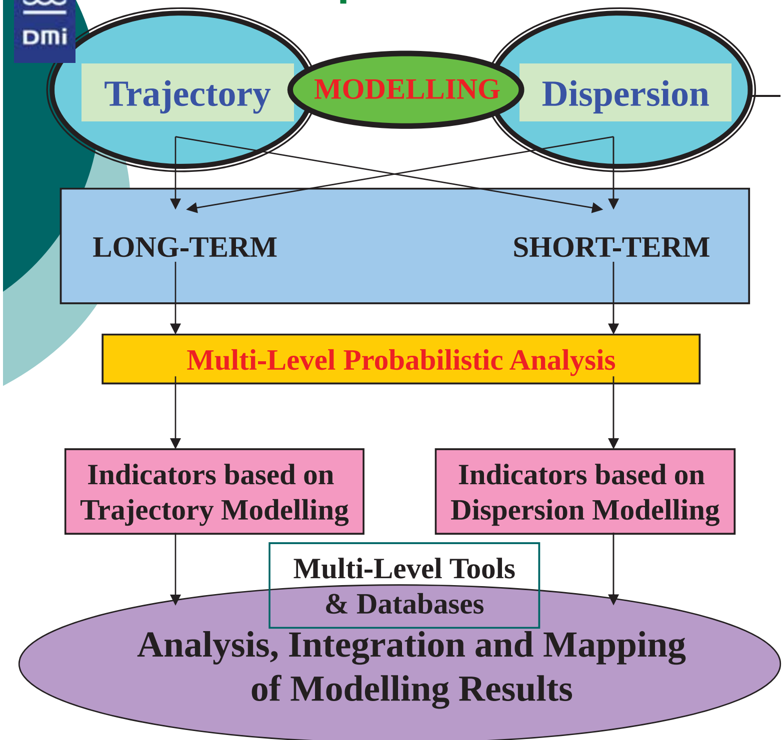
DMI

Applications for Short- and Long-Term Modelling for Atmospheric Patterns & Pollutants in the Arctic



- Identify source regions for elevated/lowered measured pollutant concentrations;
- Evaluate atmospheric transport pathways, dominating airflow patterns;
- Estimate multi-scale concentration and deposition patterns of pollutants;
- Estimate impacts/ risks/ consequences/ etc. on population and environments

MODELS USED:

For Meteorological Modelling -
- **HIRLAM**

HIgh Resolution Limited Area Model
- **NCEP**

National Center for Environmental Prediction
- **ECMWF**

European Center for Medium-range Weather Forecast

For Trajectory and Dispersion modelling –
- **DERMA**

Danish Emergency Response Model for Atmosphere
- **HYSPLIT**
- **CAMx**

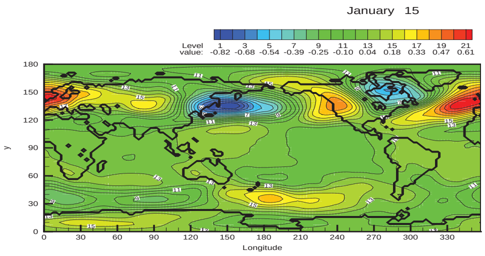
For Aerosol Feedbacks Integrated modelling –
- **Enviro-HIRLAM**

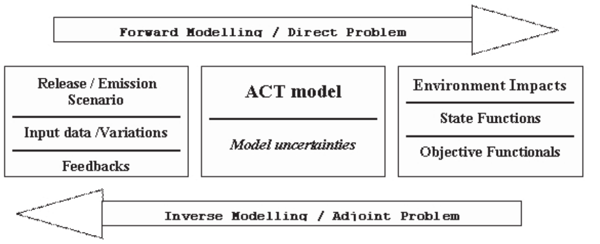
Online coupled Chemistry/Aerosol-Meteorology model

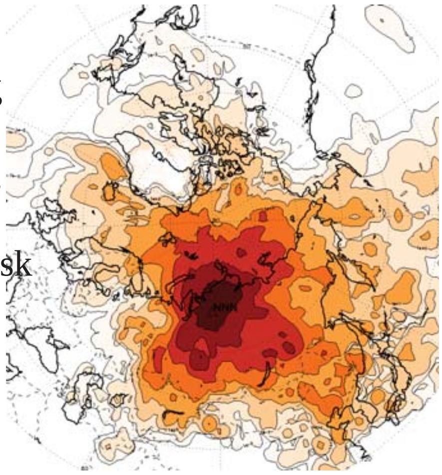
Computing: supported by High Performance Computing grants (+use of NECs & CRAYs supercomputing facilities (EU & USA)

CMM contribution

Direct and Inverse Problems in Variational Concept of Environmental Modelling



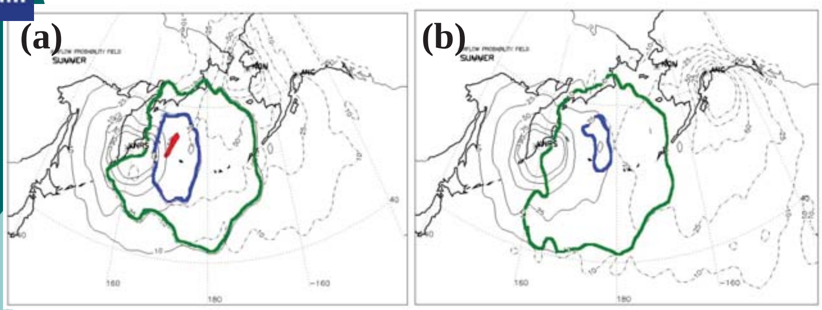




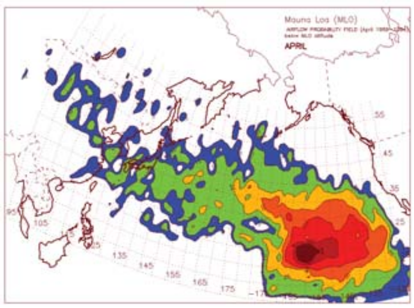
- Development of concept for environmental forecasting
- Algorithms of realisation, variational approach, sensitivity studies, inverse problems, data assimilation, risk assessment, scenario approach, principle factors
- Studies for Siberian and Arctic regions: probabilistic risk assessment and by means of inverse methods

CMM contribution

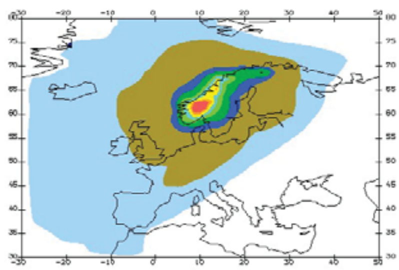
Evaluation of Source-Receptor Relationship for Atmospheric Pollutants



Sensitivity functions for source (KNRS, Kamchatka site, Russia) vs. receptor points: a) Nome (NOM) and b) Anchorage (ANC), Alaska, US.



Airflow probability fields during April for the Mauna Loa observatory, Hawaii, US below the site altitude (3.5 km).

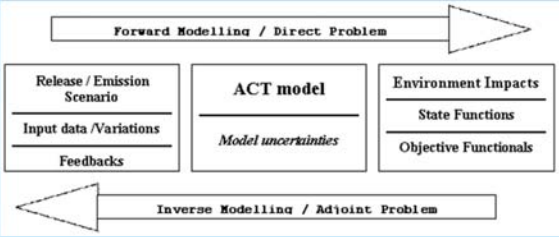


Sensitivity function for Norway

- Methodology based on trajectory (forward and backward) modelling, cluster and probability fields analyses
- Identification of potential source/ receptor regions based on individual trajectories, clustering, probabilistic fields, combined analysis
- Analysis of results of multiple studies based on interpretation of trajectory modelling outputs

Direct and Inverse Modelling for Environmental Risk Assessment and Emission Control in Arctic

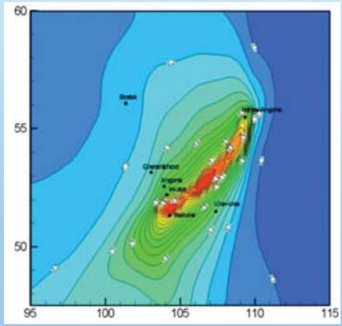
Concept of Environmental Modelling



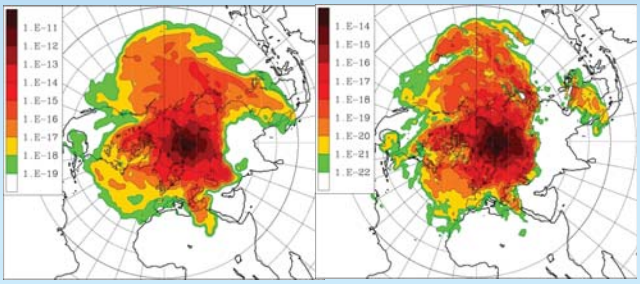
Applications for Arctic and Siberia:

- ***Scenario approach***
- ***Long-term Environmental Impact***
- ***Principle factors***
- ***Risk assessment***

Sensitivity functions:
Total estimates of the relative contribution of pollutant emission from acting and potentially possible sources to the **Baikal Lake**.



Results of the long-term dispersion modelling: annual **time integrated air concentration** & **wet deposition** patterns



for sulphates from the **Norilsk nickel plant**

Risk/vulnerability/sensitivity functions (reference values) for Siberian industrial regions**:**