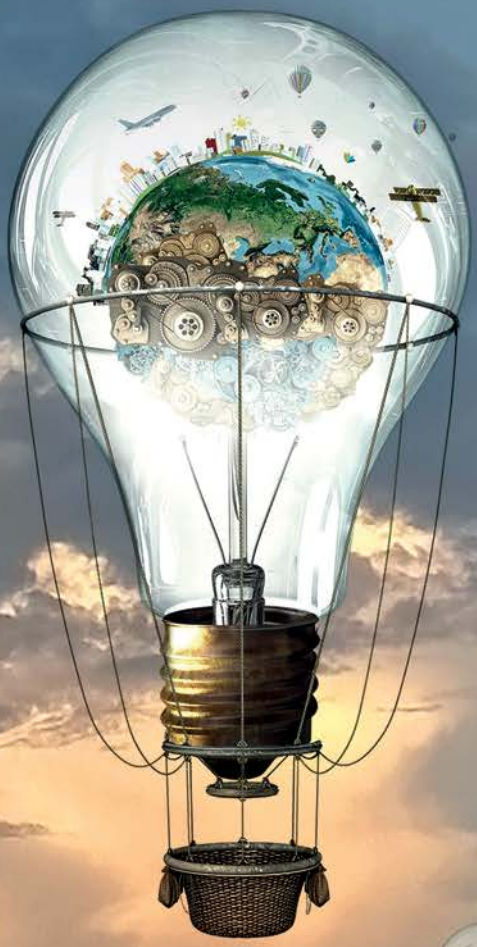
Driving Innovation Together: The World Weather Research Programme



WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

WWRP WORLD WEATHER RESEARCH PROGRAMME

WMO-No. 1191

Chairperson, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 80 40
E-mail: publications@wmo.int

ISBN 978-92-63-11191-3

Cover illustration: WMO photomontage with photos by Vinay Chhalotre and Adobe Stock

Contents

Foreword 3

Driving Innovation Together: The World Weather Research Programme 4

WWRP Mission/goals and how we measure results: excellence, relevance and impact 4

High-Impact Weather Project 5

High-Impact Weather highlights 6

High-Impact Weather looking forward 7

High-Impact Weather Project in figures 8

Polar Prediction Project 9

Polar Prediction Project highlights 10

Polar Prediction Project looking forward 11

Polar Prediction Project Project in figures 12

Sub-seasonal-to-Seasonal prediction project 13

Sub-seasonal-to-Seasonal prediction project highlights 14

Sub-seasonal-to-Seasonal prediction project looking forward 14

Sub-seasonal-to-Seasonal prediction project in figures 16

Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) 17

Objectives of SDS-WAS: 17

Aviation Research Demonstration Project (AvRDP) 18

Objectives of AvRDP: 18

Key publications from the High-Impact Weather, Polar Prediction and Sub-seasonal-to-Seasonal projects since 2014: 19

Foreword

Science and innovation are at the heart of the WMO strategy for improving national capacity to face weather hazards in a changing climate, and to provide better weather and climate related services to all citizens worldwide. The WMO World Weather Research Programme (WWRP) aims to expand the frontier of weather science by exploring new predictive capabilities, connecting weather and climate communities, and improving all elements of the weather information value chain.

Over the last decades, a number of major international research initiatives have accelerated the rate of progress in weather science. For example, the Observing System Research and Predictability Experiment (THORPEX) – a 10-year WWRP project launched in 2003 – led to a significant increase in weather forecast accuracy. However, critical questions arose from its, and other, scientific breakthroughs. These were the focus of the first World Weather Open Science Conference (Montreal, Canada, 2014), jointly organized by Environment and Climate Change Canada and the WWRP. Among the topics discussed were the possible sources of predictability on weekly, monthly and longer time-scales; seamless prediction for the minutes to months ahead; optimal use of local and global observing capabilities and effective massively-parallel supercomputing. Today's state of the art technologies offer a unique opportunity for weather science to address these challenges, a synthesis that forms the backbone of the WWRP implementation plan.

The WWRP aims for 2016–2023 will be achieved through research activities in the three core projects on High Impact Weather, Polar Prediction, and Sub-seasonal to Seasonal prediction. The scientific guidance, technical advice and coordination that the WWRP Working Groups and Expert Teams will bring to these projects, will be key to their success. WWRP aims can be achieved through its projects, dedicated workshops and training opportunities, as well as the strong connection with other programmes and partners to provide a favourable framework for stimulating research activities and collaborations across a broad range of disciplines.

A clear benefit of WWRP activities to WMO Members is in the exchange of scientific and technical knowledge, which help to make the latest advances in research more accessible and usable, especially for developing countries. Projects that demonstrate the use of breakthrough research in an operational framework play a vital role in helping to strengthen national research capacity and services worldwide, and thereby contribute to sustainable development aspirations.

We would like to express our gratitude to all those who contributed to the three core projects of WWRP in the past few years and hope that we can rely on their continued support in the years to come.

(P. Taalas)
Secretary-General

Driving Innovation Together: The World Weather Research Programme

WWRP Mission/goals and how we measure results: excellence, relevance and impact

The WMO World Weather Research Programme (WWRP) promotes international interdisciplinary research aimed at improving the accuracy and reliability of weather and climate forecasts on all timescales – for the next minutes or the seasons ahead. By expanding this frontier of weather science, WWRP plays a role in enhancing resilience to high-impact weather events and the value of weather information. Seamless prediction – the ultimate goal of WWRP – will be realized by increasing the convergence between weather, climate and environmental approaches. To achieve this goal, WWRP strengthens academic partnerships and interdisciplinary collaborations, and enhances the role of Early Career Scientists.

The WWRP plays an essential role in getting questions that have arisen from research addressed in the international arena. Three core projects have been developed by the WWRP to connect past achievements to research that address core challenges to achieving seamless prediction:

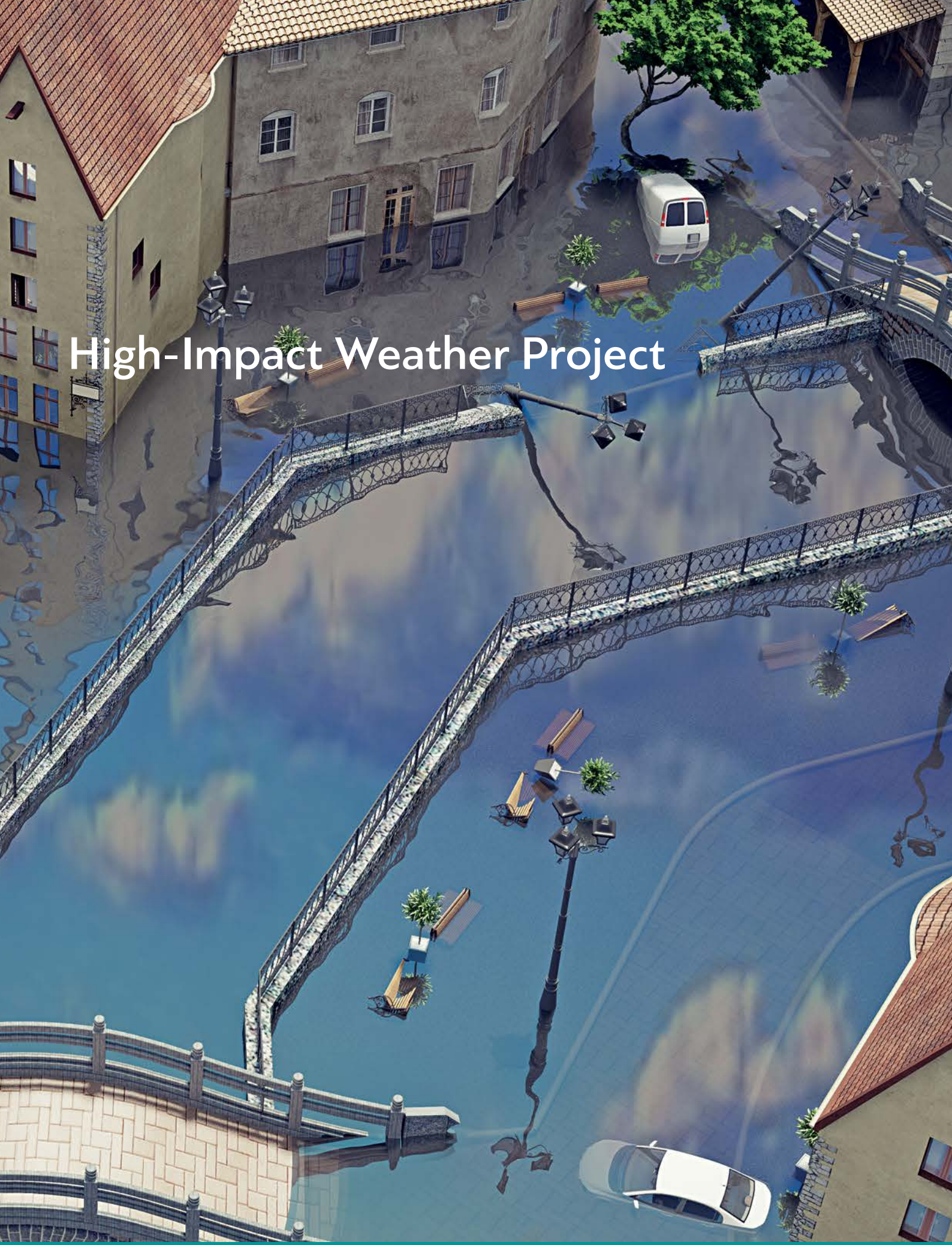
(a) The Sub-seasonal to Seasonal Project (http://s2sprediction.net/), developed and run in collaboration with the World Climate Research (WCRP) Programme, aims to improve forecast skill on sub-seasonal to seasonal timescales, and to promote increased use of S2S information in operational centres and the user community.

(b) The Polar Prediction Project (www.polarprediction.net/) promotes research that explores the requirements for and evaluates the benefits of enhanced prediction information and services for stakeholders in polar regions.

(c) The High-Impact Weather Project (www.wmo.int/pages/prog/arep/wwrp/new/high_impact_weather_project.html) fosters research aimed at achieving a dramatic increase in resilience to high-impact weather worldwide by improving forecasts on timescales of minutes to two weeks and by enhancing their communication and utility in social, economic and environmental applications.

These will guide WWRP research activities for the next decade. All three projects will benefit from the international exchange and interdisciplinary cooperation that has been developed within WWRP. These projects also provide excellent new opportunities to promote collaborative research and knowledge exchange in the framework of the WWRP.

The WWRP has a Scientific Steering Committee (SSC) that provides overall scientific guidance, identifies priorities and makes recommendations on core projects, while its International Coordination Offices support the activities of the three core projects. Progress and achievements are monitored through peer-reviewed based processes that focus on excellence, relevance and impact. This is carried out in SSC meetings and/or through an independent review by a panel of experts that look at the achievements, gaps and unresolved challenges.



High-Impact Weather Project

High-Impact Weather Project

Climate change is expected to increase the frequency and intensity of high-impact weather events, exacerbating their social and economic blow on people and infrastructure, especially in areas experiencing rapid population growth and increasing urbanization. Significant progress and advances in scientific understanding, monitoring and prediction of weather have been made in recent years; however, statistics on weather-related losses show that there are gaps in the application of this knowledge to both the routine and complex weather-related problems faced by society.

The following steps have to be taken to close the gap in the application of scientific breakthroughs to the weather-related problems:

(a) Interdisciplinary collaboration between the research community, stakeholders and users of weather information is required to identify the gaps and address them

(b) Seamless prediction of high-impact weather events at a wide range of scales – from nowcasting to seasonal prediction – must be improved, with a particular focus on smaller scales

(c) Relevant and targeted communication of forecasts and warnings, including information on potential consequences of high-impact events, together with user-oriented verification, is crucial for capitalizing on the achievements made in the prediction of high-impact weather events.

THE HIGH-IMPACT WEATHER PROJECT WILL ADDRESS THESE BY COORDINATING RESEARCH IN FIVE AREAS:

1. Processes and Predictability
2. Multi-scale Forecasting
3. Vulnerability and Risk
4. Communication and
5. Evaluation

THE OUTCOMES FROM ALL FIVE AREAS ARE GOVERNED BY THE FOLLOWING PRINCIPLES:

(a) Application in the operational forecasting process

(b) Observing networks that support small and large scale capability

(c) Uncertainty predictability from meteorology to hazards and the reaction of people

(d) Field campaigns and demonstration projects to build local capacity and understanding

(e) Knowledge transfer in the areas of forecasting, warnings and communication

(f) Verification to inform and evaluate research

(g) Impact forecasting that will mitigate weather-related hazard impacts

(h) Data management and archiving.

High-Impact Weather highlights

North Atlantic Waveguide and Downstream Impact Experiment (NAWDEX) (nawdex.ethz.ch/index.html)

The goal of NAWDEX is to increase physical understanding of the effects of diabatic processes on disturbances to the jet stream near North America, as well as their influence on downstream propagation across the North Atlantic, and their consequences for high-impact weather in Europe. The NAWDEX field campaign, conducted from 19 September to 16 October 2016, sampled key dynamics and processes associated with the triggering, propagation and downstream impact of disturbances along the North Atlantic waveguide, providing a unique observational dataset. NAWDEX focuses on both weather and climate timescales. It addresses one of

the four key questions of the Grand Challenges of the World Climate Research Programme, namely on Clouds, circulation and climate sensitivity (www.wcrp-climate.org/grand-challenges/gc-clouds).

EXPECTED OUTCOMES:

1. NAWDEX will increase knowledge of the physical and social factors limiting our capability to predict, communicate and mitigate high-impact weather events

2. NAWDEX will identify how these limitations can be overcome

3. NAWDEX will demonstrate resulting improvements for specific high-impact weather events at short to long lead times, from global to local, for different users in different parts of the world.

High-Impact Weather looking forward

During 2016, High-Impact Weather project leaders identified national research activities to support its goals in the Australia, Germany, New Zealand, Switzerland, United Kingdom (UK) and United States of America (US). Doctorial positions were identified at Massey University (New Zealand) and the Swiss Federal Institute of Technology in Zurich (ETHZ) to lead projects on:

1. the use of unconventional observations for impact forecasting/evaluation of warnings

2. relevance of governance structures to early warnings decision-making processes, respectively.

These initiatives will foster methods to verify forecasts and warnings of high-impact weather and their consequences. They will also demonstrate the benefit of these methods and our current ability to simulate high-impact weather events.

Waves to Weather (W2W)

This European project is closely linked to High-Impact Weather in that it aims to deliver the underpinning science for a new generation of weather forecasting systems. W2W will use and further develop a broad range of tools, including numerical models with detailed treatment of cloud processes and aerosols and ensemble forecasts with sophisticated statistical post-processing to describe uncertainty. Improved insight will be gained through the development of interactive visualization methods, which will enable rapid exploration of forecast ensembles to identify the sources and evolution of uncertainty. The European consortium uses an innovative approach for the development of early-career researchers within a strong network of experienced colleagues. This initiative will last 12 years.

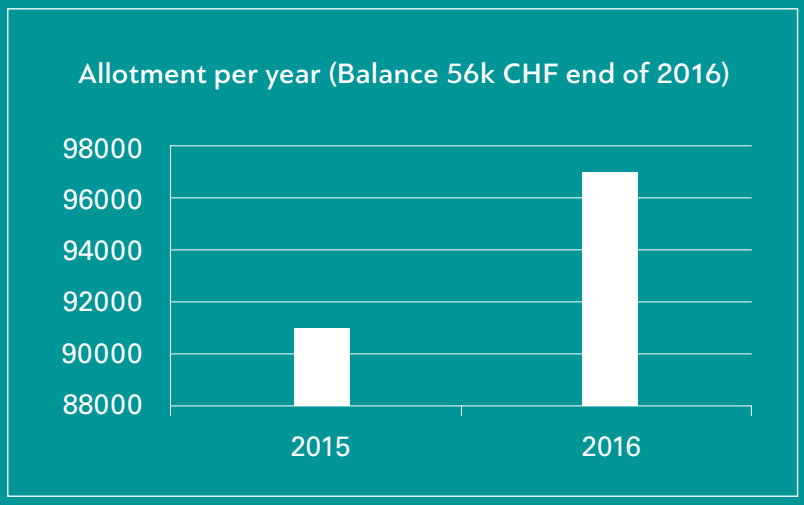
HIGH-IMPACT WEATHER LIST OF DIRECT DONORS:

- THE MET OFFICE (UK)
- ENVIRONMENT AND CLIMATE CHANGE CANADA (Canada)
- NORWEGIAN METEOROLOGICAL INSTITUTE (Norway)
- DEUTSCHER WETTERDIENST (Germany)

HIGH-IMPACT WEATHER LIST OF INDIRECT DONORS:

- Hosting of meetings: China, UK
- Hosting of communication website: New Zealand
- Field campaign funding for NAWDEX by various donors

High-Impact Weather Project in figures



High-Impact Weather

+

Interaction with users

+

Communication

=

Better decision making
for aviation

The illustrations shown in this diagram are only examples

Polar Prediction Project

Polar Prediction Project

The regions of the Arctic and Antarctic are attracting growing interest due to concerns about the amplification of anthropogenic climate change. Increasing economic activities and transportation in polar regions are driving demand for sustained and improved availability of integrated observational and predictive weather, climate and water information in support of decision-making processes. However, partly as a result of the strong emphasis in previous international efforts on lower and middle latitudes, there are many gaps in weather, sub-seasonal and seasonal forecasting in both regions.

The goal of the WWRP Polar Prediction Project is to promote cooperative international research to enable the development of improved weather and environmental prediction services for the two regions on time scales from hours to seasonal. This project constitutes the hours-to-seasonal research component of the emerging WMO Global Integrated Polar Prediction System (GIPPS). A closely related WCRP Polar Climate Predictability Initiative covers GIPPS research on seasonal-to-decadal time scales.

The Polar Prediction Project identified eight key research goals in order to meet the growing demand for skillful and reliable predictions in polar regions and beyond:

(a) Improve the understanding of the requirements for, and evaluate the benefits of, enhanced prediction information and services in polar regions

(b) Establish and apply verification methods appropriate for polar regions

(c) Provide guidance on optimizing polar observing systems, and coordinate additional observations to support modelling and verification

(d) Improve representation of key processes in models of the polar atmosphere, land, ocean and cryosphere

(e) Develop data assimilation systems that account for the unique characteristics of polar regions

(f) Develop and exploit ensemble prediction systems with appropriate representation of initial condition and model uncertainty for polar regions

(g) Determine predictability and identify key sources of forecast errors in polar regions

(h) Improve knowledge of two-way linkages between polar and lower latitudes, and their implications for global prediction.

Polar Prediction Project highlights

Historically, WMO is one of the few international organizations that uses large field campaigns to improve scientific knowledge. Examples are its Global Atmospheric Research Programme (GARP) and Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment (TOGA COARE). The Polar Prediction Project requires enhancing international and interdisciplinary collaboration by developing strong linkages with related initiatives, strengthening linkages between academia, research institutions and operational forecasting centres and promoting interaction and communication between research and stakeholders. The first White House Arctic Science Ministerial meeting in Washington, D.C., on 28 September 2016, which convened high-level officials from 25 countries to discuss Arctic research priorities, satisfied this requirement. The follow-up fact sheet lists the Year of Polar Prediction (YOPP) as a major WMO activity aiming to significantly improve environmental prediction capabilities for the polar region and beyond. Preparation for YOPP (2018–19) has started during 2015.

To foster education and outreach, the First Polar Prediction School was conducted at Abisko, Northern Sweden. Twenty-nine early career polar scientists from

16 countries gathered for this event, held 5–15 April 2016 at the Abisko Field Station.

Polar Prediction Project looking forward

The Year of Polar Prediction (YOPP) is one of the key elements of the Polar Prediction Project. YOPP is scheduled to take place from mid-2017 to mid-2019. By coordinating a period of intensive observing, modelling, verification, user engagement and education activities, YOPP will enable a significant improvement in environmental prediction capabilities for the polar regions and beyond. YOPP will contribute to the knowledge base needed to manage the opportunities and risks that come with polar climate change. Funding proposals were also approved for funding to ensure the needed support for future research. A series of short videos about research (i.e., Frostbytes – see http://www.youtube.com/user/apecsis) is planned, which will act both as a tool for dissemination of PPP scientific findings and to provide science communication training to those who produce them.

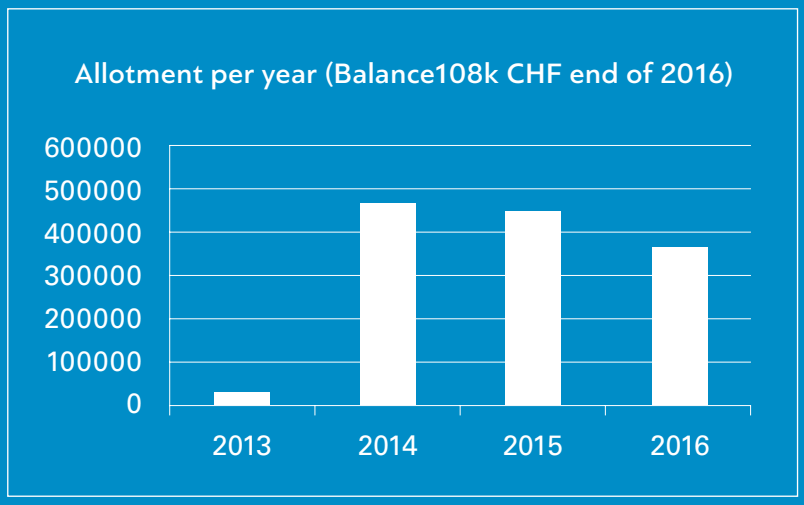
POLAR PREDICTION PROJECT LIST OF DIRECT DONORS:

- THE MET OFFICE (UK)
- ENVIRONMENT AND CLIMATE CHANGE CANADA (Canada)
- NORWEGIAN METEOROLOGICAL INSTITUTE (Norway)
- DEUTSCHER WETTERDIENST (Germany)
- BUREAU OF METEOROLOGY (Australia)

POLAR PREDICTION PROJECT LIST OF INDIRECT DONORS:

- European Union Commission EU Horizon 2020
- Hosting of meetings (PPP): Canada, Italy, Norway, Spain, United Kingdom of Great Britain and Northern Ireland
- International Coordination Office (ICO) for PPP: Germany, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI)

Polar Prediction Project Project in figures



Optimised observation networks

+

Process in models

+

Data assimilation

=

Improved global predictions

The illustrations shown in this diagram are only examples

Sub-seasonal-to-Seasonal prediction project

Sub-seasonal-to-Seasonal prediction project

The Sub-seasonal-to-Seasonal prediction project (S2S) started in 2013 as a collaborative structure set up by WCRP, WWRP and THORPEX for an initial 5 years, with a possible extension subject to positive review of progress and achievements and a need to fill any important remaining research gaps. The goals of this project are:

(a) To improve forecast skill and understanding on the sub-seasonal to seasonal timescale with special emphasis on high-impact weather events

(b) To promote the uptake of results by operational centres and exploitation by the applications community

(c) To capitalize on the expertise of the weather and climate research communities to address issues of importance to the Global Framework for Climate Services.

RESEARCH PRIORITIES:

(a) Evaluate potential predictability of sub-seasonal events, including identifying windows of opportunity for increased forecast skill

(b) Understand systematic errors and biases in the sub-seasonal to seasonal forecast range

(c) Compare, verify and test multi-model combinations from these forecasts and quantify their uncertainty

(d) Focus on some specific extreme event case studies.

Sub-seasonal-to-Seasonal prediction project highlights

The Sub-seasonal-to-Seasonal Database (Data Portals at the European Centre for Medium-Range Weather Forecasts (ECMWF) and China Meteorological Administration (CMA)): More than ten models are now available in the database, which has more than 700 registered users from roughly 60 countries – and the numbers are increasing. About 12 Tb of data are downloaded per month from the ECMWF and CMA data servers by 70 active users. Using this data, current studies are assessing the skill of the S2S models and identifying their strengths and their weaknesses. This data set provided an ideal testbed for the development of new products, like those that identify signals for extreme events at the sub-seasonal timescale.

The Sub-seasonal-to-Seasonal Prediction and Application to Drought Prediction two-week capacity-building school was conducted in Italy in 2015. This event aimed to make the new S2S database as usable as possible for some 45 researchers tackling different predictability studies, all from developing countries. Additional S2S training events were organized in Cameroon (July 2016) and Senegal (November 2016) using hands-on exercises to access and exploit the S2S database.

Sub-seasonal-to-Seasonal prediction project looking forward

The Modeling, Analysis, Predictions and Projections (MAPP) Program of the National Oceanic and Atmospheric Administration's (NOAA) Climate Program Office has awarded 14 research projects on Sub-seasonal-to-Seasonal Prediction. This will represent an important contribution to the S2S research plans for the near future.

The S2S project team is currently busy writing the needed reports and future plans to extend the initial five-year project for the five additional years that will be needed to address their research goals and complete the research projects started in 2014.

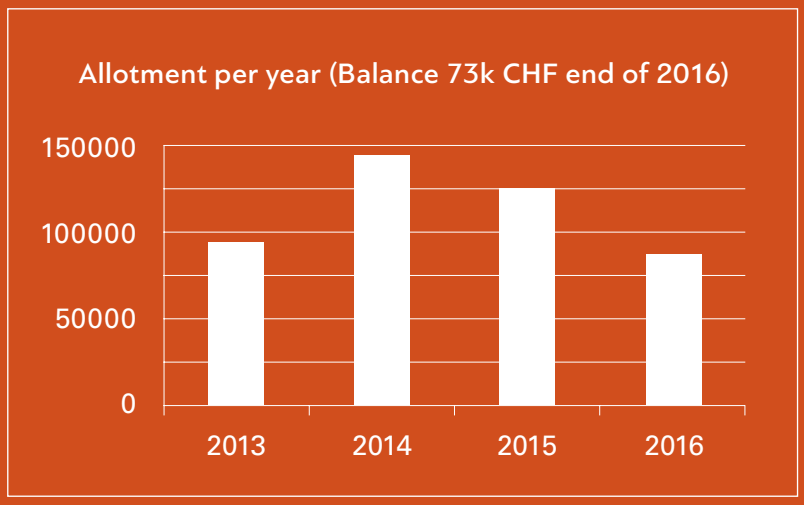
SUB-SEASONAL-TO-SEASONAL PREDICTION PROJECT LIST OF DIRECT DONORS:

- THE MET OFFICE (UK)
- ENVIRONMENT AND CLIMATE CHANGE CANADA (Canada)
- BUREAU OF METEOROLOGY (Australia)

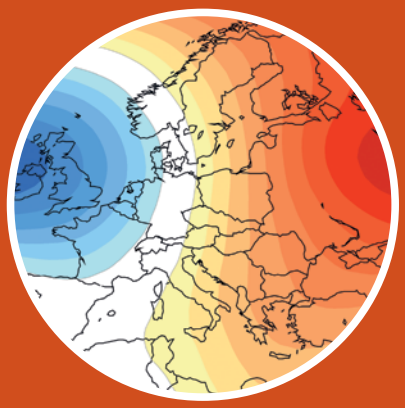
SUB-SEASONAL-TO-SEASONAL PREDICTION PROJECT LIST OF INDIRECT DONORS:

- European Union Commission EU Horizon 2020
- Hosting of meetings (S2S): Cameroon, China, USA, Canada, Italy, Senegal, South Korea, UK
- International Coordination Office (ICO) for S2S: South Korea
- Hosting of S2S databases: ECMWF (UK) and CMA (China)

Sub-seasonal-to-Seasonal prediction project in figures



Extended data base of sub-seasonal predictions

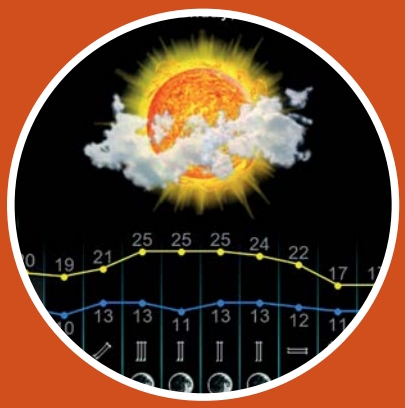


+

Compare, verify and test

+

Improved use of products and applications



=

Better decision making for farmers

The illustrations shown in this diagram are only examples

Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)

WMO established SDS-WAS in 2007 when 40 of its Members expressed their intent to improve capabilities for more reliable sand and dust storm forecasts. Research forecasting products from atmospheric dust models may contribute substantially to risk reduction in many socio-economic areas. Today, more than 15 organizations in different geographic regions provide daily dust forecasts – societal benefits depend on the real-time delivery of their products. SDS-WAS integrates research and user communities, for example, medical, aeronautical and agricultural users). SDS-WAS consists of a federation of partners organized around regional nodes. It operates through the Global SDS-WAS Steering Committee and three regional nodes:

(a) WMO SDS-WAS Regional Centre for Northern Africa, Middle East and Europe, coordinated by a Regional Centre in Barcelona, Spain, hosted by the State Meteorological Agency (AEMET) and the Barcelona Supercomputing Centre (BSC)

(b) WMO SDS-WAS Regional Centre for Asia, coordinated by a Regional Centre in Beijing, China, that is hosted by the China Meteorological Administration (CMA)

(c) WMO SDS-WAS Regional Centre for the Americas, recently established in the USA, with a possible regional centre hosted by the Caribbean Institute for Meteorology and Hydrology (CIMH) in Barbados, will focus on the health implications of airborne dust.

The SDS-WAS mission is to achieve comprehensive, coordinated and sustained observations and modelling capabilities in order to improve the monitoring of sand and dust storms. The aim is to enhance its sand and dust storm prediction capabilities by increasing understanding of dust processes.

Objectives of SDS-WAS:

(a) To enhance operational SDS forecasts through technology transfer from research

(b) To improve observation technology

(c) To provide users access to forecasts and observations

(d) To promote research and applications related to the sand and dust storm process

(e) To build capacity of countries to utilize SDS products

(f) To build bridges with other relevant communities.

SAND AND DUST STORM WARNING ADVISORY AND ASSESSMENT SYSTEM LIST OF INDIRECT DONORS:

- Hosting of meetings: Jordan, China, South Korea, Turkey

Aviation Research Demonstration Project (AvRDP)

The overall mission of the AvRDP is to, through international collaboration, develop, demonstrate and quantify the benefits of end-to-end nowcasting of aviation weather services for terminal area, with a focus on high impact weather. AvRDP will focus on nowcasting aviation weather, including the respective uncertainty/confidence estimation, over the Terminal Control Area for 0–6 hours ahead. Worldwide, six airports are participating in the project. More details on the project can be found on its official website (http://avrdp.hko.gov.hk).

Objectives of AvRDP:

AvRDP will preliminarily focus on a number of scientific questions:

(a) What is the current state-of-art nowcasting and mesoscale modelling techniques applicable for Meteorological Services for Terminal Area? In other words, what is the gap between the current meteorological capability and the expected meteorological capability in Aviation System Block Upgrade?

(b) What would be the suitable aviation nowcasting and modelling methodologies, deterministic and probabilistic, for meeting the Aviation System Block Upgrade requirements?

(c) How to evaluate the performance of aviation nowcast/forecast products for continuous improvement monitoring?

(d) How to transfer the technology to WMO Members for enhancing their capability for the provision of Meteorological Services for Terminal Area and trajectory based operations to meet the Aviation System Block Upgrade requirements?

APART FROM THE ABOVE MET RESEARCH, AVRDP WILL ALSO ADDRESS A NUMBER OF OPERATIONAL ISSUES:

(a) How to translate the meteorological nowcast/forecast products into aviation impact?

(b) How to integrate the meteorological information, including uncertainty/confidence information, into Air traffic managment operation/decision?

(c) How to quantify the benefits of the new meteorological information from Air traffic managment perspective?

(d) Which type of new meteorological information should be included as standard or recommended practices for high density airports?

AVIATION RESEARCH DEMONSTRATION PROJECT LIST OF INDIRECT DONORS:

- Hosting of meetings: China

Key publications from the High-Impact Weather, Polar Prediction and Sub-seasonal-to-Seasonal projects since 2014:

(Early Release) The Sub-seasonal to Seasonal Prediction (S2S) Project Database. Available at: http://s2sprediction.net/file/documents_publications/bams-d-16-0017.pdf.

Bauer, P., Thorpe, A. and Brunet, G. 2015. The quiet revolution of numerical weather prediction. Nature 525, 47–55 (03 September 2015) doi:10.1038/nature14956.

Goessling, H.F., Jung, T., Klebe, S., Baeseman, J., Bauer, P., Chen, P., Chevallier, M., Dole, R., Gordon, N.D., Ruti, P., Bradley, A., Bromwich, D.H., Casati, B., Chechin, D., Day, J.J., Massonet, F., Mills, B., Renfrew, I.A., Smith, G., Tatusko, R. 2016. Paving the Way for the Year of Polar Prediction, *Bulletin of the American Meteorological Society*. doi: http://dx.doi.org/10.1175/BAMS-D-15-00270.1http://dx.doi.org/10.1175/BAMS-D-14-00246.1

Jung, T., Gordon, N.D., Bauer, P., Bromwich, D.H., Chevallier, M., Day, J.J., Dawson, J., Doblas-Reyes, F., Fairall, C., Goessling, H.F., Holland, M., Inoue, J., Iversen, T., Klebe, S., Lemke, P., Losch, M., Makshtas, A., Mills, B., Nurmi, P., Perovich, D., Reid, P., Renfrew, I.A. , Smith, G., Svensson, G., Tolstykh, M. and Yang, Q. 2016. Advancing polar prediction capabilities on daily to seasonal time scales, *Bulletin of the American Meteorological Society*. doi:10.1175/BAMS-D-14-00246.1

Jung, T., Francisco Doblas-Reyes, Helge Goessling, Virginie Guemas, Cecilia Bitz, Carlo Buontempo, Rodrigo Caballero, Erko Jakobson, Johann Jungclaus, Michael Karcher, Torben Koenigk, Daniela Matei, James Overland, Thomas Spengler and Shuting Yang. 2015. Polar Lower-Latitude Linkages and Their Role in Weather and Climate Prediction. *Bulletin of the American Meteorological Society*, 96, ES197–ES200, doi: dx.doi.org/10.1175/BAMS-D-15-00121.1.

Robertson, A.W., Kumar, A., Pena, M. and Vitart, F. 2015. Improving and Promoting Subseasonal to Seasonal Prediction. BAMS, 96, ES49-ES53.

Spengler, T., I. Renfrew, A. Terpstra, M. Tjernström, J. Screen, I. Brooks, A., Carleton, D. Chechin, L. Chen, J. Doyle, I. Esau, P. Hezel, T. Jung, T. Kohyama, C. Lüpkes, K. McCusker, T. Nygård, D. Sergeev, M. Shupe, H. Sodemann and T. Vihma, 2016. High Latitude Dynamics of Atmosphere-Ice-Ocean Interactions. *Bulletin of the American Meteorological Society* doi:10.1175/BAMS-D-15-00302.1, in press.

Thoman Jr., R., J. Dawson, D. Liggett, M. Lamers, E. Stewart, G. Ljubicic, M. Knol and W. Hoke, 2016. Second Polar Prediction Project (PPP) Societal and Economic Research and Applications (SERA) Meeting focused on end user use of weather and climate information. *Bulletin of the American Meteorological Society*. doi:10.1175/BAMS-D-16-0195.1, in press.

WWOSC book "Seamless Prediction of the Earth System: from Minutes to Months", 2015. (chapter 19) – available online at http://library.wmo.int/pmb_ged/wmo_1156_en.pdf.

WWOSC book "Seamless Prediction of the Earth System: from Minutes to Months", 2015. (chapter 20) – available online at: http://library.wmo.int/pmb_ged/wmo_1156_en.pdf.

For more information, please contact:

World Meteorological Organization

Research Department

World Weather Research Programme

7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland

Tel.: +41 (0) 22 730 81 11 – Fax: +41 (0) 22 730 81 81

E-mail: cpa@wmo.int

Website: http://www.wmo.int/pages/prog/arep/wwrp/new/wwrp_new_en.html

JN 17380