Targeted Research for Improved Services:

WWRP Implementation Plan 2016-2023

Supporting Activities by Projects and Working Groups

(2nd Booklet – Draft 8Apr2016)

Introduction

This is a companion document to the main WWRP Implementation Plan 2016-2023.

It provides planned activities by Projects and Working Groups to support the overall WWRP programmatic goals for each of the four Themes and 18 Action Areas listed in that document.

It also gives more detail on planned education, training, and capacity building activities to facilitate progress on research, and transfer from research into operations.

In square brackets after each bullet-pointed activity are given the projects and working groups involved, including collaborations with key partners outside WWRP.

High-impact Weather :
And its socio-economic effect in the context of global change

Action Areas

The Action Areas for this Theme *Address Limitations*, cope with *Uncertainty,* use *Fully Coupled* models, develop *Applications*, apply *Verification*, and assist with *Attribution* of events to climate variability and change.

AA 1: ADDRESS LIMITATIONS

Increase knowledge of the factors limiting the capability to predict, communicate and mitigate the impacts of high-impact weather events; identify how these limitations can be overcome; demonstrate the resulting improvements for specific high-impact weather events from minutes to months, from global to local, for different users in different parts of the world

Use diagnostic and verification information to identify capabilities and limitations in predictions of high-impact weather on time scales out to seasonal

- Promote research into atmospheric error growth at km-scale so as to inform data assimilation and ensemble methodologies, as well as to support predictability assessments [HIWeather, DAOS, PDEF, NMR, WGNE]
- Continue to develop the S2S database and use it to assess state-of-the art models and their skill at predicting high-impact weather events such as tropical cyclones, heat/cold waves and their socio-economic impacts [S2S, WGTMR]
- Assess the capability of, and opportunities to improve, predictions of tropical cyclone landfall and its impacts, and predictions of severe monsoon weather phenomena and their impacts [WGTMR]
- Promote FSOI (Forward Sensitivity Observation Impact) and other tools which verify against observations as a more precise way of diagnosing the areas where there are model deficiencies [DAOS]
- Improve the observational and algorithmic tools used to identify, ameliorate and/or represent systematic and stochastic elements of model error [PDEF]
- Hold workshops on systematic model errors, and conduct projects which use sensitivity experiments to understand differences and deficiencies in parameterizations [WGNE]
- Carry out research into verification methods appropriate to identifying limitations in model predictions on all scales; and to documenting and quantifying model improvements resulting from research [JWGFVR]

Through targeted research on specific meteorological processes associated with high-impact weather (e.g., convection, scale interactions, etc.) improve understanding of those processes, and where possible develop the observational, algorithmic and numerical capacity to better predict them

- Conduct research and development in nowcasting and mesoscale modelling at specific airports to assess capabilities and address limitations in support of aviation trajectory based operations [AvRDP, NMR]
- Support and facilitate participation from the mesoscale modelling community in projects involving modelling physical processes (e.g., WGNE Grey Zone, GLASS/GABLS-4) ; ensure that improved understanding of high resolution modelling of physical processes is included in RDPs, as appropriate) [NMR, with WGNE]
- Conduct research into priority areas, including high-resolution modelling and dust interaction with clouds and radiation [SDS-WAS]
- Conduct research on improved predictions of tropical cyclone landfall and associated impacts, unusual behaviour of tropical cyclones, tropical cyclogenesis, severe convective events in monsoons, and monsoon onset and intraseasonal oscillations through FDPs and RDPs [WGTMR]

Through targeted research increase abilities to observe, understand, and predict variability and changes of the coupled air-ocean-ice-land system in polar regions, and specifically to advance forecasts and services for high-impact variables such as sea ice from hourly to seasonal time scales

- Address limitations on polar prediction through the Year of Polar Prediction (YOPP) core phase (mid-2017 to mid-2019) and subsequent consolidation phase [PPP, S2S, DAOS, PDEF, NMR, WGNE, SERA]

Achieve better understanding of where, when, how and why weather has high-impact, including how meteorological and socio-economic conditions antecedent to specific high-impact weather events contribute to their high-impact, and why some forecast users fail to act

- Investigate the relationship between meteorology and its impact for five selected hazard areas (floods, high winds, wildfires, disruptive winter weather, heatwaves and pollution) [HIWeather, SERA]
- Gather and review information on how people respond to warnings, and develop guides to good practice on how to communicate so as to optimise the response [HIWeather, SERA]

Incorporate better understanding of vulnerability and risk in forecasts of high-impact weather through seamless modelling and conceptual approaches

- Review evidence and develop guides to good practice on modelling impact as a function of hazard and vulnerability; considerations will include the availability and use of vulnerability data in different countries, and the dynamics of vulnerability as people move around during their daily/weekly/seasonal activities, and how to represent this in predictive models [HIWeather, SERA]

Increasingly work with social scientists, hydrologists, wave and storm surge forecasters and other users of high-impact weather information as science partners to develop more effective hazard forecasts and warnings and improve community response

- Conduct an RDP on "Understanding the societal and economic dimensions of weather-related warnings systems" [SERA]

Transfer new science on effective communication, including appropriate strategies for different societies, into operational weather forecasting

- Prepare guidance on communicating warnings and the application of social media [SERA]
- *** More (or combined activities with SERA) from HIWeather?

Support operational demonstrations of end-to-end high-impact weather and impact prediction, improved decision making, and evaluation

- Engage with SWFDPs, and sponsor FDPs that offer an opportunity to demonstrate and evaluate HIWeather research, both in the improvement of hazard forecasts and in their use in warnings [HIWeather, NMR, with CBS]
- Carry out case studies to demonstrate the capability of S2S models to predict high-impact weather events, and the usefulness of S2S forecasts from improved decision making [S2S]
- Test and demonstrate improved polar predictions as part of YOPP [PPP, SERA, JWGFVR]
- Test and demonstrate improved meteorological services in the terminal area and derived ATM products [AvRDP, NMR, JWGFVR, with CAeM]
- Test and implement sufficiently mature and evaluated research SDS-WAS components into operations tailored to needs of end-user communities (aviation, health, ground transport, agriculture) [SDS-WAS]
- Improve high-impact tropical weather prediction through TLFDP (Typhoon Landfall Forecast Demonstration Project) extended to 2018, SCMREX (South China Monsoon Rainfall Experiment) extended to 2018, and UPDRAFT (Understanding and Prediction of Rainfall Associated with Landfalling Tropical Cyclones) [WGTMR]

AA 2: UNCERTAINTY
Identify and characterise analysis and forecast uncertainty, and develop communication mechanisms which support decision making

Improve quantitative description of the uncertainty of the analysis state and its evolution forward in time – not only of meteorological fields in standard analysis/forecast error covariance sense, but also of impacts

- Intercompare data assimilation approaches for km-scale prediction, including knowledge of initial uncertainty [HiWeather, DAOS, NMR]
- Explore the predictability and reliability of sub-seasonal to seasonal forecasts and use of ensembles, through use of the S2S database [S2S]

- Share advanced methods for estimating forecast-error covariances in data assimilation as part of the 4-yearly international WMO Symposium on data assimilation [DAOS]
- Encourage theoretical and observational based research, including the specification of perturbations, aimed at producing ensembles that more accurately represent the distribution of possible true states at analysis and forecast times [PDEF]
- Conduct workshops on estimating model uncertainty in data assimilation and ensemble forecasts [DAOS, PDEF, WGNE]
- Encourage the development of quantitative measures of uncertainty in observations used in verification; develop and promote the use of methods of expressing uncertainty in verification measures [JWGFVR]

Co-design communication mechanisms of uncertainty with users (e.g., civil protection)

- Assess and provide guidance on best practices for communication of risk and uncertainty, including from "warn-on-forecast" systems [HIWeather, SERA]
- Determine the confidence level of ATM-translated products (deterministic or probabilistic) through collaboration with ATM experts to facilitate their risk assessment and decision-making [AvRDP]
- Ensure the inclusion in FDPs of both probabilistic services and the involvement of external users [NMR]

Improve ensemble-based meteorological predictions to be more reliable and better resolving, and connect hazard probability (weather event) to impacts on space and time scales where decisions are made

- Address issues of ensemble prediction at km-scale, including specification of perturbations [HIWeather, NMR]
- Provide guidance to operational centres on best practice for sub-seasonal prediction, including ensemble generation [S2S]
- Develop stochastic physics techniques, ensuring that the scientific basis of these is physically sound, and consistent across weather and climate timescales [WGNE]
- Explore the predictability of the atmosphere-cryosphere-ocean, with a focus on sea ice, on time scales from days to a season [PPP, NMR, WGNE]
- Explore the predictability of tropical cyclones and monsoons on different time scales, focusing on development of predictability theory, methods, and techniques [WGTMR]
- Develop Sand and Dust Storm user-oriented warning systems based on probabilistic ensemble predictions [SDS-WAS]

Develop improved diagnostics and verification tools from high resolution ensembles that assist operational forecasters in predicting and warning for high-impact weather; "warn on forecast" will get closer to reality

- Use evidence from existing "warn-on-forecast" systems as exemplars to share strengths and weaknesses of extending warning lead times in this way [HIWeather]
- Assess how to measure the skill of risk-based warnings, and how to measure responses to warnings [HIWeather, JWGFVR, SERA]

- Develop polar-specific forecast verification methods, in particular related to sea ice, as a prerequisite to quantify analysis and forecast error/uncertainty [PPP, JWGFVR]
- Determine the confidence level of terminal area aviation forecasts by using statistical or ensemble techniques to quantify their uncertainties [AvRDP, NMR, JWGFVR]
- Continue to promote research into best verification practices for probabilistic forecasts, taking into account the needs of users [JWGFVR]

AA 3: FULLY COUPLED

Work with different science communities to ensure that modelling systems fully integrate all relevant components of the earth system; link to and utilise socio-economic models and data to assess impacts

Improve, develop and assess fully coupled data assimilation systems, including all earth system components

- Develop improved (coupled) data assimilation systems accounting for challenges in the polar regions such as sparseness of observational data [PPP, DAOS]
- Assess the impact of coupled versus uncoupled assimilation on coupled predictions of the various environmental system components (atmosphere, land, sea ice, ocean, wave, snow) [PPP, DAOS]
- Study the impact of coupled data assimilation on S2S forecasts [S2S, DAOS]
- Develop and test operational capabilities of dust models based on assimilated dust-related data (from lidars, satellites, ceilometers, etc.) [SDS-WAS, DAOS]
- Organize workshops on coupled data assimilation, which facilitate the initialization of improved coupled forecast models and provide a tool for exploring the realism of coupled simulations [DAOS]
- Assess the present state of, and promote, the use of a wide range of high resolution remote sensing observations in combination with advanced surface assimilation algorithms, in order to enhance the description of the surface and the surface-atmosphere interaction [NMR, DAOS]

Investigate the assimilation of impact data (e.g., fire spread) in coupled numerical modelling

- Support and promote activities coupling nowcasting/NWP systems to observations and models of impact (e.g., coupled fire modelling and assimilation efforts in Australian Bushfire & Natural Hazards Cooperation Research Centre) [NMR]

Demonstrate coupled analysis/reanalysis capabilities

- Support and facilitate high resolution coupled reanalysis proof of concept projects [NMR]
- Update current global and regional model reanalyses by assimilating newly available dust-related observations [SDS-WAS]

Work with social scientists in development of assimilation systems for socio-economic models that will ultimately lead to the coupling/linking of these models with physical models

- Develop and promulgate guidelines for good practice in impact forecasting, and investigate opportunities for integrating impact prediction into coupled hazard models [HIWeather, SERA]

Develop cross-domain coupled modelling systems, in partnership with scientists and users from other disciplines, that integrate weather and other data to meet user needs, and evaluate their effectiveness according to user-relevant metrics

- Facilitate progress in the development of km-scale coupled hazard prediction systems, including land surface hydrology, through sharing of information and evidence and, in particular, through workshops on areas of specific challenge [HiWeather, NMR]
- Study the impact of air-sea interaction on organized convection [S2S, WGNE]
- Collaborate on fully coupled extended prediction of severe monsoon and tropical cyclone occurrence [S2S, WGTMR]
- Develop improved representation of key polar processes in coupled models used for prediction [PPP]
- Carry out model experiments including operational versions of medium range prediction models with coupled atmosphere-ice-ocean-hydrology [PPP]
- Carry out coupled versus uncoupled predictions of the various environmental system components (atmosphere, land, sea ice, ocean, wave, snow) [PPP]
- Extensively validate coupled dust-atmospheric models against dust-related observations [SDS-WAS]
- Assess capabilities of dust-atmosphere coupled forecasts to further improve the accuracy of both NWP and climate models [SDS-WAS]
- Carry out coupled versus uncoupled predictions of the ocean-wave model, to study the impact of oceans on tropical cyclone intensity and structure change [WGTMR]
- Advance research focussed on understanding coupled model dynamics and processes; encourage new methods for diagnosing systematic and stochastic components of coupled model forecast error; facilitate the development of improved methods for representing stochastic components of forecast error within ensemble forecasting systems [PDEF]
- Facilitate knowledge sharing between WWRP and WCRP communities on model components, including the development of aerosol schemes for use in NWP models using the experience of the climate community, and the development of coupled atmosphere-ocean models, including identifying the priorities for atmosphere model development in order to reduce errors in the coupled system [WGNE]
- Work with modelling and other scientific communities to ensure that relevant and effective verification methodologies are in place to demonstrate the relative benefits of coupled modelling, compared to uncoupled models [JWGFVR]

Make significant advances with respect to coupling meteorological and hydrological models in particular, to enhance hydrological prediction (see Water Theme below)

AA 4: APPLICATIONS

Develop end-to-end approaches from meteorology to impacts, in application areas of public health, commerce, industry, transport, energy, defence,

agriculture, etc., taking into account the differing user needs in different parts of the world

Improve understanding of the requirements (timeliness, type of data most helpful, etc.) of health, commerce, transport, etc., areas with respect to environmental data and predictions, and of how that information is ultimately used operationally by these application areas

- Promote improving sea-ice forecasting capacity and explore corresponding user needs [PPP, in collaboration with JCOMM's Expert Team on Sea Ice, IICWG, and national ice services]
- Review user needs including aviation nowcast and mesoscale modelling technologies and translation of ATM impact products via Training Workshops [AvRDP]
- Further study dust impacts, and establish close collaboration with users to identify diverse needs of different end-user groups [SDS-WAS, SERA]
- Assess societal benefits of SDS-WAS products [SDS-WAS, SERA]
- Collaborate with user communities to promote and participate in the development of impacts verification methods; determine the needs for collection of impacts data for use in verification [JWGFVR, SERA]
- Progress research and application of disaster/benefit assessment and prediction of tropical cyclones and monsoons from a multidisciplinary perspective [WGTMR, SERA]
- Organize a scientific meeting to discuss new topics including societal impacts for the purpose of advancing the Total Warning System concept and for the sharing of relevant experiences [WGTMR, SERA]

Facilitate collaborations between meteorological application developers and end users on to development of end-to-end applications, with strong user involvement throughout the planning, testing, implementation and continuous improvement stages, ensuring that the most relevant information for their decision making is produced

- Extend the Nowcasting community's skills and experience in the area of user- relevant products to post-processing of very short range nowcasting/NWP products [NMR, AvRDP, HIWeather]
- Coordinate with ATM experts to develop models to translate deterministic/probabilistic MET information into ATM products, such as airport capacity, air-space capability, airport acceptance/departure rate, aircraft delay, fuel consumption, etc. [AvRDP]

Gain experience in working with different sectors on specific applications, to contribute to an improved knowledge base within the meteorological community on how to effectively develop end-to-end applications in partnership with users; AND

Define some well-developed end-to-end examples/case-studies for service delivery

- Generate good practice guidance for provision of services in various application areas [HIWeather, SERA]
- Develop user-oriented indices and verification for monsoon prediction [S2S]

- Develop end-to-end S2S prediction for agriculture and human health over Africa [S2S]
- Promote applications of S2S forecasts to disaster risk reduction communities, including food security in developing countries and humanitarian aid, for early warning and early action, such as forecast-based financing [S2S, SERA, in collaboration with IFRC and WFP]
- Demonstrate the benefits of using predictive information for a spectrum of user types and services in polar regions [PPP, SERA]
- Intensify existing and introduce new scientific and technical services to achieve a routine delivery of tailored dust-related products to interested user communities, including aviation (visibility and dust-cloud ice nucleation), ground transport (visibility), health (air polluted by dust), agriculture (soil degradation), etc. [SDS-WAS]
- Ensure that "end-to-end" applications include verification tools and methods [JWGFVR]

Ensure that SERA science increases in importance in weather impact research

- Build up the community of social scientists involved in high-impact weather research [HIWeather, SERA]
- Engage the Tropical Cyclone operational community with social scientists to provide education and training for communication of risk to end users based on warnings and forecast uncertainty [WGTMR, SERA]

AA 5: VERIFICATION

Develop methods to verify forecasts of high-impact weather and demonstrate their benefit, with a focus on probabilistic and impact-based methods, including collecting and processing suitable observations (particularly non-conventional weather observations by non-conventional means); assessing the impact of near misses and false alarms; evaluating the end-to-end forecast chain with emphasis on what is of value to the user

Develop new methods for verifying impact-based forecasts and apply these to hazard impact forecasts, demonstrating their benefit and supporting their further improvement

- Identify techniques that properly measure errors in timing and duration; establish standard methods for incorporating observation uncertainty in verification metrics; and develop ensemble verification techniques derived from the recently developed spatial verification approaches [HIWeather, JWGFVR]
- Develop and promote good practice in verification of hazard forecasts [HIWeather, JWGFVR]
- Consider verification methods that help in the assessment in the discrimination of precipitation type (for high-impact winter weather) [JWGFVR]
- Develop new methods for verifying impact-based S2S forecasts and apply these to hazard impact forecasts, demonstrating their benefit and supporting their further improvement [S2S, JWGFVR]
- Collaborate on appropriate verification for high-impact polar weather — e.g., polar lows [PPP, HIWeather, JWGFVR]
- Put a special emphasis on improving sea ice verification [PPP, JWGFVR]

- Develop suitable verification metrics for aviation MET products using the results obtained via the IOPs held at various participating airports [AvRDP, NMR, JWGFVR]
- Collaborate on developing and implementing verification methodologies specifically applicable for high-impact dusty weather [SDS-WAS, JWGFVR]
- Collaborate on tropical cyclone verification [WGTMR, NMR, WGNE, JWGFVR]
- Further extend the assessment of models from traditional verification of large-scale dynamical variables to include more physical variables such as precipitation (especially heavy) and possibly others (e.g., cloud, near-surface wind, near-surface temperature) [WGNE, JWGFVR]
- Support and facilitate the development by the mesoscale modelling community of calibration and verification methods for high resolution ensemble nowcast/short range forecast systems (e.g., in Eumetnet/SRNWP-EPS project, in FDP's where relevant) [NMR, JWGFVR]
- Help guide strategies for testing probabilistic forecasts of high-impact weather that ensure that "near-miss", "false-alarm" and "hit" cases are appropriately included in assessments [PDEF]

Enable impact data to be shared more easily and widely using mutually agreed standard data formats

- Collect observations of hazards and their impacts both for data assimilation and for evaluation [HIWeather]

Increasingly use information sourced from social networks and other non-conventional data for verification and forecast quality improvement

- Develop an international collaboration to collect social media, volunteer and other professional data for use in verification [HIWeather, JWGFVR]

Ensure that social scientists and social science methodologies (e.g., surveys, analysis of social media data, etc.) are increasingly included in end-to-end evaluation of projects and applications through to end-users, with appropriate planning and resourcing, and that weather scientists improve their skills in these areas

- Improve general verification of polar weather and environmental predictions as part of YOPP, to obtain better quantitative knowledge on model performance, and on the skill, especially for user-relevant parameters [PPP, JWGFVR, SERA]
- Collect ATM data, such as airport capacity, air traffic data, etc., to conduct ATM impact product verification and validation; involve ATM experts in the verification and validation processes to identify the useful verification methods from the end-users' perspective [AvRDP, JWGFVVR, SERA, with CAeM]
- Explore methods of assessing the value of forecasts to users; encourage and participate in collaborative research on this topic [JWGFVR, SERA]
- Collaborate with user communities to promote and participate in the development of impacts verification methods; determine the needs for collection of impacts data for use in verification [JWGFVR, SERA]

Complete and validate impact-based forecasting demonstration projects

- Promote and manage international research projects focused on the development of verification methods for high resolution models (e.g., MesoVICT) [JWGFVR]

- Complete and validate impact-based S2S forecasting demonstration projects [S2S]
- Use the YOPP Core Phase to test verification methodologies, including impact-based and user-oriented verifications [PPP, JWGFVR, SERA]

Together with CBS, ensure that verification standards are fully in place to compare deterministic and EPS skill at global and regional scale, and all time scales

- Collaborate on the development and promulgation of verification standards [JWGFVR, with CBS]

Work with CBS to enhance the international sharing of datasets, both conventional and non-conventional

- Explore co-development of an "observation database" capability, whereby observations, model forecasts and analyses at observation locations, ensemble information, quality control information, and more is archived and easily accessible; this will facilitate creative methods for forecast verification [DAOS, with CBS]

AA 6: ATTRIBUTION

Connect knowledge and abilities to simulate high-impact weather events at high spatial and temporal resolution with larger scale climate change expertise to more confidently attribute linkages to longer term climate variability and change

Bring the weather and climate scientific communities closer together, through deeper engagement on problems of common interest; AND

Ensure that weather scientists and practitioners have a better understanding of the climate variability/climate change context of high-impact weather, and that they have a better understanding of how climate extremes are manifested as high-impact weather events

- Enable scientific understanding and modelling developments on high-impact weather to be informed by adaptation requirements, and to inform those providing climate services for adaptation, so as to increase scientific and public confidence in model projections of future changes in high-impact events, as a result of more robust attribution and explanations of their causes, whether natural or human [HIWeather, S2S, with WCRP grand challenge on extreme events]
- Improve understanding of linkages between polar regions and lower latitudes and assess skill of models representing these linkages, to help elicit the influence of polar climate change and variability on lower latitude weather [PPP]
- Improve understanding of linkages between tropical regions and higher latitudes and assess skill of models representing these linkages, to help elicit the influence of tropical climate change and variability on higher latitude weather [S2S]
- Incorporate attribution and sensitivity studies (including the impact of spatial and temporal resolution) for case studies of extreme events [S2S]

- Encourage the development of improved methods for using observations and ensembles of climate forecasts to improve multi-model ensemble climate forecasts [PDEF]
- Encourage the application of the same assessment techniques to both weather and climate models in order to identify where there are deficiencies [WGNE]
- Deepen research on dust-climate interactions [SDS-WAS]
- Hold a workshop on the impact of the climate change on tropical cyclones and monsoons [WGTMR]
- Issue updates as needed to "Statement on Tropical Cyclones and Climate Change" [WGTMR]
- Build a consistent and "seamless" suite of verification tools that are applicable to high-impact weather on all forecast scales and ranges, to aid in the understanding of linkages between high-impact weather events and longer term climate variability and change [JWGFVR, WGNE/WGCM Climate Metrics and Diagnostics Panel]

Ensure that the science of attributing high-impact weather events to climate variability and change makes use of high resolution modelling to support conclusions; AND

Facilitate the use of state of the art Numerical Environmental (ocean-sea-ice-hydrology) and Weather Prediction (NEWP) convective scale limited area models in regional climate modelling

- Develop the capacity to simulate as well as predict on km-scales [HIWeather, NMR]
- Facilitate the development and use of convective scale NEWP models for downscaling climate change scenarios and for the performance of regional attribution studies [HIWeather, NMR, with WCRP]
- Encourage research in the use of high resolution models to infer the climate probability distribution of observed occurrence rates of high-impact events with much shorter spatio-temporal scales than those typically considered in climate studies under a range of differing green-house gas forcing scenarios [PDEF]
- Encourage weather and climate centres to participate in HiResMIP (a CMIP6 project) to help determine where resolution is and is not a major contributor to model error [WGNE]

Water :
Modelling and predicting the water cycle for improved disaster risk reduction and resource management

Action Areas

The Action Areas for this Theme cover the full *Integrated Water Cycle*, assess and exploit *New Observations*, improve knowledge and prediction of *Precipitation*, and consider links to *Hydrological Uncertainty.*

AA 7: INTEGRATED WATER CYCLE

Improve understanding, observation, assimilation and modelling of the components of the integrated water cycle, and its global, regional and local interactions

Improve data assimilation for moist processes and coupled systems; AND

Improve assimilation of weather radar data from all sites globally; AND

Improve use of remote sensing observations (soil moisture, discharge, vegetation) in land data assimilation systems

- Carry out research and development on coupled data assimilation, including sea ice as appropriate [S2S, PPP, DAOS]
- Organize and conduct workshops on coupled data assimilation [DAOS]
- Hold workshops on improvement of data assimilation in km-scale NWP models, with a focus on assimilation of radar data [HIWeather, DAOS, NMR]
- Collaborate on international standards for observation data exchange for convective scale very-short-range forecasting including radar data [NMR, with CBS]

Improve coupled modelling of atmosphere/land/ocean/water; in particular, some weaknesses in exchange processes (both vertical and lateral) are better understood and modelled; AND

Improve land surface models in coupled modelling systems to incorporate more hydrological processes; better represent snow; and use higher resolution land use information, including temporal variability

- Develop coupled modelling systems for PPP/YOPP including aspects such as sea ice, snow, and river run-off as integral components [PPP]
- Carry out research on polar clouds; in particular, mixed-phase clouds in the stable boundary layer, utilising YOPP observations and modelling [PPP]
- Carry out research and development on air-sea interaction [S2S, WGNE/MJO-TF]

- Collaborate on improved land surface models [S2S, with GEWEX/GLASS]

Better understand and model atmospheric moist processes, including cloud-aerosol-radiation interactions, air-sea exchanges, and surface-vegetation-atmosphere feedbacks

- Support the NAWDEX RDP which has a primary objective of better understanding the role of moist processes in cyclone wave development and their connection to downstream high-impact weather (field phase in 2016) [HIWeather]
- Support and facilitate the involvement of the mesoscale modelling community in modelling studies to improve the description of cloud-aerosol-radiation-microphysics interactions on km-scales (e.g., ICE-POP, SURF, future extension of WGNE Grey Zone project) [NMR, WGNE]
- Identify and address common deficiencies in parameterizations (e.g. convection) [WGNE, with GASS]
- Promote a wide range of diagnostic techniques to identify systematic errors — e.g., for the Year of Maritime Continent field campaign (2017-2019) [WGNE]
- Progress research into the specific roles of tropical cyclones and monsoons in local and global water cycles, including UPDRAFT [WGTMR]

Improve numerical forecasts for catchment conditions through collaboration of meteorological and hydrological scientists; AND

Increasingly use ensemble and probabilistic approaches to provide seamless precipitation and hydrological predictions across time and space scales

- Promote development of km-scale coupled atmosphere-ocean-land hydrology prediction systems with a primary aim the improvement of flood predictions for urban areas, whether from sea, river or surface water flooding; particular emphasis will be on coupled data assimilation and coupled ensemble prediction [HIWeather]
- Support and facilitate participation in high resolution modelling projects focussing on the hydrological cycle [NMR, PPP, RDP's/FDP's with, e.g., GEWEX]
- Develop ensemble methods with high-resolution prediction models for improving precipitation and tropical cyclone intensity forecasts [WGTMR]
- Improve forecast skill and understanding of prediction on S2S time scales including extreme events such as floods, droughts and storm surges [S2S, WGTMR]
- Advance methods to better initialize and propagate the highly non-Gaussian uncertainty distributions that are associated with many water-related variables in ensemble forecasts [PDEF]
- Carry out research into verification methods appropriate to both identifying limitations in model predictions on all scales (model diagnostics) and documenting and quantifying model improvements resulting from research [JWGFVR]
- Ensure that verification methods are user-oriented — designed and implemented according to the needs of the users of the verification results (modellers or users in the hydrometeorological prediction community) [JWGFVR]

AA 8: NEW OBSERVATIONS
Assess and exploit new in-situ and remotely sensed hydrometeorological observations

Evaluate the potential of new instruments or opportunities for observation of the water cycle variables (e.g., cloud radar, water vapour lidar, GNSS for water vapour/soil moisture/snow)

- Assess unconventional observations for coupled assimilation, including particularly the land surface [HIWeather, DAOS]
- Assess the utility of improved satellite measurements for soil moisture, root zone soil moisture, snow pack (snow water equivalent), sea ice (thickness) as a means to tap predictability from slowly varying processes/boundary conditions [S2S]
- Promote the rapid adoption of new observational assets and monitor the health of existing ones [DAOS]
- Gain an understanding of the relative biases of different data sources, including new ones [JWGFVR]

Increasingly share and process radar and other ground-based remote sensing as regional networks, then optimally blend with gauge and satellite data to improve coverage, accuracy and utility

- Support moves to improve the international exchange of radar and other hydrological observations [HIWeather]
- Assess, and liaise with existing regional networks for data exchange (e.g., Eumetnet/OPERA for radar data) on availability, timeliness and quality control aspects relevant for enhanced use of those data in convective scale nowcasting and very-short range NWP [NMR]
- Communicate nowcasting and very-short range forecasting user requirements on hydrometeorological observations to satellite data providers such as Eumetsat in various fora [NMR]
- Include sessions on blended precipitation analyses in symposia [NMR]

Characterise errors in remotely sensed hydrometeorological observations over most areas of the globe (some regions may yet be too hard, e.g., polar regions) and use to inform data assimilation, verification, and user applications

- Assess remotely sensed hydrometeorological observations [DAOS]

Routinely assimilate observations sensitive to all components of moist processes into numerical models; this will partly come about through improvements in data assimilation algorithms and moist processes modelling

- Improve assimilation of radar data for km-scale NWP models, through workshops and intercomparisons [HIWeather, DAOS, WGTMR]
- Include a session on assimilation of new water cycle observations in Data Assimilation Symposia [DAOS, NMR]

Increase the use of remotely sensed precipitation observations for evaluation of model precipitation forecasts

- Validate polar precipitation forecasts and calibrate satellite-derived estimates using in-situ data (in particular those collected during YOPP and MOSAiC) to the extent possible [PPP]
- Encourage increased use of remotely-sensed observations (radar and satellite) data in verification activities, including of ensemble forecasts [JWGFVR, PDEF]
- Exploit appropriate ground-truthing and quality control methods (e.g., model-independent) to improve the quality of hydrometeorological verification datasets [JWGFVR]

AA 9: PRECIPITATION

Improve understanding, observation and modelling of aerosol, cloud and water vapour aspects of precipitation processes, with a view to improved estimation and predictions of precipitation

Improve the understanding of organic aerosol hygroscopicity, since one of the largest uncertainties in radiative forcing for weather and climate models is the cooling effect of atmospheric aerosols via their ability to act as CCN

- Evaluate case studies of aerosol impact on NWP through the aerosols project [WGNE]

Make improvements to model physics and related data assimilation to better utilise observations of aerosols, cloud, and water vapour in initialising models and predicting convective initiation, rainfall enhancement/suppression, and other precipitation processes

- Facilitate progress on research, and testing of improvements in precipitation processes in a variety of climates [HIWeather]
- Use relevant polar supersite, field programme, and intensive observing period observations (including MOSAiC) during and after YOPP for precipitation process studies [PPP]
- Improve the understanding, observation and modelling of cloud and water vapour aspects of precipitation processes over the Maritime Continent, with a view to improved estimation and predictions of the MJO [S2S, WGNE/MJO-TF]
- Collect relevant meteorological data during the IOPs over different airports for precipitation process studies, and share through data server [AvRDP]
- Promote studies on the use and impact of a wider range of aerosol, cloud and water vapour information from high resolution remote sensing observations, in combination with advanced data assimilation algorithms [NMR, DAOS, HYMEX, and RDP/FDP such as ICE-POP, SURF, UPDRAFT]
- Facilitate the more rapid improvement of data assimilation schemes and improved usage of observations through supported workshops and international symposia [DAOS]
- Advance methods to better initialize and propagate the highly non-Gaussian uncertainty distributions that are associated with aerosols, clouds and precipitation in ensemble forecasts [PDEF]

- Share diagnostic techniques and encourage the use of satellite simulators for evaluation of cloud against active and passive satellite instruments across timescales [WGNE]
- Conduct a review of weather modification activities and science and publish as book or report [ETWM]
- Promote international collaboration in weather modification research [ETWM]

Develop new/better convective parameterisations for non-convection-permitting models (which remain relevant)

- Encourage use of field programme data to ensure convective scale model precipitation is well calibrated; use these models as a baseline for parameterizations [NMR, WGNE]

AA 10: HYDROLOGICAL UNCERTAINTY
Characterise how QPE and QPF uncertainty translates to hydrological uncertainty (and vice versa)

Develop improved estimates of QPE and QPF and its associated uncertainty

- Support and facilitate advances in ensemble QPE techniques [NMR]
- Support and facilitate the use of, and advances in, convective scale very-short-range ensemble forecasting of QPF; promote research and exchange of experiences on using hydrological information for evaluation of/assimilation in convective scale ensemble systems [NMR]
- Improve routine precipitation verifications [WGNE, JWGFVR]

Use ensemble QPE/QPF to drive ensemble hydrological predictions

- Promote coupling of km-scale NWP ensembles with rain-runoff and river-flow models, together with appropriate assimilation of soil moisture and other land surface information [HIWeather]
- Develop a methodology that enables the propagation of errors in QPF estimates, which are input to river-flow models, to errors in the resulting river-flow [JWGFVR]
- Assist in the identification of appropriate verification methodologies to demonstrate the impacts of improved QPF estimates on hydrological forecasts, including probabilistic forecasts [JWGFVR]
- Encourage and help guide the introduction of QPE and QPF uncertainty information into the end-to-end hydrological forecasting chain [PDEF]

Develop and apply effective post-processing methods for downscaling precipitation from atmospheric models to derive more realistic space-time rainfall distributions that are better suited for hydrological prediction

- *** Suggested activities needed from NMR, HIWeather, …?

Use results from sensitivity experiments to different types of QPE/QPF uncertainty (bias, random error, spatial structure, etc.) to develop modelling and post-processing methodologies to improve hydrological prediction on a variety of space and time scales for different applications

- *** Suggested activities needed from NMR, HIWeather, …?

Urbanization :
Research and services for megacities and large urban complexes

Action Areas

The Action Areas for this Theme are to *Understand Needs*, improve *Observations and Processes*, and work towards *Information Systems* to support decision making.

AA 11: UNDERSTAND NEEDS

Improve understanding and knowledge of the relationship between the unique socio-economic nature of the urban physical and built environment and population, and the needs for integrated weather-related environmental services

Improve understanding of how the built environment of urban areas, coupled with the varying demographics of the areas, determine the appropriate "messaging" for populations within the urban areas

- Engage with urban stakeholders and conduct user needs analysis [HIWeather, WGTMR, SERA, with GURME]

Develop spatial hazard/vulnerability/impact layers, through partnerships between meteorological agencies and urban/civil authorities, that can be viewed by forecasters and used in applications to predict the impact of weather and environmental conditions on urban areas

- Establish and promulgate key requirements for data, and prototype systems that combine layers to produce vulnerability, risk and impacts maps [HIWeather, WGTMR]

Develop multi-layer information systems (air quality, meteorology, hazard, vulnerability, energy consumption, etc.) adequate for urban planning and decision-making

- Use case studies and reviews to assess required information content and delivery methods needed by different warnings recipients, especially emergency management, and what formats are need to enable layers to be ingested in emergency management systems [HIWeather, WGTMR, SERA]
- Ensure that verification activities are carried out in all research and development projects related to urban models, using metrics and data-processing methods appropriate to the needs of the user community (modellers, forecasters, urban/civil authorities, etc.) [JWGFVR]

AA 12: OBSERVATIONS & PROCESSES

Improve observations and understanding of the unique urban physical processes, including dynamical, chemical and hydrologic

Increasingly use third party networks, data from air quality monitoring sites, and crowd-sourced and other non-conventional data to help fill the gaps in the measurement networks in urban areas; understanding the error characteristics of these data will be critical to using them effectively

- Hold one or more workshops on the use of observations from non-conventional sources including citizen observations and social media sources, both for data assimilation and for forecast/warning evaluation [HIWeather]
- Promote the collection of third-party data for use in assessing urban models [JWGFVR]
- Promote the international access to, and use of, data from dense urban networks and/or large urban observation campaigns like TOMACS and SURF [NMR, with GURME]

Better characterize the unique dynamical, physical, chemical, and hydrological processes occurring in urban environments

- Promote RDPs that address hazards in megacities (current examples are RELAMPAGO in the La Plata basin of South America, and SURF in Beijing) in which the comparison of multiple prediction systems with dense observations in such experiments is a valuable route to defining both model and observation requirements [HIWeather]
- Improve and share urban water management information, especially river flooding in megacities of rapidly increasing population [WGTMR]
- Improve understanding and representation of urban hydrological processes including run-off in heavy monsoon precipitation and landfall tropical cyclone [WGTMR]

Use observing system simulation experiments (OSSEs) and modelling studies to help understand the requirements for urban observation networks and their potential benefits on model prediction accuracy

- Provide a forum for international collaboration on OSSEs [DAOS]
- Identify the requirements for observations to effectively assess the accuracy of urban models (they differ from the requirements for modelling and data assimilation) [JWGFVR]
- Promote studies on the use and impact of existing urban network data for data assimilation in high resolution models over urban (megacity) areas [NMR]

Identify and model key sources that modify atmospheric composition (industry, transportation, energy) and assimilate the distribution of these aerosol and chemical constituents — not just from the source

- Support efforts to make available emissions inventories and detailed land use maps — a key requirement for model comparisons of pollution [HIWeather, with GURME]

- Progress on methods to estimate the contribution of mineral dust to the total aerosol load measured by air quality monitoring stations [SDS-WAS]

Improve understanding and modelling of unique urban physical processes

- Support and facilitate urban modelling and the development of urban surface exchange models – building on TOMACS legacy [NMR]
- Identify and improve the simulations of the land surface, including the further development of land surface tiling (including urban land surface types) [WGNE, with GLASS]

AA 13: URBAN PREDICTION

Develop, validate and demonstrate urban prediction capabilities, toward building urban environment integrated information systems to support decision making for different applications in different parts of the world

Develop and validate high-resolution atmospheric models suitable for being run in complex urban environments and capable of producing reliable forecasts of basic meteorological variables and relevant human health related chemical concentrations

- Promote improvements to the representation of the urban fabric, possibly coupled with sub-km resolution (but not urban canyon resolving), to assist in addressing the urban heat wave and pollution hazard [HIWeather, with GURME]
- Support and facilitate urban scale modelling, including for megacity areas – building on the TOMACS legacy; promote international participation in SURF [NMR]
- Collaborate on urban modelling and jointly organize a cross-cutting multi-disciplinary workshop on urban environment and prediction [NMR, with GURME]
- Support the continued development of the larger-scale models which drive high resolution urban models (e.g., air quality models) [WGNE]
- Ensure that meaningful objective verification is carried out to characterize the quality of urban model output, in comparison with other sources of forecast information [JWGFVR]

Develop and validate post-processing approaches which blend downscaled larger scale model information with high resolution observations and nowcasts

- Support and facilitate urban prediction; plan and conduct an urban RDP/FDP [NMR, JWGFVR, with GURME]

Improve numerical analysis and predictions of air quality, through integrated global, regional, and local modelling

- Promote development of coupled models, including atmospheric chemistry sufficient to enable the prediction of air quality [HIWeather]

Jointly develop new urban applications in partnership with external stakeholders, and demonstrate through FDPs and other activities, building on the successes of INCA-CE, MHEWS, TOMACS and other experiments; and adapt for application to other cities

- Develop case studies to demonstrate the benefit of S2S prediction for urban applications [S2S, HIWeather, SERA]
- Transfer into operational applications the outcomes from TOMACS or urban research projects, especially severe monsoon precipitation [WGTMR]

Evolving Technologies : Their impact on science and their use

Action Areas

The Action Areas for this Theme invest in *Advanced Methods*, enhance access to global *Support Facilities*, develop and share *Tools*, prepare for *New Observations*, and inform the design of the *Future GOS*.

AA 14: ADVANCED METHODS

Invest in methodological research (numerical methods, coupling strategies, assimilation methods, observational and model data information exploitation, including post-processing) to ensure that scientific enhancements can be implemented in future forecasting systems, and that systems can provide timely services

Focus new development on models and coupling strategies that take advantage of more scalable computer architectures and GPUs

- Encourage the development of next-generation dynamical cores, through the WGNE-endorsed DCMIP project and summer schools on dynamical cores [WGNE]
- Develop vertical coordinates system of a high resolution model using hybrid methods to reduce errors in the stratosphere [WGTMR]

Improve exploitation of multi-sensor, high resolution information

- Develop techniques to fully utilize the ultra-high density and frequently updated MET observations, such as Dual-polarization Doppler radar, LIDAR, radiometer, AMDAR, ADS-B, wind profilers, surface anemometer, etc. collected during the IOPs at various airports for km-scale data assimilation and nowcasting [AvRDP, NMR]
- Develop and apply a new sensor synergy for studying Land/Atmosphere interaction on convective scales [NMR]
- Develop and apply new remote sensing technology for simultaneous measurement of water vapour and temperature profiles from surface to lower troposphere [NMR]

Improve and implement efficient strategies for strongly and weakly coupled data assimilation to enhance the accuracy of predictions on long and short time scales

- Progress the successful assimilation of km-scale detail that will determine the km-scale evolution in the first few hours at the same time as refining the synoptic scale advection and forcing and without upsetting the synoptic scale dynamical balances that will determine the longer lead time evolution (currently an unsolved problem) [HIWeather]
- Research and develop coupled atmosphere/sea-ice/ocean data assimilation techniques [PPP]

- Promote the evaluation of methods for treating model uncertainty in ensemble prediction systems; data assimilation provides a direct tool for understanding whether novel model uncertainty methods will improve the short-term fit of forecasts to observations [DAOS]
- Support and facilitate studies on the development of data assimilation techniques suited to meet the operational needs and constraints of (probabilistic) very-short-range forecasting (RUC/RR techniques, ensemble nowcasting, …) [NMR, DAOS]

Gain a better understanding of ensemble strategies – mixed physics, initial conditions, number of members needed

- Promote work on ensembles for km-scale hazard prediction that address the issues of synoptic scale forcing uncertainty, perturbations of the km-scale initial state produced by data assimilation, and the details of cloud microphysics and turbulent mixing [HIWeather]
- Explore the capability of ultra-high resolution, rapidly updated ensemble NWP for generating uncertainty estimation for aviation end-users' risk assessment and decision-making [AvRDP, NMR]
- Encourage research focussed on fundamental aspects of dynamics, the understanding of predictability and the design of ensemble forecasting systems [PDEF]

Improve and implement efficient strategies for regional ensemble forecasting systems to be used by smaller NMHSs

- *** Suggested activities needed from (perhaps) HIWeather, NMR, PDEF

Develop and share strategies for optimising the use of compute cycles to balance the competing computing requirements of ensemble size, resolution, complexity, and post-processing for different applications

- *** Suggested activities needed from WGNE

Develop rapid-update convection-permitting NWP assimilating a variety of conventional and non-conventional observations, to underpin improved short-range forecasts and warnings for high-impact weather ("warn on forecast")

- Promote and facilitate work on km-scale coupled prediction systems that are expected to be run on frequent rapid update cycles, and that will deliver predictions of hazards and their impacts in the forms required to support warnings [HIWeather, WGTMR, NMR]

Develop and apply improved post-processing methodologies to value-add to numerical predictions to improve accuracy and generate products.

- Conduct research into processes that will turn hazard forecasts into the products required to support user response — including statistical adjustment, diagnosis of non-model variables, graphical rendering of forecasts, threshholding etc. [HIWeather]
- Conduct forecast post-processing methodology research in the S2S Verification and products sub-project, including computation of forecast probabilities and comparison of different ensemble forecasting systems configurations to evaluate the benefits of the multi-model ensemble approach [S2S]

- Develop novel blending technologies for aviation application purposes by combining observation-based nowcast (radar-based, satellite-based or hybrid) and high resolution mesoscale NWP forecasts [AvRDP, NMR]
- Develop effective models for translating MET information into ATM impact products [AvRDP, with CAeM]

Provide improved tools for visualization of forecasts and their impacts

- Address visualisation as one class of tools for communicating warning information to emergency managers [HIWeather]

AA 15: SUPPORT FACILITIES

Enhance access to services (observations, model output, data collection and pre-processing and global models) that require exceptional HPC and data handling, as an enabler for WWRP research

Continue to support TIGGE, S2S, and similar data collection efforts, to enable and accelerate research worldwide. In light of increasing data volumes, develop policies and methods for distributed data archival/retrieval.

- Establish specific databases to common standards for each associated RDP, FDP or field programme [HIWeather, NMR]
- Develop a YOPP data portal that links to all relevant modelling and observational data sets [PPP]
- Publish a special issue on YOPP in the data publishing journal Earth System Science Data [PPP]
- Continue development of the S2S database [S2S]
- Develop an S2S data portal at IRI for interfacing with different user communities via tailored online analyses and maprooms [S2S]
- Contribute to the development of real-time S2S data exchange in collaboration with the WMO LC-LRFMME [S2S]
- Facilitate the sharing of forecast analysis and verification codes for S2S forecasts using a GitHub type mechanism [S2S]
- Make available to the research community, via an AvRDP data server, the dense and large variety of meteorological data (observation and nowcast/forecast) and ATM data collected during the IOPs over the participating airports [AvRDP]
- Continue providing observational and forecast products from different suppliers through the SDS-WAS web portals [SDS-WAS]
- Progress more active and effective forecast and observation data exchanges among countries and regions affected by tropical cyclones and monsoons based on FDPs and RDPs [WGTMR]
- Encourage more standardization of practices between projects which produce data, especially between the weather and climate communities, to facilitate the use of common assessment tools across timescales[1] [WGNE]

[1] Specifically, WGNE is encouraging:

Develop and share (open source) tools and lessons learned for handling and pre-processing such datasets and developing applications

- *** There is mention of the S2S portal above. It would be good to have more comment or activities from, perhaps, S2S, HIWeather, NMR, JWGFVR, PDEF.

Prepare and make available to the international community model datasets in formats suitable for post-processing and verification to enable smaller NMHSs to carry out these activities with their own national observation datasets (e.g., as support to SWFDPs)

- *** It would be good to have more comment or activities from, perhaps, S2S, HIWeather, NMR, JWGFVR, PDEF.

AA 16: TOOLS

Share specialist methods and tools enabling complex modelling systems to be run by a wider community, including beyond WWRP

Facilitate the creation of easily deployable, linked community forecast and impact models for research and operations with the necessary training (e.g., community workshops) to run these models

- Build forecasting capacity and co-design software tools through collaborative FDPs, and especially through the SWFDPs [HIWeather, NMR]
- Encourage/participate in workshops on running of NWP, data assimilation, nowcasting for developing countries [NMR]
- Participate in the development of user-friendly tools for verification; share among research and operational forecast centres; promote their use in the wider community [JWGFVR]
- Promote the sharing of assessment tools between the weather and climate communities; specifically, closer collaboration with the Climate Metrics and Diagnostics Panel to share knowledge and tools [WGNE, JWGFVR]

Establish national and international "virtual laboratories" hosted by a modelling centre or a consortium of modelling partners, offering the capability to run models and visualise output

- *** This was an overall programmatic goal suggested by an SSC member and agreed by others. Perhaps could have some activities from NMR, JWGFVR, HIWeather?

  - Consolidation of portals where possible (consider extending existing portals for new projects rather than developing new portals for projects — e.g., following the ESGF example of the climate community).
  - Standardisations of data formats – all portals should offer the ability to download data in CF-netCDF and GRIB formats.
  - Where possible, making observational and model data available through shared portals with common formats (e.g., obs4mips)
  - Increasing the number of variables being saved so that there are common diagnostics available amongst WWRP and WCRP projects.

Involve smaller centres into these "virtual laboratories" as a way to support capacity building and at the same time accelerate the development of complex modelling systems

- *** Similarly, perhaps could have some activities from NMR, JWGFVR, HIWeather?

AA 17: NEW OBSERVATIONS

Prepare for exploitation of information from new, advanced observing systems, as well as commodity-technology-based data

Develop a much better understanding of the information content of new types of observations (e.g., sensors on mobile phones, transport-based sensors, new satellite sensors, etc.)

- Actively seek out and support novel observation sources that deliver high spatial and temporal resolution, that deliver the environmental variables required for coupled modelling, and that deliver information on hazards, their impacts and responses to warnings [HIWeather]
- Promote YOPP as providing a framework for testing innovative observing systems (e.g., aircraft deployable ice observing systems) [PPP]
- Deploy and assess new observation platforms such as vertically pointing X-band radar, dual-polarization Ka-band radar, profiling microwave radiometer, LIDAR, icing detector [AvRDP]
- Facilitate collaborations on the use of OSSEs, OSEs, and forward sensitivity observation impact for novel observation types [DAOS]
- Assess new non-conventional observations which appear suitable for operational use: report on access, quality, impact studies performed on convective scale [NMR]
- Monitor the availability of new (pre-operational) observation sources and incorporate them in nowcasting and mesoscale research projects / RDP's/FDP's where relevant – demonstration and validation; provide feedback on this to the operational observation community (CBS/CIMO, …) [NMR]
- Encourage aspects of research (into new types of observations) focussed on fundamental aspects of dynamics, the understanding of predictability and the design of ensemble forecasting systems [PDEF]
- Demonstrate the application of new observation types to verification activities [JWGFVR]

AA 18: FUTURE GOS

Inform the design of the future global observing system

Improve understanding and quantification of the positive impact of existing and new observation data streams on the accuracy of numerical prediction, especially in the mesoscale where there is currently a poorer idea of how best to assimilate observations

- Promote the development of methodologies for mesoscale data assimilation, such as through organization of relevant workshops [DAOS, HIWeather, NMR]
- Facilitate international coordination of OSSEs, OSEs, and FSOI for estimating observation impact of novel observation sources [DAOS]
- Facilitate the near real-time gathering of observational products, including definition and homogenization of data formats [SDS-WAS]
- Promote assessments of the information content of new observation sources in the context of developing km-scale data assimilation capability for short range hazard predictions [HIWeather]
- Assess the impact on high resolution aviation forecasting of additional aircraft observations, (including measurements of inflight turbulence measurement, icing, and moisture), for both nowcasting and NWP data assimilation [AvRDP, NMR]
- Demonstrate the increases in knowledge and confidence in the measurement of model accuracy gained from the exploitation of research datasets [JWGFVR]

Better understand the potential global and regional benefit of additional observing systems deployed to remote regions (oceans, polar regions)

- Facilitate the near real-time gathering of research data for YOPP into WMO's WIS/GTS [PPP]
- Assess the impact of existing and supplementary observations during YOPP, mainly through OSEs and OSSEs [PPP, DAOS]
- Assess the impact of existing and supplementary observations on S2S forecasts during YOPP and YMC [S2S, PPP, DAOS]

Design a prototype more comprehensive global observing system that takes greater advantage of non-conventional data sources (crowd-sourced, cell phone, etc.)

- Suggested activity from DAOS?

Design a prototype adaptable observing system that (in a statistical sense) minimizes analysis and forecast uncertainty

- Regularly inform data providers such as EUMETSAT, ESA, NASA, etc., on the data requirements (availability, timeliness, quality) for NWC/mesoscale NWP purposes [NMR]
- Help identify observational network designs that are well-suited for identifying and quantifying stochastic elements of model error, as part of a focus on better representing stochastic model error in ensemble forecasts [PDEF]
- Run "Systematic Errors Workshops" that provide a focal point for drawing together information on model errors and lead to specific recommendations for improvement to the observing system [WGNE]

Develop quality control methodologies and data formats for new kinds of observations

- Review developments in observational quality control [DAOS]

Education & Training or Capacity Building Activities 2016 to 2023

- Organize additional S2S training courses for early career scientist in collaboration with ICTP and APCC [S2S]
- Organize workshops and AGU/EGU sessions on S2S [S2S]
- Run PPP/YOPP/PCPI Polar Prediction Schools for early career scientists [PPP]
- Run Polar Prediction Webinars, in collaboration with APECS [PPP]
- Run training workshops on the aviation nowcasting, mesoscale modelling and translation models technologies obtained during AvRDP [AvRDP, NMR, CAeM]
- Run workshop in 2018 focussing on the translation of ATM Impact products as well as the respective verification and validation, and demonstrating the benefits of the technologies in aviation [AVRDP, JWGFVR, CAeM, CBS]
- Run Tutorial workshops in basic verification methodology every two to three years [JWGFVR]
- Maintain and update a web page containing concise information on verification techniques that have entered general practice [JWGFVR]
- Carry out "roving tutorials" at the request of WMO Members [JWGFVR]
- Participate actively in SWFDP training workshops, including organizing hands-on laboratory sessions on verification topics, with the goal of enabling NHMSs to undertake their own verification activities, and understand the results that are obtained [JWGFVR]
- Build capacity by developing simple-to-use tools to carry out verification and make them available to NMHSs and other users [JWGFVR]
- Prepare "Guidelines for the verification of mesoscale forecasts", following results from the research project MesoVICT, along the lines of previous guidance on verification of precipitation, cloud, and tropical cyclones [JWGFVR]
- Conduct training in association with RDPs and FDPs [NMR]
- Participate in SWFDP training events [NMR]
- Hold the regular International Symposium on Nowcasting and Very-short-range Forecasting [NMR]
- Conduct a workshop on urban-scale modelling [NMR, with GURME]
- Organize workshops, summer schools and conference sessions on aspects of the PDEF focus areas [PDEF]
- Hold the quadrennial International Workshop on Tropical Cyclones (IWTC) and International Workshop on Tropical Cyclone Landfall Processes (IWTCLP) in conjunction with TLFDP, UPDRAFT, and EXOTICA [WGTMR]
- Hold quadrennial International Workshop on Monsoons (IWM) series in conjunction with the International Training Workshops on Monsoons [WGTMR]

- *** More similar activities from others? Distinction between training and symposia though. Nothing yet from HIWeather, DAOS, WGNE, SDS-WAS, SERA, WGNE or ETWM.

ATTACHMENT 1: TERMS OF REFERENCE

This will include all the appropriate terms of reference for Working Groups and Projects, including processes for chair selection, membership renewal, and review.

Terms of Reference of the WWRP Scientific Steering Committee (SSC)

Membership

The Chair of the SSC is selected by CAS. The members of the SSC are appointed by the CAS Management Group upon recommendation by the SSC Chair. The membership currently consists of the Chair and/or Co-chair of the WWRP WGs and Programme, and additional members to meet the need for scientific and geographical representation. The term of SSC members is four years and can be renewed.

Functions

a) To provide scientific guidance for the WWRP including making appropriate comments on major project activities;

b) To develop a strategic science and implementation plan for the WWRP and a work programme aligned with the WMO Strategic Planning Process;

c) To review and assess the development of all elements of the WWRP, including FDPs, RDPs and forecast evaluation methods, to formulate recommendations to guide further actions and to report on the progress of the programme to the president of the Commission for Atmospheric Sciences (CAS);

d) To facilitate, coordinate and prioritize weather research and development activities, which are planned and implemented through the project committees and working groups, to meet the objectives of CAS;

e) To facilitate the exchange of information among scientists participating in the programme and relevant scientific institutions and agencies, at the national and international levels;

f) To collaborate, as appropriate, with OPAG-EPAC, the Commission for Basic Systems (CBS) and other technical commissions, relevant groups of the JSC/ World Climate Research Programme (WCRP) and the WCRP projects committees, academia, users of forecast products and other partners; and

g) To delegate to each working group and expert team, as required, the responsibility to promote the timely exchange of information, data and new knowledge through publications, workshops and meetings.

General Terms of Reference of WWRP Working Groups (WG)

Membership

Chairs and co-chairs of WWRP WGs are appointed by the CAS Management Group upon recommendation of the SSC Chair, the CAS President and the WMO Secretariat after seeking advice from the members of SSC and the Working Group. WG members are appointed by the CAS Management Group upon recommendation from the WG Chair, the SSC Chair and the WMO Secretariat. The term of WG members is four years and can be renewed.

Functions

a) To advise the WWRP SSC, CAS and the WMO Secretariat on the current research status in their area of expertise and to recommend priorities and strategies for future research that are well suited to advancement through international collaboration. These recommendations should factor in both scientific knowledge and the potential implications of advances in research to meet the needs of Members of the WMO to improve their prediction of and response to high-impact weather;

b) To work toward advancing the science in their area of expertise and to work, often in partnership with others, to foster the utilization of research knowledge and techniques for societal and economic benefit including the transition of research into operational practice within NMHSs;

c) To act as an international focal point and resource for research in their area of expertise by bringing together scientists from the academic, research institution and operational communities with users of weather products;

d) To endorse, guide, develop, and/or implement RDPs, FDPs, Societal and Economic Demonstration Projects, (SEDPs), Testbeds, and other research projects that advance the underlying science and the utilization of weather information;

e) To publish findings on WWRP activities in refereed journal articles, WMO Technical Documents and other appropriate venues and to publicize their results through the web and other means;

f) To convene symposia, conferences, workshops and other meetings as necessary to advance these goals;

g) To establish panels and expert teams and other subgroups as needed to support these activities. If these panels function on a continuous basis, they need to obtain SSC approval;

h) To undertake these goals in conjunction with partnerships with WMO Members and other programmes, projects, and organizations both internal and external to the WMO and the UN System; and

i) To assist, when appropriate, in the resource mobilization necessary to undertake these activities. Appropriate activities include seeking co-sponsorship of conferences, symposia and large workshops of the WWRP or submitting proposals to regional and national funding sources for projects and activities initiated by the WWRP WGs.

Terms of Reference of Regional Rapporteurs on the WWRP

Designation

Regional rapporteurs on the WWRP are designated by the SSC Chair, from the members of the SSC, the WWRP WGs and Committees. The term of a regional rapporteur on the WWRP is four years and can be renewed.

Functions

a) To promote and facilitate the participation of NMHSs, academia and related organizations and agencies of the Region in weather research and development projects and activities, in particular through the CAS working structure;

b) To keep the regional associations and CAS informed on relevant WWRP plans and activities in the area, specifically those requiring the support and engagement of the Region; and

c) To assist the Secretariat and WWRP in the exchange of information and support of cooperative research and monitoring projects in the field of weather prediction research in the Region.

_____

Terms of Reference of the Expert Team on Weather Modification Research (ET-WMR)

Membership

The Chair of the ET-WMR is appointed by the CAS Management Group upon recommendation of the SSC Chair, the CAS President and the WMO Secretariat, after seeking advice from the members of the SSC and the ET-WMR. The members of the ET-WMR are appointed by the CAS Management Group upon recommendation from the Chair of the ET-WMR, the SSC Chair and the WMO Secretariat. The term of the ET-WMR members is four years and can be renewed.

Functions

a) To keep under review, on behalf of OPAG-WWRP and OPAG-EPAC, relevant research, advise CAS on issues requiring attention related to weather modification and suggest mechanisms for addressing such issues;

b) To review the criteria for conducting weather modification research to ensure the quality of the science, from the initial design to the final evaluation of field experiments, taking into account advances in supporting fields, including cloud physics, atmospheric chemistry, numerical modelling and SEAs;

c) To serve as a focal point and provide advice and assistance to Members on the manner and means of transferring competence for planning scientific experiments; and

d) To assist in the drafting of WMO documents on the status of weather modification and guidelines for providing advice to Members and to propose revisions to these documents where necessary.

_____

RDP and FDP criteria

This Annex presents the Guidelines for Developing and Submitting a Research and Development Project (RDP), a Forecast Demonstration Project (FDP) as well as a Developing Country Forecast Demonstration Project (DC-FDP).

1. Guidelines for Developing and Submitting a Research and Development Project (RDP)

RDPs can be field campaigns, model or assimilation based, or geared to social science research. The RDP focus is on advancing knowledge in research topics relevant to improving the prediction of high-impact weather and/or the development of improved tools, techniques, and models. RDPs can address any component of weather forecasting (e.g., observations, data assimilation, modelling, forecast, dissemination and the utilization of weather products). Thus RDPs should be based on the priorities of the Working Groups and Programme(s) of the WWRP including those of the WGSERA. In addition, the RDPs are encouraged to contain a SERA type component.

The following text presents guidelines for submission of RDP proposals to the WWRP SSC. In many cases, RDPs have specific science plans. Thus another option for the proposal process is to submit the full science plan with a short document that covers any topic not well represented in the science plan such as a SERA component, explaining how this project will meet the priority needs of the WWRP and/or facilitate the operational transition.

The SSC will define, prioritize, and where appropriate endorse candidate projects within the WWRP. The endorsement is limited to the duration of the project. The SSC is under no obligation to endorse or otherwise participate in any project brought to its attention. By its very nature, the WWRP can be most effective by focusing on a relatively few project areas, to create a critical mass of research effort associated with forecast problems of highest priority determined, in part, by their broad societal impact and technical achievability.

Proforma for a Research and Development Project Proposal to the WWRP

TITLE

Proposer(s) Name(s) and Institution(s)

CONTENTS

Acknowledgements

References

Supporting Documentation

Project Summary

The project summary will provide a concise summary of the proposal. It should start with the specific aim or goal of the programme, including a list of any specific recommendations and expected outcomes.

The entire document should be kept to a reasonable length, generally not more than 15 pages, not including supporting documentation.

Background

A brief discussion of events that have lead to the proposal should be included here. Examples include workshop recommendations, background events, etc. Also included here should be a discussion of the WWRP recommendations arising from the preliminary proposal. The proposal must specifically address weather system research that fits with the WWRP Goals to undertake the necessary R&D leading to the development and demonstration of improved and cost effective forecasting techniques, with emphasis on high-impact weather, and to promote their application among Member States.

High Impact weather is defined as weather that affects quality of life, is economically disruptive, or is life threatening and is prominent among the concerns of the International Decade for Natural Disaster Reduction (IDNDR). High-Impact Weather can occur in forecast ranges from the very short-range to the long-range, up to a season.

RDP Proposal

This section should address the full programme of research that is being proposed and will form the bulk of the proposal. The contents are up to the individual, but should be in the form of an expansion of the preliminary proposal, addressing any recommendations from the SSC. The following WWRP R&D requirements must be addressed:

- Specification of the problem to be addressed and especially its scientific basis;
- A review of current knowledge in the area, together with a highlight of where knowledge is deficient; and
- A comprehensive discussion of how the programme will undertake the research and development, including methodology to be adopted, envisaged field programmes (and their justification), and time scale. If desired, several sections and subsections can be devoted to the RDP Proposal.
- Length of the project

RDP Management

This section should address the management structure of the programme. As a minimum requirement the WWRP requires that two groups be formed:

A Scientific Steering Committee comprised of 6-8 scientists in the relevant disciplines. This committee will be responsible for producing the science proposal and the scientific implementation of the programme, should it be approved by the SSC. Complex programmes may choose to include additional specialist subcommittees working under the Scientific Steering Committee.

A Community Advisory Group comprised of representatives from end users, community groups, industry, forecast offices, etc. This group will be utilized to provide an impacts perspective on the programme and a review of the plans that are produced. The WWRP SSC is happy to help with recommendations on the membership of these two groups. This section should also indicate the organizations and institutions that are supporting, or are expected to support the programme. Please note that the WWRP will only support programmes that are international in nature.

This part should describe also the resource mobilization component, detailing which will be the funding resources and their effectiveness. WMO is not under obligation to financially support RDP.

Societal Impacts

This section must discuss:

- How end users have been involved in the development of the research proposal;
- The manner in which the research is expected to impact on society; and
- The proposed method whereby societal impacts are to be incorporated into the RDP.

Prospects for operational transition including Forecast Demonstration Projects

This section must address potential FDPs or related programmes arising out of the RDP. Future FDPs may be highly developed in some cases, or presented as a planned approach in cases of more strategic RDPs. All FDPs must follow the WWRP requirements.

Acknowledgements

Acknowledge any funding sources, contributors, etc.

References

Please use the format of either the AMS Journals, or the QJRMS for referencing. Reports that are not readily available should have copies of the relevant pages included in the supporting documentation.

Supporting Documentation

Supporting documentation in the form of resolutions from workshops, etc, should be attached here. Also include a short CV for each of the main proposers.

2. Guidelines for Developing and Submitting a Forecast Demonstration Project (FDP)

WWRP SSC will define, prioritize, and where appropriate endorse candidate projects within the WWRP. The SSC is under no obligation to endorse or otherwise participate in any project brought to its attention. By its very nature, the WWRP can be most effective by focusing on a relatively few project areas, to create a critical mass of research effort associated with forecast problems of highest priority determined, in part, by their broad societal impact and technical achievability. The proposal should meet the scientific mission of the WWRP and include a societal component.

Forecast Demonstration Projects should be submitted for review to the Chair of the SSC and the WMO Secretariat for the WWRP. The proposal will then be sent for comments to members of the relevant Working Groups and/or members of the SSC. Proposals for FDPs, along with the comments of reviewers, are typically presented at the annual meeting of the SSC of the WWRP. The role of the SSC is to review these FDPs in order to determine if the proposal sufficiently meets the guidelines below, suggest improvements in the proposed project and determine if the project should be endorsed as a WWRP activity. The endorsement is limited to the duration of the project.

Proforma for a Forecast Demonstration Project Proposal to the WWRP

TITLE

Proposer(s) Names and Institutions

Contents

Project Summary

The project summary will be a maximum of one page and provide a concise summary of the proposal. It should start with the specific aim or goal of the programme, including a list of any specific recommendations and expected outcomes.

The entire document should be concise and generally not more than 10-15 pages in length, not including supporting documentation.

Background and motivation

A brief discussion of events that have lead to the proposal should be included here. Examples include workshop recommendations, background events, etc. FDP proposals must follow the WWRP requirements:

FDPs will serve to exhibit and formally quantify the benefits to be derived from improved understanding and enabling technologies. The improved understanding and technological advances, the benefits of which are to be demonstrated, may or may not be a direct consequence of other WWRP activities. FDPs will involve the dissemination of forecast information to real users in real-time. Candidate FDPs will be selected by the JSC on the basis of readiness of the science, timeliness of the demonstration, and feasibility of technology transfer and training.

FDP Proposal

This section should contain an outline of the proposed FDP in sufficient detail for the WWRP committee to arrive at a conclusion on its merits. The contents are up to the individual, but address as a minimum the WWRP FDP requirements noted above. The proposal should specifically address the following issues:

- Basis of the proposal (e.g. what new research outcome or forecast technique is to be demonstrated);
- Forecast procedure, hosting organization and method of disseminating forecasts;
- Expected impact of the proposed programme on society; and
- Validation and verification methodology to be adopted including a means for measuring impacts of the forecast improvement on users
- Length of the project

FDP Management

This section should address the management structure of the programme. As a minimum requirement the WWRP requires that two groups be formed:

An FDP Steering Committee comprised of 6-8 people in the relevant disciplines. This committee will be responsible for producing the FDP proposal and the implementation of the programme, should it be approved by the SSC. Complex programmes may choose to include additional specialist subcommittees working under the FDP Steering Committee.

A Community Advisory Group comprised of representatives from end users, community groups, industry, forecast offices, etc. This group will be utilized to provide an impact perspective on the programme and a

review of the plans that are produced. The WWRP SSC is happy to help with recommendations on the membership of these two groups.

This part should describe also the resource mobilization component, detailing which will be the funding resources and their effectiveness. WMO is not under obligation to financially support FDP.

Acknowledgements

Acknowledge any funding sources, contributors, etc.

References

Please use the format of either the AMS Journals, or the QJRMS for referencing. Reports that are not readily available should have copies of the relevant pages included in the supporting documentation.

Supporting Documentation

Supporting documentation in the form of resolutions from workshops, etc, should be attached here. Also include a short CV for each of the main proposers.

Attachment 1: Societal impacts

Research and Development Projects and Forecast Demonstration Projects will lead to societal benefits if and only if that research is successfully turned into products that are used by decision makers. Thus, the societal aspects of weather are an essential area of complementary research. Four areas of investigation are identified:

- *Obtaining an improved understanding of the nature of the problem and the opportunity:* These include the costs of weather related events and who incurs those costs. Results obtained from this research, in conjunction with knowledge of predictability, etc., can help scientists to more effectively prioritize research objectives. More broadly, such research can provide information to help policy makers focus national priorities.

- *Use of forecasts by decision makers:* Even the most accurate forecast is of little value if it is not well used. To this end, it is important to understand what information decision makers could effectively use and also effective ways to communicate that information. Research in this area can help to identify those conditions necessary and sufficient for forecasts to contribute to the needs of decision makers.

- *The process of transitioning research to the operational community:* This process focuses on the needs of forecasters seeking to provide information of use to decision makers. Both the structure of the process and the content of the information being transferred should be evaluated from the standpoint of the penultimate goal of producing useful products. Thus in addition to research on the

use of forecasts, appropriate research might include the institutional structures through which the transfer process takes place.

- *Evaluation of forecasts:* There are many measures of forecast "goodness." Such evaluations are an important component of the programme's ability to assess progress with respect to its goals. Evaluation from a user perspective is an important component of these projects.

3. Guidelines for the Development and Submission of a Developing Country Forecast Demonstration Project (DC- FDP)

DC-FDPs will serve to demonstrate the benefits derived from improved understanding and enabling technologies, and improved prediction capacity in developing countries. It involves a partnership between a developing country (or countries), a relevant Regional Specialised Meteorological Centre (RSMC) and a developed country (or countries), with the aim of:

- Developing the research capacity in the developing countries and relevant RSMC; and
- Operational application of improved and cost effective forecasting techniques in developing countries for the benefit of societies.

DC-FDPs will involve the development or implementation of new or enhanced technologies in an operational environment in developing countries, and the dissemination of forecast information to real users in real-time.

The following attributes, which must be addressed in proposals, will be considered as a basis for the endorsement of DC-FDPs within the overall WWRP:

- The project addresses forecasts of weather of international or regional applicability, with the emphasis on high-impact weather;
- The strength and nature of the partnership between a developing country, a relevant RSMC and a developed country;
- The existence of clear evaluation protocols;
- The expectation of success and level of support available;
- The suitability of the techniques, systems or skills and prospect of clear advance on current operational practice within developing countries; and
- The forecasts will be provided in real-time and forecast information will be communicated for user utilisation and subsequent impact evaluation.

ATTACHMENT 2 LIST OF ABBREVIATIONS

A

AGU ..... American Geophysical Union
APCC ..... APEC Climate Centre
APECS ..... Association of Polar Early Career Scientists
ATM ..... Air Traffic Management

C

CAeM ..... Commission for Aeronautical Meteorology
CBS ..... Commission for Basic Systems
CCN ..... Cloud Condensation Nuclei
CF-netCDF ..... Climate and Forecast data conventions for Network Common Data Format
CIMO ..... Commission for Instruments and Methods of Observation
CMIP ..... Coupled Model Intercomparison Project

E

EGU ..... European Geophysical Union
ESA ..... European Space Agency
ESGF ..... Earth System Grid Federation
EXOTICA ..... Experiment on Typhoon Intensity Change in Coastal Area

F

FSOI ..... Forward Sensitivity Observation Impact

G

GABLS ..... GEWEX Atmospheric Boundary Layer Study
GASS ..... Global Atmospheric System Studies (GEWEX)
GAW ..... Global Atmosphere Watch
GEWEX ..... Global Energy and Water Cycle Experiment
GLASS ..... GEWEX Global Land/Atmosphere System Study
GNSS ..... Global Navigation Satellite System
GOS ..... Global Observing System
GRIB ..... GRIdded Binary data format
GTS ..... Global Telecommunication System
GURME ..... GAW Urban Research Meteorology and Environment project

H

HiResMIP ..... High Resolution Model Intercomparison Project
HYMEX ..... HYdrological cycle in Mediterranean EXperiment

I

ICE-POP ..... International Collaboration Experiment for Pyeongchang Olympics & Paralympics
ICTP ..... International Centre for Theoretical Physics
IFRC ..... International Federation of Red Cross and Red Crescent Societies
IICWG ..... International Ice Charting Working Group
IOP ..... Intensive Observing Period
IRI ..... International Research Institute for Climate and Society
IWM ..... International Workshops on Monsoons
IWTC ..... International Workshop on Tropical Cyclones
IWTCLP ..... International Workshop on Tropical Cyclone Landfall Processes

J

JCOMM ..... Joint Commission for Oceanography and Marine Meteorology

L

LC-LRFMME ..... WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble

M

MesoVICT ..... Mesoscale Verification Intercomparison over Complex Terrain
MET ..... Meteorology (aviation abbreviation)
MJO ..... Madden-Julian Oscillation
MJO-TF ..... Madden-Julian Oscillation Task Force
MOSAiC ..... Multidisciplinary drifting Observatory for the Study of Arctic Climate

N

NASA ..... National Aeronautics and Space Administration
NAWDEX ..... North Atlantic Waveguide and Downstream impact EXperiment
NEWP ..... Numerical Environmental and Weather Prediction
NMHS ..... National Meteorological and Hydrological Service
NWC ..... Nowcasting
NWP ..... Numerical Weather Prediction

O

obs4mips ..... Observations for Model Intercomparisons
OPERA ..... Operational Programme for the Exchange of weather RAdar information
OSE ..... Observing System Experiment
OSSE ..... Observing System Simulation Experiment

P

PCPI ..... Polar Climate Predictability Initiative (WCRP)

Q

QPE ..... Quantitative Precipitation Forecasting, Quantitative Precipitation Estimation

R

RELAMPAGO Remote sensing of Electrification, Lightning, And Meso-scale/micro-scale Processes with Adaptive Ground Observations
RF ..... Rapid Refresh
RUC ..... Rapid Update Cycle

S

SCMREX ..... South China Monsoon Landfall Experiment
SRNWP-EPS ..... Short Range Numerical Weather Prediction-Ensemble Prediction Systems
SURF ..... Study of Urban Rainfall and Fog/haze
SWFDP ..... Severe Weather Forecast Development Project

T

TIGGE ..... The International Grand Global Ensemble
TLFDP ..... Typhoon Landfall Forecast Demonstration Project
TOMACS ..... TOkyo Metropolitan Area Convection Study

U

UPDRAFT ..... Understanding and Prediction of Rainfall Associated with Landfalling Tropical Cyclones

W

WCRP ..... World Climate Research Programme
WFP ..... World Food Programme
WGCM ..... WCRP Working Group on Coupled Models
WIS ..... WMO Information System

Y

YMC .....Year of the Maritime Continent
YOPP .....Year Of Polar Prediction