31st SESSION OF THE WORKING GROUP ON NUMERICAL EXPERIMENTATION (WGNE-31)

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Supported by
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1. INTRODUCTION

The 2016 WGNE meeting started at 09:00 on Tuesday, 26 April 2016 in the Knowledge Commons on the CSIR Campus in Pretoria, South Africa. Francois Engelbrecht, acting on behalf of the local host, welcomed WGNE participants to the CSIR facilities and provided some logistical information.

The WGNE co-chairs, Ayrton Zadra and Keith Williams expressed their appreciation of the excellent logistical arrangements, the meeting facilities and support by CSIR staff. They also welcomed all participants, including the South African observers, to the meeting.

The WGNE members, ex-officio members and South African observers were then afforded the opportunity the introduce themselves and provided short background information on their areas of expertise.

2. WELCOME BY CSIR EXECUTIVE DIRECTOR

Prof. May Hermanus, Executive Director of Council for Scientific and Industrial Research (CSIR) Natural Resources and the Environment (NRE) opened the 31st Meeting of WGNE, held at the Knowledge Commons conference facility of the CSIR. She welcomed the WGNE members and additional attendees from the CSIR, South African Weather Service, Agricultural Research Council, North West University, University of Pretoria, the University of the Witwatersrand (Wits) and ESKOM (main power producing company in South Africa). She expressed her gratitude to Deon Terblanche (Director: Atmospheric Research and Environment Branch) of the WMO and the WGNE co-chairs (Keith Williams and Ayrton Zadra for agreeing for WGNE to be hosted by the CSIR – the first time for WGNE to be hosted in Africa. She finally welcomed Swadhin Behera and Yushi Morioka of JAMSTEC, collaborators of the CSIR, who have also decided to attend WGNE. Prof. Hermanus proceed to provide some background on the CSIR to the WGNE members. She pointed out that the CSIR performs multidisciplinary research and technological innovation with the aim of contributing to industrial development and the quality of life of the people of this country - and increasingly on the wider continent. She stated that the CSIR believes that science is the foundation to a better future.

Prof. Hermanus proceeded to debrief the audience on the development of the first African Earth System Model the CSIR. The CSIR is in 2015 became a registered CMIP6 (Coupled Modelling Intercomparison Project Phase Six) modelling group and is working towards CMIP6 contributions in time for Assessment Report Six of the IPCC. At CSIR, model development is performed through an African lens, towards more reliable weather prediction and projections of future climate change over Africa. Developing the first African-based Earth System Model is an enormous task but the CSIR is confident this will be seen through in collaboration with the CSIR's international partners, towards contributing to better informing climate change adaptation in Africa, and the betterment of the lives of the people of Africa. Prof. Hermanus also gave an overview of the state of drought in southern Africa, and acknowledged the role that WGNE plays in the improvement of atmospheric models and forecast systems for more skilfull early warning systems to be applied globally and over

Africa. Prof. Hermanus concluded by wishing the WGNE members a week of fruitful deliberations.

3. MEETING GOALS AND ACTIONS FROM LAST MEETING

Ayrton Zadra presented the WGNE action items as updated and attached in Annex 1.

He also gave a short presentation on WGNE, its terms of reference and how it relates to the World Climate Research Programme (WCRP) and the WMO Commission for Atmospheric Sciences (CAS), which includes the World Weather Research Programme (WWRP) and the Global Atmosphere Watch (GAW) Programme and their working structures. An overview on WGNE is provided at: https://www.wmo.int/pages/prog/arep/wwrp/rescrosscut/resdept_wgne.html

4. WCRP and CAS MATTERS

4.1 WCRP matters and implications for WGNE

Deon Terblanche presented the WCRP presentation prepared by Michel Rixen.

In this overview the increasing convergence of visions between weather, climate and environmental communities towards seamless research and transition to operations was highlighted. Strategically, WCRP, WWRP and GAW are facing a number of new challenges requiring enhanced collaboration between their programmes.

He stressed the importance of the Earth System Grid Federation and its associated observational (obs4MIPs) and reanalysis (ana4MIPs) components, as the recommended archive and dissemination platform within WCRP and the need to interface such infrastructure with WMO protocols and standards. He noted the on-going development of two new WCRP Grand Challenges on Long-term Climate Predictions, and Carbon Feedbacks in the Climate System.

He reviewed the outcomes of the 5th WCRP Data Advisory Council session which was held at NCEI, Asheville, USA, 6-7 April 2016, in particular the progress made in the following areas:

- obs4MIPs: publication of more than 50 data sets on the ESGF and another 100+ in the pipe
- fluxes: identification of data sets to improve coupling in Earth System Models
- the development of a new WCRP-GCOS Data Prize
- the development of a consolidated WCRP Data Policy
- the launch of the WCRP-FPA2 Polar Challenge with a Prize money award of 500K Swiss francs

On the WCRP Modeling Advisory Council side, he highlighted:

- The WCRP/WWRP International Prize for Model Development
- The 2nd Summer School on Model development to be held at CPTEC in Spring 2017
- The 5th WMAC session, which met on 25-27 April 2016 (along the 37th session of the WCRP Joint Scientific Committee) to discuss some emerging topics such as the joint meeting of WCRP Working Groups ('Modeling Summit') planned for 2017 and the development of the new WCRP strategic plan. The WGNE co-chairs joined the WMAC session remotely on 25 April and provided the following feedback to WGNE:
    - WMAC was reminded of the purpose of WGNE, that it has responsibilities across all timescales for improving atmosphere models. A list of current WGNE projects was provided and more details were given regarding the MJO-Task Force, WGNE drag project and WGNE/WGCM climate metrics and diagnostics panel (CMDP). The desire for closer working between the CMDP and Joint Working Group for Forecast Verification Research was conveyed.
    - The WGNE co-chairs intend for WGNE to focus on its core task of diagnosing and fixing systematic errors, and as part of this intend for closer working with GEWEX GASS and GLASS. Concern was expressed regarding the current lack of GASS chairs. The next WGNE systematic errors workshop will take place 19th-23rd June 2017 in Montreal. All WMAC members asked to distribute the information and encourage participation. The WMAC co-chairs suggested a wide-ranging steering committee.
    - The WGNE co-chairs raised the issue that coupled models are now used across all timescales and wondered whether the remit of WGNE should be modified more towards the development of physical rather than atmosphere models. It was decided Decision to discuss this further at future the planned joint WGNE/WGCM/WGSIP meeting at the Met Office, October 2017.

Action Item 1: *The WGNE Co-chairs to provide WMAC with information on what WGNE wants from the new WCRP strategy. These include:*

- *Increase science to service component.*
- *Strong recommendation for closer working with the weather side with specific suggestion that WMAC be extended to cover WWRP modelling groups - e.g. DAOS, PDEF, S2S.*
- *Also note the cross-timescale work of GEWEX.*
- *WCRP should consider diverting some funds from big science towards infrastructure given changing computer architectures/scalability issues.*
- *WCRP should consider changing the balance of computing resources in favor of model development rather than large numbers of scenario simulations.*

4.2 CAS & WWRP matters and implications for WGNE

Oystein Hov presented on the work in CAS which is to do science for service, judged by its quality, relevance and impact. The 10 year priorities of CAS (2013-2022) are concerned with high Impact weather and its socio-economic effects in the context of global change; water: modeling and predicting the water cycle for improved DRR and resource management; integrated greenhouse gas information system in support of climate change mitigation; aerosols and their impacts on air quality, weather and climate; urbanization - research and services for megacities and large urban complexes; and evolving technologies and their impact on science and its use.

Science in the weather service should be linked to the value chain of service delivery to the main users, which include the public at large and the main societal sectors (energy production, transportation including aviation, food production, water management). In the value chains or production chains models, data assimilation, EPS-systems are developed and put to operations; and downwind post processing models set up and put to use dependent on user needs (for the general public, aviation, the energy sector, water management, forecasting of flooding, landslides, avalanches, for air quality, shipping routes, road weather, offshore operations including harvesting of marine resources, wave forecasting, agriculture, tourism, emergency preparedness, high impact weather warnings). Verification is an important component of the value chain. User interaction is essential in order to iteratively develop and enhance the value of the results from R&D. The value chain delivers to the users through backend specialized data streams, frontend Internet applications and through man-man or man-machine interactions.

The overarching goals of WWRP is «towards environmental prediction», integrating modeling components (hydrology, sea-ice, ocean, atmospheric composition, etc.) to improve and develop new services, «towards a seamless predictive capability», developing a unified modeling approach on the weekly to monthly time scale, and «towards impacts forecasting», building community resilience in the face of increasing vulnerability to extreme weather events.
The organization of research and development need to reflect that services are becoming more and more specialized, Internet based and without a clear institutional brand. WIGOS is developing into an important integrating mechanism where observations and eventually modelling results can be identified and retrieved through the application of standardized metadata and where IPR is accounted for. The evolution of sustainable data management depends on WIGOS. The global weather enterprise is under change due to new opportunities linked to the Internet, the capability of individuals to feed information into the value chains, and the willingness to invest in meteorological infrastructure outside of the NMHSs. It is a challenge for WGNE and WMO to embrace these new opportunities, at the same time as the public sector is under economic pressure throughout the world. («Big data» may become an important supplement to traditional WMO controlled observational data flows, but require study).

The meeting considered the emerging role of the private sector, specifically the emergence of modelling groups, within WMO and WGNE.

Recommendation 1: *WGNE suggested to the president of CAS that the CAS-17 TECO in July 2017 could provide an opportunity to engage Panasonic and other private sector modelling groups to work with WGNE towards a contribution in the session under emerging technologies.*

WGNE considered the request by WWRP on the optimal balance between ensemble size, resolution and complexity and available computational power to optimize benefit cost ratio.

Action Item 2: *Junichi Ishida and Caroline Reynolds to provide a summary of centre views on ensemble size, resolution and complexity and available computational power to optimize benefits in order to address the WWRP request related the development of the new WWRP Implementation Plan.*

Action Item 3: *Michael Ek and Francois Engelbrecht to engage with Thomas Jung as liaison to PPP and YOPP.*

Action Item 4: *WGNE members make their centers aware of YOPP and contact PPP through Michael Ek and Francois Engelbrecht in instances where there is a commitment to contribute.*

4.3 GAW matters and implications for WGNE

Kobus Pienaar argued that the Global Atmospheric Watch program is well-known to many atmospheric scientists but the perception of its scope does not always reflect reality. GAW was, and still is, a very ambitious global undertaking with a very big impact and footprint on a global scale.

The vision for the next decade of GAW is to grow the international network of high-quality atmospheric observations across the global to local scale to drive high quality and impact science while co-producing a new generation of research enabled products and services. It is foreseen that GAW-lead activities will play an enhanced role in supporting society and that a greater integration of enhanced observation and modeling capabilities will be needed.

The global collaboration across disciplines within the GAW network is one of the key success factors of the program. The eight Science Advisory Groups (on: Total Atmospheric Deposition; Reactive Gases; UV Solar Radiation; Aerosols; Ozone; Greenhouse Gases; SAG on NRT Applications; GURME and IG3IS) in the GAW network provide expertise and knowledge not only on a wide range of topics but is also globally representative to ensure information from more places and over different time and spatial scales are available to the community.

The relevance and usefulness of information and knowledge from the different SAGs to WGNE were briefly mentioned. The SAG on TAD recently produced a global assessment on deposition and it was published as a review article in Atmospheric Environment. And for the first time a global map of the chemical composition of rain water was produced. Atmospheric deposition allows determining the temporal and spatial evolution of atmospheric chemistry and is also a pertinent indicator to evaluate natural and anthropogenic sources. At this stage it is still a challenge to be able to predict (model) these differences and the impact they have on the environment on regional and global scales.

Activities and products of the reactive gases SAG are of more direct importance to WGNE. One example of the importance of high resolution time and spatial information is the very high NO2 hot spot over South Africa, and the quick conclusion was that it must be due to all the power station on the Mpumalanga Highveld operating without scrubbers. Modeling the processes did not result in results that agree with this conclusion and a more in-depth local study indicated that vehicles and other anthropogenic sources in Gauteng contribute largely to this hot spot. The shift focus of GAW to include a local scale of observations and the involvement of local knowledge are thus very important to understand global observations.

From a GAW perspective, increased collaboration on:
- model expertise exchange and joint model development;
- model-observation integration among the SAGs;
- integrating observation with model development, including, but not only, model evaluation, data assimilation and source attribution;
- stimulating the atmospheric chemistry community worldwide to engage on model development going further than models use only;
- identifying local/regional needs in terms of operational products and services;
- guiding design and implementation of local/regional atmospheric chemistry operational forecasting systems;
- performing global/regional model reanalysis in order to build up a multi-model database resources for model applications;
- carrying on global/regional assessments via observation-modeling integration;
- developing common reference on skill standards for chemical composition models and products for evaluation purposes.

The discussion that followed highlighted the growing recognition of the role of atmospheric composition as an additional source of predictive skill in models at all time ranges. Furthermore the impact of air quality on health and the environment is substantial. It was decided that it would be to the benefit of both WGNE and GAW to maintain strong links.

Action Item 5: *The GAW SSC Chair to be invited as an ex-officio member of WGNE.*

4.4 SPARC report and WGNE role

Quentin Errera reported that SPARC (Stratosphere-troposphere Processes and their Role in Climate) is one of the core projects of WCRP. It focusses on three themes: atmospheric dynamics and predictability, chemistry and climate, and long-term records for climate understanding. To tackle these themes, SPARC is organized around several activities and some of them have been presented at WGNE-31: S-RIP, ACAM and QBOi. S-RIP (SPARC Reanalyses Intercomparison Project) has started in 2013 and should provide its final report in 2018. Reanalyses are key climate data sets to understand processes and variability in the atmosphere. The goals of S-RIP are to (1) create a communication platform between the SPARC community (middle atmosphere, UTLS, etc.) and the reanalysis centers, (2) understand current reanalysis products and contribute to future reanalysis improvements in the middle atmosphere region (including

UTLS, strato-tropo coupling, etc.) and (3) write up the results of the reanalysis intercomparison in peer reviewed papers and two SPARC reports.

ACAM (Atmospheric Composition and the Asian Monsoon) is a new joint SPARC/IGAC activity. The monsoon system is relevant to regional air quality, climate change, and global chemistry-climate interaction. Accurate representation of this system in global chemistry-climate models (CCMs) is critical to predict future change in this region. To characterize and quantify the impact of the monsoon, integrated study is essential, including observations (in situ and remote sensing) from the surface through the troposphere and stratosphere as well as modeling from regional to global scales. To achieve this goal, ACAM has built an international team bringing various expertizes and resources.

QBOi (Quasi Biennale Oscillation initiative) is also a new SPARC activity. The QBO influences the exchange between the troposphere and the stratosphere. The goal of this activity is to evaluate the QBO representation in different GCM, will evaluate the impact of inter annual forcing on modeled QBO. This will be used to quantify the uncertainty of climate prediction due to the QBO.

WGNE members are welcome to get involved in these activities.

Action Item 6: Quentin Errera to advertise the systematic errors workshop scheduled for June 2017 among the SPARC community.

Action Item 7: Quentin Errera to provide feedback on the availability of ERA-5 data to WGNE members.

5. OUTCOMES FROM RECENT WORKSHOPS RELEVANT TO WGNE

5.1 WWRP/WCRP/SPARC Blocking workshop (Reading, UK, 6-8 April 2016)

Keith Williams reported on this workshop which was attended by over 100 scientists incl. most of the key researchers in the field.

Slides available from http://www.met.reading.ac.uk/~ben/blocking2016

Key points include:
Still no agreement on what is blocking (is a PV reversal required or is a stationary PV ridge sufficient) – organizers tried hard to reconcile this – may become a BAMS article.

General improvement over recent years in the ability of models to simulate blocking – most of the issues are now beyond week 1.

Biases vary between models (no longer a problem of too little blocking globally), however most models struggle to simulate enough wintertime European blocking.

Resolution is important in some, but not all, models and ocean resolution may be particularly important for Atlantic/European blocking. Suggested that resolution is important in situations where it improves the mean state of the storm track.

5.2 Understanding modelling and predicting weather and climate extremes, 5-7 Oct 2015, Oslo.

This workshop brought together national and international experts and early career scientists from weather, climate and statistical sciences with the goal to discuss some of the scientific challenges as emphasized in the WCRP Grand Challenges on Weather and Climate Extremes white paper (http://www.wcrp-climate.org/index.php/gc-extreme-events). In particular, the workshop will address:

• Dynamical and physical processes (e.g., large-scale modes of variability, atmospheric blocking, land-atmosphere and snow feedbacks) that affect the occurrence and amplitude of weather and climate extremes
• The representation of these processes in models and their usefulness and potential for prediction of extremes
• The development of statistical methods and tools to incorporate this information into model performance metrics.

The main purpose was to identify opportunities for cross-community collaborations to address the challenges (e.g., modeling experiments, data needs, storylines for model evaluation, scale issues) and to coordinate future research and communication of results.

Breakout discussions focused on what are the relevant definitions of extremes on all timescales. What are the necessary observations and model output requirements to analyze these extremes? What processes are driving these extremes? How do we best evaluate extremes? (i.e. is the model right for the right reason)? What are the relevant sources of predictability of events that can support attribution, prediction and projection of extremes on the 2, 5 and longer time scales.

5.3 Model Uncertainty Workshop

Nils Wedi reported on the model uncertainty workshop (April 11-15 2016 WWRP co-sponsored; detailed information and outcomes on www.ecmwf.int)

There has been some discussion on the definition of model error and model uncertainty representation in data assimilation, short and medium range forecast, seasonal and climate time scales and if the seamless concept also applies here, and equally distinction from initial uncertainty as well as random vs systematic error. There are approaches to identify model error from data assimilation but is not independent from observation distribution and observation error assumptions.

6. REPORTS

6.1 YOPP report

Thomas Jung made a remote presentation on the Polar Prediction Project and the related Year of Polar Prediction (YOPP). He first reminded the rationale behind PPP and YOPP based on the rapid changes in Polar Regions, the emerging needs for improved understanding and predictions and the need to enhance observations and conduct specific process and modelling studies and development to achieve the objectives.

He gave an overview of the YOPP Summit which took place at WMO, Geneva from 13 to 15 July 2015, attracting 116 participants from 20 nations. Through live streaming up to 750 users were online at the same time. The decisions are summarized in YOPP Summit report and the meeting report published in BAMS (early online). The recommendation made at the summit were incorporated in YOPP Implementation Plan v2.0. Thomas also explained the rationale behind the Multidisciplinary drifting Observatory for the Study of the Arctic (MOSAiC) initiative.

He reviewed the previous WGNE action items and summarized the progress (on all items) and concluded with way forward on the modelling activities as per the final slide on his presentation.

6.2 GOV report

Hal Richie made a remote presentation on GODAE OceanView and its Coupled Prediction Task Team. GODAE OceanView continues the legacy of GODAE in providing leadership in consolidating and improving R&D for global & regional ocean analysis and forecasting systems. The mission goal of the CP-TT is to draw together the international scientific and technical expertise in ocean, sea-ice and wave prediction and to seek collaboration with equivalent expert groups in atmospheric-land surface-hydrology prediction to accelerate the scientific and technical development of fully coupled systems for short- to medium-range prediction. Hal highlighted a number of high priority research areas and current CP-TT activities.

Following the discussion it was agreed to have a more focused meeting on coupled modeling for shorter ranges in fall 2017.

7. NUMERICAL METHODS

7.1 Improving ECMWF's IFS model

Starting with constraints on energy and big data flow Nils Wedi reviewed the status of global modeling dynamical cores and the spectral transform method in particular. A new approach investigated at ECMWF looks at a hybrid strategy. The Escape project is introduced to address scalability challenges. Then several examples are given for an integrated approach to earth system modeling and current challenges, namely convection and boundary layer interaction, coupled processes, and model uncertainty representation.

Themes in the systematic errors workshop to include coupling between dynamics and physics.

7.2 Recent developments in Numerical Methods

Michael Baldauf gave an overview on numeric developments partly by contributions of WGNE members, but mainly by reporting from the 'PDEs on the sphere' workshop held in Oct. 2015 in South Korea hosted by KIAPS, and by the SciCADE conference, hosted by University of Potsdam in Germany.
The following topics had been addressed:

Horizontal grids in global models.
Most popular is the cubed-sphere grid. Also the icosahedral grid is applied. A bit less often used is the Yin-Yang-grid. The pure latitude-long grid is outdated (otherwise grid point extraction near the poles should be used, leading to a reduced grid). Grid refinement capabilities are now almost a standard in new global model developments, either by grid stretching or by 2-way nesting.

Spatial discretization of the Euler Equations.
Pure finite difference (FD) based dynamical cores are a bit outdated (however still used). Many new models use a mixture of finite volume (FV) (for continuity eq. and tracer eqns., possibly also for energy equation) and finite difference for momentum equation. There is an increasing interest in finite element (FE) based methods, because they lead to higher order discretization. Two main flavors are the spectral elements (or continuous Galerkin) method and (less favored) the discontinuous Galerkin method. Though higher order methods have several advantages (e.g. less grid imprinting) there are still problems to solve. One example is to construct monotonic schemes, which are not too diffusive.
Spectral dynamical cores are still under consideration, based either on spherical harmonics or on double Fourier series expansion.

Time integration schemes.
The basic ideas are still the semi-implicit scheme (often combined with Semi-Lagrangian advection) or the horizontally explicit – vertically implicit approach (either split-explicit or non-split).
Newer developments are the use of exponential integrators (still expensive) and the slowly emerging parallel-in-time procedure.

Advection schemes (for tracers).

Though probably FV schemes are often used, special consideration of conservative Semi-Lagrangian schemes can be observed.

New test cases presented at the PDEs 2015 are
an (almost) exact analytic solution of the linearized shallow water equations, a moist version of the Held-Suarez test, and an exact solution for the 3D vector diffusion equations.
The DCMIP initiative will perform a summer school in June 2016 focusing on 3 test scenarios.

Finally a short survey over the possible managing with new emerging computer architectures from the developer's viewpoint was given.

Action Item 8*: Michael Baldauf to add the timing of the dynamics and physics and peak performance in the center summary table.*

8. MODEL EVALUATION

8.1 Deterministic and ensemble verification scores?

The talk by Nils Wedi provided an overview on the evolution of deterministic and ensemble prediction scores from the different global forecasting centers for the period 1998-2016.

The presentation includes verification measures for precipitation and a set of scores comparing different analyses and forecasts over the Arctic and Antarctic regions in preparation for YOPP. Finally, a reminder to use and contribute to the WMO-LCDNV website hosted at ECMWF.

Francois Bouyssel remarked on the fact that all centers still not apply the CBS recommended verification scores.

Nils Wedi and Marion Mittermaier remarked on the new guidelines for the exchanged of verification scores and on the roles of individual centres and that of ECMWF.

Recommendation 2: *WGNE recommends to WMO/CBS to encourage modeling centers to adopt and exchange the WMO recommended verification upper air scores. See GDPFS manual: https://www.wmo.int/pages/prog/www/DPFS/Manual/documents/485_Vol_I_en.pdf*

8.2 TC verification

Junichi Ishida (JMA) made a report about TC verification for 2014. Eleven NWP centers (BoM, CMA, CMC, DWD, ECMWF, JMA, KMA, Météo-France, NCEP, NRL and Met Office) participated in the project this year. Overall ECMWF, NCEP and Met Office achieve the best forecast on average in almost all basins. The error dispersions by NCEP, JMA and CMC are relatively small. There is a significant slow bias for JMA, BoM and NRL in WNP basin. Good linear relationship is found for NCEP, CMA and NRL especially in weak TC at initial time. All models failed to

predict deep TCs around the east of Philippine and the east of Mariana Islands. JMA has conducted new verification of false alarm rate to follow the action item of WGNE 30 meeting. ECMWF achieved best performance of FAR and JMA, BoM and NCEP follow in WNP and NAT region. Tropical cyclone size verification was carried out as an additional verification. There is a large discrepancy of radius of maximum wind speed (RMW) among models. ECMWF reproduces smallest RMW followed by JMA and Met Office. BoM, CMC and Météo-France show large RMW with large initial central pressure difference. JMA noted a plan to submit a paper with a title of "WGNE Intercomparison of Tropical Cyclone Forecast by Operational Global Models: A Quarter-Century and Beyond" to follow the recommended item of WGNE 30 meeting.

Marion Mittermaier raised the possibility of an establishment of a lead center for TC verification along the CBS lines followed by a short discussion highlighting the approach of WGNE that is focused on model improvements.

Julio Bacmeister enquired whether precipitation verification is done in the context of tropical cyclone and it was confirmed that this is not done at present.

Action Item 9: *That the TC verification information compiled by WGNE, including the overview paper being prepared for BAMS, be brought to the attention of the WWRP Working Group on Tropical Meteorological Research and CBS by Junichi Ishida, to ensure relevant coordination and to keep WGNE co-chair informed of progress.*

Action Item 10: *WGNE requests centers to submit full resolution model output for TC verification.*

8.3 Precipitation Verification

An overview of recent activities on quantitative precipitation forecast (QPF) verification was presented by Francois Bouyssel based on contributions (slides and responses to a survey) provided by 10 centers.

An evaluation of global model precipitation forecast against data from national rain-gauge networks has been started in 1995 and is now performed by several centers. These inter-comparisons have evolved to take into account increased spatial resolution of NWP models and research advances on QPF verification methods. It has been very useful over the years to evaluate QPF improvements of operational global NWP models. Evolutions from latest WGNE meeting have been highlighted. There are some interests to increase forecast data resolution in time (at least 6h) and space. Some centers (CPTEC, CSIR, KMA) have expressed willingness to contribute to these inter-comparisons.

The survey on the use of recommended methods for the verification of NWP based QPF against "high resolution limited area observations" (JWGFVR, Nov 2013) confirms that most centers have implemented recommended scores for deterministic model evaluation using climatological rain-gauges network and/or gridded precipitation analysis (combined rain gauge-radar; combined rain gauge-satellite). Few centers are computing recommended scores on EPS but many have plans to do so.

Elena enquired how to reference the precipitation verification guidelines prepared by the Joint Working Group on Forecast Verification Research (JWGFVR) and reviewed by WGNE in 2013.

Action Item 11: *Marion Mittermaier and Deon Terblanche to follow up on the fate of the precipitation verification document, its update etc. and provide feedback to WGNE members.*

8.4 Subjective evaluation of NWP operational French models

Francois Bouyssel reported on some systematic problems of MF operational global ARPEGE and AROME systems as seen from forecasters are illustrated over France. The mean sea level pressure gradient in case of mid-latitudes winter storms is sometimes overestimated in ARPEGE, a known problem linked with convection modelling in the gray zone. There are still recurrent large errors in modelling low level cloudiness (fog, stratus, stratocumulus) with NWP models, generally there is an underestimation, but an overestimation is sometimes occurring over ocean. Wind gustiness are more realistically simulated by the kilometric scale model over orography and under thunderstorms, but with also with a higher false alarm rate. Some variability between successive forecasts of the convective scale system happens is some situations, which might be the consequence of low predictability or insufficient assimilated observations. Anyway, there is a very positive balance sheet of kilometric scale AROME system use by forecasters. There are several advantages of AROME versus global model ARPEGE, such as see breeze, precipitation features, fog and low clouds, precipitations and winds over orography, resolution of strong convection, etc. Some problems of false alert occur sometimes on gustiness and heavy rainfall, but have been reduced with the new AROME 1.3km version. Next challenge for forecasters will be to work with the AROME EPS (to be operational by end of 2016).

Ayrton Zadra remarked on some common errors seen in the Canadian model and encourage the exchange and scrutiny of this type of information.

Keith Williams suggested that the types of synoptic situations that lead to certain types of precipitation errors deserves a closer look.

Marion Mittermaier remarked on the grey zone issues related to 1 km scales models. She remarked about the post-processing and probabilistic techniques that could be applied before providing the information to forecasters.

Michael Ek made reference to the relevance of GEWEX expertise (within GASS) relevant to the above matters.

8.5 Using satellite simulators for cloud evaluation

Keith Williams reported on the CFMIP Observational Simulator Package (COSP) contains forward models for a number of satellite instruments and is designed for use within a general circulation models to produce diagnostics which emulate the observational products in a consistent way (the package can also be run offline with high temporal resolution 3D input fields).

The presentation gives examples of how the package has been used at the Met Office to improve the simulation of cloud in the model across timescales. The use of multiple simulators has been found to reduce the risk of introducing compensating errors in the model.

COSP is being widely used in the climate community with the diagnostics forming part of the core set for CMIP. Discussion is proposed on whether COSP is being used within the NWP community; would it be valuable to have an intercomparison of COSP diagnostics for NWP models and, if so, when (now or after the launch of Earthcare)?

A discussion followed to identify whether centers should join this work.

Action Item 12: *Keith Williams to draft an outline of what is expected from centers regarding joining an inter-comparison exercise based on satellite cloud simulators.*

9. MJO-TF current activities and next steps

Steve Woolnough reported that the MJO Task force was renewed in December 2015 for further 3 years (2016-2019), its activities are broadly organized in 5 subprojects (see below). Eric Maloney is to stand down as co-chair from 1st of May 2016 and will be replaced by Daehyun Kim.

Development of process-oriented diagnostics/metrics for MJO simulation: This is a continuation of existing activity in this area, to develop process orientated diagnostics to inform model development. Emerging plans are to improve the links between these diagnostics and theoretical models for the MJO, and to develop process orientated diagnostics related to prediction skill.

Ongoing evaluation of real-time forecasts and hindcasts of tropical intraseasonal variability, including assessment of hindcasts in the S2S model database: This is a continuation of existing activity in this area. New plans include linking with the S2S sub-project in the analysis of MJO forecast skill, developing analysis of the relationships between MJO forecast skill and predictive skill in models for MJO related weather variability. We're also discussing with the S2S sub-project about the production and sharing of tropical ISV indices from the S2S database
Develop, coordinate, and promote analyses of MJO air-sea interaction: This is a relatively new activity to improve our understanding of air-sea interaction in the MJO. We have recently published a review paper (DeMott et al, 2015), highlighting gaps in our understanding and make recommendations for future experimental design and analysis. A further paper is in review on some proposed diagnostic approaches.

Advance understanding of MJO interactions with the Maritime Continent: This is a new sub-project joint with S2S Project. Our major activity this year has been the organization of a joint workshop on "The interactions of the MJO with the Maritime Continent", hosted by the Meteorological Service Singapore, April 11-13, 2016. This workshop had around 60 invited participants with invited and contributed talks and posters on topics including the interaction of the MJO with the diurnal cycle, synoptic systems and monsoons in the Maritime Continent,

air-sea interaction and land surface interaction, and simulation and prediction. The Task Force and S2S project are using the discussions at this workshop to identify research priorities and develop ideas to take them forward.

Develop, coordinate, and promote analyses of MJO interactions with the extratropics: This activity has only recently begun, and is in collaboration with the S2S sub-project on teleconnections. Its goals are to improve our understanding of MJO teleconnections, their dependence on the slowly varying background state, and their representation in weather and climate models.

DeMott, C. A., N. P. Klingaman, and S. J. Woolnough (2015), Atmosphere-ocean coupled processes in the Madden-Julian oscillation, Rev. Geophys., 53, 1099–1154, doi:10.1002/2014RG000478.

Action Item 13: *The co-chairs of the MJO Task Force should come to an agreement regarding on responsibilities between MJO Task Force and S2S on the assessment of MJO index forecast and other related matters and then to inform WGNE and WWRP accordingly.*

Action Item 14: *The WGNE Co-chairs undertake to sign an appropriate letter on behalf of WGNE in support to the Year of Marine Continent initiative with input from Steve Woolnough.*

A general discussion on systematic error related issues that should be addressed by WGNE to be reported at the systematic error workshop in September 2017.

Some of the issues to include in the workshop:
- Weak precipitation biases in NWP and climate models, e.g. looking at which precipitation parameterization produces the precipitation (Francois Bouyssel) and Marion and Nils to look into whether ECMWF could possible assist in the partitioning of these errors.
- Teleconnections relevant S2S and the MJO-TF (relevant co-chair)
- Tropical cyclone intensity especially at shorter time ranges (Junishi Ishida) and for centers to submit full resolution data to look at this issue.
- Model activity and errors in the maritime continent.
- Low cloud biaises including at high latitudes / poles.
- Rain biases over summer continents.

Action Item 15: *For Nils Wedi and Marion Mittermaier to prepare a partition SEEPS score for the systematic error workshop.*

10. OTHER ACTIVITIES LINKED TO WGNE

10.1 CMIP timescales, esp. WGNE involvement in HIGHRESMIP

Julio Bacmeister presented on the CMIP activities.

CMIP6 in General

CMIP6 Organization and Design has been finalized. CMIP6 endorsement of MIP proposals is also final. Timelines are in place for forcing datasets. CMIP6 simulations to take place 2016-2020. Infrastructure is in development (including

data request) by WGCM Infrastructure Panel (WIP). More than 30 groups are participating using a hierarchy of models.

CMIP6 will address three broad questions: (i) how does the Earth system respond to forcing?, (ii) what are the origins and consequences of systematic model biases?, and (iii) how can we assess future climate changes given climate variability, predictability and uncertainties in scenarios? New scenarios span the same range as the RCPs, but fill critical gaps for intermediate forcing levels and questions for example on short-lived species and land-use.

Stronger focus on routine model comparisons with data - coordinated by the WGNE / WGCM climate diagnostics and metrics panel in collaboration with the CMIP Panel

Meetings

31 Oct - 4 November 2016: WGCM-20 (Princeton, USA)

Special issue in CMIP6 in *Geosci. Model Dev.*

http://www.geosci-model-dev.net/special_issue590.html

- Overview of the CMIP6 Design and Organization (Eyring et al., GMDD, 2015)
- Experimental design from all CMIP6-Endorsed MIPs (submission by 31 March 2016)
- Description of the CMIP6 forcing data

HighResMIP

HighResMIP is still open to participation from new NWP centers. Leads Haarsma and Roberts hope participation in tier 1 historical 1950-2015 (or sub-period) AMIP is feasible. Note HighResMIP requests these be done with 0.25^{o} daily SST data sets described in GMD paper. Please comment on HighResMIP paper during discussion phase in GMD – open until 07 June 2016.

QBOi

QBOi is an intercomparison project focusing on simulations of the quasi-biennial oscillation in the tropical stratosphere. Focus is on climate model sensitivities and climate change sensitivities of QBO, but seasonal QBO forecasting using atmospheric initial conditions is also being done. Meeting:

SPARC QBO Workshop: 26-30 September 2016, Oxford, United Kingdom

Registration Deadline: May 31, 2016; Abstract Decision: 7 June, 2016

A discussion on the use of prescribed daily SSTs in HighResMIP followed.

Recommendation 3: WGNE members to encourage their centers to contribute (at least the tier 1) contributions to the activities of HighResMIP.

10.2 WGNE blue book – status and proposed changes

Elena Astakhova presented on the WGNE Blue Book and provided a comprehensive history and the current status of the WGNE Blue Book Research Activities in atmospheric and oceanic modelling are overviewed. Since 2015 this electronic edition has been prepared at the Hydrometcentre of Russia. In 2016 the contributions were submitted via the Web interface. Some updates of the Blue Book structure are suggested including the addition of information about WGNE activity and supported projects as well as modification of the list of sections to better reflect the current tendencies in atmospheric and oceanic research.

Keith comment on the drop on contribution probably the pressure on scientists to publish in peer-reviewed journal and the lack of a DOI.

Nils mentioned the requirements of several centers to introduce model changes only if peer reviewed and the possibility to provide links to internal reports.

Keith mentioned the need to update and possibly find a host for a more modern WGNE website.

Action Item 16: *Elena Astakhova to take forward the possibility of RosHydromet to host the WGNE website and the integration of the Blue Book, to which all members should contribute, in such a site*.

10.3 Simulating the radiative forcing effects of Antarctic stratospheric ozone on southern African climate variability

Francois Engelbrecht (CSIR) presented on recent predictability experiments performed at the CSIR within the context of seasonal forecasting. His talked commenced with an overview of the CSIR-based model VRESM (Variable-resolution Earth System Model) developed by the CSIR and international partners towards CMIP6 contributions. This model uses as atmospheric component CCAM/VCAM of the CSIRO, the CABLE land-surface model of the CSIRO and the new ocean model VCOM developed at the CSIR. All these models use cube-based grids. He proceeded to present results on AMIP simulations performed using CCAM. These simulations were performed for the period 1979-2005 using the standard AMIP configuration (control simulation), and for a second sensitivity test that employed time-varying stratospheric ozone concentrations as a radiative forcing. Each experiment consisted of 12 ensemble members obtained using a lagged-average forecasting approach. It was shown that significant improvements in the skill of simulating summer-time anomalous atmospheric circulation over southern Africa may be obtained from time-varying ozone forcing. Moreover, anomalous stratospheric ozone forcing may be a mechanism that explains why the ENSO teleconnection to southern Africa is not linear.

10.4 Operational implementation of GRAPES global forecast system

Jian Sun could not participate in the meeting but provided a presentation as included in WGNE-31 presentations.

10.5 Current developments in the INPE/CPTEC modelling system

The CPTEC's presentation by Ariane Frassoni aims to show the recent developments on the modeling system of INPE/CPTEC. I'll show the main improvements of the regional model BRAMS and AGCM. The main improvement of the BRAMS model of the implementation of the GF convective scheme (Grell and Freitas, 2014, ACP) and Bechtold et al. 2014 to better represents the transition between shallow to deep convection, with impacts on the diurnal cycle over Amazon. About the global model, a new version was released in January 2016 with several improvements in comparison with the old version. Even with the improvements implemented, the AGCM still has low performance compared to other models.

Issues related to precipitation over the Andes and the investigating of ETA vertical coordinate.

Recommendation 4: *Promote using the Andes and the Amazon as standard verification test cases by modelling centers and request Araine Frassoni to lead this initiative.*

Action Item 17: *For Marion Mittermaier and Ariane Frassoni to follow-up regarding interest by South American colleagues to participate in MesoVICT.*

10.6 Research in atmospheric modelling in Russia

Elena Astakhova presented a list of numerical models currently operated at the Hydrometcentre of Russia. The introduction of a new version of the global SLAV model with increased spatial resolution (up to ~20 km) to operational practice is noted. The results of three research works are briefly described. 1) A new approach to EnKF and EnVar is suggested - the Hierarchical Bayes Ensemble Filter (HBEF). In tests made with a doubly stochastic advection-diffusion-decay model on the circle HBEF outperforms both EnKF and variational data assimilation. 2) The work on introducing a new aerosol climatology to the COSMO model includes a comparison of the new climatology (Kinne etal 2015) to AERONET observations at the meteorological observatory of the Moscow State University and numerical experiments on the sensitivity of radiation characteristics to updating the aerosol climatology. 3) A limited-area spatio-temporal Stochastic Pattern Generator (SPG) was developed with a goal to apply it in generation of model-error perturbations. SPG provides realistic non-separable spatio-temporal correlations and satisfies the proportionality of scales which is widespread in geophysical fields (i.e. longer spatial scales “live longer” than shorter spatial scales, which “die out” quicker). SPG is now being implemented to the official COSMO code.

11. MODEL EVALUATION (CONT.)

11.1 Report from JWGFVR

Marion Mittermaier reported on the activities of the JWGFVR.

Outreach activities included the roving training tutorial presented by 4 working group members 17-19 November 2015 Jakarta. Other outreach activities include continued involvement in training for SWFDPs. Another milestone is the release of the Mausam special issue with papers from the 6th international verification methods workshop in Delhi in 2014. The EMS-ECAM verification session in Sofia, Bulgaria in September 2015 was a particular highlight. It was the largest parallel session at the conference and by far the best attended. Many times it was standing room only. There are several meetings in the pipeline. In our continued attempt to reach out to the climate community the verification session organized by members of the WG in the EMS-ECAC meetings continues this September 2016 in Trieste. There will also be a "Mesoscale Verification Intercomparison in Complex Terrain" (MesoVICT) session at the conference. This will be followed the following week the WG annual meeting (19-20 September) and the second MesoVICT workshop (21-23 September) in Bologna. Planning for the 7th international verification methods workshop in Berlin is also advancing. Provisional dates are 15-18 May 2017 with the tutorial the week before (10-13 May). The plan is to extend the workshop by one day to include joint sessions with the Climate Metrics Panel to foster continued convergence and enhanced collaboration between the weather and climate communities.

A key activity for the WG is the "Best new user-oriented verification metric" challenge which was launched in September 2015 at the EMS-ECAM conference. WGNE members are encouraged to encourage colleagues to consider entering.

HIW activities have included meetings of the evaluation task team, which involves a number of WG members. Much effort went into the development of two H2020 bids, I-REACT and Meteo-INFORMED, only I-REACT was successful, whilst Meteo-INFORMED had a larger verification component. Nevertheless the people working on the unsuccessful bid have continued to work together to identify and apply to other funding streams to facilitate the work that needs to be done around the utilization of novel data sources, how existing methods could be adapted or new methods developed to make use of them for the verification of weather impacts and hazards.

The WG has also been very involved in the drafting of the implementation plan for S2S and in doing the work. This includes the preparation of a questionnaire on sub-seasonal verification practices in operational centers and a summary of collected results received from the 12 WMO GPCs. A document on S2S application-oriented activities and operational needs has been drafted.
A literature survey on verification methods of relevance to S2S verification has been completed as well as published literature on S2S verification.

For PPP a document on verification in Polar Regions is being drafted. There are already some very novel and useful new user-oriented methods being developed, e.g. for the verification of ice edge forecasts.

It was recommended that the TC verification document commissioned by WGNE (WWRP 2013-7) is to be turned into a set of metrics to be exchanged by global centers (CBS-style). This has not begun as it requires interaction between many groups and the consultation and ratification process is lengthy.

A review of selected science highlights was provided; several examples of observation uncertainty and limitations e.g. sondes, radar rainfall estimates and

temperature. There are several examples of where weather (NWP) diagnostic methods are being applied to recent climate simulations. This was also presented in an invited presentation at the recent M-Clix workshop in Oslo (http://www.wcrp-climate.org/extremes-modeling-wkshp-agenda-presentations). An update of the MesoVICT project was also provided, suggesting that many centers have contributed km-scale runs of case 1 with the latest model configurations. Development of new methods is less easy to gauge but the use of the SpatialVx R package is increasing rapidly within the community. (https://cran.r-project.org/web/packages/SpatialVx/SpatialVx.pdf).

With respect to the precipitation recommendations document commissioned by WGNE several years ago, there are good grounds to think it will need to be revised in the next few years with the impending changes in the CBS exchange of global surface verification scores and outcomes from the MesoVICT project for example. An overview of what will be exchanged was provided. The document presented does not cover km-scale models and issues with the double penalty effect adequately. Whilst there is an emphasis on the development of gridded data sets, the fact that the size of the grid squares is converging towards a point means that verification of forecasts at observing sites must be included and this is where the treatment of forecasts becomes important.
The link between post-processing and verification was highlighted and the need to treat km-scale NWP output differently, i.e. not at the grid-scale, but probabilistically.

A discussion introduced the issue how to make model testing as cheap as possible to test whether improvements are statistically significant as a challenge for the JWGFVR.

The process to facilitate the introduction of operational tropical cyclone verification under CBS was discussed.

Action Item 18: *Marion Mittermaier to take forward the development of SEEPS for CBS.*

11.2 WGCM/WGNE climate metrics and diagnostics panel (CMDP)

Peter Gleckler presented on the status of CMIP6 which is arranged in a more continuous and distributed manner. He highlighted the 21 endorsed MIPs that will form part of the initiative, ranging from HighResMIP (focusing of regional issues) to VolMIP (characterizing forcing). Peter also provide an overview of the timeline towards 2020 and the planning beyond, with status on progress and an outlook. He pointed out the use of the Earth System Grid Federation used for data exchange since CMIP5 which involved in the order of 5Pb of data.

Peter then gave an overview of obs4MIPs, a project for identifying, documenting and disseminating observations for climate model evaluation. An initiative to intercompare model performance and to display this was also shown.

11.3 General discussion on the links between the JWGFVR and CMDP

Marion Mittermaier suggested that a member of the CMDP could become a member of the JWGFVR to facilitate coordination. Peter Gleckler proposed that the development of a catalog of the various tools and their status of development should be shared between the two groups. The meeting also considered the role of community verification tools (eg. The SpatialVx R package).

Action Item 19: *Peter Gleckler to email the CMDP members to ask a volunteer to join JWGFVR.*

Action Item 20: *Marion Mittermaier to send Peter Gleckler the detail of the SpatialVx R verification package.*

Recommendation 5: *For the OBS4MIPS initiative to make data available at higher spatial and temporal available to facilitate joint efforts across time scales.*

12. PARAMETRIZATION DEVELOPMENT

12.1 Drag project – progress report

Ayrton reported that a short summary of the results from the WGNE Drag Project, led by him and Julio Bacmeister, were presented at the SPARC-SSG23 (Nov 2015) and GEWEX-SSG28 (Jan 2016) meetings. A. Zadra was then invited to present more detailed results in the 2016 SPARC Gravity Wave Symposium (May 2016) and SPARC DynVar Workshop & S-RIP Meeting (June 2016).

ECMWF is organizing a workshop on “Drag processes and their links to large-scale circulation”, in Reading, UK, Sep 2016, with support from WCRP, WWRP, SPARC, GEWEX and NCAR. The scientific committee includes the two co-leads of the WGNE Drag Project, J. Bacmeister and A. Zadra.

An article by Sandu et al. 2015, entitled 'Impacts of parameterized orographic drag on the Northern Hemisphere winter circulation”, recently published in the Journal of Advances in Modeling Earth Systems, shows interesting results from a sensitivity study partly inspired by the results from the WGNE Drag Project. A. Zadra is one of the co-authors.

WGNE members to consider the inclusion of “momentum budget and surface drag” in the list of relevant themes for the 2017 WGNE workshop on Systematic Errors.

Following a discussion the understanding of the cascading of influences should also be addressed at the systematic error workshop.

Action Item 21: *Michael Ek and Francois Engelbrecht to discuss with YOPP possible projects on drag and momentum processes.*

Action Item 22: *Ayrton Zadra to consider studies on the difference between models as to how the drag signal propagates into the upper atmosphere.*

12.2 Implementing the Cloud Layers Unified by Binormals (CLUBB) scheme in the Community Atmosphere Model (CAM)

Julio Bacmeister reported that CMIP6 developments for CESM are underway. Physics changes include introduction of a new higher-order turbulence scheme that prognoses 10 moments involving w', T' and q' (Cloud Layers Unified by bi-Normals- CLUBB). Closures are calculated via assumed joint bi-normal PDFs for w', T' and q'. The CLUBB scheme performs well in reproducing distributions of low-level clouds and resulting shortwave cloud forcing. Quantities related to momentum, e.g., sea-level pressure, appear to be less well treated by the new scheme. Sensitivities to momentum mixing parameters are being explored.

Precipitation biases over high tropical topography were also examined. Test simulations in which moist heating is artificially suppressed over rough terrain reveal that these biases may have significant effects on regional climate. In CESM a pronounced dry bias over the entire Amazon basin is drastically reduced when spurious precipitation over the Andes is eliminated. The mechanism for these remote effects is not clear, nor is it clear how to remove orographic precipitation biases without resorting to unphysical "hacks" of the model's parameterization schemes.

From the discussion it followed that the model with CLUBB is 150 to 200% more computationally expensive.

Potential theme for inclusion in the systematic errors workshop - the influence and impact of the Andes.

12.3 Development of a new prognostic convection scheme for NWP and Climat Arpege global model

Francois Bouysel reported on a new convection scheme called PCMT (Prognostic Clouds, Microphysics and Transport) that has been developed based on 5 prognostic equations for convective hydrometeors (cloud droplets, ice crystals, rain, snow) and vertical velocity. The same microphysics scheme (Lopez, 2002) is used for resolved and convective precipitations (called twice). The validation of the scheme is based on using a hierarchy of configurations (1D, NWP, seasonal, AIP, CMIP), from the most to the weakly constrained, to characterize and better understand the development of model errors.

PCMT is in many aspects an improvement over the previous convection scheme (diurnal cycle of convective precipitation, precipitation intensity PDF, etc.). This scheme will be used in operational NWP, monthly to seasonal forecasts and in CMIP6 simulations, even if not in a full seamless manner (changes in parameters). The scheme code is including numerous options such as the choice of convective closure (intensity) or lateral cloud entrainment, which provides a numerical laboratory for convection studies.

Work in progress concerns downdrafts and density current. In order to define the ascent (or descent) profile, it is planned to use of a new and more appropriate thermodynamic variable beyond the moist static energy.

12.4 Issues with convection parametrization in the UM and ongoing work to them

Keith Williams reported that many of the performance issues with the Met Office Unified Model (UM), particularly in the tropics, are believed to be the result of deficiencies in the representation of sub-grid convection and it's interaction with the large scale dynamics. In common with many models, issues for the UM include a poor diurnal cycle, lack of a slow growth of convection through a congest phase, temporal and spatial intermittency of convection, and no correlation between convection and the large scale dynamics on the timestep/gridpoint level (although well correlated when spatial or temporal meaning is applied).

Work is currently progressing to implement the idea of 'convective memory'. This comprises a 3D, fully advected, prognostic being introduced which measures recent convective activity based on convective precipitation rates. Convective entrainment is set to a higher value if there hasn't been recent activity, forcing convective systems to evolve more slowly. Significant improvement is seen in the simulation of the diurnal cycle and some improvement in the intermittency although there is more work to do on this.

12.5 Paramaterization issues and related modelling challenges at the CMC

Ayrton Zadra described some of the systematic errors currently observed in the CMC forecasting systems, e.g. variability in the cyclonic activity, temperature biases associated to episodes of rain over snow, poor forecast of "dirty highs", excessive moisture fluxes over the oceans, cold biases under stable conditions. He described some of the processes currently missing or poorly represented in the physical parameterizations, as well as issues in the coupling between parameterizations or between dynamics and physics, and issues related to vertical resolution.

He pointed out that lessons were learned from collaboration with forecasters, with other centres, and from the participation in international inter-comparison projects. Testing NWP models outside their "mandate forecast range" have also proved useful.

To address systematic errors, he reminded us of the importance of the need of (1) more observational data and/or better use of existing data, (2) improved verification and diagnostic tools and (3) continued emphasis on inter-comparison projects and collaborations.

12.6 Recent developments in Mesoscale/high resolution NWP and new research development projects

Deon Terblanche presented on behalf of the current and future co-chairs of the WGNMR (Paul Joe, Jeanette Onvlee and, Estelle deConing and Peter Steinle).

WGNMR focus on 0-6 hour time frame and developments at convective scale (or higher). As the science between traditional nowcasting and high resolution are

merging the previous WG's also merged. It was highlighted that FDPs and RDPs are major tools for realizing the goals. The projects often provide high quality, high density observation sets for model development as is available currently for Summer (TOMACS) and winter (ICE-POP) conditions.

The value of convective scale models well-established but there is a need to move beyond standard verification scores into stochastic modeling and verification. There are major developments in modeling, including tuning, data assimilation, verification and observation networks but many challenges remain.

Advances in high resolution NWP has led to major progress in bridging the gap to nowcasting but there is still need blended nowcasting for the first 1-2 hours.

12.7 Recent progress in convective-scale and next generation global modelling at KMA

Dong-Joon Kim reported that KMA has performed several numerical experiments to enhance performance of convective-scale, short-range prediction systems, which includes expansion of the model domain for greater consistency, application of LETKF technique for generation of initial perturbation of convective-scale EPS system, etc. Preliminary results from those numerical experiments are shown in the presentation.

Recent progresses in Korea's next-generation global model development project (KIAPS project) are also introduced, which includes development of hydrostatic/non-hydrostatic dynamical core, physical parameterizations, observation pre-processing and data assimilation systems. The prototype of KIM (KIAPS Integrated Model) system is currently being tested and verified in near real-time.

12.8 What are the differences in physical parametrizations between Météo-France models (NWP vs Climate, global vs convective scale)?

Francois Bouyssel reported that a convergence on physical parameterizations has been undertaken based on multi-scales validations ranging from short range NWP forecast to coupled ocean-atmosphere climate simulations. A common physical package has been developed for global NWP and climate models, sharing several physical schemes with convective scale physics. A surface modeling platform "SURFEX" (Masson et al., 2013) is progressively used in all models using mostly same physiography and surface schemes. Same radiation schemes are used in all models. An EDMF "eddy diffusivity mass flux" scheme is progressively used for modeling turbulence. The prognostic turbulence scheme (Cuxart et al., 2000) is used in all configurations. The scheme representing PBL thermals in AROME (Pergaud et al., 2009) has been adapted for long time step with an implicit solver for mass flux and diffusion terms and validated on the globe in ARPEGE highlighting some weaknesses in the entrainment formulation. Statistical cloud schemes and prognostic microphysics are used both in ARPEGE and AROME models, but with different degrees of sophistication. A statistical sedimentation scheme for hydrometeors is used in all models. A new convection scheme has been developed for ARPEGE NWP and Climate models including a prognostic treatment for convective vertical velocity and cloud condensates.

However, the development of a complete seamless physical package remains a great challenge, in particular for the parameterization of convection (deep and shallow). The priorities will remain different in function of model resolution. For instance the development of sophisticated microphysics and 3D physical schemes (turbulence, radiation) will have a much higher priority for modelling hectometric scales than for hydrostatic ones.

12.9 Modelling convection with the operational kilometer scale model Arome: recent improvements and remaining issues.

Francois Bouyssel reported that the convective-permitting scale AROME-France system is now running with a horizontal resolution of 1.3 km and 90 vertical levels. This increase of spatial resolution done simultaneously with a modified semi-lagrangian scheme taking into account the flow deformation and a revision of numerical diffusion coefficients, brings a significant improvement in precipitation scores. The 3D-Var assimilation cycle has evolved from a 3h to a 1h time-window allowing to triple the number of observation assimilated for radar, SYNOP, ground GPS and aircrafts data. The density of radar observations, both reflectivities and radial winds, has been increased from 16 km to 8 km.

A parametrization of orography/radiation interactions (Senkova et al, 2007) has been implemented in the SURFEX version. It concerns 3 effects: orographic shadowing and slopes concern solar direct radiative fluxes, whereas reduced sky view factor concerns diffuse-solar and thermal radiative fluxes. Impact studies over the French Alps show a significant impact, at 2,5km grid-mesh, which increases at higher resolution (1,25km and 500m). A 2-moments microphysics scheme, called LIMA, is under validation process in the research model Meso-NH, using for instance aircraft data from the HYMEX dataset. Concerning the turbulence scheme, an on-going work quantifies the theoretical horizontal and vertical eddy-diffusivities and the related mixing lengths at resolutions of the gray zone of turbulence where the turbulence is non-isotropic.

12.10 Lessons learned from JMA global and regional model development

Junichi Ishida (Japan Meteorological Agency) presented the lessons learned from the recent development of its operational global and regional models. JMA global model (GSM) was upgraded in March 2016 and Local forecast Model (LFM) with a horizontal resolution of 2km was upgraded in January 2015, respectively. Though there were a lot of developments in both upgrade, Junichi focused on following lessons through the development; Cloud scheme and Cumulus parameterization of GSM and Grey zone of convection at LFM.

GSM employs a prognostic Arakawa-Shubert type parameterization for deep convection and PDF (a top hat function)-based scheme (Smith 1990) for cloud. During the development of both scheme, JMA recognized the necessity to modify cloud scheme in order to adjust to the change of characteristic of new convection scheme. It was clarified that midlevel humidity in the tropics is quite sensitive to PDF width with a top hat type function. It was also revealed that the uncertainty of the PDF width is too large and difficult to determine it and modification of not cloud scheme but radiation scheme seems to be better to consider the effect of convection to cloud and radiation.

Verifications show that LFM is able to predict smaller scale heavy precipitation, but also reveal serious problems that start of convective heavy rain is often delayed and the convective precipitation intensity is too high. To solve the shortcoming, JMA focused on the three processes of convection; vertical transport, entrainment / detrainment and trigger. While LFM can explicitly resolve vertical transport, LFM cannot resolve entrainment / detrainment and trigger explicitly. It would be recognized as a grey zone problem of convection in km-scale model. JMA tried to employ Smagorinsky type horizontal diffusion scheme to parameterize entrainment / detrainment but failed, because it was only worked at the top of convection. JMA also developed a parameterization for trigger based on existing deep convection scheme and it achieved improvement of the timing of convection.

12.11 GASS report

Keith Williams presented on behalf of Jon Petch.

GEWEX has struggled to find leadership succession to follow on from Steve Klein and Jon Petch, however GASS remains active through a range of projects. The GASS science steering committee (SSC) met recently and agreed GASS, or something like GASS, should continue but would benefit from a reinvigoration. GASS has failed in recent years to entrain younger scientists into the “family” and the SSC would like the next generation of model developer to be entrained. Christian Jakob (an SSC member) has provisionally offered to host a Pan-GASS science conference in 2018 with a strong theme related to developing the next generation of scientists in model development. The SSC will continue to look to kick start other activities to address the young scientist issues. Further discussion of GASS’s future activities may take place at the Trieste meeting of Clouds Grand Challenge/CFMIP in July 2016.

12.12 GLASS report

Updates on WCRP/GEWEX/GLASS Projects most relevance to WGNE were presented by Michael Ek and reviewed by the meeting. (1) PALS-PLUMBER is a multi-model examination of land-surface models using pre-defined metrics in a web-based database of model simulation and observational land surface datasets, initially using 20 flux sites worldwide, identifying diurnal and seasonal systematic biases in the partition of the surface energy budget that can be used to improve LSMs. (2) Project for the Intercomparison of Land Data Assimilation System (PILDAS) is slowly spinning up in 2016 and will compare land DA systems and methods (e.g. EnKF, EKF, etc), conduct sensitivity studies of assimilation input parameters (e.g. model and observation errors), and provide guidance and priorities for future land assimilation research and applications, ultimately, produce enhanced global datasets of land surface fields for model initialization. (3) Diurnal land/atmosphere coupling experiment (DICE) project involves study of land-atmosphere interaction, with initially 12 models participating using a summertime grassland case study, where the format is stand-alone land-surface model (LSM; forced by atmospheric observations) and stand-alone single column model (SCM; forced by surface fluxes), then coupled LSM-SCM, then sensitivity of LSMs and SCMs to variations in forcing. Summary: large errors in evaporation dominate the signal and impact of coupling; further: examine surface momentum flux and momentum profiles, nocturnal fluxes and

boundary layers, soil-surface coupling sensitivity. Follow on: "DICE-over-ice" (Antarctic case) to study the interactions between the ice/snow-surface and atmospheric boundary layer under strong stability conditions. (4) Local Land-Atmosphere Coupling (LoCo) Project is an effort to understand, model, and predict the role of local land-atmosphere coupling in the evolution of land-atmosphere fluxes and state variables, including clouds, on a larger horizontal domain than the paradigm of LSM-SCM coupling (as in DICE). The LoCo-SGP (Southern Great Plains) Testbed has provided “Enhanced Soundings for Local Coupling Studies” from summer 2015, where a number of metrics from the "LoCo Coupling Metrics Toolkit" will be evaluated using this dataset.

In the general discussion that followed the relative lack of young people involved in GASS and current co-chair situation was raised. Mentioned was made of the relevance of field experiments off the Namibian costs (Oracles by NASA and CLARIFY by the UK MetOffice).

Action Item 23: *Michael EK to provide feedback to GEWEX on the gap related to atmosphere–ocean–sea ice exchanges.*

Action Item 24: *WGNE co-chair to communicate the WGNE concern about the lack of GASS co-chairs to GEWEX.*

Action Item 25: *WGNE co-chair to request GEWEX to prepare a paragraph which can be sent to WGNE members on how young scientist can get involved in GEWEX activities (participation, leading projects, chair etc.).*

Action Item 26: WGNE co-chair to inform GEWEX on the key systematic errors not currently covered by projects: a. convective rain over orography, b. light rain (convective, drizzle problems), c. boundary layer cloud, fog, Stratocumulus over land, d. 2-4 km resolution models which have too intense rainfall rates, and e. aerosols.

13. AEROSOL PROJECT PROGRESS REPORT

Ariane Frassoni presented, on behalf of Saulo Freitas, the progress of studies related to the impacts of aerosols on Numerical Weather Prediction: 4th Report

The activities realized during the last year were:

- Processing new datasets

o ECMWF sent a new dataset for the DUST case in May 2015.

o JMA produced new dataset as they found problems with the first run. Data was sent to CPTEC at the end of July 2015 and was re-processed.

o NOAA/ESRL sent a dataset using WRF-Chem model for the SAMBBA case in July 2015.

o CPTEC/Brazil provided the dataset with BRAMS model for the SAMBBA case in September 2015.

- Developed tools for processing the observational data provided by CPTEC and CMA for the SAMBBA and Beijing case, respectively.

- Performed quantitative model evaluation of the variables:

o 2-meter temperature

o 10-meter wind (magnitude and direction)

o Rainfall (accumulated over 6 hours)

In terms of impacts of including aerosols processes in the NWP models we found that the
2-meter temperature shown the mot significant impact. On the other side, a much lower impact was found for
10-meter wind (magnitude and direction) and the rainfall amount.

The next steps proposed are:

- Finish and re-check the quantitative model evaluation for SAMBBA and Beijing cases,

- Produce a comprehensive report and submit to the centers,

- Prepare a paper with the most relevant results for publication in ACP/EGU or BAMS.

All data provided by the Centers are on-line available at the web-site http://meioambiente.cptec.inpe.br/wgne-aerosols

Action item 27: *Ariane Frassoni to request Saolo Freitas to include estimates of statistical significance of the impacts of aerosols in the case studies.*

Recommendation 6: *For GEWEX to consider a project with GASS on how to move the aerosol role/impact initiated by WGNE forward.*

Action Item 28: *Ariane Frassoni to propose GO-AMAZON protocol.*

Recommendation 7: *Co-Chairs to suggest to S2S to take forward what has been done so far on by WGNE on aerosols to seasonal timescales.*

Oystein Hov requested WGNE to keep a close eye on aerosol related matters in light of its growing importance.

Action Item 29: *Francois Engelbrecht to take forward biomass stratocumulus interactions on climate timescales under CORDEX.*

14. HOST SCIENCE TALKS

14.1 Mary-Jane Bopape (CSIR) 'Simulating the Convective Boundary Layer with a Dynamic Smagorinski Model' by MM Bopape, RS Plant and O Coceal

The grid spacing used in Numerical Weather Prediction is approaching the grey-zones in the atmospheric boundary layer. There are currently no boundary layer parameterization schemes designed for the grey zones. The lagrangian-averaged scale-dependent dynamic Smagorinsky model has been suggested as one of the models that might be suitable for the grey-zones. Simulations of a convective boundary layer were made with grid spacings ranging from 25m to 400m with the Smagorinsky model and three variations of the dynamic Smagorinsky model, the plane-averaged scale-independent model, the Lagrangian-averaged scale-independent model and the Lagrangian-averaged scale-dependent model. Mean profiles of temperature and winds using the different subgrid models do not vary significantly as was found in previous studies, however, the structures simulated by the dynamic models compare better to the coarse-grained 25m resolution simulation. At 400m all simulations became unstable when used without stability functions. Preliminary work on the simulation of low clouds and the morning transition of the atmospheric boundary layer suggests that the Lagrangian-averaged scale-dependent model performs better than other subgrid models. More simulations are planned to further test the dynamic model in the grey-zones.

14.2 Willem Landman (University of Pretoria) 'Progress in seasonal forecasting in South Africa'

Willem Landman provided an overview of the development of seasonal prediction systems in South Africa. The presentation highlighted the development from the early 1990 of the science of seasonal forecasting in South Africa with particular emphasis on operational forecast production. Forecast models used during the early days were based on statistical models developed in South Africa that related oceanic and atmospheric variables to seasonal rainfall. Later on these statistical methods were employed to recalibrate or downscale forecasts from global circulation models (GCMs). These GCMs were administered by a number of South African institutions, including the South African Weather Service (SAWS) which were, as a result of their model development and operations, granted Global Producing Centre for Long-Range Forecasting status by WMO. The use of regional climate models for operational forecast production was tested and tried for one season, but it was found that statistical downscaling produced superior levels of forecast skill and required only a fraction of the computing resources required by regional climate models. Owing to low verification scores obtained from consensus forecasts over about 10 years, it was decided to develop objective forecast systems that combined forecasts mathematically, i.e. the development of multi-model forecasting systems. SAWS

has been using multi-model systems for operational forecast production since 2008. The next level of model development involved the establishment of fully coupled ocean-atmosphere models. These coupled models have the potential to outscore atmospheric GCMs, but when the latter is supplied with skillfully predicted sea-surface temperature anomalies (mostly obtained from coupled models), they can be a strong competitor for coupled models. The presentation concluded on how the seasonal forecast models developed over the years have been successfully employed to tailor forecasts for agriculture and for hydrological applications.

14.3 Swadhin Behera (JAMSTEC): 'The SINTEX-F seasonal predictability and its applicability for southern Africa'

Swadhin Behera described the SINTEX-F1 is a climate prediction system developed under the EU-Japan collaborative framework and is operational since 2005 at JAMSTEC. Since its inception, the model has predicted most of El Nino/Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) events sufficiently ahead of time. Usually ENSO events are predicted several seasons ahead and IOD events are predicted at least a couple of seasons ahead. Encouraged by the model's performance of predicting ENSO, IOD and associated teleconnection, a couple of application projects are developed for southern Africa. In the first project completed a couple of years ago, applications for agriculture and streamflows were developed. In a new project called iDEWS, started in 2014 and to continue until 2019, a climate prediction based early warning system is under development for infectious diseases, like malaria, diarrhea and pneumonia. Further, the SINTEX-F2, developed with better spatial resolutions and improved model physics, has shown better skills in predicting the southern African climate, which is very encouraging for the iDEWS project.

14.4 Yushi Morioka (JAMSTEC): 'The role of mid and high latitude air-sea interactions in interannual to multi-year climate variations over southern Africa'

The interannual-decadal climate variability in the southern Africa is investigated by conducting a series of CGCM experiments with SINTEX-F2. The model results suggest that besides the remote forcing such as ENSO, sea-ice variability in the Weddell Sea plays an important role in the interannual climate variability over southern Africa. For the decadal climate variability, an eastward propagating air-sea coupled signal from the South Atlantic to the southwest Indian Ocean is found to contribute to the rainfall variability over southern Africa. These findings would help better understanding and skillful prediction of climate variability over southern Africa.

15. PROJECTS RELATED TO COUPLED MODELLING

15.1 PDEF report

Oscar Alves presented remotely on the activities of PDEF.

Action Item 30: *Keith Williams to provide John Methven with T-AMIP description and use SPARC DynVar leaders to identify climate dynamics contacts in modelling centers.*

Action Item 31: *WGNE members to remind colleagues about the existence of, and encourage centers to more actively use TIGGE data.*

15.2 Recent developments in Ensemble Prediction

Junichi Ishida and Carolyn Reynolds summarized inputs from WGNE members on ensemble system operational upgrades and research, respectively. Junichi Ishida noted that most operational centers now provide ensemble forecasts, with improvements continuing in both the global and regional systems. The horizontal resolution of some centers global EPS was upgraded or is planned to be enhanced. ECMWF enhanced the horizontal resolution of its global EPS by introducing a cubic-octahedral grid. NCEP also enhanced the horizontal resolution. Met Office and JMA have a plan to change horizontal resolution. ECMWF and NCEP showed the benefit of upgrade. DWD has a plan to operate new global EPS using DWD global non-hydrostatic model ICON. Some centres noted the hindcast (reforecast) issues (change of configurations) and verification issues (tools by DWD, WMO/CBS lead center activity by JMA and so on). Several centers also implemented or have planned upgrades to their regional EPS. DWD extended forecast length of its regional EPS from 27h to 45h. Met Office has a plan to extend horizontal domain, forecast range and horizontal resolution. JMA has a plan to increase a number of members from 11 to 21. There are various objectives of regional EPS. DWD and Météo-France use it not only for weather forecast / warnings but for renewable energy.

In terms of research, interest in data assimilation, model uncertainty, and calibration and post-processing remains high, as the number of publications in all these areas continues trending upward. Centers are showing improvements in the global EPS systems through resolution upgrades (e.g. ECMWF, NCEP) and improvements to model formulation and initial perturbation formulation (NCEP). Centers are improving regional EPS performance through resolution upgrades (e.g., RHMC) and improved boundary conditions (e.g, JMA). There is increasing interest in producing probabilistic products for high impact weather. Examples include probabilistic thunderstorm prediction by MeteoFrance, and improved tropical cyclone intensity forecasts at ECMWF. NRL and NOAA find improved track and intensity forecasts through multi-model tropical cyclone ensembles. Other examples of interest in probabilistic forecasts for high-impact weather include two planned workshops this summer, one on “Probabilistic Prediction of Severe Weather Phenomena”, to be held in Bologna, Italy, in May, and the 2016 HEPEX workshop on ensemble for better hydrological forecasts, to be held in Quebec, Canada, in June. Many centers have efforts focused on ensemble data assimilation including hybrid variational assimilation methods. Improvements in

accounting for uncertainty in model formulation, initial conditions, and boundary conditions are important research issues at almost all centers. Several centers noted efforts to extend global ensemble forecast lengths to cover monthly and seasonal prediction periods.

Action Item 32: *WGNE members to check whether their centers are contributing EPS data to JMA lead center.*

15.3 Recent developments in Data assimilation and DAOS report (incl. coupled DA)

Tom Hamill provided (remotely) a brief report on the activities of DAOS, the WWRP Data Assimilation and Observing Systems working group.

There are no current major issues with respect to the status of the conventional observation network nor the satellite instrumentation and network. For the former, the number of available observations from commercial aircraft continues to grow, exceeding 750,000 per day in 2015. For the latter, with multiple countries fielding both polar-orbiting and geostationary satellites, there is now some redundancy in the crucial information being provided, such as microwave radiances. There are issues related to weather radars, in particular with non-Gaussian DA as radar users now impinging on the radar frequencies for telecommunications. There was a recent Bulletin of the American Meteorological Society on this topic (http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-15-00048.1).

Hamill spent extensive time reviewing a presentation of Mark Buehner to DAOS. Buehner is at the forefront of research on the combination of 4D-variational and ensemble-based assimilation methodologies. In his recent work, Buehner showed that it may be possible to eliminate the need to maintain both an ensemble Kalman filter and a variational method to do ensemble-based global DA. The process Buehner outlined generates an deterministic analysis using 4D-En-Var, a 4D-variational technique where error covariances during the assimilation window are estimated with ensembles of forecasts instead of the tangent linear and adjoint. The ensemble perturbations were updated using a simplified variational assimilation procedure, 3D-Var with a simplified error covariance model. The results compared favorably to the updating of perturbations with a full EnKF system.

Workshops: DAOS is currently preparing to host a workshop on coupled data assimilation in Toulouse France in October 2016. DAOS also is doing the preliminary work for the 2017 WMO international workshop on data assimilation. We have two strong proposals from Météo-France and Brazil, and we are evaluating these two. Expect a choice between the two venues in the next month or so.

With regards to DAOS membership, Hamill is aging off DAOS, and so a new co-chair is being sought. There is a current member of DAOS who will be nominated to replace Hamill, and whose nomination will be considered at the 2016 meeting of the WWRP Science Steering Committee. DAOS will need to replace two other committee members; we are seeking qualified nominees and welcome WGNE suggestions. In particular, we seek nominees with experience in

coupled data assimilation, data assimilation that relaxes assumptions of linearity / Gaussianity (e.g., particle filters), expertise in aerosol DA, and expertise in the global assimilation of satellite data. If possible, qualified experts from South America and Japan are particularly sought to provide international balance.

Action Item 33: *WGNE members to consider possible suggestions for new DAOS members to cover the areas as highlighted in Tom Hamill's WGNE-31 presentation.*

Action Item 34: *Tom Hamill to follow up on the demise of the LIM sounder and its impact on DA systems.*

15.4 S2S project report

Frederic Vitart reported that the sub-seasonal to seasonal prediction project (S2S) is organized around 6 sub-projects (Verification, Africa, Extremes, Monsoons, Madden-Julian Oscillation and Teleconnections) and a series of cross-cutting activities (e.g. impact of resolution, initialization strategies..). A first deliverable of the project has been the establishment of a database of near real-time (3 weeks behind real-time) and re-forecasts from 11 operational centers. Data from 9 centers is currently available to the research community since May 2015 from the ECMWF data server and November 2015 from CMA. So far more than 600 users have registered to either the ECMWF or CMA S2S database. Future plans include the archiving of the 2 remaining centers by the end of 2016, add ocean sub-surface variables which would make the database useful for air-sea interaction studies and also create a database of indices computed from the S2S database (e.g MJO RMMs, tropical cyclone tracks, weather regimes...).

Sub-project activities have started with a series of workshops (e.g. S2S monsoon workshop in June 2015), literature reviews. The MJO sub-project is focusing its activities on the interaction between the MJO and the Maritime Continent in coordination with the WGNE/MJO-TF and the year of maritime Continent. The monsoon sub-project is developing a set of metrics which are scientifically and societally relevant for all monsoon systems. The extreme Weather sub-project is assessing the skill of the various S2S models to predict weather regime transitions, and their relation to extreme weather, like heat waves. A studies on tropical cyclone activity shows that the S2S models are able to simulate a realistic modulation of tropical cyclone activity by the Madden Julian Oscillation and a case study on tropical cyclone Pam suggests potential skill in predicting tropical cyclone activity up to 3 weeks in advance. The Teleconnection sub-project is launching a virtual field campaign called Year of Tropics-Mid latitude Interactions and Teleconnections (YTMIT) which main goal is to explore the links between the tropics and mid-latitudes for a better prediction skill at intraseasonal time-scale.

15.5 Integrated coupled modeling approach at NCEP

Michael Ek reviewed the current NCEP production suite of weather, climate, ocean and other operational models, including upgrades to major systems in the

past year. The unification of the NCEP production suite is moving towards a coupled earth system based on emerging requirements, where input for those requirements was solicited from many governments, academic and private stakeholders, and following recommendations from an external NCEP model advisory committee for a more unified/streamlined production suite. A new "business model" for model development and upgrades is being defined that includes more effective engagement of stakeholders, and a more comprehensive process for model improvement. The basic approaches for data assimilation, atmosphere (and other systems) and coupling, for time scales from nowcasts to seasonal/annual prediction are presented, including new dynamics and physics. In the global setting this is described as a Unified Global Coupled System (UGCS) for both data assimilation and model forecasts, with atmosphere, land-hydrology, ocean, sea-ice, waves and aerosol components. Finally, an overview of computational needs is presented.

16. DECISIONS AND ACTIONS

16.1 Summary of recommendations

Recommendations WGNE-31
Recommendation 1: WGNE suggested to the president of CAS that the CAS-17 TECO in July 2017 could provide an opportunity to engage Panasonic and other private sector modelling groups to work with WGNE towards a contribution in the session under emerging technologies. WGNE considered the request by WWRP on the optimal balance between ensemble size, resolution and complexity and available computational power to optimize benefit cost ratio.
Recommendation 2: WGNE recommends to WMO/CBS to encourage modeling centres to adopt and exchange the WMO recommended verification upper air scores. See GDPFS manual: https://www.wmo.int/pages/prog/www/DPFS/Manual/documents/485_Vol_I_en.pdf
Recommendation 3: WGNE members to encourage their centers to contribute (at least the tier 1) contributions to the activities of HighResMIP.
Recommendation 4: Promote using the Andes and the Amazon as standard verification test cases by modelling centers and request Araine Frassoni to lead this initiative.
Recommendation 5: For the OBS4MIPS initiative to make data available at higher spatial and temporal available to facilitate joint efforts across time scales.
Recommendation 6: For GEWEX to consider a project with GASS on how to move the aerosol role/impact initiated by WGNE forward.
Recommendation 7: Co-Chairs to suggest to S2S to take forward what has been done so far on by WGNE on aerosols to seasonal timescales.

16.2 Summary of action items

Action Items WGNE-31
Action Item 1: The WGNE Co-chairs to provide WMAC with information on what WGNE wants from the new WCRP strategy. These include: • Increase science to service component. • Strong recommendation for closer working with the weather side with specific suggestion that WMAC be extended to cover WWRP modelling groups - e.g. DAOS, PDEF, S2S. • Also note the cross-timescale work of GEWEX. • WCRP should consider diverting some funds from big science towards infrastructure given changing computer architectures/scalability issues. • WCRP should consider changing the balance of computing resources in favor of model development rather than large numbers of scenario simulations.
Action Item 2: Junichi Ishida and Caroline Reynolds to provide a summary of center views on ensemble size, resolution and complexity and available computational power to optimize benefits in order to address the WWRP request related the development of the new WWRP Implementation Plan.
Action Item 3: Michael Ek and Francois Engelbrecht to engage with Thomas Jung as liaison to PPP and YOPP.
Action Item 4: WGNE members make their centers aware of YOPP and contact PPP through Michael Ek and Francois Engelbrecht in instances where there is a commitment to contribute.
Action Item 5: The GAW SSC Chair to be invited as an ex-officio member of WGNE.
Action Item 6: Quintin Errera to advertise the systematic errors workshop scheduled for June 2017 among the SPARC community.
Action Item 7: Quintin Errera to provide feedback on the availability of ERA-5 data to WGNE members.
Action Item 8: Michael Baldauf to add the timing of the dynamics and physics and peak performance in the center summary table.
Action Item 9: That the TC verification information compiled by WGNE, including the overview paper being prepared for BAMS, be brought to the attention of the WWRP Working Group on Tropical Meteorological Research and CBS by Junichi Ishida, to ensure relevant coordination and to keep WGNE co-chair informed of progress.
Action Item 10: WGNE requests centers to submit full resolution model output for TC verification.
Action Item 11: Marion Mittermaier and Deon Terblanche to follow up on the fate of the precipitation verification document, its update etc. and provide feedback to WGNE members.
Action Item 12: Keith Williams to draft an outline of what is expected from centers regarding joining an inter-comparison exercise based on satellite cloud simulators.
Action Item 13: The co-chairs of the MJO Task Force should come to an agreement regarding on responsibilities between MJO Task Force and S2S on the assessment of MJO index forecast and other related matters and then to inform WGNE and WWRP accordingly.
Action Item 14: The WGNE Co-chairs undertake to sign an appropriate letter on behalf of WGNE in support to the Year of Marine Continent initiative with input from Steve Woolnough.
Action Item 15: For Nils Wedi and Marion Mittermaier to prepare a partition

SEEPS score for the systematic error workshop.
Action Item 16: Elena Astakhova to take forward the possibility of RosHydromet to host the WGNE website and the integration of the Blue Book, to which all members should contribute, in such a site.
Action Item 17: For Marion Mittermaier and Ariane Frassoni to follow-up regarding interest by South American colleagues to participate in MesoVICT.
Action Item 18: Marion Mittermaier to take forward the development of SEEPS for CBS.
Action Item 19: Peter Gleckler to email the CMDP members to ask a volunteer to join JWGFVR.
Action Item 20: Marion Mittermaier to send Peter Gleckler the detail of the SpatialVx R verification package.
Action Item 21: Michael Ek and Francois Engelbrecht to discuss with YOPP possible projects on drag and momentum processes.
Action Item 22: Ayrton Zadra to consider studies on the difference between models as to how the drag signal propagates into the upper atmosphere.
Action Item 23: Michael EK to provide feedback to GEWEX on the gap related to atmosphere–ocean–sea ice exchanges.
Action Item 24: WGNE co-chair to communicate the WGNE concern about the lack of GASS co-chairs to GEWEX.
Action Item 25: WGNE co-chair to request GEWEX to prepare a paragraph which can be sent to WGNE members on how young scientist can get involved in GEWEX activities (participation, leading projects, chair etc.).
Action Item 26: WGNE co-chair to inform GEWEX on the key systematic errors not currently covered by projects: a. convective rain over orography, b. light rain (convective, drizzle problems), c. boundary layer cloud, fog, Stratocumulus over land, d. 2-4 km resolution models which have too intense rainfall rates, and e. aerosols.
Action item 27: Ariane Frassoni to request Saolo Freitas to include estimates of statistical significance of the impacts of aerosols in the case studies.
Action Item 28: Ariane Frassoni to propose GO-AMAZON protocol.
Action Item 29: Francois Engelbrecht to take forward biomass stratocumulus interactions on climate timescales under CORDEX.
Action Item 30: Keith Williams to provide John Methven with T-AMIP description and use SPARC DynVar leaders to identify climate dynamics contacts in modelling centers.
Action Item 31: WGNE members to remind colleagues about the existence of, and encourage centers to more actively use TIGGE data.
Action Item 32: WGNE members to check whether their centers are contributing EPS data to JMA lead center.
Action Item 33: WGNE members to consider possible suggestions for new DAOS members to cover the areas as highlighted in Tom Hamill's WGNE-31 presentation.
Action Item 34: Tom Hamill to follow up on the demise of the LIM sounder and its impact on DA systems.

17. CLOSURE

The co-chairs invited members to comment on the format of the meeting and to come forward at any time with suggestions how best to enhance the effectiveness of WGNE meetings. Members in general were happy with the

format of WGNE-31. It was also decided that center reports should be made available at least one week before meetings. Members were further requested to advertise the systematic errors workshop in their centers.

It was reconfirmed that WGNE-32 will be held in October 2017 at the MetOffice in Exeter in conjunction with WGCM. It was further decided to schedule two teleconferences in between in view of the relative long period between physical meetings.

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Annex 1

Record of ongoing actions from WGNE-29

Item #	Action	Status
1	WGNE members and their modelling centers to consider offering to host the modelling summer schools and to make available lecturers for these events. (all)	**closed**: So far 1 offer confirmed (CPTEC, Brazil, march or July 2017) NCEP possible in 2018 Michael Ek to confirm.
15	Operational modelling centers to move quicker to adopt new verification techniques for precipitation and to extend to regional models. (all)	**closed**
16	Andy Brown, Peter Gleckler and Jon Petch to discuss ways to archive and preserve precious historic GASS data sets. (Keith Williams replacing Andy Brown in this item?)	**closed**: Recent data from GASS-MJO put in SGF; too difficult to do this with older data (e.g. TOGA-CORE, TWP-ICE, etc.)
18	Xue Shun to investigate the availability of additional data from China related to the Beijing aerosol case study. (Jian Sun replacing Xueshun in this action?)	**ongoing**: Did not receive list of requested data; might be available; will check Ayrton to contact both Saolo Freitas and Jian Sun for an update.
19	Jean-Noël Thépaut, Tom Hamill and PDP co-chairs to discuss and propose ways forward for verification against analyses.	**ongoing**: part of PPP activities Niels showed relevant slides and Tom to provide further clarity in his presentations.

Record of ongoing actions from WGNE-30

Item #	Action	Status
1	Saulo Freitas and Greg Carmichael to liaise and explore enhanced GAW (incl. GURME)-WGNE collaboration (e.g. 2016 workshop on WGNE aerosol case studies - Beijing pollution case, promote possible COST action EUMETCHEM Phase II); update contact points; develop a publication; centers to submit latest data (Oct 2015).	**closed**: report to be presented at WGNE31
2	Ayrton Zadra to promote WGNE surface drag project forthcoming Workshop on Momentum Budget and its Role in Weather and Climate, at University of Reading April 2015; and explore with SPARC expansion of the project to assess momentum budgets; report back to WGNE (May 2015).	**closed**: A. Zadra attended the Momentum Budget Workshop and the SPARC-SSG meeting.
3	Julio Bacmeister to contact WGNE with QBOi experimental protocols (May 2015).	**closed**
4	WGNE, SPARC/GEWEX, DAOS, GOV representatives to attend YOPP Summit (WGNE Co-chairs & Paolo Ruti, 15 April 2015).	**closed**: A. Zadra attended the summit.
5	WGNE to provide inputs/slides to and seek feedback from PPP, and together with DAOS to further the characterization of analysis uncertainties in Polar Regions (Junichi Ishida and Tom Hamill, 15 May 2015)	**closed**
6	Explore options for Systematic Error Workshop in 2017 collaboration with S2S (maybe joined with WGNE32?, Canada?, Jeju?, France? Jointly with pan-GASS?); consider a potential teleconnection session (WGNE Co-chairs and members, Oct 2015)	**closed**: confirmed for Montreal, June 2017; try to engage groups in organizing committee

7	Centers to consider exploiting T-AMIP/YOTC-MJO data sets (all).	**closed:** should be treated as a recommendation
8	Develop a concept-document on TRANSPOSE-CMIP (Keith Williams, GOV-Hal Ritchie, NCAR-Julio Bacmeister, NRL-Carolyn Reynolds, NCEP-Mike, GFDL-Ming Zhao, BoM-Oscar Alves, PPP-Thomas Jung, Dec 2015).	**closed**: The final WMAC4 report has now been published at http://www.wcrp-climate.org/WMAC-4/documents/WMAC4_report.pdf. See the relevant Transpose-CMIP stuff on page 7 and 18.
9	Report also on TC false alarm ratio (Junichi Ishida, WGNE31).	**closed**: Junichi presented.
10	Organize a survey to review current precipitation verification practices and check NWP centers' willingness to exchange high resolution precipitation model and observational data sets for WGNE research activities (and possibly for other verifications) and report to next session (Francois Bouyssel, WGNE31).	**closed**: see Francois Bouyssel's presentation
11	Invite members to contribute to Polar verification (WGNE Co-chairs, Oct 2015).	**closed:** See Niel's presentation
12	JWGFVR to engage with METRICS panels and S2S to collaborate towards a strategy for seamless metrics and verification – maybe through a joint activity in 2017 – e.g. systematic error workshop (report at WGNE31, co-chairs JWGFVR/METRICS/S2S panels).	**closed**: The JWGFVR in May 2017 will include timescales up to seasonal.
13	Circulate CREATE-IP white paper to WGNE for comments (Michel Rixen, 1 June 2015).	**closed**
14	NWP centers are strongly encouraged to participate in HighResMIP (all members, ex-officios) and explore ways to relax the 100-year constraints with HighResMIP leads. Julio to prepare a letter to be sent to WGNE (Julio	**closed**: Julio participated in Dubrovnik meeting; will send link to protocol

	Bacmeister, 15 April 2015)	
15	WGNE to start dialogue among WCRP, CAS, CBS on seamless data archives and dissemination (e.g. grib-netcdf interfacing) (Michel Rixen, Paolo Ruti, June 2015).	**closed**: report on progress will be presented at next WGNE meeting
16	Explore possible joint workshop among WGNE, DAOS, PDEF on stochastic parameterization (see also upcoming ECMWF workshop, possible presence of WGNE reps) (Jean-Noel Thépaut, April 2015)	**closed**: to be explored by PDEF; possible contribution to Systematic Error Workshop
17	GOV–WGNE workshop on modeling and data assimilation in 2017 (Michel Rixen to follow-up with GOV-Hal, Dec 2015).	**closed**: probably in 2016; WGNE to be kept in the loop
18	WGNE to consider new agenda structure encouraging center overview to focus on lessons learned and for themed overviews (e.g. “recent advances in physics”) to focus on specific topics (e.g., “convection”,“radiation”). (Co-chairs and members inputs, WGNE31).	**ongoing:** obtain feedback and suggestions on the new format
19	Next WGNE conference call (Rixen, fall 2015).	**closed**
20	Next session, similar time frame, South-Africa (Francois Engelbrecht as host) – Doodle (Michel Rixen, June 2015).	**closed**: 26-29 April, Pretoria; clash with HIW meeting

Recommendations from WGNE30

Item #	Recommendation	Status
1	DAOS to provide advice on YOPP observational strategies for model development and to consider data denial experiments during YOPP (Michel Rixen to forward WGNE30 report, June 2015).	**closed**: so far, 1 suggestion (UKMO)
2	GOV to provide advice on ocean/atmosphere/sea-ice coupling case studies (Michel Rixen to forward WGNE30	**closed**

	report, June 2015).	
3	JMA to consider preparing a publication on the results from the TC verification.	**closed** with support from WGNE

Annex 2
Centre Reports

Météo-France centre report (F. Bouyssel)

The global and regional NWP systems have undergone significant changes, in two steps, in April and in December 2015.

The horizontal resolution of the global deterministic system is improved, from 10 to 7.5 km over Western Europe and from 60 to 36 km over Southern Pacific (spectral resolution TI1198 linear grid with a stretching factor 2.2). The two minimizations resolutions in 4DVar analysis are now TI149 and TI399. The vertical resolution is increased from 70 to 105 levels, with a lowest model level at 10m.

Background error covariances used in the 4D-Var analysis are better sampled thanks to the implementation of a new version of the ensemble data assimilation (EDA), based on 25 members at uniform resolution TI479 L105, with a temporal average reduced to one day and a half (instead of 4 days), and an update of correlations every 6 hours (instead of 24 hours).

The 35 members horizontal resolution of the global ensemble prediction system (EPS) is improved, from 15 to 10 km over Western Europe (spectral resolution TI798 linear grid with a stretching factor 2.4) with 90 vertical levels. Background states and the mean of EDA are used for computing EPS initial conditions. A new set of 10 physical packages including a new prognostic convection scheme “PCMT” is being used to represent model errors.

The convective-permitting scale AROME-France system is now running at a horizontal resolution of 1.3 km, namely a halving relative to the previous version. Vertical resolution has also been increased, with a change from 60 to 90 levels with a lowest model level at 5m. Two of the most significant changes are a move towards a more continuous data assimilation process (1h instead of 3h time window) and a change in the spatial density (from 16 km to 8 km) of radar data (reflectivities and radial winds) used in the assimilation.

New observations are assimilated in these systems, such as 6 sounding channels of SAPHIR on Megha-Tropiques, surface winds from RapidSCAT, AMV and CSR data from Himawari 8, etc.

Two new systems have been introduced in the operational NWP suite for: i) nowcasting (called AROME-PI) with hourly analysis with 10' cut-off plus 6h short-range forecast with the same 1.3 km configuration than AROME-France, ii) weather forecasting over five overseas territorial collectivities (called AROME-OM) with configurations at 2.5 km running four times par day up to 48h range.

The upgrade of the BULL HPC (phase 2) is on-going. The first cluster is available including 1800 nodes with “Broadwell EP” cores. The second cluster will be available next autumn.

In 2016, the increase of computing resources will be used to put into operation a new numerical weather prediction system: the AROME Ensemble Prediction System (called

PEARO). The configuration of this system, currently developed, uses 12 perturbed forecasts of the AROME-France model with a 2,5km horizontal resolution and 90 vertical levels, coupled with the ARPEGE ensemble prediction system (PEARP). Each member is perturbed in order to represent the main sources of uncertainty, including the error on initial conditions, surface conditions, lateral boundary conditions and the model. The PEARO system will run twice a day, at 09 and 21 UTC, to provide forecasts up to a 45h range.

A new NWP e-suite (CY42_op1) is currently prepared. The most significant modifications will likely be the implementation of a new prognostic convection scheme, called “PCMT”, and a surface model, called “SURFEX” in global systems based on ARPEGE model (deterministic, EDA and EPS). A parameterization of orography effects decreasing sky view factor on radiative fluxes will be introduced in AROME model. New observations will be assimilated: higher density of CSR of geostationary satellites, GMI/GPM data, first OPERA radars, etc.

In 2017/2018, several changes are foreseen such as the implementation of a regional EDA system based AROME 3DVar, the addition of 03 and 15 UTC production hours for PEARO and a resolution upgrade of global systems.

Council for Scientific and Industrial Research (CSIR, South Africa) Centre report
(F. Engelbrecht)

Development of the first African-based Earth System Model

The CSIR is working towards completion of the first African-based Earth System Model, the Variable-resolution Earth System Model (VRESM). The model development effort relies strongly on model development activities at the CSIRO and uses as atmospheric component the cube-based CCAM/VCAM model of the CSIRO. The CSIR has developed a cube-based ocean model VCOM as ocean component of VRESM, and is in the process of coupling this model to the PISCES biochemistry model PISCES. The land-surface component of VRESM is the CSIRO Atmosphere Biosphere Land Exchange (CABLE) model The CSIR intends to launch its DECK and ScenarioMIP simulations for CMIP6 in 2017.

Participation in CORDEX

The CSIR has completed a set of 50 km resolution global projections of future climate change for CORDEX, using the coupled CCAM-CABLE model to downscale six CMIP5 GCMs integrated for RCP8.5 (low mitigation), and similarly for RCP4.5 (modest-high mitigation). All these simulations were performed for the period 1961-2100. The CSIR is currently post-processing these projections toward delivery to the CORDEX Earth Systems Grid Federation (ESGF) data server.

Seasonal forecasting and AMIP simulations

The CSIR obtains an operational seasonal forecast system. The forecasts are issued twice a month, and consist of a 12-member ensemble initialized using a lagged-average forecasting approach. These forecasts rely on the CCAM model integrated globally at a resolution of 200 km in the horizontal. A set of hindcasts mirroring the operational system is available for the

period 1983-2012. These forecasts/hindcasts are atmosphere-only simulations forced at their lower boundary with predicted SSTs (the latter is obtained by combining the SST predictions of a number of CGCMs, with the latter obtained from the IRI).

Short-range forecasting

The CSIR obtains an operational short-range forecast system over southern Africa. Forecasts are initialised using the Global Forecast System (GFS), has a horizontal resolution of 15 km and extend 7 days ahead. These forecasts are obtained using the CCAM model and are issued four times a day (model initialisation takes place at 0 Z, 6 Z, 12 Z, and 18 Z).

Naval Research Laboratory Center Update (C. Reynolds)

For the global assimilation and forecasting system, a hybrid version of the 4D-Var data assimilation system, NAVDAS-AR, in which an ensemble-based background error covariance is ombined with the static background error covariance, has been delivered to Fleet Numerical Meteorology and Oceanography center and is expected to become operational in the next few months. This upgrade will also include ozone assimilation from OMPS and SPU/V, and MetOp A/B Global AVHRR Atmospheric Motion Vectors. New satellite assimilation components that became operational in late 2015 include CrIS radiances, geosationary clear sky radiances, SSMIS Upper Atmosphere Sounding (UAS) sounding channels, IASI/AIRS water vapor radiances and Himawari-8 Atmospheric Motion Vectors. The next Navy Global Environmental model (NAVGEM) upgrade, scheduled for summer 2017, will include an increase in resolution to T681L80 (19 km grid spacing) and 0.01 hPa model top from the current T425L60 (31 km grid spacing) with 0.04 hPa model top. NAVGEM has been coupled to the HYCOM ocean model, the Los Alamos CICE sea ice model, and Wave Watch 3 under the Earth System Prediction Capability effort. Preliminary multi-month ensemble forecasts from the summer of 2015 indicate a promising start in the prediction of El Nino and September arctic sea ice extent. NAVGEM physic improvements result in improved prediction of tropical phenomena such as the Madden Julian Oscillation. Planned spring 2016 upgrades to the Navy Global Environmental Model Ensemble Forecast System (EFS), include an increase in resolution (from T259L50 to T359L60) and upgrade in the model physical parameterizations, resulting in substantial improvements in fields such as 10-m temperature. The global Navy Aerosol Analysis and Prediction System (NAAPS) will begin assimilating MODIS Collection 6 aerosol optical depth assimilation in 2016. NAAPS will include organic aerosols by the fall of 2016, reducing biases in polluted areas and improving particle composition and properties. Assimilation of aerosol products from geostationary sensors is actively being developed at NRL.

For the mesoscale assimilation and forecasting system, the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), coupled to the NCOM ocean model and SWAN and WWIII wave models, has undergone several system upgrades including recent improvements to the boundary layer, and microphysical parameterizations. The COAMPS operational data assimilation will be upgraded from 3D-Var to 4D-Var in the fall of 2016. Recent improvements to the current 3D-Var scheme include an upgrade to increase the number of assimilated satellite Atmospheric Motion Vectors and add the capability to

assimilate AMSU-A radiances. The COAMPS-TC (tropical cyclone) ensemble continues to be a critical component of the NOAA Hurricane Forecast Improvement Project multi-model ensemble. The Atmosphere-Ocean coupled version of COAMPS-TC will be transitioned to operations this summer. COAMPS-OS (On Scene) operational upgrades include a ship-following COAMPS capability that is scheduled to become operational this summer. New capabilities to use WW3 curvilinear grids in COAMPS-OS are planned in the winter of 2016. Development continues on the Navy Environmental Prediction System Utilizing the NUMA Core (NEPTUNE) with a flexible cubed sphere or icosahedral grid and spectral element discretization. Recent capabilities added include improved physical parameterizations, a land surface model, and a physics grid that ensures consistent use of the physics package independent of the order of the basis functions in the dynamical core.

JMA Centre Report (Junichi Ishida)

A list of recent developments which are implemented to JMA global model (GSM) is as follows.

24 MAR 2016 : Major upgrade was made to the model. Major changes were,

- Land surface processes by introducing new land surface model,
- Upgrade of deep convection parameterization,
- Upgrade of cloud scheme,
- Upgrade of radiation scheme,
- Upgrade of treatment of sea ice,
- Optimization of Legendre Transform,
- Start of assimilation of the GPM Microwave Imager (GMI) data.

17 MAR 2016 : Assimilation of Himawari-8 AMV and CSR data was started.

08 OCT 2015 : Assimilation of METAR surface pressure data was started.

Usage of ASCAT ocean surface vector wind data was improved.

25 JUN 2015 : Assimilation of Megha-Tropiques/SAPHIR data was started.

The latest list is available by following webpage.

http://www.wis-jma.go.jp/ddb/latest_modelupgrade.txt

A list of recent developments which are implemented to JMA Meso Scale Model (MSM) with a horizontal resolution of 5km and Local Forecast Model (LFM) with a horizontal resolution of 2km is as follows.

24 MAR 2016: Assimilation of GPM DPR and GMI data for MSM was started.

Assimilation of GNSS Radio Occultation data for MSM was started.

(GRACE-A,B/BlackJack, COSMIC/IGOR, Metop-A,B/GRAS,

Terra-SAR-X/IGOR, TanDEM-X/IGOR)

17 MAR 2016 : Assimilation of Himawari-8 AMV data for MSM and LFM was started.

Assimilation of Himawar-8 CSR data for MSM was started.

24 DEC 2016: Major upgrade of MSM analysis was made. The changes are.

- Update of background error covariance,

- Start of assimilation of ASCAT ocean vector data,

- Improved usage of upper-air data at domestic radiosonde stations.

25 AUG 2016: Change of treatment of saturated vapour in LFM analysis.

05 MAY 2016: Major upgrade of MSM was made. The changes are

- Improvement of a planetary boundary layer scheme,

- Upgrade of diagnostic scheme of surface temperature over the sea.

A list of plan of upgrade of JMA GSM is as follows.

Improvement of land-surface model which was implemented in March 2016

Improvement of radiation scheme which was implemented in March 2016

Change of climatology of sea ice

Modification of roughness over the sea

Introduction of EDMF PBL scheme

Unifying weekly EPS and typhoon EPS to global EPS

Enhancement of forecast length of global EPS up to 18 days

Start of assimilation of Suomi-NPP/ATMS and CrIS data

Start of assimilation of SSMIS (183GHz) data

Start of assimilation of ISS/RapidSCAT data

Replacement to ROPP8

A list of plan of upgrade of JMA MSM and LFM is as follows

Introduction of new dynamical core “ASUCA” and physics package into MSM

Introduction of new variational DA system “ASUCA-Var” into MSM

Upgrade of ASUCA and physics package in LFM to the latest version.

Start of assimilation of Suomi-NPP/ATMS and CrIS data into MSM

Start of assimilation of SSMIS (183GHz) data into MSM

Start of assimilation of soil moisture retrieved from satellite data into MSM and LFM

Recent updates / upgrades at the Canadian Meteorological Centre (CMC) (Ayrton Zadra)

April 14th, 2016: Installation of the FireWork Prediction System for the Summer Season of 2016 - FireWork is a seasonal modelling system based on the Regional Air Quality Deterministic Prediction System (RAQDPS) which incorporates additional emissions from wildfire events over North America.

April 7th, 2016: Major Upgrade to the Regional Air Quality Deterministic Prediction System (RAQDPS) - This update includes the following changes new chemical lateral boundary conditions and updates to the chemistry module.

Wednesday March 16, 2016: Replacement of MTSAT-2 by Himawari-8 plus addition of AMV from NPP and ISS-RapidScat - Only the data assimilation component was modified with

- Replacement of AMV (Atmospheric Motion Vector) and CSR (Clear Sky Radiance) observations from the Japanese satellite MTSAT-2 by those from Himawari-8 in the GDPS and RDPS.

- Addition of AMV data from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on board the SUOMI National Polar-orbiting Partnership (NPP) satellite in the three systems GDPS, GEPS and RDPS;

- Addition of marine winds from the RapidScat Scatterometer mounted on the International Space Station (ISS) in the three systems GDPS, GEPS and RDPS.

- Regarding the CSR observations, the spatial thinning algorithm for geostationary satellite observations will be modified.

Tuesday December 15, 2015: Major Upgrade to Version 5.0.0 of the Global Deterministic Prediction System (GDPS) - Changes to the forecast model:

- Overlapping LAM domains (in Yin-Yang grid formation) replace a global uniform lat-lon grid (horizontal resolution remains at 25 km).

- Introduction of the trapezoidal method for trajectory calculation, combined with a cubic interpolation scheme.

- Addition of an extra momentum level to the vertical coordinate above 10 hPa to improve computing efficiency.

- Modification to the rate of flattening of the terrain-following levels.

- Addition of two diagnostic levels at 1.5 m and 10 m above model ground level.

Changes to the assimilation system and observations:

- Introduction of the same staggered vertical coordinate used by the forecast model.

- Addition of radiance observations from 17 channels of the Advanced Microwave Sounding Unit (ATMS).

- 103 additional Cross-track Infrared Sounder (CrIS) channels.

- More than 600 additional ground-based GPS sites (mostly in Europe).

- Introduction of inter-channel correlations for all infrared and microwave radiances.

December 15, 2015: Upgrade to Version 4.1.0 of the Regional Deterministic Prediction System (RDPS) - Changes to the forecast model:

- The horizontal grid spacing of the global driver model decreases from 33 to 25 km.

- The lateral boundary conditions of the driver model are now provided every 30 minutes (rather than every 60 minutes).

Changes to observations:

- Addition of radiance observations from 17 channels of the Advanced Microwave Sounding Unit (ATMS).

- 103 additional Cross-track Infrared Sounder (CrIS) channels.

- More than 600 additional ground-based GPS sites (mostly in Europe).

- Introduction of inter-channel correlations for all infrared and microwave radiances.

December 15, 2015: Upgrade to Version 4.1.1 of the Global Ensemble Prediction System (GEPS) - The changes included

- Numerical diffusion of the potential temperature field is now applied for all ensemble members (rather than only half the members).

- A damping gradient is applied to limit the diffusion of potential temperature near the poles.

- New observation errors for radiance data and GPS Radio-Occultation (GPS-RO) observations.

- Addition of radiance observations from the Advanced Microwave Sounding Unit (ATMS).

- Addition of GPS-RO observations from the TanDEM and GRACE-B satellites.

- The reforecast period is extended from 18 to 20 years.

December 15 2015: Upgrade to Version 4.1.0 of the High Resolution Deterministic Prediction System (HRDPS) - The changes included in this upgrade the use of an implicit convection scheme Kain & Fritsch and a correction for freezing rain events that were largely under-estimated in the HRDPS-4.0.0

September 17, 2015: The Canadian Meteorological Centre (CMC) installs its Regional Ice Prediction System (RIPS) version 2.2 - The major changes included

- Assimilation of AMSR2 data

- Assimilation of Canadian Ice Center regional (weekly) charts data

- Modifications to the passive microwave data processing:

- Thinning of SSMIS data along the satellite track (assimilate only 1 of 3 scan lines)

- Reduction of the observation-error standard deviation of SSMIS data from 0.1 to 0.05 (because of thinning)

- Reject all data over lakes (as in version 1.0)

- Wind filter to eliminate spurious ice concentration retrievals

June 23, 2015: Experimental Global Deterministic Wave Prediction System (GDWPS) - The development of the GDWPS was made through a partnership with NCEP/NOAA.

June 11, 2015: Upgrade to the Regional Air Quality Deterministic Prediction System (RAQDPS)– Included a new emissions set is based on the 2010 Canadian Inventory/2011 USA Inventory, updating from the 2006 Canadian Inventory/2005 USA Inventory.

June 03, 2015: Upgrade to the Regional Deterministic Precipitation Analysis (RDPA (CaPA)) version 3.1.0 - This version will lead mainly to the assimilation of a higher number of solid precipitation observations.

Met Office center report April 2016 (Keith Williams)

Over the last year there have been the following changes to the operational suite:

- Aug 2015: PS36 Port to new supercomputer (IBM Power 7 to Cray XC40). Largely science neutral (a few bug fixes)

- Mar 2016: PS37 Satellite package including introduction of variational bias correction (VarBC) and revised DA cov-stats for global model; routine science package for convective permitting models.

Presentations at WGNE30 showed the Met Office analysis to have a warmer lower troposphere over ocean regions than other analyses. From this initial state, the forecast would then cool such that the lower tropospheric temperatures several days into the forecast were more consistent with analyses/forecasts from other centres. The problem was traced to the bias correction being applied to the satellite data used in the data assimilation process and VarBC in PS37 goes a long way to address this. It was also found that as the cooling (from the overly warm analysis) was taking place through the forecast and geopotential heights falling, in certain situations mid-latitude synoptic systems could over-deepen with resulting double penalty problems. As VarBC largely addresses the problem, PS37 should bring improvements in CBS scores.

Planned operational suite changes for the coming year are:

- Sep 2016: PS38 Extend domain of regional model (UKV) and the regional ensemble and extend 00Z and 12Z runs to 5 days. Routine satellite changes for global model.

- Jan 2017: PS39 Implement GA7/GC3 science package in all global systems. Increase horizontal resolution of global deterministic model to around N1024 (~12km).

Global Atmosphere (GA) 7 is a reasonably large package of physics changes, primarily associated with clouds and radiation. It also includes a new multi-layer snow scheme. Global Coupled (GC) 3 uses the GA7 atmosphere and also includes multi-layer sea-ice along with a number of ocean improvements. The global deterministic model and NWP ensemble will implement GA7 whilst the seasonal and decadal systems will implement GC3.

For climate systems, GC3 will also form the physical model to be submitted to CMIP6, and will have earth system components (interactive chemistry, interactive land surface, etc.) built onto it to form UKEMS1 – the UK's Earth System Model to also be delivered to CMIP6, and hence used for climate change projections in the next IPCC report.

ECMWF Centre update

On 8 March 2016, ECMWF introduced a new model cycle of the IFS into operations. Cycle 41r2 represents a significant step forward in accuracy and resolution and it is currently the highest resolution global forecasting system in the world. The main change is an increase in horizontal resolution in most parts of the forecasting system. For HRES and ENS the grid point resolution is roughly doubled to 9 km and 18 km, respectively, while for the Ensemble of Data Assimilations (EDA) it is tripled to 18 km. In combination with several other scientific and technical changes, this has led to a significant increase in forecast accuracy and computational efficiency. The ENS was also improved by moving the step decrease in resolution of the forecast (going from 'medium range' at 18 km to 'monthly extension' at 36 km) from day 10 out to day 15, thus ensuring consistent high forecast resolutions throughout the medium range to 15 days. In more detail:

- Introduction of a new form of the reduced Gaussian grid, the octahedral Gaussian grid, for HRES, ENS and ENS Extended;

- Horizontal resolution of the HRES increased from TL1279 / N640 to TCo1279 / O1280, where subscript C stands for cubic and o for octahedral, with a model time step of 450s;

- Horizontal resolution of the ENS increased from TL639 / N320 to TCo639 / O640 for ENS (Days 0 - 15) with a model time step of 720s and from TL319 / N160 to TCo319 / O320 for ENS Extended (Days 16 - 46) with a model time step of 1200s;

- For the medium-range ENS there will no longer be a decrease of resolution at day 10: the ENS Days 11 - 15 will be run at the same TCo639 / O640 resolution as ENS Days 0 - 10;

- Increase of the HRES-WAM resolution from 0.25 to 0.125 degrees and the ENS-WAM Days 0 - 15 from 0.5 to 0.25 degrees;

- Horizontal resolution of the EDA outer loop is increased from TL399 to TCo639 with its two inner loops increased from TL159 / TL159 to TL191 / TL191, respectively;

- Horizontal resolution of the three 4DVar inner loops is increased from TL255 / TL255 / TL255 to TL255 / TL319 / TL399, respectively.

On 22nd November 2016 ECMWF introduced cycle 43r1. With this cycle upgrade, the medium-range ensemble and its monthly extension see a major upgrade in the dynamical ocean model (NEMO): the resolution is increased from 1 degree and 42 layers to 0.25 degrees and 75 layers (ORCA025Z75). Furthermore, NEMO model version v3.4.1 with the interactive sea-ice model (LIM2) is implemented. The ocean and sea-ice components of the ENS initial conditions are provided by the new ocean analysis and reanalysis suite ORAS5, which uses the new ocean model and revised ensemble perturbation method. In more detail:

- Introduction of the higher resolution ocean model with horizontal and vertical resolutions of the ocean model (NEMO v3.4.1) used by ENS increased from 1 degree and 42

layers to 0.25 degree and 75 layers (ORCA025Z75). An interactive sea-ice model (the Louvain-la-Neuve Sea Ice Model - LIM2) is introduced so that sea-ice cover evolves dynamically. Previously it was persisted for 15 days; over the next 30 days of the forecast, it was relaxed towards the climatology of the previous 5 years.

- A new ocean analysis/re-analysis (ORAS5), based on NEMOVAR with a higher-resolution version of the ocean model NEMO (0.25 degrees with 75 vertical layers: ORCA025Z75) has been implemented. This uses the same ocean model version (NEMO v3.4.1) as ENS. ORAS5 uses a new perturbation strategy for the surface fluxes and to simulate observation errors. It also includes an improved quality-control scheme for ocean observations. Sea ice is assimilated within NEMOVAR, with a weakly coupled assimilation to the ocean dynamics. The analyses have been run from 1975 and continue in real-time to provide initial conditions for the ENS forecasts and re-forecasts.

- The sea-surface temperature (SST) perturbations used in the EDA have been upgraded to a recently developed climatology based on the HadISST.2 dataset. This makes the perturbations statistically consistent with the error characteristics of the analysis cycles.

- The EDA-derived background error estimates used in 4DVAR are now computed at spectral resolution TL399 (previously TL159) and a new wavelet-based filtering algorithm is used to control sampling noise. The background error variance has been increased by ~16%.

- The weak constraint option of 4DVAR has been reactivated using a model error forcing term active in the stratosphere above 40 hPa and a new estimate of the model error covariance matrix.

- The land surface assimilation of SYNOP screen level observations now accounts for the vertical distance between the observations and model grid points. A new vertical structure function has been introduced that follows the approach used at Environment Canada and at Météo-France in MESAN-SAFRAN. The vertical correlation is expressed as a Gaussian function, consistent with that used for snow depth analysis. This gives more weight to observations from stations that are vertically closer to the model grid point (and less to observations less representative of the model altitude).

- Radiance assimilation will now take the viewing geometry more fully into account, by evaluating the radiative transfer along slantwise paths (instead of vertically). This is done for all clear-sky sounder radiances when interpolating model fields to observation locations.

- A better treatment of observation uncertainty for IASI and CrIS has led to updated observation error covariance matrices and a change of ozone anchor channels in bias correction.

- The channel selection for the hyperspectral infrared instrument CrIS has been revised and now uses 117 rather than 77 channels

- The aerosol detection scheme for IASI has been revised making it independent of the bias correction. The scheme is also applied to both CrIS and AIRS.

A new CAMS ozone climatology is now used, consisting of monthly means of a re-analysis of atmospheric constituents (CAMSiRA) for the period 2003 to 2014.

- Changes to boundary layer cloud for marine stratocumulus and at high latitudes.
- Modifications to surface coupling for 2 metre temperature.
- Assimilation of snowfall from the NEXRAD RADAR network over the USA.
- New model output fields include four cloud and freezing diagnostics (for aviation), a new direct-beam solar radiation diagnostic and improvements to the sunshine duration diagnostic.
- A global fix for tendency perturbations in the stochastic model error scheme SPPT to improve global momentum, energy and moisture conservation properties.