27TH SESSION
OF THE CAS/JSC WORKING GROUP
ON NUMERICAL EXPERIMENTATION (WGNE-27)

NCAR, Boulder, CO, USA, 17-21 October 2011

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1 Introduction

The twenty-seventh session of the joint World Climate Research Programme/Commission for Atmospheric Sciences (WCRP/CAS) Working Group on Numerical Experimentation (WGNE) took place from 17-21 October 2011 in Boulder, Colorado, USA. The meeting was hosted by the National Oceanic and Atmospheric Administration (NOAA) at the National Center for Atmospheric Research (NCAR). The Co-chairs of WGNE, Dr. Andy Brown and Prof. Christian Jakob and the participants express their sincere gratitude to both NOAA and NCAR for the excellent hospitality the group experienced during the week.

For the first time the WGNE session included a joint session with the WCRP Working Group on Coupled Modeling to explore various areas of collaboration and exchange of expertise. This follows the obvious realization that more and more numerical weather prediction (NWP) models are run for climate research purposes and vice-versa climate models are being run in NWP mode as well. Efforts at the intersection of WGNE and WGCM time scales such as YOTC, MJO, WGSIP and the newly created WWRP/WCRP Sub-seasonal to Seasonal Prediction research initiative have been discussed. The session was considered a great success by all participants (see below).

The Terms of Reference for WGNE broadly identify three types of activity, all of which support the overall aim of developing atmospheric models and data assimilation techniques for all space and time scales, these are:

- provision of advice and liaison,
- coordinated numerical experimentation,
- organization and support of meetings, workshops and publications.

Discussions relevant to each of these are discussed below. A full list of decisions and actions can be found in Annex A. Annex B includes the meeting agenda and Annex C provides a list of participants at the meeting.

2 Sponsors and liaison

2.1 CAS

Michel Béland, **president of the Commission for Atmospheric Sciences (CAS)**, gave a presentation inspired from the one given at the latest WMO congress, restated the CAS mission which are to reduce and mitigate natural disasters, protect the environment and enhance our understanding of environmental change. Keys to success of the program include a unified approach to weather, water, climate and earth system prediction, the development of chemical weather concept, enhanced greenhouse gas observations and the evolution of the WWRP research program including the implementation of THORPEX TIGGE and YOTC.

2.2 WCRP

Michel Rixen, on behalf of the WCRP JSC chair and D/WCRP Dr Ghassem Asrar, provided an update of the program governance and structure changes which follow the ICSU visioning process, the establishment of the Global Framework for Climate Services and the IOC Framework for Climate Observing. NWP centers are looking to extend their forecast into the sub-seasonal to seasonal range whilst the climate research community has been pushed to deliver more operational services through the newly established Global Framework for Climate Services (GFCS). A new joint WCRP-WWRP effort called "Sub-seasonal prediction research project" will address the predictability potential at these intermediate scales by joining NWP and climate research forces. The WCRP is currently being establishing two new coordinating bodies: i) the WCRP Data Advisory Council (WDAC; replacing the WCRP Observations and Assimilation Panel (WOAP)) to coordinate observational and data analysis efforts across the program, and ii) the WCRP Modeling Advisory Council (WMAC), to coordinate modeling efforts across the program.

2.3 GEWEX

Kevin Trenberth, chair of GEWEX, presented the recent accomplishments of the project, including the GEWEX imperatives document proposing plans for 2013 and beyond, and the workshop on climate extremes. GEWEX has merged the GCSS and GABLS panels will be merged into the GEWEX Atmospheric System Study, a development much welcomed by WGNE. The new Regional Hydroclimate Project (RHP) is to provide regional level science and implementation that focuses on tangible results and tools.

2.4 WWRP

Gilbert Brunet, chair of the WWRP/JSC, recalled the long-term objectives of the WWRP which are to improve public safety and economic productivity by accelerating research and improvements on the prediction of high-impact weather, on the understanding of atmospheric processes, and to enhance related training and capacity building. WWRP has recently established a 10-member Joint Scientific Committee to oversee the scientific progress and development of the program and a Societal and Economic Research and Application Working Group (SERA) WG to advance the science of the social and economic application of weather-related information and services. A WWRP Earth-system Open Science Conference is being planned around 2013.

2.5 THORPEX

Tetsuo Nakazawa, chief WMO/WRD provided an update on **THORPEX. Of particular interest are the new** Sub-seasonal to Seasonal project (joint with WCRP) and Polar Prediction project. WGNE encouraged involvement of the model development community in the planning of these projects.

3 Centre reports

All members presented reports on recent activities in their home institutions. Major common developments in those reports were:

- A clear trend to seamless (or unified) model development across temporal and spatial scales.
- A continued interest in both the weather and climate communities in the simulation of aerosols and atmospheric chemistry at levels adequate to the application of the models.
- A continued interest in increasing the resolution of global and regional forecasting systems.
- A continued interest in the use of ensemble prediction systems, including the representation of model error for instance through the use of stochastic physics approaches.

The details for each of the centre's developments can be found in the individual presentations available at:
http://www.wmo.int/pages/about/sec/rescrosscut/resdept_wgne.html

4 Recent developments

4.1 High resolution NWPs

Bill Lapenta and Gary Dietachmeyer summarized recent developments in the area of high-resolution NWP. Regional NWP centres continue to develop models of a few kilometre resolution, as the gains of representing the local topography and meso-scale processes better outweigh the known issues in the so-called grey zone of resolutions (2-10 km for deep convective system, see also grey-zone project below). An interesting question raised in the discussion was what is known on the predictability of many of the phenomena targeted by high-resolution NWP, such as high-impact weather events.

4.2 Numerical methods

M. Tolstykh and M. Baldauf reported on recent workshops on non-hydrostatic models (ECMWF) and on tracers modeling (NCAR), and on supercomputing trends. It is evident that future supercomputer developments (see also the contribution by J Hack below) are playing a major role in the current development of new numerical schemes for all model types. **M Tolstyksh** conducted a small survey of all the centre's current plans with the following main results:

- Almost all centers work or plan to work on a new dynamical core, some of them global non-hydrostatic.

- The spatial representation varies between centers and includes spectral, grid-point (FD), averaged grid cell (FV) or a mixture of both FV and FD.
- Latitude-longitude grids are used by many centers. Icosahedral grids are currently used by one and considered by 2 other centers. A Ying-Yang grid is considered by 3 centers.
- Roughly half of the centers opted for semi-implicit schemes, half of them consider horizontally explicit – vertically implicit schemes. Some centers consider both. None considers split-explicit schemes.
- Most centers already using semi-Lagrangian advection, work or plan to work on mass-conserving semi-Lagrangian advection.
- Most of the centers are concerned about computational (numerical and parallel) efficiency of their dynamical cores on future computer systems. There is a growing demand for mass conservation due to inclusion of atmospheric chemistry.
- It is envisaged that within 10 years a few global centers will use 10 km resolution models and many of them will have refinement possibilities.
- The rationale for maintaining and developing regional models is to have convection-permitting models, especially for national centers without own global modeling capabilities.

4.3 Data assimilation

Florence Rabier and Jean-Noël Thépaut reviewed recent developments in data assimilation and the use and impact of observations. Two workshops focused on the topic, an ECMWF seminar held 6-11 Sep 2011 and a THORPEX DAOS workshop. The use of adjoint sensitivity of the forecast error to the observations is increasing in the community. Quite a large effort is devoted to the use of satellite data over land and of radar data, both at fine and large scales. A number of hybrid Var/EnKF methods are currently being developed and used. There are currently two main hybrid approaches: (1) Alpha control variable method (Met Office, NCEP/GMAO, CMC) and (2) Ensemble of Data Assimilations method (Météo-France, ECMWF). Other aspects discussed include pre and post-processing in DA, specific challenges in the stratosphere (vertical spreading of information through covariances, separation of model and observation error biases, etc), the impact of stratosphere improvement on the troposphere and the potential benefit of coupled DA and non-linear DA (e.g. particle filters) in the future.

4.4 Ensemble Prediction

Tom Hamill and Chiashi Muroi pointed out the growing unification of ensemble forecasting and data assimilation thanks to the increased importance and maturity of treating model uncertainty in ensembles through improved initial conditions and background error covariances. The workshop on “Representing model uncertainty and error in numerical weather and climate prediction models” at ECMWF in June 2011 recommended that the stochastic parameterization paradigm needed further development at the process level, and hence needed to be incorporated as part of general parameterization development.

4.5 Local science presentations

As is a long tradition at WGNE meetings, three science-talks by scientists working at the host institution were received with great interest and generated good discussion. **Jeff Whitaker, NOAA** presented the various advantages of hybrid ensemble variational data assimilation techniques highlighting the big advantage of the methods in providing flow-dependent information on background errors, better representing cross-variable covariances and being more suitable for massively parallel computers. **Jeff Anderson, NCAR** presented a community ensemble data assimilation facility used by 43 universities and more than 100 other sides, the Data Assimilation Research Testbed (DART, http://www.image.ucar.edu/DAReS/DART/). This public domain software for ensemble data assimilation is well tested and documented, portable, extensible and free. It can be used for education, exploration, research and operations and works for many geophysical models (e.g. global and regional atmosphere, ocean and land models, space weather). **Bill Skamarock, NCAR** presented the Model Predictions Across Scales (MPAS) model a highly flexible non-hydrostatic modeling framework.

5 Rainfall verification

Several speakers reported on results of verifying precipitation forecasts for their region. As in previous years, this is necessitated, as high-resolution rainfall data sets are typically not shared by the countries that own them, so instead WGNE members distribute their forecasts and have then verified in the country that owns the data. WGNE stressed again that this is not a satisfactory state of affairs and while functional for the group is not a good service to the community. The discussion also highlighted that there is only limited insight into the physical reasons for model errors and that more work in this area is required. There is also a need for error bars, which are not often indicated in comparisons.

6 WCRP projects review

6.1 GASS

Jon Petch briefed on the Global Atmospheric System Studies (**GASS**), a fusion of GCSS and GABLS efforts under GEWEX, as a community who carry out and use observations, process studies and model experiments with a focused goal of developing and improving the representation of the atmosphere in weather and climate models. GASS will have an increased focus on climate dynamics and radiative transfer. A Pan-GASS science meeting will be held 10-14 Sept 2012 at NCAR in Boulder.

Current projects under GASS that were reported on include an effort on polar clouds (ISDAC), an MJO vertical structure and diabatic processes project, a TWP-ICE multi-model comparison, and a Stratocumulus to Cumulus Transitions Model Intercomparison (jointly with the EUCLIPSE project).

WGNE welcomed the establishment of GASS within GEWEX and expressed its desire for a tight collaboration between the groups.

6.2 GLASS

Joseph Santanello provided an update about **GLASS,** the GEWEX Global Land-Atmosphere System Study, whose mission is to support improved estimates and representation of land states and fluxes in models, the interaction with the overlying atmosphere and maximize the utilized fraction of inherent predictability from land surface memory. Several areas of common interest between WGNE and GLASS were identified. One of these is in the area of land – and possibly coupled - data assimilation. GLASS has a special project in this area (PILDAS). PILDAS-1 will focus on systems targeted for weather and seasonal forecasting at operational centers and research institutions, on soil moisture assimilation. WGNE recommends to all its members to consider participating in this project. Another project of great potential for collaboration that was identified is the benchmarking effort covered by PALS (Protocol for the Analysis of Land Surface Models). As for PILDAS, GLASS is inviting WGNE members to investigate how they can become involved in PALS and to provide feedback of what benchmarking efforts would be of use to them.

There was a discussion on bringing the GLASS, GASS and WGNE activities together in a fully coupled (in the land-atmosphere sense) process study framework. A potential candidate for such a project would be to study the diurnal cycle of tropical convection using data from the planned 2014 field study in Brazil.

6.3 SPARC

Saroja Polavarapu briefed on **SPARC**, i.e. "Stratospheric Processes And their Role in Climate". Two major activities of relevance to WGNE arose from previous workshops in Exeter (2010) and Brussels (2011), a SPARC Reanalysis Intercomparison Project (S-RIP) and a Stratospheric Network on Assessment of Predictability (SNAP). Both projects will be discussed at the next SPARC SSG.

S-RIP focuses on middle atmosphere/climate community needs for reanalyses/analyses to understand atmospheric processes (current), to validate climate models (e.g. CCM-Val) and to potentially to provide trend analysis. SNAP is motivated by studies that have shown that the stratosphere-troposphere link can aid tropospheric forecasting skill on 5-15 days on large planetary scales in extratropics. This effort will try to quantify the impact of the stratosphere on medium range weather forecasting skill and is naturally of great interest to WGNE. WGNE is looking forward to hearing back at its next session if the SNAP project is funded and is again encouraging all its members to consider their participation in the project.

7 WGNE connected projects

[See also section 10 on joint session with WGCM]

Pier Siebesma provided an update on the **Grey Zone Project**, focusing on resolutions from 1 to 10 km. This is a key project for WGNE over the coming years and will investigate the treatment of convection at resolutions where it is not resolved yet and where the parametrization assumptions of statistical equilibrium between the resolved and unresolved scales break down. The Project presented its plans, which encompass an integrated numerical experiment based on a cold-air outbreak experiment over the North Atlantic in January 2010. The plan includes the use of a suite of models ranging from global to regional NWP models as well as LES models applied in a Lagrangian framework. WGNE congratulated the project on the excellent progress made and endorsed the existing plan. Pier Siebesma and Christian Jakob were charged to investigate writing a proposal for additional computing resources for the project for the US DOE. WGNE also encouraged the project to consider early work on a tropical case involving deeper convection than the cold-air break case used in the first phase of the project.

James Hack briefed on recent development in the ORNL's Titan **Supercomputing** project which experiences a paradigm shift with more cores per chip, more chips per system but also more power requirements.

Saolo Freitas provided an update on **aerosol and air quality modeling** at various centres. The session provided an excellent overview over what air-quality systems are executed at the various centres. Despite some tentative results the role of aerosols and chemistry for meteorological forecast quality remains largely unknown. Just like for microphysical processes, there is no clear understanding how sophisticated a treatment of aerosols/air chemistry is required to make good weather forecasts. WGNE feels that it should aim to develop a project in this area in collaboration with other groups, e.g., GURME and GAW.

C. Fairall provided an update on the **Surface Flux Analysis (SURFA)** project. Progress on comparing NWP fluxes to buoy data continues to be made, but it remains unclear how useful the information is for the centres and how much use they make of it. Discussions ranked around two issues, i) how SURFA might be better integrated in a concerted surface flux effort within WCRP and ii) whether some of the data analysis could be made available in real time to provide more immediate feedback to the centres. Both issues will need to be followed up throughout the year and discussed again at next year's meeting.

8 Forecast verification

Laurence Wilson presented an update on the **Joint Working Group on Forecast Verification Research (JWGFVR)**. It was highlighted that the 5th International Verification Methods Workshop will be held in Melbourne, Australia, 1-7 Dec 2011. Documents on cloud verification, and tropical cyclone verification are still in revision and draft form respectively. A spatial method intercomparison project 2 (ICP2) is being planned to address scale-resolving methods.

There was significant discussion around issues arising from verification of forecasts against their own analysis. It was suggested that such verification usually overstates the accuracy of the forecast (and to different degrees for different systems and for different variables and regions). WGNE felt that this is a very important issue and appointed several members to progress a potential project in this area.

Chiashi Muroi provided an update on **Tropical Cyclone (TC) Track verification**. 11 NWP centers now participate in the project for global models, showing the excellent uptake of this great activity supported by JMA. A new web site for this activity will be available in Nov 2011 at http://nwp-verif.kishou.go.jp/wgne_tc/index.html. In addition to global models, five regional models now also participate in the project, which is a great development welcomed by WGNE.

Jean-Noël Thépaut and **Florence Rabier** illustrated **Polar Verification** based on radiosondes and Concordiasi dropsondes. Concordiasi provided an unprecedented data coverage of meteorological observations over Antarctica. Most models have problems predicting the lowest level temperatures over the continent and also winds at 300hPa and at the surface.

9 Workshops

J. Teixeira briefed on the **Earth System Physics Workshop** to be held 20-23 March 2012 in Pasadena, USA. The workshop will focus on key problems in the representation of physical processes in weather and climate models and aims to produce some recommendations regarding organizational and institutional strategies for accelerated model development. It will be organized around 3 multi-disciplinary sessions, one per day, with afternoon break-out sessions and posters and evening discussions. The four days will cover high-latitudes, tropical weather and climate, clouds and climate physics, and recommendations respectively.

Glenn White and **Bill Lapenta** presented a proposal for a **Joint WGNE-GOV Workshop** entitled "**Status, Needs and Challenges in Short- to Medium-Range Coupled Prediction of the Earth System**" to be held in Washington DC in the third quarter of 2012 with an expected attendance of 50 participants. The workshop would be motivated by recent results demonstrating the improvement in weather prediction by coupling with ocean models. The workshop would invite members of the WGNE and GODAE OceanView community with interests in developing coupled high-resolution systems for short- to medium- range prediction and would present the latest evidence of the impact of coupled modelling on the earth system analysis and forecasts. WGNE remains strongly supported the workshop but cautioned on the timing and recommended a move to early 2013 if possible.

Peter Lauritzen provided an update on WGNE-sponsored activity and plans for the **2012 NCAR Summer School and Model intercomparison Workshop on Non-Hydrostatic Global Models**. The 2012 event will be attended by around 30 students/postdocs with a special attention to emerging non-hydrostatic dynamical cores, by establishing new non-hydrostatic dynamical core test cases and by involving possibly UKMO, ECMWF NASA GEOS-6, FV, MPI and CSU cores.

It was agreed that the next WGNE systematic error workshop will be held in Exeter in spring 2013. Keith Williams will chair an organizing committee and ensure involvement of all key partners. In discussion with WGCM it was agreed that the programme should be broad (e.g. considering errors on multiple timescales). It was also suggested that a session on the effect of resolution on systematic error be included.

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10 Joint WGCM/WGNE session (19 October 2011)

10.1 Overview of WGNE and WGNE activities and WCRP matters

10.1.1 WGCM

S. Bony reviewed the three main WGCM missions and stressed the need to balance Simulations – model Evaluation – and process Understanding. The first mission of WGCM is to review and foster the development of coupled climate models - now evolving into Earth System models - in particular through several collaborations are in place through IGBP/AIMES, SPARC, CLIC and joint activities such as the joint WCRP/WWRP-THORPEX "survey on model evaluation and improvement". The second mission of WGCM is to Coordinate model experiments and inter-comparisons, which is achieved through several efforts such as CMIP, PMIP, WGSIP, Transpose-AMIP WGNE/WGCM and CORDEX to address natural climate variability, predict climate response to natural and anthropogenic perturbations at various scales. The third mission of WGCM is to promote and facilitate model validation and diagnosis of shortcomings through the development of metrics and synergies between global modeling, observations and process studies such as the CFMIP observations simulator, Obs4MIP effort and coordinated CFMIP/GCSS station output.

Many opportunities for increased collaboration between WGCM and WGNE are possible. NWP groups may be further involved in CMIP5, for example in the atmosphere-only AMIP runs and idealized experiments. The CMIP5 community has an opportunity to feedback model diagnostics to model developers. Shortfalls in understanding the link between model errors and model formulation require further coordinated experiments to address physical parameterization and the effect of model resolution in particular. It was suggested to create dedicated Climate Process Teams (CPTs) to that effect.

10.1.2 WGNE

C Jakob provided an overview of the WGNE ToR, focusing on modeling and data assimilation. WGNE was established 27 years ago, under the sponsorhip of WCRP and CAS. A recent focus and positive outcome of this group has been the progress in seamless prediction, as demonstrated by the fact that several centers now use the same model for NWP and climate modeling such as the UK MetOffice. The importance of ex-officio memberships of WGNE such as GEWEX is acknowledge and provide WGNE with an opportunity to interface with important efforts such as SURFA which develop the surface fluxes data sets and analyses. NWP models are entering the grey zone, a range of high resolution where the behavior of models is poorly understood and current parameterization schemes is showing limitations. This is an issue climate models may have to address soon as well. Opportunities for increased WGNE/WGCM collaboration are suggested on initiatives such as AMIP and THORPEX efforts, on topics such as rainfall verification, model uncertainty, ocean-atmosphere coupling, which may benefit both communities.

10.1.3 WCRP

M. Rixen provided an update on WCRP matters relevant to both WGNE and WGCM communities. The NWP and climate research communities have a growing common interest to collaborate. NWPs are looking to extend their forecast into the sub-seasonal to seasonal range whilst the climate research community has been pushed to deliver more operational services through the newly established Global Framework for Climate Services (GFCS). A new joint WCRP-WWRP effort called "Sub-seasonal prediction research project" will address the predictability potential at these scales by joining NWPs and Climate research forces. The WCRP is currently being revisited with the transition of the WCRP Observations and Assimilation Panel (WOAP) into a WCRP Data Advisory Council (WDAC) to coordinate observational and data analysis efforts across the program, and the establishment of a WCRP Modeling Advisory Council (WMAC), to coordinate modeling efforts across the program.

10.2 Review of WGNE/WGCM relevant modeling projects

10.2.1 CMIP5

Karl Taylor provided a review of CMIP5, its structure and funding and tiered approach with the core and optional simulations. Currently 23 groups are providing 50+ models. The Earth System Grid Federation led by PCMDI serves CMIP5 simulation outputs to analysts worldwide by linking 13 data nodes. The system has allowed a much wider end-user community but is still experiencing some difficulties or limitations such as web searching and bandwidth. Nevertheless a selection of interesting new science results were presented (e.g. on abrupt quadrupling of CO2, cloud radiative feedback sensitivity, and transient climate response versus equilibrium climate sensitivity). Papers need to be submitted by 31 July 2012 and accepted by 15 March 2013 to be cited in IPCC AR5.

The CMIP5 workshop will run over 5 days, 5-9 March in Honolulu, Hawaii, and attendance will be limited to 150 people. The selection of abstracts will be made by the committee. The conference will consist of posters mainly plus short oral presentations.

10.2.2 Climate model metrics

Peter Glekler provided an update on the WGNE/WGCM Climate Model Metrics Panel which aim is to quantify model agreement with observation with a broad perspective by looking at different aspects of model skill. Such metrics have proved extremely valuable to the NWP community over many years, and good progress has been made with the climate metrics. Important next steps are to continue to expand the range of metrics to look in more detail at crucial processes (e.g. MJO, cloud regimes, annual and seasonal cycles) and thus get a more complete view of model performance. All were invited to provide ideas to the metrics panel.

10.2.3 Transpose AMIP

Keith Williams, reviewed progress with the joint WGNE/WGCM Transpose-AMIP effort, which consists in running climate models in NWP-mode, as opposed to AMIP, which is an Atmospheric Model Intercomparison project. The core experiments are to run models initialized from ECMWF YOTC analysis spread through annual and diurnal cycles during 2008/2009. Good progress is being made with 8 centers have announced their participation and with the first data available for download. Examples of actually using results from across a range of timescales to understand and alleviate model problems were also shown. Centres not currently involved are encouraged to perform the Transpose-AMIP experiments and submit their data, and all are encouraged to consider proposing and performing diagnostic projects with the data.

The group also discussed the desirability of a co-ordinated study looking systematically at the effects of resolution of AMIP simulations. However it has proved difficult to find an individual to champion this. The WGNE and WGCM co-chairs will consider further options. Pragmatically, if any centres who are submitting high resolution (e.g. 25-50km resolution) AMIP runs to CMIP5 could also submit lower resolution results with the same model, then that would at least allow further study of the issue.

10.2.4 CFMIP

Sandrine Bony presented an update on the Cloud Feedback Model Inter-comparison Project. Good progress in being made, and a particular strength of the project is the bringing together of global modellers, observationalists and process modelers. The COSP cloud simulator is also proving very useful both for looking at global climate model performance (and their performance in the short-range through Transpose-AMIP) and also for some NWP models. A user interface (http://climserv.ipsl.polytechnique.fr/cfmip-obs.html) provides an easy access to observational data (ground based (e.g. ARM, CloudNet) as well as satellite) and will soon allow for the extraction of multiple satellite observations and 3-hrs ERA-interim data over CFMIP stations.

The next Joint Euclipse/CFMIP meeting will focus on cloud bias characterization, role of clouds in current climate and climate change cloud feedback.

10.2.5 YOTC/MJO

Mitch Moncrieff and **Duane Waliser** reviewed progress with YOTC and the MJO task force. The YOTC focus period 2008/2009 provides a diverse set of conditions e.g. modest El Nino, La Nina, evident MJO, and also interesting Kelvin-Rossby wave interactions and case studies for diabatic heating experiments which are being performed as part of a new YOTC/GASS study and to which about 20 modelling groups are contributing.

The MJO task force also continues to develop metrics on the MJO which provide a quantitative assessment of forecast skill. Many operational centres routinely contribute to this effort. It is likely that the task force will propose that the set of metrics is somewhat increased to allow more detailed evaluation of variability. This idea was welcomed.

10.2.6 WGSIP

David Dewitt provided an overview of activities within WGSIP, consisting of the CHFP, Decadal and Sub-seasonal projects and stressed the large potential for societal applications at these scales. About a dozen groups contribute to CHFP, and half of them have already completed their simulations, which results are hosted on the CIMA server at **http://chfps.cima.fcen.uba.ar/.** Key efforts include those on the importance of the land surface (GLACE), of the stratosphere (SHFP) and of sea-ice initialization (IHFP).

It was noted that in order to aid interpretation of model results on seasonal timescales (and cross-linking to results obtained on weather and centennial climate timescales), it would be useful to have documentation of the models, in particular in terms of whether they were connected to those used for NWP or CMIP5.

10.2.7 CORDEX

Colin Jones review the progress on **CORDEX** activities, which focuses on the sources of uncertainties in regional climate downscaled model evaluation (forcing by ERA-interim boundary conditions) and projections (RCP approach). CORDEX is currently active over several continents, with an initial focus on Africa. It was pointed out that the Task Force Regional Climate Downscaling (TFRCD) mandate extended by 1-year in Feb 11 was extended by one year, but that the TF would be replaced by a WCRP Regional Climate Science and Information Working Group (WGRC). A pan CORDEX conference was held in Trieste in March 2011 and training workshops will be held on Cape Town in Nov 2011 and early 2012. A similar group is being formed in South Asia led by IITM. Discussions are now occurring with the South East Asian Bank to support a similar capacity building and impacts/evaluation panel for South East Asia. All capacity building efforts are a WCRP/START collaborative effort. CORDEX East Asia had a workshop in Sept 2011 hosted by KMA. Euro-CORDEX will have a meeting Nov 17-18 to plan CMIP5 downscaling over Europe (esp. 0.11° RCM simulations). The Polar-CORDEX (Arctic and Antarctic), coordinated by John Cassano, U. Colorado will hold the 1st planning meeting in Sweden March 2012.

In discussions the importance was emphasized of continuing to compare regional model outputs with those of the driving global models in order to robustly ascertain where value was being added. It was also suggested that it would be good to more strongly involve the community working on and developing the regional climate models with other model development efforts (e.g. projects run by GASS and WGNE and WWRP).

A. ANNEX WGNE-27 Decisions and Actions

This appendix summarizes the actions and decisions of WGNE-26 in accordance with the full report above. Initials mark the responsible WGNE Co-Chair (AB = Andy Brown, CJ = Christian Jakob) or JPS staff (MR = Michel Rixen). ALL indicates that all members should contribute.

a. Liaison

WMO general

1) Express concern in the WGNE report about the lack of sharing of high-resolution precipitation data among countries to appropriate WMO body (CJ, MR)
2) Encourage future joint meetings/days of the major WGs (MR) given the success of the WGNE/WGCM meeting

Sub-seasonal and polar prediction efforts

3) Invite reports on the polar and sub-seasonal prediction projects at the next WGNE (CJ)
4) Ask the respective planning groups to consider adding model developers to their teams (CJ)

WWRP Mesoscale Working Group

5) Consider joint meeting for the next few years (AB, Jeanette Onvlee)
6) Encourage participation of the group members in the Grey Zone Project (AB, Jeanette Onvlee)
7) Encourage participation of the group members in the GASS activities (AB, Jeanette Onvlee)

WOAP / WCRP Data Council

8) Jean-Noel Thépaut is proposed to continue to represent WGNE in the WCRP Data Council that will replace WOAP (CJ, MR)

THORPEX

9) WGNE proposes that the THORPEX DAOS consider techniques used for reanalyses
10) Consider a talk on the predictability of small-scale events at one of the future WGNE meetings (AB)
11) Ask the THORPEX PDP to help energize the stochastic physics community to participate in the existing GEWEX activities (AB, PDP co-chairs)

GEWEX/GASS/GLASS

12) Ask GASS to try and entrain the stochastic physics community into their activities and perhaps design special experiments (CJ)
13) Ask GASS to entrain the RCM community from CORDEX - Contact: Ruby Leung (CJ)
14) Ask GASS to document the link of the SCMs used in their experiments and to encourage groups to submit standard versions as well as their latest development versions (CJ, GASS Chairs)
15) Ask WGNE members to participate in the GLASS PILDAS Land Data Assimilation experiments (AB)
16) Ask GLASS to report back at next WGNE how members are and could be involved in the PALS activities (CJ, GLASS Chairs)
17) Ask GEWEX community to think about a unified Land-PBL-Convection case, maybe around the AMMA or SAMBA field experiments (CJ@2012 GEWEX SSG)

WGCM/WGNE Metrics panel

18) WGNE strongly supports the continuation of the work of this very successful panel in its current form - Communicate to WGCM chairs and WMO (CJ)

MJO Task Force

19) Remind WGNE members that they can participate in the operational validation of the MJO (CJ)
20) Ask the MJO Task Force to provide a proposal for more variables to be submitted in support of extended MJO verification (CJ)

WGSIP

21) Ask WGSIP if they can document which of the operation SP systems are related to operational NWP or climate models

WCRP JSC

22) Provide a written note as input to the WCRP mini-JSC in Boulder (CJ)

b. Coordinated Experiments and Projects

The Grey Zone Project

23) Help to identify leaders for the various sub-projects (ALL)
24) Write a short proposal for funding of computer time at the Oak Ridge DOE facility (CJ, Pier Siebesma)
25) Encourage some early ground work on a tropical case (CJ, GASS, Pier Siebesma)

Role of Aerosols in NWP

26) Individual members to carry out experiments on the effect of aerosols on standard forecast quality measures and report back in 2012 (ALL)
27) Contact GURME to check on their activities in this area (AB)
28) Contact WGSIP to check on their experience in this area (CJ)

Transpose AMIP

29) Ask the T_AMIP Steering Group to consider connections to the DART project for the provision of initial conditions (CJ)
30) Ask WGNE members to participate in the forecasts and their analysis (CJ)

SURFA

31) Try and generate some quick looks for operational centers who submit data to SURFA - find funding for such an activity (AB, CJ)
32) Discuss how SURFA fits into the wider surface flux activities across WMO (CJ, GCOS chair)

Verification

33) Encourage more verification of surface weather at WGNE by extending activities beyond existing precipitation verification talks - Members to report on their activities in this area in 2012 (ALL)
34) Commission more research into issues related to verification against own analyses (AB)
35) Form a small working party consisting of Tom Hamill, Jean-Noel Thépaut, a member of the Joint Working Group for Verification Research and one more volunteer
36) Charge the working party to propose a plan of action at the next WGNE meeting

Numerical techniques

37) Mikhail Tolstykh to circulate the results of his survey on numerical methods at the operational centres to all WGNE members (CJ)

Climate Process Teams

38) Decision: WGNE and WGCM support the principal idea of forming international process teams to tackle specific model issues
39) Ask the new modelling council to consider this issue (CJ)
40) YOTC-MJO-GASS work is seen as an example for such a team - Ask the three groups involved to consider forming at CPT
41) Ask forthcoming workshops to make recommendations for specific teams (ALL)

c. Workshops, Publications, Meetings

Physics in Climate models

42) Ask organizers to rename the workshop to "Physics of Weather and Climate Models" and include WWRP in the list of sponsors (CJ)
43) Nominate participants from the various WMO groups (ALL)

Dynamical Core Workshop

44) Send email addresses of WGNE members to the workshop organizers so they can make contact (CJ, AB)
45) Encourage the workshop organizers to survey what happens to the careers of the students who attended (AB)

WGNE/GOVST Workshop on coupled NWP

46) Encourage organizers to form an organizing committee (AB)
47) Set a date for the workshop keeping in mind that Fall 2012 is already very busy (AB)

WGNE Systematic Errors Workshop

48) Decision to hold workshop at the MetOffice in April 2013
49) Keith Williams to lead the organizing committee and set the dates (AB)

WGNE Website

50) Review the current WGNE website(s) and try and consolidate them and keep them up to date (CJ, AB, MR)

Blue Book

51) Ask members to encourage submissions to the book (AB)

Next WGNE meeting

52) The next WGNE meeting will be held from 5-9 November 2012 in Toulouse hosted by Météo-France.

B. ANNEX Meeting agenda

MEETING AGENDA

Monday 17 October

08h30 - 10h30 **Welcome, Adoption of the Agenda, Local Arrangements** (10 min)
C. Jakob, A. Brown, T. Hamill

Welcome by NOAA/NCAR (10 min)
B. Brown

Meeting Goals and Actions from last meeting (10 min)
C. Jakob, A. Brown

CAS matters (45 min)
M. Béland

WCRP matters (45 min)
M. Rixen

10h30 - 11h00 Coffee

11h00 - 12h30 **GEWEX** (30 min)
K. Trenberth

WWRP (30 min)
G. Brunet

THORPEX (30 min)
T. Nakazawa

12h30 - 13h30 Lunch

13h30 - 15h00 **Centre Reports** (4, 20 min each)
DWD, BOM, UKMO, Korea

15h00 - 15h30 Coffee

15h30 - 17h00 **Centre Reports** (4, 20 min each)
Brazil, Canada, NCEP, JMA

Tuesday, 18 October

08h30 - 10h30 **Recent developments in high-resolution NWP** (30 min)
B. Lapenta, G. Dietachmayer

Recent developments in Numerical Methods (30 min)
M. Tolstykh, M. Baldauf

Recent developments in Data assimilation (30 min)
F. Rabier, J.N. Thépaut

Recent developments in Ensemble Prediction (30 min)
T. Hamill, C. Muroi

10h30 - 11h00 Coffee break

11h00 - 12h30 **Centre Reports** (4, 20 min each)
France, China, Russia, ECMWF

12h30 - 13h30 Lunch

13h30 - 15h00 **Centre reports** (2, 20 min each)
NCAR, GFDL

Rainfall verification with a specific focus on diagnostics studies (40 min)
Participants led by Co-Chairs

15h00 - 15h30 Coffee break

15h30 - 17h00 **Science talks** (3x30 min each)
Development of ensemble Kalman filter and variational hybrid
J. Whitaker, NOAA

DART, the Data Assimilation Research Testbed
J. Anderson, NCAR

MPAS, Model Predictions Across Scales
B. Skamarock, NCAR

Wednesday, 19 October

Joint WGCM-WGNE Sessions

08h30 - 10h30 **Welcome** (10 min)
J. Meehl, S. Bony, C. Jakob, A. Brown

Overview over WGCM activities (10 min)
J. Meehl, S. Bony

Overview over WGNE activities (10 min)
C. Jakob, A. Brown

WCRP JSC overview (30 min)
G. Asrar, A. Busalacchi

CMIP (30 min)
K. Taylor

Climate Model Metrics Panel (30 min)
P. Gleckler

10h30 - 11h00 Coffee break

11h00 - 12h30 **Tanspose AMIP** (30 min)
K. Williams

CFMIP (30 min)
S. Bony

YOTC and new MJO experiments (30 min)
M. Moncrieff, J. Petch, D. Waliser

12h30 - 13h30 Lunch

13h30 - 15h00 **WGSIP report** (30 min)
D. DeWitt

High resolution AMIP and resolution in climate models (30 min)
Discussion introduced by P. Gleckler

CORDEX (30 min)
F. Giorgi, C. Jones

15h00 - 15h30 Coffee break

15h30 - 17h00 **Model development and the prospect of international CPTs** (30 min)
Discussion introduced by S. Bony and C. Jakob

Workshops in particular CMIP5 and Systematic errors (30 min)
Discussion introduced by S. Bony and C. Jakob

General discussion on joint activities (30 min)
J. Meehl, A. Brown to chair

17h30 - 20h00 Reception

Thursday, 20 October

08h30 - 10h30 **GASS/GCSS/GABLS report and discussion** (60 min)
J. Petch, G. Svensson

GLASS report and discussion (30 min)
J. Santanello

10h30 - 11h00 Coffee break

11h00 - 12h30 **SPARC report and discussion** (30 min)
S. Polavarapu

Earth System Physics workshop (20 min)
J. Teixeira

GOVST workshop (20 min)
G. White, B. Lapenta

Follow up and decision on Systematic Error Workshop (20 min)
C. Jakob

12h30 - 13h30 Lunch

13h30 - 15h00 **The grey zone project** (60 min)
P. Siebesma, J. Onvlee

Recent developments in supercomputing (30 min)
J. Hack

15h00 - 15h30 Coffee

15h30 - 17h00 **Current state of aerosol and air quality modelling at the centres** (60 min)
Participants led by S. Freitas & G. Dietachmayer

SURFA (30 min)
C. Fairall, A. Brown

17h00 - 19h00 **Early Career Scientists Assembly Poster Session -** Mesa Lab Cafeteria

Friday, 21 October

08h30 - 10h30 **Report of JWGV** (45 min)
L. Wilson

TC verification (30 min)
C. Muroi

Polar Verification activities (20 min)
Participants led by F. Rabier and J.-N. Thépaut

Discussion on verification against own analysis (20 min)
Participants led by F. Rabier and JWGV

10h30 - 11h00 Coffee

11h00 - 12h30 **Meeting summary and discussion of future WGNE activities, including workshops and projects**
C. Jakob, A. Brown, Participants

12h30 - 13h00 Closing Session

Decisions and Actions
C. Jakob, A. Brown

C. ANNEX List of participants

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D. ANNEX Tables of NWP Operational Models

WGNE List of Operational Global Numerical Weather Prediction Systems (as of 01. Jan. 2012)

Forecast Centre (Country)	Computer (Sustained in TFlop/s)	High resolution Model (FC Range in days)	Ensemble Model (FC Range in days)	Type of Data Assimilation
ECMWF (Europe)	IBM p6 575, 272 nodes x 2 (2x15)	T_L1279 L91 (10)	T_L639 L62; (10) T_L319 L62 (+5)	4D-Var 12h (T_L255)
Met Office (UK)	IBM Power 6 106 nodes x2 (2*6)	~25 km L70 (6)	~60km L70; M24 (15)	4D-Var (~60km)
Météo France (France)	NEC SX9, 2x10 nodes (2x3)	T_L798(C2.4) L70 (4)	T_L538(C2.4) L65; M35 (4)	4D-Var (T_L323)
DWD (Germany)	NEC SX9; 2x30 nodes (2x9)	20 km L60 (7)	No global EPS	3D-Var
HMC (Russia)	SGI Altix4700; SGI ICE8200 (1.8; 1.3)	0.72°x0.9° L28 (10) T169 L31 (10)	T85L31,M13+T169L31, M1+0.72x0.9L28,M1 (10)	3D-OI
NCEP (USA)	IBM p655 (Cluster 1600) (2x1.9)	T574 L64 (7.5) T190 L64 (16)	T190L28; M45 (16)	3D-Var (T574)
Navy/FNMOC/NRL (USA)	SGI and IBM (800 proc) (3.2)	T239 L30 (7.5)	T119 L30; M16 (10.5)	3D-Var
CMC (Canada)	IBM p575+, 2X131 nodes (2x6)	0.45°x0.3° L80 (10)	0.6° L40; M20 (16)	Det: 4D-Var (1.5°) EPS: EnKF M192 (0.9°)
CPTEC/INPE (Brazil)	NEC SX6, 12 nodes (0.8) CRAY XT6 30528 cores (16.6)	T299 L64 (7); T126 L28 Coupled (30)	T126 L28; M15 (15)	3D-Var (T299) LETKF (T126)
JMA (Japan)	Hitachi SR11000-K1, 2*80 nodes (2x0.7)	TL959 L60 (9)	TL319 L60; M51 (9)	4D-Var (TL319)
CMA (China)	IBM p655/p690 120 nodes (2.1)	TL639 L60 (10)	T213 L31; M15 (10)	3D-Var
KMA (Korea)	Cray X1E-8/1024-L (2x0.7)	T426 L40 (10)	T213 L40; M32 (17/cycle) (10)	3D-Var
NCMRWF (India)	IBM P6 - 1280 processor (2.4)	T574L64 (10)	No global EPS	3D-Var (T574)
BoM (Australia)	SUN Constellation, 576 nodes (2.5)	80km, L50 (10)	No global EPS	4D-VAR (120km)

WGNE Overview of Plans at the NWP Centres with Global Forecasting Systems

Part I: Computer (Sustained Performance in TFlop/s based on main deterministic model)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF (Europe)	2x15	2x42	2x42	tbd	tbd	tbd
Met Office (UK)	2*33	2*33	2*33	tbd		
Météo France (France)	2x3	2x3	tbd	tbd	tbd	
DWD (Germany)	2x9	2x9	2x27	2x27	tbd	
HMC (Russia)	1.8+1.3	1.8+1.3 +3	35	35	tbd	
NCEP (USA)	2x27	2x27	tbd	tbd		
Navy/FNMOC/NRL (USA)	tbd	tbd	tbd	tbd		
CMC (Canada)	2x13	2x13	2x13	tbd	tbd	tbd
CPTEC/INPE (Brazil)	16.6	16.6	16.6	tbd		
JMA (Japan)	2x0.7	2x30	2x30	2x30	2x30	2x30
CMA (China)	2.1 5	tbd	tbd	tbd	tbd	
KMA (Korea)	2x17	2x17	tbd	tbd		
NCMRWF (India)	2.4	2.4	tbd	tbd	tbd	
BoM (Australia)	2.5	5 - 6	5 - 6	tbd		

Assuming twin 6 frame systems with UM delivering 6% of peak

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems

Part II: Global Modelling

a) Deterministic Model (Resolution and number of layers)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF (Europe)	T_L1279 L91	T_L1279 L137	TL1279L137	TL2047 L137	TL2047 L137	TL2047 L137
Met Office (UK)	25km L70	tbd (15 - 25km; L85?)	tbd	tbd		
Météo France (France)	T_L798c2.4 L70 (10km on W Europe)	TL798c2.4 L70 (10km on W Europe)	TL1200c2.2 L105 (8km on W Europe)	TL1200c2.2 L105 (8km on W Europe)	tbd	
DWD (Germany)	20 km L60	20 km L60	20 km L100 (5km in Europe)	20 km L100 (5km in Europe)	tbd	
HMC (Russia)	0.72°x0.9° L51 T169 L31	0.72°x0.9° L51 T169 L31	0.18°x0.225° L60 T339 L31	0.18°x0.225° L60 T339 L63	tbd	
NCEP (USA)	T878; L64 (7.5) T382; L64 (16)	T878; L64 (7.5) T382; L64 (16)	T878; L91(7.5) T382; L91 (16)	TBD		
Navy/FNMOC/NRL (USA)	T479 L60	T479 L60	T511 L64	T511 L64		
CMC (Canada)	(0.35°x0.23°) L80	(0.2°x0.2°) L90	(0.2°x0.2°) L100	(0.17°x0.17°) L125	(0.17°x0.17°) L125	(0.13°x0.13°) L160
CPTEC/INPE (Brazil)	25 km L64	20 km L96	10 km L96	10 km L128	tbd	tbd
JMA (Japan)	T_L959 L60	T_L959 L60	T_L959 L100	T_L959 L100	T_L959 L100	T_L959 L100
CMA (China)	T_L639 L60 GRAPES 50 km L35	TL639 L60 GRAPES 50 km L35	GRAPES 25 km L60	tbd	tbd	
KMA (Korea)	25 km L70	20 km L90	tbd	tbd		
NCMRWF (India)	T574; L64	T574; L64	tbd	tbd	tbd	
BoM (Australia)	40 km L70	25 km L70	20 km L90	20 km L90	17 km L110	

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems

Part II: Global Modelling

b) Global Ensemble Prediction System (Resolution, number of layers, number of members, forecast range in days)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF (Europe)	T639 to D+10 T319 to D+15 L62	T639 to D+10 T319 to D+15 L92	T639 to D+10 T319 to D+15 L92	T1023 to D+10 T511 to D+15 L92	T1023 to D+10 T511 to D+15 L92	T1023 to D+10 T511 to D+15 L92
Met Office (UK)	60km L70; M12*2;15	tbd (40km? L85?)	tbd	tbd		
Météo France (France)	T538c2.4 L65; M35; 4 days	T538c2.4 L65; M35; 4 days	tbd	tbd		
DWD (Germany)	nil	nil	40 km L100; M30 3	40 km L100; M30 3	tbd	
HMC (Russia)	T169 L31, 0.72°x0.9°L28? M14? 10	T169 L31, 0.72°x0.9°L28? M22? 10	T169 L63, 0.72°x0.9°L51? M22? 10	T169 L63, 0.72°x0.9°L51? M22? 10	tbd	
NCEP (USA)	T254 L42; M21; 16	T254 L42; M21; 16	T382 L64;M21; 16	T382 L64;M21; 16	tbd	
Navy/FNMOC/NRL (USA)	T119L30; M20; 16	T239L42; M20; 16	T239L42; M20; 30	T239L42; M20; 30		
CMC (Canada)	GEM (0.6°x0.6°) L58 M20 16	GEM (0.45°x0.45°), Yin-Yang L58 M20 16	GEM (0.30°x0.30°), Yin-Yang L58 M20 16	tbd	tbd	
CPTEC/INPE (Brazil)	45 km, L42, M40; 15	40 km, L64, M60; 15	40 km L64; M60; 15	tbd	tbd	
JMA (Japan)	T_L319 L60; M51; 9	T_L319 L60; M51; 9	T_L479 L100; M13; 18 T_L479 L100; M14; 9	T_L479 L100; M13; 18 T_L479 L100; M14; 9	T_L479 L100; M13; 18 T_L479 L100; M14; 9	T_L479 L100; M13; 18 T_L479 L100; M14; 9
CMA (China)	T213L31; M30 (BGM,10)	T213L31;M30 (BGM, 10)	GRAPES 50km L35 M15,10	tbd	tbd	
KMA (Korea)	40 km L70; M24; 15	40 km L70; M24; 15	tbd	tbd		
NCMRWF (India)	No Global EPS	T190 L28 M21; 10	tbd	tbd	tbd	
BoM (Australia)	nil	nil	MOGREPS, 60 km L90; M24; 10	MOGREPS, 60 km L90; M24; 10	MOGREPS, 35 km L90; M24; 10	

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Part II: Global Modelling

c) Global Data Assimilation Scheme (Type, resolution, number of layers)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF (Europe)	4D-Var 12h (EDA 10 m T399); T_L1279 /T_L255 ; L137	4D-Var 24h (EDA 25m T399); T_L1279 / T_L399 ; L137	4D-Var 24h (EDA 25m T511); T_L1279 / T_L399 ; L137	4D-Var 24h (EDA 25m T511); TL2047 / TL399 ; L137	4D-Var 24h (EDA 25m T511); TL2047 / TL399 ; L137	4D-Var 48h (EDA 50m T511); TL2047 / TL399 ; L137
Met Office (UK)	4D-Var (hybrid); 60km; L70	4D-Var (hybrid); resolution tbd	tbd	tbd		
Météo France (France)	4D-Var 6h and EDA 6m TL798C2.4 with TL323 final inner loop; L70	4D-Var 6h and EDA 6m TL798C2.4 with TL323 final inner loop; L70	4D6Var 6h and EDA, other features tbd	4D6Var 6h and EDA, other features tbd	4D6Var 6h and EDA, other features tbd	
DWD (Germany)	3D-Var; 20 km; L60	3D-Var; 20 km; L60	3D-Var+ensemble; 20 km; L100	3D-Var+ensemble; 20 km; L100	tbd	
HMC (Russia)	3D-Var 0.72°x0.9° L28	3D-Var 0.72°x0.9° L51	3D-Var + ENKF 0.5°x0.5° L80	3D-Var + ENKF 0.5°x0.5° L80	tbd	
NCEP (USA)	Advanced-Var; T878; L64	Hybrid enkf-3Dvar; T878; L64	Hybrid Enkf-3D-Var T878; L91	Hybrid Enkf-4D-Var T878; L91		
Navy/FNMOC/NRL (USA)	4D-Var T479 L60	4D-Var T479 L60	4D-Var T511 L64	4D-Var T511 L64		
CMC (Canada)	Det: 4D-Var (0.9°x0.9°), (0.35°x0.23°) L80 EPS: EnKF M192 (0.6°x0.6°)	Det: En-Var (0.45°x0.45°) Yin-Yang, (0.35°x0.23°) L90 EPS: EnKF M192 (0.45°x0.45°), Yin-Yang	Det: En-Var (0.3°x0.3°) Yin-Yang, (0.3°x0.2°) L90 EPS: EnKF M192 (0.3°x0.3°), Yin-Yang	tbd	tbd	
CPTEC/INPE (Brazil)	3D-Var + LETKF T299L64; T126L28	3D-Var + LETKF T299L64; T126L29	Hybrid 3D-Var + LETKF T299L64; T126L30	tbd		
JMA (Japan)	4D-Var; TL319; L60	4D-Var; TL319; L60	4D-Var; TL319; L100	4D-Var; TL319; L100	4D-Var; TL319; L100	4D-Var; TL319; L100
CMA (China)	GSI GRAPES_3DVAR 50 km; L35	GSI GRAPES_3DVAR 50 km; L35	GRAPES_3DVAR,50km;L35	tbd	tbd	
KMA (Korea)	4D-Var; 75km; L70	tbd	tbd	tbd		
NCMRWF (India)	3D-VAR; T574; L64	3D-VAR; T574; L64	tbd	tbd	tbd	
BoM (Australia)	4D-VAR; 80 km L70	4D-VAR; 50 km L70	4D-VAR; 40 km L90	4D-VAR; 40 km L90	4D-VAR (Hybrid); 35 km L110	

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Part III: Regional Modelling

a) Regional deterministic model (number of gridpoints, resolution, number of layers)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF (Europe)	-	-	-	-		
Met Office (UK)	600*360; 12 km; L70 768*960; 1.5 km; L70	768*960; 1.5 km; L70	tbd	tbd		
Météo France (France)	750x720; 2.5 km; L60	750x720; 2.5 km; L60	target 1.3 km; L100	target 1.3 km; L100	target 1.3 km; L100	tbd
DWD (Germany)	665x657; 7 km; L40 421x461; 2.8 km; L50	665x657; 7 km; L40 421x461; 2.8 km; L50	zooming 5 km; L100 724x780; 2.2 km; L80	zooming 5 km; L100 724x780; 2.2 km; L80	tbd	
HMC (Russia)	700x620, 7km, L40 2 dom. 420x470,2.2km,L50	700x620, 7km, L60 2 dom. 420x470,2.2km,L80	700x620, 7km, L60 2 dom. 500x500,2.2km,L80	700x620, 7km, L60 2 dom. 500x500,2.2km,L80	1800x680, 7km, L60 2 dom. 500x500,2.2km,L80	
NCEP (USA)	1371x1100; 4 km; L70 595x625; 6 km; L70 373x561; 3 km; L70 241x241; 3 km; L70	1371x1100; 4 km; L70 595x625; 6 km; L70 373x561; 3 km; L70 241x241; 3 km; L70	2193x1760; 2.5 km; L80 1071x1125; 3.33km; L80 559x841; 2 km; L80 361x361; 2 km; L80	2193x1760; 2.5 km; L91 1071x1125; 3.33km; L91 559x841; 2 km; L91 361x361; 2 km; L91	1182x1014; 2.25km; L91 1190x1250; 3 km; L91 621x935; 1.8 km; L91 401x401; 1.8 km; L91	
Navy/FNMOC/NRL (USA)	27/9/3 km; L40	27/9/3 km; L50	9/3/1; L50	9/3/1 km; L60		
CMC (Canada)	10 km; L80 LAMs at 2.5km; L58	10 km; L80 LAMs at 2.5km; L58	8km; L80 LAMs at 2.5km; L58	2.5 km; L125	2.5 km; L125	1.5 km; L160
CPTEC/INPE (Brazil)	379x779, 15km, L50; 419x625, 5 km, L50; 259x469, 5km, L50	500x1000, 10 km, L60; 419x625, 5 km, L60; 259x469, 5km, L60	500x1000, 10 km, L60; 1500x2000, 2 km, L60	tbd		
JMA (Japan)	721x577; 5 km; L50	817x661; 5 km; L75 551x801, 2km, L60	817x661; 5 km; L75 1581x1301, 2km, L60	817x661; 5 km; L75 1581x1301, 2km, L60	817x661; 5 km; L75 1581x1301, 2km, L60	817x661; 5 km; L75 1581x1301, 2km, L60
CMA (China)	502x330, GRAPES-1 5km; L33	502x330, GRAPES-15km; L33	1650x990, GRAPES-5km; L60	tbd	tbd	
KMA (Korea)	540x432, 12 km, L70 1.5 km, L70	540x432, 12 km, L70 1.5 km, L70	tbd	tbd		
NCMRWF (India	-	-	-	-	-	
BoM (Australia)	Regional (R), City (C), On-Demand (O) [R] 1090x750; 12km L70 [6xC] 250x250; 4km L70	[R] 1090x750; 12km L70 [6xC + 1xO] 250x250; 4km L70	[R] Nil [6xC + 2xO] 670x670; 1.5km L70	[R] Nil [6xC + 2xO] 670x670; 1.5km L70	[R] Nil [6xC + 2xO] 670x670; 1.5km L90	

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Part III: Regional Modelling

b) Regional Ensemble Prediction System (Resolution, number of members, forecast range in days)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF (Europe)	-	-	-	-		
Met Office (UK)	16 km; M12 (6 hrly); 2 2.2 km; M12 (6 hrly); 1	2.2 km; M12 (6 hrly); 1	tbd	tbd		
Météo France (France)	15 km; M35; 4	15 km; M35; 4	15 km; M35; 4	2.5km; M8; 1.5	2.5km; M8; 1.5	
DWD (Germany)	2.8 km; M40; 1	2.8 km; M40; 1	2.2 km; M50; 1	2.2 km; M50; 1	tbd	
HMC (Russia)	tbd	14 km; M12; 3	14 km; M12; 3	14 km; M12; 3	14 km; M12; 3	
NCEP (USA)	22 km; M25; 4cyc; 4day	22 km; M25; 4cyc; 4day	22 km; M25; 4cyc; 4day 3 km; M6; 2	10km;M25;4cyc; 4day 3 km; M6; 2	3km nested; M6; 24cyc(hrly); 1day 2.5km; M10; 2	
Navy/FNMOC/NRL (USA)	27/9 km; M20; 3	27/9 km; M20; 3	tbd	tbd		
CMC (Canada)	15 km L40 M20 3	15 km L48 M20 3	15 km L60 M20 4	10 km L60 M20 5	10 km L80 M20 5	2.5 km L100 ? M20 2 ?
CPTEC/INPE (Brazil)	40 km, M11, 11; 5 km, M5, 3	20 km, M21, 15 5 km, M5, 3	tbd	tbd		
JMA (Japan)	T_L319 L60; M11; 4 times/day; 5	T_L319 L60; M11; 4 times/day; 5	T_L479 L100; M25; 4 times/day; 5	T_L479 L100; M25; 4 times/day; 5	tbd	tbd
CMA (China)	No regional EPS	No regional EPS	GRAPES 15 km; M30; 72 hr	tbd	tbd	tbd
KMA (Korea)	12 km; M24; 3	12 km; M24; 3	tbd	tbd		
NCMRWF (India	No regional EPS	No regional EPS	tbd	tbd	tbd	
BoM (Australia)	Nil	Nil	MOGREPS; 24km L90; M24; 3	MOGREPS; 24km L90; M24; 3	MOGREPS; 16km L90; M24; 3	

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Part III: Regional Modelling

c) Regional Data Assimilation Scheme (Type and resolution)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF (Europe)	-	-	-	-		
Met Office (UK)	4D-Var, 24 km 3D-Var , 1.5 km	3d-Var, 1.5km	tbd	tbd		
Météo France (France)	3D-Var, 2.5 km	3D-Var, 2.5km	target 3D-Var 1.3km	target 3D-Var 1.3 km	target 3D-Var 1.3 km	
DWD (Germany)	Nudging; 7 km Nudging; 2.8 km	Nudging; 7 km Nudging; 2.8 km	LETKF; 2.2 km	LETKF; 2.2 km	tbd	
HMC (Russia)	none	3D-Var + EnKF 15 km	3D-Var + EnKF 12 km	3D-Var + EnKF 5 km		
NCEP (USA)	Advanced-Var; 12/6/4/3 km	Hybrid enkf-3dvar; 12/6/4/3 km	Hybrid enkf-3dvar; 10/3.33/2.5/2 km	Hybrid enkf-4dvar; 10/3.33/2.5/2 km		
Navy/FNMOC/NRL (USA)	4D-Var 27/9/3 km	4D-Var 27/9/3 km	4D-Var 9/3/1 km	4D-Var 9/3/1 km		
CMC (Canada)	Continental: 4D-Var 65 km L80	Continental EnKF 20 km, 48 nested levels (N48)	Continental EnKF 20 km N48 National 20 km N48	Continental EnKF 20 km N48 National 20 km N48	Continental EnKF 10 km N48 National 10 km N48	
CPTEC/INPE (Brazil)	3D-Var 10 km	3D-Var + LETKF; 10 km	3D-Var + LETKF; 10 km	tbd		
JMA (Japan)	4D-Var, 15 km	4D-Var, 10 km 3D-Var, 5km	4D-Var, 10 km 3D-Var, 5km	4D-Var, 10 km 3D-Var, 5km	4D-Var, 10 km 3D-Var, 5km	4D-Var, 10 km 3D-Var, 5km
CMA (China)	GRAPES-3DVAR, 15 km	GRAPES-3DVAR, 15 km	GRAPES-4DVAR,30km	tbd	tbd	tbd
KMA (Korea)	4D-Var, 24 km 3D-Var, 1.5 km	4D-Var, 24 km 3D-Var, 1.5 km	tbd	tbd		
NCMRWF (India	tbd	tbd	tbd	tbd	tbd	
BoM (Australia)	Regional (R), City (C), On-Demand (O) [R] 4D-VAR; 36 km; L70 [6xC] Forecast-only	[R] 4D-VAR; 36 km; L70 [6xC + 1xO] 3D-VAR; 4 km; L70	[R] Nil [6xC + 2xO] 3D-VAR; 1.5 km; L70	[R] Nil [6xC + 2xO] 3D-VAR; 1.5 km; L70	[R] Nil [6xC + 2xO] 3D-VAR; 1.5 km; L90	

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Part IV: Atmospheric composition

a) Global atmospheric composition modelling (Type [Aerosols? Chemically reactive gases?] and resolution)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF **(Europe)**	Data assimilation and 5-day forecasts of O3, CO, SO2, NOx, and aerosol at T255L60. Additional chemical species at 1.125 by 1.125 degrees at 60 levels	Data assimilation and 5-day forecasts of O3, CO, SO2, NOx, and aerosol at T255L60. Additional chemical species at 1.125 by 1.125 degrees at 60 levels	Data assimilation and 5 day forecasts of O3, CO, SO2, NOx, and aerosol at T255L60. Additional chemical species at 1.125 by 1.125 degrees at 60 levels	tbd	tbd	tbd
Met Office **(UK)**	Prognostic sea-salt, biomass, non-interactive prognostic dust	Prognostic sea-salt, biomass, interactive prognostic dust	Prognostic sea-salt, biomass, interactive prognostic dust	tbd		
Météo France (France)	Finalize comprehensive aerosol scheme (including SOA, ammonia,…)	tbd. CPU permitting, increase to target resolution : 1° + implement a data assimilation step	tbd. CPU permitting, increase to target resolution : 1°	tbd. CPU permitting, increase to target resolution : 1°	tbd. CPU permitting, increase to target resolution : 1°	tbd. CPU permitting, increase to target resolution : 1°
DWD **(Germany)**	Nil	Nil	20 km / 5 km ICON-ART; alert system for volcanic ash	20 km / 5 km ICON-ART; alert system for volcanic ash	tbd	
HMC (Russia)	Nil	tbd	tbd	tbd	tbd	tbd
NCEP **(USA)**	Passive dust aerosols 75 km	Passive dust and smoke aerosols 75 km	Full aerosol sources (dust, smoke, anthropogenic & Sea-salt) w/ simple sulfate chemistry 50 km	Full aerosols w/ simple sulfate chemistry 50 km	Simple tropospheric gas-phase chem + full aerosols 26 km	
Navy/FNMOC/NRL **(USA)**	Dust, Smoke, Sulfates, Sea Salt 50 km; L36	Dust, Smoke, Sulfates, Sea Salt 27 km; L60	Dust, Smoke, Sulfates, Sea Salt 25 km; L64	Dust, Smoke, Sulfates, Sea Salt 25 km; L64	Dust, Smoke, Sulfates, Sea Salt 26 km; L64	
CMC (Canada)	tbd	tbd	tbd	tbd	tbd	
CPTEC/INPE (Brazil)	T256 L68 with gas phase chemistry using RACM/RELACS chemical mechanism.	T256 L68 volcanic ash and sulfates, soil dust, black carbon and sea salt aerosols and gas phase chemistry using RACM/RELACS chemical mechanism.	tbd	tbd	tbd	
JMA **(Japan)**	Stratospheric Ozones 300km; L68, Tropospheric Ozones 120km; L30 Aerosols 120km; L30	Stratospheric Ozones 300km; L68, Tropospheric Ozones 120km; L30 Aerosols 120km; L30	Stratospheric Ozones 120km; L68 Tropospheric Ozones 60km; L48 Aerosols 60km; L48	Stratospheric Ozones 120km; L68 Tropospheric Ozones 60km; L48 Aerosols 60km; L48	Stratospheric Ozones 120km; L68 Tropospheric Ozones 60km; L48 Aerosols 60km; L48	tbd tbd
CMA (China)	tbd	tbd	tbd			
KMA (Korea)						
NCMRWF **(India**	tbd					
BoM (Australia)	tbd					

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Part IV: Atmospheric composition

b) Regional atmospheric composition modelling (Type [Aerosols? Chemically reactive gases?] and resolution)

Forecast Centre (Country)	2012	2013	2014	2015	2016	2017
ECMWF (Europe)	MACC European air quality analyses/forecasts from a 7 model ensemble at variable resolution (0.15° - 0.5°)	MACC European air quality analyses/forecasts from a 7 model ensemble at variable resolution (0.15° - 0.5°)	MACC European air quality analyses/forecasts from a 7 model ensemble at variable resolution (0.15° - 0.5°)	MACC European air quality analyses/forecasts from a 7-model ensemble at variable resolution (0.15° - 0.5°)	Pending contract negotiations with EC	
Met Office (UK)	Aerosols+chemistry 12km	Aerosols+chemistry 12km	Aerosols+chemistry 12km	tbd	tbd	
Météo France (France)	Finalize comprehensive aerosol scheme (including SOA, ammonia…)	tbd. CPU permitting, increase to target resolutions: Europe 0.2° and France 0.05° + data assimilation step	tbd. CPU permitting, increase to target resolutions : Europe 0.2° and France 0.05°	tbd. CPU permitting, increase to target resolutions : Europe 0.1° and France 0.025°	tbd. CPU permitting, increase to target resolutions : Europe 0.1° and France 0.025°	
DWD (Germany)	7 km COSMO-ART; alert system for volcanic ash	7 km COSMO-ART; alert system for volcanic ash	7 km COSMO-ART; alert system for volcanic ash	tbd	tbd	tbd
HMC (Russia)	Nil	Nil	7 km COSMO-ART	7 km COSMO-ART	tbd	
NCEP (USA)	Chemically reactive Gas-phase only Passive wild-fire smoke and dust 12	Chemically reactive Gas-phase only Passive wild-fire smoke and dust 4 km	Chemically reactive Gas-phase only Passive wild-fire smoke and dust 4 km	Chemically reactive Gas-phase and full aerosols 2.5 km	Chemically reactive Gas-phase and full aerosols 2.25 km	
Navy/FNMOC/NRL (USA)	Dust 45/15/5 km; L40	Dust, Smoke, Sulfates, Sea Salt 27/9/3 km; L40	Dust, Smoke, Sulfates, Sea Salt 27/9/3 km; L50	Dust, Smoke, Sulfates, Sea Salt 9/3/1 km; L50	Dust, Smoke, Sulfates, Sea Salt 9/3/1 km; L50	
CMC	Continental air quality: GEM-MACH 15 km [aerosols: 2 size bins,8 chemical species; NOx/VOC/O3 oxidant chemistry]	Continental air quality: GEM-MACH 10 km [aerosols: 2 size bins,8 chemical species; NOx/VOC/O3 oxidant chemistry]	Continental air quality: GEM-MACH 10 km [aerosols: 2 size bins,8 chemical species; NOx/VOC/O3 oxidant chemistry]	Continental air quality: GEM-MACH 8 km [aerosols: 2 size bins,8 chemical species; NOx/VOC/O3 oxidant chemistry]	Continental air quality: GEM-MACH 8 km [aerosols: 2 size bins,8 chemical species; NOx/VOC/O3 oxidant chemistry]	tbd
(Canada)				GEM-MACH 2.5km [aerosols: 2 size bins,8 chemical species; NOx/VOC/O3 oxidant chemistry] - 1 window	GEM-MACH 2.5km [aerosols: 2 size bins,8 chemical species; NOx/VOC/O3 oxidant chemistry] - 1 window	tbd
CPTEC/INPE (Brazil)	25 km volcanic ash and sulfates, soil dust, black carbon, anthopogenic and sea salt aerosols and gas phase chemistry with RELACS chemical mechanism. Domain cover: South America	15 km volcanic ash and sulfates, soil dust, black carbon, anthopogenic and sea salt aerosols and gas phase chemistry with RELACS chemical mechanism. Domain cover: South America	15 km using Matrix aerosol module and gas phase chemistry with RELACS chemical mechanism. Domain cover: South America	tbd	tbd	
JMA (Japan)	tbd	tbd	tbd	tbd	tbd	tbd
CMA (China)	tbd	tbd	tbd	tbd	tbd	
KMA (Korea)	tbd					
NCMRWF (India	tbd					
BoM (Australia)	tbd	tbd				