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REPORT OF THE TWENTY SECOND SESSION OF THE CAS/JSC WORKING GROUP ON NUMERICAL EXPERIMENTATION

(National Centre for Atmospheric Research, Boulder, USA, 25-27 October 2006)

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The twenty-second session of the CAS/JSC Working Group on Numerical Experimentation (WGNE), was kindly hosted by National Centre for Atmospheric Research, Boulder, USA, 25-27 October 2006. The session was opened at 0900 hours on 25 October by the Chair of WGNE, Dr M. Miller. There was ajoint session with the WCRP Modelling Panel (WMP) on 24 October. The list of participants in the session is given in the Appendix A.

Dr D.Williamson, the local host and former member of WGNE, welcomed the participants on behalf of Dr T. Kileen, Director, NCAR. On behalf of all participants, Dr Miller expressed his thanks to Dr Kileen, and Dr Williamson for hosting this session of WGNE and the excellent arrangements made. He expressed his appreciation also to the staff of National Centre for Atmospheric Research, for the efforts and time they had put into the organization of the session.

The Chair continued by extending his greetings to the participants in the session. He welcomed Dr M. Beland, President, Commission for Atmospheric Science (CAS). The Chair was pleased to welcome the invited experts.

ROLE OF WGNE IN SUPPORT OF WCRP AND CAS

WGNE, as a joint working group of the JSC and CAS, has the basic responsibility of fostering the development of atmospheric models for use in weather prediction and climate studies on all space and timescales. In the WCRP, WGNE is at the core of the global modelling effort and co-ordination between WGNE, WGCM and WGSIP is maintained primarily through ex officio meeting attendances. WGNE also works in close conjunction with the WCRP Global Energy and Water Cycle Experiment (GEWEX) particularly in the development of atmospheric model parametrizations, with WGNE sessions held jointly with the GMPP (but not in 2006). The WGNE Chair is a member of WMP, with WGNE represented on WOAP also. WGNE also has specific THORPEX sessions at its meetings. The close relationship that exists between WGNE and operational (NWP) centres underpins many of the activities of WGNE, and it is the work of these centres that provides much of the impetus for the development and refinement of the physics and dynamics of atmospheric models.

1. RELEVANT RECOMMENDATIONS FOR THE DEVELOPMENT OF WGNE/GMPP ACTIVITIES

1.1 Twenty-seventh session of the Joint Scientific Committee (JSC) of the WCRP

V. Satyan briefed the session on the relevant main recommendations from the twenty-seventh session of the JSC, Pune, India, 6-11 March 2006:

- JSC appreciated the continued progress by WGNE and reiterated its support to the Systematic Errors Workshop planned for February 2007 in San Francisco, USA.
- JSC strongly endorsed the WGNE/GCSS proposal on a coordinated effort on convection (and associated physics). JSC observed that convection is central to many problems in current modelling efforts on almost all space and time scales and that it cuts across most WCRP groups. As a next step, JSC suggested that a small group consisting of Chair of WGNE, Co Chairs of WGCM and Dr.T.Palmer should discuss this proposal.
- JSC supported WGNE's proposal to strengthen membership in ensemble prediction and /or coupled modelling.
- JSC expressed the view that the CLIVAR and GEWEX monsoon panels should work more closely together. CLIVAR and GEWEX (with SPARC and CliC) should establish focal points (with a JSC Representative) to define how to bring the monsoon studies into a more coordinated program for discussion at next JSC. WMP should coordinate the modelling parts of the two projects together with SPARC and CEOP. JSC strongly supported WGNE and THORPEX participation in these activities, particularly in the focus on the diurnal cycle.
- JSC urged CliC to take steps to provide inputs to modelling groups with a view to improving collaborations and the transfer of new modules to WGCM, WGNE, WGSIP, WMP and TFSP.
- JSC supported joint meeting of WGSF with WGNE on SURFA in Boulder (October 2006) and the joint meeting of WGSF representatives with SOLAS in Heidelberg (September 2006).

1.2 First session of the WCRP observations and assimilation Panel (WOAP)

A.Lorenc, WGNE representative on WOAP, reported on the WOAP meeting in Ispra, 28-30 August 2006. A summary is available from http://copes.ipsl.jussieu.fr/Organization/COPESStructure/WGOA.htmlhttp://copes.ipsl.jussieu.fr/Organization/COPESStructure/WGOA.html

WOAP hopes that there will be increased attention on coupled data assimilation for climate studies in future, and requested WGNE's help in promoting this.

1.3 Report on the WGSIP meeting, 2006

M.Deque, WGNE representative on WGSIP, reported on a recent WGSIP meeting. The last WGSIP meeting took place in Wellington (NZ) in February 2006. A call for participation in the international reforecasting experiment has been sent by WCRP in summer 2006. The meeting to present the first results will take place in Barcelona in June 2007. There will be a WGNE presentation at this meeting with the results of the San Francisco meeting on Systematic Errors (M. Déqué and possibly T. Stockdale). The participation of seasonal forecast modellers in the Pacific cross-section intercomparison is encouraged by WGSIP.

1.4 Relevant Activities under Commission for Atmospheric Sciences (CAS)

M. Beland, the CAS President, made a presentation on CAS activities relevant to WGNE, including major outcomes of the Fourteenth Session of the WMO Commission for Atmospheric Sciences (CAS-XIV) held in Cape Town, South Africa, from 16 to 24 February 2006, and the major activities of WWRP-THORPEX in 2005/2006 as well as those related to research on nowcasting, mesoscale weather forecasting, tropical meteorology, verification and societal and economic applications of weather prediction, and WMO Sand and Dust Storm Early Warning System. The presentation was entitled "Improved High Impact Weather and Air Quality Forecasts, through Globally Coordinated Research: WMO WWRP-THORPEX".

In particular, the Group was informed that new Terms of Reference of the CAS identified main priorities in the implementation of Atmospheric Research and Environment Programme, which are GAW and the WWRP including THORPEX, with emphasis on the connection to climate research activities. The CAS-XIV adopted a new working structure and established two Open Programme Area Groups (OPAGs) on: (a) World Weather Research Programme (WWRP); and (b) Environmental Pollution and Atmospheric Chemistry (EPAC). It identified the main elements of the work programme within each OPAG and established working bodies.

The Group was particularly pleased with the progress made towards the development of the WWRP-THORPEX Interactive Grand Global Ensemble (TIGGE), which is a prototype for a multi-model ensemble forecast system that would guide the development of a possible Global Interactive Forecasting System (GIFS). In its first phase, TIGGE would provide to all WMO Members near-real-time access to ensemble forecast products for research purposes.

2. STUDIES AND COMPARISONS OF ATMOSPHERIC MODEL SIMULATIONS

2.1 General Model Intercomparisons

Model inter-comparison exercises are a key element in meeting a basic WGNE objective of identifying errors in atmospheric models, appreciating their causes and reducing or eliminating these errors.

Atmospheric Model Intercomparison Project (AMIP)

The Atmospheric Model Intercomparison Project (AMIP), conducted by the Programme for Climate Model Diagnosis and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory, USA, with the support of the US Department of Energy has been the most important and far-reaching of the WGNE-sponsored intercomparisons.

P. Gleckler briefed the session on the developments at PCMDI. Regular updates of the overall status of AMIP, model integrations, diagnostic subprojects are posted on the AMIP home page http://www-pcmdi.llnl.gov/amip. Current priorities at PCMDI included evaluation of coupled models including WCRP Benchmark Intercomparisons CMIP, AMIP2, CAPT/Transpose AMIP, Climate Change Detection, and software development.

WGNE congratulated PCMDI for continuing to maintain and enhance a valuable infrastructure for processing model outputs at PCMDI and establishing efficient data formats etc for such exchanges of model simulations. The recent outstanding achievements in the context of the IPCC/AR4 are of particular note.

PCMDI has offered to receive high resolution NWP AMIP-type runs to complement their ongoing CMIP activities.

Systematic Errors Workshop

PCMDI is the local host for a pan-WCRP/CAS workshop on Model systematic errors in February 2007. This is being organized by PCMDI and WGNE with input from WGCM and GMPP, and the programme is structured by timescales to emphasis the 'seamlessness' of many model errors. See Appendix D for a report on the workshop.

Aqua-Planet Experiments (APE)

D.Williamson presented the report. WGNE continues to endorse the application of atmospheric models to very simplified surface conditions for the purpose of examining the behaviour of physical parameterizations and the interactions of parameterizations with the dynamical cores. In particular, "aqua-planet" experiments with a basic sea surface temperature distribution offer a useful vehicle in this regard. Thus one WGNE project is an intercomparison, the Aqua-Planet Experiment (APE), being led by staff from the University of Reading, NCAR and PCMDI. The details of the experiment are available at http://www.met.reading.ac.uk/~mike/APE

The experiment is designed to provide a benchmark of current model behavior and to stimulate research to understand differences arising from: (1) different models, (2) different subgrid-scale parameterization suites, (3) different dynamical cores, and (4) different methods of coupling model dynamics and parameterizations.

As reported in the twenty-first session of the WGNE, a Workshop was held 20-22 April 2005 at the University of Reading, UK to discuss theresults, summarize current model behaviour and produce a summary of research questions arising from the experiment. Many of the ideas discussed at that workshop appear in the report of the twenty-first session of the WGNE. At the time of the APE workshop most participating groups had completed only the "CONTROL" experiment and the data for many of the other experiments in the intercomparison were not available.

Fourteen groups have now submitted their completed simulations to the APE database at the University of Reading. These data have been quality controlled, with minor problems corrected, and made available to the participating groups. Additional data are being collected to allow the diagnosis of the vertical structures of the primary tropical propagating features in the models. Comparative analysis is now underway. The second and last APE Workshop is planned to be held in Choshi, Chiba, Japan in mid-November 2007. The workshop will review and discuss the diagnostic studies arising from the intercomparison and drafts of papers being prepared. Topics to be discussed at the workshop include:

1. The basic intercomparison diagnostics highlighting areas of agreement and spread between the models. These will cover global budgets, the hydrological cycle, mean state response to the meridional SST profile, etc.

2. The response to zonally asymmetric SST anomalies.

3. Tropical variability including both the diurnal cycle and tropical wave activity.

4. The zonal mean state and meridional transports with comparison with theoretical models.

5. Mid-latitude variability including low frequency modes and storm-track transients.

6. Resolution sensitivity and convergence which has been studied in only a few of the models.

7. Tropical transient features including a diagnosis of the vertical structures of the primary tropical propagating features.

There will also be discussions of possible future directions, such as models coupled to swamp oceans, with aqua planet mirror runs using SST averaged from the swamp runs, to study the role of transients and intra-seasonal variability. But any formal intercomparison will be considered a new project.

"Transpose" AMIP

Transpose AMIP is a WGNE proposal for the intercomparison of weather forecasts made by climate models being led by D. Williamson. The goal of the approach is to obtain the benefits for climate model development and evaluation that have been realized in weather prediction model development by applying climate models to weather forecasts. The goal of the intercomparison is to encourage climate modelling groups to implement this forecast strategy into their development process and to compare the characteristics of current models. The method allows direct comparison of parameterized variables such as clouds and precipitation with observations from field programs. Development of a complete analysis system is not needed. Initial conditions can be obtained from NWP reanalyses. This WGNE initiative was initially prototyped/developed jointly by NCAR and PCMDI and is described in Phillips et al. (2004).

The formal announcement of Transpose AMIP and call for participation has been sent to a subset of the WCRP mailing lists. Six groups have declared their interest in participating. They are the Numerical Prediction Division, Japan Meteorological Agency; Department of Meteorology, Florida State University; the Climate Model Development and Evaluation group of the Hadley Centre; CSIRO, Australia; Experimental Climate Prediction Center, Scripps Institute of Oceanography; and NCAR.

Details of data exchange and schedule are being developed by the participants. The proposal is initially very modest and based on what can be realistically analyzed. It is deliberately limited in order to minimize the initial effort for the participating modelling groups. Past experience has shown that once a group is set up to do forecasts with a climate model, it requires little effort to do additional forecasts. The data to be exchanged can be augmented if others are willing to do the associated analyses. In addition, it is anticipated that future intercomparisons for additional periods and other ARM-type sites will be organized to examine a variety of phenomena.

The proposed forecast periods are ARM IOPs in March 2000 and June/July 1997. 5 day forecasts are to be made daily from 00Z, initialized from ERA40. Data to be collected are RMS and Bias Skill Scores (calculated daily) averaged over each IOP for 850 and 250 mb wind in the tropics and 500 mb height, 850, 500, and 250 mb temperature and mslp in the Northern and Southern Hemispheres. In addition 3-hourly profile data for days 0-5 of each forecast at the ARM SGP site are to be submitted.The requested fields are instantaneous values of temperature, specific humidity, and precipitable water, and 3-hourly averaged values for parameterized heating, parameterized moistening, precipitation, latent heat flux, and sensible heat flux.

The intercomparison analyses will include the types of analyses included in Boyle et al. (2005) and Williamson et al. (2005) that can be performed with the data listed above. It is suggested that modeling groups retain individual parameterization terms for subsequent exchange and analyses as differences between the models are identified and hypotheses are put forward. However, it is also easy and cheap to rerun forecasts to resample.

Any additional groups that are interested in participating should email David Williamson (wmson@ucar.ucar). It is not too late to join the effort.

References:

Phillips, T. J., G. L. Potter, D. L. Williamson, R. T. Cederwall, J. S. Boyle, M. Fiorino, J. J. Hnilo, J. G. Olson, S. Xie, J. J. Yio, 2004: Bull. Amer. Meteor. Soc.,85, 1903-1915.

Boyle, J., D. Williamson, R. Cederwall, M. Fiorino, J. Hnilo, J. Olson, T. Phillips, G. Potter and S. Xie, 2005: JGR, Vol.110, D15S15, doi:10.1029/2004JD005042.

Williamson, D. L., J. Boyle, R. Cederwall, M. Fiorino, J. Hnilo,J. Olson, T. Phillips, G. Potter and S. Xie, 2005: JGR, Vol.110, D15S16, doi:10.1029/2004JD005109.

WGNE was pleased with the progress in the T-AMIP and to learn that the proposal had been sent to climate modelling groups and the model results are expected by March 2007 and reviewed at WGNE-23. WGNE asked its members to encourage participation by several more groups in the experiment.

2.2 Regional Climate Modelling

Proposal for a Regional Climate Modelling Workshop

C. Jones, Project Leader for the Canadian Regional Climate Modelling and Diagnostics Network and Regional Climate Modelling representative on the WGNE and GEWEX Modelling and Prediction Panel (GMPP), reported on a proposal to WMO and WCRP to sponsor a Regional Climate Modelling workshop, targeted to support and expand Regional Climate Modelling activities within developing nations.

In March 2004 WMO and WCRP sponsored a Workshop in Lund, Sweden titled: High-resolution climate modelling: Assessment, added value and applications. This workshop brought together many of the leading scientists in Regional Climate Modelling and explored a number of important issues in the field, including:

(i) Developing methods to better define the added-value offered by the increased resolution of Regional Climate Models (RCMs), relative to forcing Global Climate Models (GCMs).
(ii) Improving the performance of RCMs at the present and planned resolution of these models (~10-50km)
(iii) Identifying and supporting user-applications of RCMs in the fields of climate change impacts and adaptation and extended-range (seasonal) prediction.
(iv) Improving the dialogue between RCM groups and users of RCM results with a view to increasing the practical application of RCMs in the aforementioned fields.

This workshop was highly successful and helped define priority directions for RCM research and application over the following years. One outcome of this workshop was the creation of a WCRP-GEWEX Working Group: The Transferability Working Group. The remit of this group is to encourage the application and evaluation of RCMs in a variety of regions around the globe, with an aim to improve the overall performance and generality of RCMs outside of their native geographical regions.

Following the success of the Lund-2004 RCM meeting, the WGNE recommended that a follow up RCM workshop be organised. Initial discussions have taken place within the RCM community and with WCRP regarding the possible content and participation group of such a follow up workshop. *The views expressed in this* report *should be considered as preliminary in nature and may be modified as discussions with WMO, WCRP, WGNE, GEWEX and the wider RCM community continue.*

WCRP emphasised their wish that a follow-up RCM workshop engaged the existing and potential RCM science and user communities in developing nations. In particular, to investigate ways to support and expand RCM activities in developing nations and better identify and link with potential users of RCM simulations in these countries. This suggestion has received extremely strong support within the RCM community. Based on some preliminary discussions within this community 2 primary themes have been identified for such a follow up workshop:

1. Identify mechanisms by which the RCM science and user community can better support and expand Regional Modelling efforts in developing countries.
   This support should include:

   a. The provision of RCM simulations/predictions over specific developing nation areas to scientists in these countries for local evaluation and assessment.
   b. Practical support to scientists in developing nations to facilitate the use of RCMs directly within those countries, in order to build up a level of self-sufficiency in the field of regional climate modelling. Subsequent to this, ongoing collaboration around the use and development of RCMs should ensue.
   c. Assistance in identifying user groups requiring RCM simulations to support their efforts in regional climate impact assessment and adaptation. Furthermore, to provide practical experience in linking RCM simulations to the requirements of user groups in order to maximise the practical application of these simulations in local decision making.

2. RCM groups, in both developed and developing nations, should collaboratively work to evaluate and improve the performance of RCMs when applied over developing nations (mainly tropical and subtropical land regions) for the present and past climate.

   In doing this increased confidence will be gained in the application of these models for climate change projects and seasonal prediction. This activity fits with the aims of the GEWEX-Transferability Working Group (TWG) and would increase the practical use of research and development work made in the groups contributing to TWG. Furthermore, this activity would increase the critical mass of scientists with experience in running, diagnosing and improving RCMs in developing countries.

The RCM community felt that these 2 overarching goals were equally applicable both to regional climate change and extended-range (seasonal) prediction. Many of the key issues, pertaining to user needs and interaction, as well as model development are clearly common to both applications. Strong support for this workshop has therefore come from RCM scientists engaged in both regional climate modelling and seasonal prediction.

A key element for such a workshop to succeed will be the active participation of a large number of scientists and members of the user community from developing nations. This will require strong financial support. Some preliminary discussions have taken place regarding the possible location and timing of this workshop. The first half of 2008 is suggested as a suitable date, allowing sufficient lead time to secure financial support and identify key persons and groups within developing nations that should be invited to such a workshop. A number of possible venues have also been suggested, with the Abdus Salam International Centre for Theoretical Physics (ICTP) being one centre that has offered to host this workshop. With its mandate to foster advanced research in developing countries, its wide experience in both supporting RCM usage in developing nations and in hosting such workshops, ICTP seems an ideal host and has received strong support in the RCM community.

The workshop proposal was discussed at the WGNE session. Subsequent to the support of this panel, WMO and WCRP, a more detailed plan will be developed in the fall of 2006.

WGNE thanked C.Jones for his presentation. WGNE welcomed the proposal for the follow up RCM Workshop in 2008 and strongly supported it. WGNE observed that the timing of the workshop was interesting as it would enable the scientists from the BARCA/LBA campaign (planned for early 2007) to contribute to the Workshop. WGNE appreciated the good tutorial part planned for the Workshop.

Stretched-Grid Model Intercomparison Project (SGMIP)

The Stretched-Grid Model Intercomparison Project (SGMIP) was presented by M.Deque.The SGMIP targets global atmospheric models with variable horizontal resolution used as an approach to regional climate modeling. It aims at comparing stretched-grid (SG) GCMs using different numerical techniques and producing an ensemble efficient regional downscaling to mesoscales over the US. The four participants are C-CAM from CSIRO (Australia), GEM GCM from RPN (Environment Canada), ARPEGE-climate from Météo-France and GEOS GCM from NASA/GSFC. Recently, the spectral-element CAM-SEAM (Baer, Tribbia, Taylor, Wang) from NCAR-UMD has joined the project.The first phase (SGMIP-1) has been completed in 2005. It consists of 12-year (1987-98) simulations with the SG models. A paper has been published with the results (Fox-Rabinovitz et al., JGR, 2006). The second phase (SGMIP-2) has started in 2006. It consists of 25-year (1979-2003) simulations with improved (i.e. more recent) versions of the SG model and two additional simulation with uniform grids (UG) of the respective models. The first one, intermediate UG, corresponds to the same number of grid points as the SG (~1°). As a consequence intermediate UG and SG have approximately the same computation cost. The second one, fine UG, corresponds to the maximum resolution of the SG (~0.5°). More information is available on the web site of SGMIP: http://essic.umd.edu/~foxrab/sgmip.html .

The preliminary conclusions of SGMIP-2, based on the available data (centralized at UMD) are:

- Comparison of SGMIP-1 and SGMIP-2 ensemble products: both global and regional errors and their maxima vs. observations or reanalyses are smaller for SGMIP-2 than for SGMIP-1
- Comparison of SG vs. intermediate UG ensemble mean GCM: over the U. S. region of interest, SG GCMs have smaller errors, calculated vs. observations or reanalyses, than intermediate UG GCMs; over the globe, both SG-GCMs and intermediate UG-GCMs produce high quality simulations with similar errors; SG-GCM errors are sometimes smaller
- Comparison of SG-GCM vs. Fine UG ensemble products: over the U. S. region of interest, SG GCMs and fine UG GCMs have similar errors vs. observations or reanalyses (sometimes SG better than UG). Over the globe, SG GCM and fine UG GCMs simulations are rather close, although the latter produce more mesoscale patterns outside the area of interest

The plans for the next phase (SGMIP-3) are to extend the SGMIP-2 protocol to future climate simulations and to compare the model responses on global scale to IPCC results from other GCMs and on the US to NARCCAP regional scenario. SGMIP-3 may be extended to other regions (e. g. Europe).

2.3 Physical Parametrizations in Models

WGNE's close working relationship with GMPP (the GEWEX modelling and prediction panel), provides the focus for the development, refinement and evaluation of atmospheric model parametrizations, notably those of cloud and radiation, land surface processes and soil moisture, and the atmospheric boundary layer. WGNE reiterated the value of the interaction with GMPP for parametrization work, particularly with GCSS. A joint WGNE/GCSS model intercomparison study of a Pacific cross section (GPCI) to evaluate physical parametrizations along the atmospheric cross section following the trade winds is in progress, with excellent support from both NWP and climate modeling groups. The need for an expert group on parametrization to advise both WCRP and WWRP (and their Working Groups) was discussed, and further consideration will be given to this in consultation with the GMPP.

2.4 Overview of SURFA and WGSF

SURface Flux Analysis (SURFA) project will evaluate and inter-compare global surface flux products (over ocean and land) from the operational products of a number of the main NWP centres and this will provide a good opportunity for estimating and determining the quality of model surface fluxes, of considerable relevance to atmospheric and coupled modelling communities and oceanographers.

There was a joint session at WGNE-22 with the WCRP Working Group on Surface Fluxes (WGSF). Representatives of the WGSF (C.Fairall, E.C.Kent, A.Bentamy, and H.Zhang) gave a series of talks at the WGNE meeting in Boulder to put SURFA into context. The purpose was to devejop a new proposal to initiate the SURFA project with an archive at NOAA National Climate Data Center (NCDC).

SURFA was originally conceived in 2000 as a WGNE project to improve NWP and GCM representations of surface fluxes by archiving operational NWP flux products and high-quality *in situ* observations for subsequent intercomparison and analysis. After the WGSF was formed in 2004, B. Weller and P.Gleckler led the initial discussions on SURFA held at the first WGSF meeting in Halifax. Progress continued in late 2005 and early 2006 with a dialogue between C.Fairall (WGSF chair) and M. Miller (WGNE chair). It was agreed that the WGSF would attend the WGNE meeting in Boulder and present a plan for SURFA. SURFA was the main topic of discussions at the second WGSF meeting (held in Heidelberg, Germany, in September 2006). Following Heidelberg, the WG approached NOAA NCDC about serving as the SURFA archive and they agreed.

At the WGNE meeting in Boulder WGSF members made three presentations (Fairall – background; E. Kent – in situ comparisons with NWP; Bentamy – satellite fluxes and NWP). Huai-Min Zhang of NCDC made a presentation on NWP and climate archiving activities at NCDC (including the new NOMAD system). The remainder of the afternoon was devoted to discussions of NWP variables to archive, grids, time resolution, and other related details, possibilities of sources of *in situ* data, and software within the NOMAD system for easy access to the data archives (in the interest of promoting research on SURFA issues). The WGSF talks are available at ftp://ftp.etl.noaa.gov/user/cfairall/wcrp_wgsf/surfa/WGNE_06_Boulder

The results of the meeting are as follows:

- A proposed list of NWP variables is available for comment.(Appendix E)
- It was agreed that the data frequency should be 3 hourly as this is the requirement for the study of diurnal cycle.
- A strategy was developed to initially begin archiving NWP flux products from NCEP and ECMWF as a pilot study of about one year duration to evaluate and streamline the process. After the initial problems are worked out, NCDC will begin accepting data from other NWP centers.
- D.Majeweski was appointed WGNE point of contact to arrange for archiving with the NWP centers. The WGSF will coordinate archiving the *in situ* data. See Appendix F for the list of variables for the SURFA project.
- Huai-Min Zhang returned to NCDC and began to investigate arrangements to set up the archive.

While there are still steps remaining before SURFA becomes a useful reality, it has been agreed to revitalize SURFA, and an agreed set of NWP fields etc will be routinely archived at the National Climate Data Centre from a number of NWP Centres in due course. WGNE was pleased to note that NCDC has kindly agreed to archive the flux data and expressed its thanks.

2.5 Plans or Results from National Climate or Global Change Modelling Programmes

WGNE noted with interest reports of developments in climate modelling activities in Australia, Germany, Japan and USA.

Australia

K. Puri reported on the developments in climate modelling activities in Australia. The Australian Community Climate and Earth System Simulator (ACCESS) is a coupled climate and earth system simulator to be developed as a joint initiative of the Bureau of Meteorology and CSIRO in cooperation with the university community in Australia.

Over the past year a Blueprint and Project Plan for ACCESS have been prepared that define the scope and components of ACCESS. A Science Advisory Group (SAG), whose main function is to provide support to the Science Leader by providing scientific advice on the development and implementation of ACCESS, including recommendations on priorities and options, has been formed and meets once a month.

The key recommendations in the ACCESS Project Plan submitted in September 2005 that involved significant changes in the modelling activities at the Bureau and CSIRO were:

1. *ACCESS should import the Met Office atmospheric model HadGAM1 to provide the initial atmospheric model for ACCESS;*
2. *The Met Office 4DVAR scheme should be imported to form the atmospheric data assimilation module in ACCESS.*

The Met Office model and the associated data assimilation system, together with components developed at the Bureau and CSIRO, offer considerable advantages for applications to both weather prediction and climate change. Recommendations for other components of ACCESS such as the ocean and land-surface/carbon cycle models were to use locally developed systems (the ocean model is based on the GFDL MOM-4 models). These recommendations were supported at a Workshop held in November 2005 and subsequently by the Steering Committee (SC).

Significant progress has been made in the implementation of the UM and a number of applications have been successfully executed in the ACCESS environment. These include (i) daily global and limited area runs of UM from downloaded Met Office global analyses; (ii) successful full forecast/assimilation cycle from Bureau data base using the ECMWF Observation Data Base (ODB); (iii) a 3-month run with the climate version of the model and plans for an AMIP-type climate run; (iv) ability to build and run locally a single column version of the model. Although initial development of the ACCESS infrastructure has been aimed at implementing key ACCESS modules on the Bureau/CSIRO High Performance Computing and Communication Centre (HPCCC) computing environment it is recognized that ACCESS will be used by a wide group of researchers spread around Australia and the infrastructure will have to enable this.

ACCESS has the potential to become one of the biggest environmental initiatives in Australia. Significant progress has been made over the past six months. ACCESS will aim to build on this progress as more resources become available in order to meet the timelines for the various applications, and in an attempt to satisfy one of its key objectives, namely to develop a ‘world class’ modelling system.

Germany

D. Majewski reported on the joint development project ICON (Icosahedral Non-hydrostatic) of the DWD and Max Planck Institute for Meteorology (MPI-Met, which is the German Climate research centre). The goal of the ICON project is the development of a new global weather forecast and climate simulation model on the icosahedral-hexagonal grid and solving the fully compressible non-hydrostatic equations with a local zooming option. A shallow water prototype on a triangular C-grid where mass is defined at the centre of the triangles and normal wind components at the midpoints of the triangle edges underwent successfully the Williamson test suite. A 3D hydrostatic model version replacing the spectral dynamical core of the ECHAM5 climate model by the new grid point approach is being developed at MPI-Met as well as a 3D ocean version on the triangular grid. In 2007 work will begin on the 3D non-hydrostatic core based on the fully compressible Euler equations.

Japan

Y. Takeuchi reviewed some research projects on atmospheric-ocean study with Earth Simulator (ES) and the activities of Meteorological Research Institute (MRI) of JMA and Frontier Research Center for Global Change (FRCGC). MRI carried out: (i) global warming experiments with TL959 (20km) JMA-GSM for IPCC using time slice experiments and (ii) regional climate modeling for global warming climate with the JMA Non-hydrostatic Model (NHM) with resolutions of 1-5km. The 20km JMA-GSM is also a prototype of the next generation operational NWP model being developed by the Numerical Prediction Division (NPD/JMA) and is used to assess the effects of global warming on typhoons and Asia monsoon, while 5km JMA-NHM is used to assess the effects of global warming on heavy rains and it has been used as the operational NWP model (named as MSM) since March 2006. Takeuchi showed some simulation results such as rainfall amount related to Baiu front in future climate with regional cloud resolving model with 1km resolution.

FRCGC has been investigating global cloud resolving simulations using the Non-hydrostatic ICosahedral Atmospheric Model (NICAM) under a project named “A medium-range research project on global cloud resolving model simulations toward numerical weather forecasting in the tropics” for the period of October 2005 to March 2011.

Takeuchi briefly introduced the development and application of next-generation supercomputer project planned by MEXT (Ministry of Education, Culture, Sports, Science and Technology). Supercomputer was specified as “Key Technologies of National Importance” in Japan’s “3rd Science and Technology Basic Plan (JFY2006-JFY2010)” launched in April 2006. Of six goals of the Basic Plan two goals namely “Sustainable Development” and “Safe and Secure Nation” are related to simulation of climate change and natural disaster with very high resolution model. In January 2006 RIKEN Next Generation Supercomputer R & D Center (NSC) was established and the project organization started in August 2006.

USA

R. Rosen reported on NOAA’s plans for global change modeling and the steps it is taking toward developing a unified modeling framework for climate and weather analysis and prediction. He described ongoing plans at the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) to create an Earth System Model (ESM), which by early 2009 is expected to include interactive atmospheric chemistry, improved treatment of convection, a medium resolution ocean component with biogeochemistry, and a land component with dynamic vegetation and vertically-resolved soil hydrology. Rosen highlighted a roadmap for the future development of the ESM at GFDL, based on the adoption of an Earth System Modeling Framework (ESMF). ESMF provides an infrastructure to enable model advances at research institutions like GFDL and NCAR to be readily transferred to operational use at the NOAA National Centers for Environmental Prediction (NCEP). NCEP is adopting ESMF and anticipates linking its various operational components to this framework.

2.6 Climate Model Metrics

WGNE has been involved in developing standard climate model diagnostics and metrics for some years. The goal of such metrics is to objectively measure model quality or skill and suitable metrics depend on the intended applications. The application for climate models includes the prediction of future climates for which no verification data will be available within the lifetime of the model. WGNE discussed the issue of climate model metrics at some length with many questions and issues resulting. A sub group with a member from each of PCMDI, WGCM, WGNE, GMPP and the JWGV (Joint Working Group on Verification) will define the climate model metrics and standard verification data sets with the intention of asking WCRP to encourage usage of these metrics for climate models. It was decided to ensure some emphasis on climate model metrics at the February 2007 model systematic errors workshop.

The need for good metrics for climate-type models is under discussion. WGNE will discuss this further also in the context of the new ‘unified’ prediction systems.

K. Taylor provided a perspective concerning the use of metrics in the evaluation of climate models. WGNE's longstanding practice of monitoring and comparing model skill in forecasting weather has convinced it of the benefits of using metrics to promote objective evaluation of model simulations. Historically, they have advocated the routine production of standard diagnostic products when new versions of climate models are proposed. In contrast to the abundant opportunities for verification of weather forecasts, climate simulations can only be assessed against a single set of observations, taken over recent decades. For this reason, metrics devised to measure the skill of weather forecast models do not easily transfer to climate models.

Metrics can be devised that focus on specific fields, specific time and space scales, and specific phenomena or processes. From this "basket" of metrics, one could select the ones that might have the most relevance to a specific application. Examples were given showing that climate metrics can be used to 1) monitor changes in performance as models evolve, 2) quantify the relative merits of different models, 3) aid model development and selection of a new model version, and 4) weight predictions from individual models to form a more accurate consensus climate prediction.

It was stressed that a single metric has limitations in that it focuses only a single aspect of model performance. Even with a collection of metrics, care must be exercised in interpretation. For example, very little is really known about the relationship between model skill in simulating present (observed) climate and its ability to predict future changes. Without rigorous scientific justification, it would be premature to rely on some index of model performance (perhaps based on a collection metrics). Although there is active research ongoing in this area, the view was expressed that this does not yet justify using metrics as a quantitative measure of confidence in future projections.

The WCRP's interest in metrics is evident from WGNE's recent discussion concerning an ad-hoc panel to encourage research in this area and work toward a set of standard metrics for evaluating climate models. The GCSS is also working to establish a set of metrics useful for evaluating cloud and precipitation processes in climate models. Finally, the WCRP CMIP3 multi-model dataset has fostered metric development by those outside the climate modeling research centers. The Systematic Errors Workshop planned for February 2007 promises to lead to even further interest in this area.

3. DATA ASSIMILATION AND ANALYSIS

3.1 Reanalysis Activities

The WCRP is a strong advocate of multi-year reanalyses of the atmospheric circulation with state-of-the-art assimilation/analysis schemes. WGNE was briefed about progress in reanalysis projects from ECMWF and JMA.

ECMWF

M.Miller presented the work on reanalysis at ECMWF. Reanalysis activities have been concentrated on finalising the data-assimilation system, including the monitoring environment, for the ERA-Interim reanalysis. The system will provide a major upgrade of ERA-40 from 1989 onwards and will address the main deficiencies of ERA-40 for this period. Adaptive bias correction techniques will, for the first time in the reanalysis context, be used for satellite radiances. ERA-Interim will be continued in near-real time as a Climate Data Assimilation System. It will be an evolutionary step between ERA-40 and the next major ECMWF reanalysis.

A preliminary ERA-Interim reanalysis run was started, as planned, in December 2005 using T255L60 model resolution and 12 hour 4D-Var. Results showed substantial improvements over ERA-40, consistent with earlier experiments. The assimilation was continued until February 1991. The reanalysis system has now been upgraded to IFS cycle 31r1, and ERA-Interim has been restarted from 1989.

Configuration of the ERA-Interim data assimilation system

The ERA-Interim system uses IFS Cycle 31r1, with model resolution T255L60. In addition to the increased spatial resolution and improvements in the model physics, the main differences with respect to ERA-40 are:

- use of 4D-Var with a 12-hour time window (instead of 6-hourly 3D-Var FGAT)
- complete reformulation of the humidity analysis
- rain assimilation using 1D retrievals of rain-affected SSM/I radiances
- adaptive bias correction of all directly assimilated radiance data
- adaptive bias correction of SHIP and SYNOP surface pressure data
- use of a homogenised radiosonde temperature dataset and improved bias correction tables
- use of reprocessed Meteosat winds

The general quality of the new analyses has been assessed through validating medium-range forecasts run from them. These show a substantial improvement of the preliminary ERA-Interim analyses over ERA-40, which in turn showed improvements over ERA-15 and ECMWF operations for 1989 and 1990.

Japan Meteorological Agency (JMA)

Y. Takeuchi presented the progress in the reanalysis activities in Japan. The Japanese 25-year Reanalysis Project (JRA-25) is the five-year joint project of JMA and Central Research Institute of Electric Power Industry (CRIEPI) from 2001 to 2005. The calculation was completed in spring 2006 and the products have already released. JRA-25 has been handed over to JMA CDAS after 2005.

Positive features of JRA-25 against ERA-40 and NCEP reanalysis, include 1) better performance of 6-hour precipitation due to better use of SSM/I data and TOVS data, 2) better performance of low level cloud along subtropical western coasts, 3) better tropical cyclone analysis by using Fiorino’s TC wind data, 4) better snow analysis by using SSM/I snow data and Chinese surface snow data, and 5) better meridional circulation such as Hadley circulation and B-D circulation. On the other hand, some negative features such as temperature bias in the stratosphere due to model bias in the analysis and unstable ozone density due to the lack of TOMS data from May 1993 to July 1996. An experimental hindcast for the period from 1979 to 2004 shows the forecast score based on JRA-25 is much better than that of operational forecast of that time.

The JRA-25 official data from 1979 to 2004 are released in July 2006 followed by release of the single variable and single level data in September 2006. The data are available only for research use and the user can download the data via internet from a server at JMA with a simple registration. The details are described at JRA-25 official page http://jra.kishou.go.jp/index_en.html.

Takeuchi announced that the 3rd WCRP Conference on Reanalysis sponsored by WCRP, JMA and CRIEPI will be held in Tokyo from 28 January to 1 February 2008.

WGNE reiterated its strong support for the reanalysis work, the desirability of maintaining a core of experts without excessive duplication of effort and ensuring efficient phasing of these efforts.

3.2 Earth System assimilation

The new developments in the assimilation of parameters pertinent to the Earth System but not routinely analysed by current data assimilation systems are being monitored by WGNE. These include analyses of greenhouse gases, aerosols and reactive gases. Earth system assimilation such as the GEMS (Global and regional Earth-system Monitoring using Satellite and in-situ data) project will increasingly demand cross-project liaison within WCRP and CAS.

3.3 Observing System Requirements

A. Lorenc reviewed activities to determine observing system requirements and suggested that the following areas are lacking: formal consideration of relative value of observations & computers, at the high levels which fund both; observation evaluation techniques which properly value calibration & lack of bias; understanding of requirements for short-period high-resolution NWP.

4. NUMERICAL WEATHER PREDICTION TOPICS

4.1 THORPEX

THORPEX is developed and implemented as a part of the WMO World Weather Research Programme (WWRP). The international co-ordination for THORPEX has been established under the auspices of the WMO Commission for Atmospheric Science (CAS) through its Science Steering Committee for the WWRP and WGNE. The THORPEX International Science Steering Committee (ISSC) establishes the core research objectives with guidance from the THORPEX International Core Steering Committee (ICSC) whose members are nominated by Permanent representatives of countries with the WMO.

At the WGNE meeting there was a session devoted to THORPEX, which reviewed the status and plans of THORPEX and the wide-ranging opportunities for collaboration and synergy with WCRP and other bodies. The plans for the THORPEX Pacific Asian Regional Campaign (T-PARC) were of particular note, and this ‘campaign’ promises to make a major contribution to our understanding of meteorology in the Pacific basin.

The use of ensemble methods now forms a cornerstone of forecasting on all timescales, and WGNE hoped that the rapidly progressing THORPEX Interactive Grand Global Ensemble (TIGGE) project will help accelerate the effective use of ensemble forecasting information.

Presentaions at the session included (i) General report on THORPEX: including TIGGE, IPY and other WG meetings by D. Burridge and Y. Takeuchi, (ii) THORPEX Pacific-Asia Regional Campaign by D. Parsons, (iii) THORPEX and WCRP by G. Brunet, and (iv) THORPEX Regional plans by D. Burridge and K. Puri.

THORPEX PACIFIC-ASIA Regional Campaign

WGNE welcomed the proposed T-PARC campaign by THORPEX and agreed with THORPEX that it is a major experiment planned by the THORPEX community. To THORPEX this experiment is very important as its success would underpin support for THORPEX for the next 5 years. THORPEX requested the Director of NCAR to help ensure NSF support to T-PARC. WGNE queried if there are any plans for reanalysis for the T-PARC period and suggested this should be considered now and not after the campaign.

THORPEX Regional Plans

Y.Takeuchi presented the TIGGE related activities in Japan.JMA is planning to host a THORPEX verification web site the design of which is the same as the WMO/GDPFS EPS verification site at JMA. The WMO/GDPFS EPS verification site is operated by JMA as the lead centre for verification of EPS under the CBS framework. Each NWP centre participating in TIGGE as a data provider will be requested to send JMA the verification measures defined at the Attachment II.7, Table F, Section III of the Manual on the GDPFS <http://www.wmo.int/web/www/DPS/ Manual _GDPFS.html>.

WGNE discussed the importance of cloud physics research and providing these inputs to WWRP. The relevance of this topic to WGNE is obvious. The WGNE-GCSS link provides WWRP the link to cloud physics. Of late, with the WGNE-GMPP joint sessions being held in alternate years, this has not been adequate.WGNE would work more closely with GCSS to provide the inputs to WWRP-THORPEX. THORPEX with its present concern to address the ‘’second week forecast’’ problem would like to work closely with the GCSS through WGNE. WGNE would appreciate additional support from WWRP to reestablish annual joint meetings with GMPP in this regard.

4.2 THORPEX and WCRP

THORPEX/WCRP White Paper1

G. Brunet gave an overview of the THORPEX/WCRP White Paper1 entitled: A Collaborative Effort between the WMO Programs THORPEX and WCRP.The international THORPEX and WCRP communities both have the obligation to help the development of relevant scientific knowledge and a science infrastructure to provide policy- and decision-makers

- More accurate, and from a socio-economic prospective more useful, prediction of high-impact weather and environmental events.
- Information needed for the reduction of emerging and existing global and regional social, economic and environmental vulnerabilities caused by the combined effects of a changing environment and increasing economic development.

As the appreciation of the complexity of the underlying science issues grows, investigations not only must become more and more multidisciplinary in nature, necessitating a more holistic and team approach to modeling of the Earth System, but also will require a concerted international effort. Climate, air quality, water, environmental and weather modeling and prediction systems will become more integrated, move to increasingly finer space-time scales, and rely on complex systems for blending information from observations and models. There will be a tremendous increase in the variety and quality of environmental data, and in the variety and scope of weather and environmental predictions on scales from minutes to decades and beyond, as well as a broadening of prediction paradigms (deterministic as well as probabilistic). These changes will greatly enhance the capacity to meet a range of prediction challenges to increase safety and security, regionally and globally, and to provide information in support of the development of policies and services by better adapting to the constantly changing environment. As these weather and climate science issues become more global and complex, they cannot be addressed in isolation. An international and multi-disciplinary research program is essential.

A white paper (G. Brunet, Environment Canada; B. Hoskins, University of Reading; R. Morss, NCAR, J. Slingo, University of Reading; I. Szunyogh, University of Maryland; D. Waliser, NASA) is prepared in consultation with the international community for the next WMO conference of the Commission for Atmospheric Science. The white paper will propose specific means of collaboration between THORPEX and WCRP to achieve the following main scientific objectives:

- o Global climate simulations that correctly represent the variability associated with transient weather events, such as tropical and extra-tropical cyclones.
- o Extended range weather predictions that take advantage of the assumed predictability (e.g., MJO) in the intra-seasonal (10- to 90-days) forecast range.

The proposed collaboration is timely because of the unprecedented advances of the last few decades in High Performance Computing (HPC), high-speed telecommunication, ground-, space- and aircraft-based measurement technologies, systematic observations, remote sensing, field and laboratory process studies, data assimilation techniques, and in highly performing coupled numerical models of weather and climate prediction. Weather and climate research has produced numerical prediction and data assimilation systems that can efficiently exploit these technological improvements. The challenge today is to further improve the existing forecast and diagnostic products, to increase their economic and societal values and to broaden their suite of applications through the development of a seamless prediction process that eliminates the long existing separation of the weather and climate forecast processes.

The white paper will then introduce a series of high priority THORPEX/WCRP collaborative issues on numerical prediction and modelling, data assimilation and observational requirements from weeks to seasons. More specifically, they are:

1. Organization and maintenance of tropical convection (Madden-Julian Oscillation, intra-seasonal variability of monsoons, equatorial waves ...)
2. Tropical-extratropical interaction (Rossby wave train, extra-tropical transition, cold frontal/winter monsoon surge …)
3. Seamless prediction with multi-model ensembles (TFSP, TIGGE …)
4. Data assimilation as a prediction and validation tool for the climate and weather research communities (SPARC …), and a design tool for observation networks (GEO …)
5. High-impact weather in observations and models (including Regional Climate Models)
6. Societal and Economical Research Applications (SERA)

4.3 PAN-WCRP YEAR of Tropical Convection in the THORPEX context

A Year of Tropical Convection (YOTC)

D. Waliser presented an overview of the proposal for ‘A Year of Tropical Convection’ (YOTC). WCRP and THORPEX are proposing a Year of coordinated observing, modeling and forecasting of organized tropical convection and its influences on predictability as a contribution to the United Nations Year of Planet Earth to compliment the International Polar Year (IPY). This effort is intended to exploit the vast amounts of existing and emerging observations and computational resources in conjunction with the development of new, high-resolution modeling frameworks, with the objective of advancing the characterization, diagnosis, modelling and prediction of multi-scale convective/dynamic interactions and processes, including the two-way interaction between tropical and extra-tropical weather/climate. This activity and its ultimate success will be based on the coordination of a wide range of ongoing and planned international programmatic activities (e.g., GEWEX/CEOP, THORPEX/TIGGE, EOS, GOOS). It seeks to leverage the most benefit from recent investments in Earth Science infrastructure. The significant data gathering, archiving and dissemination challenges associated with the vast amounts of satellite data, disparate in-situ data sets and high-resolution model output require the breadth and functionality of the data services anticipated to come from the new WMO Information System (WIS), and thus we propose this activity as one of its initial projects.

WGNE discussed the proposal for YOTC which, as currently envisaged, is aiming to assemble a dataset that will enable focussed research on many aspects of tropical convection, which in turn should lead to significant/important advances in our NWP abilities on all timescales currently labelled under 'seamless' prediction. The discussions strongly supported the idea but felt that it was less clear how the aims of the YOTC would be achieved. Some concern was also expressed that the proposed timescales were somewhat too tight.

As this YOTC dataset will be a judicious combination of many existing datasets in a variety of forms and repositories, questions were asked as to whether this is an opportunity to harness the powers of the new WMO Information System (WIS), and what was the YOTC relationship to other planned 'global' activities such as IPY and a possible Monsoon' focus. It was suggested that WWRP and WCRP should consider these questions and the efficacy of having a working group and/or a workshop in 2007.

Recognizing that convection is central to many problems in WCRP modelling research on almost all space and time scales, WGNE/GMPP were already jointly considering a high resolution modelling experiment specifically directed towards aiding and accelerating parametrization development. This could be part of a coordinated effort to benefit the entire WCRP community.

WGNE welcomed the proposal by D. Waliser and discussed it at length. WGNE sees merit in the proposal, in its potential to improve monthly weather and seasonal forecasts by addressing the poorly understood MJO and tropical convection phenomena. The proposal aims to achieve this by creating a broader data base on tropical convection. Therefore WGNE strongly supports the proposal. However, the proposal as it stands needs to be strengthened particularly with regard to its implementation, and the modelling component should be highlighted. The final proposal should consider the ongoing/ planned efforts in CEOP, avoid overlaps, and the fact that WMO has admitted this proposal under its WIS.

4.4 Model developments

WGNE noted the substantial improvements in the resolution of global and deep convection permitting forecast models in progress or planned in the next few years. There exists a dichotomy of opinion regarding the use and interpretation of grid-lengths of several kms for forecasting. These resolutions will become affordable for GCM use in the coming years, and the prospect of climate simulations with grids of order one kilometre is an issue of international activity and debate, and WGNE will continue to monitor such developments.

Recent results showing the need for model resolutions of 100 kms or better to properly define the statistics of extra-tropical storm tracks were noted. This contrasts with typical climate model resolutions substantially poorer than this, a matter of serious concern to the group.

WGNE noted that plans for unified (coupled) forecast systems that will provide forecasts from days out to seasons, typically by progressively degrading the resolution with forecast range, will provide new opportunities for ensemble techniques, including initial perturbations, stochastic parametrizations and metrics, and bring even closer collaboration between the NWP and climate communities.

Trends in performances of the models of the main operational forecasting centres

As is usual at its sessions, WGNE reviewed the progress in skill of daily forecasts produced by a number of the main operational centres over the past year as presented by M. Miller. Examples of the twelve-month running means of verification scores (root mean square error against own analyses) for 500 hPa geopotential in the northern and southern hemisphere at lead-times of two, four and six days, are shown respectively in Figures 1 and 2. Virtually all Centres show some continuing improvements

Inter-comparison of Typhoon Track Forecasts

Y. Takeuchi reported on this topic. This model intercomparison was started in 1991 for the western North Pacific area with the participation of ECMWF, UKMO and JMA. CMC, DWD, NCEP, BoM, Météo-France and CMA joined subsequently and the verification area was also expanded to north Atlantic area, eastern north Pacific area, southern hemisphere, northern Indian ocean and central Pacific area. Eight NWP centers except for CMA participated in the 2005 intercomparison.

Many results related to typhoon track forecast including a multi-model ensemble are presented on the web site: http://nwp-verif.kishou.go.jp/wgne_tc/index.html (user id and password are required).

The performance of tropical cyclone track forecasting is measured by forecast error and detection rate. The ECMWF and JMA models show small forecast errors and high detection rates. The UKMO model is characterized by the highest detection rate for all ocean areas. NCEP also shows small forecast errors in North Atlantic area. The trends of typhoon track forecast error by a multi-model ensemble composed of ECMWF, JMA and UKMO for the last 15 years are also shown. Takeuchi remarked that four day forecast with the multi-model ensemble in 2005 reached about 300km in 2005, which is almost the same score as two day forecast in 1995, for western North Pacific area.

The overall gradually improving performance of these models in predicting cyclone tracks over the past few years has been maintained. In future statistics will be gathered to assess the skill in intensity forecasts and forecasts of cyclone genesis.

4.5 Model Verification

With global models attaining much higher resolutions, and mesoscale models being routinely run at most operational centres, consideration is being given to additional skill scores to the conventional ones that are more appropriate for such resolutions. Furthermore there is an increasing requirement to provide measures of model performance for predicting weather elements and severe weather events. The joint WGNE/WWRP working group on verification (JWGC) is now considering this important subject.

There are a number of WGNE projects involved with the validation of forecasts. New developments were discussed including the development of methods to verify high resolution spatial forecasts; verification

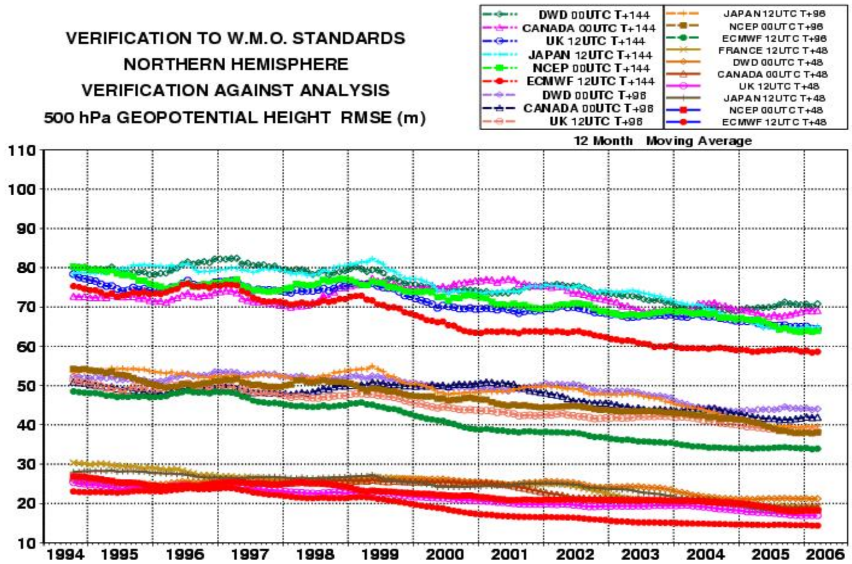

Figure 1.

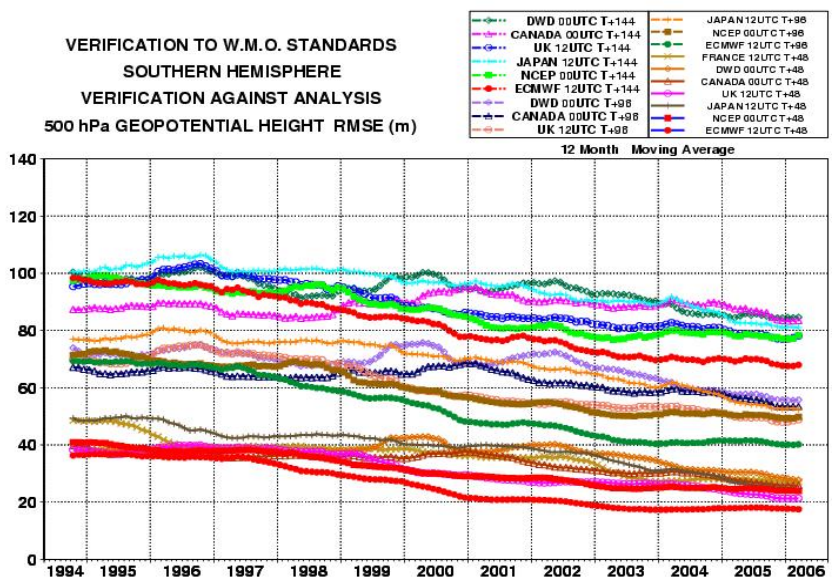

Figure 2.

methods for rare events; incorporation of scaling methods into verification processes; approaches to account for observational uncertainty in verification measures and analyses; development of methods that are customer dependent and appropriate for studies of forecast value; and verification of probability distribution functions.

As Chair, B. Brown reported on the activities of the WWRP/WGNE joint Working Group on Verification (JWGV) during the past year. A number of WGNE projects focus on verification of forecasts from numerical weather prediction (NWP) models. These projects include the compilation of the so-called WMO scores, verification of quantitative precipitation forecasts, evaluation of tropical cyclone tracks and evaluation of stratospheric analyses and forecasts. In addition, the modelling and verification communities have recognized that there is an urgent need to move forward from the traditional measures-based verification methods toward methods that are more diagnostic and represent meaningful forecast performance characteristics. In addition to addressing activities of the JWGV, Brown also described community progress in development of these new methods.

Membership in the JWGV includes F. Atger (Météo-France); H. Brooks (NSSL, USA); B. Brown (Chair; NCAR, Boulder, USA); B. Casati (MSC, Canada); U. Damrath (DWD, Germany); E. Ebert (BMRC, Australia); A. Ghelli (ECMWF, UK); P. Nurmi (FMI, Finland); D. Stephenson (U. Exeter, UK); C. Wilson (UKMO, UK); and L. Wilson (MSC, Canada).

The JWGV held one formal coordination meeting in Boulder, Colorado, USA, in June 2006 in association with the 2nd International Symposium on Quantitative Precipitation Forecasting and Hydrometeorology. This meeting helped facilitate planning for the 3rd International Workshop on Verification Methods, scheduled for 29 January through 2 February 2007 in Reading, U.K. as well as other JWGV activities.

Activities of the JWGV in the past year included participation in specific projects, research on verification methods, education and outreach, and initial investigation of methods for cloud verification that could be applied by WGNE members.

One of the specific projects is the Mesoscale Alpine Project Forecast Demonstration (MAP D-Phase); the JWGV's role in this project has primarily been advisory. In addition, E. Ebert, L. Wilson, and B. Brown continued to serve on the steering committee for the THORPEX Interactive Grand Global Ensemble (TIGGE), and coordinated with the Societal and Economic Research and Applications Program (SERA) for THORPEX. H. Brooks, B. Brown, B. Casati, and L. Wilson also participated in planning for the North American THORPEX SERA program; currently all THORPEX verification activities are contained within the SERA program.

Several members of the JWGV are also closely involved in activities associated with the Forecast and Research Demonstration Projects for the Beijing Olympics (B08FDP and B08RDP, respectively). B. Brown and L. Wilson are both members of the B08 Steering Committee, and E. Ebert and others are developing a Real-Time Forecast Verification (RTFV) system in coordination with the Beijing Meteorological Bureau. The RTFV will primarily be used to evaluate nowcasts provided by the nowcasting systems as part of the B08FDP. This effort will provide an opportunity to demonstrate the use of new verification methods, as well as the use of a real-time verification system. L. Wilson is providing guidance for verification of high-resolution mesoscale ensemble forecasts as part of the B08RDP; verification of the forecasts for this program will primarily be undertaken by the groups providing forecasts and the China Meteorological Administration (CMA). B. Brown participated in the 2nd workshop on the B08 RDP and FDP in late August 2006 and provided guidance on verification activities for both the FDP and RDP.

Recent research on verification methods has led to advances in many areas, including improved methods for evaluation of spatial forecasts, ensemble forecasts and forecasts of extremes, as well as new diagnostic approaches and user-focused verification. Examples include entity- and object-based approaches, "fuzzy" or neighbourhood methods, composite approaches, and methods that apply the statistical theory of extremes. The capabilities of many of these methods are being compared in an intercomparison project that is sponsored by and includes participants from the JWGV (http://www.rap.ucar.edu/projects/icp/index.html; this web site also includes references for many of the new methods).

The JWGV's current outreach activities include continued support for the verification web page (http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/verif_web_page.html) and a verification discussion group. In addition, L. Wilson and P. Nurmi prepared an online tutorial for EUMETCAL (the "European Virtual Organisation for Meteorological Training"). This on-line training course is available at http://www.eumetcal.org/-Learning-Modules-. The 3rd Workshop on Verification Methods will also include a training course for about 30 students. Topics to be covered include basic verification concepts, verification of continuous predictands, verification of categorical predictands, verification of probabilistic forecasts and ensemble forecasts, confidence intervals and hypothesis tests, and forecast value. In addition, the students will work on group projects to be presented at the workshop, making use of a library of verification routines available in the R programming language that was developed by M. Pocernich at NCAR. The tutorial will take place 29-31 January in the training facility at the ECMWF. The workshop, from 31 January through 2 February 2007, will include invited speakers on specific topics (e.g., ensemble forecast verification, spatial forecast verification) as well as many contributed presentations. The workshop and tutorial were advertised widely through the WMO and the home institutions of the JWGV members. In particular, the WMO and JWGV solicited student applications as well as contributed talks. Students from many countries have applied. The workshop and tutorial are being jointly sponsored by the WWRP and WGNE. In addition, COST (European Cooperation in Science and Technical Research) is providing some support for the workshop and tutorial.

Verification of Cloud Forecasts

The JWGV prepared a draft report including initial recommendations of methods to be used for evaluation of cloud forecasts provided by NWP models. This report was requested by WGNE and was presented by B. Brown. Methods suggested in the initial version of the report include use of satellite information and application of entity-based approached for evaluation of spatial coverage of clouds. The JWGV plans to expand and extend this report, incorporating recommendations from WGNE. A new version will be presented at the next WGNE meeting. In addition, the JWGV is interested in supporting any efforts undertaken by WGNE with regard to methods for evaluation of climate predictions.

Verification and Comparison of Precipitation Forecasts at various Centres

This WGNE initiative is being conducted at the DWD, NCEP, BMRC, CMA, JMA, CMC, the Met Office and Meteo-France. Quantitative global precipitation forecasts from the above are being verified against surface stations in these relatively data rich areas (some Centres also include their limited area model forecasts in the verification). A series of scores such as bias, Heike skill score, equitable threat score are used. It was noted that there is clear evidence from several Centres that the skill of precipitation forecasts in mid-latitudes was increasing. Two specific reports are detailed below.

BMRC

K. Puri presented the studies conducted at Bureau of Meteorology Research Centre (BMRC). Based on verification of NWP QPFs over Australia since 1997, it appears that rainfall prediction in the tropics has not significantly improved whereas several models have made gains in QPF accuracy in mid-latitudes. The ECMWF model continues to outperform the other models in making accurate predictions of rain system location.

The Australian QPF verification web site http://www.bom.gov.au/bmrc/wefor/staff/eee/wgne/QPFverif.html has been improved to show verification results for QPF regridded to 1º latitude/longitude resolution (for continuity with earlier results), 0.5 º, and interpolated to the locations of ~1000 rain gauge locations in Australia.

Surprisingly, in the tropics the site-based verification gave better results than the gridded verification, whereas the opposite was true in the mid-latitude domain. Since the distribution of sites in the Australian tropical domain is fairly homogeneous the advantage cannot be explained by sites clustering in an "easier to predict" location. One possibility is that the higher frequency biases of the models when verified against sites actually improved the equitable threat scores compared to verification against gridded analyses. Baldwin and Kain (August 2006 issue of *WAF*) showed that over-prediction of rain area can give improved ETS values if the predicted rain is displaced from where it was observed. Another possibility is that the analysis of mainly convective smaller-scale rain observations onto a 0.25 º grid, followed by averaging onto a coarser grid, led to analysis errors that negatively impacted the verification results. Further investigation must be done to better understand this behavior.

In recent years efforts have focused on development of verification approaches that provide more diagnostic information regarding forecast performance. As an example of this so-called user-focussed verification, "Fuzzy" multi-scale verification rewards closeness by relaxing the requirement for exact matches between forecasts and observations. The key to this approach is the use of a spatial window or neighborhood surrounding the forecast and/or observed points. The treatment of the data within the window may include averaging (upscaling), thresholding, or generation of a PDF, depending on the particular fuzzy method used and its implicit decision model concerning what makes a good forecast. The size of the neighborhood can be varied to provide verification results at multiple scales, thus allowing the user to determine at which scales the forecast has useful skill.

JMA

Y. Takeuchi reported on the intercomparison of precipitation forecasts over Japan. JMA has carried out quantitative precipitation forecast (QPF) verification over Japan under the framework of WGNE. Main purpose of the WGNE-QPF over Japan is verification of the participating model for extra-tropical cyclone, typhoon, summer monsoon, winter monsoon, and thunderstorm in summer. The verification is performed with reference data of high-dense $(17km)^2$ surface raingauge network (AMeDAS) at grid points with the resolution of 80km. BoM, DWD, ECMWF, NCEP, UKMO and JMA are participating in this verification exercise as of December 2006. Takeuchi showed verification results for 3 day QPFs to estimating the total performance. All models have bias characterized by underestimate for heavy rain and overestimate for light rain especially for early summer season. The BoM model shows large decrease of bias score in general compared to the previous year due to a model change. He also showed a case study on heavy rain in Baiu season and remarked some models succeeded in the prediction with a leading time of three days. A web page on WGNE-QPFs verification over Japan has been maintained by JMA for browsing the verification results. Takeuchi encouraged the participation of CMC and MeteoFrance, and asked for higher resolution data from BoM.

4.6 Recent Developments/Activities in Monthly and Seasonal Forecasting.

The ENSEMBLES European project (M. Déqué)

The ENSEMBLES European project includes a research theme on seasonal forecasting. Stream 1 (1991-2001) is complete with seasonal, annual and decadal hindcasts. Four models (6 expected) are already on the MARS database at ECMWF. Different perturbation approaches have been explored to generate ensembles: multimodel, random term in the equations (stochastic physics) and random choice of a few empirical parameters of the model. Stream 2 (1960-2001) is expected to be available in 2008.

MERSEA is another European project containing a task dedicated to seasonal predictability. This task concerns sensitivity of the scores to horizontal resolution. The results show the resolution of the ocean analyses, as well as the resolution of the atmosphere model has little impact on the scores. As far as vertical resolution is concerned, the improvement found with ARPEGE when going from 31 to 91 levels is statistically robust, but not robust to the choice of vertical diffusion.The EUROSIP project associates real time seasonal forecasts from ECMWF, the Met Office and Météo-France to produce 120-member 6-month forecasts. The production system will go to System 3 in 2007 with improvements in the models and size of the reference period.

ECMWF (M. Miller)

On 1 February 2006, the EPS resolution was increased to TL399L62, with T42L62 singular vectors. This change is the first of a three-phase upgrading process that will lead to the implementation of the ECMWF Variable Resolution Ensemble Prediction System (VAREPS):

- Phase 1 (February 2006): resolution increase of the 10-day EPS from TL255L40 to TL399L62
- Phase 2 (planned for late 2006): extension of the forecast range to 15 days using the VAREPS system, with TL399L62(d0-10) and TL255L62(d10-15)
- Phase 3 (planned for 2007): weekly extension of VAREPS to one month, with a TL255L62 atmospheric resolution and ocean coupling introduced at day 10 (the precise configuration of this final stage of VAREPS is still to be finalized).

ROC scores computed over each individual season since May 2003 suggest that the monthly forecasting system has performed rather well during the past year. The skill of the monthly forecasting system has also been monitored in tropical regions. Over the Indian Ocean, the model was skilful in predicting a late onset of the 2005 monsoon, and this year, the model produced surprisingly good forecasts of the Indian monsoon up to three weeks in advance. It also successfully predicted a dry period a few weeks later four weeks in advance. Results suggest that the model has some skill in predicting precipitation over India up to 3 weeks in advance. On the other hand, the skill of the monthly forecasting system to predict the African monsoon is poor, a result of importance for the AMMA project. In particular the model does not propagate the ITCZ far enough to the North in Africa.

The ‘System 3’ version of the seasonal forecasting system which is based on Cycle 31r1, is ready for final testing and operational implementation. The structure of System 3 has several important changes. Firstly, the period over which the calibration integrations are made will be 1981-2005 (compared to 1987-2001 for System 2). This extended 25 year calibration period will give users more information on the skill of the system, and allow better estimation of forecast products calibrated using actual past performance. Note that although the mean model bias can be estimated reasonably with 15 years of data, estimates of for example reliability of probability forecasts need as many past cases as possible. The ensemble size of the System 3 calibration integrations will be 11 members every month. This differs from System 2, which has only 5 member ensembles, but augmented to 41 members for November and May starts. Drift in the SST of the coupled model is generally reduced compared to earlier cycles, with an absence of tropical cooling and slightly improved seasonal cycle amplitude in the east Pacific. This is the most skilful version thusfar in terms of SST anomaly forecasts.

The climatology of the atmospheric component of System 3 also shows substantial improvements with respect to System 2. Systematic errors in geopotential height, sea-level pressure and lower-tropospheric temperature have been substantially reduced in both the tropical and the northern extra-tropical regions. Internal atmospheric variability is generally higher in System 3 than in System 2; a notable improvement is found in the amplitude of tropical intraseasonal variability in the 20-to-70-day frequency range, which includes the Madden-Julian Oscillation.

All three components of the multi-model system (EUROSIP) have run in operational mode throughout the last year. Separate suites produce graphical products from each of the models. A further multi-model processing suite produces combined multi-model products. Procedures are in place to allow easy upgrading of any component model. The Met Office introduced a new version of their forecasting system in the spring of this year - the change has a minimal impact on overall forecast skill.

BMRC (K. Puri)

No major changes were made to the ensemble prediction systems during the past year. BMRC is currently running three ensemble systems: a global EPS which is undergoing operational trials; Regional EPS which is being run in a research mode; the operational seasonal prediction system.

POAMA1 (Predictive Ocean Atmosphere Model for Australia) is the Bureau’s operational seasonal to inter-annual climate prediction system based on coupled ocean and atmosphere general circulation models. The atmospheric model of POAMA is the Bureau of Meteorology unified atmospheric model (BAM). It has a horizontal resolution of T47 with 17 vertical levels. The ocean model component is the Australian Community Ocean Model version 2 (ACOM2) which is based on the Geophysical Fluid Dynamics Laboratory Modular Ocean Model (MOM version 2). The grid spacing is 2^{o} in the zonal direction. The meridional spacing is 0.5^{o} within 8^{o} of the equator, increasing gradually to 1.5^{o} near the poles, and there are 25 levels in the vertical. The ocean and atmosphere models are coupled using the OASIS coupler. The ocean data assimilation scheme is based on the optimum interpolation technique and only temperature observations in the top 500m are assimilated. Over the past year a considerable amount of effort has gone into developing POAMA1.5 which will include the latest version of BAM, 3-hourly atmosphere-ocean coupling instead of 24 hours currently, some retuning of the ocean model, and a new nudging scheme to initialise the atmospheric model. The system is planned to be implemented operationally in 2007.

Hydrometcentre of Russia (M. Tolstykh)

Activities in 2006 on monthly and seasonal forecasting at Main Geophysical Observatory (MGO) (St.Petersburg) and at Hydrometcentre of Russia (HMC) (Moscow) were outlined.

At MGO, AGCM T42L14 was approved by Roshydromet in 2006 for one-month operational forecasts, following 5 year of quasioperational forecasts and hindcasts using NCEP reanalysis.HMC currently uses T41L15 model with statistical interpretation. Results are somewhat worse than for MGO model. Finally, HMC model is accepted operationally as a member of composite forecast (MGO + HMC + statistical scheme). Composite forecast is better than its members in most (but not all) cases.

For seasonal forecasts, MGO uses T42L14 model, HMC uses semi-Lagrangian finite-difference SL-AV model with 1.40625 x 1.125 degrees lon-lat resolution, 28 levels. A lot of experiments on historical seasonal forecasts (1979-2003) were carried out with the SL-AV model according to SMIP-2 and SMIP-2/HFP format. Quasioperational seasonal forecasts started to appear at http://wmc.meteoinfo.ru/season/ .

MGO and HMC contribute to APEC Climate Centre (APCC, South Korea) effort on multi-model ensemble seasonal prediction. The results for ensemble as well as the results for individual models are available at http://www2.apcc21.net/climate/climate01_01.php

In 2007, it is planned to upgrade parameterizations of the seasonal prediction version of the SL-AV model.

Canadian Meteorological Centre (G. Brunet)

Extended range forecasts (10-30 days)

Ten-day temperature anomaly forecasts (Verret et al., 1998) are generated once a day and fifteen-day temperature anomaly forecasts are generated once a week using a perfect prog approach from the medium-range model.

Monthly temperature forecasts based on numerical weather prediction techniques are issued at the beginning and mid-month of every month. Two ensembles of 6 runs, obtained from 24-hour time lag, are produced: 6 from the Global Environmental Multiscale (GEM) model (Côté et al., 1998a and 1998b) (1.875 degree with 50 levels in the vertical) and 6 from the atmospheric general circulation model second generation (AGCM2) of the Canadian Climate Centre for modelling and analysis (CCCma) (McFarlane et al., 1992) (T32 L10). Both models use the same initial operational analyses. SST anomalies observed over the previous 30 days are added to climatological values over the period; snow is relaxed towards climatology at the end of the first month, except for the AGCM2, where it is a prognostic variable.

Direct model surface temperature outputs ensemble means are averaged over the 30-day period and subtracted from model climatology obtained from a 26-year hindcast period (see section 7.6). The final deterministic forecasts are generated from the normalized average of both model ensemble means. These temperature anomalies are then normalised by the model standard deviation multiplied by 0.43 (to get equiprobable classes) and categorised in above, below and normal categories. Charts are produced, showing above normal, below normal and near normal temperature categories. Monthly forecast products are available on the Internet (Web address http://weatheroffice.ec.gc.ca/saisons/index_e.html).

Long range forecasts (seasonal forecasts): Season 1 forecasts (zero lead time)

Season 1 forecasts are produced using a numerical approach (Derome et al., 2001). The approach is identical to the monthly forecast one described in section 7.5. Maps are similar to those used in monthly forecasts: 3 categories, separated using the 0.43 standard deviation of observed climatology. The temperature and precipitation forecasts are produced using direct model outputs. The two ensemble means of forecasts are subtracted from their respective models' climatologies, and normalised by models' standard deviations. These normalised forecasts are then added, divided by two and used to produce a map, categorised in 3 categories, using the 0.43 value for separation. Skill maps of temperature and precipitation, as obtained over the 26 years of historical runs, are shown for each of the 4 seasonal forecasts periods. The probabilistic forecasts are done by counting members in each of the three possible forecast categories: below normal, near normal and above normal. The probabilistic forecasts are not calibrated but a reliability diagram with error bars is provided with each forecast.

The model outputs for the season 1 are now available in real time on Internet via the CCCma web site. The monthly and seasonal means for 7 fields for the 2 operational models (CCCma AGCM2 and GEM) can be downloaded. Data from both the operational and the hindcast runs are available. The operational forecast data can be accessed at http://www.cccma.bc.gc.ca/data/cmc/cmc.shtml while the hindcast data are located at http://www.cccma.bc.ec.gc.ca/data/hfp/hfp.shtml. Seasonal forecasts are now generated for twelve three month seasons and are issued on the first day of each month, the forecasts being valid for the following three months.

Season 2, 3 and 4 forecasts

Seasonal forecasts with lead times of 3, 6 and 9 months are produced, using a Canonical Correlation Analysis technique (Shabbar and Barnston, 1996). The technique uses the SST anomalies observed over the last year to predict temperature and precipitation anomalies at Canadian stations (51 for temperatures, 69 for precipitation) for the following 3 seasons. Maps of above, normal and below temperature and precipitation are produced. These are accompanied by skill maps, as obtained from cross-validation over a 40-year period. Seasonal forecast for seasons 2, 3 and 4 are available for the main four seasons of the year (winter: December, January, February; spring: March, April, May; summer: June, July, August and fall: September, October, November).

Centre for Weather Forecasts and Climate Studies-CPTEC, Brazil (P. Silva Dias)

The Seasonal forecasting suite consisits of:

- Global Spectral Model T062L28 up to 4-6 months, once a month:
  - 25 members each IRI mode (anomaly based on 50 years) with Kuo scheme;
  - running two more sets of seasonal forecasting:
    - DERF mode
    - Two alternative Cu Parameterization (Grell and Arakawa-Schubert)

Boundary conditions:

- Monthly SST: persisted anomaly (observed) or predicted (Tropical Atlantic (statistical) and Tropical Pacific)
- Initial climatological values: soil moisture;
- albedo and snow depth;
- Sea ice: considered at grid points for which SST is below -2ºC

WGNE welcomed the Seasonal prediction experiment designed by WCRP/TFSP and the TFSP- Seasonal prediction Conference in 2007 in Barcelona. WGNE would like to encourage all the NWP centres and modelling community to participate in this experiment. WGNE suggested that there should be a presentation on model systematic errors at the conference including WGNE's activities in this area. WGNE also suggested that its session next year could be held coinciding with this conference.

4.7 Recent Developments at Operational Forecast Centres

Further to the information on progress in forecasting systems in earlier sections, additional reports were given from the main operational forecasting centres on recent developments/extensions/improvements in their systems. As usual, constructive discussions on problems of mutual interest took place. A summary of the resolutions/configurations of models (global and regional) now in use, and those foreseen in the next three to five years, as well as computing resources is shown in Appendix D.

ECMWF (M. Miller)

The upgrade of all forecast system resolutions was implemented as Cycle 30r1 on 1 February, 2006, after extensive pre-operational testing (more than 300 days). Later in the year Cycle 31r1, which included a series of important changes to the model physics was also implemented.

Cycle 30r1 included the following main changes:

- Horizontal resolution increased to T799 (12 min time step);
- 2nd inner loop resolution increased to T255 (30 min time step);
- Vertical resolution increased to L91, top raised to 0.01 hPa;
- Grid-point humidity and ozone in 4D-Var;
- Changes to the wave model:
  - Deterministic model, resolution increased to 0.36°;
  - Use of Jason altimeter wave height data and ENVISAT ASAR spectra in the wave model assimilation. ERS-2 SAR spectra no longer assimilated;
- Revised coefficients (version 2.3) from Météo-France for the linearized ozone chemistry scheme of Cariolle and Déqué.
- EPS resolution increased to T399L62

Cycle 31r1, implemented on 12, Sept, 2006, included the following main changes:

- Revisions to the cloud scheme including treatment of ice supersaturation and new numerics
- Implicit computation of all convective transports
- The new turbulent orographic form drag and revisions to the orographic wave drag

- Improvements in the formulation of gusts for stochastic physics over orography
- Evaporation with qsat=98% over ocean
- Revised formulation of the assimilation of rain-affected radiances
- The variational satellite bias correction
- Thinning of low level AMDAR data

In addition to the medium-range operational forecasting system, Cycle 31r1 has also been tested favourably, and adopted, for ERA-Interim and for System 3 of seasonal forecasting. There has been continuing progress towards implementation of the VAREPS and its future merging with the Monthly forecasting system.

The model climate is significantly improved by Cycle 31r1. The precipitation in the warm pool area of the tropical Pacific is more realistic, the humidity is better in general, and the equatorial surface wind bias has been reduced. The MJO statistics are also better. Based on preliminary testing, the ENSO forecast skill seems to be remarkably improved. System 3 of seasonal forecasting should become operational early in 2007.

Significant new work on the model physics has started, especially on the cloud and convection schemes and on the land-surface scheme. There is also good progress towards the implementation of the new soil moisture Kalman-filter data assimilation scheme.

The definition of the TIGGE data base of multi-model operational ensemble forecasts has been finalized and all technical procedures to exchange data have been tested and agreed. At the time of writing the start of the TIGGE data exchanges appears to be imminent. A new “nature run” for THORPEX OSSEs has been produced.

The collaboration with CERFACS, INRIA and the NEMO consortium is developing quickly, and ambitious objectives have been set for a community ocean model and data assimilation system based on NEMO (OPA9). This should form the basis of the future System 4 for seasonal forecasting at ECMWF.

The interim reanalysis (ERA-Interim) has started.

The EU FP6 GEMS project, started on 1st March 2005, is progressing at full speed towards its deliverables. Significant first results have been obtained for greenhouse gases and aerosols modelling and assimilation. The technically more challenging sub-project on global reactive gases has developed the coupling method between CTMs and the IFS, making use of the PRISM-compatible coupler OASIS4.

The EU FP6 AMMA project (African Monsoon Multidisciplinary Analysis) began at ECMWF in January. ECMWF has provided support with the monitoring of the enhanced radiosonde network in the AMMA region. The main issue in the monitoring is the reception of soundings via GTS, as communication problems are common. There is a strong seasonal evolution of the difference between radiosonde observations and the first guess in the Sahel region. During the wet monsoon season, the observations have a lower relative humidity (from 10% to 20%) than the first guess. This is partly due to a well-known dry bias in the Vaisala radiosondes.

Hydrometcentre of Russia (HMC) (M. Tolstykh)

M. Tolstykh presented a review of the current state and prospects for the development of NWP models in Russia.

Activities in global and regional forecasting at Hydrometcentre of Russia (HMC) were described. In global medium-range forecasting, two models are used currently, spectral Eulerian T85L31, and finite-difference semi-Lagrangian vorticity-divergence SL-AV model with the resolution 0.72x0.9 degrees lat/lon and 28 levels.

The spectral model is updated to T169L31 resolution and is being tuned currently.

The SL-AV model was accepted by Roshydromet comission in January 2006 for prediction of upper-air fields and MSLP field. Precipitation forecasts are on one-year trials since 01/07/06. The following developments of the SL-AV model were carried out during 2006:

- Numerical noise reduction. This was achieved by harmonization of finite-difference operators in horizontal plane, and introduction of quasi-monotone interpolations for all prognostic variables in the semi-Lagrangian advection scheme.
- Introduction of the PBL parameterization with "interactive mixing length" developed by Meteo-France (PBL height is calculated following Ayotte-Piriou-Geleyn-Tudor)
- Linear finite-element scheme for integrating hydrostatics equation was implemented following (Hortal, Untch, QJRMS)
- ISBA parameterization developed by Meteo-France and corresponding assimilation scheme was implemented.
- Development of the non-hydrostatic core (2D version).

The ISBA scheme is under tuning now, while the first three items contributed to visible improvement of scores of the SL-AV model in 2006 as compared with 2005.

In regional forecasting, currently there is a regional model covering the whole of Europe with the resolution of 75 km, and the global variable resolution version of the SL-AV model which has the resolution of about 30 km over Russia. The membership in COSMO consortium is under evaluation.

It is planned to implement 3D-Var data assimilation scheme to replace current OI scheme. The version of this scheme for global models is expected to reach quasioperational status by the end of 2008.

The ensemble prediction system using T85L31 model is being developed. It is based on breeding method.

So far, computer resources at HMC are very limited. The planned procurement for new supercomputer is expected now in 2007. At Main Geophysical Observatory (St.Petersbourg) dealing with monthly and seasonal prediction, 0.6 Tflops machine will be installed in Spring 2007.

BMRC (K. Puri)

The current suite of global and limited area models at the Australian Bureau of Meteorology consists of:

- the global assimilation prediction (GASP) system, horizontal resolution T_L239 and 33 levels;
- the limited area prediction system (LAPS), horizontal resolution 0.375° x 0.375° and 51 levels;
- the tropical limited area prediction system with the same resolution;
- the mesoscale limited area prediction system (mesoLAPS), horizontal resolution 0.125° x 0.125° and 29 levels;
- the tropical cyclone limited area prediction system, horizontal resolution 0.15° x 0.15° and 29 levels – this only runs if a named cyclone is present in the region

In addition a 0.05° x 0.05° version of the model is run operationally twice a day for domains covering Melbourne and Hobart, Sydney, Adelaide, and Perth, with hourly output then being used to drive a CSIRO photochemical model for use by the Environment Protection Authorities for the domains (excluding Perth).

Operational changes in the past year have included (i) increase in the number of levels in the limited area system from 29 to 51; (iii) use of ECMWF blacklisting data base in both the global and regional systems.

Over the past year, a great deal of effort has gone into the sixty-level (L60) versions of LAPS and GASP. One of the primary drivers for the raising of the model lid in the L60 systems was to allow for greater use of satellite data; additionally the new configuration should allow the use of local read-out radiances in LAPS. The systems also include improvements to the physical parametrisations and efficiency improvements in the code. Extensive parallel trials of GASP and LAPS GenSI assimilation and prediction at 60 levels with AAPP based radiances have been carried out with very encouraging positive impact seen for both systems. These systems have utilised up to 5 satellites, including the latest NOAA18 satellite, as well as NOAA 15/16/17 and NOAA18 and Aqua(AMSU-A), with AMSU-B from the NOAA series also assessed. Operational implementation of the 60-level systems is planned for the second quarter of 2007. The operational mesoLAPS system currently runs twice daily. Testing is currently going on to run the system four times a day and operational implementation is planned for 2007. Moreover, mesoLAPS currently does not include any data assimilation and the initial condition is obtained by interpolating from the lower resolution LAPS. Detailed testing of a 0.1° x 0.1°, 60 level version with data assimilation is being carried out with encouraging results. With the development of the Australian Community Climate and Earth System Simulator (ACCESS) resources are being diverted from existing model development to ACCESS-related work. No new major developments will be made on the existing NWP systems GASP and LAPS once the developments listed above are implemented operationally.

Météo-France (M. Déqué)

The ARPEGE/ALADIN system has upgraded numerics by raising the model top to 5Pa, i.e. going from 41 to 46 vertical levels, by improving semi-Lagrangian vertical advection and by improving postprocessing of derived (e.g. PV) fields. It has upgraded its physics by an update of surface physiographies, a change to radiation RRTM-IR scheme from ECMWF, an introduction of a new scheme (originally developed by P. Lopez) for prognostic microphysics and by retuning entrainment in subgrid convection scheme. It has upgraded its assimilation by improving physics/dynamics coupling in TL model of 4Dvar, introducing variational observation quality, improving surface analysis of soil temperature, humidity and ice and introducing a flow-dependent observation quality control using an ensemble of 3DVar assimilations.

As far as the use of observations is concerned, the new features are:

- use NOAA-18 satellite (AMSU-A and B)
- use Meteosat-8 and MODIS (Terra + Aqua) Atmospheric Motion Winds
- move from SATOB to BUFR GEOWIND processing of geostationary satellites
- use ground GPS humidities (zenith total delay) over Europe
- use clear SSMI radiances over sea
- extend use of wind profilers
- extend use of Quikscat winds to the ALADIN mesoscale model

The mesoscale AROME system (due for operations in 2008) has been tested in near real time forecasts at 2.5km resolution for AMMA field experiment. Its most recent features are:

- fast diagnostic 3DVar analysis tool for nowcasting
- 3DVar assimilation experiments at 2.5km resolution
- ingestion of radar Doppler radial winds
- experimental humidity retrievals from radar 3D reflectivities
- improvement of fog forecasts
- new EDMF shallow convection scheme

The Météo-France system will migrate from Fujitsu VPP to new NEC SX8++ supercomputer in early 2007. The Météo-France modeling development is coordinated with ECMWF and the ALADIN and HIRLAM consortia.

Japanese Meteorological Agency (Y. Takeuchi)

A new supercomputer system consisting of a couple of HITACHI SR11000K1 (80nodes, 10.75Tflops for each) for NWP was implemented in March 2006 in addition to HITACHI SR11000J1 (50nodes, 6.1Tflops) for satellite data processing implemented in March 2005. The NWP model suite includes Global Spectral Model (GSM), Regional Spectral Model (RSM), Typhoon Model (TYM) and Meso-scale Model (MSM). A low resolution version of GSM is used in the one-week ensemble prediction system.

Major changes of the suite in March 2005 are: (1) addition of 36 hour forecasts from the initial time of 06 UTC and 18 UTC with GSM, (2) improvement of the horizontal resolution from T63 to T106 for inner model of Global 4D-Var Analysis, (3) improvement of horizontal resolution of MSM from 10km to 5km and the number of vertical level from 40 to 50 associated with refinement of the radiation scheme, cumulus parameterization scheme, and surface and boundary layer schemes, (4) doubling of MSM operation from 6 hourly (18 hour forecast) to 3 hourly (15 hour forecast), (5) improvement of spectral resolution of GSM for one-week ensemble from T106 (quadratic grid) to TL159 (linear grid) associated with implementation of a semi-Lagrangian advection scheme, (6) increase of the ensemble member from 25 to 51, and
(7) introduction of a global daily sea surface temperature data analyzed by using data from satellite microwave radiometer, satellite infrared radiometer and in-situ observation (MGSST) for TYM, RSM and MSM.

Other changes are: (1) implementation of microwave imager (i.e., SSM/I, TMI and AMSR-E) radiance data and implementation of a variational bias correction for microwave sounder and imager data for global analysis in May 2005, (2) improvement of quality check and the variational bias correction for ATOVS radiance data for global analysis in August 2006, and (3) implementation of BUFR coded AMV data from GOES-11/12 and MTSAT-1R instead of SATOB coded AMV data and hourly AMV data from MTSAT-1R for global, regional and meso-scale analysis in October 2006.

A noteworthy improvement on satellite data use is the establishment of Regional ATOVS Retransmission System in Asia-Pacific region (AP-RARS) similar to EARS for Europe and North America in June 2006. Under the cooperation among BoM, CMA, KMA and JMA, direct broadcast ATOVS data are exchanged through GTS in real-time. National Institute for Polar Research (NIPR) provides the data received at Syowa station in Antarctica.

Major plans of NWP model are as follows: (1) implementation of a new GSM with a resolution of 20km (TL959L60) instead of current GSM, TYM and RSM, (2) improvement of the resolution of inner model of the Global 4D-Var Analysis from T106 to T159, (3) extension of the forecast time of MSM from 15 hours to 33 hours at the initial time of 03, 09, 15, 21 UTC, (4) implementation of a new Meso-scale 4D-Var Analysis based on non-hydrostatic MSM (JNoVA), (5) improvement of the resolution of GSM for one-week ensemble from TL159L40 to TL319L60 associated with the replacement of the initial perturbations by breeding method to singular vector method, and (6) new implementation of a Typhoon ensemble prediction system, the initial perturbations of which are given by a dedicated for typhoon forecast, with the same GSM as that for one-week EPS.

UK Met Office (A. Lorenc)

A Lorenc reported that the Met Office continue to benefit from a unified modelling system, with the same model used for climate change, as well as global, regional and convective scale NWP. The global NWP system was upgraded in the past year with convection and boundary layer parametrisation improvements developed by a joint climate-NWP team. Resolution was increase to 40km and the 4D-Var assimilation was improved. The 4D-Var system was implemented in the regional model (12km resolution); this was necessary to bring it to a performance beating the global model. Convective scale forecasts are run at 4km for the UK, with a plan for 1.5km regions in 2007. The Met Office global and regional short-range ensemble prediction system (MOGREPS), based on a local ensemble transform Kalman filter, has performed well in a year's trial, and will probably be adopted operationally.

Deutscher Wetterdienst (D. Majewski)

The current suite of global and regional NWP models of the DWD consists of: the global icosahedral-hexagonal grid point model GME with a 40 km grid spacing and 40 layers, the non-hydrostatic local model LME covering whole of Europe with 665 x 657 grid points, a grid spacing of 7 km and 40 layers, and the hydrostatic High-resolution Regional Model HRM which is used for operational regional NWP in 20 countries world wide, including Brazil, Bulgaria, China (Guangdong province), Israel, Italy, Kenya, Mozambique, Oman, Pakistan, Philippines, Senegal, Spain, United Arab Emirates and Vietnam. GME data are provided to these countries via the internet twice a day to serve as lateral boundary conditions.

Several research projects in Germany and Europe aim at improvements of numerical weather prediction systems, namely

- SPP1167 "Quantitative Precipitation Forecast", funding Period 2004 – 2010, funded by the German Research Foundation (DFG); see http://www.meteo.uni-bonn.de/projekte/SPPMeteo/. In the framework of this project, an international observation experiment, called COPS (Convective and Orographically-induced Precipitation Study), is scheduled in June to August 2007 in the south-western part of Germany, see http://www.uni-hohenheim.de/spp-iop/.
- SPP "Metstroem", funding period 2007 – 2012, funded by the German Research Foundation (DFG); see http://emm.mi.fu-berlin.de/DFG-MetStroem/. Main emphasis of this program is on adaptive modelling, dynamic grid adaptation and concepts for adaptive parameterizations.
- European Science Foundation Project on "Very High Resolution Environmental Modelling" VHREM. Main emphasis is on the design of next-generation meteorological forecast models for the local scale (< 1 km) including terrain intersecting coordinates, cut cells, local grid refinement; see http://www.env.leeds.ac.uk/~alan/vhrem/.

D. Majewski gave an overview over the current status of the development of a very high resolution short range forecasting system for Germany. This system, named LMK, is based on a version of the LME with a 2.8 km grid spacing. Different dynamical cores have been evaluated in test suites of several months of duration. The standard three-time level leap frog scheme with second order spatial discretization has been compared with a two-time level 3rd order Runge-Kutta scheme (TVD variant) with a fifth order spatial discretizaton. For the advection of moisture variables (water vapour, cloud water, cloud ice, rain, snow, graupel) two options exists: Semi-Lagrangian advection or a positive-definite shape-preserving Bott scheme. While LMK will resolve deep convection explicitly shallow convection still needs to be parameterized. For the determination of the initial state, emphasis will be placed on a proper high-resolution description of the humidity fields using the German/European Radar DX composite in a latent heat nudging approach. LMK will go operational on 16th April 2007 providing 21-h forecasts eight times per day.

Canadian Meteorological Centre (G. Brunet)

In October 2006 major changes were implemented to the operational global forecast system using the Global Environmental Multiscale (GEM) model.

Changes to the dynamical configuration of the Global model

The forecast model horizontal resolution has significantly increased from about 100 km (400 × 200 grid points) to nearly 33 km at mid latitudes (800 × 600 grid points). The number of vertical levels has increased from 28 to 58, the top of the model remaining at 10 hPa. The time step has been consequently reduced from 2700 to 900 seconds. The sponge layer near the model lid now includes 4 levels instead of 1. In this layer, the horizontal diffusion is increased in order to minimize the negative impact of spurious waves reflected at the lid.

Changes to the physical parameterizations in the Global model

The physical parameterization of the forecast model has been substantially modified compared to the old operational version. The condensation and precipitation packages, in particular, were changed quite drastically. The Kain-Fritsch (1990, 1993) scheme has replaced the Kuo (1974) scheme for the deep convection. This allows for a larger contribution of the grid scale (resolved) condensation processes which is consistent with the increase in resolution. The Sundquist (1989) grid scale condensation scheme was modified mostly with respect to the evaporation of the precipitation below the cloud base, which is done over several levels in the new version. Another change to the condensation suite is the inclusion of a shallow convection scheme, based on a Kuo scheme closure, called Kuo transient. The surface modeling scheme known as ISBA (Interactions, Surface Biosphere, and Atmosphere) has replaced the so-called `force-restore` module. ISBA is more sophisticated in its treatment of soil, vegetation, and snow.
Together with ISBA, a land-surface 6-h data assimilation system has been implemented in order to provide initial conditions of surface temperatures and moisture. The increase in resolution of the model and the use of ISBA makes the snow analysis more precise. Another model physics modification is the use of the Bougeault and Lacarrère (Bougeault and Lacarrère, 1989, Bélair et al, 1999) mixing length for vertical diffusion due to turbulence, providing a clear improvement over the one previously used, especially for convective, well mixed, boundary layers.

Changes to the Global Data assimilation System

Several modifications and improvements have been brought to the global data assimilation system to provide analyses to the new model version (see Gauthier *et al.,* 2006 and Laroche *et al.,* 2006, for a comprehensive description of the operational 4D-Var data assimilation system). A new set if background error statistics on the 58 model levels has been computed using the so-called NMC method. As in the previous implementation of the 4D-Var, a low resolution model is used to propagate the analysis increments (T108) over the 6-hour data assimilation window. The set of physical parameterizations for this model has been changed to those now used in the new forecast model described above. However, the corresponding simplified physical parameterizations used in the tangent linear model and its adjoint model remains the same as before.

The computational efficiency of the 4D-Var data assimilation system has been improved by 40% overall. The cut-off times for the availability of observations have been slightly modified to deliver the operational analyses at about the same time as in the previous global forecast system.
The Canadian ensemble outputs are used in the North American Ensemble System (NAEFS) project, a joint initiative involving the MSC, the United Sates National Weather Service (NWS) and the National Meteorological Service of Mexico (NMSM). The following products based on the NAEFS joint ensemble forecasts are available on the WEB since October 31 2006: EPSgrams for cities in Canada, Mexico and United States, charts of Ensemble means and standard deviation and maps of probabilities occurrence of several weather.

Ensemble Prediction System

Since December 13, 2005, the 16 member Ensemble Prediction System (EPS) runs twice a day up to 16 days. Previously, the EPS would run only once a day and only up to forecast day 10. The more frequent and longer EPS runs became possible with the Canadian participation in the North American Ensemble Forecast System (NAEFS). Combining the Canadian and American ensemble forecasts, due to the improved sampling of the model error component, should extend the range of usefulness of the ensemble forecast well into week two.

Since December 13, 2005, the ensemble Kalman filter (EnKF) of CMC uses four ensembles of 24 members. The EnKF thus still uses a total of 96 members. The previous configuration, known as a double ensemble Kalman filter (Houtekamer et al., 2005), used two ensembles of 48 members. Other modifications are the inclusion of a digital filter finalization in the ensemble of 96 6-h integrations that is required by the EnKF and the addition of model error before rather than after the model integrations. These modifications lead to an improved balance in the guess fields and are in preparation for the implementation of time interpolation in the EnKF.

The trial fields are obtained using a configuration of the GEM model with a horizontal resolution of 1.2º and with 28 levels. The model top is at 10 hPa.

In principle, the EnKF can assimilate each observation for which a forward interpolation operator has been made available. The EnKF can thus, at least in principle and after testing, assimilate all data that are currently assimilated in the deterministic 4D-variational assimilation system of CMC. With the current system, we do, for instance, directly assimilate the AMSU A and B radiance observations. At this point, however, time interpolation in the 6-h assimilation window has not yet been implemented in the operational EnKF and it is consequently necessary to impose an additional data selection to discard some of the data that are outside the central 3-h window.

The 16 initial conditions for the medium-range ensemble forecasts are obtained in the following manner:

- Twice a day, at 00 and 12 UTC, sixteen representative members are chosen among the 96 analyses of the EnKF.
- The ensemble spread, of the 16-member ensemble of initial conditions, is inflated by a factor 1.8 to arrive at sufficient spread in the medium range.

Two separate models are subsequently used to produce the 16-day forecasts: the SEF spectral model and the GEM grid point model (resolution of 1.2 degree, Cote et al., 1998a and 1998b). Each model uses different configurations of the physical parameterizations.
Ensemble outputs of the following products are available on the web: 10 days mean temperature anomaly , spaghetti plots of the 500 hPa heights; composite MSLP highs and lows; cumulative precipitation amounts; forecast charts of precipitation amounts probability for various thresholds (http://www.weatheroffice.ec.gc.ca/ensemble/index_e.html).

A set of new products are under development on the EPS outputs. Bayesian Model Averaging (Raftery et al., 2005) is used to generate probability density function for temperatures. Results with Bayesian Model Averaging are available in Wilson et al. (2005). Charts of probabilities of exceeding different thresholds for different variables are also under development. A new updated Perfect Prog statistical post-processing system has been implemented in the EPS to provide statistical surface temperature forecasts from each member model outputs.

The Canadian ensemble outputs are used in the North American Ensemble System (NAEFS) project, a joint initiative involving the MSC, the United Sates National Weather Service (NWS) and the National Meteorological Service of Mexico (NMSM). The following products based on the NAEFS joint ensemble forecasts are available on the WEB since October 31 2006: EPSgrams for cities in Canada, Mexico and United States, charts of Ensemble means and standard deviation and maps of probabilities occurrence of several weather. The web site is located on the official MSC server: http://weatheroffice.ec.gc.ca/ensemble/index_naefs_e.html

A common product will be available soon. This product will be a NCEP/MSC chart of the temperature anomaly for day 8 to 14.

China Meteorological Administration (Chen Dehui)

Recent developments in the operational NWP systems at NMC of CMA

The operational implementation of GRAPES_Meso at NMC of CMA: From 2004 to 2005, GRAPES_Meso with Δx = 60km and 31 vertical levels was quasi-operationally run 1 time per day; the initial conditions and lateral-boundary conditions were provided by the operational global model T213L31; the GRAPES_3DVAR was used for the data (currently, only GTS data sets) assimilation.

In 2006: GRAPES_Meso was upgraded to Δx = 30km and 33 vertical levels;it was fully operationally run 2 times per day; the data assimilation was still with GRAPES_ 3DVAR using GTS data sets only; the I.C. & LBC were still from T213L31. So far, the previous operational regional model HLAFS, which covers the whole China territories and its surrounding areas, was fully replaced by GRAPES_Meso with 30km since 16 July, 2006.

Transplantation of SSI from NCEP to NMC's global MRF system T213L31 (the Global Model is a spectral model original from ECMWF, with OI scheme for the Global Data Assimilation): the transplantation of SSI has been started since 2003 (Derber and Parrish, 1992). A specific procedure was established for the interpolation between SSI and T213L31. After re-estimations of B.E. (NMC-M.) and O. E. (IV-M.), T213L31 with SSI was run in real-time since this summer at NMC. The results with the MRF systems using the satellite ATOVS data sets showed significant improvements have been obtained on the geopotential height forecasts. However, there was no consistent improvement in the precipitation forecasts. Further analysis and investigations are needed for full operational implementation.

Tests of the Global model for Typhoon Track Prediction

Based on the T213L31 with SSI, a special version of the new global model has been established for the global tropical cyclone track forecast. The inter-comparison of the global simulations showed that the tropical cyclone track forecast errors with the model using Bogusing scheme were reduced in comparison to the simulation with ATOVS.

Progress of GRAPES in CAMS at CMA

GRAPES_Meso has been upgraded from the Version_60 km to the Version_30km and was operationally run at NMC of CMA on 16 July, 2006.

More physical modules were added to the Physics package. The experiments of different configurations of physical schemes for the regional and global modeling have been carried out; the Partitions of the physical tendencies between the arrival point and the depart point were conducted along the Lagrangian trajectory. Further,

- a regional version of GRAPES_4DVAR is ready to be run with real data sets.
- the GRAPES_Global model continued to be tested.
- the Global 3DVAR was tested by using satellite data sets, ATOVS.
- the Yin-Yang grid system continued to be tested.

Next steps

1. To perform the global T213L31 with SSI data assimilation using ATOVS toward the operational run at NMC/CMA in 2007.
2. To upgrade GRAPES_Meso-30km to GRAPES_Meso15km with modifications of physical schemes and Regional DAS at NMC/CMA.
3. A new national key-project for GRAPES development has been approved on 14th October 2006, and will restart very soon. The new project of GRAPES will focus on 1) to operationally implement GRAPES (GRAPES_Global); 2) to develop a cloud-resolving version of GRAPES; 3) based on the global GRAPES, a version of AGCM will be developed as an atmospheric model component of the climate system model.
4. The D.A.S. using satellite data for the global model will be first priority to be performed in the next 3 years.

NCEP Environmental Modeling Center, the JCSDA and GFDL (M. Iredell)

In June 2006, the WRF-NMM (Weather Research Forecast Nonhydrostatic Mesoscale Model) was implemented in NCEP. It replaced the previous Eta coordinate model. Along with the WRF forecast model, the data assimilation scheme was replaced by the GSI (Gridded Statistical Interpolation) 3DVAR. The GSI is a successor to the global SSI and represents a unification of NCEP 3DVAR schemes. The WRF-NMM remains on the same 12 km resolution E-grid as the Eta model, but on 60 sigma-pressure hybrid levels up to 2 mb. The WRF common modeling infrastructure is used to enable more community research involvement.

NCEP is now running a real-time mesoscale analysis (RTMA) over the continental US. The resolution is 5 km, hourly. A 2DVAR version of the GSI is used, with a multitude of data sources. Anisotropic error covariances are used in areas of varied topography. The weather elements analyzed are surface layer temperature, dewpoint, winds, precipitation, and cloud cover.

In August 2006, the GFS (Global Forecast System) had an upgrade implemented. The upgrade consisted of improvements to surface forcing characteristics, ozone physics, and polar ice physics. The targets for these improvements are better Antarctic and Arctic boundary layers and better stratospheric ozone forecasts. In addition, the GFS is now a fully-compliant ESMF gridded component, though it is not run with any coupling in daily operations.

The GSI unified 3DVAR analysis in the GFS is undergoing final testing and is targeted for implementation in the first half of 2007. The GSI offers more room for improvement in defining the background errors and dynamic constraints, and it provides a path to develop 4DVAR.

In May 2006, the NAEFS (North American Ensemble Forecast System) was implemented. The NAEFS represents a combination of Canadian and US global ensemble systems. Currently, 40 Canadian members per day and 56 US members per day are used, each member making a 16 day global forecast. Each member is individually bias corrected in order to improve the ensemble statistics, and each member is also distributed as anomaly percentiles. The NAEFS is intended for more probabilistic rather than deterministic forecasts for its end users in Canada, the US, and Mexico. Unified evaluation and verification procedures are used.

The JCSDA (Joint Center for Satellite Data Assimilation) is a collaborative group for transitioning implementation of new satellite data. Instruments that have recently been implemented are EOS/AIRS radiances υ.1, EOS/AMSU-A, EOS MODIS AMVs υ.1, TERRA/MODIS AMVs. υ.1, NOAA/18 AMSU-A, NOAA/18 HIRS/4, NOAA/18 MHS, NOAA18/AVHRR, NOAA17/AVHRR, and JASON/ALTIMETER. Instruments that are in the process of being transitioned are COSMIC, CHAMP, WINDSAT, SSMIS, MODIS υ.2 (EE), AIRS υ.2 (every fov -251 channels used), AURA OMI, AMSRE(E), IASI, and GFO. The Community Radiative Transfer Model (CRTM) is the vehicle for transitioning new instruments.

Efforts are ongoing at NCEP to develop a global air quality data assimilation and forecasting system. The rationale for this development is to improve radiation parameterization, data assimilation, regional air quality forecasts, aviation and visibility forecasts, and hurricane forecasts. The development is done in collaboration with NASA and the JCSDA. The effort is coupled to the ongoing regional air quality system.

In December 2005, the HYCOM community ocean forecast model was implemented into operations. Its domain is the Atlantic Ocean between 25S and 76N. It is used for high resolution forecasts of temperature, salinity, currents, and surface elevation. The HYCOM model is used to drive the operational storm surge model in the NOAA National Ocean Service at selected sites.

The operational wave model has continued undergoing improvements. In August 2006, a Great Lakes wave model was implemented. The model is driven by winds from the NAM (North American Mesoscale atmospheric model). Ensemble wave models driven by the GFS ensemble are also being run routinely. In the pipeline are development of full wave field separation in space and time, wave steepness parameters, and a multiscale wave model.

The hurricane model also had an upgrade in 2006. The implementation included adding Ferrier microphysics and dissipative heating effects, as well as improvements to surface momentum fluxes, loop current initialization, and ocean initialization. This resulted in improved track forecasts, particularly for weaker and sheared storms. The hurricane WRF system (HWRF) is under development for 2007. It will include improved hurricane initialization using radar data and two-way coupling to ocean and wave models.

CPTEC, Brazil (P. Silva Dias)

The Weather Forecasting Operational Suite consists of:

- Global Spectral Model T215L42 (64km) (T299L62 in 2006) up to 7 days, twice a day from (a) NCEP analysis and (b) GPSAS/DAO assimilation system(6 hours);
- Regional Eta Model – 20kmL38 (15km in early 2007), up to 5 days, twice a day from NCEP analysis and from RPSAS/DAO CPTEC regional analysis with CPTEC global model BC;
- Global Ensemble T126L28, up to 15 days, twice a day, 15 members;CPTEC/FSU ensemble principal components IC perturbation scheme;
- Regional Ensemble Eta40km up to 5 days, twice a day, 5 members; BC forcing from global EPS clustering, 5 members with perturbed physics (to be implemented in early 2006);
- Global coupled ocean/atmosphere model (T126L28)+ MOM3/4 (20km), 30 days twice a day;

5. JOINT SESSION OF WGNE AND WMP

The First Joint Session of the WCRP Modelling Panel (WMP) and the CAS/JSC Working Group on Numerical Experimentaion (WGNE) was held at NCAR on 24 October 2006.Dr M.Miller, Chair, WGNE and Dr J.Shukla, Chair, WMP, welcomed the participants. The agenda for the joint session is given in Appendix C. The session was given review of WCRP events during the past year and reports by the WCRP core projects and modeling gropus. A highlight of the session was two scientific talks entitled: (i) “Thoughts on next-generation global atmospheric models", by Dr D. Randall and (ii) "Global cloud resolving simulations using the 3.5km-mesh Nonhydrostatic Icosahedral Atmospheric Model", by Dr M. Satoh.

There was general consensus that modelling development (both atmosphere and ocean) throughout the world needed strengthening.
The group discussed at length and agreed:

1. on what WCRP can do to encourage nations to support model development
2. that there was a serious problem with computing resources. Many models have inadequate resolution. There was need to enhance resources for IPCC class and also cloud resolving models.
3. that there was a need to have a more unified global modelling effort.

The WCRP-THORPEX White Paper2 would inform the governments that multi-petaflop computers are needed for next generation models. The White Paper should stress that a multi faceted effort is needed including reinforcing human resources as well as computational ones. Model development is not a glamorous subject and young people are not attracted to it. It was suggested that WCRP should urge the major modelling centres to establish post doctoral fellowships for modelling. Experience with the LBA project indicated that field activity is important to attract people to take up modelling. A wider vision which included capacity building in the realm of high-tech modelling, better utilization of ocean observations, and satellite data was needed. Here was an opportunity to make a case based on both succcesss in the past and the challenges ahead.

6. MEMBERSHIP OF THE WGNE

Membership of the WGNE was determined by consultation between the Chair of the JSC and the President of CAS. The JSC at its 27th session in Pune in 2006 approved nominations of new members or renewals of terms of appointment of current members as appropriate, with effect from 1 January 2007.The terms of Drs M. Miller (Chair), Chen Dehui, S. Lord, A. Lorenc, D. Majewski and K. Puri, which expired on 31 December 2005, were each extended by two years. Drs D. Williamson, J. Coté and V. Kattssov whose terms expired on 31 December 2005, stepped down. Drs J. Hack (NCAR, USA), G. Brunet (Meteorological Service of Canada) and M. Tolstykh (Russian Hydrometeorological Research Centre) accepted the invitation to be members of group for an initial term of four years effective 1 January 2006. The composition of the group was:

Membership	Expiry of appointment	
M. Miller (Chair)	31 December	2007
G. Brunet	"	2009
Chen Dehui	"	2007
M. Déqué	"	2007
J. Hack	‘’	2009
M. Iredell	"	2009
A. Lorenc	"	2007
D. Majewski	"	2007
K. Puri	"	2007
P.L. Silva Dias	"	2008
Y. Takeuchi	"	2007
M. Tolstykh	"	2009

7. OTHER WGNE ACTIVITIES AND FUTURE EVENTS

7.1 Publications

A key WGNE publication for many years has been the WGNE "blue cover" numerical experimentation report series, which continues to be popular with the modelling community and is prepared on behalf of WGNE by Recherche en Prevision Numerique (RPN), Montreal since its inception. WGNE thanked the RPN for printing and distributing the WGNE 'Blue book' numerical experimentation series, the annual summary of research activities in atmospheric and oceanic modelling (No. 36, produced in April 2006). The web-based publication is now well established and most contributions were submitted through the web site www.cmc.ec.gc.ca/rpn/wgne and a few still as an attachment to an e-mail message. Overall the electronic submissions are working well and make possible the production of this report on the web site. A paper version is no longer produced. This is also linked to the WCRP website: http://www.wmo.ch/web/wcrp/wcrp-home.html.

7,2 WGNE Web site

The Canadian Meteorological centre has offered to host the WGNE website. The WGNE web site is under construction at (http://collaboration.cmc.ec.gc.ca/science/wgne/). It is password-protected. WGNE thanked the Canadian Meteorological Centre for this helpful gesture.

7.3 Next session of WGNE and GMPP

At the kind invitation of the China Meteorological Administration (CMA), the next session of the WGNE, the twenty-third, will be held in Shanghai, China, 22-26 October 2007. This will be a joint session with the tenth session of GMPP.

8. CLOSURE OF SESSION

The Chair of WGNE thanked all participants for their contributions to the session and for the high level of scientific discussions. The Chair also acknowledged the excellent scientific presentations that had been given to the Session by Dr T Killeen, Director, NCAR, on ''Scientific progress, plans and new initiatives at NCAR'', by Dr P.R. Gent, Chairman of the Science Steering Committee of the Community Climate System Model, NCAR, on ''Status of the Community Climate System Model'' and Dr J.Hack, NCAR, and member of WGNE, on 'Predicting the Earth System across scales''.

Finally, on behalf of all the participants, the Chair of WGNE expressed appreciation to the National Centre for Atmospheric Research, Boulder, USA, for hosting this session of WGNE and the excellent facilities and hospitality offered. The opportunity of interacting with many scientists and experts at the NCAR had been very valuable. Sincere gratitude was voiced to Dr D.Williamson and supporting staff for the excellent arrangements, unstinting assistance, and refreshments that had been provided.

The twenty-second session of WGNE was closed at 1700 hours on 27 October 2006.

APPENDIX A

List of participants to WGNE-22/Joint WMP-WGNE session

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APPENDIX B

Recommendations/Actions from the WGNE-22 meeting Boulder, CO, USA, 24-27 OCTOBER 2006

Agenda item	Recommendation/Action
1.5 Transpose AMIP	WGNE was pleased with the progress in the T-AMIP and to learn that the proposal had been sent to climate modelling groups and the model results are expected by march 2007. WGNE asked its members to encourage participation by several more groups in the experiment.
1.7 Regional Climate modelling and future workshop	WGNE welcomed the proposal for the follow up RCM workshop in 2008 and strongly supported it. WGNE appreciated the good tutorial part planned for the workshop,
1.8 An overview of recent developments/ activities in monthly and seasonal forecasting.	WGNE welcomed the Seasonal prediction experiment designed by WCRP/TFSP and the TFSP- Seasonal prediction Conference in 2007 in Barcelona. WGNE proposed that there should be a presentation on model systematic errors at the conference including WGNE's activities in this area.
2.1 Relevant activities under CAS auspices	WGNE discussed the importance of parametrization research and providing these inputs to WWRP. The relevance of this topic to WGNE is obvious. The WGNE-GCSS link provides WWRP the link to model physics developments. Recently, the WGNE-GMPP joint sessions were being held in alternate years, this has not been adequate.WGNE would work more closely with GCSS to provide the inputs to WWRP-THORPEX. THORPEX with its present concern to address the ''second week forecast'' problem would like to work closely with the GCSS through WGNE. WGNE would appreciate additional support from WWRP to return to annual joint meetings with GMPP in this regard.
2.3 THORPEX Pacific-Asia Regional Campaign(T-PARC)	WGNE welcomed the proposed T-PARC campaign by THORPEX and noted that it is a major experiment planned by the THORPEX community. For THORPEX this experiment is important as its success would underpin support for THORPEX for the next 5 years. THORPEX requested the Director of NCAR to help ensure NSF support to T-PARC. WGNE queried if there are any plans for reanalysis for the T-PARC period and suggested this should be considered now and not after the campaign.

Agenda item	Recommendation/Action
2.6 Pan-WCRP Year of tropical convection in the THORPEX context, the role of very high resolution regional forecast experiments	WGNE welcomed the proposal by D. Waliser and discussed it at length. WGNE appreciated the potential to improve monthly weather and seasonal forecasts by addressing the poorly understood MJO and tropical convection phenomena. The proposal aims to achieve this by creating a broader data base on the tropical convection and MJO phenomena. Therefore WGNE strongly supports the proposal. However, the proposal as it stands needs to be strengthened with more details; the modelling component should be highlighted. The revised proposal should consider the ongoing/ planned efforts in CEOP, avoid overlaps, and the fact that WMO has admitted this proposal under its WIS.
2.10 Overview of SURFA and WGSF	While there are still steps remaining before SURFA becomes a useful reality, it has been agreed to revitalize SURFA, and an agreed set of NWP fields etc will be routinely archived at the National Climate Data Centre from a number of NWP Centres in due course. WGNE was pleased to note that NCDC has kindly agreed to archive the fluxes data. WGNE appreciated this gesture of NCDC and thanked them. D.Majeweski was appointed WGNE point of contact to arrange for archiving with the NWP centers. The WGSF will coordinate archiving the *in situ* data.
3.3 Inter-comparison of Typhoon Track Forecasts	The overall gradually improving performance of these models in predicting cyclone tracks over the past few years has been maintained. In future statistics will be gathered to assess the skill in intensity forecasts and forecasts of cyclone genesis. Y.Takeuchi was asked to contact ECMWF in this regard.
3.11 Next year WGNE Session	Agenda items for next WGNE session should include land surface modelling, assimilation; focus on MJO; revisit diurnal cycle; next generation and convection resolving models

APPENDIX C

SESSIONS AGENDA

24th October 2006
Joint WMP-WGNE session

0830-1230	**Chair: J. Shukla**
0830-0840	Welcome and outline of joint WMP-WGNE session (*J.Shukla, M. Miller*)
0840-0850	Review of WCRP events -JSC XXVII session, Pune, India
0850-1030	Reports from WCRP Projects (15 minutes each) - WGCM -*G. Meehl* - CLIVAR -*J. Hurrel* - GEWEX/GMPP -*J. Polcher* - SPARC -*S. Pawson* - CliC -*T. Arbetter* - TFSP -*B. Kirtman*
1035-1100	**Coffee break**
1100-1140	"Thoughts on next-generation global atmospheric models", talk by D. Randall
1140-1220	"Global cloud resolving simulations using the 3.5km-mesh Nonhydrostatic Icosahedral Atmospheric Model", talk by M. Satoh
1230-1400	**Lunch**
1400-1700	**Chair: M. Miller**
	- AMIP, CMIP, C20C and IPCC -*P. Gleckler* - Metrics for Climate models -*K. Taylor* - Systematic Errors Conference -*P. Gleckler*
1530-1600	**Coffee break**
1600-1700	Session continued - Next generation Models -*Y.Takeuchi, G. Brunet and A. Lorenc* - Pan-WCRP action on Convection -*D. Waliser*
1700-1730	Discussion
1730	**Closure of the session**

WGNE-22 MEETING
Boulder, CO, USA, 25-27 OCTOBER 2006

Wednesday 25 October

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
	Opening welcome and local arrangements etc	Chair, WGNE NCAR
1.1	Adoption of Agenda	Chair, WGNE V. Satyan
1.2	WGNE and the last JSC meeting	V. Satyan
	Report on the WCRP observations and assimilation Panel (WOAP) (Also item 2.8)	A. Lorenc, V. Satyan
1.3	Status of the Community Climate System Model	P. Gent (science talk)
1045-1100	Coffee	
1100-1230		
1.4	Report on the workshop on APE (Aqua-planet Experiment) Reading, UK	D. Williamson
1.5	"Transpose" AMIP: status of project	D. Williamson
1.6	Progress with Stretched-Grid Model Intercomparison Project (SGMIP)	M. Déqué
1.7	Regional Climate modelling and future workshop	C. Jones
1.8	An overview of recent developments/activities in monthly and seasonal forecasting.	M. Déqué and participants
1.9	Recent developments at operational forecasting Centres	Participants
1230-1330	**Lunch**	
1330-1530		
	Recent developments at operational forecasting Centres (continued)	Participants
1530-1545	**Coffee**	
1545-1730		
	Recent developments at operational forecasting Centres (continued)	Participants

Thursday 26 October

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
2.1	Relevant activities under CAS auspices	M. Béland
2.2	General report on THORPEX: including TIGGE, IPY and other WG meetings	D. Burridge
2.3	THORPEX Pacific-Asia Regional Campaign	D. Parsons
2.4	THORPEX and WCRP	G. Brunet
2.5	THORPEX Regional plans	D. Burridge K. Puri
1045-1100	**Coffee**	
1100-1230		
2.6	Pan-WCRP Year of tropical convection in the THORPEX context, the role of very high resolution regional forecast experiments	D. Waliser Chair, WGNE and Participants
2.7	AMMA: progress and developments	J. Polcher
2.8	Data assimilation activity within WCRP. Observing systems and results of OSEs, also CBS work.	A. Lorenc
2.9	Scientific progress, plans and new initiatives at NCAR	T. Killeen (science talk)
1230-1330	**Lunch**	
1330-1530		
2.10	Overview of SURFA and WGSF	C. Fairall
2.11	Surface flux comparisons of NWP and ship data	E.C. Kent
2.12	Satellite-derived fluxes and comparisons with NWP data	A. Bentamy
2.13	Activities at NCDC	H. Zhang
1530-1545	**Coffee**	
1545-1730		
	WGSF/SURFA session (continued as needed)	

Friday 27 October

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
3.1	Predicting the Earth System across scales	J. Hack (science talk)
3.2	Trends in performances of the models of the main operational forecasting centres	M. Miller
3.3	Inter-comparison of typhoon track forecasts	Y. Takeuchi
1045-1100	**Coffee**	
3.4	Report on the activities of the Joint Working Group on Verification	B. Brown
3.5	Prospects for verification of cloud forecasts	B. Brown Participants
1230-1330	**Lunch**	
1330-1530		
3.6	Verification and comparison of precipitation forecasts at various centres	D. Majewski, M. Déqué, M. Iredell, K. Puri, Y. Takeuchi
3.7	Progress in reanalysis activities at NCEP, ECMWF, JMA and CPTEC	M. Iredell, M. Miller Y. Takeuchi, P. Silva Dias
1530-1545	**Coffee**	
1545-1700		
3.8	Plans or results from national climate or global change modelling programmes, in particular updated reports on the "Earth Simulator Programme" in Japan; steps towards a unified weather prediction and climate simulation framework in the USA, PRISM	Y. Takeuchi J. Hack K. Puri A. Lorenc and others as appropriate
3.9	Discussion on future systematic errors workshop/meeting	Depends on earlier discussion
3.10	Outstanding items and actions	Chair, V. Satyan
3.11	Arrangements for publication of the 2007 edition of "Research Activities in Atmospheric and Oceanic Modelling"	G. Brunet V. Satyan
	WGNE Web page	V. Satyan
	Venue for WGNE 2007	Chair WGNE
	Close of session	

WGNE List of Operational Global Numerical Weather Prediction Systems (as of January 2007)

Forecast Centre (Country)	Computer (Peak in TFlop/s)	High resolution Model (FC Range in days)	Ensemble Model (FC Range in days)	Type of Data Assimilation
ECMWF (Europe)	IBM p690, 2x68 nodes (20)	T_L799 L91 (10)	T_L399 L62; (10) T_L255 L62 (+5)	4D-Var (T_L255)
Met Office (UK)	NEC SX6, 34 nodes NEC SX8 21 nodes (5)	~40km L50 (6)	~90km L38; M24 (3)	4D-Var (~120km)
Météo-France (France)	Fujitsu VPP5000 (1.2)	T_L358 (C2.4) L46 (3)	T_L358(C2.4) L46; M11 (2.5)	4D-Var (T_L149)
DWD (Germany)	IBM p575; 2x52 nodes (2x3.1)	40 km L40 (7)	No global EPS	3D-OI
HMC (Russia)	Itanium 4x4; Xeon 2x4 (0.10; 0.028)	T85 L31 (10); 0.72°x0.9° L28 (10)	No global EPS	3D-OI
NCEP (USA)	IBM pSeries 5 575 (18)	T382 L64 (7.5) T190 L64 (16)	T126 L28; M61 (14/cycle) (16)	3D-Var (T382)
Navy/FNMOC/NRL (USA)	SGI and IBM (800 proc) (3.2)	T239 L30 (6)	T119 L30; M10 (10)	3D-Var
CMC (Canada)	IBM p575, 2X40 nodes (9.6)	~35 km L58 (10)	SEF (T_L149); GEM (1.2°); M16 (16)	Det: 4D-Var (1.5°, 0.9°) EPS: EnKF M96 (1.2°)
CPTEC/INPE (Brazil)	NEC SX6, 12 nodes (0.768)	T126L28, T213 L42; T126L28 Coupled (15, 7,30)	T126 L28; M15 (15)	3D-Var
JMA (Japan)	Hitachi SR11000-K1, 2*80 nodes (21.5)	T_L319 L40 (9)	T_L159L40; M51 (9)	4D-Var (T106)
CMA (China)	IBM p655/p690: 21 (SW1: 0.384)	T213 L31 (10)	T106 L19; M33 (10)	3D-OI
KMA (Korea)	Cray X1E-8/1024-L (18.4)	T426 L40 (10)	T213 L40; M32 (10)	3D-Var
NCMRWF (India)	Cray X1E-64 processor (1.1)	T254 L64 (7)	T80 L18; M8 (7)	3D-Var
BMRC (Australia)	NEC SX6, 28 nodes (1.792)	T_L239 L29 (10)	T_L119 L19; M33 (10)	3D-OI

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

Part I: Computer (Peak Performance in TFlop/s)

Note: Sustained performance is 6 – 15% of peak for RISC and 25 – 35% for vector computers

Forecast Centre (Country)	2007	2008	2009	2010	2011	2012
ECMWF (Europe)	2x18.2	2x18.2	2x18.2+?	tbd	tbd	tbd
Met Office (UK)	5	5	40	40	80	tbd
Météo-France (France)	1.2	9	9	28	28	tbd
DWD (Germany)	2x3.1	2x25	2x25	2x25+	2x25+	2x25+
HMC (Russia)	0.1	9	9	9	tbd	tbd
NCEP (USA)	2x18	2x18	2x18	2x54	2x54	2x180
Navy/FNMOC/NRL (USA)	5	8	12	15	16	20
CMC (Canada)	2x4.5	2x4.5	2x4.5	tbd	tbd	tbd
CPTEC/INPE (Brazil)	0.768	20	40	40	40	40
JMA (Japan)	2x10.75	2x10.75	2x10.75	2x10.75	tbd	tbd
CMA (China)	IBM-21 SW1-0.384	IBM-21 SW1-0.384	IBM-21 SW2-50?	IBM-21 SW2-50?	IBM-21 SW2-50?	IBM-21 SW2-50?
KMA (Korea)	2x9.2	2x9.2	18.4 50	18.4 50	2x50	2x50
NCMRWF (India)	1.5	10	10	10	20	tbd
BMRC (Australia)	1.792	Upgrade planned	tbd	tbd	tbd	tbd

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)	2007	2008	2009	2010	2011	2012
ECMWF (Europe)	T_L799 L91	T_L799 L91	T_L799 L91	T_L1279 L91	T_L1279 L130	T_L1279 L130
Met Office (UK)	40 km L70	40 km L70	25 km L90	25 km L90	25 km L90	tbd
Météo-France (France)	T538C2.4 L70	T538c2.4 L70	T538c2.4 L70	T799c2.4 L90	T799c2.4 L90	tbd
DWD (Germany)	40 km L40	20 km L60	20 km L60	20 km L60	15 km L70	15 km L70
HMC (Russia)	T85 L31 ; 0.72°x0.9° L28	T169 L31; 0.72°x0.9° L31	T169 L31; 0.4°x0.5° L48	T339 L63; 0.4°x0.5° L48	tbd	tbd
NCEP (USA)	T382 L64 (7.5) T190 L64 (16)	T382 L64 (7.5) T190 L64 (16)	T382 L64 (7.5) T190 L64 (16)	20 km L90	20 km L90	tbd
Navy/FNMOC/NRL (USA)	T239 L30	T319 L36	T319 L48	T383 L48	T511 L64	T511L64
CMC (Canada)	35 km L58	35 km L80	35 km L80	35 km L80	15 km L80	15 km L80
CPTEC/INPE (Brazil)	40 km L64	30 km L96	20 km L96	20 km L96	10 km L96	10 km L96
JMA (Japan)	T_L959 L60	T_L959 L60	T_L959 L60	T_L959 L60	tbd	tbd
CMA (China)	T213 L31	T213 L60 GRAPES 50 km L61	T_L639 L60 GRAPES 50 km L61 ?	GRAPES 40 km L61 ?	GRAPES 40 km L81 ?	GRAPES 40 km L81 ?
KMA (Korea)	T426 L60	T_L799 L91	T_L799 L91	T_L799 L91	T_L 1023 L100	T_L 1023 L100
NCMRWF (India)	T254 L64	T254 L64	T382 L64	T382 L64	T382 L64	tbd
BMRC (Australia)	T_L239 L60 test Met Office UM (ACCESS) (10)	Met Office UM (ACCESS)	tbd	tbd	tbd	tbd

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)	2007	2008	2009	2010	2011	2012
ECMWF (Europe)	T399/T255 L62; M 51; 15; change of res. at day 10	T399/T255 L62; M 51; 15; change of res. at day 10	T399/T255 L62; M 51; 15; change of res. at day 10	T639L91?? Change of resolution to be determined	T639L91?? Change of resolution to be determined	tbd
Met Office (UK)	~90 km L38; M24; 15	~90 km L38; M24; 15	~60 km L90; M24; 15	~60 km L90; M24; 15	~60 km L90; M24; 15	tbd
Météo-France (France)	T538c2.4 L70; M11; 3	T538c2.4 L70; M11; 3	T538c2.4 L70; M11; 3	T799c2.4 L70; M11; 3	T799c2.4 L70; M11; 3	tbd
DWD (Germany)	No global EPS	tbd	tbd	tbd	tbd	tbd
HMC (Russia)	No global EPS	T85 L31; M20; 10	T85 L31; M30; 10	T85 L31; M20; 10	tbd	tbd
NCEP (USA)	T126 L28; M61; 14/cycle; 16 days	T126 L64; M88; 20/cycle; 16 days	T190 L64; M88; 20/cycle; 16 days	60 km L90; M88; 16	60 km L90; M88; 16	tbd
Navy/FNMOC/NRL (USA)	T159 L30; M16; 10	T239 L36; M16; 10	T239 L36; M32; 15	T239 L48; M32; 15	T319 L64; M32; 15	T319L64: M32;15
CMC (Canada)	GEM(0.9), M20; 16	GEM 400x300 L28 M20 16	GEM 400x300 L45 M20 16	GEM 500x375 L45 M20 16	GEM 500x375 L45 M20 16	GEM 600x450 L45 M20 16
CPTEC/INPE (Brazil)	80 km, L42, M15; 15	60 km, L42, M25; 15	50 km, L42, M40; 15	50 km, L42, M50; 15	40 km, L64, M60; 15	40 km, L64, M60; 15
JMA (Japan)	T_L319 L60; M51; 9	T_L319 L60; M51; 9	T_L319 L60; M51; 9	T_L319 L60; M51; 9	tbd	tbd
CMA (China)	T213 L31; M15 (BGM, 10)	T213 L31; M15 (BGM, 10)	T213 L31; M30 (BGM, 10)?	T213 L31; M15 (BGM, 10) GRAPES 50 km M40, (SV, 10)?	T213 L31; M15 (BGM, 10) GRAPES 50 km M40, (SV, 10)?	T213 L31; M15 (BGM, 10) GRAPES 50 km M40, (SV, 10)?
KMA (Korea)	T213 L40; M34; 10	T213 L40; M48; 10	T213 L40; M48; 10	T_L 511 L70; M80; 10	T_L 511 L70; M80; 10	T_L 511 L70; M80; 10
NCMRWF (India)	T80 L18; 8; 7	T80 L64; 16; 7	T80 L64; 16; 7	T170 L64; 16; 7	T170 L64; 16; 7	T80 L18; 8; 7
BMRC (Australia)	T_L119 L19; M33 (10)	New system (ACCESS)	tbd	tbd	tbd	tbd

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems
Part II: Global Modelling

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

Forecast Centre (Country)	2007	2008	2009	2010	2011	2012
ECMWF (Europe)	4D-Var; T_L799 with T255 final inner loop; L91	4D-Var; T_L799 with T255 final inner loop; L91	4D-Var; T_L799 with T255 final inner loop; L91	4D-Var; T_L1279 with T_L399 final inner loop; L91?	4D-Var; T_L1279 with T_L399 final inner loop; L130?	4D-Var; T_L1279 with T_L399 final inner loop; L130?
Met Office (UK)	4D-Var; 120 km; L70	4D-Var; 120 km; L70	4D-Var; 75 km; L90	4D-Var; 75 km; L90	4D-Var; 75 km; L90	tbd
Météo-France (France)	4D-Var; T224; L70	4D-Var; T224; L70	4D-Var; T224: L70	4D-Var; T350; L90	4D-Var; T350; L90	tbd
DWD (Germany)	3D-Var; 40 km; L40	3D-Var; 20 km; L60	Ensemble based?	Ensemble based?	Ensemble based?	Ensemble based?
HMC (Russia)	OI; 0.9x0.72; L28	OI; 0.9x0.72; L28	3D-Var	tbd	tbd	tbd
NCEP (USA)	3D-Var; T382; L64	Advanced-Var; T382; L64	Advanced-Var; T382; L64	Adv or 4D-Var; 20 km	Adv or 4D-Var; 20 km	tbd
Navy/FNMOC/NRL (USA)	3D-Var; T239; L30	3D-Var; T319; L36	4D-Var T239L36 outer lp T159L36 inner lp	4D-Var T239L48 outer lp T159L48 inner lp	4D-Var T319L64 outer lp T159L64 inner lp	4D-Var T319L64 outer lp T239L64 inner lp
CMC (Canada)	4D-Var; 1.5°, 35 km; L58	4D-Var; 0.9°, 35 km; L80	4D-Var/EnKF?	4D-Var/EnKF?	4D-Var/EnKF?	tbd
CPTEC/INPE (Brazil)	3D-Var; 60 km	LENKF; 40 km	LENKF; 40 km	LENKF; 40 km	LENKF; 20 km	LENKF; 20 km
JMA (Japan)	4D-Var; T159; L60	4D-Var; T_L319; L60	4D-Var; T_L319; L60	4D-Var; T_L319; L60	tbd	tbd
CMA (China)	SSI GRAPES_3DVar	SSI GRAPES_3DVar	SSI GRAPES_3DVar	GRAPES_4DVar	4DVAR/EnKF?	4DVAR/EnKF?
KMA (Korea)	3D-Var;	3D-Var;	3D-Var	4D-Var	4D-Var	4D-Var
NCMRWF (India)	3D-Var; T254; L64	3D-Var; T254; L64	3D-Var; T382; L64	3D-Var; T382; L64	4d-Var ?	tbd
BMRC (Australia)	3D-OI test Met Office 4D-Var (ACCESS)	Met Office 4D-Var (ACCESS)	tbd	tbd	tbd	tbd

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems

Part III: Regional Modelling

a) Deterministic Model (Number of gridpoints, resolution, number of layers)

Forecast Centre (Country)	2007	2008	2009	2010	2011	2012
ECMWF (Europe)	-	-	-	-	-	-
Met Office (UK)	600*360; 12 km; L70 288*360; 4 km; L60	600*360; 12 km; L70 288*360; 4 km; L60	600*360; 12 km; L90 768*960; 1.5 km; L80	600*360; 12 km; L90 768*960; 1.5 km; L80	600*360; 12 km; L90 768*960; 1.5 km; L80	tbd
Météo-France (France)	300x300; 9.5 km; L60	500x500; 2.5 km; L60	500x500; 2.5 km; L90	800x800; 2.5 km; L90	800x800; 2.5 km; L90	tbd
DWD (Germany)	665x657; 7 km; L40 421x461; 2.8 km; L50	665x657; 7 km; L40 421x461; 2.8 km; L50	665x657; 7 km; L40 421x461; 2.8 km; L50	665x657; 7 km; L40 421x461; 2.8 km; L50	tbd	tbd
HMC (Russia)	Var. Res.; 30 km over Russia; L28	Var. Res.; 30 km over Russia; L28	tbd	tbd	tbd	tbd
NCEP (USA)	606x1067; 12km; L60 360x809; 5 km; L35	726x1287; 12km; L60 720x1011; 4 km; L50	726x1287; 12km; L60 720x1011; 4 km; L50	8 km; L65 3 km; L55	8 km; L65 3 km; L55	5 km; L70 2 km; L60
Navy/FNMOC/NRL (USA)	45/15/5 km; L40	27/9/3 km; L40	27/9/3 km; L60	27/9/3 km; L60	9/3/1 km; L60	9/3/1 km; L60
CMC (Canada)	Var/LAM?; 15 km; L58	10 km; L58 (2/D) 2 2.5°; L58	10 km; L58 (4/D) 2 2.5°; L58	10 km; L? (4/D) 5 2.5°; L?	tbd	tbd
CPTEC/INPE (Brazil)	335 x 701, 15 km; L50	1001x2101, 5 km; L60	1001x2101, 5 km; L80	1001x2101, 5 km; L80	2001x4201, 2.5 km; L80	2001x4201, 2.5 km; L80
JMA (Japan)	721x577; 5 km; L50	721x577; 5 km; L50	721x577; 5 km; L50	721x577; 5 km; L50	tbd	tbd
CMA (China)	601x401, GRAPES-15kmL40	1200x800, GRAPES-5kmL50	1200x800, GRAPES-5kmL50	2100x1300, GRAPES-2.5kmL60	2100x1300, GRAPES-2.5kmL60	2100x1300, GRAPES-2.5kmL60
KMA (Korea)	171x191; 30 km; L40 178x160; 10 km; L40 242x330; 5 km; L40	513x573; 10 km; L40 242x330; 5 km; L40	513x573; 10 km; L40 242x330; 5 km; L70	513x573; 10 km; L40 242x330; 5 km; L70	513x573; 10 km; L40 242x330; 5 km; L70	513x573; 10 km; L40 242x330; 5 km; L70
NCMRWF (India	36km; L31	36km; L31	10km, L60	10km, L60	10km, L60	tbd
BMRC (Australia)	0.375°, L61 0.10°, L61 0.05°, L61 test Met Office UM ACCESS	Met Office UM (ACCESS)	tbd	tbd	tbd	tbd

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems

Part III: Regional Modelling

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

Forecast Centre (Country)	2007	2008	2009	2010	2011	2012
ECMWF (Europe)	-	-	-	-	-	-
Met Office (UK)	25 km; M24; 2	25 km; M24; 2	16 km; M24; 2	16 km; M24; 2	16 km; M24; 2 1.5 km; M6; 1	tbd
Météo-France (France)	No regional EPS	10km; M11; 3	10km; M11; 3	2.5 km; M11; 1	2.5 km; M11; 1	tbd
DWD (Germany)	No regional EPS	No regional EPS	2.8 km; M15; 1	2.8 km; M15; 1	2.8 km; M20?; 1	2.8 km; M20?; 1
HMC (Russia)	No regional EPS	No regional EPS	No regional EPS	No regional EPS	No regional EPS	No regional EPS
NCEP (USA)	36 km; M21	32 km; M21	32 km; M21	26 km; M25	26 km; M25	20 km; M25
Navy/FNMOC/NRL (USA)	45/15 km; M15; 3	45/15 km; M15; 3	45/15 km; M30; 3	45/15/5 km; M30; 3	45/15/5 km; M30; 3	45/15/5 km; M30; 3
CMC (Canada)	No regional EPS	15 km; M16; 2	15 km; M16; 2	10 km; M16; 2	10 km; M10; 2	tbd
CPTEC/INPE (Brazil)	30 km; M11; 5	15 km; M15; 5	15 km; M21; 5	15 km; M21; 5	10 km; M21; 5	10 km, M21, 5
JMA (Japan)	No regional EPS	No regional EPS	No regional EPS	No regional EPS	tbd	tbd
CMA (China)	GRAPES-15 km, M11, 2.5	GRAPES-15 km, M15, 2.5	GRAPES-15 km, M17, 2.5	GRAPES-10 km, M17, 2.5	GRAPES-10 km, M21, 2.5	GRAPES-10 km, M21, 2.5
KMA (Korea)	No regional EPS	No regional EPS	No regional EPS	30 km; M20; 2	10 km; M20; 2	10 km; M20; 2
NCMRWF (India	No regional EPS	No regional EPS	No regional EPS	No regional EPS	No regional EPS	No regional EPS
BMRC (Australia)	tbd	tbd	tbd	tbd	tbd	tbd

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems

Part III: Regional Modelling

c) Regional Data Assimilation Scheme (Type and resolution)

Forecast Centre (Country)	2007	2008	2009	2010	2011	2012
ECMWF (Europe)	-	-	-	-	-	-
Met Office (UK)	4D-Var, 36 km 3D-Var, 4 km	4D-Var, 36 km 3D-Var, 4 km	4D-Var, 24 km 3D-Var, 1.5 km	4D-Var, 24 km 3D-Var, 1.5 km	4D-Var, 24 km 4D-Var, 4.5 km?	tbd
Météo-France (France)	3D-Var; 9.5 km	3D-Var; 2.5 km	3D-Var; 2.5 km	4D-Var; 2.5 km	4D-Var; 2.5 km	tbd
DWD (Germany)	Nudging; 7 km Nudging; 2.8 km	Nudging; 7 km Nudging; 2.8 km	Ensemble based?	Ensemble based?	Ensemble based?	Ensemble based?
HMC (Russia)				3D-Var	3D-Var	tbd
NCEP (USA)	3D-Var; 12 km	Advanced-Var; 12 km	Advanced-Var; 12 km	Adv or 4D-Var; 8 km	Adv or 4D-Var; 8 km	Adv or 4D-Var; 5 km
Navy/FNMOC/NRL (USA)	3D-Var; 45/15/5 km	3D-Var; 27/9/3 km	3D-Var; 27/9/3 km	3D-Var; 27/9/3 km	4D-Var 9/3/1 km	4D-Var 9/3/1 km
CMC (Canada)	3D-Var; 10, 40 km; L58	4D-Var; 10, 40 km; L58	tbd	tbd	tbd	tbd
CPTEC/INPE (Brazil)	3D-Var; 30 km	LENKF; 20 km	LENKF; 20 km	LENKF; 20 km	LENKF; 10 km	LENKF; 10 km
JMA (Japan)	4D-Var, 10 km	4D-Var, 10 km	4D-Var, 10 km	4D-Var, 10 km	tbd	tbd
CMA (China)	GRAPES-3DVAR, 30 km	GRAPES-4DVAR, 30 km?	GRAPES-4DVAR, 20 km?	GRAPES-4DVAR, 20 km or EnKF?	GRAPES-4DVAR, 15 km or EnKF	GRAPES-4DVAR, 15 km or EnKF
KMA (Korea)	3D-Var; 10, 5 km	3D-Var 10, 5 km	3D-Var 10 km	4D-Var 10 km	4D-Var 10 km	4D-Var 10 km
NCMRWF (India	3D-Var	3D-Var	3D-Var	3D-Var	4D-Var?	tbd
BMRC (Australia)	3D-OI test Met Office 4D-Var (ACCESS)	Met Office 4D-Var (ACCESS)	Met Office 4D-Var (ACCESS)	tbd	tbd	tbd

APPENDIX E

List of variables for the SURFA project
WGNE, December 2006

1. Grid

All fields must be provided on a regular latitude – longitude grid at a grid spacing of 0.25° x 0.25°. The scanning mode must be from 90°N, 0°E (index (1,1)) to 90°S, 0.25°W (index (1440, 721)), the first index running from West to East, the second from North to South. Each field comprises 1440x721 grid points. The data have to be coded in WMO GRIB1 code (http://www.wmo.ch/web/www/WDM/Guides/Guide-binary-2.html#Section1).

2. Initial time and forecast ranges

All forecasts must start at 12 UTC.
For accumulated values (where the accumulation starts at the 0-h forecast) and for instantaneous values (which are valid at the given forecast range) the following forecast ranges have to be provided:
+12h, 15h, +18h, +21h, +24h, +27h, +30h, +33h, +36h.
Each forecast range has to be in a separate file.

3. List of constant fields (to be provided only for the 0-h forecast range)

Name	**Variable**	**Element No. in GRIB1**	**Level Type**	**Level**	**Unit**
ORO	model orography (geometric height above msl)	8	1	-	m
LSM	land sea mask (1: land, 0: water/sea ice)	81	1	-	Fraction

4. List of instantaneous variables

Name	**Variable**	**Element No. in GRIB1**	**Level Type**	**Level**	**Unit**
PS	surface pressure (on model orography)	1	1	-	Pa
ALBEDO	surface albedo (short wave radiation)	84	1	-	%
SEAICE	sea ice concentration (1: sea ice, 0: open water)	91	1	-	Fraction
U_10M	zonal wind component at 10 m above surface	33	105	10	m/s
V_10M	meridional wind component at 10 m	34	105	10	m/s
T_2M	temperature at 2 m above surface	11	105	2	K
TD_2M	dew point temperature at 2m above surface	17	105	2	K
T_SKIN	Skin temperature (at the interface atmosphere – surface)	11	1	-	K
TS_TOP	Over land: First (top) layer soil temperature, over water: sea surface temperature	85	111	0	K
W_SNOW	water equivalent of accumulated snow depth	65	1	-	kg/m^2
CLCH	high cloud cover (between 0 and 400 hPa)	75	1	-	%
CLCM	medium cloud cover (between 400 and 800 hPa)	74	1	-	%
CLCL	low cloud cover (between 800 hPa and surface)	73	1	-	%
TQV	column water vapor (precipitable water)	54	1	-	kg/m^2
TQC	column cloud water (liquid)	76	1	-	kg/m^2
TQI	column cloud ice (frozen)	58	1	-	kg/m^2

5. List of accumulated variables (since start of the forecast)

Name	Variable	Element No. in GRIB1	Level Type	Level	Unit
LS_PREC	Large-scale precipitation	62	1	-	kg/m^2
CO_PREC	convective precipitation	63	1	-	kg/m^2
LS_SNOW	Large-scale snow	79	1	-	kg/m^2
CO_SNOW	convective snow	78	1	-	kg/m^2
SO_DOWN	solar (short-wave) radiation flux downward at the surface	116	1	-	J/m^2
SO_NET	Net short-wave radiation flux at the surface	111	1	-	J/m^2
TH_DOWN	thermal (long-wave) radiation flux downward at the surface	115	1	-	J/m^2
THO_NET	Net thermal radiation at the surface	112	1	-	J/m^2
U_MOM_FL	Momentum flux, u component	124	1	-	Ns/m^2
V_MOM_FL	Momentum flux, V component	125	1	-	Ns/m^2
SH	surface sensible heat flux	122	1	-	J/m^2
LH	surface latent heat flux	121	1	-	J/m^2
EVAP	evaporation	57	1	-	kg/m^2

ATTENTION
Sign convention for the fluxes of radiation or other quantities: **Positive** if **downward!**
Net fluxes are the sum of upward and downward fluxes.

6. List of optional variables (depending on availability)

Name	Variable	Element No. in GRIB1	Level Type	Level	Unit
TH_DO_CS	downward thermal clear sky flux (at surface)	163	1	-	J/m^2
SO_DO_CS	downward solar clear sky flux (at surface)	161	1	-	J/m^2
PBL_DEPTH	PBL depth	221	1	-	m

7. File names

The following naming convention for the GRIB1 files containing the data is proposed:

CENT_YYYYMMDDGG_xx

where CENT is the center identifier, e.g. ECMWF,

YYYYMMDDGG is the initial time of the forecast (YYYY: year, MM: month, DD: day, GG: time, i.e. 12 (UTC))

xx: forecast range in hours.

APPENDIX F

Workshop on Systematic Errors in Climate and NWP Models
San Francisco, February 12-16, 2007
M. Miller

Introduction and summary

This was the Third JSC/CAS-sponsored WGNE workshop on model systematic errors, the previous ones being in Toronto in 1988 and Melbourne in 2000. On this occasion PCMDI provided substantial logistic and financial help for this well-attended meeting (~170 people). The workshop was structured to study model errors across multiple timescales, from NWP to climate integrations. Errors in both atmospheric and coupled ocean-atmosphere models were high on the agenda. The workshop was structured with a limited number of presentations, a large number of posters with plenty of time to view and discuss them, a number of breakout groups to discuss various issues, and a plenary session to review and discuss the meeting as a whole and to identify and address the salient themes emerging from the workshop.

Systematic errors in climate and weather prediction models are evident on a wide range of space and time scales. The root causes of these errors are often difficult to address, because the many complex processes and phenomena of the climate system interact, both in the real world and in model simulations. A key motivation for this workshop was to bring together a variety of diagnostic approaches, with the expectation that awareness and understanding of the causes of systematic errors would be increased, and lead to a more coherent strategy for future advances.
There were several main issues which emerged from the presentations and the discussions of the breakout groups:

The importance of metrics. In the NWP community, standard metrics that gauge the skill of forecasts have been routine for years. There is now increased interest in developing performance metrics for climate models. Establishment of a set of standard metrics could encourage all modelling groups to provide at least a minimal standardized summary of model strengths and weaknesses, which would facilitate monitoring and documenting of changes in model performance. A hierarchy of metrics could be designed to help assess the simulation of a variety of processes and phenomena on a range of time and space scales. Although work on optimizing the utility of metrics is in its early stages, it is widely believed that the metrics of most value will almost certainly be application dependent. Community-based efforts are underway to explore and establish a set of standard metrics relevant for climate models. The IPCC-AR4 archive typically includes results from more than thirty models and it is evident (both a priori and on looking at the model output) that not all models are created equal! The climate modelling community have traditionally been reluctant to “rank” model performance, but maybe the workshop has encouraged them to be more open about where they stand. Metrics may also be able to guide the interpretation of the model results - some models may be given more weight when making predictions of future climate change. This is a difficult and sometimes controversial area yet it is essential to perform weighting. The issue of appropriate metrics (typically based on simulation of past and present climate) is an area of ongoing work. Metrics that assess phenomena are important for intercomparison but weighting climate predictions really needs to be based on a more systematic assessment of model physics/dynamics.

The importance of short range forecasts from NWP analyses. Increasingly, our confidence in climate simulations (decades and longer) is dependent on how well they perform on much shorter time scales. What is wrong in a 100 year climate run is often going perceptibly wrong after 5 days of integration, because many errors are in the treatment of fast processes (boundary layer, convection, radiation, clouds). Short integrations from realistic initial conditions allow both detailed comparison with the latest observational data and diagnosis of the processes and tendencies in the model. This is a much simpler and cheaper experimental framework than that of a fully coupled ocean-atmosphere general circulation model (OAGCM) run for decades to centuries. A number of climate modelling groups are beginning to use such techniques (as championed by WGNE for several years with the Transpose AMIP project)

Experience thus far with several climate models in this mode has shown that the growth of systematic errors can be so prominent that residual problems of ‘spin-up’ due to imcompatibilities between analysis and forecast model are not critical for many of these studies when using the highest quality NWP analyses. Undoubtedly there is a limit to this especially when looking at surface or near-surface issues and there are opportunities for research in this area. The ability to simulate the observed climate record over long periods still remains a crucial model test.

The difficulties of accurate simulation of the diurnal cycle. It clearly stretches the capability of current models to realistically capture the coupled and local physical processes that constitute the diurnal cycle. It is generally poorly simulated in GCMs, but models with very high horizontal resolution (e.g., less than 4km) do a little better, and cloud resolving models (CRMs) also do well with sufficient resolution. Poor simulation of the diurnal cycle impacts weather forecasts, but it is also important for climate via the Earth's radiation balance or the terrestrial carbon budget. It remains unclear what impact this deficiency might have on climate change projections. Climate models have yet to be run at convection-resolving resolutions, however, careful experimentation at high enough resolutions to capture cloud systems (gridlengths~10kms) may benefit parameterization development in ways that could lead to better simulation of the diurnal cycle at typical climate resolutions. It was noted that the impact of explicitly resolving deep convection (gridlengths~1km) in a climate simulation remains to be seen and is a clear challenge in the coming decade. Results showing that the diurnal cycle had a strong impact on the momentum budget in the equatorial ocean suggest that the diurnal cycle of forcing might be important in ocean data assimilation systems. Much improved complete physics packages are needed to better handle these highly coupled situations involving a range of time and space scales.

The value of running suitably initialized coupled models in forecast mode over seasonal timescales. This is analogous to atmosphere-only runs from NWP, but allows examination of somewhat slower processes, particularly those associated with ENSO and the seasonal cycle in the tropics. Relatively short coupled runs are also natural tools for comparing modelled and observed cloud/SST interactions. An analysis of ENSO in the AR4 models shows that ENSO amplitude has a big scatter - many models are overly strong, quite a few models are overly weak, very few models look anything like reality. The experience of seasonal forecasters is that simple initialization with wind and SST data was capable of giving very good ENSO forecasts, and that by selecting a relatively limited set of initial dates a model's ability to handle a range of El Niño / La Niña / neutral conditions could be assessed. WGSIP will try to provide some "recommended" procedures and dates through the auspices of CLIVAR.

An outstanding challenge in modelling the MJO and monsoons was that active-break transitions are not forecast, and typically not represented in GCMs. The broader implications of this is that this limits medium-range and seasonal predictability, as well as ENSO forecasting, and that the simulation of extreme events is compromised. To date, many of the root causes behind errors in simulating the monsoon have not been identified.

The need for much higher resolution. The highest resolution simulations in AR4 are around T85, but the sentiment of the workshop suggested that the argument supporting much higher resolutions is now overwhelming, with several presentations demonstrating positive impacts of much higher resolution both from a dynamical and physical viewpoint. Recent experiments with high-resolution (60-90km) coupled models show that, in the tropics, the full potential of high resolution emerges if coupled models are used. Moreover, it seems crucial that high-resolution is used in both the ocean and the atmosphere.

Further workshop conclusions

There are a number of persistent model errors for which there is limited understanding of the underlying processes, and for which there are no clear solutions. Model errors affecting intermediate time-scales (e.g., monsoons and the Madden Julian Oscillation) are often subtle, and the processes responsible for them need not be local. On longer time-scales, the El Niño Southern Oscillation (ENSO) is a dominant mode of climate variability, and there continue to be simulation errors in its structure, frequency and amplitude. Other coupled atmosphere-ocean modes of variability that require improvement include the Pacific Decadal Oscillation and the Atlantic Multi-decadal Oscillation. Increasing the use of climate models for seasonal time-scale experimentation is a practical recommendation from this workshop to tackle some modelling deficiencies associated with these modes of variability.

Although there is a growing appreciation of how the climate may change, century-long simulations are still very uncertain. How the global cloud fields respond to small changes in the Earth's energy budget is a key issue, with systematic errors over the sub-tropical oceans, for example, being responsible for substantial uncertainty.

The development of Earth System Models brings new challenges not least via their need for greatly increased resources, both computational and human. It was suggested that this posed a genuine threat to the necessary studies required for minimizing existing major systematic errors evident in less complex models, and without which, reliable/stable ESM simulations will pose a major challenge for some time.

The extent to which systematic errors limit the veracity of climate model projections is a key issue. Some systematic errors are clearly sensitive to horizontal resolution, while other errors seem not to be, and are presumed to be attributable to deficiencies in the parameterized formulations of unresolved processes. Nevertheless, recent experimentation suggests that current climate model resolutions are significantly too coarse to properly resolve important atmospheric and oceanic phenomena. The exploration of systematic errors should be conducted at much higher resolution than is typical for current global climate models and hopefully high enough to be operating in a numerically convergent regime for the realistic representation of the most important climate phenomena.

Progress will also be aided by emerging observational technologies for crucial physical processes in the climate system (e.g., clouds, aerosols, precipitation, surface energy exchanges), which will help to constrain the formulation of these processes in climate models. New types of data now becoming available such as from the CloudSat/Calipso satellite, will be a great resource for looking at model errors in simulating cloud and rain.

Increased computing resources will undoubtedly accelerate progress in reducing systematic errors in climate models. In this workshop, there were striking examples of how increased atmosphere and ocean horizontal resolution (substantially higher than typical for climate) can improve the simulation of some key climate processes. However, the meeting consensus was that, while continuing enhancements in computing resources were needed, having the right scientific manpower to work with interfacing the increasingly abundant observational data with the models was just as important. Since progress is at best incremental, there was concern expressed that model development was unattractive to young scientists and that it was difficult to attract and keep young talent in a publication-driven environment.