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(Voeikov Main Geophysical Observatory, St.Petersburg, Russia, 7-11 November 2005)

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The twenty-first session of the CAS/JSC Working Group on Numerical Experimentation (WGNE), held jointly with the ninth session of the GEWEX Modelling and Prediction Panel (GMPP), was kindly hosted by Voeikov Main Geophysical Observatory, St.Petersburg, Russia, from 7 to 11 November. The session was opened at 0900 hours on 7 November by the Chair of WGNE, Dr M. Miller, and of GMPP, Dr J. Polcher. The list of participants in the (joint) session is given in the Appendix A.

In his opening address, Dr Alexander V. Frolov, Deputy Head of Roshydromet, welcomed all participants to the meeting on behalf of Dr Alexander I. Bedritsky, President of the WMO, and spoke of the importance of international co-cooperation in understanding and forecasting of the Earth system. The expertise to exploit the technological advances resides across many nations, international organisations and diverse scientific disciplines. At present, a number of international research projects are under way – THORPEX, IPY and GEOSS. Joint session of WGNE and GMPP provides a unique opportunity for deliberations on the challenges that are facing the meteorological community and for identifying how recent scientific and technological progress can offer feasible solutions in meeting the demands of the NMHS. Dr V. Kattsov, the local host and member, WGNE, also welcomed the participants.

On behalf of all participants, Dr Miller expressed his thanks to Dr A Frolov and Dr V. Kattsov for hosting the joint session of WGNE and GMPP and the excellent arrangements made. He expressed his appreciation to Dr V. Kattsov, well assisted by the staff of Voeikov Main Geophysical Observatory, 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 whilst noting with regret that two WGNE members, Professor P.L. Silva Dias and Dr S.Lord could not be present. He welcomed Dr R. Peterson who was representing Dr Lord. The Chair was pleased to welcome the invited experts.

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

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

Dr V. Satyan briefed the session on the relevant main recommendations from the twenty-fifth session of the JSC, Guayaquil, Ecuador, 14-18 March 2005.

The JSC asked the COPES (Coodinated Observation and Prediction of the Earth System) Task Force to highlight synergy with IGBP in the further revisions of the 'COPES document' and to express more clearly the ways to facilitate the development of applications. The JSC agreed to consider setting up a board of partners (patrons and sponsoring agencies) to consider WCRP user needs, priorities, alignment to operational activities and resources. The JSC accepted with gratitude a French offer to establish a WCRP/COPES support unit in Paris with the prime functions to promote and help implement WCRP's new strategy and to provide assistance to the new WCRP panels, WCRP Observation and Assimilation Panel (WOAP) and WCRP Modelling Panel (WMP).

The JSC asked the Task Force on Seasonal Prediction (TFSP) to document available seasonal predictions. The JSC supported the TFSP workshop proposed for August 2005.

The JSC re-affirmed that WOAP should focus on coordination of project activities and should consider forming a subgroup to deal with Data Management issues given their Pan-WCRP importance.

The JSC welcomed WMP's proposal to engage WGNE and WGCM by having joint meetings with each of them on alternate years.

The JSC welcomed Dr M. Shapiro's list of possible areas for fruitful collaboration between WCRP and THORPEX. In particular, the JSC responded positively to his proposal that the phenomenon of Tropical Convective Organization (TCO) affecting 1-2 week weather prediction (e.g. MJO, diurnal cycle of convection) could be an early target. The JSC recommended that, for this purpose, the TFSP should include a THORPEX representative. The JSC also recommended that WGCM should interact closely with THORPEX, and that WGSIP should get involved in the Demonstration System that THORPEX was planning for 2008/09. The interaction of WGNE with THORPEX was ongoing. The JSC also encouraged all WCRP projects and activities to consider ways of establishing links with THORPEX.

The JSC recognized and encouraged the need for stronger interaction between observational and modelling capabilities, particularly in GEWEX, WGNE and WGCM, for improving understanding and modelling of cloud-radiation feedback processes.

The JSC requested WGNE, WGCM and the wider CLIVAR community to consider how they could collectively accelerate, jointly with CliC, and in close cooperation with the WGOMD, progress in the important areas of sea-ice modelling and related data assimilation. Whilst agreeing that CliC's specific modelling requirements should be organised within its project areas, the JSC stated the need also for a mechanism to provide an overview of those activities. SNOWMIP2 would be a joint activity of CliC, GEWEX and WGNE.

Responding to the question by WGNE of the need for a dedicated Reanalysis Centre, the JSC felt that part of the success of reanalysis projects to date had been due to being able to 'leapfrog' from one centre to another; so it was desirable to continue to have multiple centres engaged in reanalysis. The JSC supported the proposal for promotion and coordination of this activity by WOAP and the plan for a further reanalysis conference to be held at a date convenient to the main reanalysis centres. The JSC strongly supported the proposal to have a workshop on Model Errors sometime in late 2006 or 2007 organized by WGNE possibly jointly with at least CLIVAR (WGCM) and GEWEX.

Regarding SURFA, the intention of WGSF to archive monthly-averaged fluxes at PCMDI was considered useful. OOPC view was that full global flux time series were needed. With the emphasis on the diurnal cycle from GEWEX and CLIVAR, higher time resolution was also needed. WGNE offered to contact NWP centres to arrange for global flux (plus associated data) products to be archived at 4-6 hourly resolution. It was hoped to archive data at one of the GODAE servers, then arrangements would be made to transmit monthly averages to PCMDI. WGSF would work with WGNE and OOPC to re-examine the NWP parameter list to be archived. NWP centres contributing data, would expect some feedback as to how these were being used. The JSC noted that SURFA and SEAFLUX had some overlapping applications. WCRP should consider combining these activities in the future and producing a single gridded ocean surface flux data set (turbulent and radiative fluxes plus precipitation).

First session of the WCRP Modelling Panel (WMP)

Dr V. Satyan briefed the WGNE members on the deliberations and issues arising from the first meeting of the WMP which was held at the UK Met Office, Exeter (5-7 October 2005). The meeting was highly stimulating as the panel debated some of the most important questions facing the modelling community. On October 5, WMP and WGCM had a joint half day session, which included presentations from WGNE, AMIP, TFSP, WGSIP and GMPP. Comprehensive papers on the agenda items discussed at the WMP meeting are available on the WMP website: http://copes.ipsl.jussieu.fr/Organization/COPESStructure/ModellingPanel.html. These included papers by Kinter and Wehner (Computing Issues), Kinter and Taylor (Data Issues), Palmer (Computing Requirements), Miller (High Resolution Models), and Shapiro and Shukla (Unified Models).

WGNE members responded to deliberations at the WMP session. Although the talks given were excellent, the WMP has only European and American members, with no Japanese members, and the session focussed only on computer resources and very high resolution models, which was somewhat over-restrictive. It was pointed out that different approaches are being followed by the European and American modelling groups. The idea of having one high resolution model for seamless prediction across the entire prediction spectrum is very debatable.

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

Dr A Lorenc, WGNE representative on WOAP, reported on the activities of WOAP. WOAP held its session in New York, 1-3 June 2005. The key issues discussed at the session included the need for continuity, reprocessing of data sets, different approaches in reanalysis, data assimilation and data management. WOAP maintains a description of its activities at: http://copes.ipsl.jussieu.fr/Organization/COPESStructure/WGOA.html, including links to reports from task groups on re-analysis and data assimilation in WCRP.

Report on the WCRP Task Force (TFSP) on Seasonal Prediciton

Dr M. Déqué, WGNE representative on the Task Force for Seasonal Prediction (TFSP), reported on its activities. The second meeting of the TFSP took place in Trieste in August 2005. The role of this task force of the COPES program is to:

- determine the extent to which seasonal prediction of the global climate system is possible with currently available models and data
- identify the current limitations of the climate system model and observational data sets used to determine seasonal predictability

- develop a coordinated plan for pan-WCRP climate system retrospective seasonal forecasting experiments

A two-tier seasonal forecast experiment has been defined. The first tier is planned for early 2007 and is based on reforecasting for 4-seasons/year from 1979 to the present. The second tier offers two options: either a 12-months/year from 1979 to the present, or a 4-seasons/year from 1958 to the present. This second tier should be finished in 2008 in connection with stream 2 of the ENSEMBLES European project. The principle of the exercise is that no data beyond the forecast start should be used (in particular, using observed SST like in PRediction Of climate Variations On Seasonal and interannual Timescales (PROVOST) or Dynamical Seasonal Prediction (DSP) is forbidden).

WGNE referred to its earlier invitation to WGSIP to participate in the GCSS/WGNE Pacific cross-section experiments (GPCI), and noted that there has no response in this regard. WGNE asked this matter to be revived.

Relevant activities under Commission for Atmospheric Sciences (CAS)

Dr Z. Lei made a short presentation on CAS activities relevant to WGNE, including major outcomes of the Eighth Session of the Science Steering Committee for WWRP held in Kunming, China, from 26 to 30 October 2005, and the major conferences and workshops organized by WWRP in the year 2004/2005 as well as the future WWRP events. In particular, the Group was informed that an Expert Workshop on the Integration of Air Chemistry Observation with Models Utilizing Chemical Data Assimilation would be held in April 2006. The aim of the workshop is to provide scientific recommendations needed to achieve integration of observing and modelling systems as recommended by the IGACO strategy (the Integrated Global Atmospheric Chemistry Observations Theme Report of IGOS).

WGNE welcomed and strongly supported the proposal for a joint WGNE/WWRP training workshop, at ECMWF, January 2007 (See also Section 5.1).

Eighth session of the WGCM

Dr K.Taylor briefed the session on the issues discussed at the eighth session of the WGCM held at the Met Office, Exeter, UK, 3-5 October 2005. One of the key issues discussed related to data management. As the value of coordinated modeling activities becomes more apparent and benchmark experiments such as AMIP and CMIP become routine parts of the model development cycle, it is desirable to establish a common approach to the sharing of model output. The IPCC exercise offered an opportunity to continue taking steps toward that goal. There are several reasons why scientists found it relatively easy to analyze model output in the IPCC database. The variables collected and the experiments performed were precisely defined, and nearly all the model output was passed through a common set of output routines, which ensured compliance with strict requirements for metadata and data structure. This output software, called the Climate Model Output Rewriter (CMOR), was designed for easy adaptation to the needs of other model intercomparison projects, so that the investment in learning how to meet the IPCC requirements will facilitate participation in future projects. The output in the IPCC database is accompanied by considerable metadata that has been written in accord with the increasingly popular Climate and Forecast (CF) Metadata Conventions for netCDF files. These conventions ensure that the data is largely "self-describing" so that scientists can automatically extract both the data and other information needed to perform analyses. The session recommended that:

- other model intercomparison projects be encouraged to adopt the model output requirements established for the IPCC output.
- the WGCM nurture and promote the CF conventions by endorsing a "white paper" describing the governance and development of these conventions.
- an oversight committee be established.
- a committee be set up to oversee the development of future variable lists for the IPCC exercise.

Acknowledging the lead role played by WGCM in data management, WGNE asked that it might be involved in this WGCM activity as WGNE has been struggling with data management problem for years. There is a need for opening this to wider modelling community, and WGNE would welcome representation on the oversight committee together with some one from the land surface community.

Seventeenth session of the GEWEX Scientific Steering Group

Drs J. Polcher and V. Oevlen briefed WGNE about the new road map of GEWEX activities. During the past year GEWEX has worked towards the development of a roadmap that will lay out the direction for

GEWEX research over the next 7 years. This roadmap has defined five to eight milestones for each GEWEX objective. In most cases the milestones are mutually supportive leading to major results relative to the objective in the 2011 to 2013 time frame. The purpose of the roadmap is to focus on the use of the intellectual and financial resources available to GEWEX and to provide a basis for communicating the coherent nature of GEWEX plans to funding agencies and the science community at large. GEWEX plans to achieve these objectives in the context of specific science questions that are critical for the COPES strategy. The milestones will be achieved by building on the heritage of research results, models and data products that have been developed during the first phase of GEWEX. Key items under the road map included

1. reviving the SURFA idea; collaboration between WGNE and GEWEX

2. enhancing understanding of how energy and water cycle respond to climate change

3. ensuring how progress in GLASS and GABLS reach the models in GMPP; it may be noted that GLACE2 is the joint project between WGNE and GMPP in this context.
4. linking the activities of the land surface modelling to the Hydrological Ensemble Prediction Experiment (HEPEX) and its products

Dr Polcher briefed WGNE on both the Monsoon Workshop and GEWEX conference in Irvine USA, emphasising that the diurnal cycle was a notable science focus.

Dr Polcher briefed the session on the progress and developments in the African Monsoon Multidisciplinary Analysis (AMMA) Project. AMMA aims to improve understanding of the West African Monsoon (WAM) and its variability with an emphasis on daily-interannual timescales. AMMA objectives will be addressed through the international coordination of ongoing activities, basic research, and a multi-year field campaign over West Africa and the tropical Atlantic including a special observing period in spring/summer 2006. AMMA builds on existing surface hydrological measurements available through the GEWEX Coupling of the Tropical Atmosphere and Hydrological Cycle (CATCH) project, and CLIVAR Atlantic Panel observational projects over the ocean. There have been significant reductions in precipitation trends in the 20th century. Large rainfall variations, as much as 80%, have been observed. Dr Polcher informed that the implemetainon plan of AMMA is being finalised and in parts already put in action. He observed that some areas are still weak and need reinforcing.

Dr Polcher referred to the key steps towards preparation of a Forecasters Handbook, and asked WGNE to recommend the request for support from WMO for funding of 130k Euros for the this preparation.

WGNE thanked Drs Polcher and Oevlen for their presentations. WGNE responded to the GEWEX road map of activities as follows:

1. it was agreed that GEWEX and WGNE will collaborate to revive the SURFA idea
2. GLACE-2 will be a joint project between WGNE and GEWEX so that research done under GLASS, GABLES, etc will provide inputs to model improvement under GMPP.
3. Hydrological Ensemble Prediction Experiment (HEPEX) products to be linked with land surface modelling activities.

WGNE discussed the report on the Monsoon Workshop, and noted with some disappointment the Monsoon community's apparent lack of interest/understanding of the important role of NWP in monsoon studies as evidenced by the Workshop's programme. Many of the studies presented use models as 'black boxes', an obvious obstacle to progress in general.

WGNE welcomed and fully supported the proposal to prepare a Forecaster's Handbook. This included workshops in March and June-September 2006, reviews by editorial board, external review of all chapters and editing process, and publication by end 2008. WGNE considered that the Forecasters handbook was a unique opportunity for capacity building. Furthermore, WGNE suggested that the possibility of a relevant WMO training programme should be explored. WGNE also suggested that experts of the Nowcasting Workshops arranged by WMO/WWRP should be invited to the AMMA workshop.

2. PHYSICAL PARAMETRIZATIONS IN MODELS – PROCESSES LINKED TO THE WATER CYCLE IN ATMOSPHERIC MODELS

WGNE's close working relationship with GMPP, 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. The discussions at the joint meetings of WGNE and GMPP, encompassing the GEWEX Cloud System Study (GCSS), the Global Land-Atmosphere System Study (GLASS), the GEWEX Atmospheric Boundary Layer Study (GABLS), the progress of the Coordinated Enhanced Observing Period (CEOP), are described in the reports of the GMPP and the GEWEX Scientific Steering Group to the JSC. The WGNE community provides comprehensive gridded output from global data assimilation systems for CEOP and an increasing number of modeling groups are utilizing CEOP data in research and development activities and this should lead to model intercomparisons during the CEOP period.

Dr J. Polcher briefed WGNE on the progress in GMPP. The GMPP coordinates the activities within GEWEX for improving the representation of the global water and energy cycle processes within Earth System models. These activites are covered by the three groups GCSS, GLASS and GABLS under GMPP. Furthermore, GMPP keeps a close link with large scale models in order to ensure that the activities within the studies are relevant to atmospheric models and that the global modelling community is aware and can take advantage of the improvements proposed in cloud, land-surface and Atmospheric Boundary Layer (ABL) conceptual models. The biannual meeting with the WGNE facilitates a close collaboration with the Numerical Weather Prediction (NWP) community. GMPP panels will meet in October 2006 in Italy. Pan-GMPP interactions will:

- develop link with GEWEX Hydrometeorology Panel/Transferability Working Group (TWG),
- manage some tasks common to all three panels at the GMPP level, and
- work out a common strategy between panels for a GEWEX roadmap.

GMPP will now turn its focus to the coupling of the systems for which the diurnal cycle was chosen as a theme. It is very likely that the climate offers many situations in which the feedbacks between the surface, ABL and clouds are at least as important as the details of how each of them is reproduced. Furthermore, one may wonder how relevant evaluations of land-surface models or cloud systems are without the coupling with the ABL for instance. It is anticipated that diurnal cycle research will address some of the strongest interactions between the land-surface, ABL and clouds. Another major future direction for GMPP involves building stronger links with the general circulation and regional climate modelling communities.

2.1 Cloud parameterizations

GEWEX Cloud System Study (GCSS)

Dr C. Jakob reported on the activities of the GEWEX Cloud System Study (GCSS). GCSS has had a very productive and busy year. The highlight of the year was the 3rd Pan-GCSS meeting on "Clouds, Climate and Models", which was held in Athens, Greece, 16-20 May 2005. The meeting attracted more than 150 scientists and consisted of plenary and poster sessions, meetings of all GCSS working groups and the annual meeting of the GCSS Science Panel. In the plenary sessions the meeting discussed many of the current science issues that GCSS is facing. Apart from general sessions on the role of clouds in the climate system and current developments in cloud modelling, two special plenary sessions were held. These focussed on metrics for moist processes in climate models and the role of precipitation in cloud systems. Both sessions were designed to discuss if and how GCSS should become involved in the important issues of measuring success in climate modelling and in the representation of microphysical processes in general and cloud-aerosol interactions in particular. The outcome of these discussions will be summarized below. The meeting was judged as an overwhelming success both in the programmatic and scientific sense. Bringing together all GCSS groups was shown to be a very efficient way of conducting the "routine" GCSS business, while at the same time discussing more general scientific advances. Including the GCSS Panel meeting as part of the overall meeting also proved very successful since all Panel members had the opportunity to experience GCSS activities first hand. The main results of the meeting, which were approved by the GCSS panel are

- A new Panel portfolio for moist process metrics was approved. This activity will be led by Dr. R. Pincus (NOAA/CDC) and will be conducted in close collaboration with other WCRP groups (WGNE, WGCM).
- A new Panel portfolio for microphysics was approved. This activity will be led by Professor U. Lohmann (ETH, Zurich). The first task in this portfolio is to provide the GCSS panel with an

overview on cloud-aerosol activities conducted in other programs and to highlight collaboration opportunities.

- The Pacific Cross Section Intercomparison has been given Working Group status. The group is led by Dr J. Teixeira (NATO).
- The Deep Convection Working Group will conduct a joint workshop with SPARC to investigate the use of Cloud Resolving Models (CRMs) to study processes in the tropical tropopause layer (TTL). Major recent field experiments conducted in the Australian tropics (Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere (SCOUT), Aerosol and chemical transport in tropical convection (ACTIVE) and Tropical Warm Pool International Cloud Experiment (TWPICE)) will form the basis for the evaluation of the performance of these models in the TTL.
- The next Pan-GCSS meeting will be held in the second half of 2007.
- Dr C. Bretherton (University of Washington) will resign as chair of the Boundary Layer Cloud Working Group and will be replaced by Dr P. Siebesma (KNMI). Dr A. Lock (UKMO) will take over the large eddy simulation (LES) portfolio in the GCSS Panel.

All GCSS working groups continued their activities over the past year. The Boundary Layer Working Group is in the finishing stages of their study of drizzling stratocumulus based on Dynamics and Chemistry of Marine Stratocumulus (DYCOMS). Several shortcomings of the parametrization of microphysics in LES models have been highlighted and the group is currently investigating improvements. These shortcomings have so far precluded firm conclusions on the behaviour of GCM parametrizations to be drawn. The Cirrus Working Group remains in a spin-up phase and is currently defining its first study based on an observational case. The Extratropical Layer Cloud Working Group is in the final stages of analyzing their simulations of the Atmospheric Radiation Measurement (ARM) Program March 2000 experiment. Current results identify the inability of GCMs to parametrize the effect of meso-scale circulations in frontal systems on the cloud fields in such systems as a major problem area. The Deep Convection Working Group is in the main phase of conducting their study of the transition from shallow to deep convection over the tropical ocean as part of the MJO. Early results indicate that GCMs develop deep convection too rapidly and with too large an effect on the large scale, not unlike their behaviour in the diurnal cycle. The Polar Clouds Working Group is conducting a new case study based on recent data from the ARM Mixed-Phase Arctic Cloud Experiment (MPACE) experiment. The focus of this study is to better understand in simulate the long-lived mixed-phase clouds frequently found at the top of the Arctic PBL. The Pacific Cross Section Working Group is currently collecting results from the participating GCM groups. Thanks to the strong collaboration of GCSS with WGNE on this project the group has already received results from more than 10 modelling groups and this number is likely to rise to more than 20. All models that participate in the GHP study on transferability will also participate in this study.

The Data Integration for Model Evaluation (DIME) activity is progressing as planned and several new cases have been added to the DIME library. Funding for the continuation of this activity has been secured by Dr W. Rossow (NASA/GISS) and the DIME website will play an increasingly important role in the GCSS activities, such as that on moist process metrics.

In collaboration with WGNE (Dr M. Miller) and CLIVAR (Dr T. Palmer) GCSS is aiming to be involved in a proposal to COPES for a concerted effort to improve the simulation of convection in climate and NWP models. At this point in time it is uncertain what shape this activity will take, but it is in GCSS' interest to be at the leading edge in defining that activity.

GCSS' success so far is based on its focus on process studies carried out in support of parametrization development. Any future direction taken has to build on this success. At the same time GCSS has always had difficulties to involve the GCM community in its activities. Recently taken steps (Pan-GCSS meeting, metrics activity, Pacific Cross Section) have strengthened that link and it is vital to use this momentum to embed GCSS in wider WCRP/COPES activities. The simulation of convection has been identified as a major problem area in climate and NWP models - hence the proposal for a concerted effort in COPES, to which GCSS can contribute its experience and knowledge in conducting process studies.

More recently GCSS has been asked to position itself in the area of cloud-aerosol interaction. While microphysics (at the heart of which are cloud-aerosol interactions) has long been an area of study in GCSS, this was mainly in support of studies of cloud dynamics, which are intimately linked to microphysics. Given the aim of GCSS to improve parametrizations and the increase in the number of parametrization that explicitly deal with cloud-aerosol interactions it is timely to assess the role that GCSS should play in such developments and which of the existing cloud-aerosol activities can provide good partnerships. First steps to align GCSS to better deal with microphysical issues have been taken recently.

Dr A. Lorenc reported on work by Drs S. Derbyshire, R. Kershaw and others at the Met Office, UK, to investigate and improve the tropical performance of the Unified Model. Related problems were identified in NWP verification and climate simulation: humidity and temperature biases and excessive tropical circulations. Aquaplanet runs were used to diagnose mechanisms. Significant impacts were shown from adaptive convective detrainment, reducing bias and improving ENSO simulation in the climate model. Preliminary results indicate also that enhanced precipitation in shallow convection could reduce Hadley-type circulations by ~10%. Packages are being prepared for implementation in the NWP and climate models in 2006.

WGNE thanked Drs C.Jacob and A.Lorenc for their presentations. WGNE also thanked the NWP centres that have agreed to participate in the Pacific Cross section intercomparison experiment.

Recognizing that convection is central to many problems in modern modelling research on almost all space and time scales,WGNE/GMPP have jointly proposed a high resolution modelling experiment specifically directed towards improving parameterization development. This effort would be a coordinated WCRP effort on convection. Since high resolution simulations are of great interest and use to other groups in WCRP projects and working groups, the proposal is expected to benefit the entire WCRP community. It is therefore proposed as a specific objective under COPES.

2.2 Land-surface processes

GEWEX Global Land-Atmosphere System Study (GLASS)

Dr P. Dirmeyer presented the report on the GLASS project. GLASS consists of the Project for the Intercomparison of Land-Surface Parameter Schemes (PILPS) (local uncoupled), the Global Soil Wetness Project (GSWP) (global uncoupled), the Local Coupled Project (LoCo) (local coupled), and the Global Land Atmospheric Coupling Experiment (GLACE) (global coupled). PILPS has several active projects; PILPS-C1 nears completion as it explored the performance of Land Surface Schemes (LSSs) in representing the carbon cycle and the accumulation of biomass at a forest site; Isotopes in PILPS (iPILPS) has completed preliminary simulations and validation of LSSs that trace stable water isotopes; and PILPS-San Pedro in Arizona is the first validation of LSSs in a semi-arid environment. PILPS-San Pedro has completed the baseline simulations; multi - criteria calibration exercises and tests of spatial transferability of parameters are beginning. The Snow Models Intercomparison Project-2 (SnowMIP-2) is a similar local uncoupled action that tests the ability of snow models to simulate snow accurately under canopies, on canopies and in clearings. GSWP-2 has completed model simulations and produced a multi-model analysis (DVD and online) that provides a demonstrably superior simulation of land surface states compared to any other global model product. Interest in LoCo is growing, as evidenced in the joint LoCo/GABLS workshop held to kickoff efforts to simulate and understand coupled land-PBL (Planetary Boundary Layer) processes. GLACE analysis has been extended beyond the “hot-spot” map to show why different GCMs exhibit such different coupling behaviour, and to compare the GCMs to observations, showing poor local representation of observed flux-state variable relationships, but better large-scale climate behaviour.

WGNE responded positively to Dr R.Koster’s proposals under GLACE-2 presented by Dr P Dirmeyer. WGNE recommended a reduced version of the model experiment with realistic soil moisture; a full-fledged experiment may be undertaken under COPES.

WGNE recommended a joint WGNE-GMPP sponsored workshop on land surface data assimilation in about two years.

It was suggested that it would be useful to prepare an inventory of ongoing activites in land surface data assimilation.

2.3 Atmospheric boundary layer

GEWEX Atmospheric Boundary Layer Study (GABLS)

Professor B.Holtslag presented the activities under GABLS. The first focus of GABLS has been on stable boundary layers (SBLs) over ice and land. Results from the first GABLS model intercomparison exercise on stable boundary layers showed large variation among 1-D models, but all operational models showing too strong a mixing. Results of Large Eddy Simulation (LES) models are in good agreement with observations in relatively homogeneous cases. On the basis of the first GABLS benchmark case, eight articles have been compiled and submitted to a special issue on GABLS in the journal of *Boundary Layer Meteorology* (to appear in February 2006). At present GABLS is focusing on the diurnal cycle of the clear boundary layer over land. As such, a new intercomparison case for 1D models has been set up on basis of

CASES99 for a period of 2.5 days (focus on PBL). Also planned is comparison of this case with a LES, at least for one diurnal cycle. Comparison of mesoscale models is in progress. At the moment about 50 scientists are actively participating within GABLS, including members of university groups seeking international cooperation. Given the GABLS findings thus far, there is still a clear need for a better understanding and a more general description of the ABL in particular, under stably stratified conditions in atmospheric models for weather, climate and earth system studies.

3. STUDIES AND COMPARISONS OF ATMOSPHERIC MODEL SIMULATIONS

3.1 General model intercomparisons

Model intercomparison 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. These encompassed a number of fairly general wide-ranging intercomparisons as outlined in this section.

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.

Dr 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, Transpose AMIP, Climate Change Detection, and software development.

WGNE congratulated PCMDI for undertaking and successfully completing the AMIP projects (AMIP-II is now complete), and for creating 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 were of particular note.

Acknowledging the lead role played by PCMDI and WGCM in this data management, WGNE felt that, in view of its own problems in this area, there was a need to widen this activity further. WGNE asked to be represented on the data oversight committee together with someone from the land surface modeling community.

AMIP-type studies will continue as a subset of CMIP in future and PCMDI has offered to receive high resolution NWP AMIP-type runs to complement their ongoing CMIP activities. WGNE thanked PCMDI for this suggestion and confirmed its interest in this. PCMDI have offered to be the local hosts for a pan-WCRP workshop on Model systematic errors in February 2007. This will be organized by PCMDI and WGNE with input from WGCM and GMPP.

PCMDI offered to receive high resolution NWP, AMIP type runs. WGNE thanked PCMDI for this offer. WGNE finds this proposal interesting as a follow up to AMIP and requested PCMDI to take it forward.

"Transpose" AMIP

Dr D. Williamson presented results from work at NCAR and PCMDI on "Transpose" AMIP. The proposal for Transpose AMIP was ready and would be sent to climate modelling groups as soon as the AMIP mailing list at PCMDI was updated.

Transpose AMIP is a WGNE proposal for the intercomparison of weather forecasts made by climate models. 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 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). Additional details of the approach can be provided as needed.

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 announcement email is being sent to determine interested participants. Details of data exchange and schedule will be developed later by mutual agreement of the participants. The proposal below is based on what Dr Williamson can realistically analyze himself and 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 mean sea level pressure (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.

Interested groups should email David Williamson (wmson@ucar.ucar) of their intention to participate and provide an estimate of when they anticipate being able to submit results. Additional design suggestions are welcome as are questions. The declared participants will then negotiate a time schedule and data exchange formats.

WGNE noted with satisfaction the very good progress in this innovative project and expressed its deep gratitude to Dr D.Williamson for his efforts.

Aqua-Planet Experiments

Dr D. Williamson reported on the developments in this activity. WGNE continues to recognize the value of applying atmospheric models to very simplified surface conditions for examining the behaviors 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 WGNE endorsed an intercomparison, the Aqua-Planet Experiment (APE), being led by staff from the University of Reading, NCAR and PCMDI. The details of the experiment and schedule 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. A Workshop was held 20-22 April 2005 at the University of Reading, UK to discuss the results, summarize current model behavior and produce a summary of research questions arising from the experiment.

Fourteen groups have now submitted their simulations to the APE database. Many groups had representatives at the Workshop. However, at that time the data for many of the experiments were not yet available. Therefore, comparative analyses are only now beginning on the complete database. More complete analyses are needed before we can say what we have learned and what are the follow-on questions. Understanding will undoubtedly require numerous exploratory experiments. Some more constrained experiments to aid understanding were discussed at the workshop and are planned. Analysis of the APE experiments is continuing for another year. A second workshop is planned to discuss the more complete analyses in the Fall of 2006 or Spring of 2007 at the University of Tokyo.

Some points brought out at the Workshop are that APE is useful to test model changes. It can help us understand how models work, establish sensitivities, and provide information about the coupling of parameterizations and dynamics. It was noted that one cannot conclude whether a model change is beneficial solely on the basis of idealized configurations such as APE: real-world experiments are also needed to establish whether they produce the same signal. The APE system is still very complex and difficult to understand, because the experimental strategy simplifies the surface boundary conditions but retains all the complexities of the moist processes and feedbacks: i.e. the models themselves are not simplified. Caution is required to avoid over simplistic deductions, especially when changing single parameterizations as opposed to entire suites of parameterizations. Nevertheless, the system can be useful to examine mechanisms and how components interact.

The models show a wide range of behavior with resolution and parameter changes, both within a single modelling environment, and across different models. For example, there are notable differences in tropical convective behaviour which manifest themselves in differences in the latitudinal structure of the ITCZ, the spectra of precipitation intensity, and the wave modes arising from convective organization. In mid-latitudes many models exhibit very low-frequency zonal wave number 5 phenomena but the details differ among the models. The basic experiments are deliberately done at "climate model" resolutions. It was speculated that the extreme variation in behaviours might arise because the models are not near a convergent regime. A few groups are examining convergence with resolution and more resolution work is needed.

The discussions at the Workshop led to plans for further diagnosis and journal papers to be developed before the next workshop. Leaders have been identified for each category of analysis. Action items for all categories are to "document" where we are and "catalogue" model simulation characteristics. The categories include tropical variability broken down into diurnal cycle, tropical wave activity, and asymmetric behavior arising from the SST anomaly experiments; the mean state and meridional transports; and mid-latitude variability, both low frequency modes and storm tracks. There was some discussion of 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 these will be left to a new project in the future.

WGNE thanked Dr Williamson for the report.

International Climate of the Twentieth Century Project (C20C)

Dr P.V. Sporyshev gave an overview of the Workshop on "Climate of the 20th Century and Seasonal to Interannual Climate Prediction" held in Prague, Czech Republic, on 4-6 July 2005, jointly organized by the CLIVAR International Climate of the Twentieth Century Project (C20C) and the Working Group on Seasonal-to-Interannual Prediction (WGSIP). The Workshop was hosted by Dr T. Halenka (Czech Republic) and the MAthematical Geophysics, Meteorology, and their Applications (MAGMA) project of the Charles University of Prague, which is funded under the European Union's Fifth Framework Programme for support to Newly Assisted States. A web page including the agenda and the presentations made at the workshop is available at http://meop0.troja.mff.cuni.cz/workshop05/. The workshop consisted of two components. The first component was a series of presentations (1) to review the current status of C20C model simulations in the "classic" SST and sea-ice forced integrations of atmospheric general circulation models and with other forcings (changing concentrations of greenhouse gases, solar variability, volcanic aerosols and sulphate aerosols); (2) to summarize possible strategies for conducting C20C experiments in a coupled air-sea modelling context; and (3) to summarize the issues and possible mechanisms for land cover change effects on climate variability and predictability. The second component was a focused discussion intended to design a common experimental protocols for model integrations that would be undertaken by the C20C modelling groups. The workshop final report may be found at: ftp://www.iges.org/pub/kinter/c20c/jul2005/C20C_Wkshp_Jul05_rep.pdf. The next C20C workshop is being planned for spring of 2007 in Exeter, UK.

WGNE thanked Dr Sporyshev for the report on the activites of the C20C project.

Impact of climate warming on the hydrological cycle in Northern Eurasia

Dr V.P. Meleshkov reported on this research activity of the Voeikov Main Geophysical Observatory. A variety of climate conditions is observed in the Northern Eurasia that comprises vast areas of tundra, boreal forests, semi-deserts and deserts. The sub-continent plays an important role in the transfer of energy, water, greenhouse gases and aerosols between the atmosphere, land surface, hydrosphere and cryosphere. This region exhibits the greatest increase in the surface air temperature over the last 30 years and model simulations also show that the climate will undergo the most substantial changes in the future.

The cryosphere plays a significant role in maintaining the intensity and phase of the hydrological cycle. In the cold season precipitation is predominantly in solid phase and largest amount of snow accumulates by early spring. Due to its melting in spring, flooding occurs over most part of the northern Eurasia.

When climate warms, precipitation increases in winter due to water vapour transport by the atmosphere with larger water holding capacity. Three possible patterns of hydrological regimes can be identified:

- all precipitation falls in liquid phase and this favours increase of winter runoff, frequency of flooding and drying of soil in spring and at the beginning of summer.
- winter accumulation of snow decreases and this results in decrease of snow melting and frequency of flooding in spring. It also contributes to enhancement of soil drying in early summer.
- due to increase of solid precipitation larger amount of snow accumulates by the end of winter. This results in larger melting and more frequent flooding in spring and wetter soil in early summer.

Changes in hydrological and cryospheric processes are evaluated in the northern Eurasia using 15 IPCC AOGCMs runs under emission scenario A2 conducted as a coordinated programme aimed at preparation of the IPCC Fourth Assessment Report. Further to analysis of climate change in the sub-continent, appropriate changes of hydrology and its interaction with cryospheric processes over watersheds of major rivers are also studied.

The ensemble projection of the 21st century climate indicates that regional manifestations of the global warming are characterized by large diversity of patterns. The greatest warming is expected in northern Siberia in winter. The ensemble mean warming is significantly higher than the inter-model scatter. Surface air temperature trends become statistically significant in all watersheds from the first half of the 21st century. Precipitation increase is largest and statistically significant as early as the first half of the 21st century in the northern Europe and Siberian watersheds.

Increase of liquid precipitation in winter results in decrease of the snow mass accumulation at the beginning of spring. Accordingly, the runoff spring maximum associated with the snowmelt becomes weaker and shifts to earlier date thus favouring a decrease of major flood frequency in the 21st century. At the same time, the increase of precipitation, in general, and solid precipitation, in particular, in the Siberian watersheds in winter due to persistence of negative surface air temperatures result in more accumulation of snow mass.

WGNE thanked Dr Meleshkov for his presentation.

3.2 <u>Developments of refined numerical algorithms for model dynamics and test cases for new methods</u>

Dr D. Williamson led the discussion on this item. Dr Dehui Chen reported on the activites in this area at the CMA. Based on the idea of Dr A. Kageyama (2004), a Yin-Yang grid was designed to deal with the problems at poles of the sphere (singular points, convergence of grid points for a latitude-longitude grid). A Yin-Yang grid is defined by overlapping two similar latitude-longitude zones (one as a usual zone, another transformed by 90°). A Lagrangian advection scheme was successfully tested on a Yin-Yang grid. This type of grid has the advantage of a regular grid box on the whole sphere with no singular points at poles. But, it has overlapped areas at the boundaries the grid. The variation of normalized computational errors showed that on the Yin-Yang grid these are slightly degraded for a cross equatorial flow in comparison to those on latitude- longitude grid, and are not further degraded with increase of resolution. However, the results showed that it is advantageous to use a Yin-Yang grid to reduce the computational errors over the poles rather than a latitude- longitude grid when the resolution is increased. The grid behaves well for flows both along the equator as well as over the poles. However, further study is needed on the interpolation method used in the overlapped areas for long time integration (accuracy and mass conservation).

WGNE thanked Dr Dehui Chen for his report.

3.3 <u>Report on the Working Group on Surface fluxes</u>

Drs S. Gulev and P. Gleckler briefly summarised the developments in this area. WCRP/JSC will be very positive in any activity that produses high resolution fluxes. WGSF requested WGNE to contribute a note for the FLUXNEWS bulletin. Dr P.Gleckler noted that there is a great deal of interest in SURFA. He observed that no progress has been made in collecting monthly means. Efforts will be made to find out what is going in GODAE activity. (See also Section 2)

WGNE thanked Drs Gulev and Gleckler for their briefings. The possibility of a joint meeting between WGNE and WGSF will be also considered, and which should lead to a new exchange of NWP fluxes.

3.4 Regional climate modelling

Dr C. Jones presented an overview of the potential uses of Regional Climate Models (RCMs) in areas such as: regional climate change projections, seasonal prediction and parametrization development. A fundamental dependency of RCMs is on the quality of the Lateral Boundary Conditions (LBCs) (usually derived from GCMs) and that RCM improvements can be rendered useless if GCM improvement does not occur in parallel. Dr Jones gave a few examples from model results and observations where high-resolution is clearly necessary to properly simulate key regional climate processes. Over Europe and North America, RCMs forced by analysed LBCs can very accurately simulate higher-order variability in the regional climate. The RCM large-scale atmospheric evolution is then well constrained to follow the observed evolution, enabling RCM results to be compared directly to collocated (in time and space) observations. This can be a profitable way to develop and improve parameterisations targeted at future high-resolution climate models.

Dr Jones briefed WGNE on the GEWEX Transferability Working Group (TWG). The aims of this group are to assess the global applicability of RCMs in regions remote from their home domain of development. Particular emphasis is being placed on the simulation of regional scale water and energy cycles in a wide variety of climatic regimes. TWG has sponsored the Inter Continental Scale Experiment Transferability Study (ICTS). In ICTS participating RCMs will run their model unchanged over 7 distinct regions around the globe, where each model domain is centred on a GEWEX Continental Scale Experiment observation centre that is contributing data to the CEOP central archive. The RCMs will be run with ECMWF and NCEP analysis on the boundaries and the respective domains will be made as uniform as is possible.

Presently, seven RCMs are contributing to ICTS and results will be archived at the CEOP central facility early in 2006. A few initial results were presented analysing the mean diurnal cycle of surface fluxes from July-September. Models were compared to CEOP observations. Most models managed to capture the phase of the diurnal cycle, but some difficulties were seen regarding the amplitude of the diurnal cycle. There was a slight suggestion that RCMs performed best on their home domains.

Dr Jones presented a selection of results from the 1st ARCMIP (Arctic Regional Climate Model Intercomparison Project) experiment. Seven RCMs are presently involved in ARCMIP. The 1st experiment is centred over the Surface Heat Budget of the Arctic Ocean (SHEBA) project observation site in the western-Arctic Ocean and all models employed the same prescribed Sea Surface Temperatures, Sea-ice cover and sea-ice temperatures. The RCMs were forced by ECMWF operational analyses at the lateral boundaries. All models had severe problems in representing the annual cycles of cloud cover and surface albedo. All models also severely underestimated the amount of cloud-liquid water observed in the winter season, simulating solely ice-clouds when mixed-phase clouds were present. This error caused a positive bias in the cloudy downwelling longwave radiation at the surface. Most models also maintained too high levels of near-surface turbulence in stable situations and therefore had too high surface fluxes of heat, moisture and momentum during the winter season.

WGNE thanked Dr Jones for his presentation.

The International Stretched-Grid Model Intercomparison Project (SGMIP)

The Stretched-Grid Model Intercomparison Project (SGMIP) was presented by Dr Côté on behalf of Dr Fox-Rabinovitz. Participants are currently from University of Maryland, U.S.A., Meteorological Service of Canada, Météo-France and CSIRO, Australia. The major scientific and computational issues studied in SGMIP are: efficient downscaling to realistic mesoscale, stretching strategies, approximation of model dynamics, treatment of model physics, multi-model ensemble calculations, optimal performance on parallel supercomputers, study of regional climate variability and the possibility to study up-scaling effects. The SGMIP experiments area of interest is over the continental U.S.A.. The period considered is 1987-1998 in SGMIP-1 and 1979-2003 in SGMIP-2. Validation is being performed against all available reanalysis and high-resolution observational data. Conclusion of SGMIP-1 were: high-quality regional (and good quality global) climate simulation, an appropriate moderate stretching design for long-term climate simulations has been defined, SG-approach works well and is robust for SG-GCMs with different dynamics and physics, advantage of the multi-model ensemble over any individual ensemble members, larger regional ensembles are desirable especially for including the impact of better resolved land-sea differences, efficient regional downscaling to realistic mesoscales is obtained with small/limited regional biases, intraseasonal and interannual variability is well represented annual, and orographic precipitation is well simulated at meso- and larger scales. In future, it is planned to complete the SGMIP-2 simulations with the possibility for other groups to join, analyze the results and extend SGMIP by exploring the possibility of collaboration with other international groups on the multi-model ensemble approach. More information can be found on the web site: http://essic.umd.edu/~foxrab/sgmip.html.

WGNE thanked Dr Côté for his presentation and noted with satisfaction the continuing encouraging progress in this area.

3.5 Other climate-related modelling initiatives

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

Australia

Dr K. Puri reported on the developments in climate modelling activities in Australia. The Australian Community Climate 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.

The key objectives of ACCESS are to create models and modelling outcomes that:

- assist the Bureau of Meteorology in meeting its statutory requirements in providing the best possible meteorological services;
- assist CSIRO by providing the best possible science for use in analyzing climate impacts and adaptation, and related fields;
- meet policy needs in natural resource management and related fields for scientific information and analysis;
- develop synergy with research in numerical weather prediction and seasonal forecasting;
- enable climate change scenarios over the 50+ year horizon;
- provide substantive linkages with relevant University research; and,
- are world-class, and will enable Australia to meet the long lead-times necessary to contribute appropriate climate projections and scenarios to the Fifth Assessment by the Intergovernmental Panel on Climate Change, which is likely to report around 2012.

Furthermore, ACCESS aims to:

- focus on the strategic timeframe (typically 7 years) while recognizing that decisions on the tactical timeframe (1 to 3 years) will need to meet immediate client needs and be consistent with the overall ACCESS planning;
- include a fully coupled carbon-cycle model covering terrestrial, ocean and atmosphere systems (incorporating a dynamic vegetation model);
- provide eventually the opportunity for incorporation of socio-economic processes;
- meet the information needs of all those interested in impacts of and adaptation to climate change in Australia, such as model output at length and time scales appropriate for simulation of the behaviour of atmospheric, marine, and terrestrial systems;
- be grounded on well-engineered and realistically achievable software and be supported by high quality IT infrastructure;
- be flexibly engineered so as to be capable of allowing for fresh and new applications, within the context of a well-defined boundary; and
- support fulfilling careers for Australian research scientists in related fields.

An ACCESS Blueprint and a Project Plan have now been prepared that define the scope and components of ACCESS. Among the key recommendations in the Project Plan are to import the Met Office atmospheric model and the VAR system.

Europe

Dr A. Lorenc reported on projects underway to build on the successful Met Office Hadley Centre climate model. HADGEM2 aims to produce an affordable Earth system Model (ESM) of limited complexity, to provide input to IPCC AR5, ready for tuning by December 2006. Other collaborative projects are developing higher resolution versions, and adding chemistry and aerosols. To enable this collaborative development, the Flexible Unified Model Environment (FLUME) project is using advanced computer science techniques, with metadata descriptions of sub-models and their interfaces, to improve the model design.

Good liaison has been established with international projects with similar goals (PRogram for Integrated earth System Modelling (PRISM) and Earth System Modeling Framework (ESMF)).

Japan

Dr Y.Takeuchi presented an overview of the collaboration projects and research projects on atmospheric-ocean study of Earth Simulator (ES) and the activities of JMA and Frontier Research Center for Global Change (FRCGC). Meteorological Research Institute (MRI/JMA) carried out:(1) global warming experiments with TL959 (20km) JMA-GSM for IPCC using a time slice experiments and (2) severe weather simulation and regional climate modeling for global warming climate with a 5km JMA Non-hydrostatic Model (NHM). The 20km JMA-GSM is 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 will be the operational NWP model (named as MSM) in March 2006. Dr Takeuchi showed some simulation results such as convective cloud related to winter monsoon, heavy rain band related to baiu front and a typhoon with regional cloud resolving model with 1km resolution.

FRCGC has been investigating global cloud resolving simulations using the Non-hydrostatic ICosahedral Atmospheric Model (NICAM). Dr Takeuchi presented the results of an aqua planet experiment with NICAM with a resolution of 3.5km. In the simulation, westward-moving cloud clusters and eastward propagation of super cloud clusters are well reproduced. FRCGC is conducting a global cloud resolution model run on the realistic land-ocean distribution and investigating tunable parameters and parameterizations. Also, FRCGC has started a medium-range research project on global cloud resolving model simulations toward numerical weather forecasting in the tropics through 2011.

Dr Takeuchi briefly discussed the possible successor to the high performance Earth Simulator supercomputer. A possible configuration of the next generation computer called “KEISOKU (10 peta speed)” consists of vector computer, scalar computer and special-purpose scalar accelerator, which is similar to a pioneering system known as the RIKEN Super-Combined Cluster.

3.6 Climate model metrics

Dr D. Williamson presented a summary of past efforts of WGNE to develop standard climate model diagnostics and 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. Suitable metrics depend on intended applications. For NWP models the application is weather forecasts and seasonal forecasts. The application for climate models is presumably the projection of future climate. But for the climate application no verification data will be available within the lifetime of models. Possible substitutes are to use the current climate, but there are no independent data sets for verification, or to use past climates, but these have insufficient data for a thorough evaluation. Therefore, for climate models, the processes creating the climate should also be evaluated, not just the climate itself.

NWP has a long history of forecast metrics such as the S1, RMS, and anomaly correlation skill scores, and generally assumes that errors in the verifying data are unimportant, but this may not be so with climate verification data. The difficult aspect for climate models is not the definition of the metrics, but the definition of fields to be assessed. They should be standard and used during model development in the same way NWP uses anomaly correlation, and the community must agree on the list.

A final question is whether standard verification data sets should be developed for model evaluation? In addition, can the quality of verification data be established, as this is likely to be a function of region. Perhaps, equally valid verification data sets should be scored against each other using the selected climate model metrics. This would provide at least a lower bound on their uncertainty.

Dr K. Taylor provided a perspective concerning the use of metrics in the evaluation of climate models. 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. In climate simulations it is not yet known what particular measures of model skill are best suited to gauge the reliability of future projections by those models. Consequently, it was suggested that a variety of metrics should be developed that together might provide a more comprehensive summary of model performance. For one set of metrics proposed, the mean climatology of a multi-model ensemble appears to agree better with observations than any of the individual models comprising the ensemble. Even when skill scores are devised that penalize for undue smoothing of the simulated fields (which commonly results when forming a multi-model mean), the multi-model mean appears superior.

WGNE discussed the issue of climate model metrics at some length with many questions and issues resulting. As a way forward, WGNE requested PCMDI to liaise with WGCM and it was agreed to set up a sub group with a member from each of PCMDI, WGCM, WGNE, GMPP and the JWGV (Joint Working Group on Verification). This group will help define the climate model metrics and standard verification data sets. In due course WGNE would take this to WCRP, through WGCM, with the intention of asking WCRP to encourage usage of these metrics for climate models. It was decided to have a session on climate model metrics in the February 2007 model systematic errors workshop.

4. DATA ASSIMILATION AND ANALYSIS

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

4.1 Reanalysis projects

ECMWF

Dr M.Miller presented the work on reanalysis at ECMWF which has comprised further documentation and support of ERA-40, preparatory work for the interim reanalysis and general work preparing for future reanalyses. There has been liaison with EUMETSAT on the reprocessing of Meteosat data for the interim reanalysis and with JMA on the supply of additional observational data used in its ongoing reanalysis, JRA-25.

The ERA-40 publication series now comprises 24 reports covering documentation of the data and assimilation system and including some results from users of ERA-40 data. The reports are available on-line for outside users (http://www.ecmwf.int/publications/library/do/references/list/192). One such report is a comprehensive atlas of the atmospheric general circulation as depicted by ERA-40 that has been produced in collaboration with the Meteorology Department of the University of Reading. A special web version of the atlas is also available (http://www.ecmwf.int/research/era/ERA-40_Atlas). ERA-40 data have been used in studies of trends and low-frequency variability in tropopause height and surface air temperature (Santer et al., 2004; Simmons et al., 2004) and to place in context the unusual split of the austral stratospheric vortex in September 2002 (Simmons et al., 2005).

The purpose of the interim reanalysis is to create a dataset that is a significant improvement on ERA-40, covers the period over which the observing system is of the highest quality and continues as a “climate reanalysis” in near real time, providing a baseline for the shorter reanalyses of atmospheric composition to be carried out within the Global Environnemental Models (GEMs) project.

One of the main problems in ERA-40 was its excessive precipitation over the tropical oceans, especially in the later years. The combination of improved humidity analysis, improved parameterization of convection and improved use of radiances, including better bias adjustment, has provided an effective remedy. Global-mean precipitation and evaporation are now in close balance. 12 hour 4D-Var with adaptive radiance bias correction gives best result by a small margin, with an imbalance no greater than 0.05 mm/day over the course of 36h forecasts. In ERA-40 the imbalance declined from about 0.6 mm/day to 0.3 mm/day over this forecast range. A cooling top-of-atmosphere radiative imbalance in ERA-40 of 7 Wm^{-2} has been replaced by a smaller warming imbalance of between 1 and 2 Wm^{-2}.

Several European groups have used ERA-40 products as input for their off-line 3D chemical transport models. The results have indicated that the Brewer-Dobson circulation is too strong and therefore the mean age of air (the time that the air has resided in the stratosphere since entering through the tropopause) is too young. This was interpreted as evidence that the ERA-40 bias correction scheme was unable to deal correctly with the relatively large model biases in the stratosphere. The mean age of air can be calculated from measurements of tracers (CO_2 and SF_6) that are conserved in the stratosphere and whose concentration increases steadily with time. The new 12h 4D-Var assimilation gives an age of air in quite good agreement with the tracer measurements, capturing in particular the marked latitudinal gradient between tropics and extratropics. The new assimilation gives better results than the year-2000 operations and much better results than the ERA-40 analysis and 6h forecast.

Japan Meteorological Agency (JMA)

Dr Y. Takeuchi presented the progress in the reanalysis activites 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 objective is to produce a comprehensive analysis data set with the JMA data assimilation system for 1979-2004. JRA-25 is being executed with 2 streams: the stream B for 1979-1990 and stream A for 1990-2004; the data for 1990 will be overwritten at the end of stream B.

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, and 4) better snow analysis by using SSM/I snow data and Chinese surface snow data. On the other hand, some negative features such as drying out of the Amazon region and jump in temperature in the stratosphere were detected and investigated.

The calculation will be completed in Spring 2006 and the products will be released for research use. JRA-25 will be handed over to JMA CDAS after 2005.

4.2 Other Assimilation activities

Met Office

Dr A. Lorenc reported on Data Assimilation (DA) activities. The 4th WMO DA Symposium, held in Prague in April 2005, was very popular, with 260 participants from 28 countries (180 in 1999). This growth in interest matches a growth in resources and observations assimilated. DA is the most important and most expensive component of operational NWP, with 5 centres now using 4D-Var in their operational NWP. DA is now seen as essential for the exploitation of most research observations, providing calibration and validation of observations, model improvements, as well as scientific hypothesis testing. DA is also expanding into new areas.

Dr Lorenc also discussed the statistical basis of 4D-Var, to see if it could be extended to a wider range of scales as part of the "seamless NWP system" being advocated by WCRP and THORPEX. The traditional deterministic formulation of 4D-Var cannot assimilate a wide range of scales, but a statistical formulation aimed at getting a best, rather than a most probable, estimate might.

5. NUMERICAL WEATHER PREDICTION TOPICS

5.1 Short- and medium-range weather prediction

The World Weather Research Programme

THORPEX: A Global Atmospheric Research Programme

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 on Atmospheric Sciences (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.

Dr D. Burridge reported on progress in THORPEX including its major component, the THORPEX Interactive Grand Global Ensemble (TIGGE). The first TIGGE workshop was held in March 2005 and a report has been issued. Phase 1 of TIGGE has helped establish central TIGGE archives at ECMWF, NCAR and CMA. The TIGGE Technical plan will be agreed to at TIGGE WG meeting and ICSC meeting in November 2005. TIGGE data archives will begin collecting available ensemble contributions in near-real time (351 global forecasts) in early 2006. In 2007-08, TIGGE will be available for THORPEX support to demonstration projects (TReCs, IPY, Beijing 2008 Olympics, regional EPS); however, if required, support could be offered to AMMA. Phase 2 plans to achieve distributed archive and to coordinate with WMO

Information System (WIS) plans. Dr Burridge also reported on the THORPEX Regional Campaigns. These included:

- The Atlantic-THORPEX Regional Campaign (ATReC) (2003; many groups are actively working with the data – a summary of current views will be available for the ICSC meeting in Melbourne, November 2005
- European ETreC – D-Phase (MAP), Convectively and Orographically-induced Precipitation Study (COPS) supported by the European regional committee
- To develop stronger links with AMMA for observing system experiments, modelling and predictability, and societal and economic applications
- Asian TRec (2008) – on tropical cyclone tracks, to coincide with Beijing Olympics Forecast Demonstration Project
- Pacific TReC (2008) – typhoons, extra-tropical transitions, tropical warm-pool physics and down-stream propagation
- Dr Burridge also outlined several research areas for possible collaboration between WCRP and THORPEX. These included:
- Together, THORPEX and COPES can bridge weather and climate forecasting
- Consideration of developing a coherent prediction system from days to decades
- Synergies in realm of
  - o Predictability studies and dynamical processes on time scales between 1 day and 1 year
  - o Design and use of unified global ensemble prediction systems
  - o Applications to real-world users (decision making)

  Possible linkages between the two programmes would include:
  - JSC/WCRP representation in ICSC and science groups
  - THORPEX in WCRP/COPES
    - o Joint project initiated to develop a unified ultra-high-resolution global weather and climate prediction system
    - o Collaboration in TIGGE
  - Collaboration in technical issues (data, archiving, policy)
  - Potential for “seamless” days-seasons development
  - Links established between TIGGE WG and TFSP

Dr Burridge also outlined areas of intersection of the two programmes with climate prediction:

- Development of a unified, ultra-high-resolution, seamless global prediction system for weather and climate that resolves extreme weather events embedded within weekly weather forecasts, and seasonal, inter-annual and decadal climate predictions;
- Development of advanced high-resolution data-assimilation systems to enhance the utility of global observations of the Earth system for the monitoring and prediction of weather and climate from hours to years.

He made two suggestions to implement this:

- Preparation of a plan on the THORPEX/WCRP joint vision, which focuses on the development of a very high-resolution global modelling system for the benefits of society and feeding into the GEOSS initiative.
- Early establishment of close collaboration between the GIFS-TIGGE Working Group and the JSC task force on seasonal forecasting (TFSP) – TIGGE for one day to one season ahead.

Dr F.Rabier reported on the A-TReC and presented an evaluation of A-TReC by showing the results from ECMWF, Météo-France, Met Office, NCEP and NRL. Dr W. Dabberdt gave a brief on the THORPEX Observing Systems Working Group (OSWG), outlining its draft terms of reference and scope. The group has the overarching goal of maximizing the likelihood that THORPEX will develop a scientifically well-founded and cost-effective design for a next generation global observing system required to support NWP on time scales of 1 to 14 days and corresponding spatial scales. The focus of OSWG will be on ocean soundings.

Dr K.Puri reported on THORPEX for the Southern Hemisphere (SH). There are three Regional Committees for the North American, European and Asian components of THORPEX. Each of these Regional Committees is in the process of developing a Science Plan and an Implementation Plan. There has been an expectation from the THORPEX ICSC that a SH THORPEX Regional Committee be established and that a Southern Hemisphere Coordinated Plan be developed. In response, a SH Science Plan has been developed to provide input to the development of an Implementation Plan for SH THORPEX, involving scientists interested in SH Meteorology working through a SH Regional Committee.

The SH Science plan develops a rationale for a SH regional focus for THORPEX that emphasises a number of features that are unique to the hemisphere. These include (i) a large percentage of the Southern Hemisphere is covered by oceans; (ii) the various countries of the hemisphere have strongly overlapping problems associated with the monitoring and forecasting of weather and climate; (iii) large differences from the Northern Hemisphere in terms of the meteorology on the 1-day to 2-week timescale which is partly due to the weaker orographic and continental forcing of the SH flow; (iv) the peculiar feature of the SH summer circulation characterized by three major subtropical fronts (South Pacific Convergence Zone - SPCZ, South Atlantic Convergence Zone - SACZ and South Indian Convergence Zone –SICZ).

The SH Plan follows closely the International Science Plan in developing the Research Objectives under four sub-programmes, namely *(i) Predictability and Dynamical Processes; (ii) Observing Systems; (iii) Data Assimilation and Observing Strategies (iv) Societal and Economic Applications*.

An important aspect that emerged from discussions between scientists across the SH is the commonality in forecast problems across the hemisphere, which provides a major justification for a coordinated SH THORPEX campaign. Examples of the commonality include:

- Fire weather is common to Australia and South Africa, and in both cases is associated with synoptic scale conditions leading to strong pressure gradients with a cross continental trajectory.
- The Madden Julian Oscillation is a major modifier of weather on the 1-2 week timescale (and longer) for the tropical portions of SH Africa, Indonesia, South America and Australia-New Zealand.
- Cut-off lows are producers of major widespread flooding events off the east coast of all three southern hemisphere continents.
- Rapid cyclogenesis causing gale-force winds and rapid sea swells have brought about major boating disasters off the east coasts of South Africa, South America, Australia and New Zealand.
- Widespread flooding and loss of life associated with tropical cyclone landfall is the major high impact phenomenon for the Australian tropical coastline, the South Pacific countries and the region of Mozambique, Madagascar and Mauritius.
- Semi-stationary mid-tropospheric (blocking) anticyclones lead to extended heat-wave conditions over southern Africa, central regions of South America and Australia.
- A focus on improving forecast system performance through the assimilation of satellite observations into high-resolution limited area models.

WGNE thanked Drs Burridge, Rabier, Dabberdt and Puri for their presentations. WGNE recognized that the THORPEX sub-structure of a) predictability and dynamics, b) observing systems, c) data assimilation and observing strategies, and d) societal and economic impacts, neatly encompassed much of the interests of WGNE, and it was agreed that WGNE will maintain a THORPEX session in its future meetings and would also make every effort to provide WGNE representation at the THORPEX workshop in March 2006 and the joint THORPEX/WCRP workshop on the MJO (also in March 2006). WGNE responded positively to the request that it should be represented at THORPEX Working Group meetings where possible.

WGNE discussed the results from THORPEX-related targeting and data denial forecast experiments. Both types of experiment focus on the 'value' or impact of observations in a specific region. WGNE felt that while these are stimulating experiments, THORPEX should nevertheless encourage more in-depth scientific investigations before promoting more (and expensive) experiments.

In the context of AMMA-THORPEX, it was WGNE's advice not to attempt a targeting campaign as the scientific basis for such work was almost non-existent for this part of the world. However, the extensive additional observations will provide excellent opportunities for impact studies of various kinds. The provision of targeting information for the driftsondes to be launched during the hurricane season later in the campaign, was however an interesting possibility.

The use of ensemble methods now forms a cornerstone of forecasting on all timescales. Recent years have seen progress in the application and use of ensemble prediction systems underpinned by the availability of supercomputer resources and rapid advances in the science of initial condition and model perturbations etc. However, WGNE remained concerned at the rather slow progress being made at a number of operational NWP centres in the effective use of ensemble forecasting information, and hoped that THORPEX, and particularly the TIGGE project, will help accelerate this. WGNE includes ensemble prediction as a regular discussion item at its meetings.

Finally, WGNE noted that its preliminary plans for more coordinated action (probably within the COPES framework) to address the wide-ranging difficulties in forecasting convection or in representing convection in GCMs were important to THORPEX, and that the proposed very high resolution (1 km) studies under consideration would be of particular relevance.

WGNE agreed with THORPEX to establish a formal mechanism for strengthening links between them.

Model Verification

Dr B. Brown reported on the activities of the WWRP/WGNE joint Working Group on Verification (JWGV) during the year. There are a number of WGNE projects involved with the validation of deterministic forecasts. These include the compilation of the so-called WMO scores, verification of quantitative precipitation forecasts, validation of tropical cyclone tracks and verification of stratospheric analysis and forecasts. There has also been the recognition that with increasingly high-resolution models, there is urgent need to move forward from the basic validation methods that have been used so far.

The JWGV held two coordination meetings during the past year, one in Reading, U.K in March 2005, in association with the TIGGE workshop, and a second meeting in Toulouse, France, in September 2005 in conjunction with the Nowcasting Workshop. These meetings facilitated planning ongoing and future activities of the group.

Membership in the JWGV remained the same as in previous years: Drs H. Brooks (NSSL, U.S.A.); B. Brown (Chair; NCAR, Boulder, U.S.A.); B. Casati (MSC, Canada); U. Damrath (DWD, Germany); E. Ebert (BMRC, Australia); A. Ghelli (ECMWF, U.K.); P. Nurmi (FMI, Finland); D. Stephenson (U. Reading, U.K.); C. Wilson (UKMO, U.K.); and L. Wilson (MSC, Canada).

Members of the JWGV continued to participate in various WWRP and WGNE related projects, either as active members of programs or as advisors. These activities include the Beijing Olympics FDP/RDP; the THORPEX International Global Grand Ensemble (TIGGE) project; and THORPEX. JWGV participation in these activities is described in greater detail below. New associations have also been developed with the Mesoscale Alpine Programme (MAP) Forecast Demonstration Project (FDP), through the leader of the MAP FDP verification subgroup, Dr M. Dorninger. JWGV also welcomes opportunities to participate in other FDPs and forecasting programs.

The JWGV also continues to be interested in opportunities to work with testbed programs such as the Finnish Meteorological Institute/Vaisala testbed; the JWGV maintains connections with this program through Dr P. Nurmi. Drs E. Ebert and H. Brooks participated in the WWRP sponsored workshop regarding establishment of an International Hydrometeorological Testbed (IHMT) at NCEP's Hydrometeorological Prediction Center (HPC).

Drs E. Ebert, B. Brown, L. Wilson, and B. Casati participated in the first TIGGE Workshop in March 2005, where E. Ebert led the discussions on the topic of verification. Drs E. Ebert, B. Brown, and L. Wilson have been asked to be members of the TIGGE Steering Committee, and Dr F. Atger has been asked to be a member of the Societal Impacts Committee for THORPEX.

The JWGV has been very involved in preparations for the Beijing Olympics FDP (B08). Dr B. Brown is a member of the B08 FDP steering committee, and participated in the B08 workshop in March and the planning meeting in Toulouse in September (Drs E. Ebert and L. Wilson also participated in the latter meeting). Dr L. Wilson has agreed to participate on the steering committee for the Beijing 2008 Olympic Games Research Demonstration Project (B08 RDP). One outcome of the B08 workshop in March was development of a verification group, including members of the JWGV as well as BMB staff. This group has prepared a draft verification plan for B08 that will be completed in the next few weeks. A major effort that is underway in preparation for B08 is the development of a Real-Time Forecast Verification (RTFV) system. This system will include standard verification approaches as well as recently developed approaches for evaluation of spatial nowcasts/forecasts of precipitation and convection.

As noted in last year’s report, the JWGV prepared a document describing a standard set of approaches and measures for evaluation of non-probabilistic precipitation forecasts. This document was provided to WGNE and is available from the JWGV. It includes recommendations of standard scores and diagnostic measures that should be computed. The document is currently being extended to include methods for probabilistic forecasts. WGNE has also asked the group to consider methods for verification of cloud forecasts, and we have begun development of a report on this topic, with an initial focus on total cloud amount forecasts from NWP models.

The JWGV has continued to support various outreach activities, including the verification web page and verification discussion group. The web page: http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/verif_web_page.html is updated on a regular basis by Dr E. Ebert as new discussion items are prepared. Some new datasets have been included on the website to demonstrate various verification approaches. Drs L. Wilson and P. Nurmi are in the process of developing a European Meteorological Computer Assisted Learning (EUMETCAL) training module on verification, and D. Stephenson recently completed a 6-month study regarding how forecasters and users assess the quality of forecast products in the UK. Several members of the JWGV participated in the Nowcasting Workshop in Toulouse, France in September; Dr E. Ebert provided an invited talk on spatial verification and Dr B. Brown served on the program committee.

The JWGV has prepared a draft proposal for a Third International Workshop on Verification Methods and this proposal is being presented to both the WWRP SSC and to WGNE. The proposed date and venue for this Workshop are January 2007 at ECMWF. This workshop follows a very successful workshop in Montreal in September 2004, which was sponsored by WWRP and WGNE, and a workshop in 2004 that did not have WMO sponsorship. The proposed third Workshop would include a 3-day tutorial session, which likely would include hands-on activities. The workshop component will include increased focus on verification of ensemble forecasts, and an effort will be made to draw in experts from other fields. Recent development of many new methods in verification make this an opportune time for both the tutorial and the workshop, and will provide a great opportunity for sharing these new ideas.

WGNE thanked Dr Brown for the presentation. WGNE recommended that a way forward for verification of cloud forecasts is for the group to produce guidelines and a list of test parameters for forecast verification in consultation with others.

Performance of the main global operational forecasting models

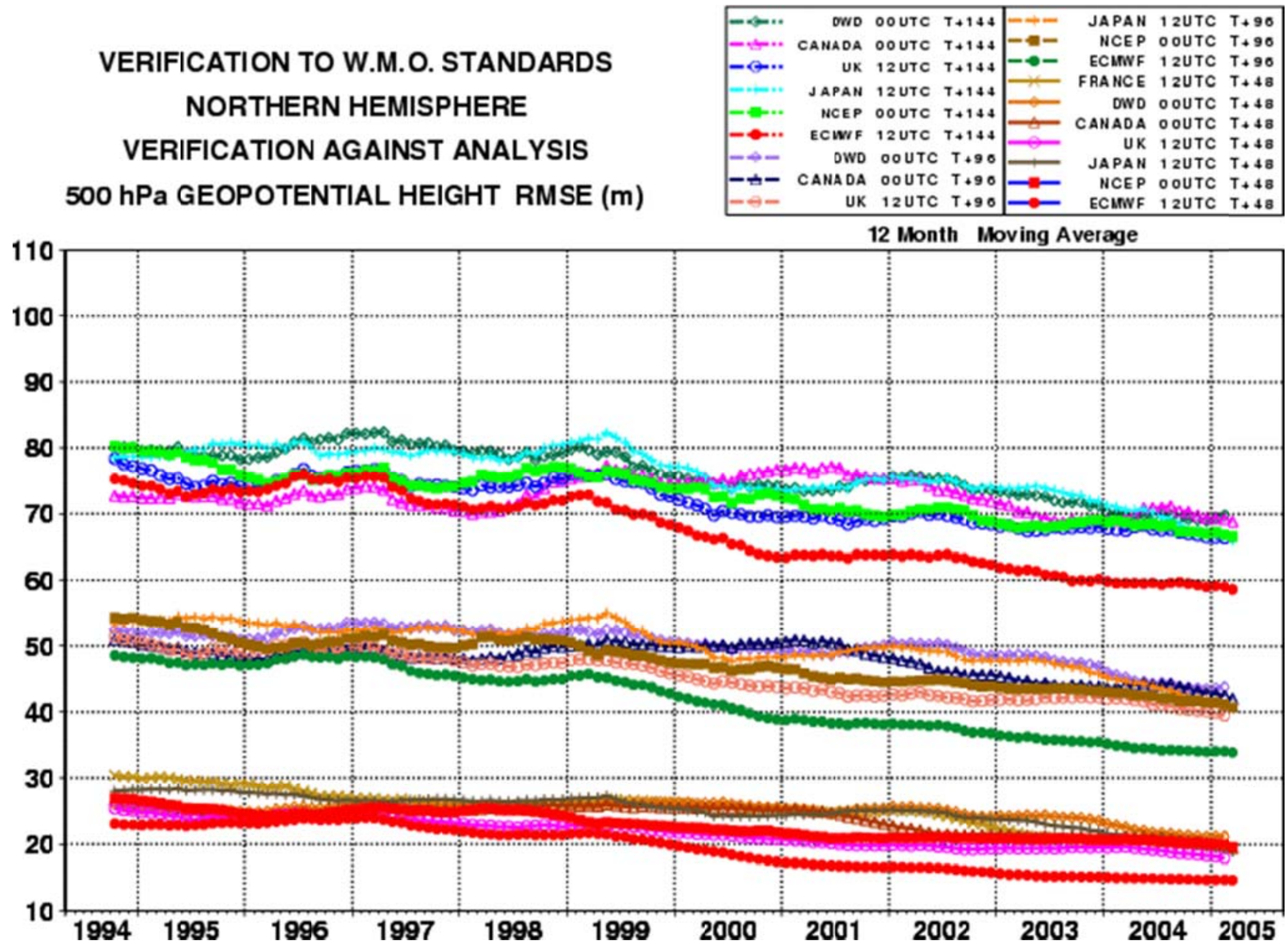
As is usual at its sessions, WGNE reviewed the progress in skill of daily forecasts produced by a number of the main operational centres over the past year as presented by Dr M. Miller. Examples of the twelve-month running means of verification scores (root mean square error against own analyses) for 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. For most centres, forecast skill continues to improve, and this improvement has now been sustained since 1999. At all time ranges, there is evidence of some convergence in skill between Centres but with the ECMWF forecasts still a clear leader. This is true for both hemispheres with larger improvements for some in the S Hemisphere. WGNE ascribed this to the increasing use of variational data assimilation schemes and an incremental improvement in the exploitation of observational data particularly in the southern hemisphere. Progressive improvements in horizontal resolution are also clearly very beneficial.

Intercomparison of typhoon track forecasts

Dr 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 and BoM 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. In 2004, Météo-France and CMA joined and NRL joined in 2005.

Many results related to typhoon track forecast including a multi-model ensemble are presented on the web site. Visit 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 model shows small forecast errors and high detection rates. The UKMO model is characterized by the highest detection rate for all ocean areas. NCEP and JMA also show small forecast errors. A case study of intensity forecast verification and the trends of typhoon track forecast error by multi model ensemble for the last 14 years have also been made.


VERIFICATION TO W.M.O. STANDARDS
NORTHERN HEMISPHERE
VERIFICATION AGAINST ANALYSIS
500 hPa GEOPOTENTIAL HEIGHT RMSE (m)
DWD 00UTC T+144
CANADA 00UTC T+144
UK 12UTC T+144
JAPAN 12UTC T+144
NCEP 00UTC T+144
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DWD 00UTC T+96
CANADA 00UTC T+96
UK 12UTC T+96
JAPAN 12UTC T+96
NCEP 00UTC T+96
ECMWF 12UTC T+96
FRANCE 12UTC T+48
DWD 00UTC T+48
CANADA 00UTC T+48
UK 12UTC T+48
JAPAN 12UTC T+48
NCEP 00UTC T+48
ECMWF 12UTC T+48
12 Month Moving Average
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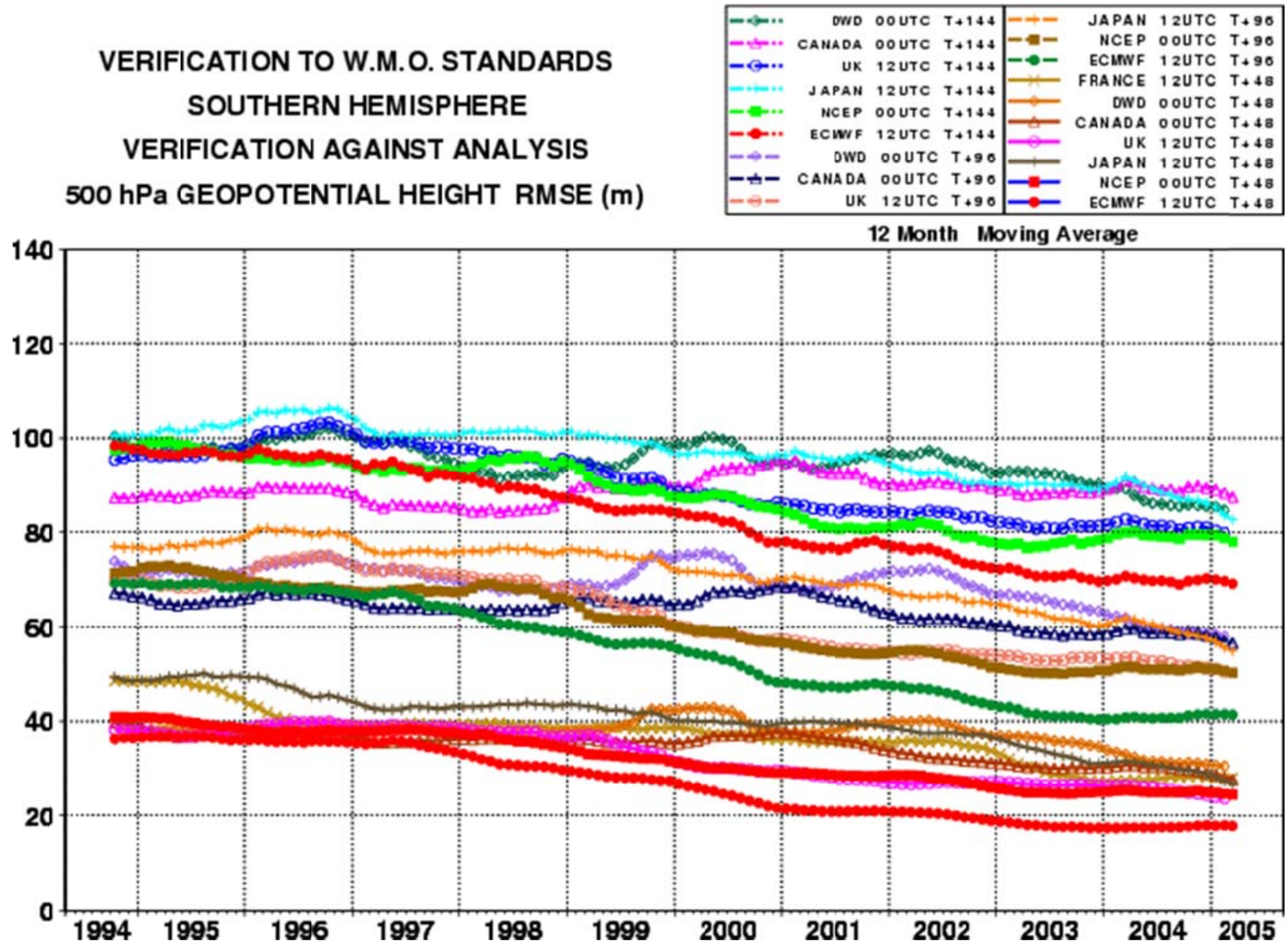
Figure 1.


VERIFICATION TO W.M.O. STANDARDS
SOUTHERN HEMISPHERE
VERIFICATION AGAINST ANALYSIS
500 hPa GEOPOTENTIAL HEIGHT RMSE (m)
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CANADA 00UTC T+144
UK 12UTC T+144
JAPAN 12UTC T+144
NCEP 00UTC T+144
ECMWF 12UTC T+144
DWD 00UTC T+96
CANADA 00UTC T+96
UK 12UTC T+96
JAPAN 12UTC T+96
NCEP 00UTC T+96
ECMWF 12UTC T+96
FRANCE 12UTC T+48
DWD 00UTC T+48
CANADA 00UTC T+48
UK 12UTC T+48
JAPAN 12UTC T+48
NCEP 00UTC T+48
ECMWF 12UTC T+48
12 Month Moving Average
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Figure 2.

The performance of tropical cyclone track forecasting is measured by forecast error and detection rate. The ECMWF model shows small forecast errors and high detection rates. The UKMO model is characterized by the highest detection rate for all ocean areas. NCEP and JMA also show small forecast errors. A case study of intensity forecast verification and the trends of typhoon track forecast error by multi model ensemble for the last 14 years have also been made.

Verification and intercomparison of precipitation forecasts

Dr K. Puri presented the studies conducted at Bureau of Meteorology Research Centre (BMRC). Quantitative precipitation forecasts (QPF) from several global NWP models and the BMRC's regional NWP model have been verified since 1997. The reference data comes from the Bureau's operational daily rain gauge analysis valid at 00 UTC. The verification was performed at 1° latitude/longitude resolution for all models.

With eight years of validation now completed it is possible to visually discern trends in QPF skill, if they exist. The time series of seasonal differences in equitable threat scores were used between the model forecast and a persistence forecast as a guide. It appears that in the tropics the Canadian model has improved slightly over time, while the ECMWF model may have actually gotten slightly worse. No trends were visible for tropical heavy rain prediction, and only the Australian regional model usually outperformed persistence. In mid-latitudes all of the models consistently outperformed persistence. Three models seemed to have improved their QPF skill over time, namely the NCEP, Met Office, and ECMWF models. The skill of the Australian regional model has improved for heavy rain in the mid-latitudes, although a trend was not evident for lighter rainfall.

The location errors for predicted rain systems were measured using the CRA verification technique of Ebert and McBride (2000). For 24h forecasts the German and Met Office models had the smallest location errors in the tropics, while the ECMWF model was most accurate in mid-latitudes. At 48 h the NCEP model was the best performer in the tropics, while the ECMWF model continued to have the least location error in mid-latitudes.

Following the recommendations from the WWRP/WGNE Joint Working Group on Verification, a web site has been set up to show QPF verification results over Australia: http://www.bom.gov.au/bmrc/wefor/staff/eee/wgne/QPFverif.html. It shows a variety of verification products including seasonal difference maps, time series, scatter plots, categorical scores, tabular statistics, and error as a function of rain rate.

In addition, a study is under way under the auspices of the International Precipitation Working Group to compare the skill of several satellite precipitation estimates with that of short range NWP QPFs. Verification data include gauge analyses from Australia and the United States, and radar data from northwestern Europe. A web site for this project is http://www.bom.gov.au/bmrc/SatRainVal/validation-intercomparison.html. The results show that the satellite estimates have an advantage over the models in the tropics, especially during summer, while the models are significantly more accurate than the satellite estimates in mid-latitude winter. Users of precipitation data may wish to combine the advantages of both sources of rainfall information.

Dr D. Majewski presented a study by Dr U. Damrath on the verification of hourly precipitation forecasts of the GME model over Germany. Four seasons have been evaluated, namely autumn 2004, winter 2004/2005, spring 2005 and summer 2005. During autumn and winter GME is able to simulate the (small) diurnal cycle of the average precipitation over Germany fairly well. But in spring and summer the timing of the (mostly convective) precipitation in the model does not match the observed one at all. The maximum of convection in GME is closely tied to the local noon whereas it is late in the afternoon in the observations. Moreover, the observed secondary nighttime maximum is not simulated at all by the model. A similar evaluation can be done for the other global models in the framework of WGNE if hourly (or at least three-hourly) precipitation forecasts are being provided to the DWD.

Dr 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 November 2005. Dr Takeuchi showed verification results for 3 day QPFs for estimating the total performance.

All models have bias characterized by underestimate for heavy rain and overestimate for light rain especially for winter season. The NCEP model shows much improvement of bias score in summer season compared to the previous year. He also showed verification results for 6 hour QPFs for estimating the diurnal-change performance. The large difference among the models reported at the previous WGNE meeting is seen to be decreased. A web page on WGNE-QPFs verification over Japan has been maintained by JMA for browsing the verification results. Dr Takeuchi encouraged the participation of CMC and MeteoFrance, and asked for higher resolution data from BoM.

Dr Dehui Chen presented verification results for China. The ETS (Equitable Threshold Score) and warm seasonal precipitation mean (from June to August 2005) were used for the verifications. Six models (T213-China Meteorological Administration (CMA), JMA, DWD, High Resolution Limited Area Forecasting System (HLAFS)-CMA, MM5-CMA, Global/Regional Assimilation and PrEdiction System (GRAPES)-CMA) participated in the inter-comparison. The results are as follows: in terms of ETS-verifications, (1) 24h as well as 48h forecasts, all models are equally skillful; (2) the forecasts delivered by the weather office is most skillful only for the smallest threshold; (3) HLAFS is less skillful than the others for all thresholds, 24h as well as 48h forecasts. For seasonal precipitation means in 2005, the observervations were characterized by two climatological patterns, less precipitation in the North-West and in contrast, more precipitation in the South-East. The heavy rain processes dominated in the South of China and in the North of Yangtze River. Along the south of Yangtze River, significantly less precipitation was observed. In comparison with the observations, (1) for 36h as well as 60h forecasts, all models can roughly predict two climatological precipitation patterns: less precipitation in North-West and more precipitation in South-East; (2) no model successfully predicted the drier zone along the south of the Yangtze River; and (3) unfortunately, nearly all models over-estimated the precipitation in the East or in the South of Tibetan Plateau.

Mumbai Heavy rainfall event

Dr K Puri also drew attention to a notable rain event. On 26 July 2005, within a span of 24 hours, Mumbai received unprecedented heavy rainfall with a suburb recording 944mm of rainfall for the day; there were reports of even heavier rainfall at a nearby location. This heavy rainfall caused serious disruption and caused a large number of deaths. A report on model guidance for the event has been prepared by the National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi. In a separate short study, WGNE members from operational Centres were asked to provide short-term (up to three days) rainfall forecasts to provide an indication of the quality of model performance. Results were obtained from the Bureau of Meteorology (Australia), ECMWF, JMA, MeteoFrance, NCEP, RPN (Canada) and the Met Office. Some Centres additionally sent forecasts from their limited area models and experimental high resolution runs. A disappointing common feature was that, apart from the Met Office global model, all models failed to capture this high impact event in the short-term forecasts. The reasons for the generally poor model performance in the short term are not clear. The Met Office model provided good guidance throughout the forecast period. A surprising feature is that in the longer term (days 5 onwards) the ECMWF high resolution trial model (T_L799) provided very good forecasts.

Experience and plans with very high-resolution global and mesoscale modeling

Dr J. Coté briefed the session on the high resolution modelling activites in Canada. A joint project called LACES (Large Atmospheric Computation on the Earth Simulator) run by the Meteorological Service of Canada, McGill University, Tokyo University and the Earth Simulator Center was completed. It consisted in running the Canadian MC2 model on the Earth Simulator to achieve a high-resolution simulation of the full lifecycle of Hurricane Earl on a large domain. The simulation was to be done at 1 km on a ($8000 \times 7300 \times 50$) grid for 174 h with a timestep of 6 s. Some of the results were reported at the “High-Resolution Workshop”, ESC, Yokohama, Japan, September 21-22, 2005. The diagnostics study is continuing and a strategy for high-resolution forecasting of hurricanes is being defined.

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 2.8 km grid spacing. Different dynamical cores have been evaluated in test suites of several months of duration. The standard three-time level leapfrog 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.

Dr J. Côté reviewed the recent developments/activities in mesoscale NWP. A limited-area modeling (LAM) strategy at the mesoscale (2.5 km) is being implemented quasi-operationally. Currently, the model GEM-LAM is run once a day in support of the meteorological operations over two windows: one covering part of Ontario-Quebec and one covering Southern British-Columbia. In the THORPEX Arctic weather and environmental prediction initiative (TAWEPI), we plan to develop a regional NWP system (10-15km horizontal resolution) over the Arctic in support of the International Polar Year (IPY) projects such as THORPEX and field measurement campaigns. The proposed model will be a version of GEM-LAM (Polar-GEM) displaced and extended over the Arctic and surrounding regions. Convective scale (1 km) windows in support of measurement campaigns are also being planned. Efforts are also underway to develop the Canadian Hydrological Ensemble Prediction Experiment (HEPEX) initiative, to couple atmosphere and hydrology. HEPEX aims to bring the international hydrological and meteorological communities together to demonstrate how to produce reliable hydrological ensemble forecasts for added value to deterministic forecasts.

Dr Dehui Chen reported on the activites in this area at the CMA. It is motivated to exploit the potentials of GRAPES at high resolution for the purposes of improving the warning of meso-scale severe weather events in advance of 3-6hr, promoting the application of remote sensing and in situ data in monitoring meso-scale weather system and meeting the needs of high quality weather services for the Beijing Olympic Games 2008. Based on the Chinese new generation NWP system (meso-scale version), a prototype of the new nowcasting system was established. To reduce the spin-up impact is one of the key-issues for a very short rang forecast. A cloud analysis component was specially developed, as a 'hot-start' method to assimilate the radar observations for better initialization of the cloud parameters in the GRAPES based nowcasting system. Some basic assumptions/simplifications were made for retrieval of cloud hydrometeors based on radar observation. The case study clearly showed that the radar data have the potential to retrieve the cloud parameters and the model hot start may improve the prediction if the storm is better initialized (by a Cloud Analysis). However, the problem of imbalance between cloud-related parameters and large-scale environment is not solved yet.

Dr M. Tolstykh reported on the constant and variable resolution versions of global finite-difference semi-Lagrangian absolute vorticity (SL-AV) model at the Russian Hydrometeorological Research Centre. Its specific features include: semi-Lagrangian advection with SETTLS scheme, semi-implicit scheme with direct FFT solver; vorticity-divergence formulation on the unstaggered grid; and fourth order compact finite-difference schemes for horizontal derivatives, including semi-implicit scheme and U-V reconstruction. The SL-AV model uses parameterizations from Meteo-France ARPEGE/IFS model with minor modifications. The model exists in versions with constant horizontal resolution 0.9x0.72 degrees (longitude x latitude), and variable resolution – 0.5625 longitude, latitudinal resolution varying between ~30 and 70 km. The variable resolution version achieves 30 km horizontal resolution over most part of Russia. There is also a constant resolution version for seasonal forecasts (1.40625x1.125 degrees lon x lat). All versions have vertical resolution of 28 sigma-levels. Some results from quasioperational tests for both versions of the model during December 2004-August 2005 are presented. Both versions of the SL-AV model demonstrated explicit advantage over current Russian operational spectral Eulerian T85L31 model.

Next generation global models, development of numerical algorithms for model dynamics and test cases for new methods

Dr D. Majewski reported on the joint development project ICON (Icosahedral Non-hydrostatic) of the DWD and Max Planck Institute for Meteorology (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. The next step is the introduction of the local zooming option by defining rectangular (or circular) areas where the grid is refined by introducing additional grid levels (subdividing coarser triangles into finer ones).

5.2 Ensemble prediction

Dr J. Côté reported on the developments in ensemble prediction in Canada.The Canadian Ensemble Kalman filter (EnKF) was implemented operationally in January 2005. It provides initial conditions for the Canadian ensemble prediction system (EPS). It is a Monte Carlo EPS that tries to randomly sample all sources of error: different members use perturbed observations and surface fields and various model versions. A double EnKF of 48 members each is used in the assimilation cycle to produce perturbed analysis and error statistics. Each member now uses the Global Environmental Multiscale (GEM) model with

300 × 150 horizontal grid and 28 vertical levels with 3D-Var analysis. It uses the same observations assimilated by the 4D-Var system, operational quality control, localization of 2800 km in horizontal and 2 units of ln p in vertical and no explicit balancing. Future EnKF projects include time-interpolation in the assimilation window to improve the accuracy of the forward interpolation operator and assimilate more data at the edges of the 6h window, use a new set of analysis variables for improved balance and finally compare 4D-Var and EnKF at equal numerical cost. Long term objectives are better ways to account for uncertainties of the model, perhaps by introducing parameterizations that are inherently stochastic, develop a regional ensemble Kalman filter, compare the singular vector approach and a (still to be built) regional EnKF for regional ensemble predictions.

Dr K. Puri reported on EPS reserch at BMRC. 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; and the operational seasonal prediction system. The global and regional systems use rather different procedures in generating the initial perturbations and in allowing for model uncertainties. The medium-range global EPS consists of a 33-member ensemble of 10 day forecasts. The perturbation strategy used in generating ensemble members follows the singular vector approach. Perturbations are scaled linear combinations of the 16 fastest growing 48h T42L19 adiabatic singular vectors localized polewards of 20^{o} latitude. The model uses a resolution of T_{L}119L19 and the system is run twice daily (00 UTC and 12 UTC). The regional Ensemble Prediction System (LAPS-EPS) uses assimilation of randomly perturbed observations during data assimilation to generate initial perturbations. Model uncertainties are accounted for by using two sets of convective closures in the Tiedtke mass flux scheme namely moisture convergence and CAPE closures, and stochastic physics formulation as originally developed at ECMWF. Lateral boundary uncertainties are allowed for by using individual members from the global EPS. Another feature of the LAPS-EPS is the use of perturbed tropical cyclone bogus data which allows the system to provide estimates of TC track uncertainties. The LAPS-EPS uses a resolution of 50km with 29 vertical levels, has 24 members and the system is run out to 3 days from the 12 UTC base times.

5.3 Recent developments at operational forecast centres, including development of long-range and seasonal forecasting systems

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 (Dr M. Miller)

Several long-standing developments have finally been implemented in Operations: the new moist boundary layer scheme representing stratocumulus clouds, the wavelet formulation of the background error statistics, the initial assimilation of rain-affected radiances from the SSM/I instrument, and the adaptive bias correction of surface pressure observations. The preparations for upgrades in all resolutions were completed and fulfilled expectations regarding the impact on forecast skill.

Changes made during 2005 (in two sets) include:

- a new moist boundary layer scheme
- a wavelet formulation of background error statistics (Jb), the tuning of which has been based on Data Assimilation ensemble runs.
- a revised use of surface pressure observations: airport hourly reports (METAR) were activated, all surface pressure data were subject to an adaptive bias correction scheme with reduced observation errors;
- MODIS winds from AQUA were activated (previously only winds from TERRA were used) and their observation error was reduced; 10 AIRS channels were blacklisted
- a new dissipation source function was introduced for the ocean wave model
- Initial assimilation of rain-affected SSM/I radiances
- Set of changes to AIRS assimilation and use of Meteosat-8 (MSG) winds
- Jb statistics from latest ensemble data assimilation

- Revised Gaussian sampling for EPS perturbations.

Also under pre-operational testing are changes for:

- Increasing the horizontal and vertical resolution
  - Deterministic forecast and analysis outer loop T_L799, 91 levels
  - First inner loop (minimization) T_L95, 91 levels
  - Second inner loop T_L255, 91 levels
  - EPS T_L399 62 levels
- Increasing the resolution of the global ocean wave model (40km horizontal resolution for the deterministic forecast, more frequencies and directions for the EPS)
- Using grid-point humidity and ozone in the inner loops of the analysis
- Using improved coefficients for the linearized ozone chemistry (version 2.3)

In addition, there has been continuous progress towards operational dissemination of the monthly forecasts and of the multi-model seasonal forecasts. Work is also continuing towards the final validation and implementation of the Var-EPS and of System 3 for seasonal forecasting. Both should become operational in 2006. Shortly thereafter, the first version of the unified Var-EPS and Monthly forecasting system should be implemented. The work towards operational implementation of the ELDAS soil moisture assimilation method has started.

Some IFS forecasts at T2047 (10km horizontal resolution) have been studied. Inspection of results did not reveal any obvious difficulty, either with the meteorological content or with the numerical behaviour and the efficiency of the model. In particular, the cost of Legendre transforms at this high resolution (a traditional subject of concern) is still limited to 21% of the total model cost, which is considered fully acceptable in view of the large efficiency of other aspects of the model dynamical core.

The performance of the ocean wave forecasts has been outstanding during the recent period. With the improving quality of the wind forecasts, it is now possible to include a more detailed description of the wave generation and dissipation mechanisms.

The Centre has expanded its participation in THORPEX. The Centre will have a leading role in the development of the TIGGE archive. Several observation system experiments (OSEs) have been concluded and others have been initiated. The effort towards assessing the value of targeted observations has increased. The Centre also committed itself to realize a new series of nature runs for future OSSEs.

The EU funded project GEMS started on 1st March 2005. Building on previous work on the assimilation of ozone and CO2, the Centre expects to progress quickly. The implementation of prognostic aerosols in the IFS is also progressing fast. Other new EU-projects include ENSEMBLES, MERSEA, PREVIEW and AMMA.

The monthly forecasting system has been running operationally once a week instead of every 2 weeks since October 2004. The monthly forecasting products are now disseminated. The dissemination includes model anomalies and climate. During the 2004/2005 winter, the model displayed some particularly strong skill in predicting a cold anomaly over Europe that lasted about two months, with ROC scores exceeding 0.7 for forecast range 19-32 days over Europe.

The evolution of seasonal forecast performance with different model cycles and different configurations has continued to be monitored. One positive development has been the reduction in timestep dependence in recent cycles. Previously it had proved necessary to run with a 30-minute timestep in order to get acceptably good performance of the coupled model in the west-central Pacific. The gap between performance with 30 minute and 1 hour timesteps has been progressively reduced, and now the performance with a 1-hour timestep is virtually the same as with a 30-minute timestep. Increasing the resolution to TL159 appears to give a modest improvement in both Nino forecast performance and the atmospheric climate. Since the higher horizontal resolution has other advantages (better representation of local topography and land-sea mask; better comparability with the high resolution used in the medium-range forecast systems), TL159 is now the target resolution for the implementation of System 3. Substantial progress has been made on the multi-model seasonal forecasting system. Both the Met Office and Météo-France forecasting systems are now running in operational mode, with all data being processed and archived in the ECMWF data systems, and with standard ECMWF graphical products from both models being produced.

World Meteorological Centre (WMC) Moscow (Dr A.V.Frolov)

Dr A.V.Frolov presented a review of the current state and prospects for the development of NWP models in Russia. He described in detail the operational models of the WMC Moscow – a global spectral model T85L31, a regional grid-point model with 75 km horizontal resolution over the territory of Europe and Northern Asia and a non-hydrostatic mesoscale model with 10 km horizontal resolution overt he Moscow region. The positive impact of more advanced physical parazemeterizations and improved horizontal resolution on the forecasts quality was clearly demonstated. Practically useful short-range numerical predictions of strong surface winds and heavy precipitation are available on a routine basis. Special attention was paid to the problem of global NWP model development using the Double Fourier- Chebyshev series on the sphere.

For monthly forecasting, intercomparison of the WMC Moscow and the Voeikov Main Geophisical Observatory (MGO) dynamical models has been made. It was found that the signal from the models in particular in winter season, was statistically significant. In seasonal forecasting, research has been ongoing at WMC Moscow and at MGO in the framework of SMIP-2, SMIP-HFP and APCN projects.

Dr Frolov presented a review of atmospheric data assimilation research and operational activity in the WMC Moscow. The operational technology relies on the 3-D multivariate OI scheme. Near - surface and upper-air observations are separated in two different batches which are treated sequentially with an appropriate change in the background-error covariance structure. It is planned to replace this analysis scheme by the 3D-Var (PSAS) scheme in 2006-2007.

This 3D-Var (PSAS) scheme is based on new 3-D Spatial Autoregression Moving Average (SARMA) filters. It gives flexibility with respect to: (a) the shape of the effective correlation functions; (b) controlling the degree of local isotropy/anisotropy; and (c) non-separability features. New covariance model is capable of reproducing complicated flow-dependent covariances. An Ensemble-Kalman-Filter-based 4D data assimilation scheme with flow-dependent covariances is under development.

In 2004, a prototype of an ensemble short and medium range forecasting system was developed in the WMC Moscow on the basis of system simulation approach. The probability distribution functions should be determined for all types of errors involved in the data analysis and forecasting processes. Specifically, it should be specified pseudo-random samples from the probabilitity distributions of: (a) observational errors, and (b) model (tendency) errors including the errors in boundary conditions. The stochastic models for observational errors are known relatively well, although this is not exactly the case for satellite and other indirect observations, e.g. radars. The model-error structure is much less known. Further research in this direction is under way.

The project on modernization and technical re-equipment of Roshydromet for 2006-2010 has been developed to enable the Russian Federation to fulfil the commitments in international hydrometeorological data exchange and carry out the functions of the WMC Moscow.The agreement on the loan of $80M for funding the Project was signed on 11 August 2005 in Moscow between the Russian Federation and the International Bank for Reconstruction and Development (IBRD). The total cost of the Project is equal to $133.3M, including the loan of $80M, and $53.3M of Russian Government financial support. The project has the following components:

- Technical re-equipment of data processing and archiving facilities, as well as computation and communications systems;
- Modernization of observing networks;
- Enhancement of institutional structure, improvement of information delivery techniques and emergency preparedness;
- Project management, monitoring and assessment.

Future plans include: procurement for the WMC Moscow of a supercomputer of 6.0 Tflops capacity, redundant array of disks, upgrading of local computer networks, enhancement of workstations at the local level, upgrading of software/hardware for Automated Data Communication System to enable telecommunications operations through the basic network which comprises the WMC Moscow, 3 regional centres and 21 territorial centres and staff training.

BMRC (K. Puri)

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

- the global assimilation prediction system (GAPS), horizontal resolution T_L239 and 33 levels;
- the limited area prediction system (LAPS), horizontal resolution 0.375° x 0.375° and 29 levels;
- the tropical limited area prediction system with the same resolution;
- the mesoscale limited area prediction system, 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) implementation in the global system of ECMWF land-surface/planetary boundary layer/vertical diffusion scheme with soil moisture nudging (note that these have been used operationally in the LAPS suite for many years); (ii) increase in the number of levels in the global system from 29 to 33 with the extra 4 levels located in the boundary layer; (iii) assimilation of scatterometer winds in both the global and limited area systems; and (iv) additional a 0.05° x 0.05° version of LAPS to run over Adelaide and Perth domains.

Over the past year, a great deal of effort has gone into the sixty-level (L60) versions of LAPS and GASP. Numerical instability issues that plagued the work now seem largely resolved. 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. 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 third quarter of 2006.

POAMA (Predictive Ocean Atmosphere Model for Australia) is a seasonal to inter-annual climate prediction system based on coupled ocean and atmosphere general circulation models. It was developed as a joint project involving BMRC, and CSIRO Marine Research (CMR), with some funding from the Climate Variability in Agriculture Programme (CVAP) of Land and Water Australia. 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° in the zonal direction. The meridional spacing is 0.5° within 8° of the equator, increasing gradually to 1.5° 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. The POAMA system has been run operationally since October 2002 and a 9-month forecast is produced daily. Operational products are issued by the BoM National Climate Centre (NCC) and research products are available on the POAMA web site (http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA/). Over the past year a considerable amount of effort has gone into evaluating different configurations of BAM (T63 vs T95, L34 vs L60, different parametrization options). A final configuration for POAMA-2 has now been chosen (T95L60 with linear/thin grid and new physics options). This final configuration is being evaluated.

Météo-France (Dr M. Déqué)

The most important model development at Météo France is the preparation for 2008 of the AROME model (2km resolution over France). Therefore, there are only marginal changes in the direct models ARPEGE and ALADIN (new aerosol and ozone distribution, new profile of turbulent mixing length). In the global assimilation, the new feature is the use of radiances (EARS). The most important development in 2005 was the 3D-VAR assimilation in ALADIN. Up to now, the French version of ALADIN started from an interpolation of the ARPEGE analysis. In a test suite, a few features have been introduced in the physics (gravity wave drag without orography envelope, new precipitation scheme, ECMWF radiation scheme), but these are not yet acceptable for operational implementation in 2005.

In Europe, two coordinated forecast exercises are about to start in late 2005. In the ENSEMBLES project, stream 1 consists of updating results from DEMETER, PREDICATE and ENACT (three former European experiments) to document the predictability at the seasonal and decadal scales using the best possible ocean assimilation. In the Marine Environment and Security for the European Area (MERSEA) project, the aim is to explore the potential gain of high-resolution ocean analysis in seasonal predictability. A recent extension of DEMETER with a stratospheric version of ARPEGE has shown an increase in northern hemisphere and tropical skill. A former study based on ERA15 reanalyses and uncoupled model (extension of PROVOST) did not show such an improvement. Exploiting DEMETER database has also proved that in the context of a cost/loss approach, the benefit of using model forecasts versus climatological forecasts is significant with the first 5 years (and of course with any longer period out of the 44 years of the hindcast experiment). This result shows that the economical value of seasonal forecasts is not just a theoretical concept.

Japanese Meteorological Agency (Dr Y. Takeuchi)

The operational NWP suites at JMA have been run on a HITACHI SR8000E1 (80nodes, 768Gflops) since March 2001. Many operational changes for operational Global Spectral Model (GSM) have been implemented since the last WGNE meeting as follows: (1) direct assimilation of ATOVS level 1C radiance data instead of the level 1C radiance data; (2) a new longwave radiation scheme; (3) a parameterization of absorption in the short-wave radiation scheme for ozone, carbon dioxide and oxygen; (4) a four-dimensional variational data assimilation method with the resolution of TL319L40 for outer loop and T63L40 for inner loop; (5) a semi-Lagrangian advection scheme; (6) an improved spectral resolution from T213 (quadratic grid) to TL319 (linear grid); (7) a minor modifications of the cumulus convection and the prognostic cloud water schemes; (8) an incremental non-linear normal mode initialization and a vertical mode initialization; (9) a new radiation scheme with better treatment of cloud effects; (10) a new ozone climatology for the radiation calculations; (11) Aqua/AMSU-A radiance data; and (12) a new thinning scheme with one-hour time slots for ATOVS data. The revision of GSM resulted in steady improvement of 1day through 5-day forecasts as was the case last year. The global spectral model for ensemble prediction system for one-week forecast were also improved by including a marine stratocumulus parameterization, a modification of the cloud water/ice scheme, revision of surface albedo of ice sheet and a modification of the cumulus parameterization.

The Meso-scale model (MSM) now uses Aqua/AMSR-E precipitable water and rain data, and Doppler radar radial wind data from eight sites.

The next generation supercomputer system at JMA consists of a HITACHI SR11000J1 with 50 nodes for satellite data processing implemented in March 2005 and two HITACHI SR11000K1 with 80nodes for NWP (to be operational in March 2006). Total peak performance of HITACHI SR11000K1 is 21.5Tflops.

JMA now runs a new non-hydrostatic Meso-scale model (MSM) with a resolution of 5km eight times a day. The number of vertical layers increases 40 to 50, and the forecast time decreases from 18 hours to 15 hours. The radiation scheme and diagnostic schemes for surface wind and temperature are revised and the parametrizations optimized for the new MSM. The verification of the model precipitation against surface rain data demonstrates much improvement of equitable threat score, rain rate dependency of bias score and detailed features of precipitation distribution.

For the global model, the resolution of the inner model for global 4D-Var was upgraded from T63L40 to T106L40; this higher resolution inner model brought comprehensive improvement of forecast scores.

Major plans for model developments at JMA are 1) a single model with a resolution of 20km for global, typhoon and regional forecasting, 2) extension of the forecast time of MSM from 15 hours to 33 hours run four times a day, and 3) a non-hydrostatic model-based variational data assimilation system (JNoVA) for MSM.

UK Met Office (Dr A. Lorenc)

Since the implementation of 4D-Var in the global NWP system in October 2004, improvements to the model, assimilation and observation usage have maintained a steady improvement in performance. The more significant improvements include: upgrade of the model physics to bring it nearer to that of the current HadGEM1 climate model; introduction of a global surface analysis which has provided data for a routine update of the global soil moisture fields (In diagnostic comparison of our global surface fields with other centres, this was identified as a significant weakness of our system); retuning the background error covariance statistics; 4D-Var improvements by inclusion of basic physics and better treatment of moisture and by a Jc term to penalise gravity waves; satellite changes including revised data thinning algorithm, use of MODIS winds, enabling NOAA-18 and retuning of Scatterometer wind bias correction. Increased horizontal and vertical resolution of N320L50 is planned for December 2005.

Establishing the 12 km North Atlantic European (NAE) model as a replacement for the UK mesoscale model with identical resolution has proved more difficult than expected. The smaller area model, nested in the global 4D-Var system, assimilates UK observations using 3D-Var. Applying 3D-Var over the

larger NAE area gives worse results for synoptic scales than the global, and hence worse UK weather forecast results. Revised covariances improved things, but the main prospect is the NAE 4D-Var assimilation planned for March 2006.
A 4km UK model, permitting deep convection, has been in pre-operational trials since summer 2005. Using 3D-Var and latent heat nudging, it is expected to become the main UK short-period forecasting tool by mid-2006. Research into higher-resolution convective-scale NWP is underway, for implementation when computers allow.

A 24 member 24km NAE regional short-range forecast ensemble prediction system is running twice per day fed by an 80km global EPS.

Deutscher Wetterdienst (Dr 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 15 countries world wide, including Brazil, Bulgaria, China (Guangdong province), Israel, Italy, Oman, Philippines, 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.

During the summer of 2005 the main computer system at the DWD, an IBM RS6000/SP with 1920 Power3 processors was replaced by an IBM p575 with 384 Power5 processors. A 174-h forecast of the GME including about 50 GByte forecast GRIB data takes 115 minutes on only 8x8 Power5 processors while it took 117 minutes on 15x30 Power3 processors mainly due to the faster switch of the new system.

Diagnostic evaluations of GME forecasts for the period September 2004 until August 2005 indicate that the hydrological cycle is well balanced in the northern hemisphere but a systematic trend is visible in the tropical region. After a spin down of the precipitation (P) during the first 24 hours and a spin up of the evaporation (E), the difference P-E steadily increases from -0.3 mm/day at +24h to +0.3 mm/day at +168h.

As a first step towards the use of satellite radiances in the global data assimilation a 1D-Var scheme for AMSU-A (on NOAA 15, 16, 18 and AQUA) data has been set up and tested in parallel runs; no SATEM data have been used in these tests. Standard forecast scores indicate improvements of the test suite especially for the southern hemisphere in comparison to the current operational suite, which uses SATEM data. The operational introduction of this 1D-Var scheme took place on Jan. 4, 2006.

Canadian Meteorological Centre (Dr J. Côté)

The CMC operational 3D-Var data assimilation for the global forecasting system has been extended to 4D-Var and after a 3-month parallel suite 4D-Var was operationally implemented on 15 March 2005. 4D-VAR has allowed new data to be assimilated. 4D-Var gives a consistent improvement in the northern hemisphere and nearly 9-h gain in predictability in the southern hemisphere while it is rather neutral in the tropics. Half the improvement comes from the use of the tangent-linear and its adjoint and the other half comes from increased number of observations at appropriate time and a set of simplified physical parameterizations in the second outer loop and trajectory updates. A delayed-cutoff time is more important in 4D-Var than in 3D-Var. Future work includes introducing 4D-Var in the regional analysis.

In July 2005 the prediction of fine particulate matter (PM2.5) was added to the operational Canadian Hemispheric and Regional Ozone and NOx System (CHRONOS).

The main implementation next year will be to increase the resolution of the global model used in data assimilation and forecasting. The main features of this so-called Global-Meso configuration of the GEM model are: 800 $\times$ 600 grid-points in the horizontal (~33 km) and 58 vertical levels, numerical poles at geographical locations, shallow convection with so called Kuo Transient, deep convection with Kain-Fritsch, modified Sundqvist scheme for grid-scale condensation, Bougeault-Lacarrère for turbulent mixing length and ISBA land surface scheme with sequential assimilation of soil moisture (based on OI). The model has gone though extensive evaluation and is targeted for implementation in June 2006. Future developments include: stratospheric version of GEM, radiation code with improved optical properties of clouds, improvement in the representation of grid-scale and subgrid-scale orography, together with improved representation of subgrid-scale roughness and low-level blocking effect of mountains, a first version of the Canadian Land Data Assimilation (CaLDAS) and off-line modeling of sea-ice.

The regional GEM model now uses a 15 km global grid with variable resolution. In March 2005, a spin-up cycle from 4D-Var was implemented, followed in June 2005 by a correction to the deep convection scheme to reduce the number of events of extreme small-scale precipitation. Its future developments include: improvement to analysis spin-up, improved surface fields, new radiative transfer and Canadian Land Data Assimilation System (CaLDAS). In the longer term a continental scale limited-area model approach at increased resolution (10 km) and a mesoscale 4D-Var regional analysis will be implemented.

A Canadian precipitation analysis (CaPA) is being developed that combines radar and *in situ* data. It is motivated by the lack of reliable precipitation analysis over Canada and the need to gather and improve existing precipitation observations and products. Among potential applications are: improved QPF verifications, data assimilation of soil moisture and precipitation and hydrological forecasts. The proof of concept was made over the Quebec region using radar and a cooperative network. Work is underway to increase the coverage.

An interdisciplinary marine environmental prediction system (MEPS) is guided and tested using advanced observing systems. A demonstration site for Lunenburg Bay, NS has been set up. A coupled atmosphere/ocean/biology/chemistry ecosystem model is focusing on coastal pollution. It also includes Atlantic storm surge component and R&D on Northwest Atlantic Ocean modeling and data assimilation.

Research on satellite data assimilation at MSC includes: SSM/I clear sky brightness temperatures, ground-based GPS zenith tropospheric delay and collocated surface meteorological observations, GPS radio-occultation refractivity profiles, SSM/I and TMI rainy sky brightness temperatures, microwave brightness temperatures and infra-red retrieved skin temperature for soil moisture analysis and AIRS infrared radiances.

China Meteorological Administration (Dr Chen Dehui)

The highlights of the recent developments in the past year in CMA included: improvements of the current operational NWP systems, progress in the new generation of NWP system GRAPES (Global/Regional Assimilation and Pr*E*diction System) and the upgradation of High Performance Computers.

The current operational NWP systems consist of a global model T213L31 (original version from ECMWF) for 10 day forecast with an OI (Optimal Interpolation) assimilation scheme; a regional model HLAFS (High resolution Limited Area Forecast System) with 0.25°horizontal resolution, 23 vertical levels and OI assimilation scheme; a typhoon model MTTP (Model for Typhoon Track Prediction) with 0.25°horizontal resolution, 20 vertical levels and bogusing initialization scheme; a global EPS with 31 members, T106L19 model and using single vector method to generate the initial perturbation. Focus was on the validation experiments for introducing the SSI (Statistic Spectral Interpolation, from NCEP) data assimilation to the global NWP system to replace the current OI assimilation scheme. The statistics over 80 days (2005.06.15-2005.09.02) showed improvements in the early medium-range except in the Southern Hemisphere, and there were no significant impacts on the precipitation forecasts. These conclusions apply to experiments using only conventional data i.e. without any satellite data.

The project to develop the Chinese new generation of NWP system was launched in 2001. Since then, the main achievements have been inclusion of variational data assimilation, generic dynamic core, model physics, GRAPES_Meso system, GRAPES_Global system and experiments for operational forecsting. GRAPES_3DVAR is a unified grid system for both global and regional configurations, with efficient algorithm for optimization, and flexible for different observational operators. It can assimilate the conventional observation via GTS, NOAA16/17 (18?) ATOVS radiance (AMSU-A/B, HIRS), cloud drift wind from geostationary satellites, Doppler radar radial wind and reflectivity, and Quickscat wind etc. GRAPES_3DVAR is ready for operational use. The GRAPES_3DVAR will be upgraded to GRAPES_4DVAR. The framework of GRAPES_4DVAR has been set up and assimilation of real data sets with GRAPES_4DVAR has begun. The GRAPES' dynamic core is a grid point model for both regional and global configurations, non-hydrostatic, Charney-Phillips vertical staggering, semi-implicit time integration, semi-Lagrangian 3D advection, modulated and parallelized computing matching HPC with different architectures. A regional meso-scale GRAPES system (GRAPES_Meso) was established. The version 2.0 of GRAPES_Meso was nationally released in March 2004. The main operational applications of GRAPES_Meso are in National Meteorological Center (NMC/CMA), Shanghai Regional Meteorological Center (SRMC/CMA) and Guangzhou Regional Meteorological Center (GRMC/CMA). In NMC/CMA, the GRAPES_Meso is run in quasi-operational mode twice daily with horizontal resolution of 0.3° (about 33km), 33 vertical layers and covering Eastern Asia. It will be in operation in winter 2005/2006. In SRMC, GRAPES_Meso is focused on tropical forecast (GRAPES_TCM, Tropical Cyclone Model) with horizontal resolution of 0.25° (about 28 km), 31 vertical layers and a bogusing scheme for initialization. In GRMC, GRAPES_meso is focused on Tropical Monsoon Modeling (GRAPES_TMM) with 33 vertical layers and 3 times nesting (0.5°/0.125°/0.025° latitude and longitude resolutions). The systematic experiments of the global GRAPES (GRAPES_Global) are ongoing with the real observations.

Based on the GRAPES_Meso (Δx= 30km, 31 vertical layers) and CAM (Canadian Aerosol Model, from Dr S.L. Gong), a new system of GRAPES_DAM (Dust Aerosol Model) was established for both sand/dust storm forecast and aerosol chemical/ physical process research. Since spring of 2005, the regional version of GRAPES_DAM was run in real time to predict the sand/dust storm, which occurred in Eastern Asia.

In summary, (1) GRAPES is near to operational implementation; (2) GRAPES shows potential to improve the routine forecast through usage of remote sensing data to overcome the difficulty of data sparseness and higher resolution and efficiency; (3) GRAPES has the flexibility to adopt new physics and ease in coupling with other models; (4) further optimization of GRAPES is necessary to meet the requirements for high quality weather forecast.

Since 1991, the capability of HPC facility has steadily increased. By the end of 2004 and beginning of 2005, a new machine IBM-SP was installed in NMIC/ CMA. The new IBM HPCS consists of 376 P655+/nodes and 6 P690+/ nodes (in total, more than 3200 CPUs), 2 sets federal switch and 30TB Fast-T900 disk array. The peak performance reaches ~ 21.5 Tflops. It is a dramatic increase in comparison to 1Gflops of peak performance in 1991!

Future plans inlcude operational developments in:(1) GRAPES_Meso in operational implementation in the winter of 2005-2006; (2) more tests of GRAPES-Global in 2006, start operational implementation in 2007-2008; (3) GRAPES-4DVar in 2007-2008; (4) GRAPES-VHR for mega cities, GRAPES-based nowcasting and GRAPES_MEPS in 2008; and (5) development of GRAPES_AGCM and EnKF. The research thrusts include: (1) modelling of the role of mountains in high resolution NWP model- a crucial issue especially in Eastern Asia; (2) parameterization (or explicit) of convection during Asian summer monsoon; (3) initializing meso-scale model with remote sensing data (e.g. radar) and others; and (4) improvement of interaction between land surface and atmosphere on time scales related to weather evolution.

NCEP Environmental Modeling Center (Dr R. Petersen)

NCEP implemented significant changes to its Global Forecast System (GFS) in May 2005. Resolution was increased from T254 (55 km) to T382 (35 km) for the first 7 days and to T170 (75 km) for days 8-15. The vertical diffusion and mountain blocking were modified. A new sea ice model was added and major improvements to the Noah land surface model were added. In addition, a new coding structure enhanced computational efficiency and made the system compatible with Earth System Modeling Framework (ESMF) principles. Improvements to global anomaly correlations were about 3% in both hemispheres in winter and summer.

In August, the Global Ensemble Forecast System was upgraded to T126 (100 km) resolution for 0-15 days, the initial perturbation scheme was improved and tropical cyclone disturbances were relocated to the observed position, considerably improving the ensemble spread and mean track forecast accuracy.

At the NASA-NOAA-DOD Joint Center for Satellite Data Assimilation (JCSDA), a new microwave surface emissivity model was developed and included in the GFS May implementation. Considerable progress on assimilation techniques for COSMIC data was also made. A new sea surface temperature (SST) retrieval technique, based on a forward radiative transfer model, was included in a high-resolution (12 km) global SST analysis. This technique was implemented by NCEP in August 2005.

The performance of the new NCEP Climate Forecast System (CFS) was evaluated for the Indian Monsoon with excellent results. Wind and rainfall forecasts with monthly lead times showed skill in many regions and regimes based on 26 years of ensemble runs. A higher resolution (T126 vs T62) version of the CFS demonstrated a vastly improved spectrum of tropical SST variability in a 40 year run, with a clear correspondence in both amplitude and period between the observed and modeled variability.

Development work in preparation for the June 2006 implementation of the Weather Research and Forecast (WRF) model continued. Explicit convection, 5 km resolution runs are now made daily with two versions of the WRF over different sectors of the USA. These “Nested Window” runs demonstrate the viability of resolvable convection as an operational strategy for the future.

In August 2005, the Short-Range Ensemble Forecast (SREF) system was upgraded to 21 members from 15 members. The 6 new members are derived from the WRF system and add system diversity and spread to the ensemble. As a result, the number of outliers is considerably reduced, as is the rms error of the ensemble mean.

A Real-Time Ocean Forecast System (RTOFS) for the North Atlantic basin was implemented in December 2005. The domain covers the Atlantic from 30 S to 70 N. The system has a resolution of 5 km close to the US mainland and 14 km near Africa. Forecasts are once daily to 4 days. Outputs describe the complete ocean state, temperature, salinity and currents, throughout the domain. While the system currently assimilates SST observations, it will soon assimilate routinely available oceanographic data including sea surface heights from altimeters and ARGO floats. The RTOFS will provide initial and boundary conditions for NCEP's coupled atmosphere-ocean hurricane model and for downscaled coastal and estuary models for storm surge forecasting and ecosystem management.

Plans are being made for the next global reanalysis. This project will support the next-generation CFS as well as a reforecast database for weekly and monthly forecasts. This project will depend on infusion of new funding.

6. OTHER WGNE ACTIVITIES AND FUTURE EVENTS

Publications

WGNE thanked the Recherche en Prévision Numérique, Montreal, for printing and distributing the WGNE "blue-cover" numerical experimentation series, the annual summary of research activities in atmospheric and oceanic modelling (No. 35, produced in July 2005). The July 2005 report was produced by inviting contributions by e-mail or through the website www.cmc.ec.gc.ca/rpn/wgne and the electronic version is available on the website. This is also linked to the WCRP website: http://www.wmo.ch/web/wcrp/wcrp-home.html. About 210 hard copies have also been produced and distributed.

WGNE Web site

A specific web page for WGNE was discussed. 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.

Next session of WGNE and GMPP

At the kind invitation of the National Center for Atmospheric Research (NCAR), the next session of the WGNE, the twenty-second, will be held in Boulder, USA, 24-27 October 2006. This will include a one-day joint session with WCRP Modelling Panel (WMP) but no joint session with the GMPP.

7. CLOSURE OF SESSION

On behalf of all the participants, Dr M. Miller, Chair of WGNE, and Dr J. Polcher, Chair of GMPP, expressed their appreciation to the Voeikov Main Geophysical Observatory, St.Petersburg, Russia, for hosting this session of WGNE and GMPP, and the excellent facilities and hospitality offered. The opportunity of interacting with many scientists and experts at the Roshydromet had been very valuable. Sincere gratitude was voiced to Dr V. Kattsov and supporting staff for the excellent arrangements, unstinting assistance, and refreshments that had been provided.

This joint twenty-first session of WGNE and ninth session of GMPP was closed at 1300 hours on 11 November 2005.

APPENDIX A

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APPENDIX B

Summary of Recommendations, Actions from the Joint WGNE-21/GMPP-9 meeting
St. Petersburg, Russia 7-11 November 2005

Agenda item	Subject	Recommendation	Responsibility
1.2	Report on the WCRP Modelling Panel (WMP)	WGNE members responded to deliberations at the WMP session: There was a sense of disappointment with the first WMP meeting, although the talks given were excellent. The WMP has only European and American members and was also too limited in its focus	
1.5	AMMA: progress and developments	WGNE welcomed and fully supported the proposal to prepare a Forecaster's Handbook based on workshops in March and June-Sept 2006, reviews by editorial board, external review of all chapters and editing process, and publication by end 2008. WGNE viewed the Forecasters handbook as a unique opportunity for capacity building. WGNE suggested that the possibility of a relevant WMO training programme for this activity should be explored. It also suggested that experts of Nowcasting Workshops arranged by WMO/WWRP should be invited to the AMMA workshop.	Chair, GMPP, Dr Z. Lei, AREP
2.1	Relevant activities under CAS auspices	WGNE welcomed and strongly supported the proposal for a joint WGNE/WWRP verification training workshop, at ECMWF, Jan, 2007	
2.2	THORPEX: Developments including TIGGE, IPY and THORPEX Workshop (March 2006)	1. WGNE agreed with THORPEX to establish a formal mechanism for strengthening links between them. 2. In response to the results from various targeting and data denial experiments, WGNE expressed concern that while these experiments were stimulating, they were far from convincing and there was rather little science underpinning them. WGNE suggested that more in depth investigation of existing experiments was a priority.	Chair, WGNE Dr D. Burridge Dr D. Burridge,
2.4	Data assimilation activity within WCRP. Observing systems and results of OSEs, also CBS work.	GMPP expressed concern about the lack of progress in data assimilation for land surface. WGNE suggested that a review of the status be undertaken.	Chair, GMPP Chair, WGNE
2.5	THORPEX Regional plans including plans for the S Hemisphere	Dr Burridge invited WGNE to the March 2006 kick off workshop. He also invited WGNE members to give talks at the workshop on data assimilation, and the THORPEX –WCRP meeting on MJO, 13-17 March 2006, Trieste. WGNE responded positively to the requests.	Dr D. Burridge, Dr Z. Lei Chairs, WGNE, GMPP
3.1	GMPP report including Report on Monsoon workshop and GEWEX Conference	WGNE received the report on the Monsoon workshop. WGNE noted with disappointment the Monsoon community's apparent lack of interest/understanding of the important role of NWP and data assimilation in monsoon studies as evidenced by the programme. WGNE was invited to give its response to the GEWEX road map of activities: 4. it was agreed that GEWEX, WGNE and WGSF will collaborate to revive the SURFA idea 5. GLACE-2 will be a joint project between WGNE and GEWEX so that research done under GLASS, GABLES, etc will provide inputs to model improvement under GMPP. 6. HEPEX products to be linked with land surface modelling activities.	Chairs, WGNE, GMPP

3.3	GCSS: Progress report including new results and case studies including the GPCI	WGNE thanked the NWP centres who have agreed to participate in the Pacific Cross section intercomparison experiment. WGNE referred to its earlier invitation to WGSIP to participate in the Pacific cross-section experiments by producing seasonal-type forecasts for these experiments and noted that there has no response in this regard. WGNE asked this matter to be revived.	 Dr M. Déqué Chair, WGSIP
3.4	GLASS; an overview of activities	1. WGNE responded positively to Dr.R.Koster's proposals under GLACE-2 presented by Dr.P Dirmeyer. 2. WGNE recommended a joint WGNE-GMPP sponsored workshop on land surface data assimilation in about 2 years. 3. It was suggested that it would be useful to prepare an inventory of what people are doing now in land surface data assimilation.	Chairs, WGNE, GMPP
3.8	Report on the activities of the WGCM	Acknowledging the lead role played by WGCM in data management, WGNE asked that it might be involved in this activity. WGNE would welcome its representation on the oversight committee together with someone from the land surface community.	Co-chairs, WGCM
3.12	Progress with Stretched-Grid Model Intercomparison Project (SGMIP)	WGNE noted with satisfaction the continuing encouraging progress in this area.	
3.13	"Transpose" AMIP: status of project	WGNE noted the very good progress in this innovative project and expressed its gratitude to Dr.D.Williamson for his efforts.	
4.5	Discussion on a possible Task Force on 'convection'	Recognizing that convection is central to many problems in modern modelling research on almost all space and time scales, WGNE/GMPP have jointly proposed a high resolution modelling experiment specifically directed towards improving parameterization development. This effort would be part of a coordinated WCRP effort on convection. Since high-resolution simulations are of great interest and use to other groups in WCRP projects and working groups, the proposal is expected to benefit the entire WCRP community. It is therefore proposed as a specific objective under COPES.	Chairs, WGNE, GMPP
4.6	AMIP, CMIP and recent results from the IPCC AR4 database	PCMDI offered to receive high-resolution AMIP- type runs from the NWP Centres. WGNE thanked PCMDI for this offer. WGNE finds this proposal interesting as a follow up to AMIP and requested PCMDI to take it forward.	Dr P. Gleckler, PCMDI
4.9	Discussion of climate model metrics and way forward	1. WGNE discussed this with PCMDI and WGCM. It was agreed to set up a sub-group with K.Taylor, B.Brown, D.Williamson, R.Pinkus and a nominee from WGCM as members. This group would develop the metrics and standard verification data sets further. 2. WGNE and WGCM should then ask WCRP to encourage usage of these for climate models generally. 3. It was decided to have a session on climate model metrics in the systematic errors workshop.	Dr K. Taylor, PCMDI, Chair, JWGV D. Williamson Chair, GCSS
4.11	Prospects for verification of cloud forecasts	The JWGV will produce some guidelines and a list of test parameters for forecast verification in consultation with others.	Chair, JWGV
	Next session (without GMPP)	WGNE welcomed the invitation to hold the 2006 meeting at NCAR, Boulder, USA, Oct. 24-27	Chair, WGNE D. Williamson

APPENDIX C

AGENDA FOR THE JOINT WGNE-21/GMPP-9 MEETING

St. Petersburg, Russia, 7-11 November 2005

Monday 7 November

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045	Opening welcome and local arrangements etc.	Chair, WGNE A. Frolov, V. Kattsov
1.1	Adoption of Agenda	Chair, WGNE V. Satyan
1.2	Discussions at the twenty-sixth session of the JSC (March 2005), future directions of the WCRP including COPES, and the role of WGNE	Chair, WGNE V. Satyan
	Report on the JSC Officers, Chairs and Directors meeting	V. Satyan
	Report on the WCRP Modelling Panel (WMP) Report on the WCRP observations and assimilation Panel (WOAP) (Also Item 2.4)	Chairs A. Lorenc V. Satyan
1.3	Report from the GEWEX Scientific Steering Group, including matters relevant to the development and status of the GMPP	Chair, GMPP GEWEX IPO
1.4	Recent developments and perspectives of NWP in Russia	A. Frolov
1045-1100	**Coffee**	
1100-1245		
1.5	AMMA: progress and developments	J. Polcher
1.6	Recent developments at operational forecasting Centres	Participants
1245-1400	**Lunch**	
1400-1545	Recent developments at operational forecasting Centres	Participants
1545-1600	**Coffee**	
1600-1745	Recent developments at operational forecasting Centres	Participants

Tuesday 8 November

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
2.1	Relevant activities under CAS auspices	Z. Lei
2.2	THORPEX: Developments including TIGGE, IPY and THORPEX Workshop (March 2006)	D. Burridge Z. Lei
2.3	THORPEX: Report on the A-TReC	F. Rabier
2.4	Data assimilation activity within WCRP. Observing systems and results of OSEs, also CBS work. Report on the Fourth WMO International Symposium on Assimilation	A. Lorenc, M. Miller, W. Dabberdt
1045-1100	**Coffee**	
1100-1245		
2.5	THORPEX Regional plans including plans for the S Hemisphere	D. Burridge K. Puri
2.6	WGNE and THORPEX: - a general discussion	D. Burridge, Chair, WGNE Participants
2.7	New ideas and progress in the use of ensembles	Participants
1245-1400	**Lunch**	
1400-1545		
2.8	Report on the COPES Task Force for Seasonal Prediction	M. Déqué, D. Burridge
2.9	An overview of recent developments/activities in seasonal forecasting.	M. Déqué
2.10	Progress in Monthly and Seasonal forecasting	Participants
2.11	Next generation global models, development of numerical algorithms for model dynamics and test cases for new methods	Participants
1545-1600	**Coffee**	
1600-1745		
2.12	Constant and variable-resolution versions of semi-Lagrangian absolute vorticity (SL-AV) model	M. Tolstykh
2.13	Experience with very high resolution global and mesoscale modelling	J. Côté, D. Majewski Participants
2.14	Strawman for a very high resolution regional forecast experiment to aid parametrization development	Chairs, WGNE and GCSS

Wednesday 9 November

Agenda Item	Subject	Responsibility/ Introductory speaker
0900-1045		
3.1	GMPP report including Report on Monsoon workshop and GEWEX Conference	Chair, GMPP
3.2	Status of CEOP including the range of data being collected, their availability and results there from	
3.3	GCSS: Progress report including new results and case studies including the GPCI	C. Jakob
3.4	GLASS; an overview of activities	P. Dirmeyer
1045-1100	**Coffee**	
1100-1245		
3.5	The progress of GABLS	B. Holtslag
3.6	Progress with land-surface/atmospheric coupling in operational models (Progress of SNOWMIP2??)	Participants
3.7	Report on the workshop on APE (Aqua-planet Experiment) Reading, UK	D. Williamson
1245-1400	**Lunch**	
1400-1545		
3.8	Report on the activities of the WGCM	A. Lorenc K. Taylor
3.9	Update on the International Climate of the Twentieth Century Project	P. Sporyshev
3.10	Hydrological and cryospheric processes in Northern Eurasia in the light of climate warming	V. Meleshko
1545-1600	**Coffee**	
1600-1745		
3.11	Regional Climate modelling	C. Jones
3.12	Progress with Stretched-Grid Model Intercomparison Project (SGMIP)	M. Déqué/J. Côté
3.13	“Transpose” AMIP: status of project	D. Williamson

Thursday 10 November

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
4.1	Status of the TWP-ICE	C. Jakob
4.2	Surface/convection interactions	P. Dirmeyer
4.3	Convection and the boundary layer	B. Holtslag
4.4	Convection-related issues in models	Participants
1045-1100	**Coffee**	
1100-1245		
4.5	Discussion on a possible Task Force on ‘convection’	Chairs
4.6	AMIP, CMIP and recent results from the IPCC AR4 database	P. Gleckler
1245-1400	**Lunch**	
1400-1545		
4.7	Metrics for climate models	K. Taylor
4.8	Cloud metrics for GCMs	C. Jakob
4.9	Discussion of climate model metrics and way forward	D. Williamson Participants
1545-1600	**Coffee**	
1600-1745		
4.10	Trends in performances of the models of the main operational forecasting centres	M. Miller
4.11	Prospects for verification of cloud forecasts	B. Brown Participants
4.12	Report on the activities of the Joint Working Group on Verification	B. Brown
4.13	Inter-comparison of typhoon track forecasts	Y. Takeuchi

Friday 11 November

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
5.1	Verification and comparison of precipitation forecasts at various centres	D. Majewski, M. Déqué, R. Petersen, K. Puri, Y. Takeuchi
5.2	Report on the Working Group on Surface fluxes	P. Gleckler
5.3	Progress in reanalysis activities at NCEP, ECMWF and JMA	R. Petersen M. Miller Y. Takeuchi
1045-1100	**Coffee**	
1100-1200		
5.4	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 D. Williamson K. Puri A. Lorenc and others as appropriate
5.5	Discussion on a future systematic errors workshop/meeting	Chair, WGNE Participants
1200-1300		
5.6	Outstanding items and actions	Chairs V. Satyan
5.7	Arrangements for publication of the 2006 edition of "Research Activities in Atmospheric and Oceanic Modelling"	J. Côté V. Satyan
	WGNE Web page	V. Satyan
	Venue for WGNE 2006	Chair, WGNE
	Close of session	

APPENDIX D

WGNE List of Operational Global Numerical Weather Prediction Systems (as of January 2006)

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_L511 L60 (10)	T_L255 L40; M51 (10)	4D-VAR (T_L159)
Met Office (UK)	NEC SX6, 34 nodes NEC SX8 16 nodes (4)	~40km L50 (6)	~90km L38; M24 (3)	4D-Var (~120km)
Météo France (France)	Fujitsu VPP5000 (1.2)	T_L358 (C2.4) L41 (3)	T_L358(C2.4) L41; M11 (2.5)	4D-Var (T_L149)
DWD (Germany)	IBM p575; 2x52 nodes (2x3.1)	40 km L40 (7)	No EPS	3D-OI
HMC (Russia)	Itanium 4x4; Xeon 2x4 (0.10; 0.028)	T85 L31 (10); 0.72°x0.9° L28 (10)	No EPS	3D-OI
NCEP (USA)	IBM p655 (Cluster 1600) (7.8)	T382 L64 (7.5) T190 L64 (16)	T126 L28; M45 (16)	3D-Var (T382)
Navy/NRL (USA)	SGI O3000 (1024 proc) (1.125)	T239 L30 (6)	T119 L30; M10 (10)	3D-Var
CMC (Canada)	IBM p690, 108 nodes (4.3)	0.9°x0.9° L28 (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 (15, 7)	T126 L28; M15 (15)	3D-Var
JMA (Japan)	Hitachi SR8000-E1, 80 nodes (0.768)	T_L319 L40 (9)	T106 L40; M25 (9)	4D-Var (T63)
CMA (China)	SW1; IBM P655/P690 (0.384; 7)	T213 L31 (10)	T106 L19; M33 (10)	3D-OI
KMA (Korea)	Cray X1E-8/1024-L (18.4)	T426 L40 (10)	T106 L30; M17 (8)	3D-Var
NCMRWF (India)	Cray SV1 24 processor (0.028)	T170 L28 (5)	No EPS	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)	2006	2007	2008	2009	2010	2011
ECMWF (Europe)	2x18.2	2x18.2	2x18.2	2x18.2+?	?	?
Met Office (UK)	4	4	4	32	32	48?
Météo France (France)	1.2	1.2	5	5	10	10
DWD (Germany)	2x3.1	2x3.1	2x25	2x25	?	?
HMC (Russia)	0.1	8	8	8		
NCEP (USA)	16	16	32	32	64	64
Navy/NRL (USA)	4.9	5.0	8.0	12.0	15.0	16.0
CMC (Canada)	4.3	?				
CPTEC/INPE (Brazil)	0.768	0.768	10	20	20	20
JMA (Japan)	2x10.75	2x10.75	2x10.75	2x10.75	2x10.75	?
CMA (China)	NO RESPONSE					?
KMA (Korea)	2x9.2	2x9.2	2x9.2	2x9.2 25	2x25	2x25
NCMRWF (India)	0.486	0.496	?	?	?	?
BMRC (Australia)	1.8	?	?	?	?	?

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)	2006	2007	2008	2009	2010	2011
ECMWF (Europe)	T_L799 L91	T_L799 L91	T_L799 L91	T_L799 L91	tbd	tbd
Met Office (UK)	40 km L50	40 km L70	40 km L70	25 km L90	25 km L90	25 km L90
Météo France (France)	T358c2.4 L46	T538C2.4 L60	T538c2.4 L60	T538c2.4 L60	T799c2.4 L90	T799c2.4 L90
DWD (Germany)	40 km L40	40 km L40	20 km L60	20 km L60	20 km L60	15 km L70
HMC (Russia)	T85 L31; 0.72°x0.9° L28	T169 L31 ; 0.72°x0.9° L28	T339 L31; 0.5°x0.4° L48	T339 L63; 0.5°x0.4° L48	T339 L63; 0.5°x0.4° L48	
NCEP (USA)	T382 L64 (7.5) T190 L64 (16)	T511 L80 (7.5) T254 L80 (16)	T511 L80 (7.5) T254 L80 (16)	20 km L90	20 km L90	20 km L100
Navy/NRL (USA)	T239 L30	T239 L30	T319 L36	T319 L48	T383 L48	T511 L64
CMC (Canada)	35 km L58	35 km L58	35 km L80	35 km L80	35 km L80	15 km L80
CPTEC/INPE (Brazil)	60 km L42	40 km L64	30 km L80	20 km L80	20 km L80	10 km L100
JMA (Japan)	T_L319 L40	T_L959 L60	T_L959 L60	T_L959 L60	T_L959 L60	T_L959 L80
CMA (China)	NO RESPONSE					
KMA (Korea)	T426 L40	T426 L40 (new model)	T426 L70	T426 L70 or T_L729 L70	T426 L70 or T_L729 L70	T426 L70 or T_L729 L70
NCMRWF (India)						
BMRC (Australia)	T_L359 L60	Met Office UM under ACCESS (?)	?	?	?	?

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)	2006	2007	2008	2009	2010	2011
ECMWF (Europe)	T399 L62; M51; 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	T399/T255 L62; M 51; 15; change of res. at day 10	?	?
Met Office (UK)	~90 km L38; M24; 3	~90 km L70; M24; 15	~90 km L70; M24; 15	~60 km L70; M36; 15	~60 km L70; M36; 15	~60 km L70; M36; 15
Météo France (France)	T358c2.4 L46; M11; 3	T358c2.4 L46; M11; 3	T358c2.4 L46; M11; 3	T358c2.4 L46; M11; 3	T550c2.4 L60; M11; 3	T550c2.4 L60; M11; 3
DWD (Germany)	No EPS	No EPS	?	?	?	?
HMC (Russia)	No EPS	T85 L31; M20; 10	T85 L31; M20; 10	T85 L31; M30; 10	T85 L31; M20; 10	?
NCEP (USA)	T126 L28; M56; 16	T170/T126 L64; M56; 16; change of res. at day 7.5	T170/T126 L64; M56; 16; change of res. at day 7.5	40 km L90; M80; 16	40 km L90; M80; 16	40 km L100; M80; 16
Navy/NRL (USA)	T119 L30; M16; 10	T159 L30; M16; 15	T239 L36; M16; 15	T239 L36; M32; 15	T239 L48; M32; 15	T319 L64; M32; 15
CMC (Canada)	SEF(T_L149) + GEM(1.2°), M16; 16	GEM(0.9), M20; 16	?	?	?	?
CPTEC/INPE (Brazil)	100 km, L28, M15; 15	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
JMA (Japan)	T_L159 L40; M51; 9	T_L319 L60; M51; 9	T_L319 L60; M51; 9	T_L319 L60; M51; 9	T_L319 L60; M51; 9	T_L479 L80; M51; 9
CMA (China)	NO RESPONSE					
KMA (Korea)	T213 L40; M34; 8	T213 L40; M34; 10	T213 L40; M34; 10	T213 L40; M34; 10	T213 L40; M34; 10	T213 L40; M34; 10
NCMRWF (India)						
BMRC (Australia)	T_L119L19; M32: 10	?	?	?	?	?

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)	2006	2007	2008	2009	2010	2011
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_L799 with T255 final inner loop; L91	?	?
Met Office (UK)	4D-Var; 120 km; L50	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
Météo France (France)	4D-Var; T159	4D-Var; T250	4D-Var; T250	4D-Var; T250	4D-Var; T350	4D-Var; T350
DWD (Germany)	OI; 40 km; L40	3D-Var; 40 km; L40	3D-Var; 40 km; L40	ETKF?	ETKF?	ETKF?
HMC (Russia)	OI; 0.9x0.72; L28	OI; 0.9x0.72; L28	3D-Var; 0.9x0.72; L28	?	?	?
NCEP (USA)	3D-Var; T382	Advanced-Var; T511	Advanced-Var; T511	Adv or 4D-Var; 20 km	Adv or 4D-Var; 20 km	4D-Var; 20 km
Navy/NRL (USA)	3D-Var; T239; L30	3D-Var; T239; L30	3D-Var; T319; L36	4D-Var	4D-Var	4D-Var
CMC (Canada)	4D-Var; 1.5°, 35 km; L58	4D-Var; 1.5°, 35 km; L58	4D-Var; 0.9°, 35 km; L80	4D-Var/EnKF?	4D-Var/EnKF?	4D-Var/EnKF?
CPTEC/INPE (Brazil)	3D-Var; 100 km	3D-Var; 60 km	LENKF; 40 km	LENKF; 40 km	LENKF; 40 km	LENKF; 20 km
JMA (Japan)	4D-Var; 120 km; L40	4D-Var; 80 km; L60	4D-Var; 60 km; L60	4D-Var; 60 km; L60	ETKF	ETKF
CMA (China)	NO RESPONSE					
KMA (Korea)	3D-Var; T426; L40	3D-Var; T426; L40	3D-Var; T426; L70	4D-Var? EnKF?	4D-Var? EnKF?	4D-Var? EnKF?
NCMRWF (India)						
BMRC (Australia)	3D-OI	Met Office 4D-VAR under ACCESS (?)	?	?	?	?

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)	2006	2007	2008	2009	2010	2011
ECMWF (Europe)	No regional models					
Met Office (UK)	720x432; 12 km; L38 270x288; 4 km; L38	720x432; 12 km; L60 270*288; 4 km; L60	720x432; 12 km; L60 270*288; 4 km; L60	720*432; 8 km; L80 270*288; 1.5 km; L80	720*432; 8 km; L80 270*288; 1.5 km; L80	720*432; 8 km; L80 270*288; 1.5 km; L80
Météo France (France)	300x300; 9.5 km; L46	300x300; 9.5 km; L60	500x500; 2.5 km; L60	500x500; 2.5 km; L60	800x800; 2.5 km; L60	800x800; 2.5 km; L90
DWD (Germany)	665x657; 7 km; L40	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	?	?
HMC (Russia)		Var. Res.; 30 km over Russia; L28	Var. Res.; 30 km over Russia; L28			
NCEP (USA)	12 km; L60	8 km; L60	8 km; L60	6.5 km; L85	6.5 km; L85	5 km; L100
Navy/NRL (USA)	45/15/5 km; L40	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
CMC (Canada)	Var . Res. 15 km; L58	Var/LAM?; 10 km; L58	10 km; L58 (2/D) 2 2.5°; L80	10 km; L58 (4/D) 2 2.5°; L58	10 km; L? (4/D) 5 2.5°; L?	
CPTEC/INPE (Brazil)	249 x 523, 20 km; L38	335 x 701, 15 km; L50	1001x2101, 5 km; L60	1001x2101, 5 km; L80	1001x2101, 5 km; L80	2001x4201, 2.5 km; L80
JMA (Japan)	325x257; 20 km; L40 721x577; 5 km; L50	721x577; 5 km; L50 2 km; L60	721x577; 5 km; L50 2 km; L60	721x577; 5 km; L50 2 km; L60	721x577; 5 km; L50 2 km; L60	721x577; 5 km; L60 2 km; L60
CMA (China)	NO RESPONSE					
KMA (Korea)	171x191; 30 km; L33 178x160; 10 km; L33	171x191; 30 km; L40 178x160; 10 km; L40 242x330; 5 km; L40	171x191; 30 km; L40 178x160; 10 km; L40 242x330; 5 km; L40	171x191; 30 km; L70 178x160; 10 km; L70 242x330; 5 km; L70	?	?
NCMRWF (India						
BMRC (Australia)	0.1^{o}x$0.1^{o;}$ L60	Met Office UM under ACCESS (?)	?	?	?	?

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)	2006	2007	2008	2009	2010	2011
ECMWF (Europe)	No regional models					
Met Office (UK)	24 km; M24; 2			16 km; M36; 2		16 km; M36; 2 3 km; M24; 1
Météo France (France)	No EPS	No EPS	No EPS	No EPS	2.5 km; M20; 1.5	2.5 km; M20; 1.5
DWD (Germany)	No EPS	No EPS	No EPS	2.8 km; M15; 1	2.8 km; M15; 1	2.8 km; M15; 1
HMC (Russia)	No EPS	No EPS	No EPS			
NCEP (USA)	32-48 km; M21; ~3.5	24 km; M21	24 km; M21	18 km; M25	18 km; M25	15 km; M25
Navy/NRL (USA)	45/15 km; M15; 2	45/15 km; M15; 2	45/15 km; M20; 2	45/15 km; M20; 2	45/15/5 km; M20; 2	45/15/5 km; M40; 2
CMC (Canada)	No EPS	No EPS	15 km; M16; 2	15 km; M16; 2	10 km; M16; 2	10 km; M10; 2
CPTEC/INPE (Brazil)	40 km; M11; 5	30 km; M11; 5	15 km; M15; 5	15 km; M21; 5	15 km; M21; 5	10 km; M21; 5
JMA (Japan)	No EPS	No EPS	No EPS	No EPS	No EPS	?
CMA (China)	NO RESPONSE					
KMA (Korea)	No regional EPS	No regional EPS	10 km; M17; 1.5	10 km; M17; 1.5	10 km; M17; 2	10 km; M17; 2
NCMRWF (India						
BMRC (Australia)	0.5^ox0.5^o; M24 > M32(?)	?				

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)	2006	2007	2008	2009	2010	2011
ECMWF (Europe)	No regional models					
Met Office (UK)	4D-Var, 36 km 3D-Var, 4 km	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?
Météo France (France)	3D-Var; 9.5 km	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
DWD (Germany)	Nudging; 7 km	Nudging; 7 km Nudging; 2.8 km	?	?	?	?
HMC (Russia)						
NCEP (USA)	3D-Var; 12 km	Advanced-Var; 8 km	Advanced-Var; 8 km	Adv or 4D-Var; 6.5 km	Adv or 4D-Var; 6.5 km	4D-Var; 5 km
Navy/NRL (USA)	3D-Var; 45/15/5 km	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
CMC (Canada)	3D-Var; 15 km Var; L58	3D-Var; 10, 40 km; L58	4D-Var; 10, 40 km; L58	?		
CPTEC/INPE (Brazil)	3D-Var; 40 km	3D-Var; 30 km	LENKF; 20 km	LENKF; 20 km	LENKF; 20 km	LENKF; 10 km
JMA (Japan)	4D-Var; 40, 20 km	4D-Var, 10 km 3D-Var, 2 km	4D-Var, 10 km 3D-Var, 2 km	4D-Var, 10 km 3D-Var, 2 km	4D-Var, 10 km 3D-Var, 2 km	4D-Var, 10 km 3D-Var, 2 km
CMA (China)	NO RESPONSE					
KMA (Korea)	3D-Var; 30,10 km	3D-Var; 30,10, 5 km	4D-Var? EnKF?	4D-Var? EnKF?	4D-Var? EnKF?	4D-Var? EnKF?
NCMRWF (India						
BMRC (Australia)	3D-OI	Met Office 4D-VAR under ACCESS				