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REPORT OF THE TWENTIETH SESSION OF THE
CAS/JSC WORKING GROUP
ON NUMERICAL EXPERIMENTATION
(Met Office, Exeter, UK, 11-15 October 2004)

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The twentieth session of the CAS/JSC Working Group on Numerical Experimentation (WGNE), held jointly with the seventh session of the GEWEX Modelling and Prediction Panel (GMPP), was kindly hosted by Met Office, Exeter, U.K., from 11 to 15 October 2004. The session was opened at 0900 hours on 11 October by the Chairman 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.

Prof. J. Mitchell, Chief Scientist, Met Office, welcomed all participants to the meeting, and spoke of the importance of the agenda to be taken up at the session, which should lead to valuable results for meteorological services.

On behalf of all participants, Dr M. Miller expressed his thanks to Prof. J. Mitchell and Dr A. Lorenc for hosting the joint session of WGNE and GMPP and the excellent arrangements made. He voiced his appreciation to Dr A. Lorenc, ably assisted by Met Office staff, for the efforts and time they had put into the organization of the session. Dr Miller expressed his gratitude to Dr K. Puri who had now stepped down as Chair, WGNE, but would continue as Member, and recalled the notable contributions made by Dr K. Puri to WGNE. Dr Miller welcomed Prof. P. Lemke, the Chair, JSC and noted that WGNE was privileged to have him on this occasion. Dr Miller also welcomed Prof. J.Shukla, Chair, WCRP Modelling Panel (WMP) and observed that WGNE looked forward to close interaction with the newly formed WMP in the context of the emerging strategic framework called Coordinated Observation and Prediction of the Earth System (COPES).

The Chairman continued by extending his greetings to the participants in the session whilst noting with regret that one WGNE member, Dr Chen Dehui could not be present. The Chairman was pleased to welcome the invited experts. (See Appendix A for a complete list)

The Chairman reminded everyone of the joint WGNE/WGSIP/WGCM Workshop on Ensemble Methods, which was to be held in the following week.

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

Scientific direction, Structure and Priorities for the WCRP

Prof P. Lemke, chair, JSC and Prof. J. Shukla, chair, WCRP WMP informed WGNE about the main decisions and recommendations adopted by the JSC at its twenty-fifth session regarding the scientific direction, structure and priorities for the WCRP.

Twenty-fifth session of the JSC

Prof P. Lemke made a brief presentation on ''future directions of the WCRP including the Coordinated Observation and Prediction of the Earth System (COPES)''. The WCRP was heading for prediction of the earth system, but starting with prediction of climate system. Significantly improved observation system, climate system modelling, our ability to predict El Niño, now enable us to extend our study to the entire earth system. A COPES discussion document has been prepared and was being circulated widely for comments. As part of the structural changes necessitated by COPES, a WCRP Modelling Panel (WMP), and a WCRP Observations and Assimilation Panel (WOAP) have been set up. The JSC oversees COPES, WMP and WOAP. Prof. Lemke noted that COPES is more a strategy than a project and work will be done through existing projects; COPES needs the support and ownership of all WCRP projects.

Prof J. Shukla, Chair, WMP, briefed WGNE about the aim and scope of the WMP. He pointed out that COPES combines predictability and the seamlessness nature of the problem of predictability. To build on the strengths of existing projects, WMP will engage the chairs of all projects. To facilitate the coordination and interaction of WGNE, WGCM, etc. under the WMP, the panel would meet in conjunction with WGCM and WGNE in alternate years, starting with WGCM in 2005. Prof. Shukla suggested that WGNE might consider having model development explicitly as a future agenda item, “next generation models”.

WGNE thanked Professors Lemke and Shukla for their presentations. WGNE acknowledged that for COPES to be successful it needs the support and ownership of all WCRP projects. Under the WMP, atmosphere-land data assimilation activity will be led by WGNE. WGNE was informed that the full assimilation effort, which involves coupled atmosphere-land and atmosphere-ocean data assimilation activities will be dealt with by the new WOAP. Concern was expressed that the WOAP did not appear to have sufficient representation of data assimilation experts and it was agreed that this concern would be conveyed to the WOAP Chair.

The need for good metrics for climate-type models was discussed and WGNE noted that the WGCM was considering this and that PCMDI is already involved in developing metrics on applications. WGNE welcomed the idea of development of metrics in the spirit of the new 'unified' prediction systems and will also consider this at its next meeting.

Eighth session of the WGCM

Dr B.M. McAvaney briefed WGNE on the eighth session of the WGCM held with a joint IGBP/GAIM session, in Yokohama, Japan, October 2004. The main issues discussed at the session included: (i) the Coupled Model Intercomparison Experiment (CMIP) under which the WGCM has set up a Climate Simulation Panel to oversee and coordinate collection, archival and analysis of model data for IPCC AR4. US CLIVAR was sponsoring an international IPCC model analysis workshop, which was taking place at the International Pacific Research Centre, University of Hawaii, in March 2005. Other CMIP activities (CMIP2+) were ongoing and CMIP subprojects and publications would contribute significantly to IPCC AR4;(ii) the international Cloud Feedback Model Intercomparison Project;(iii) development and use of climate forcings;(iv) aspects of decadal variability;(v) coordinated experiments on thermohaline circulation response to increasing greenhouse gases; and (vi) interaction with the Palaeoclimate Modelling Intercomparsion Experiment and IGBP GAIM.

The review of WGCM (as part of the wider review of CLIVAR) was generally favourable and the CLIVAR SSG noted the success of projects such as CMIP. The position of WGCM in the context of COPES was discussed. WGCM noted that almost all its members were now into Earth System Modelling (ESM). A Regional Modeller was being brought into the Panel. WGCM was also moving towards increasing cooperation with IGBP/GAIM, which has expertise in carbon cycle and chemistry and land-surface. It was therefore opportune for WGCM to reorient itself towards Earth System Modelling. At the joint session with the GAIM, IGBP there were presentations on: (i) major issues for coupled Earth System Models covering biosphere, chemistry and atmosphere and on (ii) specific topics such as C4MIP (Coupled Climate-Carbon Cycle Models Intercomparison Project), CMIP/CFMIP, PMIP and EMICS (Earth System Models of Intermediate Complexity*)*. The last session was on 'possible future activities' including IPCC Fourth Assessment: Chapters of interest to GAIM, and GAIM-WGCM co-operation.

Relevant activities under CAS auspices

A key area of collaboration between WGNE and the World Weather Research Programme (WWRP) is THe Observing system Research and Predictability Experiment (THORPEX) being undertaken as a "Research and Development Programme" of WWRP in collaboration with WGNE. The themes proposed are of major interest to WGNE, and the studies of predictability and observing system issues being taken up will have benefits throughout the WCRP. The international coordination of THORPEX is under the auspices of the WMO, WWRP and WGNE. The THORPEX International Science Steering Committee (ISSC) defines the core research objectives with guidance from the THORPEX International Core Steering Committee (ICSC) whose members are selected by national permanent representatives to the WMO. WGNE reiterated its support for THORPEX as a collaborative WWRP/WGNE experiment.

Dr E. Manaenkova reported on the activities of CAS relevant to WGNE. A particularly important issue was the role of WGNE in Implementation of an Integrated Global Atmospheric Chemistry Observations (IGACO) System. A globally coordinated approach to atmospheric chemistry observations was needed to address four outstanding global issues: climate change, ozone depletion and UV increase, air quality and human health and the oxidizing efficiency of the atmosphere. In May 2004, the Integrated Global Observing Strategy (IGOS) approved a Theme Report on Atmospheric Chemistry prepared by an international panel of atmospheric scientists (see the GAW website for the report http://www.wmo.ch/web/arep/gaw/gaw_home.html). The report is a science and technical assessment recommending action toward an IGACO system. WMO has accepted the lead in implementation working with space agencies and the research community. Thirteen target groups of chemical variables including ozone and aerosols were identified as the focus in the next 15 years. The IGACO system proposed relies upon atmospheric models as "smart interpolators" that optimally combine atmospheric observations from surface-based (in situ, remote sensing, balloon) networks, aircraft and satellites. Both real-time delivery of observations to forecast models as well as systematic collection and preparation of data sets for inverse modeling and reanalysis are involved. By matching, the global top-down framework of IGACO with specific bottom-up regional and international projects as well as common data standards and management protocols, a global atmospheric composition measurement and prediction system can be achieved to the mutual benefit of all. The Atmospheric Research and Environment Programme (AREP) has the lead for WMO in implementing IGACO together with the Space Programme. AREP requests that WGNE play an active role in

implementation particularly in assimilation, reanalysis and modelling aspects of IGACO beginning with the appointment of a WGNE representative for IGACO.

Recommendations from the seventeenth session of the GEWEX Scientific Steering Group

Dr J. Polcher and Dr R.W. Lawford briefed WGNE on the recommendations from the seventeenth session of the GEWEX Scientific Steering Group.

Dr Lawford dwelt on the approach to predictability in the GMPP, land data assimilation, and asked if a collaboration with WGNE was possible in this area; is reanalyses an area where GEWEX and WGNE should work more closely together? Another area of collaboration for GMPP was the Global Water System Project (GWSP) of ESSP. How does GMPP contribute to the new thrust (CEOP2, COPES, crosscuttng themes, GEWEX road map)? Dr Lawford raised a question whether the original objectives of WGNE, GMPP holding joint meetings are being met.

Dr Polcher informed that no closed theory of land processes exists at the macroscopic scale, although they are well developed at the microscopic scale. He noted that the implementation of diurnal cycle theme has been delayed. Commenting on the WGNE, GMPP interaction, he noted that GCSS, WGNE interaction has worked well over the years. However, interaction with GLASS has been rather weak. It was pointed out that there was increased focussing in WGCM on sensitivity of parameterization schemes. GMPP expressed the need for interaction with WGCM, where there was interest on sensitivity to land surface modelling. GMPP also expressed that close interaction with AMIP was highly desirable, especially for the analysis of the diurnal component in AMIP models. A special session on parameterizations is planned during the GEWEX SSG session in 2005.

WGNE confirmed the value of the interaction with GMPP for parameterization work, particularly with GCSS. WGNE recommended that GMPP should help GHP co-ordinate regional climate modelling and liaise with WGNE. This should ensure an appropriate usage of these models.

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

The GEWEX "modelling and prediction" thrust, with which WGNE works in close association, is devoting efforts to the refinement of atmospheric model parameterizations, notably those of cloud and radiation, land surface processes and soil moisture, and the atmospheric boundary layer. The discussion of the GEWEX modelling and prediction thrust at the joint meeting of WGNE and GMPP, encompassing the GEWEX Cloud System Study (GCSS), the Global Land-Atmosphere System Study (GLASS), and the GEWEX Atmospheric Boundary Layer Study (GABLS) is described in the report of GEWEX Scientific Steering Group to the JSC.

Dr J. Polcher briefed WGNE on the progress in GMPP. GMPP aims: to better understand which type of conceptual models are needed in NWP and climate models; to better represent the water cycle in global models; and to improve understanding of the interactions between the surface, the PBL and clouds. In addition to ongoing local scale studies a close interaction with AMIP was needed to facilitate the input of GMPP in global models and identify problem areas. Land surface models could be evaluated globally without the coupling to GSWP2. Future strategy would focus on the interactions between the land surface, the PBL and clouds and on developing pan GMPP interactions around the diurnal cycle theme. The analysis of the diurnal cycle in AMIP models would provide guidance for selecting cases and would test globally the proposed improvements. A special session on parameterizations is planned during the GEWEX SSG session in 2005. GMPP's contribution to GEWEX crosscutting activities included Precipitation crosscut and LANDFLUX. GMPP would also assist GHP coordinate regional climate modeling and liaise with WGNE, which should ensure an appropriate usage of these models.

2.1 Cloud parameterizations

Dr C. Jakob informed WGNE that a new GCSS Panel has been constituted with each panel member now having a portfolio. The previous Working Group meeting in 2003 discussed PBL clouds, preliminary results of DYCOMS-II RF01 nocturnal non-drizzling stratocumulus intercomparison and the next RF02 case. Current activities focused on cirrus clouds, deep convection and arctic clouds. A pan-GCSS meeting planned to be held in May 2005 in Athens will address: perspectives on clouds in the climate system, methodologies and metrics in assessing models, the fundamental role of precipitation in cloud systems, and advances in the representation of clouds in large-scale models. Dr Jakob proposed a joint WGNE/GCSS activity involving model intercomparison study of a Pacific cross section with a view to evaluation of physical parameterization along the cross section following the trade winds. WGNE responded positively to this, and also suggested

that there be a follow up exercise over continents, possibly in the context of African Monsoon Multidisciplinary Analysis (AMMA). WGNE also proposed that participants for the study should include the AMIP community and noted that the proposal provides an excellent opportunity to bring together NWP and climate modellers.

Dr R. Kershaw presented aspects of current work in the Met Office using high-resolution models and observations to improve NWP. These related to orographic drag convergence studies, simulation of lee waves over the Pennines, parameterization of an observed evening transition to a stable boundary layer, a turbulent parameterization of precipitating convection, and making the link between SCM results and NWP. He emphasized the importance of observations to constrain the models and discussed some of the areas of parameterization which are difficult and need improved understanding.

2.2 Land-surface processes

GEWEX Global Land-Atmosphere System Study (GLASS)

Dr P. Dirmeyer reported on the GLASS. GLASS, the land surface component of GMPP, is continuing to promote further integration of its activities with other parts of GEWEX and related activities outside GEWEX. An example of interaction with GABLS (GEWEX Atmospheric Boundary Layer Study) is the new project Loco (Local Coupled Action), which will address the role of land-PBL interaction though local coupled modelling, with a view towards improved simulation of the diurnal cycle of surface fluxes. New interactions outside GEWEX include cooperation with SnowMIP (Snow Model Inter-comparison Project), closer interaction with operational land data assimilation efforts in Europe and the USA, and the urban modelling community.

The Global Soil Wetness Project 2 (GSWP-2)

More than 16 models have participated in the Second Global Soil Wetness Project (GSWP-2), which is completing its modelling phase and is moving into the analysis phase. Baseline simulations and sensitivity studies have been completed and are being distributed for analysis. The Global Land-Atmosphere Coupling Experiment (GLACE), a multi-model project in large-scale coupled action, resulted in a *Science* paper (Koster et al. 2004,*Science,* 305,pp 1138-1140) showing the spatial variability of the strength of land-atmosphere coupling. Land surface coupling is greatest where conditions are neither abnormally wet nor abnormally dry and are most pronounced in central North America, central Africa and India. A new project, IPILPS (Isotopes in the Project for Inter-comparison of Land-Surface Parameteriz ation Schemes), has been initiated under the auspices of GLASS to contribute to a comparison of atmospheric, coupled climate, and earth system models that incorporate isotopic representation in their land-surface schemes. The GLACE project showed that while the 12 participating models differ in their land-atmosphere coupling strengths, certain features of the coupling patterns are common to many of the models. A two-part paper was being submitted for publication (Koster et al., Guo et al.; *J. Hydrometeorology*). In the Project for Intercomparison of Land-surface Parameterization Schemes (PILPS-C1 (Carbon)), comparison of both biophysical and biogeochemical fluxes from different types of models with observations at one EUROFLUX site Loobos (coniferous forest) were being made. A decision for a second phase of the project will be done after completion of the first phase.

Dr Y.Takeuchi reported on the development of the new land surface model for JMA- Global Spectral Model (GSM). JMA has been developing a new Simple Biosphere (SiB) model for the operational GSM to sort out some shortcomings of the operational SiB model. In general, southern edge of the snow cover in the Northern Hemisphere predicted in the GSM with the operational SiB tends to retreat faster than analyzed snow cover. The new SiB model has four soil layers and three snow layers. In the soil layers, heat conductivity is explicitly calculated and phase changes of soil water/ice are included. In the snow layers, partial snow cover in a grid, albedo change due to aging effect and snow densification due to comparative viscosity are included. The forecast experiments for four years demonstrate that more realistic change of snow cover in spring is predicted with GSM with new SiB.

Dr S. Milton presented results on diagnostic studies with the Met Office NWP models and plans for future model developments. Evaluation of the global model against data from the Coordinated Enhanced Observing Period (CEOP) is highlighting a number of parameterization and initialisation issues including the need for the development of a soil moisture initialisation to improve the latent/sensible heat fluxes. Tropical performance remains a problem in the global model with too much precipitation over tropical oceans and too little over land, and an enhanced tropical circulation (Hadley and Walker cells). Detailed timestep-by-timestep diagnostics from the aqua planets have revealed numerical issues with the convection scheme including too large mass-fluxes for mid-level convection, and tendency for downdraughts to terminate on occasions before

reaching the boundary layer. Work is ongoing to improve the current mass-flux convection scheme in these respects. Model developments planned for 2005/06 include enhanced global model resolution (60km/38 levels to 40km/70 levels), expansion of 12km UK area model to cover North Atlantic and European region (including 70 levels), and a 4km model for UK area by end 2005. Changes to definition of decoupled SC in the BL scheme and a new microphysics scheme are planned for January 2005. These changes give improvements in BL cloud over subtropical oceans and land. This will make the global NWP model physics the same as that in the current climate version (HadGEM1). A new prognostic cloud scheme (PC2) is being evaluated for operational implementation in 2005 (D. Wilson) and a turbulence-based approach to convection is being developed (A. Grant) for implementation at the end of 2006.

2.3 Atmospheric boundary layer

GEWEX Atmospheric Boundary Layer Study (GABLS)

Prof. B. Holtslag presented an overview of GABLS, summary of the First GABLS Intercomparison Study, some results of GABLS conference, Portland, USA, August 2004,and future activities. An intercomparison of large-eddy simulations of the stable boundary layer by 17 investigators provided 10 results sets. Results show significant spread, but convergence at high resolution, sensitivity to sub-grid model and an overall fair agreement with observations. Effective stability functions are in agreement with observations and sharper than those typically used in operational models. Activities in 2005 include a special GABLS issue on First Case in Boundary-Layer Meteorology, a second intercomparison study plus workshop, and the establishing of cooperation with LOCO/GLASS.

2.4 Cordinated Enhanced Observing Period (CEOP)

Dr M.G. Bosilovich presented an overview of the CEOP activities. As the CEOP data collection period closes (as of December 31, 2004), new scientific results are maturing and the planning for Phase II, and its relationship with GEOSS and COPES are taking shape.

Many modelling groups are utilizing CEOP data in research and development activities (Experimental Climate Prediction Center (ECPC), NCEP, UKMO, JMA, CPTEC, Global Land Data Assimilation System/Land Information System (GLDAS/LIS) and Global Modeling and Assimilation Office (GMAO)), as evidenced by results at the Third CEOP Implementation meeting (March 2004, Irvine, CA, USA). Not all these were presented at the WGNE/GMPP meeting. The GLDAS/LIS group has tested 1 km spatial resolution offline land models, using MODIS 1Km vegetation and Leaf Area Index (LAI), compared to 25KM resolution, and the results over CEOP sites show that better representation of the vegetation nearer a site, improves the land model results. JMA, UKMO, ECPC and NCEP are validating their grid space surface energy fluxes with CEOP station data. The GMAO is using the station data as independent validation for testing remotely sensed skin surface temperature assimilation impact on the energy and water fluxes.

The data collection is proceeding at a moderate pace. The processing of EOP3 in-situ data has proceeded more efficiently because of the initial testing period (EOP1) though the providers work at their own pace. The key attributes of what is ultimately called CEOP in-situ data are that the data has undergone additional quality control measures (including visual inspection of all data), and the format of the data is uniform across all providers. Eventually, this will be staged on a DODS server for increased accessibility. (See http://www.joss.ucar.edu/ghp/ceopdm/ for current status) The model data is flowing into the Max Planck Institute's Model and Data Archive (M&D). Almost all centers have provided some data so far, though gaps still exist in across the CEOP period. This is expected to improve in time. Currently the M&D archive is holding 1.3 Tb of gridded and point model data. M&D has plans to improve the efficiency and accessibility of the data (awaiting funds to proceed).

In the near future, we expect to see model intercomparisons during the CEOP period. One potential outcome may be a quantitative estimate of the uncertainty of the analyses. The Fourth CEOP Implementation Meeting will take place in Tokyo Japan, 28 February – 4 March 2005. A day will be set aside to present scientific research, after which, a special issue of a peer review journal will be discussed. The future role of CEOP in GEOSS and COPES will be further refined at the meeting.

JMA contributions to CEOP

Dr Y. Takeuchi reported on the JMA contributions to CEOP. JMA provides two kinds of data sets to the CEOP data archive center, Max-Plank Institute (MPI). One is analysis and subsequent six-hour forecast data set produced by the operational global assimilation system based on T213L40 GSM with 3D-Var assimilation in JMA. The grid point value (GPV) of the analysis and forecast is encoded in GRIB1 and the

MOLTS data, i.e. the nearest GPV without any interpolation from the original GPVs, are encoded in ASCII. These data are provided for the third Enhanced Observation Period (EOP3) and EOP4 period from 1 October to 31 December 2004. The other is the analysis data set produced by Japanese 25-year Reanalysis Project (JRA-25) based on T106L40 with 3D-Var assimilation for the period from 1979 to 2004. This data set is also provided as GPV data in GRIB1 format and MOLTS data in ASCII format. The data set for EOP3 and the first half of EOP4 has been already sent to MPI.

JMA has been developing a new Simple Biosphere (SiB) model for the operational GSM. A validation study for both the new SiB and the operational SiB against CEOP EOP1 in-situ data is carried out. Diurnal variation of 2m temperature, short-wave radiation and long-wave radiation in the models with the new SiB and the operational SiB are validated at some reference stations. The results show that the new SiB predicts the diurnal range of 2m temperature better than the operational one.

Assessment for the other physical processes of the atmospheric model, such as a boundary layer processes and cloud radiation processes are planned.

WGNE pointed out that CEOP is not connected to global data sets and expressed the need to have output from global datasets at the CEOP site. The WGNE community provides comprehensive gridded output from global data assimilation systems for CEOP. Many modelling groups are utilizing CEOP data in research and development activities and this should lead to model intercomparisons during the CEOP period.

3. STUDIES AND COMPARISONS OF ATMOSPHERIC MODEL SIMULATIONS

3.1 General model intercomparisons

A key element in meeting one of the WGNE basic objectives of identifying errors in atmospheric models, their causes, and how they may be eliminated or reduced, was a series of model intercomparison exercises. These encompassed a number of fairly general wide-ranging intercomparisons as outlined in this section, as well as more specific efforts, e.g., evaluation of snow models as employed in atmospheric circulation models or assessment of stratospheric analyses and predictions (see sections 3.4, 3.5).

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 an important and far-reaching WGNE-sponsored intercomparison. Dr P. Gleckler presented a very brief survey of results of the second phase of AMIP (AMIP2). AMIP2 was coming to a close and much of the data from these runs were available for a wide range of diagnostic sub-projects. Climatological comparisons are available for nearly every standard AMIP model output field. Overall, there have been progressive general improvements both in terms of the "median" model as well as for many of the individual models. The simulation of interannual variability and performance in specific geographical regions, as measured by global climatological statistics, also appear to be more realistic. 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. Dr Gleckler said that current priorities at PCMDI included evaluation of coupled models including WCRP Benchmark Intercomparisons CMIP, AMIP2, Transpose AMIP (also called CAPT, see later), Climate Change Detection, and software development. PCMDI looked to WGNE and GMPP to endorse its plan to formally close AMIP2, recognize community-based efforts to establish the CF convention and IPCC data guidelines and exploit them.

WGNE expressed its gratitude to PCMDI for undertaking and successfully completing the AMIP projects and for creating a valuable infrastructure for processing model outputs at PCMDI and establishing efficient data formats etc for such exchanges of model simulations. WGNE recommended closure of AMIP2 in a time frame of six months. During this period PCMDI would announce the project's completion and update its status on AMIP homepage and complete an AMIP2 Summary Paper for publication. It will also make available PCMDI diagnostics of all AMIP and CMIP runs. WGNE, WGCM, GMPP and PCMDI would discuss the future of AMIP beyond AMIP2.

"Transpose" AMIP

Dr Williamson presented results from work at NCAR and PCMDI on "Transpose" AMIP. The goal of the Transpose AMIP is to obtain the benefits for climate model development and evaluation that have been realized in weather prediction by using climate models as weather forecasting tools, but without the huge costs of developing a complete NWP system. Initially the climate models are applied at their relatively low application resolutions and are not expected to make the best weather forecasts, however the approach will also encourage higher resolution studies. The method allows direct comparison of parameterized variables such as clouds and precipitation with observations from field programmes such as Atmospheric Radiation Measurement (ARM), early in the forecast while the model state is still near that of the real atmosphere. This is in contrast to the more traditional climate model statistical analysis based on the model simulated climate balance. In that approach the parameterizations see the erroneous climate model state rather than the true observed state.

Results were presented from the NCAR/PCMDI project, Climate Change Prediction Program (CCPP) ARM Parameterization Testbed (CAPT), the prototype version of "Transpose" AMIP developed for US modelling evaluation. Results from two series of 5-day forecasts with the Community Atmosphere Model (CAM) 2.0 from ERA40 initial conditions were presented, one from the June/July 1997 ARM IOP, and the other from the April 1997 ARM IOP at the ARM CART site in Central Oklahoma. Examination of traditional skill scores of the forecasts indicate that in both seasons CAM produces reasonable forecasts of large scale atmosphere. Thus the parameterizations are being driven by realistic fields in the forecasts. These results demonstrate the viability and utility of this forecast approach for examining climate models and identifying avenues for improvement. Dr Williamson proposed that WGNE now go forward with a formal proposal to the international climate modelling community (including the AMIP mailing list) for an intercomparison Transpose AMIP. He proposed that the experiment consist of two sets of 5-day forecasts initialized 00Z from reanalyses for the March 2000 and June/July 1997 ARM IOPs.

WGNE expressed satisfaction at the very good progress made in the project, and thanked Dr Williamson for all his work done thusfar. WGNE welcomed and strongly supported a formal proposal for Transpose AMIP, recognising its potential for future field programmes. It was agreed that WGNE would make a formal proposal to the international climate modelling community (including the AMIP mailing list) for an intercomparison Transpose AMIP.

International Climate of the Twentieth Century Project (C20C)

Prof. J. Shukla briefed WGNE about the progress in C20C project. The Third workshop of the C20C project took place in Trieste, Italy, 19-23 April 2004. The workshop included: presentations of results of Phase 1 integrations and initial Phase 2 results, discussion on planning for Phase 2 and beyond and discussion from representatives of WCRP programs on how to specify/deal with forcings and coupled models. Planning for comparison with coupled models includes (i) coupling to mixed layer or dynamical ocean, (ii) maintaining the time evolution of surface forcing through imposed tropical SST, (iii) proposed new coordination with WGSIP; then WGCM, and (iv) efficient estimation of anthropogenic signals.

3.2 Developments of refined numerical algorithms for model dynamics and test cases for new methods

Dr D. Williamson led the discussion on this item. Several specialist workshops on this topic were held this year. These included the 2004 Workshop on the Solution of Partial Differential Equations (PDEs) on the Sphere, hosted by the Frontier Research System for Global Change, Yokohama, Japan, 20-23 July 2004 and the Workshop on Atmospheric and Ocean Modeling with Isentropic and Other Quasi-Lagrangian Vertical Coordinates, Washington, D.C., 17-19 August 2004. These workshops illustrate the range of approaches being followed in numerical approximations and the types of grids being developed. Details of the papers presented at the PDEs Workshop may be found at: http://www.jamstec.go.jp/frcgc/eng/workshop/pde2004/agenda.html. The next workshop is being planned for spring of 2006 in Monterey, CA, USA.

A critical component to these activities is the development of test cases, particularly for baroclinic dynamical cores. Dr Williamson discussed two cases that have recently been developed involving well resolved perturbations imposed in a baroclinically unstable state. One by Drs Polvani, Scott (of Columbia University) and Thomas (of NCAR), provides "Numerically converged solutions of the global primitive equations for testing the dynamical core of atmospheric GCMs" published in MWR, 2004, Vol. 132, pp.2539-2552. A rather strong diffusion term is added to the T and u equations, which allows a convergent solution to be determined numerically with two models. However, different forms of diffusion lead to different solutions. Thus the test can be used to determine convergence of numerical schemes with increasing resolution, but provides less information about schemes at application resolutions where inherent diffusion of the numerics

may dominate. The second was developed by Dr C. Jablonowski (University of Michigan) in her Ph.D. thesis, 'Adaptive Grids in Weather and Climate Prediction'. The aim of her test is not to compute a numerically converged diffusive solution but to assess the best possible method for solution at any resolved scale. Subgrid-scale diffusivity is considered to be part of the numerical scheme. A reference solution defined to within an identifiable uncertainty was determined by four very different dynamical cores. The uncertainty arises because different numerical truncation errors and different discrete geostrophic adjustments introduce relative perturbations which also grow with time given the unstable nature of the basic state. Thus, one cannot look at convergence with increasing resolution. Rather one can only determine at what resolution a numerical method calculates the solution to within the uncertainty of the reference solution. The accuracy of the approximations at coarser resolutions can be compared between schemes.

Dr A. Staniforth presented a review of the recent research at the Met Office on dynamical cores. The aspects covered included: properties of various equation sets; vertical coordinates; semi-Lagrangian advection and conservation; trajectory computation and dynamical equivalence; horizontal and vertical discretisation; and coupling of physical parameterizations to a dynamical core.

Dr D. Majewski reported on the joint development project ICON (Icosahedral Non-hydrostatic) of the Deutscher Wetterdienst (DWD) and Max Planck Institute for Meteorology. 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 the solving of 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 was undergoing the Williamson et al. test suite.

Aqua-Planet Experiments

Dr Williamson reported on the developments in this activity. In the past, WGNE has recognised the value in stripped down versions of atmospheric models with very simplified surface conditions for examining the behaviour of physical parameterizations and the interactions of parametrizations with the dynamical cores. In particular, "aqua-planet" experiments with a basic sea surface temperature distribution offer a useful vehicle in this regard. WGNE has 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.pcmdi.llnl.gov/projects/amip/ape/index.html and http://www.met.reading.ac.uk/~mike/APE/ape_home.html .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. Sixteen groups have declared their intentions to participate. Seven groups have submitted their control simulations to PCMDI where they have been quality controlled. Other groups will be submitting their data in the coming months. Some preliminary results were shown to WGNE which indicate a substantial spread in results with notably large variations in precipitation amounts. For example, tropical zonal average convective precipitation ranges from 5 mm/day to 15 mm/day between models, while large-scale precipitation ranges from close to zero to 5.5 mm/day. Mid-latitude precipitation shows a variation of a factor of 3 in both forms between models. A Workshop will be held during 20-22 April 2005 at the University of Reading to discuss the results, summarize current model behaviour and produce a summary of research questions arising from the experiment.

3.3 Model-derived estimates of ocean-atmosphere fluxes and precipitation

Dr P. Gleckler reported on the activities in this area. Evaluation and intercomparison of global surface flux products (over ocean and land) from the operational analyses of a number of the main NWP centres (the SURFace Flux Analysis (SURFA) project) remains a high priority for WGNE. The atmospheric and coupled modelling communities and oceanographers have very strong interest in advancing SURFA, which could provide a good opportunity for progress in estimating and determining surface fluxes. Efforts are continuing through liaison with the newly formed WCRP Working Group on Surface Fluxes (WGSF) to address the requirements of research, observations, analysis and modelling of surface fluxes within WCRP and closely related programmes such as GODAE and GCOS. It was suggested that it was more convenient for NWP centres to provide data in real time.

WGNE discussed the problems involved with adhering to data standards and noted that GODAE has been active in this area.

3.4 Model stratospheric representation

Dr K. Puri reported on this WGNE project designed to compare the stratospheric predictability capabilities of present day NWP systems and their ability to capture polar vortex dynamics in both analyses and forecasts. Better forecast skill in the stratosphere is to be expected because its flow is dominated by a quasi-stationary polar vortex rather than in the troposphere where the flow is influenced by transient, synoptic scale waves. The most difficult forecast times would be when the polar vortex is undergoing large changes.

This study, carried out for WGNE by Dr Roff, Bureau of Meteorology (BoM), Australia, relates to the period when the polar vortex underwent a sudden warming: in northern hemisphere (NH) the target period was 10 days (29 January 2000 - 7 February 2000) when there was a developing planetary wave number three in the lower stratosphere associated with tropospheric blocking, cold temperatures and a developing warming; in the southern hemisphere (SH) the target period was 14 days (20 September 2002 - 3 October 2002) during the first recorded major southern hemisphere sudden warming.

NWP data were provided by the BoM, ECMWF, NCEP, Navy Operational Global Atmospheric Prediction System (NOGAPS) and UKMO models. The data provided extended to 10, 1, 7, 10 and .3 hPa, respectively, enabling a comparison of the forecasting ability of models with low model tops (BoM, NCEP, NOGAPS) to those with high tops (ECMWF and UKMO).

This study shows that stratospheric predictability in both hemispheres has similar characteristics: stratospheric forecasting performance at 6 days is comparable to 3 days in the troposphere (though this is more obvious in the SH than the NH case); there exists large variability in the forecast skill at 6 days, often depending on how active the planetary waves are and thus how quickly the vortex distorts (this is more common in the NH and so forecast "busts" are more likely); poorer forecast skill scores occur when the vortex flow is rapidly changing; forecast errors tend to propagate from the top of the model down in a stepwise manner; there are common dynamic situations difficult for stratospheric forecasting, (28 September 2002 in the SH and 4-7 Feb 2000 in the NH); erroneous forecast planetary wave activity seems responsible for the forecast errors. The stratospheric forecast skill can be increased by increasing the stratospheric vertical resolution and raising the model top.

The SH study was reported in the 2003 ECMWF/SPARC Workshop on "Modelling and Assimilation for the Stratosphere and Tropopause" and the NH study was reported to the WGNE meeting (2004). This work is now being written-up for publication. It was presented at the GCM Reality Intercomparison Project for SPARC (GRIPS) Workshop in Toronto, 22-25 March 2005. At this workshop a possible extension of the study was suggested where the GRIPS middle atmosphere models, which have a much better represented stratosphere and mesosphere, could be run for the same period and compared.

WGNE suggested that Dr Roff, BMRC, should interact with SPARC and obtain a list of diagnostics for model intercomparison; WGNE could then take the matter forward.

SPARC Data Assimilation Project (SPARC-DA)

Prof. A. O'Neill reported on stratospheric data assimilation. It is an inherent part of the activities of SPARC, which aims to bring stratospheric expertise to bear on scientific issues concerned with climate processes and climate prediction for the benefit of the WCRP, WMO/UNEP Ozone Assessments, IPCC, and space agencies. The current areas of SPARC activities centre on chemistry-climate interactions, detection, attribution and prediction of stratospheric change and troposphere-stratosphere coupling. To address these topics, SPARC develops stratospheric modules of global circulation models (GCMs), initiates intercomparison experiments, field campaigns, and develops data assimilation.

Stratospheric data assimilation (SDA) is becoming commonplace at modern NWP centres. The SDA may include troposphere-stratosphere GCMs with parameterized chemistry, off-line chemical-transport models with sophisticated chemistry and as well GCMs with more advanced chemistry, which serve as the basis for "chemical weather forecasts". For stratospheric research, SDA is expected to be a source of long term, global multidisciplinary (dynamics, thermodynamics, chemistry, tracers, aerosols) data sets for the troposphere and stratosphere, which are free of artificial trends and are consistent with 3-D velocity fields and diabatic sources and sinks.

The SPARC Data Assimilation Working Group collects information on stratospheric data sets on meteorology and chemistry (quality, availability, software…), collects and documents information in data assimilation systems, liaises with space and other agencies on SPARC data needs and undertakes

process-focused SDA quality assessments. For example, recently the group completed an overview of the most used datasets at UK Met Office, ECMWF, NCEP, and other centres. A progress report on this topic is available at http://polar.gsfc.nasa.gov/sci-research/cooperative_ventures/sparc/index.php. There is now a website with links to information on each dataset and related publications. A test dataset is available for SPARC inter-comparisons.

The aim of process-focused quality assessments undertaken by the group is to compare different analyses using diagnostics tailored to particular problems. The specific diagnostics were developed for polar processes (Arctic polar stratospheric clouds, chlorine activation, areas of low temperatures), fine-scale structure and filamentation, mixing and transport barriers, wave propagation into the stratosphere, stratospheric – tropospheric exchange and tropics, and O_3 mini-holes. More diagnostics will be developed in the future.

The group is in contact and keeps under review the development of SDA in the following centres:

i. The Data Assimilation Research Centre (DARC), University of Reading, UK Met Office, ECMWF and the MSC;

ii. Chemical Transport Models at KNMI, BIRA-IASB, UPMC and the NASA DAO

iii. Coupled systems (e.g. at Météo-France).

The group is planning to extend the activities in cooperation with the WOAP, and existing data assimilation activities of the COST initiative in Europe. SDA should become a part of the proposal for new re-analyses including chemistry initiated by GEWEX. It is very beneficial for space agencies because it is possible through the SDA to maximize and quantitatively assess benefits of new data sources.

The group needs to work in close cooperation with WGNE. Prof. O'Neill proposed that WGNE and SPARC should set up a joint stratospheric data assimilation co-ordinated activity.

WGNE thanked Prof. O'Neill for his presentation. It was agreed to increase interactions between WGNE and SPARC including the establishment of agreed sets of model diagnostics. WGNE has already undertaken an intercomparison of stratospheric analyses and forecasts as described above.

3.5 Snow Models Intercomparison Project SNOWMIP2)

Dr R. Essery reported on the SnowMIP2: An Intercomparison of Forest Snow Process Models (SnowMIP2), which was being launched. The Working group commissioned by International Commission on Snow and Ice (ICSI) has drawn up a schedule of activities for the period 2004-2007. Three SnowMIP2 sites in Canada, Japan and Switzerland will be used, with simulations for forest and clearing at each site, simulations for two complete winters at each site, a pilot study with one model, and comparisons with ground and canopy snow loads.

WGNE thanked Dr Essery for his presentation. Both WGNE and GMPP endorsed the proposal for interaction between SnowMIP2 and GLASS.

3.6 Regional climate modelling

The Chairman of the WGNE/WGCM RCM panel, Prof. R. Laprise, briefed WGNE on this agenda item and also about the joint WGNE/WGCM international Workshop, 'High-resolution climate modelling: Assessment, added value and applications' held in Lund, Sweden, 29 March to 2 April 2004. A short report of the Workshop is given in Appendix D.

The ability of GCMs to adequately simulate the climate over regions of the globe with widely different weather regimes lends some confidence in their ability to handle the climate response to altered forcing, such as increased GHGs and aerosols. Driven by the needs of the climate impacts and applications community for high-resolution climate-change projections, the use of nested RCMs for dynamical downscaling of GCMs' projections has gained increased popularity over the last decade. Testing RCMs over several contrasting regions of the globe should be an integral part of their development and validation. Applying RCMs outside of their "native" region is a useful test to study the ability of models to simulate different climates, and possibly reveal weaknesses that would result from over-tuning an RCM in order to optimise its performance over one region; this would risk limiting the ability of a model to properly respond to changes in forcing. The "Transferability Working Group" (TWG), under the umbrella of the GEWEX

Hydrometeorological Panel (GHP) proposes numerical experimentation that addresses some aspects of RCMs' validation. WGNE-GMPP endorses / encourages this activity, as well as the further development of RCMs for improved performance. This effort should include the comparison of simulated results with available observations from measurements campaigns as well as process studies. Regions with particular climatic specificities, such as open oceans, the Arctic and the tropics, should also be considered. WGNE-GMPP also view positively and encourage the pursuance and extension of work aimed at quantifying errors associated with the nesting technique and at determining optimum configurations; this includes idealised approaches such as the Big-Brother Experiment. An internationally coordinated effort in this direction would allow to extend and strengthen the conclusions of studies to date with this approach.

WGNE has expressed concern in its reports since 1998 about the indiscriminate use, and potential misuse, of regional climate models. Considering the level of discussions that took place at the WGNE-sponsored Workshop in Lund, Sweden, 29 March – 2 April 2004, "High-resolution climate modelling: Assessment added value and applications", WGNE encourages the RCM community to consider organising another such Workshop around Spring 2006. This Workshop should emphasise the potential applications of RCMs, and trying to attract the community of model users.

The International Stretched-Grid Model Intercomparison Project (SGMIP)

Dr M. Fox-Rabinovitz presented results of the phase-1 and the design of the phase-2 of SGMIP. SGMIP has been initiated in 2002 for studying the global variable-resolution/stretched-grid (SG) approach to regional climate modelling. The maturity of the approach has been established over the last decade through national and international group efforts. The phase-1 of the project, SGMIP-1, has been successfully completed in 2004. The variable-resolution SG-GCMs participating in SGMIP-1 are the variable-resolution versions of the basic GCMs of the following four major meteorological centres/groups: Météo-France, ARPEGE model, the RPN/Canadian Meteorological Centre GEM model, the Australian CSIRO C-CAM model, and the U.S. NASA/GSFC GEOS model. SGMIP-1 has been focused on addressing the following major scientific and computational issues: stretching strategies; approximations of model dynamics; treatment of model physics including its calculation on intermediate uniform resolution or directly on stretched grids; multi-model ensemble calculations; optimal performance on parallel supercomputers.

The total number of global grid points for the SG-GCMs of SGMIP-1 is (or close to) that of the 1º x 1º uniform grid. The area of interest is the major part of North America: 20º – 60º N and 130º – 60º W. The regional resolution is 0.5º. The surface boundary forcing (SST and sea ice) is used at 2º x 2.5º or 1º x 1º resolution. The 12-year period, 1987-1998, chosen for model simulations includes the recent ENSO cycles. The existing reanalysis data as well as independent data like high-resolution gauge precipitation and high-resolution satellite data are used for model validation. These AMIP-type SG-GCM simulations are analyzed to study: the impact of resolution on efficient/realistic downscaling to mesoscales; interannual regional climate variability; ENSO related and other anomalous regional climate events (floods, droughts, etc.); major monsoonal circulations at mesoscale resolution; and water and energy cycles.

The SGMIP-1 SG-GCMs provide high quality regional (and good quality global) climate simulation products; the differences between the models are documented. Analysis of SGMIP-1 multi-model ensemble integrations confirmed that a significant reduction of the uncertainty of regional climate simulations is achieved for the multi-model ensemble mean. The successful experience obtained through SGMIP-1 resulted in a better understanding of the regional climate modelling approach with SG-GCMs. More specifically, this is what was learned through SGMIP-1:

- The appropriate moderate stretching design for long-term climate simulations has been defined.
- The SG-approach works well and is robust for SG-GCMs with/across different dynamics and physics.
- The efficient regional downscaling to realistic mesoscales is obtained with small/limited regional biases that are a fraction (~50%) of observational errors, just as a reference.
- Intraseasonal and interannual variability are well represented
- Orographically induced precipitation and other simulation products are well simulated at meso- and larger scales due to high-resolution regional forcing (e.g. the Rockies, Appalachian and coastal precipitation).

SGMIP-1 laid a solid scientific foundation for conducting the *new* (already agreed upon) *SGMIP-2* (phase-2 of SGMIP), with processing and analysis of data obtained with both enhanced *uniform and variable* resolution GCMs. SGMIP-2 will include the multi-model ensemble simulation results for the extended period of over two decades. The strong coordinated international SGMIP-2 effort, with the accompanying comparisons of enhanced uniform and variable resolution GCMs, will help in a comprehensive investigation of the diversified impacts on climate simulations due to enhanced global and/or regional model resolution,

including the multi-model ensemble results. A connection with the PCMDI group has been established to use their advanced diagnostic tools for analyzing the SGMIP-1 and SGMIP-2 results.

WGNE was pleased with the successful Workshop on High Resolution RCMs and thanked Prof. Laprise. WGNE will continue to monitor the developments in this area in its future sessions. WGNE also discussed results from SGMIP and noted that this was an extremely promising approach to higher resolution regional simulations.

3.7 Other climate-related modelling initiatives

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

Japan

Dr Y. Takeuchi reported on the collaboration projects and research projects on atmospheric-ocean study using the Earth Simulator (ES). In the first half of this fiscal year, a significant proportion of computer resources was devoted to climate simulations to contribute to the IPCC AR4 report. For example, the Meteorological Research Institute (MRI/JMA) carried out (1) global warming experiments with the JMA-GSM at TL959 (20km) for IPCC using 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 the Asian monsoon, while the 5km JMA-NHM is used to assess the effects of global warming on heavy rain events.

In the time slice experiments, SST and atmospheric parameters are predicted by an atmosphere-ocean coupled model with 270km resolution. After that the 20km JMA-GSM and 5km JMA-NHM are run for 20 years and 2 months respectively. Results from global warming experiments indicate that frequency of tropical cyclones is decreased globally. However, the frequency of tropical cyclones is increased in the North Atlantic area mainly due to SST increases in the area. Strong tropical cyclones having maximum wind speed over 40 m/s are increased in the global warming climate. In the 5km model experiments, the impact of global warming on Baiu frontal activity is investigated. Baiu fronts are more active over the southern Japan Islands, and precipitation amounts increase there, while they decrease over the northern Japan Islands and northern Korean Peninsula. 'No end of Baiu' years frequently appear. Increased heavy rainfall frequency is seen over the Japan Islands.

Europe

Dr V.Pope reported on the development of the new Hadley Centre Global Environment Model (HadGEM1). The Hadley Centre in the Met Office has undertaken an ambitious programme of model development to produce their next generation of climate models. The atmospheric component of the model includes the same schemes as the Met Office's weather forecast model, but with parameter choices and some further developments to make it suitable for coupled modelling on climate timescales. Compared with the previous model, HadCM3, the new climate model includes substantially improved representations of physical processes. It also includes increased functionality and higher resolution. Major improvements in the atmosphere model are the use of semi-Lagrangian instead of Eulerian dynamics to advect both dynamical and tracer fields, new boundary layer, gravity wave drag and microphysics schemes, and major changes to the convection, land surface (including tiled surface characteristics) and cloud schemes. Also included is representation of dynamic sea ice and improved thermodynamic properties of the sea ice. The ocean model has increased resolution and a tiling scheme allows better representation of coastlines and surface fields. In the standard version of the model natural and anthropogenic aerosols are modelled interactively and the direct and first indirect radiative effects of aerosols are included. Atmospheric chemistry and dynamic vegetation are also available but not included in the standard version.

Long standing errors common to many climate models have been substantially reduced, notably the cold and moist biases in the upper troposphere are much smaller; clouds, cloud-radiative properties, boundary-layer properties and the representation of tracers are all improved. Surface fields and aspects of variability show a more mixed response. For example, precipitation errors in the Indonesian subcontinent are larger in the new model, whereas those in the Amazon basin are smaller. An increased cold bias in the tropical Pacific SST is probably associated with excessive winds at the surface. Also in the tropics, interannual variability has worsened, and, in particular, the ENSO signal is very weak. However, intraseasonal variability, in particular the Madden Julian Oscillation is improved. Storm tracks and blocking

are generally improved in the atmosphere model, although blocking in the Pacific is substantially reduced when the model is coupled to the ocean.

USA

Dr S.Lord reported on the activities at the Environmental Modelling Center (EMC). Since October 2003, the EMC had a number of major implementations to increase its forecast services. In August 2004, a new coupled Climate Forecast System (CFS) was implemented. The CFS is composed of NCEP's 2004 global atmospheric forecast model and version 3 of the GFDL Modular Ocean Model (MOM-3). The atmosphere and ocean models are fully coupled once daily. A Global Ocean Data Assimilation System (GODAS), implemented in September 2003, enables the CFS to be initialized with realistic ocean initial conditions. In a 38 year coupled simulation, the CFS showed good ENSO response and significant predictive skill for tropical SST. Reforecast runs over the period 1981-2004 were made with 15 ensemble members per month, for each month of the year, amounting to more than 3000 years of coupled forecasts. This data set will be released to the public in early 2005. The reforecast experiments demonstrated that skill in forecasting surface temperature and precipitation was comparable to the NCEP Climate Prediction Center's Canonical Correlation Analysis (CCA) but over somewhat complementary geographical areas. Examination of predictability for extreme events (> 2 standard deviations from the mean) shows the CFS has some skill for more than one month in certain geographical regions. In particular, the 1993 Great Flood in the U.S. Midwest appears predictable at least one month in advance.

A HYbrid Coordinate Ocean Model (HYCOM) -based real-time ocean forecast system is being developed and prepared for operational implementation in 2005. Daily forecasts of ocean temperature, salinity and currents will be available; these data will drive local water level models for Bays, ports and estuaries and, eventually ecosystem and water quality models.

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; reanalyses form an important component of the sessions of the WGNE and it was briefed about progress in reanalysis projects from ECMWF, NCEP and JMA.

4.1 Reanalysis projects

ECMWF

Dr M. Miller reported on the ECMWF Re-Analysis (ERA-40) project. Reanalysis activities at ECMWF have involved both finalizing work on ERA-40 and starting experimentation in preparation for the "interim reanalysis" that will be run at least from 1991 onwards, with production beginning in 2005. The set of medium-range forecasts run twice daily from the ERA-40 reanalyses has been completed, and an "AMIP-style" simulation carried out for the ERA-40 period using the ERA-40 model and distributions of sea-surface temperature and sea ice. The pace of progress has been limited by a reduction in staffing following completion of the EU-funded stage of ERA-40 at the end of November 2003.

The ERA-40 publication series now comprises around 20 reports that either have been published or are in the final stages of the editorial process. The reports cover documentation of the data and of the data-assimilation system and its performance, and results from users of the ERA-40 data. The reports are available on-line for outside users (http://www.ecmwf.int/publications/library/do/references/list/192). A comprehensive atlas of the atmospheric general circulation as depicted by ERA-40 is being produced in collaboration with the Meteorology Department of the University of Reading. Articles for the ECMWF Newsletter and WMO Bulletin have been written, and a general journal paper is also being finalized. Many queries submitted via email by users of the data have been answered.

A detailed comparison has been made of ERA-40 data with the time series of anomalies of surface air temperature derived from monthly-mean station climate values by Jones and Moberg (2003) of the Climatic Research Institute (CRU), University of East Anglia. There is excellent agreement between the two datasets as regards temperature variations from month to month, and ERA-40 captures most of the warming since 1979 identified by the CRU analysis.

Experimentation has been started in preparation for the interim reanalysis. It is being carried out for the period September - October 1999, and uses the latest main cycle of the forecasting system. A new set of bias corrections for radiosonde temperatures has been calculated using ERA-40 statistics. New corrections for biases in satellite radiances have been derived iteratively from two separate assimilations for the period. The forecasting system version includes the new humidity analysis with improved background error modelling introduced into operations in October 2003.

Results from the experiments show a big improvement in aspects of the hydrological cycle. Comparison of precipitation rates from 6h and 12-24h forecasts from ERA-40 and the corresponding assimilation using cycle 28r1 show that the new assimilation does not exhibit the excessive precipitation over the tropical oceans that occurred in ERA-40. The global-mean difference between precipitation and evaporation (P-E) is much smaller during the 6h forecast in the new assimilation. After 24 hours P-E is close to zero.

The new system has also been used to analyse the period May-June 1944, using a small set of observations retrieved from NCEP archives and the COADS database. Despite the limited data coverage, the system captured the general situation leading up to the D-Day landings (http://www.ecmwf.int/research/era/dday/), although the analyses show a lag in the eastward movement of the key Atlantic low compared with contemporary charts. The north-easterly storm that struck the Normandy beaches two weeks later was also reproduced.

Use of 4D- rather than 3D-Var, a new radiance bias-tuning procedure and the 91-level version of the model are also being tested and evaluated for the 1999 period. Production of the interim reanalysis is planned to start in early 2005. It will cover at least the years from 1991 onwards and will be continued in close to real time.

NCEP

Dr S.Lord reviewed the status of the analysis activities at NCEP. EMC is completing development and testing of a new Gridpoint Statistical Interpolation (GSI) analysis. In collaboration with NASA Goddard Space Flight Center, the GSI will be developed further by adding situation-dependent background errors and a simplified 4D-Var system. A sigma-pressure coordinate version of EMC's spectral model is ready for testing and implementation in 2005.

The activities of the NASA-NOAA-DOD Joint Centre for Satellite Data Assimilation (JCSDA) encompass improvements for the use of cloudy radiances, a new surface emissivity model for snow and ice which allows three times more polar sounding data near the poles, development of Atmospheric Infrared Sounder (AIRS) and Moderate Resolution Imaging Spectroradiometer (MODIS) observations (with positive impact), an improved SST retrieval technique, and a large set of data sensitivity experiments using Advanced Microwave Sounding Unit (AMSU), High Resolution Infrared Radiation Sounder (HIRS), Quikscat, and GOES wind data. Results were reported at a WMO meeting in Austria in March 2004.

Japan Meteorological Agency (JMA)

Dr Y. Takeuchi reported on the progress of the Japanese 25-year Reanalysis Project (JRA-25). 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.

Performance of JRA-25 is compared with other reanalyses in reference to precipitation data produced by CMAP. The JRA does not show the known problems of excessive tropical ocean precipitation seen in ERA-40. In general, precipitation in JRA-25 has much higher correlation with precipitation in CMAP than ERA-40 and NCEP reanalysis.

All reanalyses show temperature discontinuity at 100 hPa due to gap of satellite instruments. Further investigation is needed through the exchange of satellite usage information. A noticeable weakness of JRA-25 is temperature bias in stratosphere due to the model bias used in the assimilation. Improvement of the NWP model is essential to reduce their systematic biases.

4.2 Other Assimilation activities

Met Office

Dr A. Lorenc summarised activities coordinating data assimilation (DA) research. DA sessions were planned at the upcoming WGNE/WGSIP/WGCM Workshop on Ensemble Methods Met Office, Exeter. The 4th WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography is planned for April 2005 in Prague. These meetings are proving very popular, showing the growing interest in DA. Issues of funding, and how to limit numbers, were discussed. WCRP is organising a Working Group on Observations and Assimilation, yet to meet.

Météo-France

Dr M.Déqué briefed WGNE on the activities at the Météo-France. Land surface moisture analysis is important in NWP because: (i) soil moisture determines distribution of net solar heat flux between sensible heat (H) and latent heat (LE), (ii) it has strong impact on boundary layer and (iii) has time constants of several weeks. Difficulties associated with soil moisture analysis include non-availability of observations and its wide spatial variability. In the scheme used at Météo-France, the observations used include (i) precipitations (gauge, radars), (ii) SYNOP (T2m, H2m), and (iii) satellite (MO, IR). Recent modifications to the scheme include spatial smoothing of soil moisture index, use of small-scale error statistics for T2m and H2m analysis, and modifications of deep soil moisture analysis (which include factor 2 decrease of Wp coefficients, suppression of time filter, suppression of bias, correction of T2m increments, and accounting of solar angle zenithal angle). Validation of the scheme includes (i) experiments with assimilation scheme (two months in summer: 1/5/2003 - 3/7/2003 and two months in winter: 1/12/2003 - 3/2/2004) and (ii) impact studies on forecast scores which show that the scheme is neutral for V10m, Ps; neutral for T2m and H2m in winter; and improves for T2m and H2m in summer over Europe.

Naval Research Laboratory (NRL)

Dr C. Reynolds reported on the activities in this area at the Naval Research Laboratory (NRL). Data Assimilation highlights include the transition to operations of NRL Atmospheric Variational Data Assimilation System (NAVDAS) in October 2003, and the direct assimilation of AMSU-A radiances in June 2004. The assimilation of AMSU-A radiances has a significant positive impact on hemispheric skill scores, as well as tropical cyclone track forecast errors. Plans for the coming year include the operational assimilation of MODIS winds, AMSU-B moisture retrievals, and the implantation of NAVDAS into the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS^{TM}). The development of the four dimensional version of NAVDAS (NAVDAS-AR) is continuing.

WGNE took note of the new developments in the assimilation of parameters pertinent to the Earth System but not routinely analysed by current data assimilation systems. These include greenhouse gases, aerosols and reactive gases. Earth system science will increasingly demand cross-project liaison within WCRP and CAS as discussed in the COPES context.

4.3 Observing system and observation impact studies

Dr S. English presented a summary of the outcomes of the Third WMO Workshop on the Impact of Various Observing Systems on NWP, in Alpbach, Austria,March 2004. The report of this workshop can be found on the WMO website at http://www.wmo.ch/web/www/GOS/Alpbach2004/Agenda-index.html. Results from recent Met Office observing system experiments (OSEs) were also presented. These showed that assimilating data from three satellites (NOAA-15, 16 and 17) gives superior results to assimilating data from any combination of two satellites. Using a global NWP score it was also shown that AMSU-A and AMSU-B from NOAA-15, 16 and 17 had roughly three times the positive impact of adding HIRS from NOAA-16 and NOAA-17 (NOAA-15 HIRS was not used in these experiments) compared to a baseline using no ATOVS data. However, the impact of removing HIRS from a system using AMSU was negligible, showing that HIRS has significant value in the absence of AMSU but adds little to a system already using AMSU. This was not the case for all fields; notably low-level moisture in the tropics benefited from use of HIRS. However, little use was made of low-level microwave humidity data at the time of the experiments so this most probably reflects the more mature use of HIRS.

WGNE thanked Dr English on his presentation. WGNE noted the relevance of AMMA in this context. ECMWF and Météo-France are at present directly involved in data coverage over Africa, and there is need to involve more centres. The THORPEX plans in this area are discussed later.

5. NUMERICAL WEATHER PREDICTION TOPICS

WGNE noted the substantial improvements in the resolution of global (40 km or less) and deep convection permitting forecast models (5 km or less) in progress or planned in the next few years. WGNE also took note of recent results from dynamical core experiments indicating that resolutions of 150 km (T85) or better are necessary for accurate simulation of baroclinic wave development. This contrasts with typical climate model resolutions substantially poorer than this. There exists a dichotomy of opinion regarding the use and interpretation of grid-lengths of several kms for forecasting. These resolutions will become affordable for GCM use in the coming years, and the prospect of climate simulations with grids of order one kilometre is an issue of international activity and debate, and WGNE will continue to both monitor such developments, and play a more pro-active role also.

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

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.

WGNE devoted a session to THORPEX in which presentations by Dr E Manaenkova (general background), Prof. A.Thorpe (Science Plans) and Dr D Richardson (A-TReC, Global Interactive Forecast System (GIFS) and TIGGE) provided information on the progress and plans of THORPEX and stimulated the discussions.

The 2003 Atlantic THORPEX Regional Campaign (A-TReC)

The A-TreC took place between October and November 2003, and attempted for the first time to control a complex set of observing platforms in a real-time, adaptive manner. During A-TReC it was necessary to:

- identify uncertain forecast events (or cases) to target;
- provide information on the location of sensitive areas for each case;
- have mechanisms in place to deliver extra observations in these areas at short notice.

The campaign was coordinated by EUMETNET composite observing system (EUCOS), with participation from around 20 agencies, including operational NWP centres and universities in Europe and North America. Sensitive-area predictions were provided by ECMWF, Météo-France, Met Office, NCEP and NRL using several techniques (inter-comparison of these is ongoing).

During the campaign, additional observations were triggered over the North Atlantic, Europe and northeast Canada. In total 32 cases were identified, 22 of which were targeted with additional observations. Whilst A-TReC data impact studies and investigations into the effectiveness of the data targeting techniques are ongoing, useful knowledge has already been gained from an operational network management perspective. The successful operational running of the A-TReC provides the necessary proof of concept justifying further work in developing more efficient methods and techniques to control the observing system. On behalf of EUCOS, ECMWF has generated data sets of the A-TReC observations. These are now available to download for research purposes from the ECMWF web site (data.ecmwf.int/data). A number of preliminary results from studies using the A-TReC data will be presented during the THORPEX Symposium in Montreal in December. Further results can be expected during the next years.

THORPEX Interactive Grand Global Ensemble (TIGGE)

A major research challenge of 21st century is to reduce and mitigate natural disasters and to realise the societal and economic benefits of improved weather forecasts. THORPEX will address this research challenge, thereby contributing to the development of a future truly integrated GIFS, which would generate numerical probabilistic products, available to all nations including developing countries. “Global” signifies both global participation and global application; the system would in principle use global and regional models as appropriate. An “Interactive” forecast system changes according to situation and user needs: all parts of the system from observations through data assimilation and the forecast production to the end-user applications are integrated, adaptive, and interactive.

It is not possible to say now what a future Global Interactive Forecast System will be, and one of the goals of THORPEX is to determine this. The development, evaluation and testing of a future GIFS will depend on results from all research components of THORPEX.

The THORPEX Interactive Grand Global Ensemble (TIGGE) will provide the facility to test these concepts in a prototype GIFS, and at the same time provide a framework for international collaboration in the development and testing of ensemble prediction systems. TIGGE is planned to provide the main prediction tool in THORPEX Demonstration Projects. These activities will contribute to the international development and testing of the GIFS.

The initial basic components of TIGGE will be available ensembles including those run at operational centres, collected in near-real time and stored in a common format on central servers for access by THORPEX researchers from both the operational and academic communities. Specific research objectives using this multi-model ensemble database includes comparison of initial condition methods; comparison of multi-model and perturbed physics methods; development of ways to combine ensembles; and provision of boundary conditions for regional ensembles. Wider issues in collaboration with other THORPEX projects include decision-making applications for user needs (societal and economic impacts), use in observation targeting, and regime-dependence of ensemble configuration (size, resolution, composition).

A working group (TIGGE-WG) is being set up to direct and oversee the TIGGE project. The duties of the TIGGE-WG will include:

- Design the structure of the TIGGE dataset considering potential scientific research subprojects and possible real-time applications
- Prioritise requirements of different subprojects
- Monitor work and results done with the TIGGE data
- Report on progress to THORPEX, funding bodies, data providers
- Feed progress into development of GIFS
- Take necessary action to ensure success of project

The immediate task of the TIGGE-WG is to define the scientific requirements for TIGGE and then to plan and develop the infrastructure accordingly. A TIGGE workshop will be held at ECMWF early in 2005 to collect the views of the community on what the TIGGE science aims should be, what the requirements are for use of the TIGGE data and hence what are the infrastructure requirements. Based on the input from the workshop the TIGGE-WG will initiate the planning and development of TIGGE facility and the associated research projects.

WGNE noted the direct relevance of THORPEX to its activities and interests, and was impressed by the progress of several components of its plans including the Implementation Plan itself. The commitment of the operational NWP community was very clear. WGNE considered however that it remained a major challenge to engage the academic community to a similar extent and encouraged the circulation of the draft science plan to suitable members of academia for comment and to stimulate interest. WGNE recognized that the proposed 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. It suggested that the THORPEX Implementation Plan (TIP) should recognize the fundamental importance of model development (both of the dynamical cores and of the physical parameterizations), and should make clearer its contribution to this in collaboration with existing programmes. WGNE commended the Global Interactive Forecast System (GIFS) concept for its vision, and noted that the THORPEX Interactive Grand Global Ensemble (TIGGE) plans are advancing rapidly, with the TIP including many of the research challenges that such an undertaking will entail. WGNE appreciated that the Science Plan stressed the linkages between weather and climate and the opportunities to engage this problem for the benefit of all longer time-scale modelling efforts. WGNE agreed to consider, in consultation with WGSIP, the possibilities of using seasonal forecast systems to study this issue. One possibility is to run seasonal timescale forecasts at several horizontal resolutions, including at as high as practicable, to investigate, inter alia, the resolution dependence of the atmospheric energy transports and their up- and down-scale characteristics. This would require diagnostics including suitable eddy statistics and spectra etc. Results from this should then guide the debate as to what forecast/simulation deficiencies are to be expected from the current use of relatively low resolutions. Ideally these experiments would be performed using several systems, at least one (and hopefully more) group will be in a position to undertake such experimentation in the next year or so. The Chairs of WGNE and WGSIP will monitor this further.

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 meetings during the past year, one in Reading, UK, in November 2003 and a second meeting in Montreal in September 2004 following the verification workshop (see below). These meetings facilitated planning ongoing and future activities of the group.

The JWGV organized and held an International Workshop on Verification Methods, with sponsorship from the WWRP/SSC and WGNE, as well as the Meteorological Service of Canada (MSC); Dr L. Wilson was the program chair and local organizer. The workshop took place from 15-17 September 2004, in Montreal, Quebec, Canada, at the McGill University Faculty Club. About 100 participants attended, including all members of the JWGV, many of who provided invited talks. Ms. Wang Yu from the China Meteorological Administration (CMA) also participated. Participants included verification researchers and practitioners as well as some operational forecasters and model developers. Invited talks were presented by Drs I. Jolliffe; D. Stephenson; T. Gneiting; B. Ebert and B. Brown; B. Casati; J. Lazo; and P. Nurmi. Approximately 32 contributed talks were also presented. A number of important issues and new developments were discussed and will be summarized in a journal article to be submitted later this year. Some of the issues identified include the following: development of methods to verify high resolution spatial forecasts; verification methods for rare events; incorporation of scaling methods into verification processes; approaches to account for observational uncertainty in verification measures and analyses; development of methods that are customer dependent and appropriate for studies of forecast value; and verification of probability distribution functions.

The JWGV believes that these kinds of workshops are very beneficial for the community, and it would like to organize additional workshops in the future, perhaps in collaboration with other groups. Ideally, the next workshop will be located near a national center, preferably in the European region, and near a forecasting centre. A future workshop will include more focus on ensemble forecast verification and economic value/benefits. The JWGV is also very interested in planning future training or tutorial sessions, which could not be included with the workshop this year. The workshop program and abstracts can be linked from http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/verif_web_page.html; presentations will be posted there as well.

At their meeting in November 2004, the WGNE requested that the JWGV prepare a document outlining methods to be used by the various centres for more “standardized” verification of precipitation forecasts (for the annual forecast intercomparison sponsored by WGNE). Dr E. Ebert drafted the original document with help from several other members of the JWGV. The current version focuses on deterministic forecasts; a future version will outline methods for probabilistic/ensemble forecasts. Although a draft document has been completed, the JWGV is continuing discussions to finalize some issues. The JWGV expects to have a final document to distribute to WGNE before the end of the calendar year. The final document will incorporate comments from WGNE regarding several issues, including forecast-observation matching approaches and spatial resolution of the analyses.

The JWGV was represented by Dr Brown who is a member of the advisory group convened to help plan the Forecast Demonstration Project (FDP) for the Beijing Olympics (B08); she participated in meetings at CMA and the Beijing Meteorological Bureau in July. Several members of the JWGV are very interested in planning and implementation of the verification component for B08, and a sub-group has been formed, composed of Drs Brown, Casati, Ebert, and L. Wilson. The JWGV would like to have an active role in this programme and is currently investigating the possibilities of developing a real-time verification capability as part of the FDP.

The JWGV was represented by Dr F. Atger at the the MEDiterranean EXperiment on cyclones (MEDEX) societal impacts meeting in Barcelona, and it has established contacts with several other programmes and activities (e.g., MAP, Helsinki testbed, Short-Range Numerical Weather Prediction Network (SRNWP)). Currently JWG’s role in these projects is advisory. Dr Brown is a member of the planning committee for the nowcasting workshop to take place in fall 2005. The JWGV will also continue to be interested in participating in any additional FDPs that may be developed. In addition, a role is expected in the COPES and THORPEX programs.

Outreach activities, including the verification web page and verification discussion group, continue to be an important focus for the JWGV. The web page is gradually being enhanced as new FAQs and other information pages are prepared. The JWGV continues to be interested in collaborations with other WMO verification projects and groups. A new plan for the coming year is to prepare and make available “canonical”

forecast and observation datasets that can be used to evaluate and compare the capabilities of different or new verification methodologies.

WGNE thanked Dr.Brown for her presentation and for the report on the Workshop. Following discussion WGNE recommended that the horizontal resolution for precipitation verification should nowadays be half a degree (lat/lon).

Performance of the main global operational forecasting models

As is usual at its sessions, WGNE reviewed the changes 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) 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, a marked increase in skill (as indicated by the verification scores of root mean square error of 500 hPa geopotential in the northern and southern hemisphere at various lead times out to six days) was again apparent; this increase has now been sustained since the first part of 1999. Improvements were particularly notable in the case of ECMWF, NCEP and the Met Office, and most recently both others also. At all time ranges, the advance in skill of ECMWF forecasts was noted. In the southern hemisphere too, there were distinct increases in skill in forecasts from several centres, with levels sometimes approaching those seen in the northern hemisphere. WGNE ascribed this to the increasing use of variational data assimilation schemes and an incremental improvement in the exploitation of observational data in the southern hemisphere. Progressive improvements in horizontal resolution are also clearly very beneficial.

Intercomparison of typhoon track forecasts

Japanese Meteorological Agency

Dr Y. Takeuchi reported on the intercomparison of tropical cyclone (TC) forecasts for 2003.This model intercomparison was started in 1991 for the western North Pacific area with the participation of ECMWF, UKMO and JMA. In 1994, the CMC joined the project. In 1999, the verification area was extended to cover the northern Atlantic area. In 2000, the DWD joined, and the verification area was enlarged to cover the eastern North Pacific area. Verification for the Southern Hemisphere, Northern Indian Ocean and Central Pacific areas was added in the 2002 intercomparison. In 2003 NCEP and BoM joined and Météo-France joined in 2004.

NWP centers which participated in the intercomparison for 2003 are BoM, CMC, DWD, ECMWF, NCEP, UKMO and JMA. Data used are the mean sea level pressure predicted by the global models of these five forecast centres. The initial time is 1200 UTC. For the best track data, TC positions provided by JMA were used for the Western North Pacific area. TC positions provided by Regional Specialized Meteorological Centre (RSMC) Miami are used for North Atlantic, Eastern North Pacific and Central Pacific regions, while Joint Typhoon Warning Center (JTWC) data was used for North Indian Ocean area and Southern Hemisphere.

In the mean positional errors of the 72 hours forecast, the best performance is shown by NCEP in the North Atlantic area and by ECMWF in the western North Pacific area, the eastern North Pacific area and the Southern Hemisphere. JMA and UKMO show similar performance to ECMWF in the western North Pacific areas. Southwestward mean bias errors are seen in forecasts of many centres after the recurvature, while northerly position biases are seen in forecasts of all centers in the low latitude tropics. In case of 120 hours forecast, ECMWF shows the best performance in the North Atlantic area and the Southern Hemisphere and JMA shows the best performance in the western North Pacific area.

A significant milestone was the release of a web site for WGNE international tropical cyclone comparison on 15 September 2004. 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).

Figure 1.

Figure 2.

Dr Y. Takeuchi presented some proposals from JMA toward the WGNE intercomparison of tropical cyclone track forecasts for 2004:

1. To improve the intensity verification, the possibility of collecting surface wind in addition to surface level pressure should be explored.

2. More effective data collection via Internet instead of CD-ROM should be investigated.

3. Near-real time data collection and verification on web should be investigated.

One possible idea is the unification of data transfer for the WGNE TC intercomparison and the JMA numerical typhoon prediction web site (typhoon Web) at RSMC-Tokyo. JMA typhoon web was released in October 2004 and the purpose is to improve TC forecast and warnings. The users are limited to the meteorological / hydrometeorological organization of the member countries of the ESCAP / WMO Typhoon Committee and NWP product contributors, i.e. BoM, CMC, DWD, ECMWF, KMA, NCEP, UKMO and JMA. RSMC-Tokyo has a requirement for WGNE to link with WGNE TC intercomparison web site to provide the model performance in northwestern Pacific. The merits of the unification are near-real time comparison is available and no need to produce CD-ROM for sending data. The ftp sites of NCEP and UKMO have already met the requirements for the unification.

NCEP

Dr S.Lord reported on activities in this area at NCEP. Over the past 5 years, NCEP's hurricane forecasts from the Global model have shown a steady improvement. Elimination of a wind bogusing technique in favor of a vortex relocation technique developed from the GFDL hurricane system, and major improvements to convective, radiation and cloudiness parameterizations have been major contributors. The current GFDL hurricane model is coupled to the ocean in the Atlantic and Gulf of Mexico and is coupled to a 1-dimensional ocean mixed layer model in the East Pacific basin. Coupling with the ocean improves intensity of track forecasts in the Atlantic and both track and intensity prediction in the East Pacific. Both the GFDL and global models drive ocean wave models; comparisons with altimeter data for Hurricane Isabel (2003) showed excellent results. The NCEP global model also shows some skill in tropical cyclogenesis, with 69% of a sample of 6 Atlantic storm cases in 2003 showing some cyclogenesis within 500 km of the real storm.

WGNE was very pleased with the progress in this activity. WGNE welcomed the new TC web page hosted by RMSC, Japan. WGNE agreed that this web page and data should be made more widely accessible, especially to the most vulnerable developing countries which could benefit substantiallyy from TC forecasts.

The likelihood that the latest forecasting systems had some skill in predicting genesis of TCs was discussed by WGNE, and it was agreed to consider this aspect at future meetings.

Verification and intercomparison of precipitation forecasts

As an important contribution to WGNE activities in this area, NCEP, DWD and BMRC have been verifying 24h and 48h precipitation forecasts from eleven operational centres. The validation of precipitation has become an increasingly active research area, and this WGNE project has expanded significantly with the CMA, JMA, Met Office and Météo-France also now verifying precipitation forecasts in their regions.

Dr K. Puri reported on the quantitative precipitation forecast (QPF) verification over Australia. Operational 24 h and 48 h quantitative precipitations forecasts of 24 h rainfall accumulations from the Australian Bureau of Meteorology, CMC, DWD, ECMWF, JMA, the Met Office, and NCEP were verified over Australia. The verification data comes from the Bureau's operational daily rainfall analysis (at 0.25° resolution) of 24 h gauge observations from over 1000 sites reporting in near real time, or over 5000 sites when cooperative network observations have been included. The verification is performed both on a standard 1° grid to facilitate intercomparison, and at the (received) resolution of the model output. Persistence and ensemble mean QPFs are also verified for comparison.

The performance of the models during 2003-04 was similar to previous years, i.e., with the best equitable threat scores (ETS, using a 1 mm d^{-1} threshold, verification at 1° resolution) of 0.4-0.6 during mid-latitude winter and the worst scores, 0.1-0.3, during tropical winter. The time series of QPF verification scores for Australia now extends over eight years for most of the models. Using the difference between the ETS values for each model and Persistence as a relative skill measure, it appears that only one or two of the models show any positive trend, namely, ECMWF and NCEP for mid-latitude rain exceeding 1 mm d^{-1}.

95% confidence intervals for the bias and ETS scores, computed using a resampling method, generally showed a great deal of overlap in the results among models, although there were some significant differences at certain thresholds. During tropical summer the greatest divergence among models occurred at the highest rain threshold of 50 mm d^{-1} with the Met Office model achieving the highest ETS score and the Bureau of Meteorology's regional model having the frequency bias closest to unity. In the mid-latitudes the differences among models were most (statistically) significant at the lowest threshold, 1 mm d^{-1}, where the clear "winners" were the models of ECMWF and NCEP.

Dr D. Majewski presented results from Dr U. Damrath on the WGNE intercomparison of precipitation forecasts over Germany using operational data from CMC, DWD, ECMWF, JMA, Météo-France, NCEP and UKMO. The verification is performed on a regular 1°x1° grid at which the high resolution German network with almost 4000 stations is accumulated. Almost all models overestimate the occurrence of precipitation, especially in winter, i.e. the bias score is between 1.2 and 1.5. There is a considerable season-to-season variability of the quality of precipitation forecasts (score: ETS), and there is no clear “best” model.

Dr M.Dequé reported on the QPF activities over France.Unfortunately the validation of model forecasts over France against observation network has been temporarily interrupted between October 2003 and June 2004. The results are on a new web site http://www.Météo.fr/special/minisites/WGNE/. The pages are not yet completed as some model data beyond March 2004 has not been processed. This site includes statistics of hit rates and false alarms for various thresholds, and also, (i) Threat score, (ii) Equitable threat score against persistence, (iii) Hansen-Kuiper score, and, (iv) Heidke skill score against persistence. Precipitation is accumulated for ranges 6-30, 30-54 and 54-78 (00UTC), 18-42 and 42-66 (12 UTC). Météo-France forecasts are now available for the Japan region (at 1.5°), due to the change in resolution of the model.

Dr Y. Takeuchi reported on the intercomparison of precipitation forecasts over Japan. JMA has operated QPF verification over Japan under the framework of WGNE. The main purpose of this verification over Japan is verification of the participating models for extra-tropical cyclone, typhoon, summer monsoon, winter monsoon, and thunderstorms in summer. The verification is performed with reference data of high-dense (17km^2) surface rain gauge network (AMeDAS) at grid points with the resolution of 80km. BoM, DWD, ECMWF, NCEP, UKMO and JMA participate in this verification as of September 2004. The verification results for 3 day QPFs show that all models have biases characterized by underestimates of heavy rain and overestimates for light rain especially for the winter season. The ETS for moderate rain shows generally better result in winter for all centres particularly for ECMWF and NCEP. For 6 hour QPFs used for estimating the diurnal aspects of the performance, the NCEP model shows a noticeable diurnal change with maximum precipitation in daytime. The ECMWF model shows a reduced bias for light rain in 2004 due to revision of the moisture treatment in the model. For heavy rain the NCEP model shows an increasing positive bias with forecast time. The ETS for summer implies slightly better skill at night time and slightly worse in daytime especially in summer. Also, verification of individual precipitation events in summer and winter, shows that in the summer, ECMWF, UKMO and DWD models successfully forecast a heavy rain event with 2 to 3 days lead-time. For winter monsoon precipitation, BoM and DWD models do not forecast the typical precipitation distribution in Japan. Web pages on WGNE-QPFs verification over Japan have been constructed.

Dr Y. Takeuchi presented the following recommendations and requests:

1. Participation from CMC and Météo-France is welcomed.
2. Provision of data with higher resolution from BoM is recommended.
3. Provision of data with higher temporal resolution from DWD is welcomed.
4. Exchange of the link with other verification sites in Météo-France and NCEP is requested.

Dr M.Miller presented a proposal from ECMWF for a web-page at ECMWF for verification and comparison of precipitation forecasts from all contributing Centres for the European region, using high resolution, daily precipitation data received on a monthly basis (2-6 months behind real time).

WGNE thanked Dr Miller for this proposal by ECMWF and agreed to it.

Review of the status of mesoscale numerical weather prediction

Dr J. Côté reviewed the recent developments/activities in mesoscale NWP. A number of conferences and workshops were held in the past year which covered a wide range of topics. The 16th Conference on NWP, 12-15 January 2004, Seattle (USA), had sessions on data assimilation, the Weather Research and Forecasting (WRF) model, short-range ensemble and non-hydrostatic numerical methods. The numerical

methods session featured optimization of an iterative elliptic solver with an intermediate separable grid to accelerate its preconditioning, a fully-implicit semi-Lagrangian nonhydrostatic model employing a pressure-hybrid vertical coordinate, a study of the dependence of hurricane intensity and structures on vertical resolution and finally sparse matrix techniques for coupling independent hydrological and Meteorological models. The 22nd Conference on Severe Local Storms, 4-8 October 2004, Hyannis (USA), had a session devoted to numerical modelling of severe local storm forecasting. It considered a Short-Range Ensemble Forecasting system, the Rapid Update Cycle (RUC) model of NOAA and a comparison of different versions of the WRF model at 4 km against the Eta model at 12 km. The 11th Conference on Mountain Meteorology and the Annual Mesoscale Alpine Program (MAP) was held in Mount Washington (USA). Phase I of the Terrain-induced Rotor Experiment (T-REX) had been just completed and was the subject of a session. It consisted of a ground-based observing program and a number of numerical theoretical studies of mountain-wave induced rotors. The primary objectives of Phase I were to: (1) establish quantitative characteristics of the rotor behaviour including the rotor type and location as well as the frequency distribution of the mountain-wave events, and (2) evaluate the extent to which current operational mesoscale models can reliably forecast the occurrence of rotors. The results from Phase I will be an invaluable resource in planning the deployment of ground-based and airborne instruments in Phase II of T-REX. A planning meeting for the Forecast Demonstration Project of MAP was also held; the project was given the acronym D-PHASE (Demonstration of Probabilistic Hydrological and Atmospheric Simulation in the European alps) and is planned for 2007. It aims to demonstrate the benefits of MAP to end users in the Alpine region.

Dr Côté listed a number of publications and current research activities. He noted that the Quarterly Journal of Royal Meteorological Society had contained papers on the stability of a class of explicit two-time-level semi-Lagrangian schemes, the finite-element scheme for the vertical discretization of the semi-Lagrangian version of the ECMWF forecast model and a few articles devoted to MAP. The Journal of the Meteorological Society of Japan presents case studies of X-BAIU-99 with the Regional Spectral Model (RSM) and the Non-Hydrostatic Model (NHM) at 5 km resolution; the impact of Global Positioning Satellite (GPS) measurements of short-range precipitation forecast was also examined. The new-version at higher-resolution (10-20 km) of the Rapid Update Cycle model, the only quasi-isentropic forecast model running operationally was presented in Monthly Weather Review.

Dr C. Reynolds presented recent developments in mesoscale modelling at NRL. Highlights include the full coupling of COAMPS to an ocean circulation model, the inclusion of second moment explicit microphysics, an embedded aerosol model that is interactive with both the radiation and the microphysics, and urban parameterizations. Planned work includes mesoscale ensembles and the exploration of hybrid coordinates capable of representing vertical surfaces. The development and testing of the COAMPS land surface model, including incorporation of the NCEP Oregon State University Air Force NOAA Office of Hydrology (NOAH) land surface model, is ongoing. Research on improving the boundary layer parameterization through 1) a new mixing length formulation based on turbulent kinetic energy and 2) revisions to the current scheme based on the TOGA COARE surface scheme and various data sets is showing promising results. Basic research on flow over topography, including participation in the MAP and the T-REX, and simulations at very high resolution, are ongoing.

Dr M. Déqué reported on the new Applications of Research to Operations at MEsoscale (AROME) system at Météo-France, which is under active development and should be operational in 2008. It uses a compressible non-hydrostatic model with 2.5km horizontal resolution, semi-implicit semi-Lagrangian mass-coordinate terrain-following dynamics with a 1-min timestep, 5-species prognostic cloud microphysics, prognostic TKE turbulence scheme, RRTM radiation scheme, externalised 'Interface Soil-Biosphere-Atmosphere (ISBA') surface scheme including towns, lakes, soil/vegetation, snow/ice, prognostic ocean mixed layer, 3D-Var data assimilation (ALADIN), and assimilation of radar Doppler winds and reflectivities (1D-Var retrievals with linearized cloud microphysics. The current status of the system is that the model is fully functional (ocean part to be included in 2006); with subgrid 'shallow' convection and stratiform cloud performance remaining to be examined; the assimilation is quasi-operational with the 9.5km ALADIN model and the 2.5km assimilation works in research mode (testing on AMMA field experiment).

Dr P Clark reported on the development of a deep convection permitting model at the Met Office. He showed that, despite theoretical and practical problems, a version of the Met Office's Unified Model with a 4km grid can give useful indications of extreme rainfall in cases of severe convection. The Unified model is non-hydrostatic, semi-lagrangian and semi-implicit. Developments of the microphysics for high-resolution are underway; the most important change for 4km resolution was a pragmatic limitation to the parametrised convective mass flux, so that the effects of strong convection are represented by the resolved dynamics. The Met Office plans to put such a system into operational use in 2005.

High-resolution modeling

Dr J. Côté briefed the session on the high resolution modelling activities in Canada. A joint project (LACES) of the Meteorological Service of Canada, McGill University, University of Albany, Tokyo University and the Earth Simulator has run 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 done at 1 km on a ($8000 \times 7300 \times 50$) grid for 174 h with a timestep of 6 s. The memory required was 7 Tb on a 22×180 grid of processors. The performance reached by MC2 was 13 TF on 495 nodes. Some of the main challenges are: iterative distributed memory elliptic solver, parallel I/O software, model output, restarts files. The simulation was being performed and analysis will follow.

Dr D. Majewski gave an overview of 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 LM with a 2.5 to 2.8 km grid spacing. Different dynamical cores are being evaluated in test suites of several months of duration. The standard three-time level leapfrog scheme with second order spatial discretization is compared with a two-time level 3rd order Runge-Kutta scheme (TVD variant) with a fifth order spatial discretizaton. 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.

The representation of the diurnal cycle in operational models

Dr D. Majewski presented studies performed by Drs B. Ritter and D. Mironov (DWD) on the diurnal cycle of convection precipitation in the Amazon region (for the Rondonia case, 1999) in the global forecasting model (GME) and the ECMWF model (Bechtold et al., 2004). Both global models initiated deep convection about 6 hours earlier than observed though the closure assumptions of the deep convection schemes, moisture convergence in the GME and CAPE for the ECMWF model are different. A modified version of the convection scheme of the GME where the rising parcel characteristics are averaged for a layer of about 60 hPa depth below the cloud base, resulting in a delay of the onset of deep convection by about three hours but to a reduction of the height of the convective cloud tops from an average of 9 down to 7 km.

5.2 Ensemble prediction

A major highlight this year was the joint WGNE/WGSIP/WGCM Workshop on 'Ensemble Methods: from weather forecasting to climate change' held at the Met Office, Exeter, 18-21, October. A short report on the Workshop was provided by Dr G.J. Boer. The Workshop was motivated by considerations of uncertainty. Analyses of the present and predictions of the future state of the atmosphere/ocean/land are undertaken both routinely and experimentally over ranges from hours to centuries. Uncertainty in initial conditions, in the representation of the system itself, in the external forcing of the system, and in the formulation and solution of the problem all contribute to uncertainty in the result. The characterization of this uncertainty is critical to the use and value of the analyses and forecasts. Ensemble methods, including multi-model ensemble methods, are thought to offer potentially powerful approaches to characterizing the uncertainty in analyses and forecasts on a range of timescales. An array of methodologies are possible which, however, require theoretical justification, the avoidance of pitfalls, and methods of practical application. The Workshop reviewed the state-of-the-art of ensemble methods by focusing on:

(i) the theoretical basis for ensemble approaches
(ii) applications and results of ensemble methods
(iii) verification and pitfalls of ensemble techniques

for systems and timescales ranging from weather forecasting to climate change.

The Workshop was sponsored by the three Working Groups namely the CAS/JSC Working Group on Numerical Experimentation (WGNE), the CLIVAR Working Group on Seasonal to Interannual Prediction (WGSIP) and the JSC/CLIVAR Working Group on Coupled Modelling (WGCM) with the Scientific Organizing Committee consisting of Drs G.J. Boer, T. Delworth, B. Kirtman, A. Lorenc, M. Miller, K. Puri, D. Richardson, and T. Stockdale. Local arrangements and support from the Met Office for the Workshop was very much appreciated as was the work of the Local Arrangements Committee. Support for invited speakers and a limited number of student and other attendees who could not otherwise attend was provided by WCRP, WMO/WWRP, NSF, NOAA and NASA.

The Workshop was very successful with the wide interest and activity in ensemble approaches and methods clearly reflected in the enthusiasm expressed for attending the Workshop (over 160 registrants) and

in the scientific level of the presentations made (10 invited and approximately 50 each oral and poster presentations). The electronic proceedings of the Workshop are available at http://cccma.seos.uvic.ca/ensemble/.

Dr M.Miller presented an overview of the progress in ensemble prediction system at ECMWF which includes: use of an alternative stochastic physics scheme (Cellular Automaton Stochastic Backscatter-CASBS), based on the concept of kinetic energy backscatter from the sub-grid to resolved scales; and use of variable resolution in the EPS (VAREPS). The rationale behind VAREPS is that the predictability of small scales is mainly lost relatively early in the forecast range. Therefore, while forecasts benefit from a resolution increase in the early forecast range, they do not suffer so much from a resolution reduction in the long range. Thus, it is more cost efficient to use any extra computer resources to increase the EPS's resolution as much as possible in the earlier forecast range rather than implement a more modest resolution increase over the whole forecast range. Furthermore, resources saved by running at higher resolution only during the early forecast range give the possibility to extend the EPS' forecasts from day 10 to day 14 with a limited extra cost. Preliminary results based on 5-member ensembles run up to 10 days for 13 cases (based on model cycle 26R3) indicate that the resolution increase in the early forecast range improves the quality of the probabilistic prediction of precipitation during the early forecast range. Results also indicated a small positive impact on the quality of the probabilistic prediction of geopotential height anomalies beyond the truncation time. Experimentation with a more recent model cycle (CY28R3) and with 51-member ensembles will start soon to verify whether this early positive impact is confirmed, and to quantify in a more precise way the potential impact of a configuration change from the current plain T_L255 EPS to VAREPS.

Dr K. Puri presented the ensemble prediction system at BMRC. BMRC is currently running three ensemble prediction systems: a global EPS, which is undergoing operational trials; Regional EPS, which is being run in a research mode; the operational seasonal prediction system the Predictive Ocean Atmosphere Model for Australia (POAMA). 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 $T_L119L19$ 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 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.

Dr Y. Takeuchi gave an overview of the ensemble prediction system for operational forecasting at JMA, namely, products and the verification of one-weekforecasts using an EPS based on the T106 GSM with BGM scheme. JMA plans to increase the ensemble size from 25 to 51 in 2006; thereafter, increase the model resolution to TL319L40 (60km) and the perturbed area to global in 2007. JMA will introduce a new operational EPS focused on typhoon centre track forecast in 2007. A singular vector technique is being developed to enable the objective ensemble forecast, e.g. typhoon EPS, short-range EPS, regional EPS, and heavy rainfall EPS. Currently, JMA is developing a SV scheme for EPS with high-resolution model, SV calculation using a linearized model with moist physics on the Earth Simulator, and applications supporting THORPEX with JMA promoting the international exchange of EPS forecasts. Under the bilateral cooperation, JMA and KMA, JMA and NCEP, exchange their EPS forecasts mutually for model development and preliminary study for THORPEX. Under the framework of multilateral cooperation, following the suggestion of the Expert Team (ET) on EPS, JMA hosts two sites for exchanging the EPS verification results between EPS producing centres in January 2004. As of September 2004, five centres (CMC, ECMWF, JMA, KMA and UKMO) have registered on the site. The ET on EPS plans to open such a Web site to NMHCs in order to improve the usage of EPS products in the near future. This activity will be reported to CBS in 2004.

Dr M. Déqué described the short-range ensemble forecasting project at Météo-France (PEACE). The ensemble prediction system is based on Météo-France operational global model ARPEGE (variable mesh) and uses: the T358c2.4 version (operational ARPEGE resolution); initial state uncertainties with Singular vectors; 11 members (ARPEGE operational + 10 perturbed members); and one run per day (18 UTC) up to 60h. The procedure for designing the singular vectors (SV) consists of: targetting over Atlantic Ocean and Western Europe; optimization time window (0-12h); total Energy norm (initial and final); 16 first SVs; no physics; and SV computation with a T95 regular truncation. An experimental EPS has been run with ALADIN.

This is based on 48h forecasts at 10km mesh grid. Twenty cases of heavy precipitations have been compared to observational data (~1100 rain gauges).

Dr D. Richardson described the EPS at the Met Office. The Met Office has developed an ensemble transform Kalman filter (ETKF) system for generating ensemble perturbations. It plans to start trial real-time short-range forecasts in 2005 using nested global (90km) and regional (20km North Atlantic and Europe (NAE)) ensembles. The global ensemble will be extended when computer power is available so as to be part of the TIGGE medium-range international multi-model ensemble.

Dr S. Lord briefed the session about the developments in EPS at NCEP. NCEP implemented a "model-diversity" based regional ensemble system in 2004. The ensemble system shows an improved spread-skill relationship and gives some skilful predictions of convective initiation in potentially severe weather cases.

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 E.

ECMWF (Dr M. Miller)

At ECMWF, the main developments have been the implementation of cycle 26r3 in October 2003 and cycle 28r1 in March 2004, and of the accelerated ocean analyses in May 2004. The Early Delivery System became operational at the end of June 2004. Currently, Cycle 28r3 is undergoing pre-operational testing and is expected to become operational in the autumn.

Modifications in Cycle 28r1 include; data assimilation changes (new snow analysis using NESDIS snow cover product; improved use of GOES BUFR winds; improved clouds in 4D-Var minimisation; re-introduction of ERS-2 scatterometer winds (with adjusted pre-screening and limited coverage) and variational QC corrected for 3D-Var (with impact of the BC project and ERA-40 reruns only)); numerics changes (semi Lagrangian fix for polar vortex instabilities; several code modifications to prepare the L91 version); physics changes(convection clean-up; optimisation of linearised physics and more optimisations of physics code); and oceanic Waves(introduction of subgrid scale (unresolved) bathymetry effects; a fix to the EPS wave-model interface (Charnock variable)).

The overall impact of this new cycle has been small in terms of forecast performance. However the representation of the unresolved bathymetry has resulted in an improved performance of the ocean wave system.

The introduction of the Early Delivery System is a major achievement of the Centre and will allow Member States to access the Centre's forecasts 4 hours earlier without quality loss on average.

Cycle 28r3, currently under pre-operational testing, consists in the following improvements: revisions in the convection scheme and the organization of the time step Improved vertical diffusion in the first minimization of the 4D-Var Full radiation computation every hour; improved numerics for surface-tile coupling; new TL/AD for clouds and convection Tracers in the convection; RTTOV-8 radiation package for satellite radiance assimilation; better corrections of biases for ATOVS and AIRS; assimilation of clear-sky radiances from MSG;assimilation of SCIAMACHY products; technical modifications for assimilation of the rain-affected radiances; passive monitoring of EARS data; tropical Singular Vectors on larger areas and more storms; Gaussian sampling for extra tropical SVs; and use of humidity from selected radiosondes above 300 hPa and blacklisting of SYNOP 2m RH at local night time.

Some of the next major objectives are the implementation of the wavelet-Jb, the initial assimilation of rain-affected SSM/I radiances, the new cloudy planetary boundary layer scheme, and the variable resolution EPS system. The work towards the planned increase in vertical and horizontal resolutions is also progressing fast. The Accelerated Ocean Analyses became operational in May 2004. They will be used soon for the Monthly Forecasting System, and, subject to quality evaluation, in the Seasonal Forecasting System. Significant work has been devoted to preparing the operational version of the Monthly Forecasting System, together with the associated products. The multi-model seasonal forecasting system will also become

operational soon. The new EU project ENSEMBLES will start in the autumn and build upon the results of DEMETER.

The monthly forecasting system has been run routinely every two weeks over the past year with the same configuration as described in the last WGNE report. During that time, there have been several changes in the model physics: cycles 26r3 (October 2003) and 28r1 (March 2004) in order to have the same physics as the operational suite. For each 51-member ensemble real-time monthly forecast, a 5-member ensemble is run over the past 12 years.

Work has continued towards the implementation of a multi-model seasonal forecast system. A key issue has been the development of the ECMWF data structures to handle the multi-model concept, and the implementation of the new data structures in all relevant software. A new set of ocean analyses with reduced wind perturbations (and therefore reduced initial spread) has now been completed by the Met Office, and a full e-suite of the Met Office system is expected to start during the summer.

BMRC (K. Puri)

The modelling activities in BMRC are based around the BMRC Atmospheric Model (BAM). Over the past three years a major effort has been made towards achieving a unified modelling system to allow the climate modelling and numerical weather prediction (NWP) activities at the Bureau to be carried out with the same model. Apart from the obvious efficiencies obtained by having to maintain a single system, the use of the same model for both NWP and climate modelling provides an ideal platform for any model improvements in either application to be carried over to other applications of the system. This is in keeping with common practice at major modelling Centres which are increasingly using the same model for both NWP and climate modelling. The official release of BAM3.0 in 2002 provided the first unified modelling system at BMRC. This version also enabled the Bureau's Limited Area Prediction System (LAPS) to use the same physics parameterization package. Apart from the scientific aspects of BAM, a considerable effort has been made to update the BAM infrastructure to provide greater flexibilities and efficiencies in running the system. The model is now able to run efficiently on both vector and scalar computing architectures; as an example, all the models achieved very high levels of performance in the recent tender process resulting in the major upgrade to the Bureau's supercomputing facilities. BAM is now used for all the Bureau's operational and research modelling which include: the Global Assimilation and Prediction (GASP) system; the Limited Area Prediction System (LAPS); POAMA ; the Australian Air Quality Forecasting System (AAQFS) and climate modelling research.

Météo-France (Dr M. Déqué)

During the past year, the general NWP organization in Météo-France included: ECMWF products for medium-range beyond 96h; ARPEGE 'France' (variable resolution, max=23km) for N.Atlantic/Europe forecasts; ARPEGE 'Tropics' (uniform 50-km resolution) for other areas; short-range ensemble forecasts with ARPEGE; ALADIN (9.5km resolution) for local adaptation on W.Europe; transportable ALADIN for other areas; hourly 9.5km OI diagnostic analyses over France for nowcasting; SIM (Safran-Isba-Modcou) hydrological model over France and Model Of atmospheric Chemistry At larGE scale (MOCAGE) chemistry model.

The present System details are as follows: both ARPEGEs have 4D-Var assimilations with 100km incremental resolution; only ARPEGE Tropics uses tropical cyclone bogus observations; ALADINs initial and lateral BCs are provided by ARPEGE forecasts; 14 other ALADIN models are run in real time in ALADIN cooperating countries; some ALADIN countries run the model at 2.5km resolution; all the production is done 6-hourly except ARPEGE tropics (12-hourly) and forecasts are based on provisional analysis with cutoff times of about 1h50.

ARPEGE assimilation system evolution consisted of: assimilation of cloud-cleared HIRS and AMSU-B radiances; fast ATOVS radiance acquisition using Eumetsat's EARS network; assimilation of Quikscat ambiguous sea surface winds; ship-dependent anemometre height when assimilating '10m' SHIP wind; variational quality control of observations; use of ECMWF's efficient Lanczos minimizer with preconditioning in 4D-Var; 'Jb' background error statistics are computed from ensembles of assimilations; non-linear multivariate balance in 'Jb' background error term; radiation and convection schemes are no longer used in the 4DVar linearized model; ice cover and SST analysis takes into account US SSM/I dataset and 0.5 degrees SST;revision of structure functions in the soil moisture analysis and suppression of the time filter previously applied to the soil moisture.

In ARPEGE/ALADIN systems model evolution, ALADIN has inherited all ARPEGE changes: use of monotonic interpolations in the model's semi-Lagrangian advection; revision of the mesospheric drag above

8hPa;real-time 1-column diagnostics at some European CLOUDNET instrumented sites; tuning of the soil thermal inertia; tuning of snow melting and rain evaporation speeds in large-scale precipitation scheme; revision of the cloud diagnosis scheme; correction of latent numerical instabilities in the vertical diffusion scheme; use of Fouquart-Morcrette radiation scheme (main part is called every 3 hours) and specific representation of lunar radiation, aerosols and ozone in the radiation scheme.

ARPEGE/ALADIN features planned for implementation by the end 2004 include: use of AIRS radiances; use of MODIS AMW winds; raising the model top by adding 5 extra levels; 3DVar 6-hourly assimilation cycle to provide initial state to ALADIN forecasts; use of Météosat radiances in ALADIN 3D-Var assimilation; use of SYNOP temperature, humidity and wind in ALADIN 3D-Var and 3D-Var 9.5km diagnostic analyses for nowcasting.

Dr Déqué also reported on general activities in Europe involving seasonal prediction including DEMETER. This EU project is now finished and a special issue of Tellus is under preparation. Another project, ENACT (Enhanced ocean data assimilation and climate prediction), aiming at a better ocean initialization is finishing soon. There is a new EU-project beginning, called ENSEMBLES whose plans for the first two years include: eleven 6-month forecasts (9 members) from November; eleven 12-month forecasts (9 members) from May; two 10-year forecasts (9 members) for 1965 and 1995; and seven global models (the same as in DEMETER). There is also a project, Marine Environment and Security for the European Area (MERSEA), aiming at testing high resolution (ocean analysis and atmospheric model). The experimental part consists of: twenty 6-month forecasts (9 members); twenty 6-month forecasts (9 members) high-resolution assimilation; ten 6-month forecasts high-resolution atmosphere; and three models (ECMWF, Istituto Nazionale di Geofisica e Vulcanologia (INGV) and Météo-France). The operational European multi-modelseasonal system is almost ready. The system consists of three models (ECMWF, Met Office and Météo-France); monthly production out to 6-months; 40 members plus references (more than 40 runs from past years); with the official start in early 2005. The Task Force on Seasonal Prediction (TFSP-COPES) March 2004 are proposing a seasonal prediction experiment (1979-present, 6-month lead, 10 members, all components, in real forecast mode).

Japanese Meteorological Agency (Dr Y. Takeuchi)

The operational NWP suites at JMA are operated on HITACHI SR8000E1 (80nodes, 768Gflops). The following operational changes for operational GSM have been implemented since last WGNE meeting: (1) use of Aqua and Terra MODIS polar wind data contributing the forecast score improvement especially for high-latitude area, (2) a new cloud ice fall-out scheme based on an analytic solution, (3) a new stratocumulus scheme producing realistic maritime low cloud off the west coast of continents. The revision of GSM resulted in marked improvements of 1day through 5-day forecasts after the implementation of a prognostic cloud scheme and modifications to the Arakawa-Schbert scheme in July 2003.

The targeted moisture diffusion was implemented to RSM in April 2004 and the operational hydrostatic Meso-scale model (MSM) was replaced by a non-hydrostatic MSM on 1 September 2004.

JMA plans several model changes up to early 2005 as follows: (1) revision of short-wave and long-wave radiation processes, (2) use of the ATOVS level-1C data instead of ATOVS level-1D data for GSM, (3) implementation of the original semi-Lagrangian scheme for GSM characterized by splitting the advection terms into the horizontal and vertical directions, and (4) the 4D-Var assimilation scheme for Global Analysis. As for the Meso 4D-Var, use of Doppler radar radial wind data and Aqua/AMSR-E and NOAA/ATOVS precipitable water and rain rate data near Japan are planned.

Next generation computer system for NWP at JMAwill consist of three supercomputers named HITACHI SR11000J1, and each subset has 50node, 80node, 80node, respectively. Total peak performance is 27.5Tflops.

Model developments planned for the new computer system are: (1) high-resolution model, i.e. 20km GSM and 5km MSM, (2) ensemble models, i.e. 120km one-month and seasonal models, 60km weekly forecast model, and 60km typhoon model, and (3) non-hydrostatic 4D-Var assimilation system. Major operational changes planned include: 20km GSM will be operated 4 times a day instead of twice a day, and 5 km MSM will be operated 8 times a day instead of 4 times a day.

The six-month dynamical ensemble forecast targeting the cold and warm seasons was started in September 2003 in a two-tiered way as follows; first, global SST anomalies are predicted to get the boundary condition of GSM, then, the T63L40 version of GSM is integrated for ensemble forecasts. Initial SST anomalies are assumed to persist for first two months. For the last two months of the forecast period, the Niño 3 (eastern-equatorial Pacific) SST anomaly is predicted with the El Niño prediction model (atmosphere-

ocean coupled model), the results are subsequently corrected by the MOS (Model Output Statistics) method. Then, global SST anomalies are regressed against the corrected Niño 3 SST anomaly. The regressed SST anomalies are prescribed globally as the boundary condition for the last two months. The interpolated global SST anomalies are used between the first and last two months. JMA now uses numerical prediction techniques for all ranges of operational seasonal forecasting out to six months.

Hindcast experiments for cold and warm season predictions during 1989-2001 were conducted. These confirmed that the final products made by the dynamical prediction system and PPM (Perfect Prognosis Method) for DJF and JJA surface air-temperature are superior to those of the statistical prediction method and climatological prediction. Hit rates for three categories are 45%, 37% and 33% for dynamical prediction plus PPM, statistical prediction and climatological prediction, respectively. Further effort needs to be made to improve the coupled model and the global SST prediction.

UK Met Office (Dr A. Lorenc)

In 2003 the Met Office completed its move to Exeter, including moving its two T3E supercomputers. This large project was completed on time and on budget, without interruption to forecasts. However, there was a pause in new developments. In April 2004 operational forecasts were transferred to a new NEC SX6 (about 6 times more powerful than the T3Es).

The Met Office's Hadley Centre released its new HADGEM climate model. The Met Office has a strategy of using the same "Unified Model" for NWP at various scales and atmospheric general circulation modelling. However, over the past few years the NWP models had moved ahead; however, with HADGEM they effectively caught up and re-unified the algorithms used. This strategy means that diagnostics of model performance, research into parameterization developments and research into dynamical methods can be used in mesoscale and global forecasting, as well as regional and global climate modelling.

In May 2004 the Met Office began operational assimilation in 3D-Var of a new accurate source of radiance observations from the AIRS. This is the first of a new generation of high-spectral-resolution infrared sounders mounted on polar-orbiting satellites. The change includes use of a more accurate radiative transfer model for Advanced TIROS Operational Vertical Sounder (ATOVS) data, more use of ATOVS over land (Antarctica, Greenland and other high-altitude plateaux), a new method for removing biases in satellite data and a substantial increase in the use of EUMETSAT ATOVS Retransmission Service (EARS) in short cut-off forecast runs for Europe and the North Atlantic. Impact experiments showed a positive impact from each of these changes and predicted a significant improvement in the accuracy of global numerical weather forecasts.

In October 2004 the Met Office implemented 4D-Var in its global system, by adding a simple perturbation forecast (PF) model and its adjoint to the 3D-Var system. In this initial implementation other aspects, such as the digital filter initialisation, observation selection and time-window were unchanged as optimised for 3D-Var. Despite this there was a significant improvement in performance. Developments to take better advantage of the possibilities of 4D-Var are planned for 2005.

In September 2004 the Met Office started operation forecasts from a North Atlantic - Europe (NAE) model with a 20km grid. It is intended that this model will be upgraded to a 12km grid in 2005 to take over the role of the current 12km UK mesoscale model. The UK model will eventually be replaced by a convective-scale model and in 2005 a 4km model will be run on a trial basis.

The Met Office has developed an ETKF system for generating ensemble perturbations. It plans to start trial real-time short-range forecasts in 2005 using nested global (90km) and regional (20km NAE) ensembles. The global ensemble will be extended when computer power is available to be part of the TIGGE medium-range international multi-model ensemble.

Deutscher Wetterdienst (Dr D. Majewski)

The current suite of global and regional NWP models of the DWD consists of: a global icosahedral-hexagonal grid point model GME with a 40 km grid spacing and 40 layers; a non-hydrostatic local model LM, grid spacing 7 km and 35 layers and a hydrostatic High-resolution Regional Model HRM which is used for operational NWP in 13 countries world wide, including Brazil, China, Italy, Oman, Spain, UAE and Vietnam. GME data are provided to these countries via the Internet twice a day to serve as lateral boundary conditions.

Recently, the following main improvements of the NWP system have been introduced operationally: in December 2003 pseudo-TEMPS derived from the 00 UTC analysis of the ECMWF have been introduced

into the data assimilation of the GME. These additional “observations”, over 9600 TEMPS over the oceans and Antarctica, helped to improve the analysis and forecasts of the GME considerably, especially in the southern hemisphere. Here a 20% reduction of the RMS errors was achieved; in September 2004 the grid spacing of GME was reduced from 60 to 40 km, and the number of layers increased from 31 to 40 with the lowest model layer now at 10 m above the ground (before it was at 30 m). Moreover, a new 7-layer soil model based on the solution of the heat conduction equation and including the effects of freezing/melting of soil water replaced a simple 2-layer soil model. While standard scores at 500 hPa showed only a modest improvement of the GME 40 km/L40 over the former GME 60 km/L31, temperature and dew point at 2 m improved dramatically with a reduction of the RMS errors between 10 and 20%; in April 2004 the prognostic treatment of the hydroMeteors including a full 3D-advection of rain and snow (based on an SL scheme) became operational in the LM. In the cold season, this new LM version improves the spatial precipitation pattern in mountainous regions considerably; and in the second quarter of 2005 the model domain of LM will be enlarged from 325 x 325 to 665 x 657 grid points to cover all of Europe with a grid spacing of 7 km and 40 layers.

During September 2004 scientists from all countries using HRM operationally met at Niteroí near Rio de Janeiro, Brazil, for the first HRM Workshop to enhance co-operation and co-ordinate the further development of the system. More than 30 scientists from 14 countries enjoyed the unique opportunity, which was supported by WMO.

A new headquarters for the DWD, to be ready at the end of 2007, is under construction at the site of the old one.

Russian HydroMétéo centre (HMC) and the Voeikov Main Geophysical Observatory (MGO) (Dr V. Kattsov)

Operationally, HMC uses a global spectral model T85L31 and also a regional model. The global forecasts are produced twice a day (for 3.5 days from 00UT and for 10 days from 12UT). The forecasts are based on the 3D multivariate analysis with optimum interpolation for geopotential height, temperature and wind, and 2D optimum interpolation for other variables. The HMC operational regional model has a domain which includes Europe and Northern Asia. It has 75 km resolution in the horizontal, and 30 sigma-levels. Operational forecasts (48 hr) are produced twice a day (from 00UTC and 12UTC).

The HMC SL-AV (Semi-Lagrangian Absolute Vorticity) global model is used in quasi-operational mode. It produces forecasts twice a day (00UTC and 12UTC). It has been tested quasi-operationally for the periods August-November 2003 and January-March and June-September 2004 in combination with DAS and OA. The forecasts were compared with: HMC operational T85L31; HMC operational regional model; forecasts of NCEP, UKMO and ECMWF.

For monthly forecasting, the official intercomparison of HMC and MGO has been continued and will be finished on March 31, 2005. HMC monthly forecasts are based on 5-member ensemble with HMC T42L15. MGO forecasts employ 11-member ensemble with the MGO T42L14. The forecasts are produced once a month.

In seasonal forecasting, research has been ongoing at MGO and also in the framework of SMIP-2 and SMIP2-HFP projects. MGO also participates in APCN (APEC Climate Network) project on seasonal forecasting intercomparison. The models participating in APCN are: MSC (Canada); NCC T63L16 and IAP 4x5L2 (China); CWB T42L18 (Chinese Taipei); JMA T63L40 (Japan); GDAPS/KMA T106L21, GCPS/KMA T63L21, and METRI/KMA 4x5L17 (Korea); MGO T42L14 (Russia); NSIPP/NASA 2x2.5L34 and NCEP T63L17 (USA). The number of experiments has increased from 2 times to 4 times a year. By 2004, the number of variables has increased from 8 to 11. The hindcast period has changed from the 21 year (1979-1999) to 24 years (1979-2002).

Canadian Meteorological Centre (Dr J. Côté)

The new variable resolution regional configuration of the GEM model became operationalin May 2004. It runs on the IBM system that was accepted in January 2004. The GEM model at 15 km is integrated on a variable resolution grid (575×641) of which 66% is in the uniform portion of the grid. It represents an approximate doubling of the number of horizontal and vertical grid-points. Apart from the resolution, the main change to the dynamics configuration is the introduction of a more scale-selective horizontal diffusion and a sponge layer at the model top. Physics configuration changes include more frequent computation of radiation, an improved cloud and precipitation package centered on the Kain-Frisch scheme and the inclusion of a moist turbulent energy formulation for vertical diffusion. The same physics package is expected to go in the new global model. A notable improvement of numerical guidance was noticed, more particularly

the high-precipitation amounts observed during the 2004 hurricane season. It is planned to start experimental mesoscale runs (2.5 km) on selected windows and also increase the resolution of the global system next year in 2005.

The Ensemble Kalman Filter (EPS suite) is in the process of being implemented. The Canadian Ensemble Kalman filter (EnKF) is a Monte Carlo ensemble prediction system that tries to randomly sample all sources of error. Different members use perturbed observations and surface fields and different model versions. A double EnKF is used in the assimilation cycle to produce perturbed analysis and error statistics. The number of members for the EnKF is increased and 3D-Var is now used for the analysis.

The volume of assimilated data in the global and regional suites was increased in September 2004 and parallel runs of the new global 4D-Var data assimilation are starting. Results from the pre-operational assimilation 4D-Var system were presented. The main purpose of the 4D-Var is to use more data and make a better use of it. Positive impact has been noted in all regions. 4D-Var offers a more natural framework for the assimilation of time series of data, and more specifically satellite data. Flow dependent characteristics are implicitly embedded within the analysis and precursors to synoptic development are taken into account. Future work includes bringing 4D-Var in the regional analysis.

China Meteorological Administration (Dr Chen Dehui)

During the year, developments of the new operational system at CMA/NMC included:

(1) The dust-storm numerical prediction system was running quasi-operationally in the spring.
(2) The Global typhoon track prediction system was running operationally in April 2004.
(3) The “HB-MM5” meso-scale NWP system was running operationally in May 2004.
(4) A warning system of forest fire meteorological conditions was operationally implemented by application of T213L31 model products in September 2004.
(5) The UVI operational prediction system was updated.

Recently, efforts are ongoing to:

(1) Test for updating the global medium-range model from T213L31 to T319L31.
(2) Develop background error covariance estimated system for global 3D-VAR system (SSI).
(3) Test for transferring the global data assimilation from OI to 3D-VAR (SSI).
(4) Develop global ensemble prediction system replacing the SV’s by BGM method for generating the initial perturbations.
(5) Introduce a new air quality model from Canada.

A new generation of multi-scale unified assimilation and prediction system, GRAPES - Global/Regional Assimilation and PrEdiction System, has recently been developed at CNPR (Centre for Numerical Prediction Research). In the past year, GRAPES has:

(1) Established the advanced data variational assimilation system, realized the direct assimilation of radiation data from satellite-based vertical detectors and the assimilation with other remote sensing data such as Doppler radar and satellite-derived products, as well as the assimilation of conventional observations.
(2) Developed the alternative (hydrostatic/non-hydrostatic, limited-area/global, and horizontal/vertical resolution) dynamic model framework, set as a base for the development of the new-generation mesoscale and global models.
(3) Tuned physical process modules for the models through optimization of the physical process schemes for mesoscale prediction models; tested the consistency of the physical process modules and the dynamic frame.
(4) Tested the global dynamical core of GRAPES, and began to test real case studies with the whole NWP system (dynamical core, physical package and 2D-VAR initialization).
(5) Released version 2.0 of GRAPES_Meso (regional version) in May. GRAPES_Meso was also tested in real time at NMC/CMA.

Naval Research Laboratory (NRL) (Dr C. Reynolds)

Global modelling highlights covered recent improvements to the NOGAPS including a switch to mean orography and Gravity Wave Drag (Webster et al. 2003, which has had a significant impact on low level winds), and a modification to the Emanuel cumulus parameterization to increase convective momentum

transport, which has improved tropical cyclone track forecasts. Plans for the coming year for NOGAPS include the adoption of a U-V based Semi-Lagrangian formulation, and an improved land surface model. Development of the NRL Spectral Element Atmospheric Model (NSEAM) is also continuing. The adjoint of NOGAPS and the NAVDAS have been used for observation impact studies and to provide targeted observing guidance for different field programs, including the Atlantic THORPEX Regional Campaign (A-TReC). Evaluation of A-TReC data impact highlights the importance of commercial aircraft data in forecast error reduction. Research on ensemble design, including initial-perturbation methods based on the ensemble transform, and estimates of the analysis error variance from NAVDAS, is ongoing.

CPTEC (Dr P.L. Silva Dias)

The installation of the new computer system of the Brazilian Centre for Weather Forecasting and Climate Research (CPTEC) has recently been accomplished. The NEC SX6 is now operational with 12 nodes (96 processors), with peak performance over 700 GFlops. The operational suite of CPTEC models consists of: a global spectral model, regional ETA-model; coupled atmosphere-ocean model (MOM), global wave model, hydrological model and the environmental regional model. The new computer allowed the resolution of the global model to be increased from T126L28 to T215L42 up to 7 days and an ensemble forecasting with 15 members, twice a day at T126 resolution up to 15 days. About 45% of the SX6 peak performance has been achieved with the new global model code running on 8 processors. The ETA regional model is now running in parallel mode at 20km resolution over S. America and adjacent oceanic areas for 7 days, with the global model boundary conditions. Data assimilation is performed with Physical Space Assimilation System (PSAS) for both global and regional models. Seasonal forecasting now includes a Dynamic Extended Range Forecasting (DERF) mode with 25 members and the anomalies are defined in terms of the monthly climatology based on the integration from initial conditions of the last 20 years. The standard IRI anomaly forecasting model is based on 25 members with either persisted SSTA or predicted SSTA (NCEP forecast in the Pacific and a statistical prediction in the tropical Atlantic). An IRI cycle with changes in the physical parameterization is also regularly run once a month. The coupled model will begin operation for seasonal forecasting and a 35-day forecast, twice a day for experimental long lead forecasting. The environmental model has been adapted to the SX6 architecture and new cumulus parameterizations have been included as well as changes in the radiation code to take into account the effect of the aerosols produced by biomass burning. The SIB2 with carbon is under implementation in the global model as well as in the environmental model. Downscaling of global change IPCC scenarios is under way with the ETA model. A local Kalman A filtering data assimilation system is also under study in order to replace the PSAS. Special effort is now under way to improve the forecast skill scores over S. America using specially designed perturbation techniques in the ensemble forecasting. The photochemistry model based on MOZART is also being implemented. One of the CPTEC goals is to improve environmental forecasting, mainly the impacts of biomass burning and air quality. The metrics for Operational NWP Centers as reported to WGNE (as of February 2005) are shown in Appendix E.

6. OTHER WGNE ACTIVITIES AND FUTURE EVENTS

Publications

The WGNE "blue-cover" numerical experimentation series published the annual summary of research activities in atmospheric and oceanic modelling (No. 34, produced in April 2004), again printed and distributed directly by RPN, Montreal who were formally thanked by WGNE. The April 2004 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 has now been linked to the WCRP website: http://www.wmo.ch/web/wcrp/wcrp-home.html. About 220 hard copies have also been produced and distributed.

A specific web page for WGNE was discussed. It was recommended that this could be under the WCRP web page. All the presentations made at the WGNE sessions should be kept in pdf form under this page.

Next session of WGNE and GMPP and other events

At the kind invitation of the Russian Hydro-Meteo Centre (HMC), the next session of the WGNE, the twenty first, would be held in St. Petersburg, Russian Federation, 7-11November 2005.

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 Met Office, UK 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 Met Office and hearing first hand of the research and development programme had been very valuable. Sincere gratitude was voiced to Dr A. Lorenc and supporting staff for the excellent arrangements, unstinting assistance, and refreshments that had been provided.

This joint twentieth session of WGNE and eighth session of GMPP was closed at 1300 hours on 15 October 2004.

APPENDIX A

LIST OF PARTICIPANTS

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APPENDIX B

Summary of the main Decisions, Recommendations and Actions:
WGNE-20/GMPP-8, Met Office, UK, 11-15 October 2004

1. WGNE in the context of COPES

As part of the structural changes necessitated by COPES, WMP and WOAP have been set up, overseen by the JSC. The Chair of the WMP briefed WGNE about the aim and scope of this new Panel. To facilitate the coordination and interaction of WGNE and WGCM under the WMP, this would meet in conjunction with WGCM and WGNE in alternative years, starting with WGCM in 2005.

Concern was expressed that the WCRP Panel on Observations and Assimilation (WOAP) did not appear to have sufficient representation of data assimilation experts and it was agreed that this concern would be conveyed to the WOAP Chair.

The need for good metrics for climate-type models was discussed. WGNE welcomed the idea of development of metrics in the spirit of the new 'unified' prediction systems and will consider this at its next meeting. It was also agreed that WGNE would in future have an explicit agenda item on the development of next generation atmospheric models.

2. Studies and comparisons of atmospheric model simulations

WGNE expressed its gratitude to PCMDI for undertaking and successfully completing the AMIP projects and for creating a valuable infrastructure for processing model outputs at PCMDI and establishing efficient data formats etc for such exchanges of model simulations. WGNE recommended closure of AMIP2 in a time frame of six months. WGNE, WGCM, GMPP and PCMDI would discuss the future of AMIP beyond AMIP2.
(*Chairs of WGNE, WGCM and GMPP to discuss*)

It was agreed that WGNE would make a formal proposal to the international climate modelling community (including the AMIP mailing list) for a Transpose AMIP.
(Dr D. Williamson to formalize proposal and contact modelling groups on the AMIP mailing list)

The atmospheric and coupled modelling communities and oceanographers have strong interests in progressing SURFA, and efforts are continuing through liaison with the newly-formed WCRP Working Group on Surface Fluxes (WGSF) to address the requirements of research, observations, analysis and modelling of surface fluxes within WCRP and closely-related programmes such as GODAE and GCOS. WGNE discussed the problems involved with adhering to data standards and noted that GODAE has been active in this area.
(*Dr. P Gleckler via WGSF and WGNE Chair to progress this further)*

WGNE was pleased with the successful Workshop on High Resolution RCMs held 29 March-2 April 2004, Lund. WGNE will continue to discuss the developments in this area in its future sessions. It also discussed results from SGMIP (Stretched Grid Model Intercomparison Project), noted that this was a very promising approach to higher resolution regional simulations and will continue to monitor the developments in this area in its future sessions.

WGNE recognizes that there is a great deal of potential for collaboration and liaison with SPARC and agreed to increase its interaction with SPARC.
(*Dr. K. Puri to communicate with Dr. Roff; also Chair, WGNE and Co-Chair, SPARC to discuss further*)

Both WGNE and GMPP endorsed the proposal for the new intercomparison project of Forest Snow Process Models, SNOWMIP2.

3. Physical parameterization in models

WGNE confirmed the value of the interaction with GMPP for parameterization work, particularly with GCSS. A joint WGNE/GCSS model intercomparison study of a Pacific cross section was proposed to evaluate physical parameterizations along the atmospheric cross section following the trade winds. WGNE also suggested that there be a follow up exercise over continents. It was proposed that participants for these studies should include the AMIP community and that the proposed case study provides an excellent opportunity to bring together NWP and climate modellers.
(*Chair GCSS and Chair, WGNE to coordinate*)

4. Numerical weather prediction topics

There exists a dichotomy of opinion regarding the use and interpretation of grid lengths of several kms for forecasting. These resolutions will become affordable for GCM use in the coming years, and the prospect of climate simulations with grids of order one kilometre is an issue of international activity and debate which WGNE will continue to monitor such developments.

WGNE was pleased to receive the report on progress in THORPEX including the Second Draft of the implementation plan. WGNE considered that it remained a major challenge to engage the academic community and encouraged the circulation of the draft science plan to suitable members of academia for comment and to stimulate interest.

WGNE agreed to consider, in consultation with WGSIP, the possibilities of using seasonal forecast systems to study, inter alia, the resolution dependence of the atmospheric energy transports and their up- and down-scale characteristics. Results from this should then guide the debate as to what forecast/simulation deficiencies are to be expected from the current use of relatively low resolutions in climate models. At least one group will be in a position to undertake such experimentation in the next year or so.

(Chairs of WGNE and WGSIP will progress this further)

Following a request from the WGNE, the joint (WWRP/WGNE) Working Group on Verification (JWGV) has prepared a set of recommendations for the verification and intercomparison of QPFs from operational NWP models. This first report focuses on deterministic forecasts; a future one will outline methods for probabilistic/ensemble forecasts. The JWGV is interested in collaborations with other WMO verification projects and groups.

WGNE reiterated its strong support for the reanalysis efforts and the desirability of having a dedicated 'Reanalysis Centre' at a major NWP operational centre. WGNE recommended that the concept should be part of the 'COPES', and that the JSC should try and secure funding for this.

APPENDIX C

JOINT WGNE-20/GMPP-8 MEETING, EXETER, UK, 11-15 OCTOBER 2004

AGENDA

Monday 11 October 2004

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
	Opening welcome and local arrangements etc.	Chair, WGNE A. Lorenc
1.1	Adoption of Agenda	Chair, WGNE Secretariat
1.2	Discussions at the twenty-fifth session of the JSC (March 2004), future directions of the WCRP including COPES, and the role of WGNE	P. Lemke, Chair, JSC K. Puri
	Report on the JSC Officers, Chairs and Directors meeting (Sept. 2004)	Chair, WGNE P. Lemke
	WCRP WMP and WOAP	J. Shukla
1.3	Recommendations from the GEWEX Scientific Steering Group on the development of the GEWEX modelling and prediction thrust; status of GMPP within GEWEX	Chair, GMPP
1045-1100	**Coffee break**	
1100-1245		
1.4	Overview of MO developments including plans for 4D-Var implementation	A. Lorenc
1.5	Recent developments at operational forecasting Centres	Participants
1245-1400	**Lunch**	
1400-1545	Recent developments at operational forecasting Centres	Participants
1545-1600	**Coffee break**	
1600-1745		
	Recent developments at operational forecasting Centres	Participants

(General Discussion on the role of WGNE …somewhere in the week's agenda TBD)

Tuesday 12 October 2004

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
2.1	GMPP report including diurnal cycle etc.	Chair, GMPP
2.2	Latest status of CEOP including information on the range of data being collected and their availability	M. Bosilovich (Y. Takeuchi)
2.3	GLASS; an overview of activities	P. Dirmeyer
2.4	The follow-up to SNOWMIP ---- SNOWMIP2	R. Essery
1045-1100	**Coffee break**	
1100-1245		
2.5	Progress with land-surface/atmospheric coupling in operational models	Participants
2.6	Model developments and diagnostic studies including CEOP and ARM	S. Milton
2.7	"Transpose" AMIP: status of pilot project at NCAR	D. Williamson (M. Miller)
2.8	Latest results from AMIP-II and diagnostic subprojects, Future directions for AMIP	P. Gleckler Chairs of WGNE & GMPP
1245-1400	**Lunch**	
1400-1545		
2.9	Stretched-Grid Model Intercomparison Project (SGMIP)	M. Fox-Rabinovitz
2.10	Report on the activities of the WGCM	Bryant Mcavaney *(for J. Mitchell, Chair, WGCM)*
2.11	Update on the International Climate of the Twentieth Century Project	J. Shukla
2.12	Report on the RCM Workshop (Lund); Future directions	R. Laprise
1545-1600	**Coffee break**	
1600-1745		
2.13	"Aqua-planet" experiments	D. Williamson
2.14	Progress in the implementation of "SURFA": adoption of a "near real-time" approach in collecting data	P. Gleckler
2.15	The activities of the new WGSF	Secretariat
2.16	Development of refined numerical algorithms for model dynamics and test cases for new methods	D. Williamson Participants

2.17	Even Newer Dynamics	A. Staniforth

Wednesday 13 October 2004

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
3.1	Status and plans of data assimilation/analysis. Assessment of changes in observing systems: results of OSEs, also report on CBS work. Plans for the Fourth WMO International Symposium on Assimilation in Meteorology and Oceanography	A. Lorenc
3.2	Satellites and report on the OSE/OSSE workshop	S. English
1045-1100	**Coffee break**	
1100-1245		
3.3	Relevant activities under CAS auspices	E. Manaenkova
3.4	THORPEX	A. Thorpe E. Manaenkova
	TIGGE	D. Richardson
1245-1355	**Lunch**	
1400-1545		
	WGNE and THORPEX, a general discussion	A. Thorpe Chair, WGNE Participants
3.5	SPARC – report on activities; progress of the SPARC data assimilation project. Collaboration with WGNE	A. O'Neill, Co-Chair, SPARC
3.6	Intercomparisons of stratospheric analyses and model predictive skill in the stratosphere?	K. Puri
1545-1600	**Coffee**	
1600-1745		
3.7	New ideas and progress in the generation/use of ensembles:	Participants
3.8	An overview of recent developments/activities in seasonal forecasting	M. Déqué
3.9	Progress in Monthly and Seasonal forecasting	T. Stockdale, Co-Chair WGSIP, Participants

Thursday 14 October 2004

Agenda Item	Subject	Responsibility/ introductory speaker
0900-1045		
4.1	Progress in GCSS including new results/case studies using cloud resolving or cloud system models	C. Jakob
4.2	Parameterization development and the GCSS etc	R. Kershaw
1045-1100	**Coffee break**	
1100-1245		
4.3	The progress of GABLS	B. Holtslag
4.4	Boundary layer related issues in models	Participants
1245-1400	**Lunch**	
1400-1545		
4.5	Modelling at 4 km resolution and the diurnal cycle	P. Clark
4.6	Recent developments/activities in mesoscale NWP	J. Côté D. Majewski
4.7	Experience with very high resolution modelling	Participants
4.8	Representation of the diurnal cycle in operational models	Participants
1545-1600	**Coffee break**	
1600-1745		
4.9	Trends in performances of the models of the main operational forecasting centres	M. Miller
4.10	Report on the Verification Methods Workshop (Montreal, Sept. 2004) and other activities	B. Brown
4.11	Verification and comparison of precipitation forecasts at various centres	D. Majewski, M. Déqué, S. Lord, K. Puri, Y. Takeuchi
4.12	Inter-comparison of typhoon track forecasts	Y. Takeuchi

Friday 15 October 2004

Agenda Item	Subject	Responsibility/ introductory speaker
0830-1045		
5.1	Progress in reanalysis activities at NCEP, ECMWF and JMA	S. Lord M. Miller Y. Takeuchi
5.2	HADGEM	V. Pope
1045-1100	**Coffee break**	
1100-1200		
5.3	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 J. Polcher V. Pope, and others as appropriate
1200-1300		
5.4	Outstanding items and actions	
5.5	Arrangements for publication of the 2005 edition of "Research Activities in Atmospheric and Oceanic Modelling"	J. Côté Secretariat
	WGNE Web page	
	Venue for WGNE 2005	
	Close of session	

APPENDIX D

Report on a WMO/WCRP-sponsored Workshop held in Lund (Sweden), 29 March to 2 April 2004: "High-resolution climate modelling: Assessment, added value and applications"

René Laprise

In March 2000 a "Joint WGNE/WGCM *ad hoc* Panel on Regional Climate Modelling" was established, with mission of addressing several issues that had been raised by WGNE in its annual reports of the previous two years. The Panel submitted its report entitled "Atmospheric regional climate models: A multiple purpose tool?" on 12 July 2001 and in modified form on 11February 2002. Amongst the recommendations contained in the Panel's report was to hold a Workshop to discuss the current issues in Regional Climate Modelling (RCM): this is how the Workshop held in Lund, Sweden, from March 29 to April 2 2004, came to be. Workshop sessions were grouped under the following three themes: (1) Modelling issues – Merits and limitations, (2) Applications, and (3) Reports of the European project PRUDENCE. Proceedings the Workshop have been assembled in a report of Lund University, which include a Foreword by the chair organiser, a Synthesis of the presentations and discussions, and extended abstracts for several presentations at the Workshop: *"Bärring, L., and R. Laprise (Editors), 2005: 'High-resolution climate modelling: Assessment, added value and applications'. Extended Abstracts of a WMO/WCRP-sponsored regional-scale climate modelling Workshop, 29 March - 2 April 2004, Lund (Sweden). Lund University electronic reports in Physical Geography, 132 pp".* The electronic version of the proceedings can be downloaded from the web site: http://www.nateko.lu.se/ELibrary/Lerpg/5/Lerpg5Article.pdf. Electronic copies of the presentations can also be obtained at the site: http://www.necc.nu/RCMworkshop/index.htm. This short report summarises the key points discussed at the Workshop, trying to reflect the rapid evolution of paradigm that has been taking place over the last years in the field of regional climate modelling.

The identification of the added value of regional-scale climate projections remains a key issue. The fact that high-resolution RCMs produce fine-scale details in their climate simulations is well established by now, and modellers hope that these details are useful. The added value is unlikely to be apparent in simple statistics such as monthly means and transient eddy variances, because both measures tend to be dominated by large scales for most variables. Scale decomposition is a first step to separate the fine scales that are permitted by the high-resolution computational grid from the large scales that are used to drive nested RCMs. There is an emerging view that added value may be application related and that it likely depends on the inherent limitations of the nesting data used as lateral boundary condition (LBC) of an RCM, and possibly on the nesting technique.

There is increasing evidence that, for some regions and with large computational domain, nested models may not represent a lateral boundary value (LBV) problem. Indeed, Why should LBCs control entirely the interior? Depending on weather regime and domain size, RCMs appear to be facing the predictability limits analogous to initial-value problems. In such case the internal solution will diverge in time, with little control by LBC, in a fashion similar to global models; the phenomenon is referred to as "intermittent divergence in phase space" (IDPS). The occurrence of IDPS renders impossible the deterministic, time-by-time comparison of RCMs' simulations (nested by analyses) with observations. One would hope however that the basic climate statistics would agree, despite IDPS for individual weather events. Alternatives to simple LBC nesting such as *ad hoc* nudging of large scales in the interior of the domain can be effective in preventing IDPS, as does also a reduction of domain size. The procedure to ensure an optimal control of an RCM by nesting data is an active current research field. The Lund Workshop was the forum of several discussions about existing and proposed international collaboration endeavours in regional climate modelling.

The European project PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects; http://prudence.dmi.dk) involved several global and regional modelling groups in performing climate projections aimed at improving climate-change assessment for Europe. The fundamental scientific motivation of this project was to explore the combined uncertainty in climate-change projections resulting from the use of different coupled Atmosphere-Ocean General Circulation Models (CGCMs) providing boundary conditions for different Regional Climate Models (RCMs). The availability of a wide range of model projections for a region provides a sense of uncertainty, preventing impact users from a naïve deterministic interpretation of single-model results. The project has clearly shown the benefits of collaboration between modelling groups, and as well as interactions between the modelling community and several application groups; it stands as an example for other groups around the world. The follow-up is the European project ENSEMBLES.

A "North American Regional Climate Change Assessment Program" (NARCCAP; http://www.narccap.ucar.edu) is proposed by Dr L.O. Mearns from the National Center for Atmospheric Research (NCAR). This proposal is modelled on the very successful PRUDENCE project in Europe. This

collaborative programme will have several benefits. It will permit (1) the exploration of the multiple uncertainties in regional projections of CGCMs and RCMs for North America, (2) the development of multiple high-resolution regional-climate scenarios for use in impacts models, (3) a thorough evaluation of RCMs' performance over North America, (4) the exploration of some remaining uncertainties in regional-scale climate modelling, and finally but not least, (5) the creation of greater collaboration between USA and Canadian climate modelling groups, as well as with part of the international modelling community.

A "Transferability Working Group" (TWG; http://rcmlab.agron.iastate.edu/twg) is proposed by Dr E.S. Takle from Iowa State University (ISU). The GEWEX Hydrometeorology Panel has solicited and given strong endorsement to this proposal that will explore how well understanding of physical climate processes as modelled in RCMs transfer from one climatic region to another. TWG will collect results of RCMs intercomparison projects on several continents and GEWEX continental-scale observing campaigns, to yield an overview comparison of RCMs contemporary-climate capabilities and challenges. TWG will provide a means for systematic evaluation of simulations of different climatic regions by "meta-comparison" of individual and ensemble performance among domains as well as on particular domains. A goal is to evaluate transferability of regional climate models and their components from "native" to other "non-native" regions. Such a project is an antidote against over-tuning of regional models for specific region.

A coordinated project exploiting the protocol of the "Big-Brother Experiment" (BBE; http://www.mrcc.uqam.ca/E_v/index_e.html) is proposed by René Laprise from the Université du Québec à Montréal (UQÀM). The proposed project consists in expanding the set of experiments performed to date by the UQÀM group with the Canadian RCM (see the Abstract in the Proceedings for details on the BBE protocol). The BBE permits to focus on errors specific to nested models. The BBE can serve as a useful numerical laboratory to investigate the sensitivity of RCMs' simulations to some errors in nesting data, as is the case with CGCM-simulated data, and to investigate the degree to which RCMs may actually be able to correct some of these errors. The BBE may also be used advantageously to test the impact of computational domain size, to investigate predictability issues related to domain location, to determine constraints on model resolution and domain size for a given resolution of nesting data, to diagnose the presence of artificial "domain" circulations, to quantify the magnitude of the internal variability of nested RCM and, a related topic, the degree of control exerted by lateral boundary conditions for different regions of the globe. The participation of several RCMs in a BBE would allow verifying some of the subtle conclusions obtained to date, verifying that they are not model specific.

APPENDIX E

WGNE List of Operational Global Numerical Weather Prediction Systems (as of February 2005)

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, 2 x68 nodes (20)	T_L511 L60 (10)	T_L255 L40; M51 (10)	4D-VAR (T_L159)
Met Office (UK)	NEC SX6, 2x15 nodes (1.92)	0.56°x0.83° L38 (6)	No EPS	4D-Var
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 RS6000; 120 nodes (2.88)	40 km L40 (7)	No EPS	3D-OI
HMC (Russia)	Cray YMP; Itanium 4x4 (0.003; 0.10)	T85 L31 (10); 0.72°x0.9° L28 (10)	No EPS	3D-OI
NCEP (USA)	IBM Regatta P65 (7.8)	T254 L64 (0 – 3.5 days) T170 L42 (3.5 – 7.5) T126 L28 (7.5 – 16)	T126 L28; M45 (0 – 7.5) T62 L28; M45 (7.5 -16)	3D-Var (T254)
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 (T95); GEM (1.0°); / M16 (10)	Det: 3D-Var EPS: EnKF M96 (1.33°)
CPTEC/INPE (Brazil)	NEC SX6, 12 nodes (0.768)	T126 L28 (15)	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 X1-3/192-L (2.406)	T213 L30 (3.5/10)	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 – 10% of peak for RISC and 25 – 35% for vector computers

Forecast Centre (Country)	2005	2006	2007	2008	2009	2010
ECMWF (Europe)	33	36.5	36.5	36.5		
Met Office (UK)	4	5		40		
Météo France (France)	1.2	1.2	1.2	5	5	10
DWD (Germany)				25		45
HMC (Russia)		8(?)				
NCEP (USA)		16		32		64
Navy/NRL (USA)	1.1	1.6	3.0	4.0	5.0	6.0
CMC (Canada)		11			(27 ?)	
CPTEC/INPE (Brazil)						
JMA (Japan)	6	28	28	28	28	28
CMA (China)	21	21	21	21	21	50
KMA (Korea)	2.4	18			30	50
NCMRWF (India)	0.028	1				10
BMRC (Australia)	1.792	1.792		?		

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems
Part II: Global Model (Top: Deterministic; Middle: EPS; Bottom: Type/Resolution of Assimilation Scheme)

Forecast Centre (Country)	2005	2006	2007	2008	2009	2010
ECMWF (Europe)	T_L511L60	T_L799L91	T_L799L91	T_L799L91		
	T_L255(0-10); M51	T_L399(0-7), T_L255(8-15); M51	T_L399(0-7), T_L255(8-15); M51	T_L399(0-7), T_L255(8-15); M51		
	4D-Var(T_L159)	4D-Var(T_L255)	4D-Var(T_L255)	4D-Var(T_L255)		
Met Office (UK)	40			25		
	90			60		
	120/4D-Var	80/4D-Var		50/4D-Var		
Météo France (France)	T358c2.4L41	T358c2.4L46	T511c1.8L46	T799c1.8L70	T799c1.8L70	T799c1.8L70
	ditto	ditto	ditto	ditto	ditto	ditto
	4D-Var T159	4D-Var T159	4D-Var T255	4DVar T255c1.8	4Dvar T255c1.8	4Dvar T255c1.8
DWD (Germany)		40 km L40		30 km L60		20 km L70
		No EPS		?		?
		3D Var		3D Var/Ens.		3D Var/Ens.
HMC (Russia)	T85L31	T169L31 (10 d)	T169L31 (10 d)	T341L31 (10 d)	T169L64 (10 d)	T511L64 (10d)
	No EPS	20xT85L31(10 d) & 0.72°x0.9° L28 (10) M33	20xT85L31(10 d)	30xT85L31(10 d)	30xT85L31(10 d)	30xT85L31(10 d)
	100 km	60 km	60 km 3D-var	40 km	40 km	40 km
NCEP (USA)	T382L64 (0–7.5) T190L64(7.5+)	T511L80 (0-7.5) T254L80(7.5+)		20 km L90		20 km L100
	T190L64 M80	T254L80 M80		40 km L90 M80		40 km L100M80
	3D-Var (T382)	3D-Var (T511)		3 or 4D-Var		4D-Var
Navy/NRL (USA)	T239L30	T239L30	T319L30	T319L36	T319L48	T383L48
	T119L30	T119L30	T119L30	T159L36	T159L48	T159L48
	3D VAR	3D VAR	3D VAR	3D VAR	4D VAR	4D VAR

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems
Part II: Global Model (Top: Deterministic; Middle: EPS; Bottom: Type/Resolution of Assimilation Scheme)

Forecast Centre (Country)	2005	2006	2007	2008	2009	2010
CMC (Canada)		GEM 35 km L58				GEM 24 km L80
			increase			
	4DV (150 km)		4DV (100 km)			
CPTEC/INPE (Brazil)	T213L42	T254L64	T_L511L64			
	T170L42 M15	T170L42 M25	T_L255L42 M25			
	3D-Var	3D-Var	4D-Var			
JMA (Japan)	TL319(60km) L40(9)		TL959(20km) L60(9)			
	T106(120km) L40M25(9)	TL159(120km) L40M51(9)	TL319(60km) L60M51(9)			
	4D-Var(T63 200km)	4D-Var(T106 120km)	4D-Var(T159 80km)	4D-Var(TL319 60km)		
CMA (China)	T319L40	T319L40	GRAPES-50L31	GRAPES-50L40	GRAPES-50L40	GRAPES-40L50
	T106L19-M33	T106L19-M33	T106L19-M33	GRAPES-M40	GRAPES-M40	GRAPES-M40
	SSI	SSI	3DVAR-50L31	3DVAR-50L40	3DVAR-50L40	4DVAR/EnKF
KMA (Korea)	T213L30	T426L40	T426L70	T426L70		
	T106L30	T213L30	T213L40	T213L40		
	3D-Var	3D-Var	3D-Var	4D-Var/EnKF		
NCMRWF (India)	T170L28		T254L64			
	T80L18 M8		T80L18 M16			
	3D-VAR (T170)		3D-Var			
BMRC (Australia)	T_L239L60	T_L359L60	T_L479L60	T_L479L90		
		Incr res; M50				
	3D-VAR		EnKF			

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems
Part II: Global Model (Top: Deterministic; Middle: EPS; Bottom: Type/Resolution of Assimilation Scheme)

Forecast Centre (Country)	2005	2006	2007	2008	2009	2010
CMC (Canada)		GEM 35 km L58				GEM 24 km L80
			increase			
	4DV (150 km)		4DV (100 km)			
CPTEC/INPE (Brazil)	T213L42	T254L64	T_L511L64			
	T170L42 M15	T170L42 M25	T_L255L42 M25			
	3D-Var	3D-Var	4D-Var			
JMA (Japan)	TL319(60km) L40(9)		TL959(20km) L60(9)			
	T106(120km) L40M25(9)	TL159(120km) L40M51(9)	TL319(60km) L60M51(9)			
	4D-Var(T63 200km)	4D-Var(T106 120km)	4D-Var(T159 80km)	4D-Var(TL319 60km)		
CMA (China)	T319L40	T319L40	GRAPES-50L31	GRAPES-50L40	GRAPES-50L40	GRAPES-40L50
	T106L19-M33	T106L19-M33	T106L19-M33	GRAPES-M40	GRAPES-M40	GRAPES-M40
	SSI	SSI	3DVAR-50L31	3DVAR-50L40	3DVAR-50L40	4DVAR/EnKF
KMA (Korea)	T213L30	T426L40	T426L70	T426L70		
	T106L30	T213L30	T213L40	T213L40		
	3D-Var	3D-Var	3D-Var	4D-Var/EnKF		
NCMRWF (India)	T170L28		T254L64			
	T80L18 M8		T80L18 M16			
	3D-VAR (T170)		3D-Var			
BMRC (Australia)	T_L239L60	T_L359L60	T_L479L60	T_L479L90		
		Incr res; M50				
	3D-VAR		EnKF			

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems
Part III: Regional Model (Top: Deterministic; Middle: EPS; Bottom: Type of Data Assimilation Scheme)

Forecast Centre (Country)	2005	2006	2007	2008	2009	2010
ECMWF (Europe)						
Met Office (UK)	12km NAE, 4km UK			6km NAE 2km UK		
	24km NAE			15km NAE		
	3D-Var	4D-Var for NAE 3D-Var for UK				
Météo France (France)	Aladin 10km	Alaro 10km	Alaro 10km	Arome 2.5km	Arome 2.5km	Arome 2.5km
	No EPS	No EPS	Alaro 10km	Alaro 10km	Alaro 10km	Alaro 10km
	3D-Var	3D-Var	3D-Var	3D-Var	3D-Var	4D-Var/KF
DWD (Germany)	LME, 7 km	LMK, 2.8 km		LMK, 2.8 km		LMK, 2.8 km
	No EPS	No EPS		2.8 km M15		2.8 km M30
	Nudging	Nudging		Nudging/Ens.		?
HMC (Russia)	Var. Res. (30-70 km) L28 and LM, 10 km	LM, 10 km	LM, 5 km			
	No EPS	No EPS	No EPS			
	3D –OI					
NCEP (USA)	10 km L60	8 km L70		6.5 km L85		5 km L100
	22 km M20	15 km M20		12 km M25		10 km M25
	3D-Var	3D-Var		3 or 4D-Var		4D-Var
Navy/NRL (USA)	COAMPS 6 km	COAMPS 6 km	COAMPS/WRF 4 km	COAMPS/WRF 4 km	COAMPS/WRF 2 km	COAMPS/WRF 1 km
	No EPS	COAMPS/WRF	COAMPS/WRF	COAMPS/WRF	COAMPS/WRF	COAMPS/WRF
	OI	3DVAR	3DVAR	3DVAR	3DVAR+	4DVAR

WGNE Overview of Plans at NWP Centres with Global Forecasting Systems

Part III: Regional Model (Top: Deterministic; Middle: EPS; Bottom: Type of Data Assimilation Scheme)

Forecast Centre (Country)	2005	2006	2007	2008	2009	2010
CMC (Canada)	VR 15 km L58	Multi-LAM2.5km	LAM 10 km			
	No EPS	No EPS	EPS 24 km			
	3DV FGAT	3DV	LAM 4DV			
CPTEC/INPE (Brazil)	Eta 20km L38					
	No EPS					
	3D-Var					
JMA (Japan)	RSM 20km L40 (51hrs) 4D-Var (40km)		GSM TL959 20km L60 (9d) 4D-Var (60km)			
	MSM 10km L40 (18hrs) 4D-Var (20km)	MSM 5km L50 (15hrs)	MSM 5km L50 (33hrs) 4D-Var (10km)			
			2km L60 (12hrs) 3D-Var			
	NoEPS					
	See above					
CMA (China)	HLAFS-25L23	GRAPES-15L31	GRAPES-15L40	GRAPES-10L40	GRAPES-10L40	GRAPES-4L50
			Meso-ES-M15	Meso-ES-M15	Meso-ES-M20	Meso-ES-M30
	OI	3DVAR-15L31	3DVAR-15L40	4DVAR/EnKF	4DVAR/EnKF	4DVAR/EnKF
KMA (Korea)	RDAPS/30km	KWRF/10km	KWRF/5km	KWRF/1km		
	No	Multi model	Multi model	Multi model		
	3dOI	3dVar	3dVar	3dVar		
NCMRWF (India)	MM5 30km/ L23 Eta 48km/ L38 (72 hrs)		MM5 /WRF 10km L42 Eta 22km/ L60 (72 hrs)			
	No EPS		EPS			
	3D-Var		3D-Var			

BMRC (Australia)	0.1^{o}x0.1^{o} L51	0.1^{o}x0.1^{o} L60				
	0.5^{o}x0.5^{o} L29; M24	Incr res				
	3D-Var		EnKF?			