REPORT OF THE NINETEENTH SESSION

OF THE CAS/JSC

WORKING GROUP ON NUMERICAL EXPERIMENTATION

**(Centro de Previsão de Tempo e Estudos Climáticos,
Salvador, Brazil, 10 to 14 November 2003)**

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The nineteenth 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 Centro de Previsão de Tempo e Estudos Climáticos (CPTEC), Salvador, Brazil, from 10 to 14 November 2003. The session was opened at 0900 hours on 10 November by the Chairman of WGNE, Dr K. Puri, and of GMPP, Dr J. Polcher. The list of participants in the (joint) session is given in the Appendix A.

Dr J.P. Bonatti from CPTEC/INPE 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 K. Puri expressed gratitude to Drs. J.P. Bonatti and C. Nobre for hosting the joint session of WGNE and GMPP and the excellent arrangements made. He voiced his appreciation to Dr C. Nobre, ably assisted by Ms. G. Cunha, for the efforts and time they had put into the organization of the session. Dr Puri expressed his gratitude to Dr P. Bougeault who was now leaving WGNE and recalled the notable contributions made by Dr P. Bougeault to WGNE, in particular, his paper on verification (published in WGNE Report no.18). Dr Puri welcomed Dr E. Manaenkova, the new Director of Atmospheric Research and Environment Programme of WMO.

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

Scientific direction, Structure and Priorities for the WCRP

Dr V. Meleshko and Dr K. Puri informed WGNE about the main decisions and recommendations adopted by the JSC at its twenty-fourth session regarding the scientific direction, structure and priorities for the WCRP.

The JSC thoroughly debated the proposal produced by the Task Force for a new WCRP-wide "Predictability Assessment of the Climate System" with the aim of major steps forward in climate prediction, resulting in the following decisions for the future scientific direction and structure of WCRP.

The major objectives of the WCRP should continue as they have always been, namely, to determine to what extent climate can be predicted and the extent of human influence on climate, together with the research priorities agreed at the WCRP Conference, 1997, namely:

- assessing the nature and predictability of seasonal to interdecadal variations of the climate system at global and regional scales, and providing the scientific basis for operational predictions of these variations for use in climate services in support of sustainable development;
- detecting climate change, attributing causes and projecting the magnitude and rate of human-induced climate change, regional variations, and related sea-level rise (as needed for input to the IPCC, UNFCCC and other conventions).

To recognise the renewed emphasis of WCRP on its prediction aims and the observational activity that is needed to fulfil them it was decided to develop a major overarching and integrating initiative, tentatively called the "Climate system Observation and Prediction Experiment (COPE)", to be conducted over a decade up to about 2015. It is intended that the proposed focus on the aims of WCRP, setting objectives and viewing them in the context of COPE will provide a new stimulus for the science of WCRP, and widen the recognition of its relevance and importance for a globally sustainable future.

Two new coordinating bodies, the Modelling Council and the Observation Council, should be established: their prime role will be to coordinate and integrate modelling and observational activities across WCRP, with the purpose of meeting the WCRP objectives. A new "WCRP Data Management Group" should be formed which will take care of all data needs across WCRP. Data issues are important to both the Modelling and Observation Councils. This group will interact closely and collaborate with the two Councils and also with project groups and working groups to evolve a comprehensive data policy for WCRP including mechanisms and structures necessary for data management, climate system data assimilation/ synthesis/reanalysis and model initialization.

WCRP should set itself a number of specific objectives with associated time-scales for completion. At the end of the time-period for each objective, a publication, synthesizing the scientific status and understanding of the topic should be produced: such objectives should be widely debated in the WCRP community and stakeholders should be asked for their comments.

The projects and activities should play an essential role in proposing objectives for WCRP: scientific programmes and structures may have to evolve to enable full and proper contributions towards WCRP objectives, and to COPE; at JSC sessions the contributions of projects and activities will focus more on progress towards WCRP objectives, and highlighting topics for future objectives.

WGNE noted the statement of JSC regarding its continuation to adhere to the main aims of the WCRP formulated in the original agreement between WMO and ICSU in 1980, and the establishment of the Modelling and Observational Councils, and Data Management Group. A concern with the proposed restructuring is that it could potentially result in the establishment of too many new groups that would basically end up reporting to each other.

A number of observational programs are planned for implementation during the COPE decade. These are: GCOS with the main aim to provide long-term monitoring of the climate system, the International Polar Year program for 2007/2008 aimed at enhancement of observational and modelling efforts at high latitudes of both hemispheres, and THORPEX that is focussed on enhancement of current ability to predict high impact weather. A key question to be addressed is how these and other similar observational programs will interact with COPE?

Seventh session of the WGCM

Dr B.M. McAvaney reported on the WGCM seventh session, Hamburg 2003. The main issues at the session included AMIP-OMIP interdependence, impact of COPE and data management. A joint CMIP-AMIP panel was proposed in order to coordinate model intercomparison projects. The interaction between WGCM and GEWEX was another topic in which the role of clouds and cloud forcing was discussed.

WGNE responded positively to the recommendation of a joint WGNE and WGCM panel and noted that it would provide a good framework for coordinating AMIP-CMIP.

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 (see section 5.1) 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 including a summary of the sixth session of the WWRP Scientific Steering Committee held at Oslo, September 2003. Relevant items from this WWRP session included: the good progress being made by the Mesoscale Alpine Programme (MAP); the completion of MAP re-analyses project at ECMWF (performed with latest available version of the assimilation system, 4DVAR and T511 model); efforts being made to expand the cyclone database using the ERA-40 reanalyses under the Mediterranean Experiment (MEDEX) project and to make it available on the World Wide Web; approval of the joint WWRP/WGNE draft Resolution on THORPEX; and approval of the proposal to form a Joint WWRP/WGNE Working Group on Forecast Verification. Meetings proposed in 2004-2005 jointly with WGNE include WWRP/WGNE International Workshop on Forecast Verification (2004) and CAS/WWRP/WGNE 4th International Symposium on Assimilation of Observations in Meteorology and Oceanography (2005).

WGNE noted with appreciation the activities developing at WWRP relevant to WGNE. WGNE called for a close collaboration with WWRP in order to avoid duplication and repetition of work.

Recommendations from the GEWEX Scientific Steering Group

Dr J. Polcher briefed WGNE on the recommendations of the GEWEX Scientific Steering Group on the development of the GEWEX modelling and prediction thrust. He pointed out the need for GMPP to interact with the GCM community in order to encourage process studies in GMPP: Dr Polcher referred to water management activities in GEWEX, in particular the interaction with water resource managers which has not been very successful.

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.

2.1 Cloud parameterizations

One of the main activities supporting refinement of model cloud parameterizations is the GEWEX Cloud System Study (GCSS) being conducted as a component of the GEWEX modelling and prediction panel. The goal of GCSS is to improve the parameterization of cloud systems in atmospheric models through improved physical understanding of cloud system processes. The main tool of GCSS is the cloud-resolving model (CRM), which is a numerical model that resolves cloud-scale (and mesoscale) circulations in either two or three spatial dimensions. The large-eddy simulation (LES) model is closely related to the 3D CRM, but resolves the large turbulent eddies. The primary approach of GCSS is to use single-column models (SCMs), which contain the physics parameterizations of GCMs and NWP models, in conjunction with CRMs, LES models, and observations, to evaluate and improve cloud system parameterization.

Further strides towards that goal have been made over the reporting period. The GCSS progress report was delivered by Dr C. Jakob from the Australian Bureau of Meteorology, who will replace Professor Steve Krueger as GCSS chair from January 2004, pending approval by the GEWEX SSG.

The new GCSS science plan has been published in an article in the Bulletin of the American Meteorological Society (Randall, D.A., Krueger, S.K., Bretherton, C.S., Curry, J.A., Duynkerke, P.G., Moncrieff, M., Ryan, B.F., Starr, D., Miller, M.J., Rossow, W.B., Tselioudis, G. and Wielicki, B., 2003: Confronting models with data - The GEWEX Cloud Systems Study. *Bull. Amer. Meteorol. Soc.*, **84**, 455-469).

Several GCSS-related meetings were held over the reporting period. Those include a meeting of GCSS Working Groups (WG) 1, 3 and 4 in Broomfield, Colorado, in November 2003 and the Arctic Regional Climate Model Intercomparison Project (ARCMIP) meeting in June 2003 (related to GCSS WG 5). The third Pan-GCSS meeting is scheduled to take place in May 2005 in Athens, Greece. Most working groups have successfully continued their research programs over the last 12 months. The main activities of each of the groups are summarized below.

WG1 is currently completing its work on the Dynamics and Chemistry of Marine Stratocumulus (DYCOMS) RF01 case. This case focuses on a nocturnal boundary layer topped by a non-precipitating stratocumulus layer. The intercomparison of Large Eddy Simulation (LES) to determine whether these models can simulate this type of boundary layer is nearly complete. A similar intercomparison using Single Column Models (SCM) is underway. The focus for the next 12 months is to extend the existing case study to include microphysical processes to investigate the role of drizzle in stratocumulus-topped boundary layers. In addition, WG 1 will assist the development of a case study of the diurnal cycle of convection over tropical land, currently undertaken in WG4 (see below).

WG2 identified the fall speed of ice particles in cirrus clouds as one of the major issues in the simulation of these clouds in a variety of models. The group is currently aiming to identify a suitable observationally based case to complement the successfully completed idealized case studies carried out so far and to identify which models exhibit most realism in the simulation of ice particle fall speeds.

WG3 has moved to studying extratropical cloud systems observed during an Intensive Observation Period (IOP) of the Atmospheric Radiation Measurement (ARM) program at its Southern Great Plains (SGP) site in Oklahoma in March 2000. Simulations of the entire month of the IOP with a number of Limited Area Models (LAM) have been completed and extensive use is being made of ARM and satellite observations to evaluate the storm and cloud structures simulated by the models. A first investigation into the simulation of cloud systems in the SGP region by climate models has also been carried out.

WG4 is currently focused on the study of the diurnal cycle of convection over land, the simulation of which has recently been identified as a major shortcoming in most GCMs and NWP models. For this purpose, an idealized case study has been instigated and is currently being carried out with a number of CRMs and SCMs. The focus of this study so far has been the early-morning evolution of the convective boundary layer until the onset of deep convection. The study will be extended to the afternoon evolution of convection in the near future. Dr J. Petch from the UK Met Office will be the new WG4 chair from January 2004.

WG5 for Ms an integral part of the ARCMIP. In this role the group has been involved in a radiation and surface layer model intercomparison. Dr J. Cassano from the University of Colorado will be the new chair of the group from January 2004.

A very important recent component of GCSS has been the Data Integration for Model Evaluation (DIME) project. Its goal is to provide "test kits" for model developers that span the entire range of cloud systems studied in GCSS. These test kits include all necessary data to execute and evaluate model simulations. A website for the organization and distribution of the data is now well-established at http://gcss-dime.giss.nasa.gov.

Two GCSS activities across all working groups are currently being planned. The first is the support of the GMPP diurnal cycle project, to which several GCSS WGs either already have been or will be contributing through dedicated case studies. The other is the extension of a study of the cloud system structure along a cross-section across the subtropical and tropical Eastern Pacific carried out recently by the European Study on Cloud Systems in Climate Models (EUROCS). These activities will foster a closer collaboration of the individual GCSS groups focusing on a limited set of specific scientific issues.

Several GCSS researchers have been actively involved in the organization and support of field programs namely, the DYCOMS II experiment, the Cirrus Regional Study of Tropical Anvils and Cirrus Layers–Florida Area Cirrus Experiment (CRYSTAL-FACE), the Rain in Cumulus over the Ocean (RICO) campaign and the planning of the Tropical Warm Pool International Cloud Experiment (TWP-ICE) in Darwin in 2006.

Report on Convection Workshop in Melbourne

A workshop on "Current issues in the parametrization of convection" was held at the Bureau of Meteorology Research Centre (BMRC) in Melbourne, Australia, from 13-16 October 2003. The aim of the workshop was to summarize the state of the art in convection parametrization and forecasting, and to identify key areas in which progress is most urgently required. The workshop highlighted several issues that were seen as critical for future model development.

Many convective systems contain a significant stratiform component, and while some progress has been made, the representation of that component in many parametrization schemes remains weak. The absence of anvil representations in many climate models was seen as disturbing and the workshop expressed the view that improvements in this area need to be made quickly. It is expected that the absence of such representations affect many key areas such as the realistic simulation of clouds and the momentum transport by convection as well as a realistic interaction of the parametrized convection with large-scale circulation systems, such as the Madden-Julian Oscillation.

At the other end of the scale the workshop identified the parametrization of convection in high-resolution models (O(10 km)) as another area of concern. While such models will be able to resolve motions on the anvil scale that are of concern in climate models, they will not be able to resolve the convective motions themselves. The workshop highlighted the dangers of an ad-hoc approach to this problem in the community that applies parametrizations designed for low-resolution models well beyond their range of validity, even when the resulting model simulations appear sensible. Issues such as the lack of convergence of the convective and stratiform cloud and transport parametrizations with increasing resolution, the lack of communication between grid boxes on sub-grid scales and the partial resolution of the important mesoscale motions were highlighted as requiring more attention in future research.

Other research areas identified as important by the workshop were the unification of shallow and deep convection parametrizations, the diurnal cycle of convection and the need for improved model evaluation techniques and data sets. The emerging Multi-scale Modeling Framework (also known as super-parametrization), was also discussed and is seen as an interesting tool to study the actions of convection and its interaction with other processes on various scales with a view to improving classical convection parametrizations.

2.2 Land-surface processes

GEWEX Global Land-Atmosphere System Study (GLASS)

Dr J. Polcher reported on the GLASS project, which is progressing through the various actions which were defined in the implementation plan. Within GLASS, Project for Intercomparison of Land-surface Parmeterization Schemes (PILPS) operates the off-line intercomparisons. The goal of PILPS is to contribute improved understanding of continental surface and near-surface processes through international intercomparison of current state-of the-art parameterizations employed in coupled climate, atmospheric and earth system models. Since the early 1990s PILPS has evaluated the parameterization of energy and water fluxes to and from the land-atmosphere interface. In 2002 carbon fluxes were included in this land-surface MIP (Viovy, 2002). In 2004/5 it is planned to incorporate stable water isotopes in a new phase of PILPS - "IPILPS". Two rare but naturally occurring isotopes of water, $^{1}H_2{}^{18}O$ and $^{1}H^{2}H^{16}O$, will be exploited in IPILPS as part of the overall GEWEX push into the use of isotopes in modelling and monitoring the global water cycle.

Progress for this year includes:

1) Completion of a number of studies such as the Arctic basin study – ACSYS/PILPS; tropical forest study, PILPS 1(c),
2) Continuation of studies such as the coupled comparisons under PILPS 3 (AMIPII DSP 12); carbon fluxes, PILPS C1, http://www.pilpsc1.cnrs-gif.fr/, and
3) isotopes in PILPS - IPILPS draft proposal approved by the GLASS Science Panel Aug 2003.

The Global Soil Wetness Project 2 (GSWP-2)

A 13½-year meteorological forcing data set (global 1° resolution, 3-hourly interval) was prepared for GSWP-2. It is based on the NCEP/DOE reanalysis data set prepared by COLA for the ISLSCP Initiative II data set. Additionally, land surface characteristics from ISLSCP Initiative II (soil, hydrology, topography and vegetation properties) were prepared for GSWP-2 through conversion to NetCDF and the ALMA data standard (http://www.lmd.jussieu.fr/ALMA/).

Baseline land surface model simulations have been completed by research groups on four continents, and results sent to the GSWP-2 Inter-Comparison Center (ICC) at the University of Tokyo. Analysis and validation will be a distributed effort, centered on U. Tokyo and COLA. For simulation of brightness temperatures associated with soil wetness, the L-MEB (L-band Microwave Emission of the Biosphere) model from INRA (France) has been chosen to couple with the LSSs. This model is based on the 'state-of-the-art' knowledge of passive microwave emission from various land covers (herbaceous and woody vegetation, frozen and unfrozen bare soil, snow, etc). In preparation for the analysis phase of GSWP-2, and to establish a baseline of existing global land surface data sets for climate applications, existing global data sets of soil wetness that span at least the period 1980-1999 for model-based products, or at least 1992-1999 for satellite-based products have been compiled and assessed.

Land surface modelling and assimilation at NCEP

Dr R. Petersen covered briefly the significant progress in the area of land surface modelling and assimilation at NCEP including recent upgrades to the coupled Eta/NOAH (NCEP-Oregon State University-Air Force-Hydrologic Research Lab.) and the impacts these changes had on the Eta model forecasts, and the NASA-NCEP collaboration in the development of the Global Land Data Assimilation System (GLDAS), which is presently being ported to the NCEP computing systems.

Through a multi-institution partnership largely sponsored by the GEWEX Continental-scale International Project (GCIP), NCEP has developed a real-time and retrospective North American Land Data Assimilation System (NLDAS). NLDAS consists of:

a) four land models executing in parallel in uncoupled mode,
b) common hourly surface forcing and
c) common streamflow routing -- all using a 1/8° grid over the continental U.S. (CONUS).

Results of a 3-year NLDAS execution of October 1, 1996 to September 30, 1999 (a period rich in observations for validation) emphasizes:

1) the land states, fluxes and input forcing of four land models,
2) the application of new GCIP-sponsored products, and
3) a multi-scale approach.

The validation includes:

a) mesoscale observing networks of land surface forcing, fluxes and states,
b) regional snowpack measurements,
c) daily streamflow measurements and
d) satellite-based retrievals of snow cover, land-surface skin temperature (LST) and surface insolation.

The results show substantial inter-model differences in surface evaporation and runoff (especially over non-sparse vegetation), soil moisture storage, snowpack and LST. Owing to surprisingly large inter-model differences in aerodynamic conductance, inter-model differences in mid-day summer LST were unlike those expected from the inter-model differences in Bowen ratio.

2.3 Atmospheric boundary layer

GEWEX Atmospheric Boundary Layer Study (GABLS)

Professor B. Holtslag reported on the continuing implementation of the GEWEX Atmospheric Boundary Layer Study (GABLS) which aims to improve the understanding and the representation of the atmospheric boundary layer in regional and large-scale climate models. Since much of the warming predicted by climate models is during stable conditions over land and ice (either in winter or at night), the first focus of GABLS is on the representation of the atmospheric Stable Boundary Layer (SBL). Based on previous discussions and meetings, a benchmark case was selected to discuss the state of the art and to compare the skills of single column (1D) models and Large-Eddy Simulation (LES) models. The case is based on the results presented in a study by Kosovic and Curry (2000) for a shear-driven, stable case over ice. As such, the boundary layer is driven by an imposed, uniform geostrophic wind, with a specified surface-cooling rate, which attains a quasi-steady state SBL (after about 9 hours). The specifications of the case and the forcing conditions have been distributed to the community in the previous year. Consequently, about 10 groups participated in the comparison for the LES models and more than 10 groups for the 1D models. The findings were presented at a Workshop in Mallorca, Spain, September 2003. The Workshop was attended by about 30 scientists. Discussion sessions were held on the results for the different models, and presentations were given on the specifications of the different models, as well as presentations on how to analyze the model results. Also, presentations were given on existing observations, proposals for new data (including laboratory experiments) and on recent developments in theory. The purpose of the single-column intercomparison was to check the performance of any turbulence or vertical diffusion scheme for the selected case. With the same initial conditions and forcing conditions, the models indicate a large range of results. It appears that this is very strongly related to the choice of the turbulent length scale in the turbulence schemes, and not so much to the vertical resolution. As expected, typically the operational models allow for enhanced mixing resulting in deep boundary layers, while research models, some of which have been adjusted for the present case, show less mixing (more in agreement with data and LES). This issue will be explored further. Sensitivity tests indicated that most of the remaining spread is attributable to differences in formulation and configuration of the sub-grid model. However, even at very high resolution of 2 meters, some LES models did not converge, although those that were performed at a 1-meter resolution indicated a good degree of convergence. It seems that if resolution increases, the SBL decreases. This indicates that more work on the representation of the subgrid scales in LES is still needed (in particular, near the surface). Note that LES of SBLs only began in the early 1990s and since then significant progress is made as indicated by the current findings.

At the Workshop several options were explored for future activities. It was suggested that the studies with LES and 1D models should follow different routes for SBLs. As such, it is felt that 1D proposals should be compared to real data to see if they fulfil the requirements of the climate models. Meanwhile, LES must advance more carefully towards stronger stratification, taking special consideration on the developments of the subgrid scale modelling. The 1D models are ready now for comparison with more elaborate data, such as for cases with stronger cooling over different types of surfaces and increasing complexity. As such, it was discussed to set up a new case over land dealing with the full diurnal cycle. It was also suggested to run the models (1D and mesoscale models) with a simple surface energy budget (rather than the prescribed cooling) to allow for feedbacks between the land surface and the boundary layer. It should not be difficult to find suitable cases in the existing data sets (e.g., ARM, CASES-99, Cabauw, Lindenberg (coupling to land), SABLES98 (elevated turbulence), AMERIFLUX, EUROFLUX). In addition, suggestions were made to explore observations over the Baltic Sea and at Antarctica (notably Halley). It is foreseen that the outcome of the Mallorca Workshop will be presented in a number of journal papers, as well as a meeting connected to the upcoming “Boundary Layers and Turbulence Conference,” in Portland, Maine, USA, August 2004.

Dr H. Campos Velho reported on the Brazilian contribution to modeling and analysis of atmospheric turbulence. In particular he described the application of Taylor’ statistical theory on turbulence (Taylor, 1921) to parameterize the stable and convective boundary layers (Degrazia and Moraes, 1992; Degrazia et al., 1997; Degrazia et al., 2000), and the residual boundary layer (Degrazia et al., 2003; Goulart et al., 2003a)."

The diurnal cycle: a theme for GMPP

Dr J. Polcher proposed diurnal cycle as a new theme for GMPP. It is important to study the diurnal cycle because of its large impact on land surface processes and vegetation and it is a major source of coherent variability. The climate models also have problems in representing the diurnal cycle and systematic errors in diurnal cycle have been identified. Dr Polcher suggested that the theme can be implemented by addressing it to:

(i) AMIP to take up the study of this theme (GMPP will focus on diagnostics for physical processes in GCMs to enhance standard output list),
(ii) GCSS by asking it to contribute to the theme by studies of intensification from shallow to deep convection, interaction between surface and cloud processes, and
(iii) GLASS which could contribute by studies of relation between simulated skin temperature and observed brightness temperature, heat diffusion in soil, its temporal and spatial variability, root functioning and diurnal variation of moisture stress, and diurnal cycle in conductance and plant transpiration. As for GABLS, it is still working on its first intercomparison and it is a little early to take up diurnal cycle. Dr Polcher informed that the proposal has been endorsed by GCSS and GLASS panels and that CEOP has expressed its interest in providing observations and case studies to the theme. GHP would also be involved through CEOP.

Diurnal cycle in operational models

The role of diurnal cycle has been studied in forecasting the exceptional anomalies this year by various NWP centres. Dr Miller noted that the ECMWF forecast of the exceptional heat over Europe this summer showed that the model well predicts temperature maximum over central France to within a degree or so; Dr Déqué noted that the Météo-France model forecast of the week long heat spell over France in early August was very good and could be predicted a week in advance; Dr Majewski found that over Germany it was easy to predict the heat wave as the soil was very dry. Dr Saito pointed to the unusually cold summer in Japan this year.

Dr A. Lorenc summarised some results (since published in A. Slingo, K.I. Hodges, G.J. Robinson 2004, Quarterly Journal of the Royal Meteorological Society, 130, No. 599, pp 1449 -1467) of a study validating the Hadley Centre climate model's diurnal cycle against infrared radiances observed by Meteosat 7. In most regions, results are consistent with well-documented errors in the timing of convective precipitation, which peaks before noon in the model, in contrast to the observed peak in the late afternoon or evening. But over central Africa upper-level layer-cloud due to detrainment from the convection scheme persists well after the convection itself has dissipated. This produces a decoupling between the timing of the diurnal cycles of precipitation and window channel radiance.

WGNE discussed the proposal at length. It was observed that diurnal cycle over warm oceans, especially over tropics, was particularly large. NWP centres can help in simulation of diurnal cycle, independently of AMIP. It was also suggested one needs to study diurnal cycle not only in precipitation but also in radiative physics and cloud cover where it provides a diagnostic of model performance on timescales for these processes. It was agreed that discussions on the performance of operational models in handling the diurnal cycle would be included in future WGNE/GMPP sessions.

3. STUDIES AND COMPARISONS OF ATMOSPHERIC MODEL SIMULATIONS

3.1 General model intercomparisons

A key element in meeting the WGNE basic objective to identify 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 section 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 the most important and far-reaching of the WGNE-sponsored intercomparisons. The second phase of AMIP (AMIP-II) had more than twenty-three modelling groups submitting simulations and much of the data from these runs are available for a wide range of diagnostic sub-projects. Climatological comparisons are available for nearly every standard AMIP model output field, and probably represent the most comprehensive source of the climatologies of atmospheric circulation models. AMIP research is structured round a series of diagnostic sub-projects and a clear view of how models have evolved since AMIP began nearly a decade ago has emerged. Overall, there has been a general improvement 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.

On the technical side, PCMDI has now completed an open source software system which enables much more efficient management of the voluminous AMIP data sets. An automatic system has been put in place to organize the simulations, perform extensive quality control, and make the data accessible (via FTP) to interested users, and modellers are provided rapidly with a "quick-look" summary of the performance of submitted runs.

In its review of AMIP, WGNE was briefed by Dr P. Gleckler about the recent developments at PCMDI and possible future directions of AMIP. AMIP continues to provide an ongoing benchmark diagnostic for WCRP modelling activities. PCMDI's diagnostic strategy will be towards coordinating WCRP modelling activities. Evaluation of CMIP models will be an overarching theme for PCMDI, but AMIP will continue to be supported as a complimentary diagnostic to CMIP. WGNE expressed the view that it would be very useful for the CMIP and AMIP panels to meet jointly in the near future to discuss how this could be achieved.

WGNE noted that the AMIP had become a well-defined and useful experimental protocol for testing and intercomparing global atmospheric circulation models. WGNE also noted that AMIP, in view of the powerful capabilities of PCMDI, provides a good infrastructure for handling model integrations, and so effectively facilitating the diagnosis and display of many characteristics of the results. As such WGNE continues to strongly support the continuation of AMIP. However any future planning depends strongly on the level of PCMDI support for the project. WGNE expressed the hope that the official position of PCMDI would be clarified in the near future.

"Transpose" AMIP

In Dr D. Williamson's absence Dr M. Miller presented results from work at NCAR and PCMDI which has grown out of the earlier WGNE proposal for a transpose AMIP. The NCAR/PCMDI project has been labelled CAPT, the ' Climate Change Prediction Program- Atmospheric Radiation Measurement (CCPP – ARM) Parameterization Testbed'. The goal is to obtain the benefits for climate model development and evaluation that have been realized in weather prediction by applying climate models to weather forecasting, but without the huge costs of developing a complete NWP system. An important point is that the climate models are applied at their relatively low application resolutions and are not expected to make the best weather forecast. The method allows direct comparison of parameterized variables such as clouds and precipitation with observations from field programs such as ARM, early in the forecast while the model state is still near that of the 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.

To avoid developing a complete NWP system based on the climate model the Transpose AMIP/CAPT approach maps NWP analyses or reanalyses to the climate model grid and orography using methods developed in NWP. Not basing the approach on a native analysis system has the added benefit of allowing use of atmospheric analyses from several different NWP centres to provide some information about the uncertainty or sensitivity of the parameterizations to particular analyses since each is influenced to some extent by its system model. When the parameterization errors are the same in forecasts based on different analyses one has more confidence that they are actual errors as opposed to differences between model parameterizations.

Of course, there is also benefit in having the climate model itself embedded in a complete NWP system but that requires a much larger investment.

Initialization of the land variables is more problematical than initialization of the atmospheric state variables. It is difficult to map discrete/discontinuous land variables between different resolutions, there may be different dominant land types in the two systems involved in the mapping, and there is no uniform definition of land model state variables. To date the Transpose AMIP/CAPT project has applied two procedures to spin-up land and atmospheric parameterized variables. Both involve letting the land model (and parameterizations) interact with and respond to the forcing from the atmospheric model while the atmospheric model is constrained to evolve following the observed atmosphere. One approach involves updating atmospheric state variables with the interpolated analyses periodically (e.g. 6 hourly) and letting the coupled land/atmosphere system evolve until the next update time. The other involves adding terms to the atmospheric model to relax predicted state variables toward analyses with some time scale, say 6 hours. The two produce similar initial land states.

Results were presented from forecast experiments with the Community Atmospheric Model (CAM) resident at NCAR. The land was spun up from January 1, 1997 by interacting with CAM2.0 in which the atmospheric state variables were replaced with ERA-40 interpolated variables every six hours. In fact the initial land moisture at ARM CART site is better than expected because two significant errors cancelled each other: the atmosphere rains too much and the land dries too fast. After the land spin up, the forecast latent and sensible heat fluxes are in reasonable agreement with ARM. At least their errors seem second order compared to other errors arising in the forecasts.

Two series of 5-day forecasts with CAM 2.0 from ERA-40 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 forecast of large-scale atmosphere. Thus the parameterizations are being driven by realistic fields in the forecasts. Analysis of the summer forecasts indicates that the convective parameterization is invoked too frequently and when it is invoked the model does not maintain the observed atmospheric state. In the April case the CAM forecasts the timing of precipitation events accurately, however, again when the convective parameterization is invoked it does not produce the observed atmospheric state.

These early experiments indicate that the application of climate models to weather forecasts is very useful to gain insight into model parameterization errors. The current methods for initializing the land are useful for this application because the model parameterization errors are relatively large. However, as these errors are reduced better land initialization methods will be needed.

WGNE expressed satisfaction at the substantial progress made by the pilot project since the last report and observed that time is opportune for proposing a project.

International Climate of the Twentieth Century Project (C20C)

The objective of the International Climate of the Twentieth Century Project, developed under the leadership of the Centre for Ocean-Land-Atmosphere Studies (COLA) and the UK Met Office Hadley Centre for Climate Prediction and Research, is to assess the extent to which climate variations over the past 130 years can be simulated by atmospheric general circulation models given the observed sea surface temperature fields and sea-ice distributions and other relevant forcings such as land-surface conditions, greenhouse gas concentrations and aerosol loadings.

WGNE was informed that C20C became a formal CLIVAR project at the beginning of 2003. The groups participating in C20C will expand to include the Voeikov Main Geophysical Observatory in Russia and the National Climate Center of the China Meteorological Administration.

International CLIVAR wishes C20C to become more rigorous. This is not officially happening at present, but in a step towards a possible joint project suggested by CLIVAR between the current C20C groups and a possible CLIVAR group under the Working Group on Coupled Modelling, some action has been taken. The UK Met Office, in collaboration with the climate modelling group of the National Institute of Water and Atmospheric Research, Wellington, New Zealand, will run two sets of HadAM3 experiments: a set (6 experiments from 1871, 10 from 1950) with natural forcings and observed SST and sea ice extent and another set (same experimental design) with "all forcings". These are based on forcings used by the Hadley Centre in coupled models for the IPCC TAR extended to include a new land surface forcing data set and

Milankovitch effects. The same forcings are being used in HADCM3 experiments for a European project on interdecadal to century variability. This will allow some estimates of anthropogenic effects to be made.

The Third Workshop of the C20C project will take place in Trieste, Italy on 19-23 April 2004, at which the participating C20C groups will report on progress to date. The workshop will include a discussion of future plans, to which representatives from WGNE, WGCM, WGSIP, and AMIP will be invited. The existing phase of C20C will probably not be completed until early 2005. A key aim of the workshop, which will be of value across CLIVAR, is to work towards an agreed set of forcings or ways of dealing with them. This will lead to a new, expanded phase of C20C. Another key element will be to determine the value and the methodology of running CGCMs and AGCMs with various and all forcings from about 1850-present; these runs could be useful for several aspects of CLIVAR research such as seasonal prediction to decadal prediction, climate variability, climate change detection and aspects of climate change projection. It is hoped that AGCMs at that time will be run with more than one SST and sea ice extent analysis and the coupled models would be validated against data sets that would include these different SST analyses. It is also planned to use the new global historical International Sea Level Pressure Data Set currently under development under the auspices of the GCOS Atmospheric Observing Panel for Climate (AOPC).

3.2 Standard climate model diagnostics

Over the past six or so years WGNE has developed two lists of standard diagnostics, one of the mean climate and one of variability. The lists were based on responses from the modelling community to queries concerning what diagnostics they would find useful, and from the diagnostic community as to which diagnostics were appropriate for standard application. The WGNE Standard Diagnostics of the Mean Climate are described at http://www-pcmdi.llnl.gov/amip/OUTPUT/ and the WGNE Standard Diagnostics of Variability are described at http://www.cgd.ucar.edu/cMs/Mstevens/variability/AMWG/variab.html.

These diagnostics were intended to:

(1) provide a comprehensive set of diagnostics that the community agrees is useful to characterize a climate model,
(2) provide a concise and complete summary of a model's simulation characteristics,
(3) provide an indication of the suitability of a model for a variety of applications, and
(4) provide information about the simulated state and about the processes maintaining that state. They were also intended to be diagnostics whose utility has been demonstrated and which can be calculated by each group. It was hoped that many modelling groups would adopt such diagnostics for routine model processing so that groups could easily compare the properties of their models with each other during the development phase, rather than waiting for frozen models and formal intercomparisons.

To date, the diagnostics have not received wide application. Admittedly, it is nontrivial to implement the complete lists. They have been used as the basis for Community Climate System Model (CCSM) Atmospheric Model Working Group (AMWG) model comparison for selecting atmospheric model components for future versions of CCSM, and they are a component of the “quick-look“ diagnostics provided to modelling groups upon submission of their simulations to PCMDI.

Given the lack of wide acceptance WGNE should decide how to proceed in the future. Several paths are possible. One is to do nothing for a few years and see if their application becomes more common and routine. Another is to more actively promote their use for examining models. A third is to simply consider them a part of the AMIP processing at PCMDI. It was noted that the development of diagnostics of the mean climate presented no problem. However, it is not easy to develop a standard list of diagnostics for the variability and other statistics, as there is no standard way. WGNE felt it was necessary to move forward in the matter. PCMDI has accepted to develop a list of diagnostics for the Madden Julian Oscillation.

3.3 Developments in numerical approximations

At past meetings 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 parameterizations with the dynamical cores. In particular, "aqua-planet" experiments with a basic sea surface temperature distribution offer a useful vehicle in this regard. Thus WGNE 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/amip/ape/ and http://www.met.reading.ac.uk/~mike/APE/ape_home.html. The experiment is designed to provide a benchmark of current model behaviour and to stimulate research to understand of differences arising from:

(1) different models,
(2) different subgrid-scale parameterization suites,
(3) different dynamical cores, and
(4) different methods of coupling.

Concerning the schedule, the experiment details were announced early in 2003. Experiment results were to be submitted to PCMDI at the end of September, although that deadline is not being enforced. A Workshop to discuss and summarize the results is scheduled for June 9-11, 2004 at the University of Reading, UK. The organizers hope that in Spring 2004 analyses will be exchanged between participants for consideration before the Workshop.

Dr P.L. Silva Dias made a presentation on the new method for vertical coordinates used in the Regional Atmospheric Modelling System (RAMS). All terrain following coordinate systems have difficulty in handling the steep orography in the Andes region in view of the truncation error associated with the Jacobian of horizontal operators such as the pressure gradient force and the horizontal diffusion. The numerical spurious acceleration causes significant distortion in the simulations and may lead to data rejection in the data assimilation systems due to the misrepresentation of the atmospheric field in the vicinity of the Andes, where a low level jet has been observed. A new method has been proposed for RAMS based on the finite volume representation of the discrete equations, called in the adaptive grid which is a true Cartesian grid. The apertures of the grid cell faces are adapted to topography that would block the flow. The new coordinate system has been used to answer the question: How representative is the reanalysis estimate of the Andes low-level jet (LLJ) moisture transport, considering the numerical restrictions associated with the sharp orography? The results indicate that the coarse resolution and sigma based vertical coordinates may overestimate the width of the LLJ and the magnitude of the moisture transport.

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

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 "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 real progress in estimating and determining surface fluxes. Some NWP fluxes had already been accumulated at PCMDI; however no further work has been conducted over the past year because of changing priorities at PCMDI. Unfortunately, a committed funding source has yet to be identified for SURFA. Given the importance of this effort for a variety of research communities, efforts are continuing in order to resolve the issue in the near future.

In its twenty fourth session the JSC recommended the formation of a limited-term (three years) WCRP Working Group on Surface Fluxes (WGSF) to address all the requirements of research, observations, analysis and modelling of surface fluxes within WCRP and WCRP's interests in closely related programmes (e.g. GODAE, GCOS). All relevant WCRP projects and activities, including specifically WGNE and SOLAS, will be represented on the new WGSF. WGSF will work closely with the new Modelling and Observational Councils of WCRP since their interests will overlap with those of WGSF. WGNE has nominated Dr P. Gleckler to serve on this committee.

3.5 Model stratospheric representation

In the past few years, there has been growing interest in the representation of and prediction in the stratosphere and several major global operational centres have significantly increased the vertical extent and resolution of their models and associated data assimilation and predictions in the stratosphere and into the mesosphere. WGNE is thus undertaking an intercomparison of stratospheric analyses and forecasts in the stratosphere from a number of operational models. One expects better skill in the stratosphere 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 best test would be when the polar vortex is undergoing strong changes - sudden warmings. These dramatic changes to the polar vortex occur over short time scales and provide an excellent test for short-term forecasting systems operating in the stratosphere.

This study examines the ability of NWP models to simulate the stratosphere when the polar vortex undergoes large changes. Analyses for the period from 15 September - 15 October 2002 (Days 0-30 in this study) and forecasts from 20 September - 3 October 2002 (Days 5-18) during the southern hemisphere major sudden warming of 2002 from five current NWP models (the Australian BMRC Atmospheric Model, BAM; the ECMWF IFS; the NCEP MRF; the NRL NOGAPS and the UKMO model) are compared. These models provided forecasts out to 8, 10, 10, 5 and 10 days, respectively. TOMS plots indicate that the vortex started to deform on 20 September, split in two by 24 September and had a single vortex centre again by 30 September.

Comparisons of the 30 hPa temperature RMSE between the model 5-10 day forecasts and their respective analyses show that for forecasts initiated on 20-25 September, when the vortex was in the process of splitting, all the models have almost continuously increasing RMSE for any given forecast day. Thus, for example, the error in the 48 hour forecasts initialized on these days gets worse from the 20th to the 25th of September. This implies that over this period there is a steady reduction of forecast skill and that this is an increasingly difficult period for all the models. From initialization days 25-27 September the skill in all the models is seen to improve dramatically. This is found to be true for other fields (geopotential height, zonal and meridional winds) and other levels above 200 hPa.

Can these RMSE difficulties be related to particular days? If this is true then there should be a strong dependence of the RMSE on the verification day. All the models show that the periods 27-28 September and 2 October are dynamical situations which they have difficulty with forecasting. These are periods when the split vortex is decaying and when the reformed vortex is moving westward, respectively. All the models show that these errors are generally due to the models creating a final forecast vortex which is smaller, more circular, more poleward and more westerly displaced and with a more easterly orientation, though the latter is not as obvious in the ECMWF model. The creation of a smaller, more circular and more polewardly-displaced vortex indicates that all the models are trying to create weaker and less disturbed vortices.

The analyses from all five systems are well correlated over the period of the study when the vortex is quasi-stationary; however these analyses are seen to have larger RMSE differences and become less correlated when the polar vortex is undergoing rapid changes. Also during these active periods the model analyses correlations with TOMS total column ozone decreases dramatically from the very high values found when the vortex is quiescent.

WGNE discussed the future directions in this area. It was felt that with more models extending to stratosphere, it was important that WGNE should continue its interest in this activity. The next phase in this study is to carry out a similar analysis for the northern hemisphere polar vortex and compare the stratospheric forecasting ability of these NWP models in the two hemispheres. The northern hemisphere target period has been selected as 15 Jan. - 15 Feb. 2000 and was chosen because of a developing planetary wave three in the lower stratosphere associated with tropospheric blocking, cold temperatures and a developing warming.

SPARC Data Assimilation Project (SPARC-DA)

The first SPARC-DA workshop took place in Catonsville, Maryland, USA, June 2002. NASA/Goddard Space Flight Centre Data Assimilation Office and the University of Maryland Baltimore County hosted the workshop. The results of the workshop were published in the SPARC Newsletter No. 19 in July 2002.

A SPARC DA working group has been established to:

(i) collect information on stratospheric data sets on meteorology and chemistry (quality, availability, software…);
(ii) undertake process-focused quality assessments;
(iii) collect and document information in DA systems and
(iv) liaise with space and other agencies on SPARC data needs.

In June 2003 SPARC organised two further meetings on stratospheric DA, an ASSET/SPARC workshop in Florence, Italy, and an ECMWF/SPARC workshop in ECMWF, UK. A report on the latter is available in the SPARC Newsletter No. 21. The main conclusions were as follows:

The issues requiring attention include: calibrate and retune the stratospheric background error covariances; encourage the use of non-assimilated (i.e. independent) observations; deal with systematic errors within the analysis; capture an accurate representation of the Brewer-Dobson circulation and mixing barriers, with the suggestion for future inclusion of longer-term tracer species; impose additional constraints upon the DA system, such as balance and conservation. The group recognised as particular weakness in the ECMWF the tides and the omission in the specification of explicit correlations among tracers and between the tracers and the dynamics in the error covariance.

The group emphasised the need for a robust system for meteorology and ozone DA, with AMSU being identified as a particular example of a stable, well-calibrated instrument with excellent time continuity and important for the stratosphere. Other instruments also provide good quality measurements, such as ozone column from GOME/SBUV/TOMS and ozone profiles from ENVISAT/AURA. Efforts should continue to evaluate the need for limb-viewing data and aircraft observations (e.g. MOZAIC). Radiosondes and remotely sensed winds should provide more comprehensive time and location information and humidity sensors need to be improved, along with the near real time aspects of ozone sondes and ground based data. In addition, aerosol measurements are required to support modelling, parameterization and chemistry/aerosol forecasts. A particular problem was the apparent lack of organisation and communication between the wide variety of research missions.

The group discussed the region and flow dependence of the background matrix and stressed the importance of choosing control variables and representations that facilitate the treatment of crucial regions, such as the upper troposphere/lower stratosphere (UT/LS) and shear zones, and the wider issue of stratospheric – tropospheric exchange. Strategies for incorporating constituent modelling/assimilation for both NWP and environmental monitoring should be considered. Real time observational operations should keep pace with the variety of measurements approaches and the new instrument developments.

Observing System Experiments/Observing System Simulation Experiments were suggested to assess remotely-sensed winds and humidity data in the UT/LS. The support for the ERA-40 project should continue and the 1990's should be used for validation of the Reanalyses. The group further suggested exploring the frequency and resolution of analyses and post-processed products and their external availability to chemical transport model users. The location of the upper boundary and its impacts to radiance assimilation and systematic errors were also discussed, along with the need to strengthen the association between SPARC modelling and DA activity.

3.6 Regional climate modelling

The Chairman of the WGNE/WGCM RCM panel, Professor R. Laprise, presented an overview of the regional climate modelling initiatives underway in Europe, USA and Canada. These included 'The Prediction of Regional scenarios and Uncertainties for Defining European Climate (PRUDENCE)' and 'Providing Regional Climates for Impacts Studies http://www.meto.gov.uk/research/hadleycentre/ (PRECIS)' in Europe, 'Climate-Change Science Program (CCSP)' in USA and 'Canada's Consortium OURANOS' and 'Big Brother Experiment (BBE)' in Canada. PRUDENCE activities that relate directly to WGNE and WGCM include the coordinated use of several climate models to assess, in a controlled manner, a number of numerical modelling uncertainties associated with climate-change projections. These include the use of several low resolution coupled GCMs (CGCM), atmosphere only GCMs (AGCM) and nested RCMs. AGCMs are usually run at medium resolutions, as time slices of high resolution uniform resolution models, or as variable resolution AGCMs. These models are driven with sea states based on recent climate analyses to which are added the climate change from CGCM simulations. RCMs are usually nested in AGCM simulated atmospheric states rather than CGCM atmospheric fields in order to reduce systematic biases. Professor Laprise reported on the highlights of the Workshop in Wengen, 29 Sep. - 3 Oct. 2003, which dealt with the sources of uncertainty over Europe using results from 20 model climate-change experiments.

The Hadley Centre has developed an RCM that can be run on a PC and can be applied easily to any area of the globe to generate detailed climate-change predictions. The intention is to make this modelling system (PRECIS), freely available to groups of developing countries so that they can develop climate-change scenarios at national centres of expertise. WGNE reiterated the need to provide the necessary information to users in order to avoid the indiscriminate use of such models.

Experimentation continues at the University of Quebec at Montreal (UQAM) following the so-called BBE perfect model protocol to assess the ability of nested regional climate models to reproduce with fidelity fine scales features. Earlier work using BBE focussed on the winter season over an eastern North American region where surface forcing is not dominant (Denis et al., 2002 and 2003). Further experiments have been carried out over a western North American region where there is a strong forcing exerted by orography (Antic et al., 2003), and for the summer season when surface processes exert a significant influence (Dimitrijevic et al., 2003). The overall conclusions of these perfect model experiments are as follows. One-way nested RCMs can simulate quite accurately climate in terms of both large and fine scale components of stationary and transient eddies, when driven by large-scale information in mid-latitude winter. The results are improved by the presence of strong surface orographic forcing. The RCMs' ability to reproduce accurately fine scale features is substantially reduced in summer, due to less effective large-scale control by lateral boundary nesting. Additional findings of these studies concern the acceptable jump in spatial resolution between the driving and nested models and the acceptable time interval for providing lateral boundary conditions. For a 45-km grid RCM, it appears that a maximum jump of 6 (or possibly 12) is acceptable, which corresponds to an equivalent GCM spectral resolution of T60 (or possibly T30). The maximum acceptable update interval of the lateral boundary conditions for the nesting of a 45-km grid RCM appears to be around 6 hours. It is noteworthy that the maximum acceptable values of resolution jump and boundary update interval are mutually dependent.

WGNE was briefed about the organisation of the joint WGNE/WGCM international Workshop, aiming at promoting better knowledge of the potential and limitations of RCM. The Workshop entitled “High-resolution climate modelling: Assessment, added value and applications” will be held in Lund, March 29 - April 2, 2004 (http://dvsun2.gkss.de/domino/html/Lund.nsf). The workshop is being held jointly with a meeting of the PRUDENCE Working Groups 1 and 2. The focus of the Workshop is on comparing the merits and limitations of various approaches to climate modelling at regional scale, including limited-area nested models, variable-resolution or stretched-grid global models, and uniform high-resolution global models. Contributions are invited on topics such as the role of resolution beyond physiographic details, and on the best strategy to achieve progress in regional-scale climate modelling. While the focus of the Workshop will be on climate time scales, some contributions on non-climate applications will also be considered, e.g. Numerical Weather Prediction (NWP), Seasonal to Inter-seasonal Prediction (SIP), and intermediate time scales (e.g. Project to Intercompare Regional Climate Scenarios (PIRCS)). The organising committee is composed of the following members: René Laprise (UQÀM; Chair), Lars Barring (Lund U.), Filippo Giorgi (ICTP; Lead co-author on Chap. 10 of IPCC TAR), Jens Hesselbjerg Christensen (DMI; Coordinator of PRUDENCE project), Richard Jones (the Met Office), Ben Kirtman (COLA; Member of WGSIP), Harry Lankreijer (Lund U.), Anders Lindroth (Lund U.), Markku Rummukainen (SMHI), Hans von Storch (GKSS), Werner Wergen (DWD; former member of WGNE).

WGNE was pleased with the progress towards the planning of the Workshop and stressed that the Workshop should air the concerns of WGNE including indiscriminate use of RCMs and the work of PRUDENCE bringing out errors and uncertainties in the approach.

3.7 Other climate-related modelling initiatives

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

Japan

Dr K. Saito reported on the Earth Simulator (ES) programme in Japan. This programme is conducted under the auspices of the Ministry of Education, Science & Technology of Japan (MEXT) with the collaboration of the Japan Marine Science Technology Centre (JAMSTEC) and the Earth Simulator Centre (ESC). Development of the ES programme started in 1997, and operation was started in February 2002. ES is a distributed memory, massively parallel vector computer, consisting of 640 processing nodes. The peak performance of each processing node is 64 Gflops, and total peak performance is 40 Tflops. Sustained performance of 35.8 Tflops was achieved in the LINPACK benchmark.

The ESC has been developing models for the earth simulator. These include an atmospheric GCM (AFES), ocean GCM (OFES), a flux coupler (CFES) and a sea-ice model (SIFES). Balancing among the micro-tasking, MPI and vector operations has been considered to optimize the models for the ES. The Frontier Research System for Global Changes (FRSGC) has been developing a non-hydrostatic icosahedral global model (NICAM). A 12-days integration with a grid spacing of 3.5 km has been performed. A stretched grid using Schmidt transform was implemented to perform a locally high-resolution simulation.

The Kyosei Project (Research Revolution 2002) has been started since April 2002. This is a research project organized by MEXT to use the ES. The project consists of three major missions, global warming, global water resource, common basic technology, and is divided into seven sub-missions. JMA has been participating in the Research Revolution Project since April 2002. This is aimed at the development of high-resolution climate models. In this project, the Meteorological Research Institute of JMA performs global warming experiments with a TL959 (20 km) AGCM for IPCC report and severe weather simulations with a 2-5 km non-hydrostatic model. A newly developed semi-Lagrangian version of GSM has been employed. A preliminary 1-year run with a resolution of TL959L60 was made, and a good correspondence of monthly rain between simulation and observation was obtained. Modification of physical process for high resolution run will be done to reduce overestimation of global mean precipitation in high resolution run. A non-hydrostatic regional climate model has been developed, using a spectral boundary coupling (SBC) method in the JMA non-hydrostatic model. So far, 70 days integration with 5 km resolution for 4000kmX3000km region was successfully conducted using regional analysis of JMA as the lateral boundary condition.

USA

Dr R. Petersen reported on the Earth Systems Modelling Framework (ESMF). NASA's Earth Science Technology Office proposed the creation of the ESMF in the September 2000 NASA Cooperative Agreement Notice, quoting "Increasing Interoperability and Performance of Grand Challenge Applications in the Earth, Space, Life and Microgravity Sciences". A large, interagency collaboration with roots in the Common Modelling Infrastructure Working Group proposed three interlinked projects to develop and deploy the ESMF, which were all funded: Part I - Core ESMF Development (PI: NCAR), Part II - Modelling Applications (PI: MIT), and Part III - Data Assimilation Applications (PI: NASA GMAO). Motivations for these efforts included climate research and NWP (increased emphasis on detailed representation of individual physical processes requires many teams of specialists to contribute components to an overall modelling system), computing technology (for increases in hardware and software complexity in high-performance computing, as we shift toward the use of scalable computing architectures) and software (for development of frameworks, such as FMS, GEMS, CCA and WRF, that encourage software reuse and interoperability).

The ESMF is proving to be a successfully focused community effort to coordinate the complexity of models and the computing environment. This has been accomplished by leveraging, unifying and extending existing software frameworks, and thereby creating new opportunities for scientific contribution and collaboration. The goal of the current ESMF projects is to increase software reuse, interoperability, ease of use, performance, and portability in climate, weather, and data assimilation applications. Efforts include both Model Core frameworks (software for coupling geophysical components and utilities for building components) and new applications (deployment of the ESMF in 15 of the nation's leading climate and weather models, as well as assembly of 8 new science-motivated applications and a toolkit that components use to increase interoperability, improve performance, portability and abstract common services.

ESMF has reached a level of maturity where other NWP centres are being invited to participate. To become an ESMF component, participants will need to pack model import and export data into ESMF data structures and conform to a standard calendar, use ESMF utilities internally as desired, and organize model using standard ESMF methods (Initialize, Run, Finalize, ReadRestart, WriteRestart). All of these aspects are well documented with examples available. Interested parties should see http://www.esmf.ucar.edu for additional details.

Europe

The European Network for Earth System Modelling (ENES) was set up as a think- tank to organize, plan and seek funding for efficient distributed Earth System Modelling in Europe. ENES has the long-term goal of achieving a distributed European facility for Earth System Modelling. Its first realization is PRISM, the Program for Integrated Earth System Modelling. PRISM is an infrastructure project and has 22 partners comprising of leading climate research institutes and computer vendors. The goals of PRISM are:

- to provide software infrastructure to
  - easily assemble earth system coupled models based on existing state-of-art European components models
  - launch/monitor complex/ensembles earth system simulations
  - access, analyse and share results across a wide community
- to define and promote technical and scientific standards for Earth System modelling.

More information is available at http://www.prism.enes.org/

4. DATA ASSIMILATION AND ANALYSIS

4.1 Reanalysis projects

ECMWF

Dr M. Miller reported on the ERA project. The ERA project was completed in April 2003: ERA-40 has provided analyses for a 45-year period from 1 September 1957 to 31 August 2002. A comprehensive set of 2.5°-grid single-level and pressure-level analysis or six-hour forecast fields from ERA-40 can be downloaded from the Centre's new data server http://data.ecmwf.intdata. This server also offers data from the DEMETER project and ERA-15. Data are downloadable in either GRIB or NetCDF data formats; plots of individual fields may also be produced and downloaded. A measure of the accuracy of analyses is provided by the skill of the medium-range forecasts run from them. It is seen that anomaly correlations of 500 hPa height as a function of forecast range for ERA-40 forecasts which span the period 1958 to 2001, for Europe (and also for other northern hemisphere regions) remain above 60% on average for well over five days for all years, indicating good synoptic accuracy of the analyses throughout the period. In contrast, forecasts for Australia/New Zealand are very much poorer prior to the major improvement to the observing system that was introduced for the Global Weather Experiment in 1979. The ERA-40 analyses for the southern hemisphere before 1979 must be used with more caution than either their counterparts for the northern hemisphere or the later analyses for the southern hemisphere. Basic global-mean temperature trends and low frequency variability are captured well over much of the troposphere and lower stratosphere. ERA-40 analyses reproduce both the well-documented warming that has occurred at the surface since the mid 1970s, which is especially marked over land, and the cooling that has occurred in the lower stratosphere. Interannual variability in the lower stratospheric analyses is stronger in ERA-40 than ERA-15, and more in accord with observations. The warm periods following the volcanic eruptions of Agung in 1963, El Chichon in 1982 and Pinatubo in 1991 are also clearly seen. Compared with estimates from the Global Precipitation Climate Project (GPCP) for 1979 onwards, ERA-40 precipitation is substantially too large only in the tropics, especially over the oceans. Patterns of precipitation appear realistic, but rainfall amounts in precipitating tropical oceanic areas are much higher than GPCP values, and the discrepancy is larger than can be ascribed to uncertainties in the GPCP estimates. ERA-40 precipitation is in much better agreement with GPCP in the extratropics, not only with respect to the climatological means but also with respect to the interannual variability of monthly totals.

Current activities include preparation of documentation (including production of an atlas jointly with the University of Reading), observation related studies and reprocessing, diagnosis of analysis, completion and diagnosis of twice-daily 10-day forecasts, and diagnosis of an " AMIP-style" run using ERA-40 model.

NCEP

Dr R. Petersen reviewed the status of the reanalysis activities at NCEP. NCEP has made major progress on the North American Regional Reanalysis (NARR) in an effort to create a long-term set of consistent climate data on a regional scale. The system builds upon and enhances the previous Global Reanalysis (GR) on North American domain by using a higher resolution regional model (the Eta model) combined with a fully tested set of modelling and data assimilation improvements implemented since 1995, including precipitation assimilation, direct assimilation of radiances and highly improved land-surface models. The system uses a fully cycled 3-hr Eta Data Assimilation System (EDAS) with lateral boundary conditions supplied by Global Reanalysis 2. In addition to the analyses, 72 hr forecasts will be made every 2.5 days, using GR2 forecast boundary conditions. Although pilot tests were made at 80-km, 38 layer resolution, production runs are being made using a 32-km, 45 layers configuration. The full NARR time period from 1979 to 2003 is expected to be completed before mid-2004 and will be continued later in near-real time, as in CDAS. Data sets will be available from NCEP and NCAR.

As with the GR, all available data sets were used in the reanalysis effort. Overall, the reduction in the data time-window improved the analysis results and first guess fields. The inclusion of 2-m surface temperatures over land, however, proved detrimental in that the vertical extension of the 2-m errors upward increased temperature errors at 850 and 700 hPa and affected winds into the middle and upper troposphere. As such, the surface temperature reports not associated with radiosonde reports were excluded from the system.

Initial results showed that when both the GR and NARR are fitted to radiosonde data, the root-mean-square (RMS) analysis fits are significantly better for temperatures and vector wind speeds for NARR, with wind speed improvement in the NARR being greatest in the upper troposphere, especially in winter. Although the first guess (3-hr forecast, pre-3DVAR) temperatures are not always as favourable for NARR compared to GR, winds and relative humidity improved for RR for both analysis and first guess. Near the surface, first guess fields from pilot analyses made for 1997 show surface temperature RMS improvements both in winter and in summer. For the year 1998, surface temperatures RMS were again favourable in both winter and summer, with NARR biases closer to zero and with little diurnal variation problem in summer. The 10-m winds from the NARR improved over the GR greatly in winter and slightly in summer, with slow wind biases noted in the GR improved in RR. The NARR also uses precipitation observations to prescribe the latent heat profile in Eta model, which then uses that latent heat profile to simulate precipitation. Results match observed patterns much more closely both in summer and winter. Comparison of drought and flood years illustrated the impact of summer precipitation observation data and the robustness of the system in extreme events.

Future goals include producing a sample DVD to be distributed with a BAMS article, creating the R-CDAS system to be used for operations, transition to continuing execution within NCEP operational computing environment, and hosting a Users' Workshop in 2004. Additional information is available at http://wwwt.emc.ncep.noaa.gov/mmb/rreanl.

Japan Meteorological Agency (JMA)

Dr K. Saito reported on the progress of the Japanese 25-year Reanalysis Project (JRA-25). This is a five-year joint project of JMA and the Central Research Institute of the Electric Power Industry (CRIEP) to produce a 25-year reanalysis. JMA provides a data assimilation system and CRIEP offers the computer resources. Objective of JRA-25 is to produce a comprehensive analysis data set from the JMA data assimilation system for 1979-2004, for advanced operational climate monitoring services at JMA and for various activities in climate system and global warming studies. The analysis cycle will be continued after JRA-25. The assimilation system consists of the T106L40 version of GSM and a 3D-Var assimilation system. Land surface analysis is implemented, and COBE SST and sea-ice data set, daily 3D ozone profiles are employed. As well as data archived at JMA from 1975 to the present, the ERA-40 observation data set including NCEP/NCAR data used in the ERA-40 are assimilated. A range of satellite observations (TOVS level 1c data, reprocessed GMS and METEOSAT cloud motion wind, and SSM/I) and wind retrieval data around historical tropical cyclones provided by Dr Fiorino of PCMDI/LLNL are assimilated as well. As a new observation, Chinese snow depth observation digitised by MRI have been added. Comparison of experimental results with the NCEP Reanalysis and ERA-40 shows good performance of JRA-25 in snow coverage and 100 hPa temperature fields. Analyzed data are available on the web site of JRA-25 (http://www.jreap.org/indexe.html).

WGNE was very pleased to note the successful completion of the ERA project and making ERA data available in the public domain. WGNE, through the Chairman, would express its gratitude to the Director, ECMWF for this action. WGNE reiterated its strong support to the reanalysis efforts and reiterated the desirability of setting up a dedicated 'Reanalysis Centre' at a major NWP operational centre. WGNE recommended that the concept should be built into the new initiative 'COPE' and that it should be part of the modelling council. WGNE urged that the JSC should work towards securing funding for setting up such a 'Reanalysis centre.'

4.2 Observing system and observation impact studies

Dr A. Lorenc summarized a report from Dr P. Menzel, Chairman of the CBS Expert Team on Observational Data Requirements and Redesign of the Global Observing System. This has been meeting since 1999 and has several achievements: systematic studies of users requirements and observing system capabilities, organisation of Observing System Experiments, studies of candidate observing systems, recommendations for the evolution of the Global Observing System, and a vision for the GOS of 2015 and beyond.

Dr A. Lorenc also summarized the WCRP Satellite Working Group Report on "Update of Space Mission Requirements for WCRP" by G. Duchossois and G. Sommeria (January 2003). Space observations from the current and planned missions will offer an unprecedented potential for climate research provided joint coordinated efforts are made between WCRP and Space Agencies to turn the separate sensor/satellite data into globally integrated products for climate research. This potential will be further enhanced with the approval of new priority space missions as recommended by the Working Group.

Dr A. Lorenc reported on a very successful Symposium in memory of Roger Daley, held in Montreal Canada in September 2003. Invited lectures were selected to span Roger's areas of interest, covering developments since his 1991 book. There were also some excellent submitted papers, covering a wide range of applications of assimilation.

WGNE was also briefed about the plans for the Fourth WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography in 2005.

4.3 Co-ordinated Enhanced Observing Period (CEOP)

The status of the planning and steps towards implementation of the GEWEX Co-ordinated Enhanced Observing Period (CEOP) were reviewed. To aid in the development of various hydroclimatological datasets, CEOP has requested the WGNE community to provide comprehensive gridded output from global data assimilation systems. This requested output includes not only standard meteorological output but also output allowing study and analysis of water and energy processes in the atmosphere and land surface. In particular, detailed Model Output Location Time Series (MOLTS) have been requested at 41 international locations, where there are extensive in situ measurements and where extensive satellite products are being developed. This small data set will be complemented by more comprehensive 3 dimensional globally gridded data. Minimum output will include analysis variables, every 6 hours, as well as variables every 3 hours from a 6 hour forecast made every 6 hours as part of the analysis cycle. Every day at 1200 UTC, a corresponding 36 hour forecast is also requested, since this will provide some measure of how the models are adjusting (spinning up) to the initial state. This model output data should be sent to MPI, which is developing a comprehensive model output archive. NWP Centres are only being asked for comprehensive analysis and forecast output for the period July 1, 2001 - December 31, 2004.

In his presentation, Dr J. Roads noted that CEOP had made substantial progress since the last WGNE meeting. WGNE has previously stated that the model output data would be useful because:

(1) CEOP brings atmospheric and land model fluxes together with observations, and potentially this would be an important combination if good contact points can be made with each of the field experiments; experience has shown real progress can be achieved when the field scientist works closely with the modeller (and vice-versa);
(2) if there is a central archive of CEOP reference data, which is readily available and an easy to read format then NWP centres could make good use of it.

Dr Roads observed that besides helping to document water and energy processes during CEOP, there are a number of reasons why this output will be useful: for example, there have previously been a number of extensive model intercomparisons (AMIP, CMIP, SMIP, PIRCS, PILPS) that have revealed systematic errors in models. By contrast there has not been any systematic comparison made for analyses. It is not known what the error in comparison to observations is as well as what the differences in the modelled hydroclimatological processes are between various models. Given its focus on high-resolution temporal sampling of a comprehensive number of hydrometeorological processes and variables from observations and NWP analyses, CEOP is well positioned to begin to coordinate efforts with modelling groups on observing and modelling the global hydrologic cycle on diurnal to seasonal time scales. Understanding and improving current model deficiencies of various hydrometeorological processes should aid in efforts to improve model simulations and predictions on longer times scales.

Dr K. Saito commented on the progress of CEOP in Japan. JMA started to provide GRIB formatted MOLTS Data to the Max Plank Institute (MPI) data archive center in May 2003. A special data server has been set up at JMA to receive archived data from MPI. JMA MOLTS data over Siberia and Amazon have been compared with observations in EOP1 (Jul.-Sep. 2001). Diurnal changes of radiation budget and heat transports were generally good, but the maximum temperature tends to be under predicted. A new cooperative research program has been started between the University of Tokyo and JMA relating to CEOP. In this project, JMA will provide an operational global land surface model and the University of Tokyo will develop a new satellite data assimilation system for land processes.

5. NUMERICAL WEATHER PREDICTION TOPICS

5.1 Short- and medium-range weather prediction

The World Weather Research Programme

THORPEX: A Global Atmospheric Research Programme

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

The core research objectives of THORPEX are to:

- Contribute to the design and demonstration of interactive forecast systems that allow information to flow interactively between forecast users, numerical forecast models, data-assimilation systems and observations. Interactive forecast systems include the concept of targeted observations.
- Advance the knowledge of global-to-regional influences on the initiation, evolution, and predictability of high-impact weather.
- Collaborate with numerical forecast centres in the development of advanced data-assimilation and forecast model systems. Research will include:
  - i) improving the assimilation of existing and experimental observations, including observations of physical processes and atmospheric composition;

ii) developing adaptive data-assimilation and targeted-observing strategies;
iii) incorporating model uncertainty into data-assimilation systems and in the design of ensembles.

- Develop and apply new methods to enhance the utility of improved weather forecasts. This research will identify and assess the societal/economic costs and benefits of THORPEX recommendations for implementing interactive forecast systems and improvements in the global observing system.
- Perform THORPEX Observing-System Tests (TOSTs) and THORPEX Regional field Campaigns (TReCs).
- Demonstrate the full potential of THORPEX research results for improving operational forecasts of high-impact weather on time-scales out to two weeks.

At the WGNE session, Professor A. Thorpe (Co-Chair, ISSC) and Dr M. Beland (Chair, ICSC) made presentations on THORPEX. WGNE was informed of the THORPEX response to last year's resolution and an update on THORPEX developments over the year. The updated International Science Plan was also presented and discussed. WGNE reiterated its support for THORPEX as a collaborative WWRP/WGNE experiment. A draft of the joint WWRP/WGNE THORPEX Resolution was discussed. The draft joint Resolution, in accepting the Science Plan, commends the co-Chairs of the ISSC at the steady progress made in the past year and views the development of a succinct and visionary THORPEX Science Plan as a positive step forward. It further notes and approves THORPEX's aspiration to become a Global Atmospheric Research Programme, encompassing a wide range of research to accelerate improvements in the accuracy of 1 to 14-day high-impact weather forecasts for the benefit of society and the economy, and that the possibility of renaming THORPEX to make this aspiration clear should be explored. The Resolution notes that the stage has now been reached where a detailed THORPEX Implementation Plan needs to be developed to set up procedures for selection of projects and experiments to be managed within the THORPEX programme, and establish linkages to enable input from THORPEX into existing programmes and structures.

Dr R. Petersen reported on NOAA's participation in THORPEX. NOAA's THORPEX objectives are to develop new forecast procedures which will improve operational NWP forecasts and/or adapt cost/benefit tools which can measure resulting societal impact. NOAA would consider the THORPEX program successful if the newly developed cost/benefit analysis tools indicate that the forecast improvements due to the new THORPEX procedures can be achieved operationally in a cost-effective manner. THORPEX fills the critical gap between NOAA's short-range weather and climate programmes. Although existing programs are aimed at the short-range forecast problem, and seasonal and climate forecast problem (CLIVAR, GAPP, etc.), the NOAA service improvement plan requires rapid improvements in intermediate periods to facilitate issuance of skilful 3-7 day precipitation forecasts and 8-14 day daily weather forecasts.

Dr Chen Dehui briefed WGNE about the developments in the Asian THORPEX. At the first meeting of the THORPEX International Core Steering Committee (ICSC) held in Oslo, Norway in October 2002, representatives from Asian countries (China, India, Japan, Republic of Korea and Russia) reached an agreement that they, together with USA, will establish the Asian THORPEX community with which they will collaborate to promote THORPEX aims by targeting the high impact weather events in Asia. A planning meeting of the Asian THORPEX community was held in February 2003 at the Japan Meteorological Agency to discuss research targets and possibility of international collaboration.

Model Verification

There are 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 models attaining increasing resolutions there is urgent need to move forward from the gross validation methods that have been used so far. Accordingly, WGNE has prepared a position paper on verification (see " The WGNE survey of verification methods for numerical prediction of weather elements and severe weather events", by Dr P. Bougeault, CAS/JSC WGNE Report No. 18, Appendix C, WMO/TD-NO. 1173,2003).

Verification is of considerable importance for both WGNE and WWRP projects. It has therefore been decided to form a joint Working Group (JWG) on verification. It was recognised that a joint working group will be valuable to coordinate efforts and share ideas and results, and that the JWG will allow the formation of unified approaches to solve common verification problems. Proposed members of the JWG are: B. Brown (chair; NCAR), F. Atger (Météo-France), H. Brooks (NSSL), B. Casati (U. Reading), U. Damrath (DWD), B. Ebert (BMRC), A. Ghelli (ECMWF), G. Greed (UKMO), P. Nurmi (FMI), D. Stephenson (U. Reading), and L. Wilson (MSC).

The JWG has identified a number of specific goals, including the following:

- Encourage greater cooperation between users and verifiers of forecasts to ensure the relevance and integrity of the practice of forecast verification; this includes development of useful, meaningful and statistically sound verification measures, as well as working with both forecast users and developers;
- Encourage the development and application of improved diagnostic verification methods to assess and enable the improvement of the quality of weather forecasts, including forecasts of weather elements and forecasts from numerical weather prediction and climate models; some of the issues that are of concern include partitioning error according to scale, verification of forecasts of probability distributions, spatial forecast verification, assessing uncertainty in verification statistics, and the use and processing of high resolution remotely sensed observation data for verification;
- Encourage the sharing of observational data for verification purposes;
- Encourage greater awareness in the research community of the importance of verification as a vital part of numerical and field experiments; and
- Encourage collaboration among scientists conducting research on various aspects of forecast verification, and with model developers and forecast providers.

WGNE welcomed Dr B. Brown, Chair, JWG on Verification who made a presentation on the proposed JWG. WGNE formally approved the formation of the JWG and suggested that Dr Bougeault's review paper on Verification could serve as a good starting point for the JWG as most of the points of interest are contained there. WGNE pointed out that ensemble prediction verification is of great interest to the scientific community and should be included in the JWG's plans.

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. At all time ranges, the advance in skill of ECMWF forecasts was outstanding. 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 capability of using 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 beneficial.

Intercomparison of typhoon track forecasts

Dr K. Saito reported on the Intercomparison of Tropical Cyclone (TC) Track Forecasts for 2002. This model intercomparison was started in 1991 for the western North Pacific area with the participation of ECMWF, UKMO and JMA. In 1994, the Canadian Meteorological Center (CMC) joined the project. In 1999, the verification area was extended to cover the northern Atlantic area. In 2000, the Deutscher Wetterdienst (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.

NWP centres which participated in the intercomparison for 2002 are ECMWF, UKMO, DWD, CMC 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 NOAA are used for North Atlantic and Eastern North Pacific regions, while Joint Typhoon Warning Center (JTWC) data was used for Southern Hemisphere and Northern Indian Ocean, and Regional Specialized Meteorological Centre (RSMC) Honolulu, for Central Pacific area.

In the mean positional errors of the 72 hours forecast, ECMWF shows the best performance in the North Atlantic area and the Southern Hemisphere. JMA shows the best performance in the western and eastern North Pacific areas. Southwestward mean bias errors are commonly seen in forecasts of all centres after the recurvature, while northerly position biases are seen in the low latitude tropics. In case of 120 hours forecast, ECMWF shows the best performance in almost all comparison areas.

Figure 1.

Figure 2.

A multi-model ensemble forecast was verified using the TC track forecasts of the three forecast centers (ECMWF, UKMO and JMA) for the western North Pacific region. After 1996, the ensemble mean forecast demonstrates the best performance among the all forecasts for all forecast times from 24h to 96h. This result shows the validity of the multi-model ensemble forecast for TC tracking. Similar results for TC track prediction have been obtained from a multi-model ensemble study being conducted at the Naval Research Laboratory (J. Goerss).

Dr R. Petersen reported on activities in this area at NCEP. NCEP has made a number of upgrades to its forecast and assimilation systems during the past several years which have led to significant improvement in hurricane track forecasts. In June 2000, revisions were made to the hurricane relocation system to make it consistent with the GFDL technique and an improved tracking algorithm was implemented. Then, in May 2001, a major upgrade to NCEP GFS physics substantially reduced previously noted spurious vortices. In addition, the assimilation system was expanded to include SSM/I precipitation observations. The combined changes resulted in major improvement relative both to previous NCEP models (~30% improvement in the Atlantic basin for all periods out to 72 hours and 25% to 55% improvements in 12 to 72 hour forecasts respectively in the eastern Pacific basin) and to other global models. Significantly, the combined effects of improved physics and SSM-I precipitation assimilation indicate some apparent skill in forecasting cyclogenesis.

The intercomparison project has shown quite clearly the significant advances in TC track prediction by operational global models in the past decade. With models moving to higher resolutions and improvements in data assimilation and physical parametrisations it was felt that time is right to study the TC intensity problem. As a start WGNE recommended that the activity be extended to include the study of intensity of TCs starting in central and west Pacific.

Verification and intercomparison of precipitation forecasts

As a principal 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 important activity. Accordingly this WGNE project has expanded significantly and the CMA, JMA, Met Office and Météo-France have also started verifying precipitation forecasts in their regions.

Dr K. Puri reported on the quantitative precipitation forecast (QPF) verification over Australia. Operational 24h and 48h QPF of 24h rainfall accumulations from the Australian Bureau of Meteorology, CMC, DWD, ECMWF, JMA, the Met Office, and NCEP are verified over Australia. The verification data comes from the Bureau's operational daily rainfall analysis (at 0.25° resolution) of 24h 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 verification focuses on a limited number of statistics, namely the frequency bias, the equitable threat score (ETS) for rain thresholds of 1 mm d^{-1} and 20 mm d^{-1}, and the location error of the forecast rain system determined by CRA (contiguous rain area) verification (Ebert and McBride, *J. Hydrology*, 2000). Results are computed separately for a tropical region (equatorward of 20°S) and a mid-latitude region (poleward and eastward of 25S, 135E). In the tropics the models achieved the best scores during the autumn months (MAM), with bias values near unity and ETS ranging between 0.3 and 0.4 for a 1 mm d^{-1} threshold. The models performed poorly in winter (ETS ~ 0.2), but this is partly because tropical rainfall is rare in winter. 24h and 48h forecasts performed similarly. The ETS of the persistence forecast is similar to that of the models in all seasons, leading us to conclude that the models add little value where tropical rain is concerned. A notable exception is for tropical cyclones, where the models are clearly able to simulate the larger scale systems. The models are more accurate in predicting mid-latitude rainfall, with bias for rain exceeding 1 mm d^{-1} of about one, and ETS values of 0.3-0.5 in summer and 0.4-0.6 in winter (far outperforming persistence). For rain exceeding 20 mm d^{-1} most models were biased low, with correspondingly lower ETS scores, 0.1-0.4 (but still better than persistence). The ensemble mean provided a more accurate forecast for moderate rain thresholds, 2-20 mm d^{-1}. Typical location errors for the model forecast rain systems were on the order of 100 km. QPF verification has been ongoing in Australia since 1997. After seven years it is difficult to spot any time trend in the performance of the models, relative to persistence (although there may be a slight positive trend for NCEP QPFs in mid-latitudes – the statistical significance needs to be tested).

Dr D. Majewski reported on the "Schwerpunktprogramm" SPP1167 financed by the DFG (Deutsche Forschungsgemeinschaft) during the period 2004 – 2009 which is expected to accelerate research and development in the field of QPF. The SPP1167 aims to:

- Identify the physical and chemical processes mainly responsible for current deficiencies in QPF,
- Determine and explore the potentials of existing and new datasets and process descriptions to improve QPF,
- Determine the predictability by statistical-dynamical analysis of QPF.

A copy of the operational NWP system of the DWD will be extensively used by scientists during SPP1167 as a numerical test-bed of advanced data assimilation and modelling suites. More information on SPP1167 is available at http://www.meteo.uni-bonn.de/projekte/SPPMeteo.

Dr R. Petersen reported on NCEP's precipitation verification studies. These focused on 24-48 hour accumulated precipitation biases and equitable threat scores over the contiguous US for the period from October 2002 through September 2003. Global model comparisons were made between NCEP GFS, ECMWK, UKMET and DWD. The results showed that:

1) ECMWF and UKMET have higher rain/no rain skill,
2) UKMET has higher skill for heavier rainfalls,
3) ECMWF had corrected the previous problem in high bias for heavier rain events and
4) NCEP has a high bias across all precipitation amounts.

A second set of comparisons were shown between the US and Canadian models, including both global and regional (mesoscale) forecast systems. These results showed that:

1) mesoscale models outperform global models in determining rain/no rain,
2) for high precipitation amounts, the GFS and CMC mesoscale model have high biases, while the Eta and CMC global models are biased low, and
3) the CMC global model has little skill in differentiating rain/no rain.

Dr K. Saito reported on the intercomparison of precipitation forecasts over Japan. Precipitation forecasts from five NWP centres (BoM, DWD, NCEP, UKMO and JMA) obtained via ftp are compared. Verification area is the land area of Japan, and the size of verification grid is 80 km^2. Reference data is surface rain-gage observation of rainfall by AMeDAS, JMA's unmanned surface observation network with horizontal resolution of (17 km^2). The verification period is from August 2002 to September 2003. In summer (June - August 2003), the bias scores for 48h to 72h forecasts from BoM and DWD tend to decrease for intense rain. In summer of 2002, similar tendency was seen in the JMA model, but this small bias tendency for intense rain was ameliorated in 2003 by the revision of the Arakawa-Schubert scheme of GSM implemented in May 2003. In winter (December 2002 – February 2003), the bias scores of DWD and JMA tend to decrease for intense rain, while the bias scores of BoM and NCEP are large for weak rain. Verification results for 6-hour precipitation forecasts show that most models except UKMO tend to overestimate rain in daytime in summer. No significant diurnal changes of bias scores are seen in winter.

Dr Chen Dehui reported on QPF intercomparison over China. The operational global models of JMA, DWD and CMA were used for the summer of 2003 (June, July and August). Five thresholds were used for the verification: R>0.1mm, R>10mm, R>25mm, R>50mm and R> 100mm. Since the beginning of 2003, precipitation forecasts by the global models of JMA, DWD and CMA are available for use in weather forecast office of NMC/CMA. It was seen that threat score (TS) decreased with forecast time; the three models have similar TS for >0.1mm threshold; the JMA model gives better results in general; the DWD model gives better results for higher threshold (>50mm); and forecasts are not skilful for the highest threshold (>100mm).

Performance of models in high latitudes

Dr Kattsov informed WGNE on the ongoing international activity in the field of high-latitude climate modelling, in particular, on the findings of the Arctic Climate Impact Assessment (http://www.acia.uaf.edu) related to systematic errors in simulations of the Arctic atmosphere by global models used in projections of future climate change. He also informed on preliminary steps towards creating Arctic System Reanalysis (ASR) – a regional reanalysis, whose atmospheric component would provide fields for which direct observations in the Arctic are sparse or problematic, at higher spatial and temporal resolution, and with greater reliability, than from existing reanalyses. The groundwork for an Arctic regional reanalysis can now be performed by capitalizing upon ongoing efforts such as ERA-40 and NCEP's North American Regional Reanalysis (NARR), as well as recently compiled Polar Pathfinder products from satellites.

Review on status of mesoscale numerical weather prediction

Dr J. Côté reviewed the recent developments/activities in mesoscale NWP. A number of international workshops relating to mesoscale modelling were held in the past year which covered a wide range of topics. The international workshop on NWP Models for Heavy Precipitation in Asia and Pacific Areas in Tokyo (Japan) had sessions on: NWP systems, numerical models, basic studies, data assimilation for heavy rain, variational methods, global models and the Earth Simulator, general discussion for heavy rain prediction and THORPEX. The joint International Conference on Alpine Meterorology and Mesoscale Alpine Program (MAP) Conference in Brig (Switzerland) had sessions on: orographic precipitation, the VERTIKATOR project, planetary boundary layer, observational means and techniques, operational aspects, MAP, mountain hydrology, societal impacts, rotor dynamics, gravity waves, gap winds and flohn, synoptic-scale aspects, mountain climates, snow and glaciers. All MAP data are now freely available from the MAP Data Center. The MAP working group on numerical methods is active and an intercomparison of numerical models on IOP2 is taking place. The future MAP Forecast Demonstration Project will aim to show the progress of operational NWP following MAP and the impact on end-users such as hydrological authorities. The next experiment in mountain meteorology will be the "Terrain-induced Rotor Experiment" (T-REX). It will be devoted to mountain-wave induced rotors causing low- and upper-level turbulence in airflow over complex terrain. The 10th Conference on Mesoscale Processes in Portland (USA) had sessions on: predictability, numerical models, balance and gravity waves and circulations. The keynote address stressed the need for rational network of observations and for vertical resolution for water vapour from satellites and noted that convection is resolved only at O(100 m) while mesoscale cellular convections (MCCs) still remain largely unknown.

Dr Côté listed a number of recent publications and current research activities. Stability of iterative approaches for 2 time-level schemes for non-hydrostatic models have been studied by Bénard. Bryan et al have noted that scales less than 6-delta x in models are deficient and should not be relied on. Vigh et al show that ensemble tropical cyclone forecasting costs less for similar accuracy than deterministic ones. It is important to insure numerical consistency of metric terms in z terrain-following coordinates (Klemp et al). Zaengl has attempted to alleviate disadvantages of the s-coordinate by adapting Schaer hybrid coordinate. The transparent lateral boundary conditions are shown to be better than the usual Davies-Kallberg relaxation scheme by McDonald. Marbais et al are trying to optimize relaxation in regional climate models. Vannitsem shows that the error growth in limited area-models is compatible with that of global model provided that the domain is large enough. Flux form semi-Lagrangian advection schemes are presented by Peng et al and Hubbard et al. Satoh presents a conservative scheme for moist processes in a non-hydrostatic model. A special issue of the QJRMS has been dedicated to MAP while Monthly Weather Review had one devoted to Antarctica.

As a conclusion it was noted that: old methods are being revisited; short-range ensembles are now more widespread; double counting in physical parametrization at short-scale is becoming an issue; boundary effects in one-way nesting are still being studied; the real physical resolution is coarser than the grid resolution; conservation in the semi-Lagrangian method is necessary for climate simulations; vertical structure in models continues to be an active research topic.

High-resolution modeling at Deutscher Wetterdienst (Dr D. Majewski)

During the cold season the spatial distribution of precipitation in mountainous regions simulated by the non-hydrostatic Local Model (LM) of the DWD shows characteristic errors: There is too much precipitation on the upwind side of the mountain, the maximum values are overestimated and shifted into the upwind direction, and there is a distinct underestimation in the lee of the mountain. For the case study of 20 February 2002 a detailed evaluation revealed that the neglect of advection of the hydrometeors (especially snow) was the main cause of this erroneous spatial distribution in southwest Germany. The strong westerly wind (between 25 to 30 m/s) at 500 hPa transported the snow particles which were generated due to the upward motion west of the Black Forest Mountains more than 70 km eastward. In the operational version of the LM this horizontal drift is neglected and all precipitation generated in a column is assumed to reach the ground within one model time step. Numerical experiments with LM at mesh sizes of 28, 14 and 7 km showed that the erroneous spatial distribution is very similar at all resolutions but the amplitude (overestimation on the upwind side, underestimation in the lee of the mountain) increased with decreasing mesh size. Including the horizontal (and vertical) advection of precipitation particles in an experimental 2-time-level version of the LM greatly improved the spatial distribution of precipitation at the ground. More than 15 case studies of strong wintertime precipitation events in this region resulted in similar improvements. Thus the prognostic treatment of precipitation (especially snow) seems to be essential at mesh sizes below 30 to 40 km.

The increasing use of high-resolution mesoscale models operationally and in research raises a number of important issues related to the adequacy of physical parametrisations, model numerics and data assimilation at these scales. WGNE suggested that these important issues should be included as a discussion item in future WGNE sessions.

5.2 Ensemble prediction

Dr A. Lorenc reported on test of a 'Poorman's Ensemble Prediction System' (PEPS) for short-range probability forecasting by A. Arribas, K.B. Robertson and K.R. Mylne (since submitted to the Monthly Weather Review). Despite a smaller ensemble (10 versus 50), the PEPS gave better results than ECMWFs EPS at short-range. A hybrid ensemble (using the ECMEF EPS) is the best approach for most variables and regions. Model error has an important role, even at short-range.

Dr K. Saito reported on the application of EPS to typhoon centre track forecasts. Following an EPS meeting held at Geneva in October 2003, JMA is preparing an ftp site for exchange of EPS data and a web site for display of verification results on trial basis.

Dr Chen Dehui reported on the developments at NMC/CMA. The multi-model ensemble techniques are not yet tested at NMC/CMA. But, JMA, KMA and CMA have launched a trilateral collaboration for the East-Asia seasonal climate prediction. One of the aspects of collaboration is to develop the multi-ensemble prediction based on their own climate models.

WGNE looked forward to the joint WGNE/WGCM/WGSIP Workshop on 'Ensemble Methods' in October 2004 in Exeter following the WGNE session. The Group agreed that WGNE should actively consider concrete proposals for possible EPS-related activities.

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

Further to the information on progress in ensemble prediction systems presented in section 5.2, reports were given by participants in the session from the main operational forecasting centres on recent developments/extensions/improvements in systems. As usual, constructive discussions on problems of mutual interest took place. A summary of the status 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 Table 1.

ECMWF (Dr M. Miller)

The main advances in the Centre's forecasting systems have been the implementation of cycle 25r4 on 14 January 2003, the migration of all systems to the IBM machine, and the beginning of the Experimental suite (E-suite) testing of cycle 26r3 at the end of June. Cycle 25r4 featured several major changes. The 4D-VAR algorithm was extensively revised. Additional satellite data include: GOES WV radiances, MODIS winds, more HIRS channels and SAR ocean-wave data. SSM/I radiances are now assimilated directly. The model changes comprise two main components: an extensive revision of the cloud-scheme numerics and a substantial change to the convection scheme. Convective clouds are now allowed to form from any level below 700 hPa. This change greatly improved the analysis and 24h forecasts over North America, and the medium-range forecasts over the Atlantic and Europe. Overall cycle 25r4 resulted in a major improvement of the forecasts scores.

The Centre's operational systems were successfully migrated to the IBM machine. Optimization on the IBM machine is continuing with a strong constraint that all changes remain fully compatible with vector processors.

A major change to the observation handling system was implemented operationally on 29 April 2003. The new system, called BUFR2ODB, will allow substantially more satellite data to be supplied to the 4D-VAR. It has a multi-level parallelism and will also facilitate OSEs by giving quicker access to large sub-ensembles of data.

The E-suite of cycle 26r3 was progressing quickly and satisfactorily. It is expected that by the end of the summer, 7 months of parallel running will be available and a decision regarding operational implementation can be confirmed. Research is progressing with major efforts in the following areas: assimilation of rain and cloud affected radiances, development of observation operators for limb-observing satellite instruments, rationalization of the observation operators for the nadir-observing sounders, calibration/validation of ENVISAT instruments, improvement of the PBL and convection schemes, preparations for the upcoming model resolution increase, moist singular vectors for the EPS, test of the OPA ocean model, implementation of the multi-model seasonal forecasting system, development and test of an approach for forecasting freak waves. In the real-time seasonal forecasting system, System-2 (S2) is operational and the products are now made available from 12z on the 15th of the month. With the shutdown of the Fujitsu VPP5000 at the end of March System-1 (S1) came to an end. The forecasts for Niño 3.4 have generally been good for the recent El Niño. Not all forecasts have verified quite so well as Niño 3.4: Niño 4 forecasts tended to underestimate the continued warm conditions in the central west equatorial Pacific. S2 does not perform as well in the Niño 4 region as did S1. Although S1 is dead, we expect to have real-time multi-model forecasts available shortly which should help to partly offset this.

A comprehensive User's Guide has been prepared on seasonal forecasting and is available on the web. An extensive comparison of S1 and S2 has been made and results are further compared with hindcasts using observed SSTs. A technical report covering these results is also available on the web. Substantial systematic errors in the coupled system are shown to be of atmospheric origin and not a result of coupling.

S2 has an improved set of products available on the web, plus further real-time products which are available for research. Plots on the web include probabilities of tercile and 15%-ile categories. The tropical Pacific plumes are now available for Niño 3.4 and Niño 4, in addition to Niño 3. A full 40-member ensemble has been run for the 15 years from 1987 for both November and May initial conditions. The 40-member ensemble size allows a useable, though far from perfect, sampling accuracy of these probabilities. A slightly enhanced set of ocean analysis products is also available: for example meridional sections in the Pacific and Atlantic oceans.

Performance scores of S2 are now available on the web, based on the hind casts for the period 1987-2001. The 40 member ensembles are used where available (May and November starts); otherwise 5 member ensembles are used. Statistics include tercile ROC scores (maps and curves), mean square skill scores, anomaly correlations, biases and statistics for certain indices. Many of the scores are based on emerging WMO recommendations, and we are grateful to MetOps, who have done most of the work in creating these scores. Comparable information from S1 is also shown, although for a shorter verification period.

One parameter which is now plotted routinely is forecast soil moisture. Although this is a quantity of great interest, and although there are areas where the forecasts appear to be of reasonable quality, it is clear that in certain areas the forecasts are badly biased. This is because of changes in the soil moisture model and analysis scheme introduced operationally in 2000; the soil moisture initial conditions in some areas are systematically very different between the real time forecasts and most of the back integrations. This problem will be substantially reduced in future systems which will use the ERA-40 initial conditions, but the importance (and possible difficulty) of maintaining compatible real-time and historic soil moisture analyses is an issue which we will need to keep in mind.

The Met Office seasonal forecast model was ported to the IBM. The forecasting system has been running well in research mode for some time, and following some changes related to ensemble spread, is expected to become operational in the next few months. It is run in a mode very closely paralleling S2. The atmospheric data are archived into MARS. As yet no multi-model products between ECMWF and the Met Office systems are available on the web but they are being developed and should be available in the near future. Météo-France has expressed interest in joining the real-time multi-model seasonal forecast activities.

The character of the ocean observing system is changing: the distribution of XBTs is declining, that of ARGO floats is increasing. In order to begin to assess the relative importance of these data networks on the ocean analyses, a series of OSE experiments is in progress. A full observing system (altimetry with global coverage of the sea surface, TAO, XBT and ARGO) is first used in an ocean reanalysis covering the altimeter period 1993-2002. Reanalyses are then performed, withdrawing one of the observing systems. The impact of withdrawing the ARGO float data over the period 1998-2002 (ARGO only really started after 1998 and is still building up) is largest in the extra-tropics and in the equatorial region of the Atlantic.

The method used to generate the 40-member ensemble consists of trying to sample uncertainty in ocean initial conditions as well as using stochastic physics throughout the integration. Uncertainty in ocean initial conditions can arise through uncertainty in the winds that are used to force the ocean during the analysis stage. Additional uncertainty arises through imprecise knowledge of the sea surface temperature. A five-member ensemble of ocean analyses is used, and then each of these has its SST perturbed 8 times.

Several experiments have been done to study the growth of error over the first month and over the 6 months resulting from the wind perturbations, the SST perturbations, stochastic physics, all three together, and the lagged average approach (used for S1 but not for S2). A further experiment using wind and temperature perturbations and stochastic physics but in the absence of ocean data assimilation was also done. Wind perturbations and stochastic physics have similar growth rates. They start from small spread in SST and it takes about 3 months to reach a spread comparable to that of the SST perturbations or lagged average approach. It is seen that that the model error is important which can be addressed in part through the multi-model approach.

A way to assess the predictability of certain events is to conduct experiments where observed SST forces the atmospheric model. In all other respects, these experiments are the same as the coupled runs. We call these experiments "Provost" integrations (from the name of an EU project). Results from "Provost" experiments may set up an upper limit for predictability in a perfect model scenario. Together with the operations department, a suite to run "Provost" experiments in a routine manner was setup and migrated to the IBM. The suite will run twice a year, for November and May starts, with a delay of 6 months to acquire observed SSTs. As for the coupled integrations, the atmosphere-only runs require calibration. For this purpose, a set of back integrations have been performed, for the same period as for the seasonal runs (1987-2001), and with 15 ensemble members, to be able to assess predictability in mid latitudes.

The first integration performed in the IBM corresponds to the initial conditions November 2002. The atmosphere-only hind cast for DJF is overall quite similar to the forecast with the coupled model. The cold anomaly over Central and Northern Europe was not predicted by either coupled or uncoupled experiments.

A series of ensemble-experiments was undertaken to examine the sensitivity of the ECMWF model to both horizontal resolution (T63/T159/T255) and sea-surface temperature anomalies in a case of extreme seasonal rainfall over Western Europe in autumn 2000. Results indicate only small sensitivity to horizontal resolution. However, they also suggest a deficiency of the representation of warm-pool convection and a significant dynamical connection between warm-pool SSTs and autumn teleconnection patterns.

BMRC (K. Puri)

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

- the global assimilation prediction (GASP) system, horizontal resolution T_L239 and 29 levels;
- the limited area prediction system (LAPS), horizontal resolution 0.375^o x 0.375^o and 29 levels;
- the tropical limited area prediction system with the same resolution;
- the mesoscale limited area prediction system, horizontal resolution 0.125^o x 0.125^o and 29 levels;
- the tropical cyclone limited area prediction system, horizontal resolution 0.15^o x 0.15^o and 19 levels.

In addition a 0.05^o x 0.05^o version of the model is run operationally twice a day for domains covering Melbourne and Sydney, with hourly output then being used to drive a CSIRO photochemical model for use by the Environment Protection Authorities. A global ensemble prediction system is undergoing final trials prior to operational implementation.

Over the past year considerable effort has been made in completing the Generalised Statistical Interpolation scheme (GenSI) to eventually replace the current multivariate statistical interpolation scheme (MVSI) that has been operational for several years. GenSI is an observation space-based assimilation scheme which has a number of attractive features. It allows for a flexible prescription of background error and leads naturally to the application of Ensemble Kalman Filters. A key feature of GenSi is that it can be used in both the global (spectral) and the regional (grid point) systems; the system has been unified so that the same executable is used for both applications. Detailed testing of the scheme has been carried over several months, initially using the same database as the operational system even though GenSI allows data from a wider variety of observation platforms to be used. Results of these trials have shown a positive impact in both the global and regional systems. Tests to include new observations such as scatterometer winds, SSM/I data have commenced. Operational implementation of GenSI is planned for the second quarter of 2004.

An extended version of the global system (50 vertical levels with the top level at 0.1 hPa) has been developed which allows the full forward calculation of ATOVS radiance first-guess values in the 1D-VAR retrieval scheme. Extensive global assimilation experiments have been conducted and medium-range prediction performance in the stratosphere has been substantially improved. Scatterometer (QuickScat) data are now being assimilated on an experimental basis within GASP (T_L239/L33 vs operations T_L239/L29), and has shown a modest positive impact on medium-range prediction in the Southern Hemisphere. Quality control procedures have been supplemented with background checks of wind direction to remove incorrectly de-aliased data. The scatterometer data is expected to be included into the operational global system as part of the next major upgrade.

Problems with GMS-4 satellite have resulted in GOES-9 to be located in the western Pacific. The local cloud drift wind scheme has been used to generate wind from GOES-9. Trials in LAPS have shown a positive impact in the forecasts. Based on these results the local winds were implemented operationally.

An upgrade to the operational LAPS to use a detailed bulk explicit microphysics was made in April 2003. Detailed parallel trials showed that this scheme had a positive impact on quantitative rainfall forecasts over Australia.

POAMA (Predictive Ocean Atmosphere Model for Australia) is a seasonal to inter-annual climate prediction system based on coupled ocean and atmosphere general circulation models. It was developed as a joint project involving BMRC, and CSIRO Marine Research (CMR), with some funding from the Climate Variability in Agriculture Programme (CVAP) of Land and Water Australia. The atmospheric model of POAMA is the Bureau of Meteorology unified atmospheric model (BAM). It has a horizontal resolution of T47 with 17 vertical levels. The ocean model component is the Australian Community Ocean Model version 2 (ACOM2), which is based on the Geophysical Fluid Dynamics Laboratory Modular Ocean Model (MOM version 2). The grid spacing is 2° in the zonal direction. The meridional spacing is 0.5° within 8° of the equator, increasing gradually to 1.5° near the poles, and there are 25 levels in the vertical. The ocean and atmosphere models are coupled using the OASIS coupler. The ocean data assimilation scheme is based on the optimum interpolation technique and only temperature observations in the top 500m are assimilated. The POAMA system has been run operationally since October 2002 and a 9 month forecast is produces daily. Operational products are issued by the BoM National Climate Centre (NCC) and research products are available on the POAMA web site.

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 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° 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 parametrizations – Tiedtke mass flux and Kuo cumulus convection, and stochastic physics formulation as 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 75km with 29 vertical levels, has 16 members and the system is run out to 3 days from the 12 UTC base times.

The joint BoM-CSIRO High Performance Computing and Communications Centre decided on a NEC SX-6 upgrade which will occur in two stages. In the first stage to be completed in early 2004 an 18 node NEC SX-6 system delivering a peak capacity of 1152 gflops will be installed together 2x12 CPU TX-7 front end computer and 14 tbytes GFS disc storage. In the second stage to be completed in the fourth quarter of 2004 an upgrade will be made to a 28 node SX-6 system delivering a peak performance of 1792 gflops, 2x16 CPU TX-7 from end and 22 tbyte of GFS disk storage. The global and limited area models achieved sustained performance of 35-40% of peak during tests on 16 SX-6 nodes. The Meteorological Archival and Retrieval System (MARS), a software package developed at the ECMWF, was made available to the Bureau late in 1998. MARS has now been implemented in the Bureau and is currently used to archive selected global model and global ensemble system output, in addition to research experimental data.

Météo-France (Dr M. Déqué)

The major feature of the improvement of the Météo-France operational forecasting system is the upgrade of the Fujitsu VPP5000 from 32 to more than 100 nodes. The numerical model is based on a global stretched grid model run at TL298 with 41 vertical levels and a stretching factor of 3.5 (with highest resolution over France), a global unstretched model run at TL149L41 (for the tropical prediction) and a limited area model over France with 9 km resolution. The global model is named ARPEGE and the regional model ALADIN.

Many changes have been made in the physical parameterizations, in order to reproduce, at a lower computational cost, the behaviour of the physical parameterization package of the climate version. These pertain to radiation at the surface, vertical diffusion in the planetary boundary layer, deep and shallow convection, and cloud scheme.

In June 2003, the truncation of the main global model was increased to TL358 and the stretching factor was decreased to 2.4. The 4DVAR minimization is run at TL107 (first loop) and at TL149 (second loop). As far as data assimilation is concerned, HIRS radiances of NOAA16 and NOAA17 have been introduced, and 6-hourly low-resolution winds from Meteosat have been replaced by 90-min high-resolution winds.

In Europe, the numerical seasonal prediction research activities have been coordinated by DEMETER. This EU-funded project was led by ECMWF and terminated in September 2003. Seven European coupled GCMs were used to re-forecast the ERA-40 period with 6-month 9-member 4-season/year forecasts. The period available for analysis and scoring varies from 20 to 44 years, according to the models. DEMETER also includes application partners in the domain of tropical diseases and crop production. A wide range of scores can be found in the DEMETER web pages of http://www.ecmwf.int. In particular Niño 3 SST from months 1 to 6, and winter northern hemisphere 500hPa height have a significant predictability when the average of the models is considered (multimodel). The great advantage of the multimodel is that the uncertainty about a forecast is no longer underestimated, and that probability forecasts are reliable. The skill of probability forecast is evaluated through the so-called cost/loss approach. Another approach, compatible with multimodel, but suitable with a single model, uses the analogy between members of different forecasts to build an ensemble containing only observed fields. Some DEMETER forecasts have been repeated with persistent SSTs and with observed SSTs. It is shown that in the tropics, the DEMETER forecasts are close, in terMs of scores, to forecasts with perfect SST. In mid-latitudes, coupled forecasts are closer to forecasts with persistent SSTs than to forecasts with observed SSTs.

COPE is a WCRP initiative which aims at covering numerical forecasts between the time scales of THORPEX and those of IPCC, i.e. 10 days to 10 years. A specific objective of COPE is devoted to seasonal prediction. This component has a Task Force led by Ben Kirtman (COLA). The task force met in Honolulu the week before the WGNE session. It was decided to organize a reforecasting exercise using as many coupled GCMs and as many years as possible. WCRP subprojects will be invited to provide guidance in specifying the initial conditions of cryosphere and surface/soil. The experimental setup is still open. Additional experiments, e.g. using observed boundary conditions to drive the models, are encouraged.

A notable change in operational numerical prediction at Météo-France is the departure, after almost 20 years as the Head of this service, of Jean-François Geleyn. He has led the ARPEGE and ALADIN projects, and represented Météo-France at WGNE for many years.

Japanese Meteorological Agency (Dr K. Saito)

Dr K. Saito reported on the NWP system and recent developments at JMA. NWP at JMA started in 1959, and the current system, which was replaced in March 2001, is the 7th generation. The main computer is the Hitachi SR8000E1, which attains 768 Gflops with 80 nodes. Another supplemental system, a 'mini-super' HITACHI SR8000F1 (8 nodes, 115 Gflops), was implemented in October 2003 for developmental work.

JMA has five main forecast models. The global spectral model (GSM) run at T213L40 is run twice a day. The forecast time is 216 hours (12 UTC) and 90 hours (00 UTC). The regional spectral model (RSM) is a model for short-range forecasts and covers East Asia with a horizontal resolution of 20 km (L40). This model is run twice a day and the forecast time is 51 hours. The mesoscale model (MSM) is for disaster prevention and covers Japan and its surrounding areas with a horizontal resolution of 10 km (L40). This model is run 4 times a day (6 hourly) and forecast time is 18 hours. The typhoon model (TYM) is for track and intensity forecasts of tropical cyclones. Its horizontal resolution is 24 km (L25) and is run 4 times a day (6 hourly) up to 84 hours when a tropical cyclone exists in the Northwestern Pacific. The Ensemble prediction model (EPS) is for one-week and long-range forecasts. For one-week forecasts, a low-resolution version of GSM (T106L40) is used and a 25 member-ensemble is run daily (216 hours) from 12 UTC. For one-month forecasts, the T106 model with 26 members is run once a week up to 34 days.

JMA started EPS for seasonal forecast in March 2003. A low-resolution version of GSM (T63L40) with 31 members is run once a month up to 4 months. Since September 2003, 7 months integrations have been operated five times a year (Feb., Mar., Apr., Sep., and Oct.) as an extension of the 4-month predictions.

JMA implemented a 4D-VAR data assimilation system (Meso 4D-VAR) for mesoscale analysis in March 2002, which covers Japan and its surrounding area (3600 km x 2880 km) with a horizontal resolution of 10 km. The radar-AMeDAS precipitation analysis data are assimilated. With 4D-VAR, statistical performance for precipitation forecast of MSM improved dramatically. The 12 month averaged threat score of MSM for 10mm/3hr with verification grid 10 km for 9h forecasts was 0.11 before the implementation of 4D-VAR, while it jumped to 0.18 after the implementation of 4D-VAR.

A 4D-VAR assimilation system, similar to the Meso 4D-VAR, was implemented for regional analysis in June 2003, which covers East Asia (6480 km x 5120 km) with a horizontal resolution of 20 km. Assimilation window is 6 hour and incremental approach using a 40-km resolution RSM for inner loop is employed. With assimilation of the radar-AMeDAS precipitation analysis, threat scores of RSM remarkably improved. Statistical performances such as RMSE of 500 hPa height field have also obviously improved since June 2003, with the implementation of 4D-VAR.

The Arakawa-Schubert scheme in GSM was modified in May 2003. In the new scheme, entrainment and detrainment effects between cloud top and cloud base in convective downdrafts are considered and evaporation of convective precipitation was removed to eliminate the cooling bias of the GSM in the lower atmosphere over the tropical region. Direct assimilation of ATOVS radiance data (HIRS/3, AMSU-A and AMSU-B of NOAA15 and NOAA16) was also started in May 2003 to replace the use of NESDIS retrieved thickness data. The RTTOV-6 package of ECMWF is used as the fast radiative transfer model. Assimilation of QuikSCAT SeaWinds in Global 3D-VAR was also started in May 2003. By virtue of above modifications, statistical performances of GSM as measured by the RMSE of 500 hPa height field have been clearly improved since May 2003.

Operational assimilation in Meso 4D-VAR analysis of the precipitation and TPW data retrieved from TMI and SSM/I was started in October 2003. The water vapour field in analysis was improved, and threat scores of MSM were increased in later half of the forecast period.

Dr Saito also reported on the recent progress in developments of a Semi-Lagrangian scheme for GSM, an operational non-hydrostatic mesoscale model, and 4D-VAR assimilation system for Global Analysis.

UK Met Office (Dr A. Lorenc)

Since August 2002, the Met Office's NWP system has been based on a semi-implicit semi-Lagrangian non-hydrostatic dynamical core and revised physical parametrisations. Following this major upgrade the global model performance in the extratropics continues to show improvements over previous years. For instance, the northern hemisphere T+24 RMS error in sea-level pressure reached a record low for each month. Tropical 850HPa winds maintained similar errors at T+24, but upper levels and longer ranges were slightly degraded by systematic errors. Despite this, forecasts of the position and intensity of tropical cyclones were the best ever. Introduction of the MOSES II land surface scheme in Dec. 2002, and revised diagnosis of shallow convection with targeted diffusion in Mar 2003 both gave small improvements in tropical performance. The MOSES II scheme gave global improvements in screen-level temperature and humidity, but highlighted the need for the global soil moisture analysis which is being developed. The unified model system means that similar parametrisation developments were implemented in the mesoscale model.

The operational assimilation remained based on 3D-VAR. Additional use of Quikscat and Meteosat BUFR winds, plus an incremental digital filter initialisation and revised balance condition gave improvements in the global model (Dec. 2002). Reduced weights for the MOPS cloud data, and revised covariances, improved the UK forecasts in Dec. 2002, and reduced latent-heat nudging of radar precipitation data, plus use of AMSU-A & B gave more improvements in March 2003. The stratospheric system was brought into line with the global model and assimilation, but with 50 levels, in Oct. 2003.

Other work was directed towards the relocation of operations to Exeter in August 2003, and an expected six-fold increase in power from new SX6 computers. The main global run, which had a 3hr data cut-off, was merged in Dec. 2002 with the preliminary run with a 1hr50min cut-off, in order to allow the introduction of a 20km European Limited Area Model (Euro-LAM). The reduced cut-off slightly degraded some forecasts; it will be increased again on the SX6. Plans for 2004-5 are to introduce 4D-VAR in the global and then the Euro-LAM, increase vertical resolution (absorbing the stratospheric configuration into the global), and increase horizontal resolutions to about 50km global, 12km Euro-LAM and 4km UK.

A new 40-ensemble coupled ocean-atmosphere global seasonal prediction system (known as GloSea) was implemented as the Met Office's real-time system in March 2003, with forecast production moved towards operational status. GloSea, a version of the HadCM3 climate model, has replaced the "two-tier" 9-ensemble HadAM3 system (forced with persisted SST anomalies), formerly used for real-time seasonal prediction since January 1998. The GloSea system is initialised using an ensemble of ocean analyses and runs on the ECMWF computing facility in parallel configuration with the ECMWF System-2 seasonal prediction model as part of a developing European multi-model system. GloSea forecasts are initialised from the first day of each month and run out to 6 months ahead. A range of forecast products are made available to NMSs (via a password protected website), Regional Climate Outlook Fora, UK government agencies, the public (www.metoffice.com/research/seasonal/) and to commercial companies. Extensive assessment of GloSea performance has been conducted using a 43-year hindcast dataset generated as part of the EU project DEMETER. A range of diagnostic output may be viewed at http://www.ecmwf.int/research/demeter/. In general, prediction skill for seasonal anomalies in 2-metre temperature and precipitation is similar with GloSea and the two-tier HadAM3 system. However, GloSea provides better performance in the northern winter and spring seasons at longer (3-month) leads.

Deutscher Wetterdienst (Dr D. Majewski)

The current suite of global and regional NWP models of the DWD consists of:

- the global icosahedral-hexagonal grid point model GME, mesh size 60 km, 31 layers,
- the non-hydrostatic local model LM, mesh size 7 km, 35 layers, 325x325 grid points,
- the hydrostatic High-resolution Regional Model HRM which is used for operational NWP in 13 countries worldwide, including Brazil, China, Italy, Oman, Spain, UAE and Vietnam.

Several upgrades of the operational NWP system have been recently implemented, e.g. prognostic cloud ice on 16 September 2003. In July 2003, the IBM RS6000 SP computer system has been extended from 1280 to 1920 Power III processors. For 2004, the following major upgrades of the operational NWP system are planned:

- Use of ATOVS data with a 1D-VAR scheme in the global data assimilation,
- GME with mesh size 40 km and 40 layers,
- LME (LM-Europe) with mesh size 7 km and 40 layers for whole of Europe,
- Prognostic treatment of rain and snow (esp. horizontal drift) in LME.

With the help of the "Aktionsprogramm 2003" it was possible to employ 11 young scientists on three-year contracts for NWP development. Six of those will concentrate on global modelling (3D-VAR assimilation and use of satellite data, diagnostics and tuning of GME), the other five will develop the very high resolution LMK (LM-"Kürzestfrist") which will provide 18-h forecasts eight times the day including explicit prediction of deep convection. For LMK the main research and development steps consist of the usage of radar data based on latent heat nudging, model development for the meso-γ scale (higher order numerics, 3D turbulence scheme, prognostic graupel) and objective interpretation, presentation and verification of LMK forecasts.

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

HMC is both an operational forecast and a research centre. Operationally, HMC produces forecasts twice a day (for 3.5 days from 00 UTC and for 10 days from 12 UTC) using a global spectral model T85L31. The model has been developed from an old version of ECMWF model. 3D multivariate objective analysis is used with optimum interpolation for geopotential height, temperature and wind, and 2D optimum interpolation for other variables. Other models at HMC include a finite-difference global semi-Lagrangian (SL-AV) model, a regional model, and a local mesoscale model for Moscow region.

The SL-AV model uses the absolute vorticity as a prognostic variable and compact high-order finite differences on unstaggered grid. Parameterizations used are from the ARPEGE/IFS model (France). Currently, this model with the constant resolution of 0.72° x 0.90° on a latitude-longitude grid and 28 levels is being tested quasi-operationally. A variable-resolution version of the model has been validated with the resolution of 1.40625 degrees in the longitude, and latitudinal resolution varying between 70 and 220 km. Results from a series of five-day forecasts show the benefit of using the variable resolution over Russia. Currently, a variable-resolution version is being implemented with the resolution 0.9° in the longitude, the latitudinal resolution varying between 40 and 180 km. The HMC regional model has a continental-scale domain (Russia and Europe) and the resolution of 75 km in the horizontal and 30 sigma-levels in the vertical. Versions of the regional model customized to the Russian Far East and Belorussia employ 50-km resolution. The HMC mesoscale model's domain is the 300 x 300 km region centered in Moscow. The horizontal resolution is 10 km. There are 15 levels unequally spaced in the vertical from surface up to height of 11 km. The model is driven by the regional model with a three-hour time interval.

Current research activity at HMC includes developing a T169L31 model; improving precipitation in the currently operational T85L31 model; testing the SL-AV in seasonal forecasting and in quasi-operational medium-range NWP; and 3D-VAR.

On 1 April 2003, HMC and MGO started an official intercomparison of independent one-month forecasts, produced at the both centres quasi-operationally once a month. The intercomparison is to be completed on 31 March 2005 by which time 24 forecasts will have been produced by each centre.

Canadian Meteorological Centre (Dr J. Côté)

The main operational changes this year were: switching from NEC SX-5 to NEC/Cray SX-6, implementing the distributed memory version of the Global Environmental Model (GEM-DM) model, increasing the volume of satellite data, assimilating raw radiances. The whole operational suite is being prepared for the move on the new highly parallel IBM computer based on the Power4 scalar chip. The initial configuration will consist of 864 processors giving an increase in performance of 2.5 over the former system. The planned implementations for next year are the regional configuration at 15 km covering North America, the global configuration at 35 km, Ensemble Kalman Filter, four-dimensional variational assimilation (4DVar), limited-area model (LAM) configuration at 2.5 km.

In the testing of 4DVar, the operational 3DVar with all current observations, and GEM-DM in the operational configuration were used and assimilation was carried in a 6-h window. Over North America the impact was clearly positive for 48-h forecasts and an improvement in the tropical region was also noted. 4DVar in the future will use more asynoptic data. The impact of changes to the background-error covariances on analyses, and forecasts improvement from the use of simplified physics in the assimilation will be studied.

A unified cloud package is being developed for the global and regional configurations. The new cloud suite can represent the large variety of clouds that exists at large scale and mesoscale during winter and summer. An off-line comparison of surface models Intéractions Sol-Biosphère-Atmosphère (ISBA) and Canadian Land Surface Scheme (CLASS) was performed over North America from May 2002 to April 2003. ISBA is used in NWP while CLASS was developed for climate modelling. A more detailed in-line comparison is planned.

New or improved operational environmental prediction models and products are developed to protect life and property with regard to extreme weather events. The Marine Environmental Prediction System (MEPS) is a demonstration site for Lunenburg Bay, Nova Scotia. The goal is to perform interdisciplinary marine environmental prediction which is guided and tested using advanced observing systems. For this purpose a coupled atmosphere/ocean/biology/chemistry ecosystem model is being developed. A wind atlas is being produced over Canada for wind-energy purpose with a statistical-dynamical downscaling.

NCEP (Dr R. Petersen)

The NCEP summary focused on four areas: Hindcast skill in the new coupled ocean-atmosphere model for climate, Weather Research and Forecast (WRF) model activities, Ocean modelling efforts, and status of the Earth System Modelling Framework (ESMF).

A new global coupled atmosphere-ocean model has recently been developed at NCEP/EMC. Components include: a) the T62/64-layer version of the current NCEP atmospheric GFS (Global Forecast System) model and b) the 40-level GFDL Modular Ocean Model (version 3). The ocean component uses initial conditions obtained from the NCEP Global Ocean Data Assimilation System (GODAS), which was implemented in September 2003 and uses real time global ocean data bases, including ARGO (1000 reports/month), altimeter, XBTs, buoys, SST in standardized formats with embedded quality controlled meta data. The global ocean data assimilation system also produces salinity analysis (improved use of altimeter observations) and uses an upgraded GFDL-MOM ocean model (MOM-3). This system is expected to replace the current operational NCEP coupled model (CMP14) for SST prediction in 2004.

The model was tested using direct coupling with no flux correction. Results for 38 years produced realistic SST anomalies while showing extremely small and random biases. Results of ensemble forecasts initialized in April for 22 years showed greater skill than either existing dynamical models (for more than 8 months into the future) or proven statistical methods (for at least 5 months into the future). Runs initialized in January showed less overall skill than in the April tests, but the new system was again comparable or better than the other comparative system for up to 8-month forecasts. For both periods, the timing and amplitudes of the forecast SST anomalies matched observations much better than the alternative methods, as did the spatial variations of the anomalies in the Pacific throughout the forecast cycle.

Over the United States, the system produced realistic surface temperature anomalies which had skill equal to or greater than that obtained with statistical methods, although the skill areas covered somewhat different geographical areas. The skill of the April forecasts was again greater than that of the January forecasts. Likewise, precipitation forecast skill was greater with the new system, especially during the earlier months of the forecast, but again over different areas than with the statistical methods.

Progress on the Weather Research and Forecast (WRF) model during the past year has focused on establishing parallel end-to-end system to run in an 8-km High Resolution Window (HRW) configuration. Progress areas this year included the FSL WRF Standard initialization, the NCAR WRF Eulerian mass core, the NCEP WRF physics and Non-hydrostatic Mesoscale Model (NMM), and the NCEP WRF post-processing & verification packages. More details are available at http://www.emc.ncep.noaa.gov/mmb/mmbpll/nestpage/.

A WRF-based ensemble will run in the current High-Resolution Window domains beginning in September 2004. The 6-10 member ensemble will include 2 control members using both the NMM core (discussed later, Dx = 8 km) and the Eulerian mass core (Dx = 10 km), with 4-8 additional members using alternative physics and/or initial condition bred modes and lateral boundary anomalies from SREF. Results from 120 test cases covering all four seasons will be used to qualify the dynamical cores and evaluate potential ensemble members as per the WRF Test Plan.

The aforementioned NMM (Janjic et al. 2001) has been in testing at NCEP for several years and consists of a Hybrid sigma pressure vertical coordinate, Arakawa E-grid with 3:1 nesting ratio, Adams-Bashforth time differencing, conservation of kinetic energy, enstrophy and momentum using 2^{nd} order differencing equations, separate sets of equations for hydrostatic and non-hydrostatic terms, Eta model physics, NOAH land-surface sub-surface model, as well as full links needed to run within WRF infrastructure.

NCEP has also been actively upgrading its short-range ocean forecast models. WAVEWATCH III is an in-house ocean wave model, based on the well-known community model WAM. The development of WAVEWATCH III was initiated in 1993 because design features of WAM hampered further development. The model was accepted for operational implementation in 1998 and forms the basis of a model suite consisting of six models from 2000 through 2003.WAVEWATCH III includes modern software design, more complete governing equations (wave-current interactions), improved numerics (propagation and physics) and improved physics parameterizations. Currently the model is run at different resolutions to meet global (1.25 x 1.0 degree) and regional [Alaska (0.5 x 0.25), western North Atlantic and eastern North Pacific (0.25 x 0.25)] using 24 wave directions and 25 frequencies. Use of a consistent data assimilation system has further contributed to reducing biases and improving skill, especially in the first several forecast days.

The next step in expanding the functionality of WAVEWATCH III is to generate a multi-scale version with two-way nesting of models with different scales that run simultaneously, moving nests to follow features of interest (shown to be particularly important for hurricanes), hurricane nests plus coastal nests (to remove the need for running separate large regional models), and selective application of highest resolution nests (making ensemble wave forecasting more feasible). Simultaneously, improvement of model physics continues, as well as investigation of more advanced data assimilation techniques.

On a larger ocean scale, NCEP is developing a Real Time Ocean Forecast System for Deep and Coastal regions, based on the HYbrid Coordinate Ocean Model (HYCOM). It is intended to establish operational high-resolution (eddy resolving) ocean forecast systems for short term forecasts (~1 week) in the Atlantic and Pacific oceans, with US deep and coastal waters well resolved. Nowcasts and forecasts will include sea levels, currents, temperature and salinity. The system will also provide boundary and initial conditions to regional ocean physical and bio-geo-chemical models, as well as providing coupled circulation-wave ocean models with one-way and two-way interactions. On the longer time ranges, the system will provide operational medium resolution (~1/4 degree) world oceans forecast system for periods up to 6 weeks. It will also provide boundary conditions for basin ocean models, SST estimates to support NWP (regional and global), coupled global atmosphere-ocean forecast system (mid-range), and coupled regional atmosphere-ocean forecast systems (Hurricane and Mid-latitude storms) with relocatable grids. The model will include:

- Deep open ocean processes, shallow coastal ocean processes, and the transition from one regime to the other need to be accurately resolved.

- Consistent and unified modelling approach and a generalized vertical coordinate model suitable to simultaneously reproduce the important processes in the deep, intermediate, and shallow domains of an ocean basin.
- Model structures which are consistent with ESMF and HOME requirements
- Implementations between from 2005-2007.

NCEP is also taking advantage of its experiences in transferring research systems into operations by teaming with NASA, NSF, DOE and others on the Earth Systems Modelling Framework (ESMF).

China Meteorological Administration (Dr Chen Dehui)

Steps to improve the current operational NWP systems at NMC/CMA include:

(1) operational implementation of the new medium-range NWP system (T213L31 from ECMWF) on the IBM/SP parallel computer,
(2) improving the sand-dust storm numerical forecast system. The sand-dust storm system, originally developed by Dr Shao Yaping (from the University of N.S.W., Australia) consists of an atmospheric prediction model, surface model, wind-erosion model, geographic information system, remote sensing data application scheme and
(3) conducting experiments on typhoon track prediction using a global model.

A new generation of multi-scale unified assimilation and prediction system, GRAPES - Global/Regional Assimilation and PrEdiction System, has recently been developed at CNPR (Center for Numerical Prediction Research). The system uses a variational approach for data assimilation, a semi-implicit and semi-Lagrangian scheme, and fully compressible non-hydrostatical approximation. Assimilation of conventional, radar and satellite data in GRAPES for a number of case studies of summer heavy rainstorms and tropical cyclones in 2003 has produced very encouraging results. Multi-scale application of GRAPES was investigated by increasing the horizontal resolution from hundreds of kilometres to several tens of kilometres to 1 kilometre (the resolution increased up to 100 meters for idealized tests). These investigations confirm the feasibility of using the multi-scale unified dynamical core.

An Overview of Numerical Weather and Climate Prediction at CPTEC (Dr J.P. Bonatti)

The Center for Weather Forecasting and Climate Prediction (CPTEC) is a Brazilian center for operational numerical weather and climate predictions with research and development activities. The CPTEC operational forecasting suite is banded on:

(a) Global spectral model T126L28 up to 7 days, two times a day (00 and 12) using NCEP analysis and CPTEC/JMA assimilation (6 hours);
(b) Regional Eta model 40kmL38, up to 5 days, two times a day, using NCEP global analysis and CPTEC global model boundary conditions;
(c) RPSAS/GMAO-NASA CPTEC regional analysis with CPTEC global model boundary conditions and
(d) Global Ensemble T126L28, up to 7 days, once a day, 15 members using CPTEC/FSU ensemble principal components scheme.

The operational seasonal climate prediction is performed in the following way:

(a) Global Spectral Model T062L28 up to 4-6 months, once a month: 15-25 members for each boundary condition;
(b) Boundary conditions: monthly sea surface temperature: persisted anomaly (observed) or predicted (Tropical Atlantic with CPTEC scheme and Tropical Pacific from NCEP) and
(c) Initial climatological values for soil moisture, albedo and snow depth and sea ice is considered at grid points for which SST is below -2ºC.

CPTEC supercomputer and an archive system is:

(a) NEC-SX4/8A: 1 node, 8 processors, 8 Gbytes of memory, 270 Gbytes of disk, 16 Gflops peak performance;
(b) NEC-SX6/96M12: 12 nodes with 8 processors, 64 Gbytes of memory and 64 Gflops of peak performance for each and 16 Tbytes of disk (total: 96 processors, 768 Gbytes of memory and 768 Gflops) and
(c) SUN-STORAGE TEK: 15 Tbytes of disk and 200 Tbytes (slots for 1.2 Pbyte) of tape (HSM).

Other Important CPTEC Operational modeling activities are:

(1) Brazilian regional centers model (called BRAMS): to provide for the Brazilian regional forecast centers a homogenous model RAMS 5.0 (beta version) with improvements done at CPTEC and IAG-USP;

(2) (2) Environmental predictions: using a model transport coupled to the RAMS atmospheric model to forecast plumes of CO and aerosols;

(3) (3) Ocean-Atmosphere coupled model: using the OGCM MOM_3 (modular ocean model of GFDL/NOAA) coupled to the CPTEC/COLA AGCM T042L28 with RAS convection with coupling of daily interactions of predicted anomalies of taux, tauy, heat fluxes and precipitation from AGCM to OGCM and predicted SST from OGCM to AGCM;

(4) Hydrological Model: using precipitation anomalies of the ensemble climate predictions to make river discharge probabilistic forecast;

(5) Sea Waves Model (WAN/WWatch regional 30 km and global 100 km): use as input taux and tauy from CPTEC AGCM T126L28 to forecast significant height, direction and peak period of the sea waves and

(6) Data Assimilation: it is operational on an old global 3d-VAR JMA scheme since 1995, the RPSAS (GAMAO/NASA) with Eta regional model is already in operational test and GPSAS with AGCM is beginning the operational tests.

The Numerical Weather Prediction System at INMET-Brazil (Dr R. Silveira)

The Instituto Nacional de Meteorologia (INMET) in Brazil installed the High Resolution Model MBAR(*Modelo Brasileiro de Alta Resolucao*), during year 1999. The model was obtained from the Federal Republic of Germany, under a technical agreement between INMET and the Deutscher Wetterdienst (Offenbach). A first version of the model, the Europa Model of the Deutscher Wetterdienst (EM/DM) (Majewski, 1991), was installed in May 1999. However as the EM/DM was discontinued by the DWD, it was replaced by the HRM v.1.5, called MBAR, which have been installed on September 1999. It became operational in November 1999.

The MBAR is hydrostatic, uses primitive equations, with domain at INMET covering South America, from 90 W to 20 W and from 60 S to 15 N. The average mesh size is about 25 km, i.e. 301 x 301 gridpoints, 31 vertical layers. The model is initialised with the analyses and boundaries obtained from DWD Global Model (Majewski et al., 2002) for 00 UTC and 12 UTC. Since October 1999, MBAR in Brazil has been undergoing intensive operational development, including multi-processing tasks; post-processing visualization tools; creation of many scripts for operation of the model and development of verification tools. On December 24th it was released to the public through INMET´s web page at www.inmet.gov.br. MBAR outputs include the basic fields at surface and upper air levels, such as sea level pressure, temperature, winds, geopotential, humidity, cloud cover and meteographs for specific locations. The current computational environment consists of 2 SGI Origin supercomputers, with 32 (the 2400 model) and 80 (the 3800 model) processors respectively; one vector SGI CRAY SV-1A, with 8 processors and one COMPAQ/HP Alpha 8400 cluster, with two computers of 6 processors each. The total deliverable is about 100 Gigaflops with storage of about 1 terrabytes. The main goal of the use of MBAR at INMET is to provide the forecasters, at the headquarters and regional centres, with good and reliable tools to help them make more accurate prognoses, as well as to assist them with the dissemination of the weather conditions to the public in general.

An important feature of WGNE sessions is presentation from local scientists. A number of presentations were made by scientists from CPTEC/INPE, LAC/INPE, INMET, and the University of Sao Paulo. Dr C. Nobre presented a modelling study of multiple biome-climate equilibria for tropical South America. The existence of multiple climate-vegetation equilibria in Tropical South America was shown under present-day climate conditions with the use of an atmospheric general circulation model coupled to a potential vegetation model. The potential vegetation model developed at the Brazilian Centre for Weather and Climate Forecasting (CPTEC) has a novel parameter to represent the seasonality of rainfall regimes. In comparison with similar potential vegetation models, this new parameter allows for a better representation of forest-savanna boundaries. Two stable equilibria were found. One corresponds to the current biome distribution. The second is a new equilibrium state: eastern Amazonian forests are replaced by savannas and a semi-desert area appears in the driest portion of Northeast Brazil. If sustainable development and conservation policies were not able to halt the increasing environmental degradation in those areas, then land use changes could tip the climate-vegetation system towards this new alternative drier stable equilibrium state with potential adverse impacts on the rich species diversity in the former region and water resources in the latter.

The atmospheric transport of biomass burning and anthropogenic emissions in South America and Africa has been monitored by CPTEC in collaboration with the University of Sao Paulo (www.cptec.inpe.br/meio_ambiente). A real time operational monitoring transport system was implemented using the on-line 3-D transport model CATT-BRAMS (Coupled Aerosol and Tracer Transport to the Brazilian developments on the Regional Atmospheric Modelling System) coupled to an emission model. In this method, the mass conservation equation is solved for carbon monoxide (CO) and particulate material PM2.5. Source emissions of gases and particles associated with biomass burning activities in tropical forest, savanna and pasture are parameterized and introduced in the model. The sources are spatially and temporally distributed and assimilated according to the biomass burning spots obtained by remote sensing. The advection, at grid scale, and turbulent transport, at sub-grid scale, are provided by the RAMS parameterizations.

Dr E.D. Freitas made a presentation on pollution dispersion studies at the university of Sao Paulo. The Town Energy Budget (TEB), a physically appropriate parameterization for the representation of urban heat island effects, is applied to study pollution dispersion in the Metropolitan Area of Sao Paulo (MASP) during wintertime. During this period, very effective mechanisms for pollution dispersion such as thunderstorms and frontal systems occur with less intensity and thermally induced local circulations become very important in these processes. The model used in this study is the Regional Atmospheric Modeling System (RAMS). Comparisons between model results and surface observed data during a period of 72 hours of simulation during the winter of 1999 show that the parameterization provides excellent results with correlation coefficients greater than 0.9 for temperature and greater than 0.8 for relative humidity in all stations analyzed, capturing most of the features observed in MASP.

Table 1.
METRICS FOR OPERATIONAL NWP CENTERS AS REPORTED TO WGNE - NOVEMBER 2002
NWP Systems in WGNE Forecast Centers (as of Feb. 2004)

Forecast Center	Computer*	Global Model (High resolution)	Global Model (Ensemble)	Assimilation
ECMWF (Europe)	IBMp690*2 (10Tflops)	TL511 L60 (10 days)	TL255 L40 M51 (10 days)	4D-Var (TL159)
Met Office (UK)	Cray T3E (0.792Tf) Cray T3E (0.768Tf) (NEC SX6 in trials)	0.56x0.83deg L38 (6 days)	NO EPS	3D-Var
Météo-France (France)	Fujitsu VPP-5000*2 (**1.92Tflops**)	TL358L41(C2.4)(3 days)	NO EPS	4D-Var (TL149)
DWD (Germany)	IBM SP Power3 (120Nodes, 2.88Tflops)	60km L31 (7 days)	NO EPS	3D-OI
NCEP (US)	IBM Regatta H32 (7.3 Tflops)	T254 L60 (0-7 days) T170 (80km) L42 (7–16 days)	T126 L28 M21 (0-2.5 days) T62 L28 M21 (2.5-16 days)	3D-Var
CMC (Canada)	IBM p690 (108nodes, 4.3Tflops)	0.9 x 0.9 deg L28 (10 days)	SEF(T95)+GEM(1.95deg) M16 (10days)	3D-Var
JMA (Japan)	Hitachi SR8000-E1 (80Nodes, 0.768Tflops)	T213 L40 (9 days)	T106 L40 M25 (9 days)	3D-Var (T106)
BMRC (Australia)	NEC SX-6 (18 Nodes, **1.152Tflops**)	TL239 L29 (7 days)	TL119L19M33	3D-OI
CMA (China)	SW1 (0.384Tflops) IBM SP (75Gflops)	T213 L31 (10 days)	T106 L19 M33 (10 days)	3D-OI
HMC (Russia)	CRAY YMP (2.5Gflops) Itanium2 4*4(35Gf)	T85 L31 (10days) SL-AV 0.72 x 0.9 deg L28 on trials (5 days)	NO EPS	3D-OI

*Peak performance (**Vector machines in bold**)

Plans at WGNE NWP Centers (Global Model)

	2002	2003	2004	2005	2006	2007	2008
ECMWF (Europe)	TL511 (40km) L60 (10days)		TL511 (40km) L91	TL799 (25km) L91			
	TL255 (80km) L40 M51 (10days)		TL255 (80km) L62	TL399 (55km) L62			
	4D-Var T159 (120km)		TL159 (120km) L91	TL255 (75km) L91			
Met Office (UK)	UM 0.56x0.83deg L38 (6days)		L50	50km L70			
	No EPS			Short range EPS			
	3D-Var		4D-Var				
Météo-France （France）	TL298L41 (3 days) T199 L31 C3.5 (4 days)	TL358L41 (C2.4)		T403L41			
	No EPS						
	4D-Var (TL149)						
DWD (Germany)	GME60km L31 (7days)		40km L40		30km L45		
	No EPS						
	3D-OI			3D-Var			
NCEP (US)	T170(80km) L42 (0-7days) T62(200km) L28 (7–16days)	T254(50km) L64 T170(80km) L42 T128(100km) L28		TL511 (40km)		TL30km	
	T126 (100km) L28 M21 (0-2.5days) T62 (200km) L28 M21 (2.5-16days)			Multi-model 80km		Multi-model 60km	
	3D-Var			4D-Var			
CMC (Canada)	0.9x0.9 deg L28 (10days)		0.45x0.3 deg, L58	0.45x0.3 deg L80			
	SEF(T95)+GEM (1.95deg) M16 (10days)			0.9x0.9 deg L58M32			
	3D-Var (170km)		4D-Var				
JMA （Japan）	T213(60km) L40 (9days)		TL319(60km) L40			TL959 (20km) L60	
	T106(120km) L40 M25 (9days)		TL159 (120km) L40			TL319 (60km) L60 M51	
	3D-Var (T106)		4D-Var (T63)		T106	T213L60	TL359L60
BMRC (Australia)	TL239L29		TL479L60				
	No EPS	TL119L19M33					
	3D-OI						
CMA (China)	T213 (60km) L31			GRAPES 40km			20km
	T106 (120km)			80km			60km
	3D-OI			4D-Var			
HMC (Russia)	T85 150(km) L31 (10days)		T169L31, SL-AV 0.72 x 0.9 deg L28				
	Multi–model ensemble			T85L31, T40L15 (10days)			
	3D-OI				3D-var		

Upper：High resolution model、Middle：Ensemble model、Bottom：Assimilation

Plans at NWP Centers (Regional Model)

	2002	2003	2004	2005	2006	2007	2008
Met Office (UK)	UK 12km (36hrs) 3D-Var	UK 12km Euro 20km	Euro 12km	UK 4km 70L Euro 12km 4DVAR			UK 2km Euro EPS
Météo-France（France）	ALADIN 9.5kmL41						AROME 2-3km
DWD (Germany)	Lokal Model (NHM) 7km L35 (48hrs) Nudging	LM 7km L45 (3days)			LM 7km L50 LM 2km L50		
NCEP (US)	Meso Eta (Hydro) 12km L60 3D-Var	Eta10km		WRF(NHM)8km 4D-Var		WRF5km	
	Eta,RSM,48km L45 M10 (63 hrs)	32km M15		27km M25		WRF22km M25	
CMC (Canada)	GEM 24km L28 (48hrs) 3D-Var	GEM24km L28 (48hrs) 10km L35 (24hrs)	GEM 15km L58 LAM 2.5 km L45(12hrs)	LAM 5 areas	LAM 10km L60 LAM 4D-Var		4D-Var
JMA（Japan）	RSM 20km L40 (51hrs) 3D-OI	4D-Var			Global TL959 （20km）		
	MSM 10km L40 (18hrs) 4D-Var		NHM10km L40		NHM5km L50	NHM5km L50 (33hrs) NHM 4D-Var	
						2km L60 (12hrs) 3D-Var	
BMRC (Australia)	0.125x0.125 deg L29						
CMA (China)	HLAFS 25km L20 3D-OI			GRAPES 15km 4D-Var			5km
	Meso Model (MM5) 6km				GRAPES 3km		
HMC (Russia)	75km L30		SL-AV 40 km L28				

6. OTHER WGNE ACTIVITIES AND FUTURE EVENTS

Publications

One publication had been produced in the WGNE "blue-cover" numerical experimentation since the eighteenth session of the group, namely the annual summary of research activities in atmospheric and oceanic modelling (No. 33, produced in April 2003), again printed and distributed directly by RPN, Montreal. The process of electronic publication of the report has been made more robust. The April 2003 report was produced by inviting contributions by e-mail or through the web site www.cmc.ec.gc.ca/rpn/wgne and the electronic version is available on the website. About 260 hard copies have also been produced and distributed to those who preferred them.

A 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 Met Office, UK, the next session of the WGNE, the twentieth, would be held in Exeter, UK, 11-15 October 2004. It will be followed by the joint WGNE/WGSIP/WGCM Workshop on Ensemble Methods.

7. CLOSURE OF SESSION

On behalf of all participants, Dr K. Puri, Chair of WGNE, and Dr J. Polcher, Chair of GMPP, expressed deep appreciation to Centro de Previsão de Tempo e Estudos Climáticos (CPTEC) for hosting the session of WGNE and GMPP, and the excellent facilities and hospitality offered. The opportunity of interacting with many scientists and experts at CPTEC and hearing first hand of the research and work going ahead had been very valuable. Sincere gratitude was voiced to Dr C. Nobre and supporting staff for the excellent arrangements, unstinting assistance, and refreshments that had been provided.

The joint nineteenth session of WGNE/seventh session of GMPP was closed at 12.30 hours on 14 November 2003.

APPENDIX

LIST OF PARTICIPANTS

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