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**CAS/JSC WORKING GROUP
ON NUMERICAL EXPERIMENTATION**

RESEARCH ACTIVITIES IN ATMOSPHERIC AND OCEANIC MODELLING

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From the Editor

There is considerable international activity in the development of numerical models for the purpose of climate simulation and for forecasting on various timescales. This publication is an attempt to foster an early interchange of information among workers in these areas. The material in the publication is the response to a "call for contributions" sent to approximately 650 scientists worldwide. Contributions obtained in response to this call are included if they are related to the CAS/JSC numerical experimentation programme, if they give new results, and if they are of suitable length and size. Reports that do not meet these criteria, have been previously published, or are purely theoretical may be rejected. Contributors do not routinely receive any correspondence concerning the contributions.

The most appropriate reports give results of new numerical experiments in the form of a succinct explanation accompanied by suitable tables and figures. The contributions are collected into subject groupings as appropriate. The range of subjects is expected to vary with time and depends on the submissions received. The large number of contributions from around the world indicates the wide scope of activities in numerical experimentation, and the valuable addition that this type of report makes to the refereed journals. Comments and suggestions for improvement to the publication are welcome. To facilitate location of specific contributions, they are ordered alphabetically by author in the various subject areas. An overall index by author is also included.

This year we have taken a major step in the progression towards handling this report electronically. Contributions were submitted as an attachment to an e-mail message, or through the web site www.cmc.ec.gc.ca/rpn/wgne. A few documents still arrived by mail. Although there were some difficulties with electronic submissions, overall they worked well and enabled production of an electronic version of the report which is available on the web site. About 200 copies have also been printed in black and white and mailed directly from Montreal. Special thanks are expressed to Yves Chartier of RPN for his expert development of the web site and procedures, and a major effort to generate the electronic volume.

This will be my final volume as editor, with the responsibility now transferring to colleague Jean Côté. I am confident that you will give him your continuing cooperation. I want to especially thank Roger Newson for his advice and steady support which have facilitated the preparation of this report for numerous editors over the years.

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ACTIVITIES OF THE CAS/JSC WORKING GROUP ON NUMERICAL EXPERIMENTATION (WGNE)

WGNE has the central responsibility in the World Climate Research Programme (WCRP) for the development of the atmospheric component of climate models, and together with the WCRP Working Group on Coupled Modelling (WGCM), lies at the core of the climate modelling effort in WCRP. There is evidently a need for close contact and co-ordination between WGNE and WGCM and activities being undertaken by WGCM are briefly outlined in section 15. WGNE also works in close conjunction with the WCRP Global Energy and Water Cycle Experiment (GEWEX) in the development of atmospheric model parameterizations, and, in this respect, WGNE sessions are held jointly with those of the “GEWEX Modelling and Prediction Panel” (GMPP).

With regard to its role in support of the WMO Commission for Atmospheric Sciences (CAS), WGNE also reviews the development of atmospheric models for use in weather prediction on all timescales, and WGNE sessions always include presentations of progress at operational centres in topics such as data assimilation, numerics, physical parameterizations, ensemble predictions, seasonal prediction, forecasting tropical cyclone tracks, and the verification of precipitation forecasts. WGNE also strongly collaborates with the CAS World Weather Research Programme (WWRP), in particular through the involvement in the planning of The Hemispheric Observing System Research and Predictability Experiment (THORpex) (see section 12).

The following paragraphs describe a selection of recent activities undertaken by WGNE in support of the WCRP and CAS objectives and related subjects, particularly including several of the items of interest and recommendations arising from the seventeenth session of the group, kindly hosted by the Deutscher Wetterdienst, Offenbach, Germany, 29 October-2 November 2001.

1 MODEL INTERCOMPARISON PROJECTS

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, is a series of model intercomparison exercises.

Atmospheric Model Intercomparison Project

The most important and far-reaching of the WGNE-sponsored intercomparisons is 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. AMIP, based on a community standard control experiment simulating the period 1979-1996, is now reaching the end of its second phase (AMIP-II). Twenty-three modelling groups have submitted simulations and much of the data from these runs are available for a wide range of diagnostic sub-projects. A few further groups may provide integrations before the end of the year, the time limit recommended by WGNE for the current phase of AMIP. In addition to the standard runs, ensembles and runs at varying horizontal resolutions are being archived for specific research 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.

WGNE pointed out that AMIP has become a well-defined experimental protocol for testing global atmospheric circulation models. However, although useful, model intercomparison by itself leaves many questions unanswered. Thus, the "I" in AMIP might now also stand for "Infrastructure" in view of the powerful capabilities PCMDI has built for handling model integrations, and so effectively facilitating the diagnosis and display of many characteristics of the results. Efforts are also underway to increase co-ordination with the Coupled Model Intercomparison Project (CMIP) (see section 15), in particular to encourage the preparation of an AMIP simulation using the atmospheric component of coupled models, as has been recommended by WGNE.

A Second International AMIP conference will be held in Toulouse, France, 12-15 November 2002. The conference will highlight the results from the AMIP-II diagnostic sub-projects and provide an opportunity for activity reports from the participating modelling groups. An initial announcement has been distributed.

Looking beyond the conference, WGNE strongly supported the continuation of AMIP as an experimental protocol providing an independent evaluation of atmospheric models and facilitating increasingly advanced diagnostic research. It was considered that AMIP should evolve into an ongoing activity, with modelling groups submitting updated (standard) runs with new versions of their models every few years and that a centralized library of these simulations (including a model median) should be maintained as a gauge of progress in atmospheric modelling.

For more information on AMIP, including the status of AMIP-II and information on the diagnostic sub-projects and results being obtained, please consult the AMIP home page (address as above). Details of the AMIP Conference are also being posted on this page.

"Transpose" AMIP

In operational NWP, models used for forecasting and data assimilation are tested against reality routinely, sometimes several times a day. The requirement to provide as accurate analyses and forecasts as possible is a powerful stimulus to careful refinements of the parameterization of physical processes in operational models. It appears unlikely in general that use of an atmospheric climate model (at the type of resolutions typically employed) in an operational system would approach the level of skill and realism of a state-of-the-art NWP model. The question is how to obtain the benefits conferred by application of a model operationally in forecasting and assimilation for developing the parameterizations in climate models. The basic idea of a "transpose" AMIP (or a similar exercise "Initial Tendency Error Analysis" being considered by PCMDI) is to examine how well climate models predict the detailed evolution of the atmosphere at the spatial scales resolved by these models, and to explore whether errors occurring in short-range forecasts (six hours up to a few days) with climate models might suggest how the physical parameterizations could be improved. How best to take advantage of field programme data (e.g., from the Atmospheric Radiation Measurement programme, ARM) to refine models and the possible relationship between initial (forecast) errors and long-term systematic errors were other key aspects. Forecasts from operational analyses and/or reanalyses using (atmospheric) climate models need to be prepared and compared (on a climate scale) with verifying analyses in regions with adequate data (so that the background operational model forecast does not dominate the analysis). The climate model forecasts could also be compared with data collected in, for example, ARM field campaigns, although care is required to allow for the different spatial scales involved.

The initialization and spin-up of forecasts are likely to be critical aspects. The basic approach will be to map the climate scales as represented in the analyses onto the climate model grid. In principle, such a mapping of atmospheric variables of state is straightforward except insofar as changes in orography and the vertical co-ordinate system are required. The handling of other physical parameters which have a time history (e.g., cloud water) was less obvious, but might be possible if details of the parameterizations in both the climate model and analysis model were known. Land-surface variables are even more problematic in face of the difficulties of mapping discrete/discontinuous variables, different representations of land surfaces in different models, and the lack of a uniform definition of land-surface variables. It would be necessary to spin up the land surface variables and possibly certain other key variables in atmospheric parameterizations for a period of a few months. In the case of the former, a start would be made from a land model climatology with attention given to achieving appropriate values for those variables affecting surface fluxes (deep, slowly evolving soil layers near to climatology would probably not present a problem). During this process, either the atmospheric state could be updated with analyses periodically (e.g., daily), or a term added to the model variables to relax the predicted state towards the analysis.

WGNE is duly developing a project on these lines, but it is recognized that there are a number of questions to be resolved. Appropriate contacts will be taken with potential participants in discussing how to proceed. Advantage will also be taken of the experience in the Global Land-Atmosphere System Study (GLASS) (see section 5) where the planning of global scale interactive integrations has faced similar difficulties in the initialisation of land surface and soil variables. For more information, please contact Dr. D. Williamson at NCAR (e-mail: **wmson@ucar.edu**).

Snow Models Intercomparison Project (SNOWMIP)

SNOWMIP is being undertaken by Météo-France (Centre National de Recherches Météorologiques, Centre d'Etudes de la Neige, CNRM/CEN) under the auspices of WGNE and the International Snow and Ice Commission (ICSI) of the International Association of Hydrological Sciences. Liaison is also maintained with the Global Land-Atmosphere System Study (GLASS). The project is aimed at intercomparing and evaluating the variety of snow models that have been developed for applications ranging from climate modelling, hydrological simulations, snow stability and avalanche forecasting. The basic approach is the point validation of the simulation of several properties of the snow-mantle (snow depth, snow water equivalent, snow temperature profile, and in some cases the fine scale characteristics of the snow). Initial conditions and forcing data from four sites at various altitudes (Col de Porte, France; Weissflujoch, Switzerland; Sleepers River, Appalachions, USA; Goose Bay, Canada) were supplied to participating groups at the end of 2000. In accord with WGNE advice, the snow models could also be run coupled with underlying soil models rather than with the prescribed heat fluxes from the ground. Twenty different groups have submitted simulations from twenty-four snow models, with preliminary results being discussed at the IAMAS Scientific Assembly (Innsbruck, Austria, July 2001). A large scatter in results from different models is apparent and further detailed analysis is being undertaken. However, there is little difference in using an underlying soil model or prescribed heat flux (the heat flux from the ground is very small anyway). More information is available at http://www.cnrm.meteo.fr/snowmip/.

Comparisons of stratospheric analyses and predictive skill in the stratosphere

In the past two or three 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 initially undertaking a new intercomparison of stratospheric analyses, to be followed by an assessment of model predictive skill in the stratosphere. Interested groups are being invited to submit analyses for the period January-February 2000 using their centre's own analyses. Forecasts to at least ten days should be carried out, and up to twenty days would be preferred in order to be able to assess the limit of useful predictability in the stratosphere. Analyses at daily intervals of u, v, z, T, RH on pressure levels (1000, 850, 500, 200, 100, 70, 50, 30, 10, 1 hPa) on a 2.5° x 2.5° latitude/longitude grid in netCDF or GRIB format, as well as sea-level pressure and isentropic potential vorticity at 500K, will be collected. Comparisons would be made with UKMO analyses (in pressure co-ordinates). This activity is being led on behalf of WGNE by Dr. G. Roff at BMRC (e-mail: **G.Roff@bom.gov.au**).

The WCRP study of Stratospheric Processes and their Role in Climate (SPARC) is also fostering activities in the area of stratospheric data assimilation. The objective is to ensure that the advances in data assimilation techniques in many operational centres are exploited to obtain global quality-controlled, internally consistent data sets of the dynamic and chemical state of the stratosphere (as well as, where possible, the upper troposphere and mesosphere). The data sets will be especially designed to support SPARC-related studies of chemistry-climate interactions, with attention initially being given to making full use of the data becoming available from the ENVISAT and EOS/AURA satellites. A range of error statistics related to the utilisation and/or validation of instruments and for validation of models will also be produced. The type of effort undertaken will include comparisons of global analysed data sets complementing the WGNE work, assembly of documentation on data production methods and data quality at the SPARC Data Centre, and organization of workshops to consider how the methodology of data assimilation in the stratosphere could be refined (e.g. to include new variables such as aerosol loadings). It is also the intention to draw on analysed data sets to prepare reports of particular aspects of interest (e.g. stratospheric water vapour and its evolution). A small SPARC working group bringing together representatives from several of the active leading centres preparing stratospheric analyses has been formed to guide the work necessary. Close co-ordination and liaison is being maintained with WGNE. For more information, please contact Professor O'Neill, University of Reading, UK (e-mail: **alan@met.reading.ac.uk**).

SPARC has also been undertaking for a number of years an intercomparison of model stratospheric simulations (the "GCM Reality Intercomparison Project for SPARC", GRIPS). As reported in last year's edition (No. 31) of "Research Activities in Atmospheric and Oceanic Modelling", major progress was made in 2000 in collecting and summarizing the results of the first phase of GRIPS which included an intercomparison of basic features of model stratospheric simulations. Findings have been published in the Bulletin of the American Meteorological Society and the Journal of Geographical Research. The past year has been one of consolidation. A number of activities within the first phase remain to be completed (e.g. studies of the treatments of sudden warmings, tropospheric-stratospheric interactions). In the second phase of GRIPS (impacts of different parameterization schemes), tests of radiative codes are underway and this will lead to an investigation of gravity wave parameterizations. Studies of model response to formulations of mesospheric drag have been completed.

The third phase of GRIPS is concerned with explaining the observed variability in the stratosphere taking into account natural variability and the forcing by changes in aerosol loading, in solar radiations, and in atmospheric concentrations of ozone and carbon dioxide). A few groups have begun the experimentation required (some in connection with the European projects "Solar Influence on Climate and the Environment" (SOLICE) and "Stratospheric Processes and their Impacts on Climate and the Environment" (EUROSPICE)). For further details on GRIPS, please contact Dr. S. Pawson, NASA/GSFC (e-mail: pawson@polska.gsfc.nasa.gov) or Dr. K. Kodera, Meteorological Institute of the Japan Meteorological Agency (e-mail: **kodera@mri-jma.go.jp**).

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 Center 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. The initial experimentation being undertaken has involved carrying out "classic" C20C/extended AMIP-type runs using the observed sea surface temperature and sea ice as the lower boundary conditions (the HadISST 1.1 analyses provided by the Hadley Centre) for the period 1949-1997, with a minimum ensemble size of four members. Some participating institutions began the experiments from an earlier date (HadISST 1.1 extends back to 1871). A small common set of diagnostics has been saved from the integrations to facilitate comparison and quantitative analysis. The project is complementary to other internationally co-ordinated numerical experimentation projects, notably AMIP, and the general guidelines are similar to these activities. Fifteen groups are participating.

A second (optional) ensemble of experiments is planned with specified values of most of the known external forcings, both natural and anthropogenic (again ensembles of at least four members starting from 1871 or 1949). A third set of experiments (also optional) is being designed to explore the role of the land surface in recent climate change and variability, particularly at the regional scale, probably beginning from 1970.

A workshop was convened in Calverton, MD, USA in January 2002 jointly by the Hadley Centre and COLA to review the results that had so far been obtained from the C20C model integrations (mainly the first set of runs). For further information and details of results being obtained, please contact either Professor J. Shukla or Dr. J. Kinter at COLA (e-mails: **shukla@cola.iges.org**; **kinter@cola.iges.org**) or Drs C. Folland or Dr. D. Rowell at the Hadley Centre (emails: **ckfolland@metoffice.com**; **dprowell@metoffice.com**).

2 STANDARD CLIMATE MODEL DIAGNOSTICS

The WGNE standard diagnostics of mean climate have now been in use for a number of years and, in particular, were the basis for the "quick-look" diagnostics for AMIP simulations computed by PCMDI (see section 1). (The list of these standard diagnostics is available at
http://www.pcmdi.llnl.gov/**amip/OUTPUT/WGNEDIAGS/wgnediags.html**)

The diagnostics of mean climate included certain variance and eddy statistics, but additional parameters to describe large-scale climate variability at a range of frequencies are needed. Over the past two years, attention has thus been given to preparing a list of "WGNE standard diagnostics of variability". For the present, these are focussed on summarising the variability simulated in the troposphere of atmospheric climate models. The diagnostics being considered should already have been used and demonstrated (with examples from a specific model), easily computed (perhaps with code supplied), and stable (in the sense of not being strongly influenced by natural variability so that representative values can be obtained from a single AMIP simulation without ensembles being required). The proposed list of variability or phenomenological diagnostics includes those related to intraseasonal variability, the Madden-Julian Oscillation, ENSO, blocking, wavenumber-frequency power spectra, precipitation rates, the seasonal cycle, and atmospheric angular momentum.

3 DEVELOPMENTS IN NUMERICAL APPROXIMATIONS

The range of approaches being followed in numerical approximations for integrating partial differential equations on a sphere, and the types of grids being tried, were well illustrated by the scope of presentations at the 2001 Workshop on the Solution of Partial Differential Equations on the Sphere in Montreal, Canada, May 2001. Examples included, for the shallow water equations, techniques for using icosahedral, cubed sphere, and spherical grids. Likewise for baroclinic systems to which much more attention was now being given, methods using isosahedral, cubed sphere, spherical grids with variable resolution, and adaptive meshes were described.

In the vertical, although an example of the application of finite elements was presented, traditional "sigma" co-ordinates are still very much in use. Additional studies in this area (e.g., to take advantage of isentropic co-ordinates) are now definitely needed. The problem of representation of the "pressure gradient" term also remains somewhat neglected.

Specific consideration is also being given to the development of new methods for application in climate models, and for simulation of atmospheric transport (e.g., of aerosols, trace chemicals) where local conservation and preservation of the shape of distributions are essential. Energy conservation in climate models is of particular importance. In practice, conservation of better than 0.1 wm^{-2} is needed, whereas schemes with non-linear intrinsic diffusion (e.g., Lin-Rood, monotonic semi-Lagrangian) can lose energy at a rate of 1.5 wm^{-2}, as can explicit diffusion schemes. This loss should be converted to heat, but this might not be the correct approach. This is still a basic uncertainty in model formulation that must be kept in mind.

There is considerable continuing activity in this area with various workshops in the course of the coming year that should bring together the atmospheric modelling and the computer science communities, but these links need to be reinforced. The numerical representation of orography and transport modelling remain particular issues which WGNE intends to follow. Another important component of activities in this area is the development of tests of the various numerical schemes/grids in a baroclinic system before introduction into complete models where complex feedbacks can obscure effects of new schemes. In this respect, two new baroclinic tests have been devised, firstly a polar vortex test including complex dynamical features (a primary potential vorticity tongue and secondary instability causing roll-up into five sub-vortices) and, secondly, the simulation of a growing baroclinically unstable wave. As well as these tests, the interactions of physics parameterizations with each other and with the dynamics need to be examined. Stripped down versions of atmospheric models with very simplified surface conditions, in particular "aqua-planet" experiments with a basic sea surface temperature distribution, offer a useful vehicle in this regard, with considerable potential to understand the performance and effects of different dynamical cores and different representations of physical processes. For example, at NCAR, aqua-plant simulations with Eulerian and semi-Lagrangian dynamical cores coupled to the CCM3 parameterization suite produced very different zonal average precipitation patterns. Analysis showed that the contrasting structures were caused primarily by the different timestep in each core and the effect on the parameterizations rather than by different truncation errors introduced by the dynamical cores themselves. When the cores were configured to use the same time step, and same three time-level formulation and spectral truncation, similar precipitation fields were produced.

WGNE has recognized that aqua-planet experiments could have wide application in testing basic model numerics and parameterizations in the way described above and has duly endorsed the proposal for an "aqua-planet intercomparison project". This would be led by the University of Reading together with NCAR and PCMDI. The objective would not just be to assess current model behaviour and to identify differences, but to establish a framework to pursue and undertake research into the differences. An experimental design and data to be collected is being developed and a list of diagnostics to be computed and compared being considered. For additional details and to receive the formal announcement of the project, please contact Dr. R.B. Neale, University of Reading, UK (e-mail: **R.B.Neale@reading.ac.uk**).

4 MODEL-DERIVED ESTIMATES OF OCEAN-ATMOSPHERE FLUXES AND PRECIPITATION

Work continues on the updated 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). As well as the increasing concern in NWP centres with improving the treatment of surface fluxes, this activity responded to the request of the joint JSC/SCOR Working Group on Air-Sea Fluxes (WGASF) for a WGNE initiative to collect and intercompare flux products inferred from operational analyses. Furthermore, the GCOS/GOOS/WCRP Ocean Observations Panel for Climate has underlined the requirement for high quality surface flux products that need to be provided from routine operational analyses to meet the objective of implementing the ocean observing systems and assembling the data sets for the purposes of climate studies. The Global Ocean Data Assimilation Experiment (GODAE), aiming to provide a practical demonstration of real-time global ocean data assimilation as a basis for complete synoptic descriptions of the ocean circulation at high spatial and temporal resolution, also had requirements for high quality global real-time products. Moreover, the intercomparison of land-surface fluxes was of importance in the context of the Global Land Atmosphere System Study (GLASS).

In an initial pilot study, eleven operational NWP centres were invited to submit global fields (for 1999) of a number of various surface products and related parameters at various time intervals to PCMDI. Several groups provided the requested fields, but it was apparent that extracting historical data presented a number of difficulties. Because of this and since the real interest lies in the performance of current operational systems, a "near real-time" approach for collecting data was being adopted, with a near real-time link being established with interested centres. The primary objective will be to make the data collection from the centres and the handling of the data at PCMDI as easy and efficient as possible and "real-time" data are now being received by PCMDI from NCEP and ECMWF. Efforts are being made to extend this to other operational centres. At the same time, steps are being taken to have available relevant oceanographic data (e.g., from the TAO/Triton array) for comparing with and validating model-based estimates of surface fluxes.

High priority is being given to advancing "SURFA" in which the atmospheric and coupled modelling communities and oceanographers all have very strong interest, and which is a good opportunity for real progress jointly in estimating and determining surface fluxes. The activity is being led by Dr. P. Gleckler, PCMDI (e-mail: **gleckler@abyss.llnl.gov**) and Dr. J. Polcher, Laboratoire de Météorologie Dynamique/Institut Pierre-Simon Laplace, France (e-mail: **polcher@lmd.jussieu.fr**).

More general and comprehensive work on air-sea fluxes in the WCRP is led by WGASF. A comprehensive and authoritative assessment of the state of the art in regard to air-sea flux determination in 2000 (published in the WCRP report series, WCRP-112, Intercomparison and Validation of Ocean-Atmosphere Energy Flux fields, also available at http://www.soc.soton.ac.uk/JRDMET/WGASF). This report has proved to be very useful and has been widely appreciated in the interested scientific community. WGASF subsequently organized a major workshop (Washington, DC, May 2001) bringing together the different scientific communities interested in air-sea fluxes to review the Working Group Report and to consider what needed to be done in determining surface fluxes more accurately. The workshop was a considerable success with well over a 100 participants from 15 countries. After an initial keynote address reviewing the WGASF report, sessions at the workshop were devoted to modelling and data assimilation, validation of flux products, flux fields inferred from remote sensing, and flux measurements and parameterizations. Break-out groups then took up the issues of how parameterizations could be refined and measurements necessary, how flux estimates could be validated, and how flux products could be improved in the future. In the area of parameterizations and measurements, the case was made for an airflow distortion experiment involving suitable reference platforms and a research ship with sonic anemometers distributed around the vessel. A flux-profile study over the ocean, a radiation measurement comparison experiment, and coastal ocean studies in carefully chosen, contrasting regions conducted in a standard manner were also proposed. Regarding verification, strong encouragement was expressed for the WGNE "SURFA" project. The importance of developing error estimates for air-sea fluxes and near-surface fields from NWP was stressed, as well as the need to investigate new methods of direct precipitation measurement over the ocean and to expand and improve the on-line catalogue of air-sea flux data sets and their evaluation established by WGASF. Looking to the improvement of flux fields in the future, combination of flux and meteorological products will certainly be required (this will depend on more timely delivery of flux products and including meta data with all flux data sets), detailed studies of error estimates should be undertaken as a means of quantifying and then reducing imbalances in regional estimates in flux climatologies, and parameterizations valid over a wider range of environmental conditions (e.g. low and high winds) should be developed. The planned Global Precipitation Mission was seen as providing an essential step in obtaining higher temporal and spatial resolution fields of atmospheric and ocean basic variables and air-sea fluxes. The full report of the workshop including all the main findings, conclusions and recommendations and extended abstracts of the presentations has been published as WCRP-115, Intercomparison and Validation of Ocean-Atmosphere Flux Fields (and can also be accessed via the web at http://www.soc.soton.ac.uk/JRDMET/WGASF/workshop/report/html).

The JSC/SCOR Working Group on Air-Sea Fluxes formally came to the end of its mandate following the workshop in Washington in May 2001. However, in view of the number of outstanding questions relating to physical air-sea interactions in the WCRP and follow-up required to the work of WGASF, it has recognized that a new WCRP "air-sea interactions" group will need to be established.

5. ATMOSPHERIC MODEL PARAMETERIZATIONS

The GEWEX "modelling and prediction" thrust with which WGNE works in close association is devoting substantial efforts to the refinement of atmospheric model parameterizations, notably those of clouds, land surface processes and soil moisture, and, as a recently commenced activity, the atmospheric boundary layer.

Clouds

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 thrust. This is aiming to achieve a better understanding of the coupled physical processes at work within different types of cloud systems, but the overall emphasis is on determining the effects of cloud acting as systems rather than as individual clouds or the role of individual cloud processes. In GCSS, five different cloud types are now being specifically studied: boundary layer; cirrus extra-tropical layer clouds; precipitating convectively driven cloud systems; polar clouds. In each area, a series of case studies drawing on observations from various field studies is being conducted to evaluate the simulations of cloud-resolving or cloud-system models and the treatment of the relevant processes. Single-column models are also valuable tools particularly in making connections between general circulation models and data collected in the field, thereby facilitating observationally based evaluations of new parameterizations in isolation from the large-scale dynamics. Ultimately, cloud parameterizations must, of course, be tested in full climate simulations or in numerical weather prediction models and the organization of such activity is being considered. Attention is being increasingly given to parameterization development, and assessing new treatments and their performance in single-column or cloud system models. Full details of the scientific issues being addressed in GCSS and the studies carried out or underway are described in the GCSS Science and Implementation Plan (http://www.gewex.com/gcss_sciplan.pdf). A general GCSS meeting is being planned in Canada in May 2002 (jointly with an ARM workshop).

Land-surface processes

Progress is being made in the planning and implementation of the Global Land Atmosphere System Study (GLASS), aiming to encourage the development of a new generation of land-surface schemes for incorporation into general circulation models in support of weather and climate prediction on all time scales. New schemes will, in particular, include biophysical processes and the evolution of vegetation and give increased importance to the horizontal complexity of the surface. To facilitate the range of testing, validation and intercomparison of land-surface schemes required, GLASS has been structured round four main scientific thrusts:

i local-scale/off-line intercomparisons: this is essentially a continuation of the activities initiated by the Project for Intercomparison of Land-surface Parameterization Schemes (PILPS);

ii global-scale/off-line intercomparisons: this builds on the existing Global Soil Wetness Project, using ISLSCP data to drive off-line simulations of soil moisture and its interannual variability over a ten-year period;

(iii) local-scale/coupled intercomparisons: the plan here is to employ a (common) simplified single column model and extend PILPS-type experiments by including coupling with the atmosphere. ARM/CART data will be used as a basis for the experimentation and intercomparisons. This work should help in clarifying the feedbacks between land-surface schemes and the planetary boundary layer, the effect of surface heterogeneities on the planetary boundary layer, and whether the behaviour of land-surface schemes is different in off-line mode to when coupled with the planetary boundary layer;

(iv) global scale/coupled intercomparisons: this aims to assess the role of land surface processes in determining climate sensitivity to anthropogenic forcing, and in climate variability and predictability. The first step being taken is to explore the impact of improved specification of land-surface conditions on short-range forecasts, in particular such aspects as the geographical distribution of the strength of the land-atmosphere feedback, its inter-model variation, and the part played in the predictability of the hydrological cycle.

These scientific thrusts are complemented by work to set up an infrastructure to facilitate GLASS intercomparisons and to help the community involved to move towards standard methods for coupling land-surface schemes to atmospheric models. Standards for data transfer are being specified, the continued availability of data from past experiments ensured, and software for modelling and analysis of land-surface processes distributed. The full GLASS implementation plan contains details of the activities foreseen (http://hydro.iis.u-tokyo.ac.jp/GLASS).

Recent specific work includes simulations of surface hydrology at high latitudes in Sweden, of carbon fluxes over a forested area (in the Netherlands), and, regionally, of the Rhone basin. With regard to studies under (iii) and (iv) above, evidence is mounting that the sensitivity of land-surface models operating in coupled mode is different from that indicated in off-line mode. Thus, for the latter, methods may be needed to provide forcing as if in a coupled application i.e., the effects or feedback from the planetary boundary layer should be included. For thrust (iv), a simplified experiment has been designed and tested to evaluate the feedbacks between the atmosphere and land surface in four different models. The set up is being generalized and expanded to a larger ensemble of models.

Atmospheric boundary layer

The "GEWEX Atmospheric Boundary Layer Study" (GABLS) has the principal objective of improving the representation of the atmospheric boundary layer in general circulation models, based on advancing the understanding of the relevant physical processes involved. GABLS will also provide a framework in which scientists working on boundary layer research issues at different scales can interact. The initial focus of GABLS will be the treatment of the stable atmospheric boundary layer over land, for which understanding and parameterizations are limited. The planning for the work needed will be developed at a workshop at ECMWF, Reading, UK, in March 2002, in which process-oriented experts and large-scale modellers will be brought together.

6. GEWEX CO-ORDINATED ENHANCED OBSERVING PERIOD (CEOP)

An important activity which should provide a wealth of data to enable further extensive testing of atmospheric model parameterizations is the GEWEX Co-ordinated Enhanced Observing Period (CEOP), in which the basic objective is to collect synchronous common data sets from all the regional GEWEX hydrological-atmospheric studies for a period from 2001 to 2003. (The regional studies being undertaken, aiming to characterize energy and water budgets on the scale of continents, include the USA Continental-scale International Project, GCIP; the Baltic Sea Experiment, BALTEX; the GEWEX Asian Monsoon Experiment, GAME; the MacKenzie River GEWEX Study, MAGS; the Large-scale Biosphere-Atmosphere Experiment in Amazonia, LBA. Progress is being made in the organization of an investigation of the Coupling of the Tropical Atmosphere and Hydrological Cycle, CATCH, in the Sahel region of West Africa with the objective of improving predictions of the impact of climate variability on water resources management. Australia is now also starting the "Murray-Darling Basin Water Project"). The primary objectives of CEOP are to:

- document, better understand and improve the simulation and prediction of water and energy fluxes and reservoirs over land for water resource applications
- document the seasonal march of the monsoon systems and better understand their physical driving mechanisms and their possible connection.

A full account of CEOP may be found at: **http://www.gewex.com/ceop.html**.

The plan is to create a database of in situ and remotely-sensed measurements, including those from a number of carefully selected reference stations closely linked to observing sites in the GEWEX hydrological-atmospheric studies as well as model output. A pilot global hydro-climatological data set will be compiled to assess and improve the representation of water and energy cycle processes in global and regional models. This work needs to be closely co-ordinated with WGNE and various NWP and modelling centres to optimise the overall strategy and to determine how best to bring together observational and model data. WGNE is duly working with CEOP to consider how model data, in particular, should be used in practice, and how maximum benefit can be gained from CEOP for operational centres. In this latter respect, the importance of the data collected in CEOP being available in real time was strongly emphasized.

7. REANALYSES

ECMWF

The ambitious and comprehensive 40-year reanalysis project at ECMWF (ERA-40), with support from the European Union, is progressing well. The assembly of a merged data set of conventional observations carried out in collaboration with NCEP and NCAR is complete. A surprisingly large amount of extra data is available compared to the earlier 15-year reanalysis (ERA-15), with, in particular, a significant increase in the number of radiosonde and pilot wind soundings from the NCEP data base. Discussions are also in hand with EUMETSAT regarding the reprocessing of wind products from METEOSAT-2. The reanalysis itself is being undertaken in three streams covering the periods 1987-2001 when TOVS, SSM/I, ERS, ATOVS and CMW data were available, 1972-1988 with VTPR, TOVS and CMW data, and 1957-72 (the pre-satellite era), using a 60-level, T159 forecast model coupled with an ocean-wave model. Nearly seven years of analysis starting from September 1986 have been prepared. Two years of analysis from July 1957 and one year from January 1972 have also been completed, with VTPR radiance data being successfully assimilated towards the end of the latter period. However, serious deficiencies in the analysed hydrological cycle were noted. These have been traced to an error in encoding some of the SYNOP data for the period, and problems with the time assignment of certain radiosonde data used in the assimilations in both the 1950s and 1970s have also been detected. Corrected data sets have been prepared and production has recommenced.

Tests of the assimilation of SBUV and TOMS ozone data have proceeded in parallel, and have given satisfactory results. SBUV and TOMS assimilation was thus added to the production system from January 1991 onwards. Ozone analyses for 1989 and 1990 will be produced off-line. In this connection, the ERA-40 experience has been invaluable in the development of operational assimilation of ozone at ECMWF.

A number of assessments of the ERA-40 analyses for the late 1980s and early 1990s have been made by the partners in the project (from ECMWF Member States and NCAR). In almost all respects, the quality of the ERA-40 analyses appeared to be superior to that of the ERA-15 analyses. The validation studies have identified some deficiencies; the extent of these in the longer time series of analyses that were gradually emerging as production progresses would be carefully assessed.

Comprehensive information on ERA-40, including the current status of production and archiving and monitoring plots can be consulted via **http://wms.ecmwf.int/research/era**.

NCEP

The original NCEP/NCAR reanalysis from 1948 is continuing to be carried forward to the present in a quasi-operational manner (two days after data time) and has now been extended to a total period of nearly fifty-four years. The recent period March 1997-September 2001 has been reanalysed to correct for a modification in the processing of TOVS data. The reanalyses distributed through NCAR, CDC and NCDC are readily available either electronically or on CD-ROM. A joint NCEP/DOE reanalysis (NCEP-2) for the period 1979-1999 has also been produced (available electronically). This was based on an updated forecast model and data assimilation with corrections for many of the problems seen in the original NCEP/NCAR reanalysis and also improved diagnostic outputs. In particular, hourly fields were provided to support the compilation of the International Satellite Land-Surface Climatology Initiative II data set. An additional initiative is the preparation of a regional reanalysis over the USA for the period 1982-2003 (perhaps 1979-2003). This should provide a long-term consistent data set for the North American domain, superior to the global reanalysis in both resolution and accuracy. The regional reanalysis will be based on the Eta model (and the Eta data assimilation system) (with the global reanalysis used as boundary conditions). Important features will be direct assimilation of radiances and assimilation of precipitation (over the USA), as well as recent Eta model developments (refined convective and land-surface parameterizations). A range of data (including all those used in the global reanalysis, various precipitation data sets, TOVS-1B radiances for certain periods, profiler measurements, and lake surface data) has been assembled and some pilot runs carried out. Considerable improvements are apparent in the monthly precipitation fields produced over the contiguous USA, especially in runs where precipitation was assimilated. However, some unrealistically intense episodic precipitation events occurred in the summer period in locations off the Mexican coast (now remedied). The fit to the geopotential heights (as observed by radio-sondes) is also notably better than that of the global reanalysis.

Japan Meteorological Agency (JMA)

An exciting development is the planning of a 25-year reanalysis by JMA (JRA-25) for the period 1979-2004. This will form the basis for a dynamical seasonal prediction project and global warming study, for advanced operational climate monitoring services at JMA, and for various activities in climate-system studies. The reanalysis is a five-year joint initiative of JMA, which is providing the data assimilation expertise and forecast system, and the Central Research Institute of the Electric Power Industry, a private foundation, furnishing the computer resources. A 3DVAR system (operational since September 2001) with a model of resolution of at least T106 and 40 levels in the vertical will be employed. As well as data archived at JMA from 1975 to the present, the NCEP/NCAR data set used in the NCEP reanalysis and the merged ECMWF/NCEP data sets in ERA-40, a range of satellite observations (including reprocessed GMS cloud motion wind data) will be assimilated. The project is expected to be completed by 2005, with the products available to scientific groups contributing to the evaluation of the reanalyses and who provide feedback on improvements that could be made.

8. THE MESOSCALE ALPINE PROGRAMME

The objectives of the Mesoscale Alpine Programme (MAP) are to improve the understanding and prediction of:

- orographically influenced precipitation events and related floods, involving deep convection, frontal precipitation and run-off;
- the life cycle of Föhn-related phenomena, gap flows, gravity-wave breaking and the Alpine wake in general;
- the turbulent boundary layer within Alpine valleys.

The MAP Special Observing Period took place from 7 September to 15 November 1999 with the participation of many European and North American meteorological services and science agencies. In terms of ground systems, MAP was probably one of the largest field experiments ever conducted in Europe. In the special Observing Period of 70 days, there were also seventeen Intensive Observing Periods totalling 42 days. Statistical evaluation has shown that 1999 was a very good year from the perspective of the frequency and distribution of MAP-relevant atmospheric events (all occurred more frequently than expected compared to the average over the last ten years).

Since then, using the data collected, research has been undertaken into a range of scientific topics including:

- orographic precipitation mechanisms involving studies of the small scale dynamics of precipitating systems and their interaction with topography, and of the detailed growth mechanisms of precipitation particles;
- incident upper-tropospheric potential vorticity anomalies ("PV-streamers"), focussing on the dynamics of such anomalies approaching the Alps from the west at tropopause level and their role as precursors of severe precipitation events in the Alps;
- hydrological measurements and flood forecasting, assessing the near-real time forecasting capabilities of hydrological flood models, soil moisture monitoring techniques, the significance of soil moisture initial conditions, and the utility of information on water storage for hydro-electric power companies;
- dynamics of gap flow, investigating the three-dimensional velocity distribution at the Brenner Pass and within the Wipp Valley, its space-time variability in relation to flow above the mountain top, and key questions of stratified fluid dynamics such as the possible formation of a hydraulic jump downstream of the gap;
- non-stationary aspects of the Föhn in a large valley, specifically examining the four-dimensional variability of the Föhn flow in the Rhine valley (upstream of Lake Constance) and the dynamical processes involved, in particular those responsible for the removal of the pool of cold surface air frequently present in the Rhine valley at the onset of Föhn;
- three-dimensional gravity wave breaking, seeking answers to basic questions such as its role in clear-air turbulence, its space-time distribution, the predictability of gravity waves in meso-scale models, the vertical distribution of momentum fluxes in the presence of breaking gravity waves, and the associated potential vorticity generation;
- potential vorticity banners, including examination of the high resolution structure of the Alpine wake at or below mountain-top level, and documenting the existence and cross-stream spatial flow of well-defined potential vorticity banners extending downstream over several hundred kilometers (as suggested in modelling studies);
- structure of the planetary boundary layer over steep orography, including its depth, the three-dimensional distribution of turbulent fluxes within a steep valley, the interaction of boundary layer turbulence and local winds, and the exchange of air mass and atmospheric constituents between the boundary layer and the free atmosphere.

A detailed description of the MAP Special Observing Period and the scientific questions being investigated was published in 2001 in the Bulletin of the American Meteorological Society, 82, 433-461. For further information on the MAP scientific studies and results being found, please contact Dr. P. Bougeault at Centre National de Recherches Météorologiques, Météo-France (e-mail: **philippe.bougeault@meteo.fr**).

9. PERFORMANCE OF THE MAIN GLOBAL OPERATIONAL MODELS

As 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. 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 seven 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.

10. VERIFICATION TECHNIQUES FOR MESO-SCALE MODELS

Whilst rms errors, anomaly correlations, skill scores etc. are objective indicators of large-scale model performance, consideration needs to be given to providing measures for the much higher resolution and/or mesoscale models now increasingly employed and for verifying predictions of weather elements and severe events. Work is now being undertaken in this area for parameters such as quantitative precipitation forecasts (an excellent prototype), two-metre temperature and humidity, ten-metre winds, cloudiness etc. For verification purposes, the basic observational data used are SYNOPs, with data from automatic and climate network stations also increasingly important. Additionally, radar data and high resolution satellite observations have significant potential in this area.

A basic question is how the model should be compared to the observational data. Whilst, currently, a "nearest grid point" or "interpolation from model grid to observation location" approach is common, upscaling techniques are developing rapidly. These latter techniques appear to improve verification scores especially for large grids and when small rainfall amounts are involved. However, there may be difficulties in comparing models with different horizontal resolutions, and a "double penalty effect" may come into play at high resolutions. To avoid this, errors need to be partitioned between displacement, amplitude and pattern, or higher moments of the distribution of parameters computed, or a Fourier decomposition attempted to separate errors in various scales. Another method may be the use of the "observation operators" from variational data assimilation to infer a "synthetic radar reflectivity" or "satellite radiances" from model fields for comparison with observations. In looking at two-metre temperature and humidity and ten-metre winds, additional difficulties arise including the need for altitude corrections, accounting for wind exposure effects, and representivity problems. For models with tile surface schemes, there is the option of using the temperature of the appropriate tile rather than that at the grid-point, but in this case, knowledge of the observation environment is needed (soil, vegetation type etc.).

Other questions arise in connection with the actual scoring method (e.g. percentage correct, Heidke, frequency bias, threat or equitable threat) - all have different advantages and drawbacks which need to be taken into account depending on the parameter and characteristic being verified. Further outstanding points are the requirement to standardize definitions/notation etc., providing the statistical significance of the results, and comparison with known references such as climatology, persistence or chance.

There is general consensus that new methods are needed for the verification of mesoscale models, that there should be enhanced international exchange of the relevant data, and that intercomparison of model scores can be useful if done thoroughly and consistently. WGNE will consider this whole topic in much greater depth at its next session.

11. INTERCOMPARISON OF TYPHOON TRACK FORECASTS

An intercomparison of forecasts of typhoon tracks in the western North Pacific has been conducted by the Japan Meteorological Agency on behalf of WGNE for a number of years. The intercomparison has recently been extended to cover also the North Atlantic and eastern North Pacific regions. The operational centres submitting forecasts now include ECMWF, the Met Office, the Canadian Meteorological Center, Deutscher Wetterdienst, and the Japan Meteorological Agency. Results show considerable variability from year to year and from basin to basin in the distance error of the forecast. A report summarizing the results of the intercomparisons over the period 1991-2000 is being prepared by the Japan Meteorological Agency.

12. THE HEMISPHERIC OBSERVING SYSTEM RESEARCH AND PREDICTABILITY EXPERIMENT (THORpex)

The Hemispheric Observing System Research and Predictability Experiment (THORpex) is being undertaken as a "Research and Development Programme" of the CAS World Weather Research Programme (WWRP) in collaboration with WGNE for numerical experimentation. The themes proposed are of major interest to WGNE, and the studies of predictability and observing system issues being taken up will have benefits throughout the WCRP. THORpex is particularly targetted on the outstanding challenge of the skilful prediction of high impact weather associated primarily with synoptic-scale systems which often contain significant embedded mesoscale features. Activities will include:

- observing system experiments with real and "virtual" observations to determine optimal observing and data assimilation strategies for improved predictions of high impact weather ;
- diagnostic studies of life-cycles of high impact weather systems;
- establishing the relative importance of errors in models and initial conditions on forecasts;
- assessing the potential of advanced ensemble prediction systems to indicate the probability of high impact weather events;
- identifying regions where new observations (in situ or remotely-sensed) would have the greatest impact;
- an ambitious field campaign testing possible enhancements to the operational observing system and providing guidance for the design of permanent and targetted components of the observing system;
- regional field tests to study specific predictability issues and new observing systems;
  determining economic and societal benefits of improved forecasts of high impact weather.

WGNE is strongly supporting THORpex as a collaborative WWRP/WGNE experiment. At the WGNE session, the next steps in the development of THORpex were reviewed in conjunction with the authors of the proposal and the Chair of the CAS Scientific Steering Group for the WWRP (Dr R. Carbone). A focussed science plan will now be prepared, laying out a schedule of activities and resource requirements. To oversee the preparation of the plan and its implementation, an international science committee should be established, to be supported later by an international management committee to secure and guide the use of resources (WGNE will take part in these committees). Bearing in mind the primary goal of forecasting cyclones originating over the ocean and remote continental regions taking advantage of new technologies, targetted observations, and advanced data assimilation methods, it has been suggested that THORpex should initially focus on the North Pacific region, and observing/analysing developing mid-latitude baroclinic waves. This could have an immediate impact on short-range forecasts in North America and medium-range forecasts in Europe. Subsequently, an area for attention should be the western Pacific, to explore tropical cyclone track prediction. The importance of collaboration with the World Weather Watch and other projects requiring sustained observations in remote regions was stressed.

13. VERIFICATION AND COMPARISON OF PRECIPITATION FORECASTS

Several centres represented on WGNE (in particular, BMRC, NCEP and DWD) have been pursuing activities in this long-standing WGNE initiative.

BMRC has been verifying twenty-four and forty-eight hour quantitative precipitation forecasts from eleven operational NWP models for a five-year period against rain gauge observations over Australia in order to assess the skill in predicting the occurrence and amount of daily precipitation. It has been found that quantitative precipitation forecasts have greater skill in mid-latitudes than the tropics where the performance was only marginally better than persistence. The best agreement among models, as well as the greatest ability in discriminating rain areas, occurred for a low rain threshold of 1-2 mm/day. In contrast, the skill for forecasting rain amounts greater than 20 mm/day was generally low, pointing to the difficulty in predicting precisely where and when heavy precipitation may occur. Location errors for rain systems, determined using pattern matching with observations, were typically about 100 km for twenty-four hour forecasts with smaller errors for the heaviest rain systems. Other centres are finding similar results.

Overall, quantitative precipitation forecasts do not appear to have improved significantly over the four to five year period examined. Certainly, as new model versions were introduced, the skill in the various aspects of precipitation forecasting assessed changed - but not always for the better. This finding underlines the complexity of juggling improved model numerical and physical parameterizations. Unless the accurate prediction of rainfall is made a top priority by NWP centres, only slow advances can be expected in the skill of model precipitation forecasts.

The work undertaken is now being written up for publication, and will also be presented at the International Conference on Quantitative Precipitation Forecasts due to be held in Reading, UK in September 2002. WGNE is prominently involved in the organization of this Conference.

14. REGIONAL CLIMATE MODELLING

A joint WGCM/WGNE ad hoc panel was established in 1999 to summarize the current state-of-the-art in the field of regional climate modelling and to take up the questions that have been raised. These included technical items noted by WGNE (choice of domain size, scale dependency of model parameterizations, consistency of simulated energy and water budgets in inner and outer models, the care needed in handling the lateral boundary conditions) as well as aspects such as the limitations imposed by the performance of the global driving model, and the predictability/reproducibility of smaller scales simulated in regional climate models. An initial draft of the report "Atmospheric regional climate models: a multiple purpose tool" prepared by the panel (R. Laprise, University of Québec, Montéral, Canada: convener; R. Jones, Hadley Centre, UK; B. Kirtman, CLOAS, USA; H. von Sotrch, GKSS Research Centre, Germany); W. Wergen, Deutscher Wetterdienst, Germany) has now been produced.

The report points out that there is no doubt that dynamical atmospheric regional climate models (RCMs) have matured over the past decade and now allow (and are used in) a very wide spectrum of applications. At horizontal scales of 300km and larger, simulations are consistent with the nesting (driving) data. At fine spatial and temporal scales, the RCM-simulated patterns of important surface variables, such as precipitation and winds, often have demonstrable skill. However, grid spacing is currently often constrained by computing resources to typically about 50km, which limits the amount of detail available at the finest scales. Future increases in computer power and applications of multiple nesting techniques would be likely to allow increases in resolution to grid spacing of order of 1km (this would require the use of fully non-hydrostatic models and scale-dependent parameterisations).

It is recognised that RCMs have deficiencies and improvements are required. The sensitivity of RCM-simulated results to computational domain size, to the jump in resolution between the nesting data and the RCM, to errors or deficiencies of nesting data, and to nesting techniques, needs further investigation. Moreover, the added value provided by regional modelling should be assessed relative to simpler statistical post-processing of coarse-grid data. An assessment of the performance of an RCM requires climate data on much finer spatial and temporal scales than traditionally used for validating global models. In some regions such data are available but not necessarily easily accessible, and appropriate gridded analyses have not been prepared. Where such data are not available, methods of validation other than comparison with standard climatological variables ought to be developed or applied. The performance of different RCMs should be compared both in their simulation of current climate and in their use as a dynamical downscaling tool to provide high-resolution climate-change information. This is necessary both to guide future developments in regional climate modelling and to contribute to the assessment of uncertainty in regional climate simulations and projections.

The Panel reiterated that the final quality of the results from a nested RCM depended on the realism of the large scales simulated by the driving general circulation model. The reduction of errors, systematic or otherwise, in general circulation models must therefore remain a priority for climate modellers.

The various recommendations made by the Panel included the following points:

i Obviously, all numerical models suffer from various defects and are a reduced image of a considerably more complex reality. In this sense, all models should be made more realistic in very many different ways, but the process of improving models should be guided by the needs of the specific applications.

ii An international RCM workshop should be organised bringing together, not only RCM modellers, but also global climate modellers, diagnosticians and dynamicists, users of RCM results, research managers and funding agencies, under the theme "The added value of Regional Climate Model simulations" in many applications. The Panel suggested holding the workshop during 2003 in the Southern Hemisphere, possibly in Buenos Aires, Argentina, where there was growing community of scientists who could contribute to the essential local arrangements.

iii The assessment of RCM climate simulations continues to be hampered by the lack of high-resolution observed gridded climate data over many regions of the globe. Regional data re-analysis projects using observations from national archives should be encouraged.

iv Long, multi-decadal RCM simulations nested within an ocean-atmosphere model and forced by observed SST could be made to assess RCM skill in reproducing fine-scale features associated with large-scale year-to-year anomalies. This would constitute a "Regional (climate) Model Intercomparison Project", RMIP, analogous to AMIP, for global circulation models. The recently-completed European project MERCURE has delivered such simulations for the European region using three RCMs and could act as a model for such an exercise.

v When intended for climate-change projections, the RCM should be validated in different climate regimes in order to establish their general applicability. It would be valuable to organize a co-ordinated international modelling effort to nest a number of global model-simulated data sets over a few regions. This would be a major undertaking requiring strong international support and convincing funding agencies of the importance of such a project. The new European project Prediction of Regional scenarios and Uncertainty for Defining European Climate-change risks and Effects" (PRUDENCE) which would compare simulations and climate change over Europe from several general circulation models and RCMS could be an important component in such a project.

WGNE welcomed the report and agreed with most of the points that had been made. Other points where it was thought additional discussion was needed are:

- the risk of "blind application" of a regional climate model and the need to educate less experienced users of models and the data produced, in particular advice on the limitations of regional climate model results consequent to the shortcomings in skill of the simulations of the forcing general circulation in representing large-scale circulation features (oscillations, seasonal variability)
- the differing vertical resolution between a regional climate model and the driving general circulation model, and the interpolation (in the vertical) from the outer grid and nested grid
- the role of regional climate models in testing and paving the way for the next generation of high resolution general circulation models and testing model parameterizations (e.g. land-surface schemes)
- the importance of checking conservation properties
- the need to test the regional climate model physics in different "climates"/geographical region
- comparison of model results with a statistical down-scaling approach.

An updated version of the report is now being produced and will be made available through the web. Also, an edited version will probably be submitted as review article in the Bulletin of the American Meteorological Society.

In view of the various outstanding questions and the progress and development continuing to be made, regional climate modelling will certainly continue as an item on the agenda of the annual WGNE session.

15. ACTIVITIES OF THE WCRP WORKING GROUP ON COUPLED MODELLING (WGCM)

The most recent session of the JSC/CLIVAR Working Group on Coupled Modelling (WGCM) was kindly hosted by the new Chair of the group, Dr. J. Mitchell, at his home institution, the Hadley Centre for Climate Prediction and Research, the Met Office, Bracknell, UK, from 4 to 7 February 2002.

WGCM discussed a range of outstanding issues to be addressed in the development of coupled models, drawing from the list of uncertainties and priorities in the IPCC Third Assessment Report and from the experience of members. Among items stressed were:

- improved methods of quantifying uncertainties in climate projections and scenarios, including development and exploration of ensembles of climate simulations;
- increased understanding of the interaction between climate change and natural climate variability;
- the initialization of coupled models;
- the reduction of persistent systematic errors in cloud simulations, sea surface temperature etc.
- the variations in past climate as a tool in understanding the response to climate forcing factors;
- the reasons for different responses in different models;
- improved knowledge of cloud/climate forcing and the direct/indirect effect of aerosols (including refined methodologies for refining the analysis of feedback processes);
- improved simulation of regional climate and extreme events.

With specific regard to climate feedback, as noted in the IPCC Third Assessment Report, "the sign of net cloud feedback is still a matter of uncertainty, and various models exhibit a large spread." New approaches to this long-standing problem are needed, and, in particular, use of analysis methods that are conceptually linear are likely to be inadequate given the complex coupling of energy and water cycles in clouds. WGCM is thus joining with the GEWEX Radiation Panel in the organization of a workshop with the objectives of evaluating current methods for analysing feedbacks and results, identifying the main questions and issues, examining analysis methods from other disciplines and selecting new methods that could be investigated further for application in the climate area. At the same time, WGCM noted and encouraged other work aimed at evaluating cloud feedback, including improved methods of evaluating model clouds against satellite data, and techniques to separate dynamically and non-dynamically forced cloud changes that have picked out aspects of observed cloud variation which may be useful proxies for cloud feedbacks in a changed climate. WGCM is also continuing its climate sensitivity studies, now focussed on a systematic intercomparison of cloud feedbacks as simulated in models with ISCCP data, and in a slab ocean experiments (with 1 x CO_2 and 2 x CO_2).

The Coupled Model Intercomparison Project (CMIP) is one of the most important and long-standing initiatives of WGCM, having been started in 1995. There are now three components: CMIP1 to collect and document features of global coupled model simulations of present-day climate (control-runs); CMIP2 to document features of control runs and climate sensitivity experiments with CO_2 increasing at 1% per year; CMIP2+, as CMIP2, but all fields, all data, monthly means and some daily data are being collected. The range of extra fields at higher temporal resolution being assembled in CMIP2+ (compared to the limited fields, time-averaged blocks, monthly mean time series in CMIP1 and CMIP2) is enabling in-depth study of many additional aspects of coupled model simulations (e.g. feedback mechanisms, ocean processes, why different models have different responses, higher frequency phenomena). A complete list of the diagnostic sub-projects being undertaken can be consulted at http://www-pcmdi.llnl.gov/cmip. As well as the publication by individual authors of sub-project results, the IPCC Third Assessment Report drew substantially on several CMIP sub-projects, and included an analysis of CMIP models. A workshop to review results of CMIP is being planned for late in 2003. Subsequently, a new phase of CMIP, again in the form of a specified standard experiment, will be organized. This will be supplemented by separate co-ordinated "sensitivity" experiments, including in particular experiments designed to throw light on mechanisms which may play a part in ocean-atmosphere variability and predictability on decadal timescales.

As a manifestation of the increasing co-operation in global change research, WGCM is now working closely with the IGBP Global Analysis, Integration and Modelling (GAIM) element of IGBP, including especially the planning of the "Coupled Carbon Cycle Climate Model Intercomparison Project" (C4MIP). In the first phase, interested groups are being invited to undertake a historical land-atmosphere experiment with global models having full coupling between radiation, biogeochemical cycles and carbon dioxide with specified sea surface temperature forcing, carbon dioxide emissions, and land-use change. Key diagnostics will include the model-predicted carbon dioxide fluxes and concentrations. Growing interactions between WGCM and GAIM are foreseen in the task of developing the comprehensive Earth system models that will be needed. To this end, it is hoped that the next session of the two groups will be held jointly and that, in 2003, a joint workshop on Earth system modelling will be held.

(Kamal Puri)
Chairman, WGNE

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Vladimir Penenko and Elena Tsvetova	Russia	01-48	Variational Fast Data Assimilation Algorithms
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Paul Poli and Joanna Joiner	USA	01-51	Assimilation Experiments with GPS/MET Refractivity
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Yoshiaki Takeuchi and Tadashi Tsuyuki	Japan	01-59	The operational 3D-Var assimilation system of JMA for the Global Spectrum Model and the Typhoon Model
Kyuichiro Tamiya	Japan	01-61	Imposing penalty both on gravity and Rossby modes in the Variational Initialization
Maria Tomassini and Christoph Schraff	Germany	01-63	Assimilation of Integrated Water Vapour from Ground-Based GPS Observations at DWD
V.I. Tsvetkov, O.V. Snopova and I. A. Rozinkina	Russia	01-65	Using of the Chebyshev-Laguerre Polynomials for Representing the Vertical Structure of the Atmosphere
Mikhail D. Tsyroulnikov, M. A. Tolstykh, A. N. Bagrov, R. B. Zaripov	Russia	01-67	Development of a variable-resolution global data assimilation system
William Lahoz, Ivanka Stajner, and Richard Swinbank	UK	01-69	SPARC Data Assimilation Working Group

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Ross D. Brown and Bruce Brasnett	Canada	02-01	Development of a Gridded North American Monthly Snow Depth and Snow Water Equivalent Dataset for GCM Validation
Craig Burke, Ian Simmonds and Kevin Keay	Australia	02-03	Seasonal features of Arctic synoptic activity
Irina V. Chernykh and Oleg A. Alduchov	Russia	02-05	Detection of Cloudiness from Temperature and Humidity Profiles for Different Resolution of Radiosonde Sounding by Various Methods
Martin Goeber, S.F. Milton and C. A. Wilson	United Kingdom	02-07	WGNE assessment of Quantitative Precipitation Forecasts from Operational Numerical Weather Prediction Models over the U.K.
Christopher Grassotti, Ross Hoffman, Enrique Vivoni and Dara Entekhabi	USA	02-09	Intercomparison of Radar and Rain Gauge Observations over the Arkansas-Red River Basin

K. A. Hilburn, M. A. Bourassa and J. J. O'Brien	USA	02-11	Development of Scatterometer-Derived Research Quality Surface Pressure Fields for the Southern Ocean
Vladislav N. Ivanov and Anna V. Khoklova	Russia	02-13	On the Features in the Spectra of Meteorological Variables in Wide Band of Frequencies
Vladislav N. Ivanov and Anna V. Khoklova	Russia	02-15	On The Modulation of Diurnal Modes of Meteorological Variables by Low-Frequency Processes
I.I. Mokhov, V.A. Bezverkhny and A. A. Karpenko	Russia	02-17	Mutual dynamics of atmospheric components and climatic characteristics during last 420,000 years from Vostok ice core
Malaquias Peña, Eugenia Kalnay and Ming Cai	USA	02-19	The life span of intraseasonal atmospheric anomalies: dependence on the phase relationship with the ocean.
E.V. Perekhodtseva	Russia	02-21	Hydrodinamical-statistical model of forecast to 36 hours ahead of dangerous convective daytime and nighttime phenomena - squalls, tornadoes and rainfalls
Ryan J. Sharp, Mark A. Bourassa, James O'Brien, Kristina B. Katsaros and E. B. Forde	USA	02-23	Early Detection of Tropical Cyclones Using Seawinds-Derived Vorticity for the 2001 Hurricane Season
Ian Simmonds and Kevin Keay	Australia	02-25	Trends in mechanical energy input into the Northern Hemisphere oceans
Charles E. Tilburg and James J. O Brien	USA	02-27	A comparison of climatic wind and sea surface temperature data sets using a numerical model
Kevin E. Trenberth, David P. Stepaniak and Julie M. Caron	USA	02-29	Accuracy of atmospheric energy budgets

3. Computational studies including new techniques, the effect of varying model resolution, parallel processing

Pierre Bénard, Josef Vivoda, Petra Smolikova and Jan Masek	France	03-01	Theoretical examination of semi-implicit time-scheme for nonhydrostatic NWP
Mike Cullen and Deborah Salmon	United Kingdom	03-03	Use of a predictor-corrector scheme to couple the dynamics and physics in the IFS model
Mike Cullen	United Kingdom	03-05	Use of a potential vorticity as a control variable in a 4DVAR assimilation system.
Almut Gassmann	Germany	03-07	A two timelevel integration scheme for the nonhydrostatic Lokal-Model (LM) of DWD
Keiichi Katayama	Japan	03-09	Development of an Ultra High Resolution Global NWP Model
Chiaki Kobayashi and Masato Sugi	Japan	03-11	Comparison of the model climate of various horizontal-resolution
Humphrey Lean and Peter Clark	United Kingdom	03-13	Horizontal and Vertical Resolution Dependence of the Representation of a Rapidly Developing Extratropical Cyclone in a Mesoscale Model
John McGregor, Kim Nguyen and Jack J. Katzfey	Australia	03-15	Regional climate simulations using a stretched-grid global model
John McGregor	Australia	03-17	RMIP simulations with the conformal-cubic model
Vicky Pope and R A Stratton	United Kingdom	03-19	Should we expect climate models to converge when we increase resolution?
Kazuo Saito	Japan	03-21	Time-splitting of gravity waves in the Meteorological Research Institute/Numerical Prediction Division unified Nonhydrostatic Model
Fredrick Semazzi, George Pouliot and Jeffrey Scroggs	USA	03-23	A Global Nonhydrostatic Semi-Implicit Semi-Lagrangian Variable Resolution Atmospheric Model

A. Untch and M. Hortal	United Kingdom	03-25	A finite-element scheme for the vertical discretization in the semi-Lagrangian version of the ECMWF forecast model

4. Parameterization of important atmospheric and surface processes, effects of different parameterizations

I. V. Akimov	Russia	04-01	Calculation of the average melting rate of precipitation particles.
Stéphane Bélair, Jocelyn Mailhot, Louis-Philippe Crevier and Bernard Bilodeau	Canada	04-03	Operational Implementation Of the ISBA Land Surface Scheme in the Canadian Regional Forecast Model
Eric Bazile, M. ElHaiti, A. Bogatchev and V. Spiridonov	France	04-05	Developments on the snow parameterization in ARPEGE
L. R. Dmitrieva-Arrago and E. V. Anisimova	Russia	04-07	On the cloud amount parameterization
G. Doms, D. Majewski, A. Müller and B. Ritter	Germany	04-09	First validation of the prognostic cloud ice scheme in the global model GME
Erdmann Heise and Reinhold Schrodin	Germany	04-11	A multi-layer soil model including freezing/melting processes
Edgar Herrera and René Laprise	Canada	04-13	Evaluation of a mass-flux convection scheme for mesoscale atmospheric models
Hiroto Kitagawa and Syoukichi Yabu	Japan	04-15	Impact of a Revised Parameterization of Cloud Radiative Forcings on Earth's Radiation Budgets Simulation
Gueorgui V. Mostovoi, Pat J. Fitzpatrick and Yongsuo Li	USA	04-17	Correction of a Surface Wind Speed due to Surface Averaging
David Noone, Christopher Still and William Riley	USA	04-19	A Global Biophysical Model of ^{18}O in Terrestrial Water and CO_2 Fluxes
Jean-Marcel Piriou	France	04-21	Diurnal cycle of tropical deep convection: a diagnostic study in ARPEGE
Matthias Raschendorfer and Dmitrii Mironov	Germany	04-23	Operational implementation of the new turbulence parameterization
Bent H. Sass and Claus Petersen	Denmark	04-25	Very short range atmospheric forecasts using a nudging procedure to combine analyses of cloud related variables with a numerical forecast model
Volf Shnaydman	USA	04-27	Two-equation turbulence closure for quantitative description of boundary layers
Mitsuru Ueno and Jun Yoshimura	Japan	04-29	Impact of physical processes in a GCM on the frequency of tropical cyclones

5. Development of and studies with regional and smaller-scale atmospheric models

L.V. Berkovich, Yu.V. Tkacheva and V. A. Shnaydman	Russia	05-01	Weather forecasting of meteorological variables for Moscow and Moscow Region
Noel E. Davidson and Gordon E. Jackson	Australia	05-03	The Australian Tropical Cyclone Limited Area Prediction System
Ramon de Elia, René Laprise and Bertrand Denis	Canada	05-05	Short-Term Downscaling with a Limited-Area Model: Diagnostic Verification in a Perfect-Model Approach
Hisaki Eito, Teruyuki Kato and Masanori Yoshizaki	Japan	05-07	Numerical Simulation of Heavy Snowfall Systems Observed on the Southern Coastal Area of Sea of Japan on 16 January 2001
Pat J. Fitzpatrick, Gueorgui V. Mostovoi and Yongzuo Li	USA	05-09	MM5 10-M Wind Direction Forecast Skill Over Bay of Bengal During Spring 2001

6. Developments in global forecast models, case studies, predictability investigations, ensemble forecasting monthly and seasonal forecasting

T.S.V. Vijaya Kumar, T.N. Krishnamurti, Mike Fiorino and Masahi Nagata	USA	06-07	Multimodel Superensemble Forecasting of Tropical Cyclones in the Pacific
Masayuki Kyouda	Japan	06-11	The Ensemble Prediction System for Medium-Range Weather Forecasting at JMA
Sujata K. Mandke and V. Satyan	India	06-13	Simulation of monsoon disturbances during summer monsoon 1997 in an AGCM
S.F. Milton, G.T. Greed, D. R. Cameron, I. D. Culverwell, J.T. Heming and Dingmin Li	United Kingdom	06-15	Pre-Operational trials of the new Met Office Global NWP Model
Jean Nicolau	France	06-17	Short Range Ensemble Forecasting at Météo-France : a preliminary study
Yury A. Pichugin	Russia	06-19	Spectrum of Linearized Operator of Atmospheric Circulation Hydrodynamic Model: Method of Evaluation and Applications
Adam A. Scaife, Richard Swinbank, Terry Davies and Rachel Stratton	United Kingdom	06-21	Extended configuration of the Met Office Unified Model
Siegfried D. Schubert, Max J. Suarez and Philip J. Pegion	USA	06-23	Simulations of Long-Term Drought in the United States Great Plains
D. W. Shin, S. Cocke and T. E. LaRow	USA	06-25	Superensemble Precipitation Forecasts using TRMM and DMSP Satellite Microwave Imager Products
Wontae Yun, T. N. Krishnamurti and T. S. V. Vijaya Kumar	USA	06-27	Improvement of Long-Term Forecasts Using Multi-Model Superensemble Technique

7. Global and regional climate models, sensitivity and impact experiments, response to external forcing

Kläre Cassirer, Klaus Fraedrich, Heiko Jansen, Wolfgang Joppich, Michael Kürschner, Edilbert Kirk, Marc Lob, Ute Luksch, Frank Lunkeit, Lars Pesch, Sabine Pott, Michael Preuhs, Ulrich Trottenberg	Germany	07-01	Development of a Modular Interactive Planet Simulator
Michel Déqué and A. L. Gibelin	France	07-04	High versus Variable Resolution in Climate Modelling
Leticia Hernandez Diaz and René Laprise	Canada	07-06	Energetics of African Easterly Waves using the Canadian Regional Climate Model (CRCM): A first approach
Manon Faucher, Daniel Caya, François Saucier and René Laprise	Canada	07-09	Interaction between atmosphere and ocean-ice regional models over the Gulf of St- Lawrence area (Canada)
Anne Frigon, Michel Slivitzky and Daniel Caya	Canada	07-11	Investigation of hydrology simulated by the Canadian Regional Climate Model over Québec and Labrador.
Congbin Fu, C.B. Fu, W. Gutowski, H. Kato, J.W. Kim, D.K. Lee, J. McGregor, Y. Sato, B.,K. Su, S. Y. Wang and Z. Xiong	China	07-13	Regional Climate Model Inter-comparison Project for Asia
Deborah E. Hanley, Shrikant Jagtap, Timothy E. Larow, James W. Jones, Steve Cocke, David Zierden and James J. O'Brien	USA	07-17	The Linkage of Regional Climate Models to Crop Models
R.S. Harwood, I.A. MacKenzie, and D.S. Stevenson	United Kingdom	07-19	Chemistry and Climate Studies with the Met. Office Unified Model

Vyacheslav Ch. Khon	Russia	07-21	Analysis of water cycle changes in Siberian rivers basins in XX and XXI centuries from model simulations
Dmitry V. Khvorostiyanov	Russia	07-23	Modeling the Variations of the North Atlantic Oscillation under Anthropogenic Scenarios
Akio Kitoh, Manabe Abe and Tetsuzo Yasunari	Japan	07-25	Effect of mountain uplift on warm pool: a study with the new MRI coupled GCM
Timothy E. LaRow and Steven Cocke	USA	07-27	Multi-Convection as a Multi-Model Proxy for Climate Studies
Philippe Lucas-Picher, Vivek K. Arora, Daniel Caya and René Laprise	Canada	07-29	Incorporating river routing in the Canadian Regional Climate Model
I.I. Mokhov, J.-L. Dufresne, V. Ch. Khon, H. Le Treut and V.A. Tikhonov	Russia	07-31	Regional regimes with drought and extreme wet conditions: Possible changes in XXI century from IPSL-CM2 simulations
Dominique Paquin and Daniel Caya	Canada	07-33	Dealing with atmospheric water in a nested RCM
V.P. Parkhomenko	Russia	07-35	Statistical Analysis of Interannual Arctic Sea Ice Modeling.
Edouard Kamdem Penlap and Christoph Matulla	Germany	07-37	Assessing the performance of statistical downscaling setups in Cameroon
Sébastien Riette and Daniel Caya	Canada	07-39	Sensitivity of short simulations to the various parameters in the new CRCM spectral nudging
Oliver Stenzel and Jin-Song von Storch	Germany	07-41	Modelling of Atmospheric Angular Momentum in a simple AGCM
Sebastian Wagner	Germany	07-43	Climate Variability within the climate model ECHO-G during the Dalton Minimum
Richard Wardle and Ian Simmonds	Australia	07-45	Reconstructing Australian environments of the last glacial cycle through quantitative modelling
Bin Yu and George J. Boer	Canada	07-47	Surface Temperature and Heat Flux Variability and their Changes with Global Warming

8. Development of and advances in ocean modelling and data assimilation, sea-ice modelling, wave modelling

A. A. DEO, D. W.Ganer and P. S. Salvekar	India	08-01	Ocean mixed layer response to the tropical cyclone moving in different directions in the south Indian Ocean.
Saleh Abdalla and Peter Janssen	United Kingdom	08-03	The Use of Wind Gustiness and Air Density in Wave Modelling: Implementation at ECMWF
Saleh Abdalla and Luigi Cavaleri	United Kingdom	08-05	The Use of Wind Gustiness and Air Density in Wave Modelling: Impact and Implications
A. A. Androsov, A. V. Nekracov, D. A. Romanenkov and N. E. Voltzinger	Russia	08-07	Simulation of the Red Sea Tides
Mike Bell, A. Hines, P. Holland, M. J. Martin, M. E. McCulloch and D. Storkey	United Kingdom	08-09	The Forecasting Ocean Assimilation Model (FOAM) System
Mike Bell, A. Hines and M. J. Martin	United Kingdom	08-11	Developments to the Data Assimilation Methods used by the Forecasting Ocean Assimilation Model (FOAM) System
D. W. Ganer, A. A. Deo, P. S. Salvekar and K. Annapurnaiah	India	08-13	Impact of Different suface winds on SST in the north Indian Ocean
Naoyuki Hasegawa	Japan	08-15	Development of a High Resolution Ocean Model for ENSO Forecasting

Steven L. Morey, Mark A. Bourassa, Xujing Jia, James O'Brien and Jorge Zavala-Hidalgo	USA	08-18	Impacts of Satellite Scatterometer - Derived Wind Forcing on the West Florida Shelf Ocean Circulation
Arnt Pfizenmayer and Reiner Schnur	Germany	08-20	A conditional first-order autoregressive wave-generator
Arkadiy S. Safray and Igor V. Tkatchenko	Russia	08-21	Numerical Investigation of the Internal-Wave Transformation During Expansion of the Deep Water from the Open Sea to the Shelf by M2 Tidal Forcing
Simon Senneville, François J. Saucier, P. Gachon, R. Laprise and Daniel Caya	Canada	08-23	Development of a Coupled Ice-Ocean Model of Hudson Bay
Volf Shnaydman and A.G. Tarnopolskiy	USA	08-25	Hydrodynamic modeling the coastal surface currents for the water pollution problems.
J. Staneva, M. Wenzel and J. Schröter	Germany	08-27	Oceanic State During 1993-1999 Determined by 4-D Var Data Assimilation
Akiyoshi Wada	Japan	08-29	Improvement Of SST Prediction by Diurnal Cycling Algorithm in the MRI Mixed Layer Ocean Model
Jorge Zavala-Hidalgo, Steven L. Morey and James J. O'Brien	USA	08-31	A Numerical Study of the Circulation on the Western Shelf of the Gulf of Mexico

9. Development of and studies with coupled ocean-atmosphere models

Ming Cai and Eugenia Kalnay	USA	09-01	Coupled ENSO instabilities derived with breeding
Ralf Döscher, Ulrika Willén, Colin Jones, Anna Rutgersoon, H.E. Markus Meier, Ulf Hansson and Phil Graham	Sweden	09-03	On the coupling of a 3D Baltic Sea model to a regional atmospheric model
Jeff Knight, Rob Allan, Chris Folland and Michael Vellinga	United Kingdom	09-05	An Assessment of Natural Variations in the Thermohaline Circulation and Climate Using a 1400 Year Coupled Model Calculation
I.I. Mokhov, J.-L. Dufresne, V. Ch. Khon, H. LeTreut and V.A. Tikhonov	France	09-06	Regional regimes with drought and extreme wet conditions: Possible changes in XXI century from IPSL-CM2 simulations
Harold Ritchie, Pierre Pellerin and Serge Desjardins	Canada	09-08	Recent Developments in RPN Coupled Numerical Modelling
Akiyoshi Wada and Hiroshi Mino	Japan	09-10	Implementation of the JMA Typhoon Model Coupled with the Mixed Layer Ocean Model and its Application for Typhoon Bilis

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