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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 welcomed. 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.

The web-based publication is now well established and most contributions were submitted through the web site www.cmc.ec.gc.ca/rpn/wgne and a few still as an attachment to an e-mail message. Overall the electronic submissions are working well, thanks to Djamel Bouhemhem and Inès Ng Kam Chan, and make possible the production of this report on the web site. I would like to thank Yves Chartier who has been instrumental in setting it up. About 200 copies have also been printed in black and white and mailed directly from Montreal.

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

The JSC/CAS Working Group on Numerical Experimentation (WGNE) has the central responsibility in the WCRP for the development of the atmospheric component of climate models and, together with the Working Group on Coupled Modelling (WGCM), lies at the core of the climate modelling effort in WCRP. Close co-ordination is duly maintained between WGNE and WGCM. Furthermore, WGNE works in 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 the "GEWEX Modelling and Prediction Panel". Liaison is also maintained with the SPARC "GRIPS" project (focussed on the intercomparison of model stratospheric simulations) and will be developed with the new SPARC initiative on stratospheric data assimilation.

WGNE additionally has an important role in support of the WMO Commission for Atmospheric Sciences (CAS) in reviewing the development of atmospheric models for use in weather prediction on all timescales. The close relationship between WGNE and operational (NWP) centres by virtue of the CAS connection underpins many aspects of WGNE work and provides a strong impetus for the refinement of the atmospheric component of climate models. WGNE sessions duly include reviews 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. A particularly strong area of collaboration is in the planning and development of THORPEX: A Global Atmospheric Research Programme.

The following paragraphs review the main activities of WGNE in support of WCRP objectives, emphasising items arising at its twentieth session which was kindly hosted by the Met Office, Exeter, U.K., from 11 to 15 October 2004.

1. WGNE in the context of COPES

The Chair of the JSC made a brief presentation on '' future directions of the WCRP including the Coordinated Observation and Prediction of the Earth System (COPES)''. A COPES discussion document has been prepared and was being circulated widely for comments. It was emphasised that COPES is a strategy or framework and not a project, and work will be done through existing projects. As part of the structural changes necessitated by COPES, a WCRP Modelling Panel (WMP), and a WCRP Observations and Assimilation Panel (WOAP) have been set up, overseen by the JSC. The Chair of the WMP briefed WGNE about the aim and scope of this new Panel. To build on the strengths of existing projects, the WMP will involve the Chairs of all projects. To facilitate the coordination and interaction of WGNE and WGCM under the WMP, this would meet in conjunction with WGCM and WGNE in alternative years, starting with WGCM in 2005. It was also agreed that WGNE would in future have an explicit agenda item on the development of next generation atmospheric models.

Concern was expressed that the WOAP did not appear to have sufficient representation of data assimilation experts and it was agreed that this concern would be conveyed to the WOAP Chair.

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

2. Studies and comparisons of atmospheric model simulations

Model intercomparison exercises are a key element in meeting a basic WGNE objective of identifying errors in atmospheric models and reducing or eliminating them.

Atmospheric Model Intercomparison Project

The Atmospheric Model Intercomparison Project (AMIP), conducted by the Programme for Climate Model Diagnosis and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory, USA, with the support of the US Department of Energy has been an important and far-reaching WGNE-sponsored intercomparison. The second phase of AMIP (AMIP-II) is coming to a close and much of the data from these runs are available for a wide range of diagnostic sub-projects. Climatological comparisons are available for nearly every standard AMIP model output field. Overall, there have been progressive general improvements both in terms of the "median" model as well as for many of the individual models. The simulation of interannual variability and performance in specific geographical regions, as measured by global climatological statistics, also appear to be more realistic. Regular updates of the overall status of AMIP, model integrations, diagnostic subprojects are posted on the AMIP home page **http://www-pcmdi.llnl.gov/amip**.

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

"Transpose" AMIP

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

Results were presented from the NCAR/PCMDI project, CAPT, the prototype version of "Transpose" AMIP developed for US modelling evaluation. These results demonstrate the viability and utility of this forecast approach for examining climate models and identifying avenues for improvement. It was agreed that WGNE would make a formal proposal to the international climate modelling community (including the AMIP mailing list) for an intercomparison Transpose AMIP.

Aqua-Planet Experiments

WGNE has endorsed an intercomparison, the Aqua-Planet Experiment (APE), being led by staff from the University of Reading, NCAR and PCMDI. The details of the experiment and schedule are available at http://www- pcmdi.llnl.gov/projects/amip/ape/index.html and http://www.met.reading.ac.uk/~mike/APE/ape_home.html .The experiment is designed to provide a benchmark of current model behavior and to stimulate research to understand of differences arising from: (1) different models, (2) different subgrid-scale parameterization suites, (3) different dynamical cores, and (4) different methods of coupling. Sixteen groups have declared their intentions to participate. Some preliminary results were shown to WGNE which indicate a substantial spread in results with notably large variations in precipitation amounts. A Workshop will be held to discuss the results, summarize current model behaviour and produce a summary of research questions arising from the experiment.

Model-derived estimates of ocean-atmosphere fluxes

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

Regional Climate Modelling

The Chairman of the WGNE/WGCM RCM panel briefed WGNE about the joint WGNE/WGCM international Workshop, 'High-resolution climate modelling: Assessment, added value and applications' held in Lund, Sweden, 29 March to 2 April 2004. The Workshop focussed on the application of nested, limited-area models (LAM) for regional-scale climate simulations and climate-change projections. Among the recurring themes at the Workshop were the validation procedure and the identification of the added value beyond the simple increase in resolution. The relative merits and limitations of various approaches used for achieving high-resolution climate simulations (such as time slices of high-resolution GCM, variable-resolution GCM, LAM) and the ensuing climate-change impact analyses were also discussed. The Workshop was the forum for several proposals for collaborative endeavour which included: (i) an inter-comparison project of regional-scale climate-change projections for North America, NARCCAP, (ii) a "Transferability Working Group" (TWG, and (iii) a coordinated project exploiting the protocol of the "Big-Brother Experiment" (BBE). An electronic version of the Workshop proceedings is available from http://www.natgeo.lu.se/Lars.barring/RCMworkshop/RCMhome.htm.

WGNE also discussed results from SGMIP (Stretched Grid Model Intercomparison Project) noted that this was a very promising approach to higher resolution regional simulations. It will continue to monitor the developments in this area in its future sessions.

Stratospheric analyses and forecasts

Following a presentation by the SPARC Co-chair it was agreed to increase interactions between WGNE and SPARC including the establishment of agreed sets of model diagnostics. WGNE has already undertaken an intercomparison of stratospheric analyses and forecasts from a number of operational (NWP) models and a report is being prepared for publication.

SnowMIP2

A new Intercomparison of Forest Snow Process Models, (SnowMIP2) is being launched. The Working group commissioned by ICSI has drawn up a schedule of activities for the period 2004-2007. Three SnowMIP2 sites in Canada, Japan and Switzerland will be used, with simulations for forest and clearing at each site, simulations for two complete winters at each site, a pilot study with one model, and comparisons with ground and canopy snow loads. Both WGNE and GMPP endorsed the proposal.

3. Physical parameterizations in models

The GEWEX "modelling and prediction" thrust, with which WGNE works in close association, is devoting efforts to the refinement of atmospheric model parameterizations, notably those of cloud and radiation, land surface processes and soil moisture, and the atmospheric boundary layer. The discussion at the joint meeting of WGNE and GMPP, encompassing the

GEWEX Cloud System Study (GCSS), the Global Land-Atmosphere System Study (GLASS), the GEWEX Atmospheric Boundary Layer Study (GABLS), and the progress of CEOP is described in the report of the GEWEX Scientific Steering Group to the JSC.

Collaboration with WGNE in the related activities of land data assimilation, and reanalyses was discussed, and WGNE confirmed the value of the interaction with GMPP for parameterization work, particularly with GCSS. GMPP also considered that close interaction with AMIP is highly desirable. The analysis of the diurnal cycle in AMIP models will reinforce this. A special session on parameterizations is planned during the GEWEX SSG session in 2005.

A new GCSS Panel has been constituted, and a pan-GCSS meeting will be held in May 2005 in Athens. This will address clouds in the climate system, methodologies and metrics in assessing models, the fundamental role of precipitation in cloud systems, and advances in the representation of clouds in large-scale models. A joint WGNE/GCSS model intercomparison study of a Pacific cross section was proposed to evaluate physical parameterizations along the atmospheric cross section following the trade winds.

WGNE responded positively to this proposal and also suggested that there be a follow up exercise over continents. WGNE also proposed that participants for the study should include the AMIP community and that the proposal provides an excellent opportunity to bring together NWP and climate modellers.

The WGNE community provides comprehensive gridded output from global data assimilation systems for CEOP. Many modeling groups are utilizing CEOP data in research and development activities and this should lead to model intercomparisons during the CEOP period.

4. Re- analysis and data assimilation

Reanalysis projects

The ERA-40 reanalysis at ECMWF is complete and experimentation in preparation for the "interim reanalysis" has begun. This will run at least from 1989 onwards, with production beginning in 2005. The set of medium-range forecasts run twice daily from the ERA-40 reanalyses has been completed, and an "AMIP-style" simulation carried out for the ERA-40 period using the ERA-40 model and distributions of sea-surface temperature and sea ice. The ERA-40 publication series now comprises around 20 reports covering documentation of the data and of the data-assimilation system and its performance, and results from users of the ERA-40 data. The reports are available on-line for outside users (http://www.ecmwf.int/publications/library/do/references/list/192). A comprehensive atlas of the atmospheric general circulation as depicted by ERA-40 is being produced in collaboration with the Meteorology Department of the University of Reading.

The Japanese 25-year Reanalysis Project (JRA-25, 1979-2004) is now well in progress. Performance of JRA-25 is compared with other reanalyses in reference to precipitation data produced by CMAP. The JRA does not show the known problems of excessive tropical ocean precipitation seen in ERA-40. In general, precipitation in JRA-25 has much higher correlation with precipitation in CMAP than ERA-40 and NCEP reanalysis.

WGNE reiterated its strong support for the reanalysis efforts and the desirability of having a dedicated 'Reanalysis Centre' at a major NWP operational centre.

Earth System assimilation

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

5. Numerical weather prediction topics

Model developments

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

Unified forecast systems

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

THORPEX: A Global Atmospheric Research Programme

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

Model Verification

There are a number of WGNE projects involved with the validation of deterministic forecasts. These include the compilation of the so-called WMO scores, verification of quantitative precipitation forecasts, validation of tropical cyclone tracks and verification of stratospheric analysis and forecasts. There has also been the recognition that with increasingly high resolution models, there is urgent need to move forward from the basic validation methods that have been used so far.

Verification is of considerable importance for both WGNE and WWRP and following the formation of the joint (WWRP/WGNE) Working Group on Verification (JWGV). It has held two meetings during the past year. The JWGV organized and held an International Workshop on Verification Methods, with sponsorship from the WWRP/SSC and WGNE, as well as the Meteorological Service of Canada (MSC). A number of important issues and new developments were discussed including the development of methods to verify high resolution spatial forecasts; verification methods for rare events; incorporation of scaling methods into verification processes; approaches to account for observational uncertainty in verification measures and analyses; development of methods that are customer dependent and appropriate for studies of forecast value; and verification of probability distribution functions. The workshop program and abstracts can be linked from http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/verif_web_page.html; presentations will be posted there as well.

Following a request from the WGNE, the JWGV has prepared a set of recommendations for the verification and intercomparison of QPFs from operational NWP models. This first report focuses on deterministic forecasts; a future one will outline methods for probabilistic/ensemble forecasts. The JWGV verification web page and verification discussion group, continue to be an important focus, with the web page gradually being enhanced as new FAQs and other information pages are prepared. The JWGV is interested in collaborations with other WMO verification projects and groups. A new plan for the coming year is to prepare and make available “canonical” forecast and observation datasets that can be used to evaluate and compare the capabilities of different or new verification methodologies.

6. Workshops

In collaboration with other WMO Working Groups the following International Workshops have been held in 2004:

- The WGNE/WGCM Workshop, “High-resolution climate modelling: Assessment, Added value and Applications”, Lund, March 29 - April 2
- The WGNE/WGSIP/WGCM Workshop on Ensemble Methods: From weather forecasting to climate change’, Exeter, 18 – 21 October
- The WWRP/ WGNE Workshop on Verification, Montreal, 13-17 September

There will also be an Aqua-Planet intercomparison Workshop, Reading, UK, in April 20-22 2005.

Martin Miller

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Chairman,WGNE

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