

The diurnal cycle : a theme for GMPP

Jan Polcher, Paul Dirmeyer, Peter Gleckler, Bert Holtslag, Steve Krueger

August 11, 2003

The GEWEX Modelling and Prediction Panel (GMPP) was founded some 3 years ago to coordinate groups working on the numerical representation of key aspects of the water and energy exchanges in the atmosphere and over continents. The fields covered are : cloud processes with the GEWEX Cloud System Study (GCSS), land surface processes with the Global Land/Atmosphere System Study (GLASS) and the planetary boundary layers with the GEWEX Atmospheric Boundary Layer Study (GABLS). Although these groups deal with different processes in the system, their common aim is to improve the representation of the energy and water cycles in large scale models using similar methodologies. In all cases we deal with macroscopic processes for which physics only proposes microscopic theories. The macroscopic interpretation of the physical laws known at the molecular level is not unique and as a consequence GMPP will always be faced with a large variety of models. They will differ in the scales which are explicitly represented and those which are treated by conceptual representations of varying complexity.

All three GMPP groups have learned to take advantage of the diversity of models and have made substantial progress in the understanding of the various conceptual representations by performing model inter-comparisons. These comparisons have occurred at locations with sufficient data to ensure validation, or where phenomena occur which were believed to be poorly represented by the models. In all cases the comparisons involved models designed to represent a variety of spatial scales or designed for various applications. This approach was able to attract large numbers of participants as for each inter-comparison scientific questions existed and triggered important discussions. These exchanges and collaborations between modellers have resulted in general progress within the community. The challenge for GMPP now, is to extend the methodology to improve the representation of the interactions between the surface, the atmospheric planetary boundary layer and the cloud processes in large scale models.

In order to achieve this we propose to choose a theme for GMPP which will guide the activities in all three groups and encourage a closer study of the couplings which exist. Through the collaboration with AMIP, the theme will also strengthen the link with global climate models. The theme we would like to propose is the diurnal cycle. This aspect of climate has not received sufficient attention over the past few years although it is one of the most prominent cycles in the water and energy exchanges within the system and is considered to be an ideal test bed for general circulation models and their parametrisations [Lin et al., 2000]. A number of reasons have motivated this choice :

- AMIP has shown that the annual cycle is well represented in many respects in the current generation of general circulation models (GCMs). The next natural cycle which should be evaluated and probably requires the most improvements in GCMs is the diurnal one. Regional climate models as well as numerical weather prediction models will probably show similar deficiencies in the representation of the diurnal cycle and also benefit from the proposed theme.
- Systematic errors in the representation of the diurnal cycle have been documented in a number of large scale atmospheric models and could be attributed to the representation of the water and energy exchanges by turbulence, surface processes, convection and radiation [Viterbo et al., 1999, Yang and Slingo, 2001, Betts and Jakob, 2002].

- The diurnal cycle is the dominant fluctuations in the interactions between the surface, the atmospheric planetary boundary layer and cloud processes in many regions of the world [Ek and Holtslag, 2003, Nesbitt and Zipser, 2003, Yang and Slingo, 2001]. Thus, a better representation of the diurnal cycle by models will be the result of a better understanding of these interactions.
- A correct representation of the diurnal cycle in models is essential for comparing models to observations. If the atmospheric model does not represent the diurnal variations well, then sampling it in the same way as the observations used for validation will induce systematic biases and render the comparisons difficult even at longer time scales. Such problems have for instance been encountered in the validation of simulated clouds with observations from polar orbiting satellites [Salaby and Callaghan, 1997, Fowler et al., 2000].
- To make global atmospheric models more relevant for regional applications the diurnal cycle needs to be well represented. The diurnal cycle forces land/sea and mountain/valley circulations which are important at regional scales [Nesbitt and Zipser, 2003, Yang and Slingo, 2001].

GMPP proposes to evaluate the ability of our models to represent the diurnal cycle using model inter-comparisons as it has proven its value in previous GMPP activities. The strategy envisaged is to diagnose the diurnal cycle in parallel on the processes with which GMPP deals and on the global climate scale before moving onto the analysis of the interactions between clouds, the atmospheric boundary layer and land-surfaces. Three phases can thus be identified in the implementation of this GMPP proposal :

1. In a first phase GCSS, GLASS and GABLS will evaluate in off-line model inter-comparisons (i.e. with limited feedbacks) currently underway or planned, the ability to reproduce the diurnal cycle. This effort should allow us to identify problem areas but also explore the limits of the off-line approach for the evaluation of the associated processes. The planned evaluation by GMPP of single-column models should be able to determine if the deficiencies in the diurnal cycle are specific to the parametrizations for large-scale atmospheric models or if they also exist in cloud resolving models. The Global Soil Wetness Project (GSWP) could for instance identify the regions in which land-surface schemes most consistently fail to reproduce the diurnal cycle despite an acceptable forcing. This phase should not change the way GMPP projects work but only refocus some of the diagnostics being done.
2. During this period AMIP should identify the geographical regions, seasons and weather regimes for which atmospheric models show the most significant deficiencies in the diurnal cycle. This could either be done with the 6 hourly output available in the current AMIP database or by requesting from participants higher frequency output for one representative year from the AMIP period (1979-1996). The results from this analysis should be compared to the problem areas identified in off-line inter-comparisons in order to evaluate the role of the feedbacks in amplifying or damping the deficiencies in the representation of the various processes.

This type of analysis could be fostered by climate and weather forecasting centres reporting problems in the diurnal cycle they have identified in their models to GMPP. The ubiquity of the deficiency could then be verified in the AMIP database.

To make these evaluations more systematic, GMPP will propose diagnostics which will be added to the AMIP standard output list.

3. Once the problems have been identified in the off-line mode and the large scale atmospheric model environment then attempts should be undertaken to reproduce them in a limited coupled environment by progressively introducing feedbacks. For example, this could be done by using a common land-surface model instead of prescribing the surface fluxes in a single column model (SCM). The SCM's convection scheme would then affect the diurnal cycle of the surface fluxes

but the errors of the land-surface model would also come into play. The same process will need to be repeated with the convection and atmospheric boundary layer parameterizations and with the land-surface and atmospheric boundary layer parameterizations. Through the progressive re-introduction of the feedbacks the problem areas identified in large scale atmospheric models will be reproduced in a simplified environment and the key interactions identified. This should allow us to propose efficient remedies for the representations of these physical processes in atmospheric models which would improve the representation of the diurnal cycle.

4. To obtain the same synoptic evolution and large scale weather patterns in the AMIP runs, new runs should include gentle relaxation towards analysed fields above the atmospheric boundary layer (say 1000 m), as well as prescribed values for the sea surface temperature. Such a procedure follows Viterbo et al. [1999] in their study of the coupled land surface-atmosphere system and allows to cut-off the dynamical feedbacks on errors in the diurnal cycle. An alternate solution would be to perform dynamical compositing of the output of GCMs in order to eliminate in a first approximation the dynamical feedbacks.

With this approach we hope to foster the interactions between the various GMPP activities and ensure that the progress made in our conceptual models of moist processes translate into improved general circulation models. This effort should allow GMPP to connect more efficiently with the development work underway in numerical weather prediction centres as well as climate modelling institutions.

Timeline

To be discussed with the three GMPP panels.

References

- [Betts and Jakob, 2002] Betts, A. and Jakob, C. (2002). Study of the diurnal cycle of convective precipitation over amazonia using a single column model. *J. Geophys. Res.*, 107(D23):4732–4745.
- [Ek and Holtslag, 2003] Ek, M. and Holtslag, A. A. M. (2003). Influence of soil moisture on boundary-cloud initiation. *J. Hydrol.*, in press.
- [Fowler et al., 2000] Fowler, L. D., Wielicki, B. A., Randall, D. A., Branson, M. D., Gibson, G. G., and Denn, F. M. (2000). Use of a gcm to explore sampling issues in connection with satellite remote sensing of the earth radiation budget. *J. Geophys. Res.*, 105(D16):20757–20772.
- [Lin et al., 2000] Lin, X., Randall, D. A., and Fowler, L. D. (2000). Diurnal variability of the hydrologic cycle and radiative fluxes: comparisons between observations and a gcm. *J. Climate*, 13(23):4159–4179.
- [Nesbitt and Zipser, 2003] Nesbitt, S. W. and Zipser, E. J. (2003). The diurnal cycle of rainfall and convective intensity according to three years of trmm measurements. *J. Climate*, 16:1456–1475.
- [Salaby and Callaghan, 1997] Salaby, M. L. and Callaghan, P. (1997). Sampling error in climate properties derived from satellite measurements : Consequences of undersampled diurnal variability. *J. Climate*, 10:18–36.
- [Viterbo et al., 1999] Viterbo, P., Beljaars, A. C. M., Mahfouf, J.-F., and Teixeira, J. (1999). The representation of soil moisture freezing and its impact on the stable boundary layer. *Quart. J. Roy. Meteor. Soc.*, 125:2401–2426.
- [Yang and Slingo, 2001] Yang, G.-Y. and Slingo, J. (2001). The diurnal cycle in the tropics. *Mon. Weather Rev.*, 129:784–801.