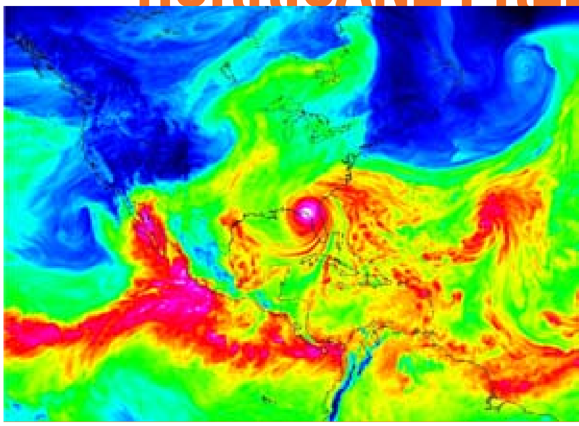
EXPERIMENTAL HIGH-RESOLUTION WEATHER/ HURRICANE PREDICTIONS WITH THE NASA FVGCM



SCIENCE MISSION DIRECTORATE

BO-WEN SHEN
NASA Goddard Space Flight Center
(301) 614-6251
Bo-Wen.Shen.1@gsfc.nasa.gov

ROBERT ATLAS
NOAA Atlantic Oceanographic and Meteorological Laboratory
(305) 361-4300
Robert.Atlas@noaa.gov

Figure 1: *This continental-scale view shows total precipitable water from 5-day forecasts initialized at 0000 UTC September 1, 2004 with the 1/8-degree finite-volume General Circulation Model (fvGCM). The track forecast of Hurricane Frances (2004) is documented in Shen et al. (2006a).*

Project Goals and Objectives: Hurricane forecasts pose challenges for General Circulation Models (GCM), the most important being the horizontal grid spacing. The main goal of this project, supported by NASA's Weather Data Analysis and Assimilation Program, Earth Science Division, is to study the impacts of increasing resolution on numerical weather/hurricane forecasts, aimed at improving forecast accuracy.

Project Description: Previously, we had demonstrated the superior computing power of the NASA Center for Computational Science's Halem supercomputer by successfully completing high-resolution (1/2-degree) global weather predictions [2]. To further investigate the impact of high-resolution modeling on weather predictions, and to improve the model in both accuracy and efficiency, we deployed the finite-volume GCM (fvGCM) at higher (1/4- and 1/8-degree) resolutions on the Columbia supercomputer. This work was in support of our NASA-sponsored project, "Application of the High-Resolution NASA finite-volume GCM to Medium-Range Weather Predictions in Support of NASA Modeling and NOAA/NCEP Operational Weather Forecasting." The model has been running in real time to evaluate its performance on hurricane forecasts.

Relevance of Work to NASA: As accurate hurricane forecasts are important to our daily lives, this project can help address the central question of NASA's mission in hurricane research: *How can weather/hurricane forecasts be improved and made more reliable over longer periods of time using computer modeling?*

Computational Approach: With unprecedented computing resources provided by Columbia, the horizontal resolution of the fvGCM has been rapidly increased to 1/4 degree in early 2004 [1] and 1/8 degree in early 2005 [4]. Currently, the fvGCM at 1/12-degree resolution is being tested. The 1/12-degree fvGCM is the first global weather model with single-digit resolution, namely 9 kilometers (km) in the equator and 6.5 km in the mid-latitudes. A 5-day forecast of total precipitable water with the 1/12-degree fvGCM (Figure 2) clearly shows fine-scale weather events in the tropical area, which brings us to the point of overcoming the fundamental barrier between global and mesoscale models [4].

Results: As of July 2006, the team has published three important articles highlighting computations completed on Columbia since it came on-line in summer 2004. Two of them have been selected as *American Geophysical Union Journal Highlights*, and the first article about the 1/8-degree fvGCM has been cited as pioneering work (by Professor Roger Pielke, Sr. of Colorado State University). Recently, the article for the high-resolution simulations of Hurricane Katrina (2005) [5] has been highlighted in *Science* magazine [6]. These published results, along with yet more interesting results to be submitted for publication soon, are briefly summarized below.

During the 2004 hurricane season, the 1/4-degree model, which doubled the resolution adopted by most global models in operational Numerical Weather Prediction (NWP) centers at that time, was running in real time experimentally, and provided remarkable landfall predictions up to 5 days in advance for major hurricanes such as Charley, Frances, Ivan, and Jeanne [1, 4]. Moreover, the model was shown to be capable of resolving features such as erratic track, abrupt recurvature, and intense extratropical transition. In the 2005 hurricane season, a new research focus was put on validations of the 1/8-degree fvGCM's performance on hurricane forecasts, while the real-time 1/4-degree forecasts provided a baseline for comparisons. Being a global mesoscale-resolving model, the 1/8-degree model was the first global model to simulate mesoscale vortices (such as the Catalina Eddy and the Hawaiian Lee Vortex shown in [4]), which were generated by the interaction of the large-scale flows with better-resolved surface forcing. As shown in Figure 1, for 5-day forecasts, the

1/8-degree fvGCM was able to simulate detailed structures of Hurricane Frances (2004).

The 2005 Atlantic hurricane season was the most active in recorded history. There were 28 tropical storms and 15 hurricanes, four of which were rated Category 5. Accurate forecasts of these storms posed a great challenge to global and mesoscale modelers. It is especially well known that GCMs' insufficient resolutions undermine intensity predictions. Thanks to the considerable computing power of Columbia, this limitation could be overcome, as illustrated by [5], who performed six 5-day forecasts of Hurricane Katrina with the 1/8-degree fvGCM, and obtained promising intensity forecasts with small errors in center pressure of only ±12 hectopascals. It has also been shown that the notable improvement in Katrina's intensity forecasts occurred when grid spacing decreased from 1/4 degree to 1/8 degree, which is sufficient to simulate the near-eye wind distribution, and to resolve the radius of maximum winds.

Role of High-End Computing: The quantum jump in computing power at NASA provides unprecedented opportunities for advancing weather forecasting and hurricane modeling. In addition, NASA High-End Computing Program application specialists provided expert assistance with computational issues to speed up model development. While the mesoscale-resolving fvGCM has produced very promising results for the past 2 years, a great potential for further modeling advancement is still ahead of us. With the ultra-high-resolution global model, we will be able to investigate and illustrate the uncertainties of cumulus parameterizations, on which progress has been very slow during the last 40 years. We believe supercomputer power will soon enable breaking the cumulus parameterization deadlock [3] by advancing current work and inspiring related modeling research, and then open opportunities for more challenging problems, including hurricane genesis and hurricane climatology.

Future: During the past several years, substantial modeling work has been completed, and significant results have been achieved. We will document these results with a focus on illustrating the uncertainties of cumulus parameterizations with hurricane forecasts, thereby transferring our knowledge to the broader community.

Co-Investigators

- Wei-Kuo Tao, Oreste Reale, Jiun-Dar Chern, Tsengdar Lee, Johnny Chang, Christopher Henze, Jui-Lin Li, all of NASA
- Shian-Jiann Lin, NOAA Geophysical Fluid Dynamics Laboratory

Publications

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6. Kerr, R., "Sharpening Up Models for a Better View of Atmosphere," *Science*, 1040 (2006).

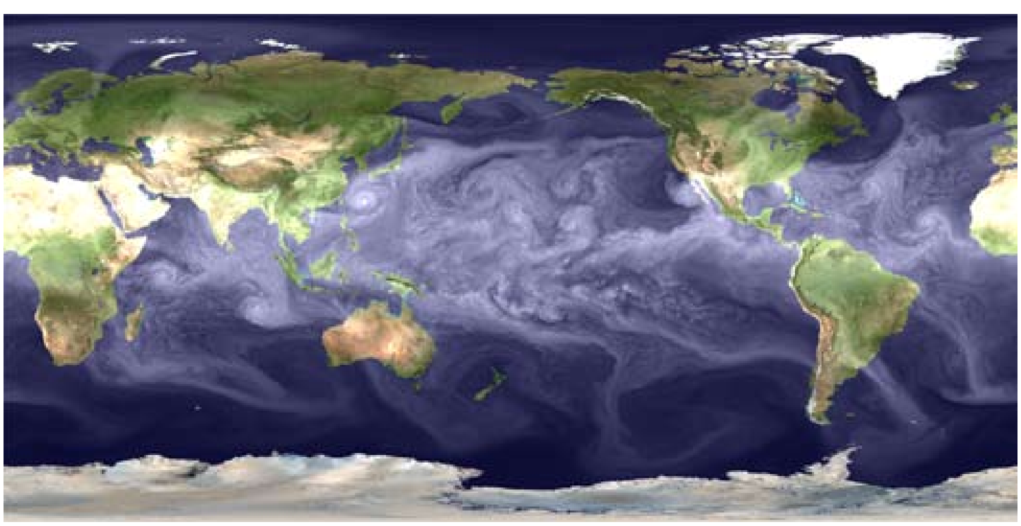

Figure 2: *This global view shows total precipitable water from 5-day forecasts initialized at 0000 UTC September 1, 2004 with the 1/12-degree fvGCM, giving a grid spacing of 9 kilometers at the equator.*