Advanced Numerical Methods for NWP Models

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LONG-TERM GOALS

The long-term goal of this project is to develop a next-generation global atmospheric numerical prediction model that can take advantage of projected computational processing technology to make efficient, high-resolution global modeling a reality. The Navy Spectral Element Atmospheric Model (NSEAM) uses icosahedral grid structures that employ local spectral elements to generate highly accurate and highly scalable global weather forecasts. NSEAM is expected to allow for the Navy to use global models to predict the weather at resolutions of 25 km and less in the coming years.

OBJECTIVES

The objective of this project is to apply state-of-the-art physical parameterizations to NSEAM, develop and test supporting pre-and-post-processing software, and interface NSEAM to a variational analysis, leading to a next-generation global data assimilation and prediction system. While the dynamics of NSEAM continue to be refined in a companion project at the Naval Postgraduate School (NPS), this project integrates the physics and supporting software from the current Navy global atmospheric model, the Navy Operational Global Atmospheric Prediction System (NOGAPS) into NSEAM. Upon the completion of the integration of the NOGAPS physics into NSEAM, NSEAM will be subjected to a variety of idealized and real-data forecast problems to validate its performance.

APPROACH

Our approach is to perform collaborative work with Dr. Frank Giraldo at the Naval Postgraduate School (NPS) to: (a) merge the dynamic core of NSEAM with the physical parameterizations used in NOGAPS, (b) develop and/or utilize existing pre-, post-processing, and validation software for applications of NSEAM to idealized and real data, and (c) interface NSEAM to the NRL Atmospheric Variational Data Assimilation System-Accelerated Representer (NAVDAS-AR) which will include the development of the NSEAM adjoint and tangent linear models (TLM). This will allow for data assimilation experiments that will lead to validation of the full NSEAM data assimilation and prediction system for operational applications as the next-generation Navy global modeling system.

WORK COMPLETED

The following work was accomplished in FY08:

1. The NSEAM with full physics is tested using aqua-plant for idealized simulation for the representation of Kelvin waves, Rossby waves, and MJO. It is found that the simulation of these

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14. ABSTRACT

The long-term goal of this project is to develop a next-generation global atmospheric numerical prediction model that can take advantage of projected computational processing technology to make efficient, high-resolution global modeling a reality. The Navy Spectral Element Atmospheric Model (NSEAM) uses icosahedral grid structures that employ local spectral elements to generate highly accurate and highly scalable global weather forecasts. NSEAM is expected to allow for the Navy to use global models to predict the weather at resolutions of 25 km and less in the coming years.

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waves and the intraseasonal oscillation is very sensitive to the specification of model levels in the lower part of the model. This sensitivity has further been identified to be closely linked to the diffusion and boundary layer buoyancy profile. A paper reporting the results has been published in *JGR* (Kim et. al. 2008).

2. The NSEAM system has been used to study tropical wave instability with a prescribed heat source representing ITCZ near the equator. The model configuration of the experiments utilizes the capability of the system to have higher resolution in the tropics. The model successfully simulated the breakdown of the disturbance, resembling tropical cyclone genesis. A manuscript on this result has been submitted.

3. The NSEAM model was tested with idealized simulations, such as the propagation of Rossby-Haurwitz waves. A problem has been identified near the edge of individual volumes with model physics that generates noises. One can use artificial viscosity to gradually remove the edge noises. Alternative approach of using Explicit Locally Adaptive Dissipation (ELAD) procedure or low-pass filter would eliminate the noise more efficiently. Research continues to solve this problem.

4. We are currently constructing terrain profiles for the NSEAM system and building the interface between the analysis fields after NAVDAS-AR and the model for testing with real cases.

RESULTS

We continued experimenting with the Aqua-planet simulations, which ensure a well-controlled environment (e. g., all-water surface, prescribed initial and boundary conditions, and fixed geophysical and radiation conditions) for model inter-comparisons. Sensitivity tests to improve the equatorial wave propagation speed have been conducted by varying the detailed design of the cumulus parameterization scheme, horizontal diffusion, vertical resolution and layer distribution, radiation time step, and boundary conditions, etc. Fig. 1 shows a comparison of simulated convective rain rate averaged the equatorial band (5S-5N) from day 30 to day 120 using different vertical levels in the model. The evenly distributed model level configurations provide stronger signal of the Kelvin waves but the propagation speed is too fast, as compared to the simulation using the unevenly distributed model levels. Fig. 2 shows the sensitivity of the convective rain rate to the details of the convective parameterization scheme. The results show that tropical convection is very sensitive to a slight modification of the convective scheme and stresses the need of further understanding and improvement of the physical parameterizations.

Tests of NSEAM with idealized initial conditions show the breakdown of an unstable ITCZ profile into possible formation of TCs (Fig. 3). This experiment illustrates the capability of NSEAM with its variable grid resolution that allows concentrated high-resolution grids in needed areas.

Sensitivity to Distribution of Vertical Levels

Convective Rain

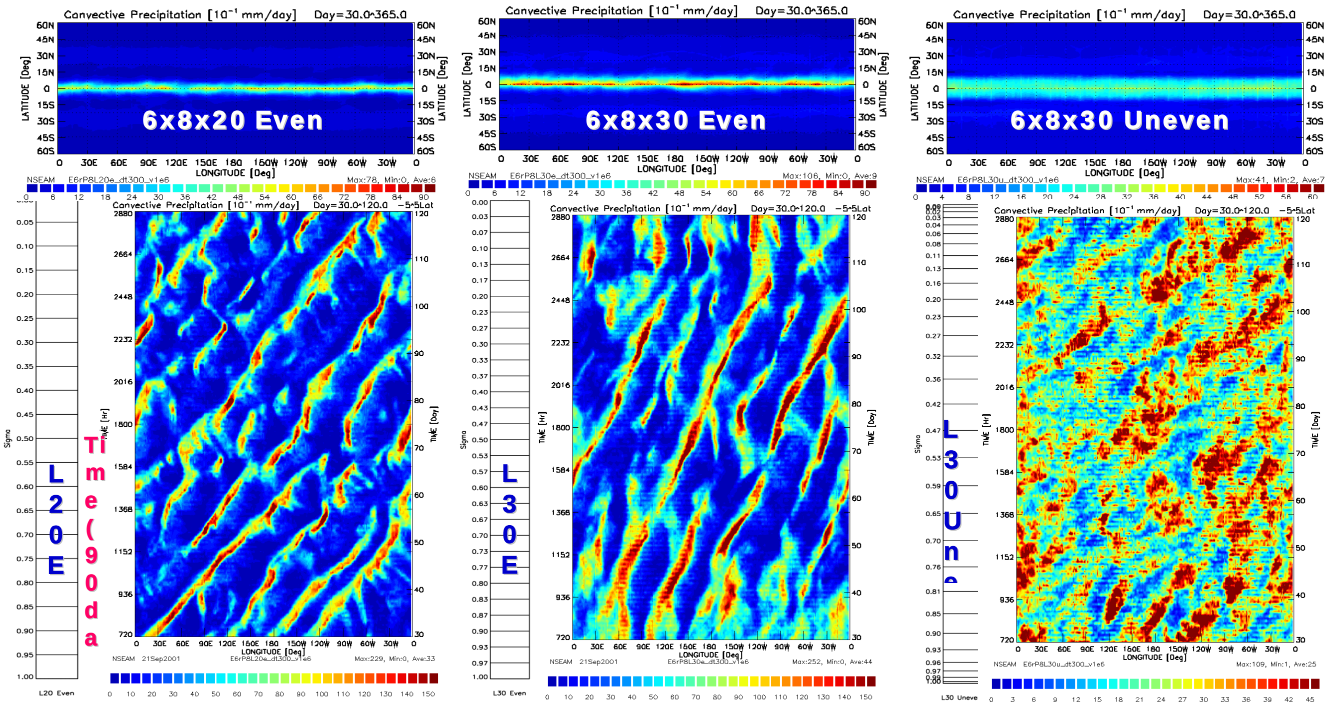

Figure 1. Convective rain rates with different distributions of the vertical levels in NSEAM. The top three panels (left: 20 evenly distributed levels; center: 30 evenly distributed levels; right: 30 unevenly distributed levels) are the horizontal distribution of the rain and the bottom three panels are the time-longitude diagram of the rain rate between 5S to 5N. The maxima represent the propagation of Kelvin waves.

Sensitivity to Physics (LCL Exp)

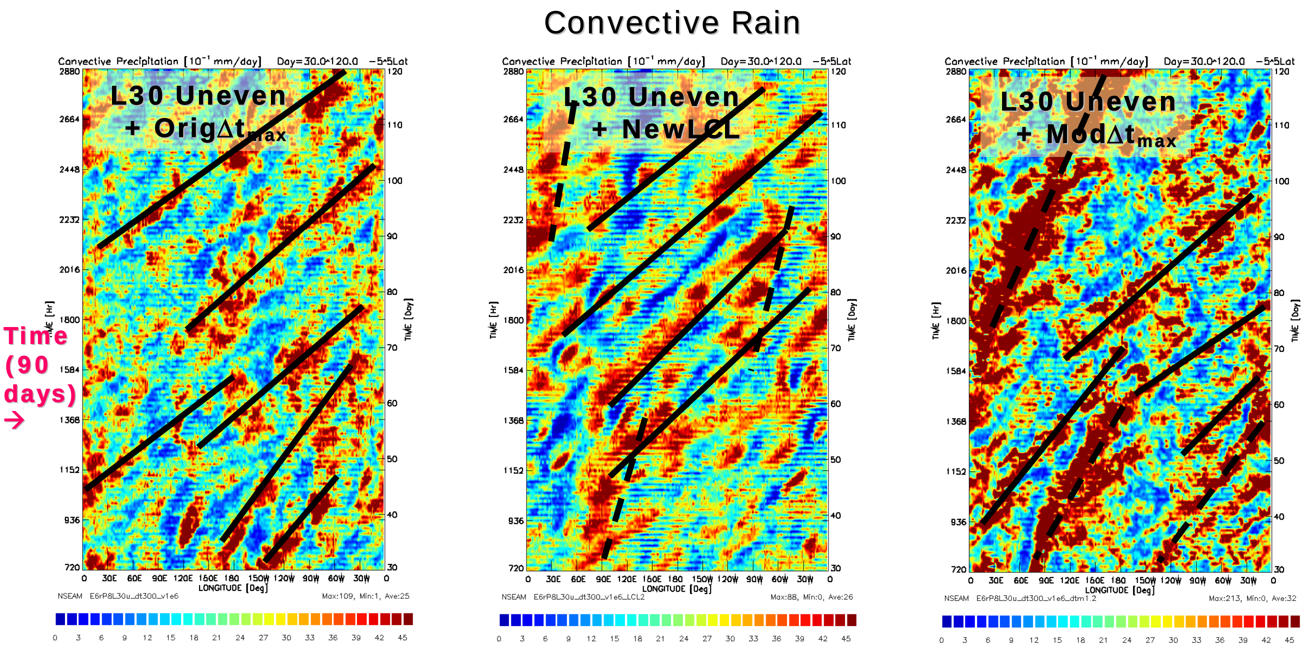

Figure 2. Convective rain rates with different versions of the convective parameterization scheme. The top three panels (left: control version; center: new computation of the LCL; right: modified sub-cloud turbulent temperature contribution) are the horizontal distribution of the rain and the bottom three panels are the time-longitude diagram of the rain rate between 5S to 5N. The maxima represent the propagation of Kelvin waves.

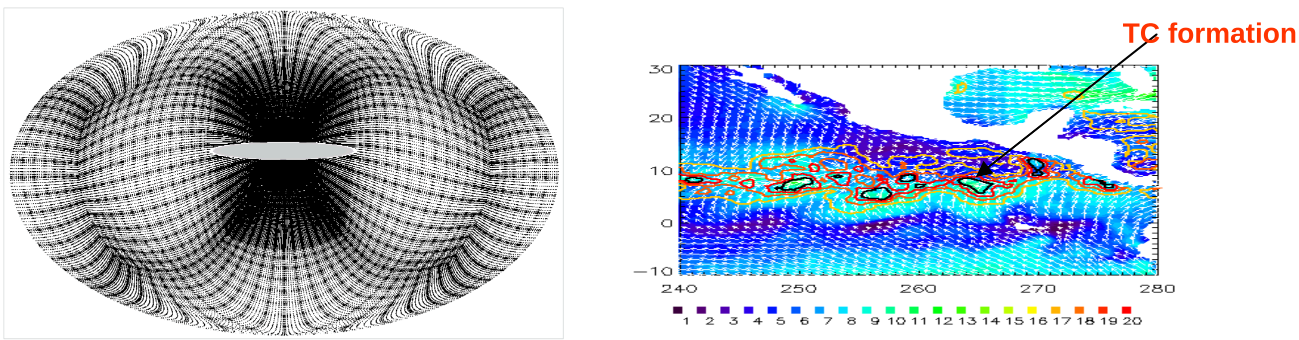

Figure 3. Simulation of ITCZ breakdown using variable grids of NSEAM. Left: Grid arrangement. Right: Rain fall pattern caused by oceanic instability waves.

IMPACT

NOGAPS is run operationally by FNMOC and is the heart of the Navy's operational support to nearly all DOD users worldwide. This work targets the next-generation of the global forecast system for massively parallel computer architectures. NSEAM has been designed specifically for efficient use of these types of computer architectures while yielding the same high-order accuracy as NOGAPS.

TRANSITIONS

Improved algorithms for model processes will be transitioned to 6.4 (PE 0603207N) as they are ready, and will ultimately be transitioned to FNMOC with future NOGAPS upgrades.

RELATED PROJECTS

Some of the technology developed for this project will be used immediately to improve the current spectral transform formulation of NOGAPS in other NRL projects.

PUBLICATIONS

Kim, Y.-J., F. X. Giraldo, M. Flatau, C.-S. Liou, and M. S. Peng: 2008: A sensitivity study of the Kelvin wave and the Madden-Julian Oscillation in aqua-planet simulations by the Naval Research Laboratory Spectral Element Atmospheric Model (NSEAM). *JGR, Atmos.* 113, D20102, doi:10.1029/2008JD009887.

REFERENCES

Giraldo, F. X., and Warburton T., 2005: A Nodal Triangle-based Spectral Element Method for the Shallow Water Equations on the Sphere. *Journal of Computational Physics,* **207**.

Giraldo, F. X., 2005: Semi-Implicit Time-Integrators for a Scalable Spectral Element Atmospheric Model. *Quarterly Journal of the Royal Meteorological Society,* **610.**