Kelvin Wave and Madden-Julian Oscillation Simulated by A Spectral Element Atmospheric Model under Aqua-Planet Conditions
**SUMMARY**

The Naval Research Laboratory (NRL) Spectral Element Atmospheric Model (NSEAM) coupled with full physics is used to investigate the organization and propagation of Kelvin waves and Madden-Julian Oscillation under the atmosphere of an Earth-like planet. The model is highly sensitive to the horizontal viscosity, temperature, zonally-averaged, and symmetrized with respect to the equator. The weak meridional temperature gradient is a result of the model physics, which determines the propagation of Kelvin waves and Madden-Julian Oscillation.

**The NRL Spectral Element Atmospheric Model (NSEAM)**

**Dynamical Core - NSEAM (Giraldo 2005)**

- Maintains the high-order accuracy of spherical harmonics
- Scales efficiently and flexibly on current and future state-of-the-art computing platforms
- Can be used with efficient time-integrators including semi-implicit and semi-Lagrangian methods
- Can be used with any grid

**Physics Package - NOGAPS (Hogan & Rosamond 1991)**

- Bulk Richardson no. dependent vertical mixing parameterization [Loulou et al. 1982]
- Cumulus parameterization [Emanuel & Zivkovis-Rothman 1999; Hogan et al. 1999; Peng & Hogan 2001]
- Boundary-layer cloud parameterization [Takeda and Hogan 2001]
- Effective surface roughness [Hogan et al. 1999]
- Geographic drag parameterization [Hoskier et al. 2003]

**Aqua-Planet Experiments [Kim et al. 2008]**

- Aquaplanet experiments for consistent model intercomparison
- No geography, land or sea, water everywhere
- Prescribed zonally uniform surface temperature field [Neale & Hoskins 2001]
- Zeta earth eccentricity and obliquity
- Fixed equatorial insolation with solar constant of 1365 W/m^2
- Diurnal cycle of solar insolation
- CO2 amount of 348 ppmv (AMIP II)
- Zonal-mean AMIP II climate, symmetrized w.r.t. the equator
- PLUS NCEP/NCAR reanalysis fields for 20G of humidity and temperature, zonally-averaged and symmetrized w.r.t. the equator

**Experiment Design [Kim et al. 2008]**

- NOGAPS operational model physics
- Start and end on 3/2/2007 (solstice condition)
- Semi-implicit time integration
- Backward difference time step
- Δt = 300 sec
- Δz = 4.5 km
- T = 12 hr
- L30 or L20 w/ top=10hPa
- Hypo-viscosity for physics (ux,uy,uz) as: N_e = 0.6 x N_g
- H = N_e x N_g x 0.086 (T+1)
- T = 300 K
- H = 6 x 8 x T^4 = 2.2°

**INITIAL CONDITIONS**

**Sensitivity to Model Vertical Structure**

- Sensitivity to model vertical structure
- Propagation of Kelvin waves and Madden-Julian Oscillation

**Sensitivity to Model Physics**

- Sensitivity to model physics
- Decomposition of convective precipitation that characterizes Kelvin Wave and MJO

**CONCLUSIONS**

- The Naval Research Laboratory (NRL) Spectral Element Atmospheric Model (NSEAM) coupled with full physics, successfully simulates the organization and propagation of Kelvin waves and Madden-Julian Oscillation under the atmosphere of an Earth-like planet.
- The tropical convective precipitation processes and associated equatorial wave dynamics are highly sensitive to the vertical structure as well as the viscosity and, in particular, the convective precipitation processes parameterized in the model, which is considered one of the most sensitive components in large-scale atmospheric models.
- The observed sensitivity may explain the difficulties in modeling of the equatorial waves and MJO in many long-scale atmospheric models, which should be properly simulated for accurate atmospheric prediction.

**Sensitivity to Horizontal Viscosity**

- Convective clouds concentrated over the equator

**KELVIN WAVES AND MADDEN-JULIAN OSCILLATION**

- Kelvin Wave and Madden-Julian Oscillation Simulated by NSEAM
- Key references

**KEY REFERENCES**