S90

Evaluation of the Effect of Latent Heat Release on an Extratropical Cyclone by Simulation and Observational Comparison

Gregory E. Tierney[1], Juan A. Crespo[2], Derek J. Posselt[1]
[1]Department of Atmospheric, Oceanic, and Space Sciences, University of Michigan
[2]Department of Earth and Atmospheric Sciences, Purdue University

Introduction

Within the synoptic-scale of extratropical cyclones, numerous meso- and microscale processes work to strengthen or weaken the entire cyclone to varying degrees. One such process is latent heat release, whose effect on a system wide scale is straightforward. Adding a bubble of latent heat at the center of a cyclone will lead to spin-up, and subsequent intensification of the cyclone (Stoelinga 1996).

However, the effect of latent heat in extratropical cyclones becomes much more complicated at the frontal scale and has merited a significant amount of study in recent years as the upscale linkages can be difficult to deconvolve. (Lackmann 2002, Reeves and Lackmann 2004, Posselt and Martin 2004, Grams et al. 2011). Our initial goal is to compare observations and modeling data of a long-lived extratropical cyclone off the east coast in November 2006. Confirming the accuracy of our model, we then proceeded to attempt diagnosing the effect of latent heat on the structure of the cyclone as a whole.

Case Selection

Because our intent is to compare and integrate observational data with model predictions in the long term, we chose an extratropical storm that lingered off the east coast of the United States in November of 2006. Remaining nearly stationary between approximately 21-23 Nov. 2006, the storm was overpassed multiple times by NASA's A-Train constellation of satellites, including CloudSat and CALIPSO. These overpasses make up datasets which verify and enhance the modeling aspect of our study.

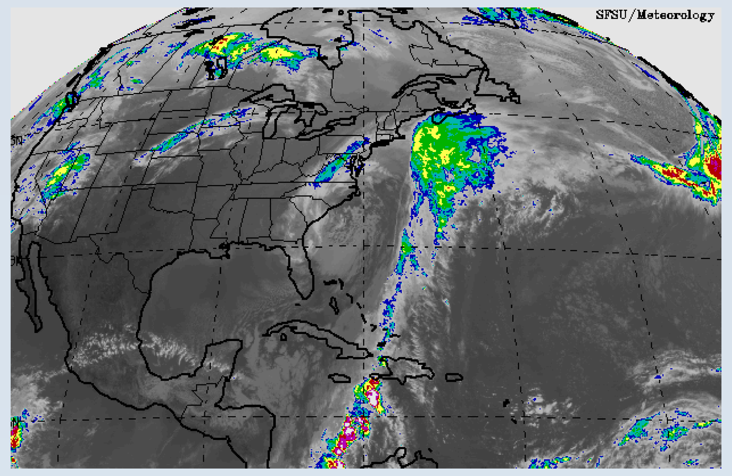


Figure 1. GOES IR image of the case storm at 18Z on 22 Nov.

Methods

- Ran two companion simulations using the Weather Research and Forecasting (WRF) model to isolate the effect of latent heat: a "full physics" model and a "no latent heat release" model, wherein the effects of latent heat release were removed.
- Our nesting domain spanned a region 6000 x 6000 km in area (Fig. 2). Horizontal grid spacing was 20 km, with 50 vertical levels as an outer nest. The nested domain was 5600 x 5600 km in area, at a horizontal grid spacing of 4km, and 50 vertical levels.
- Simulations were run for the time period from 00Z on November 21 through 18Z on November 25.

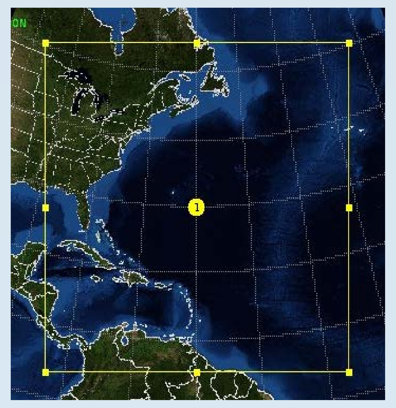
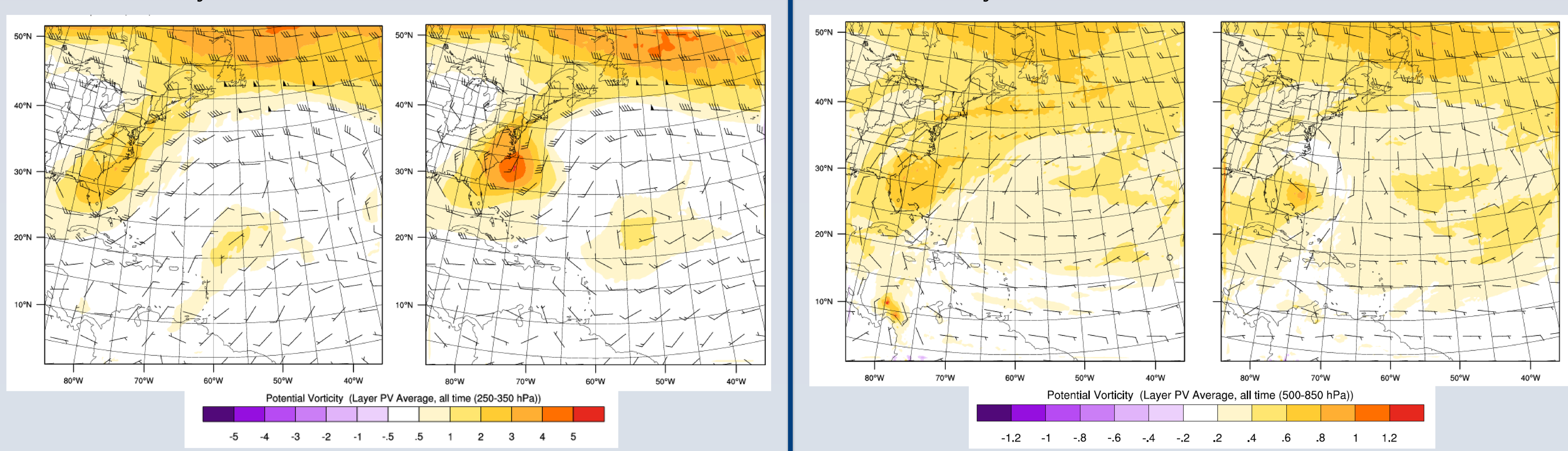


Figure 2. Domain used for WRF companion runs.

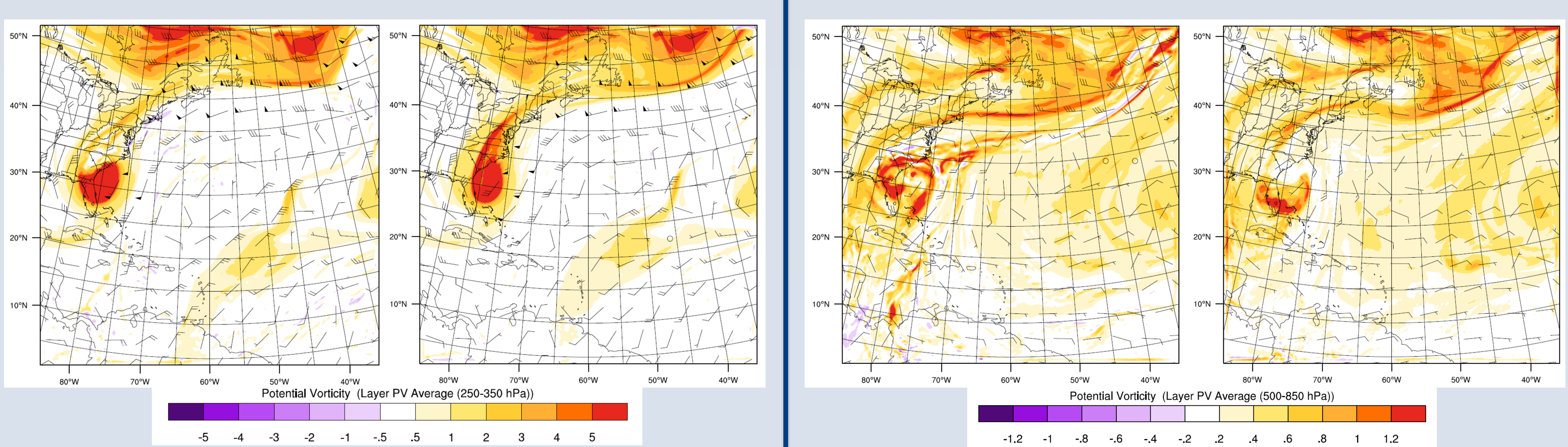
Results

Fig 3. Potential Vorticity Comparisons

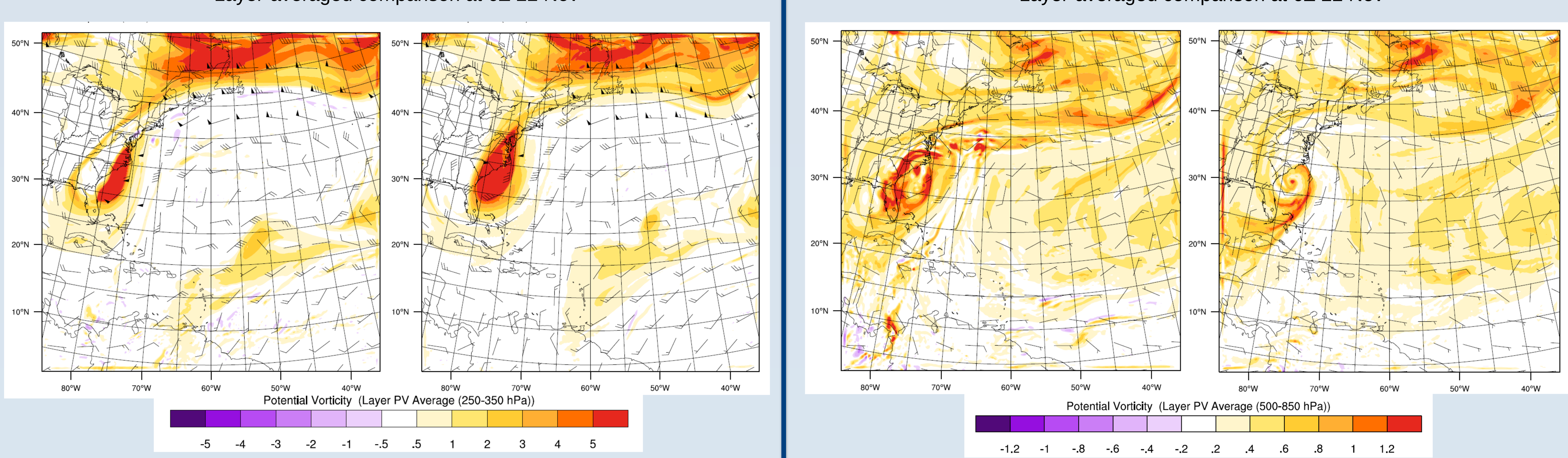
Upper Level (~250-350 hPa) — Full Physics Case | No Latent Heat Release
Lower Level (~500-850 hPa) — Full Physics Case | No Latent Heat Release



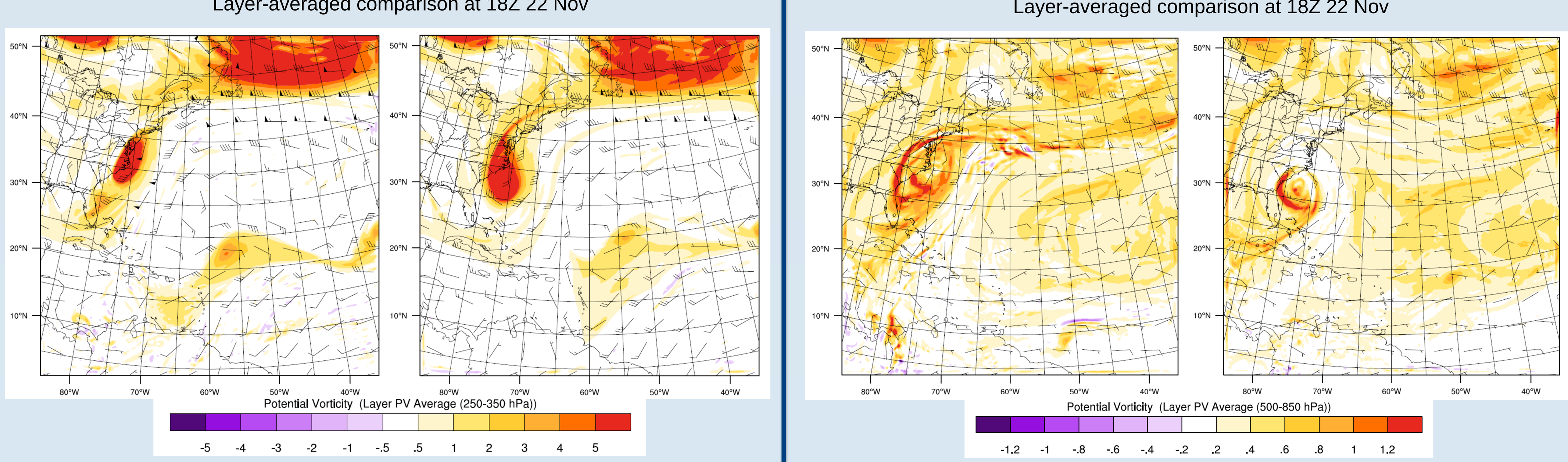
Time and layer-averaged comparison for 0Z 21 Nov. through 18Z 25 Nov. | Time and layer-averaged comparison for 0Z 21 Nov. through 18Z 25 Nov.



Layer-averaged comparison at 6Z 22 Nov | Layer-averaged comparison at 6Z 22 Nov



Layer-averaged comparison at 18Z 22 Nov | Layer-averaged comparison at 18Z 22 Nov



Layer-averaged comparison at 6Z 23 Nov | Layer-averaged comparison at 6Z 23 Nov

Conclusions and Future Work

- The latent heat release in the "Full Physics" run contributed to significant PV modification and creation in the warm sector of the extratropical cyclone.
- In the "Full Physics" run, PV generation in the lower levels of occluded sector act as a precursor to PV erosion in the upper levels of the atmosphere in the same zone, as the western portion of the Warm Conveyor Belt stretches into the cyclone.
- The removal of latent heat release stalled the propagation of the storm to the Northeast, as evidenced by the "PV Bullseye" in the time-averaged run.

Our next steps to extend and further this work include:

- Comparing our WRF model output to A-Train data (shown below in Figure 4) through use of a Satellite Data Simulator.
- Scaling our PV analysis down to our pre-existing runs at 4km, where we have already performed traditional synoptic-scale analyses.
- Exploring the effect of the "No Latent Heat Release" flag in the WRF, and modifying it to target specific areas, such as the warm frontal region, for example.

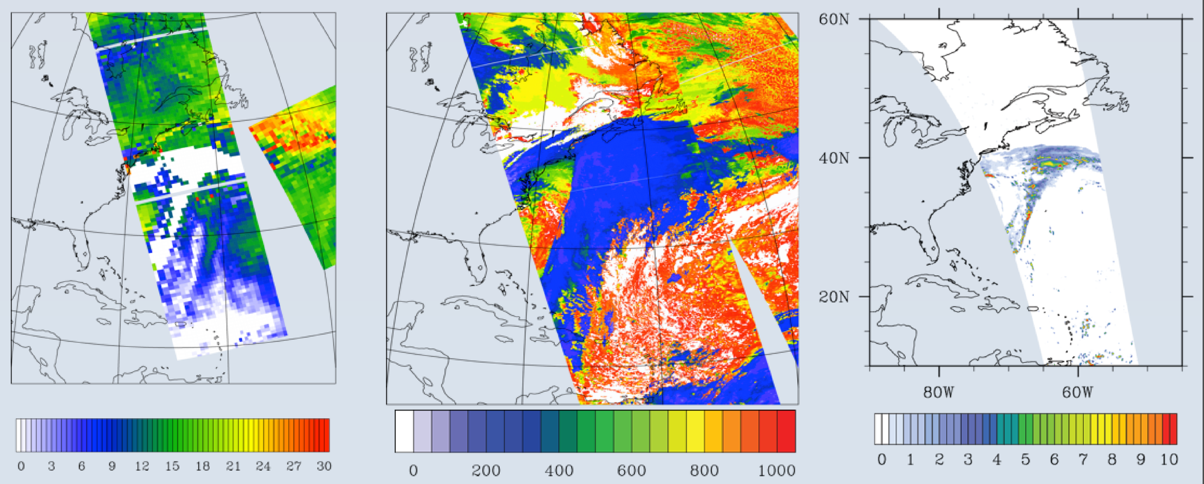
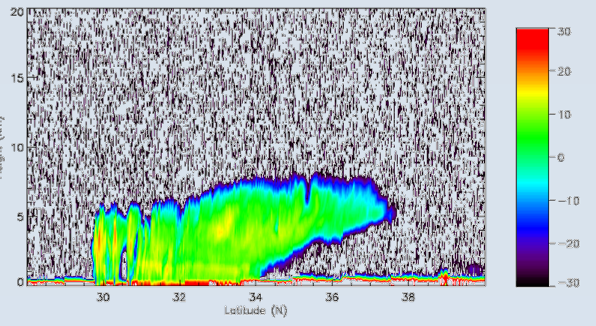


Figure 4. *Example Datasets:*

Stability from the AIRS instrument (top left)
Cloud Top Pressure from MODIS (top center)
Precipitation from AMSR-E (top right)
Radar Reflectivity from CloudSat (right)



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Acknowledgments

Financial support was provided by NASA CloudSat/CALIPSO science team grant NNX10AM20G.

* Contact: Greg Tierney – Department of Atmospheric, Oceanic, and Space Sciences – University of Michigan – Ann Arbor, MI 48109 – gtierney@umich.edu