Retrieved Products from Simulated Hyperspectral Observations of a Hurricane

A41E-0112

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Objective of the Research

Demonstrate via Observing System Simulation Experiments (OSSEs) the potential utility of flying high spatial resolution AIRS class IR sounders on future LEO and GEO missions.

The study simulates and analyzes radiances for 3 sounders with AIRS spectral and radiometric properties on different orbits with different spatial resolutions.

1) "Control run" 13 km AIRS spatial resolution at nadir on LEO in Aqua orbit
2) 2 km spatial resolution LEO sounder at nadir – "ARIES"
3) 5 km spatial resolution sounder on a GEO orbit – radiances simulated every 72 minutes

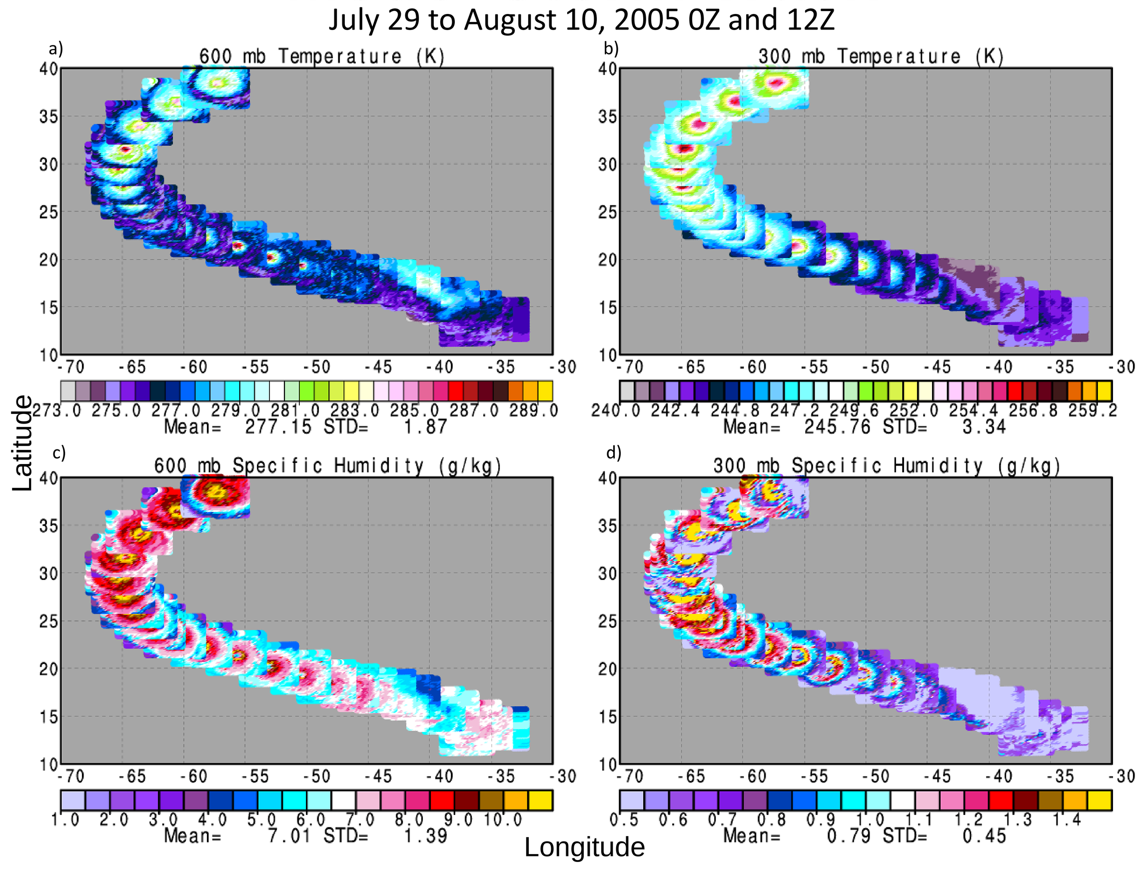
Generation of Model Truth Data Used in the Experiments

These experiments use forecast model products depicting the evolution of a simulated severe storm in the Atlantic Ocean over a 12 day period July 29 to August 10, 2005. Bob Atlas and co-workers at AOML generated the model products every 6 minutes at a 1 km spatial resolution over a moving roughly 4.5° latitude x 4.5° longitude spatial domain covering the simulated track of the center of the storm. The 1 km spatial resolution values provided by the model included surface pressure, surface skin temperature, temperature profile, water vapor profile, and cloud cover (0 or 1) at all model vertical levels. Tom Pagano and William Mathews at JPL generated three sets of "model truth" values of all parameters for each experiment by averaging the 1 km model values in the spatial domain over the instrument Fields of View (FOVs) and sampling them at the appropriate model times – every 12 hours for LEO and every 72 minutes for GEO. LEO observations were simulated for instruments with the current 13 km AIRS FOV, and also for a proposed LEO AIRS-like instrument (ARIES) with a 2 km FOV. The observations were also simulated for an otherwise AIRS-like instrument with a 5 km FOV in a GEO orbit.

We used the "model truth" data both to simulate radiance observations and also to evaluate the accuracy of the retrieved products. We simulated AIRS-like radiances for each FOV by using the operational AIRS Version-6 Radiative Transfer Algorithm (RTA) and adding actual AIRS channel random noise values. Radiance observations of IR satellite instruments in a FOV are sensitive to the amounts of fractional cloud cover of clouds with different cloud top pressures in that FOV as seen from above. The "model truth" provided values of cloud cover within contiguous groups of pressure intervals. We developed and used methodology to use model values of cloud cover in these distinct contiguous pressure groups to simulate amounts of cloud cover at different pressures, as seen from above, while making sure that the total cloud cover of all cloud fractions, as seen from above, does not exceed 1.

Model Storm Track

July 29 to August 10, 2005 0Z and 12Z

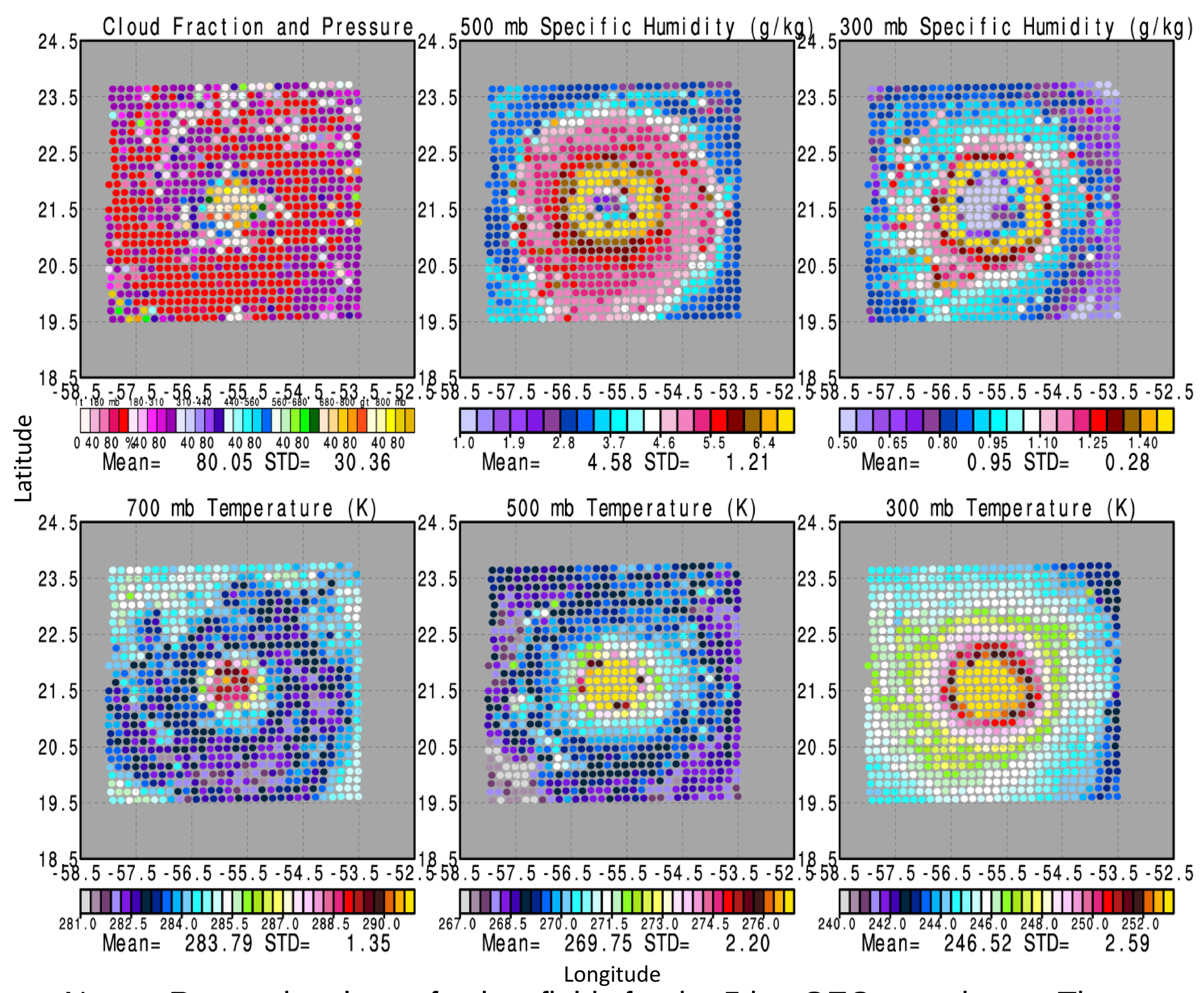


The figures above show Nature Run truth values of $T(p)$ and $q(p)$ for the 5 km GEO experiment sampled every 12 hours. The time period starts at the lower right. The storm begins to intensify around August 3 0Z. The locations of the center of the storm are clearly observed as a function of time.

Spatial Coverage and Values of Accepted Retrievals for August 5, 2005, 0Z

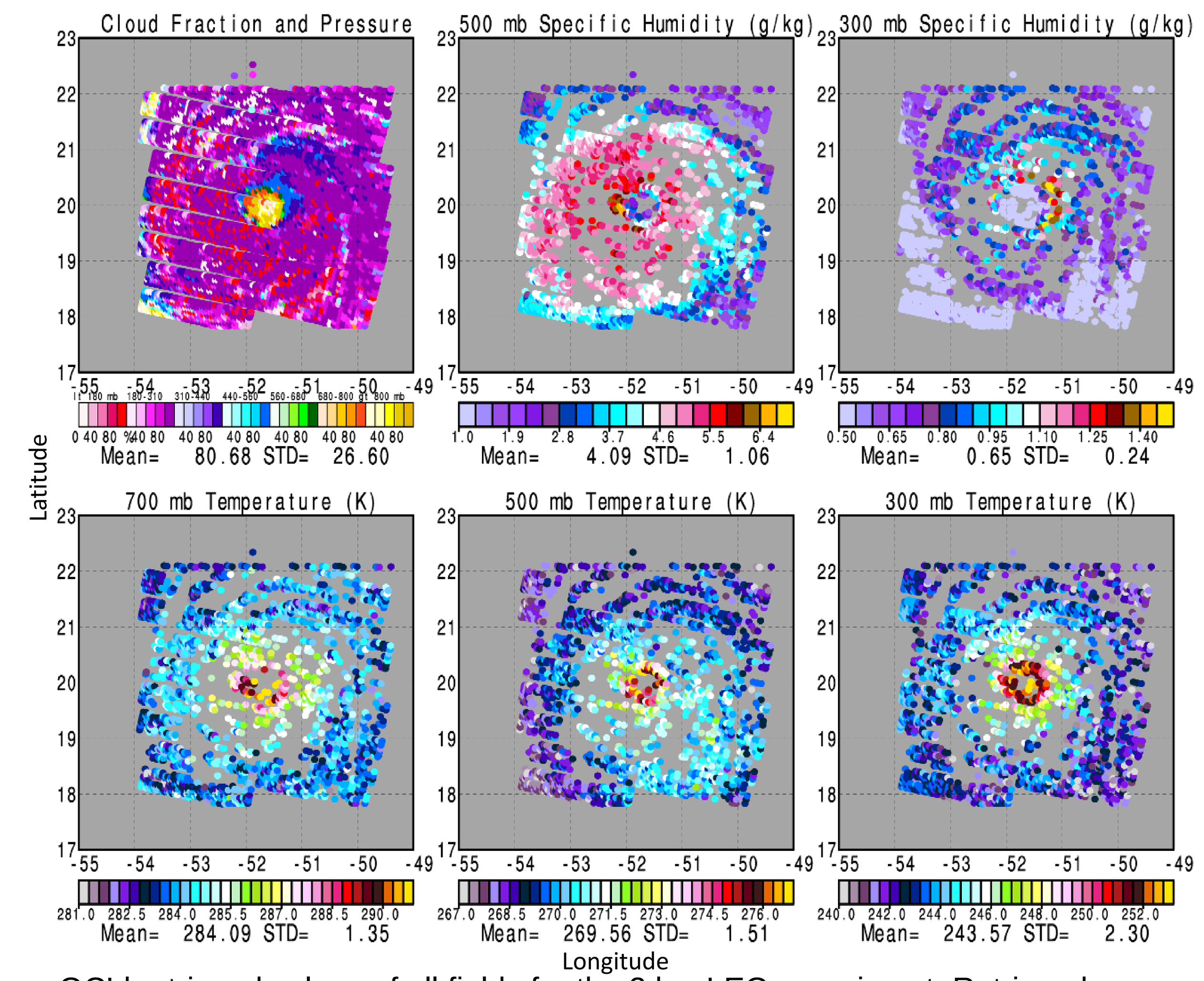
The figures below show truth and retrieved values of cloud parameters and 500 mb and 300 mb specific humidity and temperature. Cloud fractions and cloud top pressure are retrieved for multiple cloud layers in each Field of Regard. We plot effective single layer cloud fraction and pressure for each Field of Regard where the cloud cover is given by the sum of all cloud fractions as seen from above, and the cloud top pressure is given by the average of all the different cloud pressures in the Field of Regard weighted by their cloud fractions.

1) GEO 5km Spatial Resolution Nature Run "Truth"



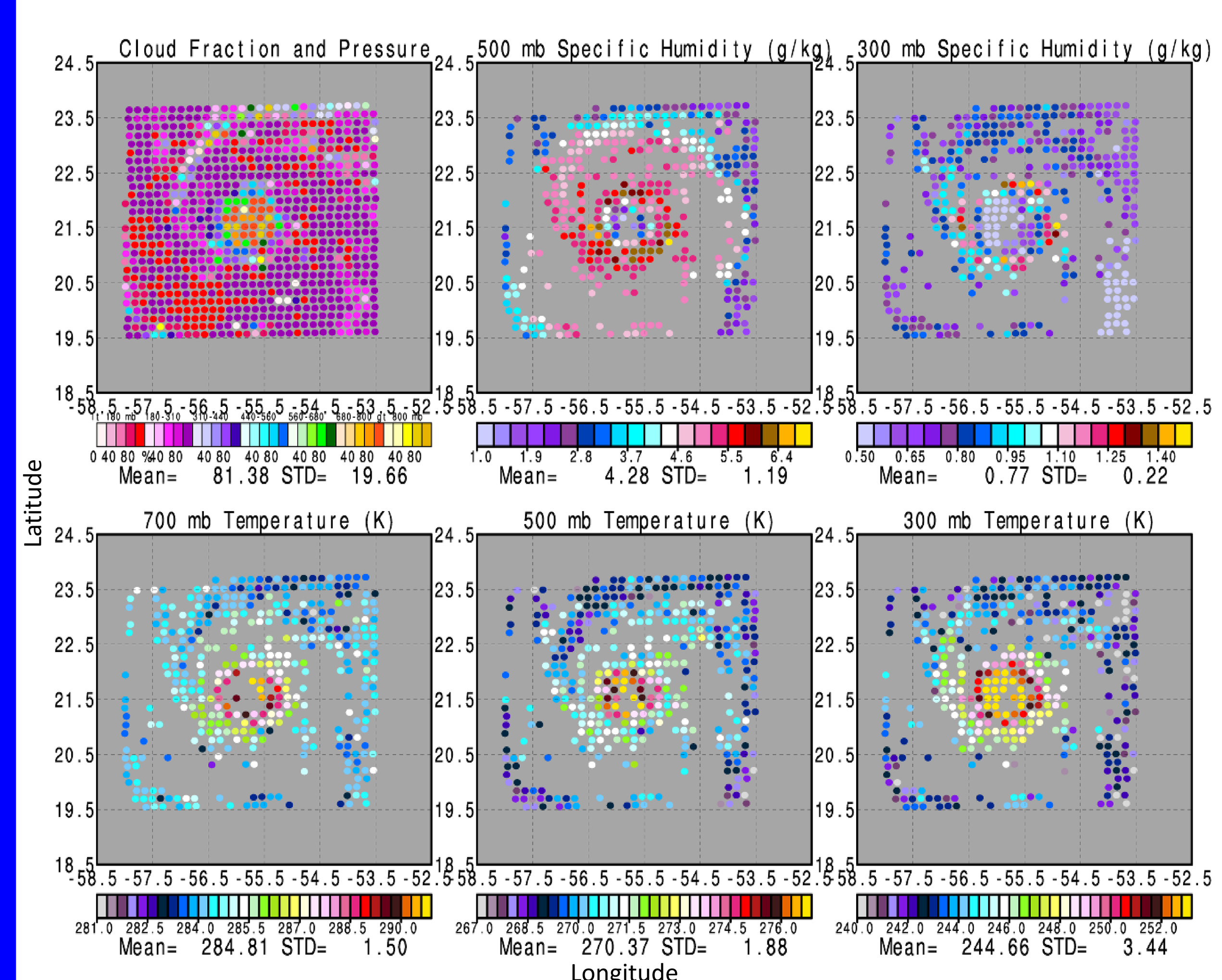
Nature Run truth values of select fields for the 5 km GEO experiment. The size of the dots are such that they roughly cover 15 km x 15 km areas. Dark red and purple colors in the cloud parameter field indicate large amounts of high cloud cover. The storm is marked by a swirl surrounding a region containing high pressure (yellow) clouds which is also locally dry and warm as shown at different pressures.

3) LEO Retrievals 2km Spatial Resolution



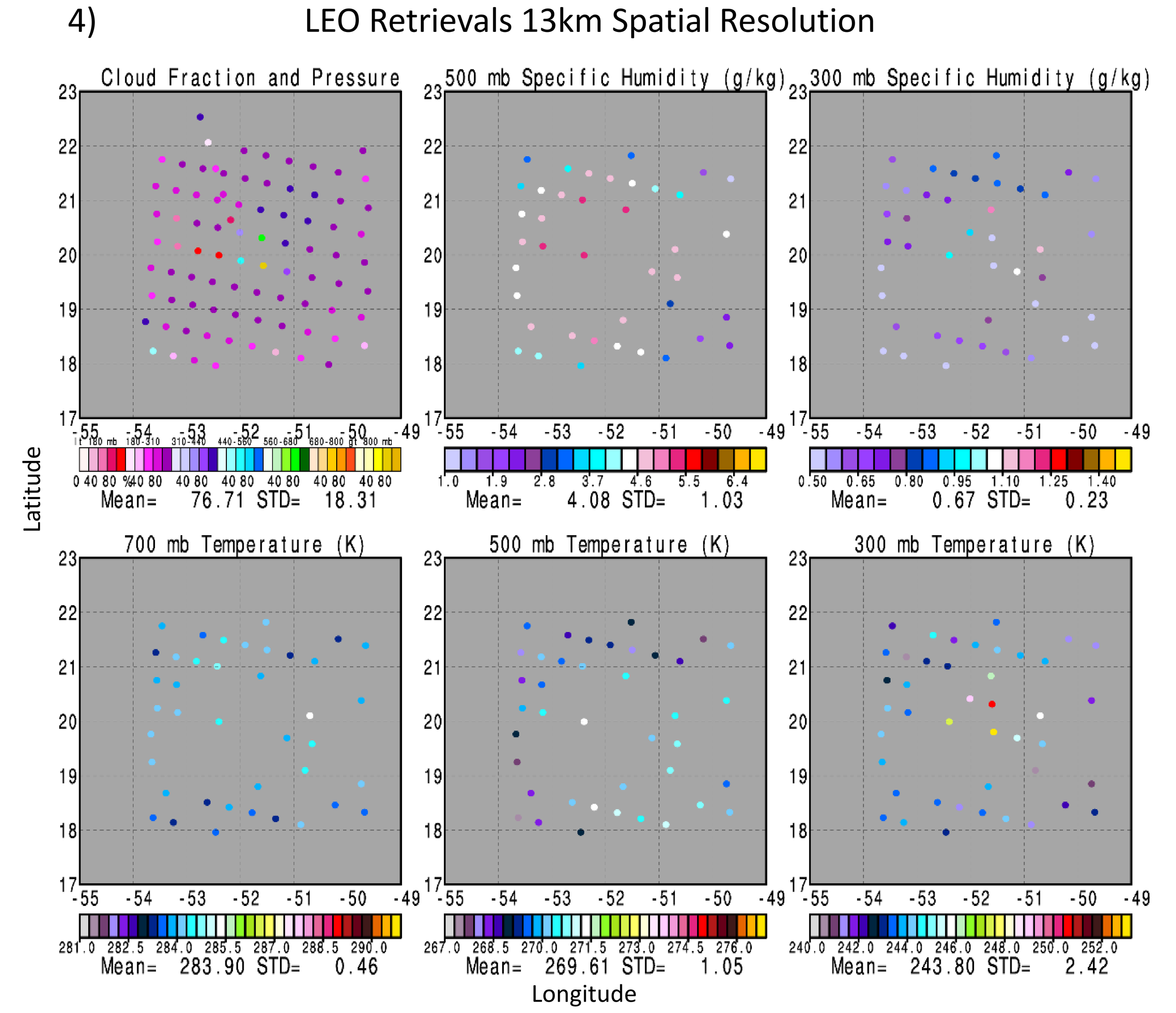
QC'd retrieved values of all fields for the 2 km LEO experiment. Retrieved values represent average values over the 6 km x 6 km FOR. FORs in which the retrieved values are rejected show up as gray. 2 km resolution retrievals show even more coherent spatial structure than do 5 km retrievals. Also, contiguous spatial areas with missing retrievals are smaller at 2 km than at 5 km.

2) GEO Retrievals 5km Spatial Resolution



QC'd retrieved values of all fields for the 5 km GEO experiment. Results are shown for the 15 km x 15 km FOR. Cloud products are always determined. FORs in which the retrieved values are rejected show up as gray. Spatial structures agree with truth very well. Retrievals are rejected in areas with larger amounts of high cloud cover.

4) LEO Retrievals 13km Spatial Resolution

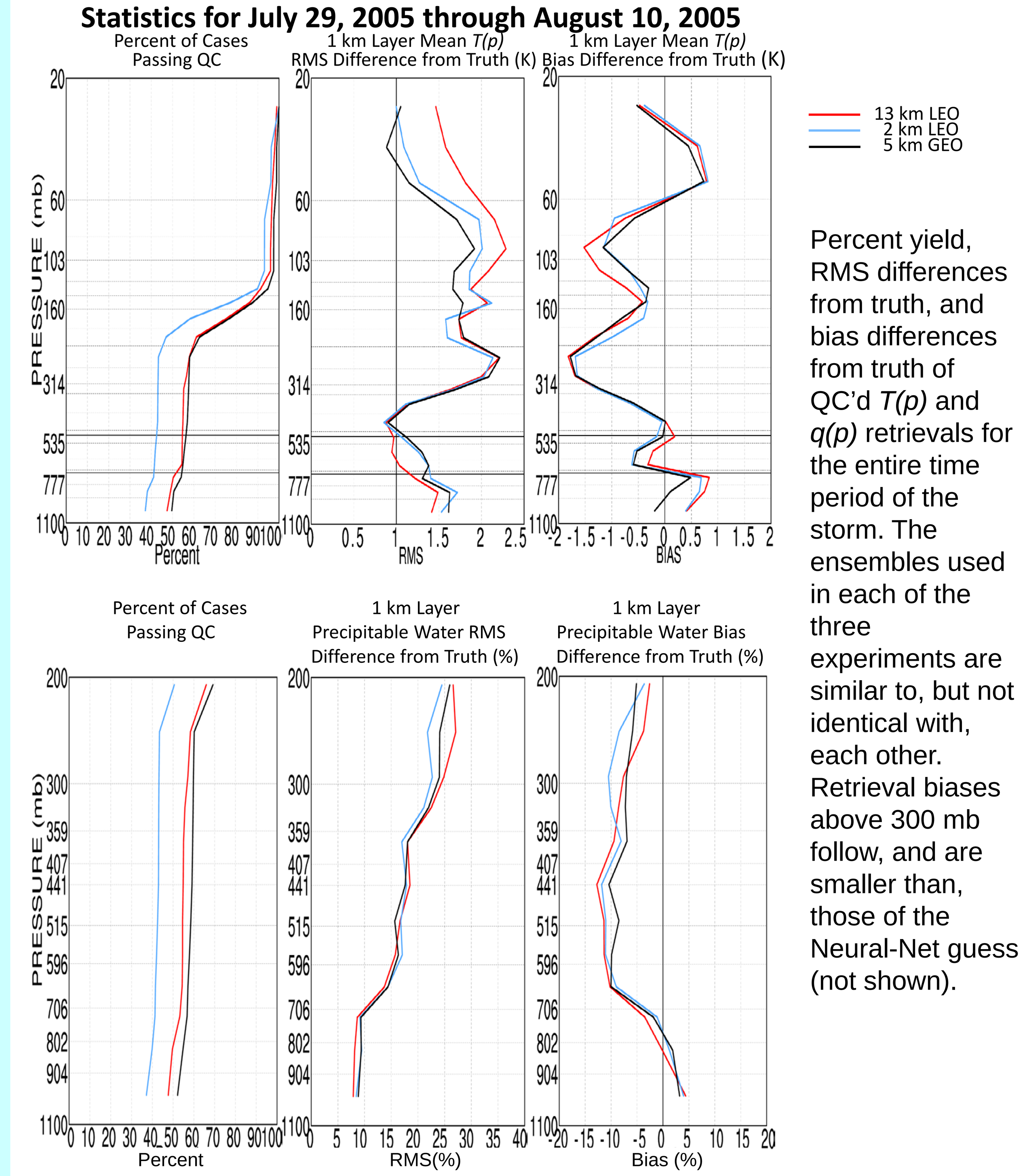


QC'd retrieved values of select fields for the 13 km LEO experiment. Retrieved values are show at the center of the 39 km x 39 km FOR. FORs in which the retrieved values are rejected show up as gray. While these retrievals are useful in the presence of a severe storm, much more information about the storm is obtained both at 5 km and 2 km spatial resolutions.

Retrieval Algorithm Used in the Experiments

We analyzed simulated channel radiance data for all three experiments in an identical fashion using the operational AIRS Version-6 AIRS Only (AO) retrieval algorithm. Version-6 AO was used because we did not simulate observations for an accompanying MW sounder such as AMSU-A. AIRS Version-6 AO uses Neural-Net coefficients which were trained on observed AIRS cloudy radiances to generate the first guesses used in the physical retrieval process. We used the same coefficients in this experiment and they performed extremely well beneath 300 mb. This shows that our simulation methodology, including the generation of multi-layer cloud cover, was very realistic. All retrievals were performed on a single 3x3 grouping of AIRS Field of Views (FOVs), referred to as an AIRS Field of Regard (FOR). Therefore the spatial resolutions of retrieval experiments are given by three times the experimental FOV sizes. Cloud fractions and cloud top pressures were determined consistent with the observed radiances and the retrieved state. Version-6 AO uses Quality Control (QC) methodology which assigns to each FOR a pressure down to which the retrieval is considered to be of high quality. Cloud products are generated and are plotted for each FOR. Temperature and water profile products are generated for each FOR, but are used only from the top of the atmosphere down to the lowest altitude accepted by the QC methodology. Consequently, both percent yield and spatial coverage will decrease to some extent at higher pressures as compared to lower pressures. Higher spatial resolution increases the spatial coverage of acceptable retrievals as a result of more cloud variability in the FORs. Higher spatial resolution also allows for the ability to better resolve features varying rapidly in space such as cloud cover and water profile.

Statistics for July 29, 2005 through August 10, 2005



Percent yield, RMS differences from truth, and bias differences from truth of QC'd $T(p)$ and $q(p)$ retrievals for the entire time period of the storm. The ensembles used in each of the three experiments are similar to, but not identical with, each other. Retrieval biases above 300 mb follow, and are smaller than, those of the Neural-Net guess (not shown).

Summary

These experiments clearly show the benefits of flying higher spatial resolution sounders in both LEO and GEO orbits. Retrieval error structures are similar for all experiments. Percentages of accepted cases at 2 km resolution are poorer than those at lower spatial resolution. This is misleading because there are many more cases at 2 km spatial resolution including many more overcast cases. Spatial coverage of retrievals, as well as the representativeness of the spatial structure of the storm, improved dramatically with decreasing size of the instrument's FOV. We sent QC'd $T(p)$ and $q(p)$ retrievals to Bob Atlas at AOML for use as input to OSSE Data Assimilation experiments.