

Comparison of NWP Cloud Products using A-Train Satellite Observations

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Introduction

- We recently started a project to demonstrate the application of the NCAR Model Evaluation Tools (MET) for forecast evaluation using A-train (currently focused on CloudSat) observations
- The goal of the project is to create a common toolkit for integrating satellite observations in a framework that permits meaningful comparisons with numerical model output
 - Evaluate forecast products and features to determine when and why forecasts are sometimes deficient

Example CloudSat/NWP Comparisons

- We performed our comparison using the RUC (<http://ruc.noaa.gov/>) cloud top height and derived reflectivity products at a spatial resolution of 20 km over the continental US
 - Two cases shown today
- Performed a seasonal (one year) correlation study of cloud top heights for different cloud types

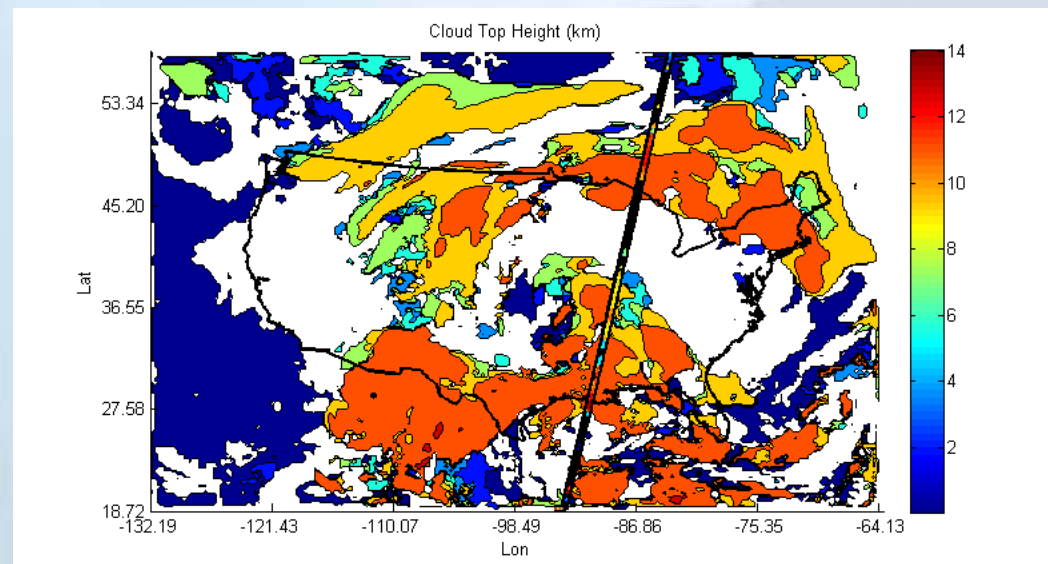
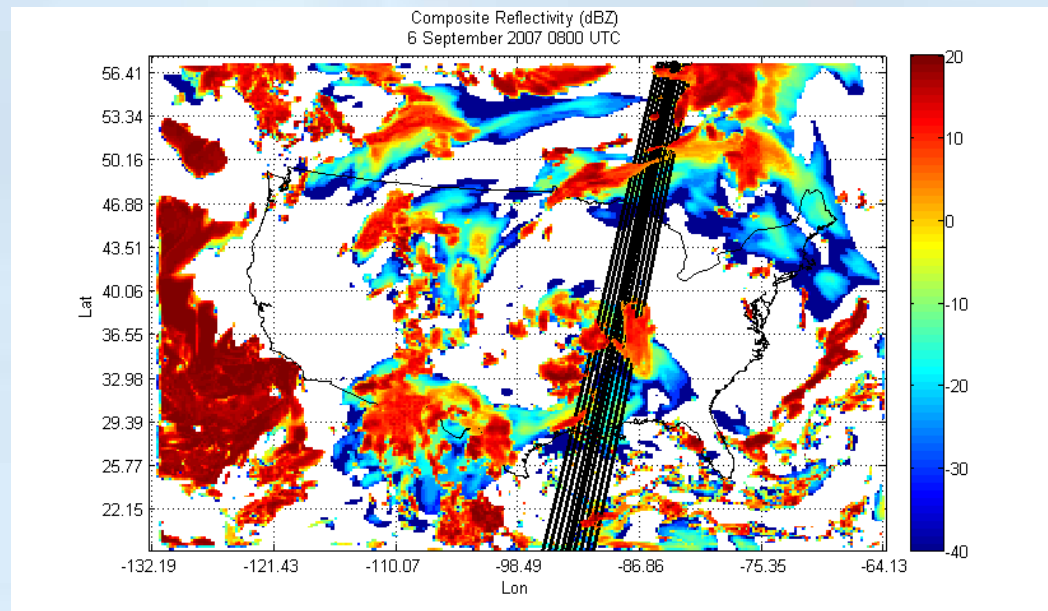
Cloud Top Height Comparisons

- Identify all CloudSat profiles and model grids that have cloud
- Identify all model grid boxes containing at least 10 CloudSat points (roughly half the number of points that could be in a grid box)
- Perform traditional statistics using multiple matching methods (nearest neighbor, mean, distance-weighted mean)

Reflectivity Profile Comparisons

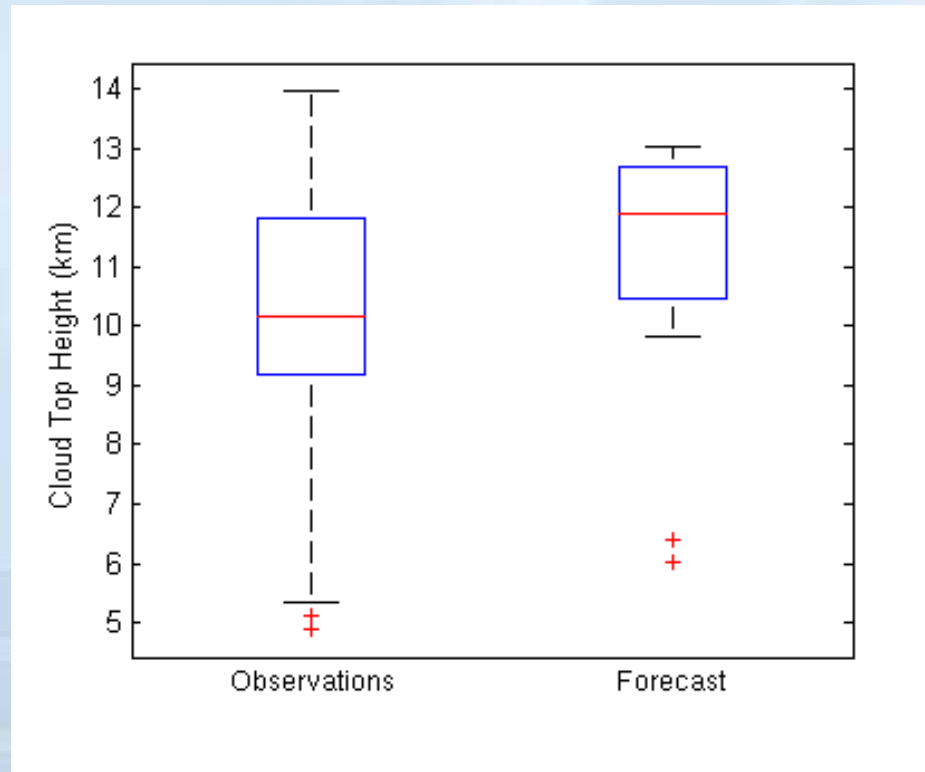
- Use RUC native grid mixing ratios (cloud water, rain, ice, snow, and graupel) and read the fields into CSU Quickbeam tool to convert to reflectivity
- Define a plane along the CloudSat path, in RUC space
- Extract RUC data along that plane
- Rotate and shift that plane

Example: 06 September 2007



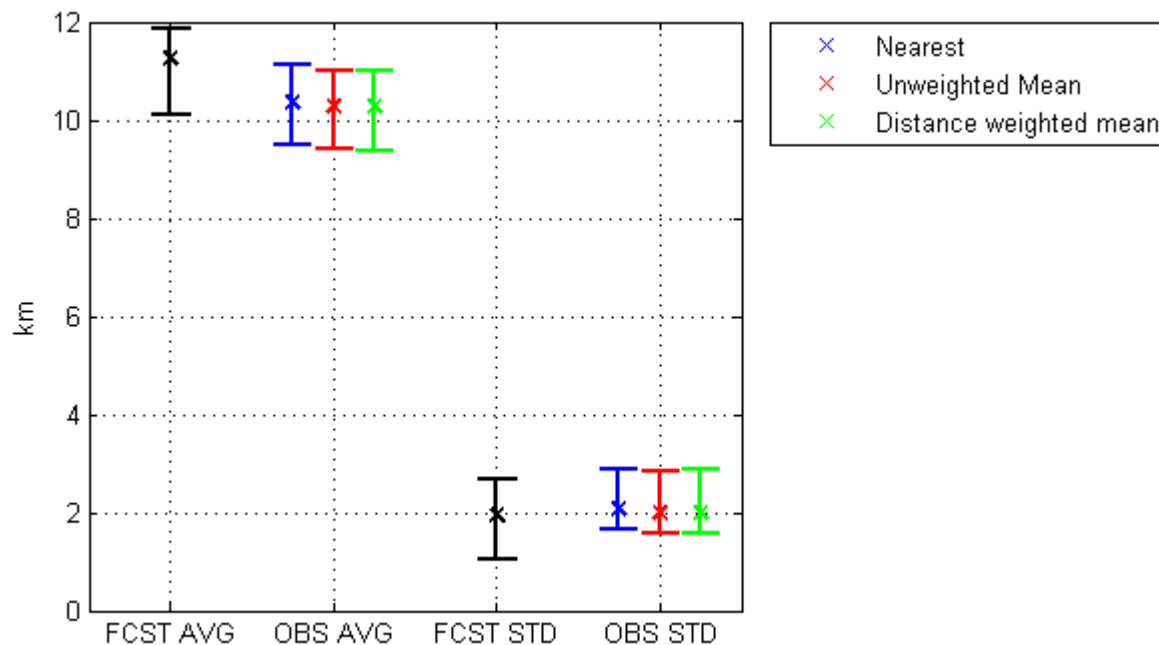
Cloud Top Height Comparisons

- Cloud Height Distributions along the track
 - All data included



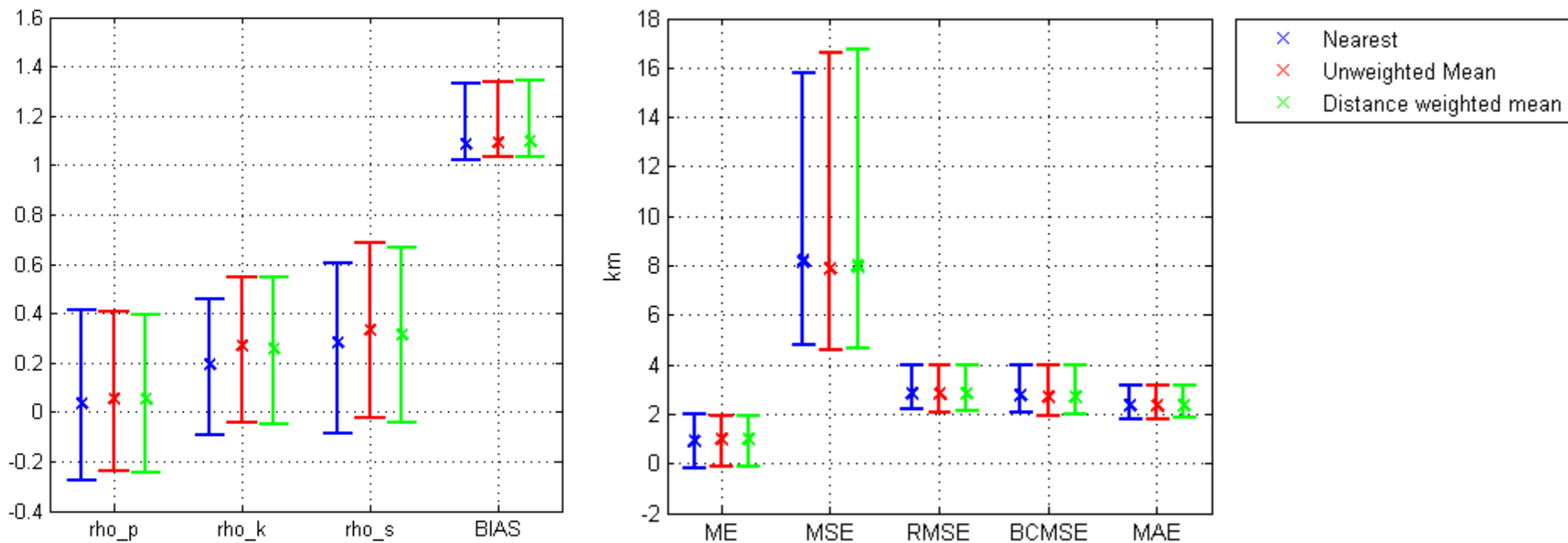
Cloud Top Height Comparisons

- Forecast mean and standard deviation with 95% confidence intervals
 - Matched pairs



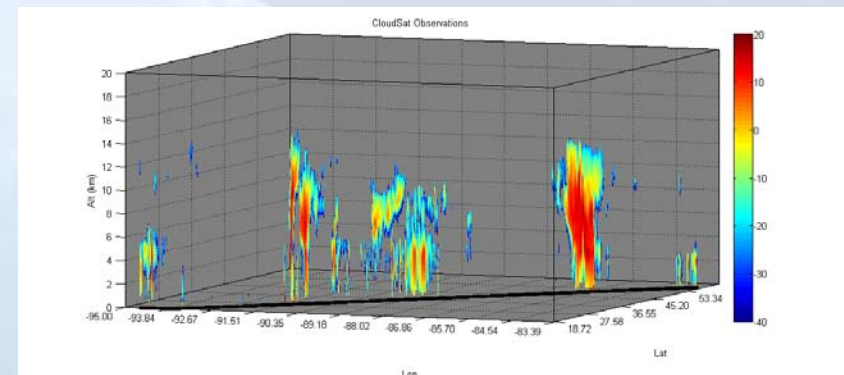
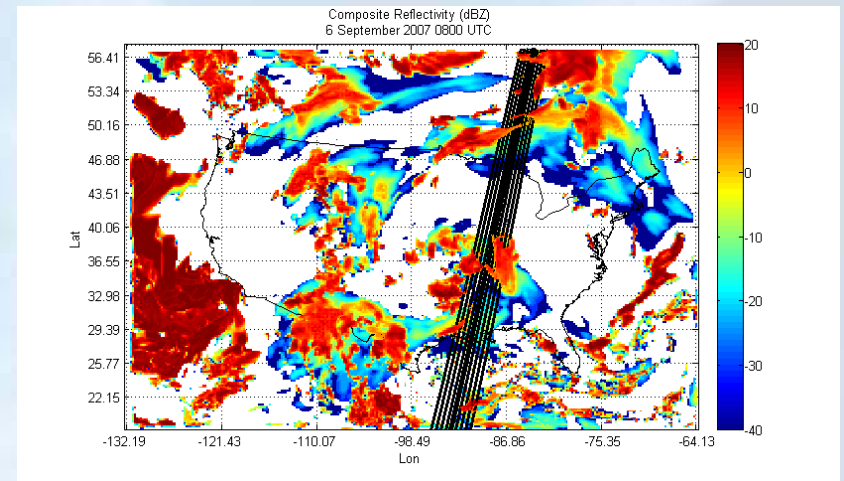
Cloud Top Height Comparisons

- Correlation (pearson, kendell, spearman), multiplicative bias, mean error, mean squared error, root mean squared error, bias corrected mean squared error and mean absolute error with 95% confidence intervals

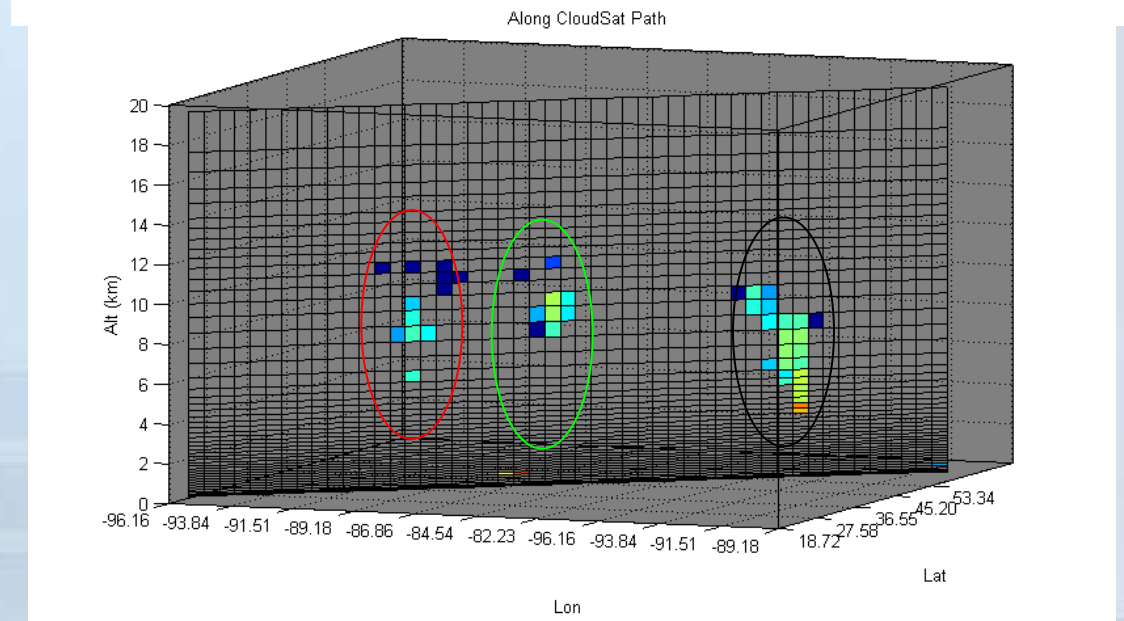
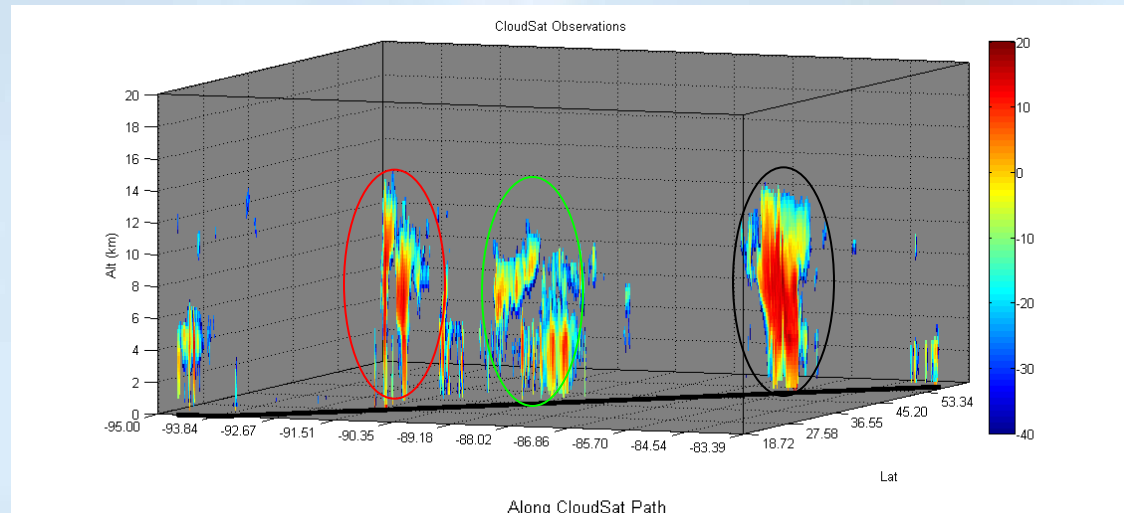


Reflectivity Profile Comparisons

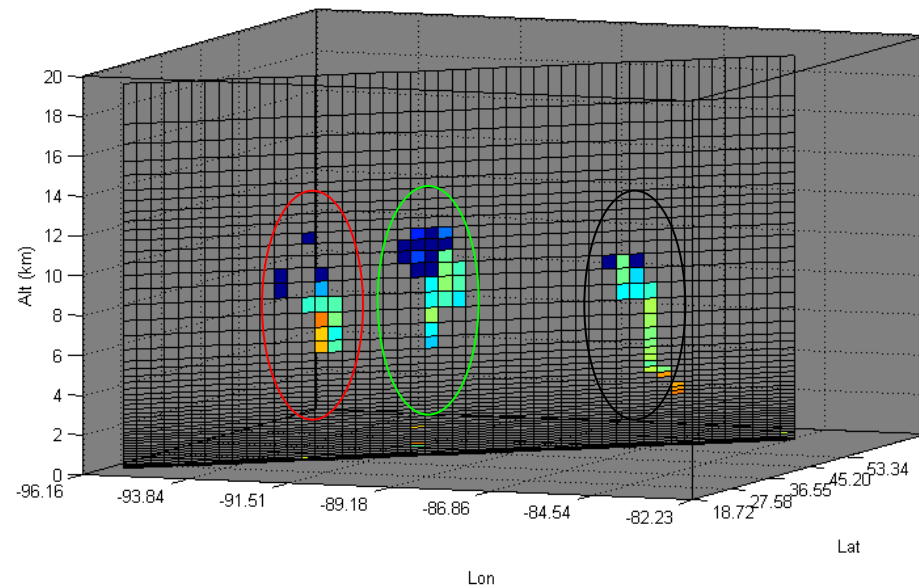
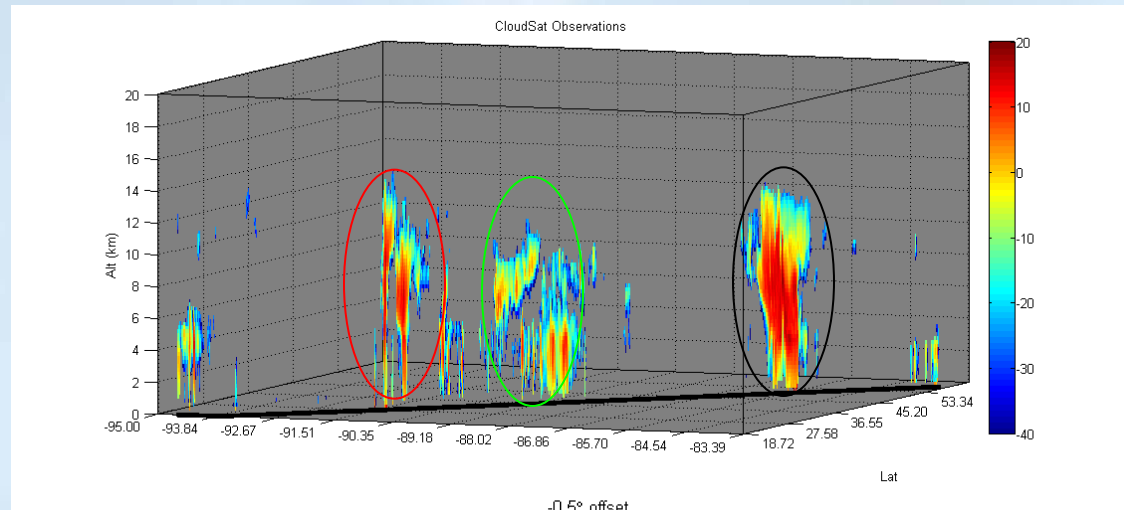
- We are exploring methods to spatially and temporally search model fields in the vertical to find matched objects:
 - parallel to track, cross track, and previous/past hours in time
- Next slides show examples of search methods



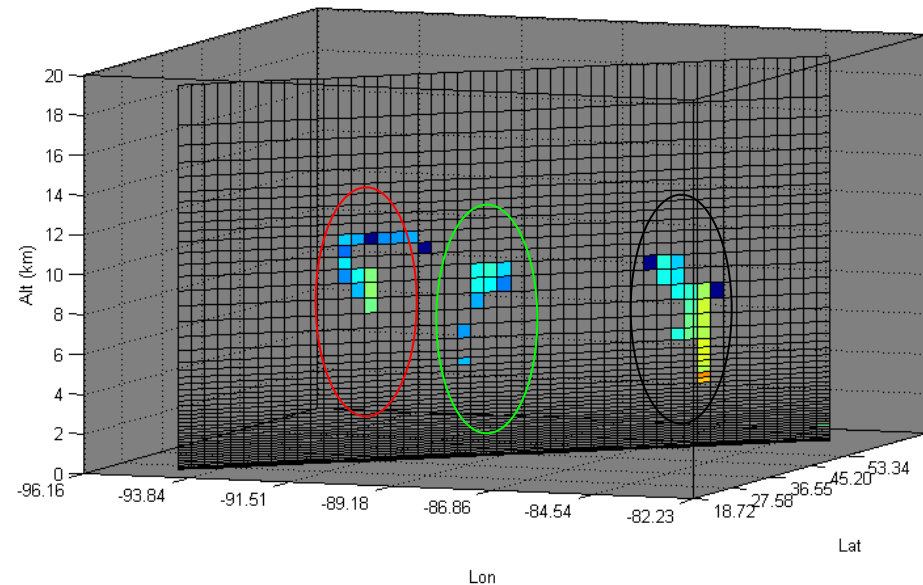
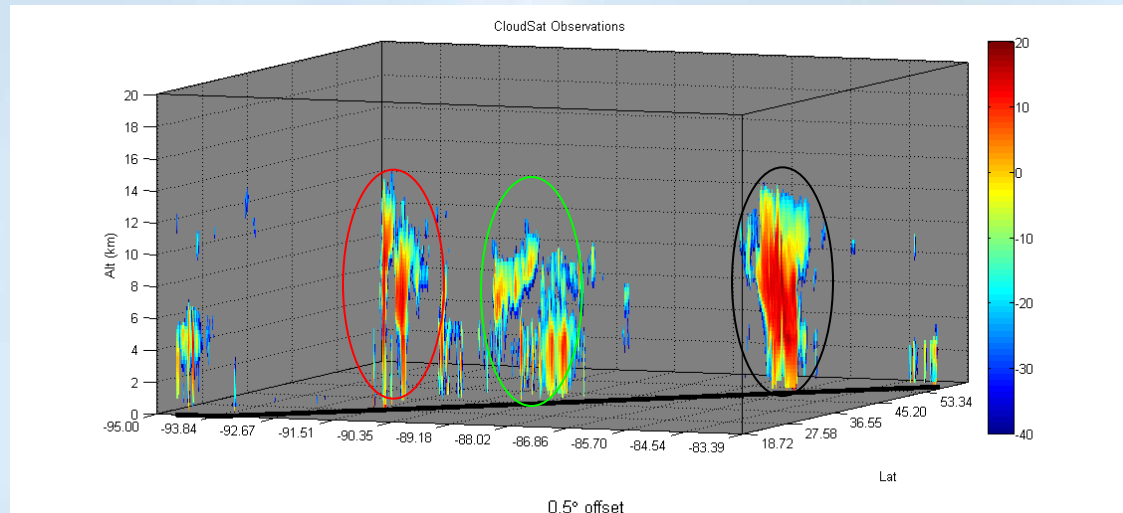
Object-based Comparison: Along Track



Object-based Comparison: Parallel to Track (Westward)



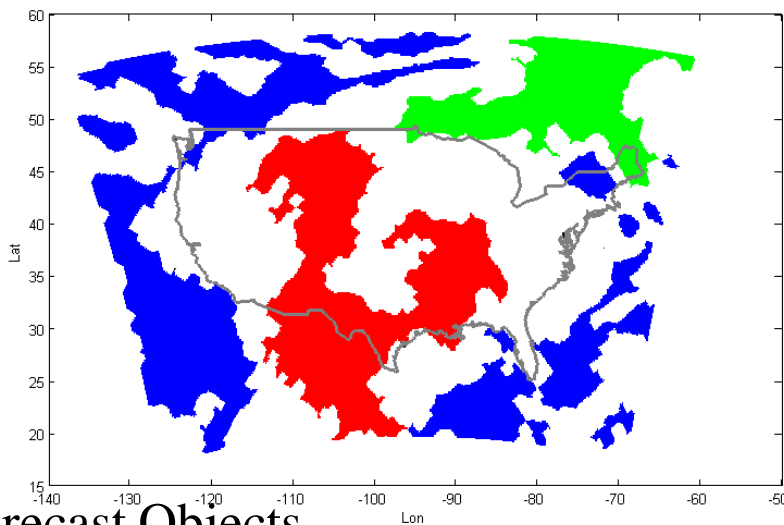
Object-based Comparison: Parallel to Track (Eastward)



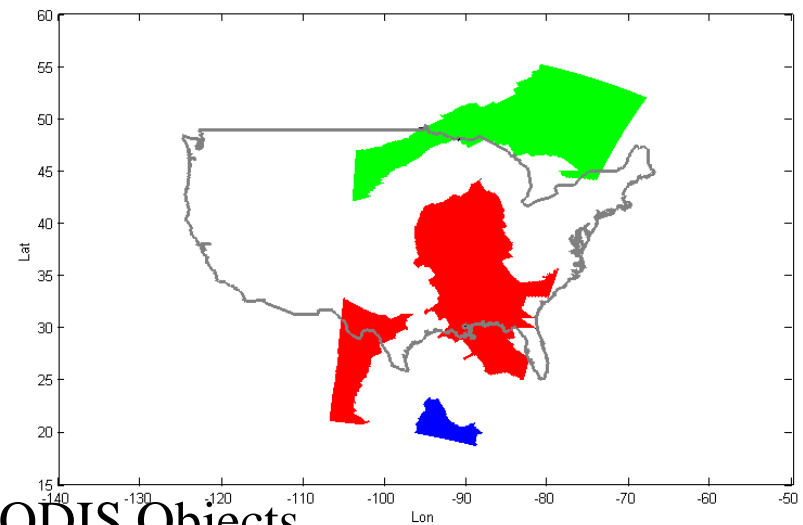


Object-based Comparison: Cross Track

- How to select the best cross track angle?
 - Possible idea is to combine it with other satellite data such as MODIS to find the best match for comparison

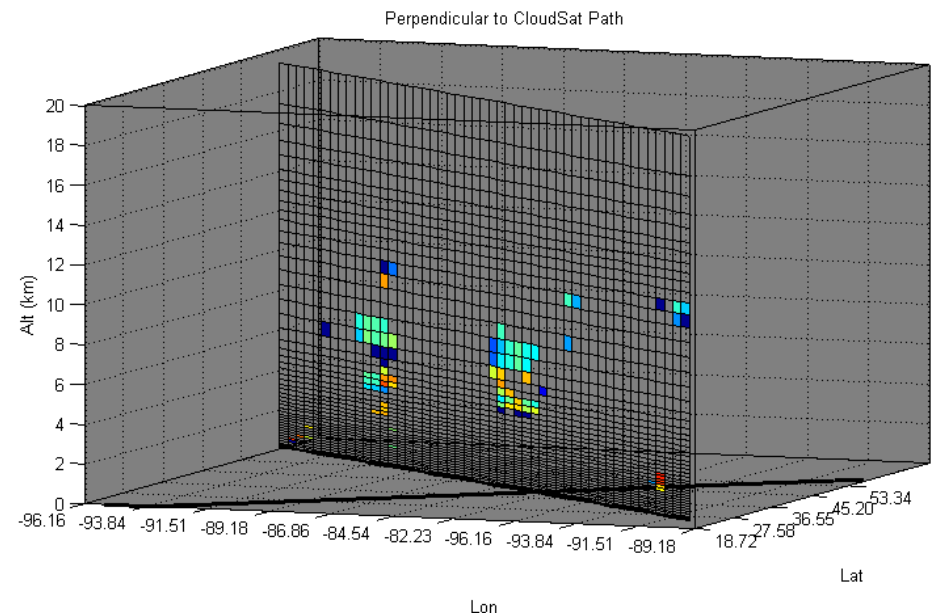
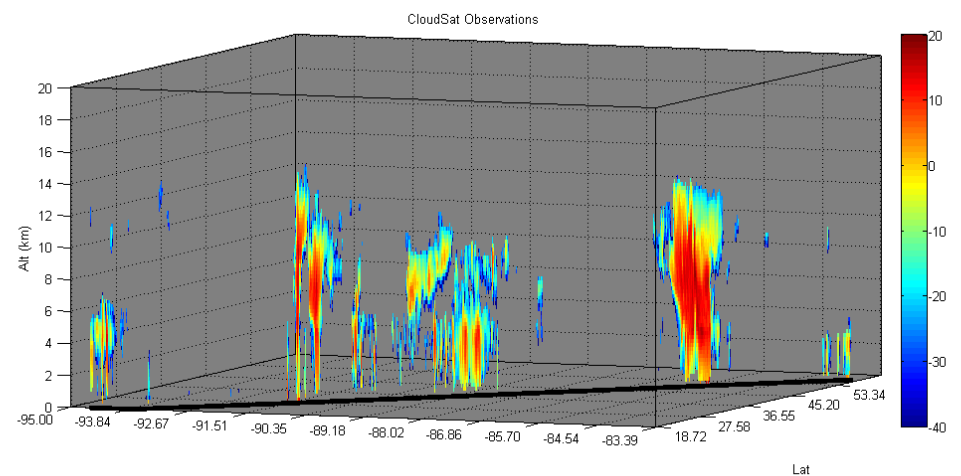
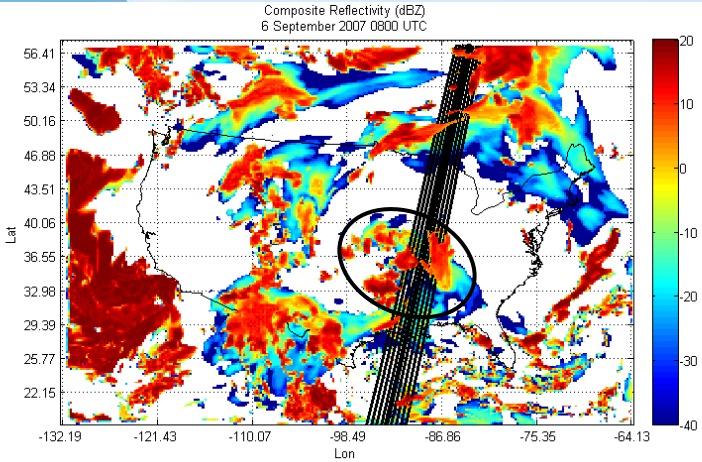


Forecast Objects

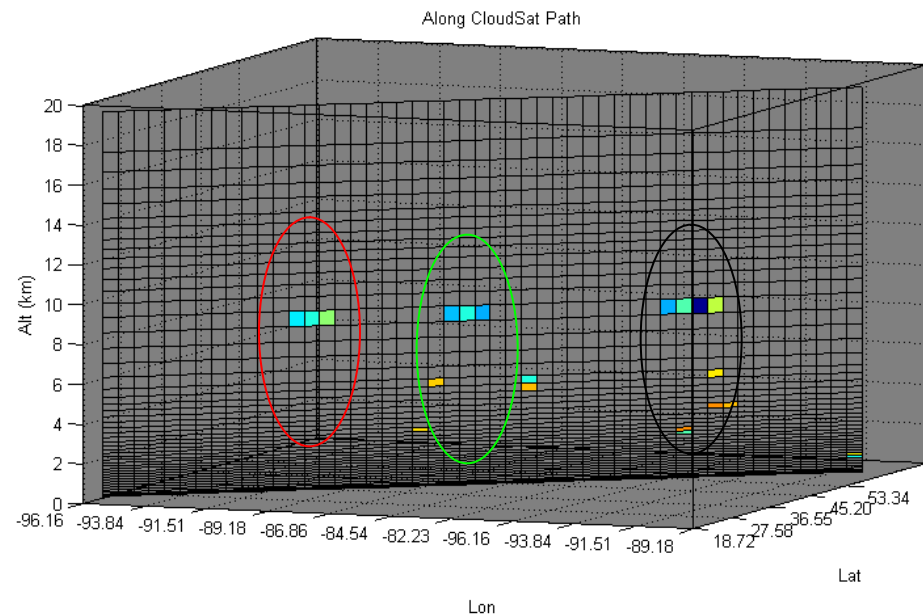
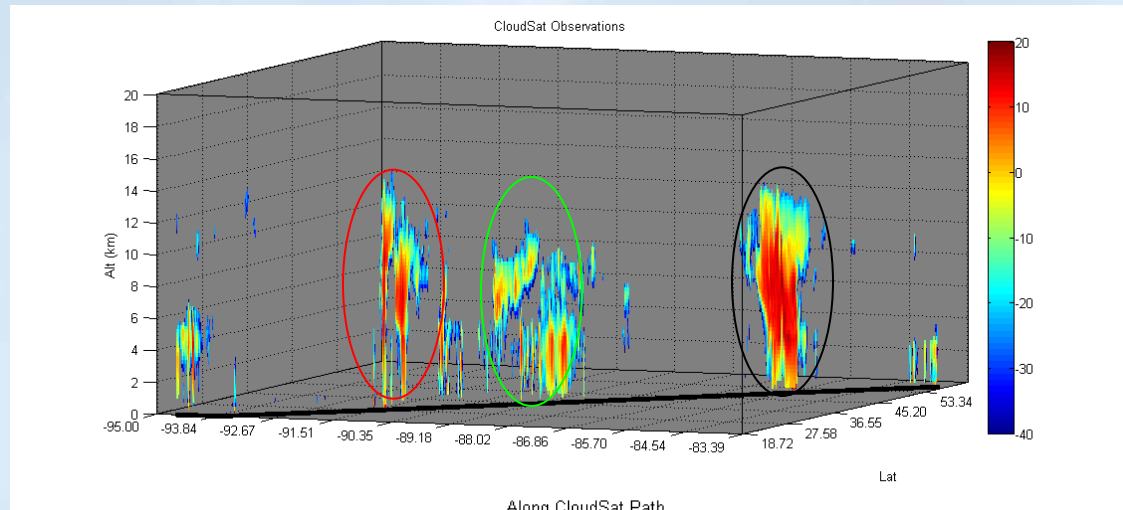


MODIS Objects

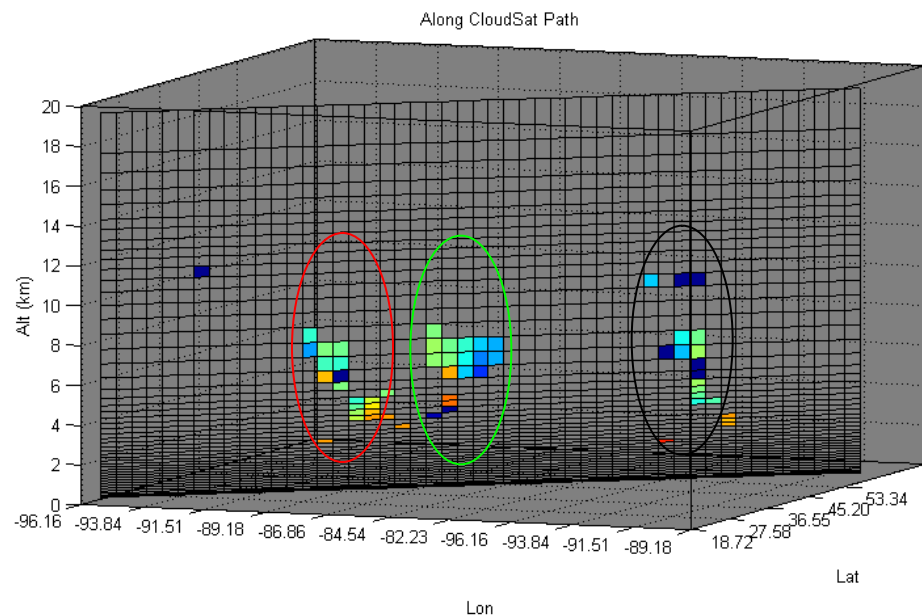
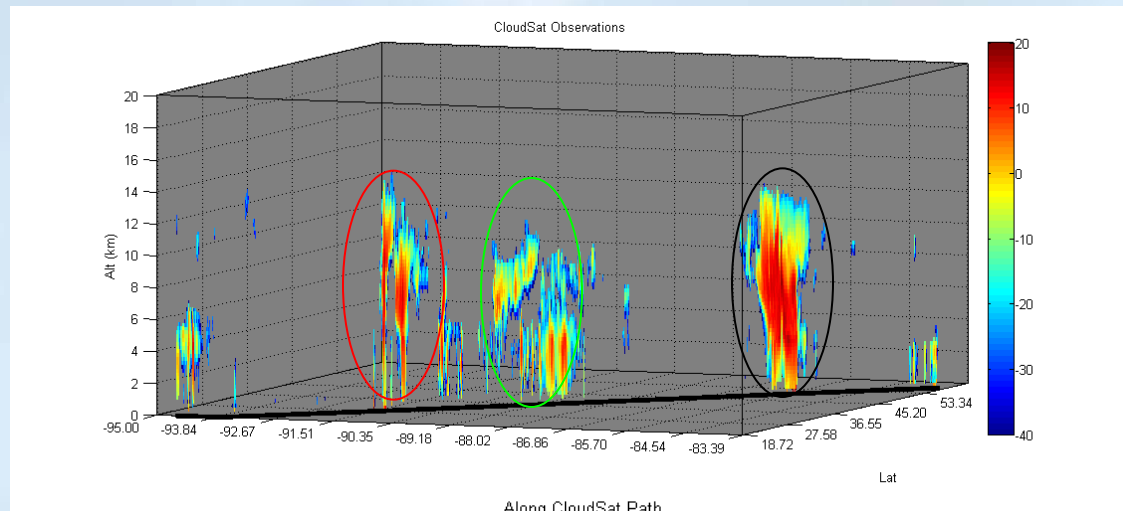
Object-based Comparison: Cross Track



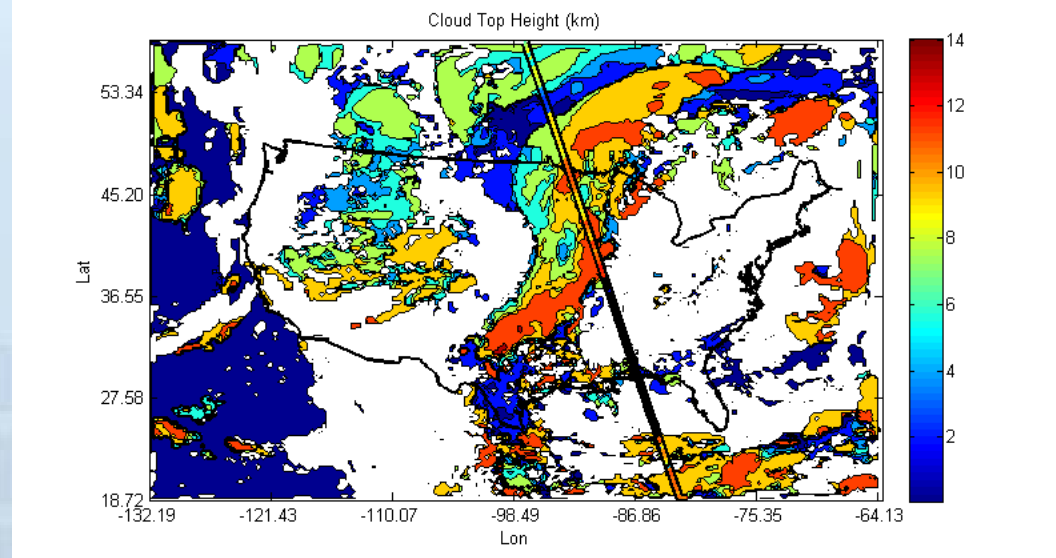
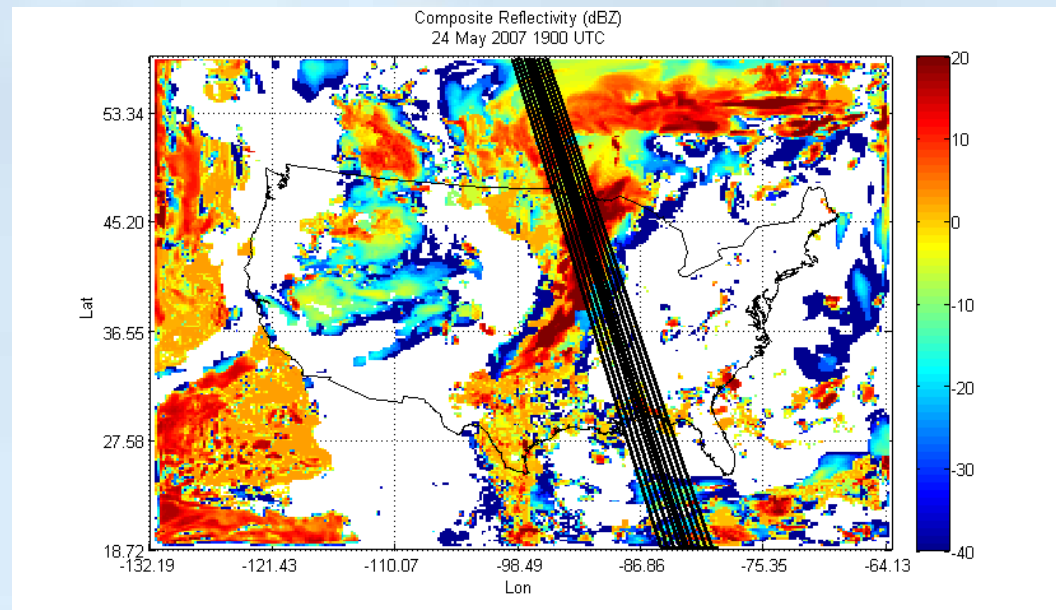
Object-based Comparison: -1 hour (0700 UTC)



Object-based Comparison: +1 hour (0900 UTC)

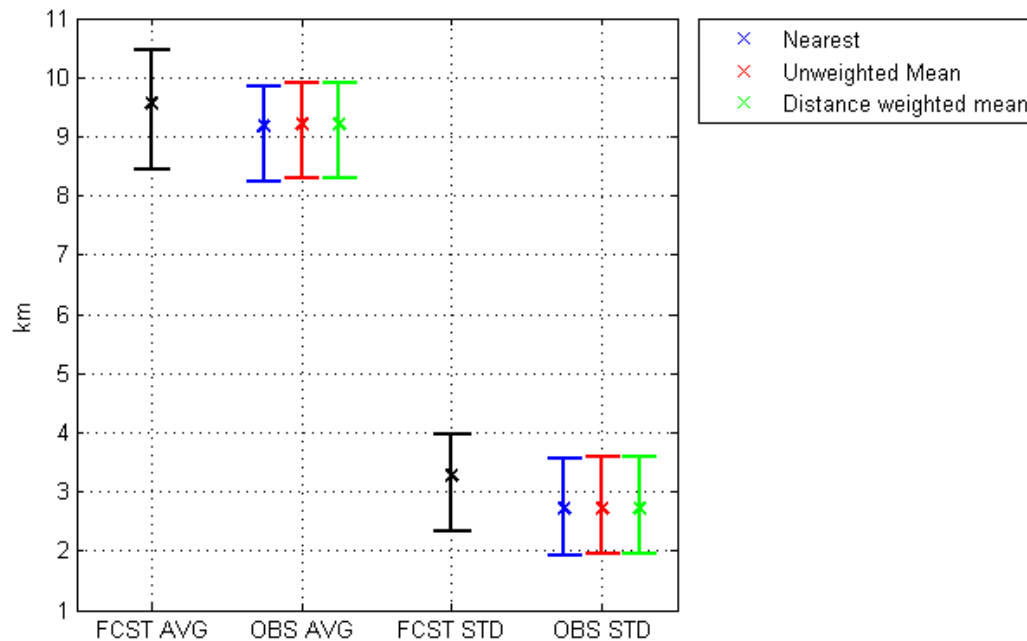


Example 2: 24 May 2007

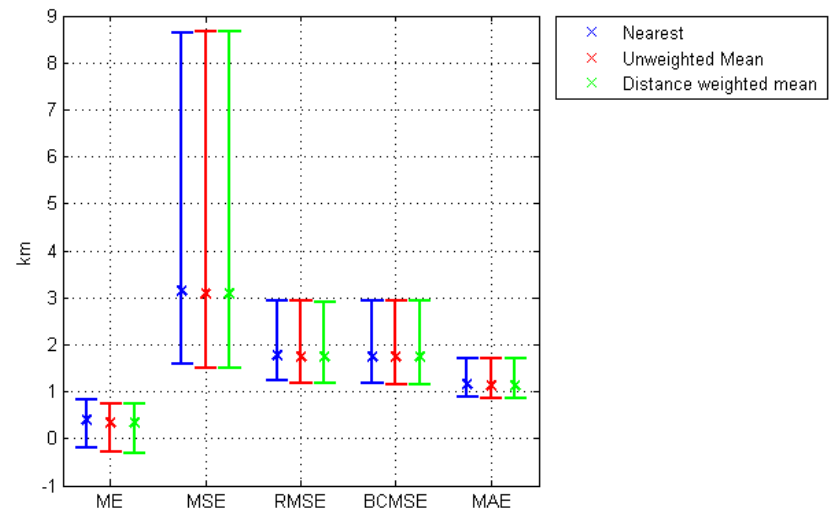
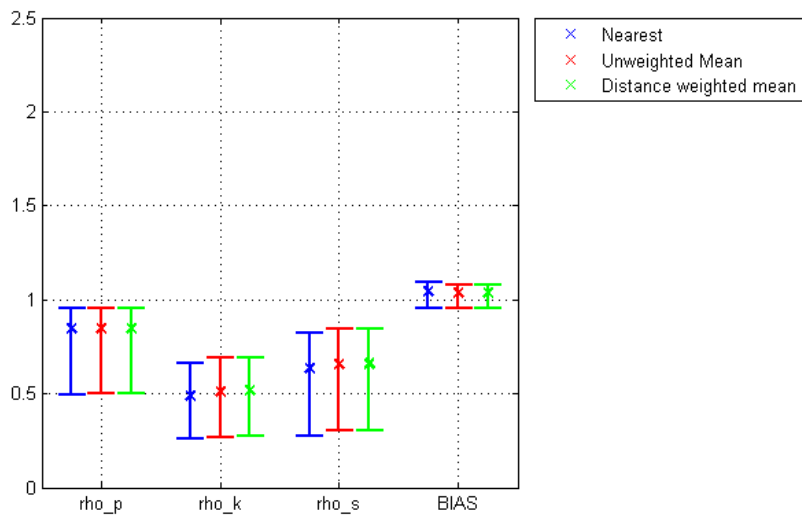


Cloud Top Height Comparisons

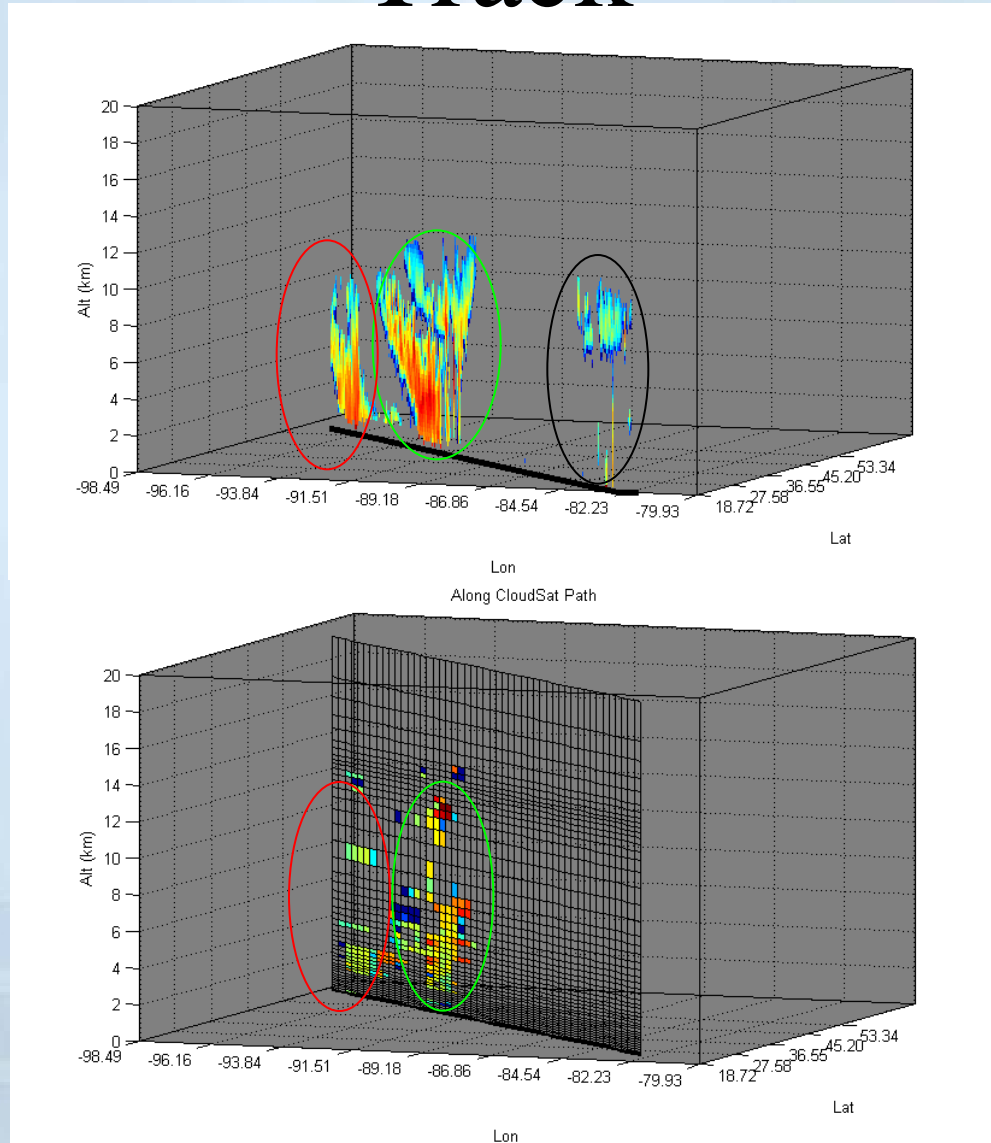
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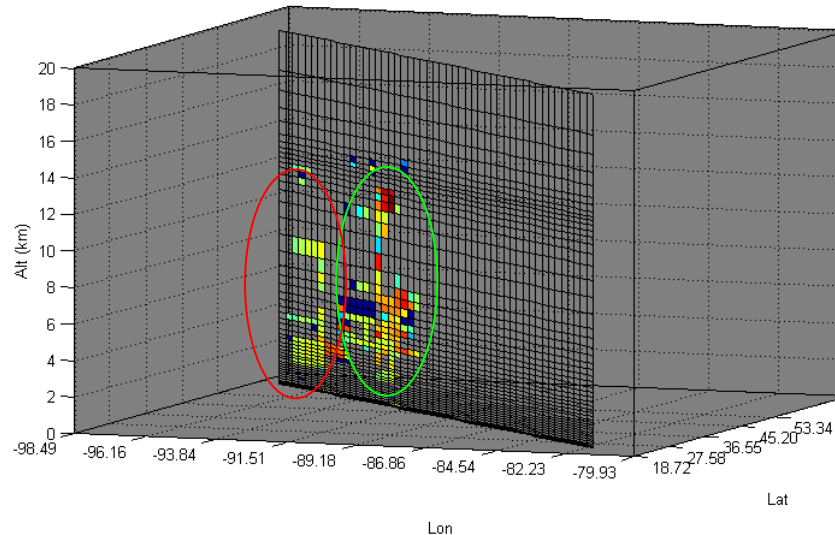
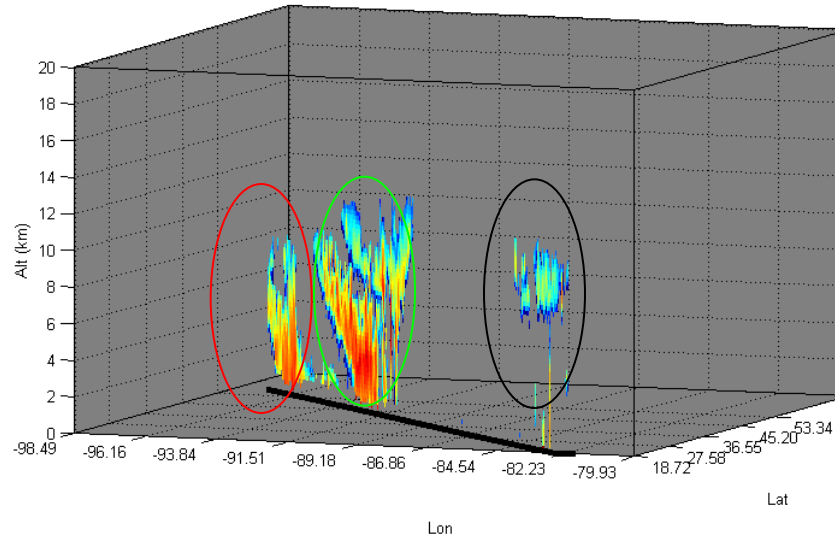
Cloud Top Height Comparisons



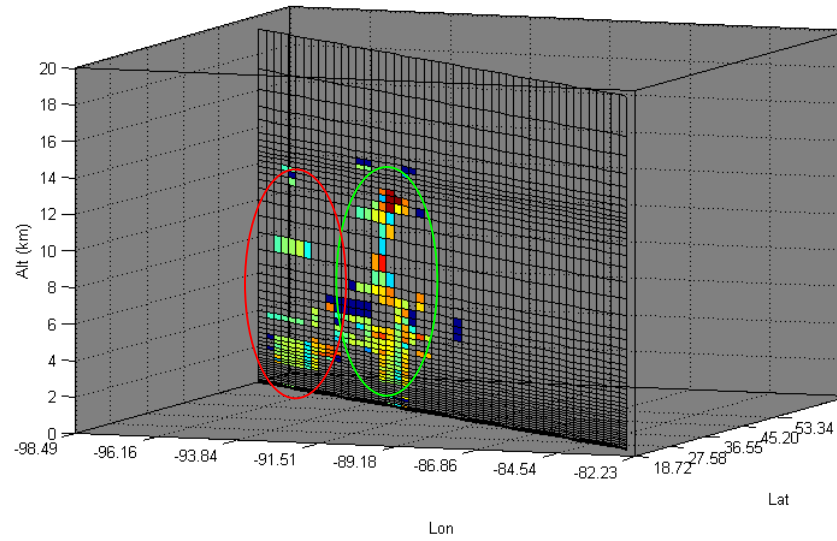
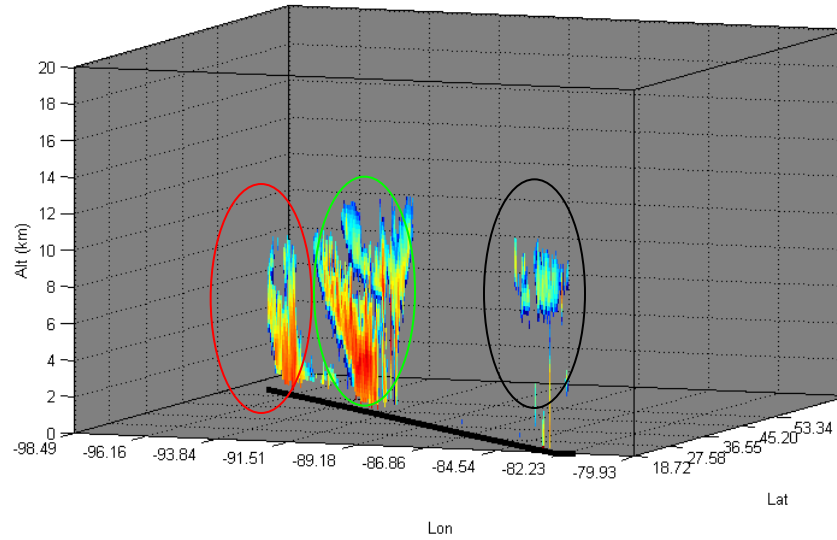
Object-based Comparison: Along Track



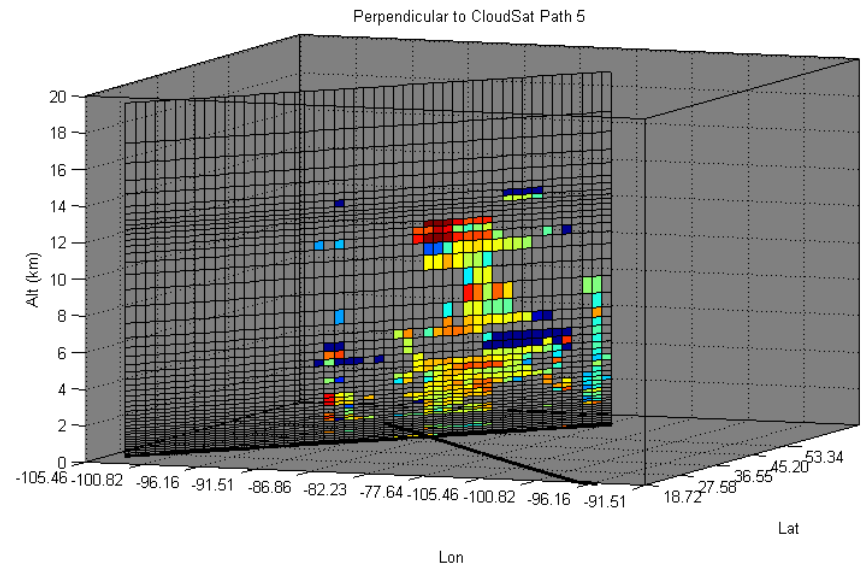
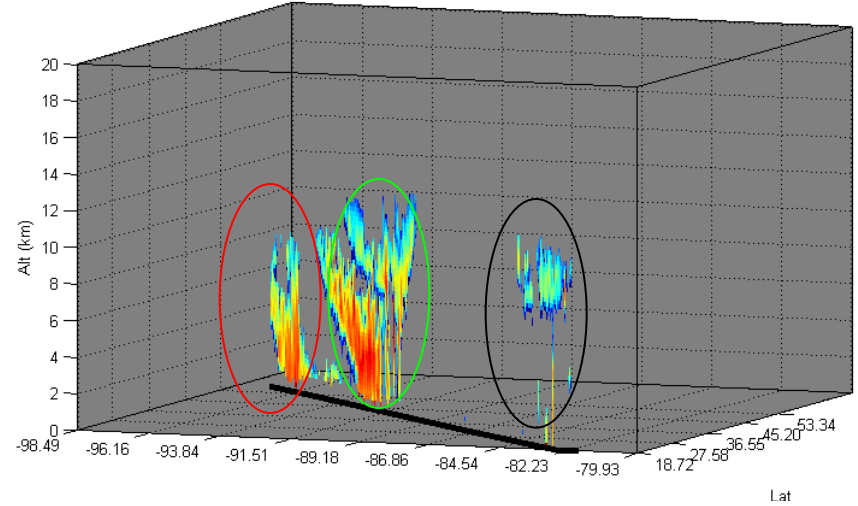
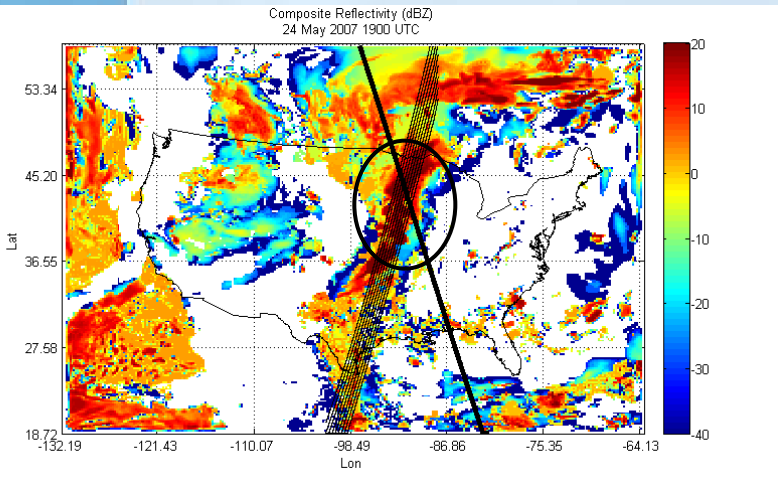
Object-based Comparison: Parallel to Track (Northward)



Object-based Comparison: Parallel to Track (Southward)



Object-based Comparison: Cross Track

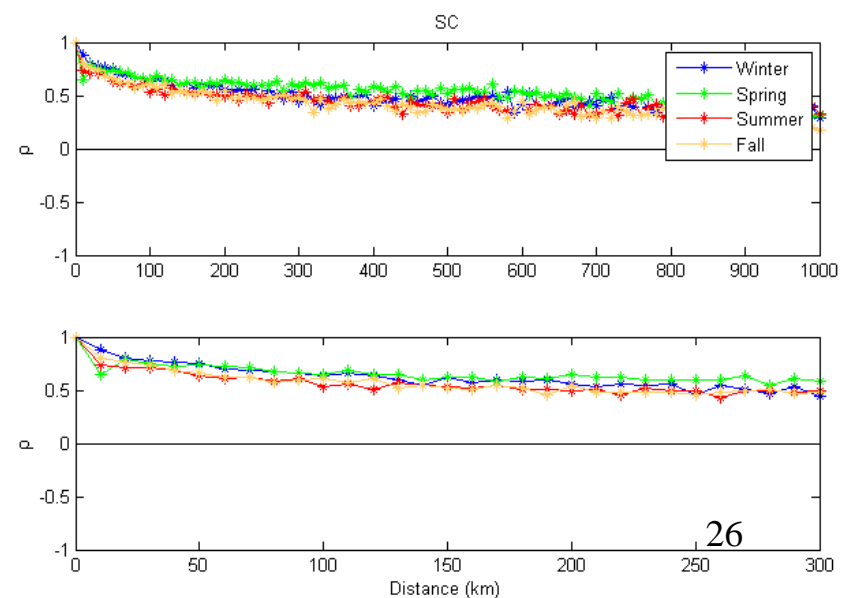
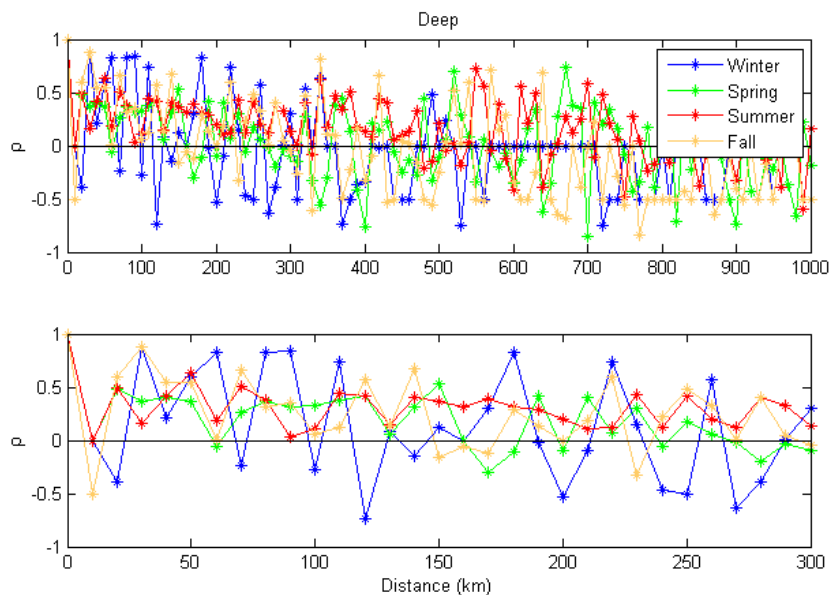


Spatial/Seasonal Comparison

- For a season of orbits, use the cloud classification product to single out clouds for each type
- Do some smoothing and merging
- Identify a bounding box and centroid for each cloud feature
- Record the top of the bounding box as cloud top height, and use the centroid distances between clouds in the same orbit
- Compute spatial correlation of cloud top height for each cloud type at various distance ranges

Spatial/Seasonal Comparison

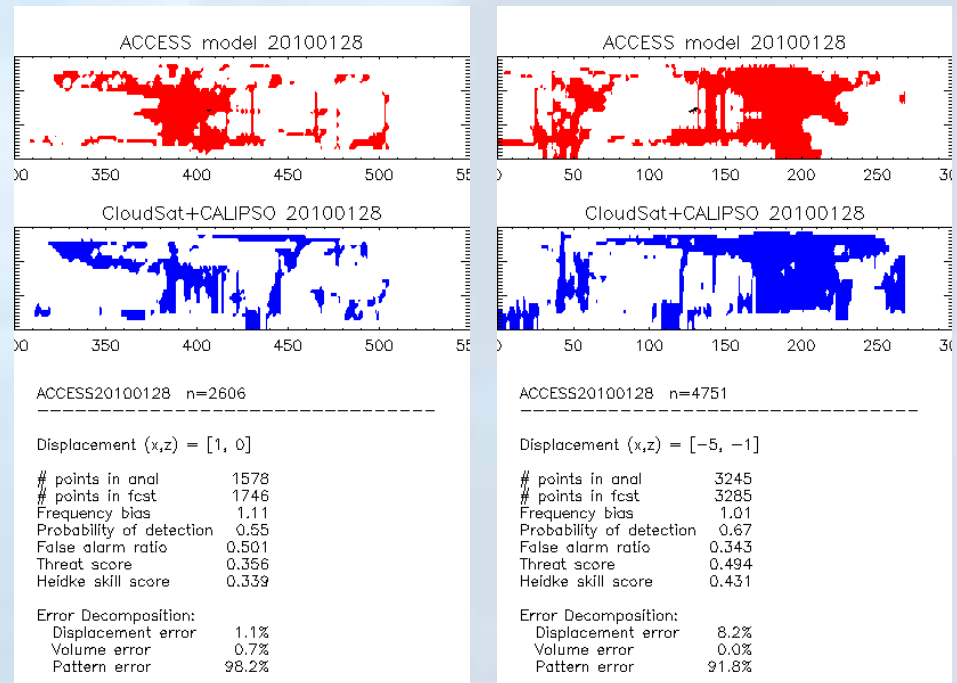
- Example spatial correlation results for different CloudSat cloud types and for different seasons (2007)
 - Over Continental US
- Combine with other datasets (e.g., MODIS) to better understand spatial cloud properties off CloudSat track



Other Feature Based Methods



- Contiguous Rain Area (CRA) Method (e.g., Ebert and Gallus 2009)
- Comparison of combined CloudSat-CALIPSO Product with the Australian Community Climate and Earth-System Simulator (ACCESS), which is based upon the UK Met Office Unified Model system

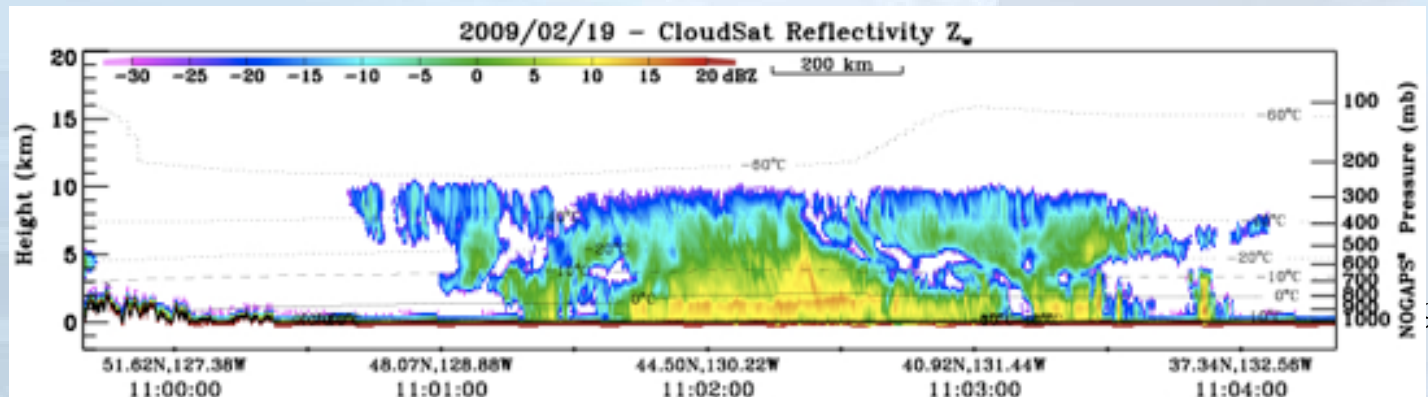


Summary

- We have seen in this and previous presentations that forecasts and A-train satellite comparisons can be useful in certain situations:
 - For well-defined events such as tropical cyclones, synoptic systems, and maybe mesoscale systems
 - For persistent features, where you're trying to diagnose systematic error in the model (might need to combine many cases)
 - For characterizing distributions of cloud properties in observations and forecasts, but without matching
- Initial exploration of identifying matched objects in the CloudSat and model products showed mixed results (case dependent)

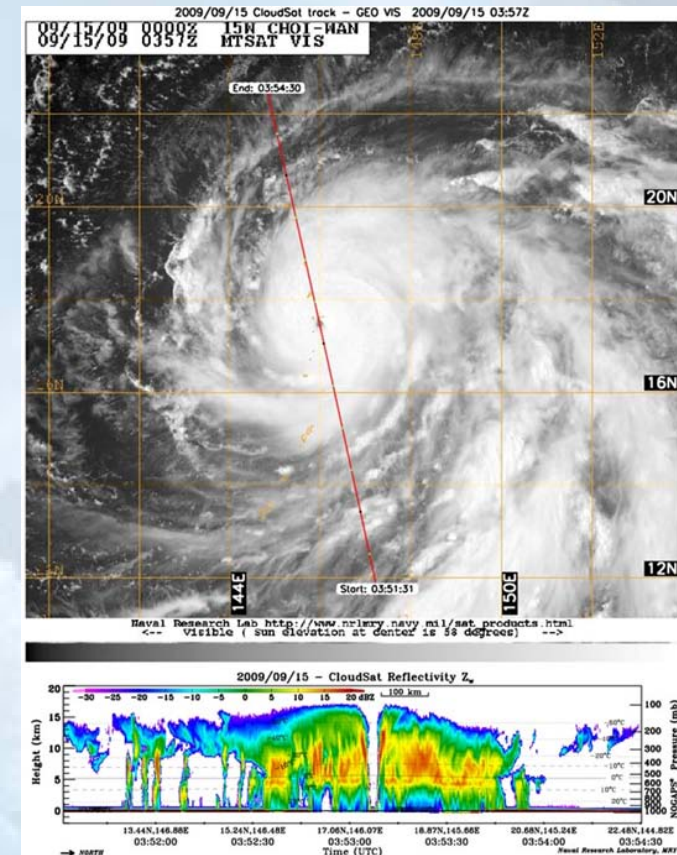
Future Work

- Future updates to MET:
 - Finish implementing code to read A-Train products into MET
 - Add object-based methods in the vertical plane to MET (e.g., MODE)
 - Improve methods for verifying cloud and precipitation properties
- Implement a display tool for visualization of satellite and model products within MET



Final Thoughts

- Future A-train comparisons
 - Cloud top height, cloud base, cloud type, cloud water content, ice water content, etc.
- We are currently developing a database of case studies for comparisons
 - Tropical storms, multilayer clouds, clouds over complex terrain, etc.
- We would like to extend the tool to other datasets such as TRMM, GPM, etc.



Acknowledgments

- We utilized Quickbeam, a tool developed by our colleagues at CSU for some of the analysis:
 - Haynes, J.M., R.T. Marchand, Z. Luo, A. Bodas-Salcedo, and G.L. Stephens, 2007: A multi-purpose radar simulation package: QuickBeam. Bull. Amer. Meteor. Soc., 88, 1723-1727.