The Retrieval of Atmospheric Profiles from Satellite Radiances for NWP Data Assimilation

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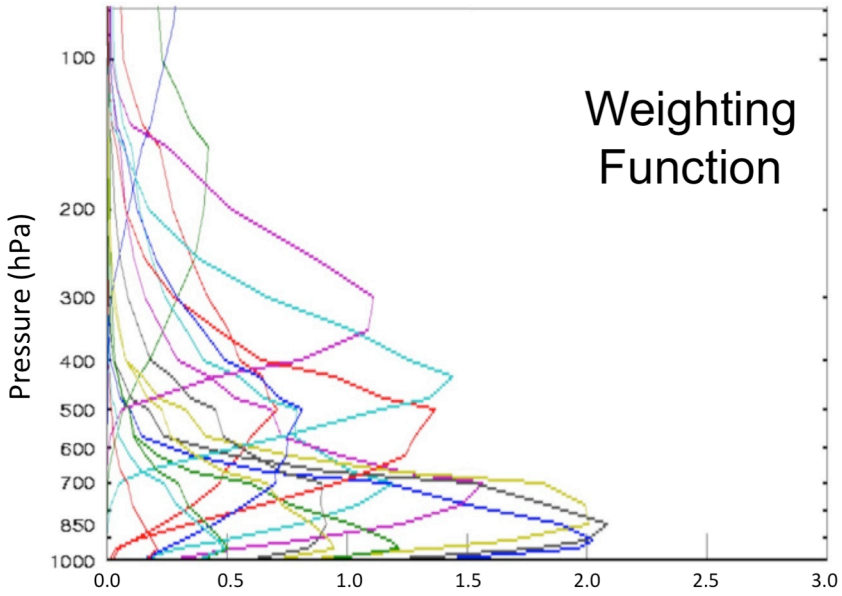
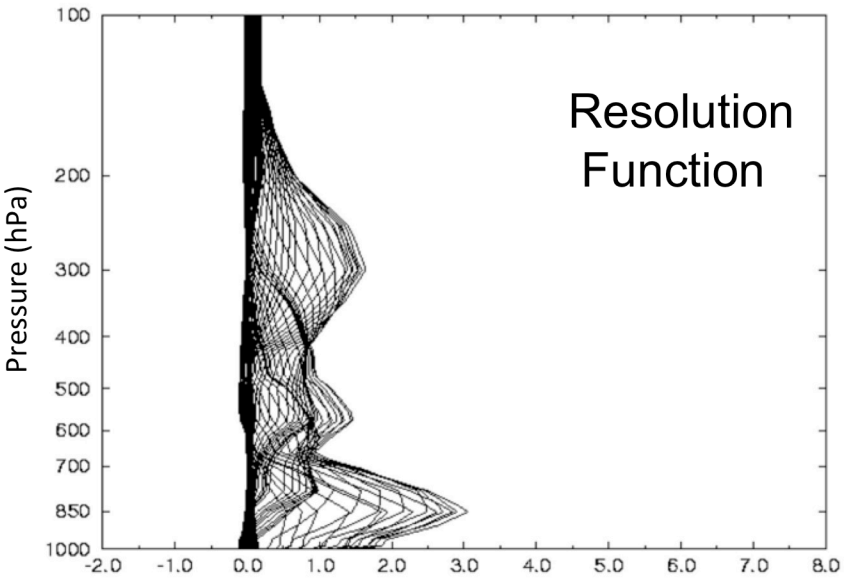
SSEC

Poor Sounding Vertical Resolution Causes Problem with Direct Assimilation of Satellite Profiles

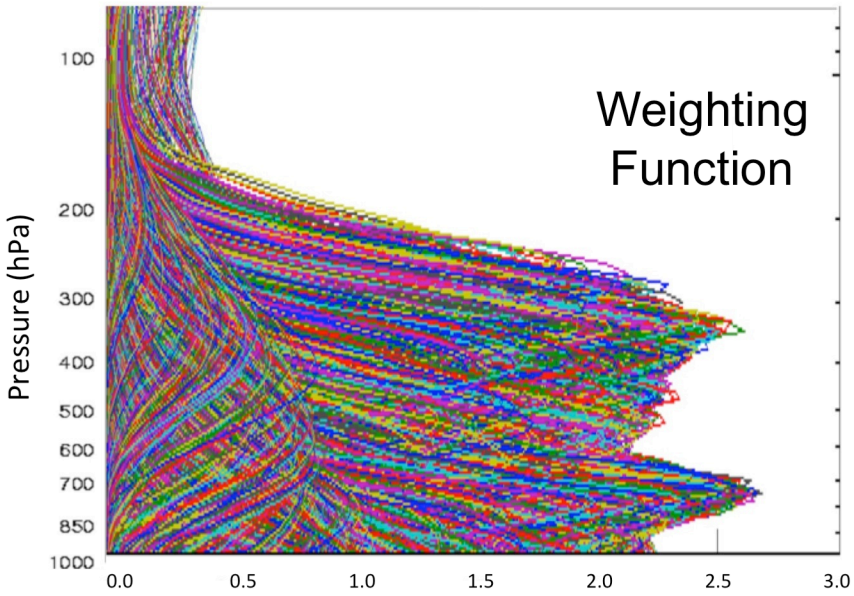
Filter Sounders (e.g., HIRS)



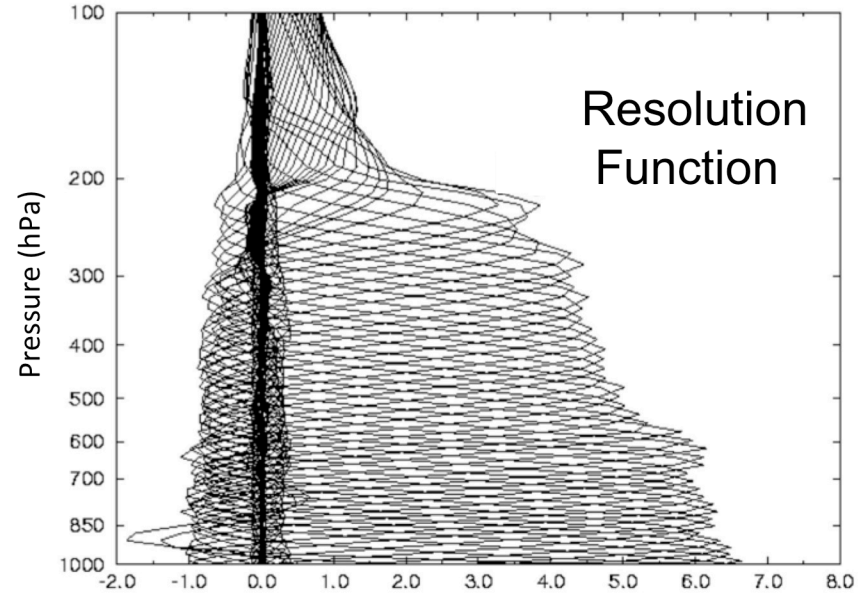
$\Delta\nu = 15\ cm^{-1}$



Interferometer Sounders (e.g.CrIS)

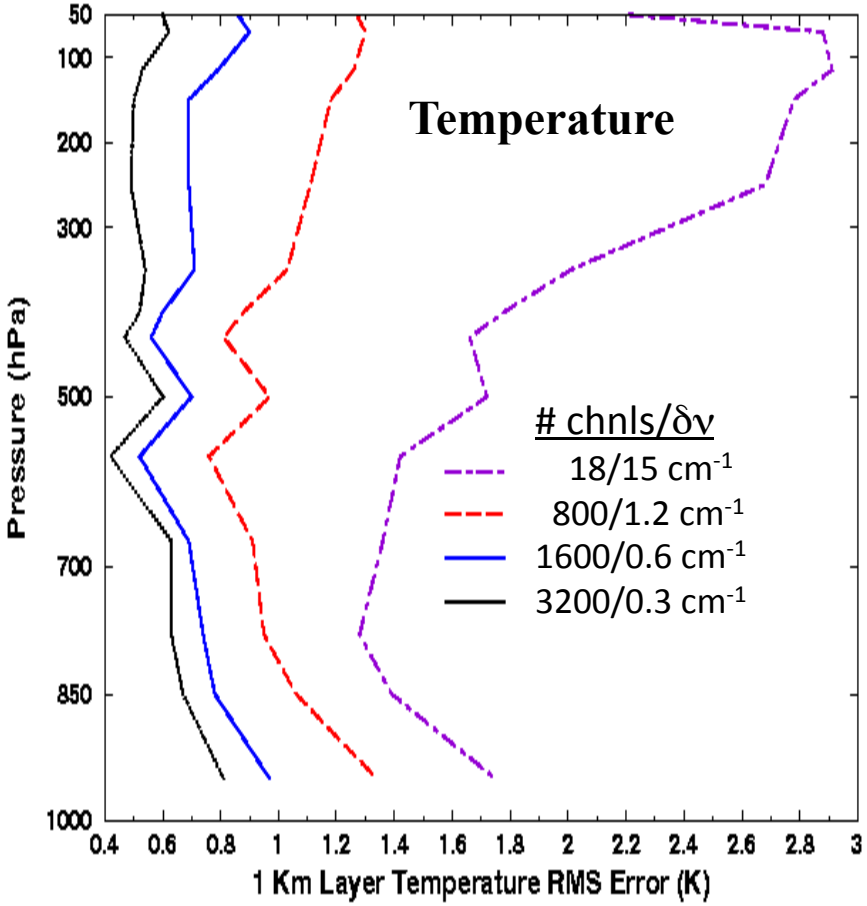


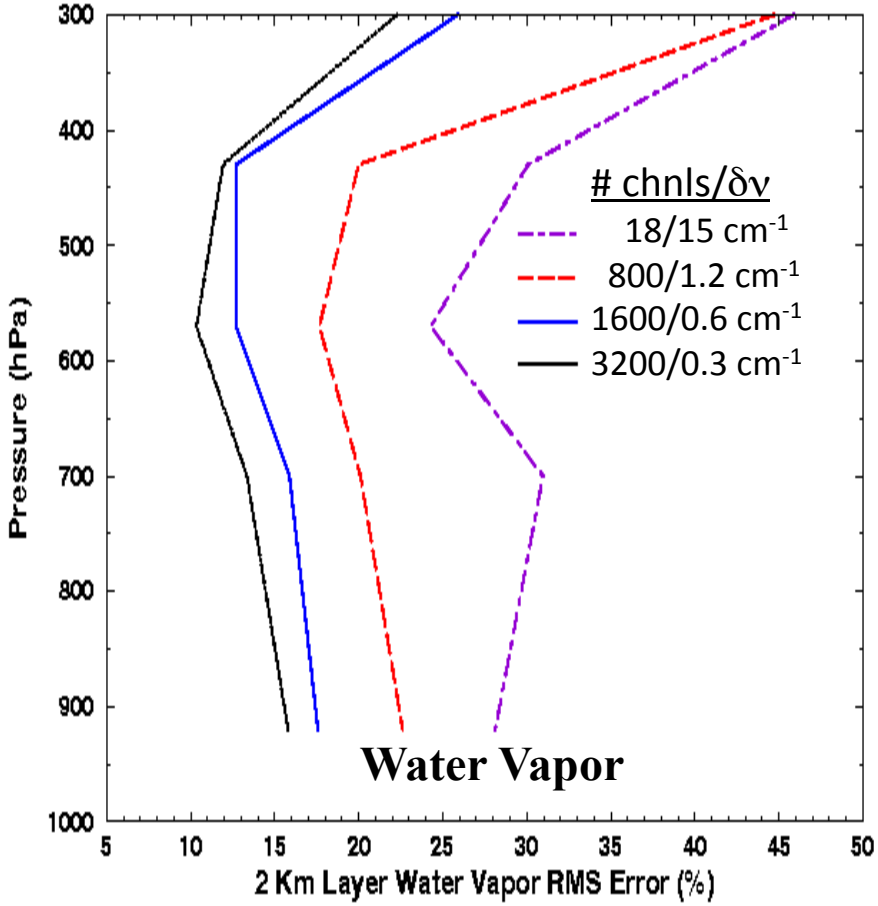
$\Delta\nu = 0.5\ cm^{-1}$



Retrieval Accuracy Vs Spectral Resolution

(i.e., number of spectral radiance observations)



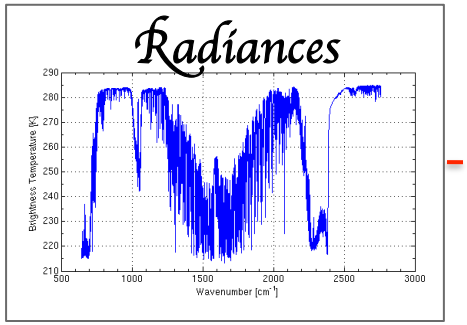


The vertical resolution and accuracy increases greatly with the number of spectral channels. The improvement is proportional to the square root of the number of channels (i.e., S/N)

The Problem

- Satellite profile retrievals exhibit vertical structure biases toward the a-prior profile (i.e., either the initial guess profile or the mean of the statistics used for regression) due to the low vertical resolution (i.e., "null space") of the radiance observations
- This bias was large for retrievals from low spectral resolution filter radiometers (e.g., TOVS) causing vertical resolution aliasing when assimilated into NWP models causing negative impact.
- Direct assimilation of the radiances, rather than retrievals, was employed to avoid vertical resolution aliasing and to achieve positive impact.
- However, for hyperspectral sounding instruments, which contain thousands of spectral channels, radiance assimilation of all the spectral radiances is currently too time consuming for operational use. As a result, only a small subset of spectral channel radiances are assimilated limiting the vertical resolution, which is maximized by utilizing "ALL" the spectral channels in the retrieval process.
- Here, a simple and time efficient method for de-aliasing full spectral resolution hyperspectral sounding retrievals is presented

"Dual-Regression" Retrieval Algorithm* Overview



Global clear soundings

Radiances (clear FM)

Clear-trained regression coefficients

Global cloudy soundings

Radiances (cloudy FM)
Cloud height classes

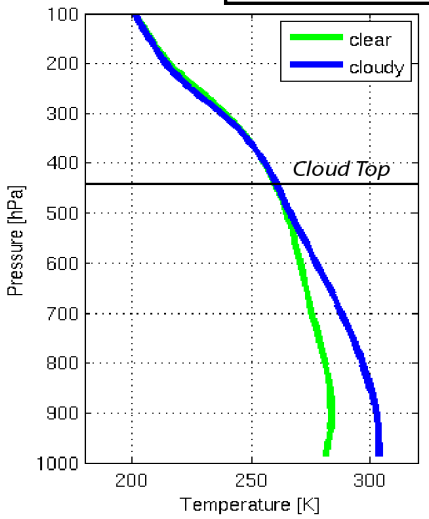
Cloud-trained regression coefficients

Theoretical Statistics

Radiance Observations

Clear-trained EOF regression retrieval

Cloud-trained EOF regression retrieval



Cloud Top Altitude
Level where $T_{cloudy} > T_{clear}$ for $p > p_{cld}$

Final Profile
Clear-trained above and cloud-trained Cloud Top

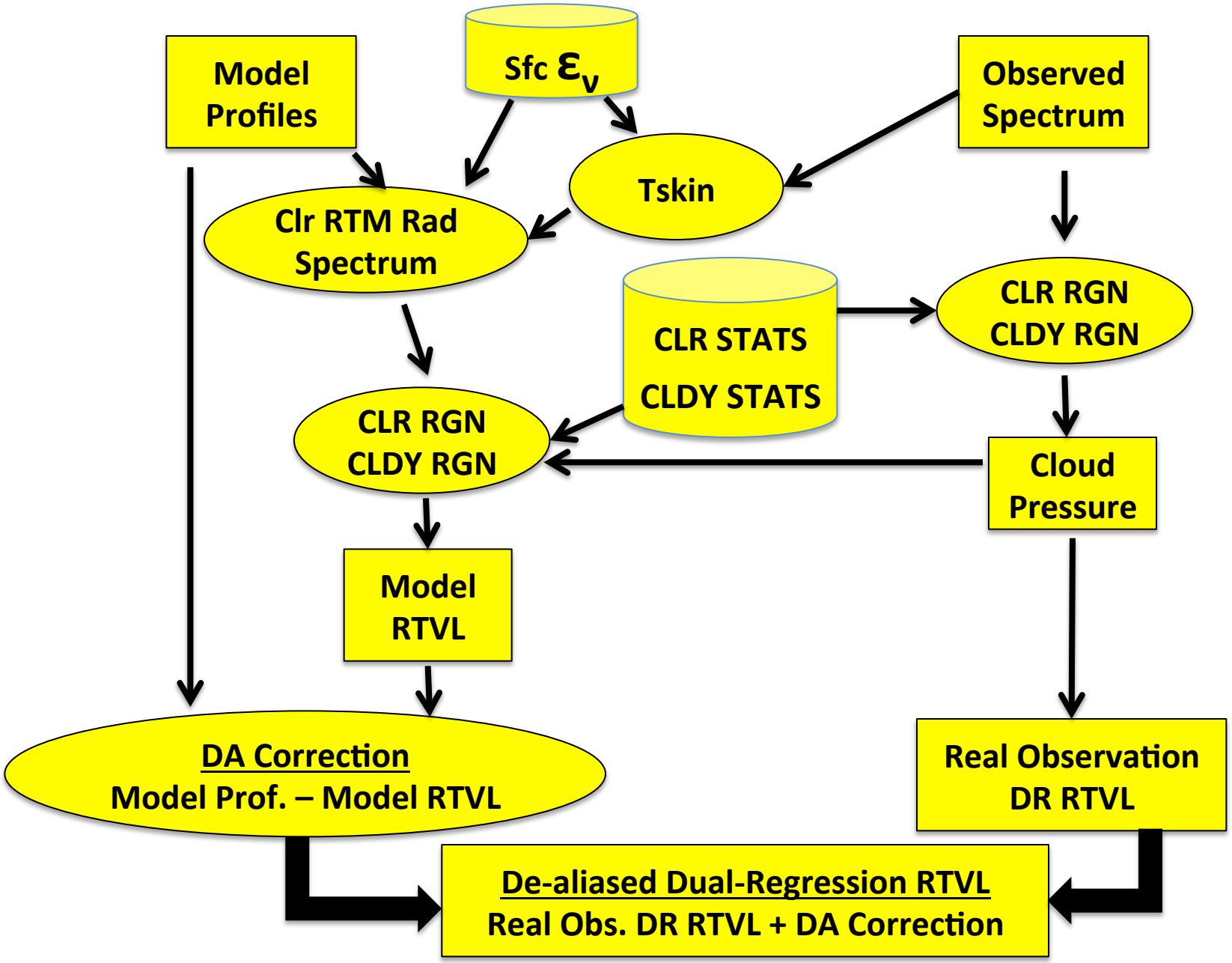
Temperature, Humidity and Ozone profiles, Surface and Cloud parameter at single FOV (0-2-km) resolution

* Smith, W. L., E. Weisz, S. Kirev, D. K. Zhou, Z. Li, and E. E. Borbas (2012), Dual-Regression Retrieval Algorithm for Real-Time Processing of Satellite Ultraspectral Radiances. *J. Appl. Meteor. Clim., 51*, Issue 8, 1455-1476.

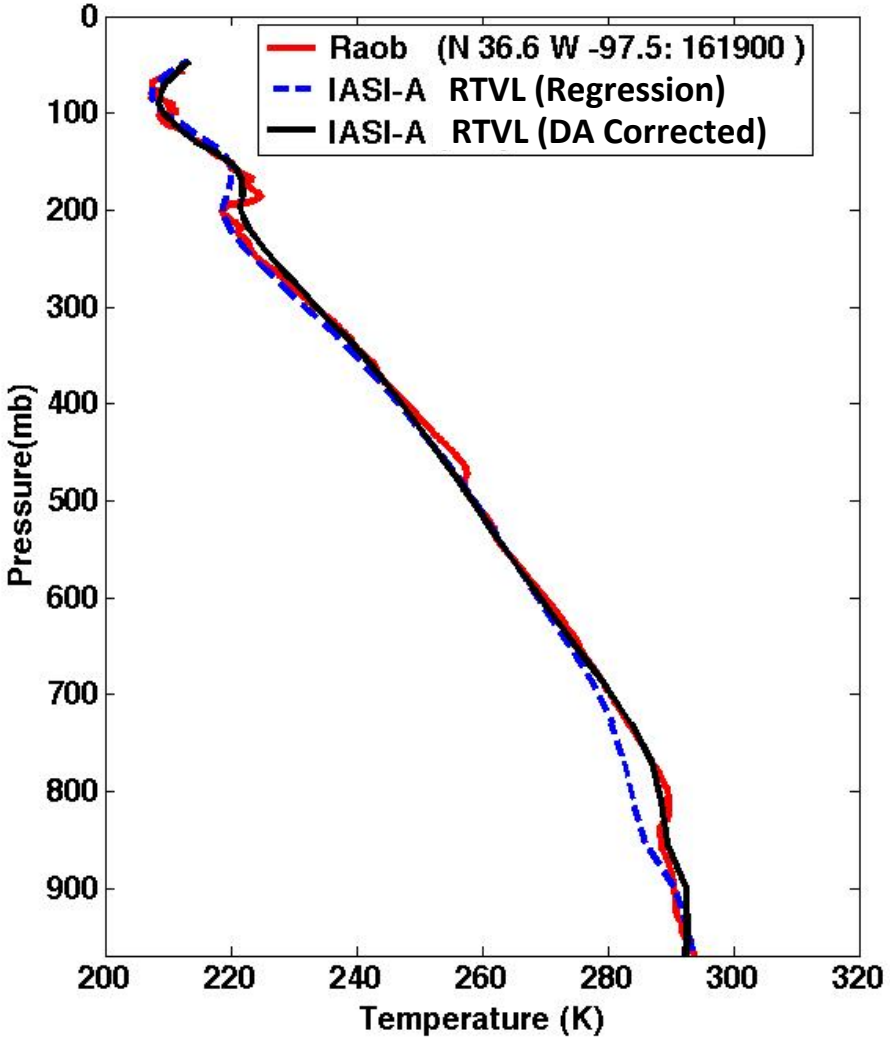
How Can We Estimate the Forecast Model Alias Produced by Assimialting Satellite Profile Retrieval ?

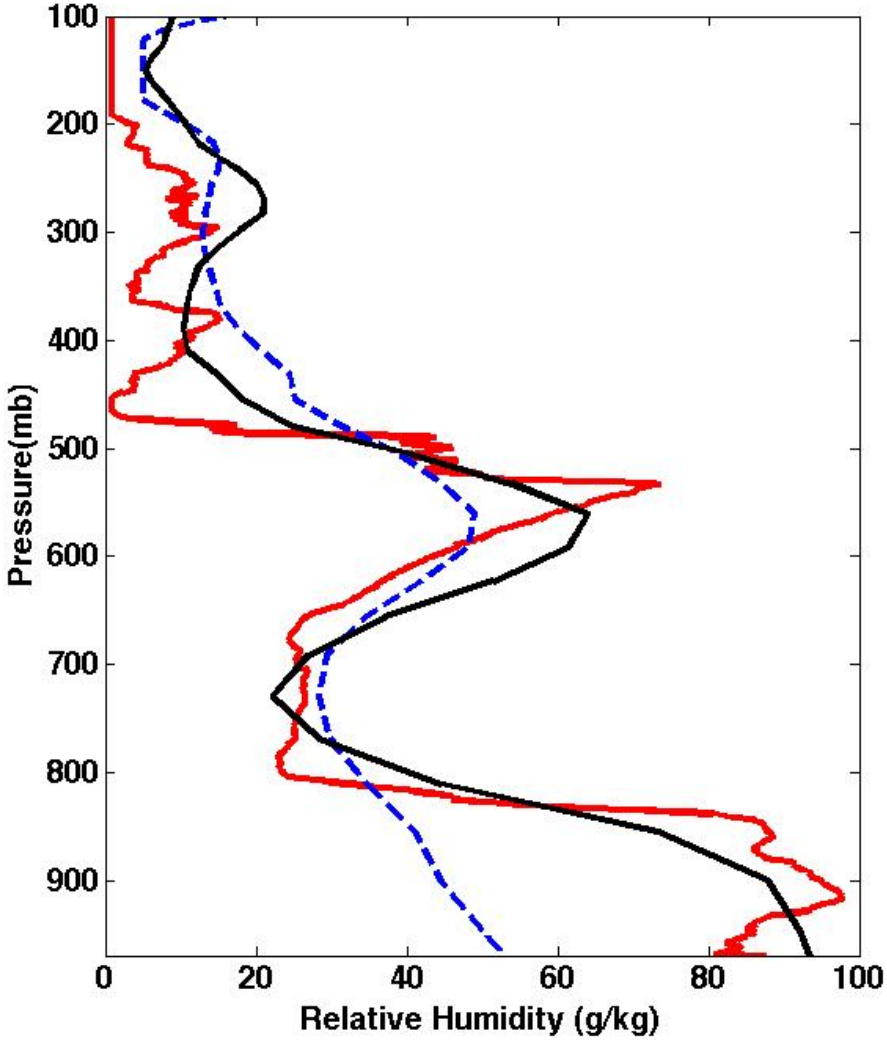
- **RTM simulate radiances from a model forecast profile co-located with the satellite observation**
- **Produce a profile retrieval from the RTM simulated satellite radiances using exactly the same algorithm used to retrieve profiles with real satellite observations**
- **The vertical resolution alias is simply the difference between the model radiance profile retrieval and the forecast model profile used to simulate the radiance observations used for that retrieval**
- **Eliminate the satellite retrieval alias by subtracting the model forecast estimated vertical resolution alias from the real satellite observation profile retrieval**

De-aliasing Algorithm

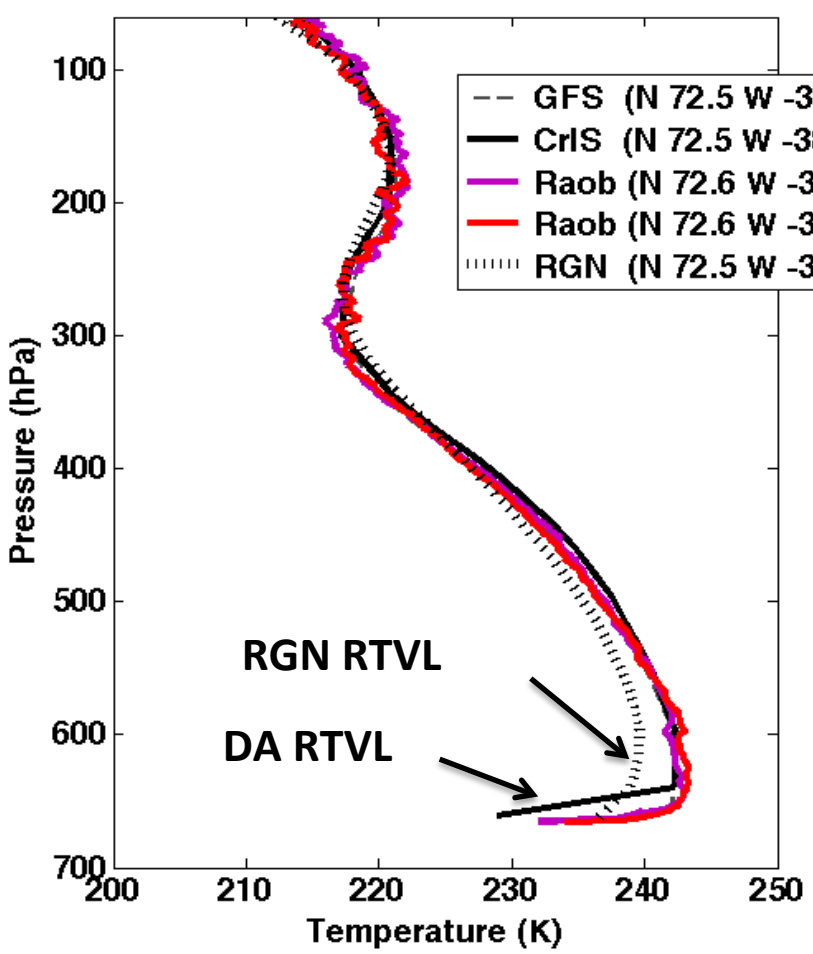


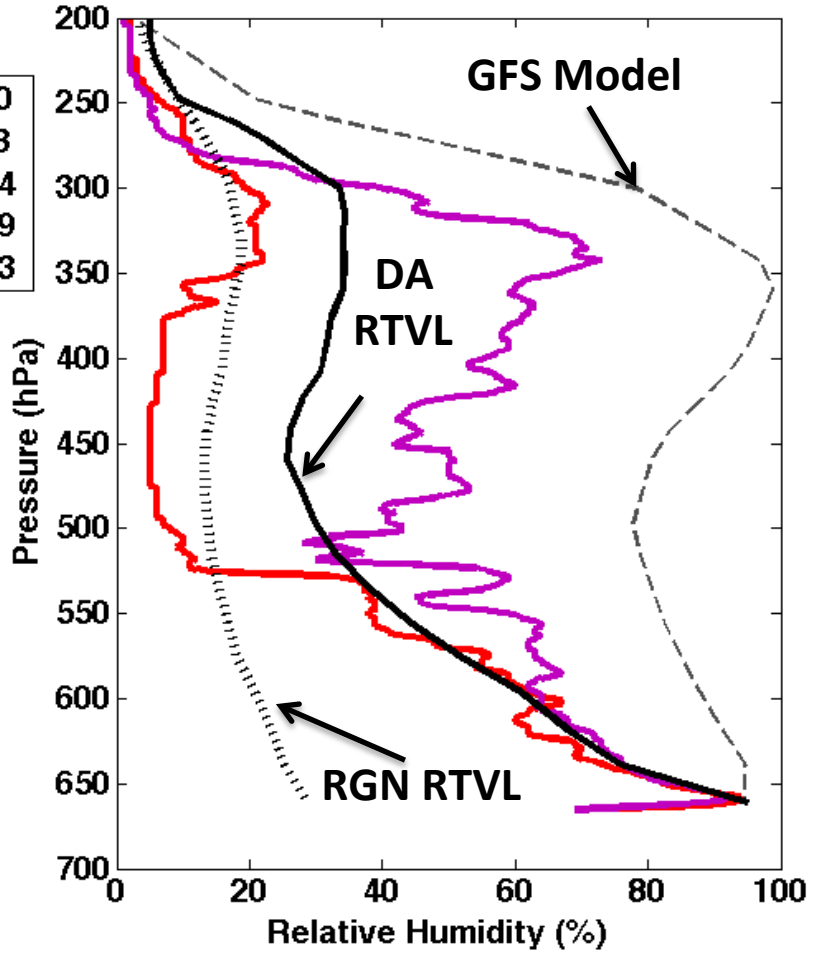
Regression Vs. De-aliased Retrieval
DOE SGP ARM-Cart-site (May 20, 2013)



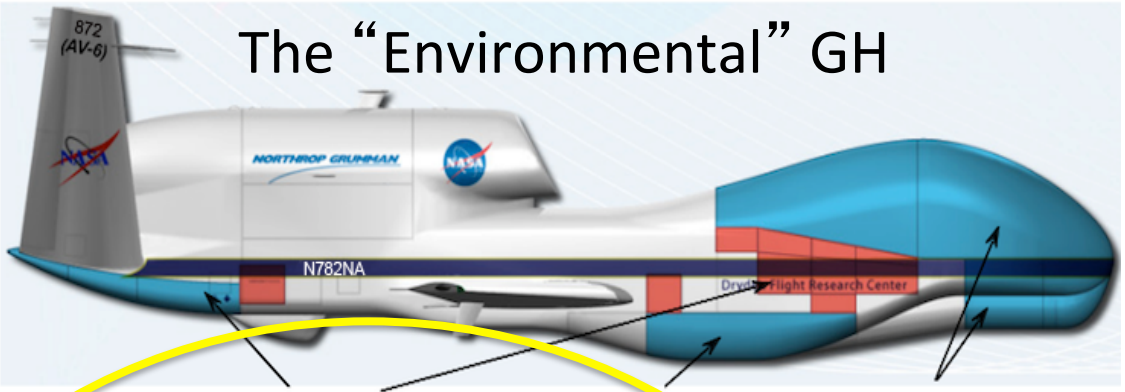


SNPP-2 Arctic (Summit Greenland)
CrIS Sounding Validation
March 23, 2015





The "Environmental" GH



NASA Hurricane and Severe Storm Sentinel HS3

Airborne Vertical Atmospheric Profiling System (AVAPS)

89 Dropsondes / flight

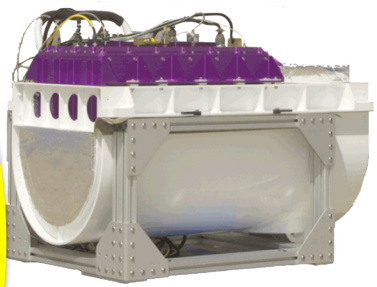
Temperature, Pressure, wind, humidity vertical profiles

Scanning High Resolution Infrared Sounder (S-HIS)

Upwelling thermal radiation at high spectral resolution between 3.3 and 18 microns.

Temperature, water vapor vertical profiles

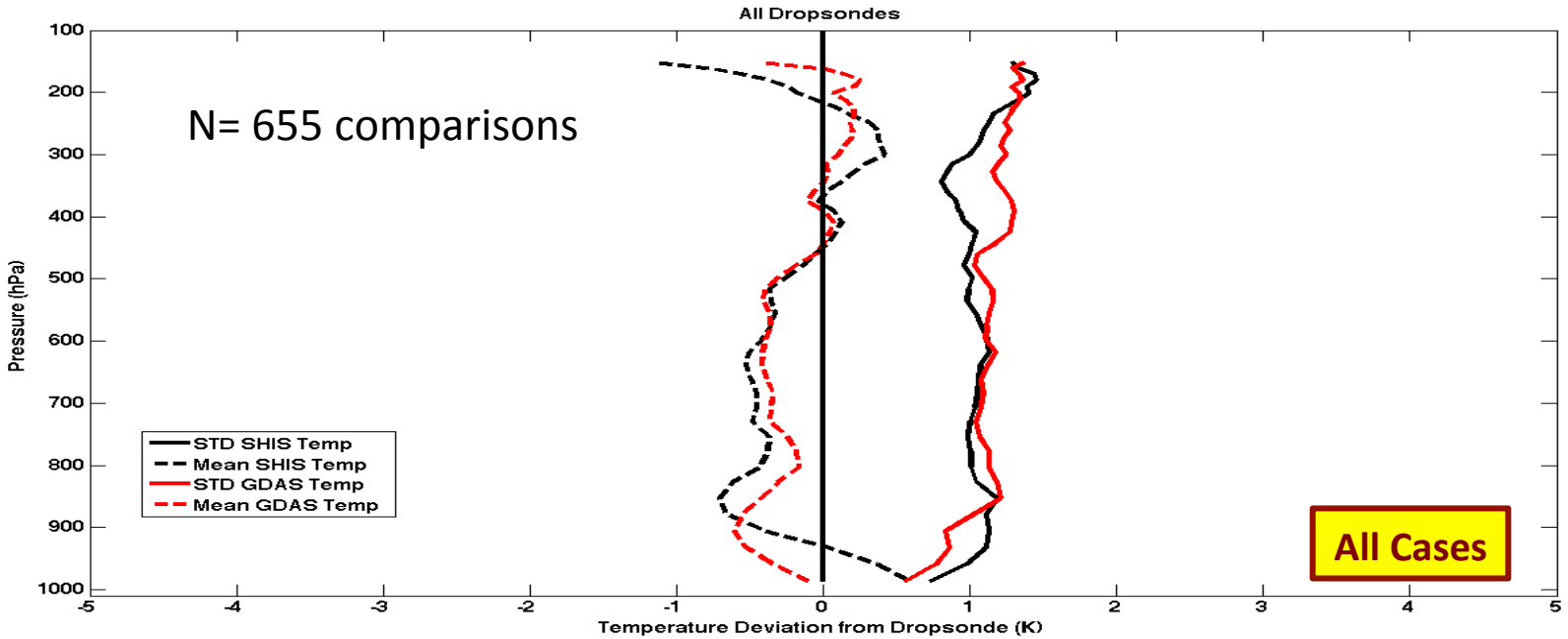
Cloud Physics Lidar (CPL)

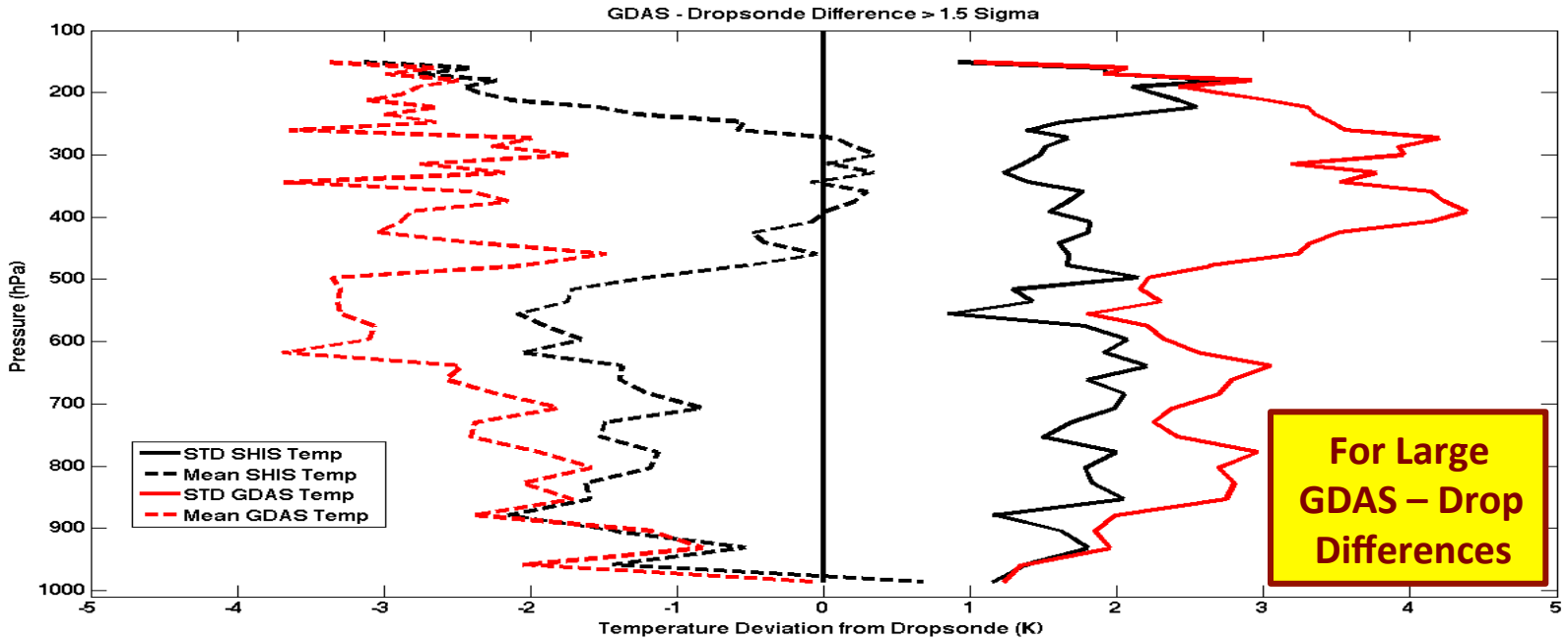


532/1064 nm Lidar Reflection

Cloud structure and depth

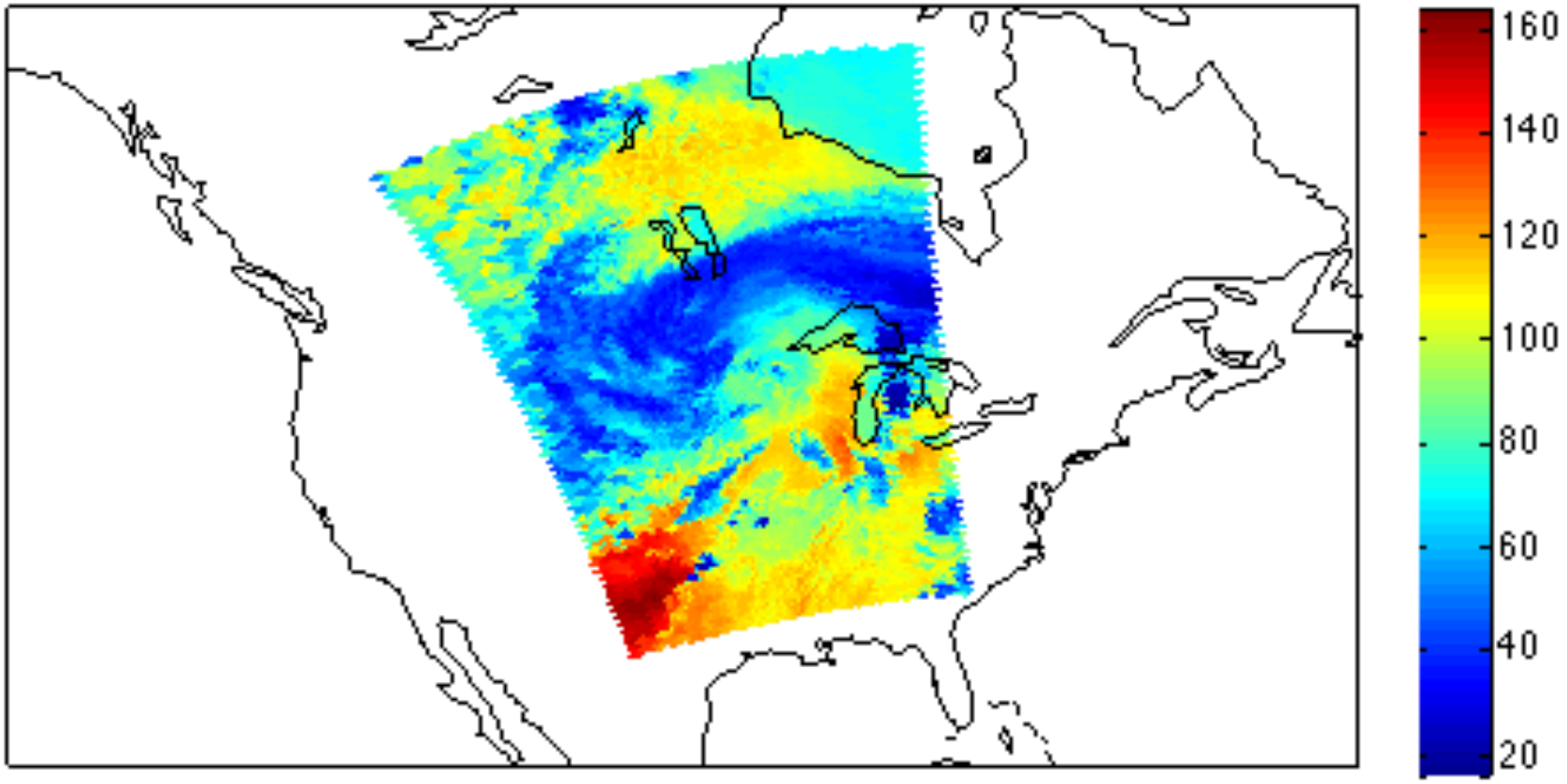
DA S-HIS Vs. Dropsonde Statistics (HS3-2014)



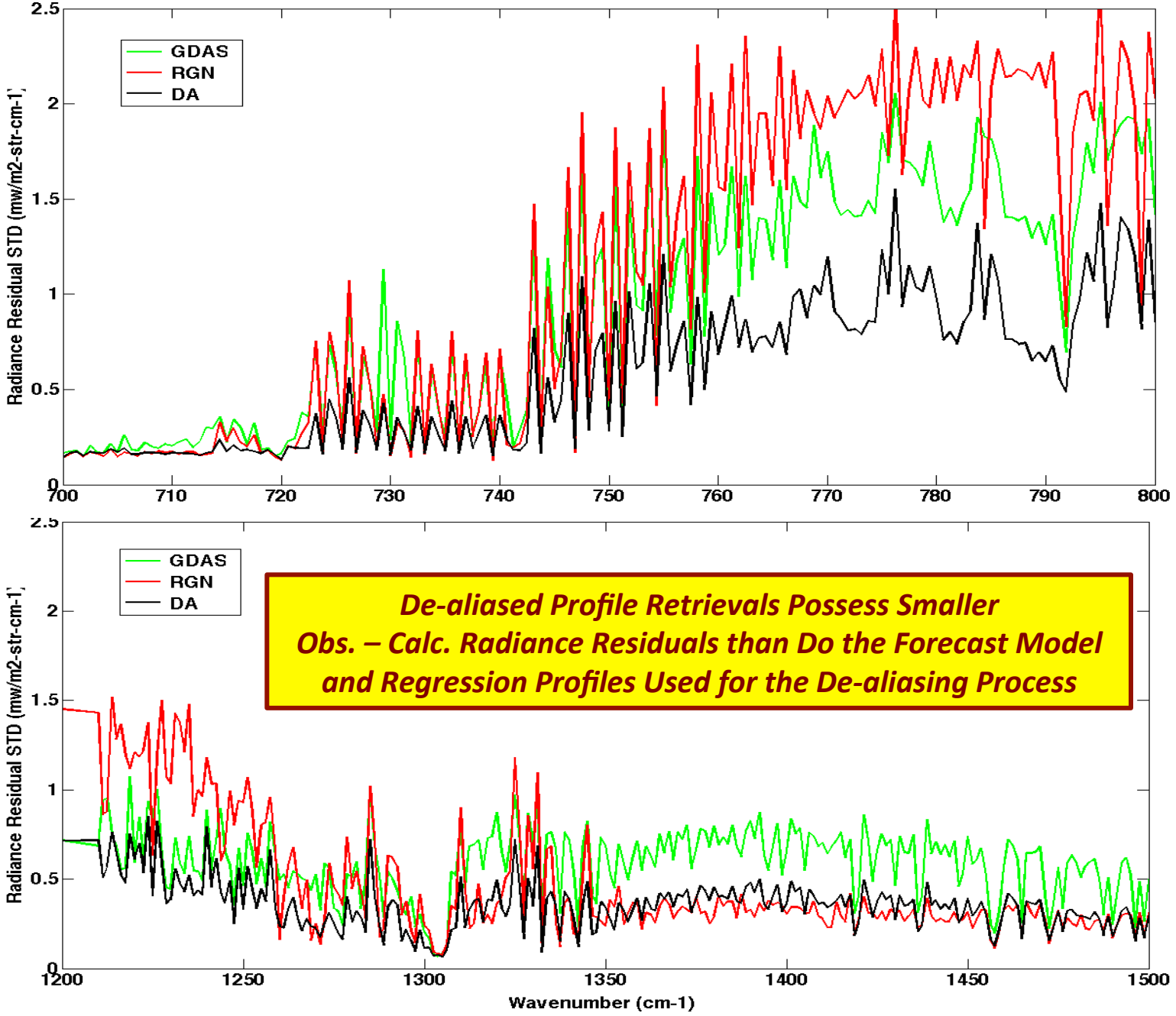


CrIS Coverage ~19 UTC
May 20 2013

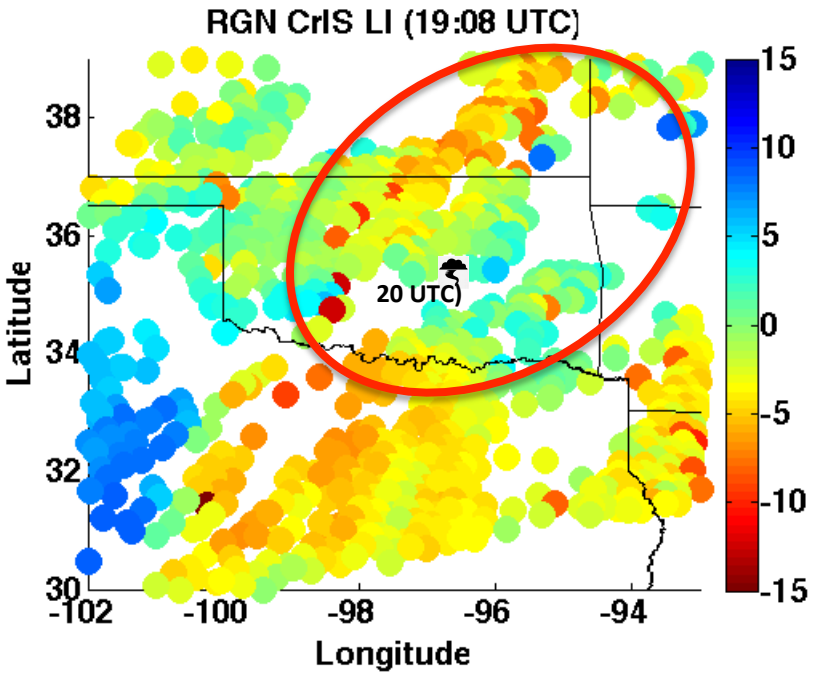
11 micron (i.e., 900 cm^{-1}) Radiance

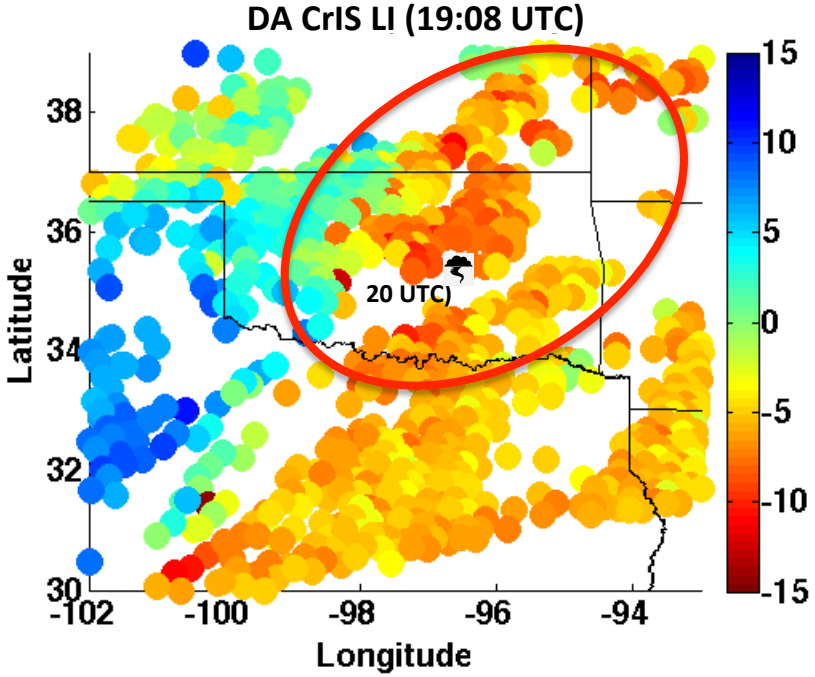


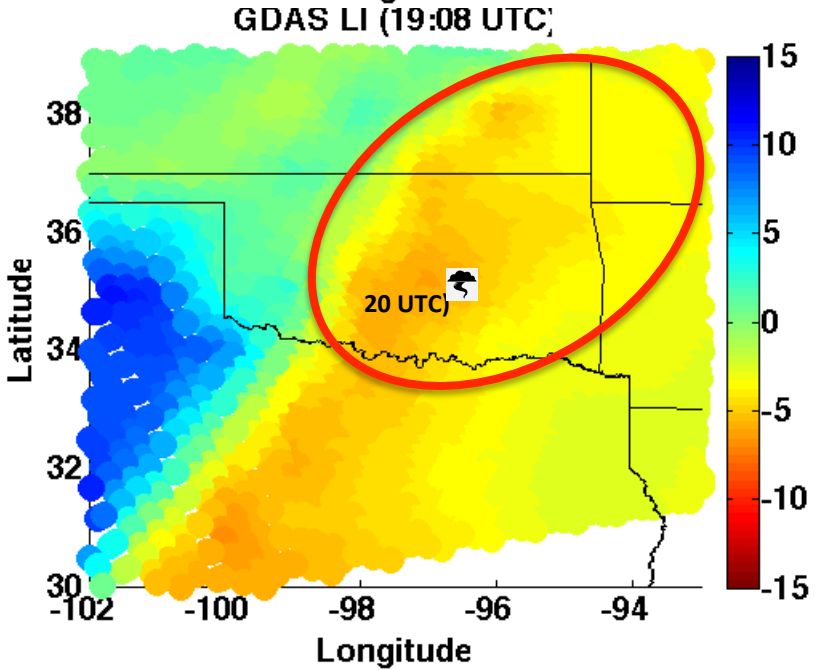
Clear Retrieval Radiance Residuals

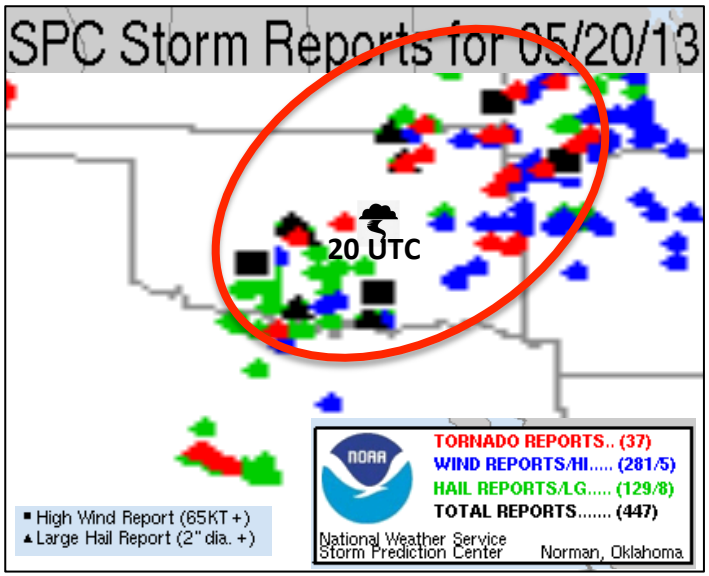


Regression Vs. De-aliased Vs. GDAS Lifted Index (May 20 2013)

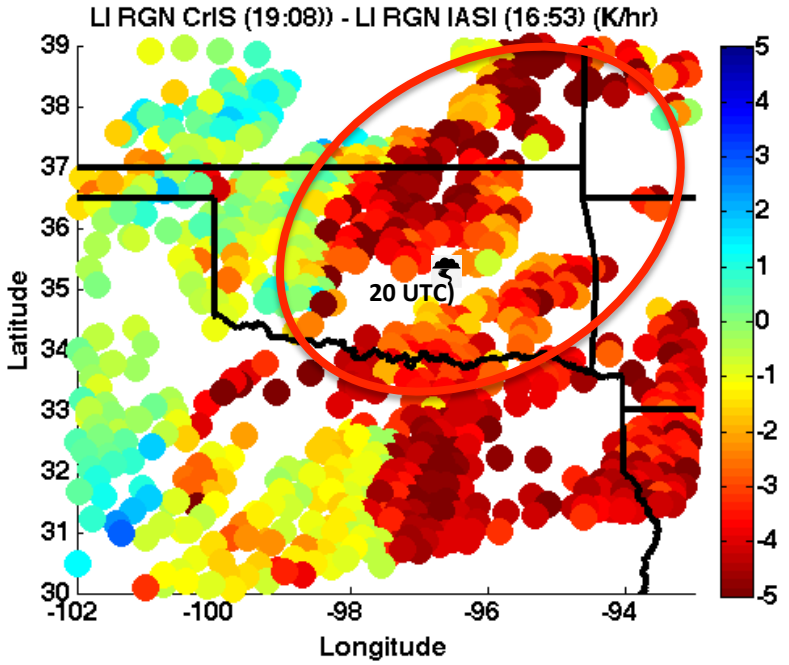


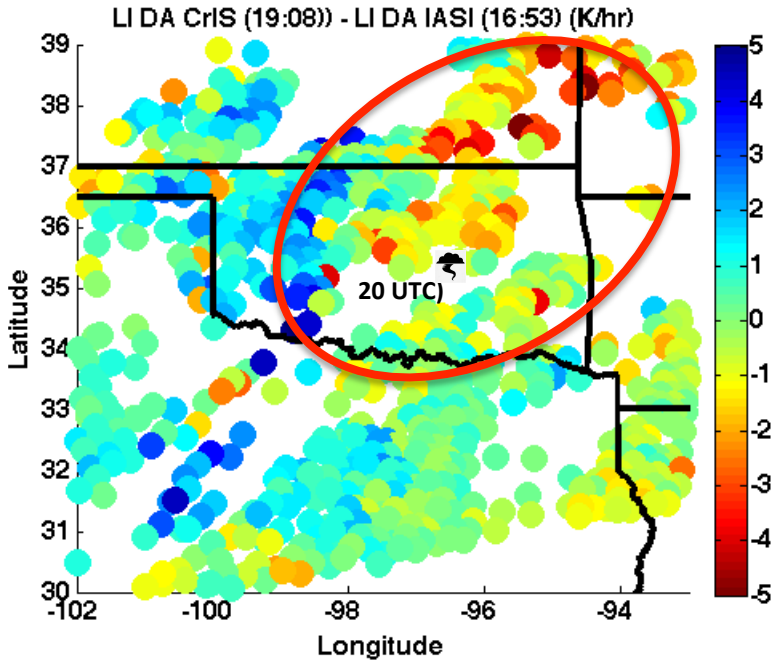


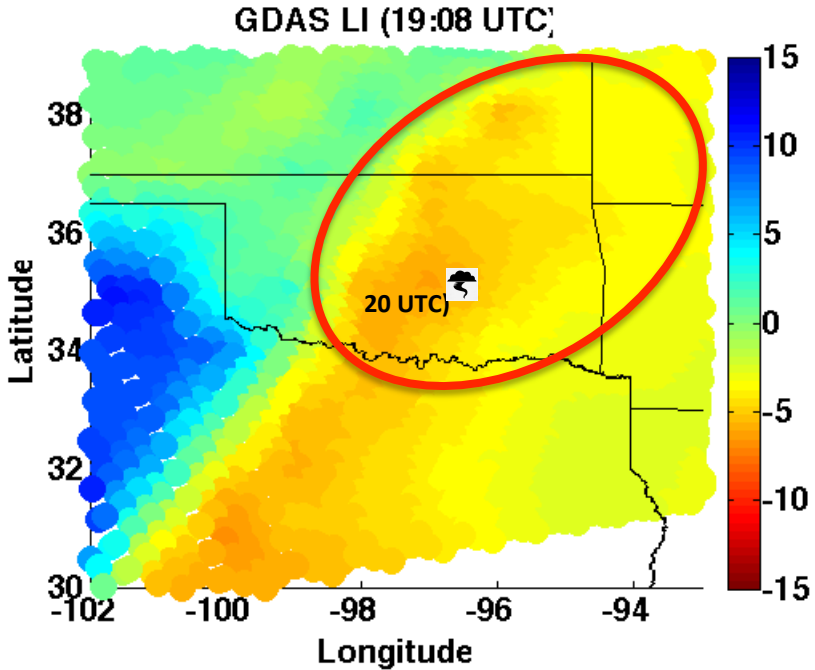


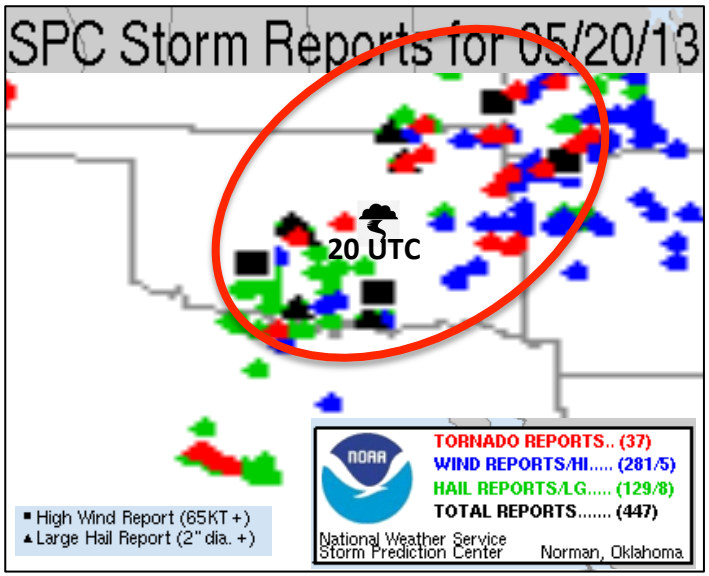


Time Tendencies of Lifted Index (May 20 2013)









Summary

- Poor vertical resolution of satellite soundings can cause a vertical alias within the NWP models that assimilate them
- The vertical alias can be determined using NWP simulated radiances and removed from the real radiance retrieval
- It is shown that the de-aliased profile retrieval is an improvement of the model profile that was used for the de-aliasing process
- Analyses of time consecutive (2-hr interval) satellite retrievals (i.e., from Metop-B IASI and S-NPP CrIS), antecedent to a Tornadic storm outbreak, indicates that the assimilation of de-aliased satellite profile retrievals will improve the forecast of the location and timing of severe weather events.
- This hypotheses now needs to be proven through the time assimilation of de-aliased hyperspectral soundings obtained from the system of Metop-A, Metop-B, S-NPP, and Aqua satellites.