SPACE SCIENCE AND ENGINEERING CENTER

Dual-Regression Surface and Atmospheric Sounding Algorithm for Initializing Physical Retrievals and Direct Radiance Assimilation

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Objective

- Provide a single field-of-view linear surface and atmospheric variable specification methods, which can be applied hyperspectral satellite data (e.g., AIRS, IASI, and CrIS) in order to:
    - -- Provide a fast non-linear the regression solution enabling high vertical resolution for all cloud and moisture conditions
    - — Provide initial surface and cloud parameters, and initial temperature and moisture profiles, useful for 1-d variational physical retrievals or for the direct assimilation of satellite radiances.
- Test the algorithm's) using regional IASI and NAST radiance data for a very complex cloud situation
- Validate the algorithm using radiosonde and dropsonde data obtained during the JAIVEx campaign

Dual-Regression Technique

"Clear-trained" and "Cloud-trained" EOF regression retrievals of: surface skin temperature, surface emissivity PC-scores, CO_2 concentration, cloud top altitude, effective cloud optical depth, and atmospheric temperature, moisture, and ozone profiles above the cloud and below thin or scattered cloud (i.e., cloud effective optical depth < 1.5 and a cloud induced temperature profile attenuation < 15 K.

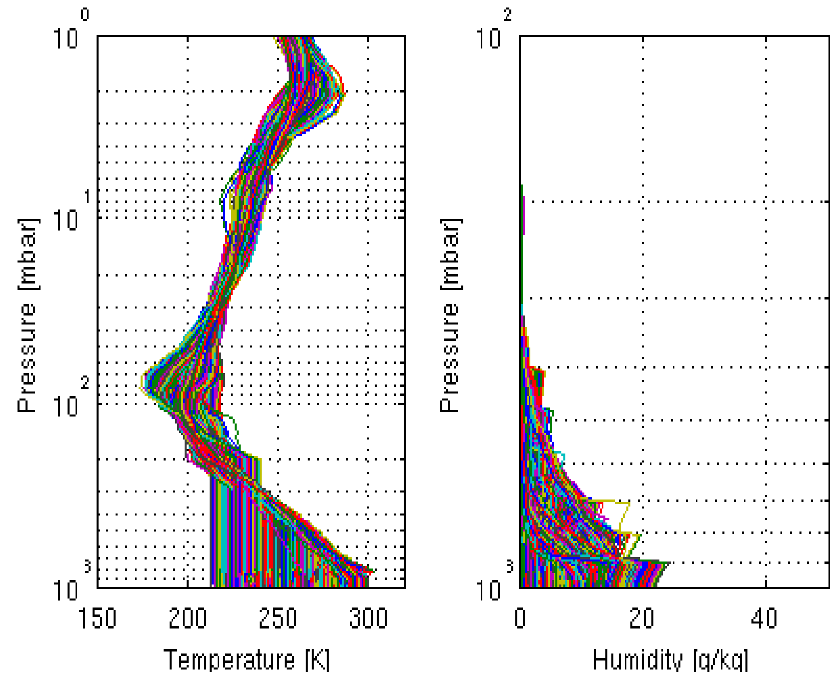
"Clear-trained" - Regression trained to predict a "clear sky equivalent" perturbed profile from a clouded radiance spectrum (e.g., an isothermal profile below an opague cloud cover).

"Cloud-trained" - Regression trained predict the true profile, both above and below cloud level, from a clouded radiance spectrum

Training Atmospheric Profiles

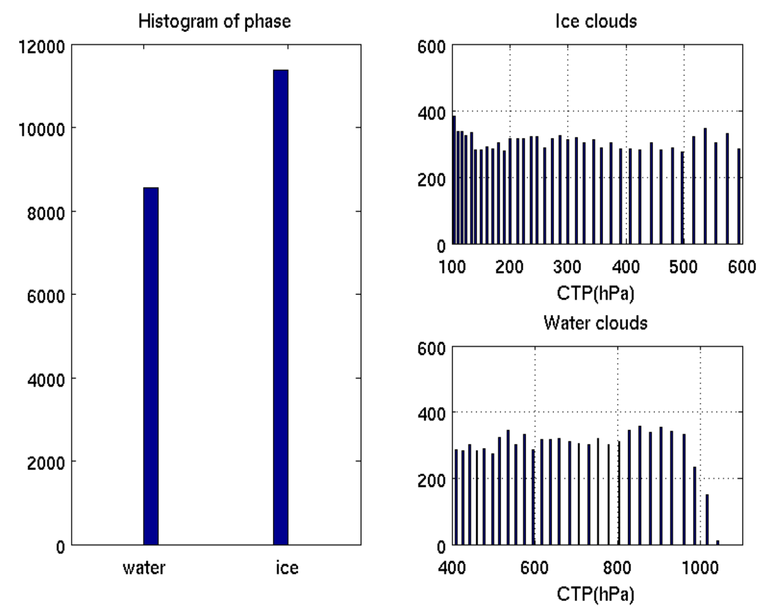
Clear Training – We use 15,000 (NOAA-88, TIGR, ECMWF) clear sky soundings uniformly distributed throughout the globe plus 15000 additional soundings made to be isothermal and saturated below the cloud pressure for each cloud height within each of 8 overlapping cloud height classes: 100-300, 200-400 ,,,,800-sfc. Equal number of unperturbed original and isothermal perturbed soundings provide representation Of any cloud fraction between 0 and 100%.

Radiances simulated with Clear Sky RTM



Cloud Training – cloud height specified using probability function P(T,RH) and uniformly distributed with altitude. Use uniform distribution of cloud optical thickness ranging from 0 – 10 and effective cloud particle diameter (10-50 μm for ice and 5-35 μm for water). Ice cloud top between 600 hPa and the tropopause; water cloud tops between the surface and 400 hPa.

Radiances simulated with Cloudy Sky RTM



Dual-Regression Technique

Selection of Optimal Cloud Class (Two Methods):

IASI/AIRS: Iterative cloud pressure EOF regression algorithm

(cloud class for which the predicted cloud pressure lies within the same cloud class providing the predicting regression relation.

NAST-I: Cloud class for which the residual between the observed spectrum and that calculated for the “clear-trained” retrieval is a minimum

Final Estimate of Highest Possible Cloud Altitude:

Altitude below which the “clear-trained” temperature retrieval remains colder than the “cloud-trained: temperature retrieval

Final Profile Estimate:

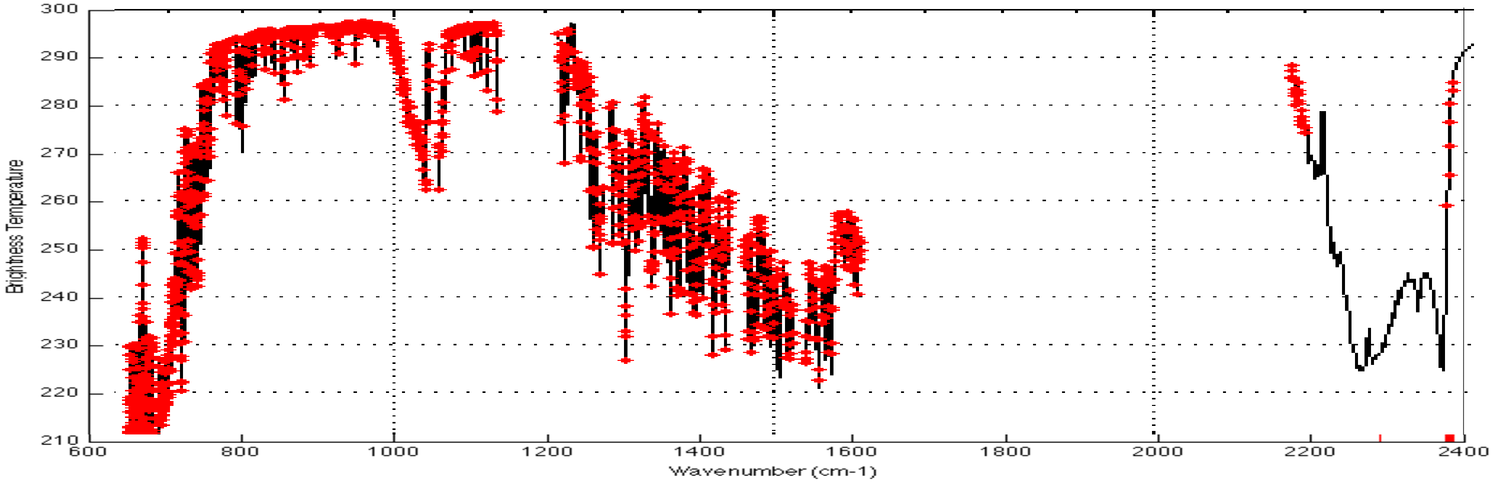
The “clear-trained” solution above cloud level

The cloud-trained solution below cloud level

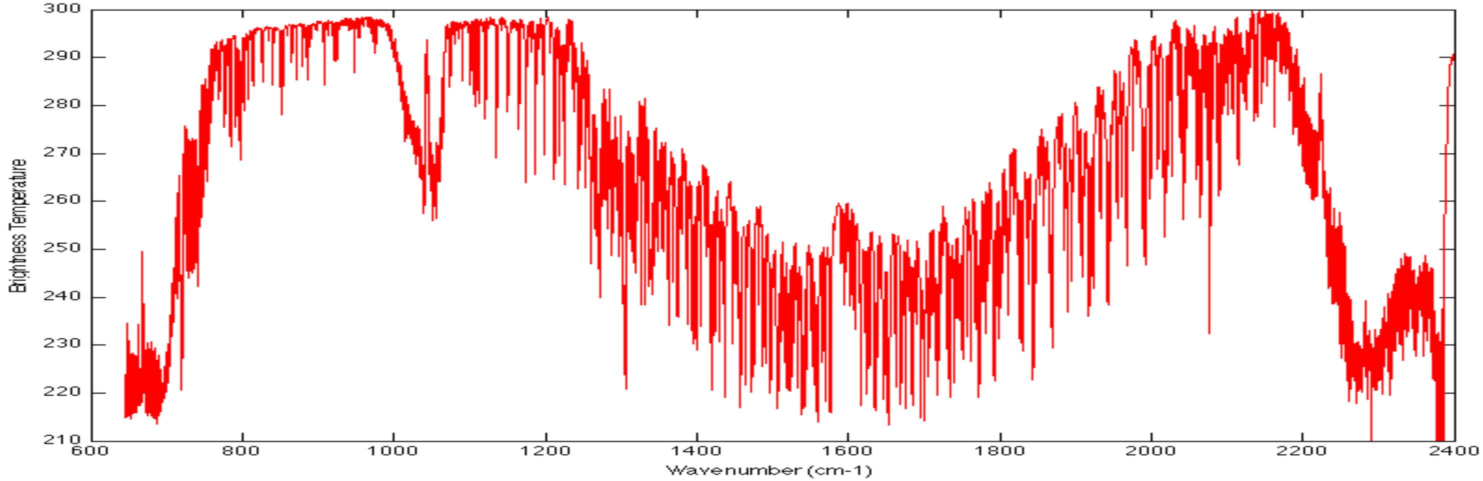
* Profile below cloud top rejected when the maximum difference between the “cloud-trained” and “clear-trained” solution exceeds 15 K.

Number of Spectral Channels for Retrieval

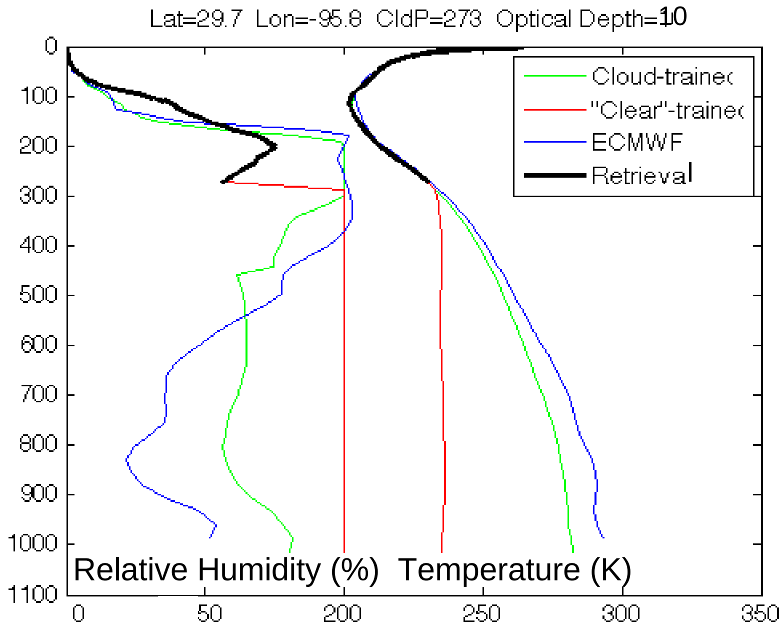
For AIRS: 1500 Channels

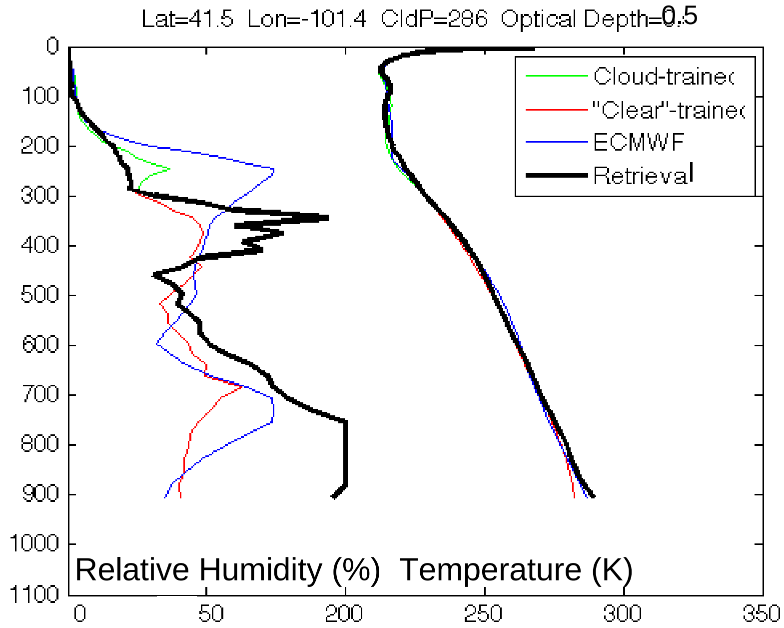


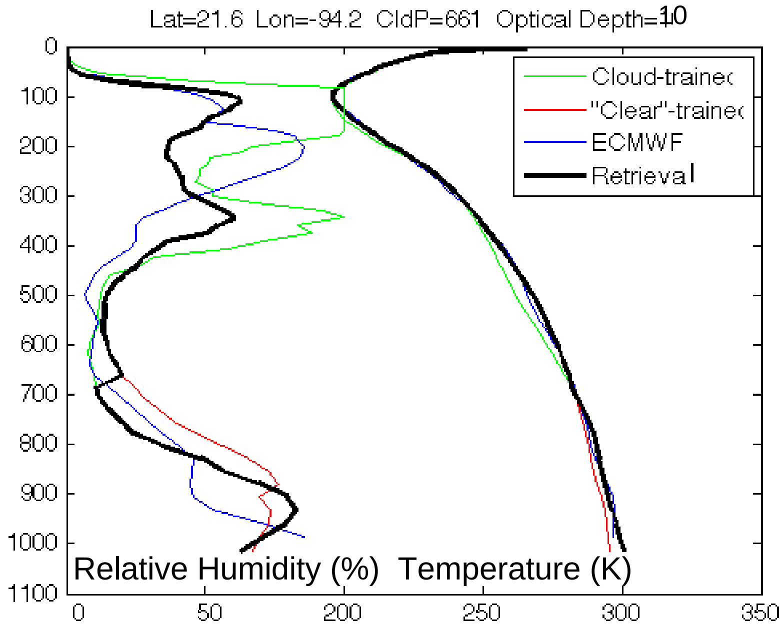
For IASI/NAST: 7021/5006 Channels

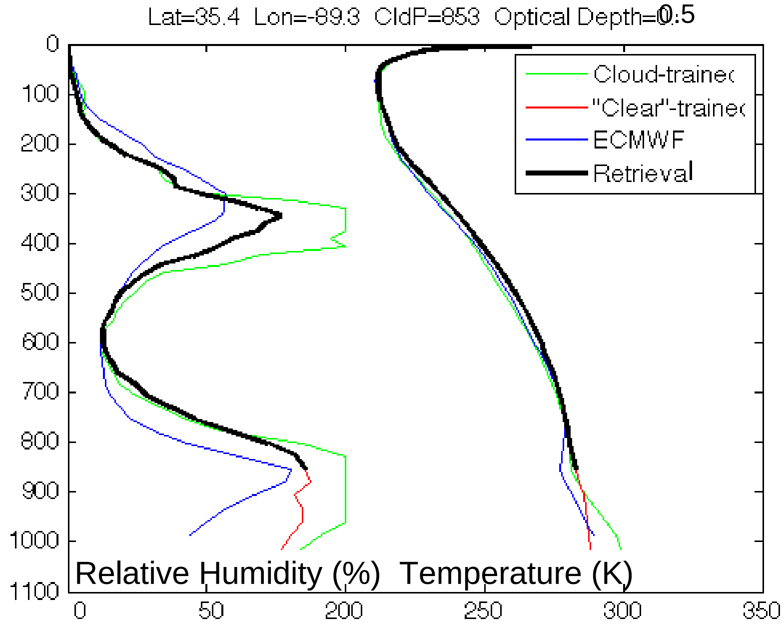


Some IASI Examples

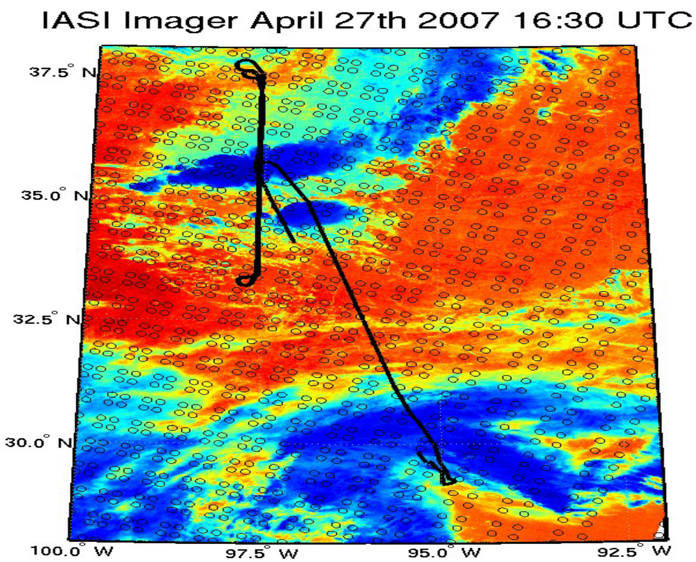


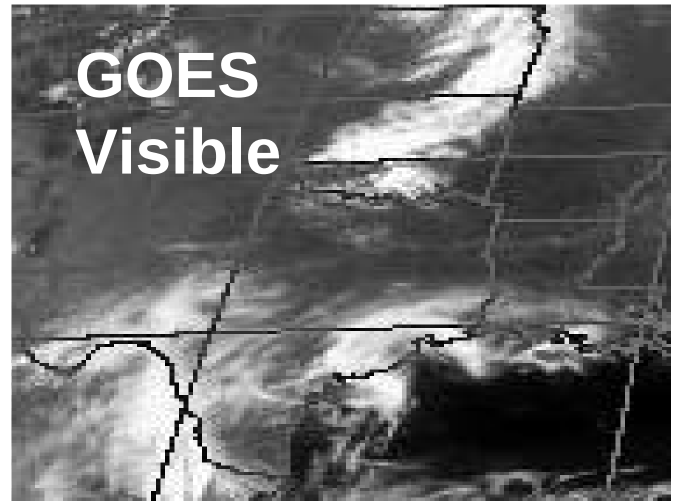


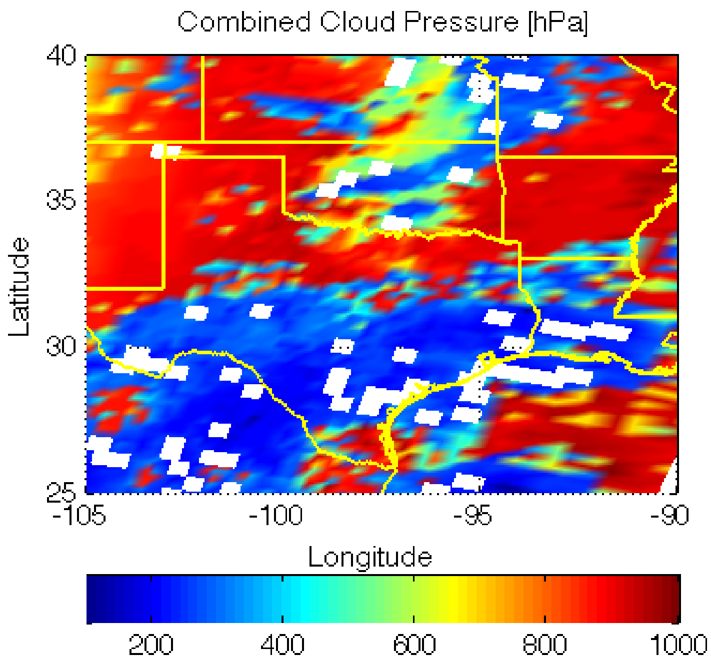


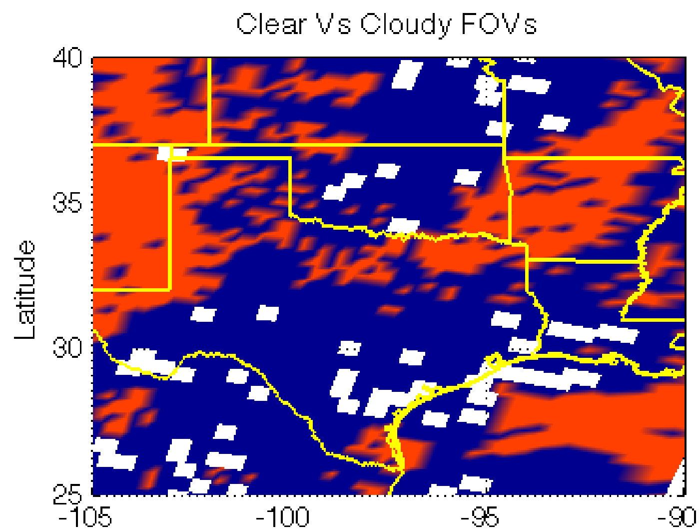


JAIVEx IASI Mesoscale Case Study



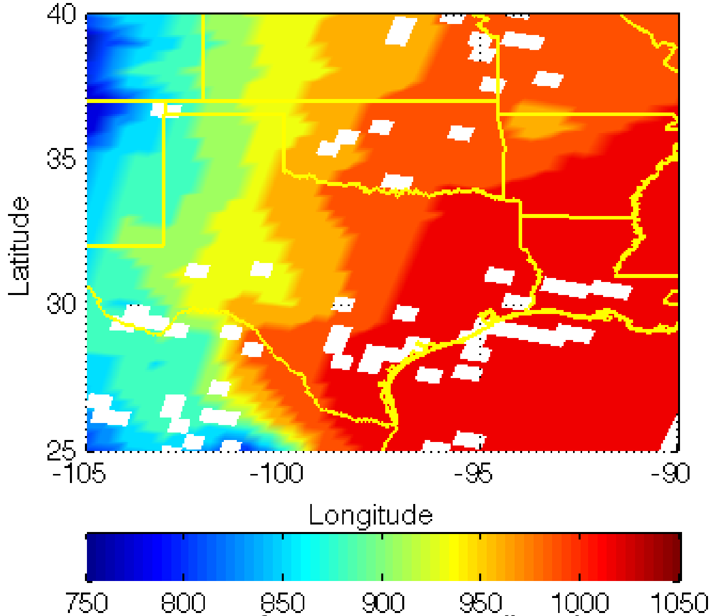




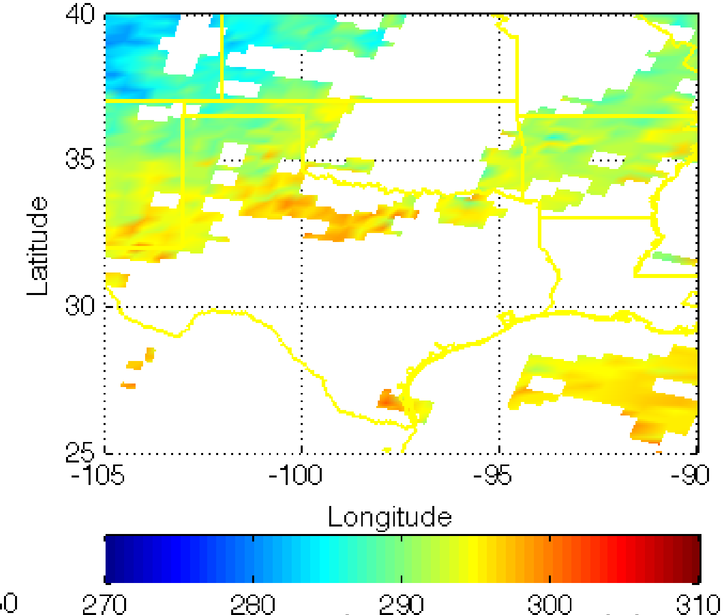


Retrieval Cloud Mask (Blue = Cloud)

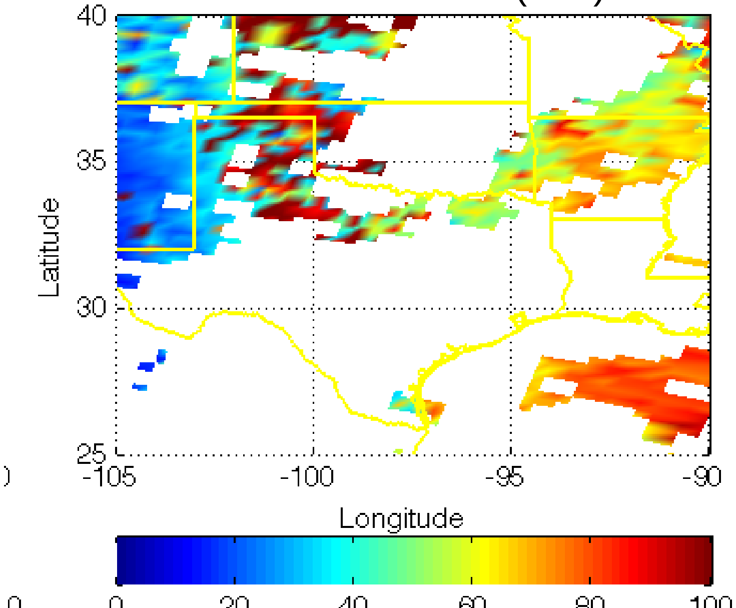
Surface Parameters



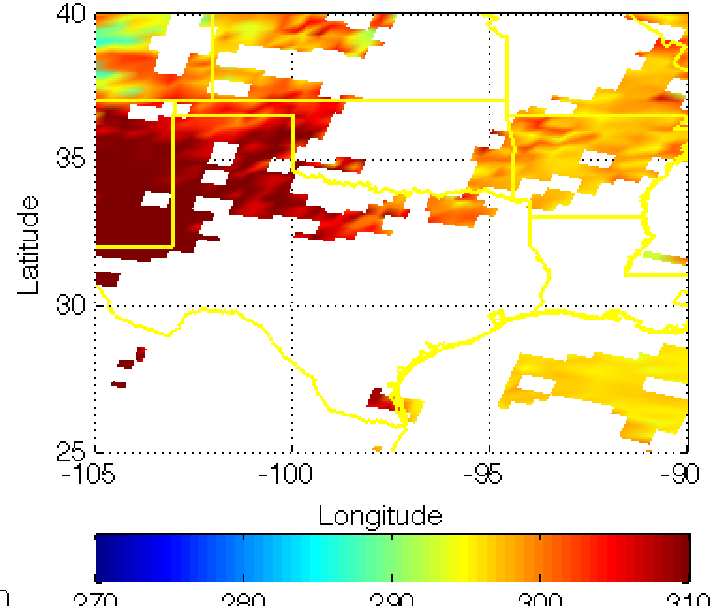
Surface Pressure (hPa)



Surface Air Temperature (K)

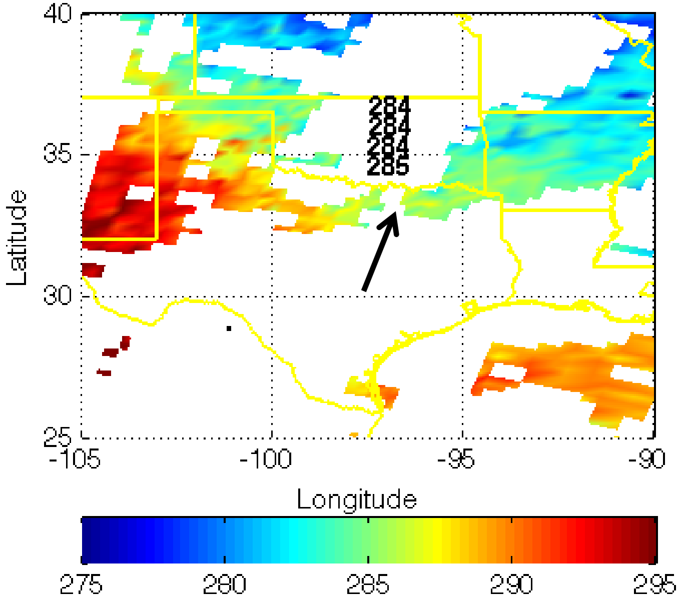


Surface Relative Humidity (%)

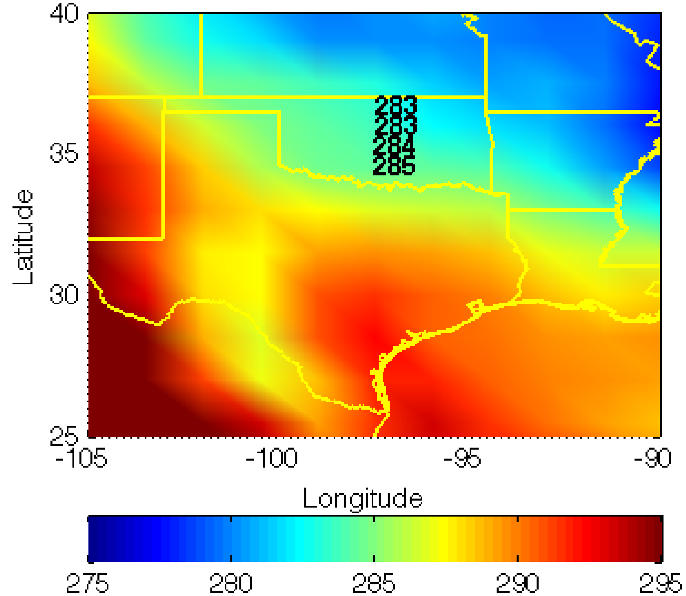


Surface Skin Temperature (K)

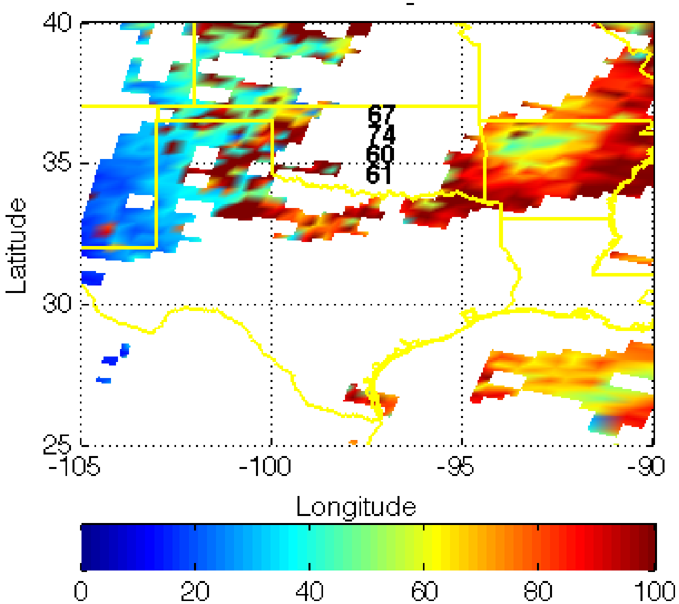
Temperature & Relative Humidity (850 hPa)



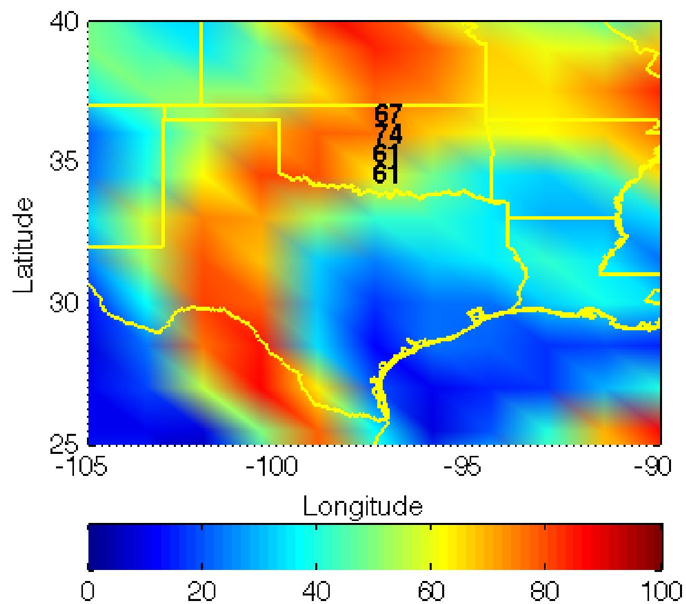
IASI Temperature (K)



ECMWF Temperature (K)

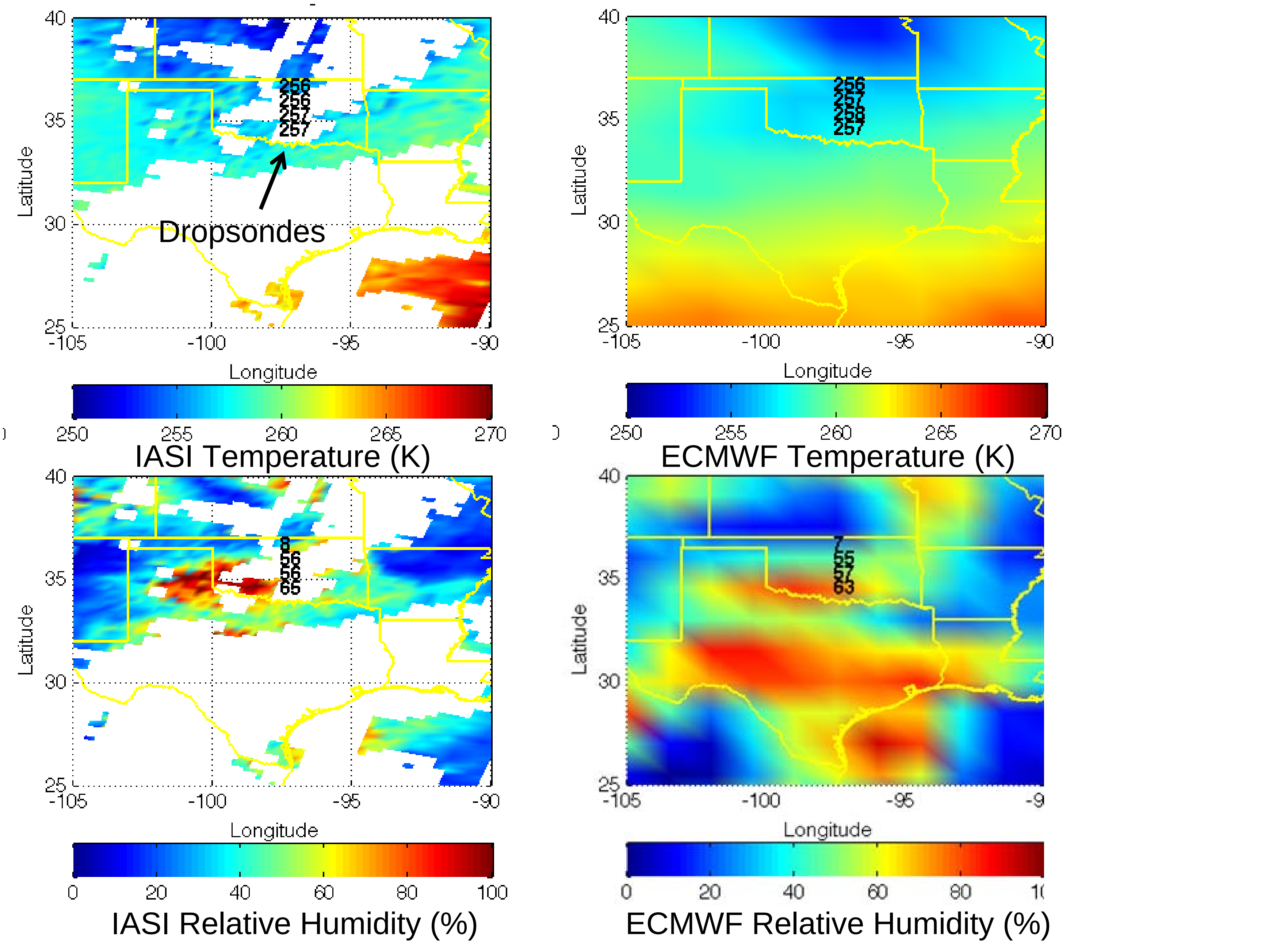


IASI Relative Humidity (%)

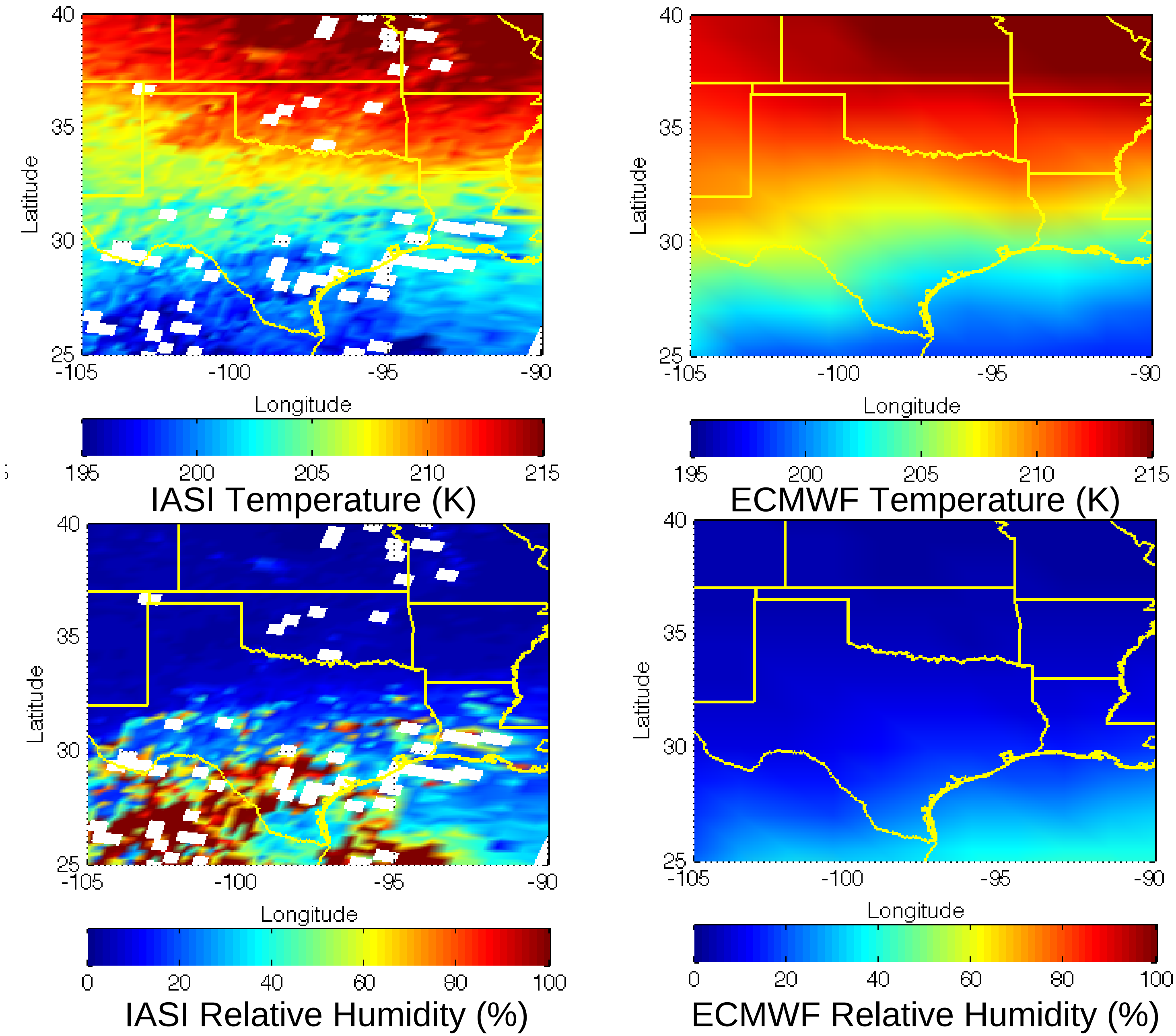


ECMWF Relative Humidity (%)

Temperature & Relative Humidity (500 hPa)



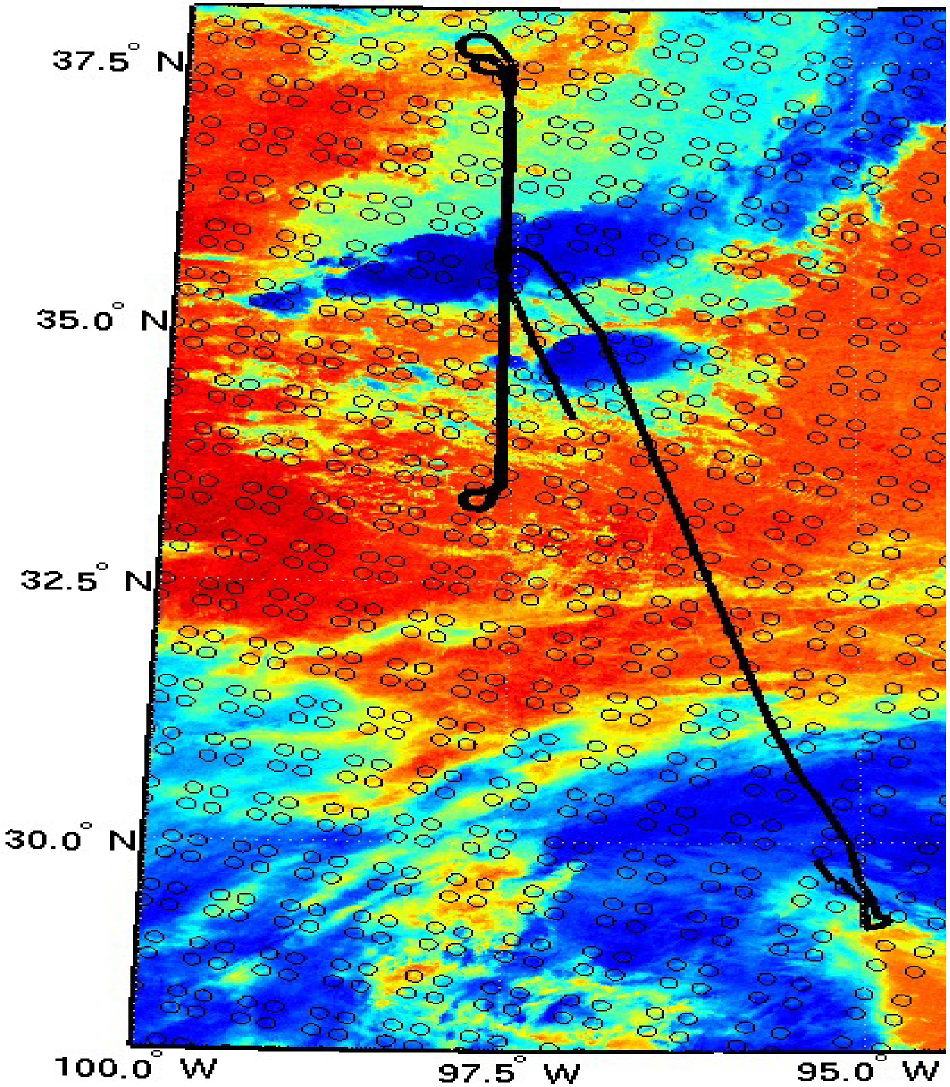
Temperature & Relative Humidity (100 hPa)



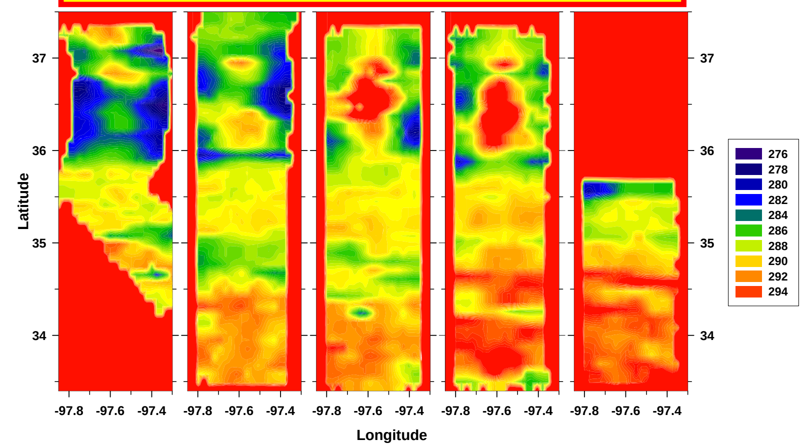
NAST-I Multi-cloud Level Classification Regression Technique

- ***Similar to IASI Dual-regression retrieval except we use 44 Cloud classes of which 34 are two cloud layer classes (e.g., 100-300 hPa and 700-900 hPa)***
- ***The optimal cloud class (i.e., one of the 44 possible) is found by choosing that one in which the residual between observed radiance spectrum and that calculated from the clear-trained retrieval for that cloud classification is a minimum.***

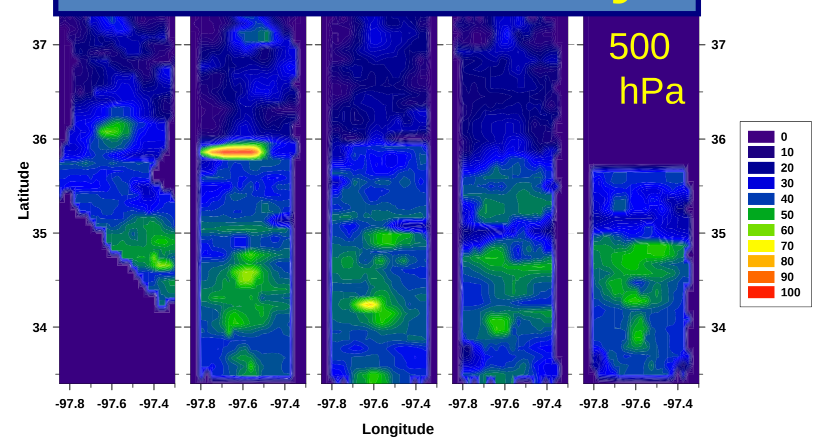
NAST Data For April 27, 2010



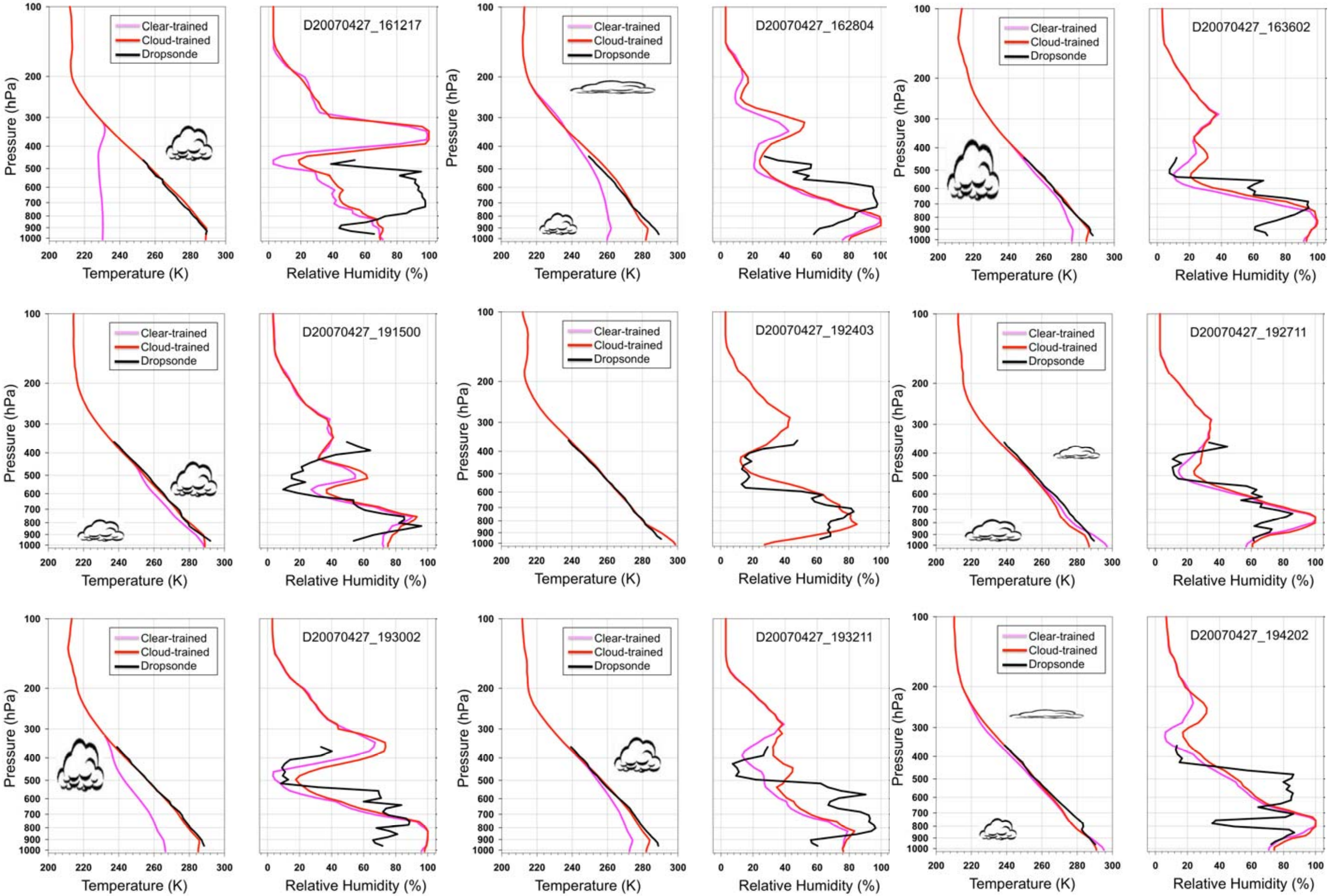
Skin Temperature

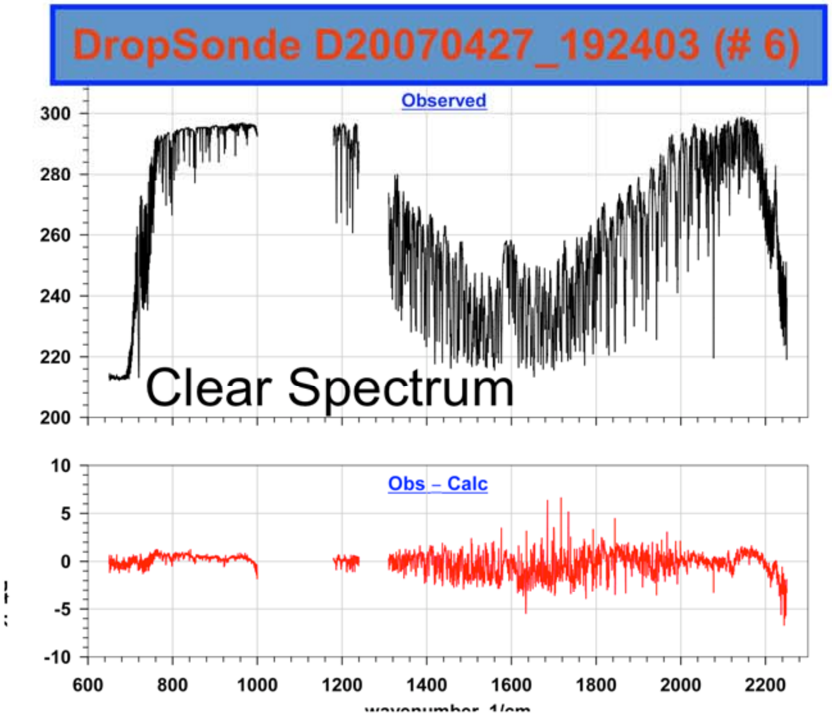


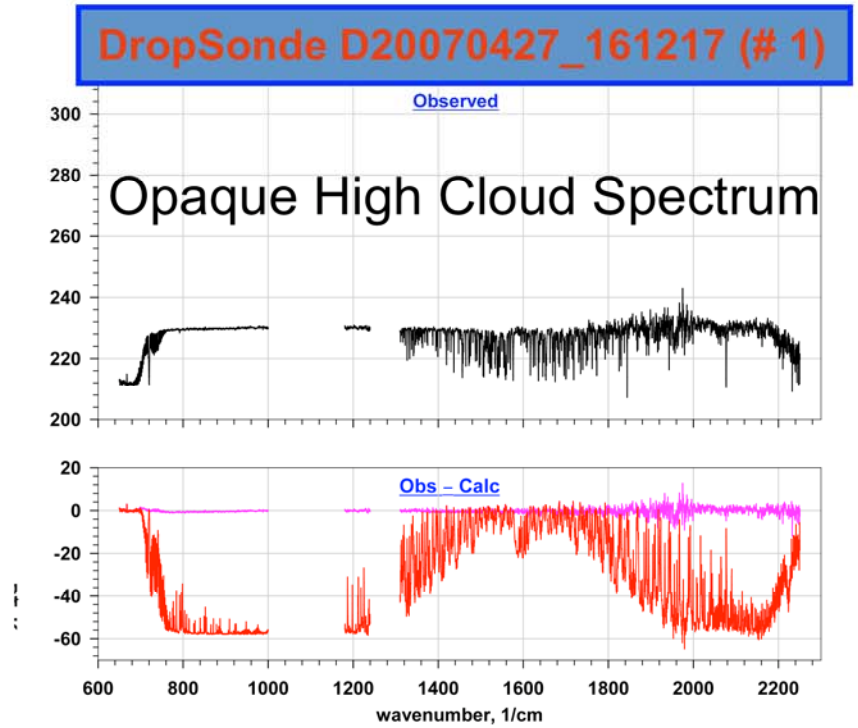
Relative Humidity

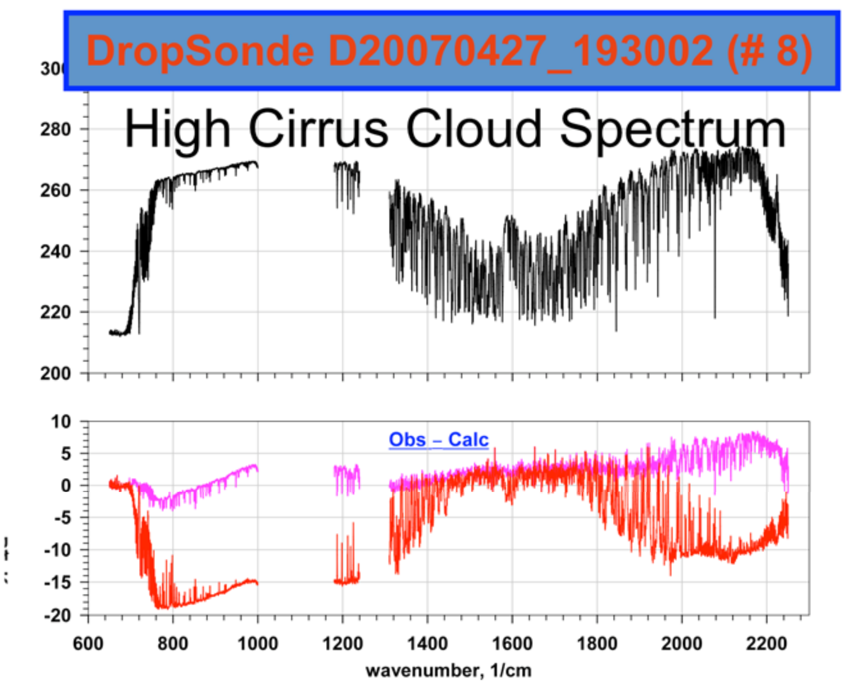


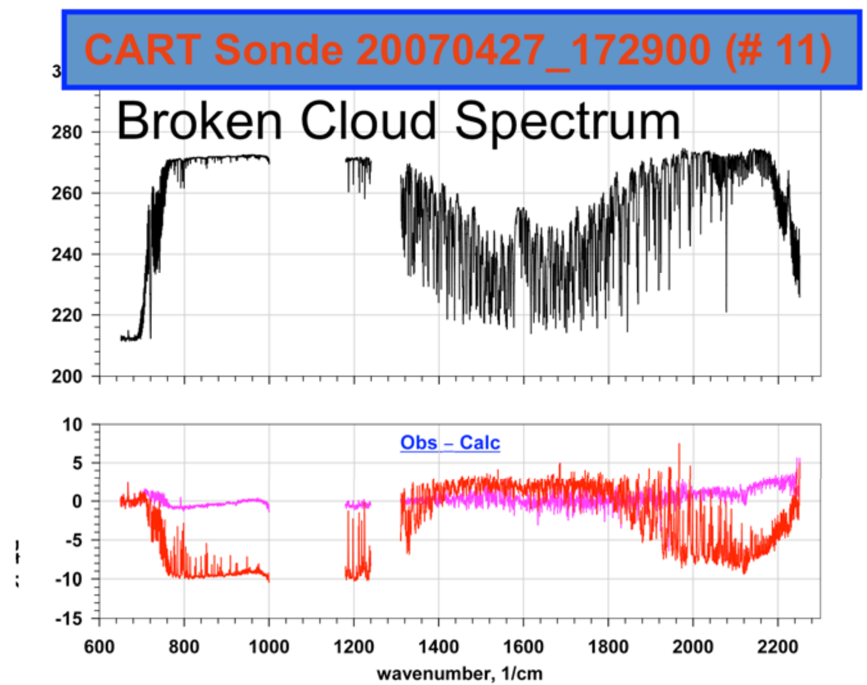
Comparison with BAe-146 Dropsondes



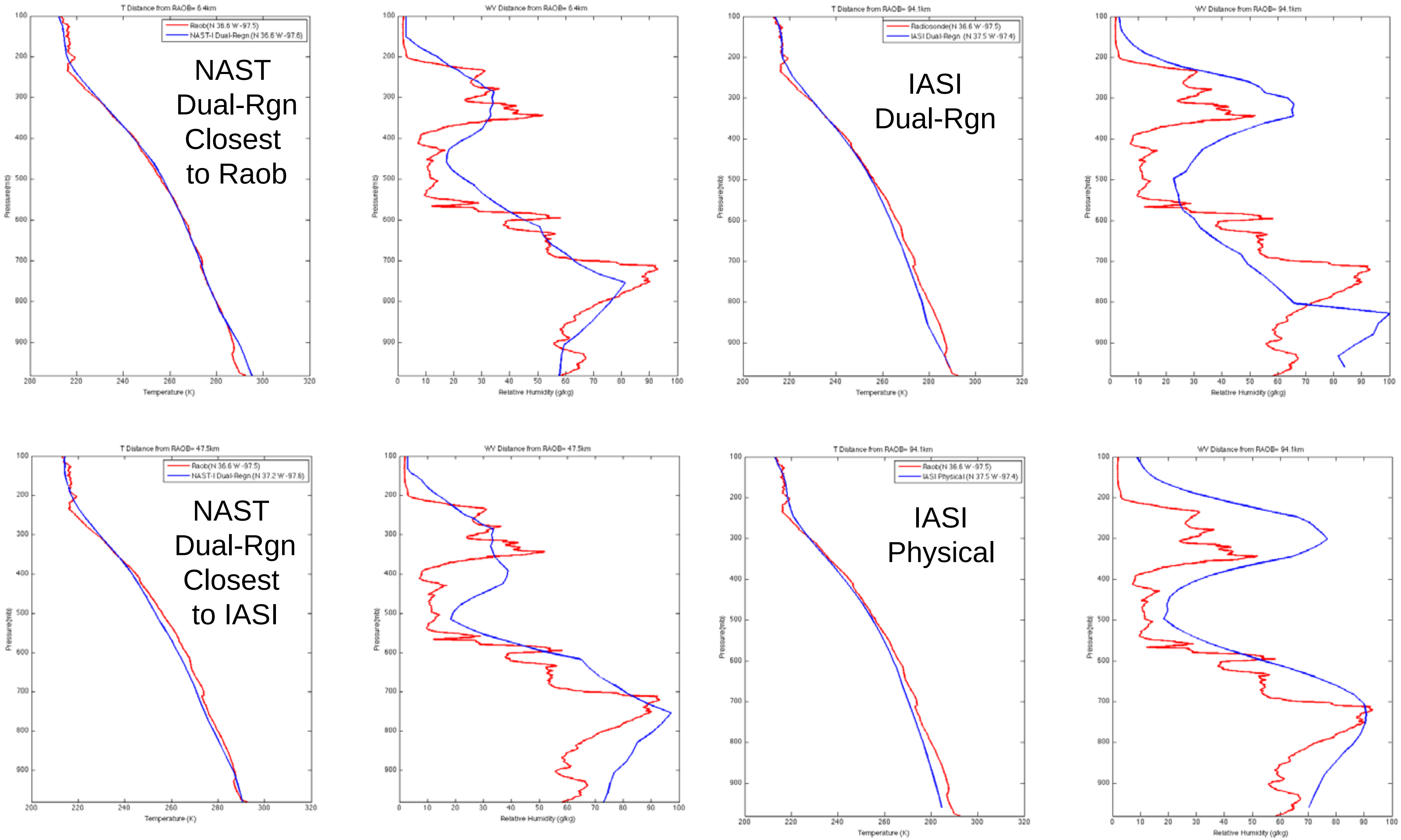

DropSonde D20070427_192403 (# 6)
Observed
Clear Spectrum
Obs – Calc


DropSonde D20070427_161217 (# 1)
Observed
Opaque High Cloud Spectrum
Obs – Calc
wavenumber, 1/cm


DropSonde D20070427_193002 (# 8)
High Cirrus Cloud Spectrum
Obs – Calc
wavenumber, 1/cm


CART Sonde 20070427_172900 (# 11)
Broken Cloud Spectrum
Obs – Calc
wavenumber, 1/cm

NAST Vs IASI Vs CART-site Radiosonde



Summary & Conclusion

Mesoscale Weather (JAIVEx April 27, 2007 Example)

- Dual (EOF) regression retrieval provides all-sky condition vertical temperature and moisture profiles with profiles being retrieved down to cloud level and below thin and/or scattered to broken clouds.
- For IASI and AIRS, a very fast iterative cloud pressure EOF regression approach is used to select the optimal cloud classification for the dual regression retrieval. 9 single layer cloud height classes are considered.
- For NAST, 44 two cloud layer height classes are assumed. The optimal class for the dual regression retrieval is chosen as that one for which the radiance calculated from the "clear-trained" retrieval agrees best with the observed radiance. The radiance residual cloud class selection is much more time consuming than the iterative cloud height regression method.
- For the JAIVEx case study presented here, dual regression retrievals are shown to have a vertical resolution and accuracy comparable to a physical retrieval using an unstratified (by cloud height) regression initial guess.
- Dual regression surface and cloud parameters, as well as temperature and moisture profiles, should useful for initializing 1-d variational physical retrievals and for assimilation of radiances into NWP models.

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