Applications of Single Footprint Retrievals : Humidity above DCCs and Trace Gases

Sergio DeSouza-Machado[a], Larrabee Strow[a]
Jing Feng[b], Yi Huang[b]

October 4, 2018

[a]Department of Physics, JCET, University of Maryland Baltimore County (UMBC)
[b]Department of Atmospheric and Ocean Sciences, McGill University, Canada

Overview

- Reminding you about our Single Footprint Retrievals
  - Surf temp, 100 layer T(z),H_2O (z),O3(z),ice and water clouds
  - 100 layer retrieval takes $\leq$ 2 seconds per single FOV
  - 8-12 hours per granule/240 processors do entire day
  - 100 layers (could be sped up if we use trapezoids?)
  - Matlab based loops
- Used to test SARTA performance
- Allows radiosonde inter-comparisons under some cloud cover
- Examine single footprint fitting residuals to uncover issues
- "Validations" presented at earlier AIRS STMs :
  - AIRS L2 ice ODs and MODIS water cloud ODs
  - GRUAN sondes
- Show and tell (this presentation)
  - Hurricane Florence quick look
  - Looking at humidity above DCC : wetting or drying?
  - CO retrievals (post-processing after thermodynamic retrieval)

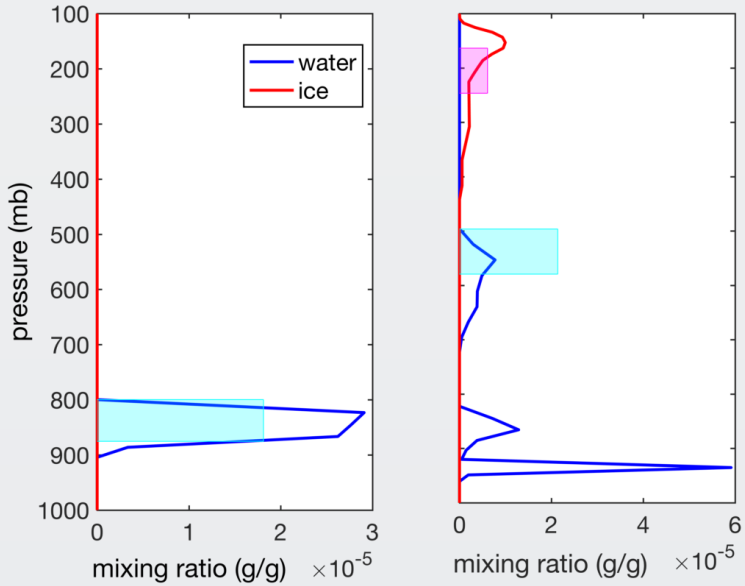
Retrievals

Single Footprint Retrievals

- 100 layer retrievals
- My QA depends on closeness to start profile (T/WV/O3 stemp) and bias(900 cm^{-1}, 1231 cm^{-1}) : low QA is not bad news
- Cloud Representation : NWP multilayer cloud converted to Two Slab Clouds (ice and water clouds)
- OEM methodology, so DOF is a natural diagnostic
- smoothing by combination of Tikonov matrices, $\sigma(i)^2 e^{-((i-j)/h)^2}$, climatology

Single Footprint Retrievals, DeSouza-Machado *et. al.*, *Atmos. Meas. Tech.*, 2018

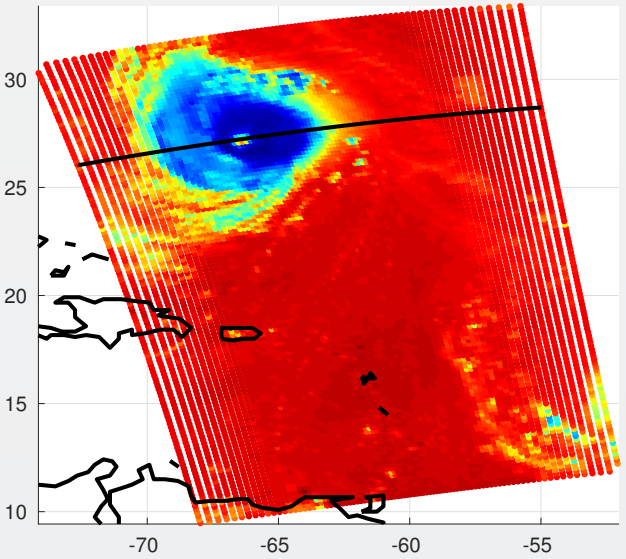
Evaluation of Radiative Transfer Models with Clouds, Aumann *et. al., J. Geophys. Res*,2018



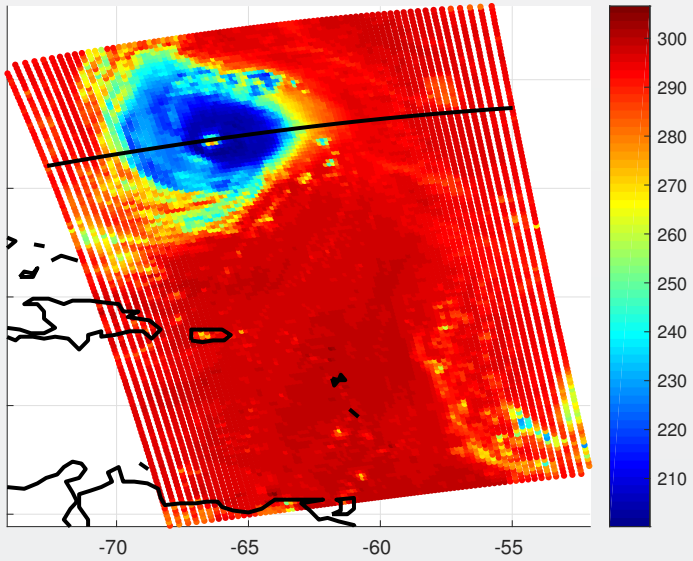
Hurricane Florence

Hurricane Florence 2018/09/11 g175 BT1231,BT1419

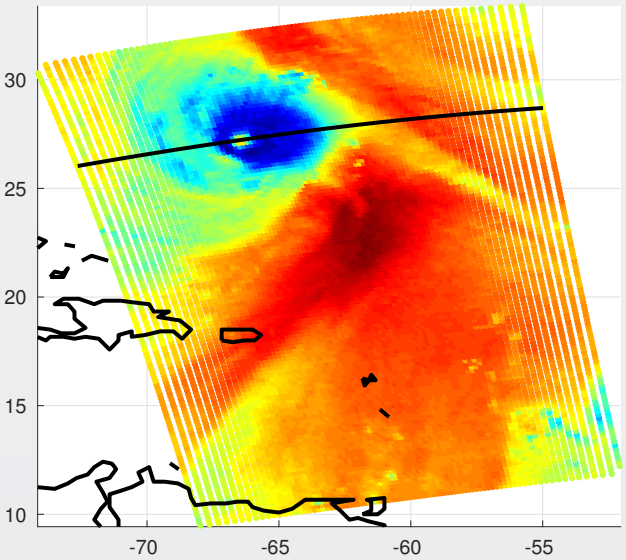
BT1231 obs



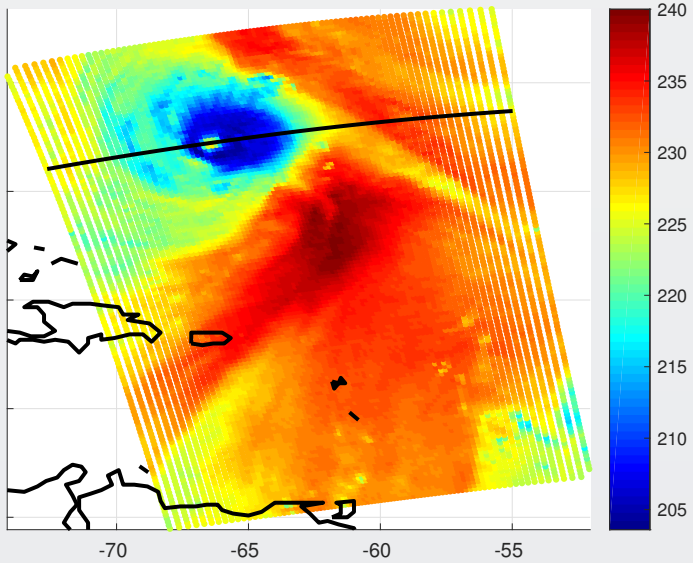
BT1231 after retr



BT1419 obs

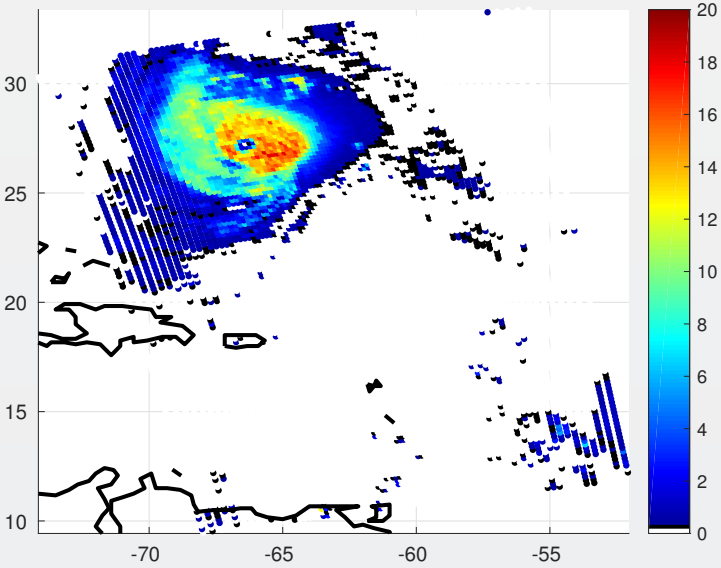


BT1419 after retr

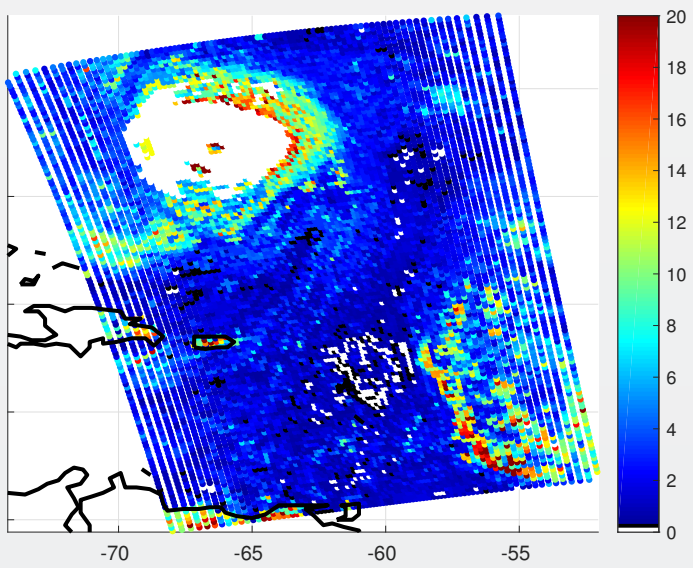


Hurricane Florence 2018/09/11 g175 Cloud OD

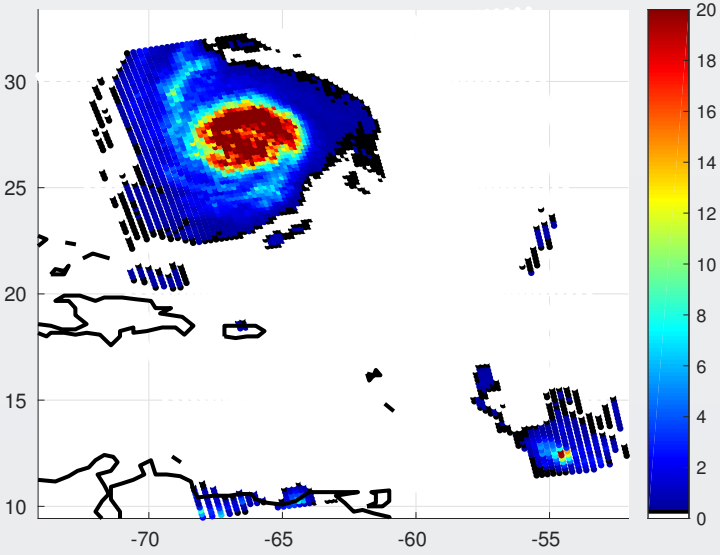
UMBC IceOD



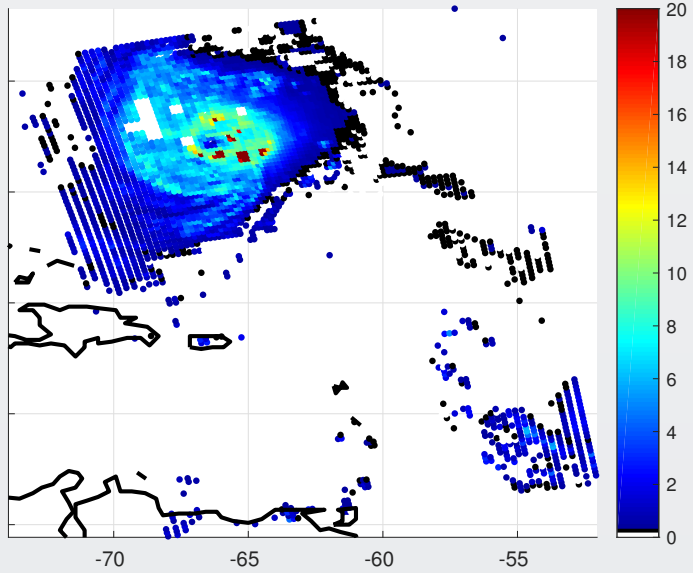
UMBC WaterOD



ECM IceOD

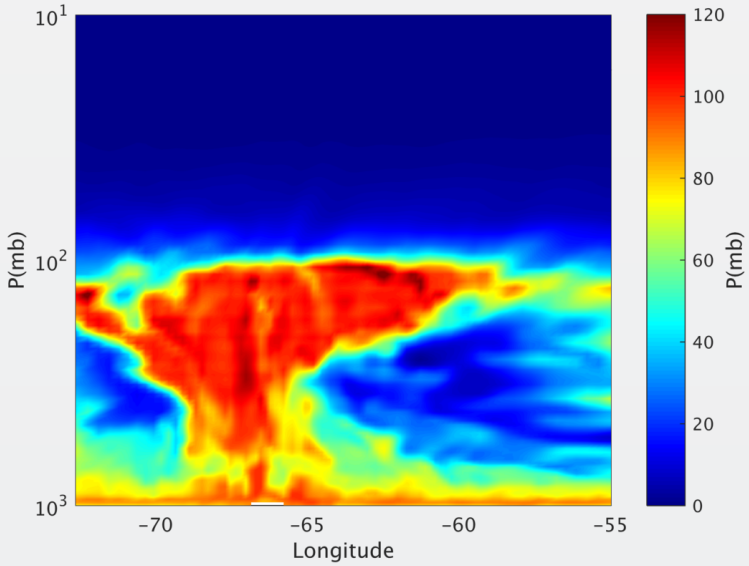


AIRS L2 IceOD

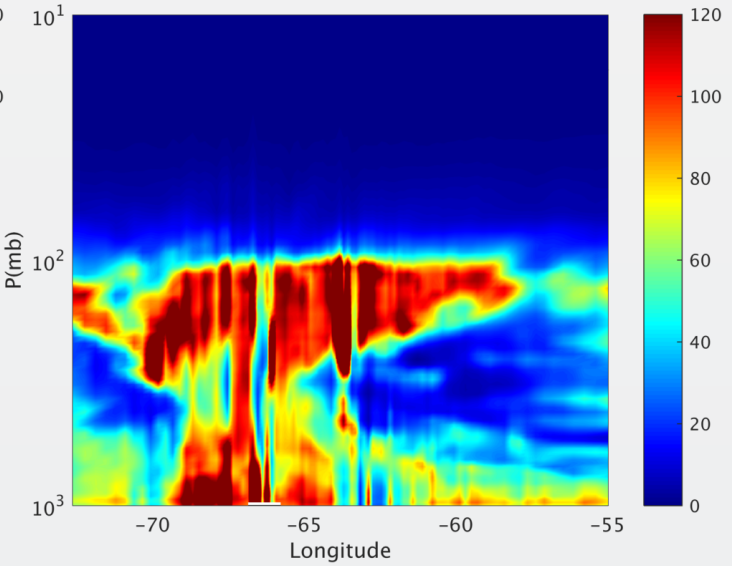


Hurricane Florence 2018/09/11 g175 RH(z,lat)

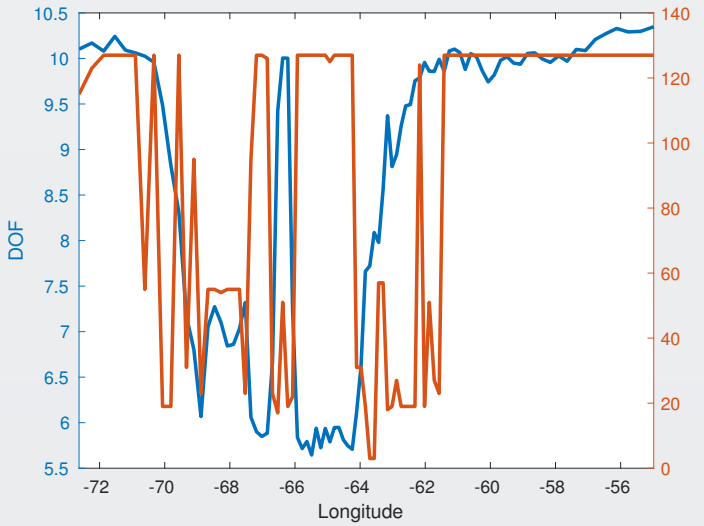
ECM RH



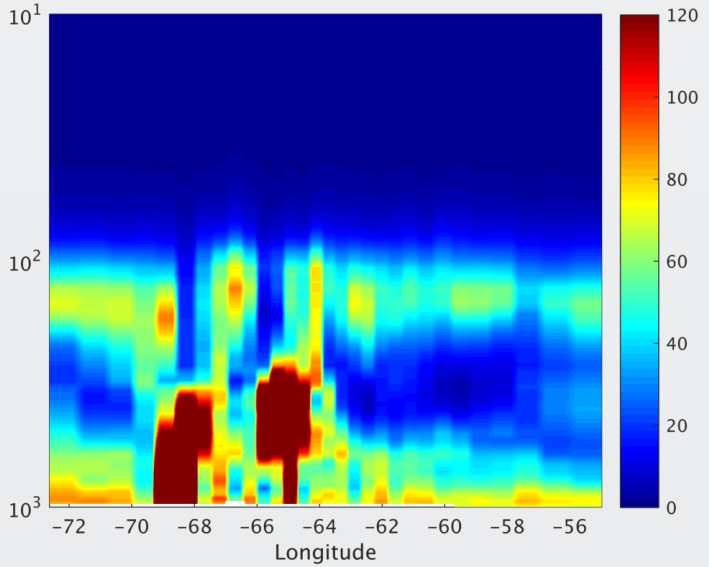
UMBC RH



DOF/QA



AIRS L2 RH



DCC

UT/LS WV above DCC

- Are deep convection processes drying or moistening UT/LS?
- Cloud clearing lowers resolution (may not show correct spatial distribution pattern)
- Can hyperspectral sounders/single footprint retrievals provide more information than eg ERA
- May also be able to get information about CH4 above DCCs

2005/06/17 g083

"Cloud-Assisted Retrieval of Lower-Stratospheric WV from Nadir-View Satellite Measurements" J. Feng, Y. Huang, JAOT 2018

Comparisons to AIRS L2 and Harvard Water Vapor instrument during Aura Validation Experiment (AVE 2005) using Single Footprint Retrievals

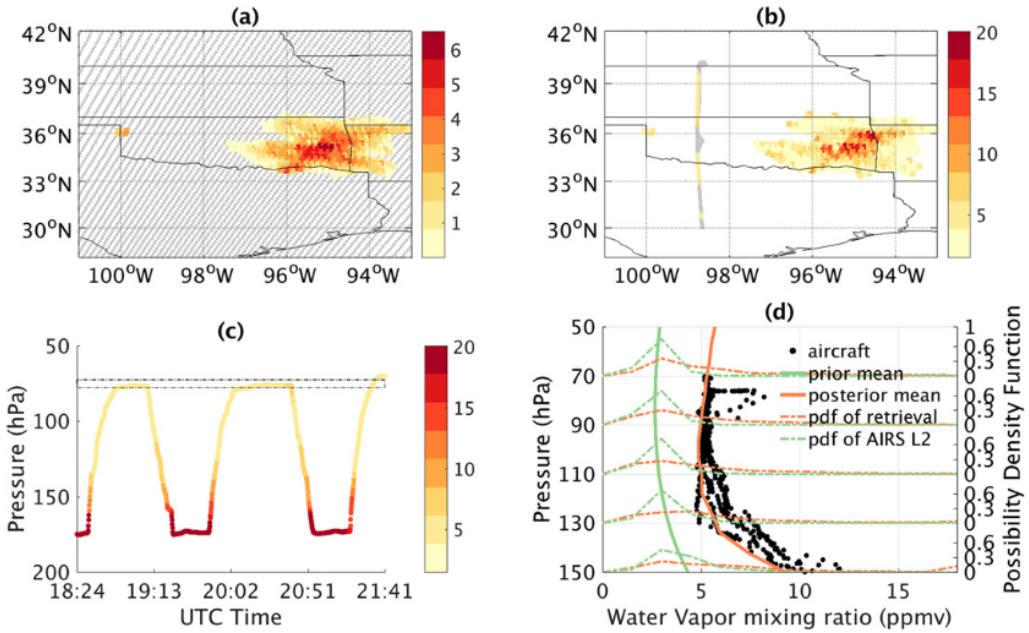
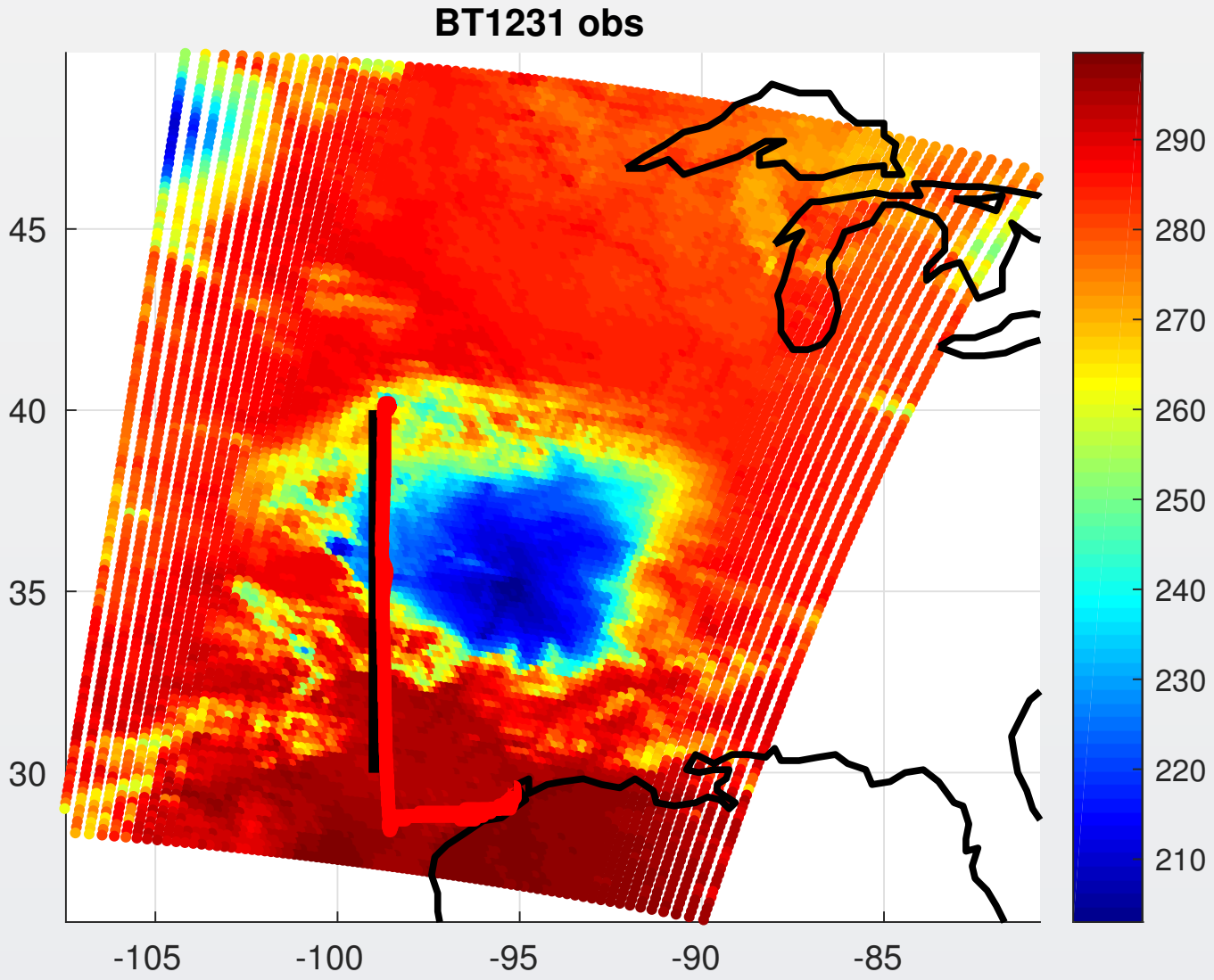
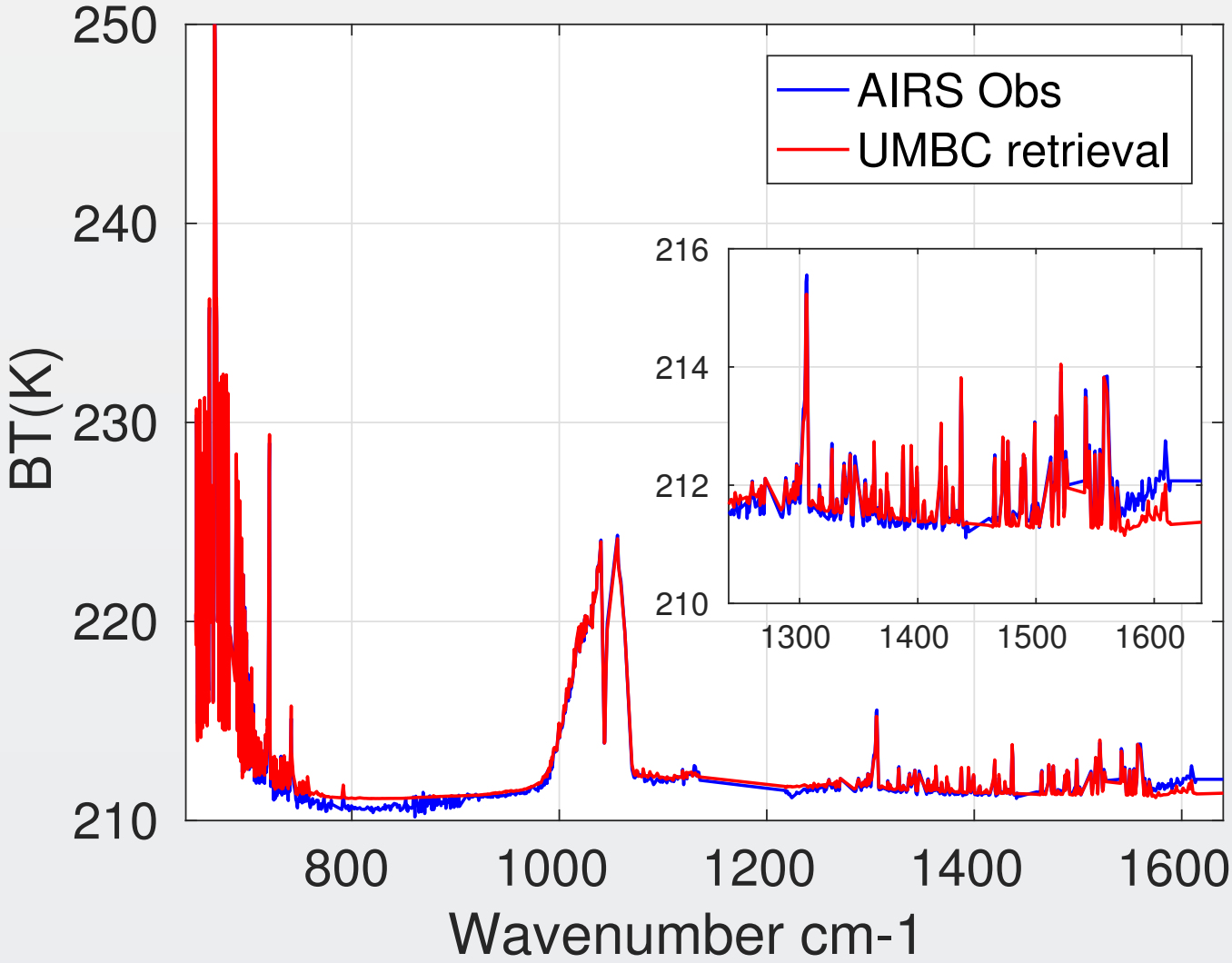


FIG. 8. Retrieval of 17 Jun 2005. (a) Brightness temperature difference (bt1419 − bt1231) in the AIRS L1B measurements. (b) Water vapor volume mixing ratio at 78 hPa retrieved from the AIRS L1B measurements and that between 75.5 and 80.5 hPa measured by the aircraft. (c) Aircraft altitude time series, color coded by measured water vapor mixing ratio. (d) Vertical distribution of retrieved water vapor mixing ratio (solid red line: mean; dashed red line: PDFs of each 20-hPa vertical interval) compared to the aircraft measurements (black dots) and the prior guess (green). Mixing ratio in ppmv in all plots.

2005/06/17 g083 : BT1231



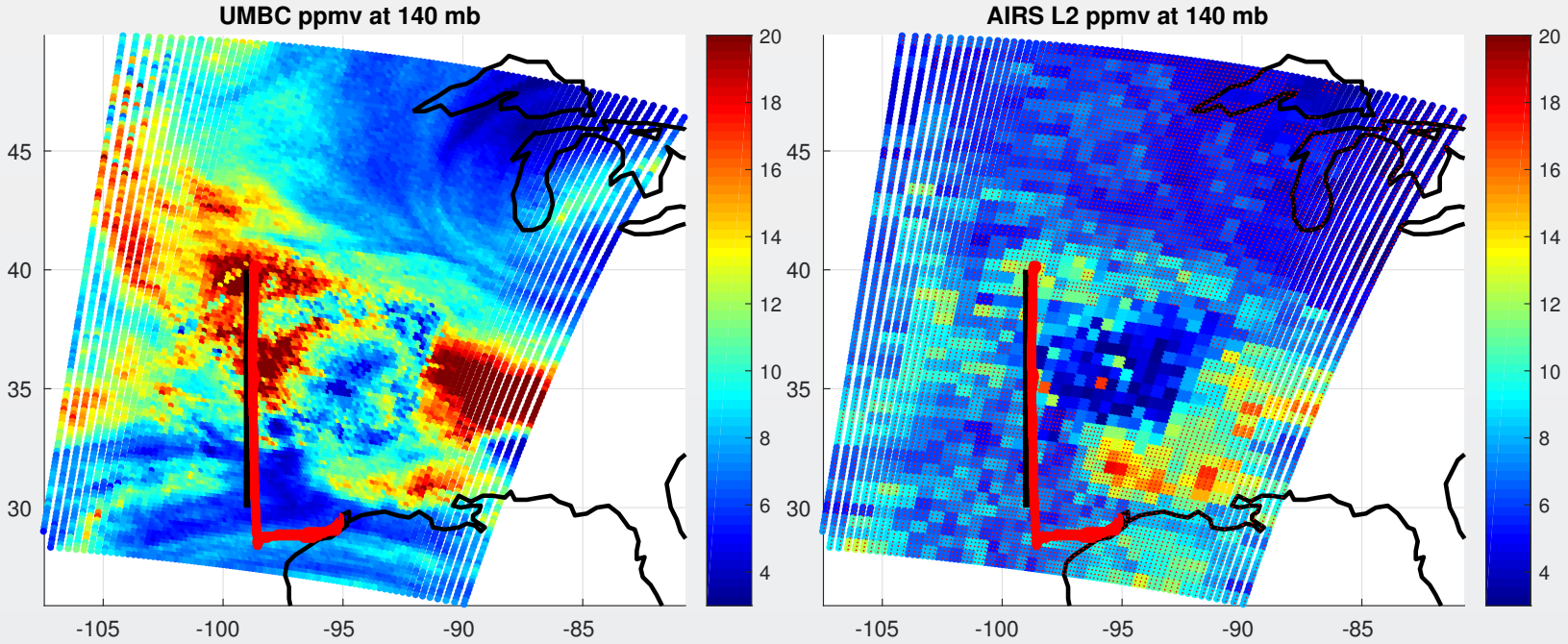
2005/06/17 g083 : spectra



g083 : 140 mb

The WV amounts are in ppmv at 140 mb

UMBC WV *AIRS L2*



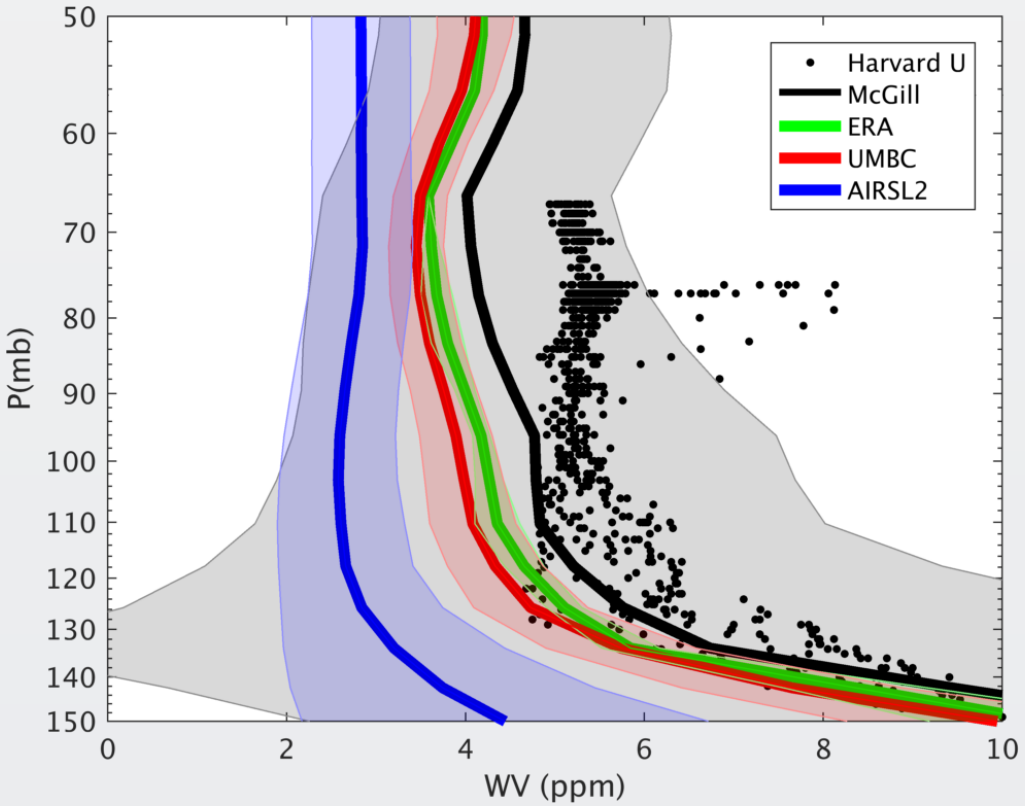
UMBC shows moistening away from the DCC

Little black dots (AIRS L2) : good/best QA TSuf/ClearSky OLR

Is UT/LS made wetter by deep convection?

Both McGill U. and UMBC are much wetter than AIRS L2!

The single footprint approach can help provide insight, as it is capable of showing spatial distribution patterns that are smeared out in AIRS L2, even at 140 mb



Some comments

- Harvard U. flight was 10 hours after g083; back trajectories show that the LS air they sampled was in the region of the DCC 10 hours earlier!
- flight had g193/g194 overpass, I've looked at AIRS L2/UMBC/ERA for that flight
  - that flight was over very clear scenes (looked at MODIS L1 images, BT1231 obs compared to ERA surf temp)
  - at 140 mb, both AIRS L2 and UMBC had 0.00 $\pm$ 0.75 ppmv bias, ERA had -2 ppmv bias
  - at 080 mb, both AIRS L2 and UMBC had 1.75 $\pm$ 0.50 ppmv bias, ERA had 1.25 ppmv bias
- Jing and I have also looked at 2014/03/04 data, see similar results over DCC : esp at 140 mb, there are biases between *in-situ* and AIRS L2, while our single footprint retrievals have much smaller biases

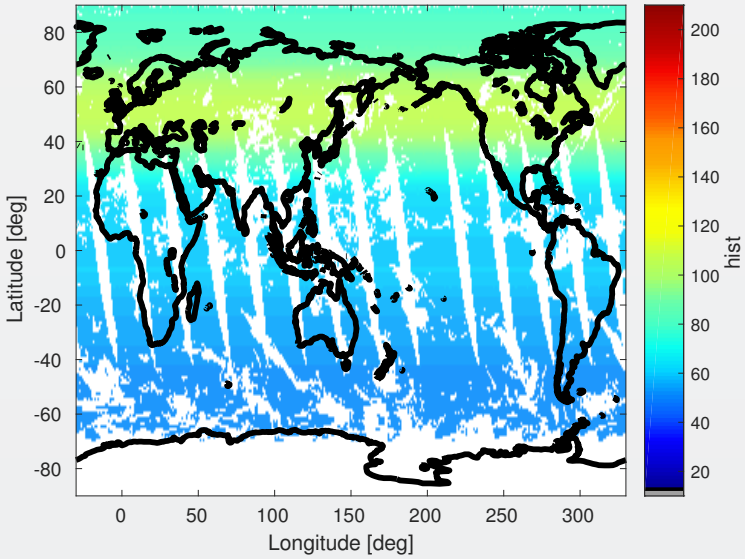
CO

CO for 2010/08/01

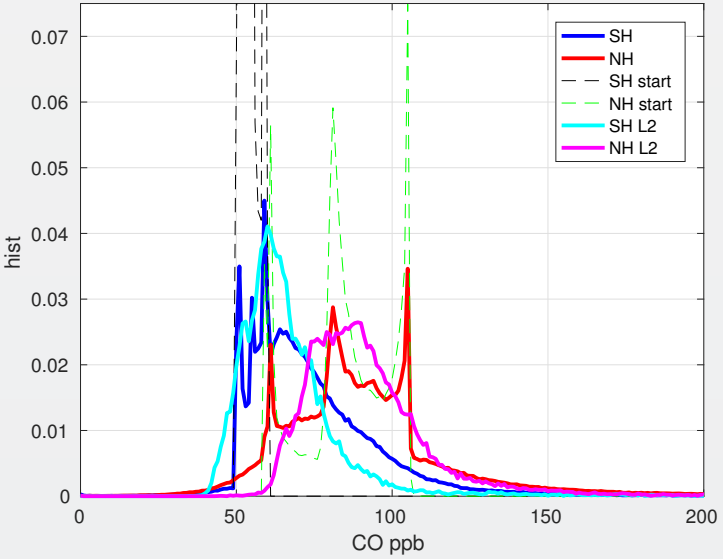
- Juying Warner, Antonia Gambacorta, Chris Barnet and Larrabee made suggestions about eg dates to try, which *a-priori*, cloud problems etc
  - First cut : Only did column CO retrieval
  - bias/std dev over 12150 profiles $\sim$ AIRS NeDT, but individual thick clouds could have $\geq$ 1 K biases (slope of ice clouds, no size fitting) in window region including CO region
  - zero out this bias in the CO region, before fitting for CO (WV/T biases still very good)
- Used "Global Atmosphere Watch reactive gases measurement network" (GAW) from Martin Schultz, see eg https://www.esrl.noaa.gov/gmd/publications/annual_meetings/2015/slide Helmig.pdf

CO 2010/08/01 UMBC QA filtered

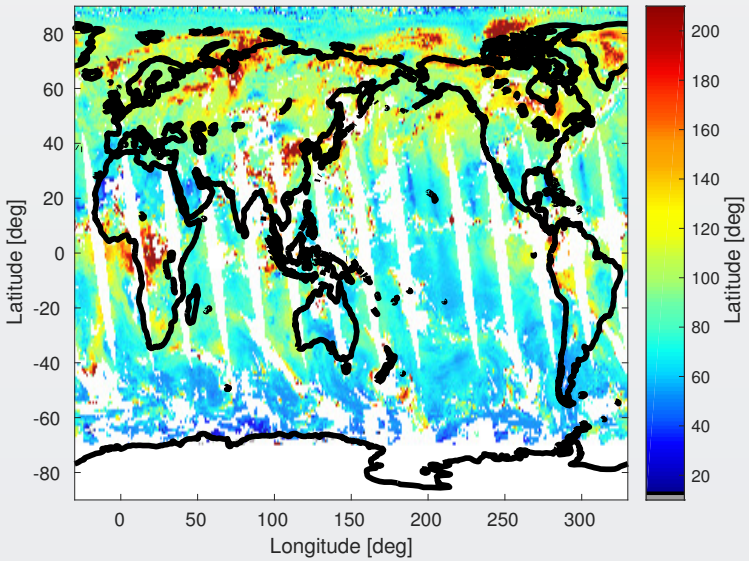
Start CO



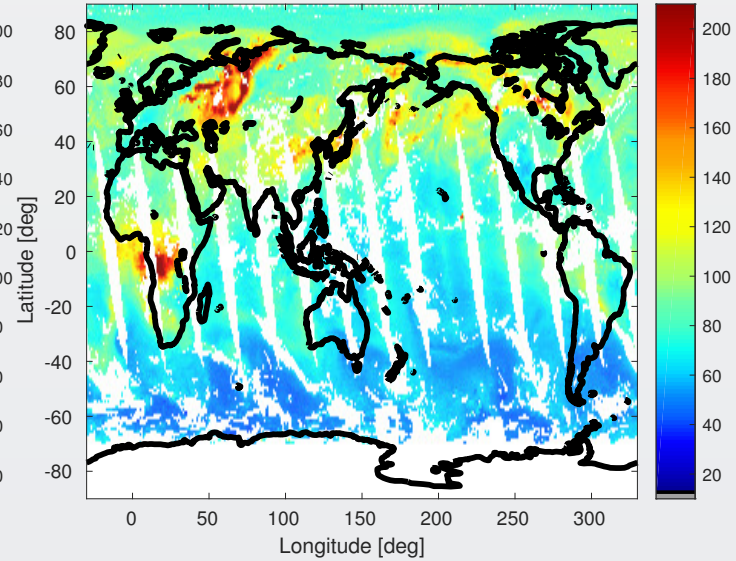
Hist. CO



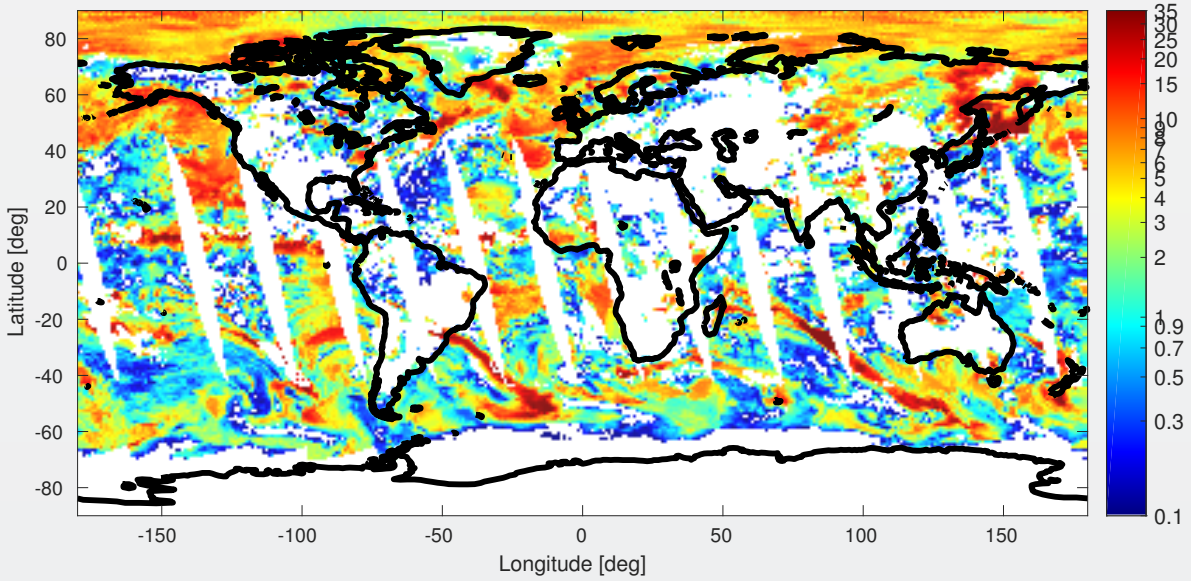
UMBC CO

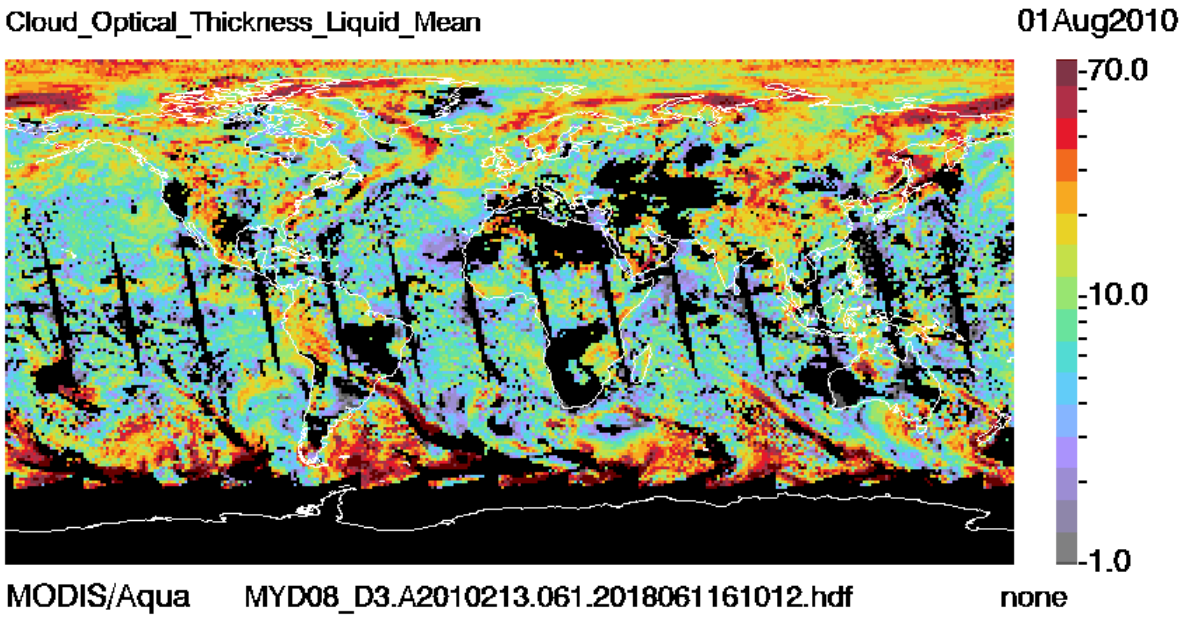


AIRS L2 CO



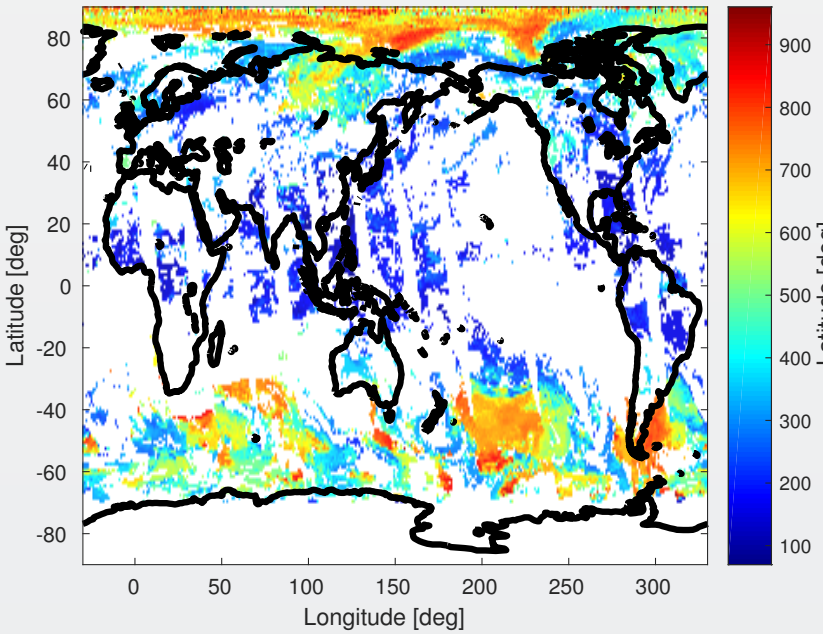
Clouds 2010/08/01 UMBC Water Cld vs MODIS L3



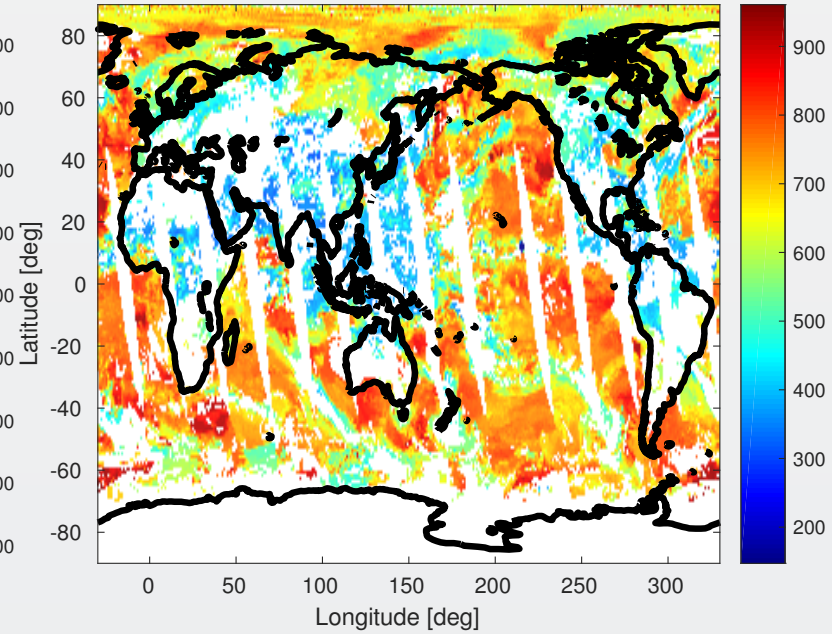


Clouds 2010/08/01 UMBC Cloud Tops

Ice Top



Water Top



Conclusions

- Single Footprint Retrievals are very promising and allow vastly improved validation of SARTA to sondes, reanalysis, etc.
- Algorithm does water cloud and ice cloud retrievals, plus Surf Temp. T(z), WV(z), O3(z); can add on trace gases
- This talk concentrated on "new" products
  - AIRS L2 water amounts above DCC clouds are sometimes incorrect; Single Footprint looks like a better approach
  - Column CO retrievals after single footprint thermodynamic retrievals are promising
    - Column CH4 retrievals showed similar patterns to AIRS L2, but with a bias! More work ...
  - Looking at the eye of Hurricane Florence
- As usual, asking for co-operation in validating our code