SINGLE FOOTPRINT ALL-SKY RETRIEVALS USING A FAST, ACCURATE TWOSLAB CLOUD REPRESENTATION

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Overview

Outline

- Motivation
- Overview of TwoSlab Cloud Representation
  - NWP multilayer cloud converted to Two Slab Clouds (ice/water)
- Application : single footprint allsky Optimal Estimation retrievals
- Show and tell results
  - This work is very preliminary "proof of principle"
  - Retrieval speeds ~ 1.5-2.0 seconds/FOV
  - AIRS L2 is 1.5 sec/FOR, NUCAPS is 0.3 secs/FOR
  - We used 100 layers, compared to ~ 20 trapezoids; also our code is "slower Matlab loops/ shell escapes"

Motivation

- Hyperspectral IR data contains cloud and/or aerosol effects
- Clear sky RTAs typically used for operational retrievals after cloud clearing or clear sky filtering

- Scattering algorithms and cloud representation (Random Overlap, MRO, ExpMRO) are varied and complicated
- This makes cloud retrievals difficult (cloud top, amount, particle size,fraction, phase)
- D of F calculations for hyperspectral IR sounders show ~ 2-5 pieces of information per cloud (eg amount, top/bottom, some profile info).
- We have developed and tested a very fast and reasonably accurate TwoSlab cloud representation (derived from NWP CIWC/CLWC/CC/TCC profiles)

SARTA TwoSlab

TOA radiance is weighted sum of at most FOUR radiance streams

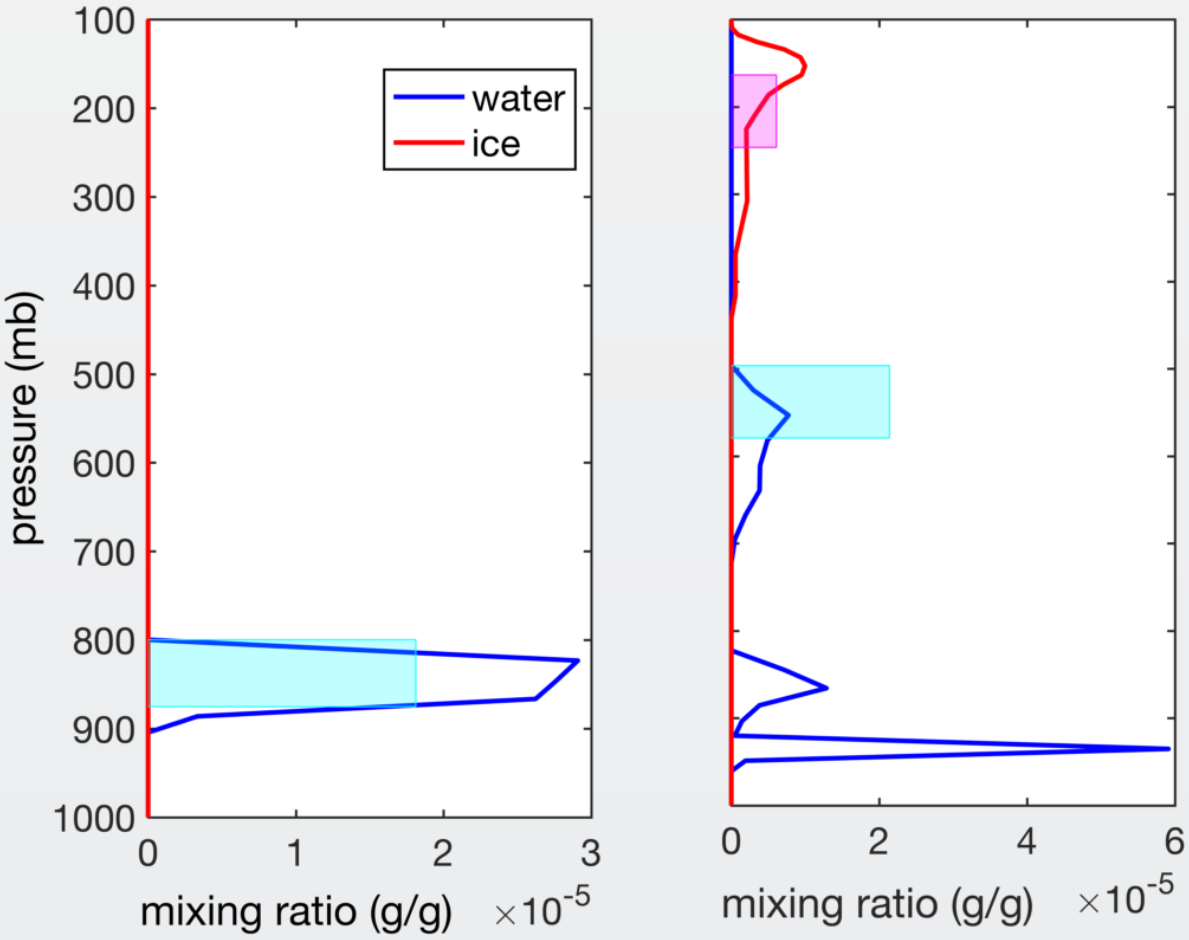
$$r(\nu) = C_{11} r_1(\nu) + C_{22} r_2(\nu) + C_{12} r_1 2(\nu) + C_{00} r_{clr}(\nu)$$

so on average code is x2 slower than SARTA clear

- MRO mode : typically multiple ($\sim$ 20-50) subpixels used
- So TwoSlab is about 5-10 or more times faster than MRO, and jacobians are straightforward
- VERY EASY to move slab clouds up/down
- embedded into SARTA (atmospheric ODs from kCARTA)

Cirrus : General Habit Model (GHM) from Ping Yang/ Bryan Baum (2013)
Water : Mie scattering, Particle Size Distribution from MODIS L2 model

Example of Profiles → Slabs



Red and blue curves come from the NWP model

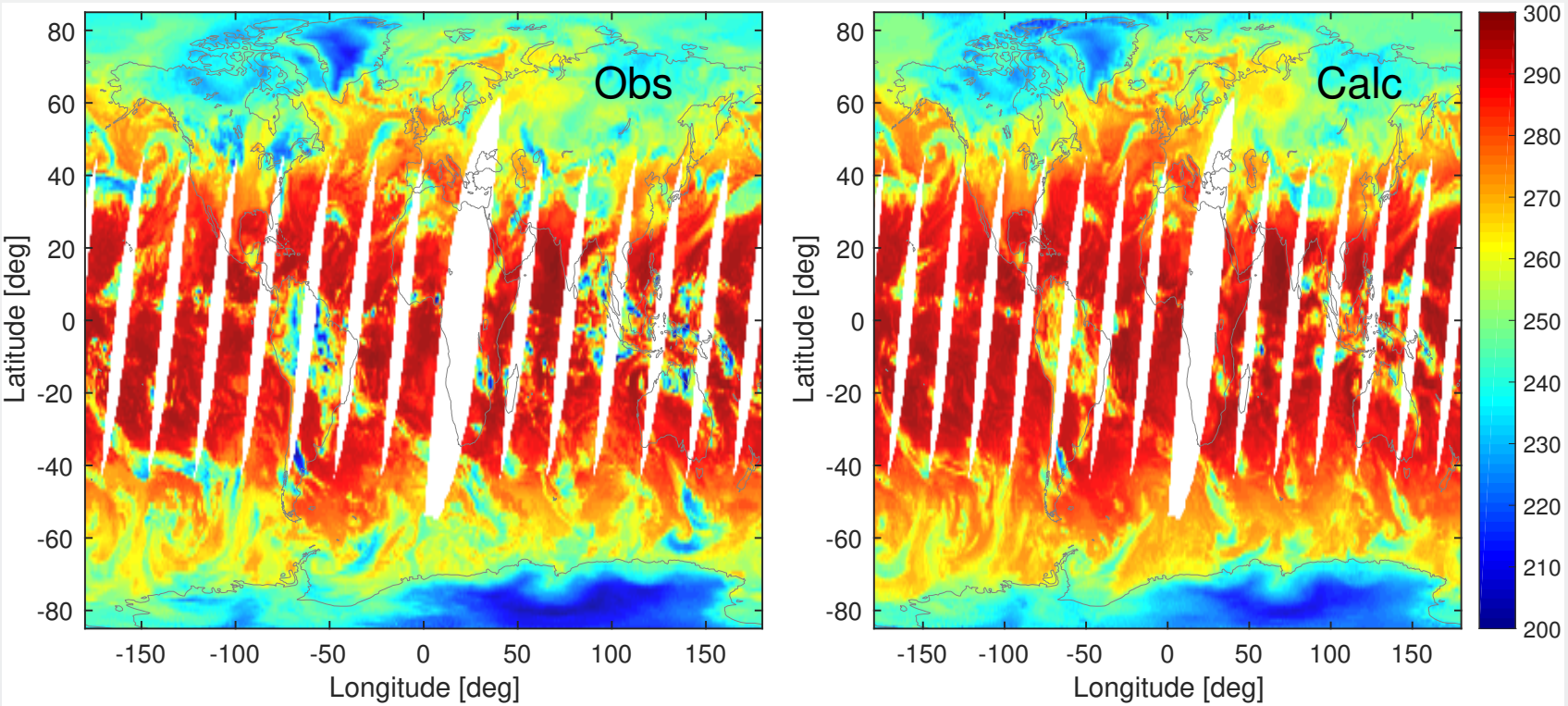
Cyan and magenta are the slab locations (and loadings)

Comparison to obs and PCRTM/MRO

BT1231 obs/calcs 2011/03/11 nighttime

(L) AIRS obs

(R) SARTA 2S

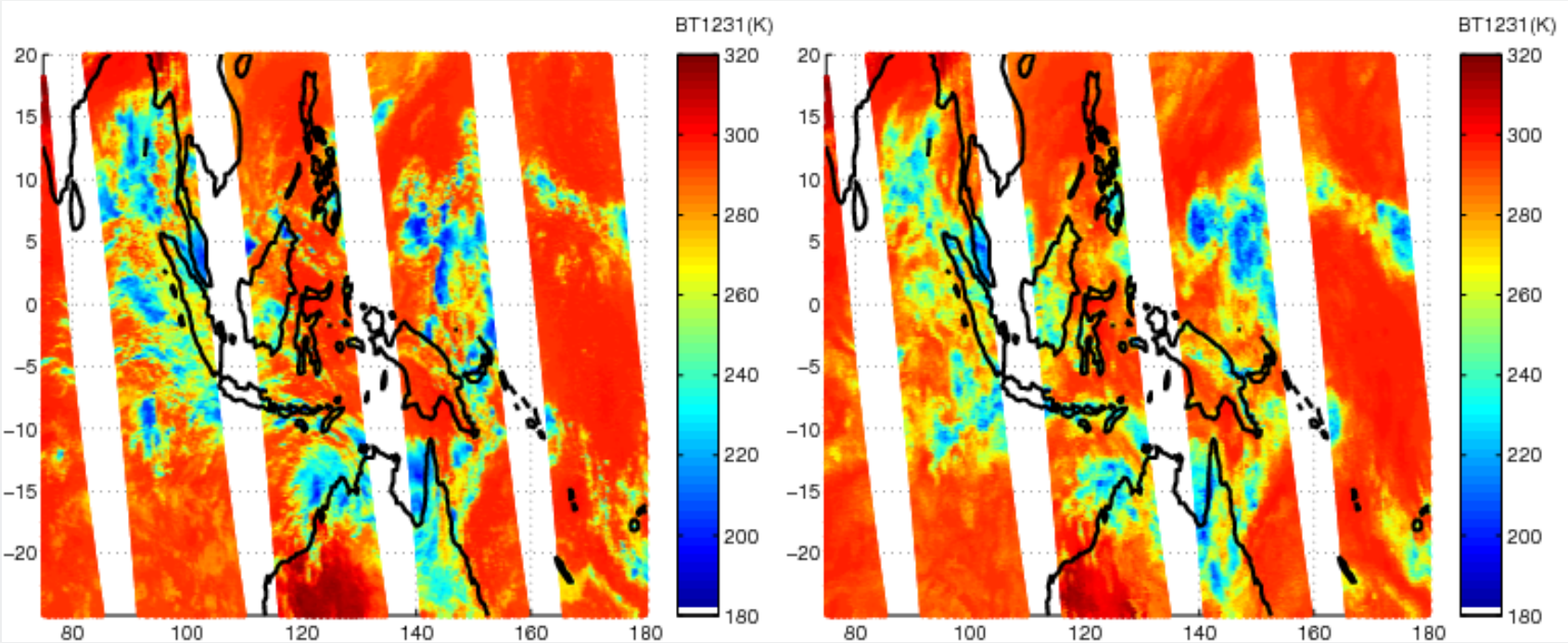


Note we have extensively compared spectra to PCRTM/MRO; BT1231 window differences are on order of 1.4 ± 5.0 K (global) and smaller in regions of high absorption (15,6.7,4.2 μm) averaged of millions of spectra

Retrieval

TWP 2011/03/11

Left panel : AIRS observations. Right panel : SARTA 2S



General locations of the deep convection regions are correct, though there are substantially fewer DCC (cloud tops below 210 K) in the simulations.

Retrieval Idea

- Use co-located NWP (or climatology) thermodynamic/cloud fields to initialize
- For each pixel, initial guess is as follows
  - Clouds : Match "closest window BT simulation" to AIRS obs
  - Keep thermodynamic fields (clim, NWP,....)
  - In future may adjust cloud top, particle size (MBL and DCC)
- OEM retrieval, *simultaneously* solves cloud amounts for ice/water clouds, and T(z), WV(z), stemp(z), col O3, col CH4

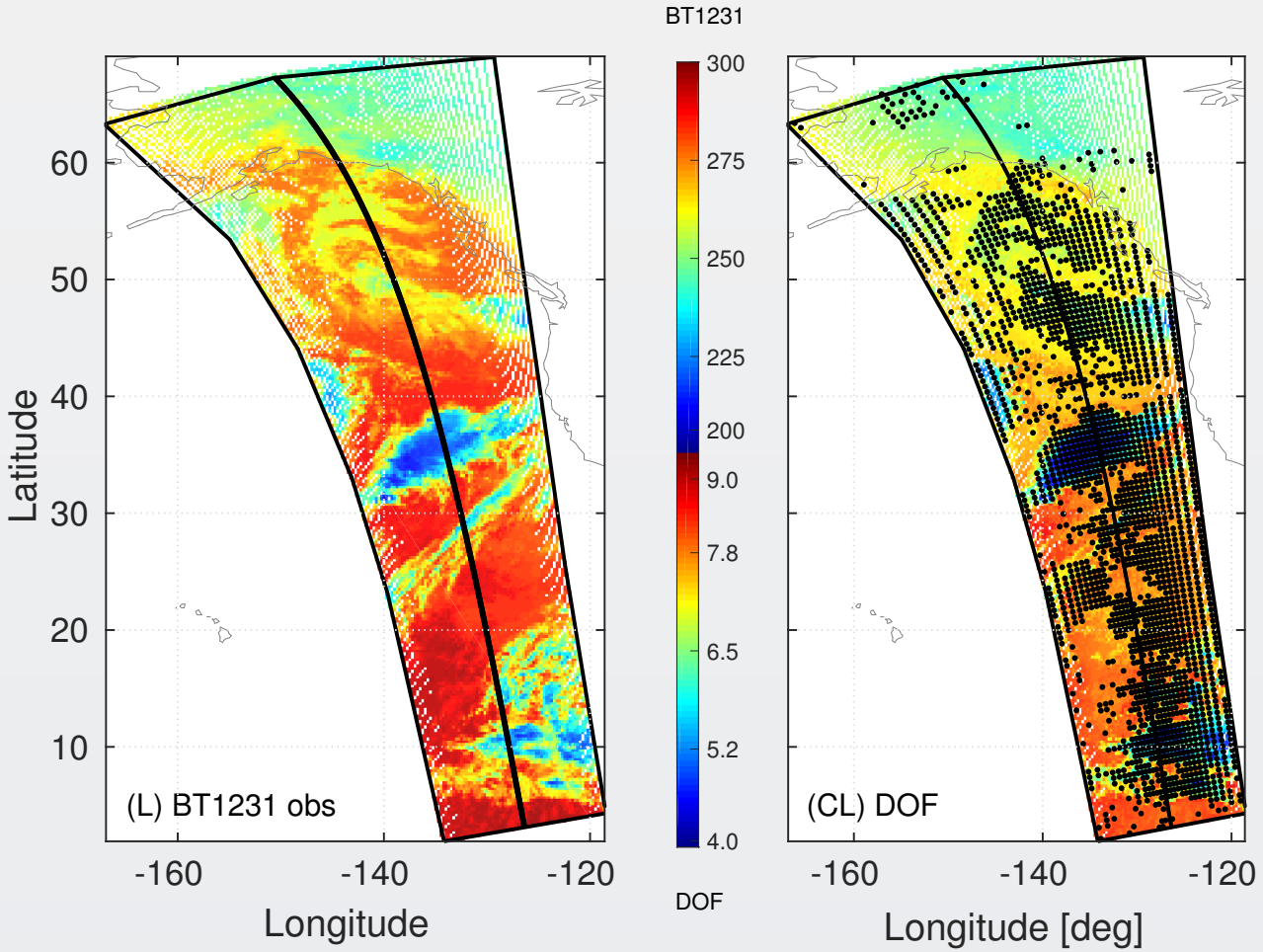
- 100 layer jacs for WV and T, $\simeq$ 300 channels (from AIRS L2 list)
- nonlinear Gauss-Newton iterative solution (Rodgers textbook)
- Run off OEM, for N=5 iterations at most, save AK, dofs etc
- QA : ($\sim$ 10%) retrievals have bad calcs, RH > 150% etc (usually co-located with thick clouds)

2014/02/08

2014/02/08 : Obs

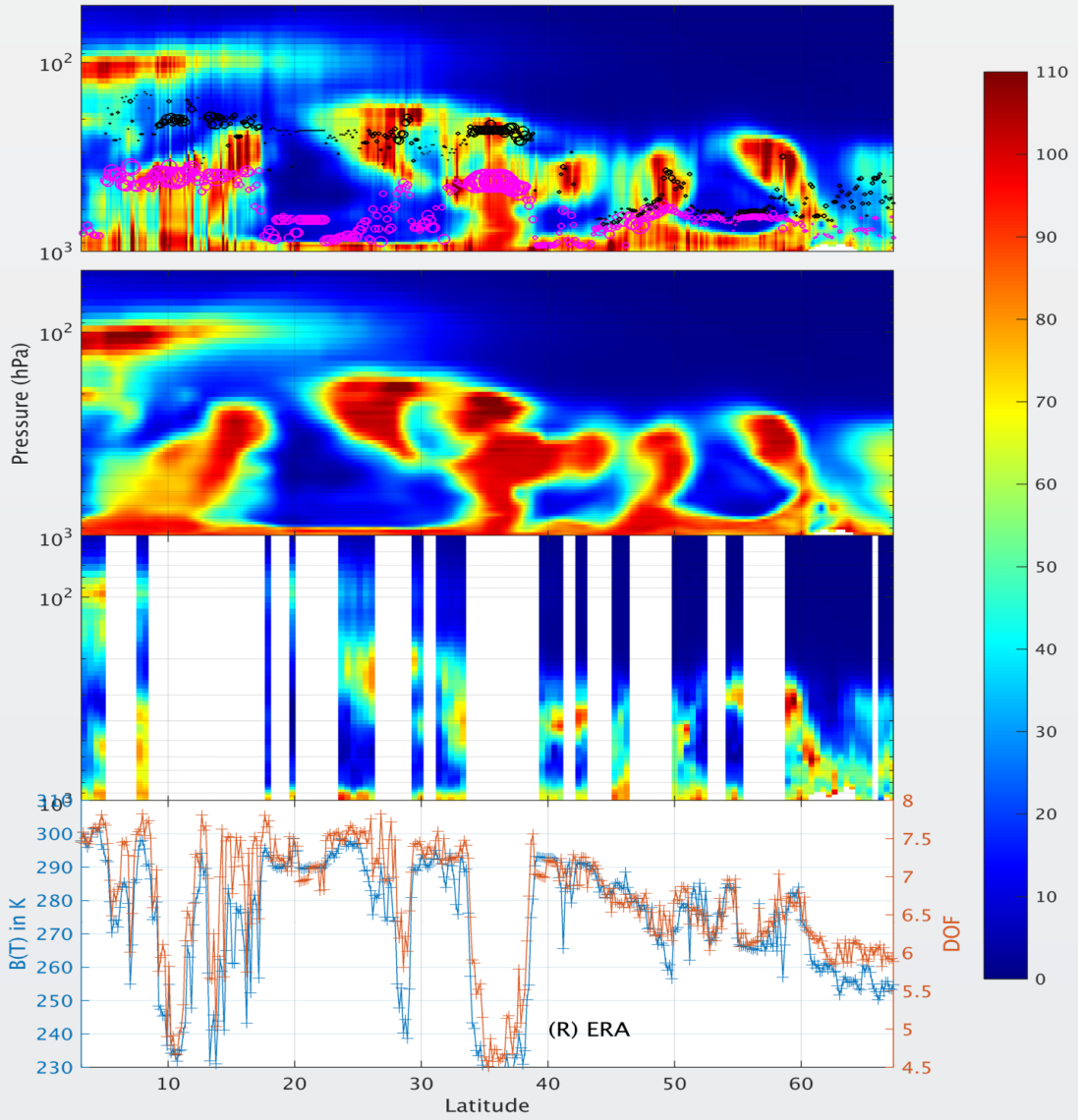
Left : AIRS BT1231 obs

Right : Retr DOF



Black dots : AIRS L2 had poor surface/clear OLR QA

2014/02/08 : RH Curtain plots, start with ERA



UMBC RH

ERA RH

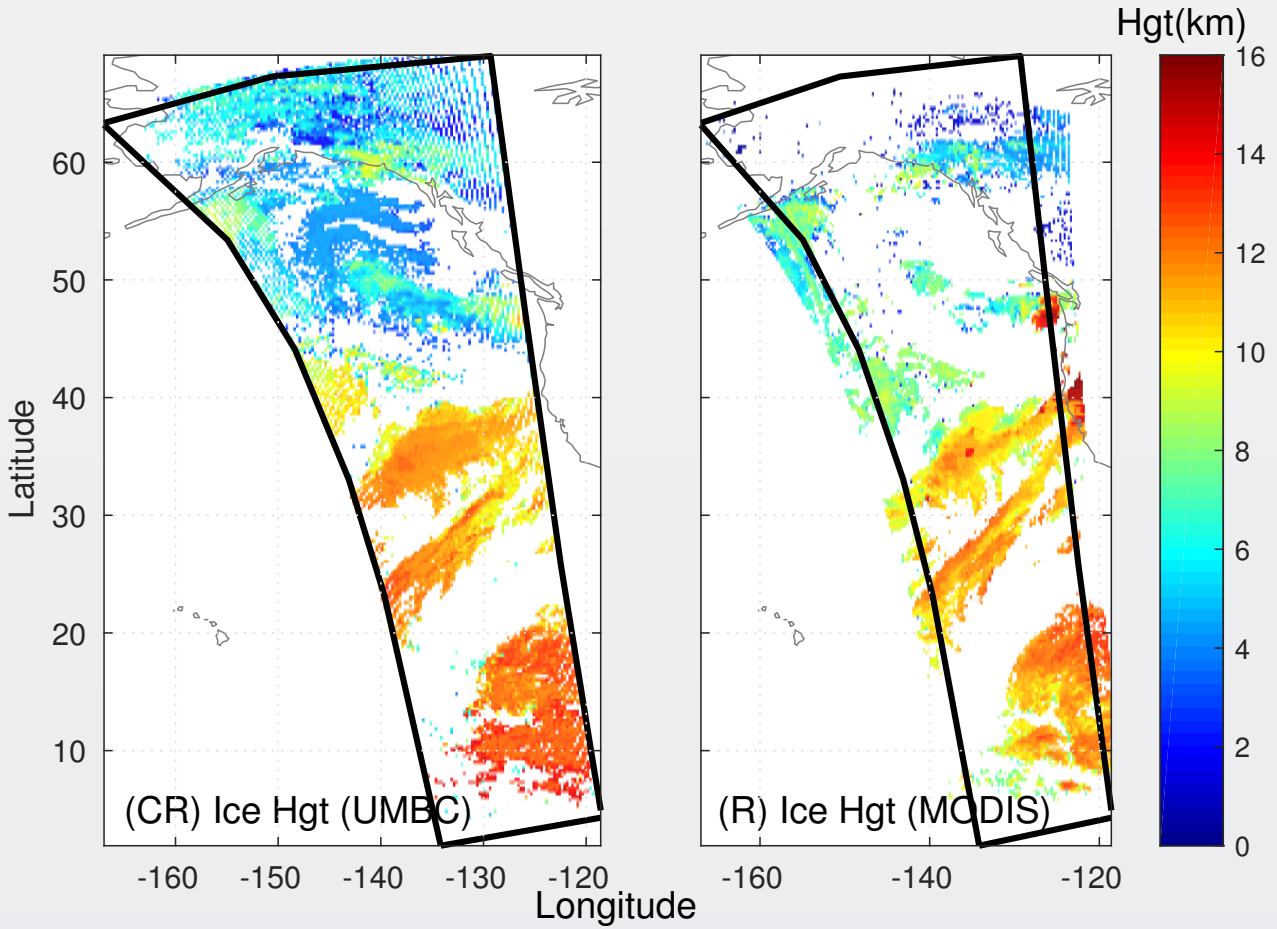
AIRS L2 RH (QA)

Obs BT1231/DoF

2014/02/08 : Clouds

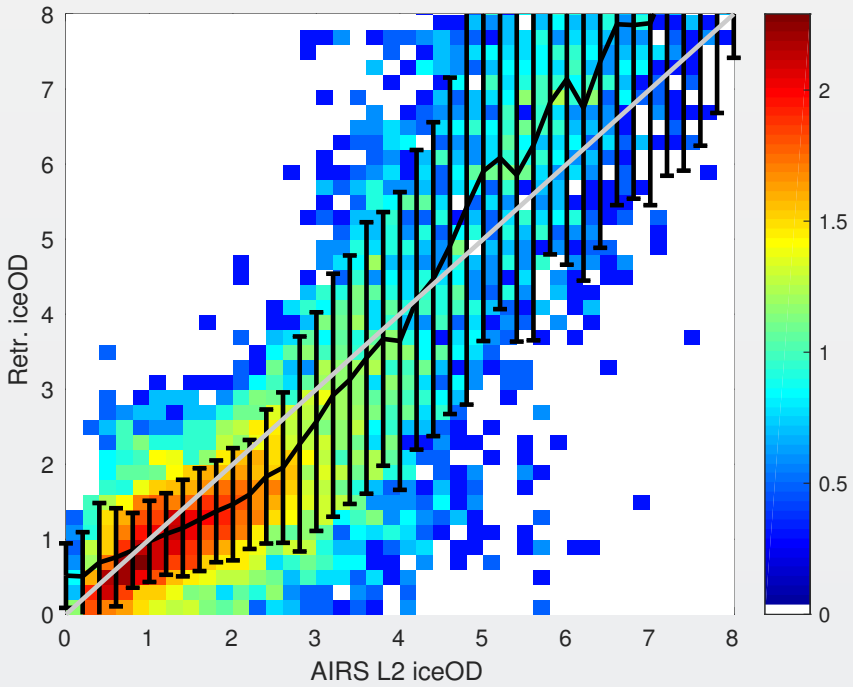
Left : UMBC IceCld

Right : MODIS L2 IceCld



Heights in km

2014/02/08 : Clouds (contd)



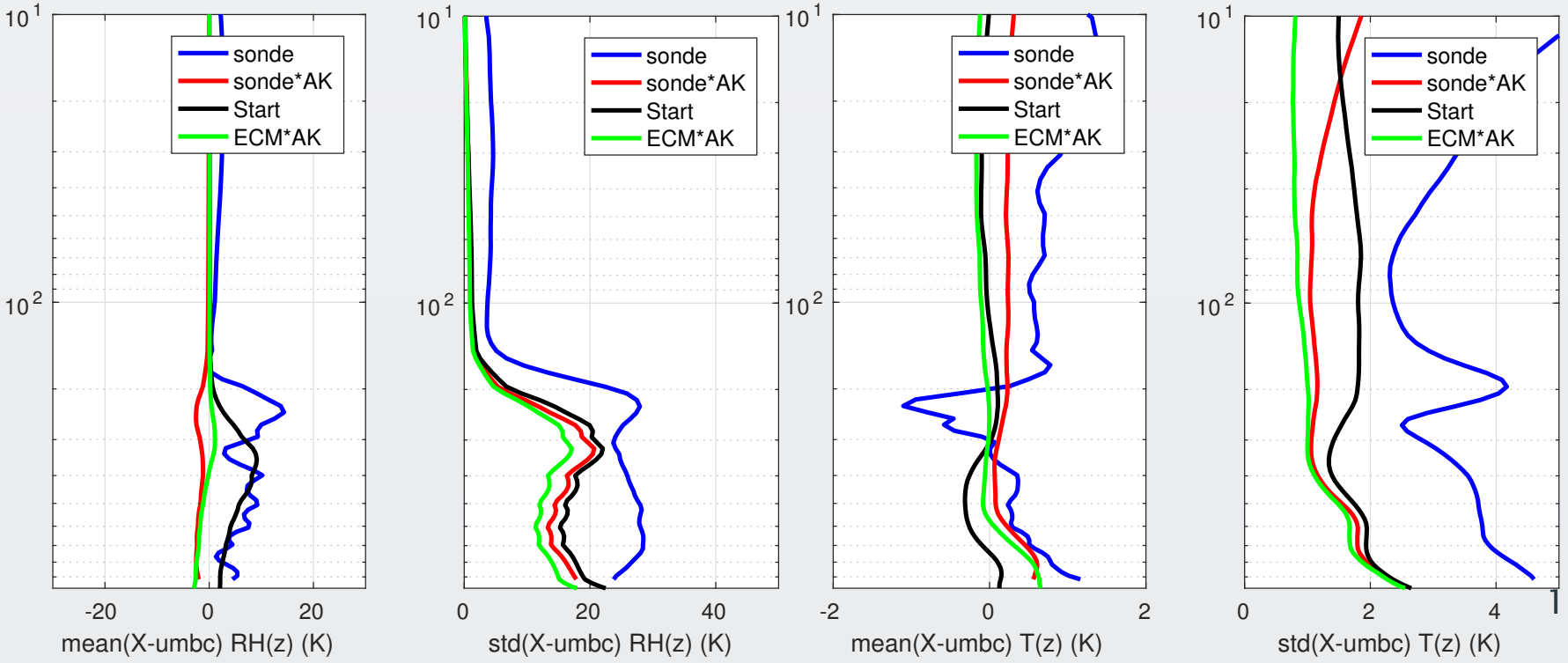
Retrieved ice ODs versus those in AIRS L2 cloud product.
Colorbar is $log_{10}(count)$ of the 2d histogram.
CLOUDS ALSO LOOK GOOD!!!

bias(ν),std(ν) = < obs(ν) - cal(ν) $>_{36000 profs}$ $\sim$ AIRS noise(ν)

GRUAN : Lindenberg, Germany (52N,14E) : X-UMBC

- 1140 sondes (about 100/month), 101521 AIRS FOVS match ups
- mean ice/water OD = 0.92,10.1; mean surf temp = 283 K, mean cldeffect = 8.1 K, mean colW = 15.5 mmH2O, 83% success

Left : δ RH(z) Right : δ T(z)



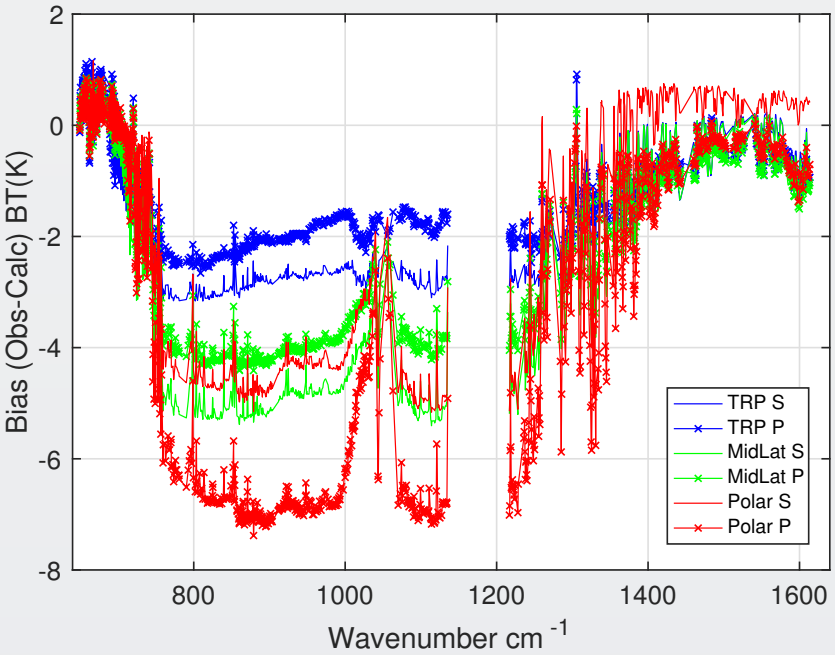
Conclusions

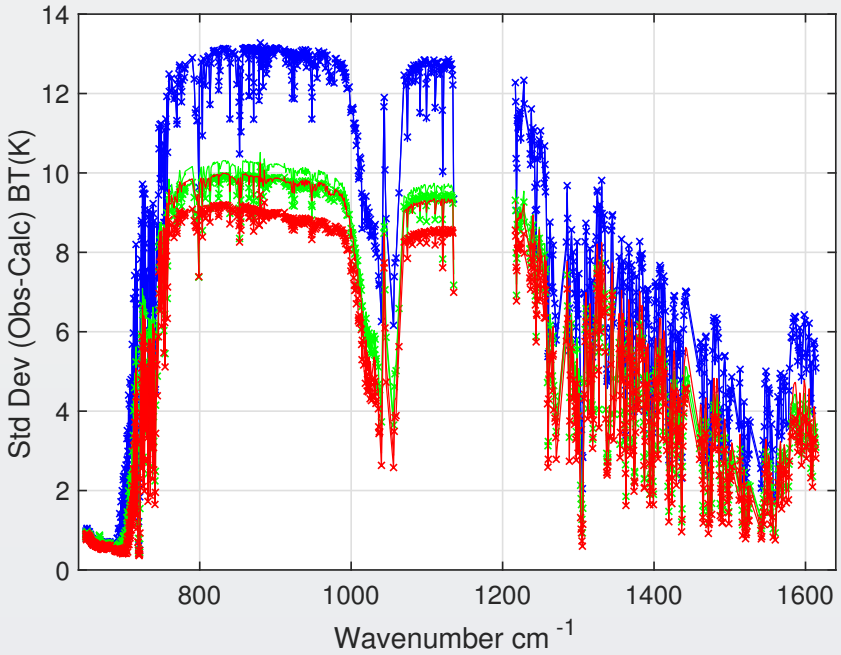
- TwoSlab is very fast, accurate method
- Retrieval uses NWP thermodynamic and *reasonably accurate cloud fields*
- Retrieve thermodynamic profiles, surf temp, col trace gases (CO2, CH4, O3), ice and water cloud parameters
- typically have about 90% yield ECM and 80% yield CLIM (problems usually for very thick clouds)
- Larrabee Strow has the AIRS to CrIS conversion in great shape, so will use same algorithm for AIRS (09/2002 →) and CrIS (02/2012 →)
- Paper accepted for publication in AMT early this week, waiting for file upload (AMT(D) paper amt-2017-261)

EXTRA

Spectral comparions : Obs vs 2S vs MRO (Ocean/night 2011/03/11)

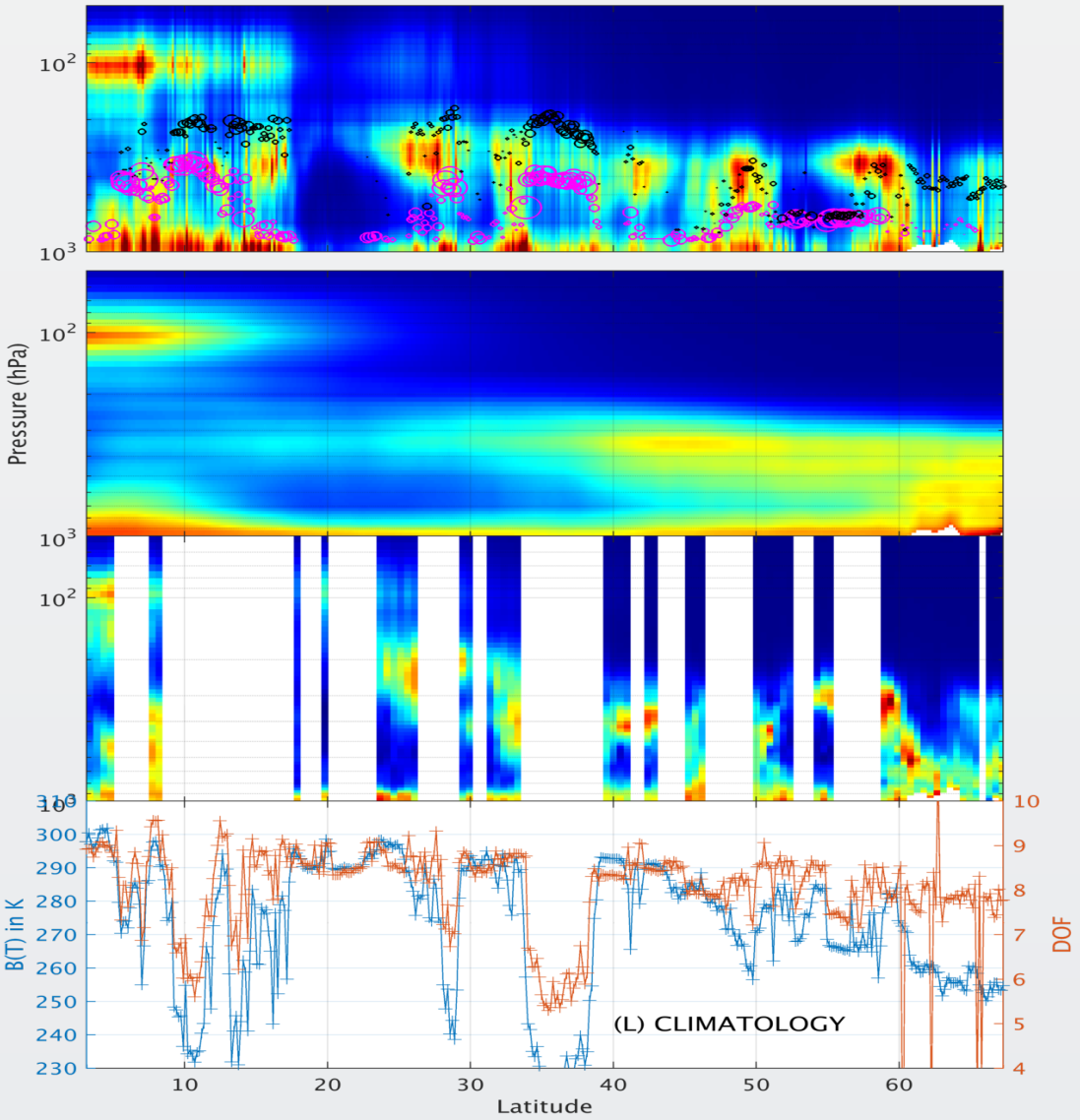
Comparing PCRTM/MRO and SARTA/2S against AIRS scenes
Globe divided into (B) Tropics, (G) MidLats, (R) Polar
Thick lines are SARTA/2S while thin lines are PCRTM/MRO
(L) Mean(obs-cal) (R) std(obs-cal)





Thanks to Xianglei Huang, Xiuhong Chen, Xu Liu for PCRTM/MRO comparisons

2014/02/08 : Curtain plots, start with monthly clim



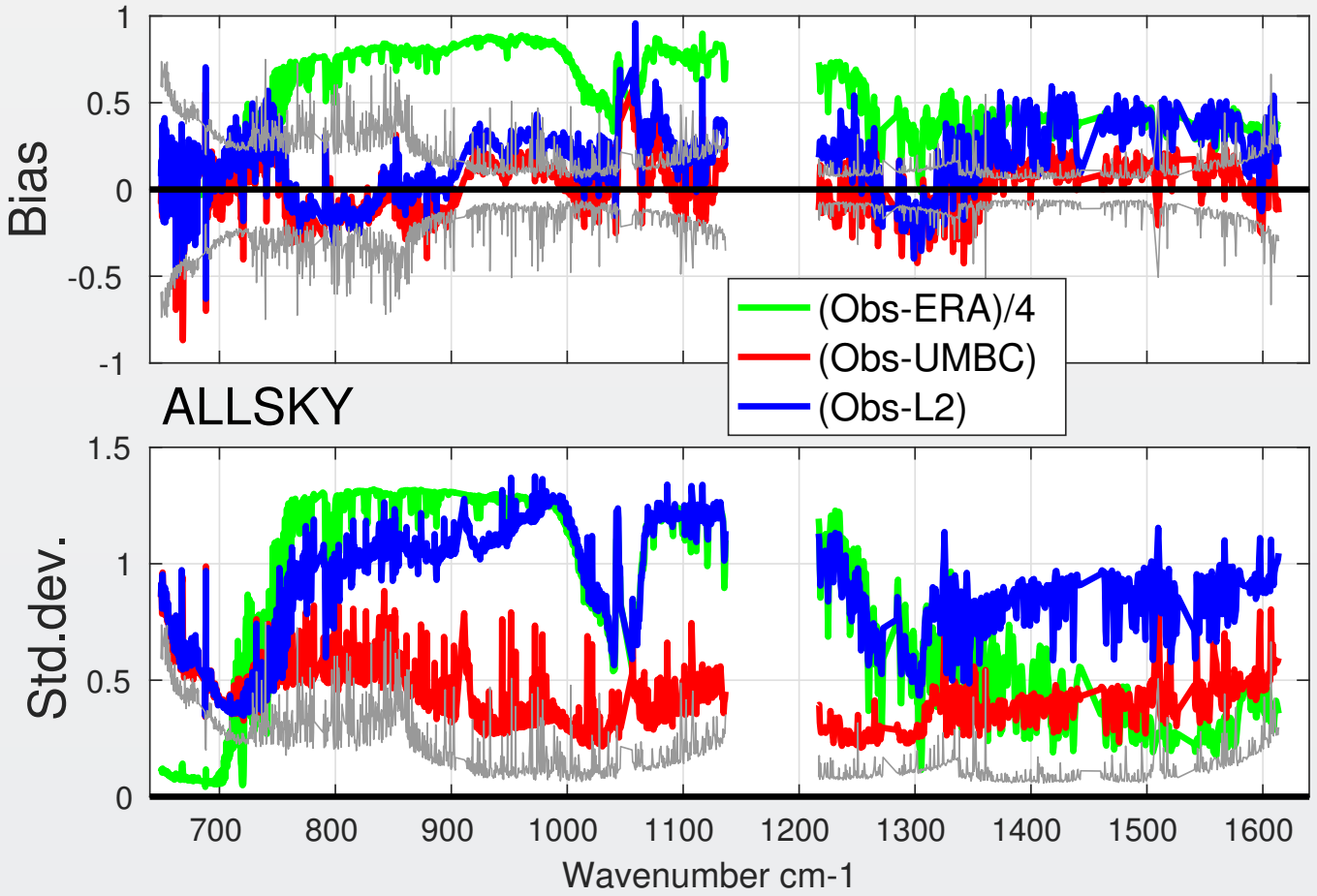
UMBC RH

CLIM RH

AIRS L2 RH (QA)

Obs BT1231/DoF

2014/02/08 : Spectral Difference



AIRS noise levels shown in light gray

Use surface AIRS QA=0,1 to filter. Top : biases. Bottom : std.dev.

Note scale factor for green