Single Footprint Retrievals with SARTA-Cloudy

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Motivation

- Most of AIRS data contains cloud and/or aerosol effects
- Current AIRS L2 retrieval uses black clouds to account for cloud effects
- Cloud retrievals can be complicated (need to initialize cloud top, amount, particle size, fraction, phase) for $N \leq 3$ cloud decks
- Scattering algorithms and cloud representation are additional complexity
- Here we use SARTA TwoSlab, with first guess from ECMWF in an Optimal Estimation Retrieval to improve retrieval yield on single footprints, with error diagnostics as part of output

SARTA and PCRTM

- SARTA and PCRTM are fast RTAs (∼ same speed)
- Molecular Gas Optical Depths for SARTA come from kCARTA, PCRTM developed from LBLRTM
- SARTA has tuning, NLTE (neither in PCRTM version that I have)
- SARTA uses PCLSAM, PCRTM uses Re/Tr using DISORT

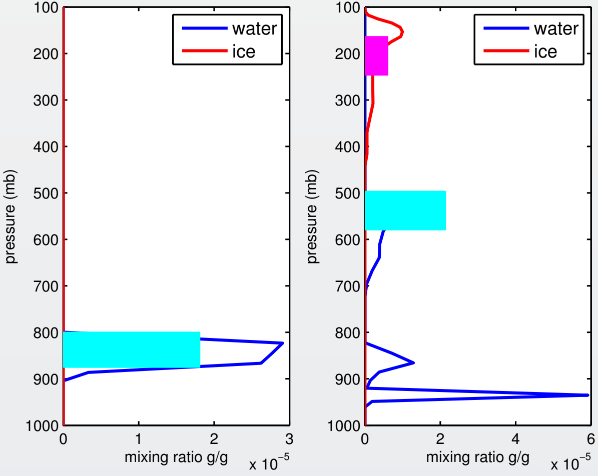
SARTA and PCRTM : TwoSlab vs Max Random Overlap

- SARTA and PCRTM can both be run in clear sky mode, 2 slab mode, 100 layer MRO
- 2 slab mode (UMBC) : 4 streams/subpixels needed (cloud1,cloud2,cloud12,clear)

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

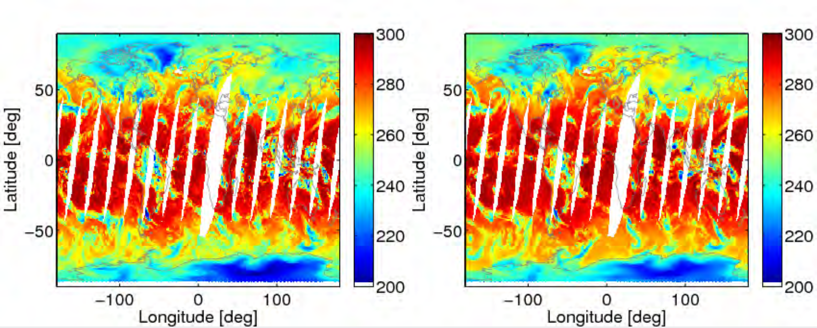
- MRO mode : multiple ($\sim$ 20-50) subpixels needed (wrapper from Xianglei Huang and Xiuhong Chen)
- So TwoSlab is about 10 or more times faster than MRO, and jacobians are straightforward
- VERY EASY to move slab clouds up/down eg put them at mean of cloud profile? or at peak of "cloud weighting function"? etc
- D of F calculations show about 2-5 pieces of information per cloud (eg amount, top/bottom, some profile info)

Example Slab Conversions



Global night-time obs/calcs 2011/03/11

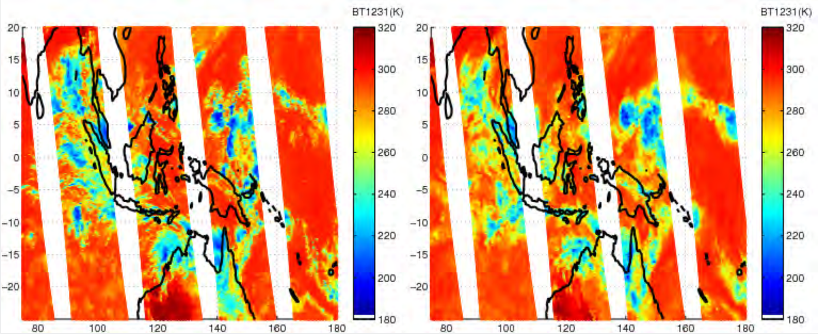
Left panel : AIRS observations. Right panel : SARTA 2S
Example : March 11, 2011 (2.9 million observations)



1 deg grid. Note the DCC in the TWP and Amazon, not well captured by ECMWF.

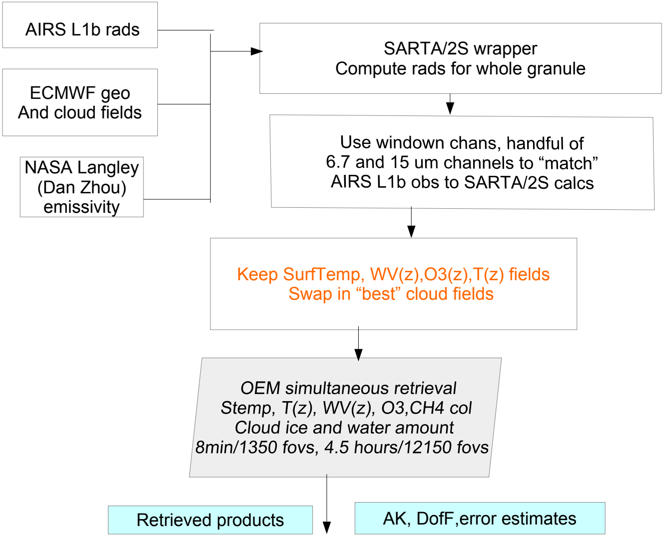
TWP G039 obs/calcs 2011/03/11

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



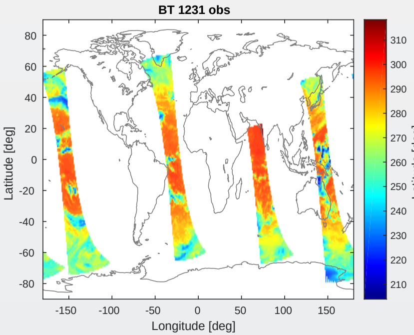
General locations of the deep convection regions are correct, though there are substantially fewer DCC (cloud tops below 210 K) in the simulations.

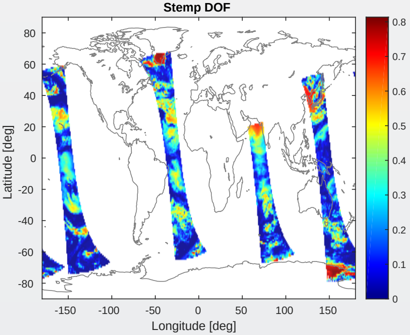
Retrieval idea



BT1231 Obs and D of F (Stemp)

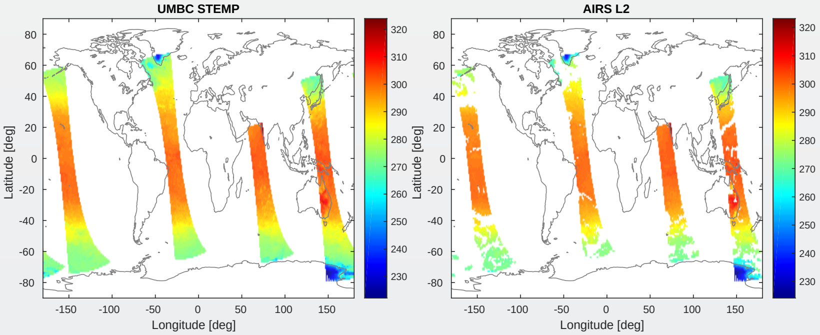
2011/03/11 : use 22 Over Ocean Daytime granules spanning variety of climate zones





(L) BT1231 Obs (R) SurfTemp DOF

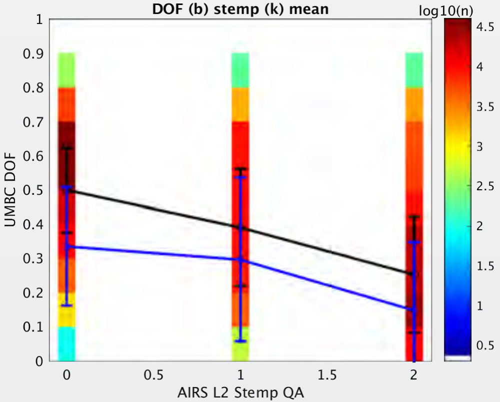
Comparing UMBC vs AIRS L2 Stemp



(L) UMBC Stemp

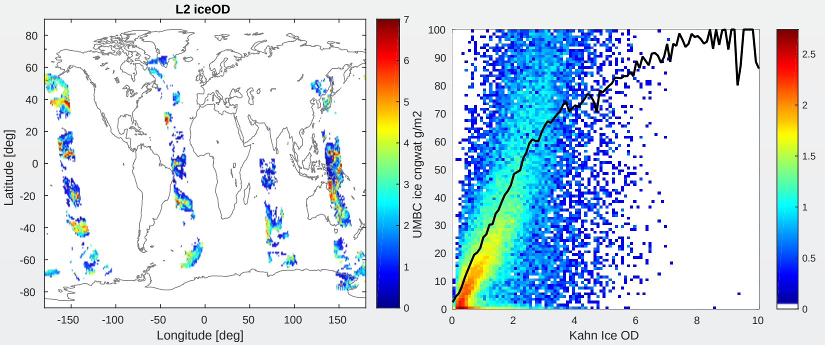
(R) AIRS L2 Stemp

Comparing UMBC DofF vs AIRS QA



more tuning of damping to get away from ECM and increase DOF

Ice OD(AIRS L2) vs UMBC ice amount

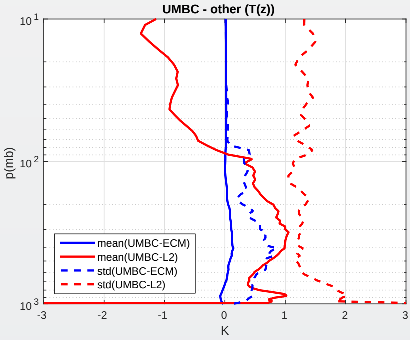


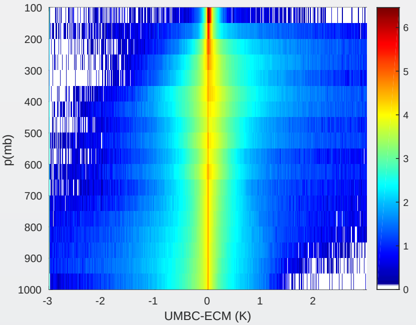
(L) AIRS L2 iceOD (R) UMBC cngwat VS iceOD

Ice Cloud/Water Cloud amounts come along with the retrieval

T(z) (UMBC - Other)

Limit to over oceans; QA <= 1





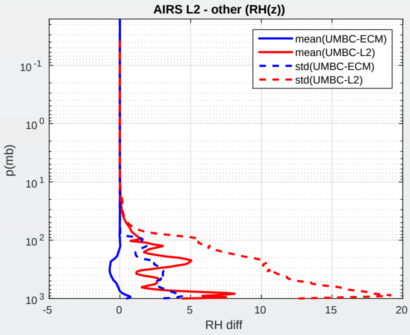
(L) T(z)
UMBC - ECM (blue)
UMBC - L2 (red)

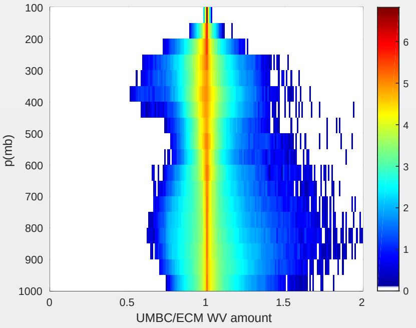
(R) T(z) histogram
colorbar = log10(n)

Can tune damping/covs to move from ECM and increase DOF

WV(z) (UMBC vs other

Limit to over oceans; QA <= 1



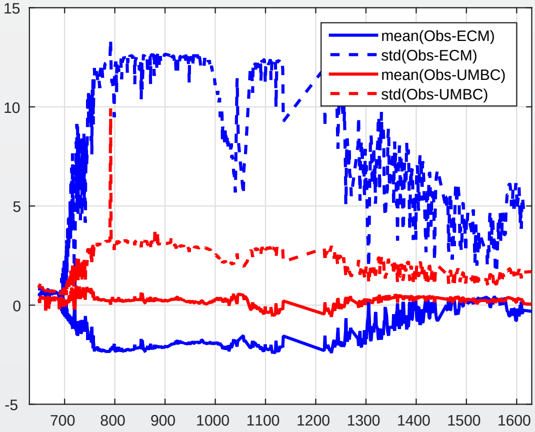


(L) RH(z)
UMBC - ECM (blue)
UMBC - L2 (red)

(R) WV(z) histogram
colorbar = log10(n)

Can tune damping/covs to move from ECM and increase DOF

Biases

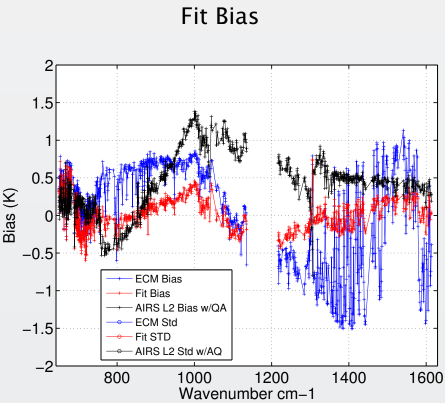


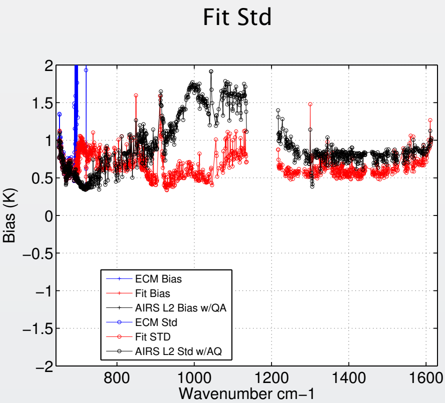
100 layer jacobian results in 4 1/2 hours per granule

"20 Trapezoids" yields comparable results (90 mins per granule)

G039 Stats: Closure

L2 is 60% Sampling, UMBC Fit is ~100% !!





Conclusions

- TwoSlab is very fast method, can be tweaked to statistically mimic MRO, or to improve bias comparisons with obs
- Can easily be used to compute jacobians
- Start with ECMWF geophysical fields, move cloud fields around according to comparisons between obs/cal
- Choose handful of channels, do 100 layer jacobians
- No optimixations of code done here!
- Need to further tune eg cov matrices, damping to get away from ECM and increase DOF, do trapezoids etc
- Output diagnostics include DOFs etc

SARTA TwoSlab

Use SARTA-clear ODs and include PCLSAM (Parametrization for Cloud Long-wave Scattering for use in Atmospheric Models, Chou et. al, J. Climate v12 pg 159-169 (1999))

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

Cirrus : General Habit Model (GHM) from Ping Yang/ Bryan Baum

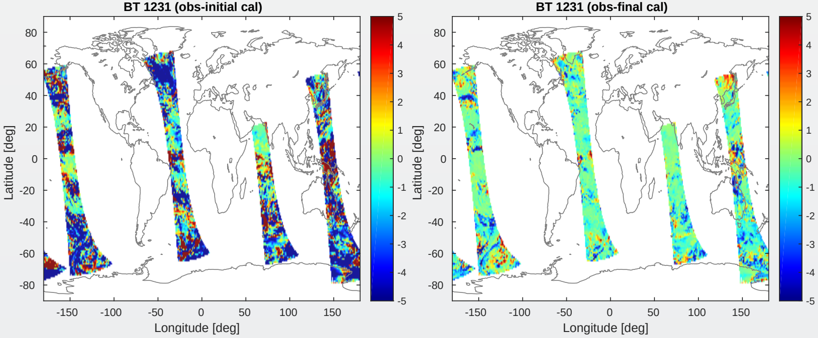
Water : Mie scattering (Particle Size Dist from MODIS L2 model)

TwoSlab NOT limited to PCLSAM .. can easily use eg DISORT

ECMWF profile → TwoSlab conversion

- Start with CIWC(z),CLWC(z)(g/g) CC(z) and TCC from ECMWF
- separately reduce each ice and water profile to slab clouds
- Cloud amount (g/m2)
  - Reduce cloud profiles to slabs either at peak or weighted toward TOA (this is "tuning")
  - integrate profile to go from g/g to cloud slab amount in g/m2
- Cloud effective size (g/m2)
  - Water : use 20 μm eff diam $\pm$ small random number
  - Ice : use effective particle size as function of cloud temperature (see eg Ou and Liou, Ice micro-physics and temperature feedback, Atm Res v35 p 127 (1995))
- Total Cloud Cover (no dimension) TCC = C1 + C2 - C12
  - If one cloud, use TCC
  - If two separate phase clouds C12 = C1 + C2 - TCC from
    C1 = $\sum CIWC(z) CC(z) / \sum CIWC(z)$
    C2 = $\sum CLWC(z) CC(z) / \sum CLWC(z)$
  - if two same phase clouds, let C1 = R * TCC, randomly select some of these, set C12 = R' * C1, for rest have C12 = 0; then find C2 = TCC - C1 + C12

Orig VS Final Cld Cals



(L) BT1231 OrigCalc

(R) BT1231 FinalCalc

Retrieval Idea

- Compute radiances using co-located ECMWF geo/cloud fields
- For each pixel, initial guess is as follows
  - Match "closest BT simulation" to AIRS observation, using some window, 15 μm, 6.7 μm channels
  - Keep geo-fields the same, swap in cloud fields from this "closest match"
  - cloud fraction, particle sizes, cloud top fixed during retrieval
- OEM retrieval : simultaneously solve for ice/water cloud amounts, and T(z), WV(z), stemp(z), col O3, col CH4
- output diagnostics include AK, D of F
- roughly 8 mins to do 1350 FOVS on one processor (0.4-0.5 sec per FOV), scales up to about 4-5 hours for 12150 FOVS
- further optimization possible (trapezoids, damping, cov matrices ...)

SARTA/2S vs PCRTM/MRO

Xianglei Huang, Xiuhong Chen (UMich) and Xu Liu (NASA Langley) have given UMBC their PCRTM/MRO wrapper

- MRO takes CIWC,CLWC and then for each FOV creates $N = 50$ subpixels with cloud fractions randomized according to information in CC
- N (50) can be varied according to cloud formation
- TOA radiance is mean radiance from these N streams

George Aumann talked about detailed comparisons I have given him (2S vs MRO vs black cloud)

Larrabee Strow presented status of Clear Sky AIRS RTA