An Accurate TwoSlab Cloud-Representation Model for Hyperspectral Infrared Radiative Transfer Codes

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Companion Talk : A11P-01 (Monday AM Moscone West Rm 3001) : An Accurate TwoSlab Cloud-Representation Model for Hyperspectral Infrared Radiative Transfer Codes, S. Machado and L. L .Strow

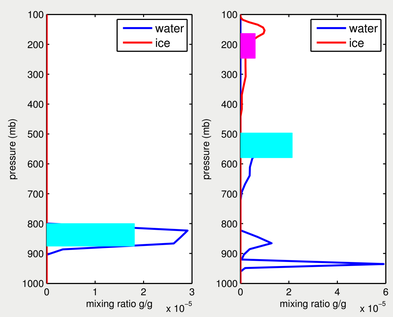
Thanks to Xu Liu (NASA/Langley) and Xianglei Huang/Xiuhong Chen (U. of Michigan) for the PCRTM/MRO cloud simulator

1 Reasons for model

- Numerical Weather Prediction (NWP) models ingest millions of hyperspectral observations, but cannot assimilate much of this because of clouds
- Models maybe "climate quality" now, but since physics is constantly evolving, need to constantly evaluate the NWP fields against observations
- One way to evaluate NWP fields is to import them into scattering Radiative Transfer Algorithms (RTAs) and do the forward calculation
- Cloud representation models such as Maximum Random Overlap are considered state of the art
  - Speed : Calc averaged over 20-50 subpixels
  - Jacobians : hard to do a 100 layer cloud jacobian!

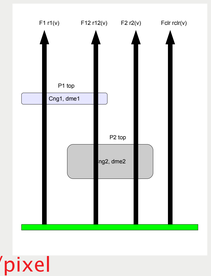
2 Approach

- We want a cloud representation model that can be generated from any NWP : requires TCC (total cloud cover $0 \le TCC \le 1$), CC(z) (cloud cover profile), CIWC(z) and CLWC(z) (cloud ice/liquid water content profile)
- model should be able to reproduce eg MRO statistically
- model must be fast
- can compute finite difference jacobians in model, for use in physical retrieval



3. The TwoSlab Model

Take the NWP cloud info (CIWC, CLWC, CC, TCC) and come up with two randomly overlapping slabs (typically one is ice, other is water, though both could be same phase)
Or of course, one or both layers could be aerosols (dust/volcanic ash)



RT weighted over ≤ 4 sub-pixels → ≤ 4 radiance calcs/pixel

$$r_i(\nu) = f_{clr} r_i^{clr}(\nu) + c_{overlap} r_i^{(12)}(\nu) + cx_1 r_i^{(1)}(\nu) + cx_2 r_i^{(2)}(\nu) \quad (1)$$

where f_{clr} is clear fraction, $cx_i, i = 1, 2$ is the exclusive cloud type i fraction and $c_{overlap}$ is the cloud overlap between the two cloud types; the exclusive cloud fraction being related to the cloud fraction via the relationship $cx_i = c_i - c_{overlap}$.

4. Implementation details

Amount/Particle Size

- cloud amount : integrate CIWC(z), CLWC(z) to get cloud loading in g/m2
- eff diam : 20 um diam (water); ice uses Ou/Liou param as fcn of T(slab)
- General Ice Habit scattering parameters from Ping Yang/ Bryan Baum
- Can put in aerosols (dust/ash) as one of the two slabs

Slab Placement

- IR sensors mostly sensitive to upper cloud levels
- Quite flexible : after smoothing CIWC(z) and CLWC(z), user can place slabs around the most prominent cloud profile peak, straddling the mean of the cloud profile or at the peak of an effective weighting function due to the cloud profile
- Slab placements affect computed radiances biases/std dev ...

Cloud Fractions

$$TCC = c_{water} + c_{ice} - c_{overlap} \quad (2)$$

- only one cloud present → $c_1 = TCC$,
- if there is one ice and one water cloud, the cloud fractions are set according to
  - $c_{water} = \sum CLWC(z) CC(z) / \sum CLWC(z)$
  - $c_{ice} = \sum CIWC(z) CC(z) / \sum CIWC(z)$
  - $c_{overlap}$ is set using Eq. 2.
- if two ice or two water clouds, $c_1 \rightarrow TCC \times f(R)$ where $0 < R < 1$ (random). Now randomly set $c_{overlap}$, then c_2 follows from Eq. 2

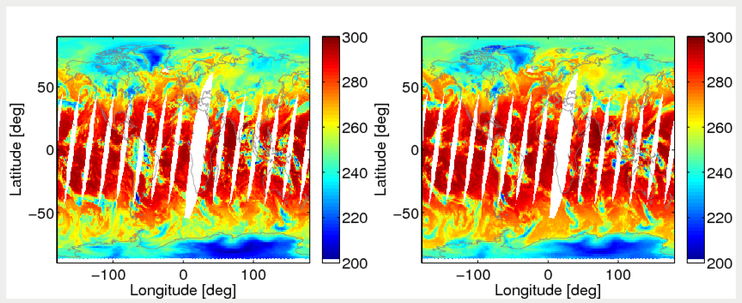
20000 ERA 60 level NWP cloud profiles → 2 slab clouds in 1.5 minutes

5. NWP model and radiance data sets

Hyper-spectral infrared data from NASA's Atmospheric Infrared Sounder (AIRS)
Numerical Weather Prediction model fields from European Center for Medium Range Weather Forecasts (ECMWF)
Maximum Random Overlap model with PCRTM (Xu Liu (NASA Langley) and Xianglei Huang/Xiuhong Chen (U. of Michigan)
TwoSLab model with SARTA (S. Machado/L. L. Strow)
Variety : have used TwoSlab with SARTA IASI and Cris, and with ECMWF forecast and re-analysis, and with MERRA, and also with LBL kCARTA
Timings : Clear sky SARTA/PCRTM : about 0.03 seconds/2378 channel spectrum
Timings : SARTA TwoSlab : about 0.04 sec/spectrum; PCRTM MRO : about 4 sec/spectrum (50 sub pixels)

6. Night-time 2011/03/11

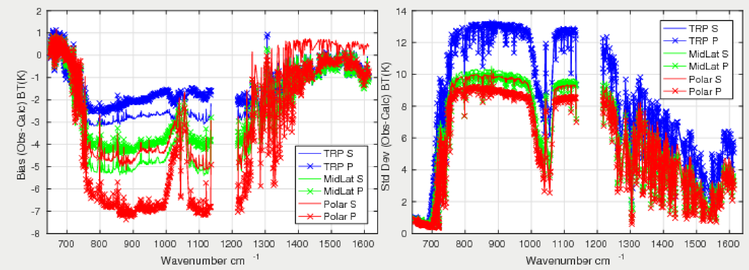
(L) AIRS OBSERVATIONS (R) Sarta 2S using ECMWF



Very good agreement, though closer inspection shows eg fewer DCC in calcs, and cloud tops are shifted

7. Global Comparison SARTA/TwoSlab and PCRTM/MRO

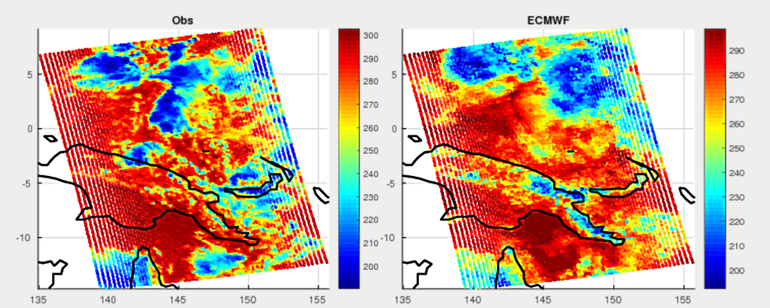
(L) Bias (R) Std Dev



GLOBAL MEANS (over 2000000 per region)

Region	Cld Forcing (K)	Bias (K)	StdDev (K)	MRO-2Slab (K)
Tropics	7.4	-2.5	13.0	-0.78
MidLats	10.2	-4.9	10.5	-0.78
Polar	12.6	-4.5	9.0	1.89

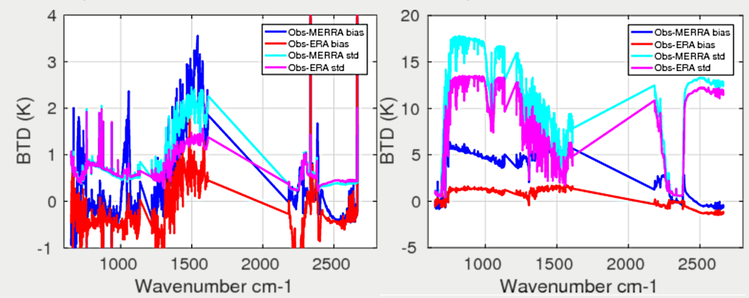
8. Zoom into daytime TWP region



Effects of cloud mis-matches between AIRS observations (1.30 pm local) and ECMWF model fields
Far fewer cold DCC in calculations than in AIRS observations

9. Tropical Night Ocean January 18, 2016 using Re-Analysis

(L) Clear Sky (R) All Sky



Successfully used TwoSlab with ECMWF forecasts, ERA Re-Analysis and MERRA re-analysis