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A11P/A21A: Advances in Remote Sensing of Clouds and Precipitation

The largest uncertainty in predicting future climate is related to clouds.

Understanding atmospheric and surface processes, including clouds and precipitation are key to advancing weather forecasting and climate models.

For this we can use infrared, microwave or radar remote sensing.

The first three talks and 8 posters discuss how this is done and results using hyper-spectral infrared sounders (AIRS/IASI/CrIS).

The following four talks and 10 posters present what can be done using passive microwave and radar (CloudSat, GPM and ground-based).

Please visit our poster session on Tuesday morning starting at 8AM in Moscone South

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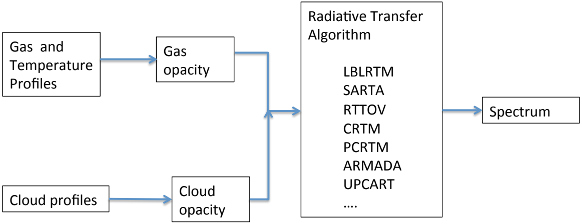
Flowchart

7377 atmospheric states for the Cloudy RTA comparison



Surface temperature from ECMWF
Surface emissivity and reflectance from climatology (lat/lon dependance)
ECMWF temperature and water profiles are specified at N=91 levels
Other gases are specified at the same N levels using climatology
Cloud liquid water and ice content profiles at N levels from ECMWF

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A11P-01 : An Accurate TwoSlab Cloud-Representation Model for Hyperspectral Infrared Radiative Transfer Codes

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December 12, 2016

Overview

7377 Profile Set : Status

- Status of all-sky radiance simulations for observation set from JPL/UMBC, using 7377 AIRS observations on 2009/03/01

TwoSlab model

- Cloud placement
- Comparisons against PCRTM MRO simulations and AIRS observations
- Very easy to compute finite difference thermodynamic/cloud jacobians
  - eg use for single footprint allsky physical retrievals

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Status of 7377 FOV dataset

Clear sky RTAs very similar (Saunders 2007, JGR v112)

- Line-by-line (eg LBLRTM, kCARTA) and Fast Model (SARTA, PCRTM, RTTOVS, σ-IASI) etc use essentially the same spectroscopy, with differences including line mixing (CO2, CH4) and water vapor (lines and continuum)
- fast models $\ll$ 1 sec/radiance spectrum (2000+ channels))

Scattering algorithms differ!

- scattering models : DISORT, PCLSAM, TwoStream, 4Stream
- scattering parameters (E,ω,g) : ice habit, water size dist
- Cloud representation : MRO, $1 < N < 100$ layer clouds
- $\rightarrow$ speed differences and how to define the jacobian? (2-4 deg. of freedom)
- can be used to compute fluxes?
- SW solar scattering

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Some metrics we could use

Channels used

- No need to look at all channels (at UMBC we look at about 6-41 channels spanning AIRS spectrum)
- Can directly compare against observations, channel against channel OR
- look at modeled vs observed inter-channel BTDs eg BT1231-BT2616 OR
- look at surface temp vs observed/modeled BTDs eg stemp-BT1231, stemp-BT2616 OR ....?

Other criteria

- Speed of the RTA (cf clear sky RTAs used in current Cloud Cleared Radiance retrievals)
- Ease : Can RTA handle *N* NWP levels directly (eg LBLRTM, RTTOV), or need to go through an interface? (eg kCARTA/SARTA)

Results in so far

TALKS (Monday AM)

- Sergio Machado, Larrabee Strow (UMBC) : SARTA TwoSlab
- Vijay Natraj (JPL) : UPCART
- Stephan Havemann (UKMO) : RTTOV + new method

POSTERS (Tuesday AM)

- Jerome Vidot et. al. (Meteo France, ECMWF) : RTTOVS
- Tianhao Le, Yuk Yung (Caltech) : ARMADA
- Q. Yang, X. Liu (NASA Langley) : PCRTM with accurate SW solar scattering
- Guido Masiello, Giuliano Liuzzi (U. di Basilicata) : σ-IASI
- Evan Fishbein (JPL) : SARTA with 4stream scattering
- George Aumann, B. Irion, C. Wilson (JPL) : Intercomparing results
- S. Machado, L. Strow, X. Liu, X. Huang (UMBC/NASA Langley/U of Michigan) : SARTA 2S/PCRTM MRO

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Cloud Overlap Models

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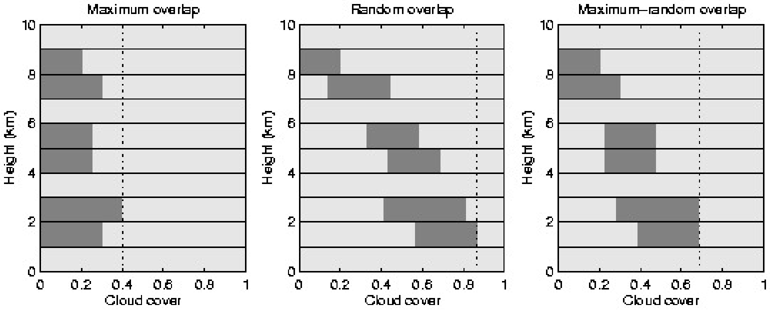
http://www.met.reading.ac.uk/research/radar/research/cloudoverlap/index.htm (Robin Hogan)

Most models now use the maximum-random overlap assumption, where clouds in adjacent model levels are deemed to be maximally overlapped, while clouds separated by an entirely cloud-free model level are deemed to be randomly overlapped.



RT averaged over S sub-pixels $\rightarrow$ 20-50 radiance calcs/pixel

Two Slab Model

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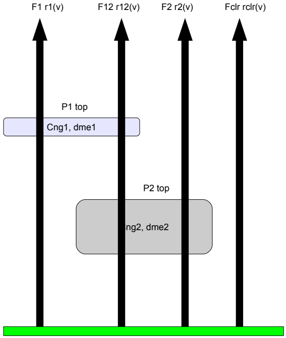
For each obs. pixel take nearest NWP cloud info (CIWC(z), CLWC(z), CC(z), TCC) to produce two randomly overlapping slabs (typically ice/water, though both could be same phase)



RT weighted over $\leq$ 4 sub-pixels $\rightarrow$ $\leq$ 4 radiance calcs/pixel

Implementation A : Amount, Particle Size

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- cloud amount : integrate CIWC(z), CLWC(z) to get cloud loading in g/m2
- effective particle size : currently 20 um diam for water, ice uses Ou/Liou parametrization as function 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

Implementation B : Slab placement

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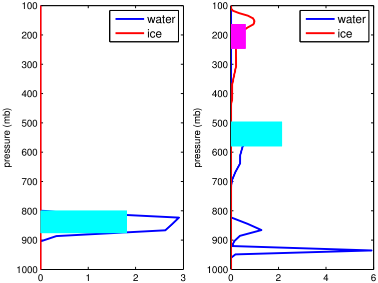
- Infrared sensors mostly sensitive to the emission from the upper cloud levels
- Quite flexible : after smoothing CIWC(z) and CLWC(z), user can place slabs around the most prominent cloud profile peak, straddling the mean of the cloud profile or at the peak of an effective weighting function due to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



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Implementation C : Cloud fractions

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Using the NWP total cloud cover (TCC), we compute two individual clouds fractions and their overlap using the following breakdown :

$$TCC = c_{water} + c_{ice} - c_{overlap} \tag{1}$$

- only one cloud present $\rightarrow$ cloud fraction $c_1 = TCC$,
- 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. 1.
- if two ice or two water clouds, $c_1 \rightarrow TCC \times f(R)$ where R is a random number between 0 and 1. Then randomly set $c_{overlap}$, after which c_2 follows from from Eq. 1

20000 ERA 60 level NWP cloud profiles $\rightarrow$ 2 slab clouds in 1.5 minutes

Nighttime AIRS 2011/03/11

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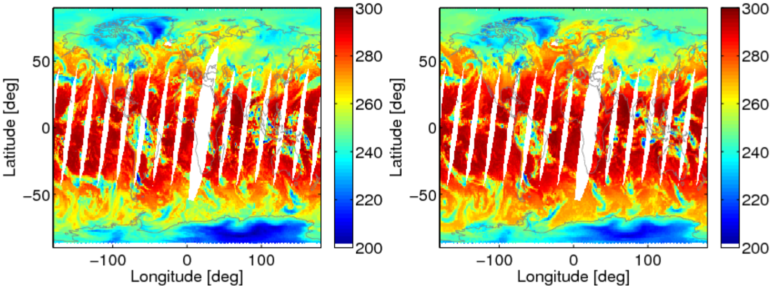
(L) AIRS OBSERVATIONS(R) Sarta 2S using ECMWF



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

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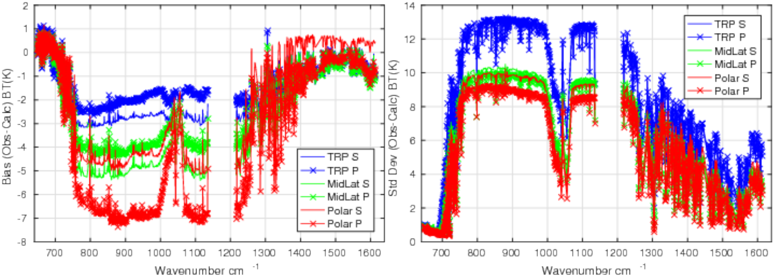
Compare PCRTM/MRO vs SARTA/2S for 2011/03/11

(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

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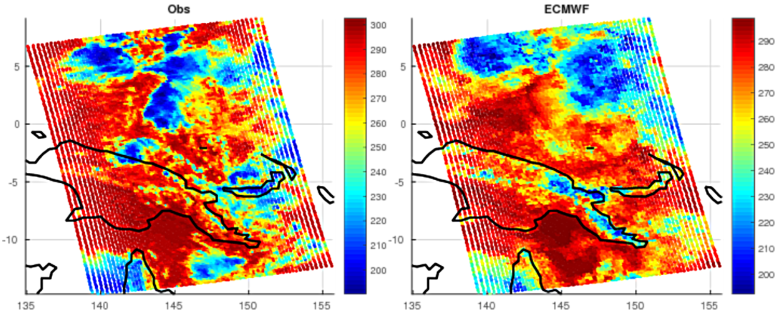
Zoom into daytime TWP region, 2011/03/11 G039

(L) OBS (R) CALCS



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

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Conclusions

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7377 profile data set

- have 5 data sets already, please advertise to other interested colleagues
- detailed inter-comparisons will be starting soon

TwoSlab model

- fast ($\leq$ 4 streams), easy to implement
- statistically compares well to PCRTM/MRO
- can produce finite difference jacobians for physical retrieval
- comparisons against NWP model fields show effects of spatial mismatches
- article being readied for submission to journal