AIRS fast forward model for version6

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2) Introduction

- AIRS v6 fast model completed May 2008
- Lastest code delivered to Eric Maddy in late May 2009
- Basic "clear sky" code very similar to v5 code
- Two new features/capabilities for v6:
- 1) variable channel frequencies
- 2) cloudy-sky radiance using black and/or transmissive clouds
- Implementation issues and options

3) Overview of basic v6 AIRS fast model

The basic v6 AIRS fast model differs from v5 as follows

- Used HITRAN 2004 database (with updates thru 2007) to update water, ozone, and nitric acid transmittances. Other gases unchanged.
- Two separate fast models for pre-Nov.2003 and post-Nov.2003 with different SRF fringes (aka channeling spectra).
- Pre-Nov.2003: -13.0, -14.0 um y-offset, and 370 ppm CO2
- Post-Nov.2003: -13.0, -14.0, -15.0 um y-offset, and 385 ppm CO2
- Only minor algorithm changes compared to v5: add new 5th CO2 and new 7th non-LTE coefficient/predictor.
- Revised optical depth tuning; very similar to v5 except for 2200 cm^{-1} region N2O and 1300 cm^{-1} region CH4.

4) Variable channel frequencies

The grating model y-offset of the AIRS channels drift back and forth roughly 0.4 um per orbit, and 0.3 um per seasonal cycle. There is also a slowly decaying monotonic drift of 0.2 (2002) to 0.05 (2008) um per year. A 1 um shift corresponds to a frequency change of 8.3 parts per million frequency, so we are dealing with relatively small changes. What to do about the drift is a topic for another day. Here we only discuss how the fast model channel frequencies can be adjusted.

- Fast model databases have been generated for multiple y-offsets
- Linear interpolation in y-offset is possible between databases. That is, the databases themselves may be interpolated via a simple weighted sum average.
- With databases D1 and D2 at y-offsets Y1 and Y2, we calculate a new temporary database D for arbitrary y-offset Y as

$$D = D1 * (Y - Y2)/(Y1 - Y2) + D2 * (Y - Y1)/(Y2 - Y1)$$

- This equation works even if Y varies by channel

5) Cloudy-sky fast model variant

A cloudy-sky variant of the fast model has been developed to allow fast computions of radiances for fields of view containing up to two black and/or transmissive/scattering clouds.

- A "black" cloud is a surface specified by cloud top: a) pressure, b) temperature, c) emissivity, d) reflectivity.
- A "transmissive/scattering" cloud is a vertical slab specified by: a) cloud top pressure, b) cloud bottom pressure, c) particle type, d) particle size, e) total cross sectional mass.
- In addition to the above, for all clouds we need to specify a cloud fraction. In the case of two clouds, we also need to specify a third cloud fraction for the overlap of the two clouds.
- The total radiance is computed as a cloud fraction weighted sum of four radiances contributions: clear, cloud1-only, cloud2-only, and both-clouds.
- With a code written to maximize efficiency, a typical cloudy-sky computation is only a few tens of percent slower than clear-sky.

6) Implementation issues: frequency shift

- Applying frequency shift adjustments to AIRS radiance calculations is simple.
- If we limit ourselves to one frequency adjustment per AIRS granule, then the database interpolation is probably best done outside the RTA code as a pre-processing step.
- If we want to allow frequency adjustment on a per FOV basis, then the database interpolation should be done inside the RTA code. A variant of the clear-sky SARTA code demonstrates how to do this. Code-wise it is relatively easy to implement, but it increases memory usage and increases runtime each time y-offset changes.
- Current we do not have a frequency-shifting cloudy SARTA (because need for it is dubious), but it is feasible.

7) Implementation issues: cloudy RTA

- The cloudy-sky code is as designed for simplicity and speed of calculations rather than accuracy. However, the need to efficiently compute up to four separate radiance contributions results in a code significantly more complex than for clear-sky.
- Getting the cloudy-sky RTA into the existing L2 code is a major job. Chris Barnet et al was tasked with this for v6, but there have been funding delays, and success is uncertain.
- The cloudy-sky code currently exists as a variant of our SARTA package. We do not understand the PGE well enough to say whether or not it might be feasible to use SARTA more-or-less as is as a callable stand-alone program somewhere within the PGE.
- The long term goal of having the cloudy-sky code in the PGE is to help improve the quality and yield of standard products under dusty and thin cirrus conditions.
- Presently unsure how to do this in the PGE's cloud-clearing based retrieval algorithm. Sergio discuss two possibilities in the following slides.

8)

- Had meeting in Sept 2008 with Joel, Chris and John
- Talked about implementing the SARTA-scattering RTA
- Also talked about how this would benefit AIRS products

9) Within L2 retrieval : More ambitious, but with more benefits

- include dust effects in the middle of the retrieval algorithm
- use GOCART height database to guess dust layer height
- use 2 um effective particle size
- (*or* retrieve dust layer height as well?)
- Improve AIRS retrieval $stemp, T(z), RH(z)$ products by including dust as a retrieved variable on FOVS where dust flag triggers
  - easiest done on cloud cleared radiances? (AIRS STM May 09)
  - start with "known" surface emissivity
  - BUT nonuniform dust will be removed from the radiances, so this could lead to physically inaccurate dust optical depths
- This would improve OLR dust forcing estimates for climate
- And can do similar retrievals for eg thin cirrus clouds (ie move away from "black cloud" assumption towards more realistic models).

10) Post processing product : Easier, but limited benefit

Do the L2 retrieval as is, but for FOVs that are dust contaminated (from dust flag), tack on an additional retrieval at the end. This means

- the dust retrieval will have the L2 retrieved profile to start with
- over ocean, default to sea emissivity (over land use eg U. Wisc or Joel's land emissivity database)
- use GOCART height database to guess dust layer height
- use 2 um effective particle size
- go ahead and do a retrieval using the OBSERVED radiances
- this would only provide a Dust Optical Depth product (for comparisons against eg MODIS)

11) Appendix: RTA accuracy/errors

- Reduced angle dependence of CO2 errors in shortwave channels; otherwise errors are similar to v5.
- Added CO2 dependence of non-LTE for v6; very minor effect.
- Frequency shift modelling errors are negligible compare to the accuracy of our estimate of the true frequencies.
- Transmissive/scattering clouds emit radiance at the layer mean temperature of each layer containing the cloud. This means a very opaque cloud will appear to emit at the temperature of the top layer containing the cloud, rather than at an interpolated temperature corresponding to the exact cloud top pressure.
- Transmissive/scattering clouds use a very crude scattering model. This is especially true in the shortwave, and even more so with regard to daytime solar scattering.