Handling Clouds for Hyperspectral Infrared Radiance Assimilation

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Motivation

• Question 1: Is direct assimilation of cloudy IR radiances in NWP realistic?

• Question 2: How does cloud detection impact IR sounder radiance assimilation?

• Question 3: How to assimilate thermodynamic information in cloudy situation?
Q: Is direct assimilation of cloudy IR radiances in NWP realistic?

A: Very challenging because:

(1) Both NWP and RTM have larger uncertainty;

(2) Big change of Jacobian at cloud level.
Q: How does cloud detection impact IR sounder assimilation?

A: Accurate cloud detection is critical for radiance assimilation in NWP.

Wang et al. (2014, GRL)
500 hPa temperature analysis difference (AIRS(MOD) - AIRS(GSI))

Poster: 11p.09 (Jinlong Li):
Near real time satellite data assimilation system (http://cimss.ssec.wisc.edu/sdat)
Q: How to assimilate thermodynamic information in cloudy situation?
A: Clear channel radiances, cloud-cleared radiances

Poster: 11p.07
(Zhenglong Li)
Aqua MODIS IR SRF Overlay on AIRS Spectrum

Direct spectral relationship between IR MODIS and AIRS provides unique application of MODIS in AIRS cloud_clearing!
AIRS/MODIS cloud-clearing (Li et al.2005)

\[ J(N^*) = \sum_i \frac{1}{\sigma_i^2} [(R_{Mi}^{clr} - f_i(R_{cc}^{cc}))]^2 = \min \]

\[ J(N^*) = \sum_i \frac{1}{\sigma_i^2} [(R_{Mi}^{clr} - f_i(\frac{R_1^1 - R_2^2 N^*}{1 - N^*}))] = \min \]

\( \sigma_i \) is NEdR for MODIS band

solve \[ \frac{\partial J(N^*)}{\partial N^*} = 0 \quad \implies \quad N^* = \frac{\sum_i \frac{1}{\sigma_i^2} [f_i(R_1^1) - R_{Mi}^{clr}][f_i(R_1^1) - f_i(R_2^2)]}{\sum_i \frac{1}{\sigma_i^2} [f_i(R_2^2) - R_{Mi}^{clr}][f_i(R_1^1) - f_i(R_2^2)]} \]

\[ R_{cc}^{cc} = \frac{R_1^1 - R_2^2 N^*}{1 - N^*} \]
(1) For each cloudy AIRS FOV, 8 pairs are used to derive 8 AIRS CC radiance spectra;
(2) Compare AIRS CC radiances with MODIS clear radiance observations within the AIRS FOV, find the best pair and the corresponding CC radiance spectrum.
Sounding bands imager are very important in IR/Imager cloud-clearing

AIRS cloud-cleared BT standard deviation (STD) compared with MODIS clear BT measurements

Bias < 0.25 K, STD<0.5 K at most MODIS bands.

The precision of AIRS/MODIS cloud-cleared radiances high rely on MODIS spectral and radiometric calibration.

Zhang et al. (2010)
• GEOS-5 model resolution: $1^\circ \times 1.25^\circ \times 72L$
• Time frame: Jan 01 to Feb 15 2004
• Other Radiance data:
  – HIRS-2/HIRS3 (clear channels)
  – AMSU-A/EOS-AMSU-A
  – AMSU-B/MHS
  – SSM-I
  – GOES Sounders

AIRS clr

AIRS clr + AIRS cc

Neutral on track forecasts, slight improvement on intensity forecasts with additional CC radiances in this case

T analysis difference at 500 hPa between AIRS clr+cc and AIRS clr
Summary

• Better cloud detection with high spatial resolution imager leads to significant NWP forecast improvement using GSI and WRF ARW systems;
• The approaches can be applied to NPP/JPSS CrIS/VIIRS and Metop IASI/AVHRR;
• IR sounder cloud-clearing with collocated imager could expand the “clear” coverage for radiance assimilation;
• Future work will focus on assimilating the cloud-cleared radiances (e.g., CrIS/ATMS, AIRS/MODIS, AIRS/AMSU) in NWP.