EVALUATING DIFFERENT HITRAN DATABASES USING AIRS AND CRIS

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Overview

Outline

- Overview of the AIRS, CrIS, IASI instruments
- Overview of kCARTA, SARTA
  - kCARTA is pseudo LBL code, fixed resolution (0.0025 cm-1 in IR, resolution chanfges with spectral band)
  - SARTA is fast transmittance model for operational NASA/NOAA AIRS/CrIS/IASI L2 retrievals
- AIRS and CrIS clear sky observations compared to calculations
- Simulated $\Delta(BT)$ using HITRAN line parameter uncertainties

Sounders


OSTM/Jason 2
(NOAA)
Aquarius
QuikSCAT
TRMM
Terra
ISS-RapidScat,
CATS
EO-1
SMAP
Landsat 7
(USGS)
Aqua
Suomi NPP
(NOAA)
SORCE,
TCTE (NOAA)
Landsat 8
(USGS)
GPM
Aura
GRACE (2)
CALIPSO
CloudSat
OCO-2

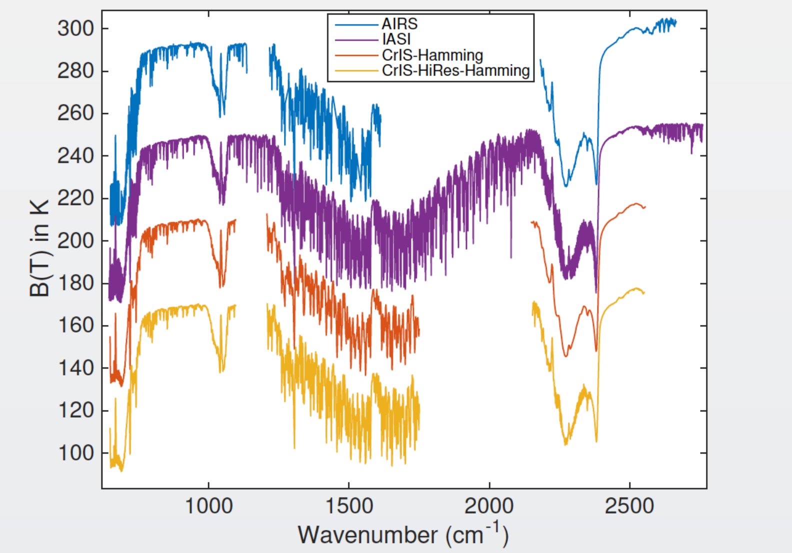
New Generation Hyperspectral Sounders (1)

- NASA AIRS : Atmospheric Infrared Sounder, on 1.30 pm Aqua platform
  - Diffraction grating, 2378 channels, $\nu/\delta\nu \sim 1200$
  - Operational since September 2002, have 17+ years of high quality radiance data, can be used for T,WV trending
- NOAA CrIS : Cross Track Infrared Sounder, on 1.30 pm Suomi NPP and JPSS platforms
  - Interferometer, 1305 channels (NSR), 2235 channels (FSR)
  - Operational since October 2011 (Suomi), and November 2017 (NOAA-20), future models scheduled to be launched
- Eumetsat IASI : Infrared Atmospheric Sounding Interferometer on 9.30 am orbit on Metop-A
  - Interferometer, 8640 channels, new gen will have even more
  - Operational since October 2006 (Metop-A), and September 2012 (Metop-B), Metop-C planned later this year

New Generation Hyperspectral Sounders (2)

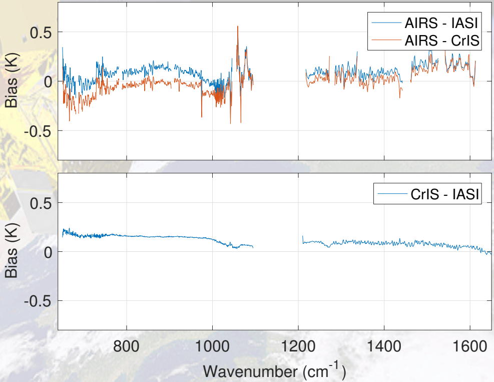
- Span 15 um to 3.7 um (roughly 640 - 2800 cm^{-1})
- Nominal footprints are 15 km, swath widths are 2000 km
- Provide accurate, detailed radiance observations for weather and climate applications (from 2002/09 onwards)
  - L. Strow/H. Motteler (UMBC) have code that turns AIRS into CRIS (NSR) and IASI
- Retrievals of atmospheric temperature and moisture, surface, trace gases (O3, CO2, CO, NH3, SO2, ...) typically done together with microwave instrument on board same platform
- Can also retrieve information about clouds (phase, optical depth, height) and dust/volcanic ash aerosols
- Need accurate spectroscopy in radiative transfer models for trace gas/temperature/humidity retrievals

Spectral Differences Among AIRS, CrIS, IASI



Intercalibration of sensors is within 0.2 K!

Larrabee Strow, Howard Motteler and Chris Hepplewhite have been analyzing Simultaneous Nadir Observations (when the fields of view are within 13 km, 20 minutes) of allsky scenes, and looking at the differences between AIRS and CrIS (H.M. has developed an accurate method to go from AIRS to CrIS NSR and AIRS to IASI)



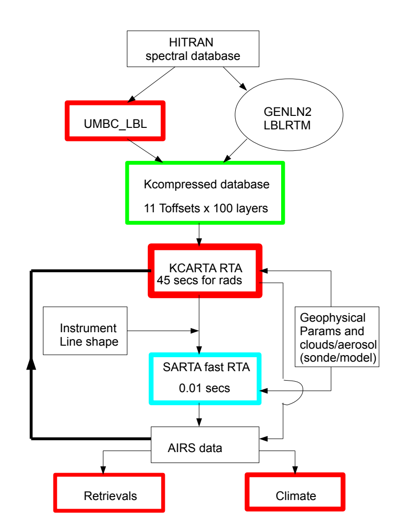
UMBC RTAs

kCARTA and SARTA

kCARTA = kCompressed Atmospheric Radiative Transfer Algorithm, (Matlab, f77,f90) pseudo LBL, 45 secs to do one radiance spectrum from 605 to 2830 cm^{-1} at 0.0025 cm^{-1} resolution

SARTA = Stand Alone Rapid Transmittance Algorithm (f77) used by NOAA and NASA for operational L2 retrievals, based on kCARTA ODs regressed over 49 realistic Earth profiles $\times$ 8 view angles; takes about 0.03 seconds to do one 2378 channel AIRS spectrum

kCARTA and SARTA



KCARTA

- SVD compressed optical depths can be rapidly uncompressed for realistic Earth Atmosphere
  - use various HITRAN databases and water continuum models
  - use 0.0025 cm-1 (0.0005 cm-1 boxcar integrated) resolution from 605-2830 cm-1 (ODs validated against eg LBLRTM, RTA through campaigns)
  - also have databases spanning 15-605 cm-1 and 2830-44000 cm-1 (667 to 0.22 μm, not validated)
- Clear sky RTA includes fast analytic jacobians
- Background thermal done at each layer/wavenumber point using accurately varying diffusive angle
- Fluxes/heating rates can be computed
  - Tests against LBLRTM/RRTM show the algorithm is accurate, but limited by kCARTA resolution
- Can include effects of scattering (TwoSlab cloud representation)

KCARTA spectral databases

- use Voigt-Van Huber for all molecules except water vapor (without basement + continuum) and CO2 (line-mixing)
- have Matlab based line-by-line code to generate optical depths, using contributions for near/medium/far lines
- Continually been using HITRAN from 1996 onwards!
  - molecular GasIDs 1-40, cross-section gases 51-80
  - Originally had our own CO2 full line-mixing code, but now plan to use LBLRTM for CO2 and CH4
  - plan to evaluate the LM package available with HITRAN 2016
  - takes about 2 weeks to generate/compress IR database on UMBC HPC cluster
- Use AER MT-CKDn for continuum models
- US Standard profiles used to compute optical depths at $T(z) - 50, T(z) - 40, ..., T(z), ...T(z) + 40, T(z) + 50$, then compress with SVD

Obs/Calcs

January 31, 2017 AIRS clear sky over ocean scenes

20000 FOVS, match to ERA (analysis output every 6 hours,± 3 hour mismatches)

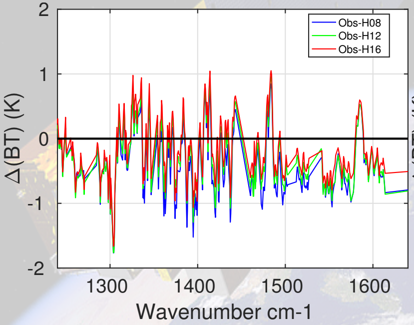
obs-cal positive in WV region too much upper atmosphere water

Do "quick" OEM T(z),WV(z), surf temp, col O3 retrieval *using SARTA* (403 ppmv CO2) and then run off different HITRAN/LBLRTM CO2 databases *using kCARTA*

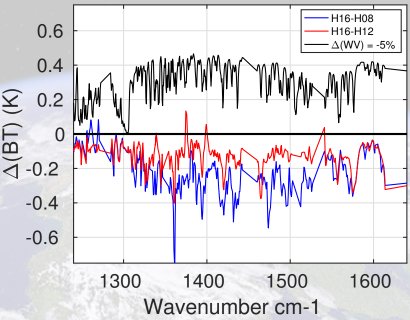
Note there are differences between SARTA (made around 2011) and kCARTA, so while the retrievals "flattened" out the biases between obs and SARTA cals, using the retrieved profiles with kCARTA re-introduces a small bias

January 31, 2017 AIRS clear sky over ocean scenes Keep CO2 constant (UMBC CO2/CH4), vary every other gas (H2008,H2012,H2016)

obs-cal

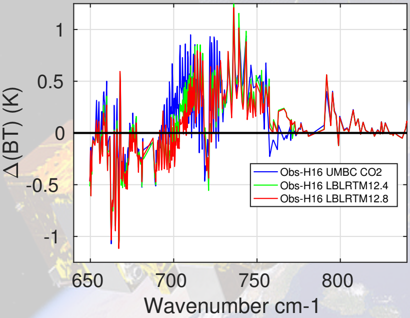


calX-cal0



January 31, 2017 AIRS clear sky over ocean scenes, Vary CO2/CH4 (UMBC, LBLRTM12.4, LBLRTM12.8), keep every other gas constant (H2016)

obs-cal



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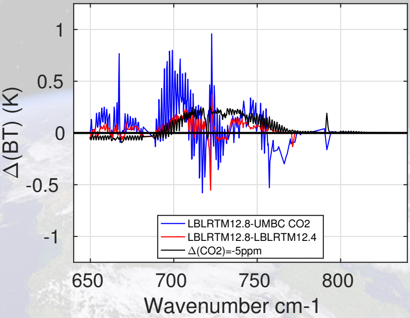


We plan to evaluate HITRAN 2016 CO2 linemix package (LM)

CH4 *abs*(LBLRTM line mix - UMBC Voigt) ≤ +0.3 K at 1305 cm^{-1}

Uncertainty

Evaluating HITRAN uncertainties

https://www.cfa.harvard.edu/hitran/uncertainty.html

Uncertainty Codes Used in HITRAN Database

	Wavenumber and Pressure shift (cm-1)		Intensity, Halfwidths, and Temperature-dependence
Code	Uncertainty Range	Code	Uncertainty Range
0	≥ 1. or Unreported	0	Unreported or Unavailable
1	≥ 0.1 and < 1.	1	Default or Constant
2	≥ 0.01 and < 0.1	2	Average or Estimate
3	≥ 0.001 and < 0.01	3	≥ 20%
4	≥ 0.0001 and < 0.001	4	≥ 10% and < 20%
5	≥ 0.00001 and < 0.0001	5	≥ 5% and < 10%
6	≥ 0.000001 and < 0.00001	6	≥ 2% and < 5%
7	≥ 0.0000001 and < 0.000001	7	≥ 1% and < 2%
8	≥ 0.00000001 and < 0.0000001	8	< 1%
9	≥ Better than 0.00000001		

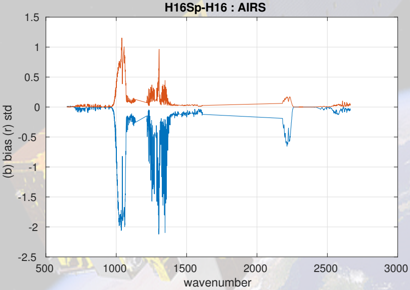
Had to put in numbers for the "unknowns", re-generate compressed database for H2O,O3,N2O,CO,CH4 for perturbations to (a) line center (b) line center shift due to pressure (c) broadening (self, foreign, temperature dependance, simultaneously) (d) line strength (e) all together randomly

0.01 cm-1 worked fine 20% was too much for line intensity

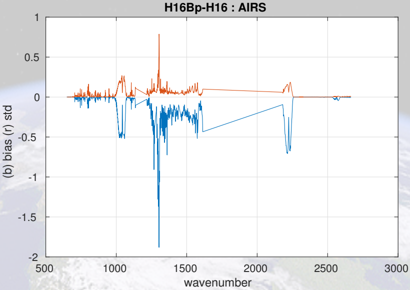
TOA uncertainty derived from HITRAN uncertainties

Use 49 regr. profiles spanning the atmosphere, do RT for nominal HITRAN ODs and ODs perturbed according to above prescription

strength pert



broad pert



checking 10 um O3 confirms many of the lines have unc code = 0

need to add in CO2 uncertainties (LM? LBLRTM?)

- *Can I simply perturb* Intens,HWVT0AIR/SELF,BHWAIR/SELF?

Conclusions

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- AIRS, CrIS, IASI are low noise, well calibrated intruments, providing long term radiance record
- Need accurate spectroscopy to retrieve temperature, humidity, trace gases from these sounders which are inter-calibrated to within 0.2 K
- This need is being met by the updates to the HITRAN databases over the years
- Sounding and NWP communities would like some dots filled in eg CO2 LM code, uncertainties ....

  Marco Matricardi (ECMWF) and Helen Brindley (Imperial College)