Trace Gas Products from Operational Hyperspectral Sounders

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and the NOAA/IOSSPDT team

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Outline

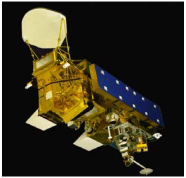
- Retrievals From Operational Hyperspectral Sounders.
  - NOAA 20 Year Strategy
  - Examples of Retrieved Products
- Trace Gas Activities
  - Core product (T/q) validation
  - Trace gas validation and optimization
- Summary

NOAA/NESDIS Stategy Using From Operational Hyperspectral Sounders

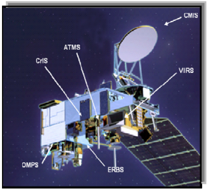
- Developing a suite of products from operational hyper-spectral passive thermal instruments (3.7 to 15.5 μm).
    - Aqua: AIRS/AMSU : AIRS has 2378 chls, 2.916 million spectra/day
    - METOP: IASI/AMSU/MHS : IASI has 8461 chls, 1.296 million spectra/day
    - NPP/NPOESS: CrIS/ATMS : CrIS has 1305 chls, 2.916 million spectral/day
- All satellite instrument systems are processed with the same code using the same spectroscopy (different coefficient files).
- Employs cloud-clearing technique - Works on $\approx$ 50% of scenes or 160,000 globally distributed "accepted" soundings per day.
- Near realtime (support intensive campaigns and operations) and reprocessing capability (quick ability to weigh changes in the algorithm over long periods of time).

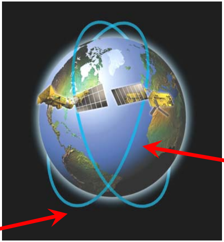
Initial Joint Polar System: An agreement between NOAA & EUMETSAT to exchange data and products.

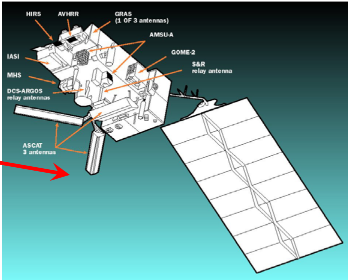
NASA/Aqua
1:30 pm orbit (May 4, 2002)



NPP & NPOESS
1:30 pm orbit
(6/2010, 2013, 2018)







EUMETSAT/METOP-A
9:30 am orbit (Oct. 19, 2006, 2010, 2015)

20 years of hyperspectral sounders are already funded for weather applications

Core and Trace Gas Product Potential from Operational Thermal Sounders

Gas	Spectral Range	Precision	d.o.f.	AIRS	IASI[1]
T(p)	various	1K	6-10	NASA DAAC	NOAA CLASS
H_2O	1200–1600	15%	4-6	NASA DAAC	NOAA CLASS
O_3	1025–1050	10%	1.25	NASA DAAC	NOAA CLASS
CO	2080–2200	15%	$\approx$1	NASA DAAC	NOAA CLASS
CH_4	1250–1370	1.5%	$\approx$1	NASA DAAC	NOAA CLASS
CO_2	680–795 2375–2395	0.5%	$\approx$1	NOAA NESDIS	NOAA CLASS
Volcanic SO_2	1340–1380	50% ??	$<$1	TBD	TBD
HNO_3	860–920 1320–1330	50% ??	$<$1	NOAA NESDIS	NOAA CLASS
N_2O	1250–1315 2180–2250 2520–2520	50% ??	$<$1	NOAA NESDIS	NOAA CLASS
CFCs	790 - 940	various	-	No plans	No plans

Range in the degrees of freedom (d.o.f.) are largely due to a dependence on the geophysical state as well as noise variability due to cloud-clearing.

Low magnitude of d.o.f. for trace gases implies that a priori assumptions dominate retrieval variability in certain situations → optimize these assumptions.

[1] available after August 14, 2008 from http://www.class.ngdc.noaa.gov/

Retrieval of Atmospheric Trace Gases Requires Unprecendented Instrument Specifications

- Need Large Spectral Coverage (multiple bands) and High Sampling (currently, we use 1680 AIRS and 14 AMSU channels in our algorithm)
- Increases the number of unique pieces of information
  - Ability to remove cloud and aerosol effects.
  - Enable simultaneous retrievals of T(p), q(p), O3(p).
- Requires High Spectral Resolution and Spectral Purity
  - Ability to isolate spectral features → vertical resolution
  - Ability to minimize sensitivity to interference signals..
- Need Excellent Instrument Noise and Instrument Stability
  - Low NEΔT is required.
  - Minimal systematic effects (scan angle polarization, day/night orbital effects, etc.)
- Need accurate T(p) and q(p) determination (upstream algorithm must be accurate and stable).

“Upstream” Trace Gas Activities

- Temperature and moisture (derived from cloud cleared radiances)
  - Validation using 350,000 operational RAOBs within ± 100 km and ± 3 hours of AIRS overpass (9/02 - present) (2002-2005 published, Divakarla 2006 JGR v.111)

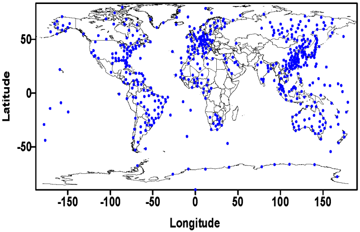
Current focus

- extend validation to polar regions (North Slope ARM site)
- assessing the “climate” potential of our retrieved products (e.g. long term trends).

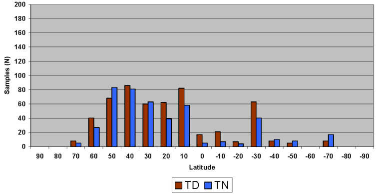
IASI and AIRS RAOB Matches

Contact: M. Divarkarla: `murty.divakarla@noaa.gov`

IASI 9:30 AM/PM

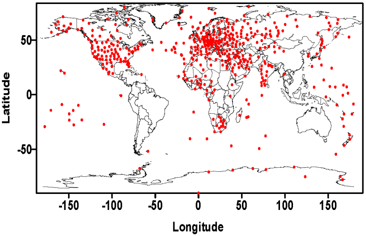


IASI - Accepted Matches :1760
Accepted Matches After Selecting RAOBs :982
(NH:63%; Tropics:20%; SH:17%)

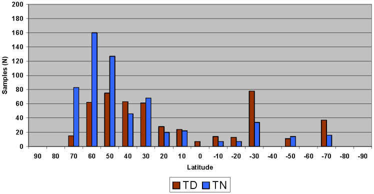


Land (N:766) /**Sea(N:216)**/**ALL(N:982)**

AIRS 1:30 PM/AM

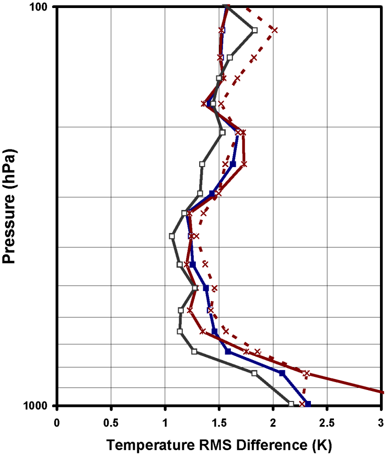


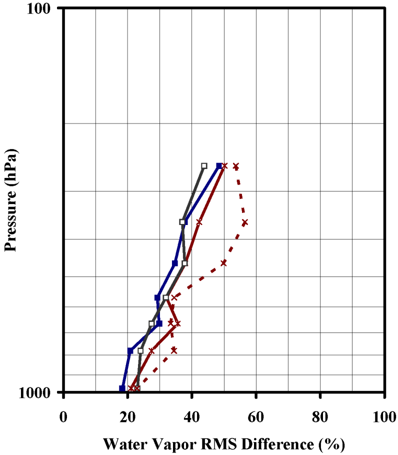
AIRS- Accepted Matches :2826
Accepted Matches After Selecting RAOBs :1092
(NH:74%; Tropics:7%; SH:19%)



Land (N:982)/**Sea(N:110)**/**ALL(N:1092)**

IASI and AIRS RAOB RMS Statistics (Global)

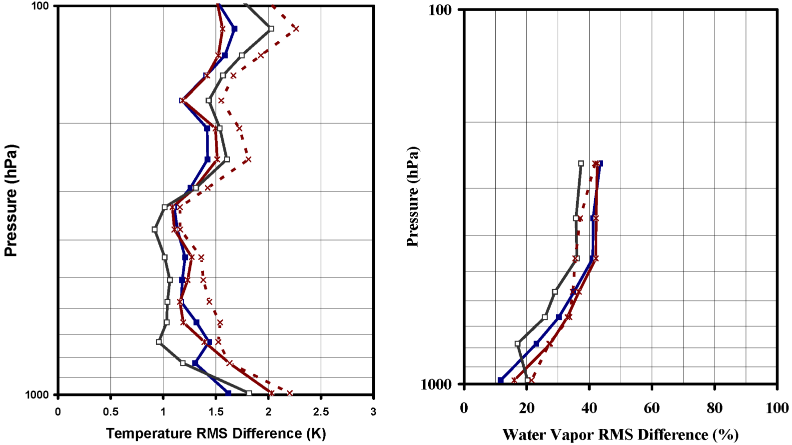




IASI vs RS   AIRS vs RS

(IASI FG -solid   AIRS FG -dotted)

IASI and AIRS RAOB RMS Statistics (Ocean Only)



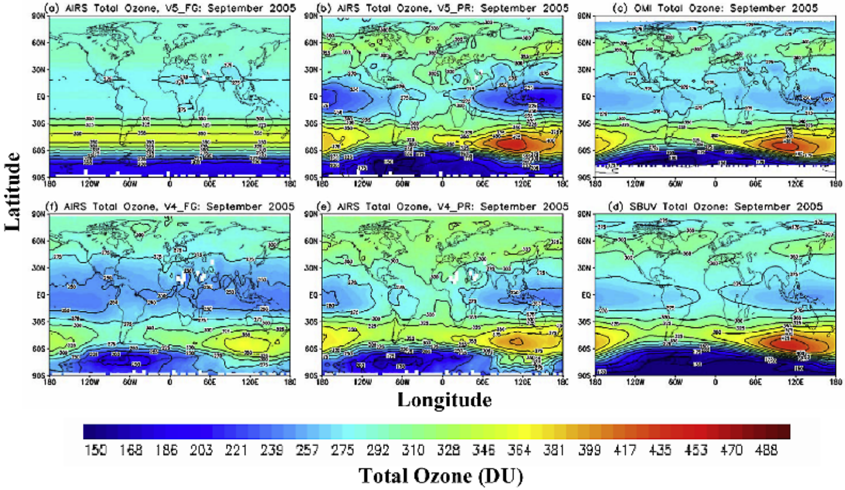
IASI vs RS AIRS vs RS

(IASI FG -solid AIRS FG -dotted)

Overview of Trace Gases

- Ozone
- Carbon Monoxide
- Methane
- Carbon Dioxide

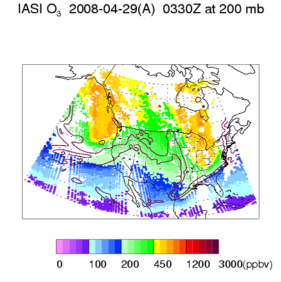
AIRS V4/V5, OMI and SBUV Total Ozone for 2005 (Murty Divakarla)

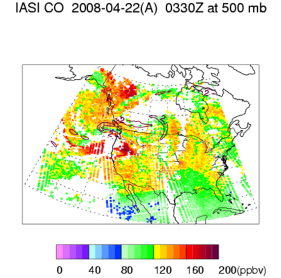


Version 4 (f, e) to Version 5 (a, b) shows improvements to the algorithm in terms of the ability to capture the Ozone Hole in September 2005 using a simple climatology.

START 2008 and Pre-HiPPO - Use of AIRS and IASI to study transport and vertical mixing (Jennifer Wei)

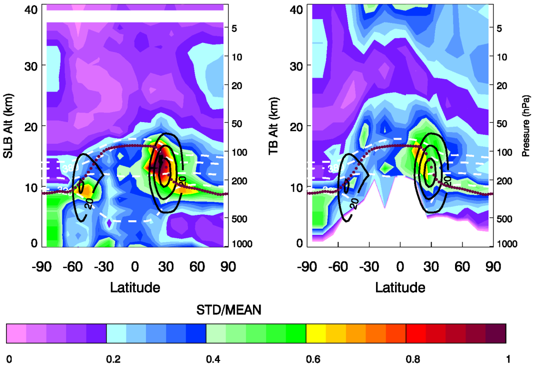
- NOAA/NESDIS/STAR participated in the START08 and pre-HIPPO experiments from April to June, 2008.
- STAR provided near real time L2 products derived from the AIRS and the IASI. Satellite derived tropopause height, H2O, O3, CO and CH4 are used for daily flight forecast. AIRS and IASI have demonstrated to be great instruments for chemical tracers predictions over the continental US region.
- **Top:** IASI derived O3 at 200 mb shows the patterns similar to the upper tropospheric dynamics (stratospheric intrusions, red contours); **Bottom:** IASI CO at 500 mb shows high CO over Oregon/Idaho due to long range transport of Siberian fire.
- Daily products and flight forecaster reports can be seen on `http://catalog.eol.ucar.edu/start08/index.html`





Development of Improved Climatology for Infrared Satellite Retrievals of Ozone (J. Wei)

- Infrared hyperspectral instruments can use tropopause height information to improve retrievals of ozone.
- Variability in the traditional first guess has been greatly reduced by using a tropopause based (TB) coordinate.

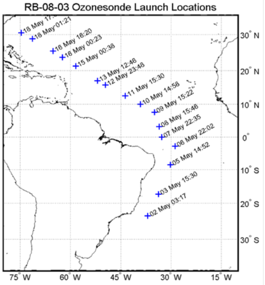


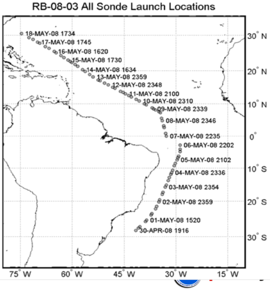
Ongoing Work

We are collaborating with L. Pan (NCAR) and J. Logan (Harvard) to develop, implement, and test a new ozone climatology for hyperspectral infrared sounding.

AEROSE 2007/2008 Piggyback Cruises (Nick Nalli)

- 2008 AEROSE took place during May onboard the Ronald H. Brown.
- **HU/NCAS** provided ozonesondes that were launched 1 time per day at the locations shown at right (V. Morris, E. Joseph)
- The **AIRS Science Team** supported this mission with RS92 Vaisala radiosondes launched 4 times/day at locations shown at right.
- Will be used for validation of AIRS and IASI within the challenging SAL marine environment.
- AEROSE 2008 complement the previous data (2004, 2006, 2007) by
  - sampling the same region during an interesting, yet distinct, month of the year (May)
  - ozonesondes were not launched in 2004 and 2006 phases.





Carbon Trace Gas Activities

Carbon Monoxide

AIRS : collaboration with Wallace McMillan & Juying Warner, Univ. Maryland, Baltimore County.
IASI : heritage algorithm & testing new methodologies at NOAA

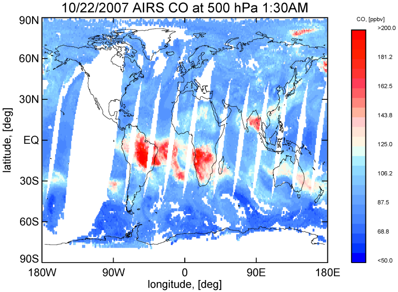
Methane: Xiaozhen Xiong, NOAA/NESDIS/STAR

AIRS : Validated vs. aircraft and models
IASI : Research product

Carbon Dioxide

AIRS : Validated vs. aircraft and models
IASI : Research product

IASI and AIRS Carbon Monoxide Products on October 22, 2007



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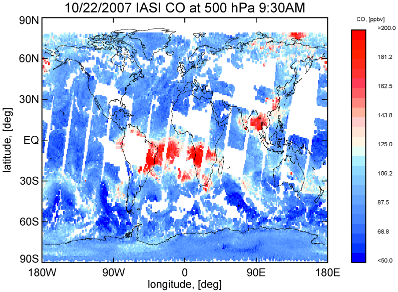

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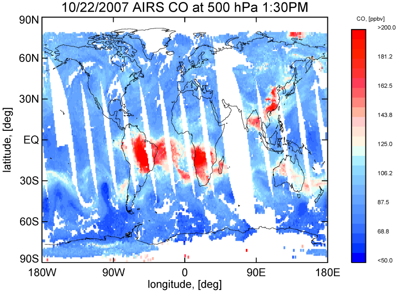

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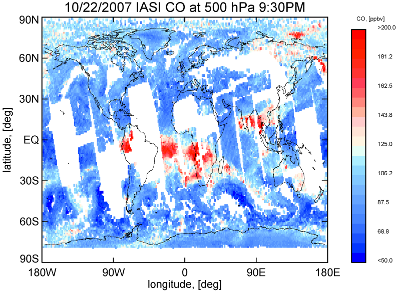

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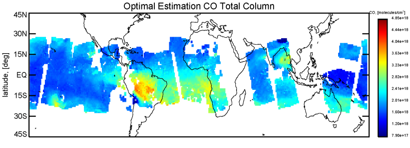
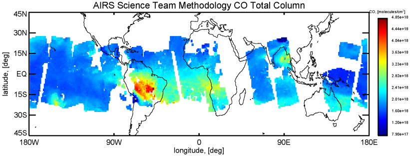
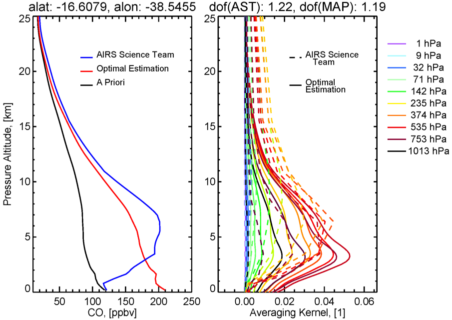
CO Retrieval from IASI over Brazil 10/19/2007

New capability to produce Optimal Estimation retrievals of trace gases and core products from hyperspectral sounder observations.

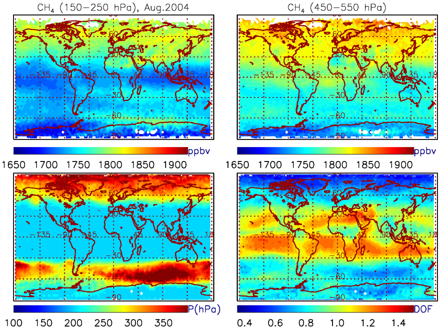




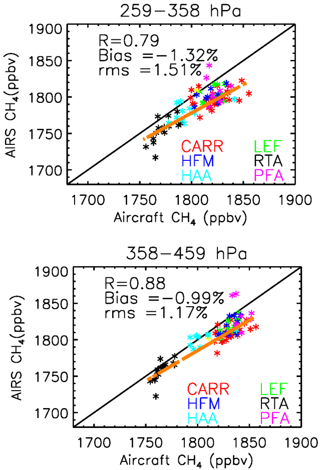


Preliminary comparison of AIRS Science Team methodolgy vs. OE retrievals over Brazil (left panel) and showing averaging kernels, which describe vertical sensitivity (right panel).

AIRS CH_4 & Validation vs. ESRL aircraft: Xiaozhen Xiong



Top : AIRS Retrieved CH_4 between 150-250hPa (left) and 450-550hPa (right).
Bottom: the pressure of maximum sensitivity (left) and DOF (right).

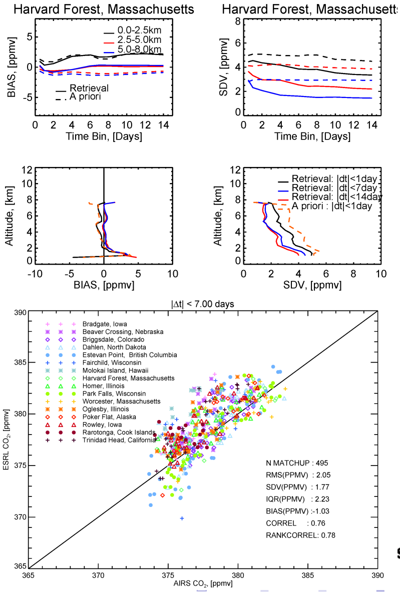


Current Work

Focuses on comparison to CH_4 models (Xiong, *ACPD*, 2008) to identify regions where AIRS data will aid in the constraint of model CH_4 budget and/or transport.

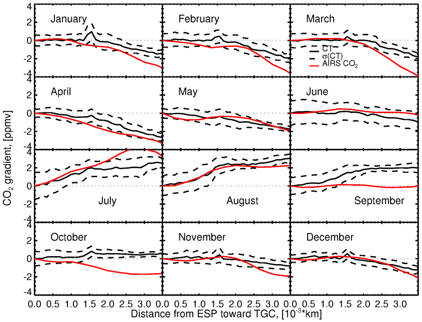
Direct Comparison: AIRS CO_2 to ESRL Aircraft

- Comparison of AIRS retrieved CO_2 shows improvement in statistics (dashed vs. solid lines) as a function of temporal averaging (e.g., Harvard Forest site, upper right) up to about 5 days of averaging.
    - Averaging removes random components of error
    - Comparisons between "point" aircraft measurements and "volume" measurements are more difficult.
- Validation scatterplot (lower right) for all ESRL/GMD sites for a collocation time window of ± 7 days shows we are within 2ppmv (0.5%).



AIRS CO_2: Comparisons with NOAA/ESRL/GMD CarbonTracker

- Utilized AIRS 3x3 gridded products (1:24 spatial sampling).
- Comparisons indicate that AIRS measurements provide similar (i.e., slightly less) performance as the NOAA/ESRL CarbonTracker in it's data rich regions (USA).
  - NOAA/ESRL CarbonTracker multiplied by AIRS CO_2 Jacobians and mapped to AIRS horizontal sampling.
  - AIRS might have impact in data poor regions (tropics, S.H.).
- Differences in gradients can be used to evaluate scene dependent (air-mass) biases – that we hope to mitigate once they are understood – hopefully without empirical corrections.



Comparison of AIRS retrievals (red line) and CarbonTracker model (dark line with dashed lines indicating standard deviation) along a track from W. Canada to Texas (3500 km), normalized to W. Canada.

Summary

- NOAA/NESDIS/STAR has large number of correlative datasets to better enable characterization and validation of the suite of trace gases retrievable from operational sounders such as IASI and AIRS.
- Our efforts show that AIRS and IASI core product (T/q) retrievals are meeting expectations at current levels of maturity.
- Hyperspectral sounder measurements contain a wealth of information regarding multiple trace gas distributions.
- On going and future efforts will be focused on the development, characterization, and validation of core and trace gas retrievals.
- Strong interest in sharing datasets and performing retrieval comparisons.