



AIRS, IASI and CrIS Advanced Processing for Data Assimilation

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NOAA/NESDIS/STAR

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JCSDA Science Working Group

Session 2: Advanced Instruments

Walter Wolf	NRT system	Tom King	NRT System
Nicholas Nalli	AEROSE Campaign	Peter Keehn	NRT System
Lihang Zhou	NRT/Regression	Zhaohui Chang	NRT/Regression
Murty Divakarla	T,q,O3 Validation	Antonia Gambacorta	Retrieval Product System, T, q val.
Jennifer Wei	O ₃ /CO/H ₂ O Correlation	Eric Maddy	CO ₂ & Aver.Kernels
Xiaozhen Xiong	CH ₄ Product	Fengying Sun	HNO ₃ /N ₂ O Products
Haibing Sun	Inst. Coregistration	Xingpin Liu	Product Generation



Topics

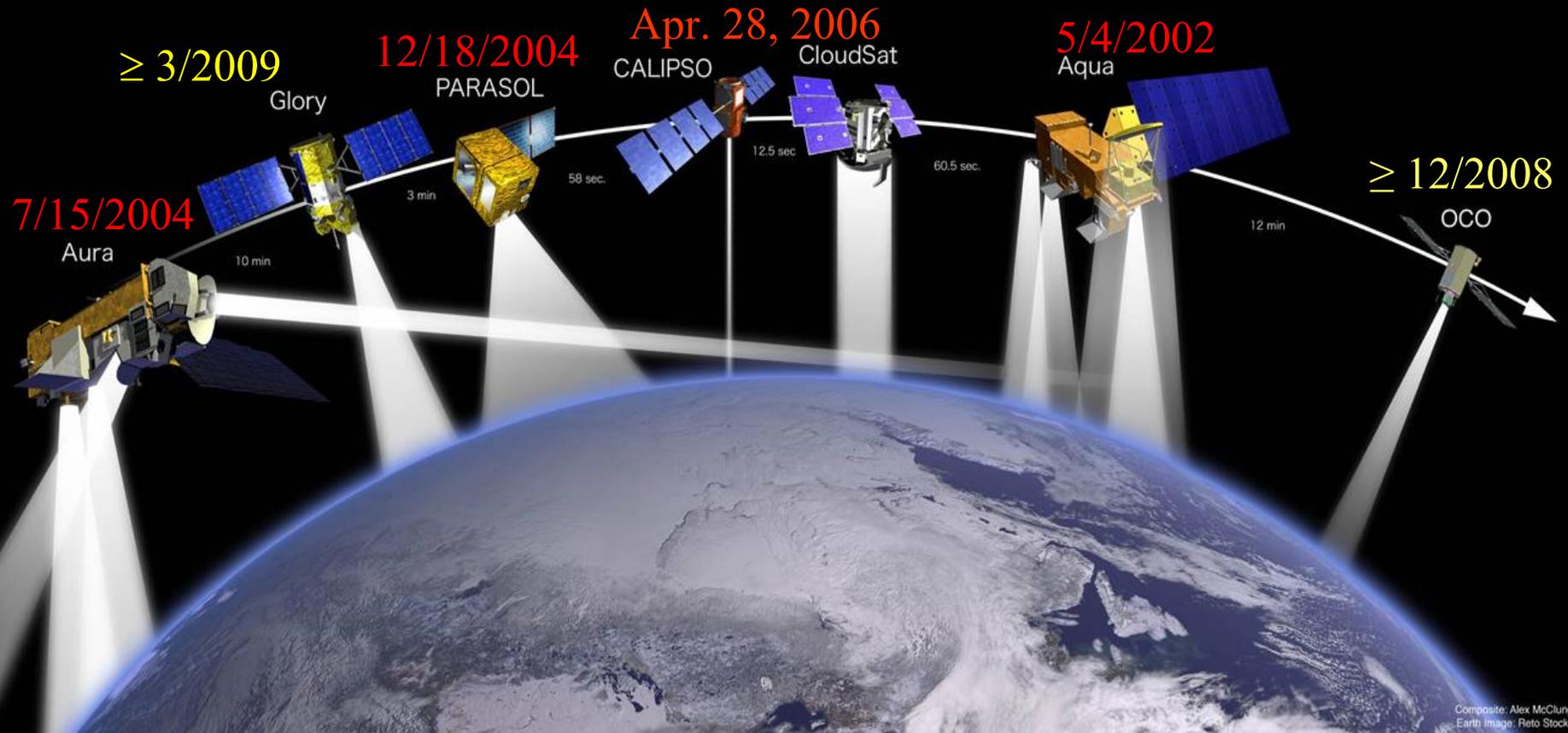
- AIRS and IASI instruments
 - Selection of channels
- Radiance and PC products
- Geophysical Products
 - Description of Products
 - Cloud Clearing
 - Trace Gas Products
 - CO₂ climatology
 - Emissivity
- Future work
 - MODIS/AIRS & IASI/AVHRR products
- Backup (slides only, will not discuss today)
 - Emissivity
 - CrIS/ATMS co-location issues
 - IASI sub-pixel ILS issue



The “A-Train”

AIRS has a Unique Opportunity to Explore & Test New Algorithms for Future Operational Sounder Missions.

The A-Train

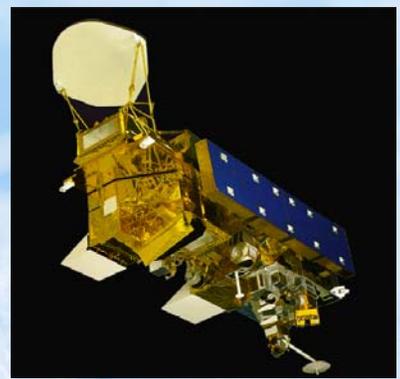




Initial Joint Polar System: An agreement between NOAA & EUMETSAT to exchange data and products.

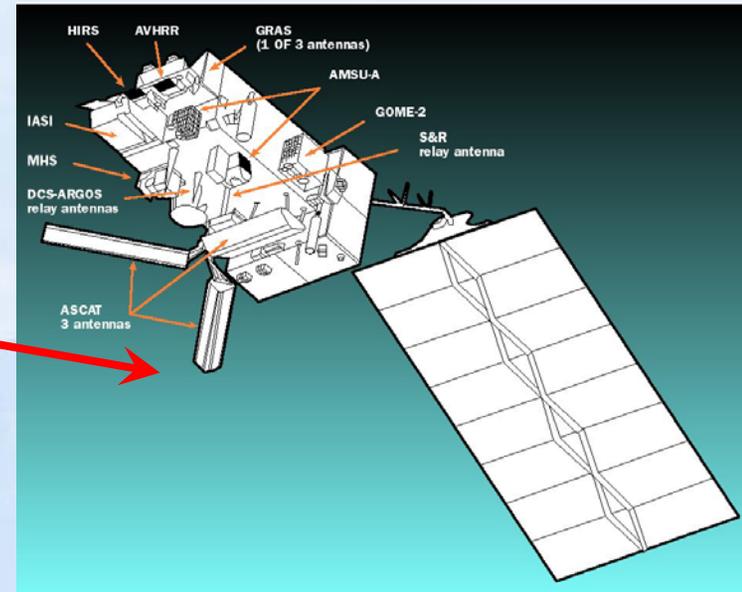
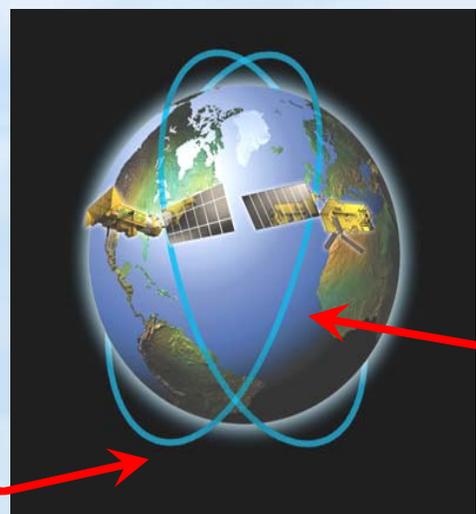
NASA/Aqua

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



NOAA/NESDIS 20 year Strategy Using Advanced Operational Sounders.

- **Now:** Develop and core & test trace gas algorithms using the Aqua (May 4, 2002) AIRS/AMSU/MODIS Instruments
 - Compare products to *in-situ* (e.g., ESRL/GMD Aircraft, JAL, INTEX, etc.) to characterize error characteristics.
 - The A-train complement of instruments (e.g., MODIS, AMSR, CALIPSO) can be used to study effects of clouds, surface emissivity, etc.
- **2007:** Migrate the AIRS/AMSU/MODIS algorithm into operations with METOP (2006,2011,2016) IASI/AMSU/MHS/AVHRR.
 - Study the impact on products due to differences between instruments, e.g., effects of scene and clouds on IASI's ILS.
- **2010:** Migrate the AIRS/IASI algorithm into operations for NPP (6/2010), NPOESS C-1 (1/2013) and C-3 (1/2018) all with CrIS/ATMS/VIIRS.
 - These are “NOAA unique products” within the NOAA NPOESS Data Exploitation (NDE) program.
- **NOTE:** All 3 instrument systems will have common algorithm (literally same code) and underlying radiative transfer. Focus is on “climate quality” of the algorithm.



STAR produces radiance and geophysical products in NRT for AIRS and IASI

- Level 1B (AIRS) and 1C (IASI) Radiance
 - Full resolution granules
 - Spatial and spectral subsets
 - Principal Component (PC) analysis
 - Reconstructed (from PC's) Radiances
 - Gridded Datasets
- NOAA Unique Geophysical (Level 2) Products
 - Cloud Cleared Radiances
 - Geophysical Products
 - Gridded Datasets



AIRS, IASI & CrIS Comparison

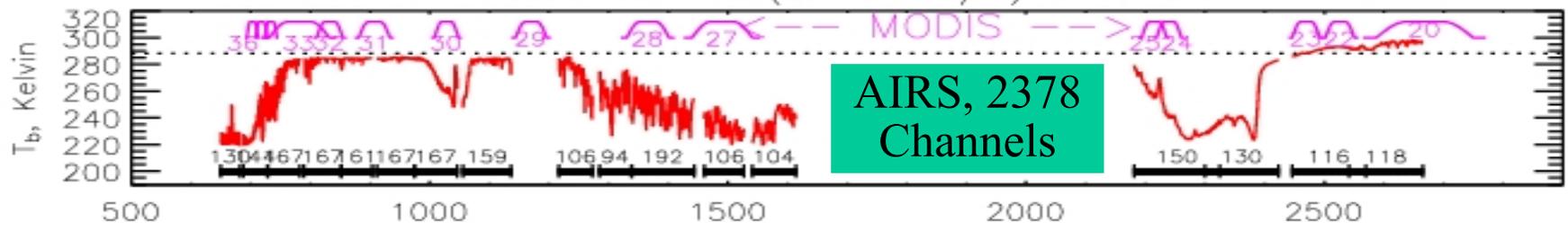
- | | | |
|--|--|--|
| <ul style="list-style-type: none">• AIRS Granules contain 6 minutes of data | <ul style="list-style-type: none">• IASI Granules contain ≈ 3 minutes of data | <ul style="list-style-type: none">• CrIS Granules contain ≈ 6 minutes of data |
| <ul style="list-style-type: none">• 240 Granules per day | <ul style="list-style-type: none">• 480 Granules per day | <ul style="list-style-type: none">• ≈ 240 Granules per day |
| <ul style="list-style-type: none">• 35 GB per day<ul style="list-style-type: none">– 9 FOV– 2378 channels | <ul style="list-style-type: none">• 30 GB per day<ul style="list-style-type: none">– 4 FOV– 8461 channels | <ul style="list-style-type: none">• 30 GB per day<ul style="list-style-type: none">– 9 FOV– 1305 channels |

- IASI system design was based on that developed for AIRS
- The same design is being used to develop the CrIS/ATMS system for NPP/NPOESS

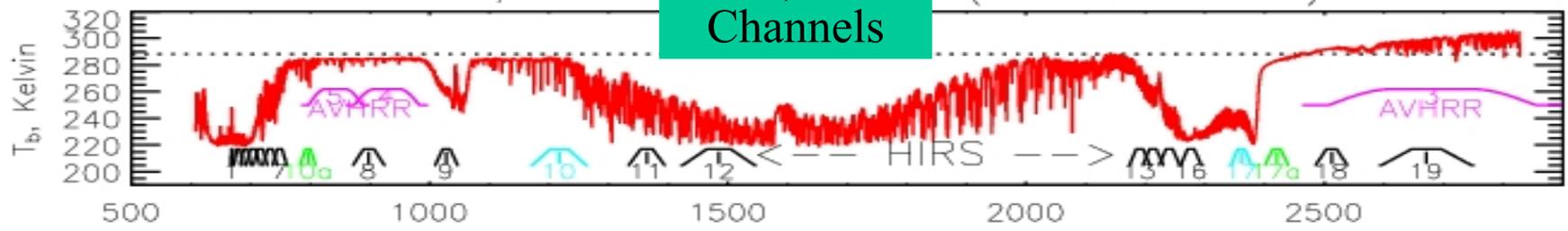


Spectral Coverage of Thermal Sounders (Example Radiances: AIRS, IASI, & CrIS)

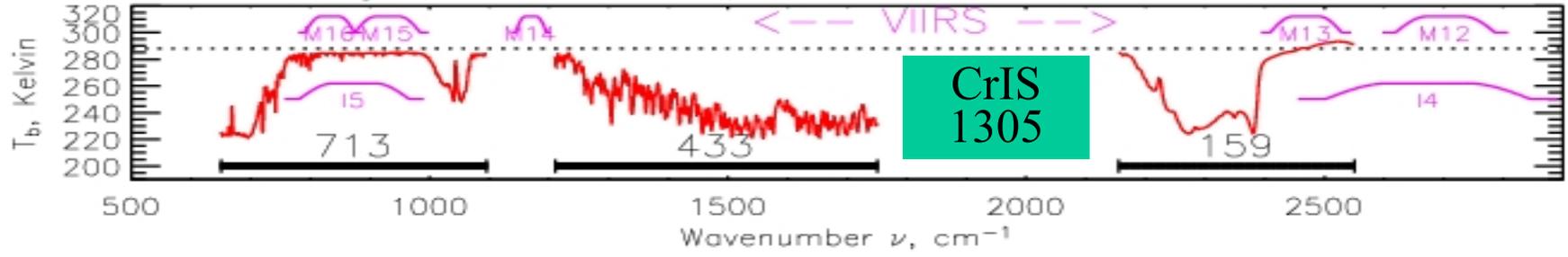
MODIS & AIRS ($\Delta\nu=2400/\nu$) Channels



AVHRR, HIRS & IASI ($\Delta\nu = 0.25 \text{ cm}^{-1}$) Channels



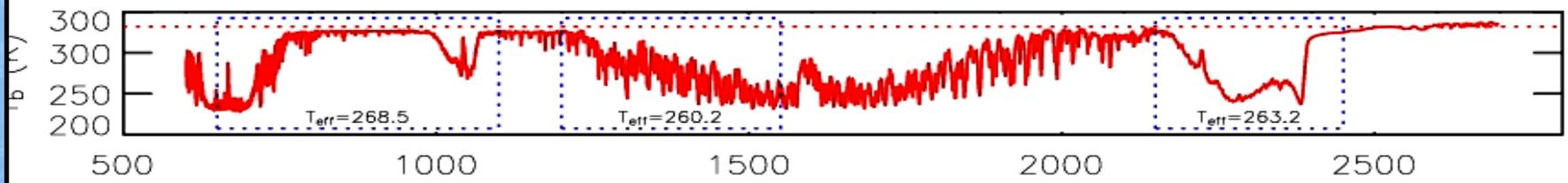
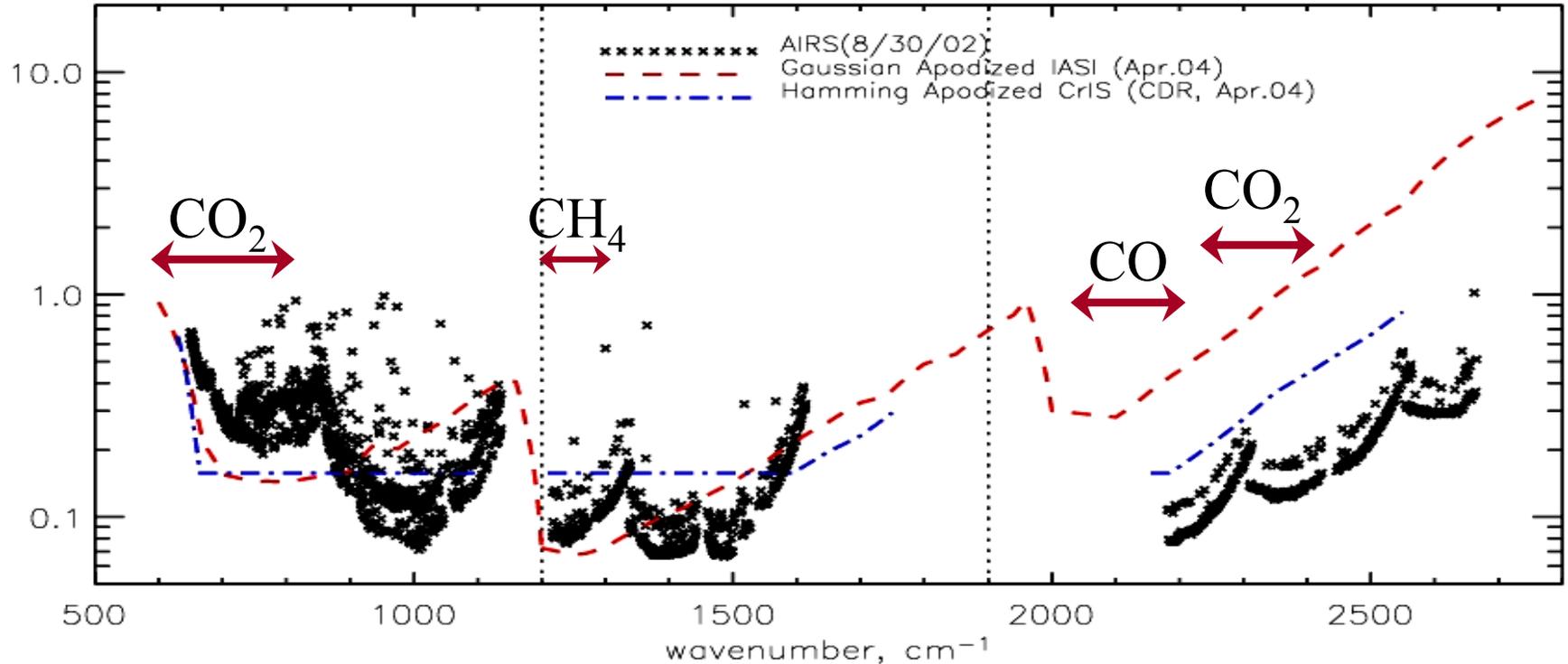
Sampling of VIIRS & CrIS ($\Delta\nu = 0.625, 1.25, 2.50 \text{ cm}^{-1}$) Channels

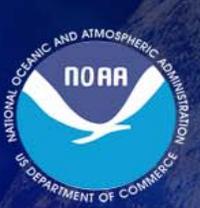




Instrument Noise, $NE\Delta T$ at 250 K (Interferometers Noise Is Apodized)

AIRS, CrIS, IASI (NOTE: CrIS and IASI noise is spectrally correlated)

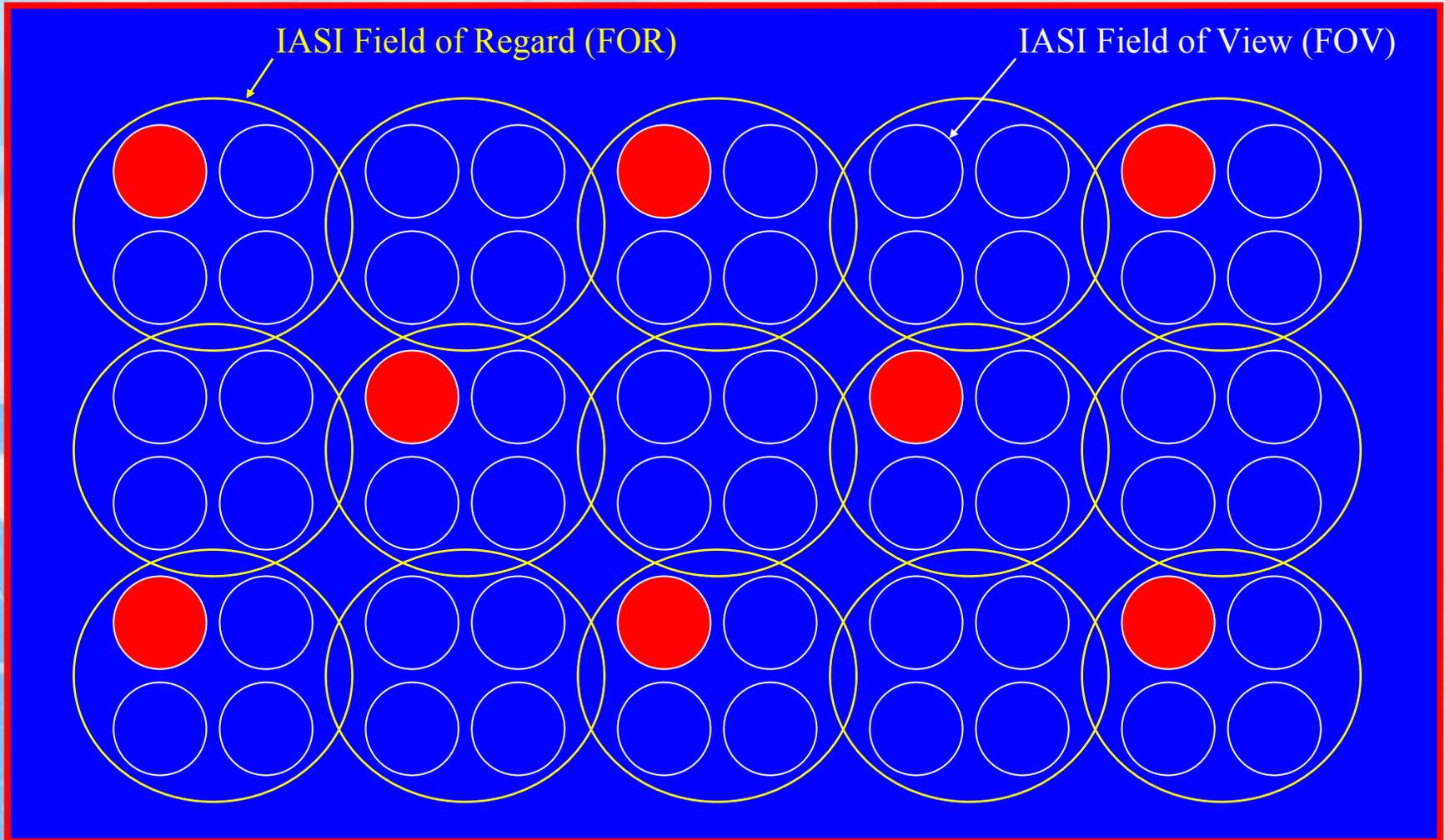




IASI Archive Products (available via CLASS)

Instrument	Processing Interval	Description	Contents	Format
IASI	Granule	Granule of IASI L1C	IASI Radiance metadata (FGDC-RSE)	EUMETSAT Binary Xml
IASI	Daily	3x3 degree gridded spatial subset of IASI FOR's	IASI, AMSU, MHS Radiances And metadata	GRADS Binary Xml
IASI	Granule	Granule of IASI cloud cleared radiances for each FOR	IASI CCR metadata	NETCDF xml
Uses IASI AMSU MHS	Granule	Granule of IASI L2 Geophysical Products for each FOR	T(p), q(p), O3(p), CO(p), CH4(p), SST/LST, surface emissivity, cloud fraction, cloud top height, convective products.	NETCDF xml

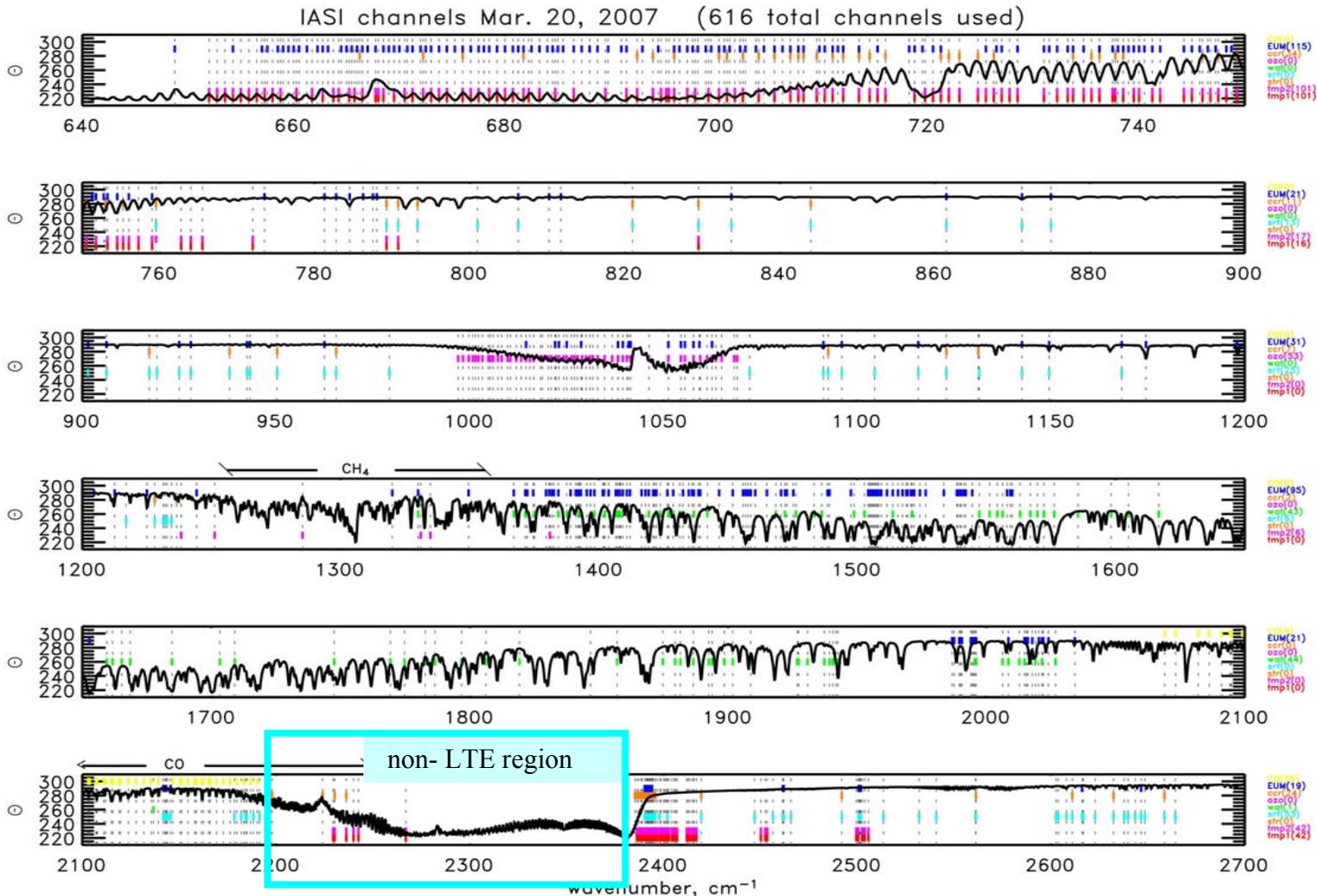
A Spatial Subset Example





Spectral Subset Selection for IASI (616 channels).

(Antonia Gambacorta)



window	96
Cloud	118
T(p)	135
q(p)	79
O ₃ (p)	53
CO	43

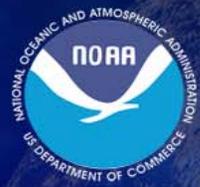


IASI L1C NRT Granule Products

Available via DDS in Near Real Time

Instrument	Spectral Subset	Data Type	Spatial Subset	Format
IASI	616 channels	IASI Radiance	Warmest FOV from every FOR	BUFR NetCDF
IASI	616 channels	IASI Radiance	First FOV from every FOR	BUFR NetCDF
IASI	616 channels	IASI Radiance	All 4 FOVs from every FOR	BUFR NetCDF
IASI	616 channels	IASI Reconstructed Radiance (1 band)	1 FOV from every FOR	BUFR NetCDF
IASI	616 channels	IASI Reconstructed Radiance (3 bands)	1 FOV from every FOR	BUFR NetCDF
IASI	616 channels	IASI Reconstructed Radiance (1 band)	4 FOVs from every FOR	BUFR NetCDF
IASI	616 channels	IASI Reconstructed Radiance (3 bands)	4 FOVs from every FOR	BUFR NetCDF
IASI	8461 channels	IASI Radiance	4 FOVs from every FOR	NetCDF
IASI	8461 channels	IASI Radiance	4 FOVs from 2 scans/granule	NetCDF

FOV = Field of View; FOR = Field of Regard. **The light green refers to internal files.**



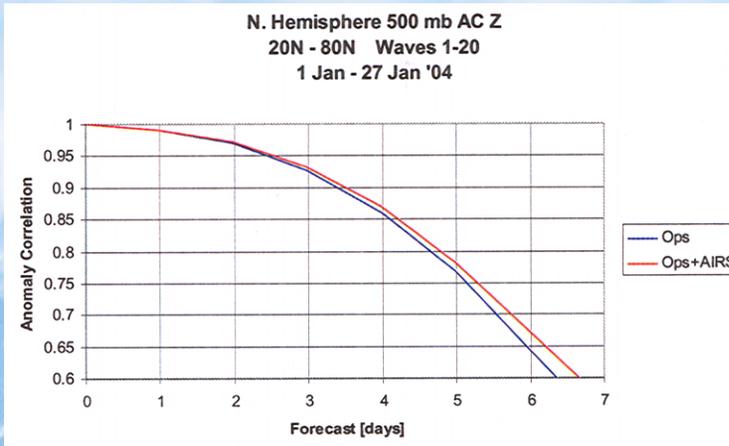
IASI L2 NOAA Unique Products Granule Products (DDS)

Instrument	Channel	Data Type	Description	IASI FOV #	Format
IASI	616	CCR	Cloud cleared radiance for each FOR	(uses all 4 FOV's)	BUFR NetCDF
IASI	n/a	Geophysical	T(p), q(p), O3(p), CO(p), CH4(p), SST/LST, surface emissivity, cloud fraction, cloud top height, convective products.	(uses all 4 FOV's)	NetCDF
IASI (using AVHRR)	616	RAD	Pick clearest IASI FOV for each FOR using AVHRR	1 (clearest)	BUFR NetCDF
AVHRR (on IASI FOVs)	5	RAD (clear and cloudy)	AVHRR channels spatially convolved to IASI FOV's	1,2,3,4	BUFR NetCDF
IASI (using AVHRR)	616	CCR	IASI CCR w/ AVHRR QA	(uses all 4 FOV's)	BUFR NetCDF

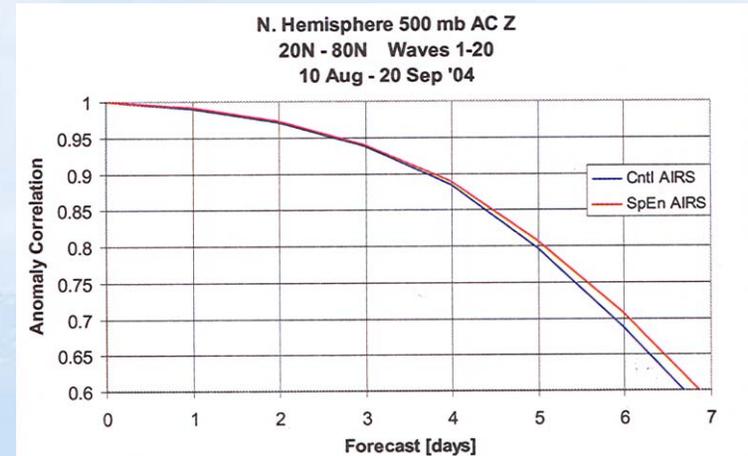
AVHRR Products will be available in FY09

Forecast Improvement using AIRS Spatial & Spectral Subsets

**Improved Forecast Prediction
1 in 18 AIRS FOV's
(6 hours in 6 Days)
Northern Hemisphere
October 2004 ***



**Additional Improvement Using
All 18 AIRS FOV's
(11 hours total in 6 Days)
Northern Hemisphere
Preliminary**



**For IASI results see Jim Jung's presentation
(talk #2 in this session)**

J. LeMarshall, J. Jung, J. Derber, R. Treadon, S. Lord, M. Goldberg, W. Wolf, H. Liu, J. Joiner, J. Woollen, R. Todling, R. Gelaro "Impact of Atmospheric Infrared Sounder Observations on Weather Forecasts", EOS, Transactions, American Geophysical Union, Vol. 86 No. 11, March 15, 2005



Principal component score (PCS) data sets from IASI



AIRS & IASI PCA

- Principal Components Analysis (PCA) is a classical approach to extract independent information
- AIRS 2378 and IASI 8461 channels can be well represented by relatively few (≈ 80) empirical orthogonal functions (EOFs), also called principle components
- Each IASI spectra can be expressed as a linear function of these EOFs by a unique set of coefficients. These coefficients are also called principal component scores (PCS).
- NOAA/NESDIS has made the IASI level 1C data products operationally available since October, 2007 (AIRS since Oct. 2002)
- NOAA/NESDIS/STAR has used PCA to process the real IASI data for the data monitoring and quality control .
- PCS and the corresponding reconstruction scores are computed in near real time.



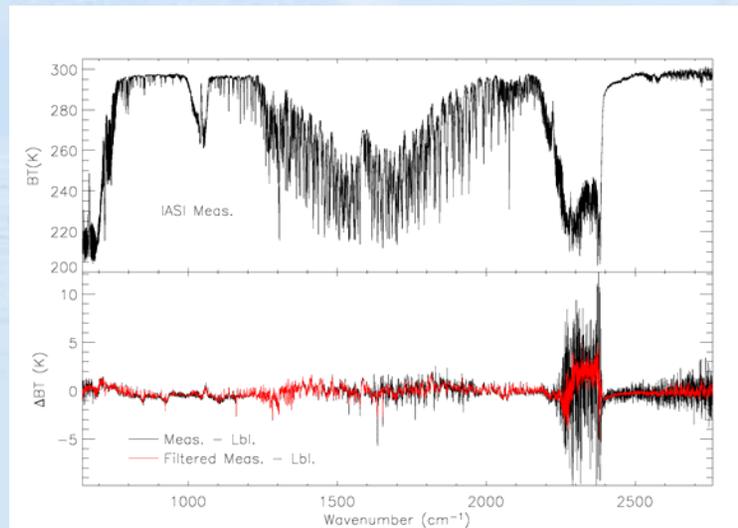
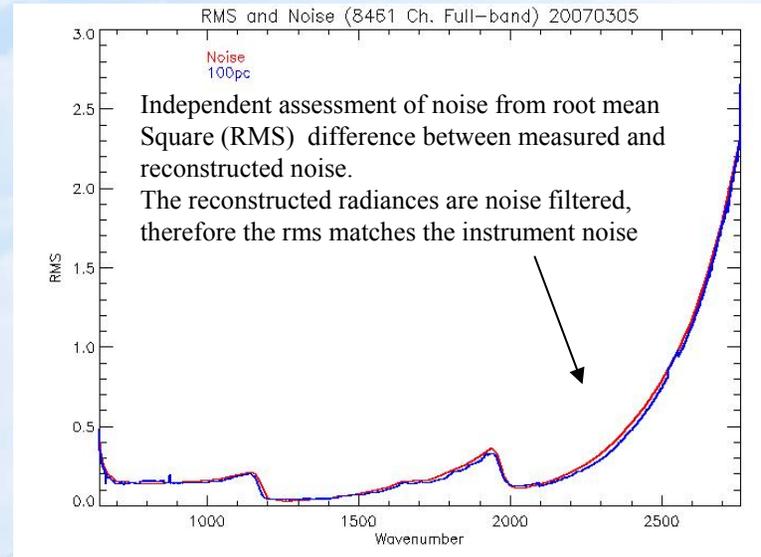
PCA Applications

- There are many important applications of PCA to IASI processing, such as:
 - Radiance Reconstruction
 - Detector Monitoring and Noise Estimate
 - Regression Retrieval of Physical Parameters
 - Climate Anomaly Signal Diagnostic
 - Data Assimilation
 - Data Compression



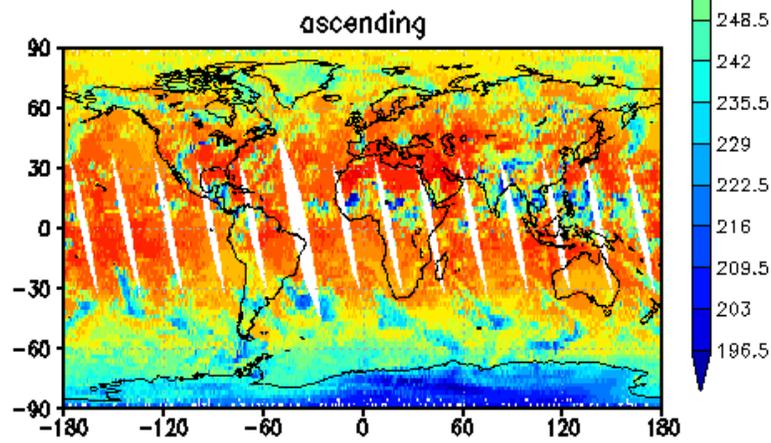
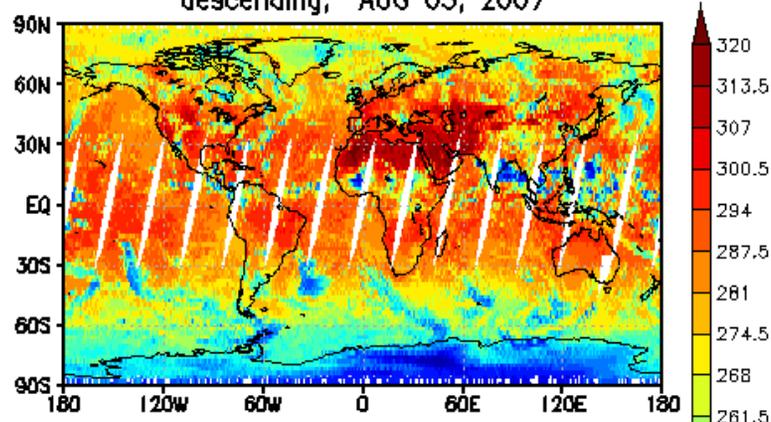
Reconstructed Radiances are a form of Noise Reduction

- Eigenvector analysis allows correlated data to be represented by a relatively small set of functions.
- 8461 channels can easily be represented by a 100 unique coefficients couples with 100 static structure functions (100 x 8461)
- Benefits: Noise filtering and data compression. Distribute and archive 100 coefficients instead of 8461 channels (85:1 lossy compression)
- Reconstructed radiances have lower random noise. Big impact in IASI SW - we can now use shortwave IR window channels for applications (LW vs SW cloud tests)

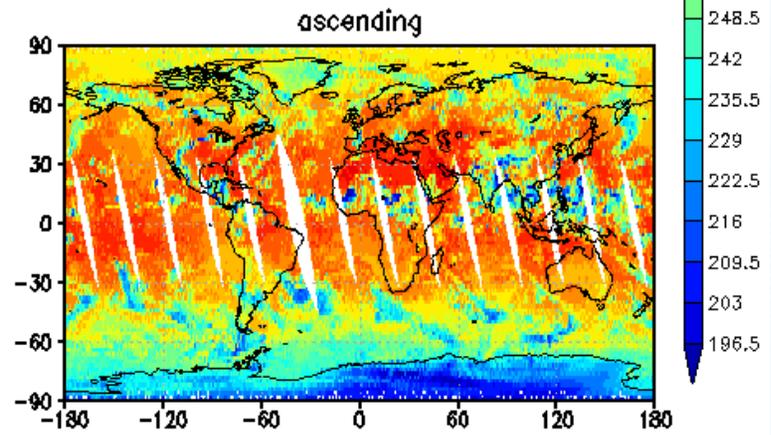
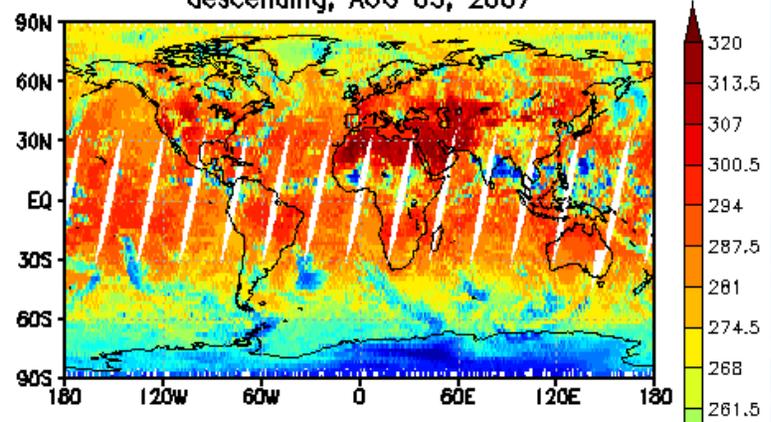


Reconstructed Radiance from PC's

Reconstructed IASI [875cm⁻¹]
descending, AUG 05, 2007



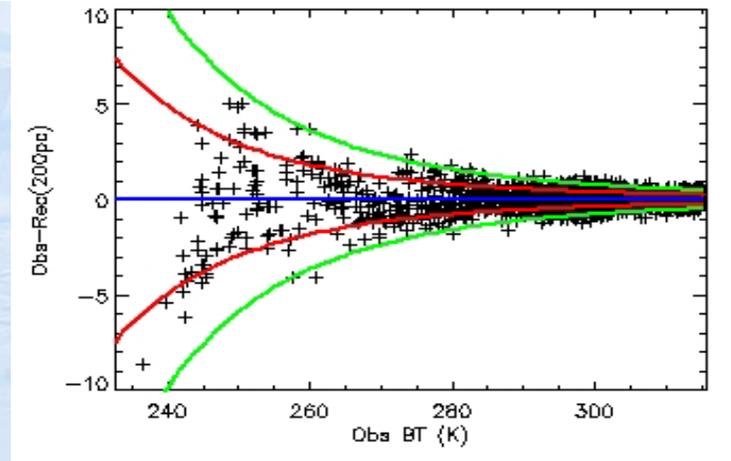
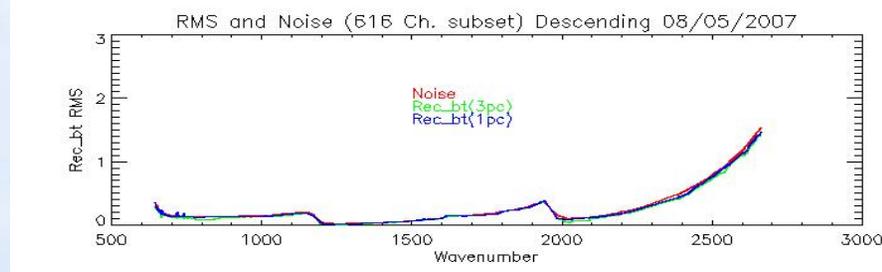
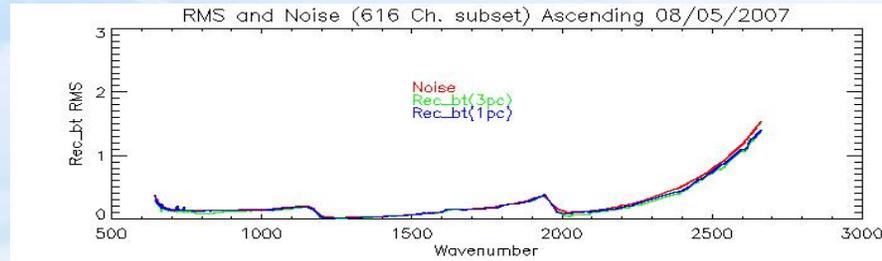
IASI Observation [875cm⁻¹]
descending, AUG 05, 2007





PC Analysis can be used to characterize the instrument noise using Earth scenes.

- PC's can be used to compute reduced noise radiance (reconstructed radiances).
- Subtracting observed radiance from reconstructed radiance gives an estimate of instrument noise derived from Earth scenes.
- At upper right is IASI noise (red curve) derived from blackbody measurements compared with noise derived from PC's. PC's generated from all 8461 channels shown in blue) and PC's generated from the 3 individual bands (green) are very similar and very close to the black body derived noise.
- At lower right is the NEDT noise estimate for a single channel (2500 cm⁻¹ on Sept. 10, 2007) shows the expected characteristics as a function of scene temperature (red lines are 1 sigma NEDT and green is 2 sigma NEDT).





Data Assimilation: Principal Component 1D-Var

- One way to exploit significantly more information from Advanced IR sounders would be to process the observations in principal component (PC) space.
- Applying eigenvectors to each incoming IASI observation would enable the compression of thousands of channels into just a few hundred PCs, containing more information about the state of the atmosphere than a similar number of selected channels.
- PC radiative transfer is now maturing, with models such as **PCRTM** (Liu et al. 2006, LaRC) and **HT-FRTC** (the Havemann Taylor Fast Radiative Transfer Code, UKMet) for use in a PC-based experimental 1D-Var.

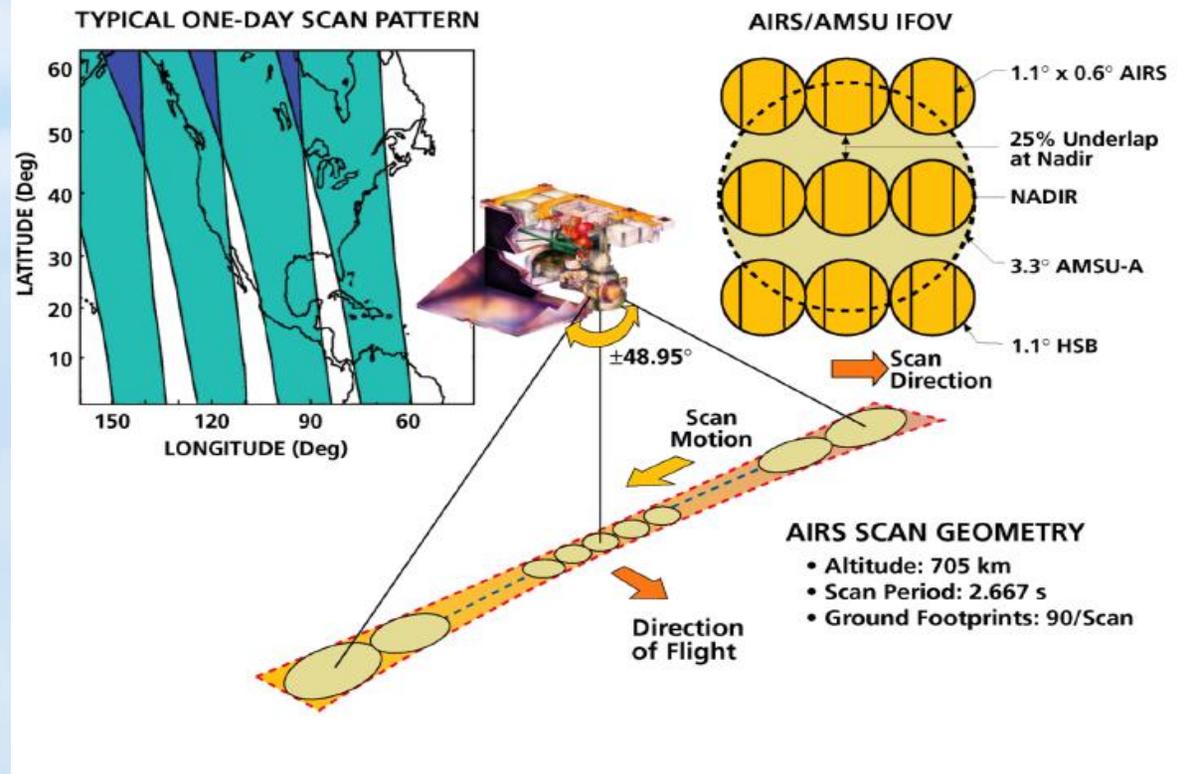


Geophysical Products

- Using a 1st principles approach
 - Products envisioned for both weather and climate applications.
 - Minimize external influence.
 - Goal is to include averaging kernel and error estimation in operations – currently available in off-line system.
- Testing new product concepts.
- Instrument and spectroscopic characterization.
 - Analyzing long term biases (*e.g.*, CO₂)
- Instrument monitoring
 - Use geophysical space and radiance space to understand algorithm and instrument issues.

Sounding Strategy in Cloudy Scenes: Co-located Thermal & Microwave (& Imager)

- Sounding is performed on 50 km a field of regard (FOR).
- FOR is currently defined by the size of the microwave sounder footprint.
- IASI/AMSU has 4 IR FOV's per FOR
- AIRS/AMSU & CrIS/ATMS have 9 IR FOV's per FOR.
- ATMS is spatially over-sampled can emulate an AMSU FOV.



**AIRS, IASI, and CrIS all
acquire 324,000 FOR's per day**

Spatial variability in scenes is used to correct radiance for clouds.

- Assumptions, $R_j = (1-\alpha_j)R_{clr} + \alpha_j R_{cld}$
 - Only variability in a set of IASI pixels is cloud amount, α_j
 - Reject scenes with excessive surface & moisture variability (in the infrared).
 - Within field of regard (4 IASI scenes) there must be spatial variability of cloud amount
 - Reject scenes with uniform non-zero cloud amount
- We use the microwave radiances and 4 sets of IASI cloudy infrared radiances to determine a set of 4 parameters and quality indicators to derive 1 set of cloud cleared infrared radiances.

$$R_{ccr} = \langle R_j \rangle + \eta_j (\langle R_j \rangle - R_j)$$
- Roughly 70% of any given day satisfies these assumptions.

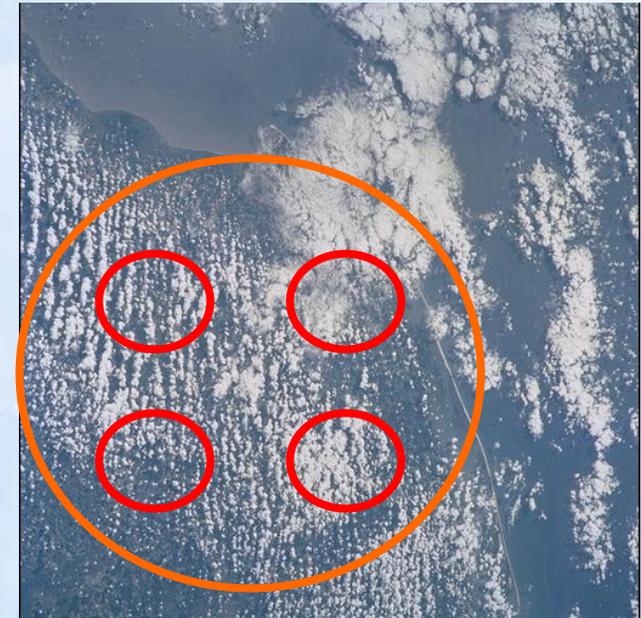
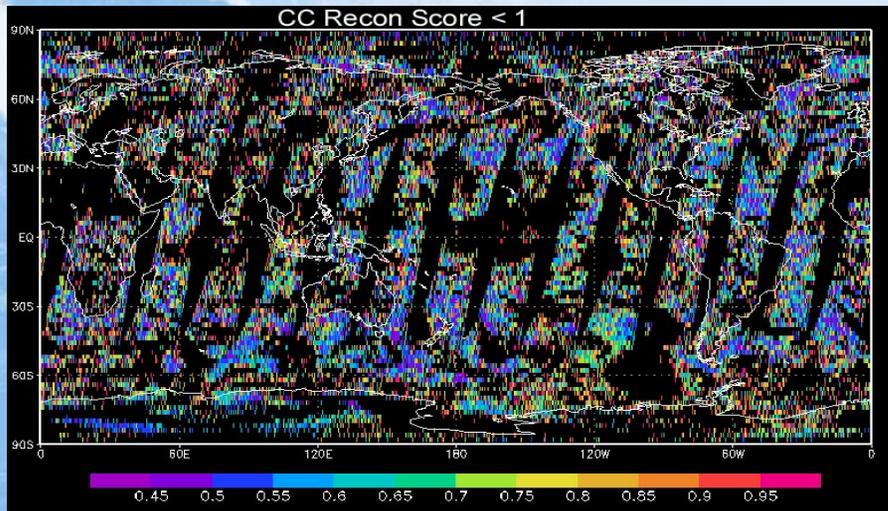
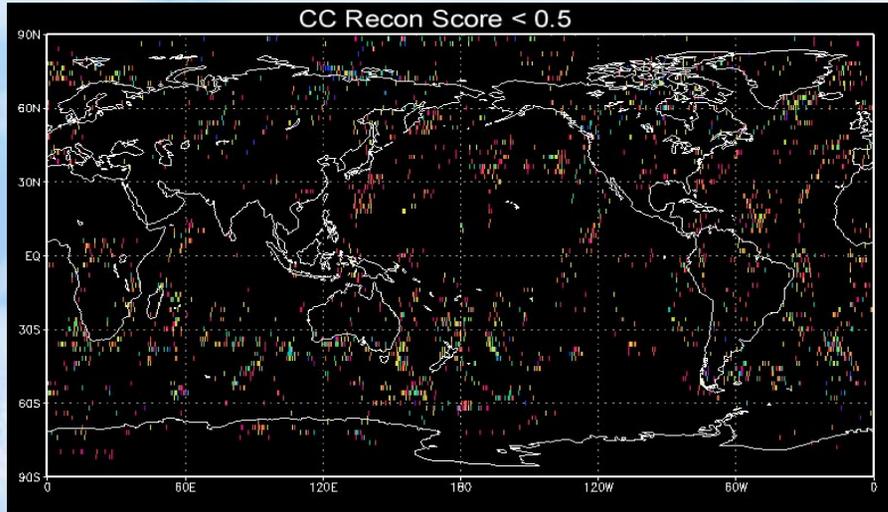


Image Courtesy of Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center (<http://eol.jsc.nasa.gov>). STS104-724-50 on right (July 20, 2001). Delaware bay is at top and Ocean City is right-center part of the images.

Cloud Clearing Dramatically Increases the Yield of Products



- *AIRS experience:*
 - Typically, less than 5% of AIRS FOV's (13.5 km) are clear.
 - Typically, less than 2% of AIRS retrieval field of regard's (50 km) are clear.
- Cloud Clearing can increase yield to 50-80%.
- Cloud Clearing reduces radiance product size by 1:9 for AIRS and 1:4 for IASI.

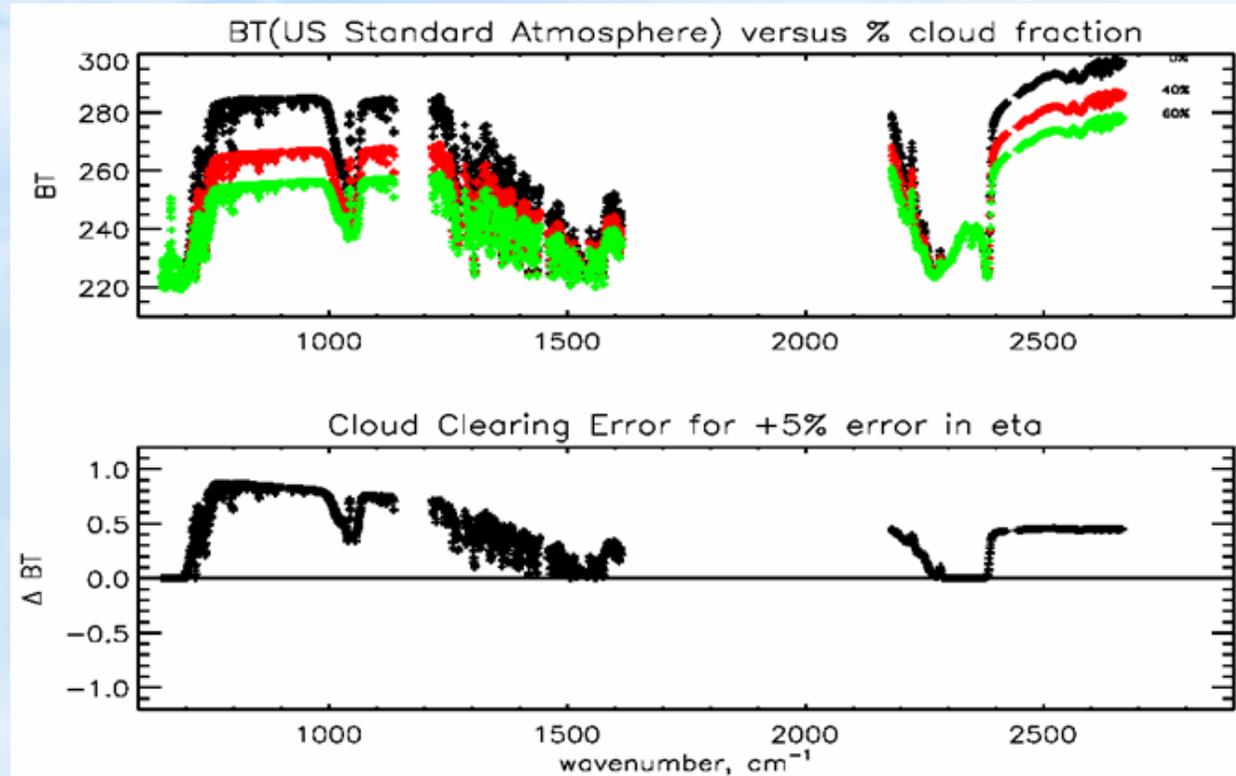


However, cloud cleared radiances are spectrally correlated.

Example AIRS spectra at right for a scene with $\alpha=0\%$ clouds (black), $\alpha=40\%$ clouds (red) and $\alpha=60\%$ clouds (green).

Radiance differences are proportional to amount of clouds, there can use a subset of channels to determine extrapolation parameters, η_j , to cloud clear entire spectrum

However errors in η produce spectrally correlated errors,

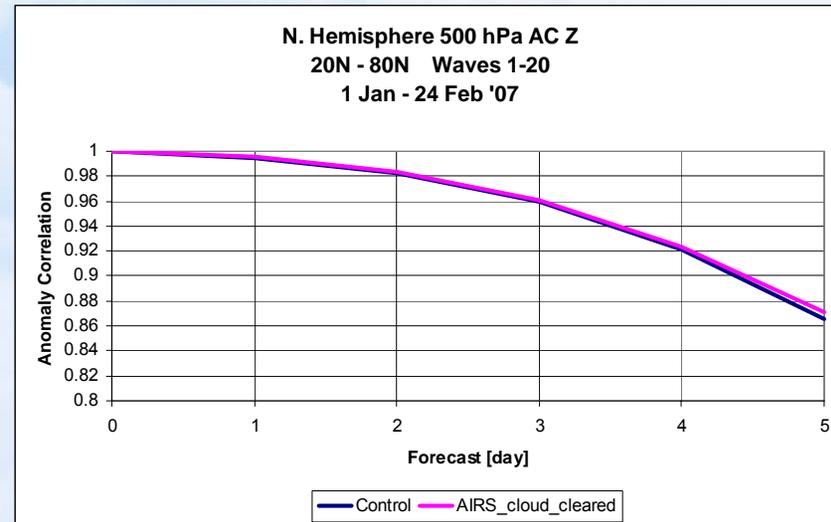


In this 2 FOV example, the cloud clearing parameters, η_j , is equal to $\frac{1}{2}\langle\alpha\rangle/(\alpha_j-\langle\alpha\rangle)$



Impact of AIRS cloud cleared radiances in data assimilation.

- John LeMarshall and Jim Jung have recently shown that AIRS cloud cleared radiances, provided by STAR, have the potential for improving coverage in the lower part of the troposphere by the use of radiances generated from the clear parts of cloudy fields of view.
- STAR is producing cloud cleared radiances from the MeTOP/IASI instrument using the AIRS science team approach. We expect this to be an operational product in July 2008.
- Big issue is how to QA the cloud cleared radiances
 - AIRS science team approach is to use an empirical error estimator trained on ECMWF.
 - Future plans are to use MODIS/AVHRR clear flagged pixels to select AIRS/IASI scenes where cloud clearing assumptions were met.

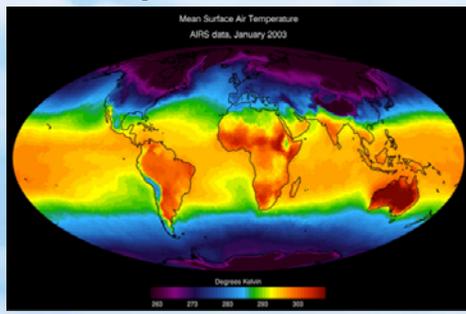


500 hPa anomaly correlations between a control (blue line) and AIRS cloud cleared radiance (CCR) experiment (pink line). The Control uses all operational observations including AIRS single field of view data. The AIRS CCR experiment is identical except AIRS single field of view data was replaced with AIRS version 4 CCR's.

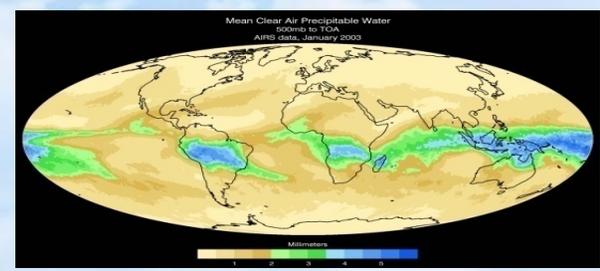


AIRS Products Derived from Cloud Cleared Radiances

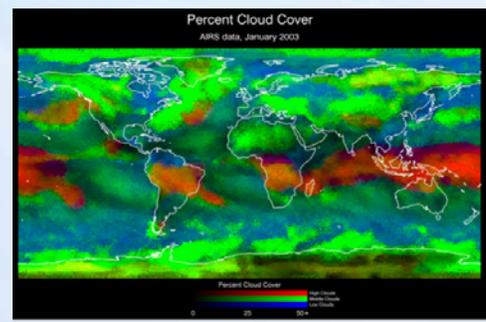
Temperature Profiles



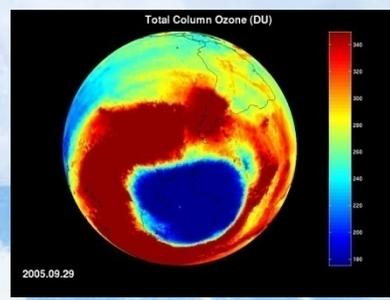
Water Vapor Profiles



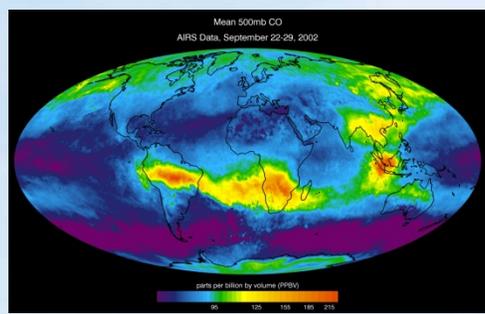
Clouds



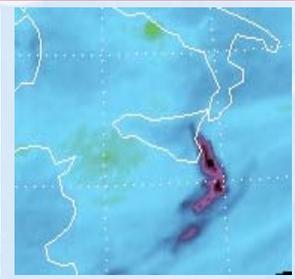
Ozone



CO

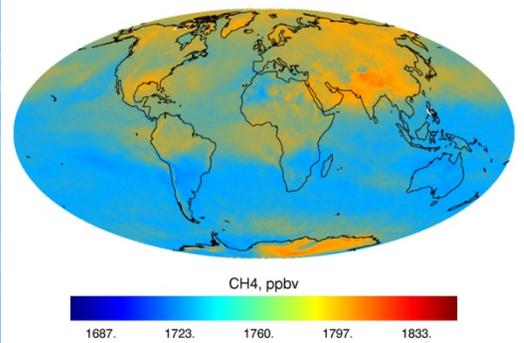


Experimental Products

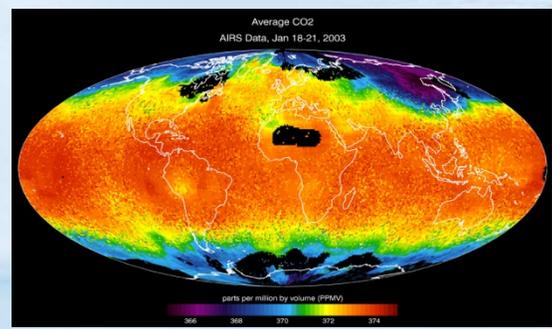


SO2

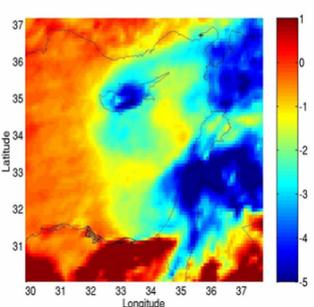
Methane



CO2



AIRS vs MODIS AEROSOLS Eastern Mediterranean Dust Storm



Dust



Thermal Sounder “Core” Products (on 45 km footprint, unless indicated)

<i>Radiance Products</i>	<i>RMS Requirement</i>	<i>Current Estimate</i>
AIRS IR Radiance (13.5 km)	3%	< 0.2 %
AIRS VIS/NIR Radiance	20%	10-15%
AMSU Radiance	0.25-1.2 K	1-2 K
HSB Radiance (13.5 km)	1.0-1.2 K	(failed 2/2003)
<i><u>Geophysical Products</u></i>	<i><u>RMS Requirement</u></i>	<i><u>Current Estimate</u></i>
Cloud Cleared IR Radiances	1.0K	< 1 K
Sea Surface Temperature	0.5 K	0.8 K
Land Surface Temperature	1.0K	TBD
Temperature Profile	1K/1-km layer	1K/1-km
Moisture Profile	15%/2-km layer	15%/2-km
Total Precipitable Water	5%	5%
Fractional Cloud Cover (13.5 km)	5%	TBD
Cloud Top Pressures	0.5 km	TBD
Cloud Top Temperatures	1.0 K	TBD



Radiances versus Products

Radiance

Retrieval Products

Product volume is large: In practice, a spectral subset (10%), spatial subset (5%), and clear subset (5%) of the observations is made

Product volume is small: all instrument channels can be used to minimize all parameters (T,q,O₃,CO,CH₄,CO₂,clouds,etc.)

Instrument error covariance is usually assumed to be diagonal. For apodized interferometers (e.g. IASI) this is not accurate.

Product error covariance has vertical, spatial, and temporal off-diagonal terms.

Require very fast forward model, and derivative of forward model.

Most accurate forward model is used with a model of detailed instrument characteristics.

Small biases in T(p), q(p), O₃(p), due to model/satellite representation error, have large impact on derived products.

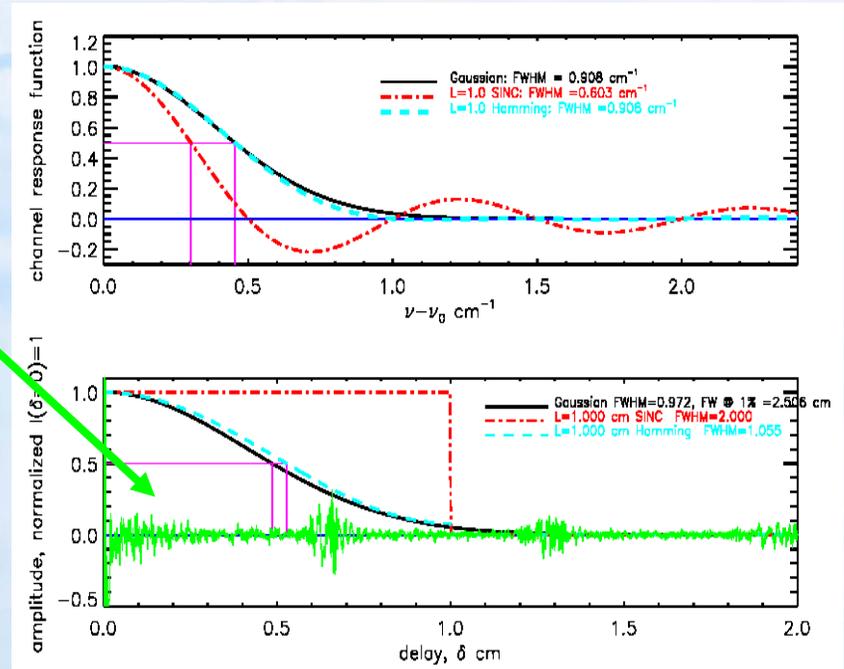
A-priori used in retrieval is different than assimilation model; however, vertical kernel information can be used to assimilate product.

Tendency to weight the instrument radiances lower (due to representation error) to stabilize the model. Need correlation lengths to stabilize model horizontally, vertically, and temporally.

Retrieval weights the radiances as high as possible, since determined state is on *instrument* sampling “grid.”

An Example of a Spectrally Correlated Noise: IASI (and CrIS) Apodization

- Interferometers measure the cosine transform (green curve) of radiance as a function of optical delay, δ
- Radiance is computed from an inverse cosine transform of the *interferogram*.
- Un-apodized transforms (red) have a $\text{SINC}(x)=\text{SIN}(x)/x$ instrument line shape (ILS).
- AIRS has a Gaussian ILS (black)
- Apodization can produce a ILS that is localized and has small ($< 1\%$) side lobes. But the tradeoff is that the central lobe is wider and the signal is spectrally correlated between neighboring channels



	Gaussian	Hamming	Blackman
FWHM / FWHM(SINC)	1.682	1.5043	1.905
Random Noise reduction	1.735	1.586	1.812
Maximum Side-Lobe	0.45%	0.73%	0.12%
% of signal in central Lobe	95.1%	87.5%	99.8%

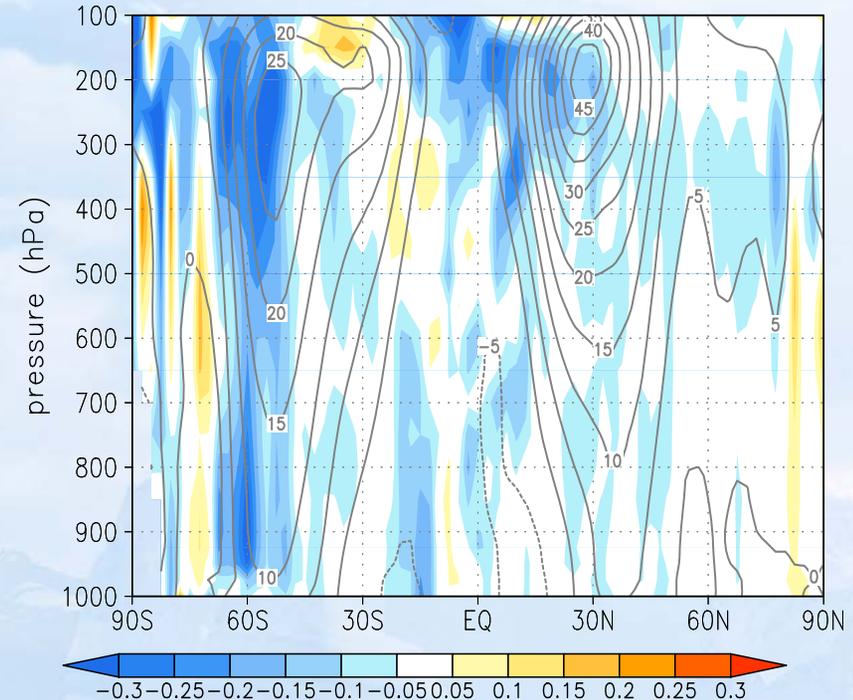
Channel Correlation

Channel	Gaussian	Hamming	Blackman
± 1	70.74%	62.5%	75.5%
± 3	25.0%	13.3%	31.6%
± 4	4.43%	-	6.57%
± 5	0.38%	-	0.53%
± 6	0.025%	-	-



AIRS moisture retrievals show positive impact in an assimilation study at UMCP

- Four years of AIRS 3°x3° gridded radiances were reprocessed using the v5 algorithm. Temperature & moisture profiles for a couple of months with ensemble covariance matrices were provided to Junjie Liu and Eugenia Kalnay at UMCP.
- The AIRS profiles were assimilated into the UMCP Local Ensemble Transform Kalman Filter (LETKF) model using a static error covariance matrix provided by STAR.
- Preliminary results of this study were presented by Eugenia Kalnay at a STAR seminar on Dec. 4, 2007.
 - Pseudo relative humidity (RH), $q/q_{\text{sat}}(T_b, q_b)$, is a better variable to use than RH or specific humidity.
 - Positive impact on global winds in the upper tropics were seen.



Difference in zonal wind RMS w.r.t. NCEP analysis between a run w/ AIRS T & q and a control run (with AIRS T profiles). Areas shaded in blue have improved (lower RMS w.r.t. analysis) with the AIRS moisture information.



Retrieval of Atmospheric Trace Gases Requires Unprecedented Instrument Specifications

- **Need Large Spectral Coverage (multiple bands) & 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.
 - Allow simultaneous retrievals of $T(p)$, $q(p)$, $O_3(p)$.
- **Need High Spectral Resolution & Spectral Purity**
 - Ability to isolate spectral features → vertical resolution
 - Ability to minimize sensitivity to interference signals..
- **Need Excellent Instrument Noise & Instrument Stability**
 - Low $NE\Delta T$ 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).**



Trace Gas Products from AIRS & IASI

gas	Range (cm ⁻¹)	Precision	d.o.f.	Interfering Gases	AIRS	IASI
H ₂ O	1200-1600	15%	4-6	CH ₄ , HNO ₃	NASA DAAC	Apr 2008
O ₃	1025-1050	10%	1.25	H ₂ O, emissivity	NASA DAAC	Apr 2008
CO	2080-2200	15%	≈ 1	H ₂ O, N ₂ O	NASA DAAC	Apr 2008
CH ₄	1250-1370	1.5%	≈ 1	H ₂ O, HNO ₃ , N ₂ O	NASA DAAC	Apr 2008
CO ₂	680-795 2375-2395	0.5%	≈ 1	H ₂ O, O ₃ T(p)	NOAA NESDIS	Apr 2008
<u>Volcanic</u> SO ₂	1340-1380	50% ??	< 1	H ₂ O, HNO ₃	TBD	TBD
HNO ₃	860-920 1320-1330	50% ??	< 1	emissivity H ₂ O, CH ₄ , N ₂ O	NOAA NESDIS	Apr 2008
N ₂ O	1250-1315 2180-2250 2520-2600	5% ??	< 1	H ₂ O H ₂ O, CO	NOAA NESDIS	Apr 2008
CFCl ₃ (F11)	830-860	20%	-	emissivity	No plans	No plans
CF ₂ Cl (F12)	900-940	20%	-	emissivity	No plans	No plans
CCl ₄	790-805	50%	-	emissivity	No plans	No plans

All products include concentrations and averaging kernels.

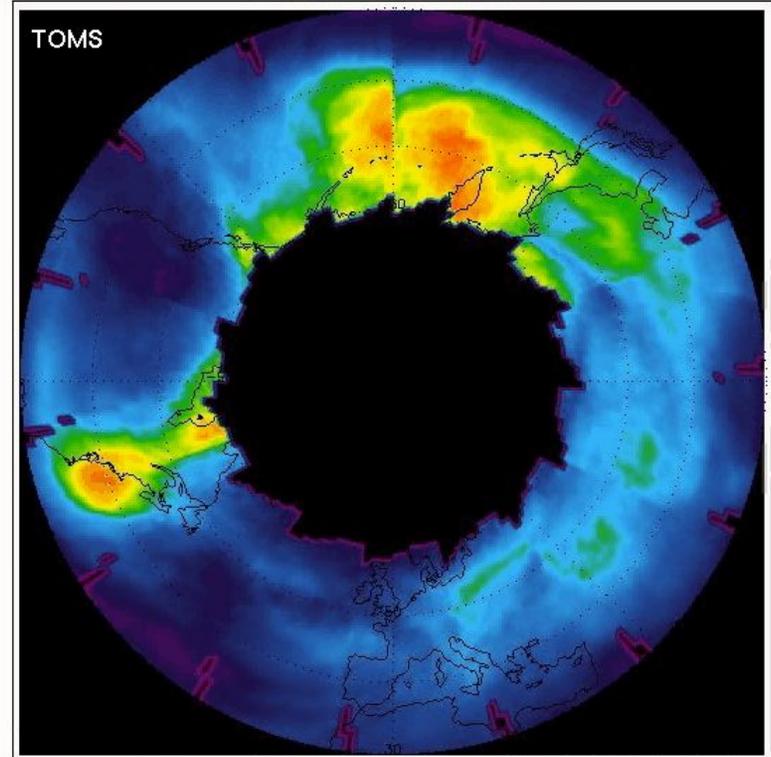
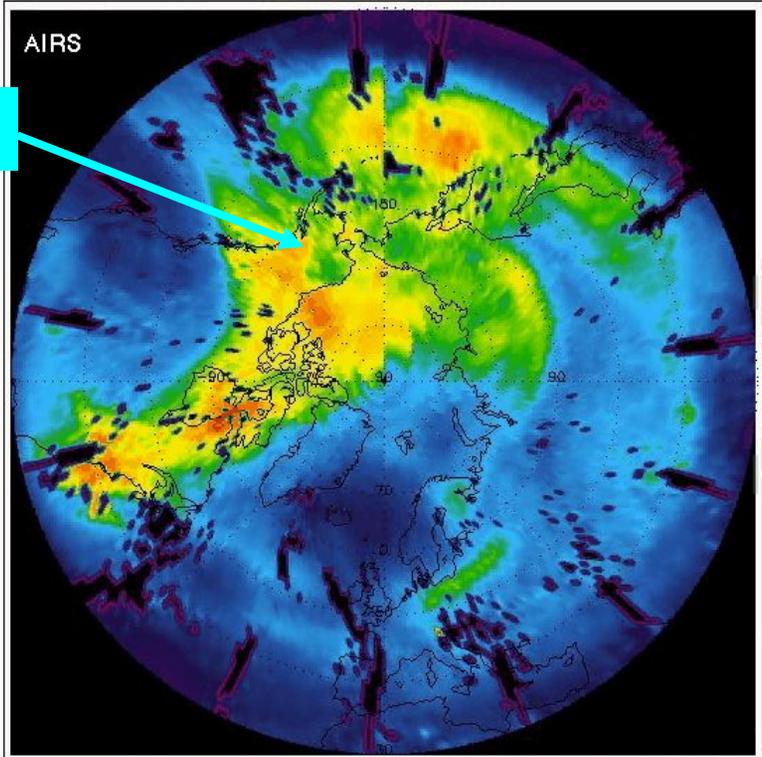


AIRS and TOMS Northern Polar Night

Mike Newchurch (UAH), Bill Irion (JPL)

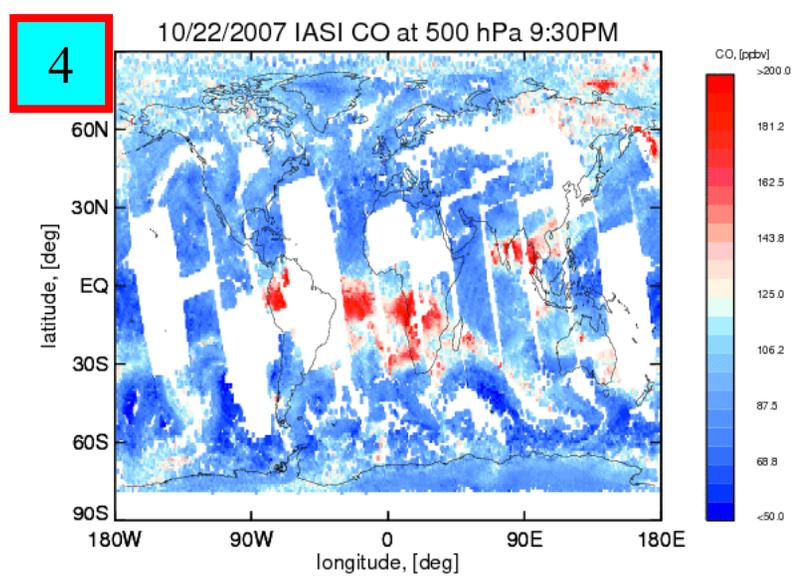
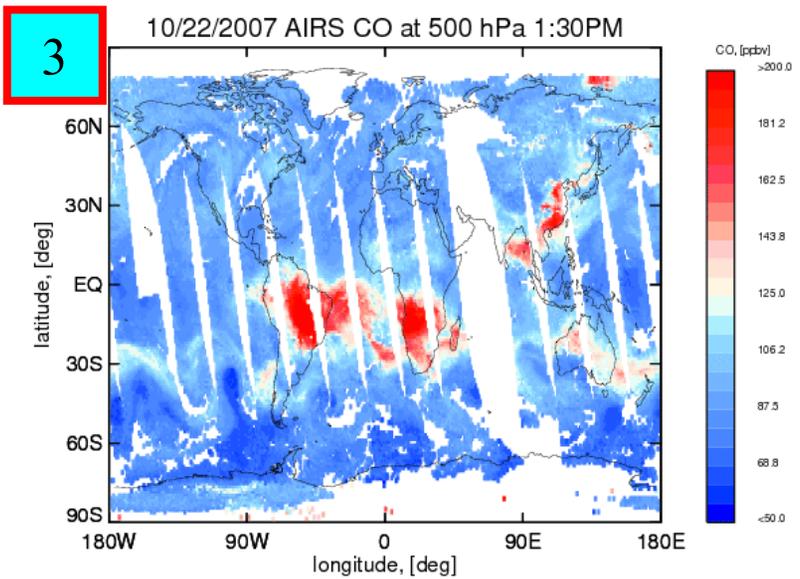
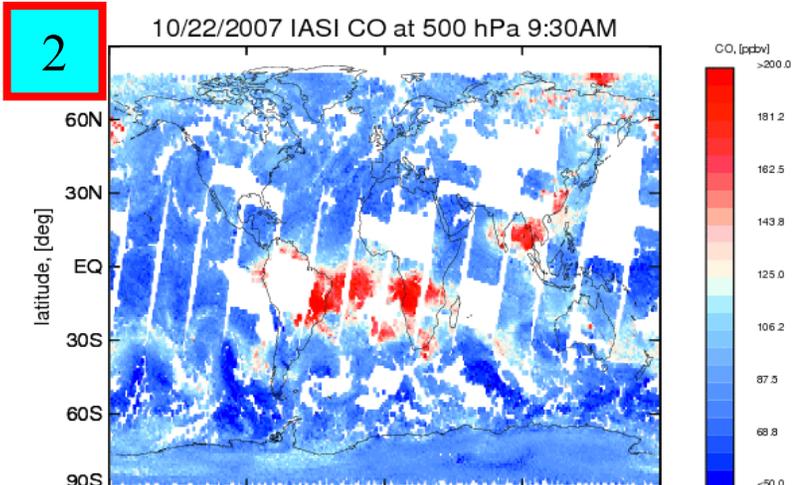
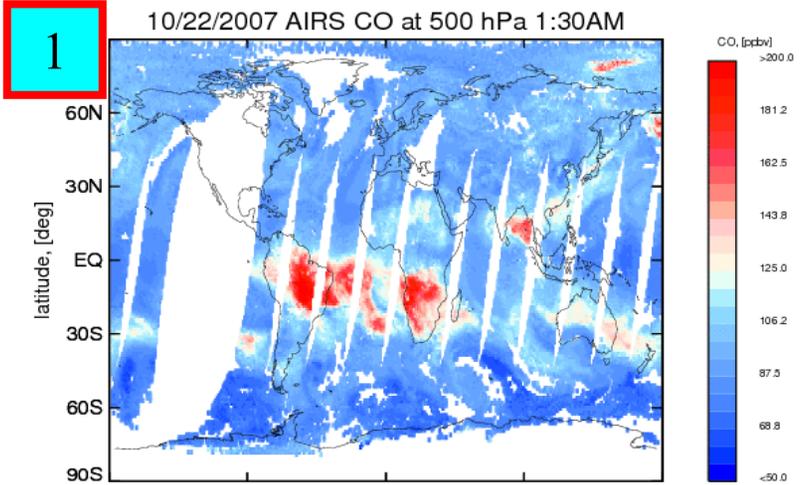
Total Ozone for 2003.01.07

EPT TOMS Ozone for 2003.01.07



Note: TOMS Ozone derived only when Sun is above horizon

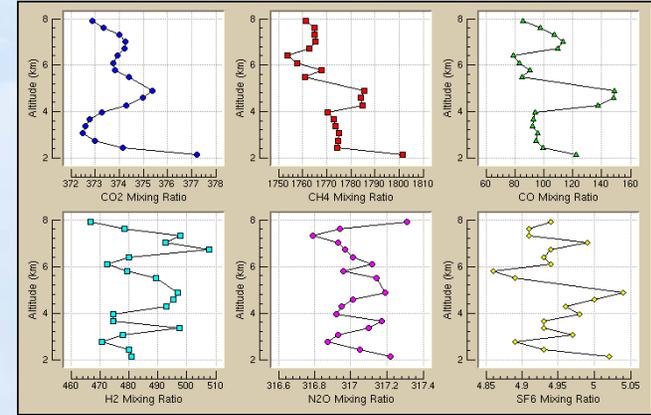
IASI & AIRS Carbon Monoxide Products on Oct. 19, 2007



NOTE: Gaps due to problems with data transmission....



Comparisons to ESRL/GMD aircraft observations (Bakwin, JGR, 2003)



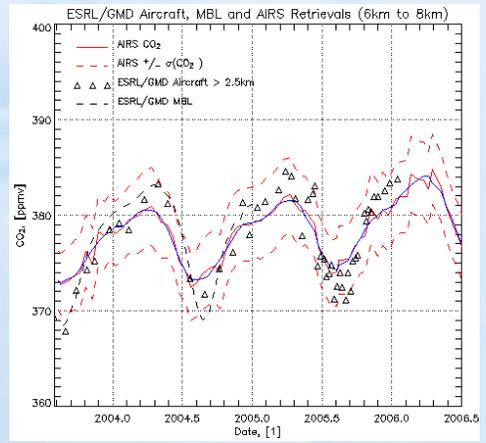
- Comparison of AIRS & ESRL/GMD flask observations..
 - Usually ≥ 5 hour time difference between aircraft and AIRS observations.
 - Aircraft altitude is typically ≤ 7 km.
 - Aircraft measures a small spatial region while it spirals downward.
- Aircraft measurement is vertically integrated to maximum flight height to emulate the thermal sounder measurement.
- Retrieval is spatially and temporally averaged of ≈ 50 “good” retrievals to achieve desired performance.



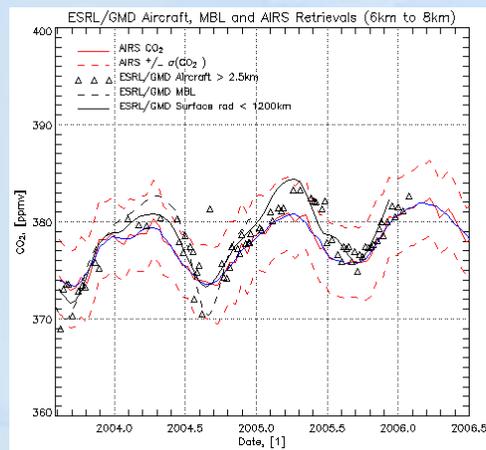
Application for Assimilation: CO₂ Climatology

- AIRS/IASI CO₂ monthly gridded product could be used to provide background for CO₂
 - Seasonal cycles
 - Latitude and longitude variability.
- AIRS/IASI product measures the CO₂ influence on infrared radiances.
 - Could reduce empirical bias corrections
 - May improve regional analysis

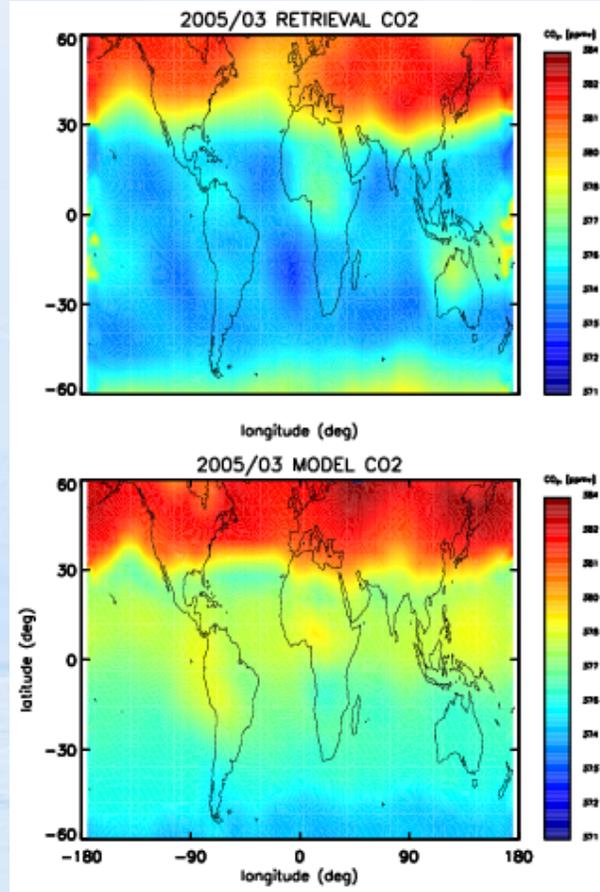
Estevan Point, British Columbia



Carr Colorado

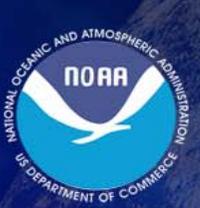


AIRS Retrieval





Future Work

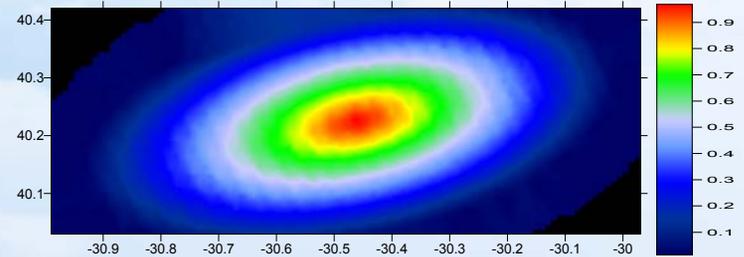


MODIS BUFR Work

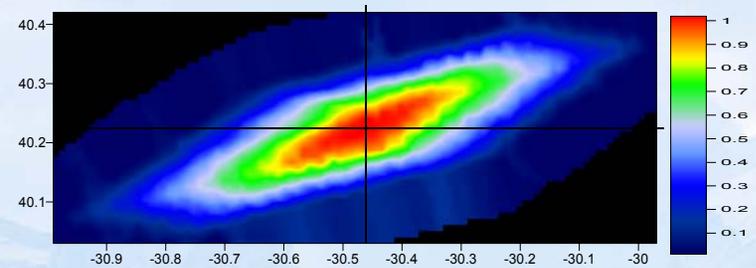
- MODIS Aerosol Optical Depth product from both TERRA and AQUA are being placed into BUFR format for NCEP.
- A BUFR Table has been created and reviewed.
- A test BUFR file has been made available and has been read by NCEP.
- Within a month, a real time flow of MODIS Aerosol Optical Depth files will be available for both TERRA and AQUA.

MODIS/AIRS Collocations

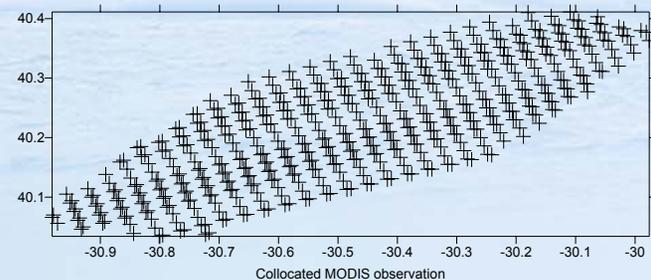
- MODIS data has been collocated to the AIRS footprints using both the spectral response and spatial response functions for both instruments.
- These collocations have enabled MODIS data to be averaged to the AIRS footprints.



Simplified AIRS EFOV SRF .Fp=1



Simulated AIRS EFOV SRF Fp=1





MODIS/AIRS Collocations

- BUFR files are being created for MODIS averaged to the AIRS footprints.
 - Can be used to QA cloud cleared radiances and/or select clear FOV's
- MODIS data that will be made available within the next year:
 - L1B
 - Level 2 products
- Similar products are envisioned for IASI/AVHRR and CrIS/VIIRS.
- If there is a prioritization of the L2 products, please let us know. Contact: chris.barnet@noaa.gov or walter.wolf@noaa.gov for more information.



BACKUP



Surface Emissivity Derived from High Spectral Resolution Sounders



Background

- Accurate infrared Land Surface Emissivity (LSE) knowledge is needed for deriving accurate retrieval of atmospheric temperature and moisture over land.
- LSE is also critical for the assimilation of sounder data over land into numerical weather prediction models.
- The observations from the new generation high spectral resolution sounders (such as AIRS, IASI, and CrIS) provide new opportunity to derive surface emissivity with high spectral resolution.
- The operational AIRS emissivity retrieval uses a NOAA regression emissivity product (Goldberg et al., 2003) as a first guess over land.
- The NOAA regression emissivity approach is based on clear radiances simulated from the ECMWF forecast and a surface emissivity training dataset.
- The training dataset is generated from the digitized observations of surface emissivity spectra, provided by NESDIS Joint Center for Satellite Data Assimilation (JCSDA).



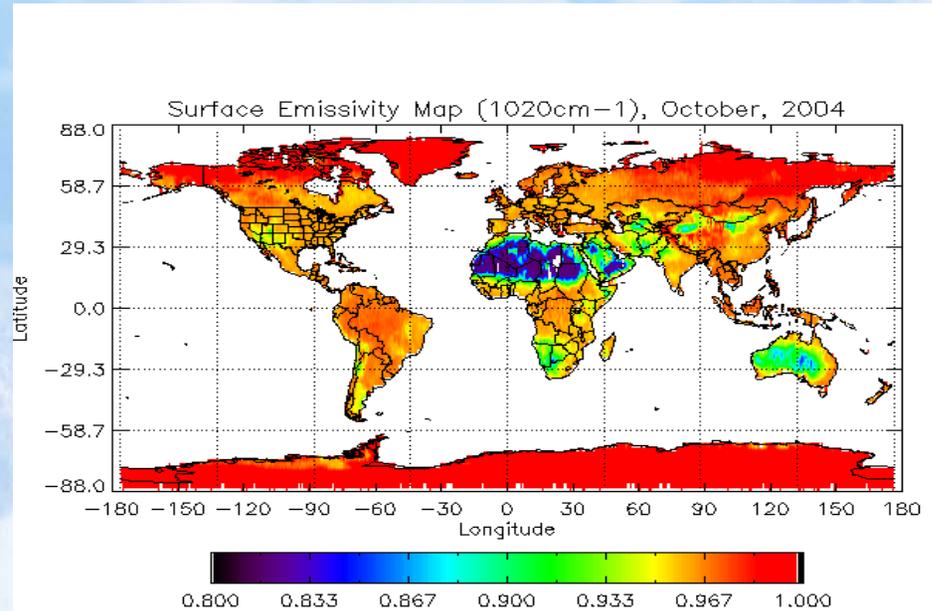
LSE Monthly Maps from AIRS

- Global monthly maps of LSE are derived by applying the regression technique on the AIRS daily global gridded datasets.
- Global coverage of LSE from AIRS is available twice daily for the past five years.
- Spatial resolution: $3^{\circ} \times 3^{\circ}$ or $0.5^{\circ} \times 2^{\circ}$
- Emissivity maps were produced for 39 hinge points:

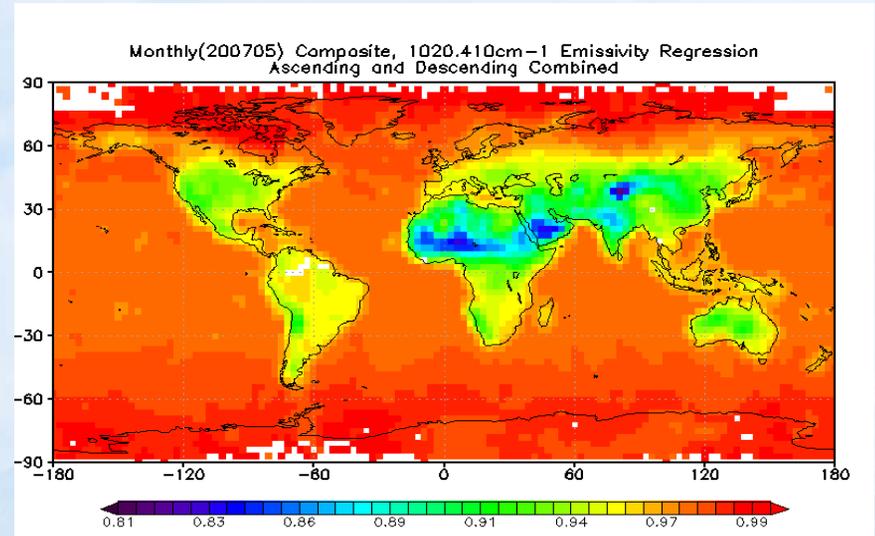
649.35	666.67	684.93	704.22	724.64
746.27	769.23	793.65	819.67	847.46
877.19	909.09	943.40	980.39	1020.4
1063.8	1111.1	1162.8	1204.8	1234.6
1265.8	1298.7	1333.3	1369.9	1408.4
1449.3	1492.5	1538.5	1587.3	1639.3
2173.9	2222.2	2272.7	2325.6	2380.9
2439.0	2500.0	2564.1	2631.6	



Monthly Averaged Surface Emissivity (1020cm⁻¹)



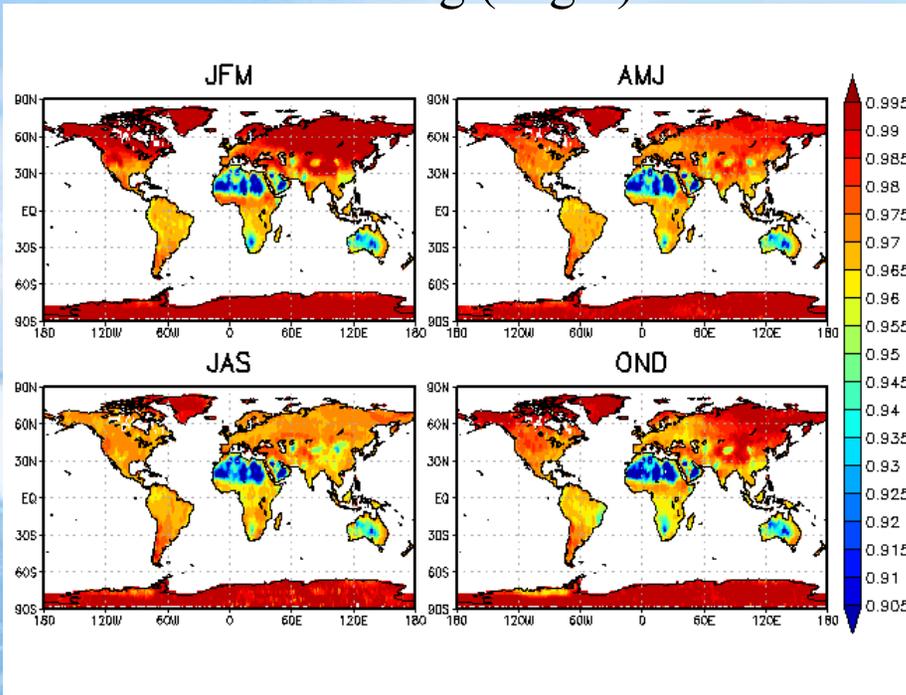
AIRS



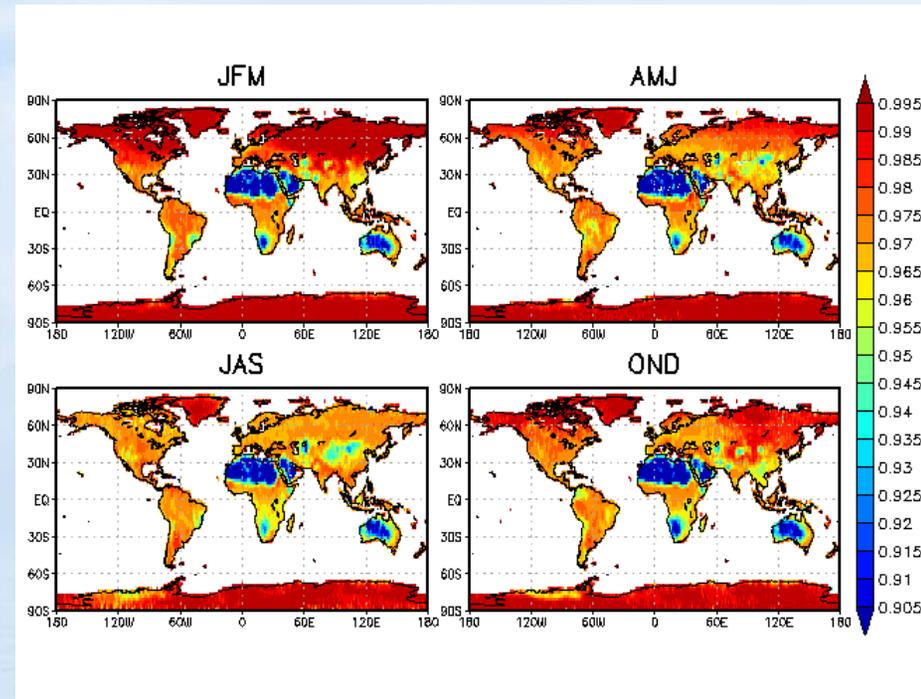
IASI

AIRS Results: Seasonal characteristics in 2005 at 980 cm^{-1}

Descending (Night)



Ascending (Day)



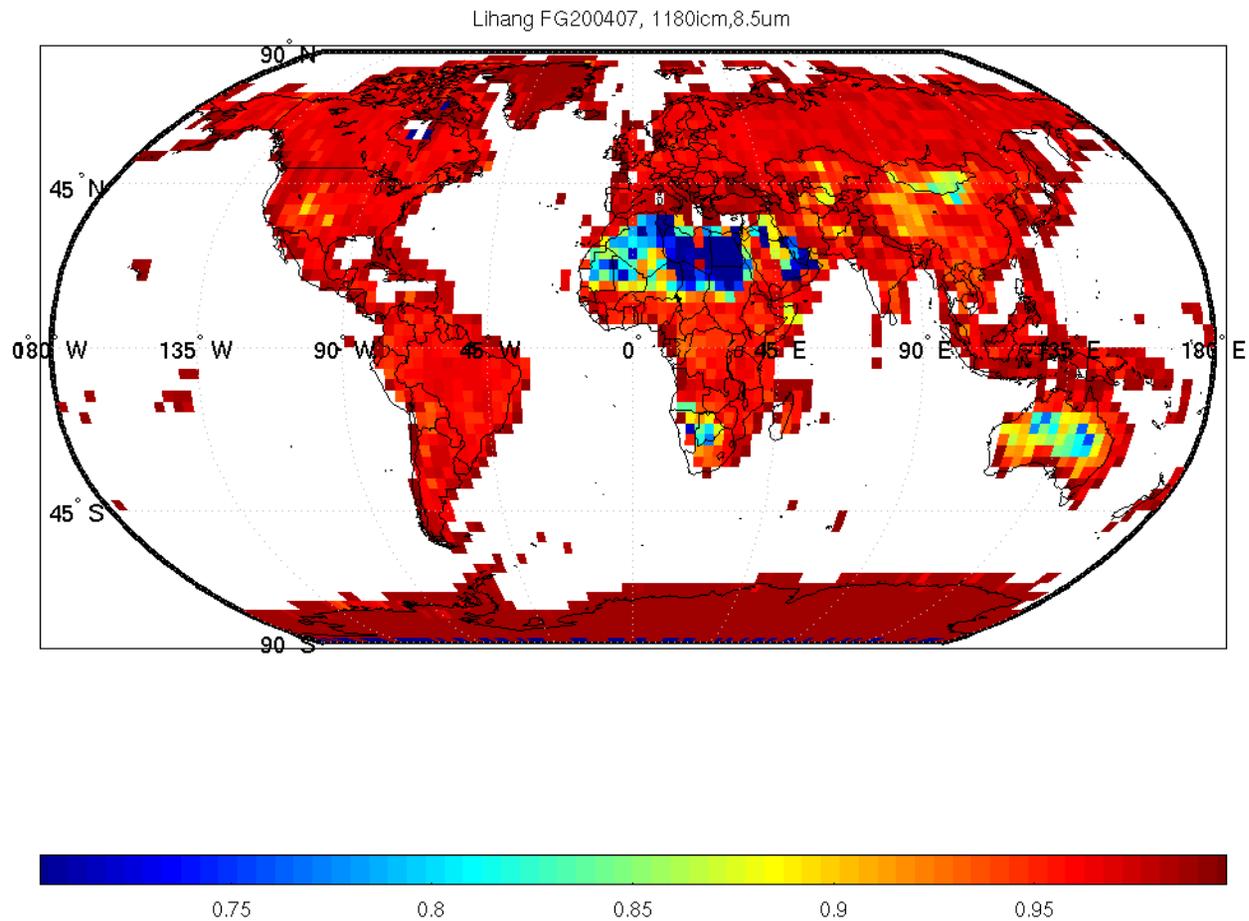


LSE Comparison:

NESDIS AIRS Regression vs. Seeman & Borbas' (S&B)

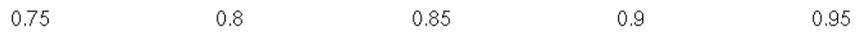
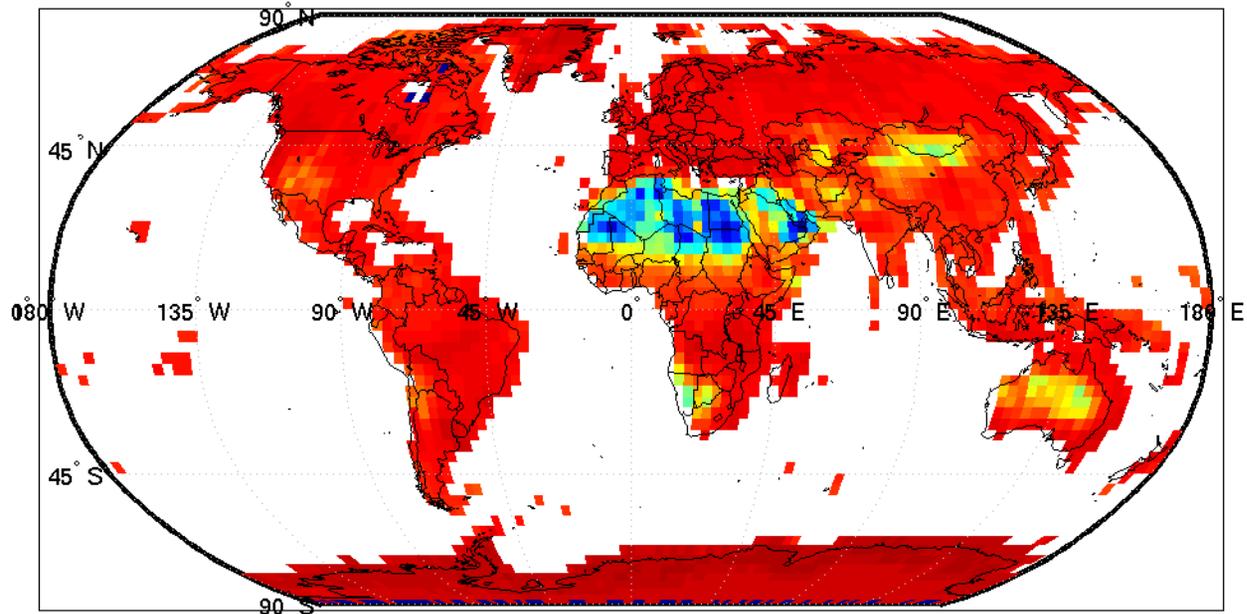
- We provided AIRS Regression Emissivity data to the Emissivity Group in Wisconsin (E. Borbas, B. Knuteson, L. Moy, S. Seeman).
- Comparisons with S&B from MODIS emissivity products were performed by the Wisconsin group (examples are shown in next slides).
 - Compared monthly averages emissivity for July 2004
 - Interpolated S&B emissivities onto AIRS wavebands
 - Averaged S&B values that fell inside AIRS grid-boxes (S&B gridding is 7200x3600, AIRS is 120x61)
- Globally, NESDIS Regression and S&B LSE agree well (difference within 1%).
- Large differences exist over coastal area, which may be due to the spatial interpolation; and the desert region, where the large variations of emissivity occur.

AIRS Regression, 8.5um

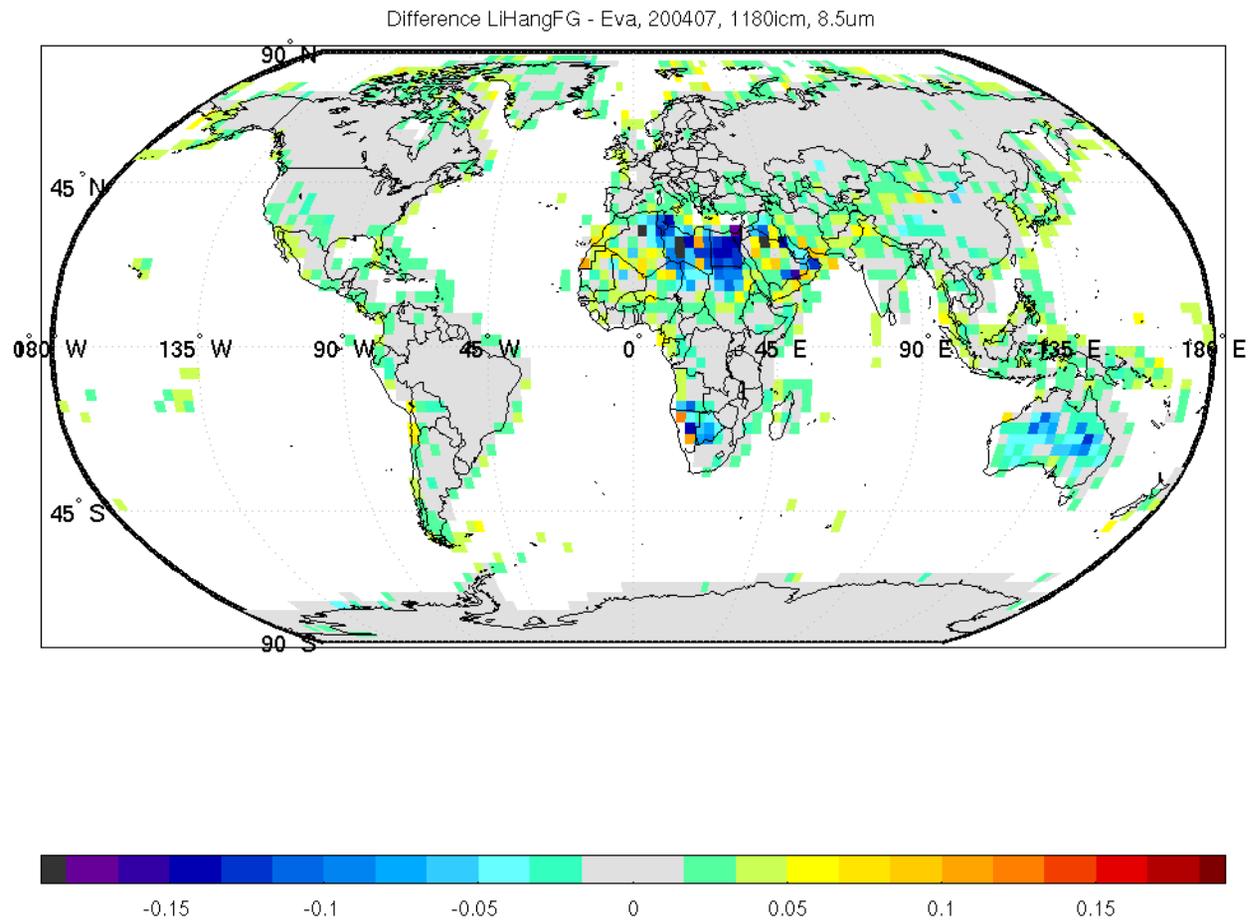


S&B, 8.5um

Eva avg onto Lihang grid, 200407, 1180icm, 8.5um



AIRS Regression - S&B, 8.5um



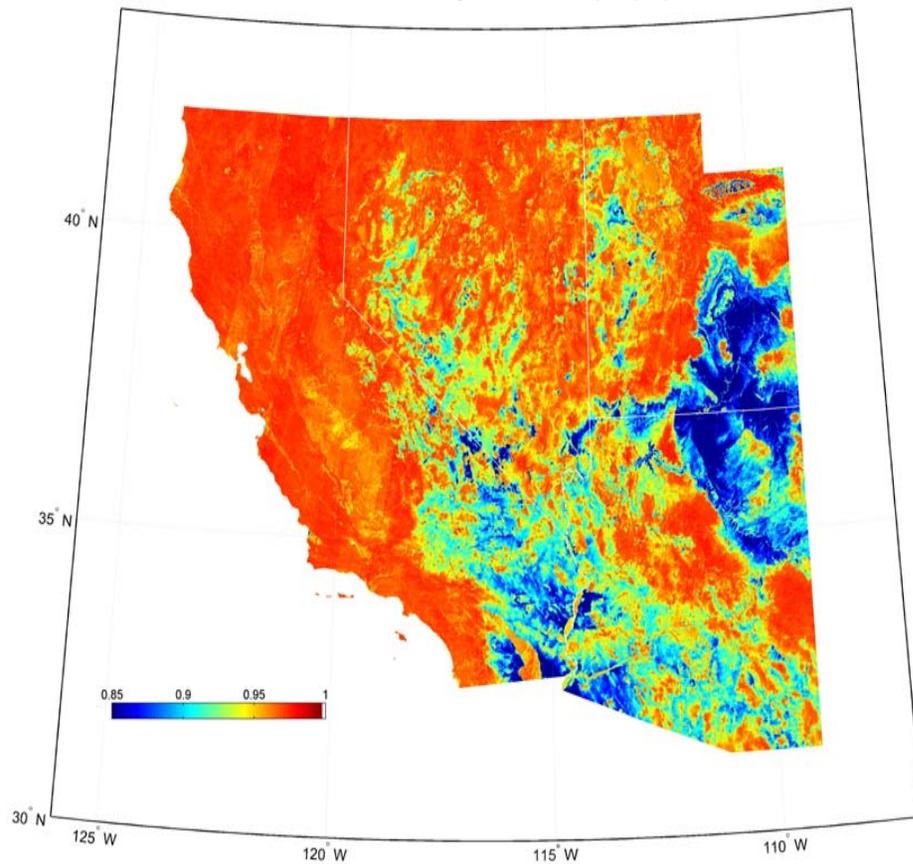


AIRS (v5.0) and ASTER Mean Summer Emissivity Comparisons

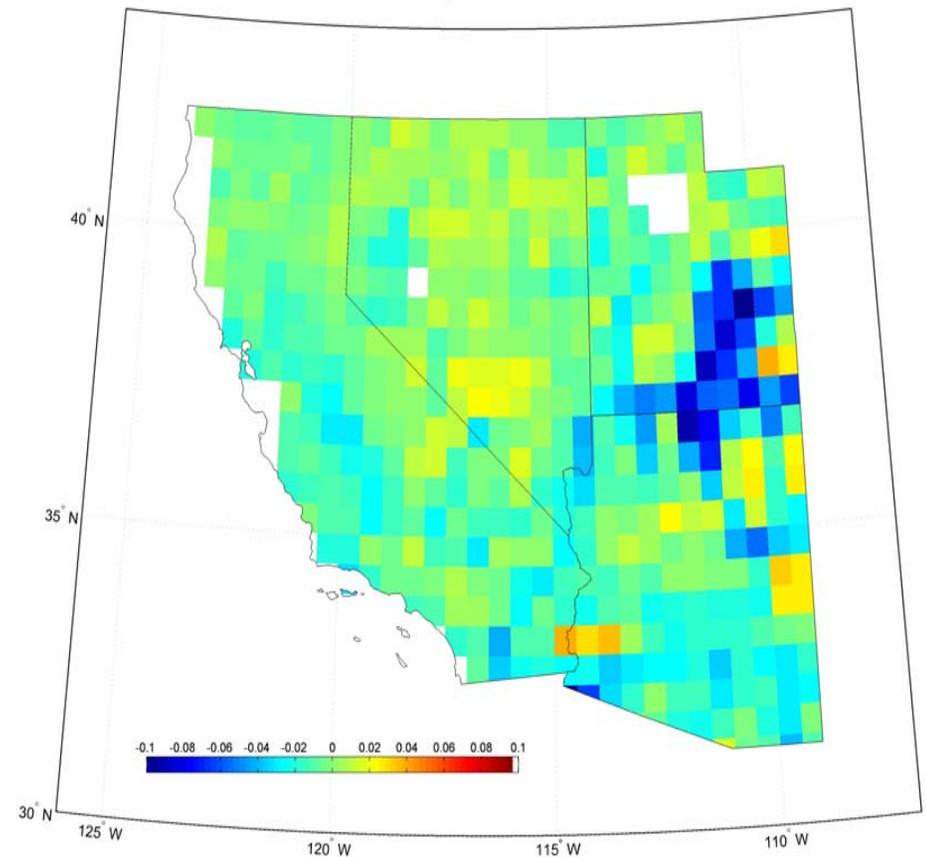
Comparison done by Glynn Hulley and Simon Hook (JPL)

Presented at AIRS Science Team Net Meeting, Mar 13, 2008

ASTER Mean Summer Emissivity for Band 10 (8.3 μm) from 2000-2008

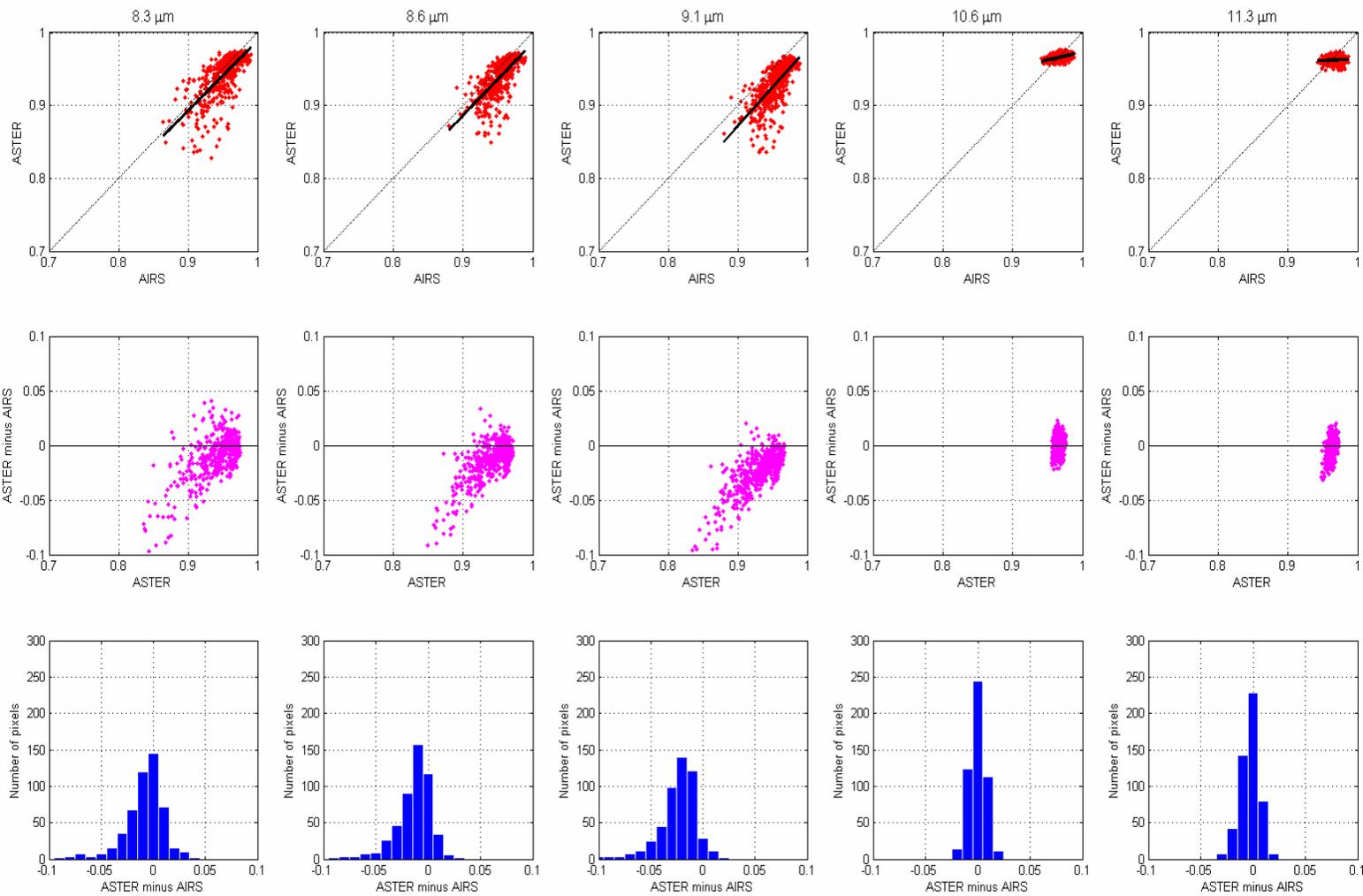


ASTER minus AIRS Mean Summer Emissivity at 8.3 μm
2002-2008, 50 km resolution





AIRS (v5.0) and ASTER Emissivity Comparisons for all 5 ASTER TIR bands





Future Activities for Emissivity Regression (First Guess) Product

- Upgrade to LSE regression:
 - Simulation with the latest RTAs.
 - Experiment with adding more surface type information.
 - Use collocate MODIS baseline LSE database for regression training.
- Providing AIRS and IASI emissivity datasets to improve the STAR Land IR dielectric constant retrieval and emissivity modeling.
- Build the global emissivity datasets tailoring to users' request (15 days, monthlies, angular bins...).



Improvements to Physical Emissivity Retrieval

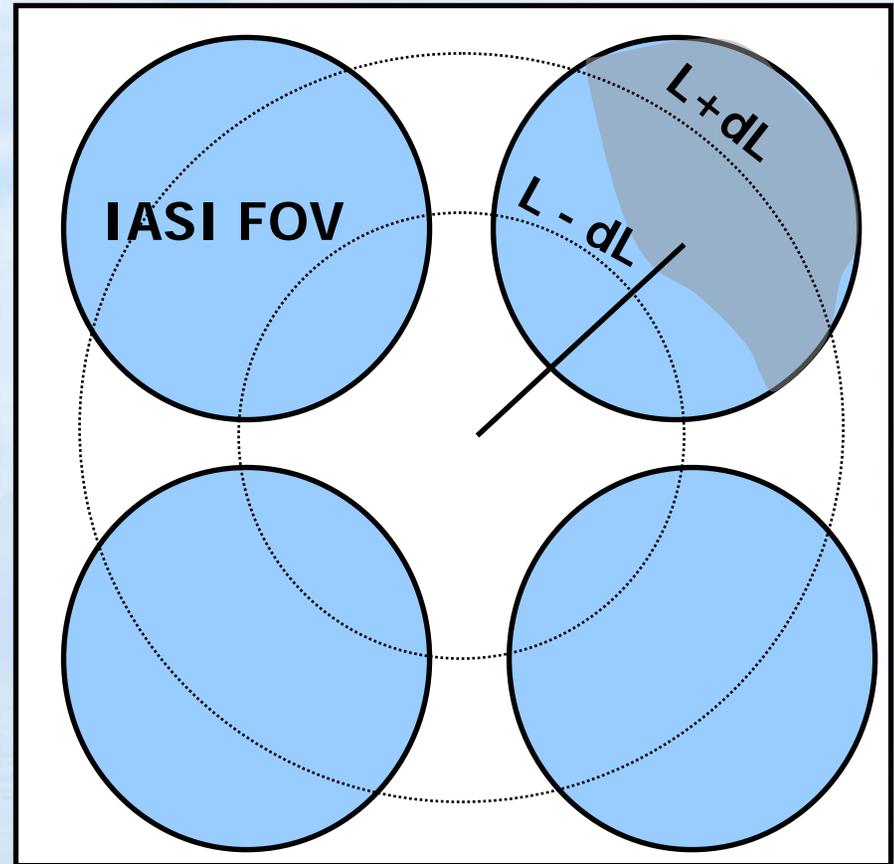
- The AIRS Science Team (Joel Susskind) has made a number of recommendations
 - Increase number of channels used
 - Improved reflectivity first guess.
 - Use SW for skin temperature
 - Solving for $(1-\epsilon)$ is more stable.
- “Truth” datasets are difficult to come by, but day and night differences tell us if the new methodology is more realistic and stable.

ILS Sub-pixel Correction

- Interferometer ILS varies over the FOV scene because of differences in the optical path, L
- Interferometer ILS for a heterogeneous scene is also a function of the distribution of radiance in the sub-pixel space

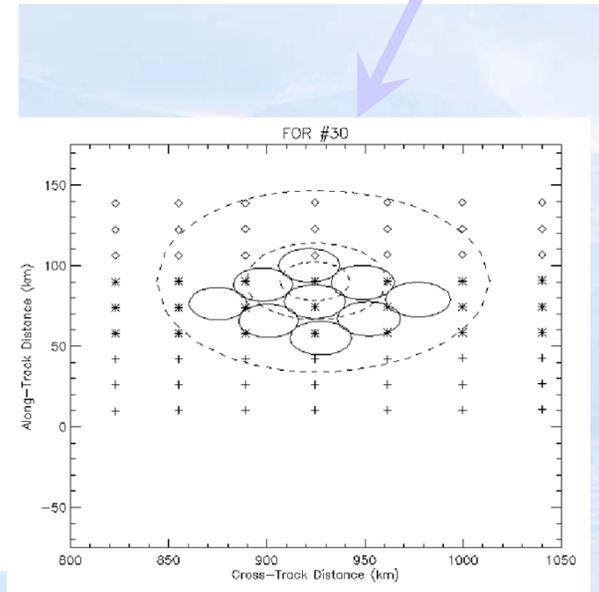
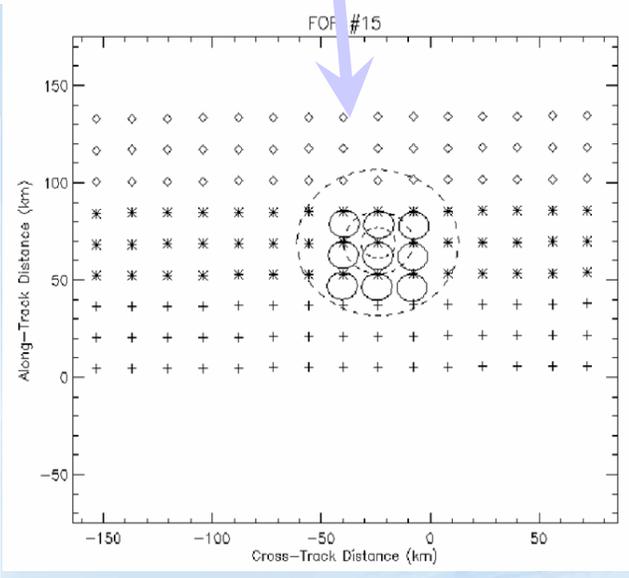
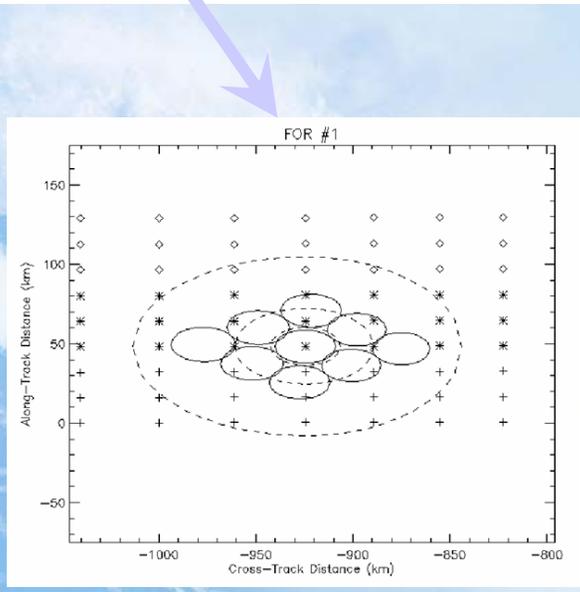
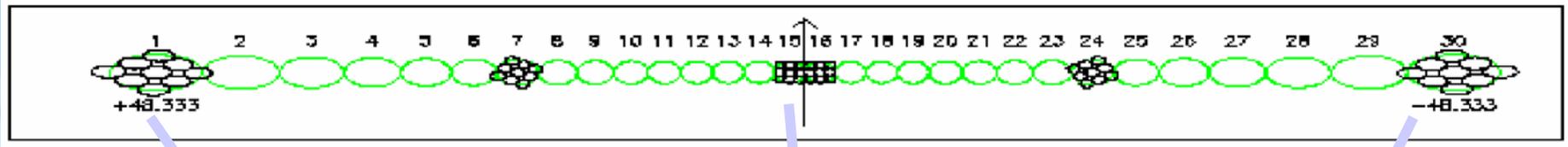
$$ILS_{FOV} = \sum_x \sum_y ILS(x, y) \cdot \omega(x, y) \approx ILS(\bar{x}, \bar{y})$$

- Initially we will add an additional error source to take this effect into account
- Later, we will add a correction in the transmittance terms of the RTA



Co-location of CrIS & ATMS

NOTE: CrIS FOV's rotate w.r.t. to sub-sampled ATMS FOV's.



From pg. 260-266 of CrIS EDR ATBD
(P1196-TR-I-4-0-ATBD-01-04, Feb. 8, 2007)