National Environmental Satellite, Data, and Information Service

Status of IASI and CrIS processing

Chris Barnet,

Atmospheric Sounding Science Team Meeting

Oct. 14, 2008

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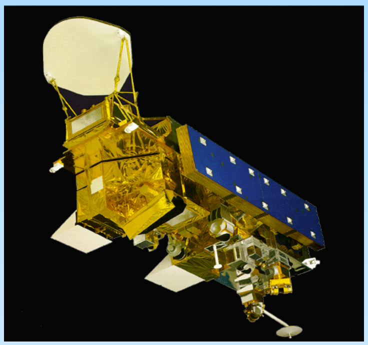
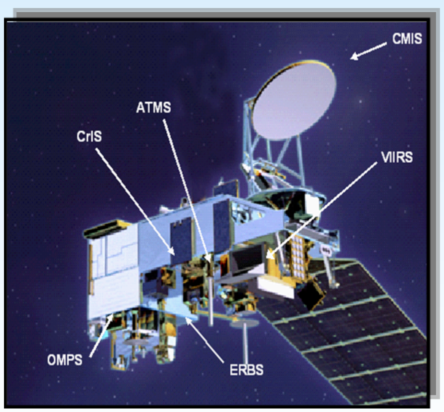
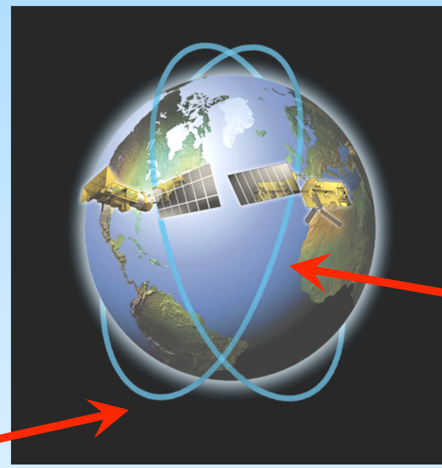
Initial Joint Polar System: An agreement between NOAA & EUMETSAT to exchange data and products.

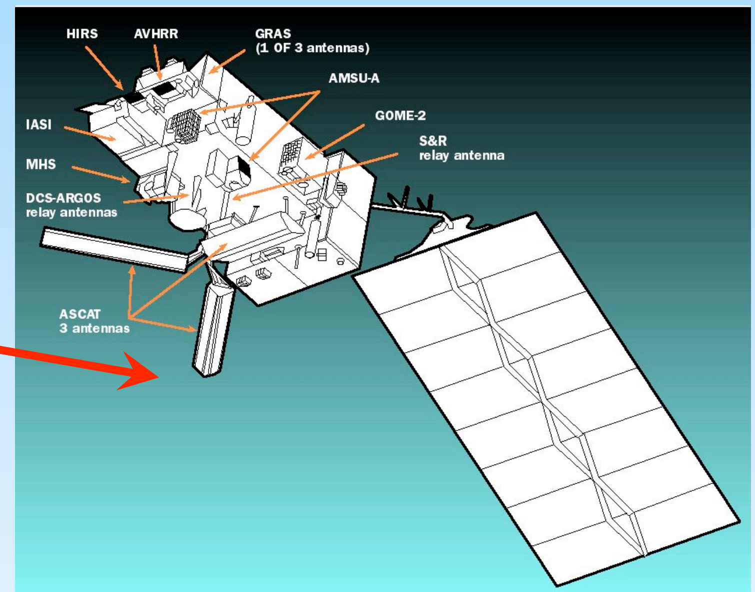
NASA/Aqua
1:30 pm orbit (May 4, 2002)



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

IASI

- Science code is the same for AIRS, IASI, and CrIS
  - File driven architecture (same code runs AIRS, IASI, and CrIS)
    - All instrument specific information is read in from files.
      - Noise file specifies instrument noise characteristics.
      - RTA file specifies instrument specifications (channels, apodization, etc).
    - Channel selection for retrieval steps is read in via namelist.
  - Code maintains backward and forward compatibility.
    - Can run all previous versions of AIRS, IASI, and CrIS including simulated and real data modes.
    - Object oriented design allows preparation for future upgrades.
  - Design is modular – retrieval modules are programmed via namelist commands.
  - Full diagnostics. Each retrieval iteration and step is compared to a "truth" state specified by the user (ECMWF, RAOBS, GFS, etc.). For operations the "truth" state is the GFS forecast.
- Operational system is a "filtered" version of the science code
  - Guarantees that off-line and on-line results are the same.

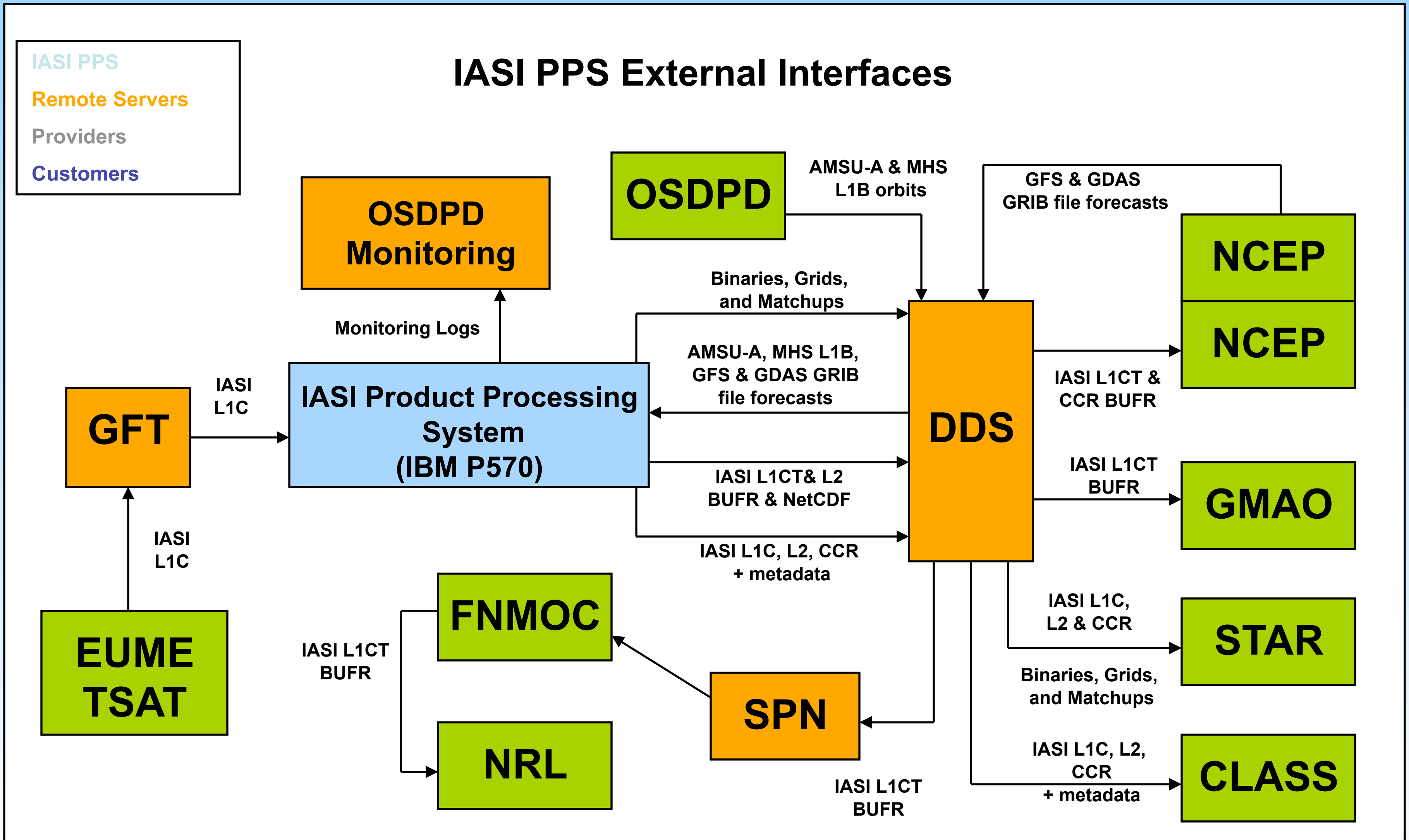
IASI Setup

- Baseline system was a mix of version 4.7 & 5.0
  - Uses IASI, AMSU, and MHS observations.
  - Channel sets are similar to v4.7 (use SW/LW for cloud clearing, LW is dominant for T(p).
  - Channel selection avoids adjacent pairs due to spectral correlation induced by apodization
  - Employs both cloudy and cloud cleared regression, both regressions use AMSU.
  - Microwave and infrared tuning is currently based on ECMWF
  - Error covariance matrices handle spectral correlation induced by apodization of FTS radiances.
- All trace gas retrievals are functional.
  - Carbon dioxide, nitric acid, and nitrous oxide are turned on.
- Diagnostic monitoring of principal components is done operationally and also off-line at STAR.
- IASI/ATMS/MHS field-of-regards for validation site's are captured and stored by operational system.
  - Ability to reprocess RAOB database with any version of the code.

IASI Products are Operational

- IASI level-1 system became operational at NOAA's Environmental Satellite Processing Center (ESPC, a.k.a. OSDPD) on July 18, 2007
- IASI level-2 pre-operational system has been running continuously on our ESPC development machines since April 2008.
- IASI level-2 system became operational at ESPC on Aug. 14, 2008
- Murty Divakarla's talk (2:30 pm Wednesday) will show IASI and AIRS temperature and moisture comparisons to RAOB's.

IASI PPS Interfaces/Users



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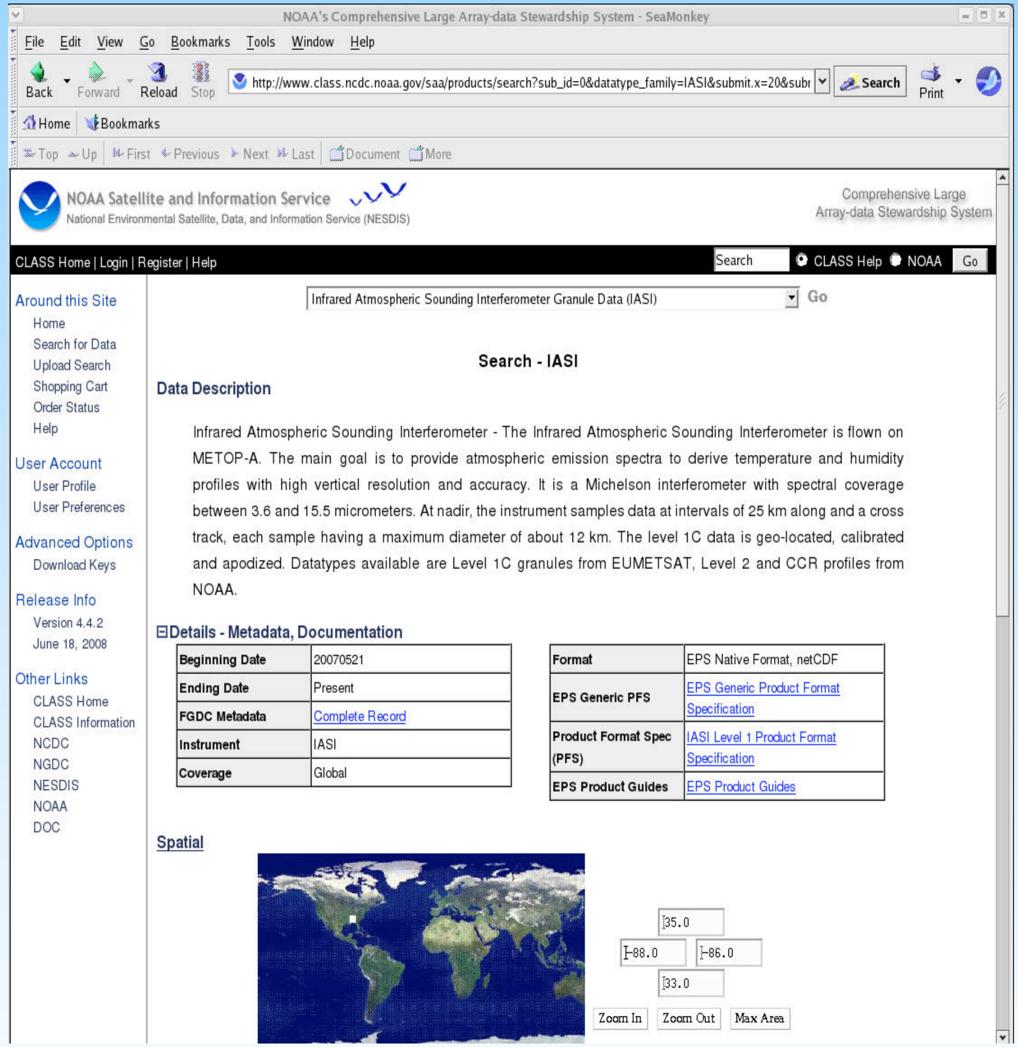
Trace Gas Products from AIRS & IASI

gas	Range (cm^{-1})	Precision	d.o.f.	Interfering Gases	AIRS	IASI
H_2O	1200-1600	15%	4-6	CH4, HNO3	NASA DAAC	CLASS
O_3	1025-1050	10%	1.25	H2O,emissivity	NASA DAAC	CLASS
CO	2080-2200	15%	≈ 1	H2O,N2O	NASA DAAC	CLASS
CH_4	1250-1370	1.5%	≈ 1	H2O,HNO3,N2O	NASA DAAC	CLASS
CO_2	680-795 2375-2395	0.5%	≈ 1	H2O,O3 T(p)	NOAA NESDIS	CLASS
Volcanic SO_2	1340-1380	50% ??	< 1	H2O,HNO3	TBD	TBD
HNO_3	860-920 1320-1330	50% ??	< 1	emissivity H2O,CH4,N2O	NOAA NESDIS	CLASS
N_2O	1250-1315 2180-2250 2520-2600	5% ??	< 1	H2O H2O,CO	NOAA NESDIS	CLASS
$CFCl_3$ (F11)	830-860	20%	-	emissivity	No plans	No plans
CF_2Cl (F12)	900-940	20%	-	emissivity	No plans	No plans
CCl_4	790-805	50%	-	emissivity	No plans	No plans

Product archive
Availability usually within 6 hours

- Products available in near-real time via NOAA/ ESPC Data Distribution Server (by subscription)
- Products available within ≈ 6 hours and archived at NOAA Comprehensive Large Array-data Stewardship System (CLASS)



www.class.ncdc.noaa.gov

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IASI L1C NRT Granule Products Available via DDS in Near Real Time

Spectral Subset	Data Type	Spatial Subset	Format
616 chls	IASI Radiance	Warmest FOV from every FOR	BUFR NetCDF
616 chls	IASI Radiance	First FOV from every FOR	BUFR NetCDF
616 chls	IASI Radiance	All 4 FOVs from every FOR	BUFR NetCDF
616 chls	IASI Reconstructed Radiance (1 band)	1 FOV from every FOR	BUFR NetCDF
616 chls	IASI Reconstructed Radiance (3 bands)	1 FOV from every FOR	BUFR NetCDF
616 chls	IASI Reconstructed Radiance (1 band)	4 FOVs from every FOR	BUFR NetCDF
616 chls	IASI Reconstructed Radiance (3 bands)	4 FOVs from every FOR	BUFR NetCDF
8461 chls	IASI Radiance	4 FOVs from every FOR	NetCDF
8461 chls	IASI Radiance	4 FOVs from 2 scans/granule	NetCDF
FOV = Field of View; FOR = Field of Regard. Orange refers to internal files.			

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IASI Archive Products (available via CLASS)

Instrument	Processing Interval	Description	Contents	Format
IASI	Granule	Granule of IASI L1C	IASI Radiance w/ metadata (FGDC-RSE)	EUMETSAT Binary Xml
IASI AMSU MHS	Daily	3x3 degree gridded spatial subset of IASI FOR's	IASI, AMSU, MHS Radiances w/ metadata	GRADS Binary Xml
IASI	Granule	Granule of IASI cloud cleared radiances for each FOR	IASI CCR w/ metadata	NETCDF xml
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

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

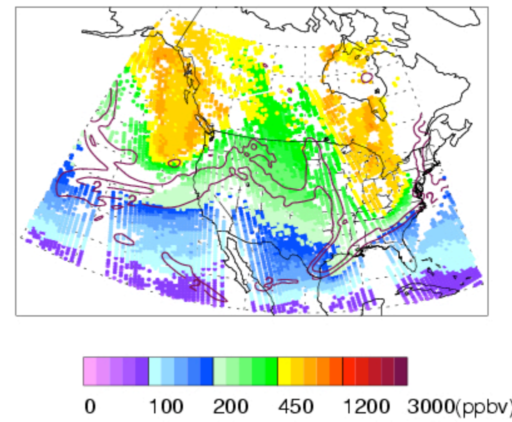
AVHRR Products will be available in FY09

Supported the Stratosphere-Troposphere Analyses of Regional Transport (START) & Preliminary HIAPER Pole to Pole Observation (Pre-HiPPO)

- STAR participated in the START08/pre-HIPPO experiment from April to June, 2008 – See Jasna Pittman/Laura Pan's talk at 3:30 today
- STAR provided near real time level-2 products derived from the Atmospheric Infrared Sounders (AIRS) and pre-operational Infrared Atmospheric Sounding (IASI).
- Satellite derived tropopause height, H2O, O3, and CC were used for daily "flight forecast".
- Figure 1: IASI derived ozone (O3) at 200 mb shows the patterns similar to the upper tropospheric dynamics (stratospheric intrusions, red contours)
- Figure 2: IASI carbon monoxide (CO) at 500 mb shows high CO over Oregon/Idaho due to long range transport of recent Russian fire.
- Daily products and flight forecaster reports can be seen on http://catalog.eol.ucar.edu/start08/index.html

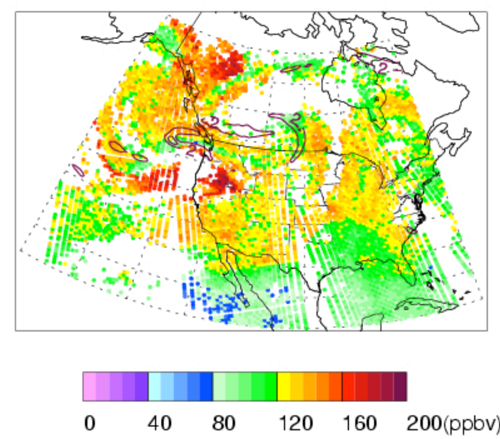
IASI O_3 2008-04-29(A) 0330Z at 200 mb

Figure 1



IASI CO 2008-04-22(A) 0330Z at 500 mb

Figure 2



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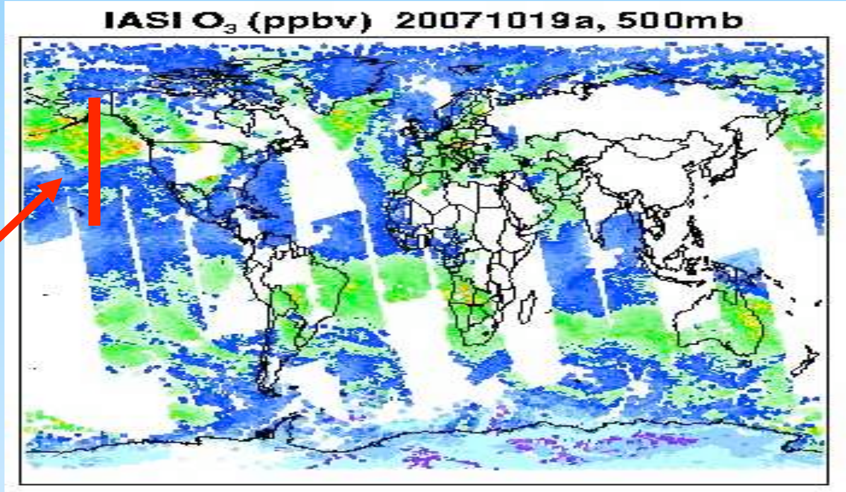
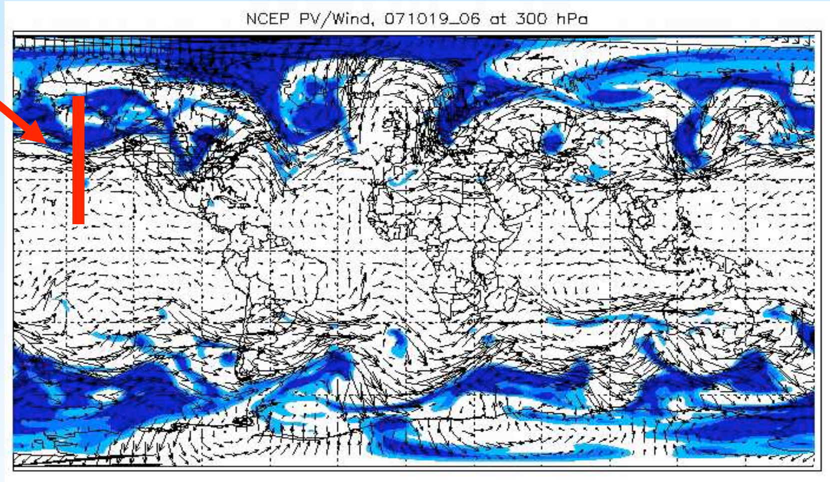
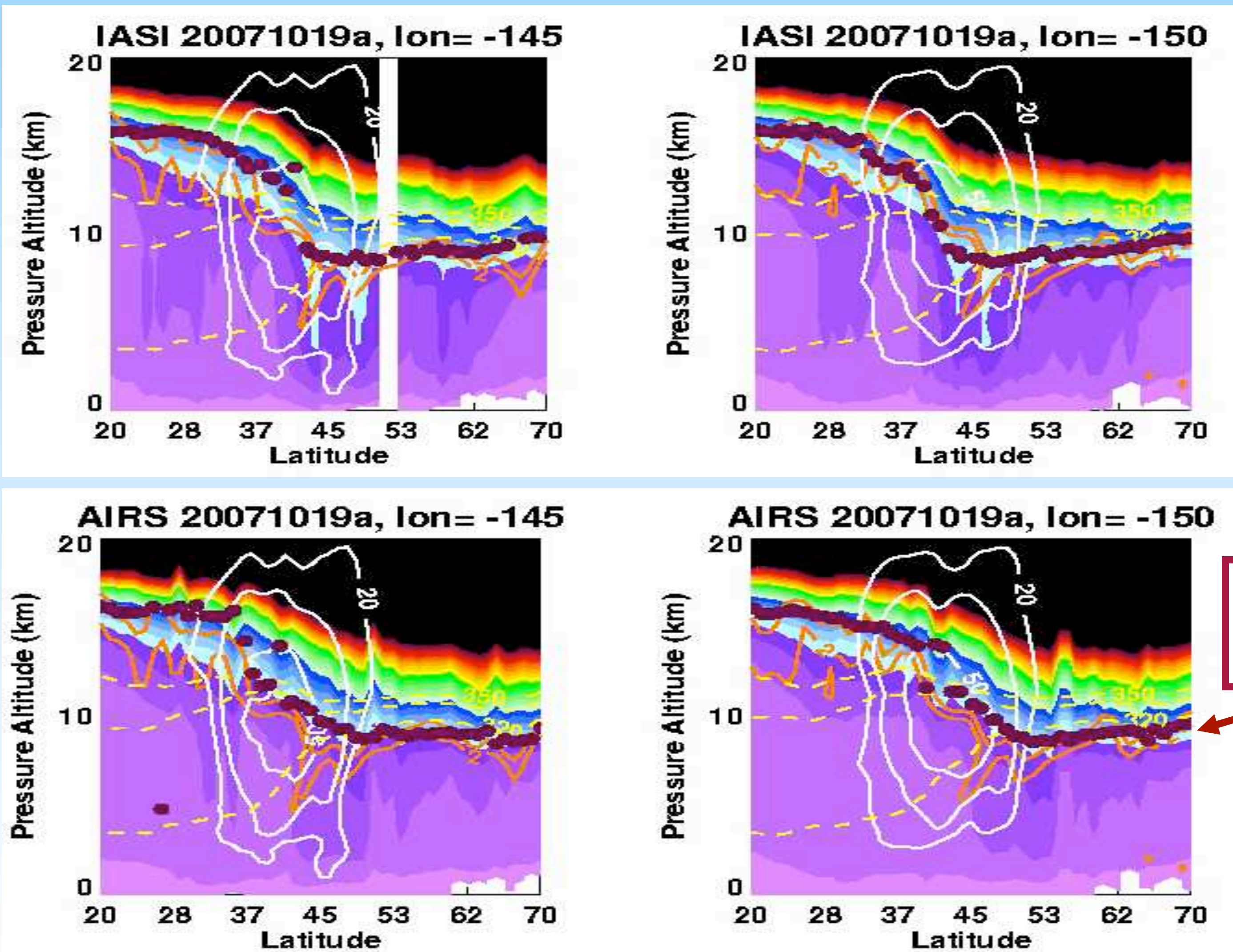
Comparison of IASI Ozone and NCEP PV/Wind

- Next slide will show retrieval cross section along 20-70 latitude and at longitude -145 and -150.
  - Shown at right as red vertical line
- Lower panel shows potential vorticity/wind
  - Areas in blue are regions of stratopheric intrusions into the troposphere.





Stratospheric Intrusion on Oct. 19, 2007 at longitude -145° and -150°



IASI 21:30
Ascending (night)

Geo-potential Temperature 350, 380, 400

PV, 2, 4

Zonal Wind

Thermal Tropopause (derived from retrieval)

AIRS 13:30
Ascending (day)

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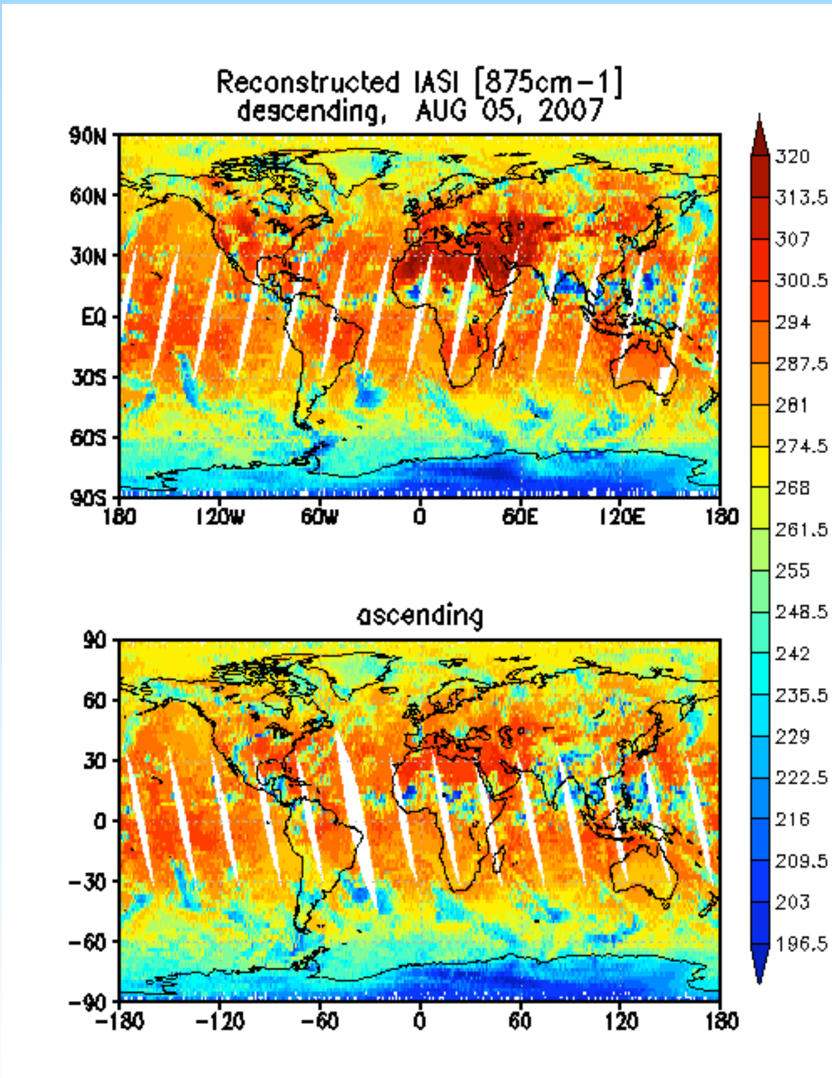
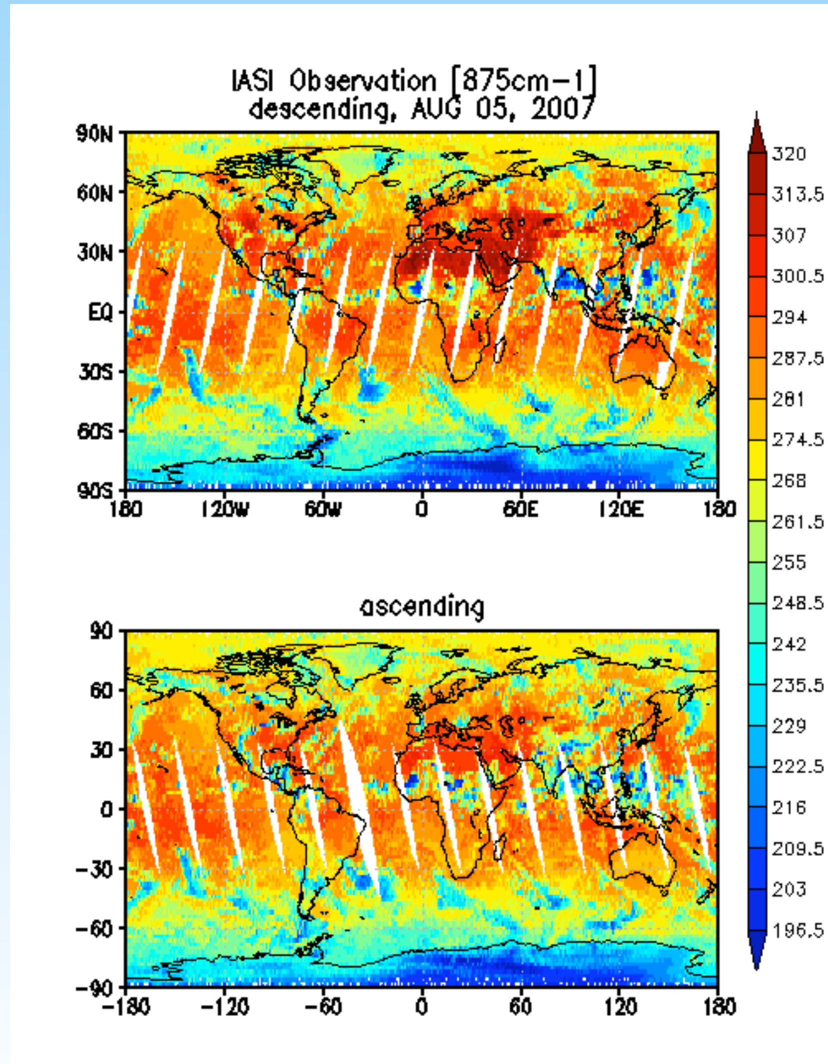
Reconstructed Radiance from IASI





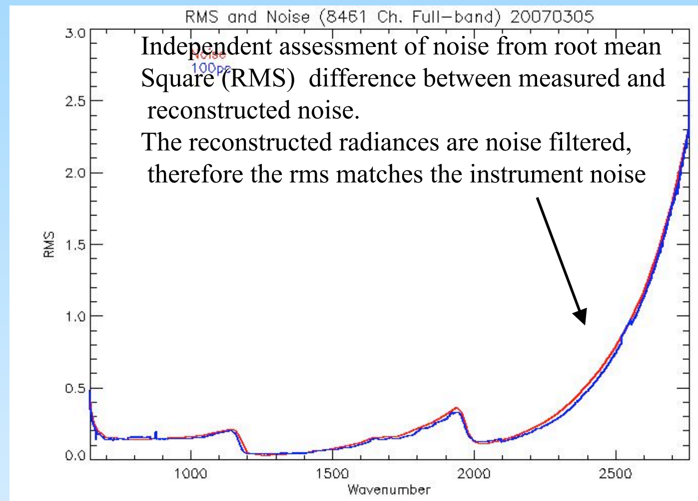
Reconstructed Radiances are a form of Noise Reduction

- Eigenvector analysis allows correlated data to be represented by a relatively small set of functions.

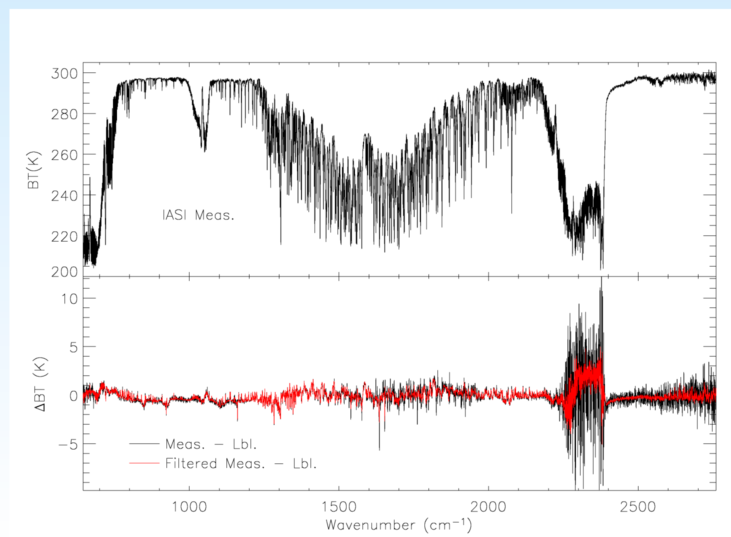
- 8461 channels can easily be represented by a 100 unique coefficients couples with 100 static structure functions (100 x 8461)

- 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)



280 K



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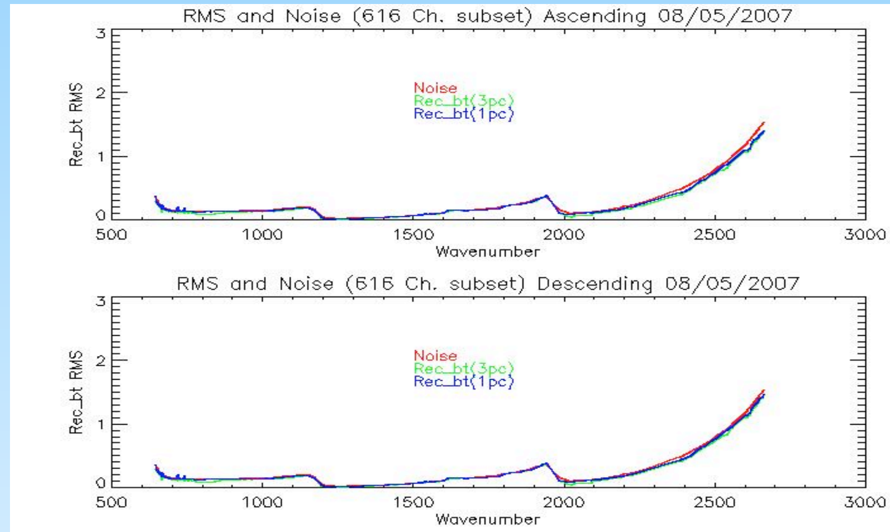
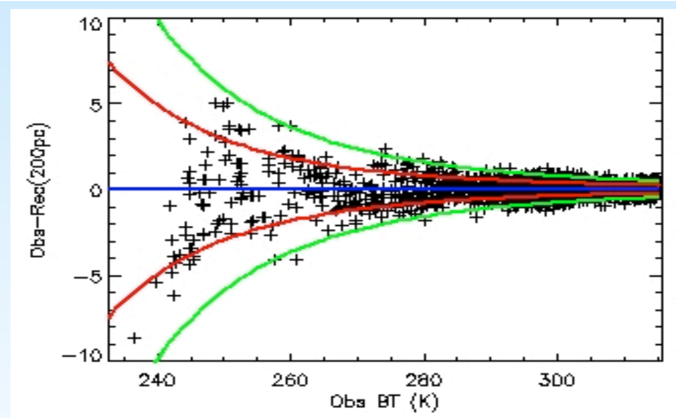
PC Analysis can be used to characterize the instrument noise using Earth scenes.

- 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).

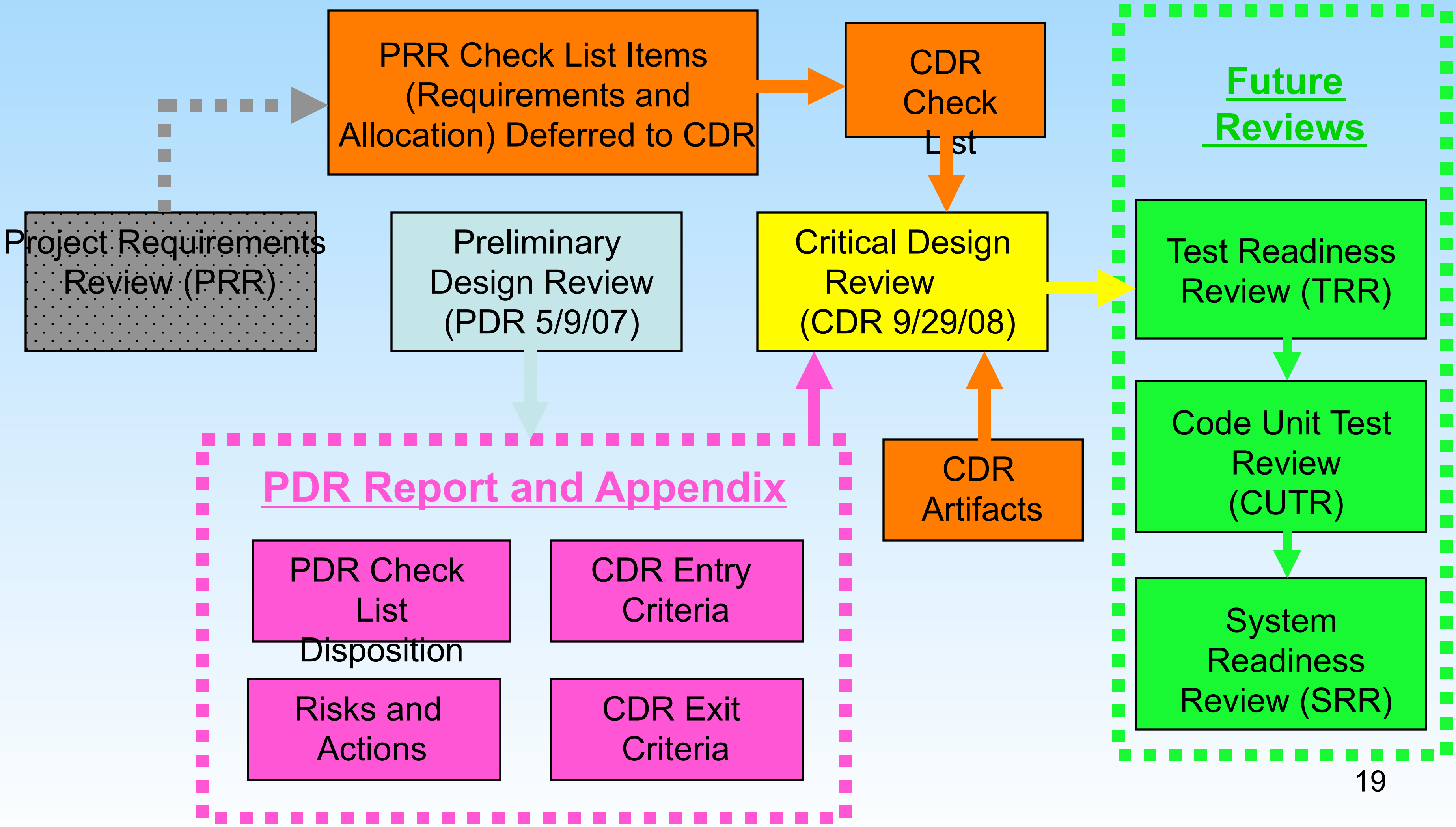




NOAA Unique Cris/ATMS Processing System (NUCAPS)

- A copy of IASI system is being built for CrIS/ ATMS
  - Same processing code will be used with new front-end to read NGST SDR format's.
  - Our code will run within the NPOESS Data Exploitation (NDE) environment.
  - CrIS local angle correction is more complex than AIRS and IASI due to rotation of field-of-regard.
  - ATMS re-sampling to CrIS FOV's is required.
- CDR was held Sep. 29, 2008.

NUCAPS employ's the STAR Enterprise Process Lifecycle (CMMI Level-3 process)



AIRS, IASI & CrIS Comparison

	AIRS	IASI	CrIS
Fields or regard (FOR) per day	324000	324000	324000
FOV per FOR	9	4	9
Channels per FOV	2378	8461	1305
Level 1 storage per day	35 GB	30 GB	30 GB
Minutes of data per granule	6	≈ 3	6
AMSU scan lines/day	45	22 or 23	45
# Granules/day	240	480	240
Level 2 products file size/granule	11.9 MB	16.5 MB	≈ 16 MB
Cloud Cleared Rad. file size/granule	10 MB	23 MB	≈ 10 MB
File format for L2 & CCR	HDF4	NETCDF	NETCDF

- *All 3 instrument systems will have common algorithm (literally same code) and underlying radiative transfer.*
- *Focus is on "climate quality" of the algorithm.*

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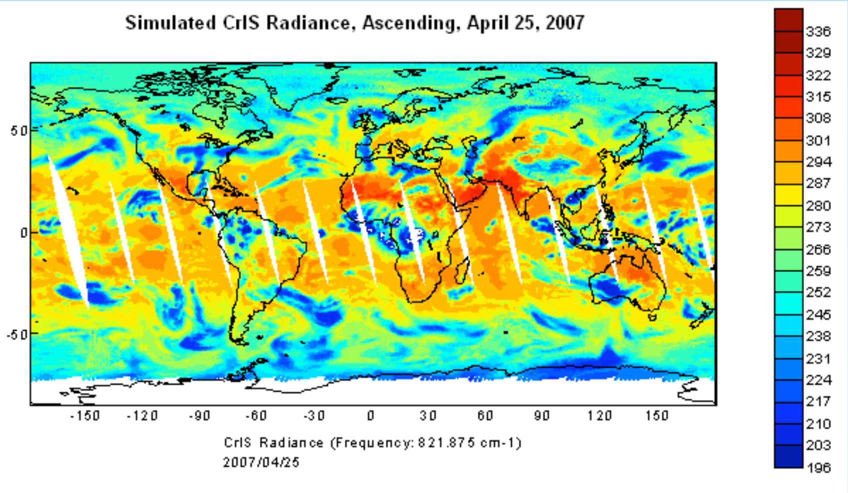
CrIS/ATMS will be simulated 24/7 for more than 1.5 years prior to launch..

- Build a reasonable atmospheric state
  - Use GFS model for T,q,clouds
  - Use climatologies for trace gases.
  - Use emissivity models for surface properties.
- Simulate the NPP orbit.
- Simulate radiances using the MIT ATMS and UMBC CrIS RTA.
- Package ATMS and CrIS radiances in NGST - SDR format (in work).
- Use simulated SDR's to build BUFR and NETCDF products
  - Run retrieval system from these products.
- At launch – flip a switch to send real data down the pipeline.



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CrIS carbon monoxide product will be degraded w.r.t. AIRS & IASI

- Hyperspectral thermal sounders have demonstrated capabilities in measuring carbon monoxide.
- Carbon monoxide is an important product.
  - **Air Quality**:
    - Estimated emission from burning of fossil fuels and biomass (both natural and anthropogenic).
    - Excellent indicator of pollution transport from local to global scales.
    - Chemical precursor to tropospheric ozone.
  - **Carbon Cycle**: Helps separate processes (burning versus photosynthetic).
- Current configuration of CrIS is incapable of providing continuity of the AIRS/IASI carbon monoxide product.
  - Optics and electronics are capable, but
  - Data is not transmitted to ground.
- Committee on Earth Observation Satellites (CEOS) action to mitigate – meeting scheduled w/ IPO/NESDIS.

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IORD-II (Dec. 10, 2001)

- 4.1.6.8.3 CO (Carbon Monoxide) Column (DOC). Measure of carbon monoxide in a specified volume of air.

	Systems Capabilities	Threshold	Objectives
a.	Vertical Coverage Total		Column
b.	Horizontal Resolution		100 km
c.	Mapping Uncertainty		25 km
d.	Measurement Range		0 to 7 μmoles/cm^2 0 to 157 DU 0 to 196 ppb
e.	Measurement Precision		3%
f.	Measurement Accuracy		±5%
g.	Latency		15 min
h.	Refresh		24 hour

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IORD II Section 4.1.6.8 (P^3I)

- Parameter 3--CO (Carbon Monoxide) Column (DOC). The presence of trace gases in the atmosphere can have a significant effect on global change. The chemical composition of the troposphere in particular is changing at an unprecedented rate. The rate at which pollutants from human activities are input to the troposphere is now thought to exceed that from natural sources (e.g., volcanic eruptions) and is known to be greater than the atmosphere's natural capacity for their removal. This EDR supports monitoring of changes in the composition of the various layers in the atmosphere and analyses of the effects of these changes on the global climate. High spectral resolution is needed to detect the absorption, emission, and scattering for individual species (trace gases). The presence of trace gases in the atmosphere can have a significant effect on potentially harmful local effects through increased levels of pollution.

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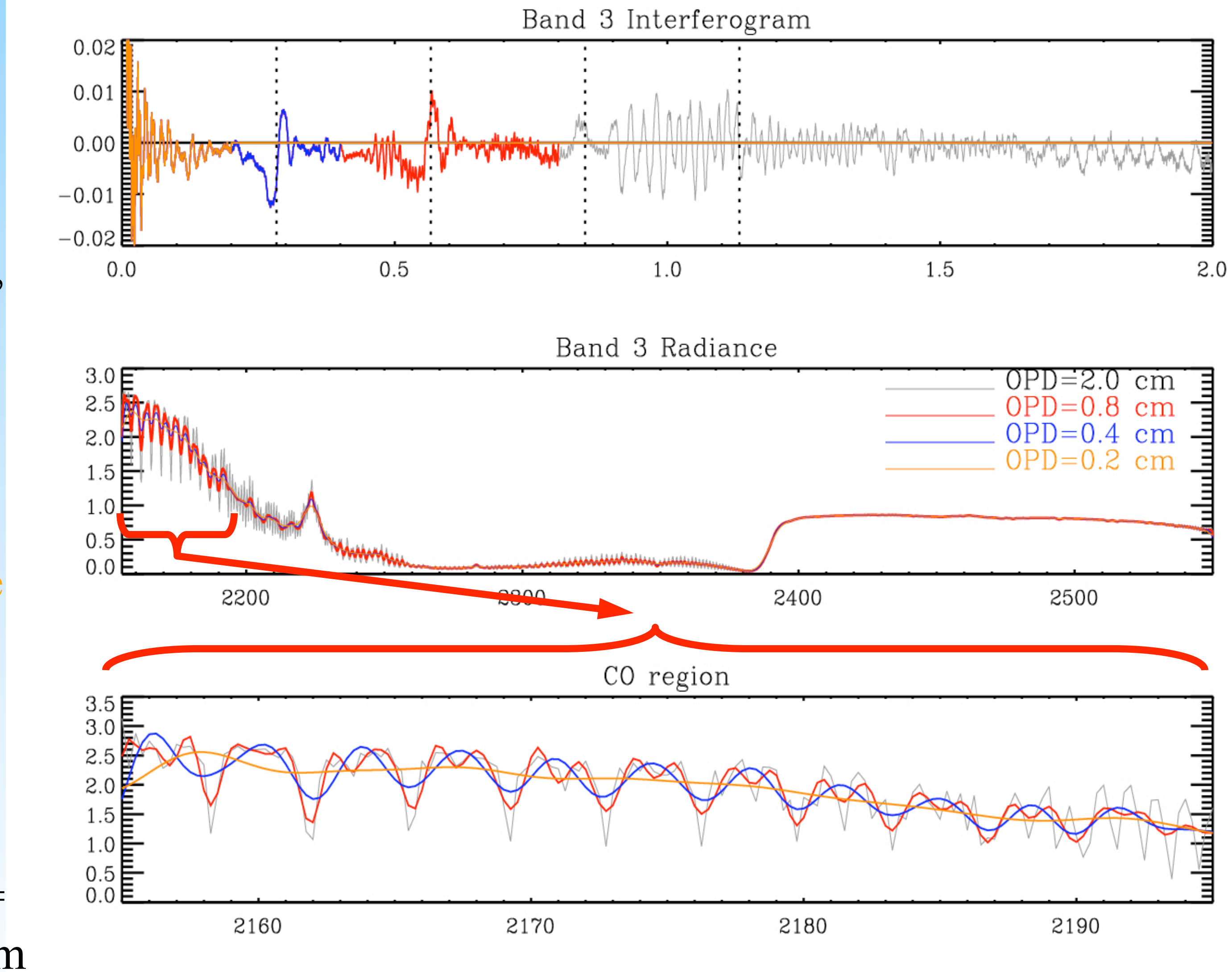
Spectral resolution is a function of interferogram optical path difference (OPD)

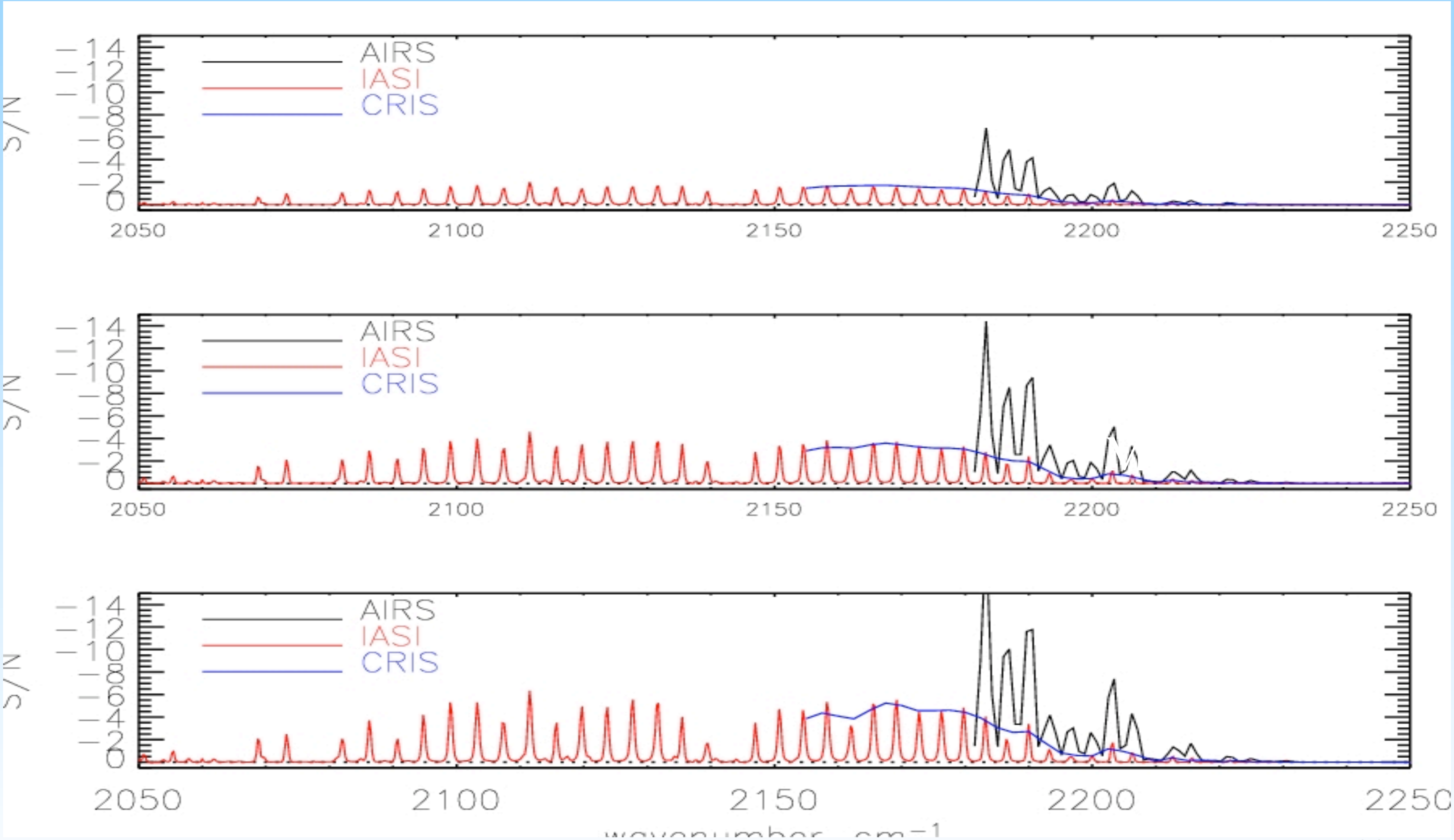
Top panel shows interferogram with location of CO resonances (0.28, 0.56, 0.85 and 1.12 cm).

Middle panel shows radiance for various truncated interferograms (orange is current CrIS configuration).

Bottom panel shows blow-up of CO region of spectrum for OPD = 2.0, 0.8, 0.4, and 0.2 cm

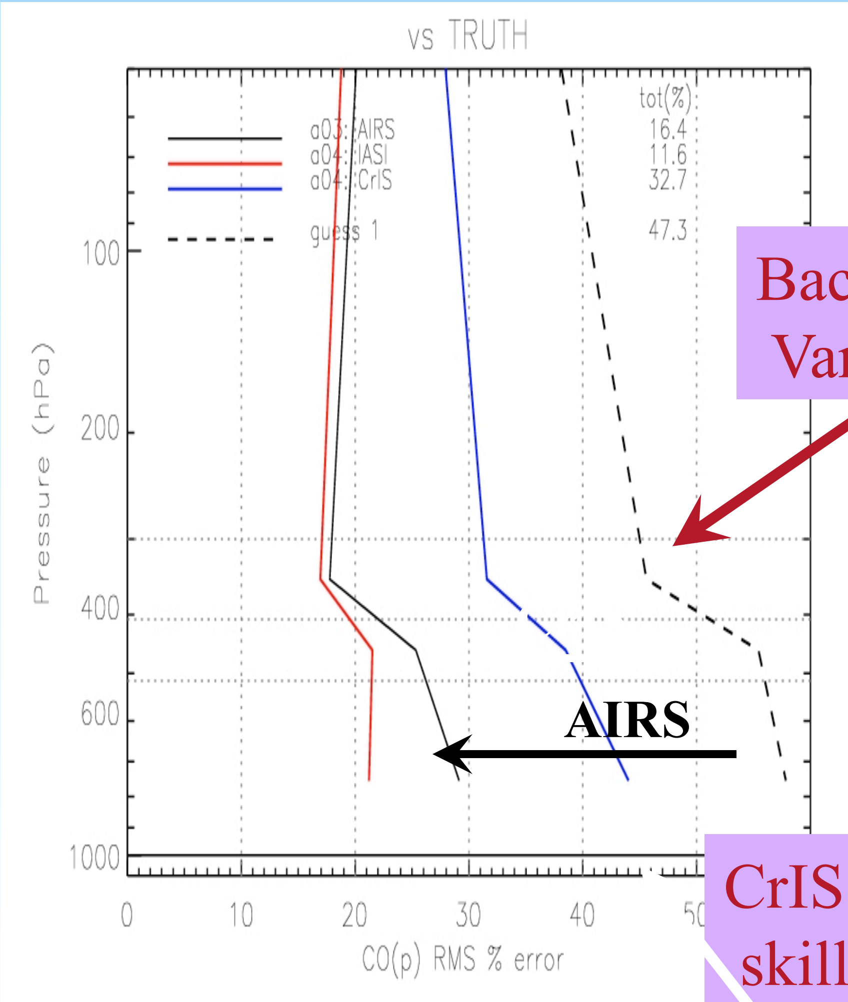


Sampling & Resolution in the Carbon Monoxide band for AIRS, IASI, and CrIS

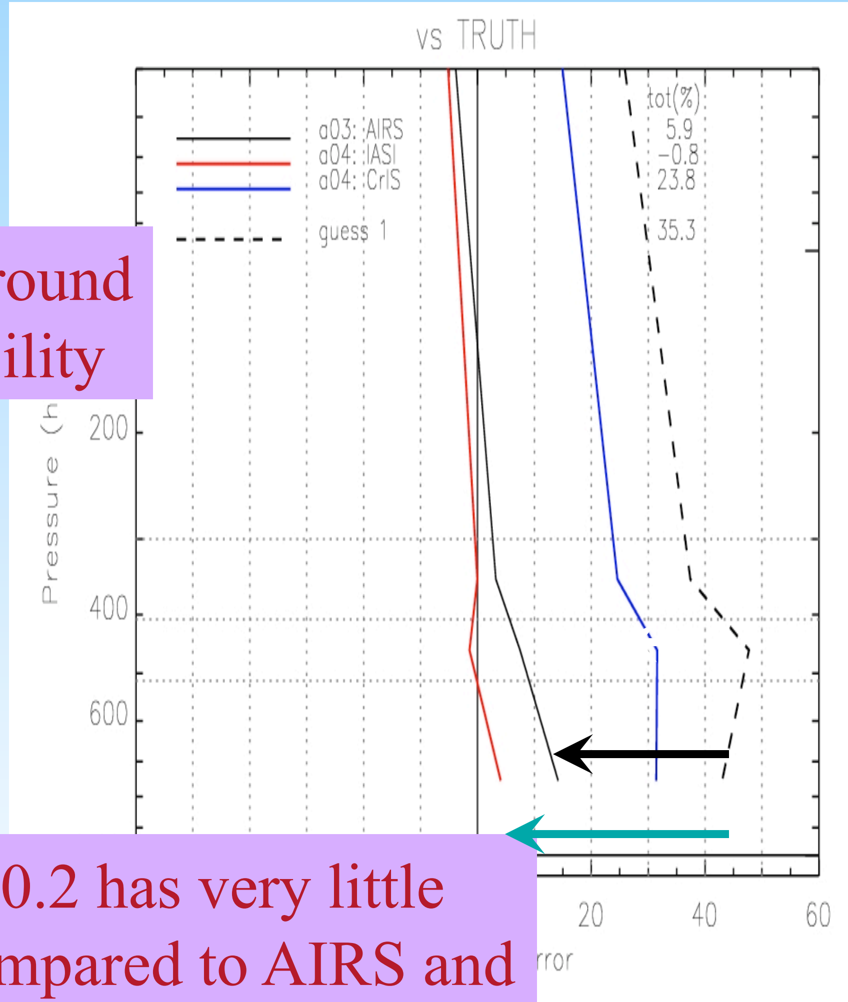


Statistics of CO retrieval from a full day simulation

RMS



BIAS



Background Variability

CrIS L=0.2 has very little skill compared to AIRS and IASI

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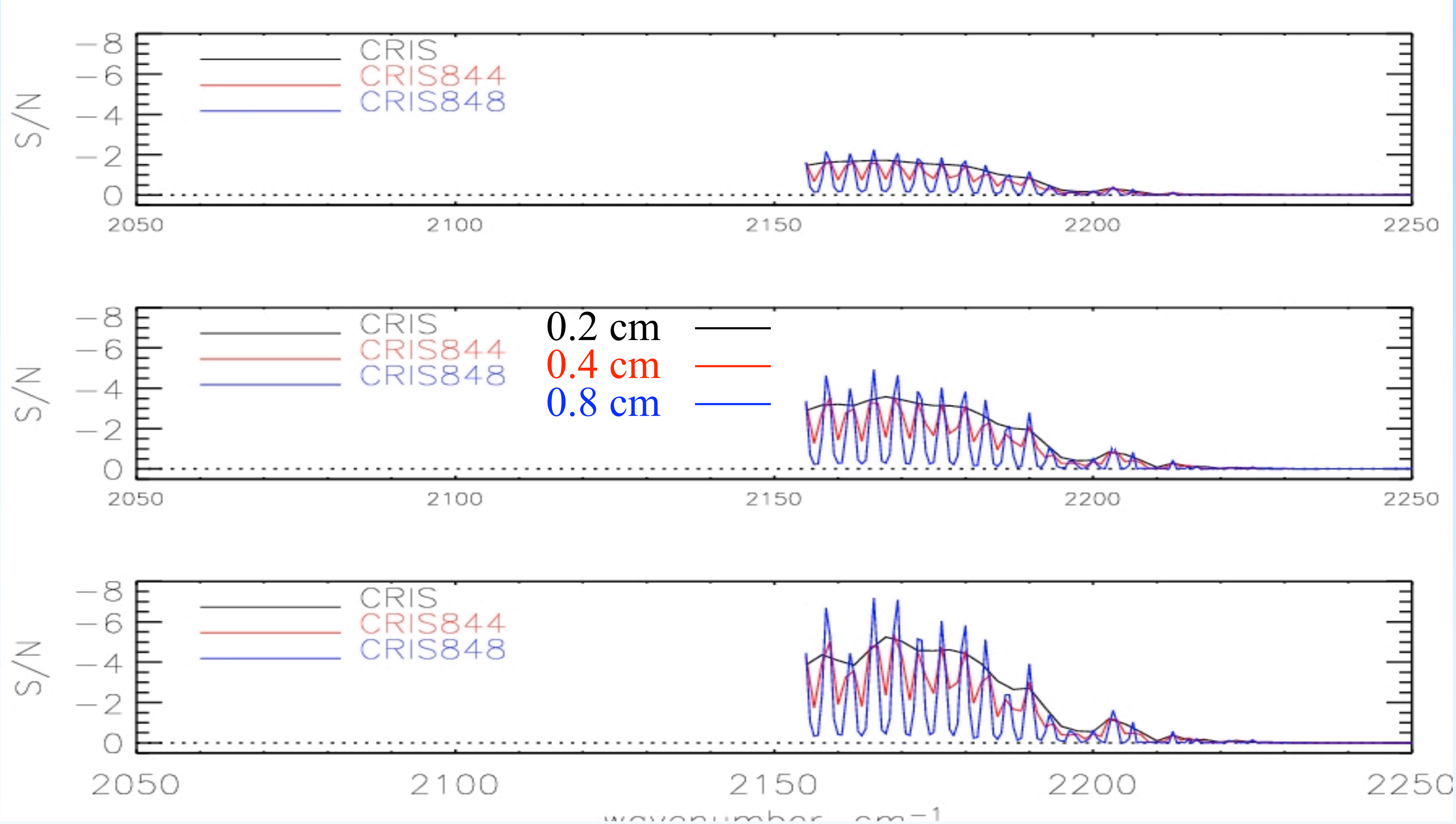
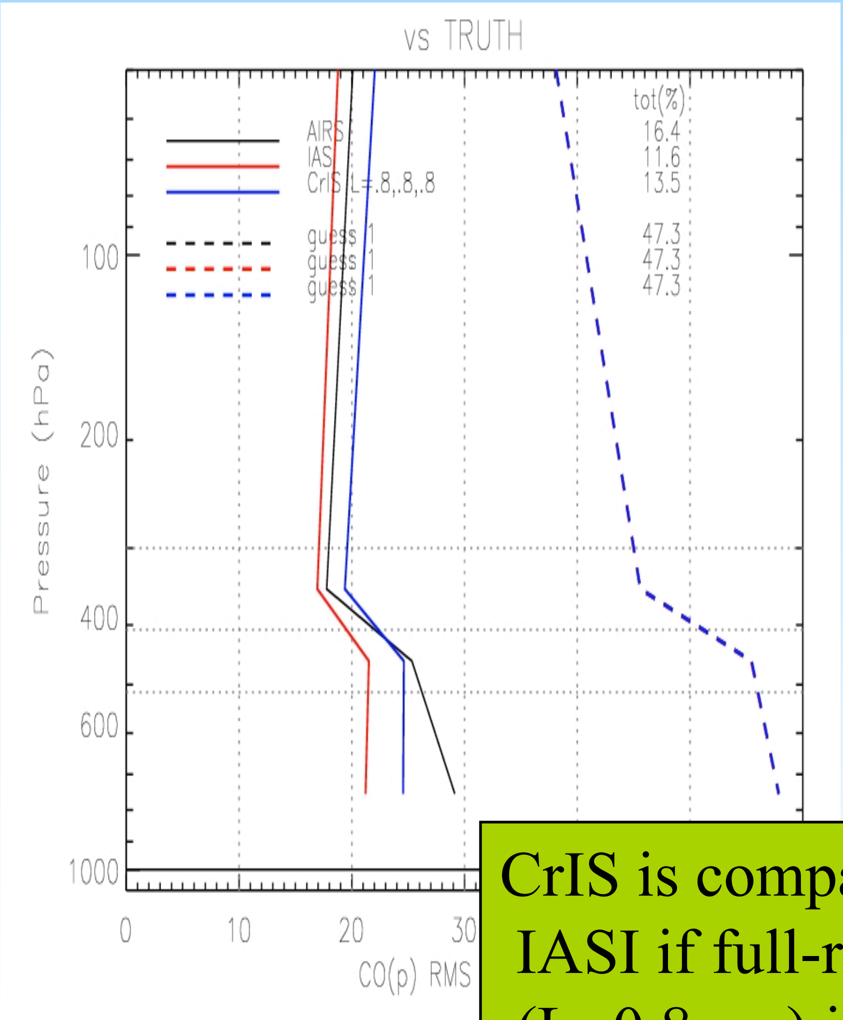
Increasing the SW sampling from L=0.2 cm to 0.4 or 0.8 would improve CO Sensitivity.

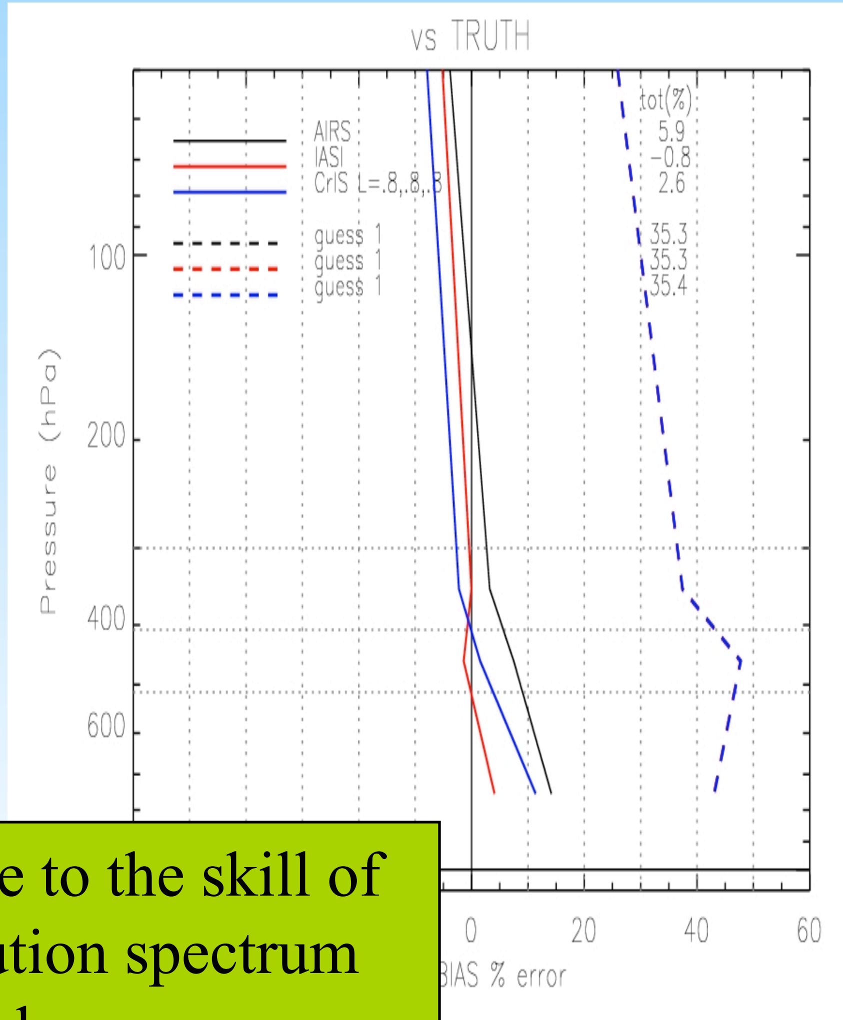


Statistics of CO Retrieval for Full Resolution CrIS & AIRS, IASI

RMS



BIAS



CrIS is comparable to the skill of IASI if full-resolution spectrum (L=0.8 cm) is used.