



# Observing Trace Gases from IASI Radiances

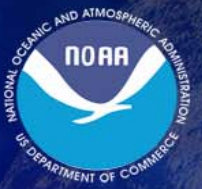
**Chris Barnet**  
**NOAA/NESDIS/STAR**  
**Nov. 15, 2007**  
**IASI Conference**  
**Anglet, France**

<b>Walter Wolf</b>	NRT system	<b>Tom King</b>	NRT System
<b>Nicholas Nalli</b>	AEROSE Validation Campaign	<b>Peter Keehn</b>	NRT System
<b>Lihang Zhou</b>	NRT/Regression	<b>Zhaohui Chang</b>	NRT/Regression
<b>Murty Divakarla</b>	T,q,O <sub>3</sub> Validation	<b>Antonia Gambacorta</b>	Retrieval Product System, T, q val.
<b>Jennifer Wei</b>	O <sub>3</sub> /CO/H <sub>2</sub> O Correlation Validation Campaigns	<b>Eric Maddy</b>	CO & CO <sub>2</sub> product, Averaging Kernels
<b>Xiaozhen Xiong</b>	CH <sub>4</sub> Product	<b>Fengying Sun</b>	HNO <sub>3</sub> /N <sub>2</sub> O Products



# 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 (9/2009), 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.



# AIRS science team algorithm: Design constraints.

- Granule end-to-end processing using  $\leq 16$  CPU's.
- Only static data files can be used.
  - One exception: model surface pressure.
  - Do not use output from model or other instrument data.
  - Maximize information coming from IASI/AMSU/MHS radiances.
- Cloud clearing will be used to “correct” for cloud contamination in the radiances.
  - Downstream algorithm must handle amplification of noise,  $A$ , because it is a function of cloud “contrast” in the scene  $0.5 \leq A < \approx 5$
  - Spectral correlation of noise is also function of cloud contrast.
- IR retrievals must be available for all Earth conditions within the assumptions/limitations of cloud clearing.
- Trace gas products contain derived concentration, averaging kernel, and information content (degrees of freedom).



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

- Assumptions,  $R_j = (1 - \alpha_j)R_{\text{clr}} + \alpha_j R_{\text{cld}}$ 
  - The only variability in a set of IASI pixels is the cloud amount,  $\alpha_j$ 
    - 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.
 
$$R_{\text{ccr}} = \langle R_j \rangle + \eta_j (\langle R_j \rangle - R_j)$$
- Roughly 70% of any given day satisfies these assumptions.

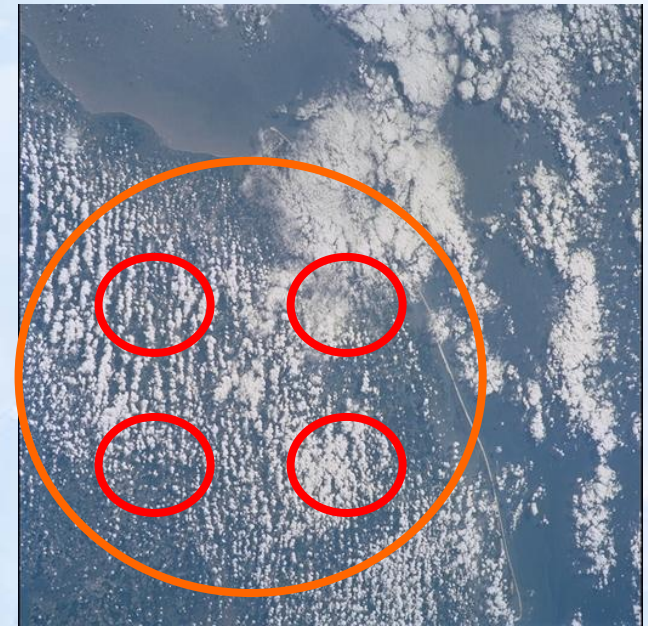
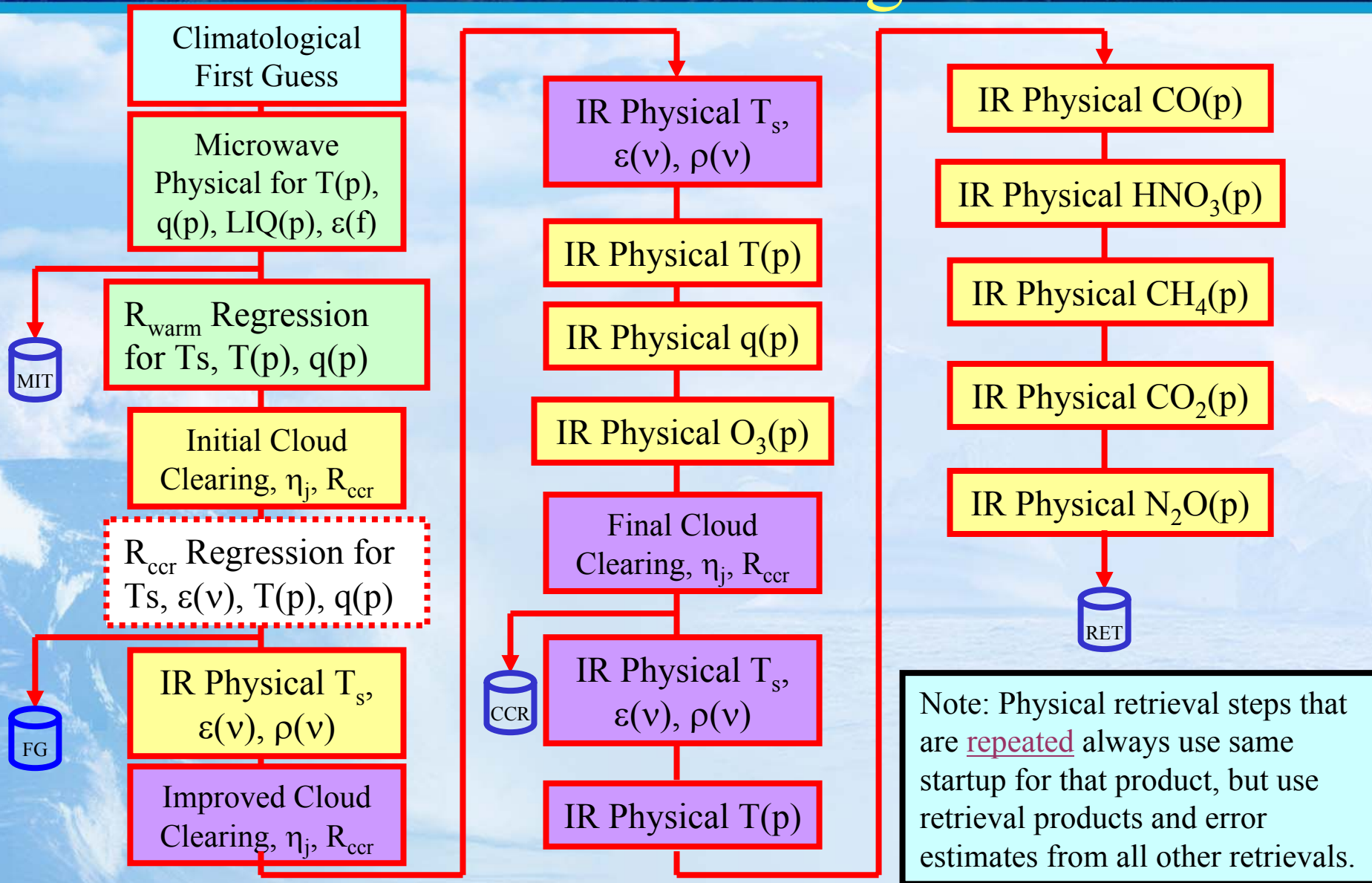


Image Courtesy of Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center (<http://eol.jsc.nasa.gov>). STS104-724-50 on right (July 20, 2001). Delaware bay is at top and Ocean City is right-center part of the images.

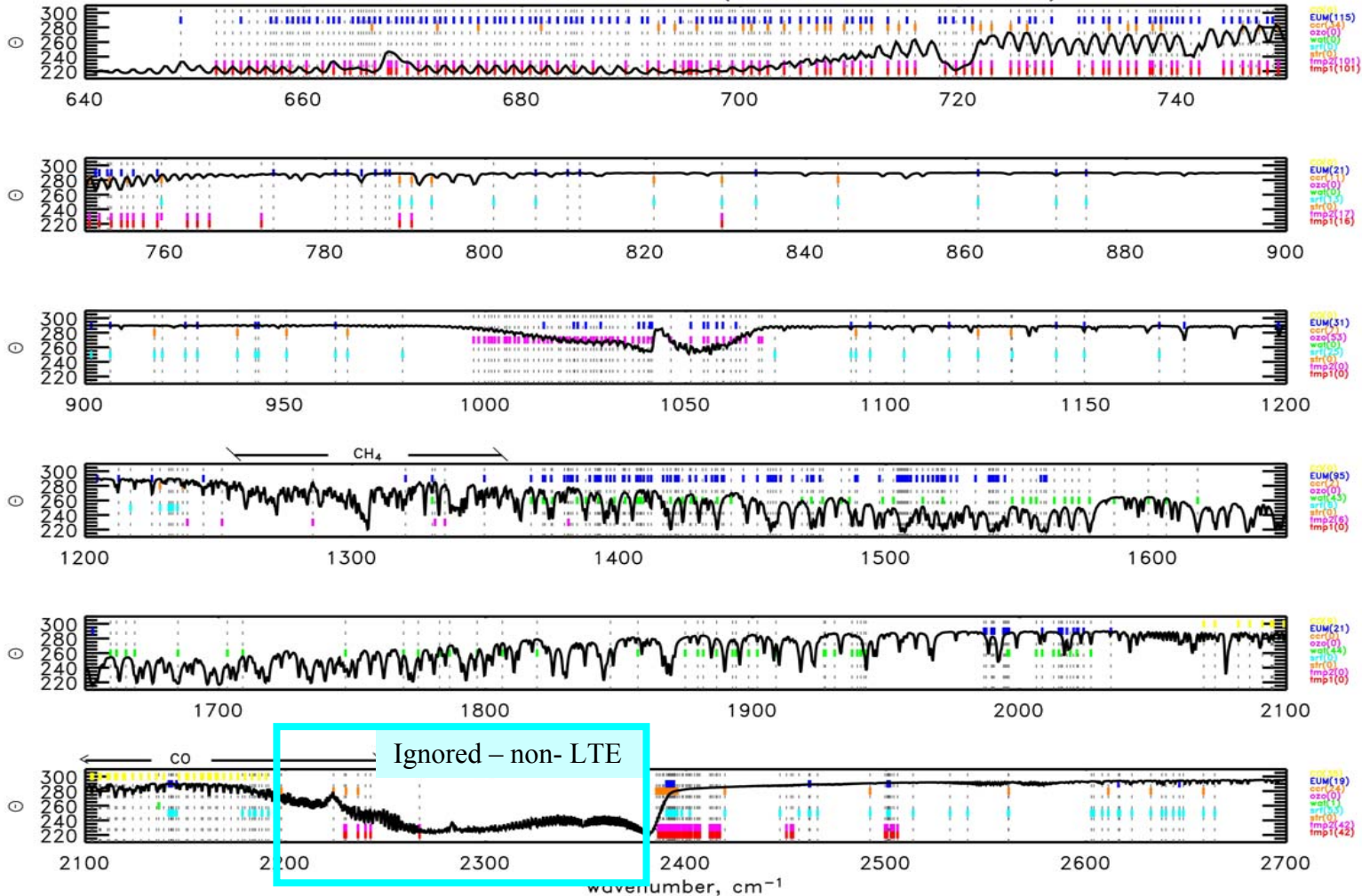
# Simplified flow diagram of AIRS science team algorithm





# Preliminary selection of IASI channels for physical retrieval. (NOTE: All channels except non-LTE are used in regression)

IASI channels Mar. 20, 2007 (616 total channels used)



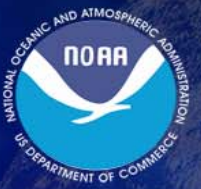
CC	69
T	152
Q	87
O <sub>3</sub>	53
CO	33
CH <sub>4</sub>	59
CO <sub>2</sub>	79
HNO <sub>3</sub>	14
N <sub>2</sub> O	58



# Trace Gas Product Potential from Operational Thermal Sounders

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





# Caveats to Preliminary Algorithm

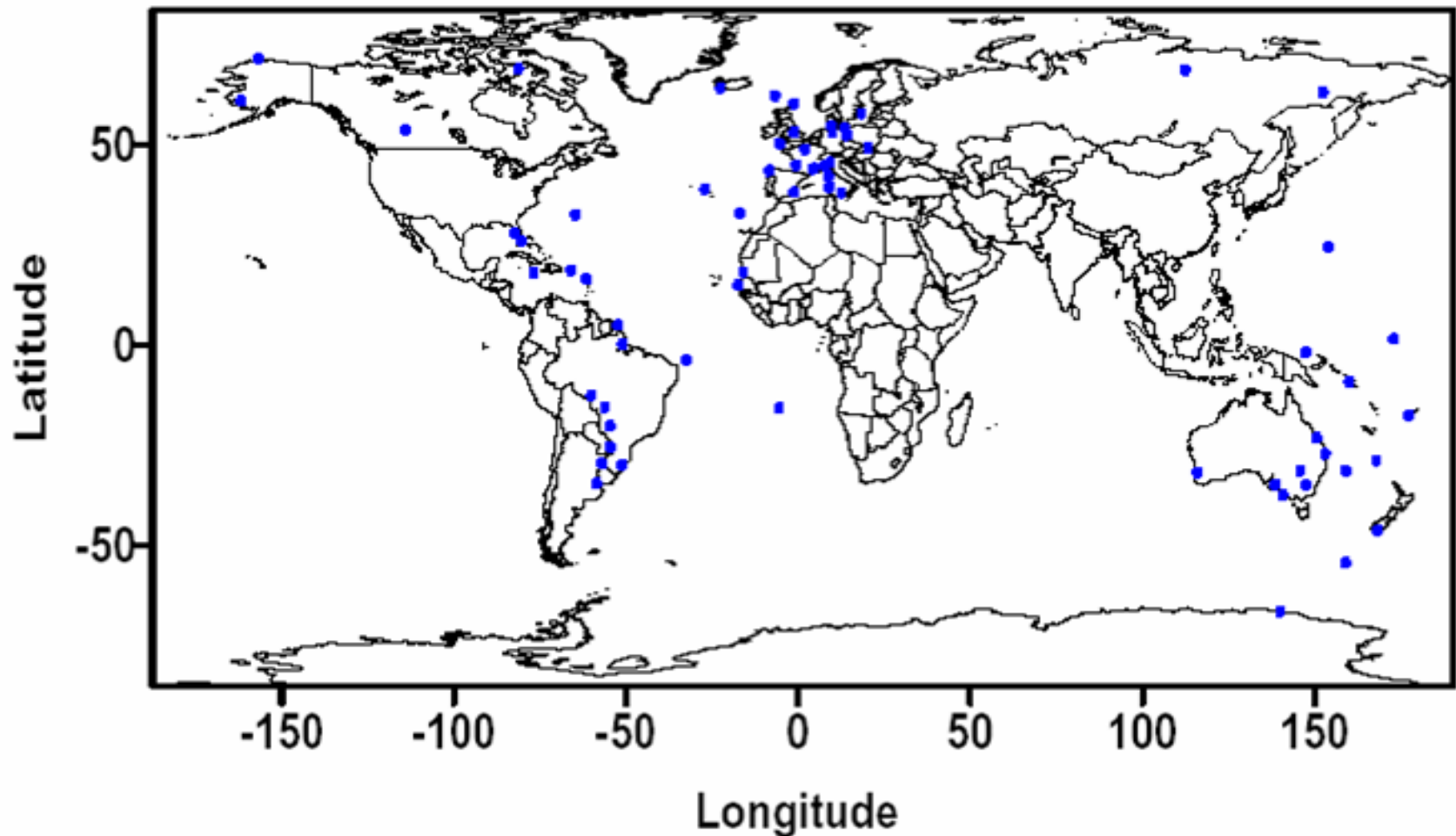
- Have not installed the regression derived from cloud cleared radiances. Will be installed in Dec. 2007.
- Have not computed tuning for AMSU & MHS (used Aqua AMSU tuning). Will be installed in Dec. 2007.
- Have not installed the local angle correction (needed for cloud clearing). Will be installed Jan. 2008.
- No attempt has been made to perform sub-pixel ILS correction.
  - There is an advantage to cloud clearing in that FOV's are averaged with clearest having highest weight.
  - This will be studied and installed in version 2.
- Only quick optimization has been done.
  - Need to derive optimal functions & regularization parameters, Jan/Feb. 2008.
  - Preliminary list of channels looks good, minor changes to channel list.
- Pre-launch Radiative Transfer Algorithm (RTA). Post-launch RTA from UMBC expected in Dec. 2008 – L. Strow (TBC)
- Empirical bias corrections, empirical noise term (to compensate for sub-pixel ILS), etc. are still very crude.



Comparisons of preliminary IASI  $T(p)$ ,  
 $q(p)$  retrievals to operational radiosonde  
observations (RAOB) within 3 hours,  
100 km

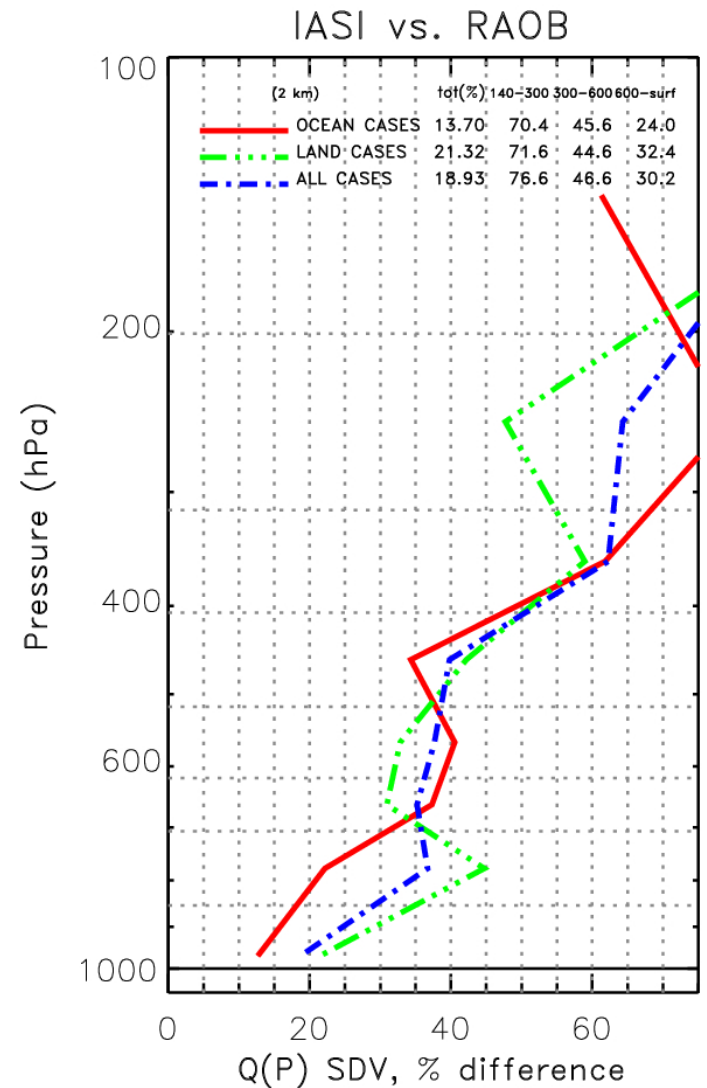
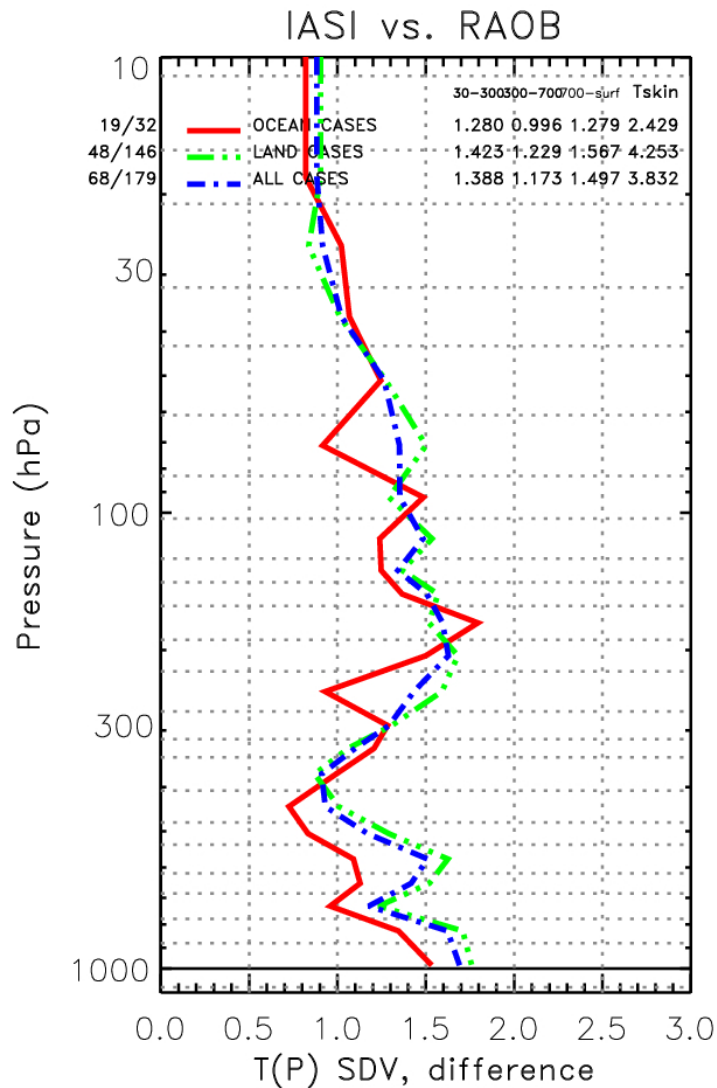
# RAOB match-up locations for Oct. 19, 2007

RAOB Locations Matched to IASI Obs. - Oct. 19, 2007  
Land Samples: 48, Ocean Samples = 20

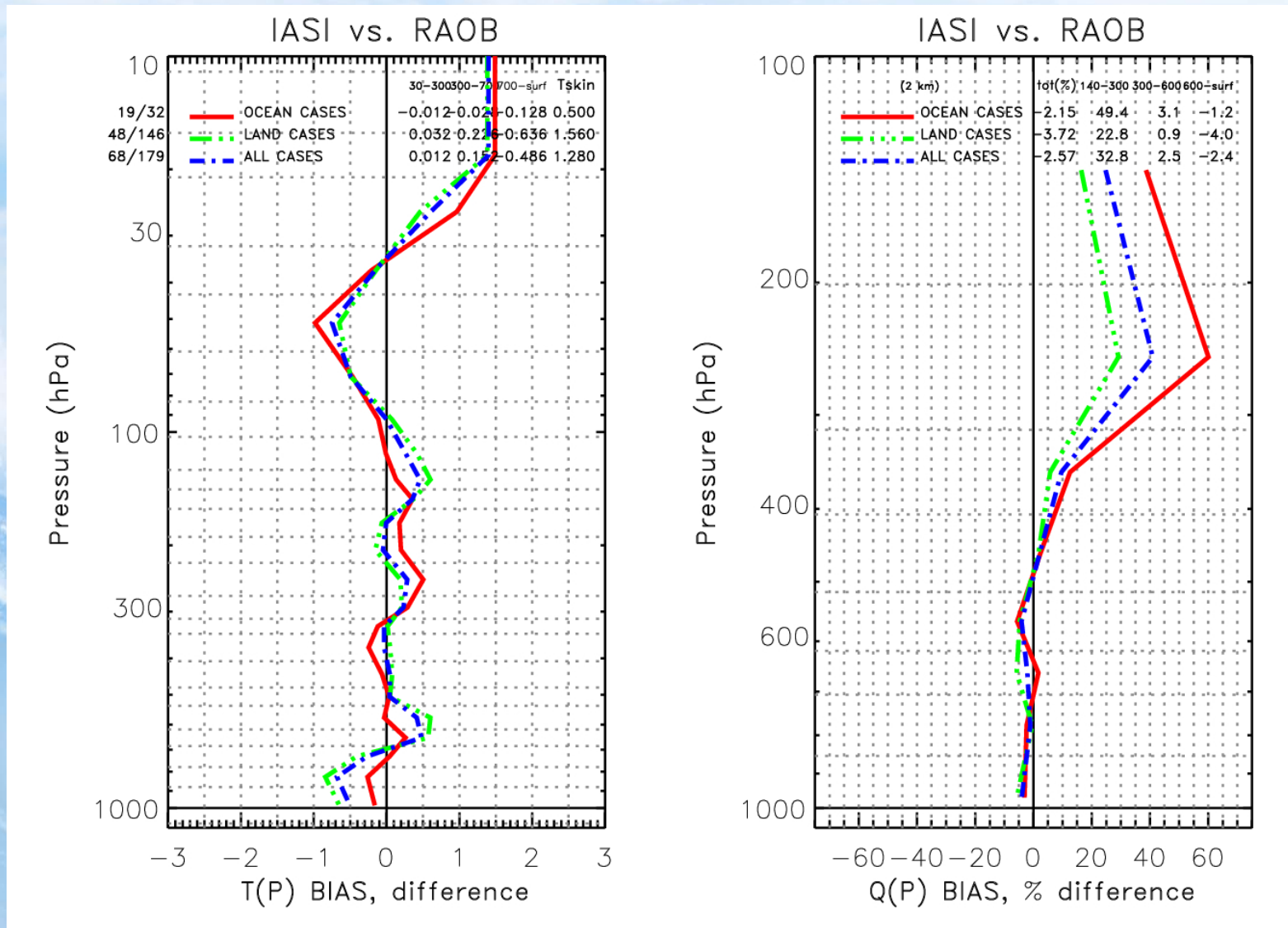




# Physical Retrieval – Standard Deviation w.r.t. RAOB's



# Physical Retrieval BIAS w.r.t. RAOB's



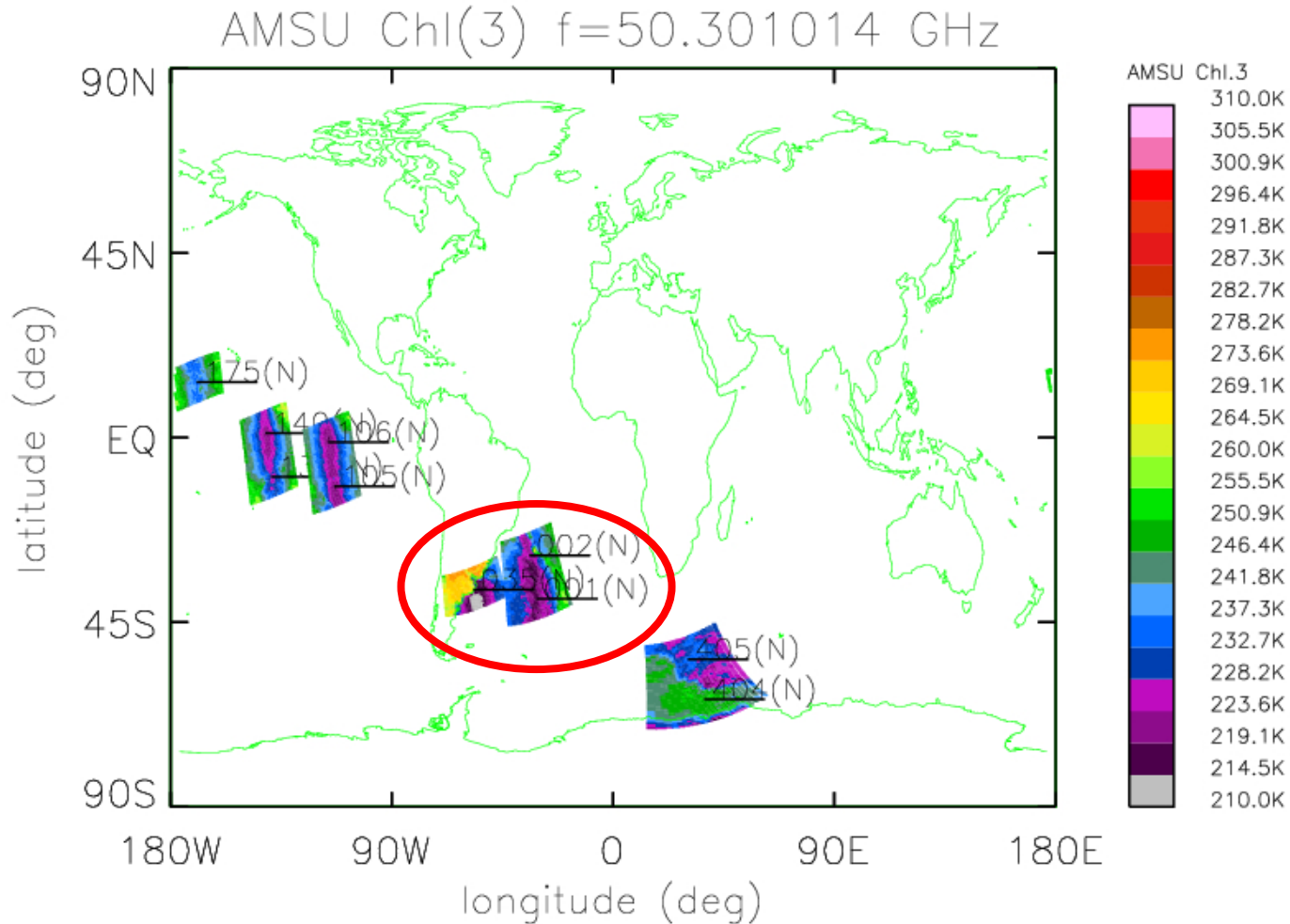


# Comparisons of preliminary IASI T(p), q(p), O<sub>3</sub>(p) retrievals to ECMWF and nearby AIRS Retrievals

see

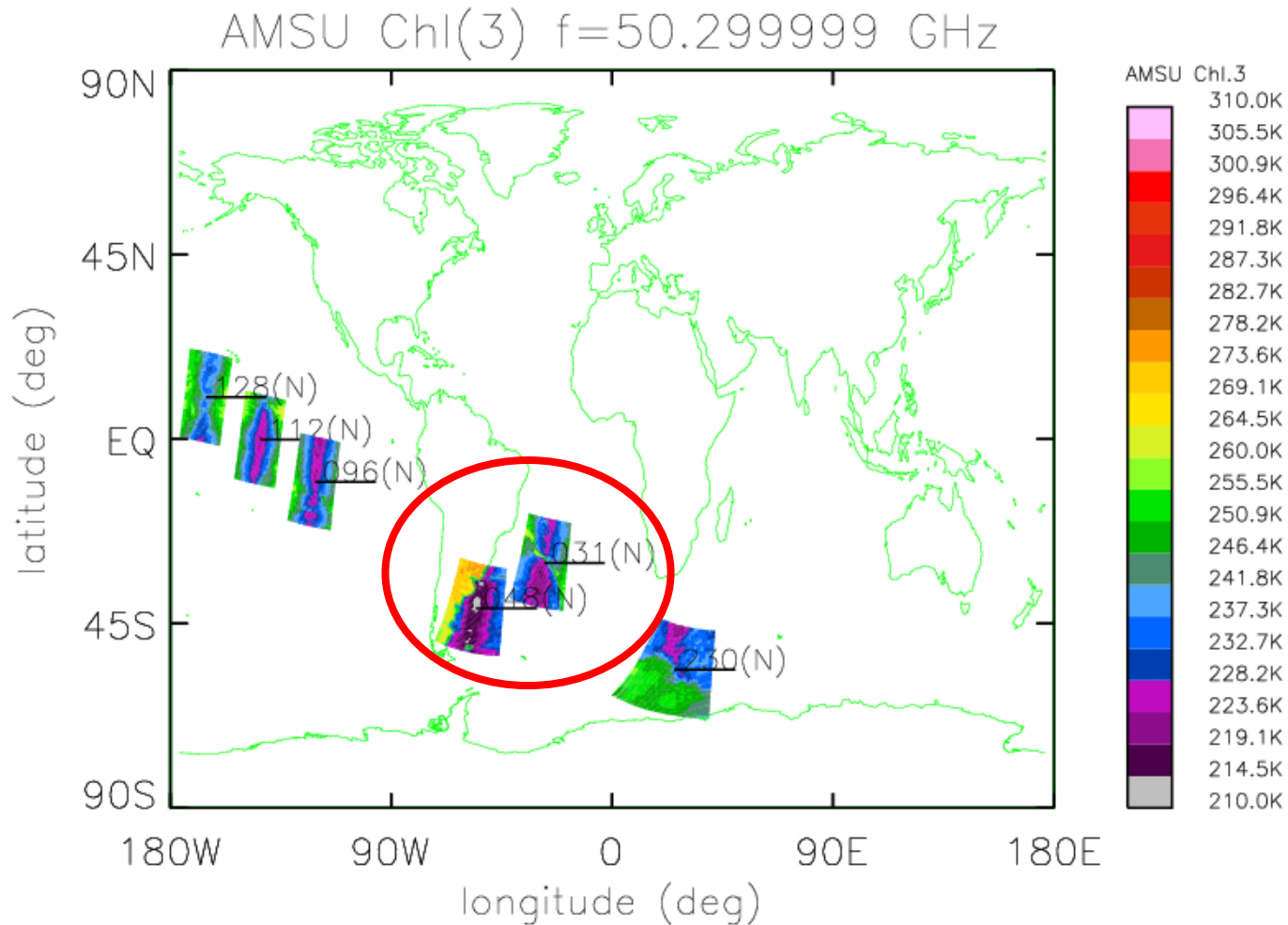
Poster #3  
Antonia Gambacorta

# Selected IASI Nighttime Ascending Granules (9:30 pm)





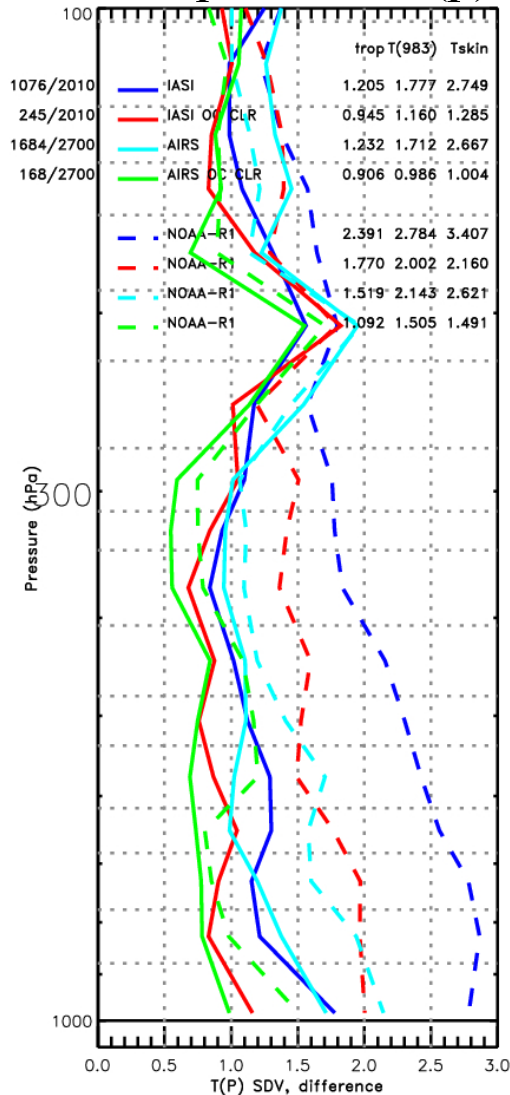
# Near AIRS Nighttime Descending Granules (1:30 am) – 4 hour difference



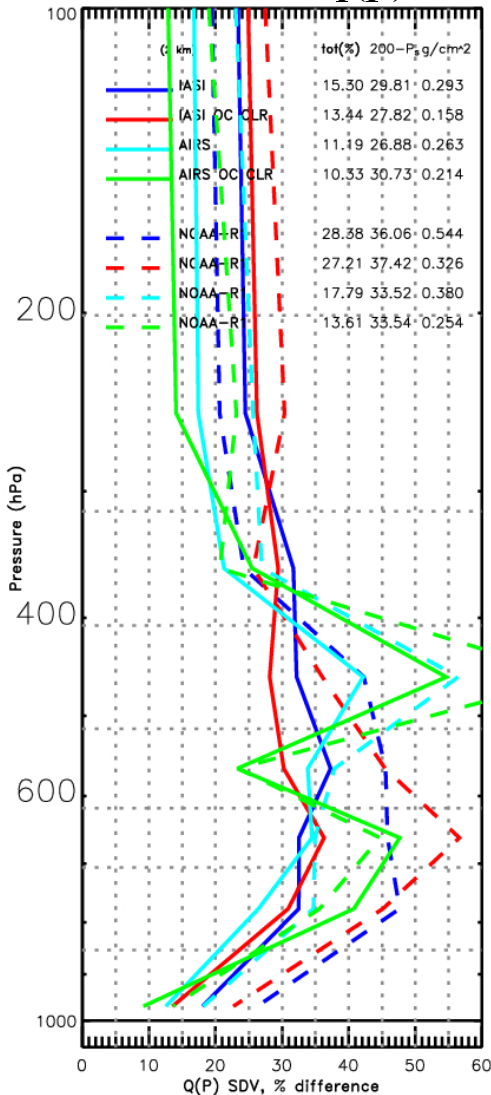
# Standard deviation of retrievals-ECMWF

IASI (blue), IASI CLEAR (red) AIRS (cyan), AIRS CLEAR (green)

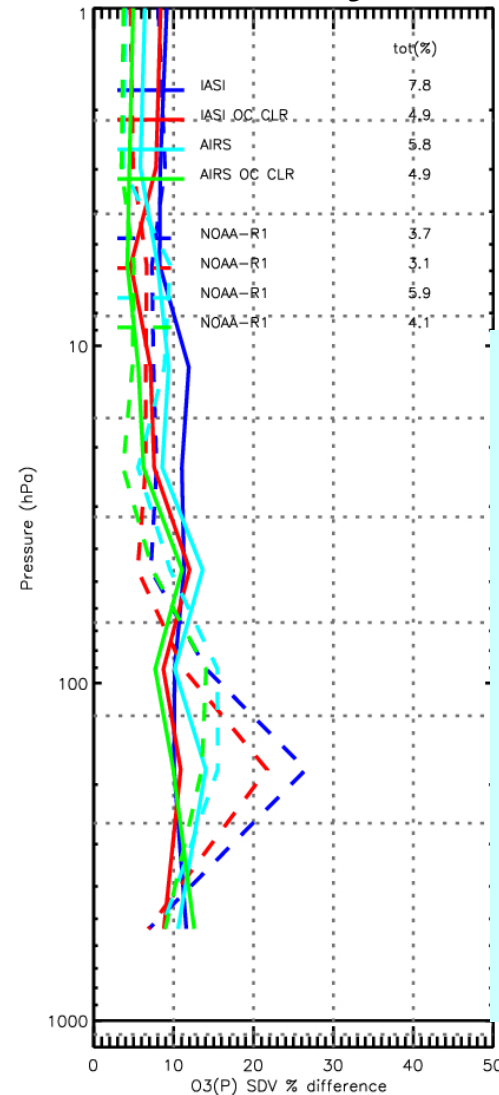
## Temperature, $T(p)$



## Water, $q(p)$



## Ozone, $O_3(p)$



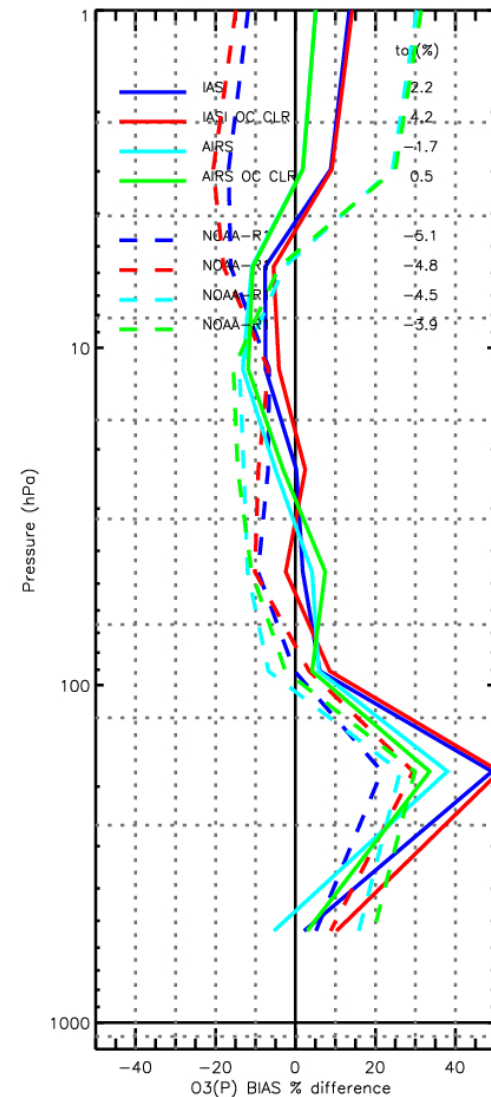
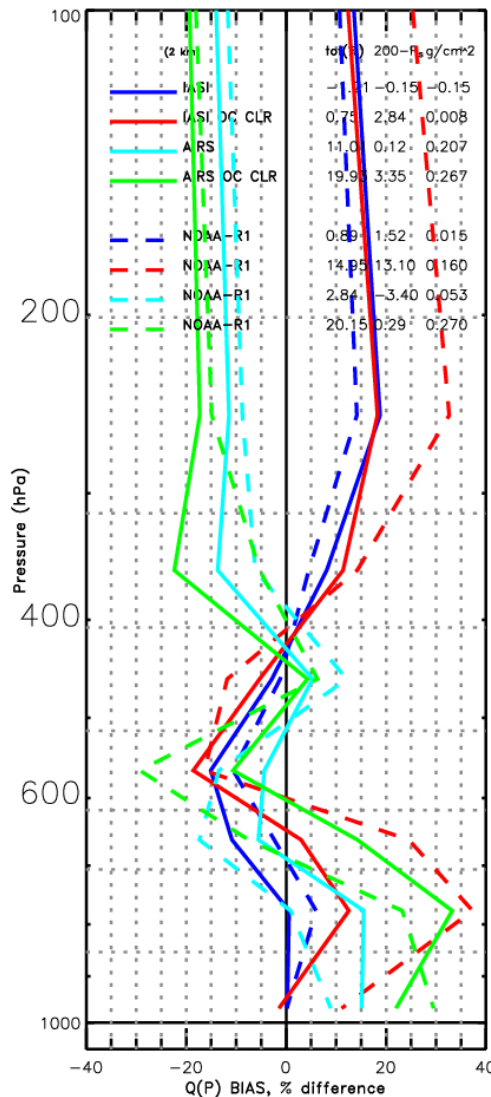
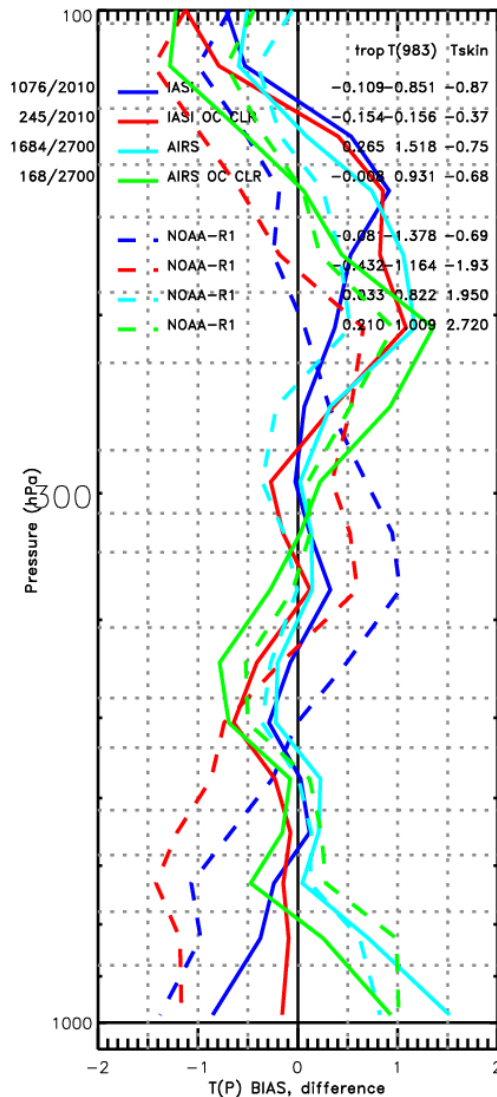
Standard  
Deviation  
w.r.t.  
ECMWF

Dashed lines  
are NOAA  
Cloudy  
Regression  
and Solid  
lines are  
Physical  
Retrieval

Using  
Physical QA

# Bias of retrievals – ECMWF

IASI (blue), IASI CLEAR (red) AIRS (cyan), AIRS CLEAR (green)



BIAS  
w.r.t.  
ECMWF

Dashed lines  
are NOAA  
Cloudy  
Regression  
and Solid  
lines are  
Physical  
Retrieval

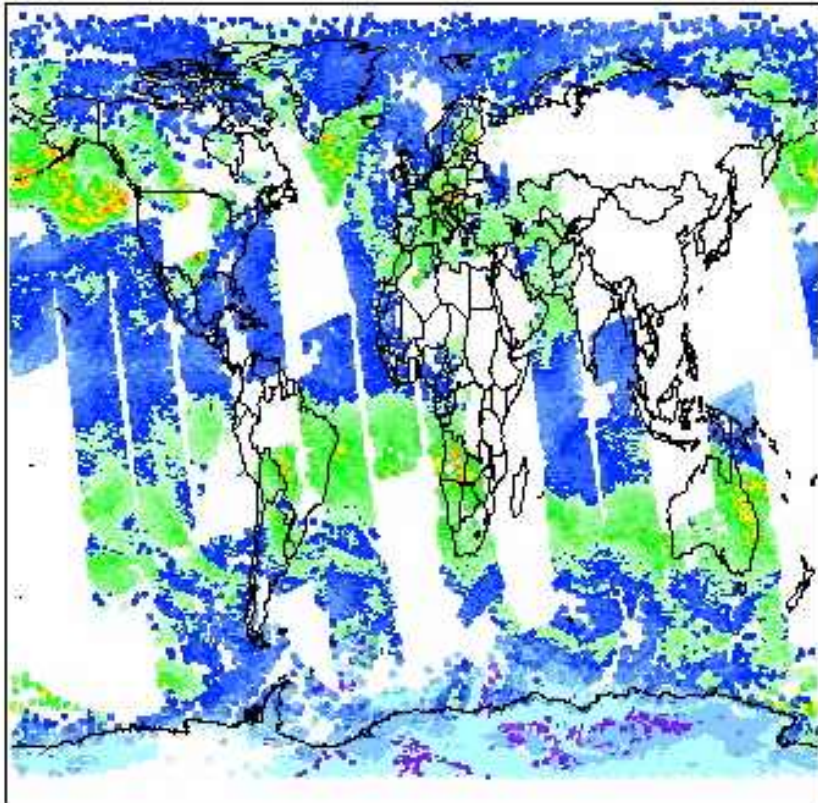
Using  
Physical QA



# Quick look at preliminary retrievals of trace gases.

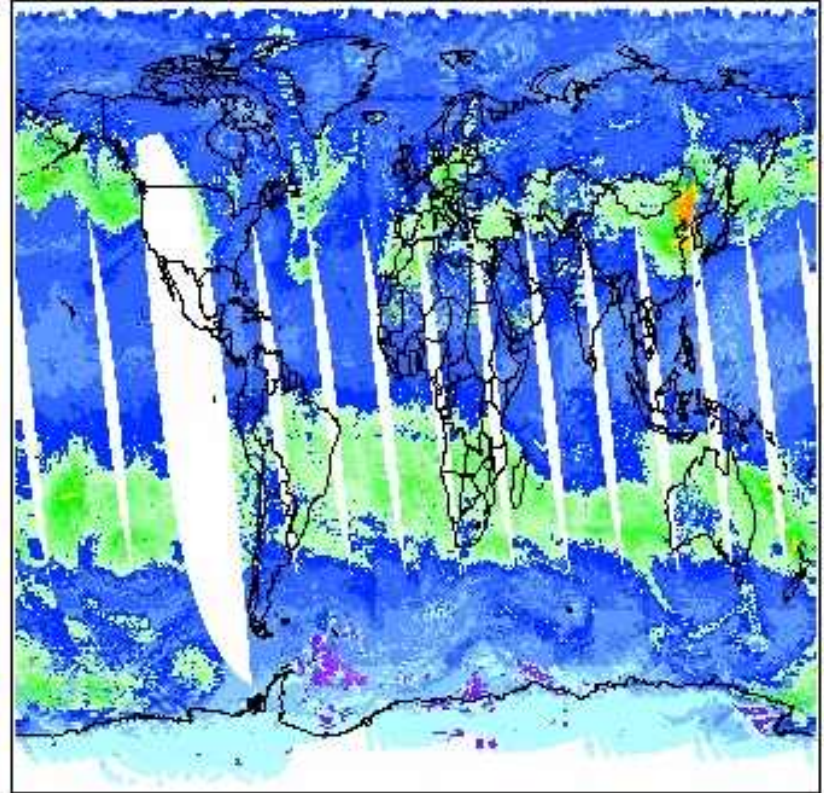
# Comparison of IASI and AIRS Ozone Product, Oct. 19, 2007

IASI O<sub>3</sub> (ppbv) 20071019a, 500mb



IASI 21:30  
Ascending (night)

AIRS O<sub>3</sub> (ppbv) 2007.10.19A, 500mb



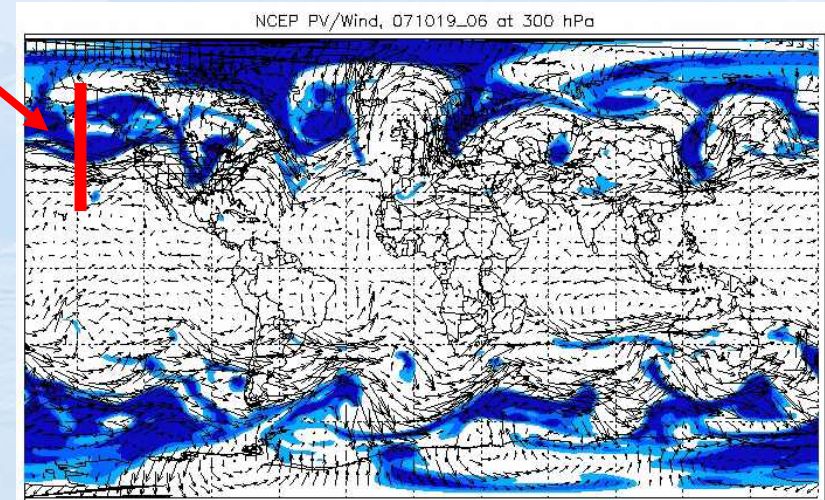
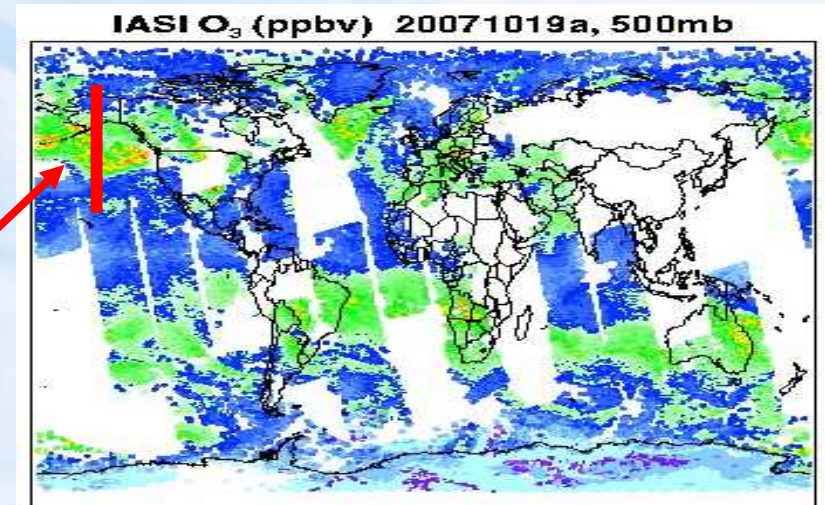
AIRS 13:30  
Ascending (day)

NOTE: Level-2 QA flag ignored for these figures.



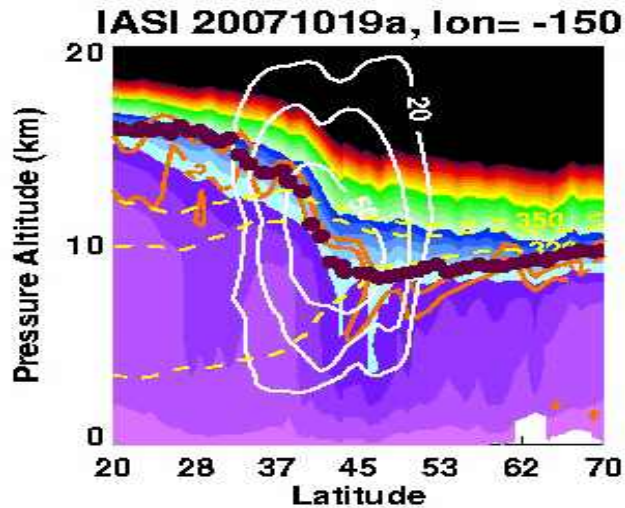
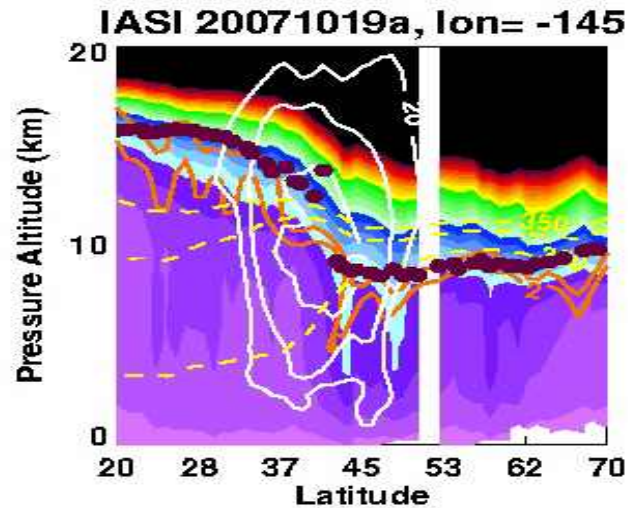
# Comparison of IASI Ozone and NCEP PV/Wind

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



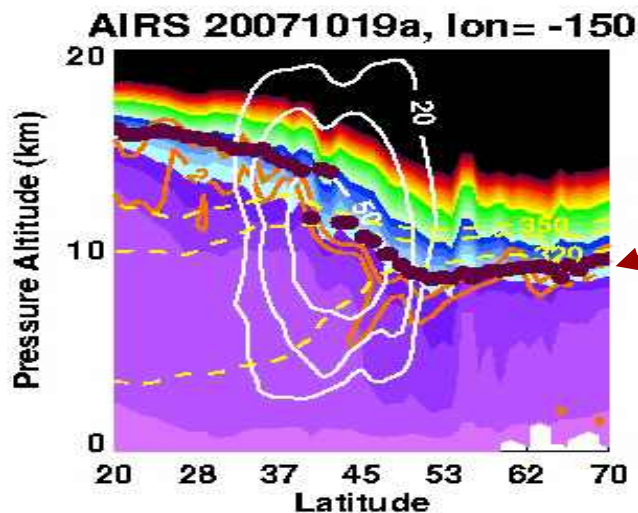
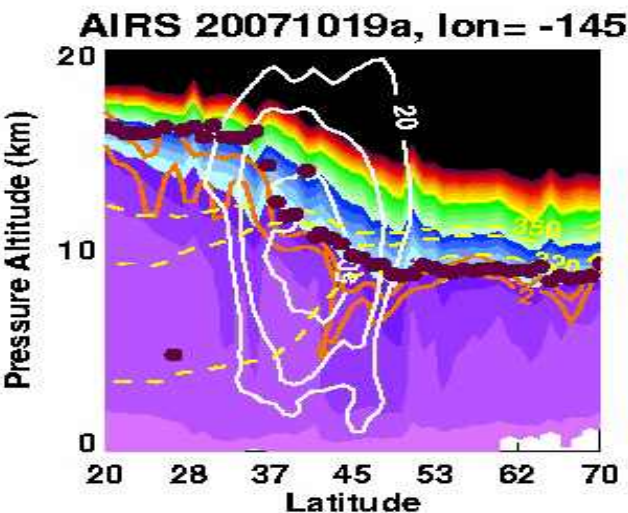


# Stratospheric Intrusion at longitude -145° and -150°



IASI 21:30  
Ascending (night)

--- Geo-potential  
Temperature 350, 380, 400  
— PV, 2, 4  
— Zonal Wind

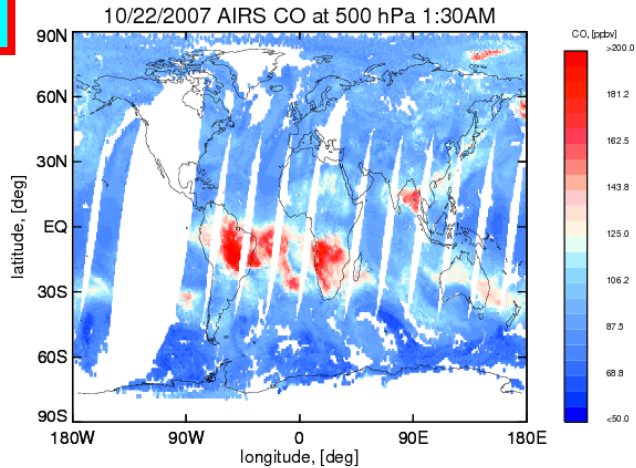


Thermal Tropopause  
(derived from retrieval)

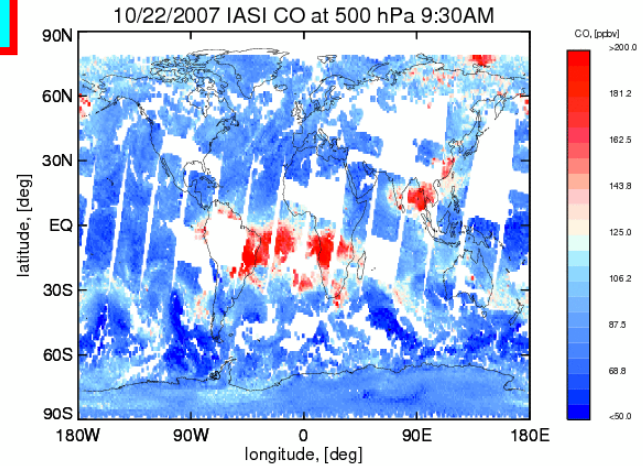
AIRS 13:30  
Ascending (day)

# IASI & AIRS Carbon Monoxide

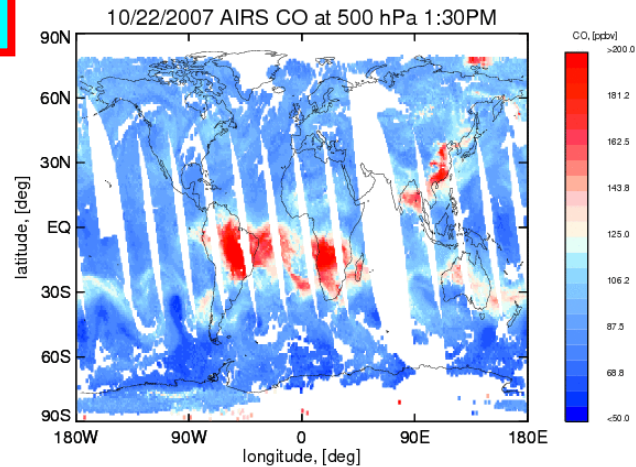
1



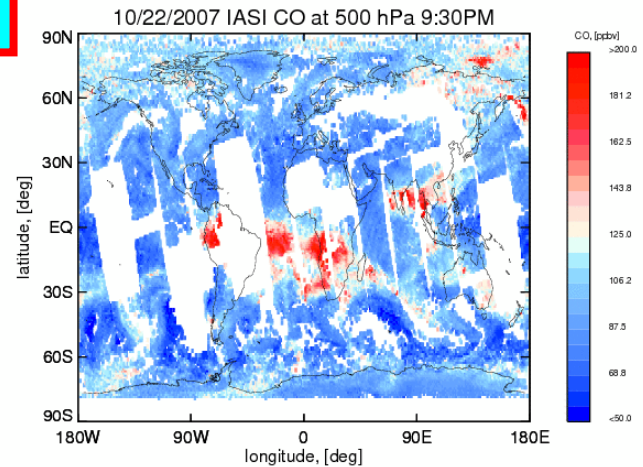
2



3



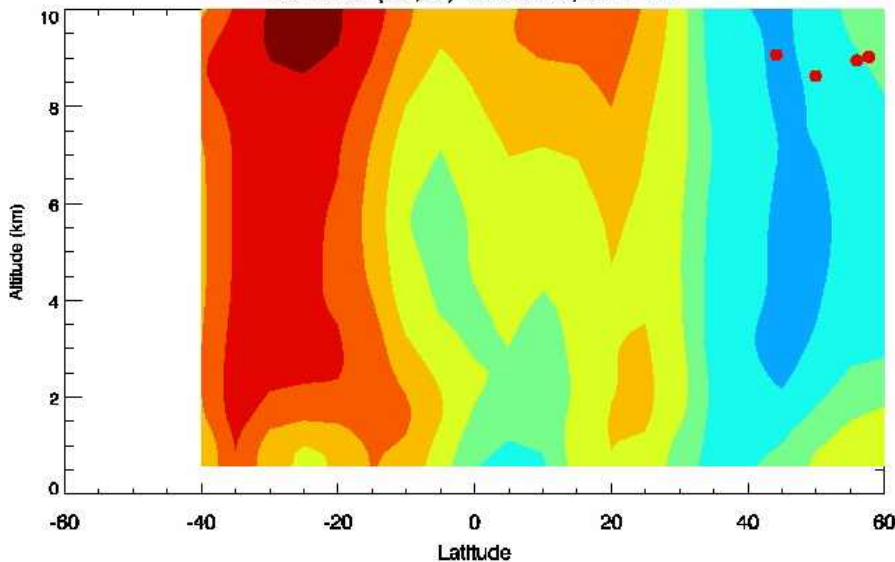
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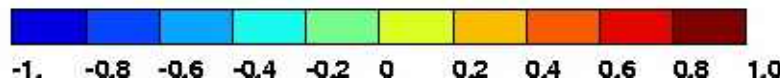
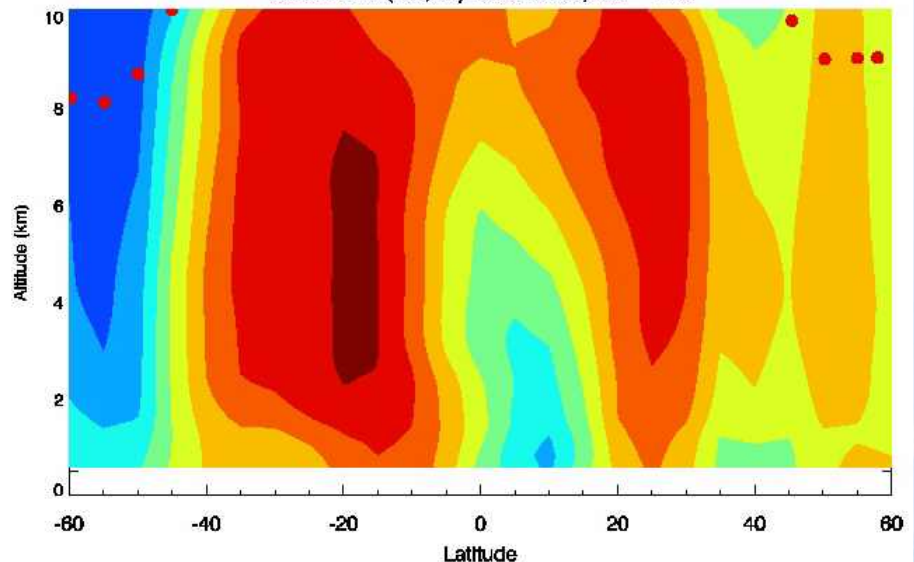


# CO & O<sub>3</sub> correlations at Longitude = -145°

IASI Rcoeff(CO,O3) 20071019a, lon= -145



AIRS Rcoeff(CO,O3) 20071019a, lon= -145

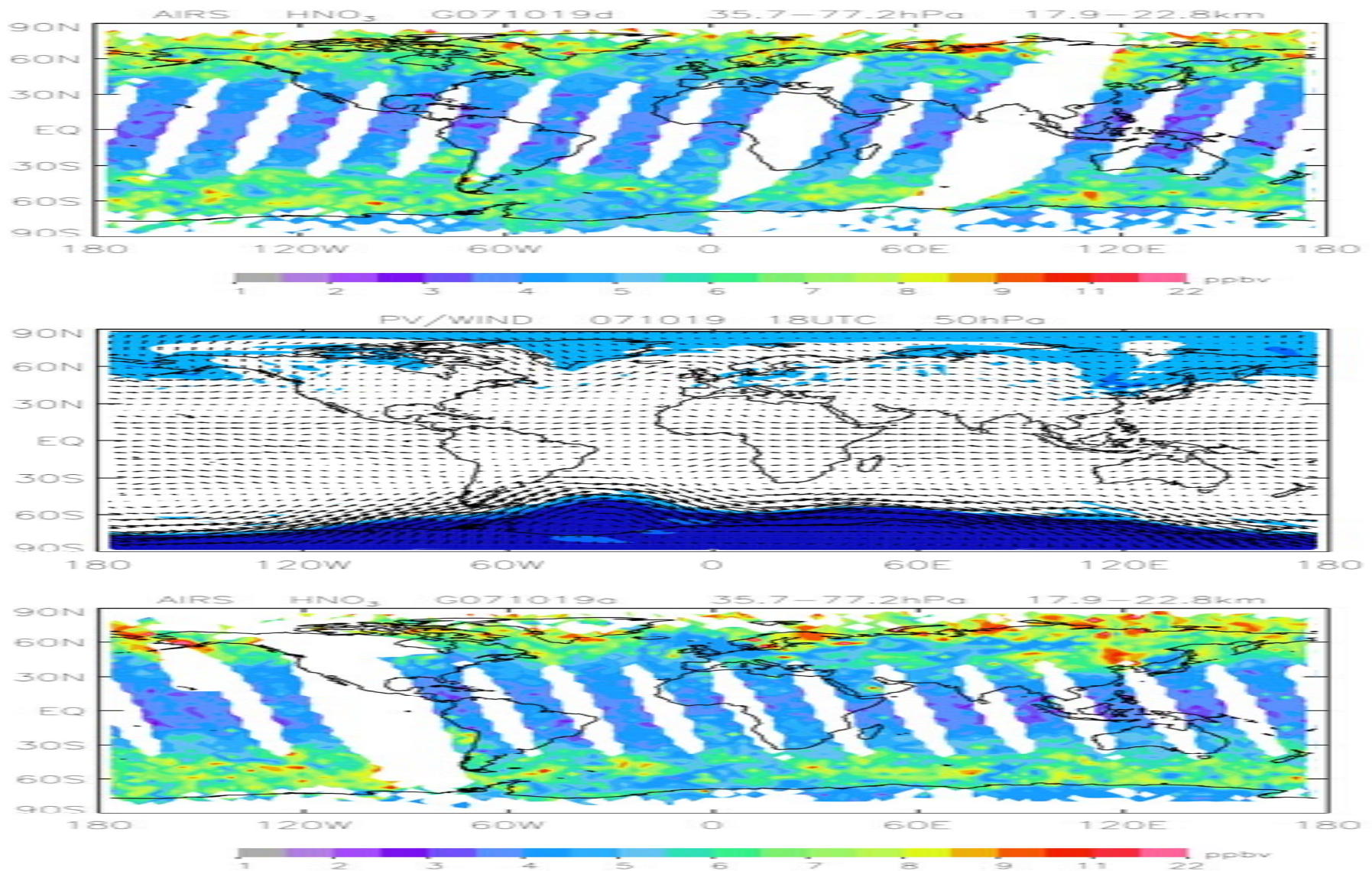


IASI 21:30  
Ascending (night)

AIRS 13:30  
Ascending (day)



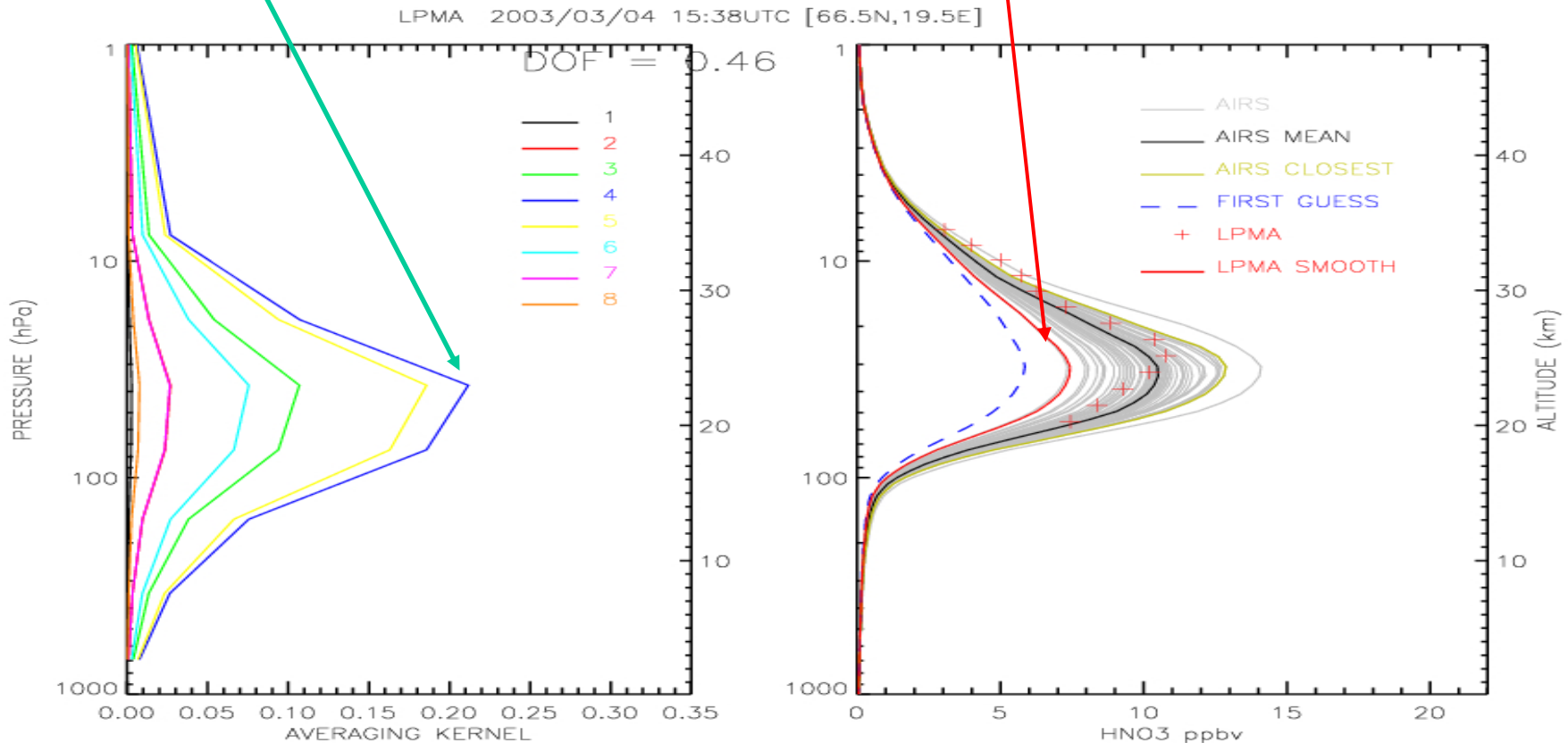
# Example of AIRS $\text{HNO}_3$ Product and comparison with NCEP Potential Vorticity



# AIRS $\text{HNO}_3$ Comparisons with LPMA (Laboratoire de Physique Moléculaire et Applications) du CNRS - Mar. 4, 2003 FTIR solar occultation sounding, Flight LPMA19

25% of the retrieval is believed at the lower stratosphere

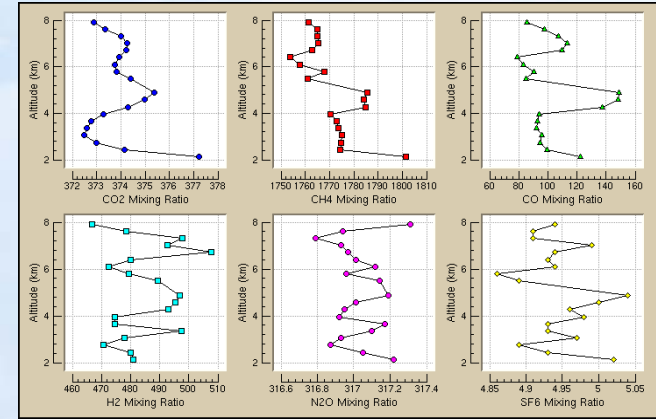
Convolved *in-situ* measurements with AIRS averaging kernel.



AIRS overestimates about 3 ppbv near the VMR peak and has large horizontal variation.



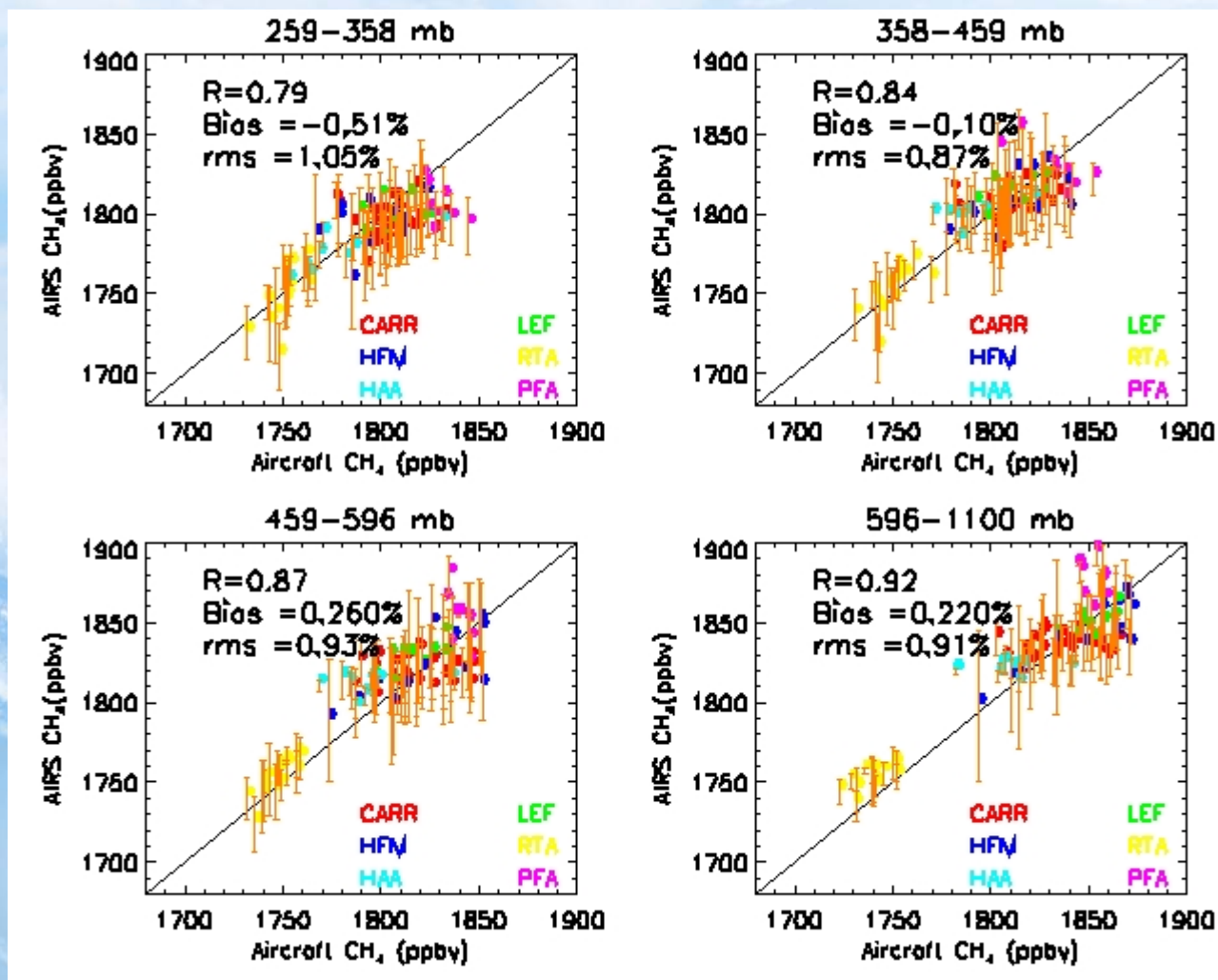
# Comparisons to ESRL/GMD aircraft observations (Bakwin, JGR, 2003)



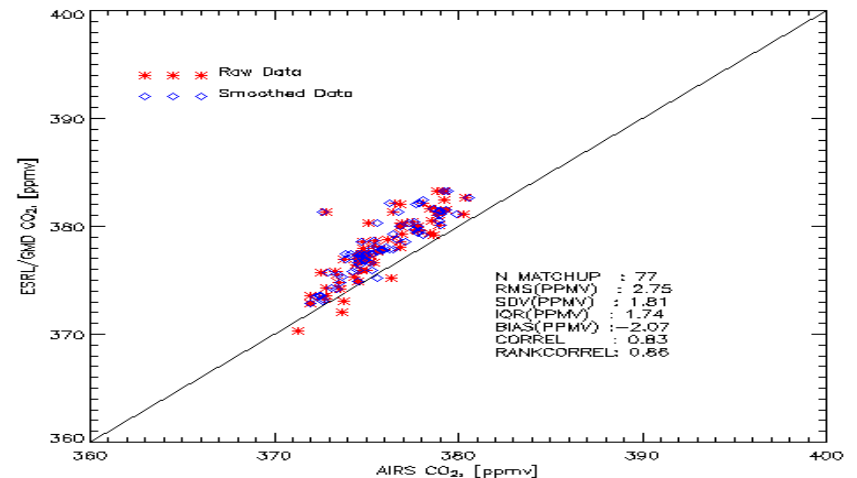
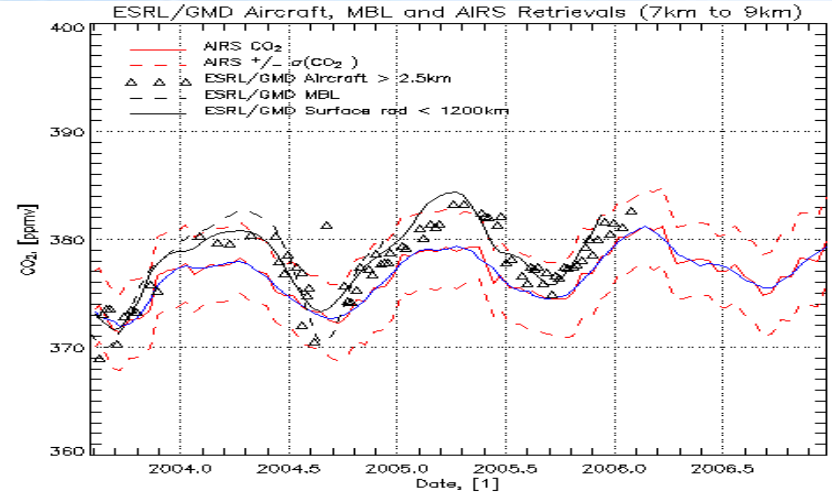
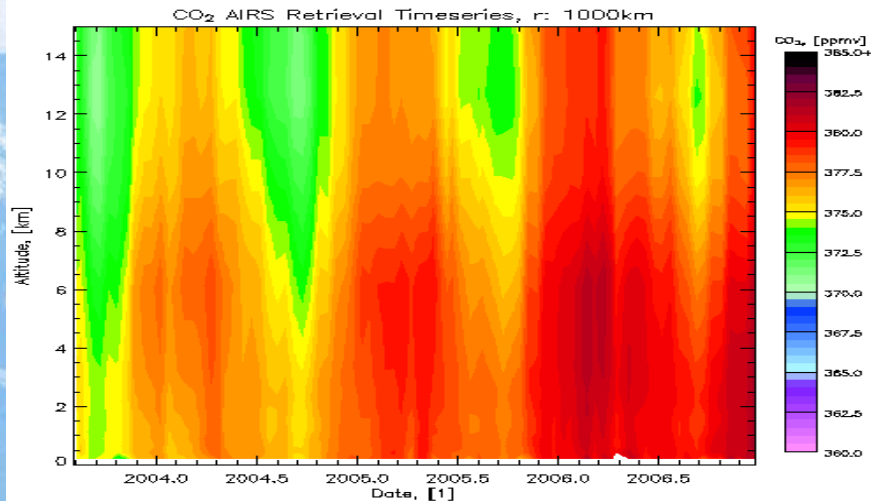
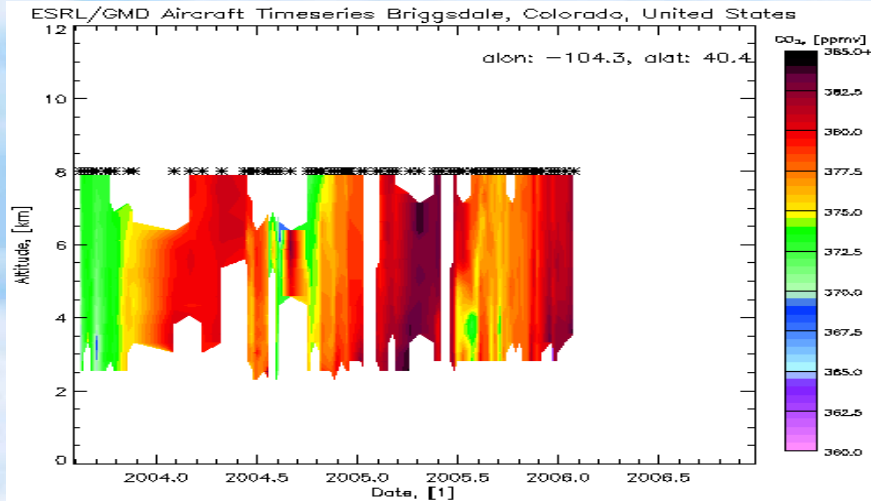
- Comparison of AIRS & ESRL/GMD flask observations..
  - Usually  $\geq 5$  hour time difference between aircraft and AIRS observations.
  - Aircraft altitude is typically  $\leq 7$  km.
  - Aircraft measures a small spatial region while it spirals downward.
- Aircraft measurement is vertically integrated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



# AIRS CH<sub>4</sub> comparison to ESRL Aircraft



# Comparison of AIRS CO<sub>2</sub> product with *in situ* aircraft at Carr, CO





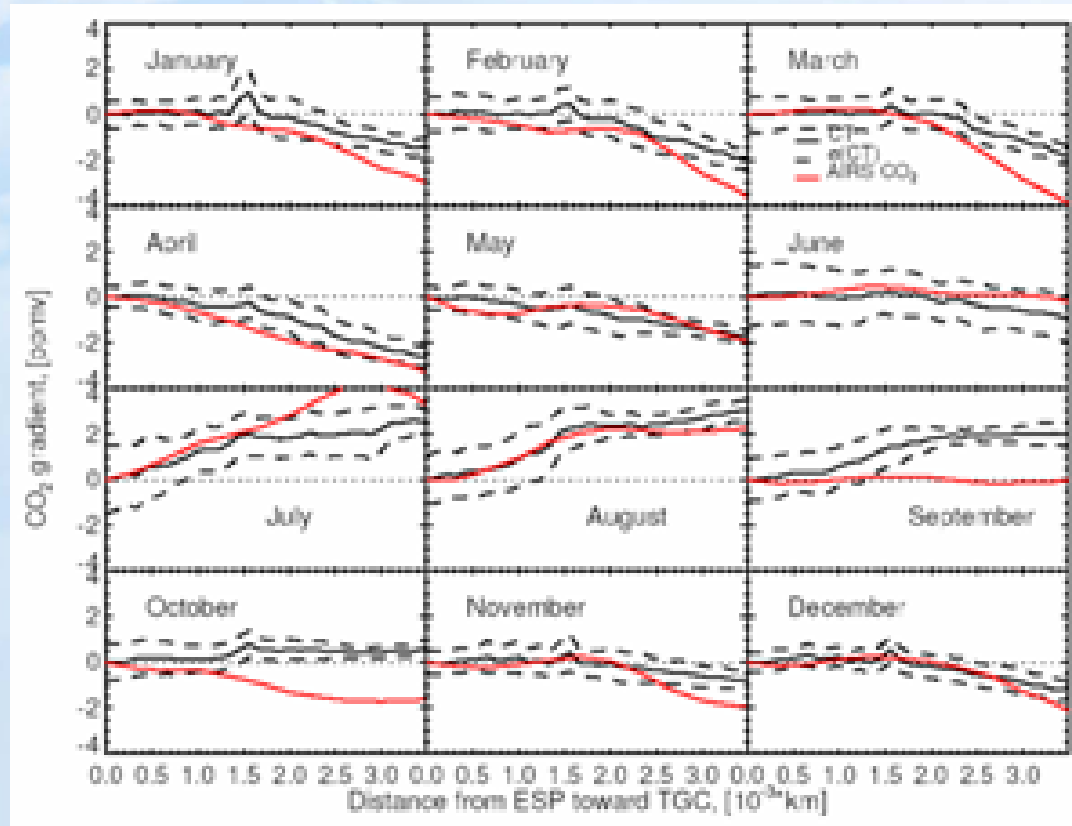
# Comparison of gradients in NOAA CO<sub>2</sub> Product & ESRL CarbonTracker Model

ESP

Estevan Point, British Columbia

TGC

Sinton, Texas



Note: These figures are from Eric Maddy's PhD dissertation defense on Nov. 6, 2007.

Black lines are from ESRL CarbonTracker with standard deviation.

Red line is AIRS retrieval

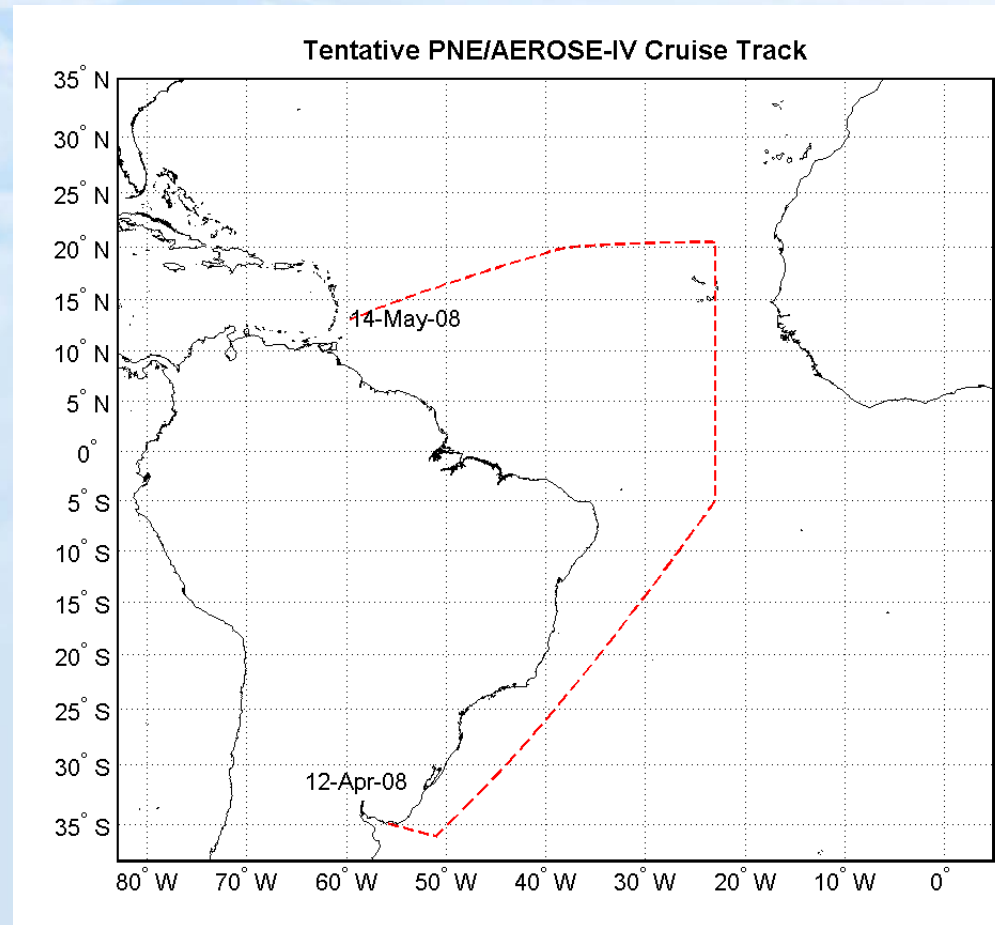


# NOAA NESDIS Participation in Retrieval Validation Activities for IASI Products



# 2008 PNE/AEROSE-IV

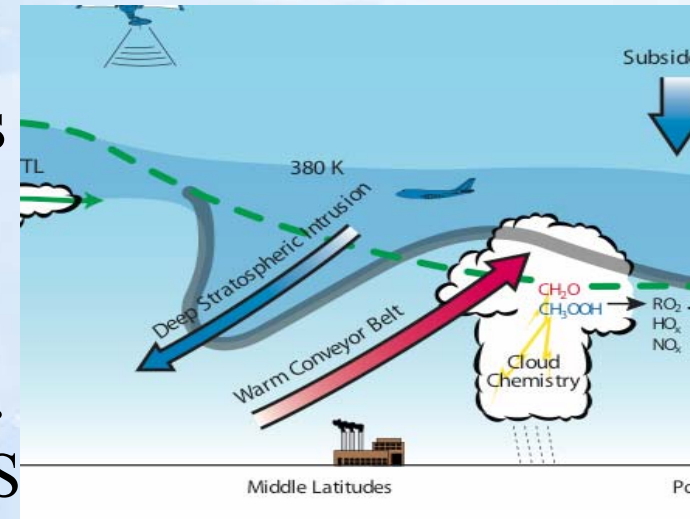
- Spring 2008: NOAA PNE Cruise provides the next opportunity for conducting an AEROSE-IV piggyback campaign onboard the NOAA Ship *Ronald H. Brown*
- NESDIS/STAR plans to partner again with the Howard University NOAA Center for Atmospheric Sciences (HU/NCAS) and the University of Miami (UM/RSMAS) in support of IASI/AIRS validation campaign
  - Funding needed for ~100 Vaisala RS92 rawinsondes
  - HU/NCAS to fund ozonesondes
  - Sondes would be launched during IASI and AIRS overpasses
- As with the previous AEROSE campaigns, *in situ* validation data will be collected under the Atlantic Saharan air layer (SAL) and dust outflows (especially along the 23°W transect), and there is good chance for biomass burning outflows from South America and Africa



Contact **Nick.Nalli@noaa.gov** for more information.

# Stratospheric-Tropospheric Analysis of Regional Transport (START) Experiment

- START05: Nov. 21 to Dec. 23, 2005, 48 flight hours using NCAR's Gulfstream V "HAIPER" aircraft.
- START08: April 21 - May 16, 2008 & June 16 - June 28, 2008.
  - Science Objective: Transport in UT/LS
  - Co-I's: Elliot Atlas (Univ. of Miami), Kenneth P. Bowman (Texas A&M), Laura Pan (NCAR)
  - Preparations for HAIPER pole-to-pole Observations (pre-HIPPO)
    - PI: Steve Wofsy (Harvard)
    - Science Objective: Mixing and Interhemispheric Transport of CO<sub>2</sub>







# START08 Instrument Payload

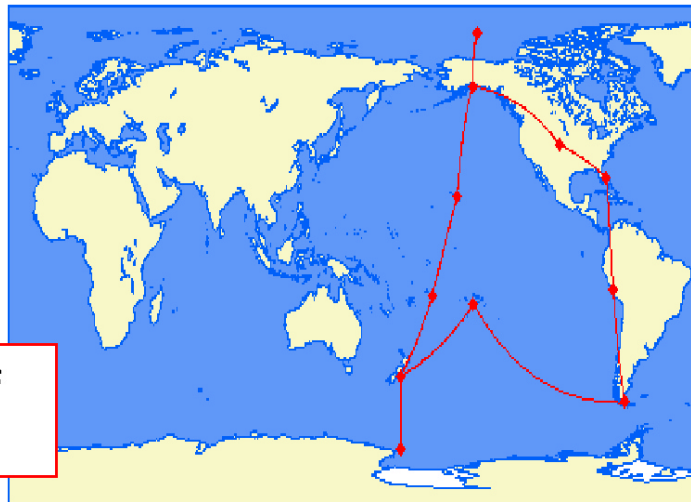
## (includes pre-HIPPO Payload checkout)

<u>Instrument/Model</u>	<u>Data product</u>	<u>Mission Objective</u>
HAIS Twin QCL	High resolution CO, CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	Tracer studies
HAIS AWAS	Grab sampling: NMHC, HCFC, RONO <sub>2</sub> , etc.	Tracer studies
PANTHER GC/MS	Medium resolution: selected trace gases	Tracer studies
UCATS*	GC analysis: CO/CH <sub>4</sub> ; continuous O <sub>3</sub> – H <sub>2</sub> O	Tracer studies
NCAR/HAIS Fast O <sub>3</sub>	>1 Hz ozone measurement	Strat-trop mixing
NCAR NO/NO <sub>y</sub>	High resolution NO, NO <sub>y</sub>	Strat-trop mixing, convective NO sources
RAF TDL H <sub>2</sub> O	High resolution H <sub>2</sub> O	Microphysics, strat-trop processes
HAIS SID-2	Small ice particle detector	Cirrus microphysics
HAIS MTP	Atmospheric temperature structure	Strat-trop processes; tropopause location
CU-CLH	Total water measurement; thin cloud detection	Microphysics, strat-trop processes
NCAR O <sub>2</sub> :N <sub>2</sub>	Measure of O <sub>2</sub> :N <sub>2</sub> ratio	Strat-trop exchange; carbon cycle objective

# Preliminary Flight Plans for START08 and HIPPO



*Pre-HIPPO/START08: Aircraft and payload testing, 1<sup>st</sup> science/exploratory flights*



*HIPPO Global: 5 missions over 3-4 years*

*Duration each 17—25 days*





# For more information:

<http://www.orbit.nesdis.noaa.gov/smcd/spb/iasi/index.html>

NOAA Satellites and Information  
National Environmental Satellite, Data, and Information Service

Satellite Meteorology  
& Climatology Division

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Statistical Results from 2nd Retrieval run (3x3 grid, v4.2, 2005/05)

- Time Average
  - Global Distribution
    - + Annual
    - + Monthly
    - + **Bi-Weekly**
    - + Seasonal
  - Latitudinal Distribution (table)
  - Latitudinal Distribution (menu)
- Time Series
  - Vertical Distribution
  - Latitudinal Distribution
  - Zonal Mean
- Animation
  - + Annual
  - + Monthly
  - + Bi-Weekly
- Vertical Weighting
- Validation
  - + BIAS & RMS
  - + Profiles

Using CMDL Aircraft Observation data, calculate BIAS & RMS for retrievals within 200 km of the six CMDL observation sites. Compare the results with the first guess and MIT retrievals. Click [here](#) to see the result images. Also plot the Retrieval, First Guess, and MIT profiles that are on the Observation date and within 200 km of the six sites. Click to see the plots.

Trace GAS web-pages allow a quick look at the trace gas products as a function of geography, time, and comparisons with *in situ* datasets.

USERID & PASSWORD

Request via e-mail:

[chris.barnet@noaa.gov](mailto:chris.barnet@noaa.gov)