Methane and Ozone Retrievals with AIRS

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NOAA/NESDIS/STAR/SPB

March 23, 2007

AIRS Science Team Meeting

Topics

- Status of NOAA Carbon Dioxide retrieval
- AIRS Ozone Product, changes in Version 5
  - Talk on Ozone Validation by Murty Divakarla on Thursday 1:30.
- AIRS Methane Product, added in Version 5
- Status of IASI Processing System

Member's of our Sounding Team who have contributed to the trace gas work.

Mitch Goldberg: AIRS & IASI Science Team, Climate Products
Walter Wolf: Near Real Time Processing & Distribution to Users
Lihang Zhou: Regression Retrieval & Near Real Time Web Page
Eric Maddy: CO_2 retrieval, "tuning", vertical averaging functions.
Xiaozhen Xiong: CH_4 retrieval & analysis.
Jennifer Wei: Ozone retrieval & trace gas correlations.
Nick Nalli: In-Situ validation & aerosol corrections.
Murty Divakarla: In-Situ Validation of core products.
Fengying Sun: Convective, N_2O, HNO_3 products
Xingpin Liu: Re-processing, Statistics, Product web-page
Antonia Gambacorta (UMBC): UTH, OLR and climate indices.

NOTE: Only a small fraction of our NASA funding goes to support trace gas work. The majority supports the core products (temperature, moisture, and ozone).

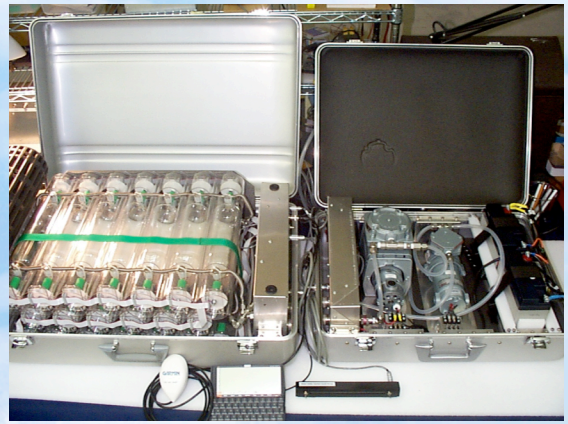
Trace Gas Product Potential from Operational Thermal Sounders

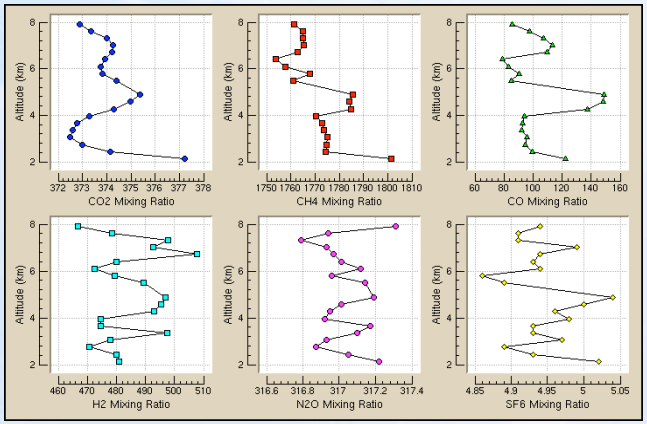
gas	Range (cm^{-1})	Precision	Interference	
UTH	**1400-1500**	**15%**	**T(p)**	**Product In PGE**
O_3	**1025-1050**	**10%**	**H2O,emissivity**	
CO	**2080-2200**	**15%**	**H2O,N2O**	
CH_4	**1250-1370**	**20 ppb**	**H2O,HNO3**	
CO_2	**680-795** **2375-2395**	**2 ppm** **2 ppm**	**H2O,O3**	**Research Product Available**
Volcanic SO_2	**1340-1380**	**1000%**	**H2O,HNO3**	
HNO_3	**860-920** **1320-1330**	**40%** **25%**	**emissivity** **H2O,CH4**	
N_2O	**1250-1315** **2180-2250**	**10%** **10%**	**H2O** **H2O,CO**	
$CFCl_3$ (F11)	**830-860**	**20%**	**emissivity**	**Held Fixed**
CF_2Cl (F12)	**900-940**	**20%**	**emissivity**	
CCl_4	**790-805**	**50%**	**emissivity**	

Haskins, R.D. and L.D. Kaplan 1993

NOAA Carbon Dioxide Products from AIRS

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

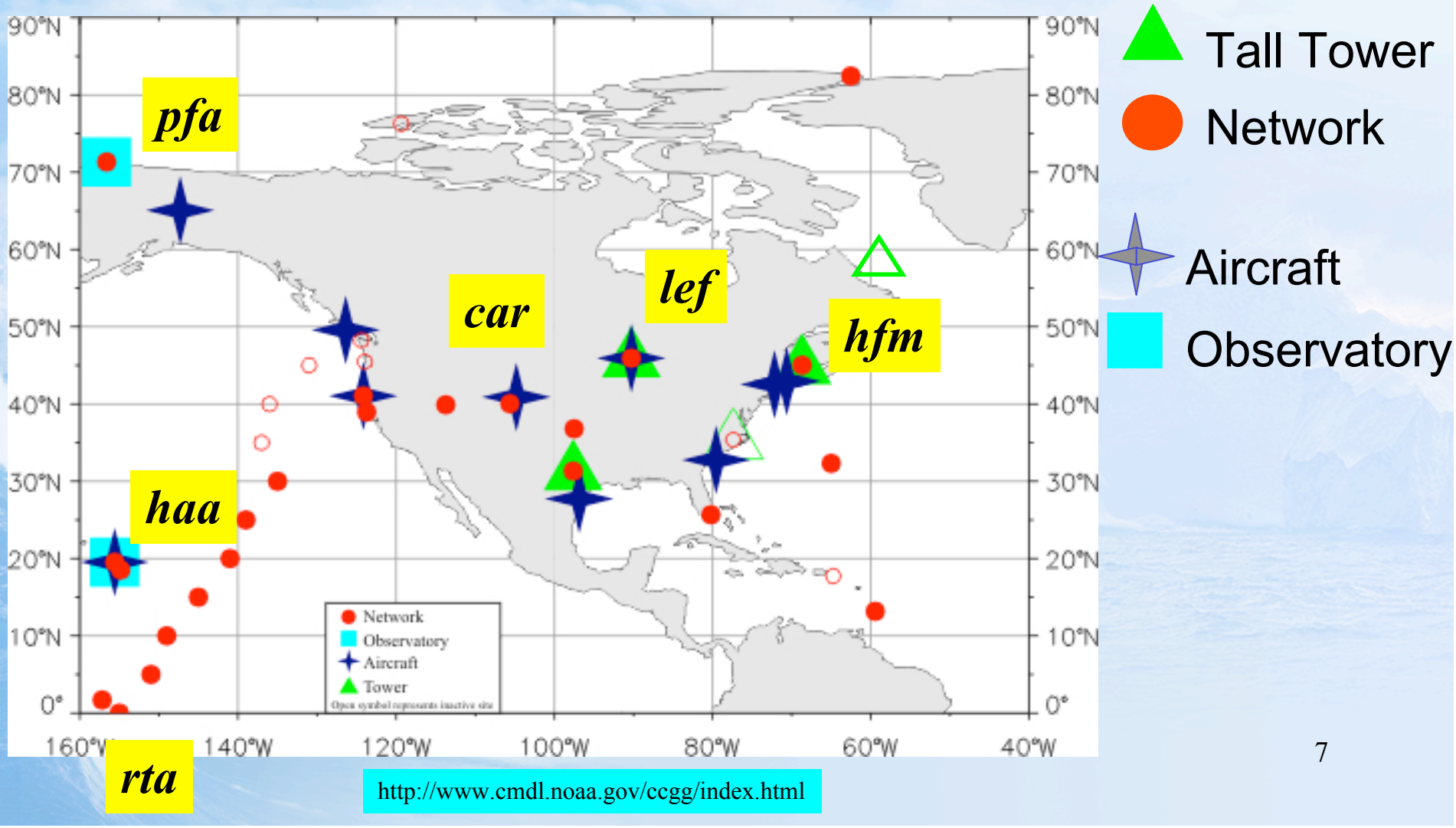




- Comparison of AIRS & ESRL/GMD flask observations..
  - Usually ≥ 5 hour time difference between aircraft and AIRS observations.
  - Aircraft altitude is typically ≤ 7 km.
  - Aircraft measures a small spatial region while it spirals downward.
- Aircraft measurement is vertically integrated to maximum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

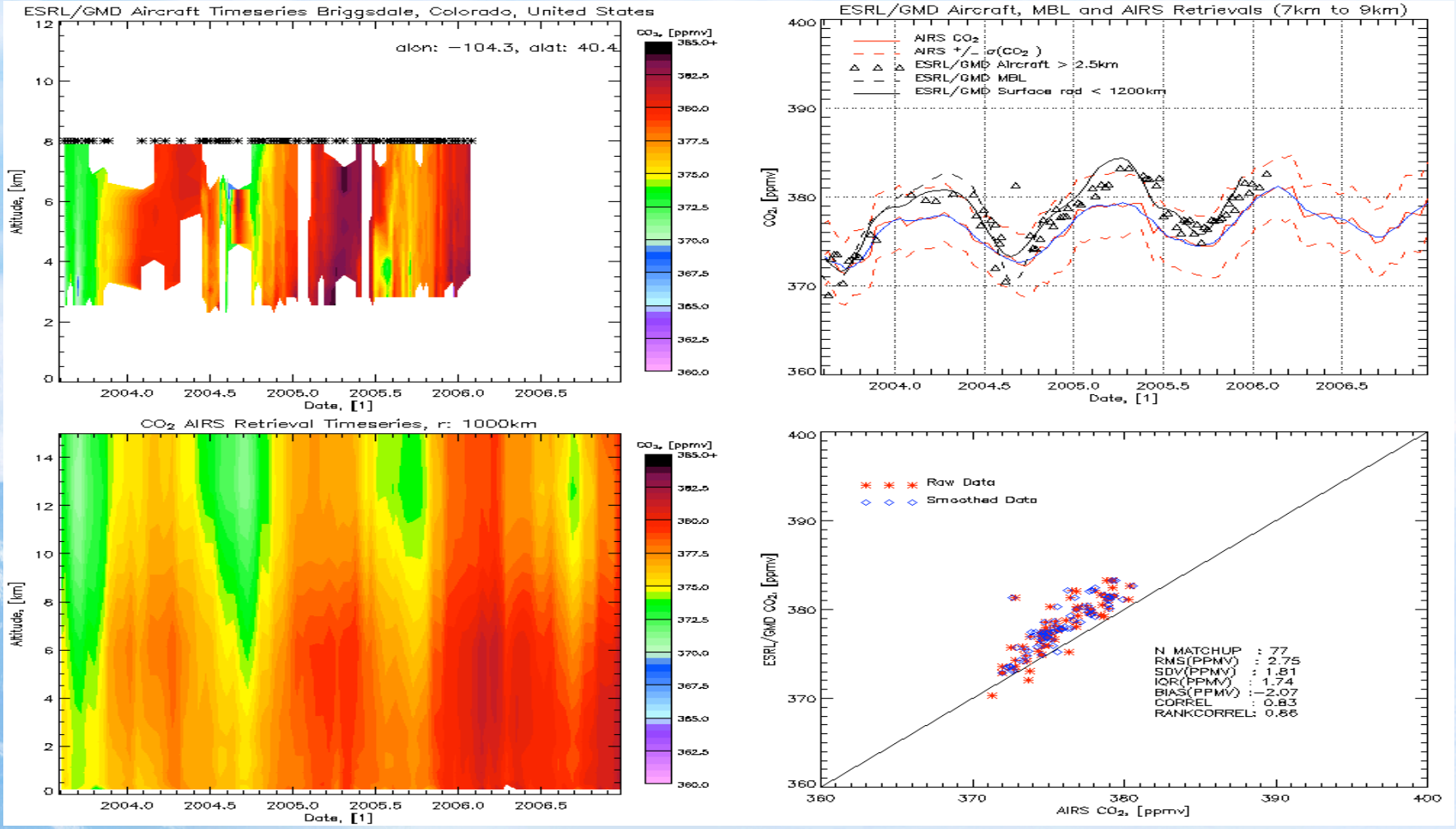
NOAA ESRL Validation Data

NOAA ESRL North American Sampling Sites



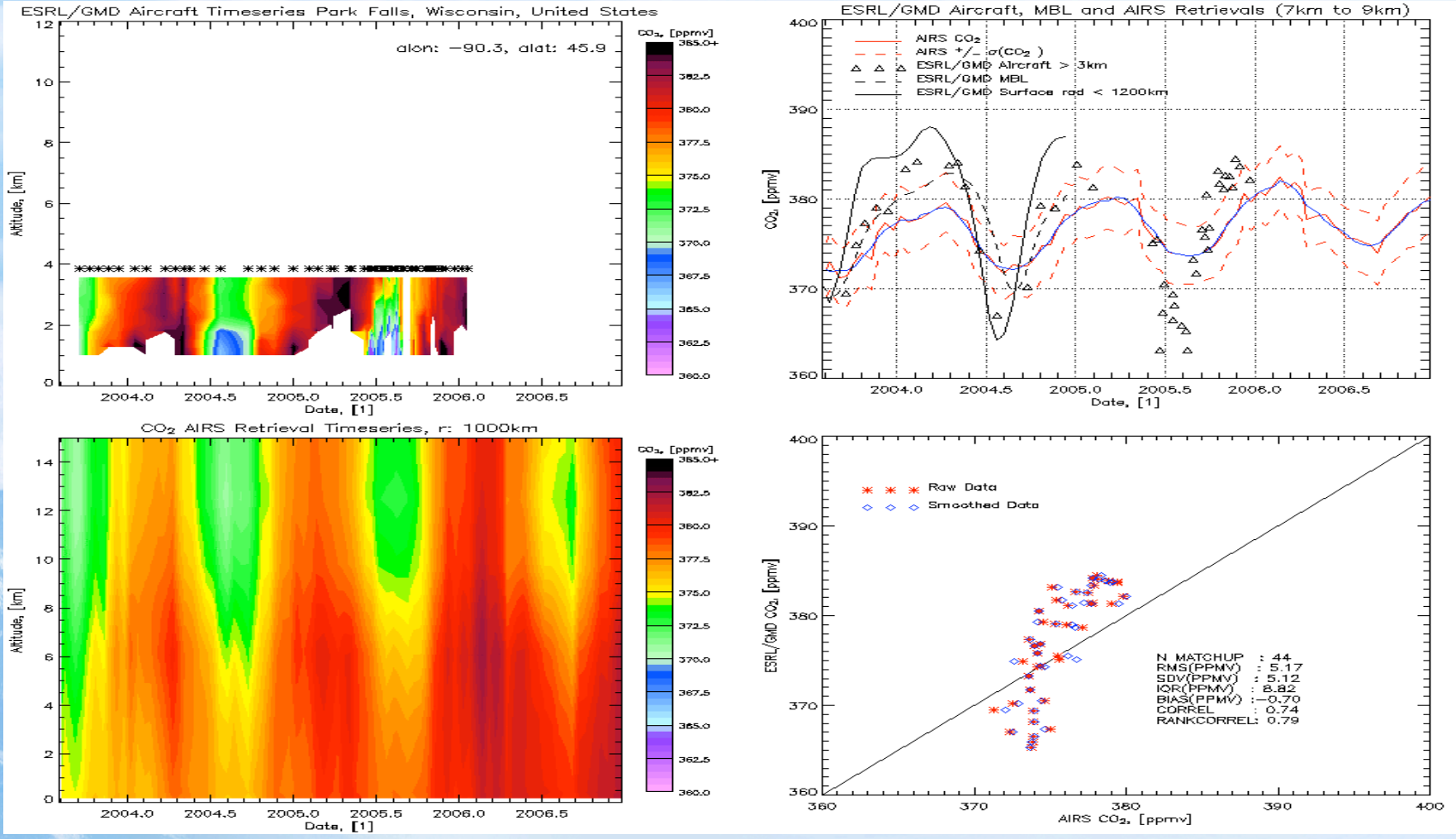
http://www.cmdl.noaa.gov/ccgg/index.html

Comparison of NOAA CO_2 product with *in-situ* aircraft at Carr, CO



NOTE: Currently we are using a 1:24 spatial sampling for these comparisons from our "3x3 global grid" reprocessing dataset.

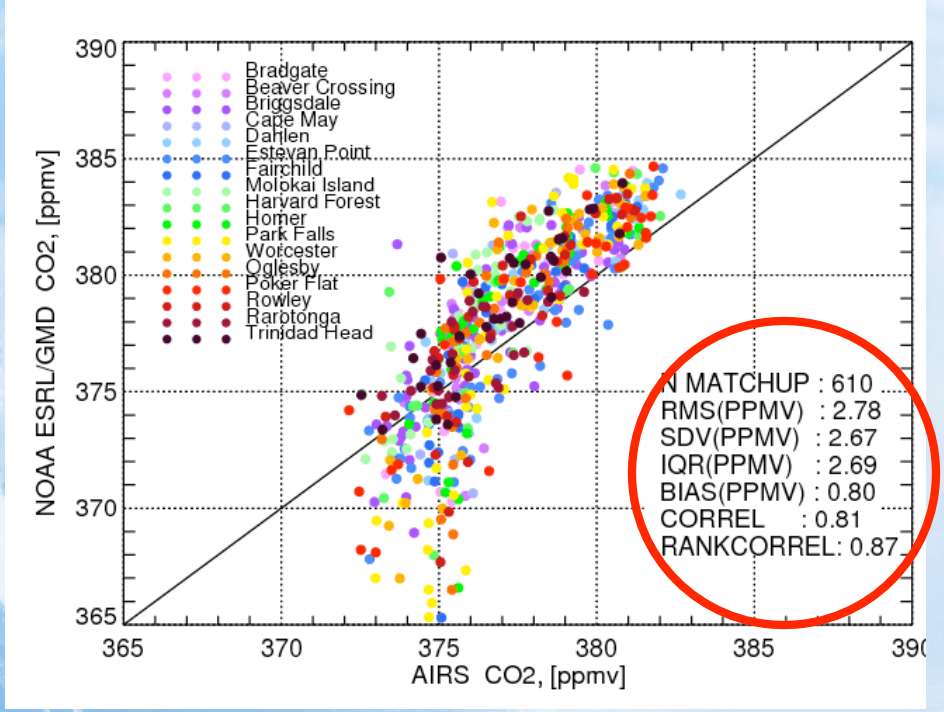
Comparison of NOAA CO_2 Product with *in-situ* Aircraft at Park Falls, WI



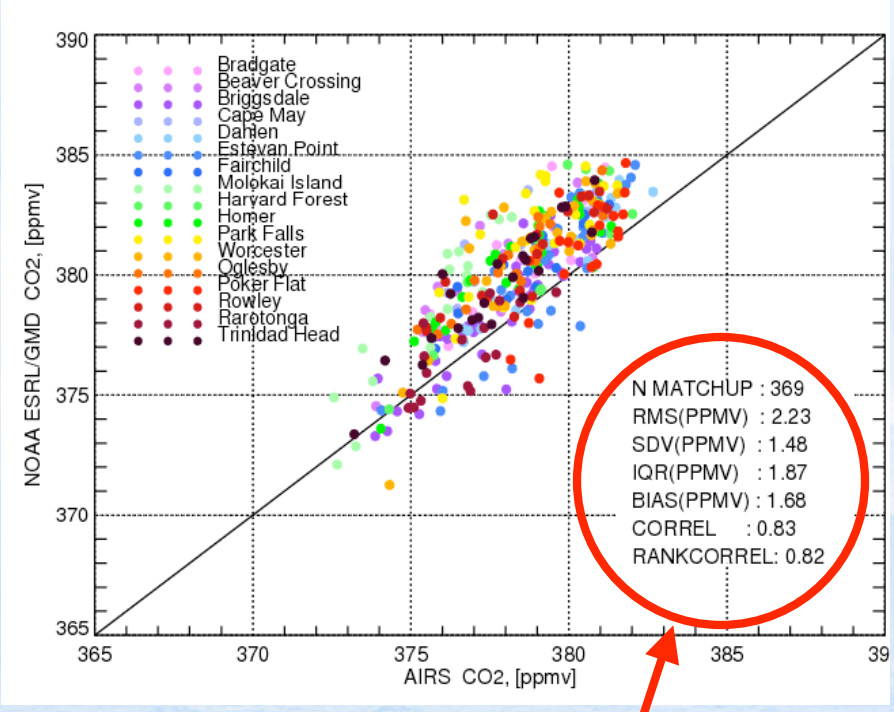
NOTE: Currently we are using a 1:24 spatial sampling for these comparisons from our "3x3 global grid" reprocessing dataset.

Comparison of NOAA CO_2 with ALL ESRL *in-situ* Aircraft

All Observations (17 Sites)



Excluding mid-summer cases



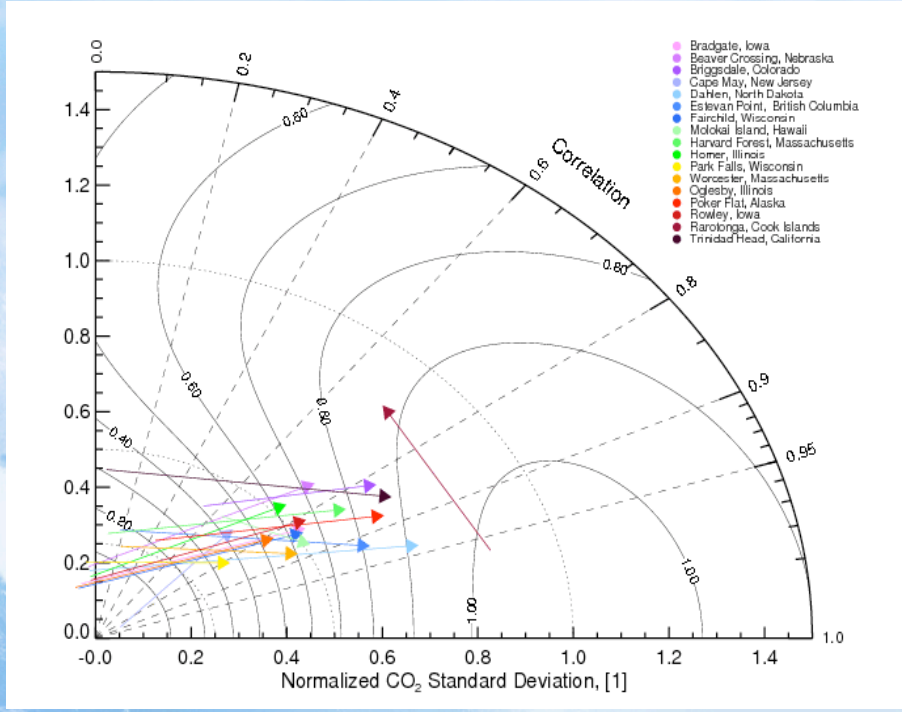
0.5% SDV from space!!

Low values of CO_2 are not seen in AIRS retrieval

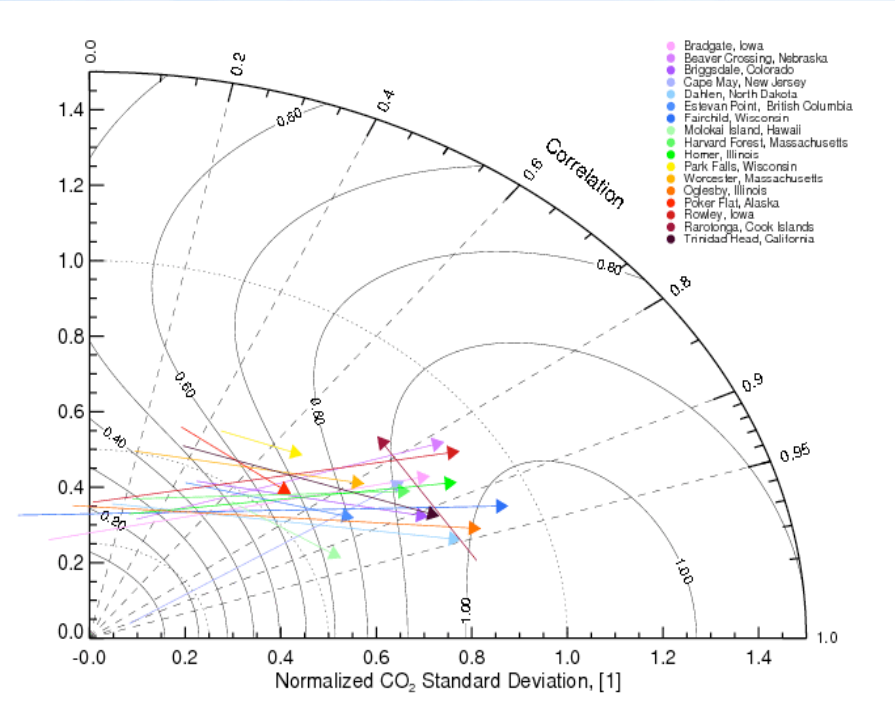
1. Aircraft samples a *significantly* smaller volume (centered over forest) and, therefore, captures more of the photosynthetic drawdown
2. Difference in sampling time/diurnal effects (we do see diurnal signals).
3. Too much regularization or large cloud clearing error.

Taylor Diagrams (JGR 106, p.7183) illustrates skill in NOAA CO_2 product

All ESRL Observations (17 Sites)



Excluding mid-summer cases



- Radius represents normalized standard deviation of AIRS product
- Angle is the correlation between AIRS product and *in-situ* aircraft
- Beginning of arrow is first guess, end of arrow is AIRS product
- Contours represent a "skill score" (Taylor Eqn. 14).

NOAA AIRS CO_2 Product is Still in Development

- Product is CO2(p) profile with associated averaging kernels.
- Measuring a product to 0.5% is inherently difficult
  - Cloud clearing error (also error estimates) strongly impacts the CO2 product.
  - Errors in moisture of ±10% is equivalent to ±0.7 ppmv errors in CO2.
  - Errors in surface pressure of ±5 mb induce ±1.8 ppmv errors in CO2.
  - AMSU side-lobe errors corrupt the ability to use the 57 GHZ O2 band as a T(p) reference point.

Reduction of Core product retrieval errors is critical for CO_2.

- Currently, we can characterize seasonal and latitudinal mid-tropospheric variability to test product reasonableness.
- The real questions is whether thermal sounders can contribute to the source/sink questions.
  - Requires accurate vertical & horizontal transport models
  - Having simultaneous O_3, CO, CH_4, and CO_2 products is a unique contribution that thermal sounders can make to improve the understanding of transport.

Planned Collaboration for our CO_2 Product Beginning this Spring.

- Randy Kawa/ Mian Chin, GSFC, CO2/CO transport modeling
- Yuk Yung, Caltech, CO2/STE model, coupled product with NASA's Orbiting Carbon Observatory.
- Rhian Evans/Paul Monks, Leicester University, AIRS/Sciamachy/model comparison
- Zan Stine/Inez Fung, UC Berkeley, CO2 biophysical modeling (PhD thesis topic).
- Monika Kopacz/Daniel Jacobs, Harvard, CO/CO2 biophysical modeling (PhD thesis topic).

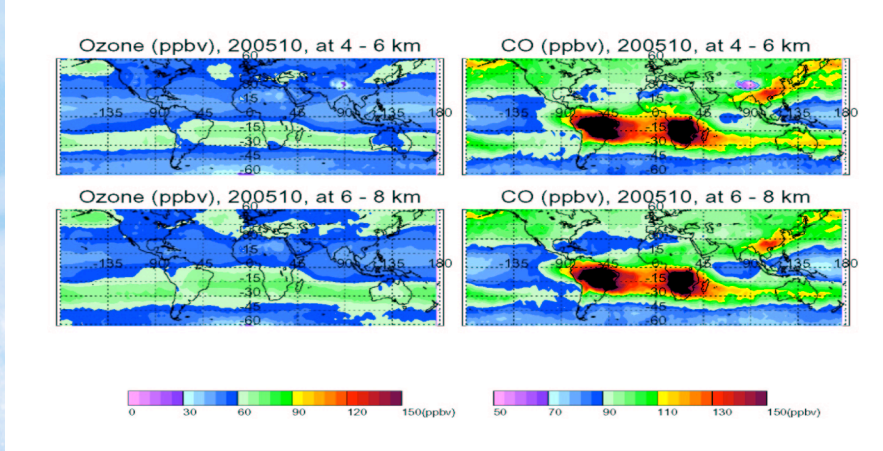
AIRS Ozone Product

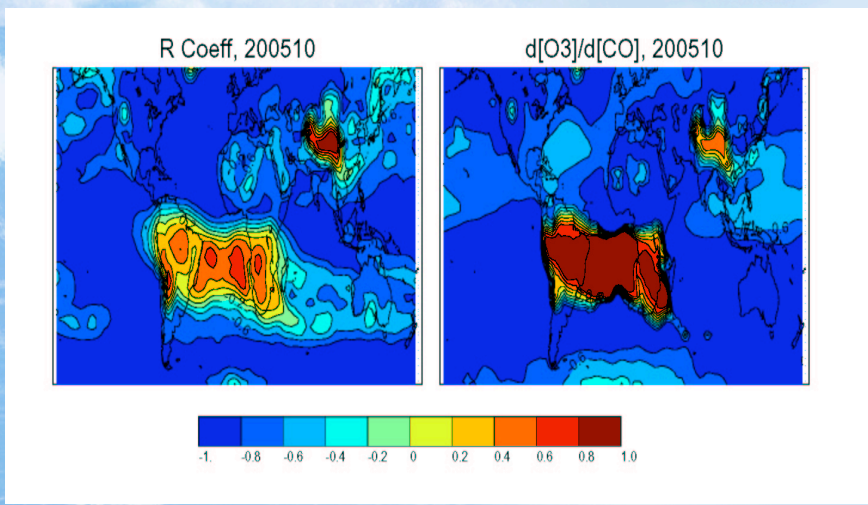
In Version 5 there were Significant Changes to the Ozone Retrieval

- Ozone regression step was turned off.
  - Regression training w.r.t. ECMWF may have been introducing biases.
  - Regression operator gets an answer that is a mixture of statistics and measurement – cannot determine whether the ozone products comes from AIRS or statistical correlations.
- Ozone Climatology was improved.
- Damping parameter for physical retrieval was reduced.
- Additional channels were used.

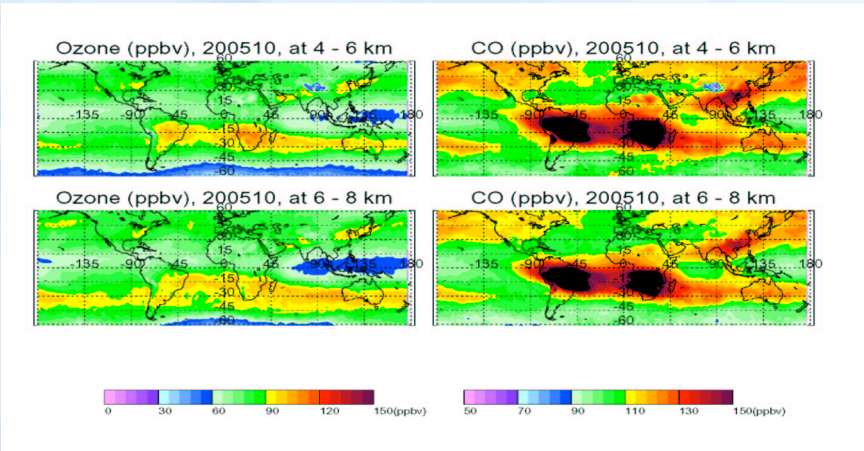
Correlation between AIRS CO & Ozone Products Is Considerably Better

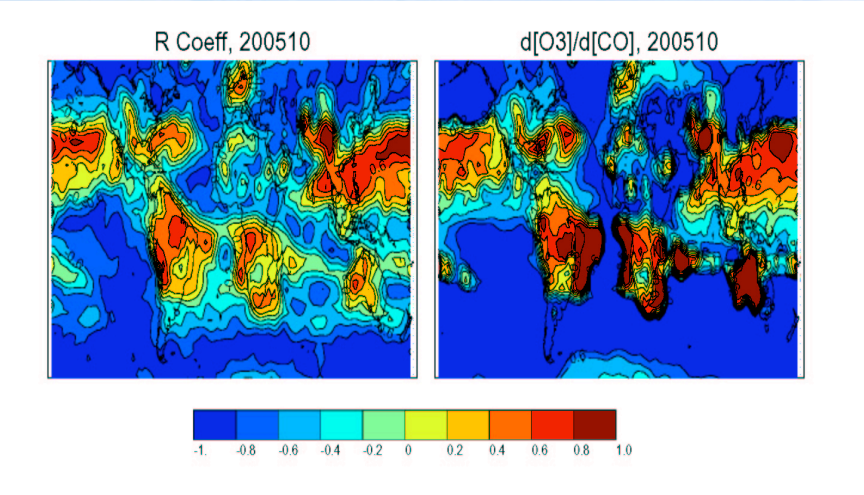
Version 5.0 (w/o O_3 regression)





Version 4.6 (WITH O_3 regression)



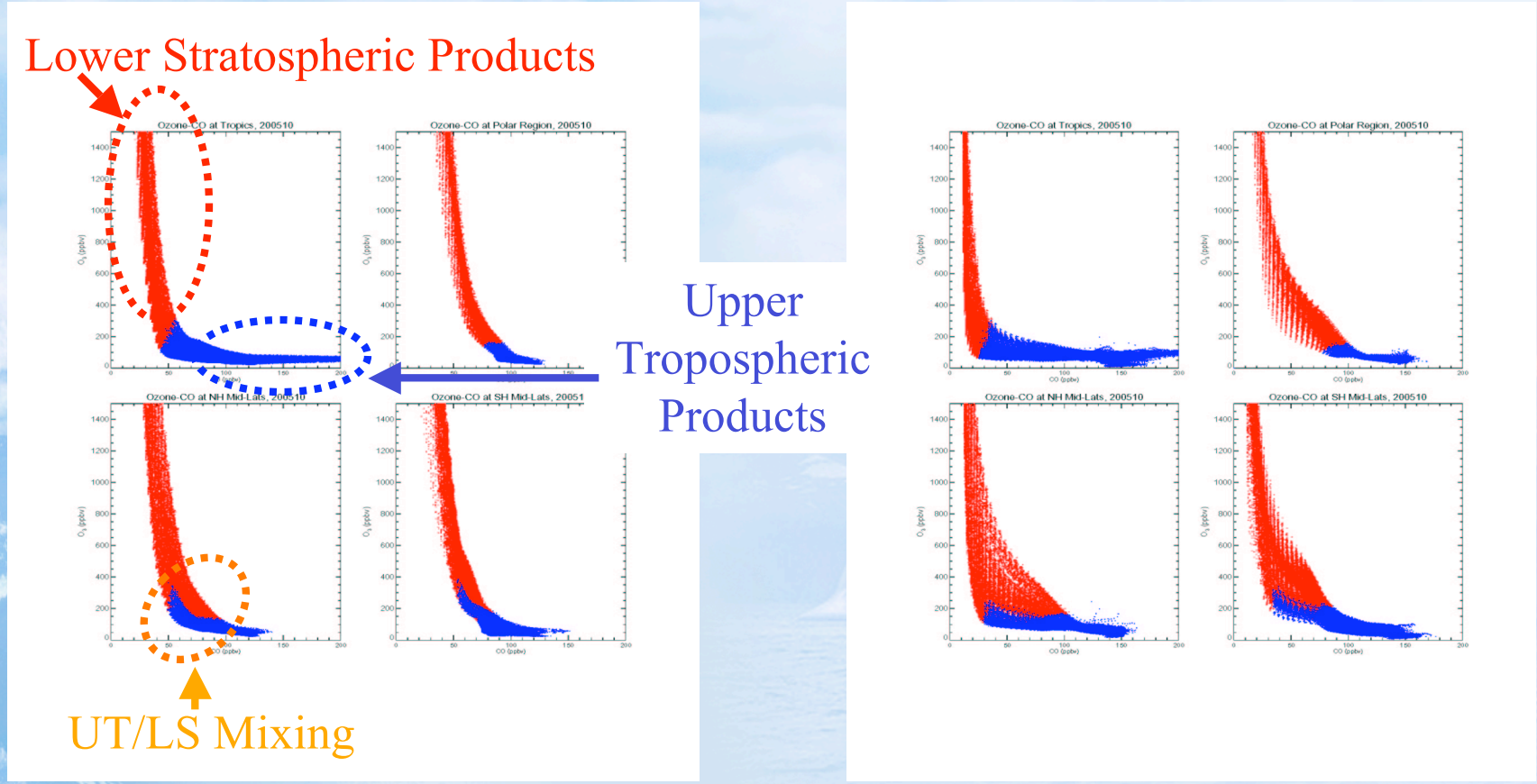


See Zhang et .al JGR 2007 for similar comparison using TES

Tracer-Tracer Correlations help define UT/LS Mixing

Version 5.0 (w/o O3 regression)

Version 4.6 (WITH O3 regression)



See L. Pan et al. JGR 2007 for details of methodology and utility in product characterization

Ozone summary

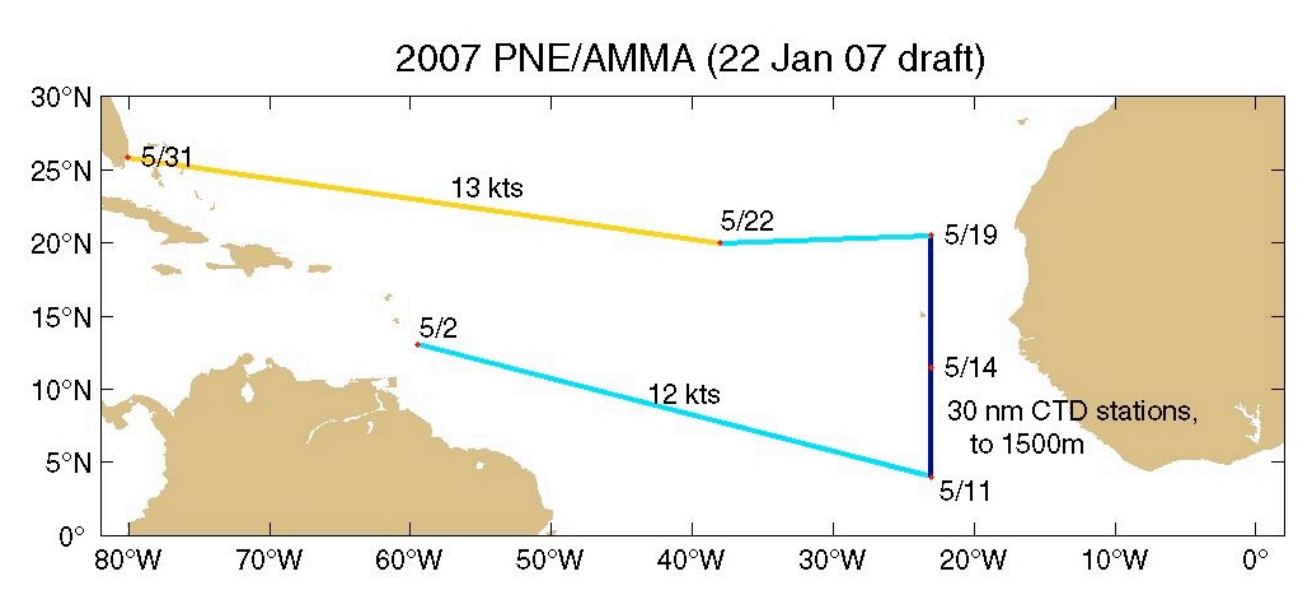
- Tracer correlations appear to be improved in Version 5.
- Product characterization is improved significantly in Version 5.
- Validation (see Murty Divakarla talk at 1:30 Thurs) shows that
  - Version 5 has better ability to capture extreme ozone values.
  - Ozone statistics are similar w.r.t. ozone-sondes. Still need to improve physical ozone retrieval.

NOAA Participation in Ozone Validation Exercises

- START: UT/LS focus
- WAVES: Urban pollution focus
  - AIRS/TES/Ozonesonde comparisons
- AEROSE II & III: Biomass-burning and Saharan dust focus
  - BUT WE NEED OZONESONDES for May Cruise
- WOUDC & Brewer Dobson Stations
  - Polar

2007 AEROSE-III Piggyback (Nick Nalli)

- 2007 **Aerosol and Ocean Science Expedition** (AEROSE-III) is set to take place during May as piggyback mission of the PNE-AMMA Cruise scheduled onboard the *Ronald H. Brown*.
- The **AIRS Science Team** is supporting the mission with **100 RS92 Vaisala radiosondes** for validation of **AIRS** within the challenging SAL marine environment.
- AEROSE-III will complement the previous data (2003, 2005) by
  - sampling the same region during an interesting, yet distinct, month of the year (May)

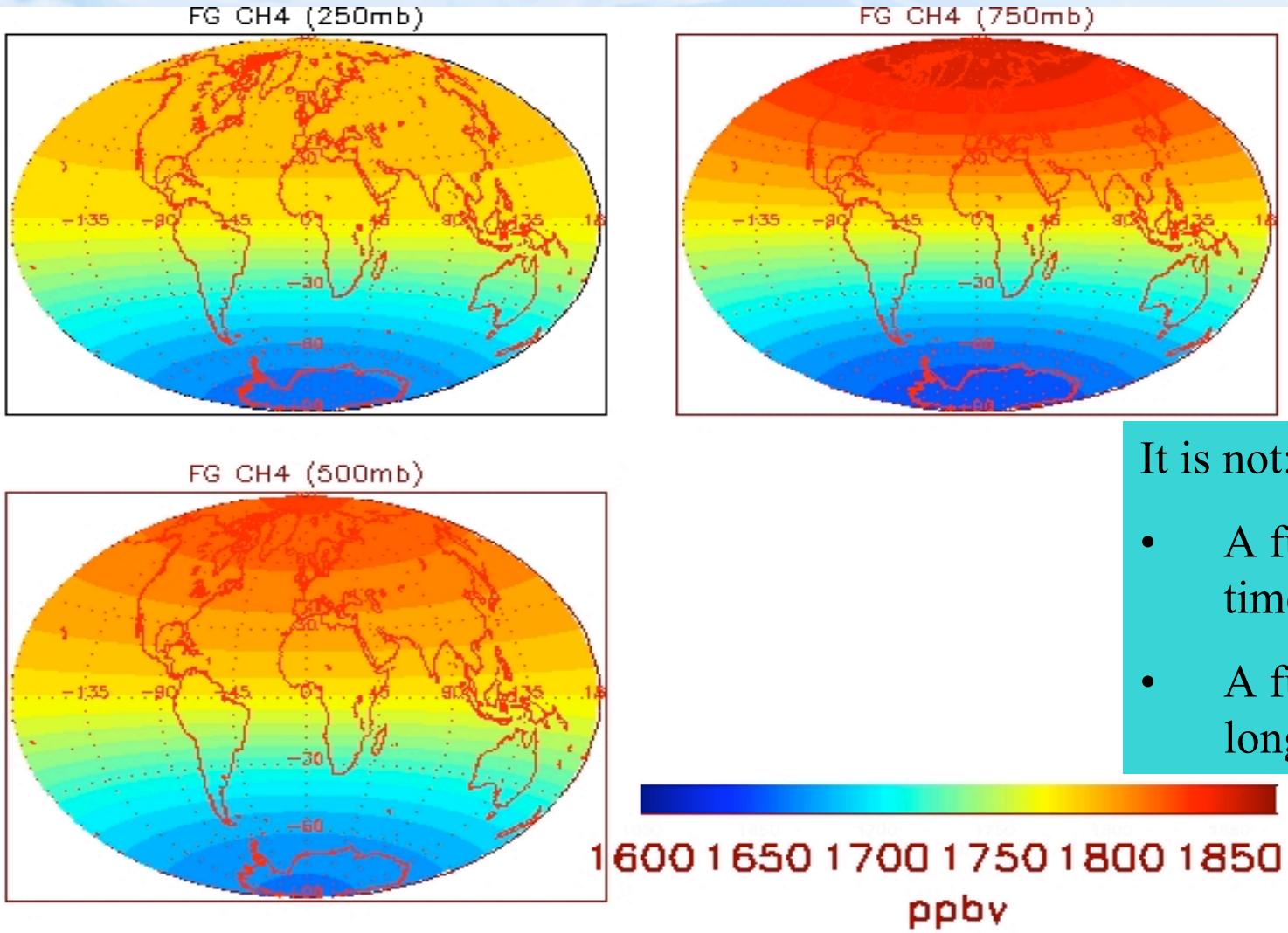


AIRS Methane Product

Methane Is A New Product in Version 5

- Added a climatological first guess for methane.
  - Based on ESRL Aircraft & HALOE data
- Retrieval methodology is the same as for Carbon Monoxide and Ozone
- Found the need for tuning of methane channels to capture reasonable shape of retrievals
  - Based on comparison of ESRL/HALOE to retrievals in clear scenes.
  - Small tuning (2%) on strong methane lines was added.
    - Affects shape of retrievals in tropical regions.
  - Methane tuning needs to be improved in version 6.
    - Lack of "truth" in upper troposphere/lower stratosphere is a big problem.

CH4 Mixing Ratio First Guess is a Function of Altitude and Latitude



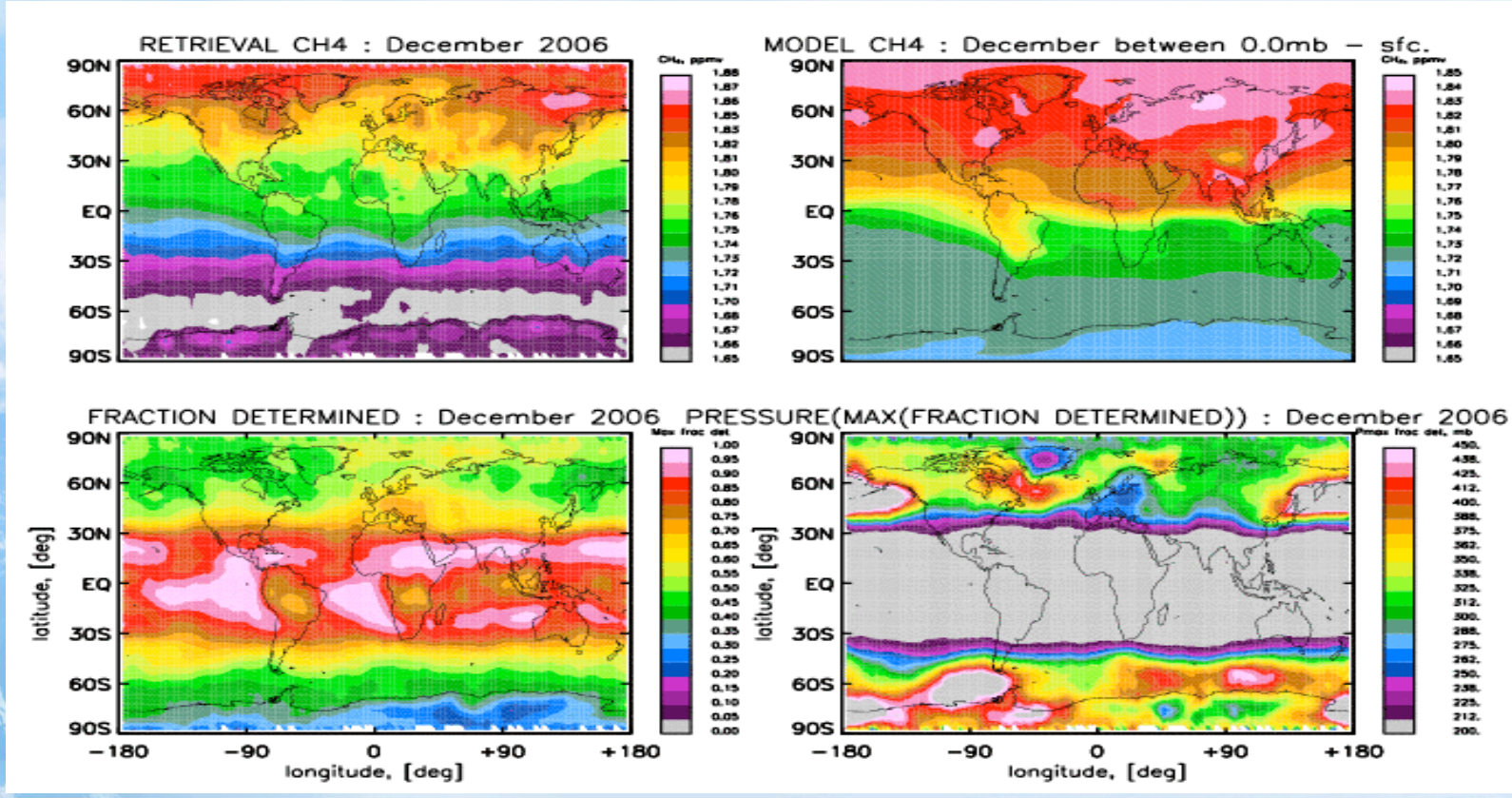
It is not:

- A function of time or
- A function of longitude.

We are computing the vertical kernel and information content to understand CH_4 product

AIRS mid-trop measurement column

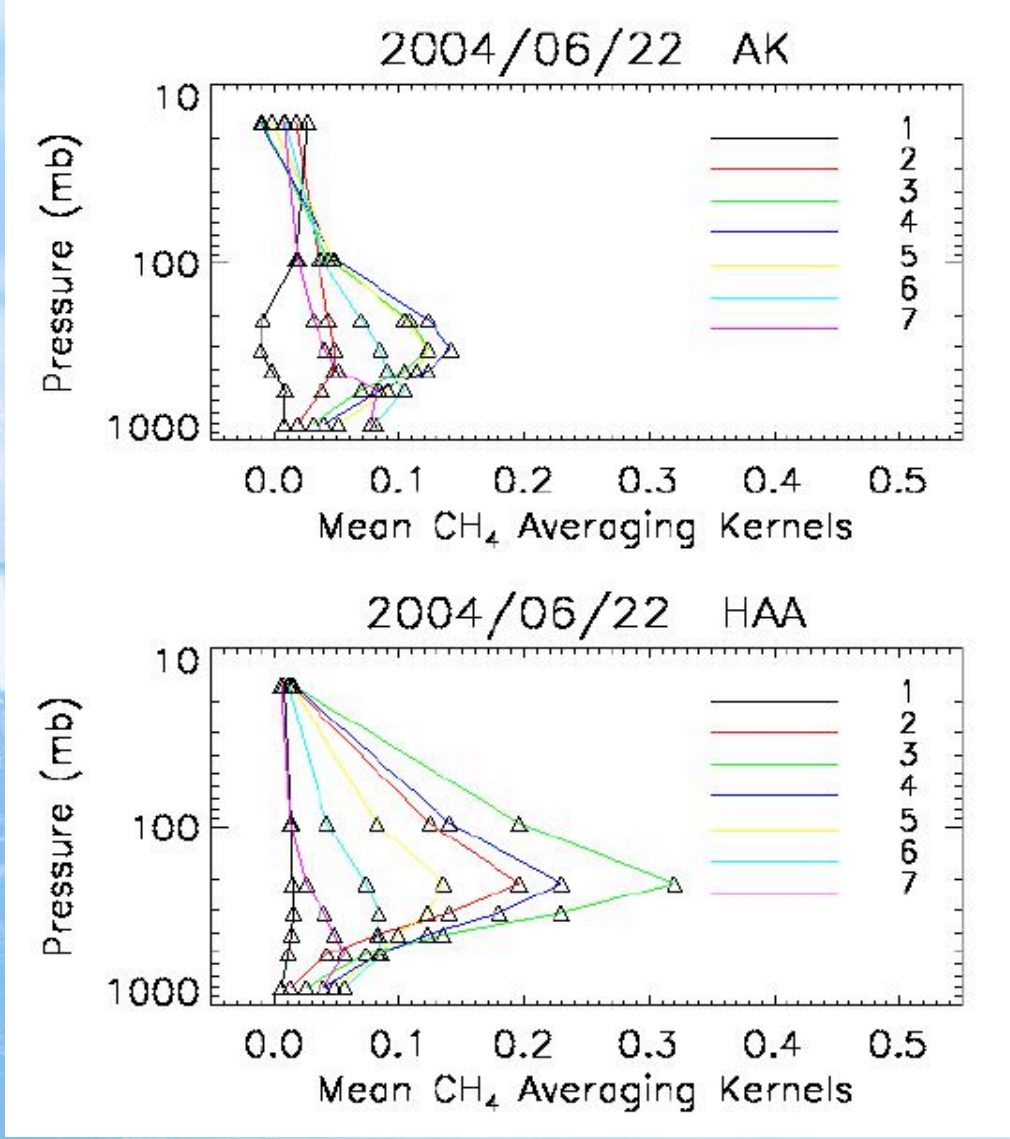
CH4 total column f/ transport model (Sander Houweling, SRON)



Fraction Determined from AIRS Radiances

Peak Pressure of AIRS Sensitivity

Example of Retrieved Methane Averaging Kernels

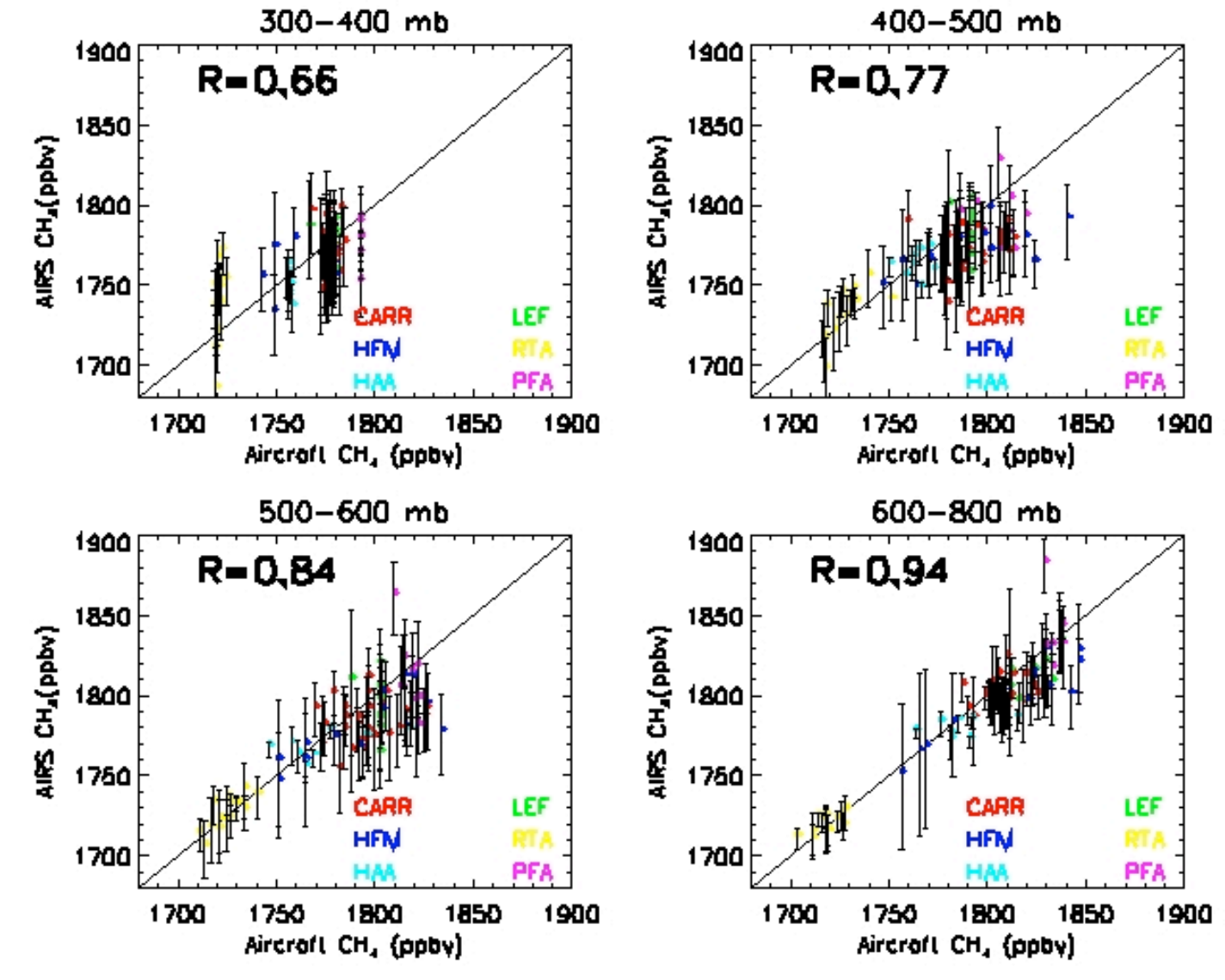


Averaging Kernels

Retrieved amount in a layer is an weighted average of ch4 in a couple of layers

Averaging kernels needs to be taken into accounts to compare the satellite retrievals with model and/or in-situ observations

AIRS CH_4 versus NOAA/ESRL Aircraft Measurements



ESRL/GMD aircraft profiles are the best validation for thermal sounders since they measure a thick atmospheric layer.

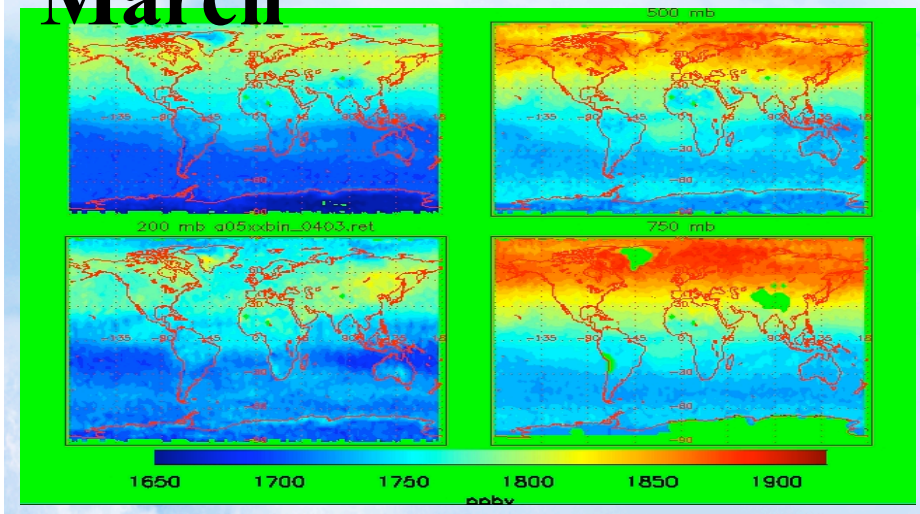
Collocation

$\Delta R < 200$ km

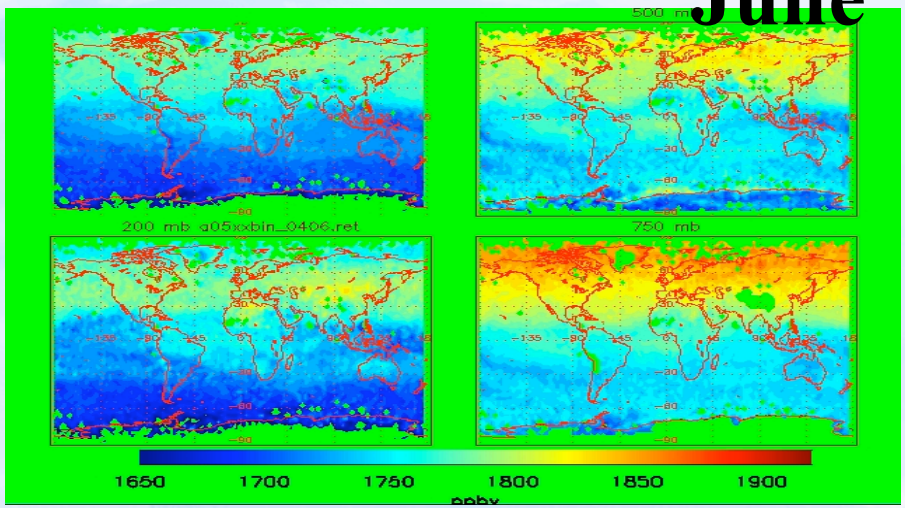
$\Delta t < 24$ hour

Example of CH4 product

March



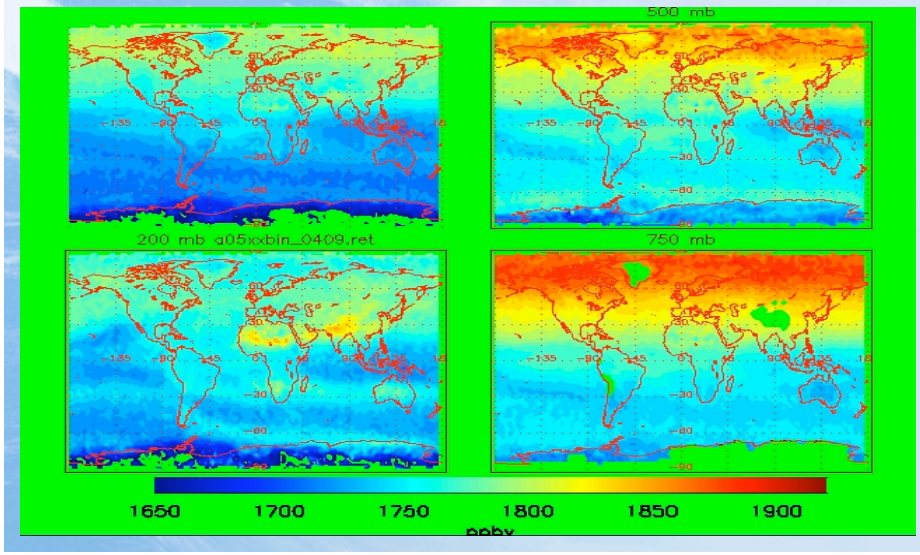
June

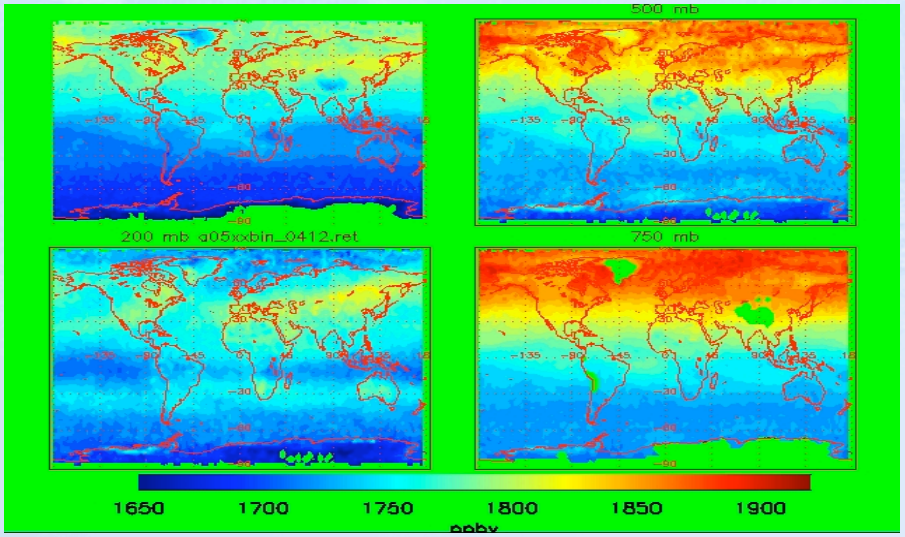


Sept

AIRS CH4 (total, 300, 500,750 mb)

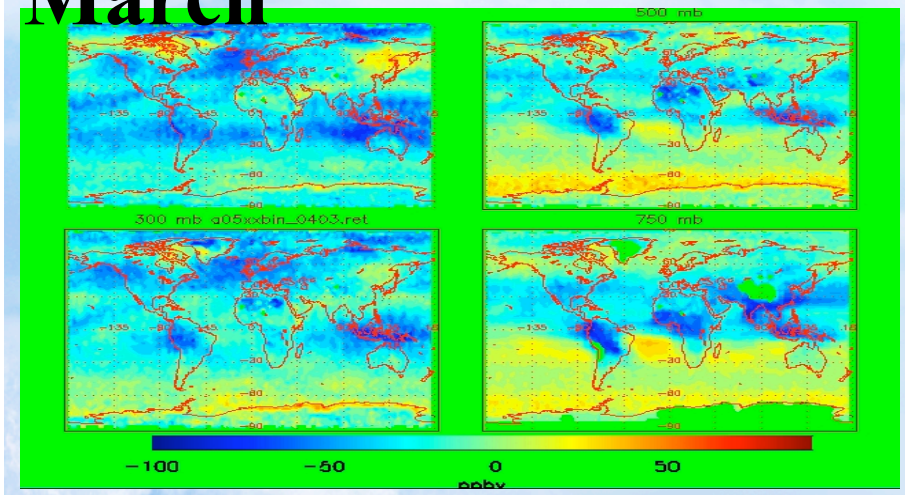
Dec.



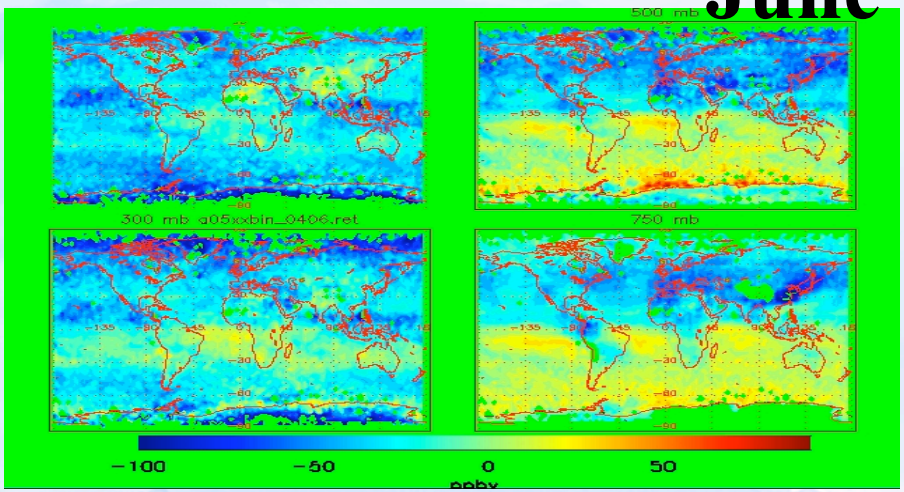


Differences from Sander Houweling's Model

March



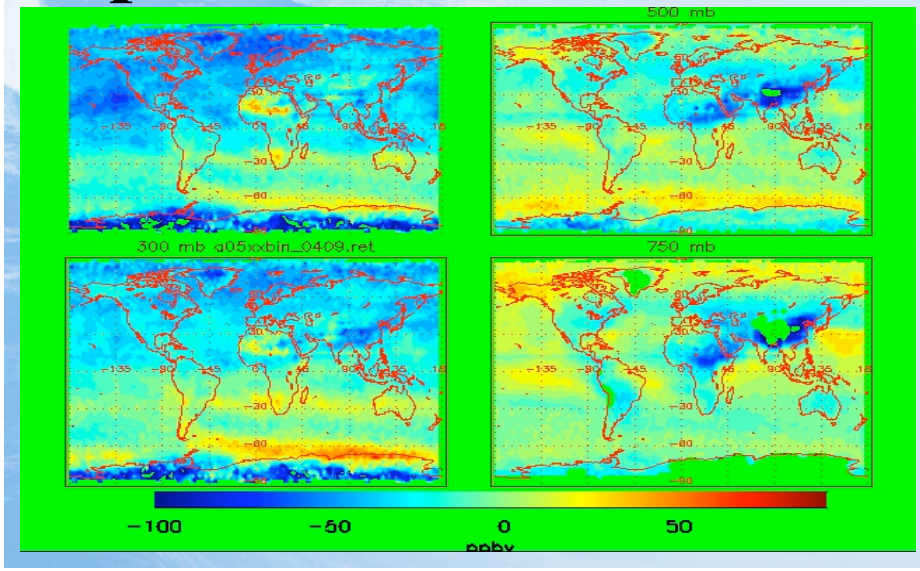
June

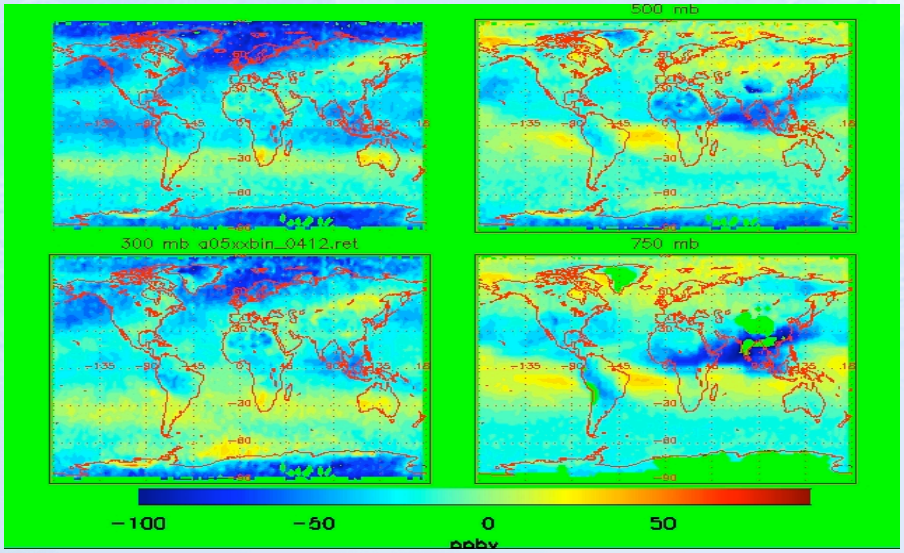


Sept

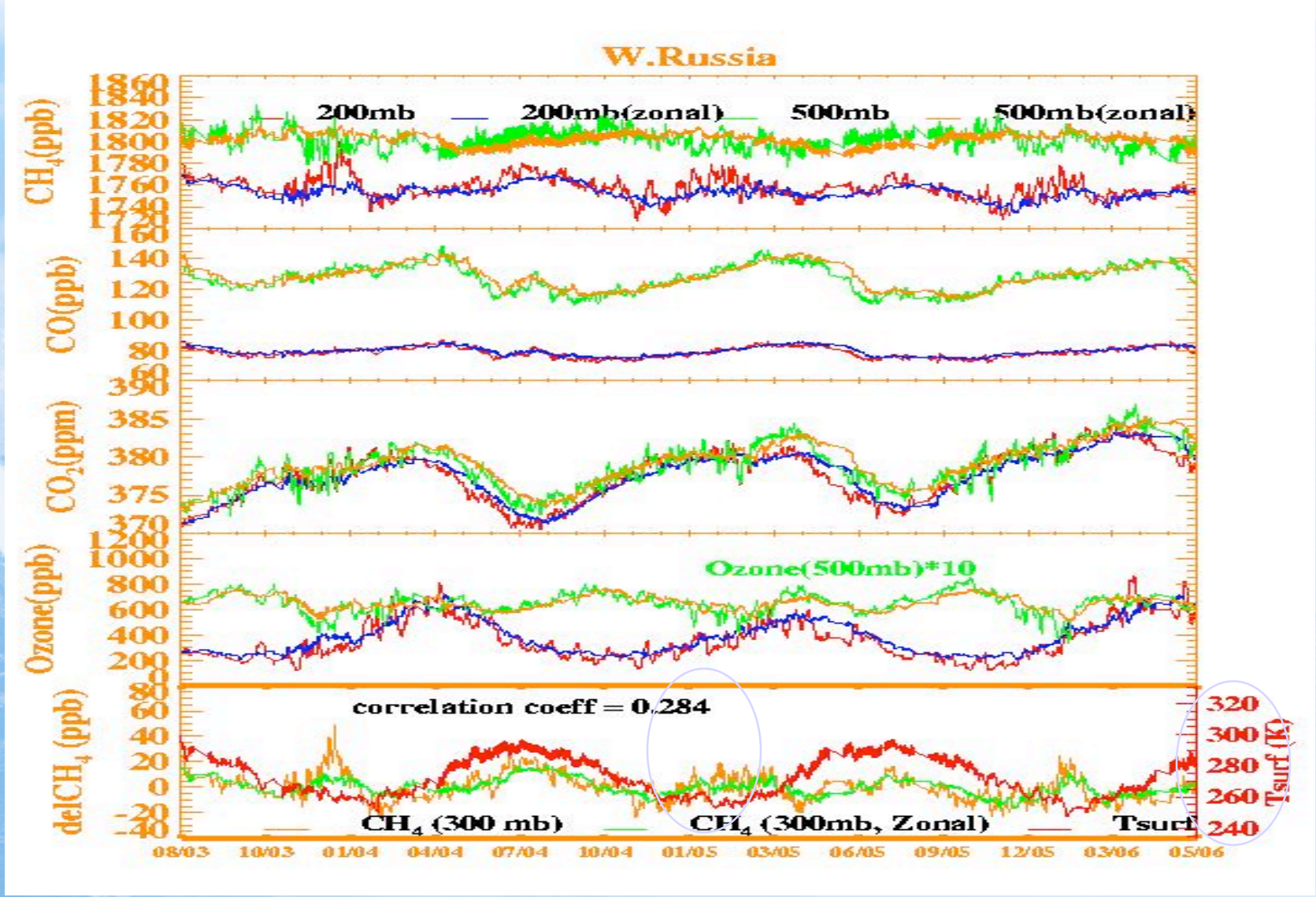
AIRS-Model at 200, 300, 500,750 mb

Dec.



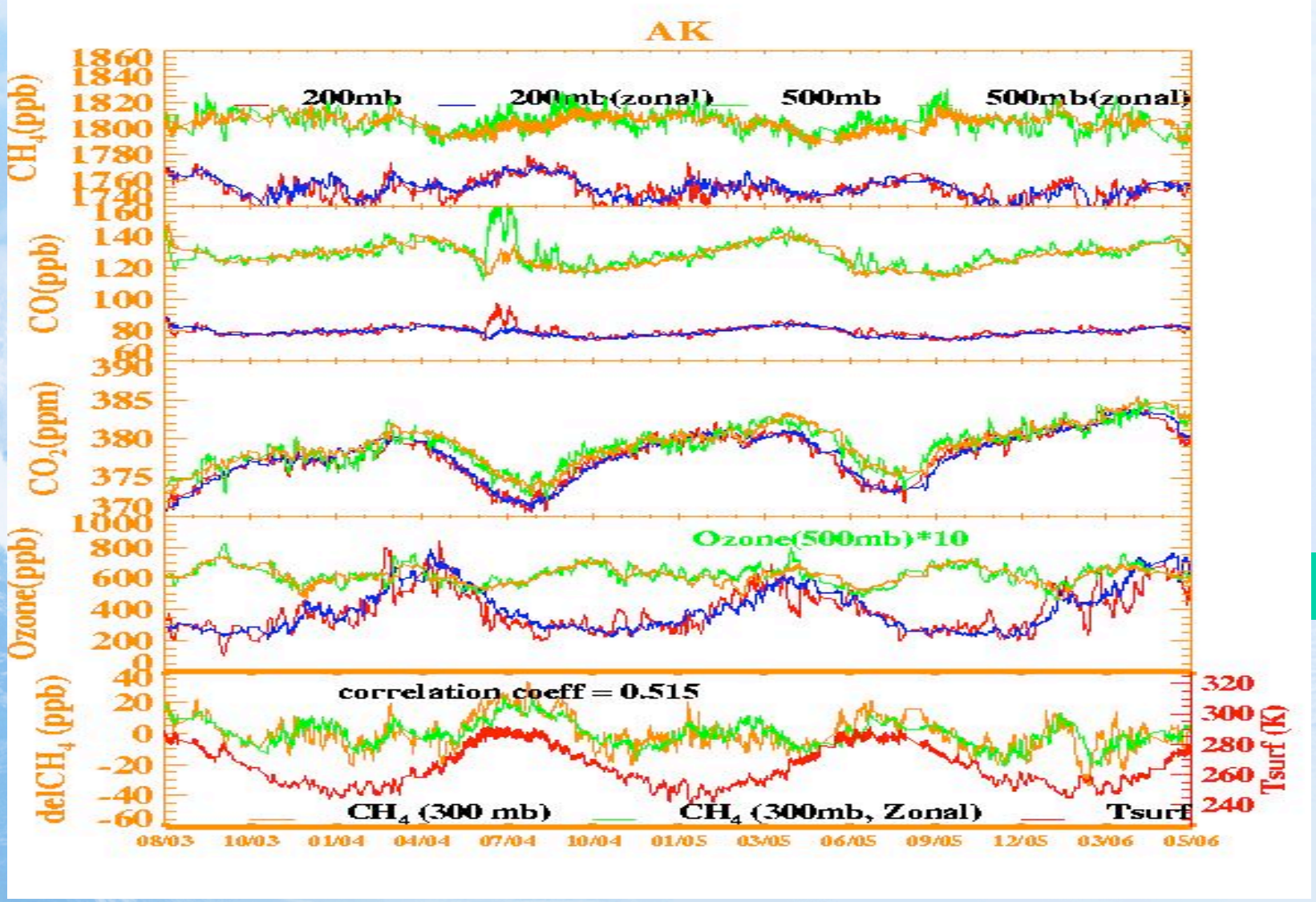


33 month time-series of AIRS products
West Russian (50 ≤ lat ≤ 70 , 30 ≤ lon ≤ 80)



Alaska & Canada Zone

(60 ≤ lat ≤ 70, -165 ≤ long ≤ -90)



CH_4

CO

CO_2

O_3

CH_4 & Tsurf

Summary

- ✓ **The accuracy of AIRS CH_4 is about 1.2-1.5% depending on different altitudes, which should be able to map seasonal variation of CH_4 and can provide valuable information of atmosphere in mid-upper troposphere.**

- ✓ **Observed significant summer enhancement of CH_4 in high northern hemisphere which correlates well with soil temperature and is most likely due to northern wetland emission in summer;**

- ✓ **Observed significant plume of CH_4 over the Tibetan Plateau, formed by Monsoon and deep convection over the region**

- ✓ **Observed high concentration of CH_4 from Southeast of China and Alaska Fire 2004, and some unusual features in Siberia in the winter.**

For more information:

http://www.orbit.nesdis.noaa.gov/smcd/spb/airs/index.html

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

Satellite Meteorology
& Climatology Division

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Channel Monitoring
MODIS to AIRS
L2 Monitoring
Level 2 Maps
Cloud Clearing
Daily Animation
Compression
L2 Re-Processing
L2 Trace Gas
Validation
EDOS Transfer Time
System Updates
Documentations
Group Members
Links

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

Status of IASI Processing System

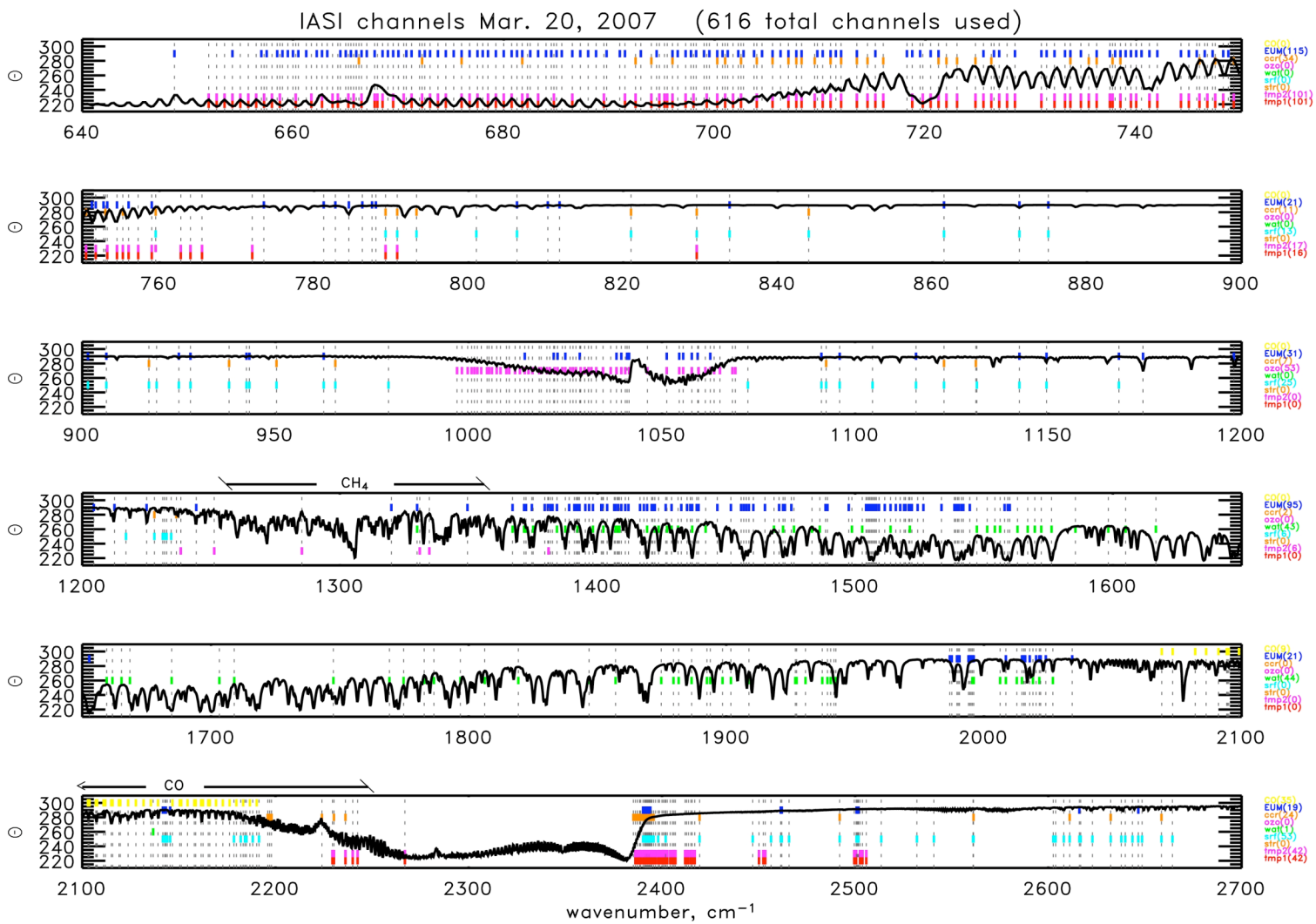
IASI Processing System was Switched from Simulation to Real Data in February

- Near real-time radiance products are being produced and will be distributed to NCEP & NRL soon.
  - EUMETSAT L1C with NOAA/NESDIS meta-data is being archived to CLASS
  - Problems with DDS capacity issues for near real-time L1 products (BUFR subsets) are being resolved – temporary work around with limited capacity is in work.
- Near real-time level-2 products are being produced, but will not be distributed until they have gone through validation (on or before March 2008).
- In Level.2 the regression step is *currently* turned off
  - Eigenvector analysis and regression training are in-work.
  - Should have regression coefficients after frequency calibration.
- Ad-hoc tuning & error terms based on obs-calc. analysis by Larrabee Strow is used to correct for frequency errors and RTA errors.
  - This is analogous to what was done with early AIRS (and was finally removed in v5!)
- All NOAA validation, monitoring, and reprocessing data-sets are part of our operational product system.

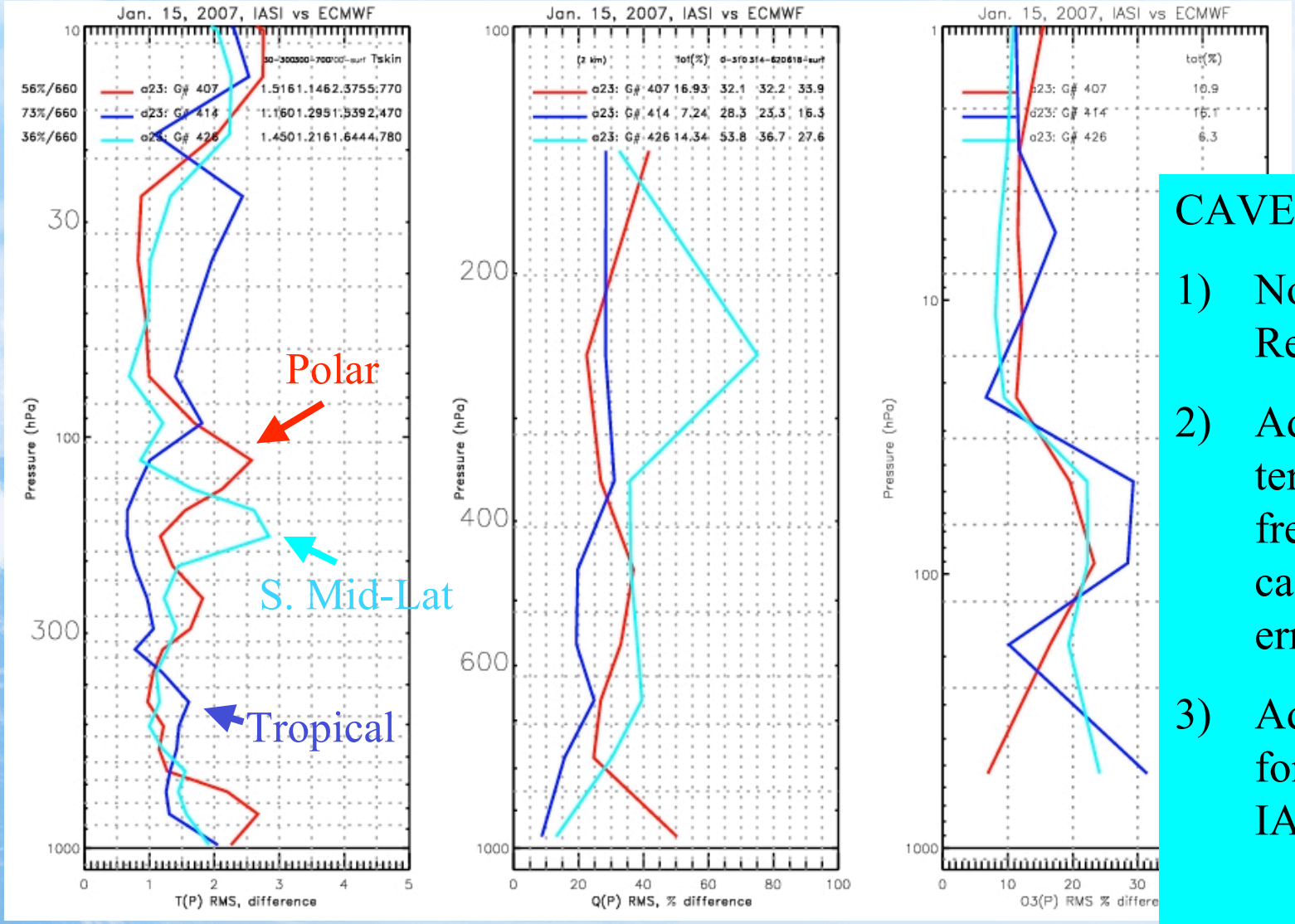
http://www.orbit.nesdis.noaa.gov/smcd/spb/iasi/index.html

- All research products, developed within the AIRS context - including all trace gas retrievals, are part of our operational level.2 product stream.

IASI 616 Channel Sub-set (for Distribution to NWP Centers)

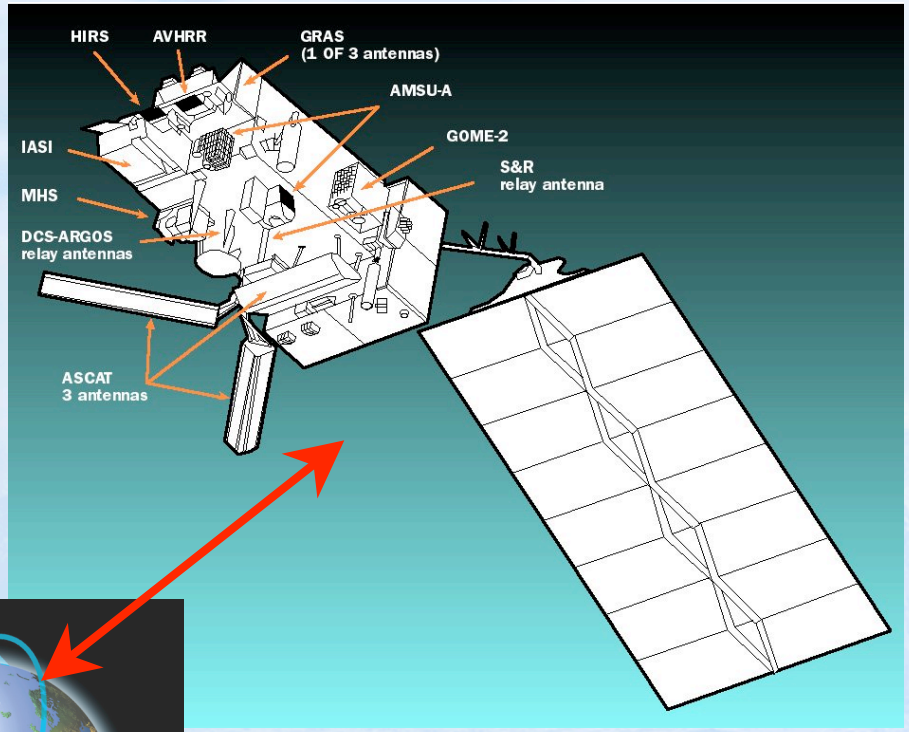
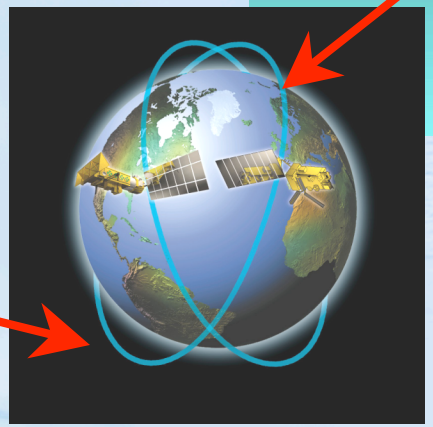
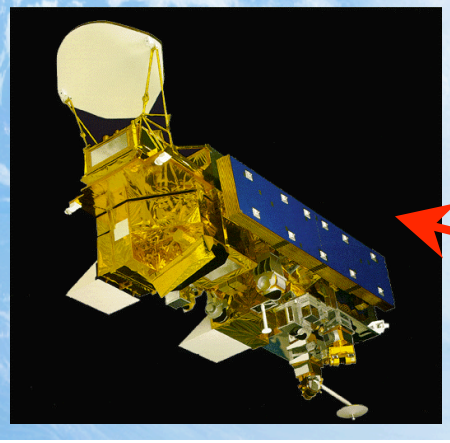


Current Status of IASI T,q,O3 retrievals w.r.t. ECMWF



CAVEATS:

1) No T,q Regression
2) Ad-hoc error terms for frequency calibration errors
3) Ad-hoc tuning for AMSU & IASI

Now we have IASI & AIRS making global measurements, 4/day

- Initial Joint Polar System: An agreement between NOAA & EUMETSAT to exchange data and products.
  - NASA/Aqua in 1:30 pm orbit
  - EUMETSAT/IASI in 9:30 am orbit (July 2006)
  - NPOESS/CrIS in 1:30 pm orbit (2009?)