Update of NOAA AIRS Methane Retrieval, Validation and Usage

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NOAA/NESDIS/STAR

PSGS

AIRS Science Meeting

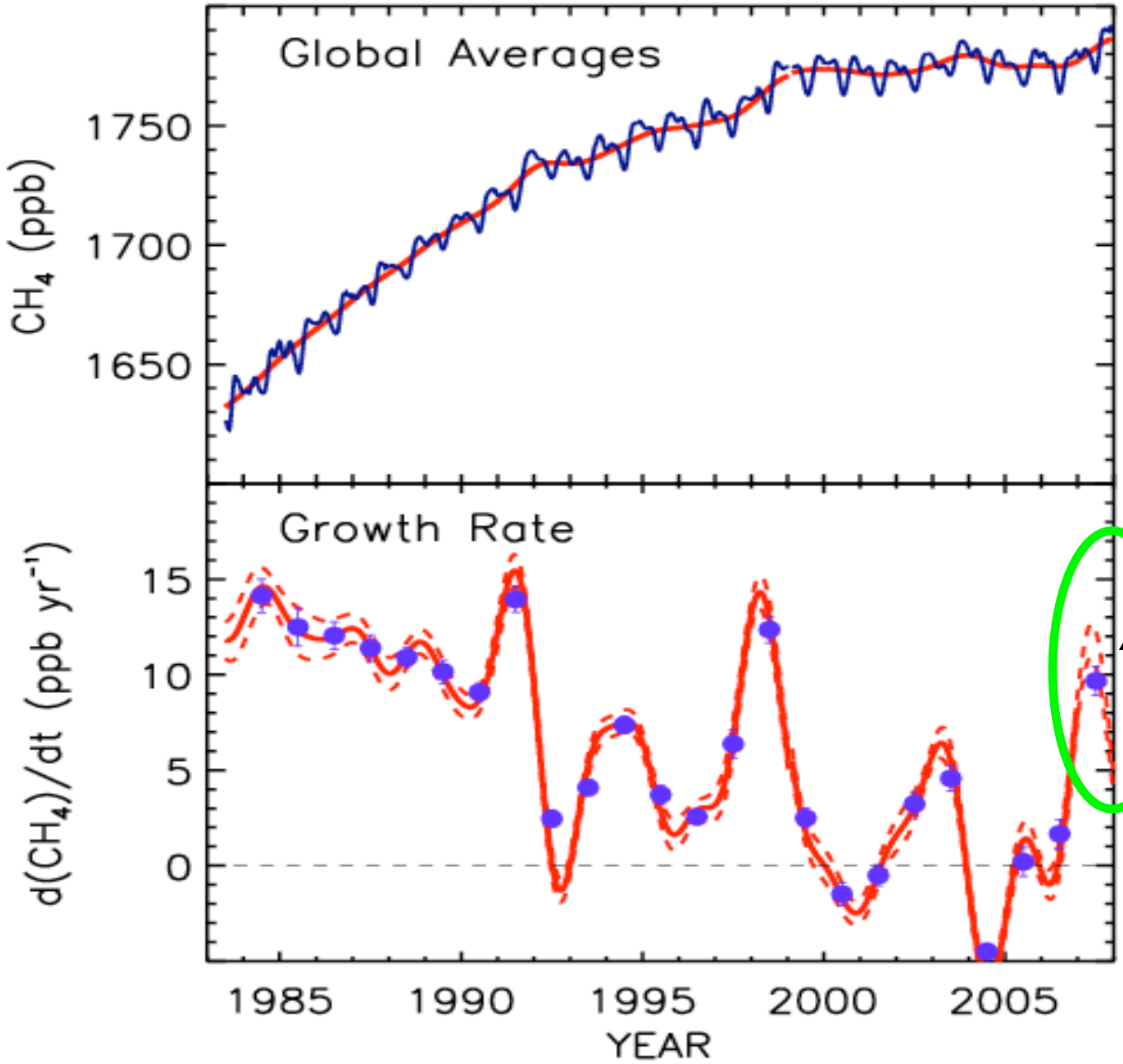
October 15, 2008

Outline

- **Scientific Applications of AIRS CH4 product (*Highlights*)**
  - ***Summer enhancement of CH_4 in the high Northern Hemisphere --- is it related with emissions from wetlands/permafrost ?***
  - ***CH_4 plume over the South Asia – a possible constraint to the model for a better estimate of Asian CH_4 sources !***
- **Validation of AIRS CH4 product (V5)**
- **Optimization and Suggestion towards the V6**
- **Summary**

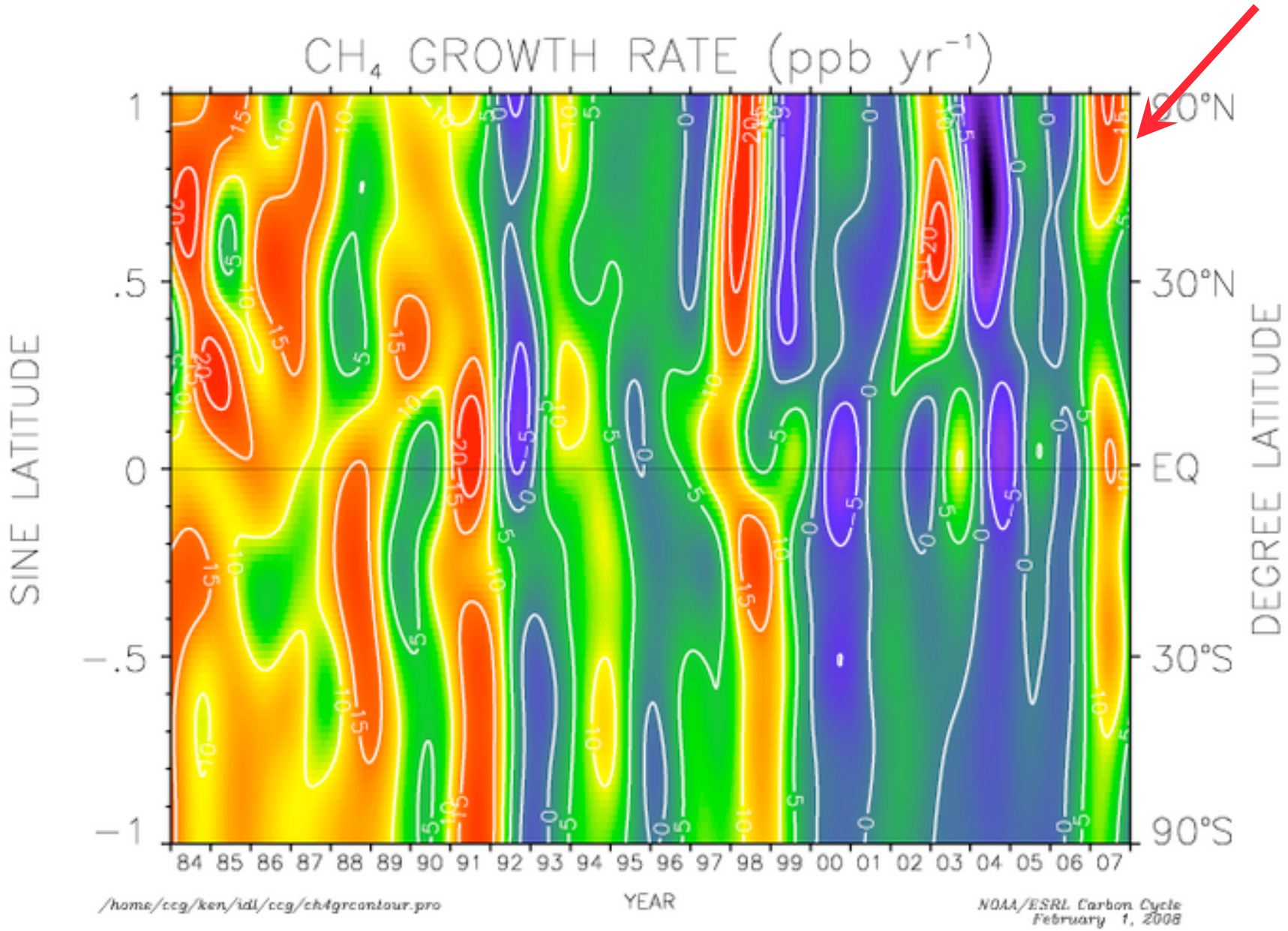
- CH4 is an important trace gas next to CO2, and i ts warming potential is >20 times than CO2

- Significant increase of CH4 in 2007 has been observed from NOAA flask network !

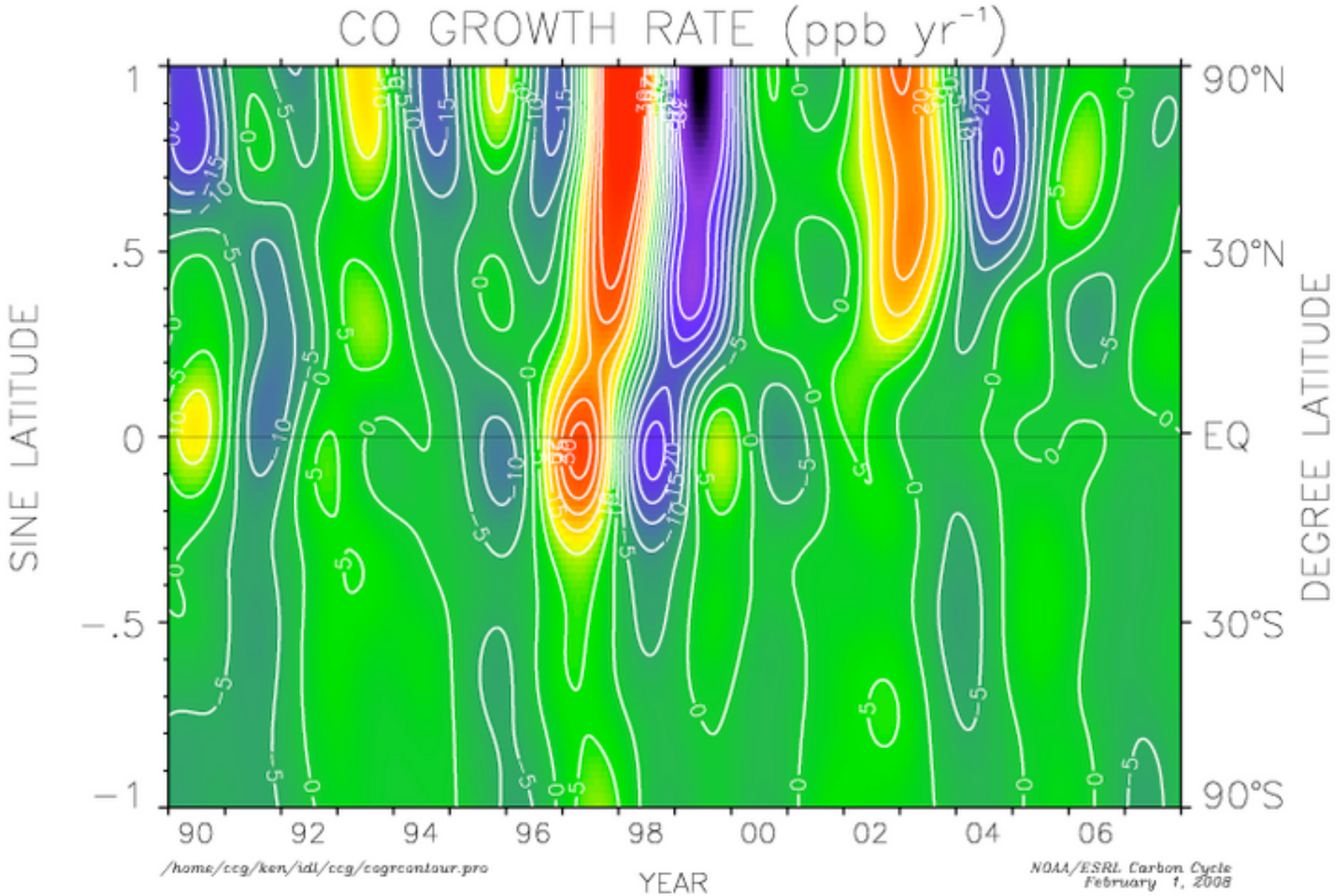


Courtesy of Ed Dlugokencky

No large increase in CO.



Courtesy of Ed Dlugokencky



Courtesy of Ed Dlugokencky

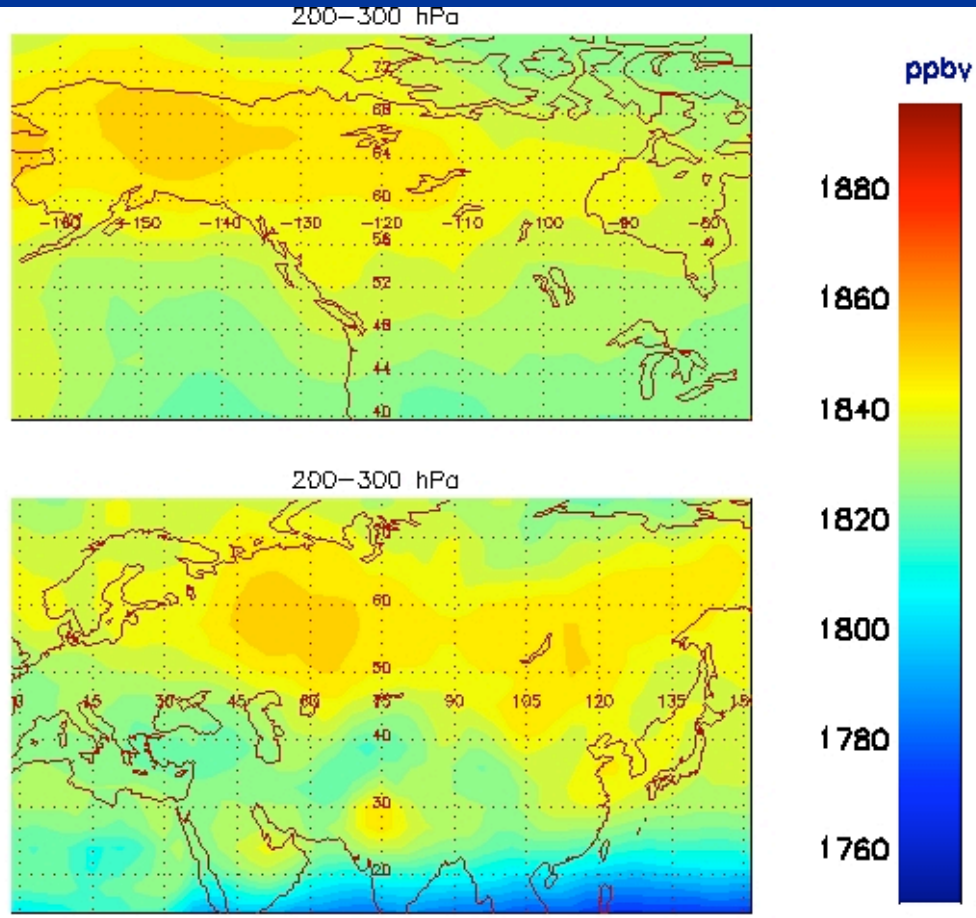
Change of Atmospheric Methane and the Use of AIRS CH4 product

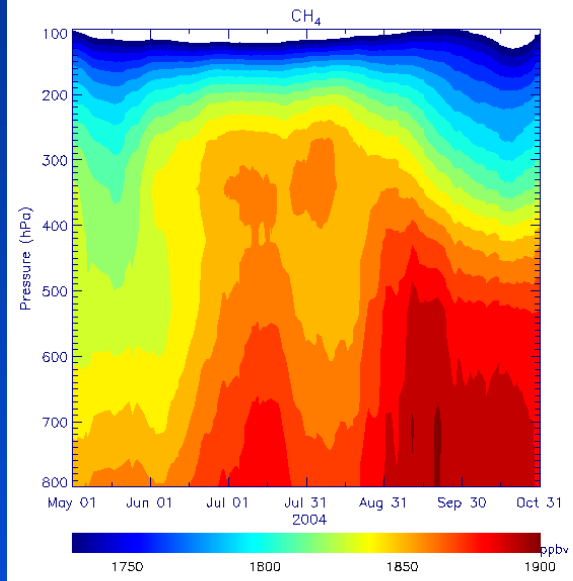
- Abnormal increase of CH4 in 2007 → pointing to large emissions from wetlands/permafrost in high northern hemisphere (HNH)

  AIRS Observed significant summer jump of CH_4 in the HNH in regions mostly underlain by the wetlands

  → Is *it related with wetlands/permafrost ?*

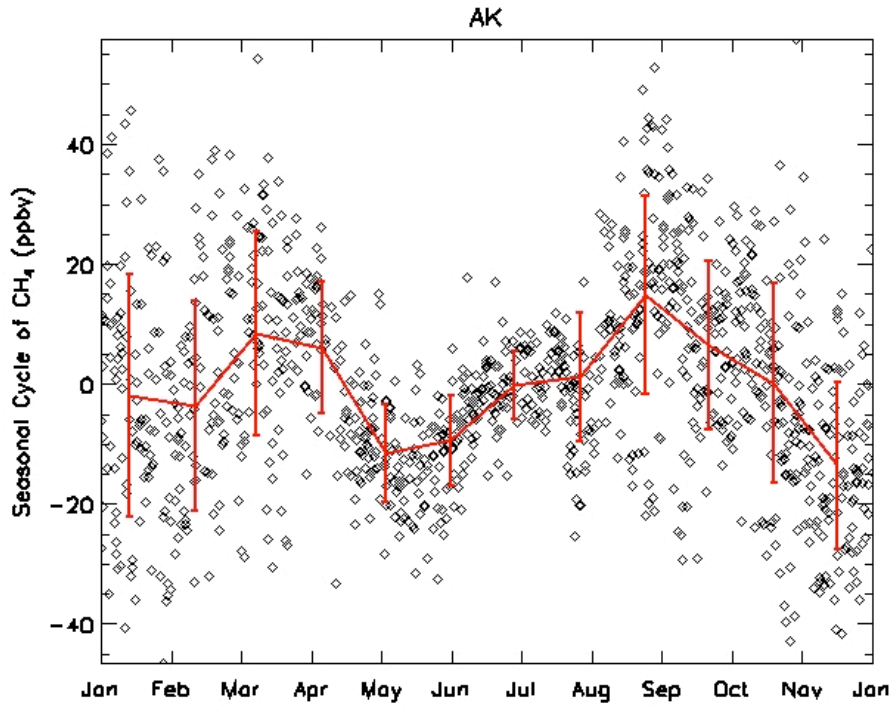
Summer Enhancement of CH4 over the HNH

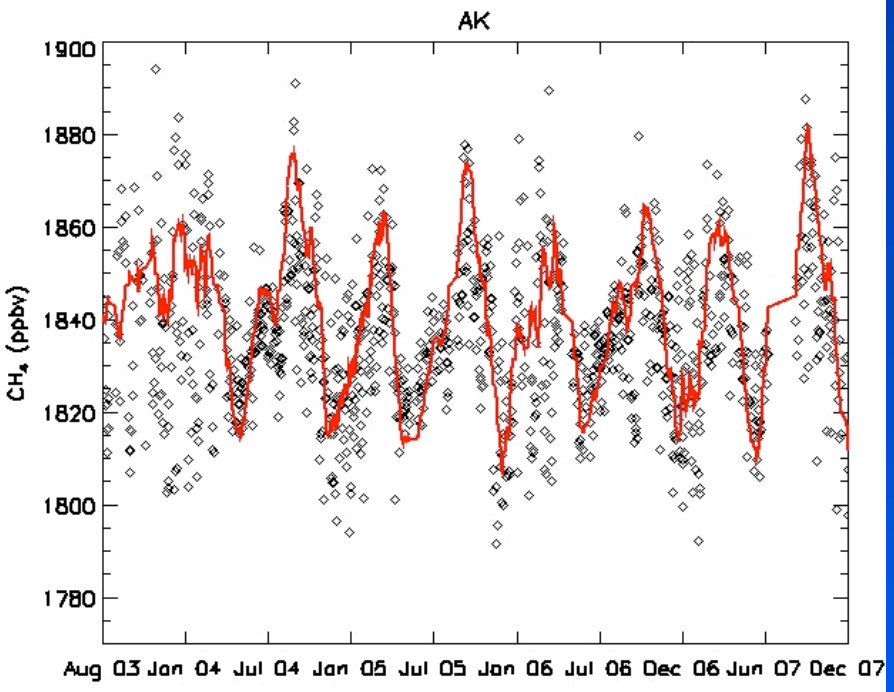


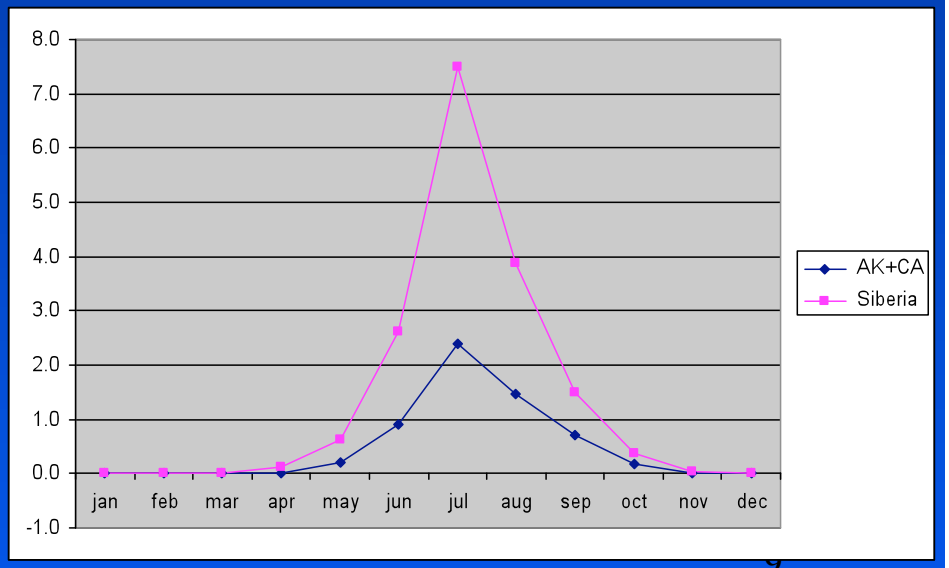


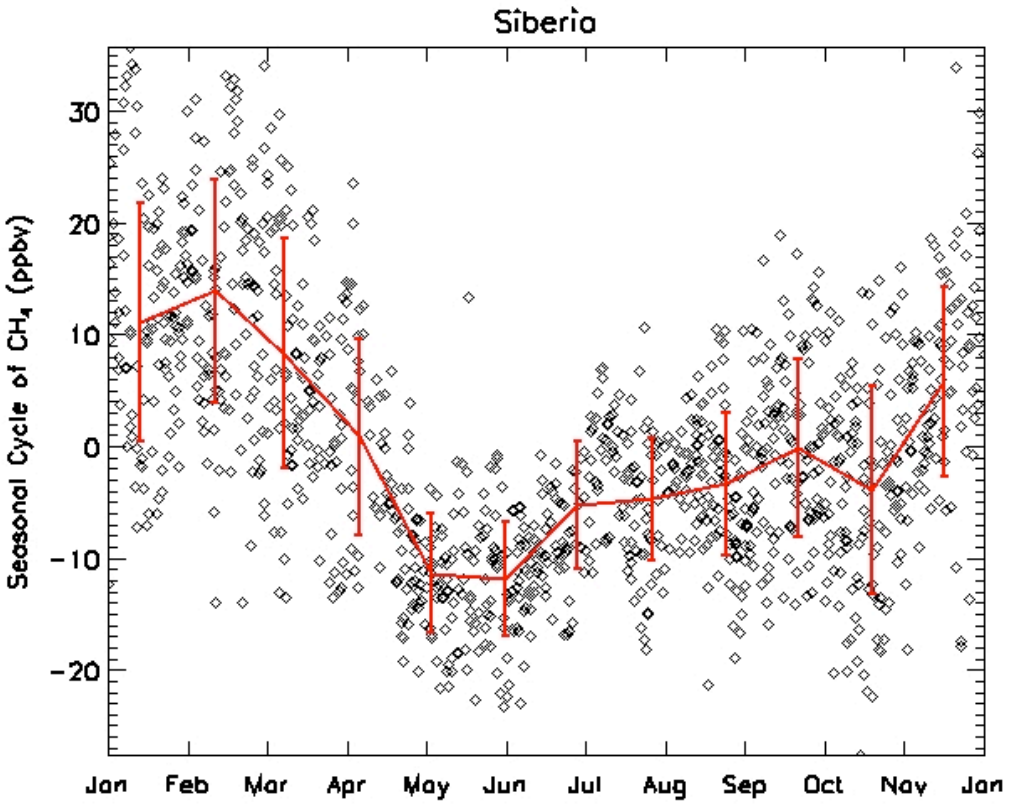
Alaska-Canada

Seasonal variation of Mid -tropospheric CH4 in HNH



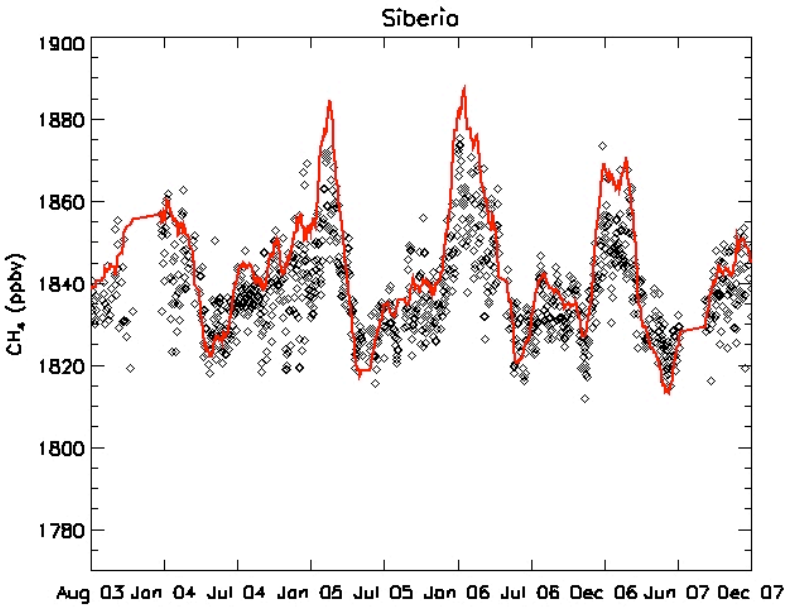






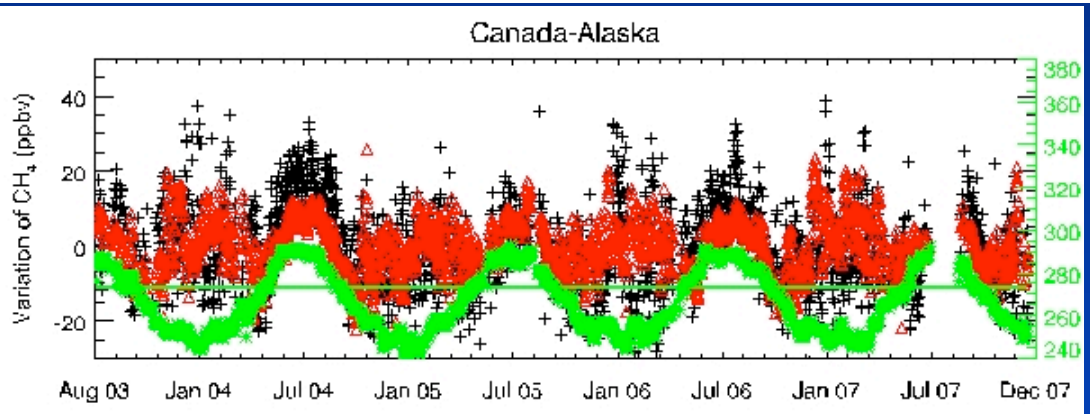
Siberia

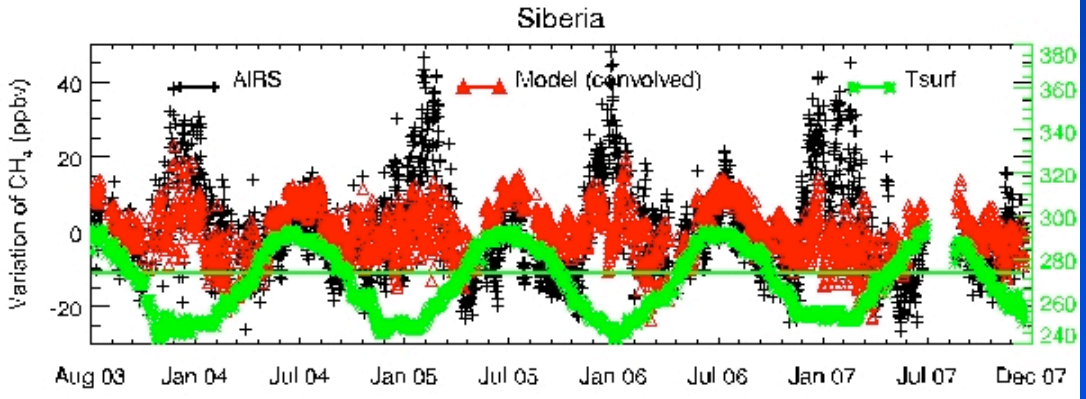
Seasonal variation of Mid -tropospheric CH4 in Siberia

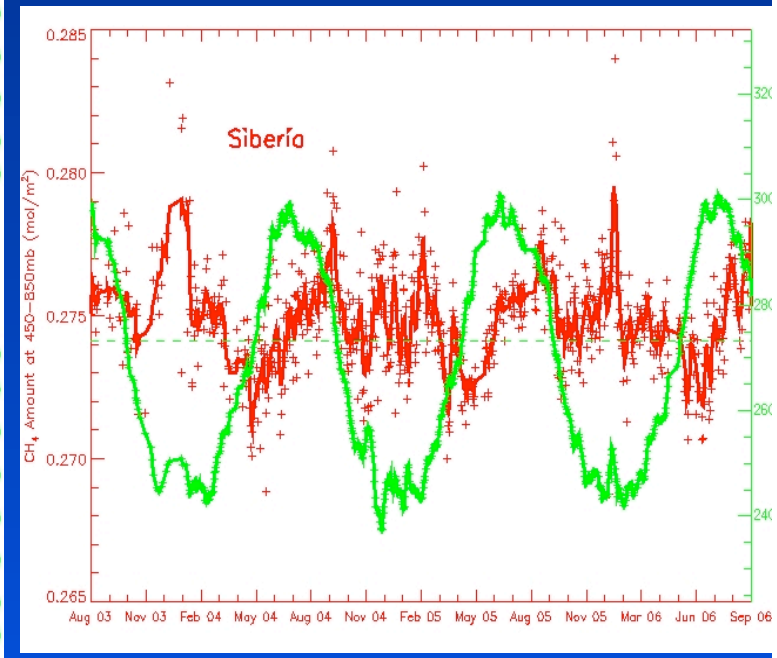


Xiong, X., Barnet, C.D. et al., 2008: Temporal and Spatial Variation of Mid-Tropospheric Methane over the High Northern Hemisphere, JGR (to be submitted).

Comparison with model and its relation with Surface Temperature

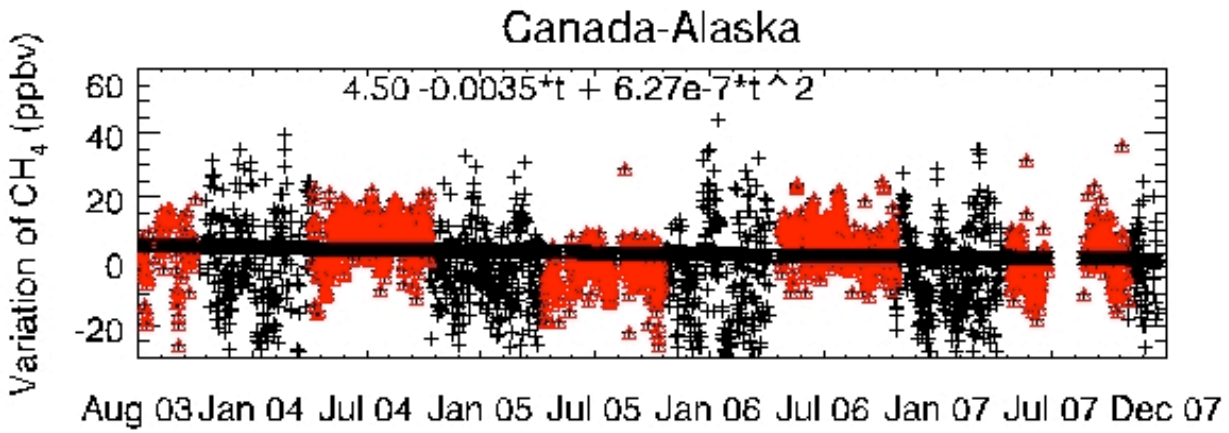


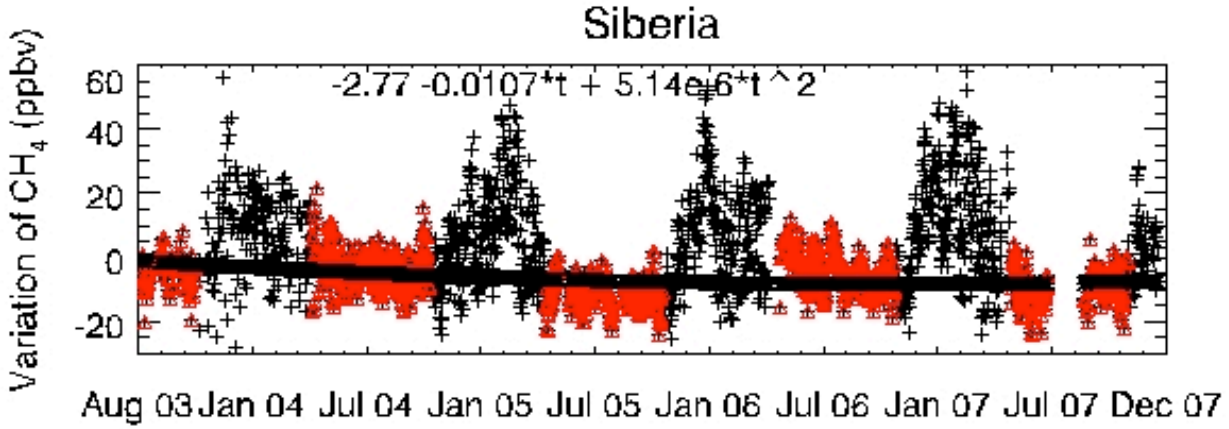




Xiong, X., Barnet, C.D., Maddy, E., Liu, X., and Goldberg, M., 2008. Variation of Atmospheric Methane over the Permafrost Regions from Satellite Observation during 2003 to 2007. *Proceedings of the Ninth International Conference on Permafrost*, Alaska, USA: 1981-1986 pp.

Any trend ?





t is the date started from Aug 6, 2003

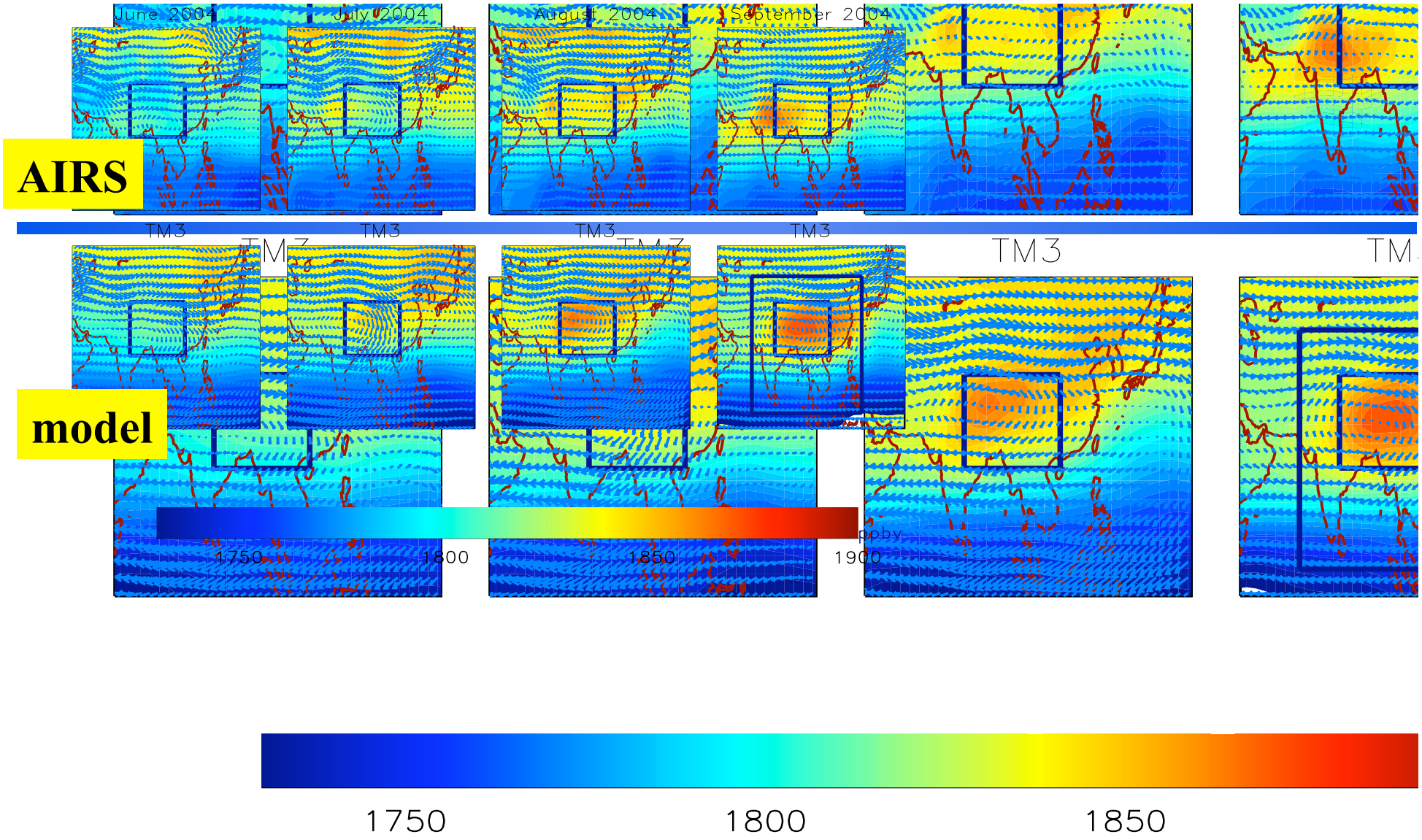
CH4 emissions from Asian and the Use of AIRS CH4 product

- IPCC (2007) : CH4 emissions from rice paddies is 31 ~ 112 Tg yr-1

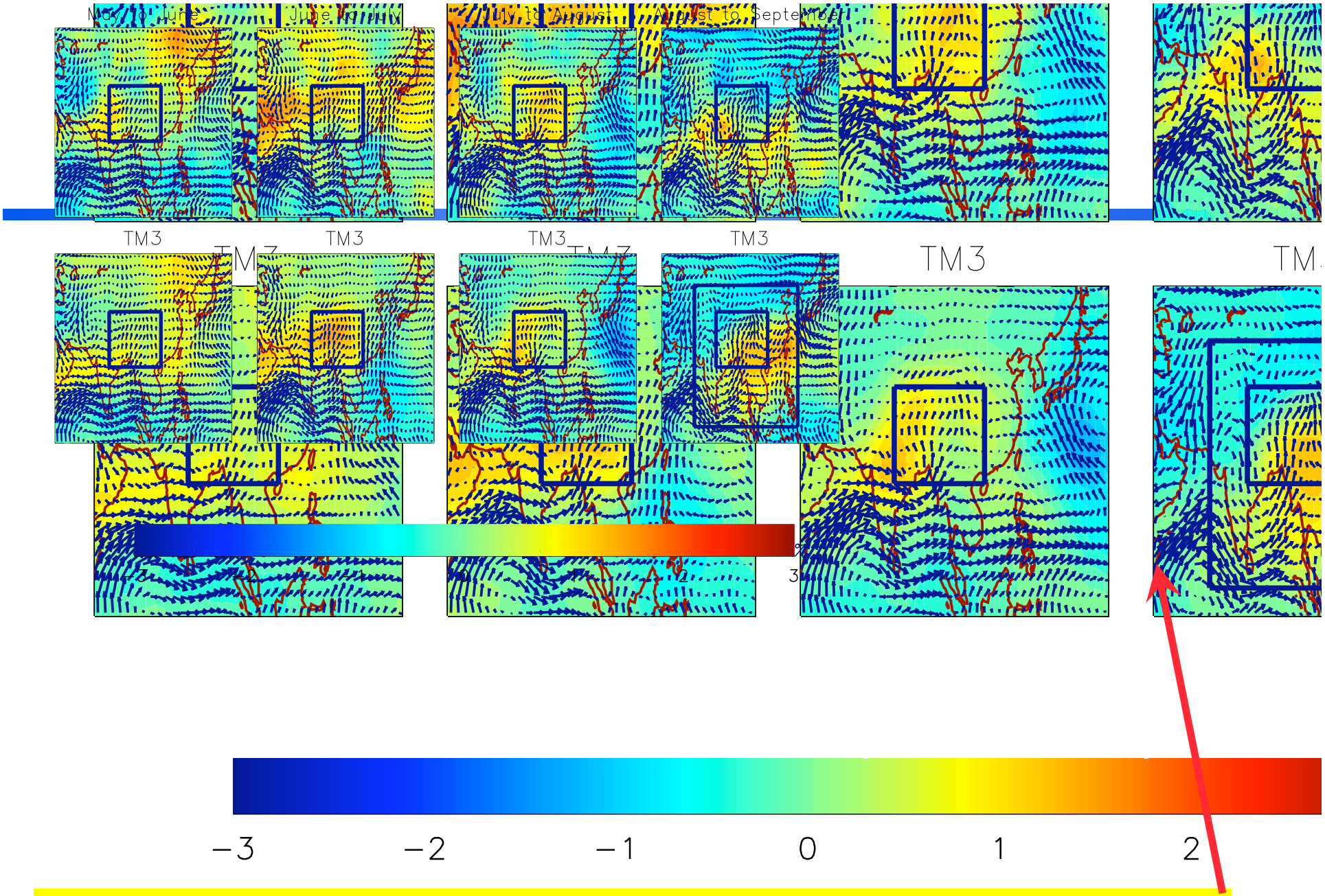
  In consistent with the model simulation, AIRS observed a CH_4 plume over the South Asia in the summer

→ Is it possible to use AIRS data to constrain the model for a better estimation of Asian CH4 sources?

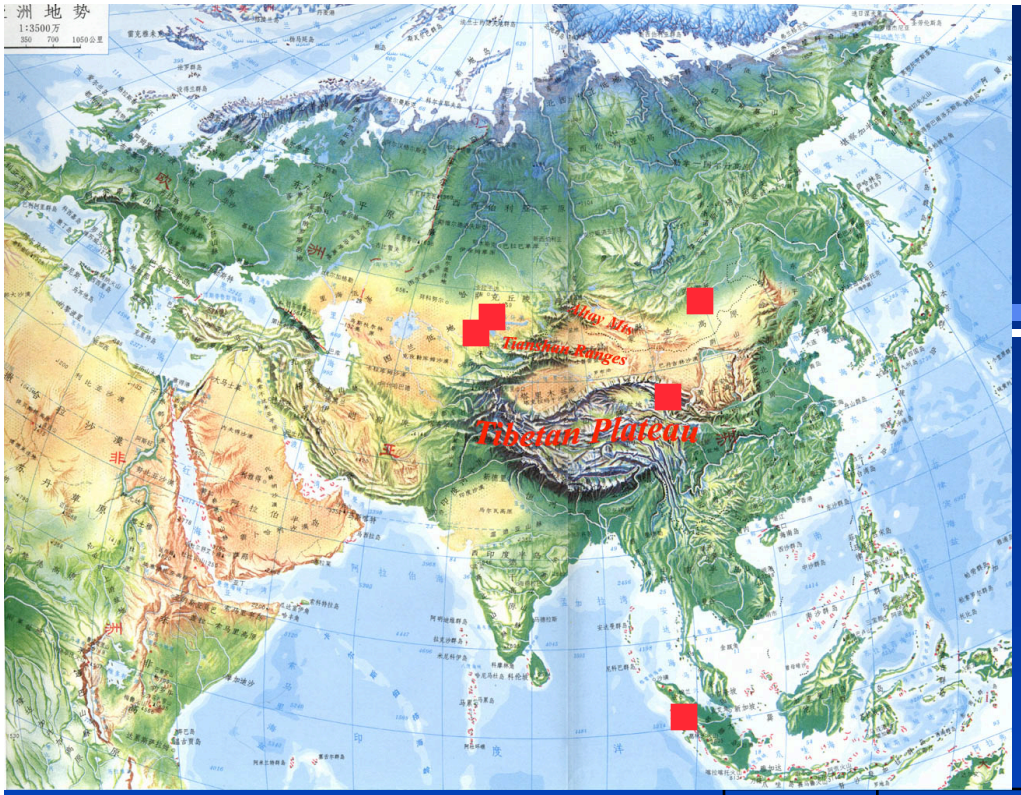
- Assuming emissions of 60 Tg yr-1
- Model sensitivity study assuming 50% increase of emissions



Xiong, X., S. Houweling, J. Wei, E. Maddy, F. Sun, C. D. Barnet, 2008, Methane Plume over South Asia during the Monsoon Season: Satellite Observation and Model Simulation, Atmos. Chem. Phys. Discuss., 8, 13453-13478, 2008.



60 Tg yr-1 is an overestimate of CH4 emissions from rice paddies.

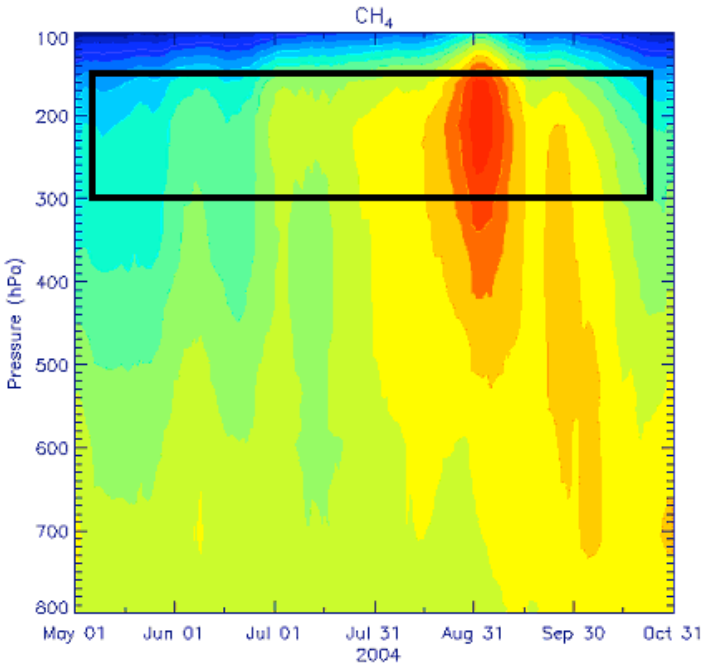


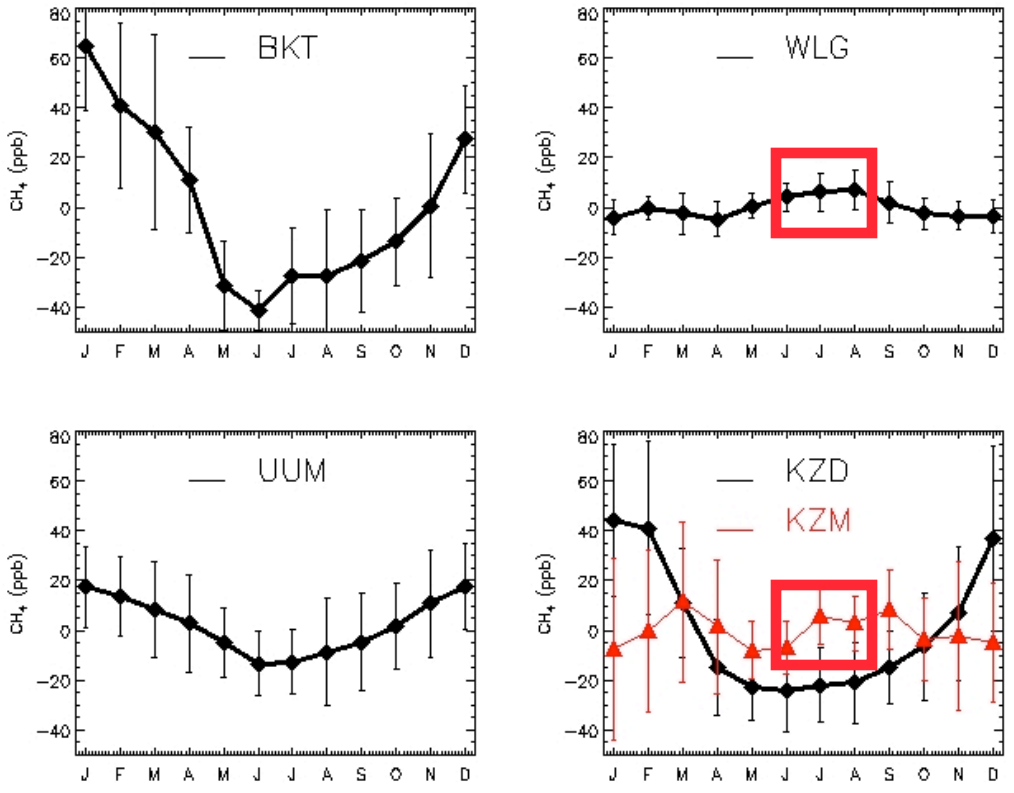
Stations at the Periphery of the Tibetan Plateau

Code	Location	Latitude, Longitude	Elevation (m)	Period
BKT	Bukit Koto Tabang, Indonesia	0°12' N, 100°19' E	864.5	2004-2005
WLG	Mt. Waliguan, China	36°29' N, 100° 90' E	3810	1992-2004
UUM	Ulaan Uul, Mongolia	44°27' N, 111°5' E	914	1992-2005
KZD	Sary Taukum, Kazakhstan	44°27' N, 75°34' E	412	1998-2005
KZM	Plateau Assy, Kazakhstan	43°15' N, 77°52' E	2519	1998-2005

Very close

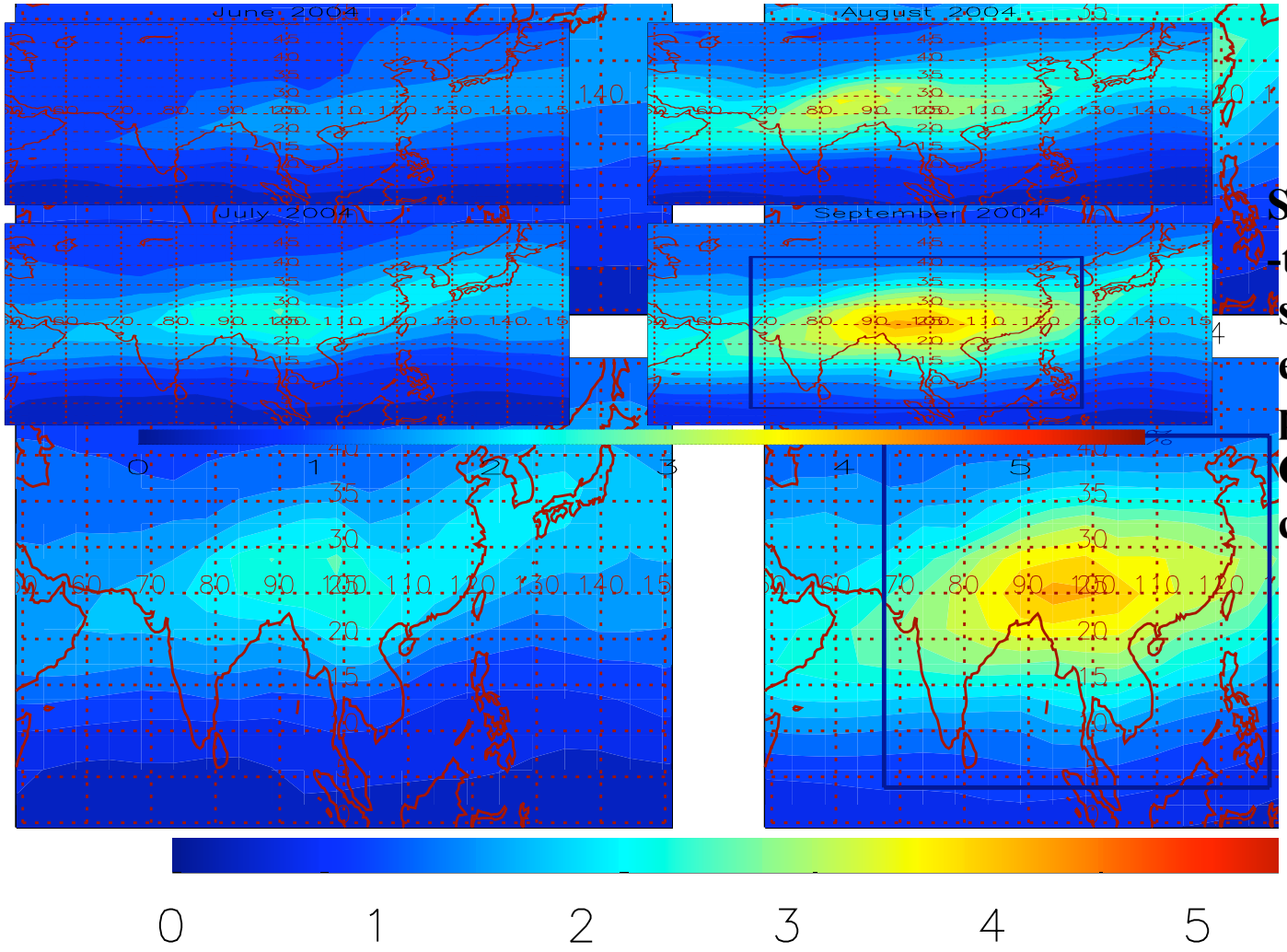
AIRS





Seasonal cycle of CH4 in 2.5-3.8 km, quite different from that in the marine boundary layer, also shows an increase in the summer, as observed by AIRS (transport is the main driver)

Relative increase of CH4 for 50% increase of emissions (from rice)



Since the mid-tropospheric CH4 is sensitive to surface emission, it might be possible to use AIRS CH4 data to constrain the model

Scientific application and Collaboration (1)

- **Invited to participate in a methane working group on "*Toward an adequate quantification of CH4 emissions from land ecosystems: Integrating field and in-situ observations, satellite data, and modeling*", CA, March 13-14, 2008.**

- **As a convener we organized a session in AGU fall meeting, B34 "Toward accurate estimates of methane fluxes over regional scales" – use of satellite observation is part of this effort.**

- **Through comparison with transport model (TM5), AIRS and measurements by SCHIMACHY to exam the optimized CH4 emissions from rice paddies in Asia and the CH4 emissions scenarios from IPCC;**

Scientific application and Collaboration (2)

- Collaborate with Russian and American scientists to examine the relationship of CH4 anomaly in 2007 with emissions from permafrost, which include the comparison with field measurement and the wetland Emission models of Purdue University;
- Two modelers are seriously comparing AIRS data with their models (Sander Houwelling/Netherlands, Prabir K. Patra/Japan).
- A few presentation in the AGU fall meeting will talk about the AIRS CH4 -- not mine !
- Comparison of TES/AURA CH4 with AIRS is started.
- In addition to campaigns in USA, CARIBIC aircraft campaigns has interest to compare with AIRS (Dr. Carl Brenninckmijer).

CH4 Validation (V5)

More Data sets have been used:

1) Aircraft data from NOAA Earth System Research Laboratory, Global Monitoring Division (ESRL/GMD) (usually below 300 hPa → only data used in the JGR paper)

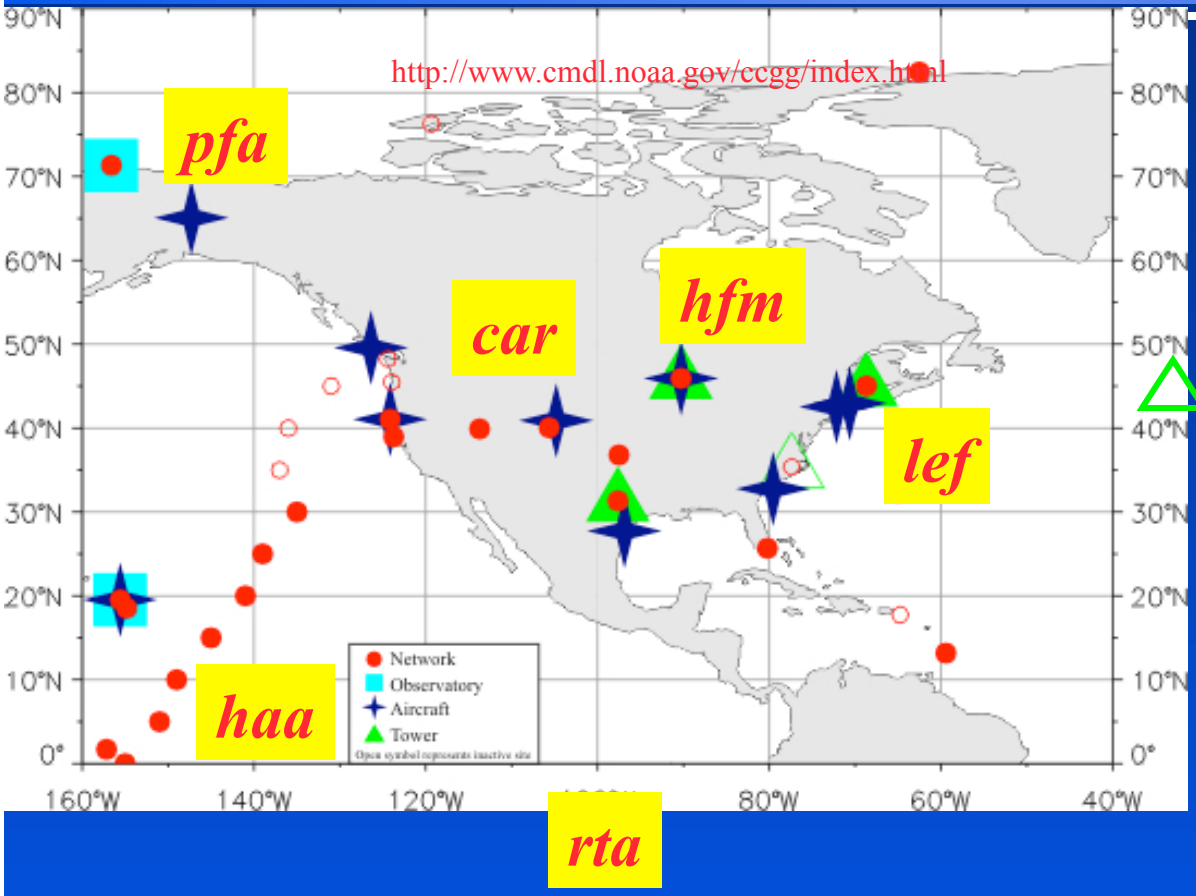
2) Aircraft or balloon measurements from ENVISAT CAL/VAL database – MIPAS

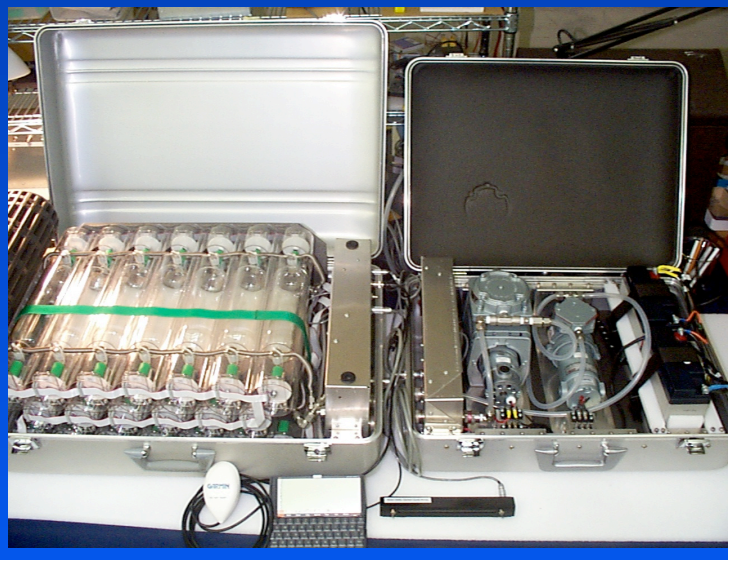
3) Campaign data: INTEX-B (… *INTEX-A, ARCTAS, START*…)

4) Ground-based Fourier Transform Spectrometer (FTIR) observation;

Validation (ESRL/GMD data)

NOAA ESRL/GMD North American Sampling Sites





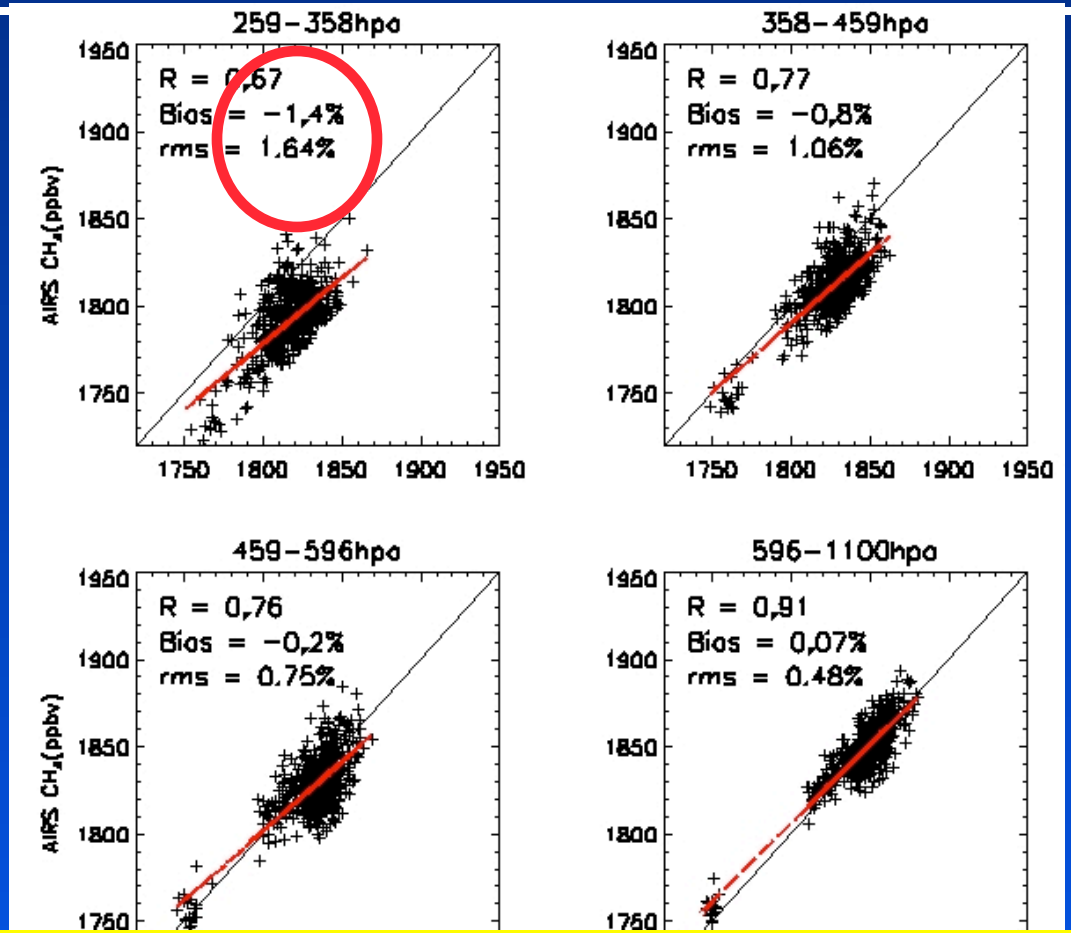
Aircraft

Tall Tower

Observatory

Network

AIRS CH_4 vs NOAA Aircraft Measurement (200, 300, 400, 650 mb --- V5)



ESRL/GMD aircraft profiles are mostly below the most sensitive region of AIRS at 200-300 hpa.

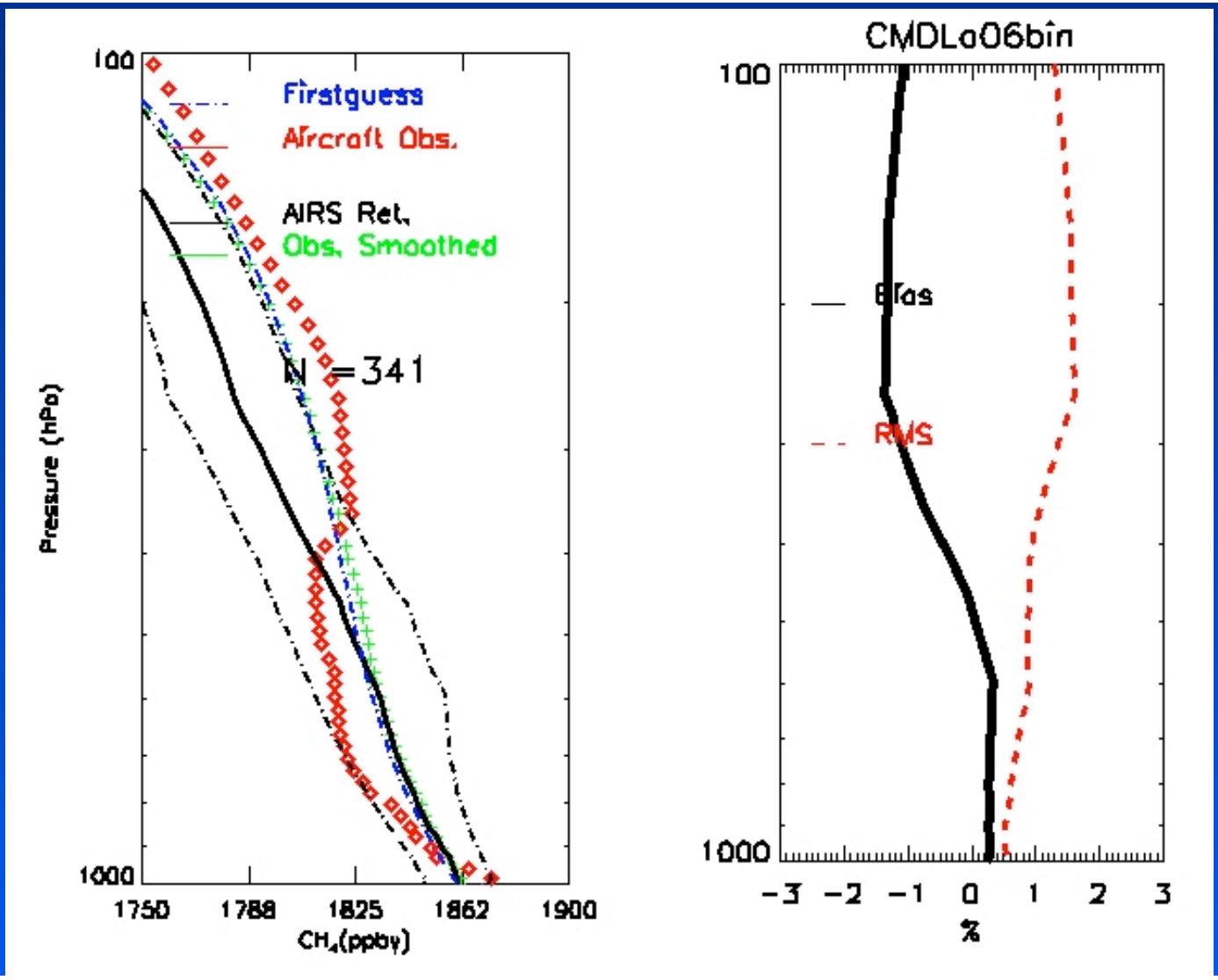
Collocation

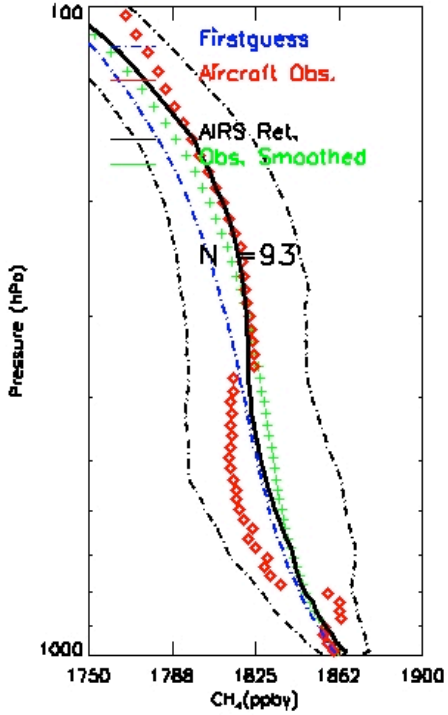
$\Delta R < 200$ km

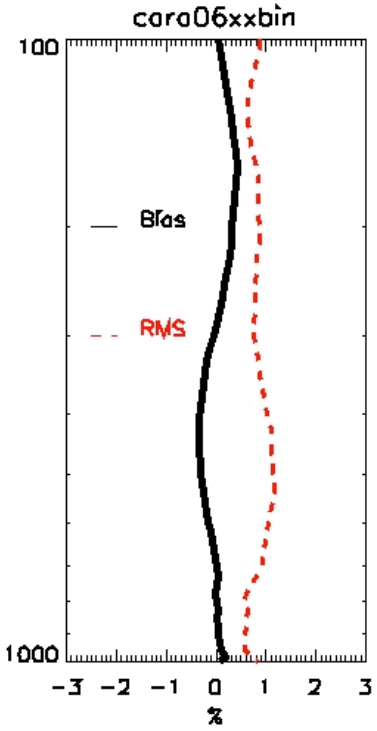
$\Delta t < 24$ hour

Xiong, X., C. Barnet, E. Maddy, C. Sweeney, X. Liu, L. Zhou, and M. Goldberg, 2008, Characterization and validation of methane products from the Atmospheric Infrared Sounder (AIRS), J. Geophys Res., 113, G00A01, doi:10.1029/2007JG000500.

Using NOAA/ESL/GMD data

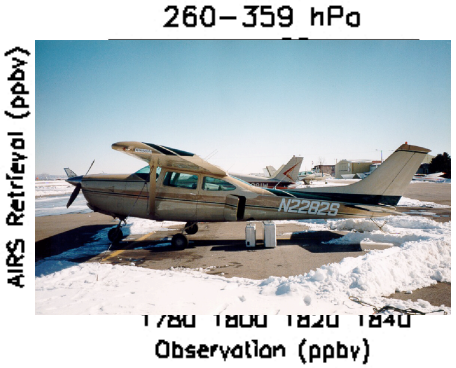


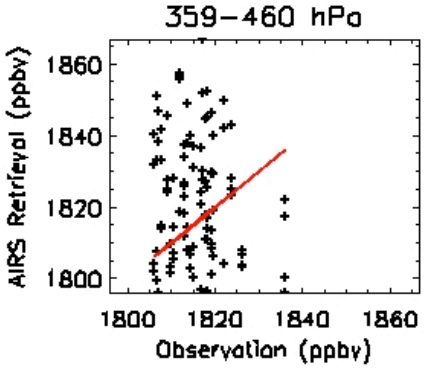


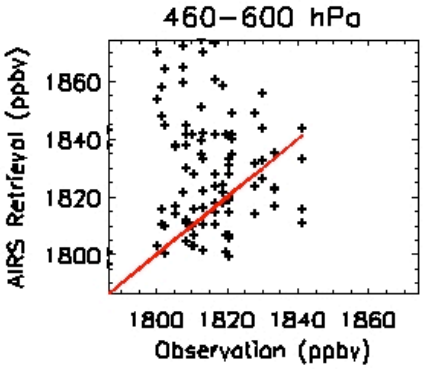


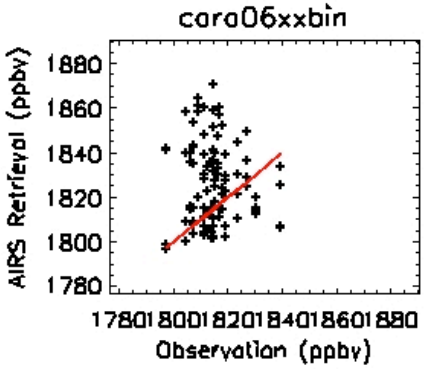
CAR, Colorado

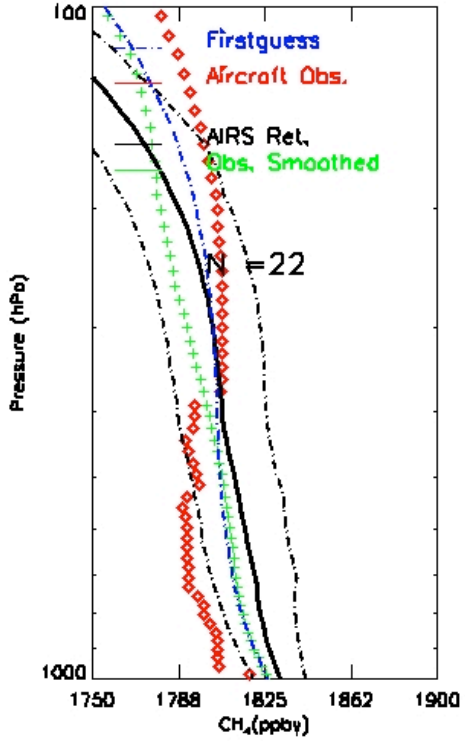
Correlation is bad !

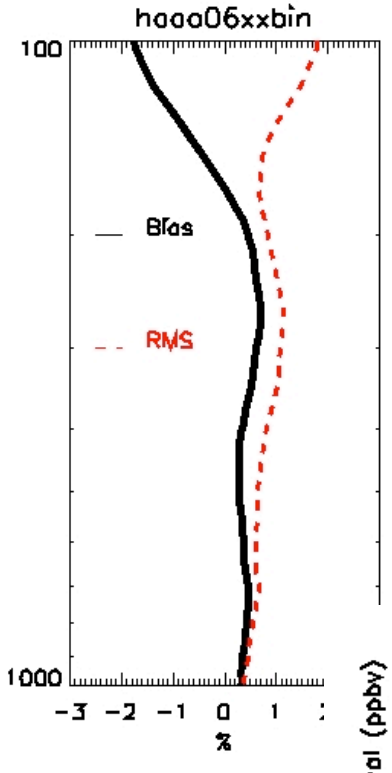









Firstguess
Aircraft Obs.
AIRS Ret.
Obs. Smoothed
N =22
Pressure (hPa)
100
1000
1750
1788
1825
1862
1900
CH4(ppbv)

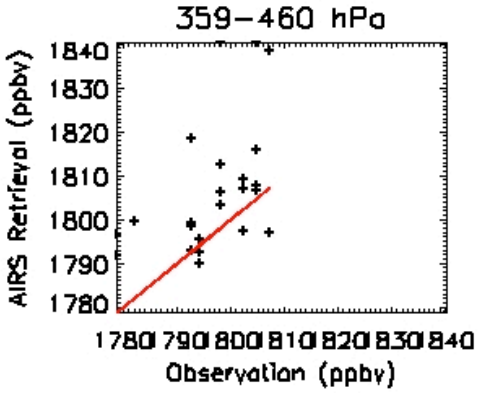

haaa06xxbin
100
1000
Bias
RMS
-3
-2
-1
0
1
%

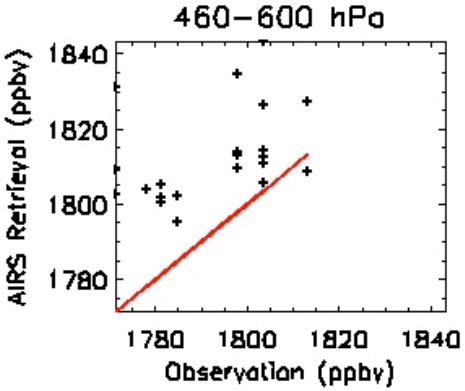

NOAA

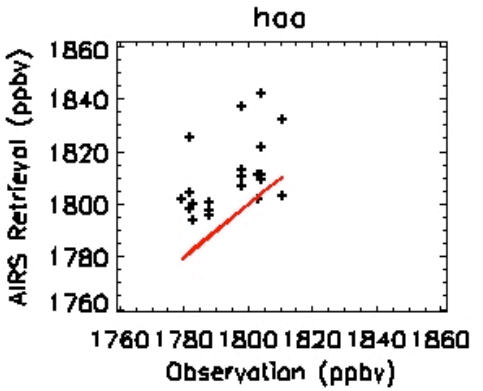
HAA, Hawaii

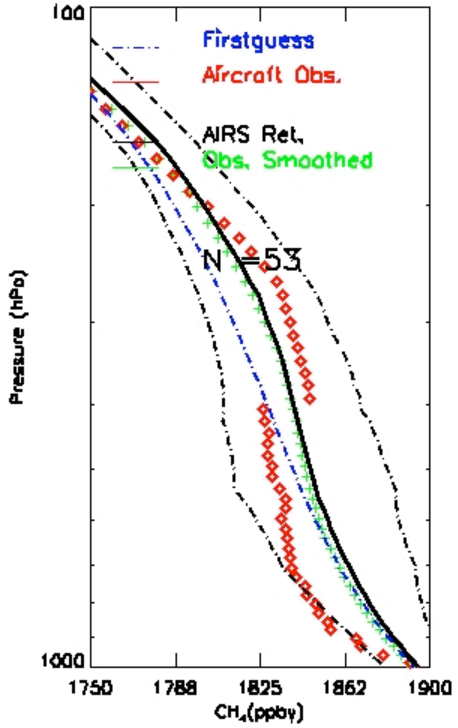

N22829

260–359 hPa
AIRS Retrieval (ppbv)
Observation (ppbv)


359–460 hPa
AIRS Retrieval (ppbv)
1840
1830
1820
1810
1800
1790
1780
1780 790 800 810 820 830 840
Observation (ppbv)


460–600 hPa
AIRS Retrieval (ppbv)
1840
1820
1800
1780
1780
1800
1820
1840
Observation (ppbv)


haa
AIRS Retrieval (ppbv)
1860
1840
1820
1800
1780
1760
1760 1780 1800 1820 1840 1860
Observation (ppbv)


Firstguess
Aircraft Obs.
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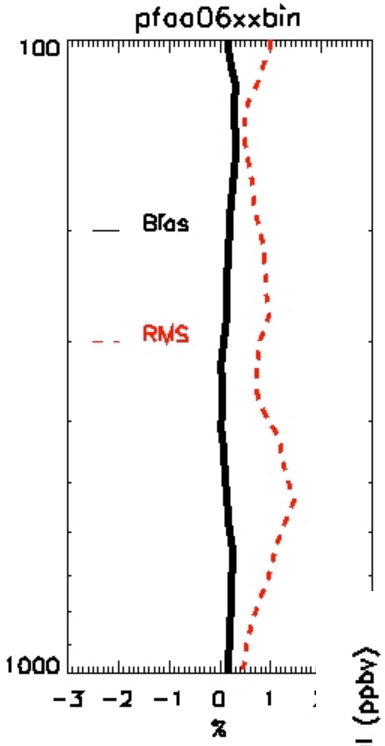
Obs. Smoothed
N=53
Pressure (hPa)
100
1000
1750
1788
1825
1862
1900
CH4(ppbv)

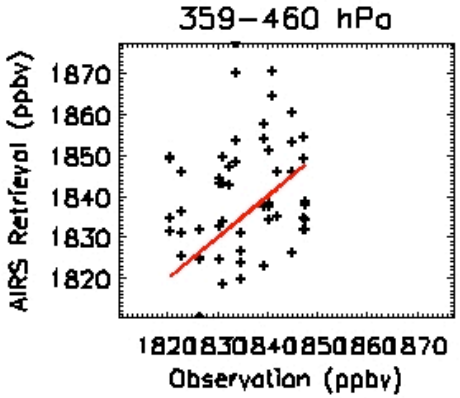

pfaa06xxbin
Bias
RMS
100
1000
-3
-2
-1
0
1
%

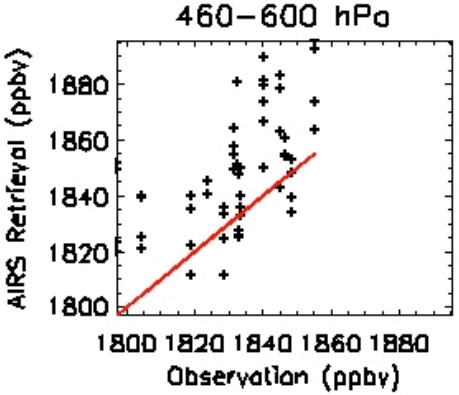

NOAA

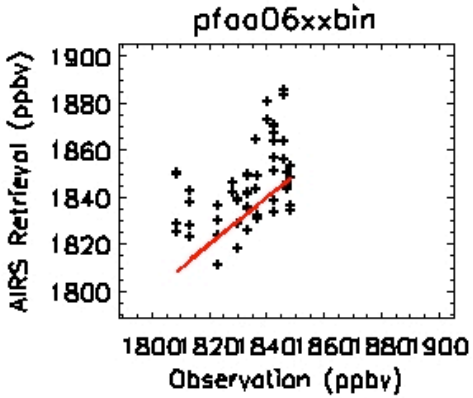
PFA, Alaska


N22825

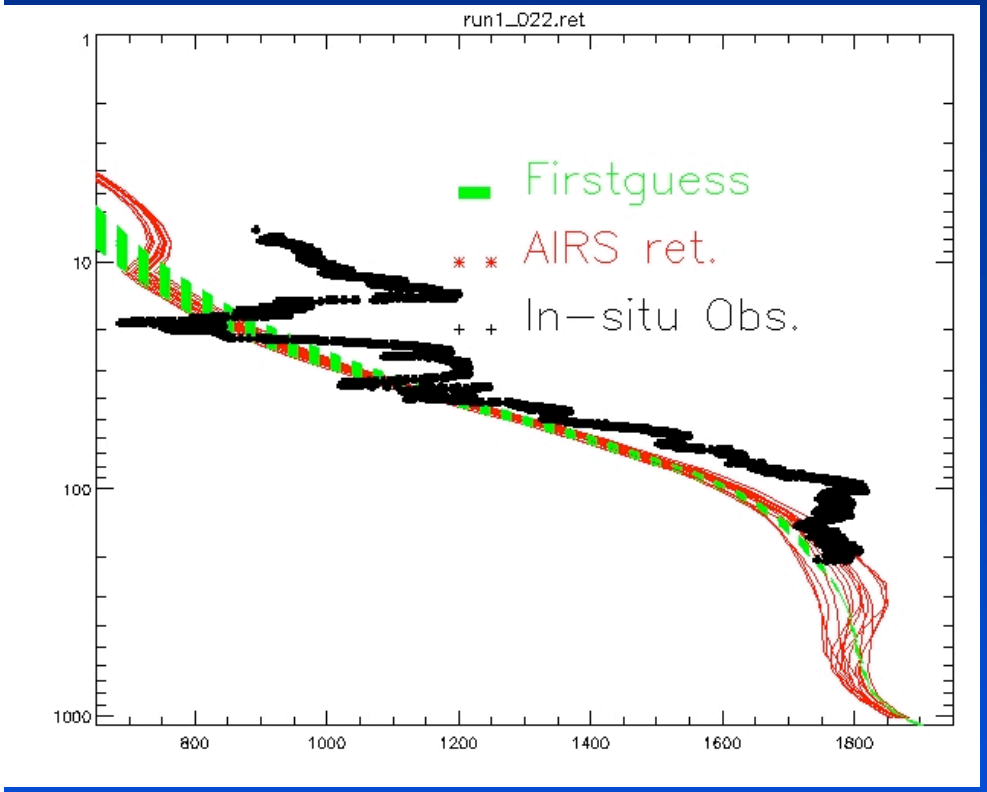
260–359 hPa
AIRS Retrieval (ppbv)
1800 810 820 830 840 850
Observation (ppbv)

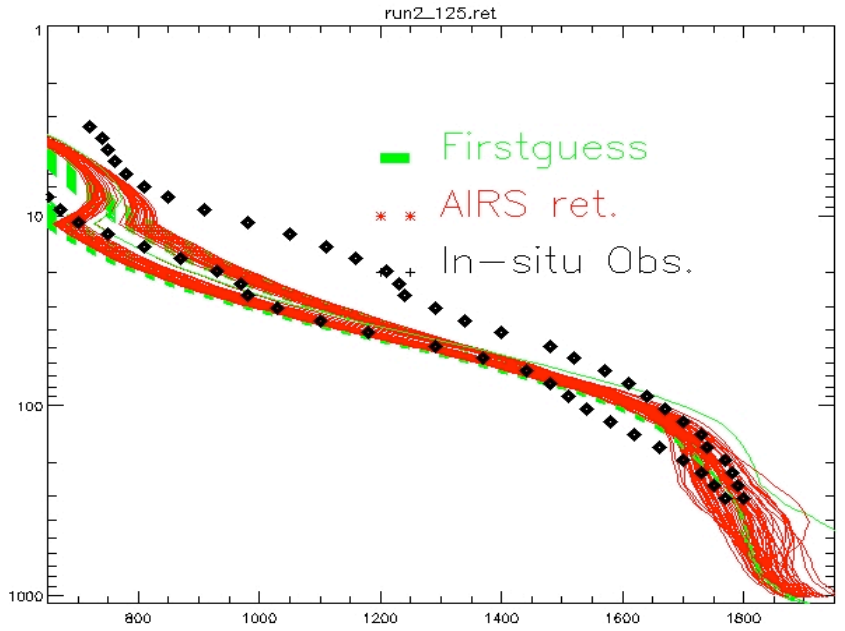

359–460 hPa
AIRS Retrieval (ppbv)
1870
1860
1850
1840
1830
1820
1820 830 840 850 860 870
Observation (ppbv)

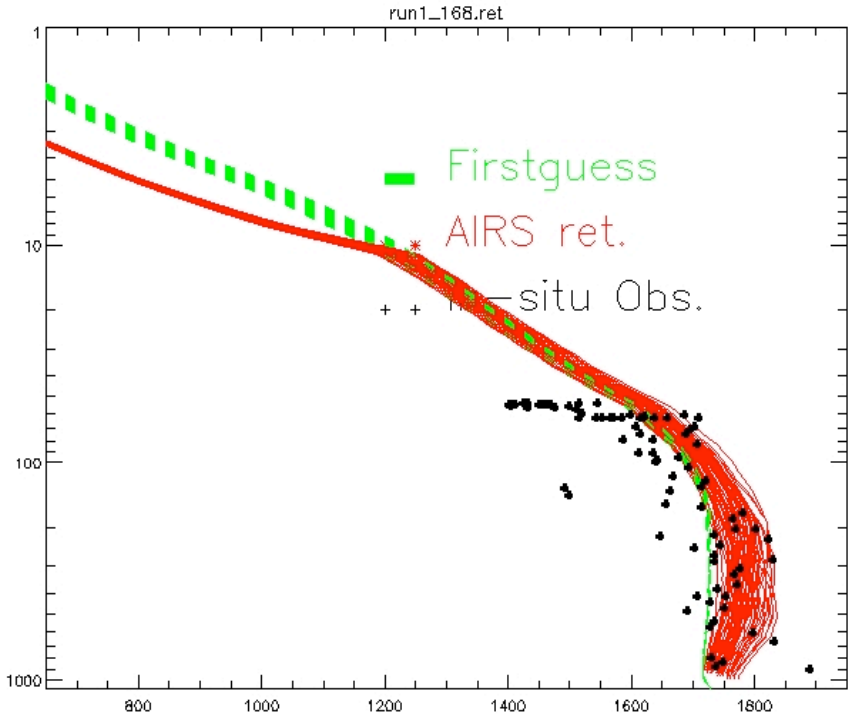

460–600 hPa
AIRS Retrieval (ppbv)
1880
1860
1840
1820
1800
1800 1820 1840 1860 1880
Observation (ppbv)


pfaa06xxbin
AIRS Retrieval (ppbv)
1900
1880
1860
1840
1820
1800
1800 1820 1840 1860 1880 1900
Observation (ppbv)

MIPAS vs AIRS

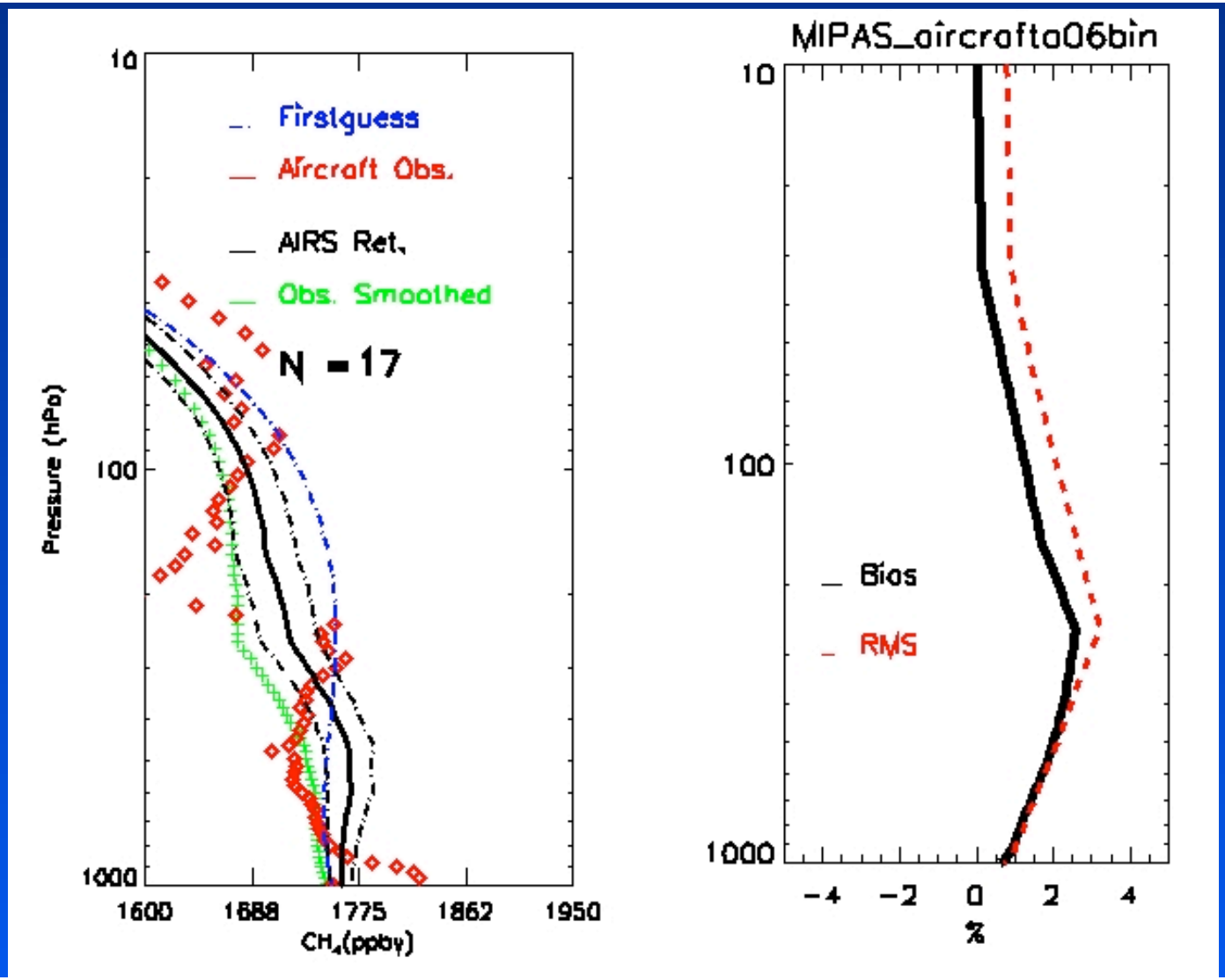




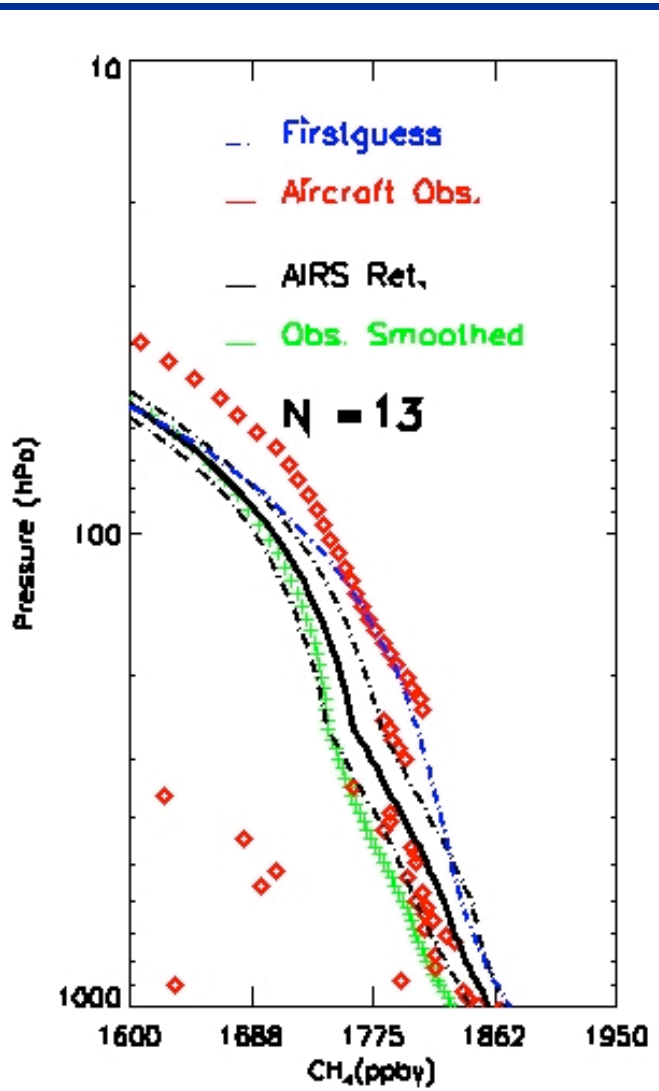


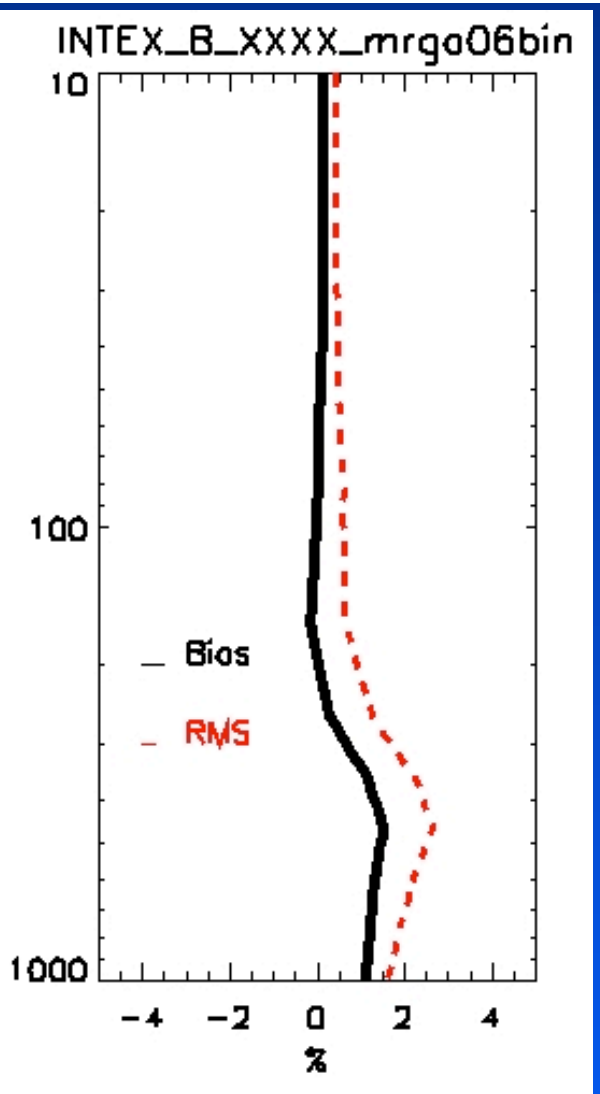
MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) onboard the ENVISAT satellite. **In-situ data is from ENVISAT CAL/VAL Database.**

ENVISAT CAL/VAL Data (MIPAS)



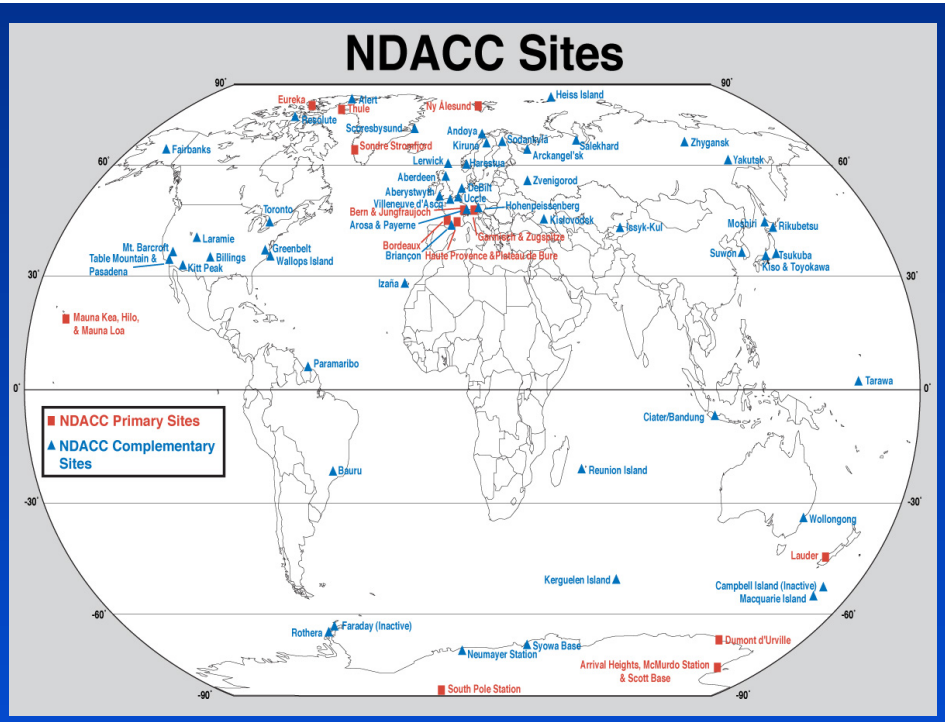
INTEX-B


Firstguess
Aircraft Obs.
AIRS Ret.
Obs. Smoothed
N = 13
Pressure (hPa)
10
100
1000
1600
1688
1775
1862
1950
CH4(ppbv)


INTEX_B_XXXX_mrgo06bin
10
100
1000
Bias
RMS
-4
-2
0
2
4
%

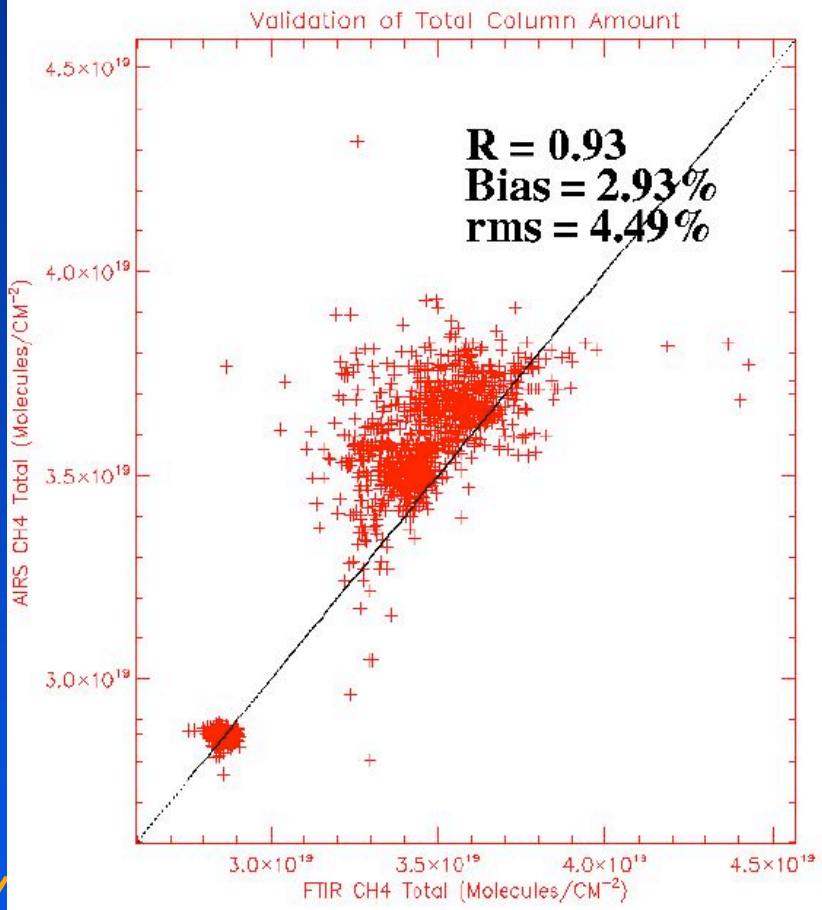
Measurement of CH4 by FTIR

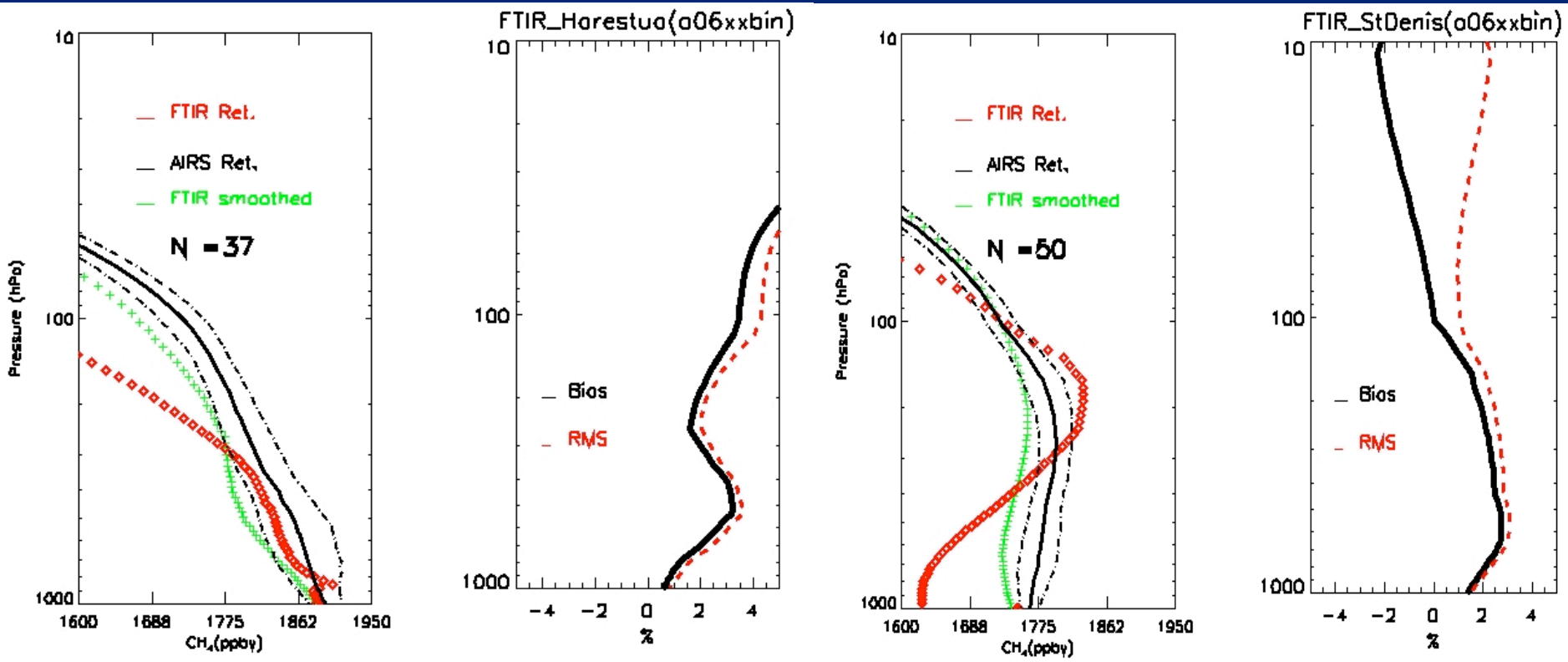
(Fourier Transform Spectrometer)



Network for the Detection of Atmospheric Composition Change (NDACC)

http://www.ndsc.ncep.noaa.gov/





FTIR vs AIRS for two sites

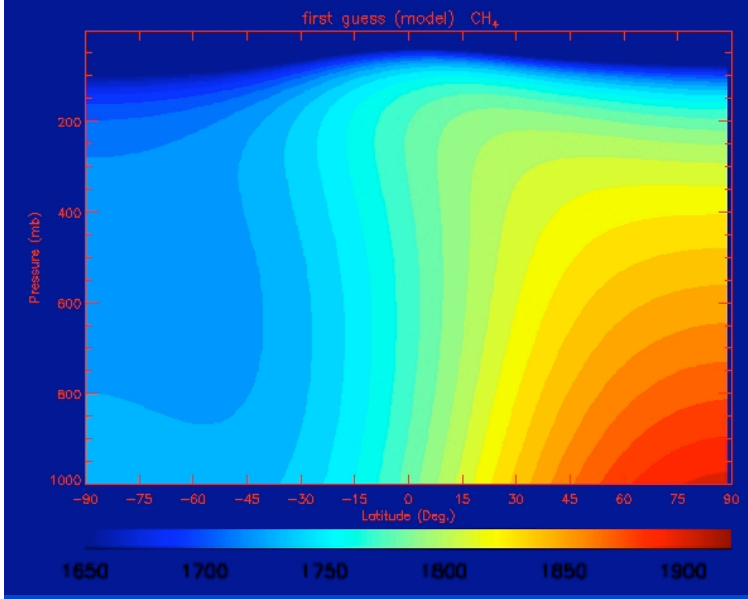
CH4 Profile data are provided by
Dr. Jeffrey R. Taylor,
Dr. Nicholas Jones
Dr. Anders Strandberg
etc.

Optimization towards V6

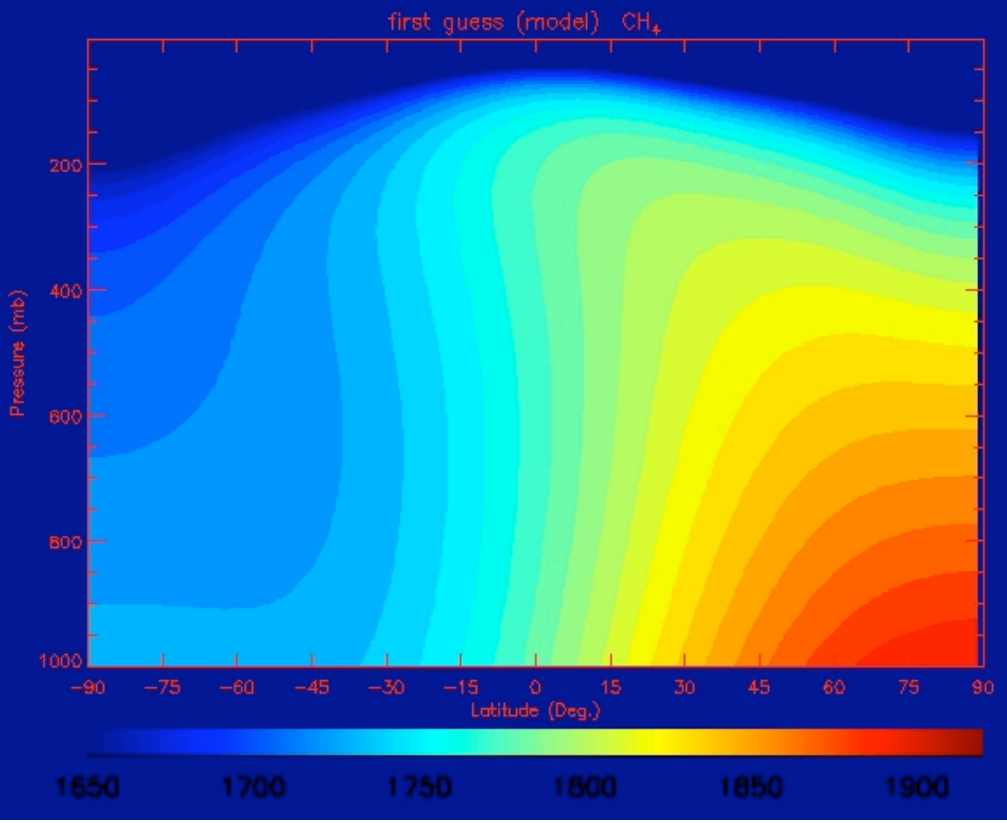
- Optimization of first guess
- Add 3 trapezoid functions (from 7 to 10)
- Channels & damping (adjust)
- Uncertainty in Spectroscopy and RTA is still a problem for CH4 retrieval;

1) Tuning to the absorption in CH4 peak channels by 2% in V5 is not always supported from validation data.
2) The use of CH4 amount as a predictor to compute the transmittance of water vapor needs more investigation.

Ch4 firstguess Optimization

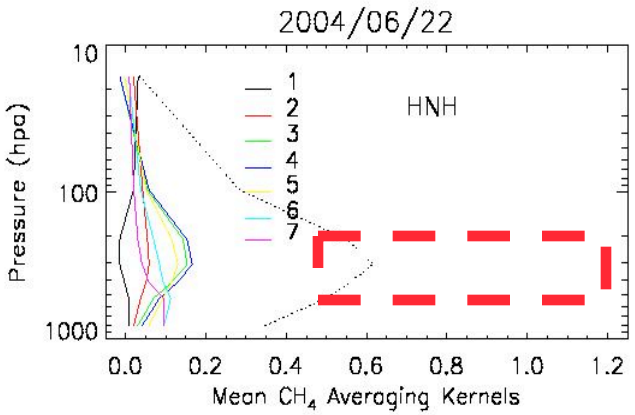


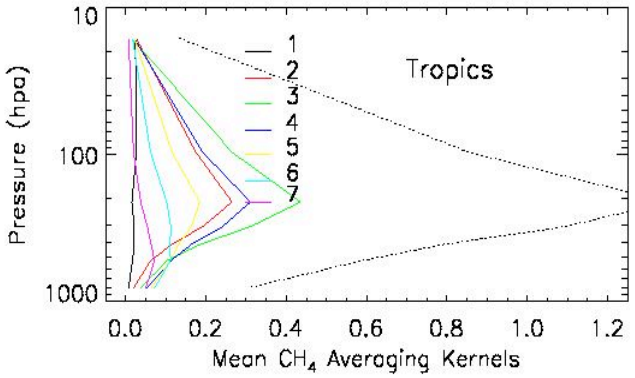
CH4 sirstguess is a smoothed function of latitude and pressure, and is obtained through a polynomial fitting to observation and model



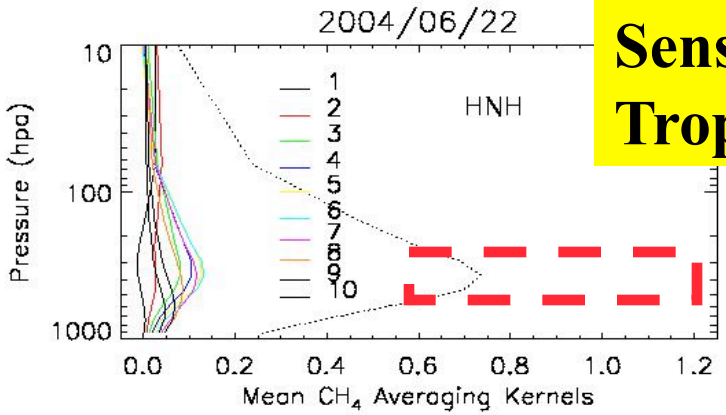
Change in Averaging Kernels

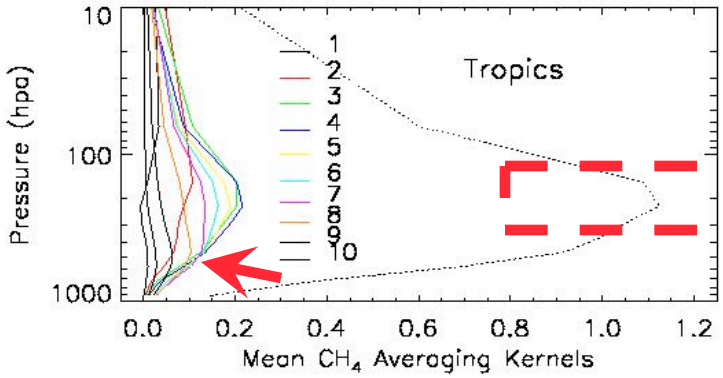
V5





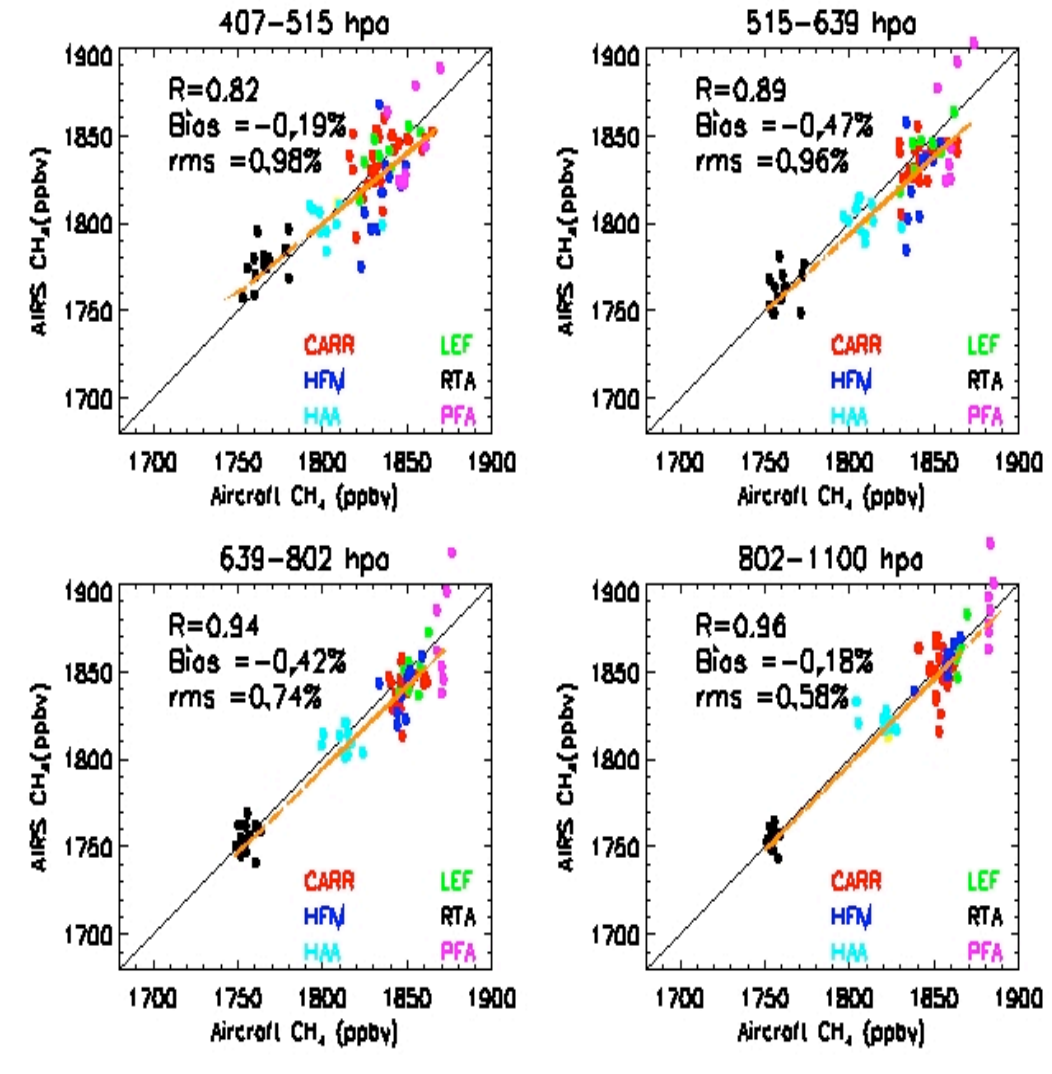
V6





Tends to be more Sensitive to lower Troposphere

Some validation to V6



Using data from six sites of NOAA/ESL /GMD

Summary (1)

- ✓ Validation using more data have been made;
- ✓ Optimizations towards V6 include the change of firstguess, and to add 3 more trapezoid functions;
- ✓ Tuning to the CH4 peak channels by 2% in V5 needs a little more study;
- ✓ We plan to use data from recent campaigns, such as ***INTEX-A, ARCTAS, pre-START08*** , to make more validation and then wrap them up toward the version 6.

Summary (2)

- ✓ AIRS data support that the CH4 emissions from rice paddies in Asia converges to the lower end of the range given by IPCC. It is possible to use AIRS CH_4 over South Asia to constrain the model for a better estimate CH4 emissions;

- ✓ AIRS CH4 support a larger summer emissions from permafrost in high northern hemisphere – its relation with surface emission and transport is under investigation.

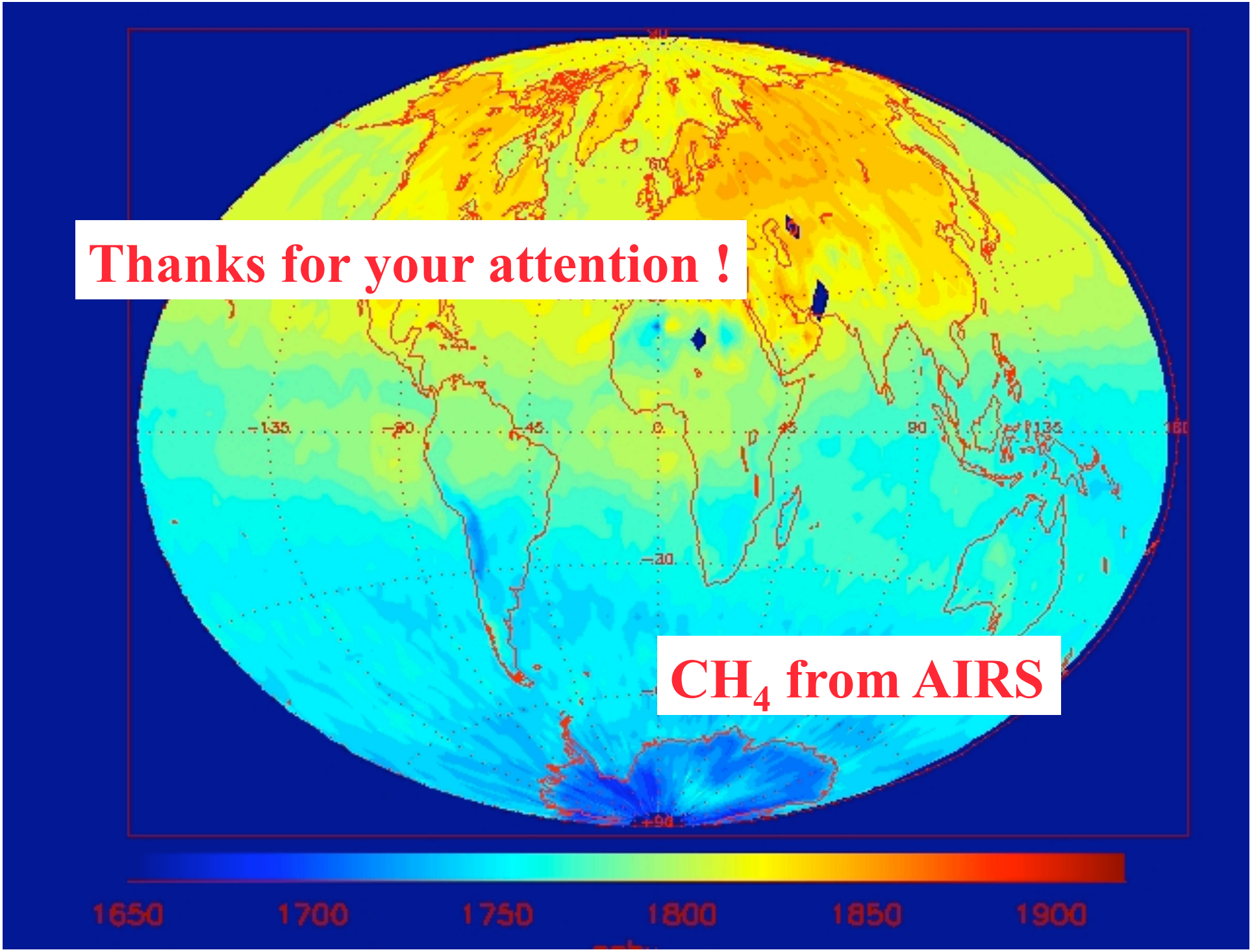
List of Publications

Xiong, X., C. Barnet, E. Maddy, C. Sweeney, X. Liu, L. Zhou, and M. Goldberg, 2008, Characterization and validation of methane products from the Atmospheric Infrared Sounder (AIRS), *J. Geophys Res*., 113, G00A01, doi:10.1029/2007JG000500.

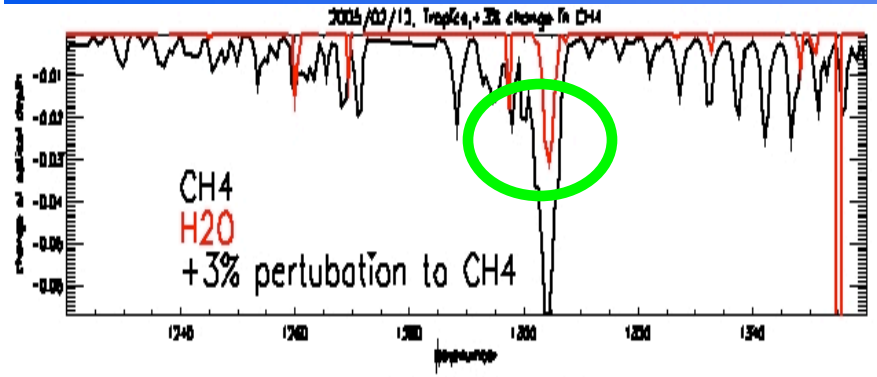
Xiong, X., S. Houweling, J. Wei, E. Maddy, F. Sun, C. D. Barnet, 2008, Methane Plume over South Asia during the Monsoon Season: Satellite Observation and Model Simulation, *Atmos. Chem. Phys. Discuss*., 8, 13453-13478, 2008.

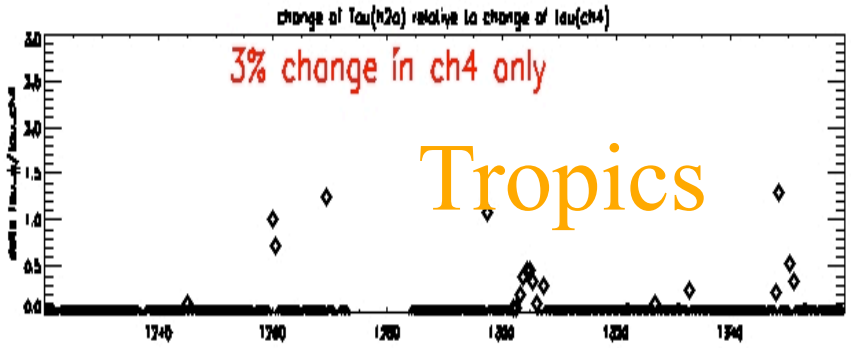
Xiong, X., Barnet, C.D., Maddy, E., Liu, X., and Goldberg, M., 2008. Variation of Atmospheric Methane over the Permafrost Regions from Satellite Observation during 2003 to 2007. *Proceedings of the Ninth International Conference on Permafrost*, Alaska, USA: 1981-1986 pp.

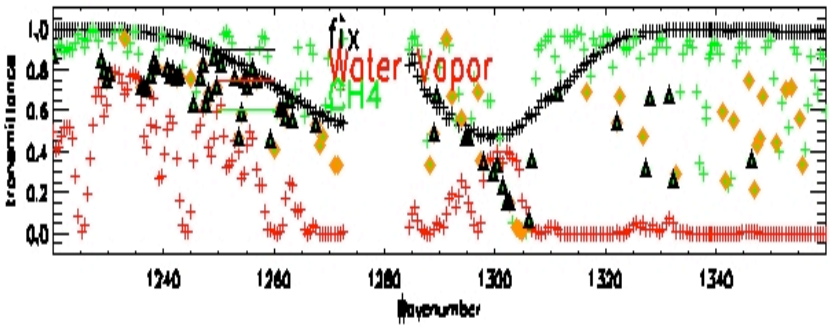
Xiong, X., Barnet, C.D. et al., 2008: Temporal and Spatial Variation of Mid-Tropospheric Methane over the High Northern Hemisphere, JGR (to be submitted).


Thanks for your attention !
CH_4 from AIRS
1650
1700
1750
1800
1850
1900

II. RTA: CH4 amount as a predictor for the computation of water vapor absorption



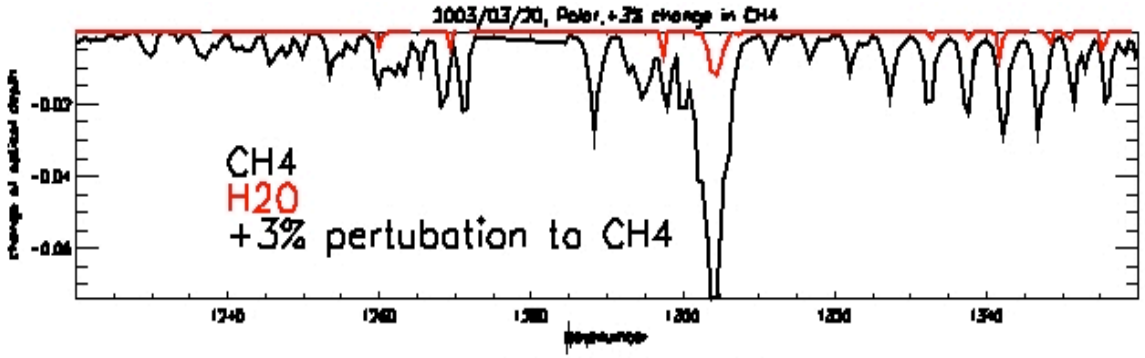


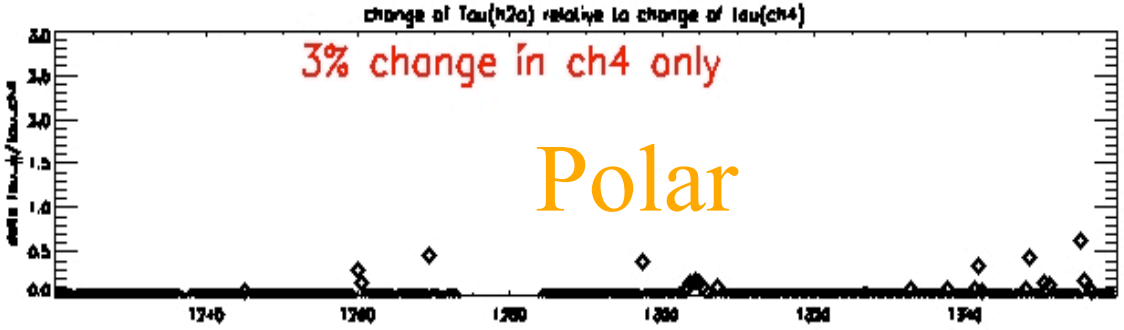


Perturbation to CH4 only also made significant change of H2O optical depth;

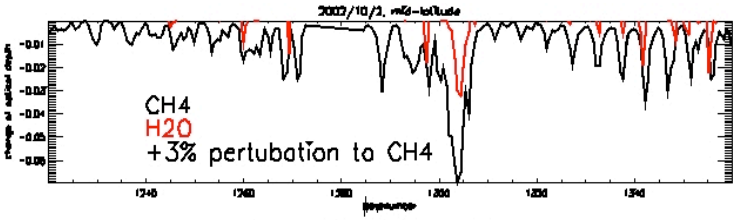
Is it real → needs to be examed using LBL model;

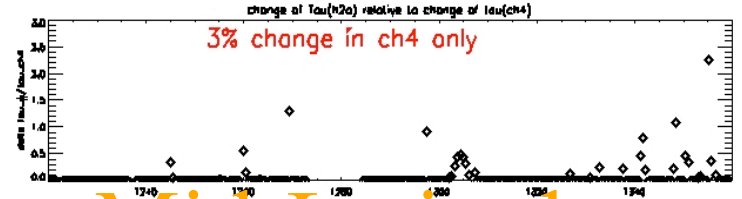
Recommendation: in order to use the CH4 peak channels, we may need to remove CH4 amount as a predictor, or use the reference amount as the predictor in the computation of H2O absorption



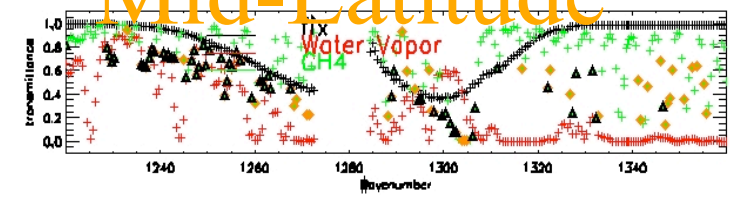


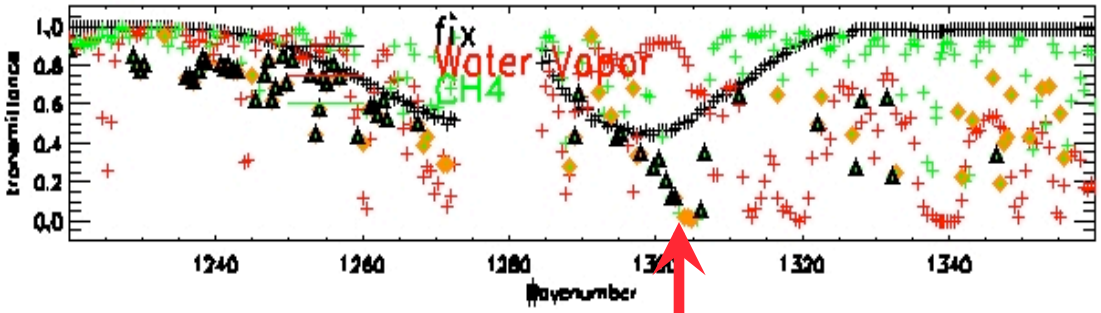
Polar





Mid-Latitude





We tried to re-selected channels by ignoring those channels Δh2o/Δch4>10%.
But we lost the most sensitive methane channels near 1305-1310. micron