Recent Improvements on CH_4 Retrieval Using CrIS FSR Data -- suggestion for AIRS-V7

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Outline

- **Requirement for CH_4 Product in J-1**
  - **The major sensitivity in mid-upper troposphere requires a good CH_4 firstguess in the lower troposphere**
  - **Recent increase of CH_4 and N_2O also calls for an update of CH_4 and N_2O firstguess**

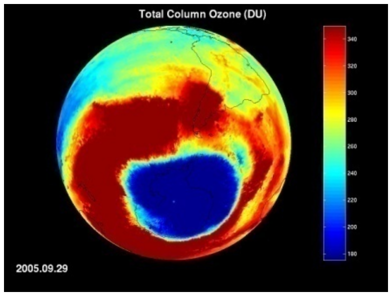
- **Recent Improvements– *Test Study Based on NUCAPS***
  - **Update of firstguess: comparison with model and ATom aircraft measurements**
  - **Other Improvements: Channel selection, re-tuning and Quality control (CH_4QC);**

- **Assessment of the Improved Retrievals**
  - **Comparison with model, AIRS, TCCON and ATom data;**

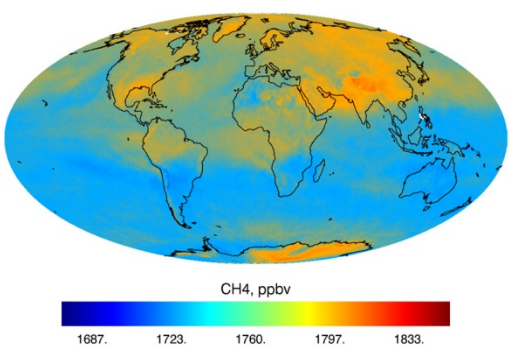
- **Summary and Future works**

Requirements of Trace Gases Products from CrIS

Ozone

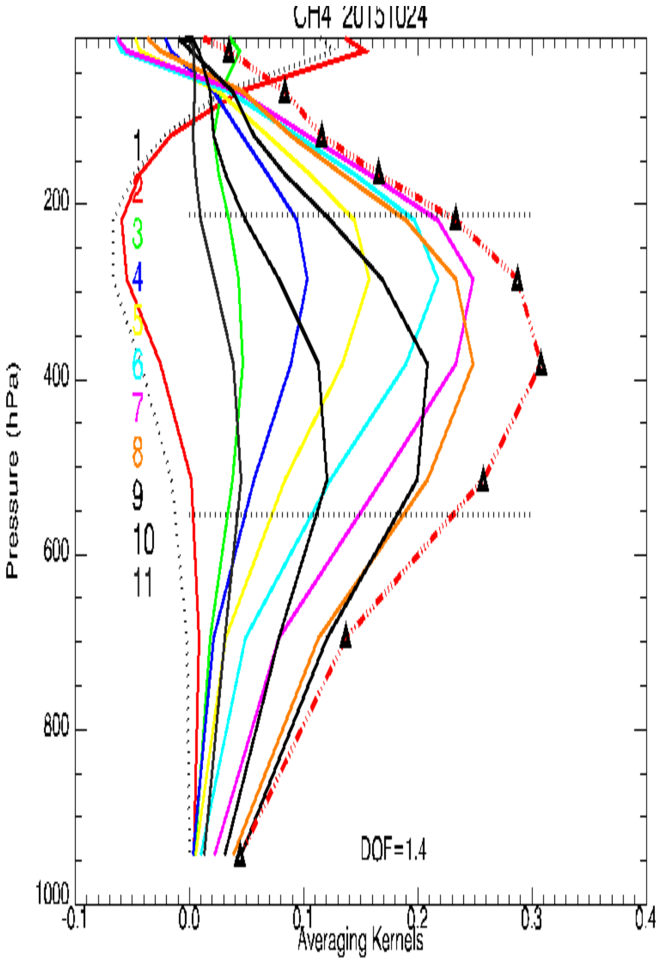


Methane



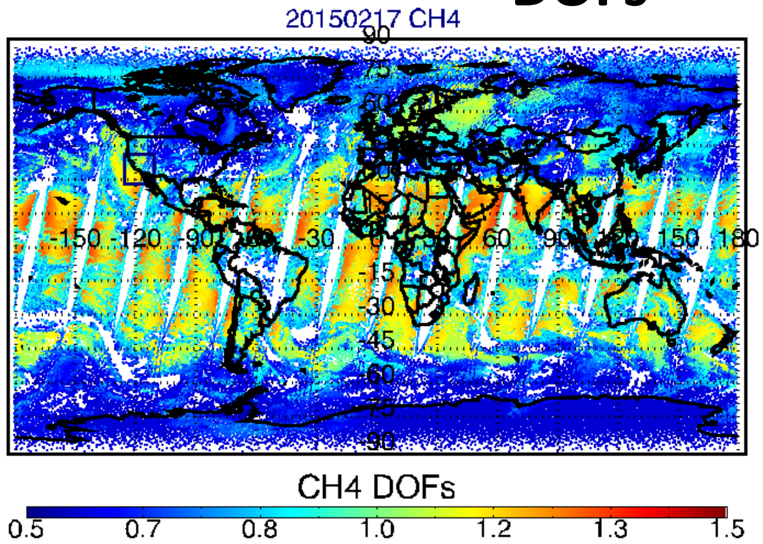
EDR Attribute	CO	CO_2	CH_4
Vertical Coverage	Total Column	Total Column	**Total Column**
Horizontal Resolution	100 km	100 km	100 km
Mapping Uncertainty, 3 sigma	25 km	25 km	25 km
Measurement Range	0 – 200 ppbv	300 – 500 ppmv	1100 – 2250 ppbv
Measurement Precision	15%	0.5% (2 ppmv)	**1% (~20 ppbv)**
Measurement Accuracy	±5%	±1% (4 ppmv)	**±4% (~80 ppbv)**
Refresh	24 h	24 h	24 h
Note			

Sensitivity of CrIS to Atmospheric CH_4



Example of Averaging Kernels

DOFs

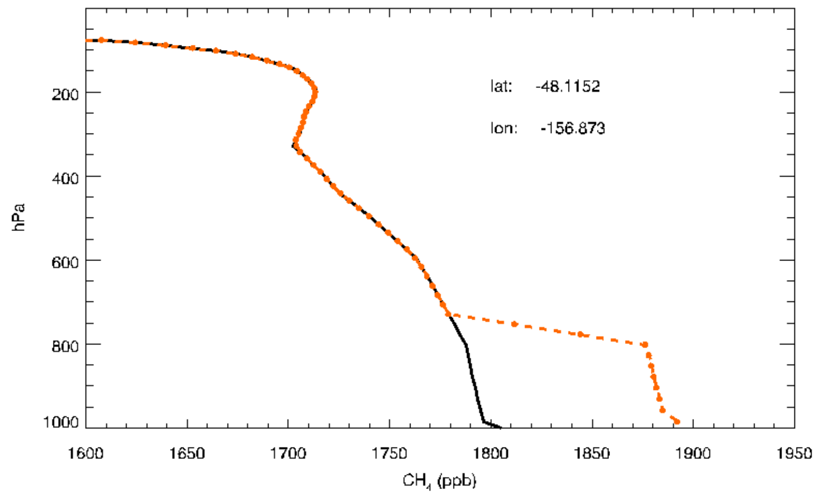


- **Major sensitivities are in the mid-upper troposphere – not near the surface where the variation is impacted by emissions;**

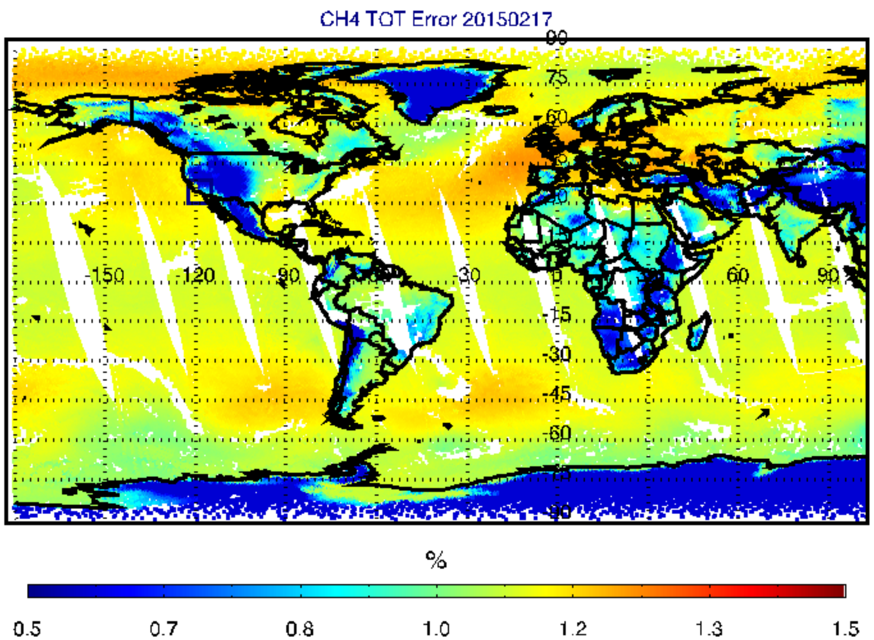
- **Sensitivities in the polar are lower than in tropics and mid-latitude**

Simple Estimate of the CH_4 Total Amount Error

assuming 5% error of CH_4 profile in lower troposphere (below 800 hPa)



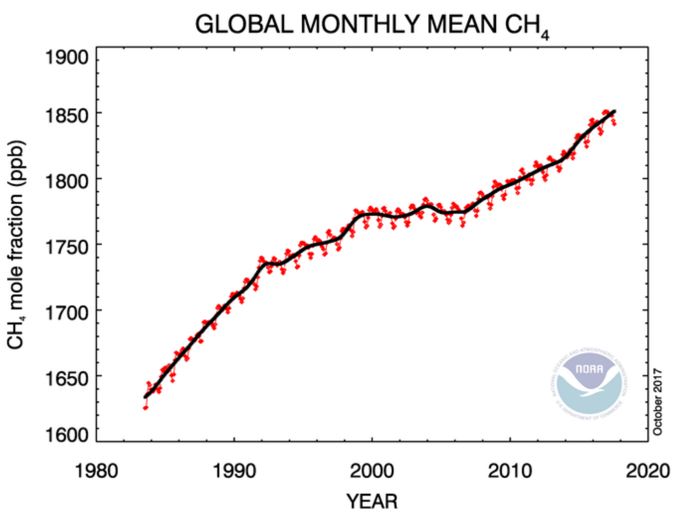
2/17/2015



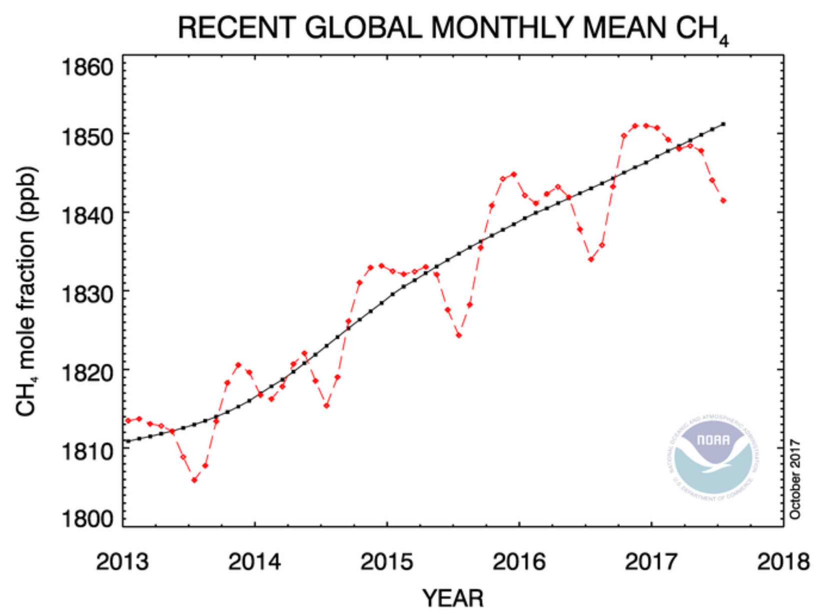
Assuming 5% error of CH_4 profile in lower troposphere(below 800 hPa), the error in total amount is about 1.2%.

- **to meet the requirement of total amount in 1%(precision) is hard if without a good a priori, particularly in the lower troposphere**

Significant Increase of CH_4 in the past 10 years

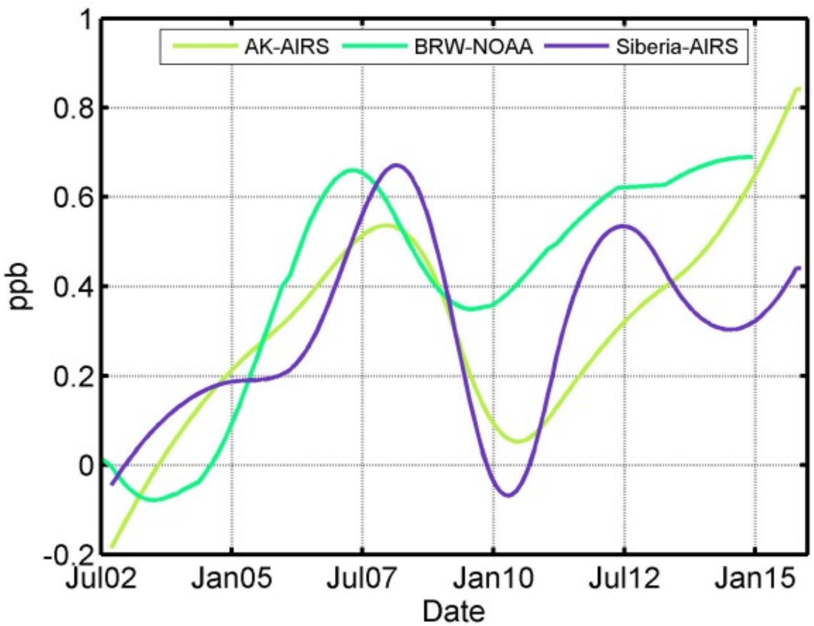


We built a fixed firstguess in AIRS-V6 in about 10 years ago → it helps us to check the possibility to monitor the trend

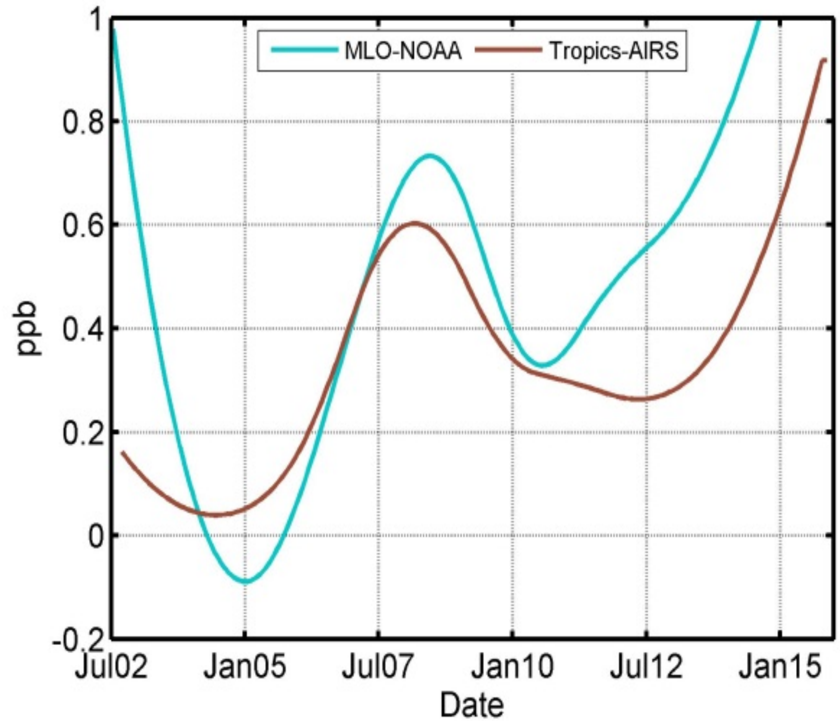


Annual Increase Rate of CH_4 from AIRS-V6 and its Comparison with NOAA Ground-based Measurements

ppb/yr

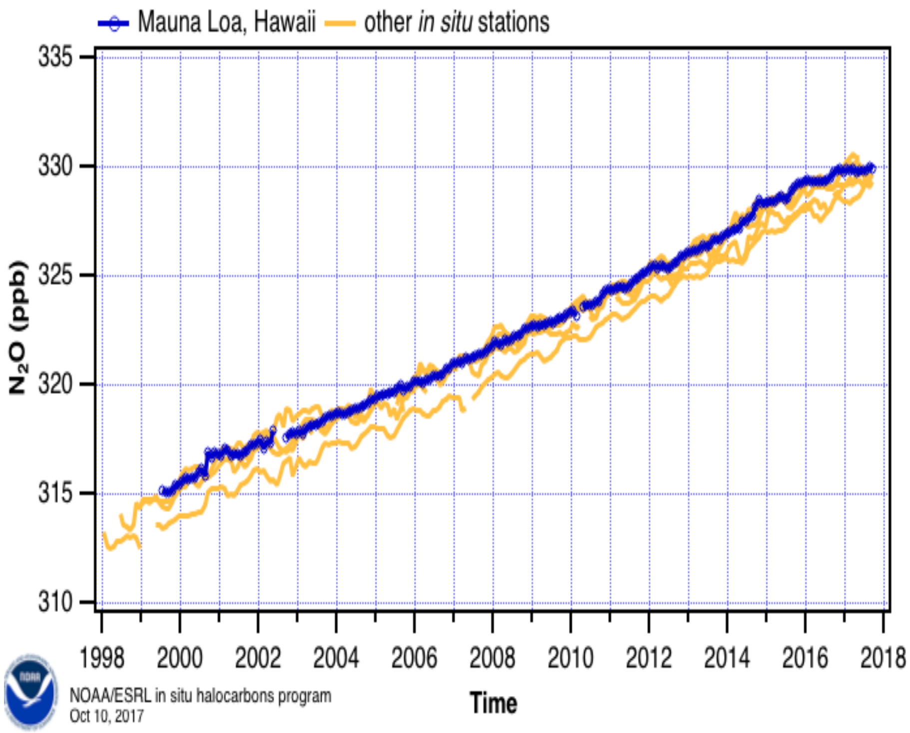


ppb/yr



Zou, M. and X. Xiong et al., 2017, Trend Analysis of Atmospheric Methane Using Space-borne and Ground-based Measurements, Remote Sensing (Submitted).

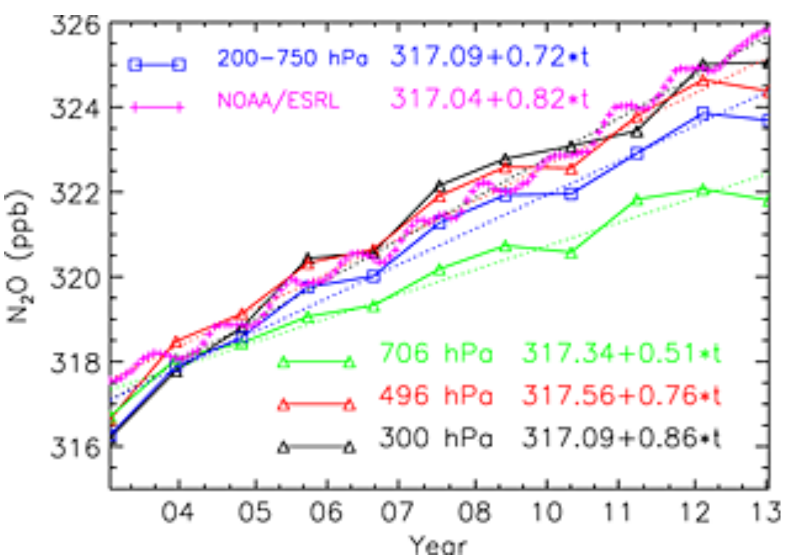
Nearly Linear Increase of N_2O



Downloaded from
https://www.esrl.noaa.gov/gmd/hats/insitu/cats/conc.php?site=mlo&gas=n2o

+ 0.26%/yr

AIRS can be used to monitor the N_2O trend (with a fixed first-guess)



Xiong, et al., 2014, Retrieval of nitrous oxide from Atmospheric Infrared Sounder: Characterization and validation, JGR, 119, 9107–9122, doi:10.1002/2013JD021406.

Questions

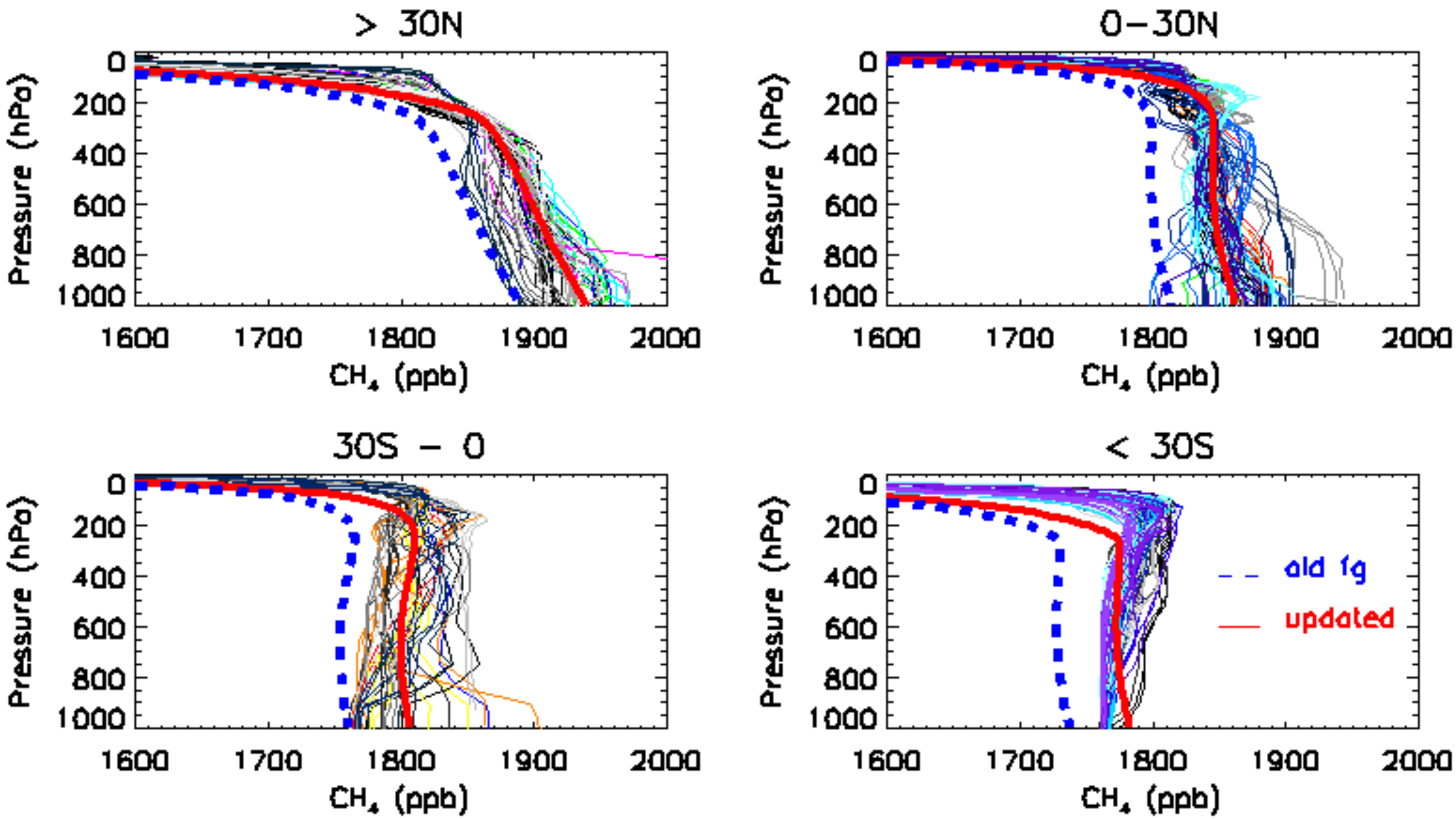
Even though we have some capability to monitor the CH_4 trend using AIRS data (with a fixed first-guess), should we include the trend in the AIRS-V7 to reprocess the data, so that we can have a better product, esp. the total amount ?

Similarly for N_2O ….

Even we do not want to add the trend for future retrieval, at least for CrIS we need to update CH_4 and N_2O firstguess to be consistent with current observation

Update of CH_4 First-guess – based on JAMSTEC Model

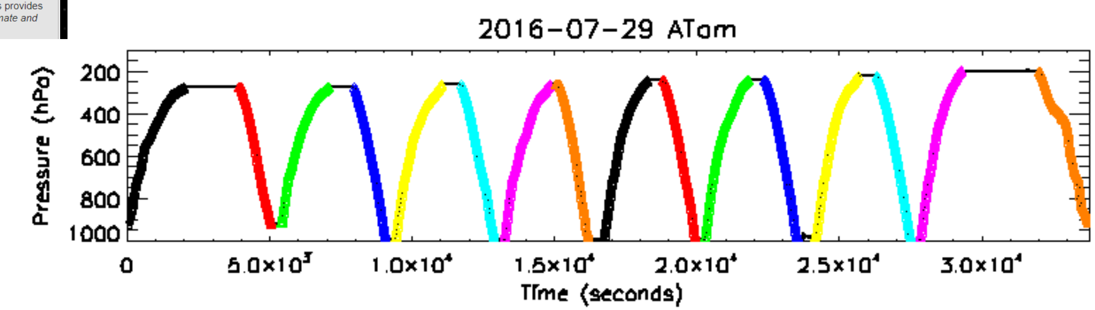
(~ 2.5%)

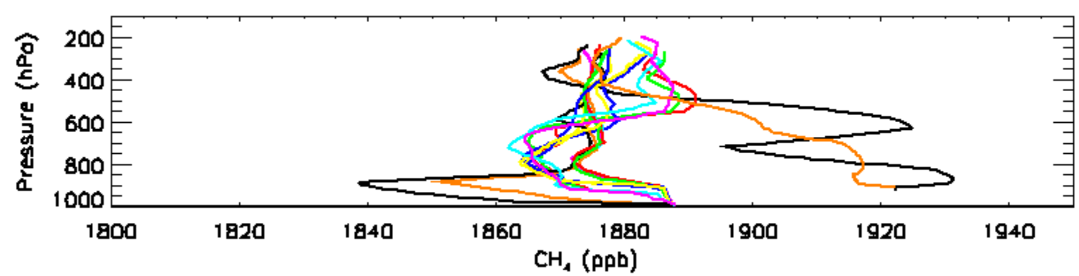


--- Old fg is the one used in AIRS-V6 and NOAA IASI system

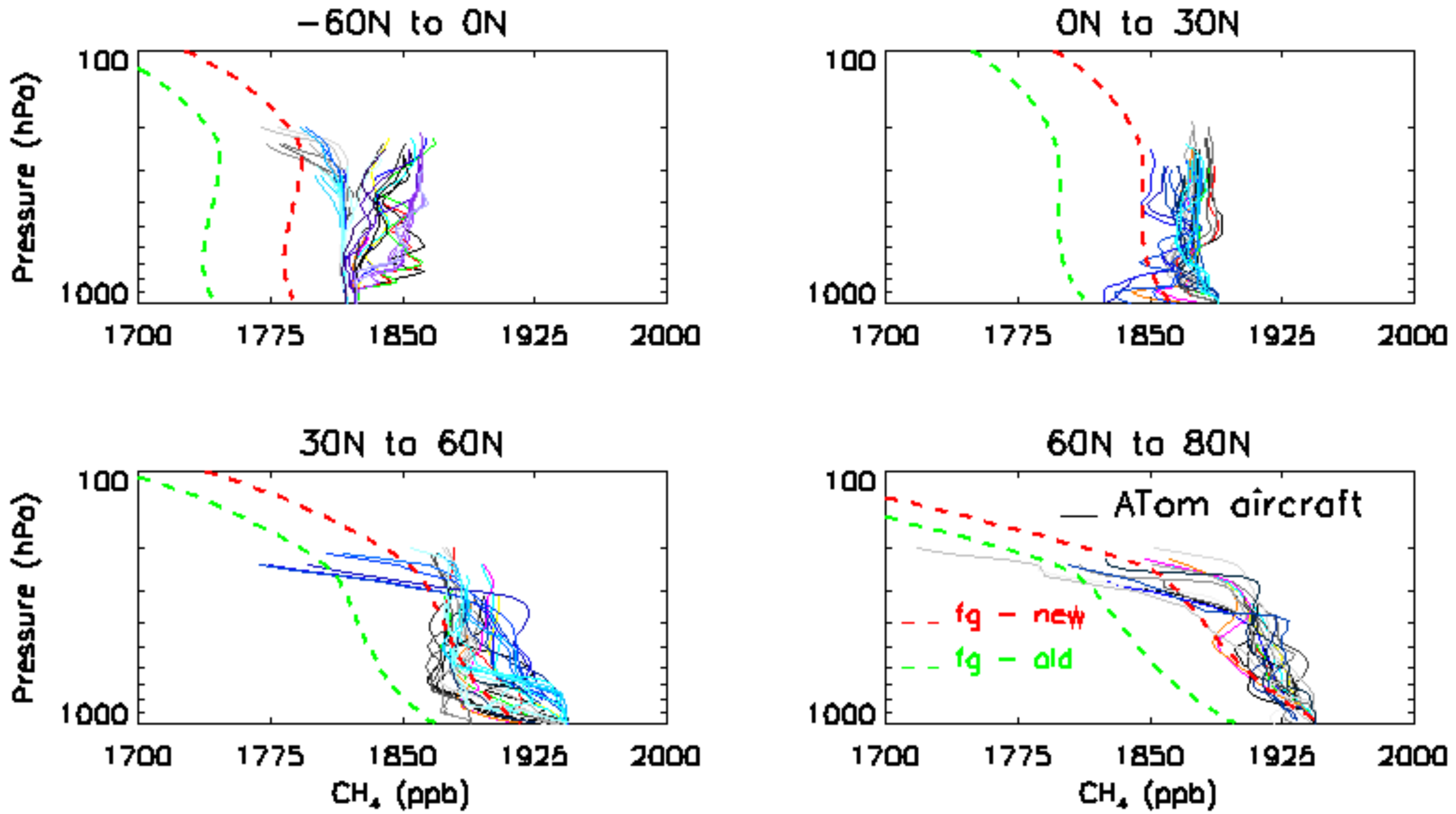
Using the Atmospheric Tomography Mission (ATom) Data for QC and Validation (July 29, 2016 – August 23, 2016)

Examples of selection of flight lags



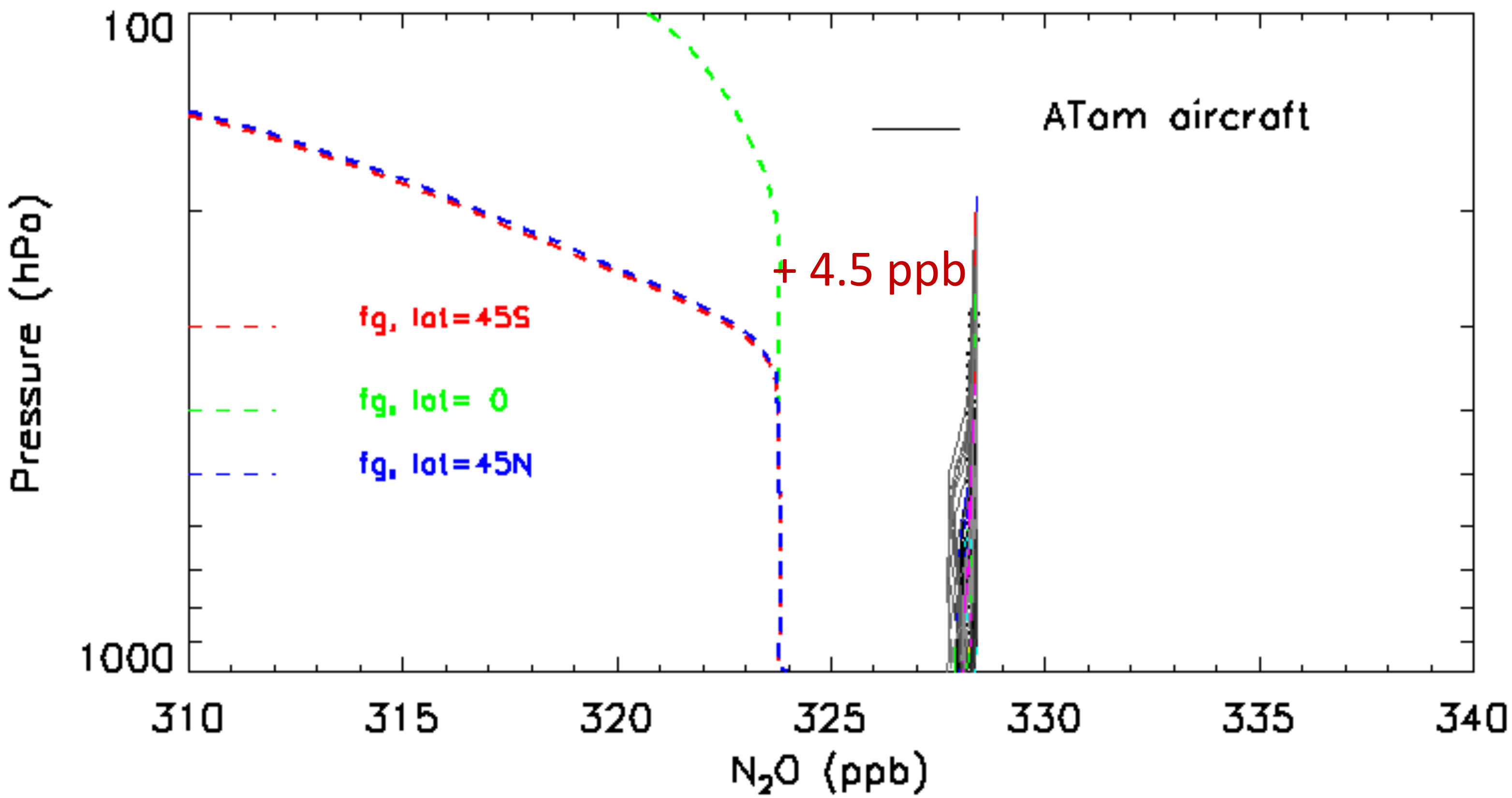


Comparison of CH_4 firstguess with ATom Aircraft Measurements

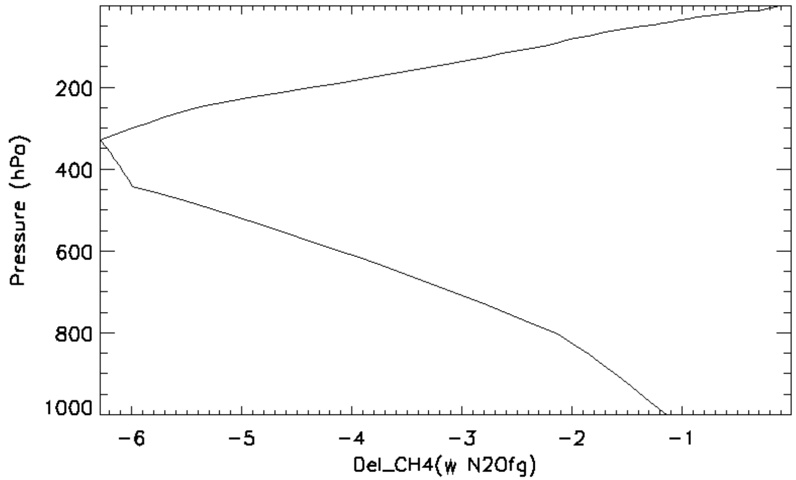


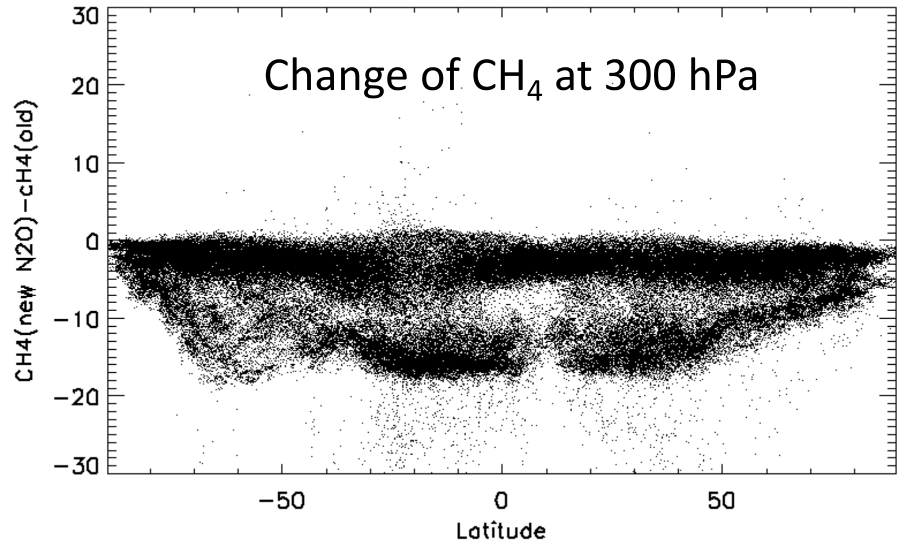
More improvement to the CH_4firguess in the southern hemisphere is needed.

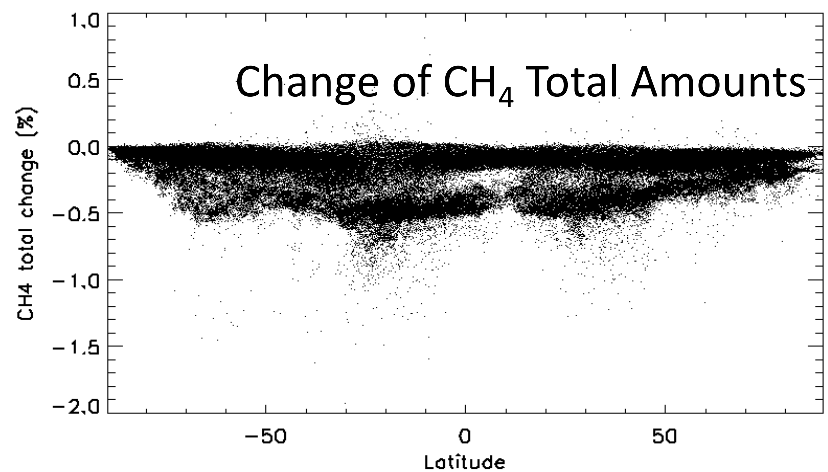
Comparison of N_2O firstguess with ATom Aircraft Measurements



Simple Estimate of the Impact of N_2O firstguess to CH_4 Retrievals



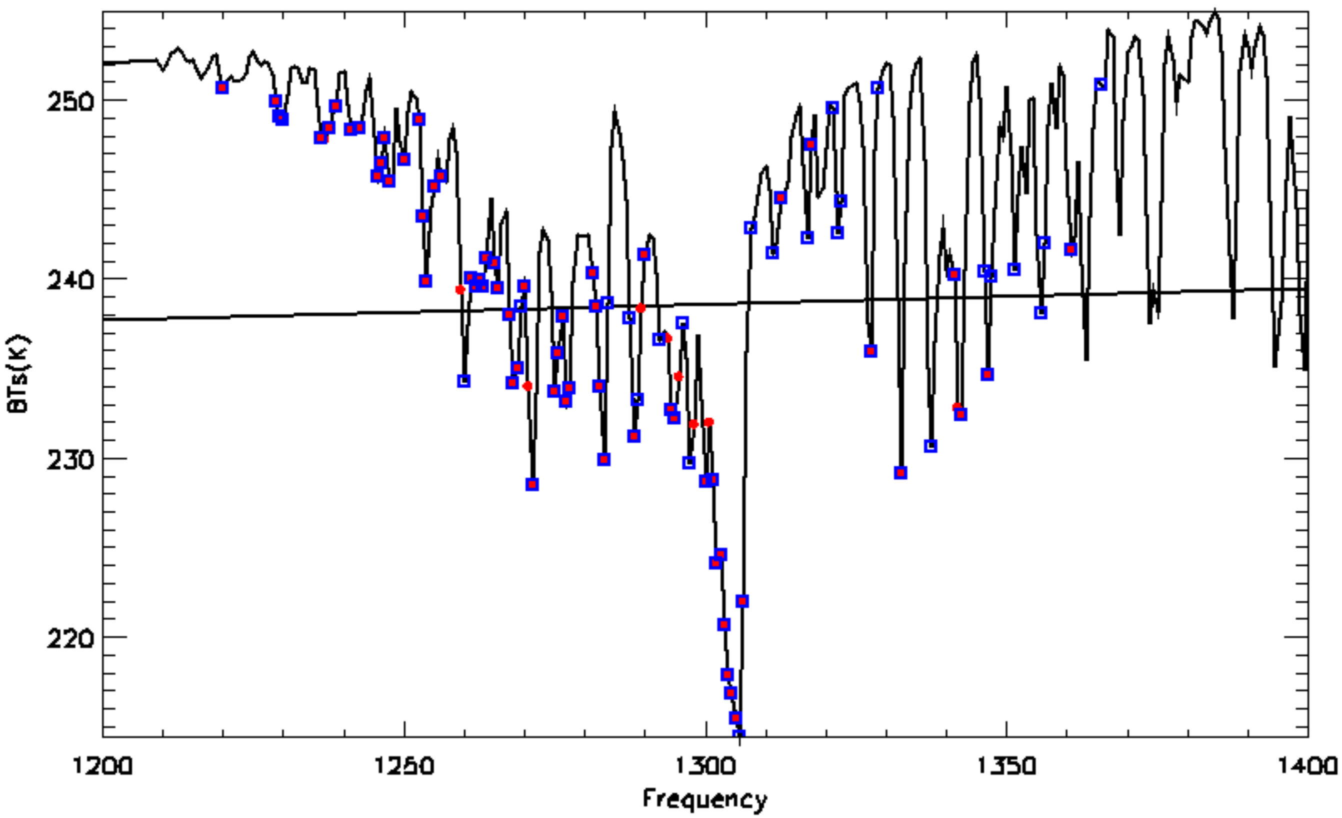




adding 4.5ppn in N_2Ofg and compared the difference of the retrieved CH_4;
Used one day data on 2/17/2015;

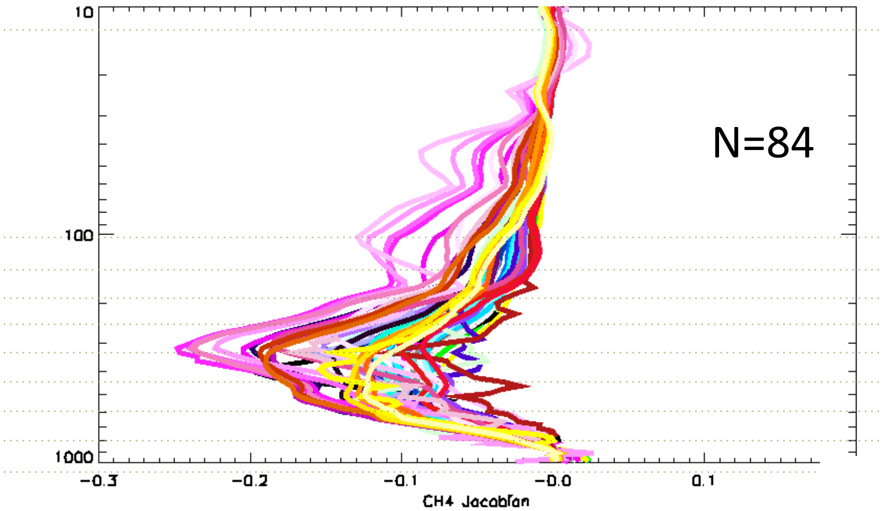
- **An update N_2O from AIRS-V6 is necessary for improving CH_4 retrieval**

Other Optimizations(1): Channel Selection

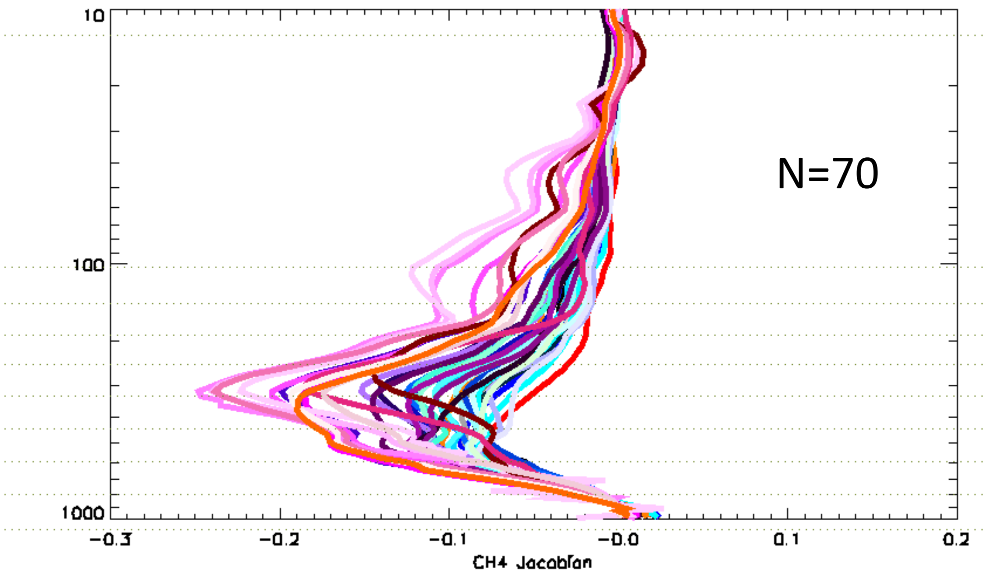


Due to the spectral resolution of CrIS (0.625cm^{-1}), our option is not many;
Not only consider the information content, I also checked the fitting error and removed some channels with strong N_2O and HNO_3 absorption;
70 channels (red) are selected (it was 84 in NUCAPS V2.0.5.4, Blue).

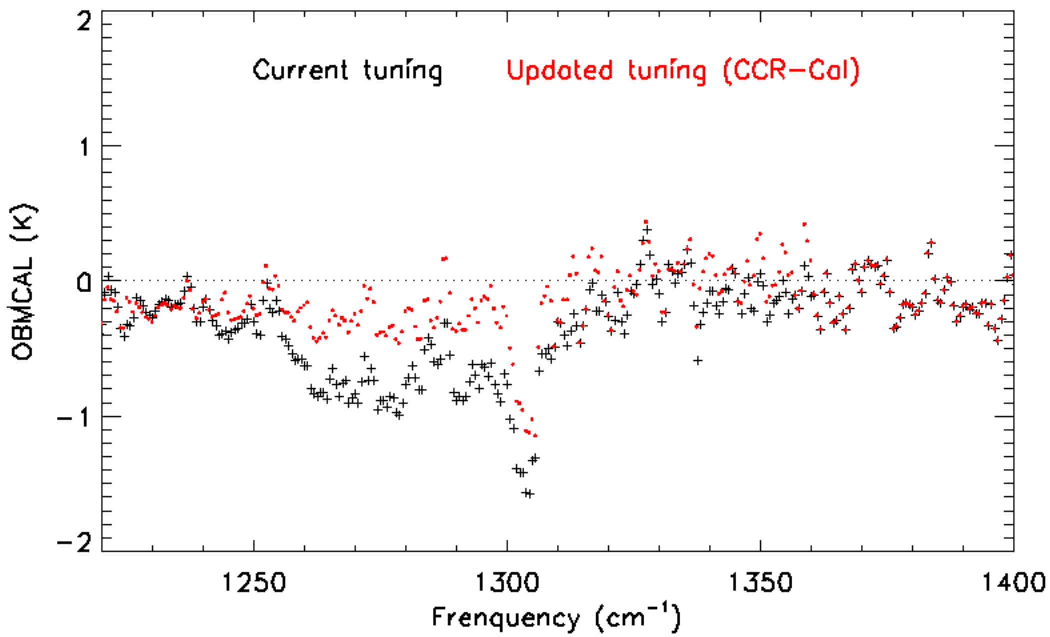
Comparison of Jacobian



Upper left is V2.0.5.4
Lower right is the recent one

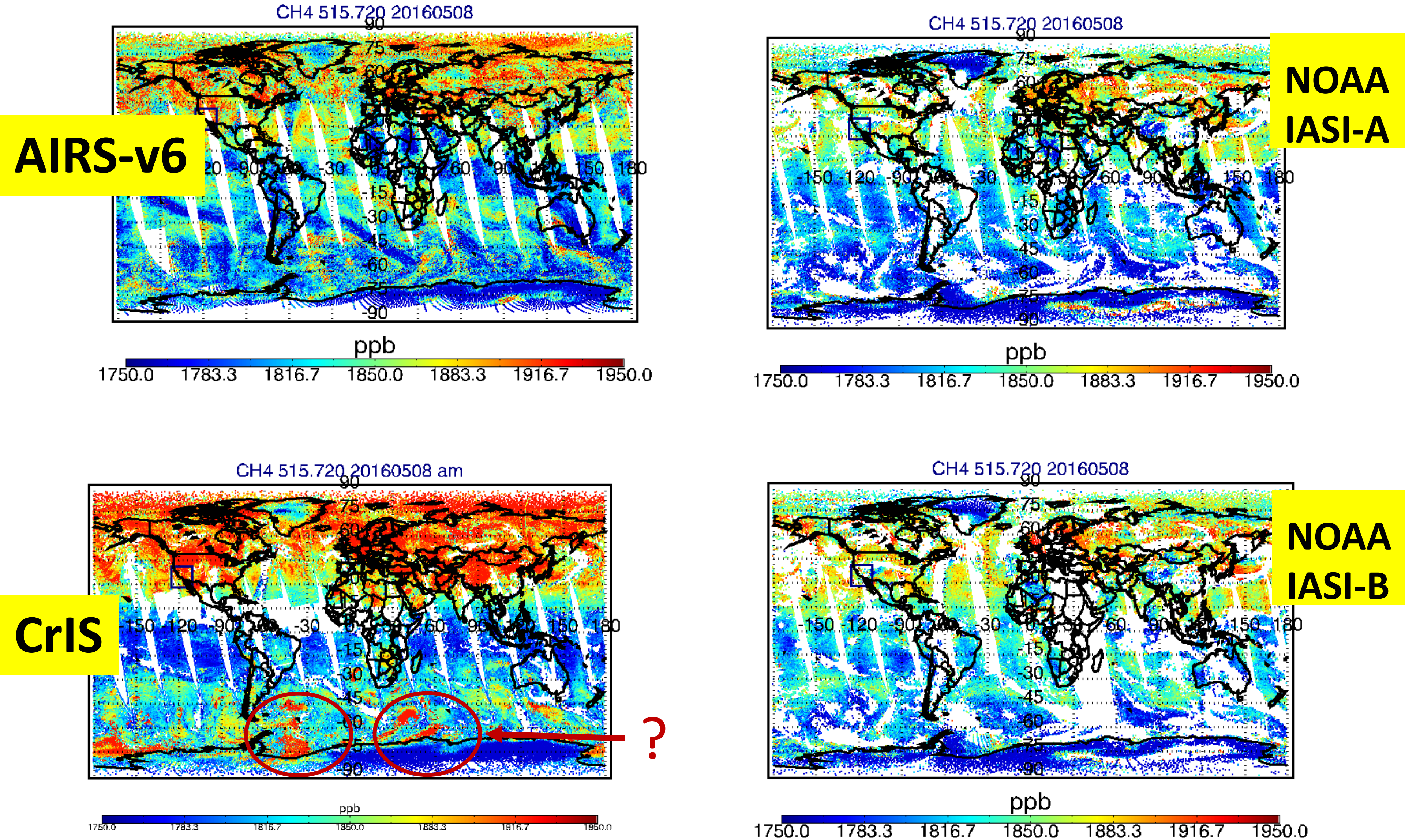


Other Optimizations(2): Re-tuning to CH_4 Bands

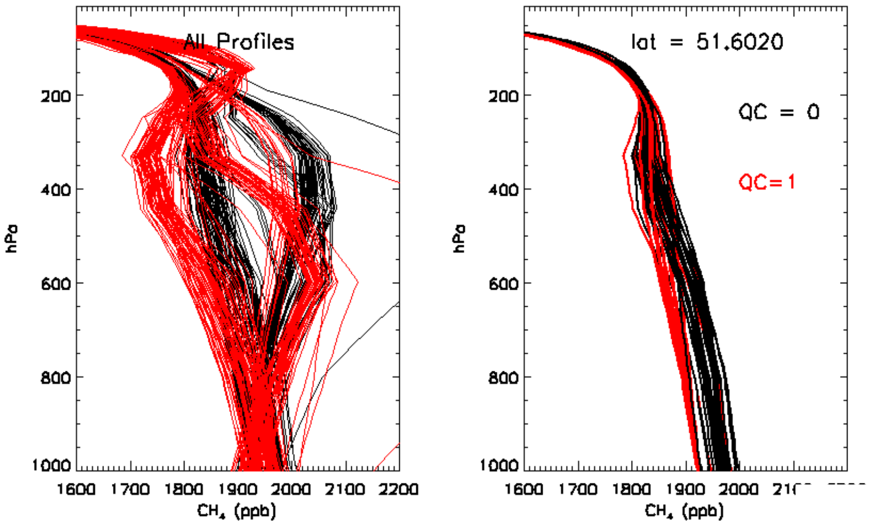


- The exist of uncertainty of CH_4 absorption (line-mixing) near 1306 cm^{-1} (Xiong et al., 2008, JGR; Xiong et al., 2015, AGU talk);
- Cloud-clearing is a good thing to increase the yield of retrievals, but it also contaminate trace gases products; Also CH_4 is very sensitive to upstream water vapor products. So a re-tuning using the upstream T, q retrievals products and cloud-clear radiance has been made.

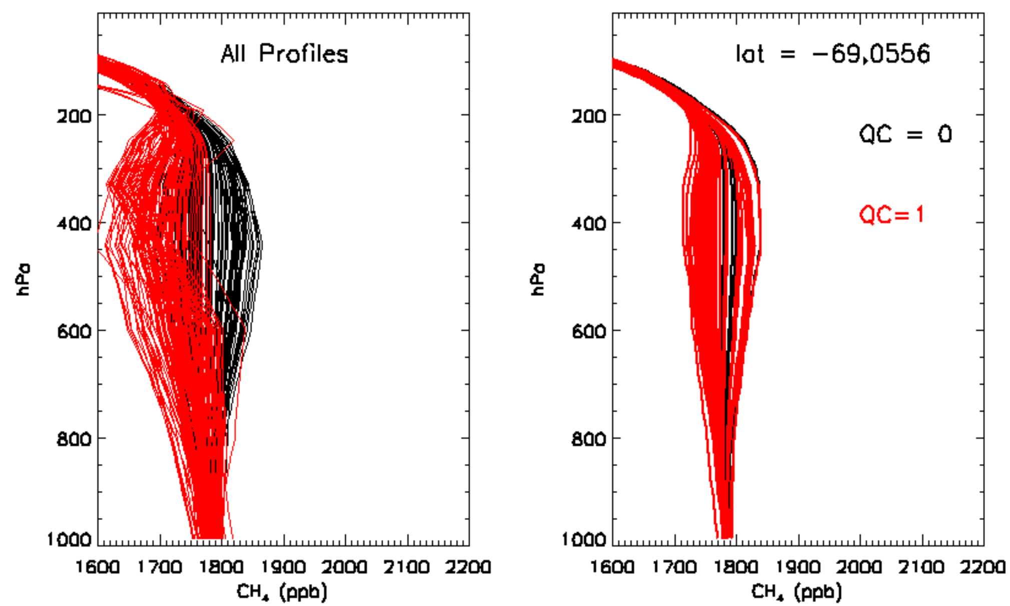
Comparison of CH_4 from AIRS, IASI and CrIS (20160508, @515hPa) – NO QC to CrIS CH_4 products



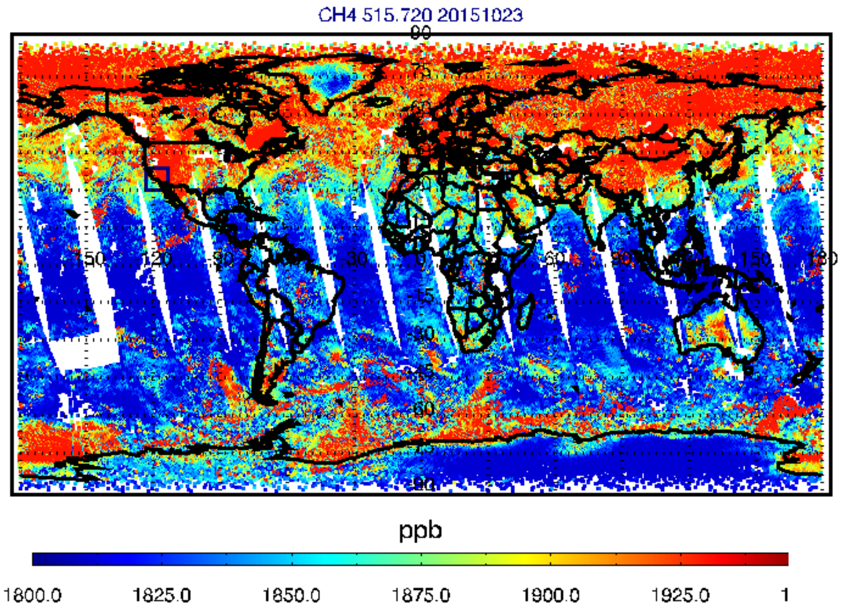
Other Optimizations(3): Quality Control (CH_4QC)



- For two granules
- Left panels: red lines are from version V2.0.5.4 (delivered in July) and black lines are from updated retrievals;
- Right panels: Profiles from updated retrieval and using CH_4QC (=0,1)

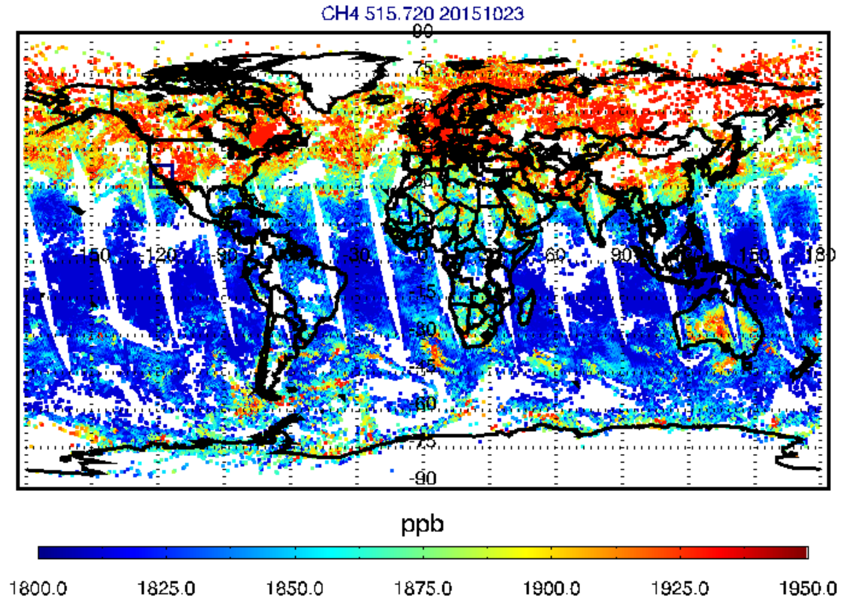


Example of CH_4 map after Preliminary CH_4QC



Preliminary CH_4QC is tailored to CH_4 products based on the DOF, surface temperature, chisq etc.

With CH_4QC



Yields after using CH_4QC

Descending	Yield (%)	Percentage relative to NO CH_4QC (%)
QC=0 (best)	37.4	45.0
QC=1 (good)	13.4	16.0
QC=2 (bad)	49.2	

50.8% (QC=0 and QC=1)

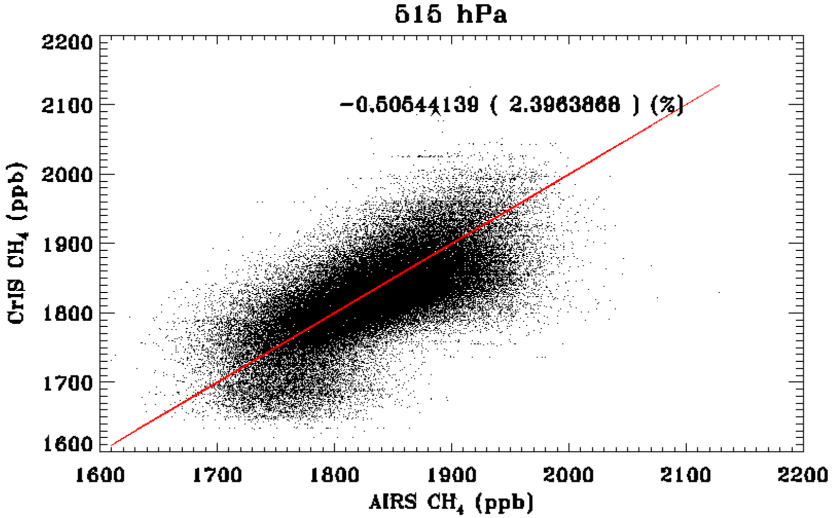
Ascending	Yield (%)	Percentage relative to NO CH_4QC (%)
QC=0	43.6	52.0
QC=1	11.1	13.2
QC=2	45.2	

54.7% (QC=0 and QC=1)

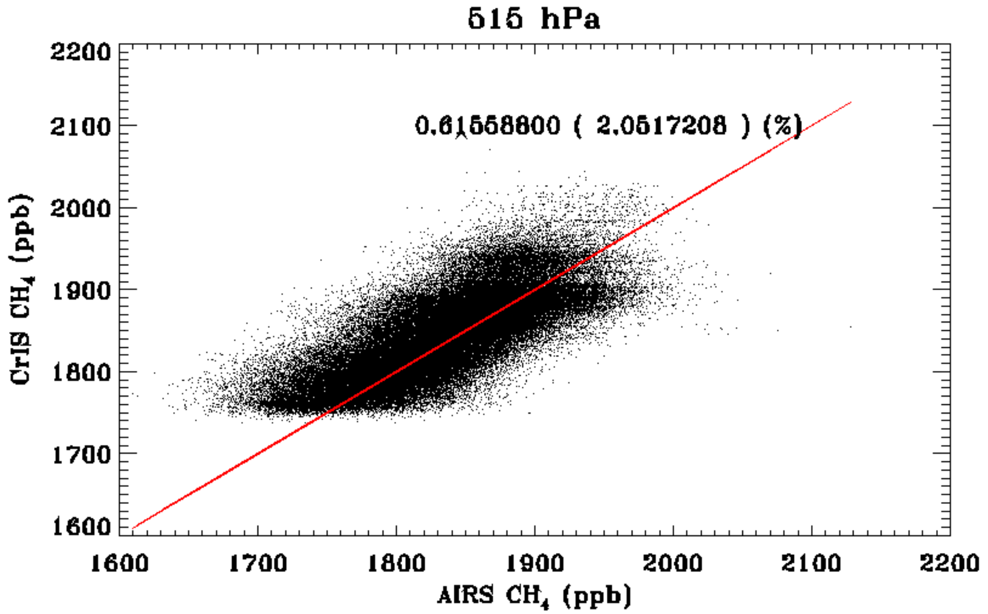
Assessment

- **Comparison with AIRS (515 hPa)**
- **Comparison with MODEL (4 different layers and total column amount)**
- **Comparison with TCCON (total column amount)**
- **Comparison with ATom (300-600 hPa)**

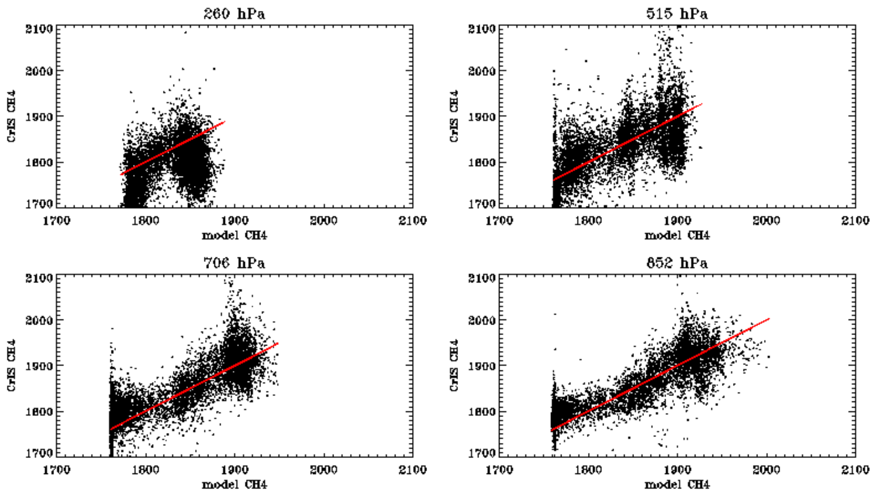
Comparison of CH_4 at 500 hPa with AIRS



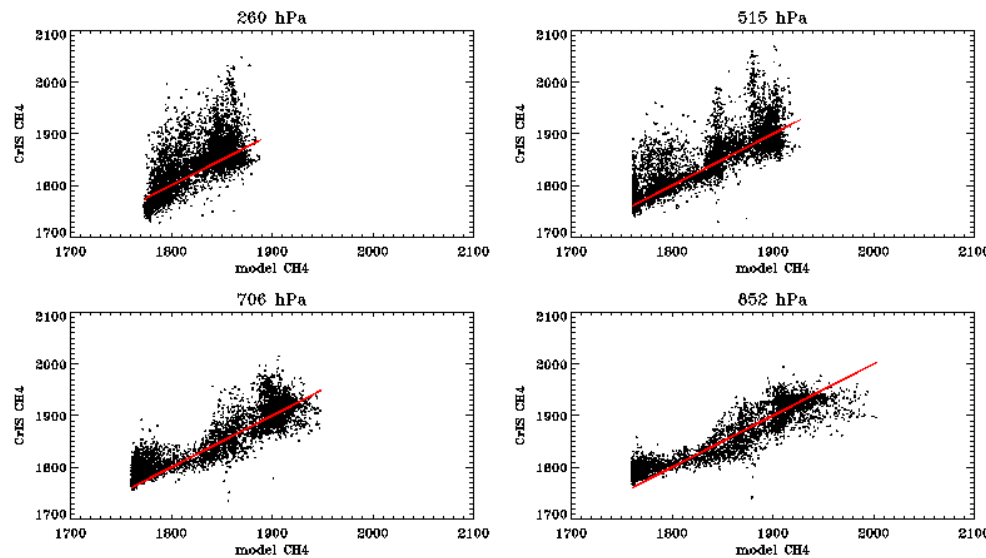
Upper left is V2.0.5.4
Lower right is the recent one



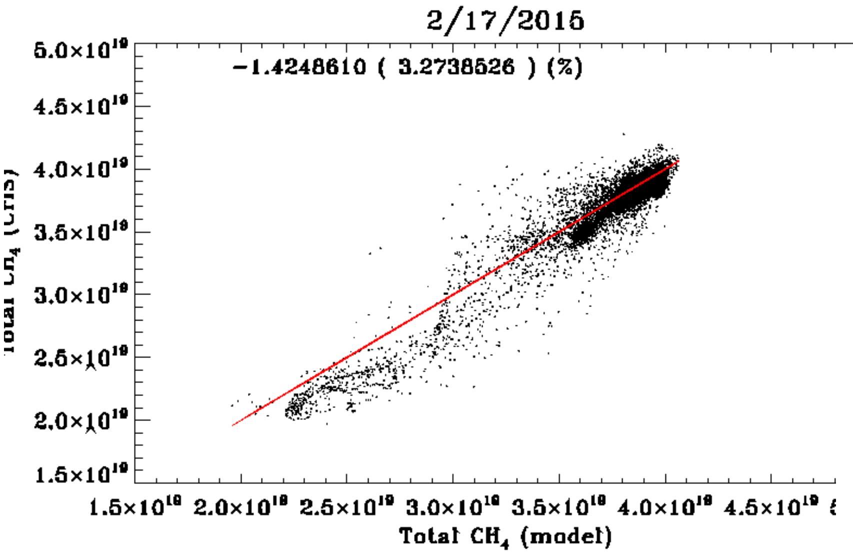
Comparison of CH_4 with Model at Four Layers (260, 515,706 and 852 hPa)



Upper left is V2.0.5.4
Lower right is the recent one



Comparison of CH_4 Total Amount with Model



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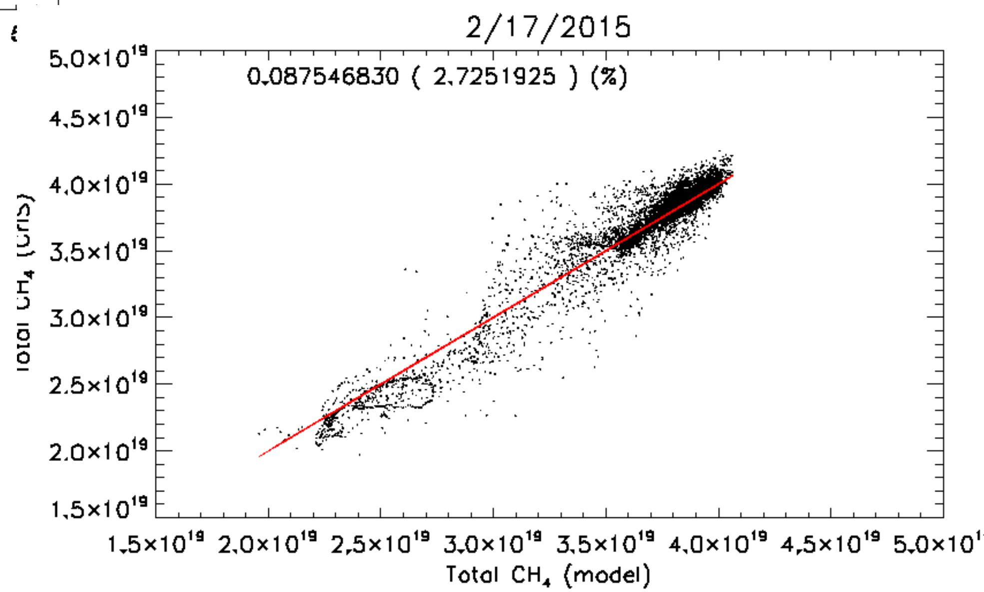
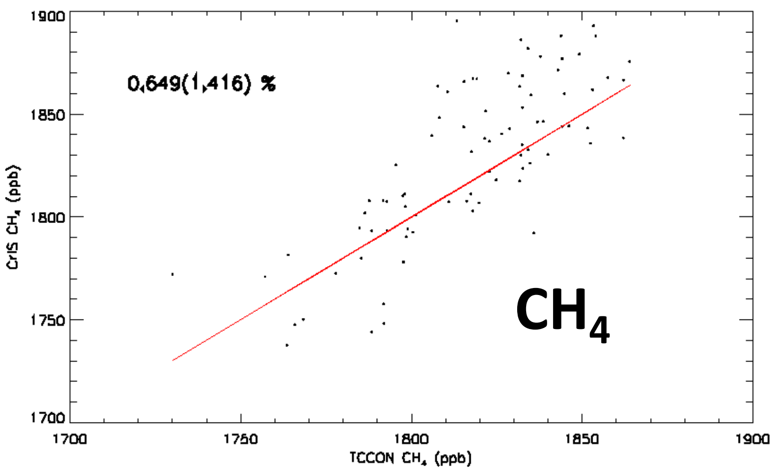
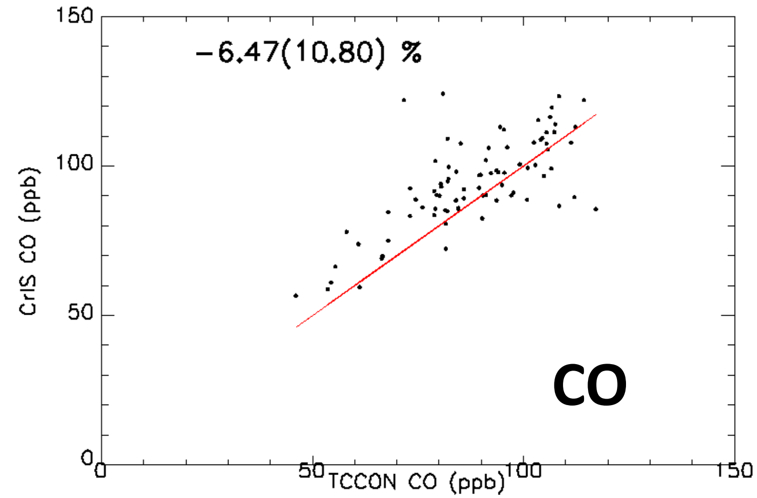
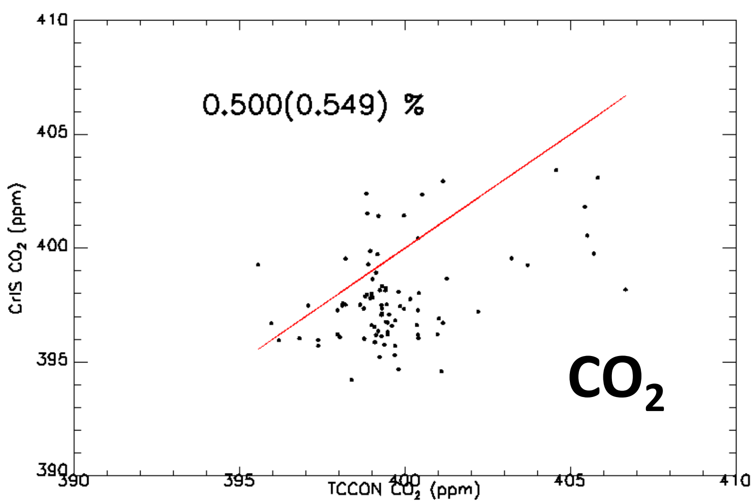


Comparison of CrIS $xCO/xCO_2/xCH_4$ with TCCON Measurements

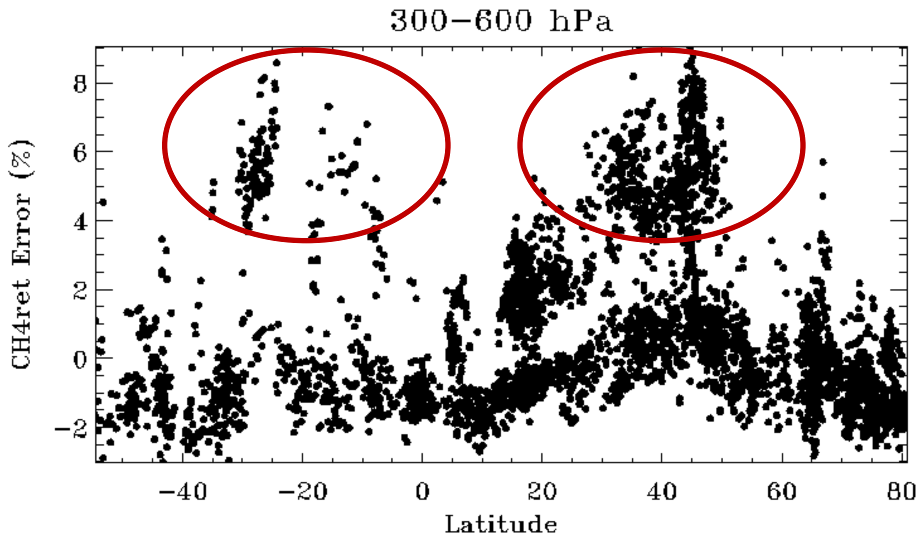






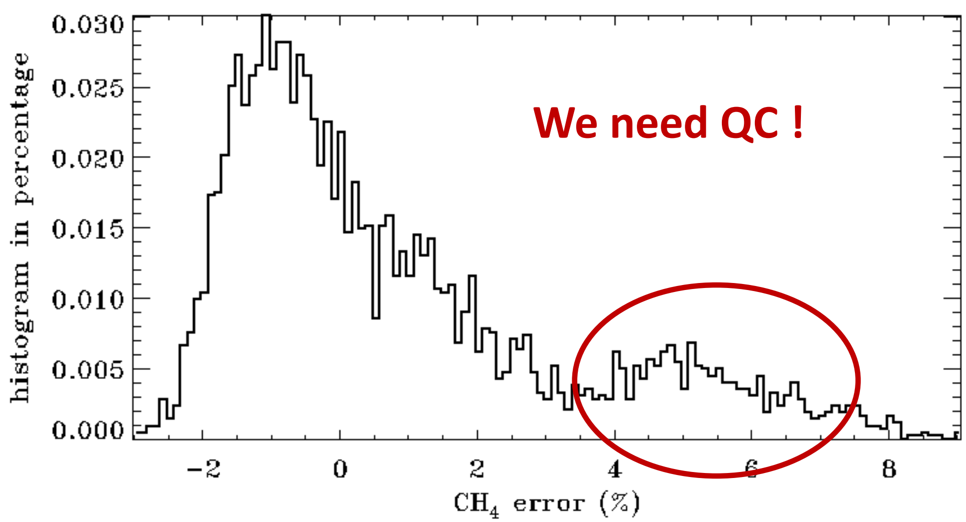
- Data of 10 days is used;
- This is a simple comparison by averaging TCCON data within 1 hours of satellite overpass and satellite data within 200 km over the ground site;
- Better agreement can be achieved if using averaging kernels

Comparison with ATom data (Preliminary)



Within 200 KM

No averaging Kernels
No QC tailored to trace gases



We need QC !

Summary and Future Works

1. The major sensitivity of CrIS is in the mid-upper troposphere. In order to meet the requirement in total amount, a good firstguess is really needed.

2. Rapid increase of CH_4 since 2007 and almost linear increase of N_2O request an update to CH_4 and N_2O firstguess in AIRS-V6;

3. Recent test of improvements (firstguess, channel selection, tuning) are promising, but more works need to be done …

4. Cloud-clearing is a major part in AIRS and NUCAPS retrieval systems, but we should be very careful to set QC for all trace gases.

A question is: should we add the increase trend in the firstguesss of CH_4 and N_2O in AIRS-V7 ?

I vote "YES" , as it impacts other products, i.e. q

Questions/Suggestions