



Recent Improvements on CH₄ Retrieval Using CrIS FSR Data -- suggestion for AIRS-V7

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Outline

- **Requirement for CH₄ Product in J-1**
 - **The major sensitivity in mid-upper troposphere requires a good CH₄ firstguess in the lower troposphere**
 - **Recent increase of CH₄ and N₂O also calls for an update of CH₄ and N₂O firstguess**

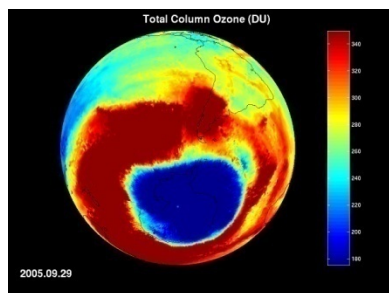
- **Recent Improvements– *Test Study Based on NUCAPS***
 - **Update of firstguess: comparison with model and ATom aircraft measurements**
 - **Other Improvements: Channel selection, re-tuning and **Quality control (CH₄QC)**;**

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

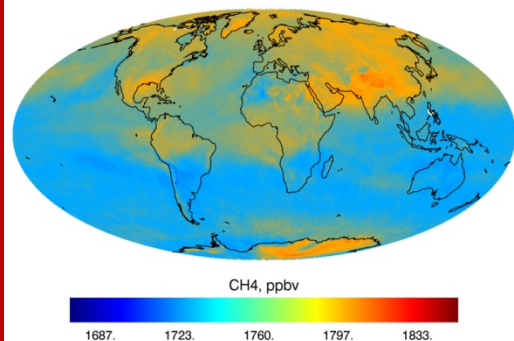
- **Summary and Future works**

Requirements of Trace Gases Products from CrIS

Ozone

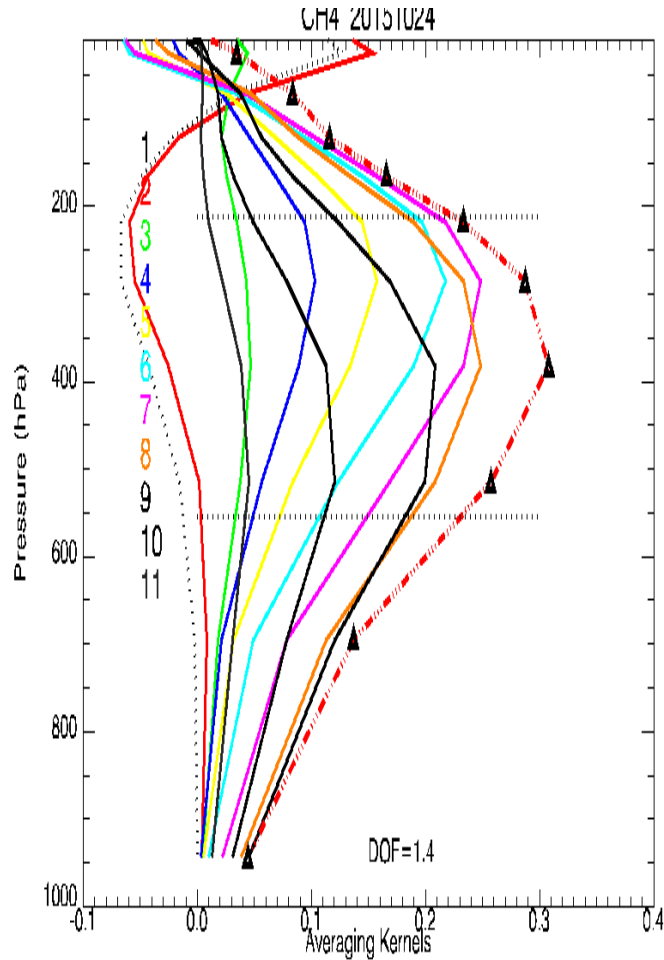


Methane

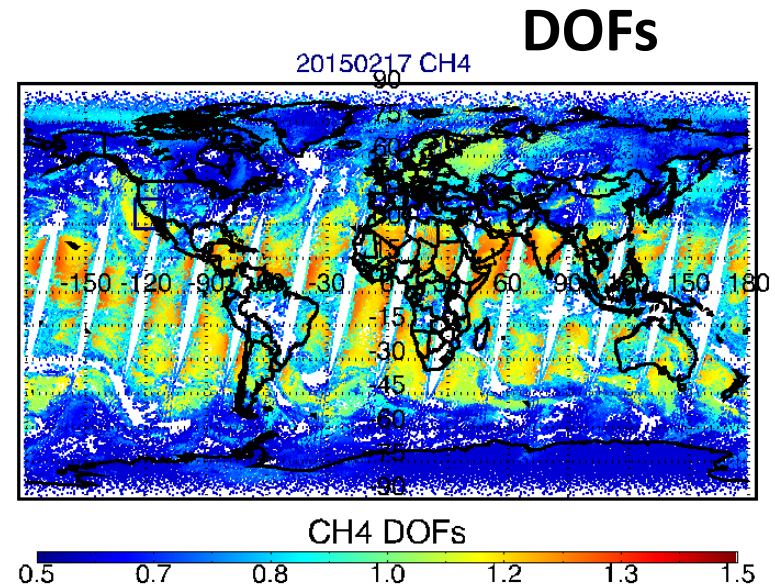


| EDR Attribute | CO | CO ₂ | CH ₄ |
|------------------------------|--------------|-----------------|-----------------------|
| Vertical Coverage | Total Column | Total Column | Total Column |
| Horizontal Resolution | 100 km | 100 km | 100 km |
| Mapping Uncertainty, 3 sigma | 25 km | 25 km | 25 km |
| 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 CH₄



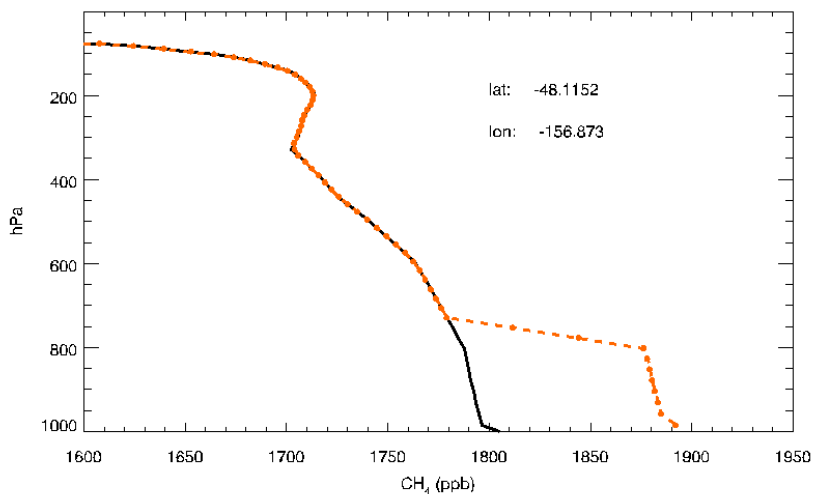
Example of Averaging Kernels



- 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 CH₄ Total Amount Error

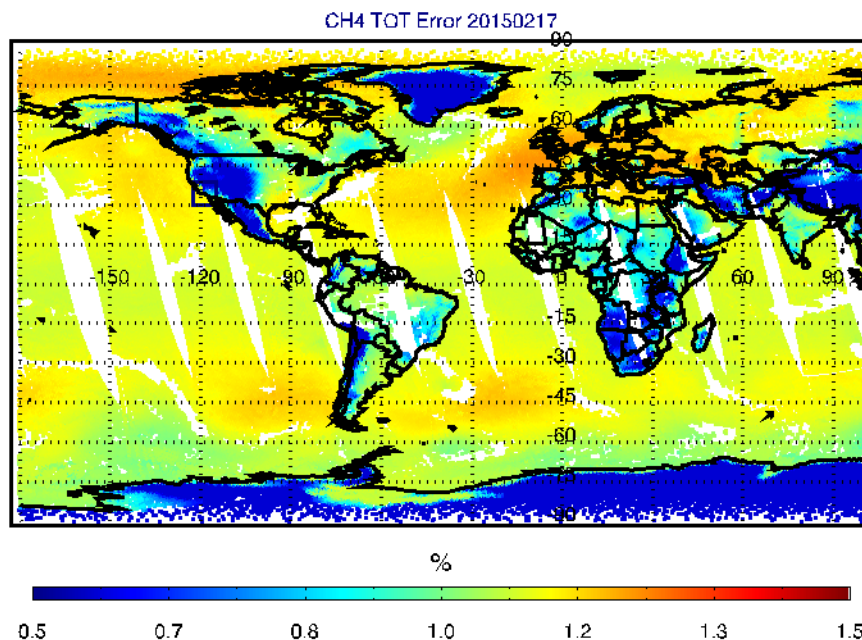
assuming 5% error of CH₄ profile in lower troposphere (below 800 hPa)



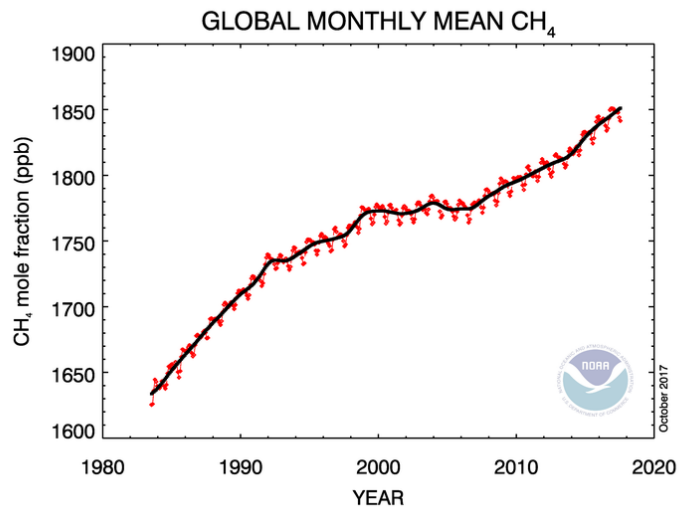
Assuming 5% error of CH₄ profile in lower troposphere(below 800 hPa), the error in total amount is about 1.2%.

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

2/17/2015

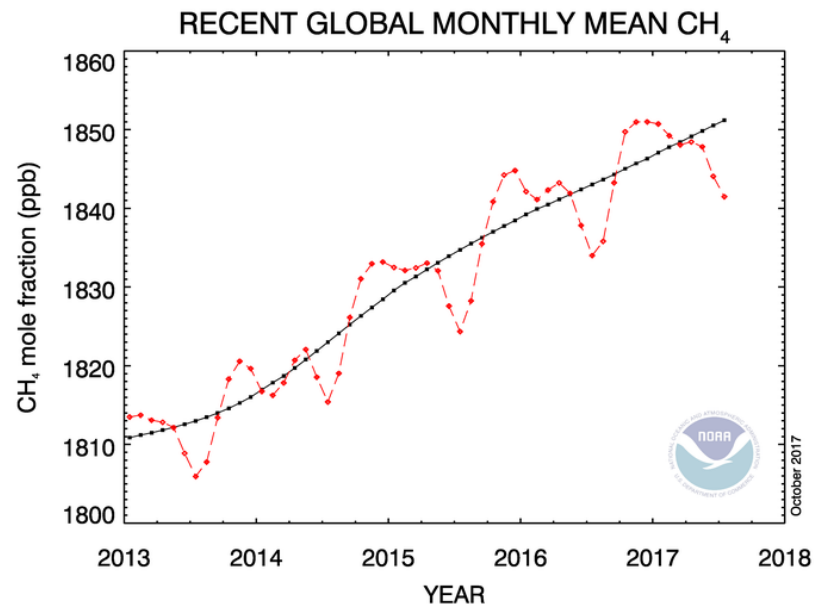


Significant Increase of CH₄ in the past 10 years



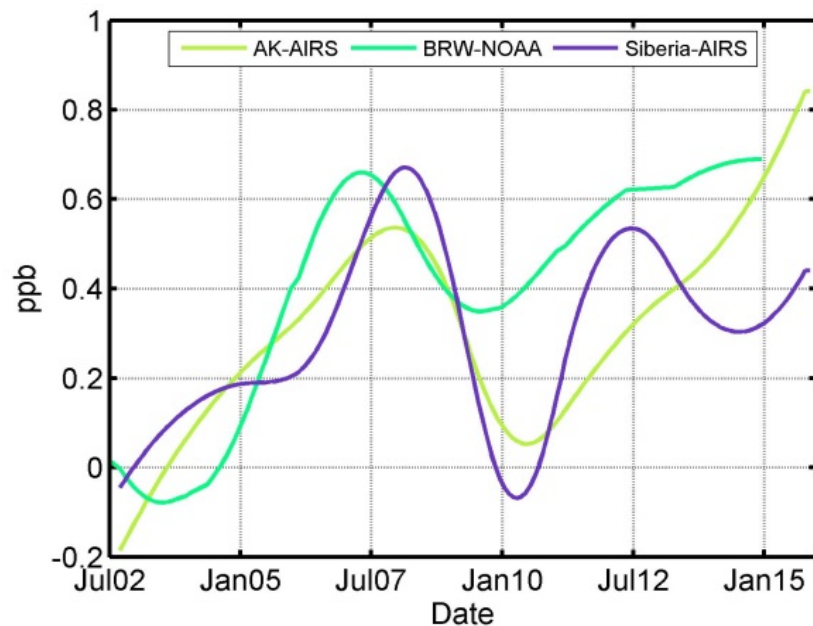
We built a fixed firstguess in AIRS-V6 in about 10 years ago → it helps us to check the possibility to monitor the trend

Downloaded from
https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/

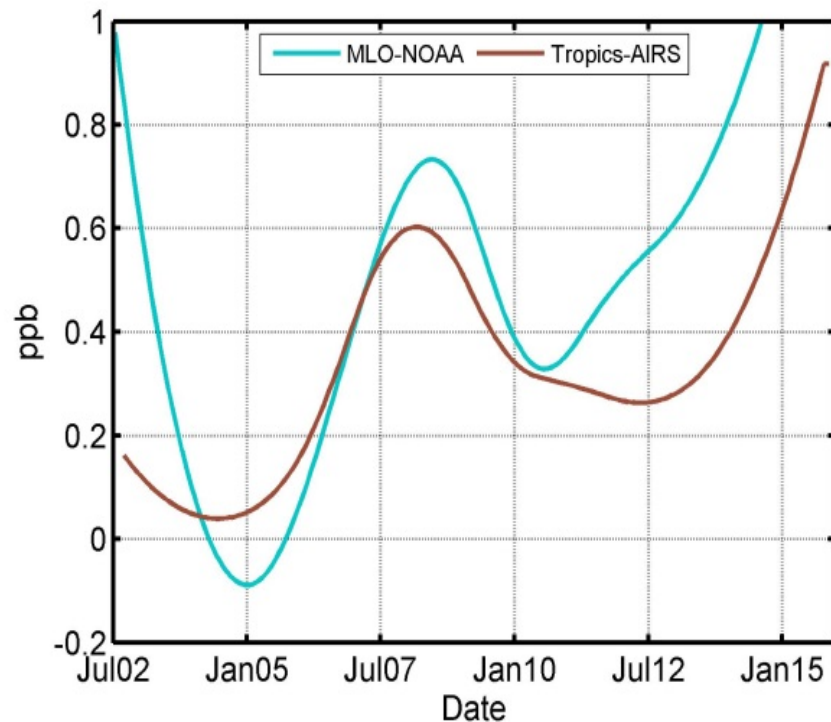


Annual Increase Rate of CH₄ from AIRS-V6 and its Comparison with NOAA Ground-based Measurements

ppb/yr

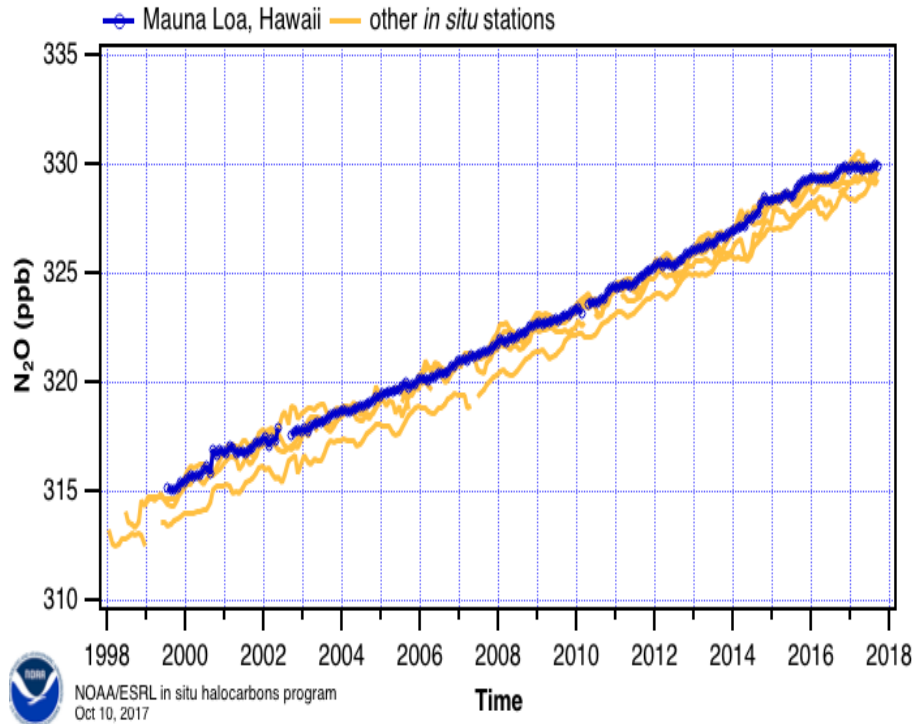


ppb/yr



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

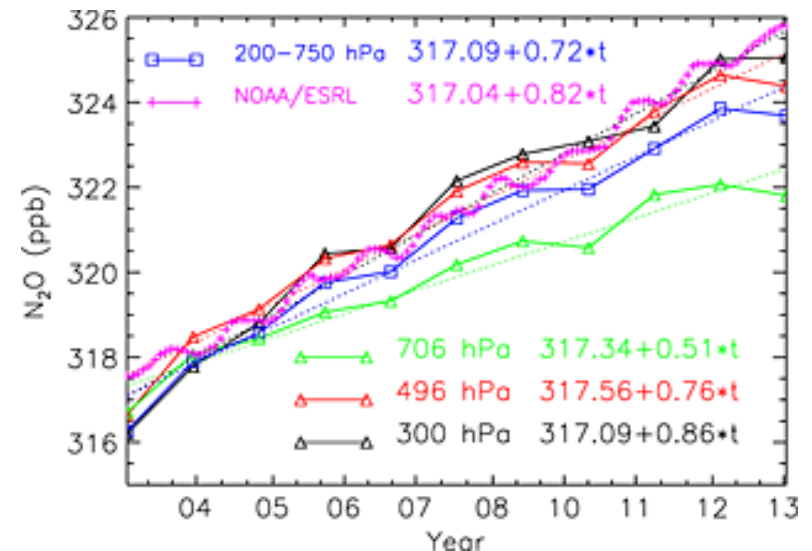
Nearly Linear Increase of N₂O



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 N₂O 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](https://doi.org/10.1002/2013JD021406).



Questions

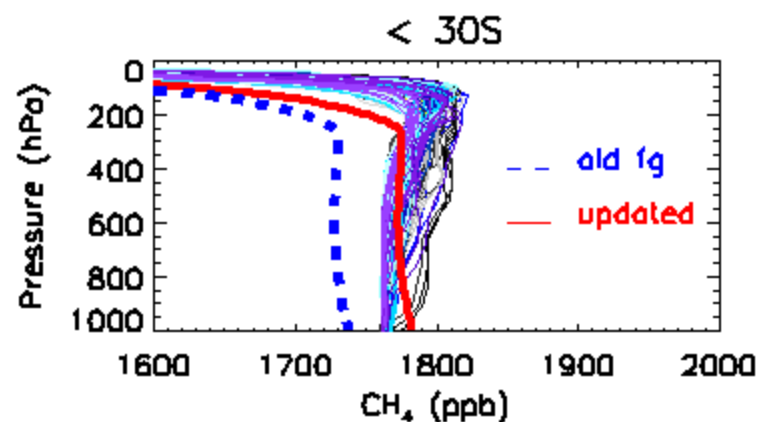
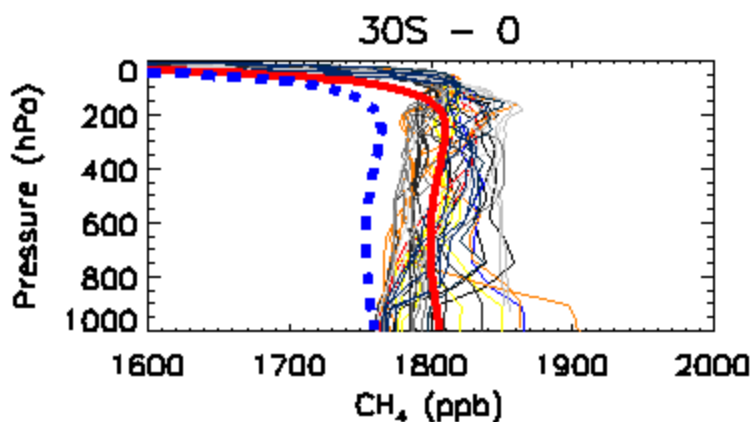
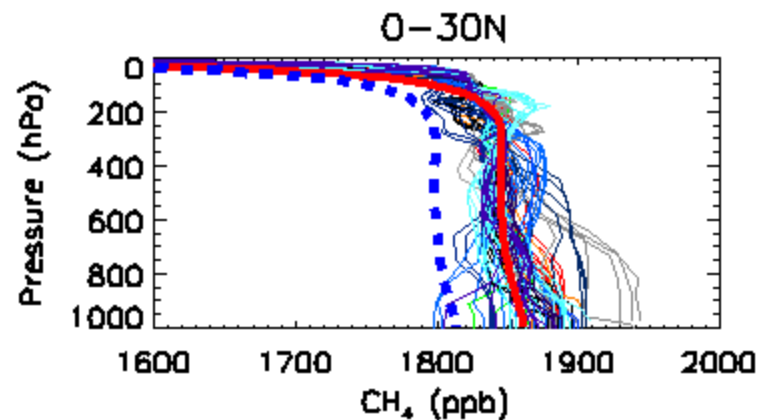
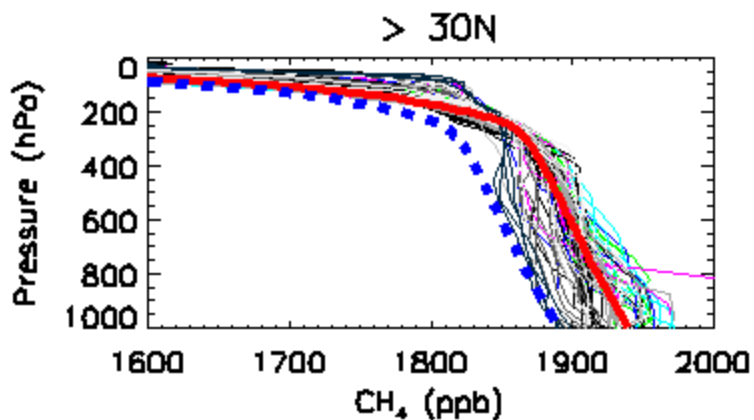
Even though we have some capability to monitor the CH₄ trend using AIRS data (with a fixed first-guess), should we include the trend in the AIRS-V7 to reprocess the data, so that we can have a better product, esp. the total amount ?

Similarly for N₂O

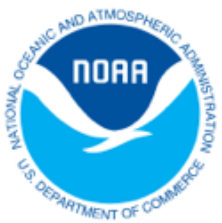
Even we do not want to add the trend for future retrieval, at least for CrIS we need to update CH₄ and N₂O firstguess to be consistent with current observation

Update of CH₄ 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)

ESPO ESPO Archive Flight Request Mission Tools

Log in to ATom Create New Account Search

ATom Home

Mission Planning

Logistics

Science

Participants

Data Archive

Platforms

Instruments

Earth Expeditions | NASA

Image Gallery

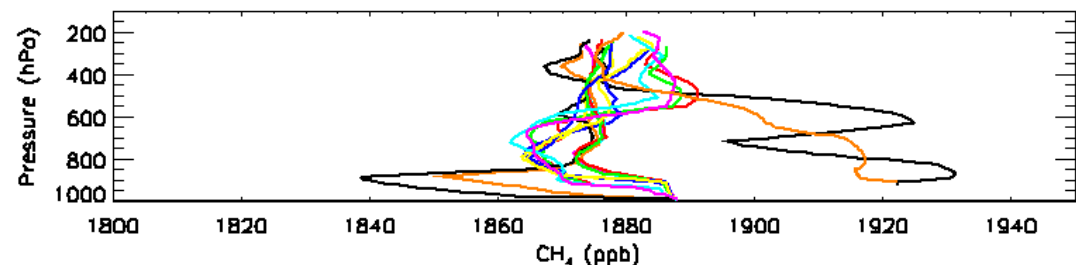
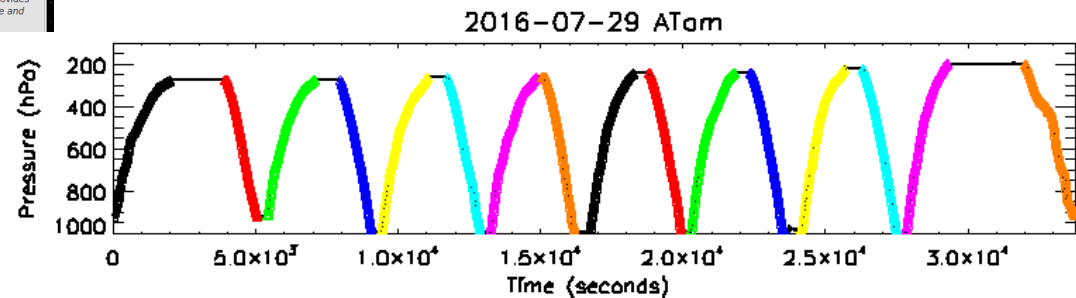
ATom

The Atmospheric Tomography Mission (ATom) will study the impact of human-produced air pollution on greenhouse gases and on chemically reactive gases in the atmosphere. Reductions of atmospheric concentrations of methane (CH_4), tropospheric ozone (O_3) and black carbon (BC) aerosols are effective measures to slow global warming and to improve air quality. Airborne instruments will look at how atmospheric chemistry is transformed by various air pollutants and at the impact on CH_4 and O_3 . Mitigation of these short-lived climate forcers is a major component of current international policy discussions.

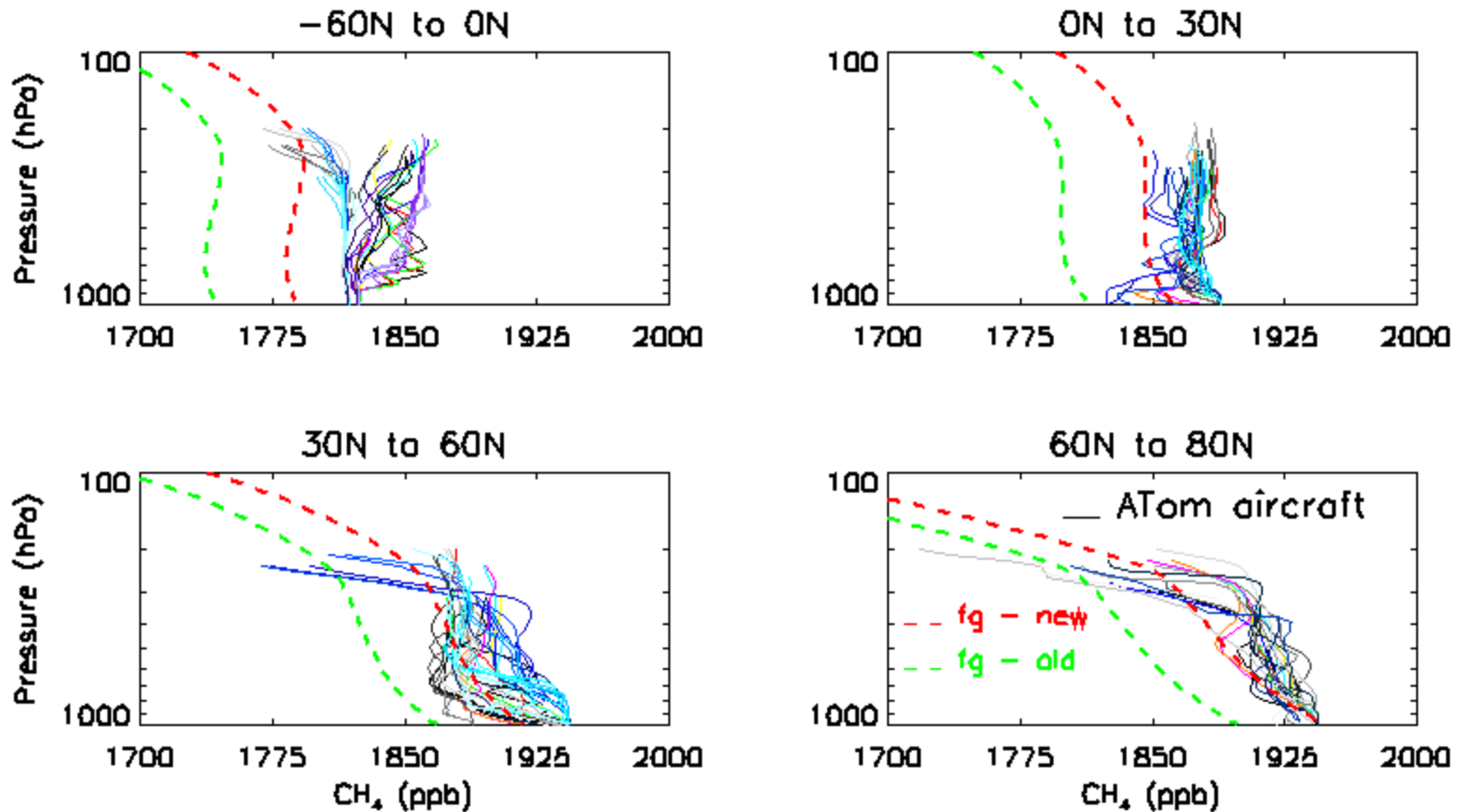
ATom deploys an extensive gas and aerosol payload on the NASA DC-8 aircraft for systematic, global-scale sampling of the atmosphere, profiling continuously from 0.2 to 12 km altitude. Flights will occur in each of 4 seasons over a 4-year period. They will originate from the Armstrong Flight Research Center in Palmdale, California, fly north to the western Arctic, south to the South Pacific, east to the Atlantic, north to Greenland, and return to California across central North America. ATom establishes a single, contiguous global-scale data set. This comprehensive data set will be used to improve the representation of chemically reactive gases and short-lived climate forcers in global models of atmospheric chemistry and climate. Profiles of the reactive gases will also provide critical information for validation of satellite data, particularly in remote areas where in situ data is lacking.

ATom's tomographic, large-scale sampling combined with parcel-by-parcel quantification of photochemical tendencies provides a strong response to the 2011 NASA Strategic Plan to Advance Earth System Science: *meeting the challenges of climate and environmental change on a global scale.*

Examples of selection of flight lags

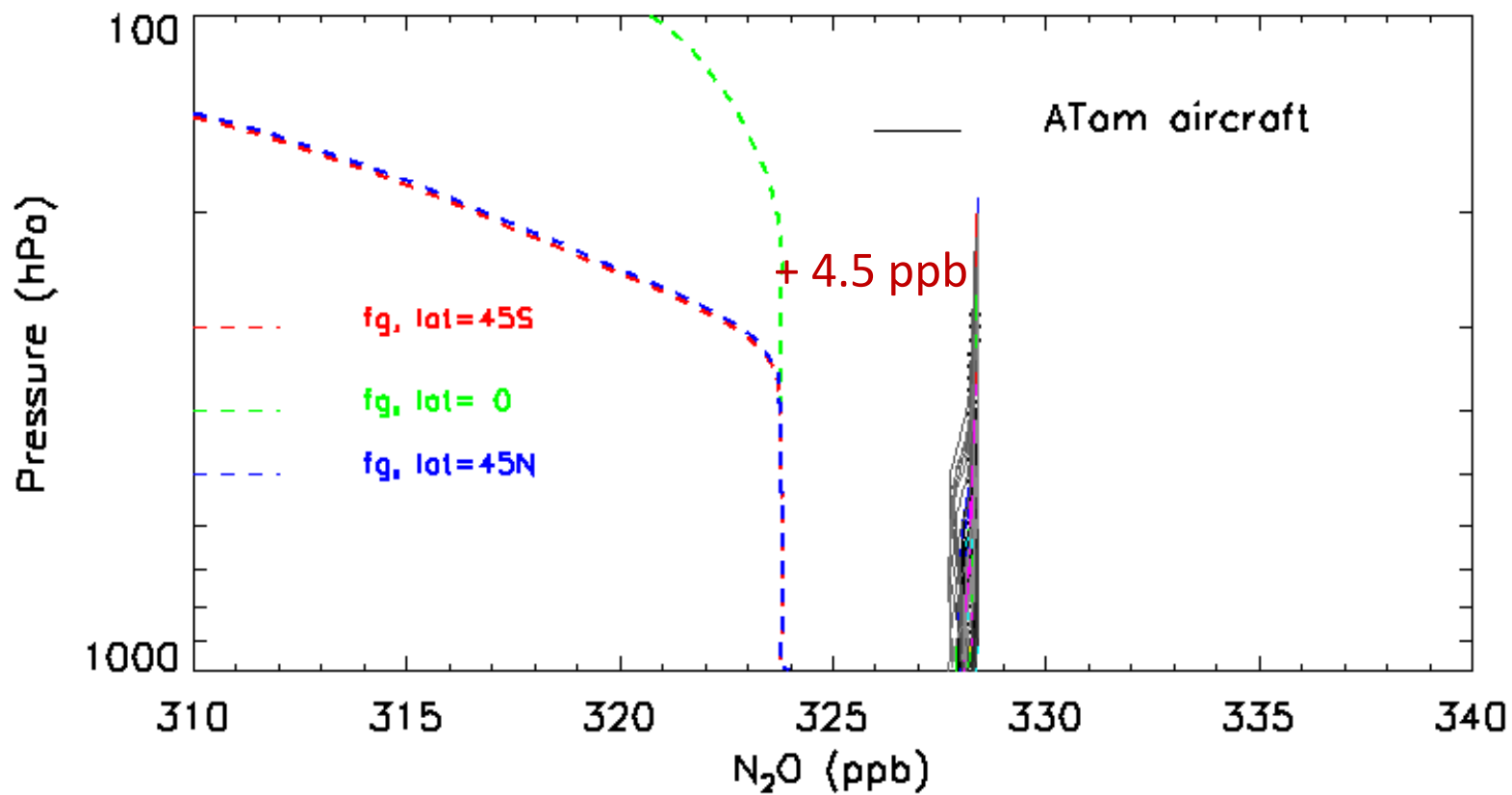


Comparison of CH₄ firstguess with ATom Aircraft Measurements

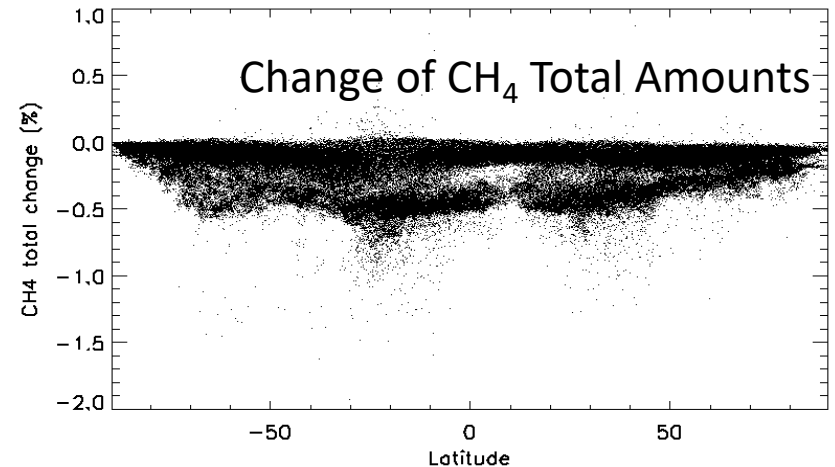
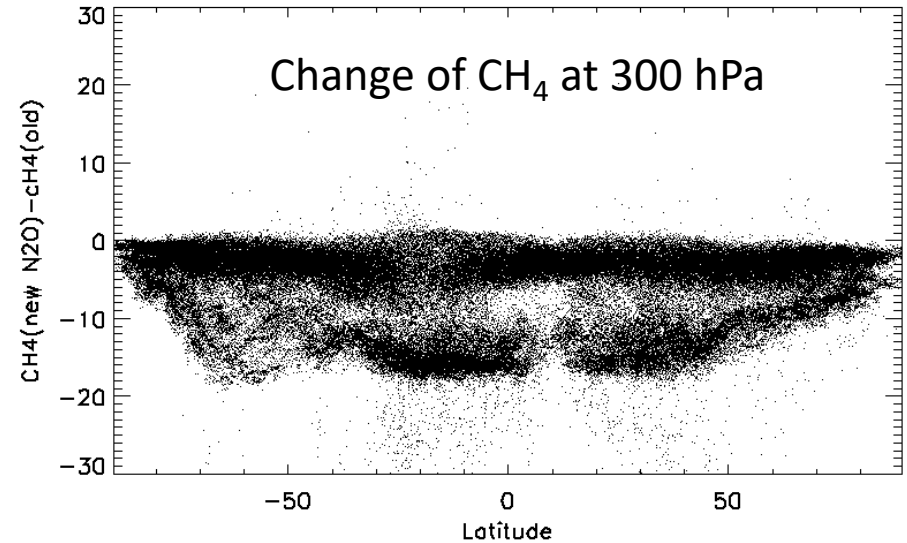
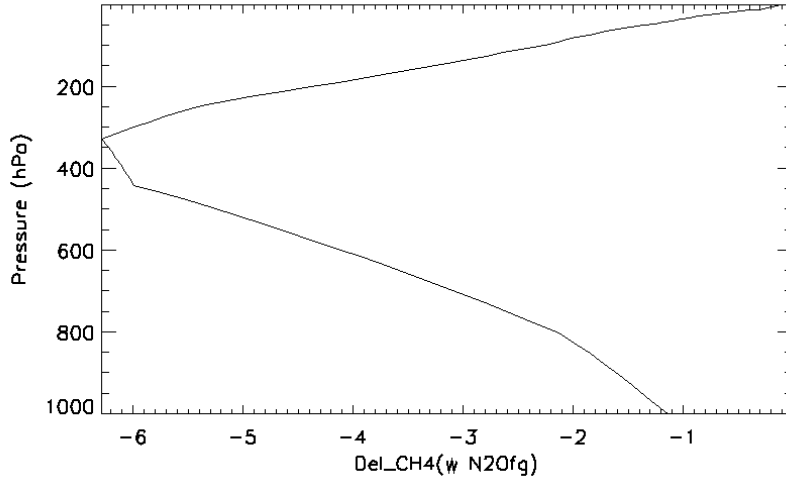


More improvement to the CH₄ firstguess in the southern hemisphere is needed.

Comparison of N₂O firstguess with ATom Aircraft Measurements



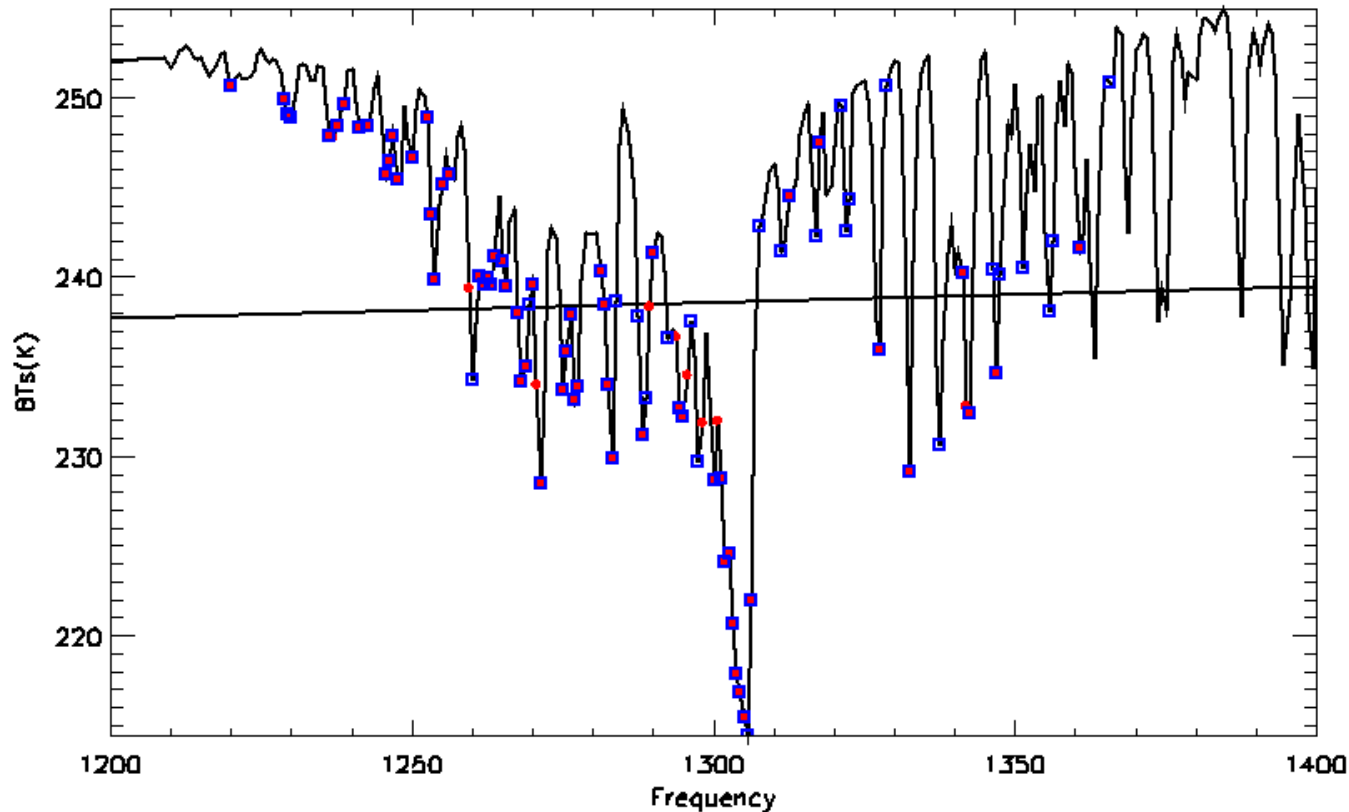
Simple Estimate of the Impact of N₂O firstguess to CH₄ Retrievals



adding 4.5ppm in N₂Ofg and compared the difference of the retrieved CH₄;
Used one day data on 2/17/2015;

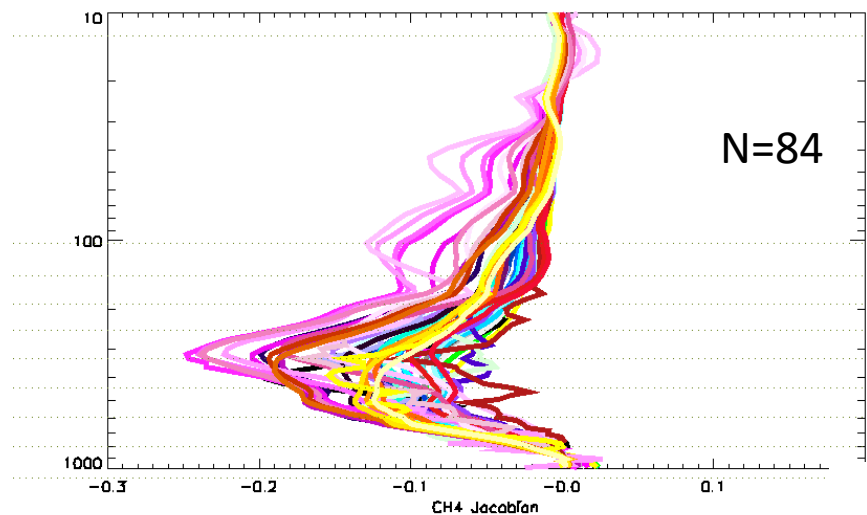
➤ An update N₂O from AIRS-V6 is necessary for improving CH₄ retrieval

Other Optimizations(1): Channel Selection

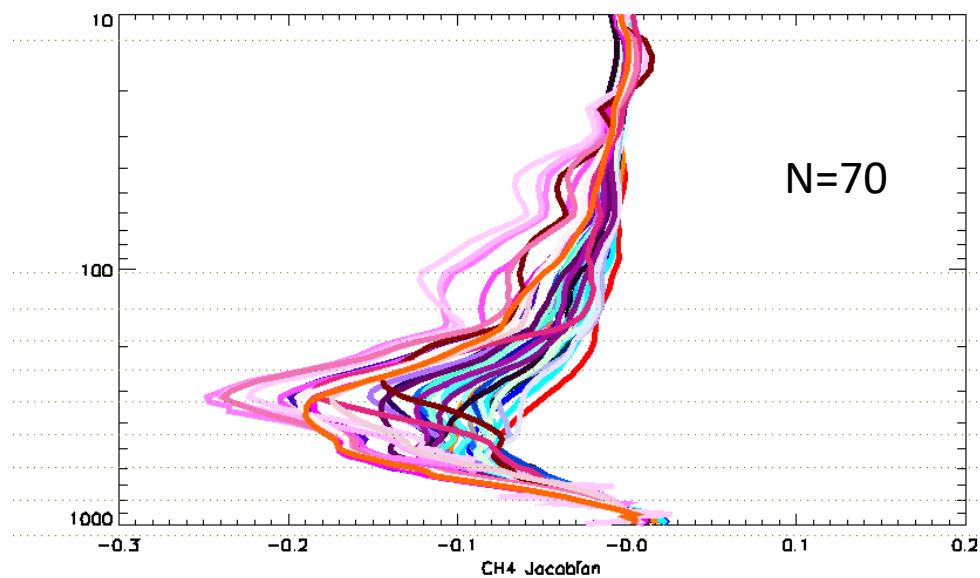


Due to the spectral resolution of CrIS (0.625cm^{-1}), our option is not many;
Not only consider the information content, I also checked the fitting error and
removed some channels with strong N_2O and HNO_3 absorption;
70 channels (red) are selected (it was 84 in NUCAPS V2.0.5.4, Blue).

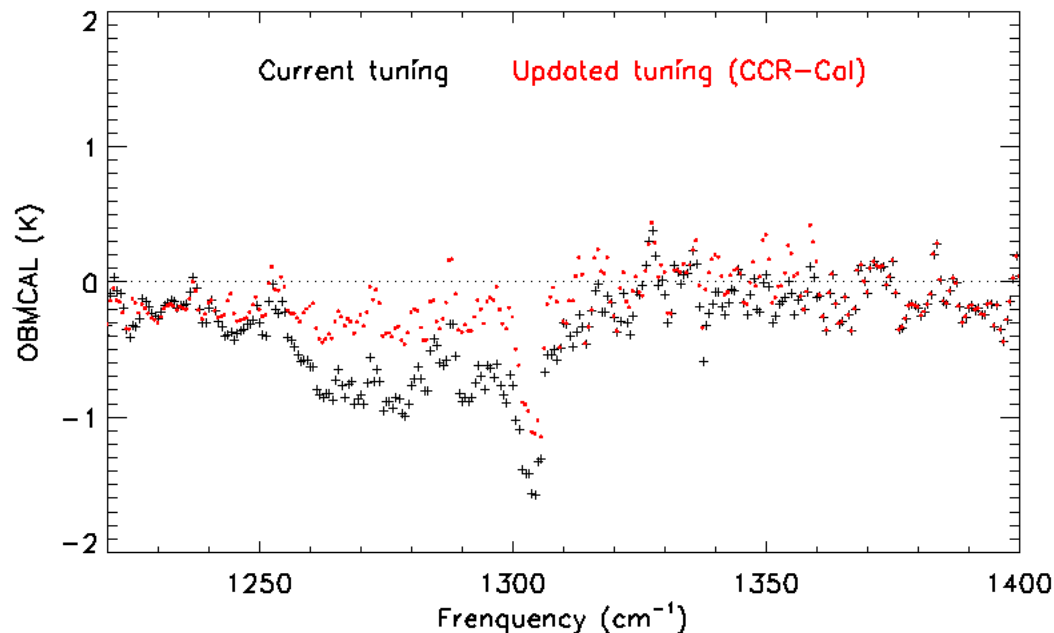
Comparison of Jacobian



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



Other Optimizations(2): Re-tuning to CH₄ Bands

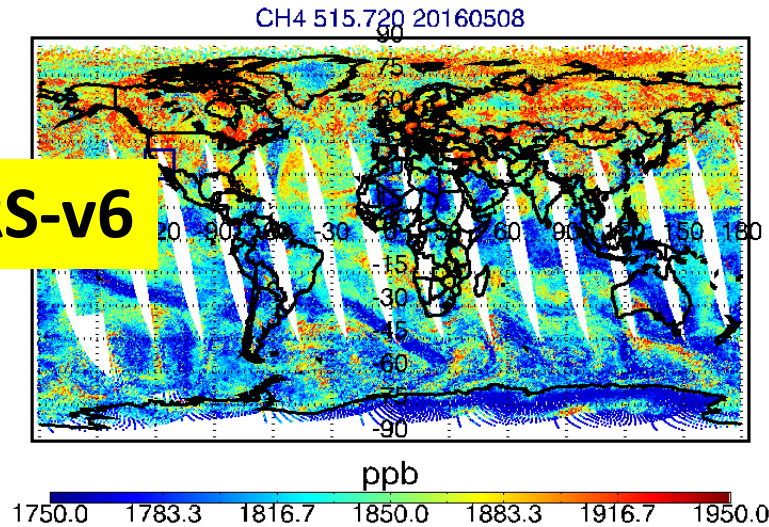


- The exist of uncertainty of CH₄ absorption (line-mixing) near 1306 cm⁻¹ (Xiong et al., 2008, JGR; Xiong et al., 2015, AGU talk);
- Cloud-clearing is a good thing to increase the yield of retrievals, but it also contaminate trace gases products; Also CH₄ is very sensitive to upstream water vapor products. So a re-tuning using the upstream T, q retrievals products and cloud-clear radiance has been made.

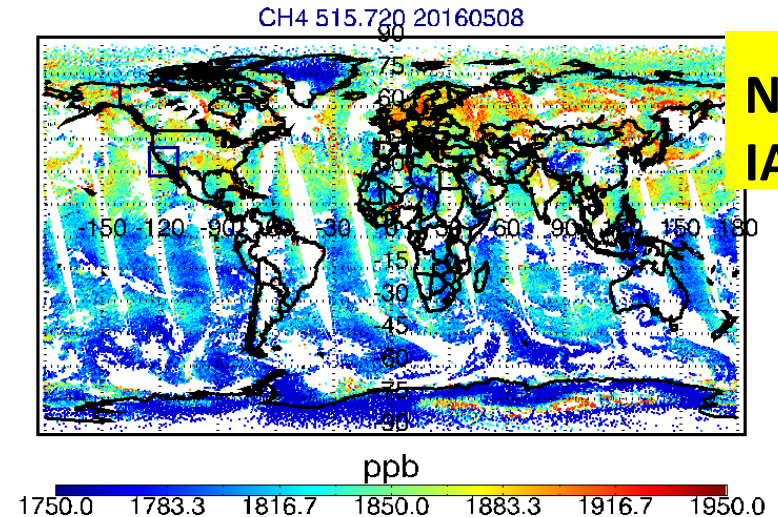
Comparison of CH₄ from AIRS, IASI and CrIS

(20160508, @515hPa) – **NO QC to CrIS CH₄ products**

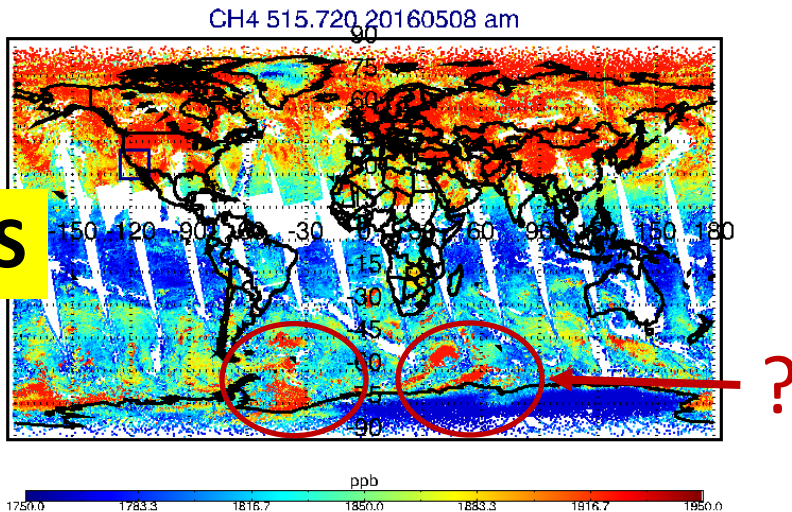
AIRS-v6



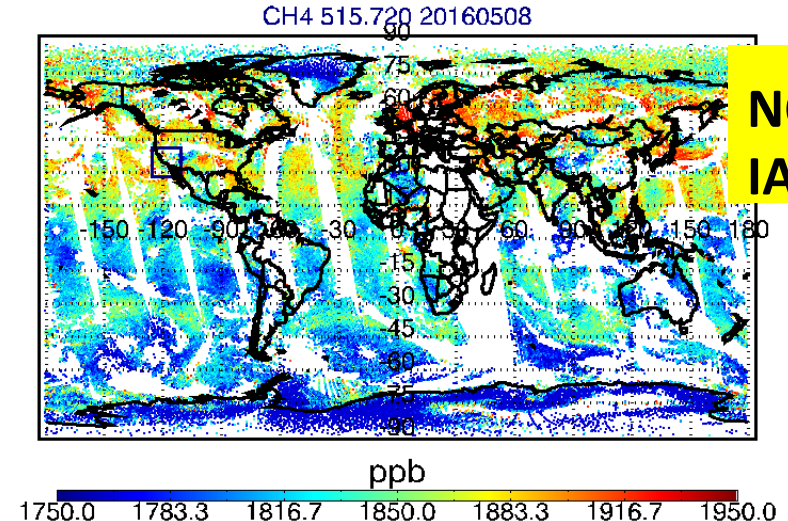
**NOAA
IASI-A**



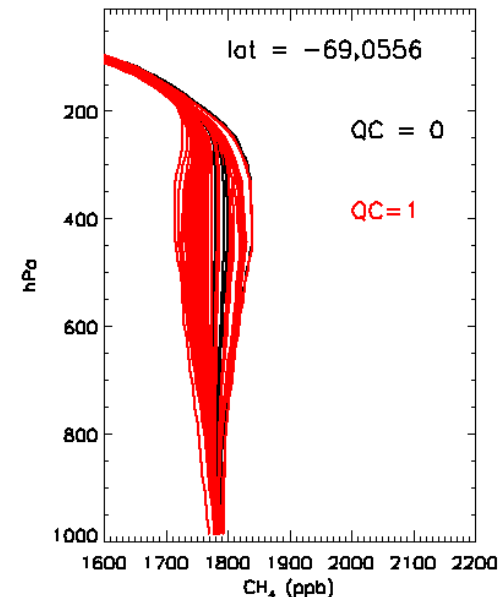
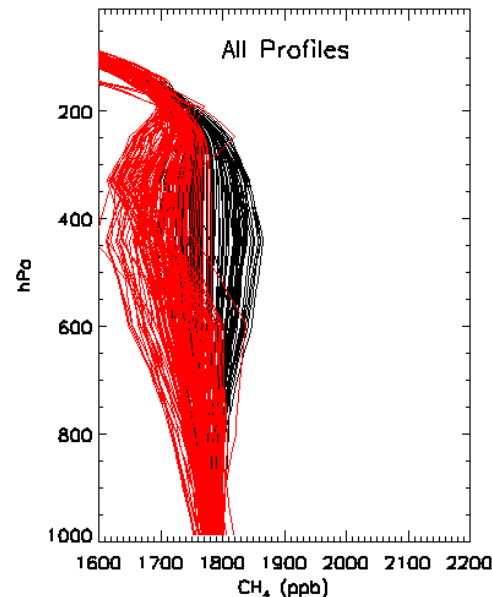
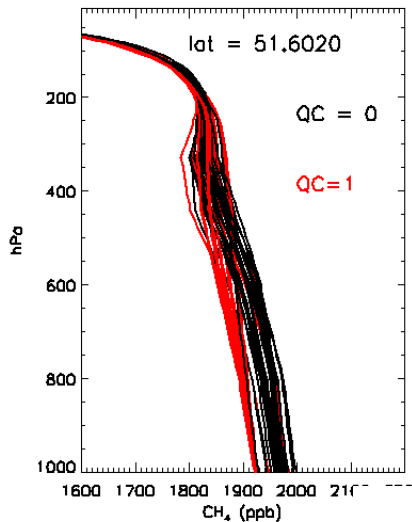
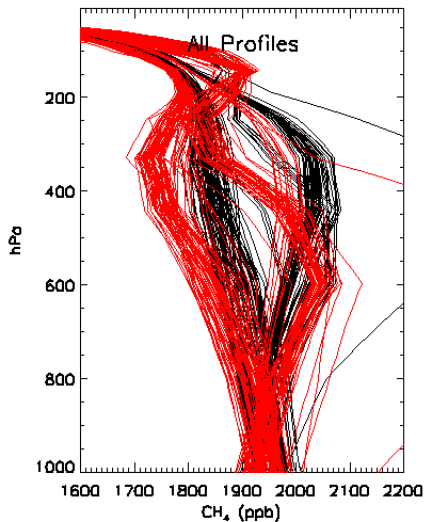
CrIS



**NOAA
IASI-B**

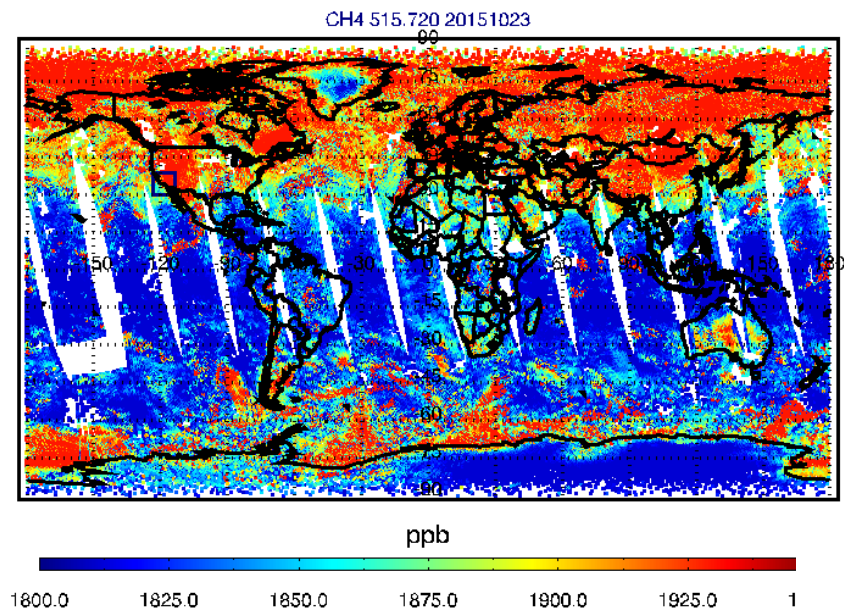


Other Optimizations(3): Quality Control (CH₄QC)



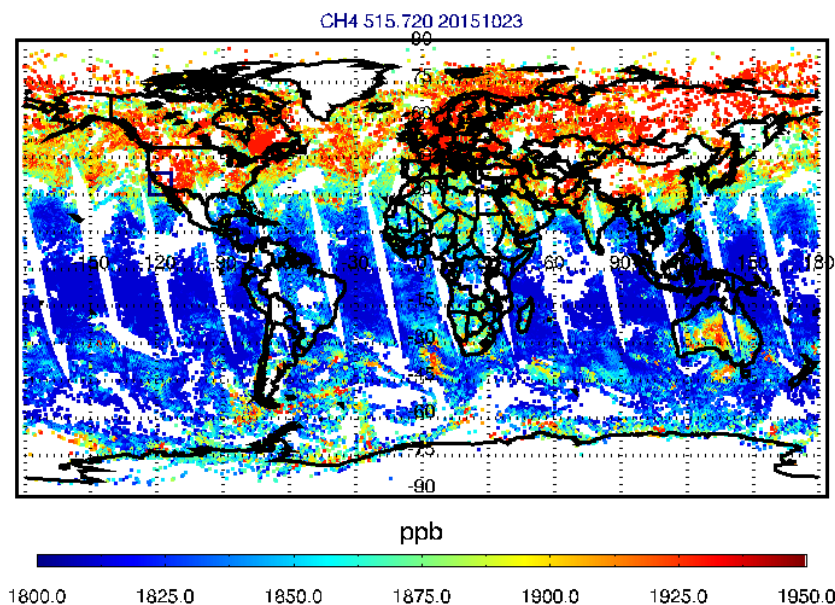
- For two granules
- Left panels: red lines are from version V2.0.5.4 (delivered in July) and black lines are from updated retrievals;
- Right panels: Profiles from updated retrieval and using CH₄QC (=0,1)

Example of CH₄ map after Preliminary CH₄QC



Preliminary CH₄QC is tailored to CH₄ products based on the DOF, surface temperature, chisq etc.

With CH₄QC





Yields after using CH₄QC

50.8%

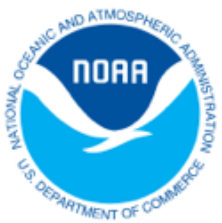


| Descending | Yield (%) | Percentage relative to NO CH ₄ QC (%) |
|-------------|-----------|--|
| QC=0 (best) | 37.4 | 45.0 |
| QC=1 (good) | 13.4 | 16.0 |
| QC=2 (bad) | 49.2 | |

54.7%



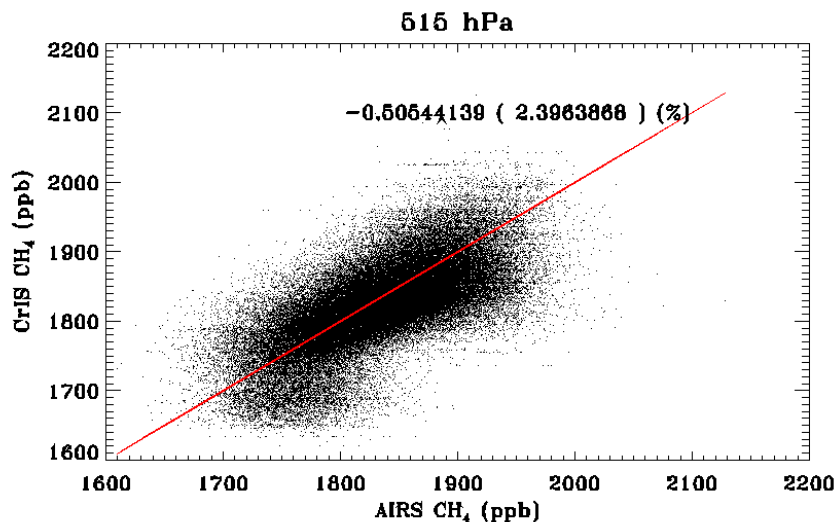
| Ascending | Yield (%) | Percentage relative to NO CH ₄ QC (%) |
|-----------|-----------|--|
| QC=0 | 43.6 | 52.0 |
| QC=1 | 11.1 | 13.2 |
| QC=2 | 45.2 | |



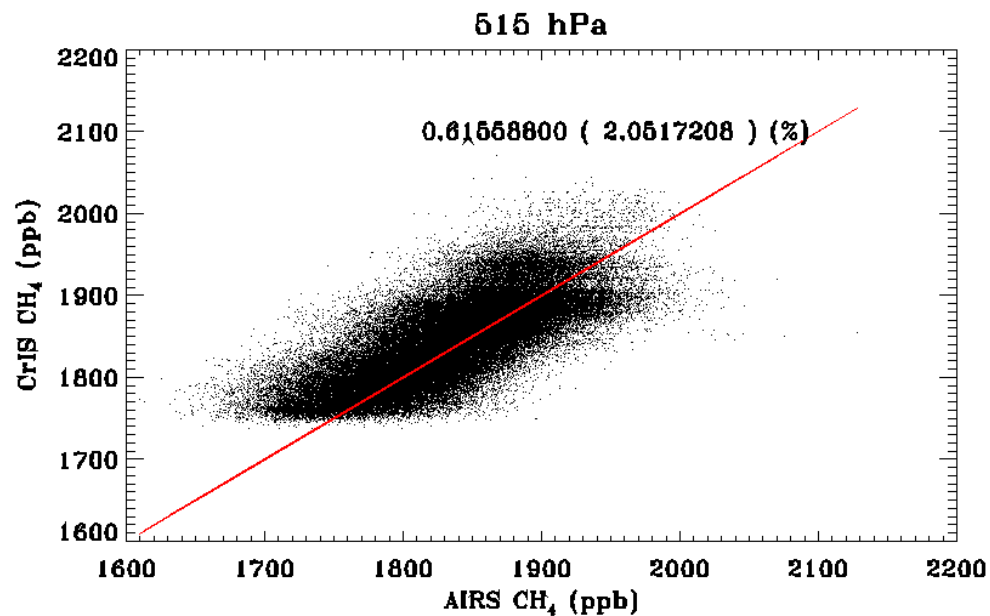
Assessment

- **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)**

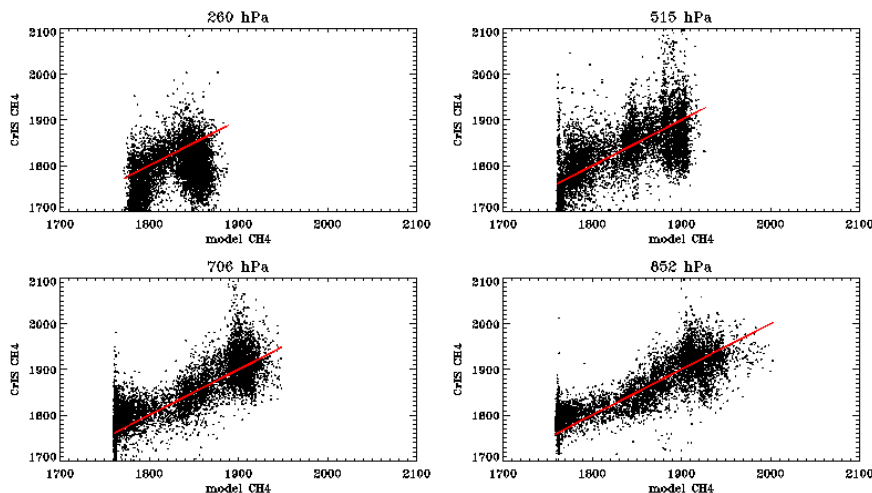
Comparison of CH₄ at 500 hPa with AIRS



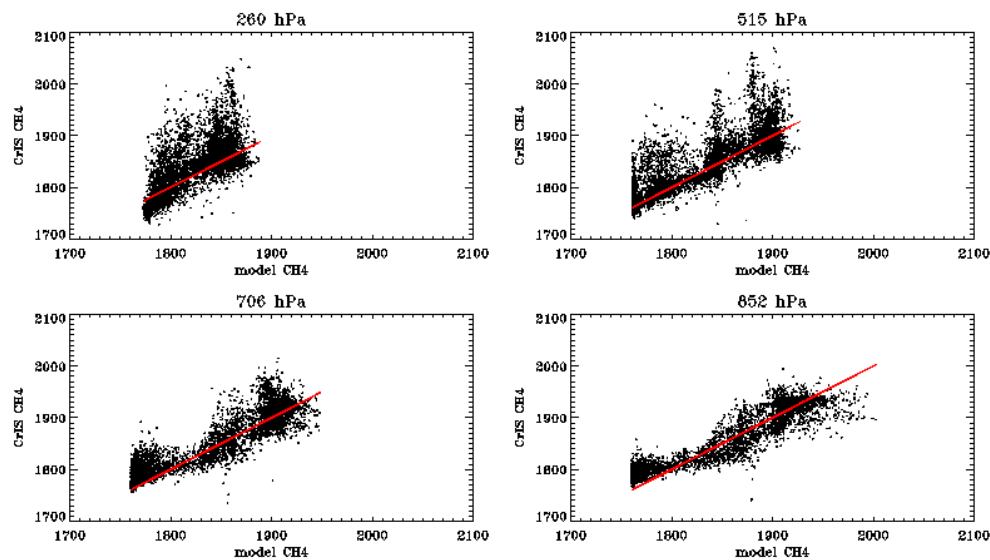
Upper left is V2.0.5.4
Lower right is the recent one



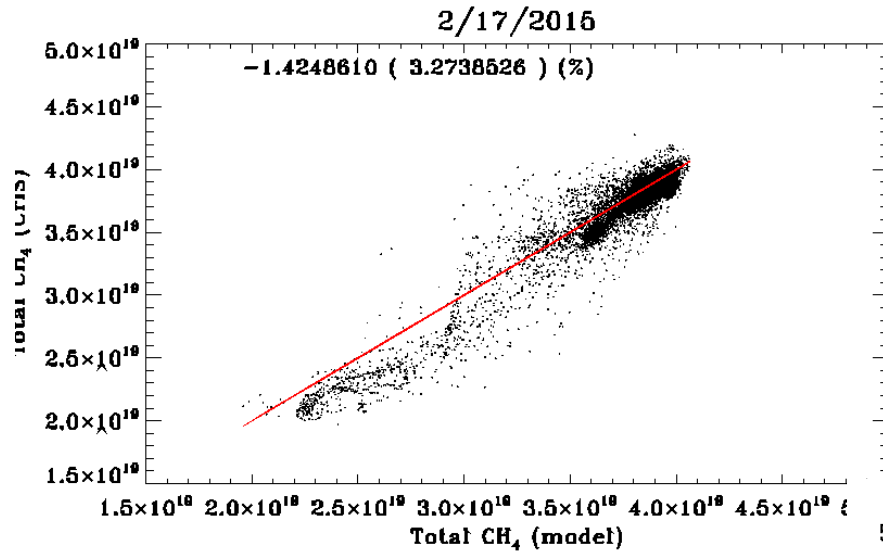
Comparison of CH₄ with Model at Four Layers (260, 515, 706 and 852 hPa)



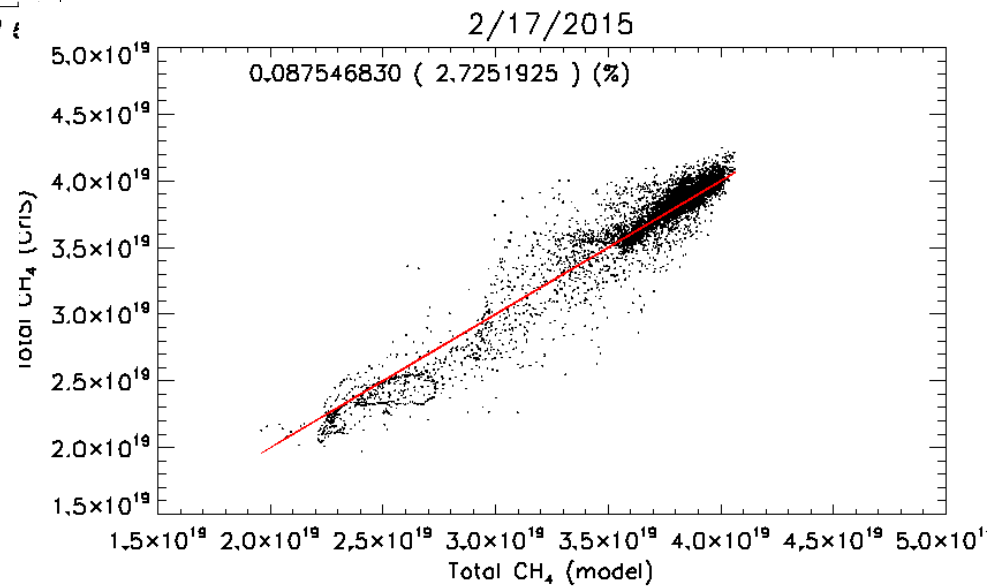
Upper left is V2.0.5.4
Lower right is the recent one



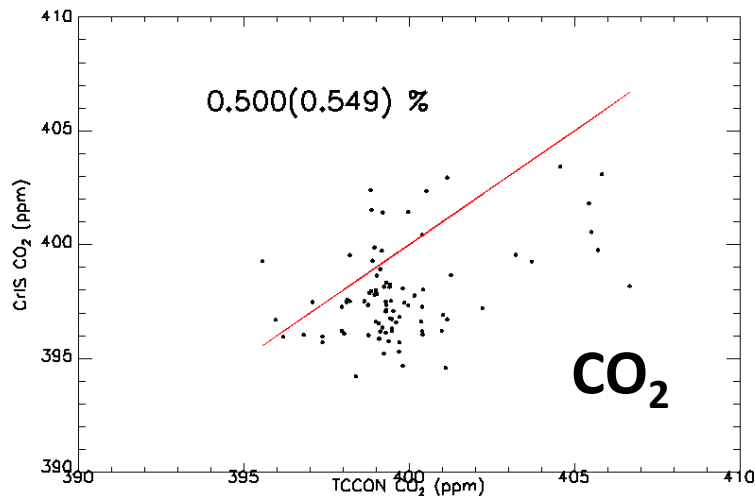
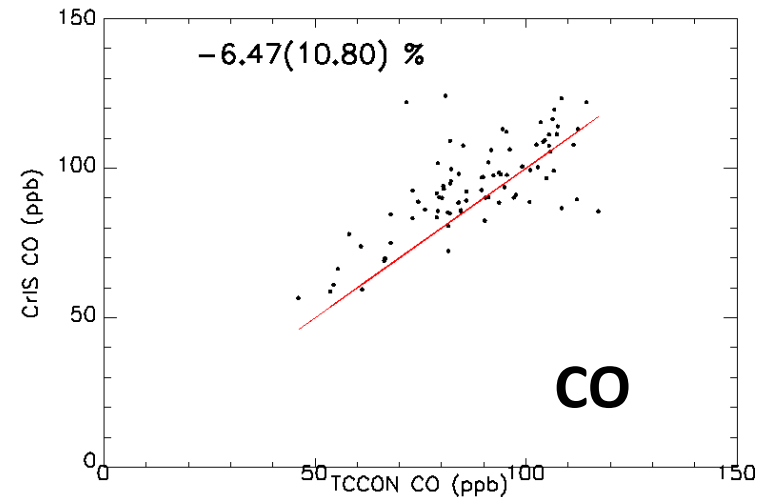
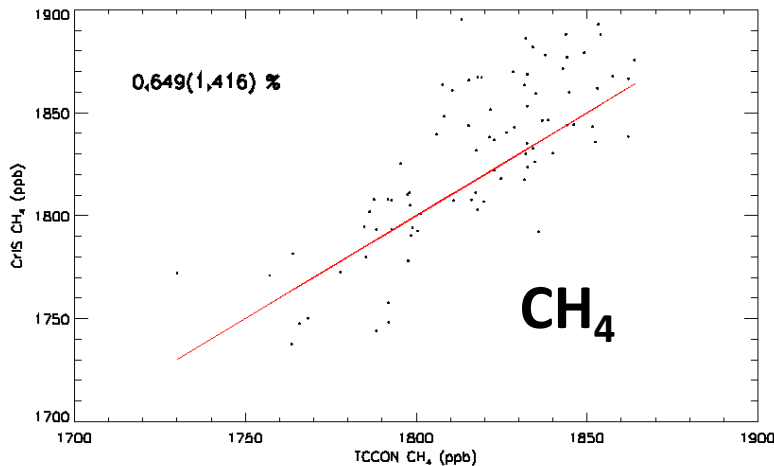
Comparison of CH₄ Total Amount with Model



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

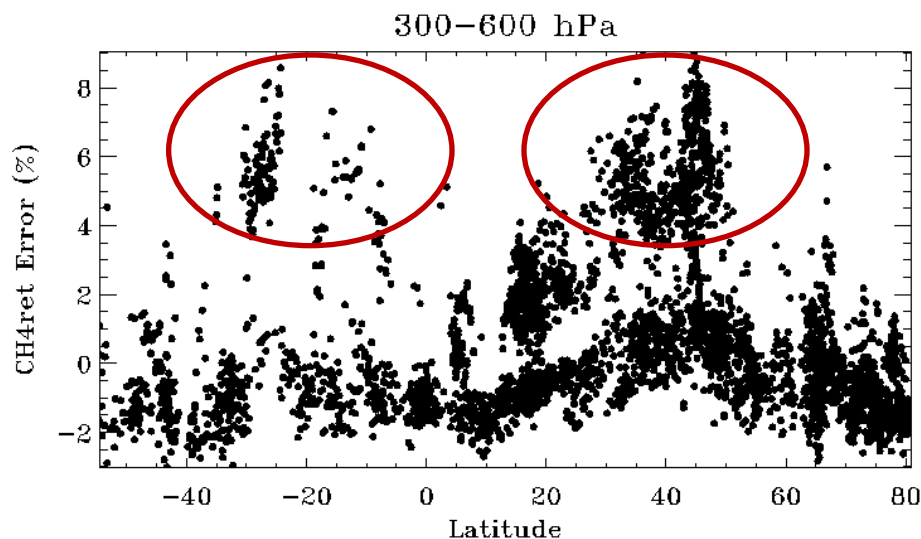


Comparison of CrIS $x\text{CO}/x\text{CO}_2/x\text{CH}_4$ with TCCON Measurements



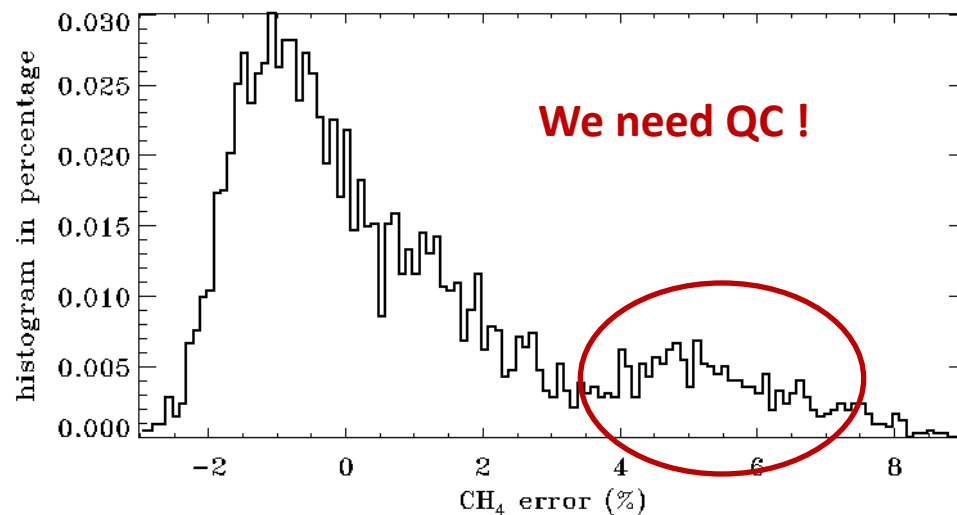
- Data of 10 days is used;
- This is a simple comparison by averaging TCCON data within 1 hours of satellite overpass and satellite data within 200 km over the ground site;
- Better agreement can be achieved if using averaging kernels

Comparison with ATom data (Preliminary)



Within 200 KM

No averaging Kernels
No QC tailored to trace gases





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

