Recent Improvement of NUCAPS CH_4 from CrIS FSR Data

Xiaozhen (Shawn) Xiong[1,2], Lihang Zhou[2]

Antonia Gambacorta[1,3], Nick Nalli[1,4] , Changyi Tan[1,4]

Flavio Iturbide-Sanchez[1,4], Kexing Zhang[1,4]

[1]CICS-MD
[2]NOAA/NESDIS/STAR
[3] STC Inc
[4] IMSG

4th NOAA JPSS Meeting, College Park, MD, 2017

Outline

- **Recent Improvements in CH_4 Retrievals from CrIS FSR Data**
  - Sensitivity (mid-upper troposphere) and Requirement of CH_4 products (based on total amount) --- need a good CH_4 firstguess in the lower troposphere;
  - Optimization: First guess, Channel Selection, and tuning;
  - **Quality control (CH_4QC) – to be added soon;**

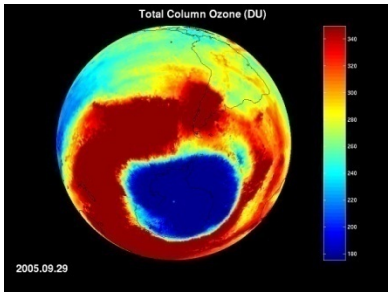
- **Validation:**
  Comparison of CrIS CH_4 profiles with model, AIRS and TCCON data;

- **Examples:**
  - Monitoring the leakage of CH_4 from California **Aliso Canyon Oil Field and Gas Storage Facility;**
  - Monitoring the CO plume from 2016 **Fort McMurray wildfire**; Monitoring the CO plume from **Indonesia Fires (9/20-11/8, 2015);**

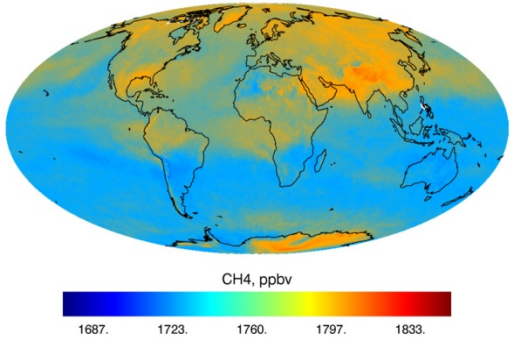
- **Summary and Future works**

Requirements of Trace Gases Products from CrIS

Ozone

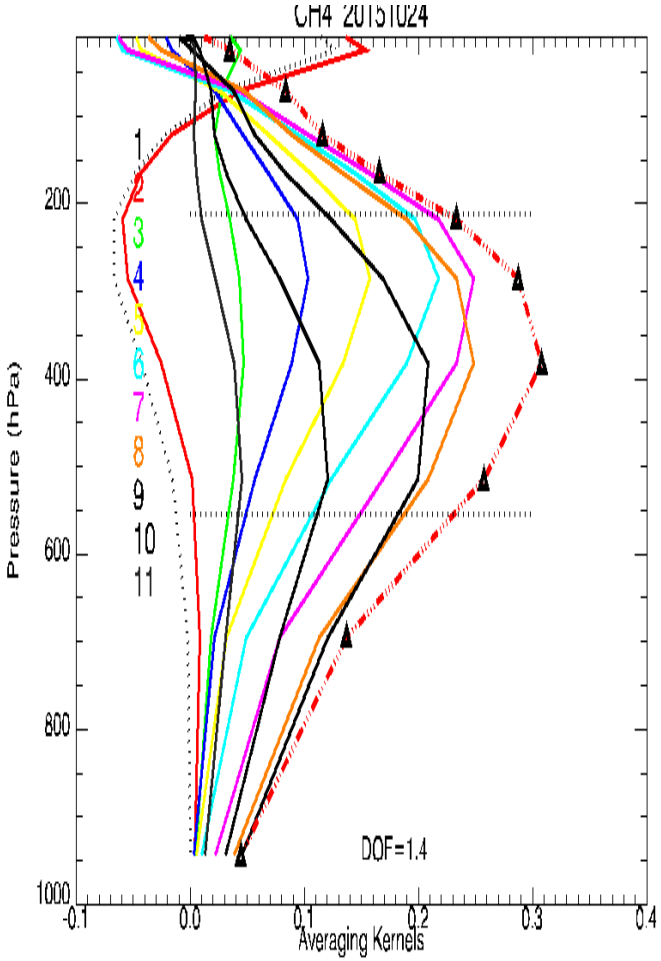


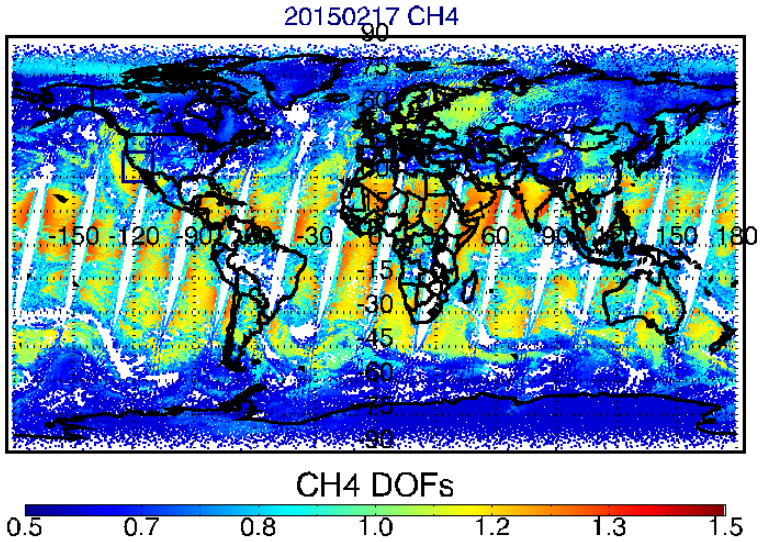
Methane



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 CH_4



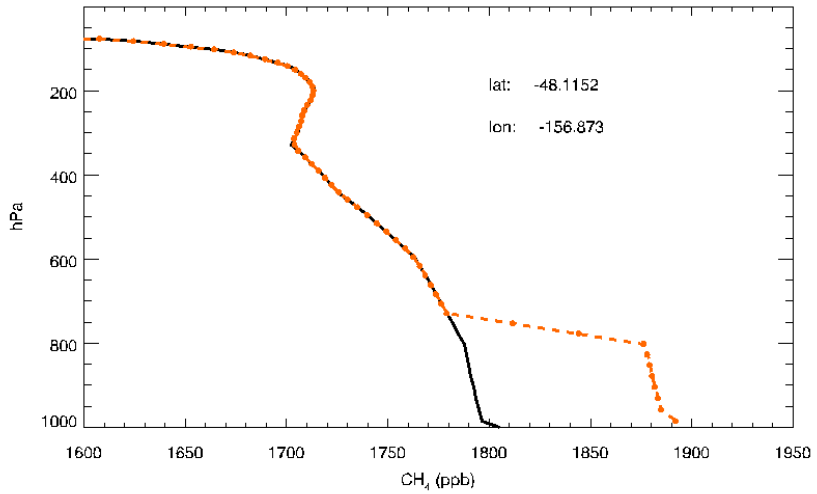


- **Major sensitivities are in the mid-upper troposphere – not near the surface where the variation is impacted by emissions;**

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

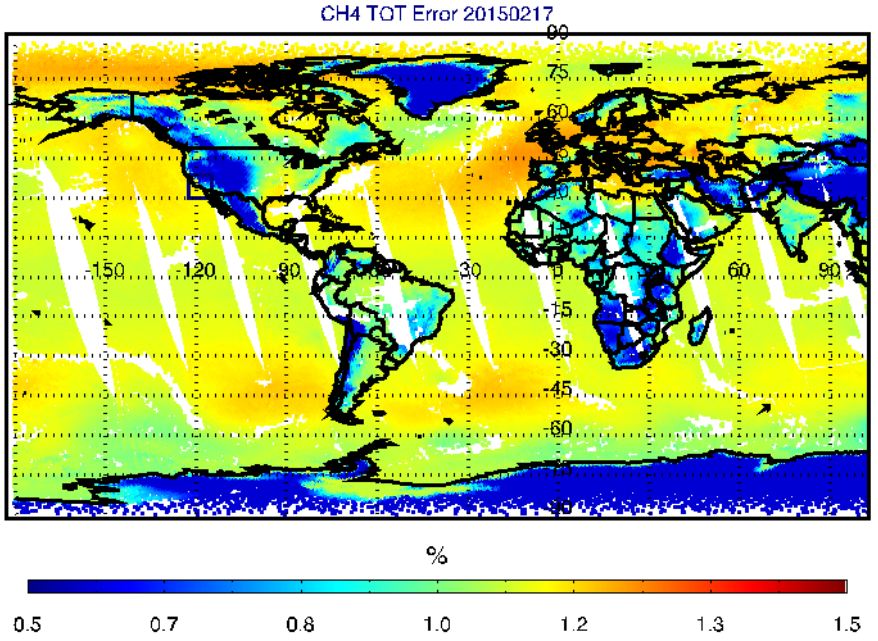
CH_4 Total Amount Error

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



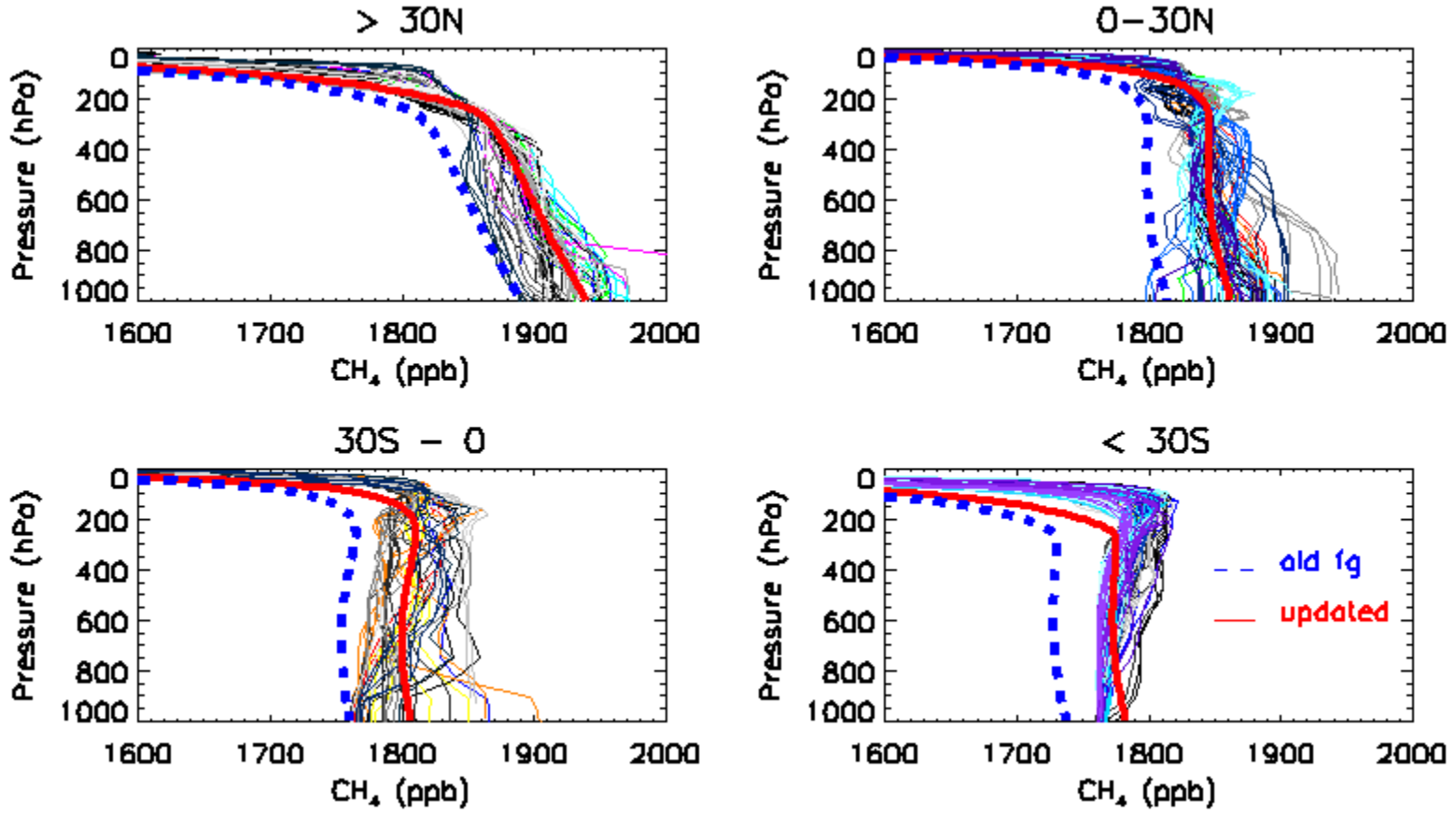
Assuming 5% error of CH4 profile in lower troposphere(below 800 hPa), the error in total amount is about 1.2%.

- to meet the requirement of total amount in 1%(accuracy) is hard;
- It requires a very good a priori



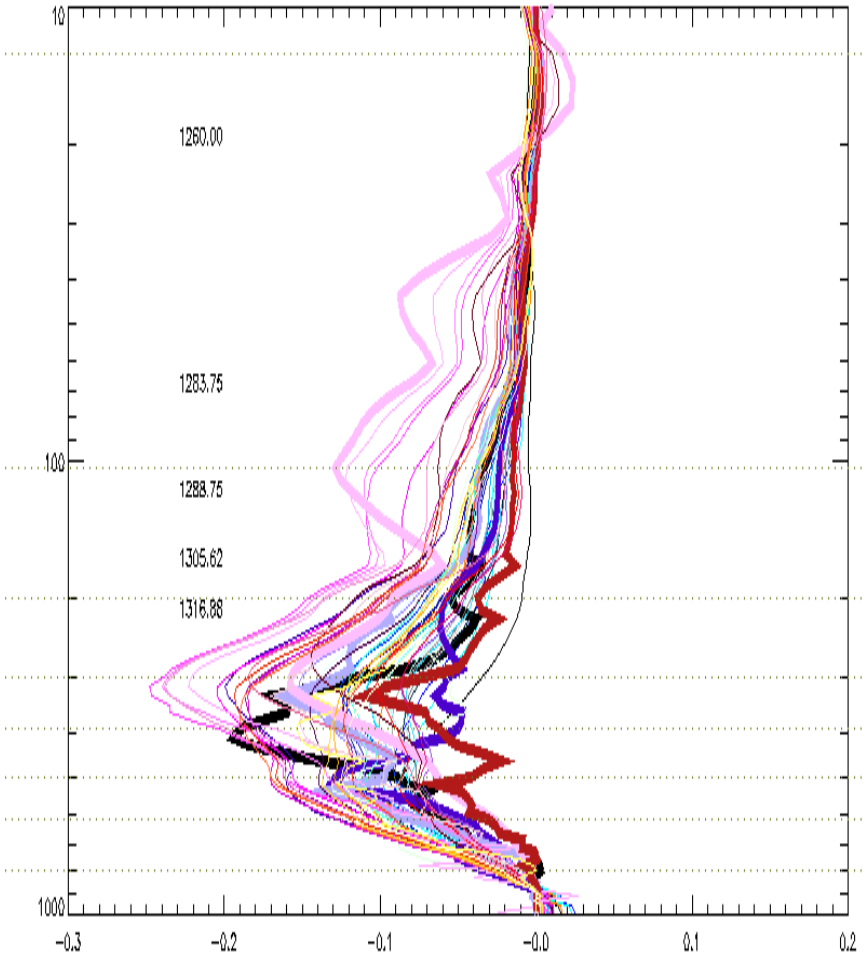
CH_4 First-guess Update

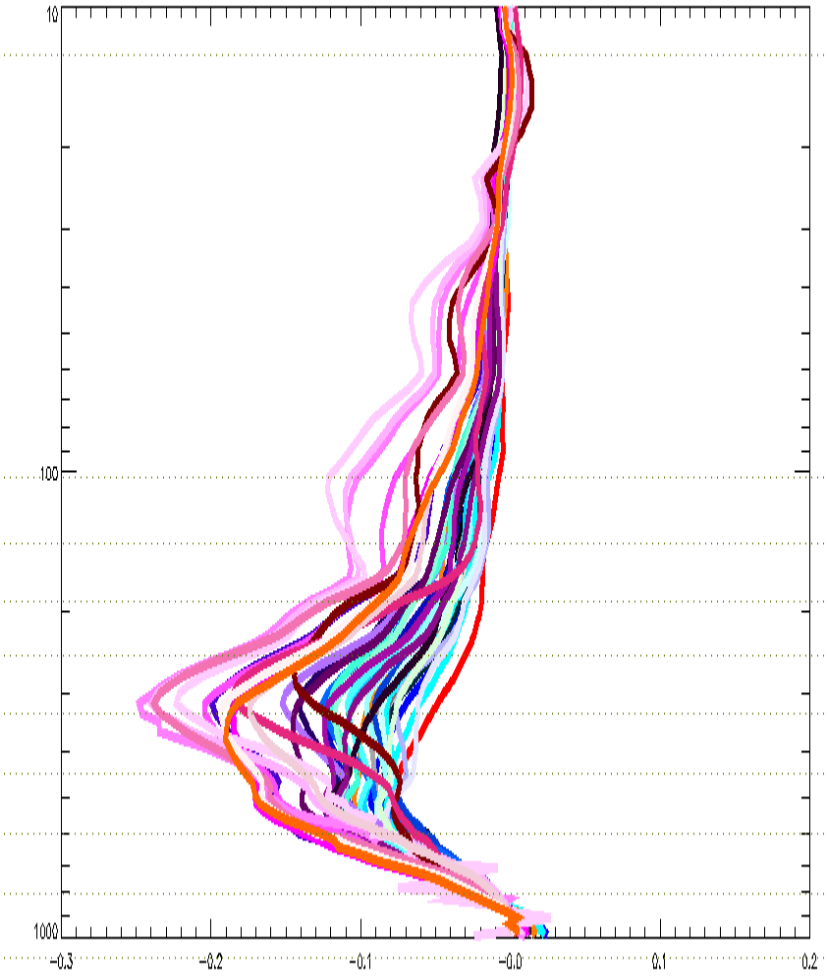
(about +2.5%)



--- Old fg is the one used in AIRS-V7 and NOAA IASI system

Continued Optimization: Channel Selection (1)

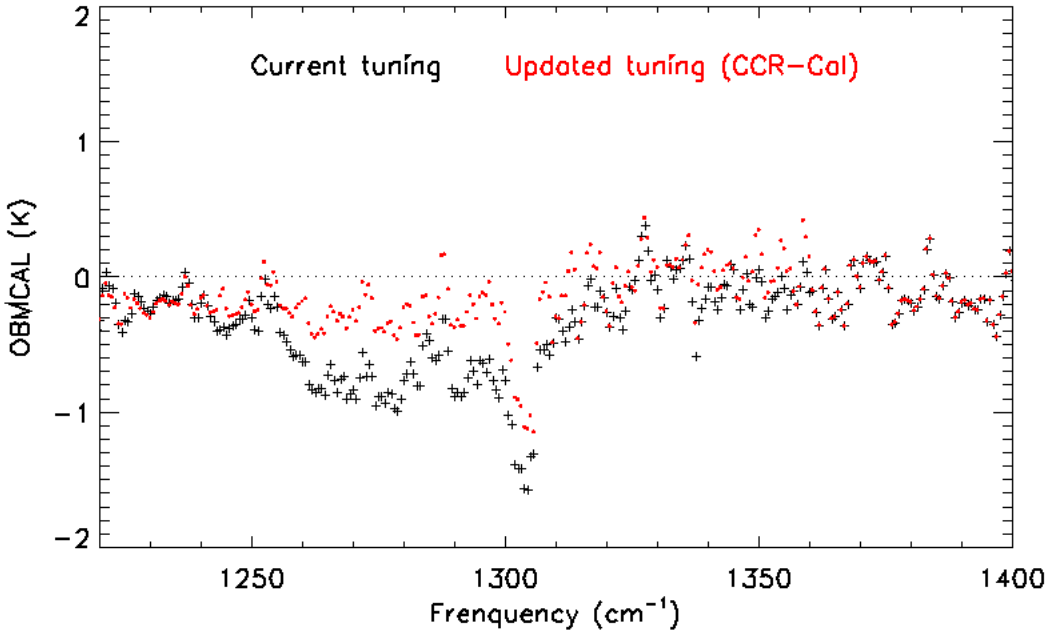




Current one – delivered in July

Updated one – to be delivered in Oct/Nov

Continued Optimization(2): Re-tuning to CH_4 bands



- CH_4 is very sensitive to upstream temperature and water vapor products;
- Cloud-clearing is a good thing to the yield of retrievals but could be poisonous to trace gases products;

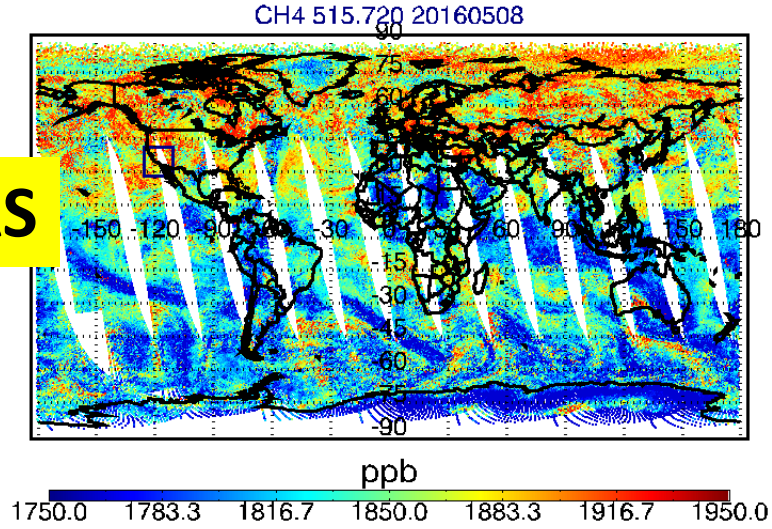
Method of Re-tuning to CH_4 bands

1) Using SARTA to simulate the global radiance with inputs
   - T,Q profiles from NUCAPS retrievals;
   - CH_4, N_2O and CO_2 from model simulations;
2) read CCR and applied QC (MW+IR) = 0;
3) Computed the difference of $[R_{simu} - R_{CCR}]$;
4) Modified the tuning file in CH_4 bands ONLY (from 1200-1360 cm^{-1}) → ***no impact to T & q products***;

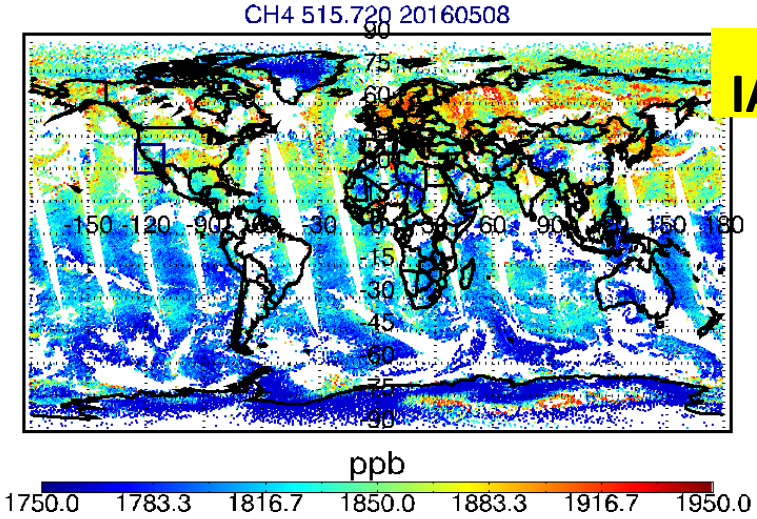
One day data (45°S-45°N) on 2/17/2015 is used;

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

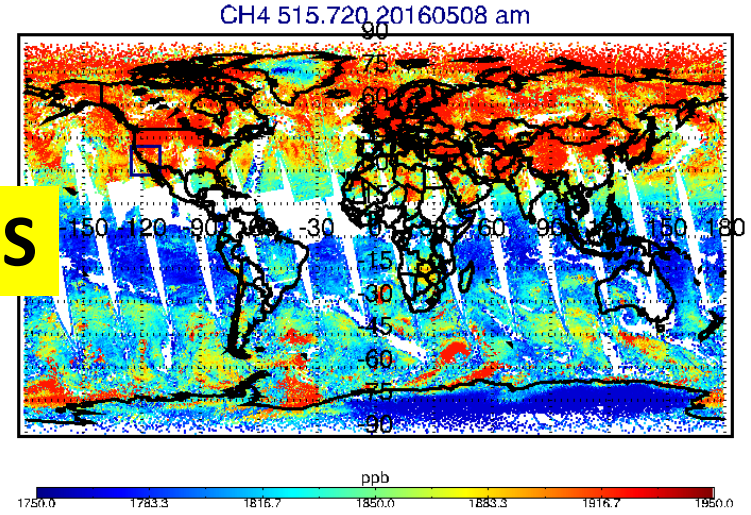
AIRS



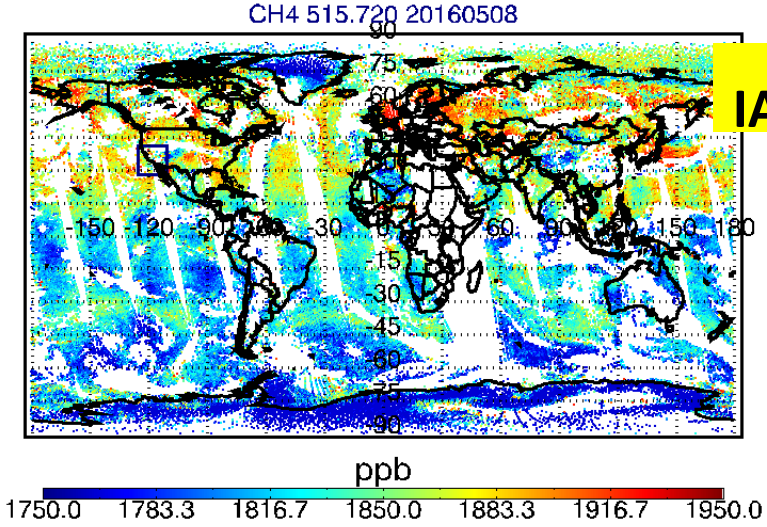
IASI-A



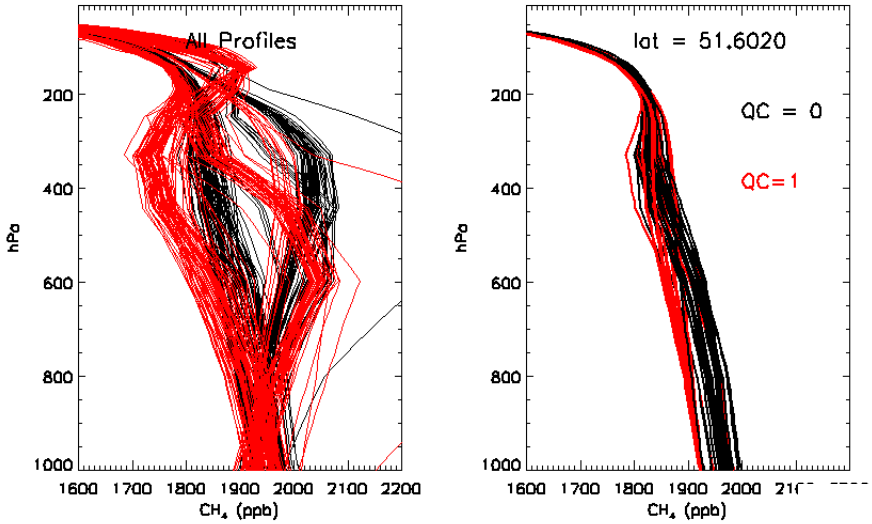
CrIS



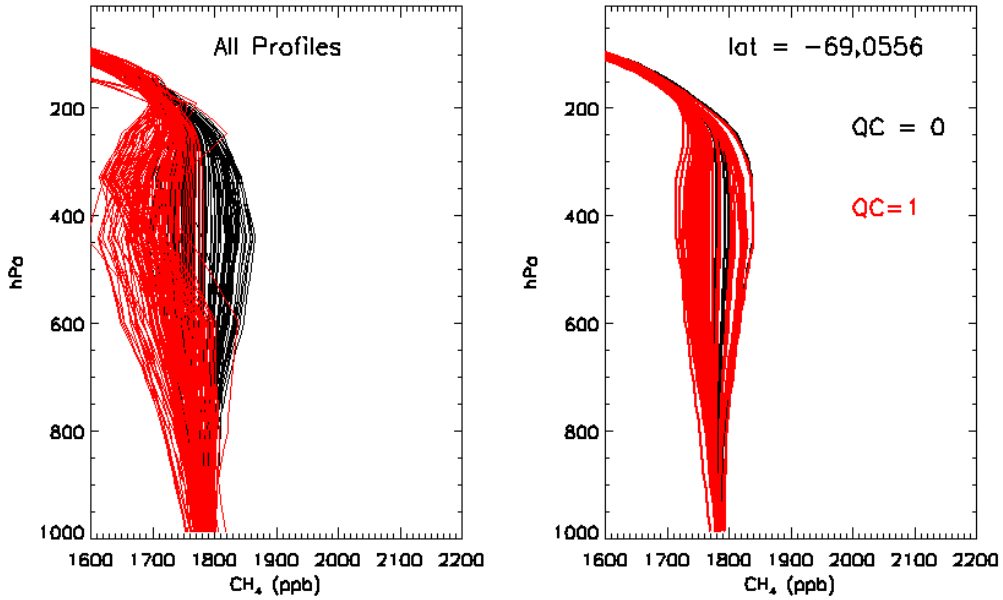
IASI-B



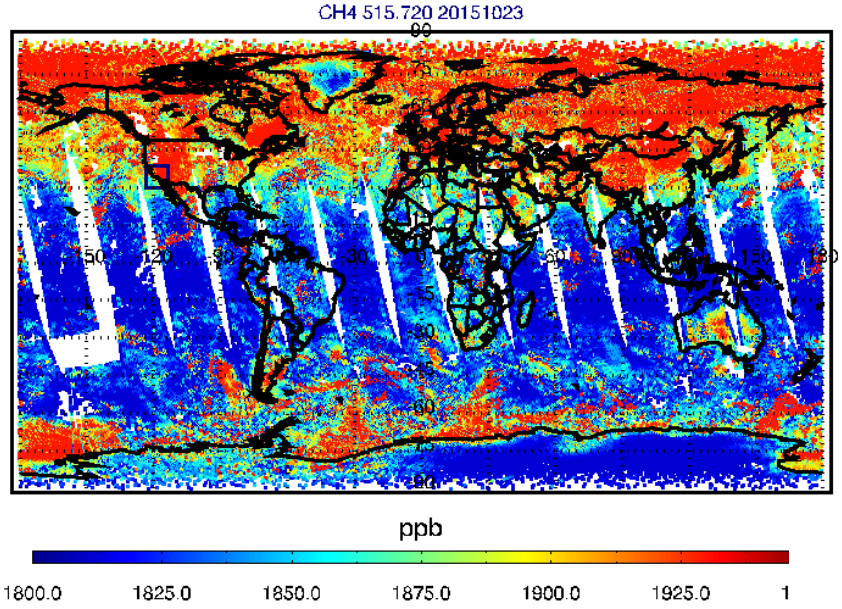
Examples of Quality Control (CH_4QC)



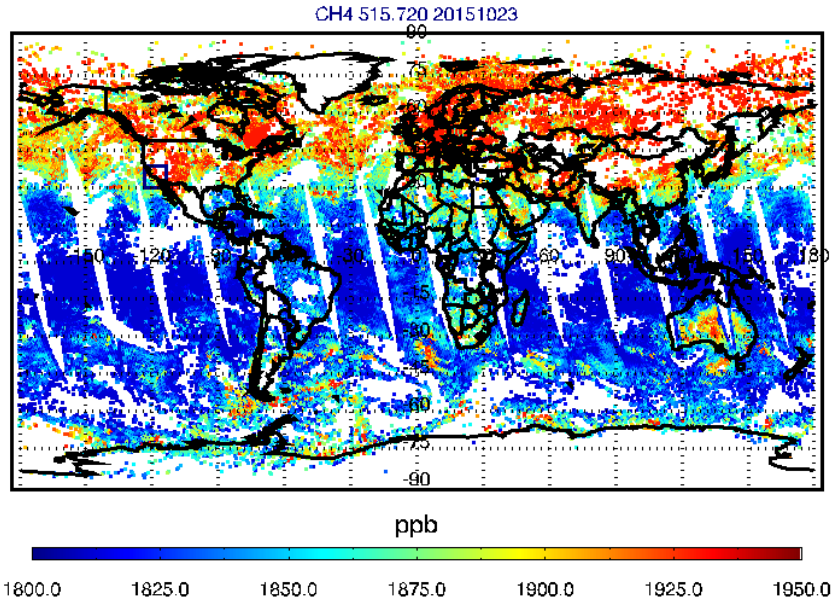
- **For two granules**
- **Left panels: red lines are from current version and black lines are from updated retrievals;**
- **Right panels: Profiles from new version and after using CH_4QC**



Example of CH_4 map with the CH_4QC



With CH_4QC



Yields after using CH_4QC

50.8%

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

54.7%

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

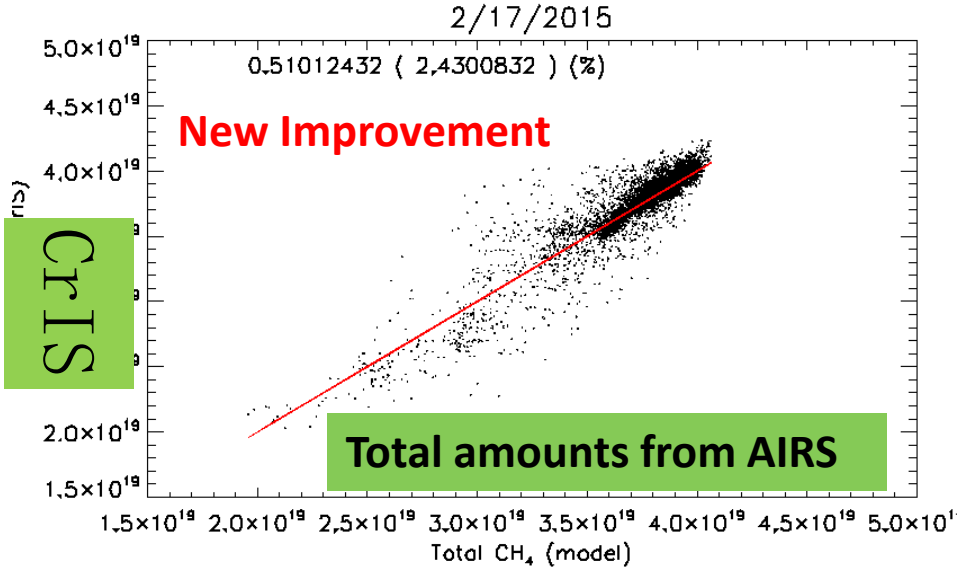
Some Results

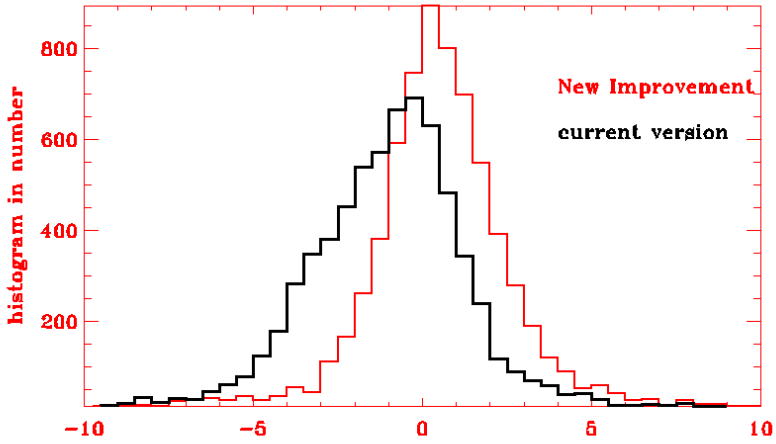
Validation: comparison with model, AIRS and TCCON data;

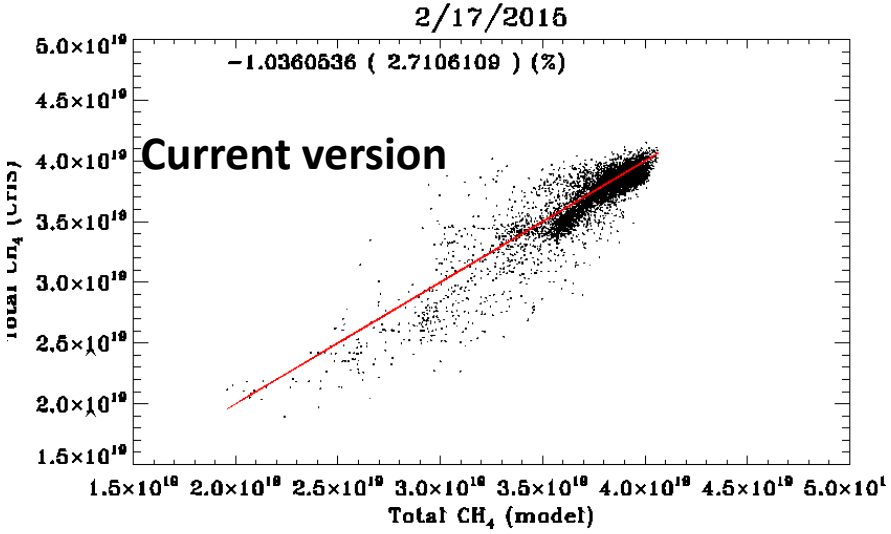
Examples:

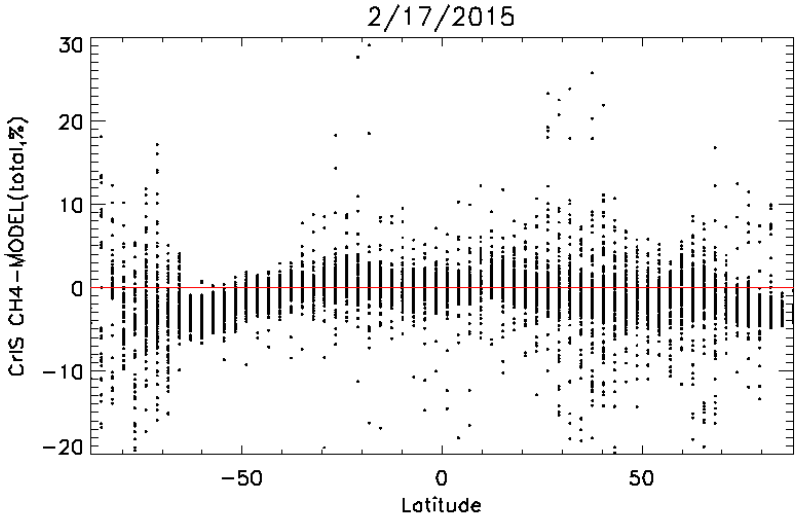
- Monitoring the leakage of CH_4 from California **Aliso Canyon Oil Field and Gas Storage Facility;**
- Monitoring the CO plume from 2016 **Fort McMurray wildfire**;
- Monitoring the CO plume from **Indonesia Fires (9/20-11/8, 2015);**

Comparison with model CH_4 – improvement is obvious but accuracy is large than 1%

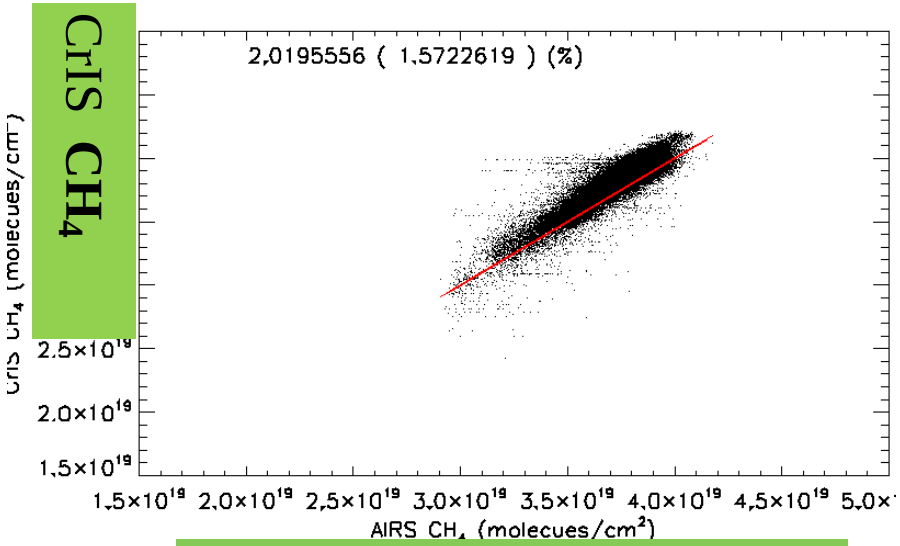




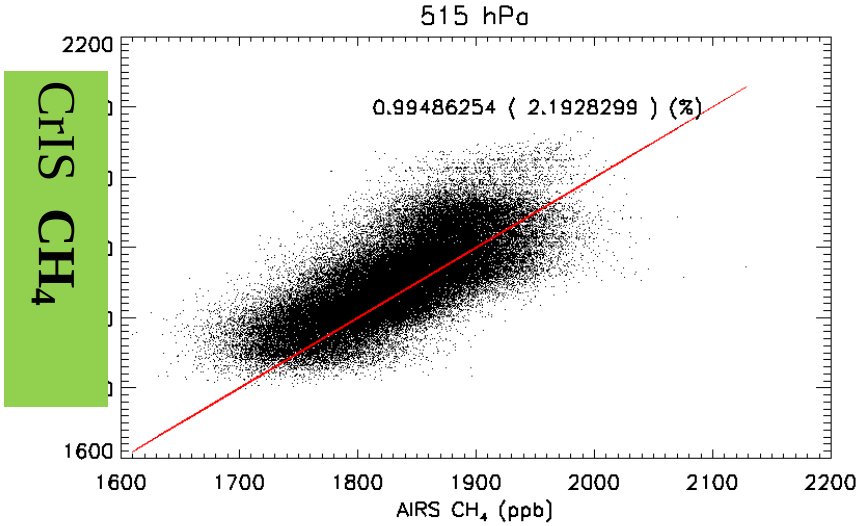




Comparison of CrIS and AIRS CH_4

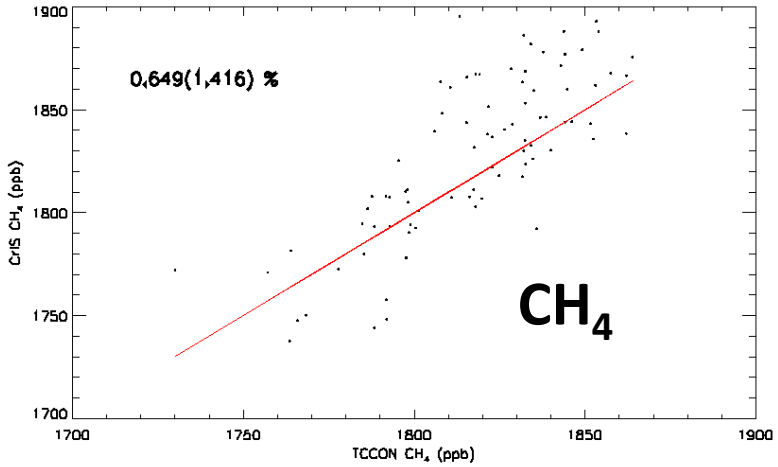


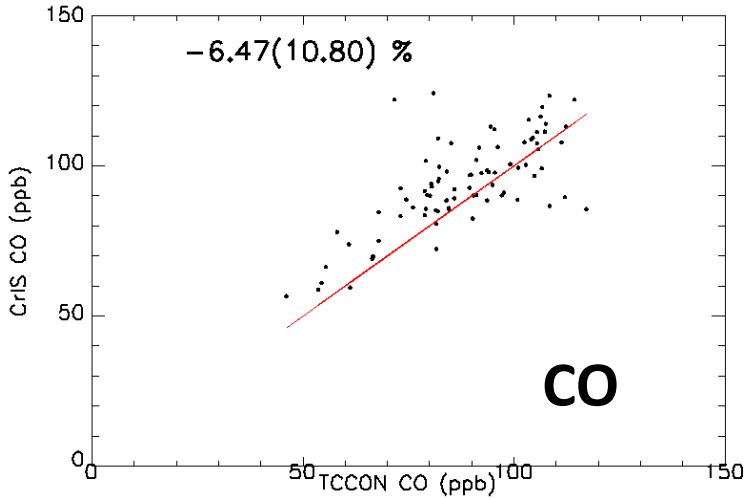
Total amounts of CH_4 from AIRS

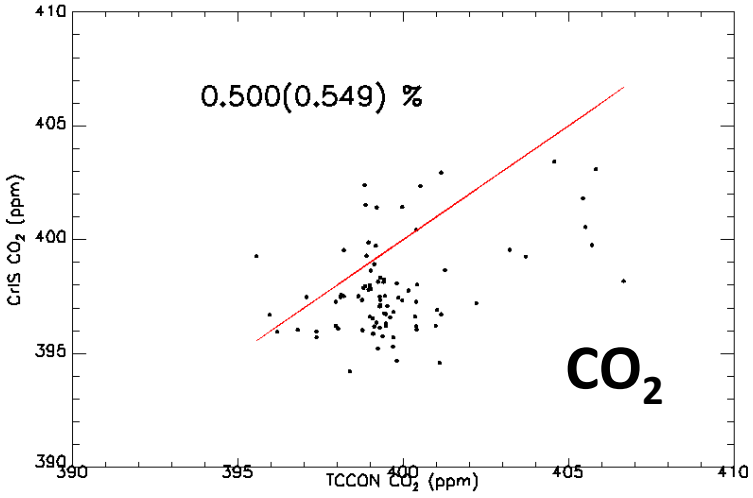


AIRS CH_4 at 515 hPa

Comparison of CrIS xCO/xCO_2/xCH_4 with TCCON Measurements



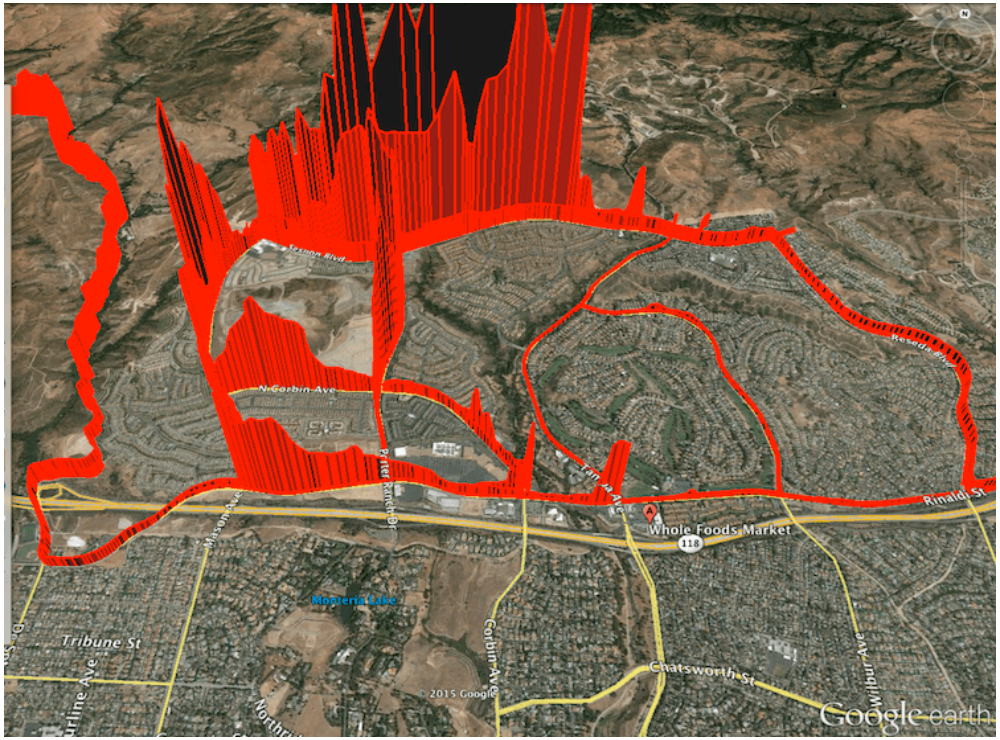




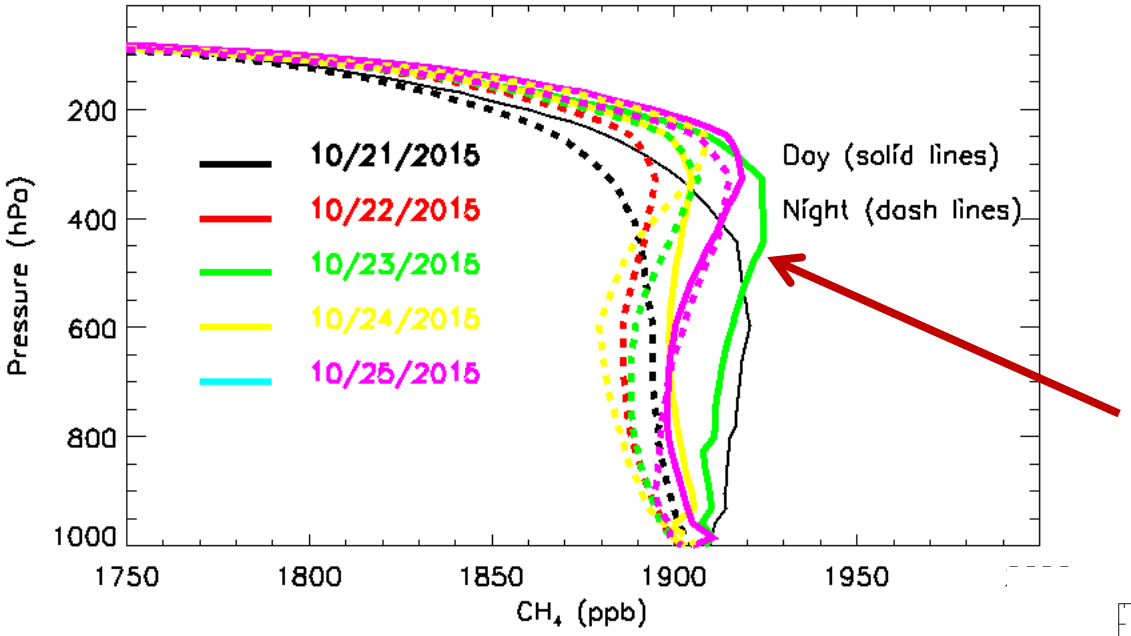
- Data of 10 days is used;
- This is a simple comparison by averaging TCCON data within 1 hours of satellite overpass and satellite data within 200 km over the ground site;
- Better agreement can be achieved if using of averaging kernels

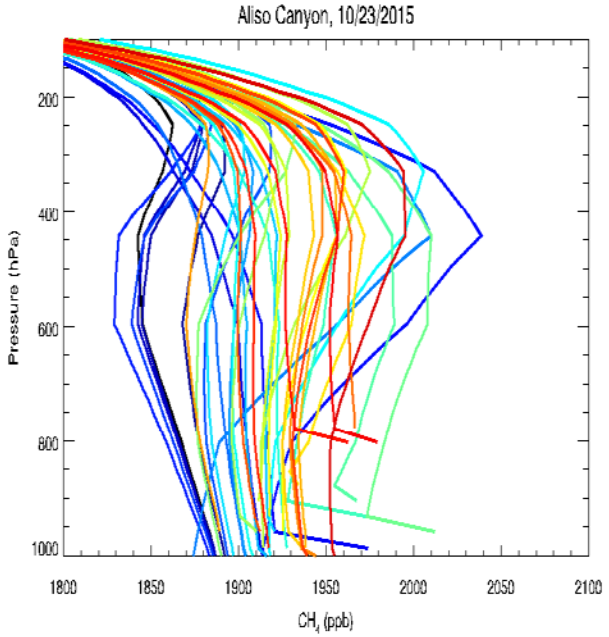
Example : Largest leakage in U.S. history
Aliso Canyon Gas Leakage (10/23/2015- 2/18/2016)

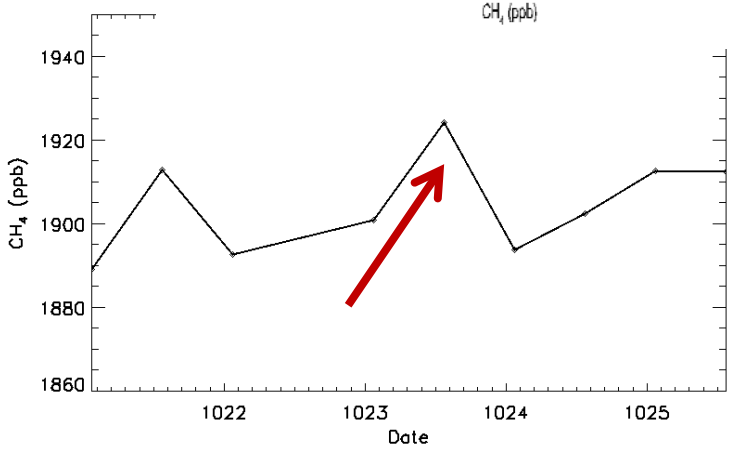
Surface Measurements



Can CrIS Capture the Leakage of CH_4?

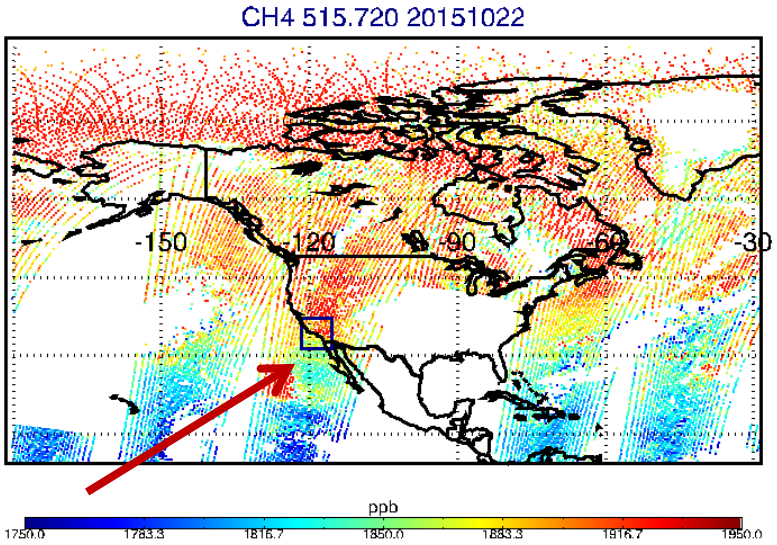


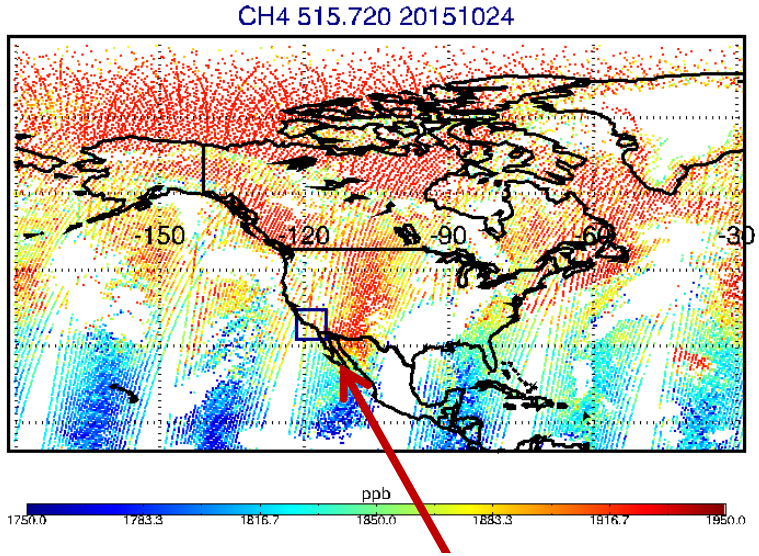


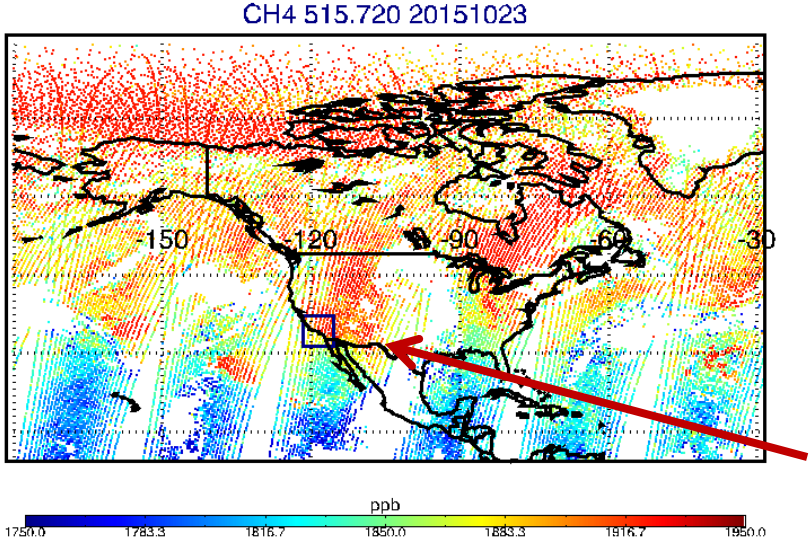


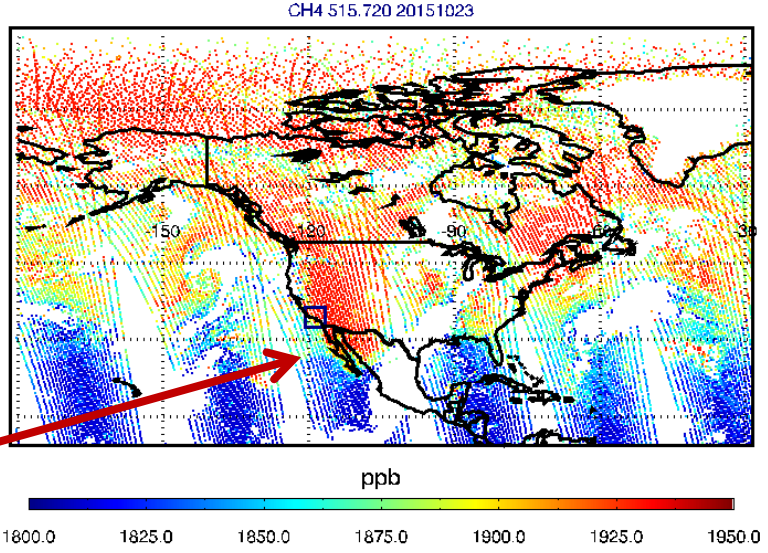
In daytime the retrieved CH_4 is larger than in the night time;
There are

Can CrIS Capture the Leakage of CH_4 – cont'd ?

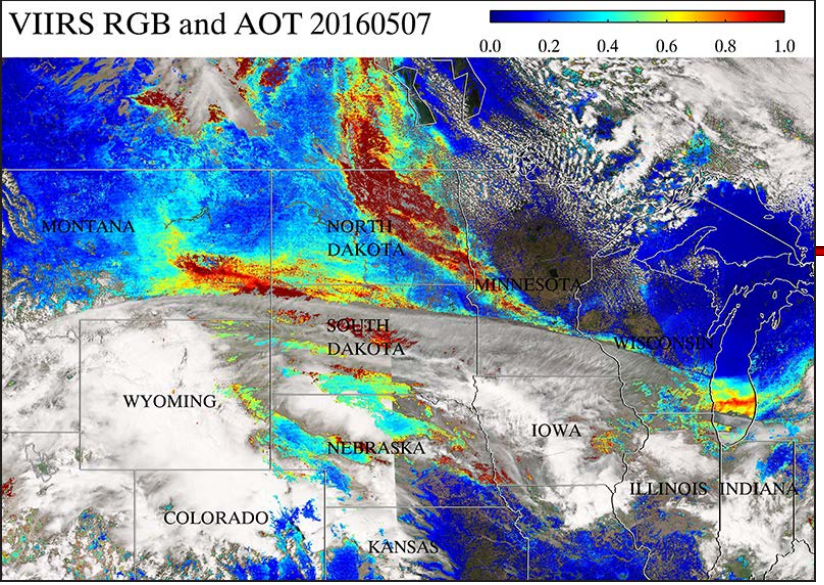






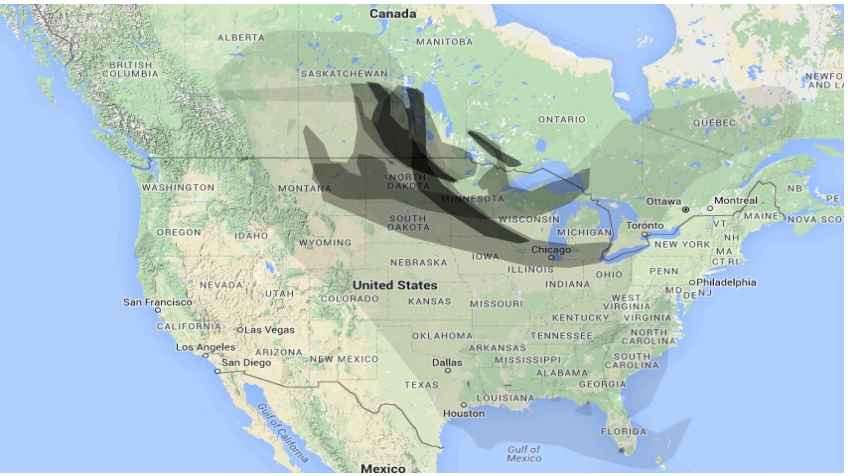


Example of CO: 2016 Fort McMurray Wildfire

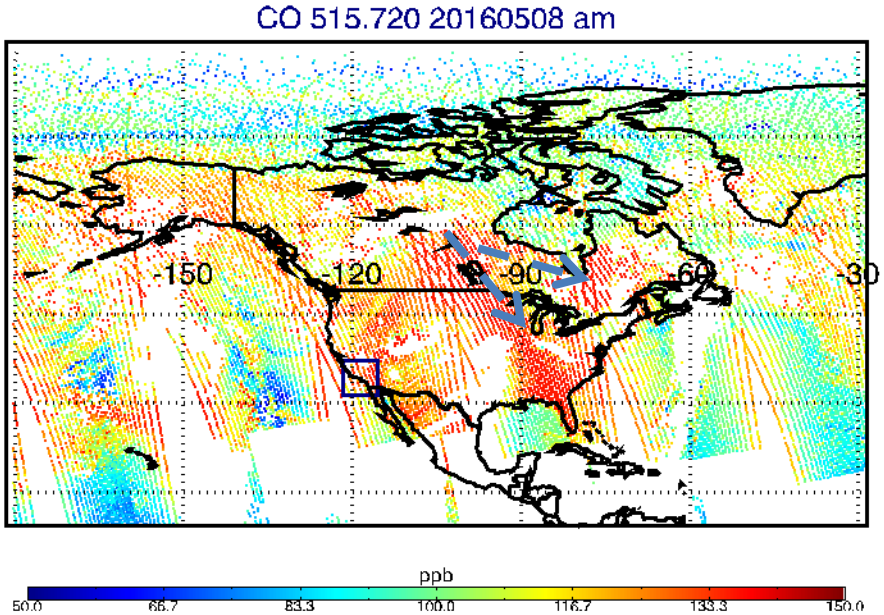


Huff and Kondragunta, EOS, V98, 6, 2017

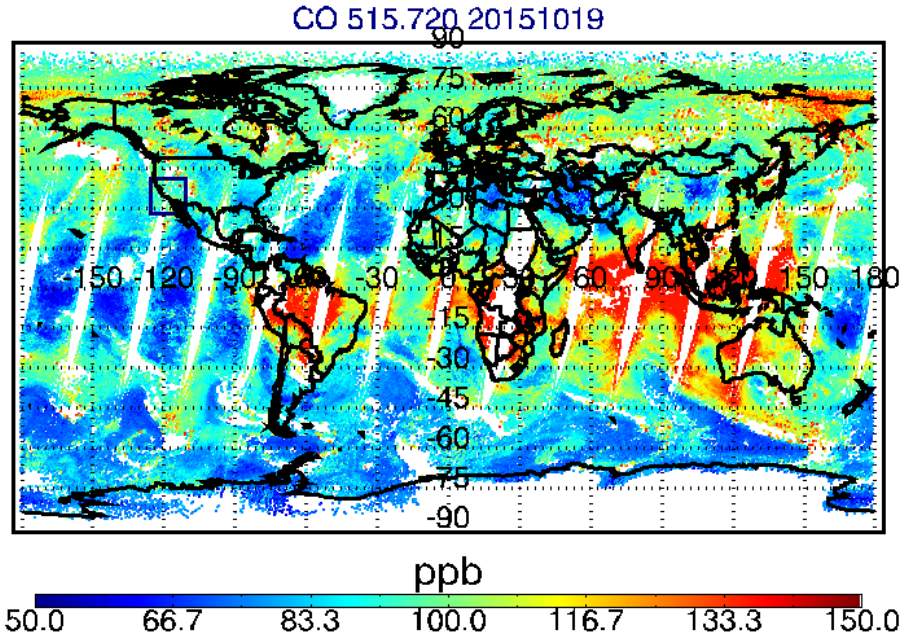
MODIS/Aqua captured smoke from the Ft. McMurray wildfire and other Canadian wildfires billowing across the Atlantic Ocean.

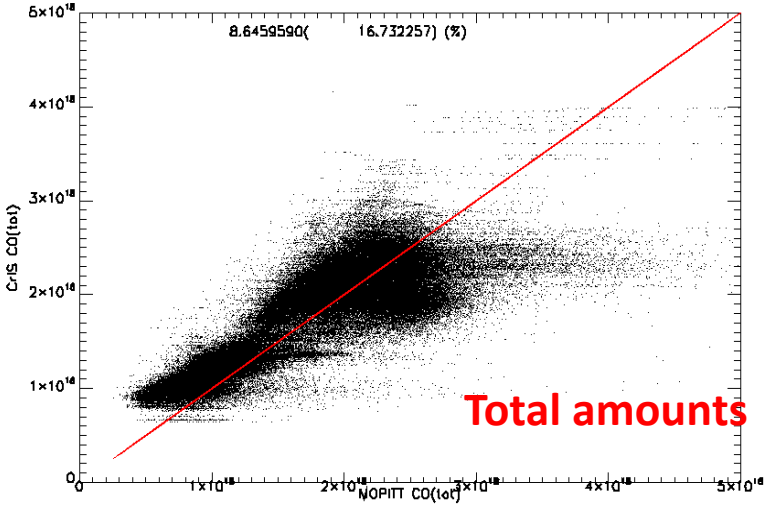


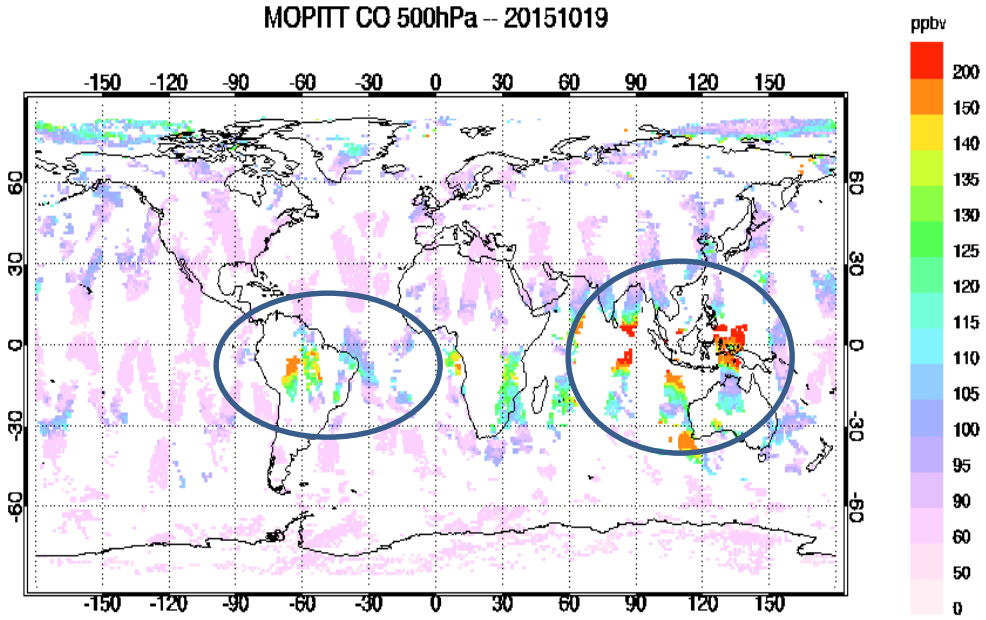
Wildfire Smoke map, 4:30 p.m. May 8, 2016, from Weatherunderground,

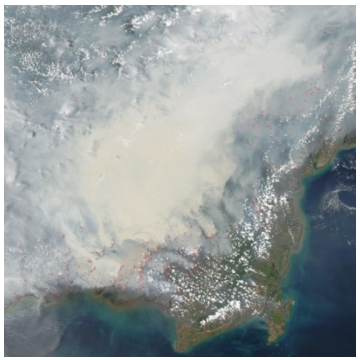


Example of CO (2): Fires in Indonesia (9/20-11/8,2015)









Brownish-gray smoke obscured the island of Borneo from MODIS in October 19, 2015. Image from [NASA Earth Observatory.]

Summary

1. The major sensitivity of CrIS is in the mid-upper troposphere but it is very small in the lower troposphere, so CrIS cannot capture the surface emission. 5% error of the firstguess in the lower troposphere will lead to 1.2% error in the total amount – making it hard to meet the requirement in 1% accuracy.

2. Cloud-clearing is a great part from NUCAPS but we have to be very careful to set QC for all trace gases;

3. Recent improvements (firstguess, channel selection, tuning and CH_4QC) are promising, but more works need to be done, particularly we need more profile validation using aircraft measurements.

4. The examples show some promising results to use CrIS to observe the **CO plume** from wildfires, and the possibility to capture the **CH_4 leakage** from Aliso Canyon Oil Field and Gas Storage Facility in California.

Future Works

- Trace gases maturity review will be made in Nov/Dec., and this is the deadline for us to finalize the update to trace gases algorithms; Another delivery will be delivered by that time frame;

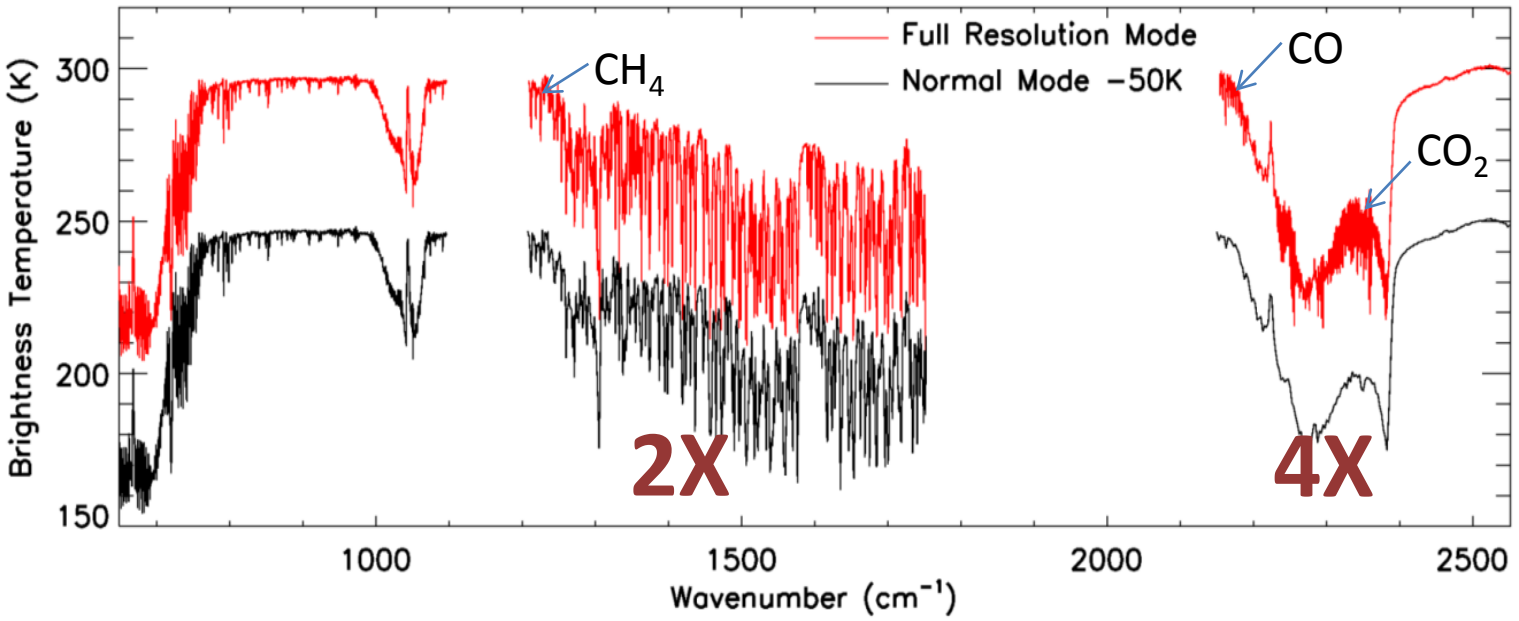
- In addition to the operational system, I will use an offline system with more update to trace gases retrievals to reprocess SNPP CrIS FSR data since Dec.4, 2014 to present. Any update with new sciences can be considered, and these work will help our future update to NUCAPS operational system.

Xiaozhen.Xiong@noaa.gov

Questions/Suggestions

Xiaozhen.Xiong@noaa.gov

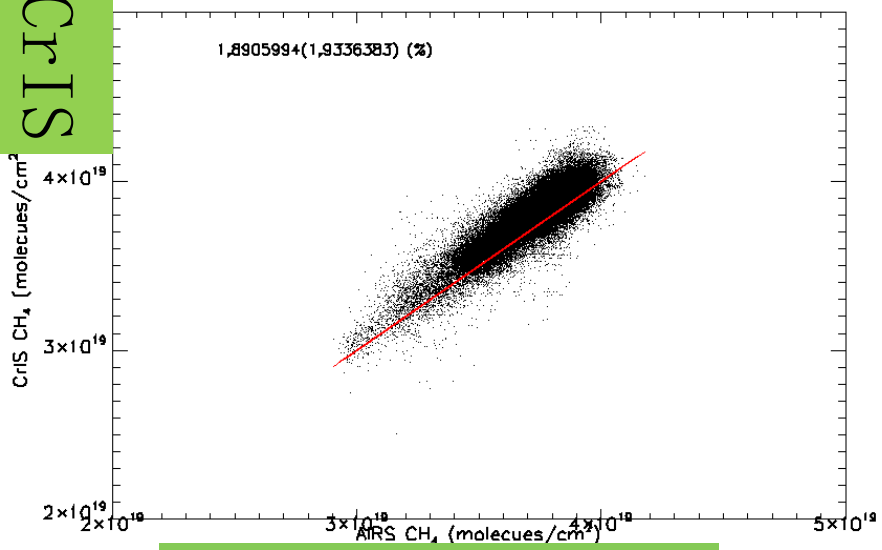
FSR Data of Cross-track Infrared Sounder (CrIS) on S-NPP



Increase of spectral resolution by 4X in SLW greatly benefits CO retrieval;
Not used for CO2 (so far)
Increase of spectral resolution by 2X in MLW benefits CH4 retrieval;

CrIS (old) vs AIRS CH_4

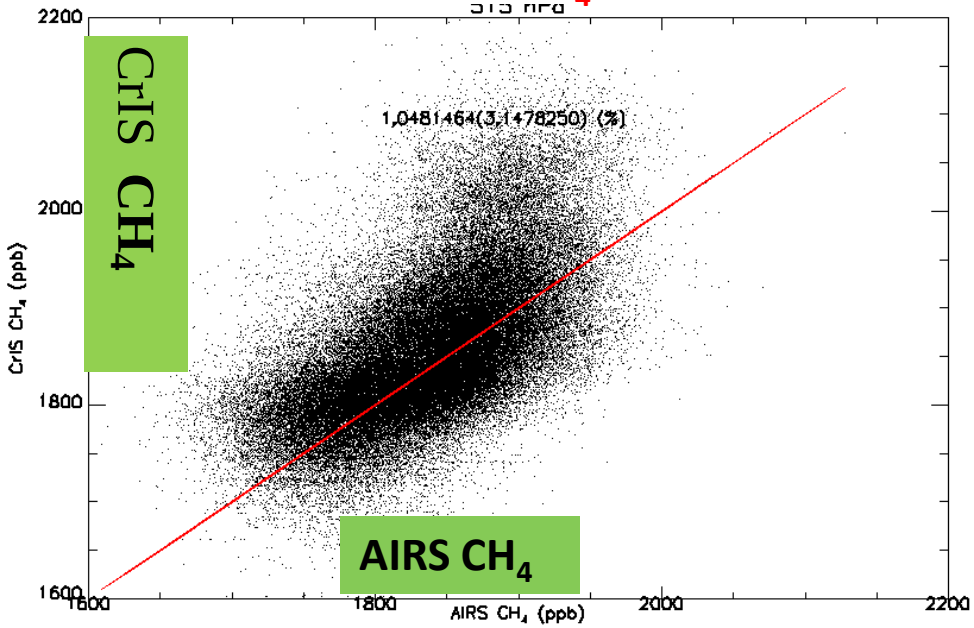
CrIS



Total amounts from AIRS

CH_4 @ 515hPa

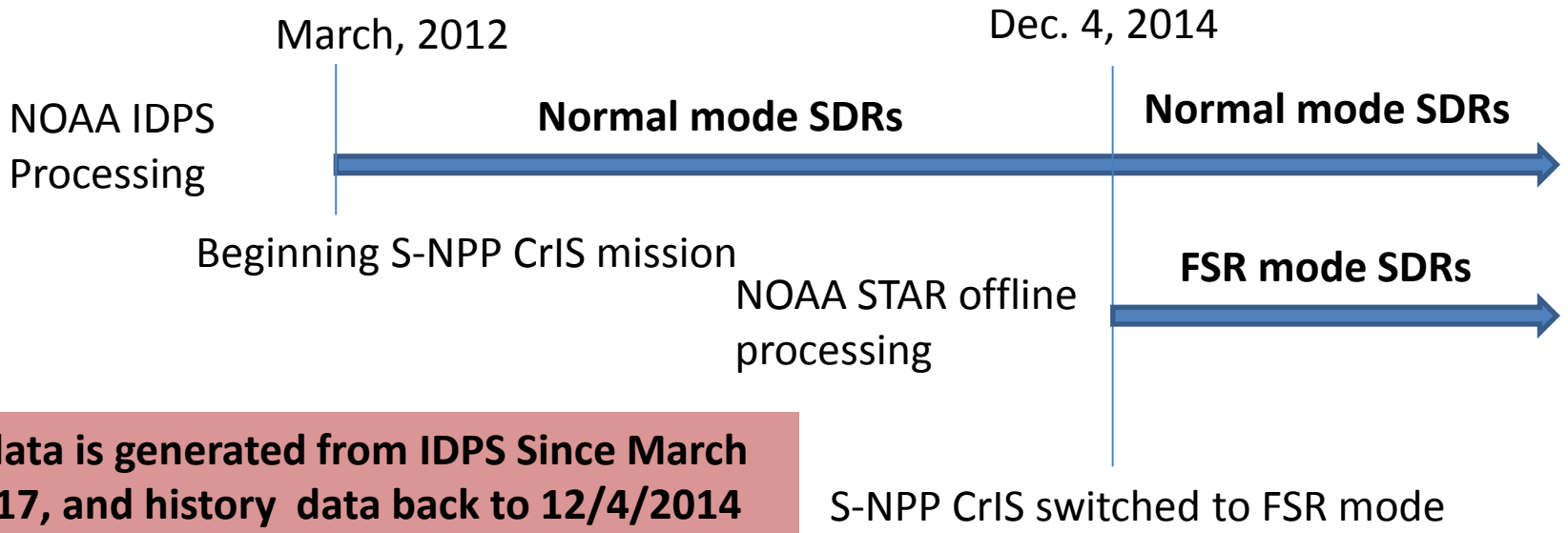
CrIS CH_4



AIRS CH_4

Cross-track Infrared Sounder (CrIS) on S-NPP and JPSS-1

Soumi National Polar-orbit partnership (S-NPP)
Joint Polar Satellite System (JPSS)



FSR data is generated from IDPS Since March 8, 2017, and history data back to 12/4/2014 can be obtained from STAR

- **CrIS started to operate in the full spectral resolution (FSR) mode since Dec.4, 2014, with spectral resolution of 0.625 cm^{-1} for all three bands, thus has 2211 channels as compared to 1305 channels in normal mode;**