Quantification of strong emissions of methane in the Arctic using spectral measurements from TANSO-FTS and IASI

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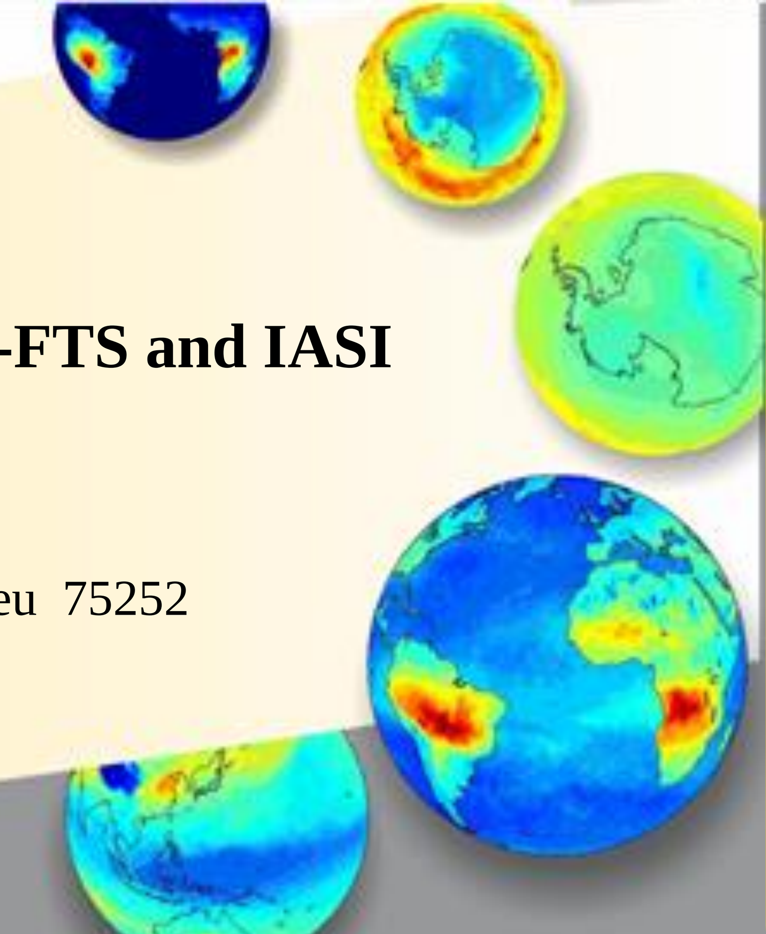

Quantification of strong emissions of methane in the Arctic using spectral measurements from TANSO-FTS and IASI

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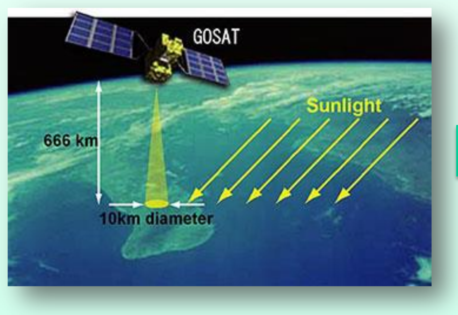
Introduction

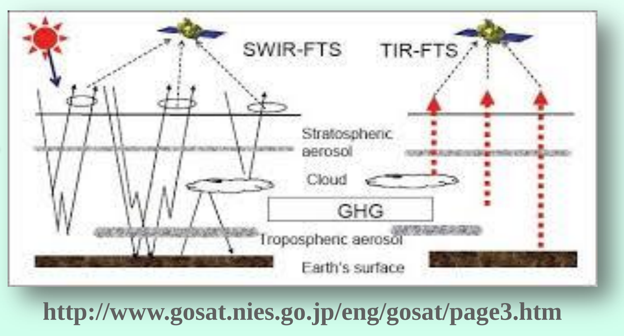
Methane is the second most important greenhouse gas in the atmosphere after carbon dioxide, but it is 25 times more effective in terms of radiative forcing (IPCC-2007). It plays also an important role in atmospheric ozone chemistry.
Since the pre-industrial times global methane concentrations have more than doubled in the atmosphere, and this increase is generally caused by anthropogenic activities like the massive use and extraction of fossil fuel, rice paddy agriculture and emissions from landfills.
In the Arctic region, methane emissions from thawing permafrost become potentially important due to climate warming and the large carbon pools stored in this region. These emissions are controlled by the temperature, and because methane is a greenhouse gas its emission could entail positive feedback, so it is very important to monitor and quantify its concentration in the atmosphere in real-time. This study consists of evaluating and quantifying methane strong emissions in the Arctic region using measurements in the TIR from IASI and TANSO-FTS.

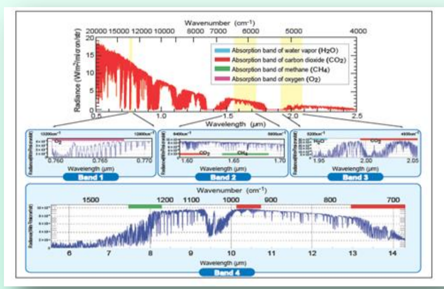
I. Instruments

1) TANSO-FTS /GOSAT

TANSO-FTS (Thermal And Near Infrared Sensor for Carbon Observations) is a nadir looking Fourier Transform Spectrometer that observes sunlight reflected from the earth's surface and the light emitted from the atmosphere and surface.





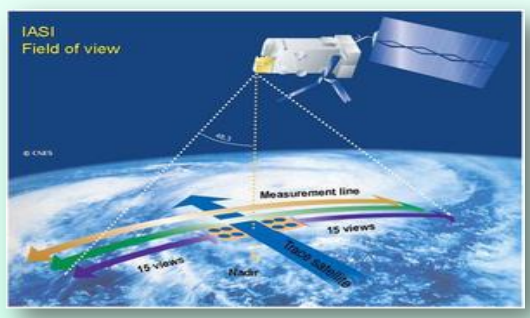


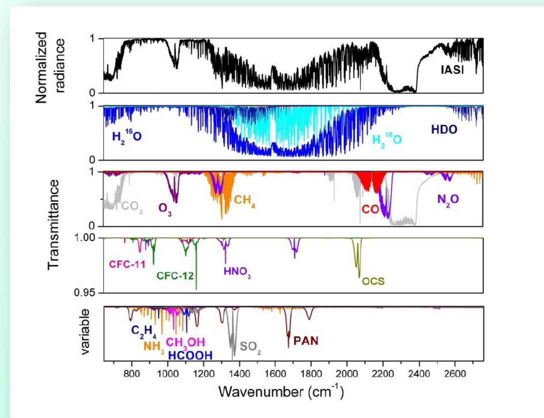
http://www.gosat.nies.go.jp/eng/gosat/page3.htm

- **Spectral resolution : 0.2 cm^{-1}**
- **Spectral coverage : 3 bands in the SWIR centered at 13158, 6250 and and 5000 cm^{-1} and one band in the TIR (700 – 1800 cm^{-1}).**
- **TANSO-FTS takes 56 000 measurements covering the globe in 3 days.**

2) IASI /MetOp

IASI (Infrared Atmospheric Sounding Interferometer) is a Fourier transform spectrometer at nadir looking based on a Michelson interferometer coupled to an imaging instrument, designed to measure the spectrum emitted by the earth-atmosphere system in the thermal infrared radiation (TIR).





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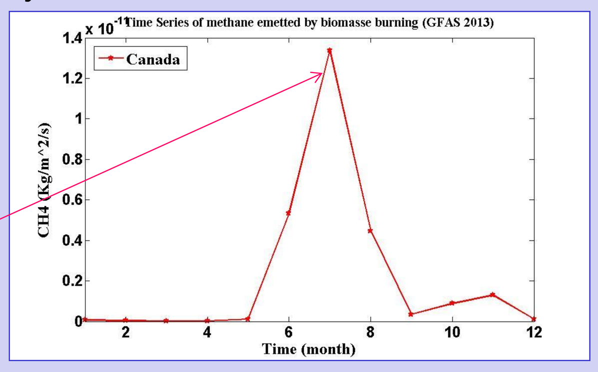
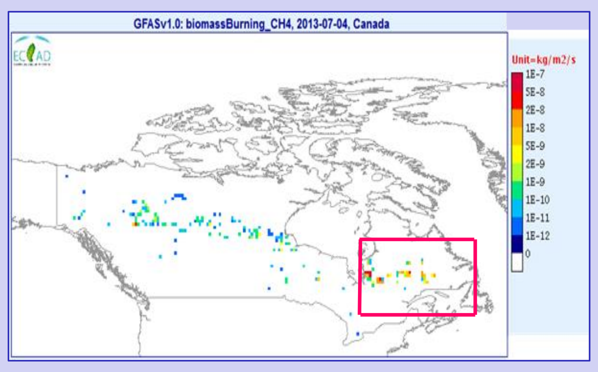
- **Spectral resolution : 0.5 cm^{-1}**
- **Spectral coverage : 645 cm^{-1} – 2760 cm^{-1}**
- **Noise equivalent at 280 K in the spectral range of interest for methane : 0.1K**
- **IASI provides global Earth's coverage twice a day.**

II. Sensibility of TANSO-FTS and IASI to detect hotspots of CH_4 on the surface

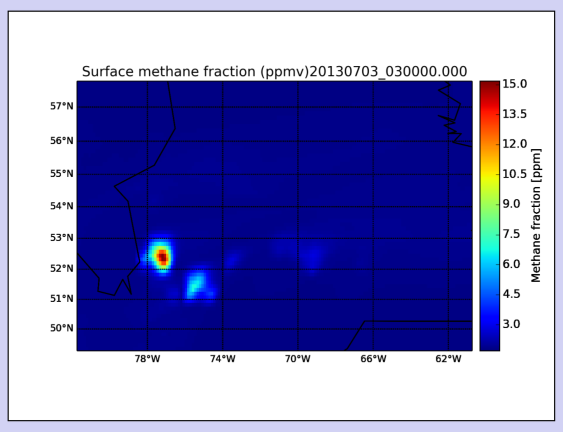
To study the sensibility of TANSO-FTS and IASI to detect high methane surface emissions, we used simulations from MACC-II (Monitoring Atmospheric Composition and Climate-II) .
MACC-II is a high-resolution model (0.125°x0.125°, 137 pressure levels and 3 hours of temporal resolution), it's based on TM5-4DVAR inverse modeling system (Bergamashi et al., 2010).
MACC-II used satellite retrievals from SCIAMACHY until end of 2011, but since the beginning of 2012 the GOSAT RemoteC PROXY v2.0 XCH4 retrievals have been used.
We choose period of high surface methane emission in Canada during 2013 according to the biomass burning emission inventory used by the model.

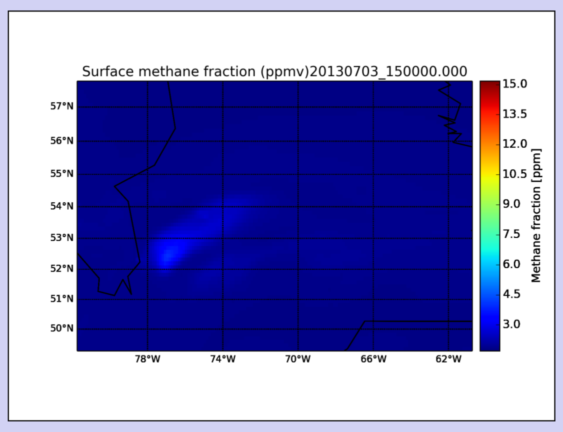
Pic of methane by biomass burning emission observed on July 2013 over Canada

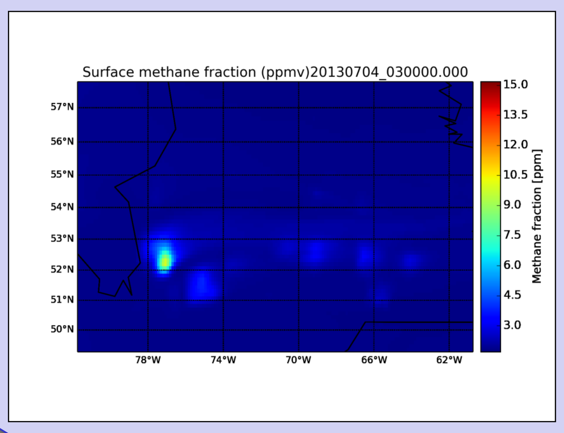


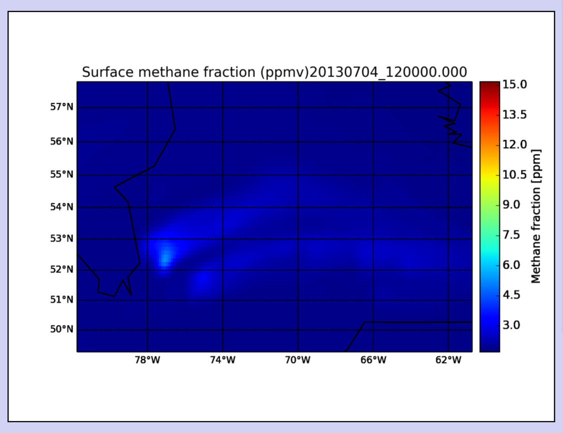


We analyzed data from MACC-II for a 8 days period (from July 1st to 8th) which correspond to the maximum of surface methane emission in the set of data.



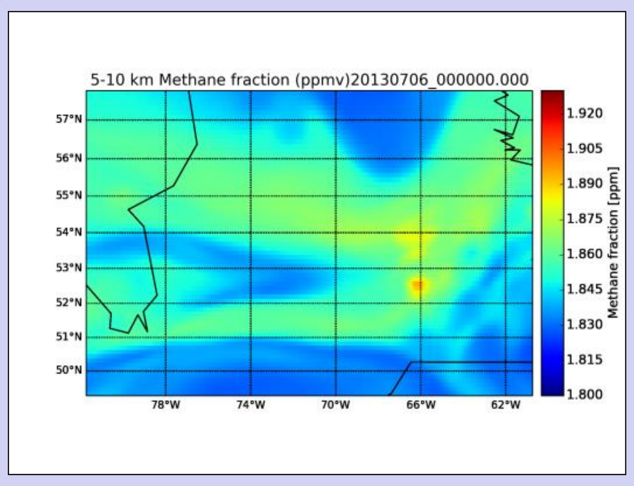




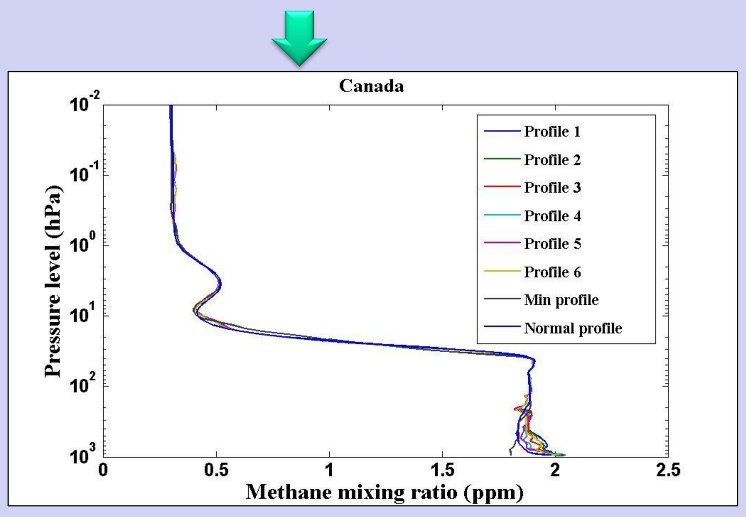


- **Strong methane surface emissions are seen on July 3rd and 4th.**
- **On July 3rd , the emission lasted 12 hours (from 3:00 to 15:00 UTC).**
- **On July 4th, it lasted 9 hours (from 3:00 to 12:00 UTC).**
- **Because the sensibility of IASI and TANSO-FTS to methane is higher between 5 and 10 km (and not close to the surface), we selected data with high column of methane between these two layers. Then, using the extracted methane profiles, we compute a set of spectra.**

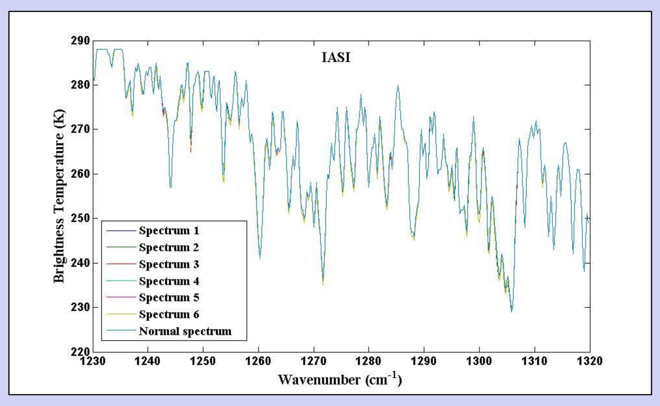
1) Results :

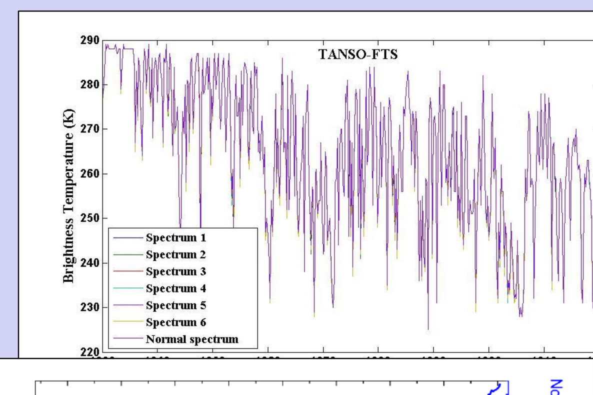


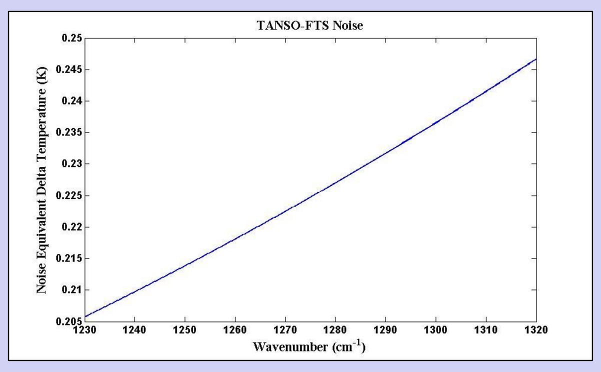
- **Maximum of methane between 5 and 10 km was observed on July 6th at midnight.**
- **We extracted set of methane profiles, which correspond to high values of methane between 5 and 10 km to simulate their spectra.**
- **To compute this set of spectra, we used LARA algorithm (LATMOS Atmospheric Retrieval Algorithm).**
- **The temperature profiles, pressure profiles and humidity profiles are extracted from ECMWF model.**
- **We used the instrumental function of IASI and that of TANSO-FTS to compute spectra for each instrument.**

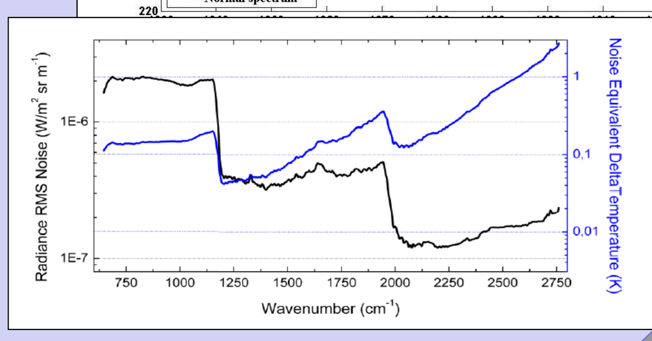


To study the capacity of TANSO-FTS and IASI to detect high values of methane due to strong emissions on the surface, we compare the differences in brightness temperature between spectra with high values of methane and that with current values to the thermal noise of TANSO-FTS and IASI.









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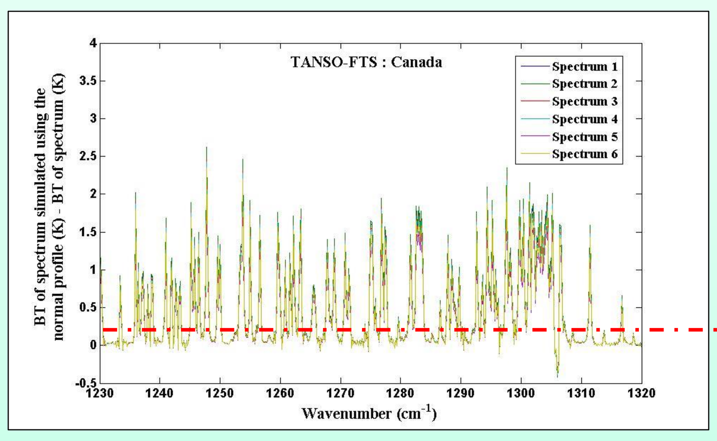
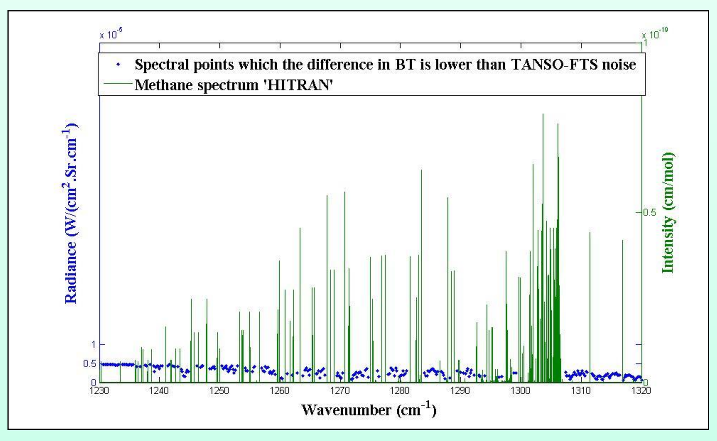
A) TANSO-FTS

- **We computed for each TANSO-FTS simulated spectrum the differences between its brightness temperatures and the brightness temperatures of the spectrum with current values of methane (spectrum of reference).**
- **We compared the differences in brightness temperature to TANSO-FTS noise equivalent delta temperature.**



TANSO-FTS Noise 0.2K

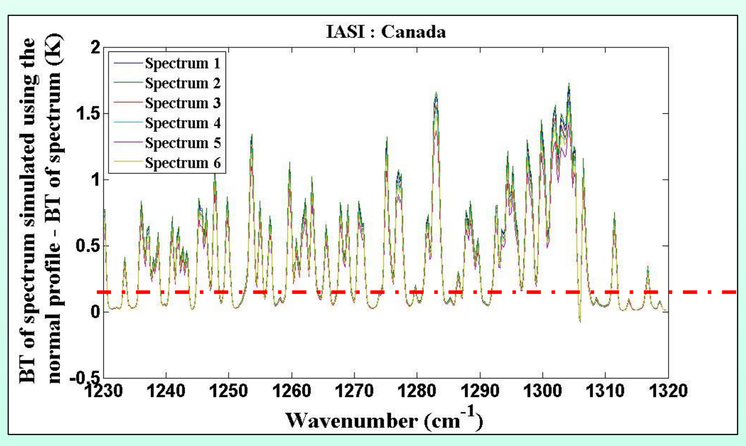


- ***The spectral points corresponding to a difference in BT < than TANSO-FTS noise does not overlap with methane lines.***

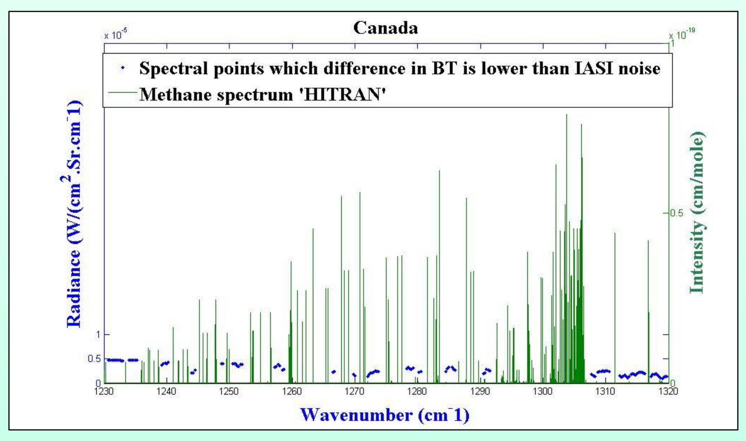
- ***TANSO-FTS is capable to detect a high values of methane due to a strong methane emissions on the surface.***

B) IASI

- **As TANSO-FTS, we compute the differences in brightness temperatures between each IASI spectrum simulated with high values of methane and that with current values of methane, and then we compare the differences in BT to IASI noise equivalent delta temperature.**



IASI noise 0.1K



- ***The spectral points which correspond to a difference in BT less than IASI noise do not overlap with methane spectrum.***

- ***IASI is capable to detect high values of methane due to a strong methane emissions on the surface.***

Conclusion and outlook

- **The results presented in this study show that TANSO-FTS and IASI allow to identify peaks of methane surface emissions with short duration transported to the layer between 5 and 10 km.**
- **We will add noise to our simulated spectra in order to study the ability of LARA algorithm to retrieve profile of methane and then model to inverse initial emission.**
- **In collaboration with LSCE laboratory, we will use the LMDZ-PYVAR to quantify methane emissions in the Arctic region.**

Acknowledgements

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