Initial Investigations into Mapping Biogenic and Abiogenic Green House Gases from Space

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1. Project Outline

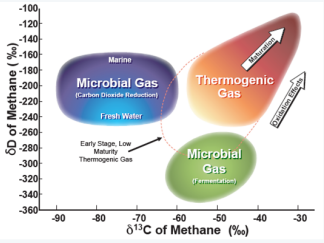


Figure 1 Composition of Methane in relation to its source. Courtesy of Raton Basin (2012)

Aim:
Map **global** distributions of biogenic and abiogenic **GHGs** from space via:
a) Retrieval of **isotopic** abundances of $^{12}CH_4$ and $^{13}CH_4$.
b) Retrieval of C_2H_6 volumes.

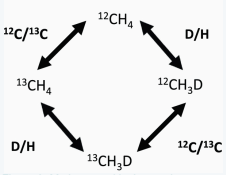


Figure 2: Methane and its Isotopologues. Courtesy of Nixon et al (2012)

What is an Isotopologue?:
Chemical species of **molecule** that contains at least one **isotope** in its structure.

Methane Sources:
The ability to **distinguish** between the **isotopologues** of methane, allows an observer to determine the source of the **methane** emissions. (Etiope 2009; (Breas, Guillou et al. 2001))

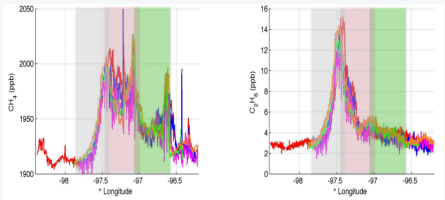


Figure 3 Methane with empathetic ethane measured over known seeps using a PICCARO CRDS (Rella, C.W & Crosson, E. 2013)

Ethane Empathy:
It has been shown that methane sources tend to emit **ethane** in measureable **ratios**. (Rella, C.W & Crosson, E. 2013)

2. EO Space Based Sensors

ACE:
We are using data from the Atmospheric Chemistry Experiment **(ACE)** Fourier Transform Spectrometer **(FTS)** which performs Atmospheric **Limb profiles** from solar occultations.

The ACE-FTS is a Fourier transform spectrometer with a spectral range of **2.2-13.3 µm** and a spectral resolution of 0.02cm^{-1}.

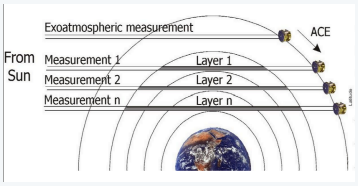


Figure 5: Representation of the orbit of ACE, whilst obtaining Atmospheric Limb profiles during Solar Occultation (Nassar 2006)

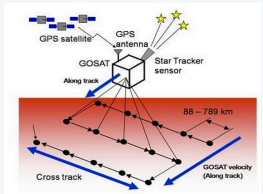


Figure 4: Representation of GOSAT retrieval via the nadir technique courtesy of JAXA

GOSAT:
The key instrument on **GOSAT** is the Thermal And Near infra-red Sensor for Carbon Observation (TANSO), which is composed of 2 separate units, **a Fourier Transform Spectrometer** (FTS) (similar to the instrument employed on ACE, but with a spectral range of **0.758-0.775µm, 1.56-1.72µm, 1.92-2.08µm & 5.56-14.3µm** and spectral resolution of 0.2cm^{-1}) and the **Cloud and Aerosol Imager** (CAI).

SCIAMACHY:
The Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY) is an **imaging spectrometer** based on the ENVISAT satellite.

The instrument is sensitive in the range of **240nm to 1700nm** with a spectral resolution of 0.2-0.5nm, and is capable of **nadir and limb** viewing geometries.

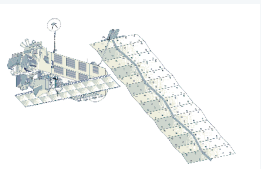


Figure 6: Representation of the ENVISAT satellite. (ESA, 2014)

3. GOSAT Gas Seep Detection

Gas Seep Detection Assessment:
An assessment of the current capability for detecting methane (CH_4) from **natural gas seeps** was carried out using the **TANSO** instrument on GOSAT, The Greenhouse Gases Observing Satellite. **Limited spatial coverage**, rather than resolution, prevents direct identification of point sources of CH_4.

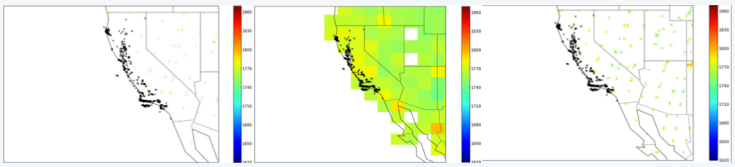


Figure 7a,b,c: California: Left to right, figure 7a: All GOSAT retrievals for August 2009 plotted as points (colour) against known seeps (black crosses). Figure 7b: All GOSAT retrievals for August 2009 averaged into 1 deg (latitude) by 2 deg (longitude) bins with known seeps (black crosses). Figure 7c: All GOSAT retrievals for August 2009 averaged into 5 by 5 km bins with known seeps (black crosses). The colour bar is ppbv. (Potts, D, et al. (2014))

Data Sources:
The proxy values of the column-averaged dry-air mole fraction of CH_4 in the atmosphere (in ppbv, also called the Volume Mixing Ratio), which is referred to as **XCH_4**, were taken from the **University of Leicester** Earth observation Science Greenhouse Gas Dataset, which contains global land coverage for 2.5 years from **mid-2009 to the end of 2011** (Potts, D, et al. (2014); Parker, R, et al. (2011)).

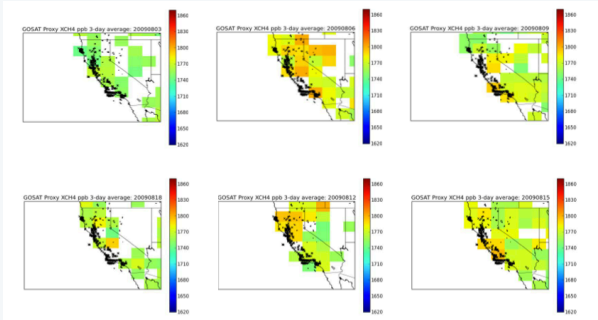


Figure 8: California: GOSAT retrievals averaged over every 3 days within the first half of August 2009 into 1 deg (latitude) by 2 deg (longitude) bins with known seeps (black crosses). The colour bar is ppbv. Dates are at the top of each plot. Time progresses left to right, top to bottom. (Potts, D, et al. (2014))

Simulations:
An assessment to find $^{13}CH_4$ & C_2H_6 lines in the **TIR** was carried out, first using the **HITRAN** database, followed by the **ORFM**. The aim of this assessment was to identify where the spectral lines for the molecules could be found using simulated **ACE and GOSAT** instruments. The results from this assessment are shows in these panels.

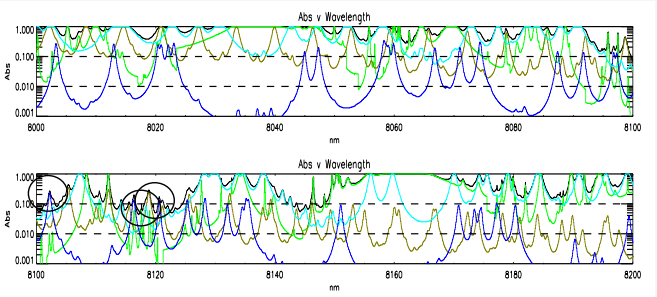
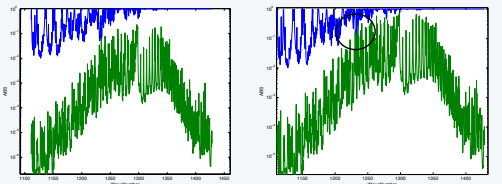


Figure 9: HITRAN data showing absorption plots (between 8000nm and 8200nm) where brown represents NO_2 **green represents H_2O**, cyan represents $^{12}CH_4$ **and blue represents $^{13}CH_4$**

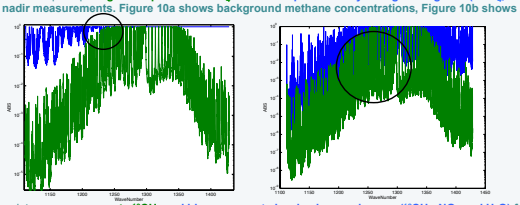
High Resolution Transmission (HITRAN):
Database of spectral lines for **multiple species** (around 50), updated every couple of years (Currently using **HiTRAN2012**).

4. Methane in the Thermal Region

Oxford Reference Forward Model (ORFM):
Freely available **Radiative Transfer Model** (RTM) developed at the University of Oxford. Originally designed to simulate the **MIPAS** instrument of ENVISAT.

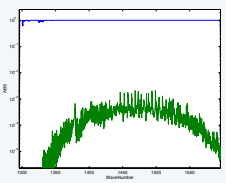


Figures 10a,10b: Absorption plots **green represents $^{13}CH_4$ and blue represents key background gases ($^{12}CH_4$, NO_2 and H_2O) from GOSAT-TANSO-FTS nadir measurements. Figure 10a shows background methane concentrations, Figure 10b shows 20ppmv concentration**

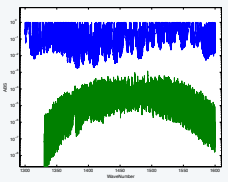


Figures 11a,11b: Absorption plots **green represents $^{13}CH_4$ and blue represents key background gases ($^{12}CH_4$, NO_2 and H_2O) from ACE-FTS limb profiles. Figure 11a shows background methane concentrations at 5km altitude, Figure 11b shows background concentration at 20km altitude.**

4. Ethane in the Thermal Region



Figures 12: Absorption plots **green represents ethane at background concentration and blue represents key background gases ($^{12}CH_4$, NO_2 and H_2O) from GOSAT-TANSO-FTS nadir measurements.**



Figures 13: Absorption plots **green represents ethane at background concentrations and blue represents key background gases ($^{12}CH_4$, NO_2 and H_2O) from ACE-FTS limb profiles at 20km altitude.**

5. Conclusions

- It is clear that in theory $^{13}CH_4$ **is observable** from both ACE and GOSAT in the **TIR waveband**.
- However C_2H_6 is **only observable** from ACE in this spectral region under **very specific conditions**, BUT the concentrations required make this **unlikely.**
- The ORFM simulations indicate that the resolution of the **SCIAMACHY** instrument will make resolving individual $^{13}CH_4$ lines **improbable** in the TIR waveband

6. References

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