Sniffing for Biogenic Methane from Space – An Investigation

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1. Project Outline

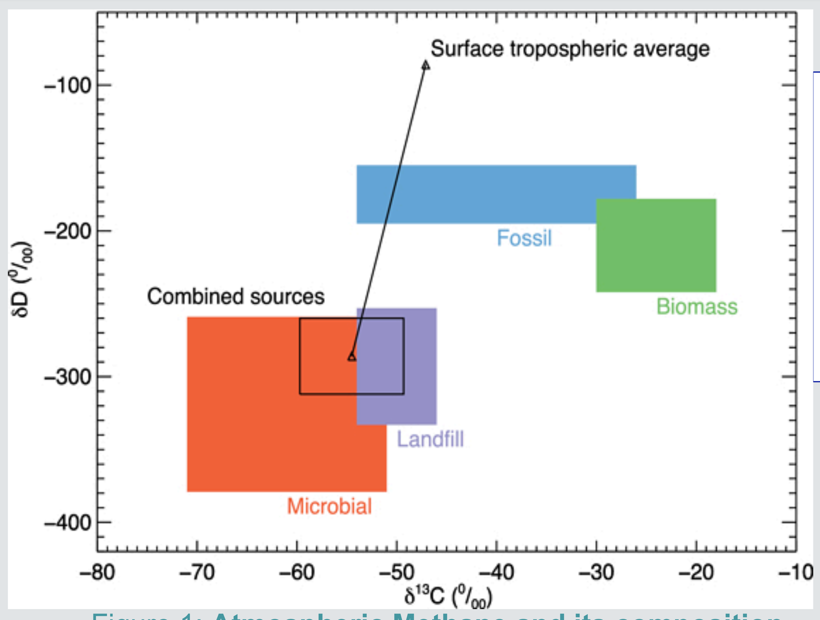


Figure 1: Atmospheric Methane and its composition. Courtesy of Rigby et al (2012).

1.1. Aim:

Map **global** distributions of biogenic and abiogenic **GHGs** from space via retrieval of **isotopic** abundances of $^{12}CH_4$ and $^{13}CH_4$.

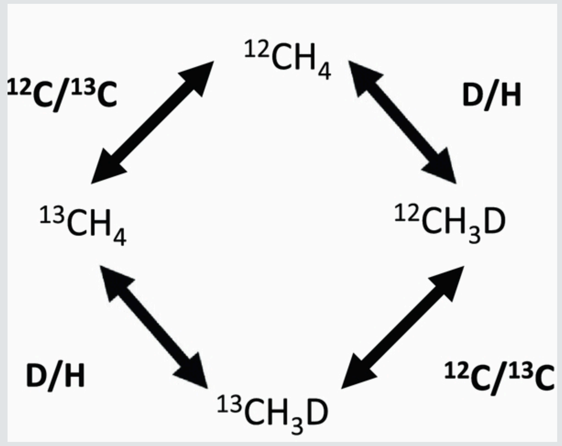


Figure 2: Methane and its Isotopologues. Courtesy of Nixon et al (2012)

1.2. What is an Isotopologue?:

Chemical species of **molecule** that contains at least one **isotope** in its structure.

1.3. 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))

2. EO Space Based Sensors

2.1. 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) 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}.

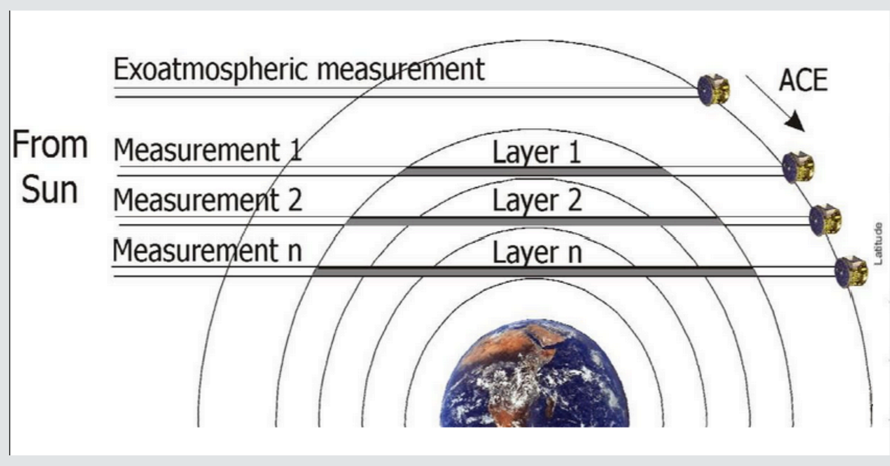


Figure 3: Representation of the orbit of ACE, whilst obtaining Atmospheric Limb profiles during Solar Occultation (Nassar 2006)

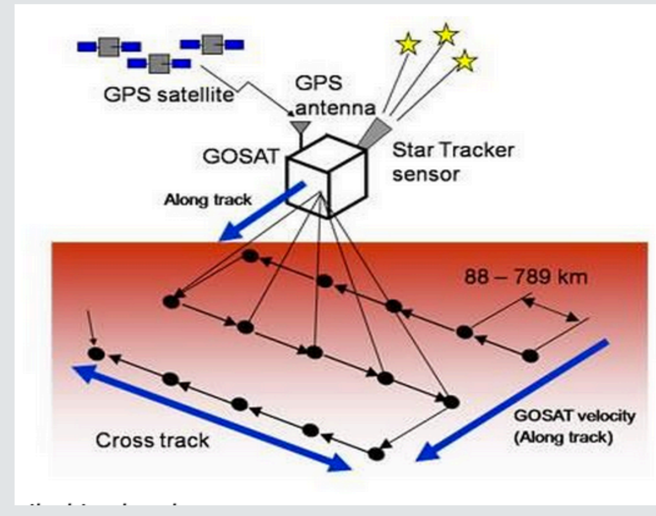


Figure 4: Representation of GOSAT retrieval via the nadir technique courtesy of JAXA

2.2. 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}.

3. Isotopologues in the SWIR Region

3.1. Simulations:

An assessment to find $^{13}CH_4$ lines in the **SWIR** 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.

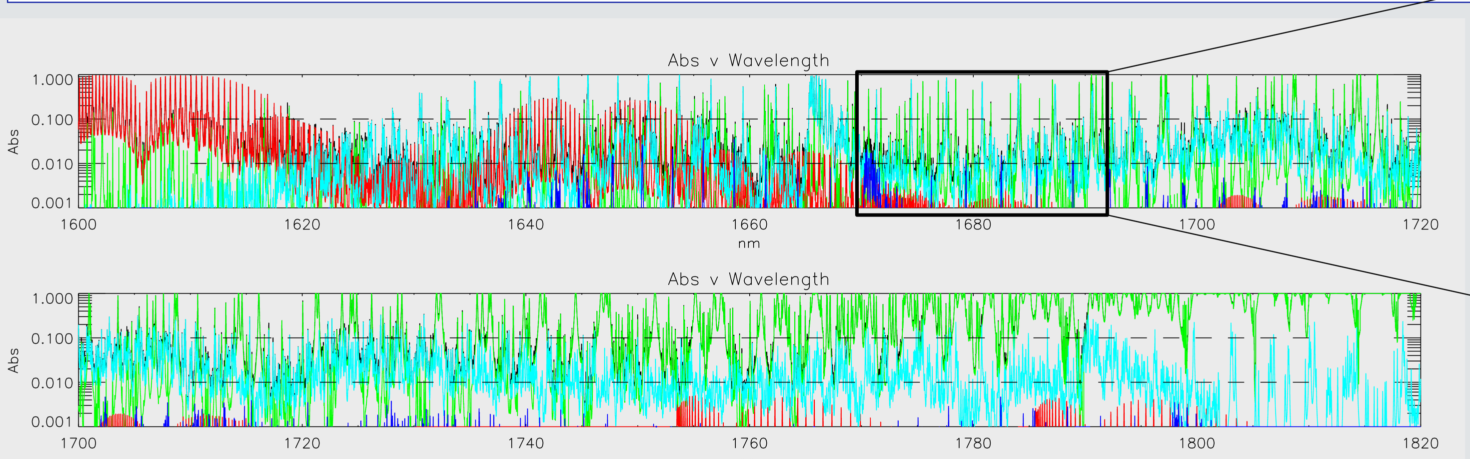


Figure 5: HITRAN data showing absorption plots (between 1600nm and 1820nm) where red represents CO_2 green represents H_2O, cyan represents $^{12}CH_4$ and blue represents $^{13}CH_4$

3.2. High Resolution Transmission (HITRAN):

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

3.3. 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. Adapted to simulate the SWIR.

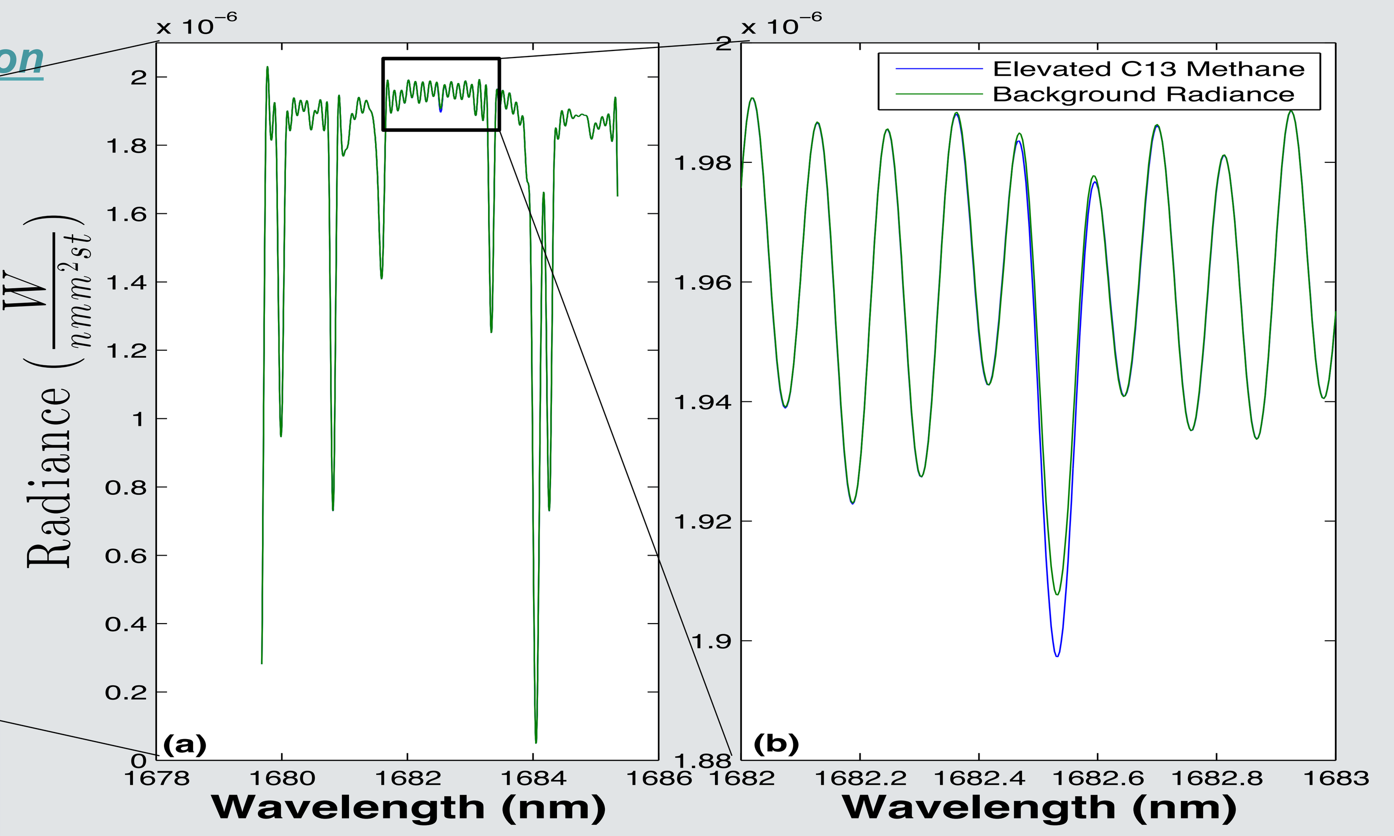


Figure 6: Radiance spectra simulated by the ORFM convolved with GOSAT-TANSO-FTS instrument line shape in a very short wave range. Background gas concentrations and elevated $^{13}CH_4$ concentrations are simulated in order to highlight $^{13}CH_4$ spectral lines

4. Isotopologues in the Thermal Region

4.1. Simulations:

An assessment to find $^{13}CH_4$ lines in the **TIR** was carried out following the methodology of the SWIR assessment above, i.e. with HITRAN and the ORFM.

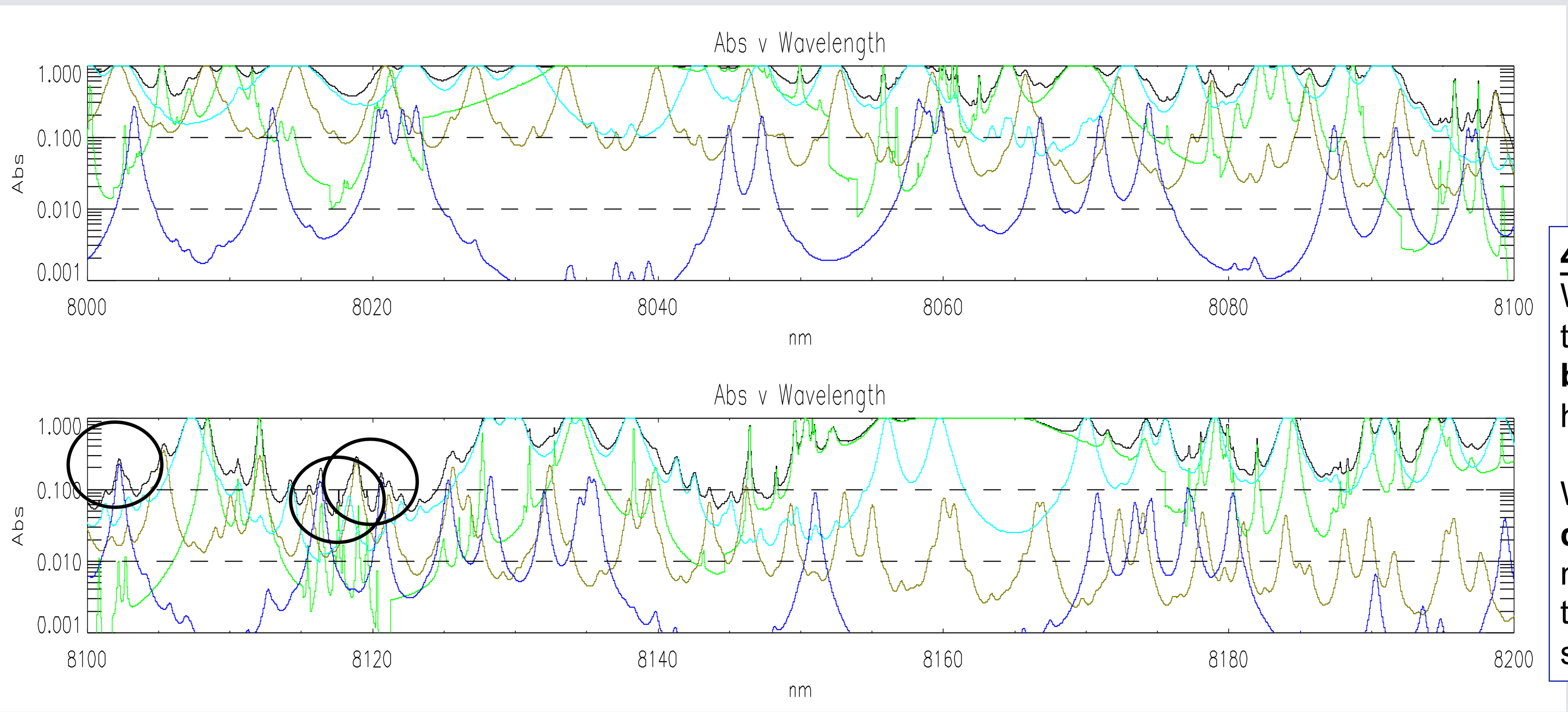
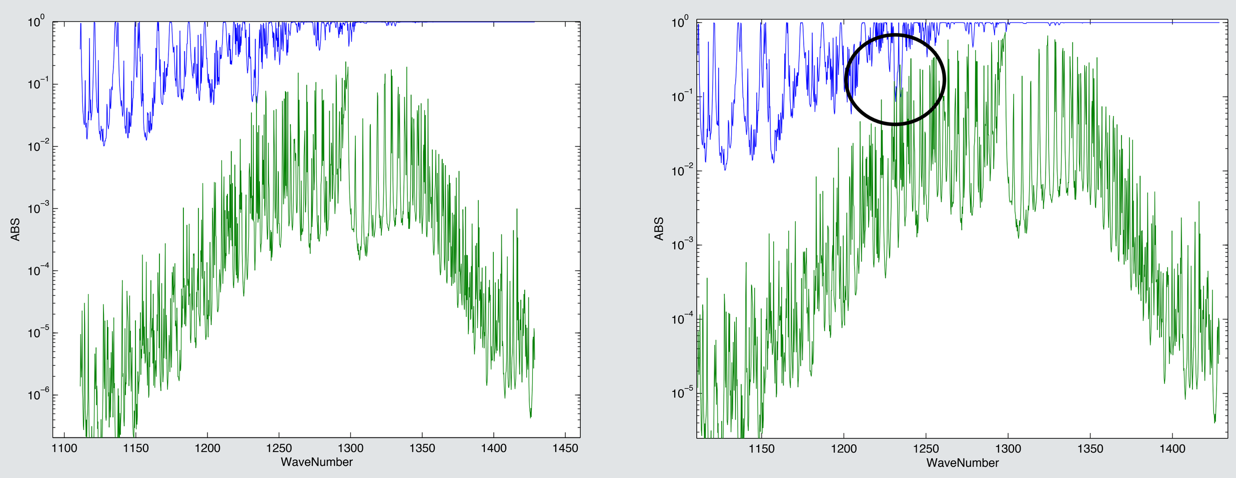


Figure 7: HITRAN data showing absorption plots (between 8000nm and 8200nm) where brown represents NO_2 green represents H_2O, cyan represents $^{12}CH_4$ and blue represents $^{13}CH_4$

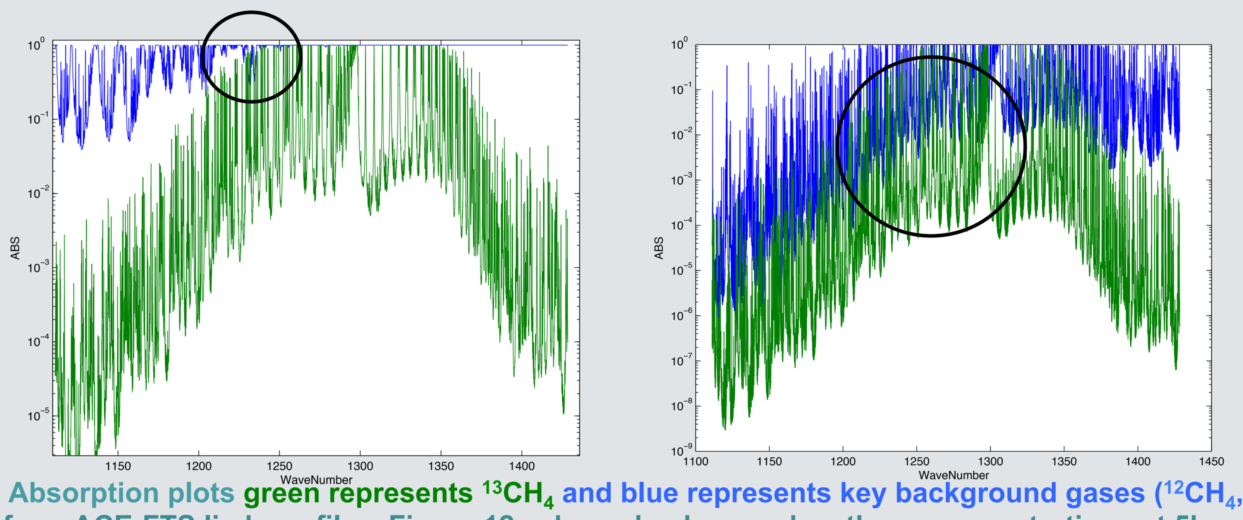
4.2. Thermal Troubles!:

We **struggle** to find $^{13}CH_4$ spectral regions that have absorption over and **above the background** gas levels with GOSAT, however it is relatively easy with ACE.

We also note that thermal remote sensing **does not provide** accurate measurements of the **lower troposphere,** thus making it difficult to identify methane sources/sinks.



Figures 8: 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 11a shows background methane concentrations, Figure 11b shows 20ppmv concentration



Figures 9: 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 12a shows background methane concentrations at 5km altitude, Figure 12b shows background concentration at 20km altitude.

5. Radiative Transfer Model Inter-comparison

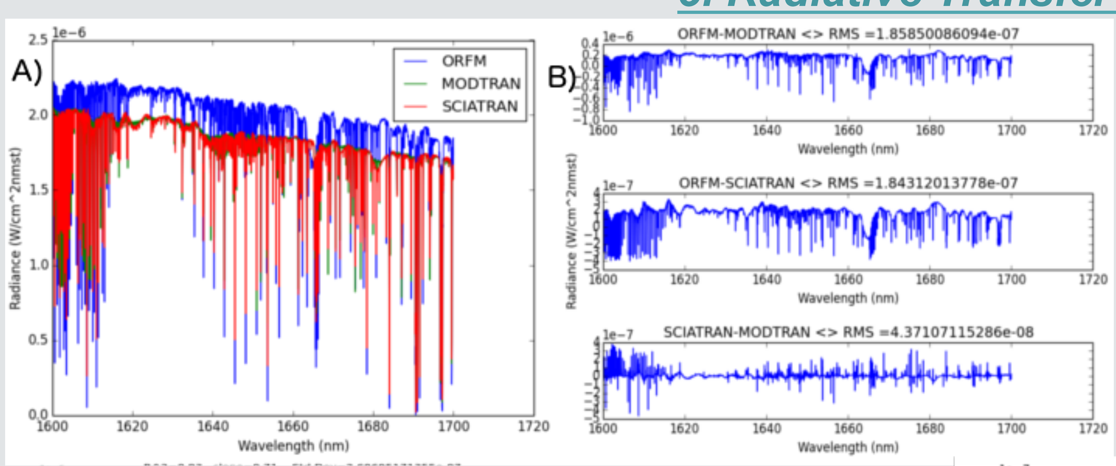


Figure 10: Radiance spectra in the range 1600-1700nm simulated by the models MODTRAN, SCIATRAN and the ORFM, under identical conditions. Figure 10A shows a direct comparison between simulated spectra and Figure 10B shows the difference between each of the models

5.1. Can we rely on RTMs?

Following the study on Isotopologues, an **investigation** was performed into identifying the accuracy of **ORFM** simulations, by comparing against the established RTMs **MODTRAN** and SCIATRAN

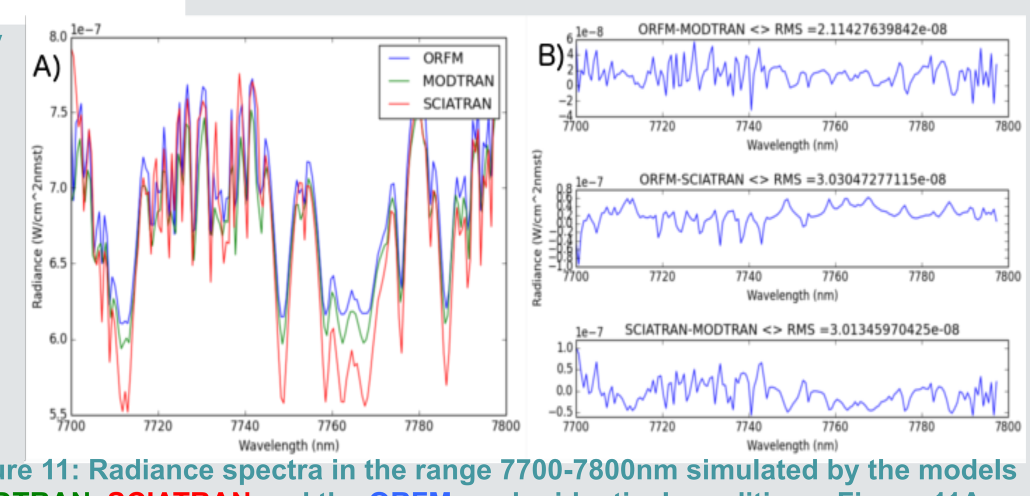


Figure 11: Radiance spectra in the range 7700-7800nm simulated by the models MODTRAN, SCIATRAN and the ORFM, under identical conditions. Figure 11A shows a direct comparison between simulated spectra and Figure 11B shows the difference between each of the models

6. Conclusions

- ORFM assessments show that there is at least **one $^{13}CH_4$ spectral line** that is resolvable with GOSAT-TANSO-FTS under **standard atmospheric conditions**.
- This suggests that in **theory it is possible** to **observe $^{13}CH_4$** from GOSAT under standard atmospheric conditions.

- It is clear that in theory $^{13}CH_4$ **is observable** from both ACE and GOSAT in the 7.7-8.3μm **TIR waveband**.
- However in the GOSAT-TANSO-FTS simulation the $^{13}CH_4$ lines are **not observable under standard condition**s, only under very high concentration conditions.

- The RTM intercomparion study shows that there is a **high level of agreement** between all three models in the **thermal** region.
- However the SWIR assessment shows a **minor bias** in the ORFM radiance simulations, suggesting that the **SWIR extension** of the ORFM can be used with caution.

7. References

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