Comparisons of methane from ACE, GOSAT, and PEARL

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1. Motivation for studying methane

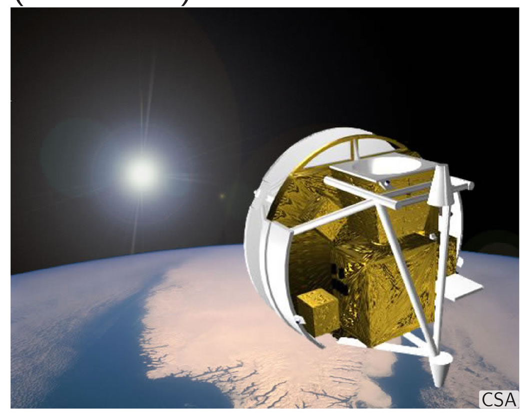
- 3^{rd} most important greenhouse gas, 2^{nd} most important anthropogenic greenhouse gas
- Sources are either anthropogenic or natural. Sources can be biogenic (natural wetlands, ruminants, landfills, ...), thermogenic (transformation of organic matter into fossil fuels on geological time scales), or pyrogenic (biomass burning) [4, section 6.3.3.2]
- Sink mostly chemical, due to reaction with OH (hydroxyl radical) in troposphere and stratosphere [4, section 6.3.3.3]
- Retrieval error dominated by complicated spectroscopy [1, 9]

Focus on the Arctic

The Arctic is a challenging place for understanding methane

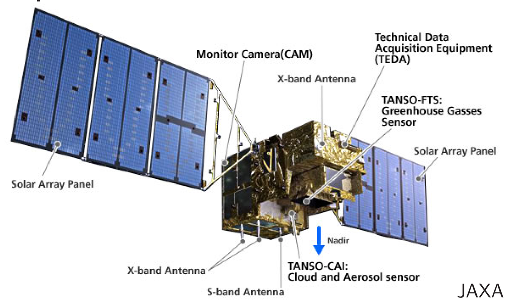
2. Instruments to be compared

Canadian SCISAT-1 (ACE-FTS)



Spaceborne Fourier Transform Spectrometer (FTS) since 2003 [2]. Orbit 650 km, 74°. Solar occultation geometry gives high Signal to Noise Ratio (SNR) and high vertical resolution, but relatively few measurements. Covers 750 cm^{-1}–4400 cm^{-1} (13.3 µm–2.273 µm) with resolution of 0.02 cm^{-1}. Present study uses version 3.5 [3].

Japanese GOSAT TANSO-FTS



Down-looking, sun-synchronous satellite since 2009 [6]. Carries FTS [10]. Good horizontal resolution, many measurements, lower SNR than solar occultation measurements. Present study uses thermal band, which covers 700 cm^{-1}–1800 cm^{-1} (5.5 µm–14.3 µm) with a resolution of 0.02 cm^{-1}. TANSO-FTS also has three solar bands.

PEARL Bruker FTIR at Eureka, Umingmak Nuna (Ellesmere Island), Nunavut, Canada

Ground-based solar occultation FTS since 2006 [1]. Located at 80° N, 86° W, 610 m. Implemented filters cover 700 cm^{-1}–4300 cm^{-1} (14.3 µm–2.326 µm) with a resolution up to 0.0024 cm^{-1}.

3. Validation methodology

Remote sensing is underconstrained: we are measuring radiance $\mathbf{y}$ which is a complicated and imperfectly known function of the desired quantity (the *state*, $\mathbf{x}$) and other quantities $\mathbf{b}$ also influencing the measurement [8],

$$\mathbf{y} = F(\mathbf{x}, \mathbf{b}) + \varepsilon$$

where ε is the measurement error. We can only *estimate* the state indirectly and using additional information using a retrieval method,

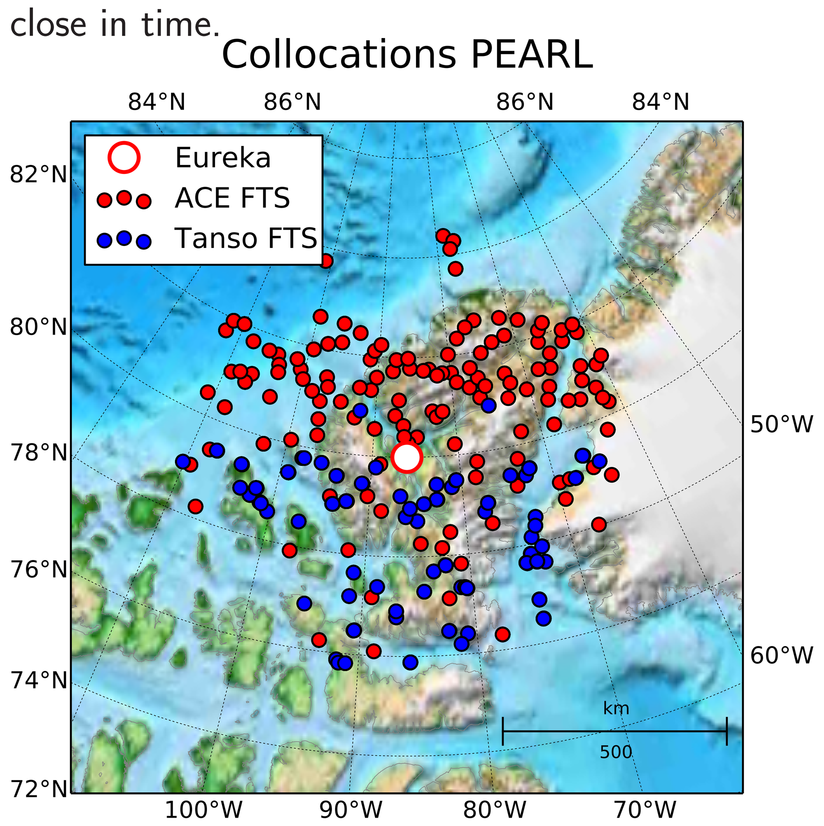
$$\hat{\mathbf{x}} = \mathcal{I}(\mathbf{y}, \hat{\mathbf{b}}, \mathbf{x}_a, \mathbf{c})$$

where $\mathcal{I}$ is some inverse model, $\hat{\mathbf{b}}$ an estimate of $\mathbf{b}$, $\mathbf{x}_a$ a prior estimate of $\hat{\mathbf{x}}$ that may or may not be used, and $\mathbf{c}$ has parameters that do not occur in F, but do affect the retrieval.

Regardless of the retrieval method, $\hat{\mathbf{x}}$ will be different from $\mathbf{x}$. **The aim of validation is to tell how different the retrieved state is from the true state.** Regrettably, *we don't know the true state*. Therefore, our second best method is to compare independent retrievals.

4. Collocations

To compare independent retrievals, we use *collocations*: instances where different instruments observe the same state sufficiently close in time.



- Maximum collocation distance is 500 km, maximum time interval 24 h. For CH_4, using tighter criteria does not improve the comparisons.
- PEARL vs. ACE: 1222 pairs, 2006-09-27 – 2011-03-12. Unique measurements: PEARL 448, ACE 138.
- PEARL vs. TANSO: 1280 pairs, 2010-04-30 – 2010-10-01. Unique measurements: PEARL 183, TANSO 174.
- We use ground-based PEARL as a reference, because it is the most well-calibrated instrument and continuously accessible.
- Still to be considered:
  - Path through the atmosphere for each observation
  - Position relative to polar vortex (using potential vorticity) which affects dynamics in polar areas; places close in distance may still observe rather different airmasses

5. Comparison methodology

Even after collocating, profiles cannot be compared directly:

- First, they need to be interpolated on a common vertical grid $\mathbf{x}(z)$.
- Then, the profile with the highest vertical resolution needs to be smoothed using the averaging kernel matrix from the profile with the lowest vertical resolution, following Rodgers and Connor [7],

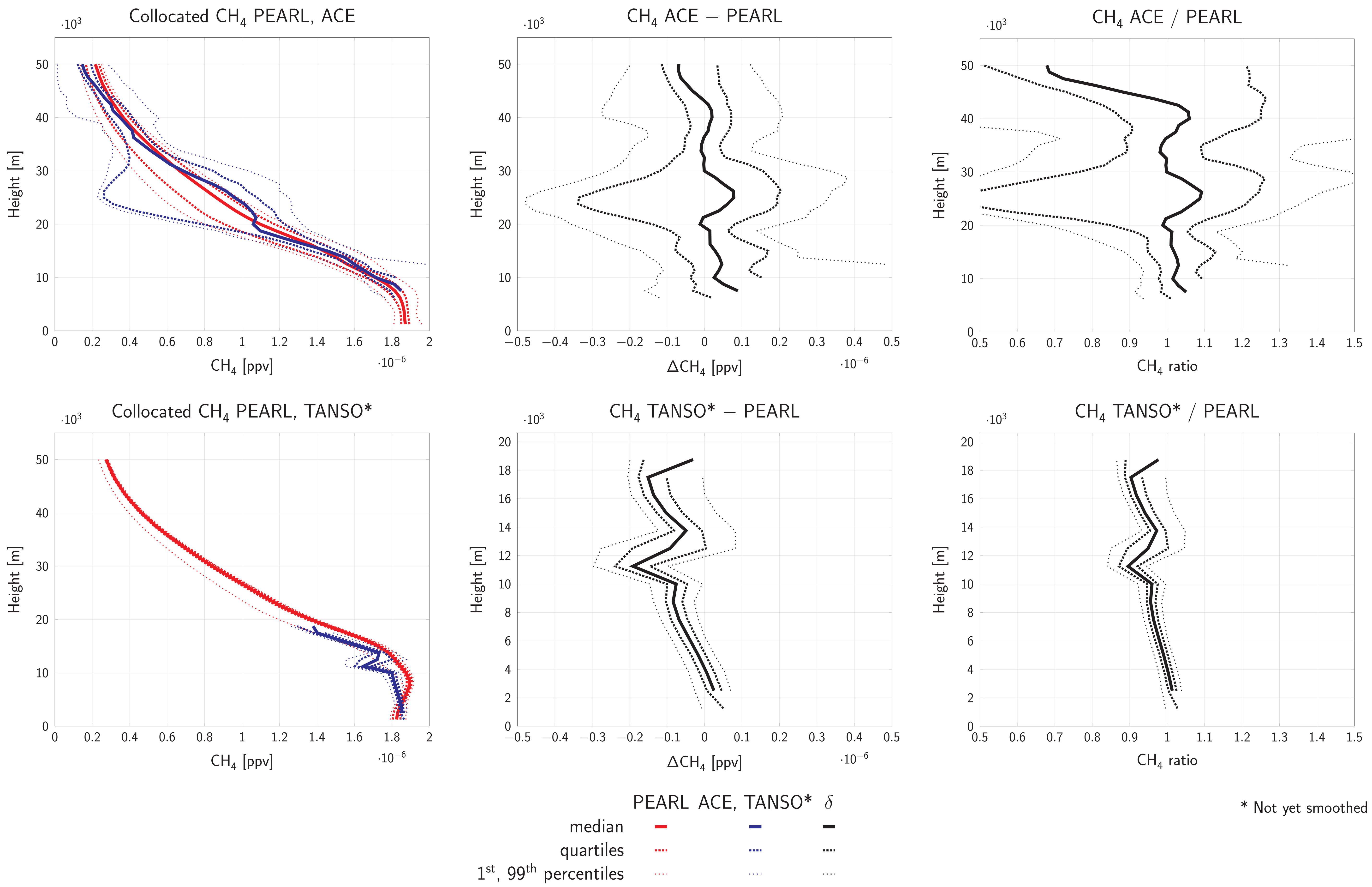
$$\mathbf{x}_s = \mathbf{x}_a + \mathbf{A}(\mathbf{x}_h - \mathbf{x}_a)\,,$$

where $\mathbf{x}_h$ is the original high-resolution profile, $\mathbf{A}$ and $\mathbf{x}_a$ are the averaging kernel matrix and the a-priori profile for the low-resolution profile, respectively, and $\mathbf{x}_s$ is the smoothed high-resolution profile, to be compared against the low-resolution profile.
- Then, following Dupuy et al. [5], we calculate the difference as a function of altitude,

$$\delta(z) = \frac{\mathbf{x}_s(z) - \mathbf{x}_{PEARL}(z)}{\mathbf{x}_{ref}(z)}\,,$$

and present the median for $\mathbf{x}_{ref} = 1$ and $\mathbf{x}_{ref} = \mathbf{x}_{PEARL}$ in the next column, for $\mathbf{x}_s$ referring to either $\mathbf{x}_{ACE}$ or $\mathbf{x}_{TANSO}$.

6. Results



* Not yet smoothed

7. Future work

- Improve collocations: consider path through atmosphere and location with respect to polar vortex
- Improve comparison: extend smoothing to TANSO, compare in terms of partial columns, consider ACE flags
- Publish results at conferences and in written form

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