Novel concept for a small, cheap space-borne methane imager: a CEOI Seedcorn Project

Hartmut Boesch[1], Robert Parker[1], Paul Palmer[2], Dan Lobb[3], Mike Cutter[3]

[1]EOS Group, Space Research Centre, Department of Physics and Astronomy, University of Leicester, Leicester, UK

[2]School of GeoSciences, University of Edinburgh, Edinburgh, UK

[3]Surrey Satellite Technology Ltd. , Guildford , UK

Project Summary

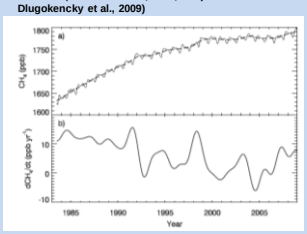
We define a novel concept for measuring atmospheric column concentrations of the greenhouse gas methane (CH_4) based on the use of discrete shortwave infrared spectral bands. We will use the CH_4 proxy retrieval method to infer atmospheric concentrations, which has proven heritage with SCIAMACHY and most recently successfully employed by Leicester University for GOSAT. Such an instrument concept offers significant advantages over existing systems in terms of size and superior spatial resolution, providing a realistic option for a small satellite payload such as the SSTL TechDemoSat platform which will also open the possibility for commercial observing systems of greenhouse gas emissions.

1. Why is methane (CH_4) is important to measure?

Overview over the global methane sources and their estimated emission (Palmer, P. I. and A. A. Bloom, NERC Planet Earth, Summer 2010 Edition)

- Atmospheric CH_4 is a potent greenhouse gas with warming potential of 20 times higher than for CO_2 and a radiative forcing comparable with CO_2 over a 20 year period
- Atmospheric CH_4 concentrations are determined by emission from several natural and anthropogenic sources and loss by OH and soils (see left Figure)
- Emissions sources for CH_4 are poorly quantified and methane growth rates (see right Figure) show significant anomalies which are not well understood
- In warming climate, CH_4 release from melting permafrost or from marine hydrates can lead to climate further accelerating warming.

Trend (top) and growth rate (bottom) in atmospheric methane (O'Connor et al., 2010, adopted from Dlugokencky et al., 2009)

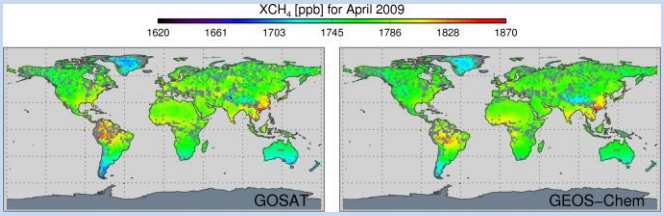


2. CH_4 Observations from Satellites

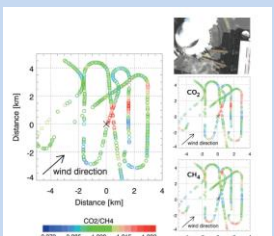
- Satellite observations are a powerful tool for monitoring atmospheric CH4 and to complement the accurate, but sparse surface networks
- Shortwave-infrared (SWIR) soundings from satellite provide global, dense and continuous column observations with high-sensitivity to the boundary layer that are well suited for constraining surface emissions
- There is now good heritage in space CH_4 column retrieval from the SWIR sensors SCIAMACHY and GOSAT

Artist impression of the Japanese GOSAT mission, the first dedicated greenhouse gas sensor launched in 2009

- CH_4 proxy retrieval method is an elegant and simple method for retrieving CH_4 columns that has been initially developed for SCIAMACHY
- CH_4 proxy retrieval method I is based on retrieval of CH_4/ CO_2 ratio from retrieval around 1.6 µm:
  - Effects of scattering from aerosol and clouds are effectively minimized (no need for dedicated aerosol bands in the instrument)
  - Can achieve denser data coverage than typical full-physics approaches
  - Can also be applied to low resolution spectra
  - Well suited for observing localized hot spots that emit either CO_2 or CH_4, e.g. power plant, land fills, volcanoes …



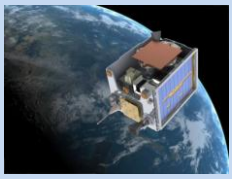
Atmospheric CH_4 retrieved with the CH_4 proxy retrieval method from GOSAT and calculated with a global atmospheric transport model (Parker et al., 2011)



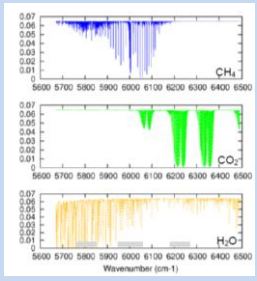
CO_2, CH_4 and the CO_2/CH_4 ratio measured with an aircraft instrument on 26 July 2007 over the power plant Jaenschwalde (black cross) located north of Cottbus (south-east of Berlin) in Eastern Germany. Most of the variability observed in CO_2 and CH_4 is removed by taking the CO_2/CH_4 ratio and the plume is clearly visible (Gerilowki et al., 2011)

3. Project Objective

- This project aims at investigating a novel instrument concept that has potential to reduce substantially the sizes and cost of sensors for climate-change gases
- This will facilitate application to a range of platforms: 1) small satellite and technology-demonstrator platforms, 2) piggy-back opportunities, 3) commercial platforms , 4) UAVs or 5) HAPS or 6) Constellations or 7) GEO platforms
- The project objectives are to
  1) Define a concept for measuring atmospheric concentrations of the important greenhouse gas methane (CH_4) mature concept of CH_4 proxy detection using of discrete shortwave infrared spectral bands
  2) Investigate its characteristics in terms of size and spatial resolution
  3) Demonstrate its potential application to the SSTL TechDemoSat platform



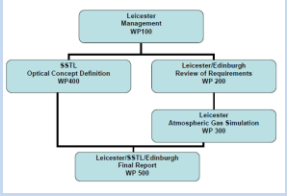
Artist impression of the TechDemoSat-1 mission



The concept will be based on discrete wavebands around 1.6 µm to observe CH_4, CO_2 and H_2O columns (indicated by grey bars). Additional bands outside of strong absorption bands will be needed to infer the baseline.

4. Project Overview

- Project is a collaboration between
  - University of Leicester – Lead and satellite retrieval of greenhouse gases
  - University of Edinburgh – Greenhouse gas modelling
  - SSTL - Optical system design



Work break-down structure of the project.

- Review of Requirements (WP200):
  - Derive basic requirements for measurement uncertainty, spatial and temporal sampling based on
    - review existing literature and reports
    - analysis of model runs using existing inventories and ground-based and aircraft data
    - assessment of emissions on city-scale and hot-spots
- Atmospheric Gas Simulation Investigation (WP300):
  - Numerical simulations will be used to
    - link measurement requirements to instrument requirements
    - establish and optimize instrument specifications (e.g. bandwidth and position, SNR)
  - Simulations will be carried out with OCO retrieval algorithm which has already been extensively used for similar projects
- Optical Concept Definition (WP400):
  - Identify and review suitable detector options and undertake radiometric analysis addressing the requirements for methane detection derived in WP200 and WP300.
  - Investigate spectral filtering requirements and constraints
  - trade-off the various design options to derive optical concept(s) to address the methane observations requirements

	Sep 2012	Oct 2012	Nov 2012	Dec 2013	Jan 2013	Feb 2013
WP100						
WP200						
WP300						
WP400						
WP500						
Meetings	▲ (kick off)		(mid-term) ▲			(final) ▲

Project schedule and associated meeting

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