AirCore-HR: A high-resolution column measurement to enhance the knowledge on the vertical distribution of CH$_4$

Olivier Membrive
olivier.membrive@lmd.polytechnique.fr

C. Crevoisier$^1$, C. Sweeney$^2$, A. Hertzog$^1$, F. Danis$^1$

L. Picon$^1$, G. Durry$^3$, N. Amarouche$^4$, A. Engel$^5$, H. Boenisch$^5$

1. Laboratoire de Météorologie Dynamique, CNRS/IPSL, Paris, France
2. University of Colorado, Boulder and NOAA/ESRL, Boulder Colorado
3. GSMA, CNRS, Université de Reims, Reims, France
4. INSU Division Technique CNRS, Meudon, France
5. Institute for Atmospheric and Environmental Sciences, University of Frankfurt, Frankfurt, Germany

Funding:
CNES (CSTB) & Ecole Polytechnique
I. Introduction – Atmospheric methane observations

Boat campaigns:
- Flasks

Ground station

Surface

10 km

30 km

70 km
I. Introduction – Atmospheric methane observations

Aircraft campaigns: CONTRAIL, CARIBIC, HIPPO...

Boat campaigns: Flasks

Ground station

30 km

70 km

700 km
I. Introduction – Atmospheric methane observations

SATELLITE OBSERVATIONS:
- IASI, AIRS (TIR): mid-tropospheric integrated content
- GOSAT (SWIR): integrated column
- ACE-FTS: profile measurements
+ Future missions: MERLIN, CarbonSat...

AIRCRAFT CAMPAIGNS:
- CONTRAIL, CARIBIC, HIPPO...

BOAT CAMPAIGNS:
- Flasks

GROUND STATION:
I. Introduction – *Atmospheric methane observations*

**Satellite observations:**
- IASI, AIRS (TIR): *mid-tropospheric integrated content*
- GOSAT (SWIR): *integrated column*
- ACE-FTS: *profile measurements*
- + future missions: MERLIN, CarbonSat…

**Aircraft campaigns:**
- CONTRAIL, CARIBIC, HIPPO…

**Balloon campaigns:**
- Measuring CH$_4$ profile from the surface up to 30 km

**Boat campaigns:**
- Flasks
I. Introduction – Atmospheric methane observations

Satellite observations:
- IASI, AIRS (TIR): mid-tropospheric integrated content
- GOSAT (SWIR): integrated column
- ACE-FTS: profile measurements
  + future missions: MERLIN, CarbonSat...

Aircraft campaigns:
- CONTRAIL, CARIBIC, HIPPO...

Balloon campaigns:
- Measuring CH$_4$ profile from the surface up to 30 km
  - AirCore-HR

Boat campaigns:
- Flasks
II. The AirCore-HR – sampling method

AirCore = an atmospheric sampling system that allows greenhouse gas measurements

1. Preparation

- **Long stainless steel tube**: treated with Sulfinert® coating to avoid interaction with water vapor

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NOAA AirCore © Karion et al. 2010
II. The AirCore-HR – sampling method

AirCore = an atmospheric sampling system that allows greenhouse gas measurements

1. Preparation
Tube is filled with calibrated standard

2. Ascent
Tube empties

Ceiling
30km
Surface
II. The AirCore-HR – sampling method

AirCore = an atmospheric sampling system that allows greenhouse gas measurements
II. The AirCore-HR – sampling method

AirCore = an atmospheric sampling system that allows greenhouse gas measurements

1. Preparation
2. Ascent
3. Descent
4. Closed

Tube empties
Ceiling
30km
Surface
Tube samples ambient air

Tube is filled with calibrated standard
AirCore = an atmospheric sampling system that allows greenhouse gas measurements

II. The AirCore-HR – sampling method

1. Preparation
   - Tube is filled with calibrated standard

2. Ascent
   - Tube empties

3. Descent
   - Tube samples ambient air

4. Closed

5. Analysis
   - Calibrated Gas Standard ≠ Fill Gas
   - Continuous Gas Analyzer
   - Mixing ratios of gases CO₂, CH₄, CO… depending on the analyzer
II. The AirCore-HR – Processing method

The analysis of the sample:
achieved at a constant flow rate with a Picarro “CRDS” analyzer that measures CO₂, CH₄ & H₂O

Mixing ratios corrected to the WMO scale assuming a constant bias with calibration standards (courtesy of LSCE M.Ramonet)
II. The AirCore-HR – Processing method

Concentration of CO\textsubscript{2}, CH\textsubscript{4} & H\textsubscript{2}O as a function of analysis time

Mixing ratios / Analysis time
II. The AirCore-HR – Processing Method

- Concentration of CO₂, CH₄ & H₂O as a function of analysis time
- Temperature of the 3 probes on the AirCore-HR & Ambient pressure

**Mixing ratios / Analysis time**

**Temperature (°C)**

**Pressure (hPa)**
II. The AirCore-HR – Processing method

Concentration of CO₂, CH₄ & H₂O as a function of analysis time

Temperature of the 3 probes on the AirCore-HR & Ambient pressure

Mixing ratios / Analysis time

Ambient Pressure / mean coil Temperature

Analysis time (s)

Flight time (h)
II. The AirCore-HR – Processing method

- Concentration of CO₂, CH₄ & H₂O as a function of analysis time
- Temperature of the 3 probes on the AirCore-HR & Ambient pressure

Profiles
Mixing ratio (CO₂, CH₄) / Ambient Pressure
II. The AirCore-HR – CH$_4$ profiles

CNES/CSA Stratospheric Balloon Campaign
Timmins, Ontario, Canada
(20/08/2014 – 31/08/2014)

First high resolution AirCore-HR CH$_4$ profile from the surface to 25km

- GSMA: Pico-SDLA (CH$_4$ & CO$_2$)
- Frankfurt University: AirCore-GUF (CO/CO$_2$/CH$_4$)
- LMD: AirCore-HR (CO$_2$ & CH$_4$)
- Other instruments

Multi-instrument Gondola

Flight preparation

- Thin structures of the atmosphere
- Slope of the CH$_4$ in the stratosphere
II. The AirCore-HR – High resolution?

Vertical resolution can be estimated thanks to:
- Molecular Diffusion
- Taylor Dispersion and is directly affected by (Length, diameter)

AirCore-HR
200 m ⅛” (3.18 mm) & 100 m ¼” (6.35 mm)

AirCore-GUF
3 tubes
40 m 2 mm & 40 m 4 mm & 20 m 8 mm

AirCore NOAA
152 m ¼” (6.35 mm)
III. Direct comparisons – All CH$_4$ profiles

- AirCore-HR (high-resolution)
- AirCore-GUF (low-resolution)

AirCore-GUF data: courtesy of H.Bönish & A.Engels / Goethe University Frankfurt
III. Direct comparisons – All CH₄ profiles

- AirCore-HR (high-resolution)
- AirCore-GUF (low-resolution)
- Pico-SDL (laser spectrometer)

Pico-SDL: courtesy of G. Durry / GSMA & N. Amarouche / DT INSU
IV. Applications for validation – Models

Comparison with transport model LMDz with optimized fluxes using GOSAT and surface observations year 2010 * (collocated in space)

Legend

- **LMDz 2010** (19 levels)
- **CH₄ AirCore-HR** (29/08/2014)

- 2010 vs 2014: increase near the surface

*see poster by R.Locatelli

LMDz data: Courtesy of P.Bousquet & R.Locatelli
IV. Applications for validation – Models

Comparison with transport model LMDz with optimized fluxes using GOSAT and surface observations year 2010 * (collocated in space)

Legend

- LMDz 2010 (19 levels)
- LMDz 2010 (39 levels)
- CH₄ AirCore-HR (29/08/2014)

- 2010 vs 2014: increase near the surface
- Increasing the number of P layers & improving underlying physics improves the description of the stratosphere

*see poster by R.Locatelli

LMDz data: Courtesy of P.Bousquet & R.Locatelli
IV. Applications for validation – Models

Comparison with CH4 forecast
IFS - ECWMF/MACC
(collocated in space & time)

- CH4 IFS/MACC (137 levels)
  (29/08/2014 12UTC)

- CH4 AirCore-HR (29/08/2014)

- very good agreement in the troposphere
  (airmass signatures)

- Not satisfactory above the tropopause
IV. Application of AirCore-HR for validation – Space Observations

Comparison with satellite observations AIRS (collocated in space & time)

Legend

- **CH₄ AIRS** (28/08/2014) (NOAA)
- **CH₄ AirCore-HR** (29/08/2014)

- Good agreement in the mid-troposphere where vertical sensitivity of AIRS is highest
- Offset near the surface and above the tropopause (a priori?)
IV. Conclusion

- **3 scientific objectives**
  - Use of AirCore Data for **transport model validation** (Number of levels, Impact of spatial resolution, Underlying convection processes)
  - Use of AirCore Data for **satellite-based remote sensing validation of GHG**:
    - total columns: GOSAT, OCO-2... Merlin, MicroCarb, CarbonSat
    - tropospheric column: AIRS, IASI and IASI-NG
    - vertical profile: ACE-FTS
  - Use of AirCore Data for validation of **ground FTS measurements (TCCON)** and underlying spectroscopy

- **Study the possibility of a network of AirCores**

- **Creation of an AirCore community**
  - First meeting: **CNES HQ, Paris, 2014 July 7th**
  - 4 Research teams involved: NOAA/ESRL, Groenigen University, Frankfurt University, LMD
  - Next meeting: *to be organised*.... **Anyone interested is welcome to join**