Cal/Val activities for IASI-NG

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The IASI instrument

- **IASI** (Infrared Atmospheric Sounding Interferometer) is a *Fourier Transform Spectrometer* that measures infrared radiation emitted from the Earth.
- It has been developed by CNES, in collaboration with EUMETSAT.

**IASI provides**
- 8461 spectral channels between 645 and 2760 cm\(^{-1}\) (15.5 - 3.63 μm)
- with a spectral resolution of 0.5 cm\(^{-1}\) after apodisation (“Level 1c” spectra)
- the spectral sampling interval is 0.25 cm\(^{-1}\).
- nadir FOV: 12 km at nadir.

Retrievals of several atmospheric and surface variables over land/sea by day/night.
A whole suite of atmospheric variables retrieved from IASI

• IASI addresses the needs of three communities that are more and more connected:
  Numerical Weather Prediction | Atmospheric Composition | Climate

• More than 25 species are observed, some well quantified (O₃, CO, CH₄), some only detected (SO₂, HNO₃, NH₃, formic acid, methanol) in special situations (fires, volcanoes).

• Monitoring of several Essential Climate Variables
From IASI to IASI-NG

<table>
<thead>
<tr>
<th>Year</th>
<th>IASI</th>
<th>Metop-A</th>
<th>Metop-B</th>
<th>Metop-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From IASI to IASI-NG

IASI

2006

IASI

Metop-A

2009

IASI-NG

Metop-SG-A1

2019

Metop-SG-A2

2021

Metop-C

2012

Metop-B

2015

Metop-SG-A3

2028

( MetIMAGE, MWS, IASI-NG, RO, UVNS/Sentinel 5, 3MI )

• Objectives of the mission:
  • To assure the continuity of IASI for NWP, atmospheric chemistry and climate applications.
  • To improve the vertical coverage of the atmosphere (lower part of the troposphere, the UT/LS region).
  • To improve the precision of the retrievals and to allow the detection of new species.

• Characteristics:
  - spectral coverage: 645 - 2760 cm\(^{-1}\)
  - spectral resolution: 0.25 cm\(^{-1}\) after apodisation (0.50 cm\(^{-1}\) for IASI)
  - spectral sampling: 0.125 cm\(^{-1}\) (0.25 cm\(^{-1}\) for IASI).
  - reduction of the radiometric noise by at least a factor of ~2 as compared to IASI.

Crevoisier et al., AMT, 2014
Impact of improved spectral and radiometric characteristics

For most of the atmospheric species, there is no difference between KBr and ZnSe scenarios.

**H₂O:** it is mostly the spectral resolution that matters

**Ozone (0-6 km)**

**Surface emissivity**

**Carbon monoxide**

**Noise** | **Improvement of the CH₄ precision**
--- | ---
IASI | 39 %
KBr | 20 %
ZnSe | 20 %

Crevoisier et al., AMT, 2014
# IASI-NG: summary

<table>
<thead>
<tr>
<th></th>
<th>IASI</th>
<th>IASI-NG</th>
<th>What the ‘NG’ brings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemistry</strong></td>
<td><strong>DOFs</strong></td>
<td><strong>Error (%)</strong></td>
<td><strong>DOFs</strong></td>
</tr>
<tr>
<td>O&lt;sub&gt;3&lt;/sub&gt;</td>
<td>3-4</td>
<td>PBL: 60% Tropo: 11%</td>
<td>4-5</td>
</tr>
<tr>
<td>CO</td>
<td>1-2</td>
<td>PBL: 16% Tropo: 8%</td>
<td>2-3</td>
</tr>
<tr>
<td>HNO&lt;sub&gt;3&lt;/sub&gt;</td>
<td>1 or less</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>NH&lt;sub&gt;3&lt;/sub&gt;&lt;sup&gt;a&lt;/sup&gt;</td>
<td>detected</td>
<td>-</td>
<td>measured</td>
</tr>
<tr>
<td>Methanol&lt;sup&gt;a&lt;/sup&gt;</td>
<td>detected</td>
<td>-</td>
<td>measured</td>
</tr>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;4&lt;/sub&gt;&lt;sup&gt;a&lt;/sup&gt;</td>
<td>detected</td>
<td>-</td>
<td>measured</td>
</tr>
<tr>
<td>SO&lt;sub&gt;2&lt;/sub&gt;-volcanos</td>
<td>If &gt; 2DU</td>
<td>-</td>
<td>If &gt; 1 DU</td>
</tr>
<tr>
<td><strong>Climate</strong></td>
<td><strong>DOFs</strong></td>
<td><strong>Error (%)</strong></td>
<td><strong>DOFs</strong></td>
</tr>
<tr>
<td>H&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>5-6</td>
<td>~13%</td>
<td>6-7</td>
</tr>
<tr>
<td>T</td>
<td>6</td>
<td>~0.6K</td>
<td>12</td>
</tr>
<tr>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>1 or less</td>
<td>~1%</td>
<td>1-2</td>
</tr>
<tr>
<td>CH&lt;sub&gt;4&lt;/sub&gt;</td>
<td>1 or less</td>
<td>~3%</td>
<td>1-2</td>
</tr>
<tr>
<td>N&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>detected</td>
<td>-</td>
<td>measured</td>
</tr>
<tr>
<td>Aerosols</td>
<td>dust</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Emissivity</strong></td>
<td>0.04 @4µm</td>
<td></td>
<td>0.02 @4µm</td>
</tr>
</tbody>
</table>
Calibration/Validation of IASI-NG

• Strong heritage from IASI and other IR sounders: several activities can be directly applied to IASI-NG.

• **For level1**: expertise of monitoring and intercomparison activities performed at CNES/EUMETSAT and some labs, especially in the framework of **GSICS**.

• **For level2**:
  
  • The challenge: more than 25 atmospheric species retrieved or detected, in addition to thermodynamics, clouds, aerosols, surface characteristics.
  
  • Aiming automatisation of validation and monitoring tools.

• But:
  - Requirements for IASI-NG are tighter
  - Some new products required for IASI-NG
  - dedicated campaigns when no coordinated network and routine data flux exist)
### Thermodynamics variable

<table>
<thead>
<tr>
<th>Product</th>
<th>Vertical Resolution</th>
<th>Accuracy</th>
<th>Reference data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature profile</td>
<td>LT, MT: 0.8 km UT, S: 2 km</td>
<td>LT, MT: 0.8 K UT, S: 1.2 K</td>
<td>Sondes, RO dry-T strato, NWP analysis, Can we demonstrate 0.8K?</td>
</tr>
<tr>
<td>Specific humidity profile</td>
<td>LT: 1.2 km MT, UT: 1.5 km S: 3 km</td>
<td>LT: 5 % MT, UT: 7 % S: 20 %</td>
<td>Sondes, NWP analysis, Ground-based Lidar, MWR, Can we demonstrate 5% ? Other? LHD?</td>
</tr>
<tr>
<td>Water vapour total column</td>
<td>N/A</td>
<td>5 %</td>
<td>Ground-based GPS, High resolution radiometer? Other?</td>
</tr>
</tbody>
</table>

- A lot has been done with IASI.
- Challenges:
  - Going towards operational.
  - how to validate improved precision wrt IASI?
## Surface characteristics

<table>
<thead>
<tr>
<th>Product</th>
<th>Vertical Resolution</th>
<th>Accuracy</th>
<th>Reference data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea surface temperature</td>
<td>N/A</td>
<td>0.3 K</td>
<td>Buoys</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>OSTIA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High resolution LEO/GEO radiometers</td>
</tr>
<tr>
<td>Land surface temperature</td>
<td>N/A</td>
<td>1 K</td>
<td>Ground-based radiometers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Space-based high resolution radiometers, e.g. SEVIRI LSA</td>
</tr>
<tr>
<td>Ice surface temperature</td>
<td>N/A</td>
<td>1 K</td>
<td>In situ measurements...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High-resolution radiometers?</td>
</tr>
<tr>
<td>Land and ice surface emissivity</td>
<td>N/A</td>
<td>1 %</td>
<td>Direct measurements?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aircraft (ARIES?)</td>
</tr>
</tbody>
</table>

Emissivity spectrum retrieved retrieved from IASI

- **IASI**
- **MODIS**

- **Tropical forest**
- **Desert**
Comparison of IASI and ARIES emissivity from the MEVEX Oman campaign, May 2009

Emissivity at 9 microns:

Capelle et al., 2014
### Clouds

<table>
<thead>
<tr>
<th>Product</th>
<th>Vertical Resolution</th>
<th>Accuracy</th>
<th>Reference data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud detection and fractional coverage</td>
<td>6 km</td>
<td>10 %</td>
<td>GEO/LEO imagery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ground-based WSI, other ??</td>
</tr>
<tr>
<td>Cloud top phase</td>
<td>N/A</td>
<td>10 %</td>
<td>???</td>
</tr>
<tr>
<td>Cloud top height /pressure</td>
<td>N/A</td>
<td>0.2 km</td>
<td>Ground-based cloud radar, Lidars</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Space-based active sensors (CALIPSO, EarthCare...)</td>
</tr>
<tr>
<td>Cloud drop effective radius at cloud top</td>
<td>N/A</td>
<td>5 µm</td>
<td>???</td>
</tr>
<tr>
<td>Cloud liquid water path from MWS and IAS</td>
<td>N/A</td>
<td>5 %</td>
<td>Ground-based radar, MWR?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Space-borne data: EarthCare, CloudSat?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Can we demonstrate 5% ?</td>
</tr>
</tbody>
</table>

- Very few validations have been done with IASI.
- Statistical comparison of cloud climatologies (e.g. GEWEX cloud assessment).
- Common plan with 3MI would be an asset.
Aerosols

<table>
<thead>
<tr>
<th>Product</th>
<th>Reference data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust AOD at 10 µm</td>
<td>GEO/LEO imagery</td>
</tr>
<tr>
<td></td>
<td>Aeronet</td>
</tr>
<tr>
<td>Dust mean altitude</td>
<td>Ground-based and airborne lidars, space lidars</td>
</tr>
<tr>
<td>Effective radius</td>
<td>?</td>
</tr>
</tbody>
</table>

Validation of IASI AOD with Aeronet

- IASI AOD
- MODIS AOD

Mean altitude from IASI

Validation of IASI alt. with Calipso

- 0.26 ± 1.02km

Capelle et al., RSE, 2017
<table>
<thead>
<tr>
<th>Product</th>
<th>Vertical Resolution</th>
<th>Accuracy</th>
<th>Reference data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide profile</td>
<td>3 km</td>
<td>3 km LT: 30 %</td>
<td>In situ measurements (airborne, ground)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MT: 25 %</td>
<td>Space-borne missions?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HT, S: 20 %</td>
<td>Other?</td>
</tr>
<tr>
<td>Carbon monoxide partial column</td>
<td>3 km</td>
<td>10 %</td>
<td>NDACC ground stations</td>
</tr>
<tr>
<td>Ozone profile</td>
<td>3 km</td>
<td>LT, MT, UT: 20 %</td>
<td>O₃ sondes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S: 10 %</td>
<td>Other space missions?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Model?</td>
</tr>
<tr>
<td>Ozone total column</td>
<td>N/A</td>
<td>5 %</td>
<td>Ground Brewer, Dobson</td>
</tr>
<tr>
<td>Sulphur dioxide total column</td>
<td>N/A</td>
<td>50 %</td>
<td>?</td>
</tr>
<tr>
<td>Nitric acid partial column</td>
<td>T, S</td>
<td>20 %</td>
<td>NDACC?</td>
</tr>
</tbody>
</table>

The challenge: more than 25 atmospheric species retrieved or detected.

How to fully validate columns?
An example: Validation of IASI CO

NDACC
Averaging kernel at Izana

Total columns

No-correction
Altitude corrected
Full correction

Kerzenmacher et al., 2012

Also done for NH3 (Dammers et al., 2016), and Ozone Total and Partial Column

Aircraft

• In IPY/POLARCAT biomass burning plumes transport has been observed from Siberia and Kazakhstan across the North Pole to North America.
• Biomass burning plumes have been used as a contrasted signal to validate spaceborne IASI measurements of pollutants (CO).

\[ x_s = x_a + A \left( x - x_a \right) \]
## Greenhouse gases

<table>
<thead>
<tr>
<th>Product</th>
<th>Vertical Resolution</th>
<th>Accuracy</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane mid-tropo. column</td>
<td>N/A</td>
<td>&lt;1%</td>
<td>AirCores, Aircraft, Space Carbon mission?, Ground-based FTIR (NDACC)</td>
</tr>
<tr>
<td>Carbon dioxide mid-tropo. column</td>
<td>N/A</td>
<td>&lt;1%</td>
<td>Models/Assimilation (CAMS)</td>
</tr>
<tr>
<td>Nitrous oxide mid-tropo. column</td>
<td>N/A</td>
<td>10%</td>
<td></td>
</tr>
</tbody>
</table>

- Mean value: ~1800 ppb.
- Stratospheric decrease: -800 ppb over 100 hPa (~10 km).
- Strong differences between atmospheric models.

**Merlin total column**

→ between the 4 profiles: différence in XCH4 between 6 and 12 ppb...

**IASI/IASI-NG : mid-tropospheric column**

→ between the 4 profiles: differences ranging from 13 to 26 ppb...
Example of validation of IASI CH$_4$ mid-tropospheric column

- AirCore: atmospheric air sampler to measure 0-30 km profiles of CO$_2$, CH$_4$, CO, C13, H$_2$O/HDO, NH$_3$, ...
- Originally designed at NOAA (Karion et al., 2010). Several EU teams now making measurements: LMD/LSCE, U. Groningen, U. Frankfurt, FMI, etc.

→ Use of profiles measured at Timmins (Canada), Kiruna (Sweden), Trainou-Orléans and Sodankylä to validate IASI CH$_4$ mid-tropo. columns:

Membrive et al., AMT, 2017

→ Validation of IASI CH$_4$ columns in the NH.
• IASI CH$_4$ from LMD and TANSO-FTS CH$_4$ from SRON are assimilated within C-IFS at ECMWF (CAMS).
• Evaluation is performed against TCCON stations (XCH4) and HIPPO aircraft profiles.

(a) TCCON stations

(b) HIPPO vertical profiles
1. **Compliance matrix**
   What data (and their merits) for what product?

2. **Short-term validation**
   - Aircraft campaigns (SAFIRE, DLR, FAAM facilities)
   - Balloon campaigns (CNES balloon program)
   - Combined ground-aircraft-balloon-surface campaigns at **super sites**

3. **Long-term validation**
   - Satellite inter-comparisons
   - ground networks → **need for continuous support!!**
   - Model comparison/data assimilation (indirect)

4. **Pre-launch validation requirements**
   - Selection of ground-based supersites
   - Instrument upgrade/validation ?
   - Validation test campaign
Validation strategy

• Coordination of validation activities between missions would be a real asset:
  - within Metop-SG (IASI-NG, 3MI, Sentinel5/UVNS, etc).
  - between different platforms.
  ➔ Best use of funding, man-power, aircraft availability, scientific objectives.

• Specifically for GHG:
  - joint validation strategies between Merlin, MicroCarb and IASI-NG (all launched around 2021).
  - preparatory activities are on-going:

  ➔ Multi-instrument campaigns at Trainou-Orléans (LMD-LSCE-LERMA):
    - 2 week-campaign in April 2017: ICOS/TCCON + EM27/SUN (KIT/LERMA)
      +0-3 km aircraft + AirCore-light + OCO-2 (target mode) + IAGOS (10 km).
    - plan: a campaign every 3 months.

  ➔ CoMet campaign (coordinated by DLR):
    - May 2018.
    - flights between TCCON EU stations.
Example of validation of IASI CH4 mid-tropospheric column

IASI CH4
Weighting Function

\[ \text{IASI-A: } 2.8 \pm 8.5 \text{ ppb} \]
\[ \text{IASI-B: } 0.4 \pm 9.9 \text{ ppb} \]

- Validation of IASI CH4 columns in the NH.

LMDz - AirCore = 12 ppbv
TM5 - AirCore = 13 ppbv
C-IFS - AirCore = 19ppbv

- Systematic overestimation of CH4 in the stratosphere by the models
## 3 CNES missions

<table>
<thead>
<tr>
<th></th>
<th>MicroCarb</th>
<th>Merlin</th>
<th>IASI/IASI-NG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date of launch</strong></td>
<td>2021</td>
<td>2021</td>
<td>2007-2012-2018 2021-2028-2035</td>
</tr>
<tr>
<td><strong>Local time</strong></td>
<td>10:30</td>
<td>6:00-18:00</td>
<td>9:30-21:30</td>
</tr>
<tr>
<td><strong>Level 2</strong></td>
<td>Total column of XCO2</td>
<td>Total column of XCO4</td>
<td>mid-tropo. column of CO2 and CH4</td>
</tr>
<tr>
<td><strong>Syst. error</strong></td>
<td>&lt; 0.1 ppm</td>
<td>&lt; 3 ppb</td>
<td>&lt; 1 ppm</td>
</tr>
<tr>
<td><strong>Random error</strong></td>
<td>&lt; 1 ppm</td>
<td>&lt; 27 ppb</td>
<td>&lt; 3 ppm</td>
</tr>
<tr>
<td><strong>Geometry</strong></td>
<td>Swath: 13km 3 FOV 40km2</td>
<td>50km</td>
<td>Swath: 2000 km FOV: 12 km@nadir</td>
</tr>
</tbody>
</table>

Coordination of validation activities between these 3 missions would be highly valuable!!
Validating CO2 columns?

- Mean value: ~395 ppb.
- Strong variation near the surface (< 4 km).
From IASI to IASI-NG

IASI  Metop-A  2006
IASI  Metop-B  2012
IASI  Metop-C  2018

Mid-tropospheric columns of CO₂

<table>
<thead>
<tr>
<th>Year</th>
<th>CO₂ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>380-400</td>
</tr>
<tr>
<td>2012</td>
<td>385-405</td>
</tr>
<tr>
<td>2018</td>
<td>390-410</td>
</tr>
</tbody>
</table>

Pressure (hPa)

Averaging kernels

- IASI (TIR)
- MicroCarb (SWIR)

\[ \frac{dC_{CO₂}}{dC_{CO₂}} (\text{ppmv/ppmv}) \]
IASI and IASI-NG spectrum
Averaged over the whole tropical TIGR situations
Computation with the 4A/OP RT code, using the GEISA-11 spectroscopic database
Validation plan

**Goal:**
- To assess the usefulness of GHG columns products for their intended scientific applications
- To assess the products quality by comparing them to data which are regarded as a reference.

**Central questions:**
- How representative are the satellite retrieved products for the actual atmospheric state?
- What are the systematic and random errors?
- How well are the temporal variations of XCO2/XCH4 captured (daily to annual)?
- How well are spatial structures captured, from local emission sources to global features?

**How:**
- Definition of quantity to be validated.
- Identification of already existing and planned instruments, networks, programs, and satellite missions which are potentially suited to be included in the validation organization.
- Identification of potential gaps (updating of existing sensors ? to start the development of missing validation instruments or concepts?)
  → organization of the scientific community (both at national and international levels).

**Scope:**
Short-term, long-term or campaign-based validation activities.
Validation plan: example of Merlin

<table>
<thead>
<tr>
<th>GAW surface networks: Mixing ratios values</th>
<th>Meth. parameter</th>
<th>Sensitivity</th>
<th>Represen.</th>
<th>SE</th>
<th>Clouds</th>
<th>On-line frequency</th>
<th>Purity</th>
<th>Albedo</th>
<th>Canopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface, passive TCCON, NDAC</td>
<td>+</td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface, active Lidar DIAL and others Cieloeter, Radar</th>
<th>Meth. parameter</th>
<th>Sensitivity</th>
<th>Represen.</th>
<th>SE</th>
<th>Clouds</th>
<th>On-line frequency</th>
<th>Purity</th>
<th>Albedo</th>
<th>Canopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balloon, in-situ Aircore, pico-SHLA</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aircraft, in-situ CRDS, TDLAS</th>
<th>Meth. parameter</th>
<th>Sensitivity</th>
<th>Represen.</th>
<th>SE</th>
<th>Clouds</th>
<th>On-line frequency</th>
<th>Purity</th>
<th>Albedo</th>
<th>Canopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft, passive r.s. DOAS, ...</td>
<td>++</td>
<td>++</td>
<td>+++</td>
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<th>Aircraft, active IPDA Lidar</th>
<th>Meth. parameter</th>
<th>Sensitivity</th>
<th>Represen.</th>
<th>SE</th>
<th>Clouds</th>
<th>On-line frequency</th>
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<th>Albedo</th>
<th>Canopy</th>
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<td>Satellite, passive DOAS, FTIR Cloud Imager SWIR</td>
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- ICOS, NOAA/ESRL, etc through GAW.
- TCCON, COCCON → total columns
- Lidars
- Balloons (AirCore, Amulse, pico-SHLA, SPECIES)
- AirCraft: in-situ (CRDS, Amulse, SPECIES)
- Passif (Bremen MAMAP, UK GHOST, ESA ACADIA, SRON SPEX)
- Actif (CHARM-F)
- Drones?

Satellites

Models, Assimilation
Balloon-borne measurements

- **CNES balloon facilities:**
- Annual BSO campaigns:
  - Open Stratospheric Balloons for heavy payloads (>100kg)
  - 3 sites: Timmins (Canada), Kiruna (Sweeden) and a future tropical site.
- Meteorological balloons (<3 kg) from Aire-sur-Adour (ASA).
- BPS ballons (e.g. Stratéole-2, ConcordIASI): See P. Cocquerez presentation.
Balloon-borne measurements

AirCore profiles and associated uncertainties

• Excellent agreement between the AirCores, especially for CH$_4$ (within 2 ppb when resolution taken into account)

For CO$_2$: <0.2ppm
For CH$_4$: <3ppb

• Important vertical gradients translate into large uncertainties.
Way forward

• Creation of a new « super-site » in the South-West of France:
  - ASA is the main candidate due to available CNES infrastructure + man power.
  - Could combine: continuous measurements of CO2/CH4/CO for ICOS + FTS (either TCCON or COCON type instruments) + regular balloon launches (AirCore, maybe Amsule) + regular SAFIRE flights.
  - Could be used to host specific campaigns.
  - Interest of a station in French Guyana to be assessed.

• Need for coordinated measurement campaigns:
  - Involvement of different vectors/space mission/scientific objectives.
  - 3 main regions of interest:
    - mid-latitudes (linking TCCON/ICOS stations)
    - tropics (benefiting from new balloon site?)
    - high-latitudes (from Kiruna: BSO + meteorological balloons + TCCON/NDACC + COCCON + YAK) → a great project!

• Participating to the funding of TCCON/NDACC networks would be greatly appreciated.
The CoMet campaign

Carbon Dioxide and Methane Missions for HALO
The CoMet campaign

Carbon Dioxide and Methane Missions for HALO

CoMet: Complementary and Innovative Payload

✓ Active Remote Sensing (CHARM-F, Lidar):
  high accuracy,
  day / nighttime, high latitudes
  insensitive to clouds and aerosol
  future satellite instruments

✓ Passive Remote Sensing (MAMAP)
  very precise
  well adapted to local sources
  similar to current satellite instruments

✓ In-situ instruments (JIG, JAS)
  highest accuracy and precision
  WMO standard
  Isotope analysis for source identification

✓ Ancillary information (BAHAMAS, mini-DOAS, dropsondes)
  meteorology, source information

Measurement of GHG columns (XCO₂ and XCH₄) between
ground and flight level

Accurate profiling
The CoMet campaign

Carbon Dioxide and Methane Missions for HALO

Tentative HALO Flights

- TCCON sites + AirCore launches
- Latitude gradients
- Coal mines (Poland)
- Power plants
- Landfills
- Urban area (e.g. Berlin)
- Volcanoes
- Orography
- Vegetation
- Albedo variations
- ...

Scientific Flights: 18 April – 17 May 2017
63 Flight hours, ~8 Flights
Base: Oberpfaffenhofen (EDMO)
La campagne CoMet

Carbon Dioxide and Methane Missions for HALO

Measurement Strategies of CoMet
En résumé…

Alt. (km)

Trainou

Profil AirCore

Trace satellite et/ou HALO