CO$_2$ from space

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Introduction

$CO_2$ is measured in different sites at the surface of Earth.

But the current network has some limitations:

- The stations are not well distributed on the globe.
- Tropics and South continents are almost not covered.
- The stations can be influenced by local sources.
- The temporal coverage may depend on the station.

The use of satellite observations, which are global and continue, should improve our capability to monitor $CO_2$.

Three techniques are currently used (or planned to be used) to infer atmospheric $CO_2$ concentration from space observations.
The principle of the measure is always the same:

1. A radiation goes through the atmosphere.

2. It is partly absorbed by $CO_2$, the absorption being controlled by its atmospheric concentration.

3. The remaining radiation measured above the atmosphere gives information on $CO_2$.

To be absorbed, the radiation must have a wavelength located in the spectral absorption bands of $CO_2$.

- The radiation is measured in terms of brightness temperatures (BT) by different channels.
- Each channel is characterized by its central wavelength and its spectral resolution.
- The higher the resolution, the better we can isolate the absorption due to $CO_2$. 

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.
**CO₂ from space**

Vertical sounding in the thermal Infrared

radiation = Earth radiation in the thermal IR.

- To retrieve **CO₂** we study the correlation between gas-sensitive channels.
- These observations are used since many years to retrieve atmospheric T, **H₂O**, **O₃** that is their first goal.

**Limitations:**
- ✓ clouds and aerosols (but detection algorithms exist)
- ✓ not sensitive to **CO₂** near the surface.

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<td>TOVS</td>
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Differential absorption in the near IR

- **radiation** = solar radiation reflected by the surface in a CO₂ absorption band.

Study of two measurements:
  - One centered on the absorption line
  - One centered on the edge.

- **two lines**: 1.6 and 2.0 µm
- mainlly sensitive to CO₂ variations in the lower part of the atmosphere.

- **limitations**:
  - aerosols and clouds.
  - solar diffraction.

Instruments:
- **SCIAMACHY** (Feb. 2002).
  - high instrumental noise
- **OCO** (2008): first instrument dedicated to the only CO₂.
**CO₂ from space**

**Active techniques (under development)**

- **✓ radiation** emitted by a known source (LIDAR) and then backscattered to the satellite.

  Then the principle is the same as absorption technique.

- **✓ two lines:** 1.6 and 2.0 µm
- **✓ the vertical sensitivity is still unknown.**

LIDAR in space (not yet for CO₂).

- **CALIPSO** (end of 2005).
Real-life: AIRS IR vertical sounder

- Each channel is sensitive to various atmospheric components.
- The variations of each component induces changes on the BT measured by each channel that are usually bigger than CO₂ ones...

A change of 1% of the CO₂ concentration induces a change of 0.04% of the signal observed on the channels.

- The signal is of the same level as instrumental noise.
- Non-linearities makes it difficult to solve this inverse problem.
Some results from AIRS: seasonal variations in the troposphere

Seven months of AIRS observations have been interpreted in terms of CO₂. Using a non-linear method based on neural networks [Chédin et al. 2003; Crevoisier et al. 2004].

Their seasonal variations show very good agreement with in situ measurement made by JAL commercial airliners in the same zone of the atmosphere.

Monthly tropospheric CO₂ maps are being produced at a 15°×15° resolution in the tropical zone.

CO₂ from space can bring information on transport phenomena and CO₂ sources and sinks at the surface.

Yet, surface measurements will always be needed, at least to validate observations from space.