Carbon dioxide satellite remote sensing and oxygen spectroscopy

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Carbon dioxide

- CO_2 , the most important anthropogenic greenhouse gas, is the main driver of current and future climate change. The rising levels of this gas in the atmosphere, resulting from anthropogenic emissions (fossil fuel burning, land use change,…), cause an increase of the greenhouse effect and disrupt the natural balance

- A direct consequence is a mean rise of the temperature at the Earth surface, with many consequences on climate and the ecosystems

Space-borne systems

- SCIAMACHY (ESA, 2002-2012), a spectrometer on the ESA's Envisat probe, was the first satellite instrument which could measure atmospheric CO_2 columns using the differential optical absorption spectroscopy

- IASI instruments (CNES-Eumesat) on board European MetOp series of weather satellites can estimate atmospheric CO_2 concentrations using thermal infrared measurements. However, they are not well suited when surface fluxes are the ultimate objective

- GOSAT (JAXA), launched in 2009, is the first satellite mission dedicated to greenhouse gases monitoring. It tracks CO_2 and also methane - the second most important greenhouse gas produced by human activity

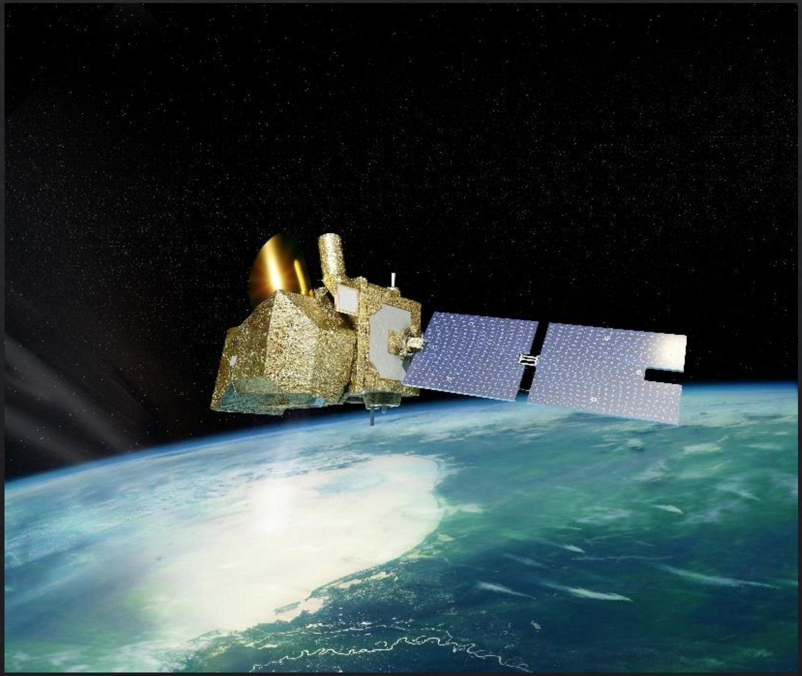
- OCO-2 (NASA) went into orbit in 2014 after the loss at launch of the OCO satellite (2009)

- TanSat, launched in 2016, is a Chinese satellite devoted to monitoring carbon dioxide in Earth's atmosphere

- In 2021, CNES will take over this role with the launch of MicroCarb

MicroCarb

- MicroCarb aims at monitoring and characterizing CO_2 surface fluxes, that is, the exchanges between sources (natural or anthropogenic) and sinks (atmosphere, ocean, land and vegetation) on a global scale



Source: CNES

- MicroCarb measures atmospheric CO_2 concentrations with extreme precision (on the order of 1 ppm) for the quantification of the current fluxes and the mechanisms governing these fluxes

- Concentration values are computed from measurements of the atmospheric spectra in some wavelengths specific to the gas. The instrument on board MicroCarb is an infrared passive spectrometer measuring atmospheric spectra for CO_2 (1.6 and 2 μm) and O_2 (0.76 and 1.27 μm)

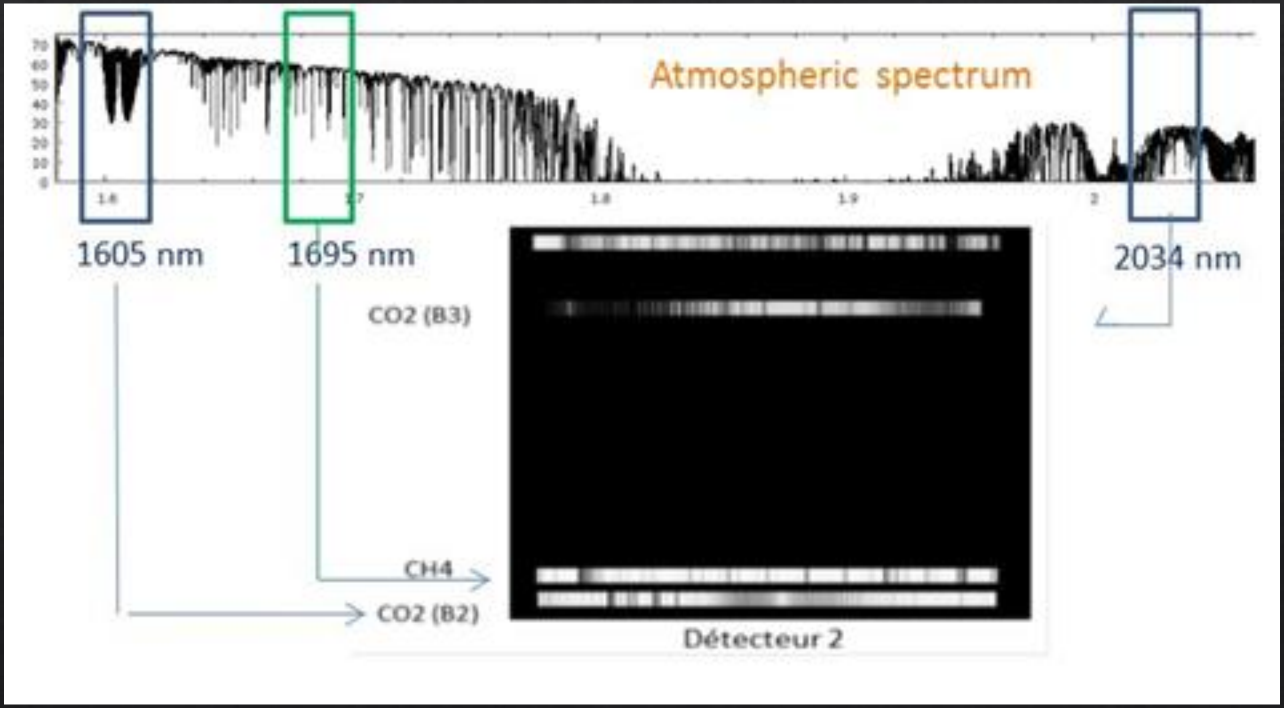
- A better understanding of the Carbon Cycle can be obtained through an analysis of the fluxes, their spatial and temporal patterns and their anomalies linked to weather anomalies

- MicroCarb will also measure atmospheric methane whose emissions are poorly known

- A launch is planned in 2021

CO_2 absorption bands

- For CO_2, the favorable wavelengths are around 1.6 and 2 µm as there are absorption lines that are well distinct from those of other gases



Source: CNES

- The weak CO_2 band wavelength, in the vicinity of 1.6 µm, is most sensitive to the CO_2 concentration near the surface. Since other atmospheric gases do not absorb significant energy within this spectral range, the 1.6 µm band measurements are relatively clear and unambiguous

- The strong CO_2 wavelength channel, in the vicinity of 2 µm, will provide a second and totally independent measurement of the CO_2 abundance. The ability to detect and mitigate aerosol presence enhances the accuracy of Xco_2. The 2 µm band measurements are sensitive to the presence of aerosols and variations in atmospheric pressure and humidity along the optical path. These variations in pressure and humidity have a known impact on Xco_2

O_2 absorption bands

- The surface pressure and atmospheric aerosols are needed for the retrievals of CO_2 and CH_4 column amounts from the measured spectra. Therefore, in addition to the absorption bands of CO_2 and CH_4 (at 1.6, 1.67 and 2.1 μm), satellite instruments simultaneously measure spectra in two absorption bands of oxygen in the near-infrared (0.76 and 1.27 μm) in order to retrieve the surface pressure and atmospheric aerosols

- The concentration of molecular oxygen O_2 is constant, well known, and uniformly distributed throughout the atmosphere. The O_2 A-band spectra (0.76 μm) indicate the presence of clouds and optically thick aerosols that preclude full column measurements of CO_2

- To correct for the optical path, most CO_2 missions (GOSAT, OCO-2, TanSat) rely on the measurement in the O_2 absorption band at 0.76 µm. However, the O_2 band at 0.76 µm and the CO_2 band at 1.6 µm are rather far apart. As a direct consequence, the optical properties of the scatterers may be significantly different between the O_2 and CO_2 bands

- The O_2 absorption band at 1.27 µm is closer in wavelength to the CO_2 and CH_4 absorption bands (1.6, 1.67 and 2.1 µm) and therefore potentially better suited for the total column amount retrieval of greenhouse gases. This is the main reason why this was retained by the MicroCarb project

Problems to be solved

- A precise modeling of the absorption spectrum of O_2 in the near-infrared is needed, in order to retrieve, from atmospheric measurements from space, the surface pressure and aerosols

- However, spectroscopic data for the 1.27 μm band are based on very old laboratory studies and cannot satisfy the precision requirement. New and precise laboratory studies are thus needed in order to retrieve reliable results from atmospheric observation

- First step

Laboratory and simulated spectra will provide a complete set of spectra which cover all atmospheric temperature and pressure conditions for all transitions. From that, the spectroscopic parameters needed for forward calculations of atmospheric spectra will be determined by the use of a very precise model (Hartmann-Tran profile)

- Second step

The new spectroscopic data and spectral model will be implanted in a radiative transfer calculation code. The improvement of precision (for atmospheric spectra modeling, surface pressure determination) provided by these new data with respect to existing ones will be quantified

Then, spectra measured by the OCO-2 satellite will be used to validate our new data and model. We will namely quantify the improvement in the retrieved atmospheric aerosols but also the CO_2 column amounts

Thank you for your attention !