Characterizing the information that space-based observations provide on the spatial distribution of surface fluxes of CO₂

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Expansion of the Carbon Observing System

**Greenhouse gases Observing SATellite (GOSAT)**
- Launched 23 January 2009
- 3-day repeat orbit
- Measurement at 12:48 local time, with a circular footprint with a diameter of 10.5 km
- Measures in glint and nadir modes

**Orbiting Carbon Observatory (OCO-2)**
- Launched 2 July 2014
- 16-day repeat orbit
- Measurement at 13:30 local time, with footprint of 3 km²
- Measures in glint and nadir modes

**Total Carbon Column Observing Network (TCCON)**
- Network of ground-based Fourier transform spectrometers (FTS)
- Measures CO₂ absorption in solar spectra

- Despite the expansion of the observing network, inverse modeling analyses do not produce robust estimates of regional fluxes of CO₂.

**Objective:** Determine what are the differences between the observing systems in their sensitivity to the surface fluxes of CO₂.
Spatio-temporal distribution of the observations

[Byrne et al., submitted to JGR]
Sensitivity to the spatio-temporal distribution of the observations

We relate variations in CO₂ at the locations and times of the observations to the fluxes by taking the derivative of the following sensitivity function with respect to the fluxes:

\[ J = \sum_{k=1}^{N} \text{CO}_2^{\text{obs}}_k \text{ ppm} \]

where \( N \) = number of observations over a season.

The sensitivity of a given set of observations to the flux in grid box \((i,j)\) is:

\[ \gamma_{i,j} = \sum_t \frac{\partial J}{\partial f_{i,j,t}} \quad \text{Unit: ppm/ (kg m}^{-2} \text{ day}^{-1}) \]

We construct the follow ideal set of observations:

**Surface**: Surface and tower observations. Fixed observations from SON 2011 for all seasons

**TCCON**: Observations from years with the most observations for each season at each site

**GOSAT**: QF=0 (Sept 2011 - Aug 2012)

**OCO-2**: WL ≤ 10, QF=0 (Sept 2014 - Aug 2015)
Sensitivity to the spatio-temporal distribution of the observations

- Surface observations capture the seasonal cycle over the northern extratropics (mainly North America and Europe)
- OCO-2 has the highest sensitivity across the tropics and southern hemisphere
- Across Eurasia, the highest sensitivity is obtained from OCO-2 in summer

[Byrne et al., submitted to JGR]
• GOSAT ocean glint data and H-gain land data provide comparable sensitivity to the surface fluxes.
• OCO-2 ocean glint data provides much greater sensitivity to the fluxes than data from the other observing modes.

[Byrne et al., submitted to JGR]
Inversion Analysis OSSEs

We conduct seasonal inversion analyses to recover the true fluxes (starting from a priori land fluxes that are 40% smaller)

- The surface data provide strong sensitivity to North American and European fluxes throughout the year.
- GOSAT and OCO-2 provide the greatest sensitivity to the fluxes mainly during boreal summer.
Summary

- The satellites (particularly OCO-2) provide the greatest sensitivity to fluxes in the extratropical northern hemisphere in summer and to tropical fluxes throughout the year.
- The surface data provide the greatest sensitivity to North American and European fluxes over the whole seasonal cycle.
- Combining the space-based and surface data will provide the greatest constraint on the global carbon cycle.

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