Sensitivity of CO_2 Flux Inversions to the Temporal and Spatial Distribution of Observations

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Introduction

- Question
  - How do differences in spatio-temporal observational coverage affect CO_2 flux estimates?
- Plan
  - Use GEOS-Chem adjoint model to look at sensitivity of observations to surface fluxes spatially and temporally for each season

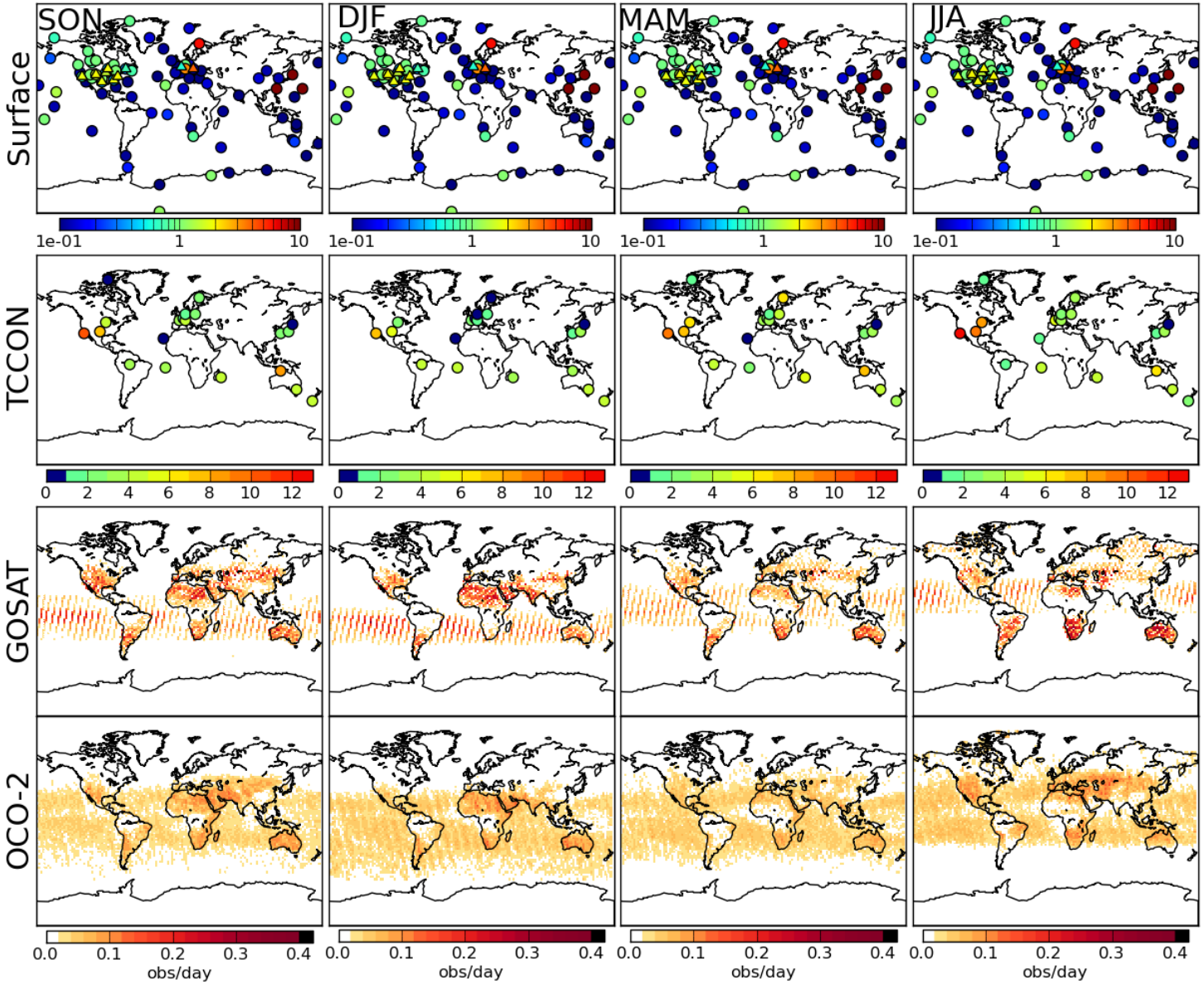
Observing Systems

- **Surface**: Network of surface and tower sites. ObsPack PROTOTYPE package contains 190 data sets from 20 labs.
- **TCCON**: Network of >20 ground-based spectrometers which make measurements of solar spectra to retrieve XCO_2.
- **GOSAT**: TANSO-FTS infers XCO_2 from reflected insolation. Glint mode over ocean, nadir over land.
- **OCO-2**: Infers XCO_2 from reflected insolation. Alternates glint and nadir modes.

Observations

- Use ideal set of observations:
  - **Surface**: Prototype surface and tower observations (similar selection to CarbonTracker). Fixed observations from SON 2011 to each season so that identical observations occur for site for each season.
  - **TCCON**: Observations from years with most observations for each season at each site.
  - **GOSAT**: QF=0 (ACOS, Sept 2011 - Aug 2012)
  - **OCO-2**: WL$\leq$10, QF=0 (ACOS, Sept 2014 - Aug 2015)
- Observations times are aggregated into 2x2.5 degree spatial grids and 1 hour time steps, such that there can only be one observation for a given grid-cell over a given time-step.

Observation Density (number per day)



Method: Calculating Sensitivities

- We relate variations in observed CO_2 at the locations and times of the observations by taking the derivative of the following sensitivity function with respect to the fluxes:

$$J = \sum_{i=1}^{N} \left[\frac{\mathrm{CO2}_i}{\mathrm{Air}_i} \right] \cdot 10^6 \quad (\mathrm{ppm})$$

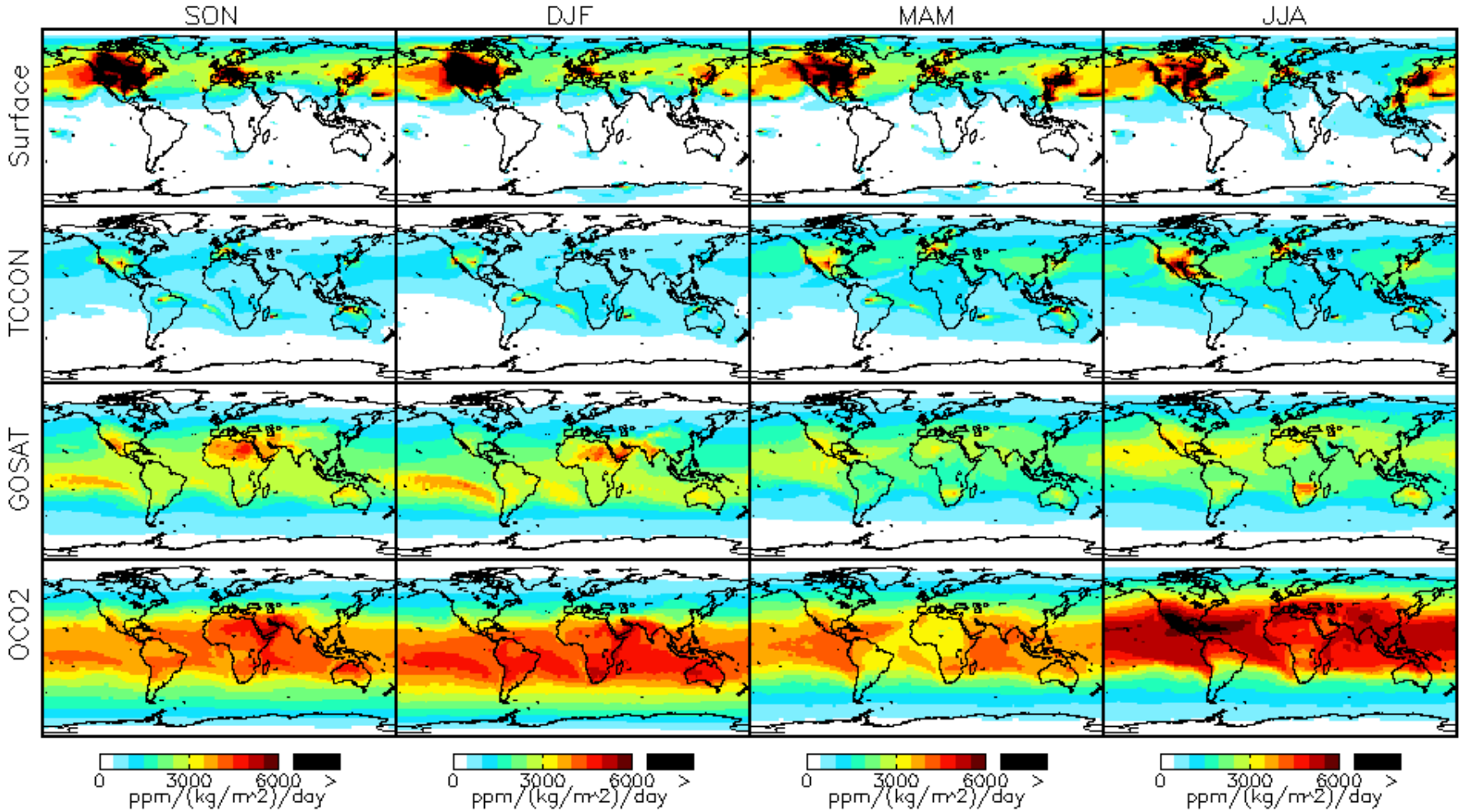
CO2 = mols of CO_2
Air = mols of Air
N = number observations (over a season)

- The sensitivity of an observation to surface fluxes is given by,

$$\gamma_{i,j} = \sum_t \frac{\partial J}{\partial f_{i,j,t}}$$

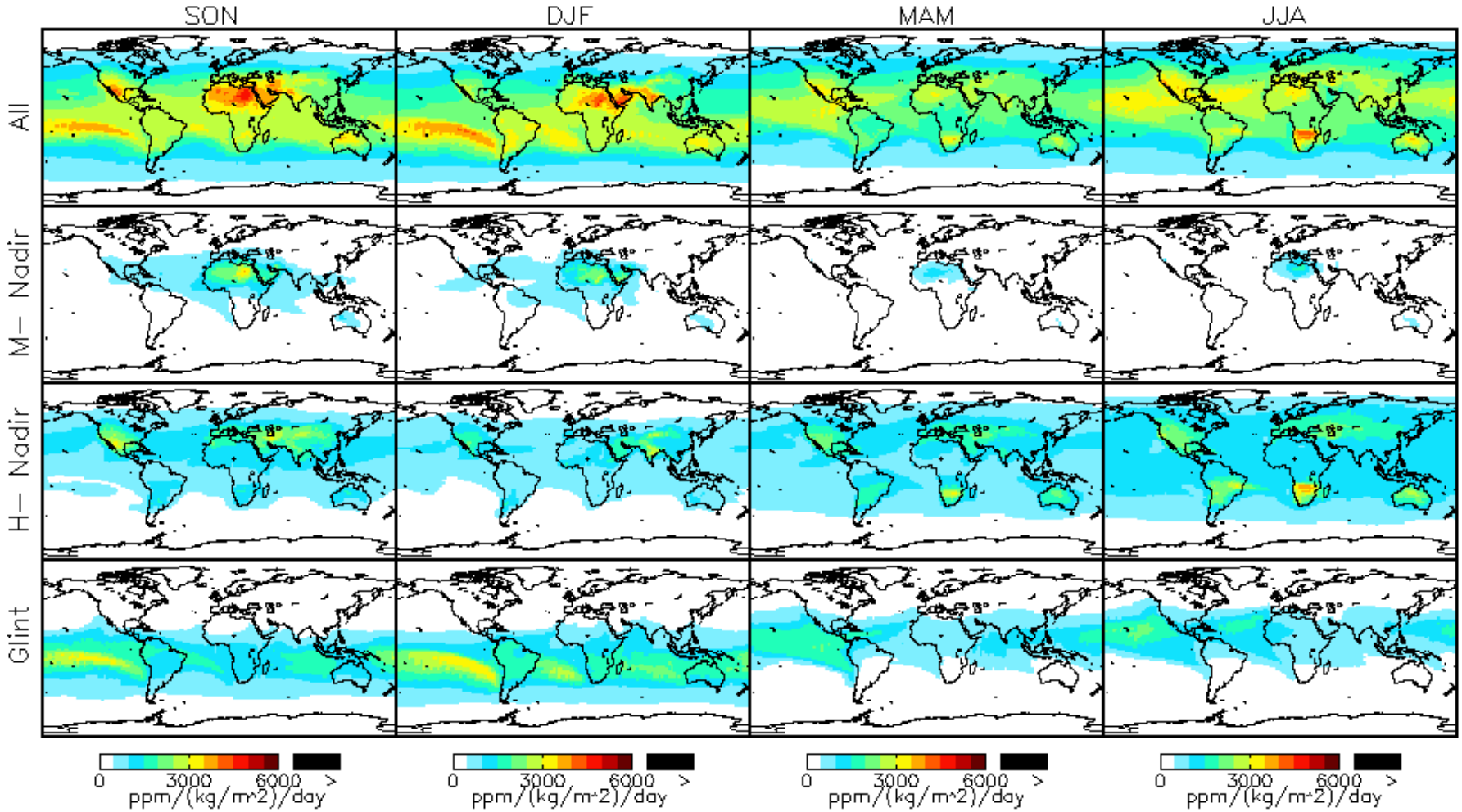
f = surface fluxes

Sensitivities



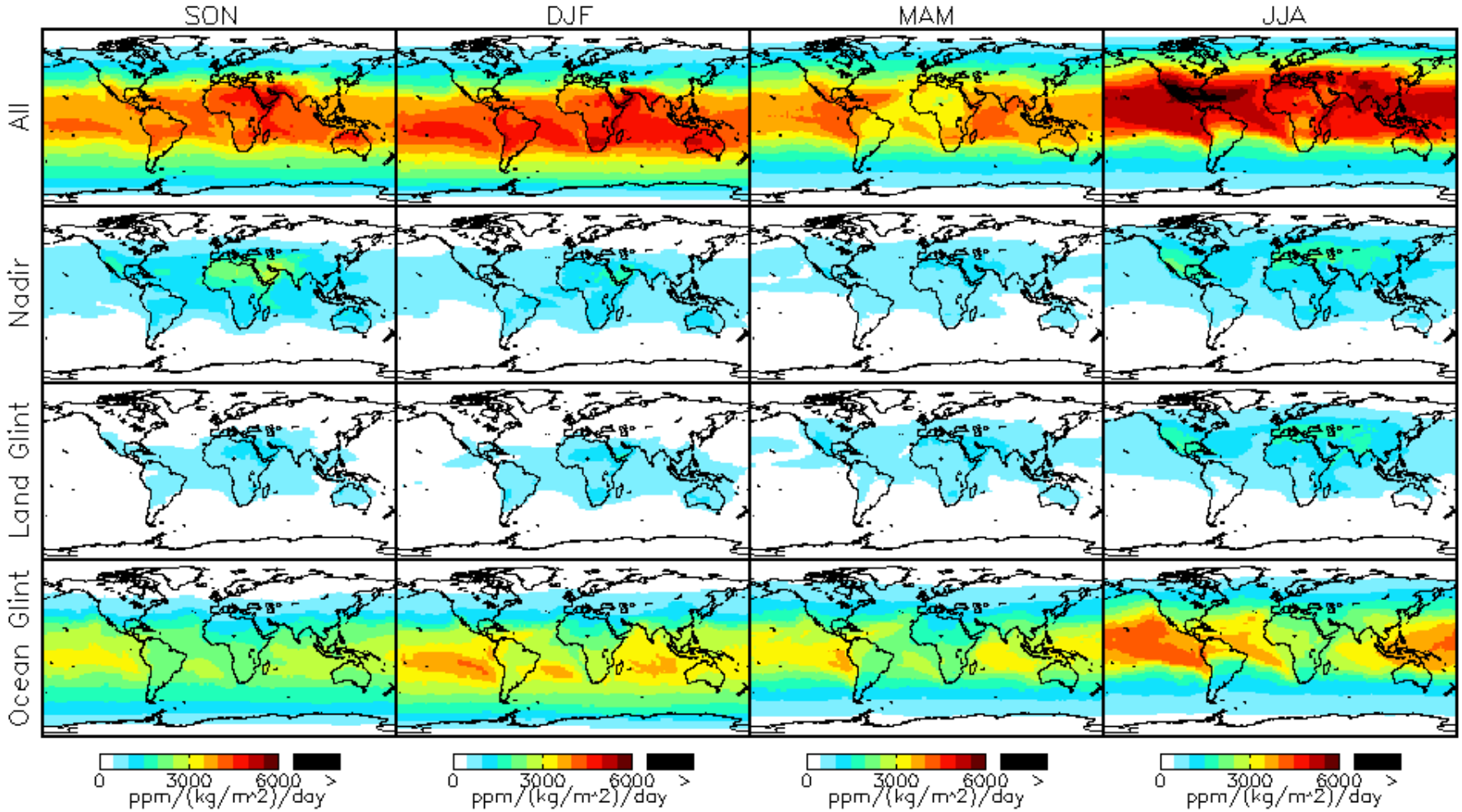
- Surface obs highest over most of northern extratropics
- OCO-2 highest in tropics and southern hemisphere

Sensitivities: GOSAT Observing Modes



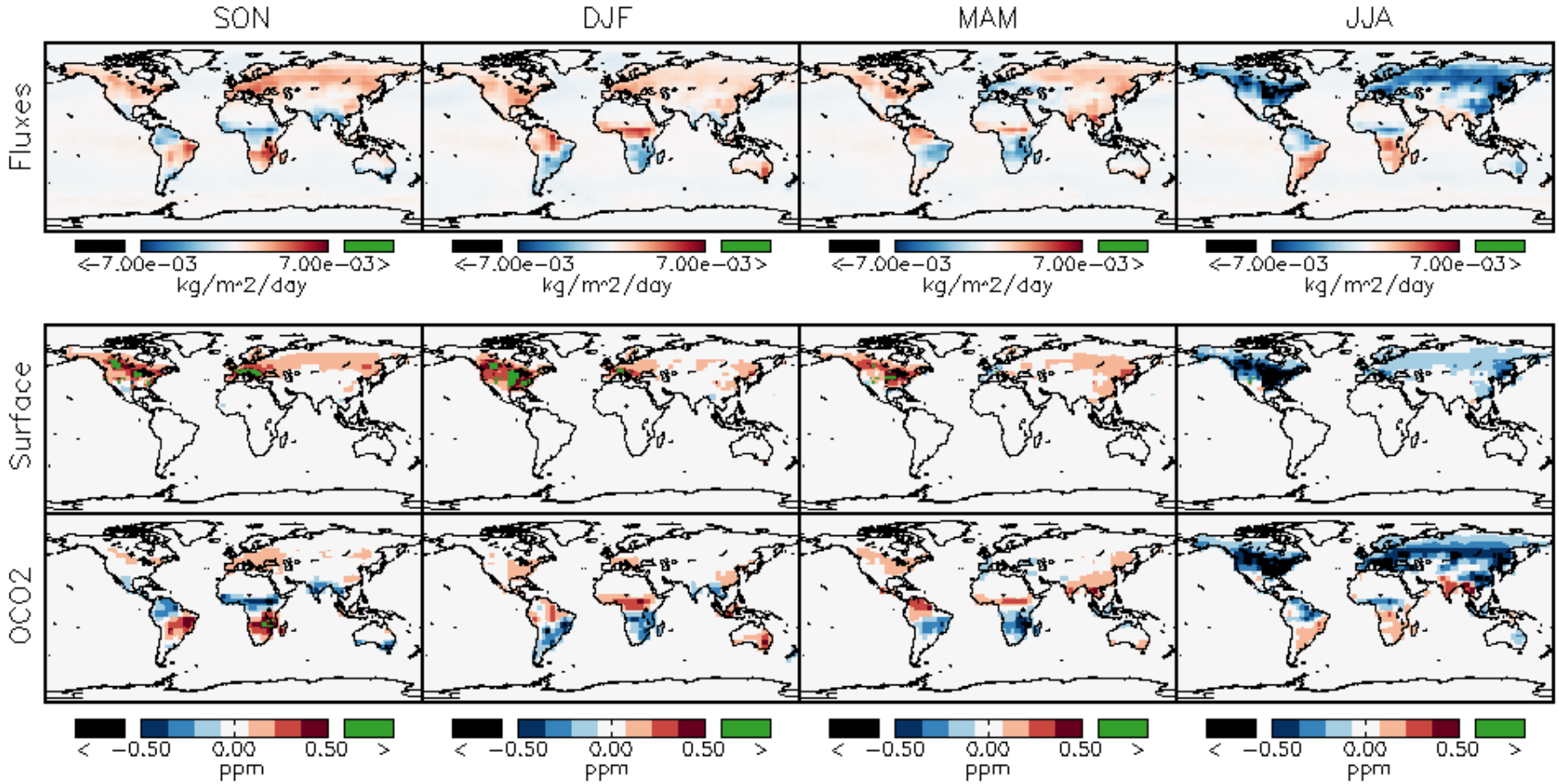
- Ocean glint and H-Gain nadir have similar importance
- Spatial distribution of ocean glint varies seasonally

Sensitivities: OCO-2 Observing Modes



- Ocean glint dominates
- Land glint and nadir are similar

Contribution: Sensitivities × Flux



- Surface observations are sensitive to North American and European seasonal cycle
- OCO-2 is sensitive to tropical seasonal cycle and northern extratropic in JJA

Conclusions

- OCO-2 has highest sensitivity for most of globe over all seasons.
  - provides the highest sensitivity to fluxes across Eurasia in JJA.
  - captures the seasonal cycle in the tropics and southern subtropics.
- Surface observations have highest sensitivity to northern hemisphere for SON, DJF, MAM.
  - captures the seasonal cycle in North America and Europe.
- Combining OCO-2 and the surface data should enable us to better capture the global seasonal cycle and the inter-hemispheric gradient in CO_2.
- The substantial sensitivity differences between observation systems means careful consideration is required in comparing inversion flux estimates.

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- Cooperative Global Atmospheric Data Integration Project. 2013, updated annually. Multi-laboratory compilation of atmospheric carbon dioxide data for the period 2000-2012 (obspack_co2_1_PROTOTYPE_v1.0.4b_2014-02-13). Compiled by NOAA Global Monitoring Division: Boulder, Colorado, U.S.A. Data product accessed at http://dx.doi.org/10.3334/OBSPACK/1001.
- TCCON data were obtained from the TCCON Data Archive, hosted by the Carbon Dioxide Information Analysis Center (CDIAC) - tccon.onrl.gov.