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Interannual variability of the global carbon cycle estimated with GOSAT and ground-based CO_2 observations for 2009-2019.

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Introduction:

- Assimilating ground-based and satellite data from continental locations, especially in densely populated regions, is not a trivial task, due to strong anthropogenic sources. High resolution transport modeling helps reducing crosstalk between various sources: anthropogenic/fossil, ecosystem sink/respiration, biomass burning

- We estimate global CO_2 fluxes with GOSAT data and high resolution (0.1 degree) CO_2 inverse modeling system, as in Maksyutov et al, ACP, 2021, which was improved with 3 new developments:

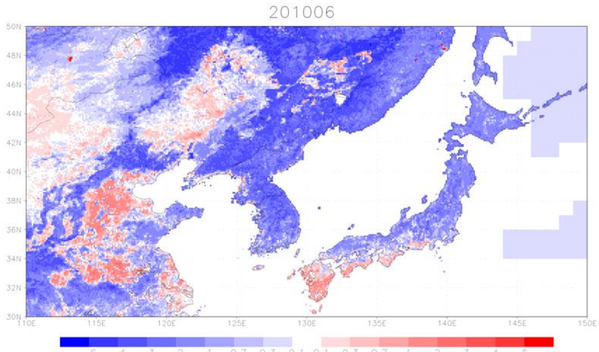
1. New meteorology by ERA-5 reanalysis – leads to improving the interhemispheric transport rate, and vertical profiles in troposphere

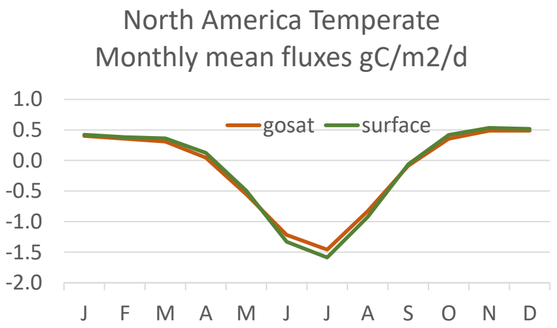
2. Observation-based prior fluxes by terrestrial vegetation (Zeng et al 2020) and ocean (Landschutzer et al 2016) – derived with machine learning (rather than process-based models in former version). Ocean prior flux scaled to increase mean sink to 2.7 GtC/year.

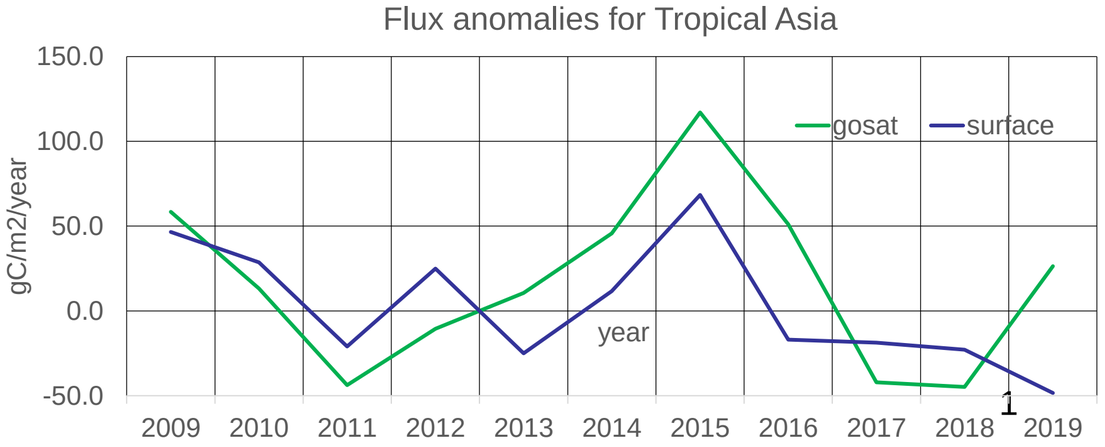
3. Storage of the large transport matrixes (>100GB/inversion) on disk, rather than RAM (typical for big data problems), allows running inversion of satellite observations by GOSAT on general purpose computer systems

Summary of results

- Simulations with prior flux are close to reproducing seasonal cycle. High concentration plumes are generally resolved.
- GOSAT level 2 v2.95 with additional bias correction - to match monthly mean averages by ground-based inversion for 5 deg latitude bands
- Estimated fluxes (GOSAT+ground-based) are consistent with those based on ground-based data only, in simulation of seasonal cycle and interannual flux anomalies.
- Both surface and GOSAT inversion give near-neutral tropical + southern extratropical mean fluxes for 2009-2019





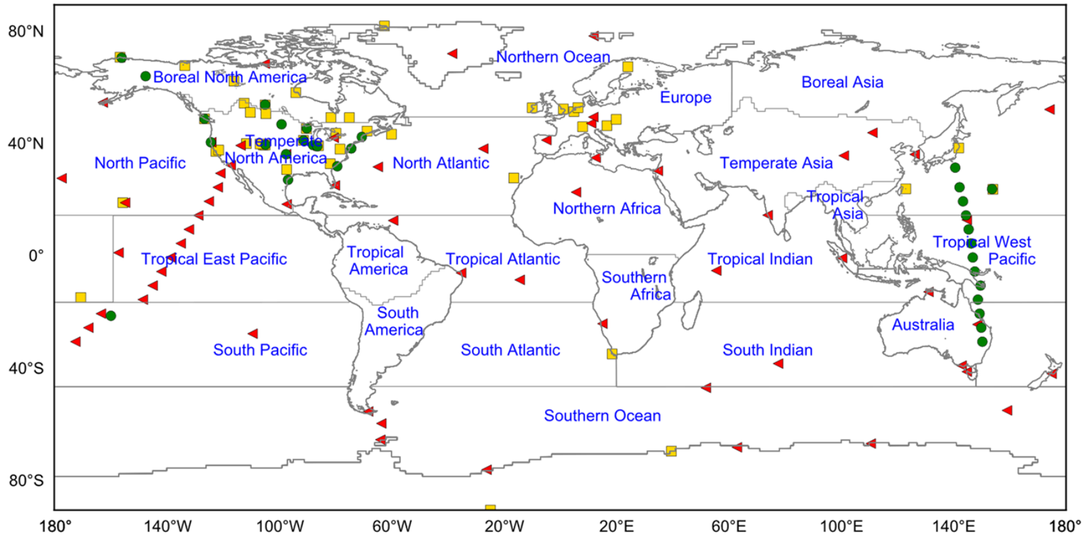


Coupled Eulerian-Lagrangian transport model (NIES TM + Flexpart), validation and input data

-NIES-TM (new meteorology/grid)
- resolution 3.75 degree
- reduced grid near poles
- mass conserving meteorology,
-mass fluxes on hybrid sigma pressure vertical coordinates (42 levels),
-winds interpolated from hourly 132 level ERA-5 winds, model (etadot) vertical velocity provided by reanalysis –improved mass conservation

-Flexpart (revised diurnal output)
-JRA-55 meteorology (interpolated to 1.25 deg, 40 model levels, 6 hourly)
-surface flux footprints estimated on 0.1x0.1 deg, daily and hourly time step
-time window 3 days (for coupling to NIES-TM at 0 GMT)
-for coupling to NIES-TM, 3D concentration footprints estimated on hybrid-sigma vertical grid

Ground-based observations (Obspack-GVP, 2019), and Transcom regions



Validation of a revised transport model by comparison to Transcom AOA experiment Krol et al GMD 2018:

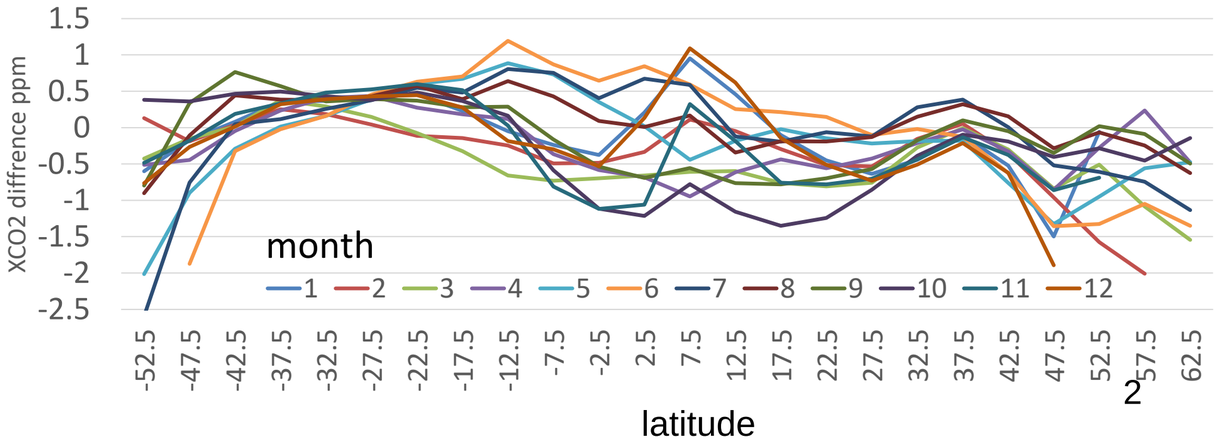
tracer	Krol 2018 model range	NIES-TM
SF6 (North-South gradient) ppt	0.36±0.01	0.35
radon: $\ln(Rn_{950mbar}/Rn_{500mbar})$	1.25 - 1.67	1.58
e90 (tropopause height) mbar	~270	~270

Preparation of Obspack and GOSAT Level 2 data

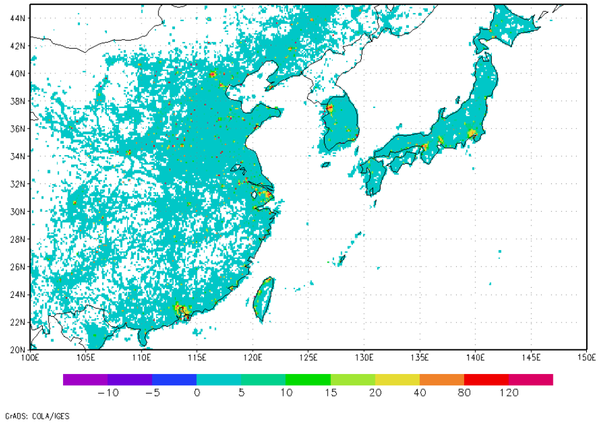
Single scan GOSAT NIES L2 v02.95 data are used without averaging, the correction is applied to remove monthly mean model-observation difference estimated for 5 deg latitude bands, model is optimized with ground-based data inversion.

Obspack data processing: pair of flask is averages onto one observation, continuous data over land averaged from 2pm to 4 pm into one observation per day

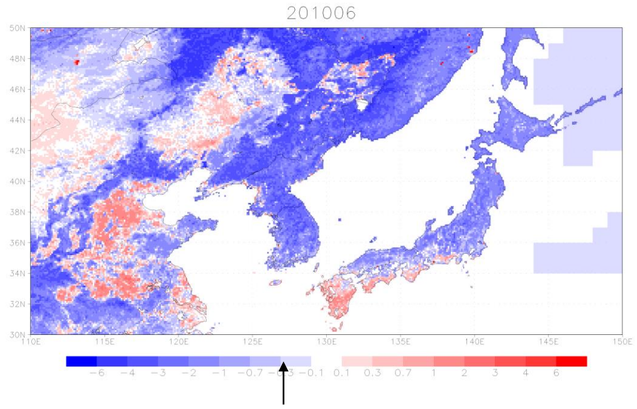
Bias correction: GOSAT v.02.95 - model



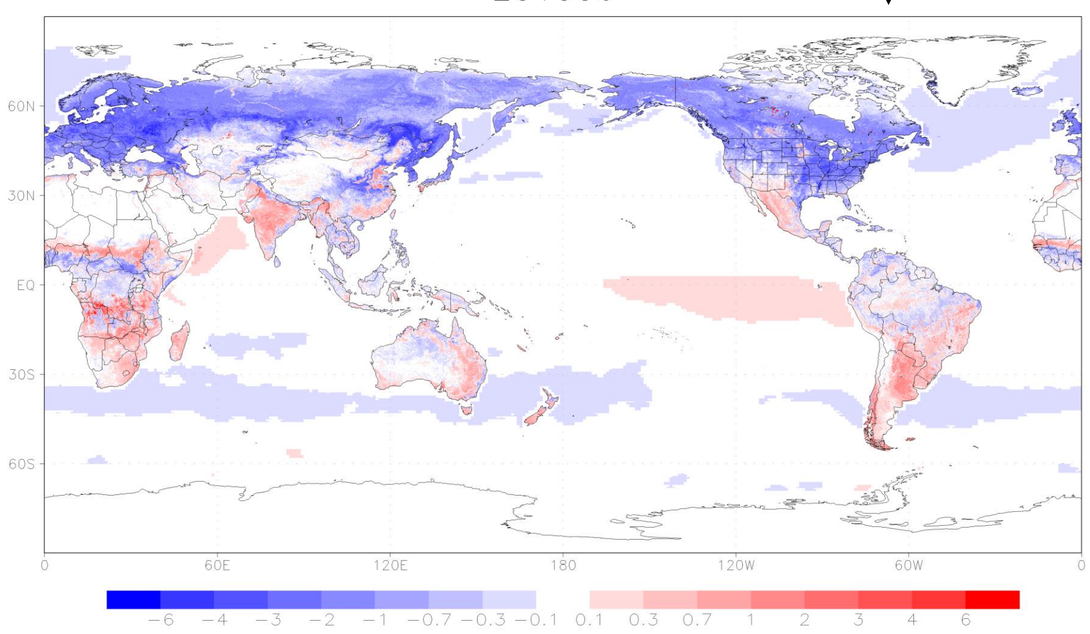
Prior fluxes: categories (wide range of amplitudes from 0.1 g/m2/day (ocean) to 100 g/m2/day (fossil and fires), and resolutions from 10 km to 100 km



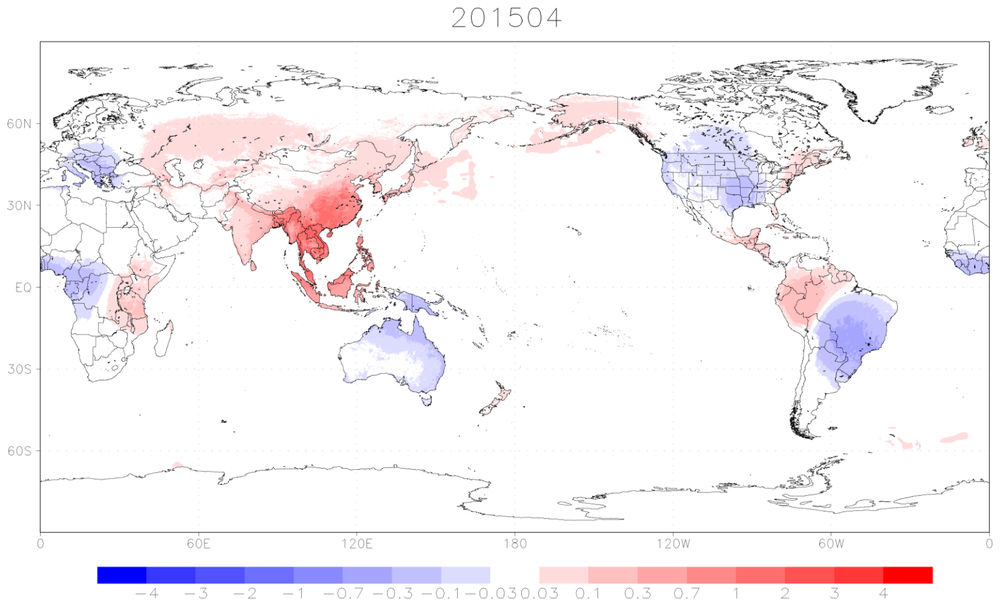
Fossil emissions ODIAC 2019

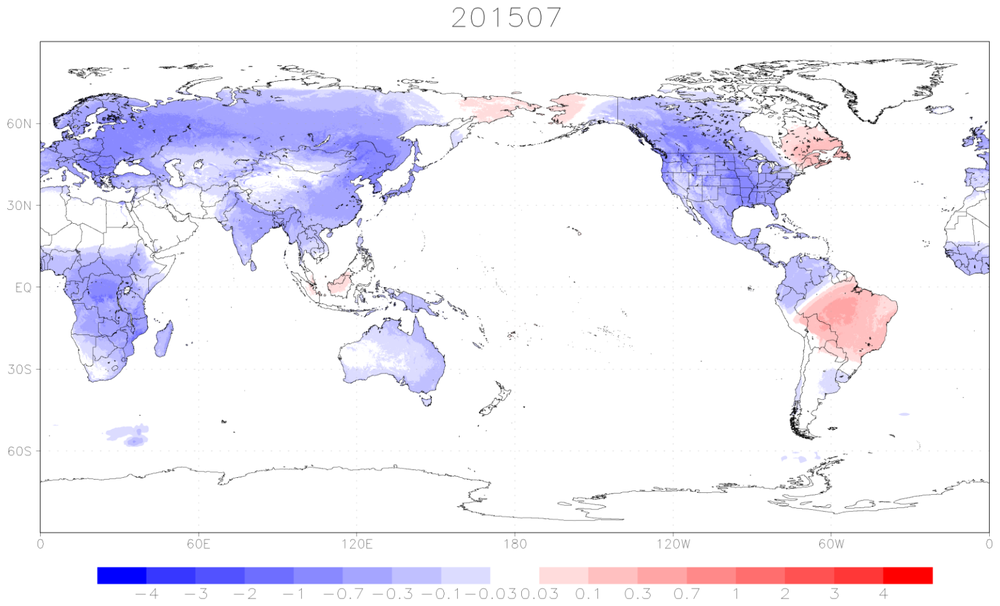


Terrestrial biosphere, flux upscaling with ML Zeng et al, Sci. Data 2020,
Ocean CO_2 surface exchange, with ML algorithm, Landschutzer et al 2015
Biomass burning: GFAS

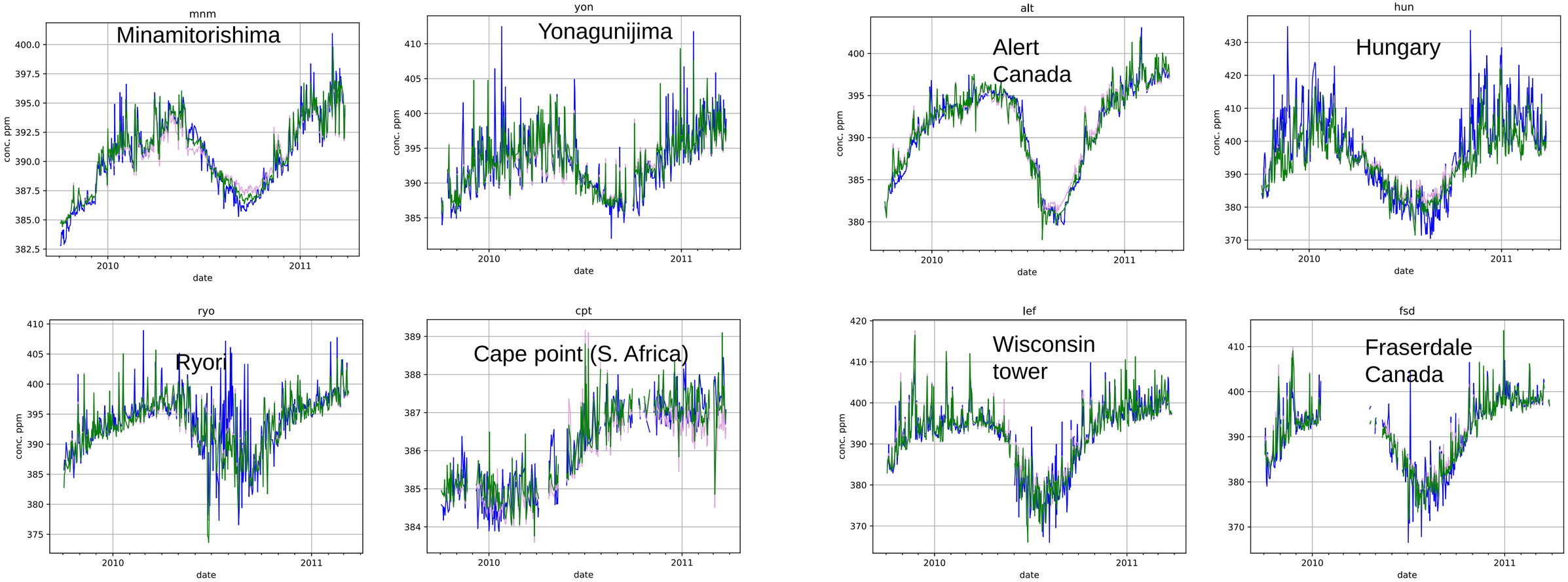


Posterior flux corrections (gC/m^2/day) for 2015/04 and 2015/07





Simulated CO_2 concentrations (GOSAT+surface data inversion)

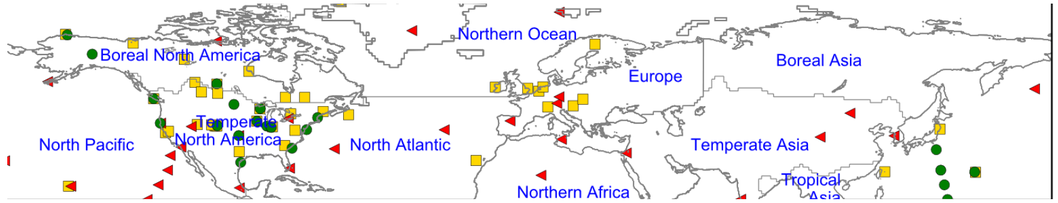


observations (blue), forward/prior (plum), inversion (green)

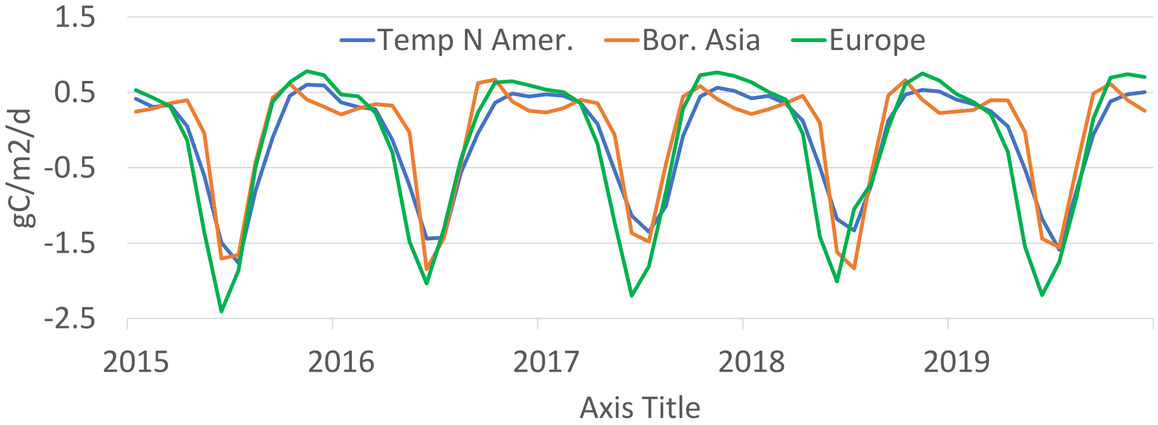
(On some sites, the fit at continuous observations sites is a little better without GOSAT, which may depend also on convergence criteria in iterative optimization)

Good seasonal cycle match even without inversion

Multiyear regional flux estimates

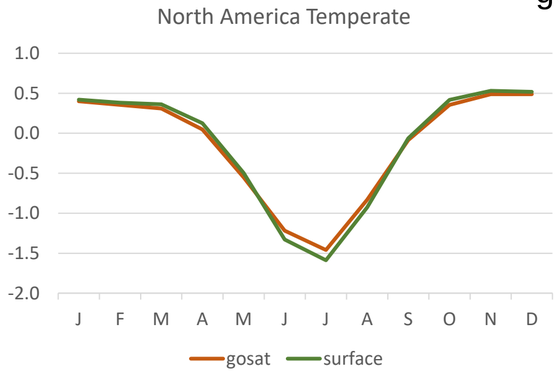


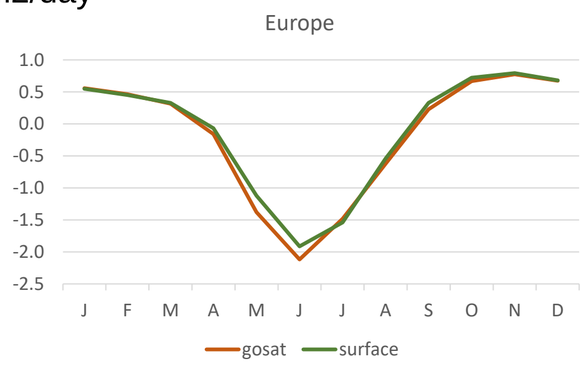
Regional fluxes estimated with GOSAT+surface data (N.Hemisphere)



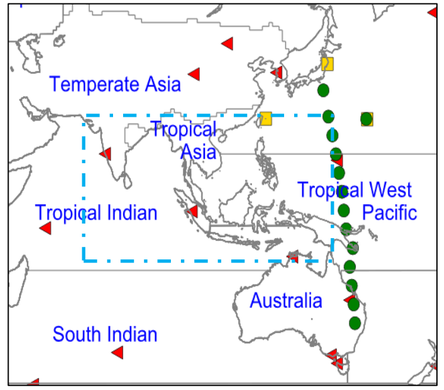
Mean seasonal cycle in the Northern Hemisphere

gC/m2/day

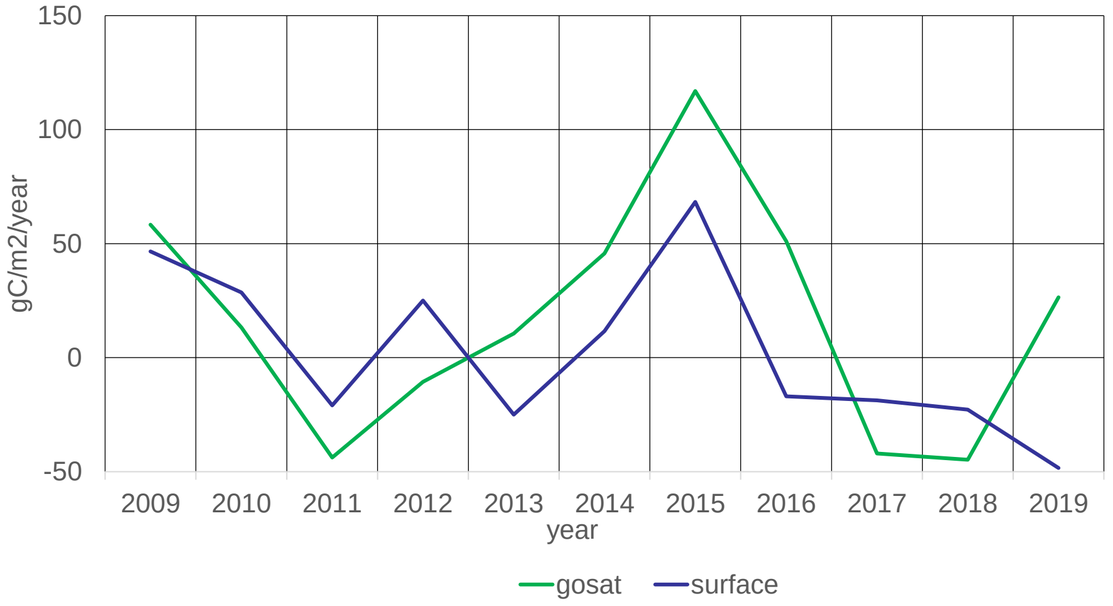




Comparison for strong 2015-2016 El-Nino anomaly in SE Asia: GOSAT estimates stronger anomaly, for other years estimates on average close to ground-based

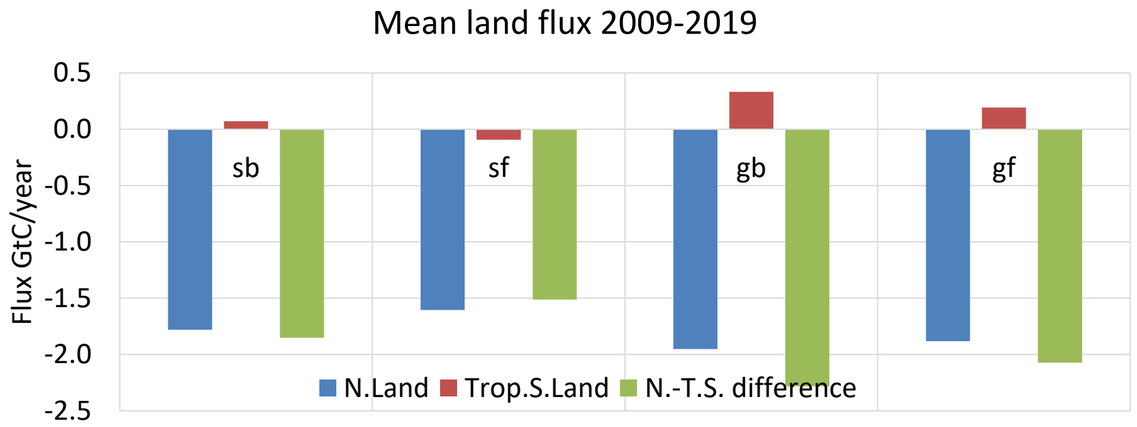


Flux anomalies for Tropical Asia



Posterior seasonal cycle estimates for N. Hemisphere continents – very similar between surface and GOSAT

Sink balance: northern extratropical land vs tropical and south



sb : surface background sites, sf : surface all sites,
gb : GOSAT+sb, gf : GOSAT+sf

Most inverse models recently tend to estimate near neutral tropical+ southern extratropical land flux

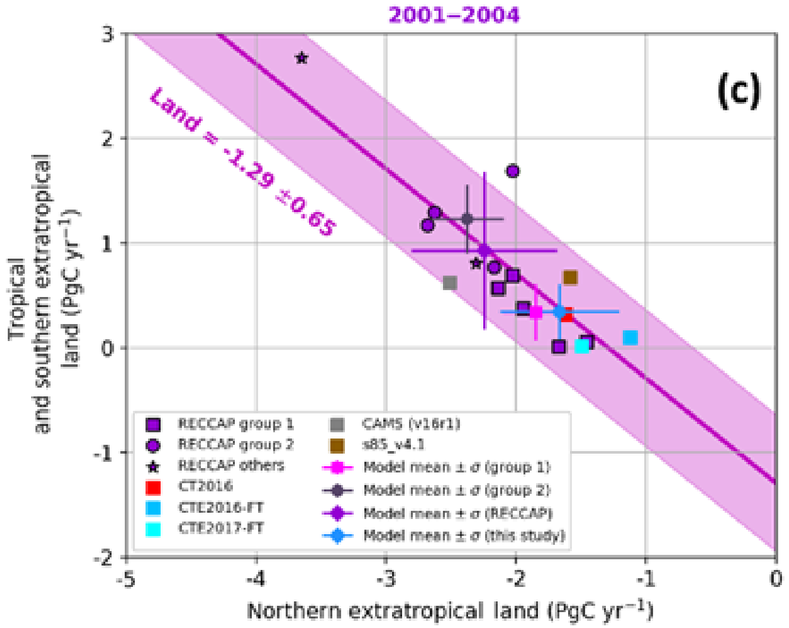
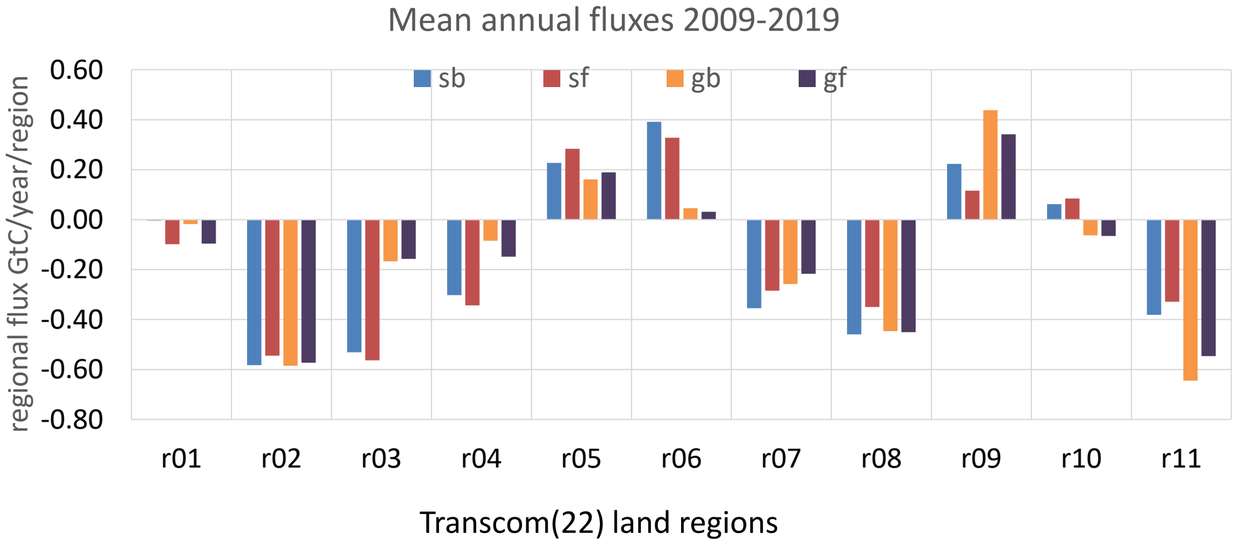


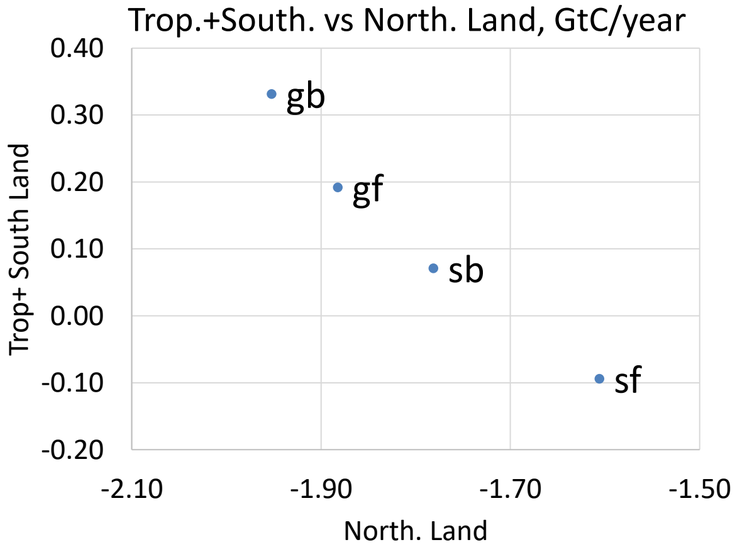
Figure from:

Gaubert et al
Biogeoscience 2019

Global atmospheric CO2 inverse models converging on neutral tropical land exchange, but disagreeing on fossil fuel and atmospheric growth rate

Mean regional fluxes for Transcom land regions





All four cases simulate near neutral tropical flux, GOSAT show stronger emissions in SE Asia, and stronger sink in Europe