The Impact of Transport Model Uncertainty on Satellite and In Situ Flux Inversions

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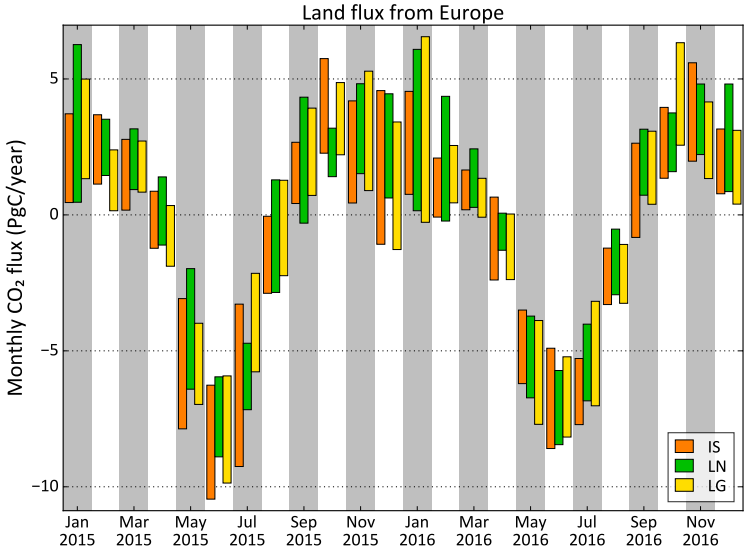
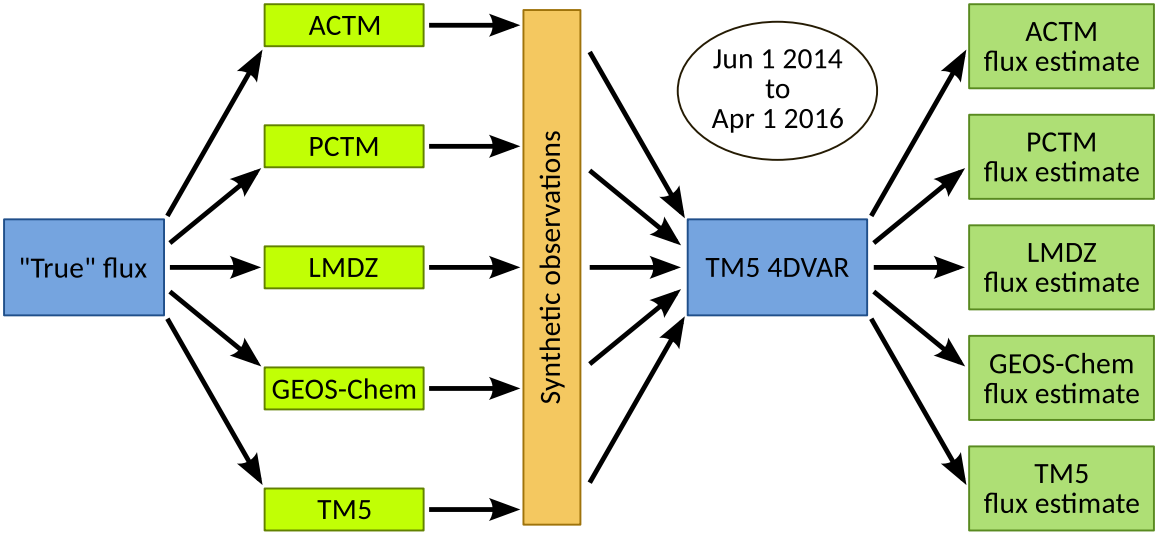
Motivated by ongoing OCO_2 flux intercomparison across research groups



- Inversions from ~10 groups with the same OCO_2 input data, data errors and fossil fuel emissions
- How much of the cross-model spread is due to modeled transport?
- Are differences in, say, IS vs LN, due to relative biases in the data streams?

Fluxes from Baker, Chevallier, Deng, Feng, Liu, Jacobson, Crowell, Schuh and Basu

The pseudo-data experiment



The pseudo-data experiment

Driver meteorology (fwd):

- ECMWF ERA Interim
- MERRA
- GEOS-5
- JRA-55

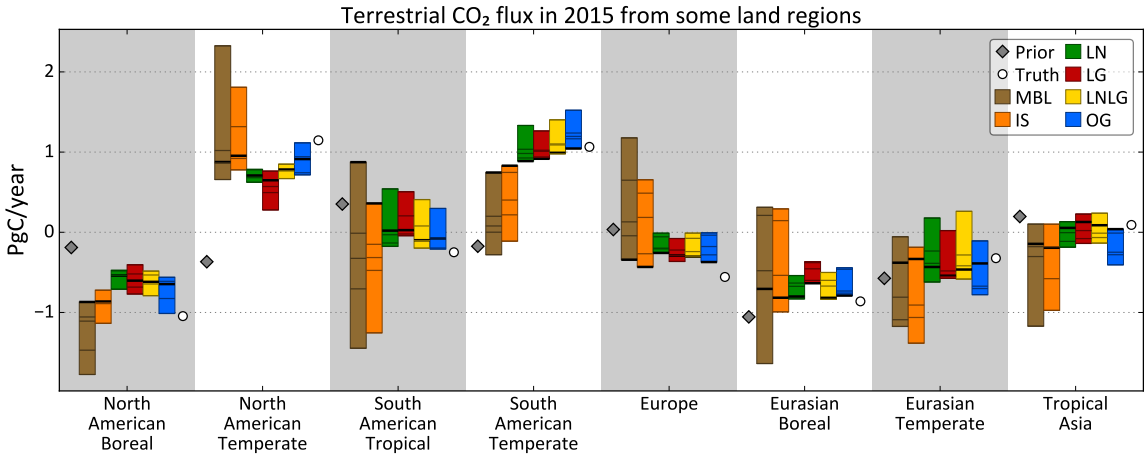
Driver meteorology (inv):

- ECMWF ERA Interim

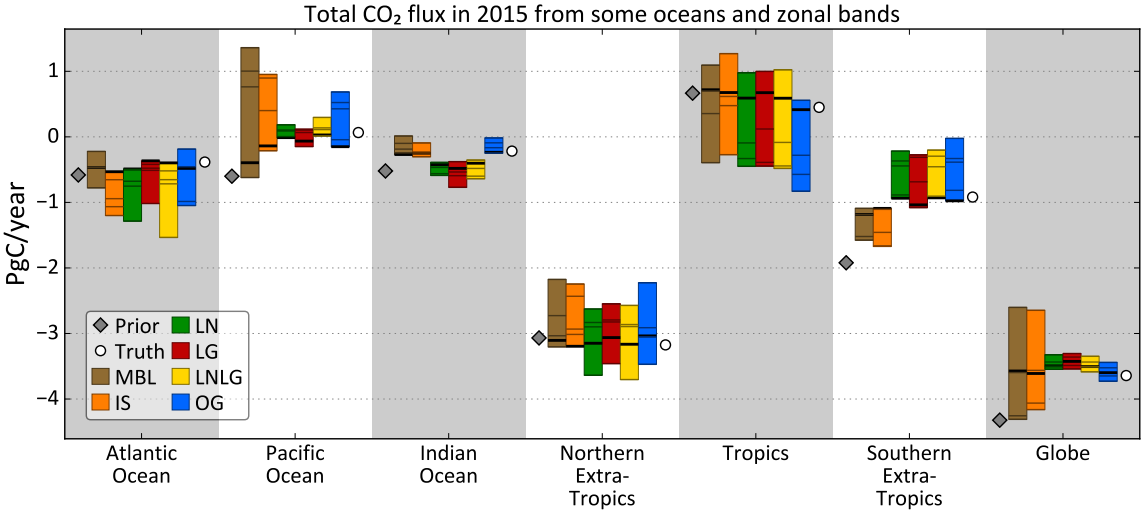
Pseudo-data selection:

- Mostly background, a la Baker et al (2006), “MBL”
- In situ, ObsPack GV+2.1 + NRT 3.3, “IS”
- OCO_2 v7 land nadir, “LN”
- OCO_2 v7 land glint, “LG”
- OCO_2 v7 ocean glint, “OG”
- OCO_2 pseudo-data binned in 10 s averages

Transport-driven uncertainty in annual fluxes

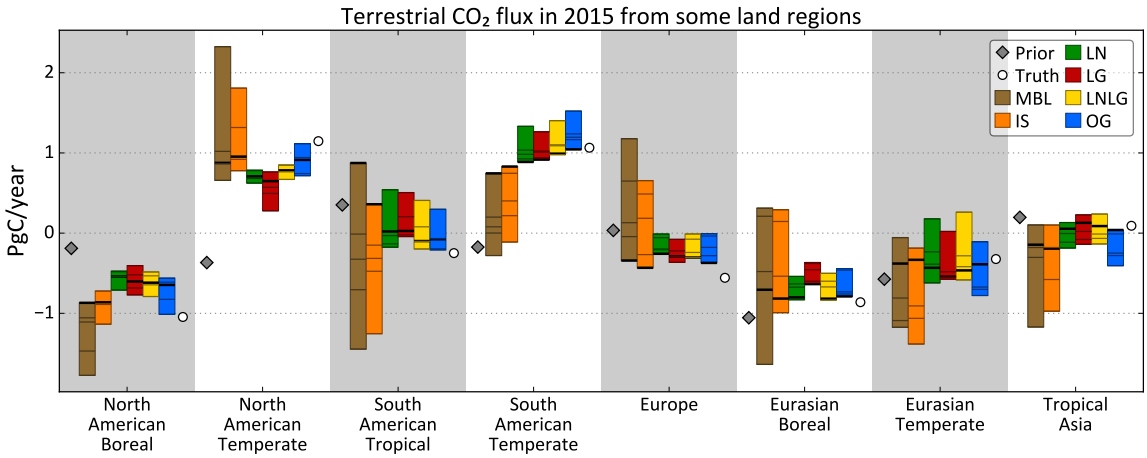


IS often results in lower spread than MBL, XCO_2 spread is often smaller than both IS and MBL



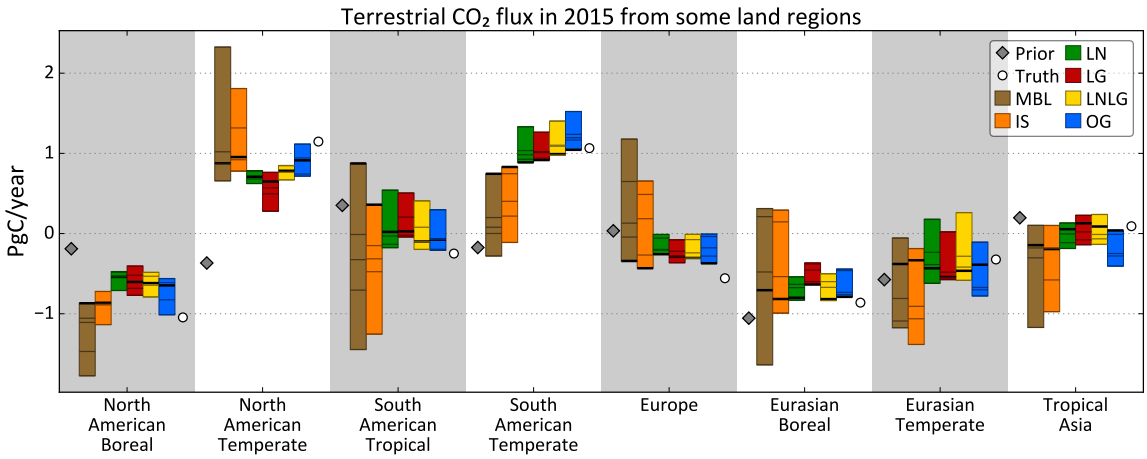
This “benefit” of column data is not as obvious over oceans or zonal bands

Transport-driven uncertainty in annual fluxes



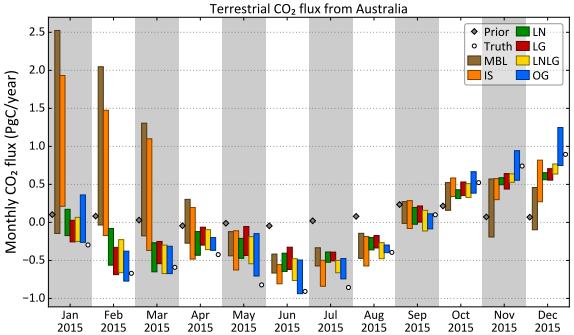
Spread due to transport is no smaller over the Tropics than over Temperate regions, unlike uncertainty due to measurement coverage

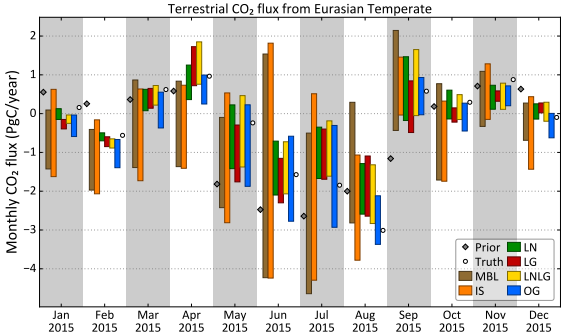
Transport-driven uncertainty in annual fluxes



Mismatches in flux estimates are from coverage + non-ideal transport, not relative biases between data streams

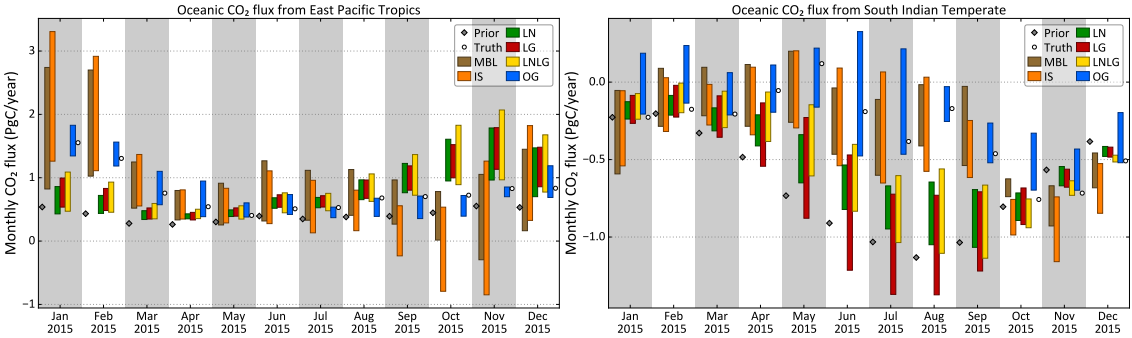
Transport-driven uncertainty in monthly fluxes





Marked seasonality over temperate latitudes, consistent with higher summertime transport uncertainty due to stronger vertical transport

Transport-driven uncertainty in monthly fluxes



Non-overlapping spread between IS and LN, or LG and OG, is not because of relative biases in the data streams. Rather, it is due to imperfect transport + sampling differences.

Sometimes, IS and MBL are close to truth, but LN/LG are not.

- We have estimates of transport model uncertainty of flux estimates which can be used to evaluate the robustness of MIP results
- Given unbiased estimates of XCO_2, transport model uncertainty is usually lower for terrestrial flux estimates using XCO_2 compared to PBL CO_2. This conclusion does not always hold over ocean regions or zonal bands.
- Spread in fluxes due to transport not smaller over temperate regions compared to tropical regions, unlike analytical flux uncertainty due to measurement availability
- Imperfect transport + selective sampling can give rise to differences in flux estimates that have nothing to do with measurement biases

Is this the right measure of transport-driven uncertainty?

Difference between two flux estimates using different transport models K_1 and K_2 and identical everything else,

$$\hat{\mathrm{x}}_i = \mathrm{x}_a + \left(I - \hat{S}_i S_a^{-1}\right)(\mathrm{x}_t - \mathrm{x}_a)$$
$$\hat{S}_i = \left(S_a^{-1} + K_i^T S_\epsilon^{-1} K_i\right)^{-1}$$
$$\hat{\mathrm{x}}_1 - \hat{\mathrm{x}}_2 = \left(\hat{S}_2 - \hat{S}_1\right) S_a^{-1}(\mathrm{x}_t - \mathrm{x}_a)$$

Crucial assumption is that transport models are unbiased, so that $\mathrm{y} = K_i \mathrm{x}_t$. This is not true for us. Instead, what I'm calculating is

$$\hat{\mathrm{x}}_1 - \hat{\mathrm{x}}_2 = \hat{S} K^T S_\epsilon^{-1}(K_1 - K_2)\mathrm{x}_t$$

where x_t are the true fluxes, K_1 and K_2 are two transport models, and K is TM5.