Detecting trends in fossil fuel emissions with $^{14}CO_2$ in the presence of transport errors and biased inventories

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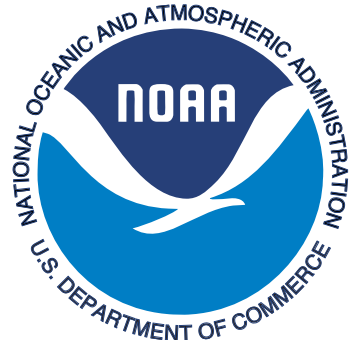
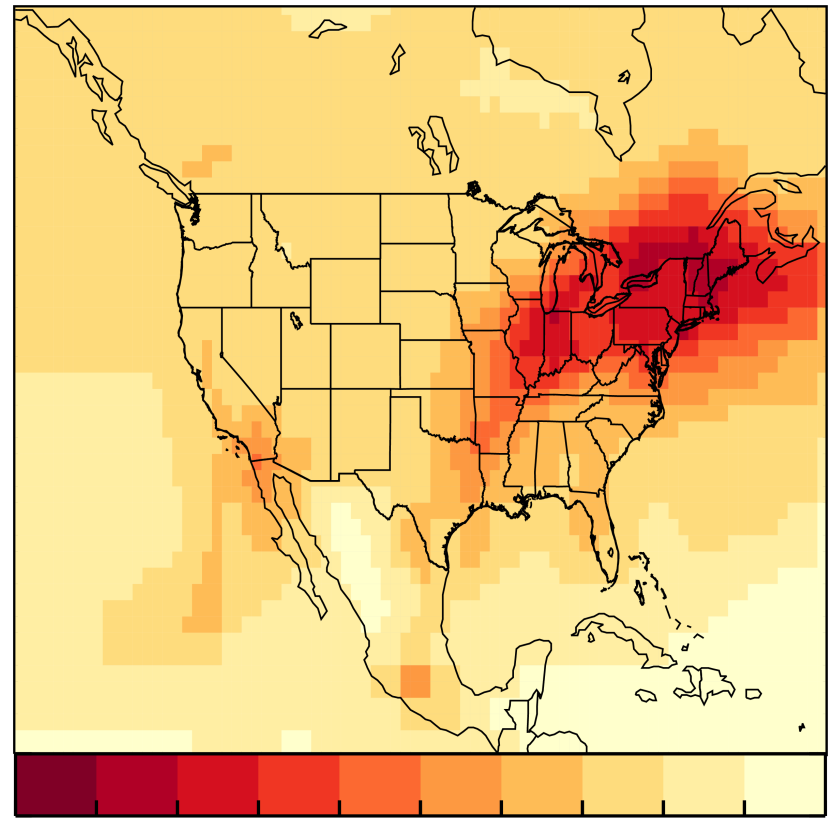


Global Monitoring Annual Conference
23rd May 2017, Boulder CO

The goal: Atmosphere-based estimate of fossil fuel CO_2 emissions

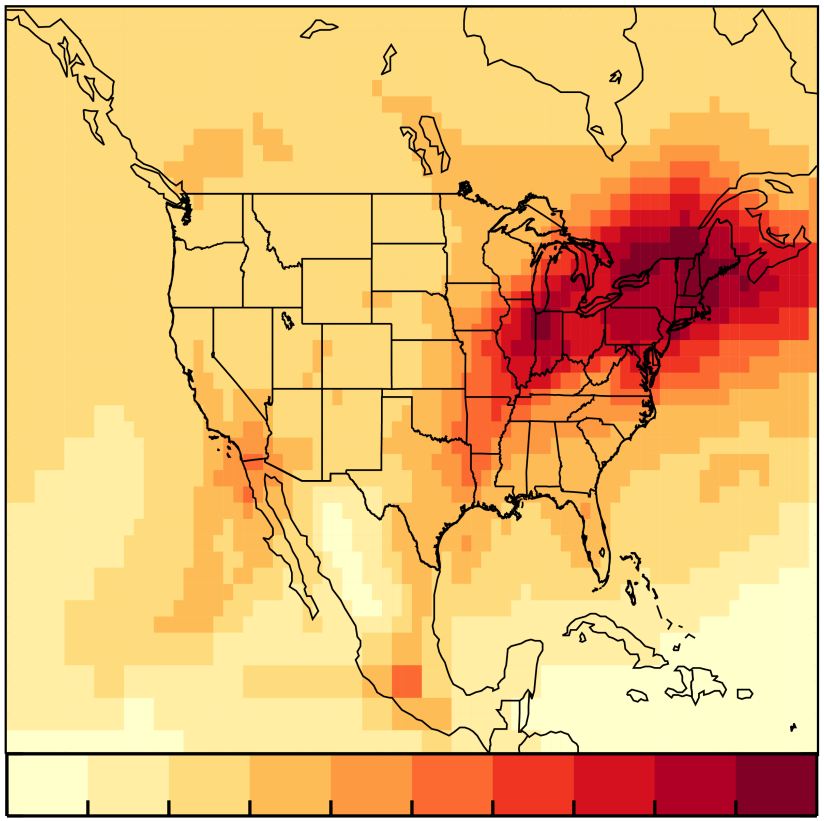
Can we estimate fossil fuel emissions from atmospheric measurements, using minimal information from inventories?



40 42 44 46 48 50 52 54 56 58 60

$\Delta^{14}C$ [per mil]

Quantity we can measure

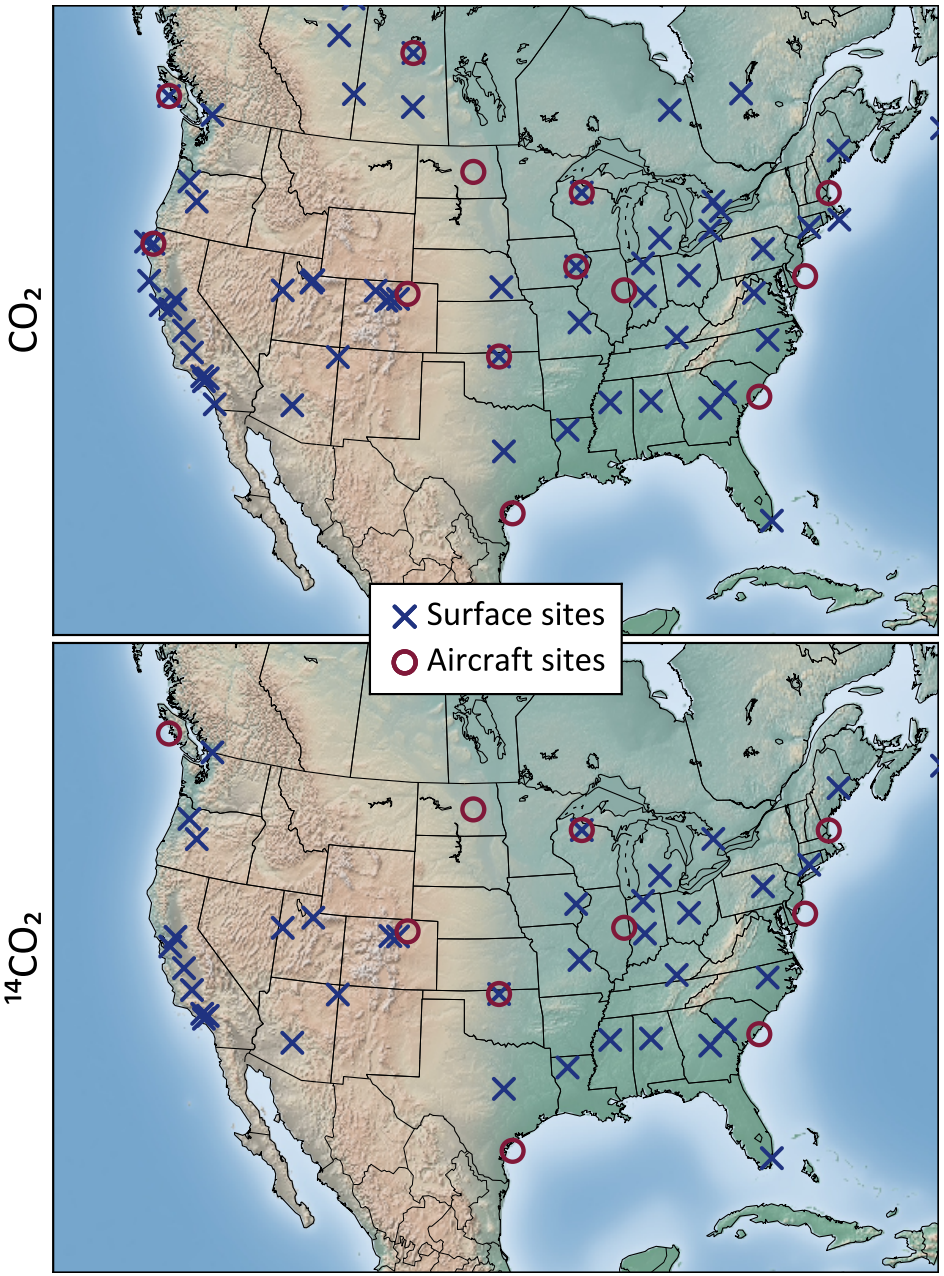


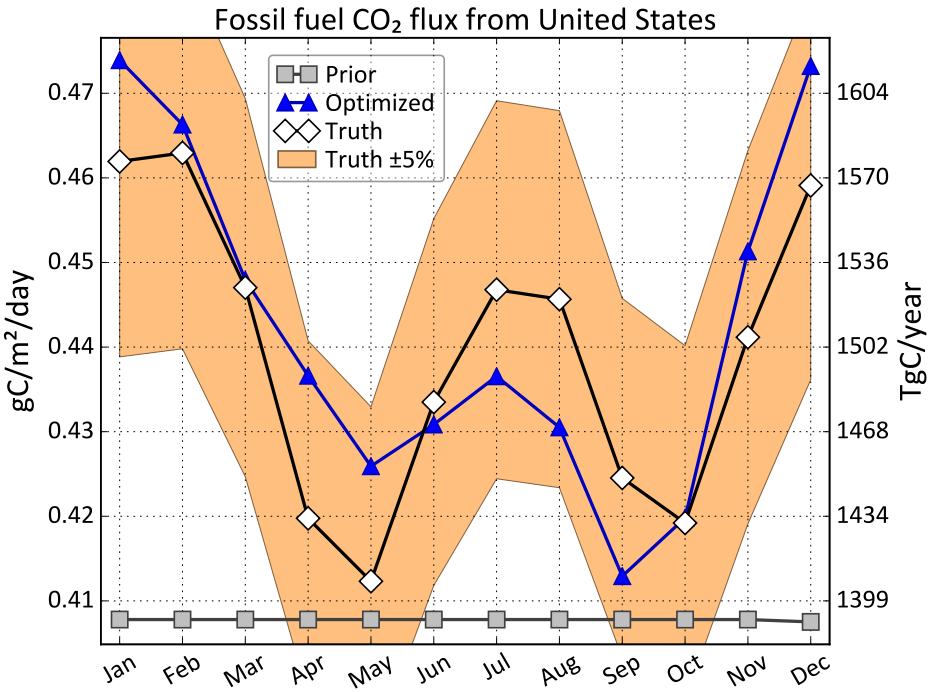
0.0 0.7 1.5 2.2 2.9 3.6 4.4 5.1 5.8 6.5 7.3

C_{ff} [ppm]

Tracer we want to estimate

The story so far: A framework for estimating FF CO_2 emissions

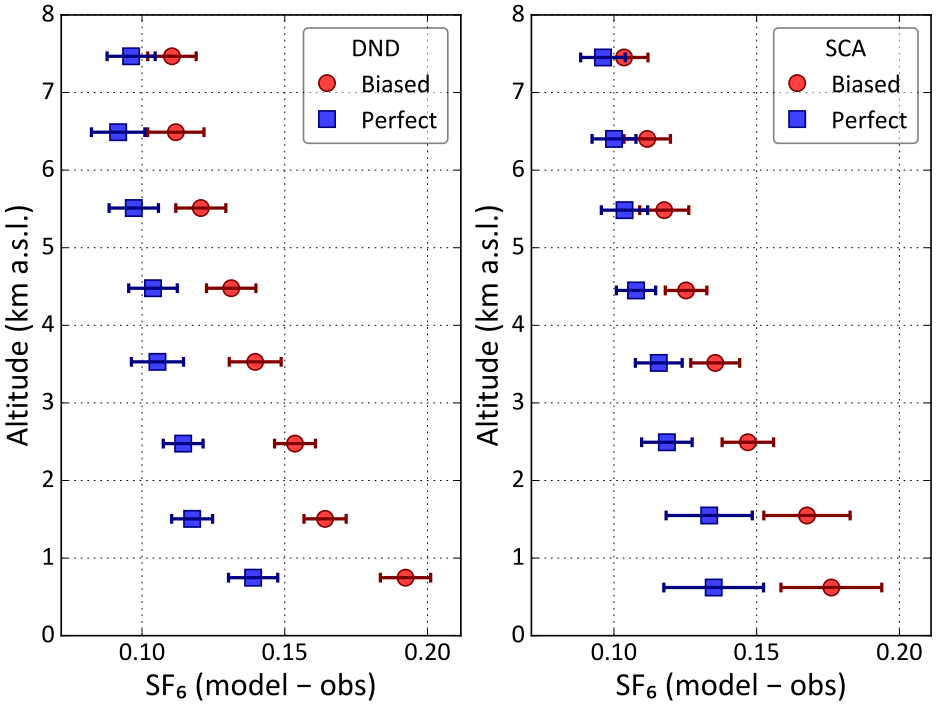




~5000 $^{14}CO_2$ measurements/year let us estimate annual total US emission to within 1%, and monthly emissions to within 5%

Basu et al, ACP (2016)

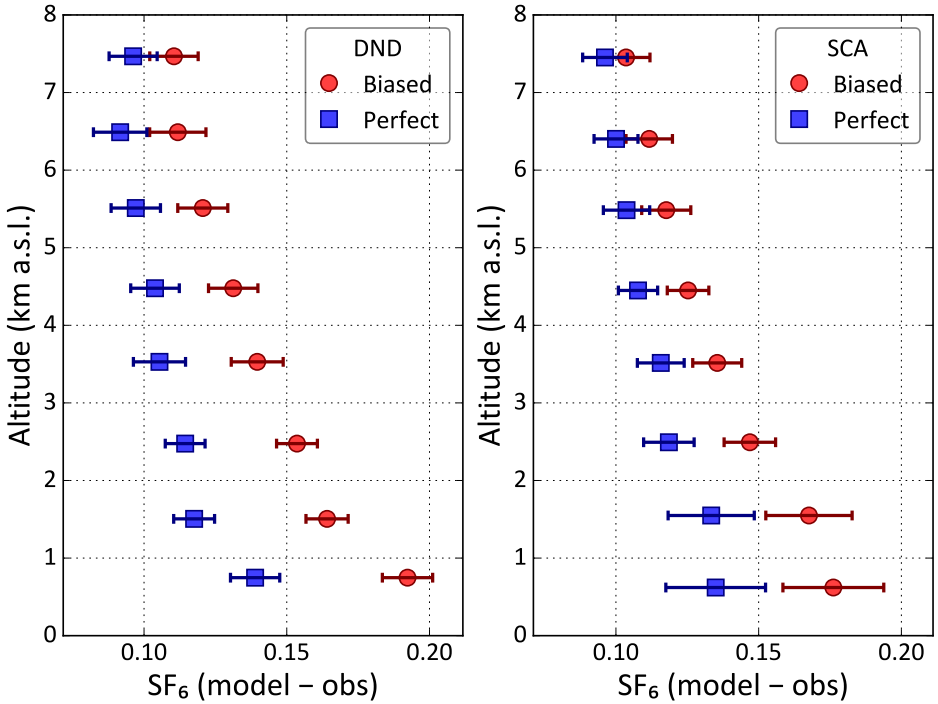
The story so far: The impact of biased transport

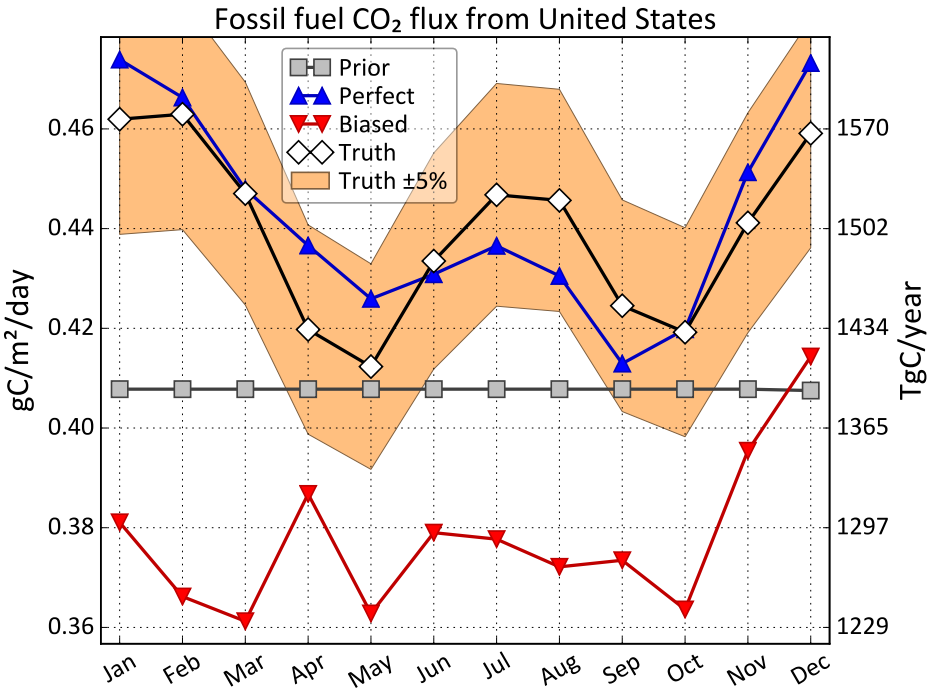


Biased transport = TM5 with different vertical transport

Basu et al, ACP (2016)

The story so far: The impact of biased transport





Biased transport = TM5 with different vertical transport

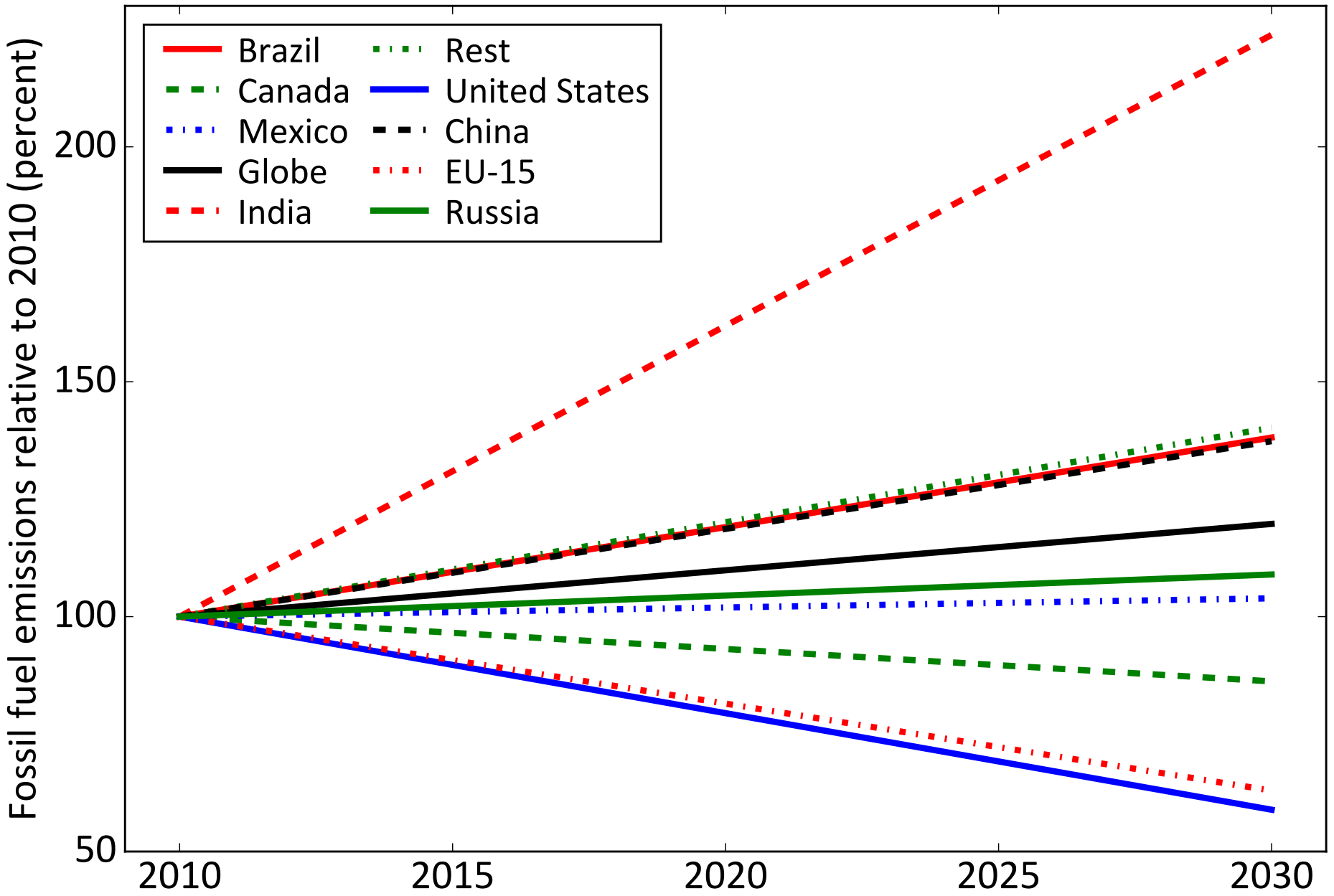
With (intentionally) biased transport, the flux estimates are uniformly biased low by ~10%

Basu et al, ACP (2016)

Detecting trends in fossil fuels

- What can we do with transport models we know are imperfect and very likely biased?
- Idea from TRANSCOM CO_2 days: Interannual variability may be more robust than individual annual estimates
- Could we detect a trend in FF emissions, such as the US INDC?

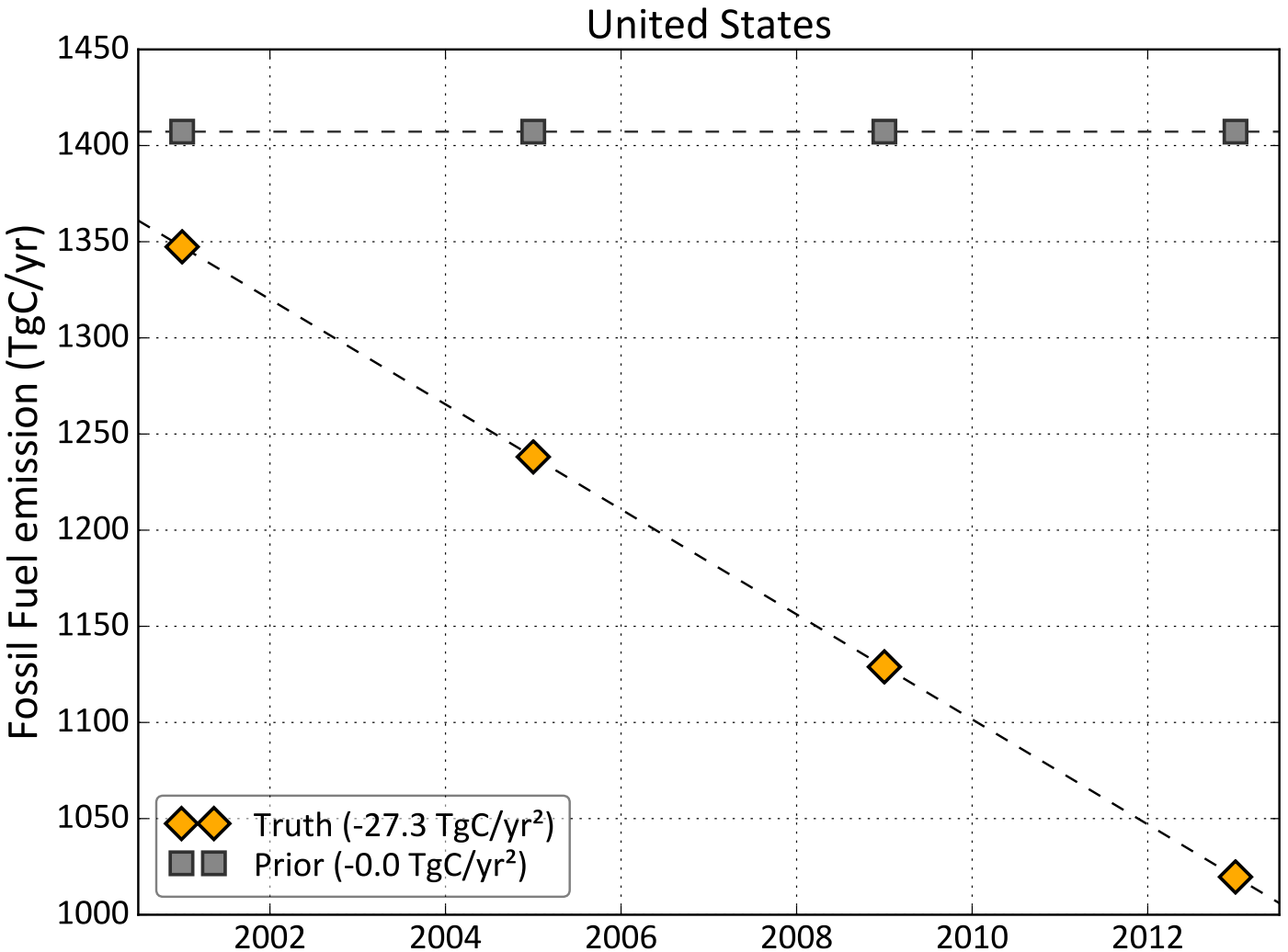
INDC scenarios can be translated to FF emission trajectories



Fawcett et al, Science (2016)

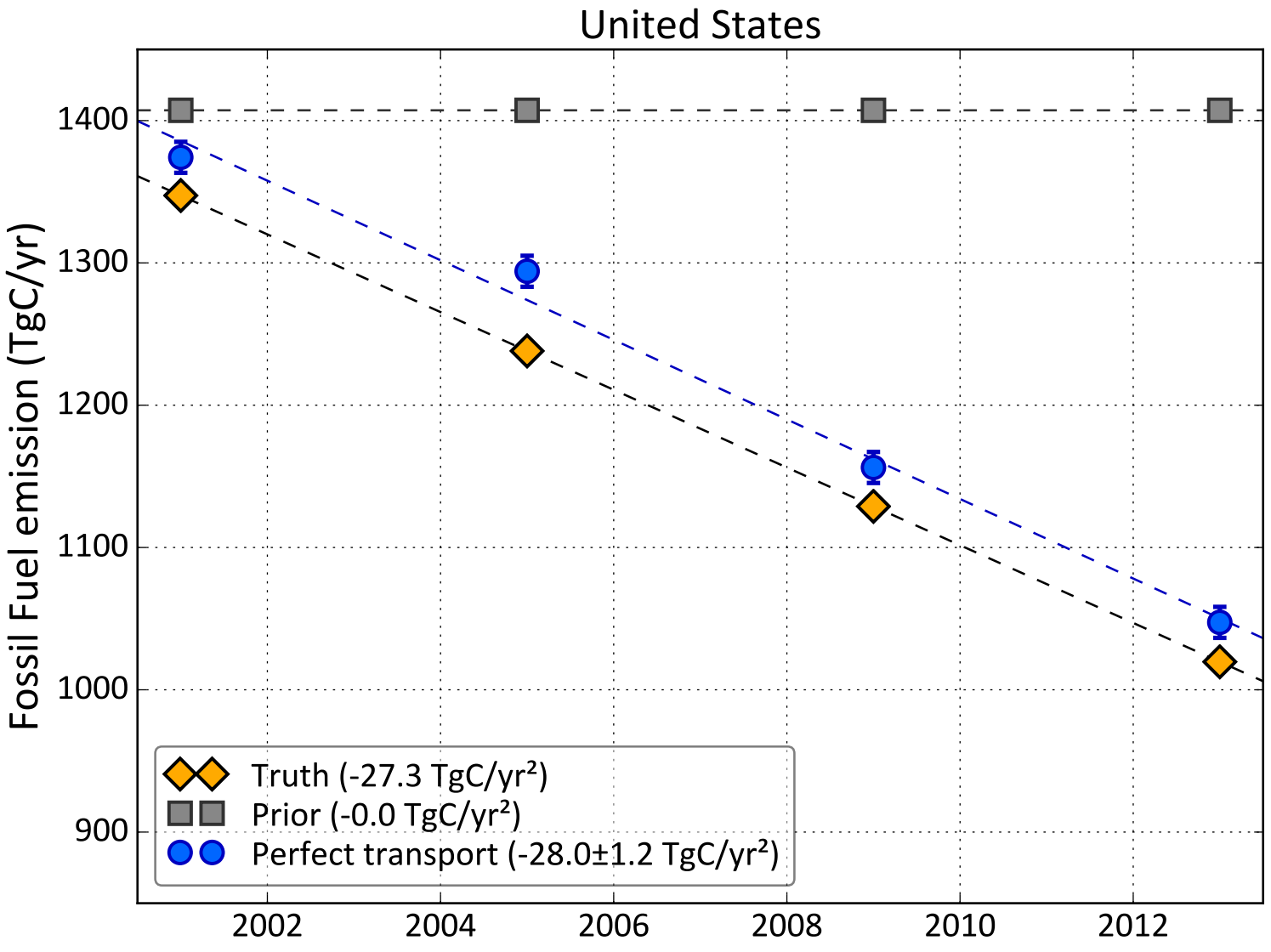
Trend detection OSSE: design

Simulate CO_2 and $^{14}CO_2$ pseudo-observations with fossil fuel emissions that have trends consistent with INDCs and CASA biospheric fluxes. Assimilate those pseudo-obs in inversions where the fossil fuel prior does not have a trend, and the biosphere prior is SiB CASA.



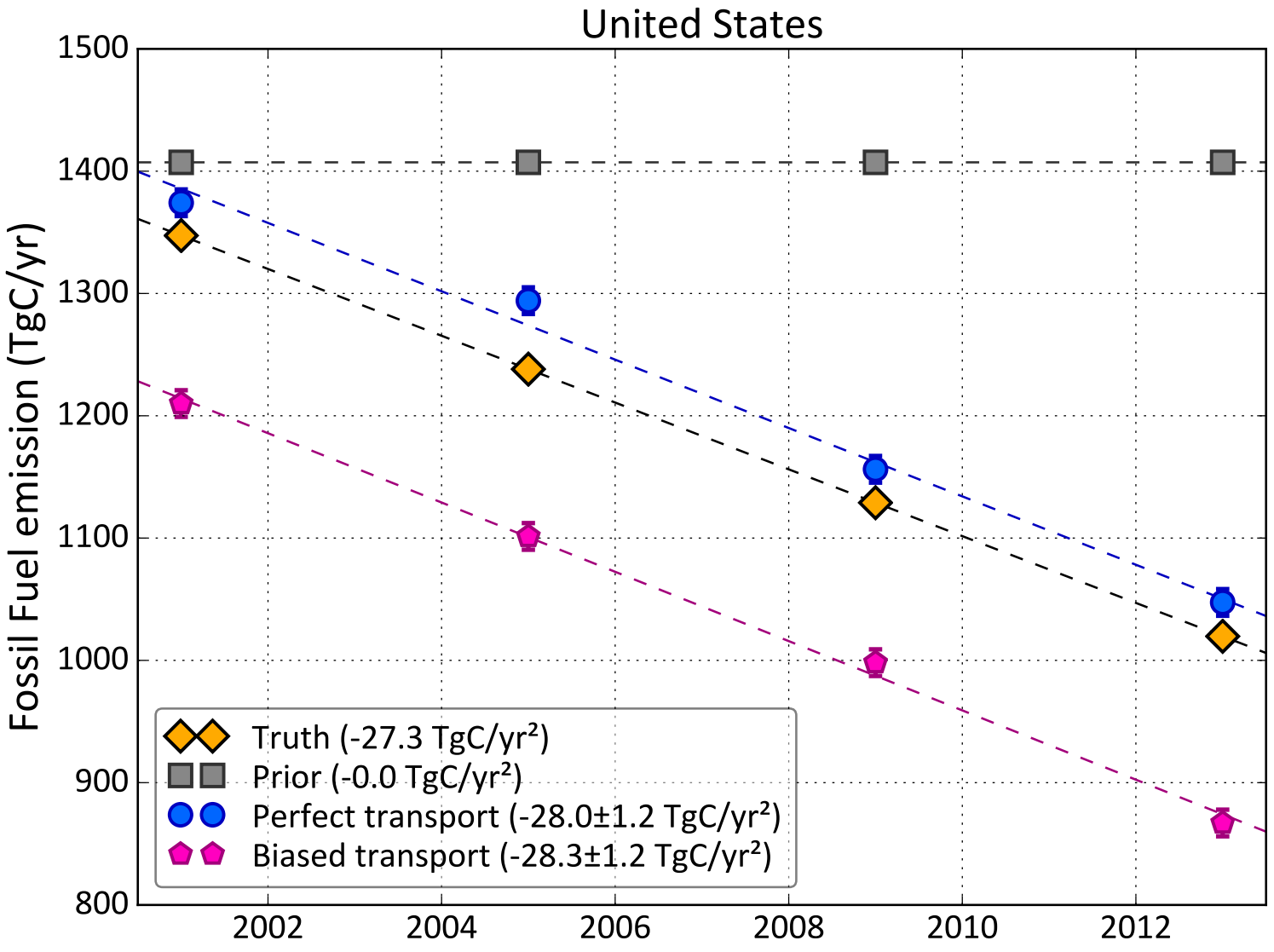
Trend detection OSSE: results

Perfectly known transport reproduces the “true” trend faithfully...



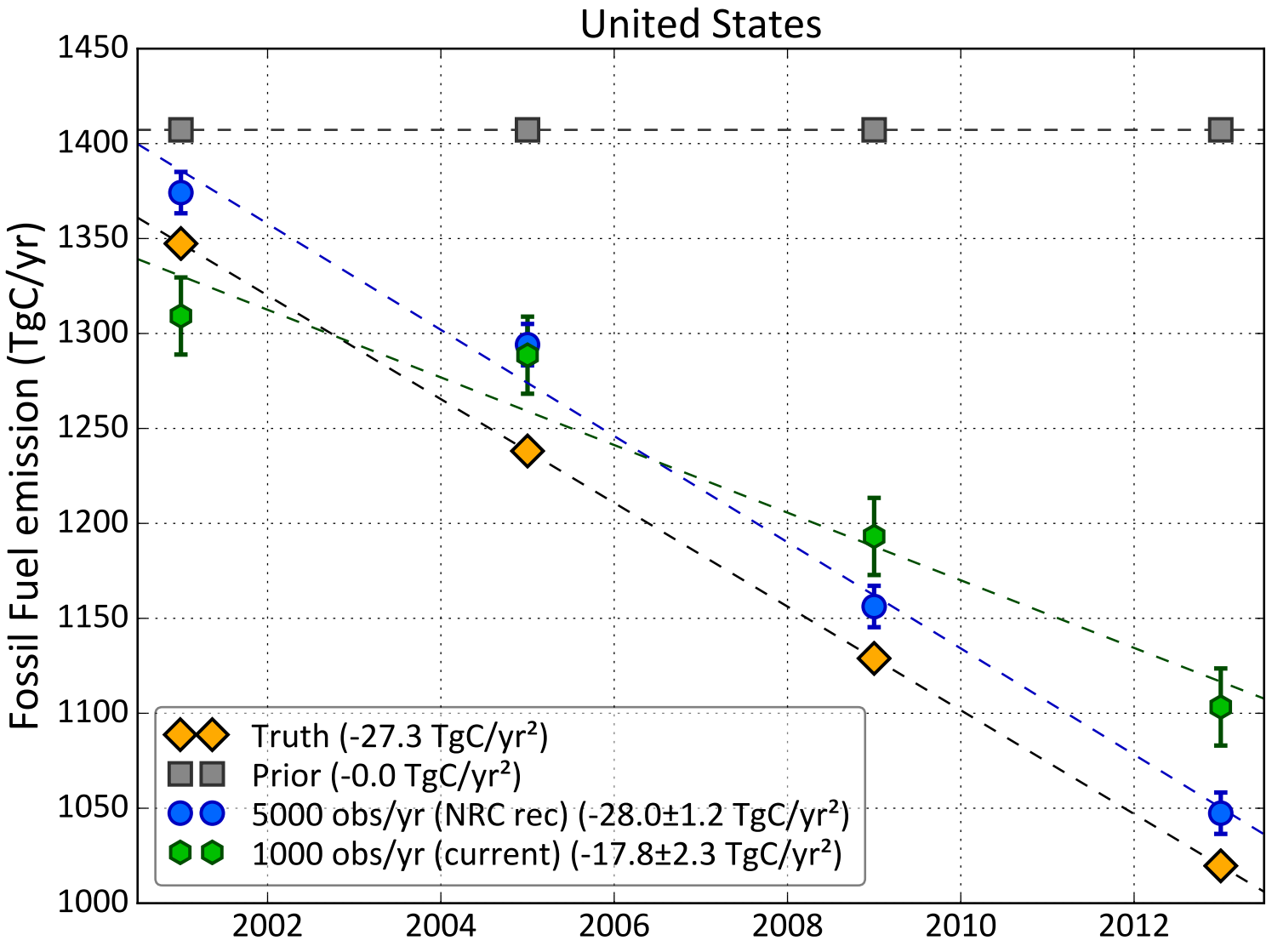
Trend detection OSSE: results

... so do the imperfect/biased transport inversions!



Trend detection OSSE: results

Caveat: Current coverage (~1000 obs/year) not sufficient



Take home points

- Even with a biased transport model, we can estimate multi-year trends in FF CO_2 emissions accurately
- However, we need increased coverage for that, if we want minimal reliance on FF inventories
- An inventory estimate off by ~35% seems unlikely for the US, but may be par for the course for other large emitters
- With a more realistic prior, this method can be used to test for deviations from intended trajectories

$$\frac{dC}{dt} = F_{oce} + F_{bio} + F_{fos}$$

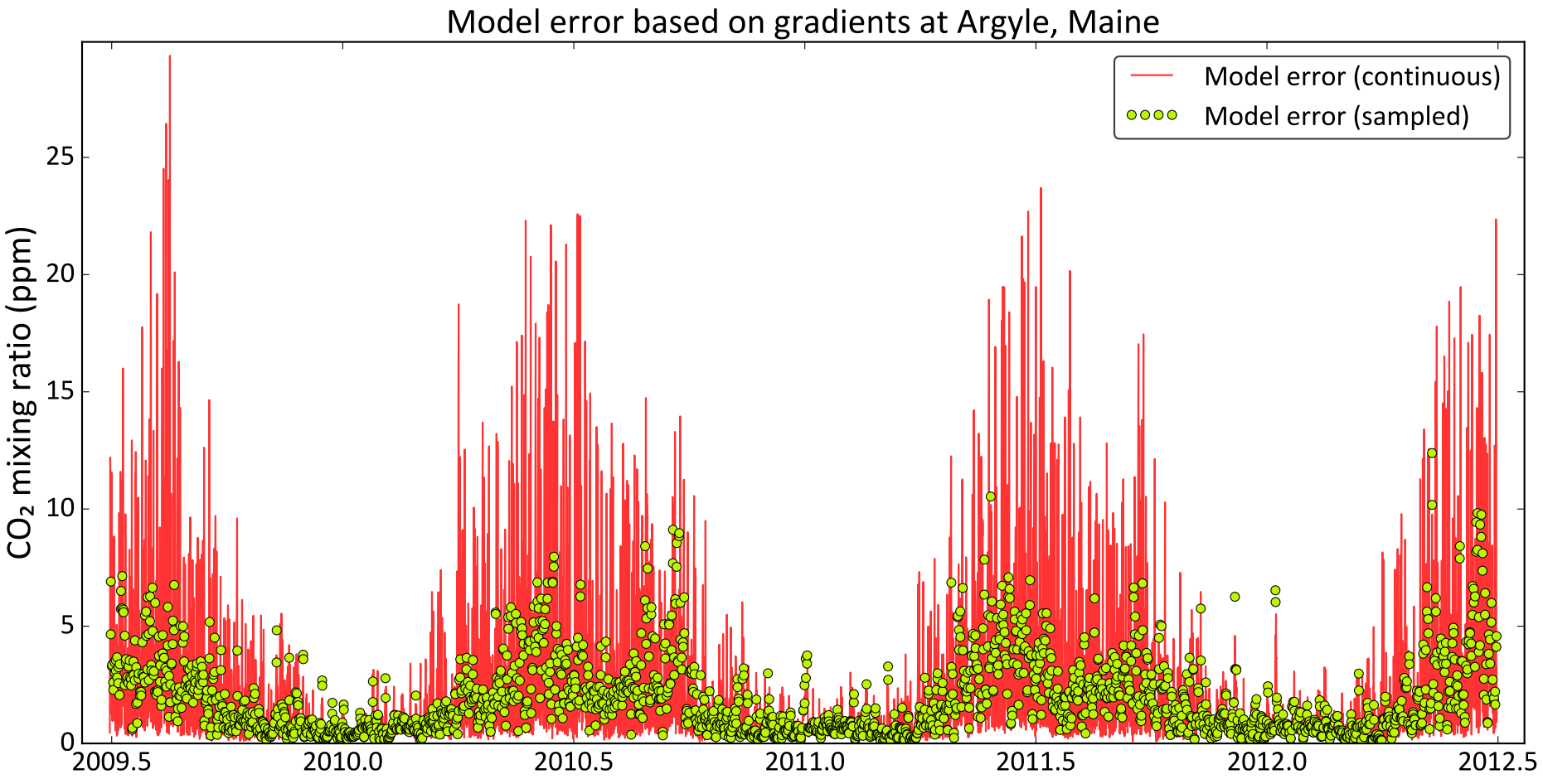
$$\begin{aligned}\frac{d}{dt}\left(C \cdot \Delta_{atm}\right) = &\Delta_{fos} F_{fos} + \Delta_{atm}\left(F_{oce} + F_{bio}\right) \\ &+ \Delta_{oce} F_{oce \rightarrow atm} + \Delta_{bio} F_{bio \rightarrow atm} \\ &+ \alpha\left(F_{nuc} + F_{cosmo}\right)\end{aligned}$$

tracers transported

fluxes estimated

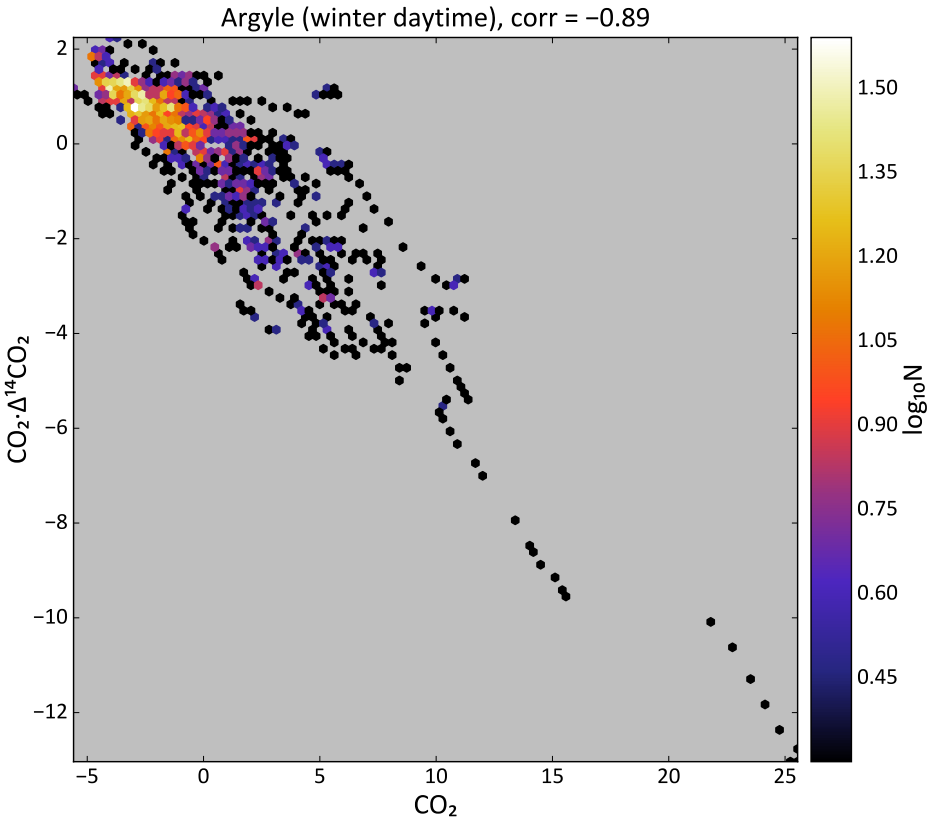
Estimation of model data mismatch

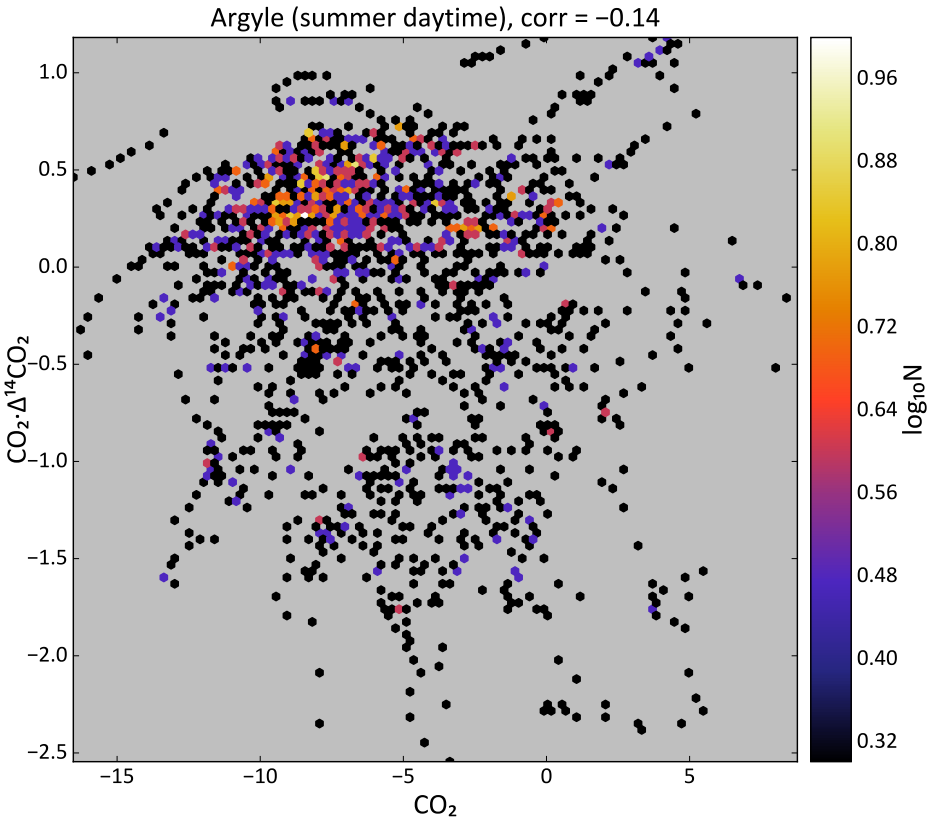
The diagonal contains measurement error as well as transport random error



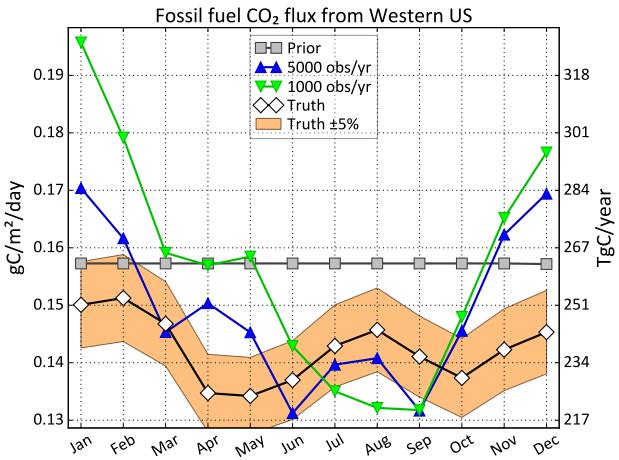
Estimation of model data mismatch

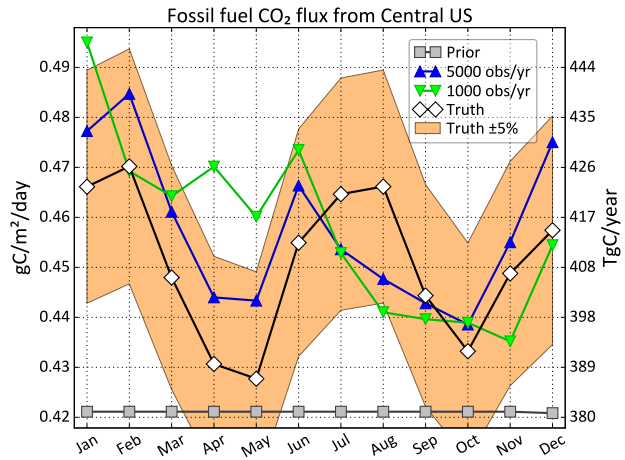
The off-diagonal contains the correlation between high-frequency variations of the tracers during mid-afteroon for each month/season

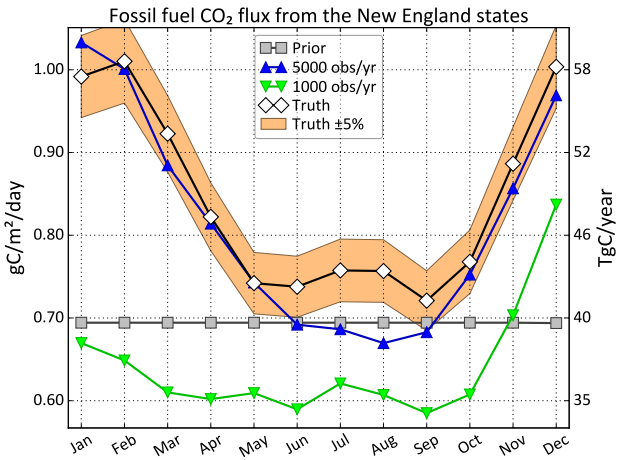


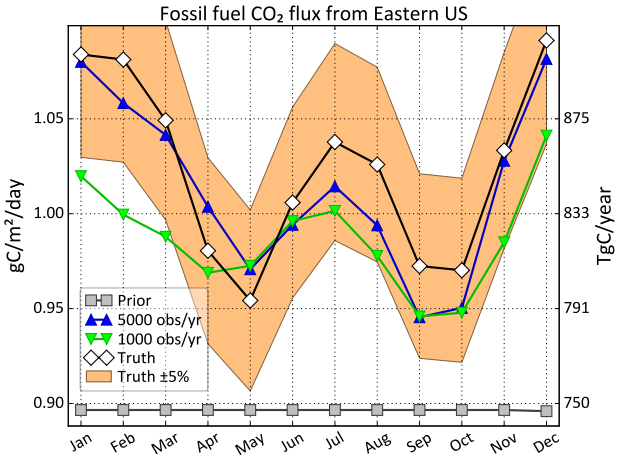


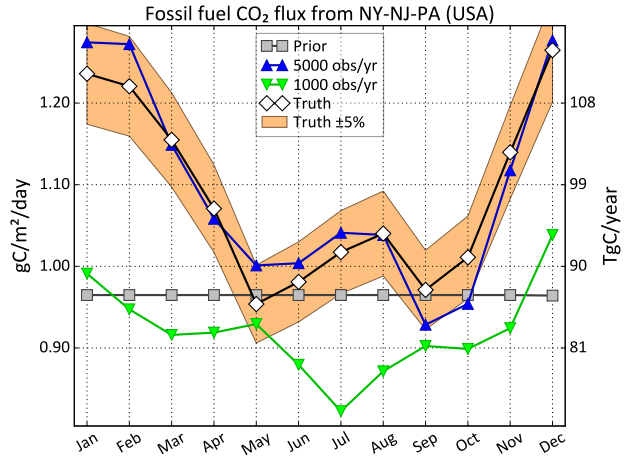
Regional estimates of fossil fuel fluxes with ~1000 & ~5000 obs/year

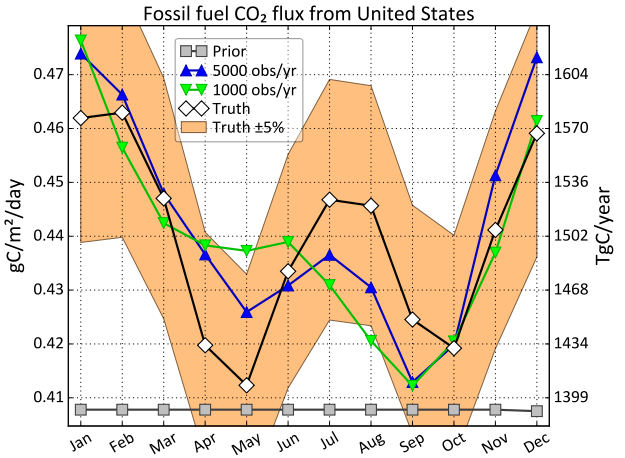












Complete set in Basu et al, ACP (2016)

Impact of uncertainty on trend detection