Constraining fossil fuel CO_2 emissions by the joint assimilation of atmospheric CO_2 and $^{14}CO_2$ measurements

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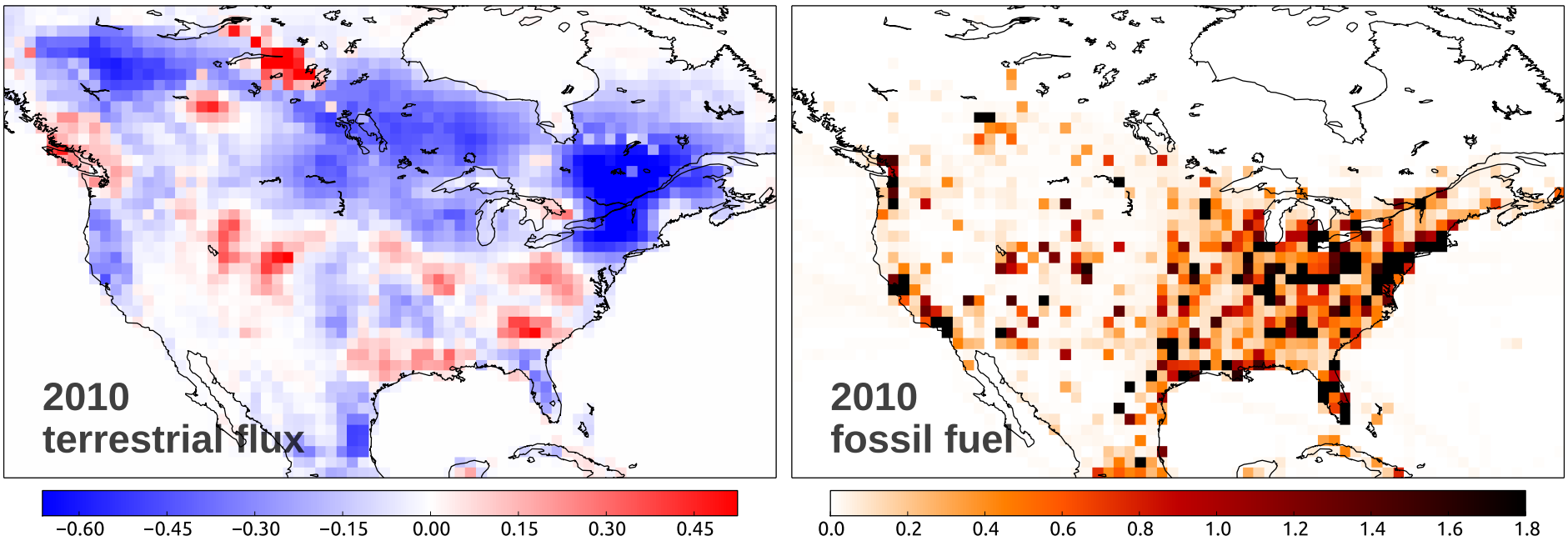
Boulder, May 2014

What is the issue?

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



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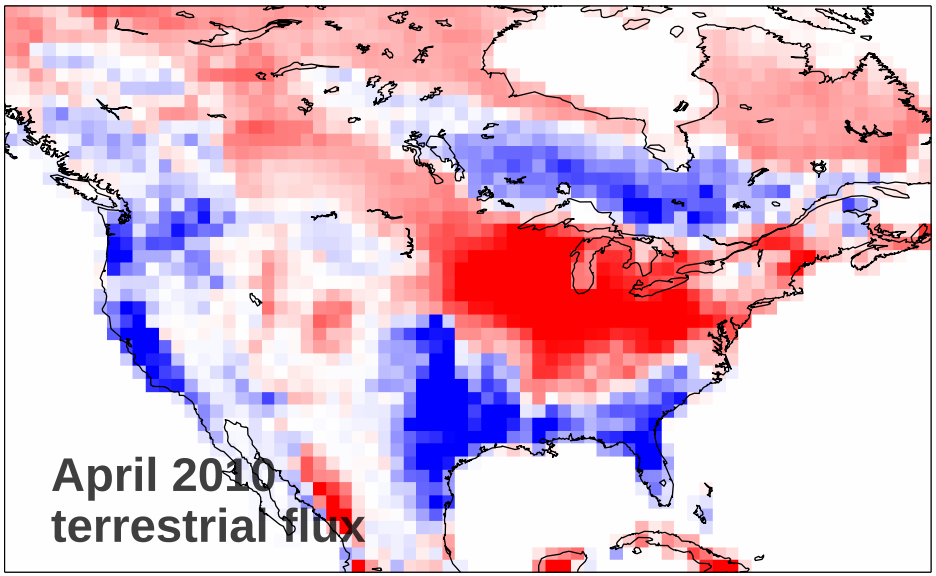
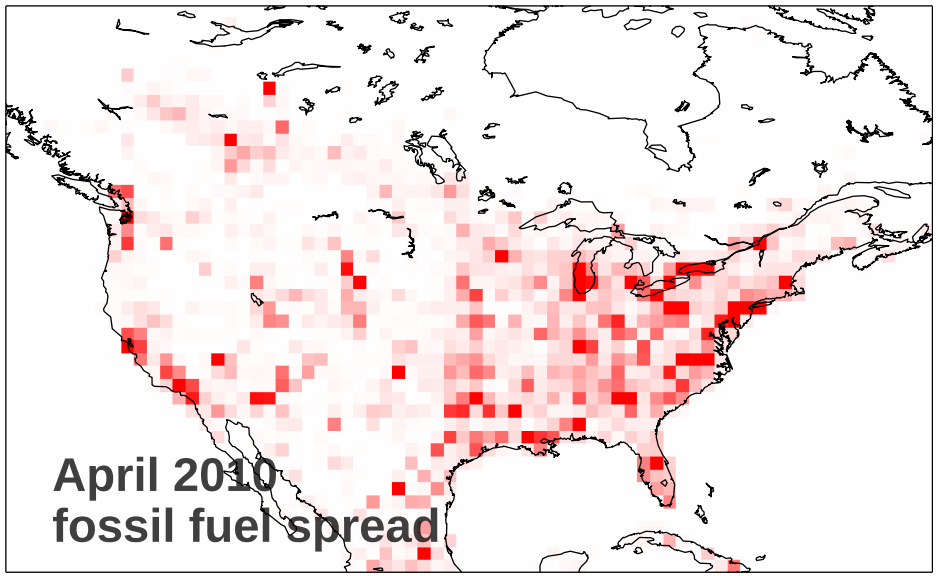
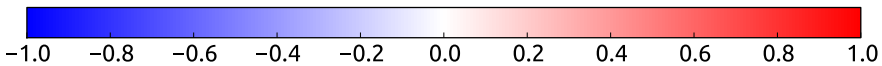
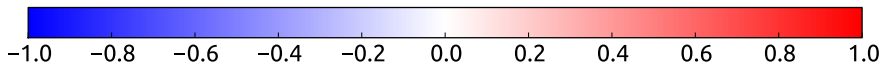






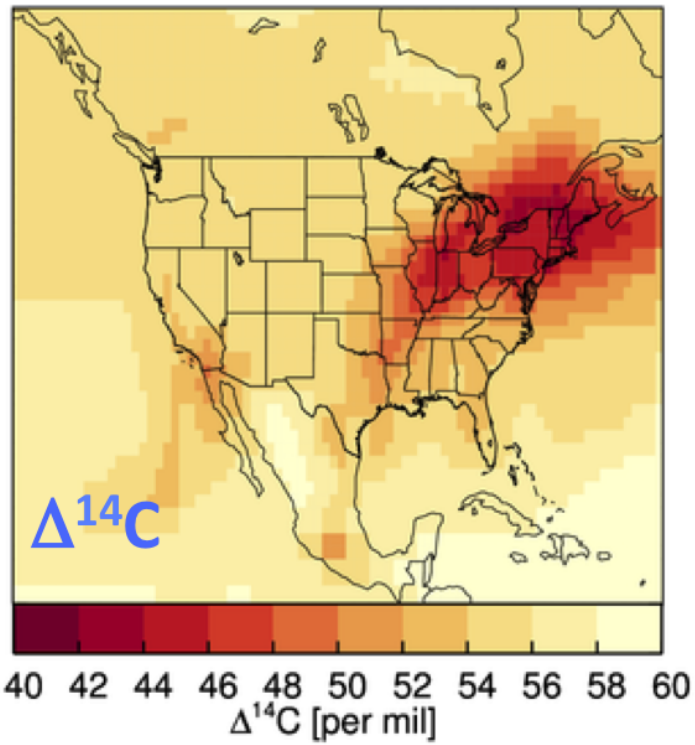


- Almost all atmospheric CO_2 inversions assume CO_2(ff) "perfectly" known, solve for natural fluxes
- Only true annually, for global and (some) national totals
- Usually not up to date, EDGAR 5 yr old, Vulcan 13 yr old

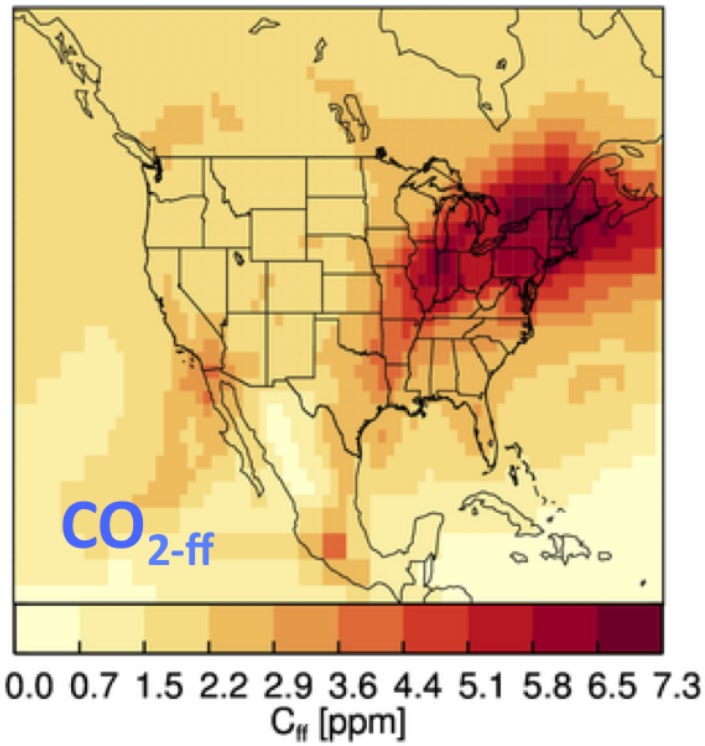
$^{14}CO_2$ is a tracer for CO_2(ff)

$\Delta\,^{14}C_{ff}$ = −1000 ‰ (i.e., zero $^{14}CO_2$)

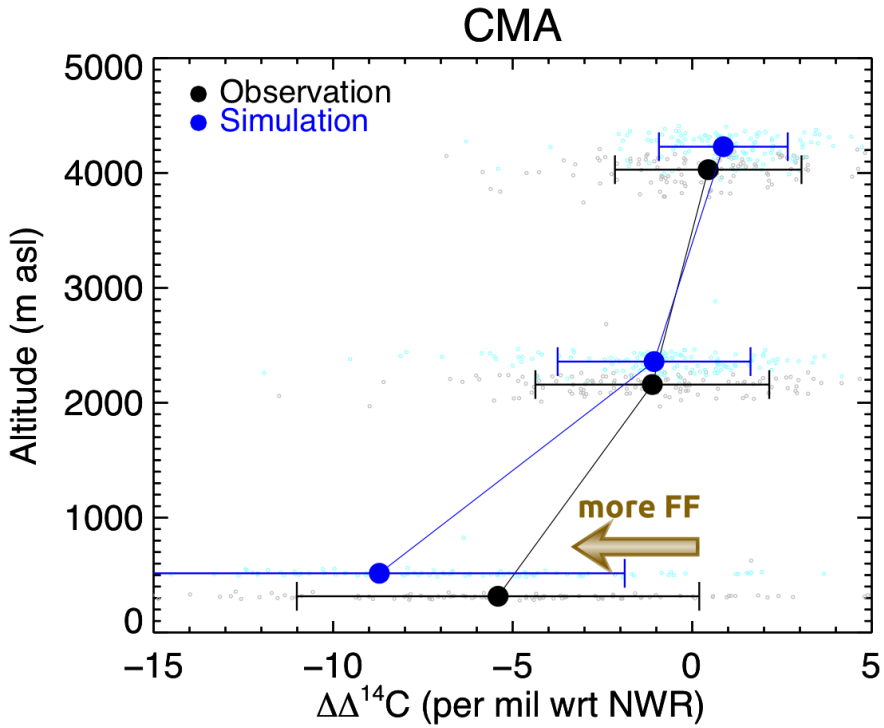
Scaling in 2006 = −2.7 ‰ $\Delta\,^{14}C$ for 1 ppm CO_2(ff)

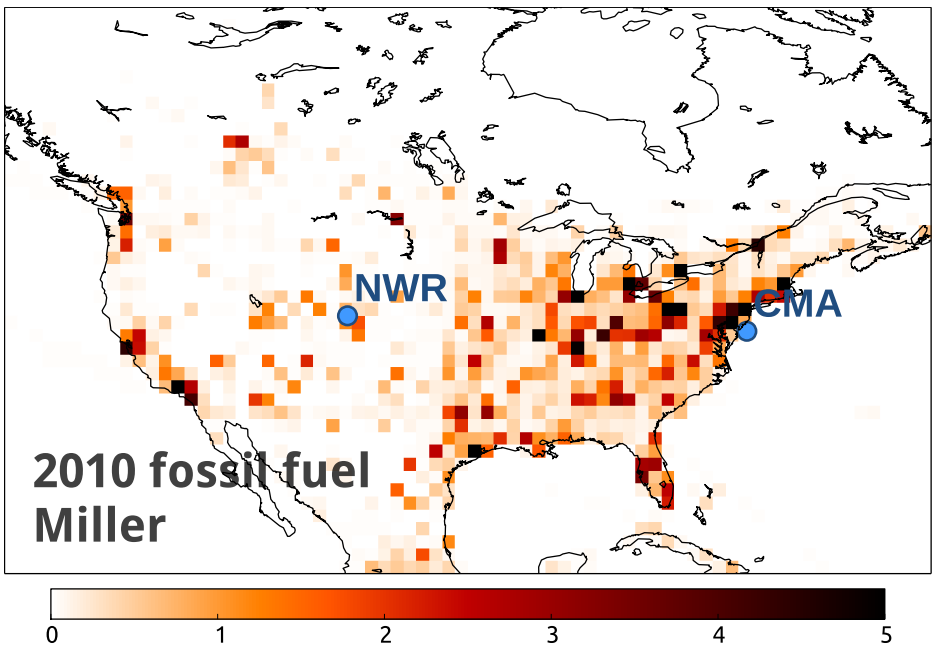


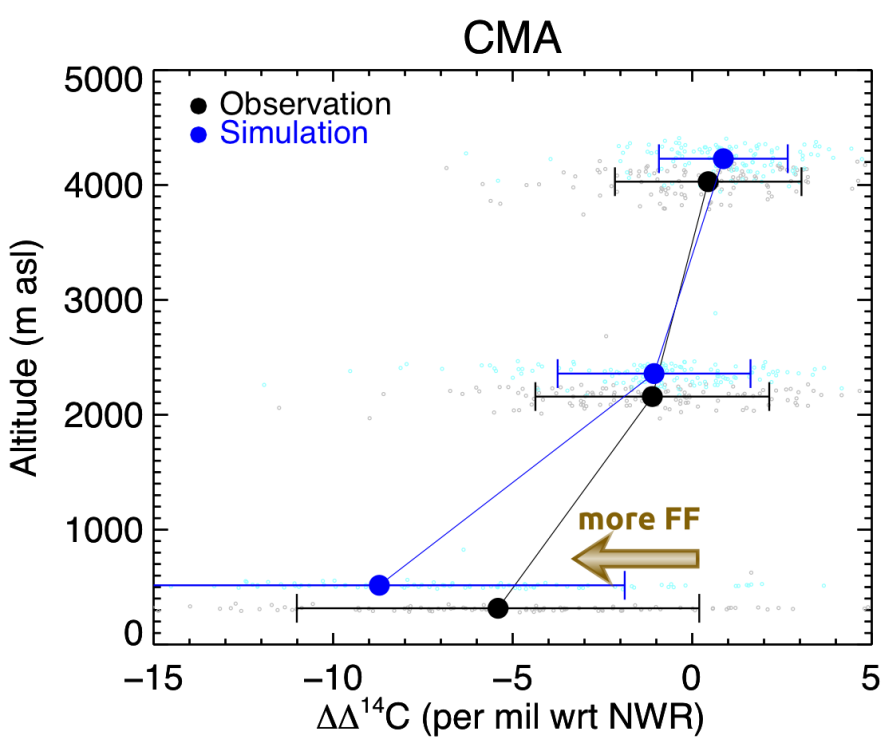
fossil fuel, ocean and land disequilibrium, nuclear and cosmogenic production



fossil fuel only


CMA
Observation
Simulation
5000
4000
3000
2000
1000
0
Altitude (m asl)
more FF
−15
−10
−5
0
5
ΔΔ14C (per mil wrt NWR)


NWR
CMA
2010 fossil fuel
Miller
0
1
2
3
4
5


CMA
Observation
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Altitude (m asl)
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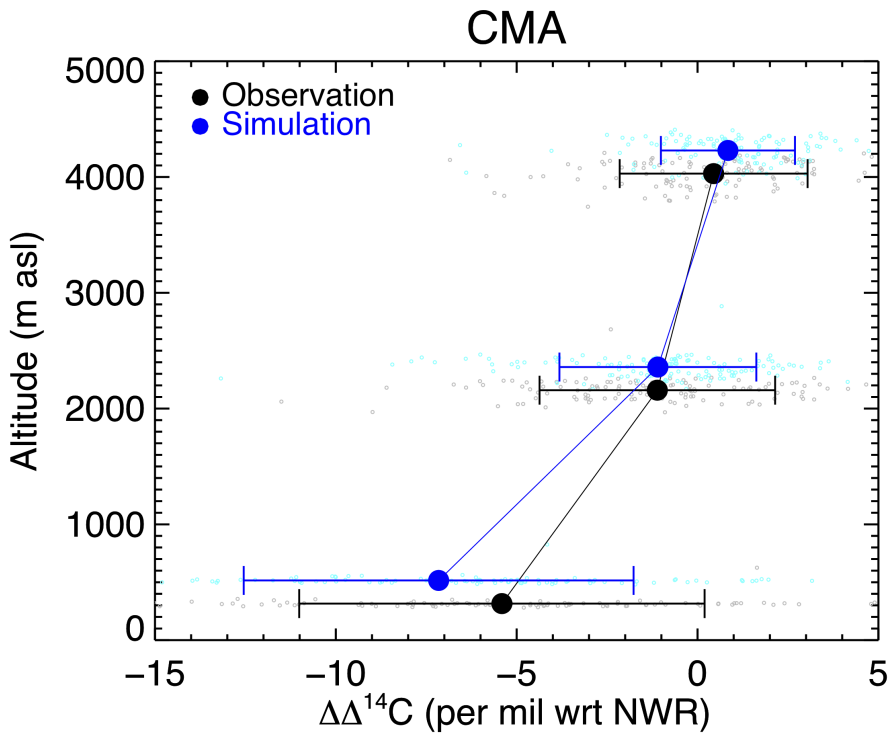
CMA
Observation
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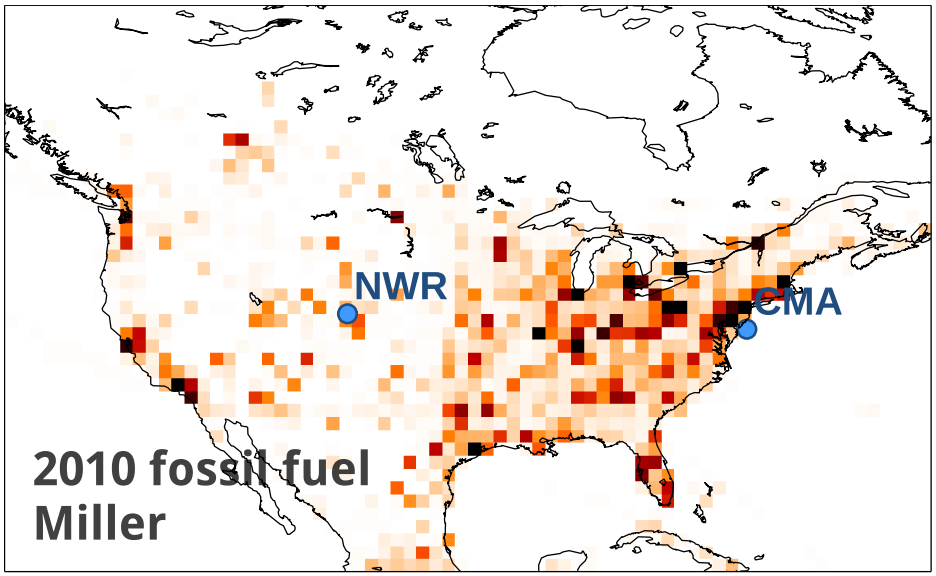
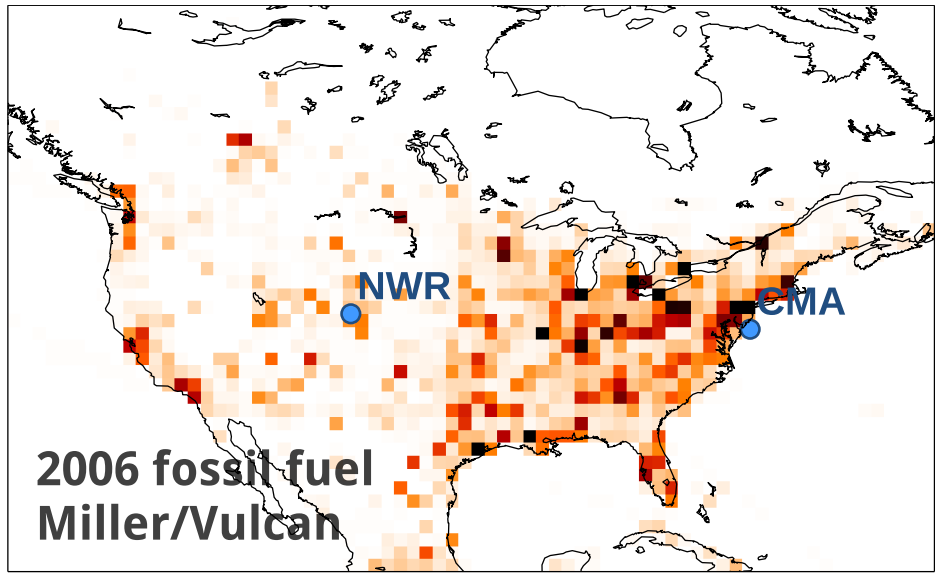
ΔΔ14C (per mil wrt NWR)


NWR
CMA
2010 fossil fuel
Miller

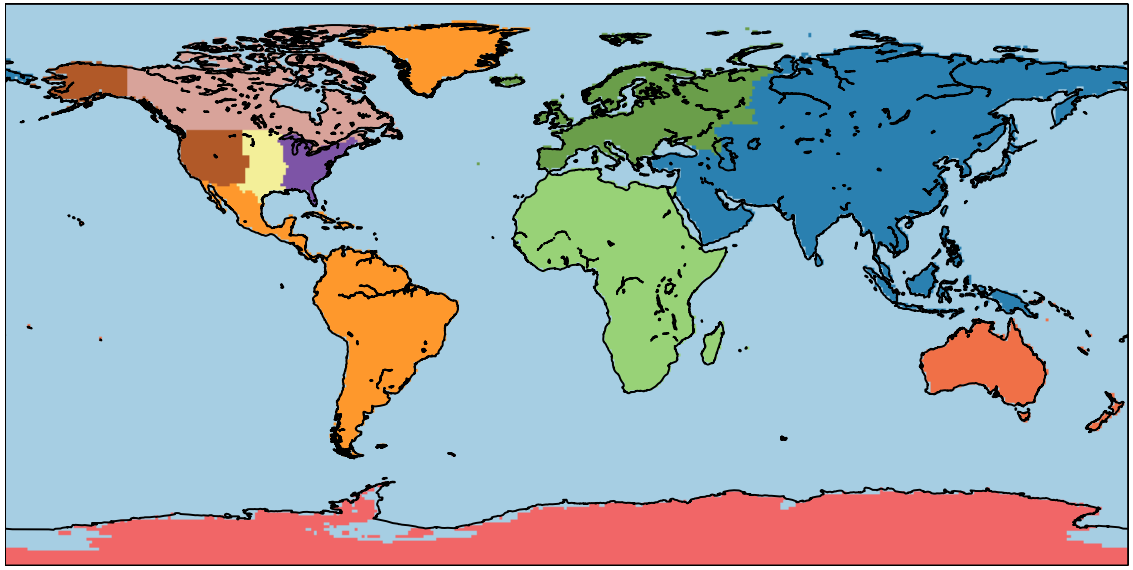

NWR
CMA
2006 fossil fuel
Miller/Vulcan


0
1
2
3
4
5


0
1
2
3
4
5


3

Prior flux uncertainties

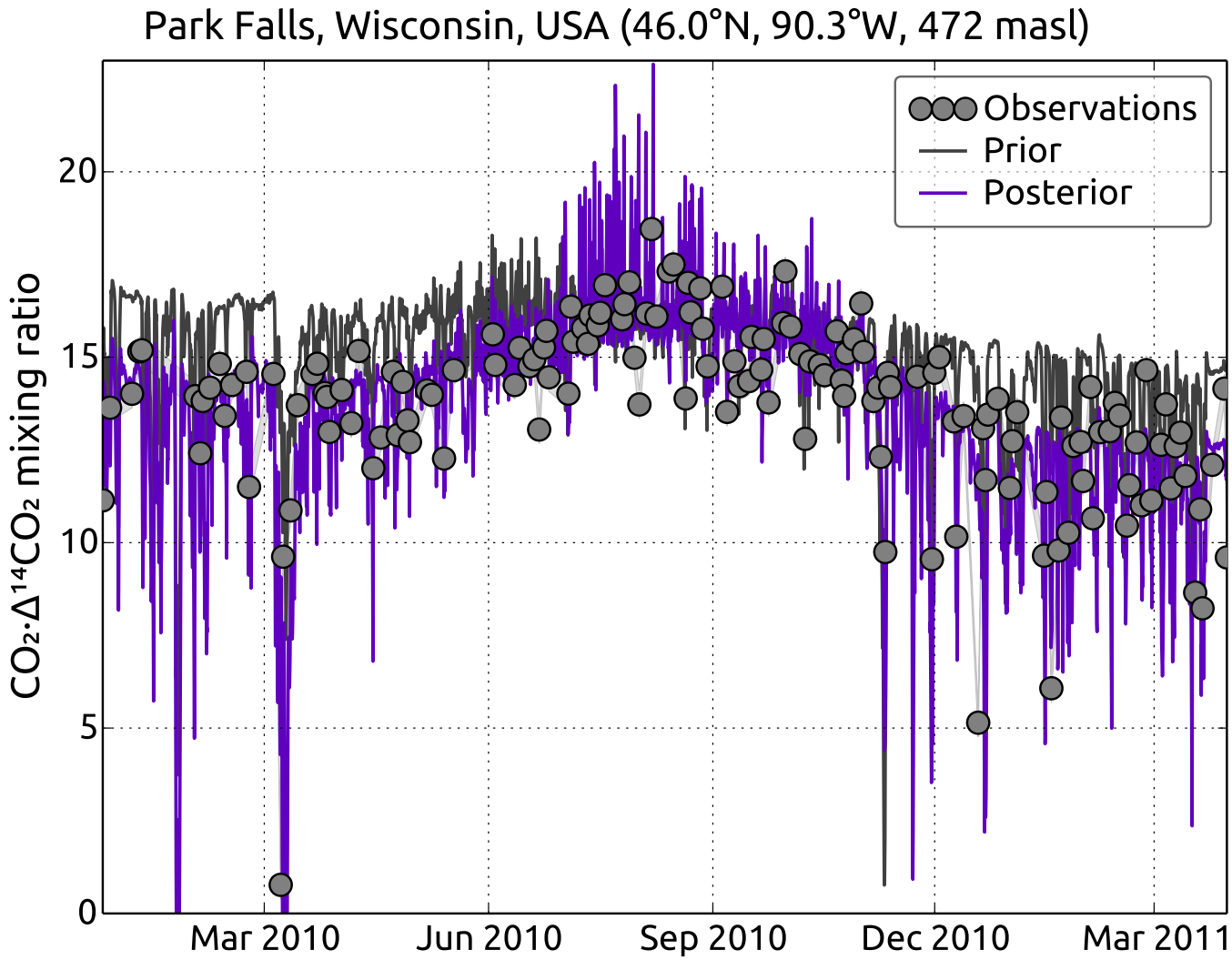


- US CO_2(ff): 5.26 $\pm$ 0.26 Pg CO_2
- Fossil fuel: 2.5 $\times$ inter-prior spread, 700 km hybrid, 3 month

- Land biosphere: 0.25 $\times$ respiration per grid cell, 200 km (e), 1 month
- Ocean: 157 $\times$ abs(net flux), 1000 km (e), 3 month
- Ocean disequilibrium: 0.2 $\times$ abs(net flux), regional, 3 month
- Land disequilibrium: 0.1 $\times$ abs(net flux), regional, 1 month

Our measurements are CO_2 and $CO_2 \cdot \Delta\,^{14}CO_2$

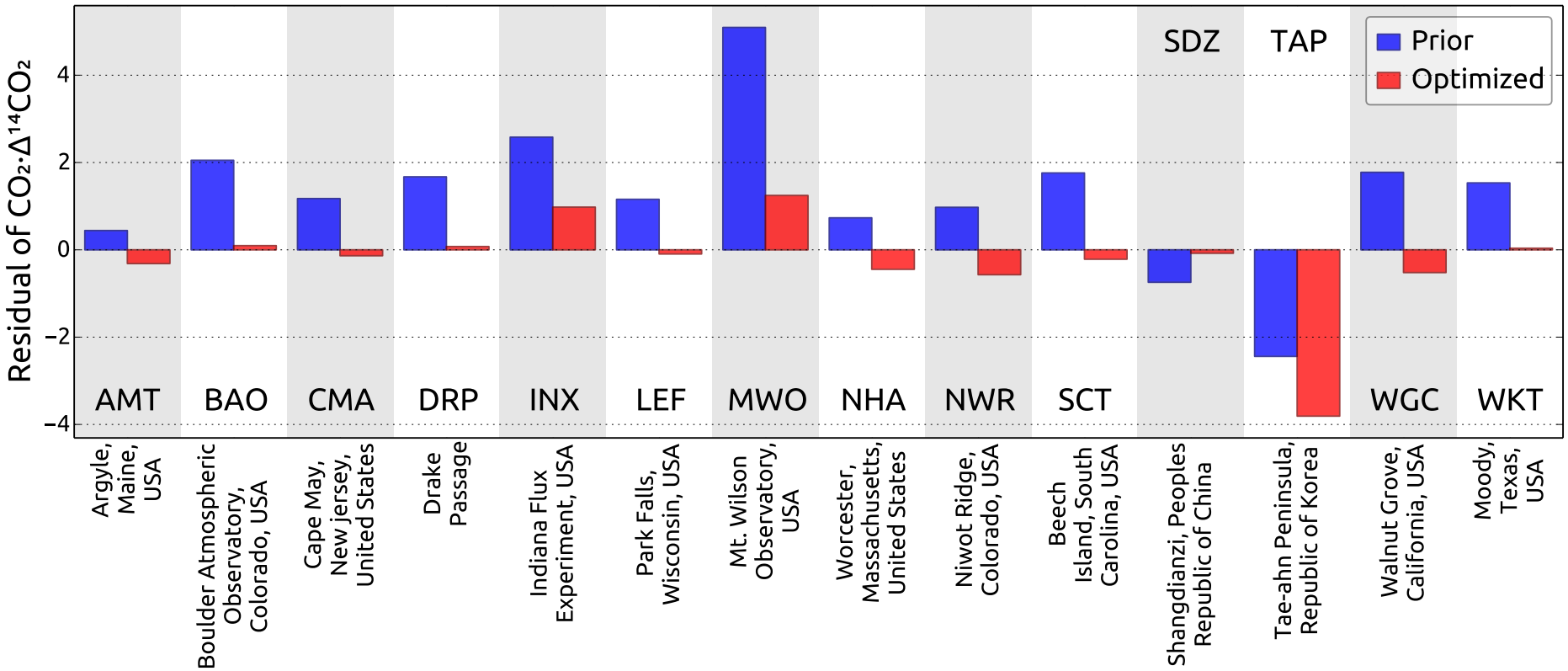
Model-observation mismatch of $CO_2 \cdot \Delta^{14}CO_2$



$$\text{Average prior mismatch} = 1.16 \times 10^3 \text{ ‰} \cdot \text{ppm}$$

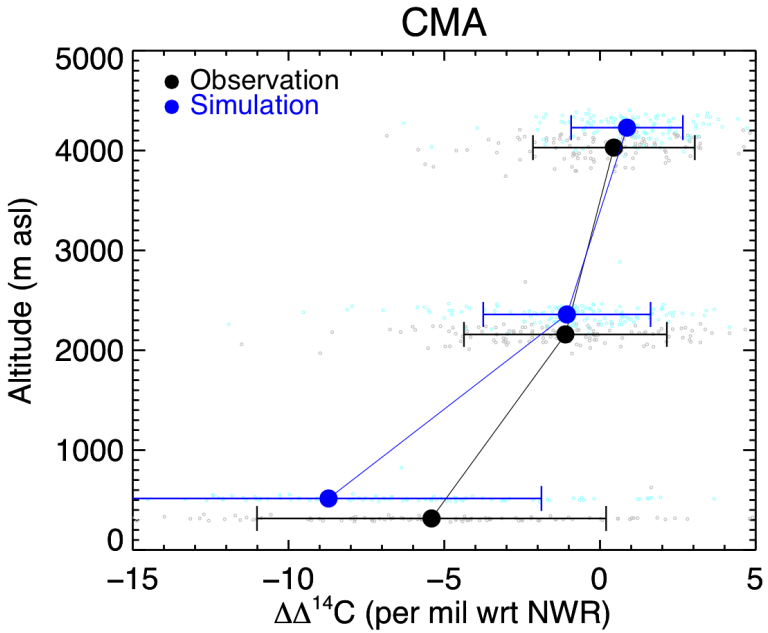
$$\text{Average posterior mismatch} = -0.10 \times 10^3 \text{ ‰} \cdot \text{ppm}$$

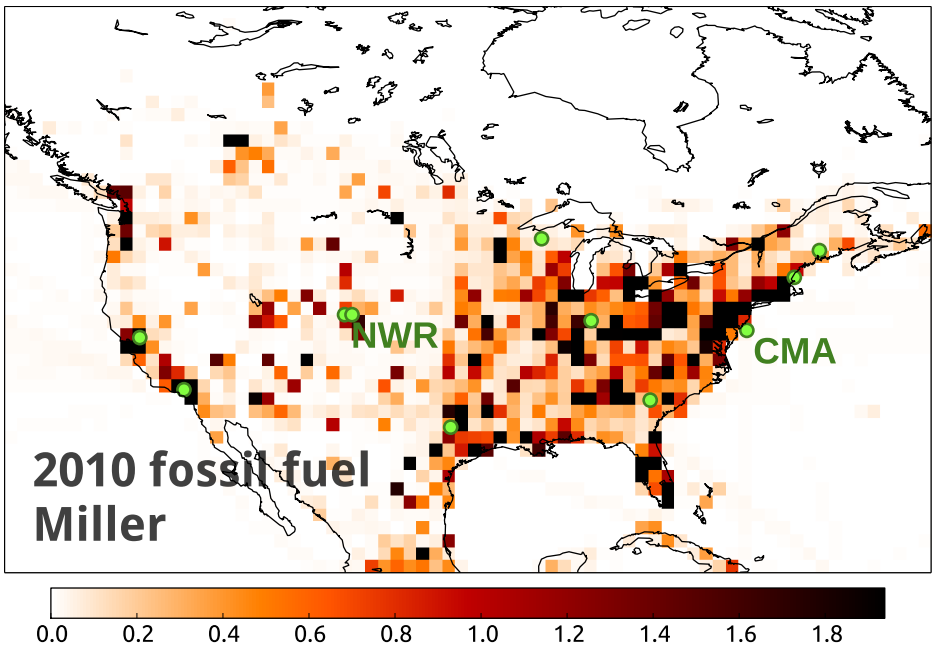
Model-observation mismatch of $CO_2 \cdot \Delta^{14}CO_2$



The inversion is doing what it is supposed to do

Adjustments to fluxes/optimized emissions





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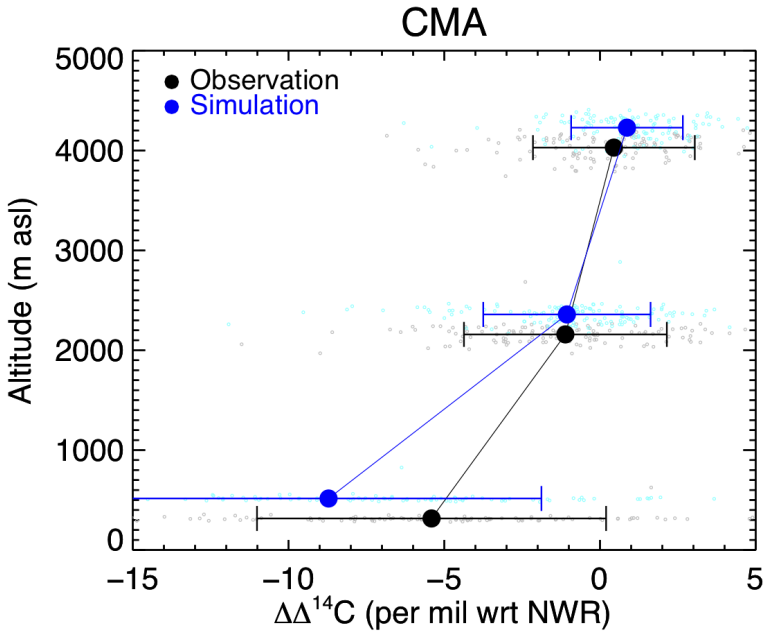
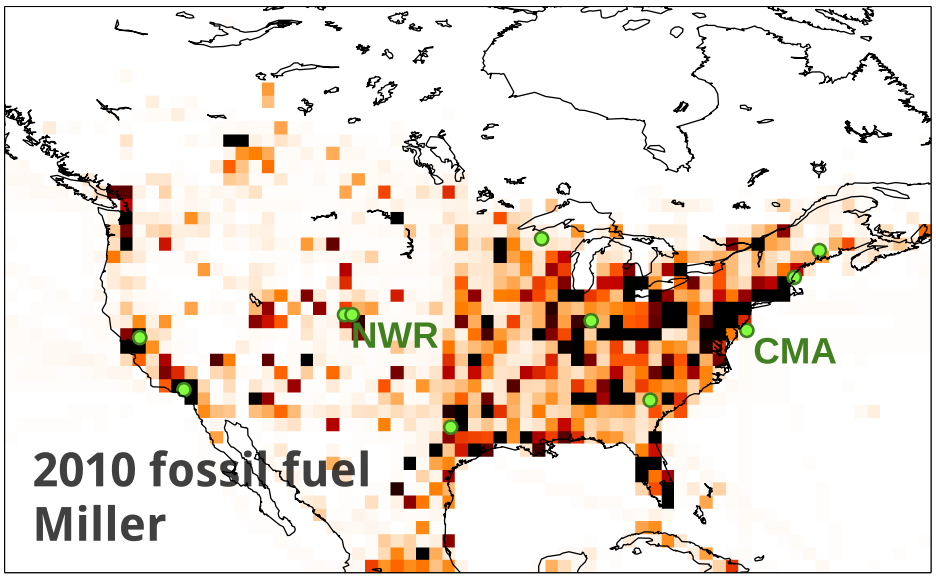
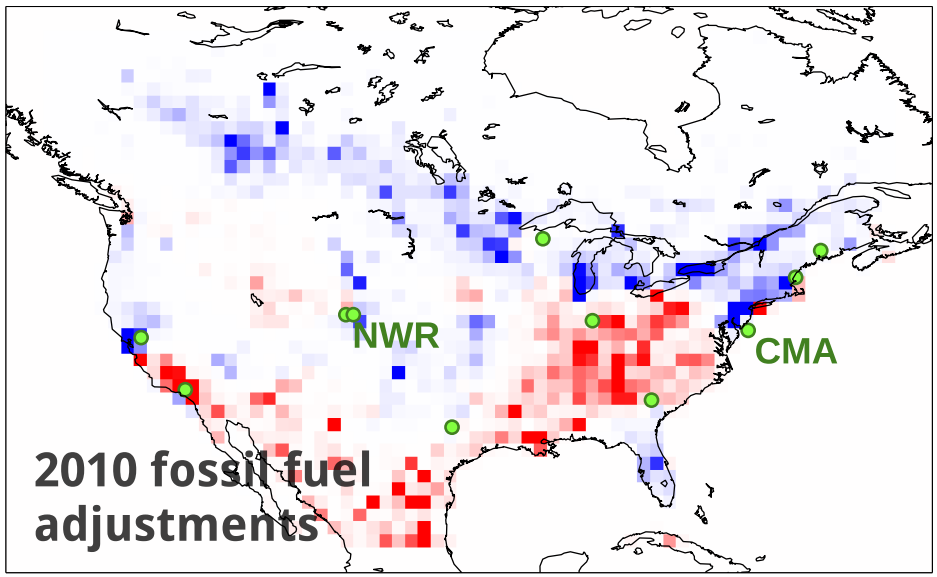
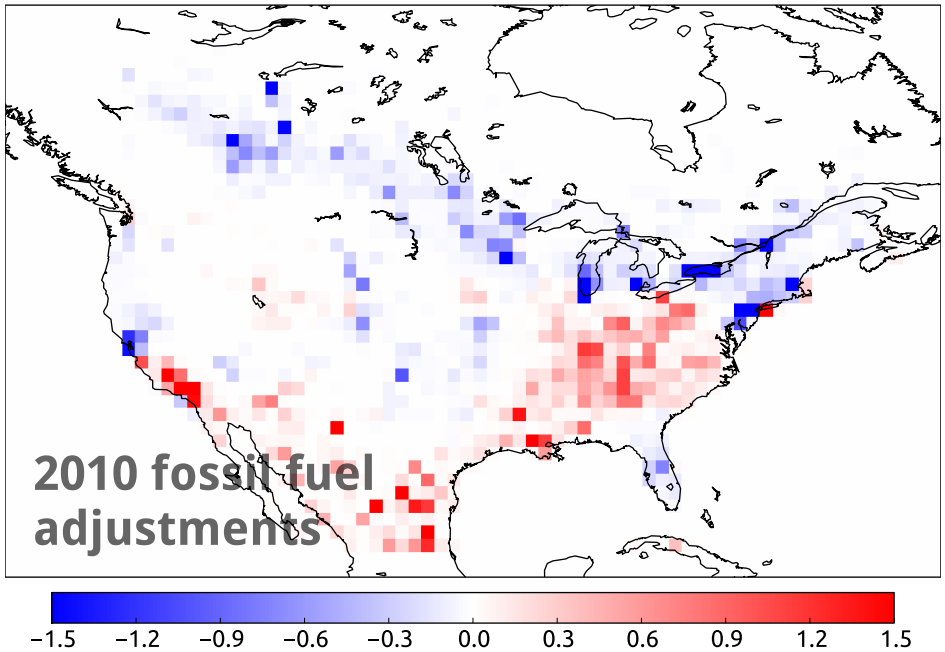


- The CMA–NWR gradient is consistent with more CO_2(ff) emission inland
- The inversion increases CO_2(ff) emission inland

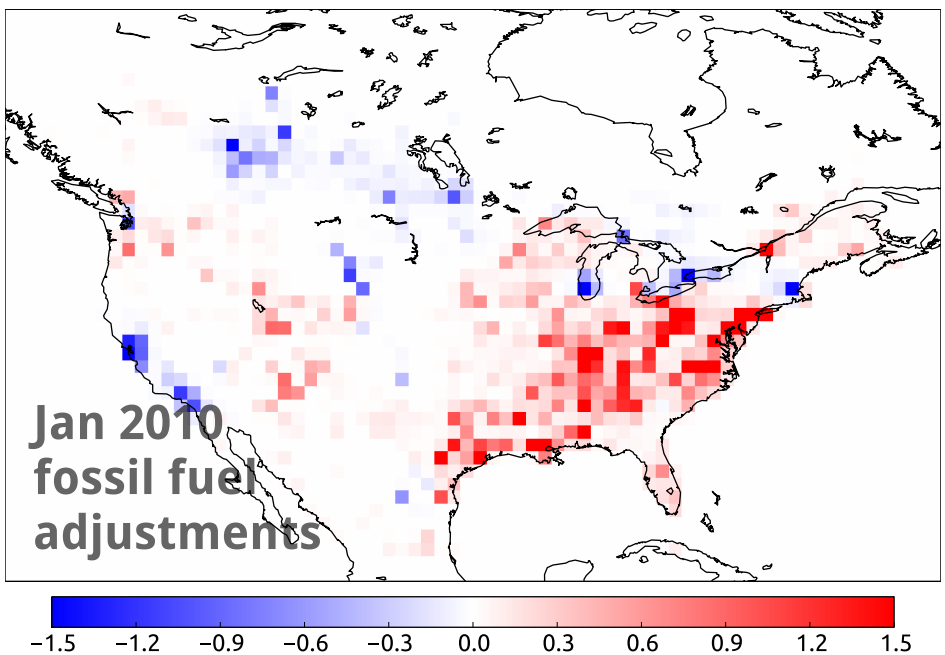


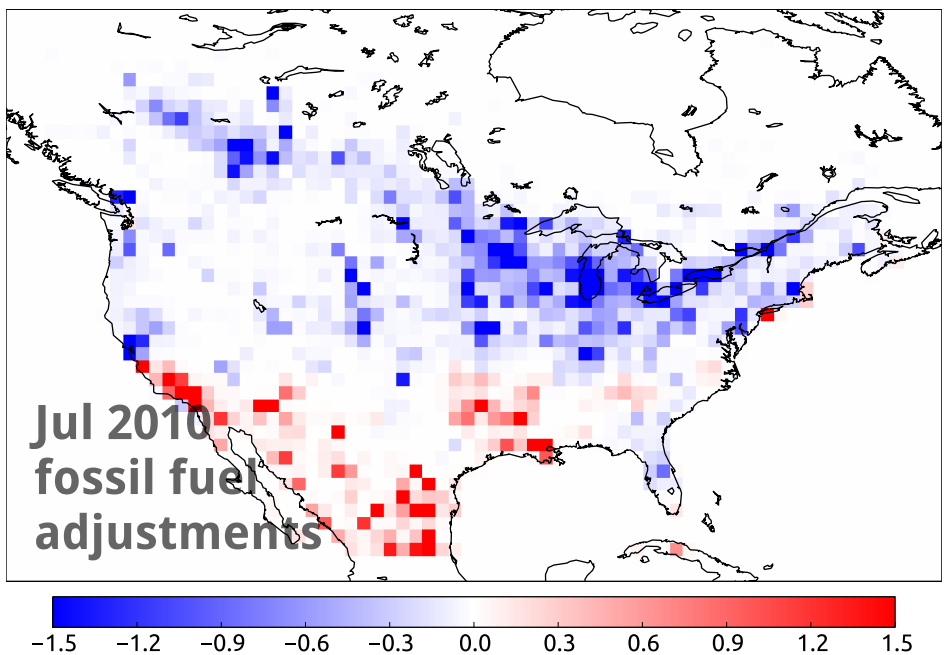


Seasonal vs annual CO_2(ff) adjustments



- Adjustments at the monthly scale are larger than adjustments at the annual scale
- Spatial patterns of the two adjustments can be different





Points to take home

- Fossil fuel CO_2 "well known" at national/yearly scales, not at regional/monthly scales
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- Very much a work in progress, not yet the optimal framework for utilizing $^{14}CO_2$ measurements

Mass balance

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

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

tracers transported

fluxes estimated

Uncertainties

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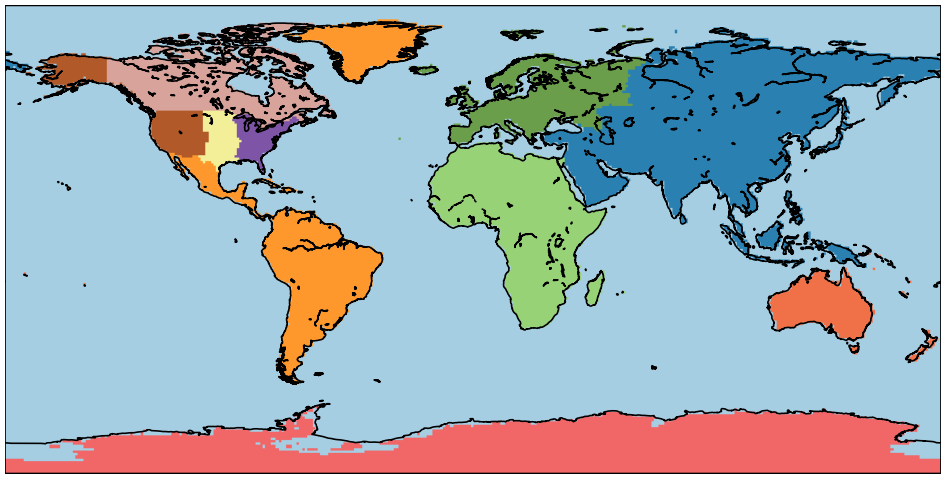

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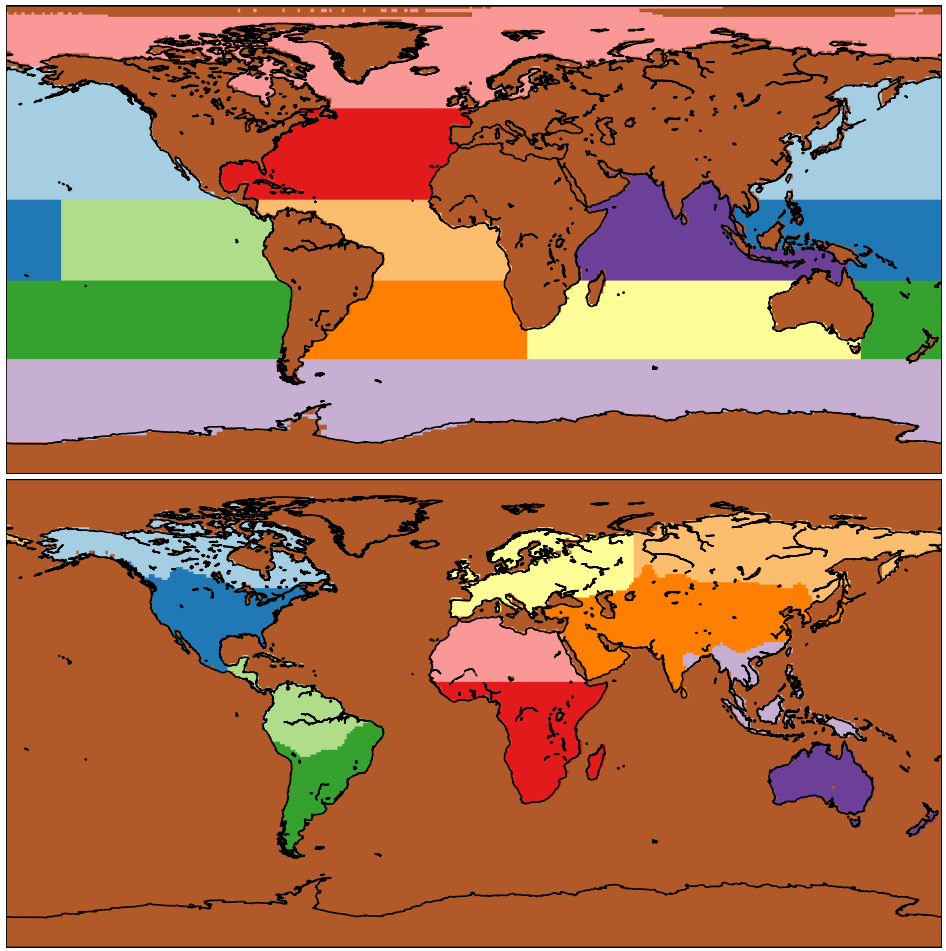

Posterior correlation between CO_2(ff) and CO_2(nat)