Exploring the sensitivities atmospheric $\delta^{13}C$ of CO_2 measurements to constrain biomes' drought stress

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ESMs divergence in present day NEE reflects lack of understanding in carbon-water coupling

SCIENTIFIC REPORTS

OPEN

Land carbon models underestimate the severity and duration of drought's impact on plant productivity

Received: 14 November 2018
Accepted: 23 January 2019
Published online: 26 February 2019

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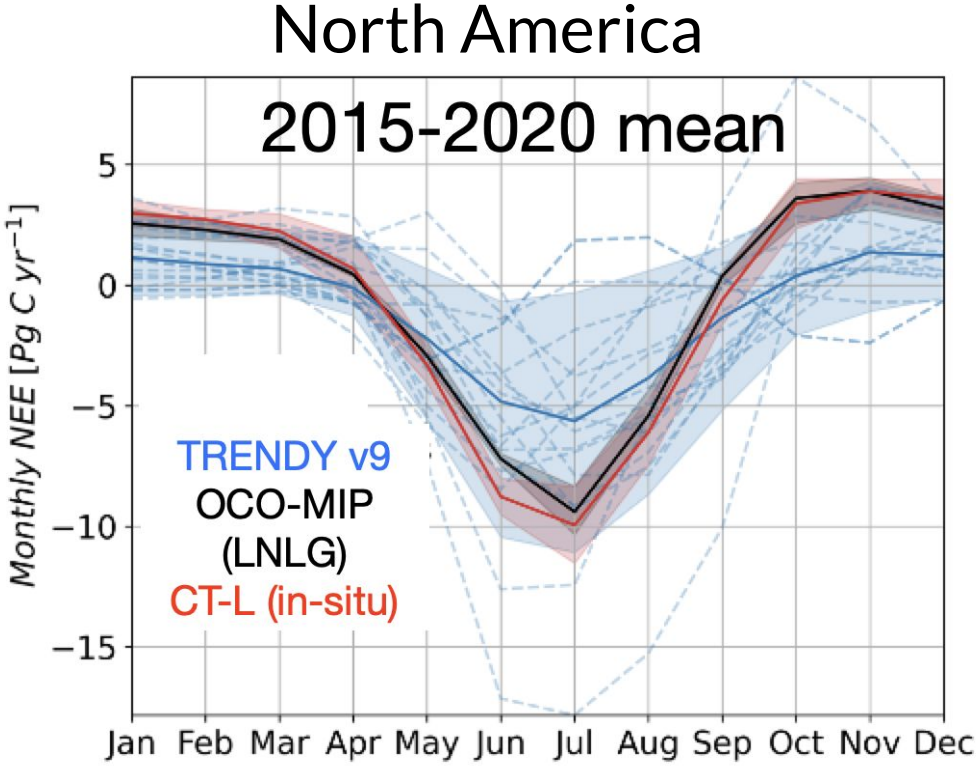


Can atmospheric measurements provide integral constraints on plant moisture stress?

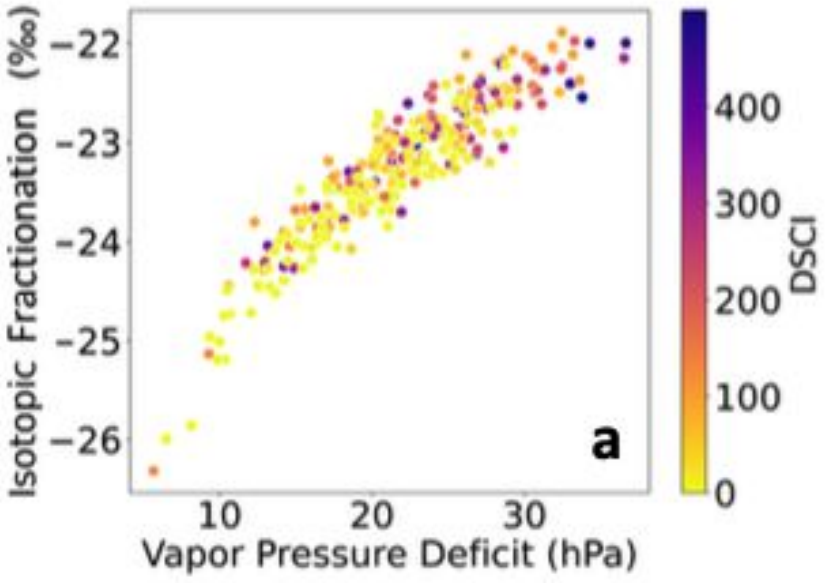
Reflected in $\delta^{13}C_{atm}$

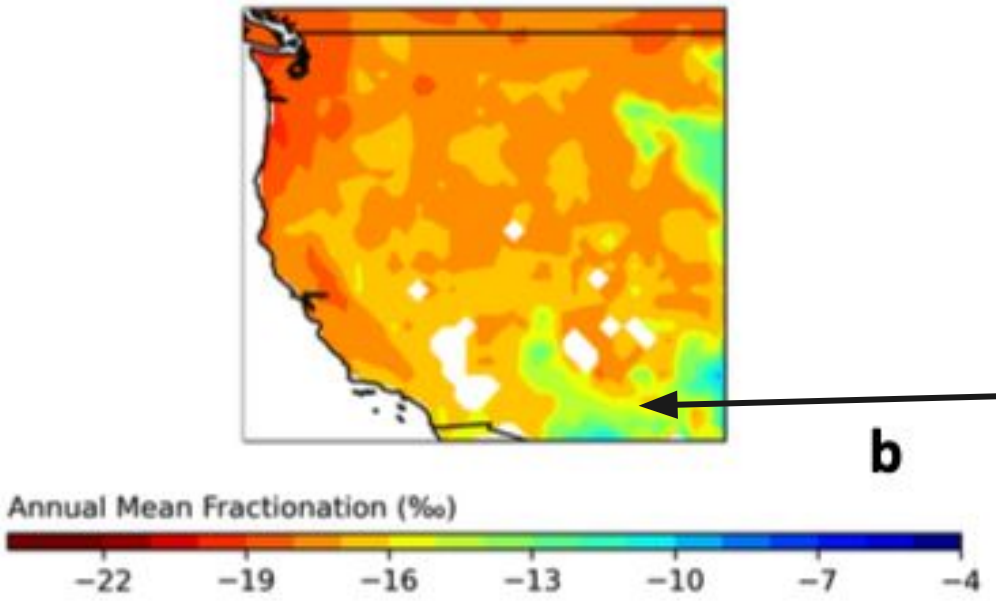
Measurable!

moisture stress

Changes $\delta^{13}C_{plant}$

Hard to detec beyond site-scale!





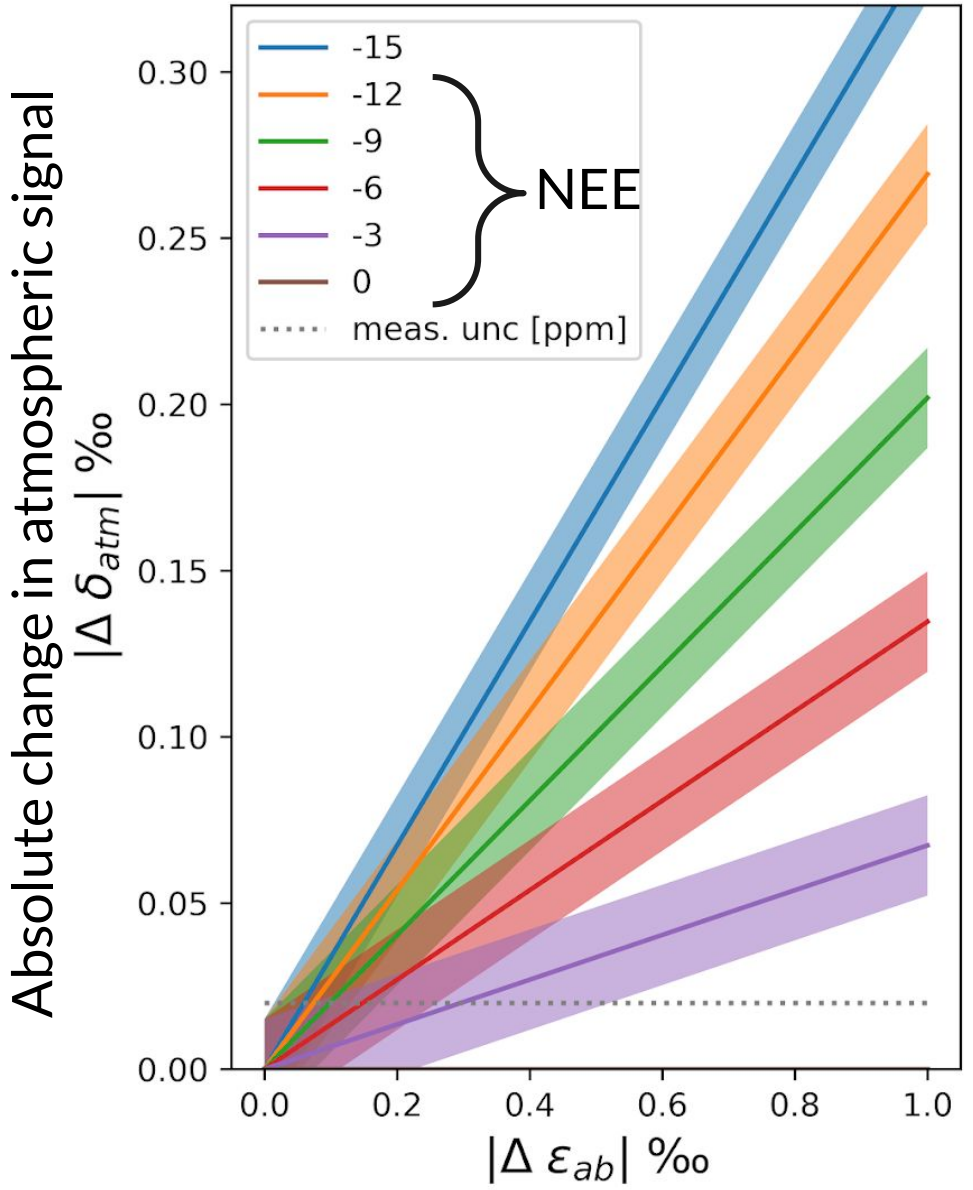
C4

Model Framework

$$\Delta C_a = \mathrm{H} \times \mathrm{F}_b + \epsilon$$

$$\Delta(C_a \times \delta^{13}\mathrm{C}_a) = \mathrm{H}(\mathrm{F}_b \delta_{b\to a} + \mathrm{DIS}_b) + \epsilon$$

$$\delta_{b\to a} = \varepsilon_{a\to b} + \delta^{13} C_a$$

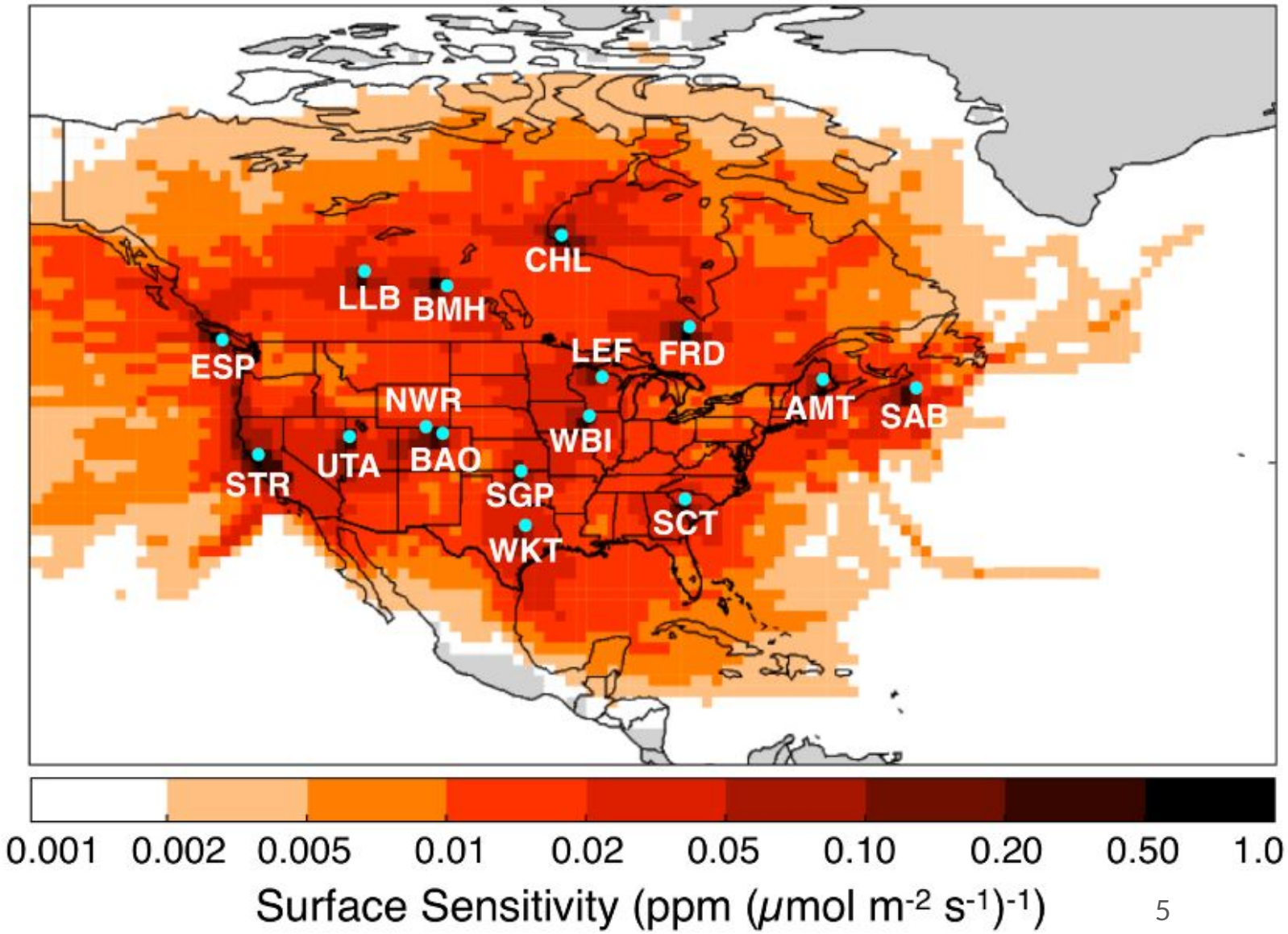


Goals

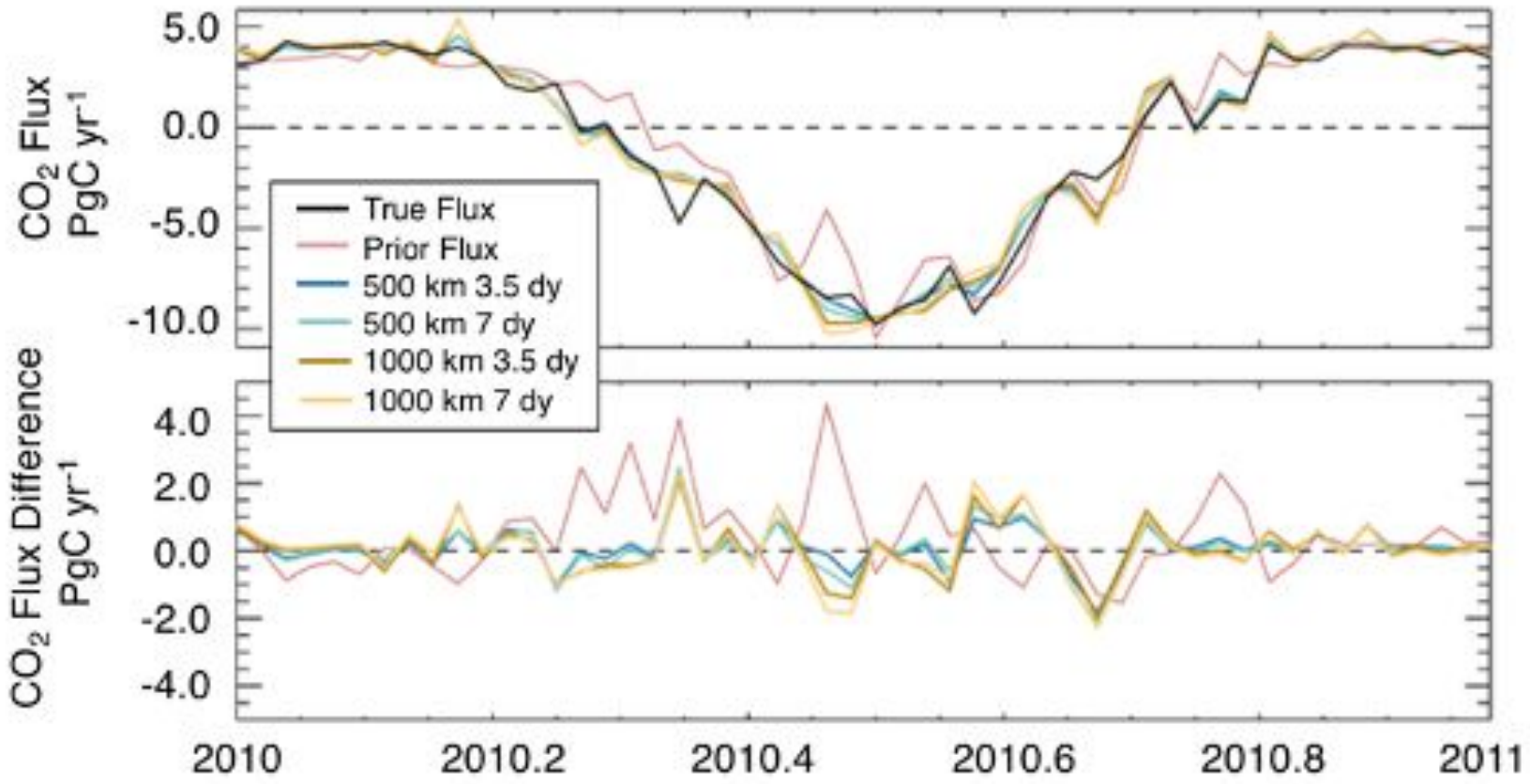
Create a synthetic data experiment to test

- Signal to Noise
- Theoretical vs actual (still theoretical) sensitivities
- Exclude complicated terms!

FLEXPART (0.5 °C x 0.5 °C x 3 hrs)



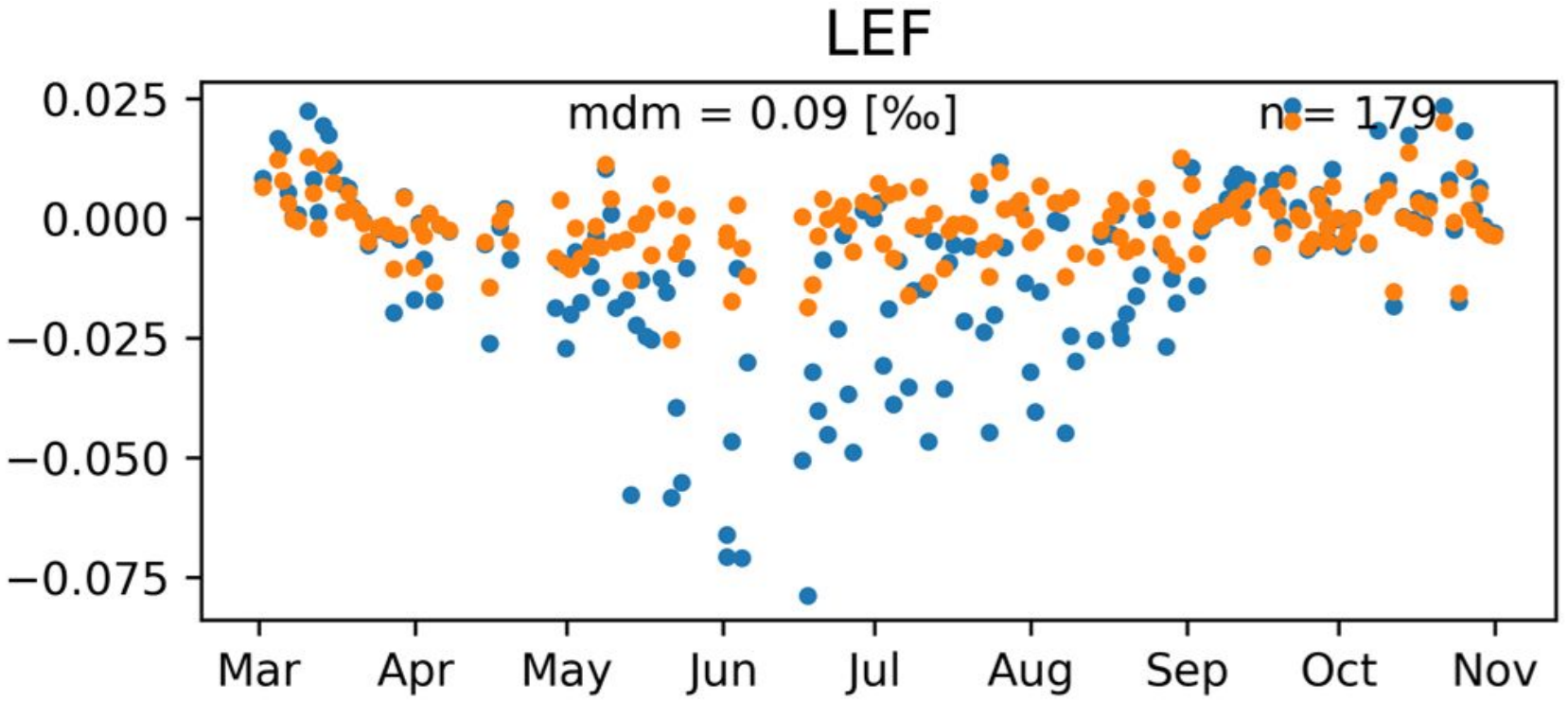
Step 1: Perform a CO2 inversion (equation 1)



Change in atmospheric $\delta^{13}C$ is a function of $\delta^{13}C_{bio}$ and dependent on NEE and H

$\delta^{13}C_{a,tru} - \delta^{13}C_{a,prior}$ [‰]

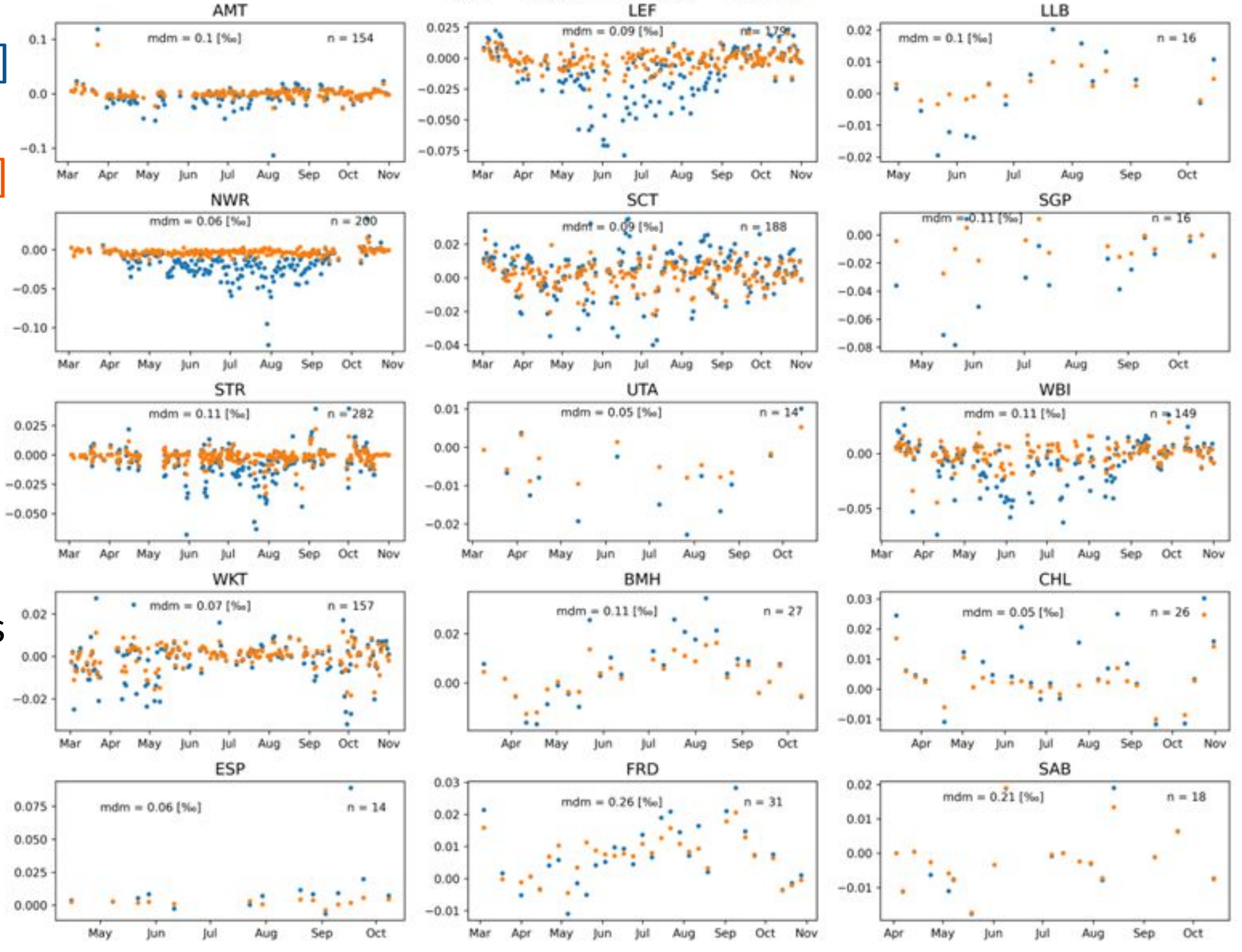
$\delta^{13}C_{a,tru} - \delta^{13}C_{a,post}$ [‰] = $H.NEE(\delta^{13}C_{bio,tru} - \delta^{13}C_{a,post})/Ca$

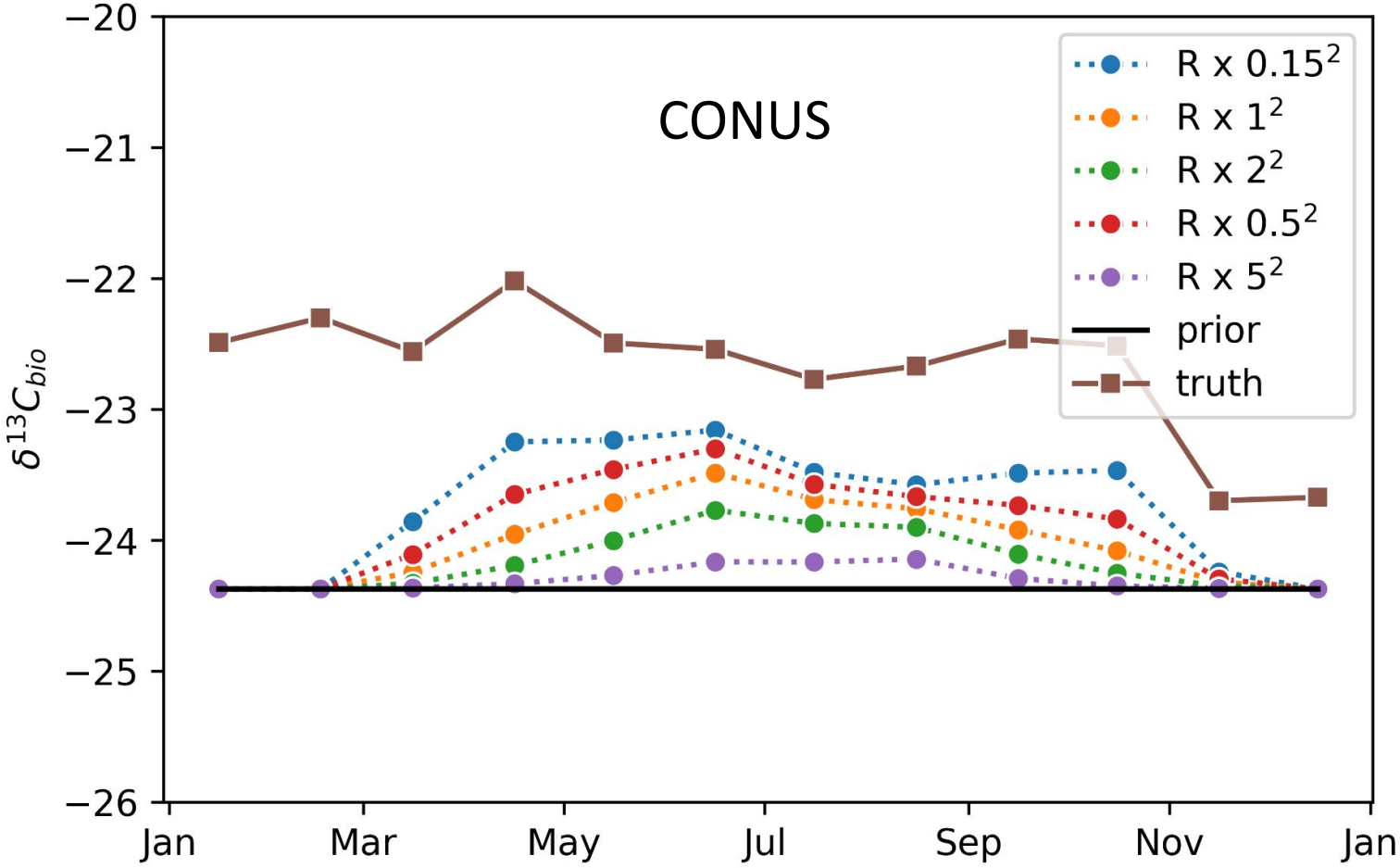


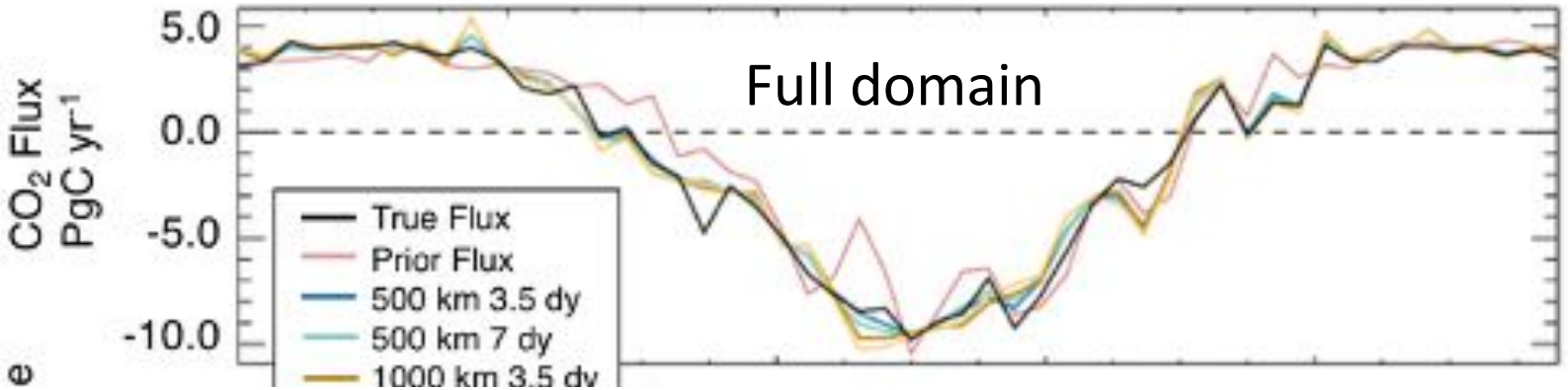
$\delta^{13}C_{a,tru} - \delta^{13}C_{a,prior}$ [‰]

$\delta^{13}C_{a,tru} - \delta^{13}C_{a,post}$ [‰]

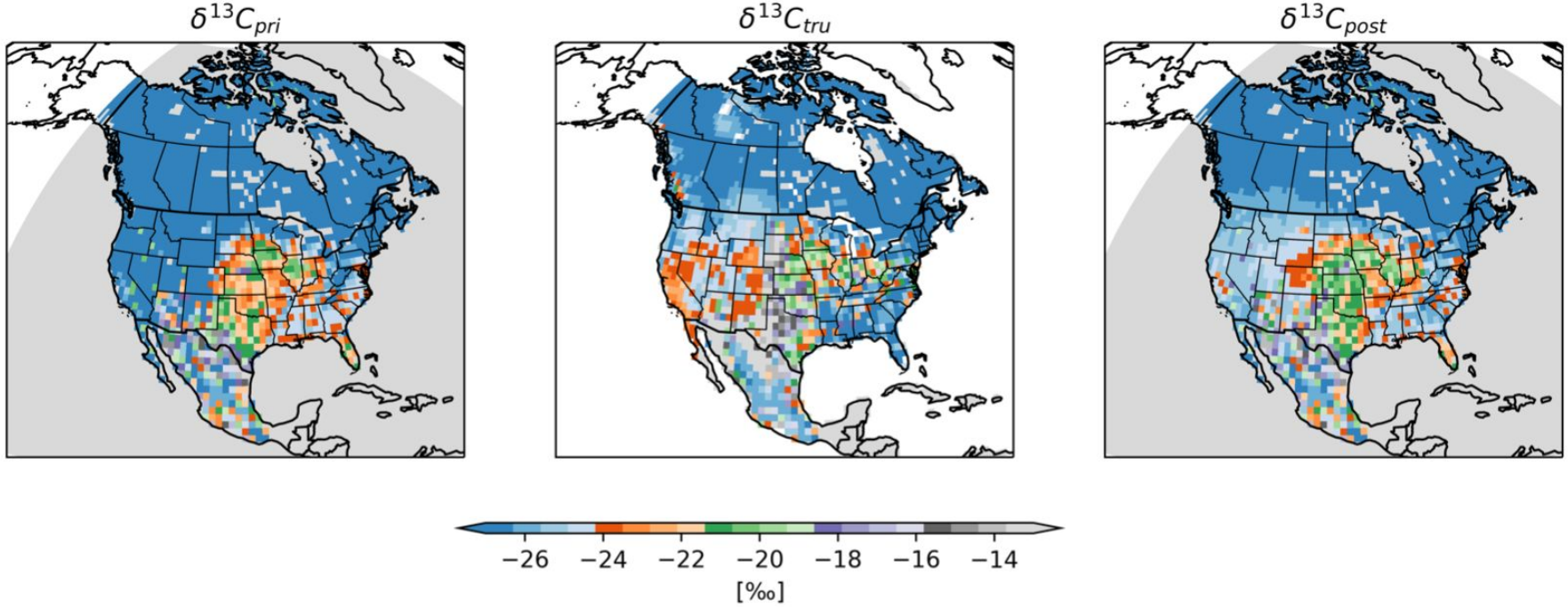
- Across sites ‘Orange’ closer to 0 than ‘blue’
- Significant data gaps at several sites

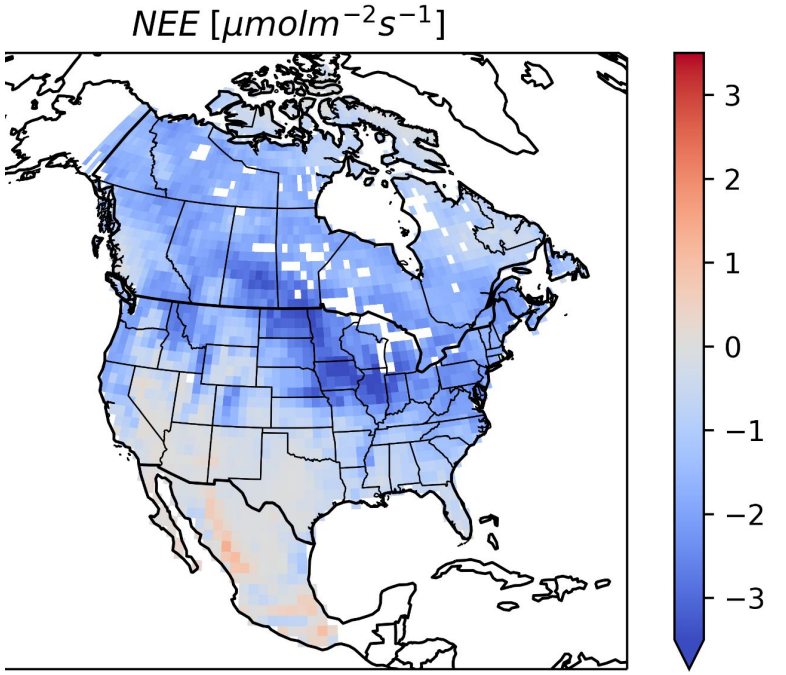


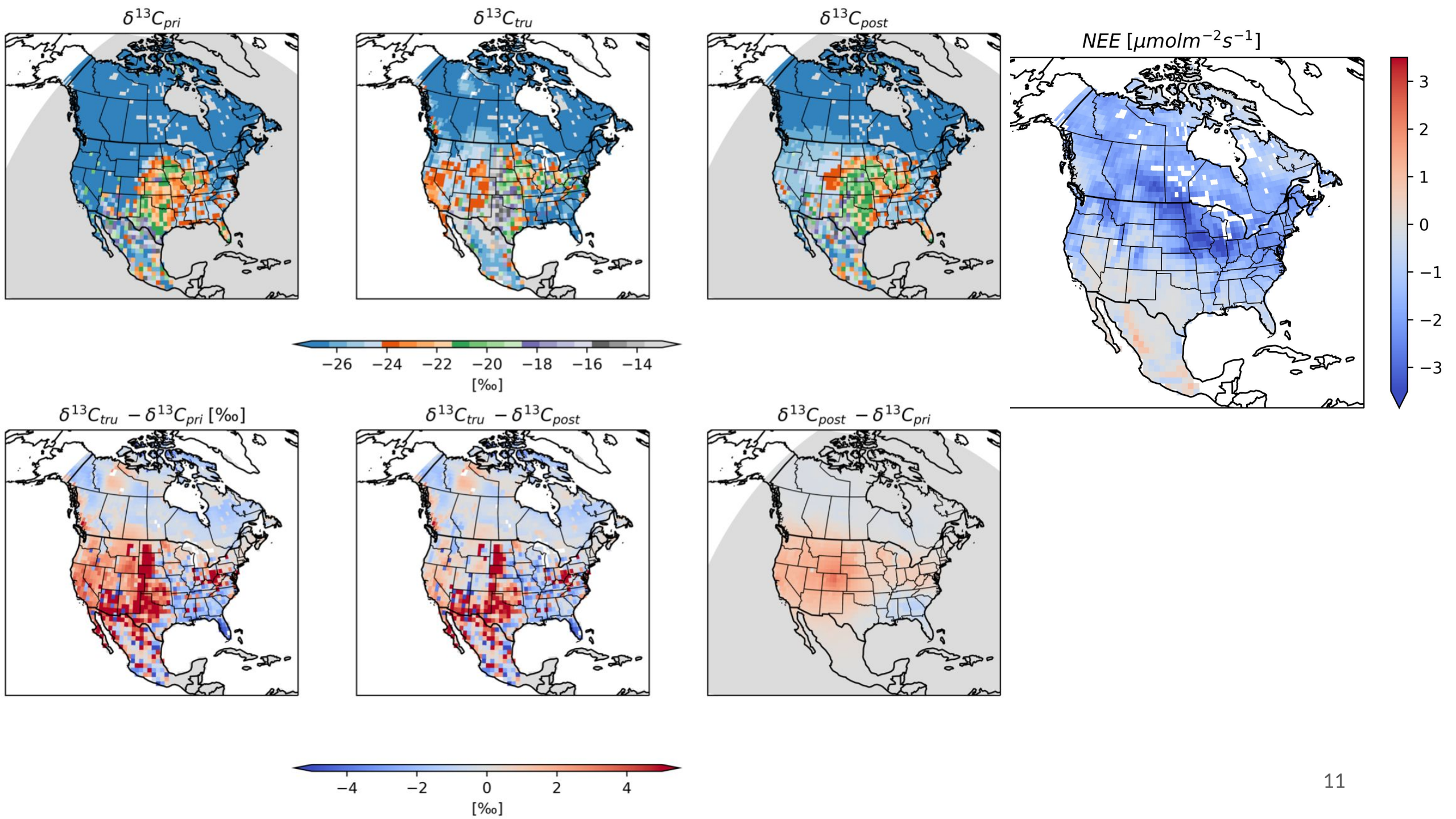


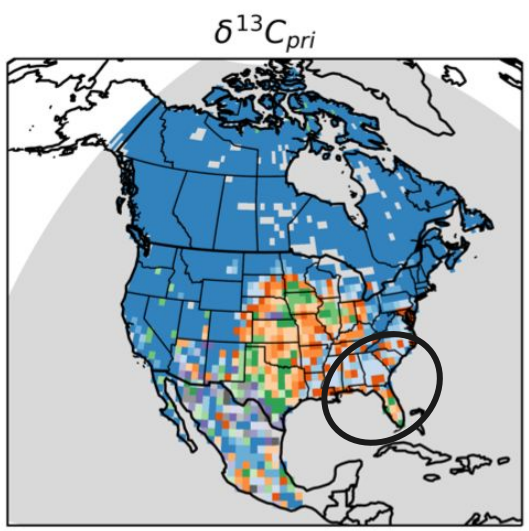


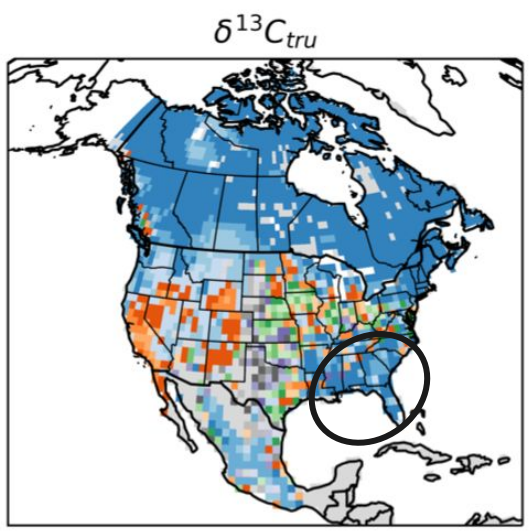
Tightening the model's ability to fit the data partially improves truth recovery

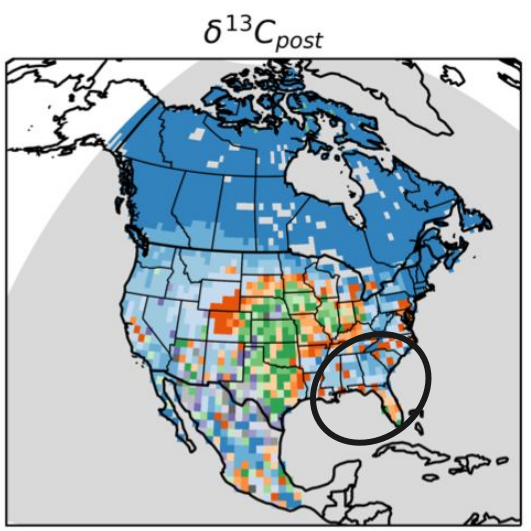

$\delta^{13}C_{pri}$
$\delta^{13}C_{tru}$
$\delta^{13}C_{post}$
−26 −24 −22 −20 −18 −16 −14
[‰]

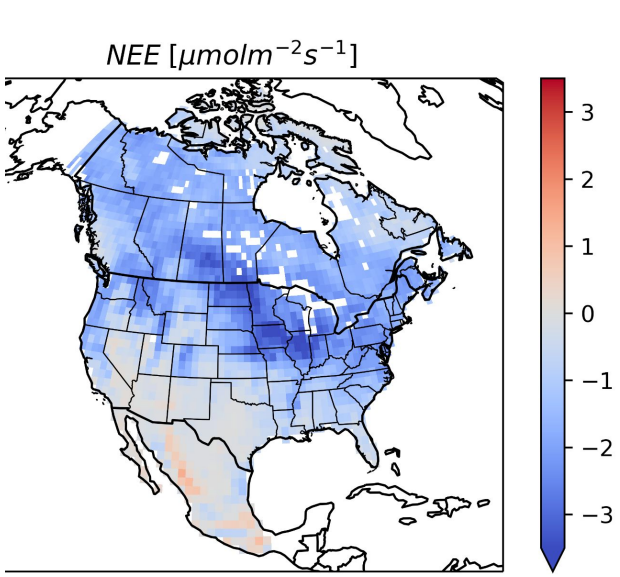

$NEE\ [\mu molm^{-2}s^{-1}]$
3
2
1
0
−1
−2
−3

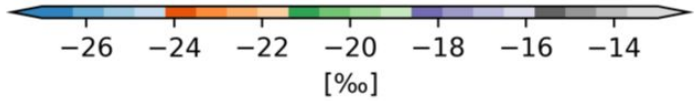

$\delta^{13}C_{pri}$
$\delta^{13}C_{tru}$
$\delta^{13}C_{post}$
$NEE\ [\mu molm^{-2}s^{-1}]$
−26 −24 −22 −20 −18 −16 −14
[‰]
3 2 1 0 −1 −2 −3
$\delta^{13}C_{tru} - \delta^{13}C_{pri}$ [‰]
$\delta^{13}C_{tru} - \delta^{13}C_{post}$
$\delta^{13}C_{post} - \delta^{13}C_{pri}$
−4 −2 0 2 4
[‰]

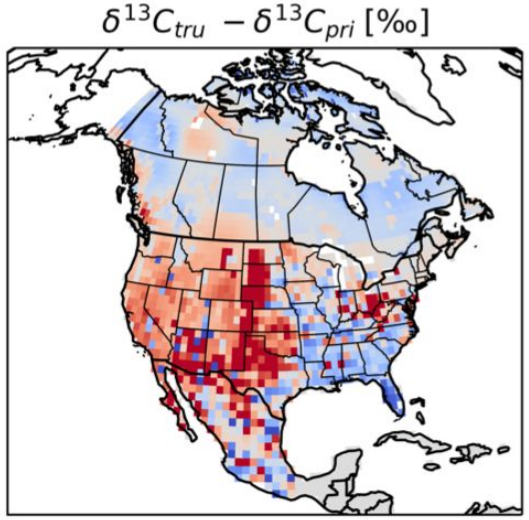


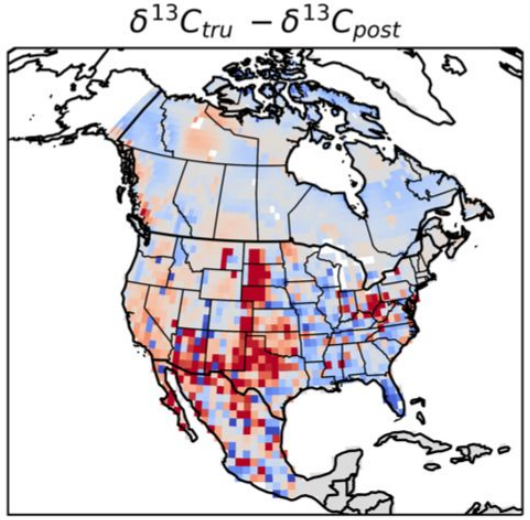


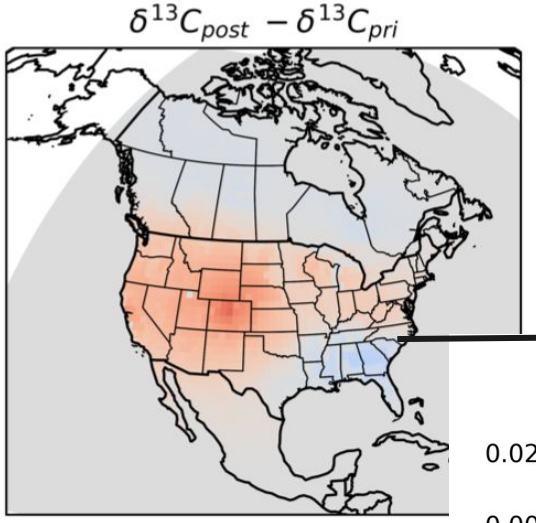


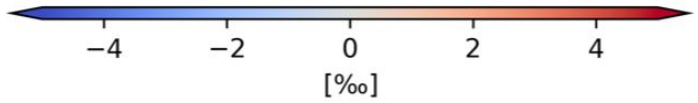




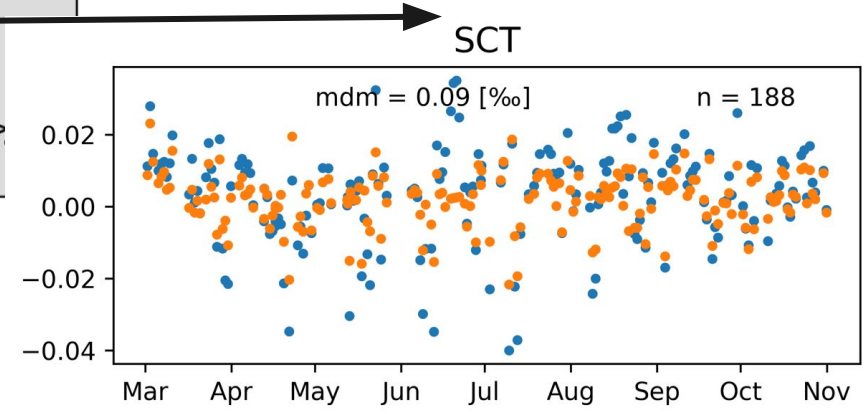


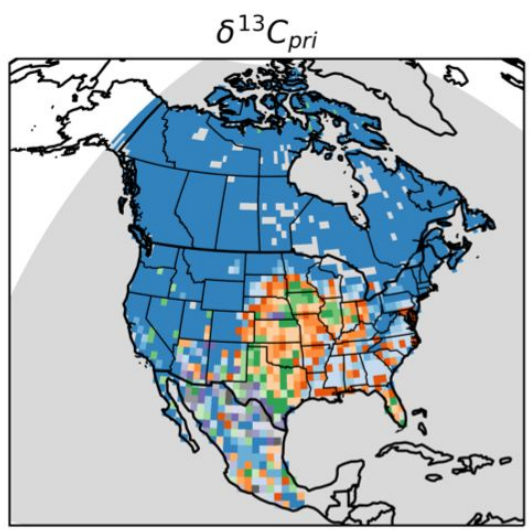


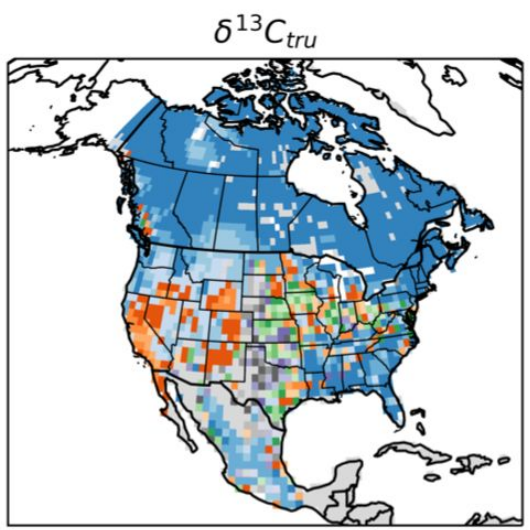


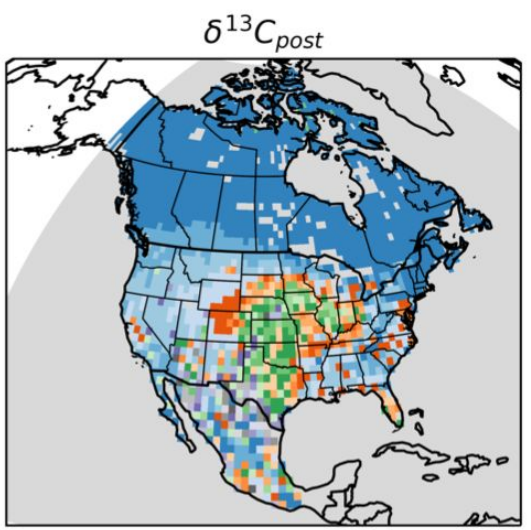


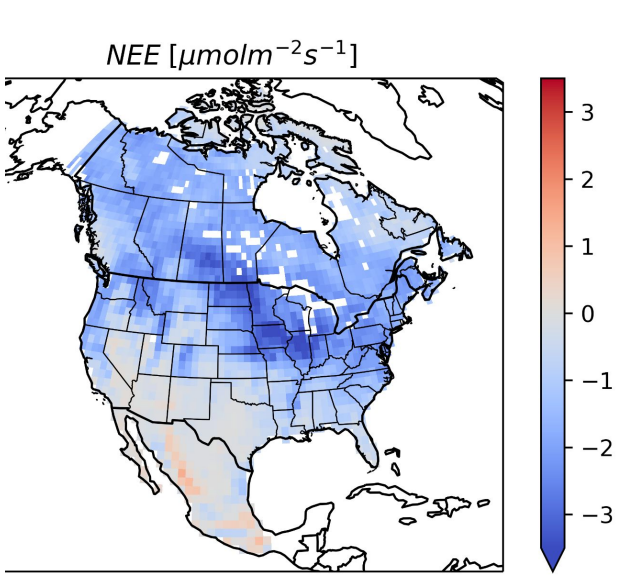
Low Signal to noise
Some deviation from the prior

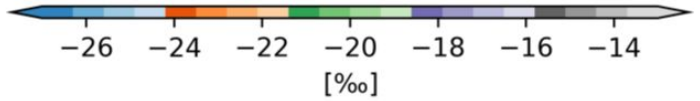


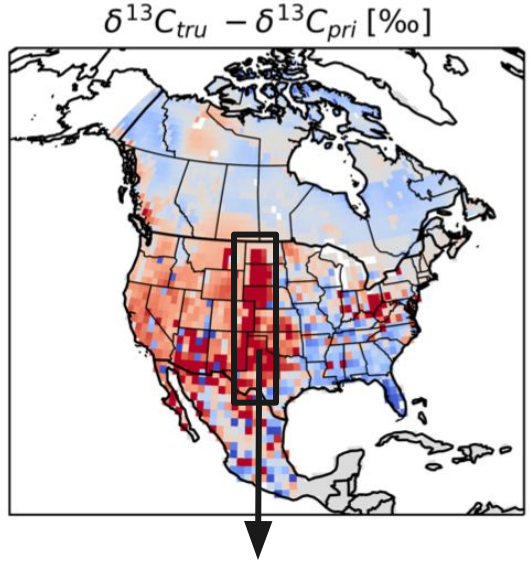


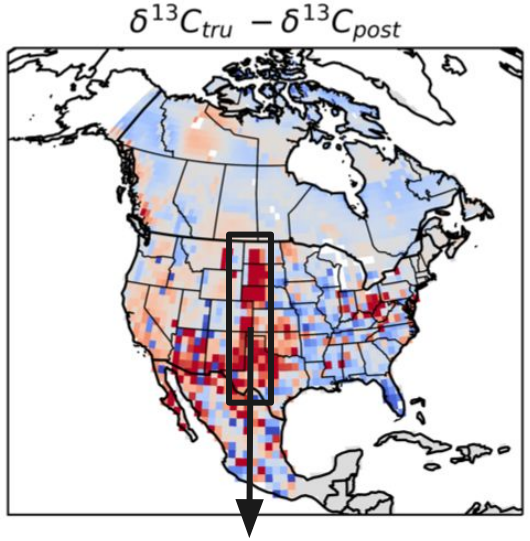


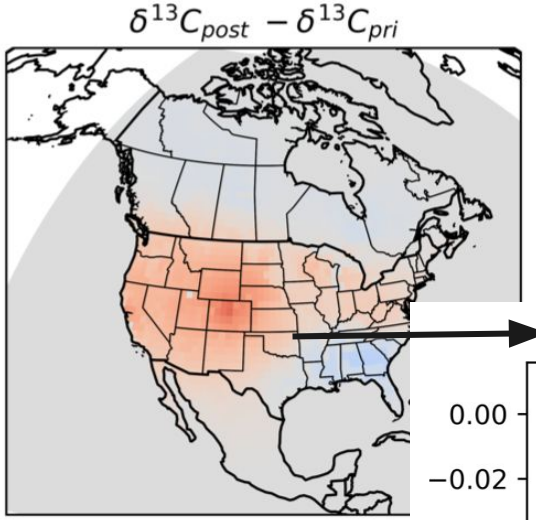






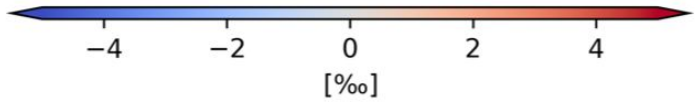


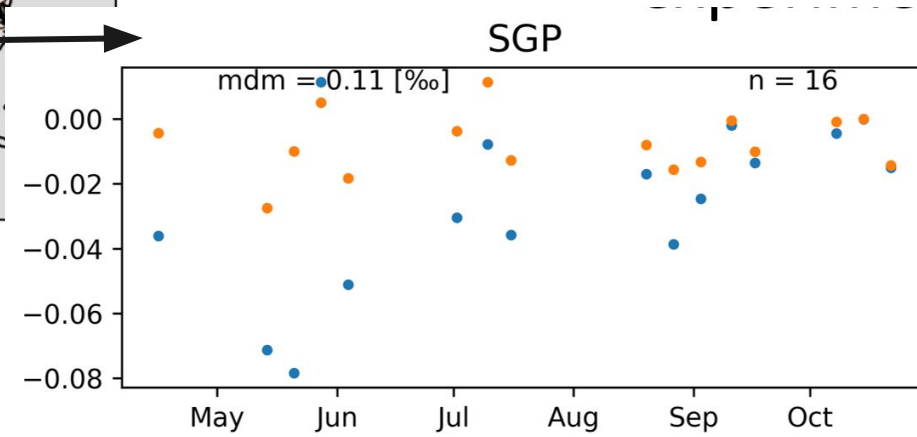


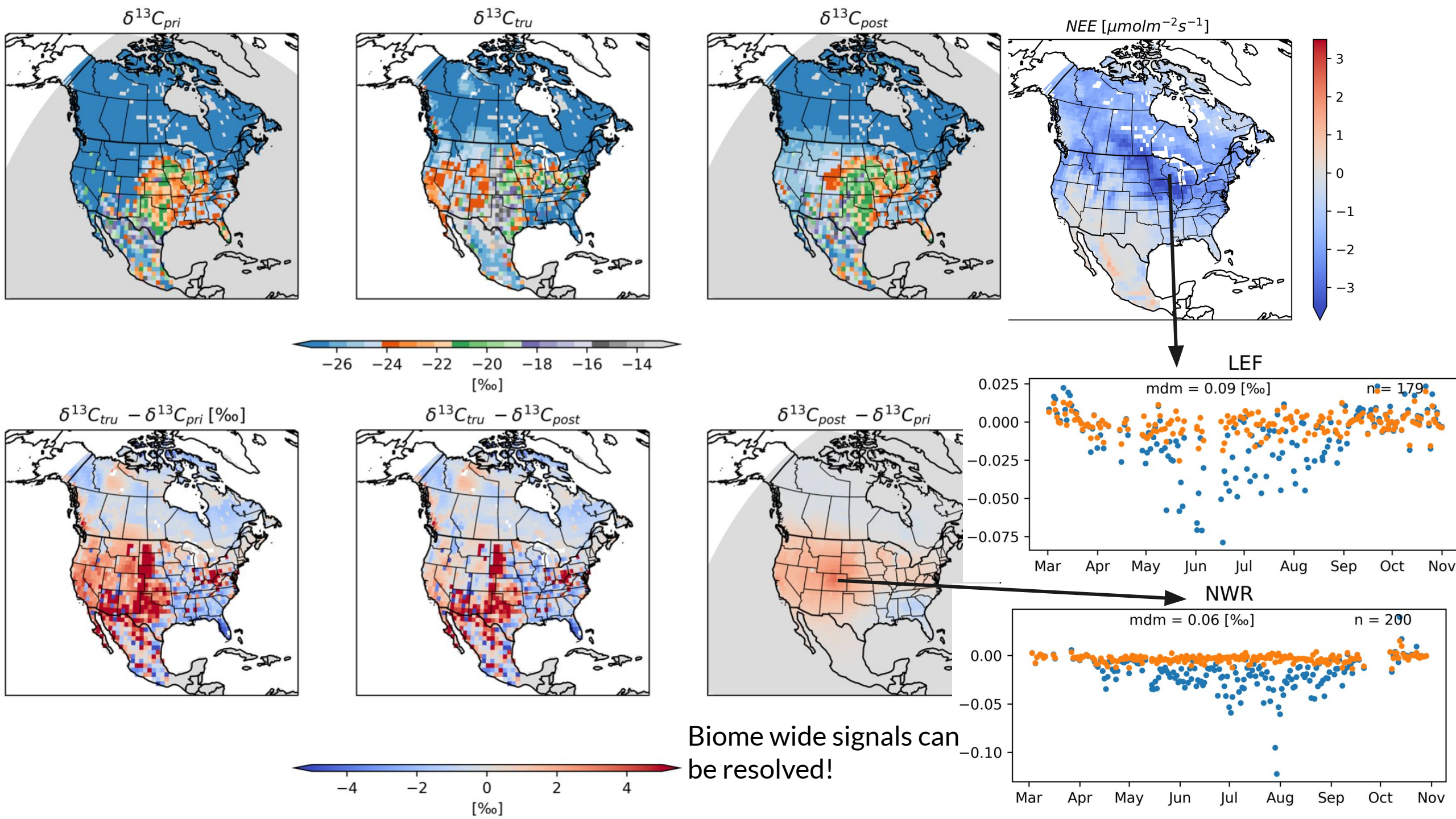


Missing data at SGP

Difference in C4 fraction in prior and ‘truth’

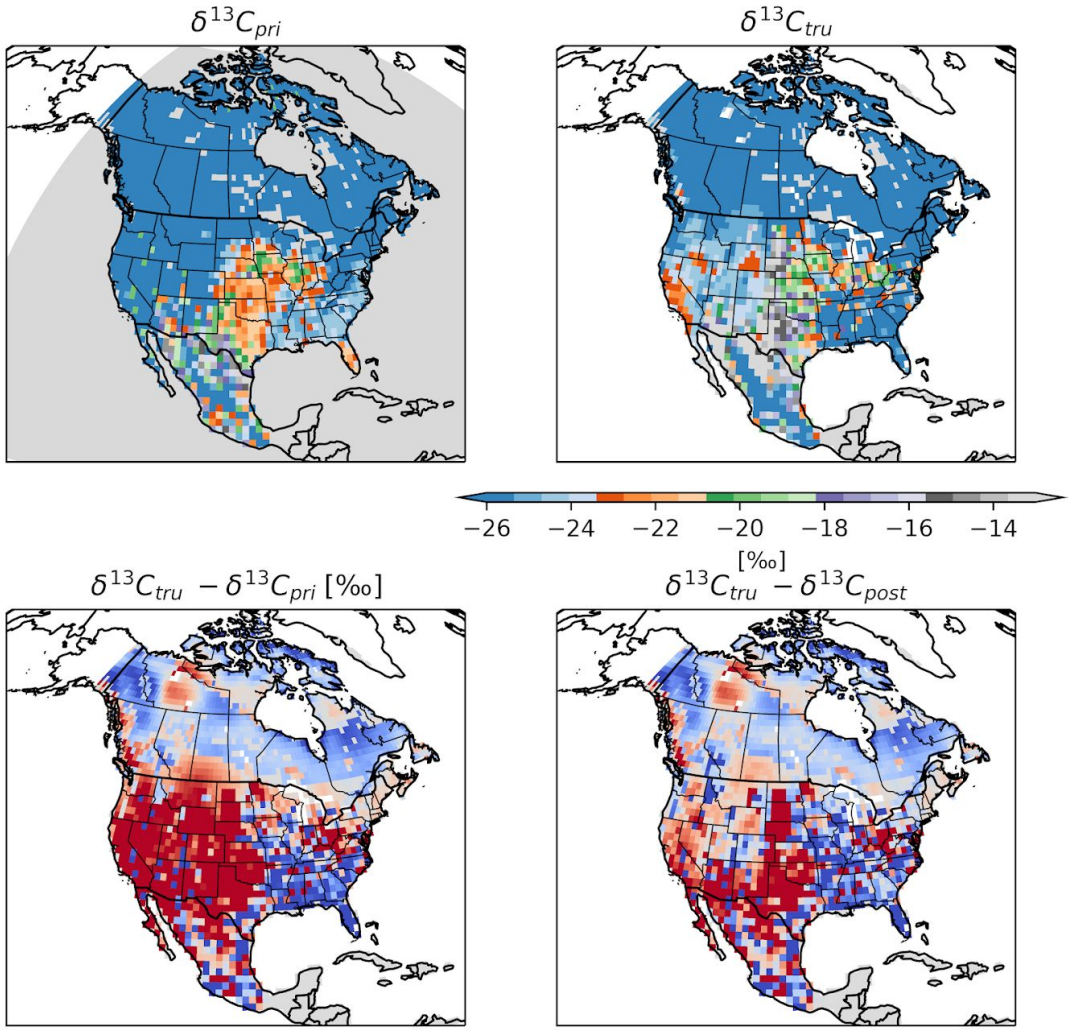


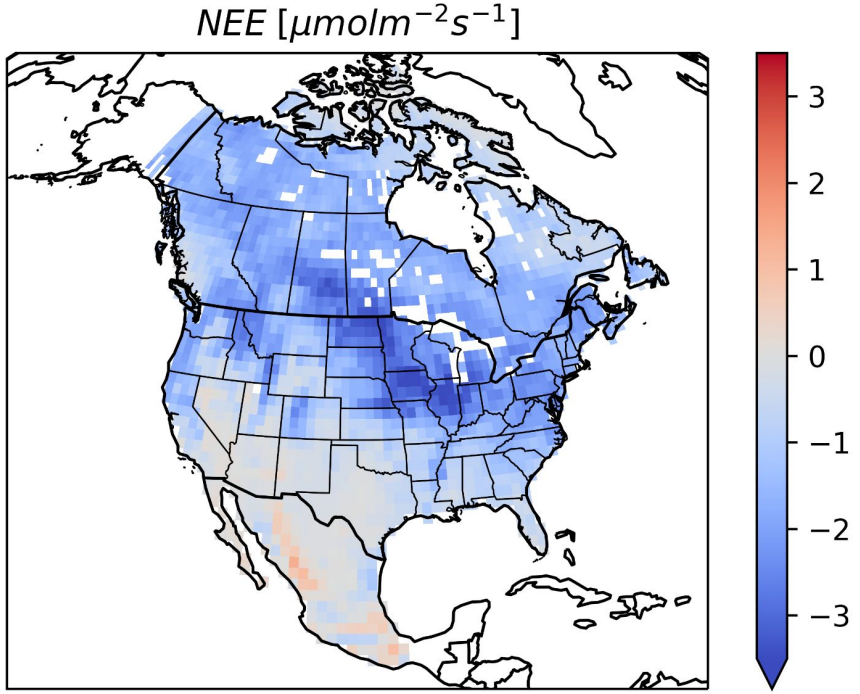



$\delta^{13}C_{pri}$
$\delta^{13}C_{tru}$
$\delta^{13}C_{post}$
$NEE\ [\mu molm^{-2}s^{-1}]$
3
2
1
0
−1
−2
−3
−26 −24 −22 −20 −18 −16 −14
[‰]
LEF
mdm = 0.09 [‰]
n = 179
0.025
0.000
−0.025
−0.050
−0.075
Mar Apr May Jun Jul Aug Sep Oct Nov
$\delta^{13}C_{tru} - \delta^{13}C_{pri}$ [‰]
$\delta^{13}C_{tru} - \delta^{13}C_{post}$
$\delta^{13}C_{post} - \delta^{13}C_{pri}$
NWR
mdm = 0.06 [‰]
n = 200
0.00
−0.05
−0.10
Mar Apr May Jun Jul Aug Sep Oct Nov
−4 −2 0 2 4
[‰]
Biome wide signals can be resolved!

Conclusions

- The sensitivity of atmospheric $\delta^{13}C$ is contingent on the magnitude of (not the change in!) NEE
- Droughts reduce NEE and therefore also the sensitivity of $\delta^{13}C$ to moisture stress
- Using a high resolution regional OSSE, we find that the measurement network partially helps overcome these theoretical limitations
- Data density is important!


$\delta^{13}C_{pri}$
$\delta^{13}C_{tru}$
$\delta^{13}C_{post}$
−26 −24 −22 −20 −18 −16 −14
[‰]
$\delta^{13}C_{tru} - \delta^{13}C_{pri}$ [‰]
$\delta^{13}C_{tru} - \delta^{13}C_{post}$
$\delta^{13}C_{post} - \delta^{13}C_{pri}$
−2.0 −1.5 −1.0 −0.5 0.0 0.5 1.0 1.5 2.0
[‰]


$NEE\ [\mu molm^{-2}s^{-1}]$
3
2
1
0
−1
−2
−3