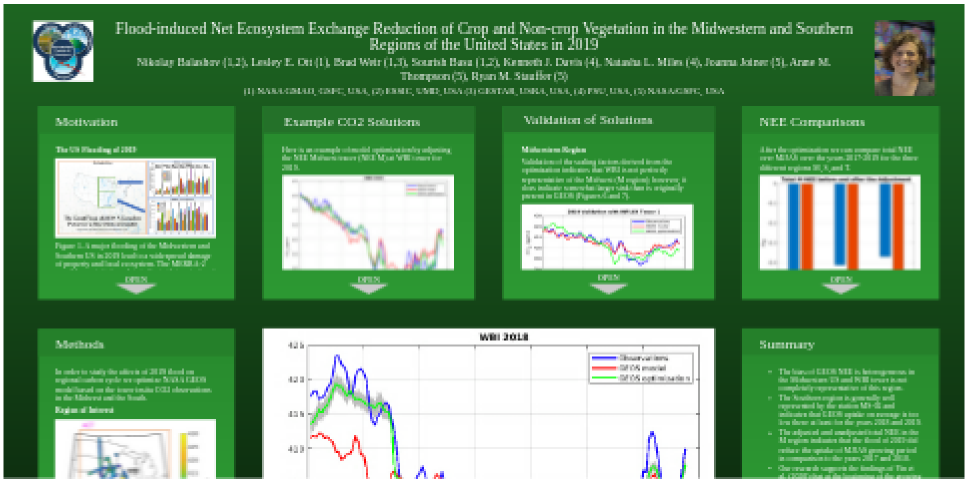
Flood-induced Net Ecosystem Exchange Alteration in the Midwestern and Southern Regions of the United States in 2019



Flood-induced Net Ecosystem Exchange Reduction of Crop and Non-crop Vegetation in the Midwestern and Southern Regions of the United States in 2019

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(1) NASA GMAO, GSFC, USA, (2) ESSIC, UMD, USA (3) GESTAR, USRA, USA, (4) PSU, USA, (5) NASA/GSFC, USA

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Summary

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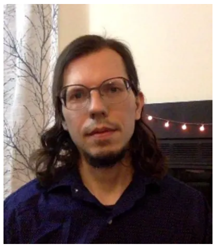

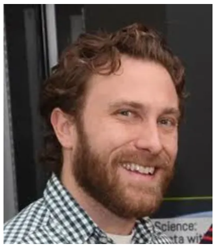

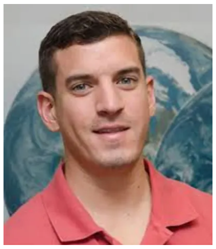

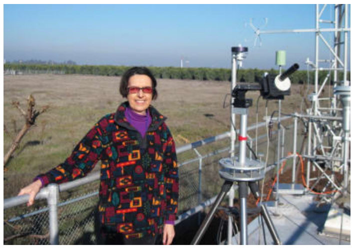

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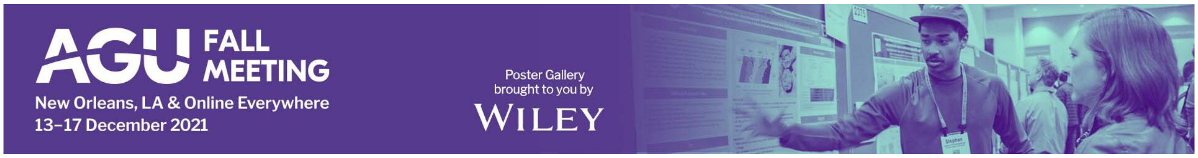


MOTIVATION

The US Flooding of 2019

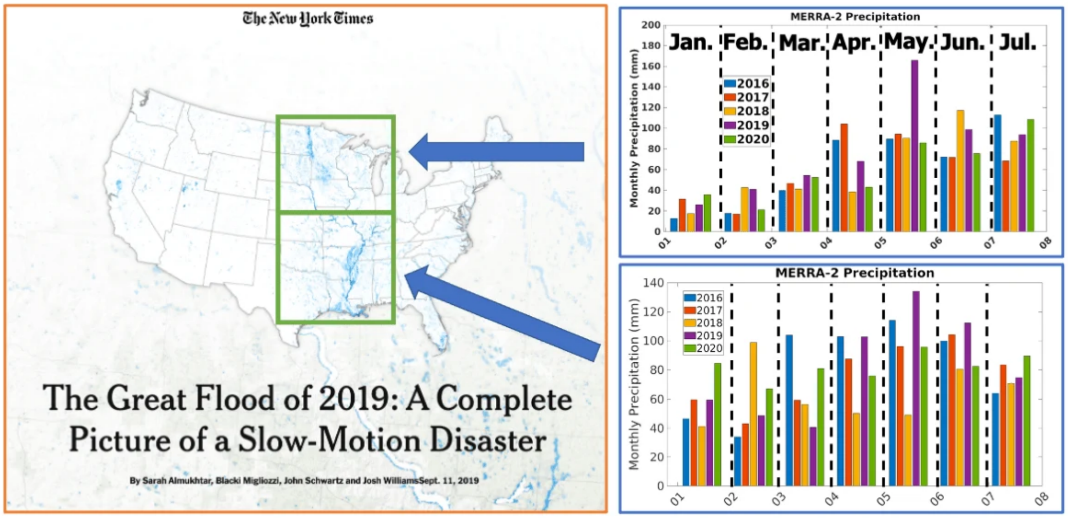


Figure 1. A major flooding of the Midwestern and Southern US in 2019 lead to a widespread damage of property and local ecosystem. The MERRA-2 monthly precipitation plots indicate that majority of flooding in the region occurred in the month of May, where the US Midwest received close to twice its regular monthly amount of precipitation. The flood was so dramatic that it generated a lot of press.

Source:

https://www.nytimes.com/interactive/2019/09/11/us/midwest-flooding.html

It is known that extreme climate events are able to significantly affect global carbon balance. In this poster we are interested in investigating effects of the 2019 flooding on regional carbon balance.

The research question is:

What are the effects of the 2019 flooding on the growing season NEE (May-September) in the affected regions (the Midwest and the South) compared to 2017 and 2018?

EXAMPLE CO2 SOLUTIONS

Here is an example of model optimization by adjusting the NEE Midwest tracer (NEE M) at WBI tower for 2019.

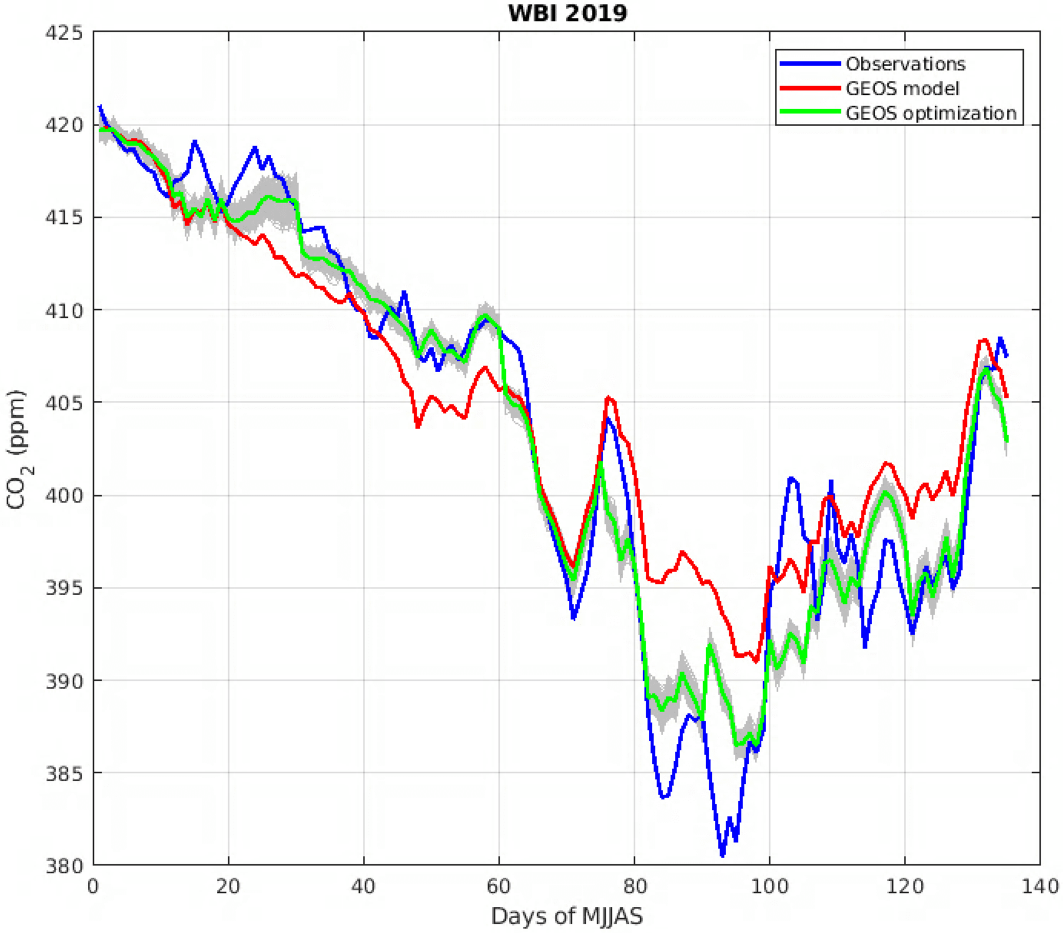


Figure 4. Model optimization (in green) at WBI for 2019.

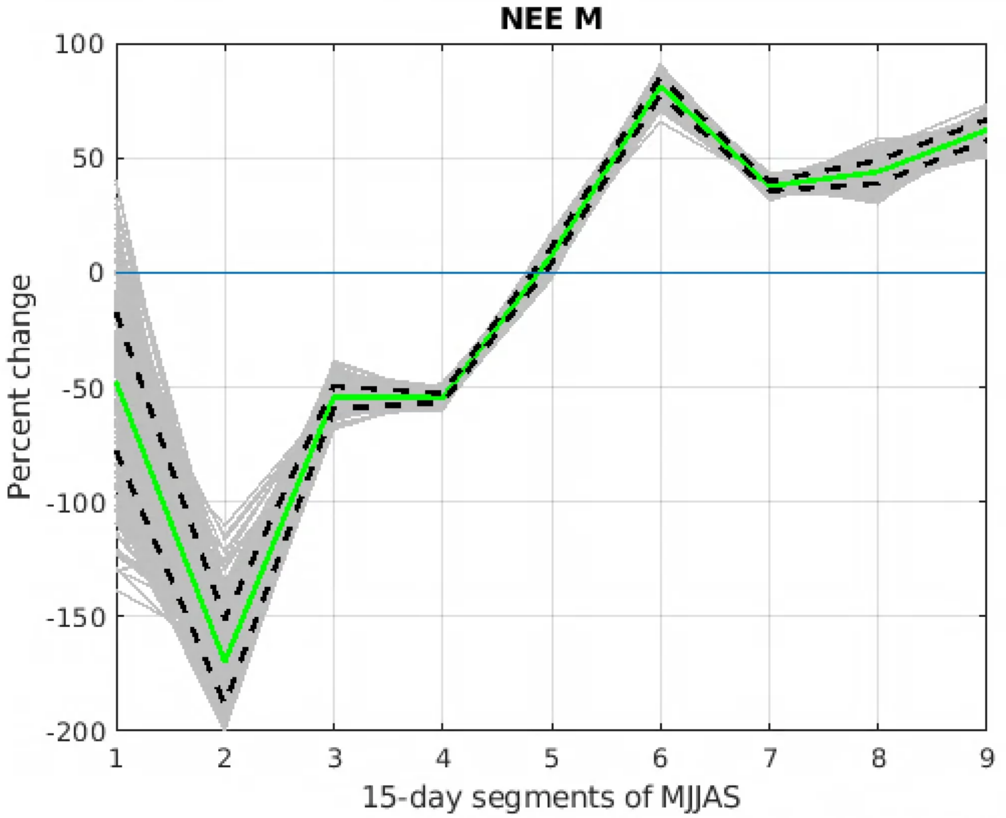


Figure 5. Optimization solution as a scaling factor for the NEE M 2019 tracer.

VALIDATION OF SOLUTIONS

Midwestern Region

Validation of the scaling factors derived from the optimization indicates that WBI is not perfectly representative of the Midwest (M region); however, it does indicate somewhat larger sink than is originally present in GEOS (Figures 6 and 7).

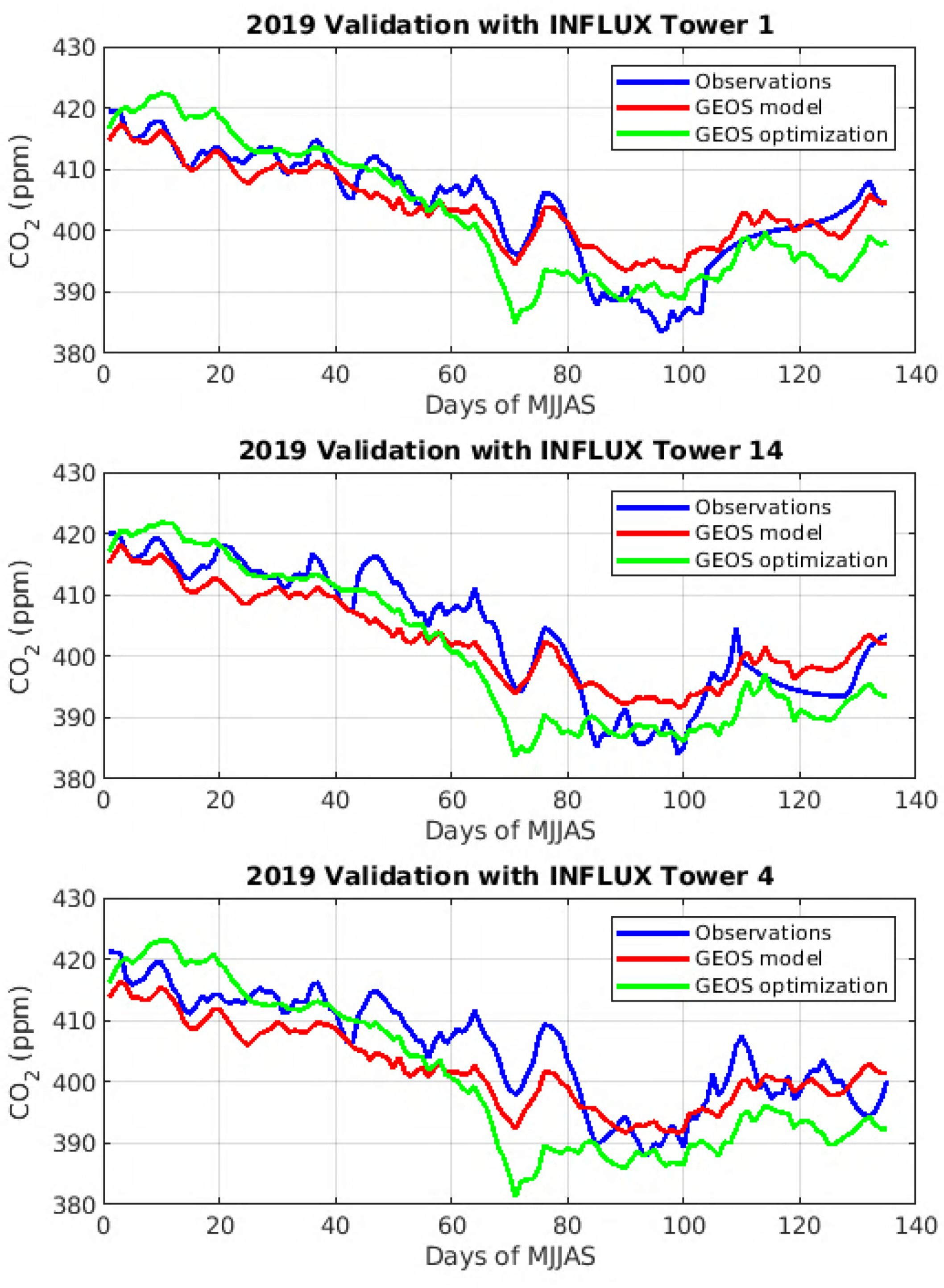


Figure 6. Validation of the optimization scaling factors at INFLUX background sites.

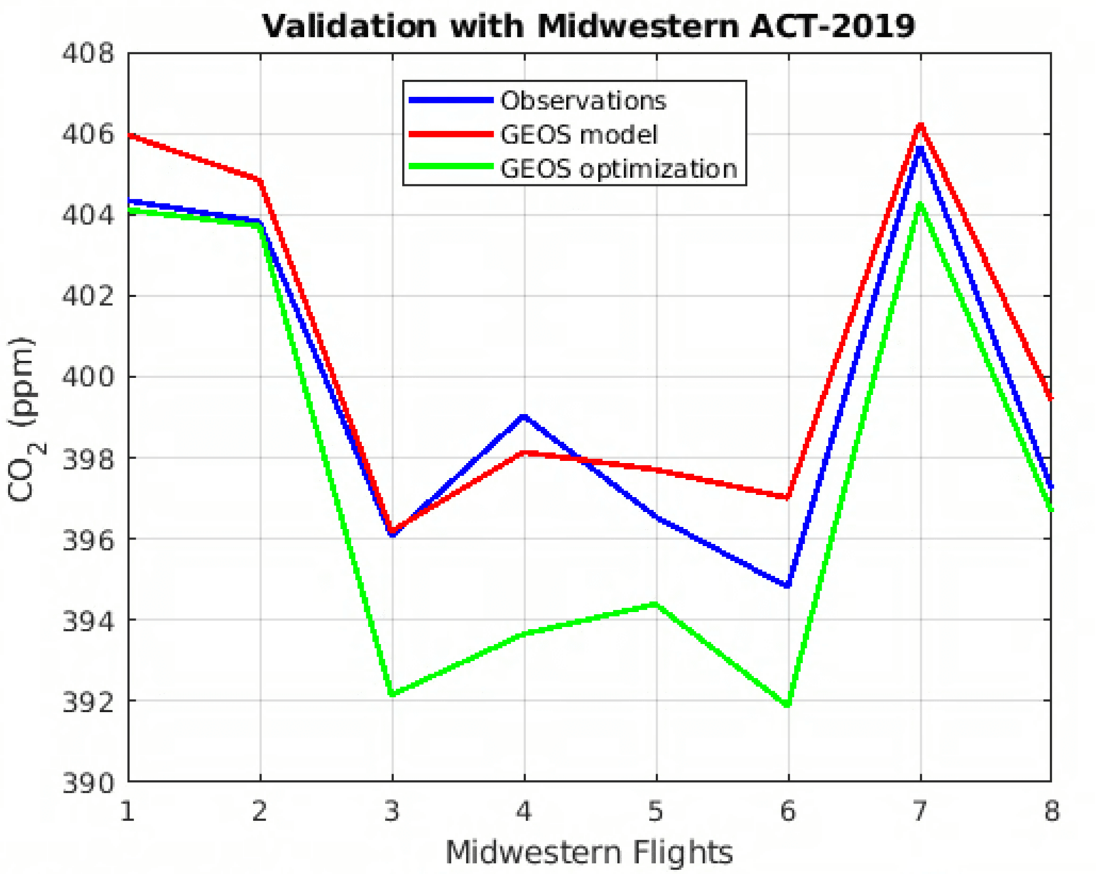


Figure 7. Validation of the optimization scaling fators using ACT-America Midwestern flights (shown in Figure 2).

Southern Region

Validation of the scaling factors derived from the optimization indicates that MS-02 (S region) provides a reasonable estimation of the mentioned factors as verified by LA-01 site in 2018 (Figure 8) and by the Southern ACT-America flights in 2019 (Figure 9).

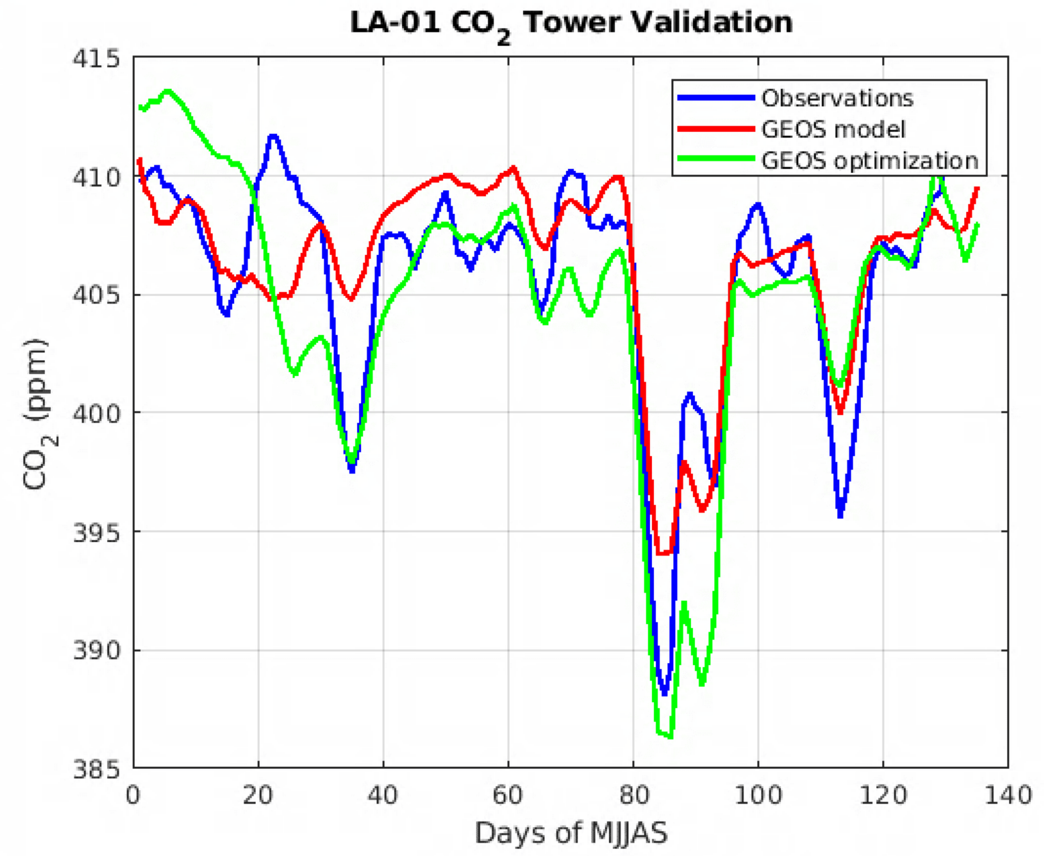


Figure 8. Validation of the optimization scaling factors at LA-01 site in 2018.

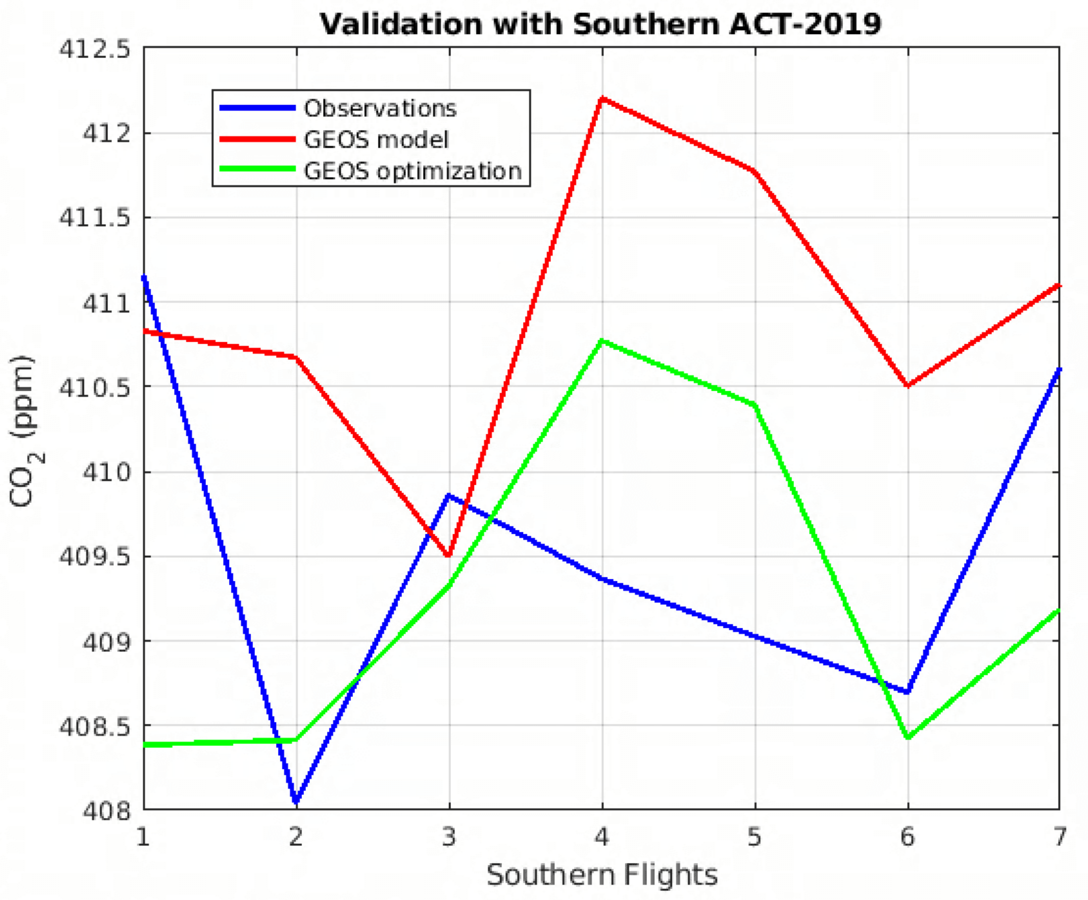


Figure 9. Validation of the optimization scaling fators using ACT-America Southern flights (shown in Figure 2).

NEE COMPARISONS

After the optimization we can compare total NEE over MJJAS over the years 2017-2019 for the three different regions M, S, and T.

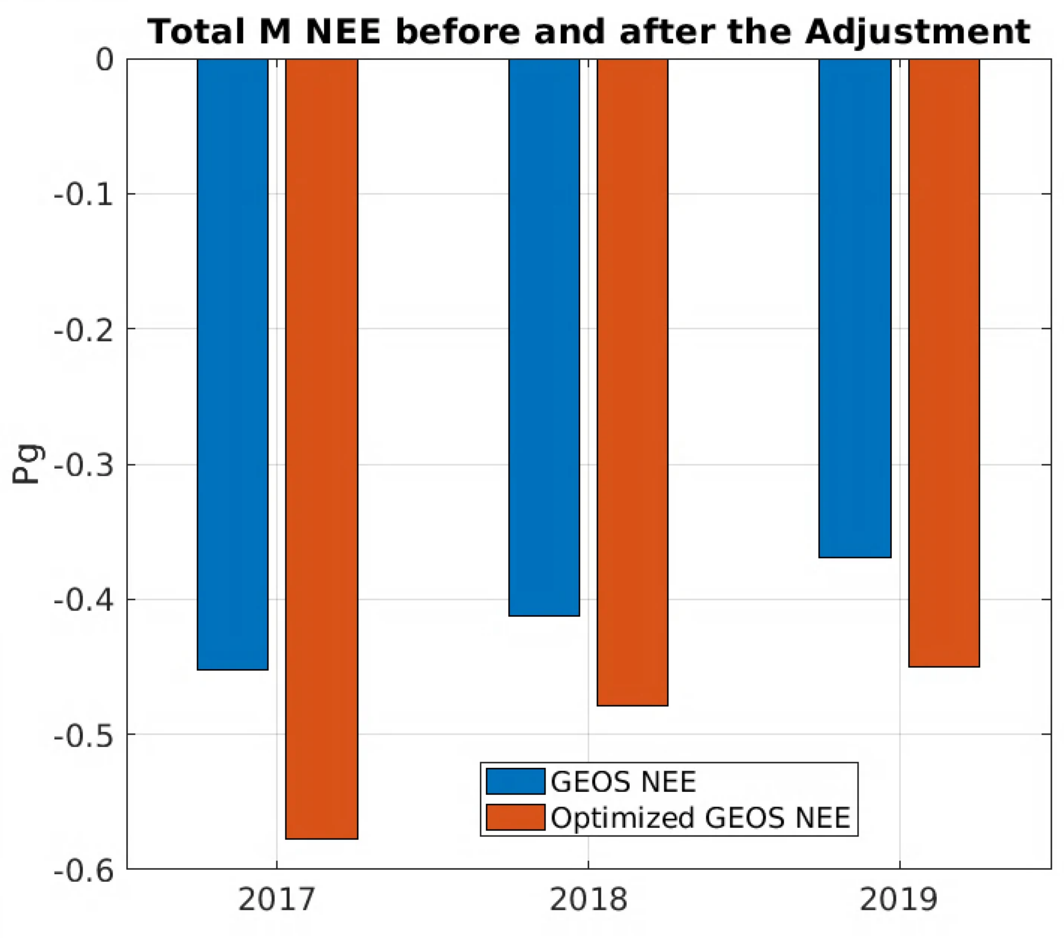


Figure 10. Total GEOS and optimized GEOS M NEE over MJJAS for the years 2017-2019.

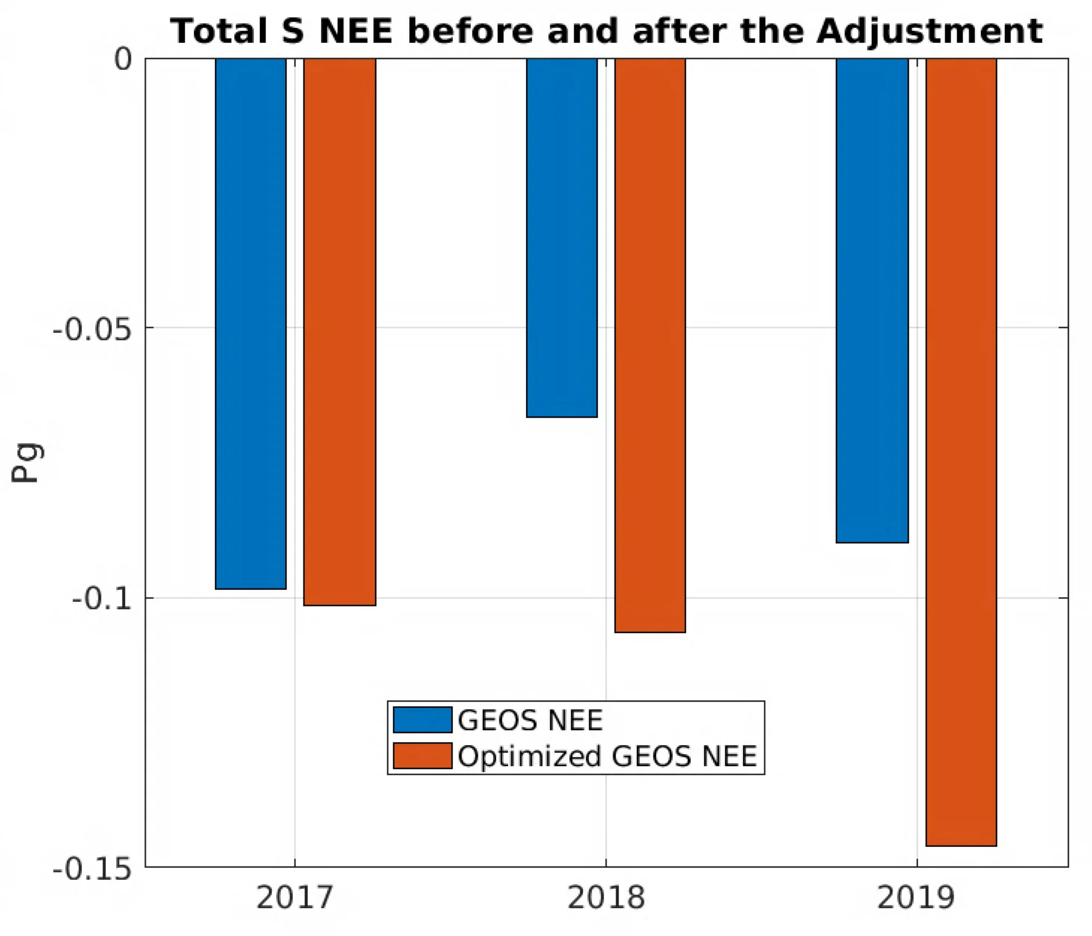


Figure 11. Total GEOS and optimized GEOS S NEE over MJJAS for the years 2017-2019.

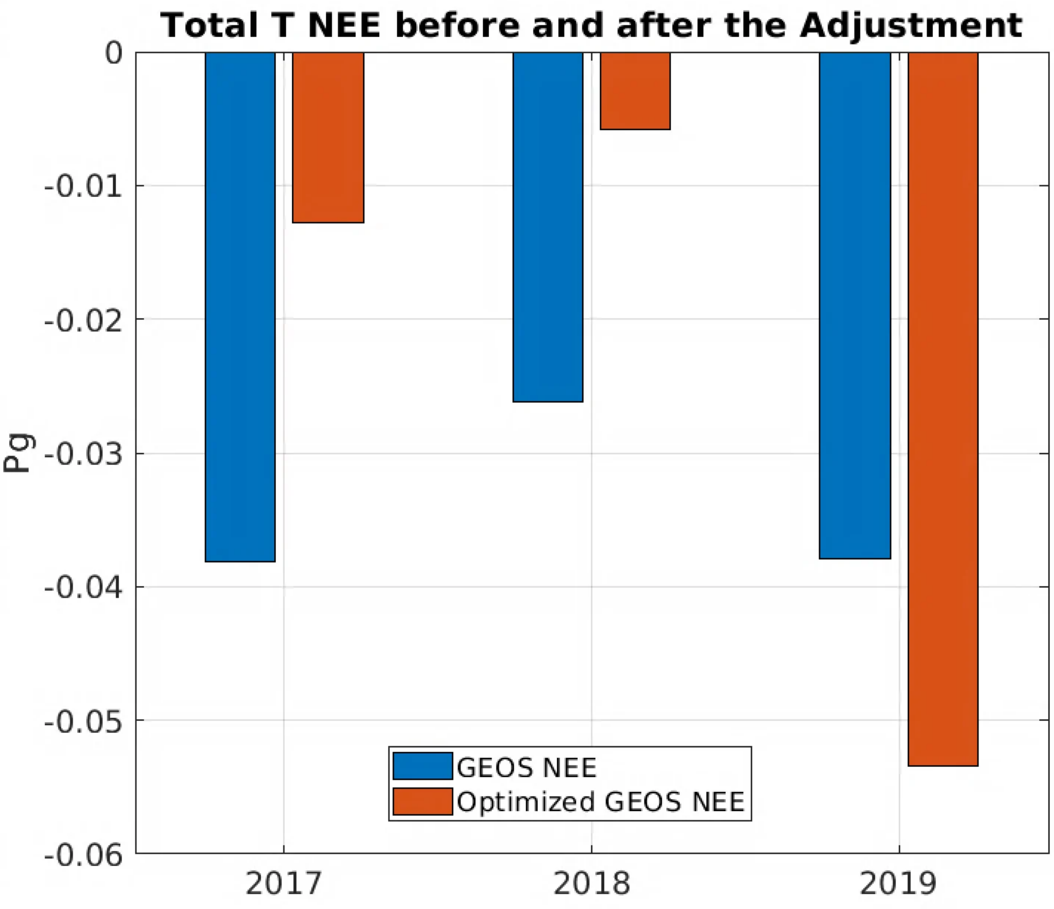


Figure 12. Total GEOS and optimized GEOS T NEE over MJJAS for the years 2017-2019.

METHODS

In order to study the affects of 2019 flood on regional carbon cycle we optimize NASA GEOS model based on the tower insitu CO2 observations in the Midwest and the South.

Region of Interest

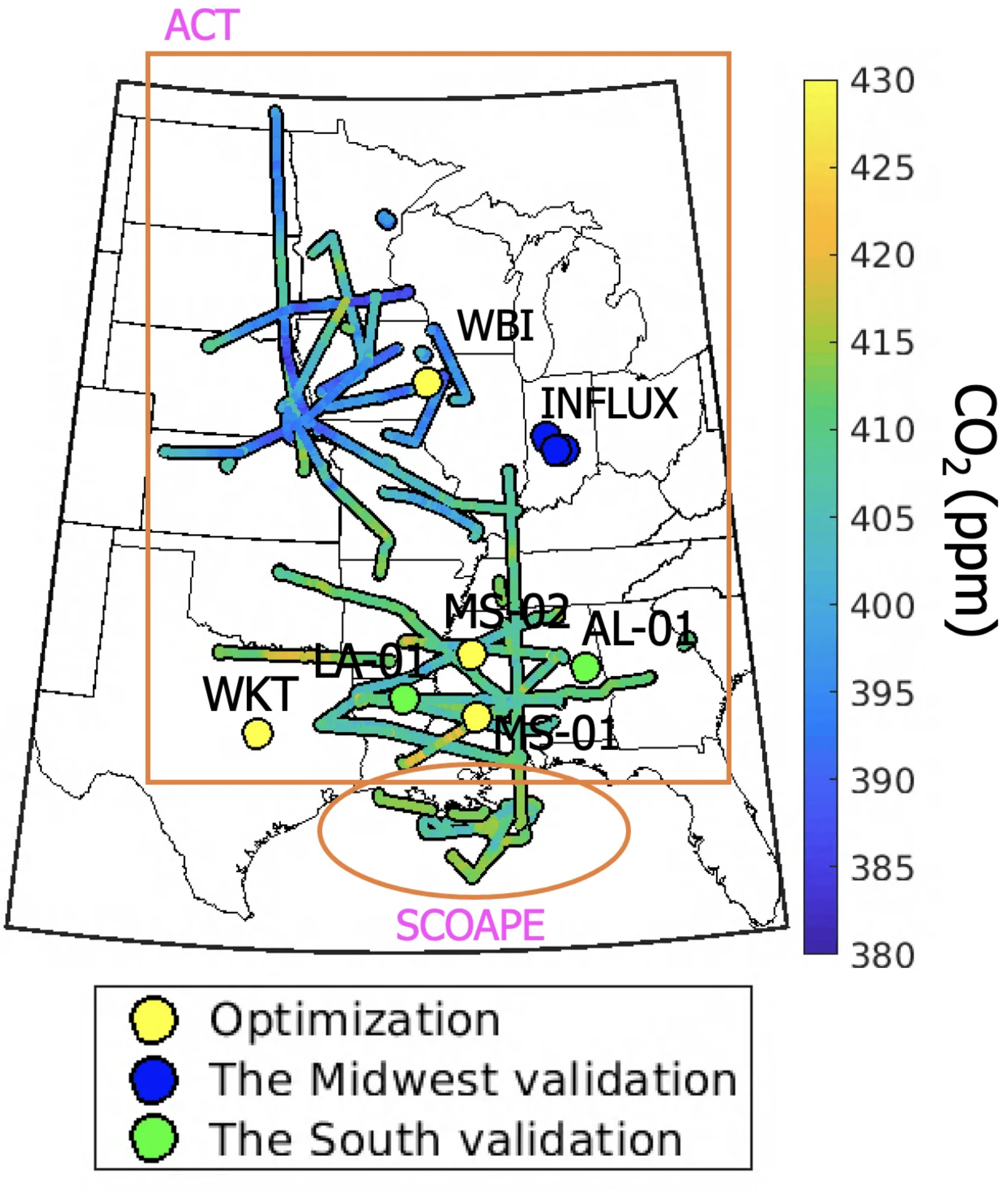
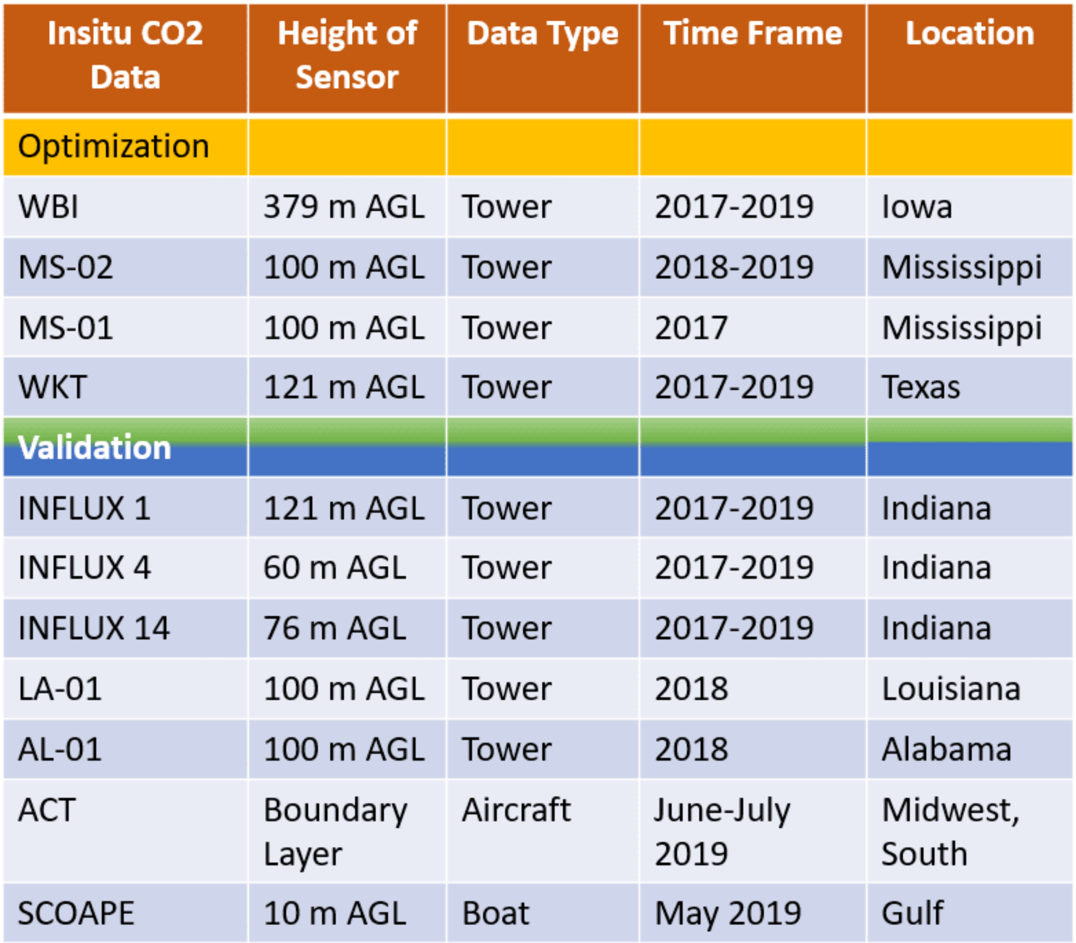


Figure 2. Observations that are used for the model optimization and validation.

Table 1. Detailed information on the data shown in the Figure 2.



Insitu CO2 Data	Height of Sensor	Data Type	Time Frame	Location
Optimization				
WBI	379 m AGL	Tower	2017-2019	Iowa
MS-02	100 m AGL	Tower	2018-2019	Mississippi
MS-01	100 m AGL	Tower	2017	Mississippi
WKT	121 m AGL	Tower	2017-2019	Texas
Validation				
INFLUX 1	121 m AGL	Tower	2017-2019	Indiana
INFLUX 4	60 m AGL	Tower	2017-2019	Indiana
INFLUX 14	76 m AGL	Tower	2017-2019	Indiana
LA-01	100 m AGL	Tower	2018	Louisiana
AL-01	100 m AGL	Tower	2018	Alabama
ACT	Boundary Layer	Aircraft	June-July 2019	Midwest, South
SCOAPE	10 m AGL	Boat	May 2019	Gulf

We utilize NASA GEOS model with low-order flux inversion (LOFI) module to simulate CO_2 over the region of interest (Weir et al., 2020; https://acp.copernicus.org/preprints/acp-2020-496/).

We optimize the model CO2 daily afternoon mixing ratios at selected towers (Figure 2) using the NEE tracers based on the region masks shown in the Figure 6: the Midwest (M) is the red mask, the South (S) is green and purple masks, and Texas (T) is orange and purple masks. The masks were generated based on the backward trajectories from the towers of interest ran with the Hysplit model for the MJJAS of 2019.

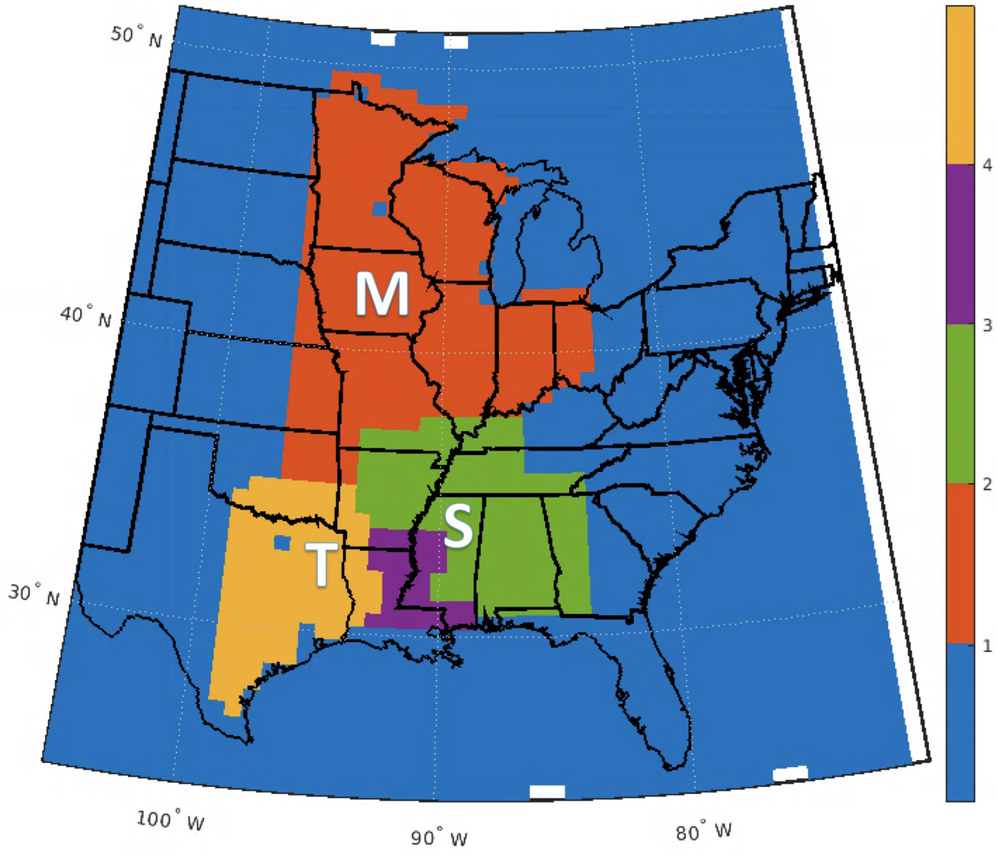
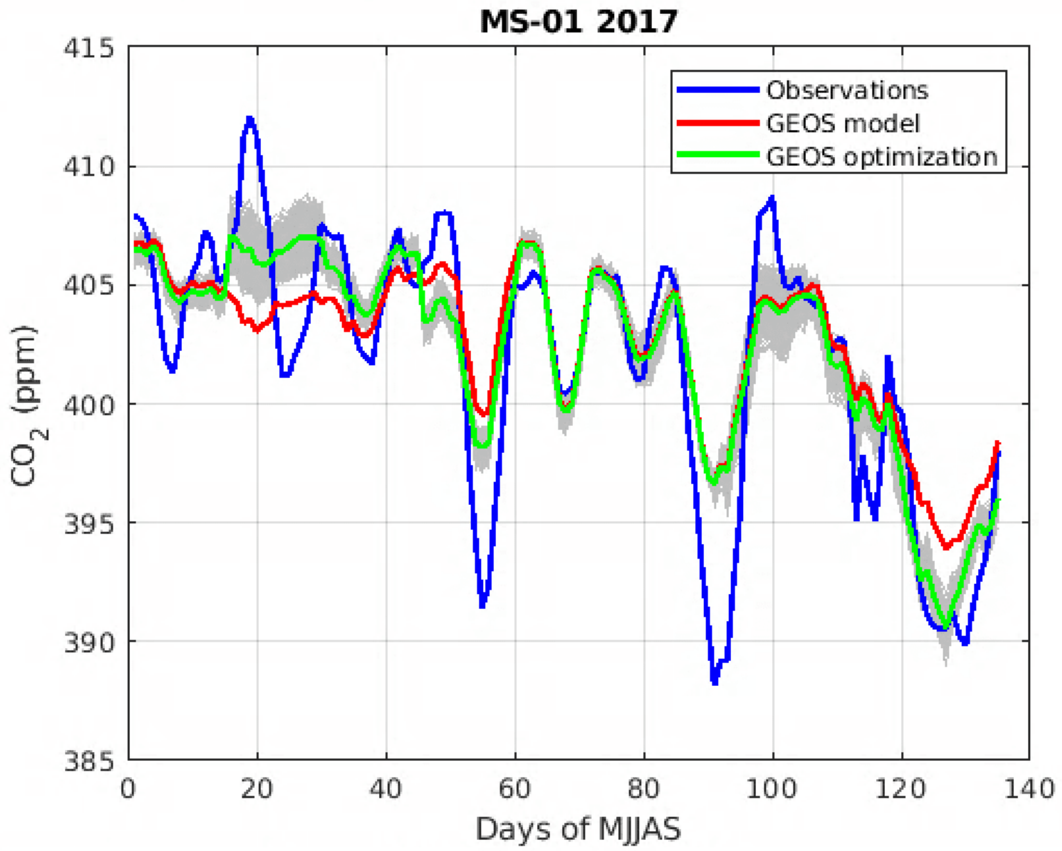


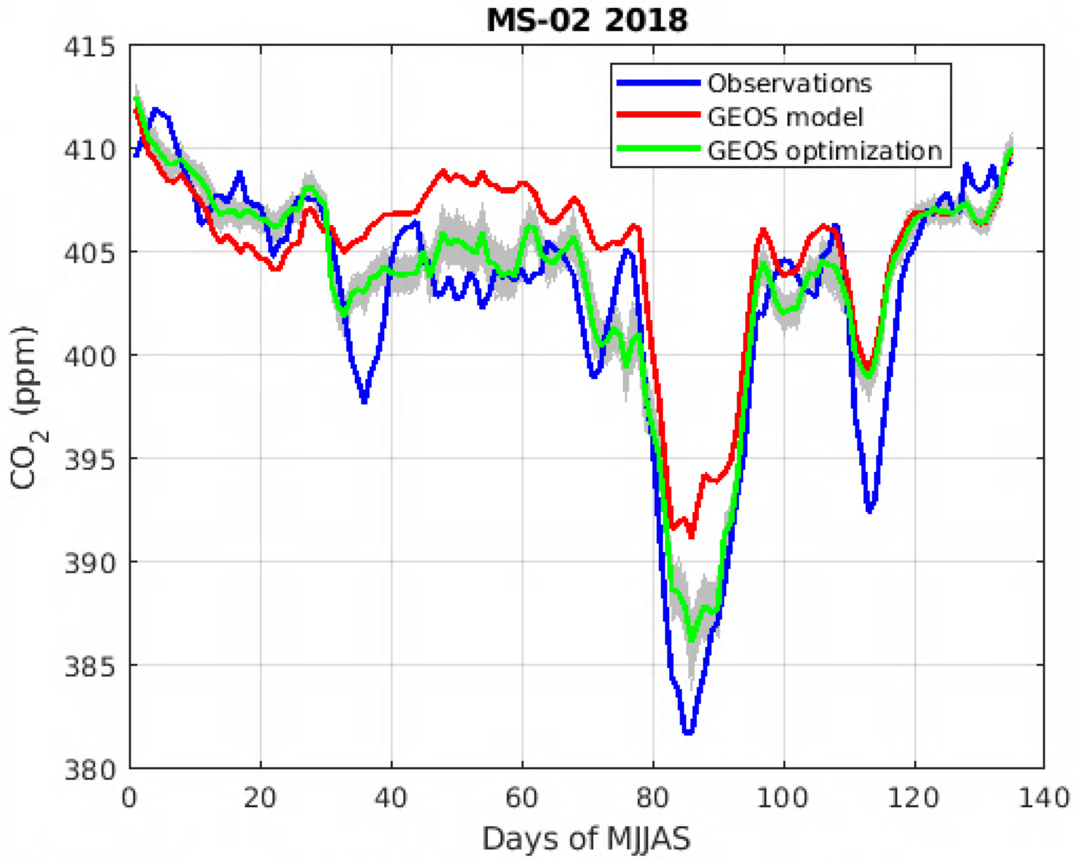
Figure 3. Masks used in the optimization.

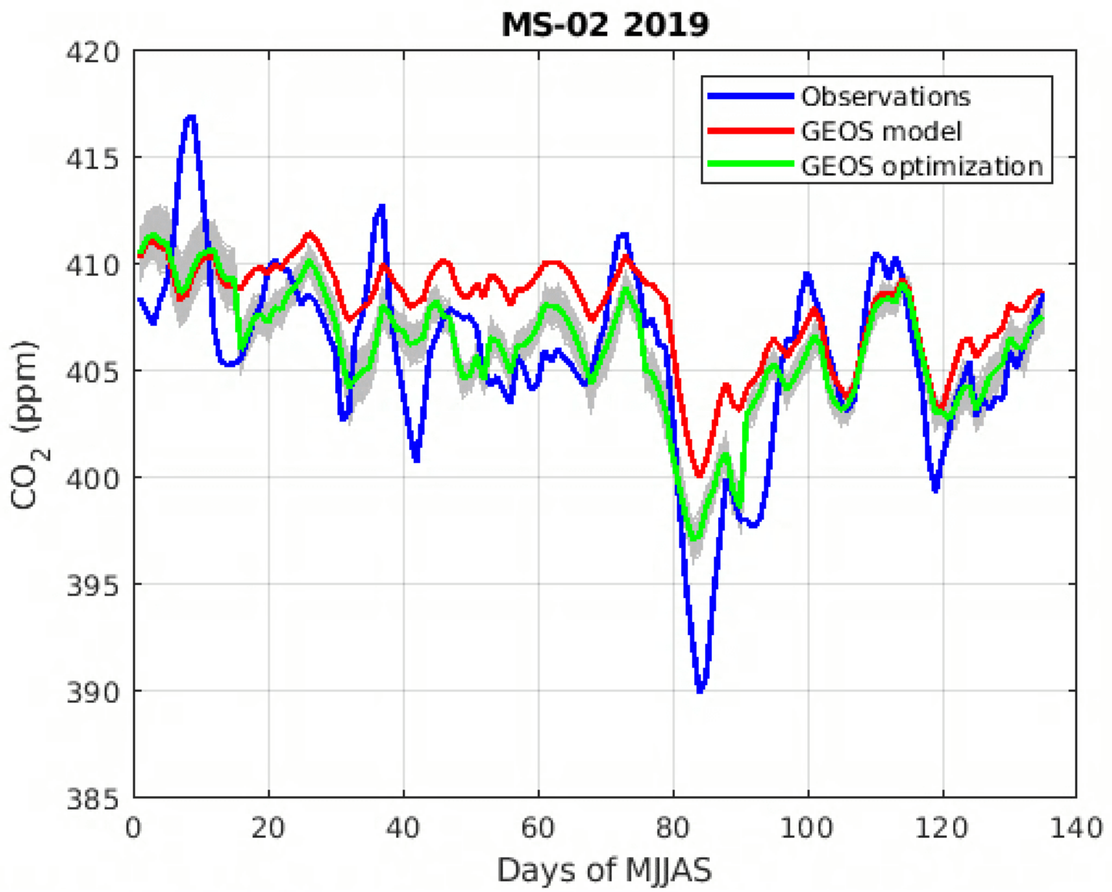
The optimization is performed by minimizing the following cost function:

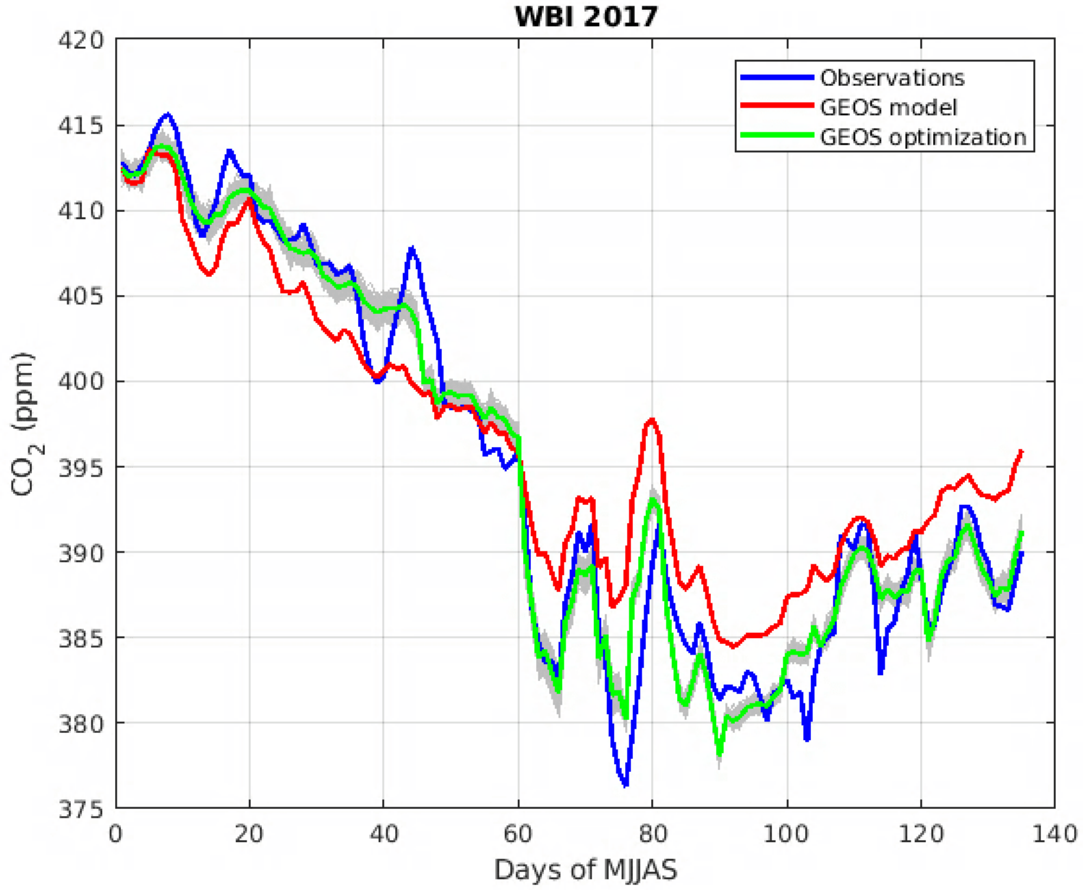
$$\begin{aligned} J(\alpha) = \tfrac{1}{2}\,&[(\hat{y} - \alpha CO2_{NEE}) - y]\ R^{-1} \\ &[(\hat{y} - \alpha CO2_{NEE}) - y]^{T} + \tfrac{1}{2} x B^{-1} x^{T}, \end{aligned}$$

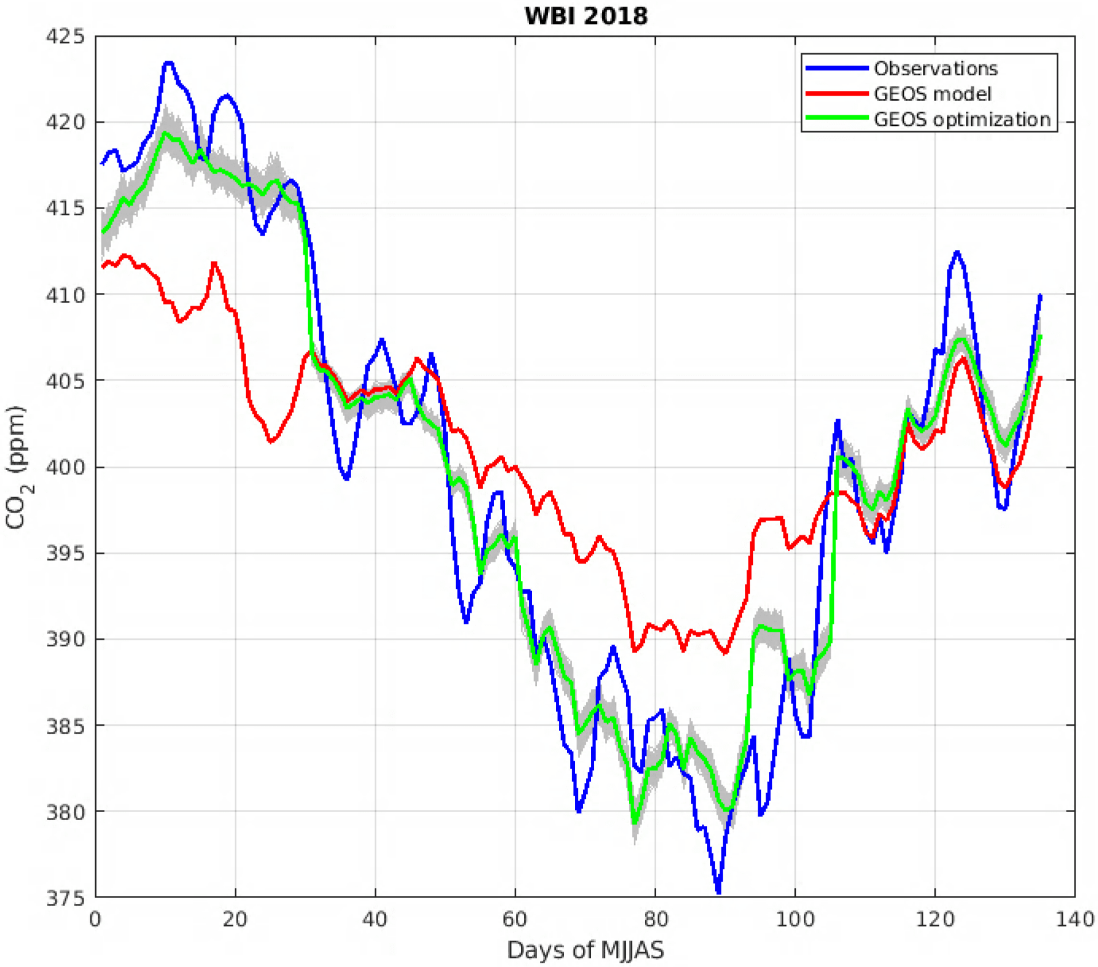
where α is a scaling factor by which fluxes need to be changed, ŷ is modeled CO2, y is observed CO2, x is the difference between α and prior scaling factor (an initial guess for the scaling factor), B is the scaling factor error covariance term, and R is the observation error covariance matrix.

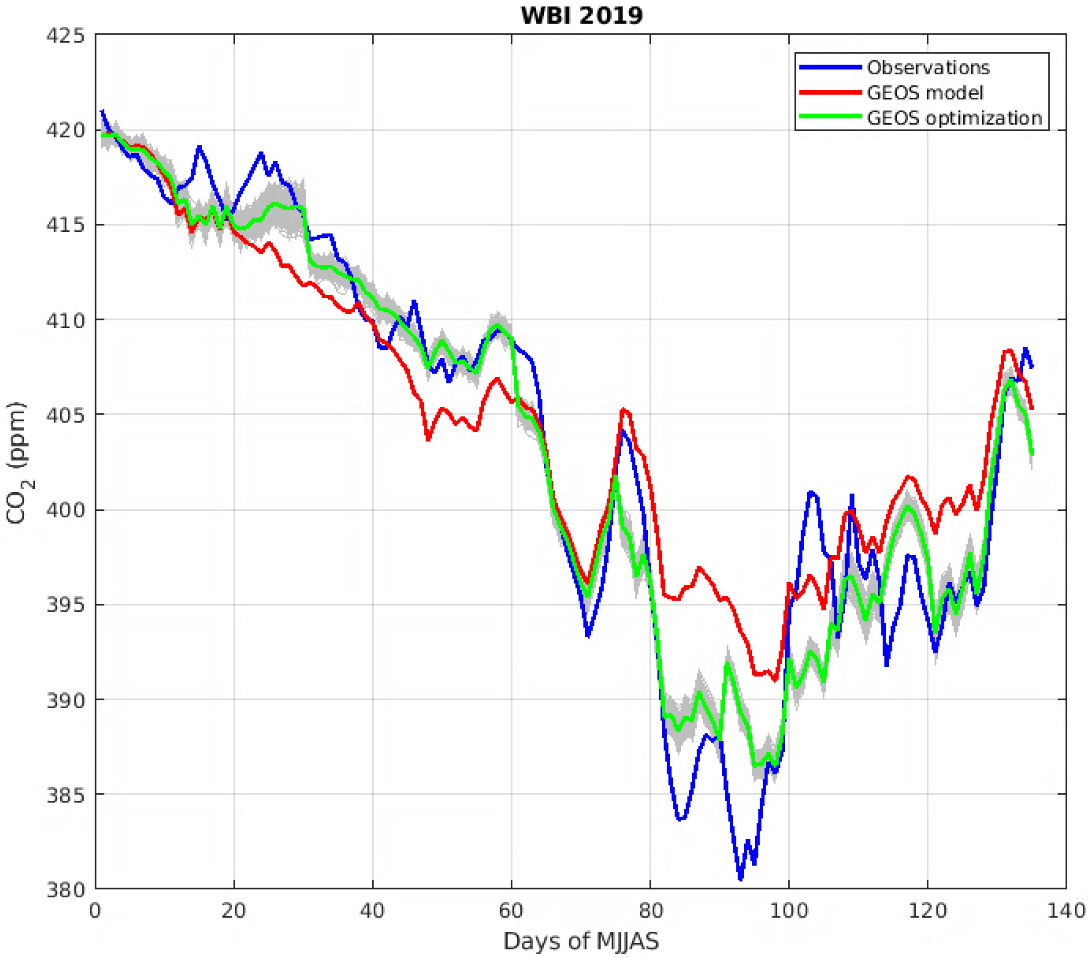

MS-01 2017
Observations
GEOS model
GEOS optimization
CO_2 (ppm)
415
410
405
400
395
390
385
0
20
40
60
80
100
120
140
Days of MJJAS

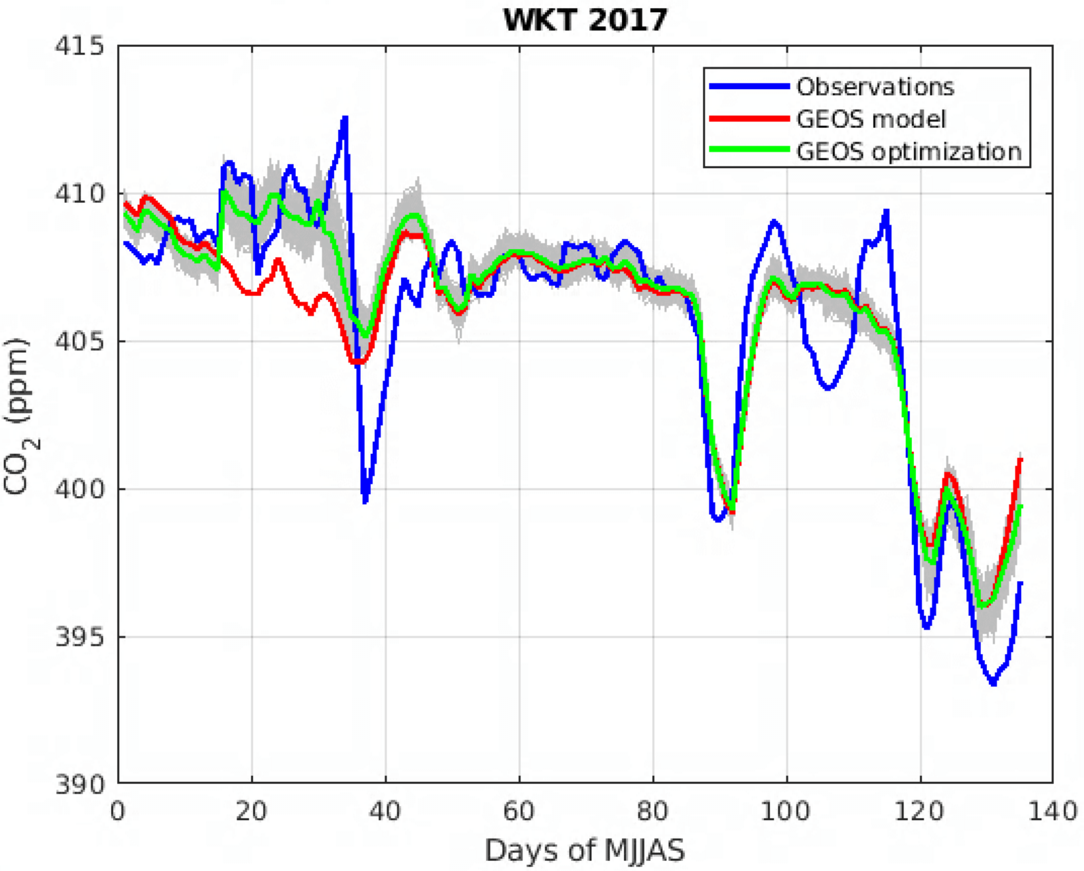

MS-02 2018
Observations
GEOS model
GEOS optimization
CO_2 (ppm)
415
410
405
400
395
390
385
380
0
20
40
60
80
100
120
140
Days of MJJAS

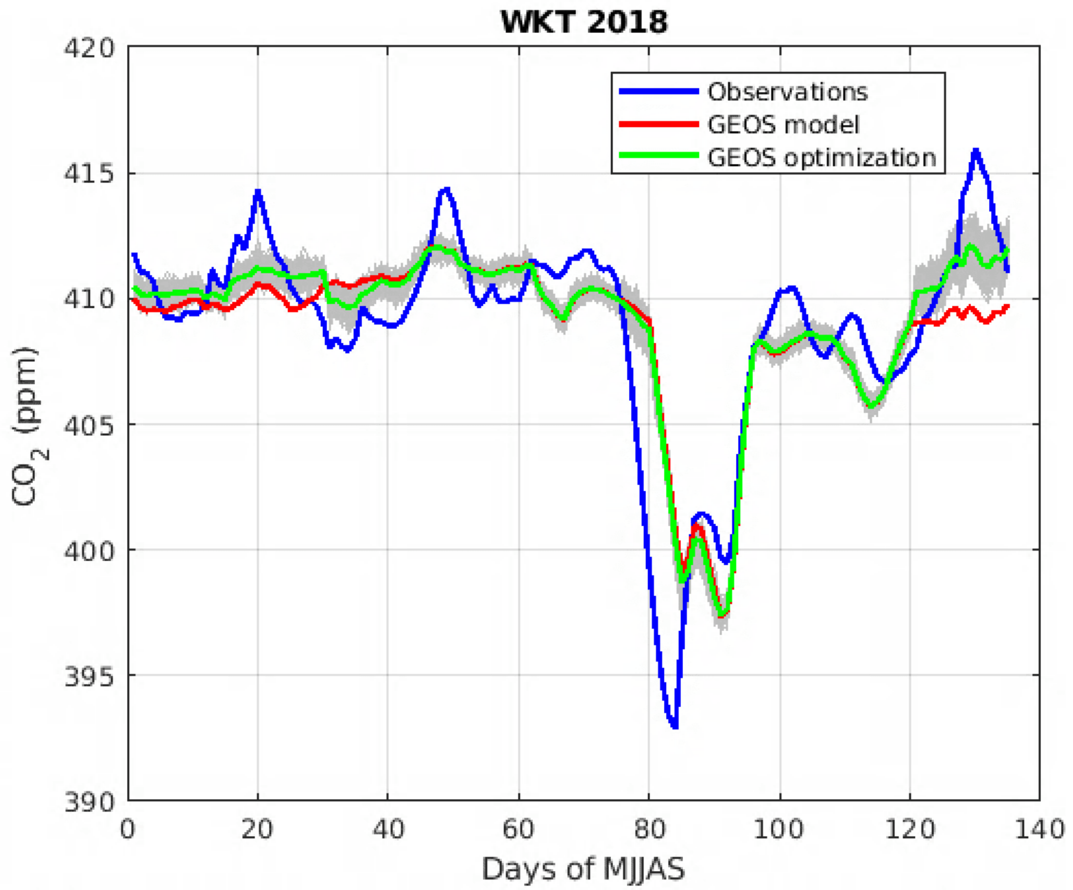

MS-02 2019
Observations
GEOS model
GEOS optimization
CO$_2$ (ppm)
420
415
410
405
400
395
390
385
0
20
40
60
80
100
120
140
Days of MJJAS


WBI 2017
Observations
GEOS model
GEOS optimization
CO$_2$ (ppm)
420
415
410
405
400
395
390
385
380
375
0
20
40
60
80
100
120
140
Days of MJJAS


WBI 2018
Observations
GEOS model
GEOS optimization
CO$_2$ (ppm)
425
420
415
410
405
400
395
390
385
380
375
0
20
40
60
80
100
120
140
Days of MJJAS


WBI 2019
CO$_2$ (ppm)
425
420
415
410
405
400
395
390
385
380
0
20
40
60
80
100
120
140
Days of MJJAS
Observations
GEOS model
GEOS optimization


WKT 2017
CO$_2$ (ppm)
415
410
405
400
395
390
0
20
40
60
80
100
120
140
Days of MJJAS
Observations
GEOS model
GEOS optimization


WKT 2018
Observations
GEOS model
GEOS optimization
CO$_2$ (ppm)
420
415
410
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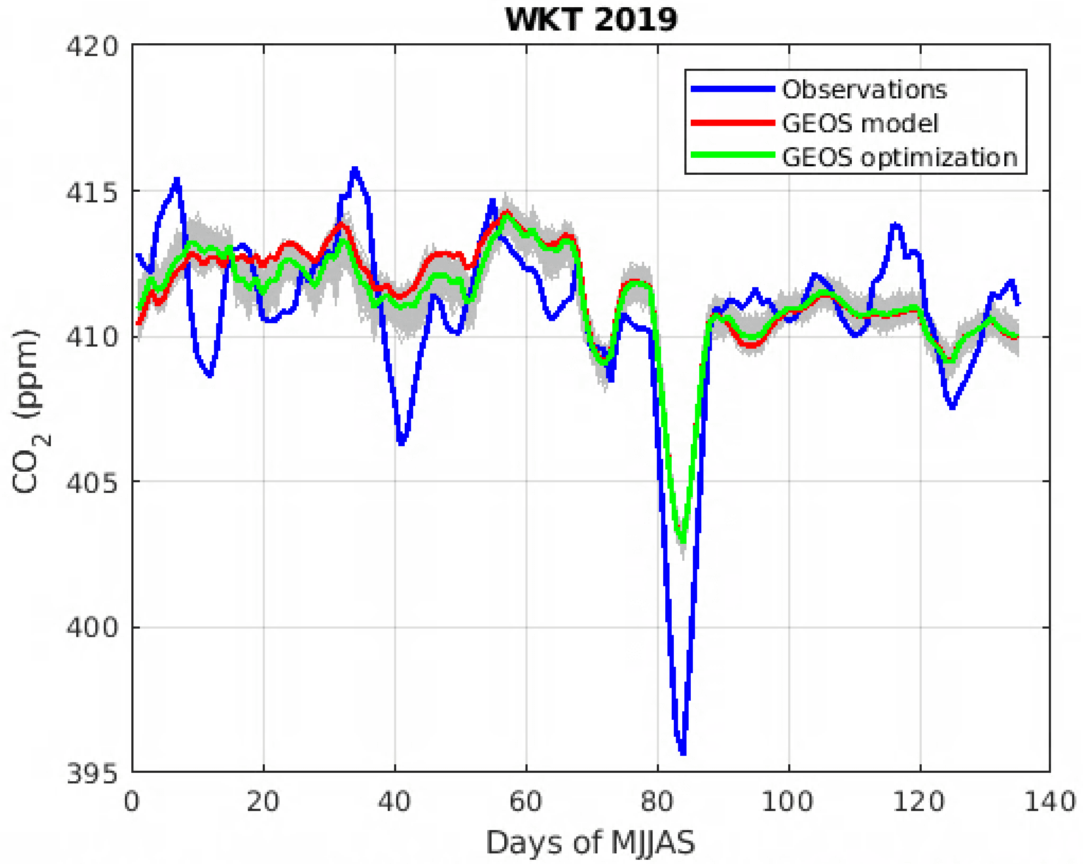
400
395
390
0
20
40
60
80
100
120
140
Days of MJJAS


WKT 2019
Observations
GEOS model
GEOS optimization
CO$_2$ (ppm)
420
415
410
405
400
395
0
20
40
60
80
100
120
140
Days of MJJAS

TAKEAWAYS

- The bias of GEOS NEE is heterogeneous in the Midwestern US and WBI tower is not completely representative of this region.
- The Southern region is generally well represented by the station MS-02 and indicates that GEOS uptake on average is too low there at least for the years 2018 and 2019.
- The adjusted and unadjusted total NEE in the M region indicates that the flood of 2019 did reduce the uptake of MJJAS growing period in comparison to the years 2017 and 2018.
- Our research supports the findings of Yin et al. (2020) that at the beginning of the growing season the uptake was significantly reduced, but later, beginning approximately in July, the uptake increased above average as the crops began to reach their maturity later than usual.
- In the S and T regions we found that vegetation (primarily non-crop) was probably enhanced due to the above-normal precipitation with upatke in 2019 being higher than in 2017 and 2018.

AUTHOR INFORMATION

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ABSTRACT

Climate extremes add considerable variability to the global year-to-year increase in atmospheric CO_2 through their influence on terrestrial ecosystems. These extremes are characterized by meteorological phenomena such as droughts, floods, heat waves, frosts, and windstorms. While the impact of droughts on terrestrial ecosystems has received considerable attention in the past, the response to extreme flooding events is poorly understood. To improve upon such understanding, we investigate how the spring/early summer Midwestern and Southern US flooding events of 2019 affected regional CO_2 crop and non-crop vegetation fluxes in comparison to years 2017 and 2018 when such floods were not observed. In our analyses, we simulate CO_2 with NASA's Global Earth Observing System (GEOS) model, where fluxes of CO_2 are typically estimated based on a suite of remote sensing observations including greenness, night lights, and fire radiative power. Then we adjust model CO_2 fluxes with available in situ CO_2 regional observations including three towers located in Iowa, Mississippi, and Florida and two campaigns, the airborne Atmospheric Carbon and Transport (ACT) - America 2019 and the shipboard Satellite Coastal and Oceanic Atmospheric Pollution Experiment (SCOAPE), to estimate the magnitude of 2019 Net Ecosystem Exchange (NEE) anomalies in the regions of interest. Additionally, we compare our model-observation estimated Gross Primary Production (GPP) values to FluxSat GPP derived from the MODerate-resolution Imaging Spectroradiometer (MODIS) instruments on the NASA Terra and Aqua satellites with the help of neural networks and FLUXNET 2015 eddy covariance tower sites. Preliminary results indicate that for crop vegetation consisting primarily of corn and soybeans, flooding contributed to about 20-30% reduction of NEE in May-July 2019 in comparison to 2018, which in turn led to corresponding rapid crop recovery in August-September 2019 with NEE enhancements of about 40% in comparison to 2018. These results are supported by independent reports of changes in agricultural activity. Some evidence indicates that NEE of non-crop vegetation was also affected by flooding and was reduced in May of 2019 by about 10-20% in comparison to 2018, but it quickly recovered in June.

REFERENCES

Yin, Y., Byrne, B., Liu, J., Wennberg, P., Davis, K. J., Magney, T., et al. (2020). Cropland carbon uptake delayed and reduced by 2019 Midwest floods. AGU Advances, 1, e2019AV000140. https://doi.org/10.1029/2019AV000140

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