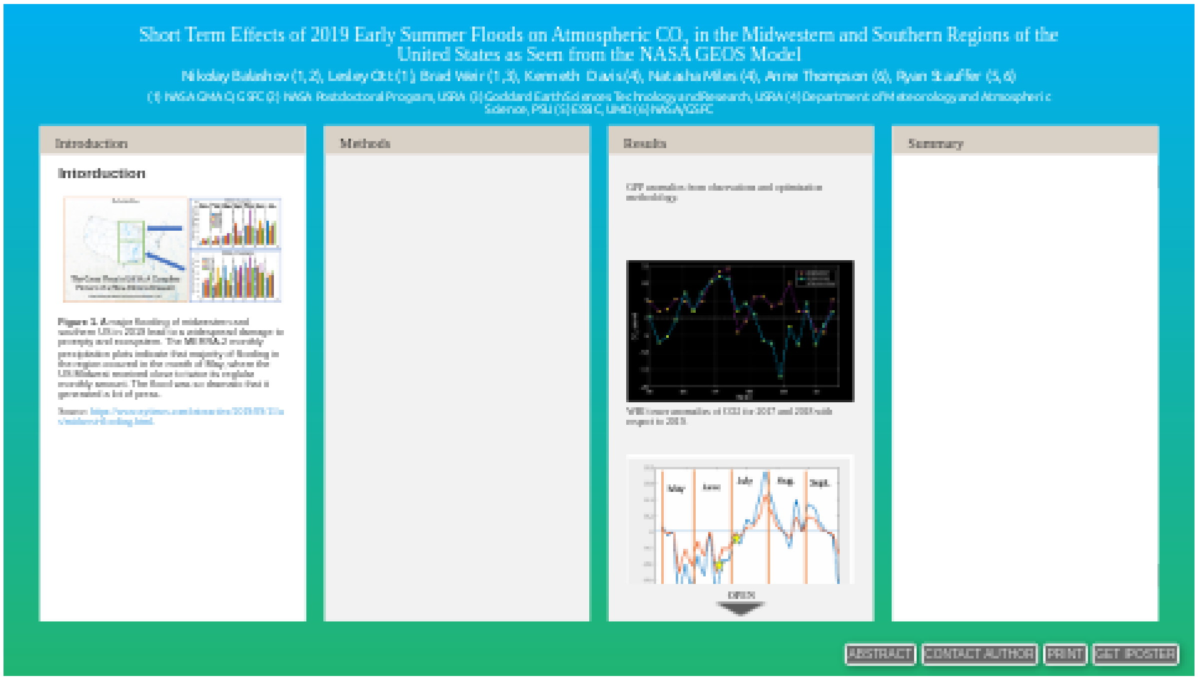
Short Term Effects of 2019 Early Summer Floods on Atmospheric CO_2 in the Midwestern and Southern Regions of the United States as Seen from the NASA GEOS Model



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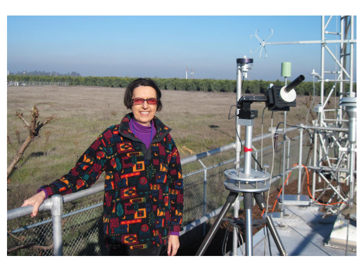


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INTRODUCTION

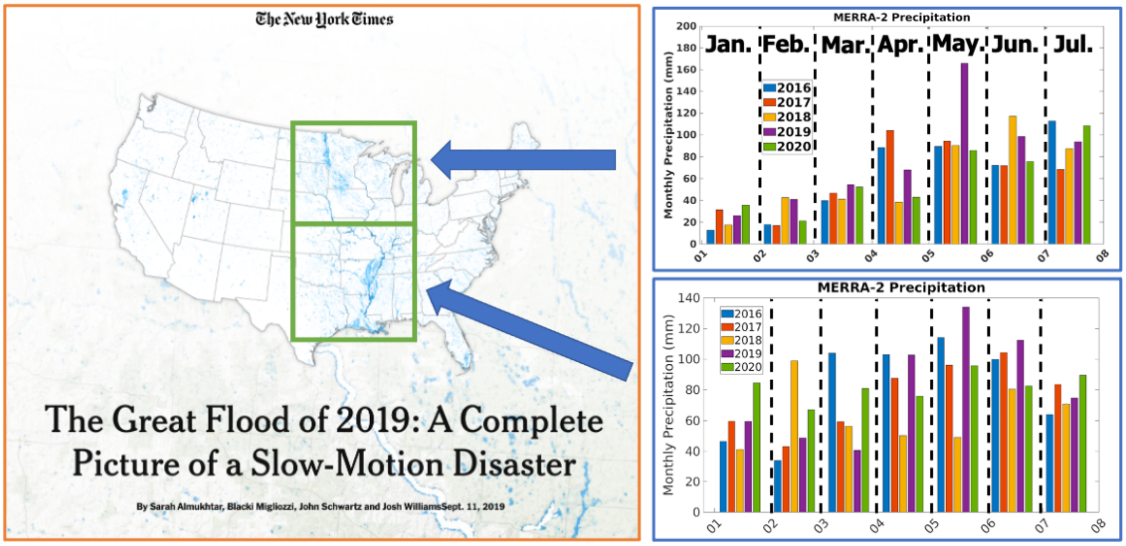

Figure 1. A major flooding of midwestern and southern US in 2019 lead to a widespread damage to property and local ecosystem. The MERRA-2 monthly precipitation plots indicate that majority of flooding in the region occurred in the month of May, where the US Midwest received close to twice its regular 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 (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.

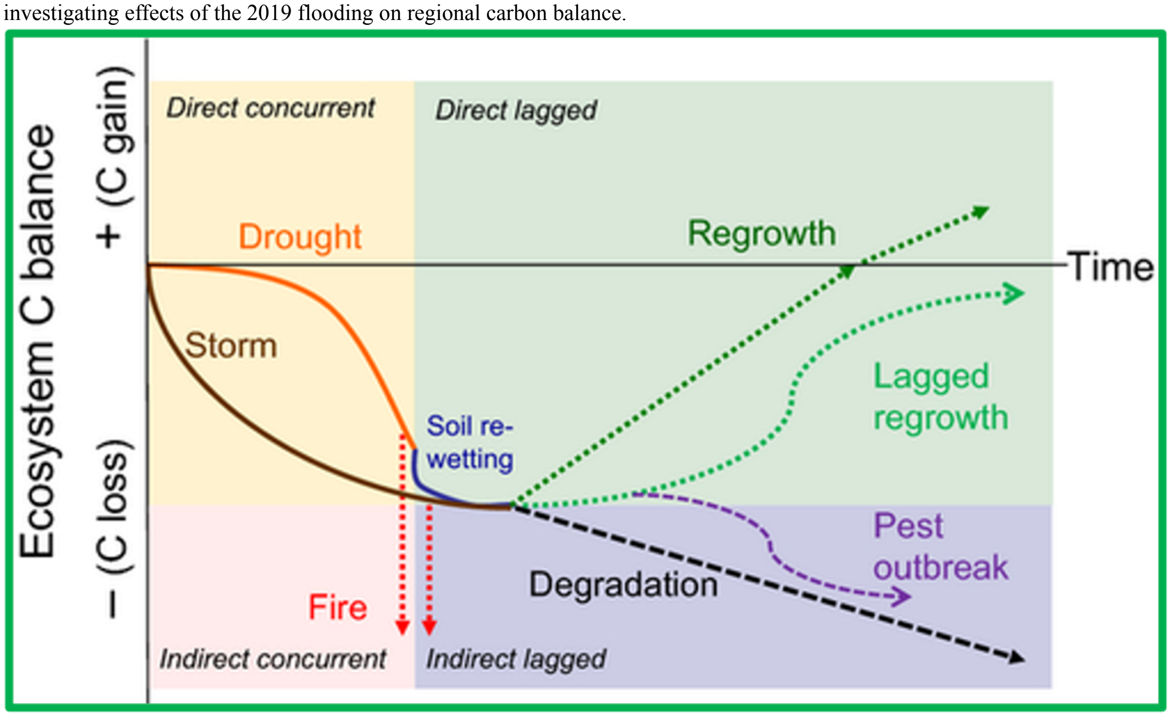

Figure 2. Climate extremes affect ecosystem carbon emissions directly and indirectly. Those effects may be concurent or lagged. In the case of flooding we could reasonably expect direct concurent influence on carbon; however, the case studies to support this are lacking and require further investigation. Source: Frank et. al. 2014 (https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.12916).

Global carbon budget 2018 report indicates that land sink of atmospheric CO_2 exhibits significant variability, in part due to extreme climate events mentioned above.

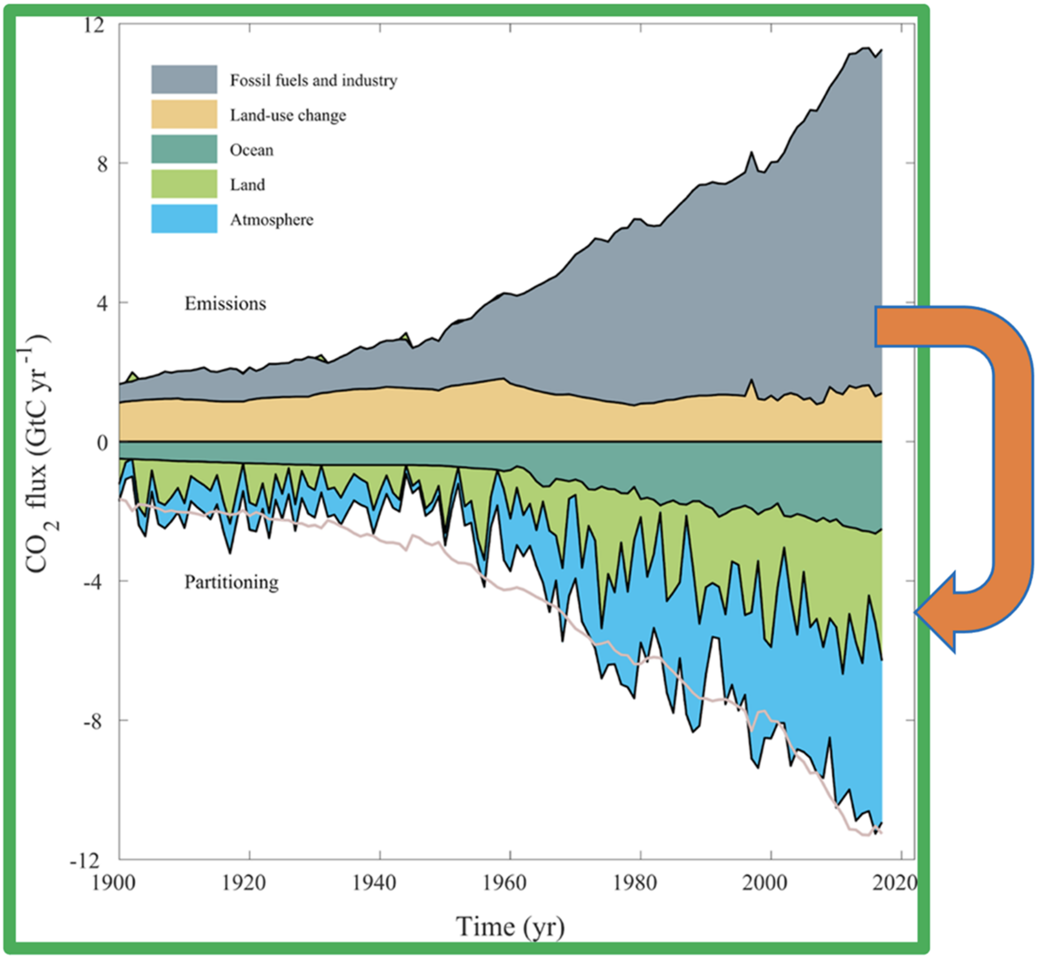

Figure 3. Large orange arrow on the right side indicates transfer of carbon from fossil fuels and land use change into 3 distinct pools: 1) ocean, 2) land, and 3) atmosphere. Rapid increase of CO_2 in the atmosphe "pool" over the past 100 years is of great concern as this process significantly affects Earth's radiation balance.

In this work we are primarily concerned with land component of global carbon cycle and how it might be affected by flooding. The task will bring us closer to a better understanding of land flux of CO_2, which is notorisouly difficult to predict (source).

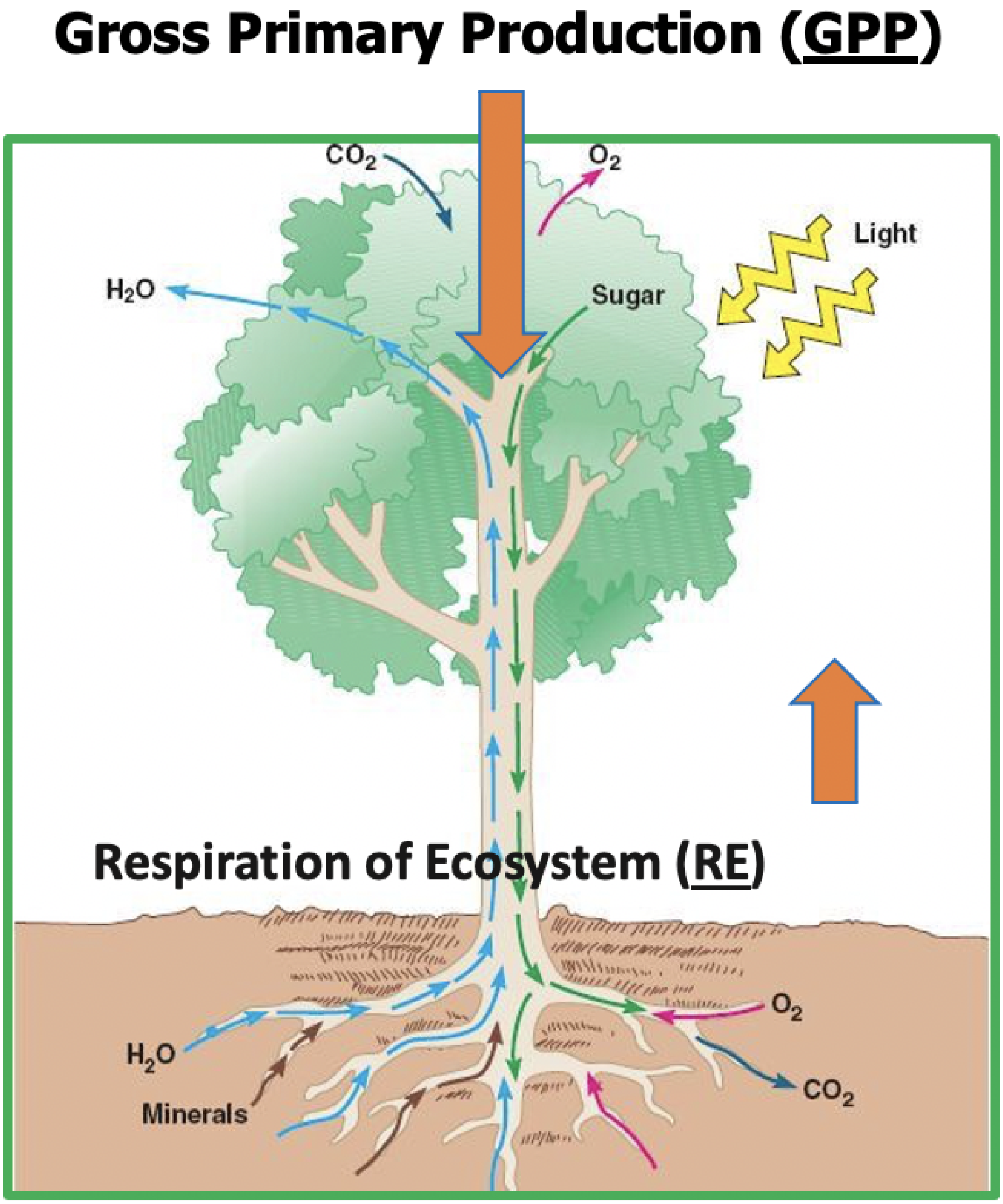

Figure 4. Land sink is mainly determined by a balance between gross primary production (GPP) and ecosystem respiration (RE). GPP is the carbon assimilated by plants in the presence of light and it is an atmopsheric CO_2 sink term. RE is a source of CO_2 from plants and tends to vary much less between day and night in conparison to GPP. The difference between RE and GPP is known as net ecosystem exchange (NEE).

Given the information above our research questions are:

Did the 2019 flooding event limit regional uptake of CO_2 due to a vegetation damage thereby contributing to global increase of atmospheric CO_2?

Are our models reliable in this type of situations?

METHODS

In order to study the affects of 2019 flood on regional carbon cycle we implement insitu observations, modeling, and satellite data.

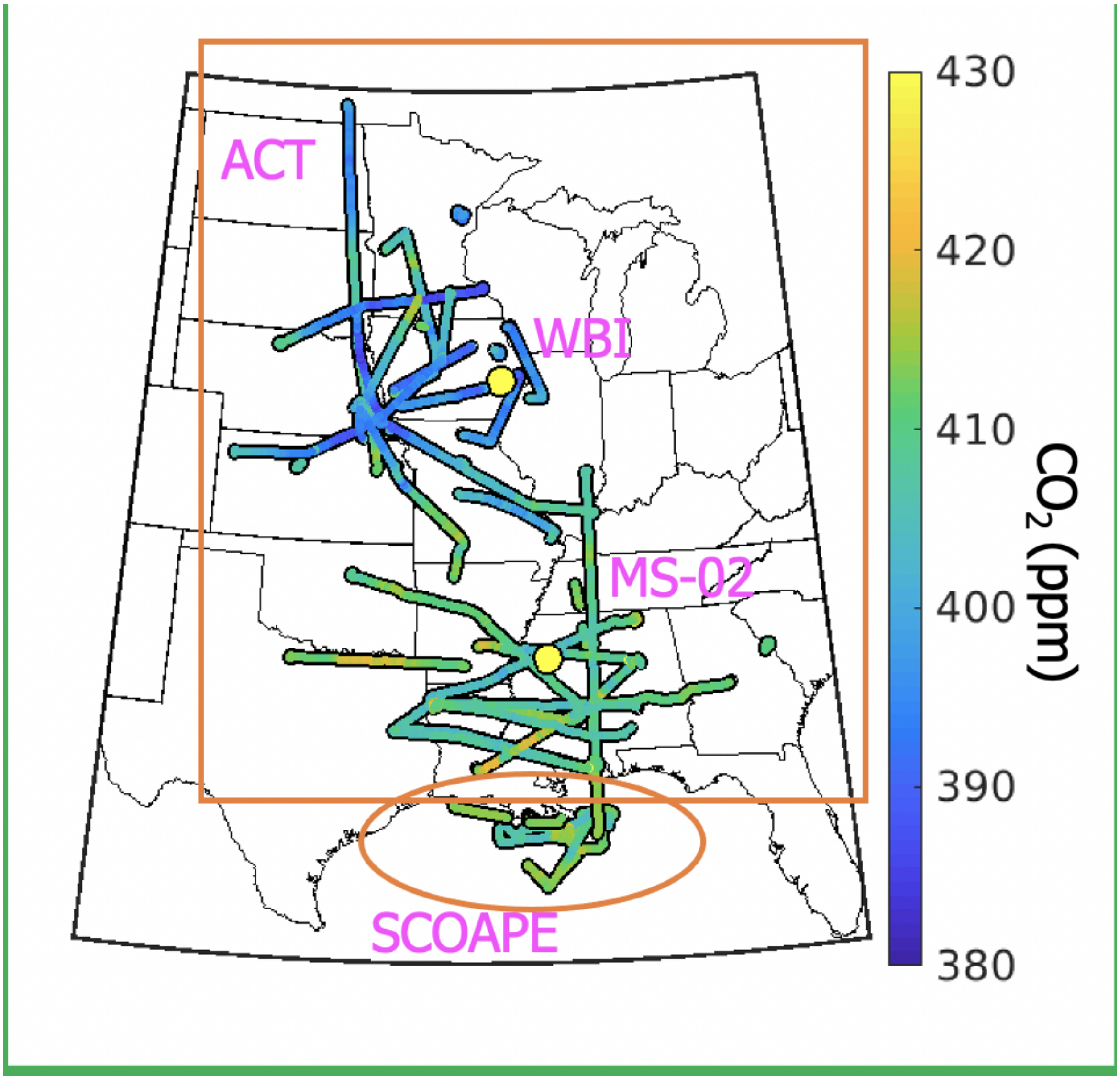

Figure 5. Our observations consist of two insitu CO_2 towers: West Branch, Iowa (WBI; 379 m AGL) and northern Mississippi (MS-02; 100 m AGL), Atmospheric Carbon Transport – America (ACT-America) 2019 Midwestern and Southern flights (June-July 2019), and Satellite Coastal and Oceanic Atmospheric Pollution Experiment (SCOAPE; May 2019) boat campaign.

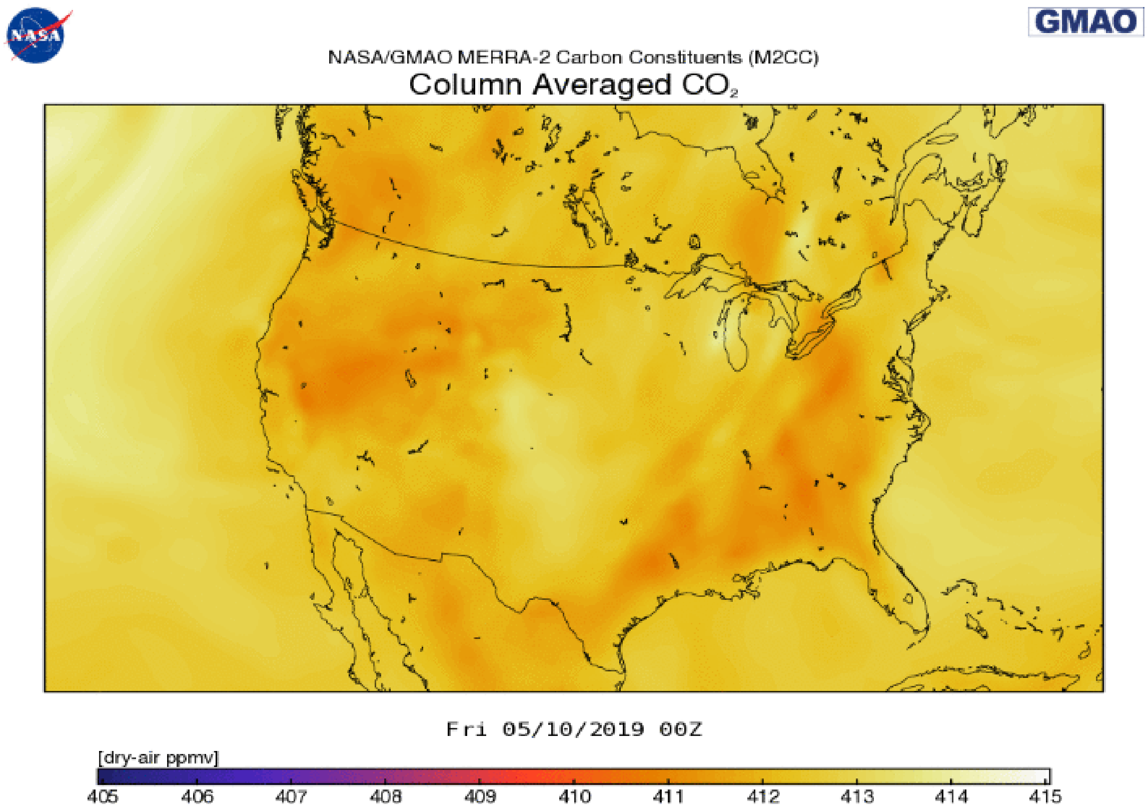

Figure 6. We utilize NASA GEOS model with low-order flux inversion (LOFI) module to simulate CO_2 over the region of interest (Weir et al., 2020 (https://acp.copernicus.org/preprints/acp-2020-496/)). The CO_2 forecasts are available at https://fluid.nccs.nasa.gov/carbon (https://fluid.nccs.nasa.gov/carbon).

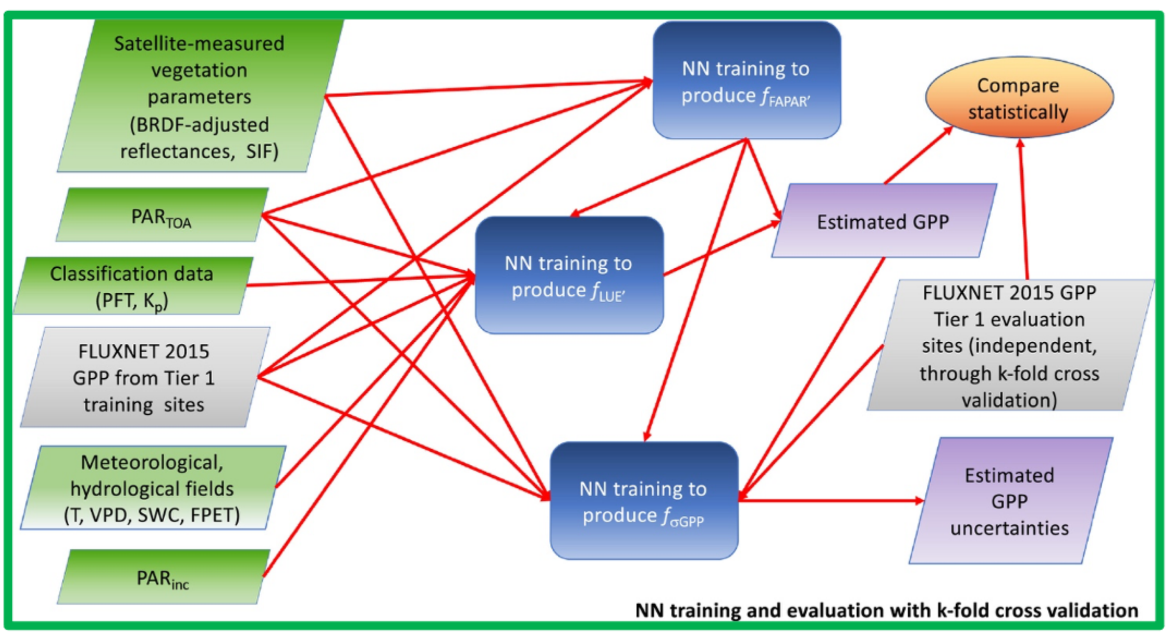

Figure 7. Additionally we use FluxSat GPP product, which utilizes parameters derived from MODIS combined with FLUXNET data and machine learning to estimate GPP (Joiner at al., 2020 (https://www.sciencedirect.com/science/article/pii/S0168192320301945#bib0094)).

Lastly we perform optimization of our 2019 GEOS model by adjusting the model using GPP tracer representing Midwestern crop areas to WBI and ACT-America airborne observations. For now the optimization is only performed for the Midwestern portion of the flooded area.

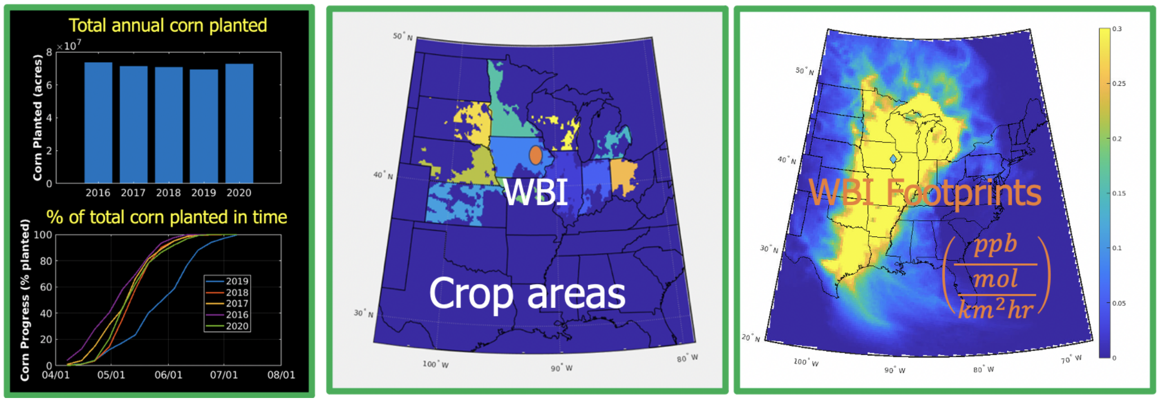

Figure 8. Crop areas that significantly affect WBI are used to derive GPP tracer from the model. The tracer then is used to oprimize the model. Crop data from (USDA) indicates that it was significantly affected by the flooding and therefore is a primary source of error for the initial model run.

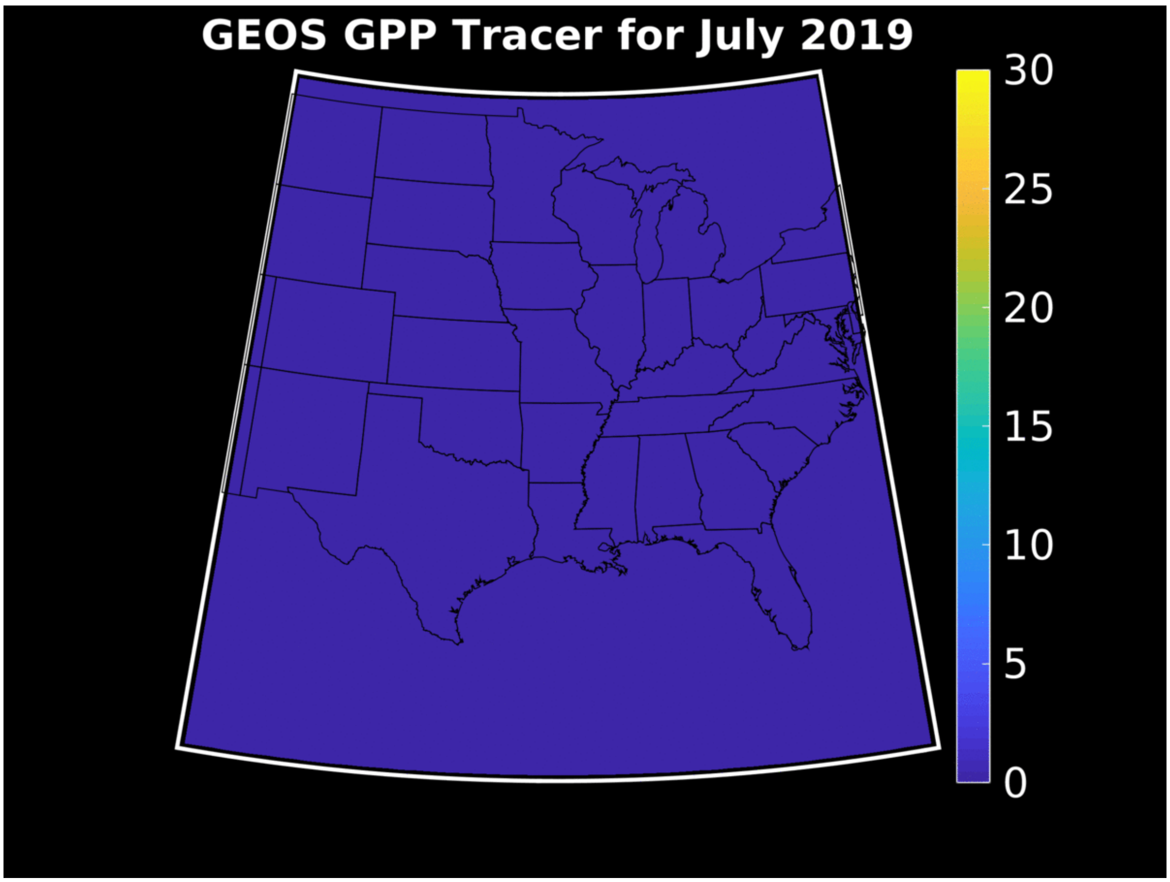

Figure 9. Animation of the GPP tracer originating from the crop mask shown in the Figure 8. The units of the colorscale values are CO_2 in ppm.

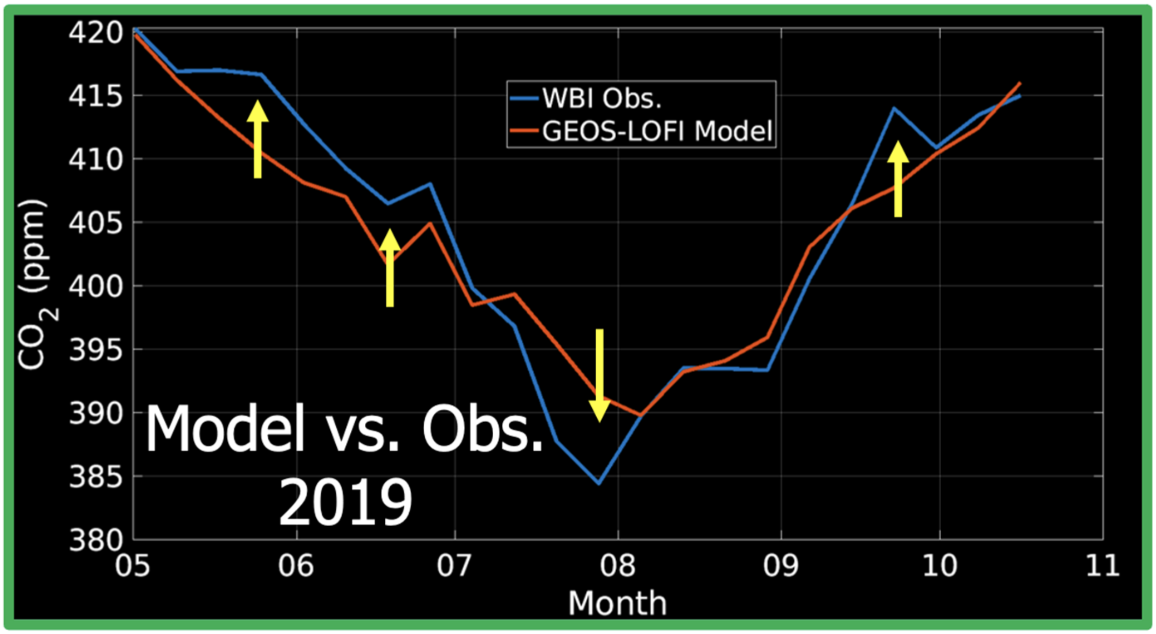

Figure 10. Schematic of the model-to-observation optimization step at WBI tower. Similar principle is used for the ACT-America 2019 flights over the Midwest.

RESULTS

As described in the methods section, we perform an investigation of how the 2019 flooding affected regional CO_2 balance using the data at WBI tower and Midwestern 2019 ACT-America flights.

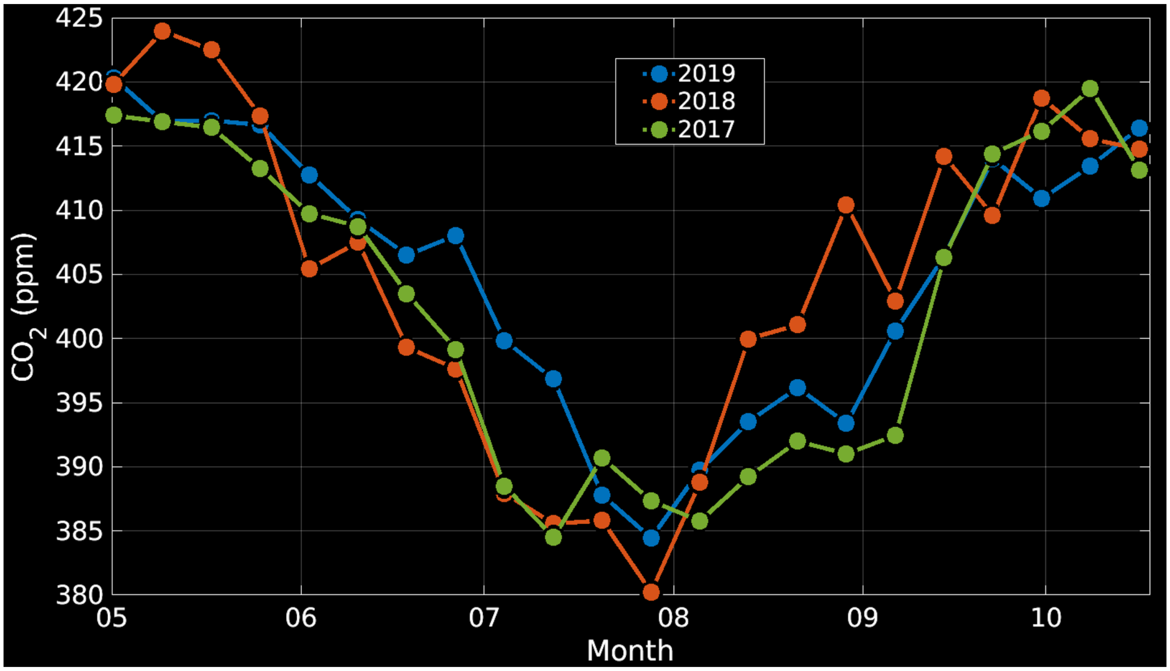

Figure 11. Trend-adjusted May-Ocotber weekly CO_2 at WBI tower for 2017-2019.

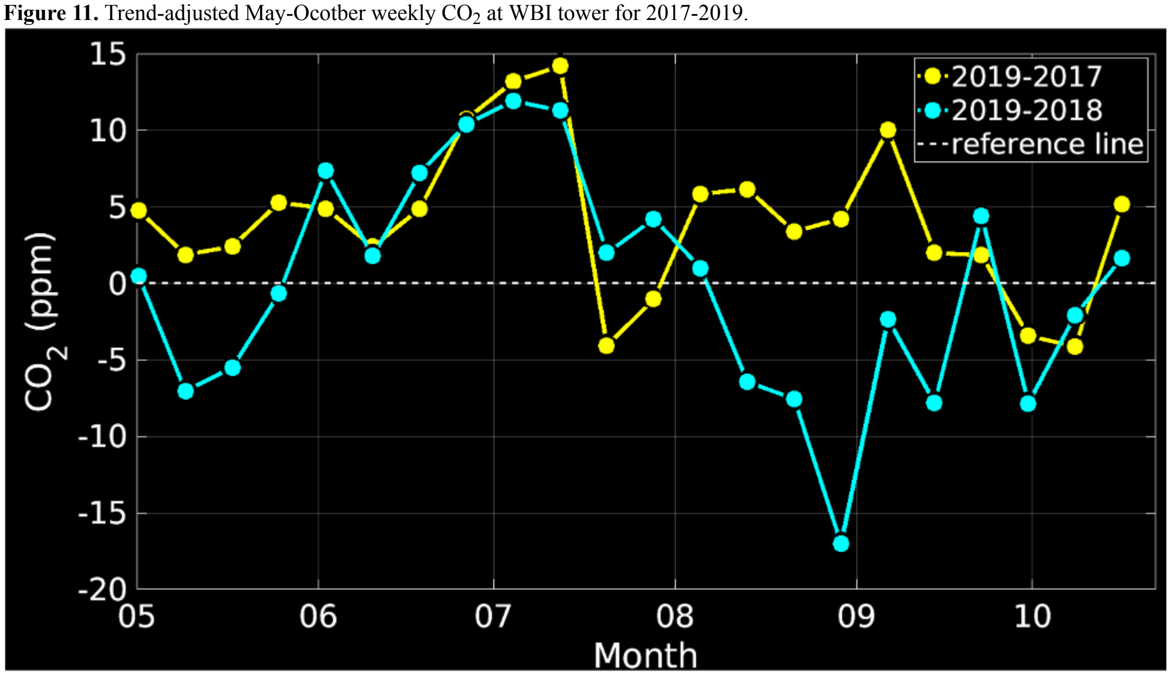

Figure 12. Differences between the CO_2 cycles at WBI shown in the Figure 11. Note that the post flooding period indicates surplus of atmospheric CO_2 in 2019 from mid-June until about mid-July.

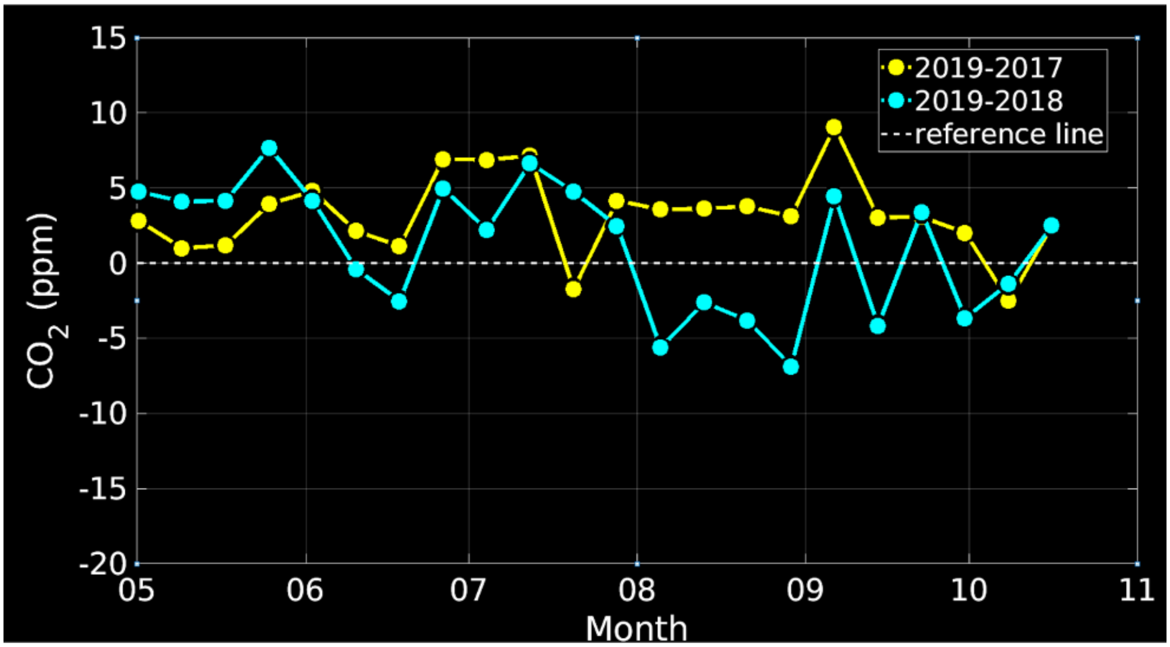

Figure 13. This figure is the same as Figure 12 only using NASA GEOS model simulations at WBI. Overall it has similar messages as Figure 12, but its magnitude and timing are noticebly off.

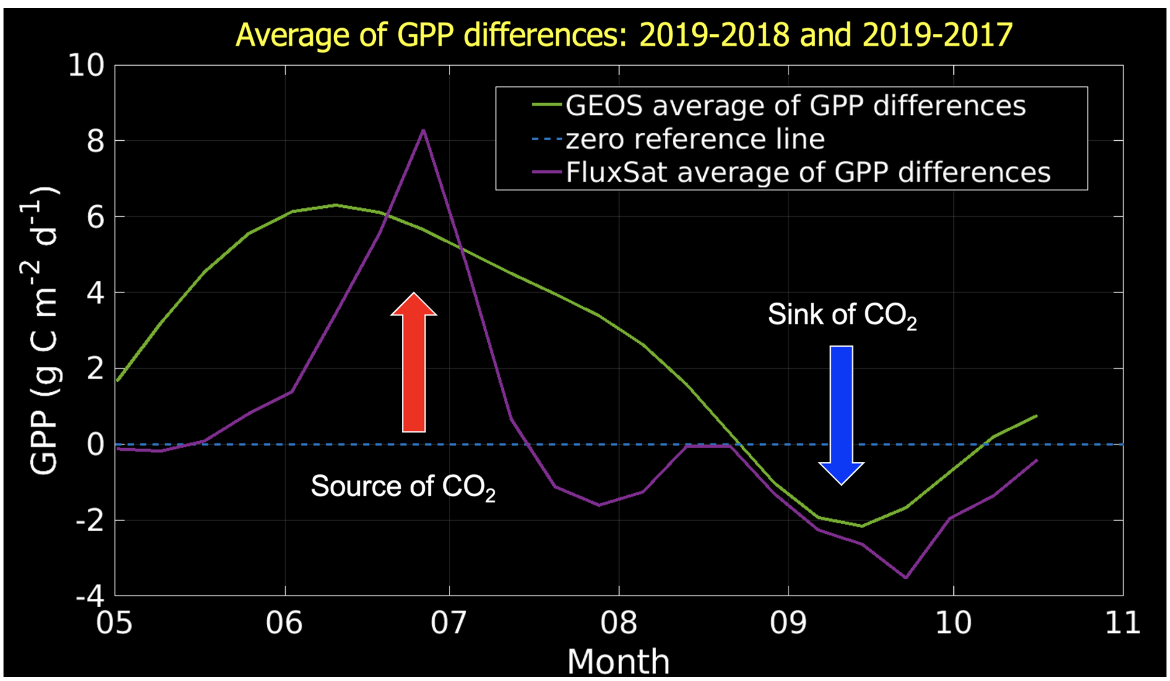

Figure 14. GEOS and FluxSat GPP differences between 2019 and 2018 as well as 2017.

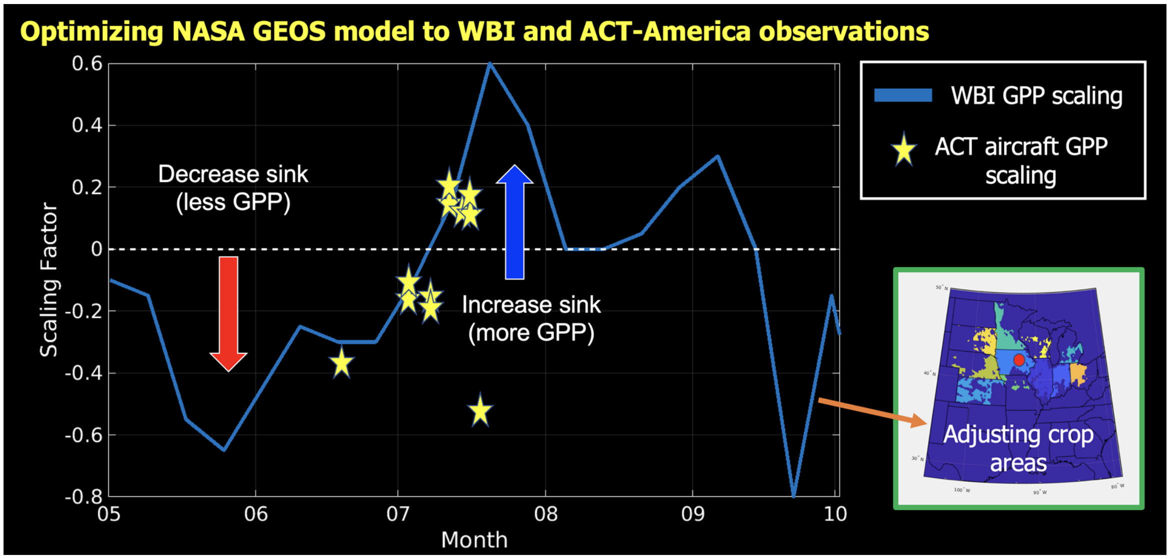

Figure 15. Optimization solutions for GEOS model crop GPP tracer (crop areas are shown on the map) for WBI tower and ACT-America flights indicated as percentage (or scaling factor) of the prior GPP profile.

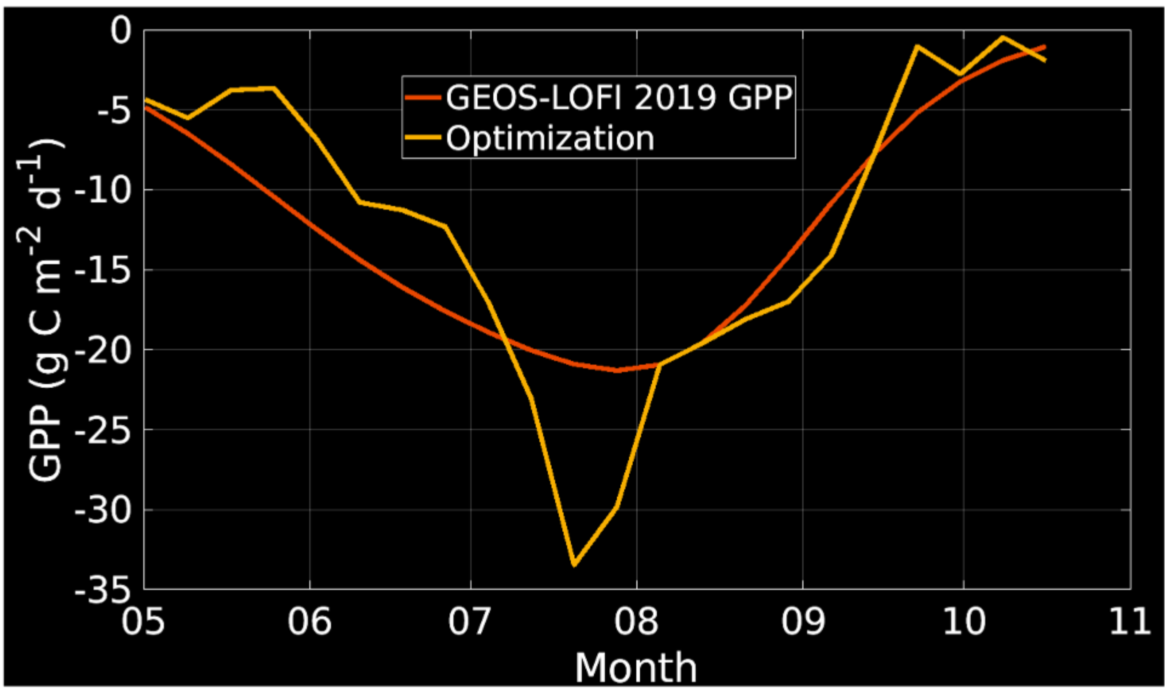

Figure 16. Adjusted prior GPP profile based on the solutions shown in Figure 15 at WBI tower.

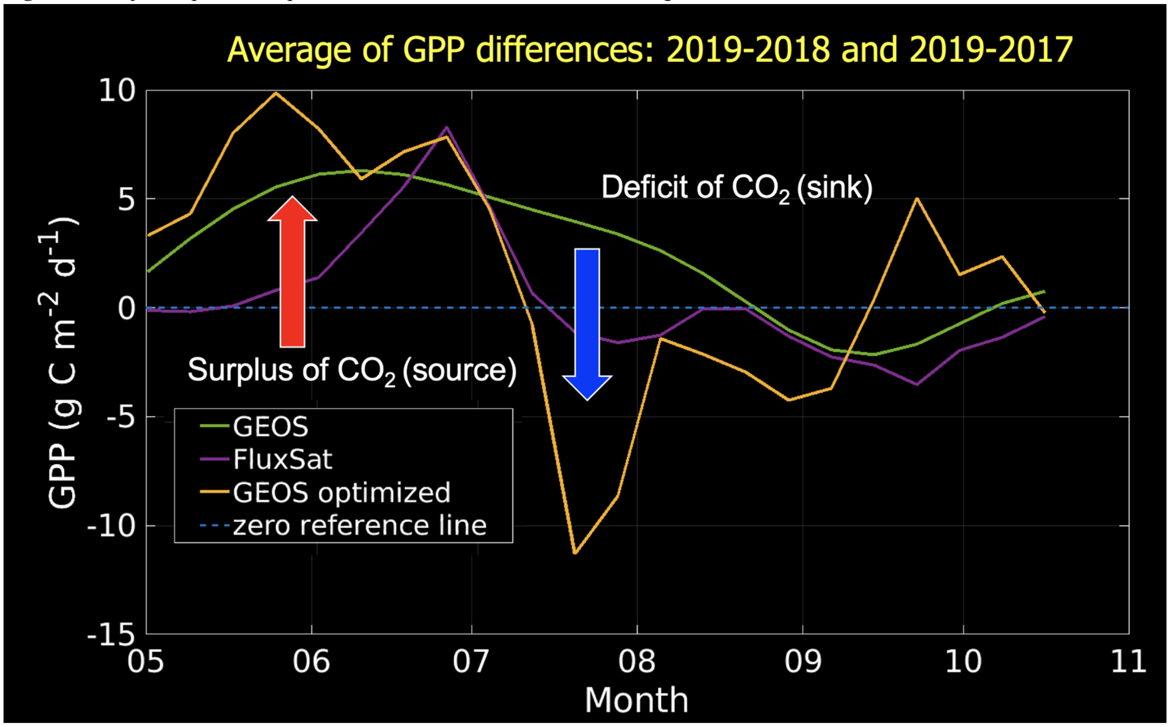

Figure 17. Original GEOS, FluxSat, and optimized GEOS GPP differences between 2019 and 2018 as well as 2017. Note the apparent recovery of crops in July in both FluxSat and optimized GEOS. The original model run was not able to capture the recovery and inidcated surplus of atmospheric CO_2 at WBI tower for the given time period.

SUMMARY

A combination of observations and models (many of which are provided by NASA) allowed us track carbon variability in the aftermath of the 2019 flooding event.

The flood decreased early summer CO_2 sink in the US Midwest; however, our results indicate that swift recovery occurred throughout July.

Our results from the West Branch, Iowa tower indicate that plants affected by flooding were mainly crops and data from the gulf region indicate that other types of plants continued to absorb CO_2 at expected rates.

These case studies help us understand how a wider variety of extreme events, which are becoming more frequent in a warmer climate, may impact the carbon cycle and the fraction of CO_2 emissions that remains in the atmosphere.

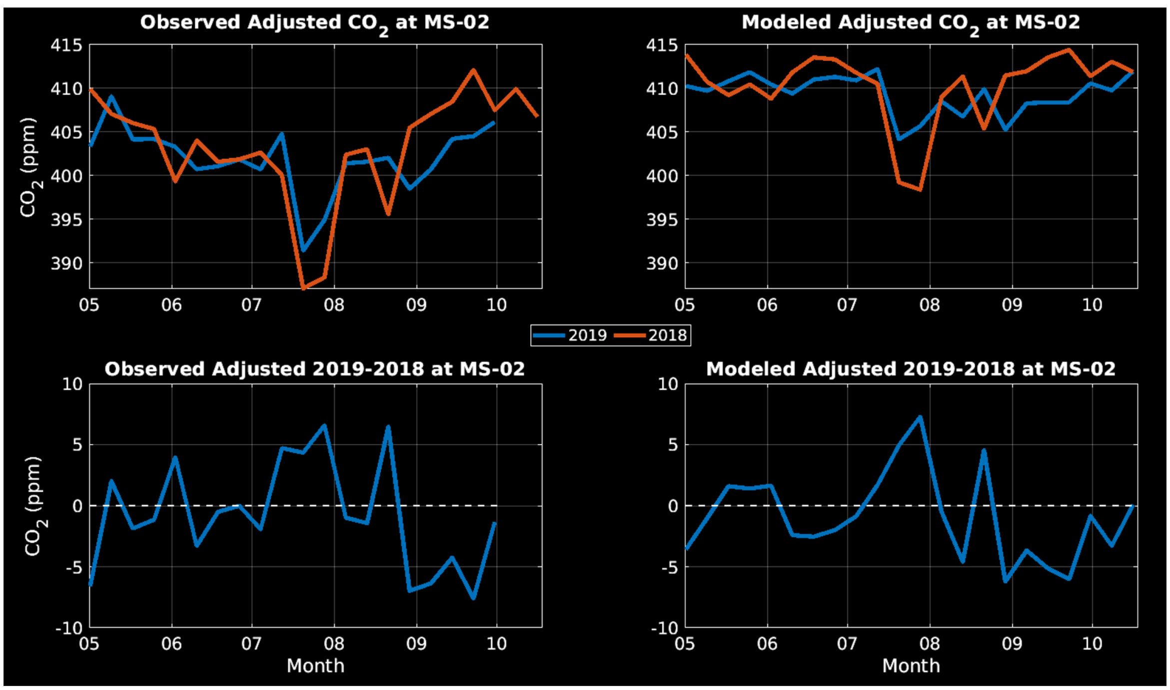

Figure 18. Preliminary results from the MS-02 tower in Mississippi indicates lesser influence of 2019 flood on May-June CO_2 in both observations and model. However, there seems to be slightly decreased uptake in July, perhaps continued rains in June in the South did have some effect on non-crop vegetation.

AUTHOR INFORMATION

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ABSTRACT

Studies show that 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 atmospheric CO_2 mole fractions. 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. As a starting point for this investigation of 2019, GEOS simulations make use of flux distributions that use spatial climatology derived from previous years. This type of formulation does not include the year-specific response to flooding, thus allowing us to use available in situ CO_2 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 Net Biome Exchange (NBE) anomalies in the regions of interest by assuming that mismatches between the model and observations can be at least partly attributed to the flooding of 2019. Preliminary results indicate that in the Midwest (mainly consists of crops such as corn and soybeans), flooding contributed to about 20% reduction of NBE in May-June 2019 and to about 10% enhancement of NBE in July 2019, which is consistent with independent reports of changes in agricultural activity. In the south (mainly forests), we hypothesize that the flooding early in the growing season contributed to NBE enhancement in May. These results demonstrate the importance of better understanding the impact of flooding events on terrestrial ecosystems.