The Effects of Hurricanes on the Carbon Cycle

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Abstract

Hurricanes cause severe impacts on the ecosystem, which substantially affects the carbon cycle at the local or regional scale. During the hurricanes, the loss of many vegetation/trees in the forest and agricultural lands causes more carbon to be released into the atmosphere. Studying the effects of hurricanes on the terrestrial carbon cycle, which includes gross primary product (GPP), net ecosystem exchange (NEE), heterotrophic respiration (Rh), and their interactions with land-use change, flood, and others are critical to understand the effect on the terrestrial ecosystem. The main objective of this research was to evaluate the impact of three hurricanes (Harvey, Irma, and Maria in 2017) on the carbon cycle and study the interactions among the flood events, land uses, and terrestrial carbon cycling in the state of Texas, Florida, Puerto Rico using satellite measurements. This study analyzed the GPP, NEE, and Rh distributions in the coastal climate zones in Texas, Florida, and Puerto Rico during hurricane season using Soil Moisture Active Passive (SMAP) carbon products. SMAP Carbon products (Res=9 km) were evaluated using CO_2 flux data measured at EC flux site on the Prairie View A&M University Research Farm, Texas. Results showed Florida (Irma) had higher carbon emissions and lower GPP during the hurricane compared to Texas (Harvey), and Puerto Rico (Maria). For example, hurricanes Harvey (08/26/2017), Irma (09/10/2017), and Maria (09/20/2017) caused 2.6, 4.1, and 3.03 gC/m^2, of carbon emissions when the recorded daily precipitations were 162, 135, and 241 mm, respectively. However, mostly carbon uptakes or low (<1 gC/m^2) carbon emissions were observed on the same day in 2016 and 2018. The analysis showed that the amount of precipitation is not the only driving factor causing increased carbon emission; the characteristics of the drainage area also affect the carbon cycle and emission. Overall, the results showed that hurricanes increase carbon emissions. This study helps to understand the impact of hurricanes on the carbon cycle through analyses of spatial and temporal variations of carbon emission and uptake during the hurricane season.

Objectives

- Evaluate the impact of three hurricanes (Harvey, Irma, and Maria in 2017) on the carbon cycle,
- Study the interactions between the flood events/storm surge, and terrestrial carbon cycle, and
- Investigate the effects of land use on the terrestrial carbon cycle

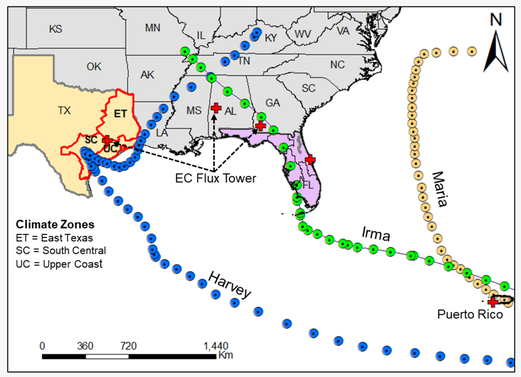

Fig. 1: Study area, which includes the path of three Hurricanes (Harvey, Irma, and Maria) in 2017.

Methods

This study used SMAP level-4 (NEE) products to determine the spatial pattern and temporal changes on NEE at three climate zones of (ET, SC, and UC) Texas (TX) during hurricane Harvey , across Florida (FL) during Hurricane Irma, and across Puerto Rico (PR) during hurricane Maria in 2017 (**Fig. 1**). Since heavy rainfall and flooding were mainly observed during the last week of August and the first two weeks of September in the south of TX, the second week of September in FL, and the third week of September 2017 in PR, analysis was only conducted for one month from Aug 15 to Sep 15 of each year in TX, and the month of September in FL and in PR (2016-2018). We analyzed satellite data each year (2016 to 2018). Spatial maps of daily Integrated Multisatellite Retrievals for Global Precipitation Measurement (IMERG) precipitation and NEE were developed for selected days/weeks (before, during, and after hurricanes). Total carbon emissions, uptakes and net carbon balances were calculated over the select three climate zones in Texas and entire states of FL and PR. Time-series graphs were developed to compare daily net carbon balances, emissions and uptakes at three climate zones to observe their distributions during one month each year (2016-2018).

Results and Discussion

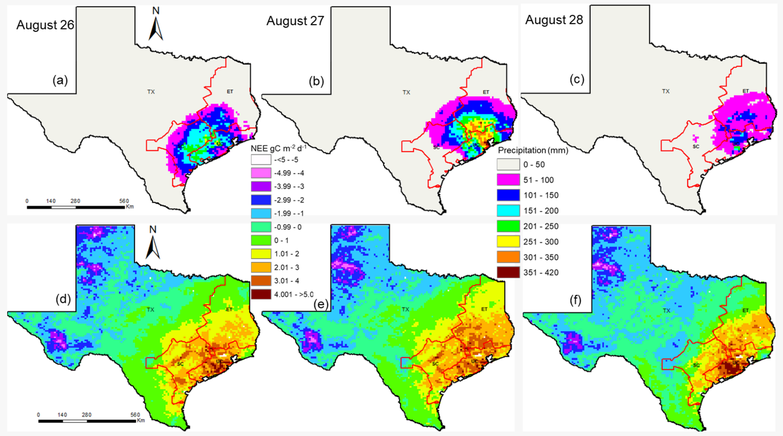

Fig. 3: Comparing SMAP's NEE before, during, and after hurricane Harvey in Houston, Texas (Aug. 15 to Sep. 15, 2017) and during the same period in 2016 and 2018. The NEE significantly increased on 27th of August at ET, SC, and UC climate zones. In addition, the areas which received higher precipitations emitted higher carbon dioxide.

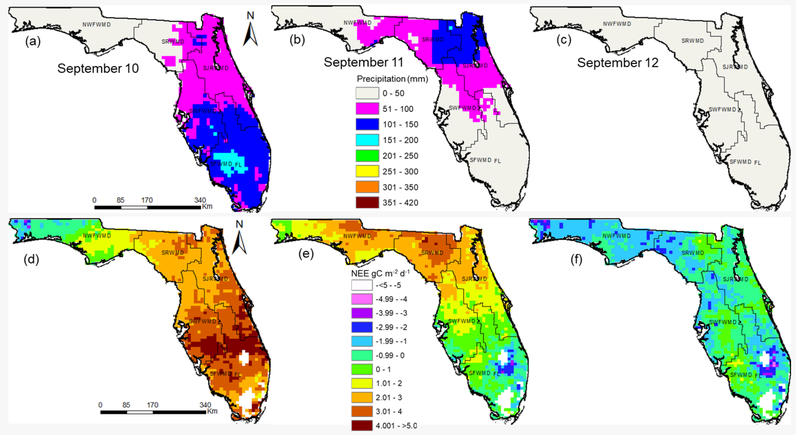

Fig. 4: Comparing SMAP's NEE before, during, and after hurricane Irma in Florida (Sep. 10, 11, & 12 2017) and during the same period in 2016 and 2018. The NEE significantly increased on 10th of September in southern Florida. In addition, the areas which received higher precipitations emitted higher carbon dioxide.

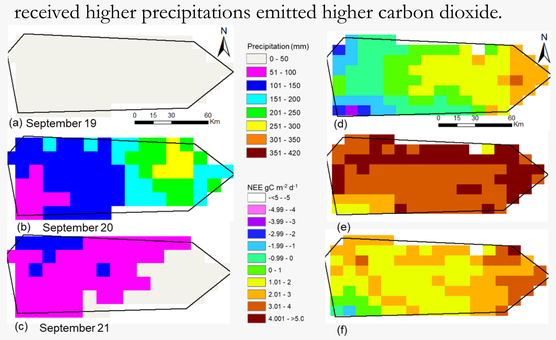

Fig. 5 Comparing SMAP's NEE before, during, and after Hurricane Maria in Puerto Rico (Sep. 19, 20, & 21 2017) and during the same period in 2016 and 2018. The NEE significantly increased on the 19th of September across the state. In addition, the areas which received higher precipitations emitted higher carbon dioxide.

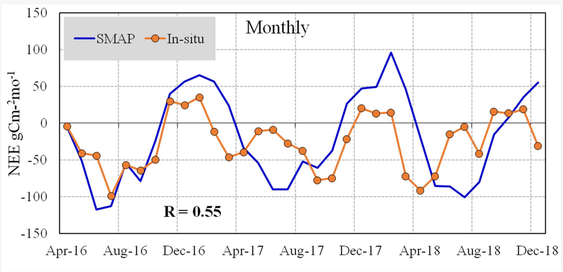

Fig. 6: Monthly SMAP and in-situ NEE at PVAMU Research Farm (2016-2018).

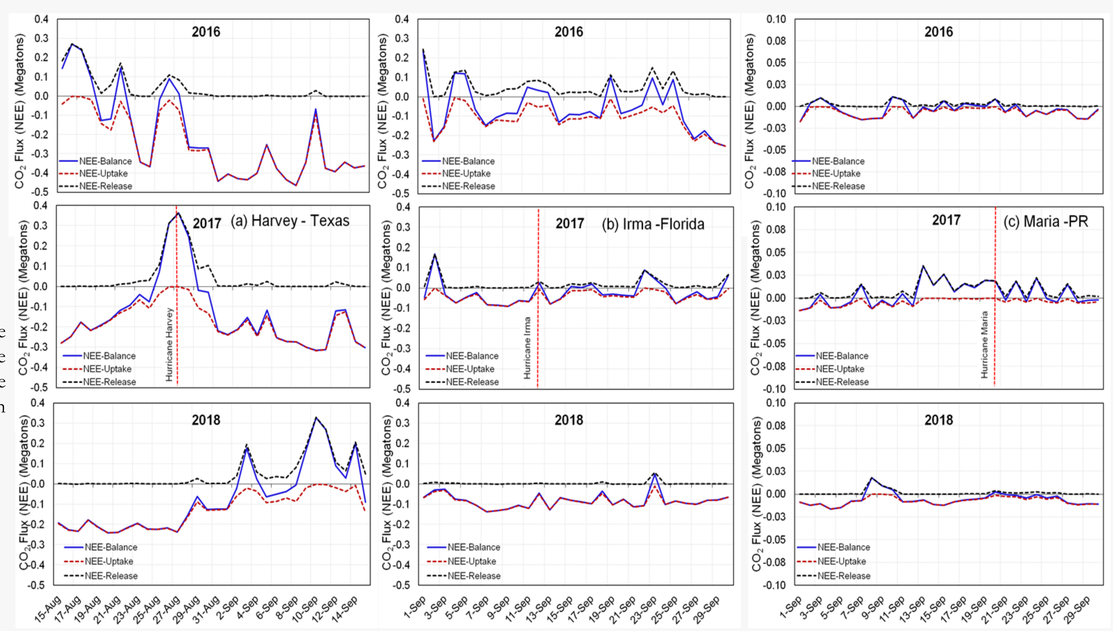

Fig. 5: Figures 5a to 5c compare daily net CO_2 balances, emissions and uptakes at three selected climate zones in Texas, and entire states of Florida, and Puerto Rico for one month as shown in figures. Results show higher NEE emission in Aug 2017 compared to Aug 2016 and 2018 in Texas. As expected, heavy precipitation and flooded land released a significant amount of CO_2, on 27th Aug 2017. However, Florida and Puerto Rico have slightly higher CO_2 emissions in September 2017 than in the same months in 2016 and 2018.

Conclusions

This study presents the analysis of CO_2 fluxes from flooded regions in south-east Texas, entire states of Florida, and Puerto Rico, which received heavy precipitation during Hurricane Harvey, Irma, and Maria, respectively, during August and September in 2017. This study compared CO_2 emission during 30 days period in August-September of 2017, 2016 and 2018. The analysis showed CO_2 rate varies with the amount of precipitation, flood, and flooding duration. The higher emission from the flooded area might be due to higher inputs of organic materials/nutrients, activation of microbes, and organic content degradation during the flood. In addition, water might replace the CO_2 from the soil pores after rain or flood. Although the carbon emissions were slightly higher during the hurricane month in Florida and Puerto Rico than before and after years of the same month, it was not significant compared to Texas. The analysis showed land cover/land use and soil types might have also played a role in carbon emissions during the hurricanes and floods. Therefore, further investigation is important to understand the impact of land characteristics on carbon emissions during hurricanes/storms and floods.

Acknowledgments

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