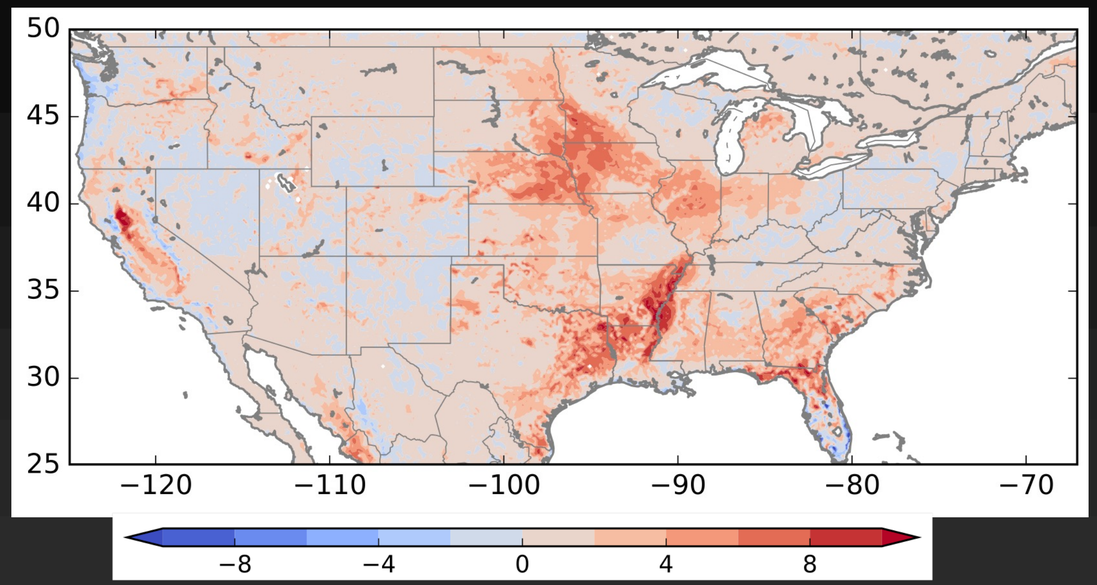
Land data assimilation to examine fire-hydrology connections

Sujay V. Kumar
Hydrological Sciences Lab
NASA Goddard Space Flight Center, Greenbelt, MD, USA

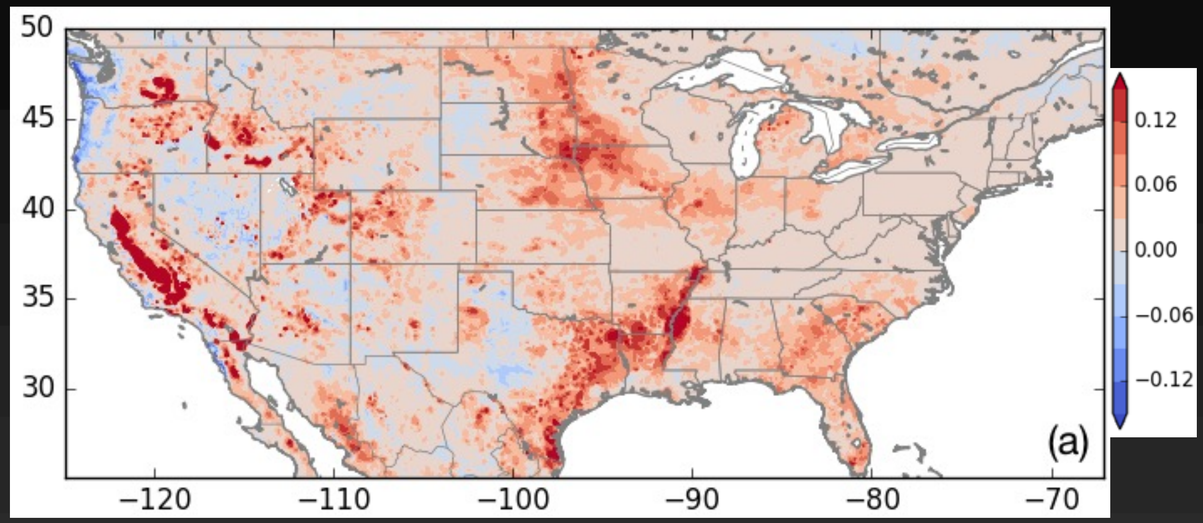
*Images from NY Times (Oct 13, 2020)

Vegetation assimilation shows promise for characterizing human management processes

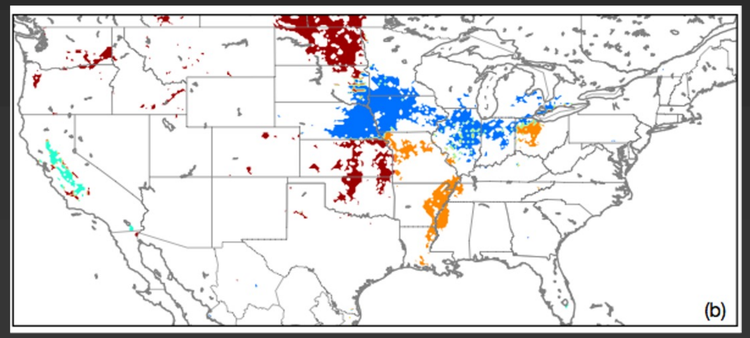
Improvements in ET from LAI assimilation (RMSE)



Improvements in ET from VOD assimilation (R)



(Warm colors indicate improvements; cool colors indicate degradations)



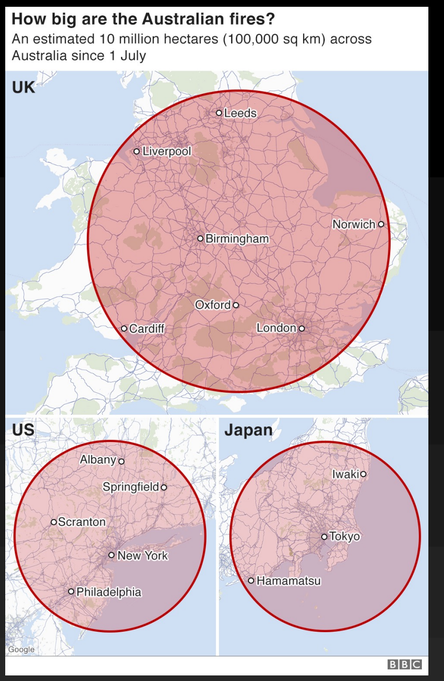
Agricultural crop areas (blue-corn; orange-soybean; brown - wheat)

Assimilation of vegetation data helps in the characterization of agricultural areas

Systematic and consistent improvements over the Central Plains, lower Mississippi, central California valley, places where significant agricultural activity occurs

Kumar et al. (2019), Assimilation of remotely sensed Leaf Area Index into the Noah-MP land surface model: Impacts on water and carbon fluxes and states over the Continental U.S., J. Hydromet.
Kumar et al. (2020), Assimilation of vegetation optical depth retrievals from passive microwave radiometry, Hydrol. Earth Syst. Sci.

The 2019-2020 Australian fires

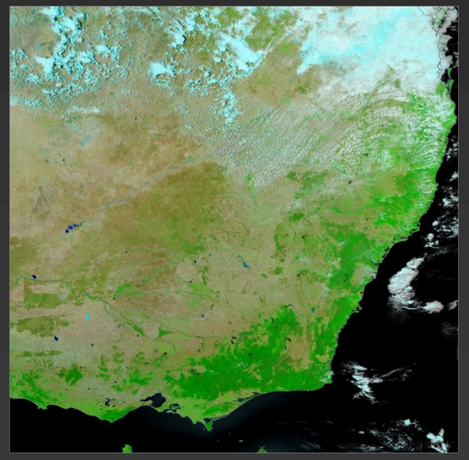


2019-2020 over the Murray-Darling basin has been the driest and hottest on record.

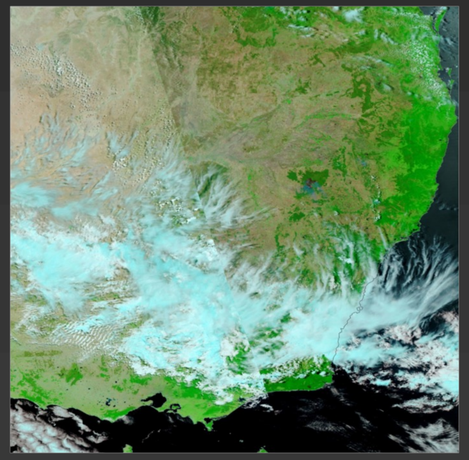
~25 million acres, including more than 21% of the Australian forests have burned from the 2019-2020 fires

False color images from VIIRS

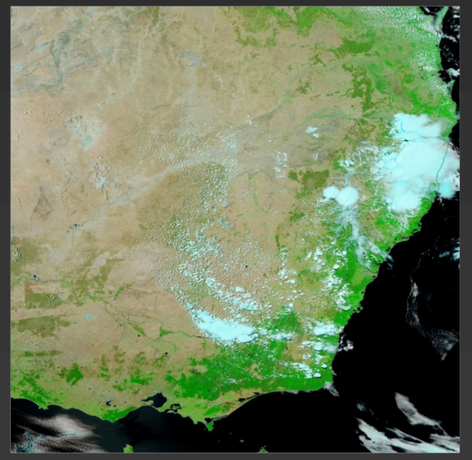
2017/01/22



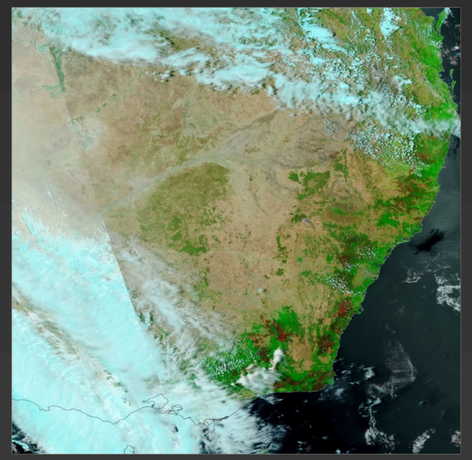
2018/01/22



2019/01/22



2020/01/22

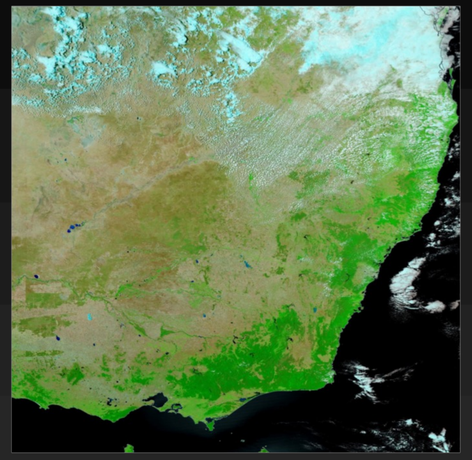


Kumar, S.V., T. Holmes, N. Andela, I. Dharssi, Vinodkumar, et al. (2021), The 2019-2020 Australian drought and bushfires altered the partitioning of hydrological fluxes, Geophys. Res. Lett.

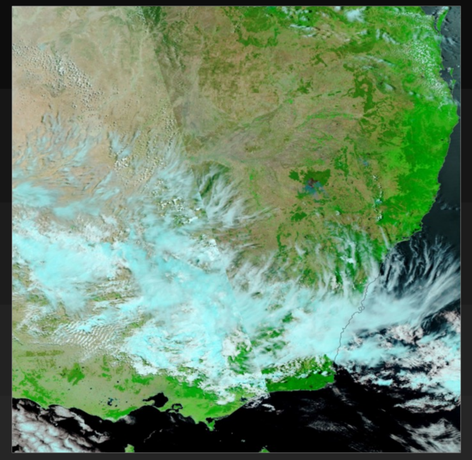
The 2019-2020 Australian fires captured by SMAP

False color images from VIIRS

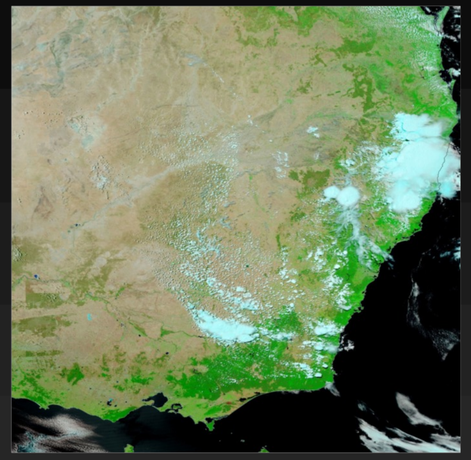
2017/01/22



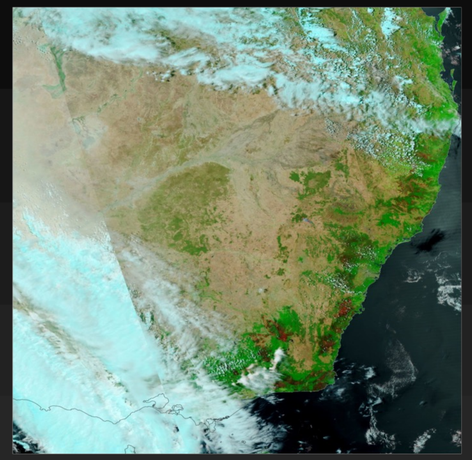
2018/01/22



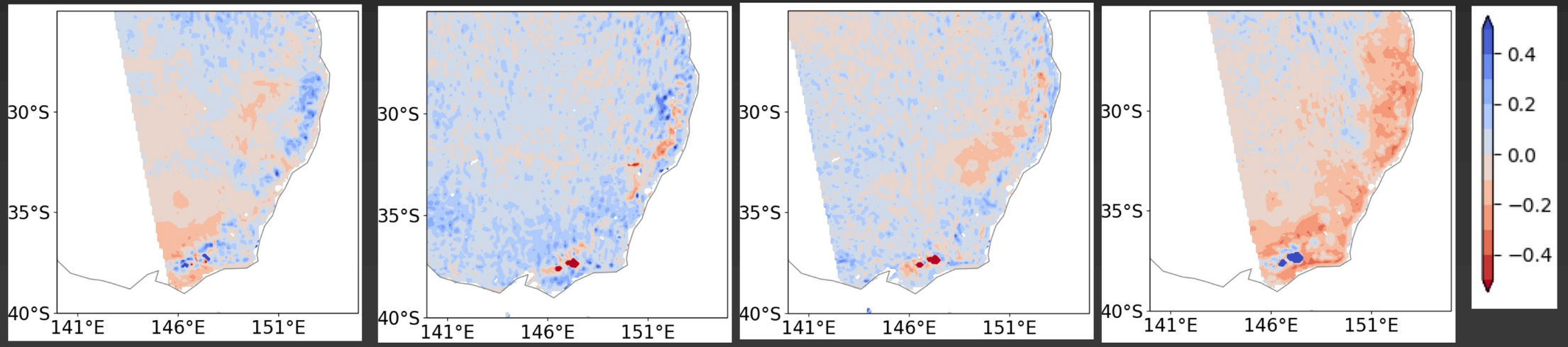
2019/01/22



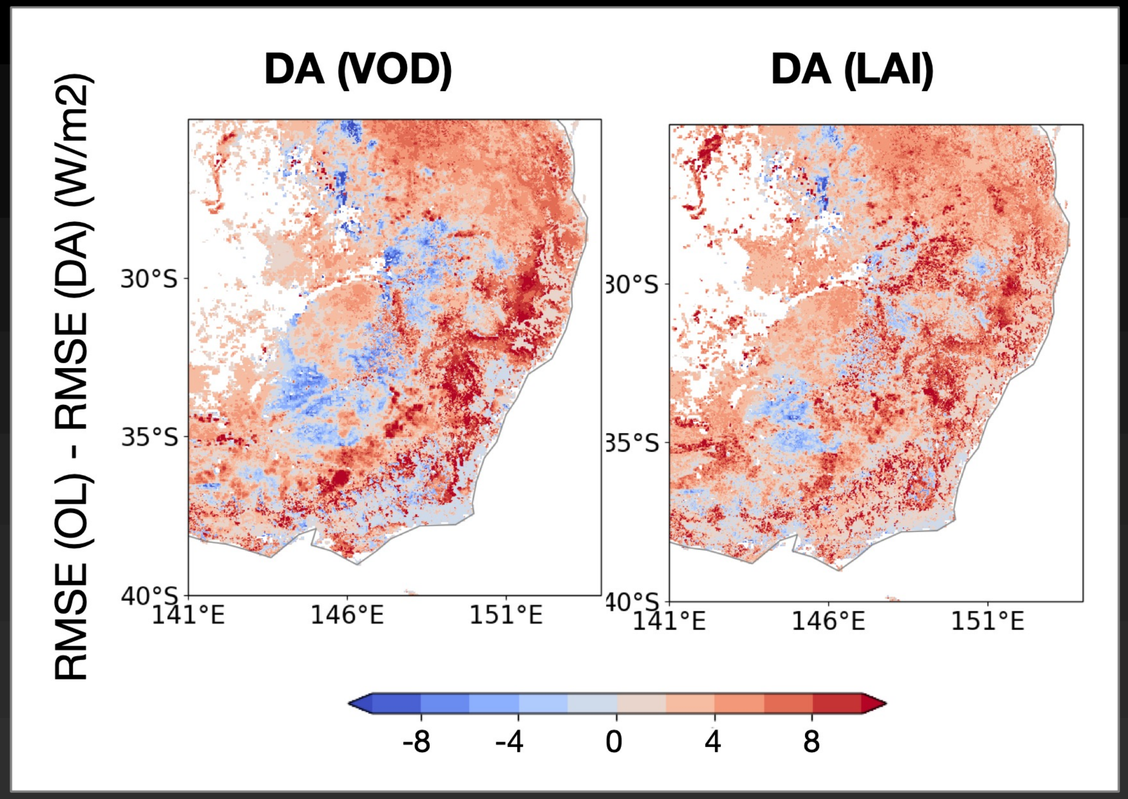
2020/01/22



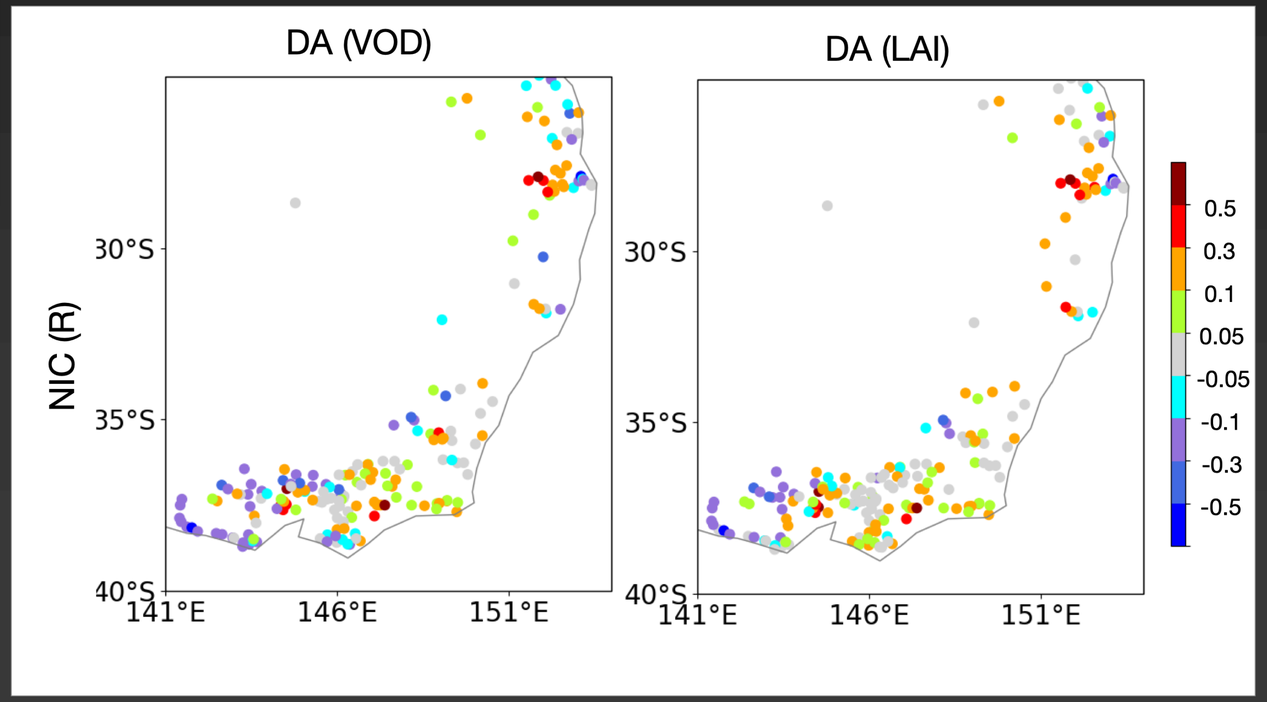
Vegetation Optical Depth (VOD) anomalies from SMAP



Assimilation impact on the water budget partition

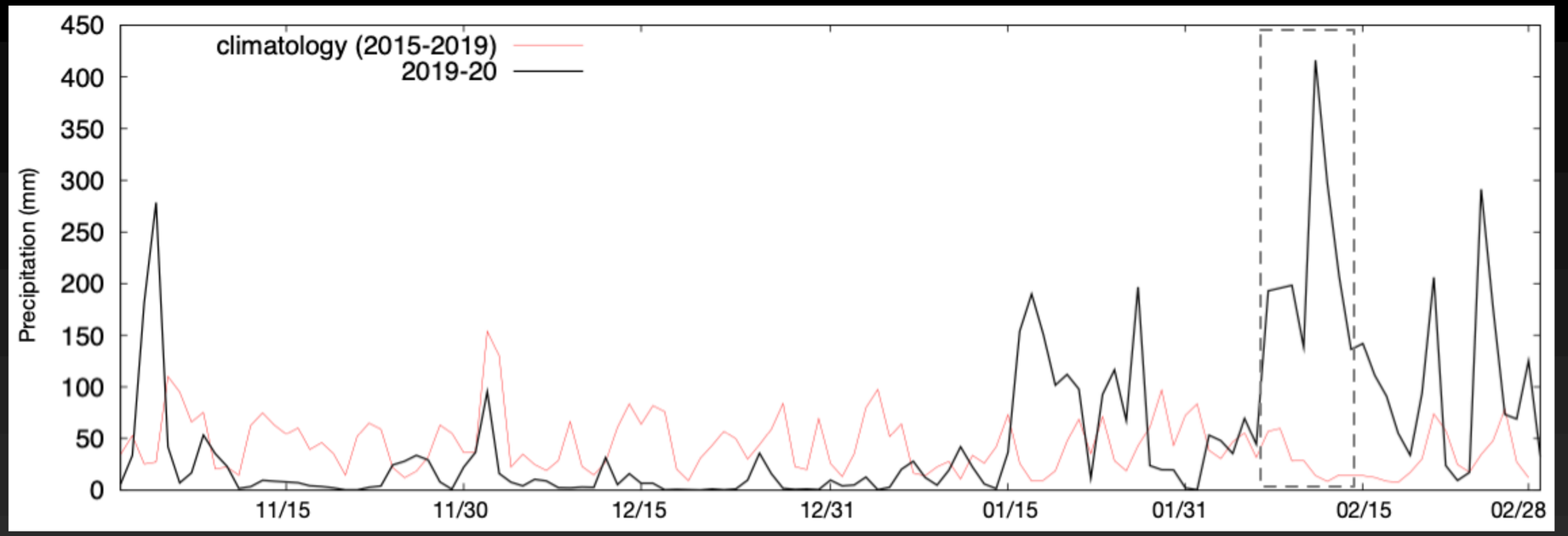


ET (compared to thermal remote sensing based ALEXI estimates) is improved from vegetation assimilation



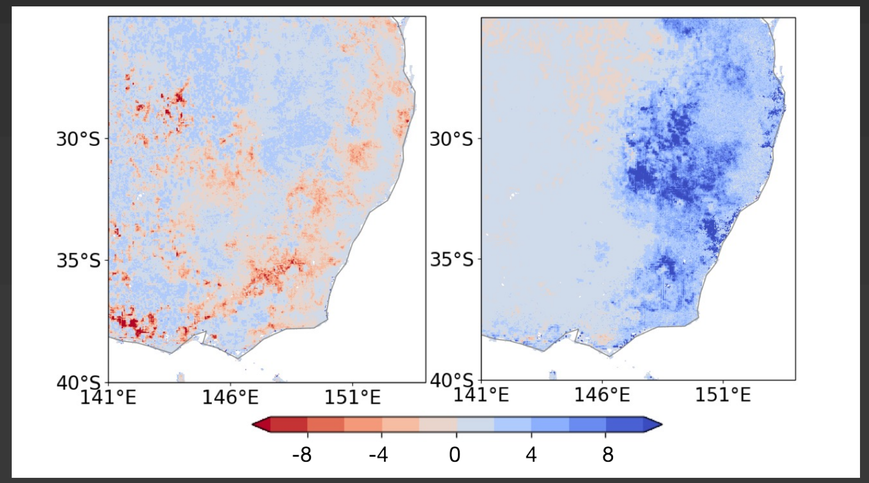
Runoff (compared to BoM gauge measurements) is improved from vegetation assimilation [Not specific to the 2019-2020 fires]

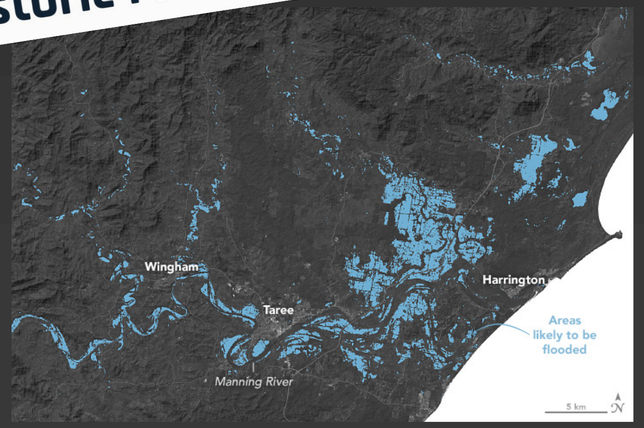
Impact of vegetation disturbances on regional water cycle

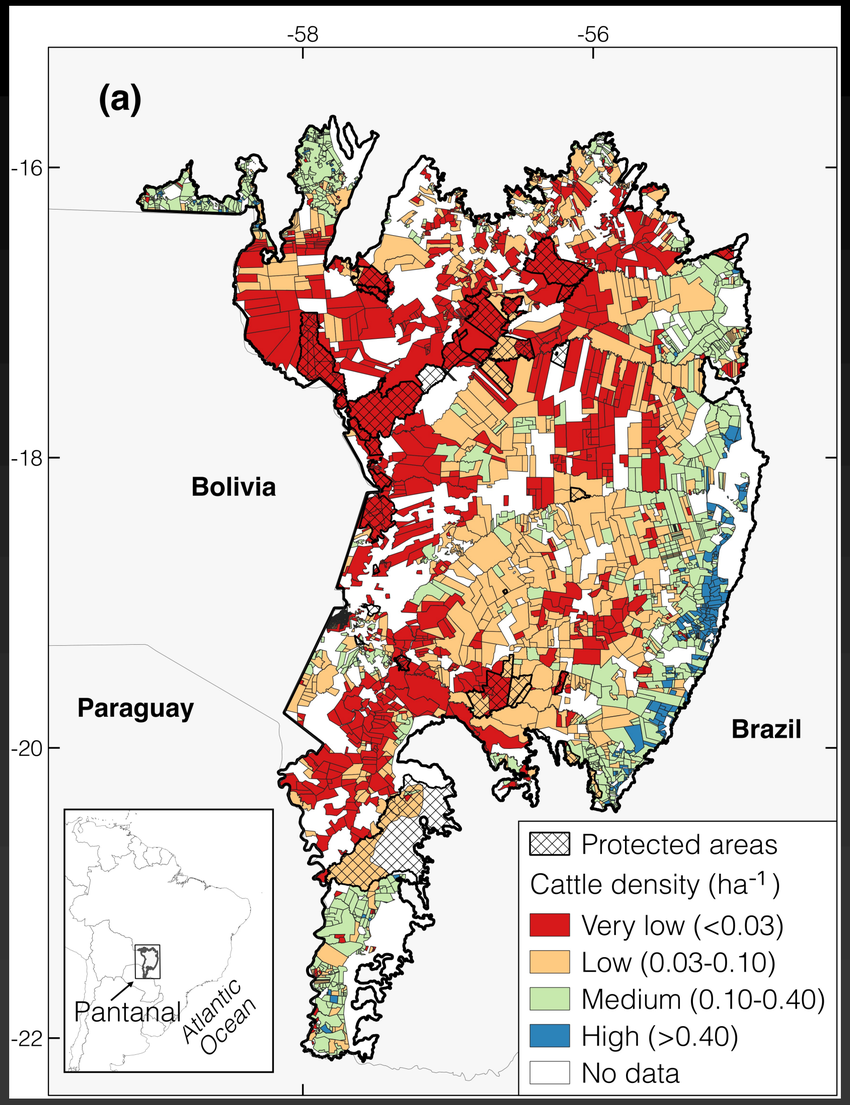


The vegetation alterations from the fires led to significant changes to the local water cycle by increasing runoff and bare soil evaporation and decreasing transpiration.

dET (%) dQ (%)







The Pantanal in central South America is the largest contiguous wetland in the world

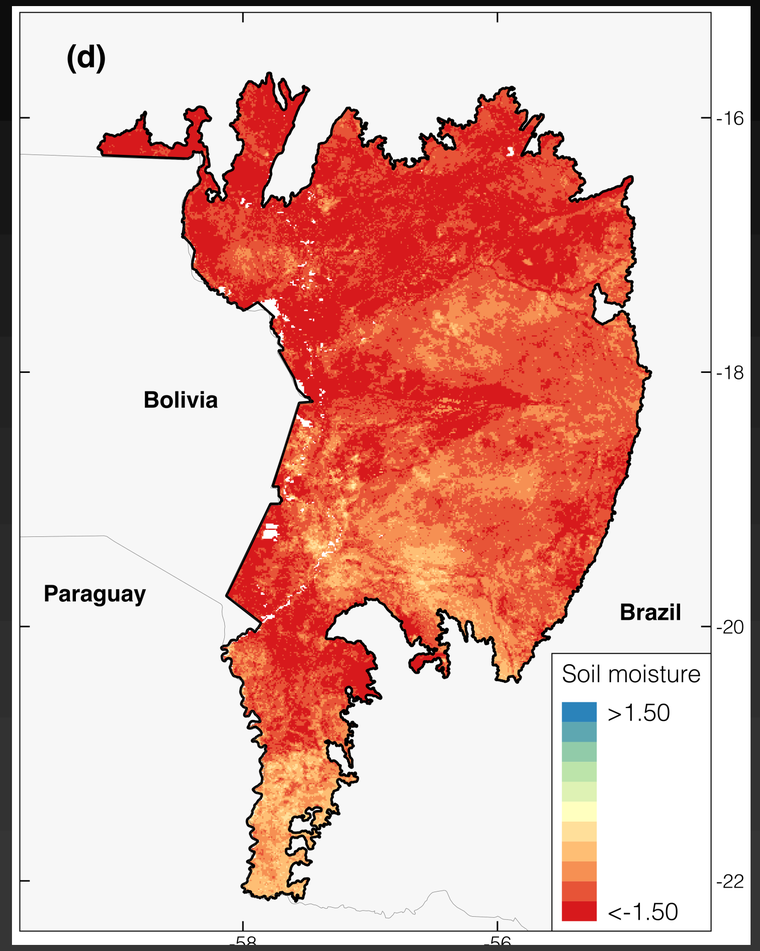
It hosts the highest concentration of wildlife in South America

Cattle ranching is a major part of the Pantanal economy with 93% of the land being private

Historically, cattle ranching has been minimal over the protected and indigenous areas

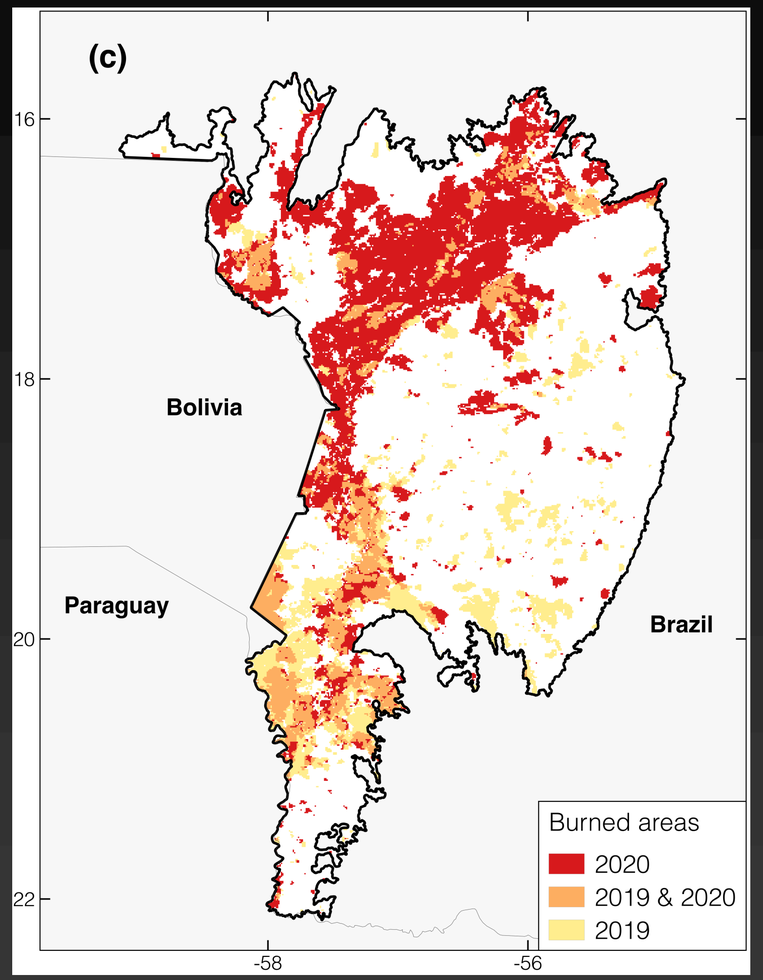
Kumar, S.V., A. Getirana, R. Libonati, C. Hain, S. Mahanama, N. Andela 2022: Changes in land use enhance the sensitivity of tropical ecosystems to fire-climate extremes, Sci. Rep 12, 964, doi:10.1038/s41598-022-05130-0

The Pantanal (and much of Brazil) has been hit by an unprecedented drought since 2018

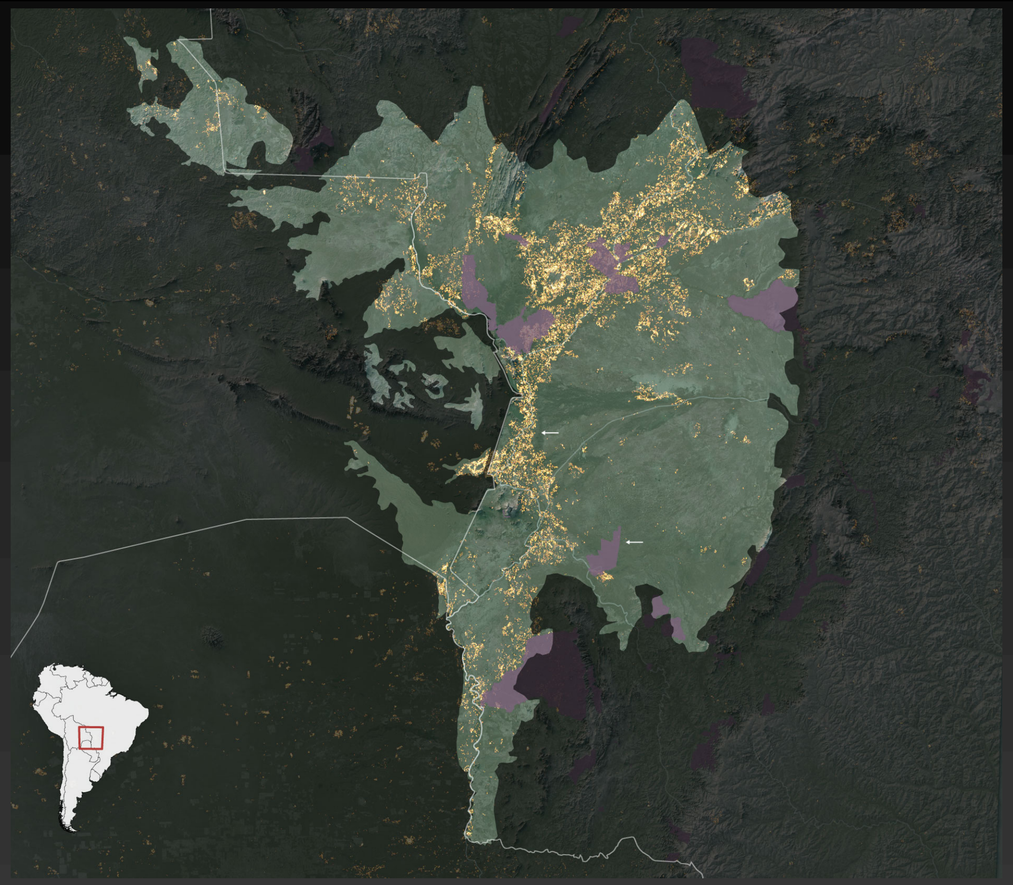


Root zone soil moisture anomalies Aug - Nov 2020

..... followed by extreme wildfires.



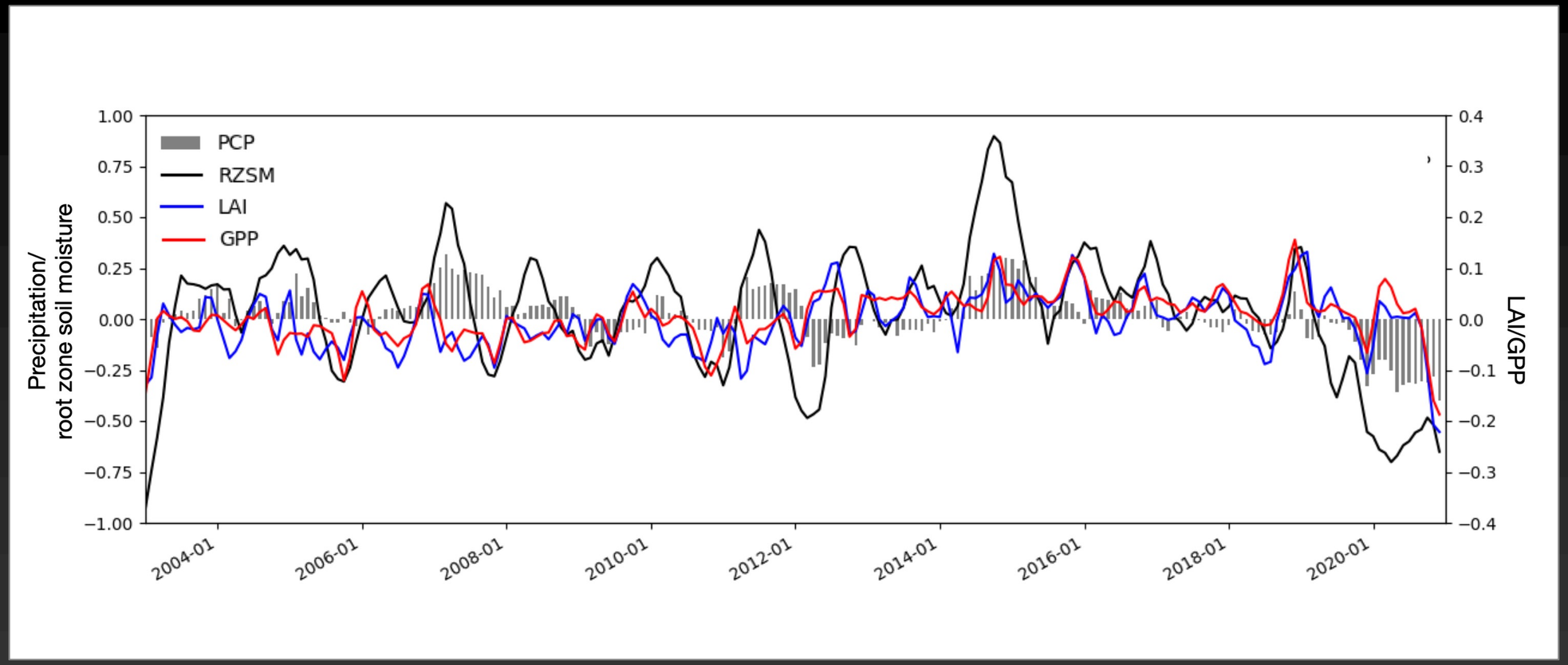
Approximately 29% of the region (~3.7Mha) burned from these fires



DA integration setup

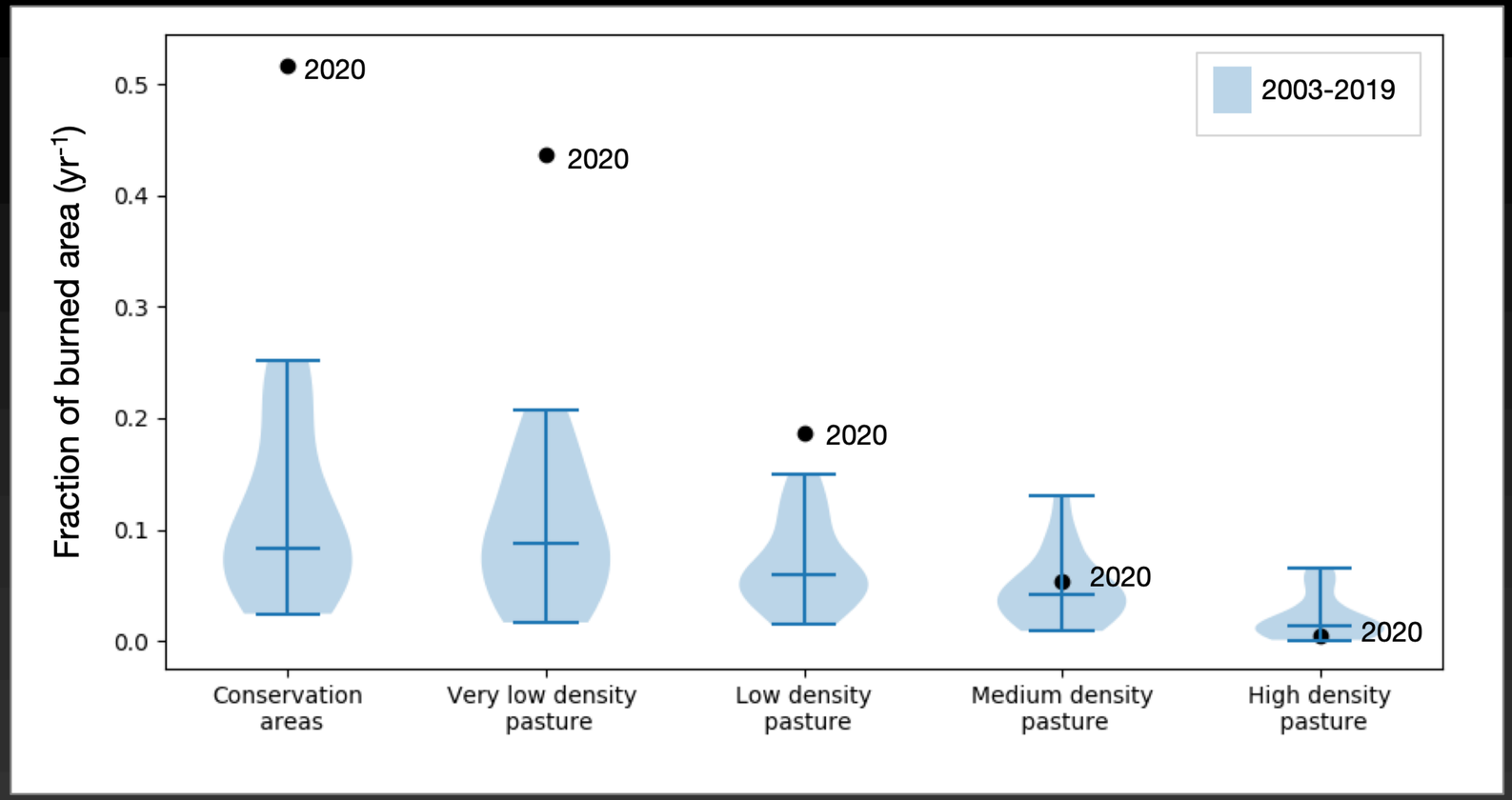
- Noah-MP LSM forced with MERRA2 and IMERG at 1km spatial resolution
- Assimilates MODIS Leaf Area Index (LAI; MCD15A2H) estimates using an Ensemble Kalman Filter (EnKF) approach
- Integrations are conducted during 2000-2020 to evaluate the long-term impacts of fire over this region

Understanding the drivers of the 2020 fire event



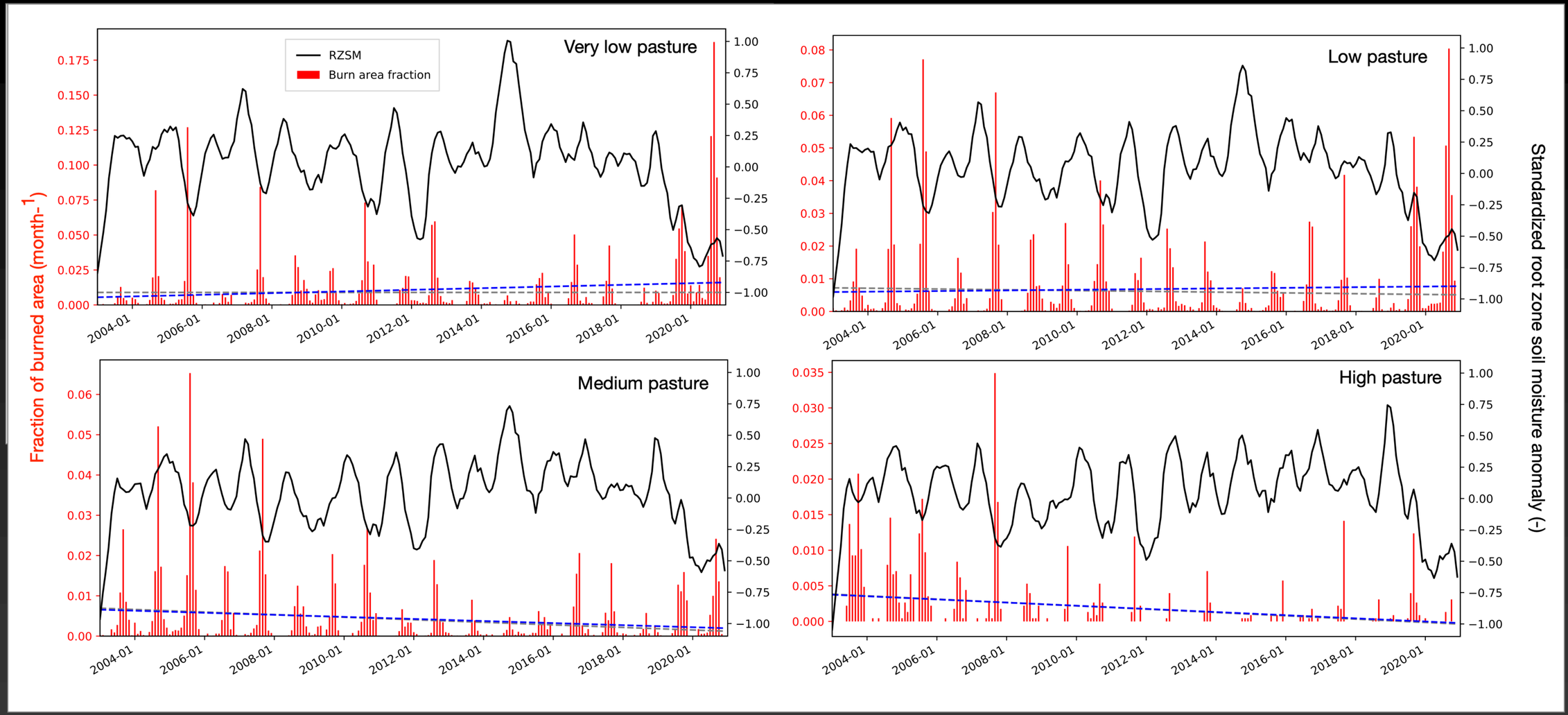
Except for 2020, the correspondence between drought and negative vegetation anomalies are weak in this region, indicating that the Pantanal ecosystem is very resilient to moisture stress conditions.

A significant drop in LAI and GPP is, however, observed in 2020.

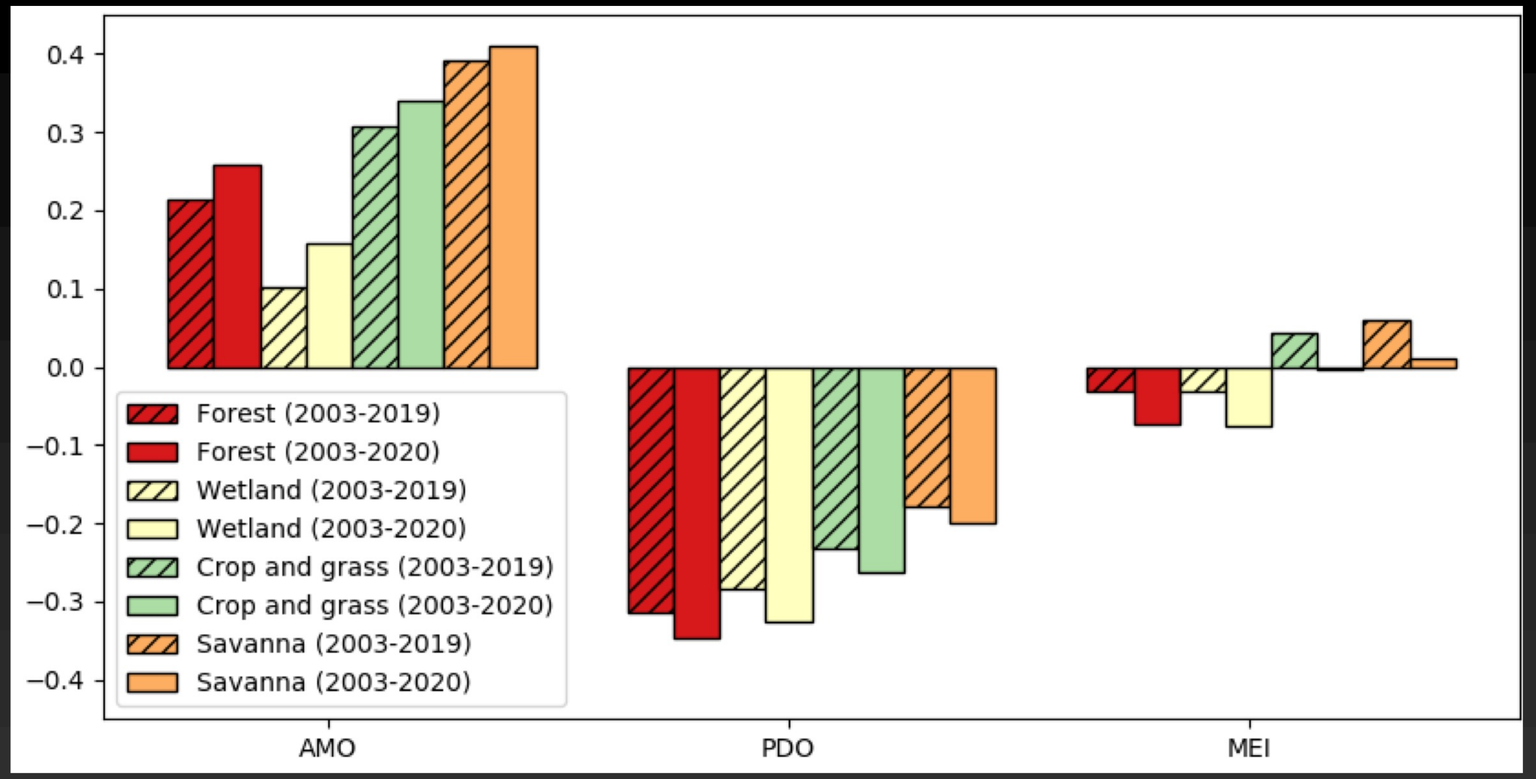


Under similar drought conditions, the influence of the 2020 fires are disproportionately over the natural areas. Over the managed areas, the % of fire occurrences is within the historical distribution.

This suggests the strong human influence in these fires, which often escape over natural landscapes (while controlled fires over areas with more grazing and pasture are not influenced by drought conditions)

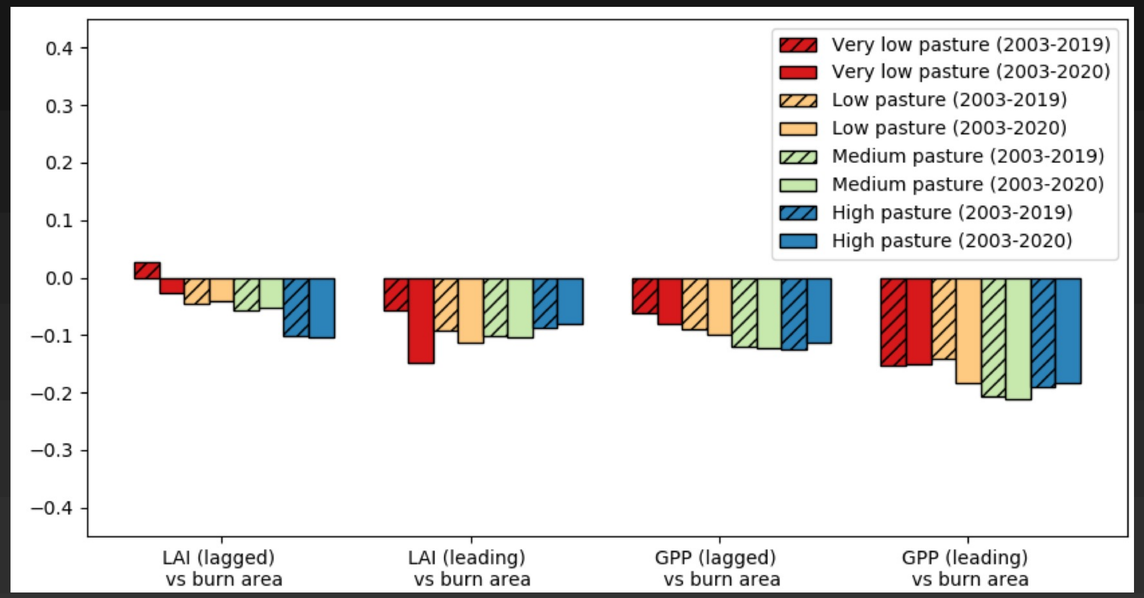


Significant increase in % of burned area over areas with low cattle pasture (357% increase compared to the long-term mean) compared to areas with high pasture (8% decrease compared to the long-term mean) though the exceptional drought is generally uniform over the entire domain



There is a general association between the climate indices and the fire instances in the Pantanal, though the change in the correlation values when the 2020 data is included (not statistically significant)

Climate influence alone cannot explain the unprecedented extent and locations of wildfires

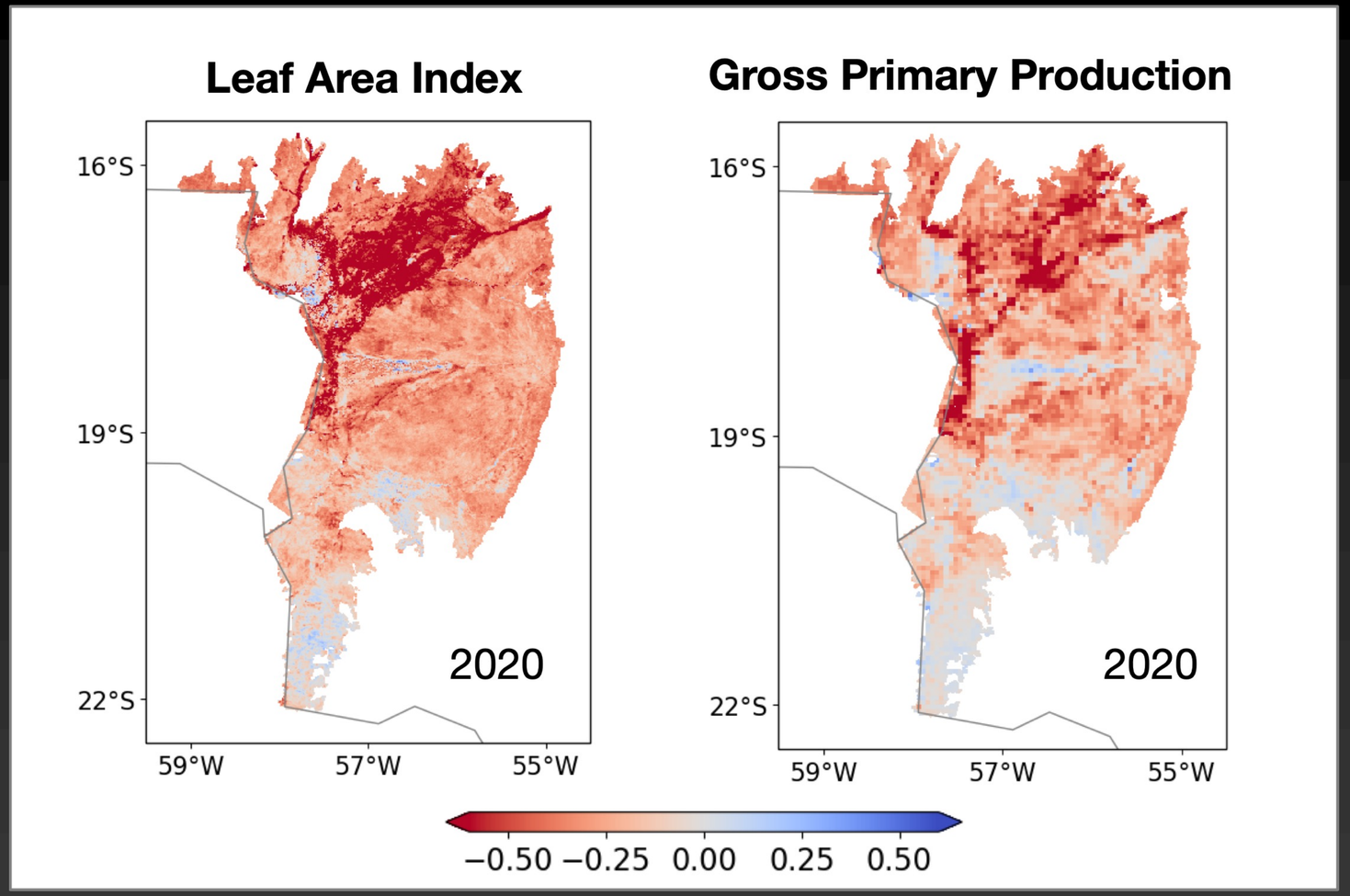


Correlation between standardized LAI and GPP anomalies and antecedent precipitation anomalies is generally small

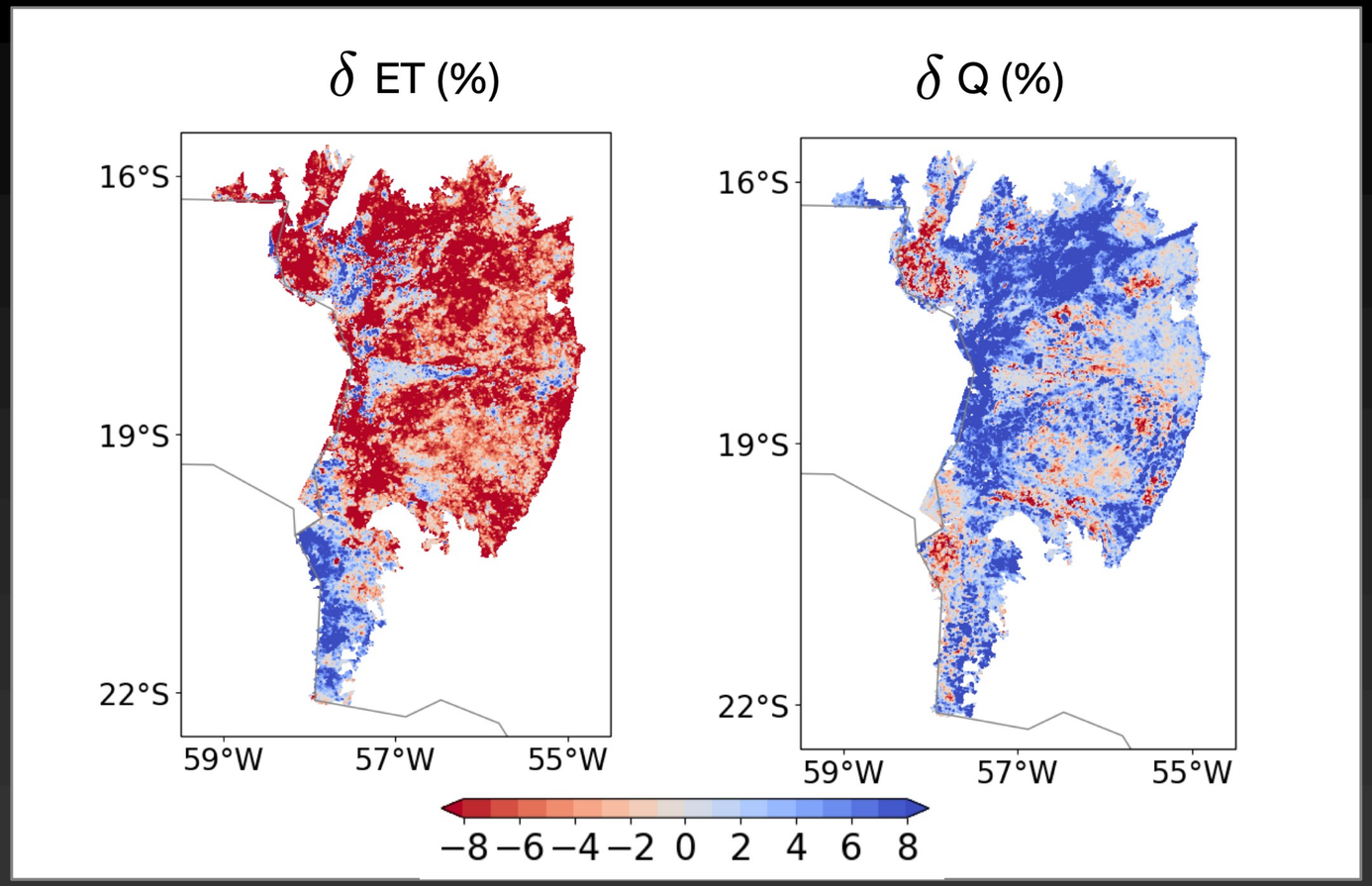
These correlations increase for correlations for leading vegetation anomalies

Antecedent vegetation conditions are not a major factor in the development of fires

standardized anomalies in LAI and GPP



Large changes in LAI/GPP are primarily observed over the conserved/natural areas.
During 2003-2019, % of conservation areas with standardized LAI values below -1.5σ is 3.3,
whereas in 2020, 35% of the conservation area has standardized LAI below -1.5σ.



Fundamental changes to the local hydrology: Evaporation is reduced, runoff is increased, which raises concerns about increased land degradation

Factors such as soil repellency are not modeled here. Therefore changes to the local hydrological response is likely underestimated.

Summary

- Assimilation of vegetation data enables the characterization of vegetation disturbances from fires
- Optical sensor-based vegetation (LAI/NDVI) and microwave-based VOD retrievals are useful in representing the vegetation disturbance impacts
- Large scale fire events have significant impacts on the regional water cycle, with possible land degradations and contributions to hydrological extremes such as floods