Sensitivity of Biogenic Emissions to Leaf Area Index and Drought

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INTRODUCTION

Biogenic emissions play an important role in ozone formation in the lower troposphere. Simulations of biogenic emissions for regulatory air quality modeling often use static leaf area index (LAI) values for the growing season. Our research aims to assess the value in using dynamically updated LAI from satellite data. LAI data show significant interannual variation, which may be caused by meteorological phenomena such as drought. Because drought is correlated with high temperatures in the Southeast US, and because high temperatures also lead to increased isoprene production, there may be a contradictory feedback in isoprene emission response to severe drought.

METHODS

To investigate this feedback process, we have first correlated LAI to a modified Palmer Drought Severity Index (PDSI) compiled by Dai for the decade 2001 to 2010. We also correlated LAI to monthly temperature and precipitation, since PDSI is a function of both. Temperature and precipitation data came from the PRISM group. As the amount of rain in months prior could have significant impact on the LAI of the current month, we also correlated LAI to the cumulative rainfall from the months before. For each grid cell, we found the number of months of cumulative rainfall with the highest correlation to LAI. Rain in an earlier season may be more important to the LAI in the given month than the rainfall of the current season. We therefore correlated the LAI of the current month to the precipitation of each previous month, again finding the number of months of lagged precipitation with the highest correlation to LAI.

We then ran the biogenic emissions model MEGAN for two years representing wet (2005) and dry (2007) conditions in the forests of the Southeast. As a first assessment, we used a single day of meteorology (July 20, 2008) repeated for the duration of both MEGAN runs to isolate the influence of drought on isoprene emissions that occurs from changes in LAI as opposed to changes in temperature or precipitation. The resulting isoprene emissions estimates were compared to drought condition in both years to find the impact of drought via LAI.

QUESTIONS

- How will future changes in drought frequency or duration affect biogenic emissions?
- How much of the interannual changes in vegetation be explained by drought, temperature, and precipitation?
- What impact does changing vegetation have on biogenic emissions?

RESULTS

Figure 1a) In March, the vegetation in most of the country shows a negative correlation to PDSI, meaning that there are more leaves during drought than during wet spells. The vegetation in these areas is not under water stress during this time of year, so that during drought, the increase in temperature and light leads to higher leaf production.

In August, the vegetation in most of the country shows a positive correlation to PDSI. Drier conditions during the summer lead to higher water stress for plants, so that drought conditions negatively impact vegetation. Some areas still show a negative correlation to PDSI, mostly in heavily forested regions. These areas present a conundrum, which will require further investigation using a stratified sample to assess factors that have the largest impact on LAI, since water does not appear to be the limiting factor on growth.

The deserts of the Southwest have a positive correlation year round to PDSI, since any increase in precipitation in the desert leads to an increase in vegetation.

RESULTS

LAI to PDSI

LAI to Temperature

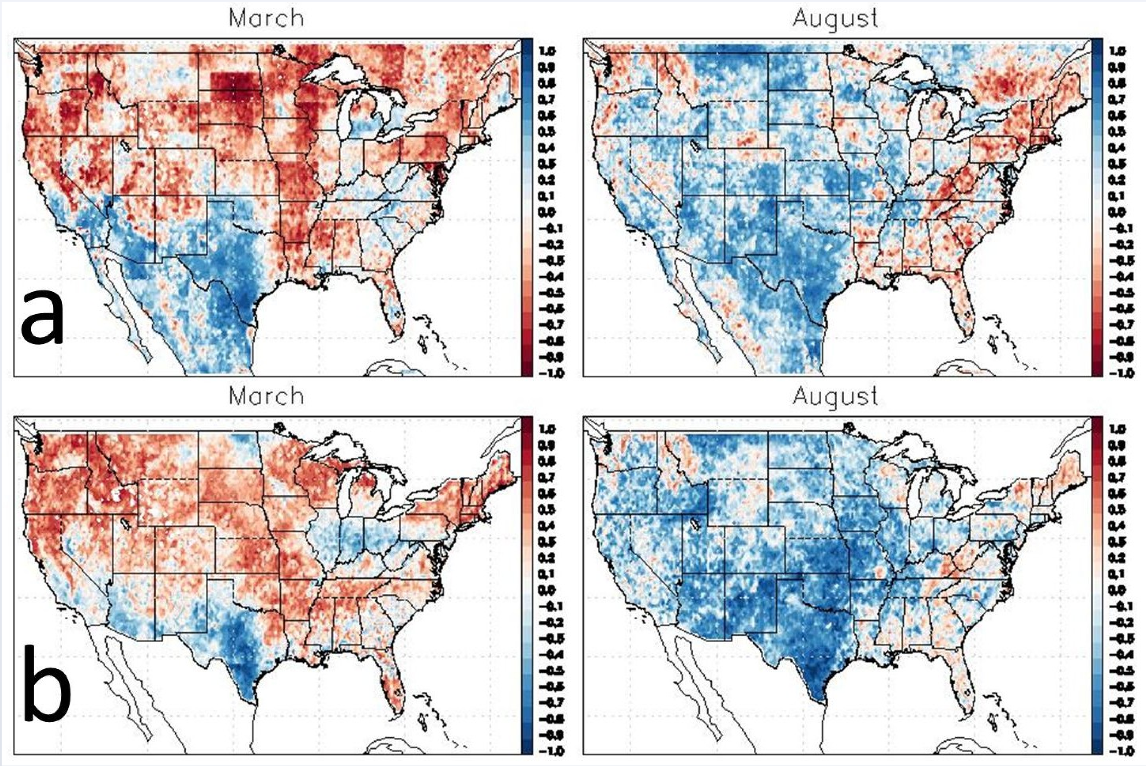

Figure 1 **a) Correlation of MODIS LAI to Dai's PDSI for March and August.**

b) Correlation of monthly average LAI to monthly average of daily maximum temperature.

Figure 1b) Due to high correlation of drought and temperature (Duncan, 2009) the regional and temporal patterns of LAI temperature correlation are similar to those of LAI-drought correlation. The color bar for these graphs is reversed for easy comparison to Figure 1, since negative values of PDSI represent drought.

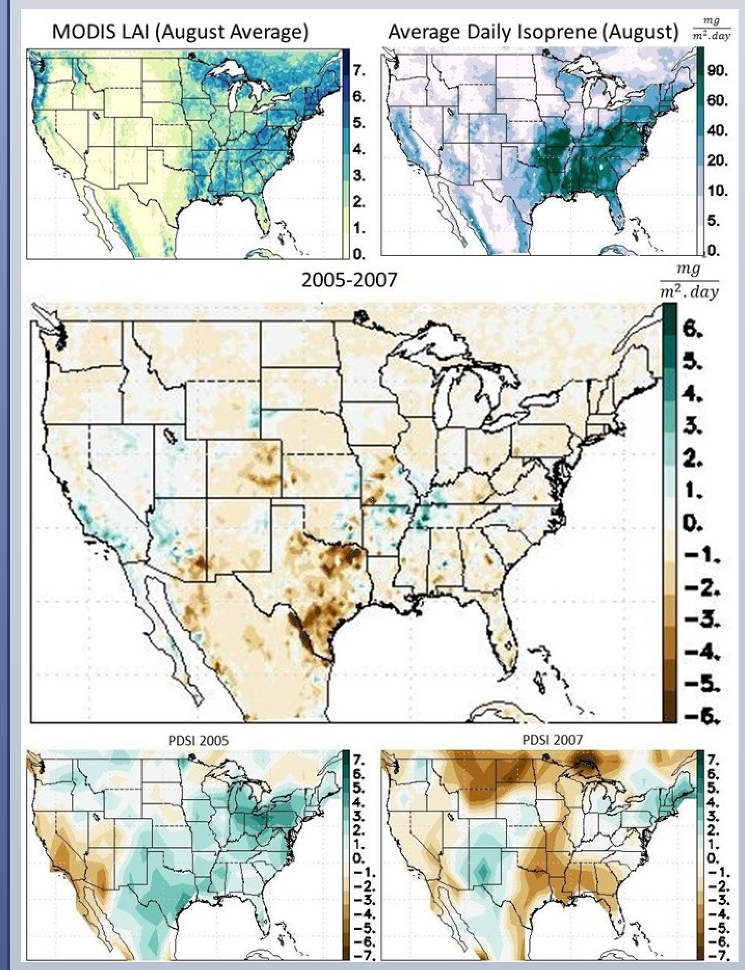

Figure 2)
MEGAN was run with MODIS derived monthly average LAI input and one day of meteorology (July 20, 2008) replicated for each day of the model run. 2005 (bottom left) was a particularly wet year in the Southeastern forests where isoprene emissions are highest, while 2007 (bottom right) was a heavy drought year in this region. East Texas shows the largest drop in isoprene, corresponding to the drastic change in PDSI. Even so, the difference in isoprene emissions over Texas estimated by MEGAN remains quite small, at less than 10 mg/m^2/day. A large part of Southern California shows an increase in isoprene, which corresponds to a decrease in drought condition.

Figure 2

Effect of drought on biogenic emissions due to changes in vegetation.

RESULTS

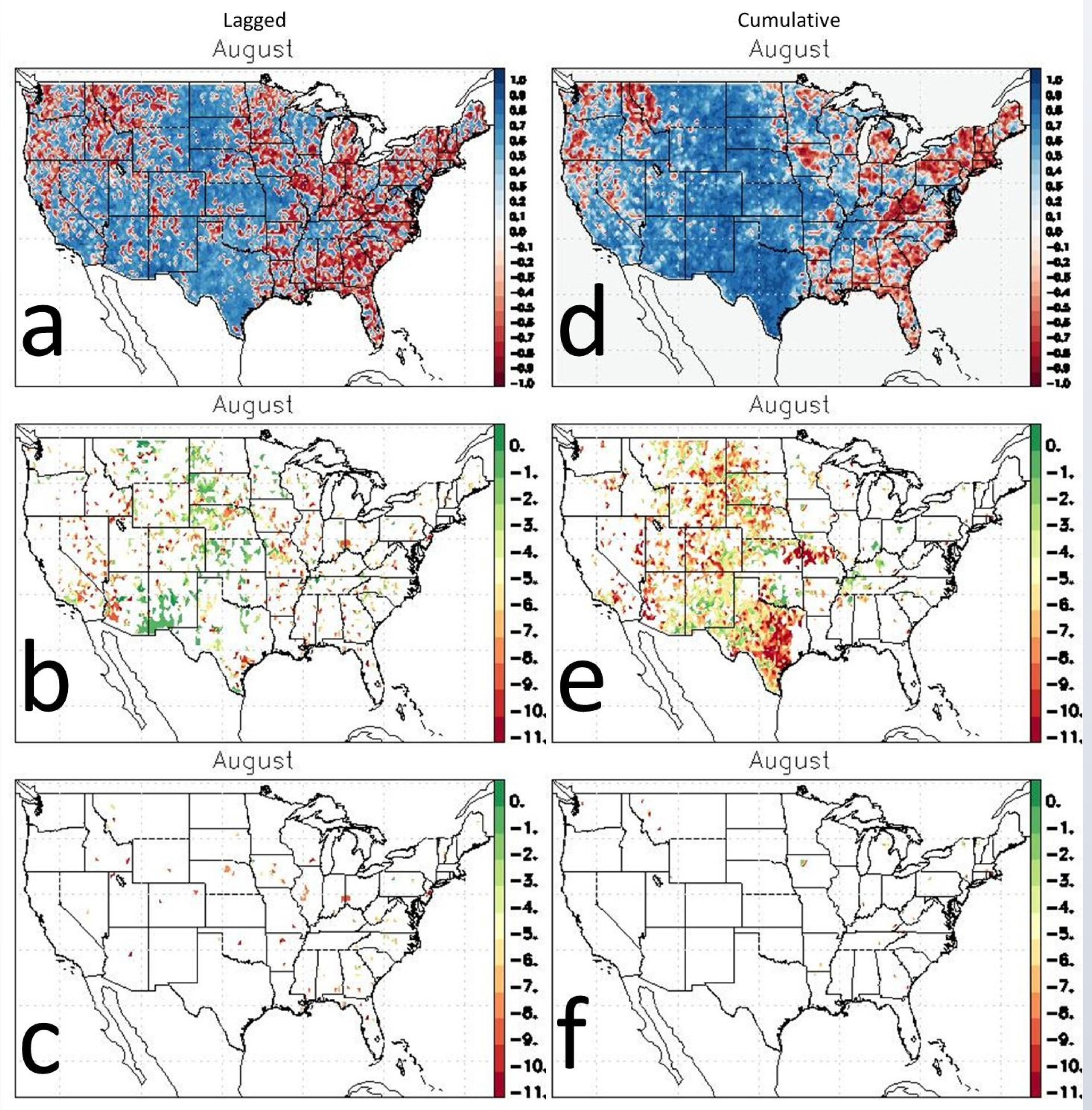

Figure 3 **Correlation of Precipitation to LAI**

a,b,c - Lagged precipitation.

The precipitation in the current month may not have as much impact on LAI as precipitation in previous months.

d,e,f - Cumulative precipitation.

A single month of precipitation may not give the best correlation of LAI.

Figure 3

a) Correlation of LAI to precipitation in each month was computed and the maximum value mapped. Regional patterns follow the same trends as correlation maps for individual lag times in regards to sign, with the composite map naturally showing a higher magnitude.

d) Correlation of LAI to accumulated precipitation for each additional month was computed and the maximum value mapped. More consistent regional patterns can be seen for cumulative precipitation than for lagged precipitation.

b,e) The number of months prior to the current month showing the maximum correlation mapped in the image above. Only pixels with the absolute value of r>0.75 are plotted.

c,f) Pixels with r<0.75 mapped. Many of the negative correlations between LAI and precipitation are not significant, which indicates that there may not be any physical significance to the data.

RESULTS

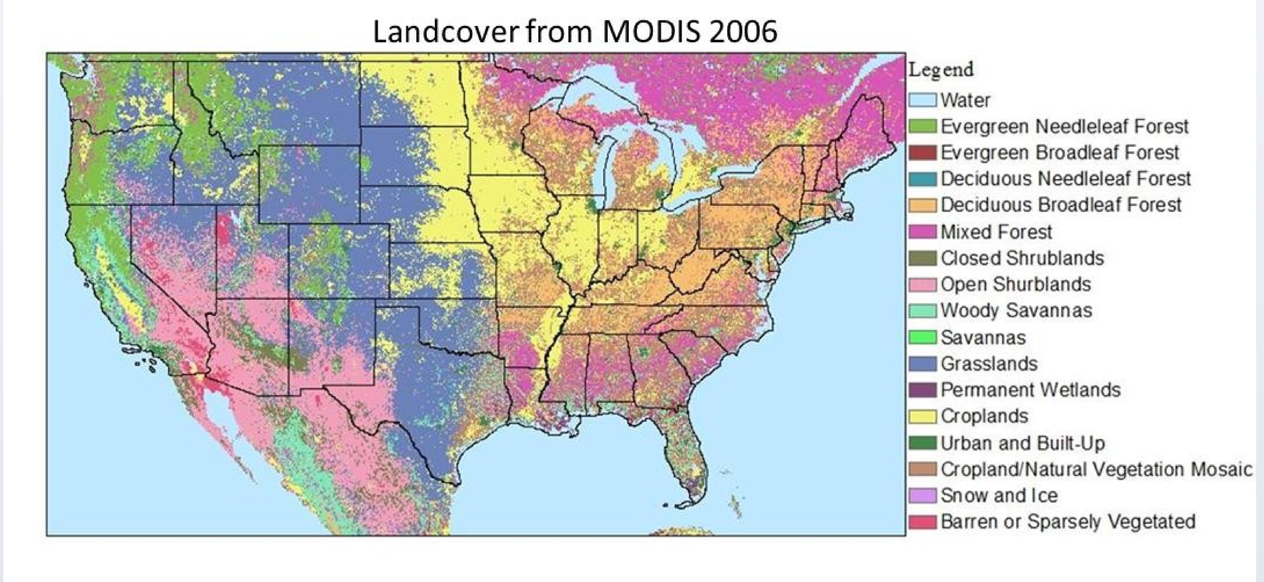

Figure 4 **Biome types as used by MEGAN from the MODIS instrument.** Different biomes display different relationships between LAI, PDSI, temperature, and precipitation.

CONCLUSIONS

- Drought causes a reduction in vegetation for most of the country, particularly grasslands, shrublands and croplands.
- Many heavily forested regions show no correlation or a negative correlation to PDSI, indicating that water stress is not the limiting factor for growth.
- Precipitation in previous months provides a better indicator of current growth than the current month's precipitation for areas with a strong positive correlation to PDSI, but cumulative precipitation does even better.
- Reduced leaf cover from drought will not significantly affect isoprene emissions since changes in LAI have such a low impact on isoprene emissions, particularly in the isoprene rich Southeast forest. Some notable exceptions can be seen in Texas, California, Colorado, and Arizona, where the change in isoprene estimated by MEGAN is 10 to 20% of the average value.

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MODIS Data were obtained through the online Data Pool at the NASA Land Processes Distributed Active Archive Center (LP DAAC),USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota (https://lpdaac.usgs.gov/get_data)

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