Seasonal Variations of Water, Energy, and Carbon Fluxes Across a Moisture Gradient

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Introduction

In an attempt to understand the productive grasslands of West Africa, various techniques are used, including; analysis of eddy covariance data collected by meteorological flux towers and analysis of surface character data collected by satellites. Unfortunately, this area has sparse surface data collection due to political conflicts. Along the same lines, the quality and quantity of satellite observations of surface character data decreases due to prolonged periods of cloud cover during the rainy season.

The red points in Figures 1 and 2 create a ten-site transect which makes up the study area. The study sites stretch through biome types 6, 7, 9, and 11. These respectively represent the following biomes; C4 broadleaf with ground cover, C4 ground cover, C3 shrubs with ground cover, and low-latitude desert.

Figure 1: January 2011

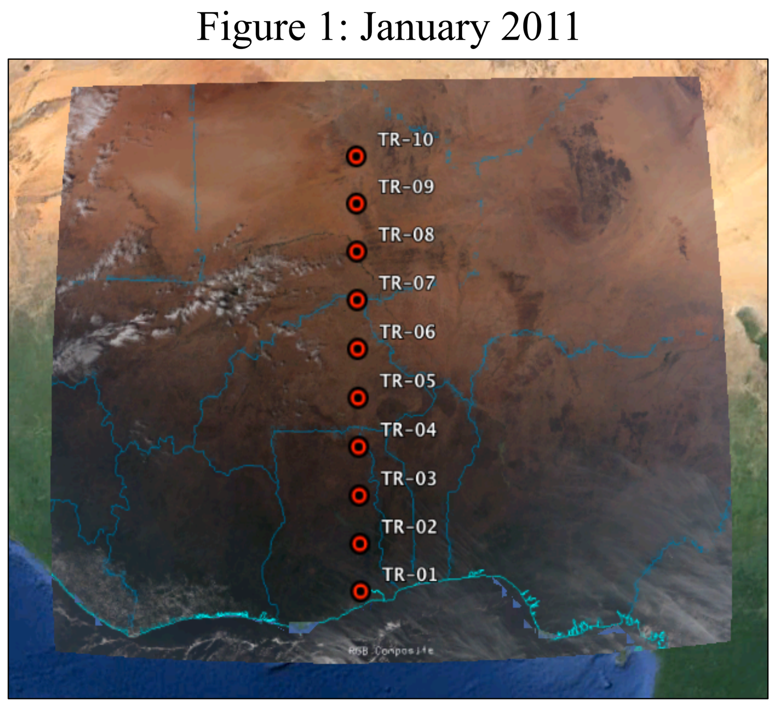
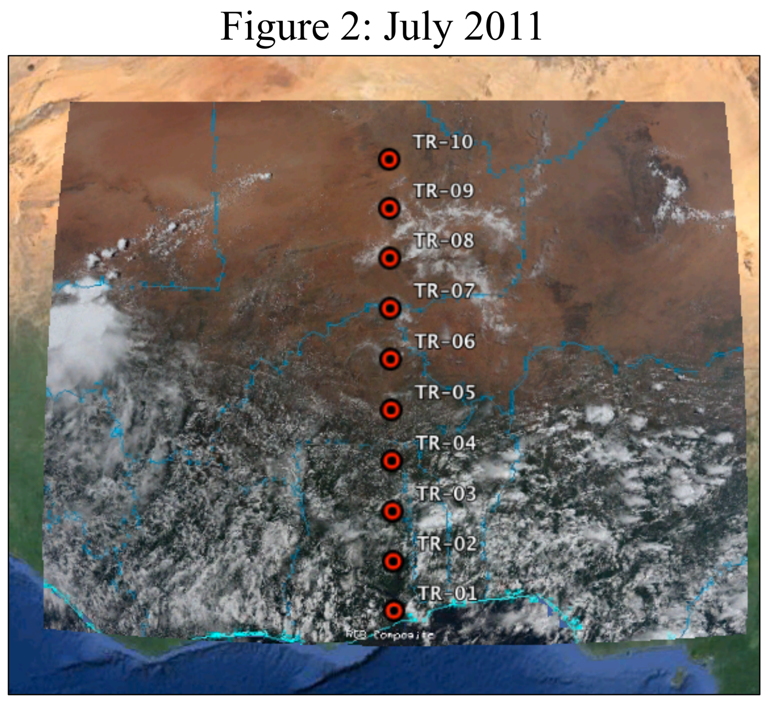


Figure 2: July 2011



Both figures contain true color imagery from VIIRS. In Figure 1 the surface is relatively unobscured from clouds. During the wet season, clouds obscure remotely sensed data collection at half of the study sites, as seen in Figure 2.

During periods of clear skies, satellite data known as fluorescence can be used as an indicator of the vegetation productivity. Fluorescence is light re-emitted from the chlorophyll within plants. It has been proven that fluorescence yield correlates with photosynthetic yield when plants are exposed to stress.

Due to the overall lack of surface and remotely-sensed data during the wet season, the specific time and reasons grasslands become green and productive is not completely understood. In this project, the Simple Biosphere Model (SiB) will be used as an alternative to observe the details of the browning and greening in the African grasslands. In the end, fluorescence data will be used as a comparison to SiB.

Key Questions

- How will SiB's meteorology and phenology impact the modeled productivity of grasslands in West Africa?
- How will remotely sensed observations compare to modeled productivity of the grasslands?

Methodology

The study site was along 0° longitude in West Africa from 6.0°N to 19.5°N. SiB output was created for every 1.5°. SiB was run for the thirty-year time period between January 1983 and December 2012. After SiB was run, all analysis was completed on the last ten years of the SiB output from January 2003 to December 2012. The study area was described annually, seasonally, and daily. Means for each year, each month of the year, and each day of the year were produced for the last ten years of the model run. Fluorescence data was obtained from NASA's Jet Propulsion Lab and annual plots were created.

Acknowledgements

This project could not have been completed without the support of CMMAP, CIRA, and CSU's Atmospheric Science Department. Thank you to Dr. Scott Denning and Dr. Ian Baker for constant guidance throughout the entire project. Thank you to Dan Lindsey for working with CIRA and NOAA to facilitate the internship. Thank you to Melissa Burt for setting up every aspect of the internship outside of the research. Thank you to Kelley Wittmeyer, Mostafa El-Kady, and Matthew Bishop for the technical support. Finally, thank you to NOAA and the Hollings Student Scholarship team for providing financial and logistical support over the past year.

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Results

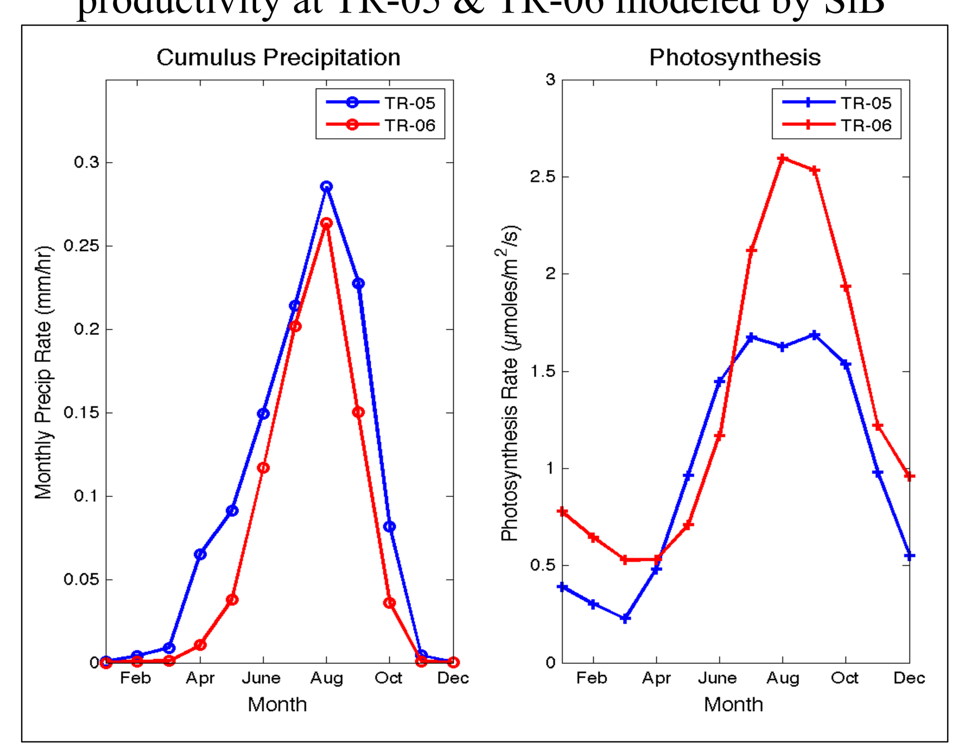
Table 1. Precipitation and productivity at each site

Station	Latitude (°N)	Biome Type	Annual Precip (mm/yr)	Annual Carbon Assim (g/m^2/yr)
TR-01	6	6	1377.8	709.7
TR-02	7.5	6	1375.6	728.9
TR-03	9	6	1312.4	611.9
TR-04	10.5	7	1009.6	420.4
TR-05	12	7	974.7	375.9
TR-06	13.5	9	634.4	498.2
TR-07	15	9	614.9	391.2
TR-08	16.5	11	266.8	75.3
TR-09	18	11	165.2	30
TR-10	19.5	11	64.3	20.5

In Table 1:

- Drastic changes in annual precipitation occur with each biome type change.
- Drastic changes in annual carbon assimilation also occur between each biome.
- Trends in annual precipitation rates are similar to trends annual carbon assimilation.
- There is an exception between biomes 7 and 9, where annual carbon assimilation increases.

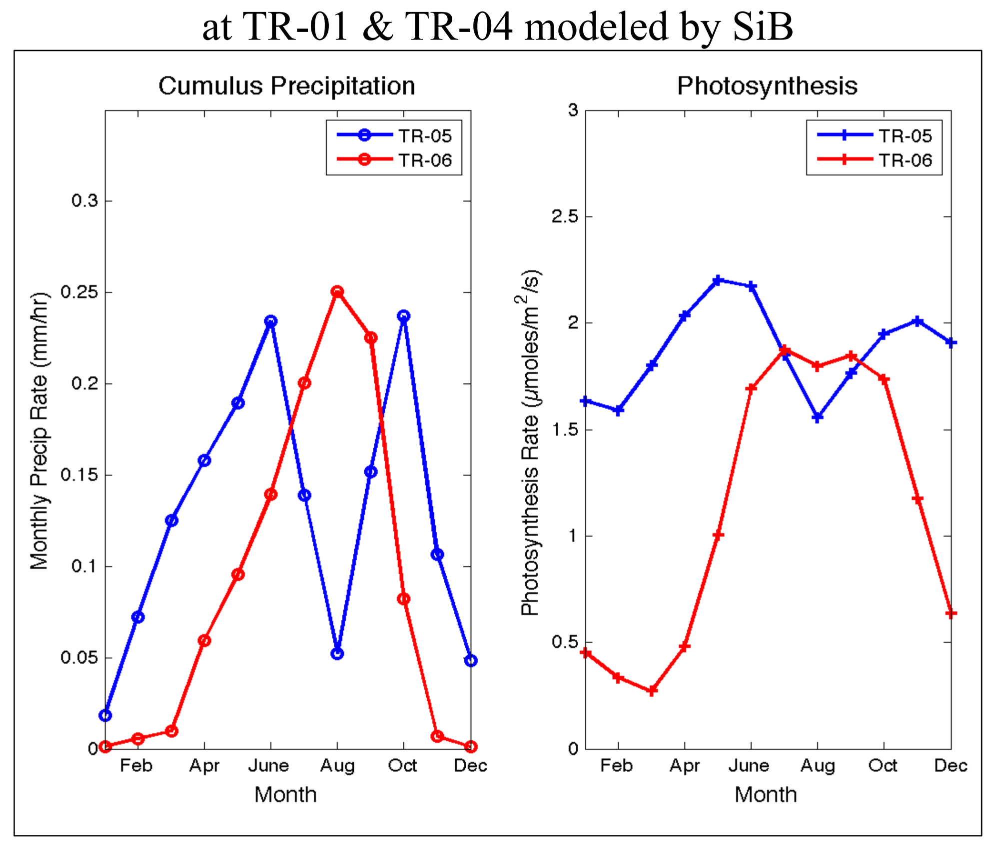
Figures 3 : Seasonality of precipitation and productivity at TR-05 & TR-06 modeled by SiB



In Figure 3:

- Productivity is greater in biome 9 than biome 7 due to a higher maximum in photosynthesis rates during the wet season.

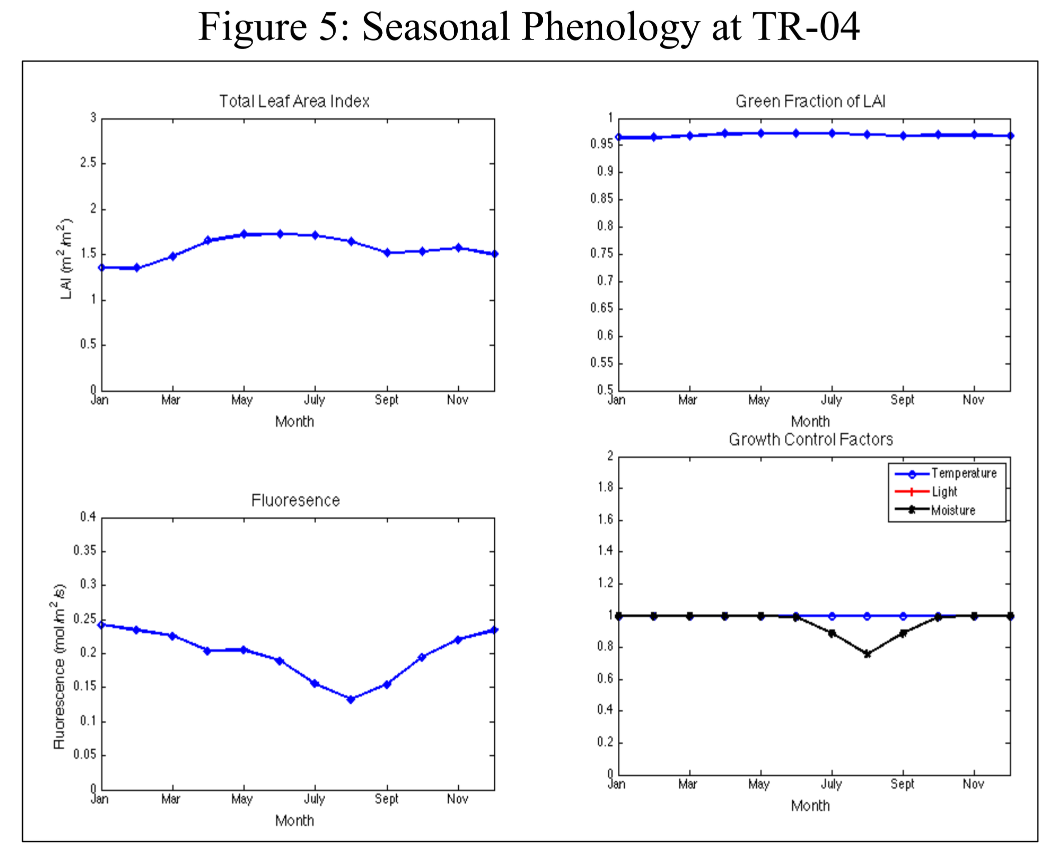
Figures 4 : Seasonality of precipitation and productivity at TR-01 & TR-04 modeled by SiB



In Figure 4:

- Maxima and minima in photosynthesis rates and precipitation occur during the same time period at all sites.
- The duration and time of the year of cumulus precipitation does not influence how responsive productivity is to the precipitation variability.

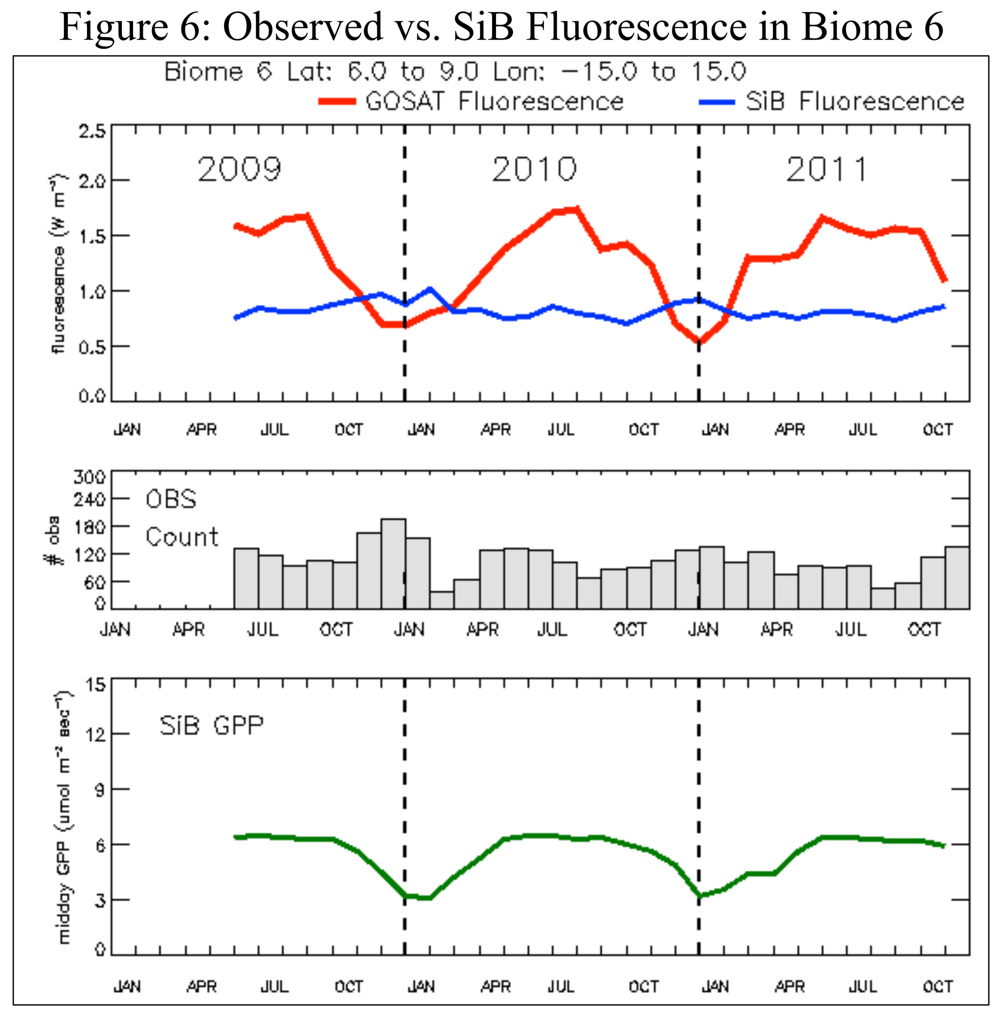
Figure 5: Seasonal Phenology at TR-04



In Figure 5:

- The factors governing the values of LAI and green fraction of LAI are the temperature, light, and moisture controls factors
- At all sites, very little seasonality is found in LAI, green fraction of LAI, and fluorescence.
- The growth controls factors exhibit a similar non-seasonality.

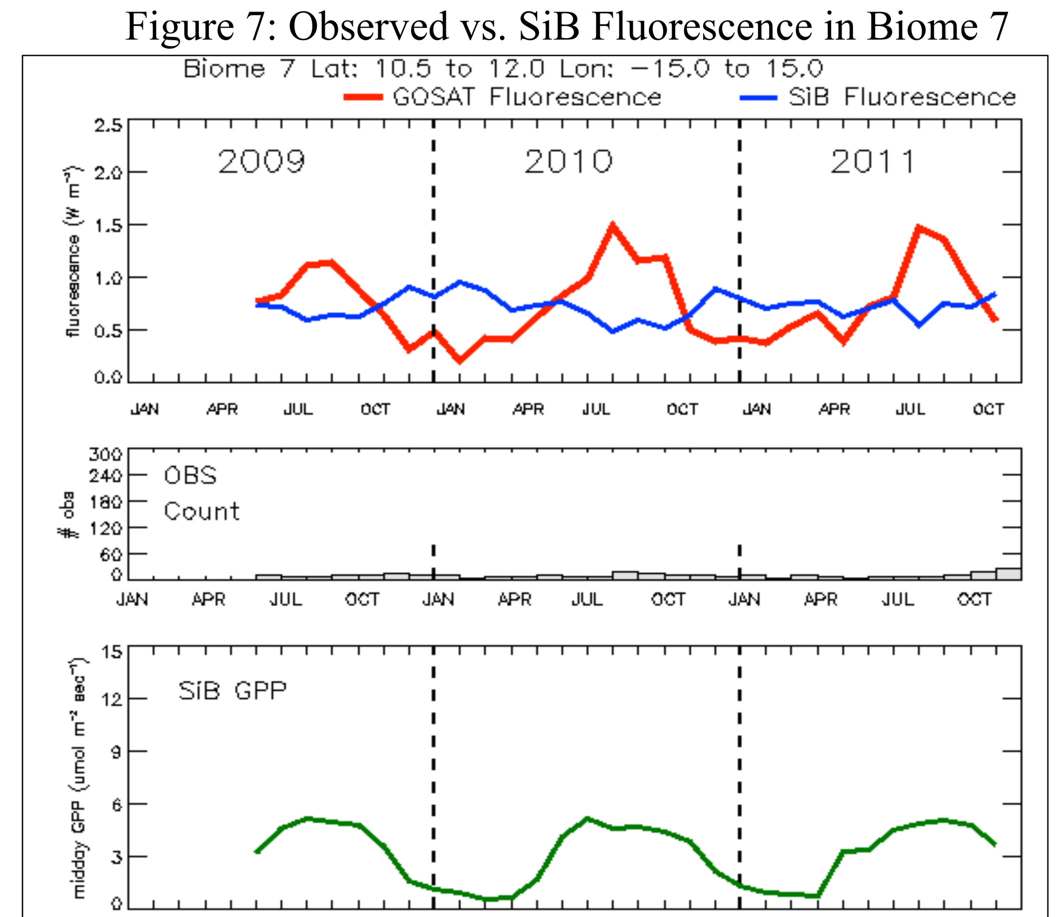
Figure 6: Observed vs. SiB Fluorescence in Biome 6



In Figure 6:

- SiB fluorescence and observed fluorescence have opposing seasonal trends.
- Observed fluorescence exhibits much greater seasonality than SiB fluorescence.
- SiB fluorescence and SiB productivity have opposing seasonal trends.
- The number of fluorescence observations has some seasonal trend, mainly dependent on cloud cover.

Figure 7: Observed vs. SiB Fluorescence in Biome 7



In Figures 6 & 7:

- In biome 7, SiB demonstrates more seasonality in fluorescence compared to biome 6.
- Observed fluorescence showed similar seasonal amplitude in biomes 6 and 7.
- Seasonality in productivity was generally the same between biome 6 and 7.
- Biome 7 had very little fluorescence observations compared to biome 6.

Conclusions

- SiB's productivity is governed by SiB's meteorology.
- No variability was found SiB's control factors which govern SiB's phenology.
- SiB's does not model fluorescence properly in this region.