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Vegetation dynamics and climate variability in North America and West Africa at seasonal– decadal scales – a study using the SSiB4/TRIFFID biophysical/dynamic vegetation model

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In the past three decades, numerous modeling sensitivity studies have established the importance of land/atmosphere interaction in climate system with specified vegetation. Recently, new evidence emerged from satellite data analyses indicates that including a fully coupled process is of imminent important in explaining the relationship discovered in these analyses. We apply the off-line Simplified Simple Biosphere Model version 4/Top-down Representation of Interactive Foliage and Flora Including Dynamics Model (SSiB4/TRIFFID) to investigate the interactions between vegetation dynamics and climate variability. The TRIFFID is a dynamic vegetation model, in which the relevant land-surface characteristics of vegetation cover and structure are modeled based on the surface carbon balance and the vegetation variables are updates, driven by carbon assimilation, allocation, and accumulation, as well as competition between plant functional types (PFT). SSiB4 is a biophysical model based on surface water and energy balance and produces carbon assimilation rate for TRIFFID with a parameterization scheme to directly relate surface albedo and surface aero dynamic resistances to TRIFFID-updated surface variables, such as leaf area index (LAI), for different PFTs.

The offline SSiB4/TRIFFID is integrated using the observed precipitation and reanalysis-based meteorological forcing from 1948 to 2006 with 1 degree horizontal resolution over North America and West Africa. West Africa is a diverse climatic and ecosystem region and suffered the most severe and longest drought in the world during the Twentieth Century since the later 1960s and North American climate and vegetation also shows strong trends during past 60 years in vegetation dynamics over several subregions due to climate change. The simulation results indicate that the model with relatively realistic forcing was able to produce reasonable vegetation PFT and LAI spatial distributions, generally consistent with the satellite products derived from satellites after the 1980s when the satellite data are available. The simulated LAI over the Sahel region exhibits interannual and decadal variability very well, consistent with the Sahel drought in the 1970s and the 1980s and partial recovery in the 1990s and the 2000s. The interannual and decadal variability in southeast U.S., mid-west and western U.S. also exhibit trends consists with satellite products. Meanwhile, the simulation deficiencies and possible causes will be discussed.

To investigate the mechanism of ecosystem, water, carbon, and radiation interactions, further sensitivity experiments are designed and analyses are conducted to find relationships between simulated LAI and environmental conditions. It is found that the vegetation characteristics simulated by SSiB4/TRIFFID responds primarily to five factors: air temperature, atmospheric carbon concentration, soil moisture, carbon assimilation rate, and absorbed photosynthetically active radiation. For instance, soil temperature plays a dominant role in northern N. America and southeast U.S, where a positive LAI trend during past two decades in both observation and simulation are substantial. In western U.S., higher temperature reduces vegetation productivity. The impact of U.S. drought on vegetation dynamics is evident. In West Africa, LAI of broadleaf trees and C4 plants generally negatively correlates with canopy temperature, and positively correlates with soil moisture. Results also indicate that the elevated atmospheric carbon concentration plays an important role in vegetation dynamics at interannual and decadal scales.