MODELING DROUGHT TOLERANCE IN AMAZONIA WITH SiB3

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ABSTRACT
The Amazon region of South America plays a significant role in global cycles of water, energy and carbon, yet it is also one of the most challenging biogeographical areas of the world to model correctly. Numerous global climate models have problems with anomalous die-back of the Amazon rain forest variously attributed to inadequate representation of rainfall, faulty soil moisture dynamics or an inability to correctly simulate the drought tolerance of the vegetation. Such misrepresentation of the Amazon in global climate models can cause larger than observed excursions of the global carbon cycle. This poster explores soil moisture and drought stress for Amazonia with the Simple Biosphere Model (SiB3) and possible reasons and solutions to the rain-forest die back problem, which should lead to more reasonable estimates of carbon fluxes at the ecosystem scale.

MODEL
SiB3 [*Sellers et al*, 1996; *Baker et al*, 2003] is a biophysical land surface model which describes the transfer of heat, water and carbon in the soil-vegetation-atmosphere continuum. SiB3 incorporates leaf-level physiology controlling photosynthesis and the Ball-Berry description of stomatal behavior which links water loss and carbon assimilation. Respiratory losses are parameterized diurnally and seasonally by partitioning respiration between the ten soil layers and the surface and regulating respiration rates through temperature, moisture and soil texture. SiB3 includes prognostic equations describing transfers of heat, water and carbon that also account for canopy air-space storage. We have also implemented the Community Land Surface model's soil moisture and temperature schemes into the SiB3 framework (http://www.cgd.ucar.edu/tss/clm/). SiB3 can be run at the ecosystem scale, as well as run coupled to regional atmospheric models and global climate models.

EXPERIMENT
Typical rooting profiles in land surface models place the bulk of the root fraction in the upper soil layers, decreasing exponentially with depth. When the thinner, upper soil layers dry out, evapotranspiration shuts down, curtailing photosynthesis as well. In tropical forests, large trees have access to deeper water reserves with tap roots, allowing them to maintain transpiration and photosynthesis in dryer seasons [*Nepstad et al*, 1994; *Canadell et al*, 1996]. We hypothesized that allowing the vegetation greater access to deep water would alleviate the excessive dry season efflux seen in SiB3. To implement this, we added a new soil water availability parameterizations to SiB3 to link total plant available water (PAW) throughout the root zone to stress on transpiration and photosynthesis. The vertical variation of transpiration in each soil layer is now dependent on both the root distribution *and* PAW by weighting the root fraction in each layer by the available water in that layer, giving a larger apparent root fraction in layers with more available water. Stress on the whole ecosystem is parameterized as a function of PAW within the total root zone, independent of root distribution.

OBSERVATIONS
The Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) is an international research initiative in the Amazon basin (http://lba.cptec.inpe.br/lba/indexi.html). In this poster we use observations from the Kilometer 83 flux tower site, a forested site that underwent selective logging in 2001 [*Miller et al*, 2003; *Miller et al*, 2004; *Goulden et al*, 2004; *Da Rocha et al*, 2004]. The Kilometer 83 site is located in the Tapajos national forest in Santarem, Para, Brazil. We used weather observations to drive the model for the years 2001 through 2003, which included 3 dry seasons (July-November). We then tested our results against observations of net ecosystem exchange (NEE), latent (LE) and sensible heat (H) flux.

RESULTS
The model was spun up from a saturated soil for five years to bring soil moisture and temperature profiles to equilibrium. It was then run from 2001 through 2003. In a typical model run, without the new PAW parameterization, dry season H is too high and dry season LE is too low. Further, dry season NEE is characterized by a large efflux of carbon not evident in the observations due to very low uptake of carbon and increased soil respiration. All of the modeled fluxes (H, LE, NEE) show too much seasonality when compared with observations.

We next ran the same simulation with the new PAW and ecosystem stress parameterizations. Though the severe drought response was delayed with the new scheme, NEE continued to show too large efflux in the dry season. The assimilation of carbon by the ecosystem was drastically reduced towards the end of the dry season while respiration remained too high. Dry season H was much greater than observed and dry season LE was much less than observed.

In SiB3, total soil depth remains constant across all biomes at 3.5 meters. This limits the total amount of water the soil profile can hold. Typical soils in the region of this study are deeper than those represented by SiB3. We hypothesized that deepening the soil column to a more realistic depth along with the new parameterization of soil water availability would give greater access to soil moisture reserves. To do this, we maintained the 10 layer soil structure in SiB3 but increased the depths of each layer by the same factor, creating a 10m deep soil column. We then ran the same simulation with the new PAW parameterization, but this time with the deeper soil column. The increase in soil depth and available soil moisture brought the simulations much closer in line with the observations, all fluxes (H, LE, NEE) showed much less seasonality. Dry season transpiration and assimilation were maintained better, though there was still too much efflux of carbon towards the end of the dry season. *Kleidon et al*, [1999] showed similar results for latent heat fluxes with deeper soil depths in the Amazon.

DISCUSSION

Model simulations for all fluxes (NEE, LE, H) showed improvement with a more realistic treatment of soil water availability and soil depth. The biggest gain came with the addition of deeper and thicker soil layers. Estimates of NEE show the model still has some difficulty with the partitioning of assimilation and respiration in both the dry and wet seasons, however the monthly mean magnitudes were much improved. It is possible that the continued seasonality problem is related to the treatment of soil respiration in SiB3. Observations show that when the top soil layers in this region become very dry, soil respiration is curtailed because of desiccation [*Saleska et al*, 2003, *Goulden et al*, 2004]. However, when the top soil layers dry out in the model they become warmer and since respiration from the soils is based on an exponential relationship with temperature, the warmer temperatures lead to increased soil respiration. Modeled soil respiration appears to be less sensitive to the decrease in soil moisture.

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