Amazonian Carbon Flux Sensitivity to Soil Depth

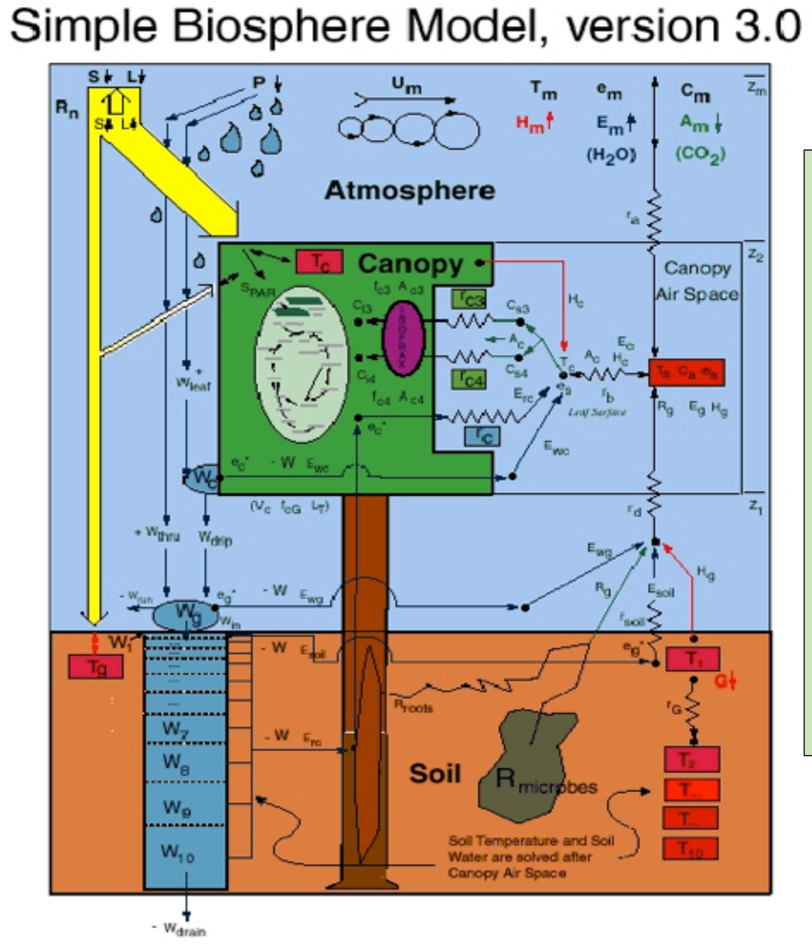
Isaac Fagerstrom[1], Ian Baker[2], Sarah Gallup[2], A. Scott Denning[2]
[1]Hamline University, St. Paul, Minnesota USA, [2]Colorado State University, Fort Collins, Colorado USA

Abstract

Models of land-atmosphere interaction are important for simulating present day weather and critical for predictions of future climate. Land-atmosphere interaction models have become increasingly complex in the last 30 years, leading to the need for further studies examining their intricacies and improvement. This research focuses on the effect of variable soil depth on Amazonian Gross Primary Production (GPP), respiration, and their combination into overall carbon flux.
We evaluate a control, which has a universal soil depth of 10 meters, with two experiments of variable soil depths. To conduct this study we ran the 3 models for the period 2000-2012, evaluating similarities and differences between them. We focus on the Amazon rain forest, and compare differences in components of carbon flux.
Not surprisingly, we find that the main differences between the models arises in regions where the soil depth is dissimilar between models. However, we did not observe significant differences in GPP between known drought, wet, and average years; interannual variability in carbon dynamics was less than anticipated. We also anticipated that differences between models would be most significant during the dry season, but found discrepancies that persisted through the entire annual cycle.

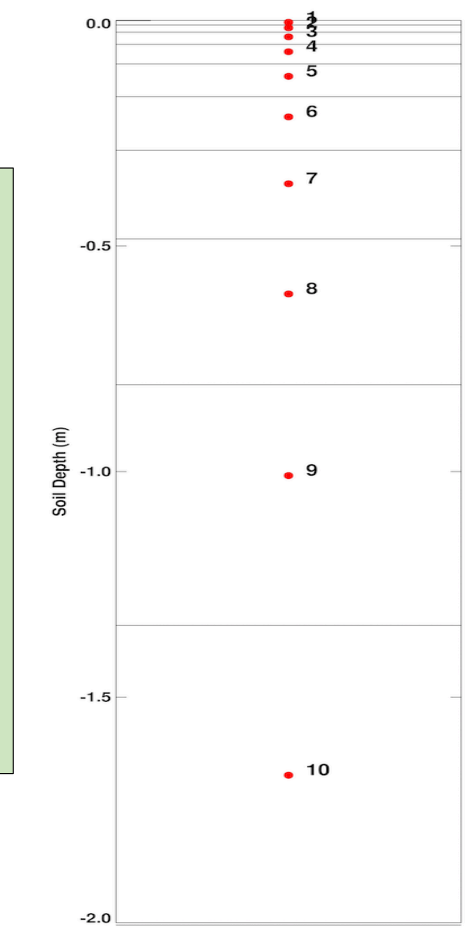
Models and Data

Simple Biosphere Model, version 3.0



SiB3

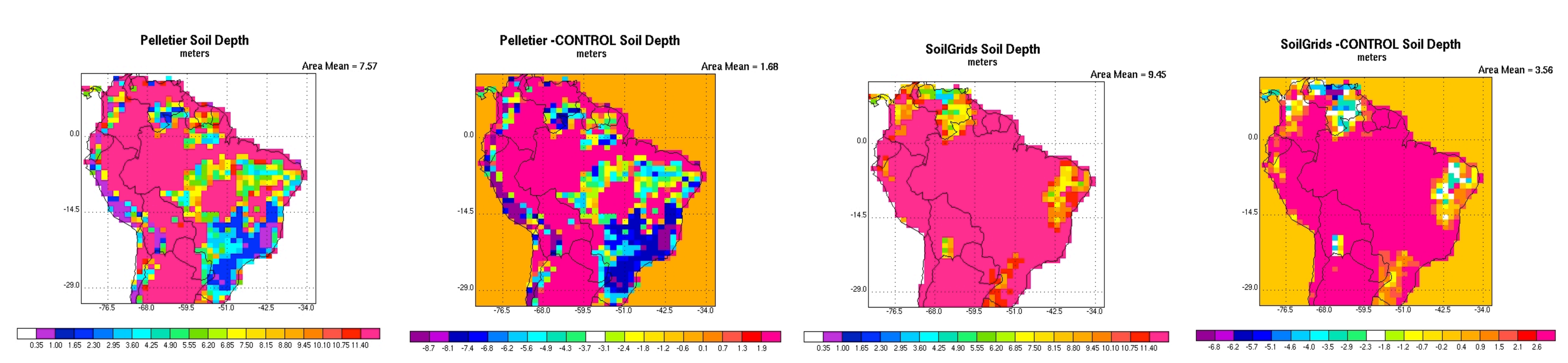
- Land-atmosphere interaction model used in this study.
- Introduced in 1986 (1986 Sellers et al., 1996 Sellers et al., 2008 Baker et al.)
- Enzyme kinetic model.
- Physically based model versus a statistical basedmodel.
- Has a long history of use as a lower boundary in climate models, mesoscale models, and decoupled applications.

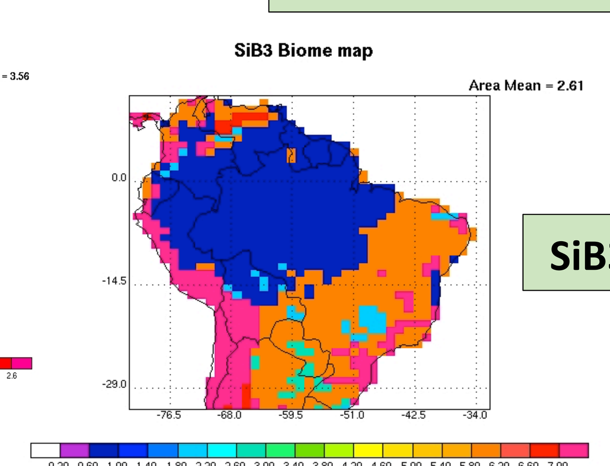


Soil Depth = 2.0
seed= 0.0146

LEVEL	NODE	DZ	LAYER
01	0.0041	0.0102	0.0102
02	0.0163	0.0161	0.0263
03	0.0364	0.0266	0.0529
04	0.0694	0.0438	0.0967
05	0.1239	0.0722	0.1689
06	0.2138	0.1190	0.2879
07	0.3619	0.1962	0.4841
08	0.6062	0.3235	0.8076
09	1.0089	0.5334	1.3409
10	1.6729	0.6640	2.0049

SiB3 Model Soil Layers at 2 Meters





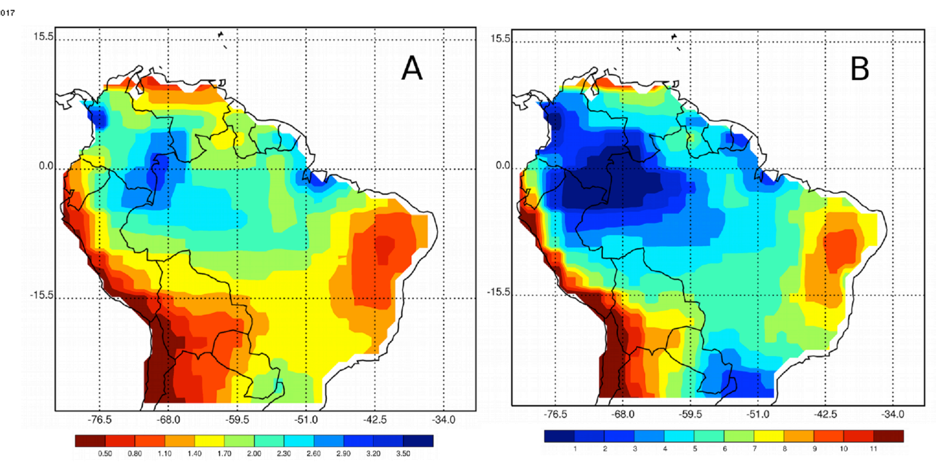
SiB3 Amazon Biome Map

Pelletier (Pelletier et al. 2015)

- Partitions data into upland hillslope, upland valley bottom, and lowland landscape components.
- Uses models specialized for each landform type to estimate thickness of subsurface layers.
- Used geologic data from sources such as the U.S. Geological Survey and UNESCO.

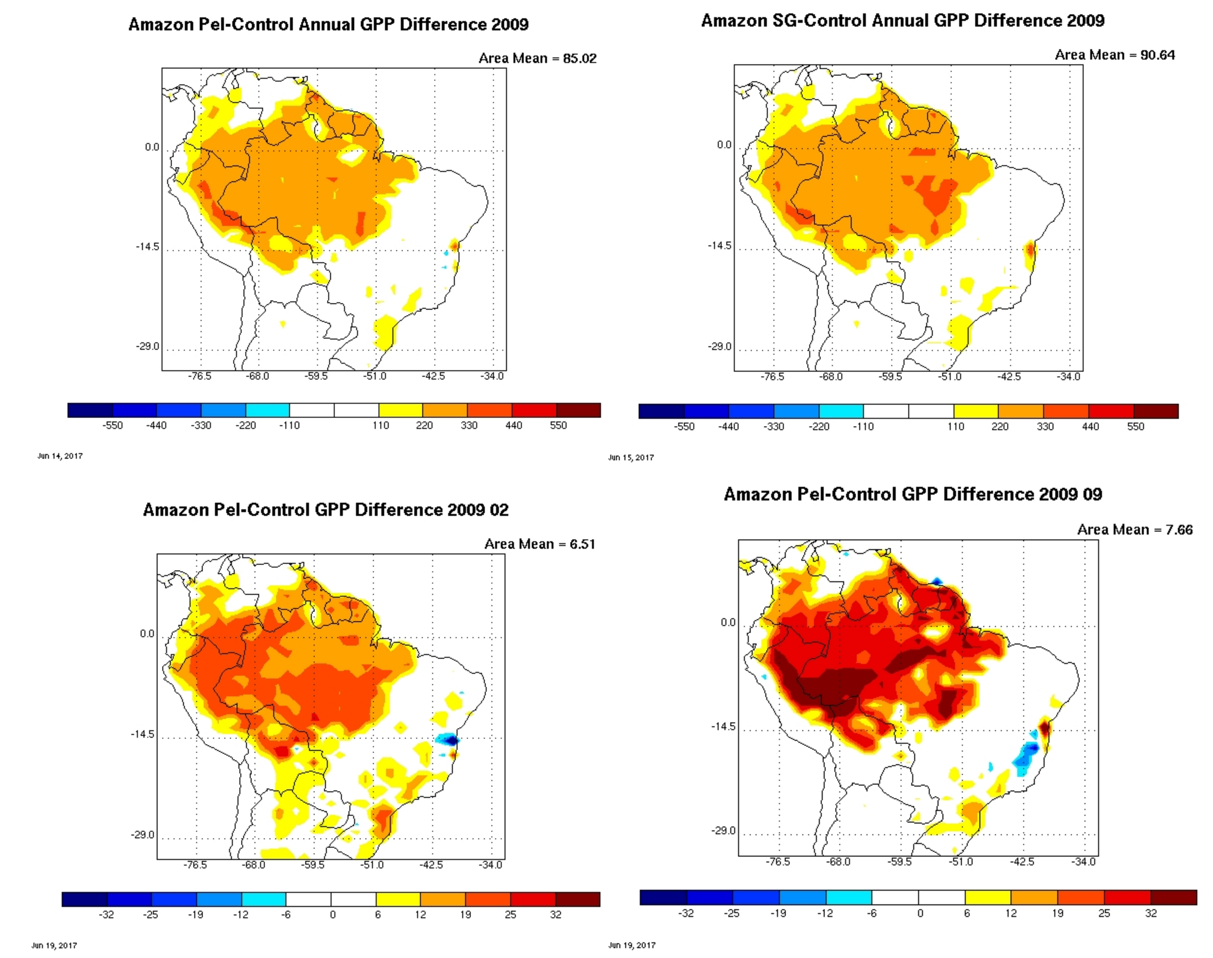
SoilGrids (Shangguan et al. 2016)

- Uses soil profile data from ~150,000 sites spread over all continents.
- SoilGrids provides global predictions for standard numeric soil properties such as: organic carbon, bulk density, Cation Exchange Capacity (CEC), pH, soil texture fractions and coarse fragments.
- Uses seven standard soil depths (0, 5, 15, 30, 60, 100 and 200 cm).



- **Plot A** is the annual mean precipitation in meters.
- **Plot B** is the length of the dry season in months (number of months where monthly precip. Is > 100 mm).
- Means are taken from 1983-2006 taken from the GPCP (Adler et al. 2003).

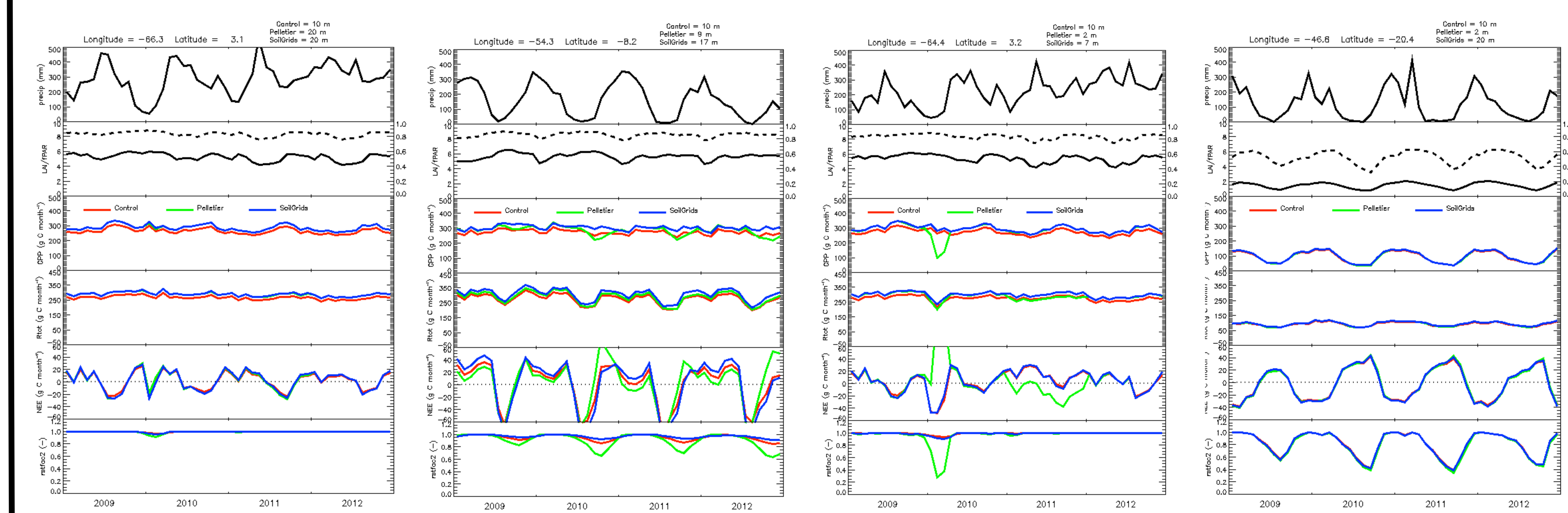
Results



- 2009 is used as an example year.
- The overall pattern of annual Gross Primary Production (GPP) reflects that of that of the soil depth maps; deeper soil gives you a higher mean annual GPP.
- Mean annual GPP patterns also follow the SiB3 Biome map, where the areas with highest GPP are in the Broadleaf Evergreen Forest.

$$FLUX_{CO_2} = \frac{\rho\, C_p}{\gamma\, r_{can}}[CO_{2a} - CO_{2i}]$$

- Areas with deeper soils were found to have more GPP.
- This causes an increase in canopy CO2 (CO2a).
- The gradient at the end of the equation increases due to the imbalance.



- Time series plots for the years 2009-2012.
- As the soil layers go below 6 meters, the top layers remain thin to allow
- Grasslands (far right) had the smallest difference between the control and experiments, and took the hardest hits during season changes due to their shallow roots.
- The 3 points from the left are all forests; despite their deeper root systems they still show little variance between models.

Conclusions and Further Work

- Main differences between models arises in areas where soil depth is dissimilar between models.
- Interannual variability in carbon dynamics was less than anticipated.
- Differences between models were found to persist throughout the year, rather than seasonally as we anticipated.
- Further studies should examine other regions of the globe, as well as use different variables to compare models.

References

Shangguan, W., T. Hengl, J. Mendes deJesus, H. Yuan, and Y. Dai (2017),Mapping the global depth to bedrockfor land surface modeling, J. Adv.Model. Earth Syst., 9, doi:10.1002/2016MS000686.
Pelletier, J. D., P. D. Broxton,P. Hazenberg, X. Zeng, P. A. Troch,G.-Y. Niu, Z. Williams, M. A. Brunke, andD. Gochis (2016), A gridded global dataset of soil, immobile regolith, andsedimentary deposit thicknesses forregional and global land surfacemodeling, J. Adv. Model. Earth Syst., 8,doi:10.1002/2015MS000526.
Sellers et al. 1986, Sellers et al. 1996, Adler et al. 2003 Baker et al. 2008

Acknowledgements

This work has been supported by the National Science Foundation Research Experiences for Undergraduates Site in Climate Science at Colorado State University under the cooperative agreement No. AGS-1461270.