Understanding the Response of Photosynthetic Metabolism in Tropical Forests to Seasonal Climate Variations

Dennis G. Dye[1], Scott R. Saleska[2], Valeriy Ivanov[3], Alfredo Huete[4], Jin Wu[2], Loren Albert[2], Rodrigo da Silva[5], Bruce Nelson[6], Luiz Aragao[7], Marciel J. Ferreira[8]

[1]U.S. Geological Survey, Western Geographic Science Center, [2]University of Arizona, Dept. of Ecology and Evolutionary Biology, [3]University of Michigan, Dept. of Civil and Environmental Engineering, [4]University of Technology, Sydney, Australia, [5]Federal University of West-Para (UFOPa), Santarem, Brazil, [6]National Institute of Amazonian Research (INPA), Brazil, [7]National Institute for Space Research (INPE), Brazil, [8]Federal University of Amazonas (UFAM), Brazil

This U.S-Brazil collaboration investigates a fundamental question in Earth system science and tropical forest ecology: what controls the response of photosynthesis in evergreen tropical forests to seasonal variations in climate? This question reflects a scientific problem that heretofore could not be solved with confidence. The seasonal patterns of photosynthesis in Amazon tropical forests simulated by state-of-the-art Earth system models disagree with observations: satellite-based records of forest "greenness" and tower-based measurements of carbon dioxide exchange. Models assume that lower precipitation in tropical forests means less plant-available water and less photosynthesis, yet the observations show that production remains constant or increases in the dry season. Such disagreement highlights a major source of uncertainty in efforts to understand global carbon-climate interactions and to forecast future climate: current Earth system models do not adequately account for the extent, magnitude, and controls on photosynthetic seasonality in evergreen tropical forests. Our research solves this problem by providing new knowledge and deeper understanding of seasonal climate-photosynthesis relations in tropical forests of the Brazilian Amazon, across a gradient of dry season length between Manaus (with a short dry season) and Santarem (with a long dry season). The methods involve intensive field campaigns to measure physiological and ecohydrologic properties of leaves and trees, camera systems to monitor forest growth at tree crown and canopy scales, and photosynthesis modeling that accounts for the 3-dimensional forest structure and light environment. Here we present recent, significant findings from the research.

Analysis of hydraulic relations in trees at our Amazon study sites, using ecohydrologic data (stem sapflow, water potential, and gas exchange), reveal distinct hydraulic strategies that convey different levels of resilience to short- (diurnal) and longer-term (seasonal) water stress periods. These hydraulic strategies appear to be inter-related with tree growth and non-structural carbohydrate dynamics, contributing to the understanding of trait coordination at the whole-plant scale. The integrated individual responses over a range of wood density and light exposure conditions show temporal changes of the forest response to 2015-2016 El Nino conditions. Our tower-based cameras enabled investigation of the phenology (seasonal pattern) of leaf dynamics in tree crowns and their relation to patterns of carbon dioxide flux. The analysis showed the synchronization of new leaf growth with dry season litterfall shifts canopy leaf composition toward younger, more light-use efficient leaves, thus explaining large seasonal increases (~27%) in ecosystem photosynthesis. Accounting for age-dependent variation among individual leaves and crowns is therefore necessary for reliable modeling of the seasonal dynamics of photosynthesis in the entire ecosystem. These results highlight the importance of tree hydraulic strategies and leaf level phenology in regulating land surface fluxes of carbon and water, and associated feedbacks to climate. This new knowledge and understanding can guide improvements in the treatment of tropical forest systems in models of the global carbon cycle and the Earth's climate system.