Geophysical Research Abstracts
Vol. 17, EGU2015-13067, 2015
EGU General Assembly 2015


# Improving carbon model phenology using data assimilation

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Carbon cycle dynamics is significantly impacted by ecosystem phenology, leading to substantial seasonal and inter-annual variation in the global carbon balance. Representing inter-annual variability is key for predicting the response of the terrestrial ecosystem to climate change and disturbance. Existing terrestrial ecosystem models (TEMs) often struggle to accurately simulate observed inter-annual variability. TEMs often use different phenological models based on plant functional type (PFT) assumptions. Moreover, due to a high level of computational overhead in TEMs they are unable to take advantage of globally available datasets to calibrate their models.

Here we describe the novel CARbon DAta MOdel fraMework (CARDAMOM) for data assimilation. CARDAMOM is used to calibrate the Data Assimilation Linked Ecosystem Carbon version 2 (DALEC2) model using Bayes' Theorem within a Metropolis Hastings – Markov Chain Monte Carlo (MH-MCMC). CARDAMOM provides a framework which combines knowledge from observations, such as remotely sensed LAI, and heuristic information in the form of Ecological and Dynamical Constraints (EDCs). The EDCs are representative of real world processes and constrain parameter interdependencies and constrain carbon dynamics.

We used CARDAMOM to bring together globally spanning datasets of LAI and the DALEC2 and DALEC2-GSI models. These analyses allow us to investigate the sensitivity ecosystem processes to the representation of phenology. DALEC2 uses an analytically solved model of phenology which is invariant between years. In contrast DALEC2-GSI uses a growing season index (GSI) calculated as a function of temperature, vapour pressure deficit (VPD) and photoperiod to calculate bud-burst and leaf senescence, allowing the model to simulate inter-annual variability in response to climate. Neither model makes any PFT assumptions about the phenological controls of a given ecosystem, allowing the data alone to determine the impact of the meteorological drivers.

DALEC2-GSI showed a more realistic response to climate variability and fire disturbance than DALEC2. DALEC2-GSI more accurately reproduced the assimilated global LAI time series, particularly in areas with high levels of disturbance. This result is supported by more ecologically consistent trait combinations generated by the DALEC2-GSI calibration. In addition, using DALEC2-GSI we are able to map global information on ecosystem traits such as drought tolerance and adaptation to repeated fire disturbance. This demonstrates that utilizing data assimilation provides a useful means of improving the representation of processes within models.