Informing carbon dynamics in the Community Land Model with Data Assimilation

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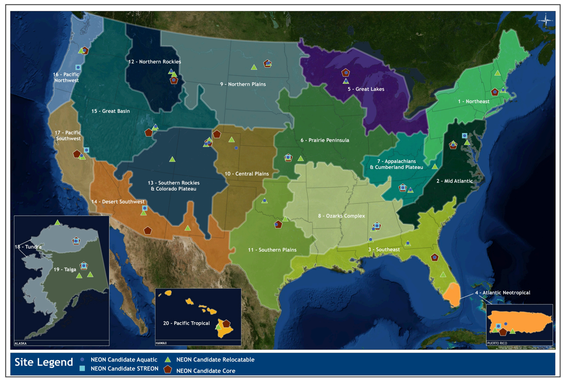
Background

Correct simulation of carbon dynamics in Earth System Models is required to accurately predict both short and long-term land carbon-cycle climate and concentration feedbacks. As new model structures and parameterizations of increasing complexity are introduced there is an ever present need for data to inform these developments, either indirectly through testing and benchmarking activities, or directly through model-data fusion techniques.

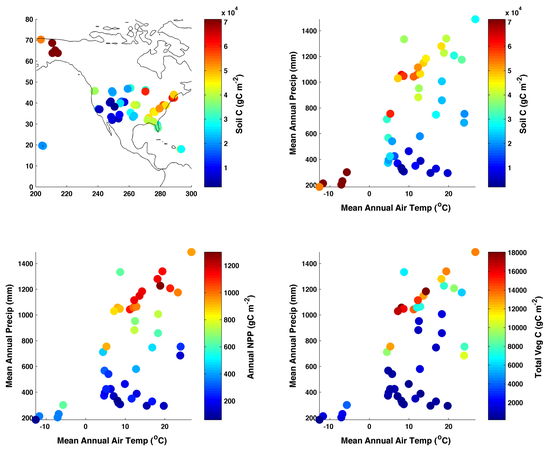
A very rich source of data will come from the National Ecological Observatory Network (NEON), a continental-scale facility under construction that will collect freely available ecological data from 60 sites representative of a full range of ecosystems and climate zones across the USA over 30 years.



NEON domains and site locations across the USA.

NEON in CLM-space

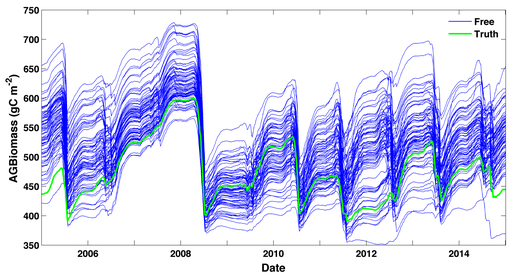
NEON sites are instrumented to observed biogeochemical and biophysical interactions between the atmosphere and land surface, and belowground. To illustrate the potential utility of these data in constraining models, we show the range of Community Land Model (CLM4.5-BGC) output at NEON site locations. In model-space it is possible to see a number of different functional responses that characterize the model in space and time.



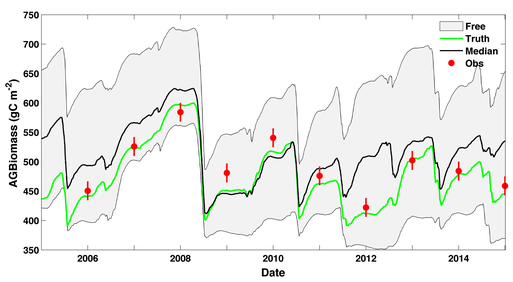
Carbon stocks and fluxes variation between NEON sites.

Observing System Simulation Experiment with Annual Observations

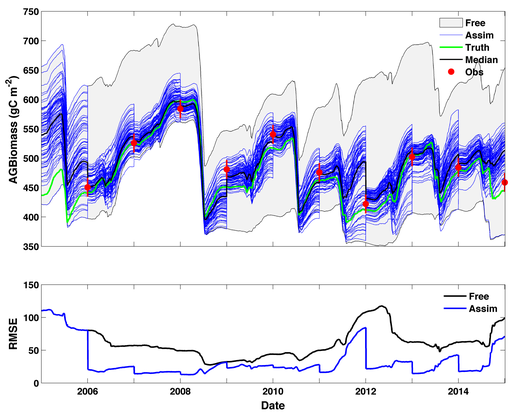
We have successfully coupled CLM4.5-BGC with the Data Assimilation Research Testbed (DART), an advanced community facility for ensemble data assimilation developed and maintained at the National Center for Atmospheric Research. Previously we have demonstrated the utility of high temporal frequency AmeriFlux and MODIS observations, here we investigate the impact of assimilating annual biomass and NPP observations. In a perfect model experiment we run 80 model ensemble members at the US-Mpj AmeriFlux site location for 10 years, treating one ensemble member as "truth" and sample with measurement error for biomass and NPP at annual timesteps.



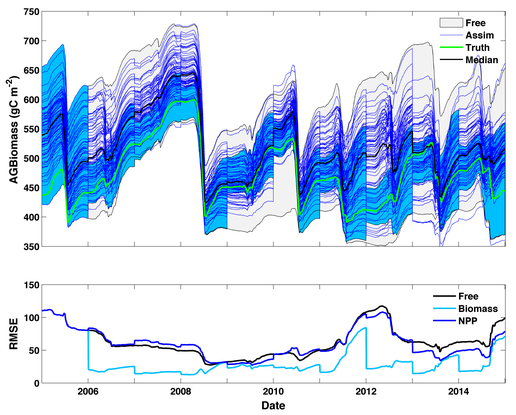
(i) Above ground biomass simulated by 80 CLM ensemble members. One member is randomly assigned as "truth".



(ii) Annual observations of biomass are generated from the truth with a prescribed observation uncertainty.

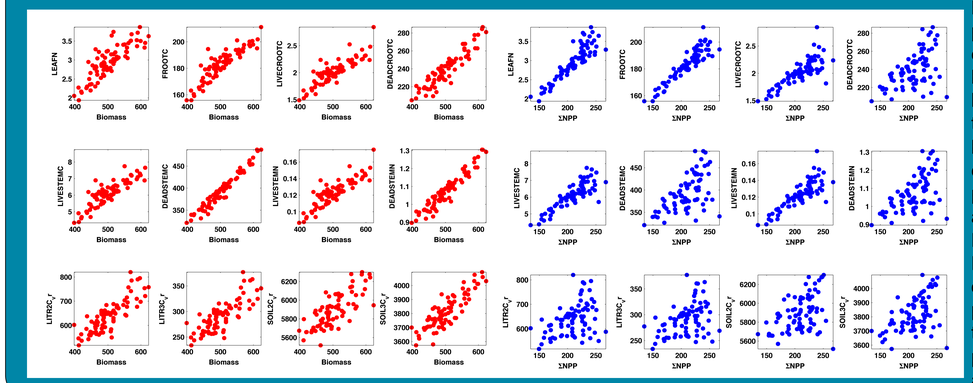


(iii) Assimilation greatly reduces uncertainty (spread) and decreases error. There is considerable inter-annual variability on the impact this has on the annual forecast.



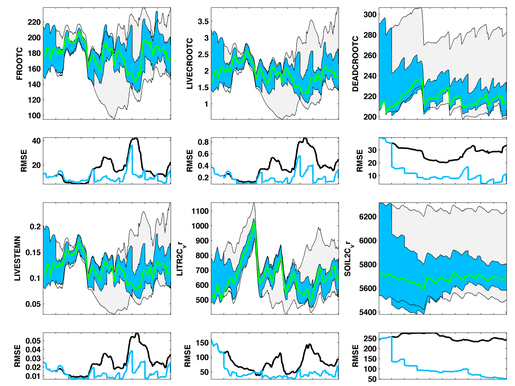
(iv) Assimilating annual NPP (data not shown) has a much more limited impact on modeled above ground biomass uncertainty and error.

Correlations between model state variables updated by the filter and annual biomass and NPP observations

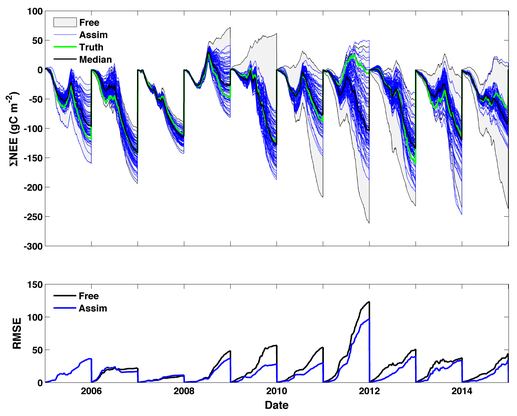


Both large and small carbon pools in the model are well correlated with above ground biomass (calculated as leafc + livestemc + deadstemc). Thus this observation type proves to be a powerful constraint. In contrast, only the small carbon pools with rapid turnover rates are well correlated with annual NPP. This is because annual NPP integrates carbon uptake over a much shorter time period relative to biomass and the relationship to large carbon pools is effected by inter-annual climate variability.

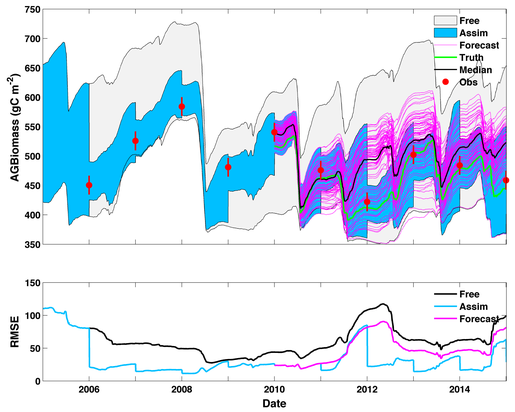
Unobserved States and Fluxes



15 additional unobserved carbon and nitrogen pools are updated in the assimilation. In all cases uncertainty and error are reduced.



The impact of these state updates on fluxes is considerable. In some years error in cumulative annual NEE forecasts is reduced by 50%.



The impact of assimilation on multi-year forecasts is demonstrated by assimilating 5 years of data, then forecasting for 5 years. Uncertainty and error remains lower than in the free run at the end of the forecast period.

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