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Can time series of plant water potential constrain carbon cycle dynamics using the CARDAMOM model-data fusion framework?

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Vegetation water content varies in response to the shifting balance between transpiration loss and water supply through the soil--plant--atmosphere continuum. These variations are coupled to carbon dynamics by stomatal regulation of gas exchange, linking transpiration and photosynthesis, and through rootzone soil moisture, determined in part by the allocation and turnover of carbon to roots. Microwave sensors have been demonstrated to be sensitive to variations in vegetation water content and related measures of plant hydraulic status, such as plant water potential (PWP). We use synthetic experiments representative of a European deciduous forest to explore whether time series observations of PWP can constrain an intermediate complexity terrestrial ecosystem model (DALEC) with fully coupled carbon and water balances using a Bayesian model-data fusion framework (CARDAMOM). To generate a synthetic truth, we calibrated DALEC using detailed site-specific inventory data from the Hainich ICOS site (DE-Hai), spanning 2006-2011, from which we generated a synthetic time series of average daily mean PWP. The Hainich forest is a temperate forest dominated by beech and established on clay-rich soil. We used the calibrated model as the basis for a series of synthetic data assimilation experiments under conditions of reduced data availability to represent information typically available from satellites and/or global products (e.g. Leaf Area Index, aboveground biomass, soil characteristics) to assess the potential to constrain C cycle dynamics using information on time varying PWP. We compared the diagnostics to a baseline experiment with no assimilated PWP information. Assimilation of PWP reduced the bias in estimates of GPP and ET relative to the synthetic "truth", with a small reduction in the width of the 90% confidence range, compared to the baseline experiment. PWP observations provided more notable constraints on model parameters that were connected to plant hydraulics and water supply, including root dynamics. The emergent constraint on root dynamics is significant, because below-ground processes are inherently challenging to observe remotely. Assimilating PWP also constrained within-ensemble covariance between certain parameter pairings, and between fluxes, particularly pairings linked to the water balance, and between the water balance and productivity, highlighting the potential for enhanced constraint through the addition of complementary information. Once the signal noise exceeded 0.20 MPa, there was very limited information transfer into either the model parameters retrieved during the inversion, or the resultant fluxes. Our synthetic experiments demonstrate the potential

for satellite estimates of PWP (e.g. through microwave VOD) to provide constraints on carbon-water coupling, that these constraints extend to both fast processes (GPP, ET), and slower processes (root dynamics), and that such observations would be highly complementary to C-cycle information from other EO data streams.