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Synthetic data experiment to test the accuracy of methods estimating carbon uptake period from atmospheric CO_2 time-series

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Atmospheric CO_2 measurements from background sites across the Northern Hemisphere have been used to study the changes in the carbon uptake period (CUP) i.e., when plants are able to grow and assimilate carbon from the atmosphere. Previous studies that use CO_2 dry air mole fraction data diagnosed CUP using zero-crossing dates (ZCD, when the detrended seasonal cycle switches from positive to negative sign and vice versa). The CUP can also be estimated using the first derivative of the CO_2 seasonal cycle. In previous work we show that applying the first derivative method to an ensemble of fitted CO_2 mole fraction curves provides better constraints to the CUP by considering year-to-year uncertainty in estimates across the ensemble members. We call this the ensemble of first derivative method (EFD method). In addition to curve fitting uncertainty and year-to-year flux variability, atmospheric transport might explain a significant portion of observed CO_2 variations at various surface stations, affecting the interpretation of the CUP and similar metrics.

Hence, in this study we examine how atmospheric transport of fluxes, and spatial variations in the start and ending dates of carbon uptake, smooth the signal in atmospheric CO_2 and affect the CUP estimates when using remote background observation sites to interpret actual fluxes. We use a synthetic data experiment where idealized NEE fluxes are transported forward (with atmospheric transport model TM3 (Heimann and Körner, 2003) and fixed year meteorology) and the atmospheric concentrations are sampled at the location of the measurement sites. A fixed year from the Jena CarboScope Inversion (Rödenbeck et al., 2003, doi:10.17871/CarboScope-sEXTocNEET_v2022) was used to generate an idealized NEE flux time series with no interannual variability in the CUP at any given pixel. Then, we prescribe changes in the CUP of NEE flux to Northern Hemisphere land pixels with clear seasonal cycles and evaluate the accuracy of the ZCD and EFD methods in capturing this known change from CUP in the surface fluxes, from the resulting CO_2 mixing ratio obtained from the forward transport run.

We find that CUP changes estimated by both EFD and ZCD based on CO_2 measurements are smaller by a factor of 2-4 than the perturbations applied in NEE space, and that the EFD method is more sensitive to surface CUP changes than the ZCD. This " dampening" factor varies across sites, depending on the mixing of spatially varying NEE signals with differing CUP

timing which integrate to a reduced atmospheric expression of CUP. We further analyse the contribution of 1) atmospheric transport by comparing simulation that uses inter annually varying meteorology 2) different TransCom-3 regions to CUP variations by selectively manipulating NEE flux from a region and repeating the experiment.

References:

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