Geophysical Research Abstracts
Vol. 18, EGU2016-14125, 2016
EGU General Assembly 2016

Influence of soil moisture-carbon cycle interactions on the terrestrial carbon cycle over Europe

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Water availability is a crucial limiting factor for terrestrial ecosystems, but relatively few studies have quantitatively assessed the influence of soil moisture variability on the terrestrial carbon cycle. Here, we investigate the role of soil moisture variability and state in the contemporary terrestrial carbon cycle over Europe. For this we use a Regional Earth System Model (RESM) based on the COSMO-CLM Regional Climate Model, coupled to the Community Land Model version 4.0 (CLM4.0) and its carbon-nitrogen module. The simulation setup consists of a control simulation over the period 1979-2010 in which soil moisture is interactive and three sensitivity simulations in which soil moisture is prescribed to a mean, a very dry or a very wet seasonal cycle without inter-annual variability. The cumulative net biome productivity varies markedly between the different experiments ranging from a strong sink of up to 6PgC in the wet experiment to a source of up to 1.2PgC in the dry experiment. Changes in the land carbon uptake are driven by a combination of two factors: the direct impact of soil moisture on plant's carbon uptake (essentially in southern Europe) and an indirect effect through changes in temperature affecting ecosystem respiration (mainly in central and northern Europe). We find that removing temporal variations in soil moisture dampens interannual variations in terrestrial carbon fluxes (Gross Primary Productivity, respiration, Net Biome Productivity) by more than 50% over most of Europe. Moreover, the analysis reveals that on annual scale about two-thirds of central Europe and about 70% of southern Europe display statistically significant effect of drying and/or wetting on the terrestrial carbon budget and its components. Our findings confirm the crucial role of soil moisture in determining the magnitude and the inter-annual variability in land CO_2 uptake which is a key contributor to the year-to-year variations in atmospheric CO_2 concentration.