Geophysical Research Abstracts
Vol. 20, EGU2018-14168, 2018
EGU General Assembly 2018

Simulating surface interactions of the carbon cycle and its impact on atmospheric CO_2 concentrations with a high spatiotemporal resolution model framework.

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Surface heterogeneity can be challenging to fully encompass by modelling studies of surfaces exchanges of CO_2. By developing a mesoscale modelling framework capable of simulating surface exchanges at a high spatiotemporal resolution, this study examines the relative importance of the marine and the terrestrial surface fluxes on the atmospheric CO_2 concentration during 2011-2014 across the complex landscape of Denmark – a country which contains many land-sea boarders along its 7300 km of coastline.

An atmospheric transport model, DEHM, with a horizontal spatial resolution of 5.6 km x 5.6 km constituted the basis of the modelling framework. A mechanistic biosphere model, SPA, was coupled to DEHM in order to simulate the terrestrial surface exchanges with an hourly temporal resolution. A tiling approach with the seven most dominant land-use classes in Denmark was applied to account for sub-grid heterogeneity. The land-use classes were parametrized in SPA by the use of experimental data from Danish sites measuring fluxes of CO_2 and energy. Detailed surface fields of surface water pCO_2 including diurnal variability were developed based on measurements obtain in the study region to simulate the air-sea CO_2 exchange. Comparisons to independent observational data showed a good level of agreement between the modelling framework and observations.

During 2012 equipment was installed in the tall tower at the Risø site located on the shore of Roskilde Fjord to measure atmospheric CO_2 concentrations, making this the first tall tower in Denmark to observe atmospheric CO_2. Here, the first data from the site are presented, and in general the model system match the atmospheric CO_2 measurements made during 2013-2014 well. The origin of the simulated CO_2 concentrations at Risø varied between seasons with fossil fuel emissions and biospheric fluxes having the largest impact on the variations, while the local impact from the Roskilde Fjord at the Risø site was difficult to detect by the modelling framework. This could indicate that the Roskilde Fjord was not sufficiently resolved in the present model system, or that the fjord simply is not in the footprint of the tall tower. However, an impact from Danish inner inner waters and the Baltic Sea were detected in the oceanic contribution to the simulated atmospheric concentrations at the site.

The relative importance of the seven land-use classes on the Danish biospheric fluxes simulated by the SPA-DEHM model system varied throughout the year according to their individual growth patterns. For 2011, the total annual Danish biospheric uptake was -6302 GgC/yr and the marine uptake was 863 GgC/yr. Relating the annual natural surface fluxes to the CO_2 emitted by fossil fuel combustions and industrial processes by Denmark, it was found that the Danish terrestrial uptake corresponded to 52% of these, while the Danish marine uptake was equal to 7%.