INSIGHTS FROM SIMULATIONS WITH HIGH-RESOLUTION TRANSPORT AND PROCESS MODELS ON SAMPLING OF THE ATMOSPHERE FOR CONSTRAINING MID-LATITUDE LAND CARBON SINKS

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ABSTRACT
Based on simulations with high-resolution transport models we investigate the detectability of surface flux signals in the atmospheric CO_2 concentration and infer some general guidelines for the sampling of the continental troposphere for the purpose of constraining mid-latitude land carbon sinks.

INTRODUCTION
Atmospheric CO_2 concentration data from the past four decades combined with fossil fuel emission data indicate the existence of a substantial sink on land. The same data show also that land carbon pools are quite dynamic. Narrowing the location and the main mechanisms responsible for land carbon uptake and flux variability however has proven difficult. Recently efforts to ameliorate the situation have started. Nonetheless, since continental near-surface CO_2 is highly variable it is not yet clear which atmospheric sampling strategy is most promising for characterizing land sources and sinks. To shed some light on this question we use in this study two spatially highly resolving atmospheric transport models.

MODEL SETUP
Both regional transport models, REMO [*Chevillard et al.*, 2002] and MM5/HANK [*Hess et al.*, 2000], are used together with the terrestrial biosphere model TURC (Terrestrial Uptake and Release of Carbon) [*Lafont et al.*, 2002] in order to include the land biosphere variability in a quite realistic way. The remaining two carbon flux components that determine the atmospheric CO_2 distribution, atmosphere-ocean CO_2 exchange and CO_2 release as a result of fossil fuel burning are prescribed from global datasets. In the current set up the horizontal grid resolution is 55 km x 55 km in REMO and 90 km x 90 km in HANK. The use of more than one model permits us to obtain a handle on the dependence of our conclusions on the representation of transport. In our study we focus on Europe and western Siberia but as the main determinants of the variability of atmospheric CO_2 are similar, the conclusions of this study should be transferable to North America as well. The simulations cover a summer period (July 1998). A comparison with observation data shows that the models reproduce the observed synoptic and diurnal variations of CO_2 fairly realistically.

DETECTABILITY OF CO_2 SIGNALS
Our analysis focuses on the ratio of the monthly mean afternoon signal of a realistic perturbation of Eurasian summer biospheric fluxes by 20% that is superposed on background "noise" created by fossil fuel emissions, an unperturbed terrestrial biosphere and ocean-atmosphere carbon exchange. In the definition of the signal-to-noise ratio we account for the temporal autocorrelation of CO_2 and also include a potential instrument precision. We restrict our analysis to a selective daytime sampling (1100 to 1700 local time) in order to avoid uncertainties due to the high nighttime concentrations close to the surface that are difficult to model because the amount of accumulated CO_2 in the shallow nocturnal boundary layer depends strongly on the local surface fluxes. The signal-to-noise ratio resulting from REMO simulations is shown in Fig. 1. Although the signal of the 20% biospheric flux difference is strongest over southern Europe and western Siberia the high temporal variability in the European area results in low

signal-to-noise ratios and larger areas with signal-to-noise ratios higher than 4 are only found over western Siberia. In HANK the overall features in the horizontal and vertical distribution of the signal-to-noise ratio are quite similar with the exception that HANK simulates low values close to the surface and maxima around 500m in the region east of 60°E while REMO results do not show a strong vertical gradient in the lowest 1000 m anywhere along the cross section as long as daytime sampling is applied. Since both models use the same set of surface fluxes these differences are caused by the different transport characteristics of the models. From the signal-to-noise we can infer a minimum sampling frequency needed to detect a given signal. The main results of our study are that several measurements per day, preferably during the afternoon, are necessary to permit the detection of a 20% difference in the biospheric fluxes at the one-sigma significance level and that there is no preferred level in the vertical for sampling. However, the signals in the free troposphere are very small given the precision and accuracy of atmospheric measurements as well as the limited realism of simulated atmospheric transport. In contrast, the signals in the PBL (Planetary Boundary Layer) are on the order of 1 ppm. This suggests that optimal sampling on continents should concentrate on the mixed portion of the PBL during afternoon. Our analysis is limited in its capability to make predictions on the necessary spatial density of sampling stations. Investigations of the spatial correlation structure of simulated atmospheric CO_2 in the PBL indicate correlation length scales on the order of a few hundred kilometers over the continent.

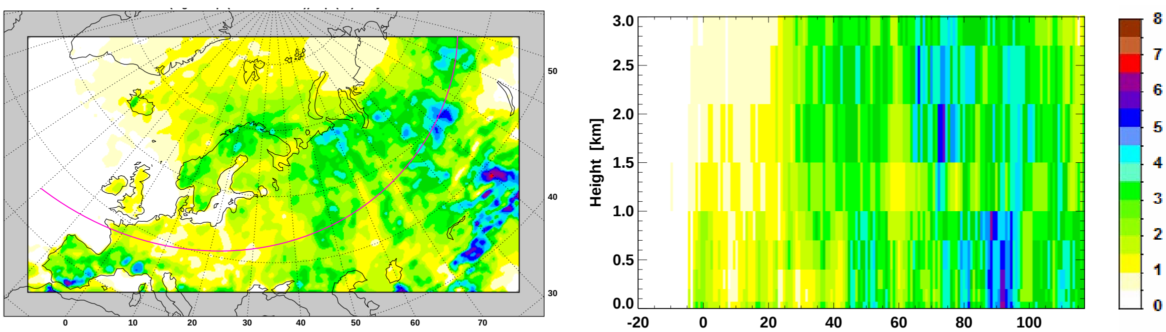

Fig.1: Calculated signal-to-noise ratio from REMO simulations, with daytime sampling (1100-1700 local time), in the PBL at approximately 300 m (left) and along cross section from 45°N/20°W to 64°N/118°E (cf. red line in maps) in the lower troposphere (right).

CONCLUSIONS

From our model study we conclude that in order to detect regional scale changes in the surface fluxes on continents from atmospheric CO_2 concentration measurements, a network of stations is needed that permits to sample the PBL several times per day and with a spatial distance between sampling stations not exceeding a few hundreds of kilometers. A possible realization is an array of continuously measuring tower sites located approximately every 300-500 km across the continent, ideally complemented by frequent vertical aircraft profiles.

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