DAILY EUROPEAN CO_2 SOURCES AND SINKS INFERRED BY INVERSION OF ATMOSPHERIC TRANSPORT

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ABSTRACT

We present a synthesis Bayesian inverse method to optimize one year of daily fluxes at model resolution (50x50 km over Europe) by inversion of continuous CO_2 measurements, daily averaged over Europe (10 sites). Based on a synthetic data analysis, we studied the impact of three different spatial and temporal correlations on flux errors. We found that the present network is too sparse to efficiently constrain European fluxes at model resolution even with the assumption of perfect transport. However, the agreement between the optimized fluxes and the true fluxes is improved when aggregated in space and time, mainly for 8-10 days fluxes over Western Europe. This region is indeed surrounded by our network. The spatial correlation scheme used was found to have a negligible impact on this agreement. Adding a white noise on pseudo-data to simulate transport model errors largely degrades the agreement. Using real data, European flux variations becomes unreasonably large due to the inability of our transport model to properly represent the CO_2 concentrations at continental sites.

INTRODUCTION

Up to now, most CO_2 inversions have used monthly mean CO_2 atmospheric concentration measurements to infer monthly fluxes. Considering the sparseness of the global CO_2 measurement network, fluxes were solved on sub-continental regions using a fixed spatial a priori pattern within these regions. With such strong constraint, estimated fluxes could be biased by non-perfect distribution of fluxes (aggregation error). Therefore, we developed a new approach where the hard constraint of a fixed distribution within a region is replaced by a soft constraint of covariances between flux errors. Continuous observations from an increasing number of measurement sites offers new challenge for inverse modelers. We thus investigate the use of 10 daily averaged observations to infer daily CO_2 fluxes at model resolution over Europe.

METHOD

We developed a global synthesis Bayesian inversion to invert daily fluxes at model resolution (50x50 km² over Europe) from daily averaged CO_2 concentrations. We estimated fluxes for the year 2001 over Europe using the 10 European continuous sites from AEROCARB network. We used the global atmospheric transport model LMDZ zoomed over Europe. The self-adjoint property of atmospheric transport of passive tracers has been implemented within LMDZ to limit the computing cost of calculating response functions. Spatial and temporal correlations between flux errors are critical new components. In this work, we studied the impact on estimated fluxes of three different spatial correlations based on distance between pixels, on climate anomalies and on biomes distribution. The first correlation set is described by an exponential decay with distance between pixels. This represents the spatial extent of synoptic events. In the second set, we added the structure of these events by correlating modeled biospheric fluxes. These fluxes are computed by a biosphere model driven by the 2001 meteorological fields analysis from the European Center for Medium Range Weather Forecasting (ECMWF). In the final set, we correlated grid cells according to their vegetation cover and the distance between them.

To study the potential of the continuous sites, we created two sets of synthetic data with the atmospheric model LMDZ and fluxes from a process-driven biosphere model (ORCHIDEE). The inversion uses prior fluxes from a different biosphere model. We also added a white noise of a standard deviation of 1 ppm to the synthetic data to study the influence of transport model uncertainty on estimated fluxes. Finally, we analyzed estimated fluxes obtained from inversion of real data.

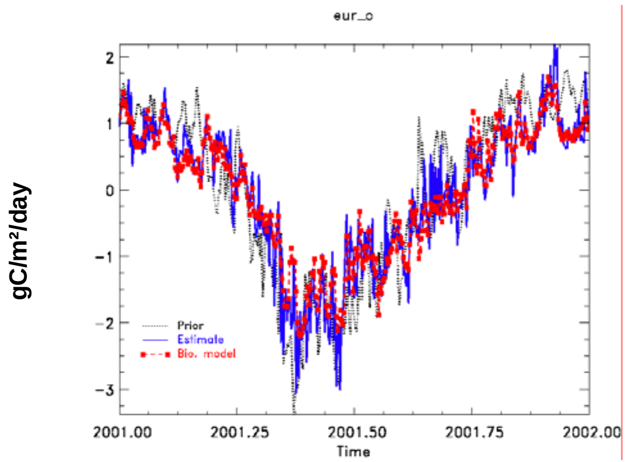
RESULTS

The analysis of the synthetic data case with perfect atmospheric transport indicates that fluxes at model resolution are not well retrieved. However, the agreement between estimated fluxes and true fluxes largely improves after we aggregates the original pixel regions into five larger regions. In particular, the seasonal cycle is quite well represented in all regions (Fig. 1a). We also analyzed residuals obtained by the subtraction of the seasonal cycle to the estimated fluxes. The best agreement between these residuals and true residuals is found for Western Europe after an aggregation in time of 8-10 days. The two sets of residuals have a correlation of 0.8 and a normalized standard deviation (NSD) close to 1. The NSD is defined as the standard deviation (SD) of estimated flux residuals divided by the SD of true flux residuals. Changes to the flux error correlation only slightly affect the favorable agreement in Western Europe but more significantly for the other regions.

The estimated daily fluxes inferred from synthetic data with a non-perfect transport shows a worse agreement (Fig.1b). The standard deviation of inverted daily fluxes is increased by a factor of 2.5 from the previous experiment with perfect transport. The sensitivity of our results by the addition of different white noises to our pseudo-data critically increases for noises above 0.3 ppm indicating a rather strong constraint on the required performance of the transport at continental sites.

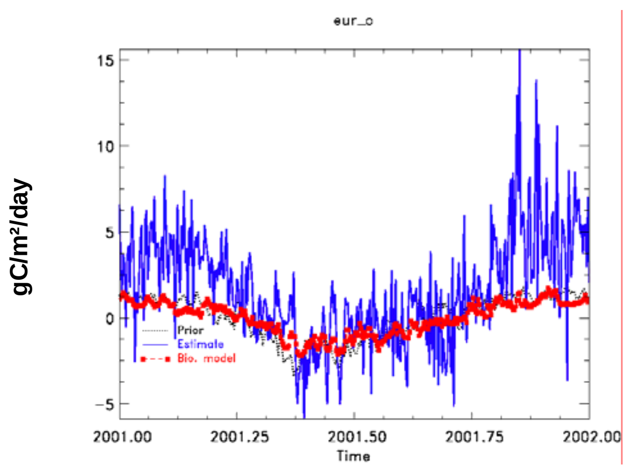
Finally, using observed data leads to non-realistic flux values and variability (Fig. 1c). At the scale of Western Europe, we can only compare with modeled biosphere fluxes. Doing so, we found a NSD of 8 for daily fluxes. Such difference is related first to the inability of the atmospheric transport model to resolve the influence of local fluxes on continental sites but also probably to the use of rather crude monthly fossil fuel statistics. We thus face to a new challenge which is to greatly improve transport mixing in the PBL in order to properly assimilate continuous measurements at continental sites.

1a.



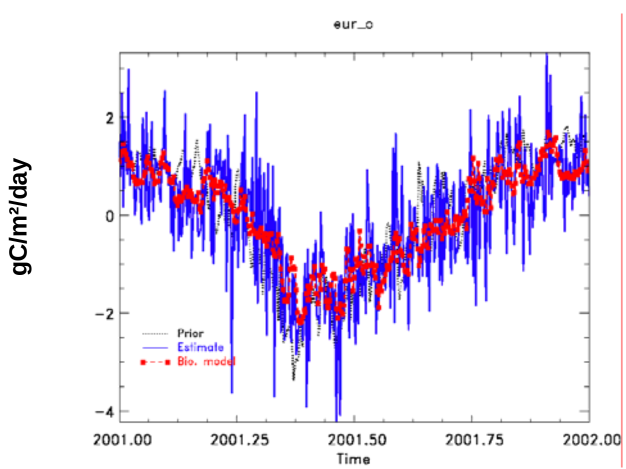
Western Europe

1b.



Western Europe

1c.



Western Europe

Figure 1 : Time series over Western Europe for prior fluxes, estimated fluxes and biospheric model fluxes (the truth in pseudo-data cases). Perfect transport model in 1a., pseudo-data with noise added in 1b., real observations in 1c.