A large terrestrial carbon sink over Europe is consistent with atmospheric observations

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Fan *et al.*[1] inferred an annual mean terrestrial sink of about 1.7 Gigatons of carbon dioxide per year (GtC a^{-1}) over North America contrasted by a minor sink of about 0.1 over Eurasia. They base their conclusion on the consistency with observed atmospheric CO_2 concentrations from a global monitoring network of some 63 sites[2]. Fan *et al.* constructed the unknown surface flux field as a linear combination of prescribed patterns, for a few of which they adjusted the coefficients in such a way that the atmospheric concentration simulated with a numerical transport model would yield the best possible fit to their observations. From an inverse modelling point of view it is evident, however, that the problem of inferring a surface flux field from point measurements is highly underdetermined: There exist an infinite number of surface flux fields that are consistent with the atmospheric observations.

As an example, using our inverse model[3], we have constructed a surface flux field, that exhibits a sink of 2 GtC a^{-1} over Europe and which at the same time matches with an average difference of less than 0.1 parts per millon volume (ppmv) the monthly observations at each monitoring station (Fig. 1). This example illustrates that the degree of consistency with the observations cannot be the single criterion: A priori information regarding the unknown surface fluxes has to be added. Fan *et al.* did this by prescribing large spatio-temporally fixed flux patterns, based on terrestrial and oceanic carbon cycle models or extrapolated flux observations. This, however, ignores the large uncertainty in the small scale structure of the CO_2 exchange fluxes.

In contrast, our field was constructed by allowing independently adjustable fluxes in every surface grid cell of the transport model. Further, we required that the fluxes be as close as possible to surface flux fields computed by models of the terrestrial biosphere, land use change, and the ocean carbon cycle. In a realistic inversion, all of these pieces of information must be weighted according to the degree of confidence assigned to it. In this demonstration excercise, however, we over-emphasised the fit to the atmospheric observations and prescribed in addition a fictituous uptake of 2 GtC a^{-1} over the European continent (any other region could have been chosen instead). Hence, while this example does not suggest a realistic source-sink distribution, it demonstrates the importance of a careful specification of the a priori information that is inevitably included in the inversion procedure. We note also that, in principle, similar examples may be constructed for an arbitrarily high number of observational sites (if necessary by employing a transport model with a higher spatial resolution).

Figure Caption:

Figure 1: A surface flux field representing an annual mean sink of 2 GtC over Europe. The (relatively well known) source component due to fossil fuel burning has been subtracted. From this field the transport model TM2[4] simulates a spatial and temporal atmospheric concentration field that matches the observed monthly mean concentrations on average within less than 0.1 ppmv at the locations indicated by crosses. The model's spatial resolution is indicated by the coast lines. **bottom**, observed concentrations with uncertainties (red), concentration simulated from a priori fluxes (black) and a posteriori fluxes (blue) at the eight sites within and closest to Europe: Azores (AZR), Mt. Cimone, Italy (CMN), Tenerife (IZO), Mace Head, Ireland (MHD), Plateau Rosa, Italy (PRS), Schauinsland, Germany (SCH), Atlantic Ocean Station M (STM), and Westerland, Germany (WES).

References

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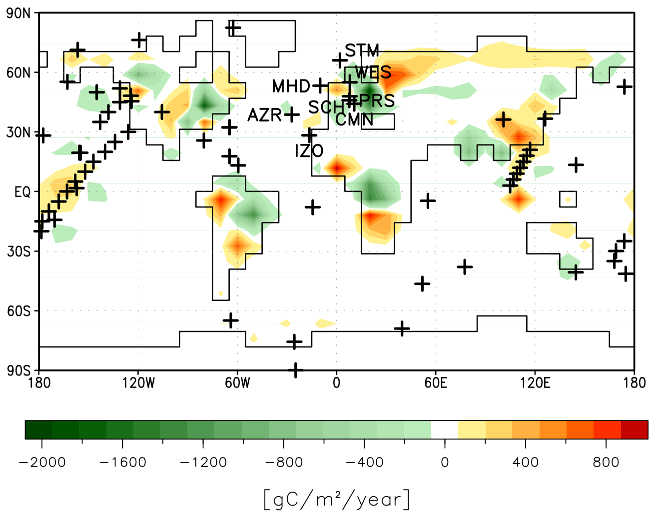
90N
60N
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STM
WES
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AZR
IZO
−2000
−1600
−1200
−800
−400
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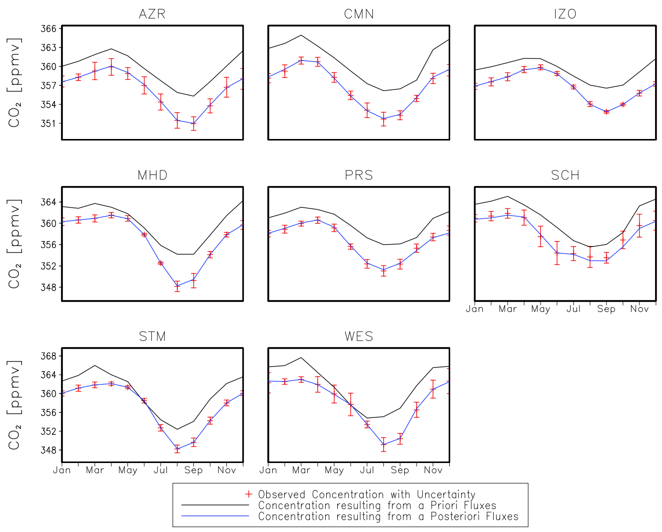
400
800
[gC/m²/year]


AZR
CMN
IZO
MHD
PRS
SCH
STM
WES
CO₂ [ppmv]
Jan
Mar
May
Jul
Sep
Nov
Observed Concentration with Uncertainty
Concentration resulting from a Priori Fluxes
Concentration resulting from a Posteriori Fluxes