WHAT CAN TRACER OBSERVATIONS IN THE CONTINENTAL BOUNDARY LAYER TELL US ABOUT SURFACE-ATMOSPHERE FLUXES

C. Gerbig[1], J.C. Lin[2], J.W. Munger[3], and S.C. Wofsy[3]
[1] *Max-Planck-Institut für Biogeochemie, PO box 100164, D-07741 Jena; cgerbig@bgc-jena.mpg.de*

[2] *Department of Atmospheric Science, Colorado State University, 1371 Campus Delivery, Fort Collins, CO 80523-1371*

[3] *Department of Earth & Planetary Science and, Division of Engineering & Applied Sciences, Harvard University, 20 Oxford St, Cambridge, MA 02138*

ABSTRACT
There are two basic approaches for inferring surface-atmosphere exchange for trace gases on regional scales: a bottom-up approach, in which local process knowledge is scaled up, and a top-down approach, in which the larger-scale constraint from atmospheric concentration measurements is applied in combination with transport models. Here we combine the two approaches, and assess the information content added by boundary layer concentration data. More specifically, we analyze the potential for inferring spatially resolved surface fluxes from atmospheric tracer observations within the mixed layer, such as from monitoring towers, using a receptor oriented transport model (Stochastic Time-Inverted Lagrangian Transport [STILT] model, [*Lin et al.*, 2003]) coupled to a simple biosphere in which CO2 fluxes are represented as functional responses to environmental drivers (radiation and temperature, [*Gerbig et al.*, 2003]). Transport and fluxes are coupled on a dynamic grid using a polar projection with high horizontal resolution (~20 km) in near field, and low resolution far away (as coarse as 2000 km), reducing the number of surface pixels without significant loss of information. To test the system, and to evaluate the errors associated with the retrieval of fluxes from atmospheric observations, a pseudo data experiment was performed. A large number of realizations of measurements (pseudo data) and a priori fluxes was generated, and for each case spatially resolved fluxes were retrieved. Results indicate strong potential for high resolution retrievals based on a network of tall towers, subject to the requirement of correctly specifying the a priori uncertainty covariance, especially the off diagonal elements that control spatial correlations.

Polar grid, explicit treatment of error covariances

Coupling biospheric fluxes (or parameters such as temperature and radiation response) to atmospheric transport at high resolution and inverting CO_2 measurements in the PBL to derive fluxes at high resolution requires a large number of gridcells (large dimension of state space), which in turn renders explicit propagation of uncertainties and their correlations impossible. However, most of the grid cells are in the far-field, away from the receptor (measurement location), where a high resolution is not required due to the large influencing region caused by atmospheric mixing.

The chosen polar representation of footprints (surface areas influencing the measurements), with the measurement location (Harvard Forest) at the origin (Fig. 1a) has a similar information content as a Cartesian representation with 20 km horizontal resolution, but reduces the dimension of the state space by about 2 orders of magnitude. This allows explicit treatment of the uncertainties in the Bayesian inversion, including the off-diagonal elements of the covariance matrices. The posterior uncertainty (when combining the a priori information about biospheric responses with atmospheric CO_2 measurements) can be shown to depend strongly on the averaging scale (area for which fluxes are to be calculated (Fig. 1 b), but also on the a priori uncertainty (both, its magnitude and the scale over which the uncertainty is spatially correlated, Fig. 1 c). When the a priori uncertainty covariance is not known, a range of possibilities exist, including significant underestimation of uncertainties (values > 1 in Fig. 1 d). The retrievals using different assumed a priori error covariances allow a conservative choice of a covariance length scale that avoids underestimation of uncertainties and thus biases in the retrieved fluxes.

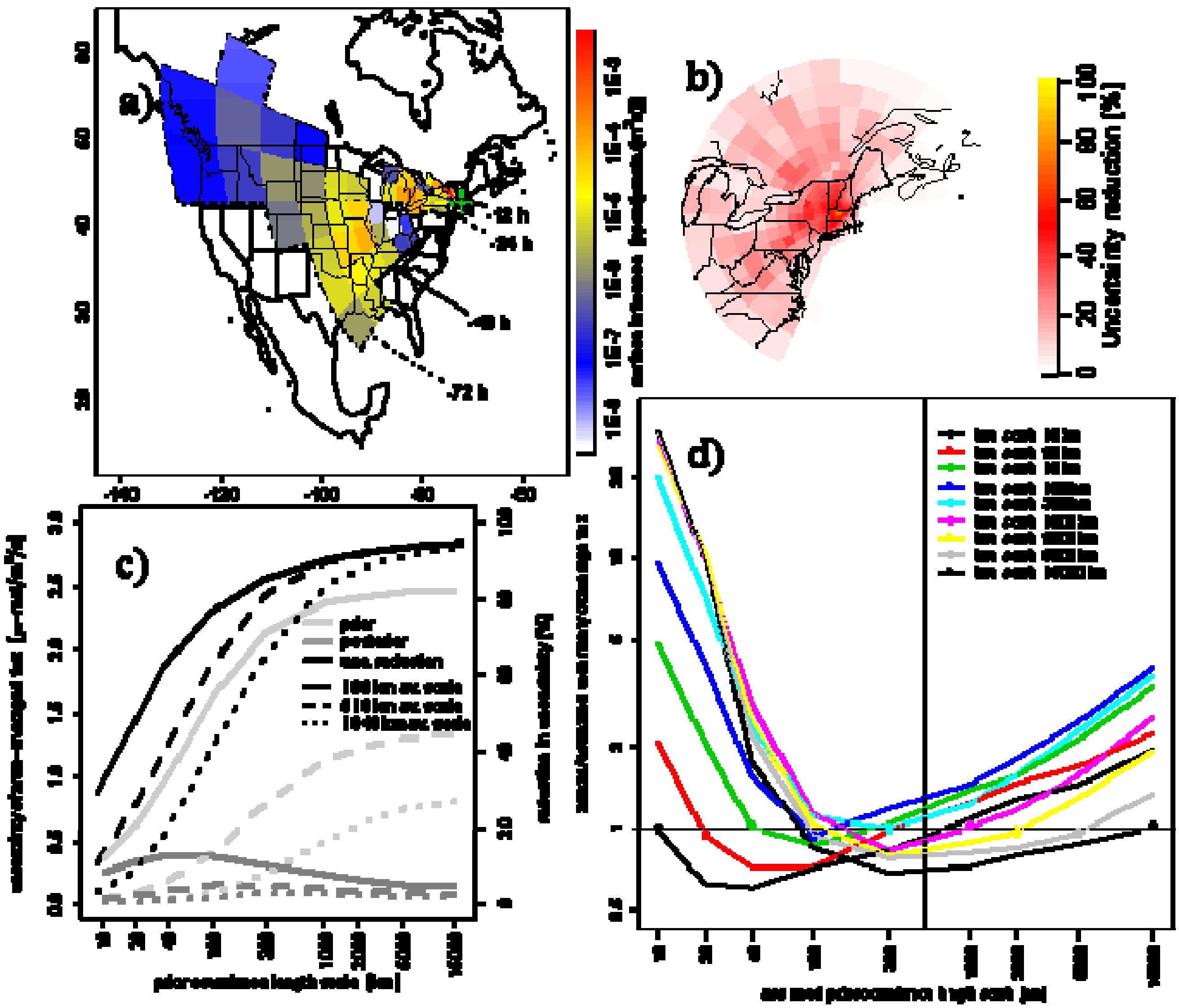

Fig. 1: (a) STILT derived footprint on 8/17/2002 at 15:00 GMT, for different times backwards and integrated over 3 hours (i.e. -12 h denotes the interval from 12 to 15 hours prior to the release time). (b) Uncertainty reduction (i.e. what can be learned from atmospheric measurements, assuming realistic measurement uncertainties) in the spatially resolved flux (averaged over the month of August 2002) for a prior uncertainty correlation scale 100 km; the uncertainty reduction reaches about 80% in the near field, and decreases to values around 20% at 1000 km distance. (c) Prior and posterior uncertainties and uncertainty reduction as function of prior uncertainty covariance length scale. (d) Ratio of actual to estimated posterior uncertainty of flux average plotted against assumed prior covariance scale l. The different lines correspond to different true covariance scales l_{true} (used for creation of prior realizations).

REFERENCES

Gerbig, C., J.C. Lin, S.C. Wofsy, B.C. Daube, A.E. Andrews, B.B. Stephens, P.S. Bakwin, and C.A. Grainger, Toward constraining regional-scale fluxes of CO_2 with atmospheric observations over a continent: 2. Analysis of COBRA data using a receptor-oriented framework, *J Geophys. Res.-Atmos. 108* (D24), 4757, doi:10.1029/2003JD003770, 2003.

Lin, J.C., C. Gerbig, S.C. Wofsy, A.E. Andrews, B.C. Daube, K.J. Davis, and C.A. Grainger, A near-field tool for simulating the upstream influence of atmospheric observations: The Stochastic Time-Inverted Lagrangian Transport (STILT) model, *J. Geophys. Res.-Atmos. 108* (D16), 4493, doi:10.1029/2002JD003161, 2003.