RESOLUTION OF ATMOSPHERIC CO_2 INVERSIONS

L.M. Bruhwiler[1] and W. Peters[2]

[1]*Climate Monitoring and Diagnostics Laboratory, NOAA, 325 Broadway, Boulder, CO 80305-3328; lori.bruhwiler@noaa.gov*

[2]*Cooperative Institute for Research in Environmental Sciences, University of Colorado, UCB 216, Boulder, CO 80309-0216; wouter.peters@noaa.gov*

ABSTRACT
We consider the ability of an inverse model framework and observations from the Cooperative Air Sampling Network to resolve fluxes at various scales over a 20-year period. During this time the observational network underwent a significant expansion. We calculate the resolution kernel to determine which continental/ocean basin scale fluxes may be resolved, and which spatial aggregations of fluxes are well resolved. In addition, the resolution kernel is used to obtain insights into how source regions are constrained by individual measurement sites.

INTRODUCTION
Estimation of CO_2 fluxes involves comparing model predictions of CO_2 abundances with observations. The resulting differences are used to deduce the distribution and strengths of fluxes. The success of such inverse modeling calculations is related to how well the regions of interest are constrained by observations. The Cooperative Air Sampling Network used in many inversion studies has expanded significantly over the period 1980 to 2005, increasing from about 25 sites in the mid-1980's to well over 100 sites more recently. Even so, current observational networks used to estimate fluxes are sparse, especially over the tropics, Boreal Eurasia, and some ocean regions. The ability of atmospheric inversions is therefore still limited. We investigate the ability of a typical inverse model framework to resolve fluxes at various scales over a 20 year period with changing networks using a diagnostic quantity known as the resolution kernel, given by

$$\mathsf{R}=QH^T(R+HQH^T)^{-1}H,$$

where H is the matrix of response functions at each measurement site from each source region, Q is the error covariance of the prior flux estimates and R is the model-data mismatch error. For a perfectly resolved system, R equals the identity matrix. Otherwise, the rows of the resolution kernel indicate the extent to which a parameter is resolved from other parameters, including parameters from adjacent time steps.

RESOLUTION AT VARIOUS SPATIAL SCALES
Starting with the largest spatial scales (using an underlying source resolution of the 22 TransCom 3 regions), the partitioning of CO_2 flux between the global oceans and land is well resolved even for the very sparse networks of the 1980's. Aggregation of the 22 regions to approximately zonal average fluxes for boreal, temperate and tropical regions also results in fairly good resolution, especially for the more dense recent network configurations.

At continental scales, the resolution varies significantly, with Temperate North America well resolved even for early networks, and Europe and Australia very well resolved as of the 1990's due to increased observational coverage for these regions. Some tropical regions, such as Tropical South America and the Tropical Atlantic, are hardly resolved at all, even with the current network configuration. It is interesting to note that the resolution kernel suggests that the zonal land/ocean partitioning can be resolved with current networks. On the other hand, the resolution kernel for continental and ocean basin scales shows that some tropical regions are unresolved. This implies that the zonal fluxes are representative of the only those regions of the tropics where measurements exist. Large spatially aggregated source regions are subject to biases arising from unevenly distributed sampling sites.

RESOLUTION OF SOURCE REGIONS BY INDIVIDUAL SITES

The resolution kernel may be used to assess how a particular measurement site contributes to the resolution of each source region by retaining only those rows of the **H** and **R** matrices that relate to the measurement site in the calculation of the resolution kernel. This allows one to determine which sites most strongly constrain each source region. For example, during the Northern Hemisphere winter, measurement sites on the coast of Japan and in Mongolia help to constrain the carbon flux estimates for Boreal Eurasia. On the other hand, during the Northern Hemisphere summer, the circulation is onshore, and the Boreal Eurasia is not directly constrained by these sites. Boreal Eurasia is therefore least constrained during the growing season. The same is found to be true for other land regions; due to the placement of many observing sites in remote marine locations, Northern Hemispheric continental regions are the least constrained by observations during the summer growing season. This implies a seasonal bias in information used for flux estimates. As more sites are added over continental regions in the future, this situation should improve.

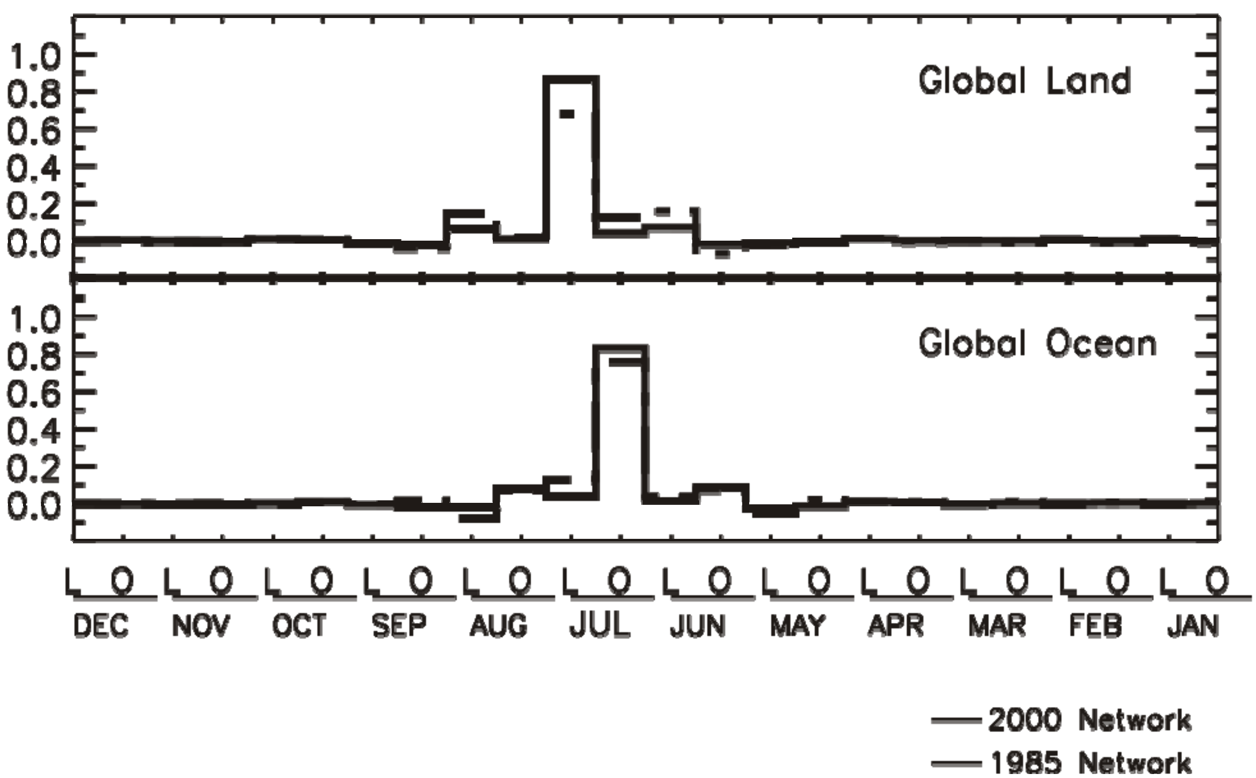

Fig. 1 The resolution kernel for the global land and oceans in July calculated by aggregating monthly average basis functions, prior flux uncertainties, and mismatch error to global scales. Note that the resolution kernel shows how well the global land and oceans are resolved relative to each other within a particular month, as well as the degree to which the estimate for July is confused with the estimates for global ocean and land regions from previous and successive months. The "L" and "O" on the horizontal axis denote land and ocean regions for the month of interest and for adjacent time steps.