CARBON CYCLE INVERSION VALIDATION USING PROFILE AND OTHER NON-SURFACE OBSERVATIONAL DATA

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ABSTRACT

We present preliminary results of a modeling experiment that compares observed vertical profiles of CO_2 with those generated by an atmospheric transport model (ATM). The ATM is driven by CO_2 flux fields generated from the inversion of monthly averaged CO_2 surface data (GLOBALVIEW). We note large differences between the best fit to the observations produced in the inversion and the same quantity simulated by the forward model. This difference arises from the nonlinearity of the advection scheme used in the transport model. When comparing with vertical profiles, we note that much of the difference between simulated and observed concentration has the same structure as the impact of this nonlinearity. Inversion schemes must therefore take nonlinearity into account. Despite these differences, the profiles are able to distinguish among inversions that fit subsets of the surface data, suggesting they are a useful validation dataset.

CO_2 inversion modelling uses high quality data routinely collected from a global network of surface observation stations. Due to the sparseness of this network, most modelers utilise as much data as possible. Consequently, little or no independent surface data is available for validation. However, there is a multitude of other non-surface data that can be used in model validation. Non-surface data presented here comes from vertical profiles collected over Cape Grim, Tasmania (GASLAB, CSIRO-AR) and Northern Colorado (CMDL/NOAA).

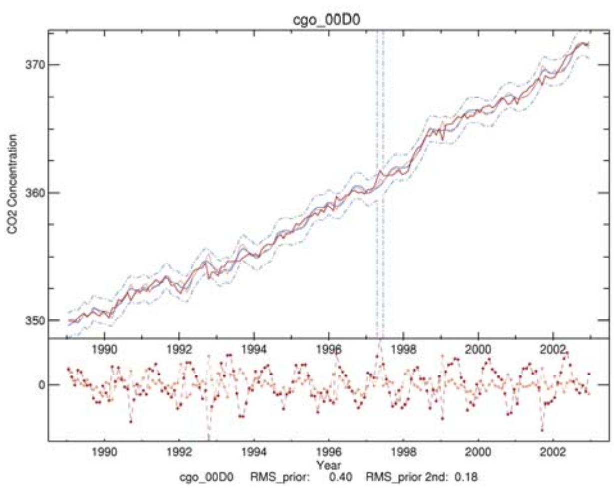
A two step process is used to produce model data that is comparable to observed data listed above. In step one, data from 77 surface observation sites were used in an inversion to generate monthly flux estimates for the period 1989 – 2002 for 139 regions. The inversion uses response functions generated from 1997 – 98 winds and produces 'best fit' estimates for the observed concentrations, subject to the assumption of a linear model.

In step two, the optimized fluxes are inserted into an ATM forced with real winds throughout the study period. The ATM is then sampled at the appropriate point in time and space to obtain CO_2 model data directly comparable to the original surface data used in the inversions and vertical profile data. The ATM used in this study is the CSIRO Cubic Conformal ATM with a 200km x 200km x 18 level grid, 1 hour time step and nudged every 12 hours using data from the National Centers for Environmental Prediction (NCEP).

The inversion fits the observed data from all 77 surface stations with a mean root-mean-square (RMS) error of ~0.4ppm. In relation to the prior uncertainties used in the inversion, this is a good result. At a station like Cape Grim, the inversion fit is very close (0.05ppm). However, the forward model data was found to fit the original surface data significantly worse than that predicted by the inversion. At Cape Grim, the forward model RMS error is 0.4ppm (fig. 1) and at Niwot Ridge the forward model RMS error is 0.71ppm (whereas the inversion fit RMS error is 0.39ppm). Importantly, this mismatch is not random in time but periodic. This difference is termed the ‘non-linearity problem’ and occurs primarily because of the use of a non-linear advection scheme. An important consequence from this result is that the assumption of a linear relation between changes in flux and changes in concentration is a serious approximation. We performed one iteration of a nonlinear optimisation using the exact forward model data. This iteration produced significant improvements in the forward model fit to the original surface observations. On average, an improvement of 30% in fit was observed across all 77 surface stations. At Cape Grim, the forward model fit improved by 50% from 0.40 to 0.18ppm (fig. 1). At Niwot Ridge, the RMS error reduced from 0.71ppm to 0.43 (~40%). A second iteration was completed but instead, the RMS errors increased, most likely because we were not updating the values in the Jacobian matrix (a task that is highly computationally intensive).

In a similar manor to that described above, model data was sampled for comparisons to 94 vertical profiles flown over Cape Grim and 286 vertical profiles flown over CAR, Colorado. A model profile averaged over 8 hours and 4 surrounding grid points was extracted for each observed profile. An example of a vertical profile is shown in fig. 2. For profiles obtained over Cape Grim, a mean RMS error mismatch between the observed and modeled profiles was 0.45ppm, although it appears to be non-random in time. While the bias (average residual) of the model profiles is close to zero, it is strongly periodic in time and appears to be closely correlated with the time-varying mismatch at the Cape Grim surface station. Therefore, it appears that the non-linearity problem is having a significant impact on our ability to model the observed profiles. However, unlike the surface fit that improves with an adjustment to the flux estimates, the model fit to the profiles is degraded. If the model fit is segmented into different layers of the atmosphere, the lower layer of the model fit improves whereas the upper layers diverge significantly.

The model results from CAR are considerably worse, owing to the fact that it is a much more difficult site to model. The mean RMS mismatch was 1.20ppm and appears to be more random with time. The same applies to the residuals and there appears to be less correlation with residuals at a nearby surface station (Niwot Ridge). However, there is a significant bias within the model profiles that is corrected when the original flux estimates are adjusted using the non-linear optimisation procedure.



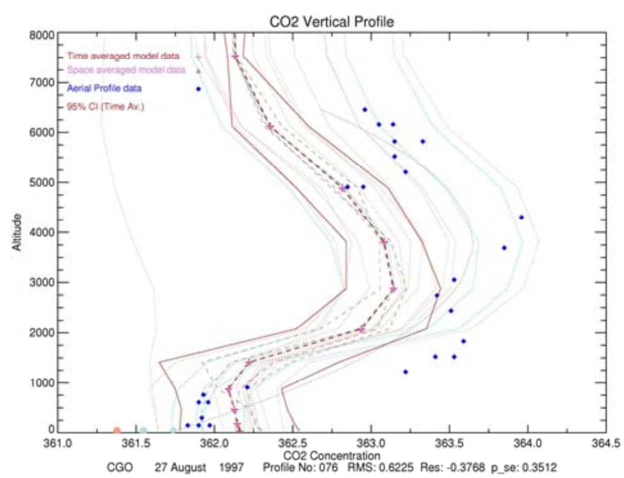


Fig.1. A time-series analysis of observed concentration and *forward model data* (including one iteration) at the Cape Grim observation station. The residuals (difference between observed and forward model data) are shown in the lower panel.