Investigating Large-scale Contemporary CO_2 Sources and Sinks Using Inverse Transport Modelling Applied to CO_2, CH_4 and CO

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1. Introduction

The carbon cycle (left) describes the flux of carbon in the atmosphere, showing the three main carbon reservoirs (or sinks) – the atmosphere, the oceans and the terrestrial biosphere.

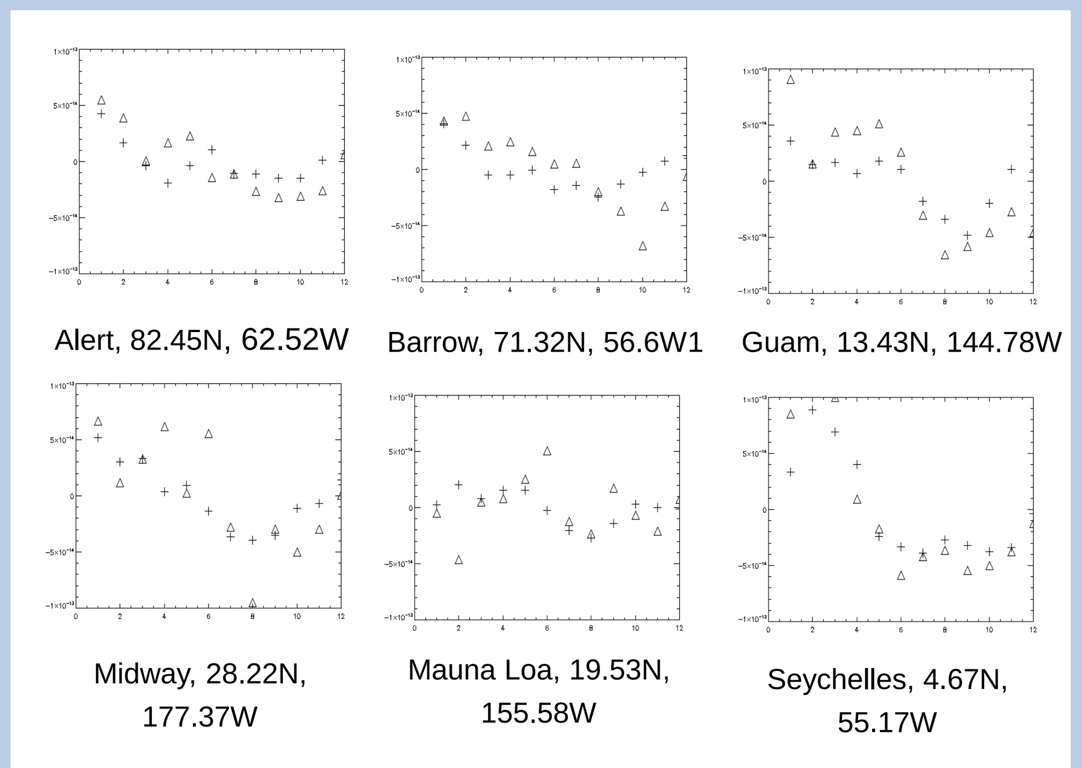
While the atmospheric and oceanic reservoirs are fairly well understood, the nature and location of the terrestrial sink is not – meaning that it is often referred to as the 'missing carbon sink'. The majority of this reservoir is believed to be in the northern hemisphere due to a smaller-than-expected north-south gradient in atmospheric CO_2 concentration.

This project aims to investigate the nature of global CO_2 fluxes through the method of inverse transport modelling using TOMCAT, a Chemical Transport Model (CTM). This poster describes the methodology of the 4D-Var method used to estimate the fluxes, and shows results of the progress made so far in carrying out this method.

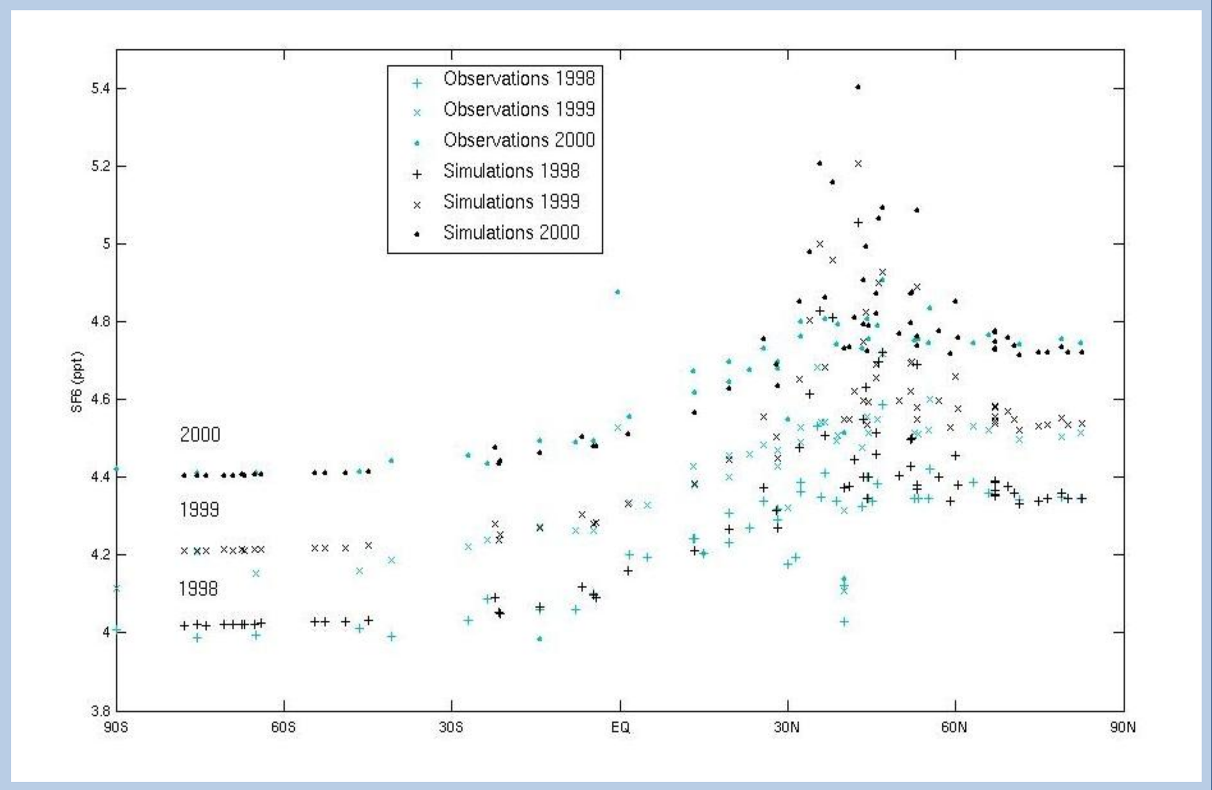
In order for a CTM to be used for inverse transport modelling, it is also necessary to test the transport in the model. Simulating the transport of SF6, an unreactive atmospheric tracer, is a good way of doing this. This poster also shows results of the testing of the TOMCAT model in this way.

2. SF_6 results

SF_6 is a species which is extremely unreactive in the atmosphere, giving it a long atmospheric lifetime of about 3200 years. This makes it ideal as a tracer to test the transport in TOMCAT. These results are from a 5.6º x 5.6º TOMCAT run with 31 vertical levels up to 10hPa. The simulated results are compared with flask station data from NOAA ESRL.



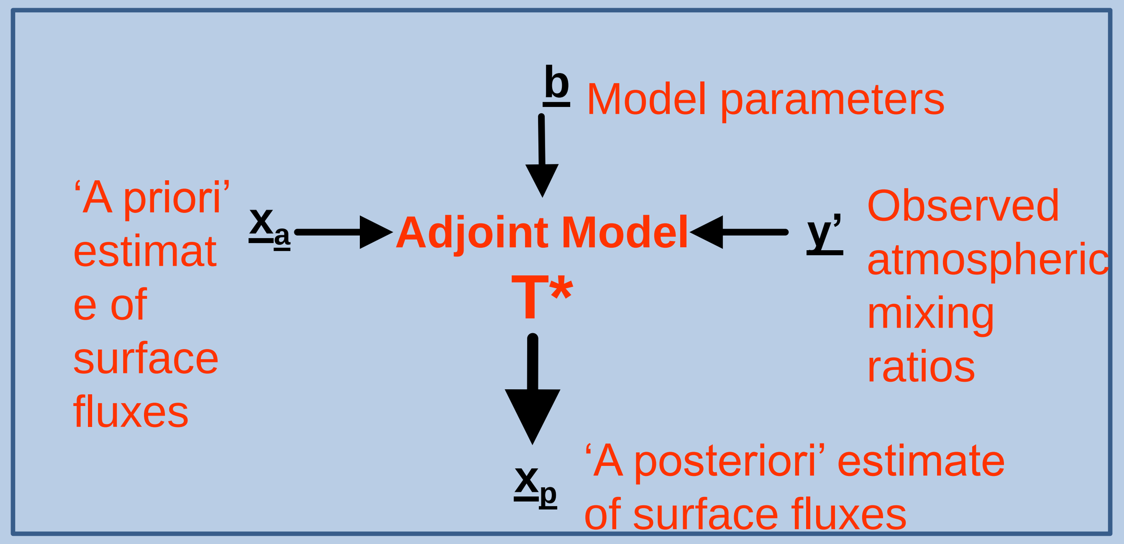
Detrended observed (triangles) and simulated (crosses) monthly mean surface records for 1998 at a number of remote stations



Comparison of observed (blue) and simulated (black) latitudinal distribution of annual mean surface data

As can be seen from these plots, the TOMCAT model simulates the transport of SF_6 well. The left-hand plot shows good correlation between results, with the season variation of SF_6 at a number of locations being picked up well by the model. The right-hand plot, meanwhile, shows that the model simulates the interhemispheric difference of SF_6 well, indicating good interhemispheric transport in TOMCAT.

3. Inverse Modelling Methodology



CTMs are used in order to produce estimates of atmospheric mixing ratios of a species, using information about surface emissions, winds, etc. The diagram to the left shows how an adjoint model is used to find an *a posteriori estimate* or 'best guess' at the surface flux of a species using atmospheric concentration data from remote sensing and an *a priori estimate* for the surface fluxes.

Details of the TOMCAT CTM used in this study:

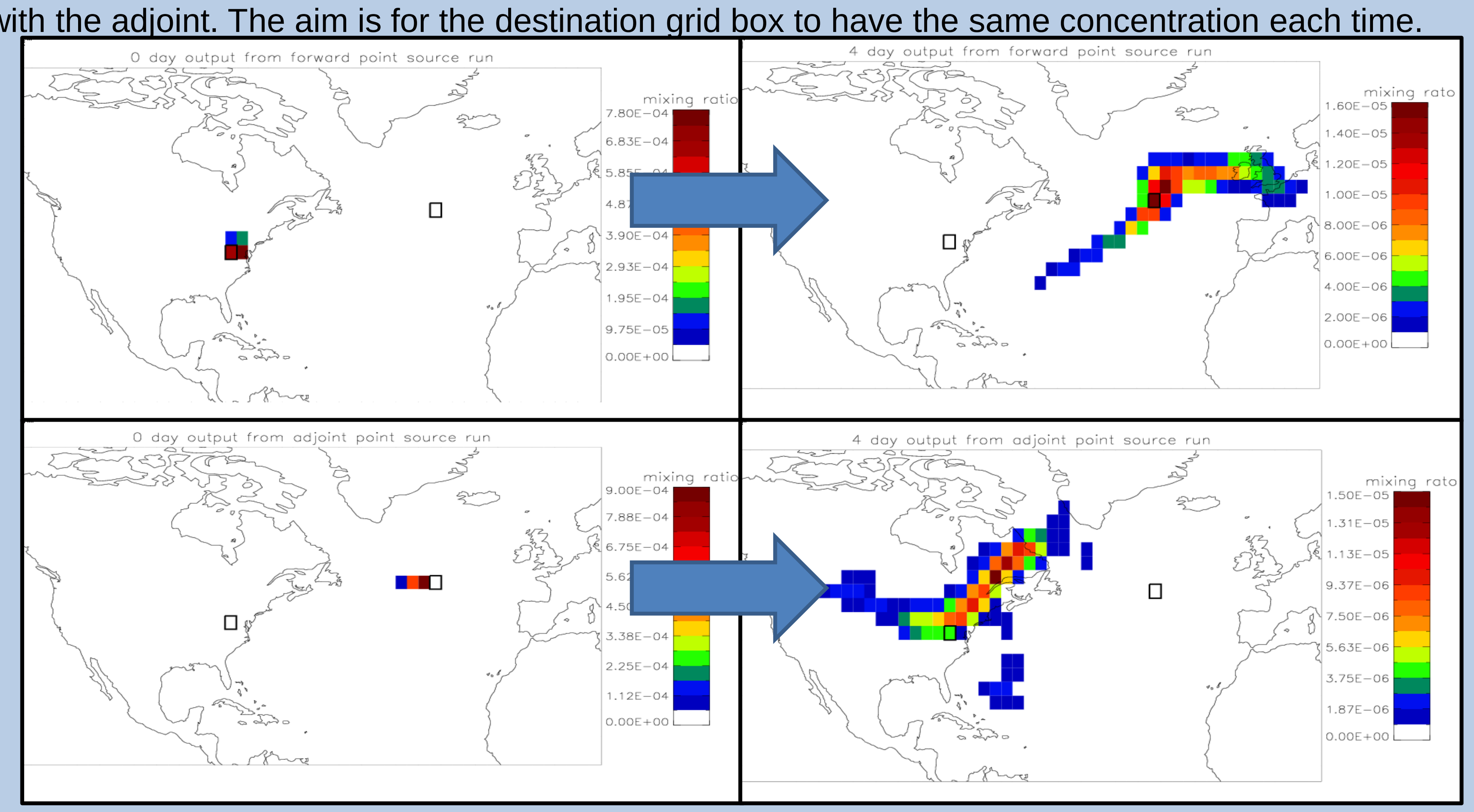
- Eulerian, grid-point off-line 3D chemical transport model
- ERA-40 ECMWF wind-files, 6 hourly
- Grid box resolution of 2.6º x 2.6º
- 60 vertical levels up to a pressure of around 0.2 hPa.

4. Testing the adjoint model

It is necessary to thoroughly test the adjoint model in order to check its accuracy before it is used. There are a number of numerical tests which can be carried out whilst writing the code, and the adjoint transport can be tested once the code is complete using the method shown here.

The method involves examining the transport of a tracer releaser instantaneously from a point source, firstly using the forward model, and then with the adjoint. The aim is for the destination grid box to have the same concentration each time.

To obtain the results shown to the right, the forward model simulated a four-day point-source run with a starting point on the East coast of the USA. The grid box with the highest concentration was chosen as the starting point for a four-day adjoint run.



As shown here, the adjoint model transported the tracer in the correct direction, giving a concentration in the original grid box similar to the high concentration from the forward run. This point source test has been carried out with a number of starting points around the globe, and the results indicate good adjoint transport.

5. Conclusions

- The transport in the TOMCAT model is suitable for inverse modelling, as shown by good SF_6 simulation results.
- The adjoint has performed well and will soon be able to be used in order to estimate surface fluxes, a method of cost function minimisation will be used in order to achieve this – the method is similar to that used by Chevallier (2005)
- Remote sensing data from the GOSAT satellite will be used in conjunction with the adjoint model to give an accurate estimation of CO_2 surface fluxes.