USING INVERSE MODELLING TO INVESTIGATE POTENTIAL IR MEASUREMENT STRATEGIES FOR CONSTRAINING THE AUSTRALIAN CARBON CYCLE.

N.M. Deutscher[1], R.M. Law[2], D.W.T. Griffith[3], and G.W. Bryant[4]

[1]*Department of Chemistry, University of Wollongong, NSW, 2522, Australia and CSIRO Marine and Atmospheric Research, Aspendale, Victoria, 3195, Australia; nmd03@uow.edu.au*

[2]*CSIRO Atmospheric Research, Aspendale, Victoria, 3195, Australia; rachel.law@csiro.au*

[3]*Department of Chemistry, University of Wollongong, NSW, 2522, Australia; griffith@uow.edu.au*

[4]*Department of Chemistry, University of Wollongong, NSW, 2522, Australia; glennb@uow.edu.au*

ABSTRACT

CO_2 and methane are important greenhouse gases, both contributing in increasing amounts towards positive radiative forcing. It is hence important to gain maximum understanding of the carbon cycle in the atmosphere, and the scale of carbon trace gas sources and sinks, not only globally but also on a more regional level. The Orbiting Carbon Observatory (OCO) satellite, scheduled for launch in 2008, is designed for dedicated global mapping of CO_2. In order to investigate the usefulness of a variety of methods, including retrievals from satellite mapping, some preliminary inverse modelling using a Bayesian synthesis technique is performed using pseudodata generated to represent possible future measurement regimes. This study will focus on the ability of in-situ measurements within Australia to reduce the uncertainties in Australian continental CO_2 flux estimates. The specific measurements investigated include a Ghan railway transect between Adelaide (34.9°S, 138.6°E) and Darwin (12.5°S, 130.9°E), and a number of continuous permanent sites. The reduction in flux uncertainties from additional measurements compared to a background inversion is examined, from which it is concluded that measuring on the Ghan railway is potentially worthwhile for reducing uncertainties associated with flux estimates.

INTRODUCTION

The carbon cycle plays a vital role in life on earth. In the atmosphere, the two major enhanced greenhouse gases are both carbon-based gases, carbon dioxide (CO_2) and methane (CH_4), and together contribute to the majority of the enhanced greenhouse effect. Atmospheric volume mixing ratios (vmrs) of both CO_2 and CH_4 have significantly increased since the beginning on the industrial era. Much scientific study is being focussed on better understanding processes that contribute to these increases, and better quantifying the processes that are understood. On a global scale, there are two approaches towards gaining better overall understanding of carbon cycle processes. These are using either a bottom-up approach, by studying individual processes, and piecing understanding together to create a global picture; or a top-down approach, which involves measuring, in essence, the end response in the form of atmospheric concentrations, and then using an inversion approach to infer the sources and sinks responsible for changes in concentration. This study employs a top-down approach, combining measurement and modelling aspects. The study attempts to gain better understanding of the Australian carbon cycle, and as such investigates possible measurement locations and strategies in the Australian continent. This is done by simulating data for a number of locations, and using this simulated pseudodata in inversion studies to determine the additional constraint applied to the source estimate uncertainty in Australia and nearby regions.

METHOD

Atmospheric Trace Gas Measurement by Fourier Transform Spectrometry

Two distinct types of atmospheric trace gas measurements by Fourier Transform Spectrometry (FTS) are used in this study. The first is solar remote sensing, which involves observing total column amounts through the atmosphere, and has previously been reported [e.g. *Griffith et al.*, 1998, *Paton-Walsh et al.*, 2004], and involves high spectral resolution infrared measurements. This method will be used as part of the OCO satellite validation network, and include an instrument located in Darwin, Australia. The second is less widely used, and is a low spectral resolution *in situ* technique, resulting in high precision simultaneous measurements of CO_2, CH_4, N_2O and CO on sub hour timescales [*Esler et al*, 2000]. The possibility of these measurements taking place at Darwin, in conjunction with the OCO validation instrument, and along the Ghan railway, which runs from Adelaide to Darwin, will be investigated.

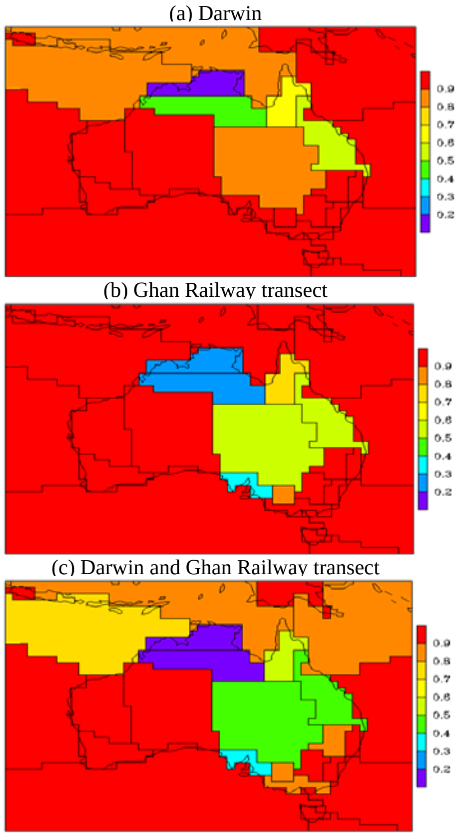

Figure 1. Relative uncertainties in flux estimates from including measurement data from: (a) Darwin, (b) Ghan Railway transect and (c) both Darwin and Ghan Railway transect, compared to the back-ground inversion

Synthetic Bayesian Inverse Modeling

Inverse modelling is used to take advantage of concentration-based measurements to constrain the strength and distribution of global and regional atmospheric fluxes, particularly of CO_2. Traditional inversions have involved the generation of a set of response functions by running pre-determined flux pulses through an atmospheric transport model and sampling the modelled concentration changes at a set of locations of interest. These response functions, in conjunction with the atmospheric measurements and initial estimates of the globally distributed flux field are then inverted for the flux estimates. This study uses CSIRO's conformal cubic atmospheric transport model (CCAM) to generate the desired response functions. CCAM is also used in a similar fashion with a set of known fluxes to generate synthetic concentration data at the possible sampling locations, including all model grid points along the Ghan railway transect. The time dependent inverse (TDI) method is used in a number of inversions, firstly with a basic background network consisting of sites from the GLOBALVIEW-CO_2 [2004] product, along with synthetic continuous data from Cape Grim. Further inversions are performed including synthetic data from sites of interest, along with the data used in the background inversion. The flux estimates and their uncertainties are examined, primarily for 16 regions over the Australian continent. The reduction in uncertainty in the flux estimates relative to the background network is used to judge the perceived utility of obtaining data at the additional sites.

RESULTS AND DISCUSSION

Addition of continuous data at Darwin reduces flux uncertainties in the region surrounding Darwin to less than 20% of previous estimates, as well as providing constraints on neighbouring regions. The Ghan Railway transect provides stronger constraints than Darwin measurements on all the regions through which the railway passes, excepting the northernmost central region which includes Darwin. Together the Ghan Railway transect and Darwin provide significant uncertainty reduction on close to half the Australian continent. The lack of uncertainty reduction in the large central region is due to the small initial uncertainty applied to that region because of its relative uniformity and desert nature. These estimates are purely theoretical, and assume the data is obtained continuously and relatively trouble-free, and is representative of the location's model grid cell. As a result, the uncertainty reductions obtained will probably be less than those estimated by this synthetic inverse study, however, the results here are encouraging for the potential usefulness of any data obtained.

REFERENCES:

Esler, M.B., D.W.T. Griffith, S.R.Wilson, and L.P. Steele (2000), Precision Trace Gas Analysis by FT-IR Spectroscopy. 1. Simultaneous Analysis of CO_2, CH_4, N_2O, and CO in Air, *Anal. Chem.*, 72(1), 206-215.

GLOBALVIEW-CO $_2$: Cooperative Atmospheric Data Integration Project - Carbon Dioxide. CD-ROM, NOAA CMDL, Boulder, Colorado [Also available on Internet via anonymous FTP to ftp.cmdl.noaa.gov, Path: ccg/co2/GLOBALVIEW], 2004.

Griffith, D.W.T., N.B. Jones, and W.A. Matthews (1998), Interhemispheric ratio and annual cycle of carbonyl sulfide (OCS) total column from ground-based solar FTIR spectra, *J Geophys Res*, 103 (D7), 8447-8454.

Paton-Walsh, C., N.B. Jones, S.R. Wilson, A. Meier, N.M. Deutscher, D.W.T. Griffith, R. Mitchell, and S. Campbell (2004), Trace gas emissions from biomass burning inferred from aerosol optical depth, *Geophys. Res. Lett.*, 31, L05116, doi:10.1029/2003GL018973.