Management and Impacts of Climate Change Programme
GICC
CRP 2000

5/00 – Quantification of emissions of non-CO_2 greenhouse gases and of their precursors using inverse modelling

Summary Report

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In recent years, the numerical models used to simulate the composition of the atmosphere and its variations in response to human activities have steadily improved in step with our understanding of the bio-geo-physico-chemical phenomena that govern distributions and of their parameterizations. At the same time, the number and quality of measurements of the composition of the lower atmosphere from *in-situ* readings and from remote sensing observations have increased considerably.

The quality of air composition measurements and of atmospheric chemistry and transport models stimulated the implementation of inverse techniques that aimed to use observations to estimate the more uncertain parameters of the models, in particular trace gas emissions and particle emissions at the surface of theearth. Following the example of developments in meteorology in the area of data assimilation and the first applications of the inverse modelling of the CO_2 cycle in the troposphere, we elaborated the tools needed to reduce uncertainties regarding the surface emissions of two chemical compounds with important roles in radiative climate forcing – methane and carbon monoxide. The inverse approach we chose considers a state variable or an unknown variable formed by a partitioning of the gas emissions. This state variable is linked to the vector containing the observations *via* a linear operator called an observation matrix. This matrix contains the response functions for each observation site and for each flux of the chosen emission partition. Determining the global sources of a tracer from observations of its distribution in the atmosphere is an under-constrained problem. In order to find a single solution, the solution to the inverse problem is restricted to the neighbourhood of an assumed estimate of the state variable. This is called a Bayesian inversion. Uncertainties or errors regarding the assumed estimate and the observations are fixed. The extent of the neighbourhood that contains the solution is directly linked to the uncertainty of the assumed emission estimate. The more uncertain this assumed value and the smaller the errors in regard to the observations, the more the inversion will be able to calculate an optimal estimate distant from the assumed estimate in order to bring the simulated values closer to the actual observations.

In this project, we developed inverse modelling methods that we applied to two types of observations. We first focused on climatological observations collected by a number of surface stations and we optimized the monthly means of emissions of the observed compounds. We then studied the very recent distributions of carbon monoxide provided by the MOPITT experiment, based on the TERRA space platform, in order to develop a methodology adapted to satellite observations, which we were able to validate with a set of independent observations.

The research work presented in this report was carried out by teams from two laboratories of the Institut Pierre Simon Laplace: Claire Granier and Gabrielle Pétron of the Service d'Aéronomie (SA), who focused more particularly on carbon monoxide, and Philippe Ciais and Philippe Bousquet of the Laboratoire des Sciences du Climat et de l'Environnement (LSCE), who worked on the inverse modelling of methane. The application of inverse modelling techniques, the development of the atmospheric chemistry-transport models and the access to in situ data and satellite data were facilitated and made possible thanks to collaboration with the Atmospheric Chemistry Division of the National Center for Atmospheric Research (Boulder, USA), the Institut d'Aéronomie Spatiale de Belgique (Brussels, Belgium), and the NOAA/Climate Monitoring and Diagnosis Laboratory (Boulder, USA).