ESTIMATION OF ATMOSPHERIC CO_2 FROM AIRS INFRARED SATELLITE RADIANCES IN THE ECMWF DATA ASSIMILATION SYSTEM

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ABSTRACT

Atmospheric CO_2 concentrations have been obtained from the Atmospheric Infrared Sounder (AIRS) radiance data within the European Centre for Medium-Range Weather Forecasts (ECMWF) data assimilation system. In a first explorative configuration, a subset of channels from the AIRS instrument has been assimilated providing estimates of tropospheric column-averaged CO_2 mixing ratios representative of a layer between the tropopause and about 700 hPa at observation locations only. Results show considerable geographical and temporal variability with values ranging between 370 and 382 ppmv. The 5-day mean estimated random error is about 1%, which is confirmed by comparisons with flask observations on board flights of Japanese airliners in the west-Pacific region. This study demonstrates the feasibility of global CO_2 estimation using high spectral resolution infrared satellite data in a numerical weather prediction data assimilation system. Currently, the system is being improved to treat CO_2 as a full three-dimensional atmospheric variable included in the forecast model. This allows more flexibility in the constraints on the CO_2 estimation as well as the possibility of assimilating other data sources (e.g., near-infrared satellite data and flasks). The CO_2 fields provided by the data assimilation system have great potential to assist the surface flask network in constraining current top-down carbon flux estimates.

INTRODUCTION

Radiance observations from the AIRS are operationally assimilated in the ECMWF 4-dimensional variational (4D-Var) data assimilation system together with many other observations to constrain the dynamics and thermodynamics of the assimilation model. For the CO_2 assimilation experiments, a CO_2 column variable was added to the minimization state vector of the analysis system at all available AIRS observation locations within the 6 hour time window of each analysis. This means that an analysis does not provide a full three-dimensional CO_2 field for each analysis cycle, as is the case for most other variables, but individual CO_2 estimates for all AIRS observation locations. There is therefore no CO_2 transport within the 6 hour analysis window and there are no a priori horizontal correlations applied to constrain the CO_2 estimation problem. The only explicit prior CO_2 constraint is in the vertical by assuming a well-mixed profile. Because the CO_2 mixing ratios are estimated within the regular minimization, they fully use the information about the other meteorological variables, such as temperature and water vapour, which are constrained by various data sources as well as the assimilating model and background state that is produced with a 3 hour forecast from the previous analysis. This is a significant difference with stand-alone satellite retrievals that generally use only observations from the same satellite platform. For the CO_2 experiments we ran the assimilation model with 60 levels at resolution T159, which is approximately 1˚ by 1˚. The value of the background estimate for the tropospheric CO_2 column was taken as a single global mean value of 376 ppmv with a background error estimate of 30 ppmv based on the approximate annual mean of 2003 for the Mauna Loa flask station on Hawaii. The CO_2 analysis error was estimated using a simple 1-dimensional Bayesian error formulation. Only 18 spectral channels, sensitive to CO_2, are used after they have been flagged as clear by the operational cloud detection algorithm [*McNally and Watts*, 2003]. A full description of the CO_2 analysis system can be found in *Engelen et al.* [2004].

RESULTS

Monthly mean results are presented by averaging on a 1˚ by 1˚ latitude-longitude grid. This 1˚ by 1˚ grid was then smoothed with a 15˚ by 15˚ moving boxcar average for clarity. Monthly mean errors were

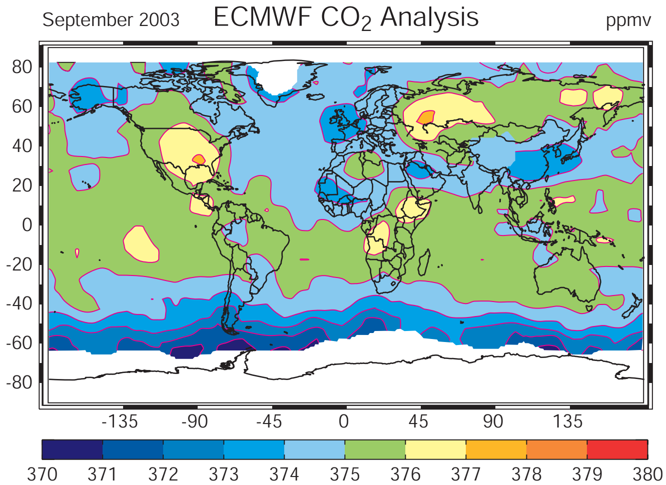

Fig. 1. Monthly mean CO_2 analysis for September 2003.

averaged on the same grid taking estimated error correlations into account. AIRS data in the period from 1 January 2003 until 31 March 2004 have been processed and Fig. 1 shows monthly mean CO_2 analysis results for September 2003. Monthly mean analysis errors range between 1 ppmv in the tropics to 6 ppmv in the high-latitudes. For validation, we compared our analysis results to CO_2 data sampled from Japanese Airlines (JAL) commercial airliners flying between Australia and Japan [*Matsueda et al.,* 2002]. These observations consist of automatic flask samples gathered at altitudes between 8 and 13 km on bi-weekly commercial flights. For the full processed period (1 January 2003 - 31 March 2004), CO_2 estimates were sampled in a 6˚ x 6˚ box around the location of the flight observation over a period of 5 days around the date of the flight observation. Fig. 2 shows the time series for the northern hemisphere region. The Figure shows that the analysis estimates follow the JAL observed annual cycle quite well. All differences fall within the 1-σ error bars and are of the order of 1 ppmv in most cases. There is a clear improvement compared to the used background, which is 376 ppmv throughout the year.

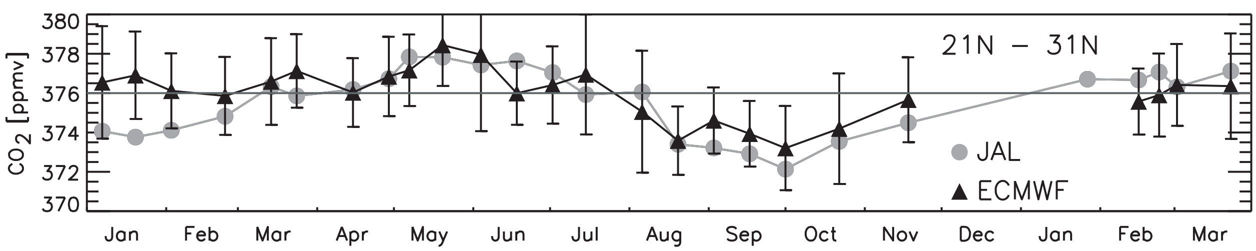

Fig. 2. Comparison of CO_2 estimates with JAL observations for the northern tropical band from January 2003 to March 2004. Missing ECMWF data are caused by extensive cloud cover in the area.

FUTURE WORK

The current system will be extended into a full 4D-Var CO_2 data analysis system in the next few years. CO_2 has already been introduced in the forecast model as a tracer including climatological surface fluxes. This will allow the transport to link the information of individual AIRS observations to produce a consistent atmospheric CO_2 field. Other greenhouse gases will be introduced as well and it is envisaged that much can be learned from such a comprehensive environmental data analysis system.

REFERENCES

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