SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year

2010 (1 July 2010 - 30 June 2011)

Project Title:

Inverse Modelling of Atmospheric CH_4 and N_2O

Computer Project Account:

spjrc4dv

Principal Investigator(s):

Dr. Peter Bergamaschi

Affiliation:

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Name of ECMWF scientist(s) collaborating to the project
(if applicable)

Dr. Richard Engelen (in the framework of the MACC project)

Start date of the project:

1 May 2009

Expected end date:

31 December 2011

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year (2010)		Current year (2011)	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	450000 +100000[1]	450000 +100000[1]	500000	~164000 (June 2010)
Data storage capacity	(Gbytes)	340 + 80[1]		375	

[1] request for increased resources (12 October 2010)

Summary of project objectives
(10 lines max)

1. Global CH_4 inversions using satellite observations (contribution to MACC project)
- pre-operational ("delayed-mode") inversions for MACC project
- CH_4 reanalysis 2003-2010

2. European CH_4 and N_2O inversions using in-situ observations
- Estimates of European sources of CH_4 and N_2O
- model comparison within NitroEurope project

3. Further development of TM5-4DVAR system
- update of observation interfaces (for new satellite data) and emission interface
- implement option to apply sub-monthly emission profiles and / or optimize emissions at sub-monthly time periods
- implement OpenMP for parallelization / and further optimizations to speed-up the TM5-4DVAR

Summary of problems encountered (if any)
(20 lines max)
……
……

Summary of results of the current year (from July of previous year to June of current year)
This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

Global CH_4 inversions using satellite observations (contribution to MACC project)

Within the MACC greenhouse gases subproject, JRC is responsible for the inverse modelling of CH_4, coupled to the ECMWF IFS system, where CH_4 satellite retrievals from the SCIAMACHY instrument onboard ENVISAT are assimilated. The major JRC deliverables are:

(1) the so called 'delayed-mode inversion' (which is delivered every six months, up to ~6 month behind real time). The first two delayed-mode inversions have been provided (covering the period 07/2009-06/2010) and are available at:
http://www.gmes-atmosphere.eu/d/services/gac/delayed/ch4_flux_inversions/

(2) re-analysis of global CH_4 emissions over the 2003-2010 period.

A preliminary reanalysis over the period 2003-2009 has been performed, using climatological OH fields.

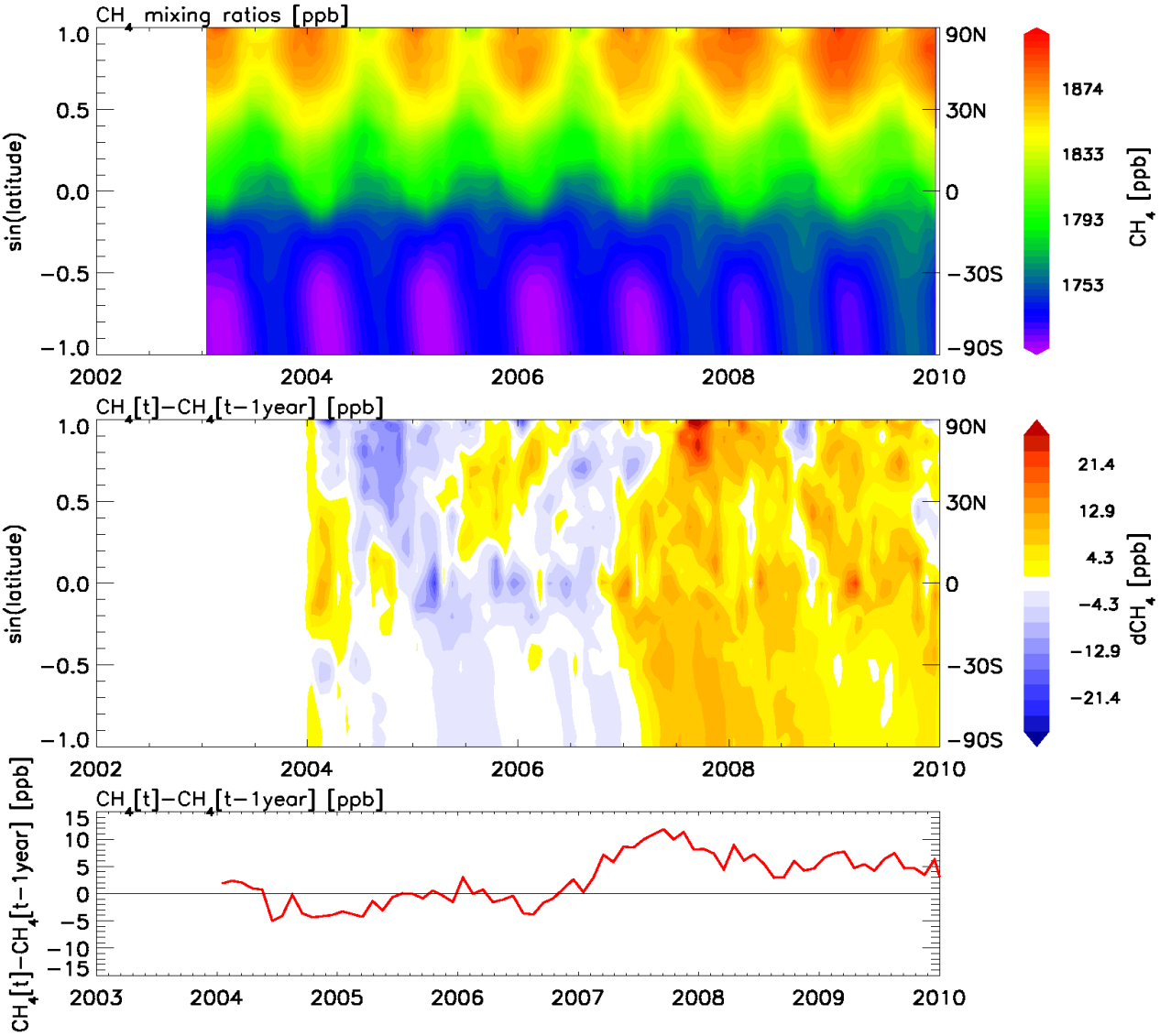

Figure 1: Preliminary reanalysis using SCIAMACHY IMAPv55 CH_4 satellite retrievals and NOAA surface observations.

The major objective of this reanalysis is a detailed analysis of global and regional CH_4 emissions, trends, and inter-annual variability (IAV). This is of particular interest in the context of the recent increase of atmospheric CH_4 mixing ratios since 2007 (see Figure 1). Despite the significant progress made to provide consistent SCIAMACHY retrieval time series (minimizing the impact of the significant pixel degradation after 2005) [*Frankenberg et al., 2011*], however, it remains very challenging to disentangle potential deficiencies of the SCIAMACHY retrievals from inter-annual variability (IAV) of CH_4 emissions. Furthermore, potential IAV of OH is expected to be in a similar order of magnitude as IAV of emissions. For the final reanalysis (to be completed by the end of the MACC project) we will include the OH fields from the MACC GRG reanalysis.

European CH_4 and N_2O inversions using in-situ observations

A detailed analysis of European CH_4 emissions 2001-2006 has been completed using the TM5-4DVAR system with zooming over Europe and using quasi-continuous observations from various European monitoring stations [*Bergamaschi et al., 2010*]. It has been demonstrated that robust top-down estimates can be provided for the CH_4 emissions from Northwest European (NWE) countries, which are relatively well constrained by the existing monitoring network.

A detailed comparisons of CH_4 and N_2O inverse models has been performed within the NitroEurope. European CH_4 and N_2O emissions are estimated for the years 2006 and 2007 using 5 independent inverse modeling systems, based on different global and regional Eulerian and Lagrangian transport models. The applied ensemble approach provides estimates of the overall uncertainties in the derived emissions.

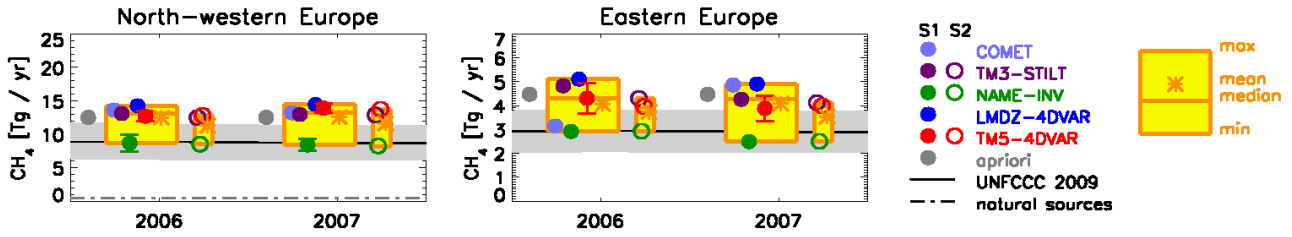

Figure 2: European CH_4 emissions derived from 5 inverse models for years 2006 and 2007 and comparison with CH_4 bottom-up inventories reported to UNFCCC. North-western Europe includes UK, Ireland, France, Germany, and BENELUX; while eastern Europe includes Poland, Hungary, Czech Republic, and Slovakia.

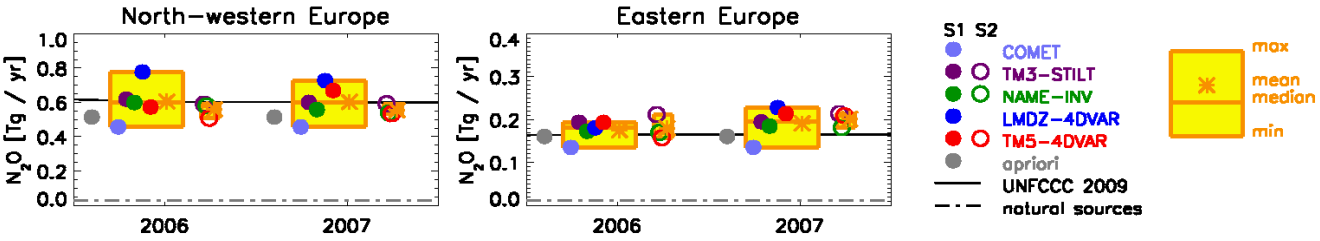

Figure 3: European N_2O emissions derived from 5 inverse models for years 2006 and 2007 and comparison with N_2O bottom-up inventories reported to UNFCCC.

A major challenge for the N_2O inversions are significant offsets seen for N_2O measurements from different laboratories at co-located sites. Therefore, we apply a bias correction scheme for N_2O developed during this project [*Corazza et al., 2011*].

This model intercomparison is currently being finalized.

Further development of TM5-4DVAR system

A major update of the The TM5-4DVAR emission interface includes the option to use daily emissions (such as from the MACC FRP biomass burning emissions), while before in general monthly mean emissions were applied. For MACC we apply this new feature for the daily MACC FRP biomass burning emissions (for the "delayed-mode" inversions)

An interface has been implemented to use 3-hourly OH fields from the MACC GRG reanalysis

Furthermore, an option has been implemented to optimize emissions at sub-monthly time periods (which required a major code update).

Finally, the code has been parallelized (using OpenMP) and further optimizations were implemented to speed-up the TM5-4DVAR. However, these new features will require further detailed testing.

List of publications/reports from the project with complete references

Bergamaschi, P., C. Frankenberg, J. F. Meirink, M. Krol, M. G. Villani, S. Houweling, F. Dentener, E. J. Dlugokencky, J. B. Miller, L. V. Gatti, A. Engel, and I. Levin, Inverse modeling of global and regional CH_4 emissions using SCIAMACHY satellite retrievals, J. Geophys. Res., 114, doi:10.1029/2009JD012287, 2009.

Bergamaschi, P., M. Krol, J. F. Meirink, F. Dentener, A. Segers, J. van Aardenne, S. Monni, A. Vermeulen, M. Schmidt, M. Ramonet, C. Yver, F. Meinhardt, E. G. Nisbet, R. Fisher, S. O'Doherty, and E. J. Dlugokencky, Inverse modeling of European CH_4 emissions 2001-2006, *J. Geophys. Res.,* 115(D22309), doi:10.1029/2010JD014180, 2010.

Corazza, M., P. Bergamaschi, A. T. Vermeulen, T. Aalto, L. Haszpra, F. Meinhardt, S. O'Doherty, R. Thompson, J. Moncrieff, E. Popa, M. Steinbacher, A. Jordan, E. J. Dlugokencky, C. Brühl, M. Krol, and F. Dentener, Inverse modelling of European N_2O emissions: Assimilating observations from different networks, *Atmos. Chem. Phys.* , 11(doi:10.5194/acp-11-2381-2011), 2381–2398, 2011.

Frankenberg, C., I. Aben, P. Bergamaschi, E. J. Dlugokencky, R. van Hees, S. Houweling, P. van der Meer, R. Snel, and P. Tol, Global column-averaged methane mixing ratios from 2003-2009 as derived from SCIAMACHY: Trends and variability, *J. Geophys. Res.,* 116(D04302), doi:10.1029/2010JD014849, 2011.

Hooghiemstra, P. B., M. C. Krol, J. F. Meirink, P. Bergamaschi, G. R. van der Werf, P. C. Novelli, I. Aben, and T. Röckmann, Optimizing global CO emissions using a four-dimensional variational data assimilation system and surface network observations, *Atmos. Chem. Phys.* , 11, 4705-4723, 2011.

Summary of plans for the continuation of the project

(10 lines max)

Final CH_4 reanalysis 2003-2010 within MACC project. This will include:
- use of MACC GRG OH fields
- updated a priori emission inventories
- improved inversion settings
- detailed validation of results

Implement interface for GOSAT CH_4 retrievals

Improve bias correction for satellite data

Finalization of CH_4 and N_2O comparison performed with NitroEurope

Extension of European CH_4 inversion to the period 1992 - 2009.

Further testing of recent upgrades of the TM5-4DVAR source code (see above)