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	2011
Project Title:	Global atmospheric chemistry modelling with EC-Earth: understanding past and predicting future tropospheric ozone in a changing climate
Computer Project Account:	SPNLCECE
Principal Investigator(s):	Dr. T.P.C. van Noije
Affiliation:	Royal Netherlands Meteorological Institute (KNMI)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Dr. M. van Weele, Dr. J.E. Williams, Dr. Ph. Le Sager, Dr. A. Strunk
Start date of the project:	01-01-2009
Expected end date:	31-12-2011

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	300,000	172,740	300,000	187,950
Data storage capacity	(Gbytes)	500	290	500	315

Summary of project objectives

(10 lines max)

(1) To further develop the TM5 atmospheric chemistry module of the EC-Earth climate model and to improve the couplings between chemistry and aerosols on the one hand and the physics and dynamics of IFS on the other hand.

(2) To understand the upward trends in tropospheric ozone that have been observed at northern midlatitudes and in the Arctic since the mid-1990s by analyzing the different factors that have contributed to these trends, including the impact of changes in emissions, tropospheric transport patterns and stratospheric circulation.

(3) Explore the range of changes in tropospheric ozone that can be expected in the first half of the 21st century because of projected changes in emissions and climate.

Summary of problems encountered (if any)

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The EC-Earth climate simulations for the Coupled Model Intercomparison Project (CMIP5) have been delayed because of bugs in the implementation of the volcanic forcings and tropospheric aerosols that were prescribed. These long-term simulations from the pre-industrial to 2100 were expected to be ready early 2011, but are now planned for the second half of 2011. This has delayed the present-day and near-term future simulations with online coupling to the TM5 atmospheric chemistry and aerosols module, which are planned in this project.

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

Activities during June 2012-June 2011 include the further technical development of the chemistry-climate model version of EC-Earth, and the execution and analysis of decadal simulations with the stand-alone version of TM5 driven by the ERA-Interim reanalysis.

Technical developments

In last year's progress report we included a short discussion on the performance of the coupled model. There we used a model version with the same vertical resolution in TM5 as in IFS. The IFS version used in EC-Earth has 62 or 91 levels in the vertical. In the stand-alone version of TM5 we normally merge the layers available in the driving meteorological fields (ECMWF operational data or ERA-Interim reanalysis fields), reducing the number of levels from 60 or 91 to 34. End 2012 a similar option was implemented in the EC-Earth model, where the exchange between IFS and TM5 takes place through the OASIS3 coupler. In the new version of EC-Earth we typically use 31 out of 62 or 34 out of 91 levels. The gain in performance of the configuration with 31 levels out of 62 was analyzed for various combinations of numbers of processors used for IFS, TM5 and NEMO, the ocean module in EC-Earth (see Figure 1).

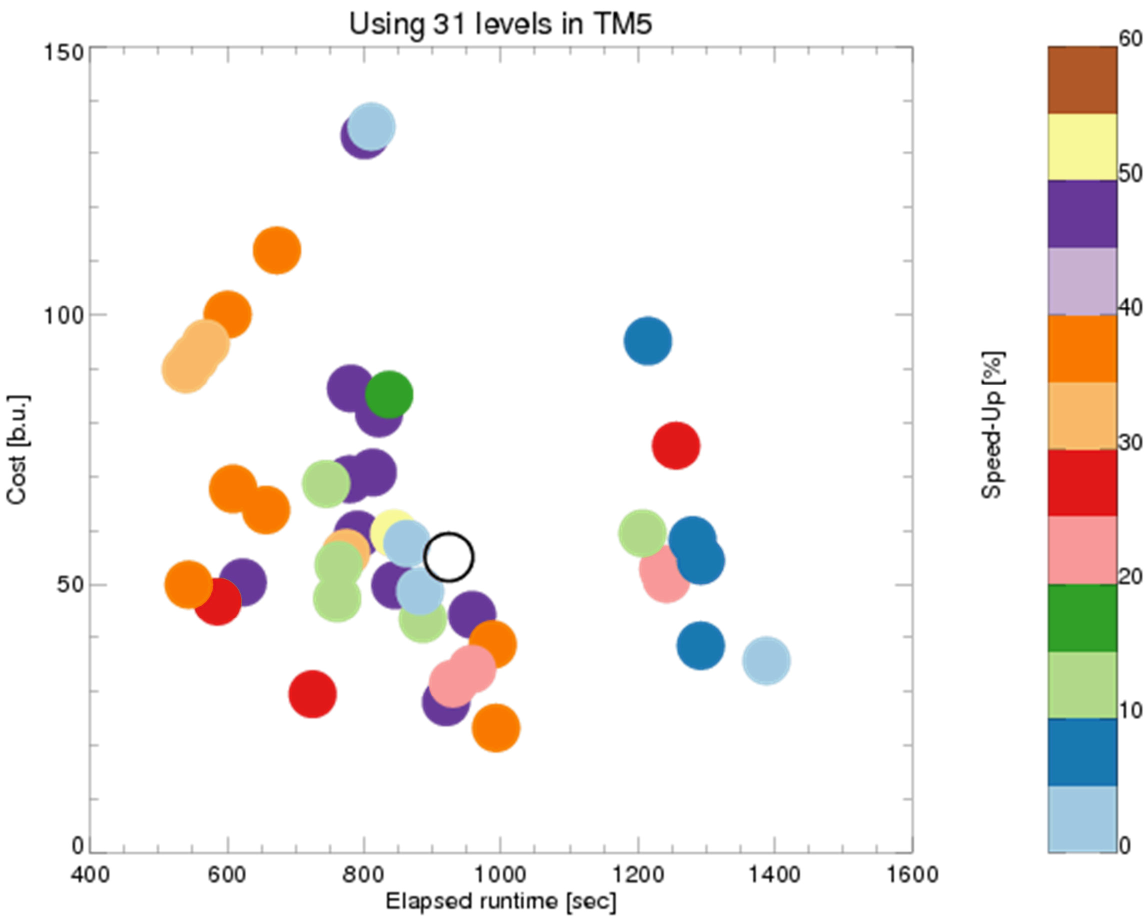

Figure 1. Costs (SBU) and elapsed runtime of EC-Earth using 31 vertical levels for TM5 at 6x4 degrees, 62 levels for IFS at T159, and 42 levels for NEMO with ORCA1 grid. Results are presented for various combinations of numbers of processors, varying independently from 2, 4, 8 and 16 for TM5 and IFS, and from 1, 2, 4 and 8 for NEMO. Colours indicate the speed-up compared to the case with 62 levels in TM5. In total about 128 2-day runs were performed.

The optimal configuration uses 8 processors for both IFS and TM5 and 2x2 for NEMO (corresponding to the orange point at the bottom left part of the graph). In this case the speed-up resulting from the reduced vertical resolution in TM5 is about 37%. The configuration with 2x1 processors for NEMO (indicated by the partially overlapping red point) has a very similar performance, but takes a bit longer to finish.

From this analysis we estimated that in the selected configuration it takes about 27.6 hours (elapsed time) or 9.1 kSBU per simulated year in the new configuration with 31 levels in TM5, compared to 43.6 hours or 10.4 kSBU with 62 levels in TM5 and 16.2 hours or 3.7 kSBU for running the IFS-NEMO coupled model without TM5, using the same number of processors for IFS and NEMO. Thus, in this configuration the inclusion of TM5 at a resolution of 6x4 degrees increases the runtime of EC-Earth by about 70%. Note that this number doesn't extrapolate to higher numbers of processors, because the current version of TM5 doesn't scale very well beyond 8-12 processors. We are currently working on improving the scalability of TM5 by changing the MPI domain decomposition of the model.

Another line of development is the inclusion of the dynamic global vegetation model LPJ-Guess in EC-Earth. Since last year's report we have made significant progress coupling LPJ-Guess to both the land surface scheme of IFS (H-TESSEL) and TM5 through OASIS. The current status is that a system has been set up in which both IFS and TM5 are able to exchange fields through OASIS with a dummy 'LPJ-Guess' model. At the same time people at Lund University in collaboration with SMHI have created an OASIS interface for LPJ-Guess. We are now merging these two parts to make the connection. The next step will be the testing of these couplings in terms of the physical and chemical responses. This will be beyond the scope of this special project.

Decadal simulation

During December 2010 and January 2011 a simulation has been performed for the years 2000-2009 using TM5 in stand-alone mode driven by meteorological fields from the ERA-Interim reanalysis. The version used for this simulation is based on that described in the paper by Huijnen et al. (2010), but with different emissions and an improved representation of emission heights, a comprehensive aerosol microphysics scheme (M7) for sulphate, black and organic carbon, sea salt and dust, and some additional aerosol diagnostics (e.g. for aerosols) included. For anthropogenic and biomass burning emissions this simulation uses one of the representative concentration patways (RCP4.5) developed for the IPCC Fifth Assessment Report (AR5). Natural emissions are taken from the MACCity inventory developed for the EU MACC and CityZen projects. A resolution of 3x2 degrees was applied with 34 levels in the vertical.

With this simulation (prepared and performed by Dr. A. Strunk) we have contributed to phase II of the AeroCom project (Aerosol Comparisions between Observations and Models). The TM5 results on e.g. aerosol burdens, surface concentrations and optical properties and a comparison with measurements can be found at the AeroCom interface at http://aerocom.met.no/cgi-bin/aerocom/surfobs_annualrs.pl.

We have also analyzed the simulated changes in tropospheric ozone and compared the results from this simulation (called AR5R45) with two other decadal TM5 simulations using different emission inventories (RETREA and FXANTH). RETREA uses annually varying anthropogenic emissions from the regional emission inventory in Asia (REAS) together with non-Asian emissions from the EU RETRO project fixed to the year 2000. In FXANTH the Asian emissions are fixed to year-2000 levels as well. For emissions from biomass burning both RETREA and FXANTH use a climatological dataset from the Global Fire Emissions Database (GFEDv2); both simulations use biogenic emissions from the ORCHIDEE dynamic global vegetation model, supplemented with emissions from other natural sources from the EU POET project. A selection of results from this comparison, focusing on ozone changes over Asia, have been presented at the Second Tropospheric Ozone Workshop held in Toulouse in April, and described in a proceedings paper by Strunk et al. Figure 2 shows a comparison of monthly mean ozone mixing ratios at 500 hPa against aircraft data measured as part of the Measurements of OZone and water vapour by in-service AIrbus aircraft (MOZAIC) project (http://mozaic.aero.obs-mip.fr). The MOZAIC composites were assembled using profile data from three Japanese airports (Tokyo, Osaka and Nagoya) and one Korean airport (Seoul).

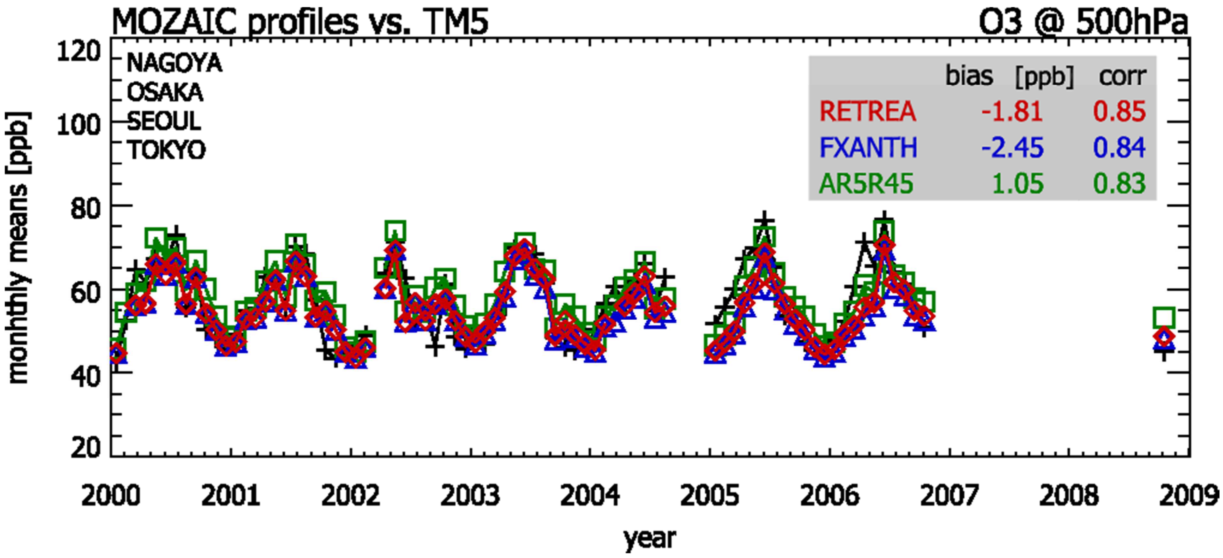

Figure 2. Ozone monthly means at 500 hPa, compared to MOZAIC profile observations over the four airports in Japan and Korea.

In general, TM5 is able to reproduce both the relative amounts and observed seasonal cycle in ozone rather well. The absolute biases at 500 hPa and 850 hPa (not shown) are lower than 2 ppb for AR5R45 and RETREA. The AR5R45 simulation has almost no bias at 850 hPa. The temporal correlation coefficients are higher than 0.68 (0.83) at 850 hPa (500 hPa). This gives confidence in the performance of TM5 in capturing the inter-annual variability of tropospheric ozone over this region.

Figure 3 shows the simulated ozone trends for Japan between 2000-2008, where the data is binned with respect to pressure and height.

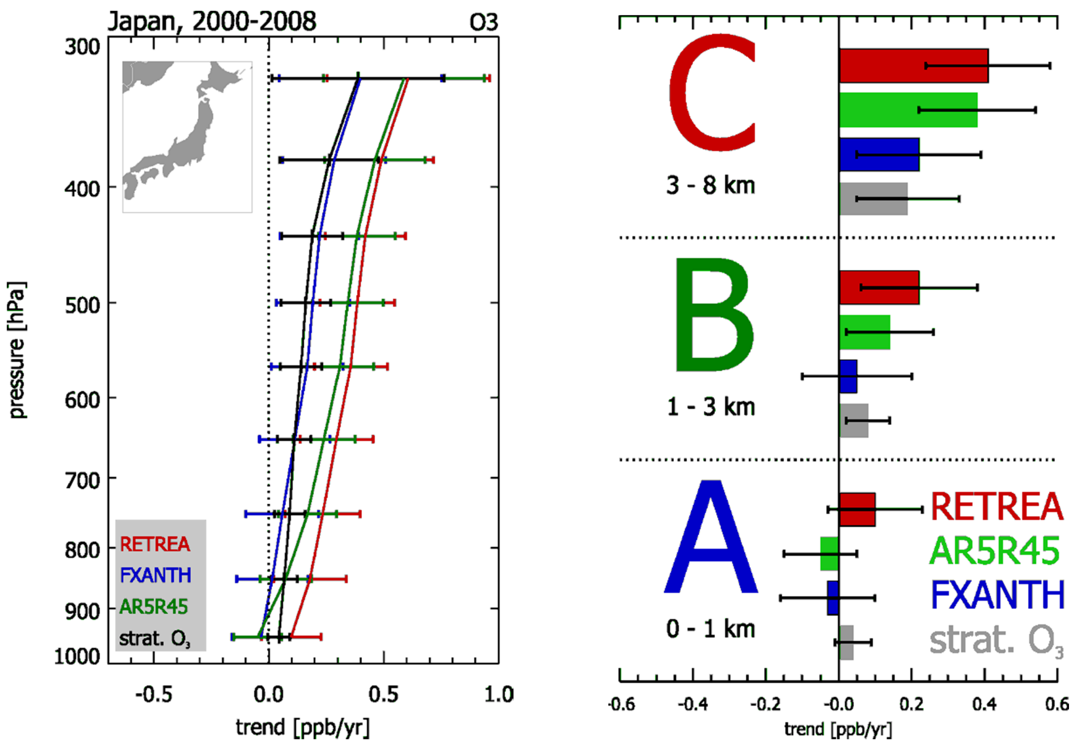

Figure 3. Modelled trends in ozone (left) over the Japanese region as a function of pressure, and the corresponding trends binned to height ranges (right). Error bars denote the 95% confidence interval.

All simulations show positive trends in tropospheric ozone up to 0.6 ppb/yr in the upper troposphere. For RETREA the trends are positive and significant throughout the whole vertical column, increasing from 0.1 ppb/yr at the surface to 0.6 ppb/yr in the upper troposphere. The AR5R45 simulation gives smaller increases than RETREA, ranging from -0.04 ppb/yr near the surface to 0.6 ppb/yr in the upper troposphere. Comparison with FXANTH shows that a large fraction of the positive trend in RETREA can be attributed to enhanced long-range transport of ozone and/or nitrogen oxide reservoir species (e.g. peroxyacetyl nitrate (PAN)). Interestingly there is still an ozone trend in the free troposphere for FXANTH. Using a stratospheric ozone tracer (Huijnen et al., 2010) this trend can be attributed to an increase in the stratosphere-troposphere exchange flux over the simulation period, as seen for other meteorological data sets (e.g. using the NCEP reanalysis). For AR5R45 the decreasing trends in surface ozone (being negative below 900 hPa) can be attributed to the decrease of local emissions in the AR5 inventory.

Reference

Huijnen, V., J. Williams, M. vanWeele, T. van Noije, et al., The global chemistry transport model TM5: description and evaluation of the tropospheric chemistry version, Geosci. Mod. Dev., 3, 445–473, 2010.

List of publications/reports from the project with complete references

Hazeleger, W., C. Severijns, T. Semmler, et al., EC-Earth: A seamless Earth system prediction approach in action, Bull. Am. Meteor. Soc., 91, 1357-1363, 2010.

Hazeleger, W., X. Wang, C. Severijns, S. Stefanescu, R. Bintanja, A. Sterl, K. Wyser, T. Semmler, S. Yang, B. van den Hurk, T. van Noije, E. van der Linden, K. van der Wiel, EC-Earth V2: description and validation of a new seamless Earth system prediction model, Climate Dynamics (in preparation).

A. Strunk, J.E. Williams, T.P.C. van Noije, M. van Weele, and P.F.J. van Velthoven, Influence of increasing anthropogenic emissions on the vertical distribution of tropospheric ozone near the Asian continent for the period 2000-2008, Proceeding of the Second Tropospheric Ozone Workshop, Tropospheric ozone changes: Observations, state of understanding, and model performances, 11-14 April 2011, Météo-France, Toulouse, France (submitted).

Presentations:

Van Noije, T., A. Strunk, P. Le Sager, A. Ekman, A. Lewinschal, and M. Kahnert, Progress report of the working group on chemistry, aerosols and clouds, EC-Earth meeting, 17-19 January 2011, ECMWF, Reading, United Kingdom.

Strunk, A., T. van Noije, and J.E. Williams, A decadal simulation of the tropospheric composition with TM5 using IPCC AR5 emissions, poster presented at the EGU General Assembly, 3-8 April 2011, Vienna, Austria.

Strunk, A., J.E. Williams, M.P. Scheele, T.P.C. van Noije, M. van Weele, and P.J.F. van Velthoven, Influence of increasing anthropogenic emissions on the vertical distribution of tropospheric ozone near the Asian continent for the period 2000-2008, Second Tropospheric Ozone Workshop, Tropospheric ozone changes: Observations, state of understanding, and model performances, 11-14 April 2011, Météo-France, Toulouse, France.

Van Weele, M., J.E. Williams, T.P.C. van Noije, and P.F.J. van Velthoven, Investigate the variability of CH_4 and H_2O throughout the UTLS in the ACCMIP simulations, AC&C ACC-MIP 1st First Workshop, 13-15 April 2011, Météo-France, Toulouse, France.

T. van Noije, The chemistry and aerosol module TM5, MERGE EC-Earth Seminar, 10 May 2011, Lund University, Lund, Sweden.

Summary of plans for the continuation of the project

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In addition to the decadal simulation with the stand-alone version of TM5 driven by meteorological fields from the ERA-Interim reanalysis, we will carry out decadal simulations with EC-Earth, both for present-day (2001-2010) and the near-term future (2026-2035). With these simulations we will provide input to the CLIMAQS project (climaqs.vito.be).