Charles University in Prague
Faculty of Mathematics and Physics
Dept. of Meteorology and Environment Protection
V Holesovickach 2, Prague 8
Czech Republic

HIGH RESOLUTION MODELLING OF CLIMATE CHANGE IMPACT ON ATMOSPHERIC CHEMISTRY IN TROPOSPHERE

Halenka T.[1], Huszar P.[1], Belda M.[1], Krueger B.[2], Zanis P.[3], Katragkou E.[4], Tegoulias I.[3], Melas D.[4]

[1]Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic
[2]Institute of Meteorology and Physics, University of Agricultural Sciences,Vienna, Austria
[3]Dept. of Meteorology-Climatology, School of Geology, AUTH, Thessaloniki,Greece
[4]Laboratory of Atmospheric Physics, School of Physics, AUTH, Thessaloniki, Greece
E-mail: tomas.halenka@mff.cuni.cz

Summary

- Recent studies show considerable effect of atmospheric chemistry and aerosols on climate on regional and local scale. For the purpose of qualifying and quantifying the magnitude of climate forcing due to atmospheric chemistry/aerosols on regional scale, the development of coupling of regional climate model and chemistry/aerosol model has been started on the Department of Meteorology and Environmental Protection, Faculty of Mathematics and Physics, Charles University in Prague. For this coupling, existing regional climate model and chemistry transport model are used. Climate is calculated using model RegCM while chemistry is solved by model CAMx. Meteorological fields generated by RegCM drive CAMx, transport a dry/wet deposition. A preprocessor utility was developed on the department for transforming RegCM provided fields to CAMx input fields and format.
- As the first step, the distribution of pollutants can be simulated for long period in the model couple. There is critical issue of the emission inventories available. The next step is the inclusion of the radiative active agents from CAMx into RegCM radiative transfer scheme to calculate the changes of heating rates. Only the modification of radiative transfer due to atmospheric chemistry/aerosols will be taken into account first, the indirect effect of aerosols will be taken into account later, there are still many uncertainties in understanding of this issue and possibility of inclusion of appropriate processes into the model. Monthly and yearly coupled climate/chemistry/aerosol model runs are scheduled in framework of ongoing projects.
- Here, the results of high resolution run nested into low resolution domain is presented. Modeled hourly and daily means of ozone concentration were evaluated against station measurements. The period of model run is year 2000.
- All the work is done in the framework of EC FP6 CECILIA Project, Work Package 7:"Climate change impacts on air quality and health" in accordance with its objectives:
  - Exploitation of the sensitivity of air-pollution levels to potential climate change based on data analysis of long simulations of offline chemistry air quality models (AQM) driven by Regional Climate Models (RCMs) for present climate and for future projections.
  - Comparison of air-pollution levels simulated by online and offline regional air-quality models during certain episodes of the present climate.
  - Estimation of the key species exceedances of the EU limits for the protection of human health, vegetation and ecosystems as well as WHO guidelines for present climate and for future projections.

Goals

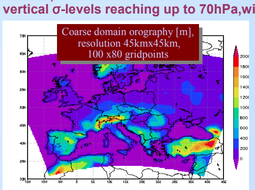
- To study the impact of climate change on air quality
- To study the contribution of air composition change to climate change impact
- To estimate the importance of bigger urban and industrial areas in local scale by high resolution modelling

Models

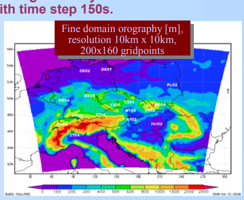
RegCM

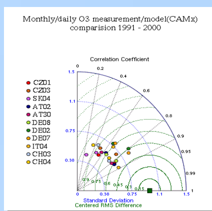
The model RegCM used here was originally developed by Giorgi et al. (1993a,b) and then has undergone a number of improvements described in Giorgi et al. (1999), and, finally, Pal et al. (2005). The dynamical core of the RegCM is equivalent to the hydrostatic version of the mesoscale model MM5. Surface processes are represented via the Biosphere-Atmosphere Transfer Scheme (BATS) and boundary layer physics is formulated following a non-local vertical diffusion scheme (Giorgi et al. 1993a). Resolvable scale precipitation is represented via the scheme of Pal et al (2000), which includes a prognostic equation for cloud water and allows for fractional grid box cloudiness, accretion and re-evaporation of falling precipitation. Convective precipitation is represented using a mass flux convective scheme (Giorgi et al. 1993b) while radiative transfer is computed using the radiation package of the NCAR Community Climate Model, version CCM3 (Giorgi et al. 1999). This scheme describes the effect of different greenhouse gases, cloud water, cloud ice and atmospheric aerosols. Cloud radiation is calculated in terms of cloud fractional cover and cloud water content, and the fraction of cloud ice is diagnosed by the scheme as a function of temperature. We use 23 vertical σ-levels reaching up to 70hPa,with time step 150s.

Coarse domain orography [m], resolution 45kmx45km, 100 x80 gridpoints



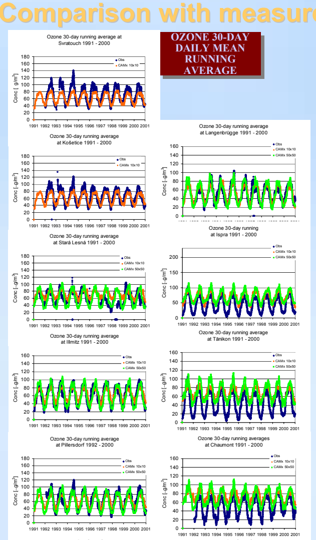
Fine domain orography [m], resolution 10km x 10km, 200x160 gridpoints



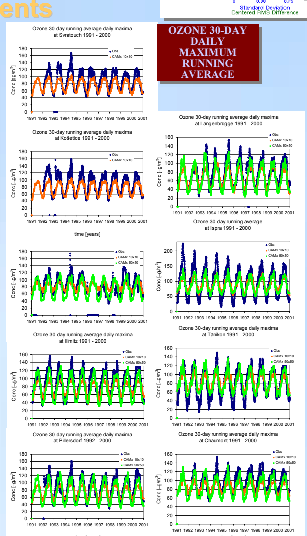


Comparison with measurements

OZONE 30-DAY DAILY MEAN RUNNING AVERAGE



OZONE 30-DAY DAILY MAXIMUM RUNNING AVERAGE



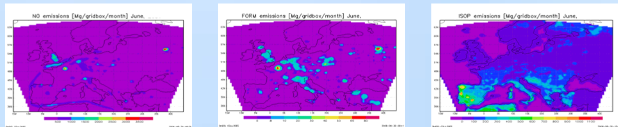
CAMx ENVIRON

Eulerian photochemical dispersion model

Capabilities:
- driving meteorological models – MM5, WRF, RAMS, CALMET
- emission inputs from many emissions processors – SMOKE, CONCEPT, EPS
- Two-way grid nesting
- Multiple gas phase chemistry mechanism options (CB-IV, SAPRC99)
- Multi-sectional or static two-mode particle size treatments
- Wet deposition of gases and particles
- Plume-in-grid (PiG) module for sub-grid treatment of selected point sources
- Ozone and Particulate Source Apportionment Technology

Emission processing

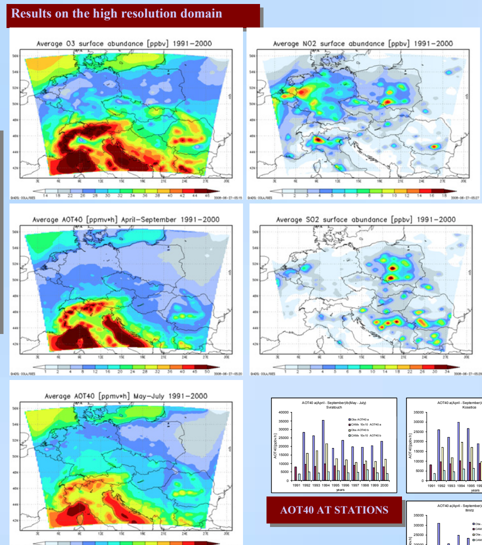
EMEP 50 km x 50 km inventories are interpolated (spatial and temporal allocation, speciation)
Biogenic emissions of isopren and monoterpenes by Guenther et al. (1993,1994). Following figures show monthly emissions from June 2000 for nitrogen monoxid, fromaldehide and isoprene on the coarse domain.



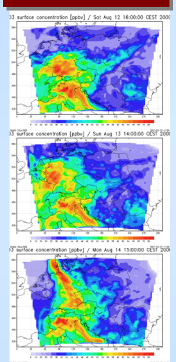
Coupling and chemistry

One-way coupling: RegCM drives CAMx's transport and dry/wet deposition. A preprocessor utility was developed for transforming RegCM fields to CAMx input fields and formats. As the first step, the distribution of pollutants can be simulated for long period in the model couple. For the coarse domain, initial and boundary conditions are set to CAMx's top concentrations (independent of time) (Simpson et al., 2003), the boundary conditions of high resolution 10km domain was taken from the concentrations on 50x50km domain run RegCM-CAMx based on ICTP ENSEMBLES RegCM@25km (see poster E. Katragkou et al.). In our setting CB-IV chemistry mechanism is used for both domains (Gery et al.,1989).

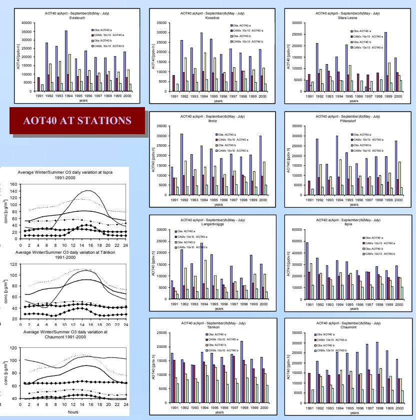
Results on the high resolution domain



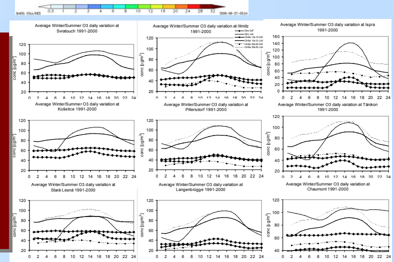
Simulated ozone episode Aug, 12 - 14th, 2000



AOT40 AT STATIONS



OZONE DAILY VARIATION



Outlooks

The next step is the inclusion of the radiative active agents from CAMx into RegCM radiative transfer scheme to calculate the changes of heating rates. Only the modification of radiative transfer due to atmospheric chemistry/aerosols will be taken into account first, the indirect effect of aerosols will be taken into account later, there are still many uncertainties in understanding of this issue and possibility of inclusion of appropriate processes into the model. The feedback of chemistry/aerosols on climate will be studied in terms of monthly and yearly averages of 2 m temperatures and of the top-of-the-atmosphere (TOA) radiative forcing, the results will provide the estimate of the effect of interactive atmospheric chemistry and aerosols on climate in regional and local scales.

Acknowledgement

This work is supported in framework of EC FP6 Project CECILIA (GOCE 037005) as well as partially EC FP6 IP QUANTIFY (GOCE 003893) and under support of the local grant of Programme Informacni spolecnost, No. 1ET400300414 and Research Plan of MSMT under No. MSM 0021620860. Authors wish to express their thanks to ICTP for RegCM and Environ for CAMx made available as well as NCEP for boundary conditions available and EMEP for the emissions.

References

Gery, M.W., G.Z. Whitten, J.P. Killus, and M.C. Dodge. 1989. A Photochemical Kinetics Mechanism for Urban and Regional Scale Computer Modeling. J. Geophys. Res., 94, 925-956.
Giorgi, F., M.R. Marinucci, and G.T. Bates, 1993a: Development of a second generation regional climate model (RegCM2). Part I: Boundary layer and radiative transfer processes. *Mon. Wea. Rev.*, 121, 2794-2813.
Giorgi, F., M.R. Marinucci, G.T. Bates, and G. DeCanio, 1993b: Development of a second generation regional climate model (RegCM2). Part II: Convective processes and assimilation of lateral boundary conditions. *Mon. Wea. Rev.*, 121, 2814-2832.
Giorgi, F., Y. Huang, K. Nishizawa and C. Fu, 1999: A seasonal cycle simulation over eastern Asia and its sensitivity to radiative transfer and surface processes. *Journal of Geophysical Research*, 104, 6403-6423.
Guenther, A.B. , Zimmerman, P.R. , Harley, P.C. , Monson, R.K. , and Fall, R. ,1993, Isoprene and monoterpene rate variability: model evaluations and sensitivity analyses, J. Geophys. Res., 98, No. D7, 12609-12617.
Guenther, A. , Zimmerman, P. , and Wildermuth, M. ,1994, Natural volatile organic compound emission rate estimates for U.S. woodland landscapes, Atmospheric Environment, 28, 1197-1210.
O'Brien, J. J., 1970: A note on the vertical structure of the eddy exchange coefficient in the planetary boundary layer. J. Atmos. Sci., 27, 1213–1215.
Pal, J. S., E. E. Small, and E. A. Eltahir, 2000: Simulation of regional-scale water and energy budgets: Representation of subgrid cloud and precipitation processes within RegCM. *J. Geophys. Res.*, 105, 29579-29594.
Pal, J. S., F. Giorgi, X. Bi, N. Elguindi, F. Solmon, A. Grimm, L. Sloan, F. Syed, and A. Zakey, 2005: The ICTP Regional Climate Model version 3 (RegCM3). Benchmark simulations over tropical regions. Submitted to the *Bull. Amer. Meteorol. Soc.*
Simpson, D. ,Fagerli, H. ,Jonson, J.,Tsyro, S.,Wind, P., 2003, Transboundary Acidification, Eutrophication and Ground Level Ozone in Europe PART I, Norwegian Meteorological Institute.