Geophysical Research Abstracts
Vol. 16, EGU2014-10432, 2014
EGU General Assembly 2014

Describing the direct and indirect radiative effects of atmospheric aerosols over Europe by using coupled meteorology-chemistry simulations: a contribution from the AQMEII-Phase II exercise

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The study of the response of the aerosol levels in the atmosphere to a changing climate and how this affects the radiative budget of the Earth (direct, semi-direct and indirect effects) is an essential topic to build confidence on climate science, since these feedbacks involve the largest uncertainties nowadays. Air quality-climate interactions (AQCI) are, therefore, a key, but uncertain contributor to the anthropogenic forcing that remains poorly understood. To build confidence in the AQCI studies, regional-scale integrated meteorology-atmospheric chemistry models (i.e. models with on-line chemistry) that include detailed treatment of aerosol life cycle and aerosol impacts on radiation (direct effects) and clouds (indirect effects) are in demand.

In this context, the main objective of this contribution is the study and definition of the uncertainties in the climate-chemistry-aerosol-cloud-radiation system associated to the direct radiative forcing and the indirect effect caused by aerosols over Europe, using an ensemble of fully-coupled meteorology-chemistry model simulations with the WRF-Chem model run under the umbrella of AQMEII-Phase 2 international initiative. Simulations were performed for Europe for the entire year 2010. According to the common simulation strategy, the year was simulated as a sequence of 2-day time slices. For better comparability, the seven groups applied the same grid spacing of 23 km and shared common processing of initial and boundary conditions as well as anthropogenic and fire emissions. With exception of a simulation with different cloud microphysics, identical physics options were chosen while the chemistry options were varied.

Two model set-ups will be considered here: one sub-ensemble of simulations not taking into account any aerosol feedbacks (the baseline case) and another sub-ensemble of simulations which differs from the former by the inclusion of aerosol-radiation feedback. The existing differences for meteorological variables (mainly 2-m temperature and precipitation) and air quality levels (mainly ozone an PM10) between both sub-ensembles of WRF-Chem simulations have been characterized. In the case of ozone and PM10, an increase in solar radiation and temperature has generally resulted in an enhanced photochemical activity and therefore a negative feedback (areas with low aerosol concentrations present more than 50 W m-2 higher global radiation for cloudy conditions). However, simulated feedback effects between aerosol concentrations and meteorological variables and on pollutant distributions strongly depend on the model configuration and the meteorological situation.

These results will help providing improved science-based foundations to better assess the impacts of climate variability, support the development of effective climate change policies and optimize private decision-making.