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SILAM AND MACC IFS OUTPUT USED FOR SIMULATING THE AEROSOL DIRECT RADIATIVE FORCING WITH HARMONIE MODEL FOR SUMMER 2010 WILDFIRE CASE IN RUSSIA

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Abstract. Hot and dry weather in the European part of Russia during summer 2010 resulted from persistent high pressure area which blocked westerly flow, creating favourble conditions for severe wildfires. The fire-induced particulate matter concentrations were high during July and August, 2010. The SILAM model is used for simulating dispersion of the smoke aerosol for this case. SILAM output is compared to MACC IFS re-analysis. Moreover, comparison of model output to *in situ* and remote sensing measurements is performed, paying particular attention to August 7 – 9, when the plume reached Baltic countries and Finland. The model results are consistent with AOD observed by MODIS and *in situ* PM2.5 measured in six monitoring stations in Estonia. However, SILAM tends to underestimate the AOD in respect to MACC IFS re-analysis. The further aim of this study is online coupled modelling based of SILAM and NWP model HARMONIE. Aimed at validation of the HARMONIE aerosol and radiation schemes, the MACC IFS re-analysis aerosol output was applied. The modelling results show significant reduction of shortwave radiation fluxes and thus, surface temperature.

Key words: *model validation, SILAM, MACC, severe wildfire, direct radiative effect*.

INTRODUCTION

This case study is performed with further aim of online coupled modelling based on atmospheric chemistry-transport model SILAM and Hirlam Aladin Research for Mesoscale Operational Numerical Weather Prediction in Europe (HARMONIE) model. The components of the system are tested separately, based on a severe wildfire aerosol pollution event in July and August 2010. Close attention is paid to August 7 – 9, when the plume from fires in European part of Russia reached Baltic countries and Finland. The direct radiative effect of the wildfire smoke on the meteorological conditions is simulated.

Hot and dry weather in the European part of Russia during summer 2010 resulted from persistent high pressure area which blocked westerly flow, creating favourble conditions for severe wildfires (Witte et al., 2011). The fire-induced particulate matter concentrations were high during July and August, 2010. Péré et al. (2014) modelled the aerosol distribution and radiation impact of these fires with CHIMERE model. They found that the daily average shortwave radiation was reduced near the surface by 80 – 150 W/m^2, resulting in reduction of near-surface temperature by 0.2 – 2.6 °C. Thus, the aerosol impact to the weather was significant, possibly resulting in effects to atmospheric dynamics.

MODEL SETUP

System for Integrated modeLling of Atmospheric coMposition (SILAM, http://silam.fmi.fi/) is used for simulating dispersion of the smoke aerosol. SILAM output is compared to Monitoring Atmospheric Composition and Climate (MACC) Integrated Forecasting System (IFS) re-analysis. Moreover, comparison of the model output to *in situ* (PM2.5 in monitoring stations in Estonia) and remote sensing measurements is performed.

MACC re-analysis data is based on European Centre for Medium-Range Weather Forecasts (ECMWF) global model IFS coupled to atmospheric chemistry-transport model (CTM-IFS) (Flemming *et al*, 2009). CTM-IFS computes the concentrations of aerosol components: sea salt, dust, organic matter, black carbon, sulphate. The aerosol advection and aerosol radiative effects are included (Morcrette *et al*., 2009). The 4DVAR system is applied to assimilate the aerosol optical depth (AOD) from satellite measurements (Benedetti et al., 2009).

The compared SILAM and MACC systems are different. For wild-land fires, SILAM model uses the emission data generated by the IS4FIRES system (Sofiev et al, 2009). Atmospheric concentrations and optical thicknesses of the plume are calculated. The MACC re-analysis is based on Global Fire Assimilation System (GFAS) fire emission data, with subsequent assimilation of Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol column optical depth. It is therefore expected that MACC re-analysis is nudged closer to the MODIS AOD fields than the SILAM results, which did not include any data assimilation.

HARMONIE model is used for the meteorological simulation. In the HARMONIE model ECMWF radiation parameterizations are used (Seity et al., 2011). Two-stream shortwave radiation scheme (Fouquart and Bonnel, 1980) with 6 spectral bands is utilised. For calculating the aerosol direct radiative effect, AOD on model levels changing in time and constant single scattering albedo and asymmetry parameter for each spectral interval is used. MACC AOD was used in HARMONIE runs.

RESULTS AND DISCUSSION

Geographic distribution of the smoke aerosol

In Figure 1 AOD values re-analysed by MACC-IFS system, forecasted by SILAM and measured by MODIS are compared. White areas in MODIS map are classified as clouds. However, in the middle of plume no clouds are expected (anticyclonal weather, see Figure 2), but the plume was dense enough to be classified as such.

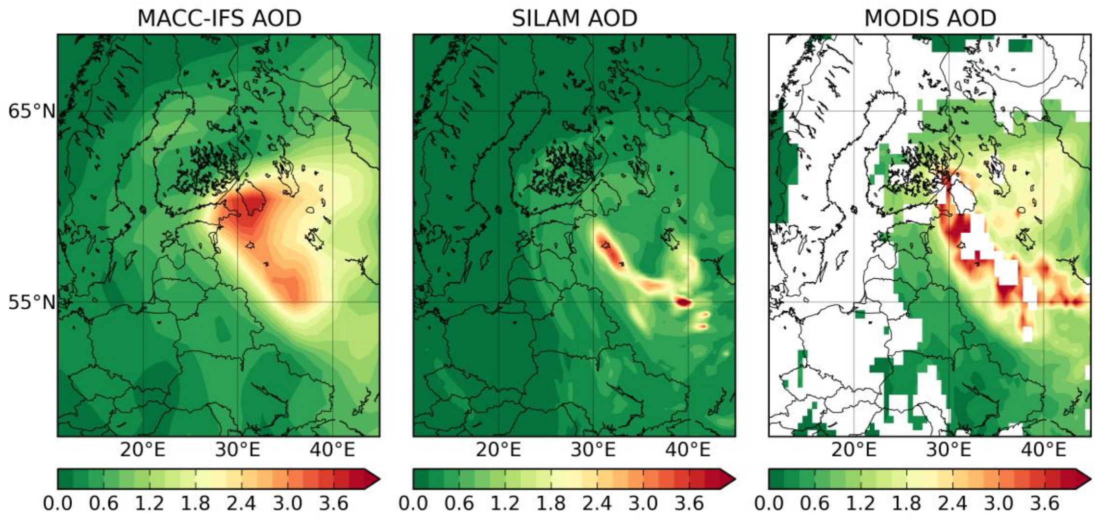

Figure 1. AOD at 09 UTC on August 8, 2010, from MACC-IFS re-analyses, forecasted by SILAM and measured by MODIS.

The plumes in Figure 1 are remarkably similar, but SILAM is expecting the narrower plume and lower AOD values outside its central part. The highest AOD values in the European part of Russia are more than 4 and smoke is located to the East of the South-Northerly situated polar front (Figure 2). However, the similarity of MACC IFS with MODIS results is expected, as the very same data are assimilated for the re-analysis.

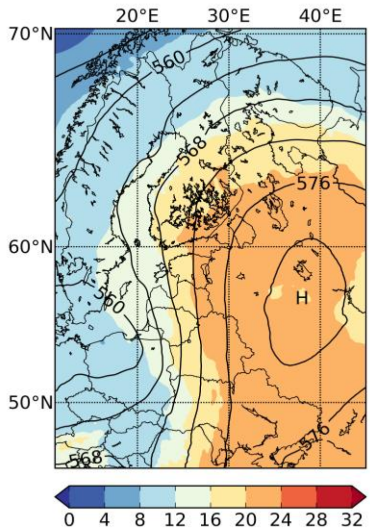

Figure 2. ECMWF analysis: 500 hPa gph (dam) with contours and 850 hPa temperature (°C) shaded at 12 UTC on August 8, 2010.

SILAM results and in situ measurements

The wildfire-induced particulate matter peak is clearly seen in five monitoring stations in Estonia out of six, where PM2.5 is measured. The plume did not reach the westernmost maritime site Vilsandi in the Baltic sea. The SILAM model forecasted the peak of August 8 with precision of a few hours for all five continental sites, an example is given in Figure 3.

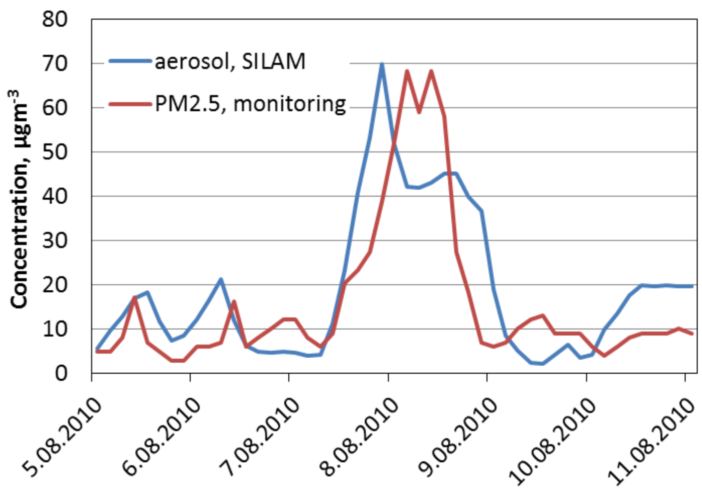

Figure 3. Concentration of modelled and measured aerosol during August 5 to 11, 2010, in Tallinn, monitoring station Rahu.

According to SILAM results, only about a half of aerosol was generated by wildfires. The rest of it was mostly anthropogenic and continental aerosol, incl. desert dust. Further investigation is needed, as IFS data assimilation system can artificially rise the concentration of the aerosol components that happen to be present in the high AOD areas in however small quantities.

The direct radiative effect of the smoke

Reduction in the shortwave radiation flux at the surface resulting from smoke aerosol direct radiative effect simulated by the HARMONIE model is more than 300 W/m^2 in the area with the highest aerosol concentrations during the most intense period causing near-surface cooling more than 3 ºC, see Figure 4 and 5. Due to the absorption in the aerosol layer, the temperature at 950 – 700 mb (nearly 500 – 3000 m) height is increased by up to 1 degree. Thus, the boundary-layer vertical convection is inhibited by wildfire smoke.

The surface cooling effect was present during entire day of August 8, when the plume stayed on Estonia, see Figure 5. The strongest influence of the smoke is seen at the midday when the solar elevation is highest. HARMONIE model tends to overestimate the reduction of the shortwave radiation flux at the ground. One possible reason for this overestimation is overestimation of AOD in this point (comparison for only one geographical point is shown). Another possible reason is misrepresentation of the direct radiative effect of the smoke by the HARMONIE model because of the constant optical properties (single scattering albedo and asymmetry parameter) or climatological aerosol vertical profile. The amplitude of the diurnal cycle of the 2-m temperature in the HARMONIE model compared to the observations is slightly underestimated.

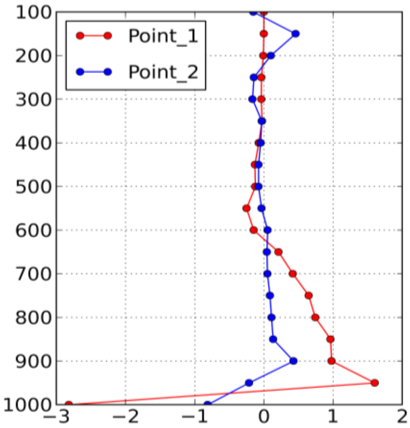

Figure 4. Simulated difference in temperature (ºC) on pressure levels (hPa) resulting from smoke aerosol influence using MACC data in point_2 in the Central Estonia (in blue) and in point_1 in the Western Russia (in red) at 12 UTC on August 8, 2010. The base case is standard (climatological) aerosol input of HARMONIE.

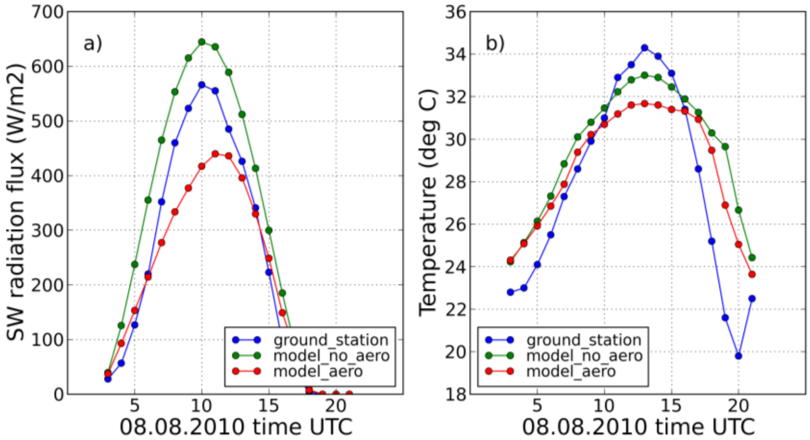

Figure 5. (a) Shortwave radiation flux at the surface (W/m^2) and (b) near-surface temperature (°C) in a ground station in HARMONIE simulation with and without aerosol influence in the North-Eastern Estonia on August 8, 2010.

CONCLUSIONS

Both SILAM and MACC system show adequate skill in simulating aerosol distributions for the summer 2010 wildfires. However, the MACC aerosol data for the investigated wildfire case is closer to the observations than the SILAM data thanks to the data assimilation of these same fields. Strong meteorological effect of the smoke is simulated by the HARMONIE model as reduction in the shortwave radiation flux at the ground of more than 300 W/m^2 is detected. Direct radiative effect with this magnitude can have considerable influence on the large scale meteorological conditions and atmospheric dynamics.

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