Evaluating aerosol impacts on Numerical Weather Prediction in an extreme dust event

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The WMO-sponsored Working Group on Numerical Experimentation (WGNE) set up a project aimed at understanding the importance of aerosols for numerical weather prediction (NWP). Three cases are being investigated by several NWP centres with aerosol capabilities: a severe dust case that affected the Eastern Mediterranean in April 2012, a biomass burning case in South America in September 2012, and an extreme pollution event in Beijing in January 2013. At ECMWF these cases were studied using the MACC-II system with radiatively interactive aerosols. Here we focus on the dust case and discuss the feedback between dust aerosols and boundary layer meteorology caused by the aerosol direct effect. As there was no cloud in this situation, the aerosol indirect effect is of no significance here.

The dust storm that affected Libya, Egypt and the middle East from 17th to 19th of April 2012 was caused by a heat low crossing Libya from Southwest to Northeast; it brought some very high dust aerosol concentrations, with Aerosol Optical Depth (AOD) at 550nm reaching a value above four at Cairo late on 18th of April 2012. The dust aerosol direct radiative forcing had a strong impact on both the shortwave down-welling radiation at surface, which was reduced by 20 to 30% and on long-wave downward radiation, which was increased by 30 to 40%. Comparison of forecasted and observed radiation at Tamanrasset (Algeria) for this event showed that forecasts were generally more accurate when taking into account the aerosol direct effect, both in the shortwave and in the long-wave spectra.

As the concerned areas are of desert type, i.e. with a sandy soil that favours strong night-time cooling, the aerosol layer radiative forcing in the long-wave spectrum, acting in a similar way as a cloud layer, had locally a large warming effect during the night : up to 4-5 K at places. This is clearly shown in Figure 1, which shows temperature, AOD and long-wave radiation at Asyut (Egypt). The minimum temperatures forecasted with experiments taking into account the aerosol direct effect were generally closer to observations for a wide range of stations in Egypt, Libya and Israel.

The impact of reduced shortwave radiation on maximum temperatures was much smaller; it was probably overshadowed by the higher night-time temperatures. Daytime warming brought by shortwave radiation was smaller when taking into account the aerosol direct effect; both because around 20% of incoming solar radiation was absorbed by the aerosol layer and because the night-time temperatures were higher.

Because of higher night-time temperatures, the lower atmosphere was less stable at night and the heat low that was at the origin of the dust storm was deeper. This in turn increased the strength of the winds over the desert. With more effective saltation processes, which are modelled as a function of 10m wind speed to the cubic power, dust aerosol sources were also significantly increased. As a consequence, dust AOD was around 20% higher during the storm when taking into account the aerosol direct effect, as shown by Figure 1. The forecasted AOD peak during the storm, which was underestimated, was brought closer to observations.

This study revealed a positive feedback between dust aerosols and boundary layer meteorology during an extreme dust aerosol event. It was already well known that aerosols impacts low and middle troposphere through the direct and indirect effect; however the fact that these modifications on boundary layer meteorology affect in turn the aerosol load appears not to have been documented yet.

References:

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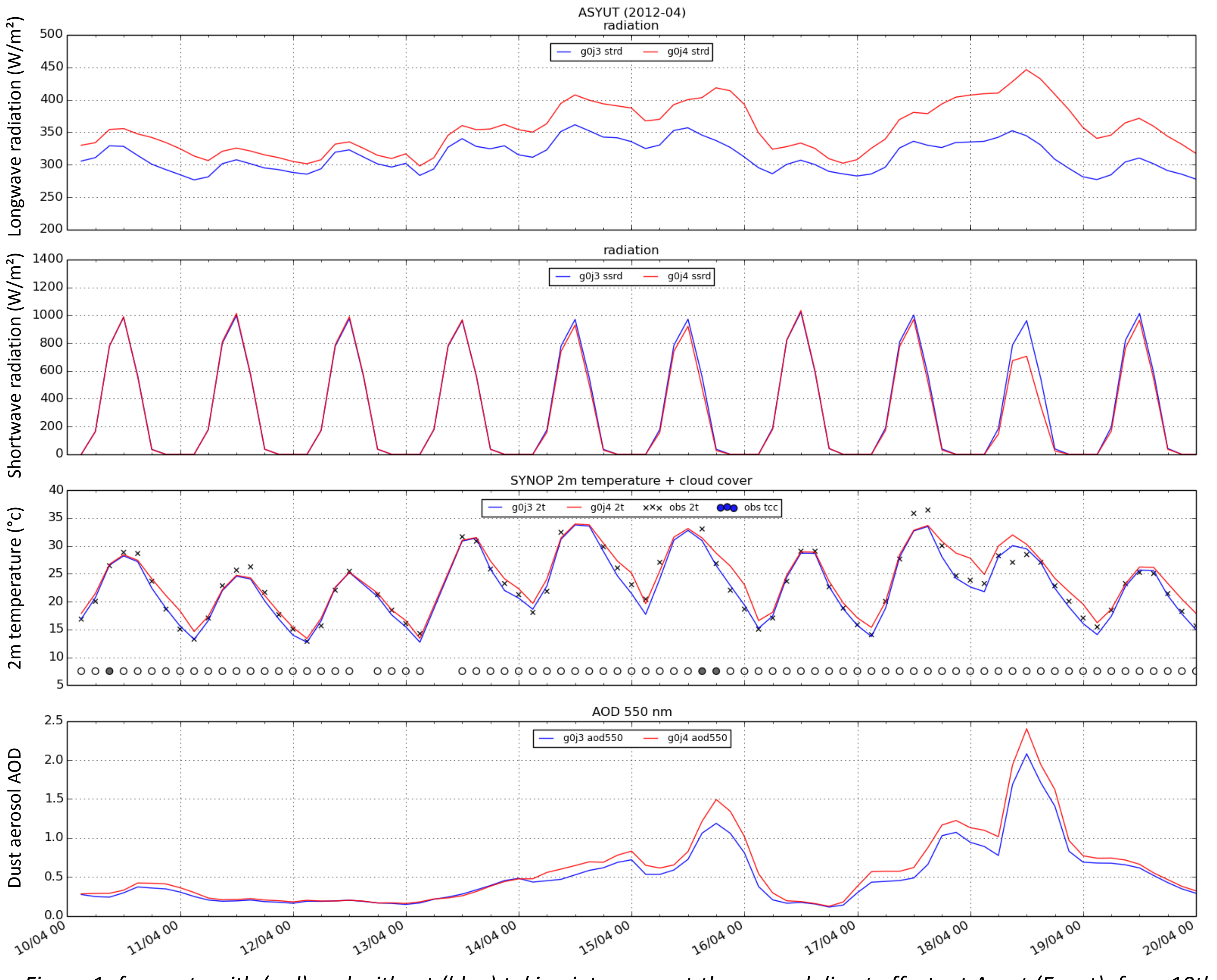

Figure 1: forecasts with (red) and without (blue) taking into account the aerosol direct effect, at Asyut (Egypt), from 10th to 20th of April 2012. Forecasts starting at 0UTC everyday, 3-24h forecast times. From top to bottom: downward longwave radiation at surface, downward shortwave radiation at surface, 2m temperature and dust aerosol AOD at 550nm. Observations of 2m temperature are also indicated with black crosses, together with cloud cover.