Forecasting the atmospheric composition with COSMO-ART in southern West Africa

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Objectives

The Dynamics-aerosol-chemistry-cloud interactions in West Africa (DACCIWA) project (Knippertz et al., 2015) investigates the influence of anthropogenic and natural emissions on the atmospheric composition over southern West Africa (SWA). Between 1 June and 30 July 2016 the DACCIWA measurement campaign took place in SWA, including ground based and airborne observations. Within this work, the model system COSMO-ART was applied for the first time for operational numerical forecasts with full chemistry and aerosols. Daily forecasts were realized during the complete measurement campaign to support the decision making of the research aircraft flights and to derive model climatologies of atmospheric aerosol and chemical composition.

Model framework

The regional-scale model framework COSMO-ART combines the operational weather forecast model COSMO of the German Weather Service (DWD) with the ART modules (Aerosols and Reactive Trace gases, Vogel et al., 2009). Gas phase chemistry and aerosol dynamics are online coupled with the meteorology. Aerosol particles are treated via a modal approach, considering mineral dust, sea salt and anthropogenic aerosols. The research domain is affected by a variety of pollution sources (e.g. emissions from coastal megacities and biomass burning emissions from central Africa). For this study a new parameterization for mineral dust and gas flaring emissions have been developed and applied with COSMO-ART. The forecasts were realized for the domain 25°W-40° E, 20° S-35° N on 50 vertical levels with a grid mesh size of 23 km. Interactions with radiation and cloud formation are not considered in this study.

Methods

The forecasts were initialized daily at 12 UTC with a lead time of 57h. Fig. 1 shows the structure for three subsequent forecast steps F1-F3. As meteorological and aerosol/chemistry boundary ICON and MOZART were used, respectively. The simulations were realized as specified in GFAS near real-time. The visualizations of the forecast results were uploaded to the dacciwa.sedoo.fr database for further analysis. The model data was archived for future analysis.

Result 1 - Stratus

The stratus layer (Fig. 2) frequently developed in SWA during the campaign. Good agreement can be seen for simulated cloud water and the observed cloud base heights. The model results were compared to CAMS in terms of absolute values and temporal evolution. The model results resonably reproduce the observations, however the overestimation in CO2 (see Fig. 5) leads to an overestimation in NO2.

Result 2 - Ozone

Near surface O3 volume mixing ratio (ppbv) temporal evolution for the 57h forecast leadtime, averaged over the period 13 June to 30 July 2016 at Savé. Shaded areas denote the standard deviation. COSMO-ART captures the diurnal cycle of O3 concentration with maximum at 15 UTC but generally overestimates the concentrations especially in the afternoon (Fig. 4). It is assumed that the overestimation in CO2 (see Fig. 5) leads to an increase in the O3 formation. A sensitivity study with reduced anthropogenic CO2 emissions has shown improvements.

Result 3 - AOD

Although the mineral dust influence on SWA is reduced during the monsoon time, it significantly contributes to the total AOD. COSMO-ART performs well compared to CAMS in terms of absolute values and temporal evolution. Sea salt influence is one order of magnitude smaller. Highest uncertainty can be seen in terms of anthropogenic aerosol. COSMO-ART seems to overestimate the tropospheric aerosol which is also reflected in the differences towards AERONET.

Result 4 - Aircraft

Fig. 6. Aerosol composition per flight campaign. The red line on each plot shows the location of the flight track at the time the flight was performed.

Result 5 - Flaring

A new flaring emission dataset has been collected, combining remote sensing observations and physically-based combustion equations (Deetz and Vogel, 2017). It considers the trace gases CO, CO2, NO, NO2, and SO2. We have applied our method to derive the flaring emissions for SWA (Fig. 6) and to include the dataset into COSMO-ART. The results were made available via dacciwa.sedoo.fr to the research community. The results of the model simulations in terms of aerosol and trace gas concentrations are compared to observations from AERONET and AEROSOLNET stations. The model results resonably reproduce the observations, however the overestimation in CO2 (see Fig. 5) leads to an overestimation in NO2.

Conclusions

During the DACCIWA campaign in June-July 2016, operational forecasts have been conducted with the regional-scale model COSMO-ART. The results were made available via dacciwa.sedoo.fr to the research community. Model results resonably reproduce the observations with a tendency to overestimate anthropogenic emissions. Further added value was contributed by the development and application of a new flaring emission parameterization. The results emphasize the need to consider flaring emissions in air pollution modeling.

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References