Modeling of aerosol indirect effects with WRF/Chem over Europe

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Astract WRF/Chem has been updated in order to simulate the aerosol indirect effects using a new parameterization for production of secondary organic aerosol. The model has been evaluated over North Sea among the ATR-42 aircraft measurements of aerosol and cloud issued in frame European Integrated project on Aerosol Cloud Climate and Air Quality Interactions (EUCAARI). WRF/Chem tends to overpredict the number of condensation nuclei. Simulated liquid water content shows a bias of +15%. Predicted cloud droplet number concentration is overestimated and radius effective droplet is underestimated.

Introduction

Aerosol particles play a key role in climate system by altering the global budget of radiation. They scatter and absorb directly (direct effect) the solar and thermal radiation [1] and affect indirectly (indirect effect) the patterns of clouds and precipitation [2]. The latter is usually referred to as "indirect effect" and arises from that the ability of aerosol particles to act as cloud condensation nuclei (CCN). An increase of aerosol particle concentration, for clouds with liquid water content (LWC) held constant, enhances the concentration of cloud droplets and reduces their size. This results in the increase of cloud albedo and is called "first indirect effect" or "Twomey's effect" [3]. Effects of first indirect effect on climate are still highly uncertain, and the representation of albedo effect is one of the most uncertainties in climatic projections [4].
In this work we present a preliminary evaluation of WRF/Chem model at medium resolution in order to assess the skill of the model to reproduce the main quantities in the aerosol-clouds interaction. The aim of the research is to understand how well a model reproduces the activation of aerosol particles in cloud droplets.

Table 1 WRF/Chem configuration.

PHYSICAL PROCESS	WRF/Chem OPTION
Microphysics	Morrison
Long-wave radiation	RRTM
Short-wave radiation	RRTMg
Surface layer	Monin-Obukhov
Land-surface model	Noah LSM
Boundary layer scheme	Mellor-Yamada Nakanishi and Niino
Cumulus	G3
Photolysis	Fast-J
Chemistry model	New RACM-ESRL [6]
Aerosol model	MADE and VBS scheme for SOA [6]
Biogenic emission	MEGAN
Direct aerosol feedback	Included [7]
Indirect aerosol feedback	Included [8]

Methods

In this paper we use the version 3.4 of WRF/Chem model [5] with some news. The model has been updated in order to include the aerosol-cloud-interaction simulation using a new chemical mechanism for a better simulation of secondary organic aerosol [6], following the works of *Fast et al*. [7] and *Chapman et al.* [8].
A simulation is carried out on 15 May 2008 using two nested domains centered on Europe. First domain extent from 35°N to 57°N in latitude and from 15°W to 27°E in longitude. The horizontal resolution is 30 km with 41 vertical levels. Second domain is centered over the Netherlands, with horizontal resolution of 10 km. The model configuration is shown in Table 1. The anthropogenic emissions (gas and aerosol species) are taken from Nederlands Instituut Voor Toegepaste (TNO) inventory [9] and are adapted to WRF/Chem following *Tuccella et al.* [10].
WRF/Chem simulation results are then compared to measurements performed onboard the ATR-42 during the European Integrated project on Aerosol Cloud Climate and Air Quality Interactions (EUCAARI) [11]. The payload of the ATR-42 included a comprehensive suite of aerosol instrumentation including two Condensation Particle Counters (CPC3010, CPC3025), a Cloud Condensation Nuclei Chamber (CCNC), a custom scanning mobility particle sizer (SMPS), a comprehensive suite of cloud droplet instrumentation, and a Gerber PVM-100 Probe for cloud water mixing ratio.. The Research Flight #52 flight is used in this study and was performed in clear sky, in the cloud vicinity as well as within the cloud layer. The flight was conducted on 15 May 2008 from 11:30 to 15:07 UTC above the North Sea.

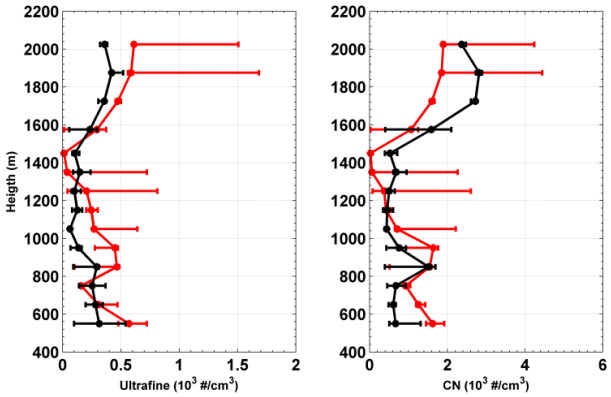

Fig. 1. Vertical profile of ultrafine particle number condensation nuclei concentrations. Black and red lines are the observed and modeled values, respectively. The dots represent the median of the distribution. The error bar denote the 25th and 75th, respectively.

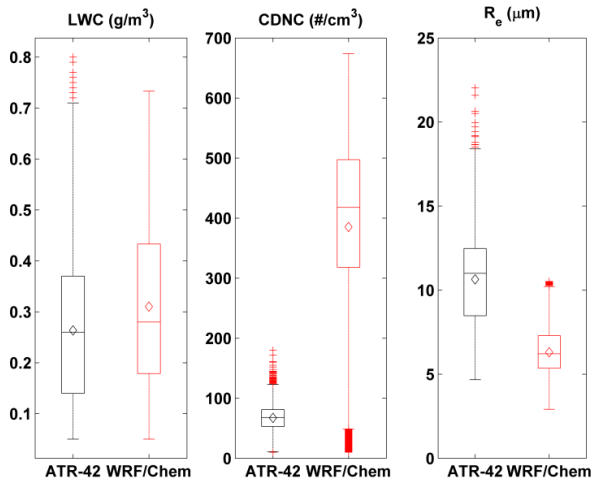

Fig. 2. Box plot of observed and simulated LWC, CDNC and R_e within the cloud layer. Whisker plots represent median, 25$_{th}$ and 75$_{th}$ percentiles, 1.5 × (inter-quartile range), and outliers.

Results

The number concentration of ultrafine particles (Dp < 15nm) is obtained from difference between the two condensation particles counters (CPC3025 and CPC3010). Figure 1 shows the comparison of WRF/Chem results to the observed ultrafine particle number concentration and total aerosol concentration (Dp > 5nm) as a function of altitude. The dots represent the 50th percentiles of the distribution,

the error bars the 25th and 75th percentiles, respectively. Although the model tends to capture the dynamical range of the observations, it exhibits a larger variability than the one observed. Generally, WRF/Chem overestimates the particle number concentration by a factor of 2-2.5. This may be due to an excessive nucleation rate or to an overestimation of the ultrafine apportionment of anthropogenic emissions. During RF52 flight, the cloud layer is simulated by the model 100-200 m lower than observed (not shown). In Figure 2, we compare through boxplots the simulated and observed boxplots of cloud liquid water content (LWC), cloud droplet number concentration (CDNC) and effective radius (R_e) of cloud droplets. WRF/Chem reproduces the observed dynamical range of LWC with a positive bias of 15-20%. Predicted CDNC is overestimated about by a factor of 5. This bias could be due to a nonlinear response to the overestimation of CN, such as an alteration of the supersaturation profile evolution. The negative bias of modeled R_e (about -30%) is directly consequence of CDNC overestimation.
Next step is to evaluate the model above the land and increase the horizontal resolution at cloud scale (2 km).

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