SIMULATION OF AEROSOL-CLOUD-RADIATION FEEDBACK WITH FULLY COUPLED "ONLINE" WRF/CHEM MODEL OVER EUROPE

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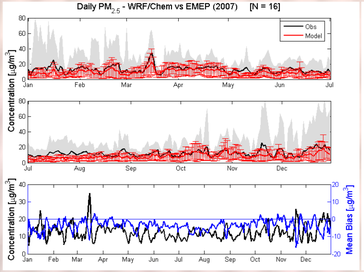
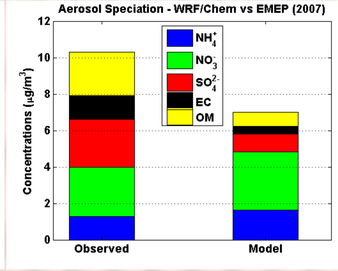
1. INTRODUCTION

In recent years, aerosols have been an important subject of study of the scientific community. Aerosol particles play a key role in climate system acting on the global budget of radiation, both directly by scattering and absorbing the incoming radiation and indirectly by altering cloud properties. The feedback among aerosol-cloud-radiation is one of the most uncertain issues in studying the climate change. In this work, we simulate the aerosol-cloud-radiation interaction with the fully coupled "online" WRF/Chem model. Two simulations are conducted over Europe: a baseline simulation with no feedbacks, and another in which we activate direct and indirect aerosol effects.

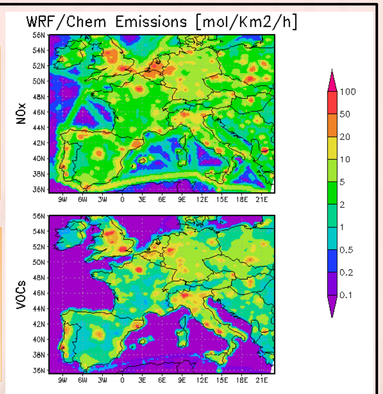
2. BASELINE SIMULATION

WRF/Chem is a fully coupled "online" model where the chemistry is consistent with the meteorological processes [1],[2]. In this study the version 3.2 of WRF/Chem is implemented over Europe. The main step for implementation is the development of an inventory of anthropogenic emissions. These are taken from EMEP database which provides the total annual emissions of main European pollutants with a resolution of 50 Km.
Baseline simulation (CTRL) is carried out through 2007 over Europe. The aim is to assess the WRF/Chem ability to simulate the main gas tracers and particulate matter.



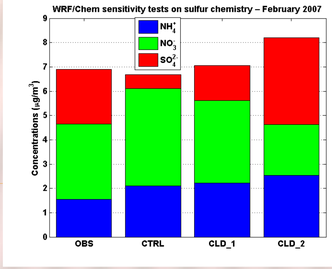


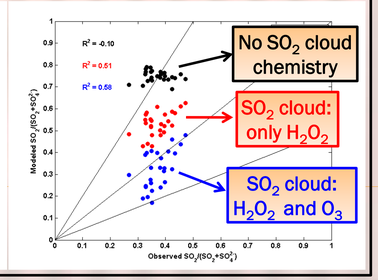
Resolution: 30 Km x 30 Km
Emissions: EMEP, Lab. D'Aero.
Boundary Conditions: Idealized
Gas phase chemistry: RADM2
Aerosol: MADE/SORGAM
Surface Measu. Data: EMEP



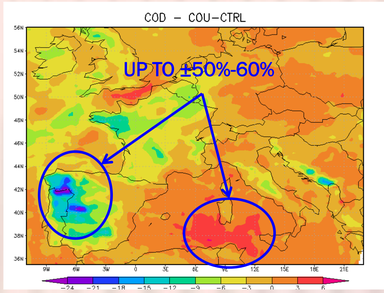
Simulated hourly ozone concentrations present a correlation with observation of 0.63 and the maxima are underestimated by about 4%. WRF/Chem tends to underpredict the daily NO_2 in cool months and overestimates it in summer.

Daily $PM_{2.5}$ aerosol mass shows a mean bias of about 5.0 μg/m^3, attributable to organic component. The model overpredicts the ammonium and nitrates by 80% and 85% respectively. Sulfates show a negative bias of 50%. Some sensitivity tests conducted in February 2007, demonstrate that the sulfate underprediction is due to the oxidation of SO_2 by H_2O_2 and O_3 in the clouds and such processes are not included in WRF/Chem. When we add these two reactions, the sulfates and ammonium are overestimated by 36% and 17% respectively and the nitrates show a negative bias of 34%.

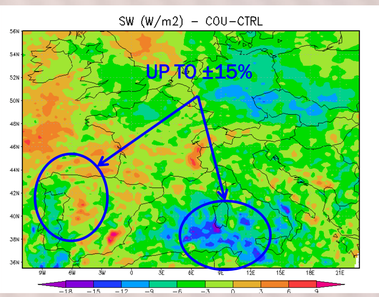




3. SIMULATION WITH DIRECT AND INDIRECT AEROSOL EFFECTS



The model is very sensitive to direct and indirect aerosol forcing. When we add these effects [2],[3] to baseline simulation (COU, only in February) we find a change in cloud optical depth (COD) of up to ±50%-60% respect to CTRL. We observe similar spatial structures of those in COD in the difference of other variables. For example shortwave radiation at surface and planetary boundary layer height display differences up to ±15%. Also, we find smaller differences of ±3% (±0.4 °C) for 2-meter temperature.

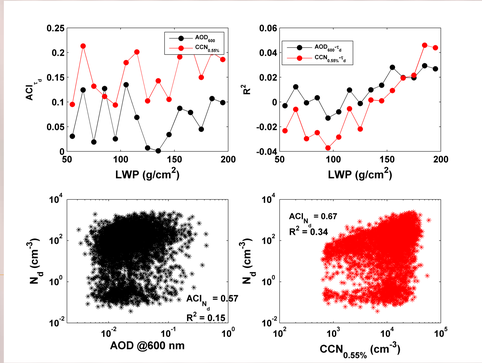


4. ESTIMATION OF AEROSOL INDIRECT EFFECTS

The aerosol cloud interaction (ACI) is estimated with WRF/Chem following McComiskey et al. [4]. ACI is defined as:

(1) $ACI_{COD}=\partial\log(COD)/\partial\log(\alpha)$, (2) $ACI_{Nd}=\partial\log(N_d)/\partial\log(\alpha)$

where N_d is cloud droplet number concentration and α is a proxy for aerosol burden. In this work we choose aerosol optical depth (AOD) and CCN at 0.55% of supersaturation as α. The equation (1) is calculated at constant cloud liquid water path (LWP). ACI_{COD} varies with LWP and ranges from 0.01 to 0.23. ACI_{Nd} is equal to 0.57 and 0.67 for the estimation done with AOD and CCN respectively. These values are comparable with those calculated from measurements. McComiskey et al. [4] found that ACI_{COD} ranges from 0.04 to 0.25 and ACI_{Nd} from 0.30 to 0.48. The correlation estimated with WRF/Chem among aerosol and cloud properties is high (0.34) only for N_d and AOD.



5. CONCLUSIONS

WRF/Chem model has been implemented over Europe. A baseline simulation has been conducted through 2007. The results indicate that the major gaps in aerosols simulation are the underestimation of organic matter and sulfates. When we include direct and indirect aerosol effect to CTRL, we found several differences respect to baseline simulation. Finally, we estimated aerosol-cloud interaction from WRF/Chem simulations. The obtained values are comparable with those calculated from measurements by other scientists.

REFERENCES

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[2] Fast et al., Evaluation of ozone, particulate, and aerosol direct radiative forcing in the vicinity of Houston using a fully coupled meteorology-chemistry-model, JGR, 2006.
[3] Chapman et al., Coupling aerosol-cloud-radiative processes in the WRF/Chem model: investigating the radiative impact of elevated point source, ACP, 2009.
[4] McComiskey et al., An assessment of aerosol-cloud interactions in marine stratus clouds based on surface remote sensing, JGR, 2009.