A simple aerosol emissions parameterization in RAMS

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Introduction

Increases in Cloud Condensation Nuclei (CCN) concentrations are able to modify the growth of precipitation within orographic "seeder-feeder" cloud systems by reducing the size of the cloud droplets , thus altering accretion rates within the super-cooled part of the cloud. This process both delays or inhibits the conversion of cloud water into precipitation and allows the horizontal wind to advect a greater amount (relative to a cleaner environment) of snow hydrometeors to the downwind side of a mountain crest (Levin and Cotton, 2009). Because mountain ridges often separate water-basins in mountainous regions, even small shifts in the precipitation distribution can lead to significant changes in the overall water resource distribution. As a result, this effect may be very important in regions where much of the water resources come from seasonal snowpack.

Methods

Our approach was to Run WRF-CHEM for one hour starting at 12 UTC for a day in September. Running WRF-CHEM for 1 hour allows the model to generate aerosol in the vicinity of point and area pollution sources (Fig. 1). After the simulation, the near surface accumulation mode aerosol number concentration was saved and used an hourly emission rate in RAMS.

A basic representation of aerosol chemistry was included in this parameterization by calculating κ at each source by taking the volume-weighted average of the aerosol species predicted by WRF-CHEM. For simplicity aerosol size is assumed constant in this scheme.

Case-Study

To validate this scheme it was used in a case-study. The time period of the case study was September 28 – October 01 2009. In this experiment the scheme was run using several different emission heights (z_e=100m, z_e=sfc, z_e=Boundary Layer Top). The RAMS model output potential CCN concentration at the grid box nearest to MVNP was compared to the observed CCN (ss=0.3%) at MVNP (Fig. 3)

Results:
The emission scheme was able to reasonably simulate the emission and transport of aerosol from the sources within the domain. The RAMS simulated potential CCN concentration compared reasonably well to the observed CCN (ss=0.3%) at MVNP. In addition to showing reasonable accuracy, the RAMS simulations required much less time than the WRF-CHEM simulations

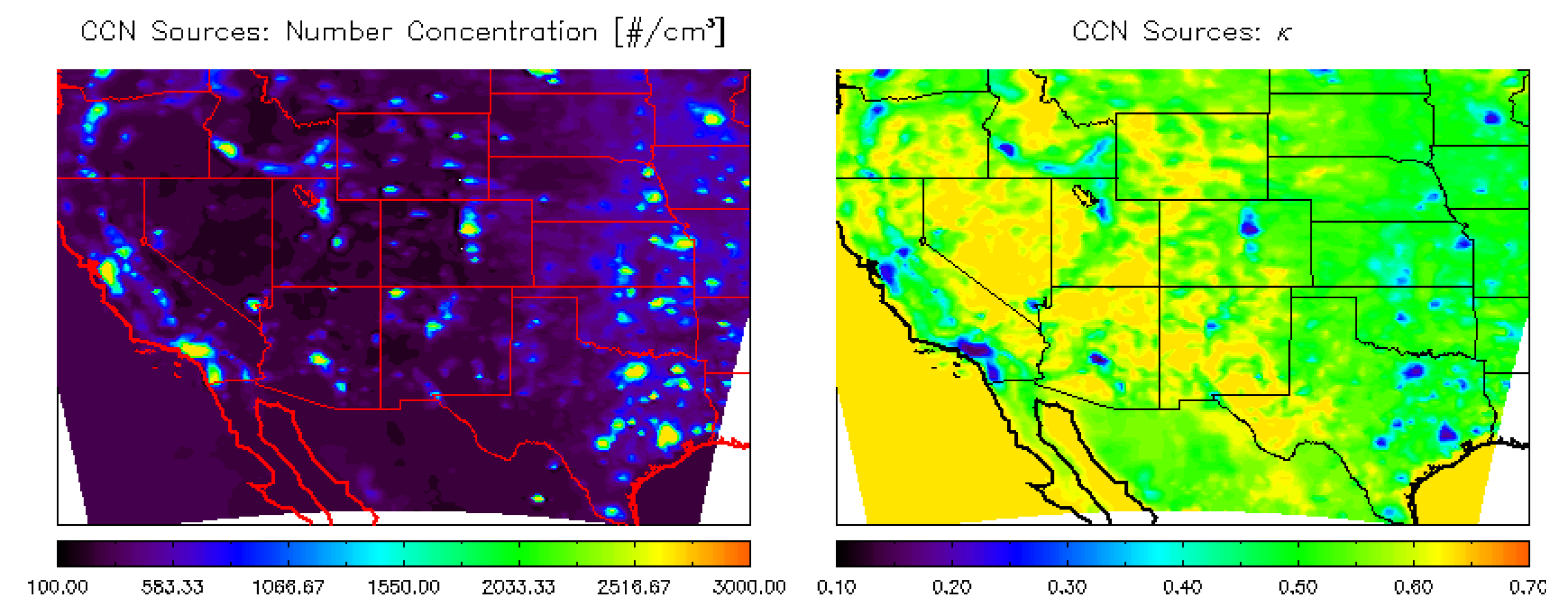

Fig. 1: Aerosol emission rates [hr^{-1}] and κ as determined from WRF-CHEM

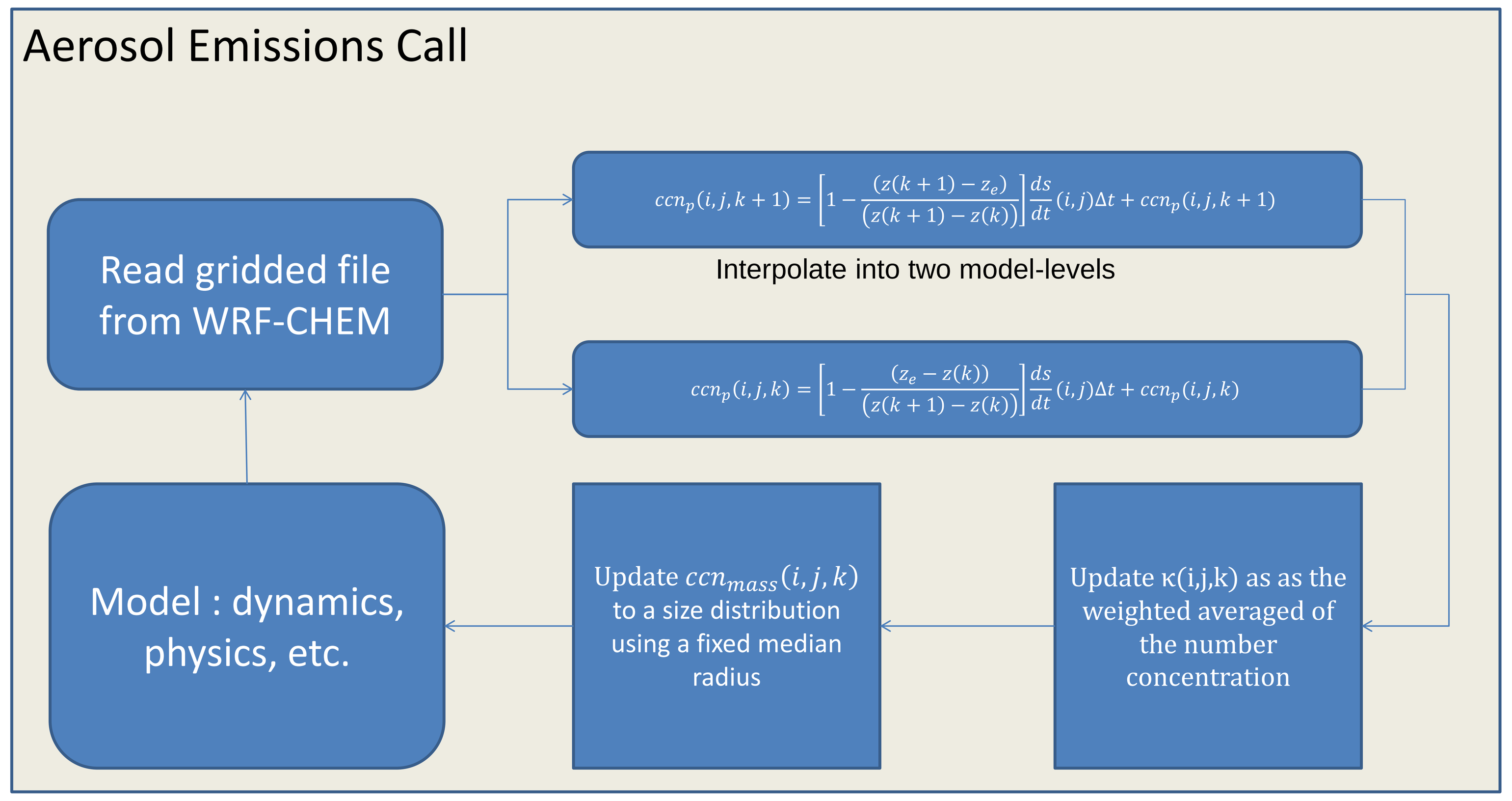

Fig. 2: Flow chart describing the aerosol emissions scheme in RAMS

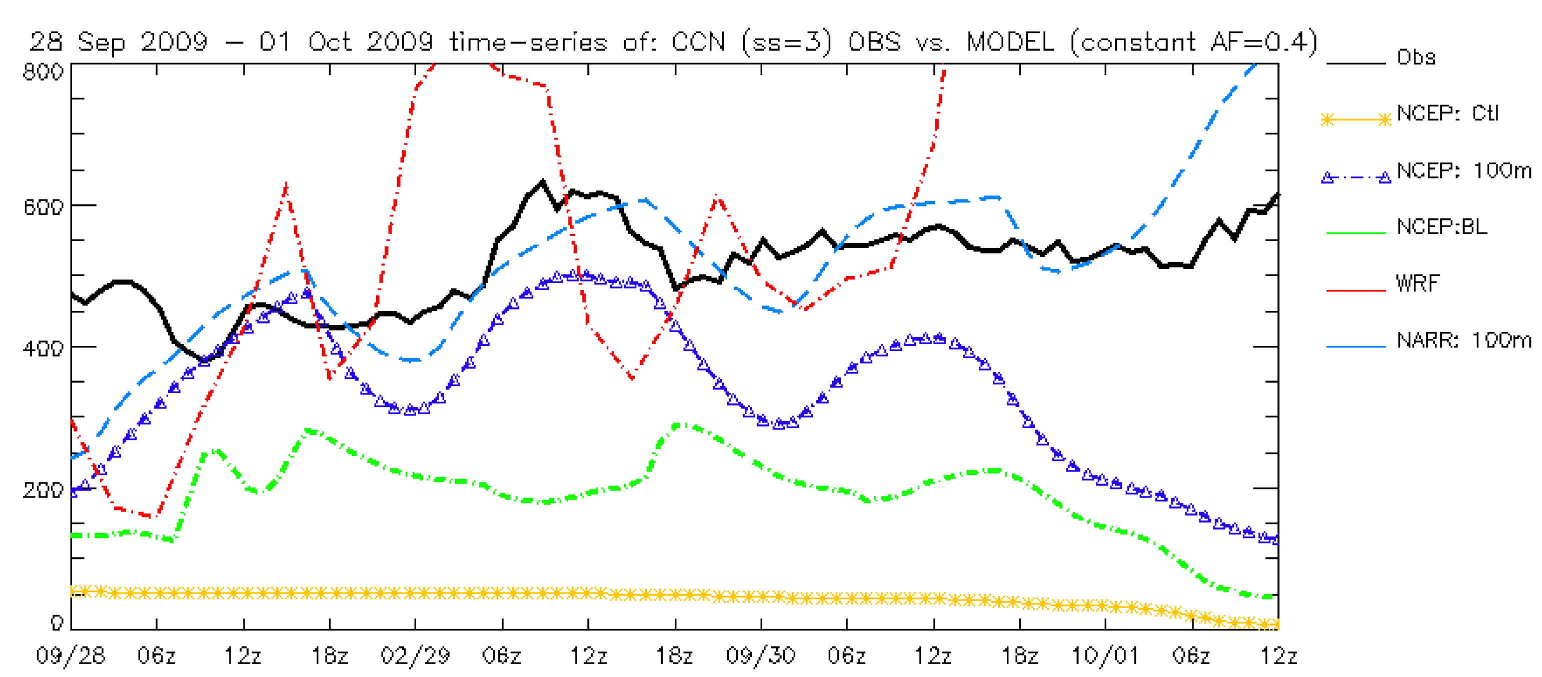

Fig. 3: Time-series of model output potential CCN concentration (multiplied by 0.4) compared to observed CCN(ss=0.3%) at MVNP

Orographic Snow Case

The emissions scheme was used in a simulation of the February 11-12 2007 Orographic snow case discussed in Saleeby et al. (2009)

Model set-up
- **Domain:** 4 two-way nested grids (60km at coarsest, 750m at finest). Stretched vertical grid from 75m to 750m. Model top: 16.5km
- **Aerosol:** CLEAN= 100 [per cc] background, DIRTY=1900 [per cc] background, EMISS=initialized with 100 [per cc] background with emissions from WRF-CHEM data file. Median radius = 40nm in all three simulations. κ initialized as 0.25 at all model levels. Z_e=100m. Aerosol radiative properties: off

Results:
The spillover effect was much less significant in the EMISS-CLEAN than it was in the EMISS-DIRTY (Fig. 4). It was found that temporally and spatially varying CCN concentrations complicate the changes in the precipitation distribution due to differing microphysical environments in orographic clouds on the smaller terrain features.

Conclusions

The simple emissions scheme in RAMS was capable of simulating the emission and transport of pollution from the pollution sources identified by WRF-CHEM. A major benefit of this scheme is the reduced computational expense compared to WRF-CHEM. The simulation of the orographic snow case revealed that aerosol impacts are much more complex with variable CCN concentrations.

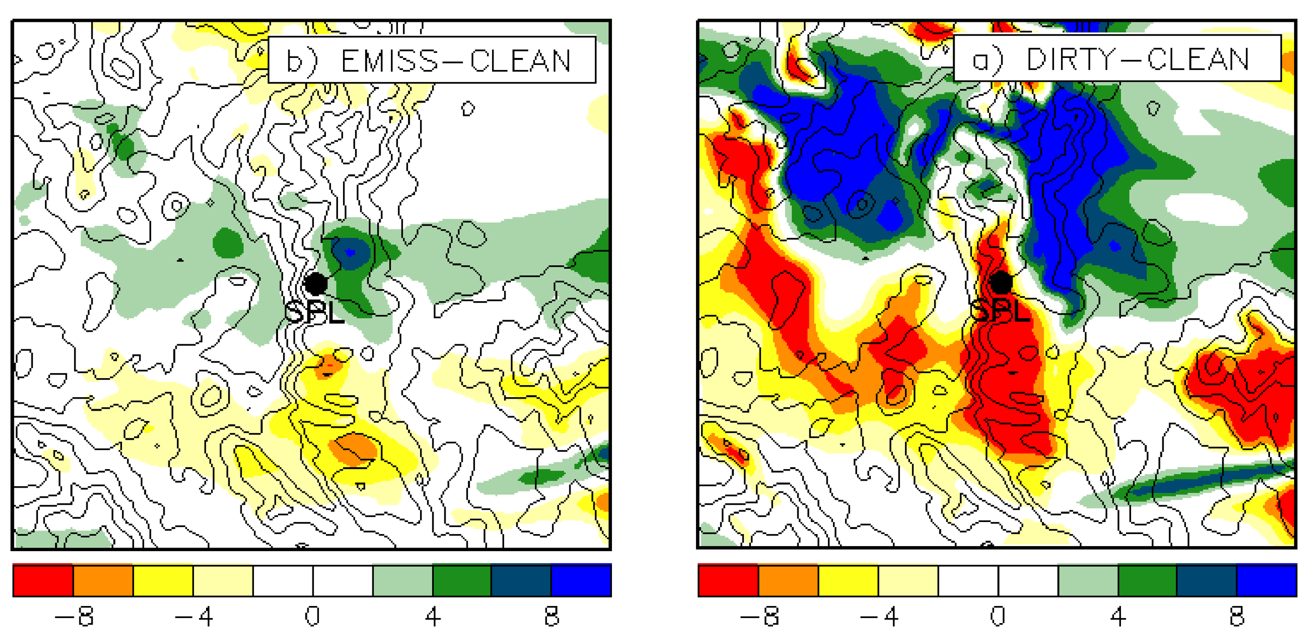

Fig. 4: Total accumulated precipitation differences (Grid 4) [mm]: a) DIRTY-CLEAN, b) EMISS-CLEAN

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