Using the WRF-Chem model to investigate the impacts of aerosol on marine stratocumulus observed during VOCALS-REx

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Purpose of this study

► Evaluate the representation of aerosol in WRF-Chem.
► Estimate the relative contributions of anthropogenic and sea salt/DMS emissions to the aerosol and droplet number concentrations.
► Investigate the impacts of aerosol on the simulated boundary layer structure and marine clouds.
WRF and WRF-Chem (V3.2) setup

- Full coupled aerosol-cloud interaction modules.
- The Model for Simulating Aerosol Interactions and Chemistry (MOSAIC) aerosol module.
- 8-bin sectional approach for aerosol size distribution.
- The YSU PBL scheme and Morrison microphysics.
- 9 km horizontal grid spacing.
Boundary Layer Structure - Vertical profiles

Water mixing ratio and virtual potential temperature

- Slightly colder and more moist

- Colder and drier

Improved inversion strength in WRF-Chem
Including aerosol lowers the PBLH:

- Improved simulated PBLH over the remote ocean.
- Lower than observation near the coast.
Aerosol - number conc.

Aerosol and droplet number concentrations

Sub-cloud aerosol
Oceanic emission contributions
In cloud droplet
Aerosol - mass

- Submicron aerosols from C130/RB/G1 measurements and from WRF-Chem simulations
Aerosols – Aerosol Optical Depth

Terra:
Mean=0.12 ± 0.06

WRF-Chem:
Mean=0.11 ± 0.05
Clouds - Radiative Properties

**Effective Radius**

**Cloud Water Path**

**Cloud Optical Thickness**
Clouds – low cloud fraction

- Including aerosol slightly alters the simulated cloud fraction.
Clouds – cloud base height and cloud depth

- Including aerosol simulated slightly thinner and lower clouds.

**Cloud Base Height**

- Frequency (%)
- Cloud base height (m)
- WRF-Chem: avg=990 m
- WRF: avg=928 m

**Cloud Thickness**

- Frequency (%)
- Cloud thickness (m)
- WRF-Chem: avg=342 m
- WRF: avg=378 m
Radiative Flux - TOA outgoing shortwave

Outgoing TOA shortwave
Rain Rate

Higher simulated drizzle rates both in and below clouds when including aerosol-cloud interactions.
Summary

► WRF-Chem simulates slightly lower aerosol number concentration and sulfate mass, and higher sea salt mass. AOD compares well with satellite data in mean values and distribution patterns.

► Strong longitudinal gradients in aerosol and droplet number concentrations due to anthropogenic emission.

► Reducing sea salt emission increases cloud droplet number concentration due to competition between sea salt and sulfate aerosols as CCN.

► Including aerosol climate effects produces improved boundary layer inversion intensity, higher drizzle rates, modifies cloud macro-structure, and changes radiative cloud properties and shortwave fluxes.
Radiative Flux - TOA outgoing shortwave

Outgoing TOA shortwave

WRF-Chem

20S

10S

85W  75W

WRF

-200 -240 -280 -320 -360 -400 -440 -480

w/m²

Difference in TOA SW (WRF-Chem – WRF)

20S

10S

85W  75W

w/m²

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