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

Qing Yang, William I. Gustafson Jr., and Jerome D. Fast

Pacific Northwest National Laboratory

3rd VOCALS Science Team Meeting, Miami, Mar. 21, 2011

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

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.

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

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.

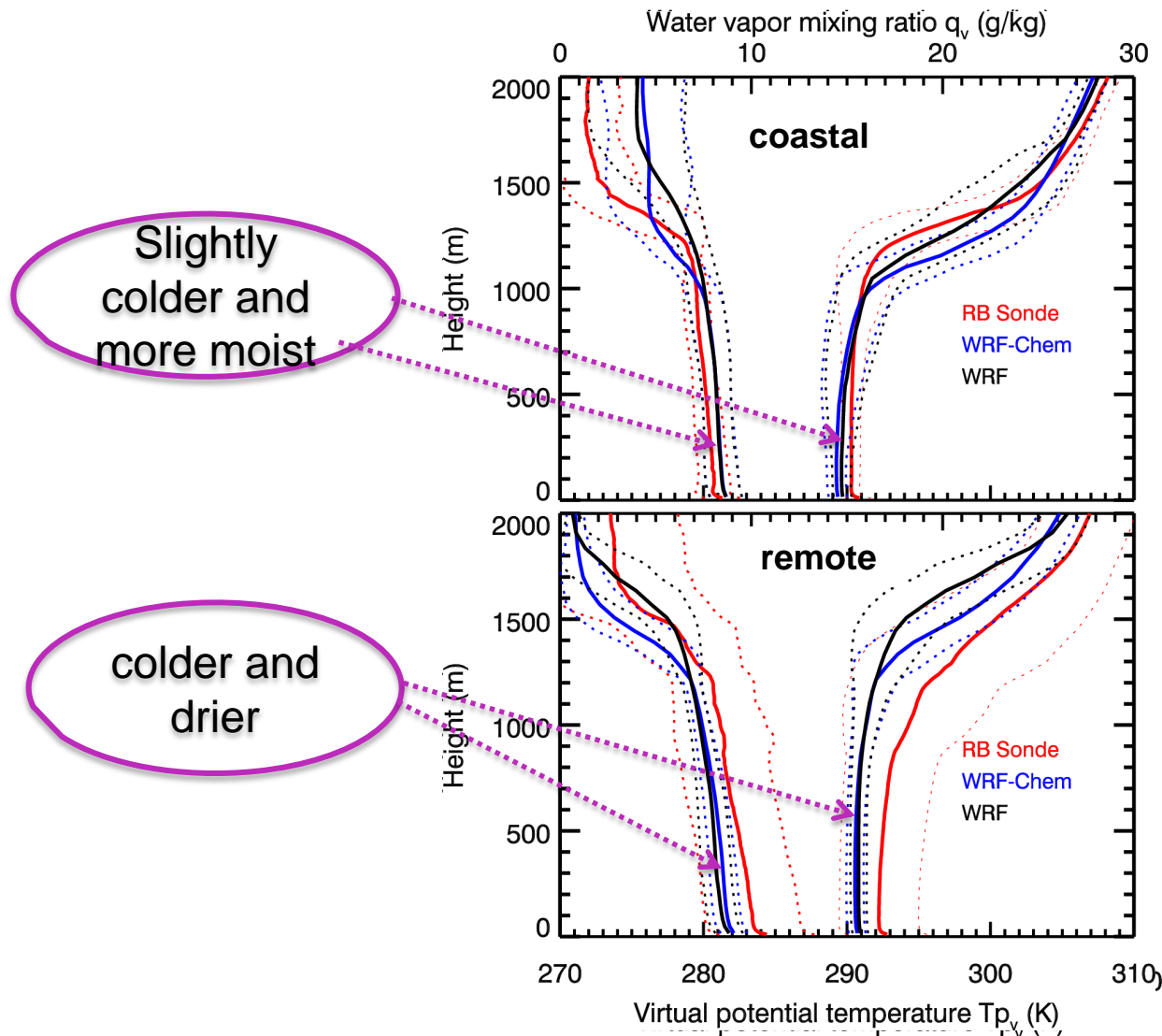▶ Simulation period: 15 October – 15 November, 2008 (during VOCALS-REx).

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

Boundary Layer Structure - Vertical profiles

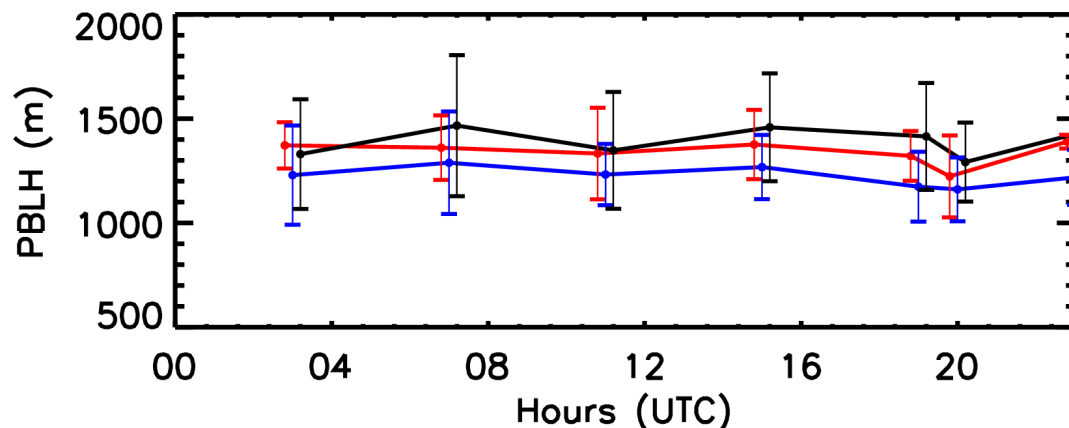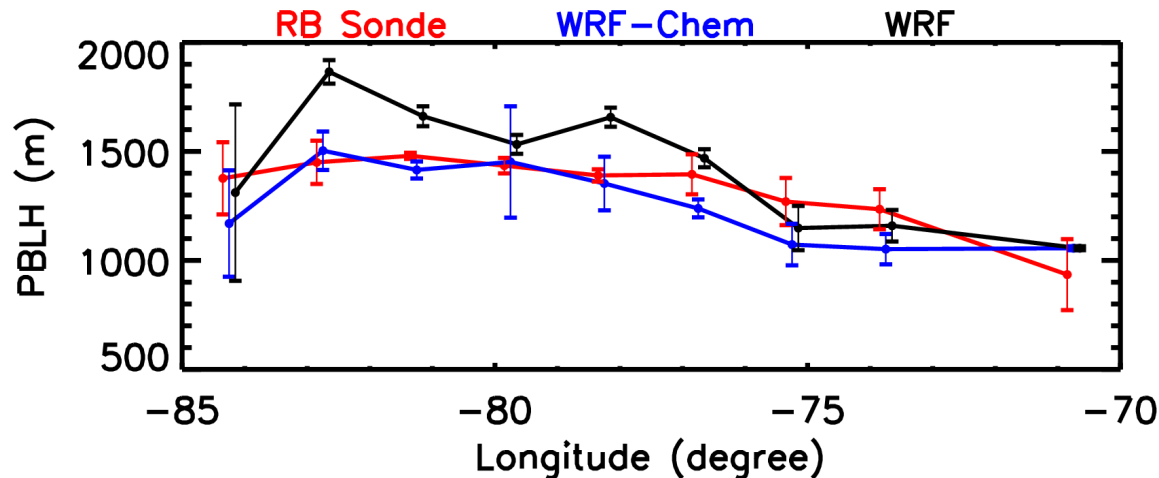▶ Water mixing ratio and virtual potential temperature

Improved inversion strength in WRF-Chem
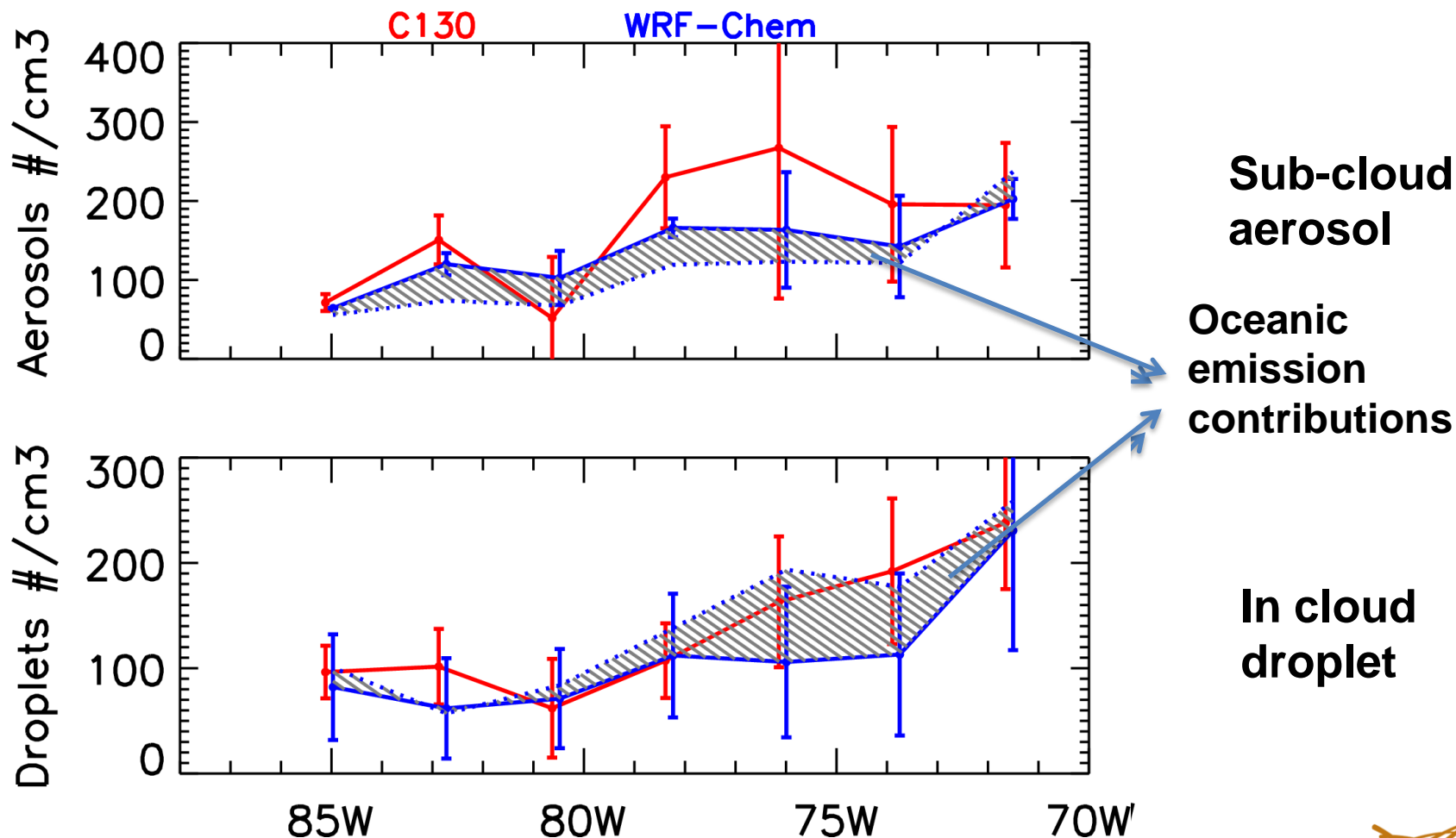
Boundary Layer Structure - PBLH

Including aerosol lowers the PBLH:

▶ Improved simulated PBLH over the remote ocean.
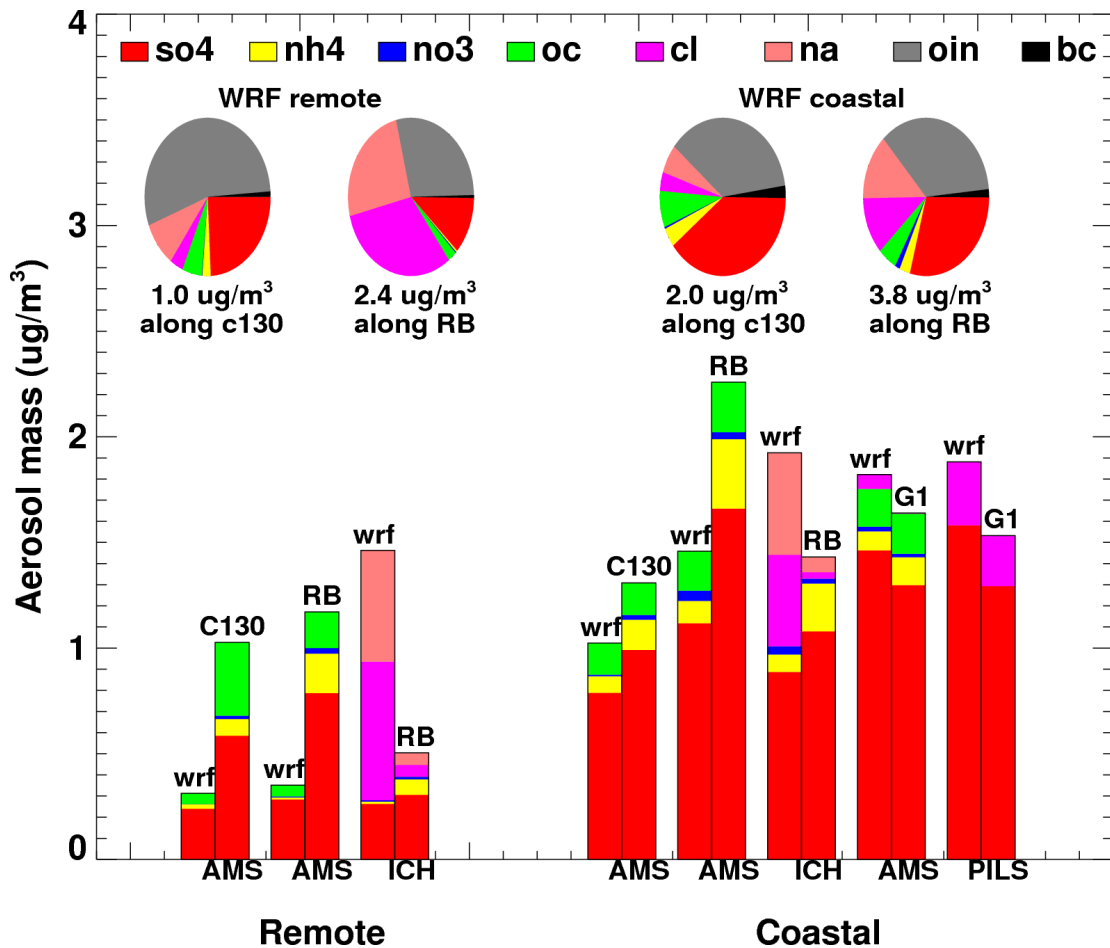
▶ Lower than observation near the coast.

Aerosol - number conc.
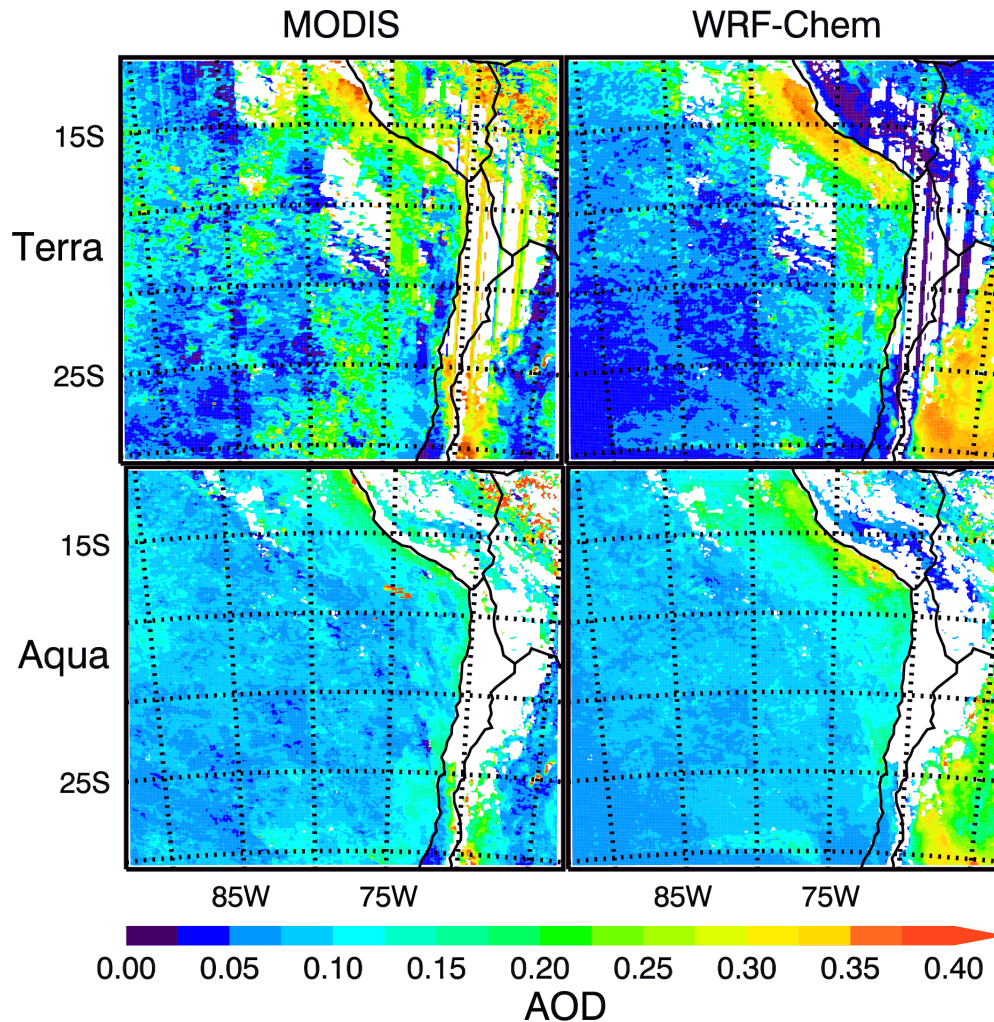
Aerosol and droplet number concentrations

Sub-cloud aerosol

Oceanic emission contributions

In cloud droplet

Aerosol - mass

▶ Submicron aerosols from C130/RB/G1 measurements and from WRF-Chem simulations

Proudly Operated by **Battelle** Since 1965
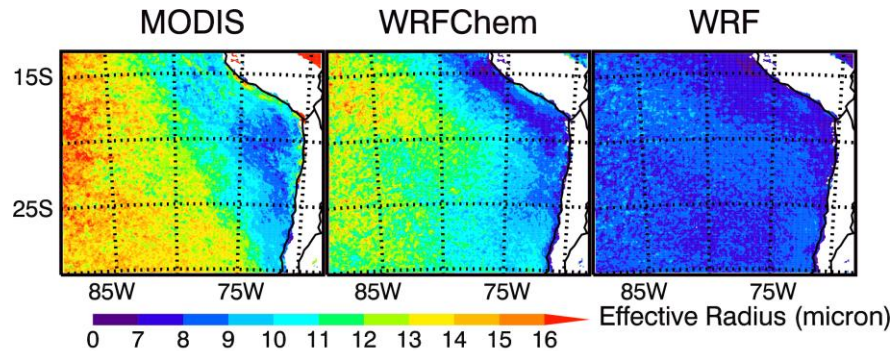
Pacific Northwest
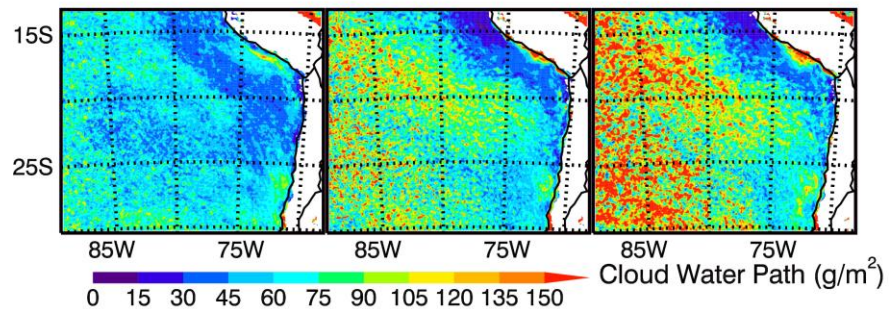NATIONAL LABORATORY

Aerosols – Aerosol Optical Depth
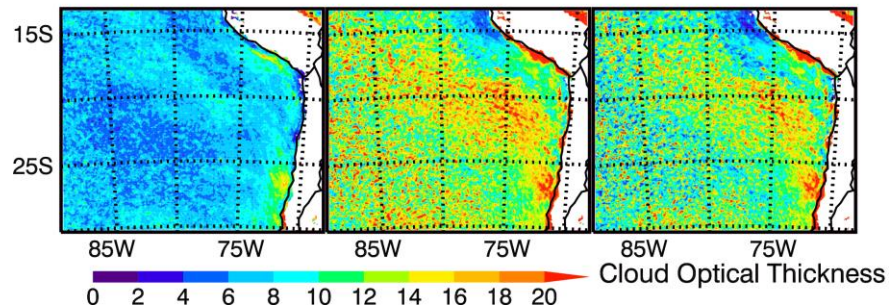

Terra:
Mean=0.12±0.06

WRF-Chem:
Mean=0.11±0.05

Clouds - Radiative Properties

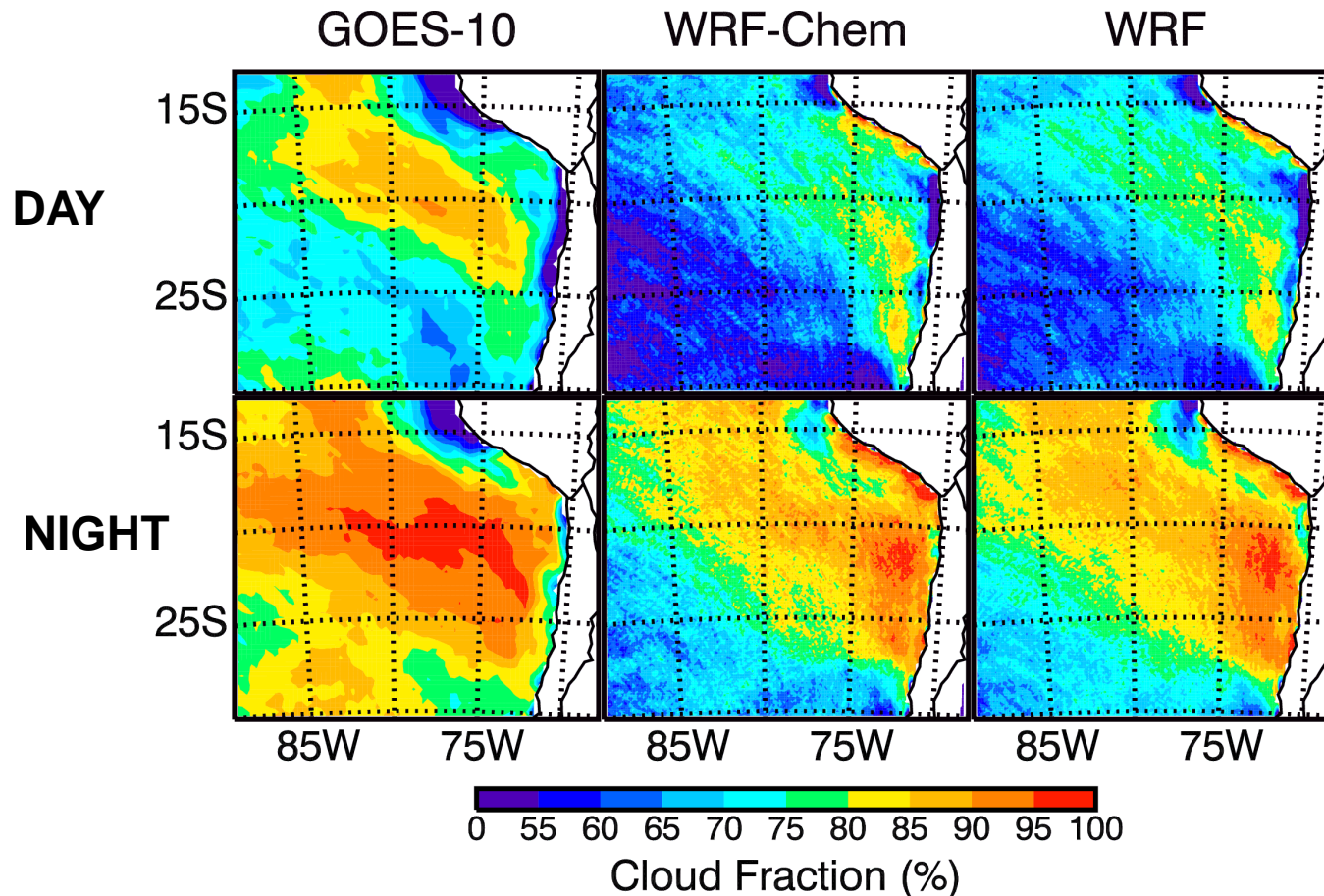Effective Radius

Cloud Water Path

Cloud Optical Thickness

Pacific Northwest
NATIONAL LABORATORY

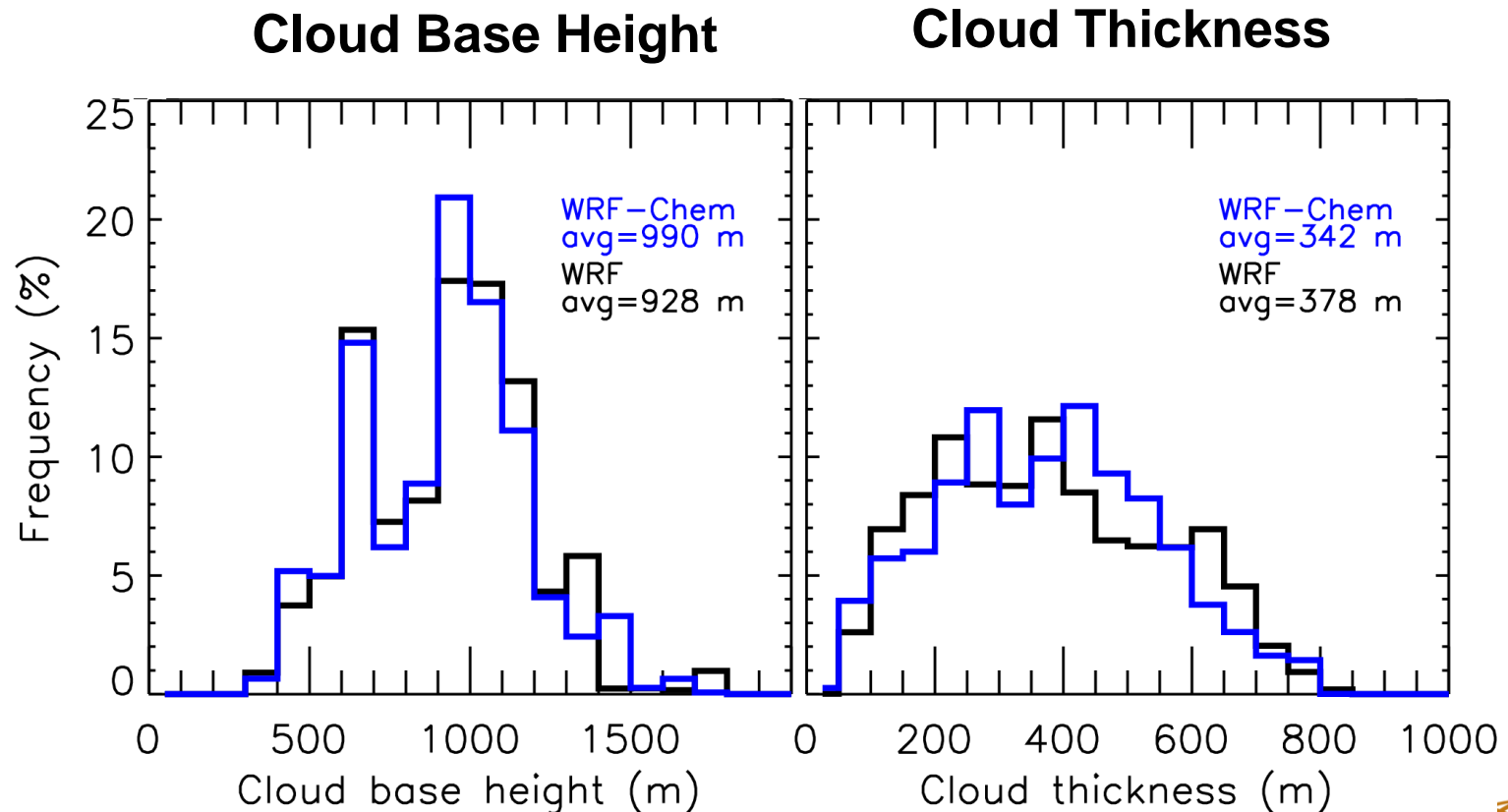*Proudly Operated by* Battelle *Since 1965*

Clouds – low cloud fraction

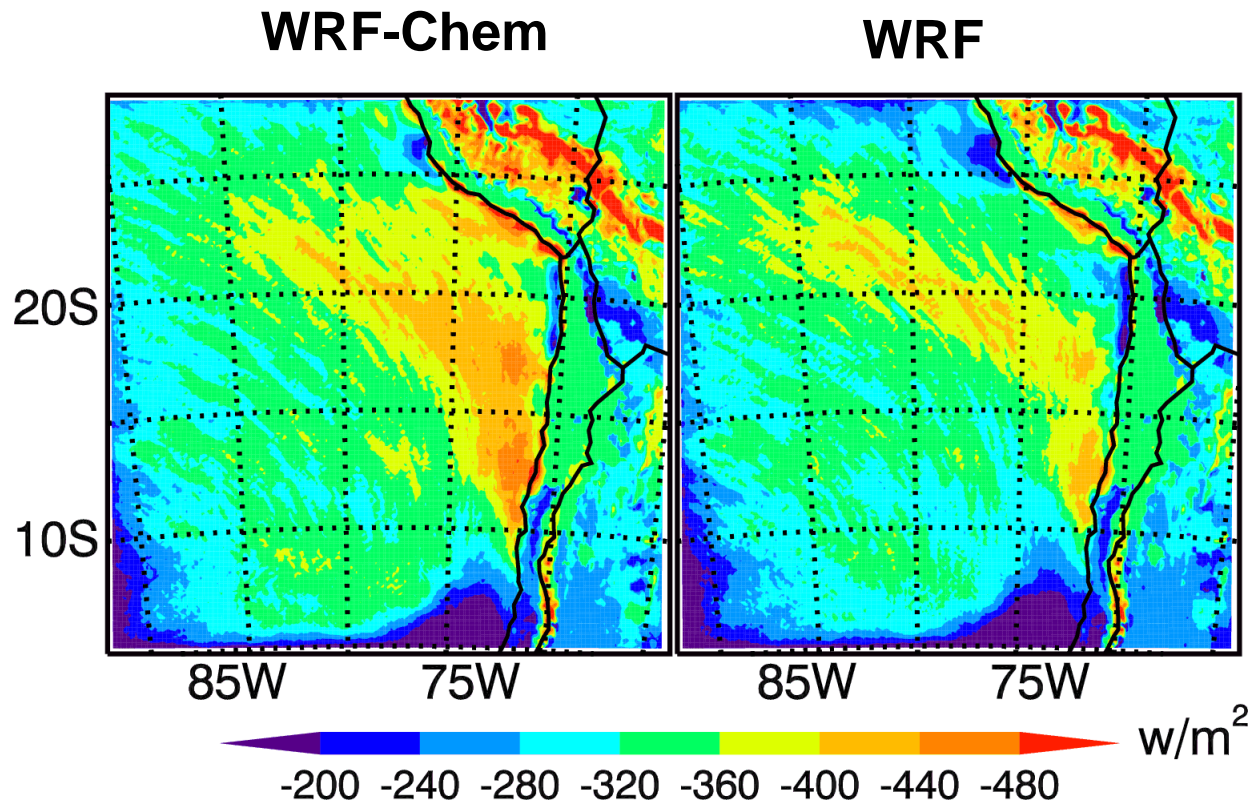▶ Including aerosol slightly alters the simulated cloud fraction.

Clouds – cloud base height and cloud depth

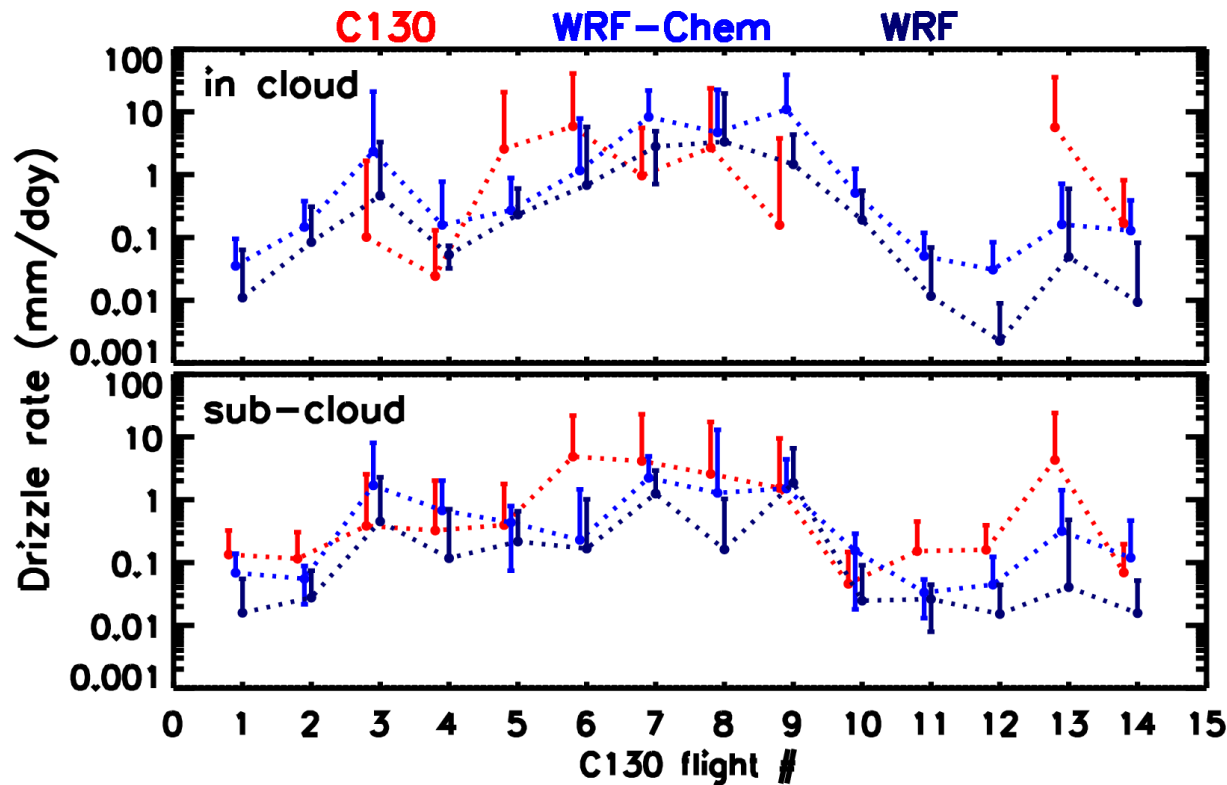▶ Including aerosol simulated slightly thinner and lower clouds.

Cloud Base Height **Cloud Thickness**

Radiative Flux - TOA outgoing shortwave

Outgoing TOA shortwave

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

Rain Rate

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

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

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.
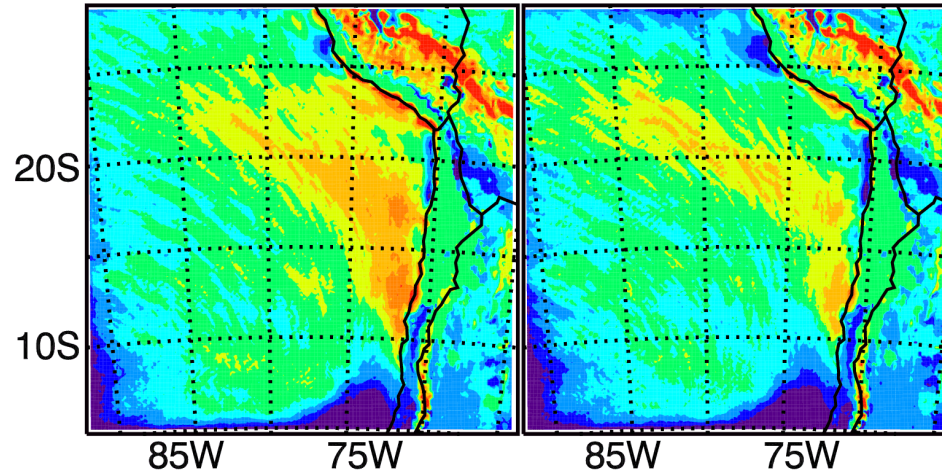
Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

Radiative Flux - TOA outgoing shortwave
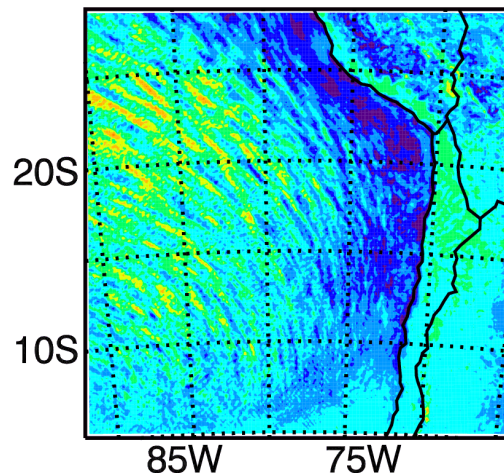
Outgoing TOA shortwave

WRF-Chem

WRF

**Difference in TOA SW
(WRF-Chem – WRF)**

Proudly Operated by **Battelle** Since 1965

Pacific Northwest
NATIONAL LABORATORY