Examples of Using WRF-Chem for Aerosol-Climate Applications

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WRF-Chem & Aerosol-Climate Investigations

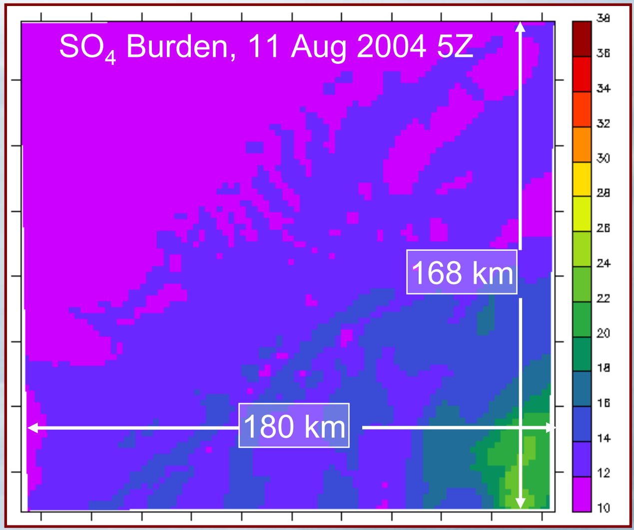
- The released WRF-Chem v2.2 now has built in capabilities for aerosol-climate investigations
- Two recent projects are presented here as examples
  - Impact of sub-grid scale CCN heterogeneity for GCMs
  - Impact of black carbon (BC) on snowpack

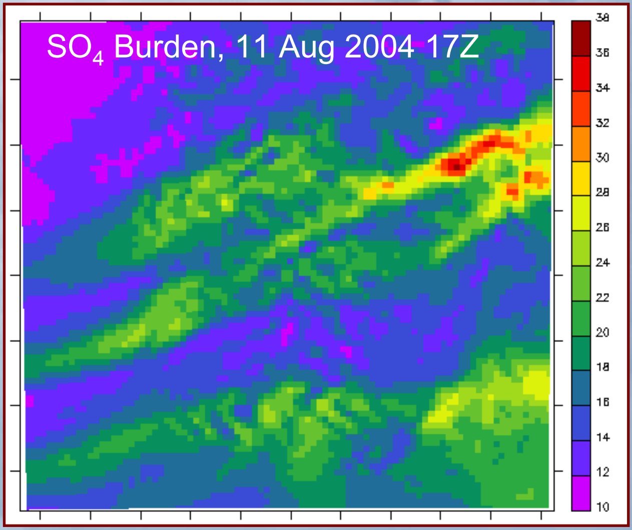
Aerosol-Climate Processes in WRF-Chem

- Direct effect for shortwave
  - Scattering and absorption by aerosols
- 1st indirect effect
  - Cloud albedo due to altered CCN counts
- 2nd indirect effect
  - Cloud life cycle changes due to altered CCN counts
- Common tie is the sectional aerosol module, MOSAIC
- More details Friday at the WRF-Chem tutorial

Application 1: CCN Heterogeneity

- GCMs represent CCN characteristics at a coarse scale
- Regions with complex aerosol distributions get smoothed out when diagnosing CCN
- What is the impact of this smoothing on cloud characteristics?





Approach for the Investigation

Simulation 1: IA

- Interactive Aerosols
- Control run
- Used to generate a realistic spatially and time varying aerosol field
  - Hygroscopicity
  - Size
  - Number

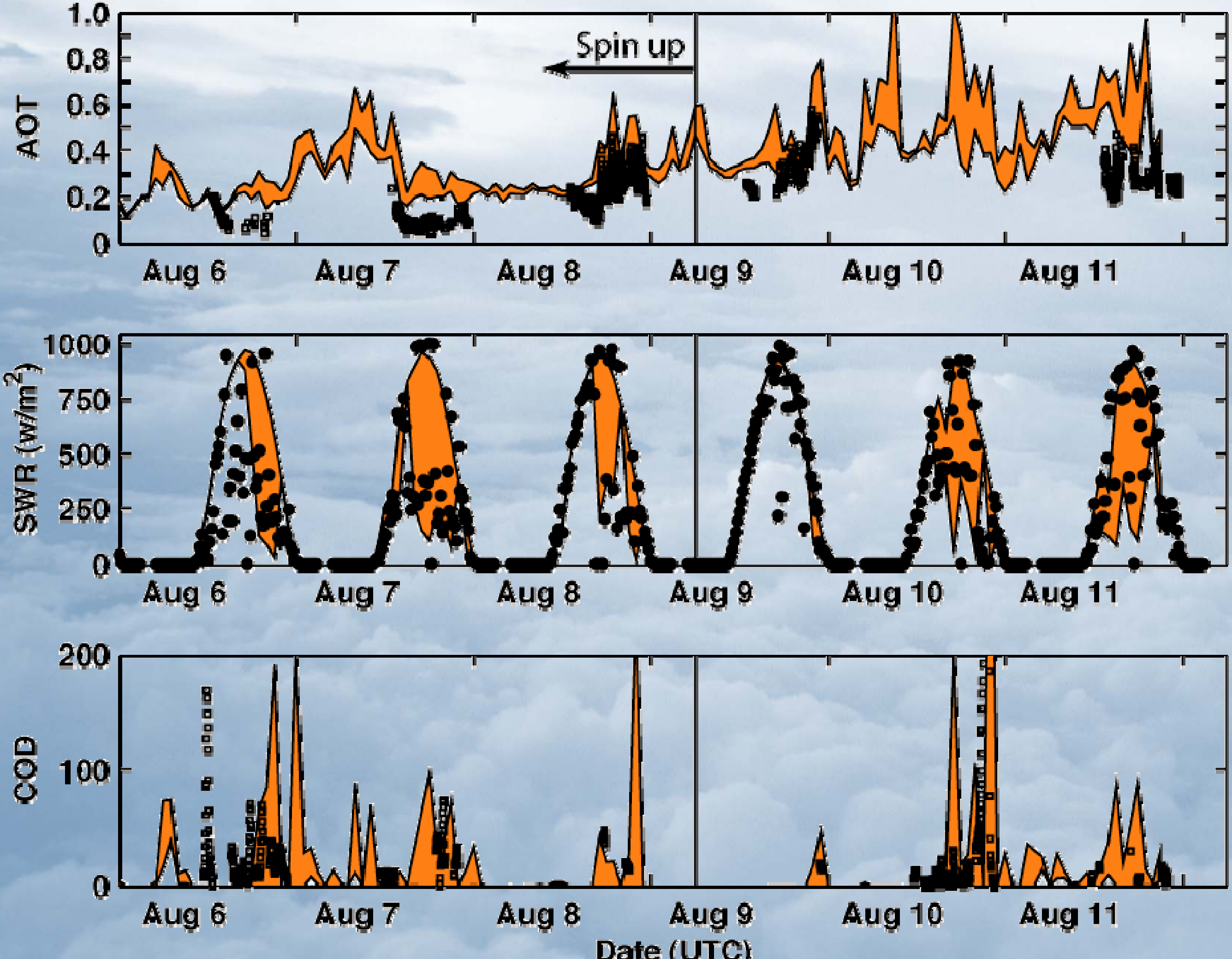
Simulation 2: PA_{XY}

- Prescribed aerosols based on horizontal (XY) average
- Aerosol distribution varies in height and time

Simulation 3: PA_{XYZT}

- Prescribed aerosols based on horizontal, time and height (XYZT) average
- Aerosol distribution is constant

Comparison to MFRSR, Indiana, PA

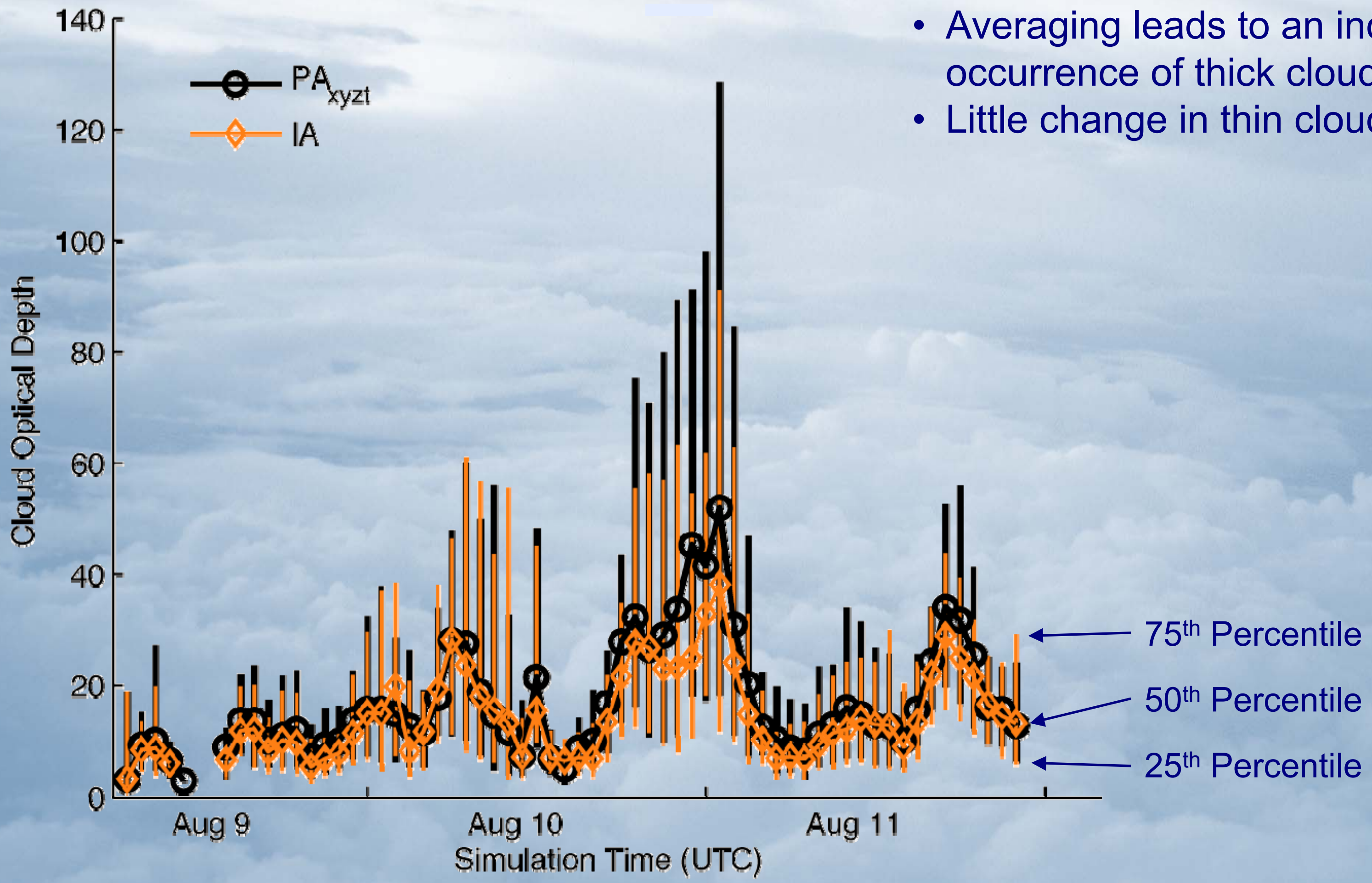


Symbols = Observations

Orange = Modeled range of values in 9 points surrounding observation location

Gustafson et al. 2007, GRL, in review

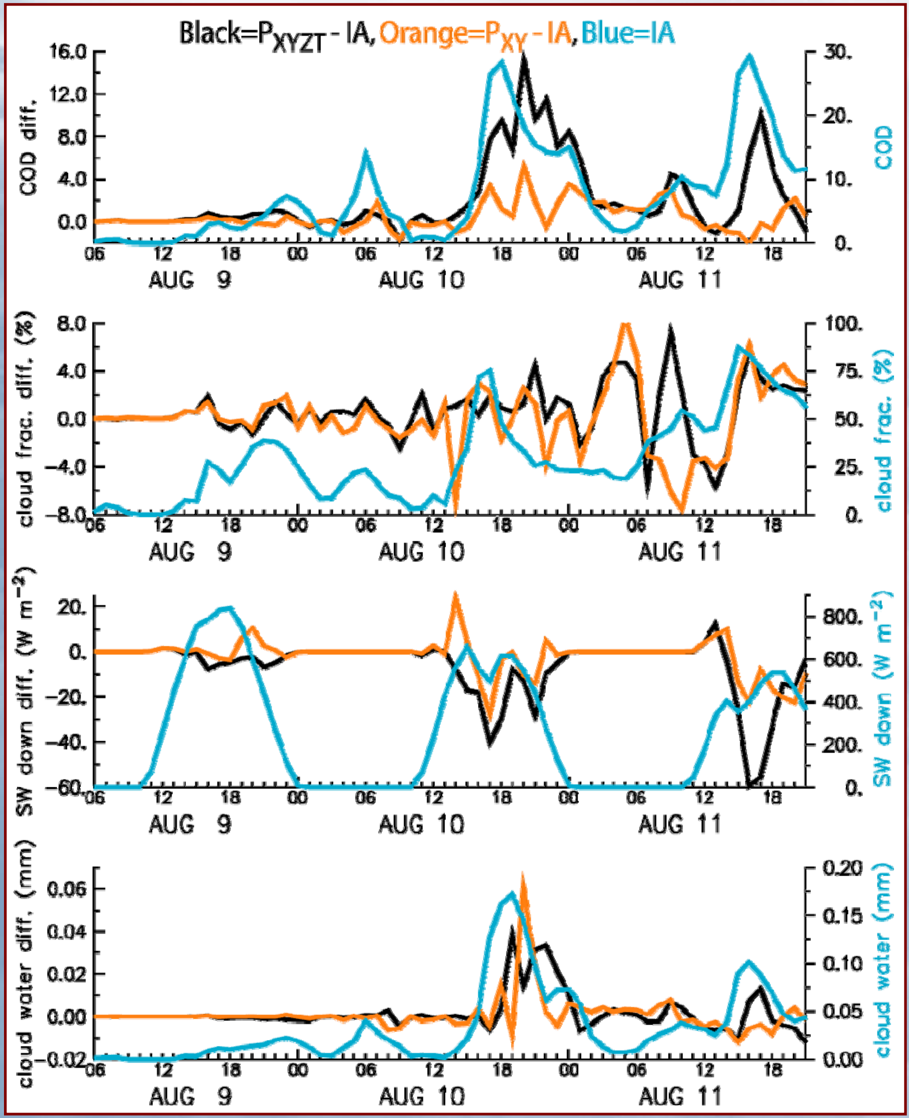
Cloud Optical Depth Percentiles



- Averaging leads to an increased occurrence of thick clouds
- Little change in thin clouds

Gustafson et al. 2007, GRL, in review

Domain Average Time Series



	Change PA_{XYZT} vs. IA	Change PA_{XY} vs. IA
Cloud Optical Depth	27%	6%
Cloud Fraction	-6% (1<COD<20) 13% (20<COD<200)	-2% (1<COD<20) 4% (20<COD<200)
Downwelling Shortwave	-3% -11 W m^{-2}	-1% -3 W m^{-2}
Cloud Water	5%	3%

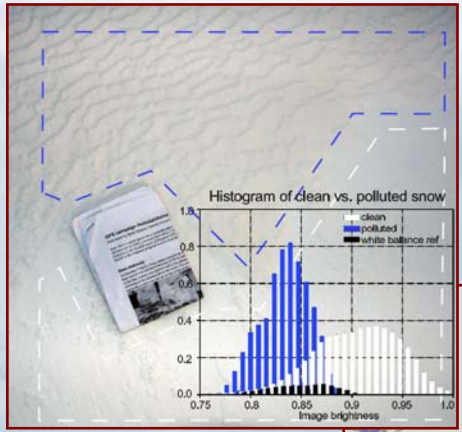
Gustafson et al. 2007, GRL, in review

Impact Summary

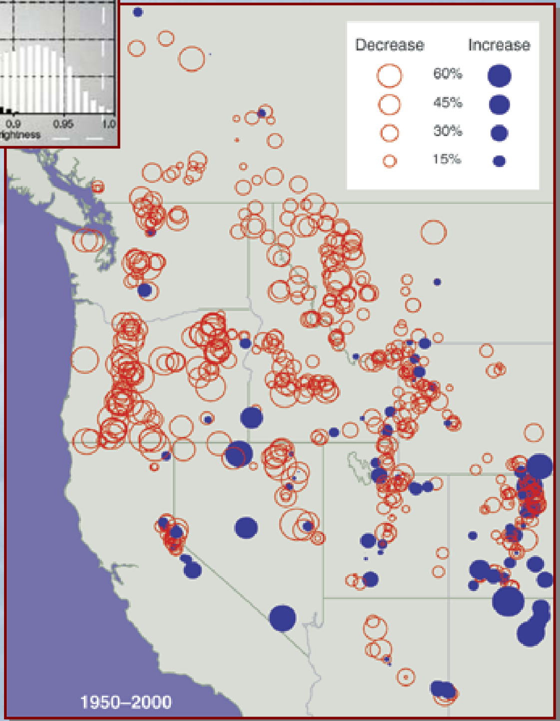
- The error from CCN in cloud characteristics is presumably smaller than from other aspects of the cloud parameterizations
- Neglecting time and height dependence of CCN leads to the largest systematic bias
- Including time and height variability of CCN reduces bias for downwelling shortwave to 1%
  - If GCMs can account for the CCN variability, then they will improve their ability to reproduce cloud characteristics
  - More extensive spatial and temporal simulations need to confirm this

Application 2: BC Impact on Snow

- Black carbon (BC) deposition on snow reduces the albedo
- Cascades have lost up to 60% of their snowpack since 1950, Northern Rockies have lost 15%
- How much of this can be attributed to BC influences?



Stohl et al., 2007, ACP



Observed Snowpack Reduction

P. Mote, 2003, GRL; Service R., 2004, Science

Approach to the Investigation

WRF-Chem

- 1-yr simulation, dx=12 km
- 4-bin MOSAIC
- Maps of BC deposition and snow

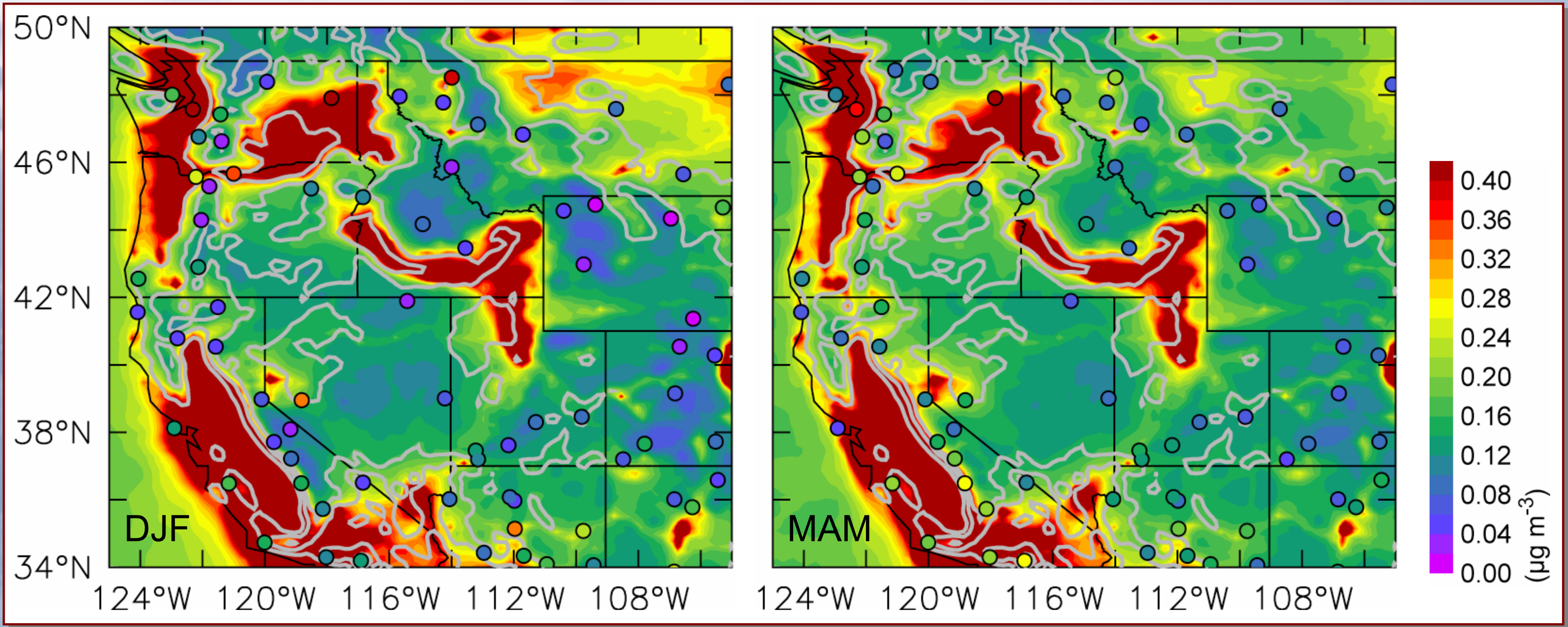
Offline BC-snow model

- BC-snow mixing ratio for radiative layer of snowpack
- Bounds for snow albedo

WRF Regional Downscaling

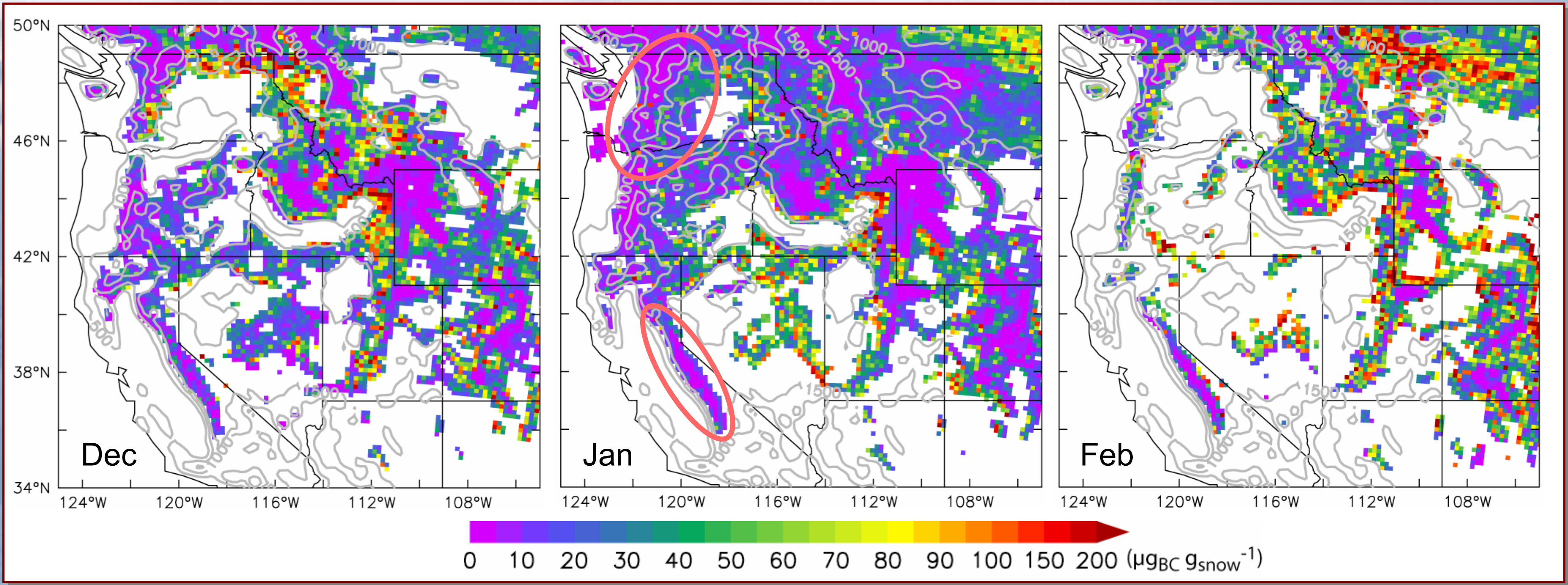
- Decade simulations
- Sensitivity runs for snow albedo guided by offline model results

WRF vs. IMPROVE, Black Carbon (0-2.5 μm)



- Large BC gradients near mountains
- WRF simulation tends to over predict surface concentrations of BC
- Partially due to “non-seasonal” emissions?

BC-Snow Mixing Ratio



- Patterns of BC-snow mixing ratio shift by month
- Lower elevations affected more in important regions, e.g. Sierra Nevada
- East-west asymmetry around Washington Cascades
- Next step… relate these monthly mixing ratios to albedo

Parting Comments

- WRF-Chem has the potential to study many types of aerosol-cloud interactions
  - Resolution studies
  - Process studies
  - Sensitivity of climate to aerosols
- Currently, interactions are limited to the liquid phase; ice phase linkages are in development
- We are looking to partner with others to link the aerosol mechanism to biogeophysical and toxics models

WRF-Chem Flow Chart