Medium Complexity Aerosol Treatment Coupled with Clouds/Precipitation/Radiation in a USA Operational NWP Model

Gregory Thompson

Additional contributors:
Mei Xu, Trude Eidhammer, Tim Juliano, Maria Frediani, Judith Berner
Lin Deng (NCAR visitor from Chinese Academy of Meteorological Sciences)
NOAA ESRL-GSD RAP/HRRR team

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Aerosol-aware microphysics

Microphysics in WRF, RAP, HRRR, etc.

- Aerosol-aware scheme operational in HRRR/RAP since 23Aug2016

  Thompson, G. and T. Eidhammer, 2014: A study of aerosol impacts on clouds and precipitation development in a large winter cyclone. *J. Atmos. Sci.*, **71,** 3636–3658.

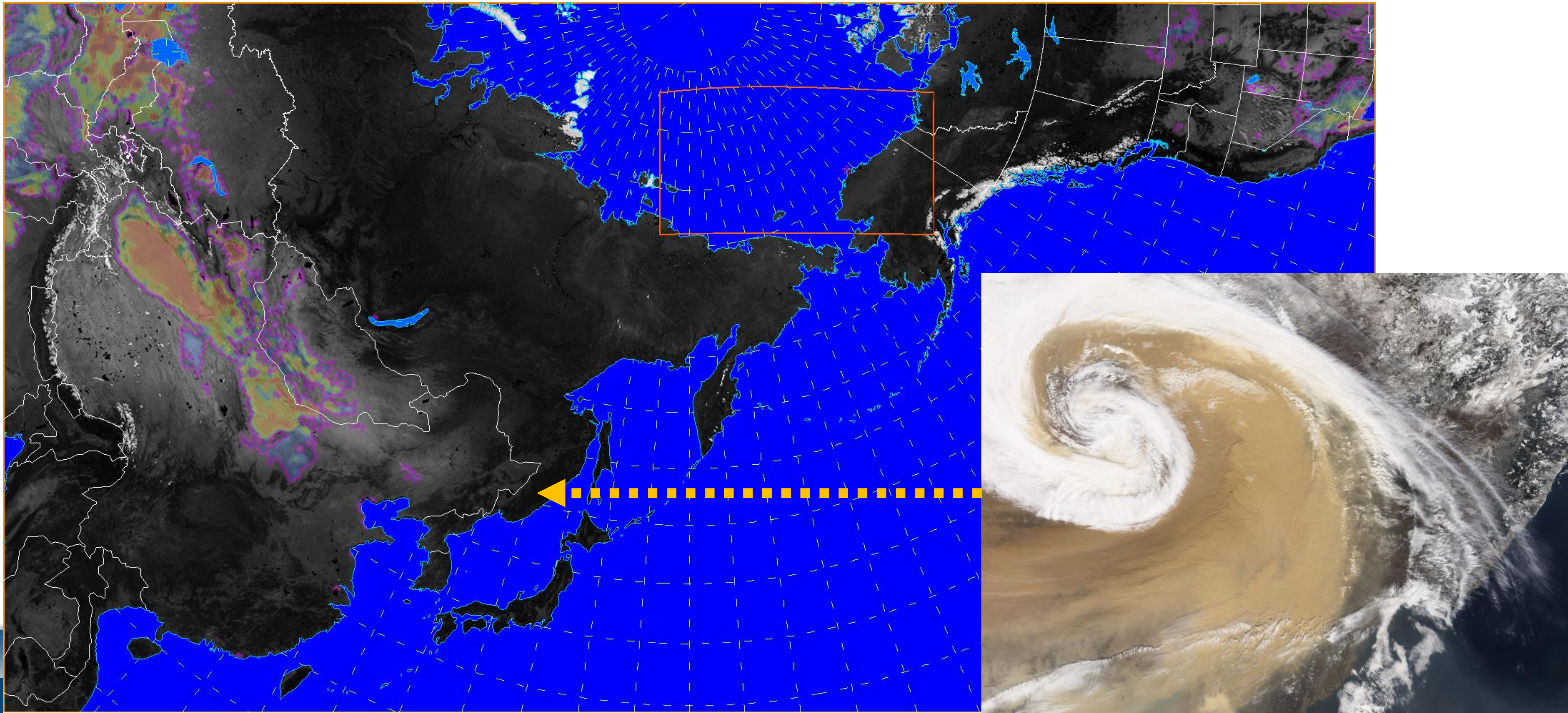
Fundamental, 1st order aerosol treatment (NWP)

- activation of CCN & IN
- depletion of aerosols – precip scavenging
- simplistic aerosol replenishment (surface emissions)
  - now including surface dust parameterization (GOCART)
- ensure physics consistency between prior scheme and new one
- directly couple with radiation for direct/indirect effects

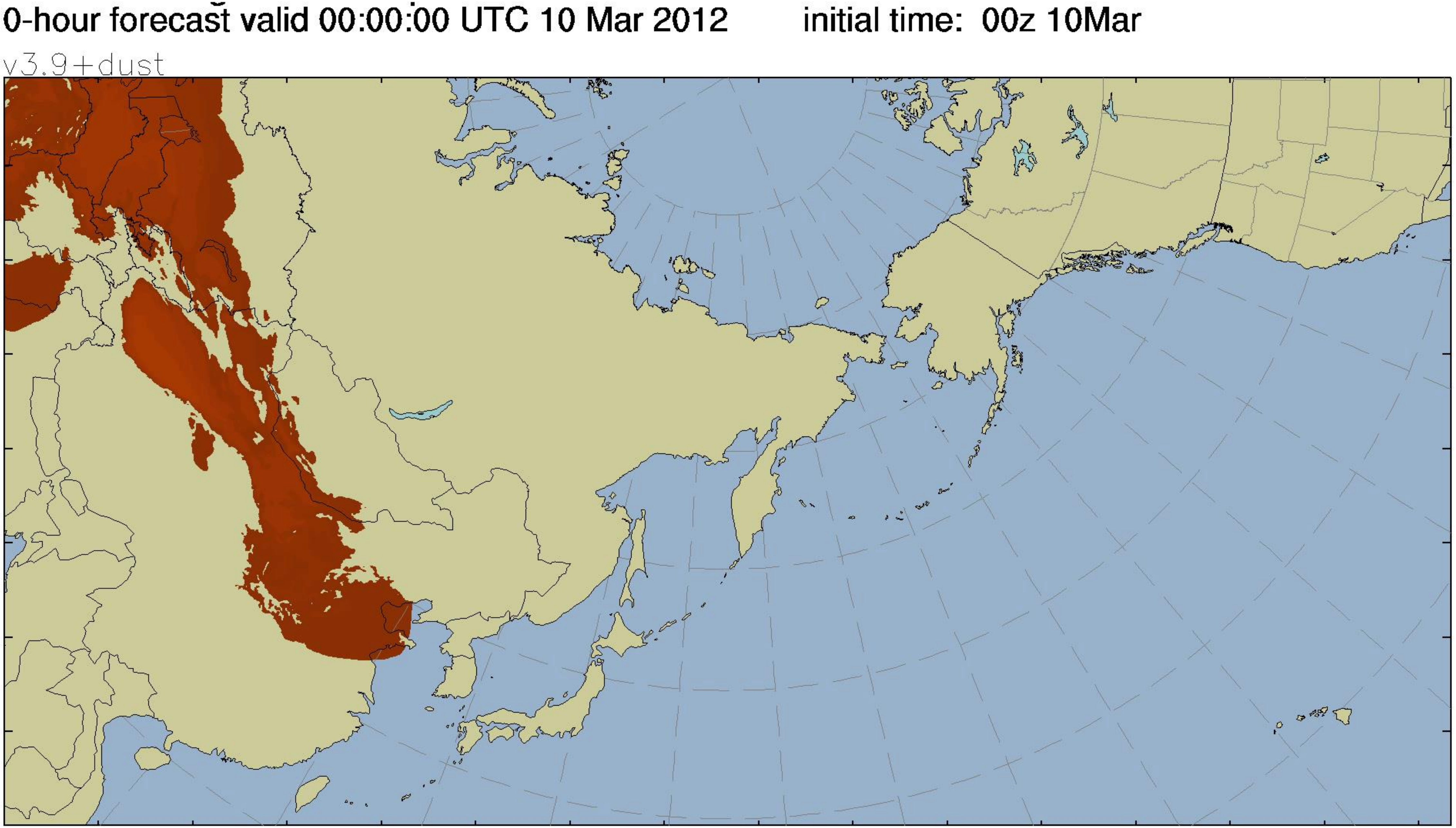
Dust Emission Scheme

Originally from WRF-Chem GOCART

- Enhanced “erodibility” using MODIS visible satellite climatological albedo



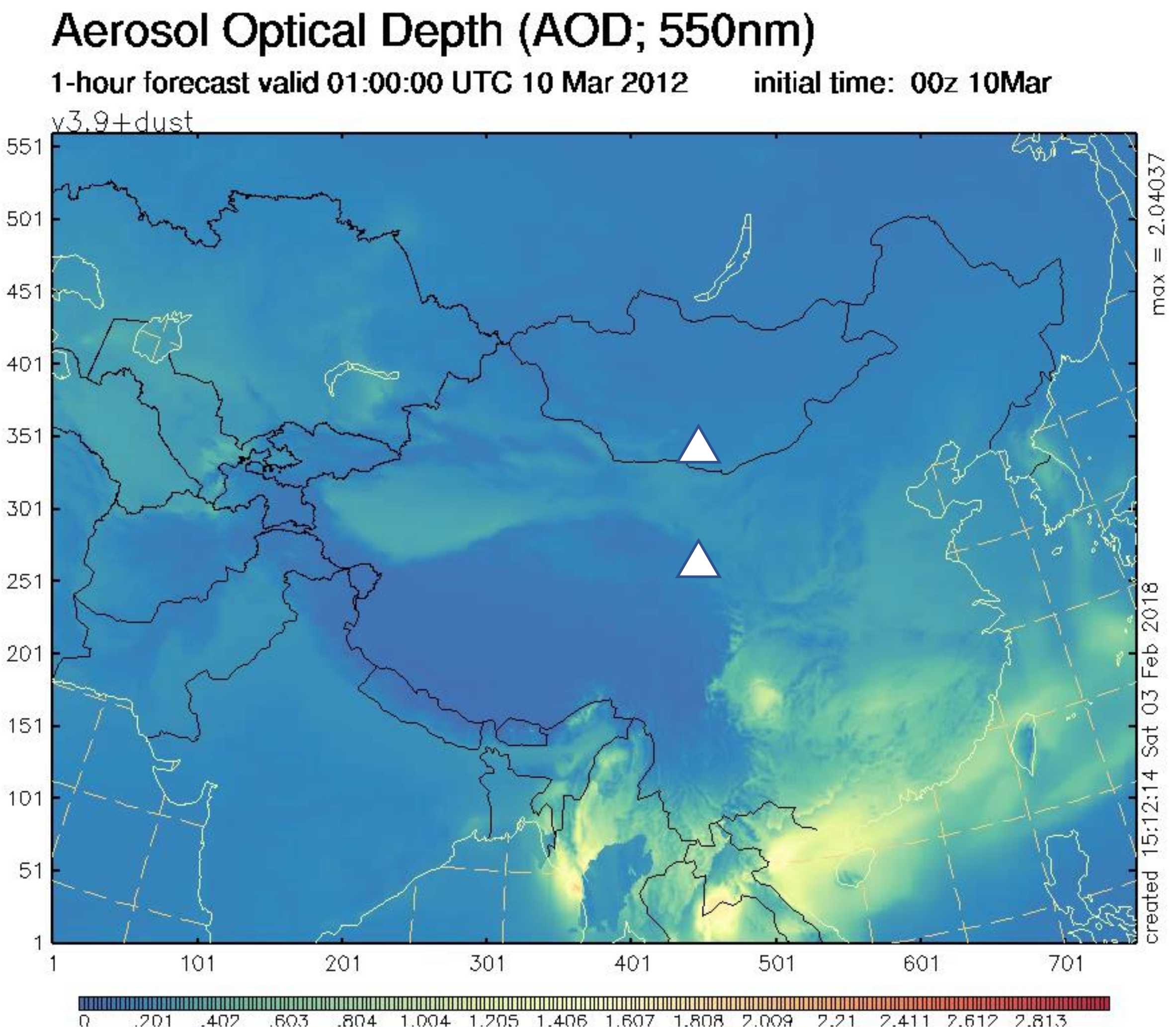
Dust Emission Example Simulation (10-day)

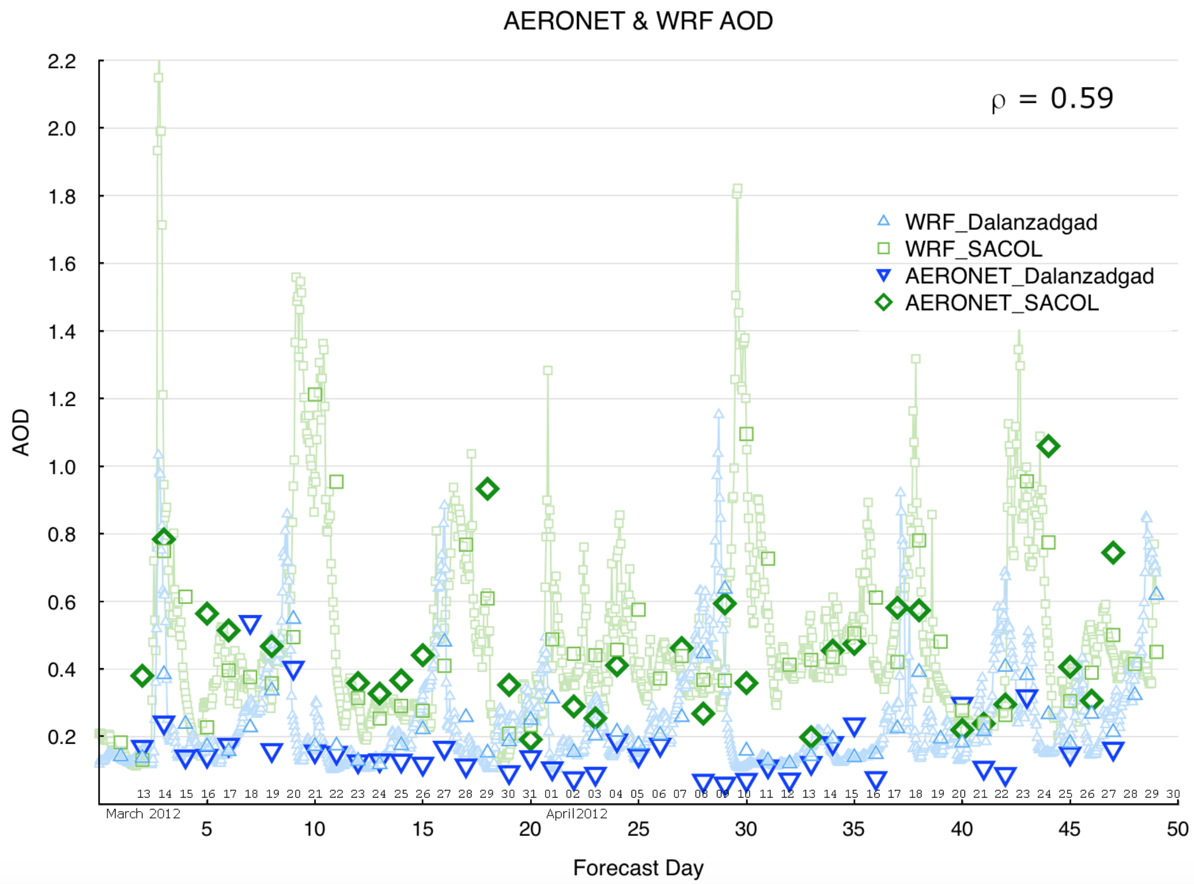


Aerosol Optical Depth (AOD)

Included into RRTMG-SW scheme

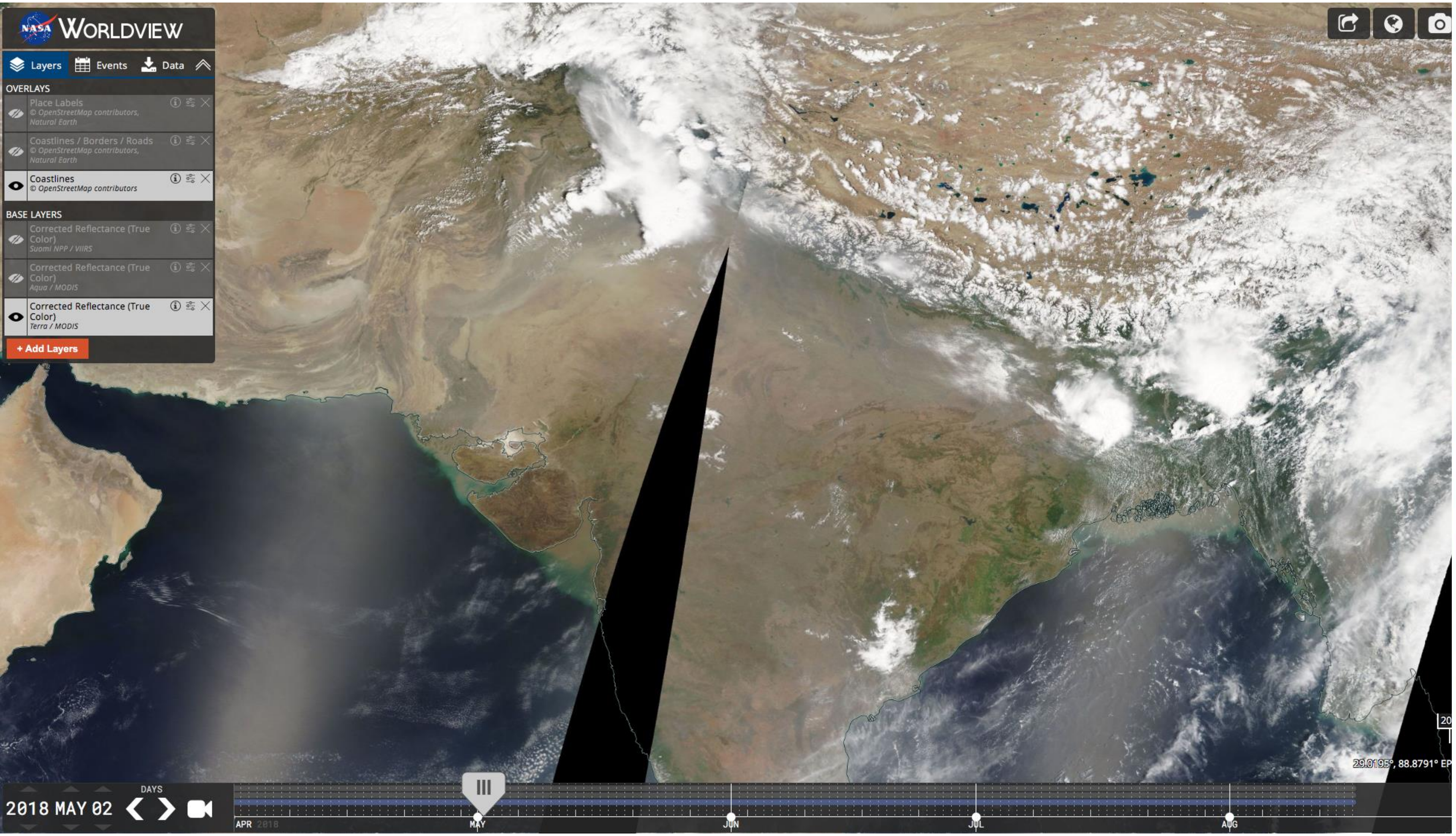
- 50-day simulation, comparison of 2 AERONET sites in China

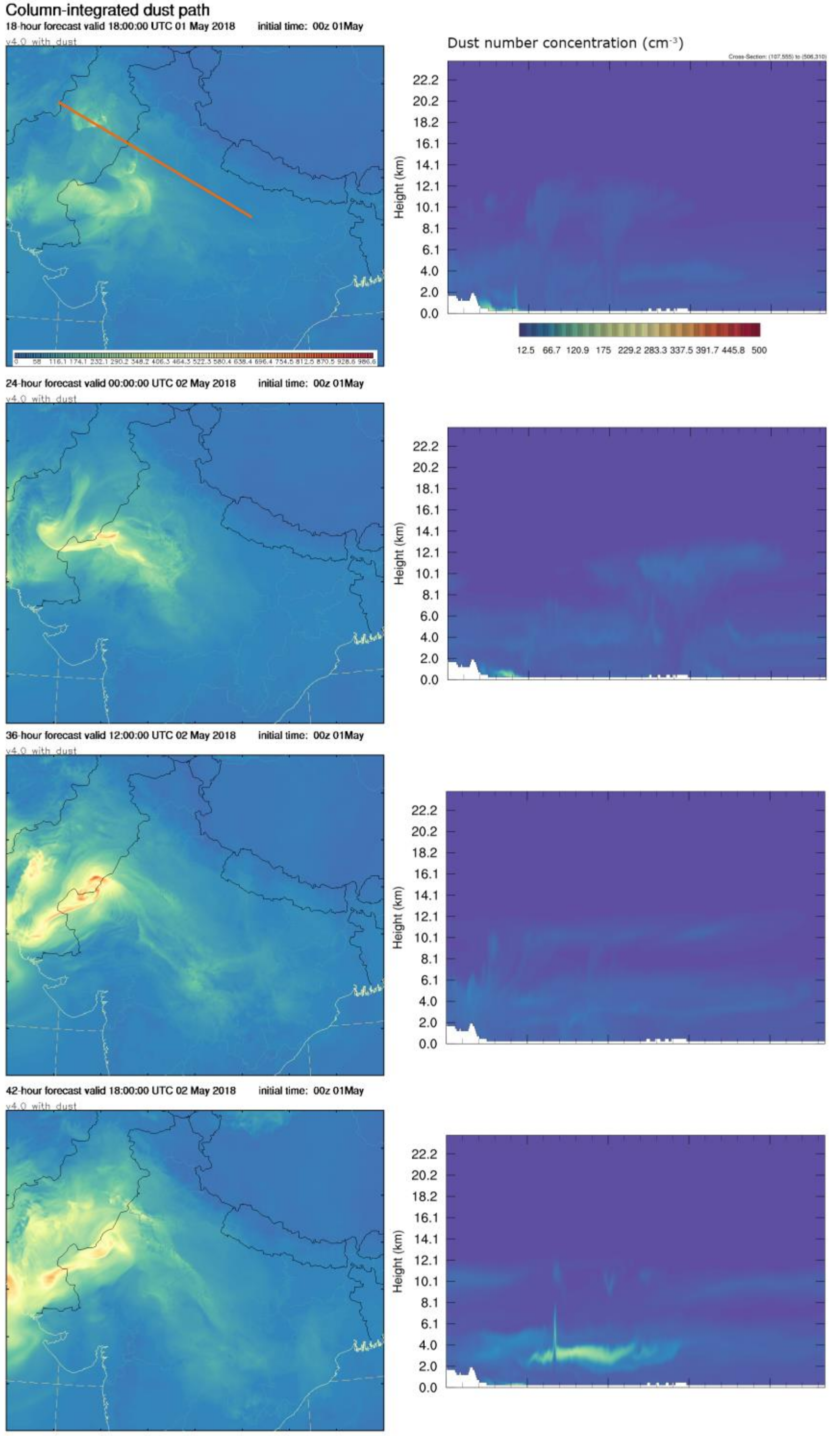




Dust Storm in India

MCS moves across Indo-Gangetic Plain (IGP)

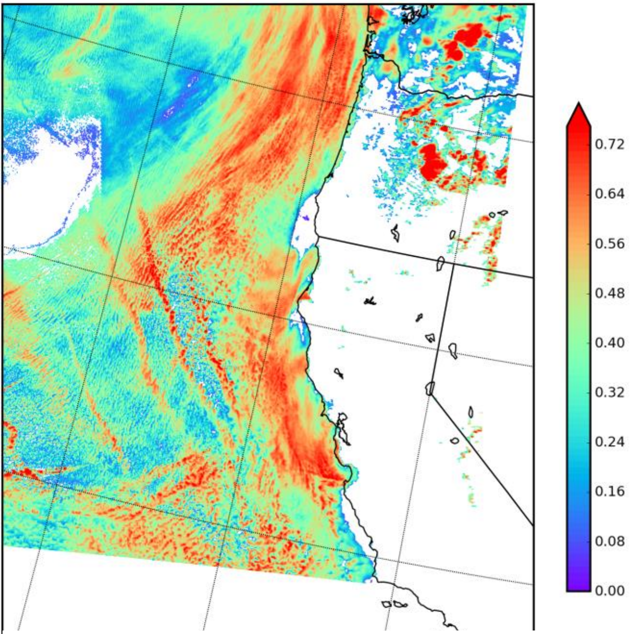




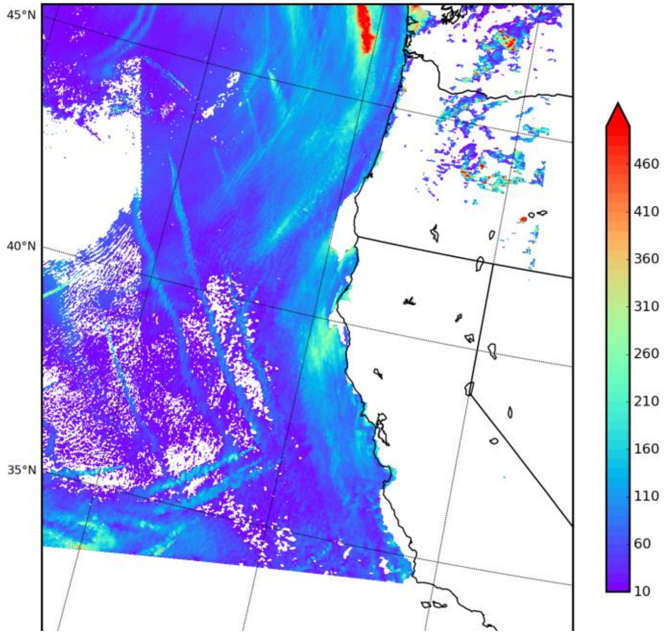
Ship Tracks

2012Jul14

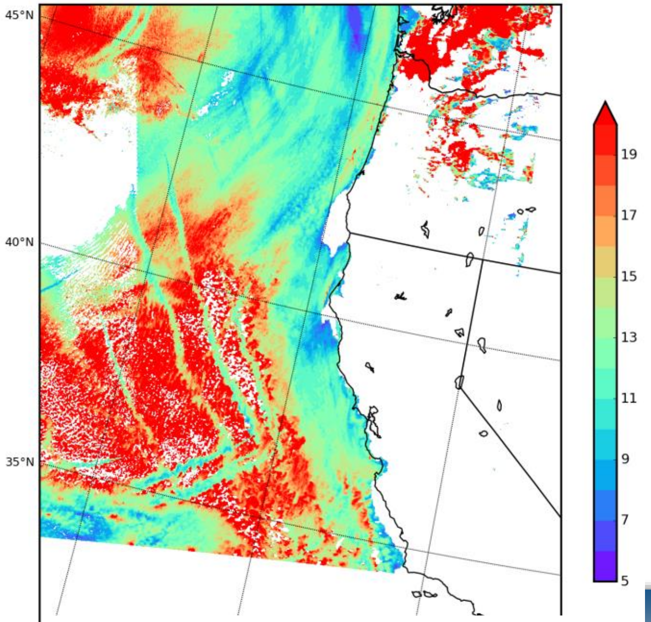
GOES-visible



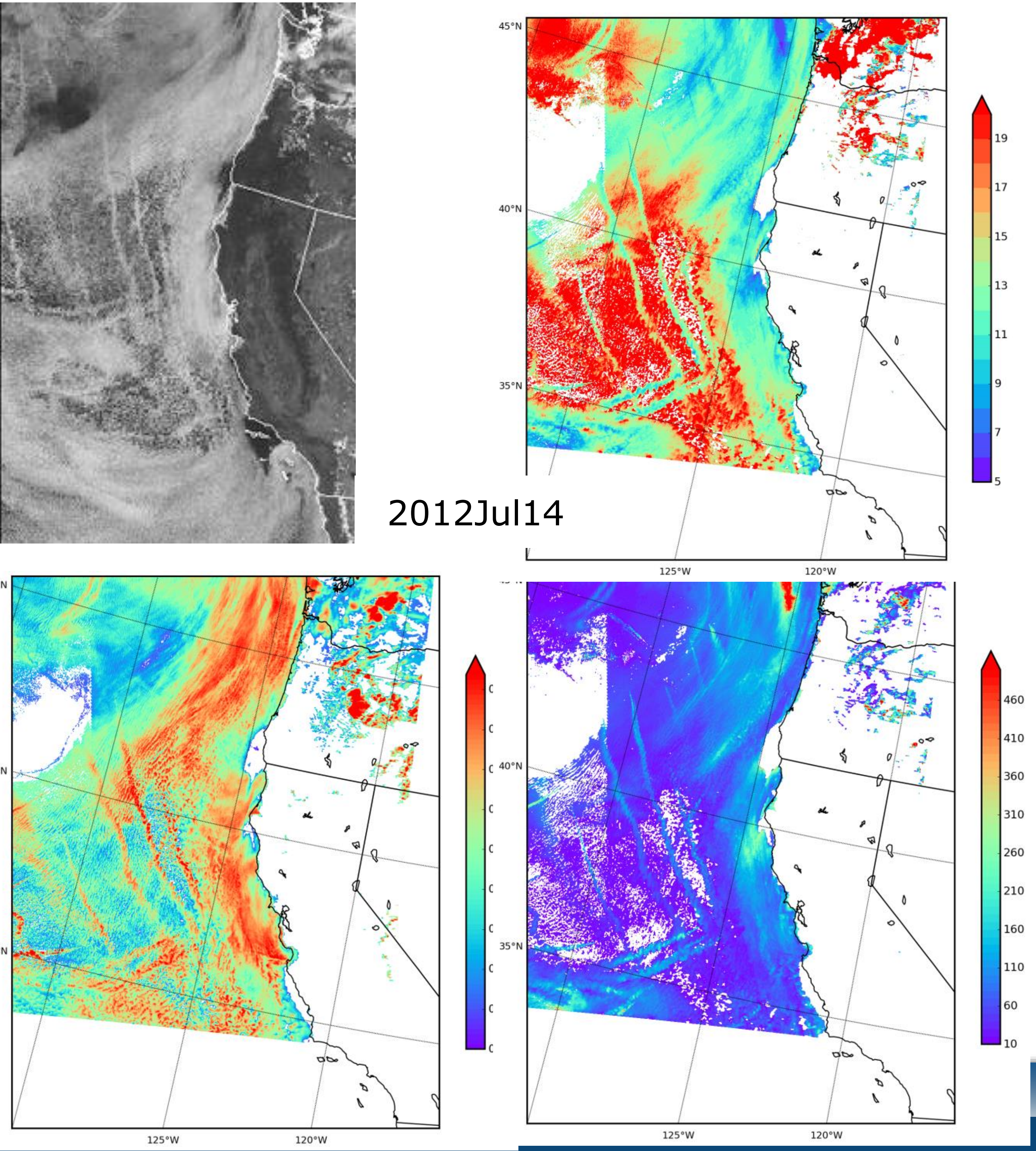
MODIS albedo



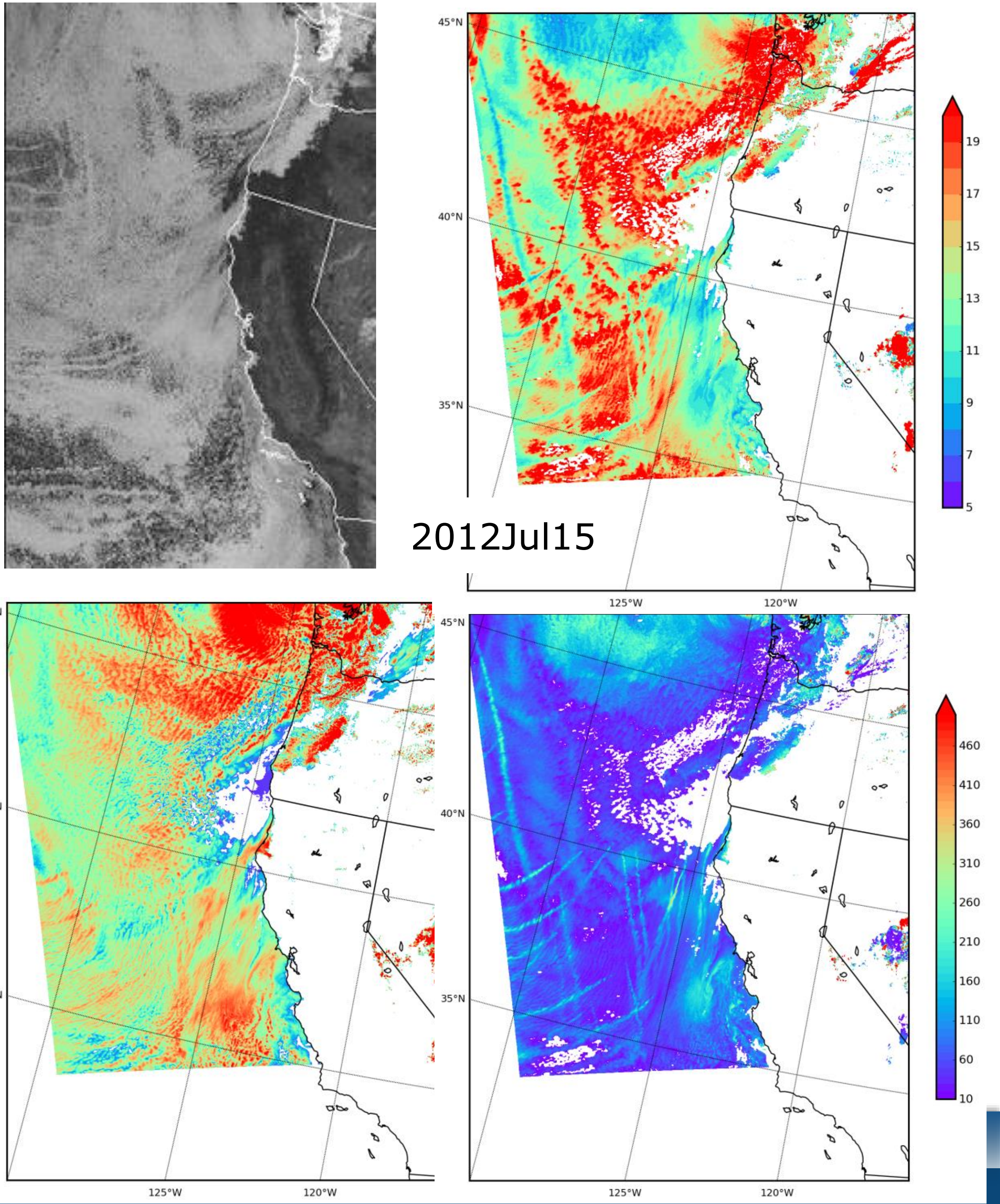
MODIS droplet #



derived effective radius

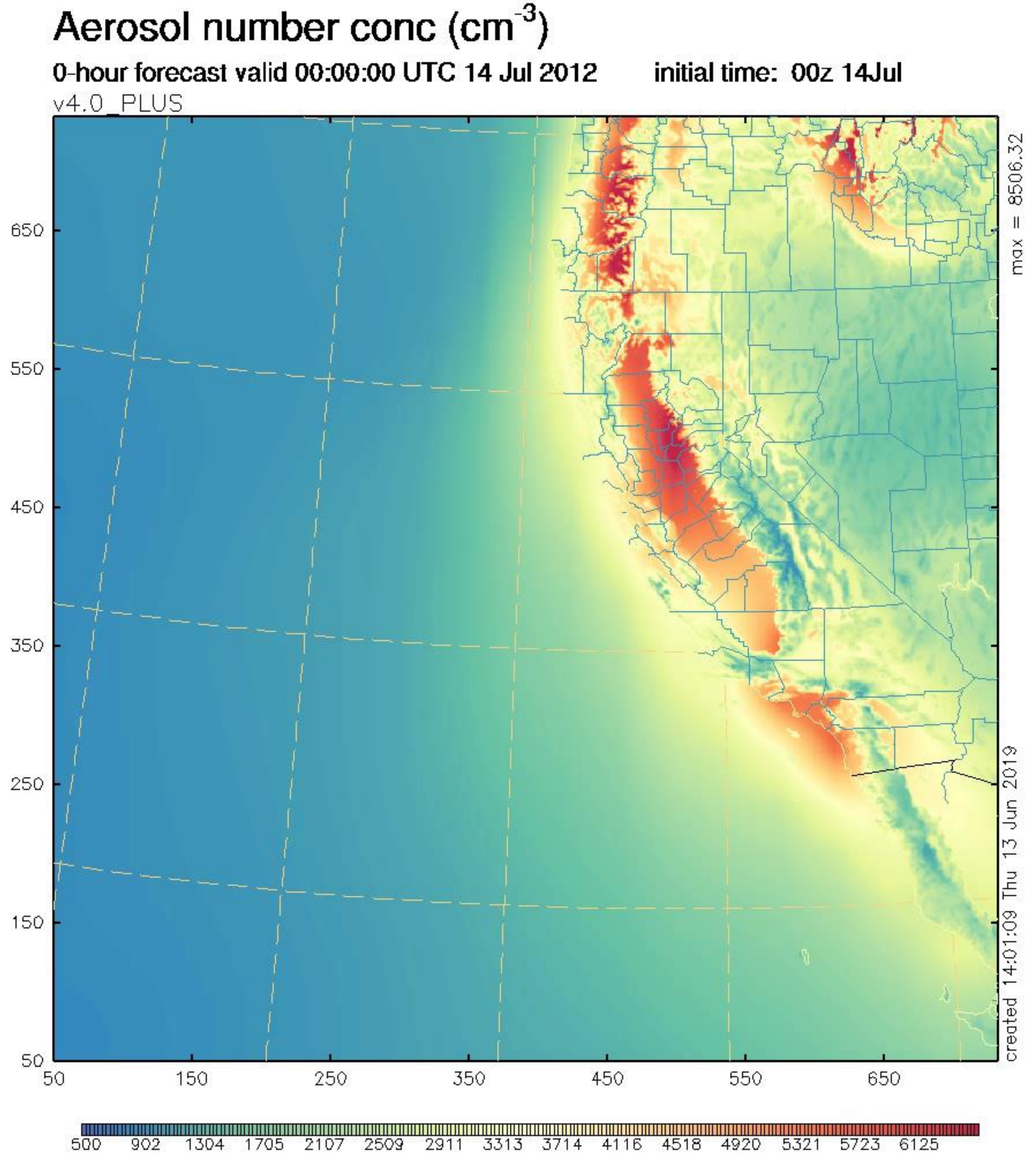


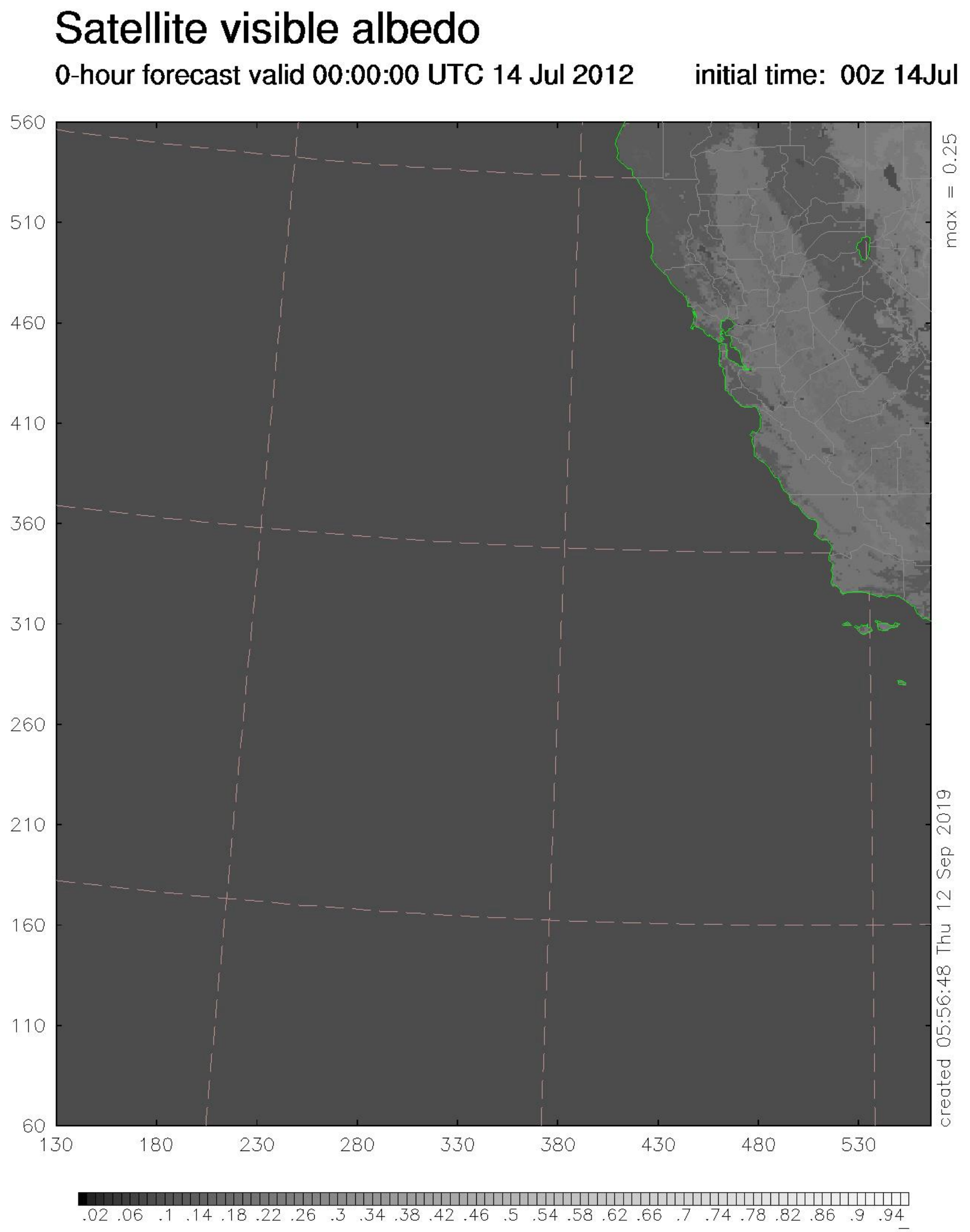
2012Jul14



2012Jul15

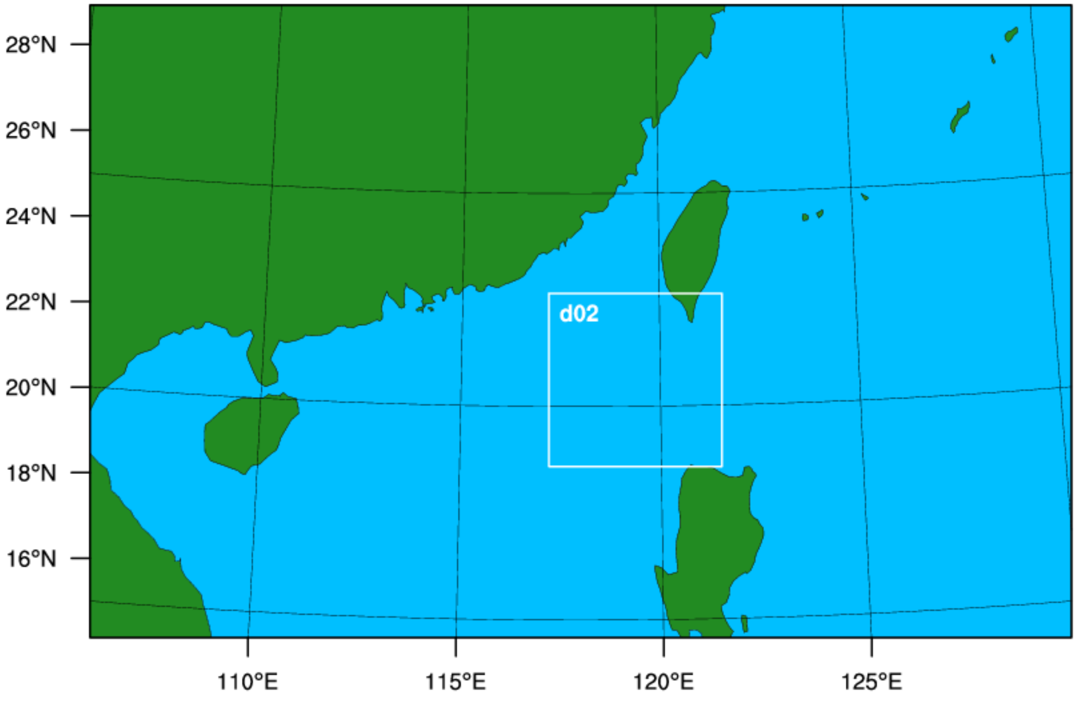
WRF Simulated Ship Tracks





Aerosol impacts on landfalling tropical cyclones in China

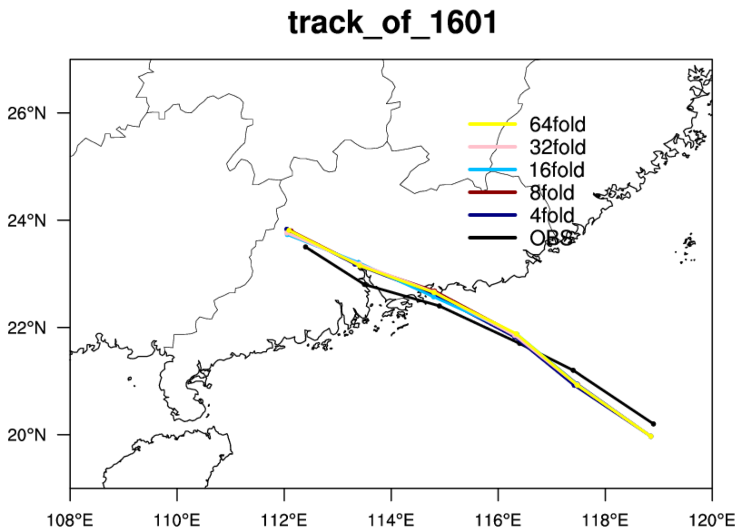
Storms: 4 currently (at least 4 more)
WRF-model simulations
5-km spacing with 1-km vortex following nest
Aerosols: urban increase of 4X, 8X, 16X, 32X, 64X



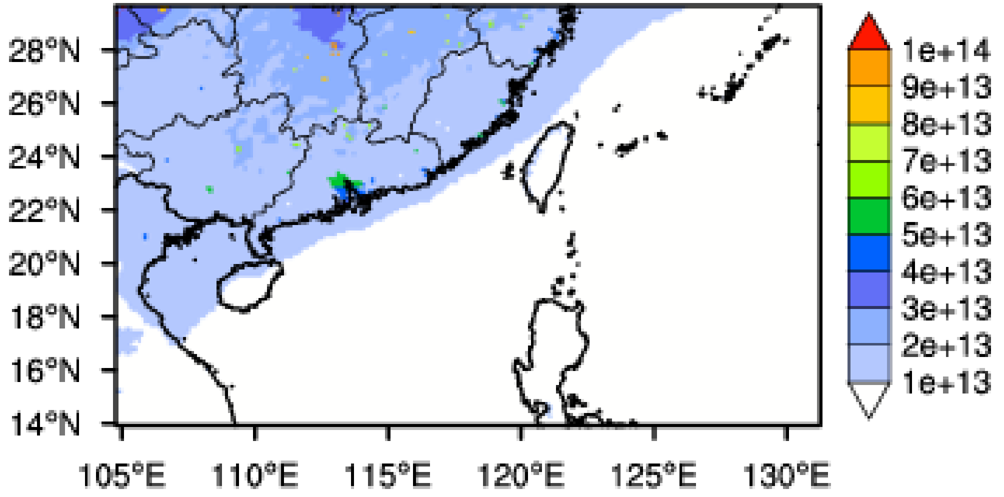
Evaluations

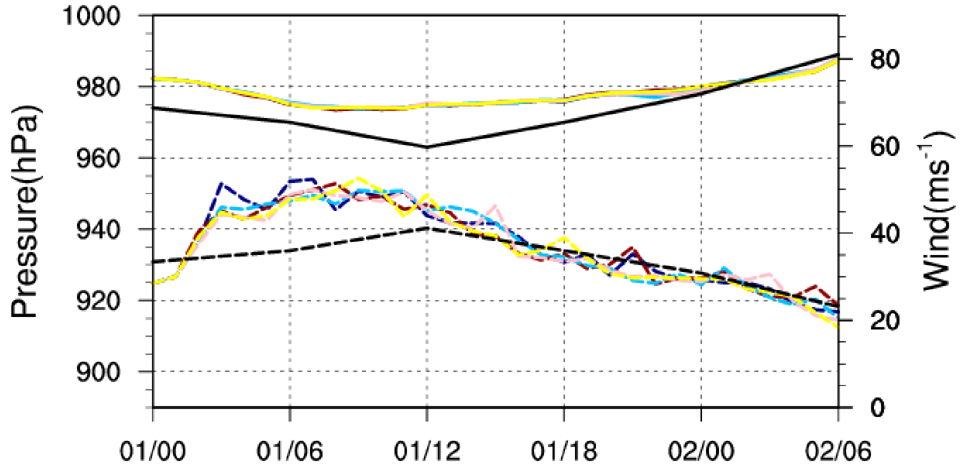
Track & Intensity
Radial and Tangential Winds
Updraft stength
Precipitation (regional & quadrants)
Cloud and rain profiles (mass/number)

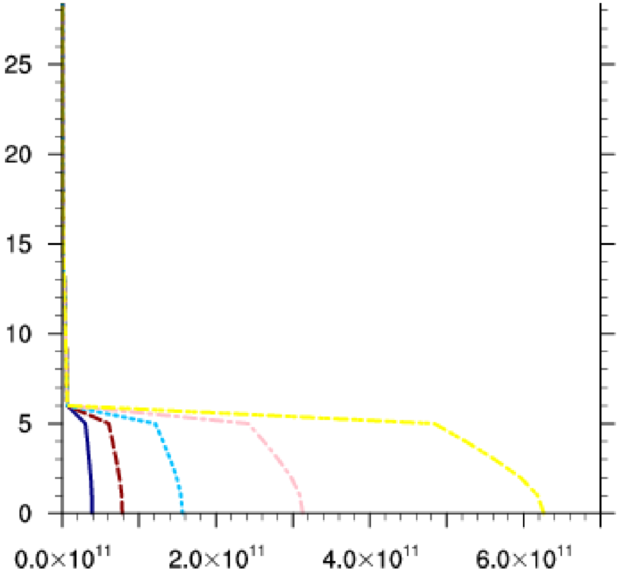
Typhoon Nida (2016Aug01)



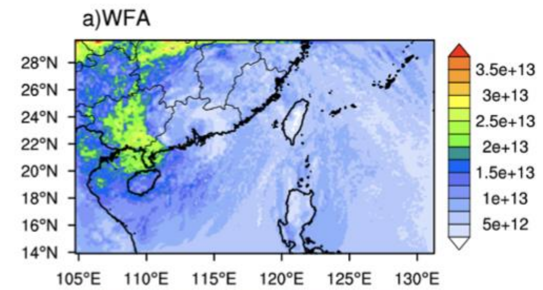
a)WFA (8X)



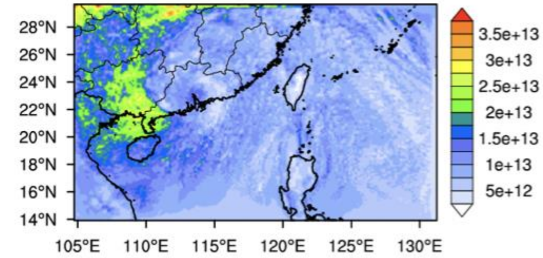




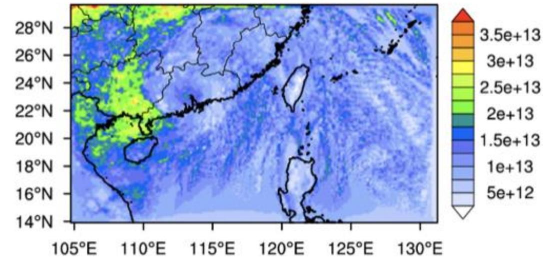
4fold



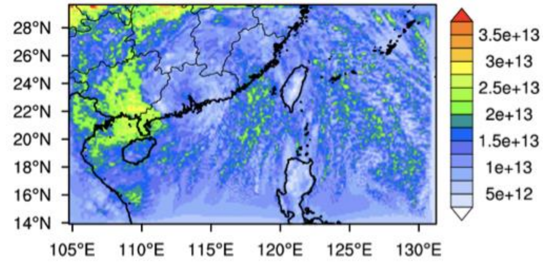
8fold



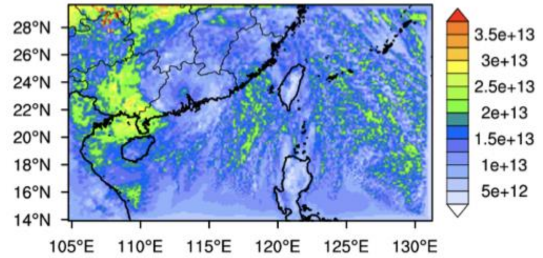
16fold



32fold



64fold

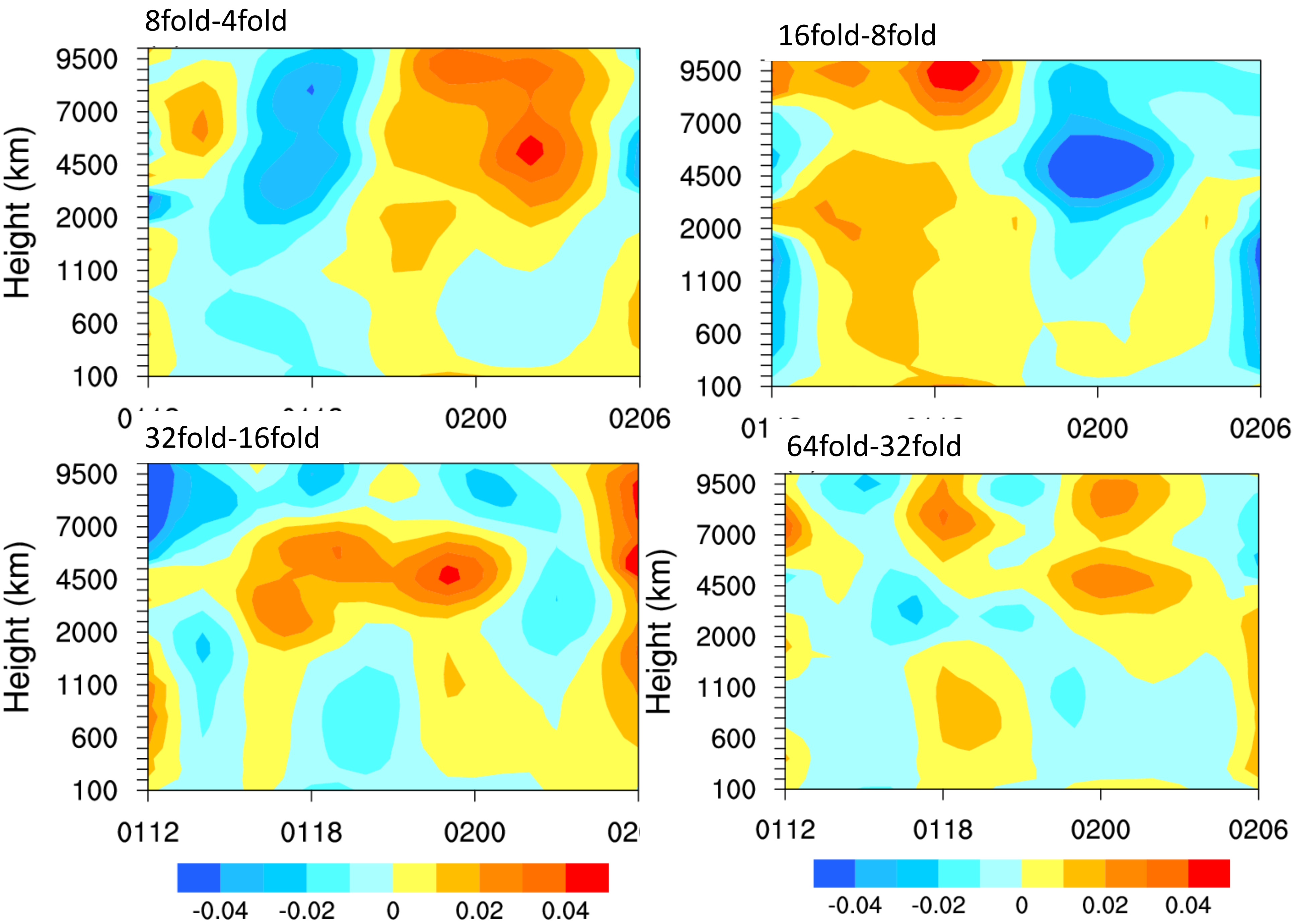


NCAR

Contributions by Lin Deng

Updrafts

experiment differences
more – less aerosols
within 150km of center

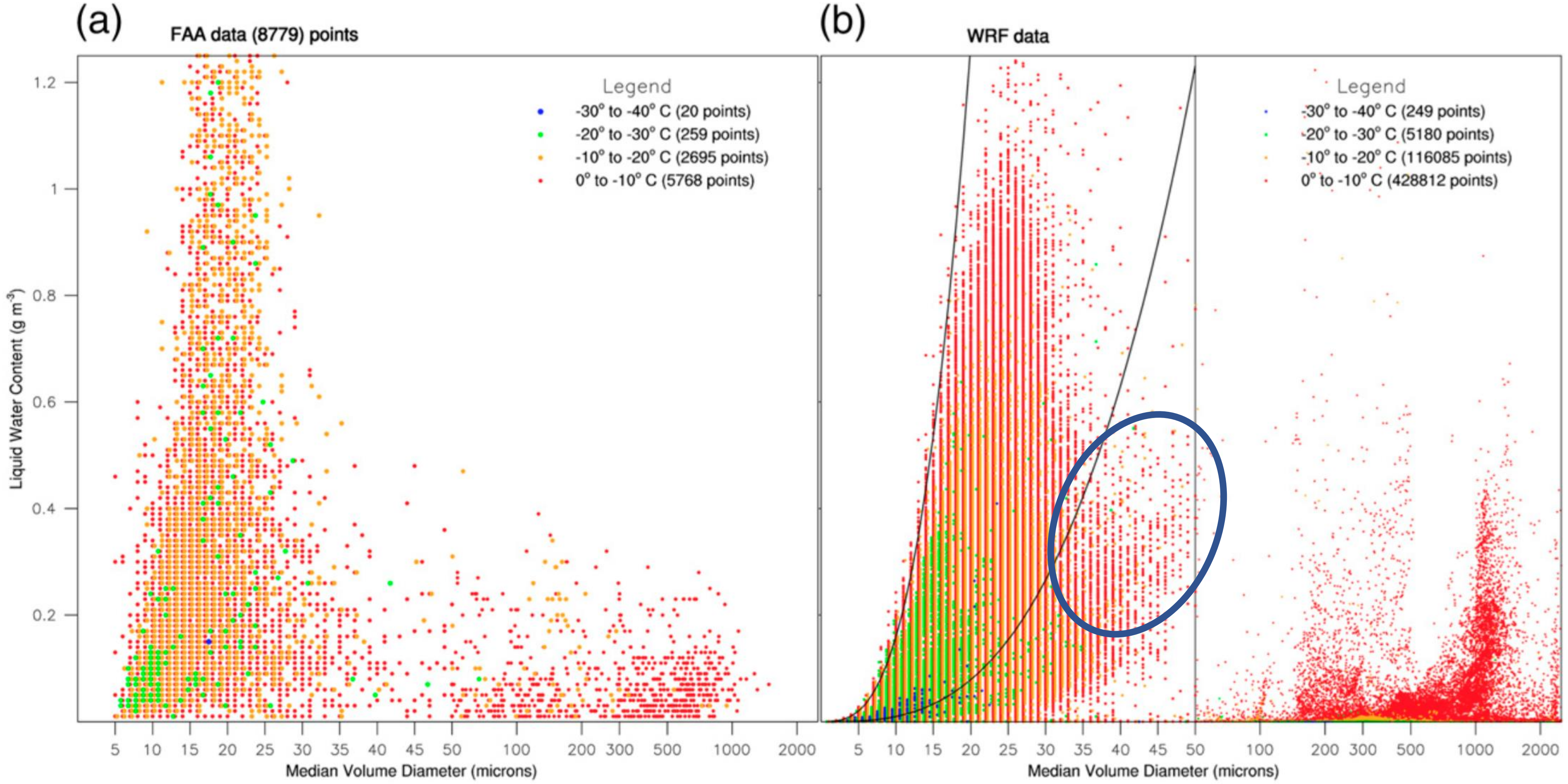


Aerosol-aware microphysics

13-year WRF simulation CONUS 4-km spacing

- WRF icing (Temp, LWC, MVD) versus FAA Tech. Ctr. icing database

Thompson, G., M. Politovich, and R. Rasmussen, 2017: A numerical model's ability to predict aircraft icing environments. *Wea & Forecasting*, **32,** 207–221.

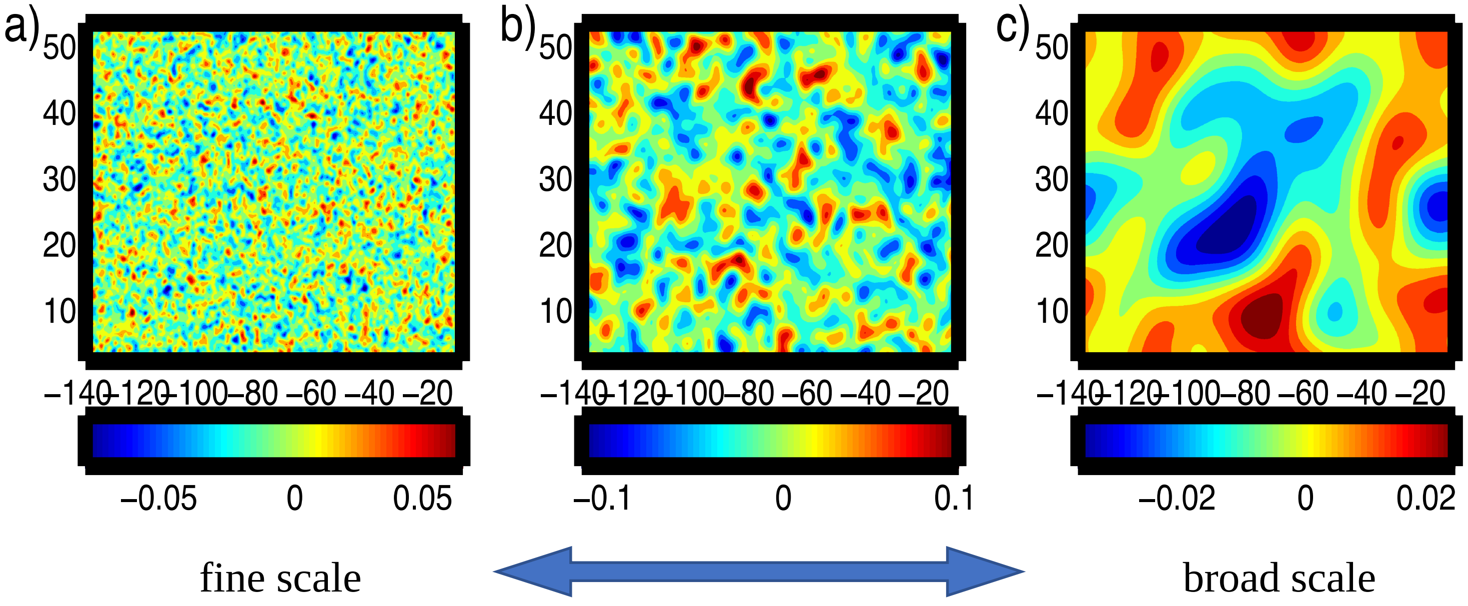


Stochastic Parameter Perturbations

Within microphysics alter CCN & IN activation

- Addressing known single-parameter uncertainties

  Griffin, S., J. Otkin, G. Thompson, M. Frediani, J. Berner, and F. Kong, 2019: Assessing the Impact of Stochastic Perturbations in Cloud Microphysics using GOES-16 Infrared Brightness Temperatures. *Mon. Wea. Rev.*, submitted.



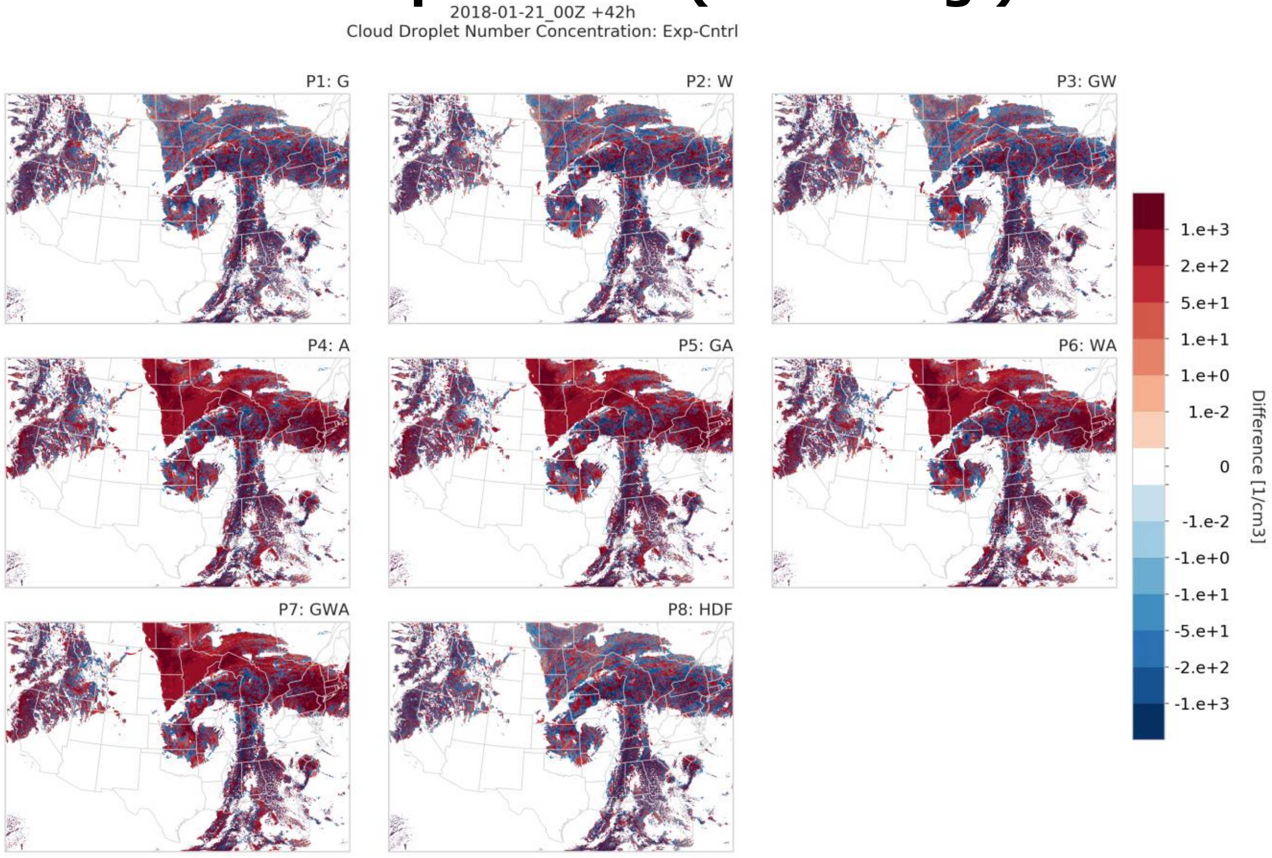
Experiment list

0	Control
WN	White noise
P1-G	Graupel
P2-W	Water (mu)
P3-GW	Graupel + Water
P4-A	Aerosol (CCN+IN)
P5-GA	Graupel + Aerosol
P6-WA	Water + Aerosol
P7-GWA	Graupel + Water + Aerosol
P8-HDF	Higher Diffusion

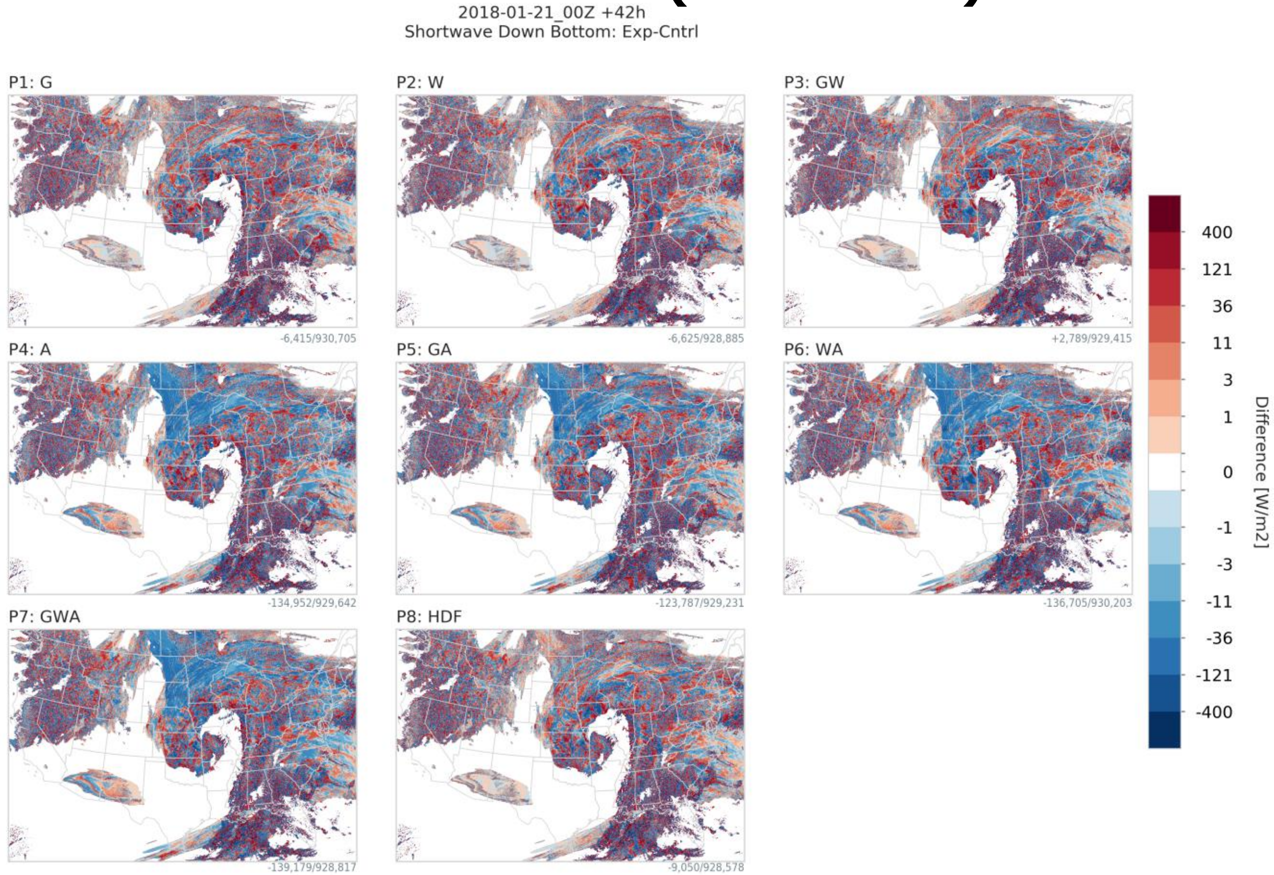
Stochastic Parameter Perturbations

Very clear signals of 1st and 2nd aerosol indirect effects

**Difference in
Cloud drop number (vert integ.)**



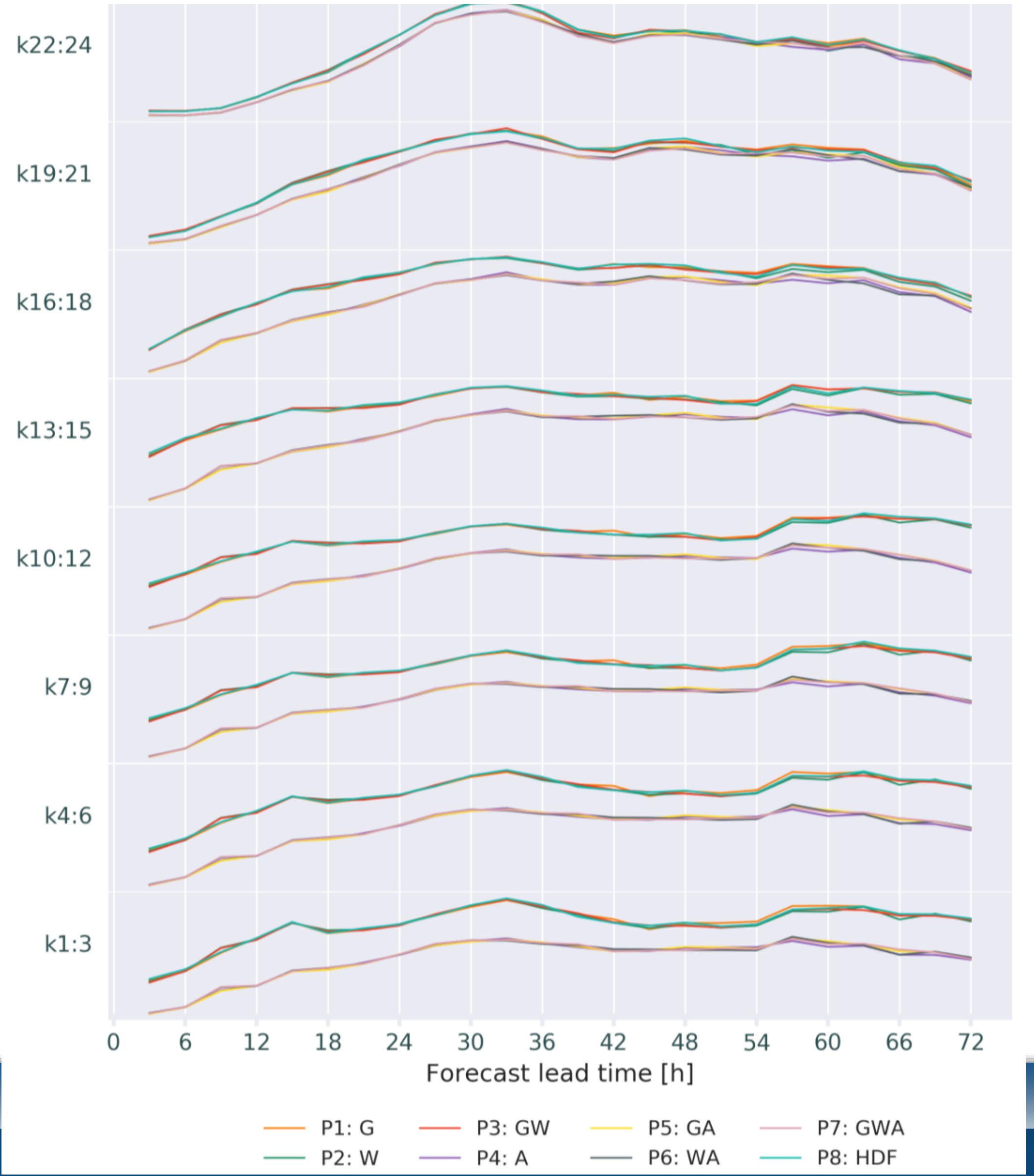
**Difference in
Shortwave radiation (at surface)**



Stochastic Parameter Perturbations

Very clear signals of 1st and 2nd aerosol indirect effects

Rain content (by altitude)



Thank you

Acknowledgements

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