Investigating the weather effects of smoke aerosols in the Unified Forecast System: A study of 2020 summer North American wildfires

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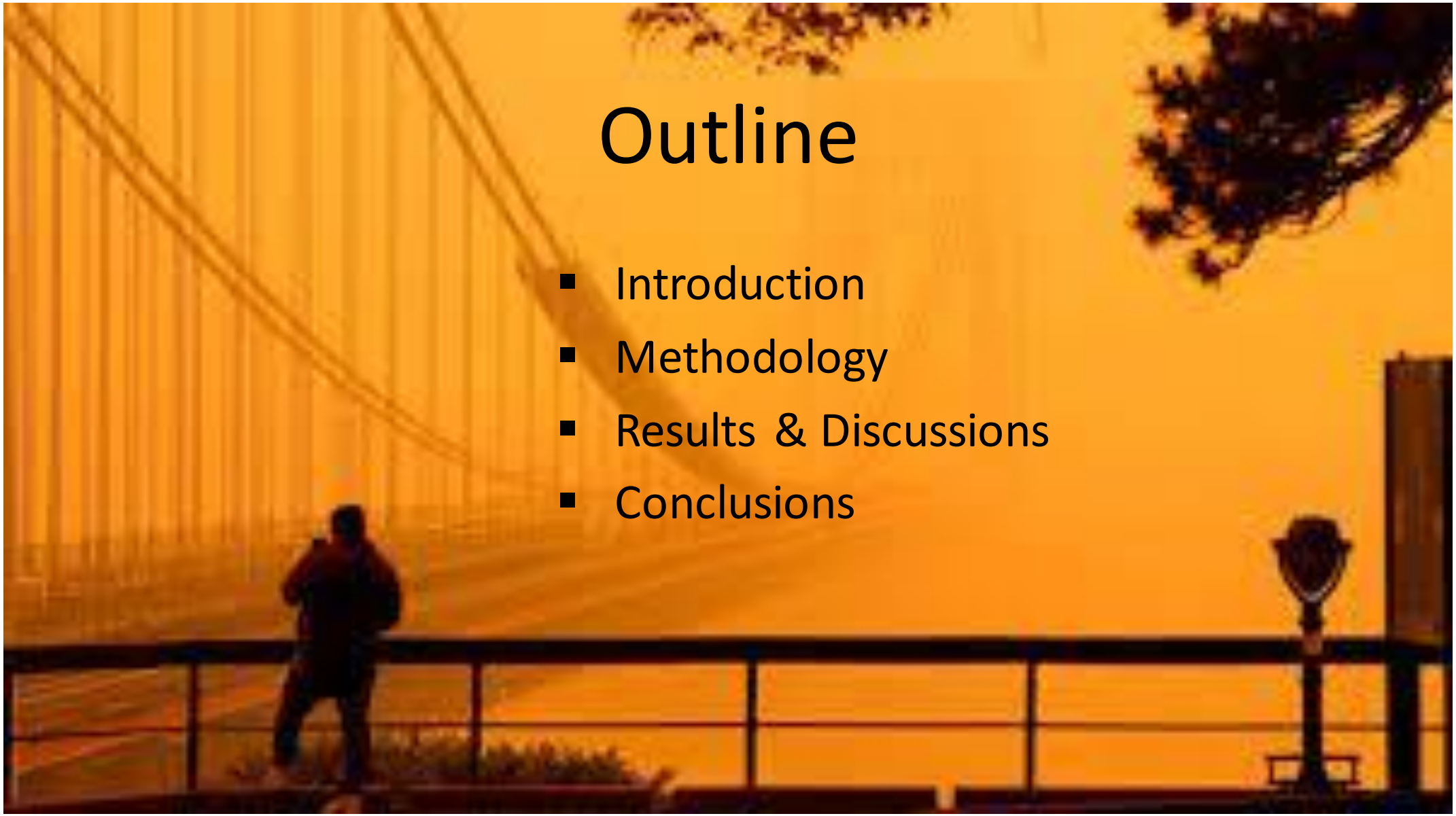


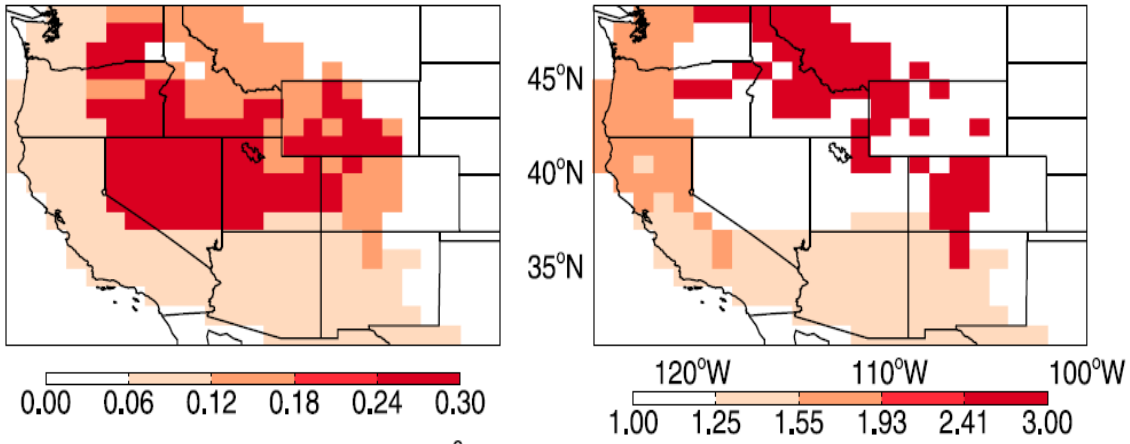
Outline

- Introduction
- Methodology
- Results & Discussions
- Conclusions

Wildfire activities under changing climate

- Wildfire activity is strongly influenced by climate/weather, fuel, ignition agents and human activities.
- Observations and model studies have shown human-induced climate change leads to an increase in areas burned and fire frequency/severity as well as extends wildfire seasons.

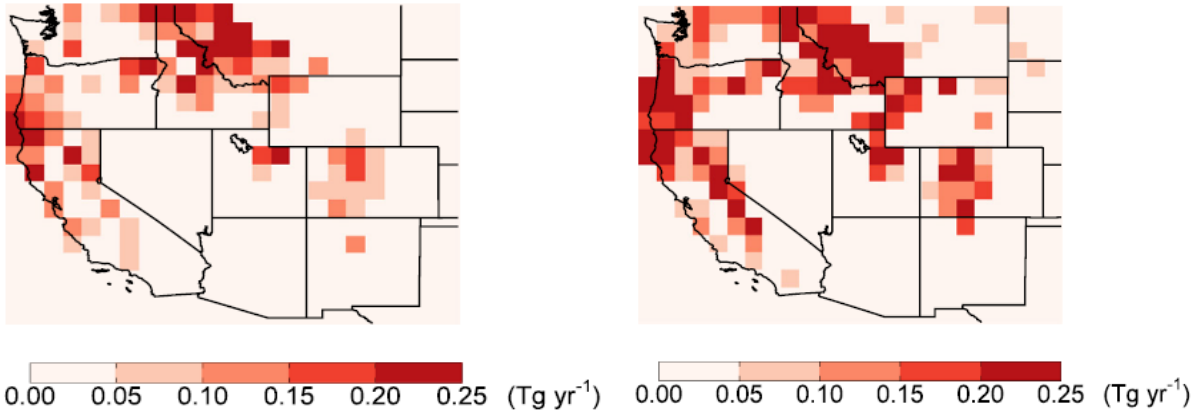
Spracklen et al. (2009)



Area burned for present day

Ratio of area burned ($\frac{2046-2055}{1996-2005}$)

Yue et al. (2013)



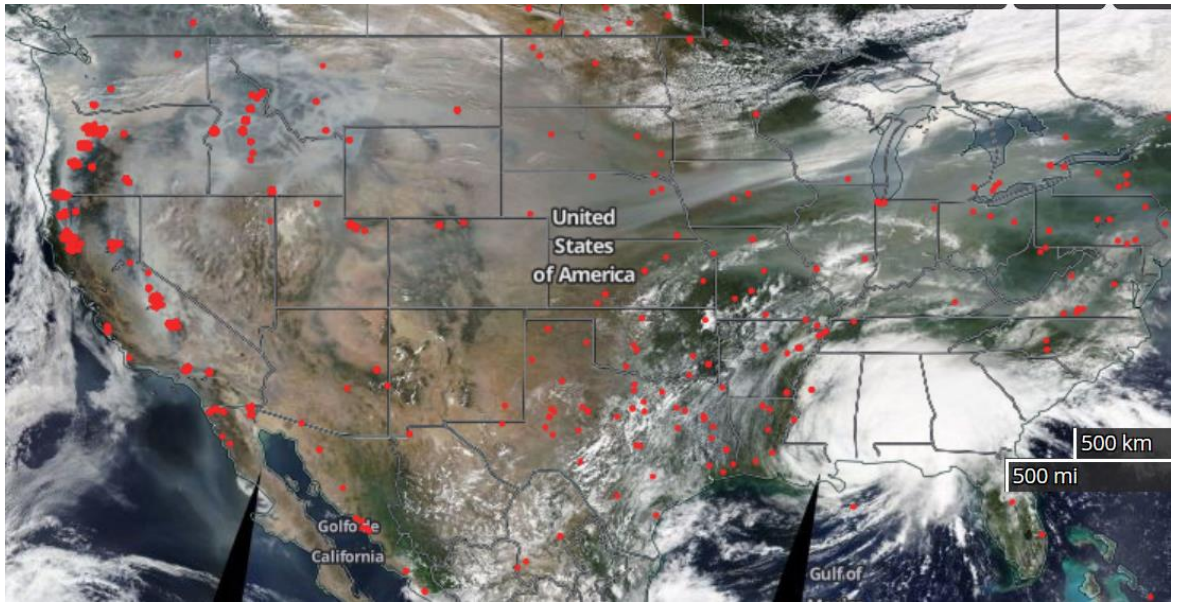
Biomass burned (present day)

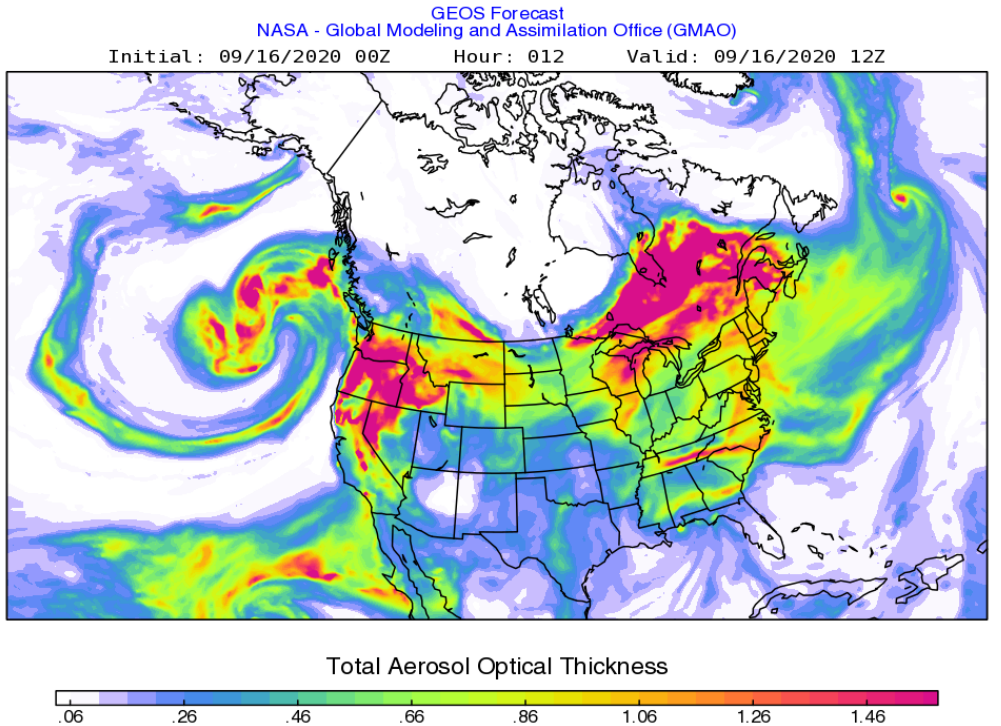
Biomass burned (Mid-21st century)

Motivating Question: What are the weather effects of wildfire aerosols?

- Smoke aerosols from wildfire affected large areas of North America and beyond.
- 2020 fire season was a record setting one for CA (worst) and US (3rd costliest , $16.5 billion).

VIIRS from WorldView (left) and NASA GEOS-5 AOD (right) for Sept 16, 2020





Experiment configuration

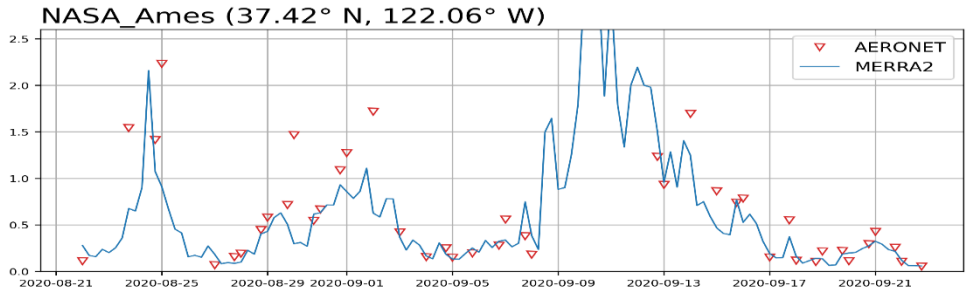
- Two Unified Forecast System (UFS) forecast experiments
  - **CLIM**: prescribed climatological MERRA-2 aerosols
  - **RR06**: prescribed instantaneous MERRA-2 aerosols every 6 hr (Rapid Refresh)
- 7-day forecast initialized on 00Z from Aug 22nd- September 18th 2020 (4 weeks)
- This study only considers aerosol-radiation feedback
- Other Specs

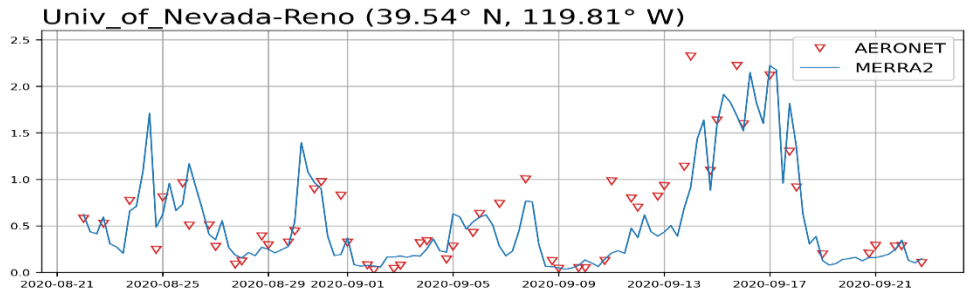
Model	UFS weather model
Resolution	C384
IC	NCEP GDAS FNL 0.25°
Radiation	RRTMG (aerosol aware)
Microphysics	MG3* (aerosol blind)

*: aerosol aware option implemented

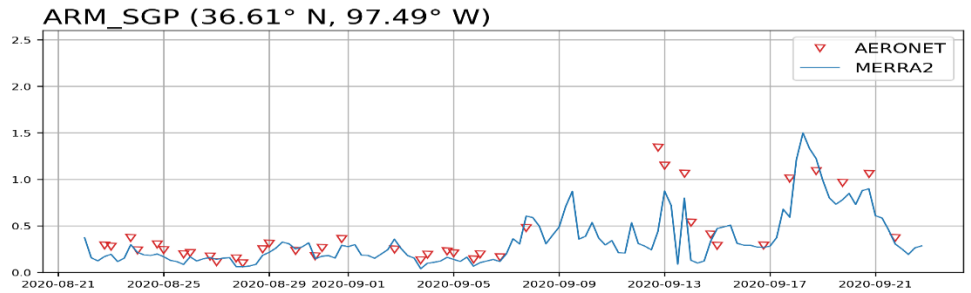
AERONET vs. MERRA-2 AOD fields

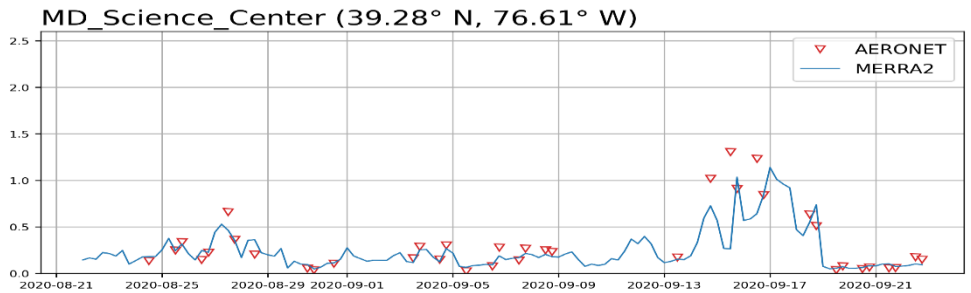
Near Source Region





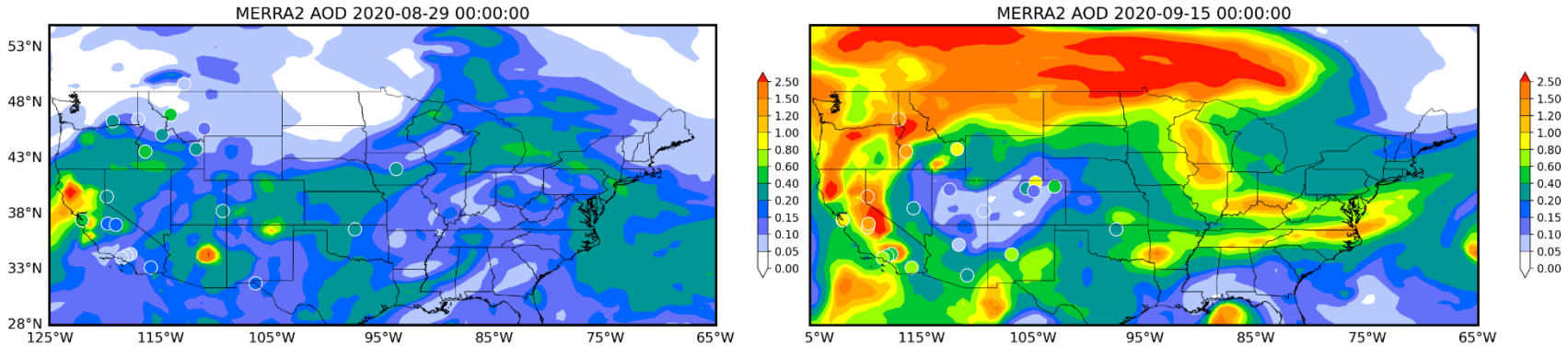
Downwind Region





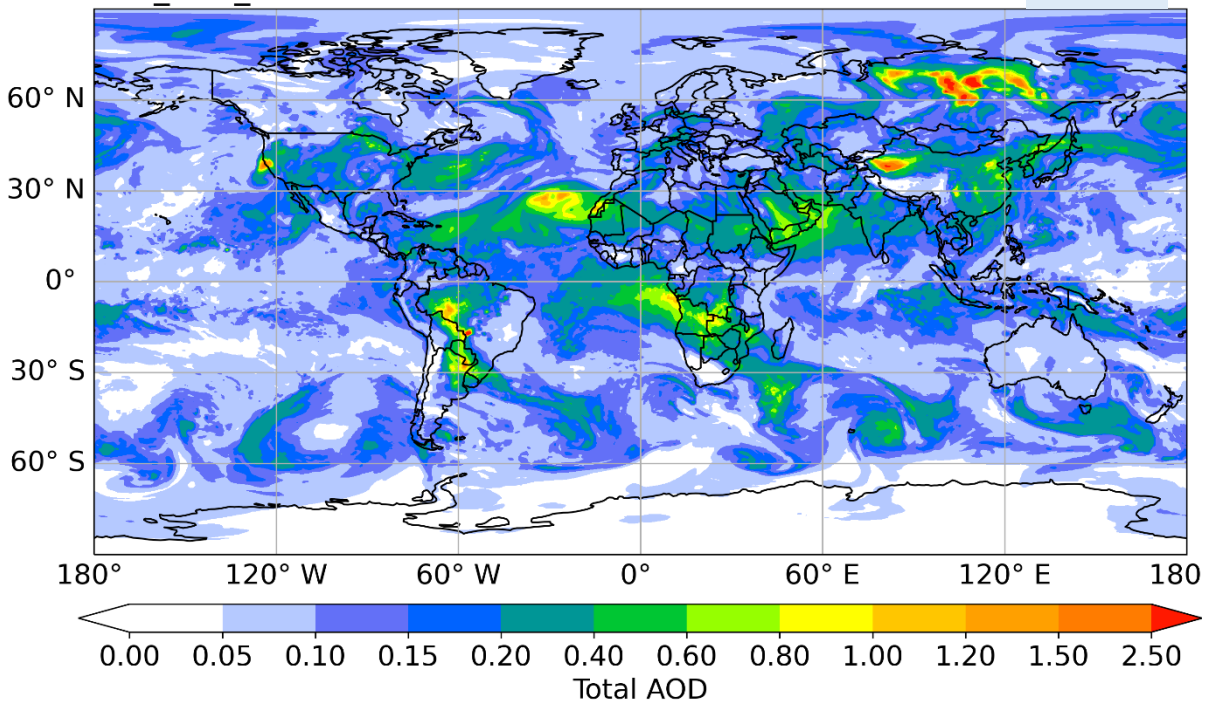
Spatiotemporal distributions:

MERRA2 AOD show general good agreement with AERONET

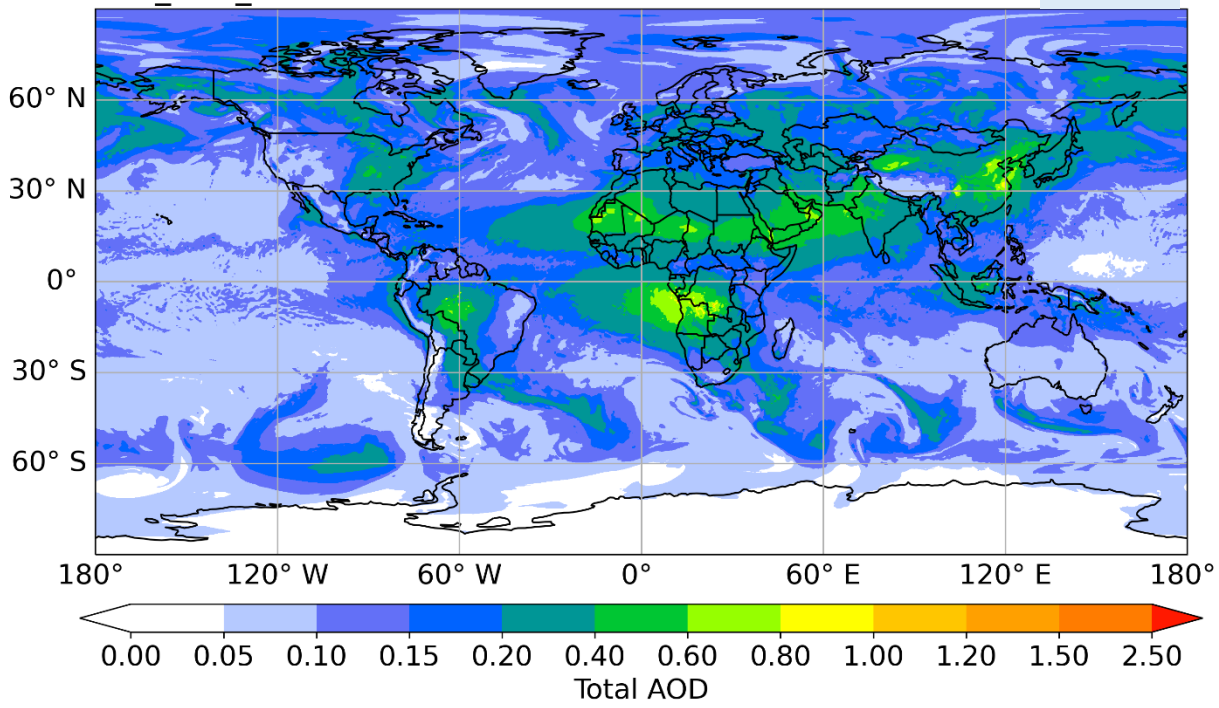


Aerosol loading in the UFS experiments

RR06



CLIM

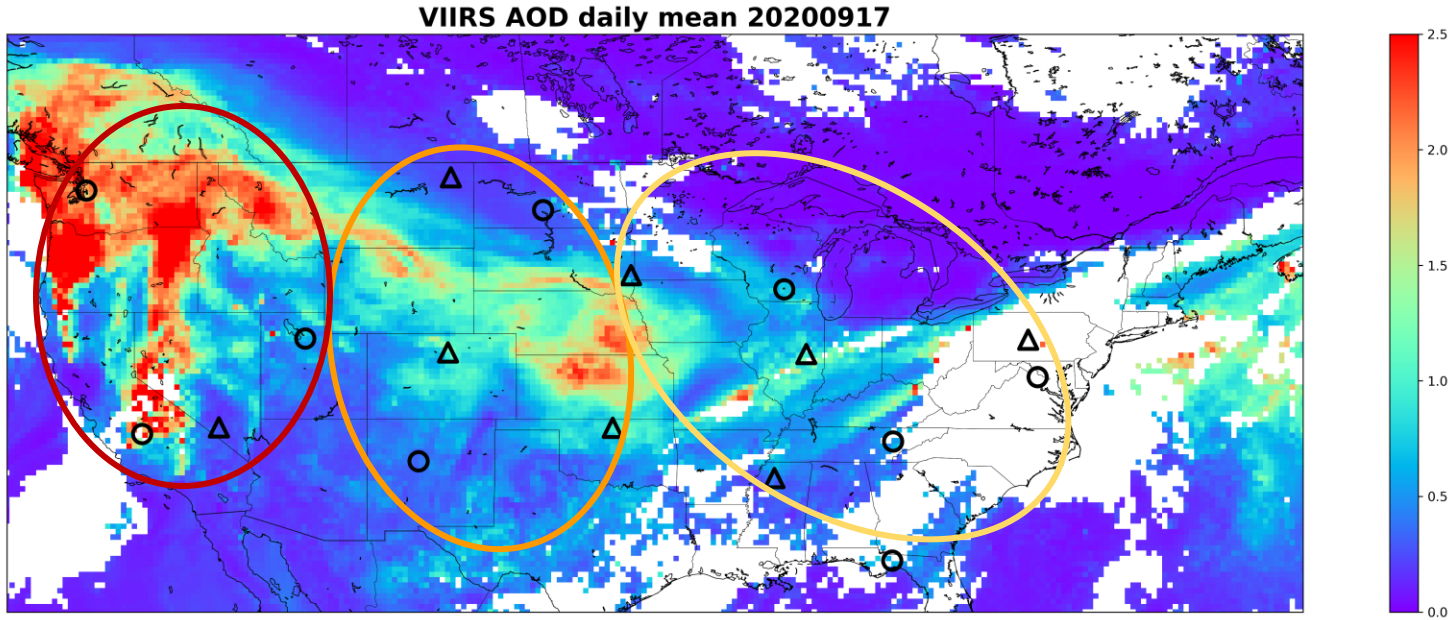


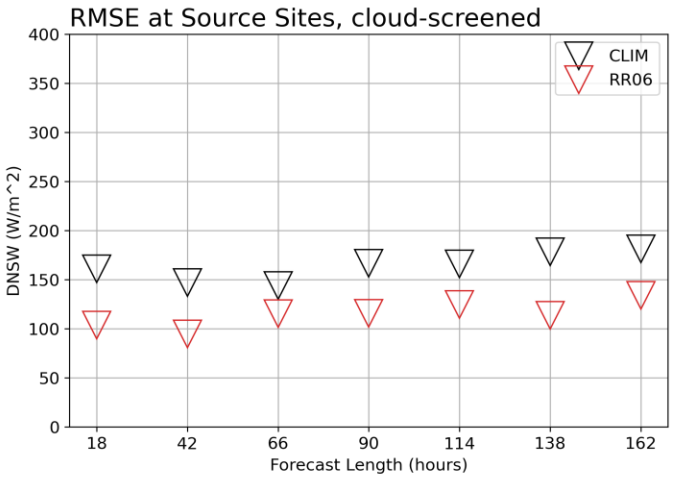
While CLIM captures general patterns (dust, sea salt, smoke, pollutants), it differs from RR06 in intensity and fine structure

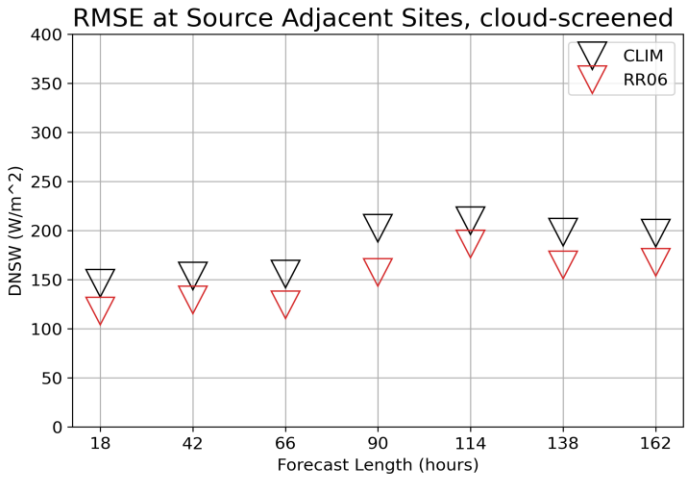
Downward shortwave radiation verification

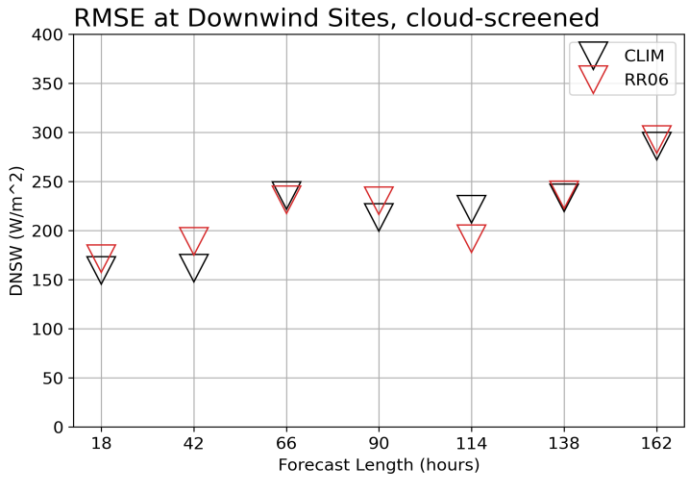
Improved DNSW in RR06,
particularly near the source region

○: SOLRAD (SOLar RADiation) network
Δ: SURFRAD (SURFace RADiation) Network

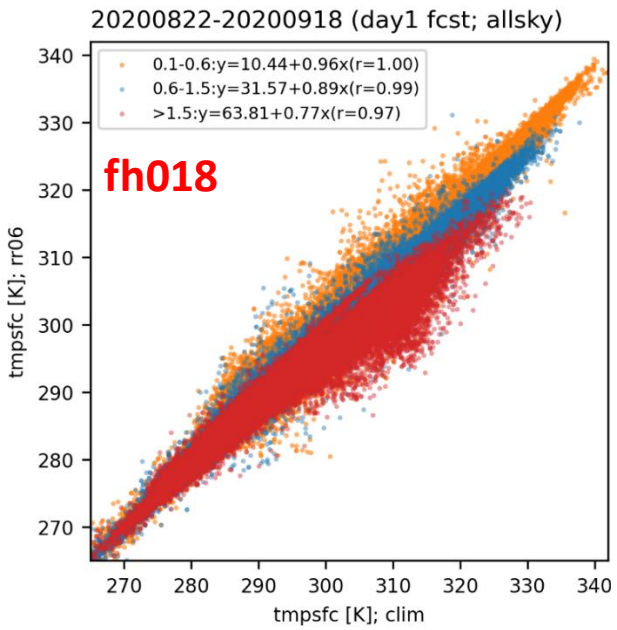


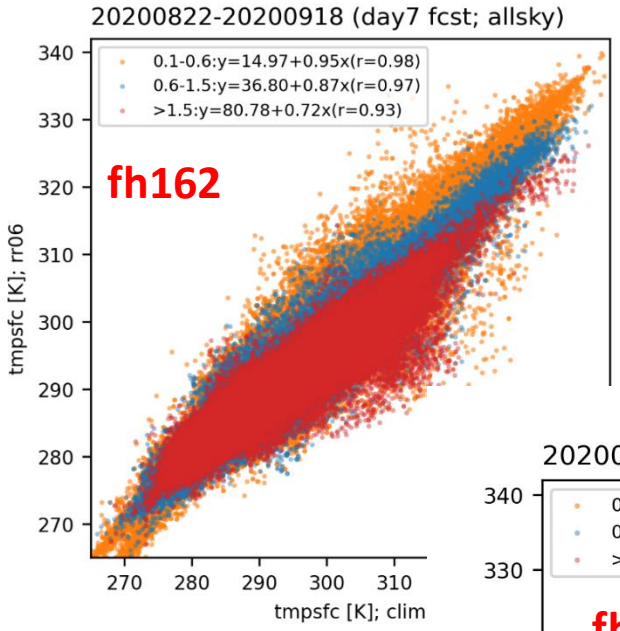






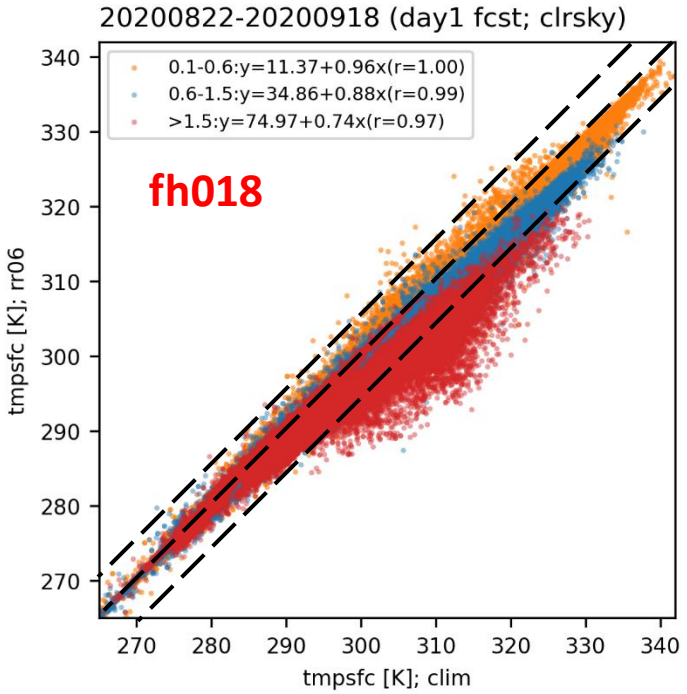
CONUS-only; Tsfc (clim) vs Tsfc (rr06), stratified by AOD (rr06-clim)

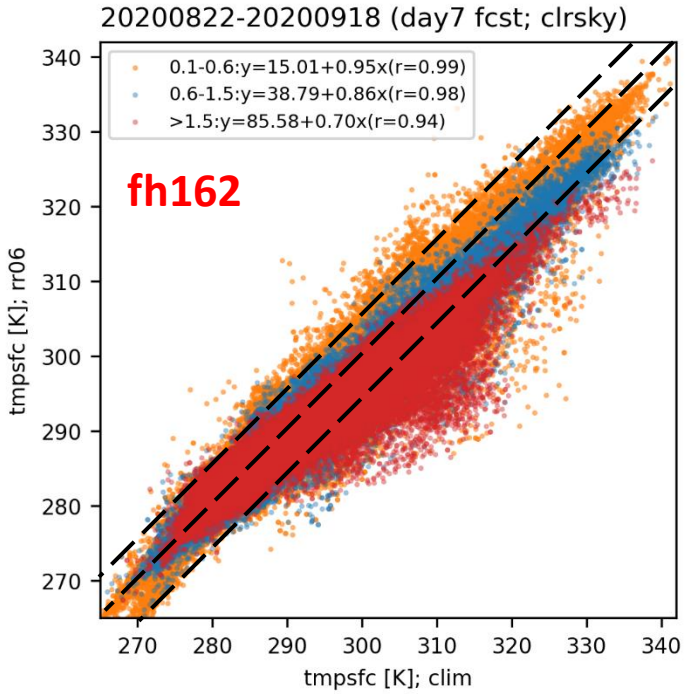




All SKY

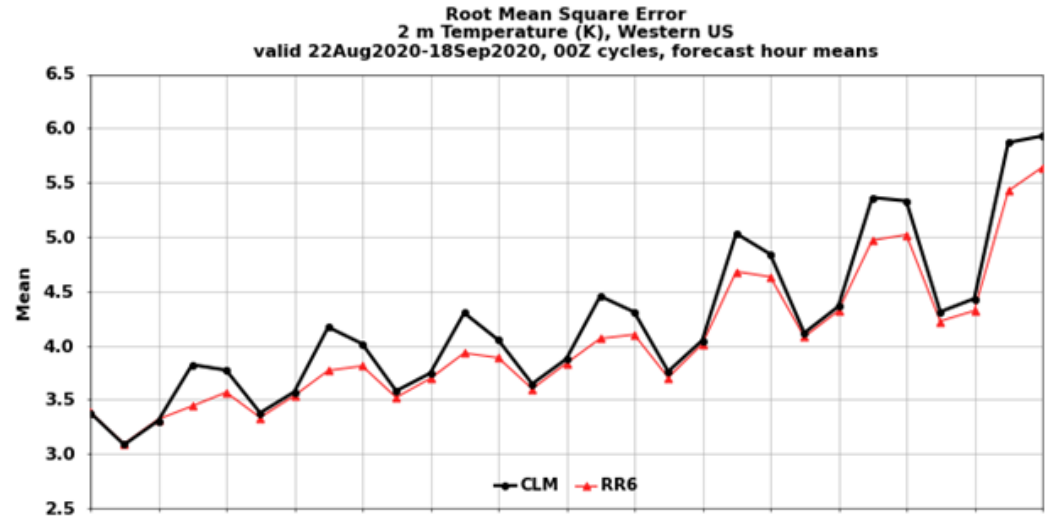
CLEAR SKY (fcld < 30%)

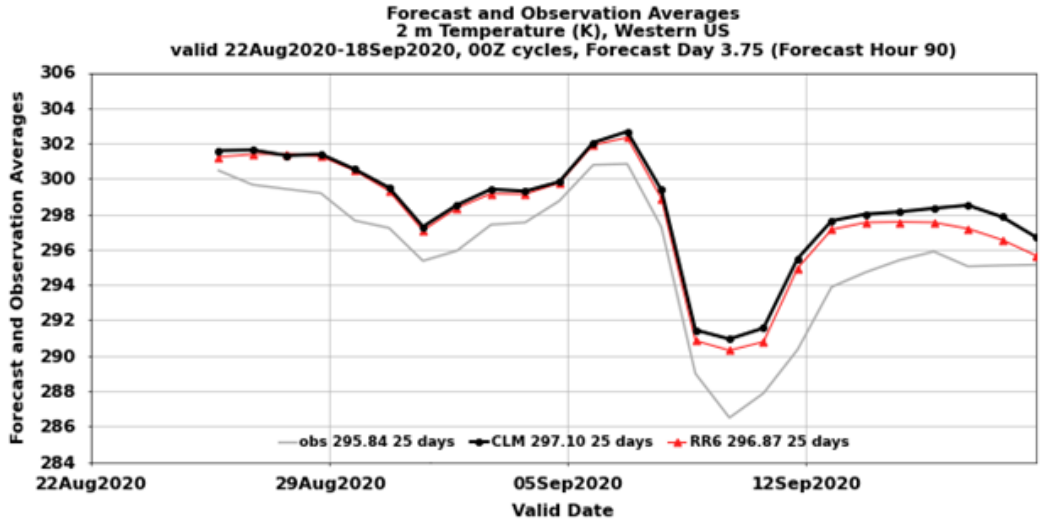


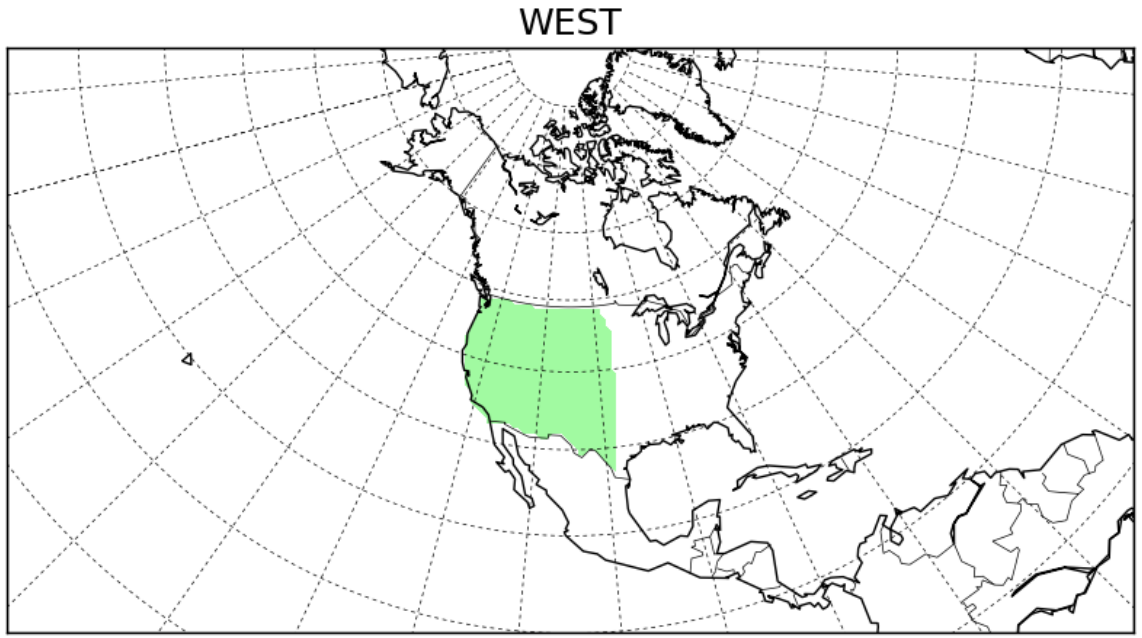


Cooler surface temperature in RR06 than CLIM06, particularly near the high AOD region

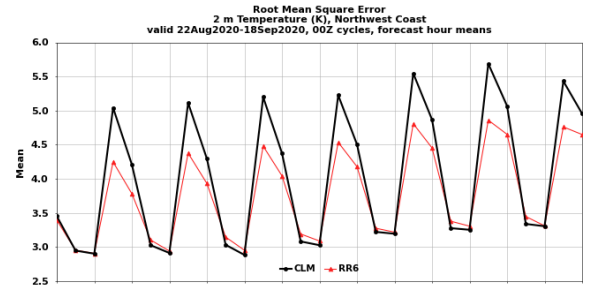
Western US: RMSE and RR06-clim against 2m T measurements

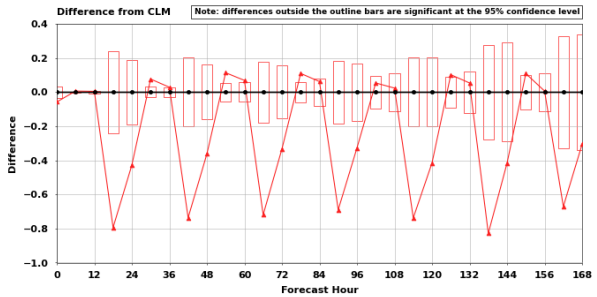


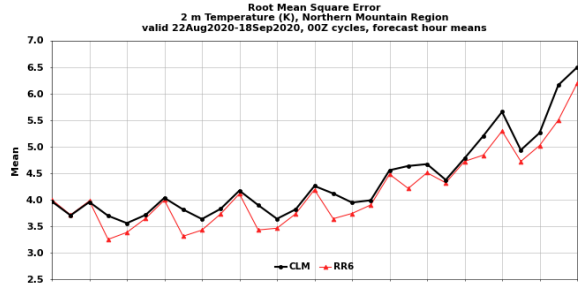


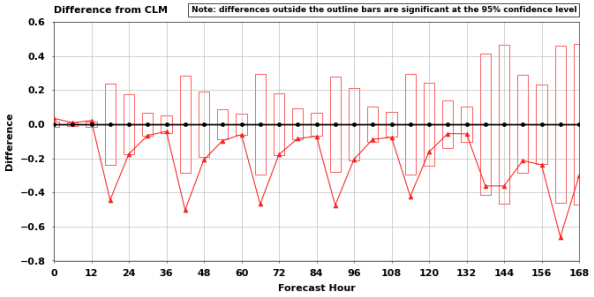


Over western US, T2m RMSE is reduced when account for real-time aerosol information in forecast


Root Mean Square Error
2 m Temperature (K), Northwest Coast
valid 22Aug2020-18Sep2020, 00Z cycles, forecast hour means
Mean
CLM
RR6


Difference from CLM
Note: differences outside the outline bars are significant at the 95% confidence level
Difference
Forecast Hour


Root Mean Square Error
2 m Temperature (K), Northern Mountain Region
valid 22Aug2020-18Sep2020, 00Z cycles, forecast hour means
Mean
CLM
RR6


Difference from CLM
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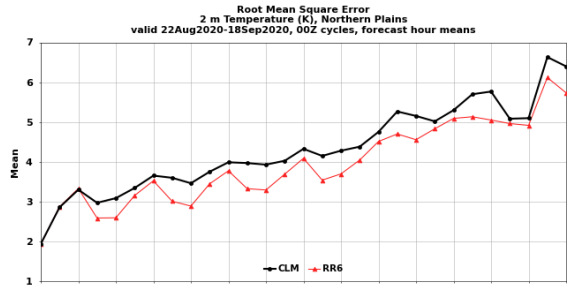
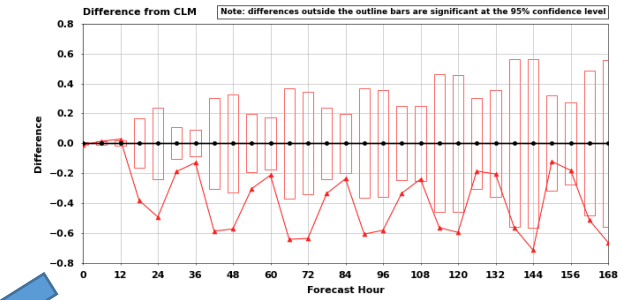
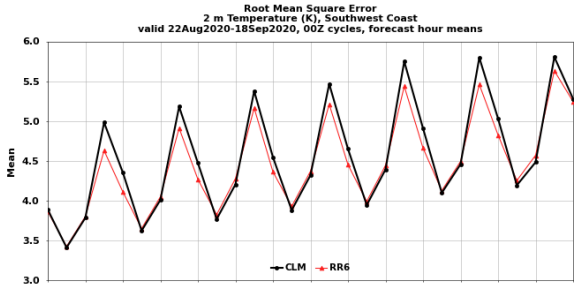
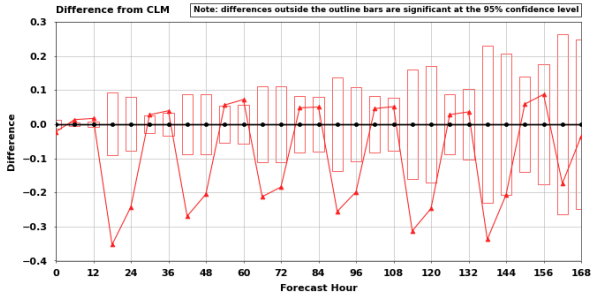
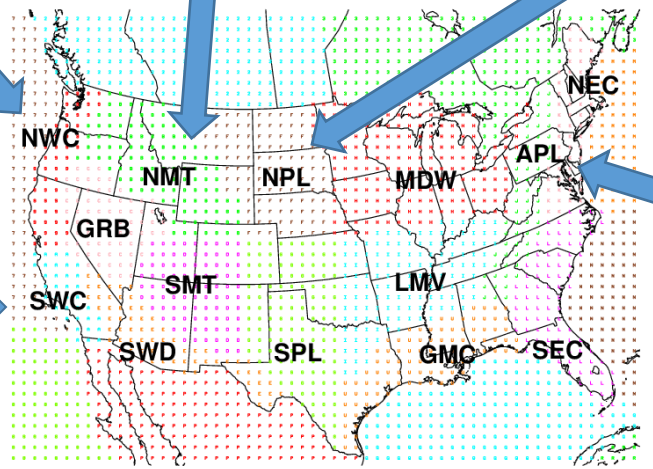
Difference
Forecast Hour

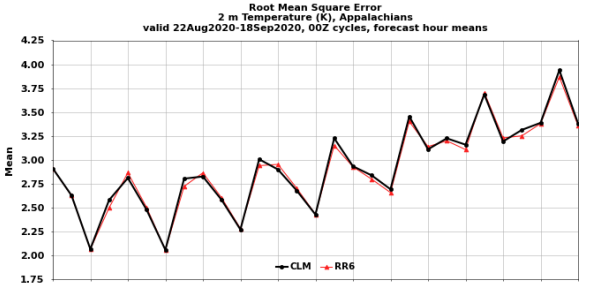

Root Mean Square Error
2 m Temperature (K), Northern Plains
valid 22Aug2020-18Sep2020, 00Z cycles, forecast hour means
Mean
CLM
RR6

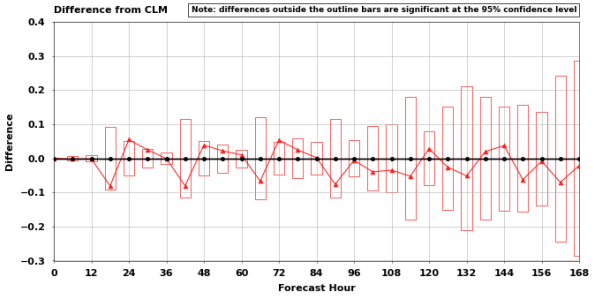

Difference from CLM
Note: differences outside the outline bars are significant at the 95% confidence level
Difference
Forecast Hour


Root Mean Square Error
2 m Temperature (K), Southwest Coast
valid 22Aug2020-18Sep2020, 00Z cycles, forecast hour means
Mean
CLM
RR6


Difference from CLM
Note: differences outside the outline bars are significant at the 95% confidence level
Difference
Forecast Hour


NWC
NMT
NPL
MDW
APL
NEC
GRB
SMT
LMV
SWC
SWD
SPL
GMC
SEC


Root Mean Square Error
2 m Temperature (K), Appalachians
valid 22Aug2020-18Sep2020, 00Z cycles, forecast hour means
Mean
CLM
RR6


Difference from CLM
Note: differences outside the outline bars are significant at the 95% confidence level
Difference
Forecast Hour

NCEP Verification AC Scores

			N. America				N. Hemisphere				S. Hemisphere				Tropics			
			Day 1	Day 3	Day 5	Day 7	Day 1	Day 3	Day 5	Day 7	Day 1	Day 3	Day 5	Day 7	Day 1	Day 3	Day 5	Day 7
Anomaly Correlation Coefficient	Heights	250hPa																
		500hPa																
		700hPa																
		1000hPa									▲							
	Vector Wind	250hPa																
		500hPa																
		850hPa																
	Temp	250hPa				▲												
		500hPa																
		850hPa	▲							▲								
	MSLP	MSL																

Overall, neutral to positive impact in RR06

Summary

In this study, we use the Unified Forecast system (UFS) that incorporates MERRA-2 aerosols into the physics schemes to investigate aerosol impacts on medium range (3-7 days) weather forecasts.

By prescribing aerosol fields into the UFS during the historical fire season of 2020, we found the following impacts on medium range forecasts over CONUS:

- RR06 run has cooler surface temperature and suppressed PBL height
- AC coefficient shows neutral results between two experiments.
- Improvement in daytime surface temperature and downward shortwave radiation fluxes in the RR06 run.

Concluding Remarks

- Aerosol is an integrated part of coupled Earth System prediction system and coupled data assimilation system
- Toward constraining aerosol effects in NWP and climate projection:
  - Refine the representation of aerosol processes in the physics suite: aerosol-cloud interaction and aerosol optical properties
  - Characterize spatiotemporal distribution of aerosols: emissions, aerosol processes, e.g., wet removal
  - Met data assimilation is often aerosol blind: toward all sky, all surface data assimilation
  - Utilization of satellite observations: constrain aerosol loading and emissions
  - Exploit the innovative opportunities from observations in a new era for space exploration

Thanks.

Questions/comments?