WRF-Solar v2: An Improved Tool for Solar Forecasts

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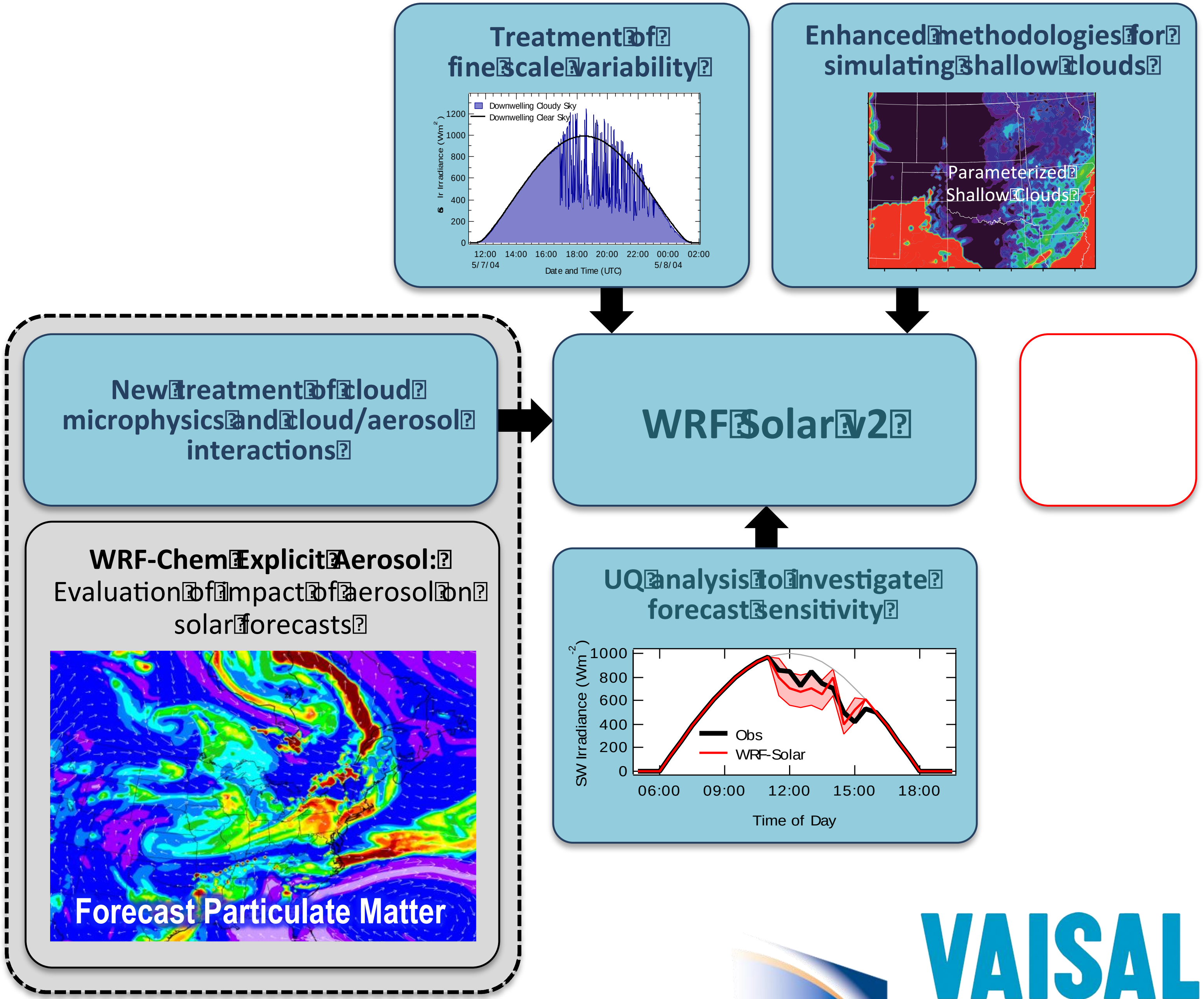
Improving physics in WRF-Solar

- Address shortcomings in WRF-Solar v1
- Specific project goals:
  - Reduce forecast errors by 25%
  - Improve ramp forecasts
  - New estimates of sub-grid variability
- New tool for the community



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Improving simulations of boundary-layer clouds

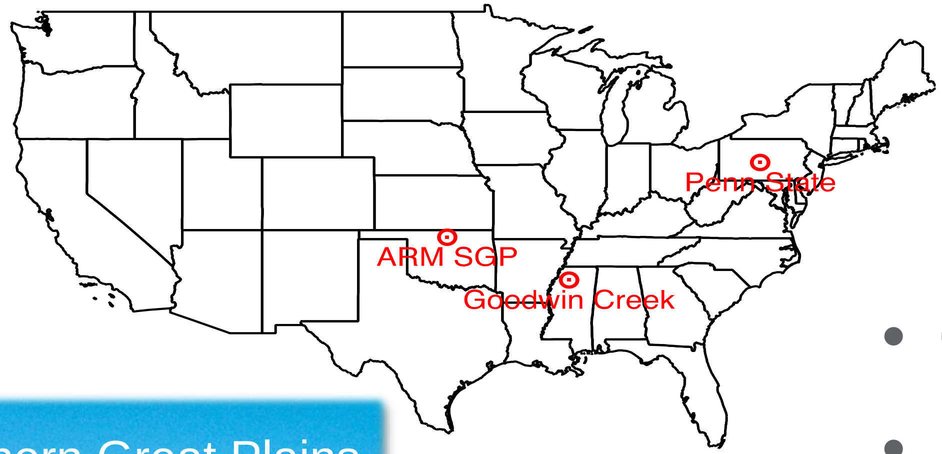
Often neglected, but significant impact: ~45 Wm^{-2} (out of 612 Wm^{2}) at DOE site in Oklahoma (Berg et al. 2011)

Tested Parameterizations:

- *Deng*-Trigger function based on boundary-layer TKE (Deng, et al. 2003)
- *Standard Kain-Fritsch (KF)*-Based on standard KF parameterization, applies an ad-hoc temperature perturbation as trigger function (Kain and Fritsch 1990)
- *KF-CuP (Cumulus potential)*—Distribution of temperature and humidity used as trigger function (Berg et al., 2013)
- MYNN-EDMF—Combines TKE based parameterization with mass flux approach. Implemented as part of WFIP2 code development (Olson et al. 2019)
- *Improved subgrid cloud microphysics and entrainment*—Focused on improved representation of stratiform clouds, but can also impact broken clouds

Data sets for model evaluation of shallow cumuli

- NOAA SURFRAD and DOE ARM sites

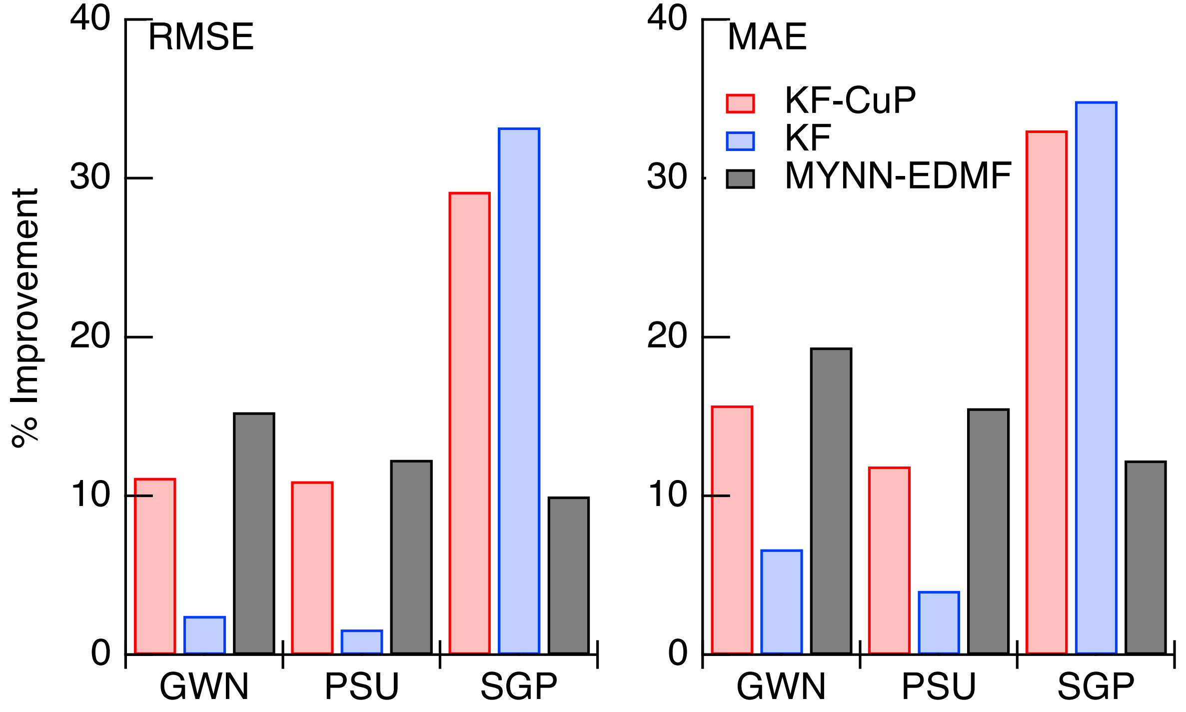


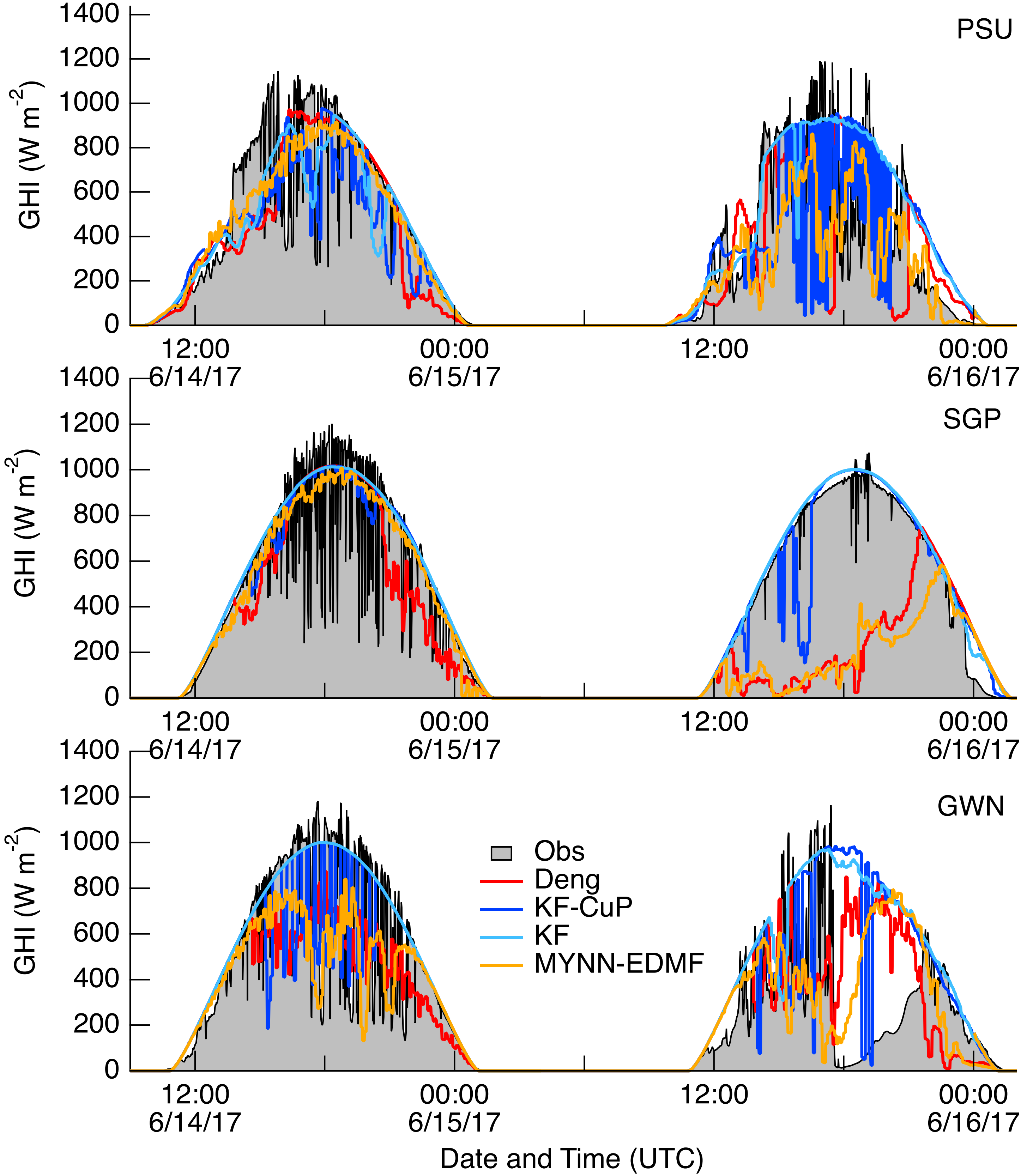
- Global Horizontal Irradiance (GHI)
- Effective Transmissivity (ET)

$$ET = \frac{f_{all\ sky}}{f_{clear\ sky}}$$

GHI time series

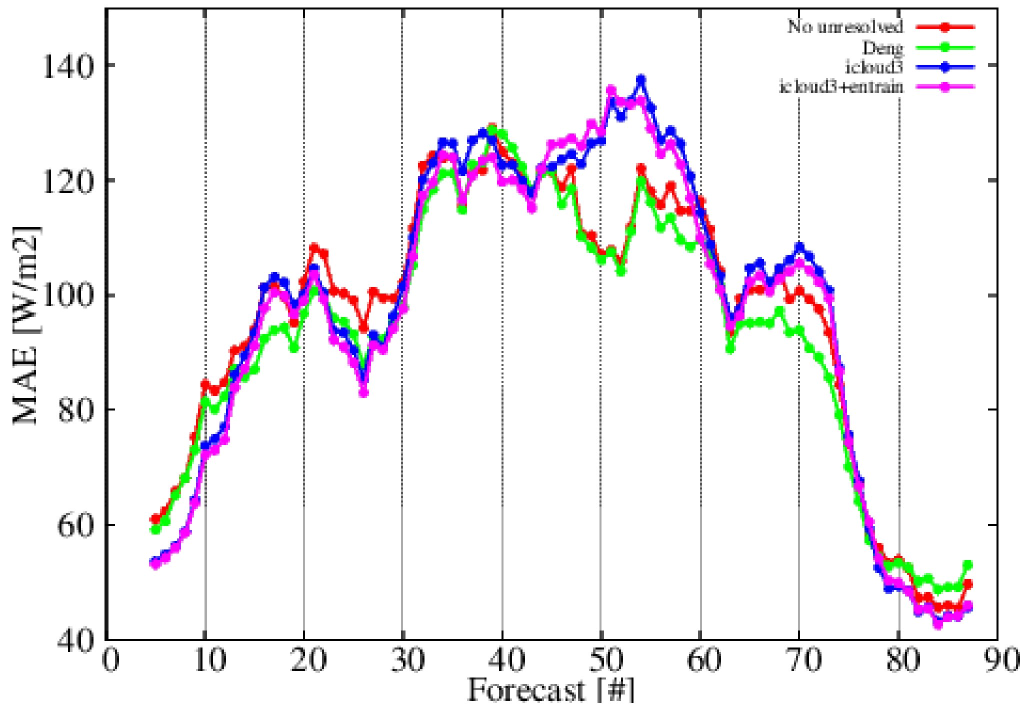
- 20 days selected with broken or clear skies at the three sites
- Large amounts of variability during periods with shallow cumuli

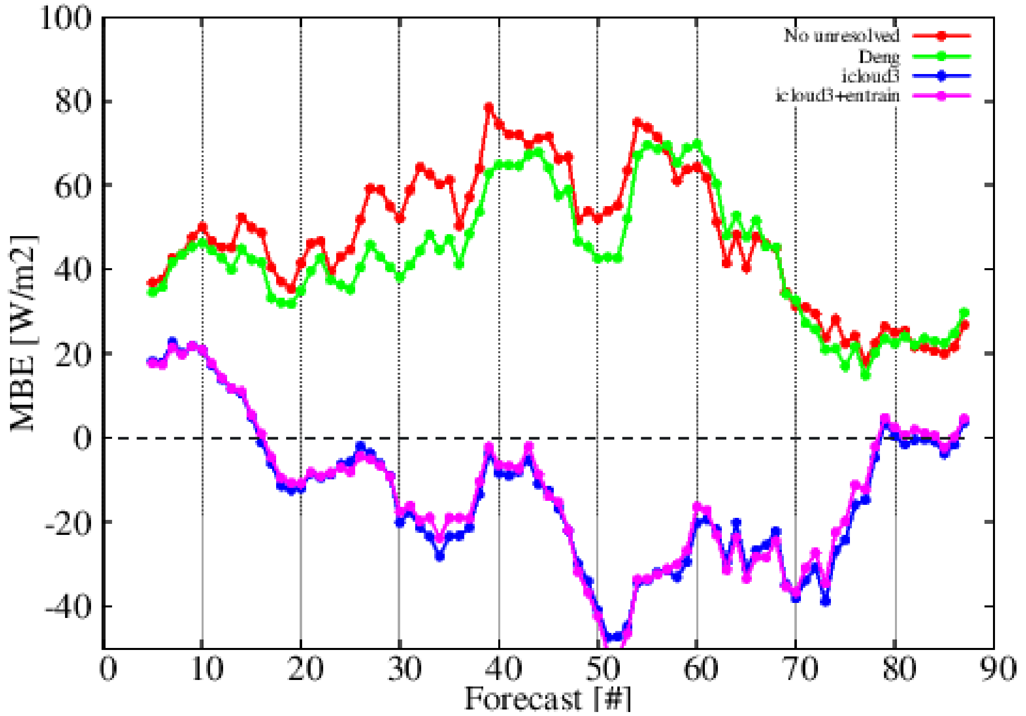




Improved treatment of sub-grid hydrometeors and entrainment

- Cloud fraction determined as a function of grid-box RH
- 48-hour reforecasts conducted for 91 days during 2018 and compared to SURFRAD observations from across the US
- Improvement in MAE and MBE during winter with sub-grid hydrometeors, little change associated with improved entrainment

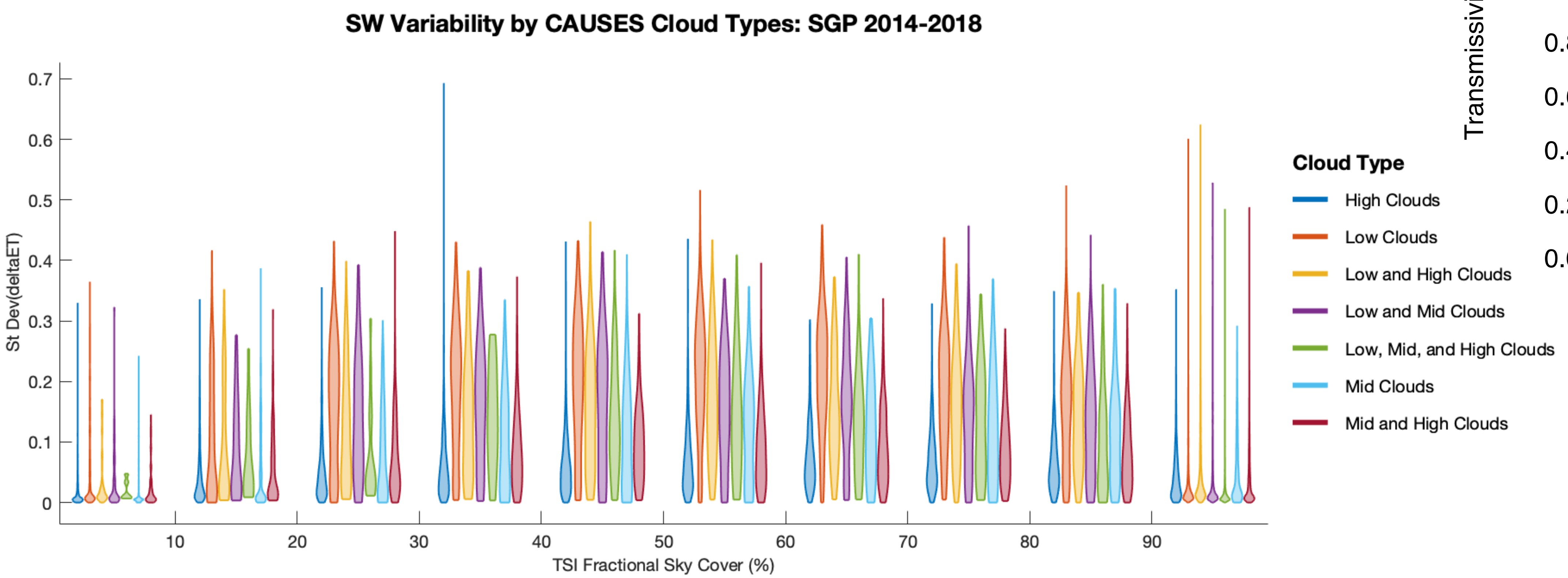


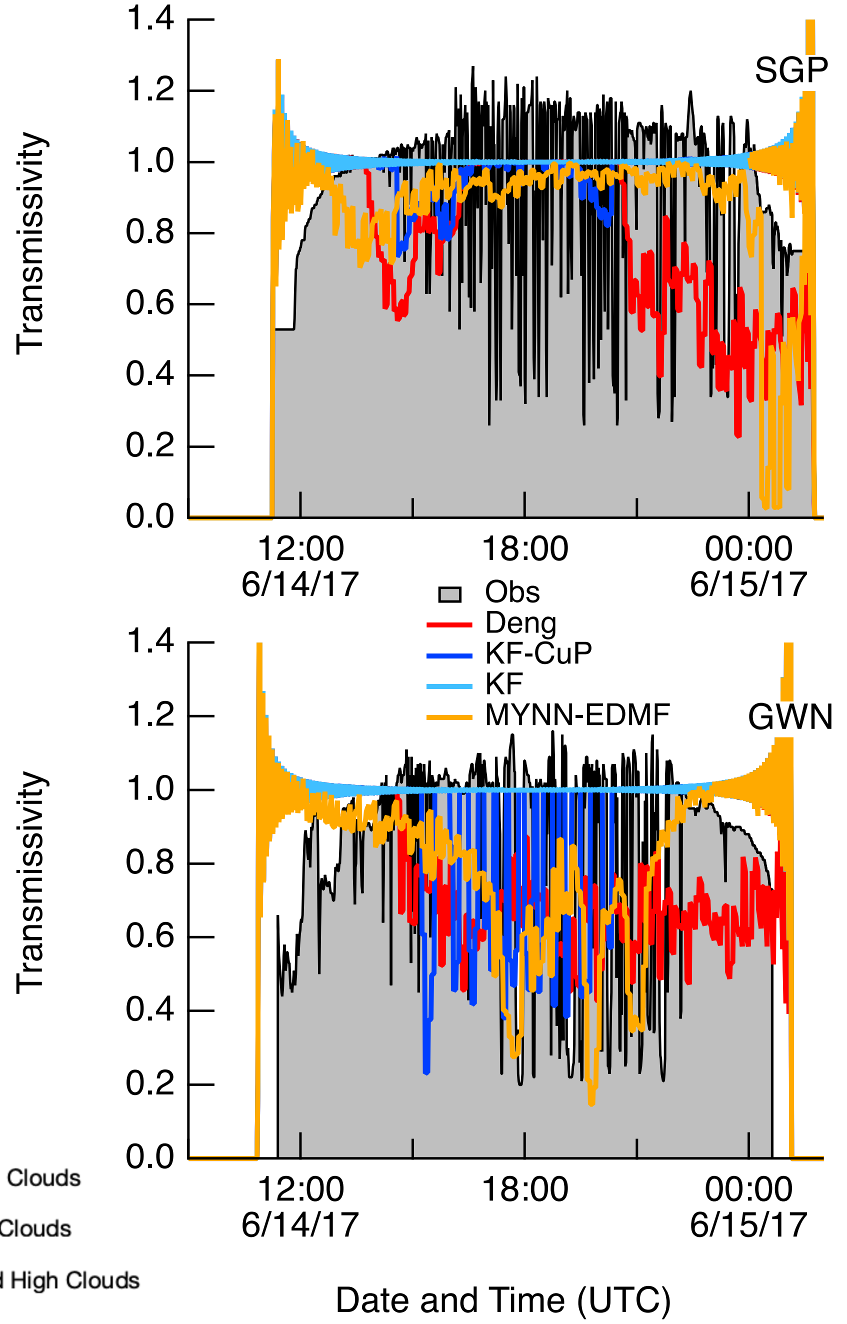


Winter Summer Winter

Representation of variability

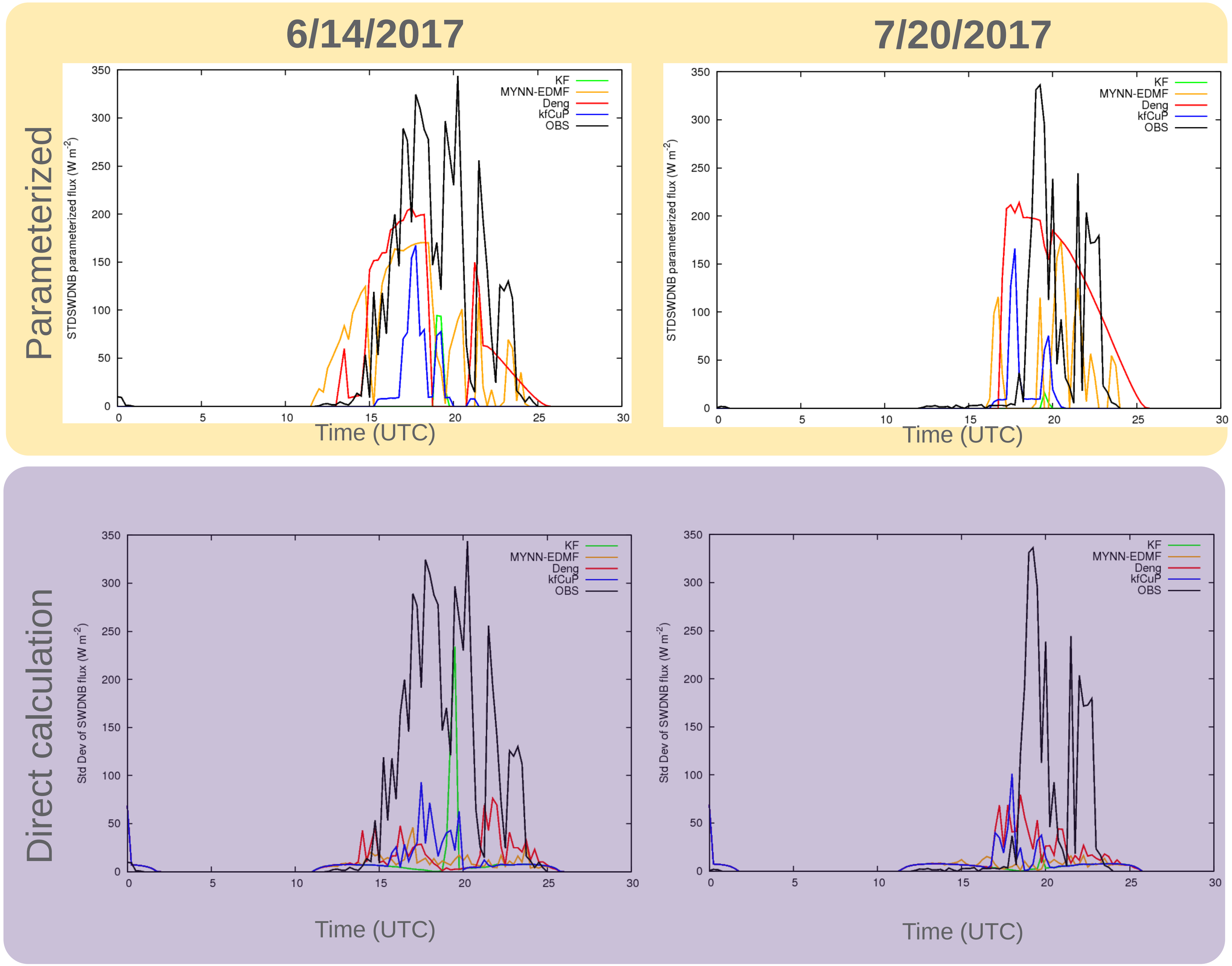
- Can we capture variability and account for it in solar irradiance forecasts?
- Definitions
  - Standard deviation of effective transmissivity (σ_{ET})—measurement of irradiance variability over a time interval (15 min)
  - Standard deviation of the change in effective transmissivity ($\sigma_{\Delta ET}$)—measurement of irradiance "ramp rates" in time interval (15 min)





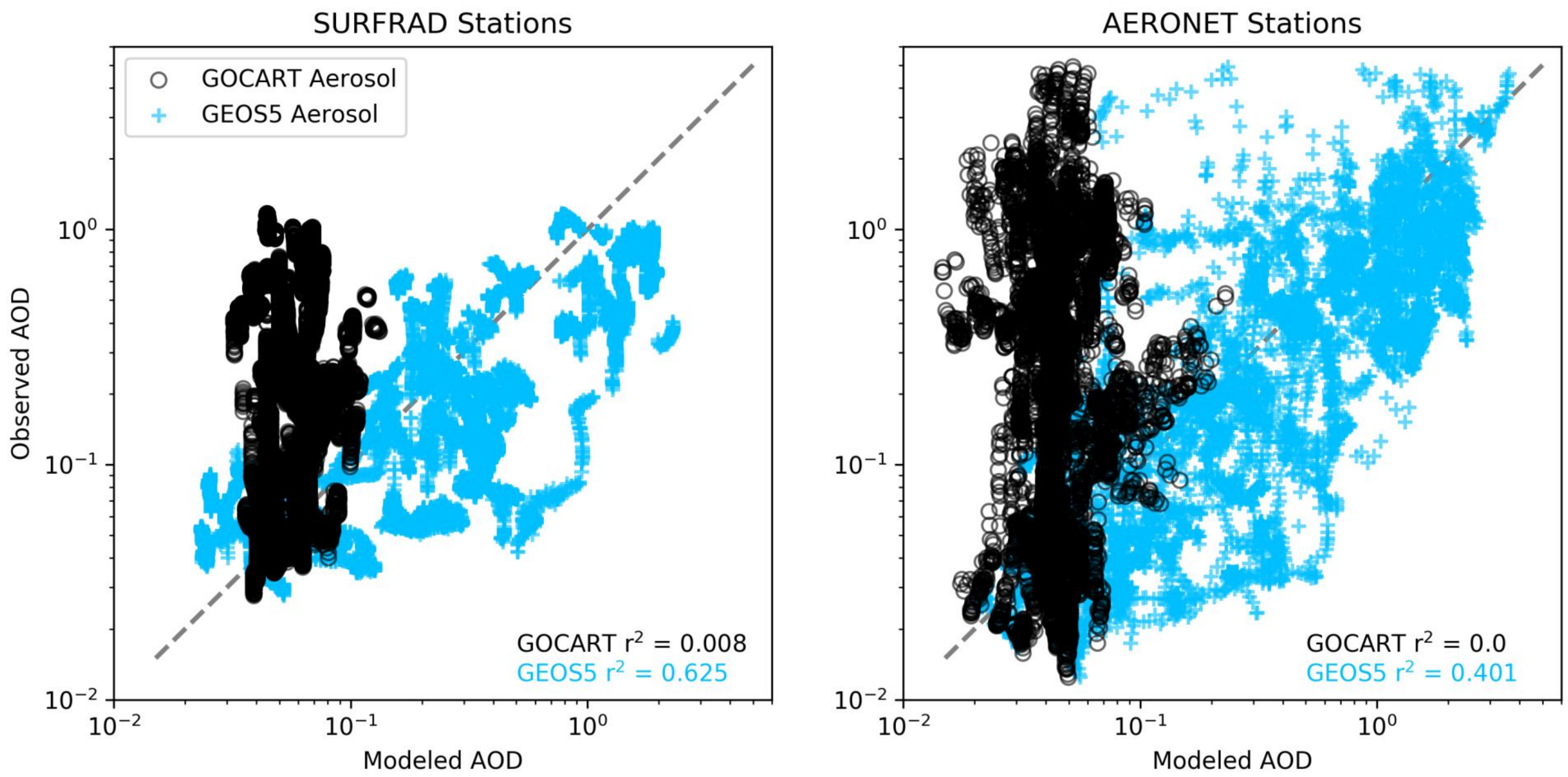
Parameterization leads to larger variability

- Parameterized variability based on observed distributions
- Direct calculation from WRF output has much smaller variability



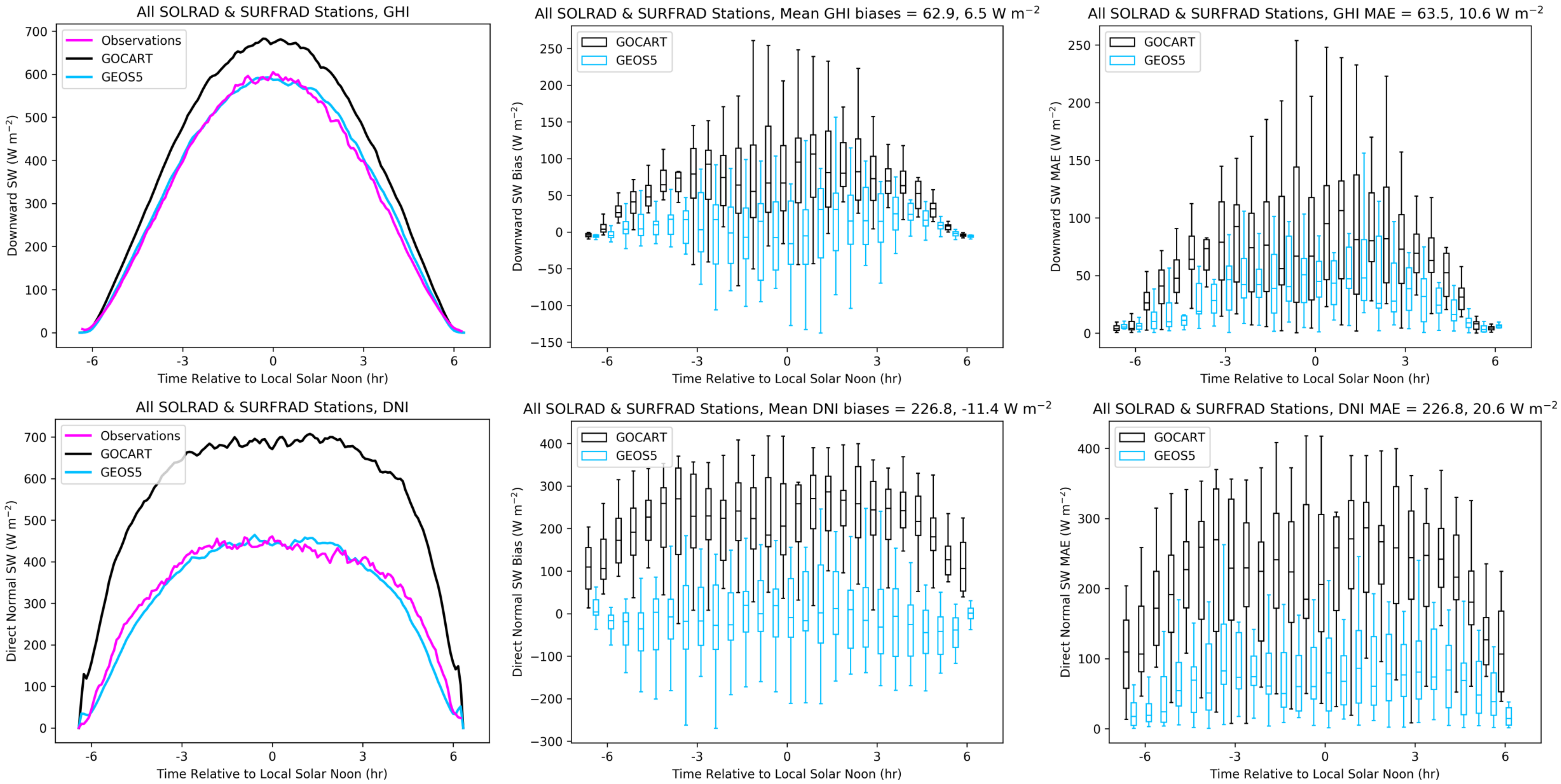
Addition of absorbing aerosol can have significant impact

- Added absorbing aerosol from industrial and biomass burning with different options for initialization:
  - GOCART climatology
  - GOES-5 analysis
- AOD over 9-day period from SURFRAD and AERONET sites for period in 2020



Comparison GHI and DNI at SURFRAD and AERONET sites

- AOD over 9-day period from SURFRAD and AERONET sites in the simulation domain



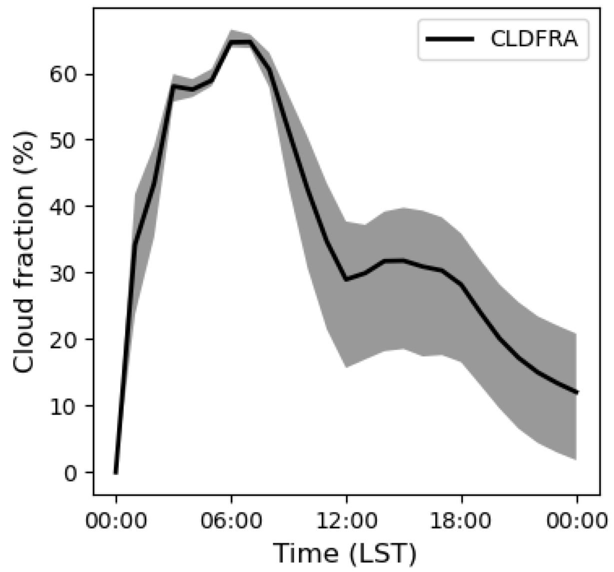
Uncertainty quantification—SGP

- Parameter list developed for sub-grid microphysics and aerosol (absorbing and scattering)
- 256 ensemble sampled using QMC
- SGP analysis focused on impact of cloud parameters

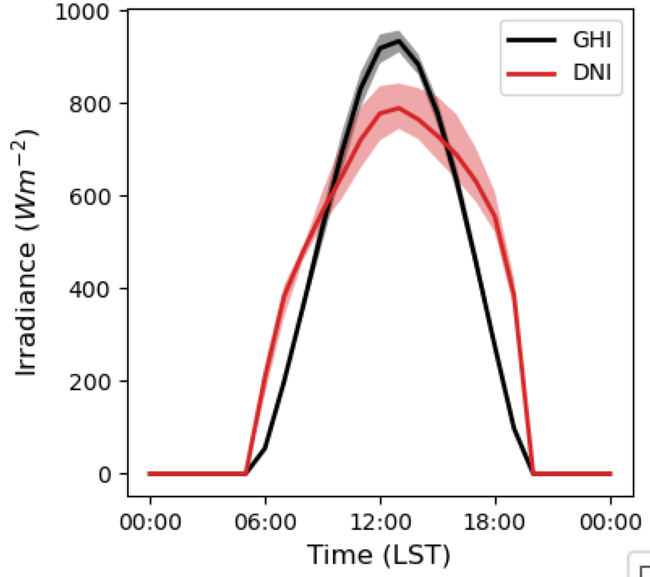
- All-sky GHI/DNI — ε, RH_a and RH_c
- Clear-sky GHI/DNI — mu, nwfa, RH_a and RH_c

mu	Median size of BC aerosol lognormal distribution.
nwfa	Factor to scale surface aerosol number concentration emissions
RH_c	Parameter determining the RH threshold of cloud condensation
RH_a	Parameter determining the RH threshold of cloud condensation
ε	Parameter controlling the entrainment rate.

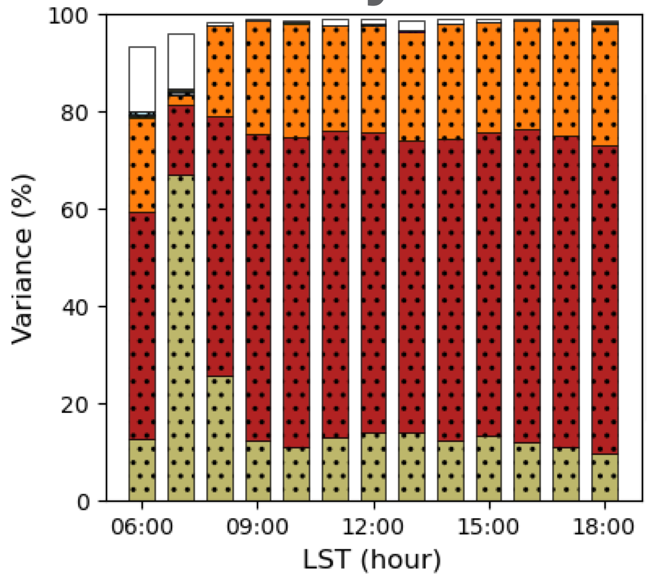
Cloud fraction



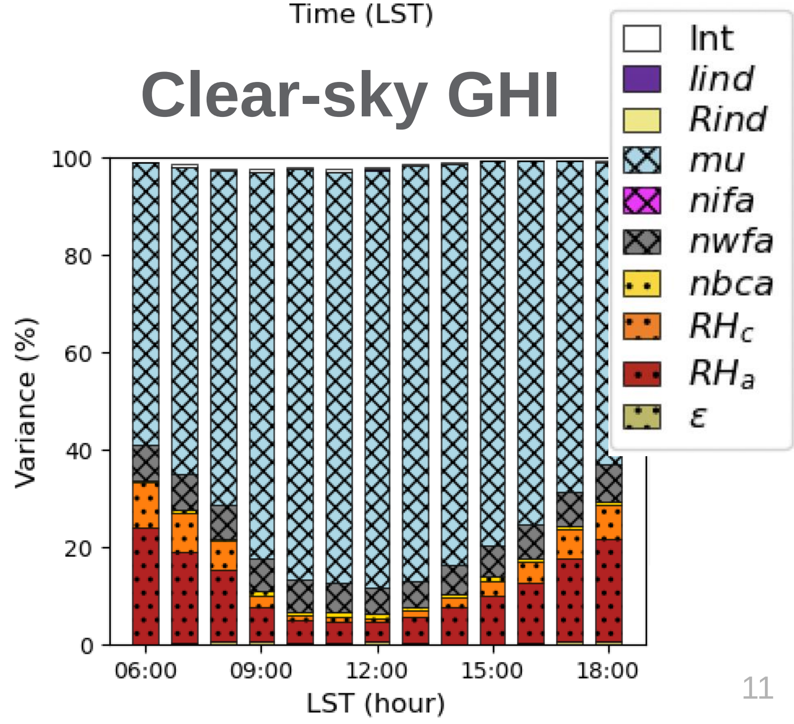
GHI and DNI



All-sky GHI

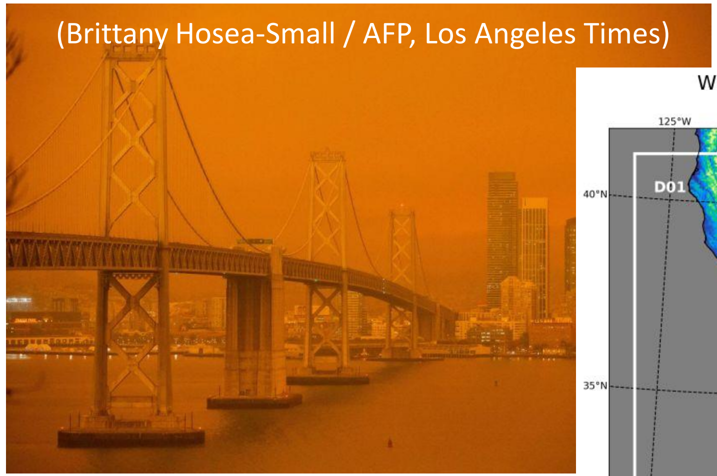


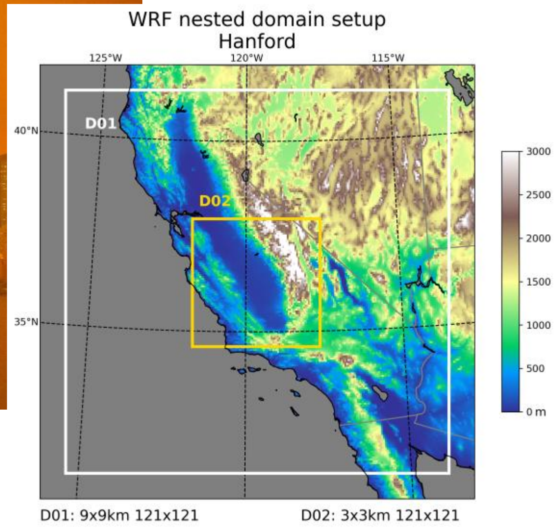
Clear-sky GHI



Uncertainty quantification—Hanford CA

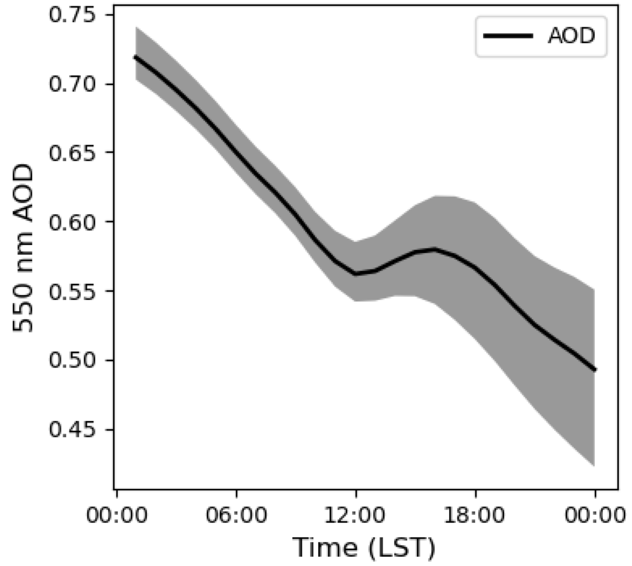
- Hanford case focused on BC aerosol



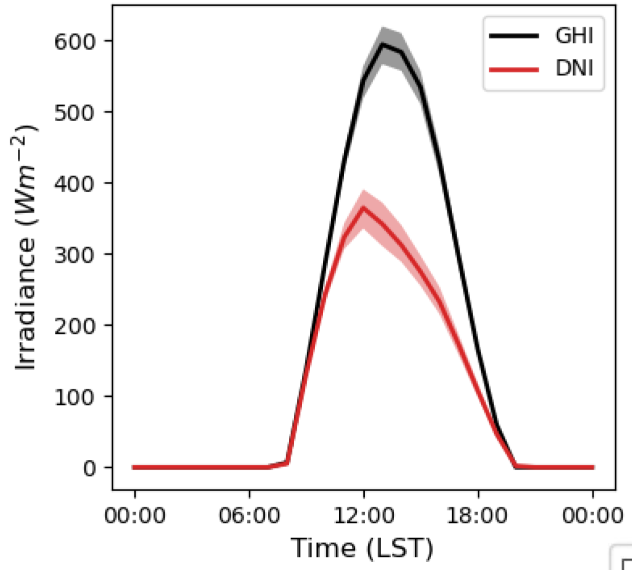


- All-sky GHI/DNI variances are dominated by $\boldsymbol{\varepsilon}$, RH_a, RH_c, mu, f_{nbca}
- Clear-sky GHI/DNI variances are dominated by mu, and f_{nbca}

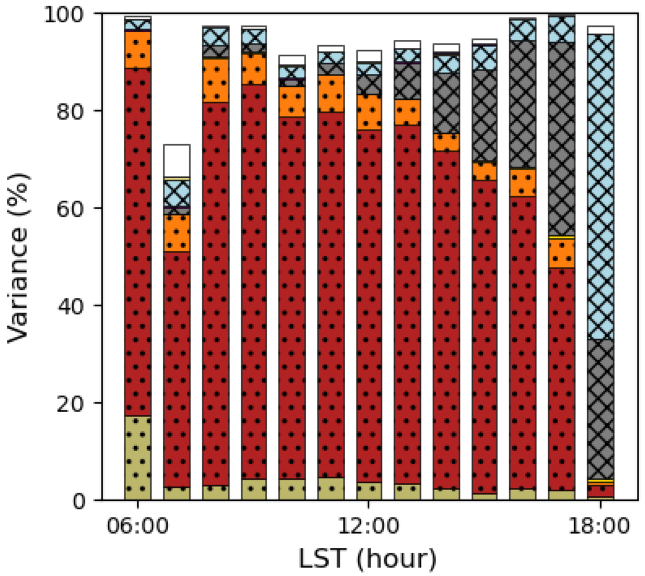
550nm total AOD



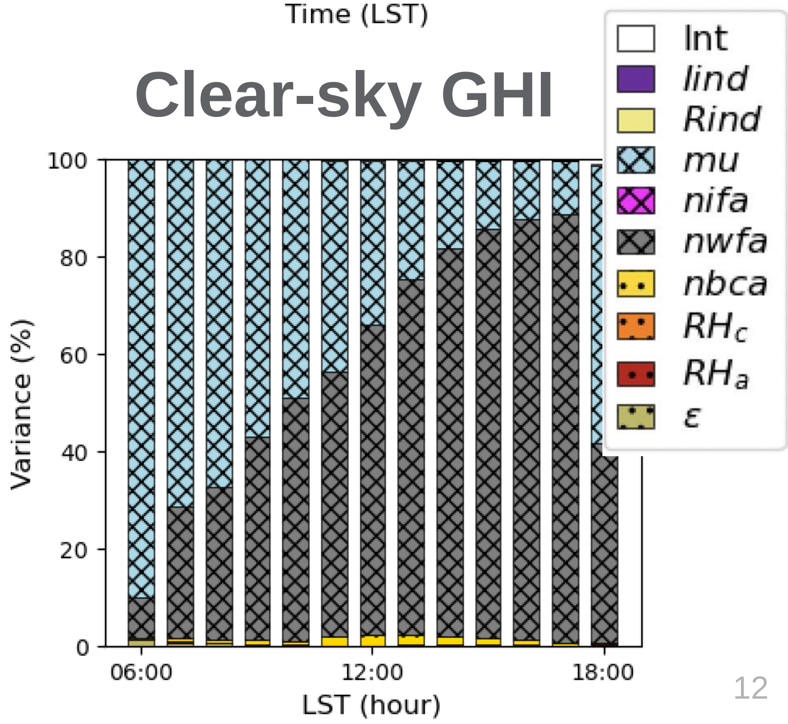
GHI and DNI



All-sky GHI

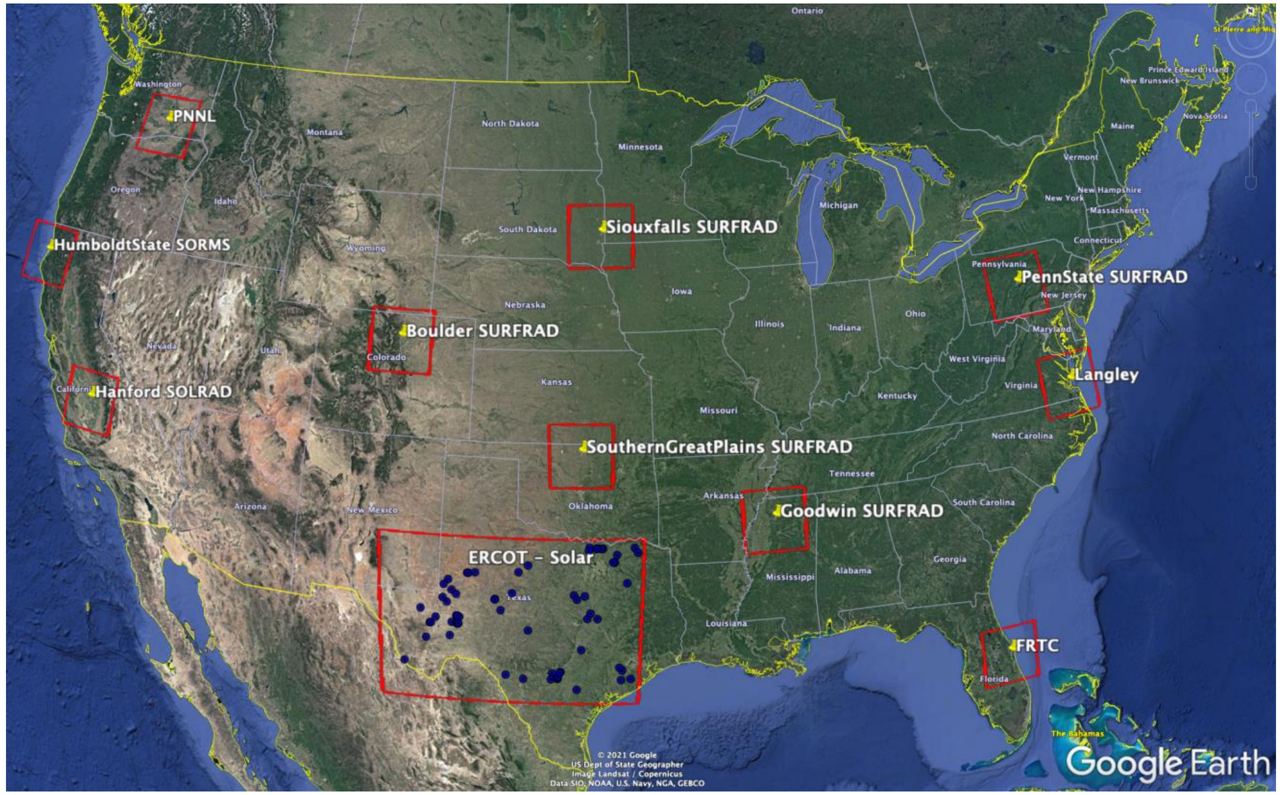


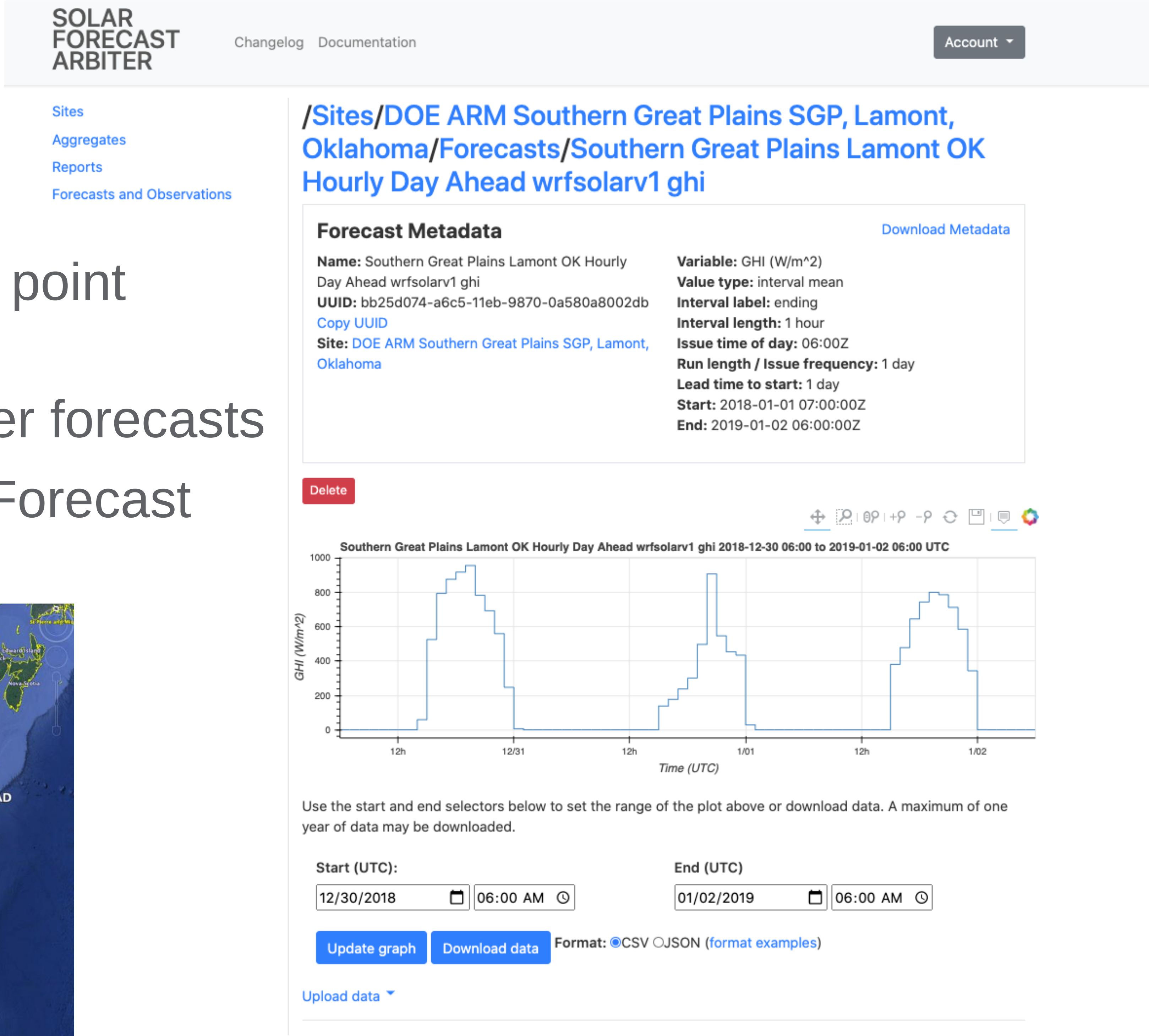
Clear-sky GHI



WRF-Solar v2 verification

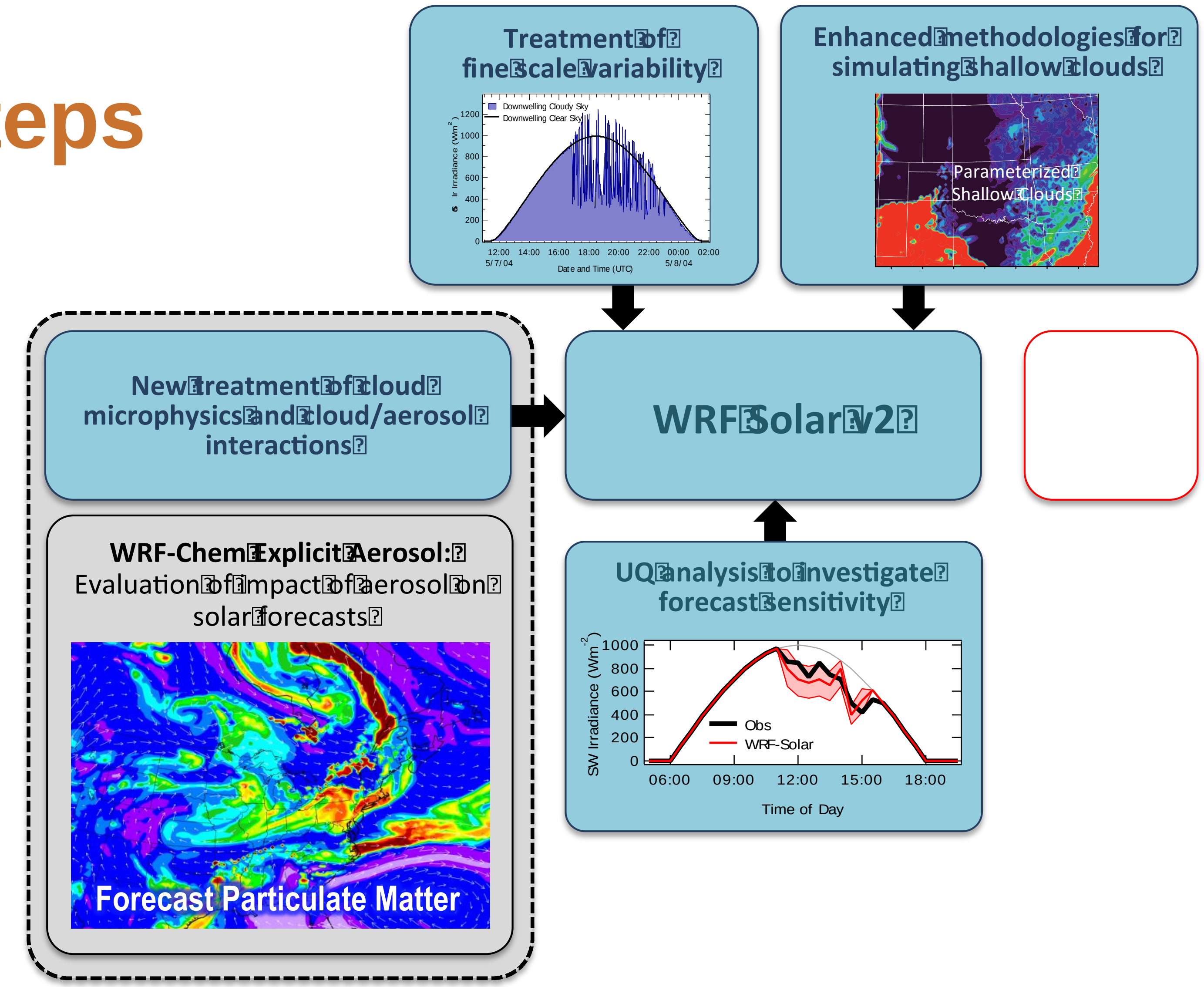
- 10 sites selected for verification of point forecasts of GHI and DNI
- 1 region selected to evaluate power forecasts
- Evaluation underway using Solar Forecast Arbiter





Summary and next steps

- Year 3 of the project includes evaluation of simulations via the Solar Arbiter (https://solarforecastarbiter.org/) for selected locations
- Code is available to the Solar Forecasting Project teams
- Will be made available to the community after additional testing



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