

The influence of Cloud Cover on the Reliability of Satellite-based Solar Resource Data

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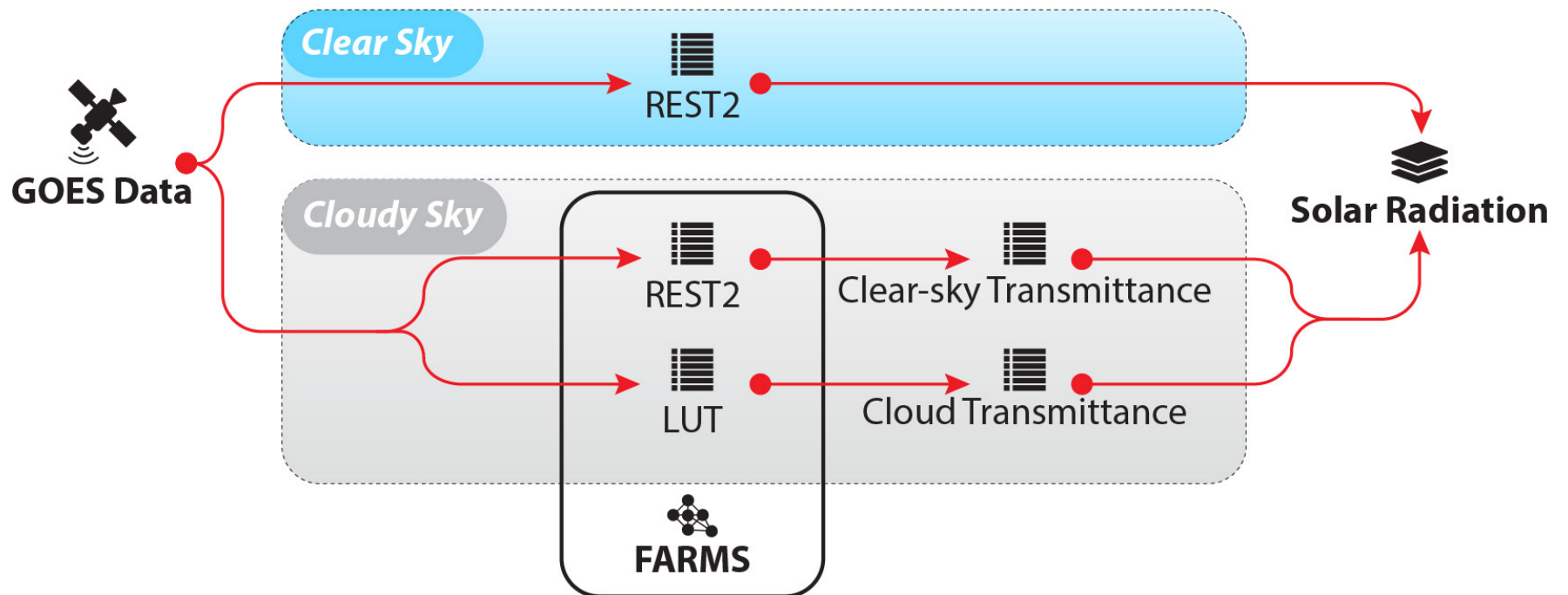
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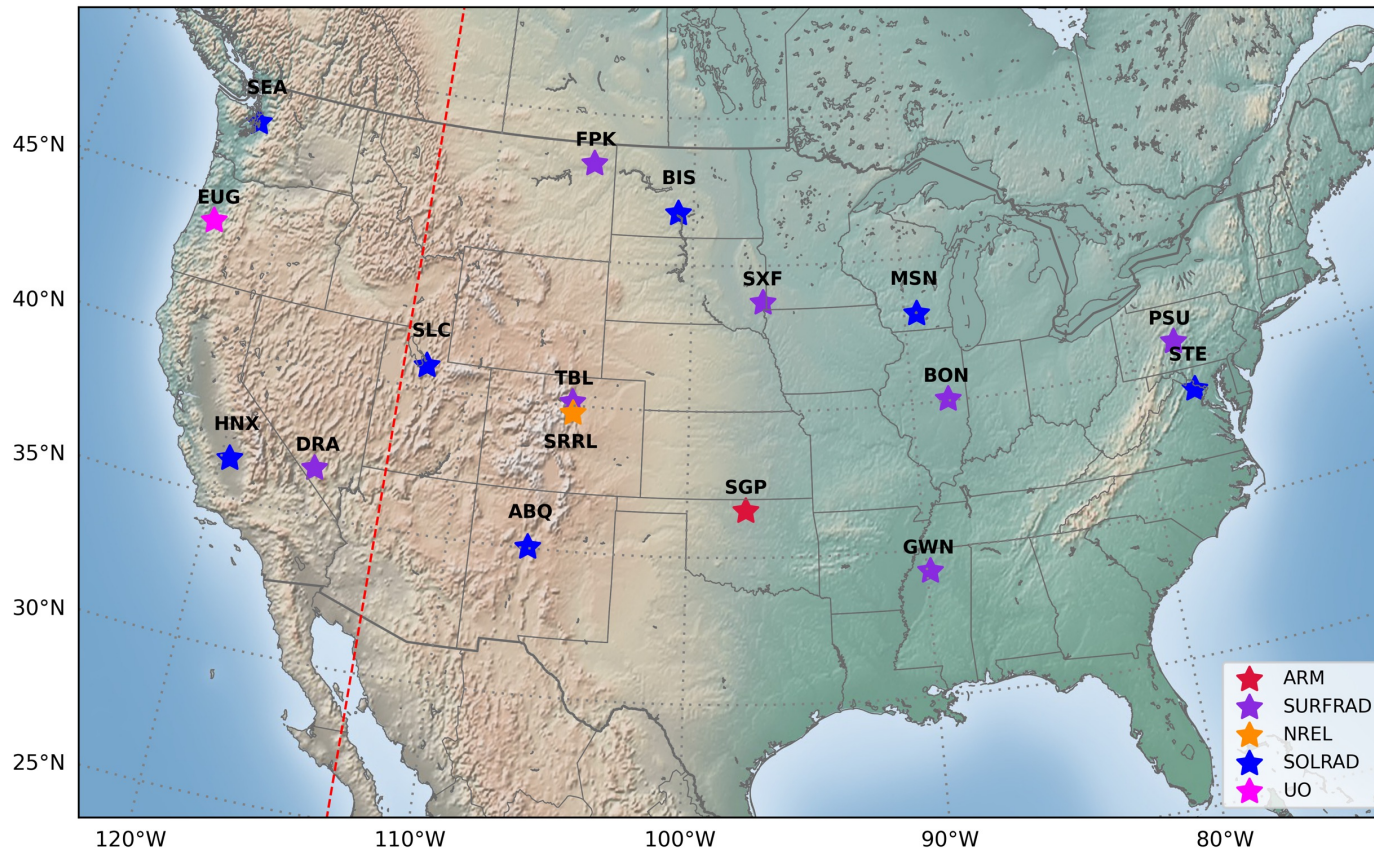
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Binary Cloud Mask Data



- Clouds in the natural atmosphere are more complex than the clear-or-cloudy distinction.
- Substantial occurrences of scattered clouds or broken clouds in real atmospheric conditions.
- Is the current computation of solar radiation oversimplified by using binary cloud mask data?

Validation Data



- GHI and DNI (2 km and 5 min) from 2019-2020 computed using the NSRDB algorithm with DISC and FARMS-DNI.
- The satellite-based data validated by surface observations.
- 4 and 13 stations (divided by the red line) validate the data from GOES-17 and GOES-16, respectively.

Estimation of Cloud Fraction

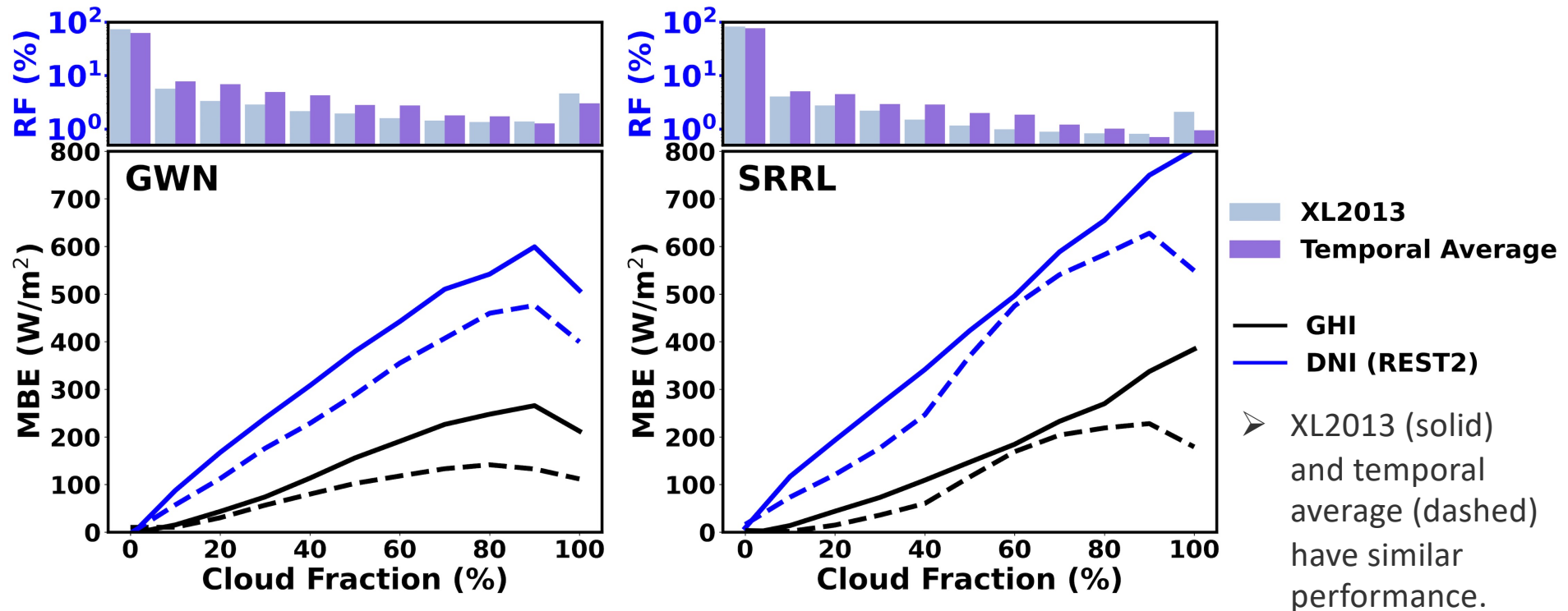
Analytical model (XL2013)

- **GHI and DNI expressed using atmospheric properties** (solar radiation, cloud fraction, cloud albedo, surface albedo...)
- **Cloud optical thickness and cloud albedo linked by a two-stream approximation**
- **Cloud fraction analytically solved** (Xie & Liu, 2013)
- **Examined by TSI data** (An & Wang, 2015)

Temporal average of cloud mask

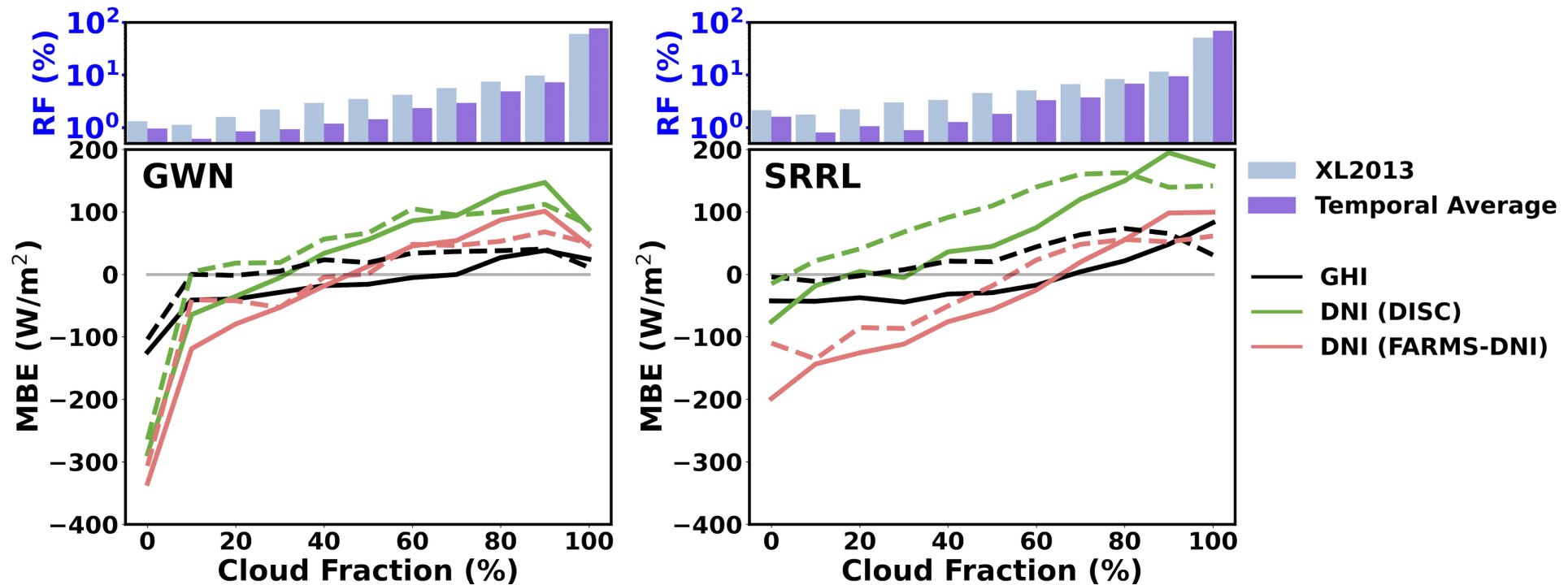
- **The proportion of cloudy-sky samples to the total samples within a time frame.**
- **The temporal average of cloud mask derived from the clear-sky index for DNI.**
- **60-minute moving average centered around the satellite time step.**

MBE for “Clear Sky”



- Most instances associated with a cloud fraction < 20%.
- Scattered clouds, broken clouds, and overcast conditions due to low resolution or bias in GOES data.
- Overestimation in GHI and DNI due to the omission of clouds. More pronounced with increasing cloud fraction. DNI is more sensitive to clouds.

MBE for “Cloudy Sky”



- Smaller uncertainty of GHI.
- When cloud fraction > 80%, DNI by DISC shows a large positive bias. The bias is reduced by FARMS-DNI.
- When cloud fraction < 20%, FARMS-DNI underestimates cloudy-sky DNI (conflicts between satellite and surface data). DISC shows better accuracy.

Cloudiness Categories



Cloudiness categories:

- Confidently clear sky ($f < 20\%$)
- Clear sky with clouds ($f > 20\%$)
- Confidently cloudy sky ($f > 80\%$)
- Partially cloudy sky ($f < 80\%$)
- Satellite-surface mismatch

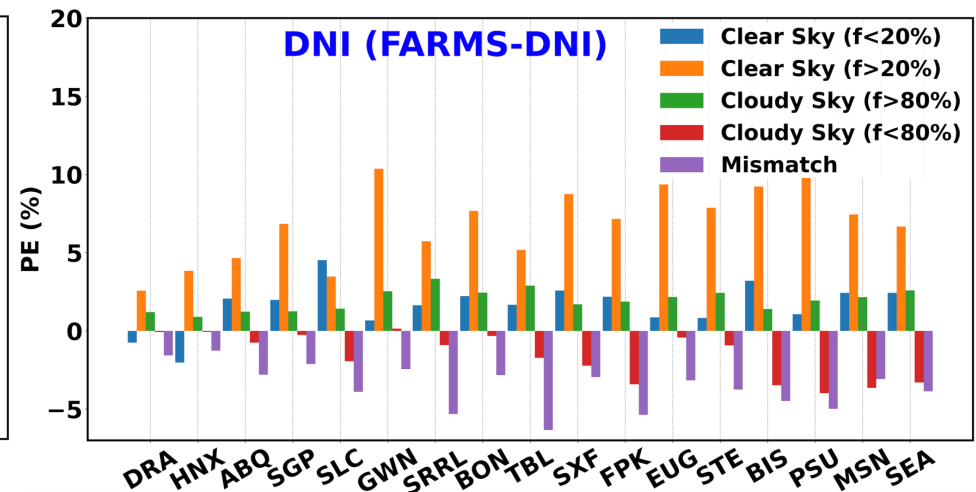
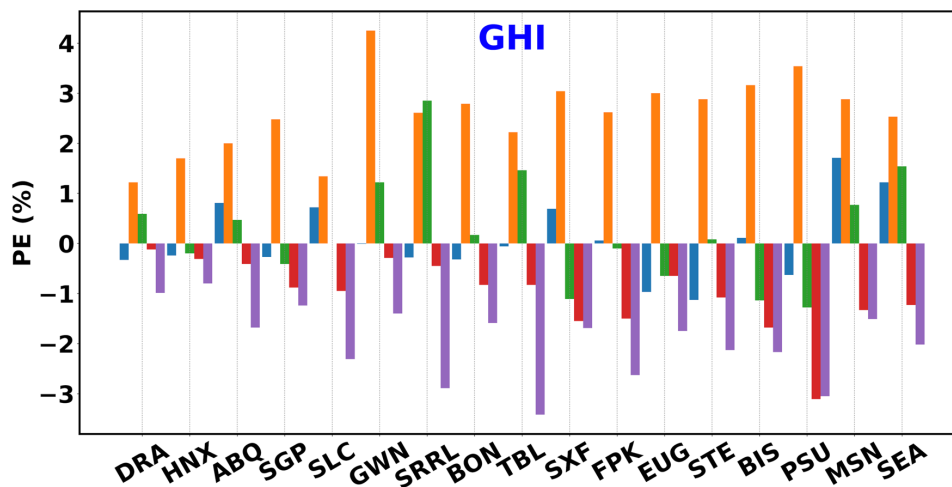
Satellite-surface mismatch

Flagged as cloudy sky by GOES but

- Surface GHI > 99% of clear-sky GHI
- Surface DNI > 99% of clear-sky DNI

The “mismatch” may result from uncertainties in satellite cloud mask data or strong cloud reflection

Percentage Error (PE)

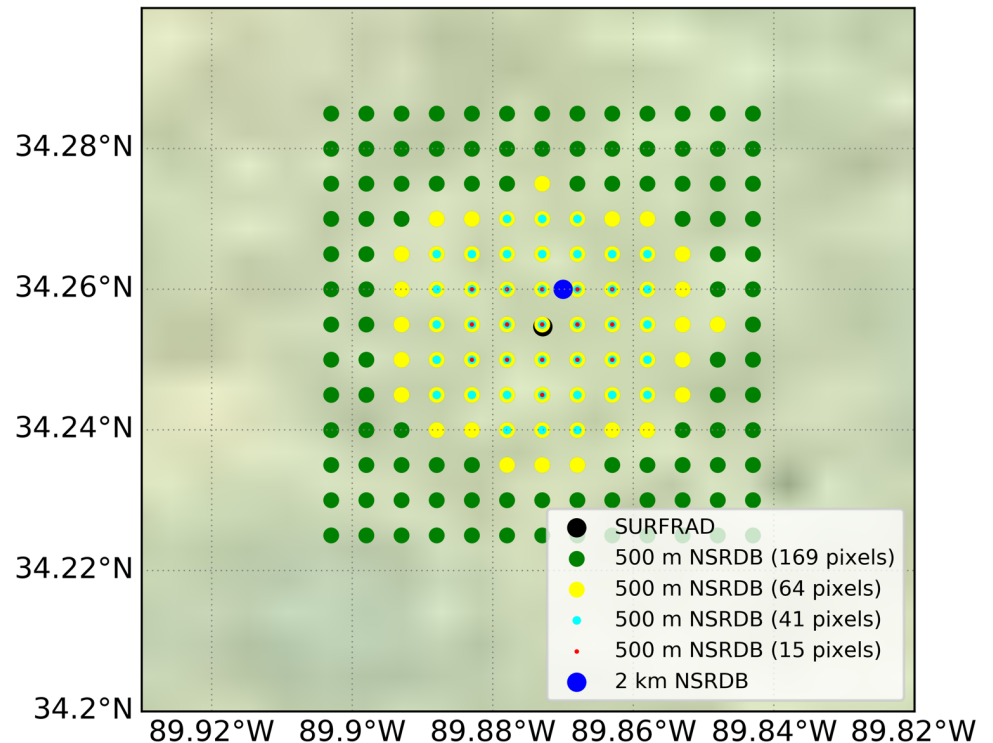


$$PE = \frac{\sum_{i=1}^m (F_{sat} - F_s)}{\sum_{i=1}^n F_s} \times 100\%$$

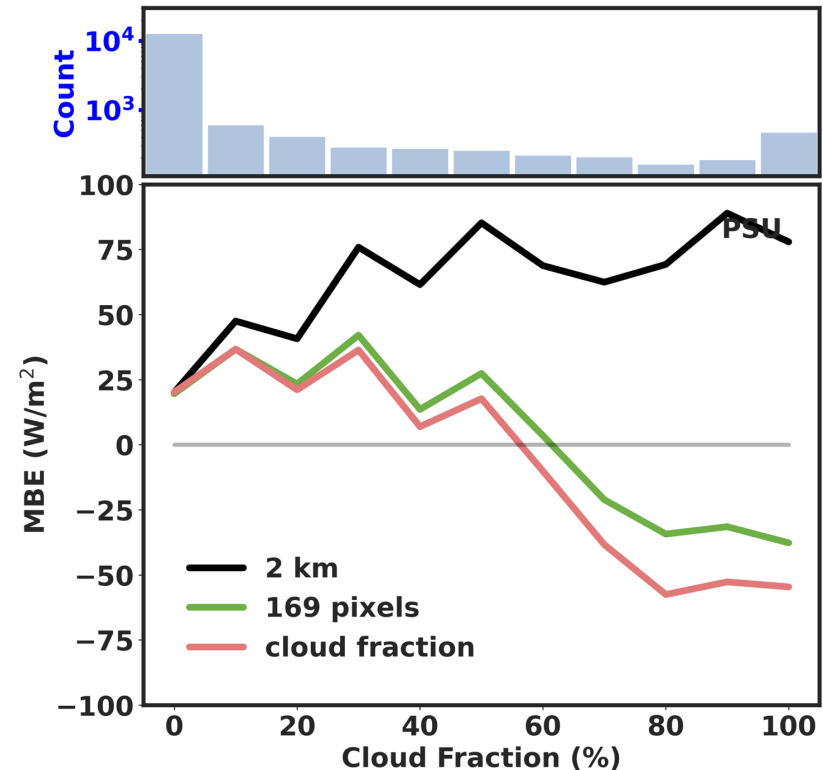
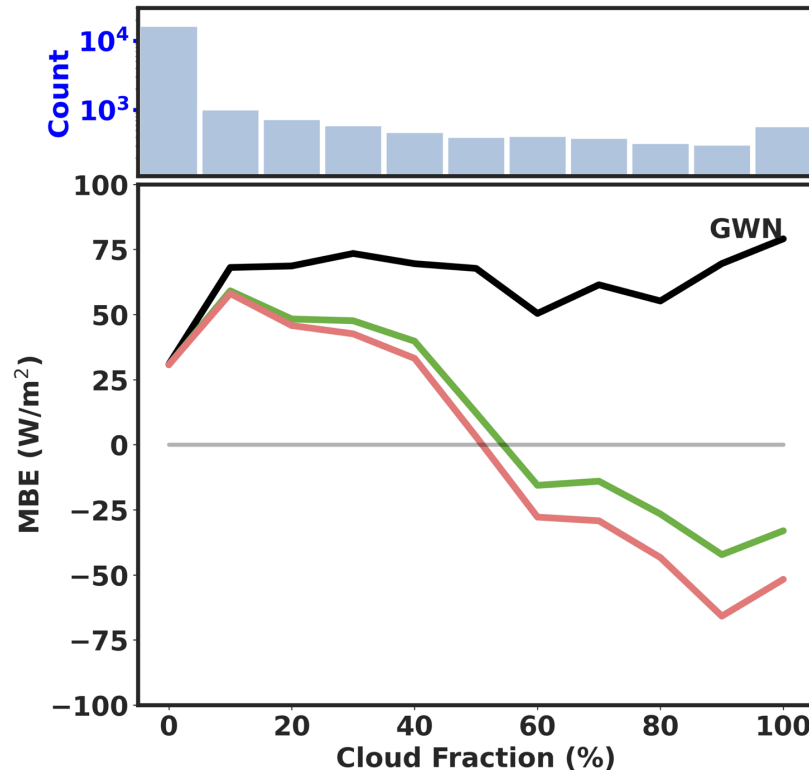
- PE represents the bias from a category as the proportion of the radiation across all scenes.
- GHI and DNI in confidently clear conditions are exceptionally accurate.
- Bias in partially cloudy conditions and mismatch is significant.
- For DNI, bias in confidently cloudy conditions is counterbalanced by partially cloudy conditions.

Summary & future work

- The bias of satellite GHI and DNI evaluated as a function of cloud fraction.
- **Clear sky:** overestimation. **Cloudy sky:** underestimation of DNI for a small cloud fraction.
- Bias in partially cloudy conditions and satellite-surface mismatch is significant.
- Cloud fraction data will be provided by high-resolution satellite data.
- Cloud fraction will be used to improve solar radiation based on the binary classification.
- Preliminary results show significant improvements.



GHI for “clear sky” (flagged by satellite data)



- Bias in 2 km cloud mask (scattered clouds). 2 km data overestimate “clear sky” GHI. Reduced bias using 500 m data.
- From overestimation to underestimation (not very cloudy). “Cloud fraction” shows smaller GHI than “169 pixels”.

Summary & future work

- 500 m cloud properties demand considerable computing resources.
 - 2 km cloud properties from 500 m reflectivity.
 - 2 km cloud fraction from 2 km data and a ML model. 500 m data for more accurate cloud fraction used in training phase.
- Test 2 km cloud properties in the NSRDB procedure.
- Implementation of the new models.

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