Developing Solar Forecasting Model Diagnostics of Cloud Impacts on Solar Variability

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Increasing use of renewables in US electric grid

California now has > 10% of electricity from Solar!
Increasing use of renewables in US electric grid

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Significant challenge in incorporating a high penetration of solar energy into the electric grid is variability!

Source: California Energy Commission, staff analysis November 2018
Variability can be better managed if we can predict it

- Clear sky surface solar radiation is variable but predictable
Variability can be better managed if we can predict it

- Clear sky surface solar radiation is variable but predictable
- Cloud effects are the toughest challenge to predict well!
Assessing and improving the utility of weather forecast models for solar forecasting using ground-based observations
Using surface irradiance measurements to evaluate model improvements in cloud parameterizations

Need new ways to predict variability from models

- Observations show large variability in irradiance with broken clouds
- That variability is not currently captured in the model
- Develop a new parameterization to include that variability in the model
Approach: Build observational metrics of surface shortwave variability under different cloud types that can be incorporated into forecast models.
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1. Separate the variability due to clouds from solar geometry.

Effective Transmissivity:

\[
ET = \frac{\text{Measured SW Irradiance}}{\text{Clear Sky SW Irradiance}}
\]

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2. Characterize the relationship between Effective Transmissivity and cloud fraction.
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Density plot of 1 year of data, all sky conditions
Approach: Build observational metrics of surface shortwave variability under different cloud types that can be incorporated into forecast models

3. Use active remote sensors to identify cloud types based on height

Example of time-height evolution of radar reflectivity from Millimeter wavelength Cloud Radar (MMCR) (shaded) (top) and classified cloud types at the ARM SGP C1 site on 24 May 2008. From Lim et al. (under review in J. Tech).
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Cloud type classification allows us to quantify cloud effects by cloud type.
Measures of irradiance variability differ by cloud type
Outlook: Installation of ceilometers at SurfRad stations will allow for cloud type variability metrics in different climate regimes!
Outlook: Incorporate spatial variability as well as temporal variability measurements.

G-Rad built 3 portable radiometer systems (RADSYS) to measure spatial variability around sites.
Summary

1. Improved shallow cumulus parameterizations being tested in WRF to improve simulations of broken cloudy conditions. This is a necessary but not sufficient condition to capture irradiance variability in solar forecasts.

2. Developing observational products to quantify irradiance variability in SGP observations:
   • Separating cloud impact from solar geometry allows better statistics of short-term variability
   • Using automated identification of cloud types shows utility in classifying irradiance variability in order to give more accurate variability statistics.

3. New measurements (ceilometers, radsys) at SURFRAD stations will allow calculation of spatial and temporal variability in multiple climate regimes!
Extra Slides
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From: J. Kleissl, *Solar Energy and Forecasting and Resource Assessment*
SW Variability by CAUSES Cloud Types: SGP 2014-2018

Cloud Type
- High Clouds
- Low Clouds
- Low and High Clouds
- Low and Mid Clouds
- Low, Mid, and High Clouds
- Mid Clouds
- Mid and High Clouds
Vertically pointing active sensors are used to classify clouds by cloud heights.

Multiple instruments (ceilometer, lidar, radar) are used to determine a comprehensive picture of multiple cloud layers.

**Treatment of temporal variability of solar irradiance:**
Development using sites with cloud instrumentation.

Active sensors at US DOE ARM sites.
Motivation: Solar Forecasting for solar energy most challenging in broken cloud conditions

Development of WRF-Solar v2—Improving Solar Forecasts

- PI Larry Berg