Simulation of PV Variability As a Function of PV Generation and Plant Size

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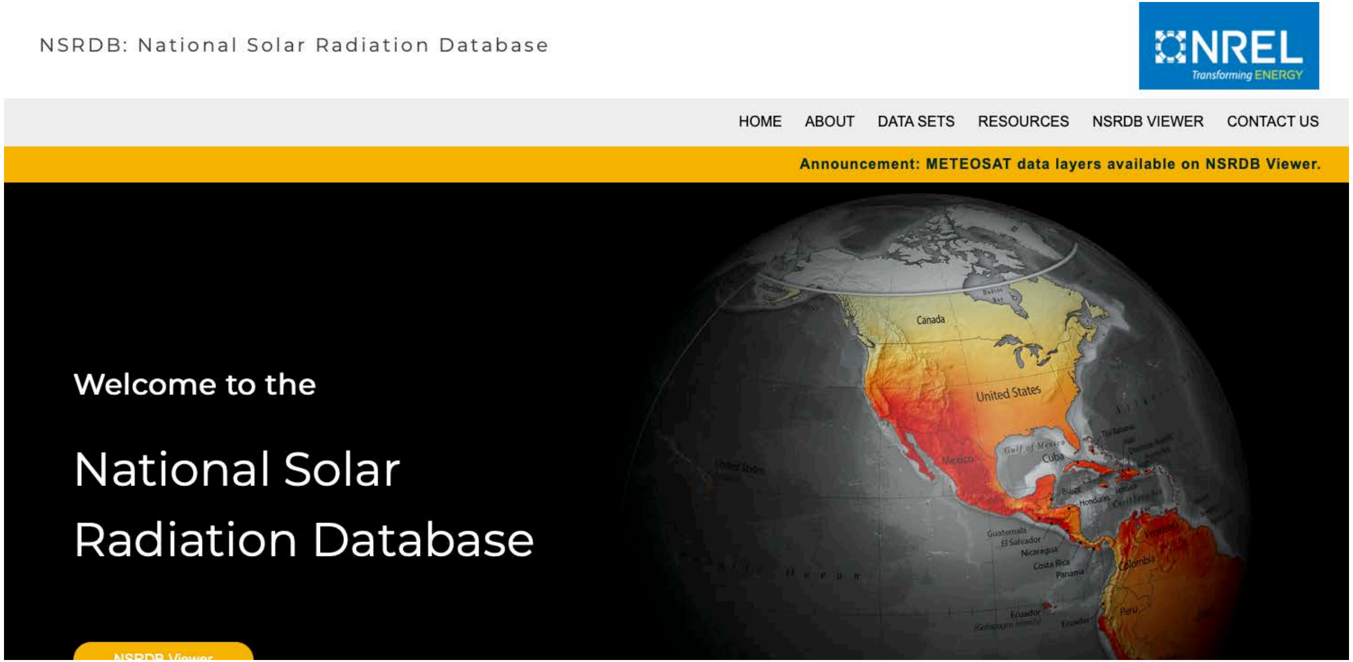
Overview

- Motivation
- Method – Metric used
- National Solar Radiation Database (NSRDB) data
- Result – Baseline analysis
- Result – Using the new method (aggregated short-term variability analysis)
- Summary.

NSRDB Data

https://nsrdb.nrel.gov



Motivation

- Some metrics in the literature to quantify short-term photovoltaic (PV) variability provide limited direct insight to guide power system operation and/or planning.
- This study focuses on a new metric that reflects the aggregated PV variability, which can be used as an indicator of PV variability's impact on system operation.
- The new metric could also assist engineers in power system planning to understand the system-level distribution of variability with an option to select various time horizon levels of variability to perform system studies.
- Forecasting such a metric in various timescales will be essential to system operators for dispatch optimization.

Normalized Variability Metric

1. $nRating_i = \frac{Rating_i}{\sum_{i=1}^{n} Rating_i}$

2. $ncf_{i,t} = \frac{all\ sky\ cf_{i,t}}{clear\ sky\ cf_{i,t}}$

3. $\Delta \text{Normalized CF}_{i,t} = (\Delta ncf_{i,\Delta t}) * nRating_i$

4. $\Delta \text{Normalized CF}_{t} = \sum \Delta \text{Normalized CF}_{i,t}$

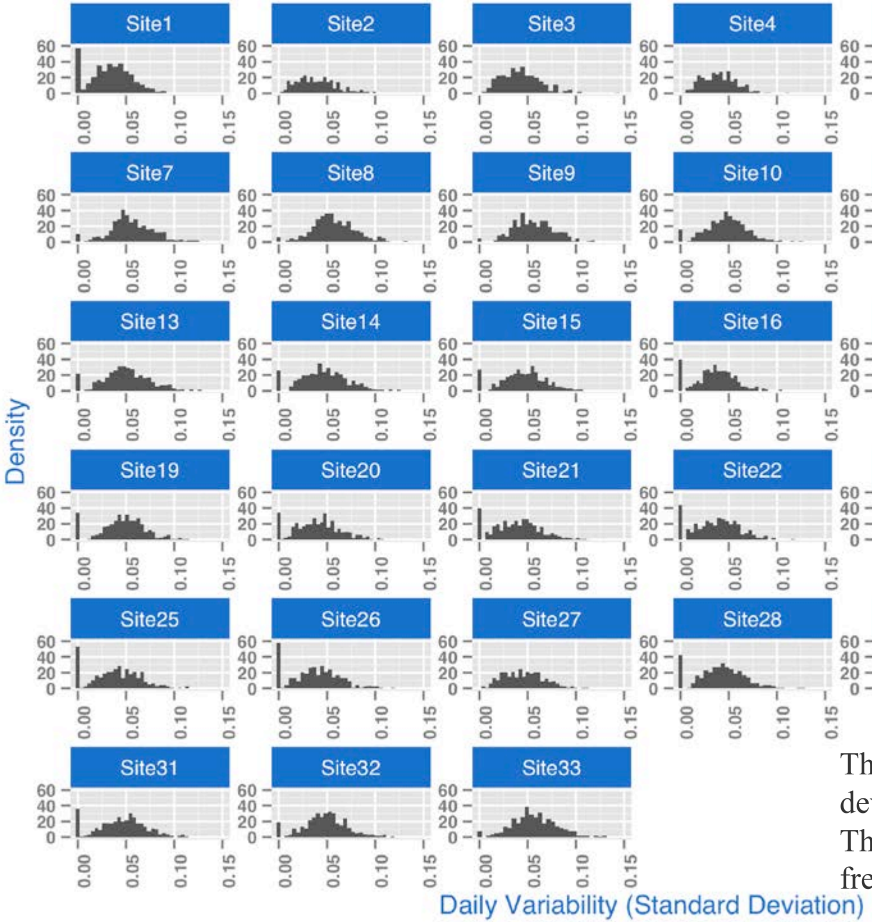
5. Variability Statistics:
   1. ***Standard deviation*** for a duration (e.g., **daily** or **hourly**)
   2. Clear and cloudy index (***average of ncf$_t$***).

1. Each plant rating was used in the analysis, and ***normalized rating*** was calculated.
2. All-sky and clear-sky capacity factors were used to generate the ***normalized capacity factor*** for each time series of each plant.
3. The ***difference in each consecutive time step (timescale)*** was calculated and then multiplied by the normalized rating (Step 1).
4. ***All the plants'*** output from Step 3 ***was summed*** to get one array of a time-series data set.
5. Variability ***statistics*** were calculated ***for the duration of interest*** (daily or hourly).

- The normalized metric varies from [0,1], with 0 representing no variability, such as a clear-sky condition. It captures the ***cloud impact***.

- Timescale is determined by Δt .
- Duration is the range within which statistics are calculated.

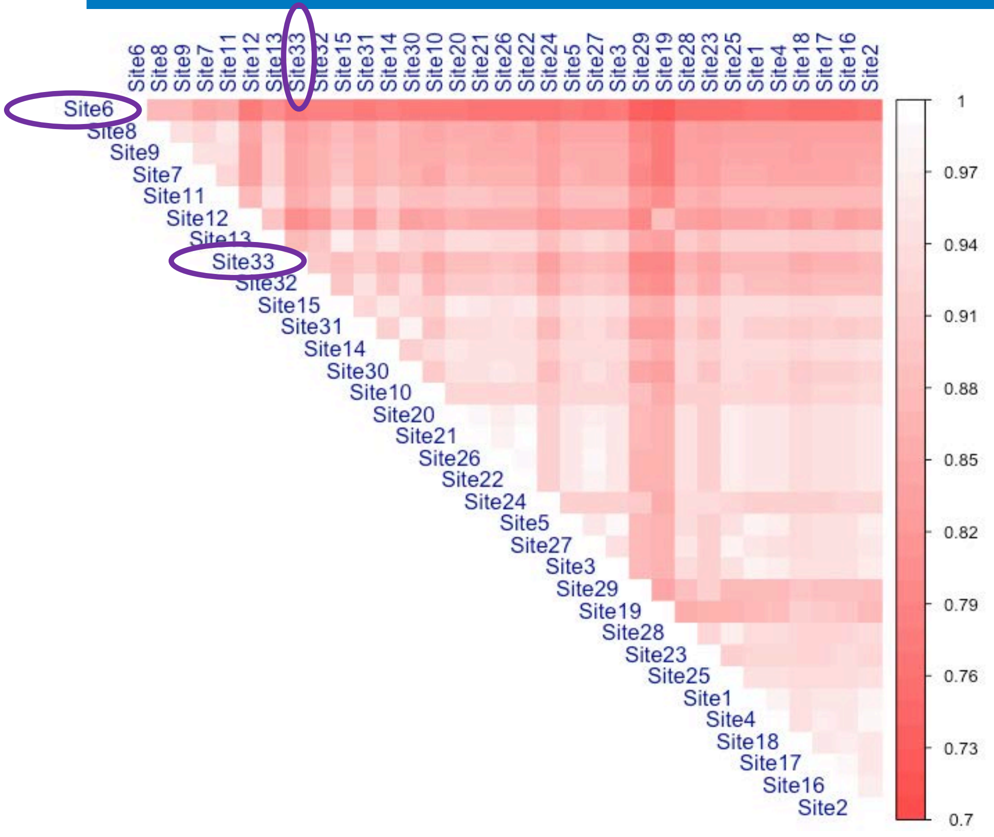
Baseline Analysis



- A baseline analysis checks the ramp rate effect for each individual site without incorporating that effect on the neighboring sites in the results.
- This kind of analysis provides interesting insight into PV plants that are off grid because the effect of the ramp rates is then independent from what occurs at nearby sites.

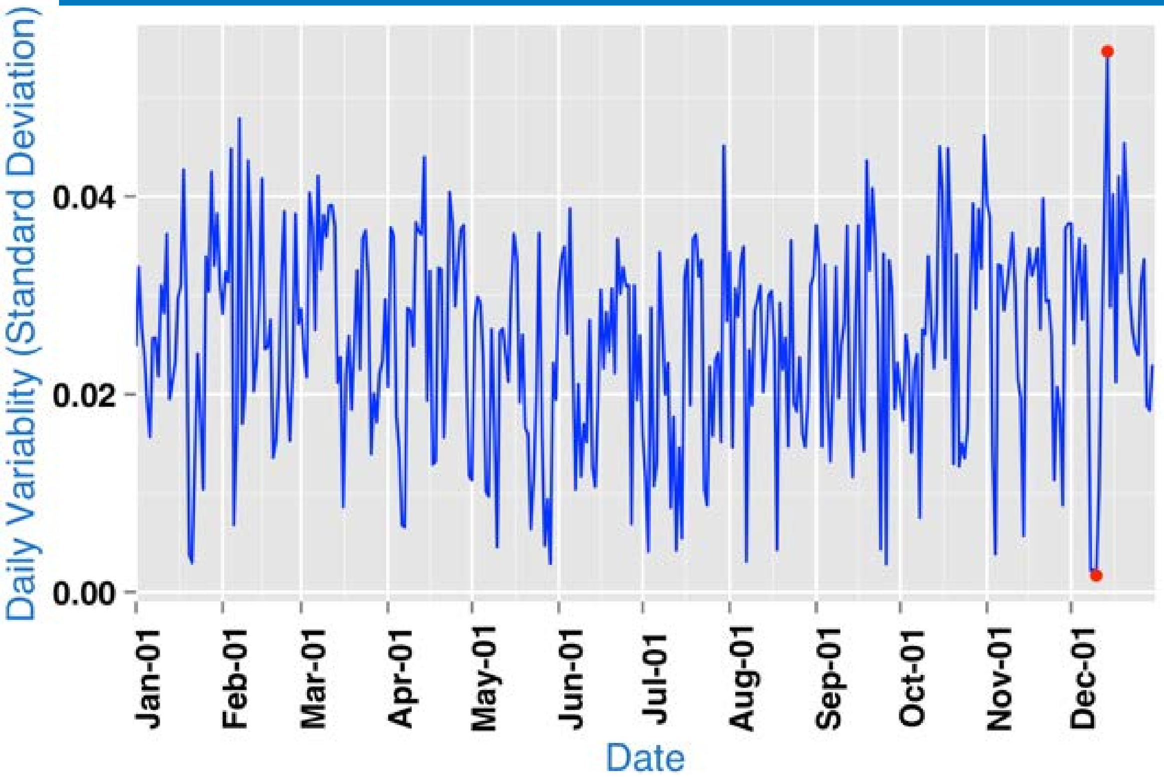
The frequency distribution of the daily variability (standard deviation) using the 1-minute timescale for each location. The first bin (at the origin of the x-axis) represents the frequency of clear days.

Baseline Analysis



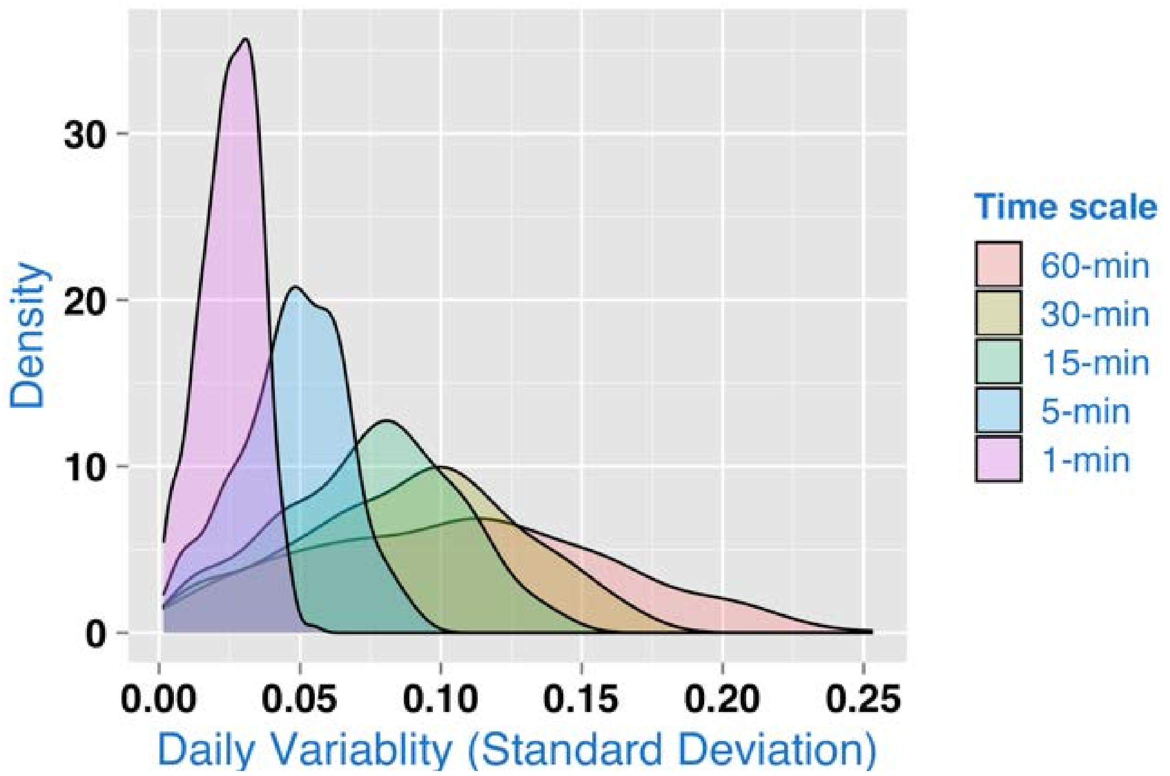
- The results of the correlation matrix are consistent with those in the previous slide.
- It is not always true that spatial correlation among sites varies inversely with distance.
  - Site 6 is relatively far (55 km) from Site 33, but the correlation between them is higher than for some of the closest sites to Site 6, which are within 15 km.

Aggregated Short-Term Variability Analysis



Nominal daily variability aggregated from the 1-minute data. The red points show the maximum and minimum variability, which coincidentally both occur during December 2019.

Aggregated Short-Term Variability Analysis



- Analysis can be undertaken using various other time resolutions, namely, with 5-, 15-, 30-, and 60-minute timescales.
- On a daily basis, hourly intervals induce higher aggregated ramp rates than the other timescales.

Summary

- Short term fluctuation in solar generation from PV cause challenges for system operations.
- These events need to be understood clearly to mitigate their effects on system operations, both for individual systems and fleets of systems at the regional scale.
- Using solar resource data from 33 sites within a relatively small—but highly inhomogeneous—region, this study provided a method to quantify these effects using a new statistical metric.
- One important finding was that the correlation between the output of different systems was not solely conditioned by their distance, contrary to what some current literature suggests.

Thank you!

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