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Comparison of High-Frequency Solar Irradiance: Ground Measured vs. Satellite-Derived

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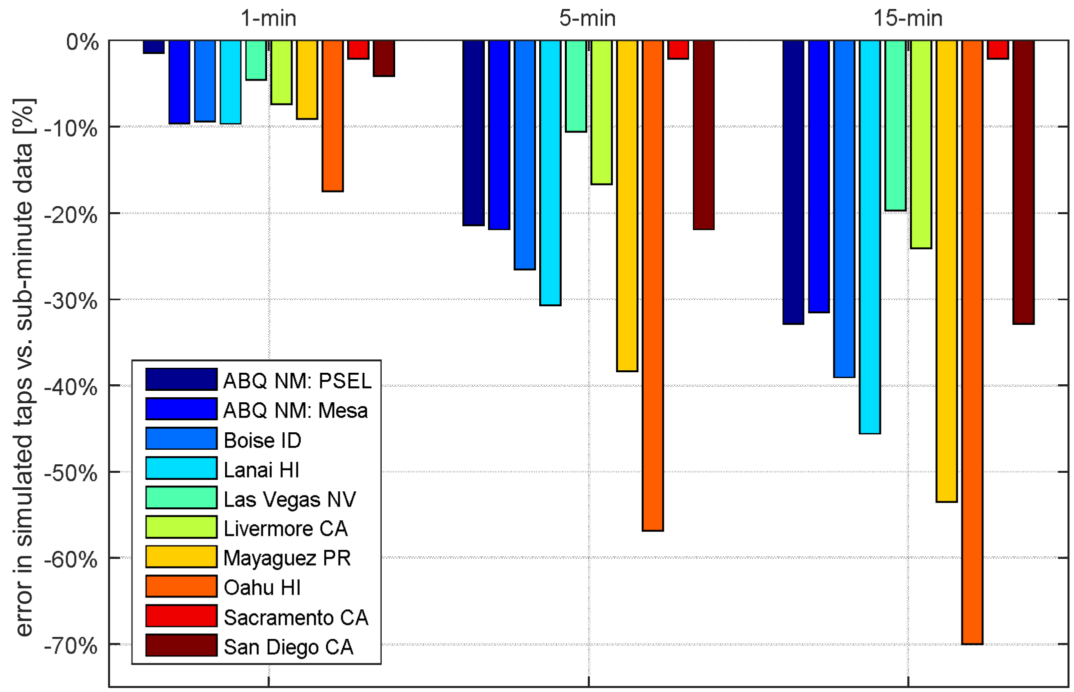
Importance of High-Frequency PV

- High-frequency solar variability is an important input to accurate distribution grid integration studies.
  - Low-frequency data always underestimates grid impacts such as voltage regulator tap change operations.
  - Errors of up to 70% when using 15-minute data instead of 30-second.

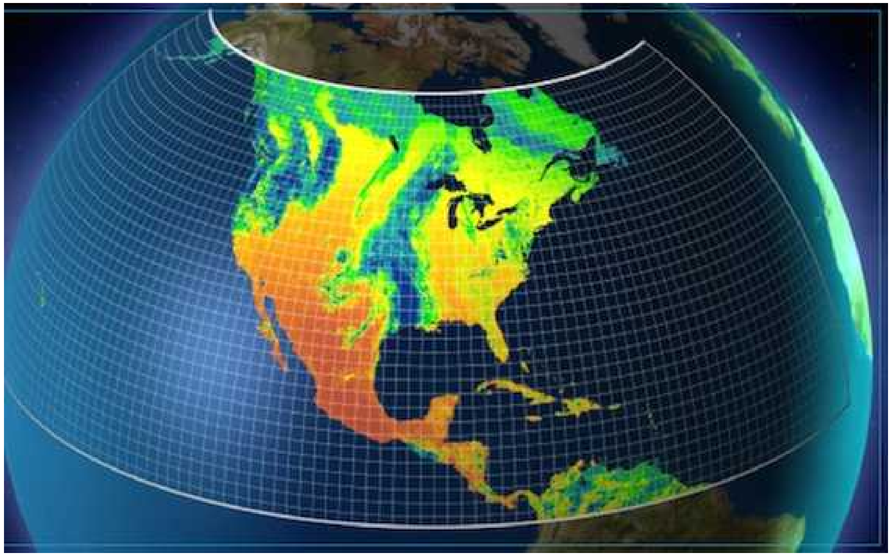


Availability of PV Data

- PV power output may be available from utilities, PV monitoring companies, inverter manufacturers, etc.
  - Difficult to obtain, typically needs an NDA
  - PV location is often approximate to protect customer privacy.

Irradiance data available from:

- Ground pyranometers
  - Spatially sparse, especially for high-frequency measurements.
  - Up to 1-second resolution, often 1-minute.
- Satellite-derived irradiance
  - Available for US and some other locations: nsrdb.nrel.gov
  - 15-minute resolution



High-Frequency Data from Satellite

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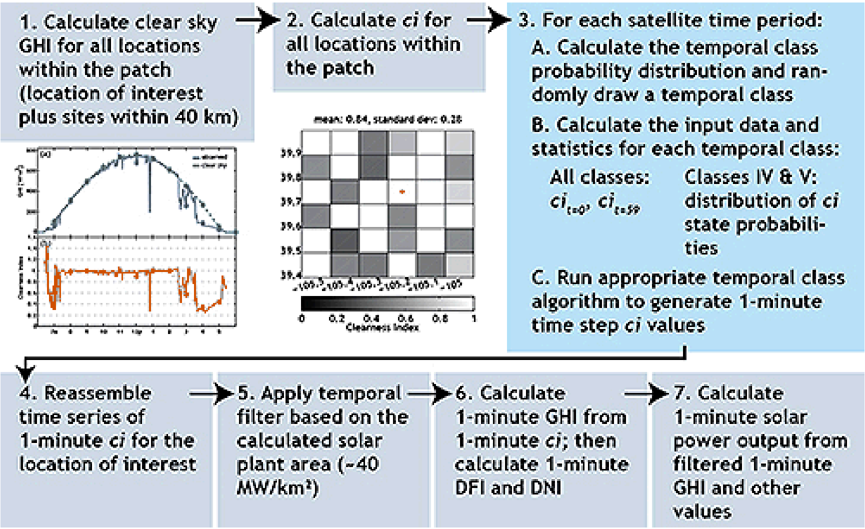
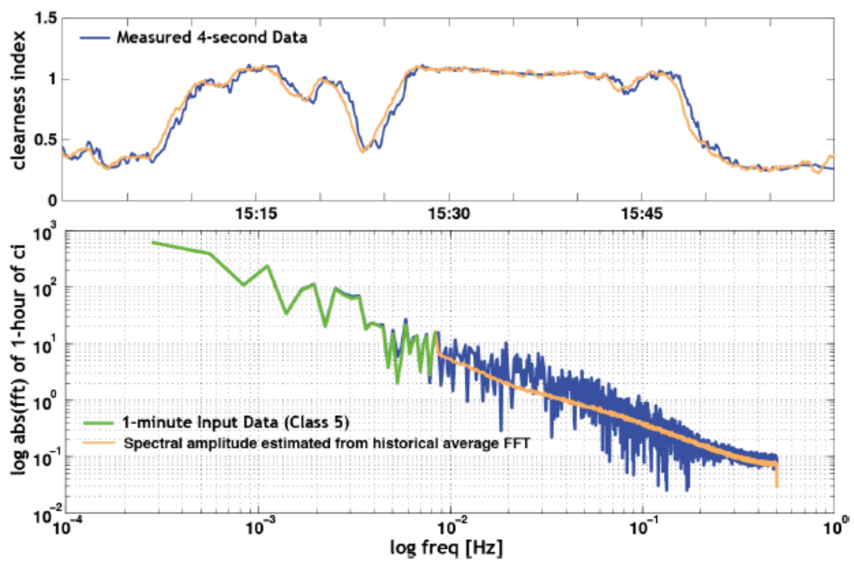
Two algorithms, together termed High Resolution Irradiance Algorithm (HRIA):

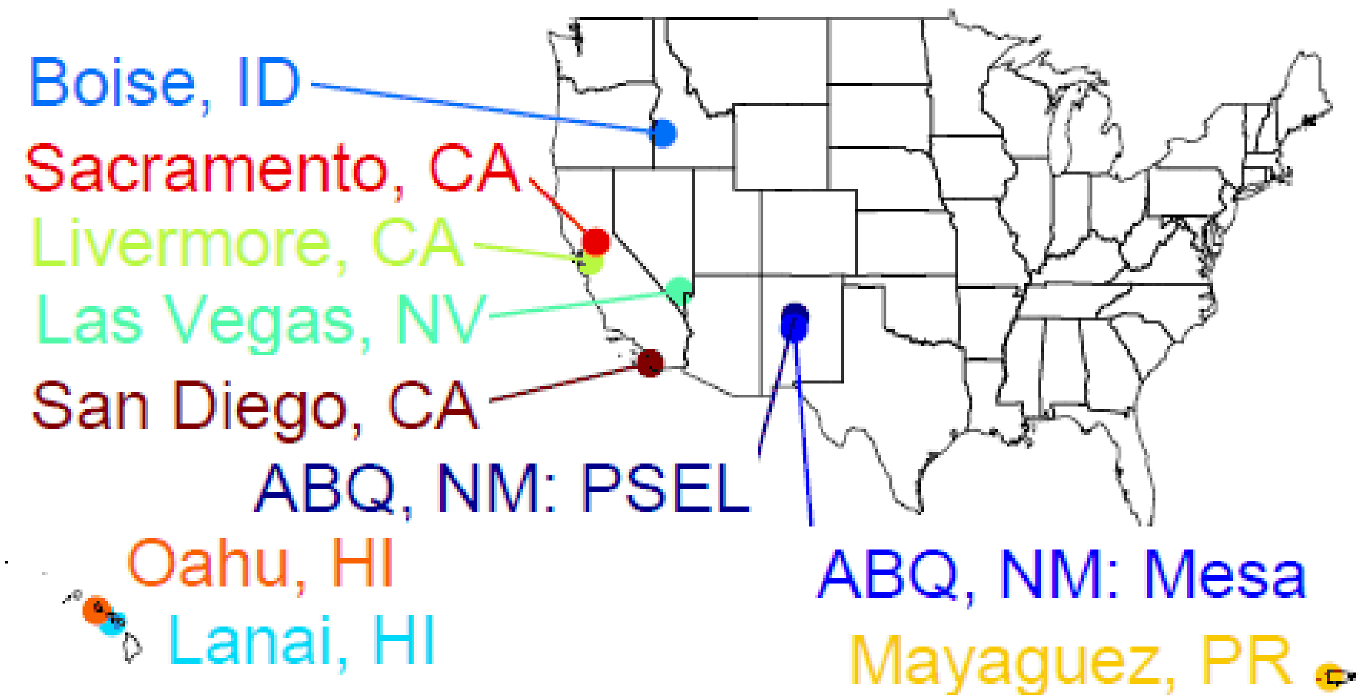
- Solar Integration National Dataset (SIND)
  - 30-minute to 1-minute
  - Based on 6 classes of cloud conditions (clear -> variable)
- 4-second algorithm
  - 1-minute to 4-second
  - Based on extension of Fourier decomposition.





Evaluation Dataset

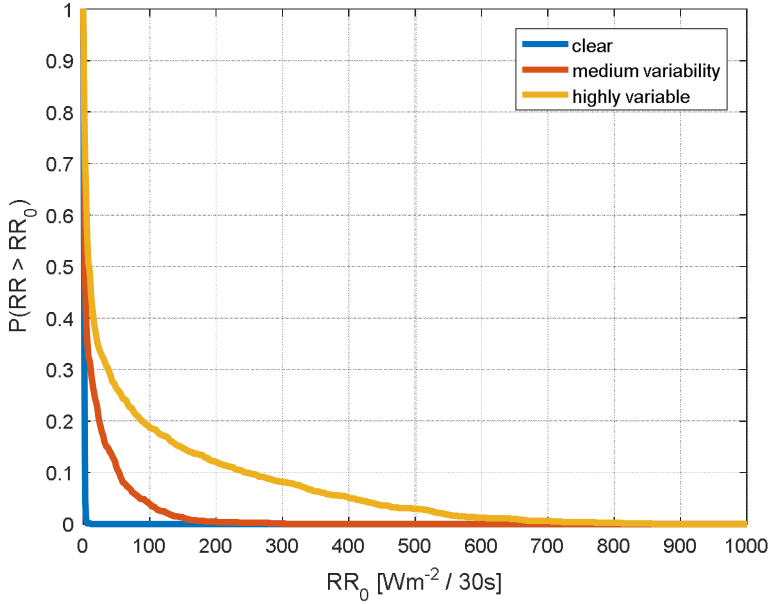
- Sandia has collected ground-based high-frequency irradiance samples at 10 different locations.
- All at 30-second or better temporal resolution.
- Approximately 1-year of data at each location.



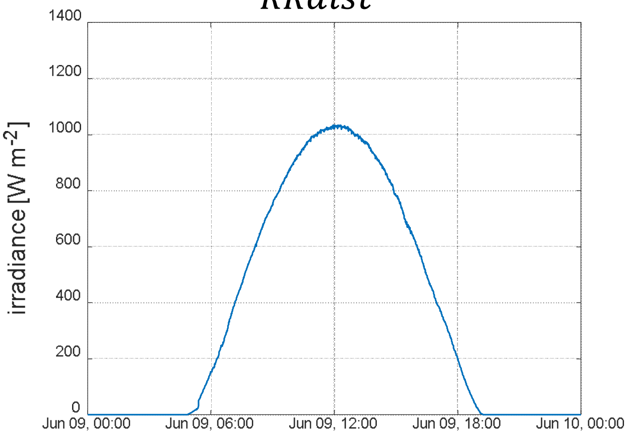
Variability Score

- Evaluation focuses on magnitude of variability rather than exact timestamps of ramps

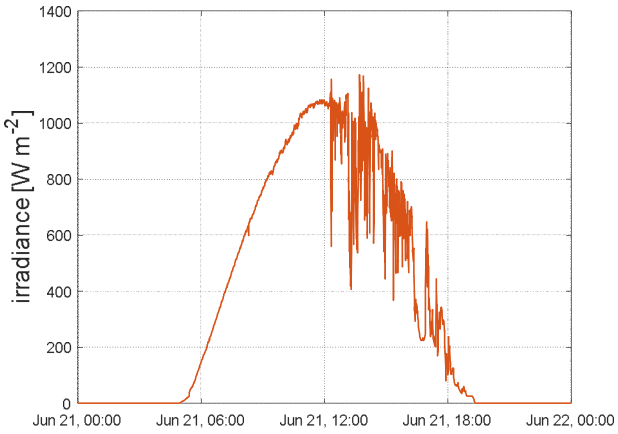
- Variability Score (VS)
  - $VS_{RRdist} =$
    $100 \times \max[RR_0 \times P(|RR| > RR_0)]$



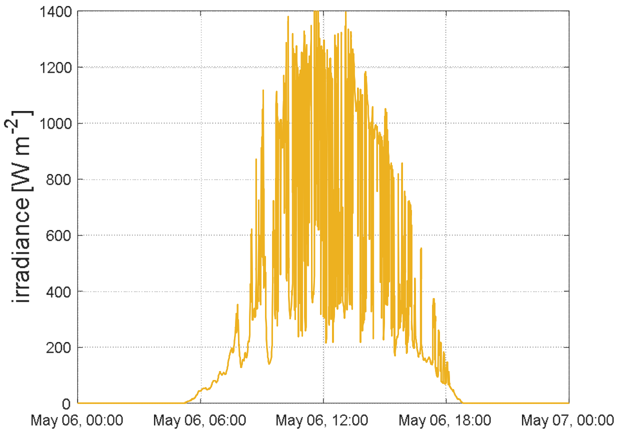
$VS_{RRdist}^{30s} = 6$



$VS_{RRdist}^{30s} = 58$

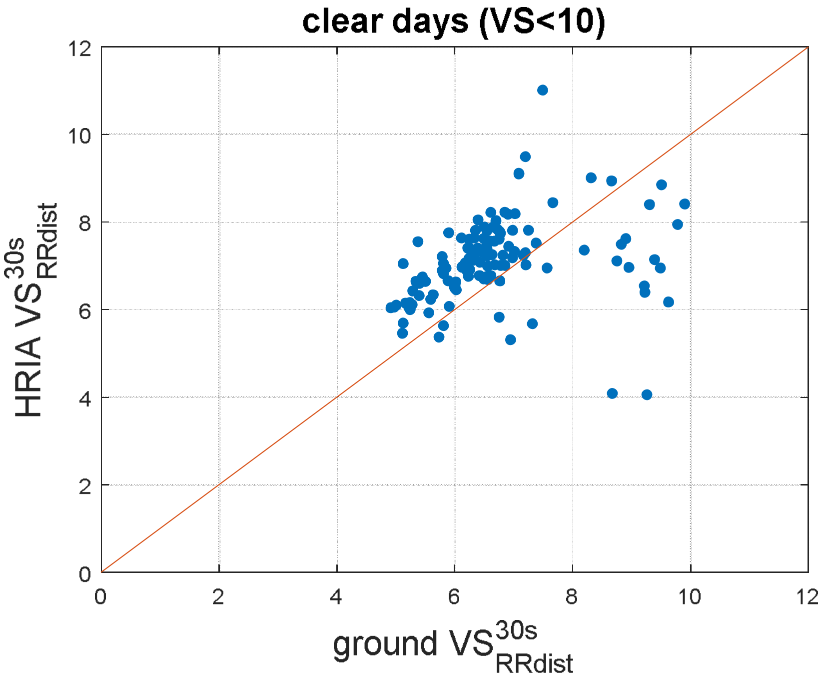


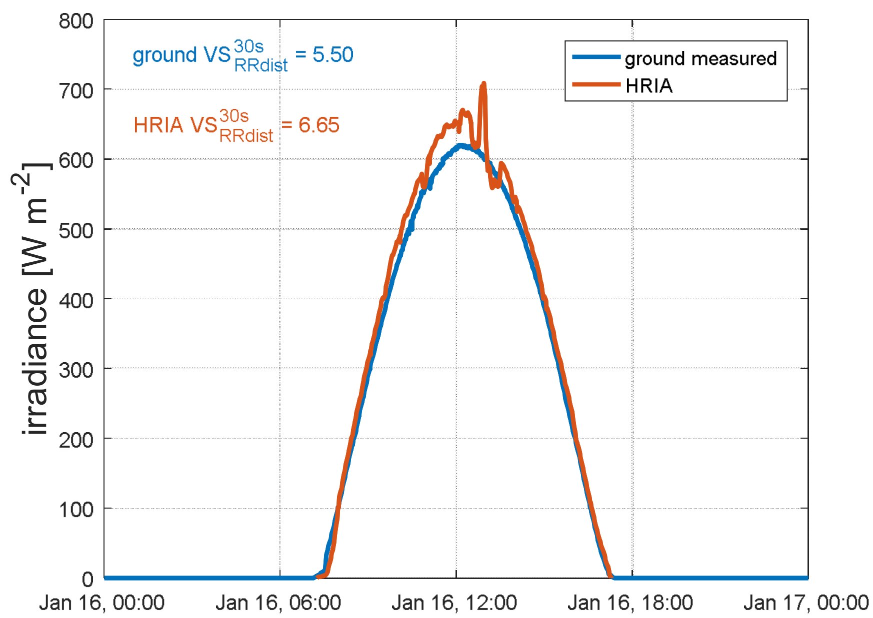
$VS_{RRdist}^{30s} = 249$



Results: Clear Days

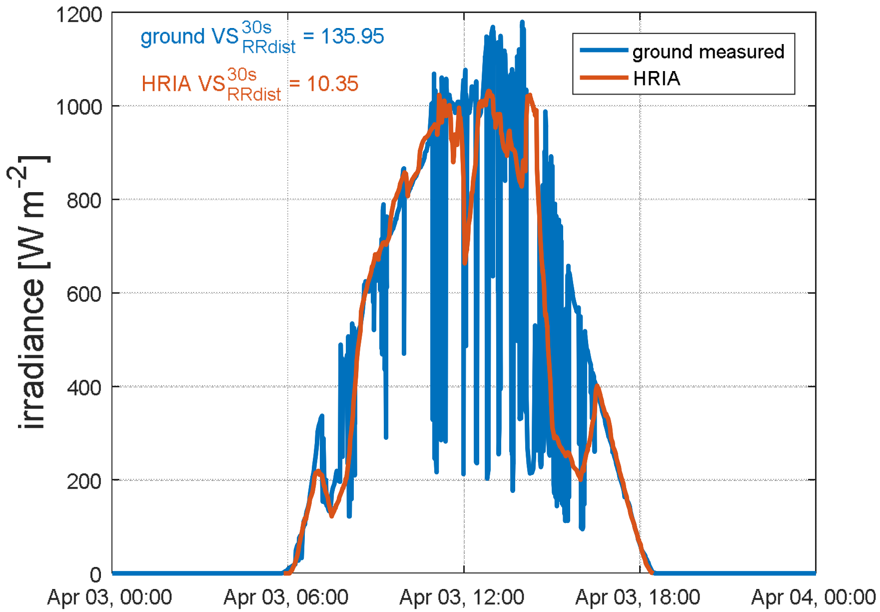
- HRIA generally matches ground clear days
- Slight overestimation of clear day variability
  - Due to periods of variability in otherwise clear days

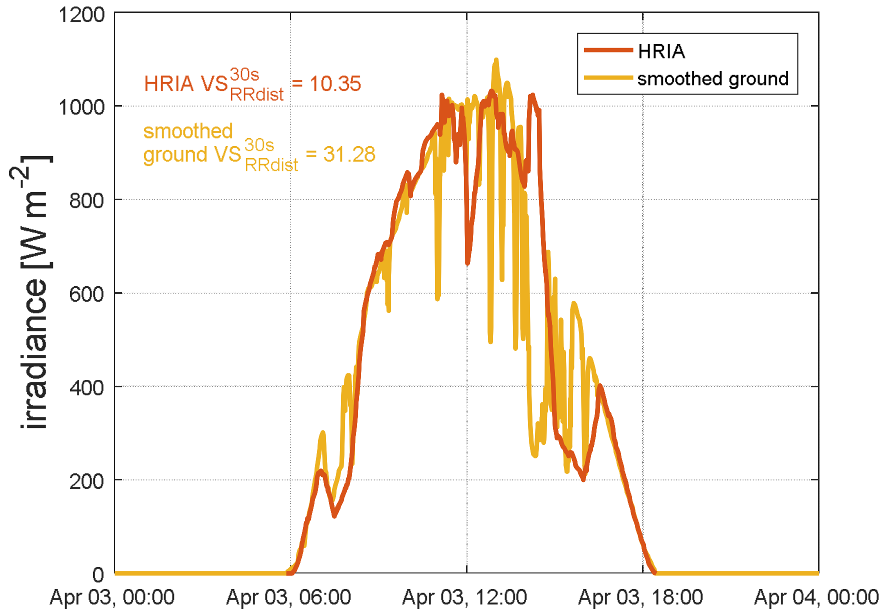




Results: Variable Day

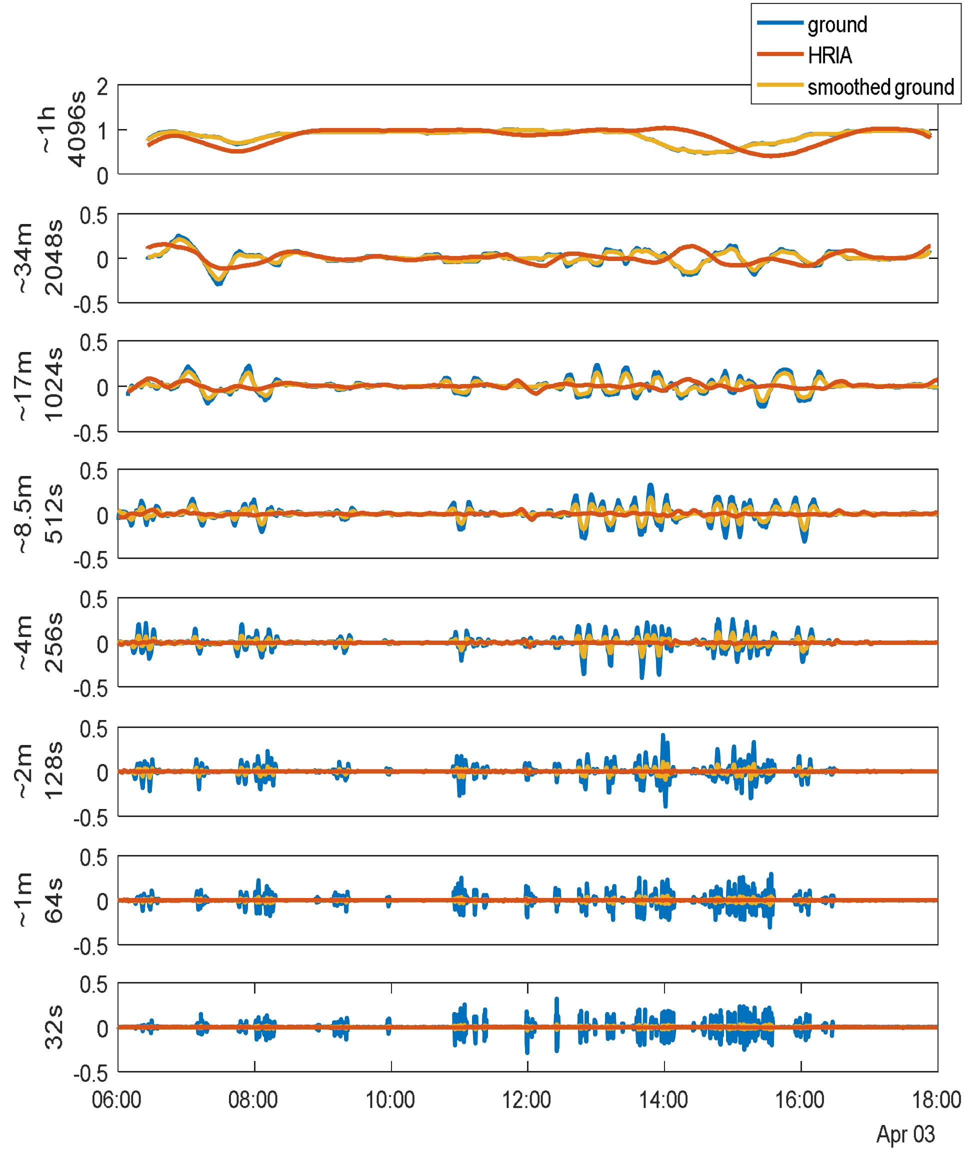
- HRIA underestimates variability on partly cloudy days
- On this example day, HRIA predicts much smaller variability than the ground irradiance point sensor
- HRIA is closer to a smoothed ground sample
  - Smoothed based on distance between 18 irradiance sensors in Oahu (on which 4-second algorithm was calibrated).





Results: Variable Day Timescale

- If HRIA doesn't match ground measured variability, may be due either to SIND (1-minute) or 4-second algorithm
- Used a wavelet transform to examine fluctuations at various timescales on the variable day
- HRIA matches at 34m timescale, but not at shorter timescales
  - SIND may be underestimating variability



Conclusions and Suggested Modifications

- HRIA accurately identified clear days
  - May need modification to use clear-sky model to avoid adding variability on fully clear days
- HRIA can underestimate the variability on cloudy days
  - Ensure accurate spatial scaling of HRIA outputs to match desired simulation area (e.g., 30MW plant more smooth than 4kW).
  - Evaluate both SIND and 4-second algorithm performance to make sure they predict enough highly variable periods

- The ubiquitous availability of HRIA-derived high-frequency irradiance samples could drastically increase the number of high-frequency solar inputs available to grid integration studies.