The Wavelet Variability Model (WVM) for Simulating PV Powerplant Output

examining the *A* value for broader application of the WVM

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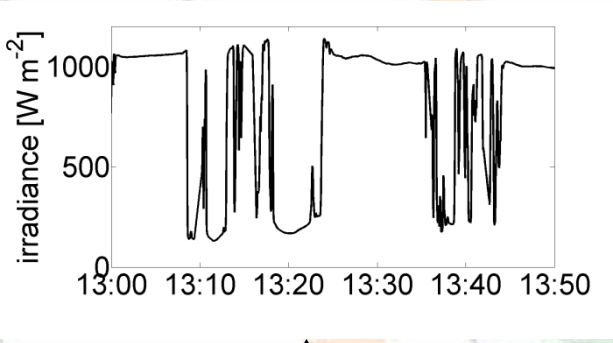
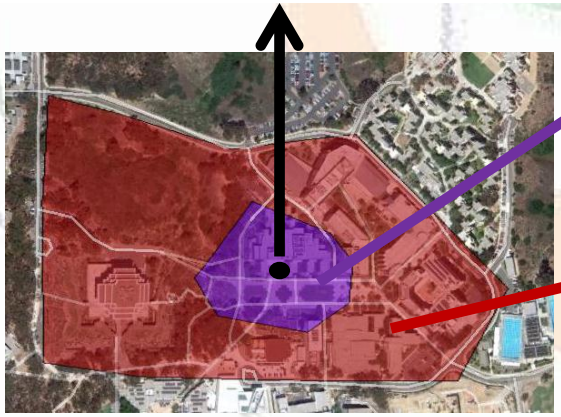
WORLD RENEWABLE ENERGY FORUM

Simulate PV Plants

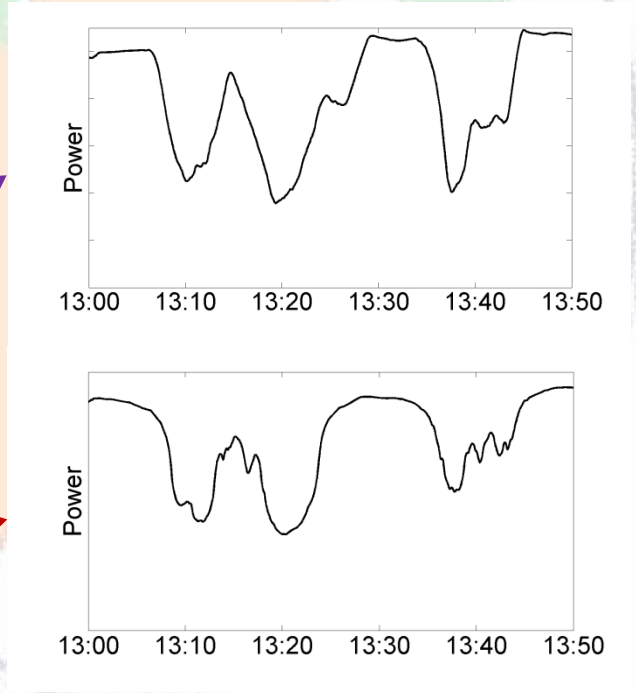
- For feeder studies, we would like to simulate PV plant output profiles.
- Geographic diversity will lead to a smoother plant output than point sensor.

point sensor





central plant

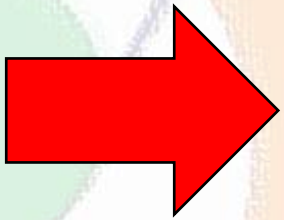


distributed plant

Wavelet Variability Model (WVM)

WVM Inputs

- PV Plant Footprint
- Density of PV
- Point Sensor Timeseries
- Location/Day Dependent "A" Coefficient



determine variability reduction (smoothing) at each wavelet timescale

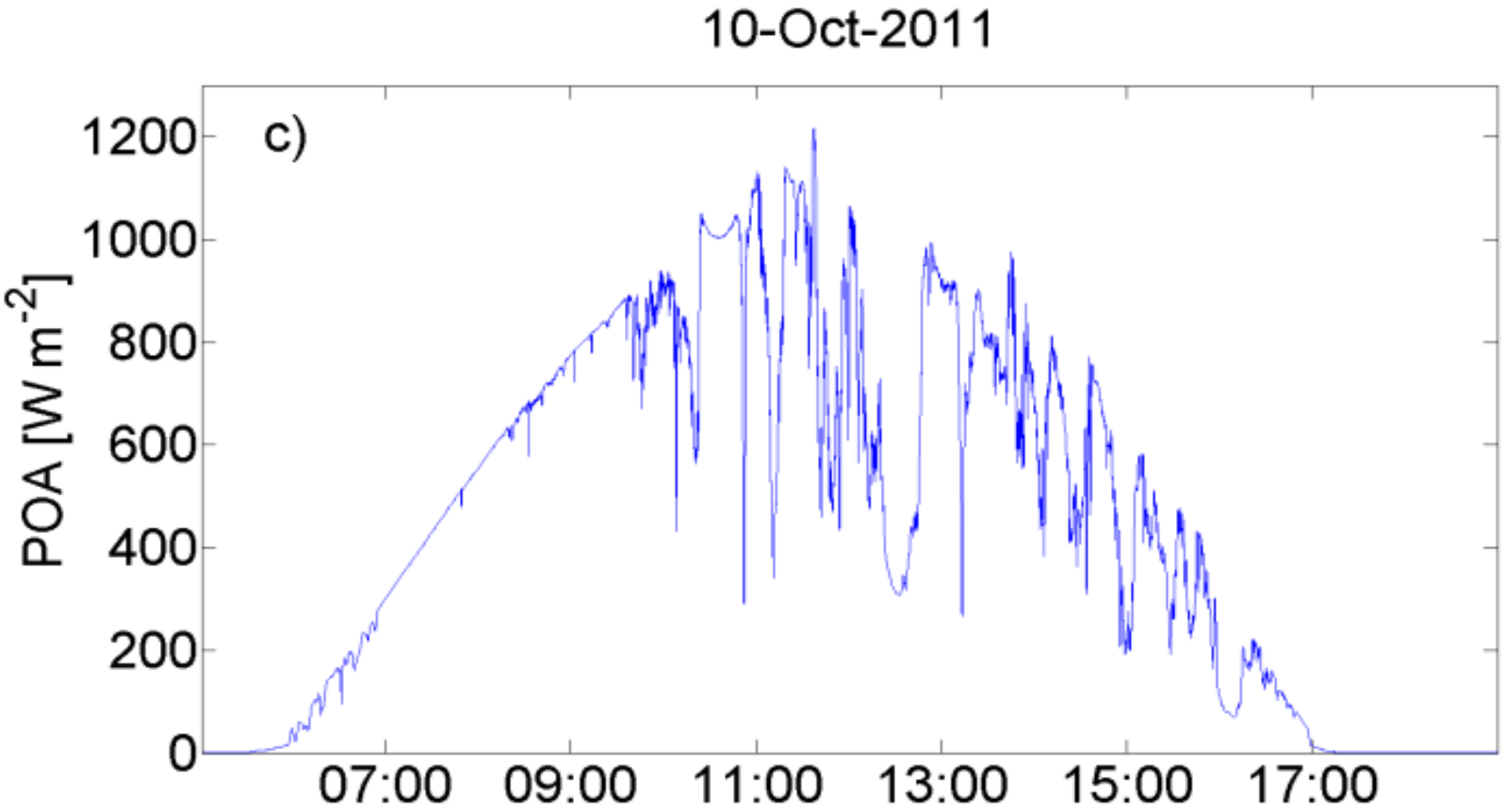
WVM Outputs

Plant Areal Average Irradiance

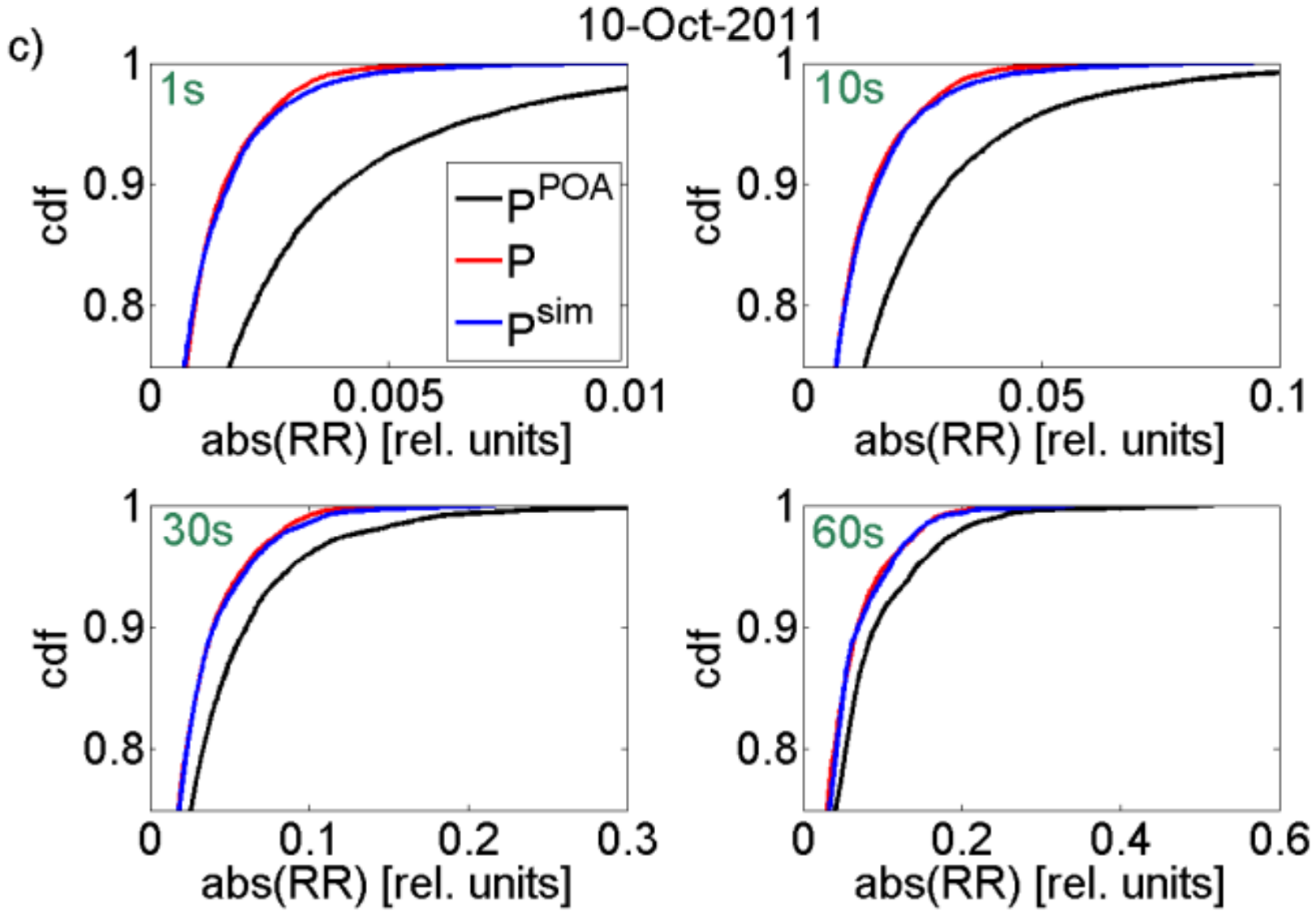
irradiance to power model

Plant Power Output

Test WVM at Copper Mountain



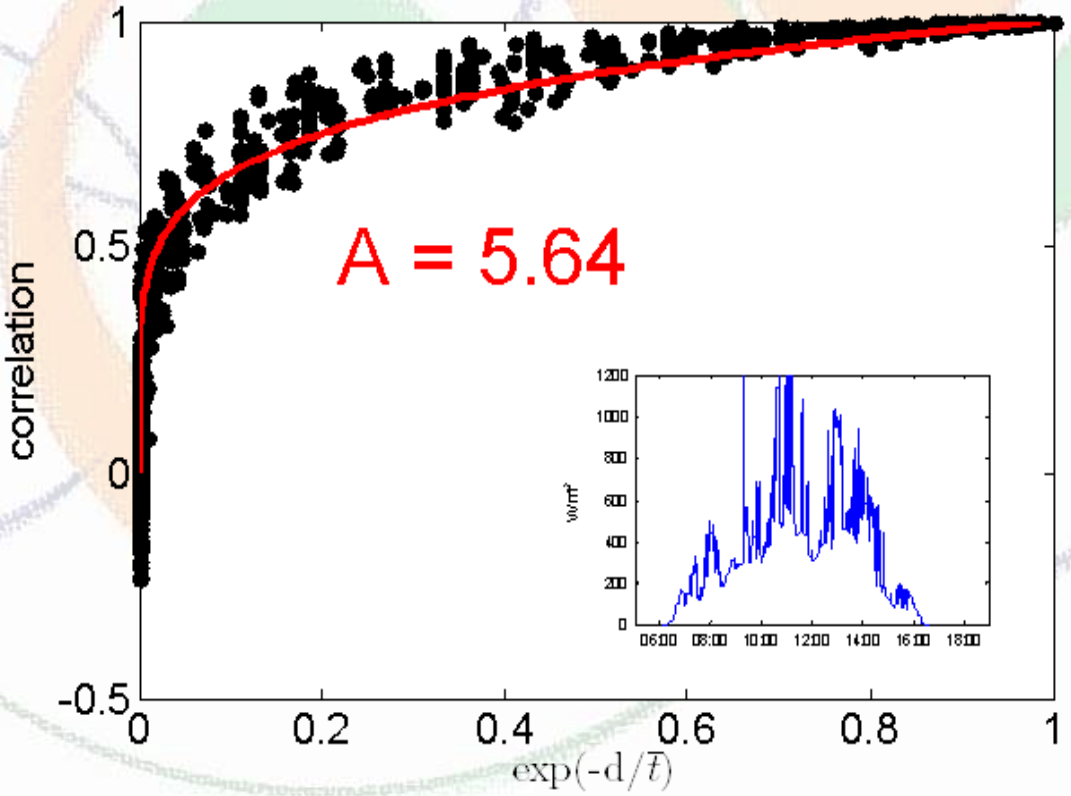
WVM RR Comparison



A value

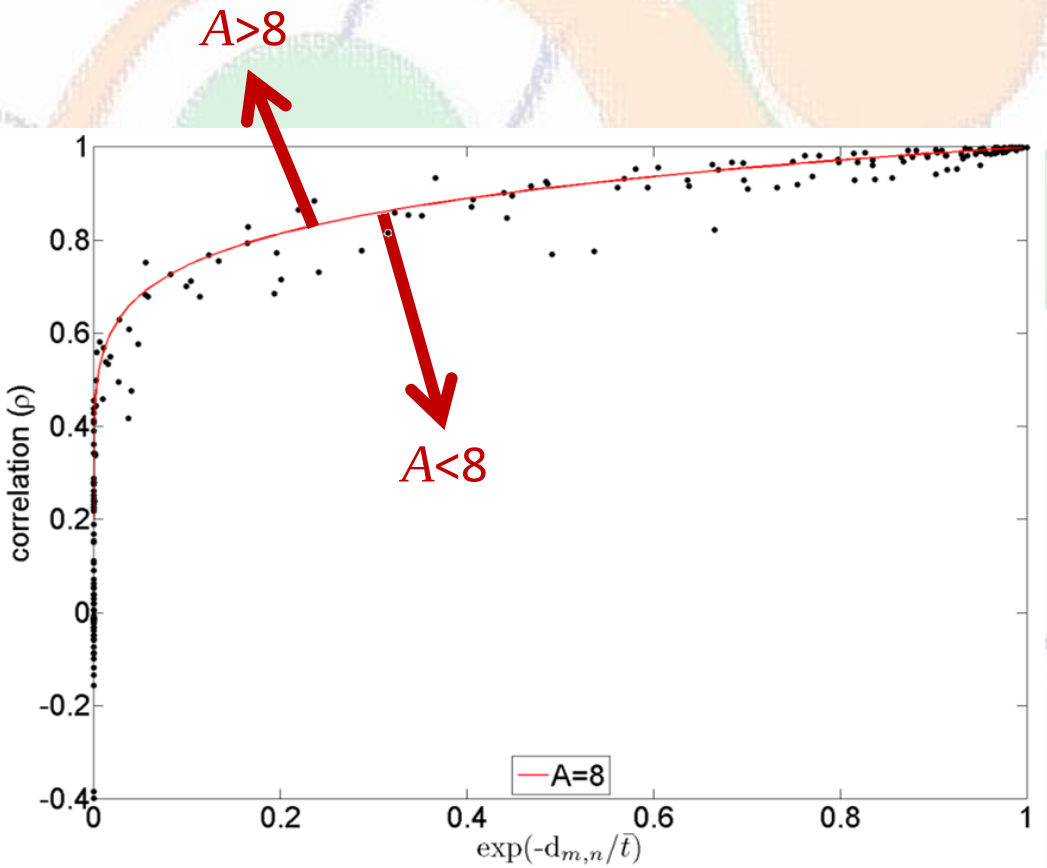
- WVM works well, but needs location/day dependent A value.

$$\rho\left(d_{m,n}, \bar{t}\right) = \exp\left(-\frac{1}{A}\frac{d_{m,n}}{\bar{t}}\right)$$



What do we know about the *A* value?

- Has units of [m/s].
- Larger *A*: higher correlations so less geographic diversity.
- *A* values typically larger inland than at coastal sites.



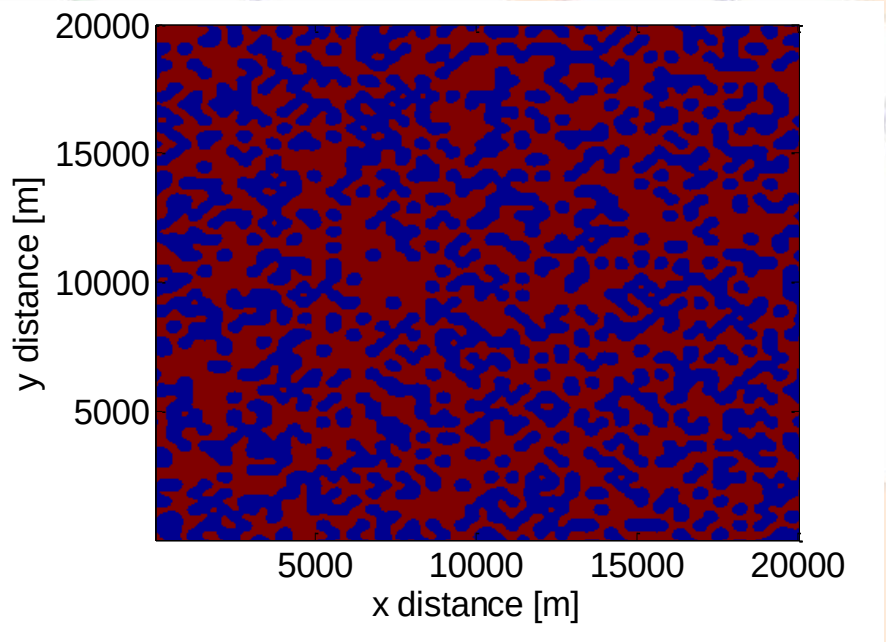
How to determine *A* value?

- Currently, the *A* value is derived from a sensor network.
  - requires ~4-6 sensors.

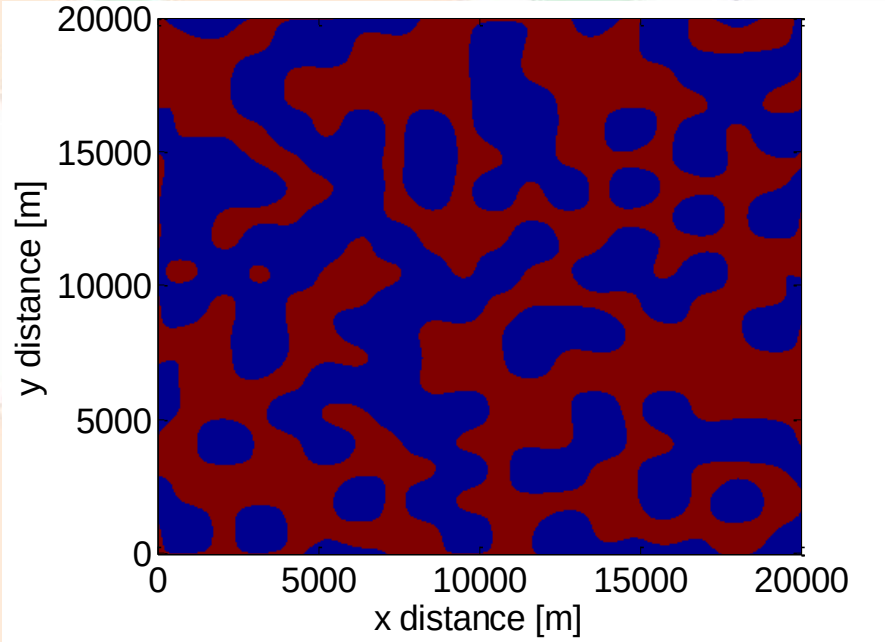
- For broader application of the WVM, need a way to estimate A value for locations without a sensor network.

How to determine *A* value?

- To test the dependence of the *A* value on cloud speed and cloud size, we created a simple cloud field simulator.



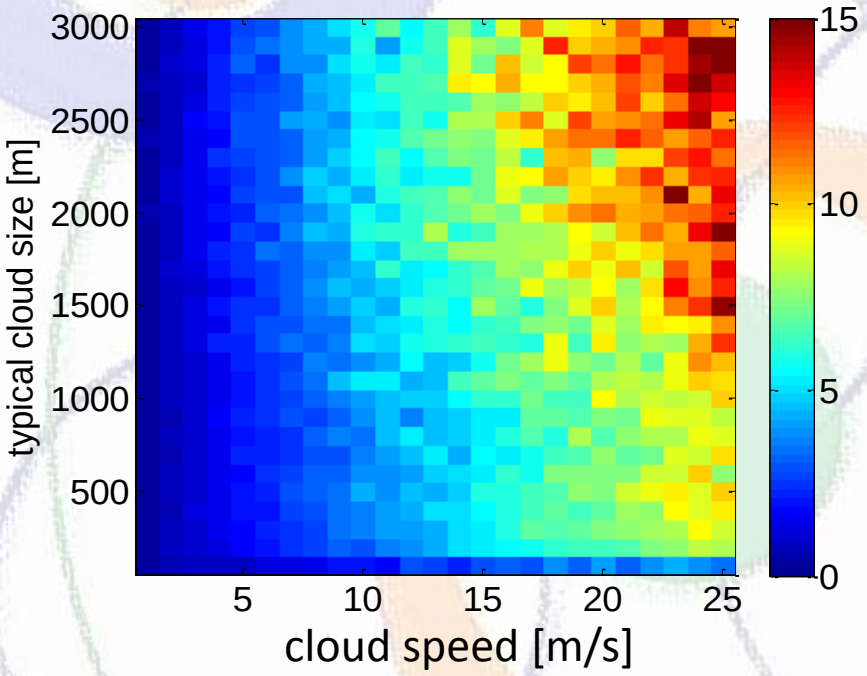
300m cloud size



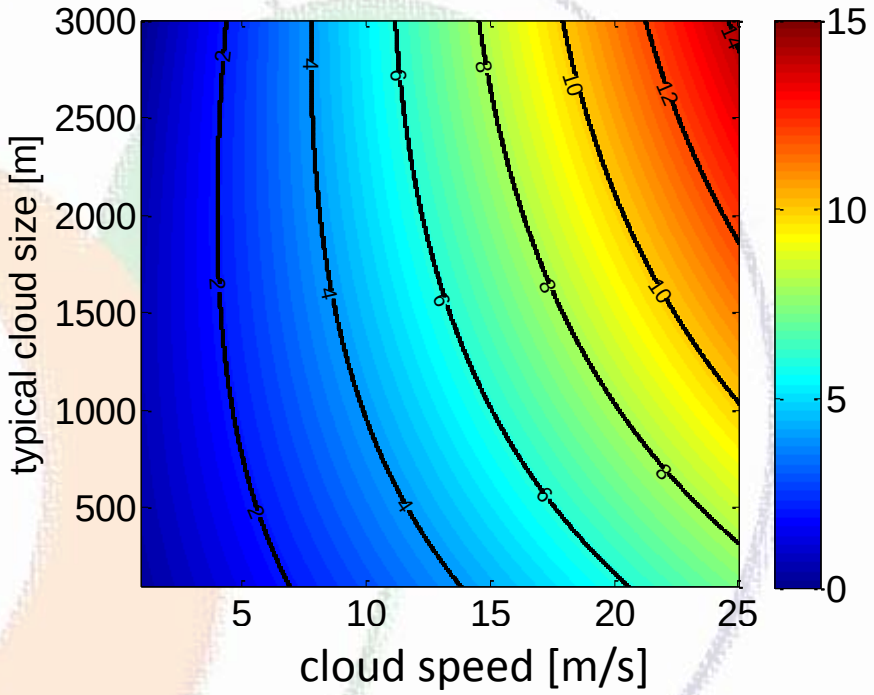
1000m cloud size

Results of Cloud Field Simulation

A values found at each wind speed and cloud size

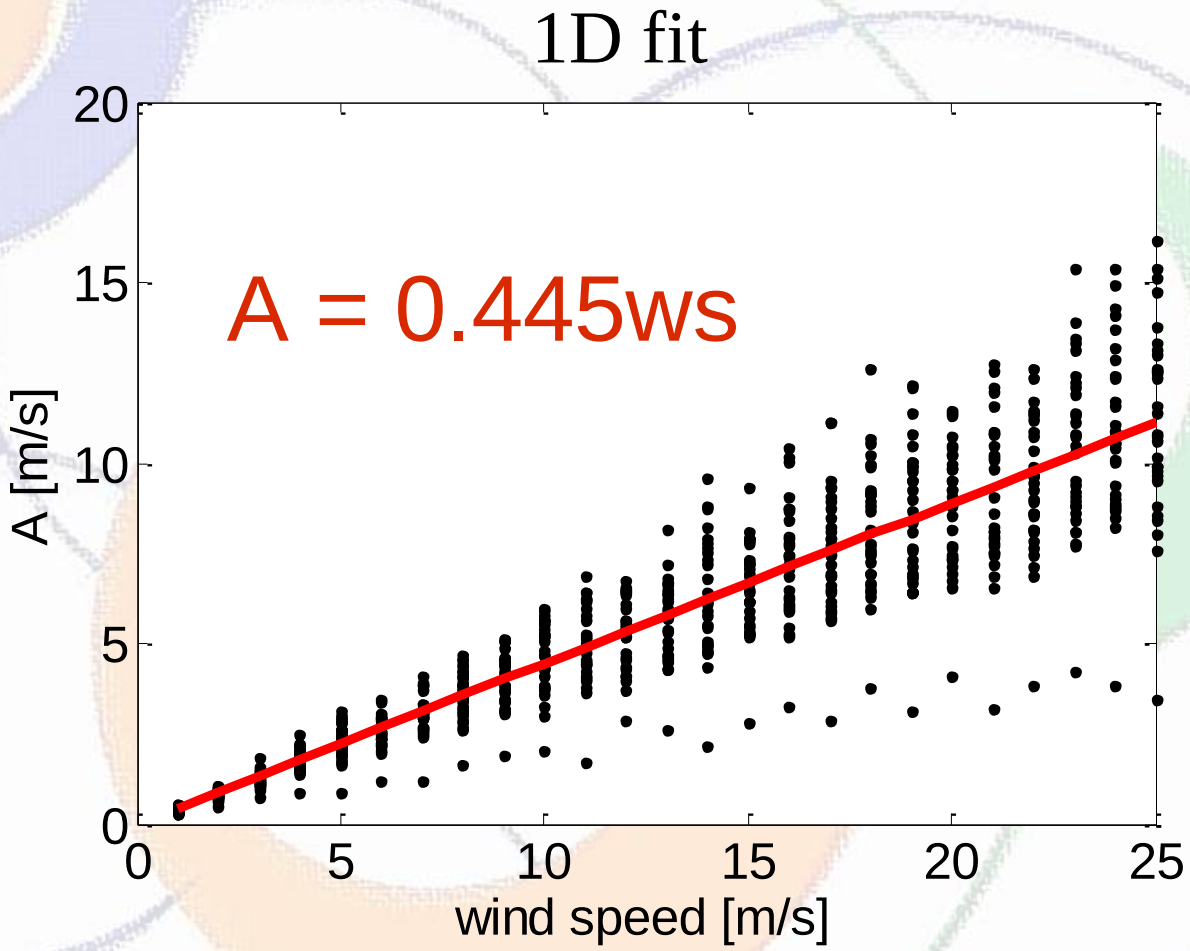


2D fit



- *A* values found to increase with both increasing wind speed and increasing typical cloud size.

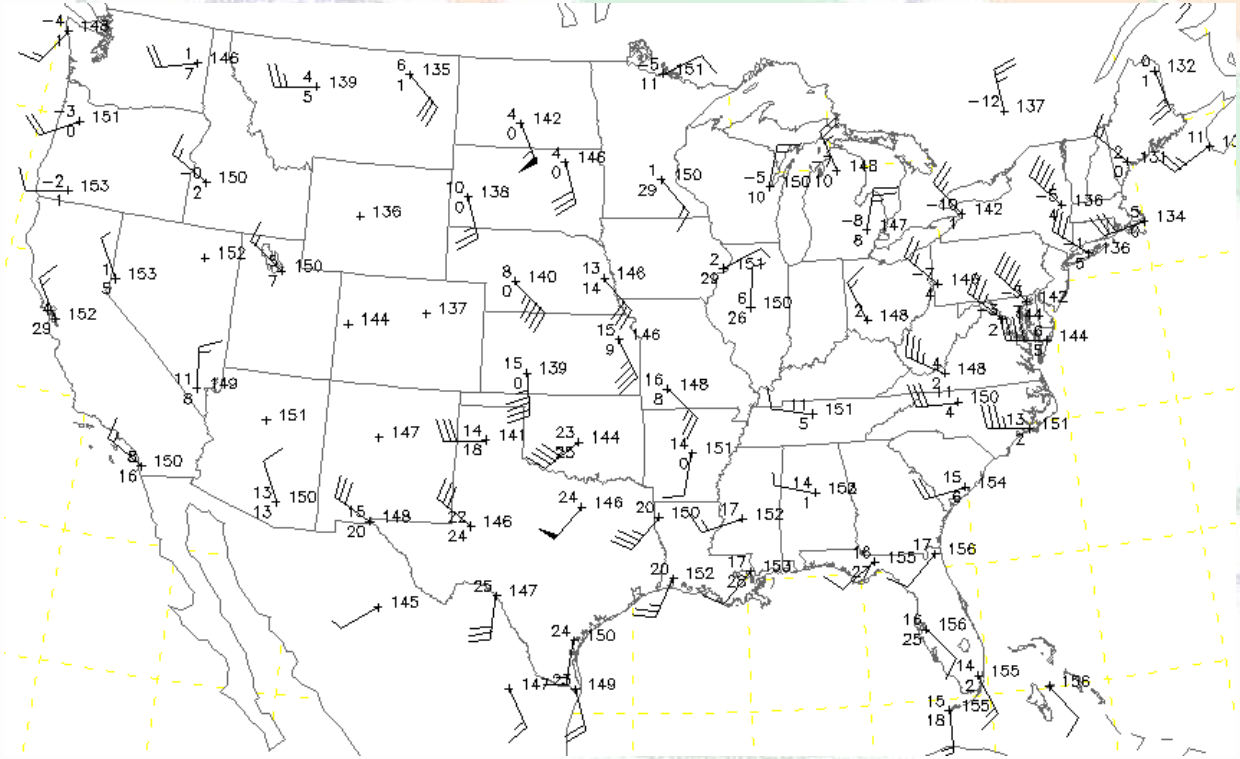
Results of Cloud Field Simulation



- Found a nearly linear relationship between *A* value and wind speed.

A value and Wind Speed

- Does this linear relationship between cloud speed and *A* hold up in real life?
- Hard to test.
- Cloud speed can be very difficult to obtain.
  - Measurements of winds aloft and cloud heights are sparse.



Real World Test

A values from UCSD, cloud speeds and heights from Miramar (NKX)

Very fast moving clouds (T-storms inbound)

Apr. 25, 5PM (2400Z)

Clouds: 7000-10000ft (2100-3000m)

Wind: 32 knots (16.5 m/s) at 2760m

Predicted *A* value: 7.34

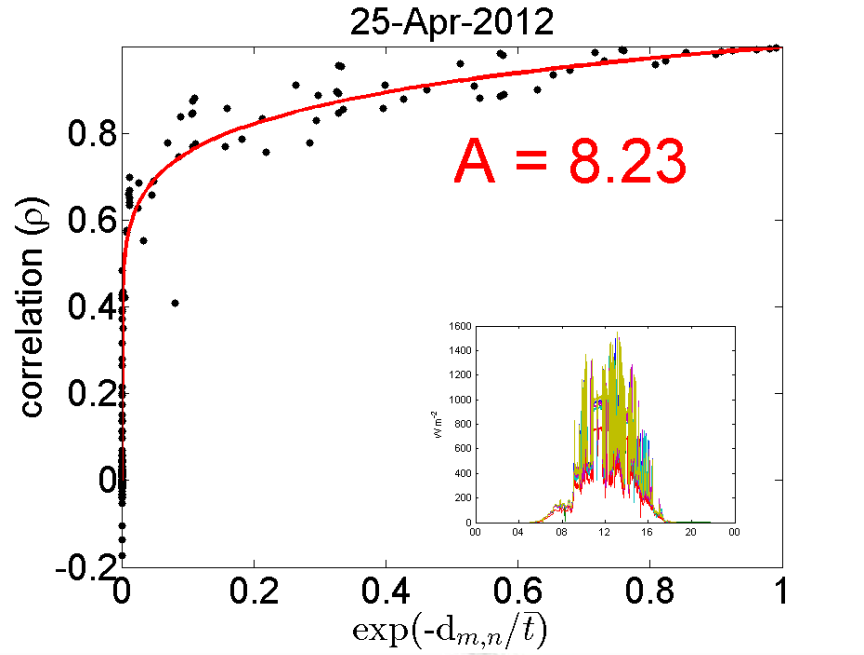
Slow moving clouds

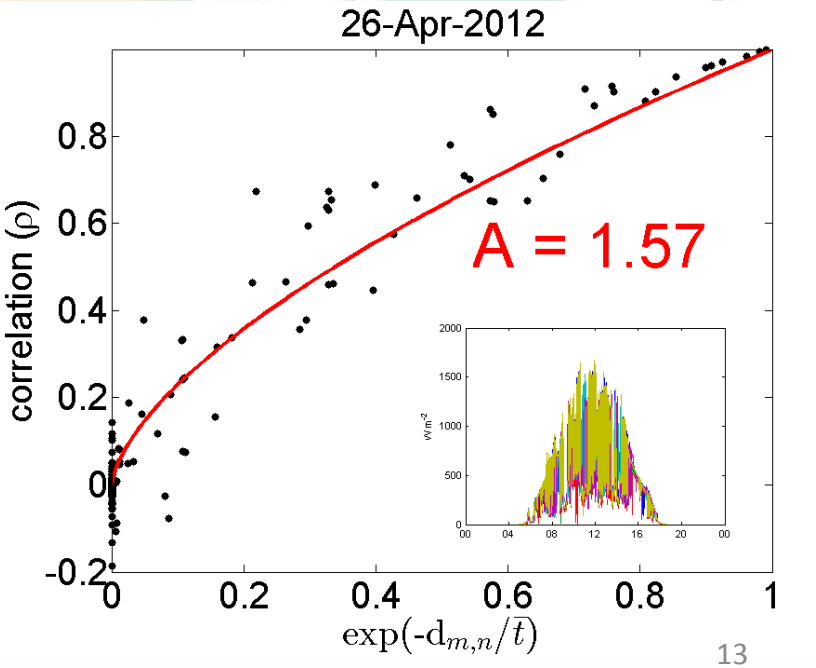
Apr. 26, 5PM (2400Z)

Clouds: 2700ft (823m)

Wind: 7 knots (3.6 m/s) at 811m

Predicted *A* value: 1.60





Summary

- WVM works well for simulating solar PV plants.
- WVM requires *A* value
  - Can be determined from sensor network.
  - Or can be estimated based on cloud speed.

Thank you!

- Thanks to Jan Kleissl, Josh Stein, Abe Ellis, and Matt Reno for their help and support in developing and testing the WVM.
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