

On Using Mesoscale Models for Solar Resource Modeling

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October, 2009

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Outline

- Background and motivation
- Mesoscale modeling status and challenges
- Mean solar patterns
- High-frequency fluctuations
- Next steps

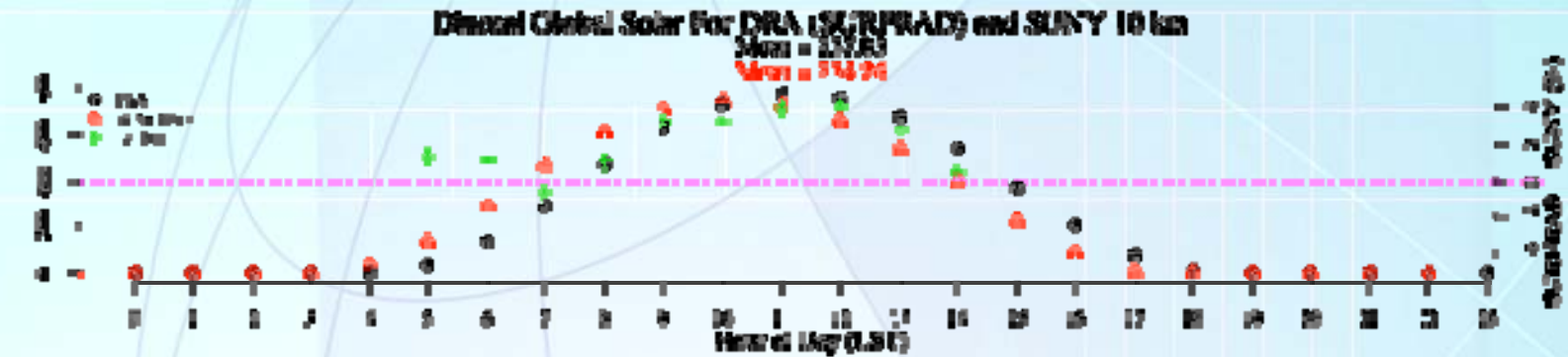


Background

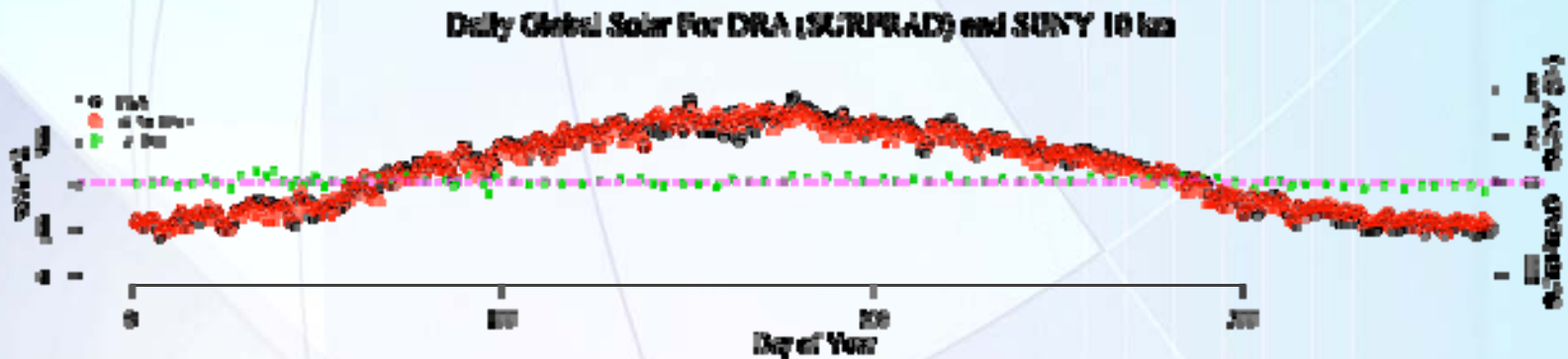
- NSRDB is currently the main nation-wide data set for solar resource assessment
- Based on a combination of
 - direct radiation measurements (1% of data)
 - cloud observations/METSTAT model
 - GOES satellite imagery/SUNY model
- Gridded data have 10 km resolution
- Time series in hourly intervals from 1991-1997 (METSTAT) and 1998-present (SUNY)
- Results compare well with direct observations

Desert Rock NV

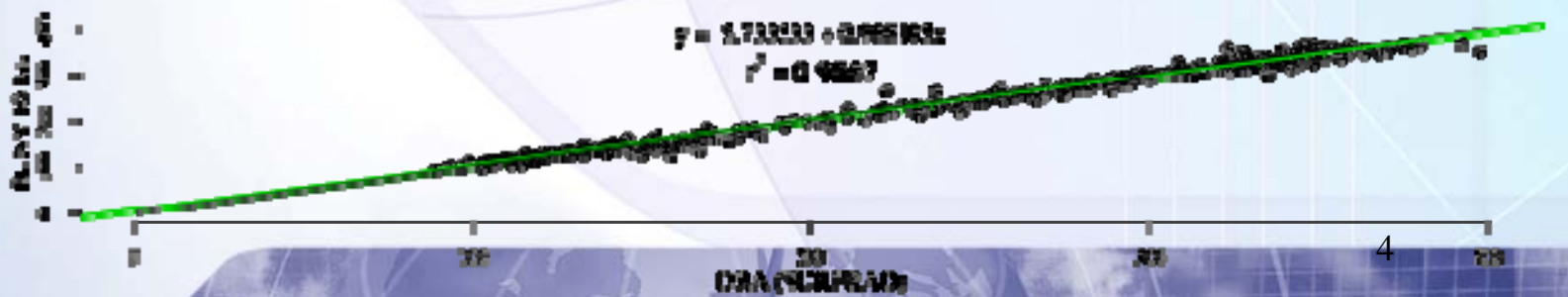
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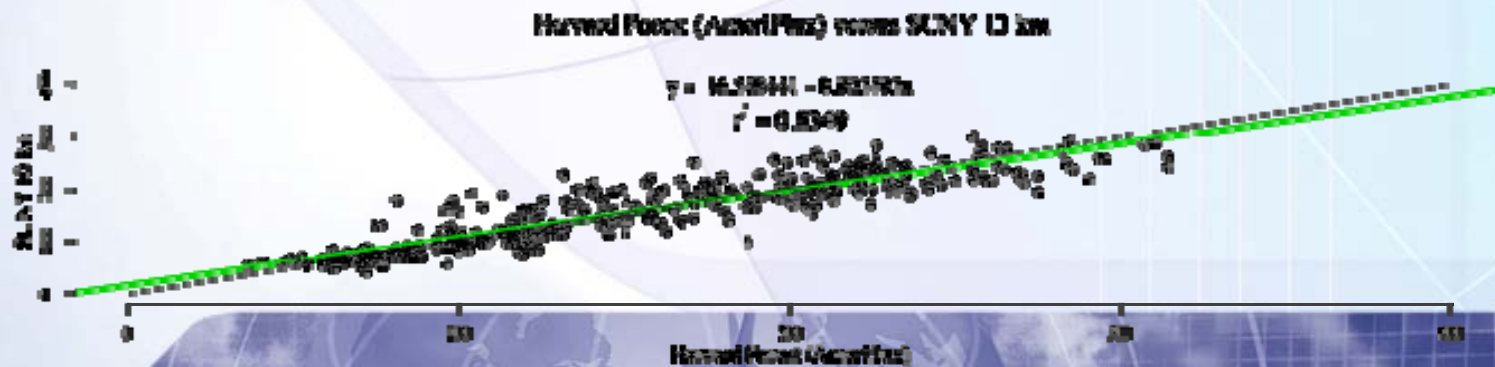
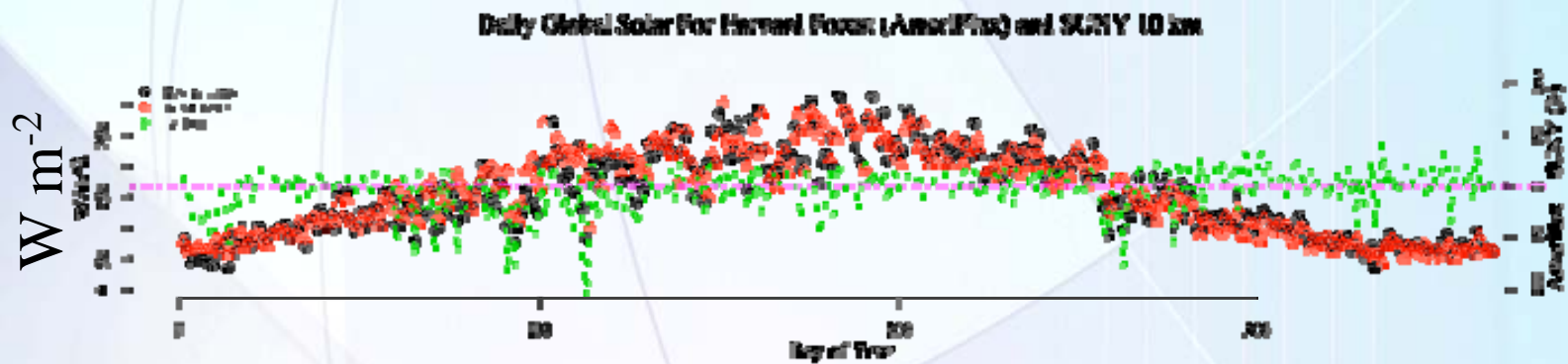
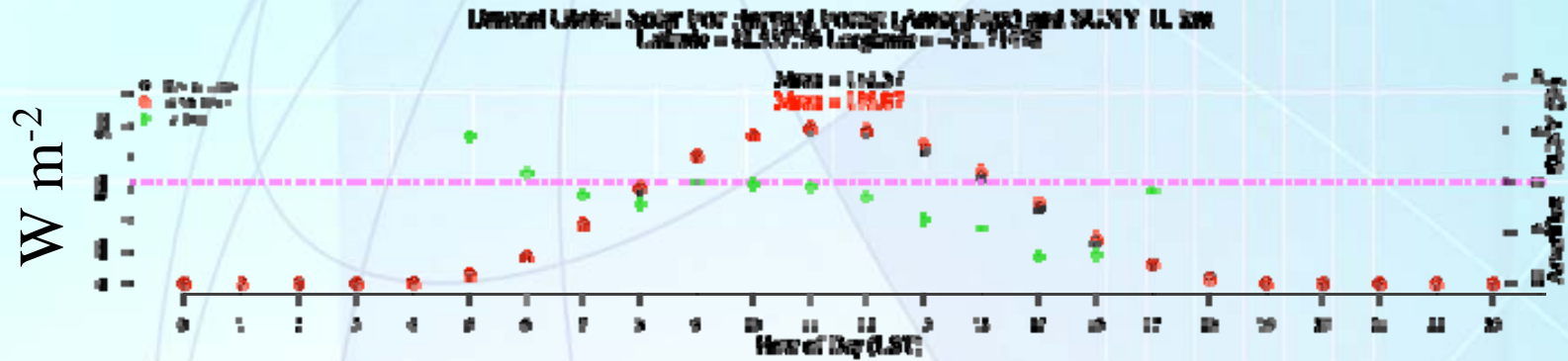
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LRA (SURPRAD) versus SUNY 10 km



Harvard Forest, MA



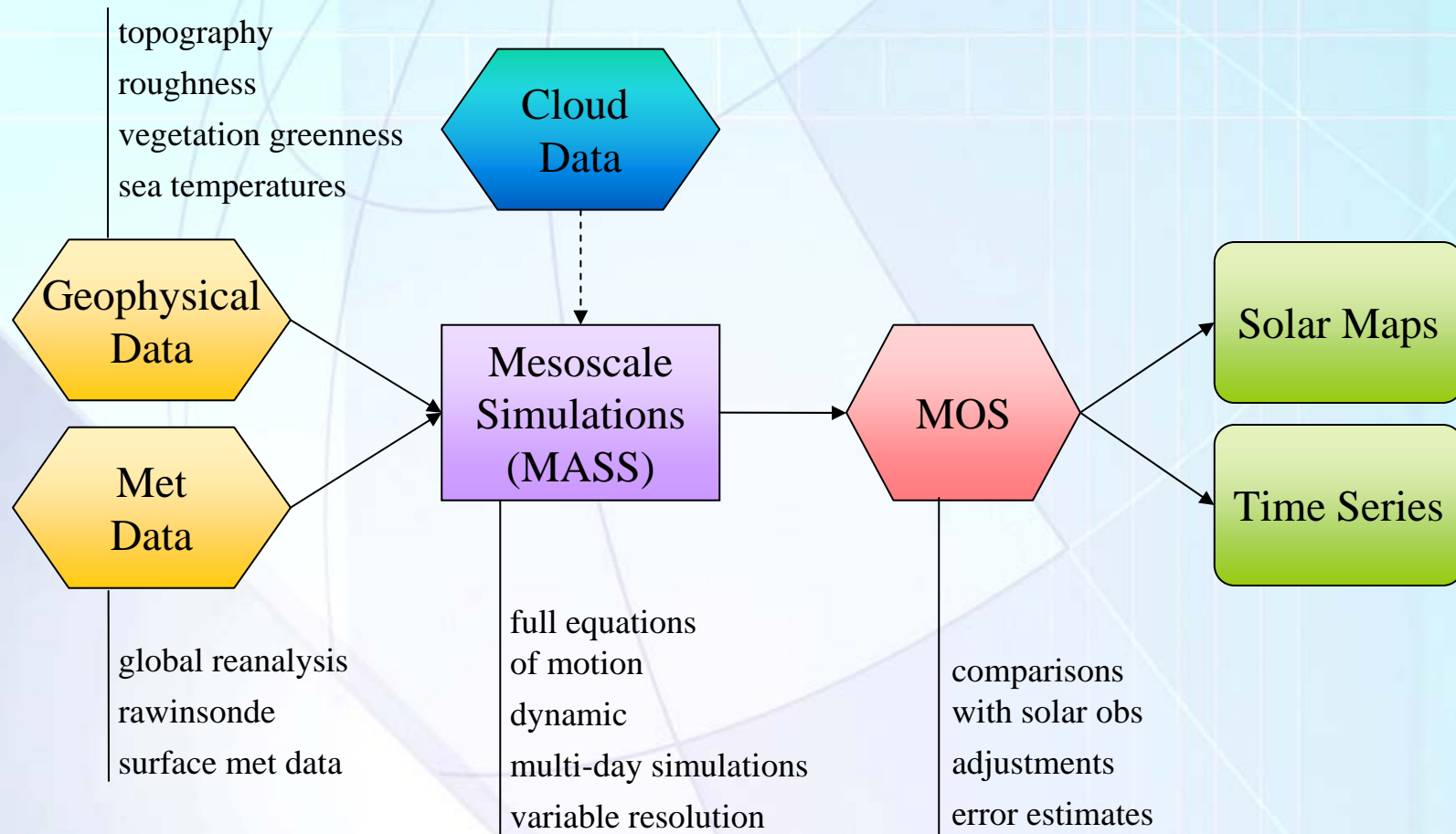
Why Consider Mesoscale Modeling?

- May be difficult to improve on SUNY model accuracy, but
- Would provide additional flexibility with respect to
 - Period of record (pre-1991)
 - Spatial resolution (down to hundreds of meters)
 - Temporal resolution (minutes)
 - Geographic regions (any area of globe may be modeled)
- Easily integrated with mesoscale-model-based wind resource mapping
- Essential for real-time solar forecasting
 - May employ satellite data to improve initial conditions

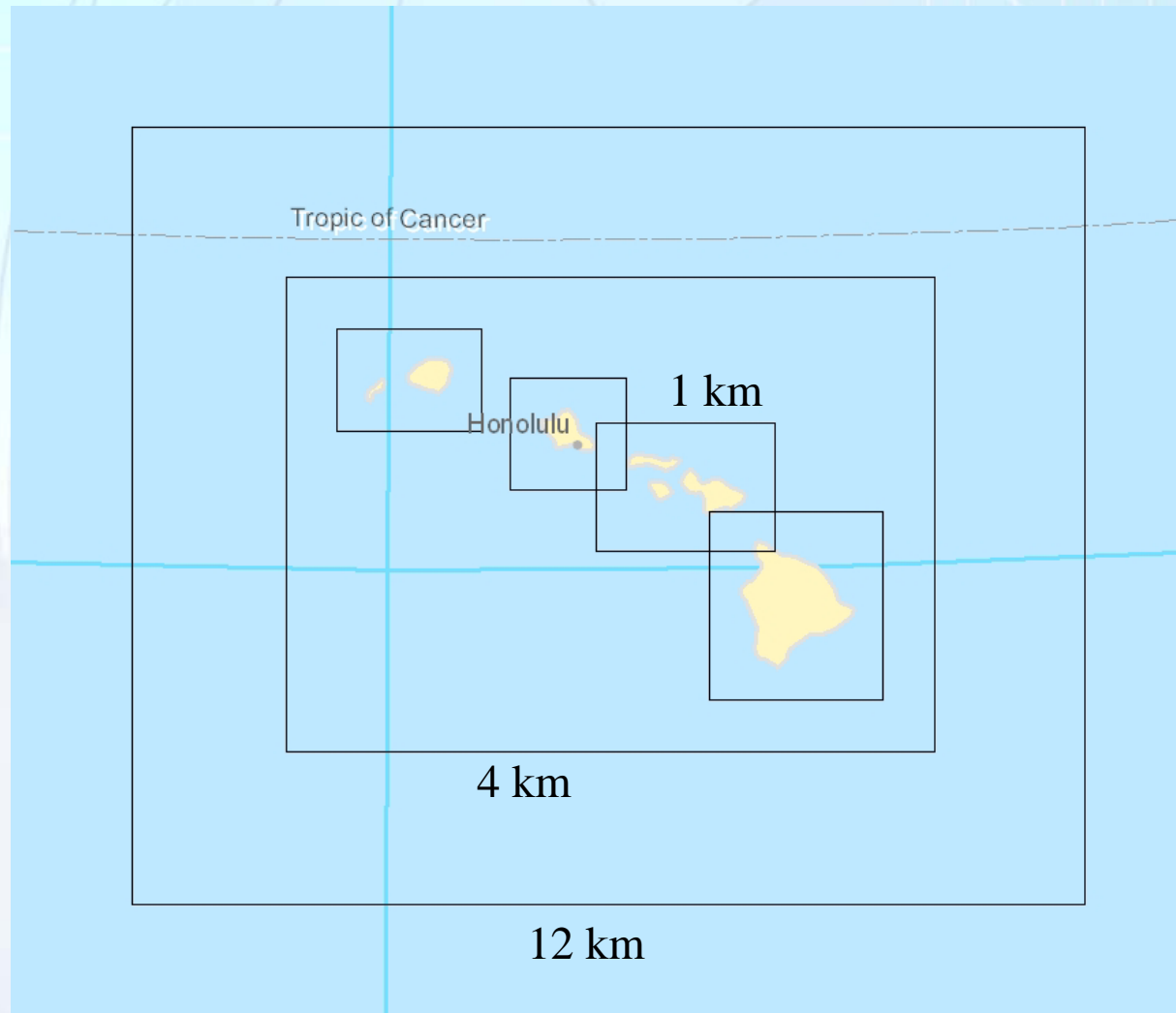
Status and Challenges

- Mesoscale modeling not commonly used for solar resource assessment
 - But there is a precedent for wind (e.g., EWITS, WWSIS)
- Accuracy of technique for solar not yet proven
 - Critical challenge: clouds
- High temporal resolution requires high spatial resolution = large CPU time

Mesoscale Modeling Process

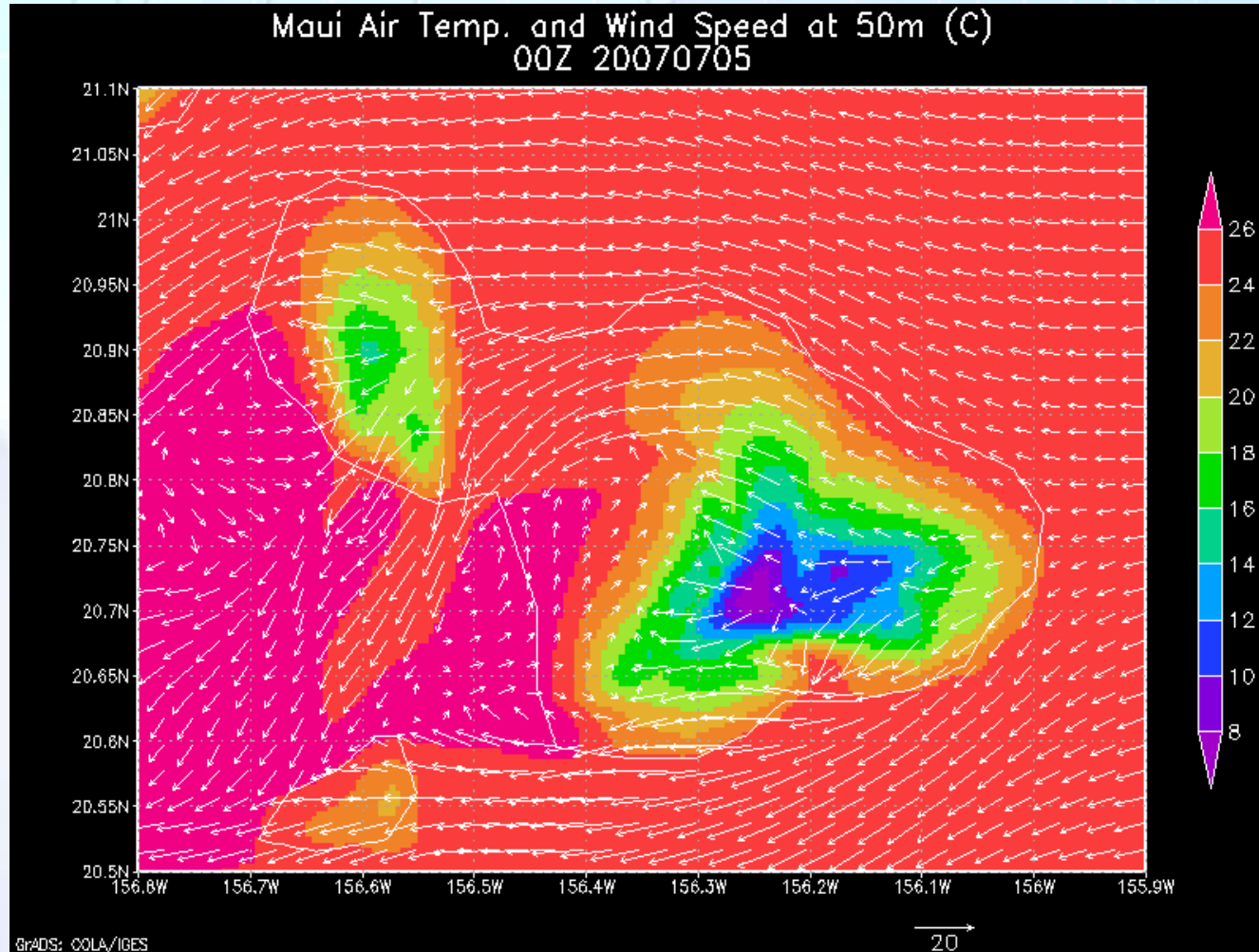


Nested Grids



Simulaton Snapshot

Wind Vectors and Temperatures

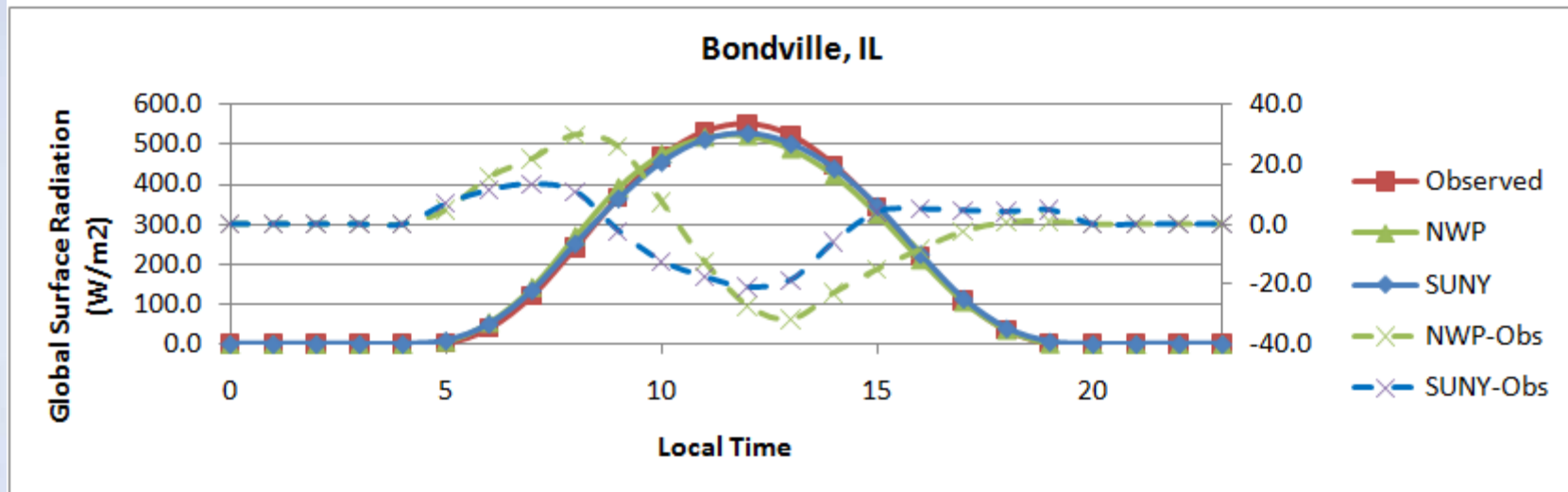
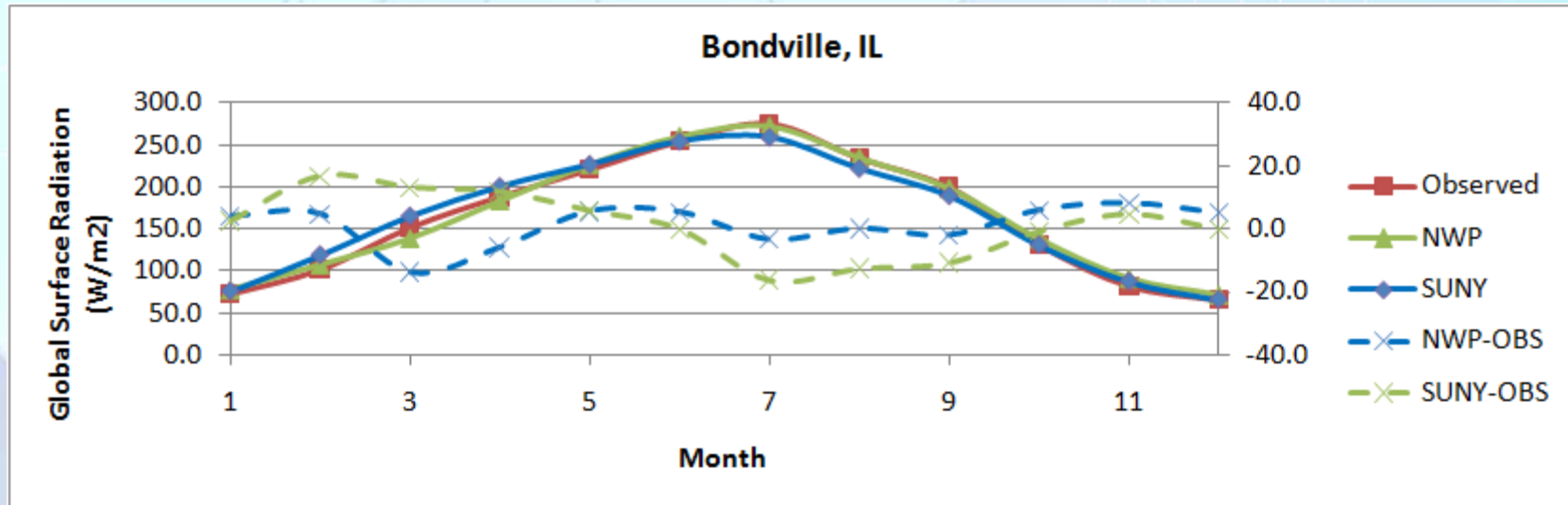


Preliminary Tests Using AWST windTrends Dataset

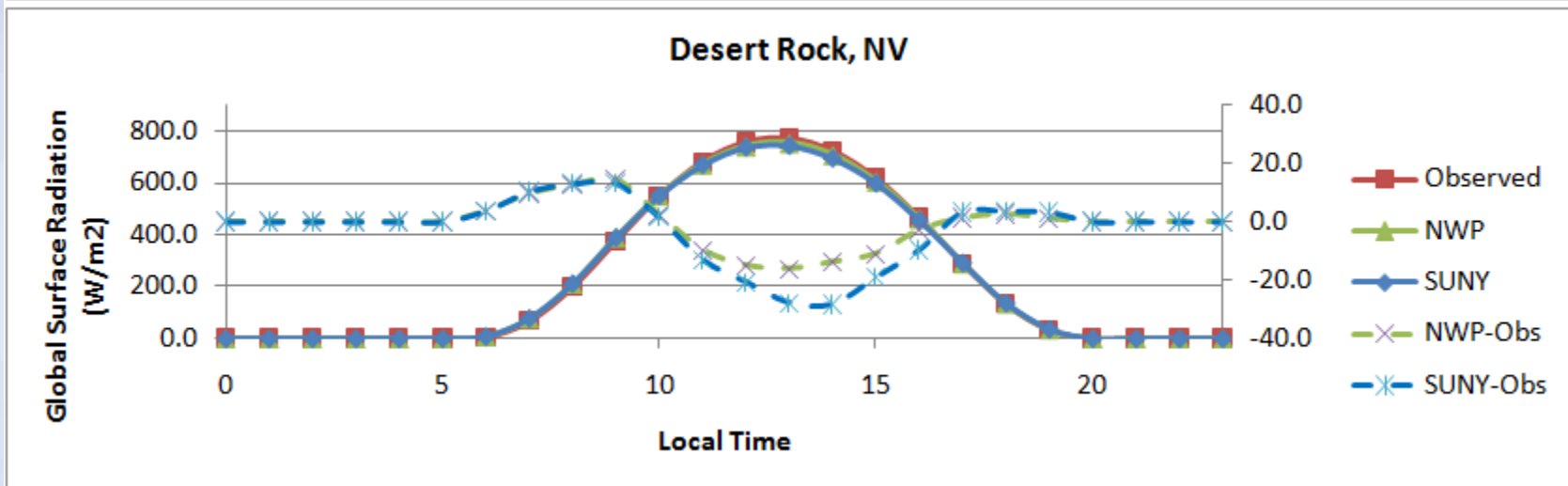
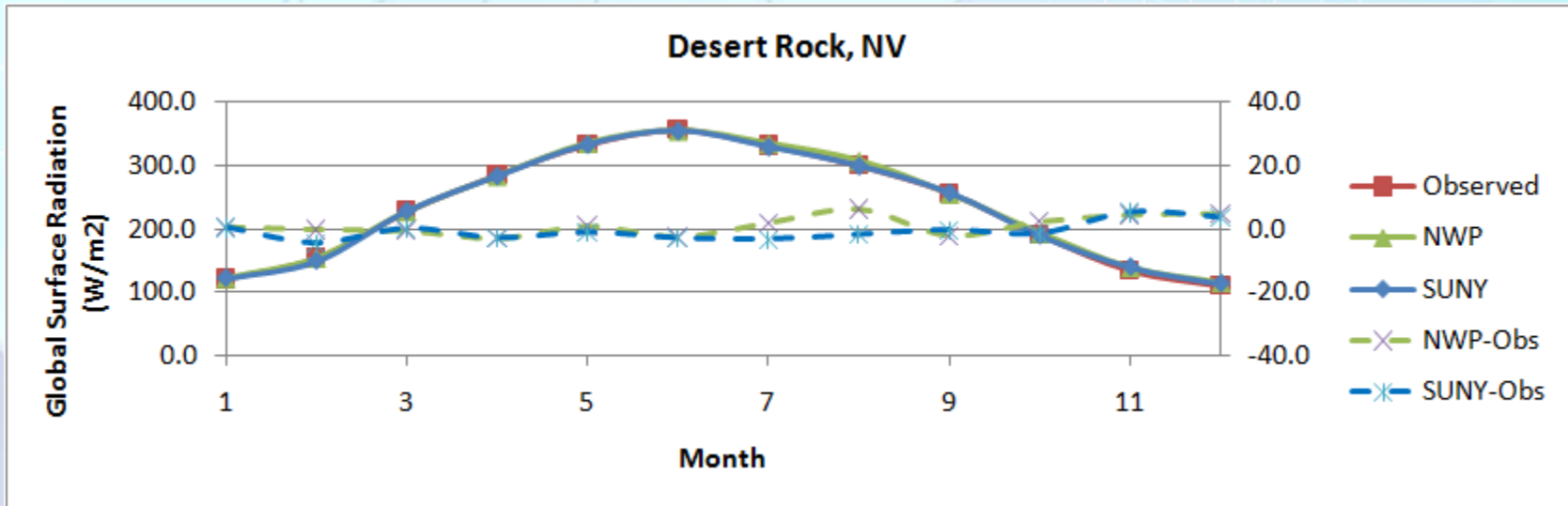


- Mesoscale simulations covering North America
- “Controlled reanalysis”
 - Assimilates only rawinsonde data at fixed heights
- 1997-present
- 20-km spatial, 1-hour temporal resolution
- Performed MOS to solar observations
(validation data not included in training data)

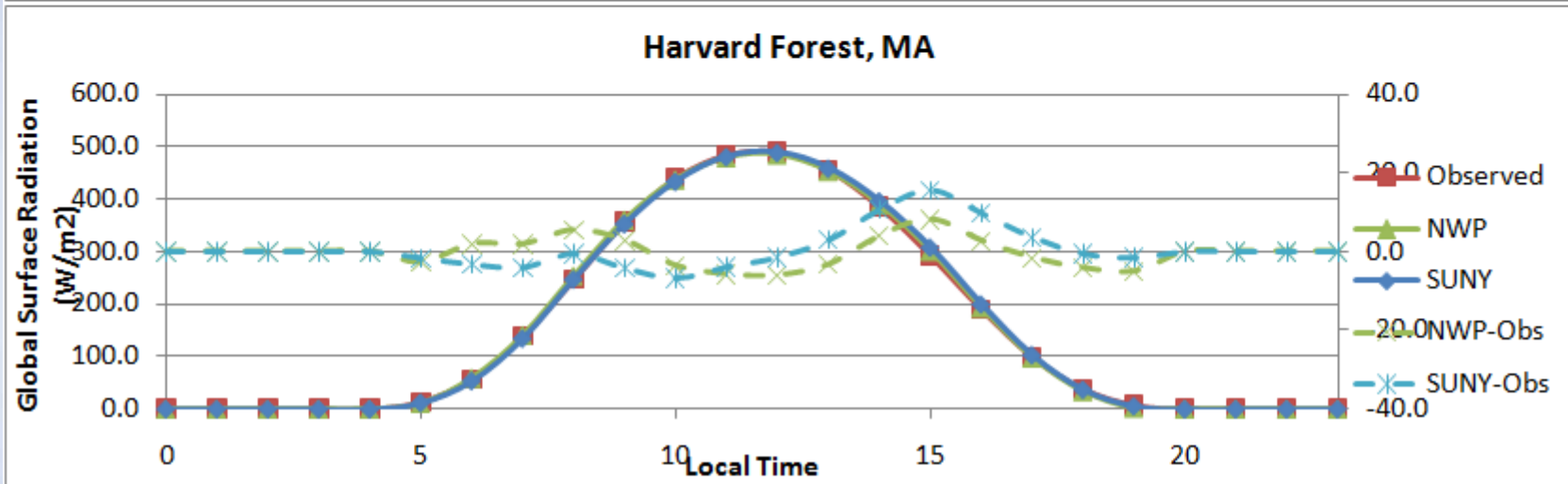
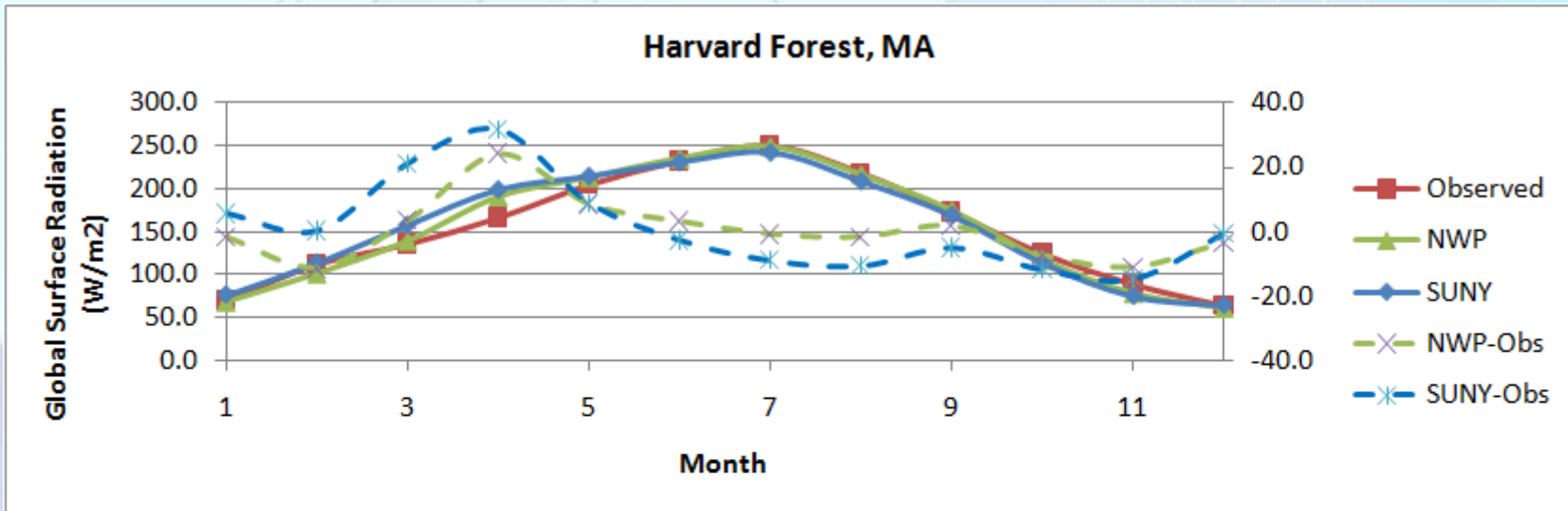
Bondville, Illinois



Desert Rock, Nevada



Harvard Forest, Massachusetts

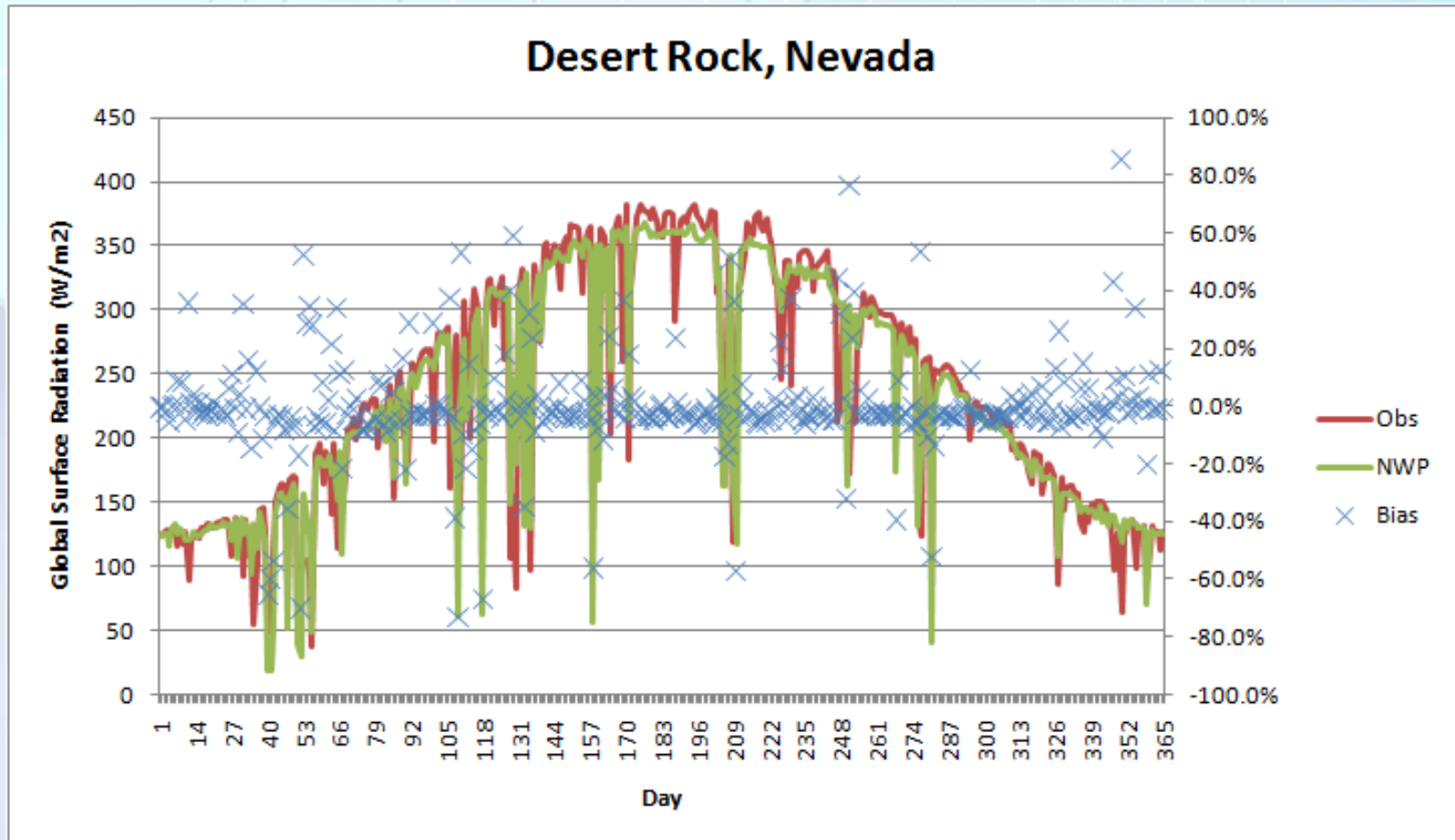


Error Statistics

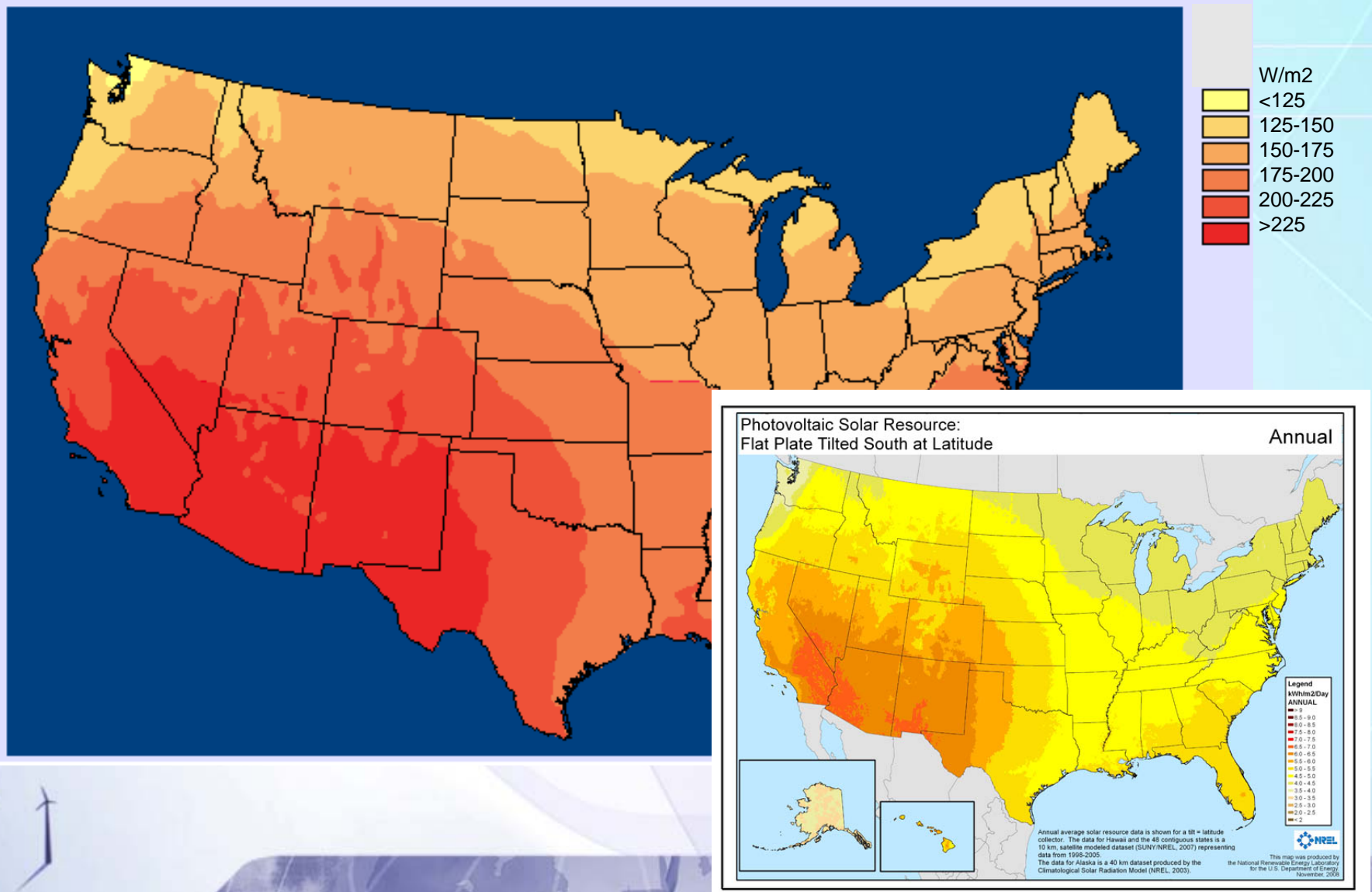
Six Stations

	Monthly Means		Diurnal Means	
	NWP	SUNY	NWP	SUNY
Mean Bias (W/m ²)	1.1	0.3	0.1	0.3
Standard Error (W/m ²)	12.8	14.3	12.0	9.1

Daily Fluctuations



Preliminary Solar Map



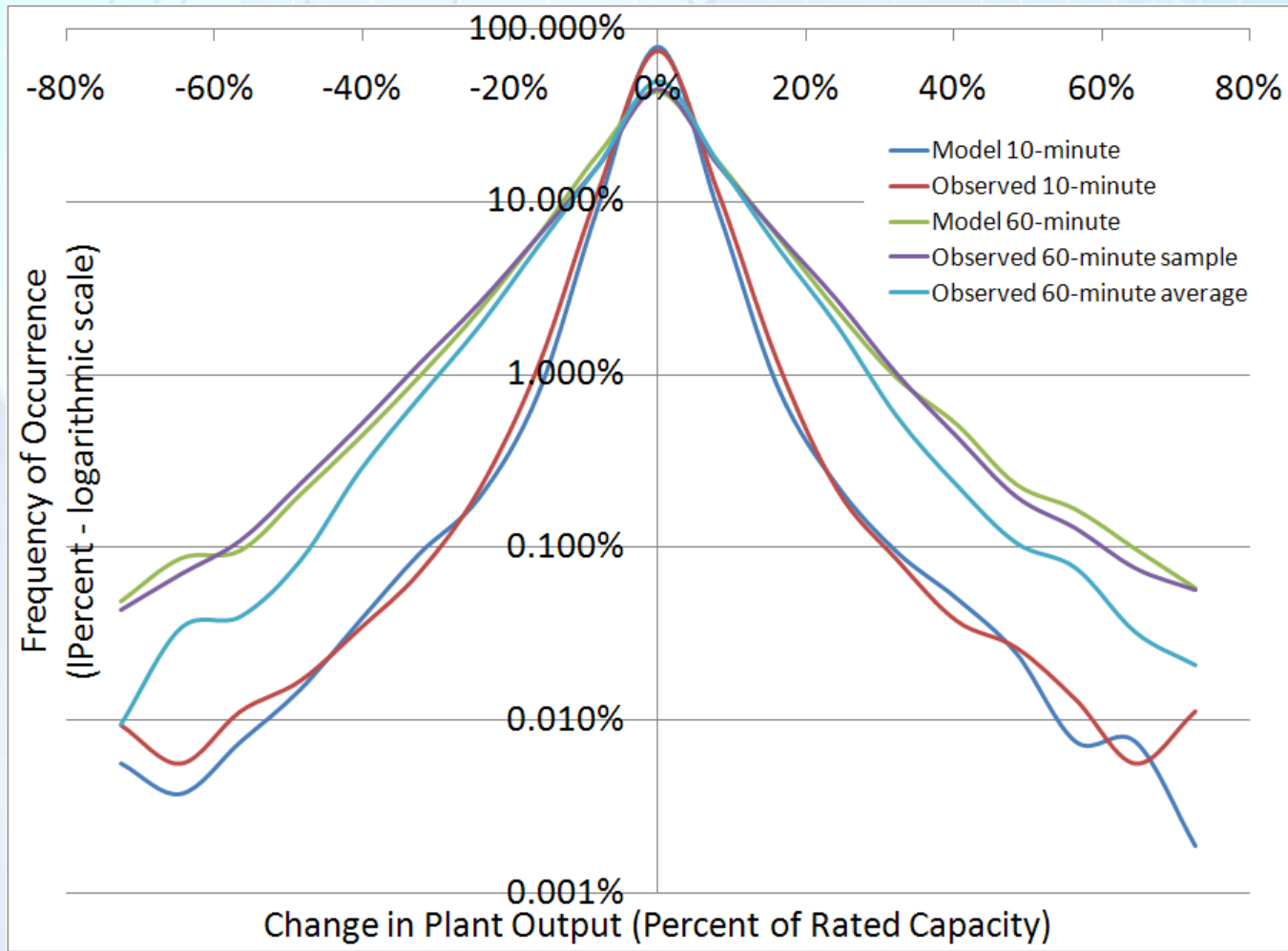
High-Frequency Fluctuations

- Cloud passage time depends on cloud height, wind speed, size of PV array. Typical ramp times: *
 - For a point measurement: 1-5 s
 - For a 50 MW PV project: 60-120 s
- Wind projects cover a larger area, and wind speeds are lower at hub height, therefore wind variability tends to be less.
 - For a 50 MW wind project: 180-320 s
- Direct mesoscale modeling for wind is practical down to 10 minute time resolution

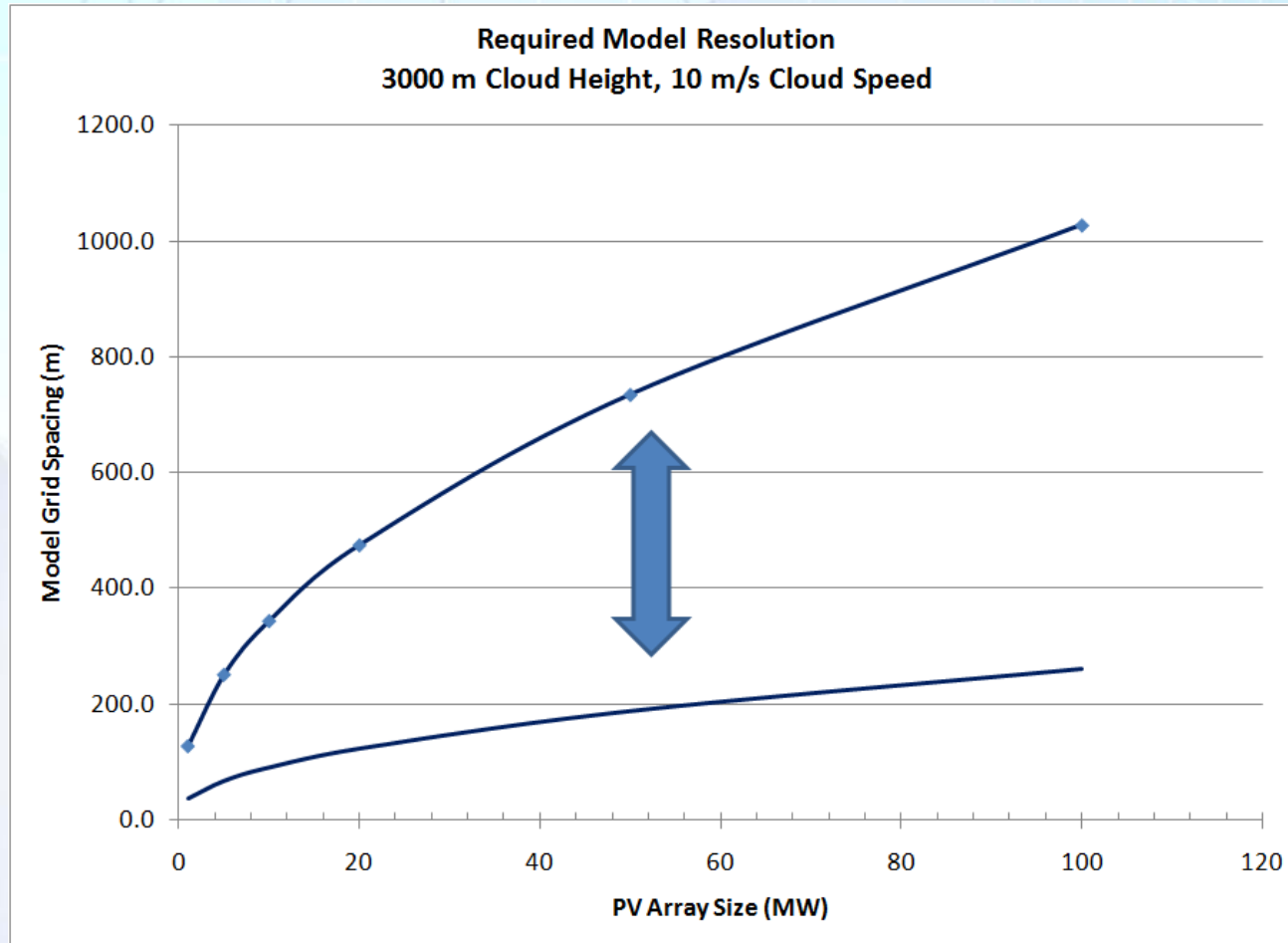
*Assumes clouds at 1000-5000 m height, 7-15 m/s speed, 10% efficient array, 1000 W/m² maximum irradiance

Wind Ramp Spectrum

10-Minute & 60-Minute Ramps



Required Solar Model Resolution To Simulate Cloud Passage Directly

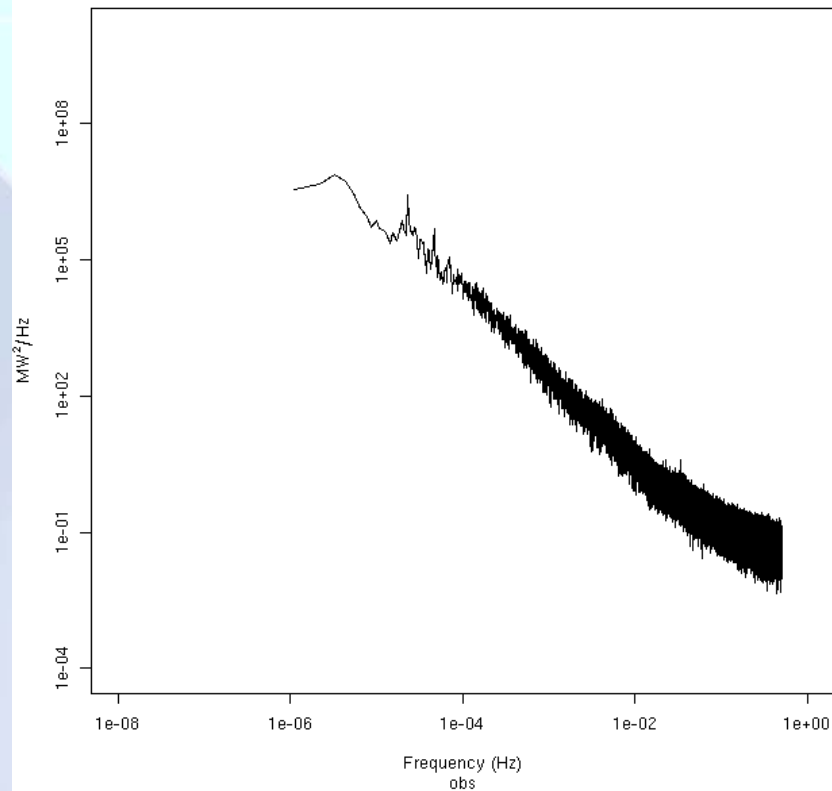


Alternative High-Frequency Variability Techniques

- Direct cloud observations (i.e., ceilometer, satellite)
 - Ground measurements have a limited range of view
 - Satellites have limited spatial, temporal resolution
- Statistical sampling of irradiance or PV data
 - Successfully applied to wind energy
 - Requires representative data from actual plants or measurements
 - Scale-up issues
 - Generally assume no correlation between projects – may need refinement to capture time lags

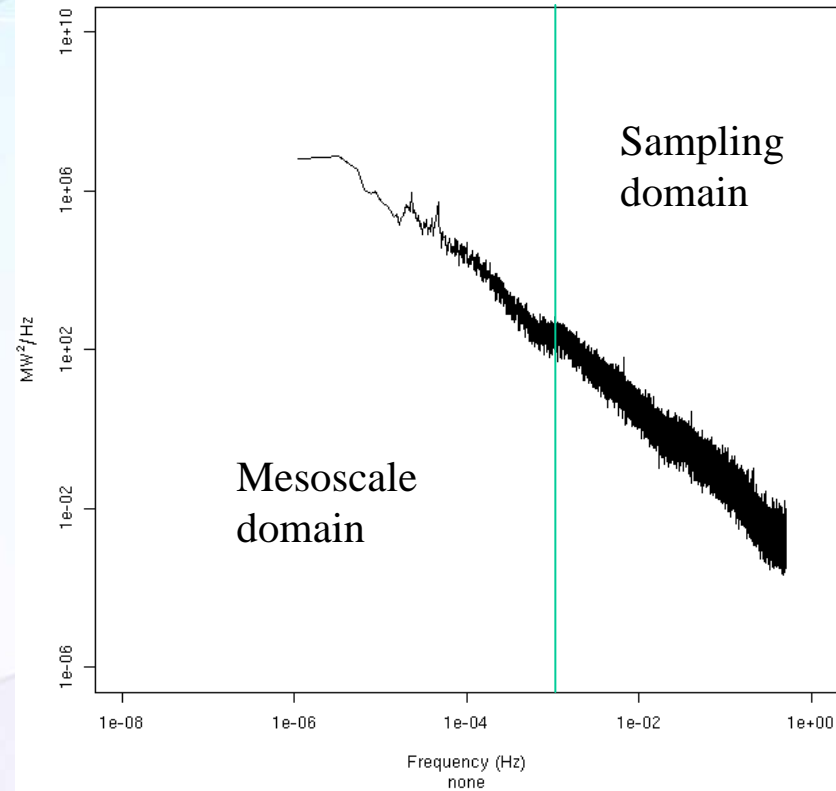
Wind Sampling Technique

Seven Segment Average PSD



Observed

Seven Segment Average PSD



Synthesized

Conclusions

- Mesoscale modeling can produce mean solar resource estimates of similar accuracy to SUNY model
- As a complementary tool, mesoscale modeling could provide additional spatial, temporal, and geographic flexibility
- High-frequency fluctuations for <100 MW PV arrays could potentially be modeled, but this would be costly in CPU; >100 MW needs to be demonstrated
- Methods combining mesoscale modeling with statistical sampling and/or direct or inferred cloud observations are likely necessary