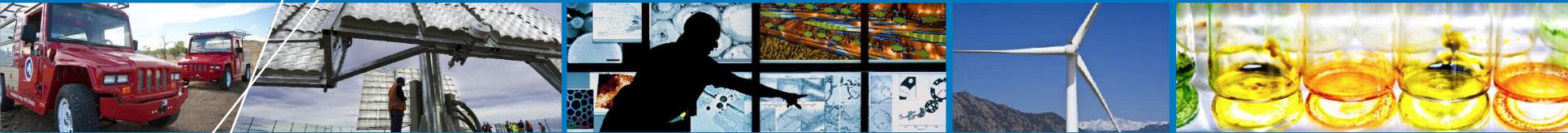


Estimating PV Losses due to Snow Coverage in SAM



2015 SAM Virtual Conference

Severin Ryberg

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Snow Coverage on PV Arrays



System Advisor Model



Overview

- Snow coverage on PV systems can have an extreme effect on the system's energy production
- Losses are highly dependent on geographic location and system design
- Large margin of error in annual snow fall predictions
- Physical dynamics of snow coverage on PV panels are non-linear

*Becker, Gerd, et al. "An approach to the impact of snow on the yield of grid connected PV systems." *Bavarian Association for the Promotion of Solar Energy, Munich* (2006).

A new Compute Module in SAM

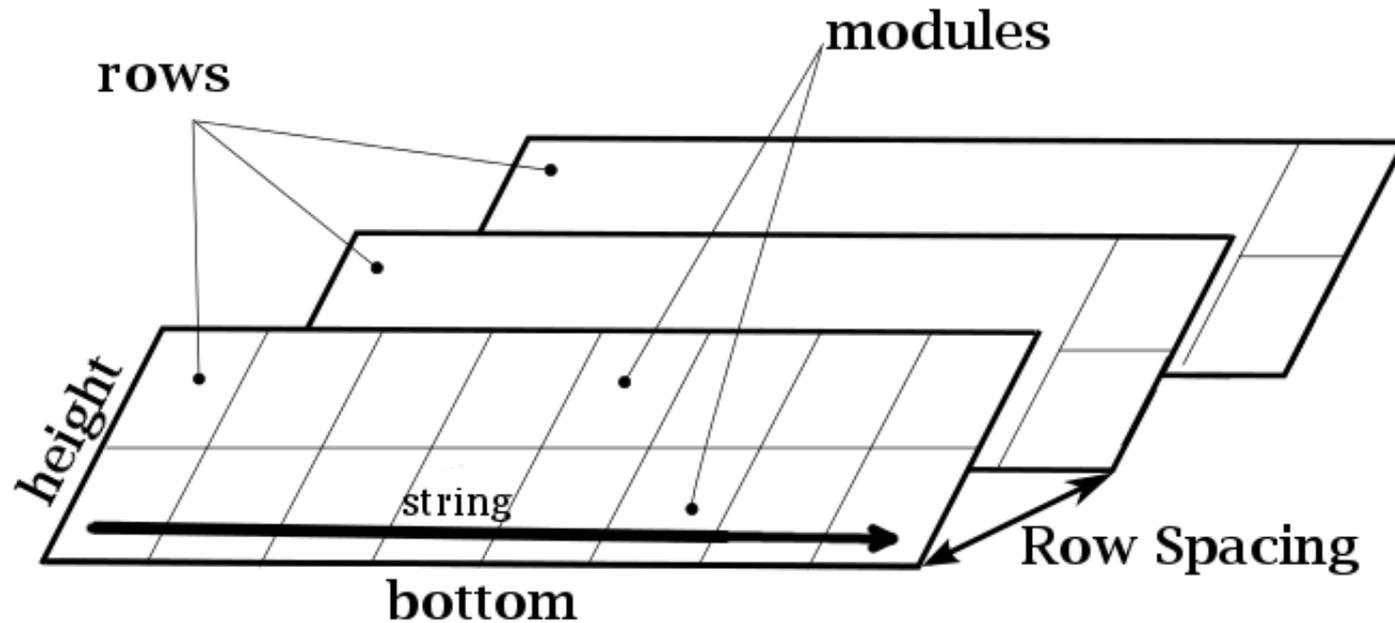


- **Implemented a PV snow coverage loss model (snow model) developed by Bill Marion**
 - Marion, Bill, et al. "Measured and modeled photovoltaic system energy losses from snow for Colorado and Wisconsin locations." *Solar Energy* 97 (2013): 112-121.
- **Calculates snow coverage on a panel based on time since last snow fall, ambient temperature, and plane of array irradiance (poa)**
- **Treats sliding as the dominant snow removal process**
 - Direct relationship between system tilt and snow sliding speed
- **Easy to invoke in SAM**
- **Good agreement with measured data in initial validation study**
- **Allows for illuminating investigations into potential PV loss trends due to snow coverage across the continental United States**

PV Array Diagram



System Advisor Model



- Snow coverage percentage is measured along the height of a PV array
- Snow is expected slide down the array and collect near the bottom
 - Behavior is slightly different for roof-mounted vs ground-mounted arrays
- If a string is even partially covered, its assumed output is zero

Snow Model Usage



SAM 2015.6.30

New Snow Model Example Help

Photovoltaic, No financial

Location and Resource

Module

Inverter

System Design

Shading and Snow

Losses

Open 3D shade calculator...

Use the shade calculator to draw a 3D representation of the photovoltaic system and nearby objects. The calculator generates a diurnal table of shading losses and automatically populates the shading factors table for each subarray in the system. (For systems with more than one subarray, use the group name in the shade calculator to identify subarrays.) See help for details.

	Subarray 1	Subarray 2	Subarray 3	Subarray 4
Modules in subarray (from System Design page)	18	0	0	0
GCR (from System Design page)	0.3	0.3	0.3	0.3
Number of modules along side of row	2	2	2	2
Number of modules along bottom of row	9	9	9	9

Module area (from Module page) 1.2440 m²

GCR = length of side ÷ row spacing
module width = module area ÷ 1.7

External Shading

Edit shading losses Edit shading... Edit shading... Edit shading... Edit shading...

Self Shading

Shading mode None None None None

Module orientation Portrait Portrait Portrait Portrait

Snow Coverage

Estimate losses due to snow

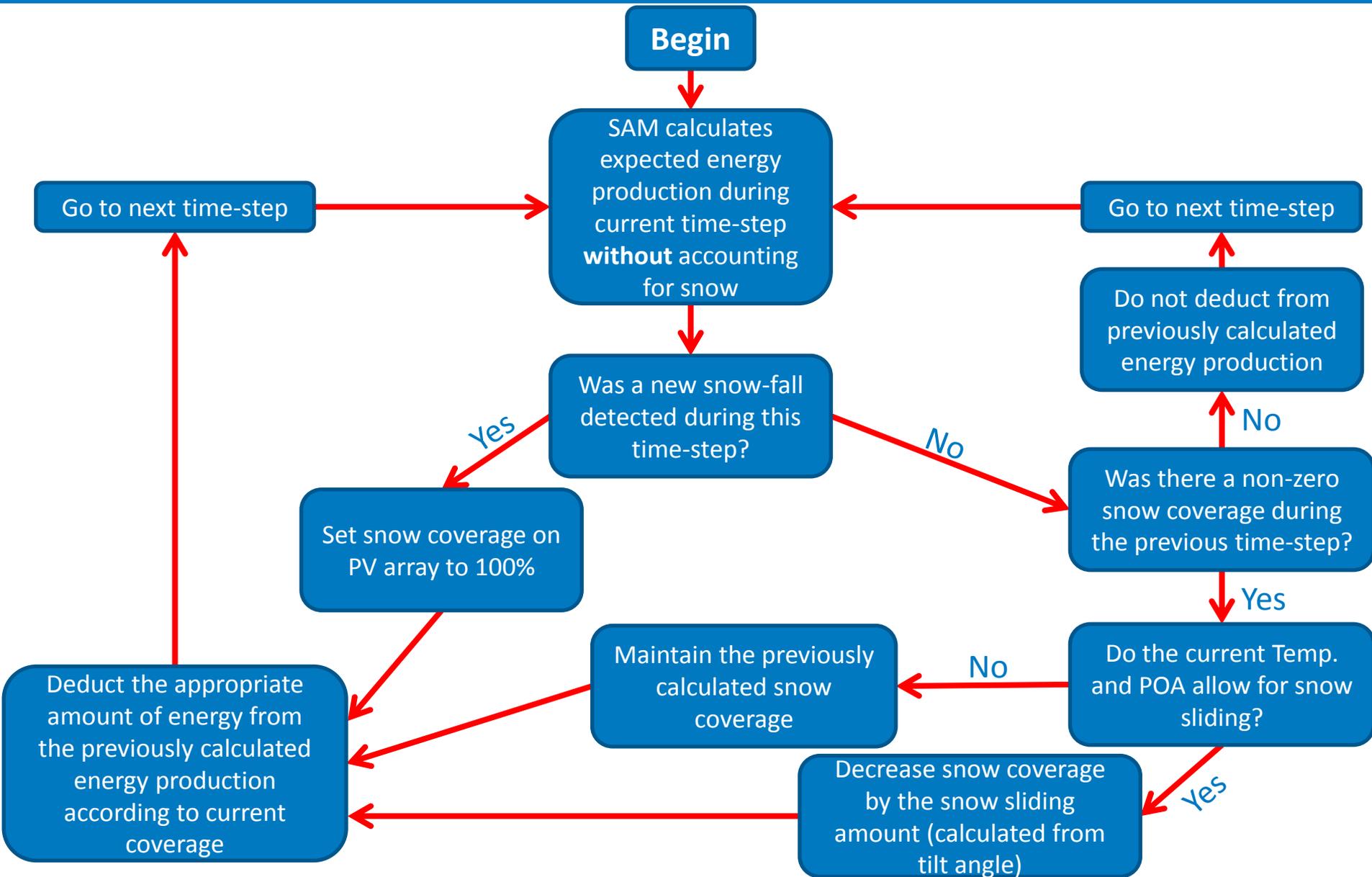
Enable to activate estimation of snow coverage losses for the designed system. This requires that the provided weather file contains hourly (or sub hourly) snow depth data in units of cm. Depth values outside the range of 0 - 600 cm are considered erroneous.

Simulate >

Parametrics Stochastic

P50 / P90 Macros

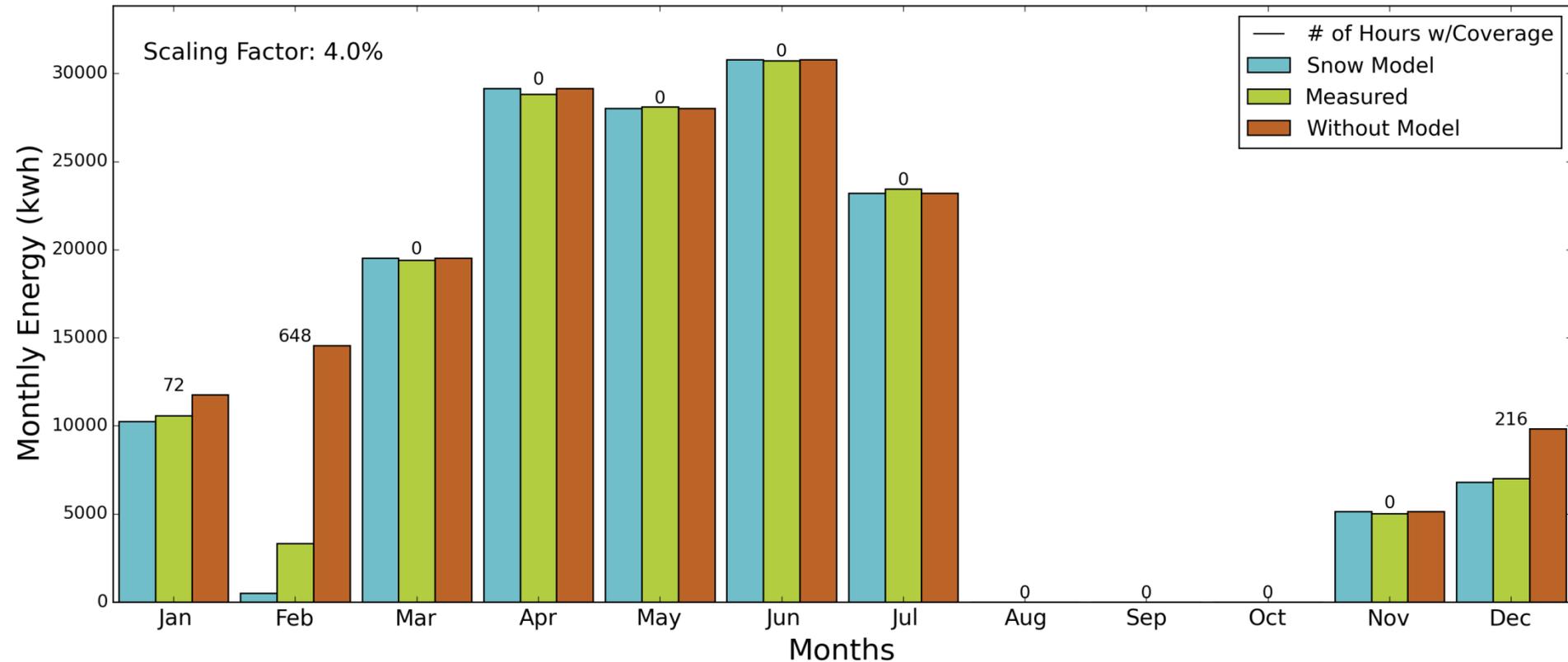
Snow Model Flow Chart



Snow Model Validation: Forrestal



System Advisor Model



- Snow model limits estimated energy production when snow fall is detected
- Observed to both over-predict and under-predict snow losses for monthly, or shorter, time intervals
- Significantly improves annual energy estimations
 - Validated against three datasets: Forrestal, RSF2, MesaTop

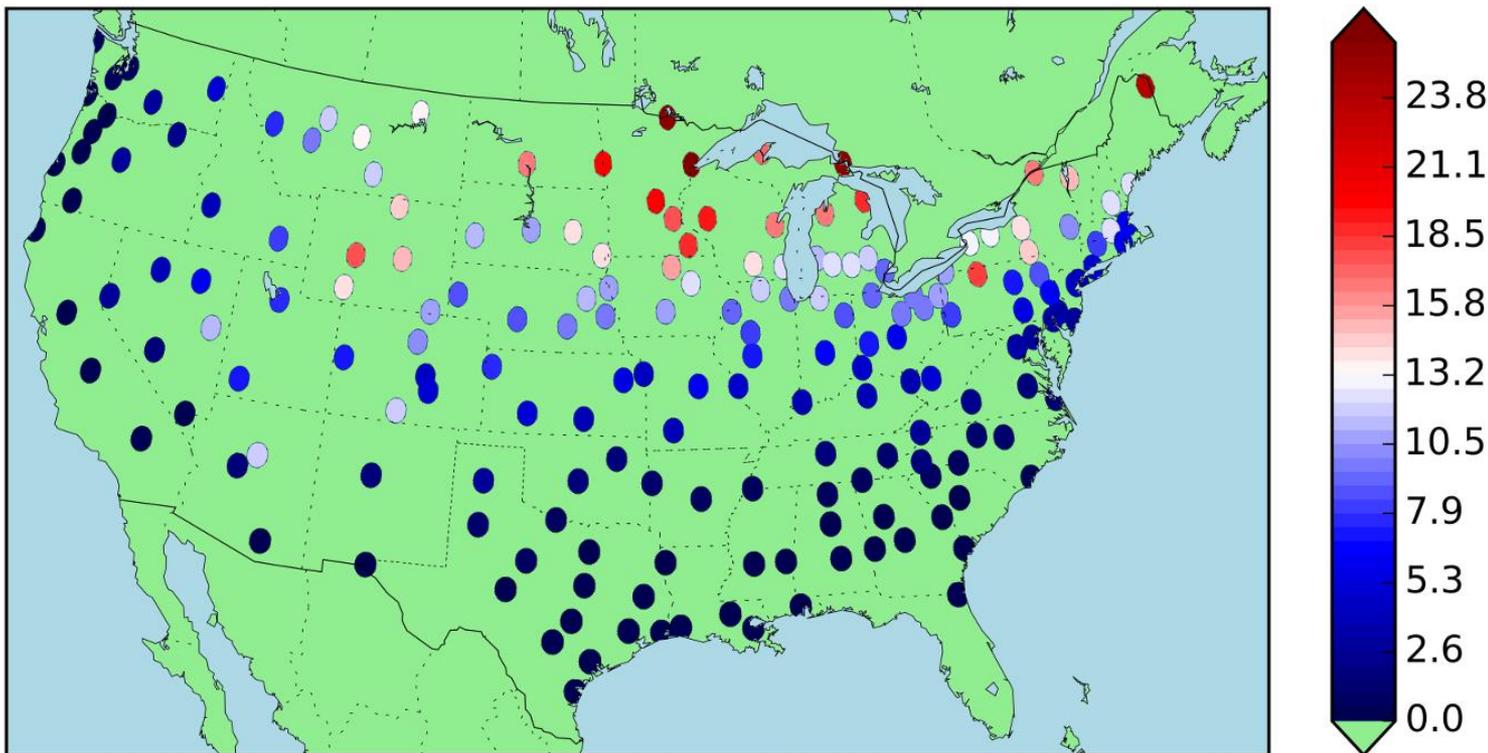


- **Interested in predicting PV snow loss trends across the continental US**
- **Considered a basic fixed-tilt system**
 - SAM defaults in 2015.1.30
 - Tilt equals latitude
- **Used the NSRDB's 1961 - 1990 dataset**
 - 239 locations across the US
 - Comprised the TMY2 dataset
 - Contains hourly weather data, including daily snow depth values

National Study: Average Loss Map



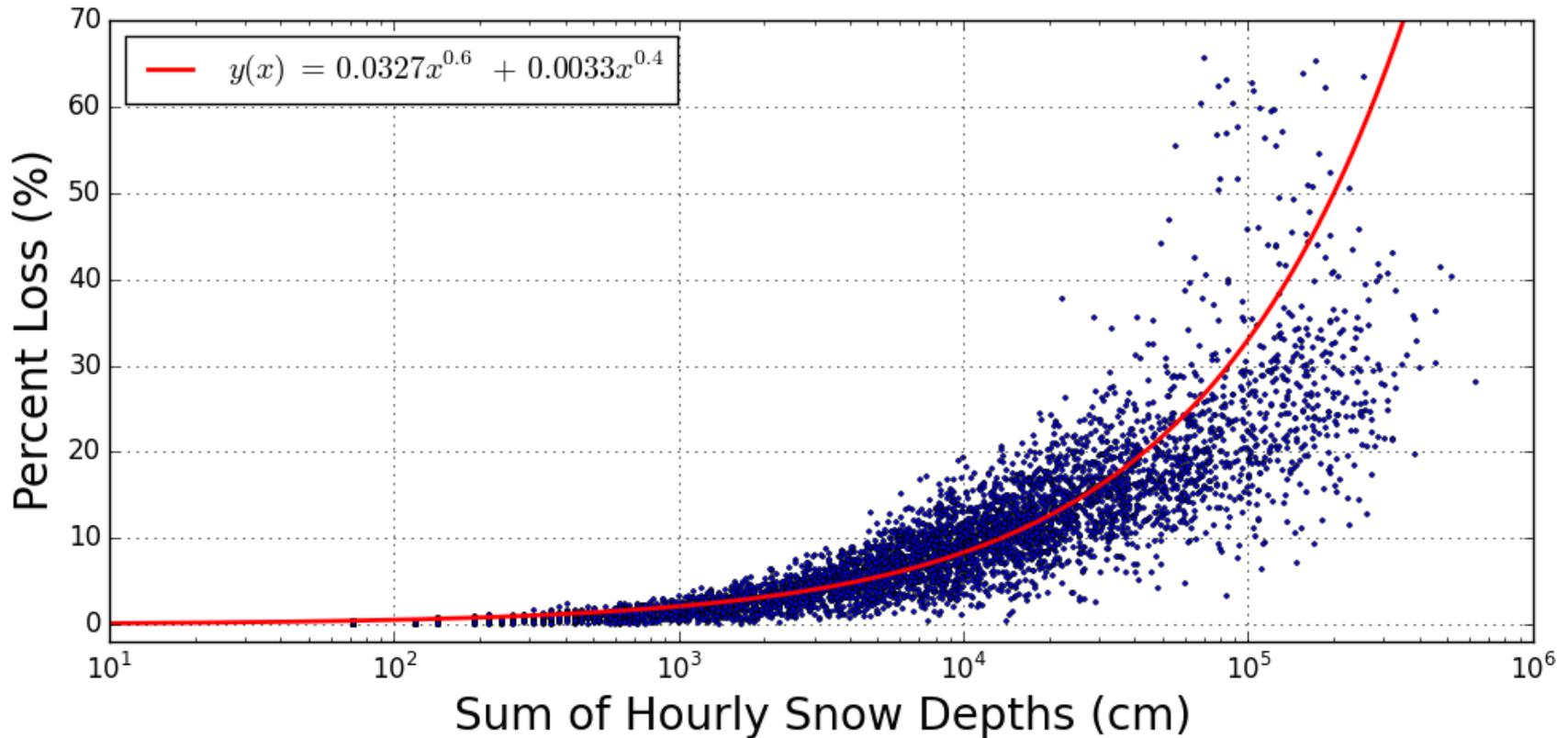
System Advisor Model



Average percent loss in annual energy production for the years between 1961 and 1990 for each location in the NSRDB TMY2 dataset. Losses are calculated by comparing simulations with the snow model activated against simulations without the snow model activated.

*Only intended for fixed-tilt, tilt-equals-latitude PV systems

National Study: Typical Losses



Scatter plot depicting the summation of the hourly snow depth array vs the percent loss (calculated in the same manner as the previous map). If snow depth data is available for a particular location not included in the TMY2 set, this plot could be used as a starting point for estimating the range of PV losses due to snow.

*Again, only meant to be valid for fixed-tilt, tilt-equals-latitude PV systems



- **A detailed report on the implemented snow model and investigations included in this presentation will be available soon**
 - “Integration, Validation, and Application of a PV Snow Coverage Model in SAM”
- **Feel free to reach out if you would like more information**
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Thank you! Questions?