Quantifying PV Output Variability

Thomas E. Hoff and Richard Perez
Clean Power Research
www.cleanpower.com

Utility-scale PV Variability Workshop
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NYSERDA
New York State Energy Research and Development Authority

Why This Topic is Important to Utilities

System Planning

Maximizing the benefits while minimizing grid impacts of PV requires utilities to influence where PV systems are installed

System Operation

Optimize utility system operation once systems are installed requires the ability to forecast PV variability

Intermittency Questions

1. What is the effect of short-term output variability?

2. What needs to be done to forecast short-term output variability?

Question #1

What is the effect of short-term output variability?

Objective

Quantify relative power output variability for a fleet of identical PV systems

Key Findings

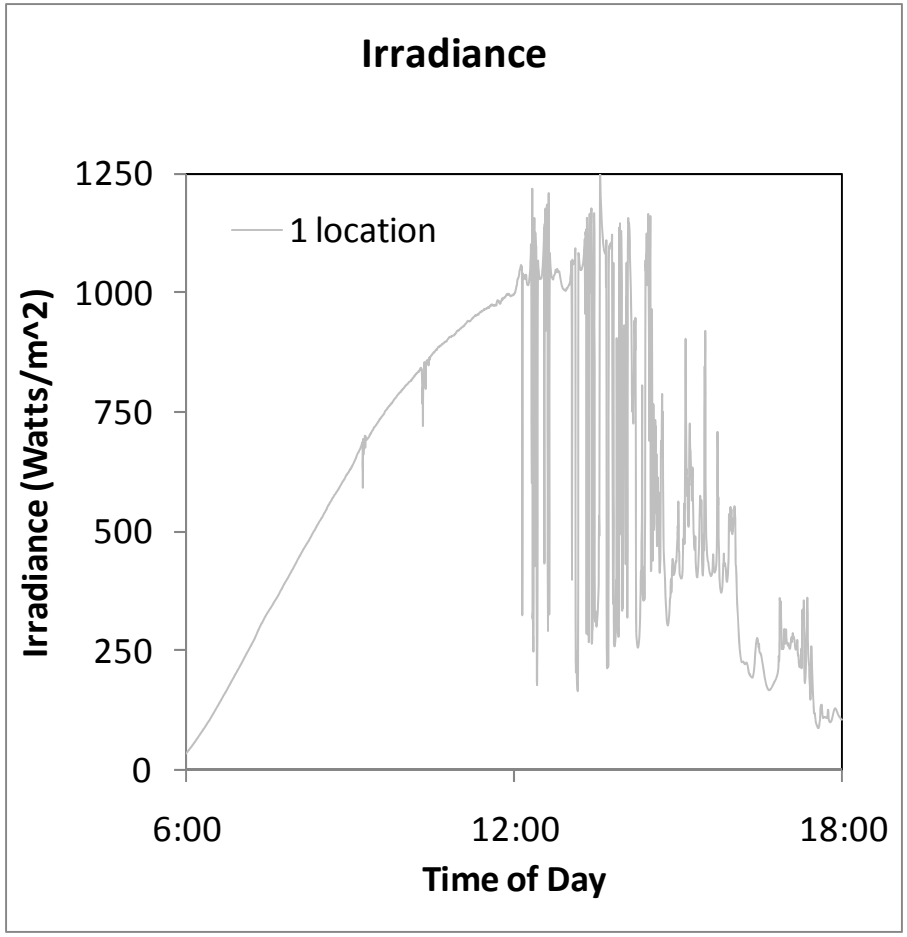
Relative Output Variability is based on:

1. Number of PV systems

2. Dispersion Factor

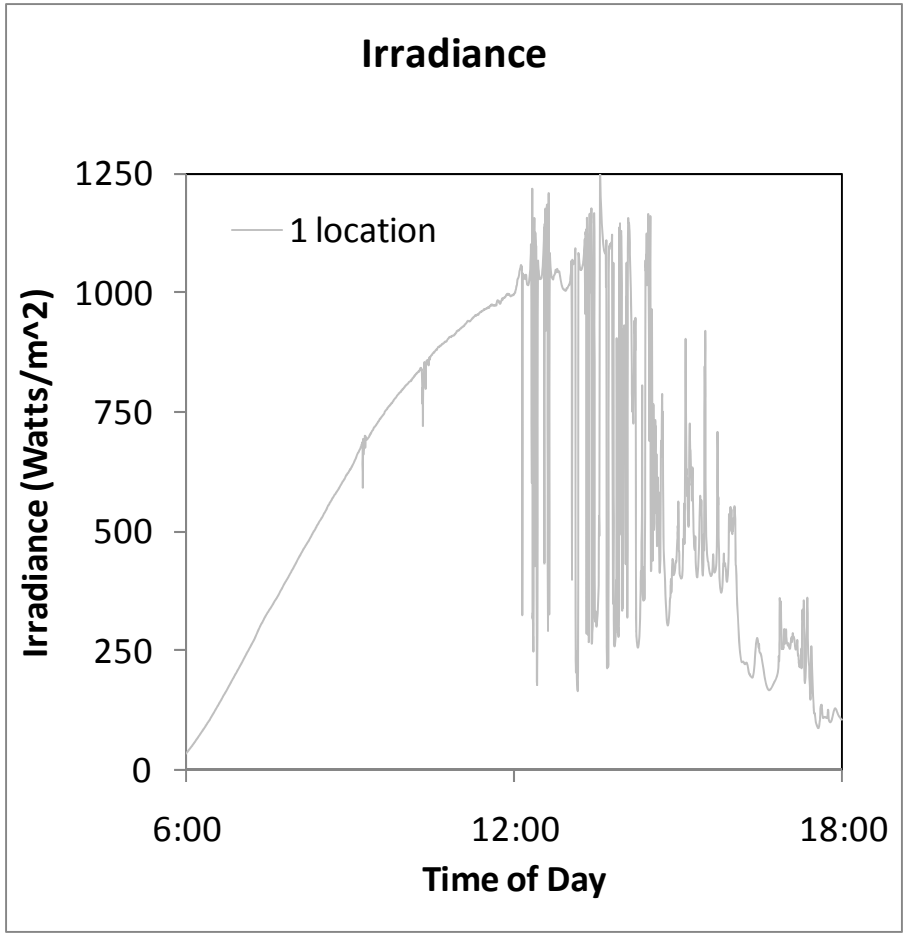
Relative Output Variability
Output variability for fleet / Output variability at single location

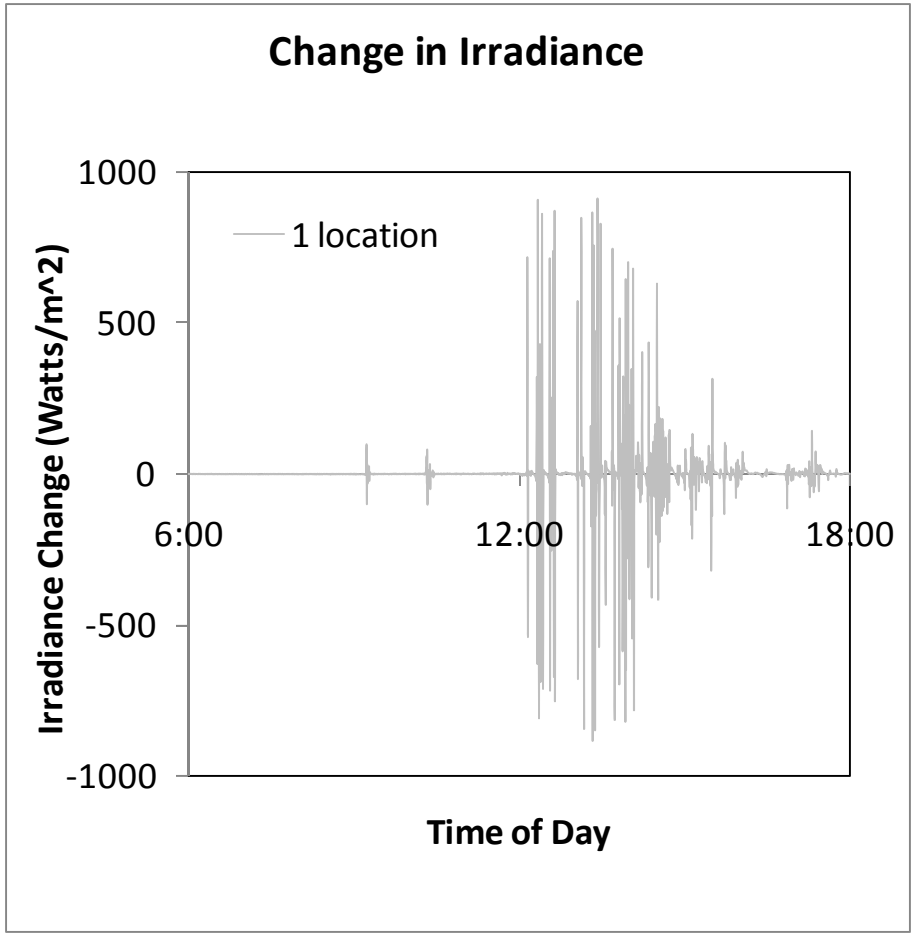
What is Meant by Variability?



Relative Output Variability
Output variability for fleet / Output variability at single location

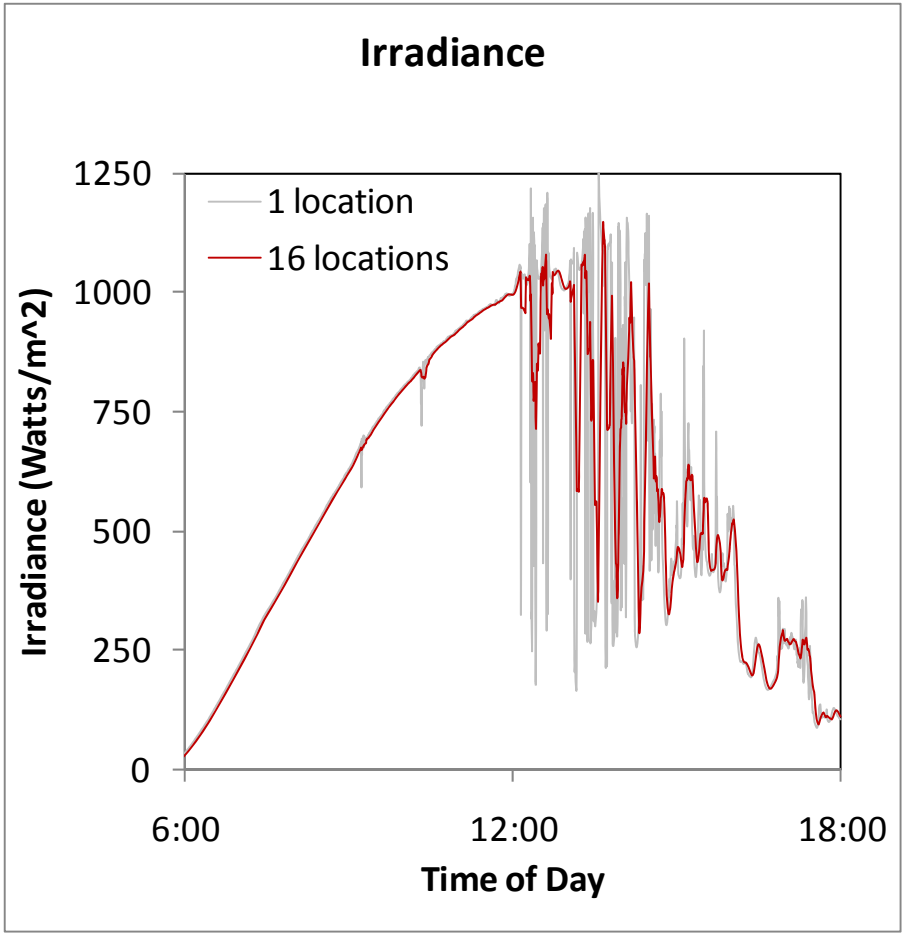
What is Meant by Variability?

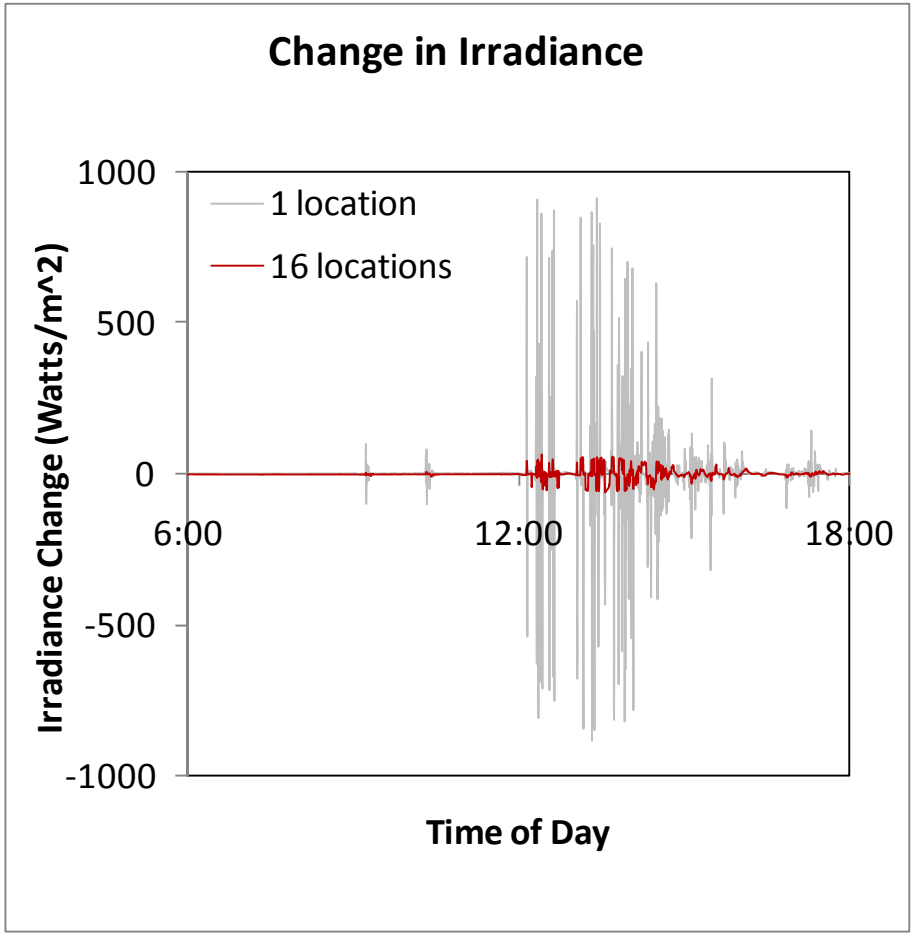




Relative Output Variability
Output variability for fleet / Output variability at single location

How Number of Systems Affects Variability





Relative Output Variability
Output variability for fleet / Output variability at single location

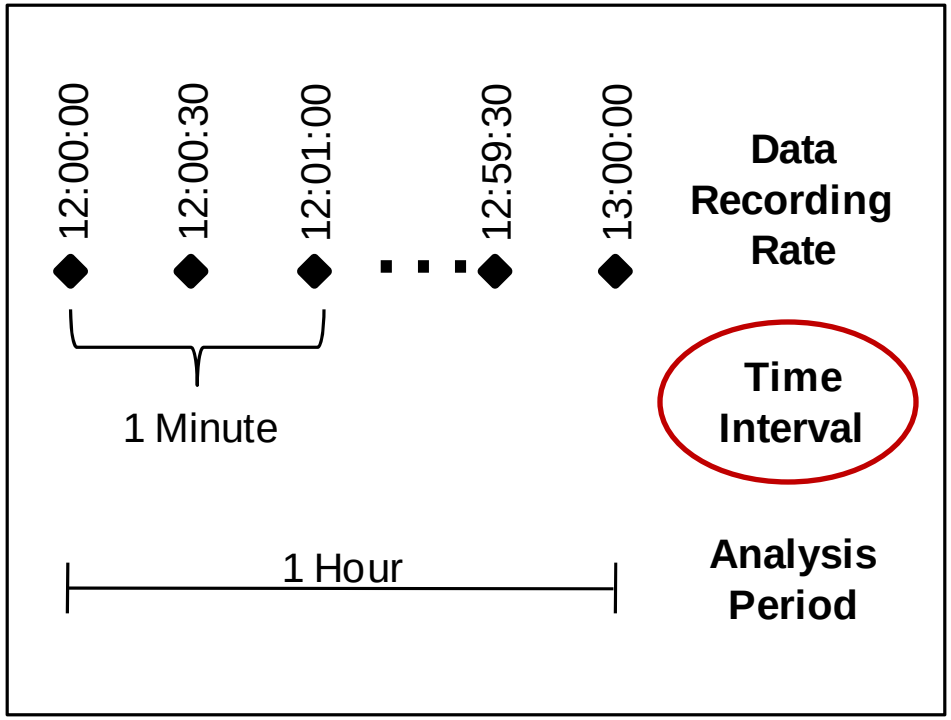
What is Dispersion Factor

- Dispersion Factor is the number of Time Intervals for a cloud to pass across the distance of the entire PV Fleet

Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

What is Time Interval?

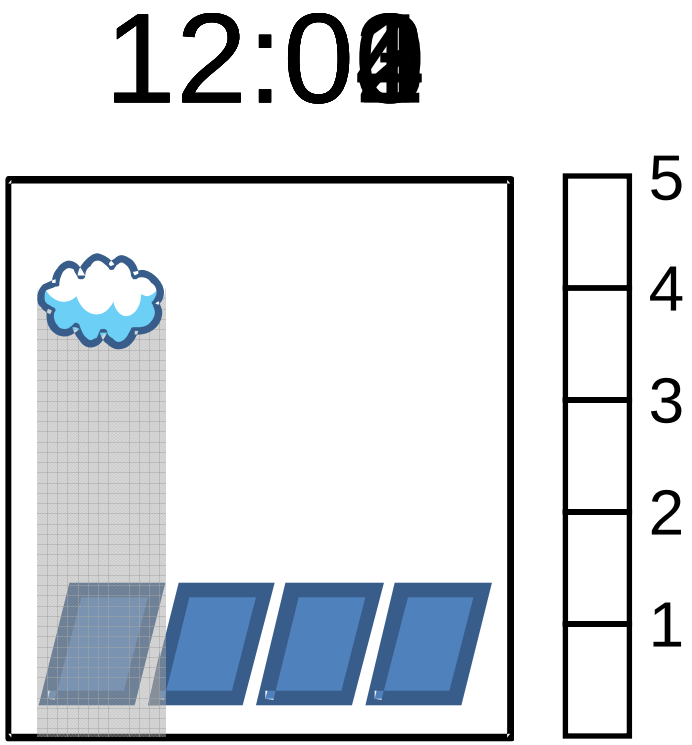


Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

Dispersion Factor For Moderate Cloud Transit Speed

Moderate Cloud Transit Speed (Dispersion Factor = 4)

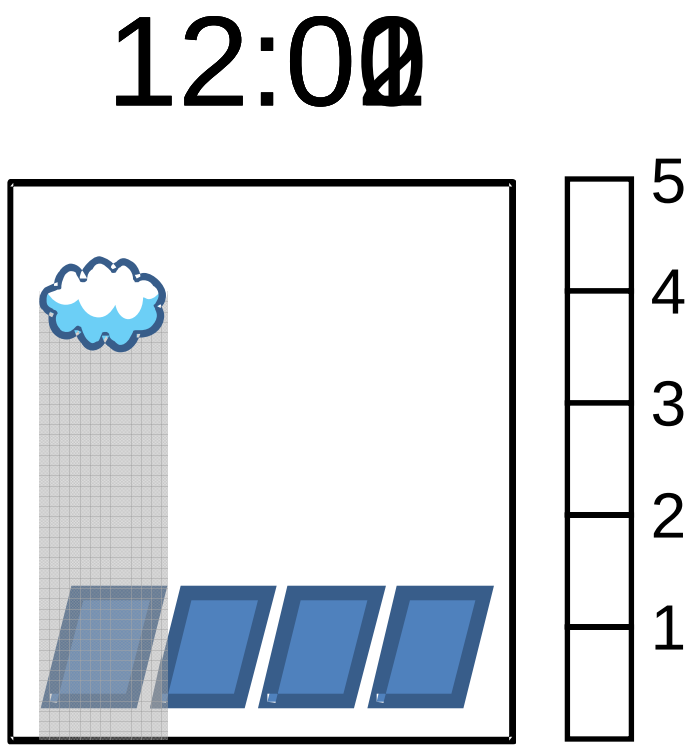


Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

Dispersion Factor

Fast Cloud Transit Speed (Dispersion Factor = 2)



Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

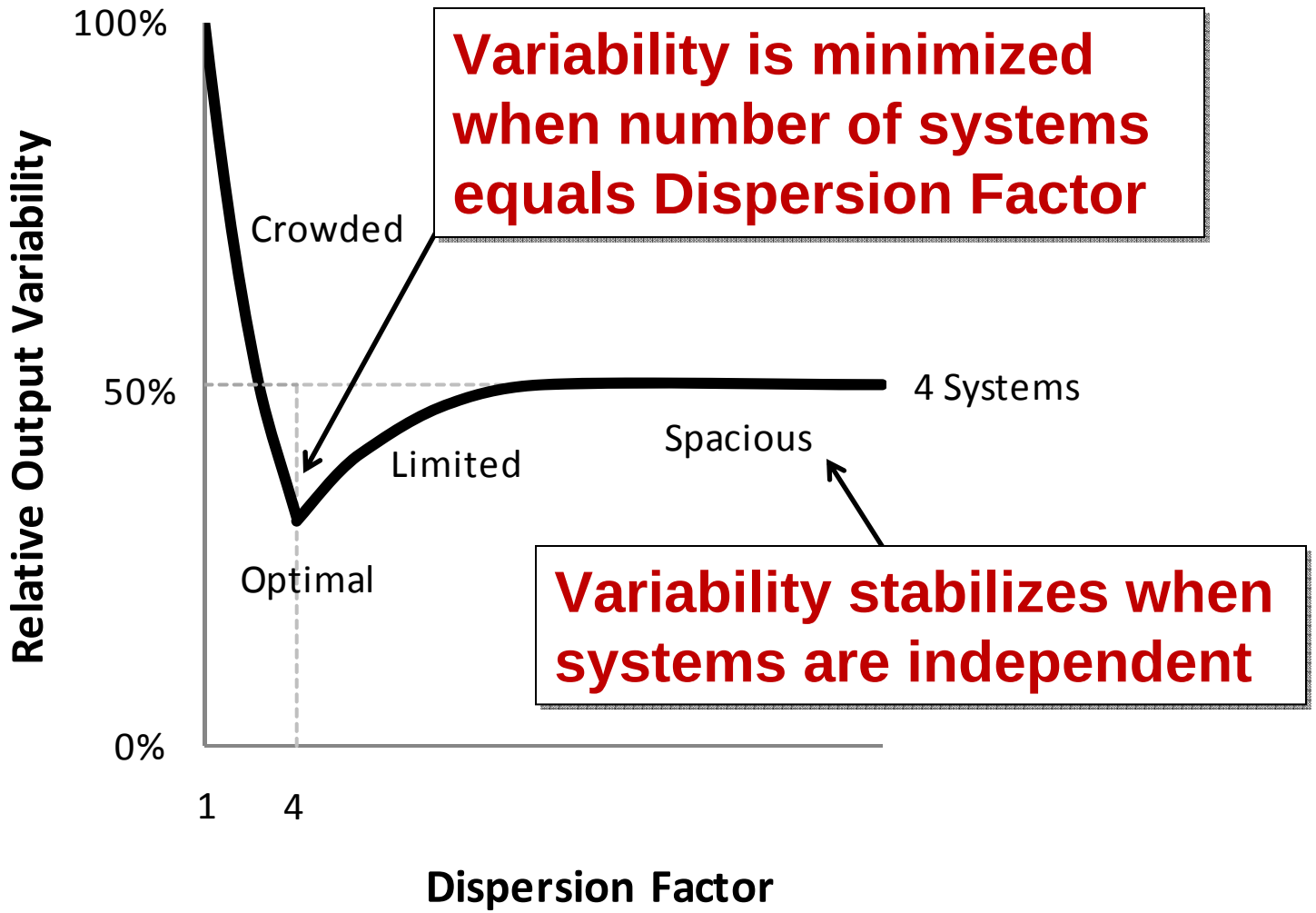
Model Results Categorized in 4 Regions

Crowded	Number of Systems > *Dispersion Factor*
Optimal (Point)	Number of Systems = *Dispersion Factor*
Limited	Number of Systems < *Dispersion Factor*
Spacious	Number of Systems << *Dispersion Factor*

Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

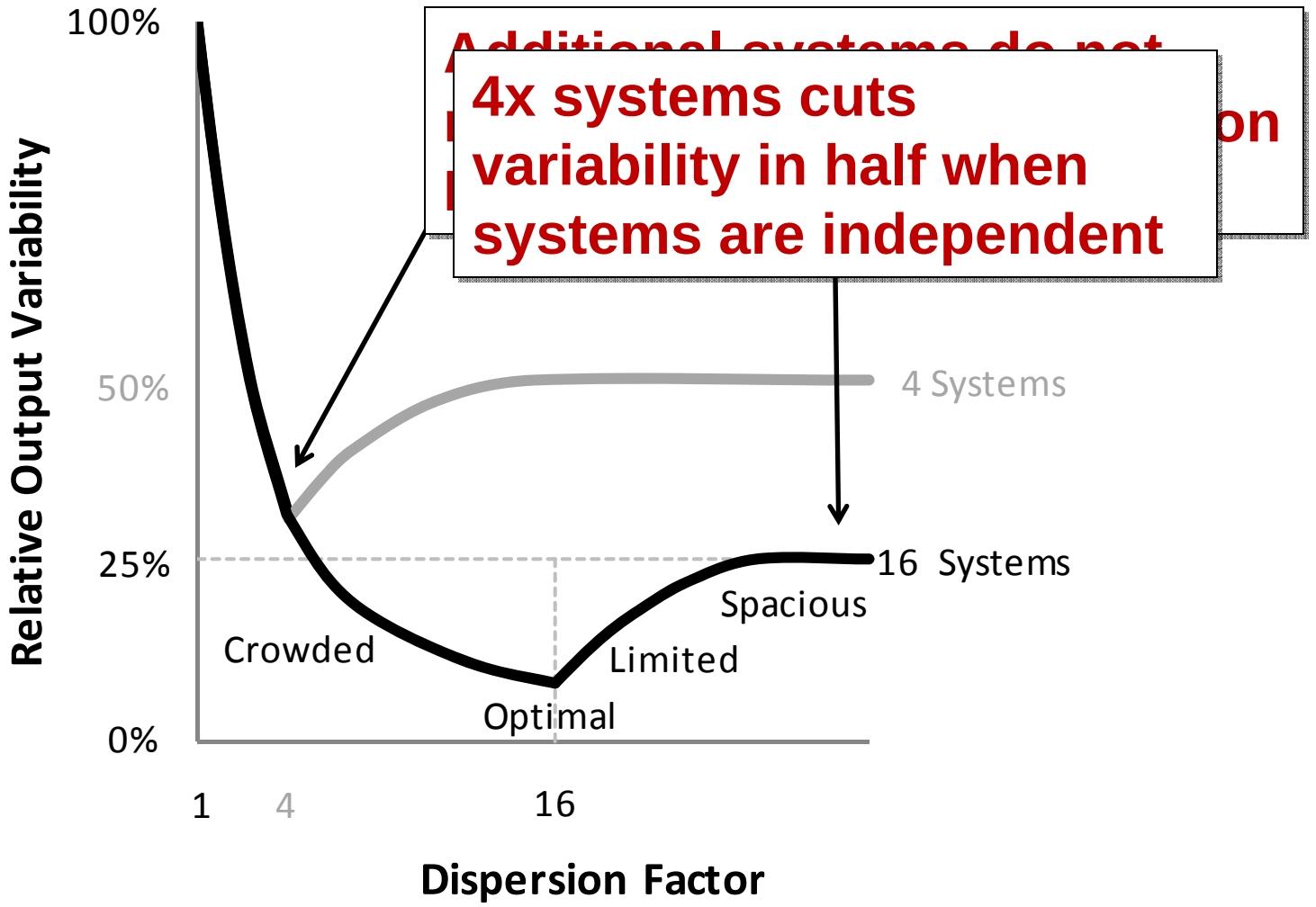
Relative Output Variability: 4 Systems



Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

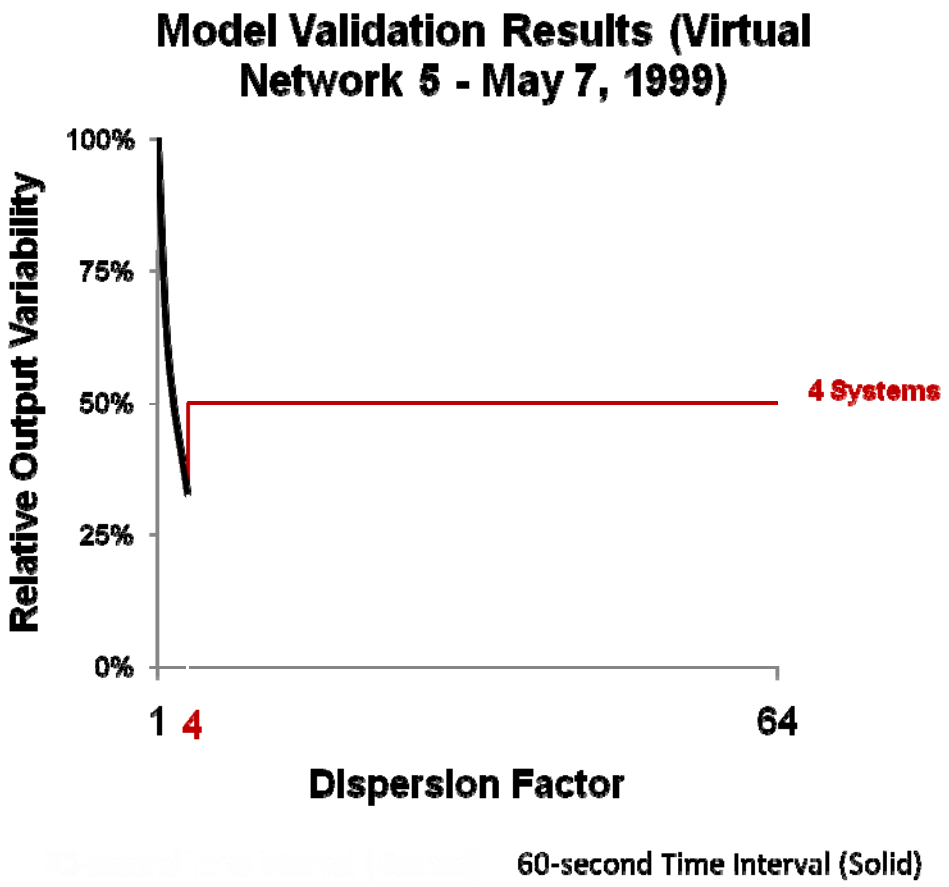
Relative Output Variability: 16 Systems



Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

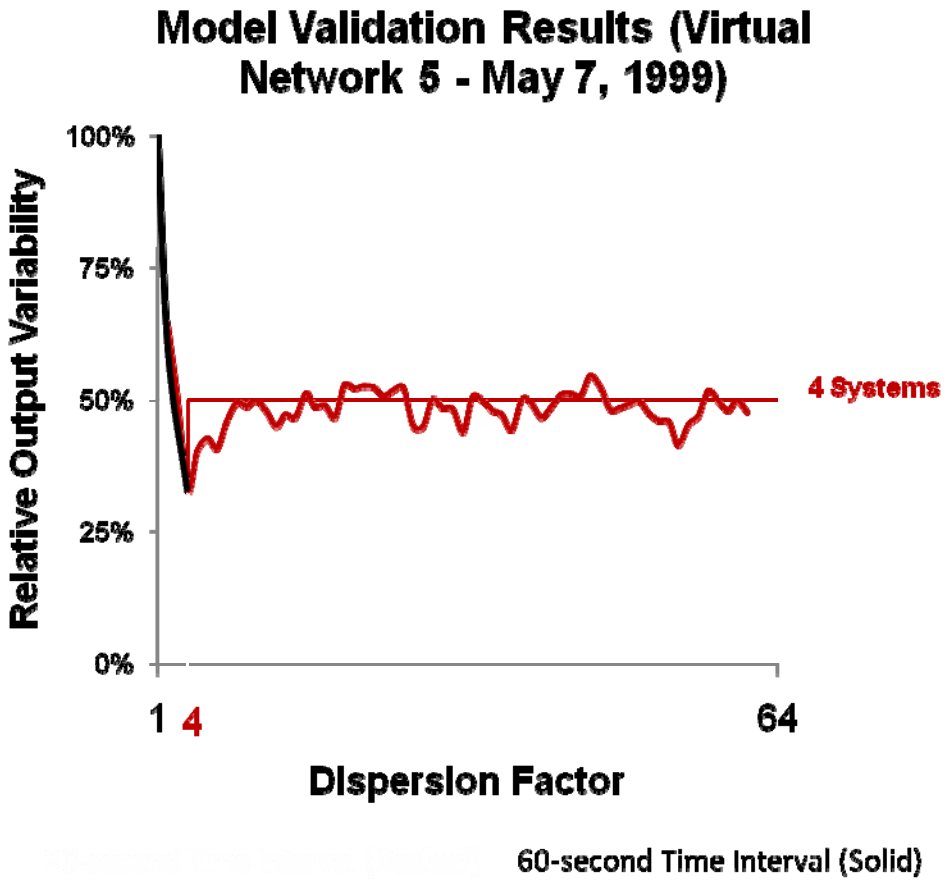
Validation: Construct Model for 4 Systems



Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

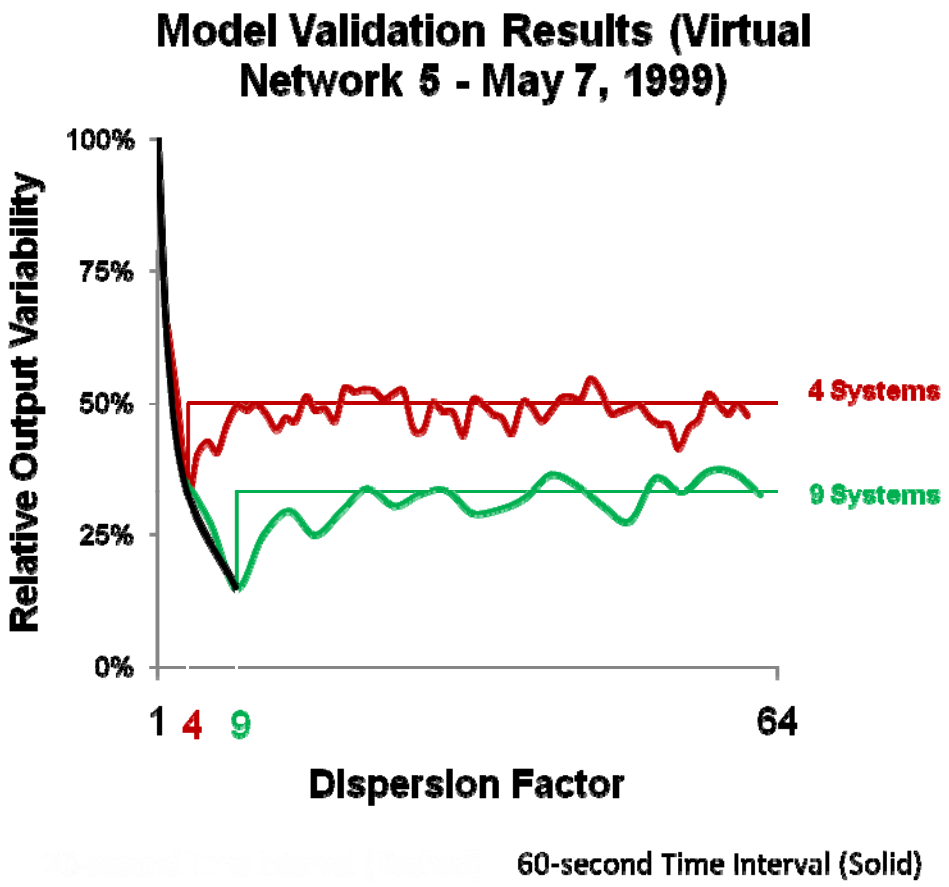
Add Measured Data



Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

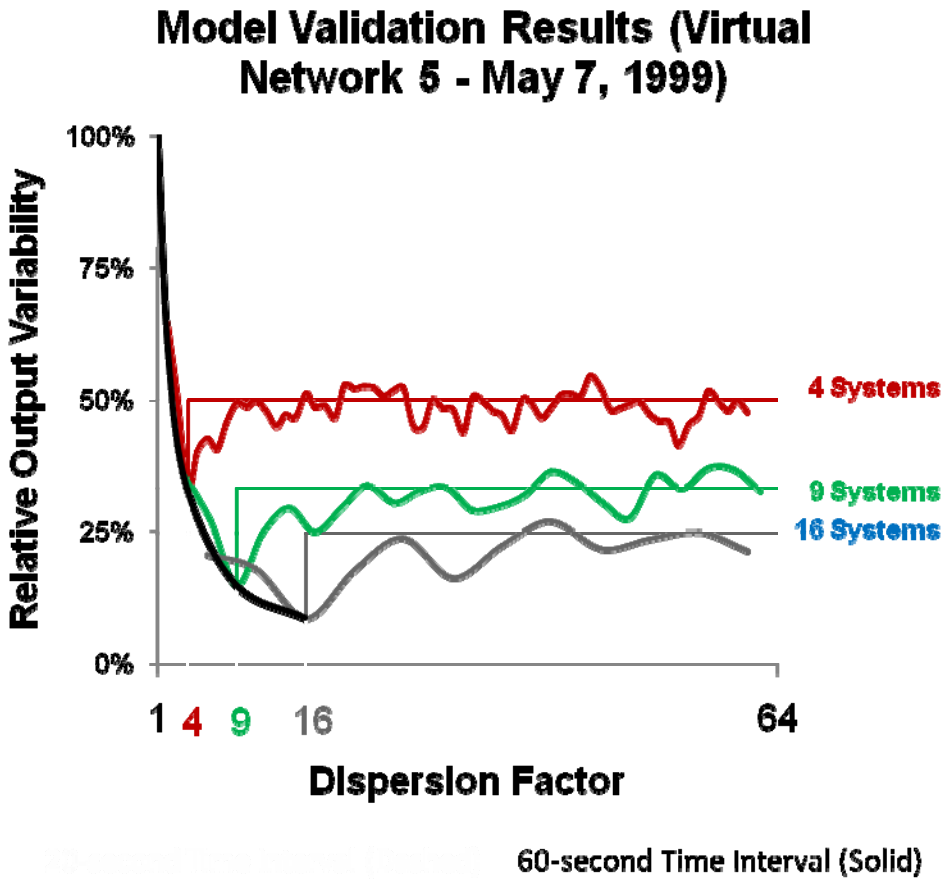
Repeat for 9 Systems



Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

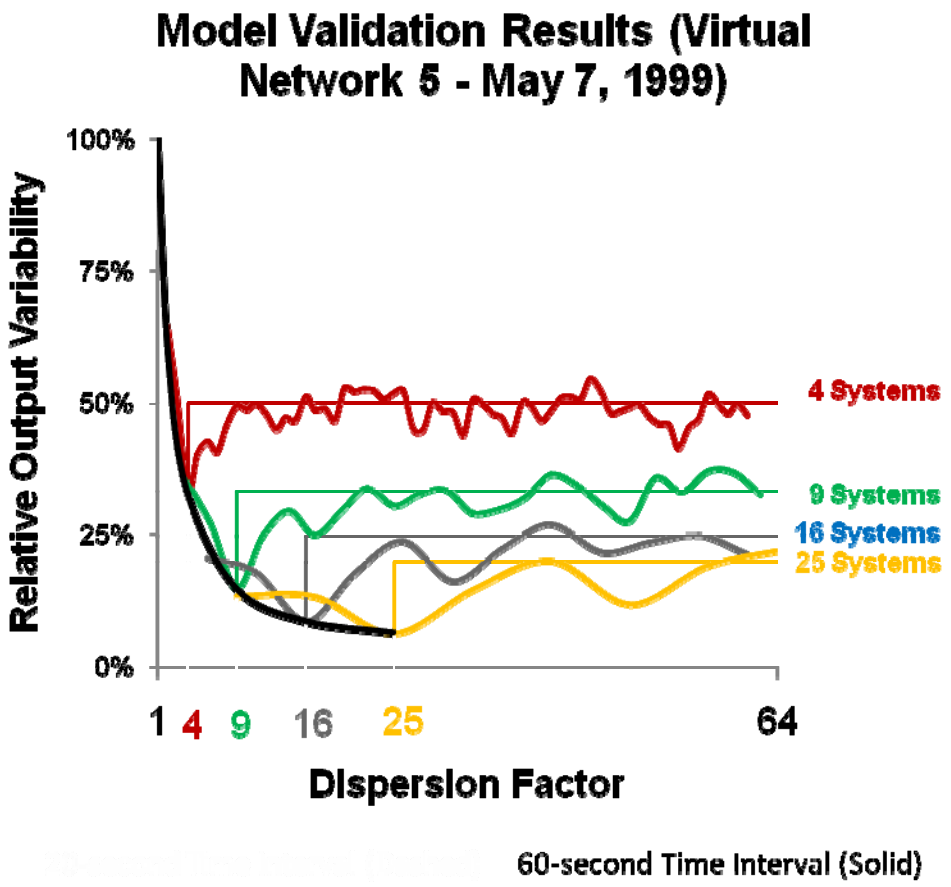
Repeat 16 Systems



Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

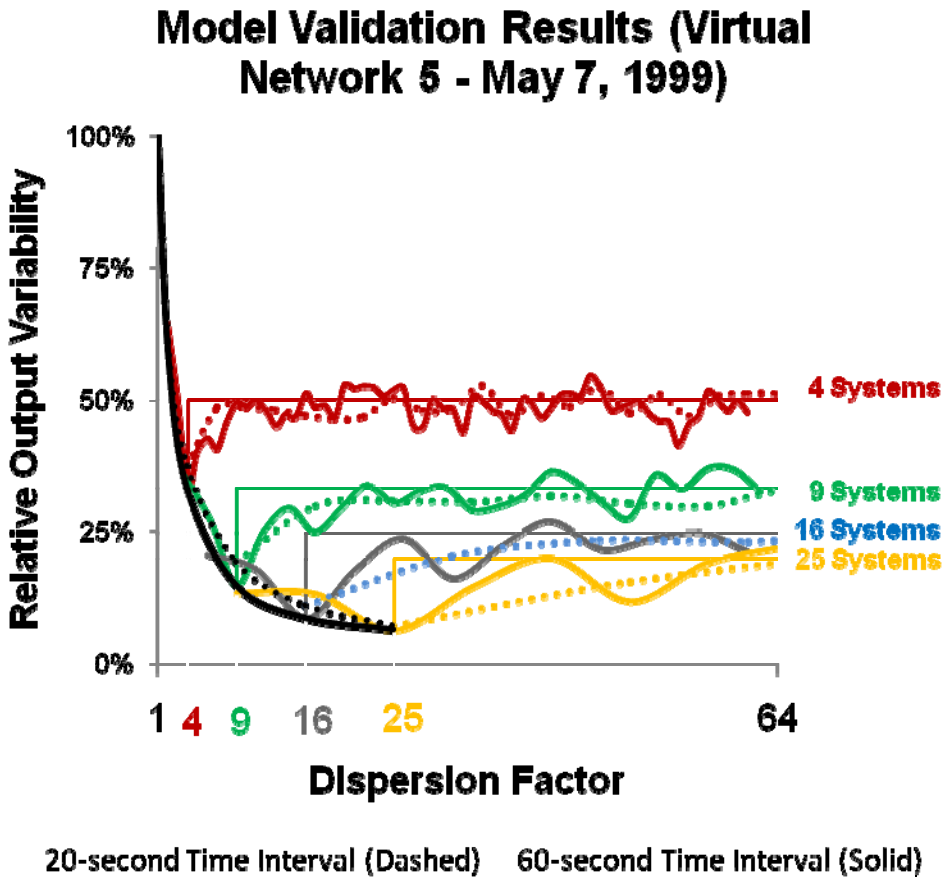
Repeat for 25 Systems



Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

Repeat w/ 20 Second Time Interval

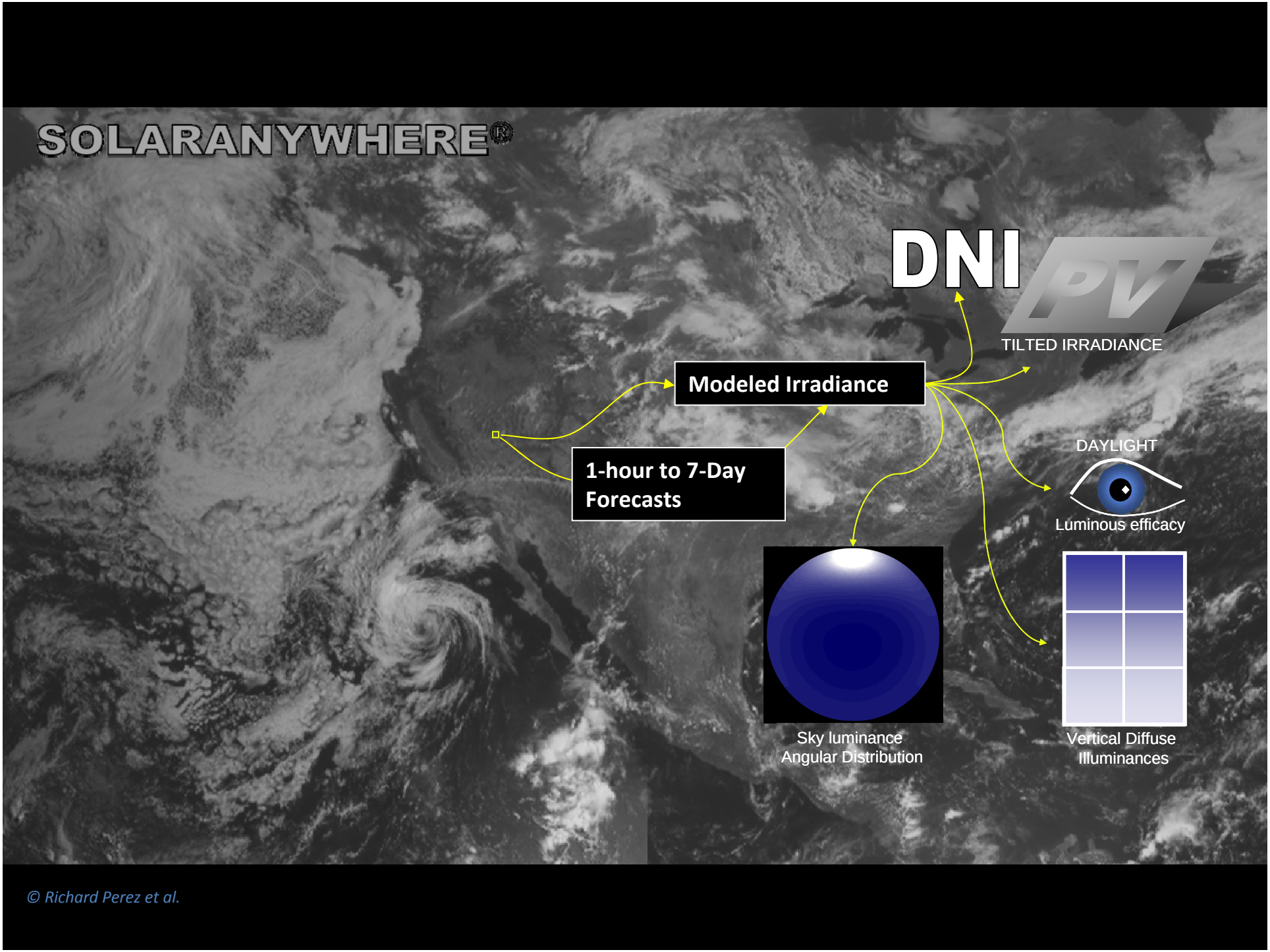


Relative Output Variability
Output variability for fleet / Output variability at single location

Dispersion Factor
Number of Time Intervals for cloud to pass across the PV Fleet

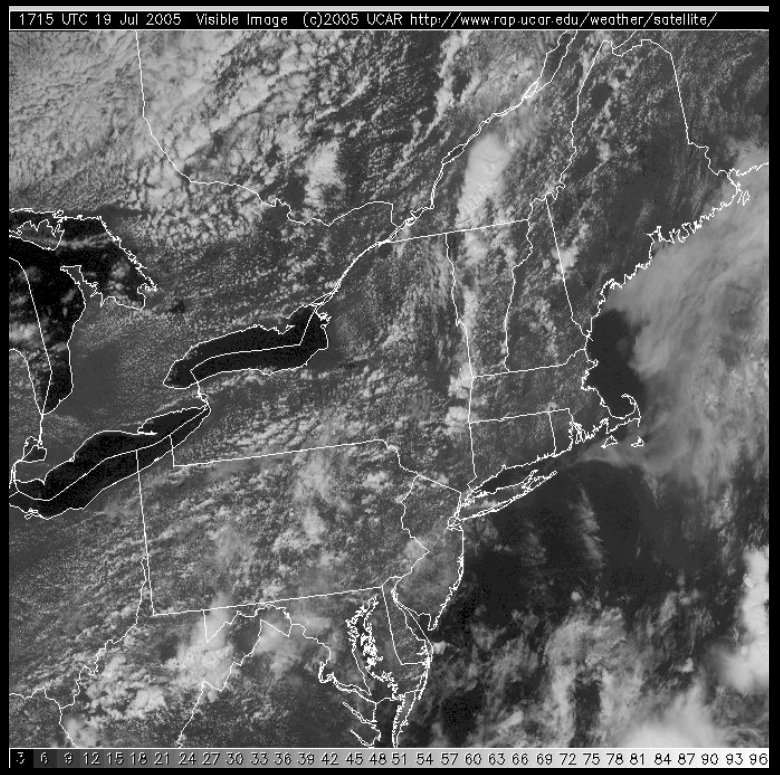
Question #2

What needs to be done to forecast short-term output variability?



Current-to-5 hours
CLOUD MOTION

Patterned after Lorenz et al.



How This Relates To Output Variability

Relative Output Variability is based on:

1. Number of PV systems

2. Dispersion Factor

   Dispersion Factor is the number of Time Intervals for a cloud to pass across the distance of the entire PV Fleet

Conclusions: Relative Output Variability

- Can be quantified based on the number of PV systems and the Dispersion Factor
- Equals inverse of the square root of the number of systems for dispersed PV systems
- Can be minimized for optimally-spaced PV systems for a given Cloud Transit Speed

Next Steps

- Further model validation
- Extend model to arbitrary fleet configuration
- Integrate with SolarAnywhere® (www.solaranywhere.com) forecasting