Implementation of Synthetic Cloud Fields for PV Modeling in Distribution Grid Simulations

PRESENTED BY

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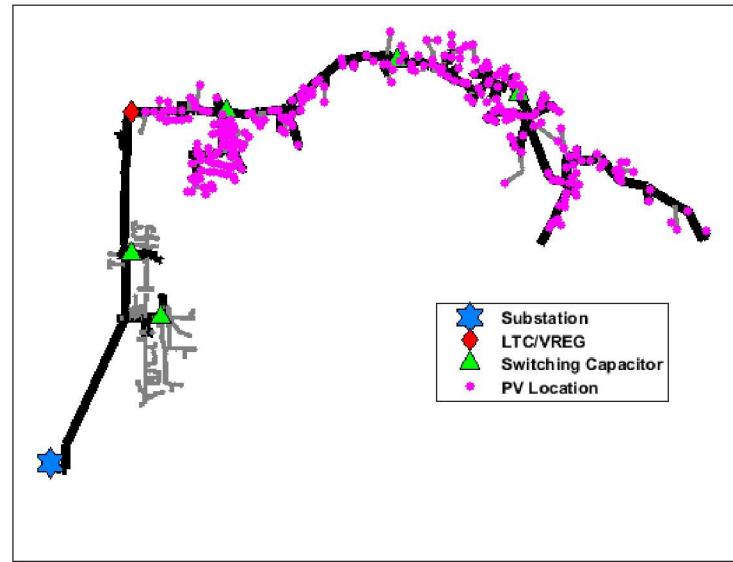
PVSC 45 / WCPEC-7
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SAND

Challenge: modeling PV power output from several PV interconnection points on a distribution feeder

Substation
LTC/VREG
Switching Capacitor
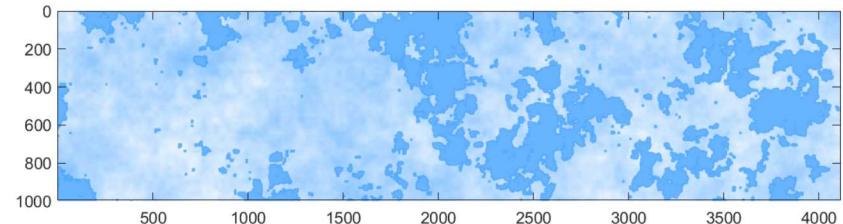PV Location

Options:

Single Sensor

- Point measurements from a single sensor applied to all PV locations
- PV power timeseries perfectly correlated
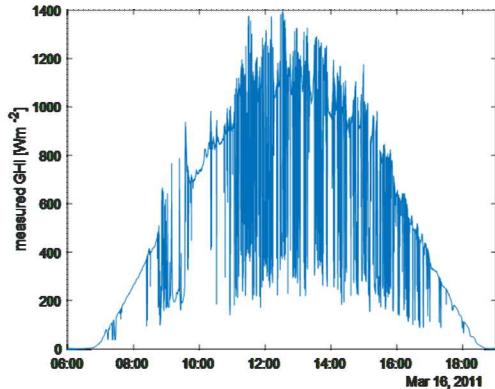

Synthetic Cloud Fields

- Simulated cloud formations
- Unique PV power timeseries at each interconnection point

Method:

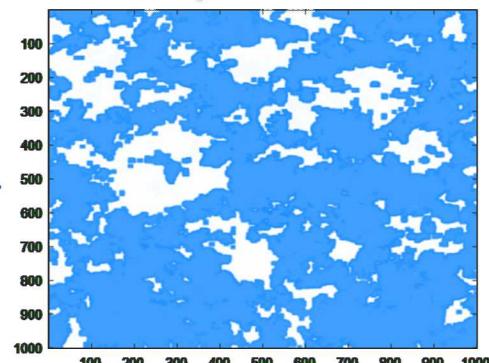Input: high-frequency measurement of irradiance

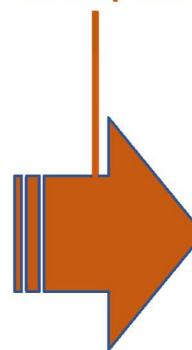Create: synthetic cloud field

Determine cloud speed

Apply: cloud field to PV interconnection points

Compute irradiance statistics:
- variability by timescale
- % clear
- cloud opacity

Output: unique PV samples

Create Synthetic Cloud Fields Step 1

fine grid
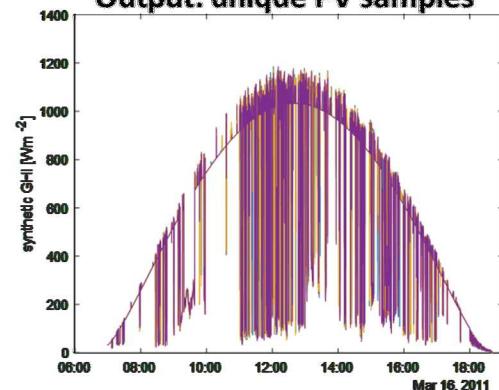
scale 1

scale 2

scale 3

1a. generate fields of random values (0,1)
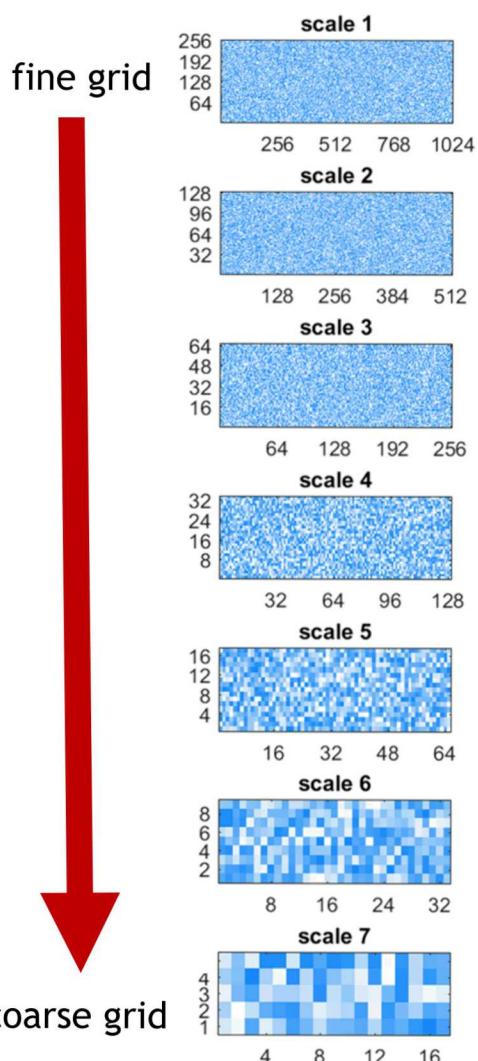
scale 4

1b. interpolate to

size of finest grid

scale 5

scale 6

scale 7

coarse grid

weight = 0.01
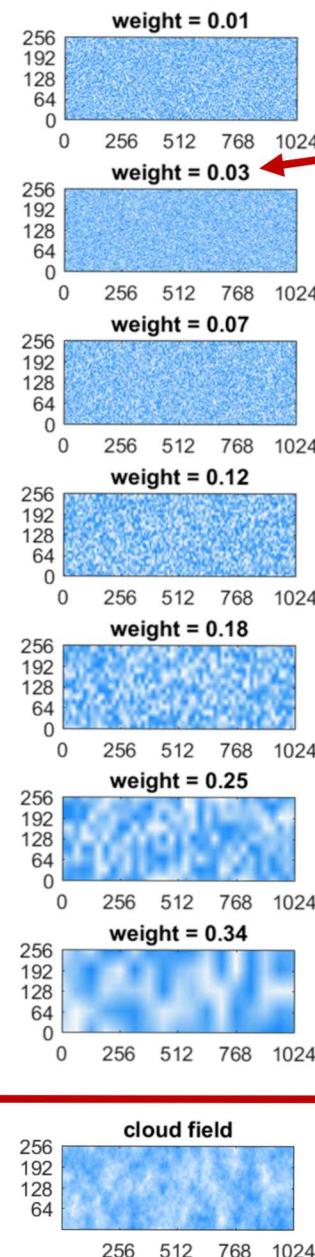
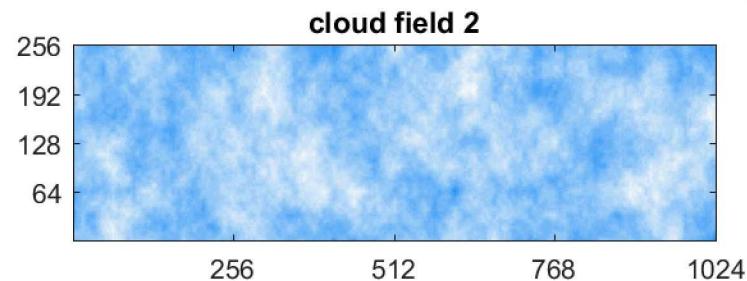**1c.** weights of each scale relate to variability

weight = 0.03

weight = 0.07

weight = 0.12

weight = 0.18

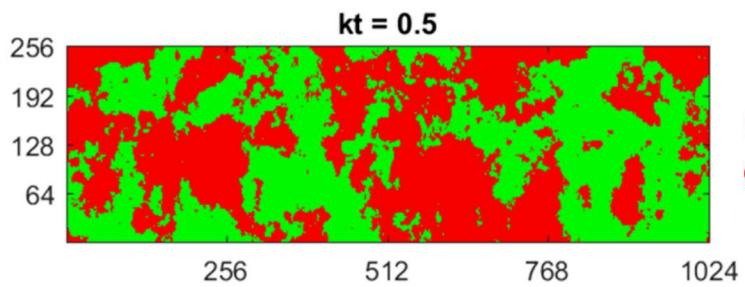weight = 0.25

weight = 0.34

1d. weighted sum creates cloud field

cloud field

Create Synthetic Cloud Fields Step 2

2a. run step 1 twice to generate two cloud fields

cloud field 1
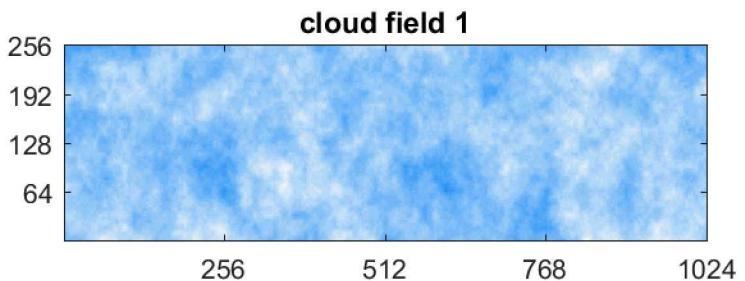
cloud field 2

2b. create cloud mask from cloud field 1 based on average clear-sky index (kt)

kt = 0.5

kt = 0.8
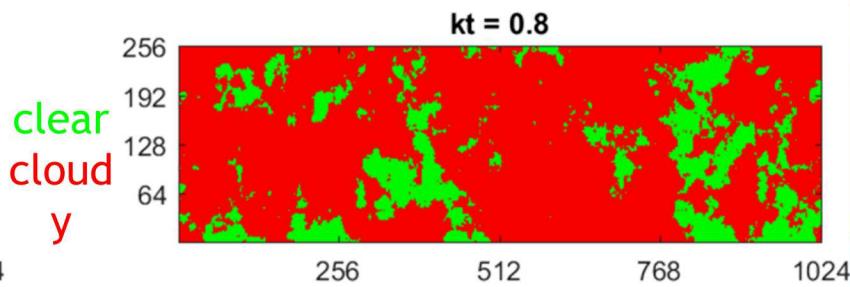
clear
cloud
y

2c. apply cloud mask to cloud field 2


kt = 0.5

kt = 0.8
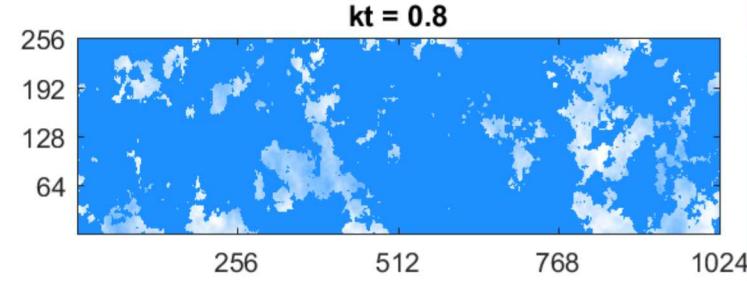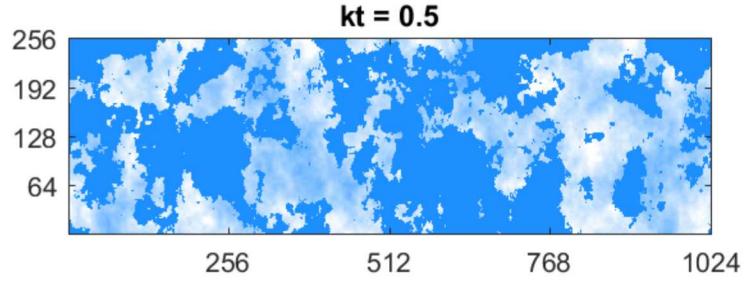
Recent method improvements have included:
1. Improved weighting of fine versus coarse cloud scales.
   - Now based on wavelet transform of input high-frequency irradiance measurement.
2. Clear-sky areas based on amount of time when clear-sky index >0.9
   - Previously based on average clear-sky index, led to clear periods even on fully cloudy days
3. Cloud opacity flexibility
   - Cloud enhancement allowed, but only at cloud edges
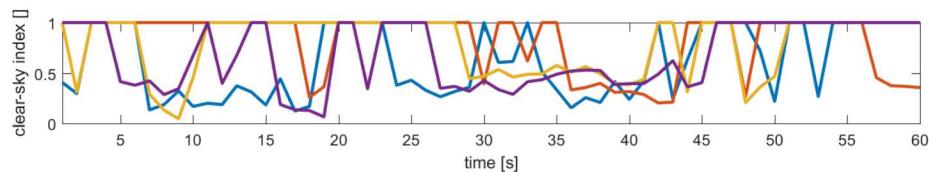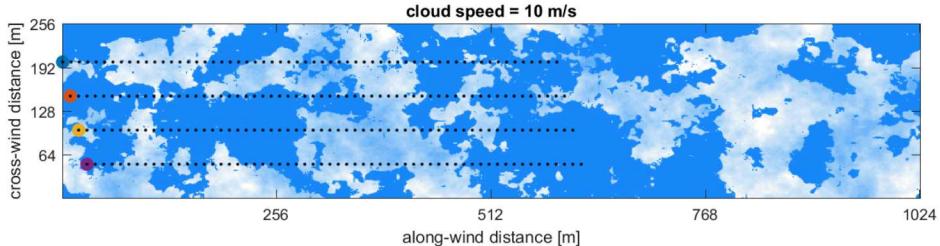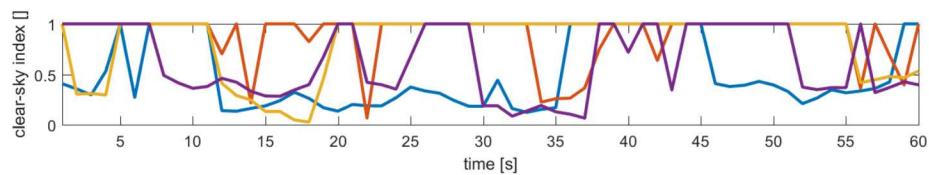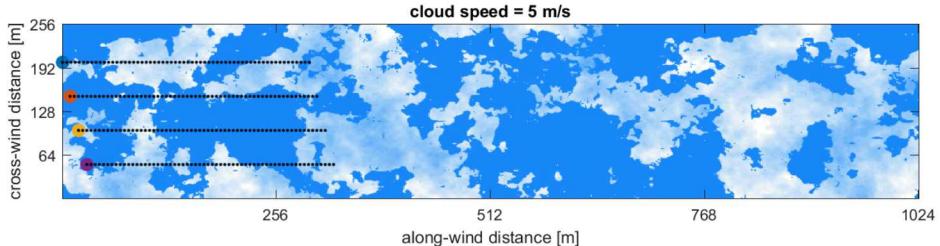   - Cloud intensity matches average clear-sky index
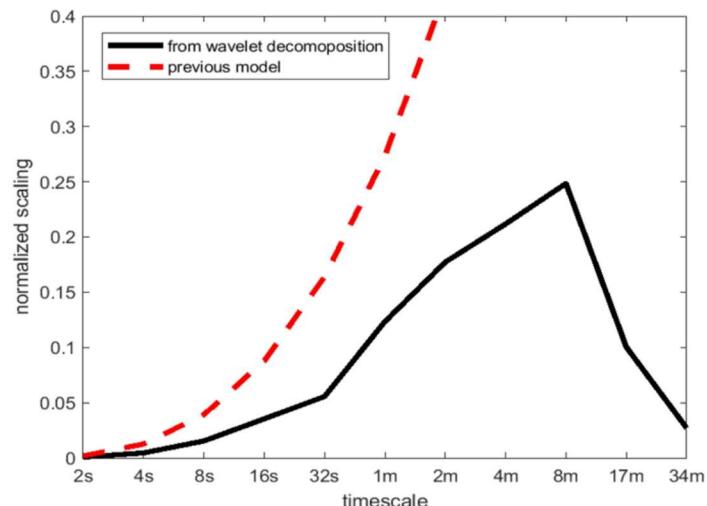
Method Improvements

Improved method allows for larger cloud features – captures long duration ramps

Old Method

Improved Method
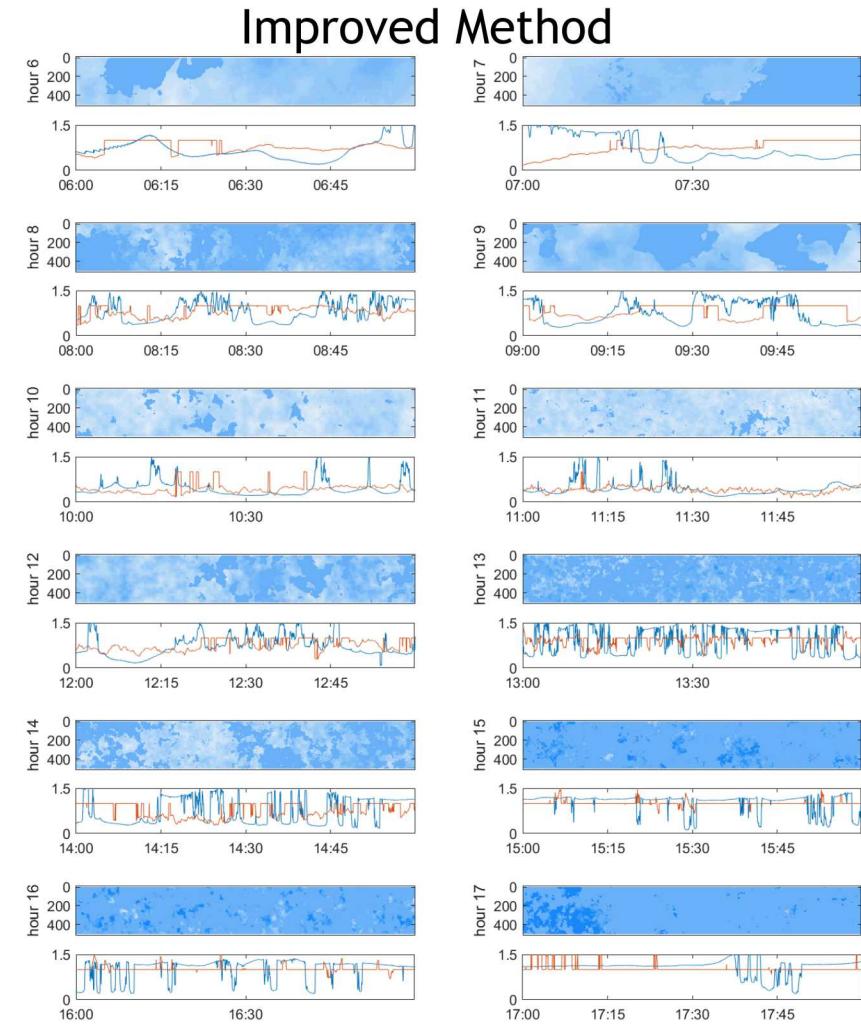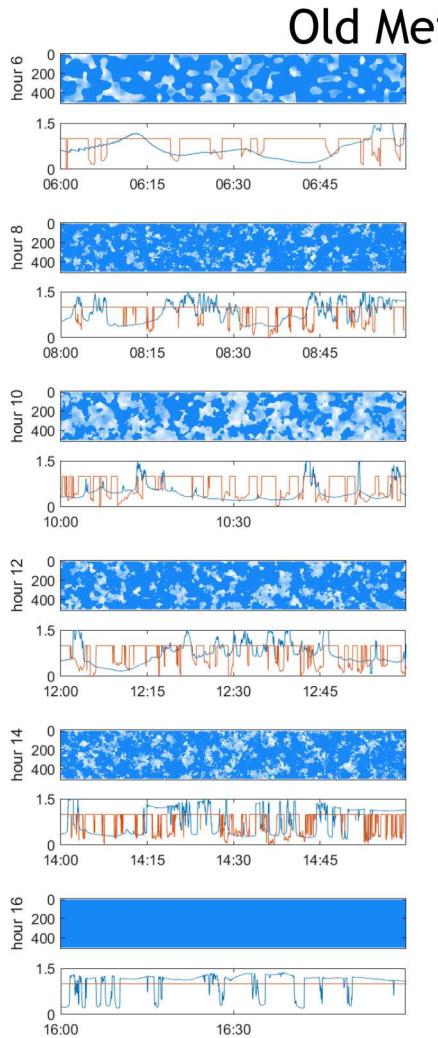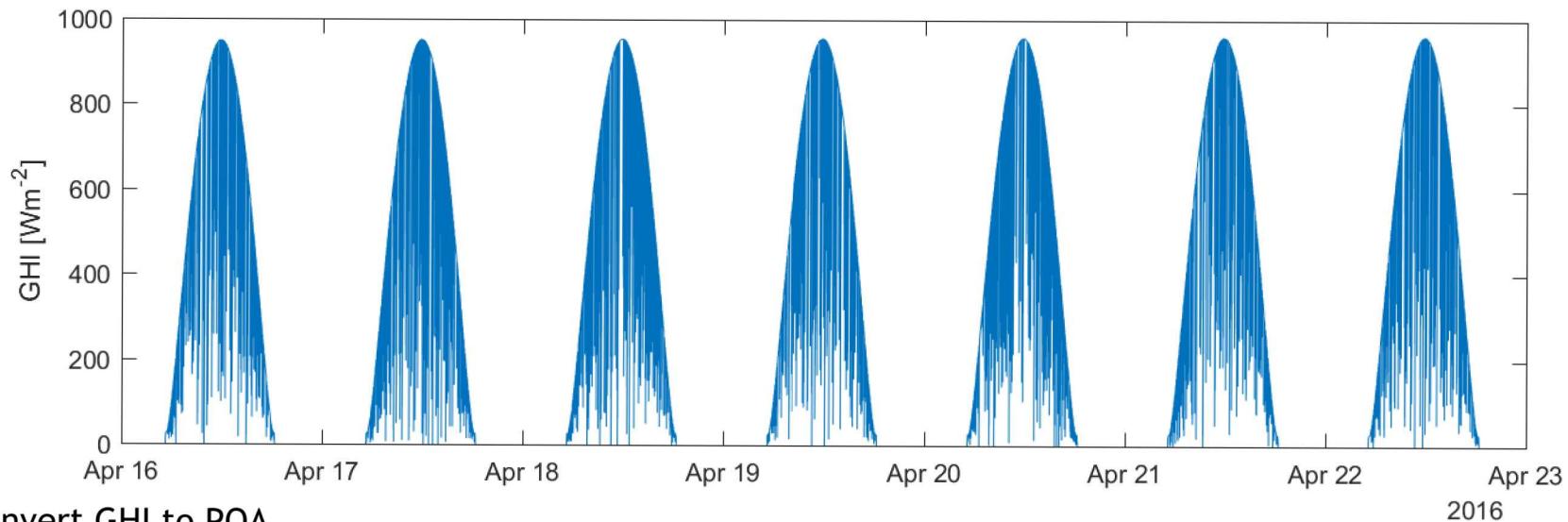
Create Synthetic Cloud Fields Step 3

3. sample from the cloud field based on the cloud speed
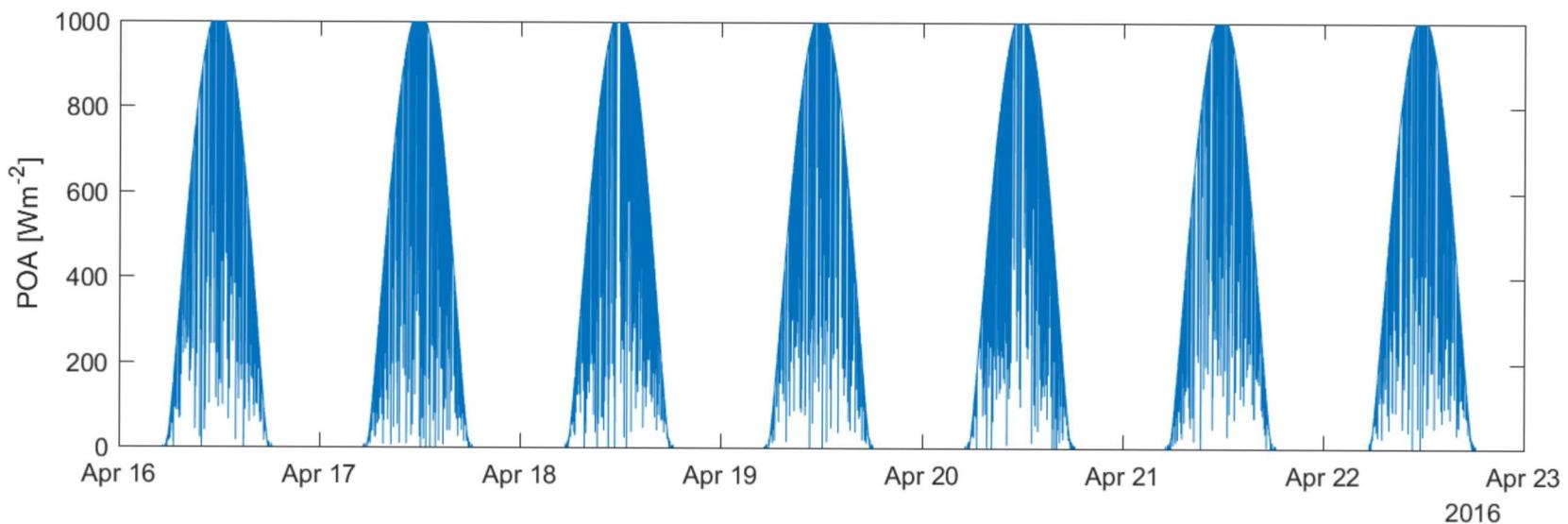
faster cloud speed = samples more spread out
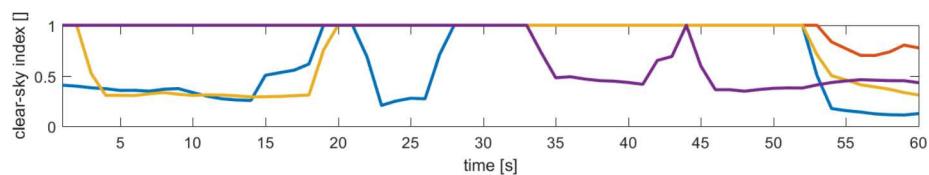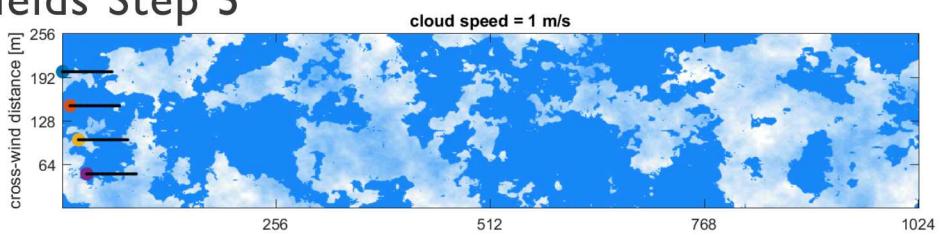
Create Synthetic Cloud Fields Step 4
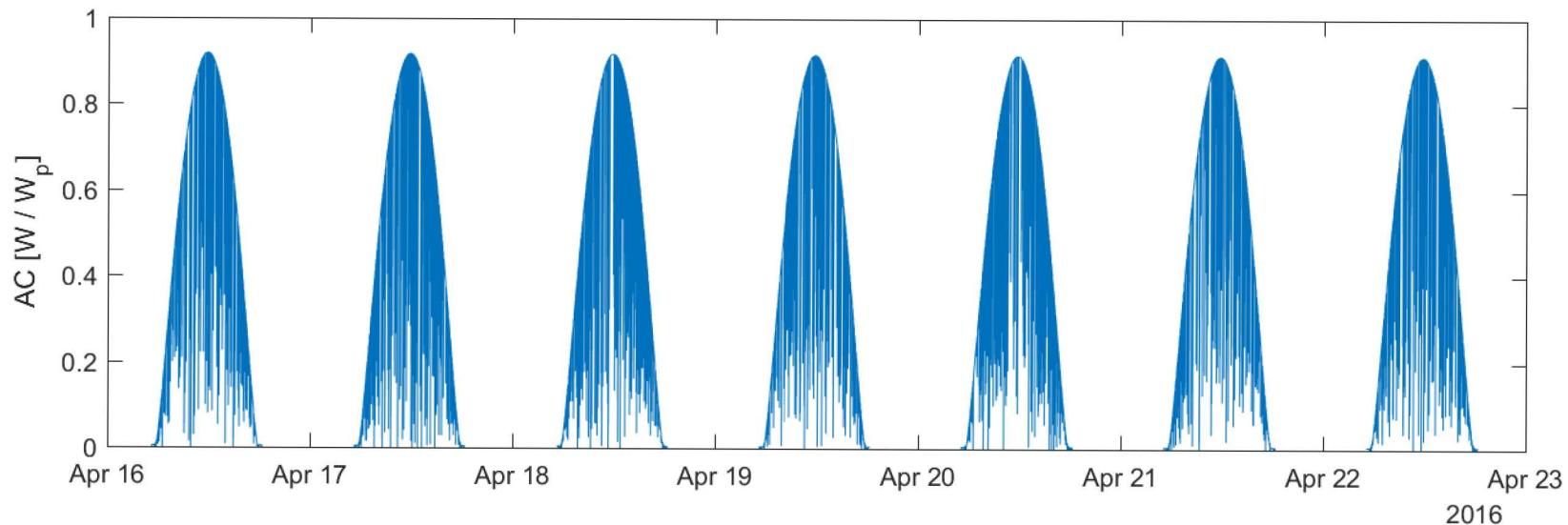
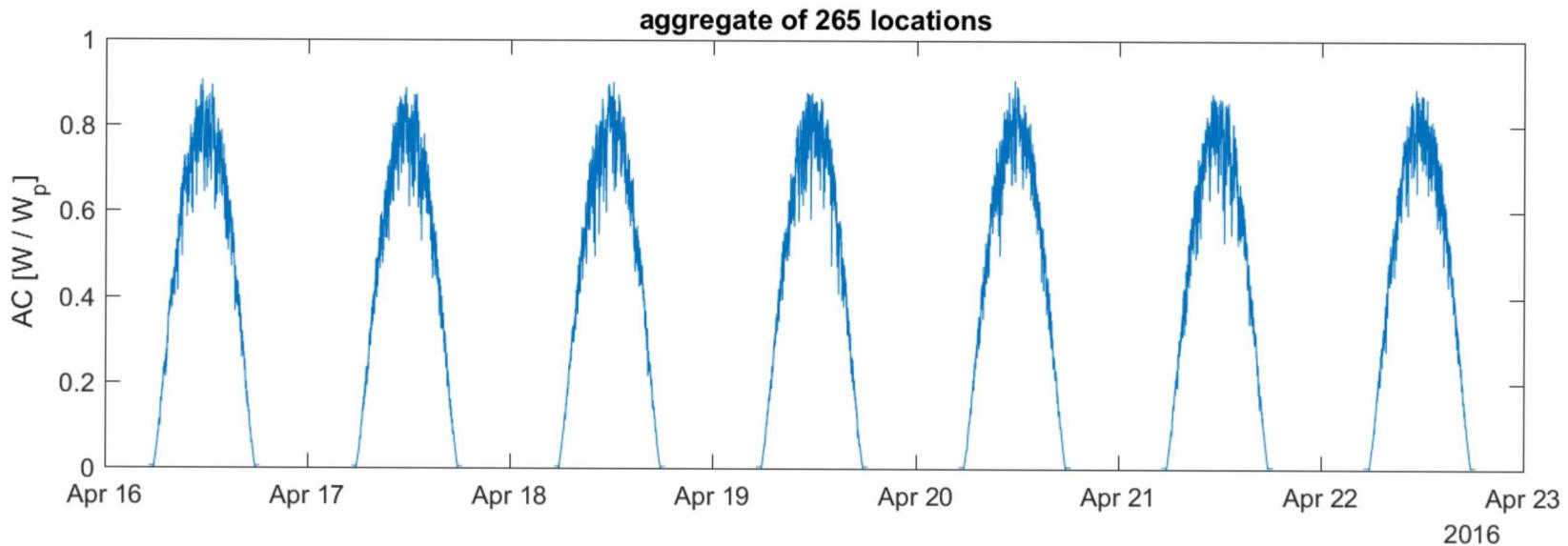**4a.** convert clear-sky index to

4b. convert GHI to POA

Create Synthetic Cloud Fields Step 5

5. convert POA to AC power

Repeat steps 4-5 for all interconnection points on

aggregate of 265 locations
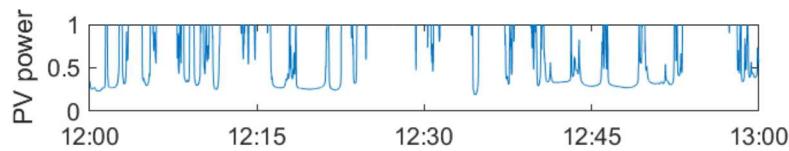
Oahu irradiance network

- Public: https://midcdmz.nrel.gov/oahu_archive/
- 1-second irradiance from 19 sensors (17 with good data)
- 1-year of data
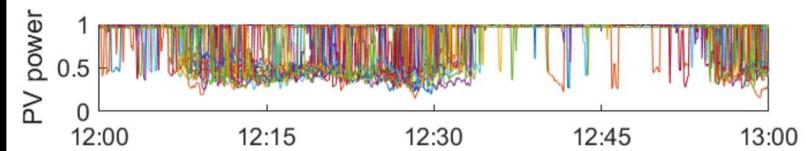- Represents a highly variable location

Single Sensor

entire area
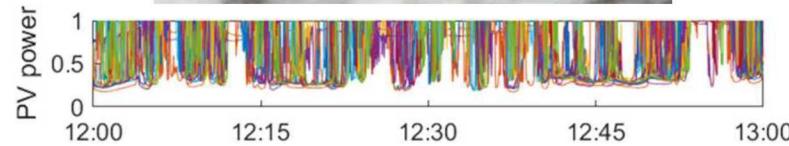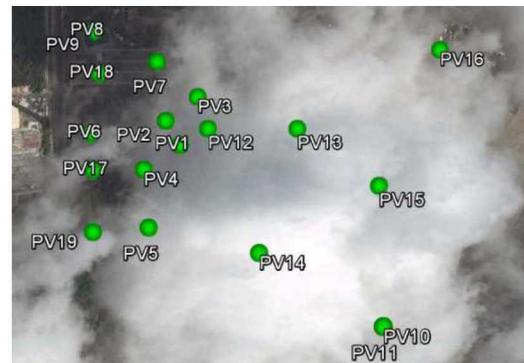follows same
pattern

Synthetic Cloud Fields

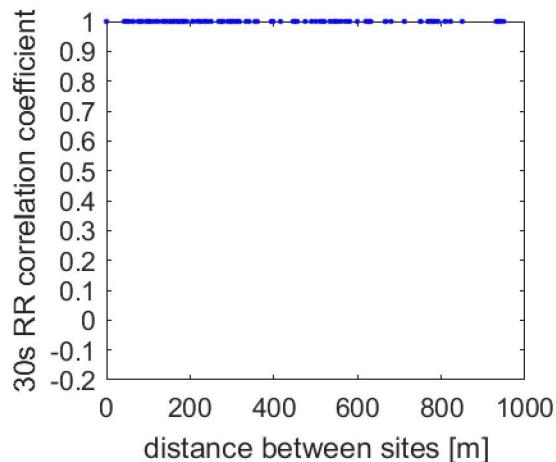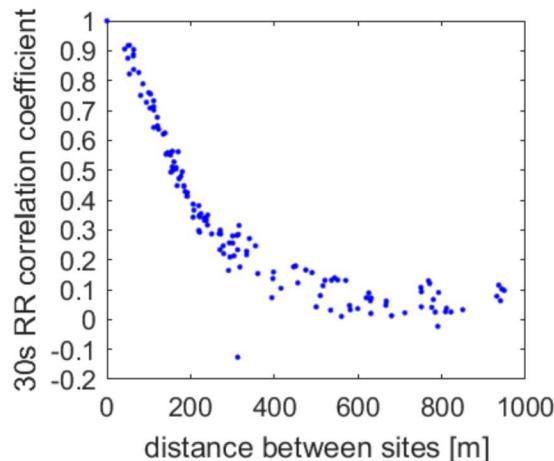cloud shapes
create different
PV profiles at
each locations

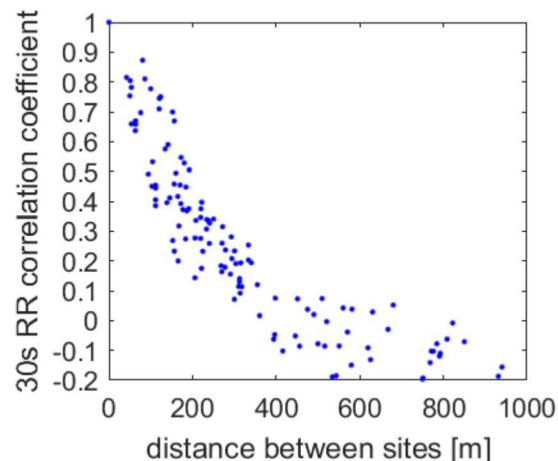## Actual

Single Sensor

all sites
perfectly
correlated

Synthetic Cloud Fields

correlation decreases as distance increases

Actual

Single Sensor
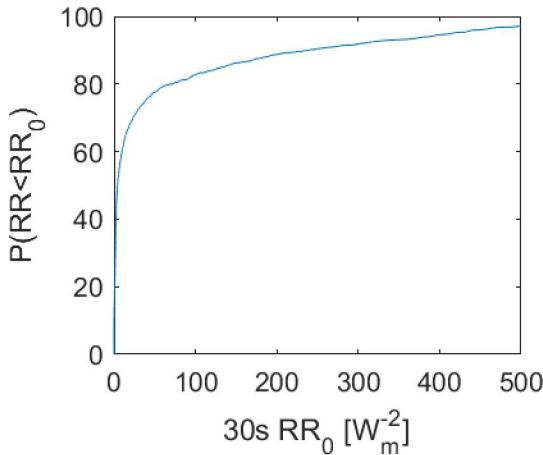
Synthetic Cloud Fields
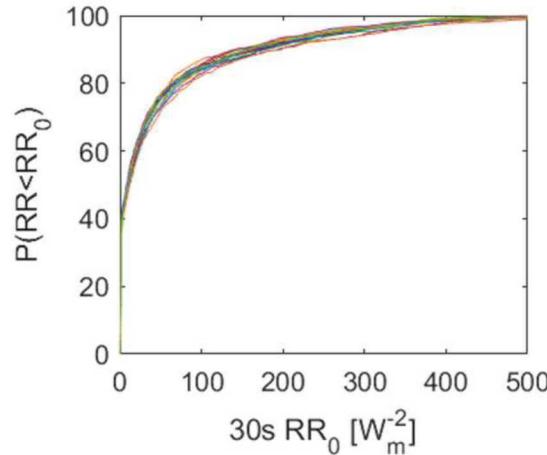
realistic
ramp rate
statistics
retained

Actual
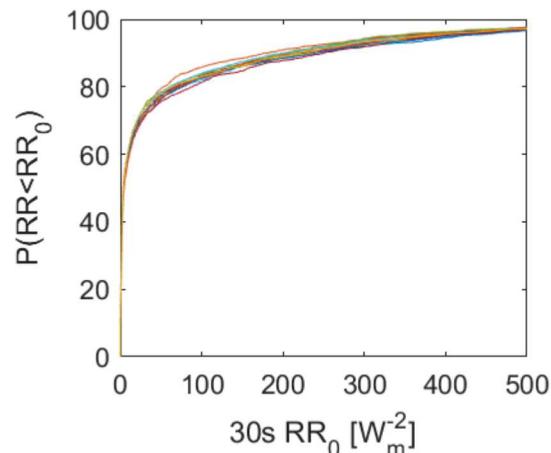
- Two PV samples:
  - Based on 17 irradiance measurements
  - Based on 17 synthetic irradiances
- PV samples spread over 265 PV transformer interconnection points (i.e., many duplicates)
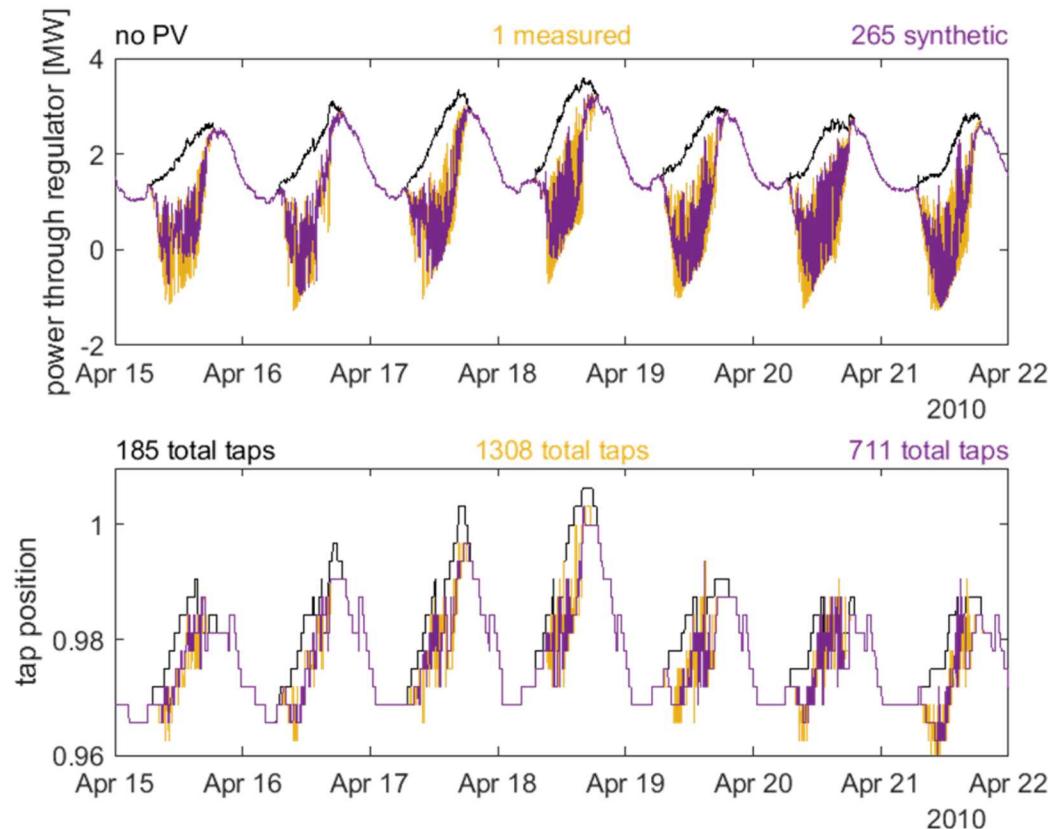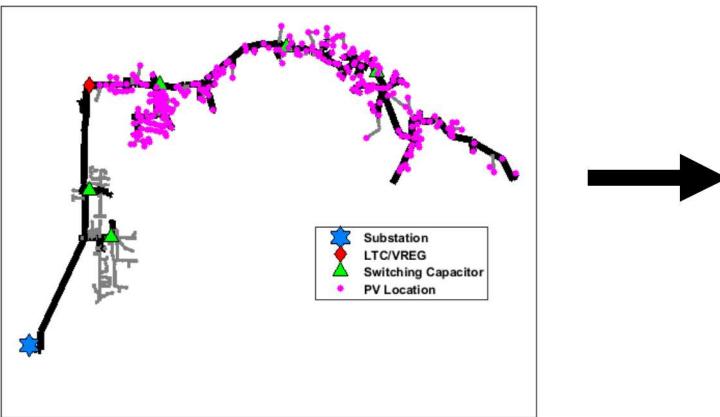- Simulated tap changes over 1-week
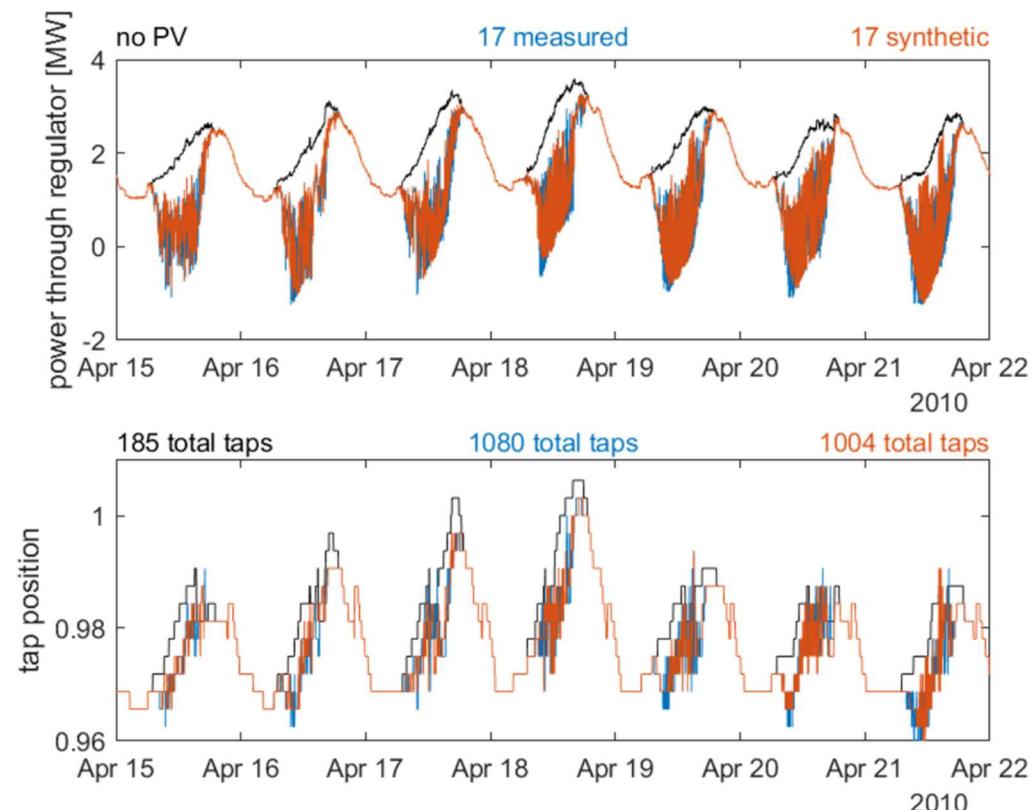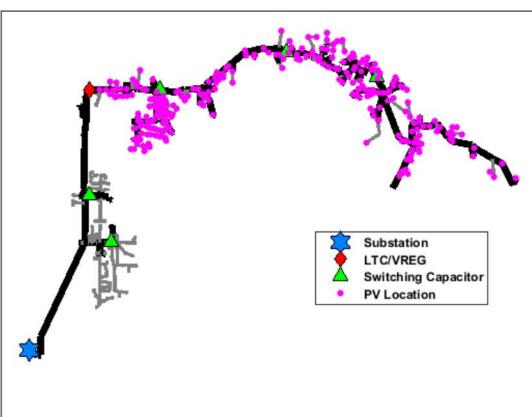
Exploration of Synthetic Cloud Fields Value

- Two PV samples:
  - Based on 1 irradiance measurement (common situation)
  - Based on 265 synthetic irradiances
- 1 irradiance measurement applied to 265 PV transformer interconnection points (i.e., all duplicates)
- Simulated tap changes over 1-week

Conclusions

- Synthetic cloud fields present an method to increase the accuracy of PV simulations in distribution grid studies
- Several recent improvements have made synthetic cloud fields more representative of actual irradiance
- Distribution grid impact results from synthetic PV samples based on cloud fields compare well to results from a measured irradiance network
- Significant errors result when applying a single irradiance measurement to represent all of the PV on the feeder (due to missed spatial smoothing)

Next steps
- Continued validation and evaluation
- Integration with methods to create high-frequency irradiance from low-frequency measurements (e.g., satellite data)
- Implementation in the GridPV Toolbox

Questions?

Thank You!

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