SAND2018-8893PE

Sensitivity Analysis of The Cloud Field Methodology

PRESENTED BY

Melvin Lugo – UPRM

Robert J. Broderick – Org. 8812

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Personal Background

Education

- MS Electrical Engineering – University of Puerto Rico at Mayaguez
  - Expected Graduation: May 2019
- BS Electrical Engineering – University of Puerto Rico at Mayaguez
  - Graduation Date: 2017
- BS Mechanical Engineering – University of Puerto Rico at Mayaguez
  - Graduation Date: 2015

Experience

- R&D Summer Intern at The Procter & Gamble Co.
  - Summer 2016, 2017
- Undergraduate research
  - Minds2Create Team – Micromouse
  - SAE UPRM – Solar Car Team Co-Captain

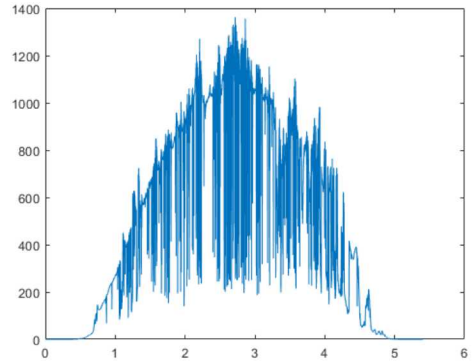
Agenda

- Introduction
- Methodology
  - Work flow
  - Location Sorting
  - Group Generation
- Results
- Discussion
- Conclusion
- Q/A

Introduction

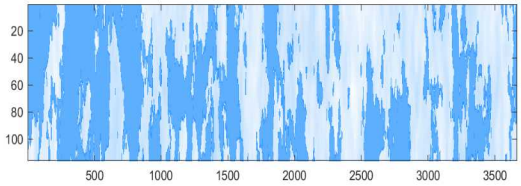
- Simulating the effect of variable cloud cover is an important aspect of the integration high-penetration photovoltaic systems with the current grid.
- The Cloud field methodology, developed by M. Lave, came about as an attempt to simulate the variability on irradiance profiles caused by clouds using high frequency irradiance data as taking high frequency irradiance data is expensive and placing many sensors spread out over a large is impractical.
- The idea is to use a single high frequency irradiance measurement and simulate the effect of clouds on the generation of a number N of PV systems around a defined area. Previous work shows the similarity of the method regarding real vs simulated irradiance profiles and the effects on the power flow in a distribution feeder.
- This work focuses on how the amount of unique synthetic irradiance profiles affect the voltage regulator tap changes on a distribution feeder.

Work Flow



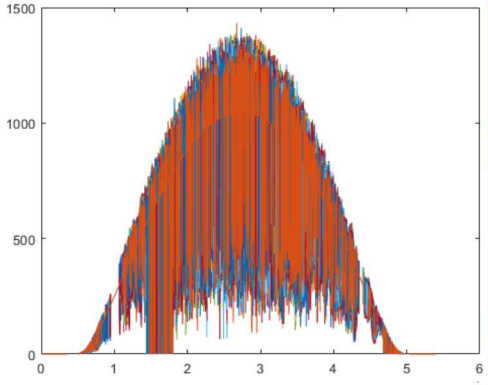
Measured Irradiance

Generated Cloud Field

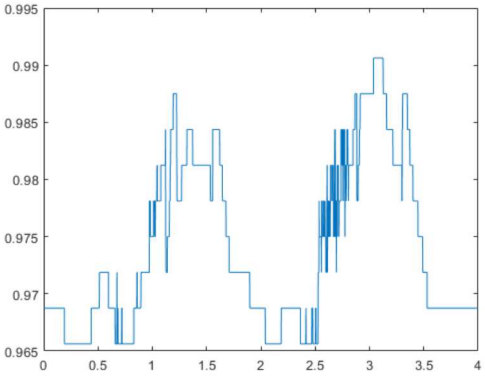


Power Flow Solver

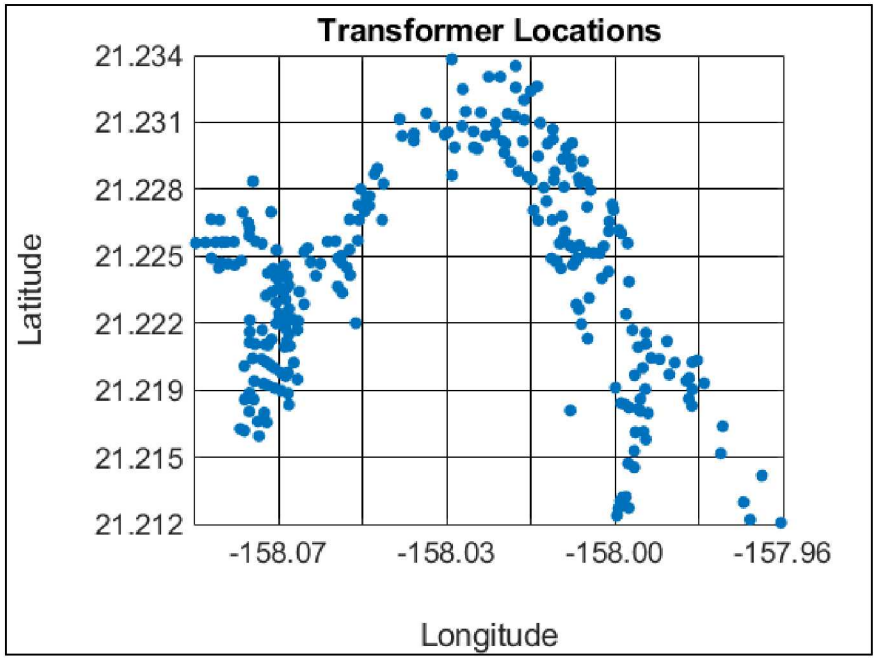
Synthetic Irradiance

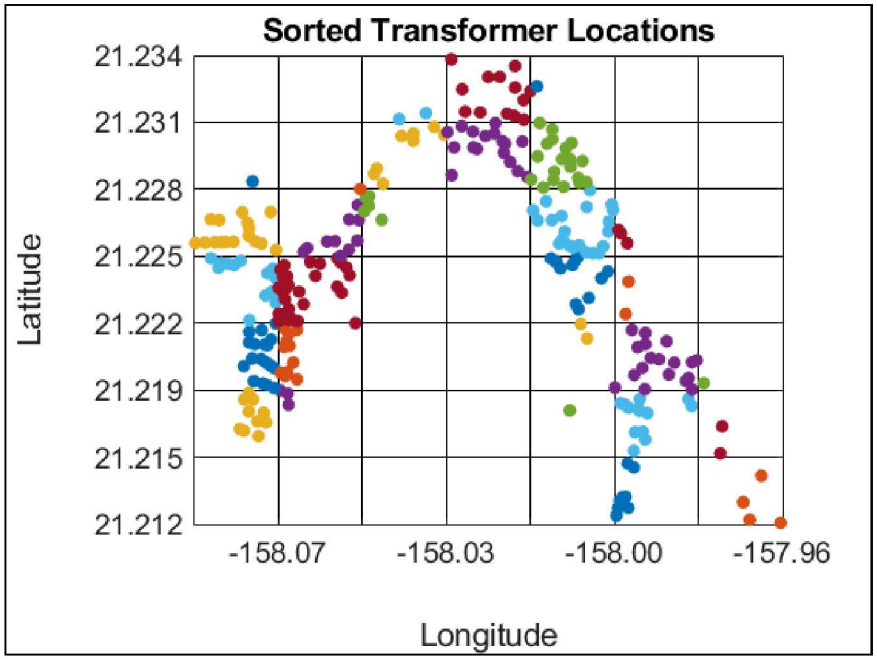


Voltage Regulator Tap Positions



Location Sorting

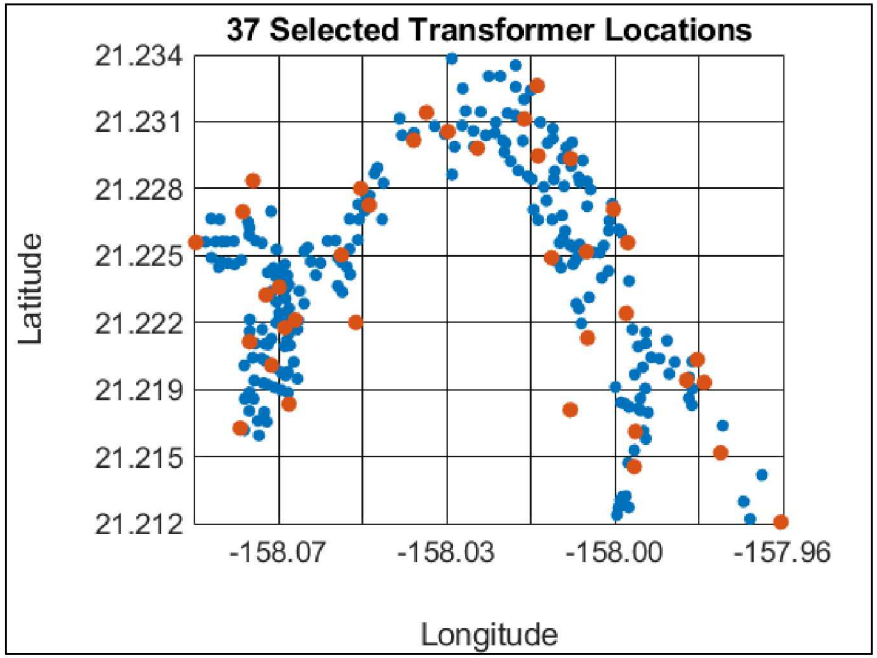


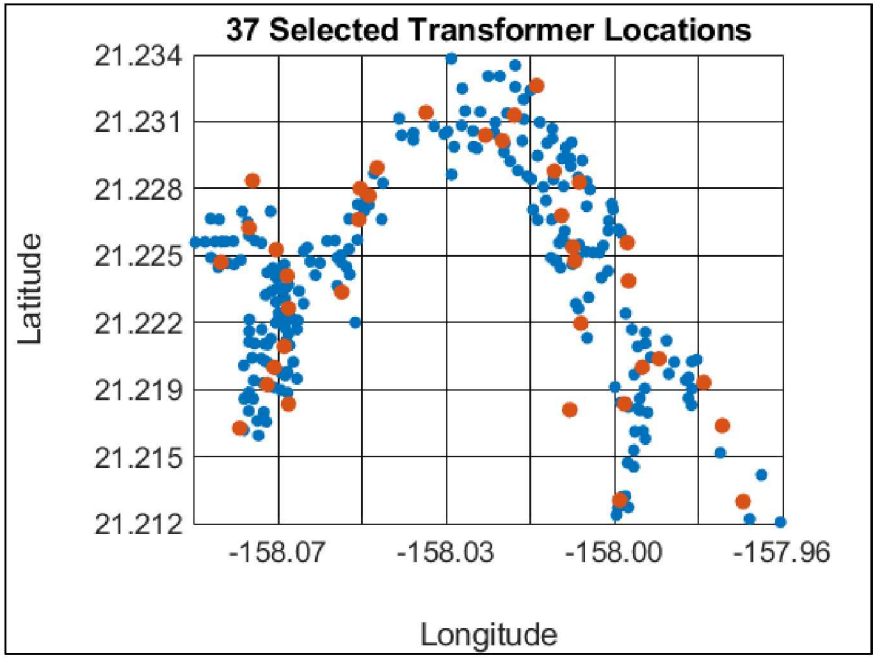


- The cloud field does not only depend on the measured irradiance.
- The location of the desired measurement is also a factor.

- The first step in the selection process is the generation of a grid and the sorting of the locations within that grid.
- The locations are then grouped according to this sorting

Group Generation

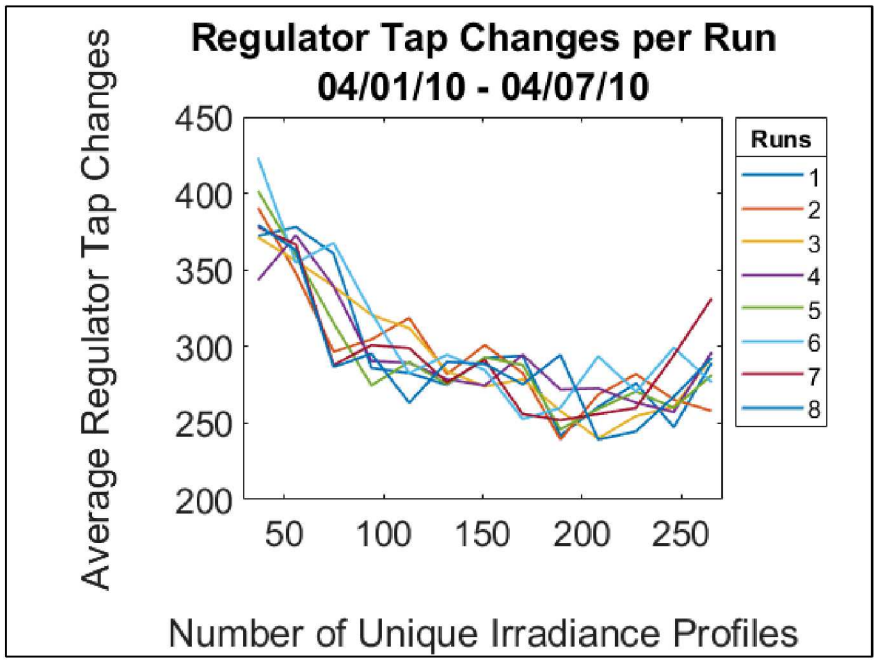


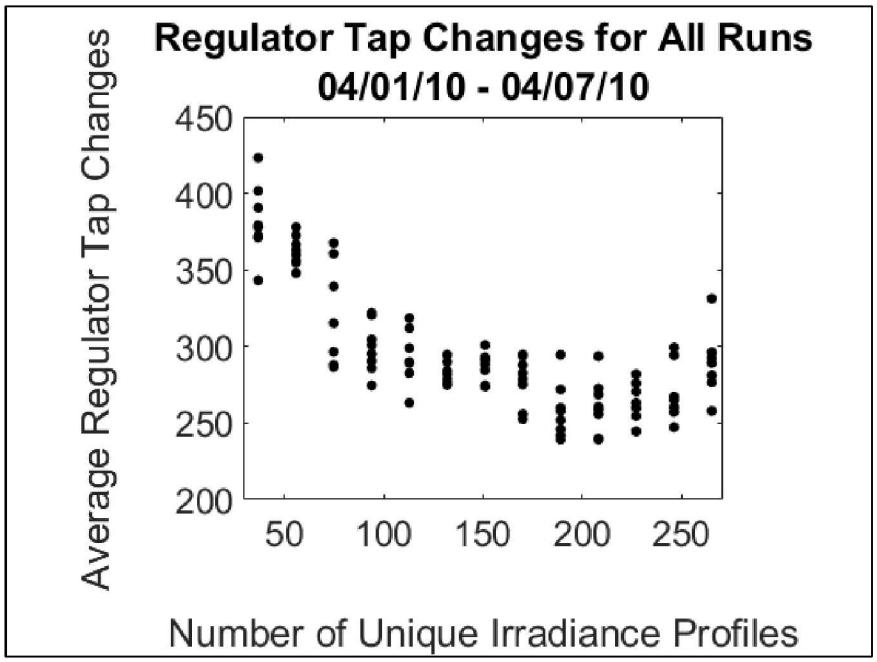


- Orange dots are the 37 selected locations.
- Blue dots show the remaining 228 locations.
- There is at least one location per cell in the grid.

- Both plots show a different group of 37 locations.
- All groups are different for the runs except the N = 265, for this is the total number of locations

Results

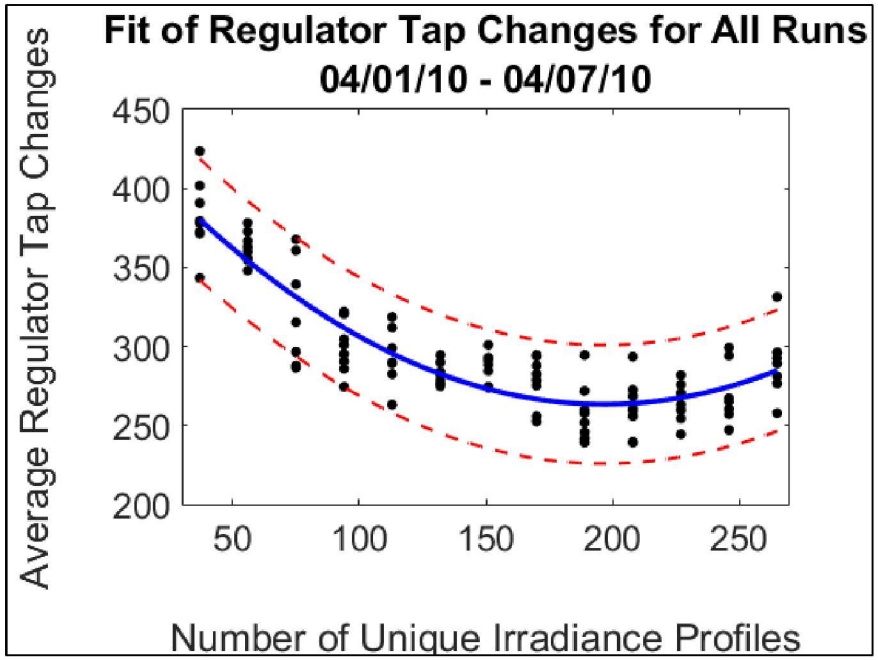




- A total of 8 runs were performed.
- Each run has group sizes 37, 56,75,…,265. For a total of 13 groups per run.
- Variation in tap changes for same group size is apparent.

- All runs are combined into one data set.
- Previous work hinted at a lowering of tap changes for an increase in the number of unique samples, this can be seen here.

Discussion



- The trend can be described with a quadratic fit, shown on the plot.
- The R^2 value of the fit is 0.7934, this could be better and more runs are needed to confirm quadratic fit.
- The difference between the upper and lower confidence intervals is ~75 tap changes.

$F(x) = 0.0046x^2 - 1.8x + 440.57 \quad R^2 = 0.7934$

- This behavior has only been described for this specific date and location.
- Measured GHI samples are dependent on the time of year and cloud cover.
- Weeks with different variation in measurements GHI should have different behavior.
- The variation in the N = 265 group size can be explained with how the cloud fields are generated.

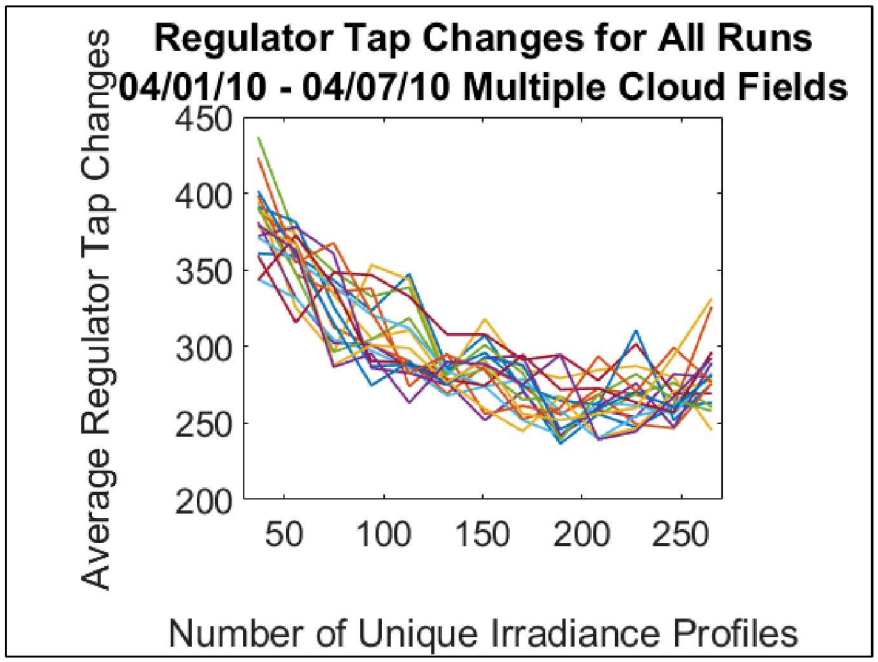
Conclusion

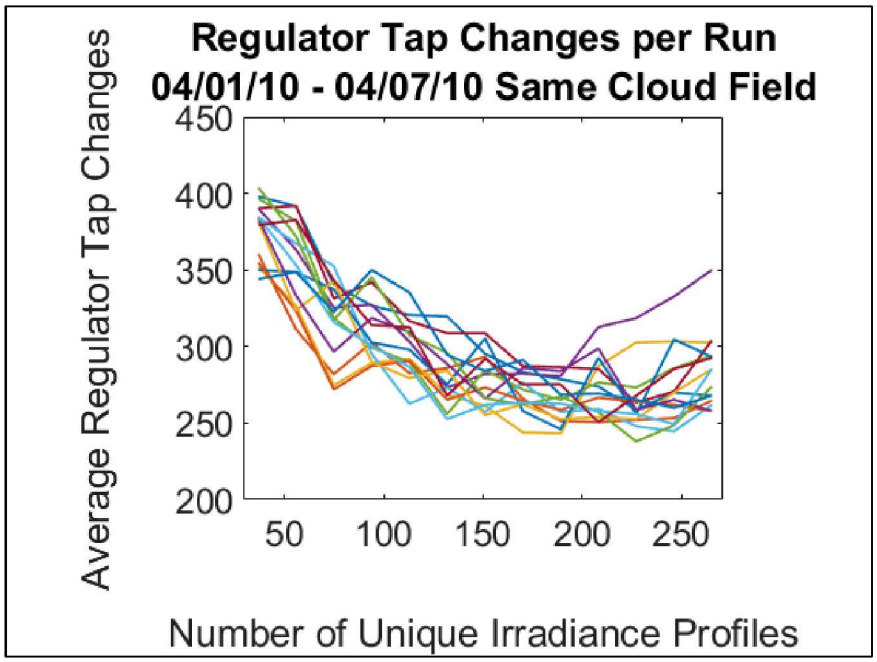
- A general reduction in tap changes with an increase in unique GHI samples occurred; the increase in tap changes as the samples approached the total number of locations was unexpected.
- Simulation could be focused around three points: a small group size, the maximum allowed locations for the area under study and an intermediate amount. This would greatly reduce the computation time.
- The ability to predict the tap change behavior using a fit equation generated from fewer locations is useful as it reduces the resources and time required for computation.
- Future work should include performing the same analysis using different dates i.e. days with more variable GHI and less variable GHI and compare the relationship between the tap changes and the amount of locations.

Questions?

Thank You For Your Attention!

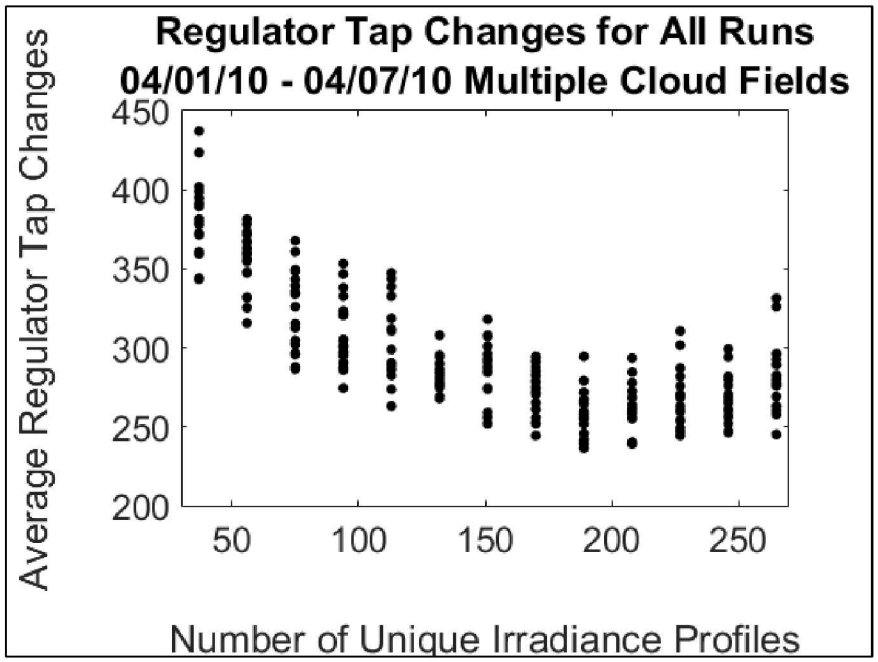
Results First Week April 2010

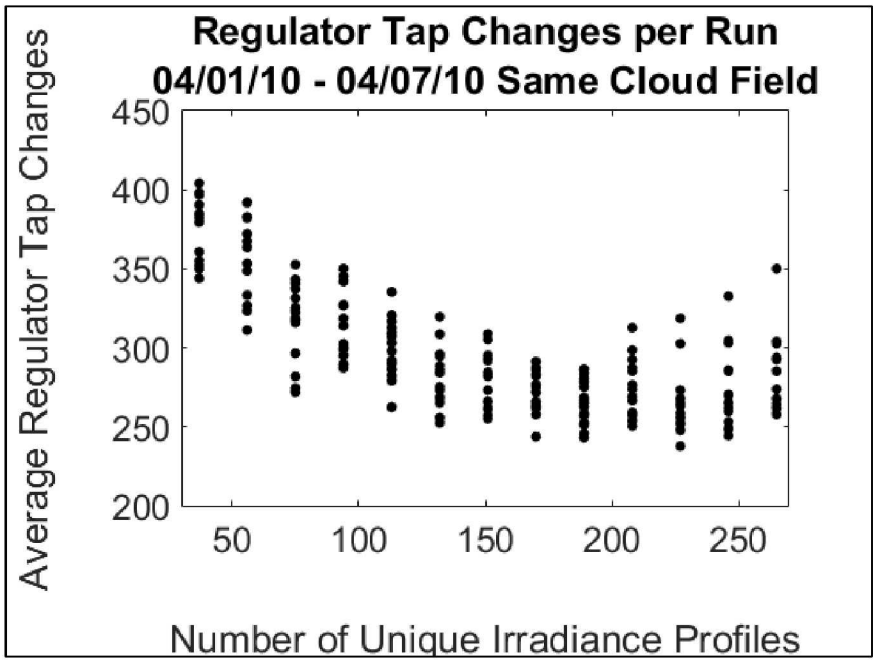




- 18 runs using different cloud fields per run, per group.
- 15 runs same cloud field for all groups and runs

Results First Week April 2010

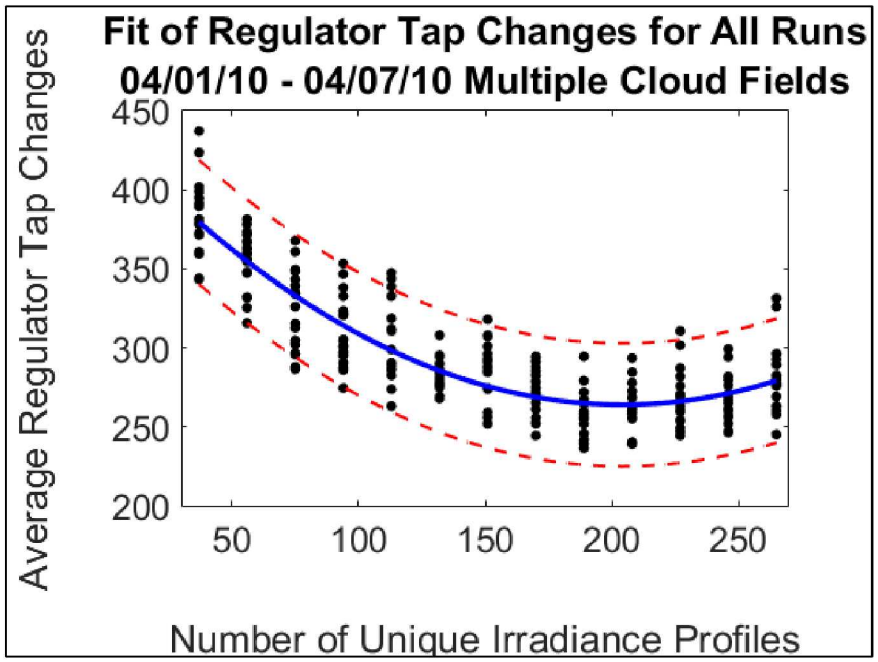


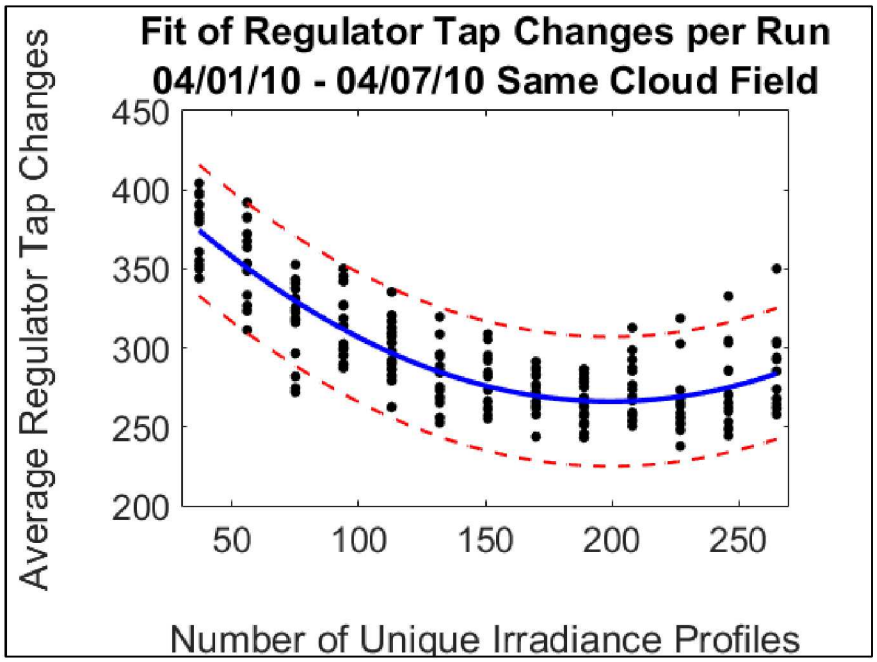


- Minimum from data:
  - 237 tap changes
  - At 189 irradiance profiles

- Minimum from data:
  - 238 tap changes
  - At 227 irradiance profiles

Results First Week April 2010



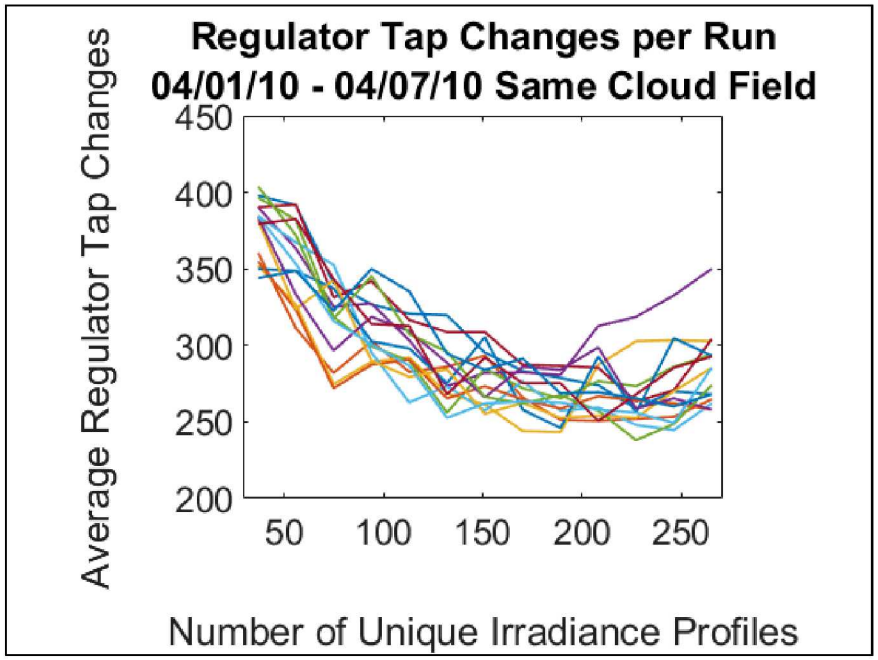


- Minimum from fit:
  - 264 tap changes
  - At 204 irradiance profiles
- Width of 95% confidence interval: ~75 tap changes

- Minimum from fit:
  - 266 tap changes
  - At 199 irradiance profiles
- Width of 95% confidence interval: ~80 tap changes

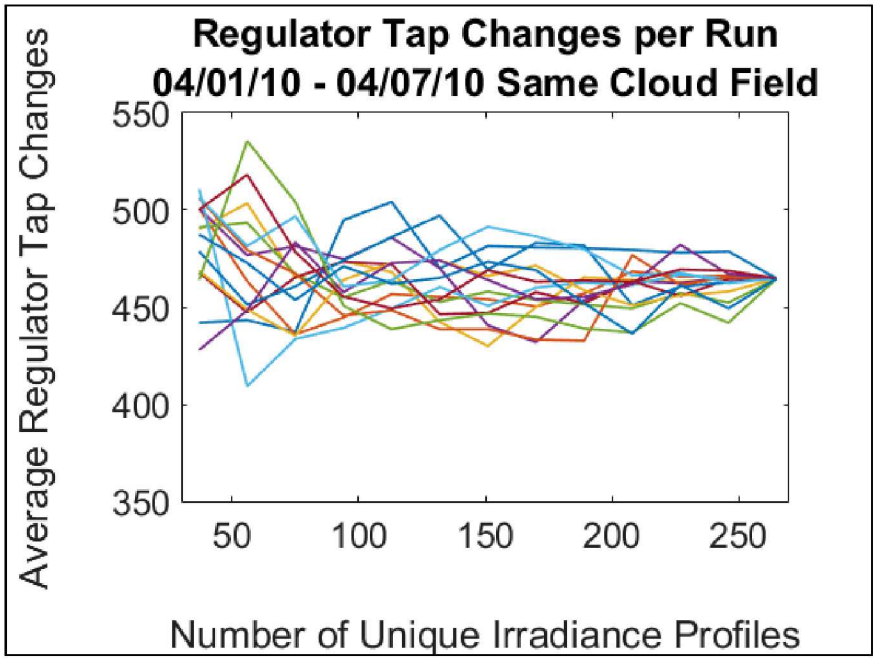
Results First Week April 2010

Old



- Single cloud field for all 15 runs.
- Previous incorrect transformer location assignments caused excessive variation at N = 265.

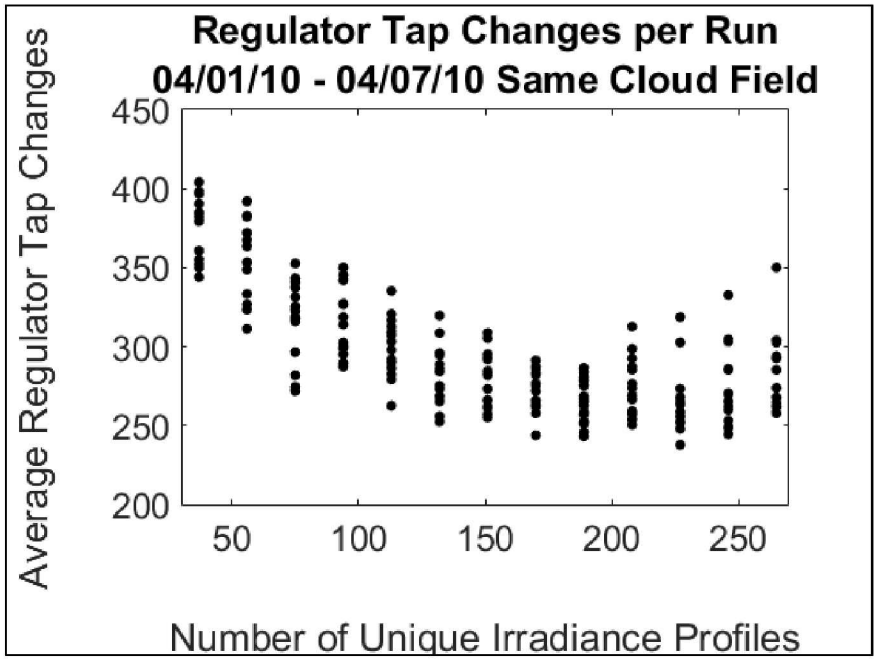
New



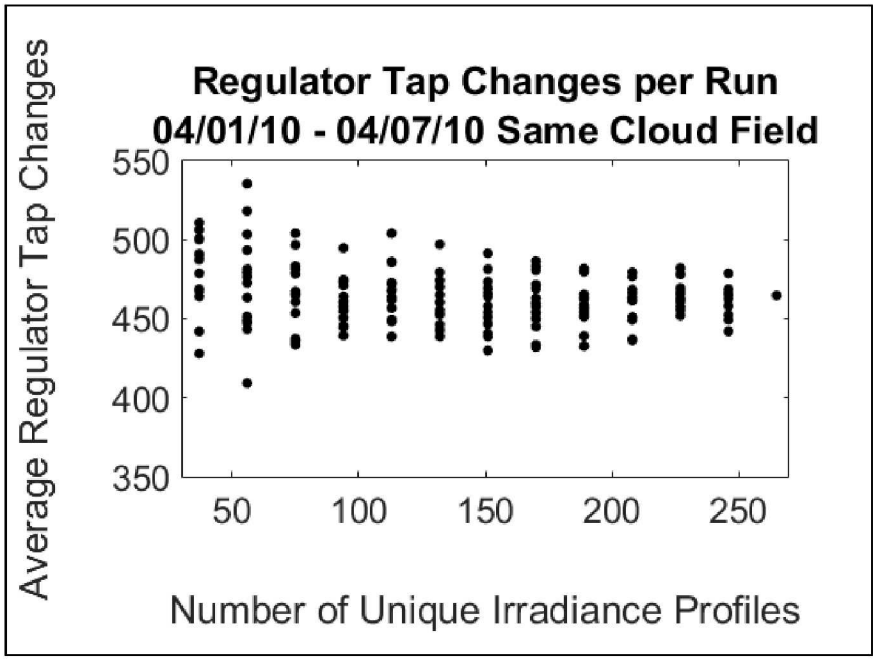
- Single cloud field for all 15 runs.
- Transformer assignment corrected, tap change values converge at a single value for N = 265.

Results First Week April 2010

Old



New

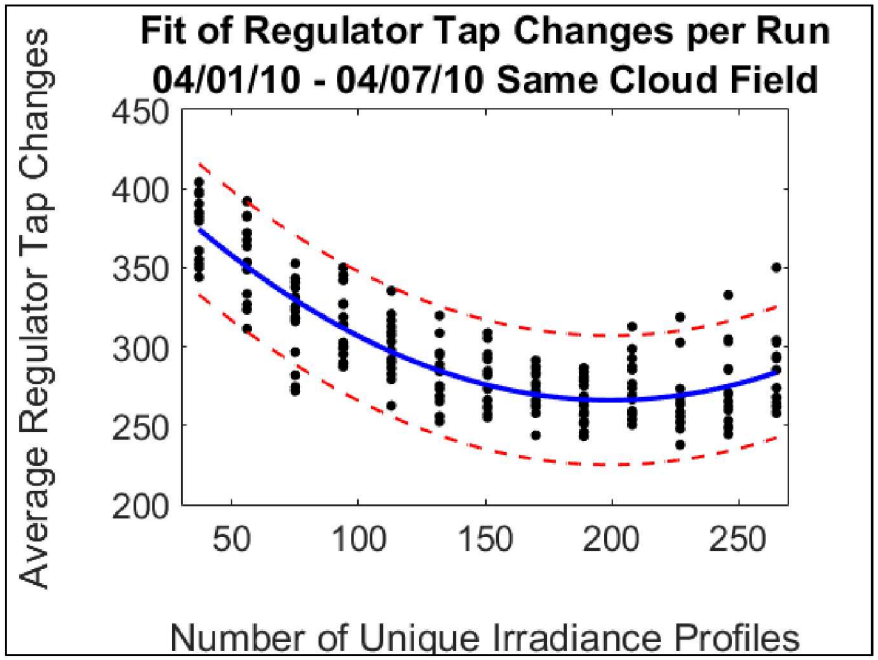


- Minimum from data:
  - 238 tap changes
  - At 227 irradiance profiles
- Rapid decrease of tap changes as number of irradiance profiles increases

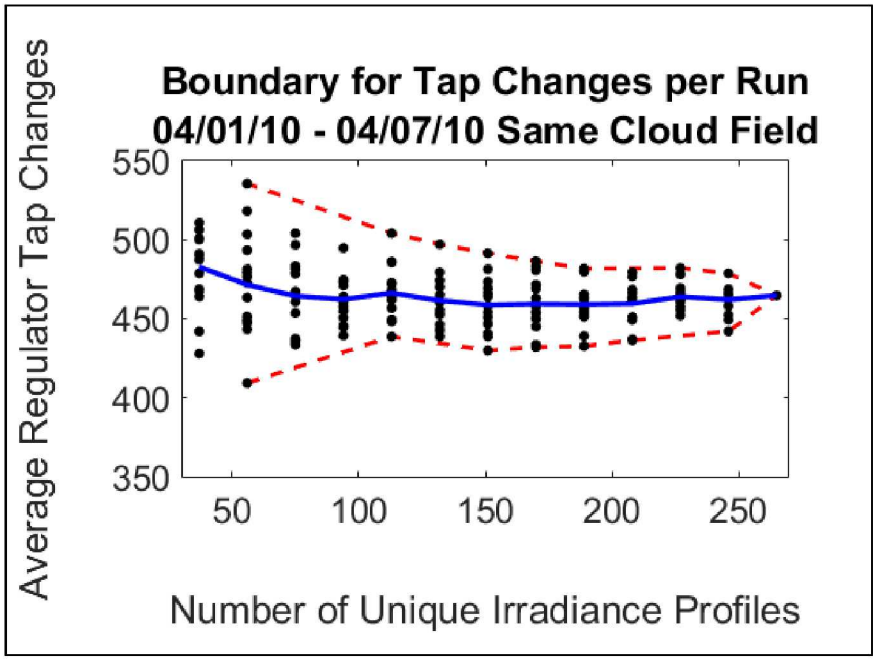
- Minimum from data:
  - 409 tap changes
  - At 56 irradiance profiles
- Tap change values oscillate around a similar average; variation decreases as number of profiles increases

Results First Week April 2010

Old



New



- Minimum from fit (blue line):
  - 266 tap changes
  - At 199 irradiance profiles
- Width of 95% confidence interval (red dashed line): ~80 tap changes

- There is no fit applied to the data, only a boundary (red dashed line).
- The blue line shows the average for each group.
- Max for blue line: 483
- Min for blue line: 459

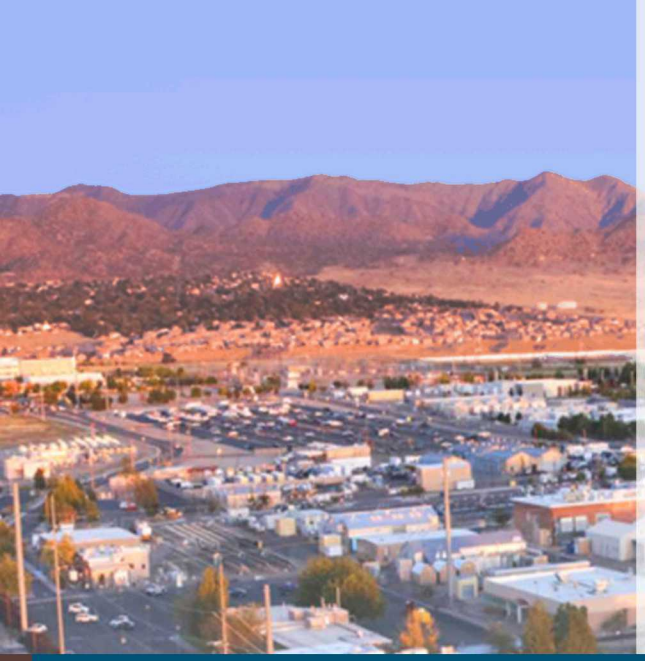
Discussion

- Previously different locations were selected to generate the irradiance profiles, but were assigned incorrectly for the OpenDSS power flow.

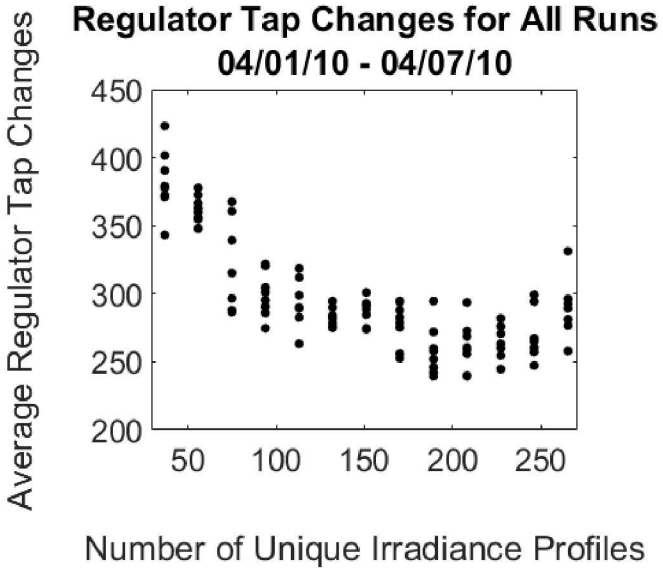
- New results have a different behavior after correct assignment. Values now oscillate around a similar average ~465 and there appears to be decrease in tap change variation as the number of irradiance profiles increase until the tap change values converge on a single point.

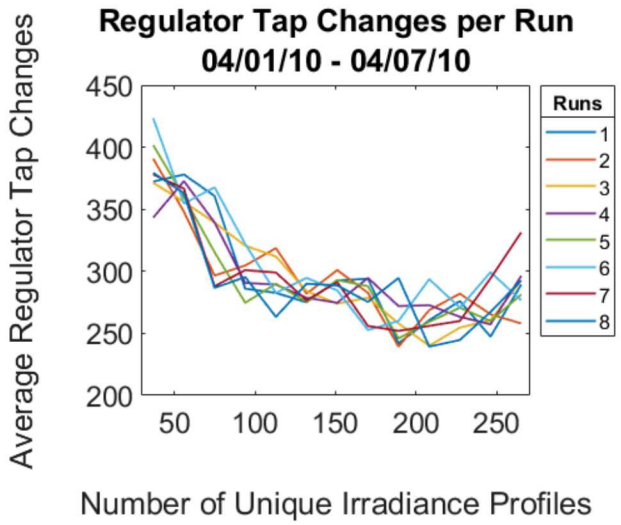
- The convergence is the expected behavior. Using all locations and a single cloud field for all runs, should yield a single common result.

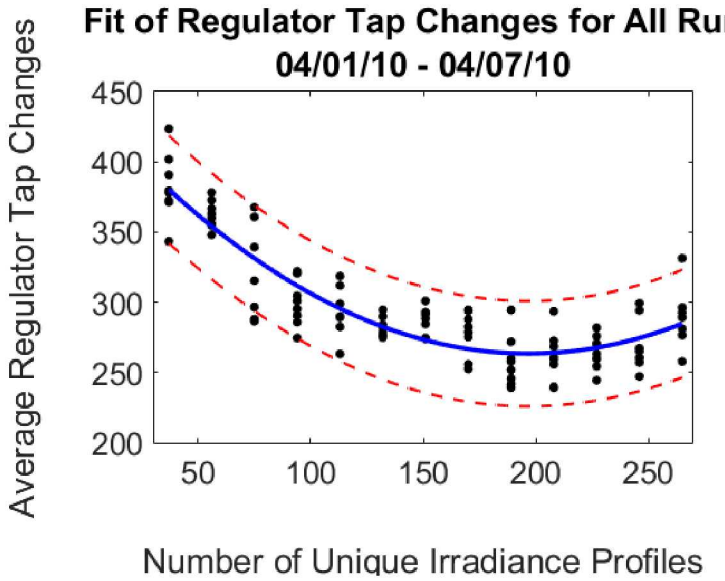
- The N = 37 group has lower variation than the next group, N = 56. This would be due to the way they are generated. The N = 37 locations are similar in all runs. The N = 56 are generated from the N = 37 by adding 19 locations randomly.

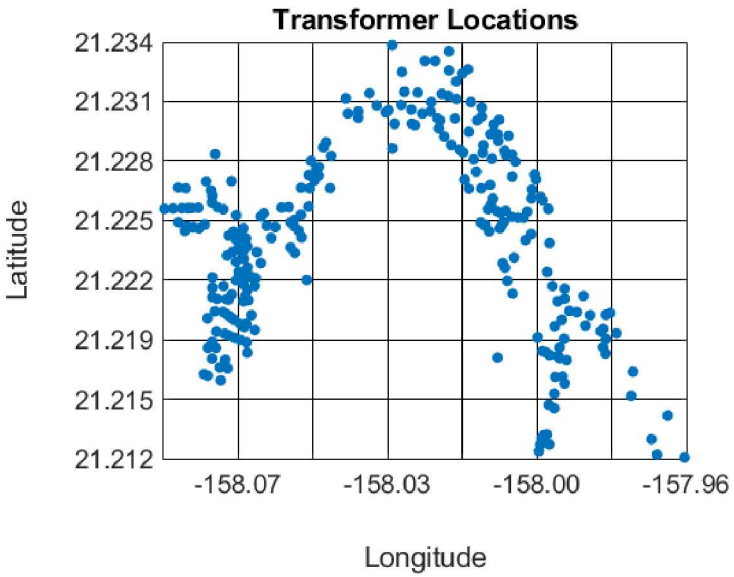


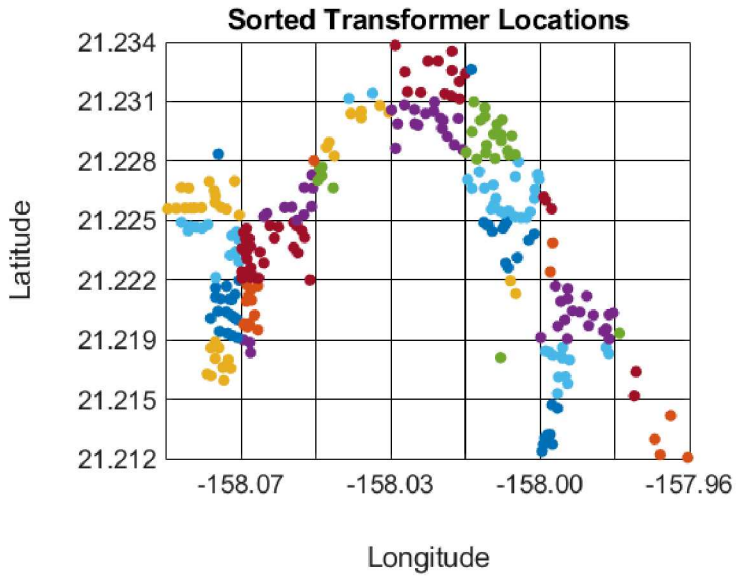
Additional Images


Regulator Tap Changes for All Runs
04/01/10 - 04/07/10
Average Regulator Tap Changes
450
400
350
300
250
200
50
100
150
200
250
Number of Unique Irradiance Profiles

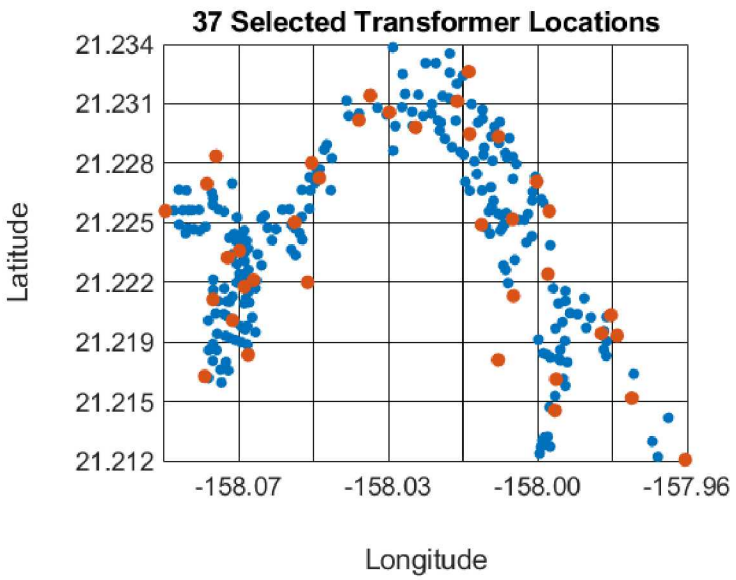

Regulator Tap Changes per Run
04/01/10 - 04/07/10
Average Regulator Tap Changes
450
400
350
300
250
200
50
100
150
200
250
Runs
1
2
3
4
5
6
7
8
Number of Unique Irradiance Profiles


Fit of Regulator Tap Changes for All Runs
04/01/10 - 04/07/10
Average Regulator Tap Changes
450
400
350
300
250
200
50
100
150
200
250
Number of Unique Irradiance Profiles

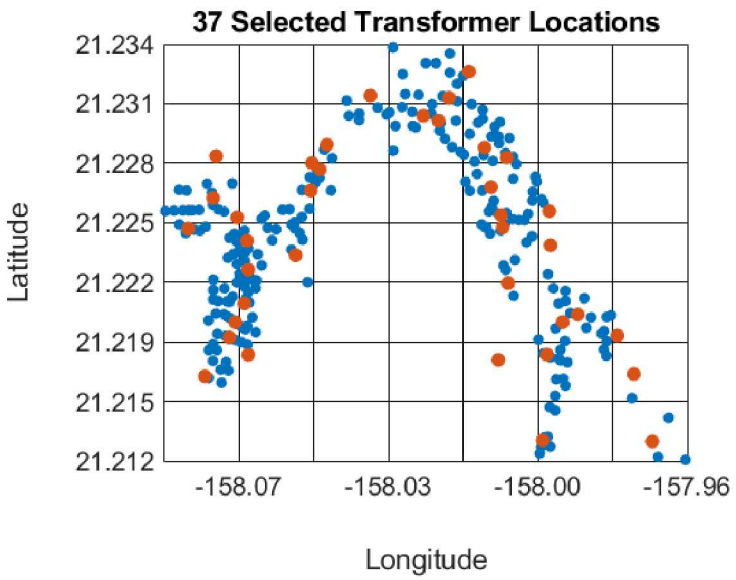

Transformer Locations
Latitude
21.234
21.231
21.228
21.225
21.222
21.219
21.215
21.212
-158.07
-158.03
-158.00
-157.96
Longitude


Sorted Transformer Locations
Latitude
21.234
21.231
21.228
21.225
21.222
21.219
21.215
21.212
-158.07
-158.03
-158.00
-157.96
Longitude

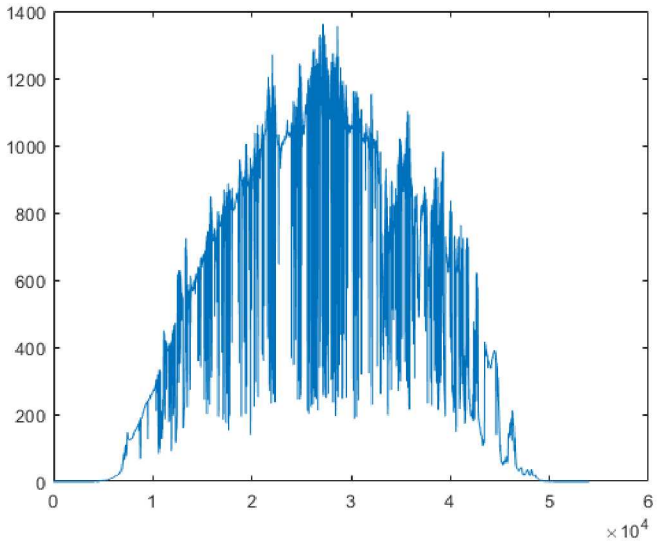
Run 1


37 Selected Transformer Locations
Latitude
21.234
21.231
21.228
21.225
21.222
21.219
21.215
21.212
-158.07
-158.03
-158.00
-157.96
Longitude

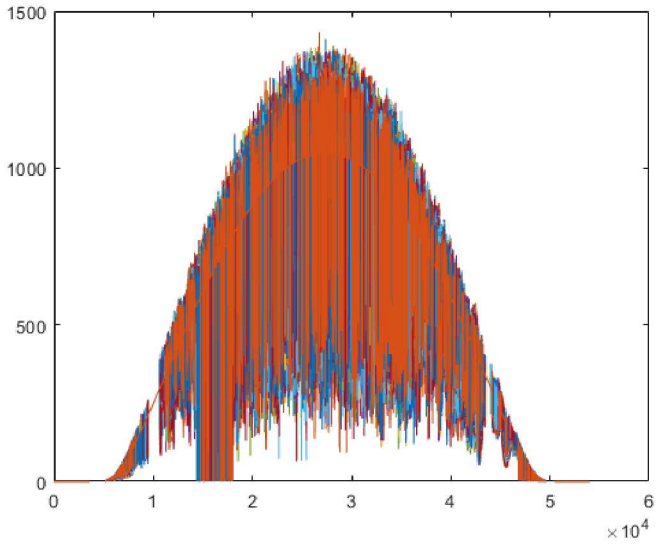
Run 2


37 Selected Transformer Locations
Latitude
21.234
21.231
21.228
21.225
21.222
21.219
21.215
21.212
-158.07
-158.03
-158.00
-157.96
Longitude

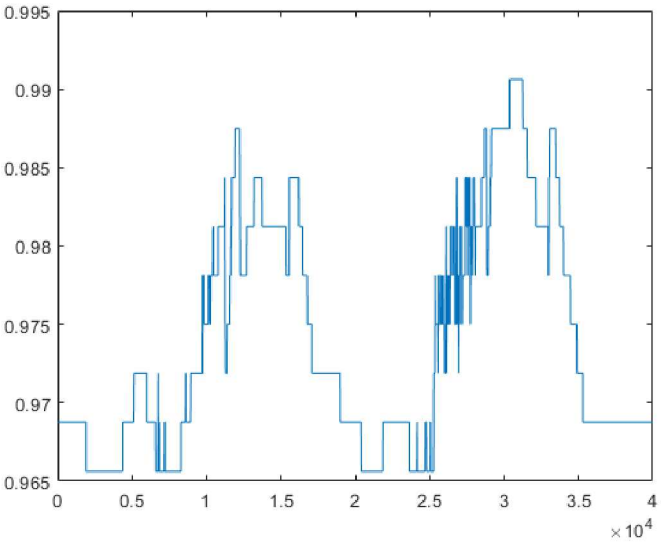
Real GHI



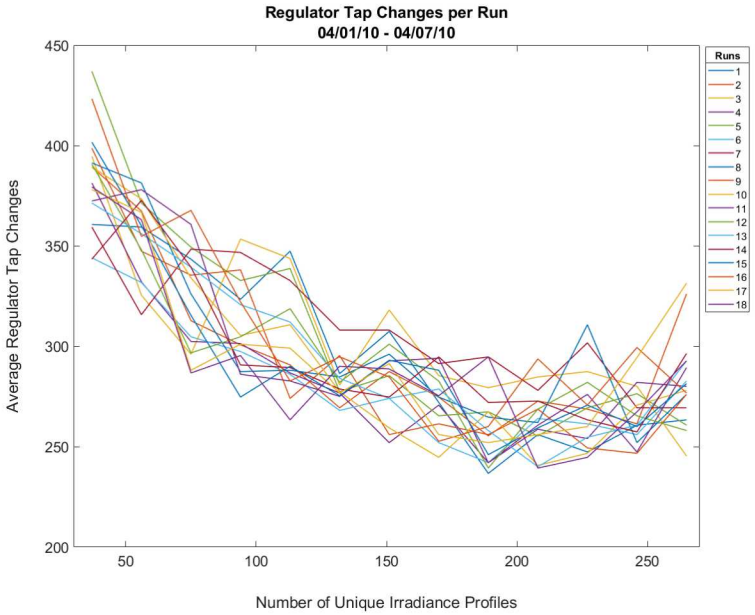
37 Synthetic GHI



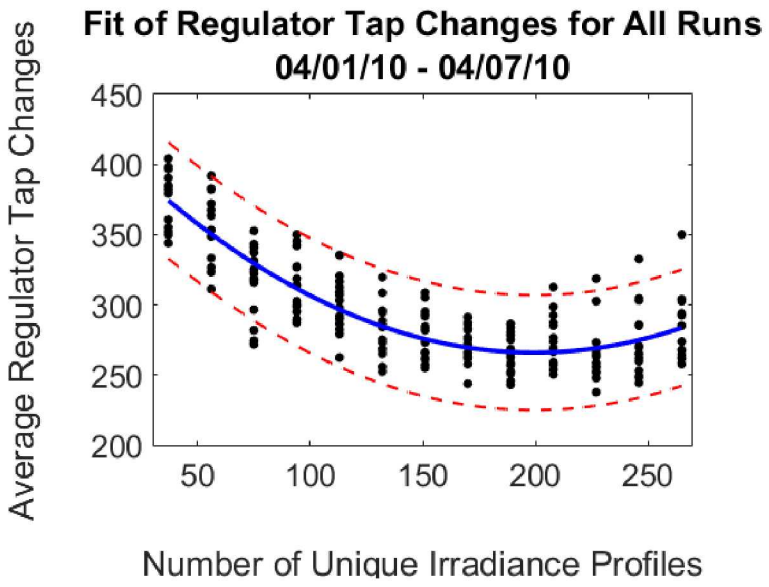
Tap position



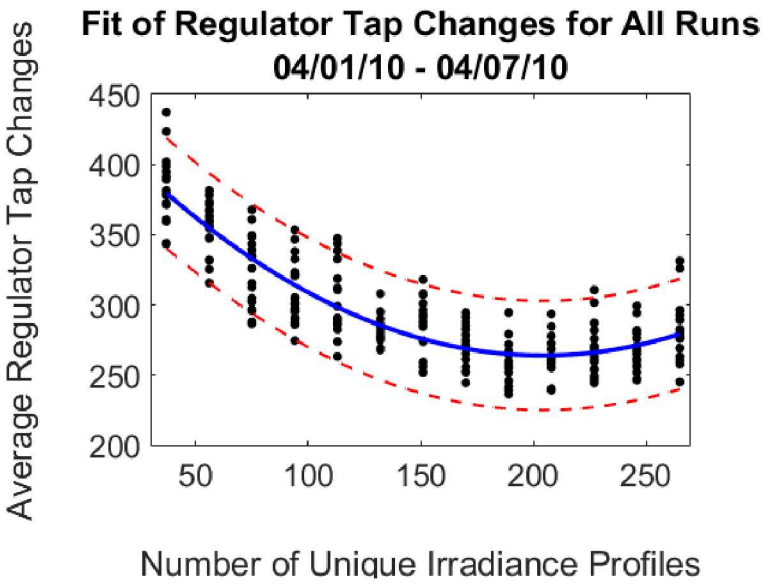
18 runs



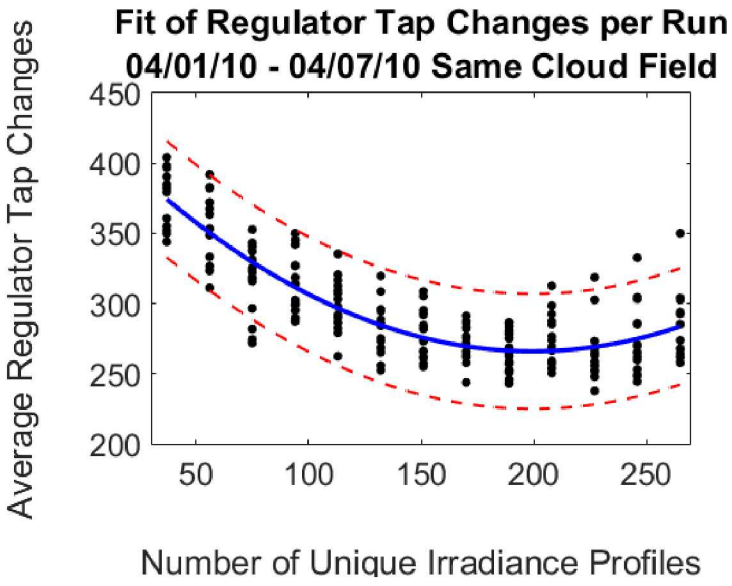
15 same field



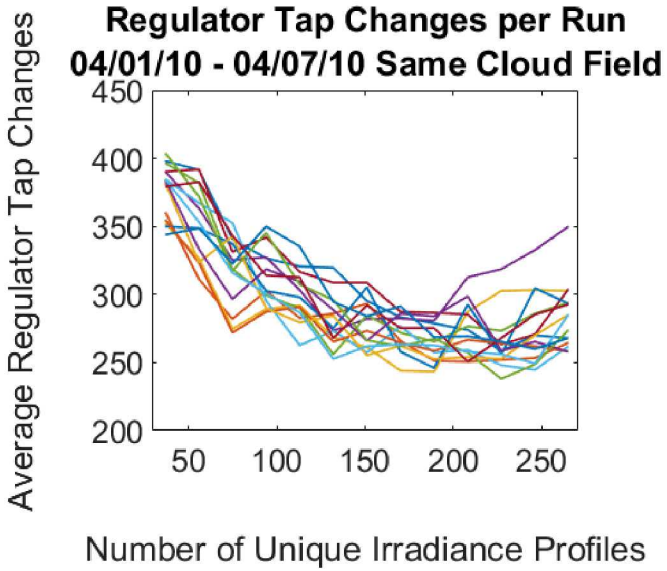
18 runs



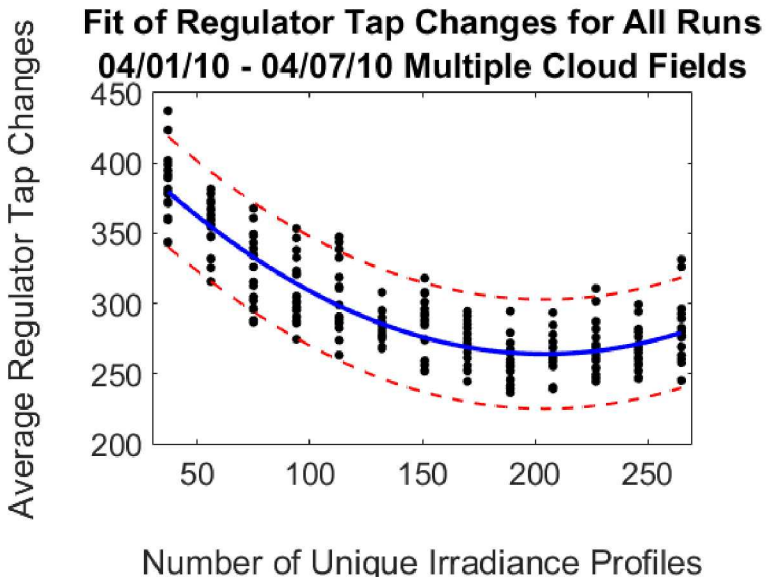
Fit same cloud field



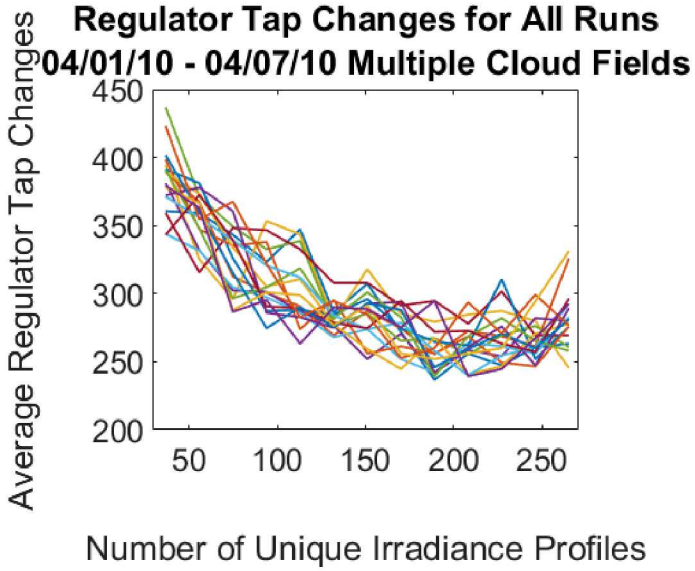
Runs 15 same cloud field

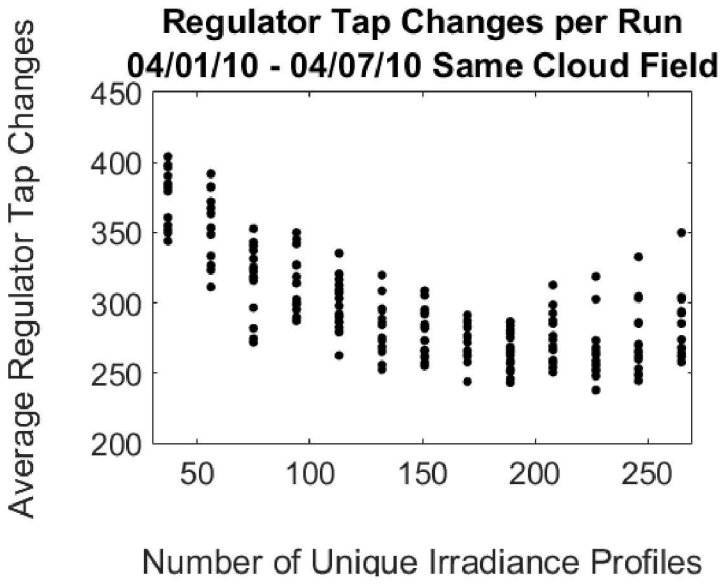


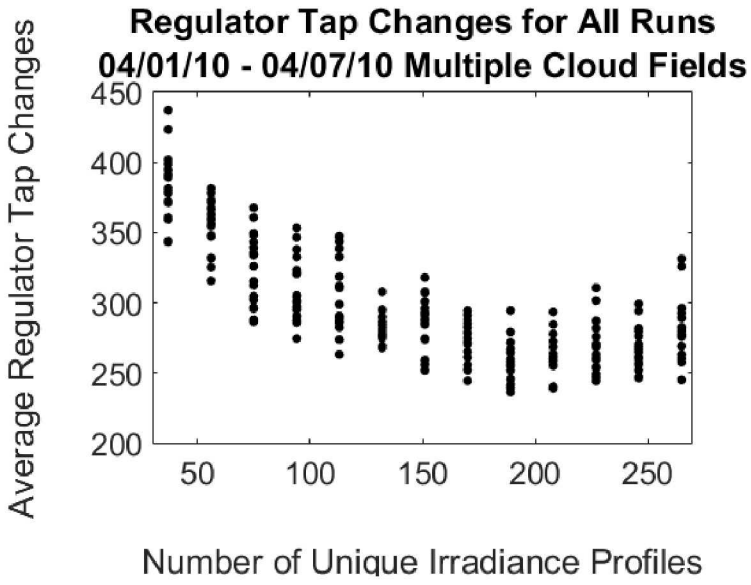
Fit multiple cloud fields



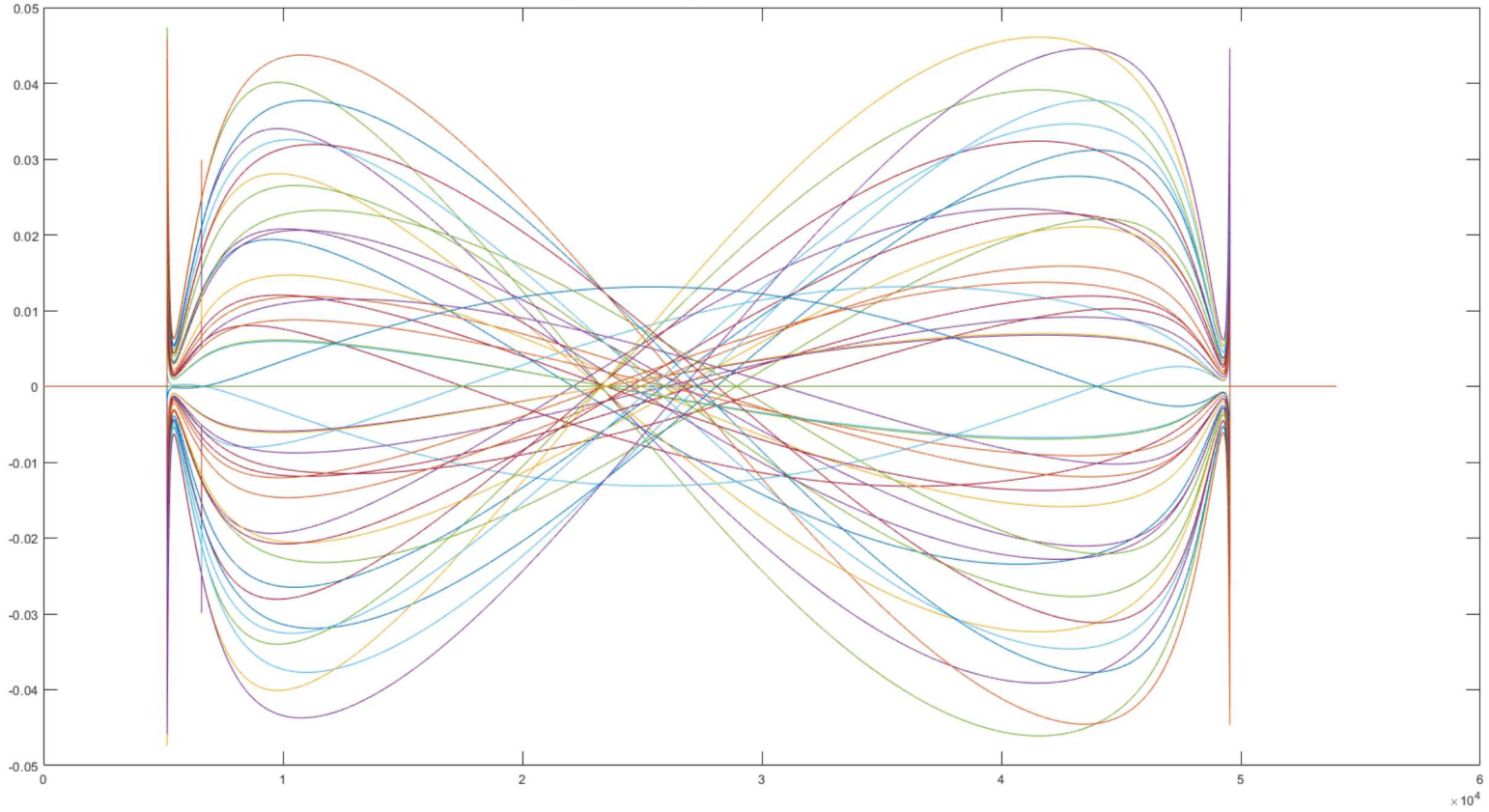
Runs 18 multiple cloud fields



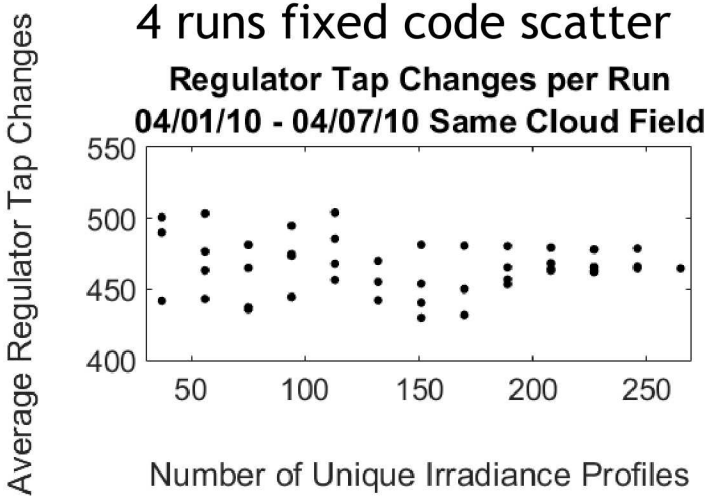

Regulator Tap Changes per Run
04/01/10 - 04/07/10 Same Cloud Field
Average Regulator Tap Changes
450
400
350
300
250
200
50
100
150
200
250
Number of Unique Irradiance Profiles


Regulator Tap Changes for All Runs
04/01/10 - 04/07/10 Multiple Cloud Fields
Average Regulator Tap Changes
450
400
350
300
250
200
50
100
150
200
250
Number of Unique Irradiance Profiles

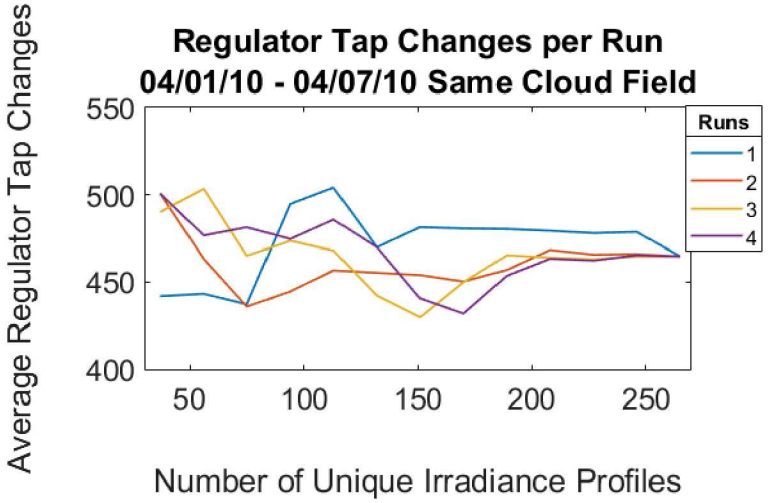
Ghi clearsky compared to 20 locations



4 runs fixed code scatter



4 runs fixed code



Corrected transformer assignment