Financial Assessment of Solar Radiation Exceedance Values in Arizona

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Abstract

We were tasked with calculating exceedance probabilities to provide hypothetical financial backers tools to assess the risk of solar farm development. We gathered Comma Separated Value (CSV) files from the Arizona Meteorological Network (AZMET) and weighted them by a Voronoi partition of the U.S. National Map boundaries for Arizona to produce a P90 of 11.34 megaJoules per square meter per day and a P50 of 20.76 with the same units.

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The problem as it was given was to calculate exceedance probabilities to demonstrate risk to hypothetical solar developers. “Exceedance Probabilities” can refer to either the value for which a distribution holds a certain probability of exceedance, or the probability of exceeding a given value; i.e. it can refer to the z score that produces a desired $1 - cdf(z)$, or vice versa. For solar radiation, it is generally understood to be the former definition, usually referring specifically to P90 and P50, and sometimes referring to P75 or P25. Importantly, these values are forecasts, not observations, however in our case there was no long-term trend to distinguish the two.

Methodology

We used a javascript web-scraper to gather raw daily and hourly data from the AZMET data directory, all of which follows the naming convention of a 2 digit station ID, 2 digit year indicator, the letter “r” to denote raw, either “h” or “d” to denote hourly or daily, and a .txt file suffix (e.g. 3616rh.txt would contain hourly records for station 36 for 2016). The data ranged from January 1, 1987 to present day and contained 1,526 files. We then used python to parse the data, remove non-detects, and flag other errors for human correction (e.g. extraneous line breaks or non-numerical entries). Of 6.2 million hourly entries, less than 9000 contained problems, and of 250 thousand daily entries, less than 500 did, so we chose to remove them instead of attempting any extrapolation. After parsing and error-correction the results were stored in a SQLite database.

We then Associated each station ID with a latitude and longitude per the station pages on the AZMET site, and used those values in grass GIS to calculate their respective areas under a Voronoi partition of the Arizona State boundaries as provided by the U.S. National Map. We used these areas to provide weightings for information from each station that would not cause clusters of stations to be over-represented in the dataset. We then used R for statistical analysis and visualization.

Results

We found the following exceedance probabilities (megaJoules per square meter per day):

Quarter	P90	P50
1	9.45	15.64
2	23.48	28.78
3	18.14	24.28
4	8.85	13.72
Overall	11.34	20.76

These values were derived from empirical CDFs. We justify this over a distribution fitting with two observations. First, there were no evident long-term trends in the data, which coupled with the relatively short lyapunov time of weather systems (on the order of magnitude of a week, as can be inferred from the length of the average weather forecast) led us to believe that predictive methods would not provide substantial value. Second, the distribution is bimodal and oddly shaped, a trait which could not be normalized with the by accounting for time of day, quarter, station, or year. This probably owes itself to non-linear effects of cloud cover, which could not be accounted for with the given data. For visualizations of this data, see the appendix.

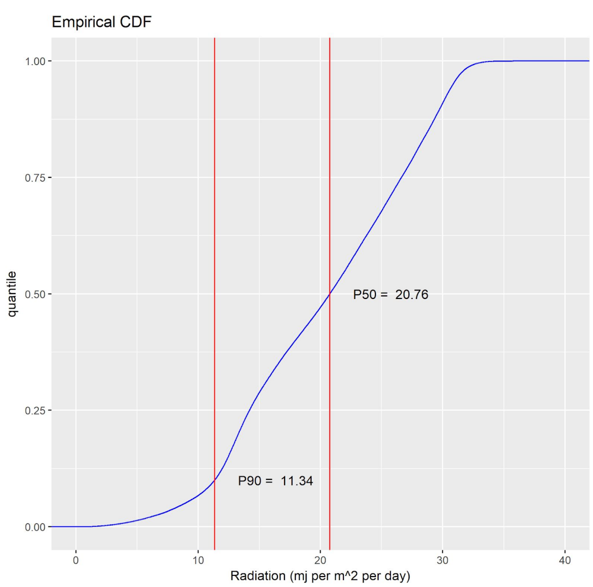
References

AZMET : The Arizona Meteorological Network - The University of Arizona. (n.d.). Retrieved May 14, 2018, from https://cals.arizona.edu/azmet/

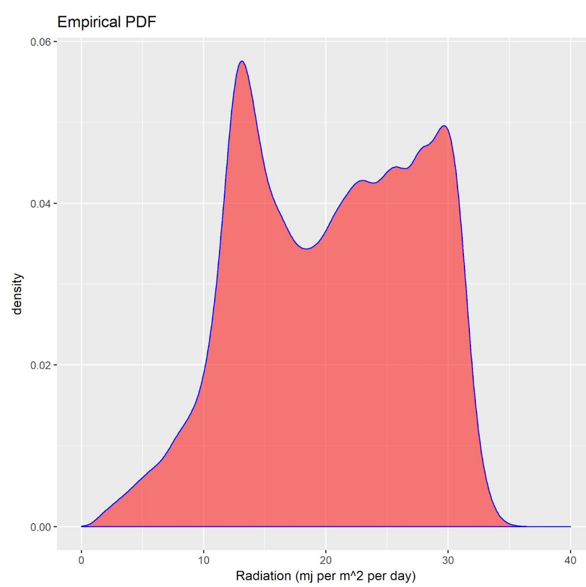
The National Map. (n.d.). Retrieved May 14, 2018, from https://nationalmap.gov/

https://www.electricitylocal.com/states/arizona/

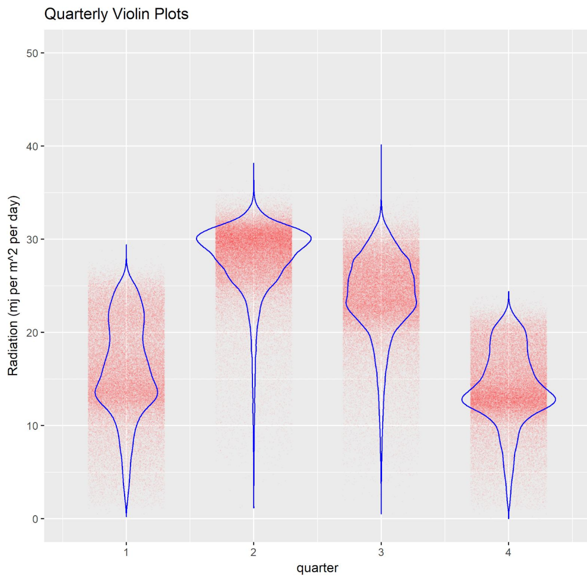
Appendix



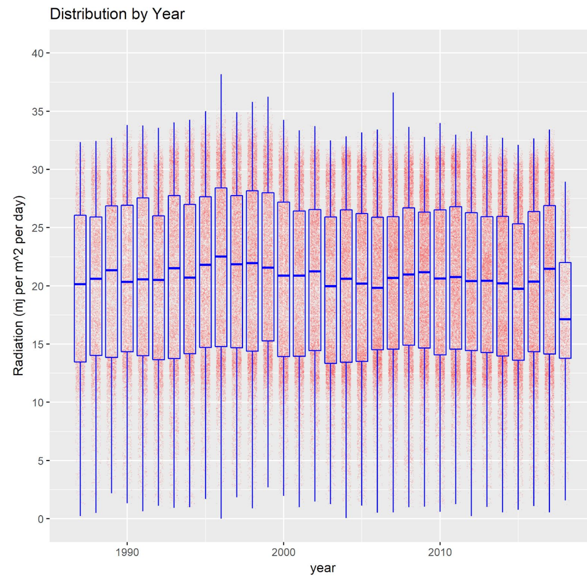
Appendix A



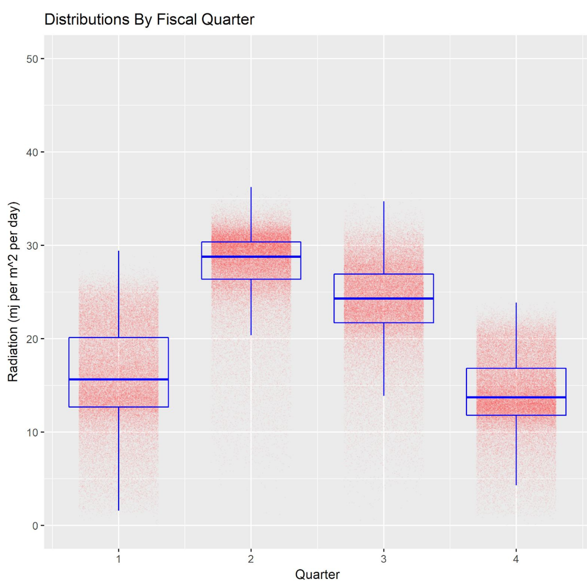
Appendix B



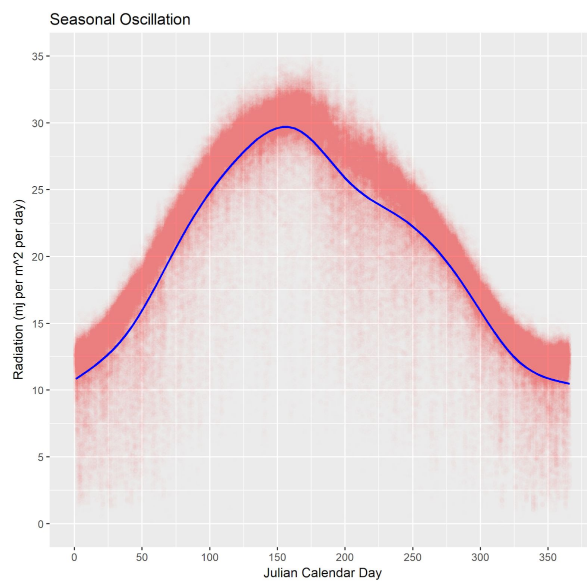
Appendix C



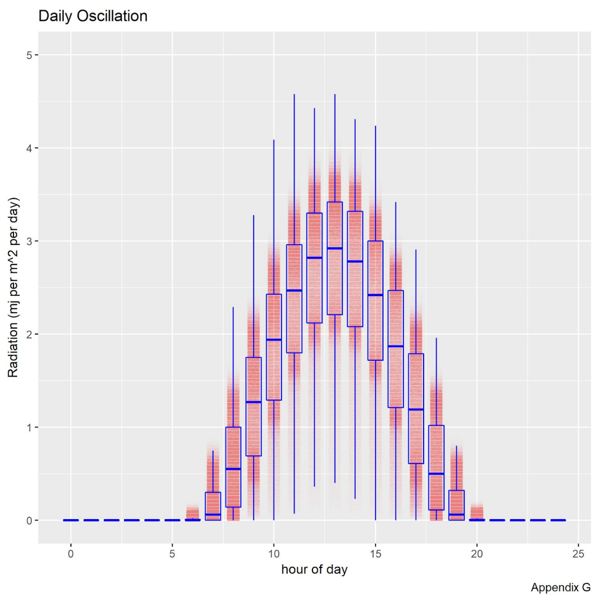
Appendix D



Appendix E



Appendix F


Daily Oscillation
Radiation (mj per m^2 per day)
0
1
2
3
4
5
0
5
10
15
20
25
hour of day
Appendix G

Financial Results:

Optimizing Operation Output:

- Increase efficiency and energy output
- Decrease downtime
- Extend lifetime
- Reduce cost of operation and management

Cost of Operation:

Employees for Maintenance Salary:

Technician: $45,760

Apprentice: $52,000

Journeyman: $74,880

Master Engineer: $106,080

Plant Manager: $98,000

Supervisor: $98,000

Depending on the size of the plan, the number of employees may vary.

Installing Solar Panels:

$.75 per Watt for a single panel in an industrial setting

Assumptions:

Solar panel size: 78” x 39”, with 250 watts per panel

Cost to run Solar Plant:

$.653 per kWh for industrial use

Further Research:

The main problem that we ran into was how do we translate the solar radiation data into a financial cost. If we had a few more weeks we maybe would have been able to find a useful correlation and thus getting a solid number for the cost of installing and running a solar farm.