Forecasting Solar Radiation for Puerto Rico: Studying Cloudiness Patterns in 2019

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Background:

- Variation in cloud cover presents a challenge for generation of energy using solar power systems. Shadows generated by these clouds impact power generation capabilities.
- As of 2019 in the US there are about 2 million solar photovoltaic installations.On a cloudy day, solar panel production can drop by at least 10% to 25% depending on the extent and type of clouds.
- Grid operators require accurate forecasts from minutes to several days of solar power availability to balance supply and demand on the electrical grid.
- Accurate forecasts allow them to optimize scheduling of power production, in turn benefiting the environment by reducing carbon emissions.

Motivation of Study:

- Numerical Weather Prediction models struggle with analysis of cloud fields.
- Satellites can fill the gap between short term forecasting below 30 minutes, which relies on local observation, and long term forecasting above 3 hours, which relies on weather prediction models.
- Some previous work suggests that machine learning methods can improve solar forecasts.
- Puerto Rico serves as a good model for solar energy outcomes due to its year round sunlight and need for more local, reliable power.
- Compared to centralized generation, rooftop solar energy is less vulnerable to the intense winds and hurricanes that the territory experiences.

Objectives:

- Understand cloudiness patterns over the island of Puerto Rico using satellite imagery.
- Develop a set of maps that shows areas with high cloudiness and cloud optical depth over the island.
- Investigate machine learning methods that could be optimal in forecasting solar radiation.

Puerto Rico Geographical Map

Fig 1: Geographical map of Puerto Rico showing mountain ranges.

Methods:

- Downloaded Advance Baseline Imagery-Level 2 Clear Sky Mask and Cloud Optical Depth data products from GOES-16 Satellite for the year of 2019, obtained from the NOAA CLASS environmental data library.
- Averaged clear sky mask data into seasons and calculated percentages of extracted cloudy pixels for each season using python and libraries such as geopandas.
- Evaluated how cloud optical depth varied between the times of 5am to 12pm, and 12pm to 7pm for a random day in January using python.

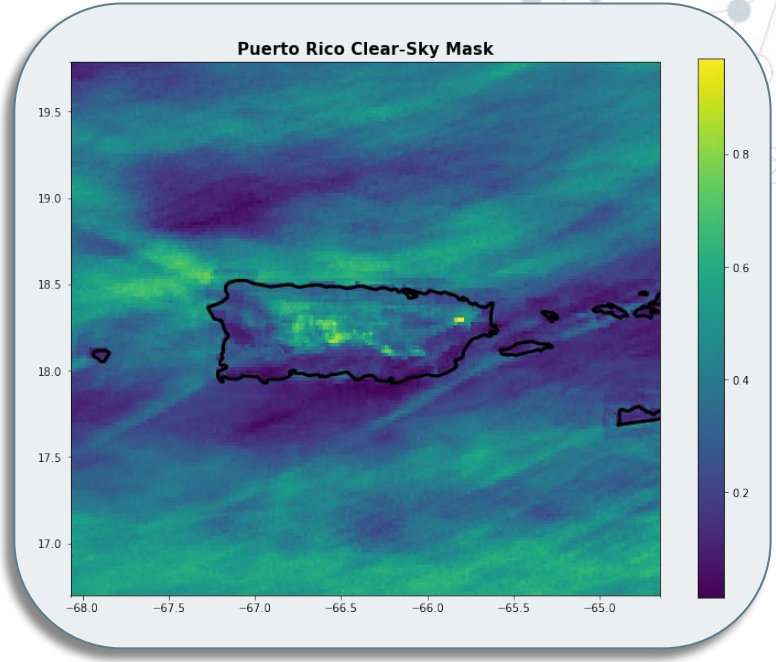

Fig 2: Example clear sky mask average for the month of January.

Results:

- Based on the seasonal average clear sky mask maps, there visually appears to be more cloudiness in the summer season, and less in the winter season.
- However, when the percentages are calculated, spring has more cloudiness by .6% compared to summer.
- Cloudiness is concentrated mostly in the southeast of the island, and increases towards the middle during the spring and summer seasons. This is where the Cordillera Central mountain range is located.
- There is high cloudiness in the northeast as well, where El Yunque National Forest is.
- There is more cloudiness on the island than in the surrounding Caribbean Sea.

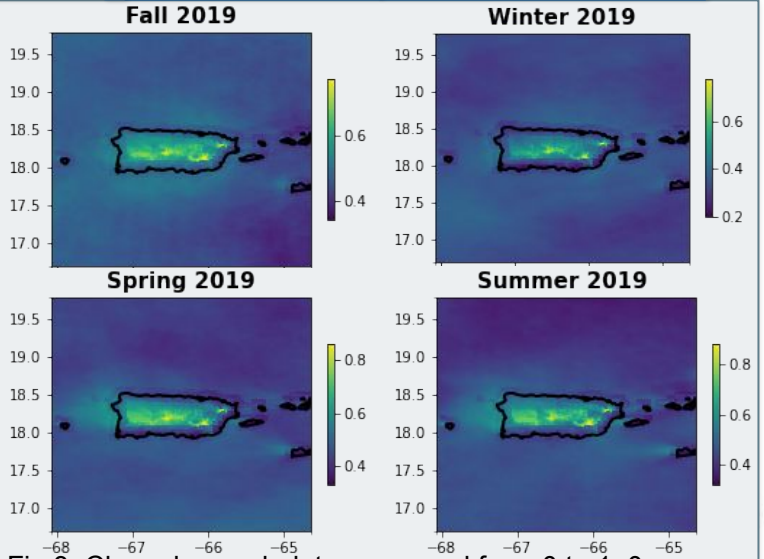

Fig 3: Clear sky mask data measured from 0 to 1. 0 means not cloudy, 1 means mostly cloudy.

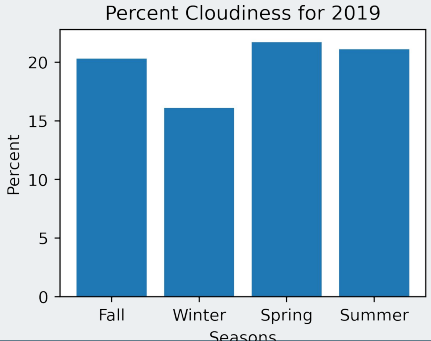

Fig 4: Graph showing percent cloudiness for Puerto Rico, excluding the surrounding ocean.

Results:

- Cloud optical depth is useful in determining the amount of solar radiation being reflected, and in determining the kind of cloud that is moving over the island.
- The cloud optical depth between 7am and 12pm can be seen in the first map, the second map represents the cloud optical depth from 12pm to 7pm.
- In the first map from earlier on in the day it can be seen that the Cloud optical depth is lower on the eastern side of the island
- In the second map in general Cloud Optical Depth decreased all over Puerto Rico compared to earlier on in the day
- Lower cloud optical depth means that the clouds would in general be higher and thinner allowing for better transmission of Solar radiation and even reflecting IR radiation back to earth

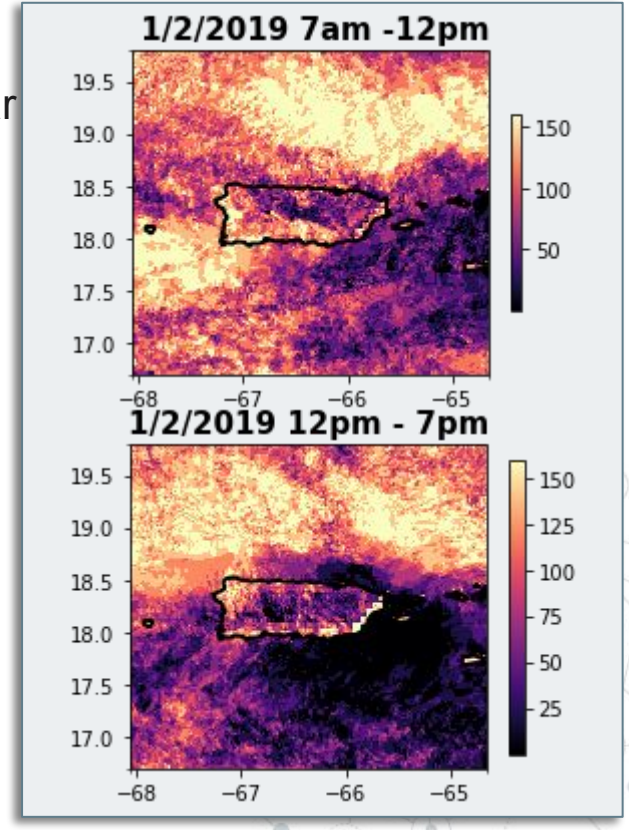

Fig 5: ABI L2+ Cloud Optical Depth at 640 nm, measured from 0 to 160, with 0 being low optical depth and 160 being high optical depth.

Conclusion:

- Cloudiness is mostly concentrated on the mountainous and forest areas of Puerto Rico. There is a decrease in cloudiness around the coast.
- Increased cloud optical depth in the morning suggests that there is an decrease of solar radiation during that time.
- Accurate forecasting of solar radiation involves various data products such as clear sky masks, cloud optical depth, and more.
- Future work will involve gathering more data products spanning several years and feeding it into machine learning algorithms.
- Continuing this research can be beneficial in improving current forecasting methods for solar radiation.
- It can also allow for sustainable methods of obtaining solar energy in Puerto Rico, which can be useful in maintaining power during turbulent weather.

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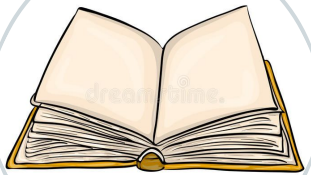

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