DATA ANALYTICS AND MACHINE LEARNING ON WEATHER IN SINGAPORE AND IMPACT ON SENSORS PERFORMANCE

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Introduction

Background

Sensors used in Radar and Electronic Warfare (EW) harness radiofrequency (RF) signals to obtain and transmit the necessary information. Atmospheric attenuation of RF waves in humid, hazy or rainy weather severely impacts sensors' performance. Being able to anticipate bad weather is thus crucial in minimising signal loss via RF attenuation.

Research Questions

- How does weather affect RF and sensor performance?
- How can we best predict the weather and utilise the information to mitigate signal attenuation due to weather?

Methodology

DATA ANALYTICS OF PAST WEATHER

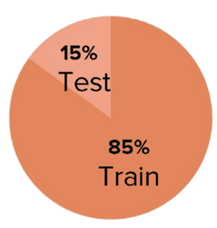
Graphs were plotted using Power BI to analyse Singapore's rainfall and temperature within a year, and across years.

Locations chosen for weather analysis:

- Sembawang (North)
- Sentosa Island (South)
- Changi (East)
- Jurong West (West)
- Ang Mo Kio Park (Central)

Machine Learning Model

Input Data (hourly)	
Temperature	Total cloud cover
Relative humidity	Low level clouds
Dew point temperature	Mid-level clouds
Total rainfall	High level clouds
Surface pressure	Wind direction
Wind speed	



Various models were trained to predict the hourly rainfall in each region - of our dataset, ~85% and 15% were used to train and test the model respectively.

XGBoost is very efficient in processing large datasets and gives extremely accurate results. Compared to Transformers, XGBoost is better at identifying trends based on time dependent data and is superior to Random Forest because of how it builds its trees.

Thus, it is the most suitable model for predicting rainfall.

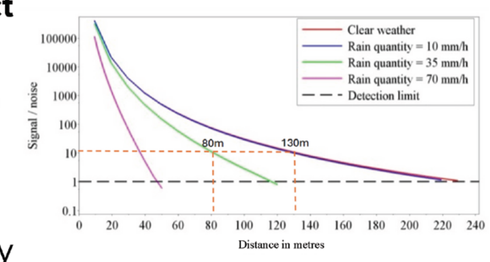
Root Mean Squared Error		
Transformer	**Random Forest**	**XGBoost**
1.17mm	1.77mm	0.960mm

Results

Weather conditions that affect signal attenuation

- Precipitation (most significant)
- Humidity
- Fog

Hence, precipitation markedly reduces effectiveness of sensors.



Graph of SNR against distance between LiDAR and target for rain droplets of radius equal to 3 mm with varying rain quantity

Analysis of Weather across Singapore

weather is affected by:

- Monsoon season, El Niño and La Niña, and Global Warming

Wettest and coldest months:

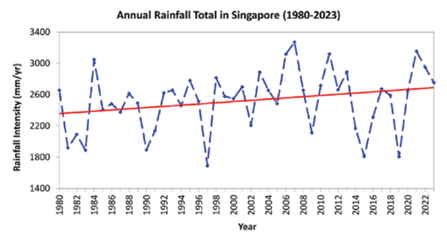
- January, November - December

Driest month:

- February

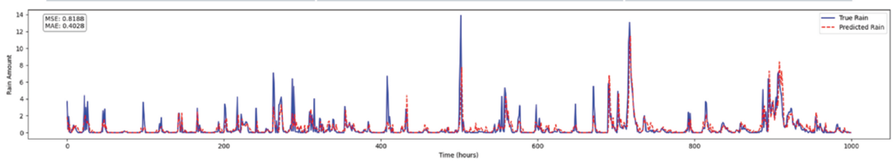
Hottest month:

- May - June



Machine Learning Model Results

Mean Absolute Error	Root Mean Squared Error	Accuracy
0.325mm	0.960mm	79.8%



The model takes rainfall below 0.1mm as no rain and above it as having rain. With this, it achieved an accuracy of 79.8%

Conclusion

Heavy rain is the greatest and most relevant cause for signal attenuation in Singapore. Of all the phenomena affecting total rainfall, the Northeast Monsoon has the greatest impact on Singapore's weather, making December and January the wettest months of the year and February, the driest.

Our machine learning model can be used to estimate rainfall that can be translated into signal attenuation and reduction in performance of sensors (e.g. detection range). Since the model is rather accurate in predicting rainfall spikes, mitigating measures can be put in place pre-emptively to mitigate the impact of such signal attenuation, like installing complementary sensors and sensor settings to improve signal-to-noise ratios.

Future Work

- Explore the impact of signal-to-noise ratio (SNR) degradation on sensor performance according to the various rainfall rates that Singapore experiences
- Train ML Model with all parameters concurrently
- Experiment with applying the same hyperparameters and normalisation to different models
- Use ML model to predict the amount of signal attenuation