Mosquito Control:

Predicting Dengue Outbreak

Here is where your mozzie bites will end

Content Page


1
Introduction

1A. Background

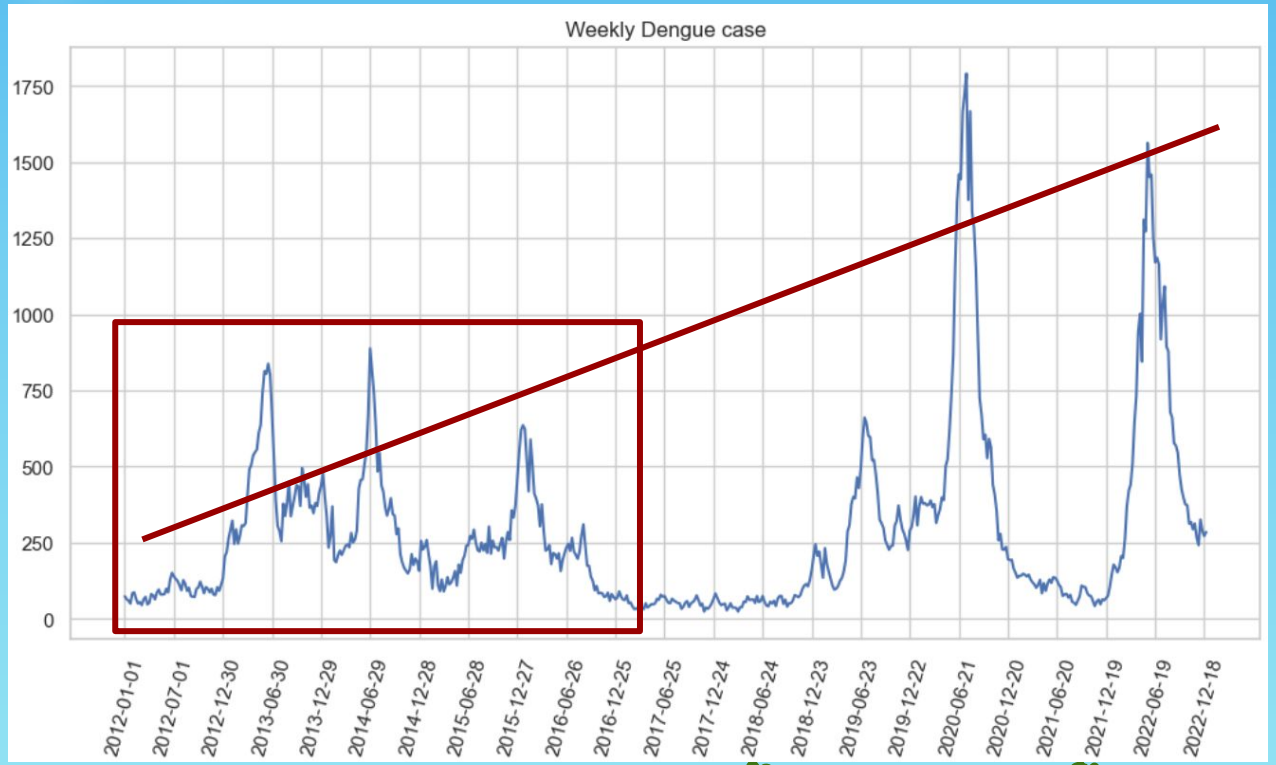
Problem

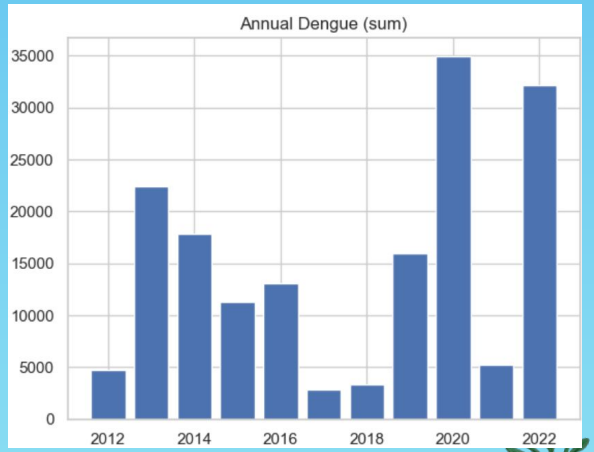
- Dengue outbreaks are **not foreign to Singapore**
- The government has been **implementing measures** to pre-emptively manage the spread of the disease, such as regular site inspections and community outreach programs to **raise awareness** about dengue prevention
- However, it is **difficult to anticipate the level of preventive measures needed** ahead of time - leading to potential **overspending during periods of low dengue cases**

Our Goal

- The National Environment Agency (NEA) of Singapore has tasked our team to **predict dengue cases in Singapore**
- Goal: A prediction model with MAPE score <=0.2
- We were also tasked to **demonstrate the cost-benefits** of applying our prediction model

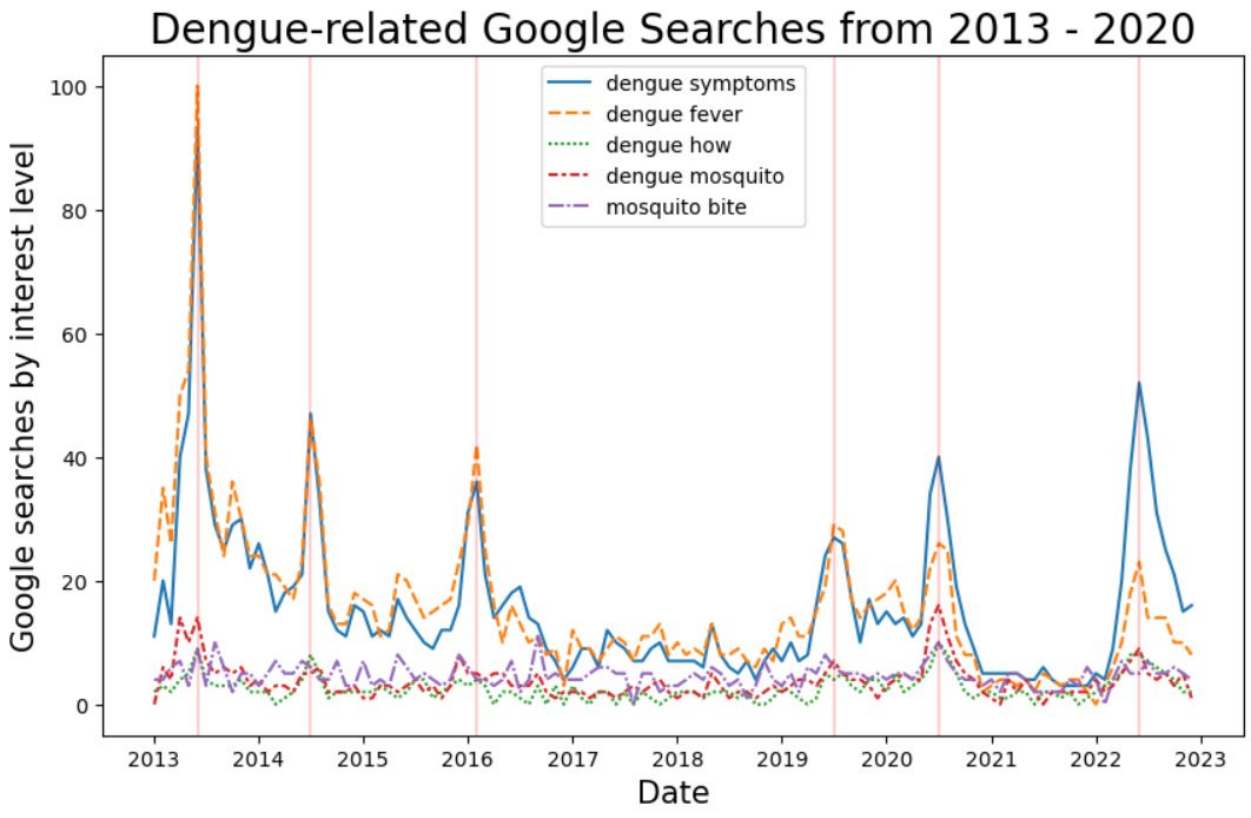
1B. Singapore Dengue Trends






2
EDA Part 1
Google Search Trends

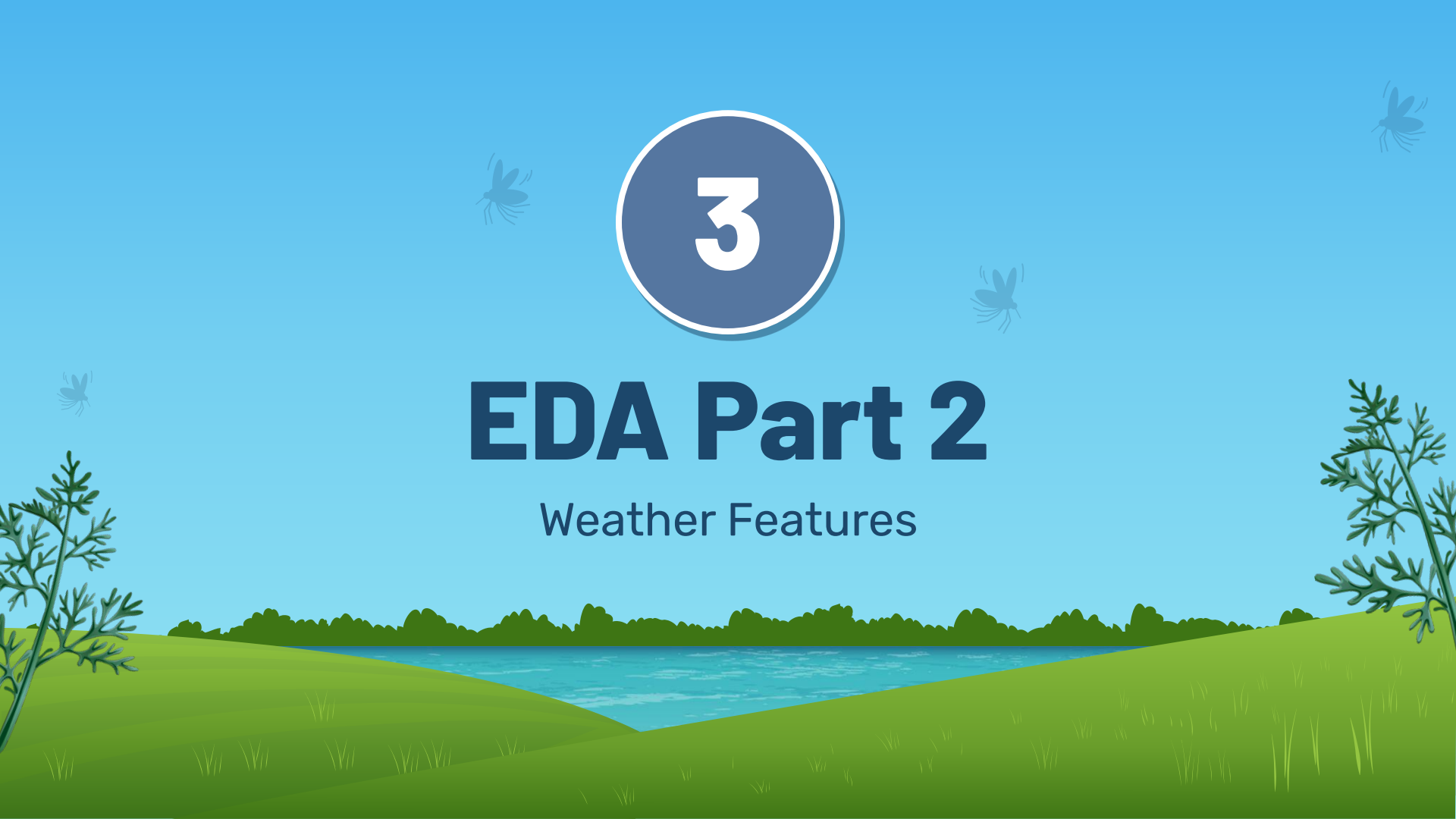
2. Google Search vs Dengue Occurrence



- The **peaks in Google searches match (in position) with the peaks in Dengue cases** in Singapore → may be useful for prediction

- However, **the peaks do not match in intensity/level** (e.g. 2022)

- Dengue peak periods: more info in annex

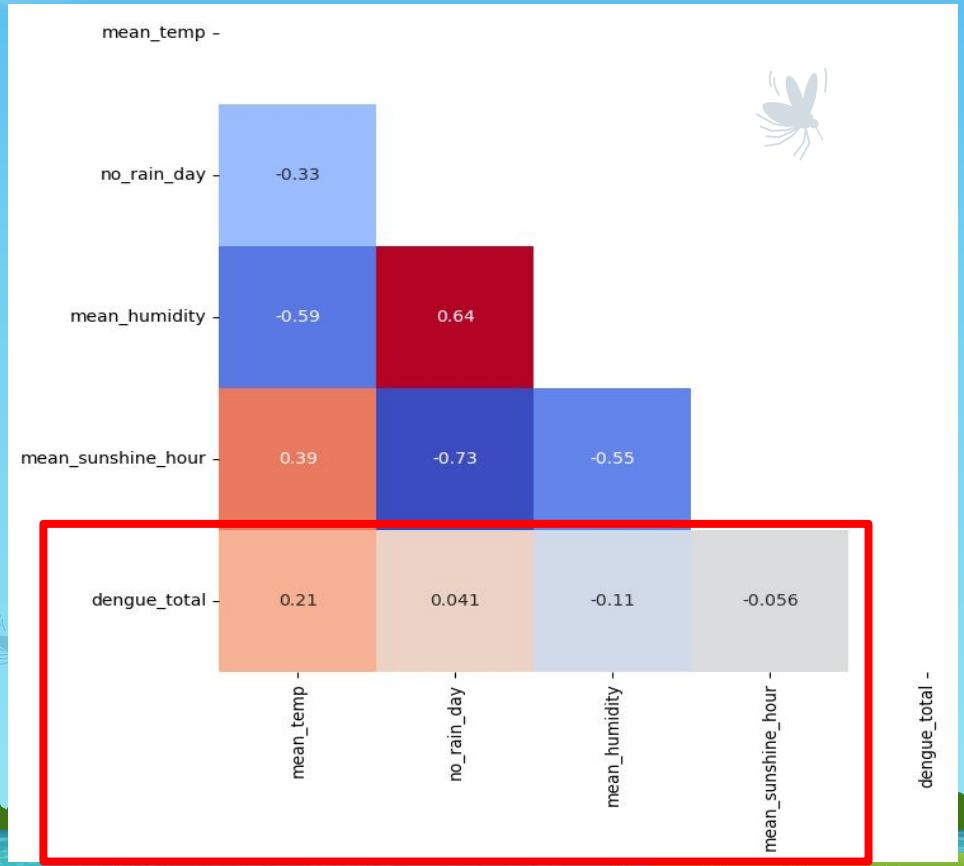

3
EDA Part 2
Weather Features

3A. Weather Features

1. Monthly mean temperature
2. Monthly mean rainy days
3. Monthly mean humidity
4. Monthly mean sunshine hours

(from data.gov.sg)

3B. Heatmap: Multi-Collinearity



- **No feature is found to be strongly correlated** to dengue_total

- All less than 0.25

- Mean_temp has the highest correlation

3C. OLS: Feature Selection

OLS Regression Results

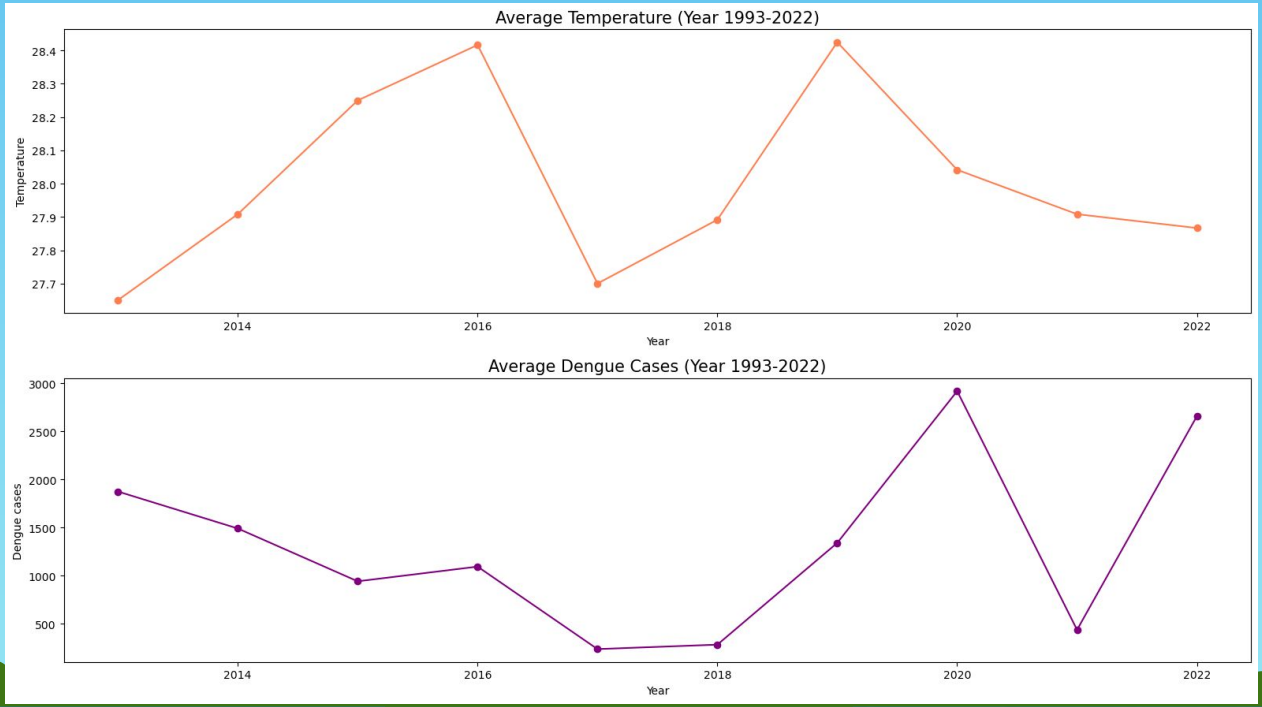
Dep. Variable:	dengue_total	**R-squared:**	0.070
Model:	OLS	**Adj. R-squared:**	0.038
Method:	Least Squares	**F-statistic:**	2.163
Date:	Sat, 04 Feb 2023	**Prob (F-statistic):**	0.0776
Time:	12:47:35	**Log-Likelihood:**	-1027.7
No. Observations:	120	**AIC:**	2065.
Df Residuals:	115	**BIC:**	2079.
Df Model:	4		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-6292.8841	8736.848	-0.720	0.473	-2.36e+04	1.1e+04
mean_temp	416.3074	206.436	2.017	0.046	7.398	825.217
no_rain_day	17.2763	34.516	0.501	0.618	-51.093	85.645
mean_humidity	-42.7328	56.628	-0.755	0.452	-154.903	69.437
mean_sunshine_hour	-156.3690	142.377	-1.098	0.274	-438.391	125.653

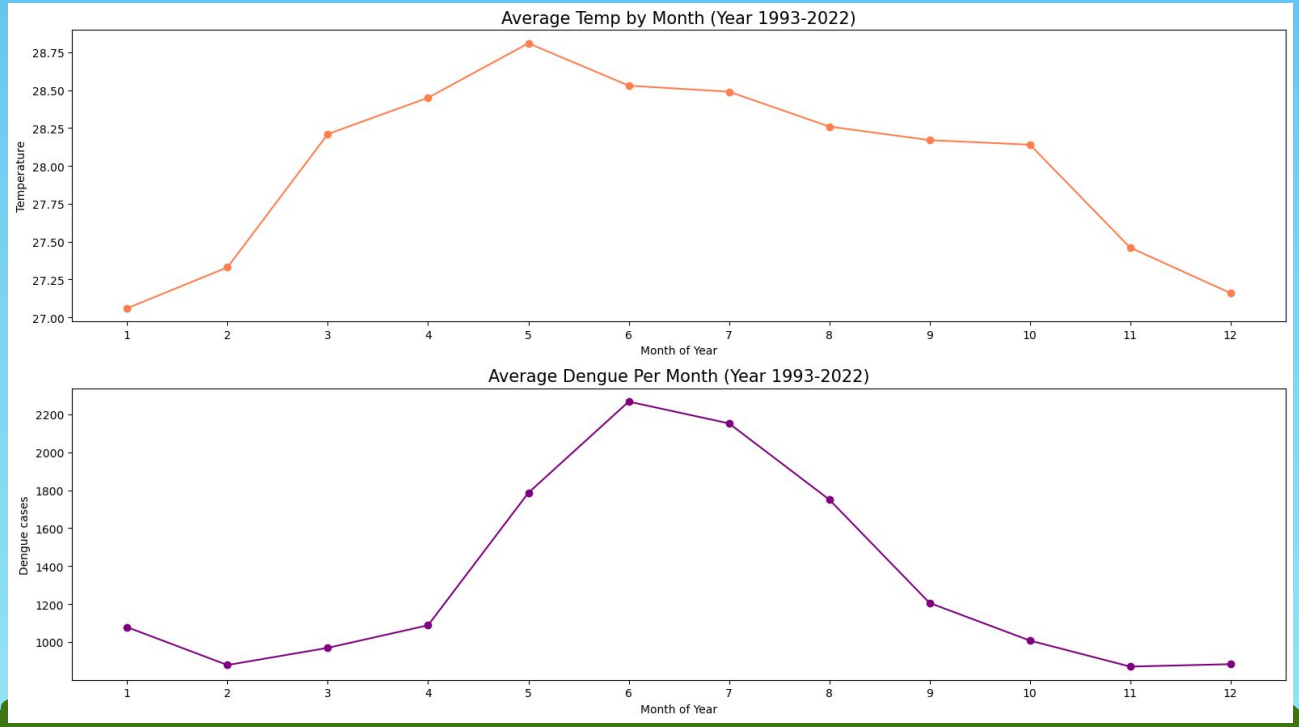
- **All features have p-value > 0.05 except mean_temp**

- Even mean_temp is near to 0.05

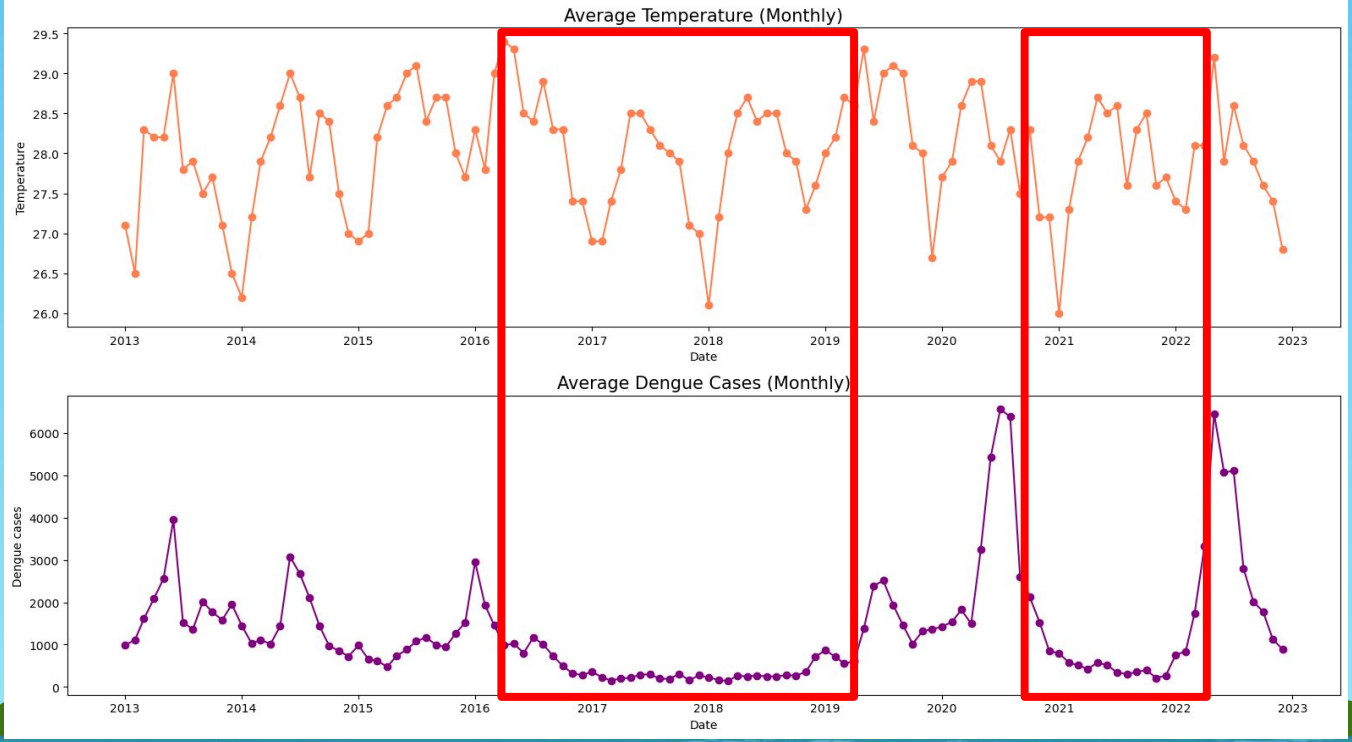
3D. Looking into Mean_Temp (by Year)

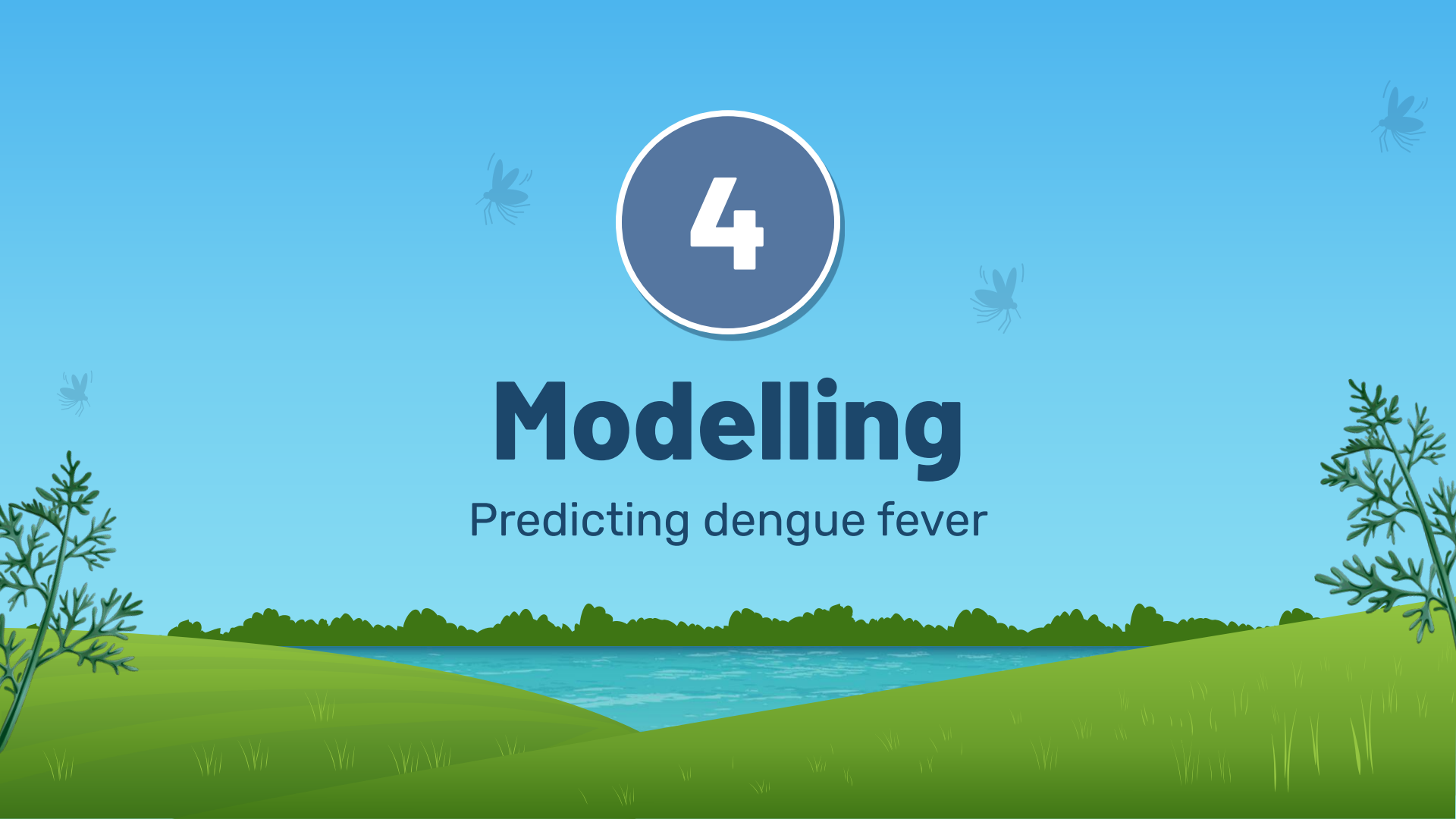


3D. Looking into Mean_Temp (by Month)



3D. Looking into Mean_Temp (Time Series)




4
Modelling
Predicting dengue fever

4A. Clinical (Model) Trials - Monthly

Baseline

- Monthly dengue cases (2013-2022)
- 1-year forecast
- ARIMA MAPE: 0.47

Model 2

- Monthly dengue cases (2013-2022)
- Google trends
- Weather data
- Human restriction factor
- 1-year forecast
- ARIMAX MAPE: 0.36

4B. Clinical (Model) Trials - Weekly

Model 3

- Weekly dengue cases (2013-2022)
- 1-year forecast
- ARIMA MAPE: 0.47

Model 4

- Weekly dengue cases (2013-2022)
- Human restri. factor
- 1-year forecast
- ARIMAX MAPE: 0.74

Model 5

- Weekly dengue cases (2013-2022)
- Last 12-week forecast
- SARIMA MAPE: 0.12

Model 6

- Weekly dengue cases (2021-2022 Sep)
- Last 12-week forecast
- ARIMA MAPE: 0.08

4C. Chosen Model with 12-Week Forecast

Model 6	
Dengue Data	Weekly (2021-2022 Sep)
Model	ARIMA
MAPE	0.08

	Q4 2022 Average Cases per month
Prediction	297.75
True Cases	305.25
% change from last quarter	-19.31%
% change from last quarter	-18.82%


5
Cost-Benefit Analysis

5A. Cost Benefit Analysis

NEA Inspections per year	Monthly Average	Avg time taken for an inspection (mins)	Manhours per month	Manpower costs (Hrly rate)	Total costs	Potential reduction on inspection needs based on avg predicted drop cases (12 Week Forecast)	Manpower Costs in SGD	Manhours saved
988000	82333.33333	3	4116.666667	$12.00	$49,400.00	-19.31%	$9,538.62	794.8848238

Foresight for early decision making | In this case, the rate of decrease

1. Potential reduction of manpower costs in $ (reduce hire of temporary dengue officers)
2. Reallocation of precious human resource used for NEA inspections to other campaigns
3. Stand down of volunteers from town councils to focus on other social improvements
   (e.g. 5000 volunteers were activated from PA grassroots organisations and CERTs to conduct house visits)

Sources:
https://www.nea.gov.sg/media/news/news
https://www.nea.gov.sg/docs/default-source/isr/nea-isr2020---financial-statements.pdf
https://www.mycareersfuture.gov.sg/

5B. Predicting an increase 12 weeks ahead...

1. NEA may allocate additional resources towards dengue inspections in response to increase in dengue cases prediction
2. This could include increasing inspections, hiring staff, or deploying volunteers
3. Cost benefit analysis shift, benefits now focused on response effectiveness in reducing impact on public health
4. Model predicts increase in cases several weeks in advance
5. NEA can proactively increase inspections and take preventative measures to contain outbreak
6. Preventative measures include increasing public awareness, vector control activities, and preparing local healthcare providers to handle increase in cases


6
Conclusion

6A. Conclusion

- Accurate predictions of decreasing dengue cases can help reduce inspections, save time and money
- Prediction of increasing cases may result in additional costs but benefits of the model can still be substantial
- Accurate and timely predictions of dengue outbreaks can help mitigate impact of outbreak
- Importance of using data-driven models in public health sector to improve health outcomes and make best use of resources.

6B. Areas for Improvement

- Improve prediction range from 12-weeks to longer time period
  - Better planning for annual budget and avoiding out-of-cycle budget requests
- Explore other exogenous features and time-series models
- Enhance and develop a spatial-temporal model
  - Provide more accurate local dengue hotspot predictions within Singapore
  - Enhance model to predict dengue cases and occurrence location for effective NEA awareness campaigns, ground inspections, and installation of gravitraps

Thank You!

Annex: Dengue Cases in Singapore

- 2013: 22,000 people were infected. It stood as Singapore's record year for the most number of dengue cases until 2020. Multiple preventive measures were introduced / reinforced, such as new community alert systems with colour-coded banners, more officers deployed to conduct mosquito breeding checks at residential and industrial areas.

- 2014: dengue resurged, with 18,000 people infected. The driving forces behind both 2013 and 2014's surge in cases were the emergence of a new DENV-1 genotype III strain of dengue (hence Singaporeans are more susceptible to it) and Singapore's high population density (and hence optimal vector density)

- 2016: 13,000 people were infected; it was a 16% rise from 2015. A total of 1,432 clusters were recorded. Residents in Housing & Development Board (HDB) flats, Landed Properties (including shop houses), Condominiums constituted 64.5%, 21.9%, 13.4% of the cases respectively

- 2019-2020: there was a dengue fever epidemic in South-East Asia. The spread of the disease was exacerbated by falling vaccination levels in certain areas, and by a growing population of mosquitoes enabled by increased human litter (e.g. plastic containers).

- 2022: 32,000 dengue cases in the year; second to 2020's 35,000 cases. The Health Sciences Authority of Singapore is reviewing the sale and use of Qdenga vaccine, which Health Minister Ong Ye Kung described as the “most advanced” among six dengue vaccine candidates in various stages of clinical development.