The Heat Is On! Singapore's Race Against Climate Change

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INTRODUCTION

According to United Nation's Intergovernmental Panel on Climate Change (IPCC),

Daily mean temperatures rose at an average rate of **0.25°C per decade** and projected to increase between 1.4°C to 4.6°C by the end of 2100.

Annual total rainfall rose at an average rate of **101 mm per decade** and will intensify in the wet months (Nov-Jan).

While the localized changes may seem microscopic, it has grave consequences on a global scale because climate change directly impacts the sustainability of **water**, **food supplies**, **ecosystems**, **coastal stability** and **public health**.

OBJECTIVE

The motivation of the project is to maximize the potential of publicly available data through the exploration of the **impact of climate change** on Singapore and how it threatens Singapore's existence.

1. Create clear and easy-to-understand **visualizations** of past trends to increase the public's awareness
2. Input parameters required for the **analysis**
3. Model and **predict** future trends to assist the government's efforts using historical data.

R programming language was used for the data processing, statistical analyses and building models. **Shiny** is used to build the web application.

R packages used include shiny, shinyWidgets, shinydashboard, tidyverse, ggrepel, DT, plotly, forecast, gstat, stats, shinyjs, ggstatsplot, gganimate, ggthemes, sf, tmap, terra, viridis, sp, raster, ggHoriPlot, tseries and tsibble.

DATA

Meteorological Service Singapore (MSS) collects and maintains long-term records of Singapore's weather. The information collected includes historical temperature and rainfall readings.

Through the **MSS Historical Daily Records** page, the public can select the respective weather station, relevant month and year and download data in CSV or PDF format.

We selected **18 stations** with complete datasets from 1980 onwards. This provides a long-term perspective on climate trends, which is crucial for accurate modelling and prediction.

Our team has utilized **Robotic Process Automation** using UiPath software to download all the necessary data. In total, we have **5,552 CSV files** over **42 years** of monthly data.

INSIGHTS

1. The most notable observation is the **consistent increase in mean temperatures across the years**, evident across all stations and regions. This **upward shift** is visually represented by the rising mean temperature values in cycle plots and time transition plots, aligning with projections made by Singapore's National Climate Change Secretariat and United Nation's IPCC on the expected rise in daily mean temperatures. It is also worth noting that the trend does not indicate a faster rate of change in recent decades.

2. Analysis of wet and dry seasons indicates a **significant difference in mean and median temperatures**. The data might reflect seasonal changes where higher temperatures correlate with a drier season (June), and cooler temperatures might coincide with a wetter season (December).

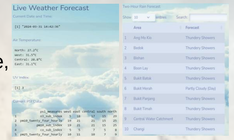
3. The presence of a downward-sloping line in correlation scatter plots suggests a **negative correlation between mean temperature and total rainfall** at several stations and regions. This implies higher temperatures might be associated with less rainfall in these stations and regions.

4. There is a **clear and reversed geospatial pattern** visible in the distribution of both temperature and rainfall. Urban areas tend to be warmer (dark orange) due to the urban heat island effect and might also have less vegetation to retain moisture, leading to lower total rainfall (light blue). This observation supports the correlation analysis.

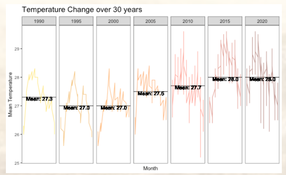
5. Through confirmatory data analysis, it can be clearly observed that the **mean temperature in the central and more urbanized area is indeed the highest**, while rainfall is the lowest. This analysis confirms the geospatial pattern that was observed.

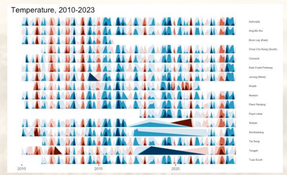
INTERACTIVE APPLICATION

Toolkit 1: Live Weather Forecast equips our user with live weather Forecast: time, date, air temperature, Pollutant Standard Index and UV Index for the next 2 hours.

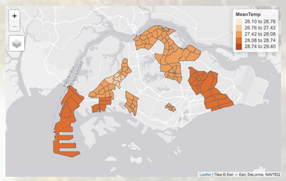


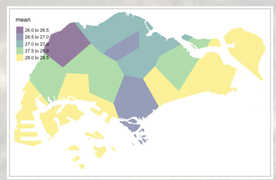
Toolkit 2: Time series analysis utilizes time-dependent decomposition and ridgeline plots to discern the variations, trends and anomalies in the weather across the years by specific periods or regions.



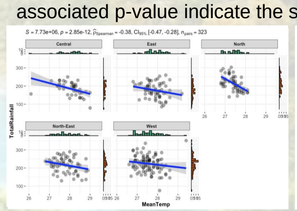


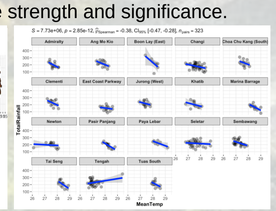
Toolkit 3: Geospatial analysis provides choropleth and isohyet maps with inverse distance weighted interpolation to show geographical climate patterns, such as urban heat issues.



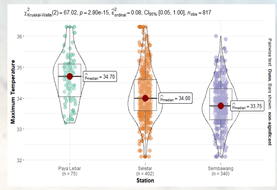


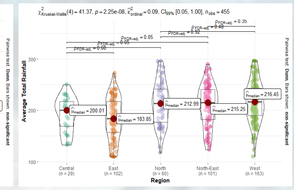
Toolkit 4: Correlation analysis of temperature and rainfall by station and region and Spearman's rho (ρ) value and its associated p-value indicate the strength and significance.



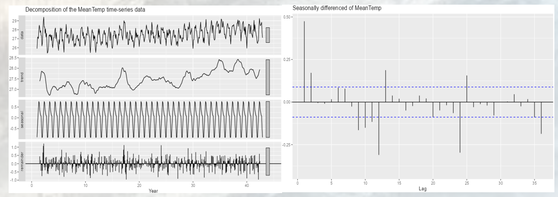


Toolkit 5: Confirmatory analysis provides statistical parameters and significant differences in the annual or monthly temperature and rainfall by weather stations and regions.

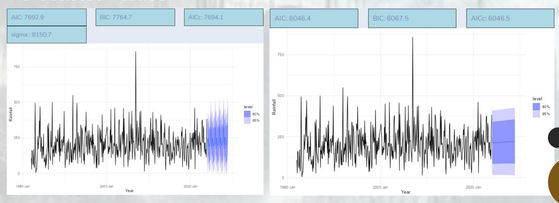




Toolkit 6: Pre-model check conducts tests to assess the stationarity of the time series data through Augmented Dickey-Fuller (ADF) or Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, and offers decomposition plots to visualize trend, seasonality and residual components as well as the partial autocorrelation of the data.



Toolkit 7: Forecast models, namely Exponential Smoothing State Space (ETS) and Autoregressive Integrated Moving Average (ARIMA). Users can select various parameters for the models to generate plots showing observed data and forecasted values.



FUTURE WORK

Our project embarked on the crucial mission of unlocking the **storytelling power of data** to illustrate the subtle yet profound shifts in Singapore's climate. Leveraging the **analytical strengths** of R programming and packages, we processed vast datasets, unearthed patterns, and decoded the narrative of our city-state's evolving weather landscape.

We hope our interactive web application built with Shiny acts as a **knowledge base**, engaging the community in a **visual dialogue** about the past, present, and potential futures shaped by climate trends. Our findings serve not only as a testament to the changes already at our doorstep but also as a **prognostic tool** guiding us towards preemptive action.

Expand data sources to refine our understanding of microclimates within Singapore.

Introduce interactive elements that allow users to simulate **"what-if" scenarios** in the web application.

Translate insights into **actionable strategies** for urban planning, disaster management, and environmental conservation.