Variance Analysis of Brightness Temperature Using High-Resolution DYAMOND Simulations and CRTM in Digital Twin Systems

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MOTIVATION

- High-resolution atmospheric models are crucial for improving the accuracy of weather forecasting and climate simulations.
- Understanding variance in Brightness Temperature (BT) is essential for refining instrument design in Digital Twin systems.
- Variability in BT impacts the effectiveness of satellite observations and can lead to errors in climate modeling.

PROBLEM STATEMENT

- Brightness Temperature varies significantly across different atmospheric layers and channels, affecting the realism of simulated observations.
- The challenge is identifying key atmospheric factors contributing to this variance and mitigating errors that affect model accuracy.

OBJECTIVES

- To explore which atmospheric variables contribute to the variance in brightness temperature (BT) using high-resolution DYAMOND simulations and CRTM, without prior knowledge of the most influential variables or channels.
- The study aims to evaluate the impact of atmospheric factors such as temperature, wind velocity, and pressure at different atmospheric layers, exploring multiple channels (Channel 5, Channel 11) to find which ones provide meaningful insights into BT variance.

DATASET

- High-Resolution DYAMOND Simulations: The data includes atmospheric variables across a 1.5 km grid resolution.
- Channels 5 and 11 represent different layers of the atmosphere, allowing us to observe both surface and upper-atmospheric processes.

METHODOLOGY

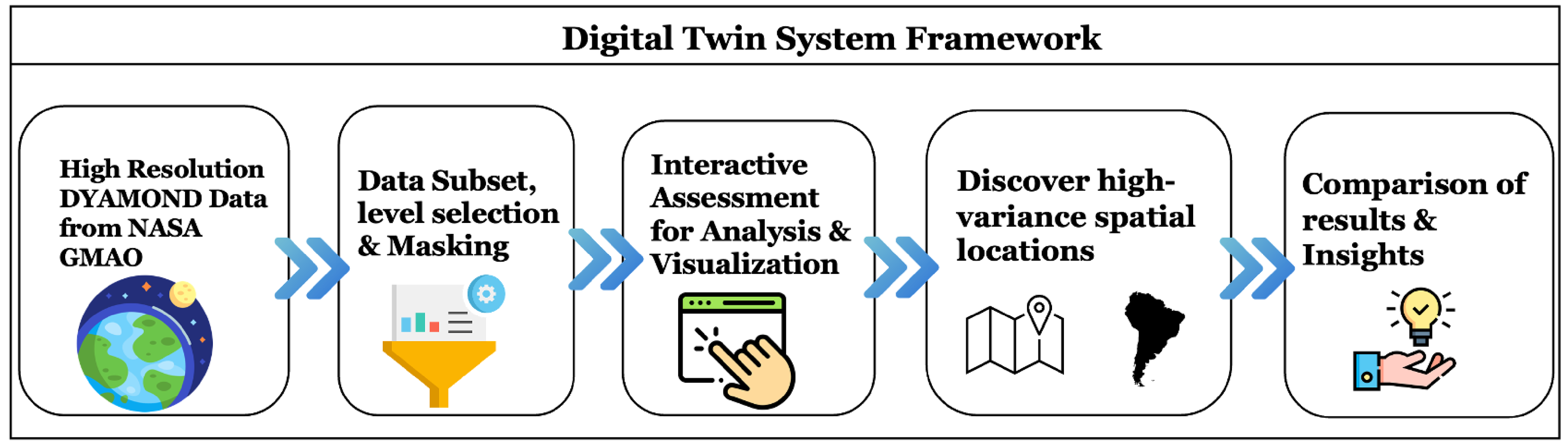

Fig 1: Digital Twin System Architecture

- Variance Analysis: We measured the variance of BT across different regions.
- Clustering with DBSCAN: Identified regions with homogeneous BT variance patterns.
- Three-Sigma Outlier Detection: Detected anomalies and extreme values in BT variance.
- Feature Importance: Machine learning techniques identified key features (e.g., wind velocity, temperature) contributing to BT variance.

RESULTS

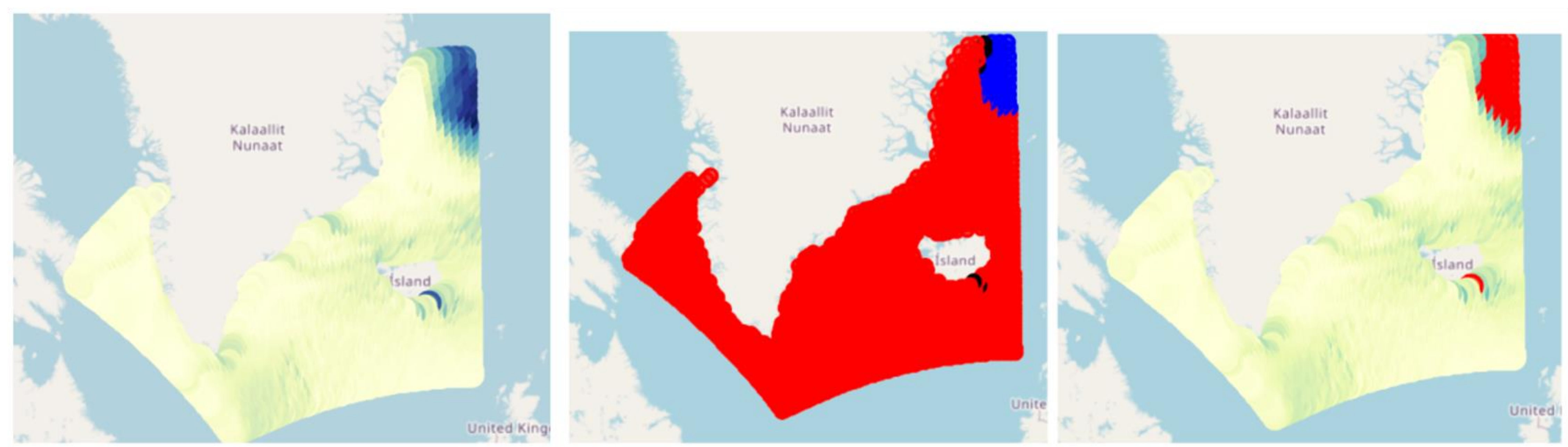

Fig 2 :(Left to Right): (a) Variance Analysis,(b) DBSCAN Clustering, (c) Outliers at level 45 out of 181 levels.

- Variance Analysis: Regions with high BT variance were identified, especially in Channel 5 and Channel 11.
- In Channel 5, wind-related variables showed higher significance.
- In Channel 11, temperature-related variables and pressure gradients played a more important role.
- Clustering (DBSCAN): Homogeneous clusters of BT variance were found, helping isolate regions of high variability.
- Anomalies (Three-Sigma Rule): Outliers were detected in regions with extremely high BT variance, suggesting areas for further investigation.
- Feature Importance: Temperature and wind velocity were consistently the most important variables for explaining BT variance across channels.

CONCLUSION

- Key Findings: Wind velocity and temperature are the most important factors influencing brightness temperature variance across atmospheric layers.
- Techniques like clustering and outlier detection allowed us to identify patterns in BT variance and detect anomalies, improving our understanding of atmospheric processes.
- Application: These findings will enhance the accuracy of digital twin systems, aiding in the design of more robust observational instruments for meteorology and climate research.

REFERENCES

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