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Harnessing Buoy data for Operational Storm Surge Forecasting

by

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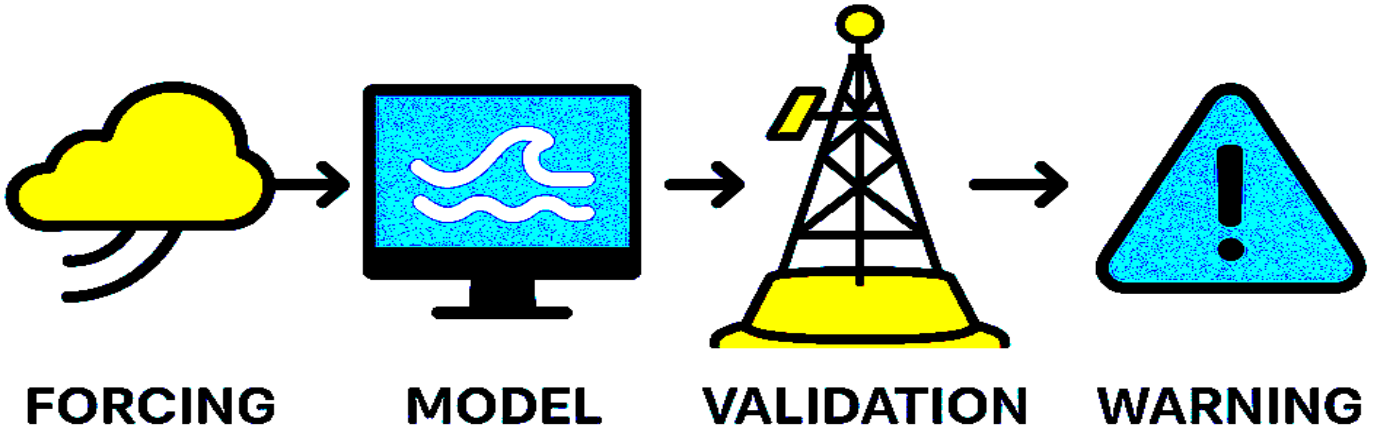
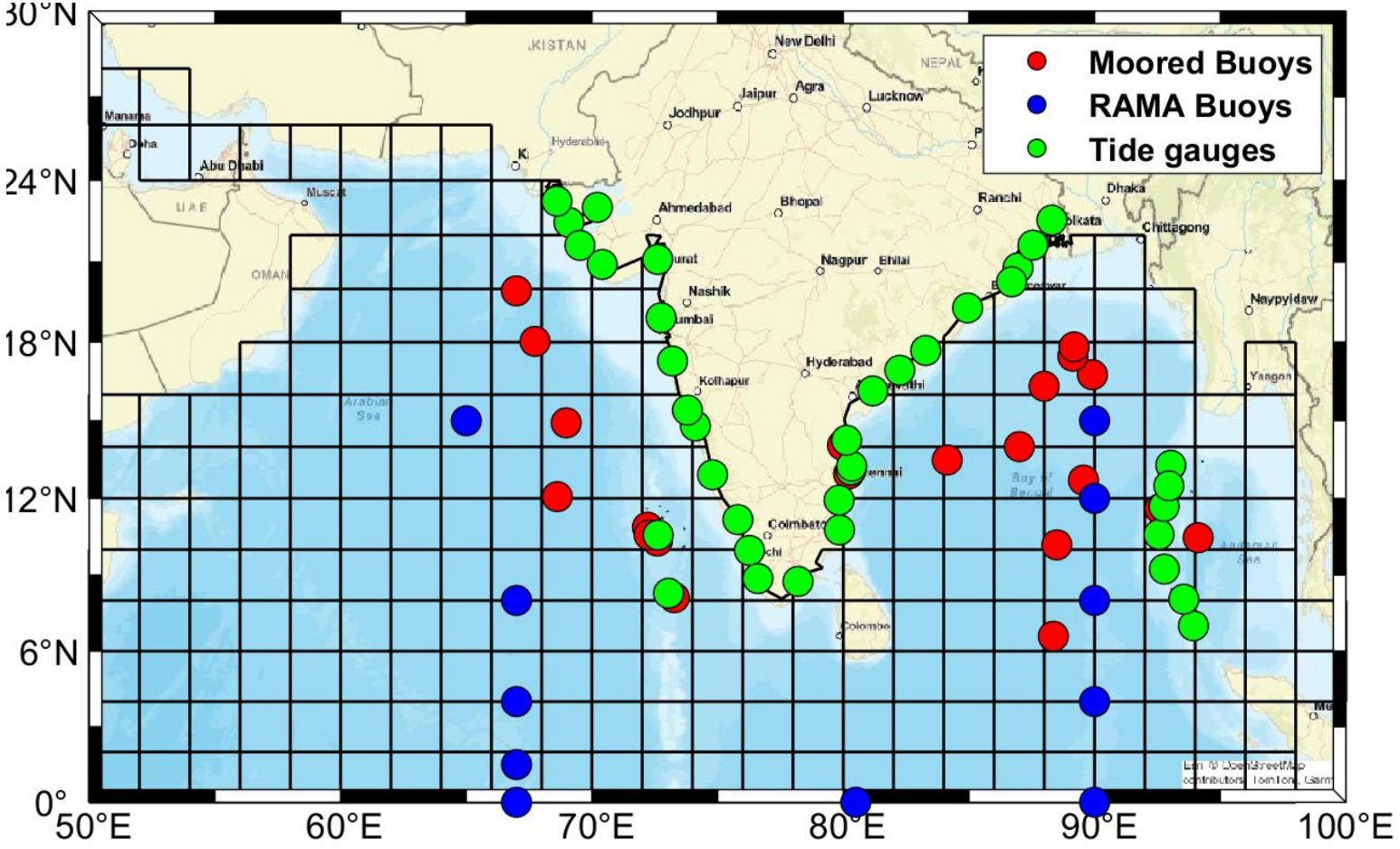
Why Buoy Data? – Strategic Need for Storm Surge Forecasting

- Cyclone-induced storm surges are the most devastating marine hazards in India.
- Real-time in-situ ocean data (wind, pressure, waves) is critical for accurate modeling.
- Buoy data supports **model initialization, validation, and situational awareness**.
- **WMO goals alignment**: "Early Warning for All" requires stronger ocean observing systems.

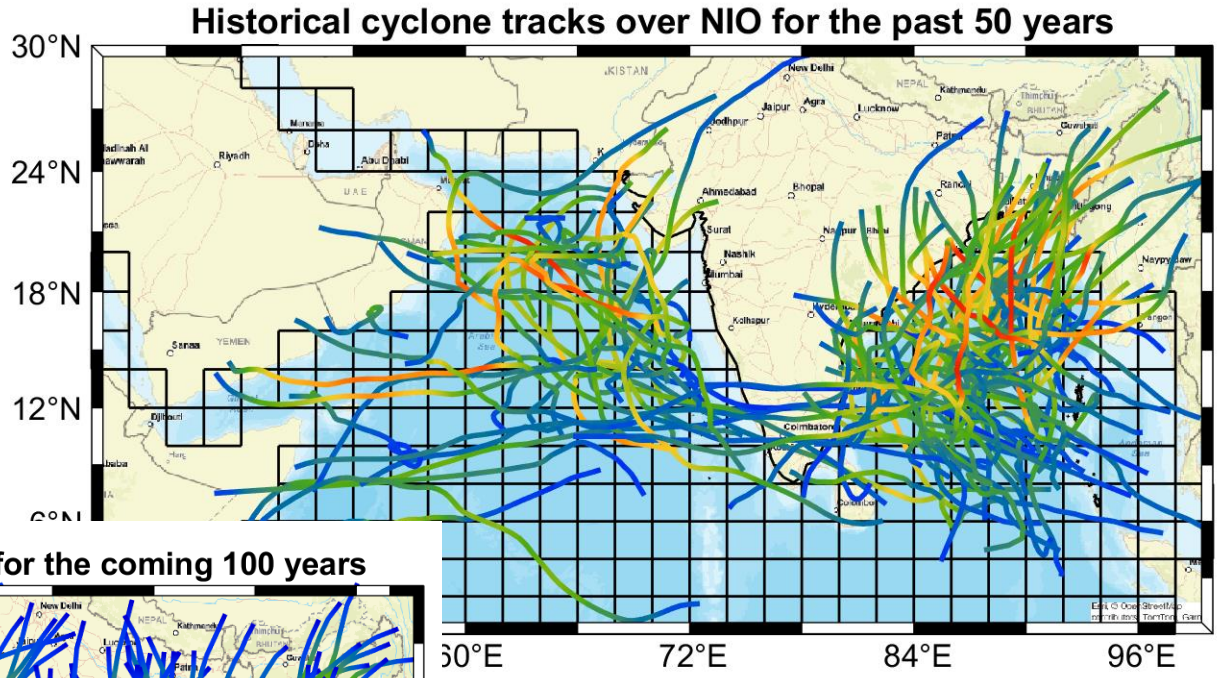
Storm Surge generation and forecast value chain

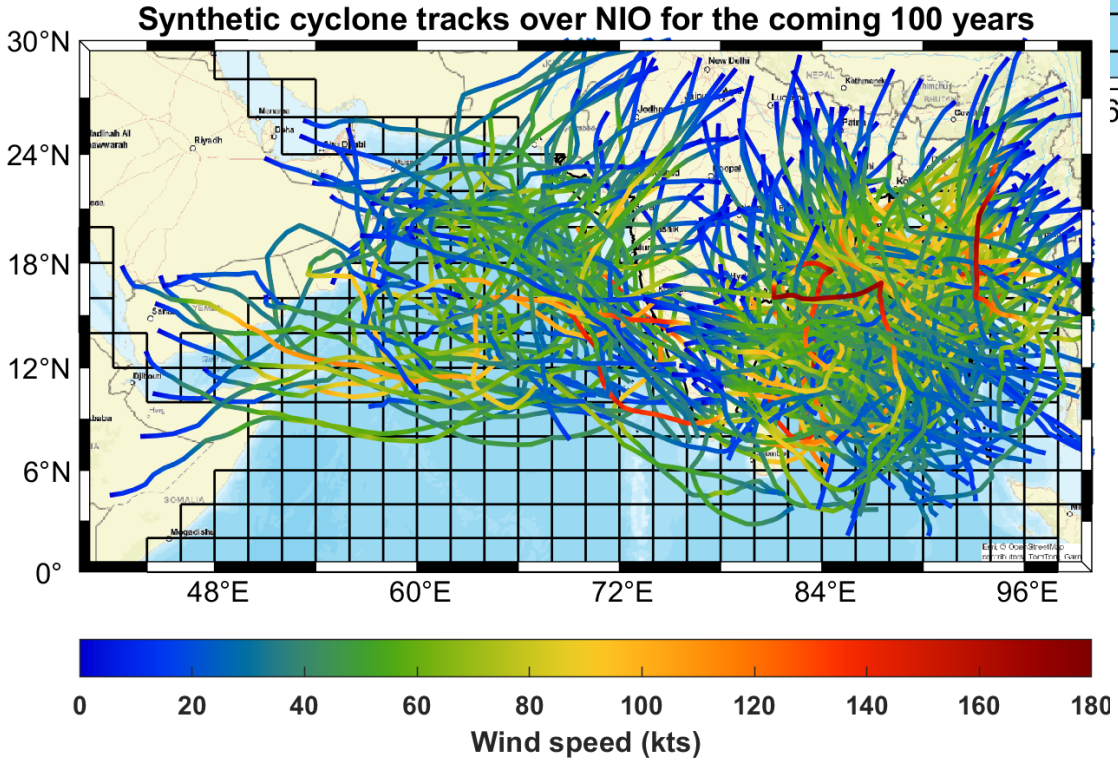


Observations Network over NIO



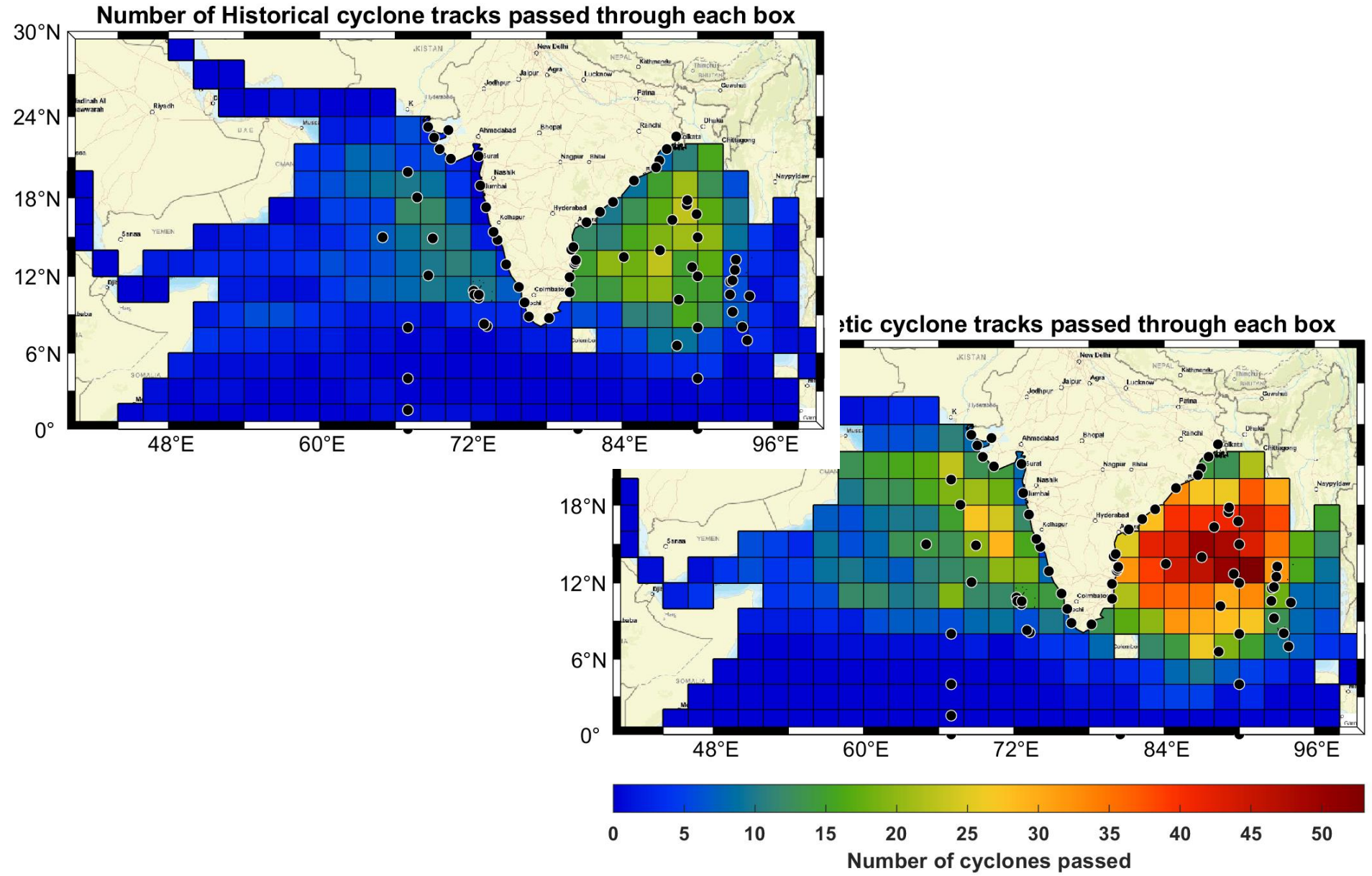
Historical Cyclone Tracks & future projections





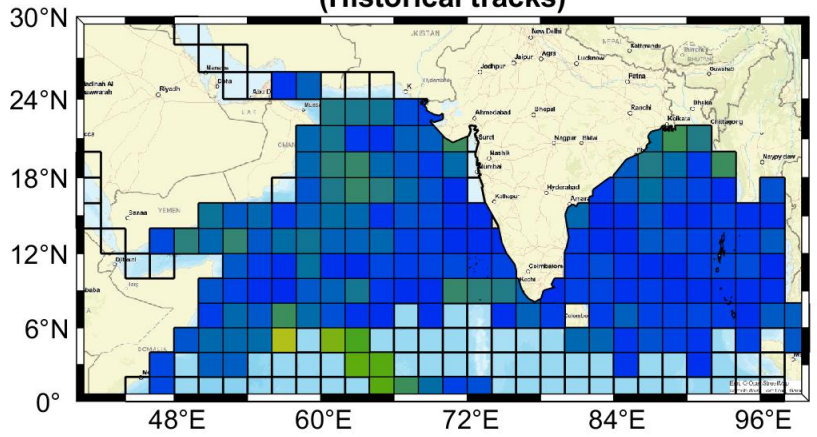
Murty et al., 2023, Journal of water & Climate Change.

Cyclone Track Density: Past Trends and Future Projections



Spatial Distribution of Cyclone Wind Extremes: Past 50 Years Vs. Future 100 Years

minimum of cyclone velocity (kts) passed through each box (Historical tracks)



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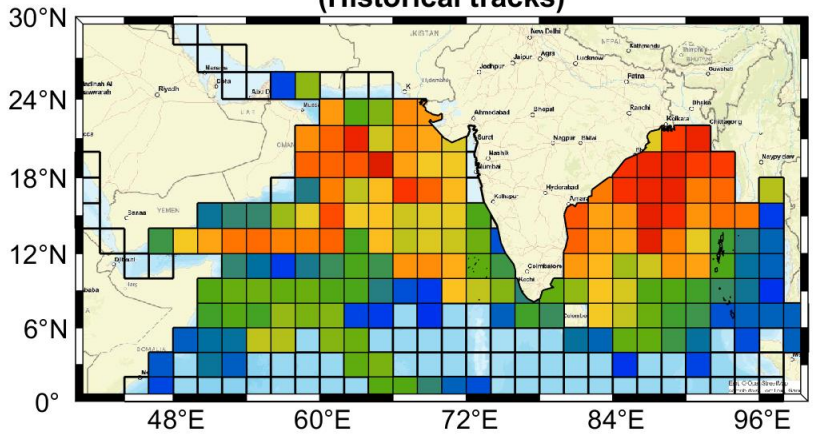
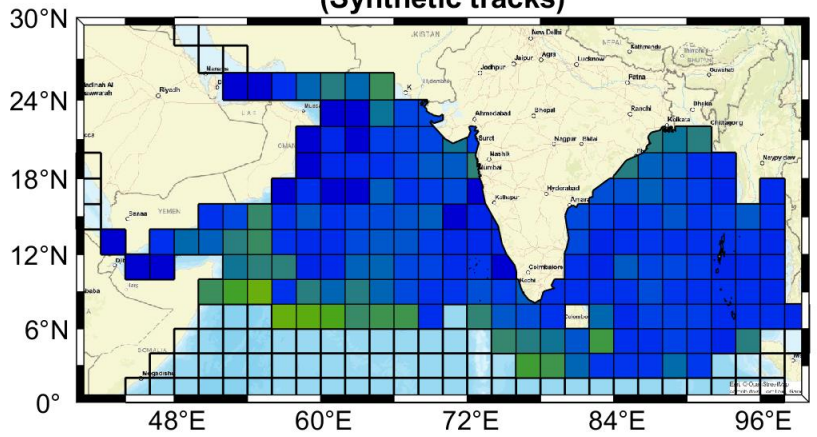


minimum of cyclone velocity (kts) passed through each box (Synthetic tracks)



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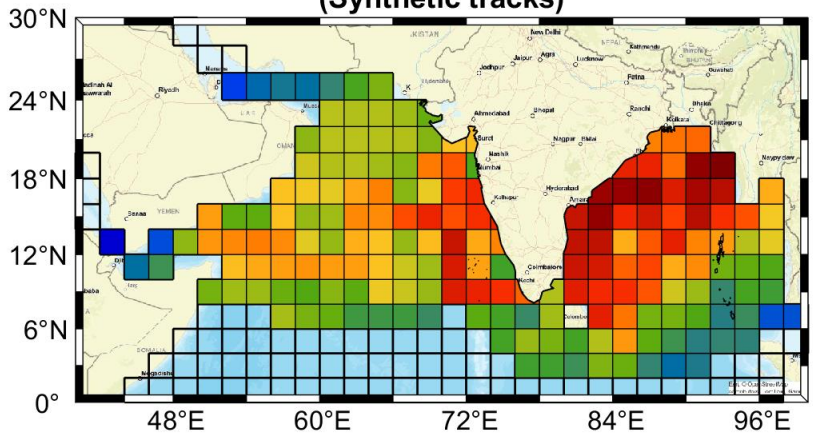
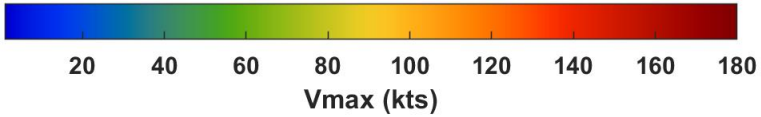
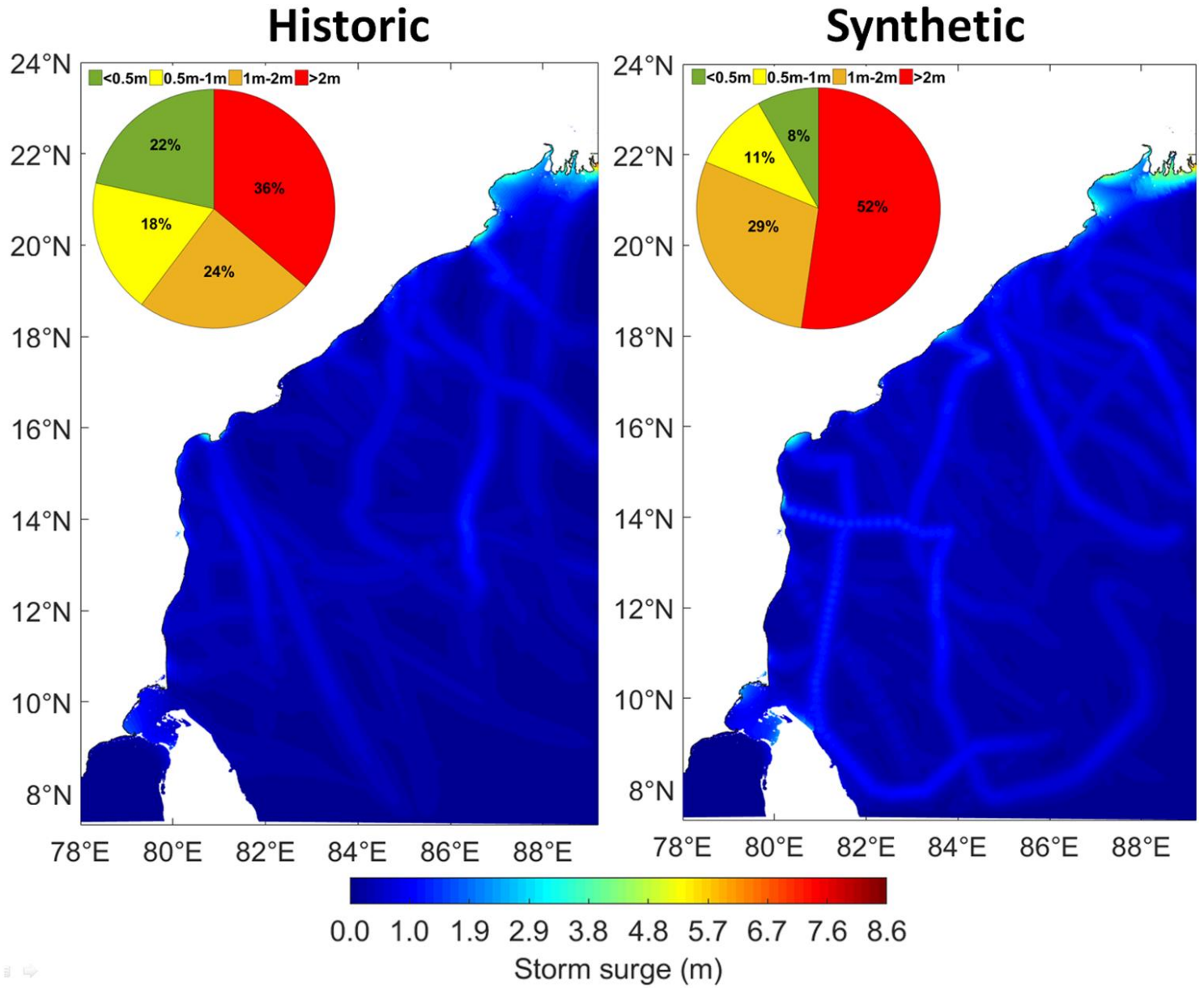




Storm surge composite maps using historical tracks that made their landfall along the ECI, and due to their projections by 2120

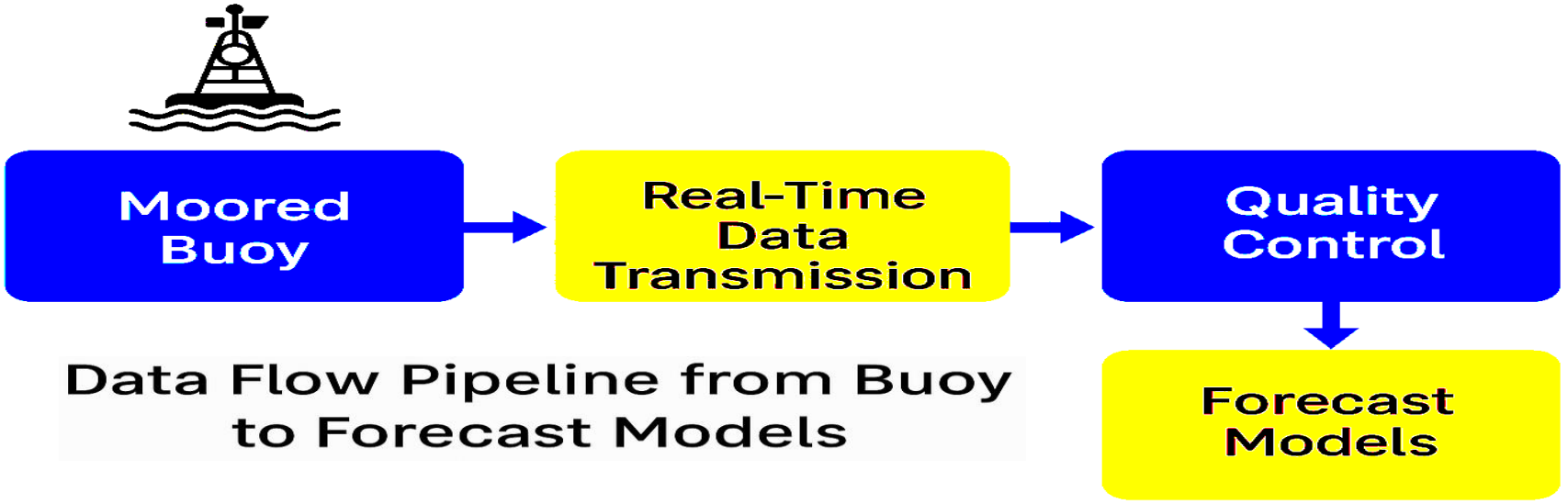


Operational Use of Buoy Data – Present Status

How buoy data is currently used at IMD/INCOIS:

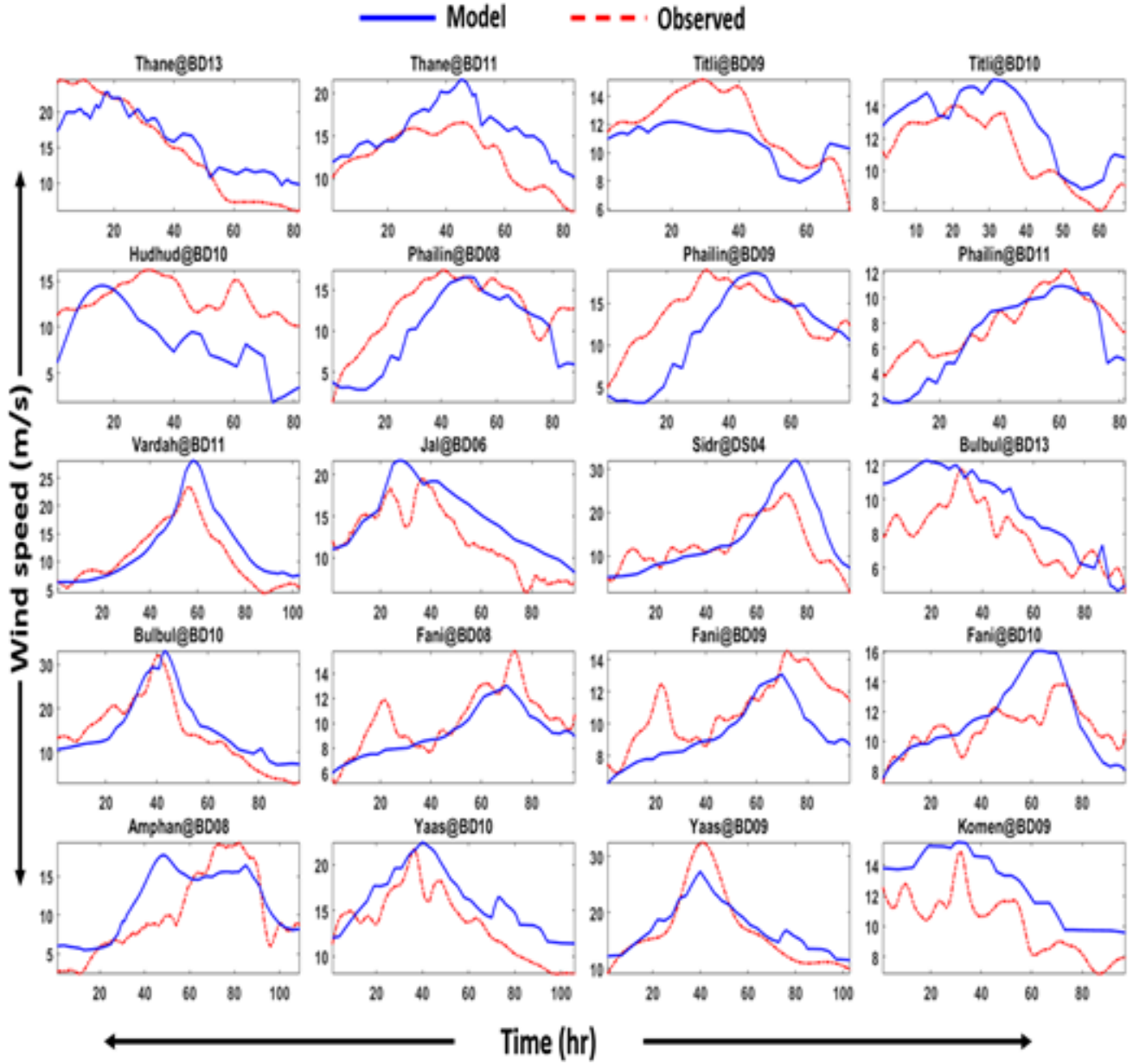
- Model wind correction
- Real-time validation
- Tracking wind jumps and pressure drops

Gaps: Telemetry delays, data sparse due to coarse network & instrument loss or during extreme events.

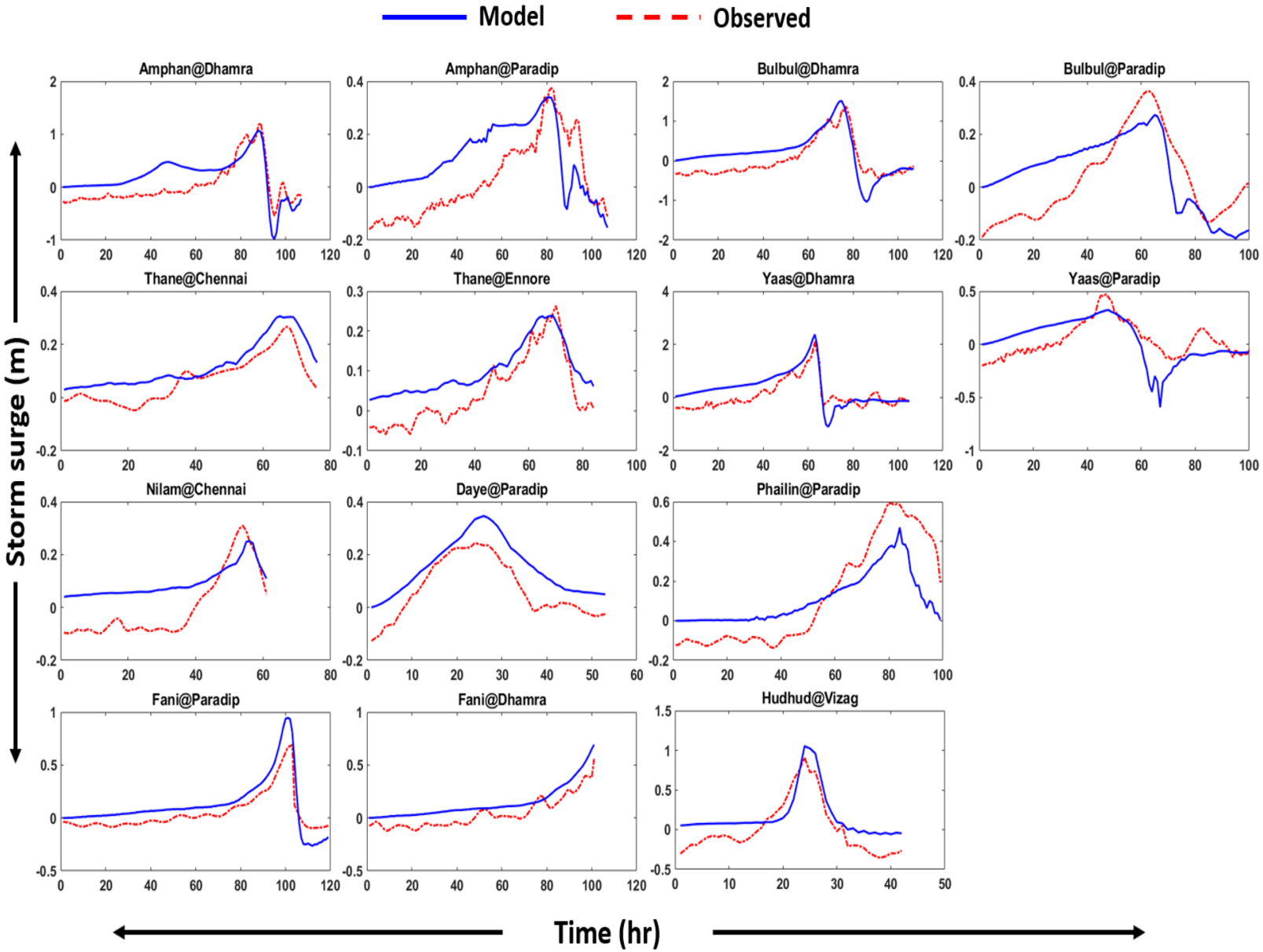


Data Flow Pipeline from Buoy to Forecast Models

Comparison of modeled wind speeds against the moored buoy records for different cyclones.



Comparison of modeled storm surge heights against the tide gauge records



Strategic Gaps and Opportunities

Bridging Gaps in Observations and Forecasting:

- **Uneven buoy coverage** across cyclone-prone zones—especially over the central & north Bay of Bengal, southeast & central Arabian Sea.
- **Lack of high-frequency real-time data** near cyclone tracks limits surge model initialization and validation.
- **Limited integration** of buoy data with regional and global surge forecast systems.
- **Sparse vertical profiling** (e.g., pressure, wind, waves) during extreme events.
- **Need for high-resolution modeling systems** that assimilate in situ observations dynamically.

Strategic Recommendations

Towards a Resilient Storm Surge Forecasting Framework:

- **Densify buoy network** in surge-vulnerable regions using risk-based prioritization (based on discussions in slides 5 – 7).
- **Deploy directional wave buoys** and real-time pressure sensors in key coastal boxes, moored buoys in the deeper waters.
- **Standardize data assimilation protocols** for storm surge models across countries in the North Indian Ocean.
- **Encourage joint experiments** (WMO–IMD–INCOIS–IITs) to evaluate impact of real-time buoy data on model performance.
- **Promote redundancy and robustness** in data relay and backup systems during extreme events.

Need for Multi-Institutional & Regional Collaboration

National: IMD, INCOIS, NIOT, IITs, NCCR, NIO, academic partners

Regional: IOGOOS, RIMES, ESCAP/WMO Panel on Tropical Cyclones

Joint field campaigns, shared data protocols, and model calibration efforts.

Summary and Strategic Call to Action

Buoy data is pivotal for accurate storm surge forecasting.

Current gaps must be addressed to meet **WMO's Early Warning targets**.

Need a **strategic expansion of coastal, off shore & deep water observing systems** over the next decade.

Invest in integrated observing systems, including buoys, tide gauges, HF radars, and satellite synergy.

Support targeted training programs for modelers and marine forecasters in surge-prone countries.

Call for support: DBCP, IOC-WMO, national agencies.

Thank You

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