Deep Learning Based Long Short-Term Memory (LSTM) Prediction System for the Indian Ocean Dipole

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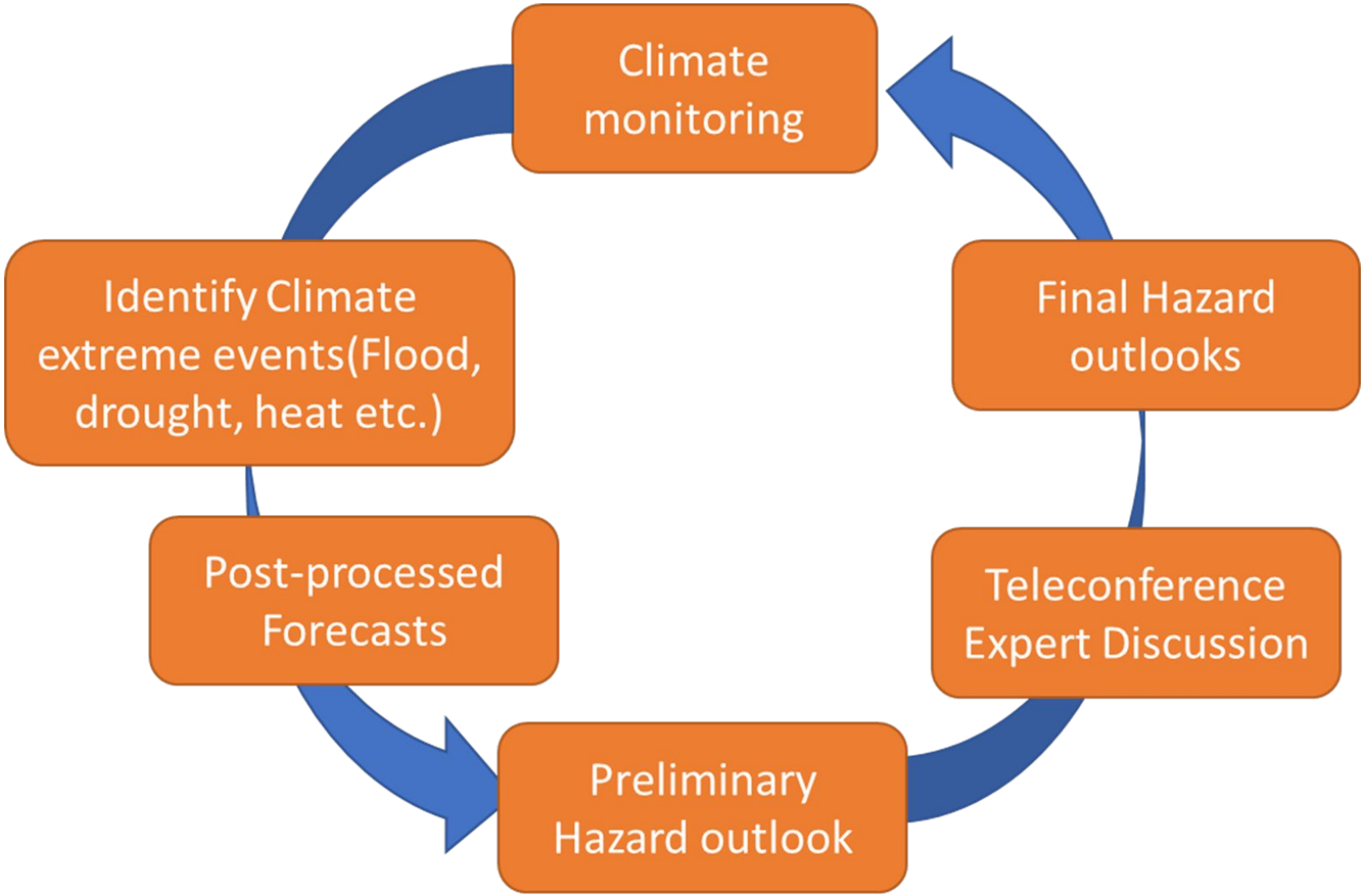
Motivation

- Estimation of extreme events, such as flood & drought, remains a significant management challenge.
- The Indian Ocean Dipole (IOD) , a climate phenomenon characterized by sea surface temperature anomalies in the Indian Ocean, plays a significant role in driving extreme weather events
- Traditional methods for estimating the Indian Ocean Dipole (IOD) have limitations, such as random and systematic errors, which reduce their effectiveness in water resources planning.
- Artificial intelligence (AI) models offer promising avenues for enhancing the estimation of the Indian Ocean Dipole (IOD).

Goal

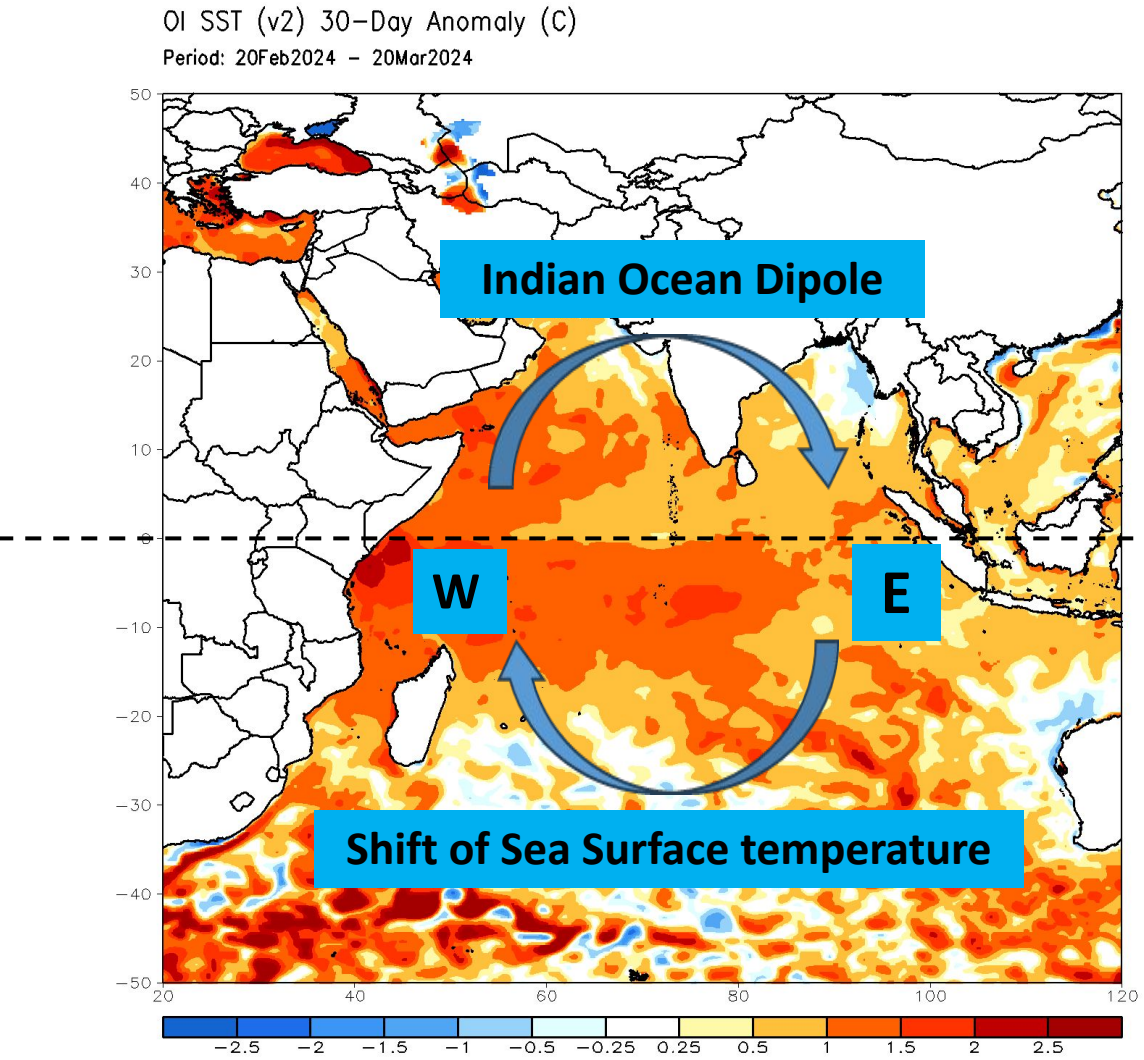

Climate monitoring
Final Hazard outlooks
Teleconference Expert Discussion
Preliminary Hazard outlook
Post-processed Forecasts
Identify Climate extreme events(Flood, drought, heat etc.)

Global Flood Exposure Map

[Tellman et. al, 2021, Nature]

Intensity of the IOD is represented by anomalous SST gradient between the western equatorial Indian Ocean (50E-70E and 10S-10N) and the southeastern equatorial Indian Ocean (90E-110E and 10S-0N). This gradient is named as Dipole Mode Index (DMI).

State of the IOD

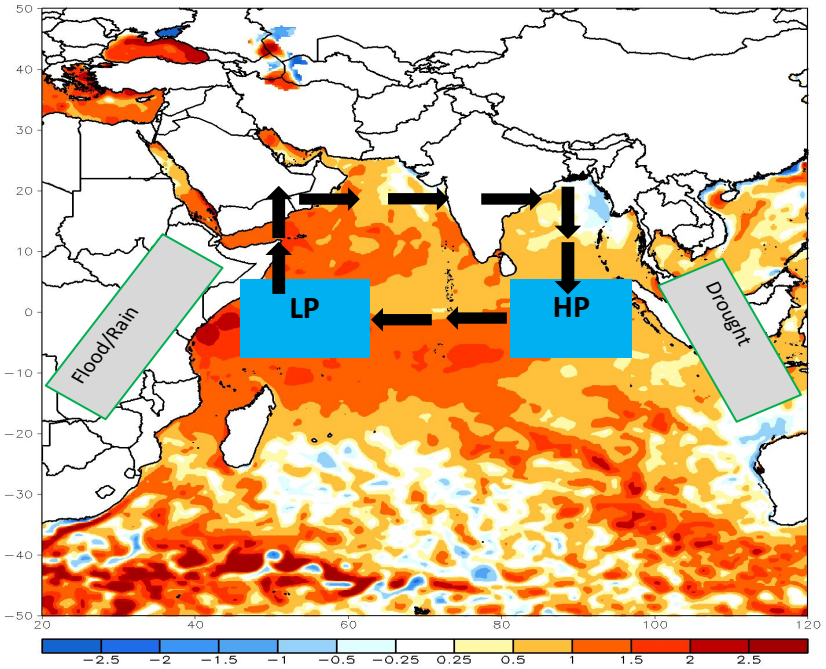


Why does the Indian Ocean have a pole?

- Arctic, Atlantic, Indian, Pacific , and Southern

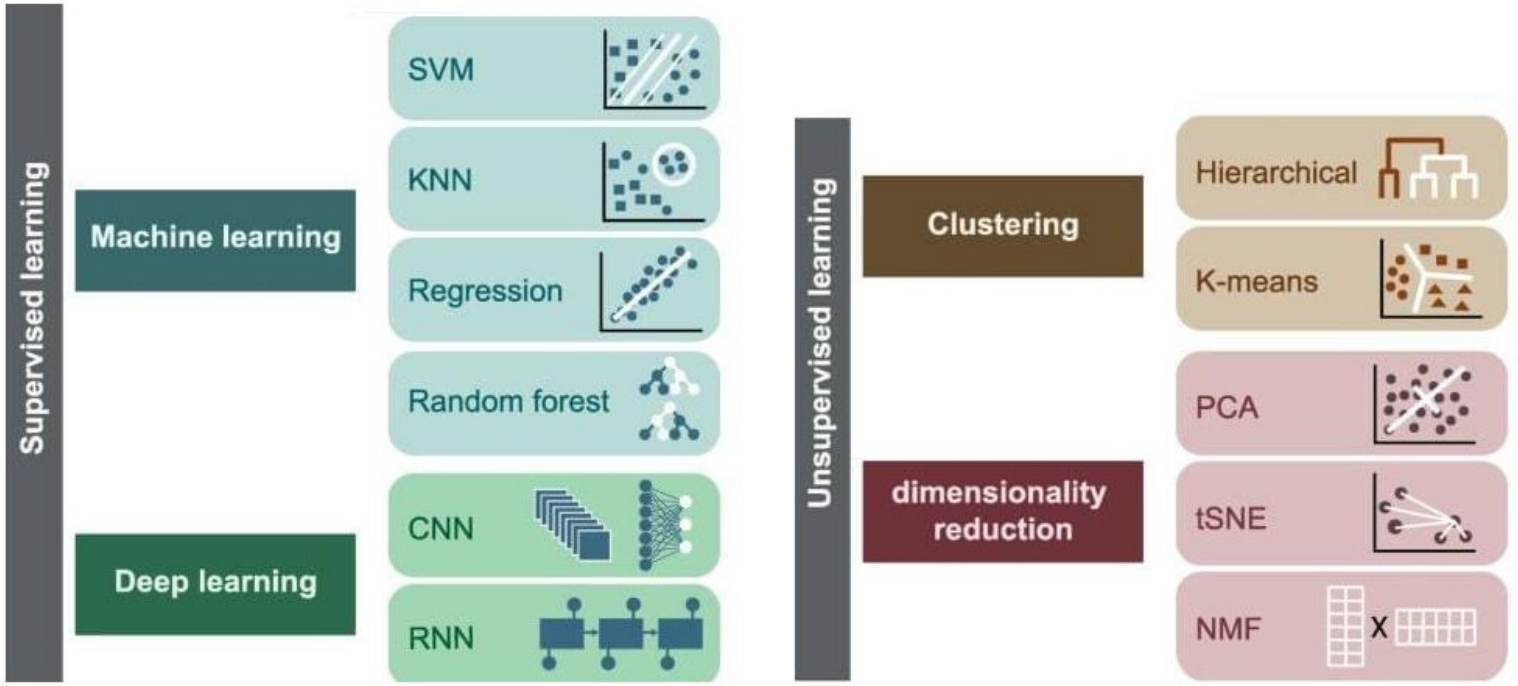
How does the Indian Ocean Dipole work?

- Positive-neutral-Negative Phase



During a positive phase, warm waters are brought up to the western part of the Indian Ocean, and in the eastern Indian Ocean, cold, deep waters rise to the surface.

AI Techniques



- Decision Tree Regressor (DT
- Random Forest Regressor (RF)
- Gradient Boosting Regressor (GB)
- Deep Neural Network (DNN)
- Recurrent Neural Networks (RNN)
- Bayesian Regression Tree(BART)

LONG SHORT-TERM MEMORY(LSTM)

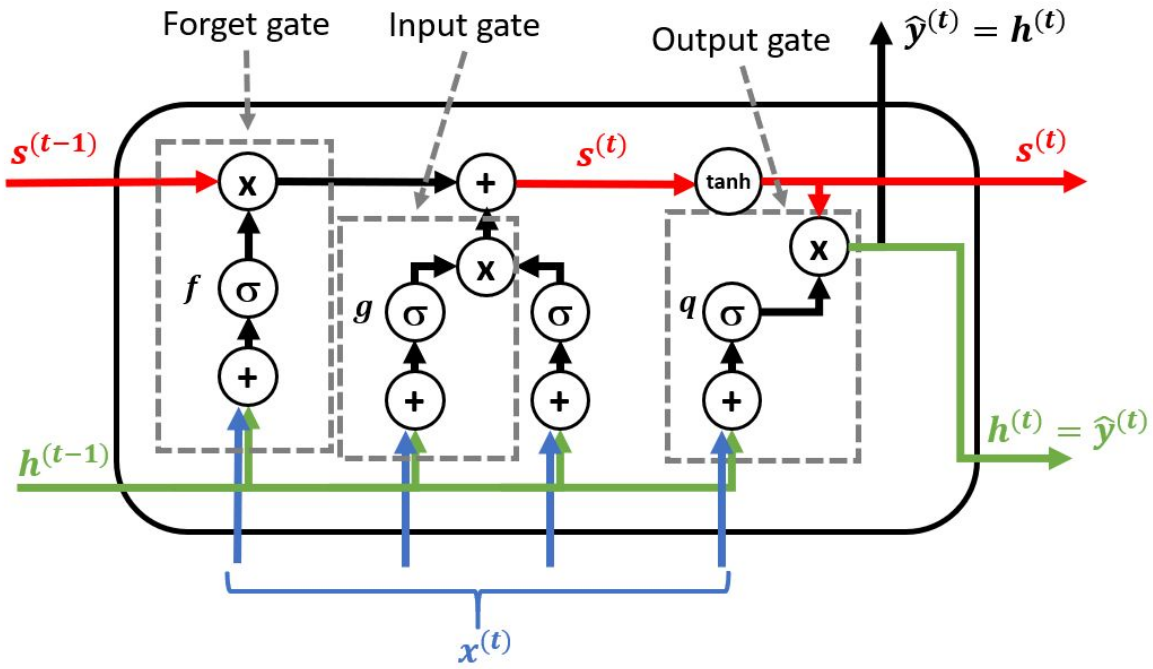
- There are three types of gates within a unit:

- **Forget Gate** : conditionally decides what information to throw away from the block.

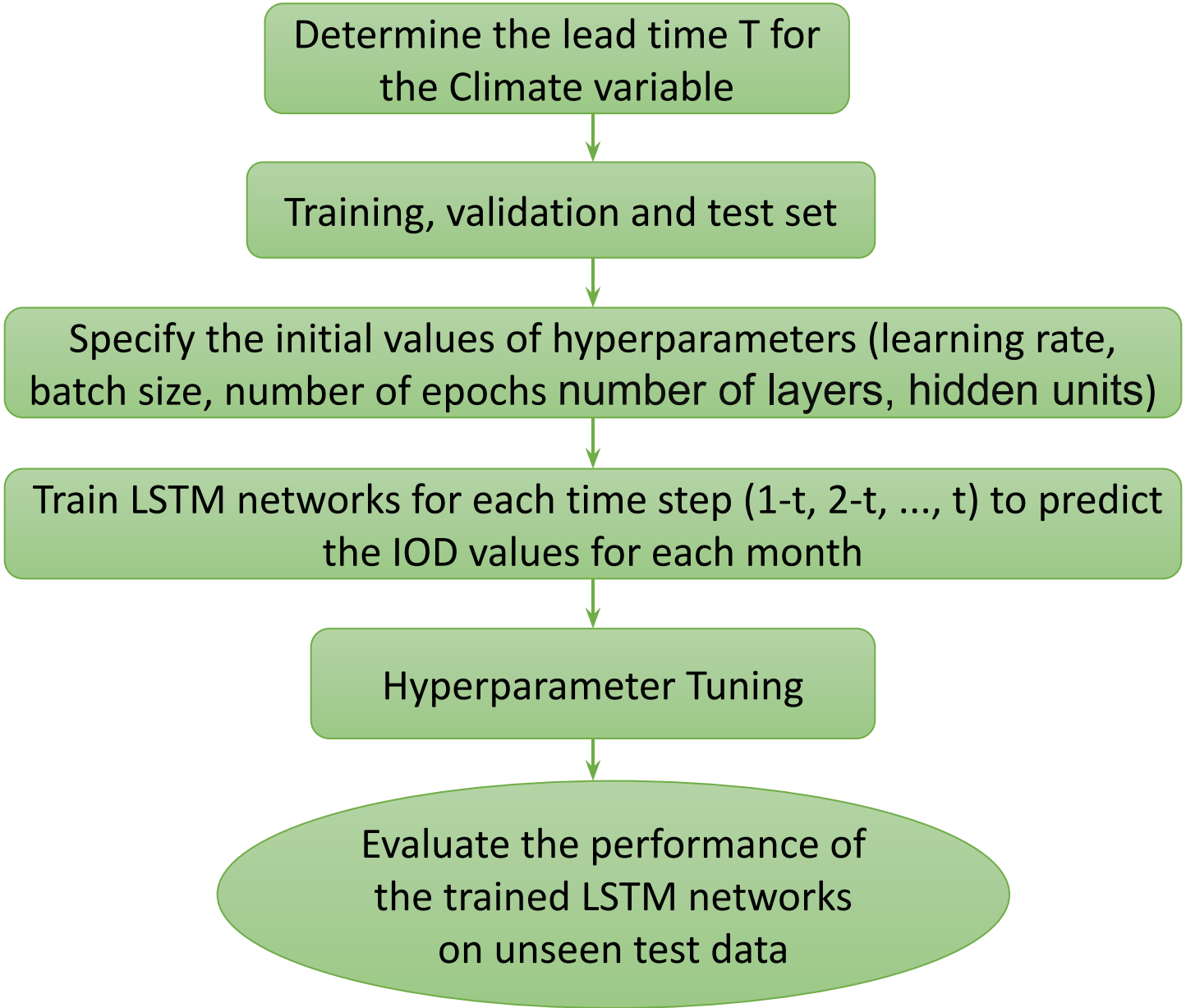
- **Input Gate**: conditionally decides which values fror the input to update the memory state.

- **Output Gate**: conditionally decides what to output based on input and the memory of the block.

- Each unit is like a mini-state machine where the gates of the units have weights that are learned during the training procedure.



Research Framework



Research Framework

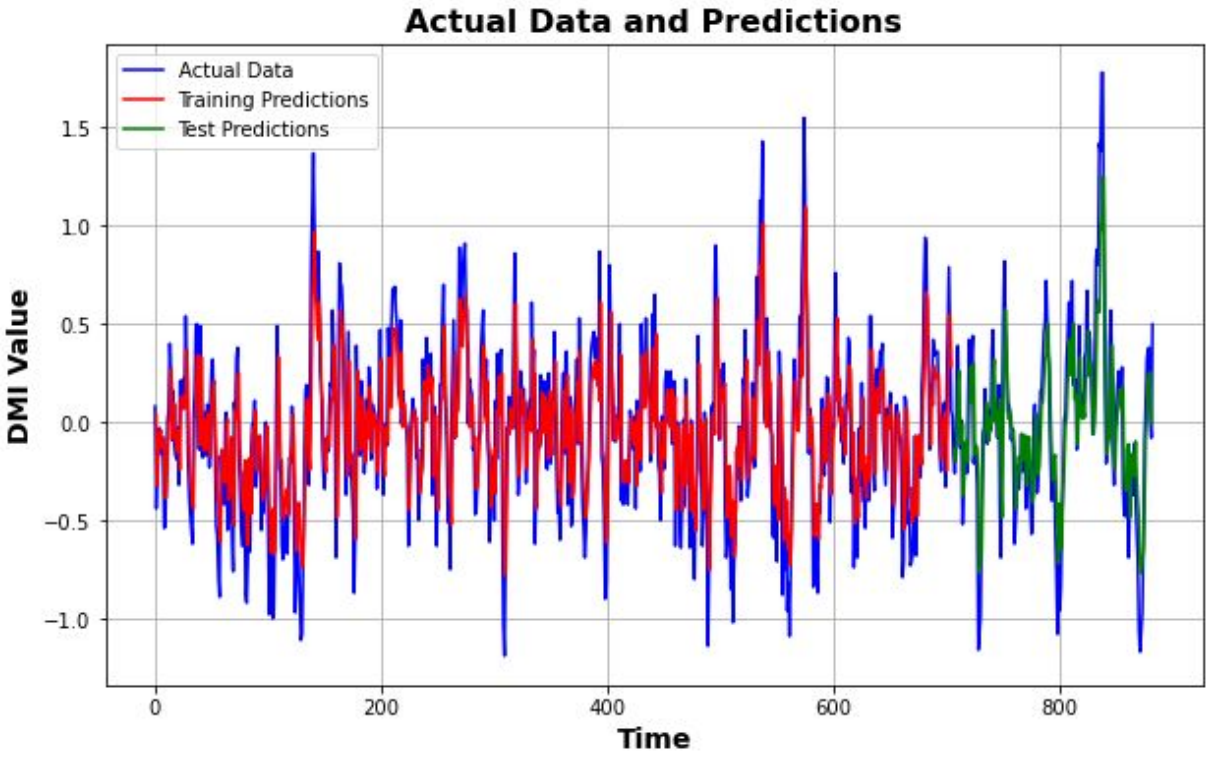
Dataset:

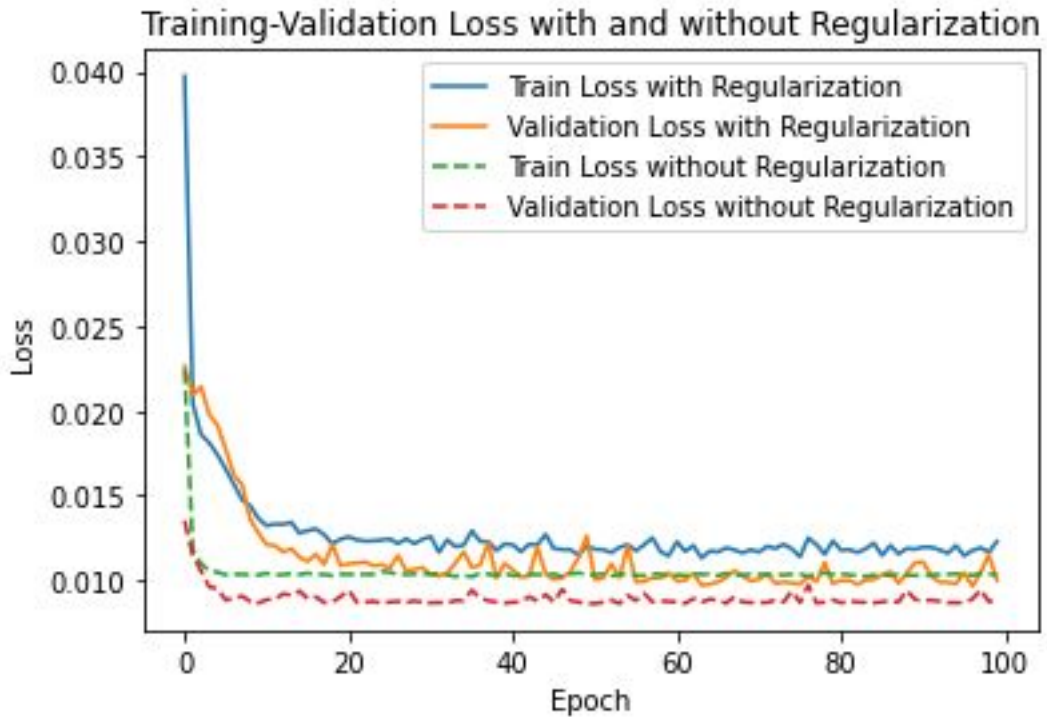
- ❑ Dipole Mode Index (DMI) which is based ERSSTv5(NOAA Extended Reconstructed SST V5)
- ❑ Date period: 1950-2024
- ❑ Temporal resolution: Monthly

Methodology:

- ❑ LSTM Model setup
- ❑ Model optimization
- ❑ Model evaluation:
  - Trained period:1950- 1990 and Testing period:1991-2021
  - Systematic/random error

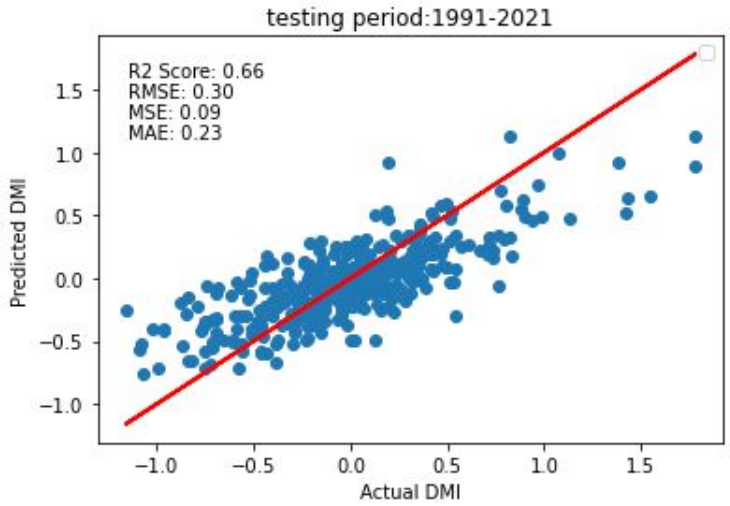
Model Optimization

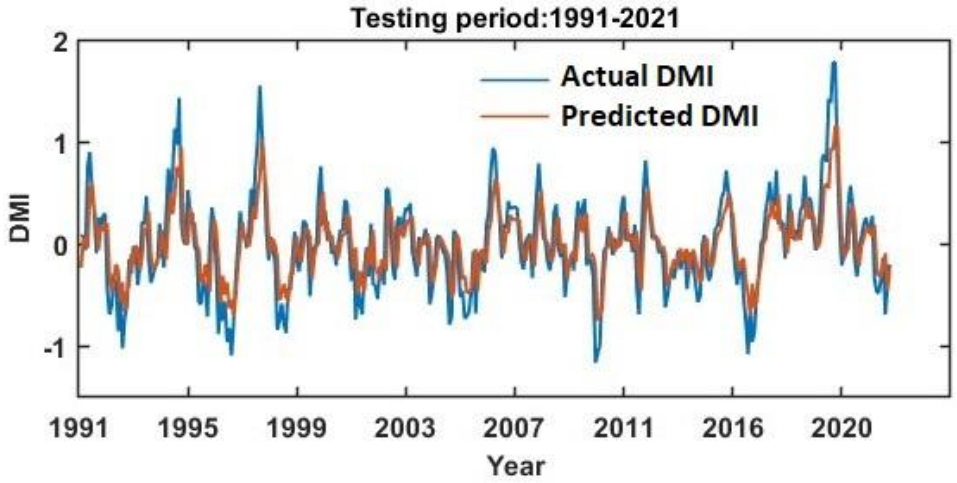




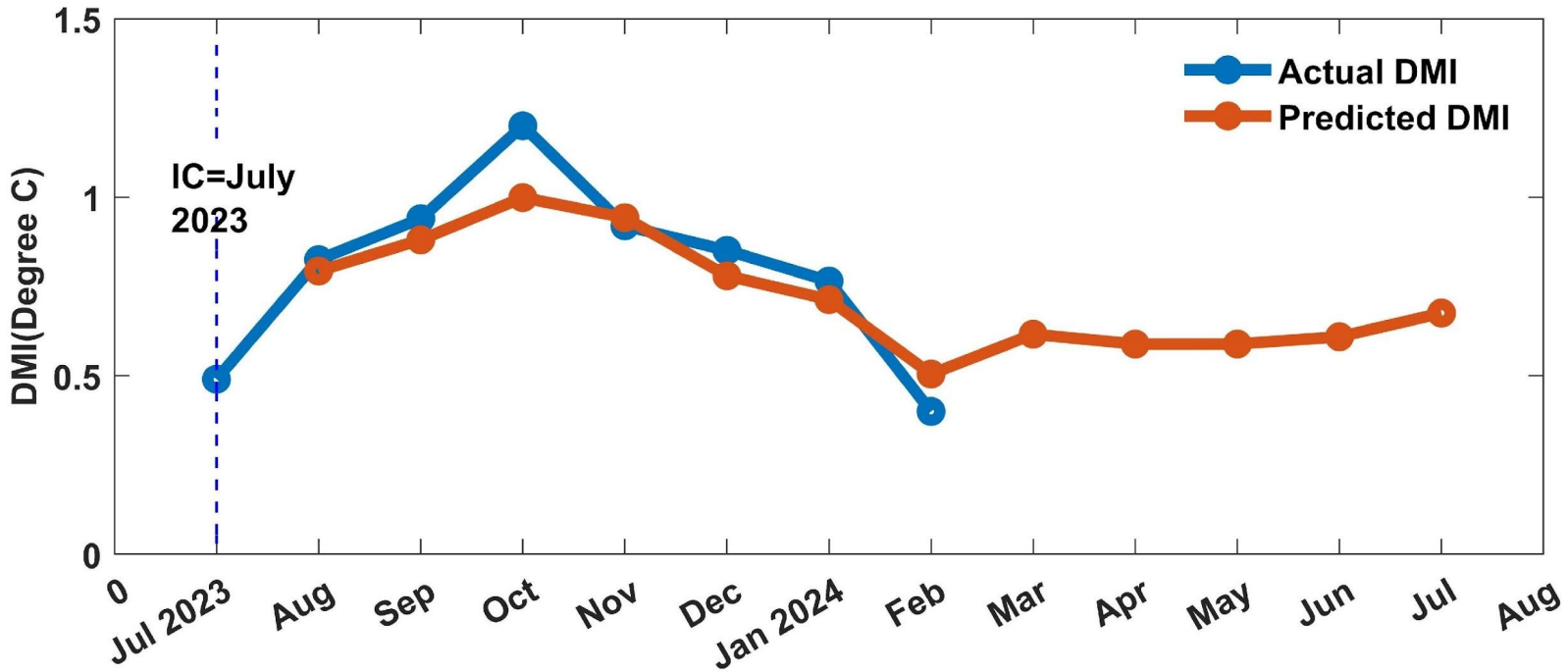
Train Score: 0.30 RMSE
Test Score: 0.28 RMSE

Model Evaluation

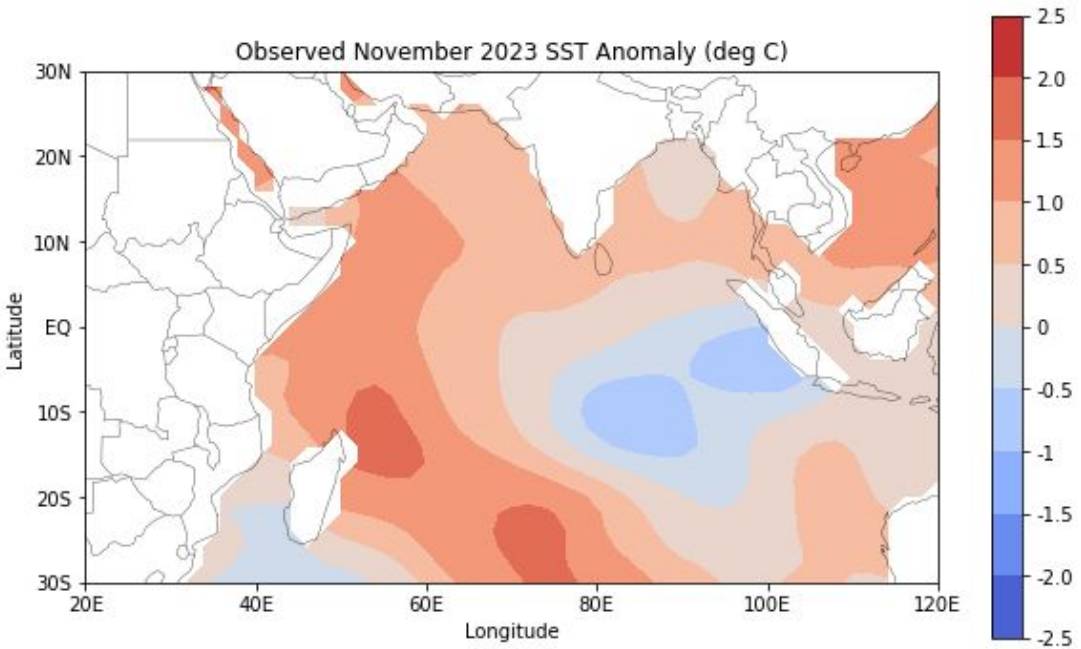


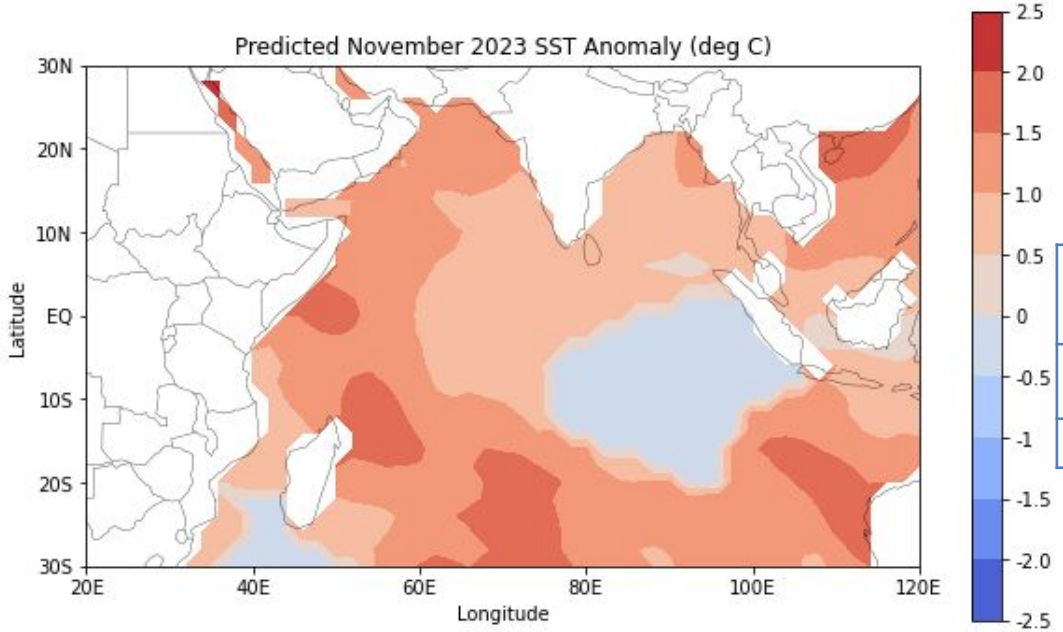


Real-time Prediction

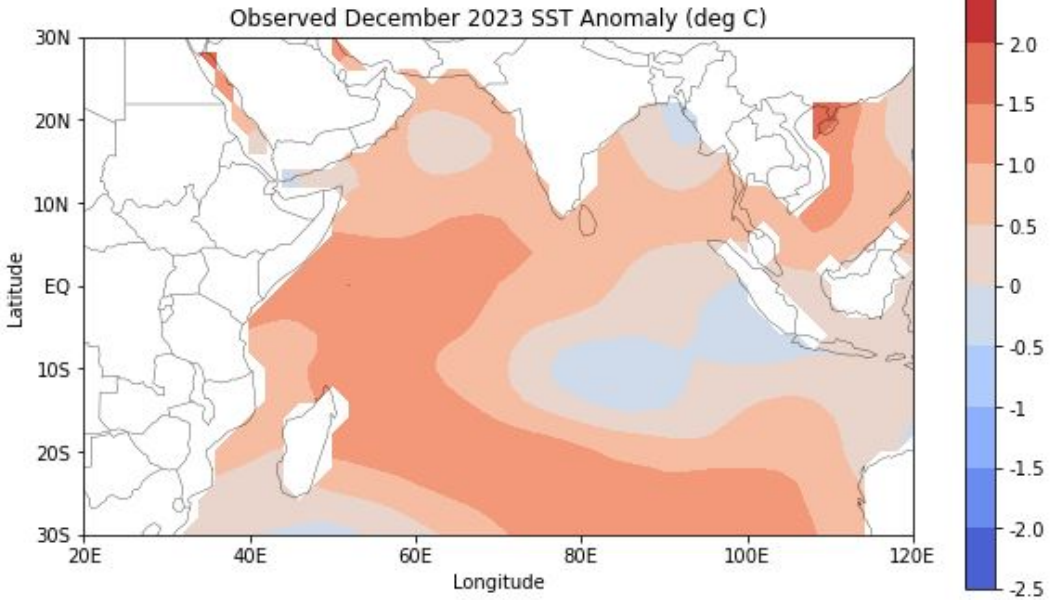


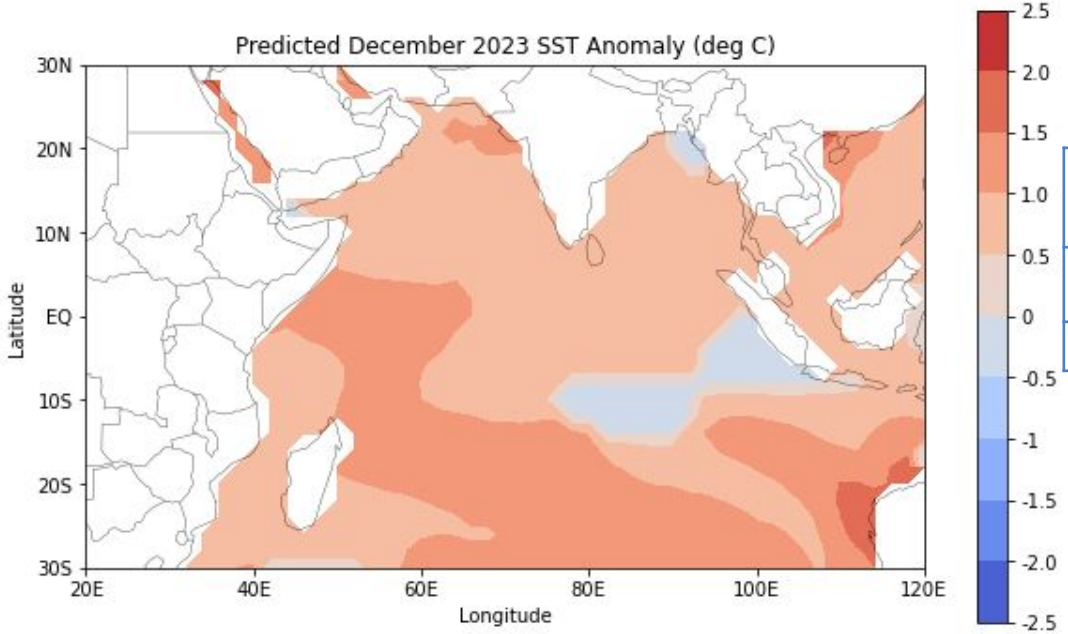
Model Evaluation



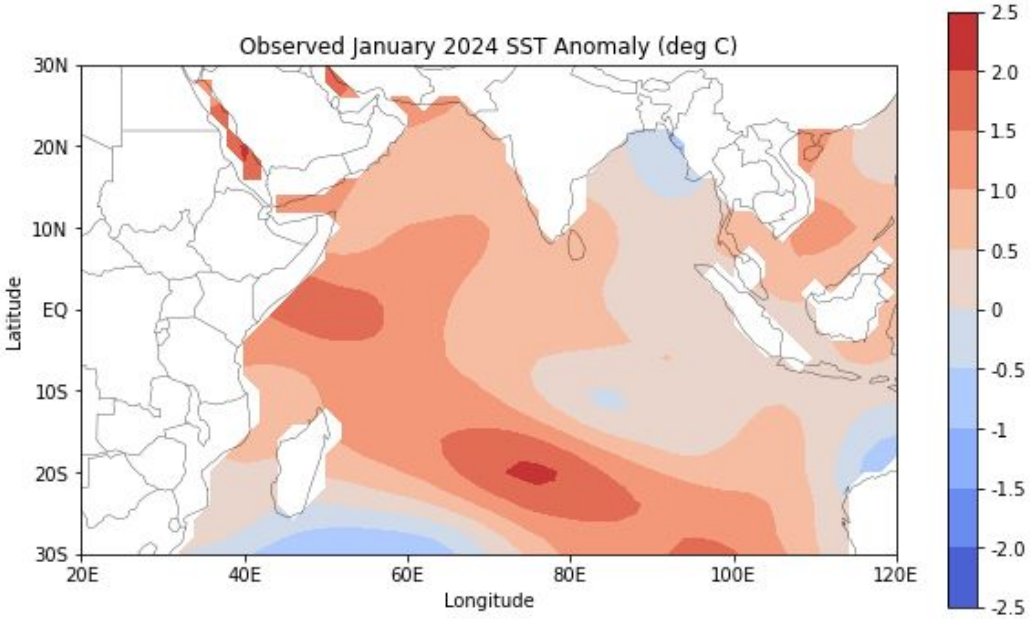


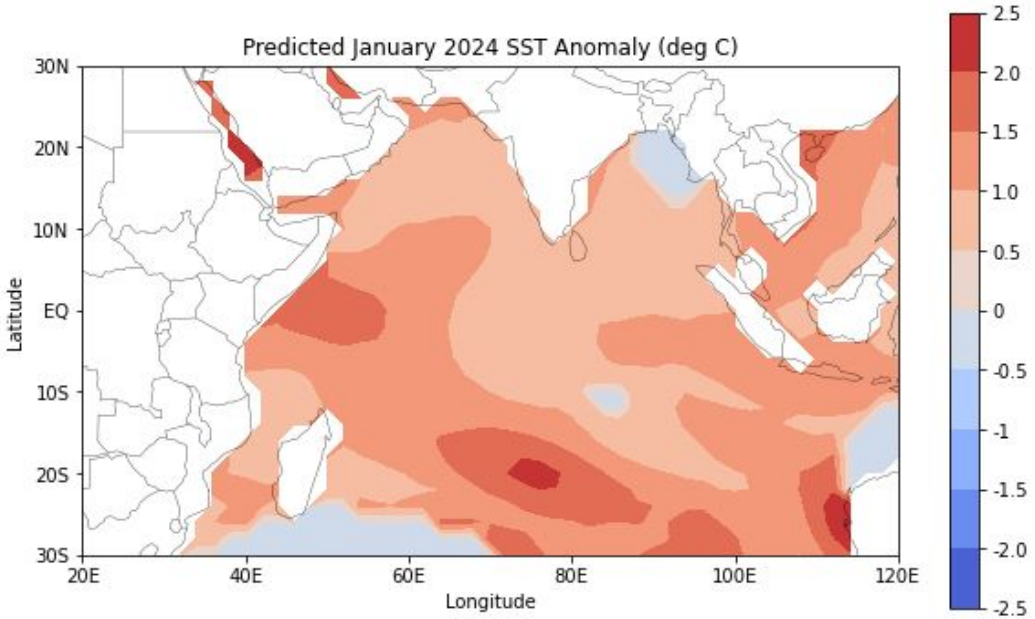
Error metrics	Magnitude
Systematic Error	12%
Random error	20%



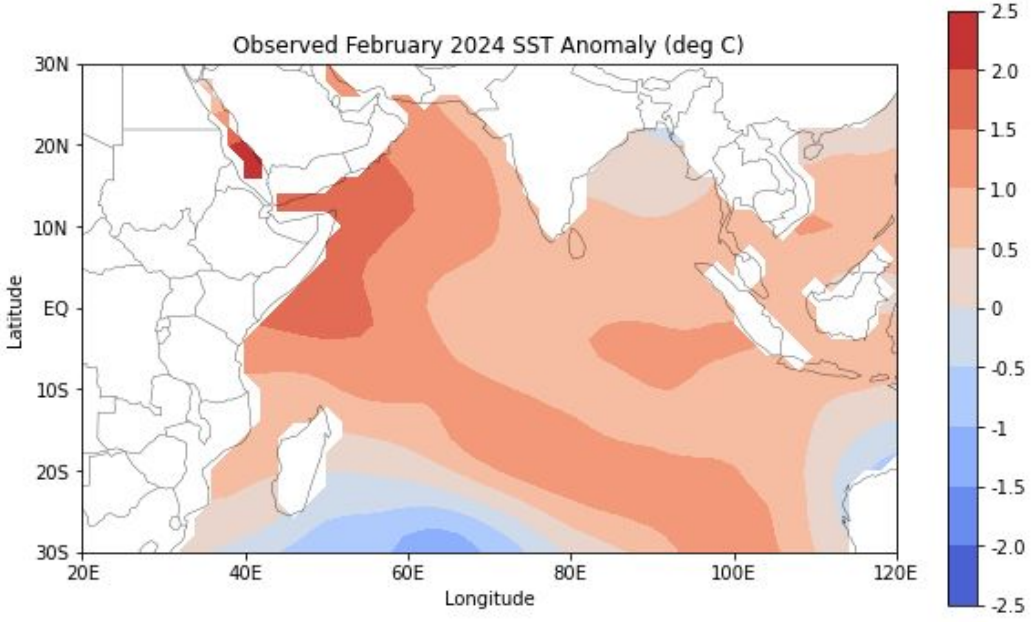


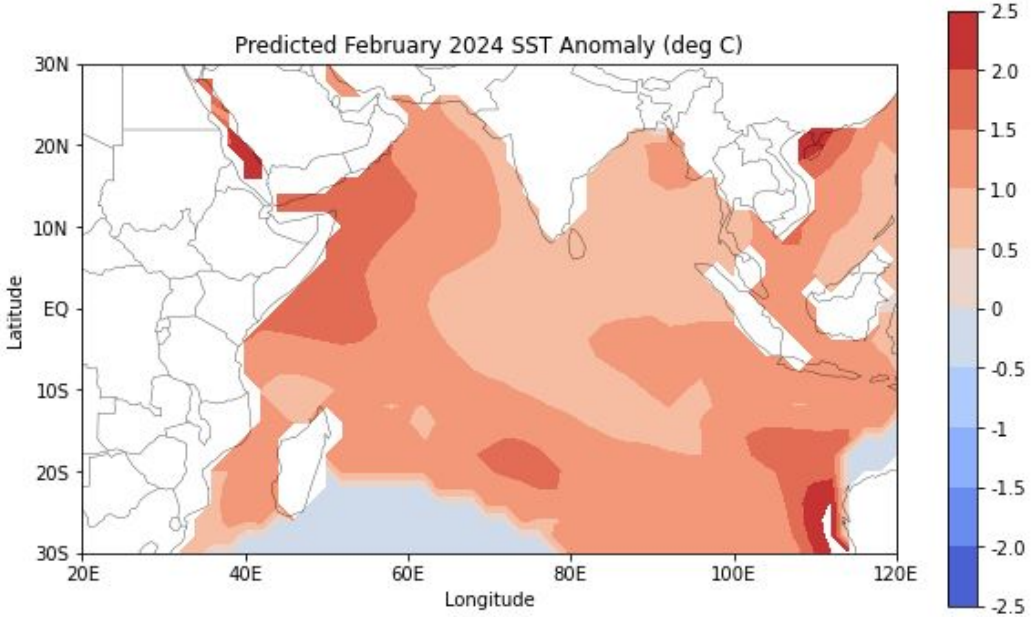
Error metrics	Magnitude
Systematic Error	15%
Random error	21%





Error metrics	Magnitude
Systematic Error	15%
Random error	23%





Error metrics	Magnitude
Systematic Error	15%
Random error	18%

Summary

- The model evaluation results indicated that the LSTM technique was able to reduce significantly the random and systematic error with high correlation coefficients.

- Realtime -12-month IOD forecasts results indicated the deep learning-based LSTM model to be capable of forecasting the IOD index (DMI) well in advance with excellent skills.

- The LSTM model forecasts are solely dependent on past observed data and hence have higher skills in forecasting the IOD index.

- The study demonstrates promising results in SST Anomaly forecasting, showcasing the potential of LSTM model as a reliable tool for climate prediction.

- Overall, the development of SST Anomaly forecasting system contributes to the advancement of climate science and contributes to building climate resilience in the Indian Ocean region

Thank you

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