Prediction of the Indian Ocean Dipole with Canonical Correlation Analysis

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Introduction

- The climate in equatorial East Africa is extremely sensitive to SST variability in Indian Ocean; Indian Ocean Dipole is a critical input for predicting October-December over East Africa.

- SST variations in the northern and southern Indian Ocean (IO) also affect summer rainfall in the northern parts of the Greater Horn of Africa. For example, model sensitivity studies showed that warmer Northern-IO and cooler Southern-IO enhance July-August rainfall over Ethiopia.

- Develop SST prediction model using Canonical Correlation Analysis (CCA) and assess the skill of the statistical predictions with that from NMME.

Methodology

- We assess the multivariate joint relationship between a predictand Y (n X q) and a set of X (n X p)predictors using Canonical Correlation Analysis. The Eigen structures

$$\boldsymbol{R_{xx}}^{-1}\,\mathbf{R_{xy}}\,\mathbf{R_{yy}}^{-1}\mathbf{R_{yx}} \qquad \boldsymbol{R_{yy}}^{-1}\,\mathbf{R_{yx}}\,\mathbf{R_{xx}}^{-1}\mathbf{R_{xy}}$$

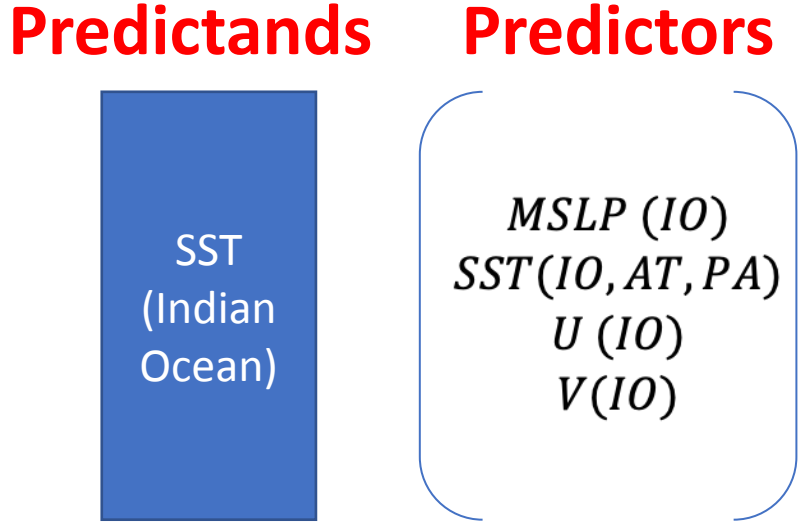
are used to compute the canonical coefficients A and B. Using $x_i = X_i - \overline{X_i}$ and $y_i = Y_i - \overline{Y_i}$, the prediction equation is given as

$$_n\widehat{\boldsymbol{y}_q} = {}_n\boldsymbol{x}_p\,{}_p\boldsymbol{A}_r\,{}_r\boldsymbol{L}_r\,{}_r\boldsymbol{B}_q{}^{-1}$$

$$_n\widehat{\boldsymbol{Y}_q} = {}_n\boldsymbol{X}_p\,{}_p\boldsymbol{A}_r\,{}_r\boldsymbol{L}_r\,{}_r\boldsymbol{B}_q{}^{-1} - \overline{{}_n\boldsymbol{X}_p}\,{}_p\boldsymbol{A}_r\,{}_r\boldsymbol{L}_r\,{}_r\boldsymbol{B}_q{}^{-1} + \overline{{}_n\boldsymbol{Y}_q}$$

Predictands and Predictors

- ERSSTv5: SST predictand over the Indian Ocean and lagged predictors over the Indian, Atlantic and Pacific Oceans;
- NCEP/NCAR Reanalyses: MSLP, zonal and meridional wind over the Indian Ocean;
- Predictand and Predictors are available for 1981 to present;
- NMME IOD forecasts for 7 models are used to compare results with CCA IOD predictions.



Prediction Strategy

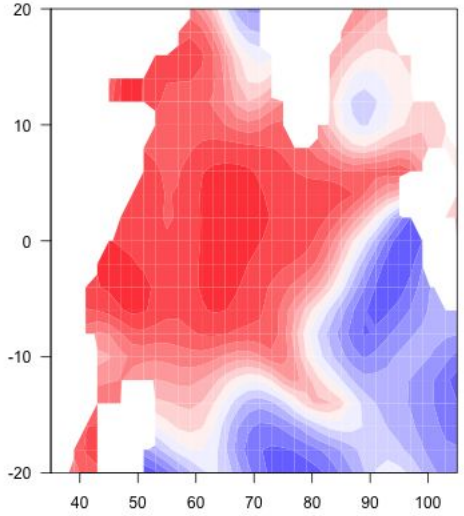
- Retroactive prediction approach is used, in which the first 30 years (1981-2010) are used to identify and select predictors and develop the prediction model, and the remaining 13 years are used for validation of prediction.

- Real-time forecasts are developed every month by repeatedly constructing models from 1981-2010 base period and increasing model development period every year until all data from 1981 to present are used.

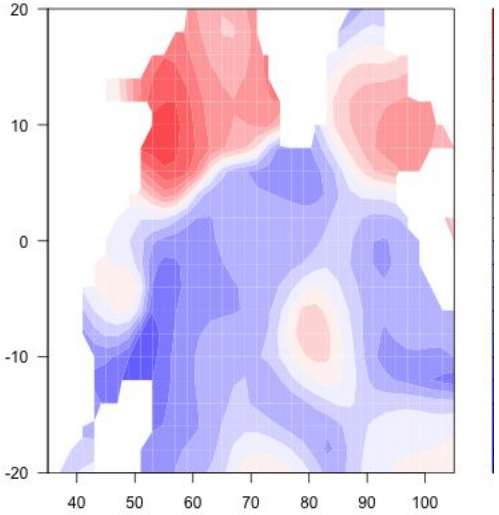
- Monthly forecasts are made for each observation month for CCA and initialization month for NMME

Single Predictor (cross-validated correlation)

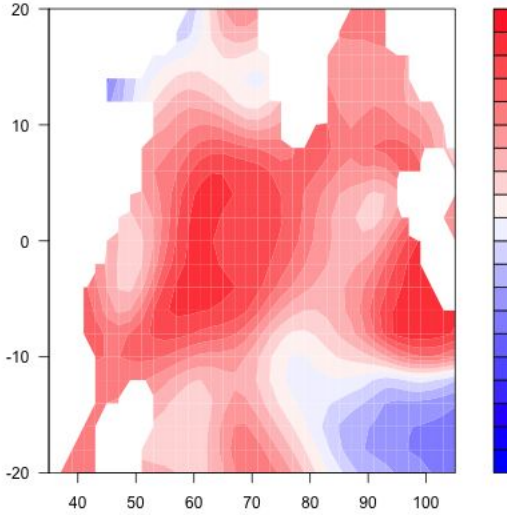
PA - SST



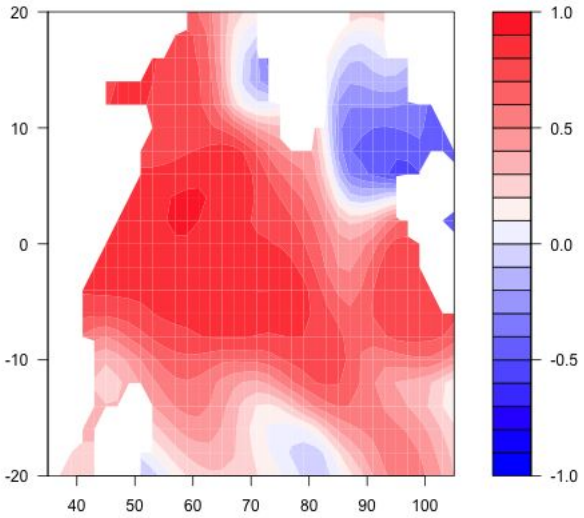
AT - SST



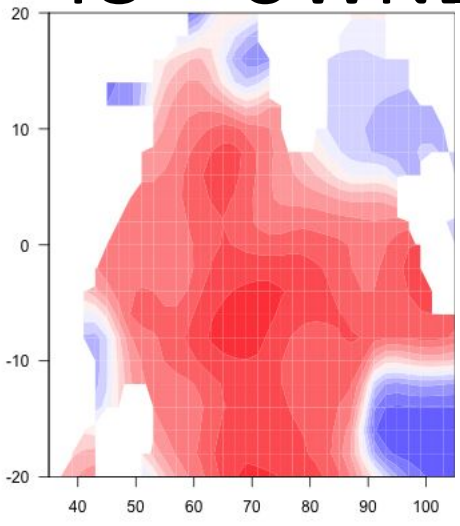
IO - MSLP



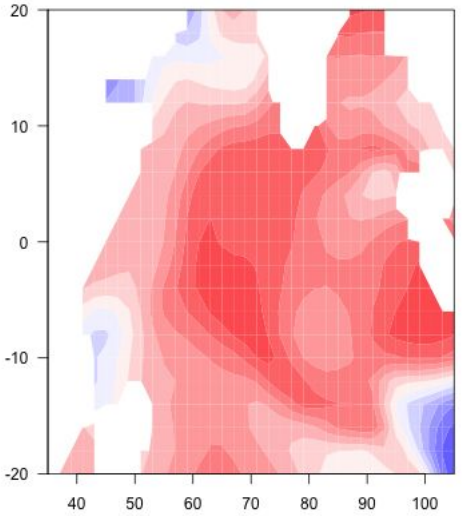
IO-SST



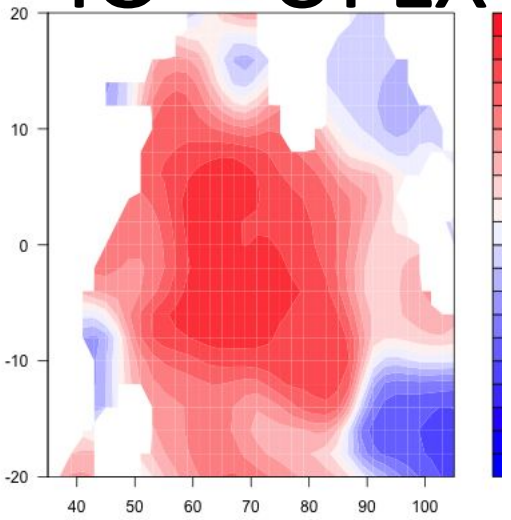
IO – UWND



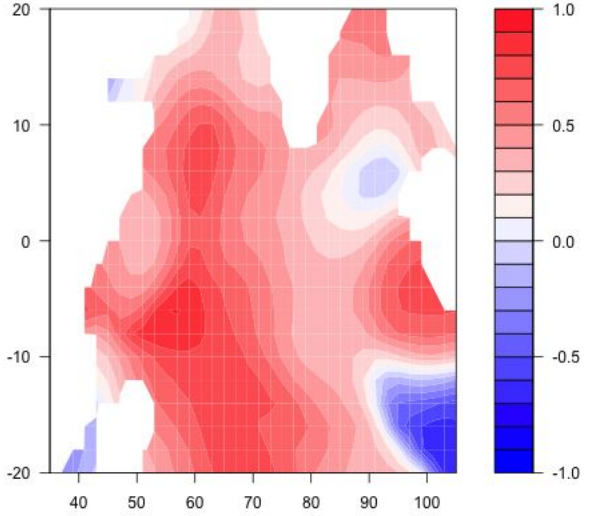
IO – VWND



IO – UFLX



IO – VFLX

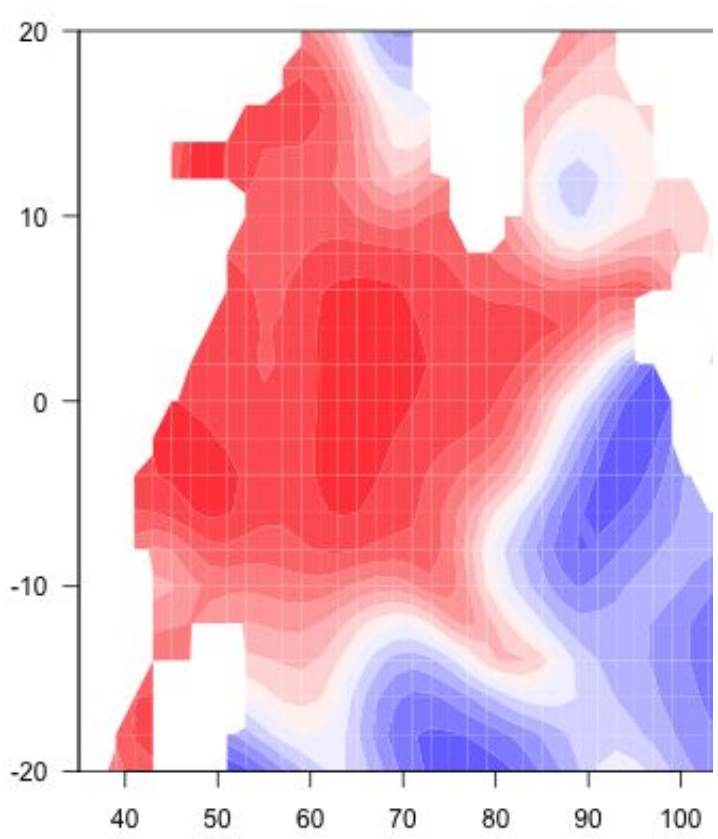


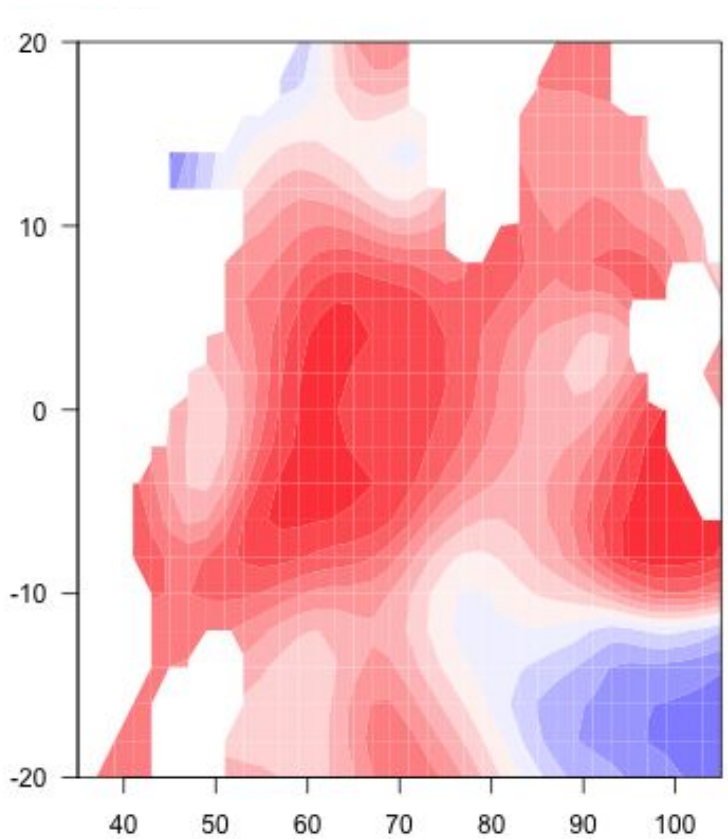
Two Predictors combinations (cross-validated correlation)

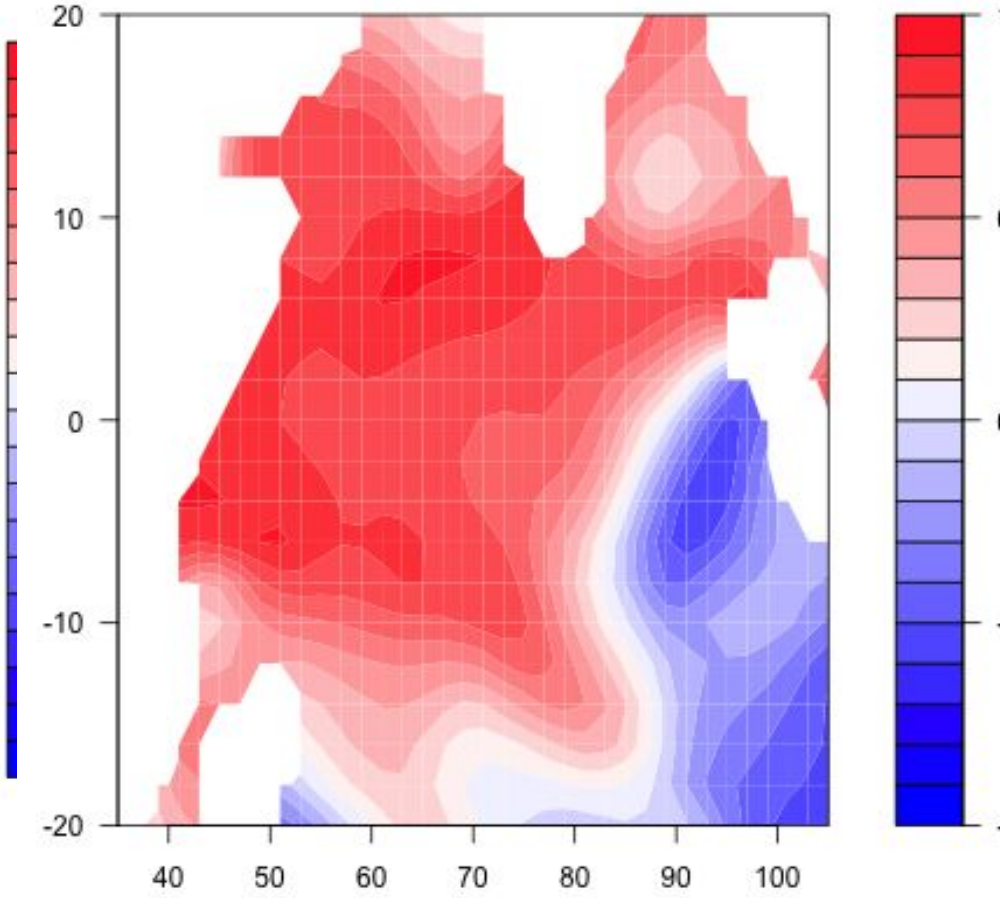
PA - SST

IO - MSLP

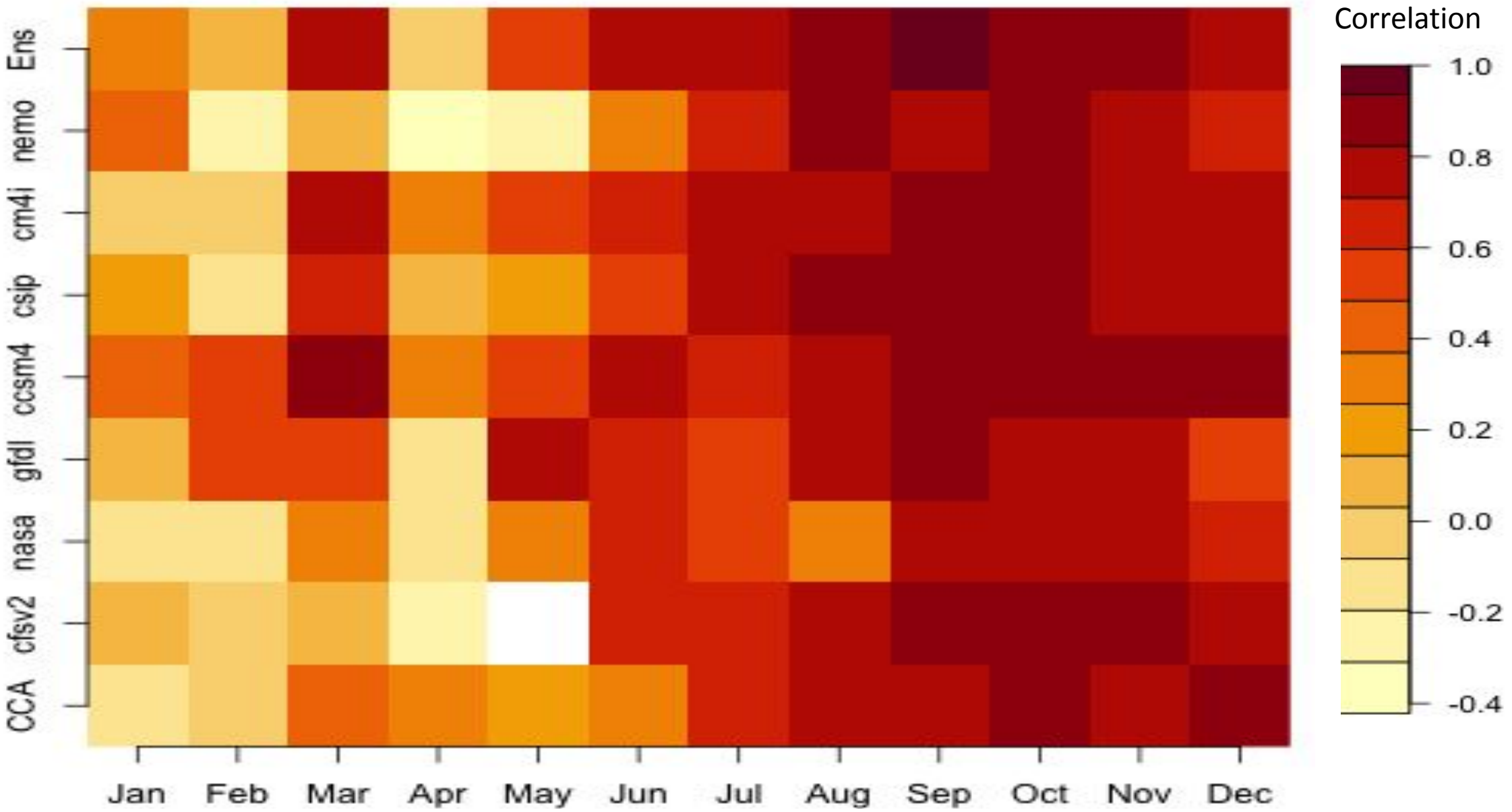
PASST - MSLP



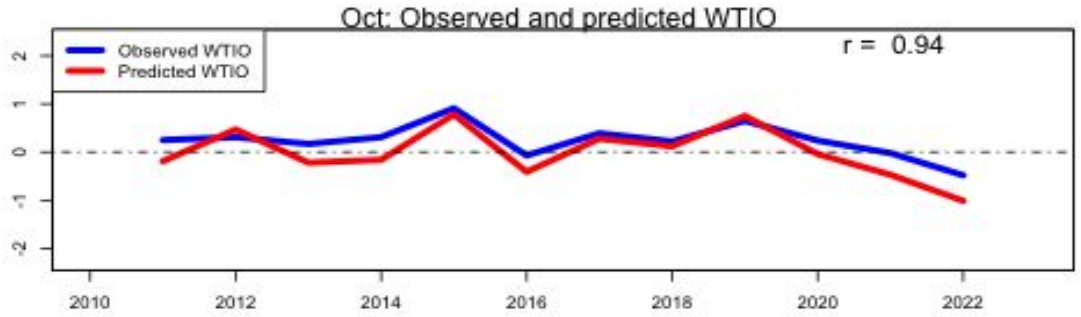


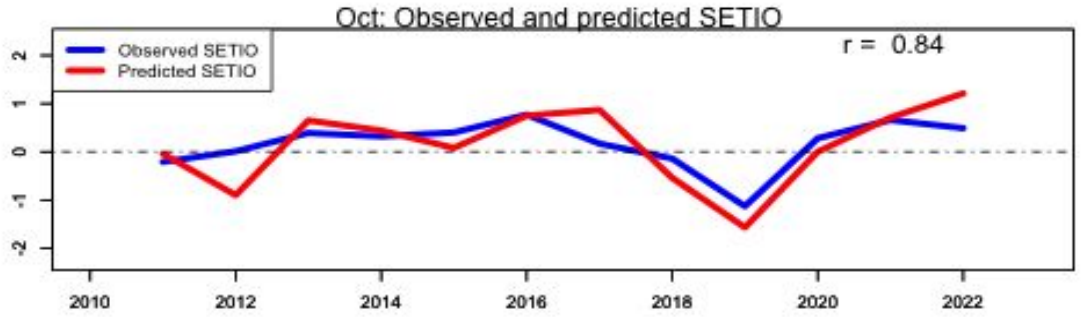


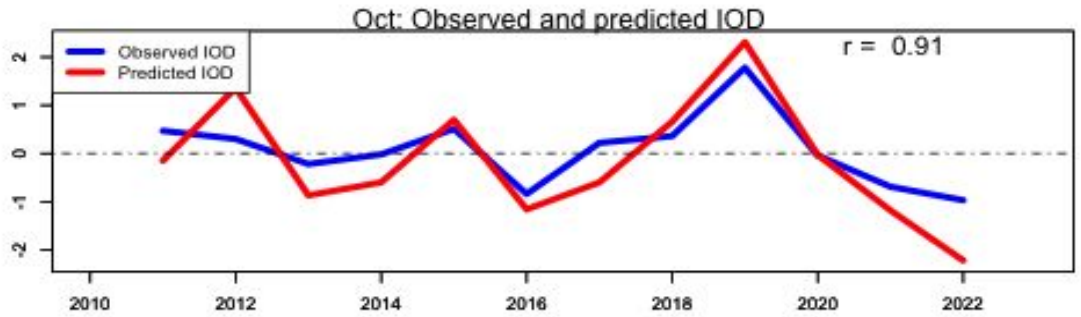
Correlation between Observed and CCA and NMME (Raw) Predicted IOD indices



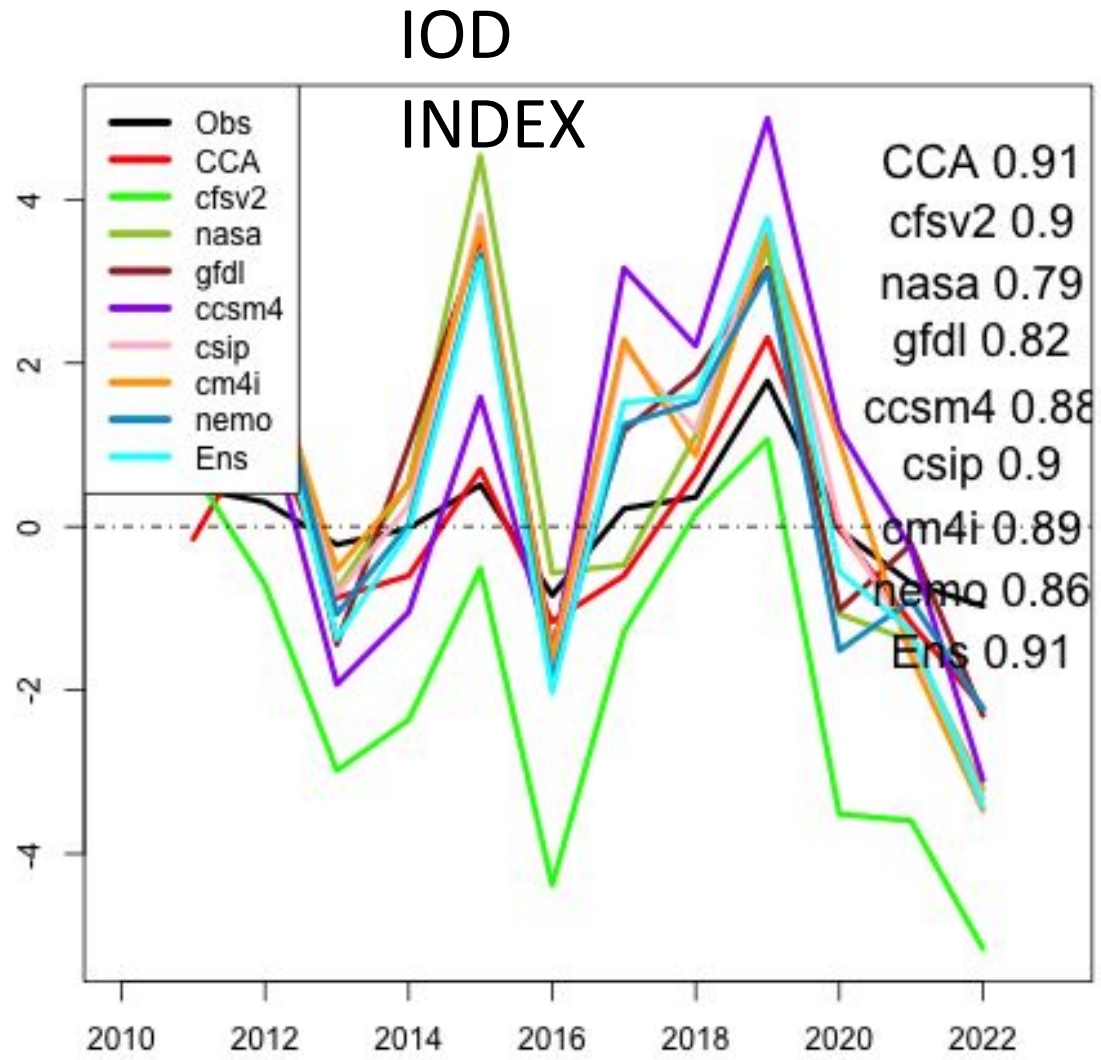
Timeseries of observed and CCA (left) and NMME (right) predicted Indices for October





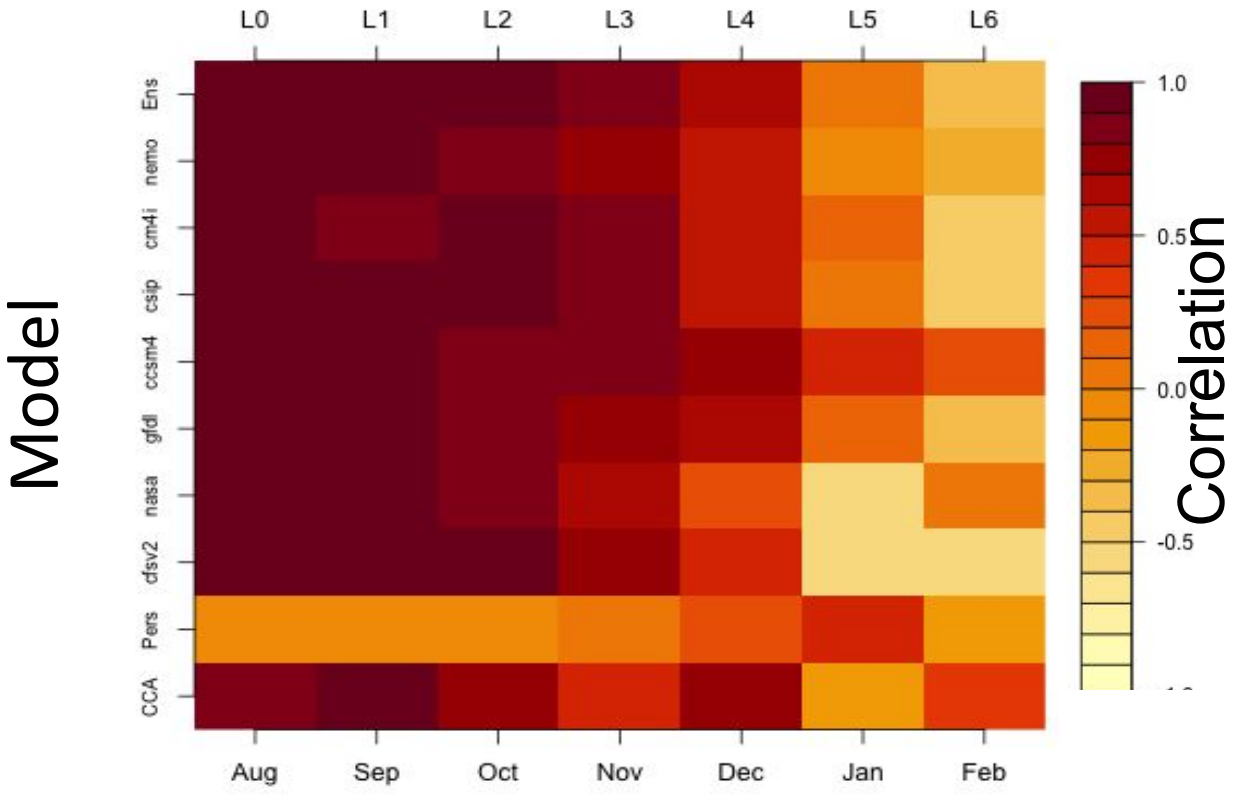


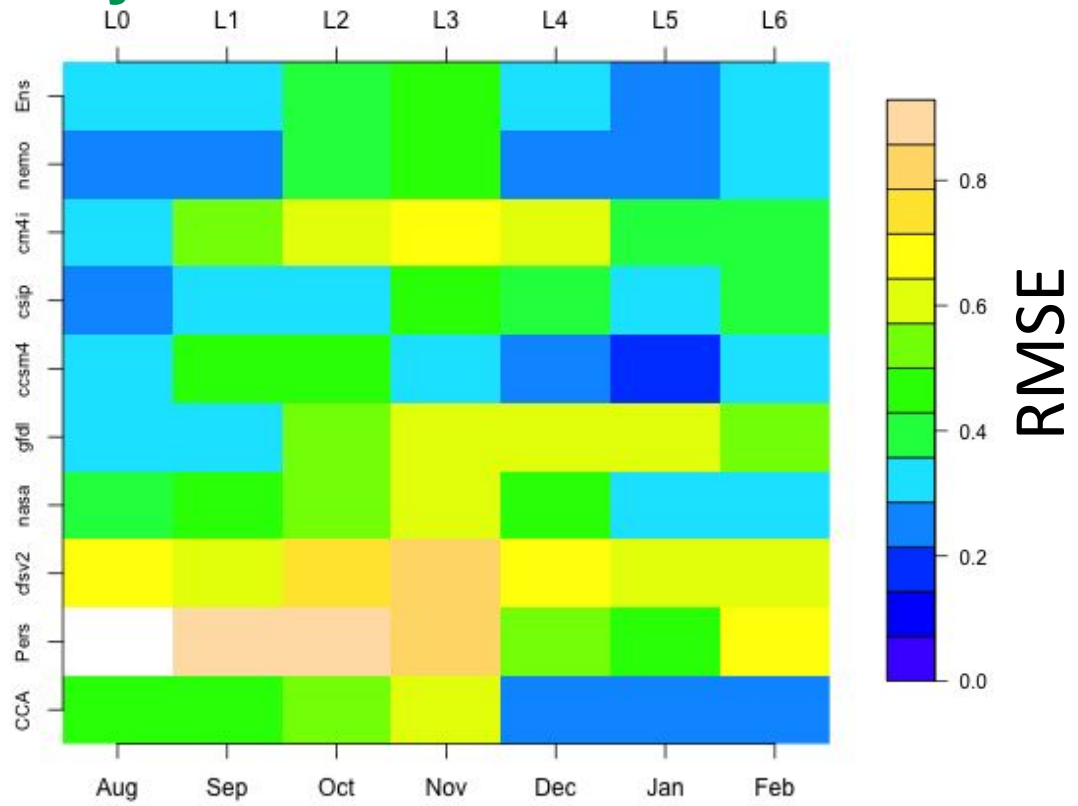
INDEX

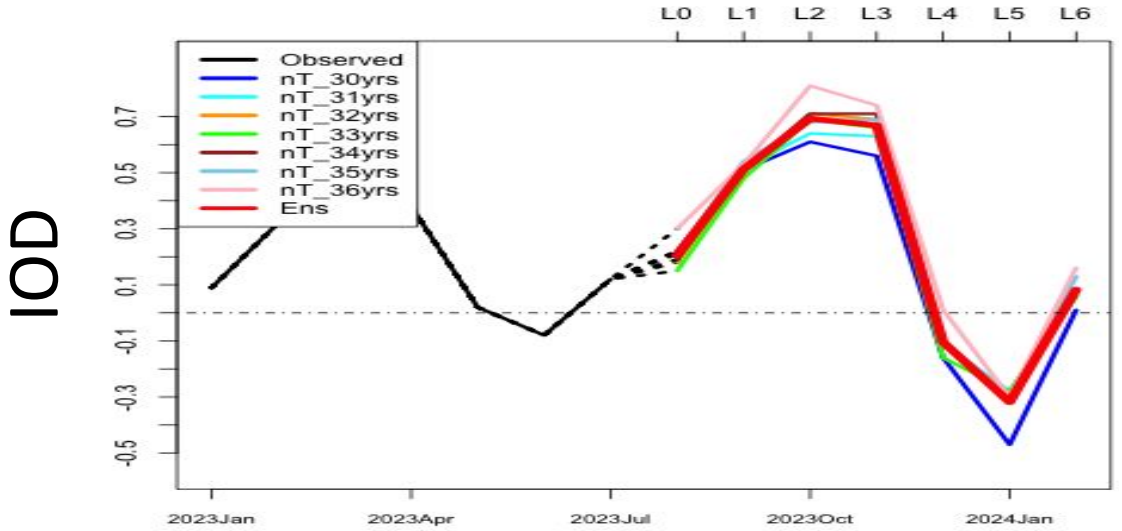


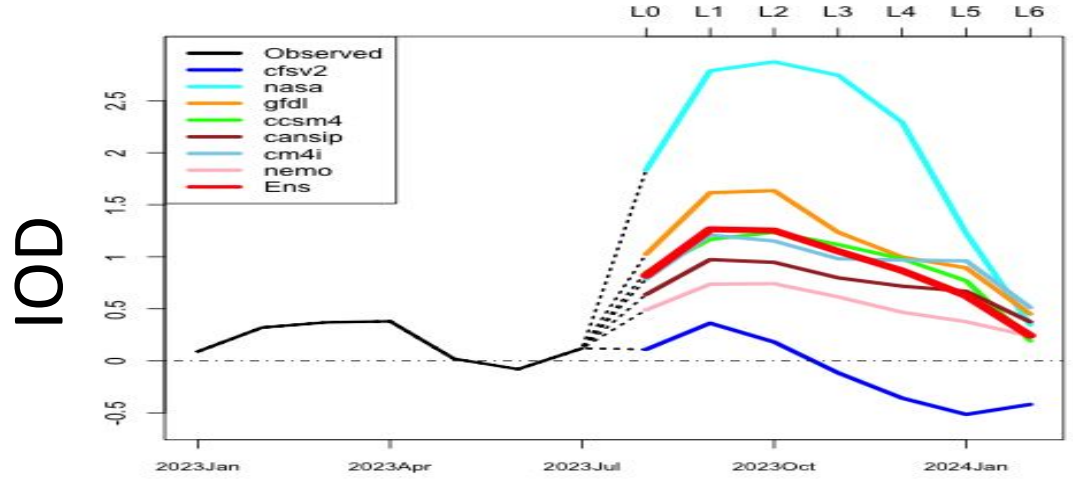
Model	CCA	CFSv2	NASA	GFDL	CCSM4	CanSIP	CanCM4i	GEM5NEMO	Ense
RMSE	0.66	2.39	1.63	1.44	1.79	1.70	1.67	1.39	1.55

Real-Time forecast from July 2023 observed SST

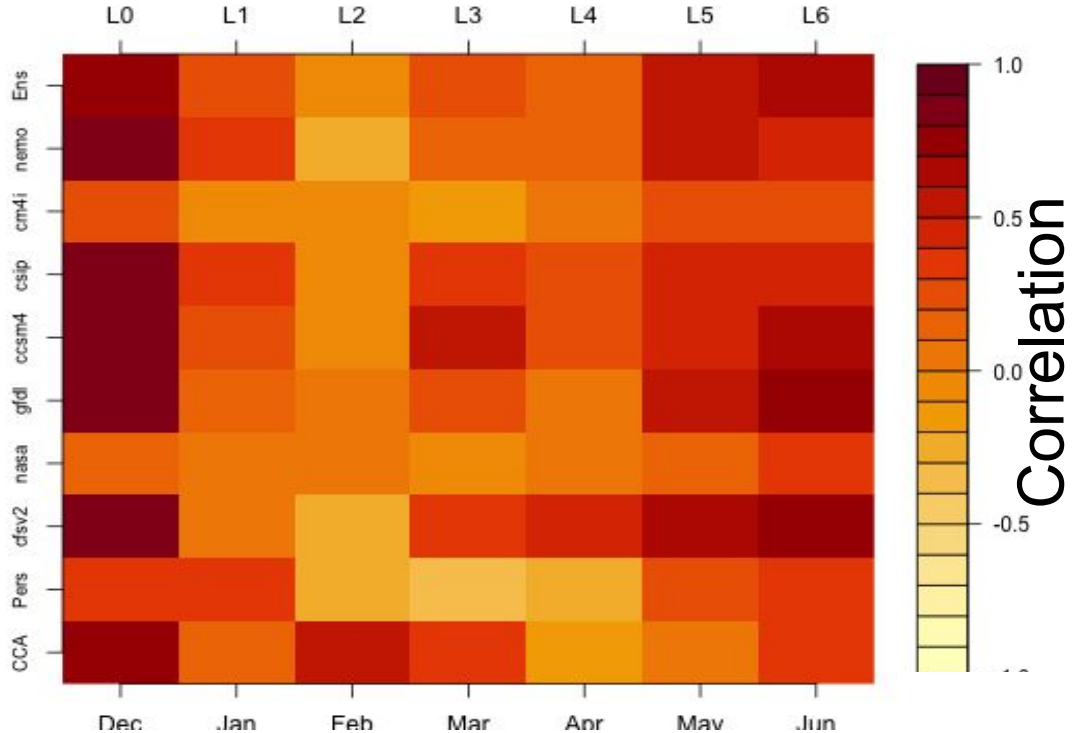


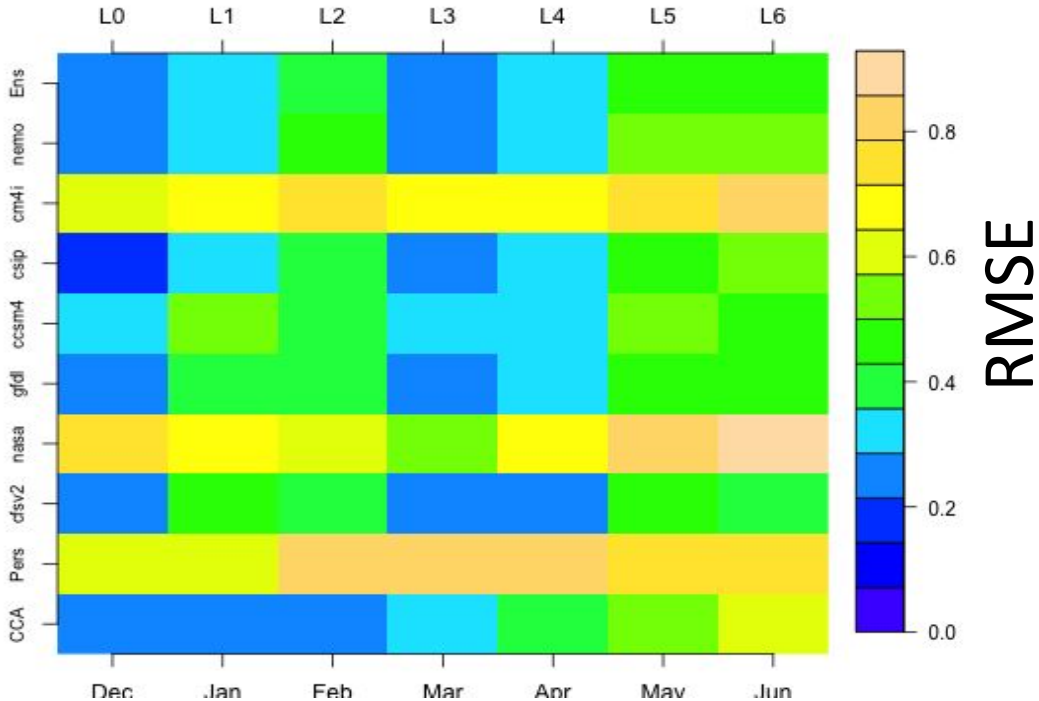


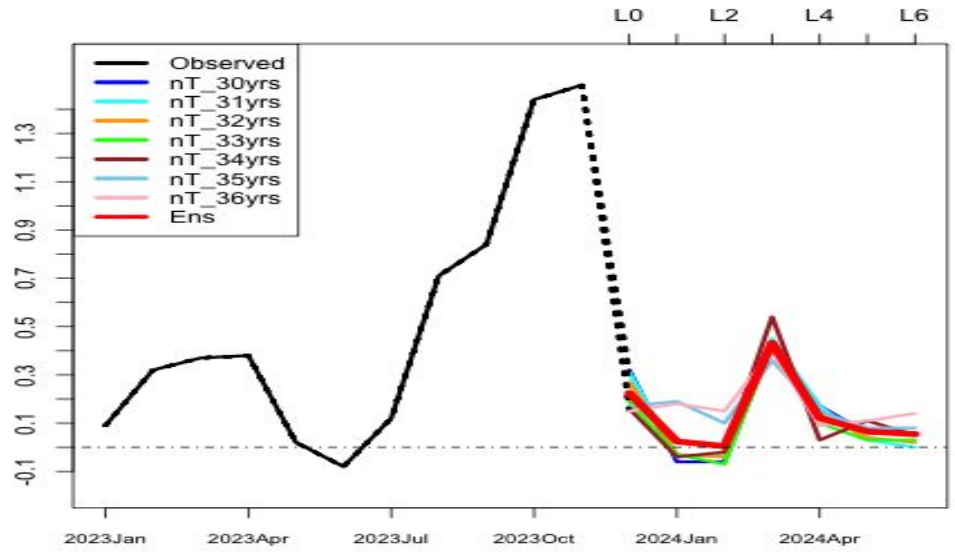


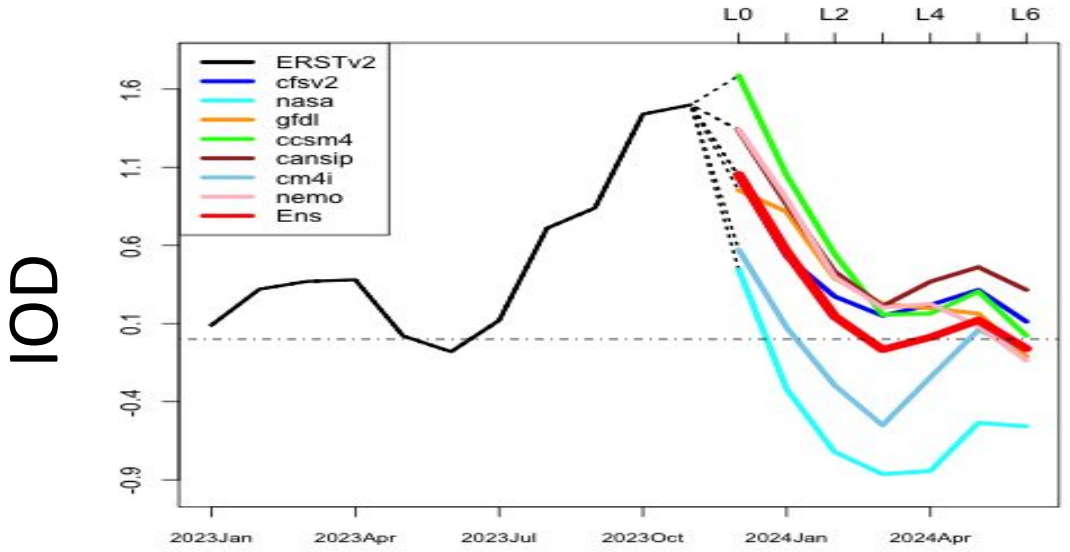


Real-Time forecast from November 2023 observed SST



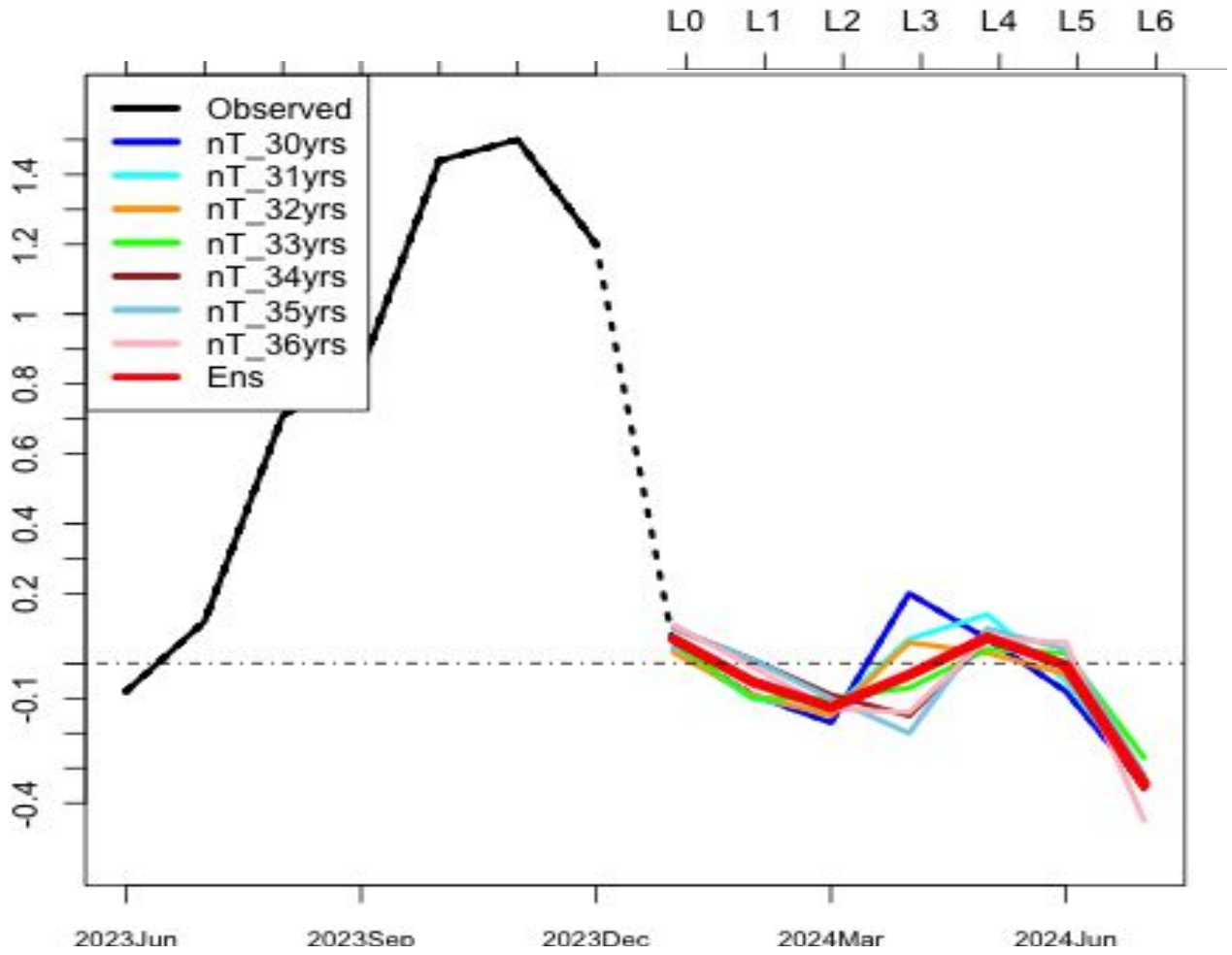


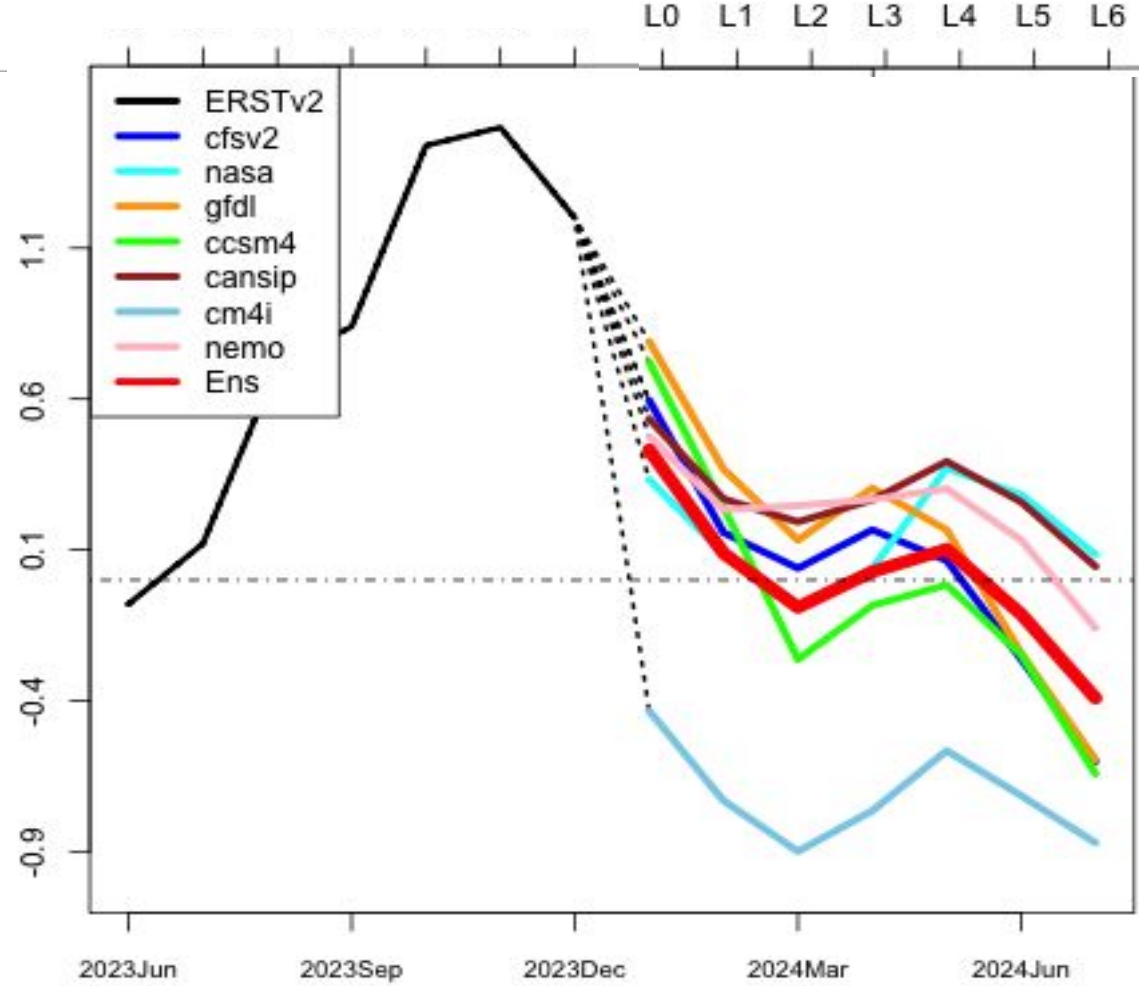




Real-Time forecast from December 2023 observed SST (Jan initialization)

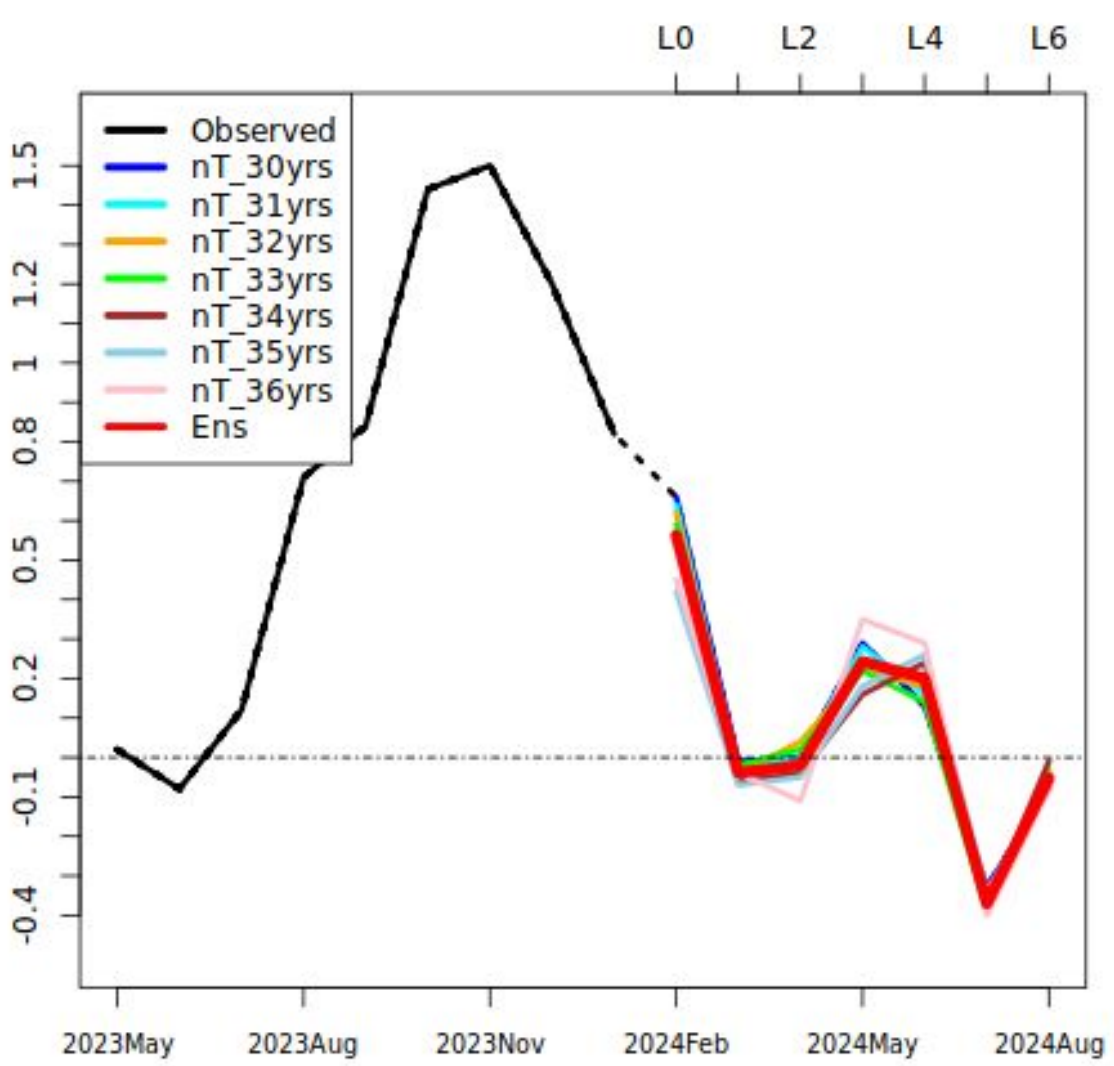
IOD

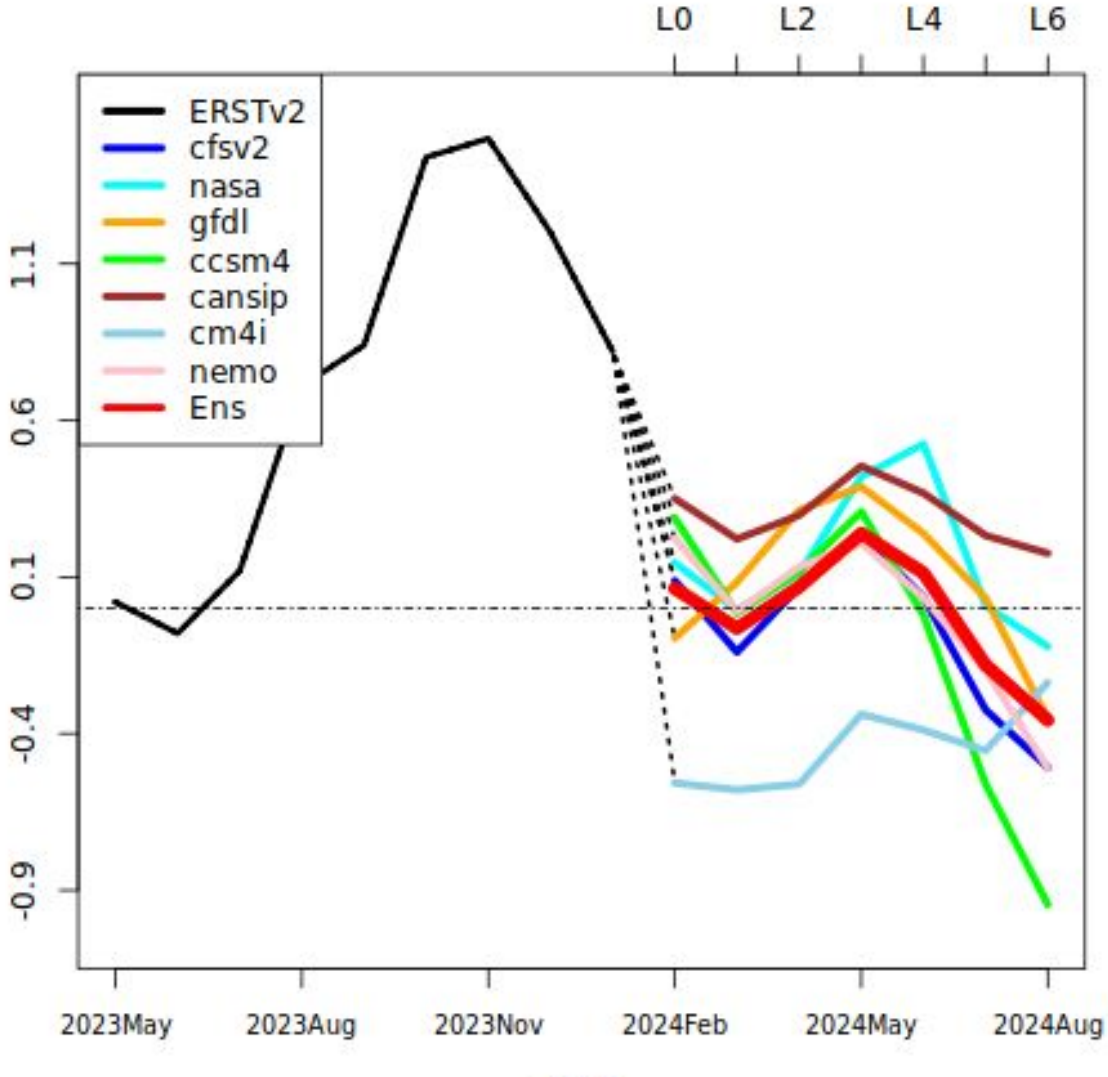




Real-Time forecast from January 2024 observed SST (Feb initialization)

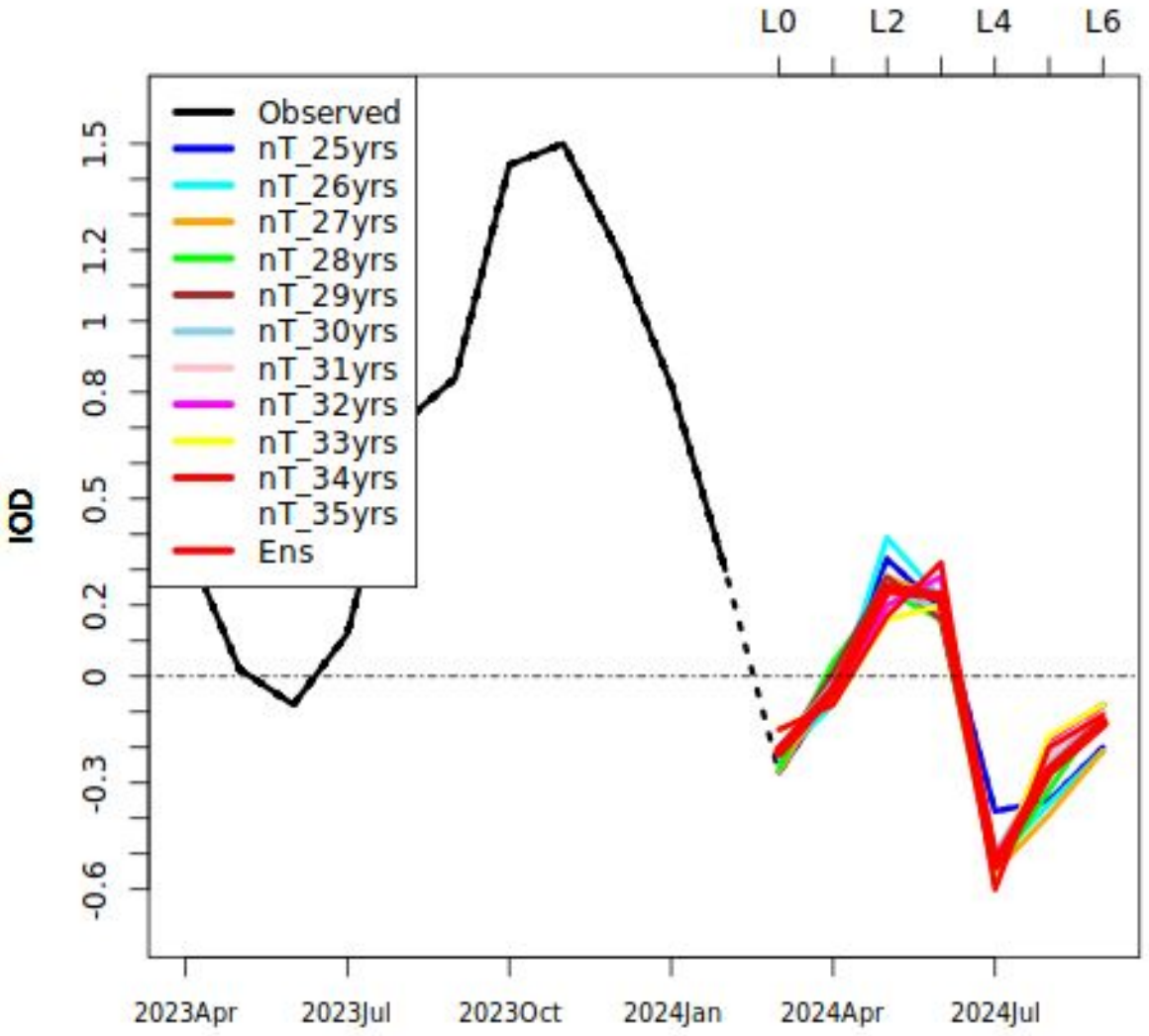
IOD

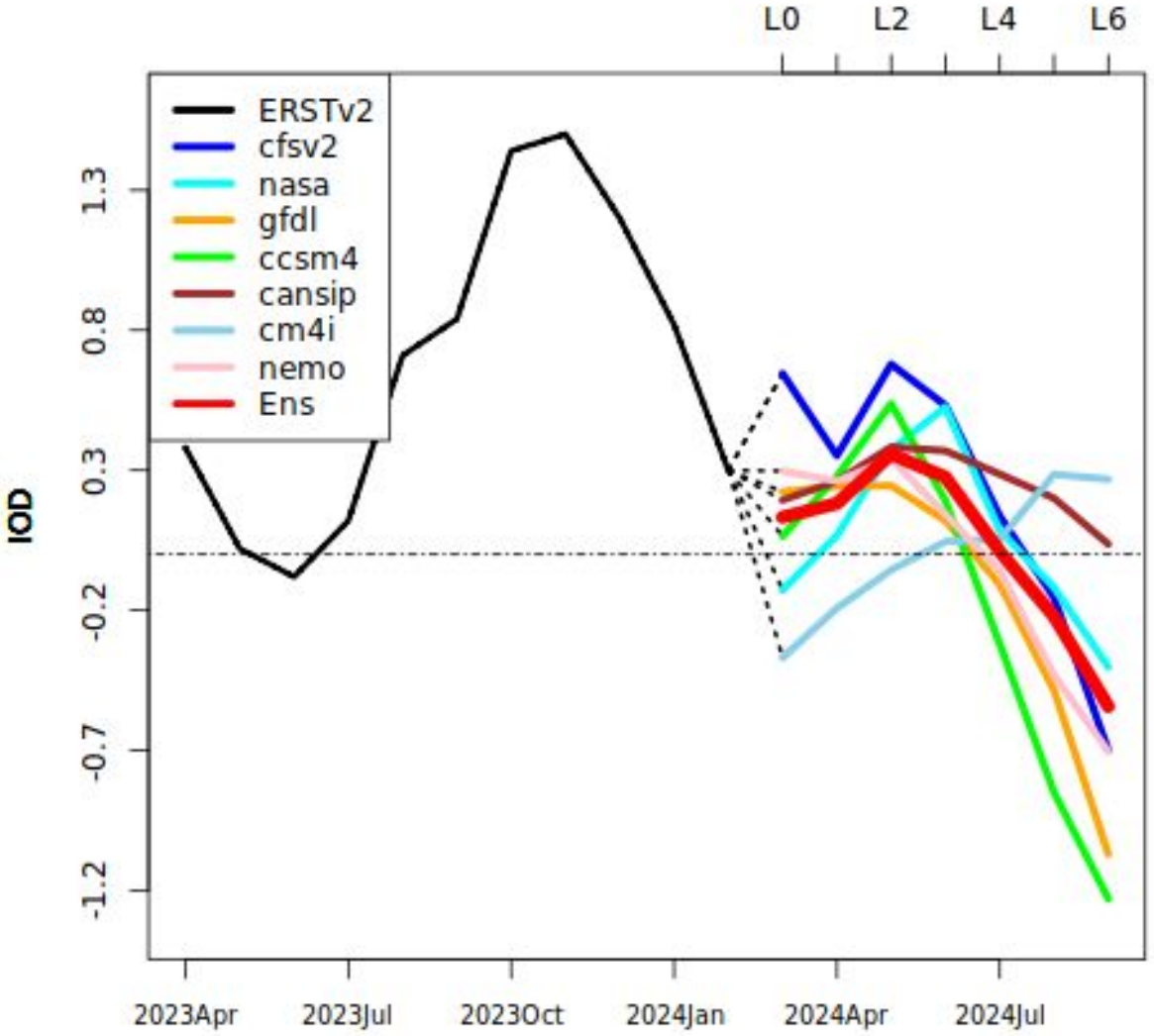




Real-Time forecast from February 2024 observed SST (Mar initialization)

IOD





Summary

- Pacific SST predictor gives the highest correlation of 0.92 over western Indian Ocean but yields strong negative correlations over southeastern Indian Ocean.
- Atlantic SST shows least skill except over the Bay of Bengal. However, it gives high correlation when used with MSLP.
- Using meridional wind predictor reduces the extent of negative correlation over southeastern Indian Ocean. However, the skill is not strong elsewhere.
- CCA and NMME perform poorly in Jan-Apr and best during Sept-December months; Prediction skill weakens around ENSO predictability barrier.
- CCA IOD skill is comparable with the raw NMME IOD predictions. The ensemble mean shows increased skill compared to individual models, especially in September.

Thank you for your attention!