# Diagnosing forecasting errors across timescales in the Indian Ocean with seamless forecasting systems

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A working group was formed in 2020 between the Met Office, The Bureau of Meteorology, ECMWF and other forecasting centres within the UM Partnership to understand and improve common biases in the Indo-Pacific region and associated teleconnections. In particular, the significant cold SST biases in the Eastern Indian Ocean have a significant impact on the prediction skill of the seasonal forecasting systems (in GloSea, ACCESS-S and ECMWF model) for tropical rainfall, Australasian monsoon system and the representation of associated key teleconnections in coupled models. The multi-disciplinary group aims to consolidate current diagnoses of model errors and develop a new set of diagnostics and metrics to understand model errors using a seamless modelling framework and measure the impact of future improvements, as well as to recommend potential model/DA developments and observation campaigns to mitigate these errors. The current strands of activities explore different hypotheses for the sources of errors in the region: the role of different initial conditions and coupled data assimilation, the bathymetry and potential role of the Indonesian throughflow, the sensitivity to various physics changes in the atmosphere and ocean models and the evolution of key biases and the air-sea interaction processes involved at different timescales using coupled NWP, sub-seasonal to climate modelling frameworks. Some results are presented here for the latest Met Office Global Coupled configuration GC5.

INDO-PACIFIC PRIORITY EVALUATION GROUP (PEG)
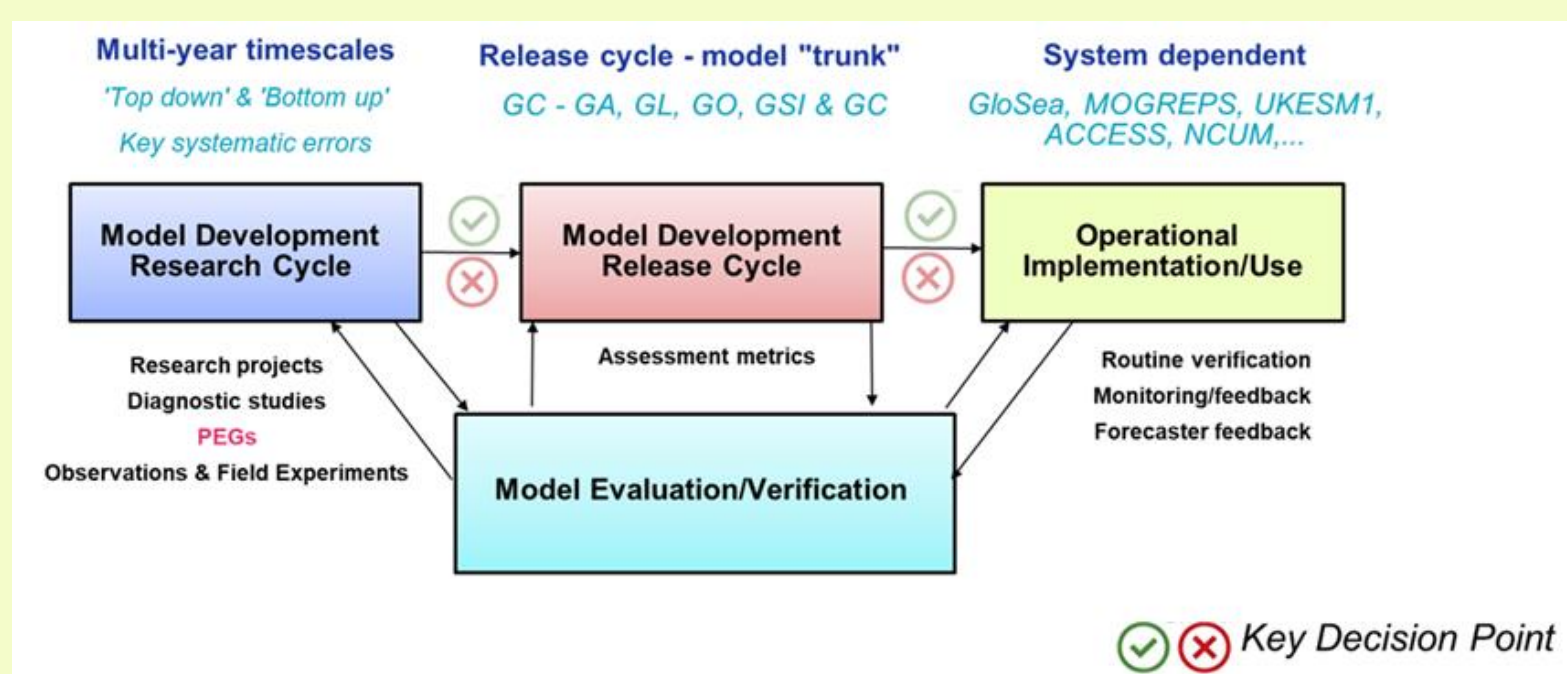
PEG: Timebound collaborative activities focused on tackling a **well defined high priority** issue with model performance, bringing together **multi-disciplinary expertise.**

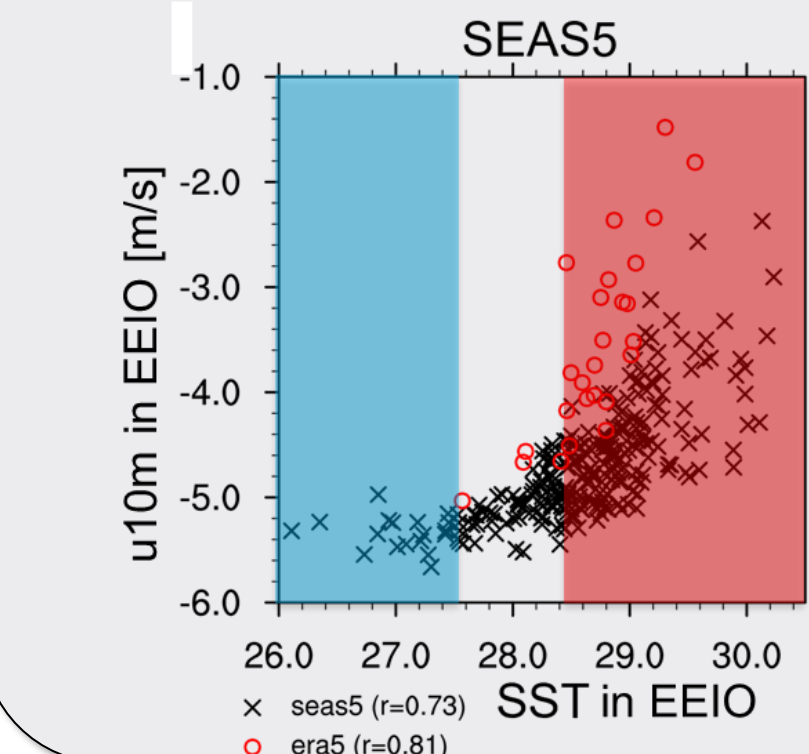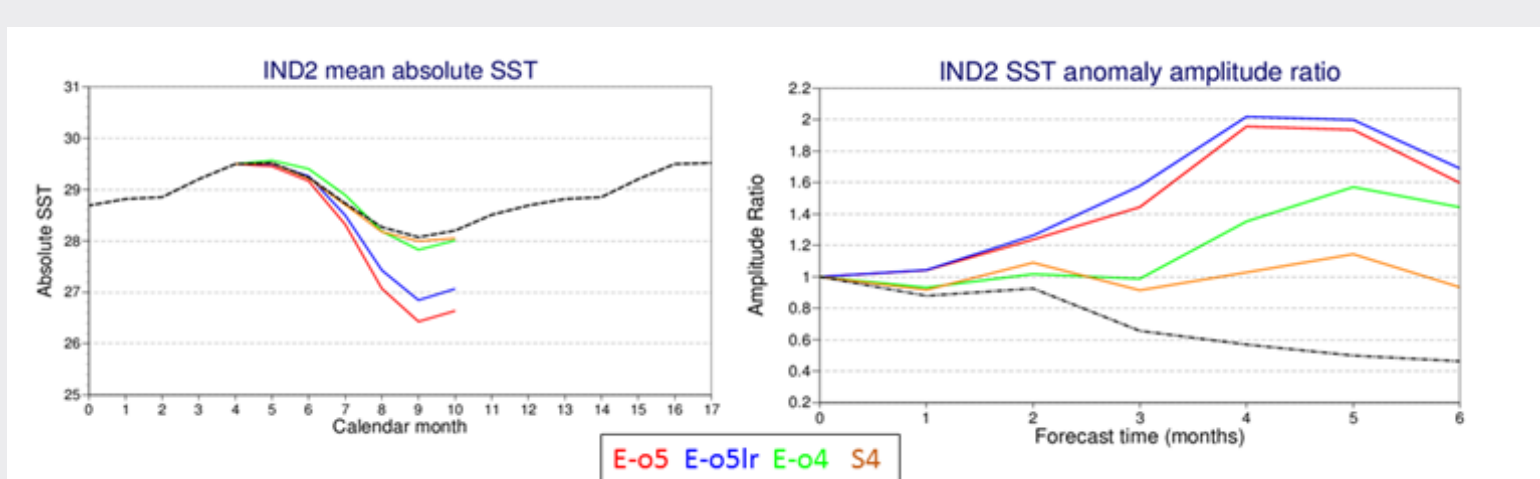| Theme	Activity
Indo-Pacific Ocean Tunnel Processes	Rossby Wave propagation through IT
	Throughflow properties and impact on mean bias in NEMO ocean model
Indian Ocean air-sea interaction	Air-sea interaction properties/biases across timescales
	Indian Ocean Teleconnections with Monsoon and monsoon forecasts
	Ocean/Atmos bridge between Pacific/Indian
	Eval SST/Precip/Wind relationships over Indian Ocean
Assessment and Intercomparison of current systems	Ocean reanalyses in Indian Ocean (used for initial conditions)
	Seasonal Forecast skill of IOD
Assessment of Model Improvements	How Good is GC4/5 in the Indian Ocean + common diagnostic package
	Impact of CoMorph on Indian Ocean
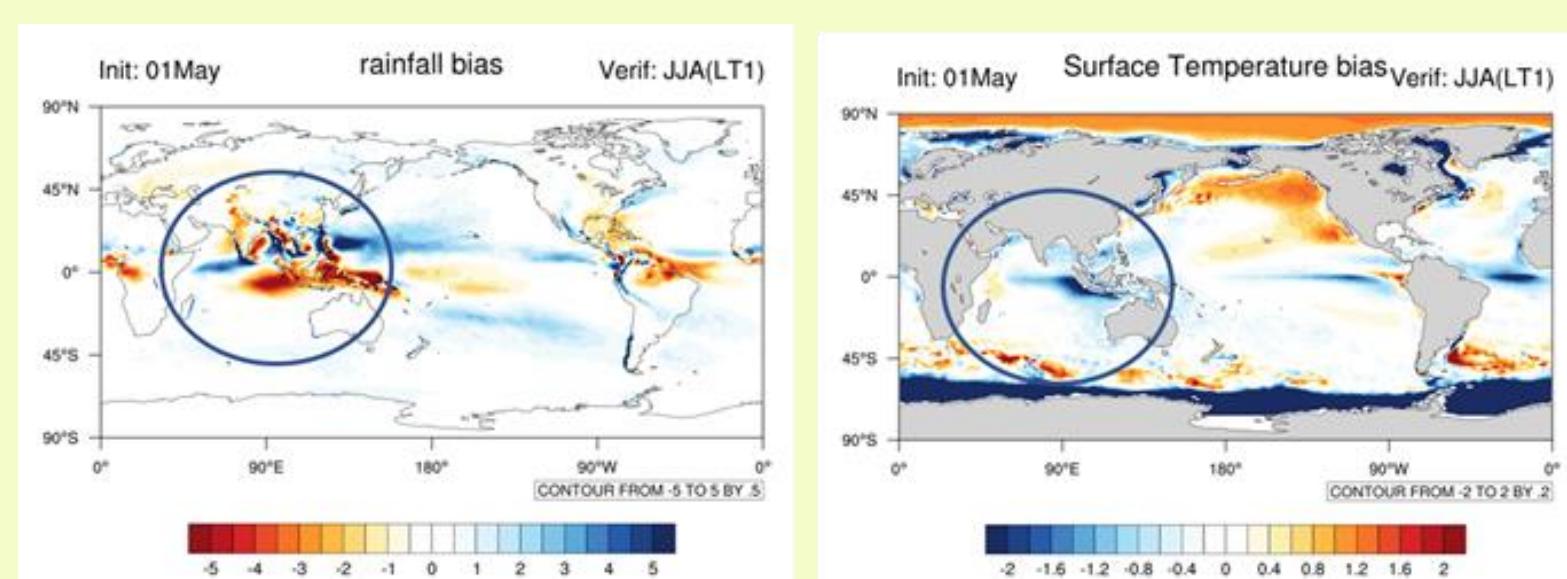
Rainfall and SST bias in ACCESS-S seasonal hindcast

Aim: Understand and improve the systematic SST and associated errors in the Eastern Indian Ocean affecting all timescales (NWP, seasonal, climate).

DEVELOPMENT OF ERRORS IN THE EASTERN INDIAN OCEAN

The SST error is initially a warm error and becomes too cold after a coupled of weeks. Results are similar in GloSea5 (not shown). It is associated with too strong easterlies.

Surface flux errors seem to dominate the initial warm SST error but the cooling then correlates with the 10m wind error.
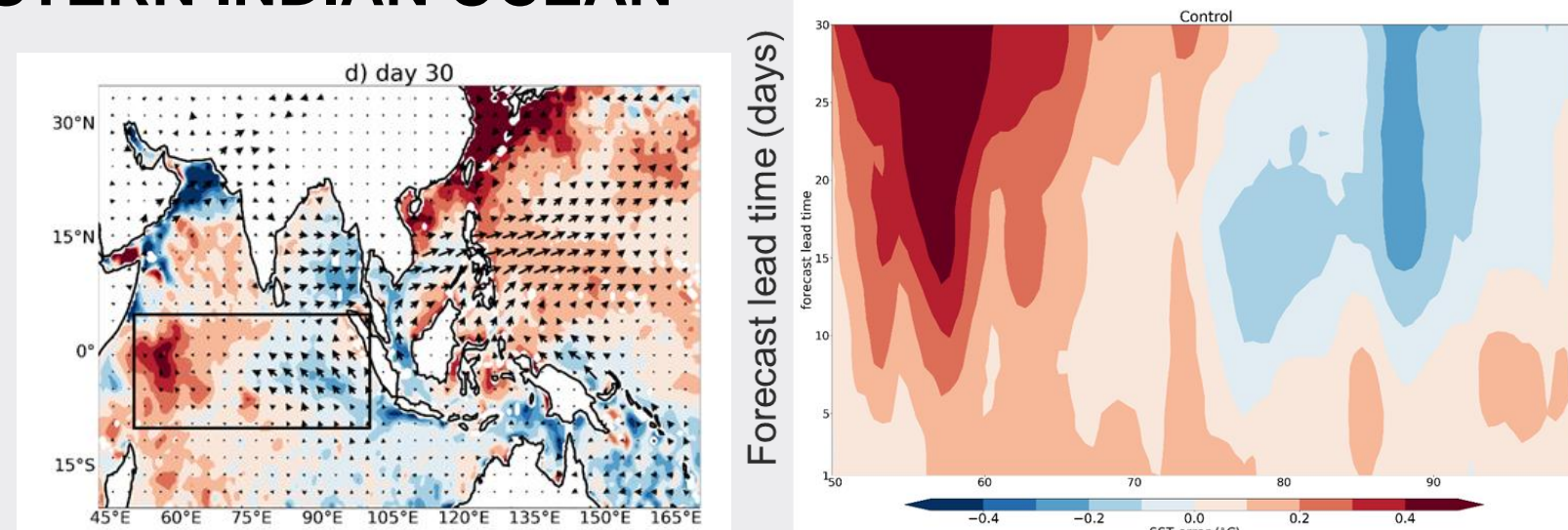

GC3.2 coupled NWP (to 30 days) errors of 10m winds, SST and surface fluxes against analysis (along the Equator top right, and around the Eastern Indian Ocean at the bottom)

SST errors in the Eastern Indian Ocean appeared when ECMWF upgraded the ocean model between SEAS4 and SEAS5.
Similar SST errors as in GloSea5, share the same ocean model NEMO
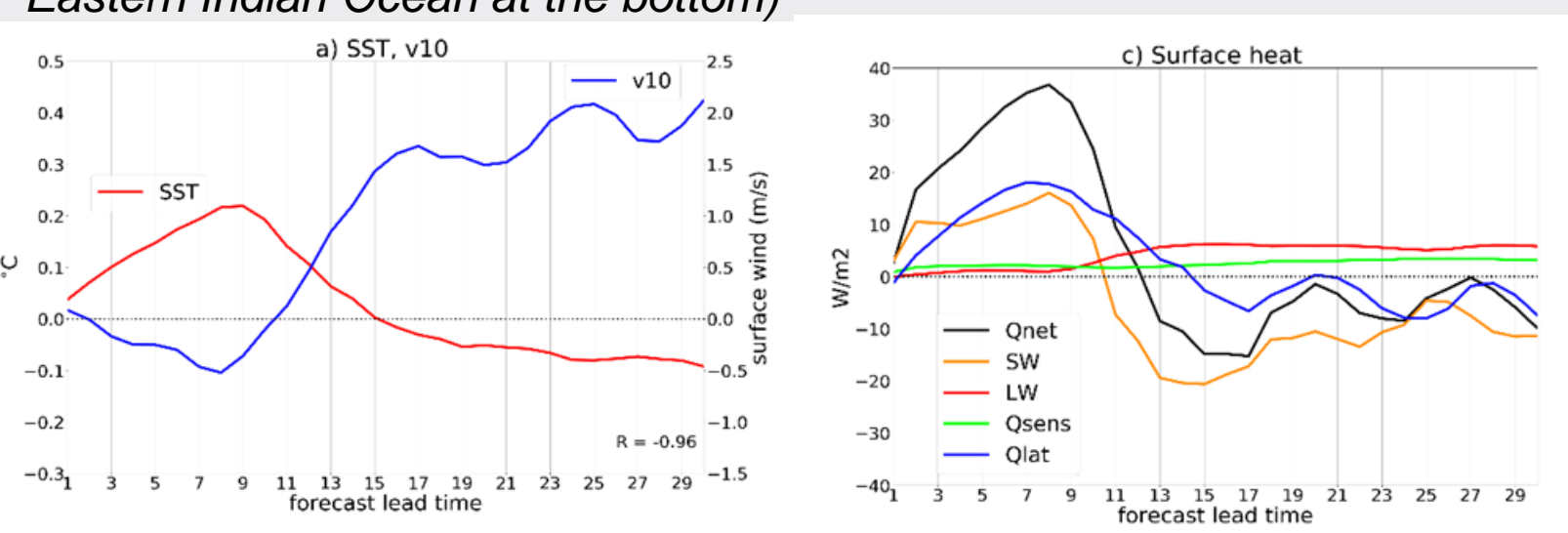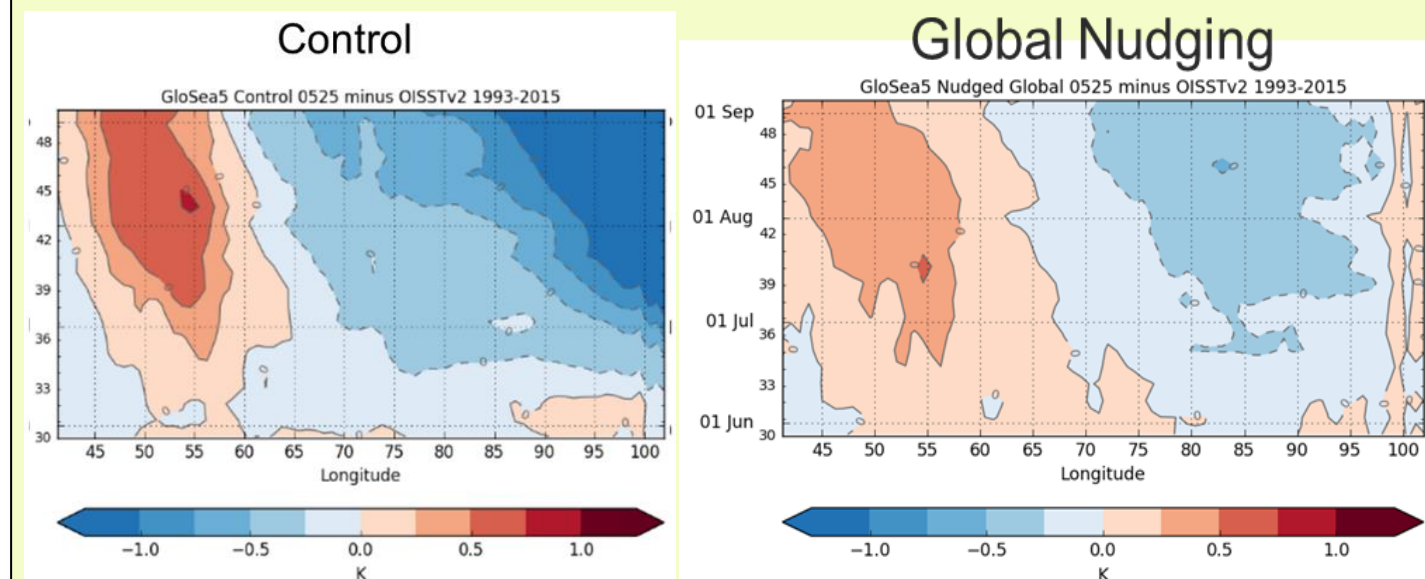
SEAS5 has too strong easterlies in the EEIO for a given SST
→ it develops a prominent negative SST bias by JJA → „cold regime bias"
→ it exhibits a very weak wind sensitivity to local SSTs → „warm regime bias"

Mayer et al. (2022). Outcomes from UGROW-IO: Forecast errors in the Eastern Indian Ocean across lead times, ECMWF Tech Memo 898.

IMPACT OF THE OCEAN MODEL

*Evolution of SST errors against analysis in GloSea5 hindcast and in a nudged hindcast with T and U, V relaxed to ERA5*
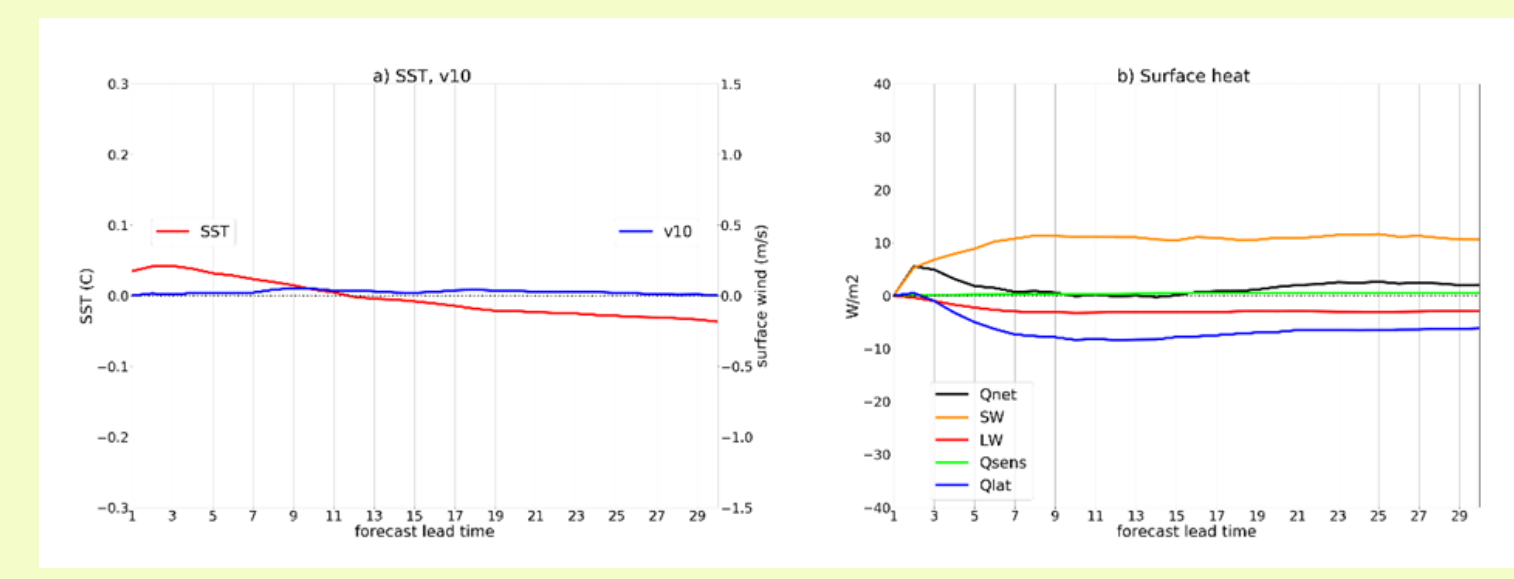
SST, 10m wind and surface fluxes errors with lead team in globally nudged coupled NWP experiments

Global atmosphere-nudging experiments with a remaining SST error not consistent with surface flux errors suggest a role from the ocean model in these coupled experiments.

During the development of the GC5 configuration, the surface cold bias and the associated sub-surface warm bias became worst. Ocean tunings mitigated these errors by:
• Reducing vertical mixing in the ocean's TKE scheme by reducing the htau length scale.
• Reducing solar penetration by increasing chlorophyll (from 0.05 to 0.1 mg/m3)
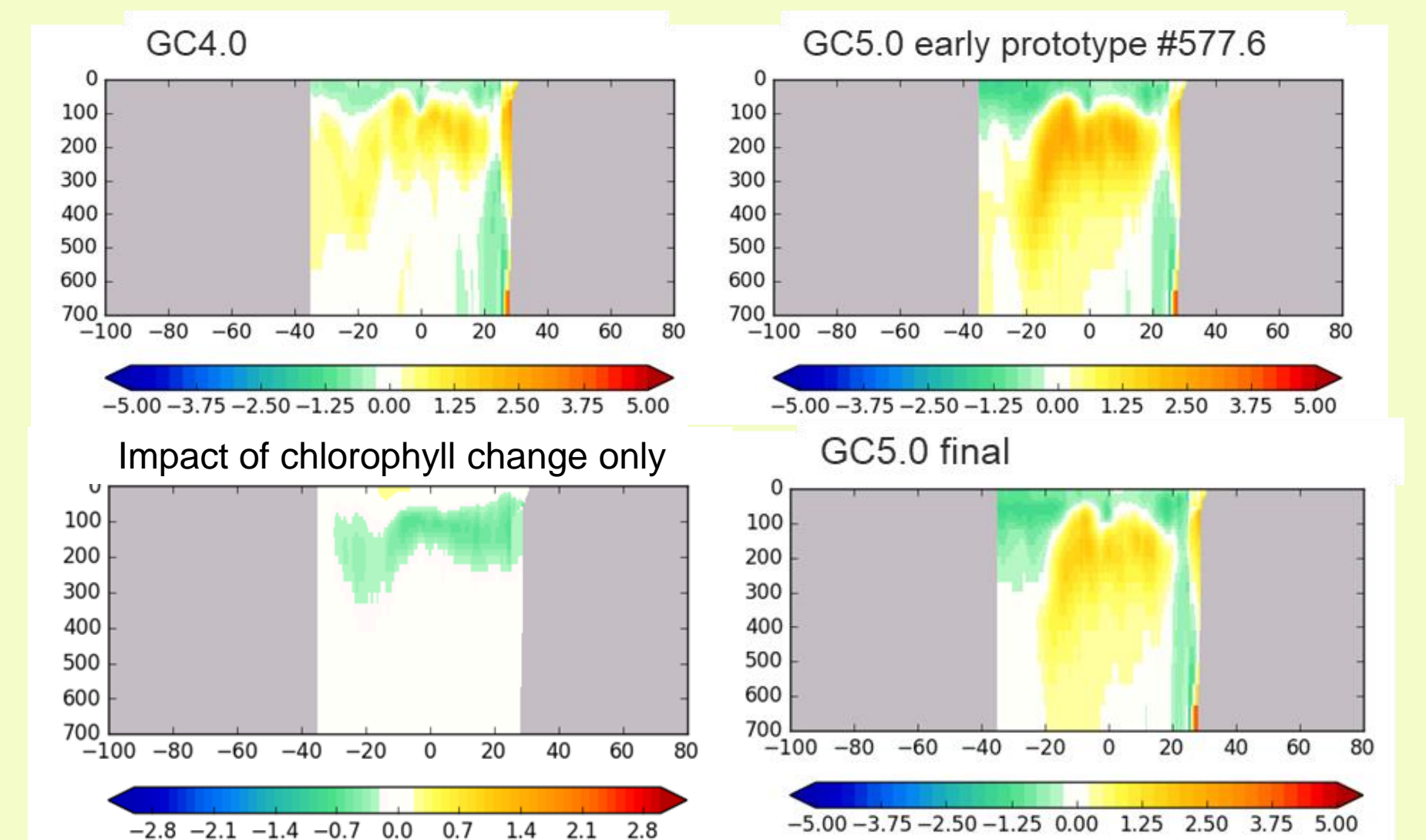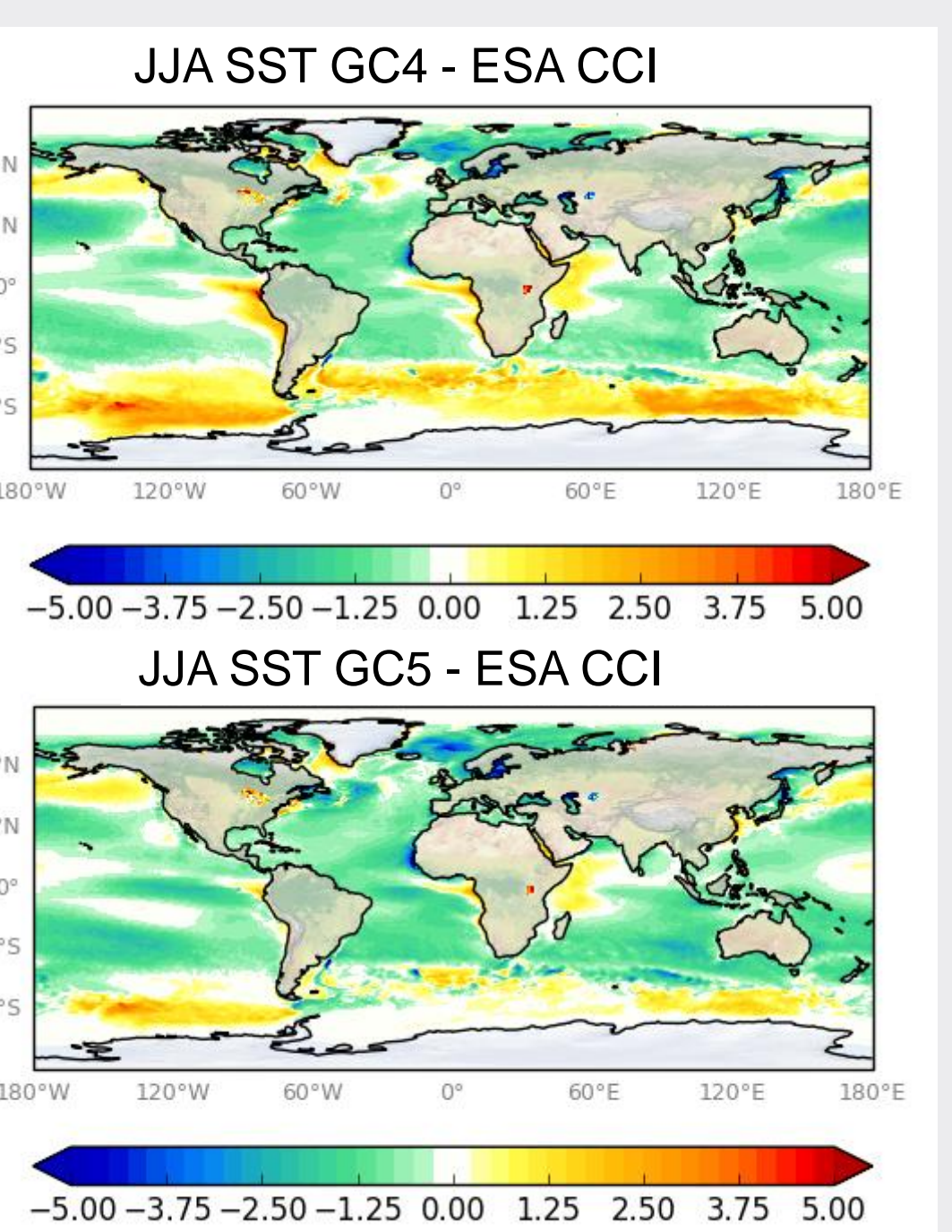

Indian Ocean temperature biases in coupled climate experiment (wrt EN4), meridional cross sections

## INDIAN OCEAN MONITORING METRICS AND MODEL DEVELOPMENT
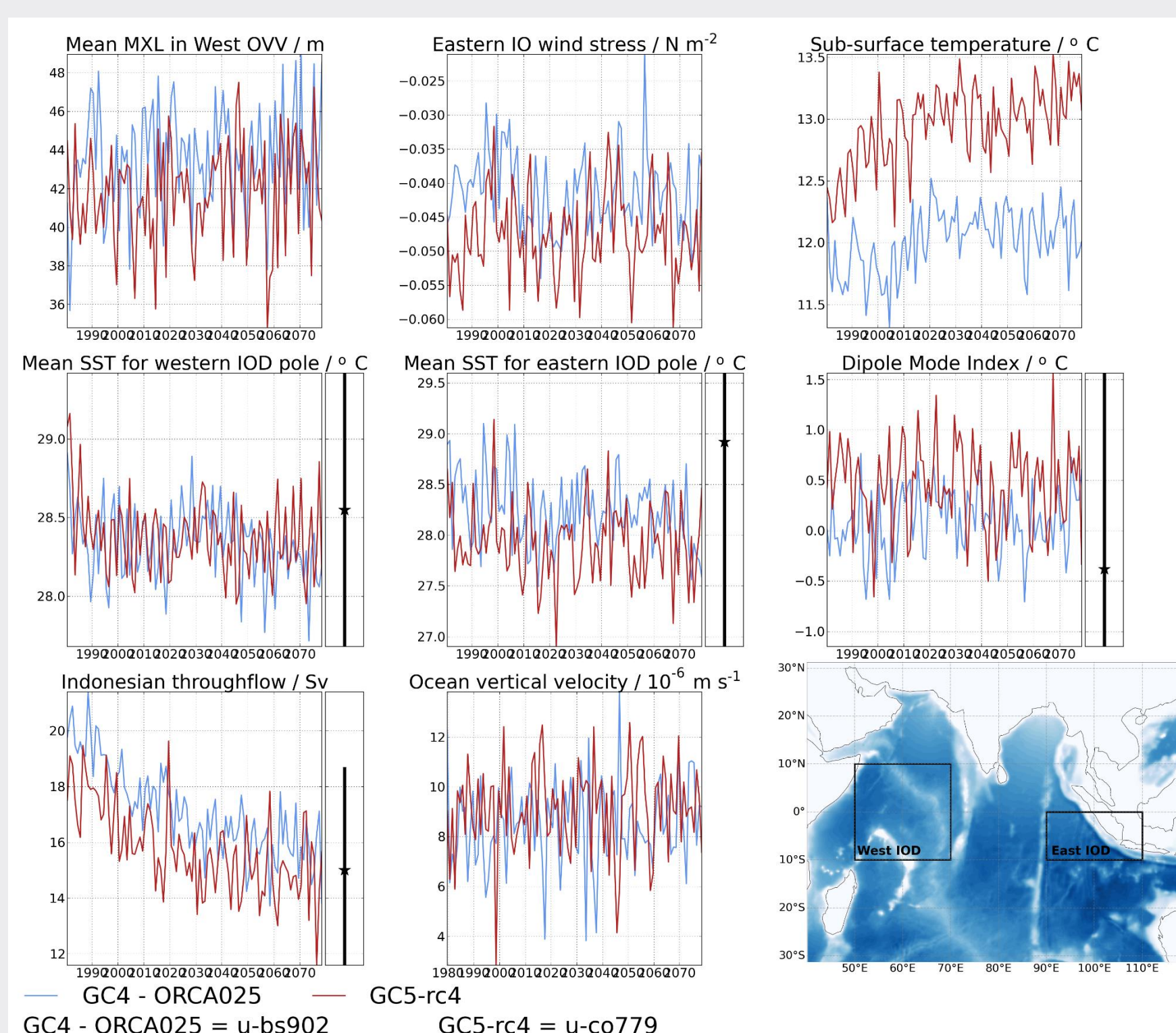
Currently developing a monitoring tool for Indian Ocean metrics tailored to help improve the performance issues

SST biases in coupled climate 100yr experiments, GC4 and recent GC5

TELECONNECTIONS

Systematic errors in the Eastern Indian Ocean matter to users as they affect teleconnections important for forecasting extreme weather events, such as droughts over Australia
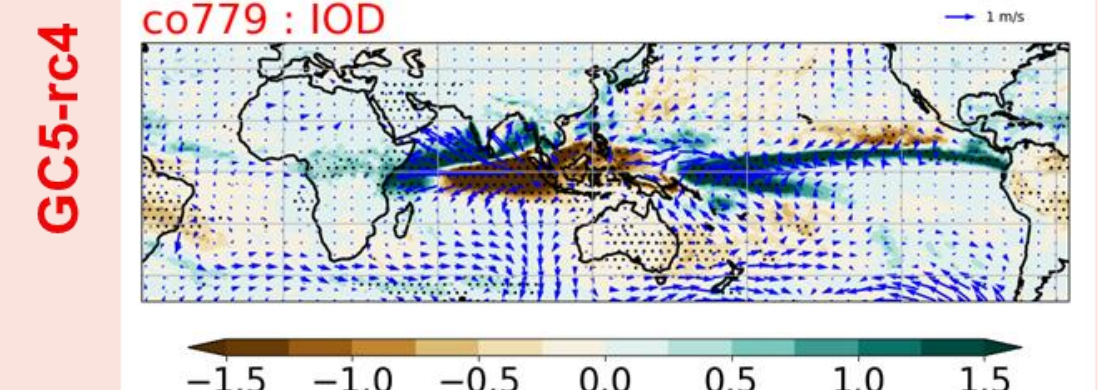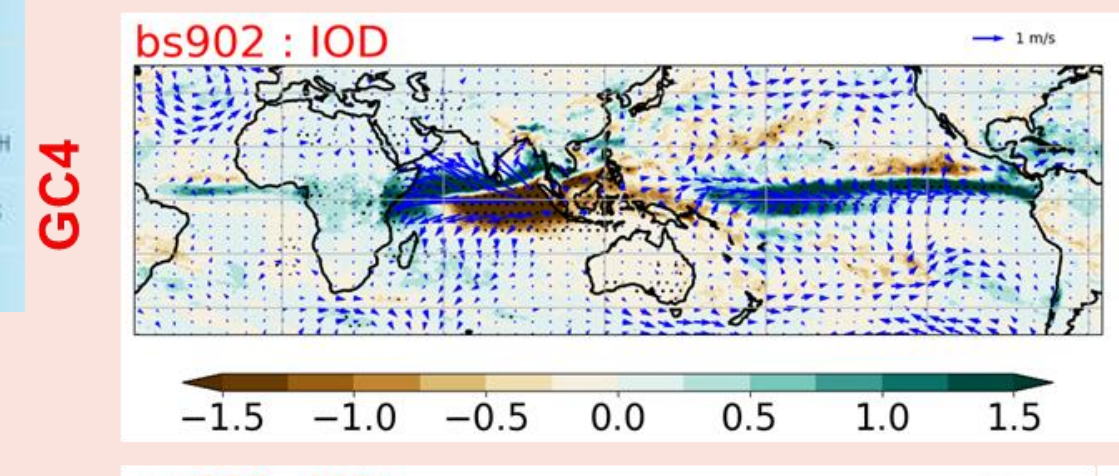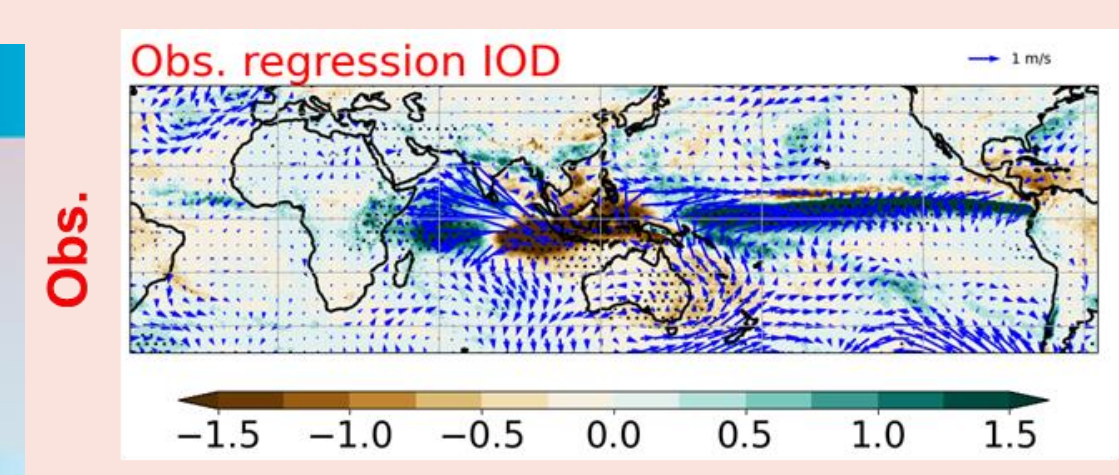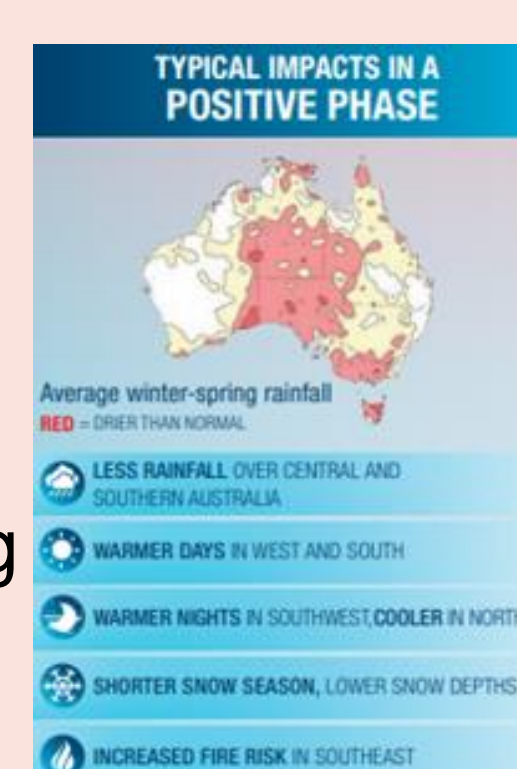
Mean SST biases in the Indian Ocean are also associated with errors in variability, with the Indian Ocean Dipole having a too great amplitude and having a too strong biennial variability

However the regression between IOD index and rainfall and surface winds indicate a better teleconnection overall and in particular over Australia in 70yrs of climate coupled simulations. These preliminary results need to be further investigated.