Tackling systematic errors over the Indian Ocean in Met Office and partners seamless coupled models

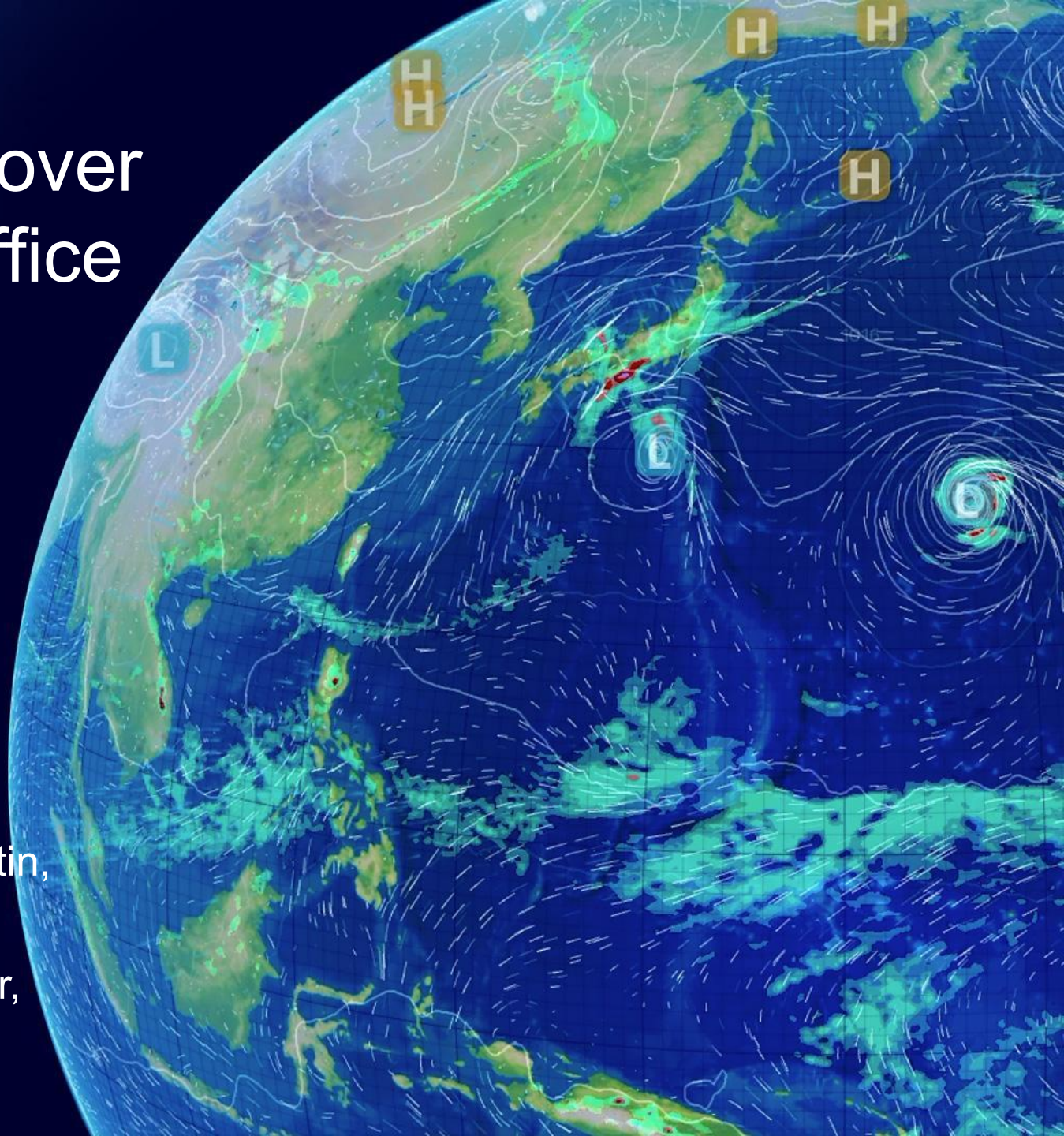
Charline Marzin, Global Coupled configuration programme manager, Met Office

Members of the Indo-Pacific PEG:

BoM: Debbie Hudson, Matt Wheeler, Chen Li, Xiaobing Zhou,

Met Office: Marimel Gler, Hannah Ellis, Gill Martin, Jose Rodriguez, Dan Copsey, Dave Storkey

ECMWF: Magdalena Balmaceda, Michael Mayer, Stephanie Johnson



Indo-Pacific PEG (Priority Evaluation Group)

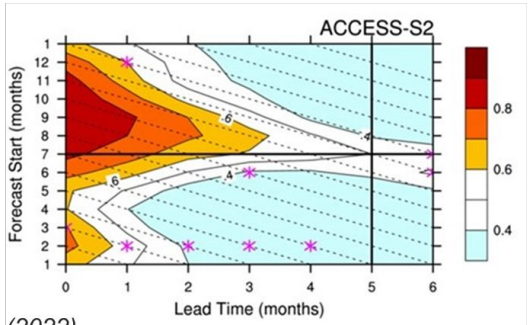
Equatorial Eastern Indian Ocean cold/dry biases

Met Office

Australian Government Bureau of Meteorology

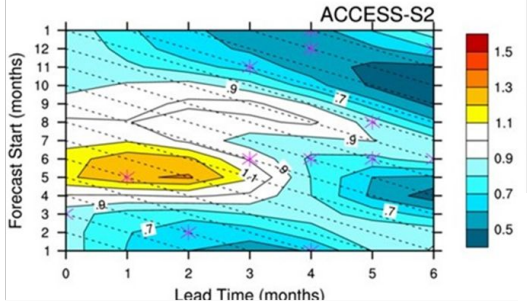
DMI

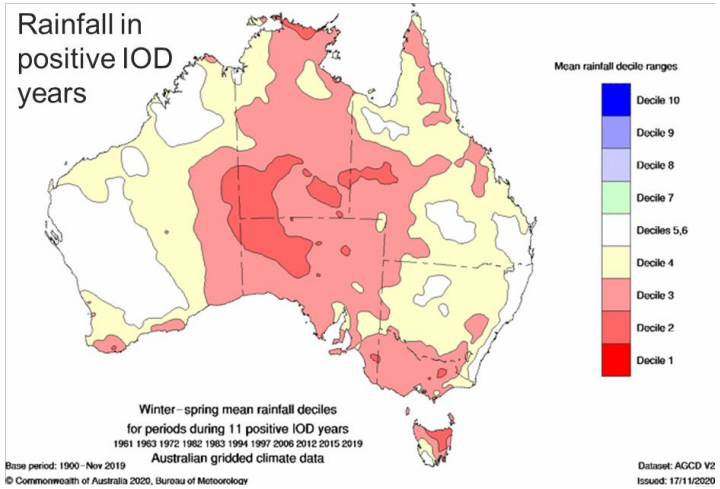
Correlation skill



Wedd et al. (2022)

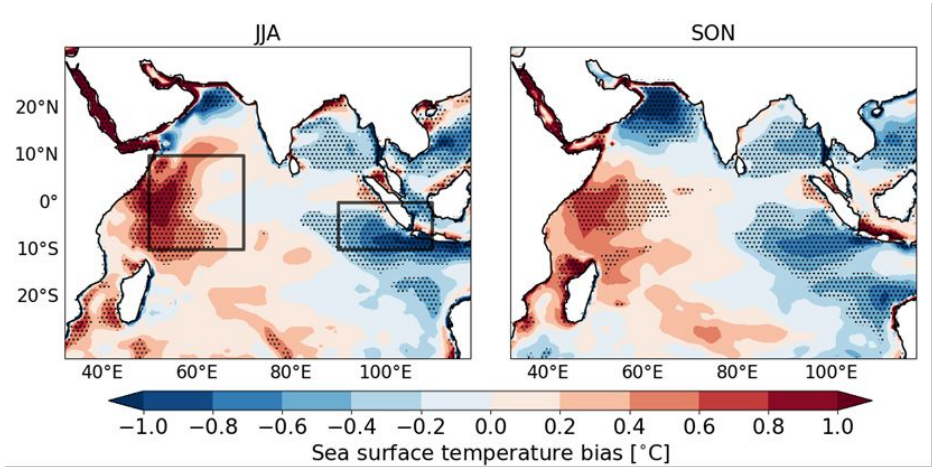
Ratio of standard deviation

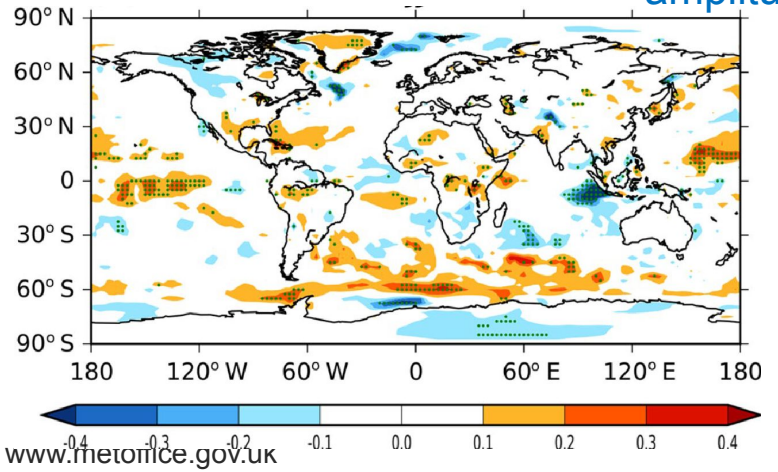




IOD has large impacts in austral winter-spring, but ACCESS-S2 has poor skill in early winter and too much amplitude.

GloSea6 hindcast mean biases



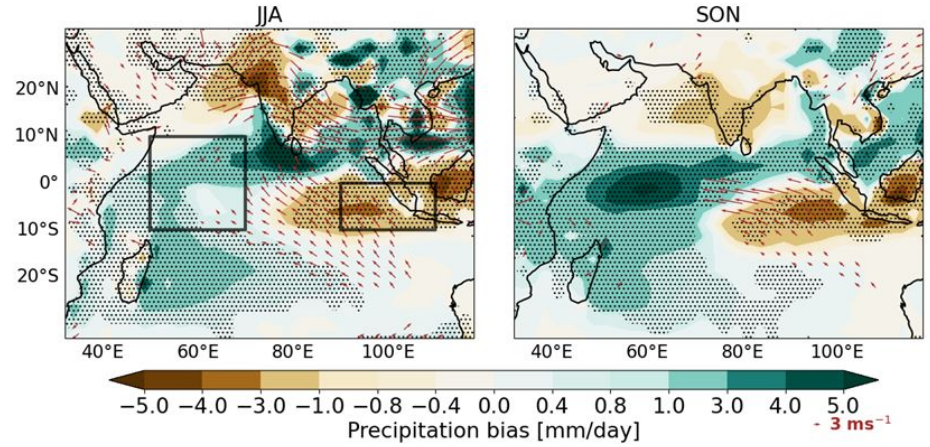


SEAS5 –SEAS4 SST forecast skill JJA

ECMWF

From Johnson et al. (2019)

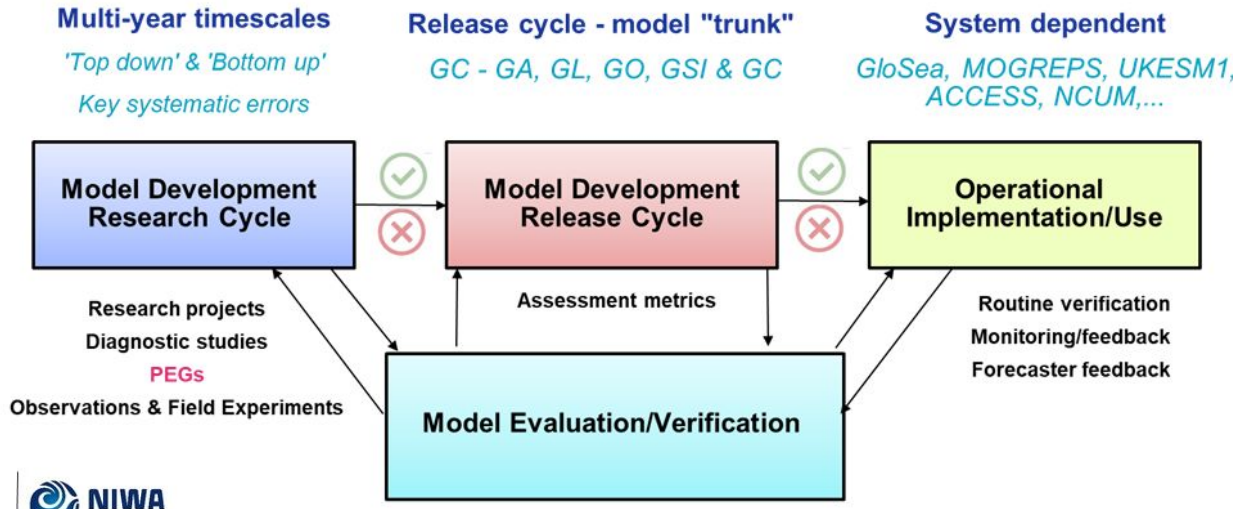
Mayer et al 2023.



Marimel Gler

PEG: Priority Evaluation Group

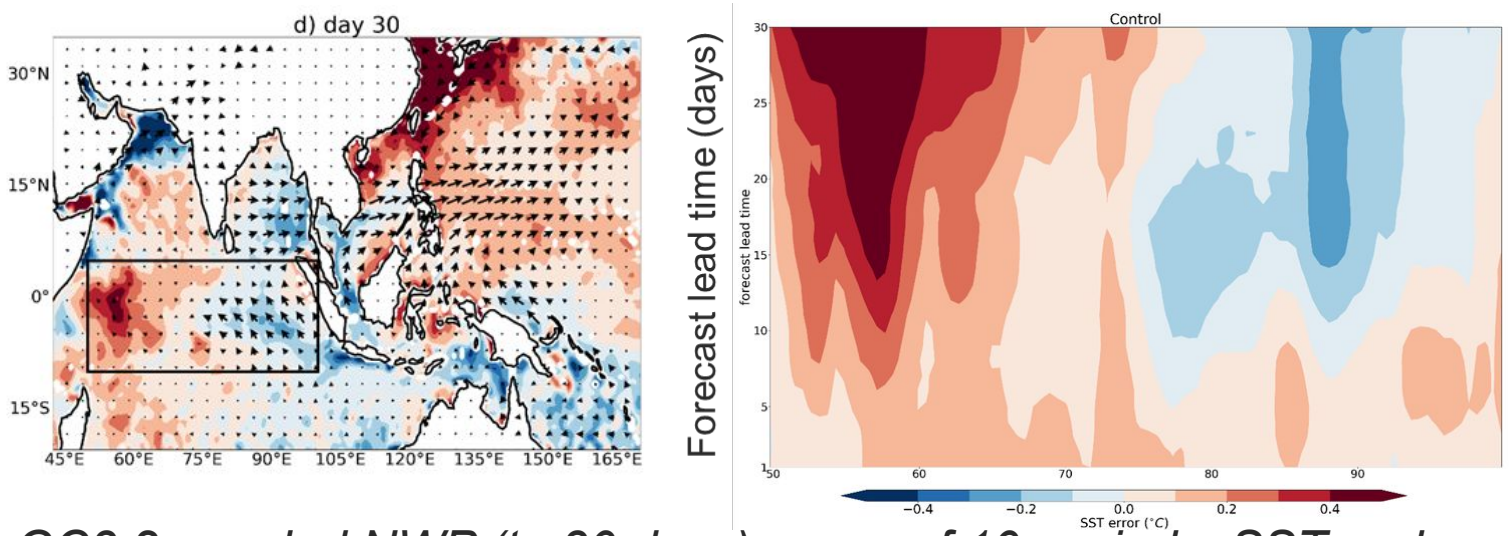
GC development process:



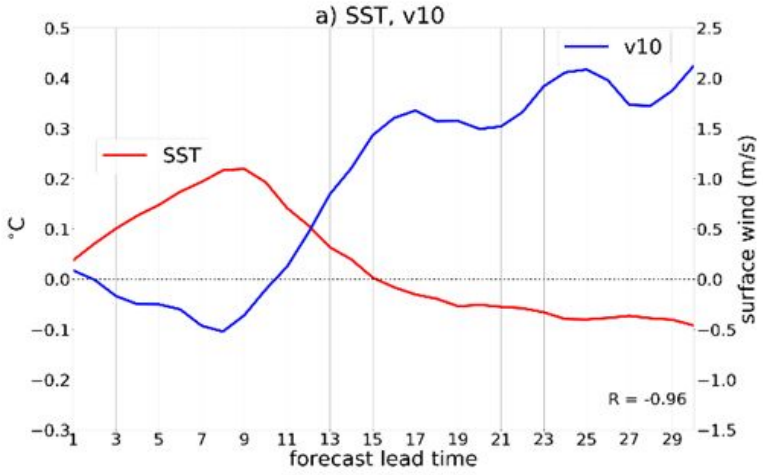
Indo-Pacific PEG: co-leads:

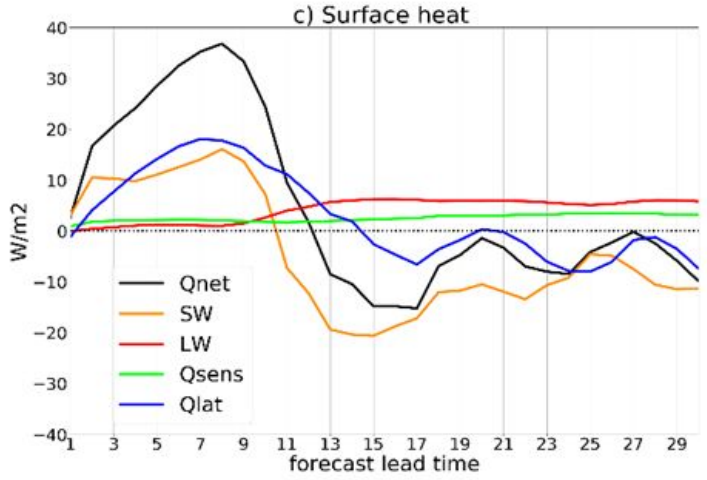
- Debra Hudson and Matthew Wheeler (BoM)
- Charline Marzin (Met Office),
- Magdalena Balmaseda (ECMWF)

Evolution of errors in coupled NWP



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)





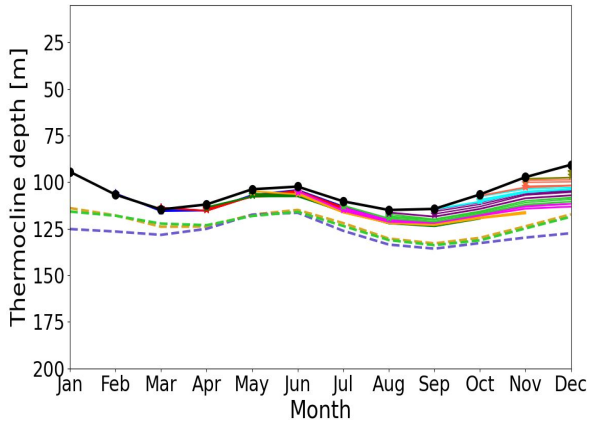
- Eastern Indian SST bias warm before drifting to cold and associated with easterly wind bias, similar in GloSea
- Surface fluxes errors also play a role

Jose Rodriguez

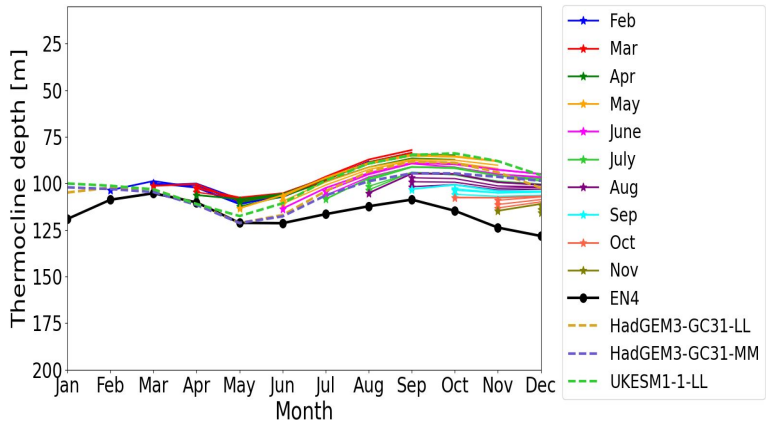
Positive Bjerknes feedback loop

GloSea6

WEIO

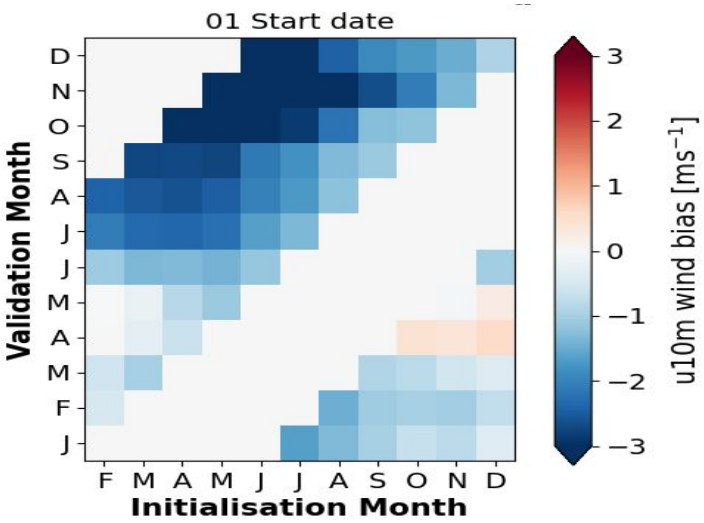


EEIO



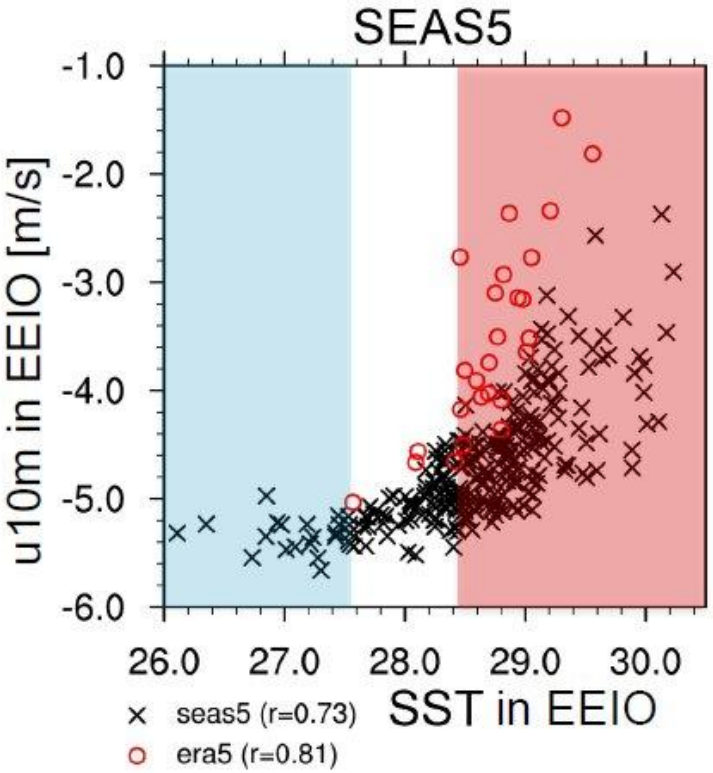
Marimel Gler

u10m bias over the CEIO



- Subsurface bias show a thermocline depth that becomes shallower in the EEIO from JJA through to SON.
- Regardless of the initialisation month, an easterly 10m wind bias develops in the CEIO from JJA through to SON. Large magnitude of wind bias during SON develops when initialised in April, May, June and July.

Michael Mayer

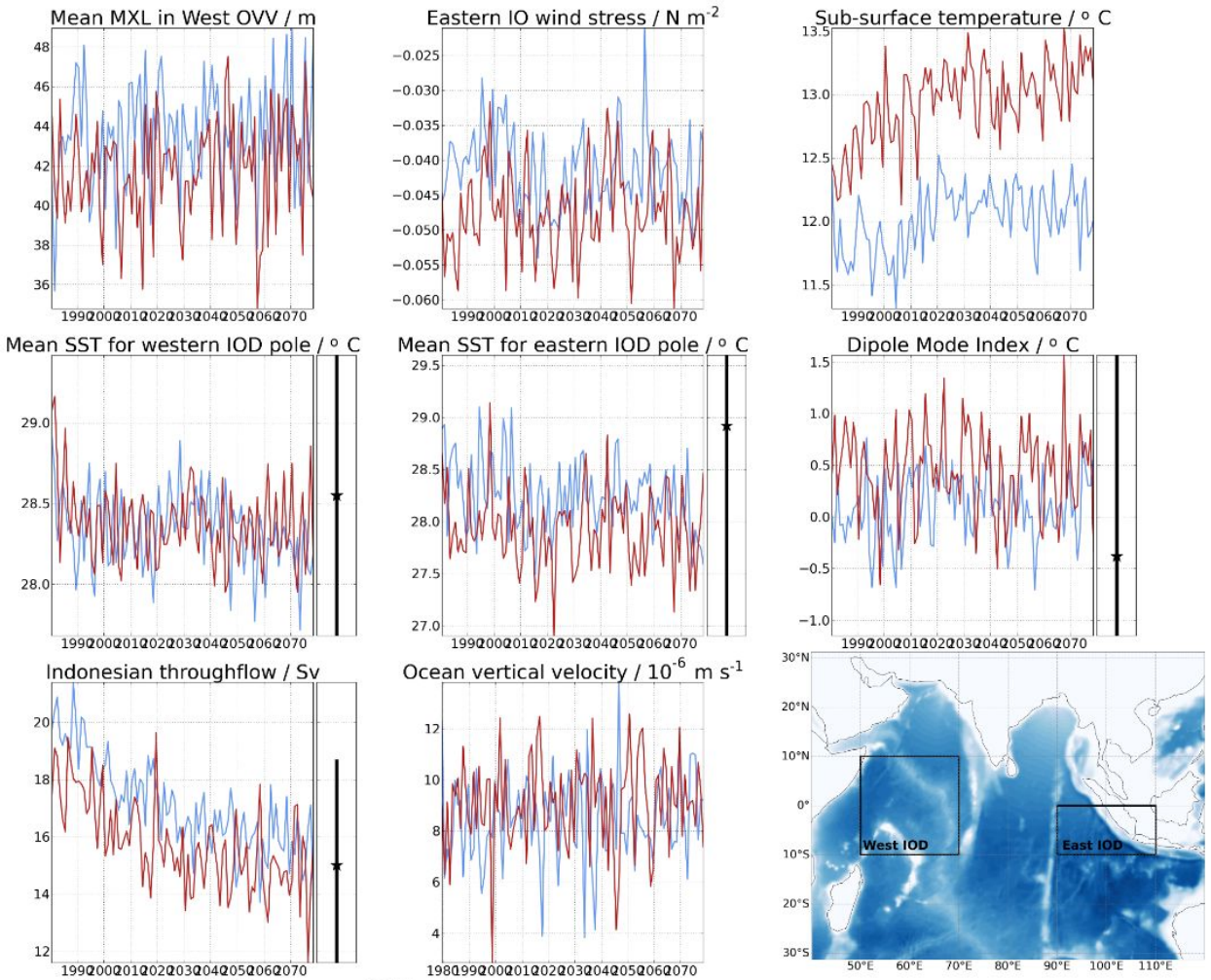


SEAS5 has too strong easterlies in the EEIO for a given SST

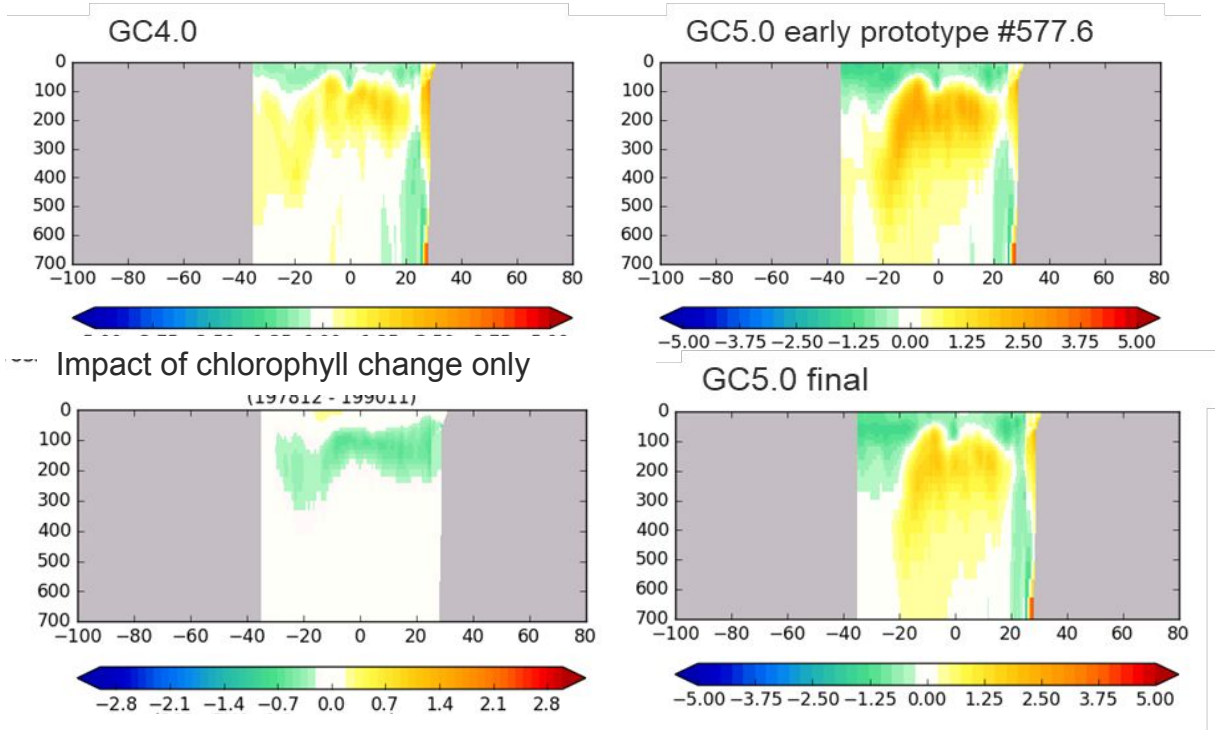
- it develops a prominent negative SST bias by JJA „cold regime bias“
- it exhibits a very weak wind sensitivity to local SSTs „warm regime bias“

Targeted GC5 development

Dan Copsey
Dave Storkey
Catherine Guiavarc'h



Hannah Ellis,
Indian Ocean monitoring tool



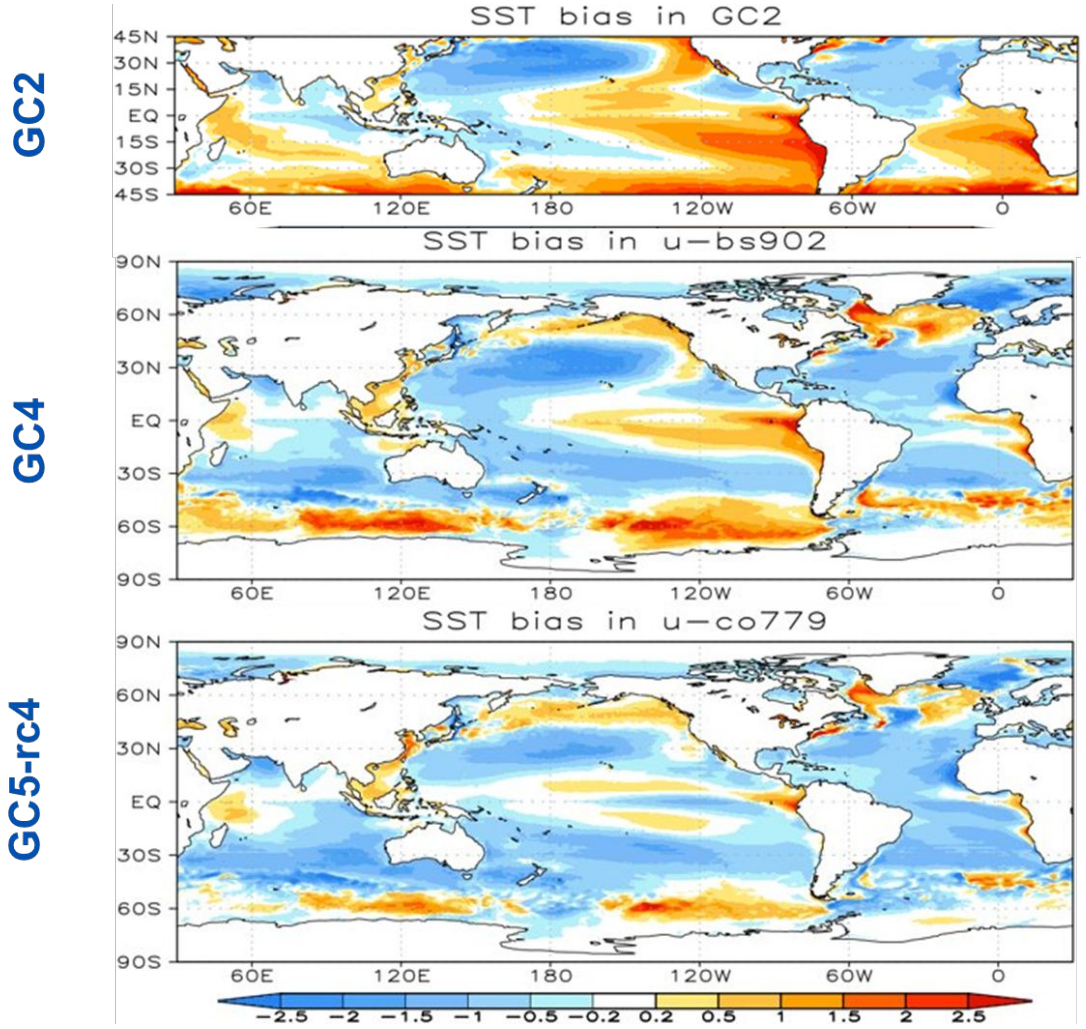
Ocean tunings mitigated sub-surface warming by:

- 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)

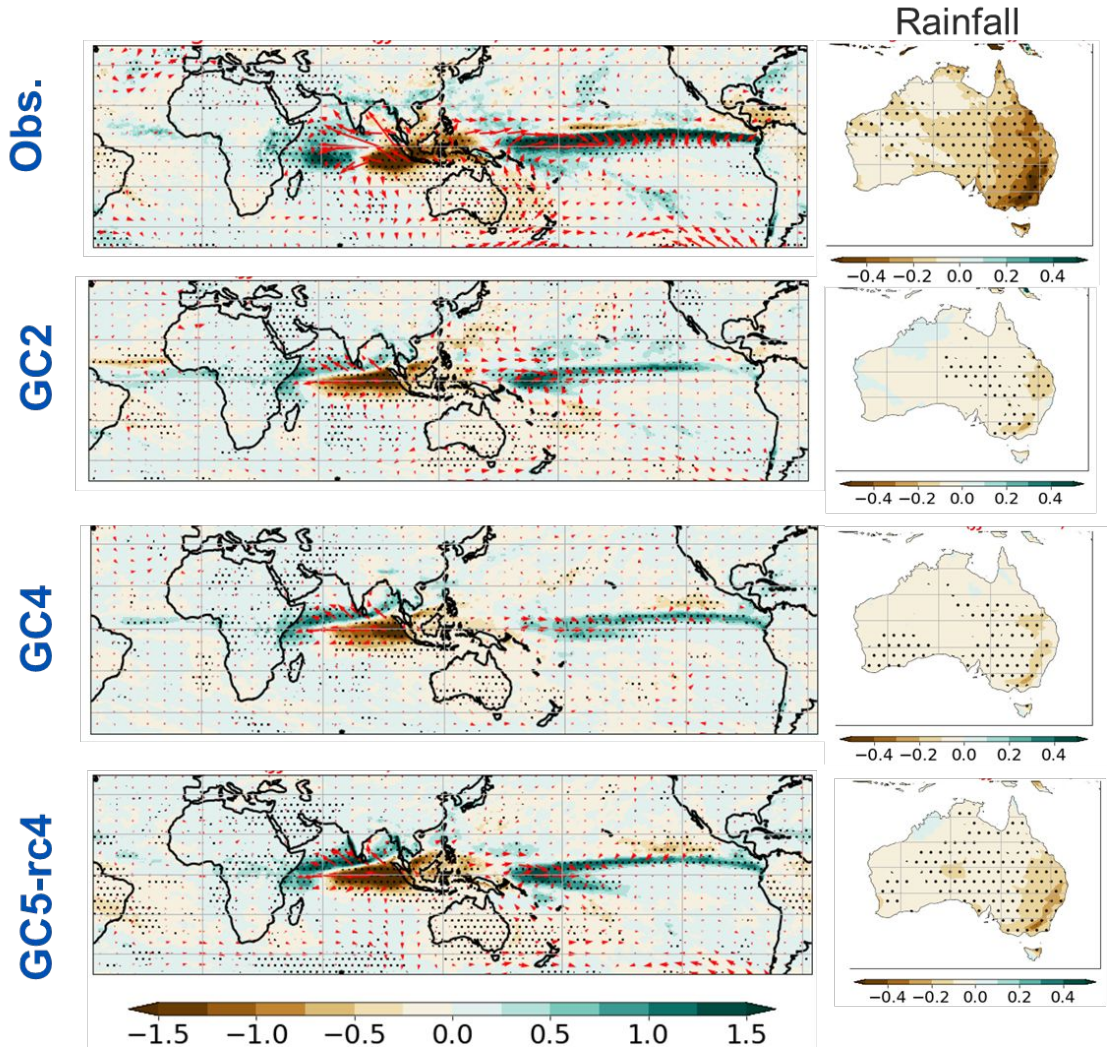
Mean errors and teleconnections in coupled climate runs over several releases

Li et al, 2023

SST annual mean - OISST



DMI regression (JJA + SON) wind and rainfall



How does the SST bias after the 7-month forecast compare to that from the coupled climate run for GC5?

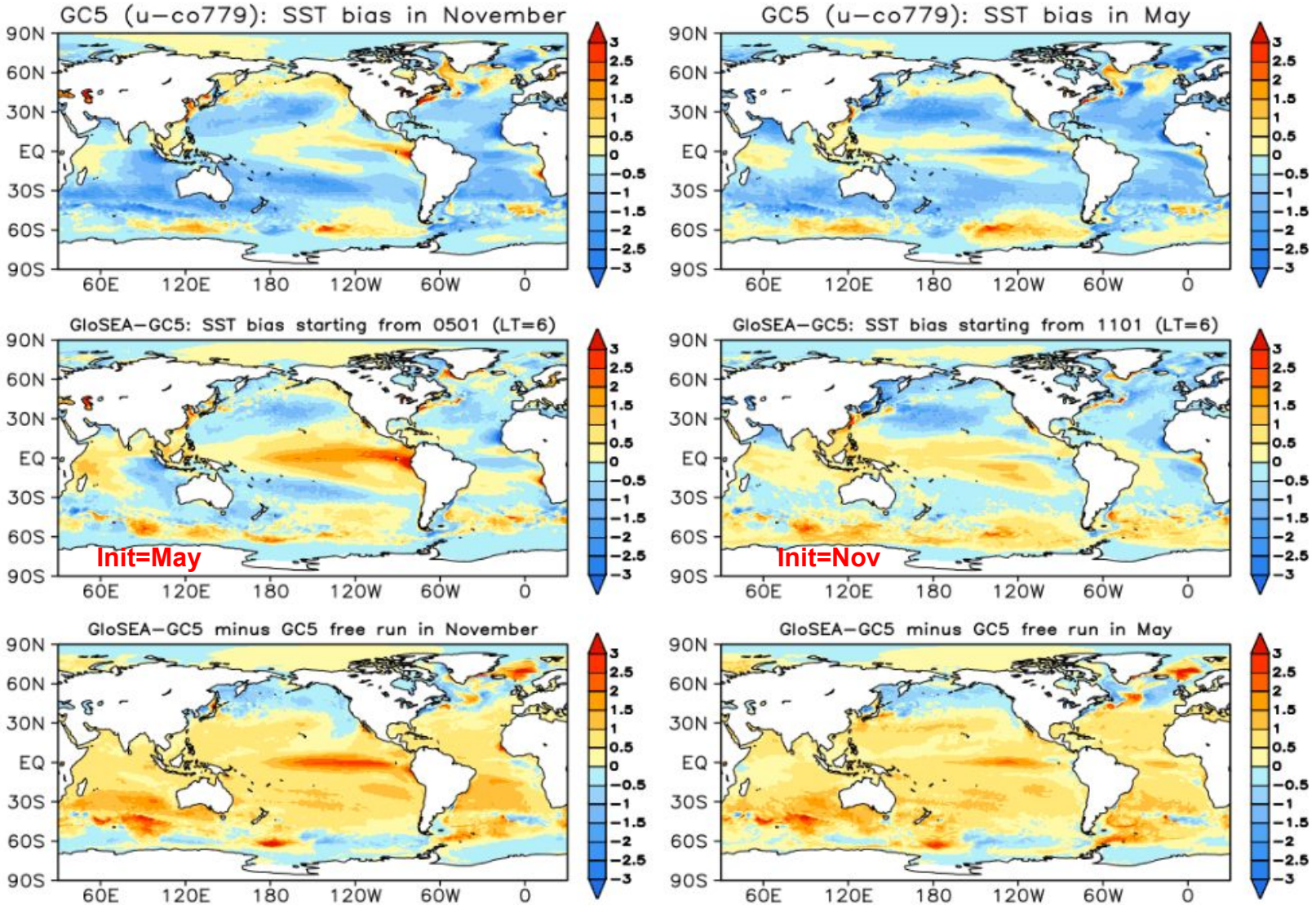
Bias in November

Bias in May

Free coupled climate run

Seasonal HC at month 7

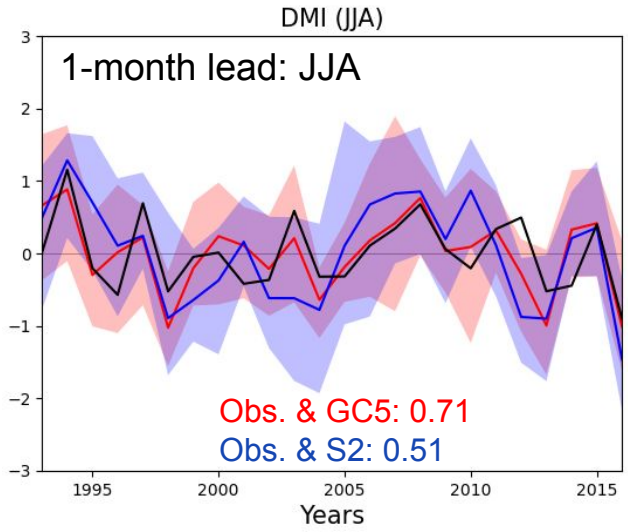
Difference

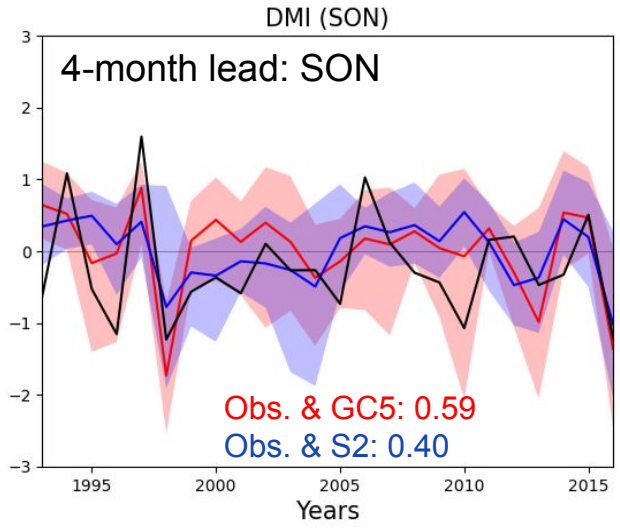


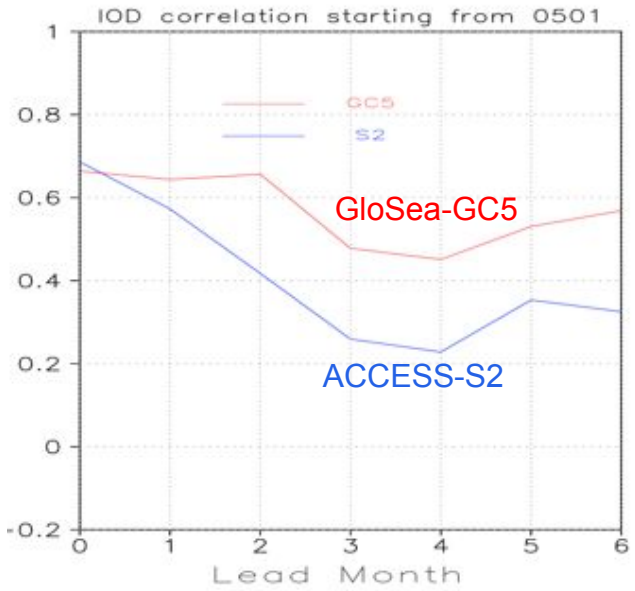
From: Xiaobing Zhou

IOD: correlation and bias (May start)

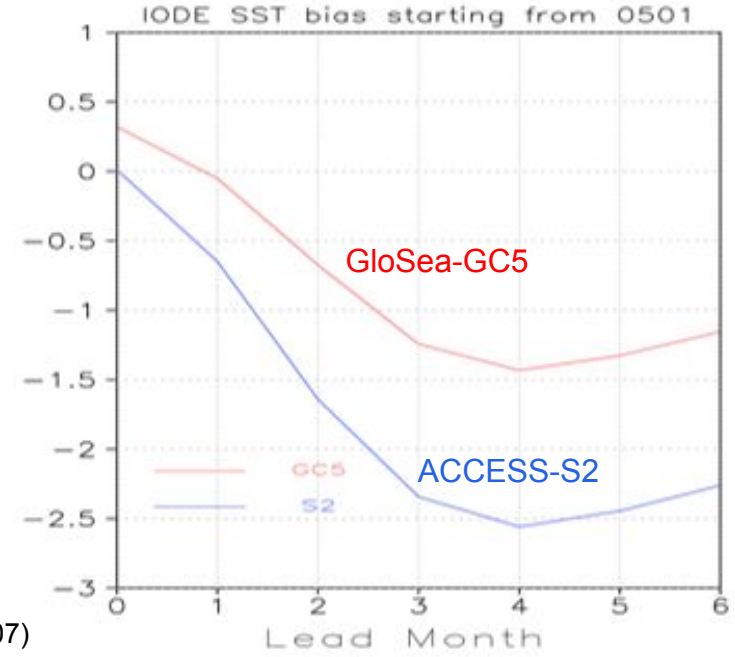
Correlation







Bias
(Eastern Pole of IOD)



Improved IOD prediction skill and reduced bias

Obs: OISST (Reynolds et al 2007)

From: Chen Li & Xiaobing Zhou

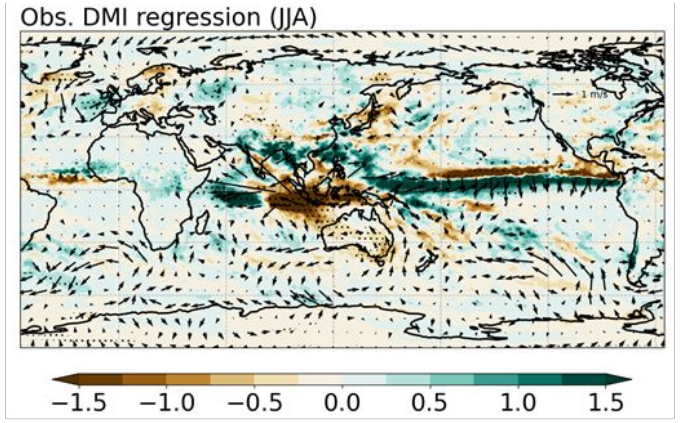
IOD teleconnections in seasonal hindcast

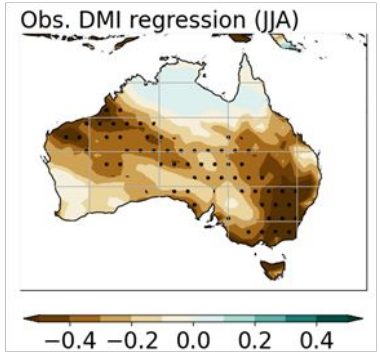
JJA IOD teleconnection

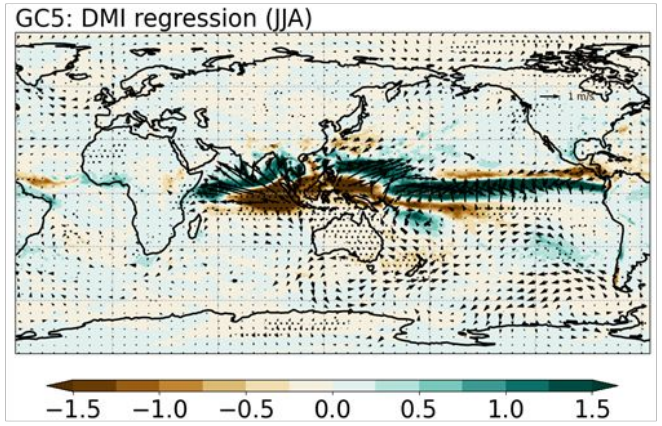
Obs.

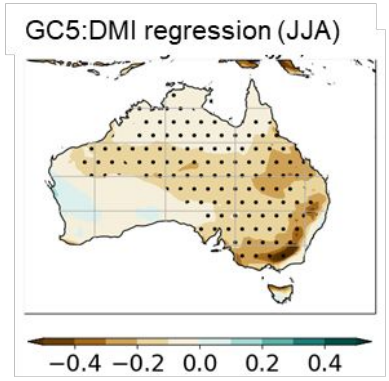
Glosea-GC5

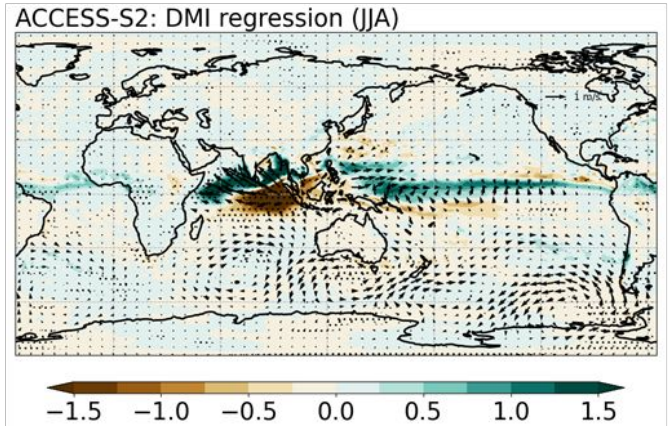
ACCESS-S2

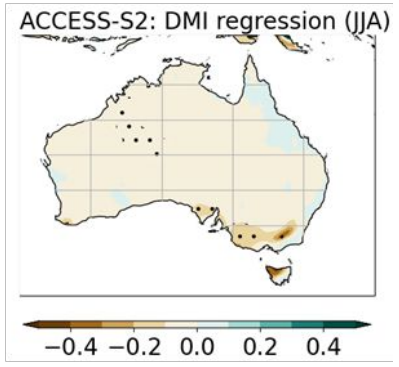












Improved IOD-teleconnection for Australian rainfall.

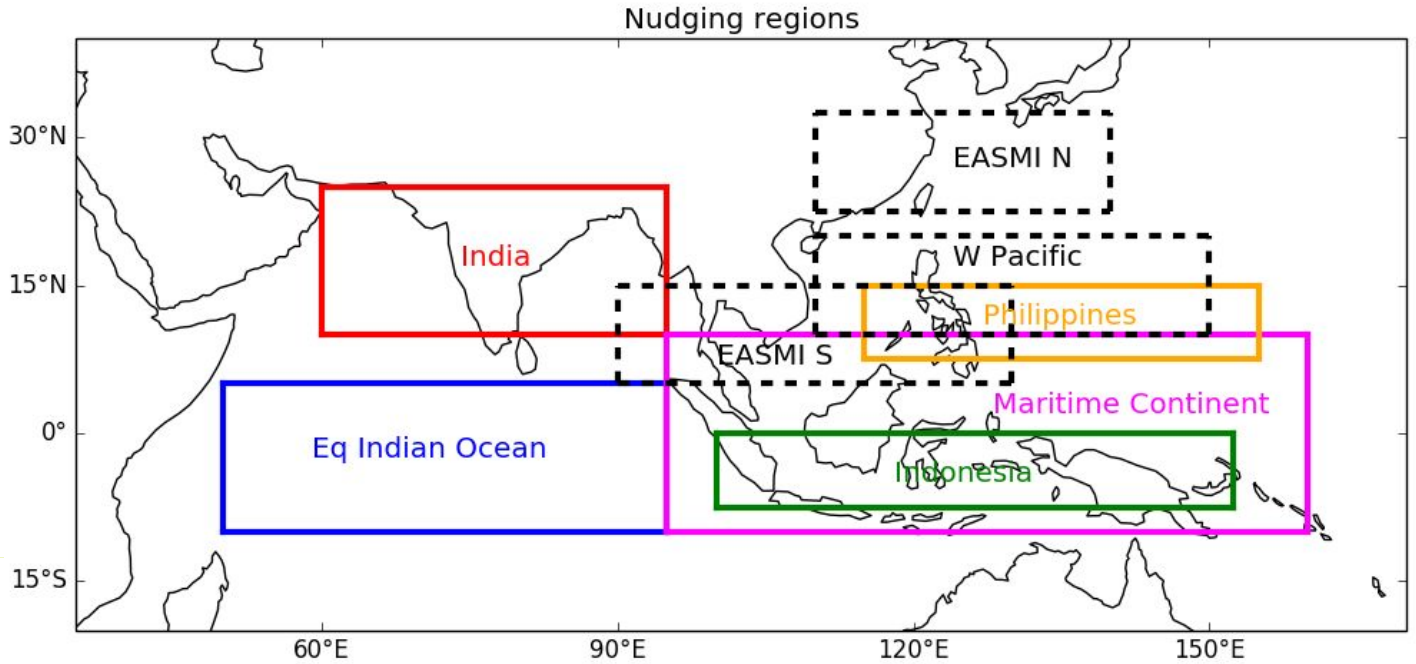
From: Chen Li

Met Office

Martin, G. M. and Rodríguez, J. M.: Using regional relaxation experiments to understand the development of errors in the Asian summer monsoon, Weather Clim. Dynam., 5, 711–731, https://doi.org/10.5194/wcd-5-711-2024, 2024

Regional relaxation (“nudging”) experiments

- Temperatures and winds “nudged” back to reanalyses with a 6-hourly relaxation time scale at all model levels.
- Assuming a linear response, the difference between the Control and the “Nudged” simulations then gives an indication of the role played by the nudged region in the biases that occur in the Control in other locations.
- Parallel experiments in GloSea5 and coupled NWP (José Rodriguez).



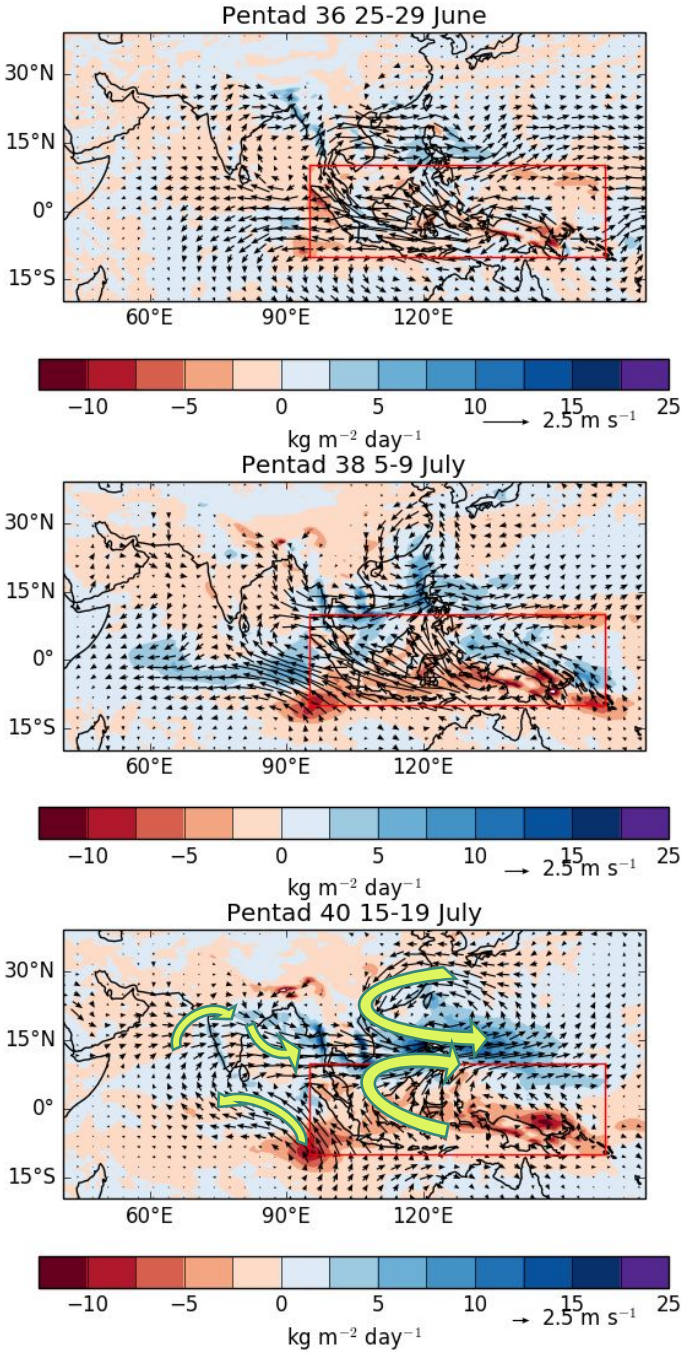
Met Office

850 hPa winds and rainfall

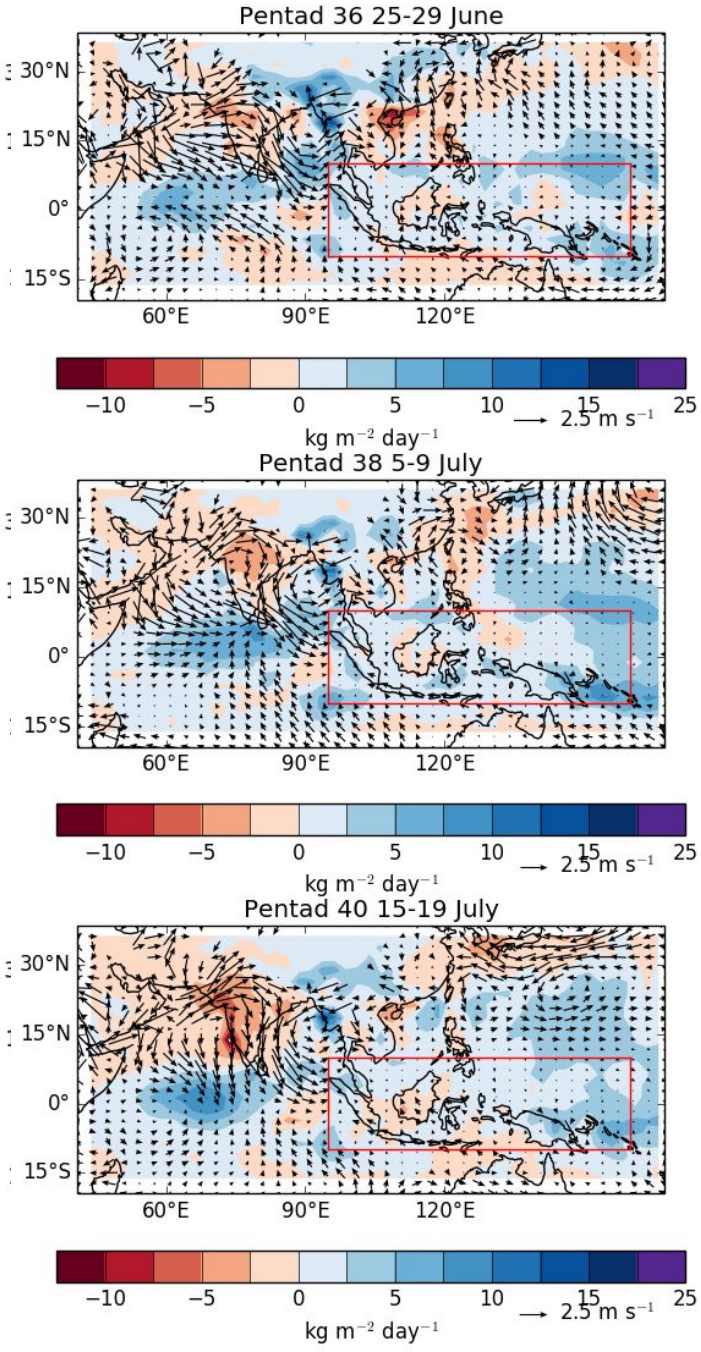
Start dates 25th June

Nudging Maritime Continent (MC)

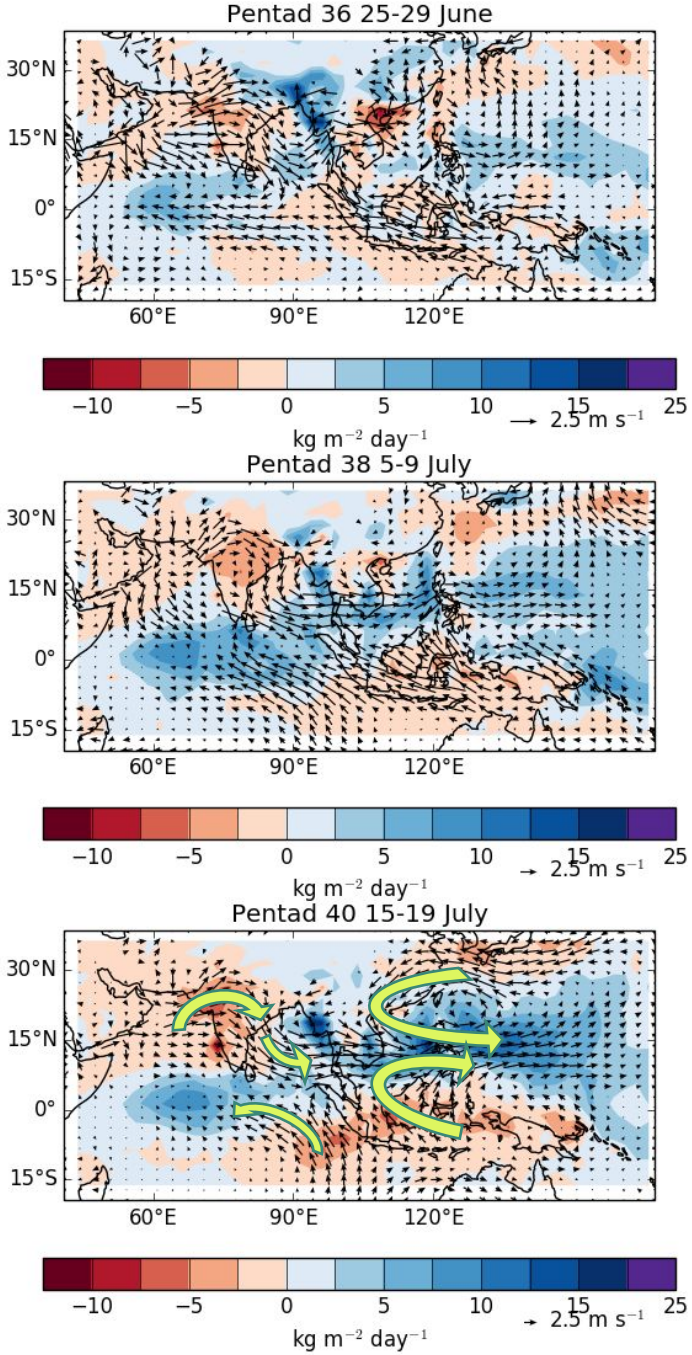
Errors contributed by MC region



Error when Nudging MC region



Control



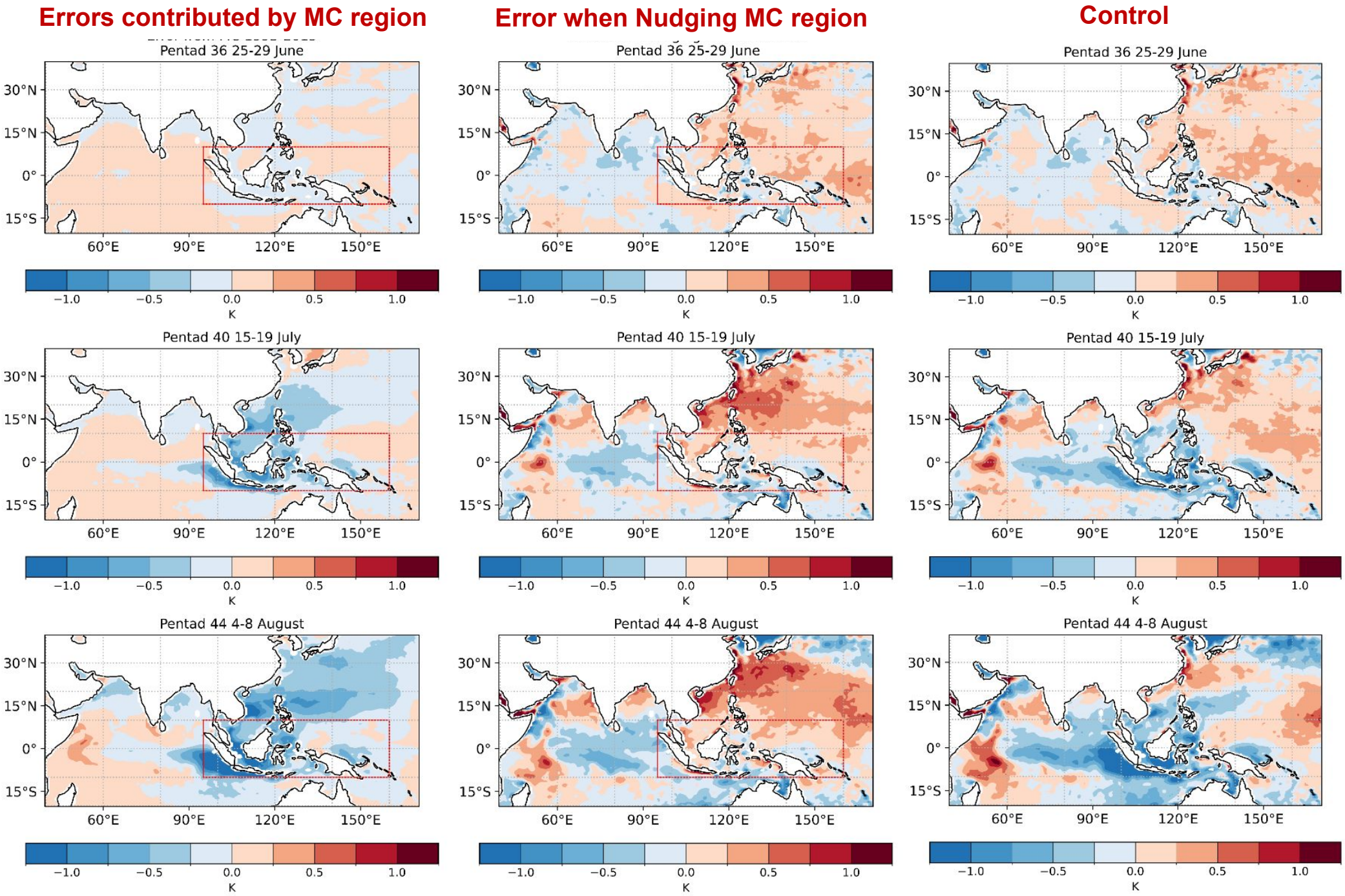
Met Office

SST

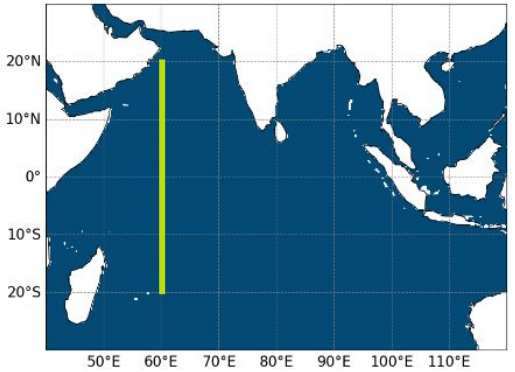
Start dates

25th June

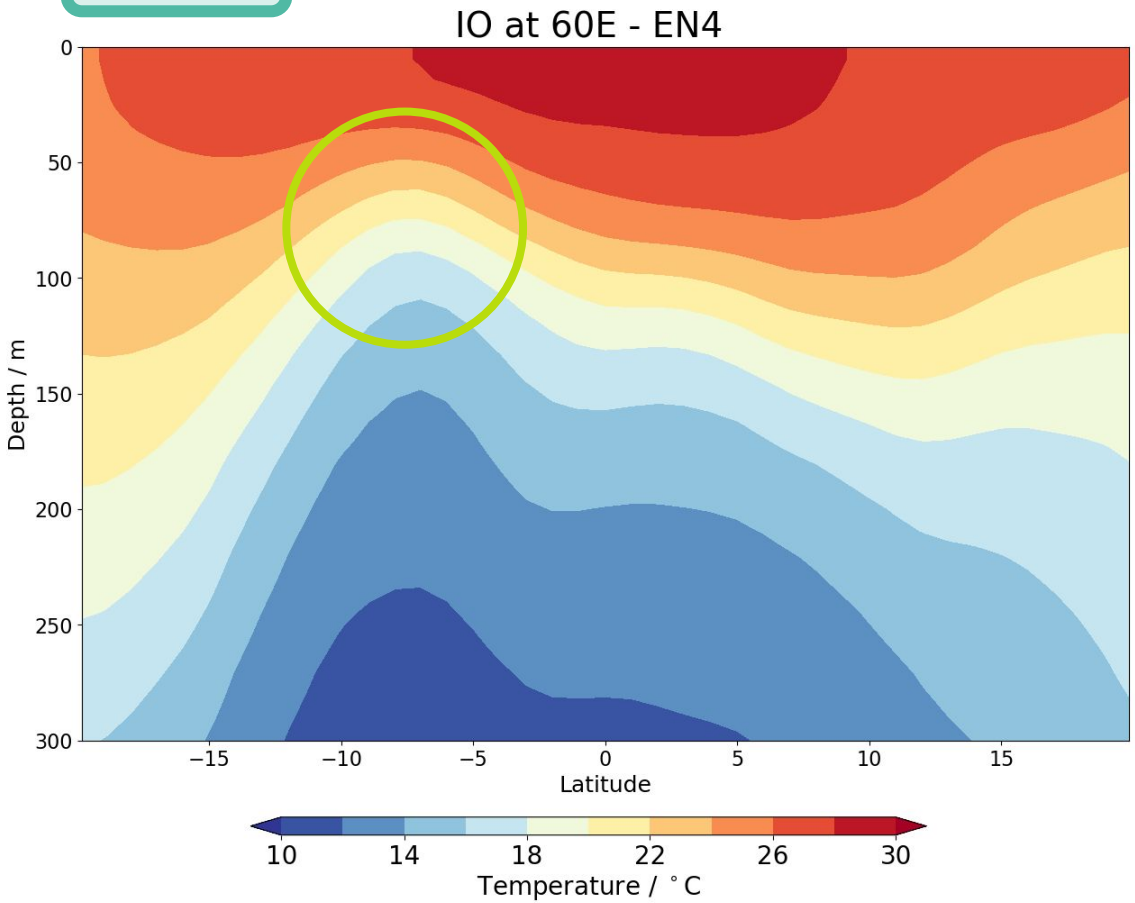
Nudging Maritime Continent (MC)



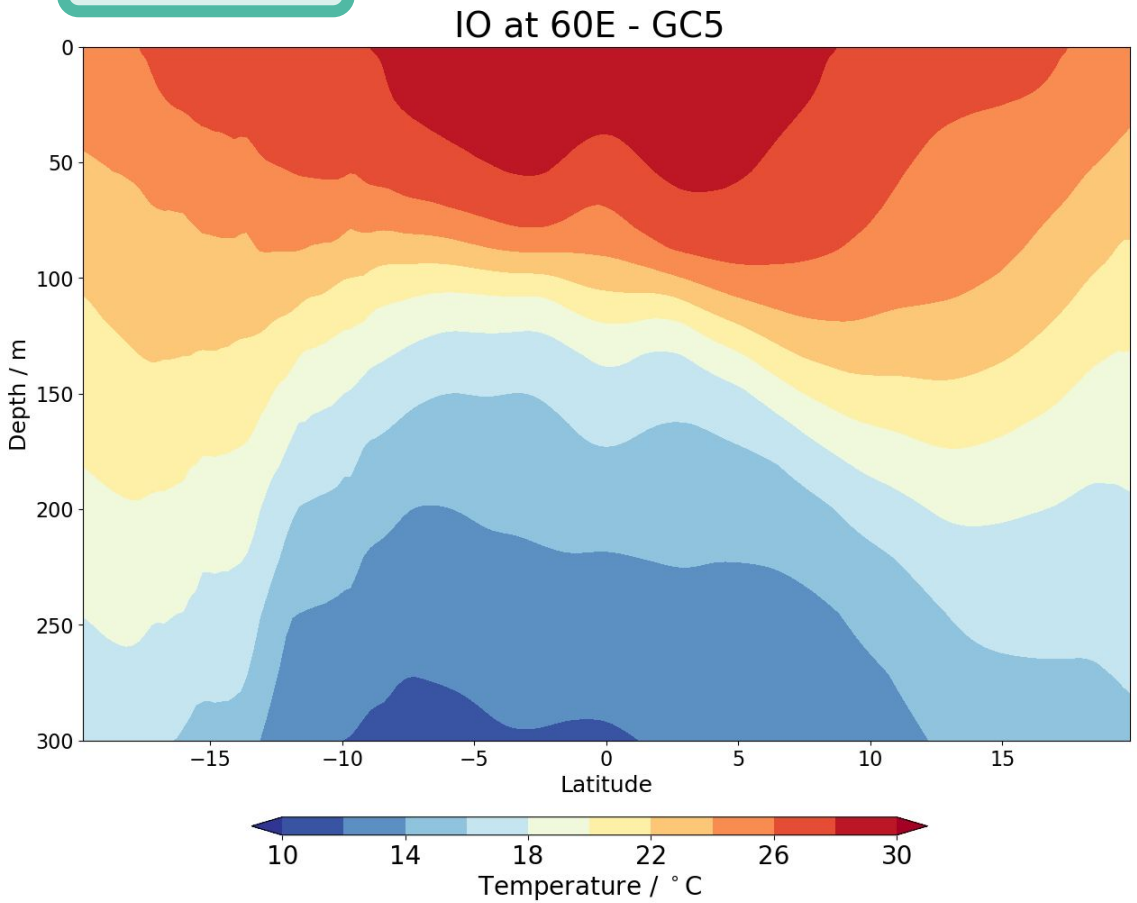
Cross-sections through the Seychelles-Chagos Thermocline Ridge



EN4



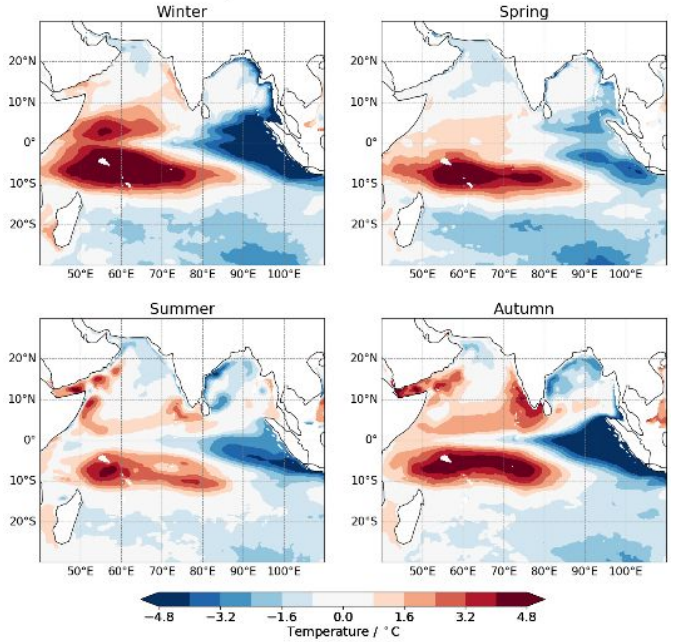
Coupled



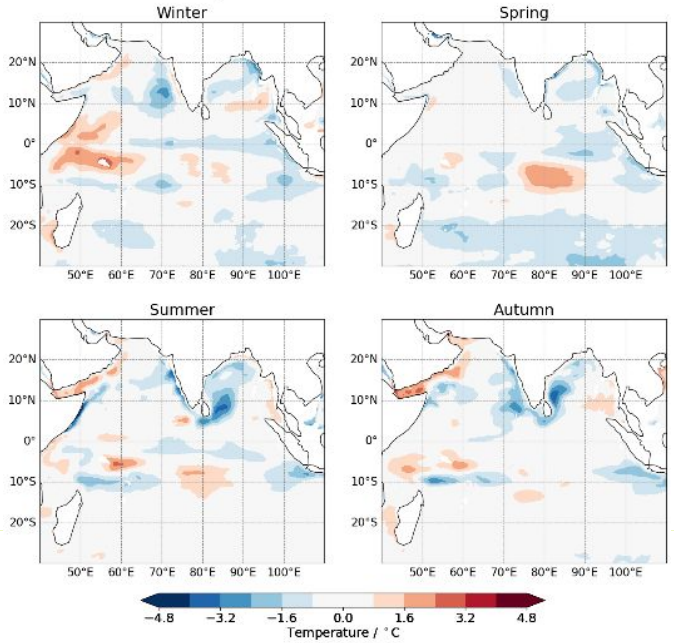
Forced ocean sensitivity experiments to wind stress curl

Hannah Ellis

Coupled

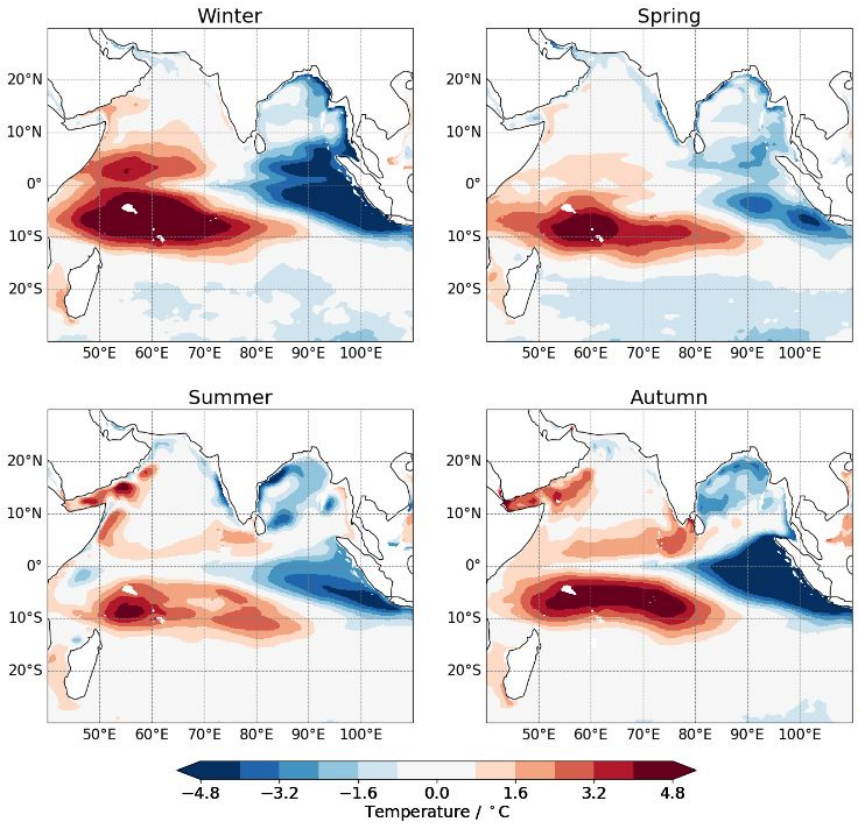


Ocean-only



Sub-surface warm bias due to lack of Ekman pumping. By using the winds from the coupled model to force the ocean-only model, this can recreate the subsurface temperature biases in the Indian Ocean almost identically, with the same location, intensity and seasonality.

Ocean-only with winds from coupled model



Challenges and next steps

- ESMVal tool metrics for Indian Ocean
- Design variability and teleconnection metrics that translate performance of free running coupled model to seasonal forecast skill for future model development
- Early testing of upcoming new ocean and atmosphere parametrisations
- Use of convective scale coupled (regional and global) for process understanding
- Further analyses of initial evolution of errors, role of initial conditions and sensitivity experiments to identify main sources