Predicting the Asian Summer monsoon and its variability on a range of timescales

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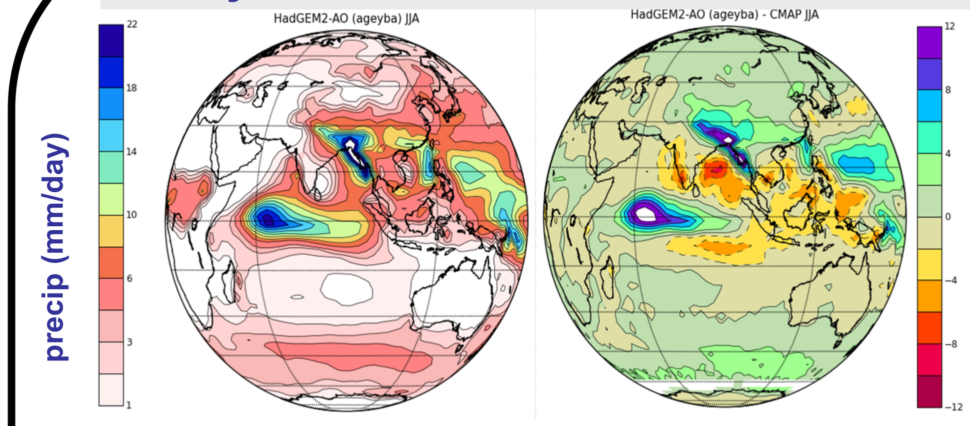
A – Introduction

The Met Office Unified Model (MetUM) consists of a general circulation model (GCM) framework, which is used for Numerical Weather Prediction (NWP), seasonal, and longer-term climate predictions. The unified modelling approach is exploited to analyse the growth of systematic errors in the MetUM simulation of the Indian summer monsoon.

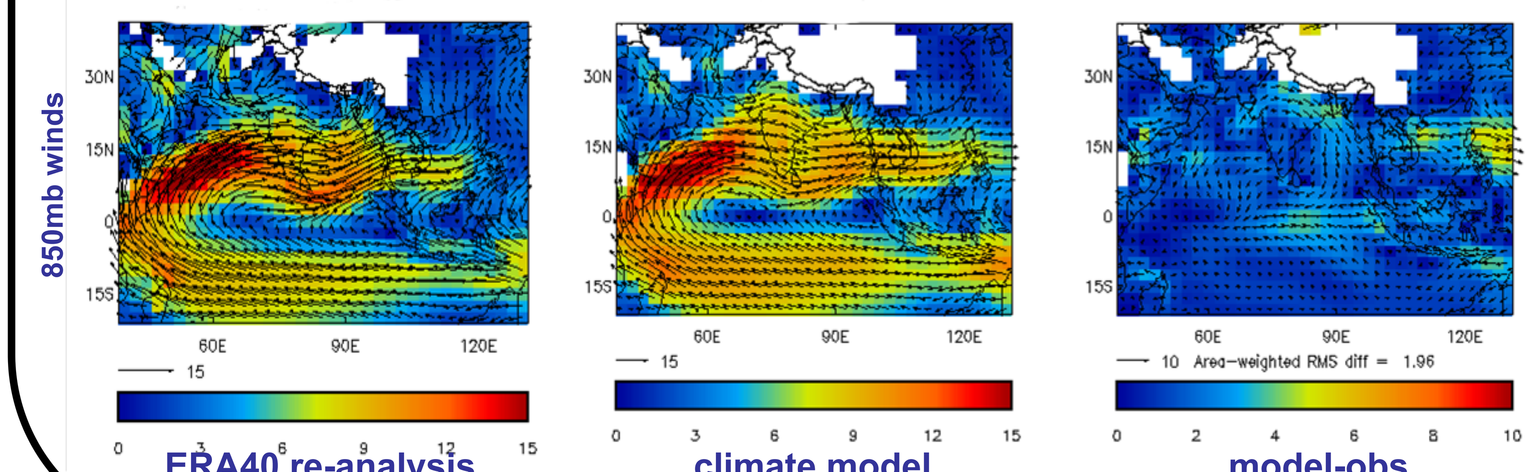
Identifying the causes of errors in the climate configuration of the MetUM is difficult as the model is run onwards for several decades from a climatological initialisation, allowing non-linear feedback processes to affect the long-term evolution. However the 1-5 day NWP and seasonal forecasts show similar error patterns.

The NWP configuration has similar model physics to the climate configuration, but uses a higher resolution horizontal grid. The seasonal prediction configuration differs from the coupled climate configuration only in the way it is initialised.

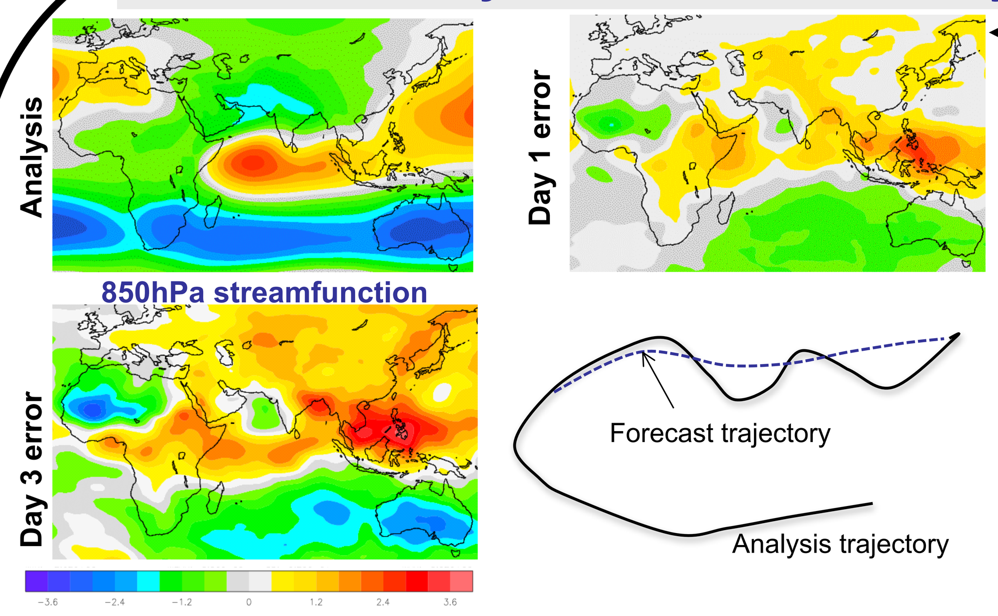
B – Systematic Indian summer monsoon error on climate time-scales



The systematic model error consists of a dry bias over India and excessive precipitation over the West equatorial Indian Ocean. This is accompanied by divergence of the low-level monsoon jet as it reaches Indian land, and a distinct lack of a monsoon trough over North India.

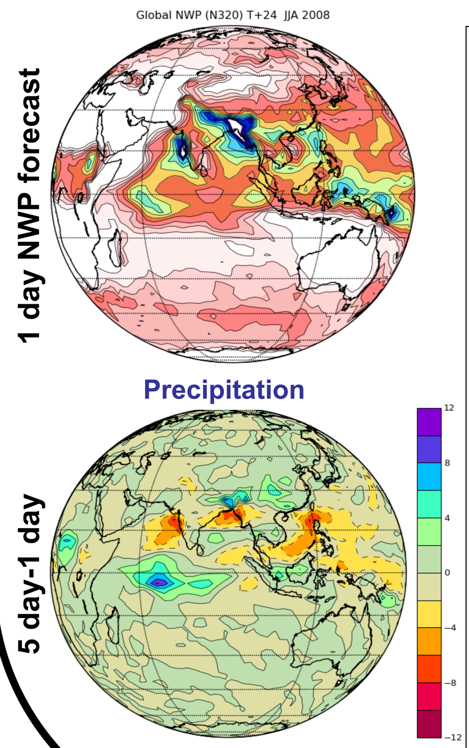


C – Growth of systematic error in 5-day and seasonal forecasts



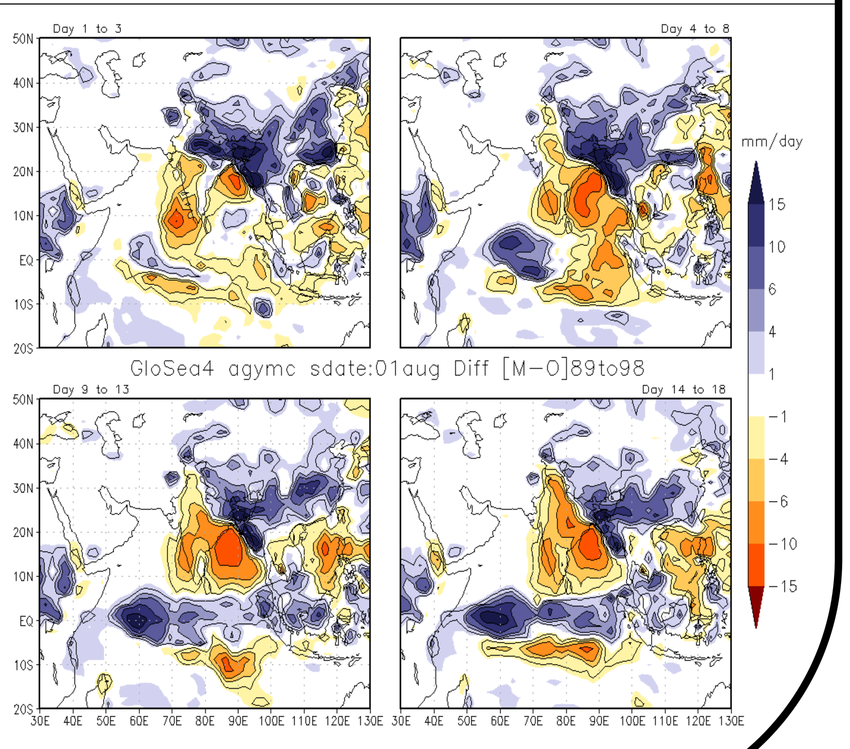
The NWP global forecasting model shows a rapid growth of the West equatorial Indian Ocean precipitation bias in the first 5 days, accompanied by a lack of a wave-like pattern in the low-level circulation.

The rapid growth of the error suggests that the error is a direct impact of a parameterization and not due to a non-linear feedback process operating on longer time-scales.



Examination of seasonal forecasts shows the Indian dry bias develops mainly within the first 10 days of the hindcast simulation of August (1989-1998 mean).

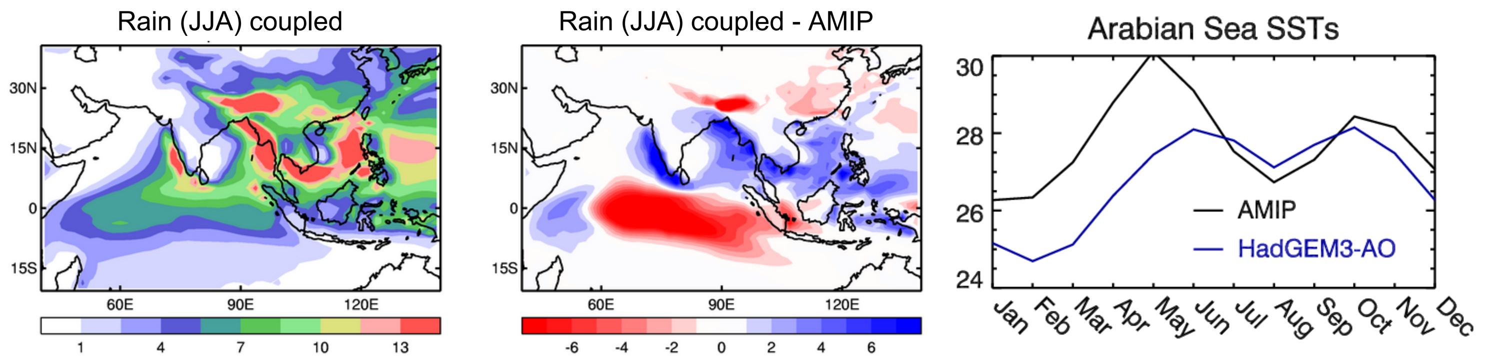
Further analysis shows that the dry bias is enhanced further on 10-20 day time-scales by a lack of northward moving rain-bands from the equatorial Indian Ocean and the Bay of Bengal.

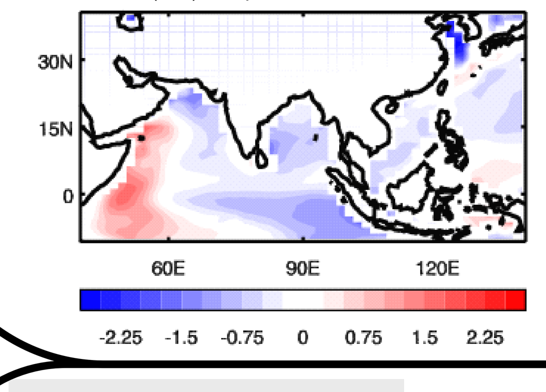


D – Coupled model – local feedbacks

The coupled model has a significant cold SST bias in the N Indian Ocean (which develops in winter) and in the equatorial Indian Ocean (as a response to excessive equatorial convection which is driven by the atmosphere model).

Equatorial rainfall is weakened over equator in the coupled model (modulated by cooling SSTs). The increased land-sea thermal contrast, combined with the reduced equatorial rainfall bias, leads to slightly more rain over India.



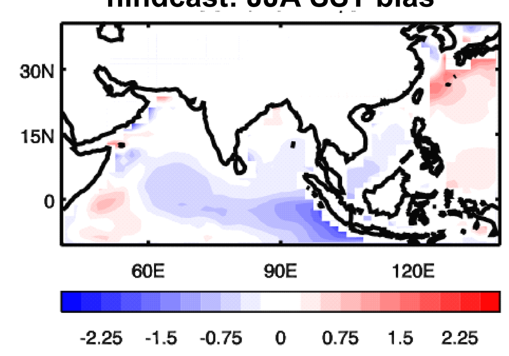


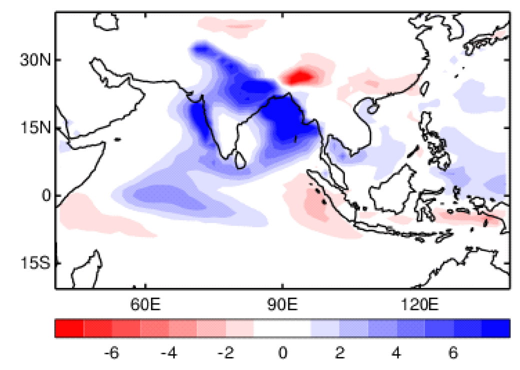
But colder N Indian Ocean SSTs tend to reduce Indian rainfall, particularly in June, by weakening moisture fluxes towards India. This relationship is also seen in observations where strong monsoons depend on additional moisture fluxes across the Arabian Sea (Levine and Turner, 2011).

(see Martin et al. poster W36B in session C28)

E – Implications for seasonal hindcast

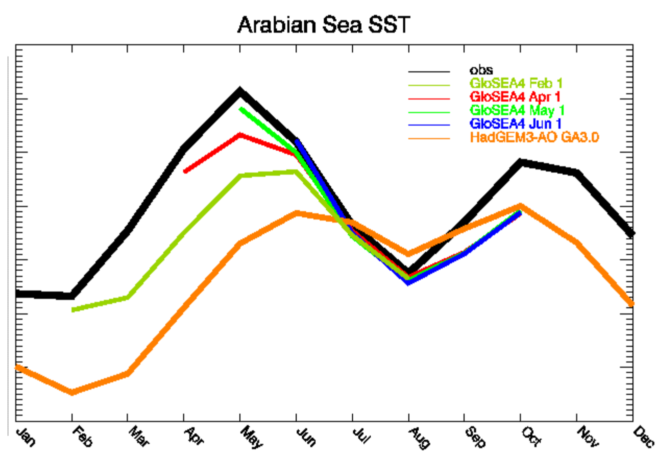
The competing SST biases develop on different time-scales, and have a far larger impact on monsoon rainfall than observed interannual variability. The timing of initialisation of GloSea4 seasonal predictions, a parallel development configuration of the Met Office's seasonal prediction system, therefore has a significant impact on the strength of the monsoon.





Rainfall anomaly: hindcast vs coupled

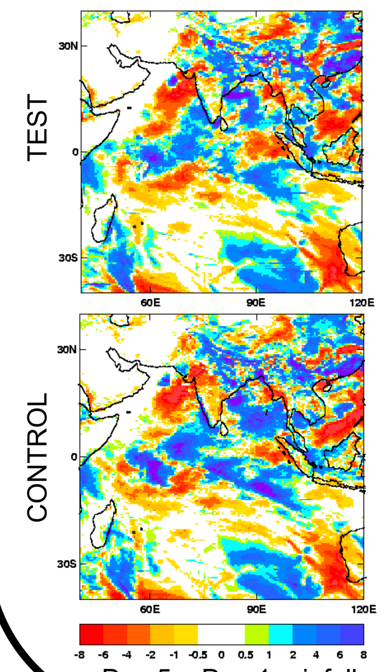
In the hindcast initialised in spring, the cold N Indian Ocean SST bias does not have time to develop, leaving the equatorial SST bias to strengthen the monsoon through the enhanced temperature gradient and the reduced equatorial Indian Ocean rainfall bias.



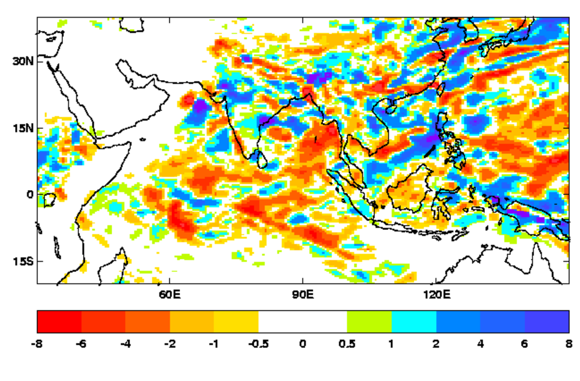
F – Sensitivity to changing physical parametrisations

Changes to the convection parametrisation which reduce the intensity of deep convection tend to reduce rainfall over the favourable region of the equatorial Indian Ocean. This allows more moisture transport towards India, significantly reducing rainfall biases over the Indian region.

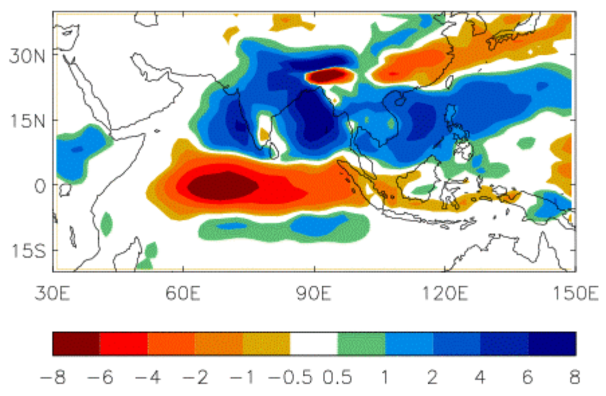
5-day forecast tests in the NWP system show the immediate impact of these changes on the rainfall distribution, and parallel climate tests show that the improvements persist to longer timescales.



Day 5 – Day 1 rainfall



Change in spin-up of monsoon rainfall over 5 days (Test – Control)



Change in monsoon rainfall climatology in 10-year AMIP run

G - Conclusions

Similar systematic errors in simulation of Asian summer monsoon rainfall are seen on a wide range of timescales in a seamless modelling system.

Some are related to physical parametrisations and are evident within the first few days of simulation.

Others are related to sea surface temperature biases which develop in coupled configurations over the months preceding the monsoon, and hence are only evident in simulations which are initialised more than a month in advance.

Compensating biases develop on different timescales, so their impact on monsoon rainfall depends on the model application.

The use of a seamless modelling system allows these biases and their timescales to be identified, so that they can be tackled efficiently.

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References
RC Levine, AG Turner (2011) Dependence of Indian summer monsoon rainfall on moisture fluxes across the Arabian Sea and the impact of coupled model sea surface temperature biases. Climate Dynamics, doi:10.1007/s00382-011-1096-z

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