Progress in simulating the Asian summer monsoon and its variability

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A – Introduction

The Asian summer monsoon is a complex large-scale climate phenomenon whose simulation has proved a challenge for modellers for several decades. Many studies have shown sensitivity to convection and boundary layer parametrisation, cloud microphysics, land surface properties and orography as well as model resolution.

Current climate models share common rainfall biases and few are able to reproduce observed intraseasonal or interannual variability, or teleconnections with Pacific sea surface temperatures. We investigate the influence of local boundary forcing and model parametrisations on the monsoon circulation and rainfall distribution.

Many models also share common sea surface temperature (SST) biases in the Indian Ocean. We explore the influence of such biases on the monsoon simulation.

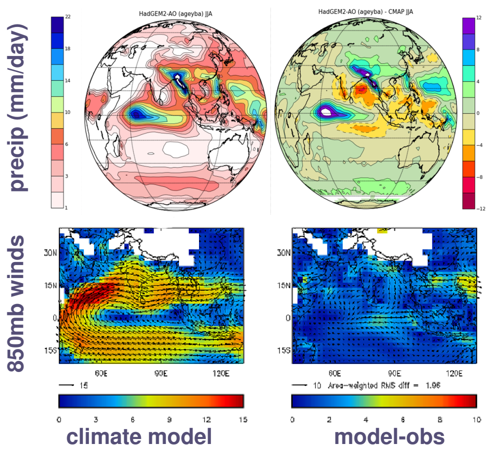
B – Typical systematic errors

Typical systematic errors include:

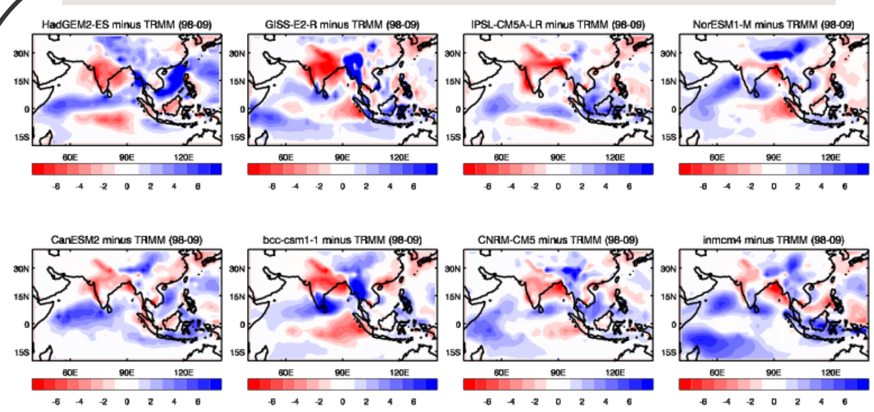
- Dry bias over India
- Excessive precipitation over the West Equatorial Indian Ocean and Himalayas
- Divergence of the low-level monsoon jet as it reaches Indian land
- Lack of a monsoon trough over North India

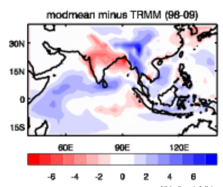
Many of these biases develop within the first few days of the simulation

(see Martin et al. poster W74B in session C25)



C – Common rainfall biases between different models



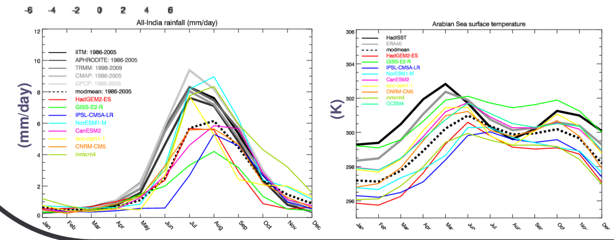


CMIP5 comparison:

Few models can simulate the major precipitation centres and their interannual variation.

Equatorial Indian Ocean precipitation / SST biases are common in many models.

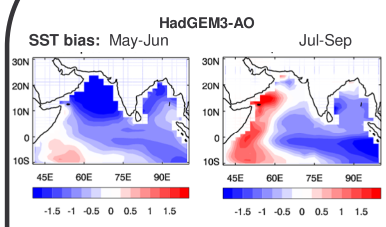
Many models underestimate rainfall over India.



Many models have difficulty in representing seasonal cycle timing and amplitude of rainfall over India.

Many models underestimate rainfall in June, which may be linked to cold SST biases in N Indian Ocean.

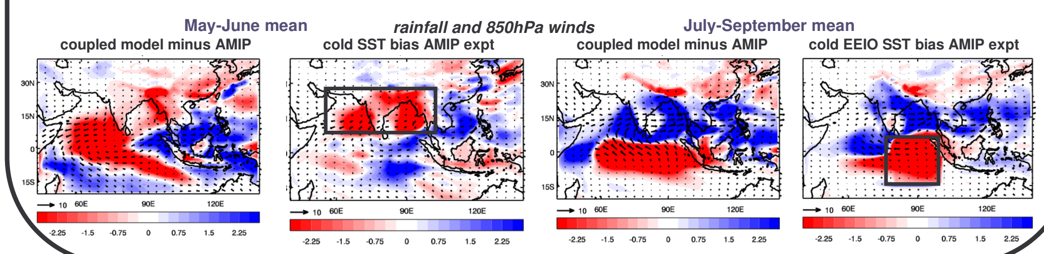
D – Sensitivity to Sea Surface Temperature biases



Cold sea surface temperature biases in the Arabian Sea and equatorial Indian Ocean form in many coupled models.

Sufficiently large Arabian Sea SST biases force changes to the atmosphere (Levine and Turner, 2011). This effect is seen when applying a coupled model-style Arabian Sea SST bias in an AMIP configuration of HadGEM3, with a weakening of monsoon rainfall as a result of reduced evaporation and atmospheric moisture content over the Arabian Sea.

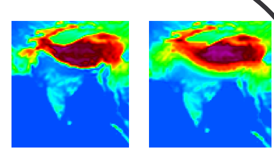
In the coupled model there is a distinct split between the early monsoon season (May-Jun), when the Arabian Sea SST bias weakens the monsoon, and Jul-Sep when the difference between coupled model and AMIP is consistent with strengthening associated with the equatorial cold SST bias.

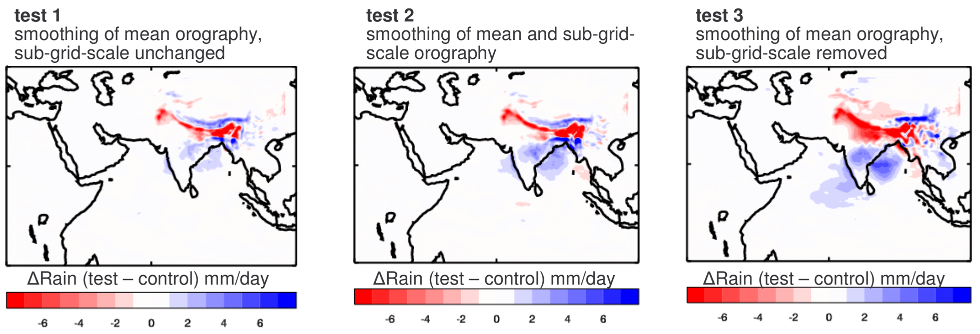


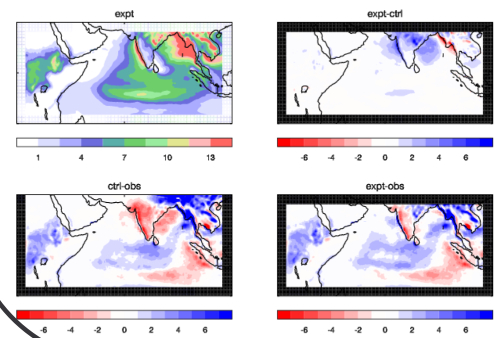
E – Sensitivity to local orography

Smoothing steep slopes results in reduced convergence - reduces the Himalayan wet bias and moves rainfall to Central India and the western Bay of Bengal (improvement)

Sensitive to the representation of both mean and sub-grid-scale variability of orography.







Removing Himalayas [and influence of bias] from RCM domain

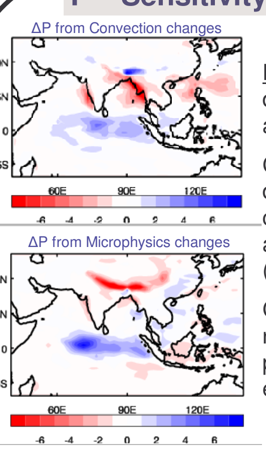
Moving northern boundary to exclude Himalayas from domain significantly reduces Indian dry bias → similar impact to smoothing steep slopes

This suggests that the Himalayan bias limits moisture transport towards Central India

→ problem with convection and/or flow near steep orography

RCM: 50km W Asia CORDEX domain forced by 6-hourly ERA interim re-analysis lateral boundary conditions [has similar systematic monsoon error to GCM]

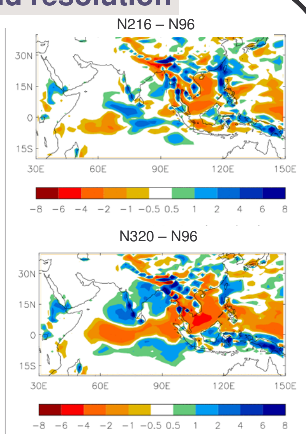
F – Sensitivity to changing model physics and resolution



Example: Changes made to convection diagnosis and cloud microphysics aimed at reducing spurious light rain.

Changes to convection diagnosis result in drying over India and Myanmar (where convection moves from deep to shallow) and enhancement of equatorial wet bias (feedback).

Changes to cloud microphysics reduce rainfall over Himalayas (where have most persistent light rainfall) and enhance equatorial wet bias (feedback).

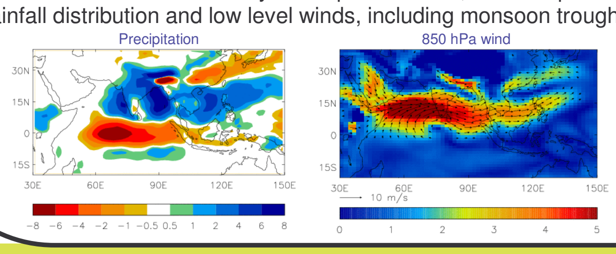


Resolution: Little sensitivity to change between N96 (1.875º x 1.25º) and N216 (0.83º x 0.56º)

We see a greater impact of changing between N96 and N320 (0.56º x 0.375º)

Changes are smaller than those seen for changing model physics.

Addition of water loading to the buoyancy calculation used in adaptive detrainment reduces the intensity of deep convection, which improves the rainfall distribution and low level winds, including monsoon trough.



G – Summary and future challenges

Models share common biases in climatology and variability of the Asian summer monsoon.

Many of the errors are forced locally (in time and space) although some are related to biases which develop during the preceding winter (e.g. Arabian Sea SST cold bias).

Sensitivity to model resolution is weaker than sensitivity to model physics.

Challenges:

- **Representation of flow and rainfall over steep orography:** What does it really look like? Are the observations good enough? How can high-resolution (convection resolving) regional simulations help?
- **Coupled model SST biases – errors in mean state feed back on monsoon climatology, variability and teleconnections:** Is increased horizontal resolution in atmosphere and ocean required? Linked to atmosphere parametrisation problems (e.g. equatorial Indian Ocean)
- **Poor ENSO – monsoon teleconnections** *(see Turner et al. poster M232A in session C1)* **:** Influenced by SST biases and overall tropical circulation biases. Incorrect convection-dynamics coupling and/or incorrect diabatic heating?

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References
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