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The monsoon in the coupled HadGEM3 system and its predictability in seasonal hindcasts

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Outline

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- The HadGEM3 model and its monsoon
- The monsoon-ENSO system in HadGEM3
- Seasonal hindcasts in the GloSea system
- Case studies and systematic biases
- Future efforts and the monsoon mission

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Coupled model set up

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- HadGEM3 version of Met Office model, running at UMvn8.5, GA6/GL6
- Coupled to ORCA025 ocean model, 0.25° horizontal resolution, L75 vertical resolution.
- Two versions of atmosphere: N96 (1.875°x1.25°) and N216 (0.83°x0.55°) horizontal resolution, L85 vertical resolution ("well-resolved" stratosphere) each with 75+ years integration.

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Mean state biases in HadGEM3

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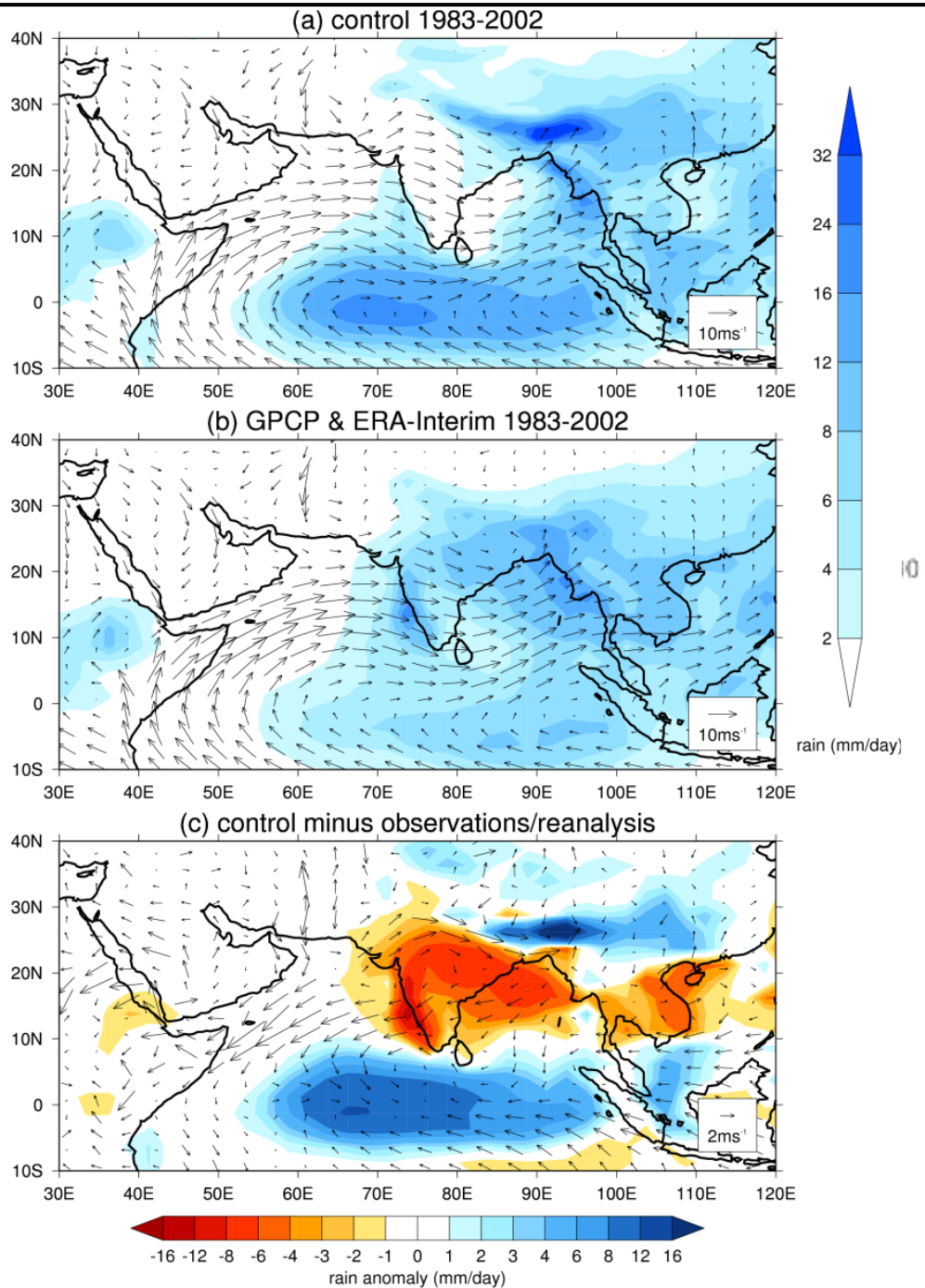


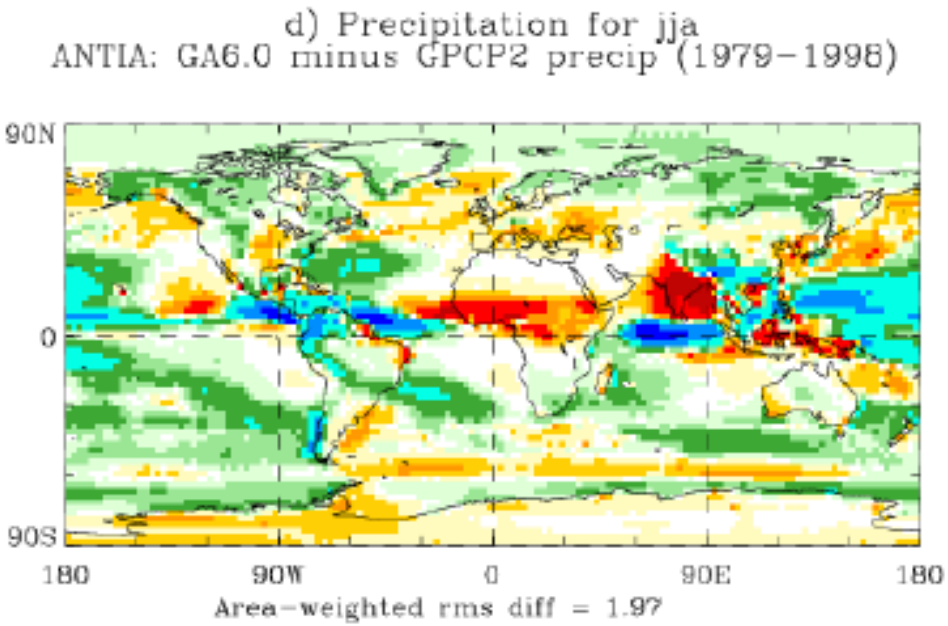
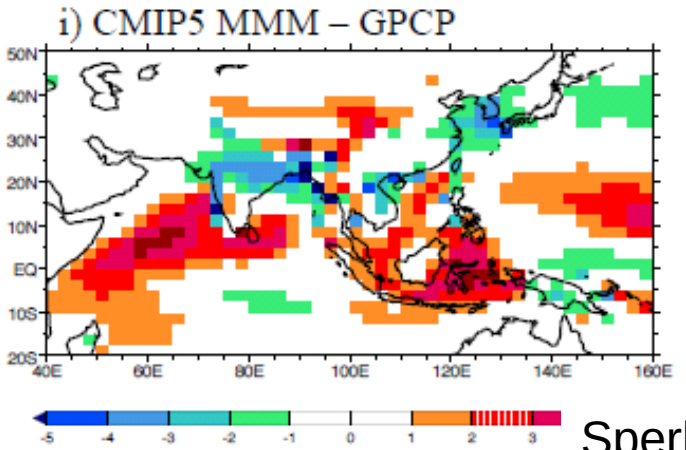


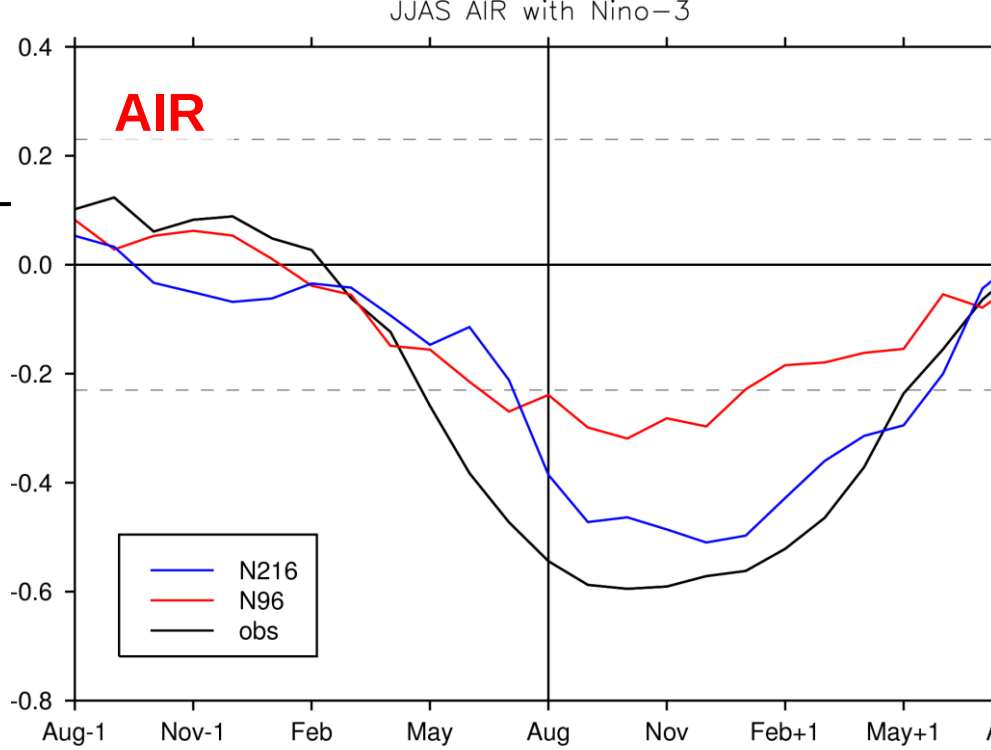
Figure from Keith Williams et al.
GC2 assessment © Met Office 2014

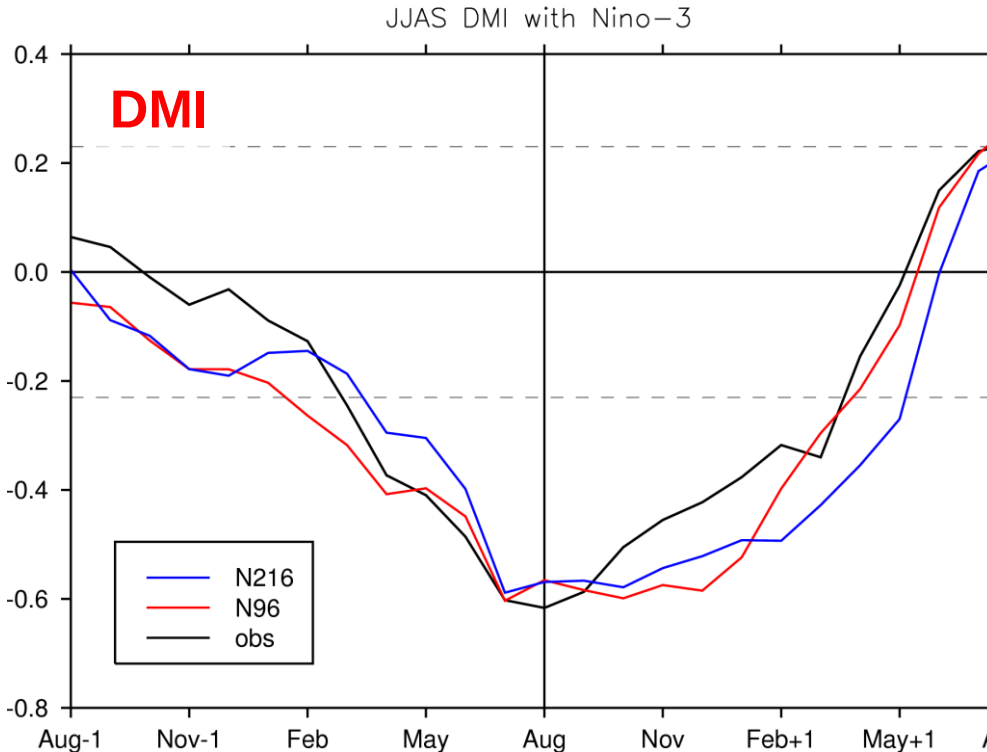


Sperber et al. (2013)
Clim. Dyn.

Monsoon-ENSO relation in coupled HadGEM3

- Observations show strong negative correlation, peaking during-to-after the monsoon season
- Substantial improvement in teleconnection with atmospheric resolution?
- Large-scale teleconnection measured using DMI is good anyway (larger domain, so we expect it to fare better than a local measure such as AIR)





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ENSO evolution in coupled integrations

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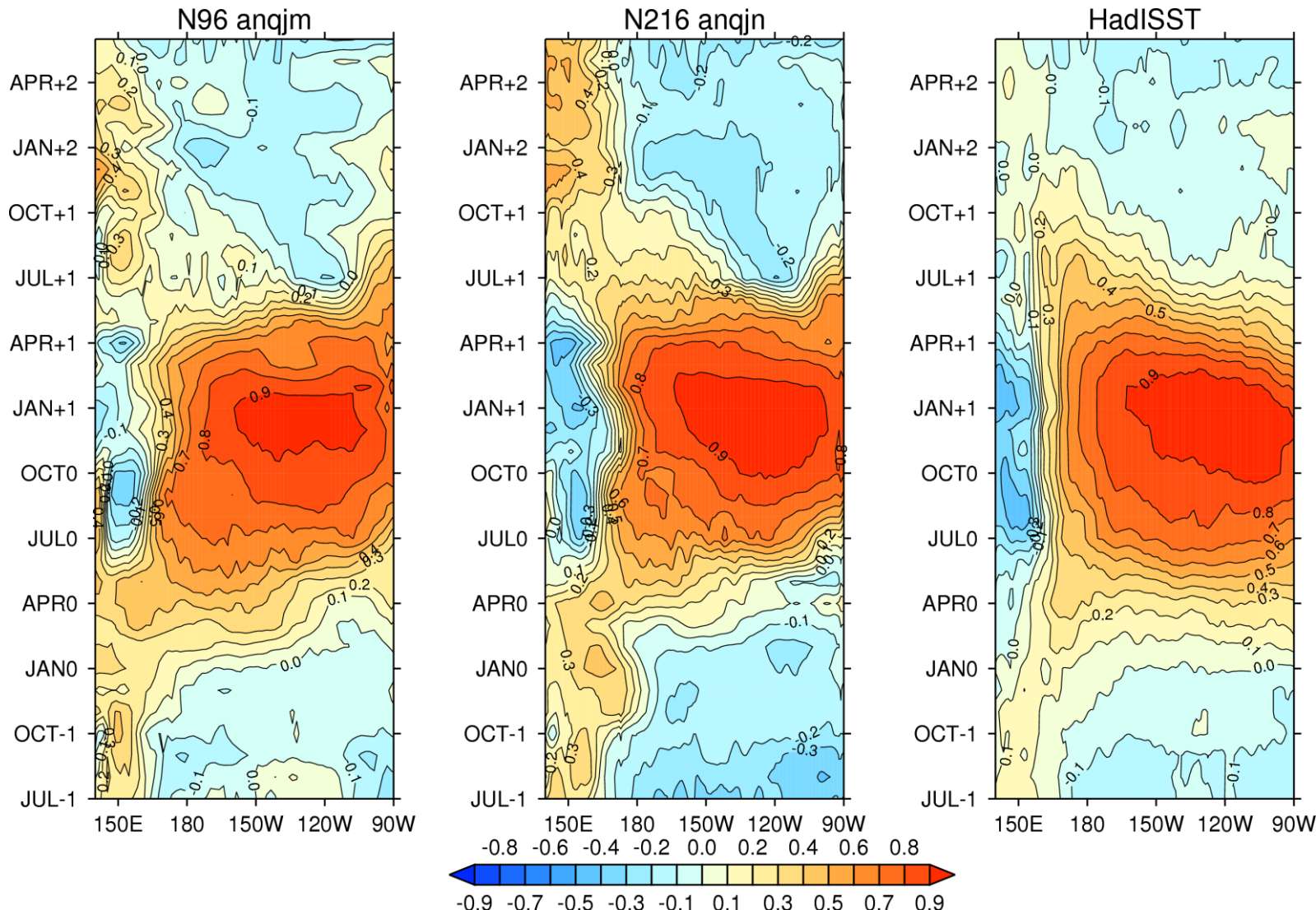
- Correlation of DJF Niño-3 SST with lagged equatorial Pacific SST (±2.5°).

• Is N216 coupled run more biennial?
• But at the same time, is the El Niño warm peak longer lasting?



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Impact of tropical Pacific mean state SST on monsoon-ENSO teleconnection

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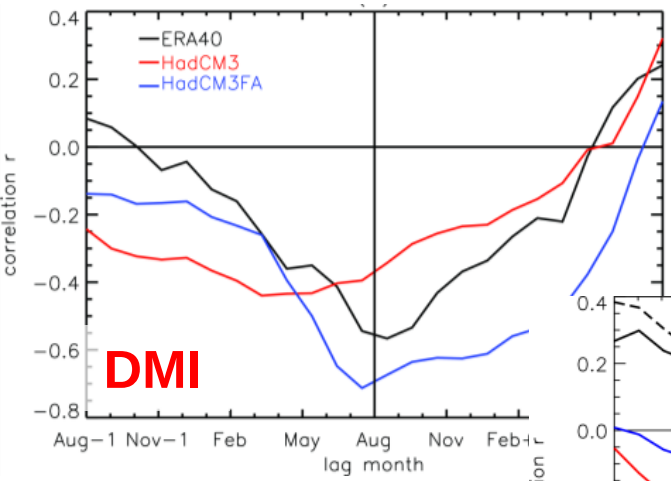

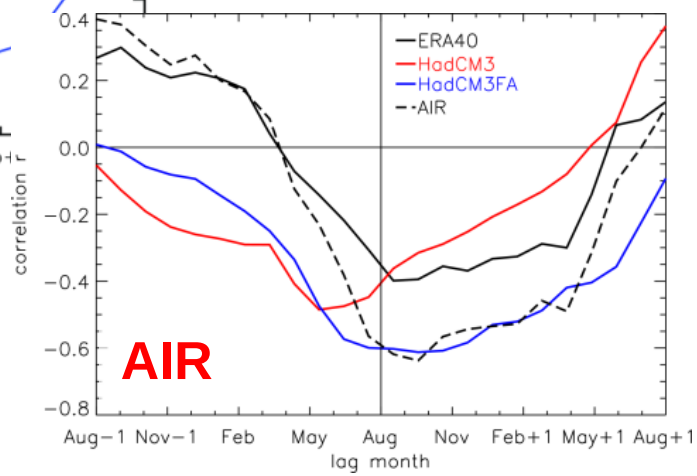

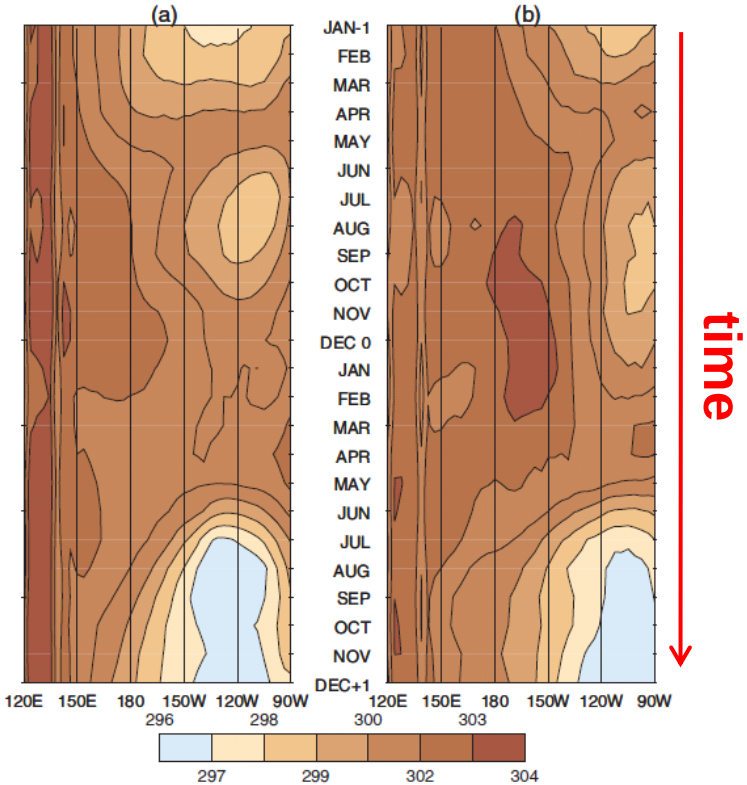

- By using heat flux adjustments to correct equatorial SST biases, Turner *et al*. (2005) showed that the monsoon-ENSO teleconnection could be improved in HadCM3.
- Composite El Niño events show the warmest waters to move further east in the flux corrected model.

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Impact of tropical diabatic heating on teleconnection in the CMIP3 models

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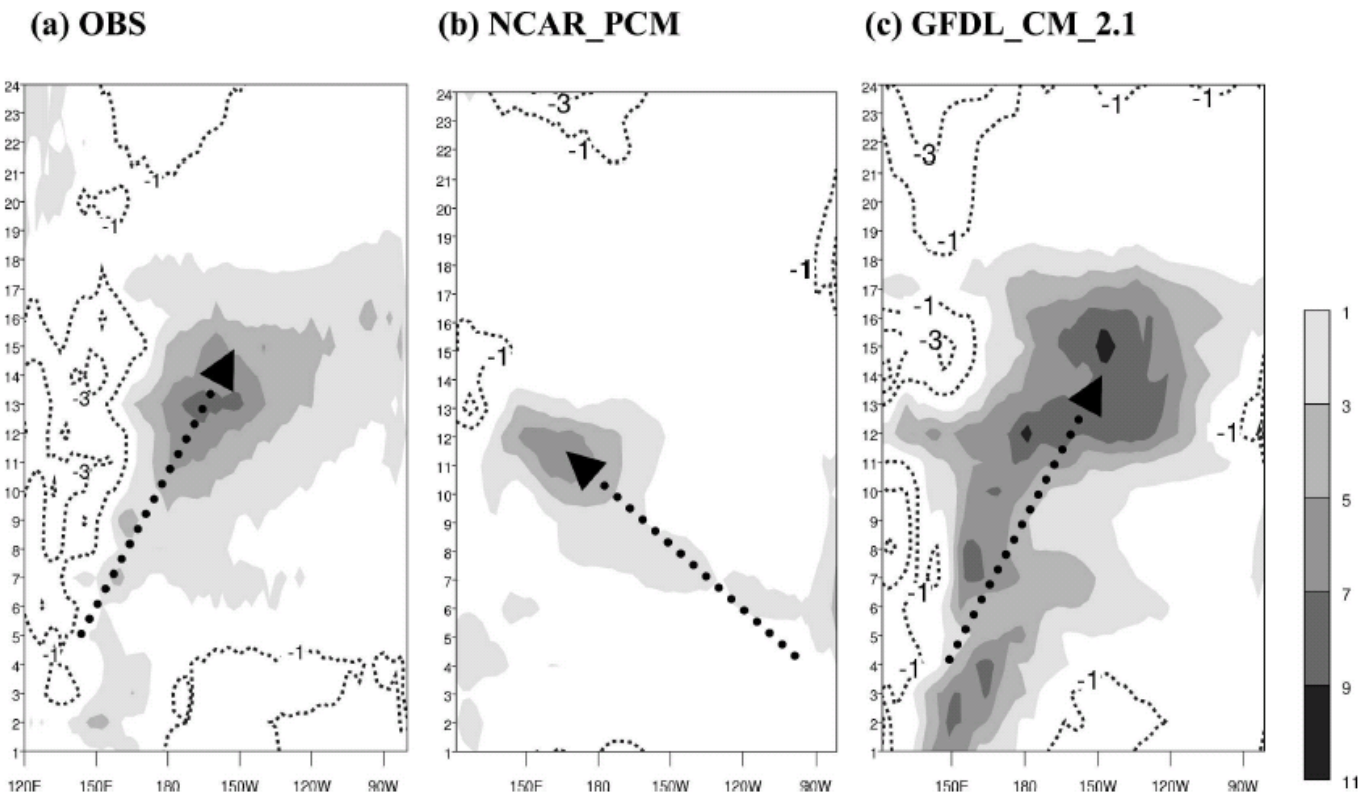

FIG. 4. As in Fig. 3 but for precipitation anomalies: (a) observations, (b) NCAR_PCM, and (c) GFDL_CM_2.1. Positive values are shaded progressively while negative values are shown in contours with an interval of 2.0 mm day^{-1}.

- Annamalai *et al*. (2007) showed importance of the correct location of diabatic heating anomalies in the equatorial Pacific to simulation of the monsoon-ENSO teleconnection.

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Coupled initialised seasonal hindcasts design

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- Coupled ocean-atmosphere system with initialised, atmosphere, ocean and sea-ice components.
- Atmosphere HadGEM3 GA6/GL6 at N216 horizontal resolution (0.83°x0.55°) with L85 in the vertical.
- Ocean ORCA0.25, 0.25° horizontal resolution, L75 vertical resolution.
- Initialised several times per year; in this case our interest is the “May” start date cases: 25th April; 1st May; 9th May.
- Hindcasts for each year of 1996-2009.
- Each start date case features 3 ensembles members, making 9 members in total analysed here.

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Hindcasts: India JJA rainfall time series 1996-2009

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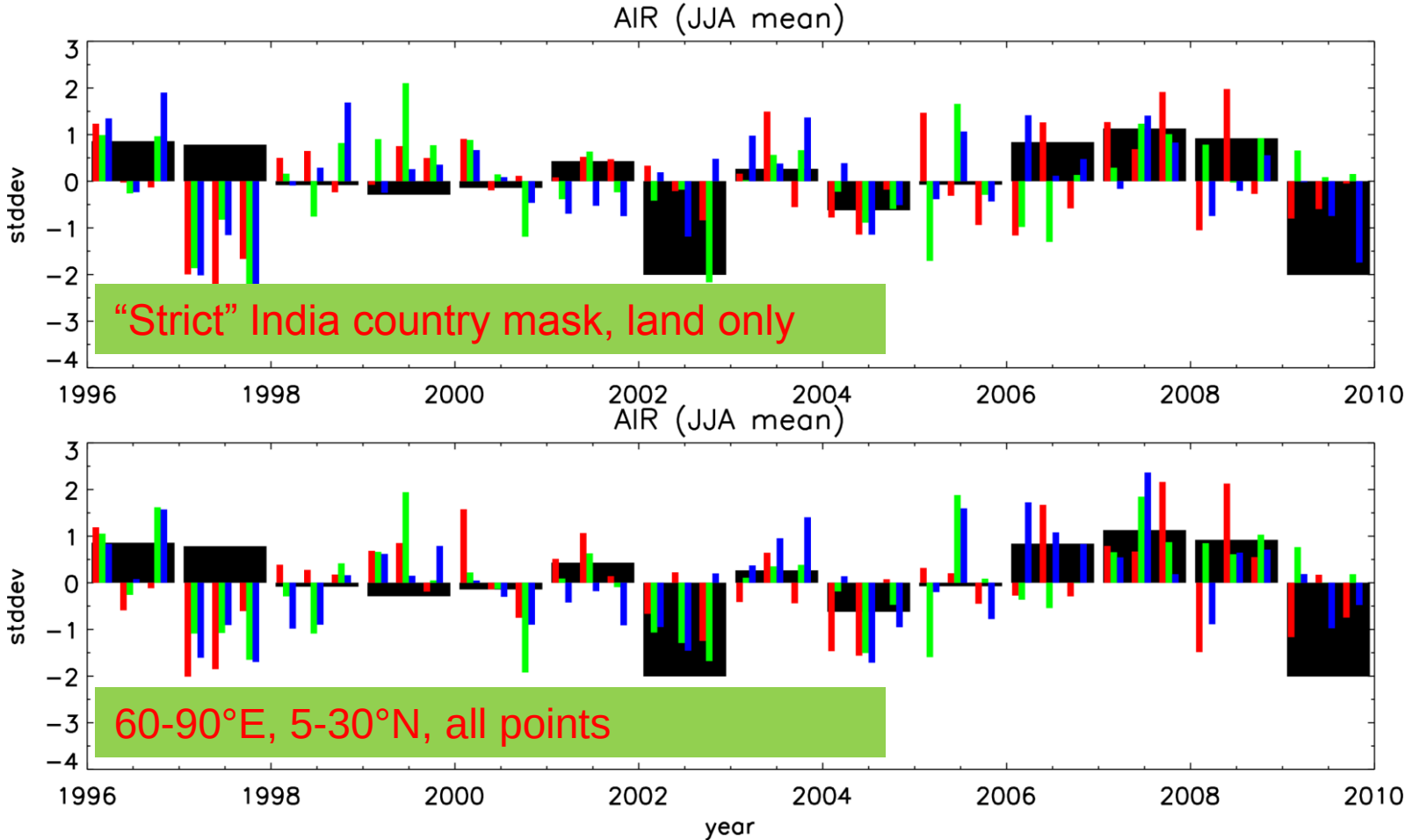
- Observed AIR (black) versus 3 members for each of 3 start date sets (0425, 0501, 0509); colours are ensemble members, dates from left to right.
- Some years do well, others do not (remember long coupled run at N216 features good teleconnection).
- 1997 fails as usual, better in 2002 and 2009.



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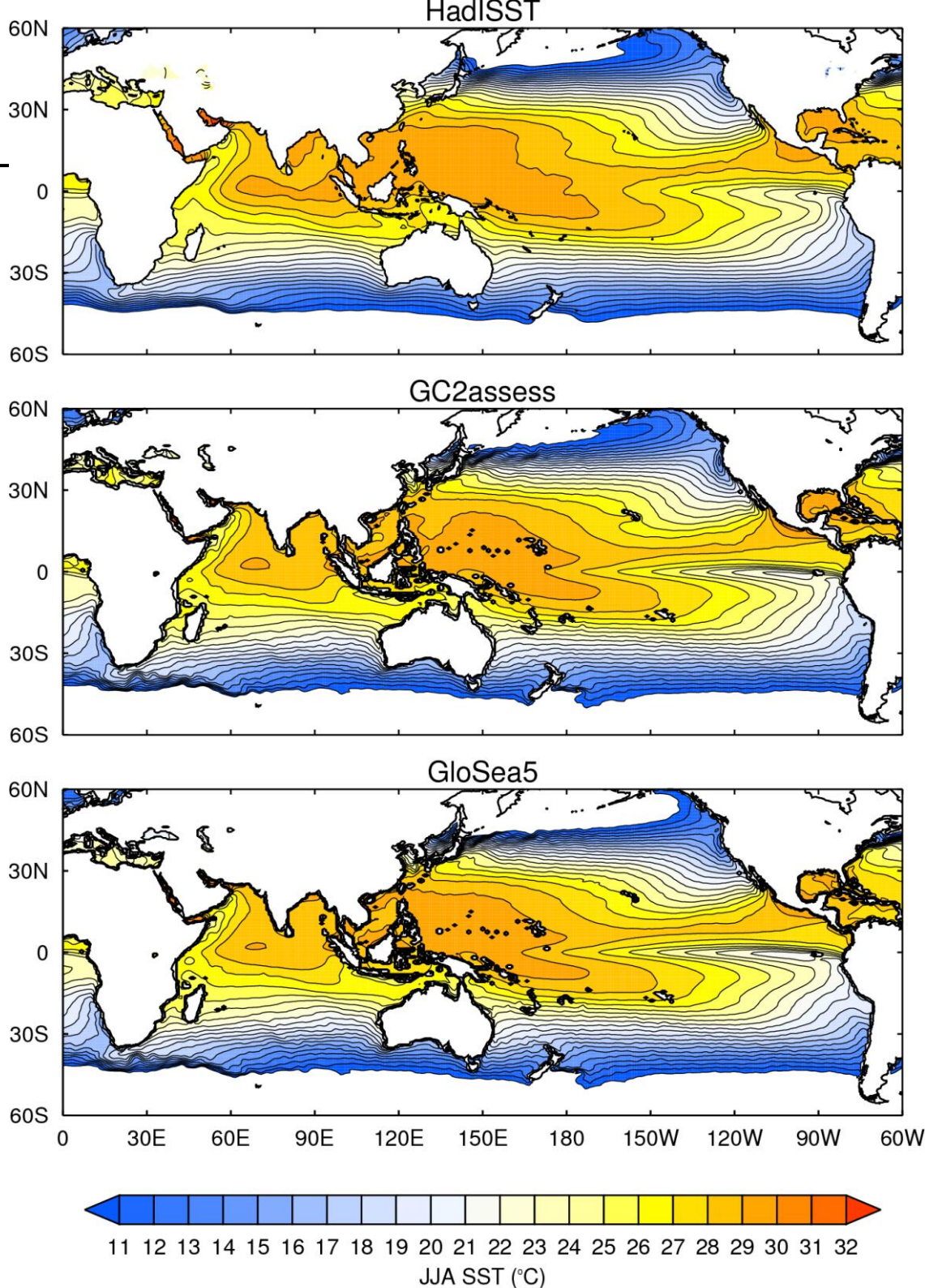
SST JJA mean state

- Some improvement in JJA mean-state SST with respect to GloSea5.
- Still missing some warmth in the Indian Ocean.



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Hindcast runs: regression of SST (left) & vp200 (right) onto Niño-3.4

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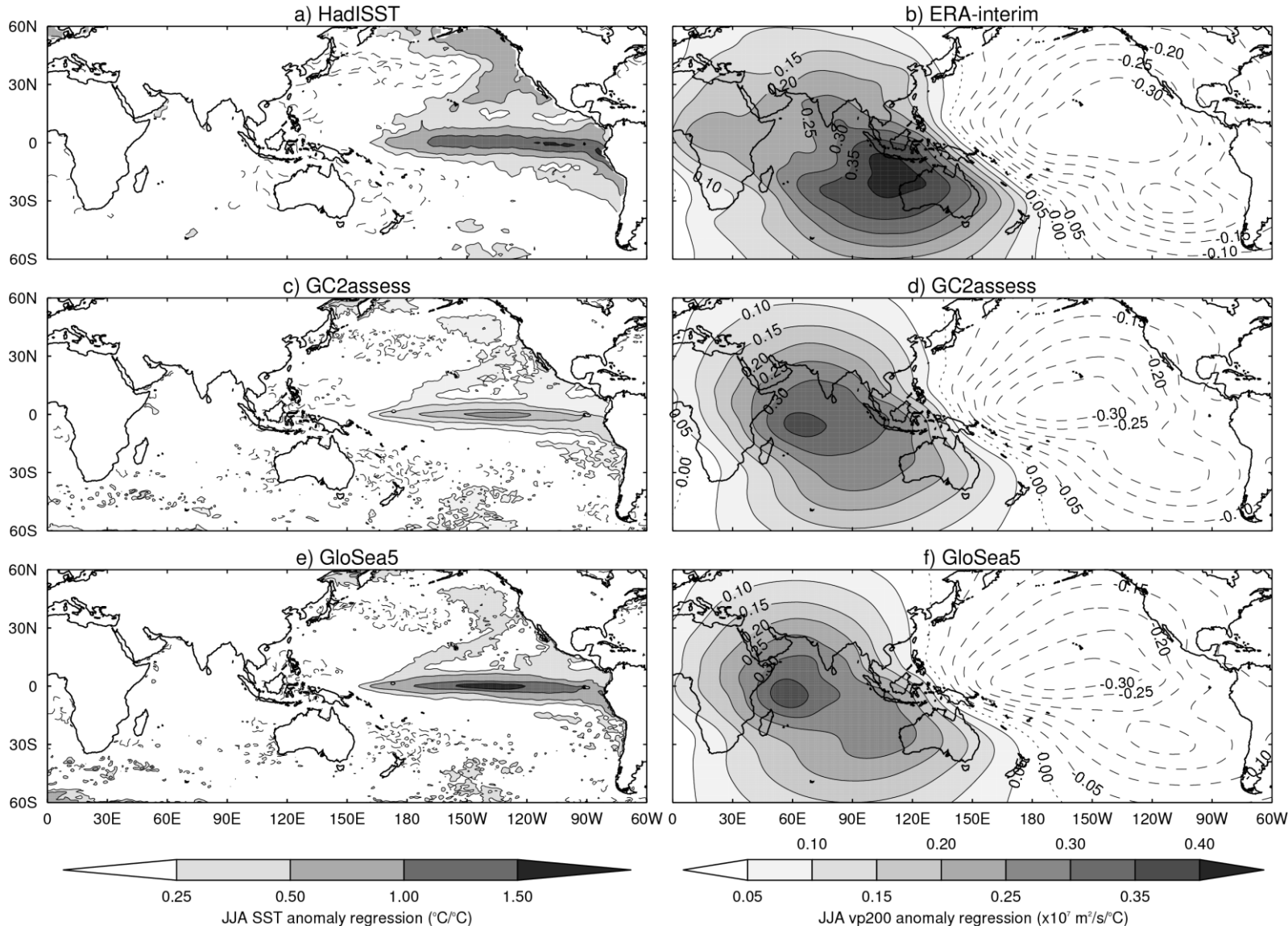
- Still too much upper level convergence over WEIO.
- Improvement in westward extent of warm anomalies associated with El Niño.



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Effect of different types of El Niño event on occurrence of monsoon drought

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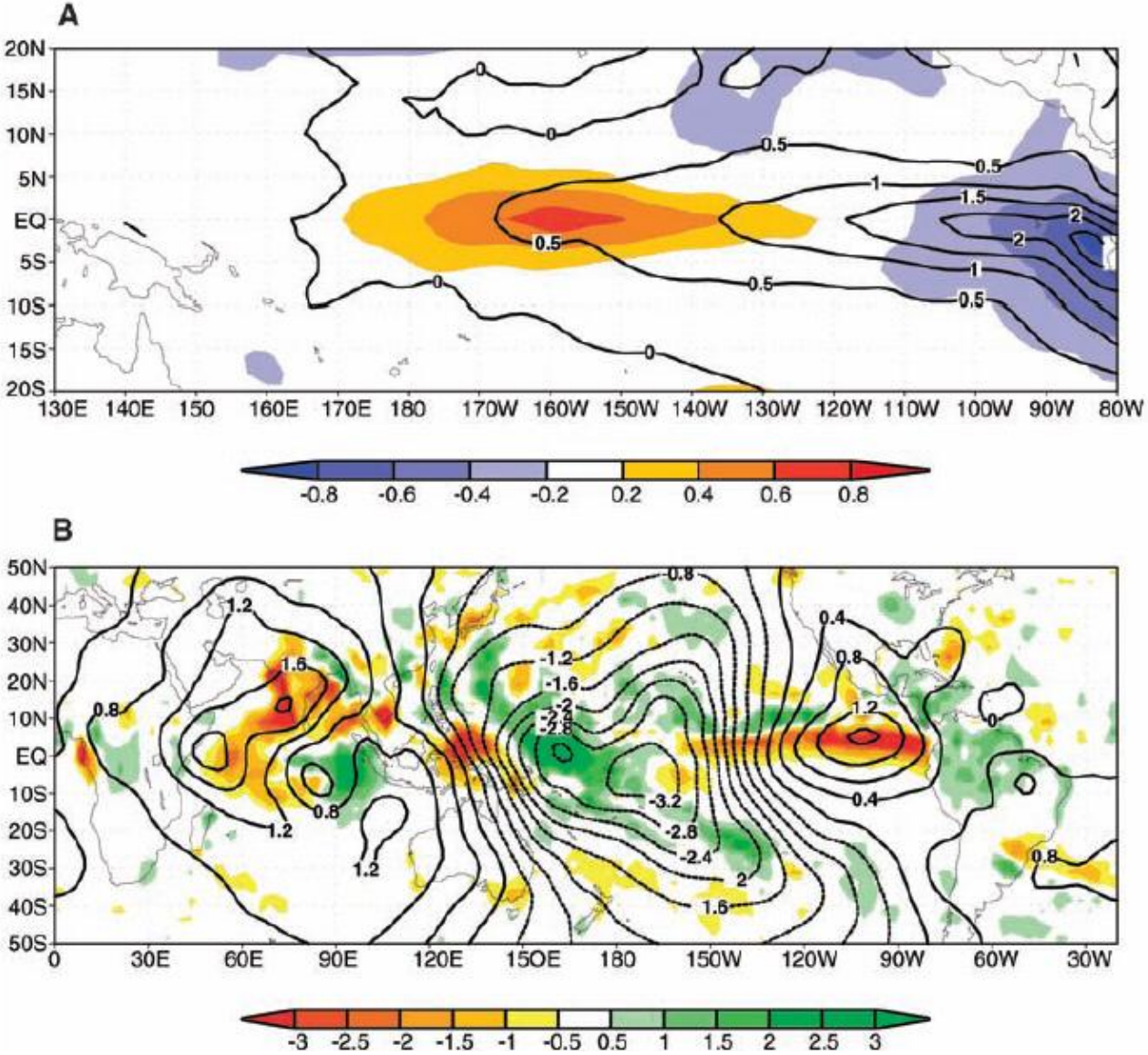

- Krishna Kumar *et al*. (2006) looked at the difference between drought and non-drought monsoons during El Niño .
- Severe droughts occurred during central Pacific events.

Fig. 2. (**A**) Composite SST difference pattern between severe drought (shaded) and drought-free El Niño years. Composite SST anomaly patterns of drought-free years are shown as contours. (**B**) Composite difference pattern between severe drought and drought-free years of velocity potential (contours) and rainfall (shaded). (**C**) PDF of all-India summer monsoon rainfall from severe-drought (red curve) and drought-free (blue curve) years associated with El Nino occurrence and from the non-ENSO years (green curve). SST and velocity potential composite differences are based on 1950 to 2004, rainfall composites are based on 1979 to 2004, and PDFs are based on 1873 to 2004.

Hindcast runs – 1997 anomalies

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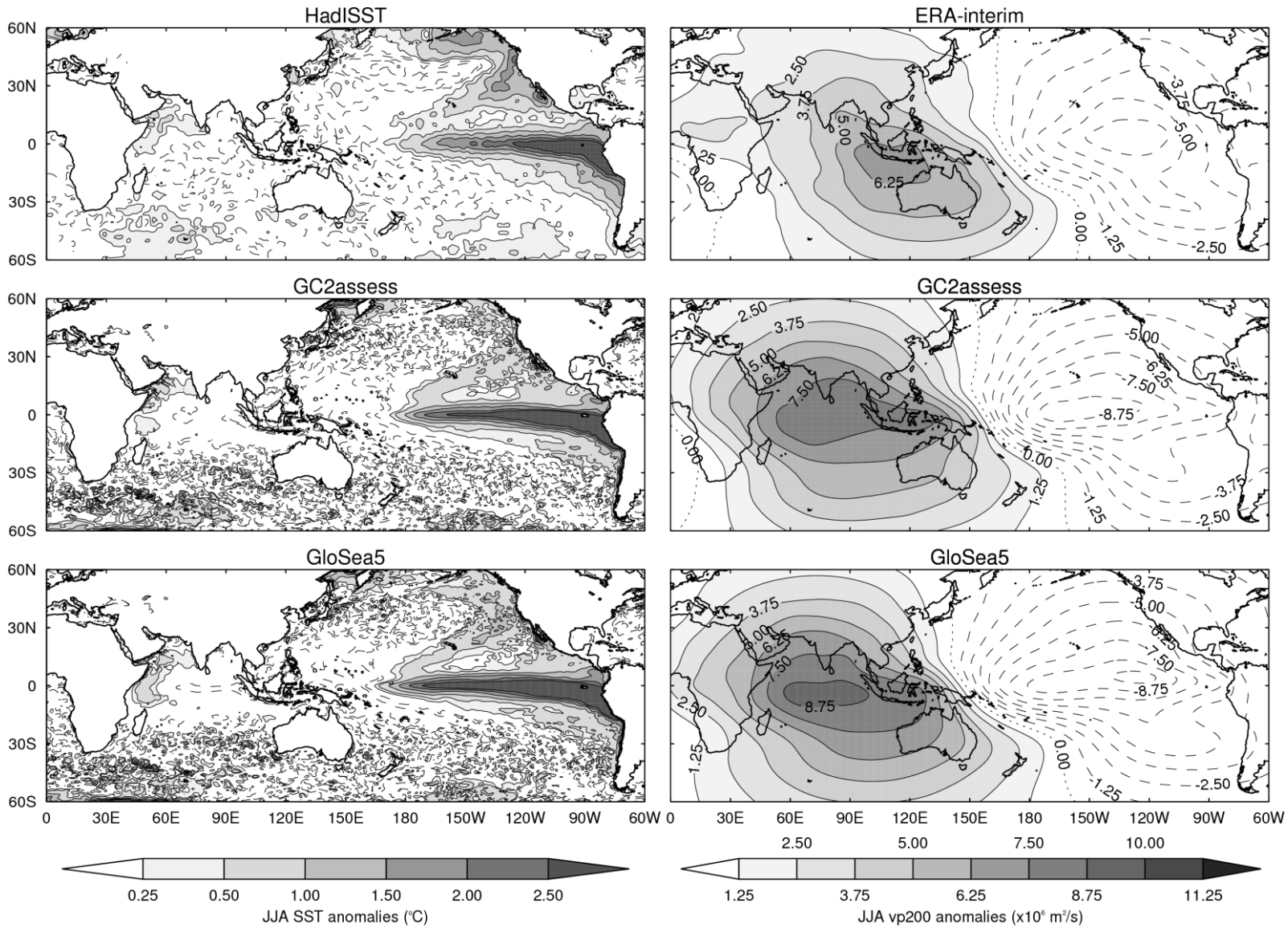
Large East Pacific El Niño, Indian monsoon ~102% LPA



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Hindcast runs – 2002 anomalies

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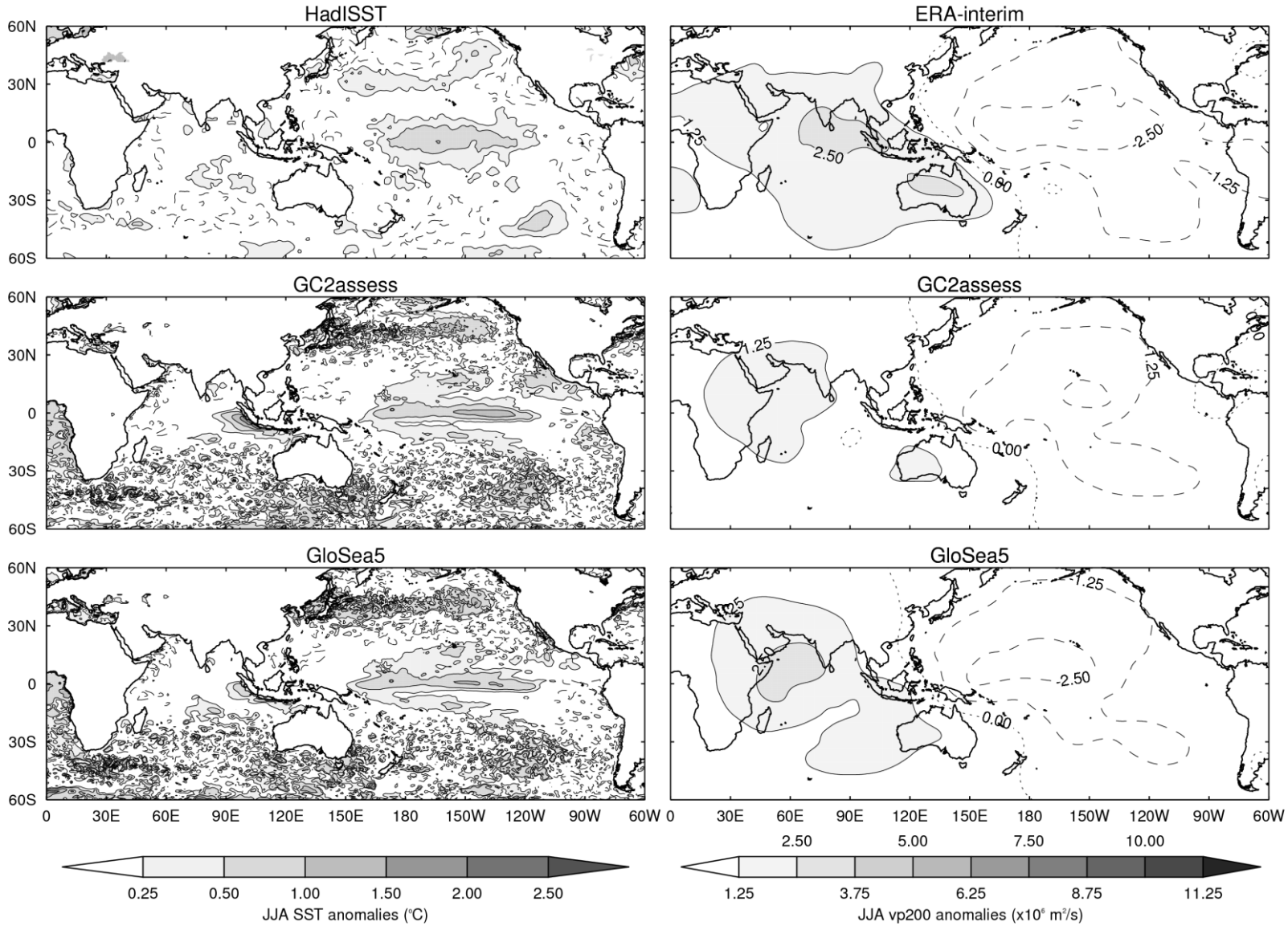
Small central Pacific El Niño (+MJO?), Indian monsoon ~81% LPA



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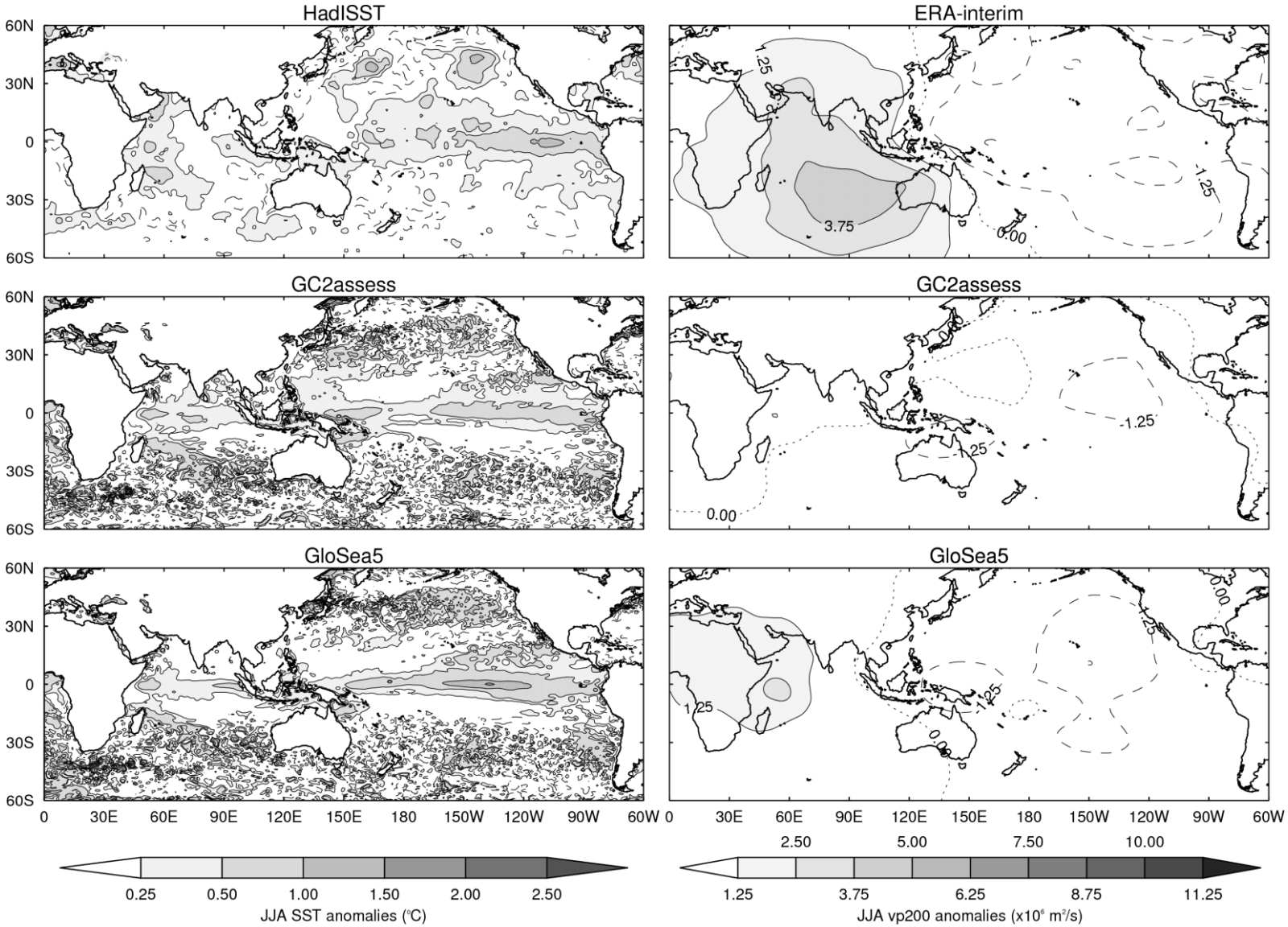
Hindcast runs – 2009 anomalies

Small central Pacific El Niño (+MJO?), Indian monsoon ~78% LPA



Hindcast runs: regression of SST (left) & precipitation (right) onto Niño-3.4

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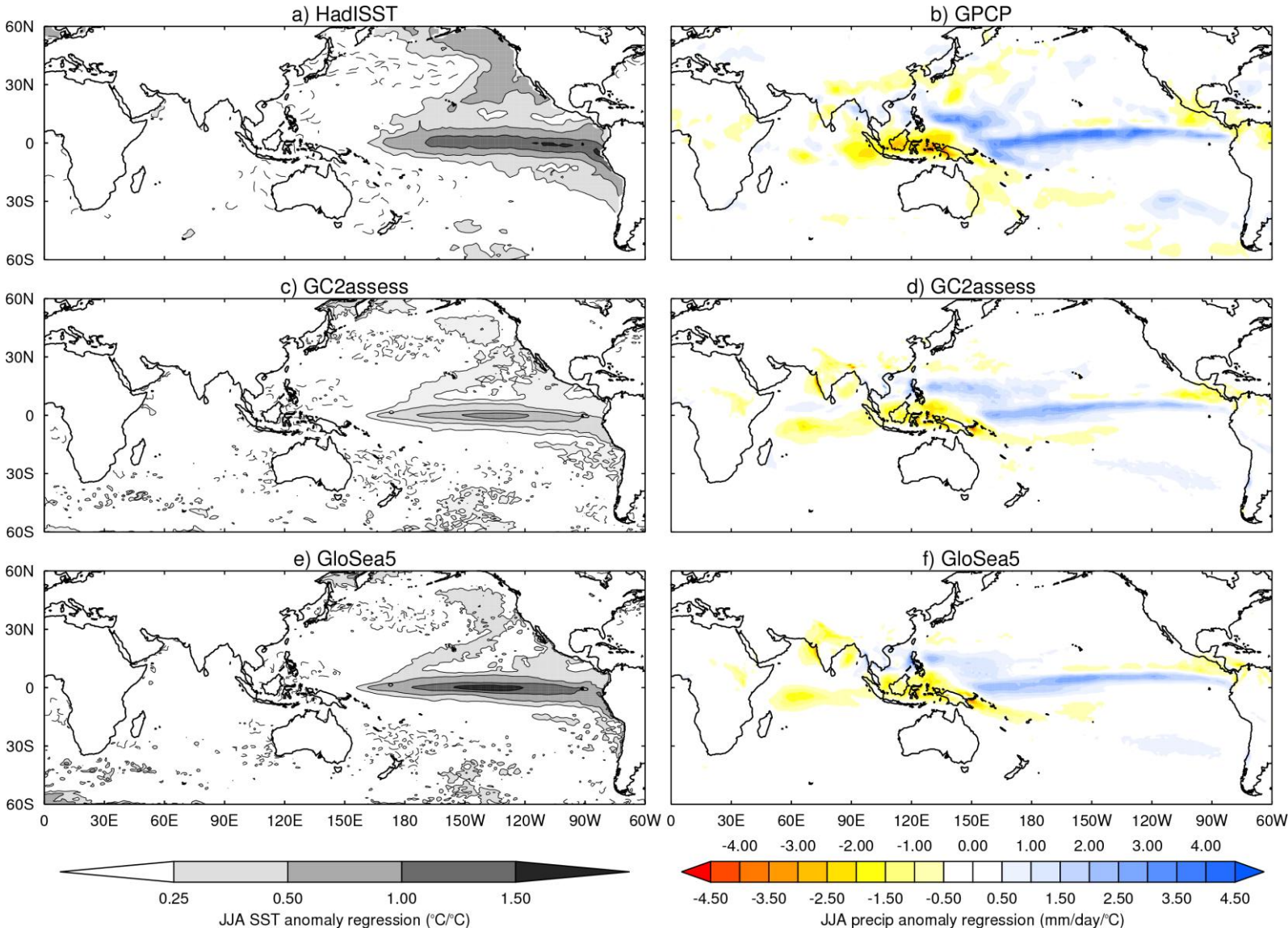
- Response of the upper-level stream function looks much better over and southern Africa/Indian Ocean.
- Notable difference over India.



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Summary

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- GC2 assessment model features good dynamical teleconnection with ENSO; the (localized) rainfall teleconnection improves with resolution (to be understood).
- Assessment hindcasts appear poor when using strict India mask but larger regional precipitation is more encouraging.
- Hindcasts certainly no worse than GloSea5.
- Westward bias in anomalous divergent circulation still evident in response to El Nino (and see 1997 and 2002/9 case studies for anomalies in those years).
- Precipitation regression looks good but some rain is off the coast/in Himalayas.

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Development of error e.g., Pacific SST

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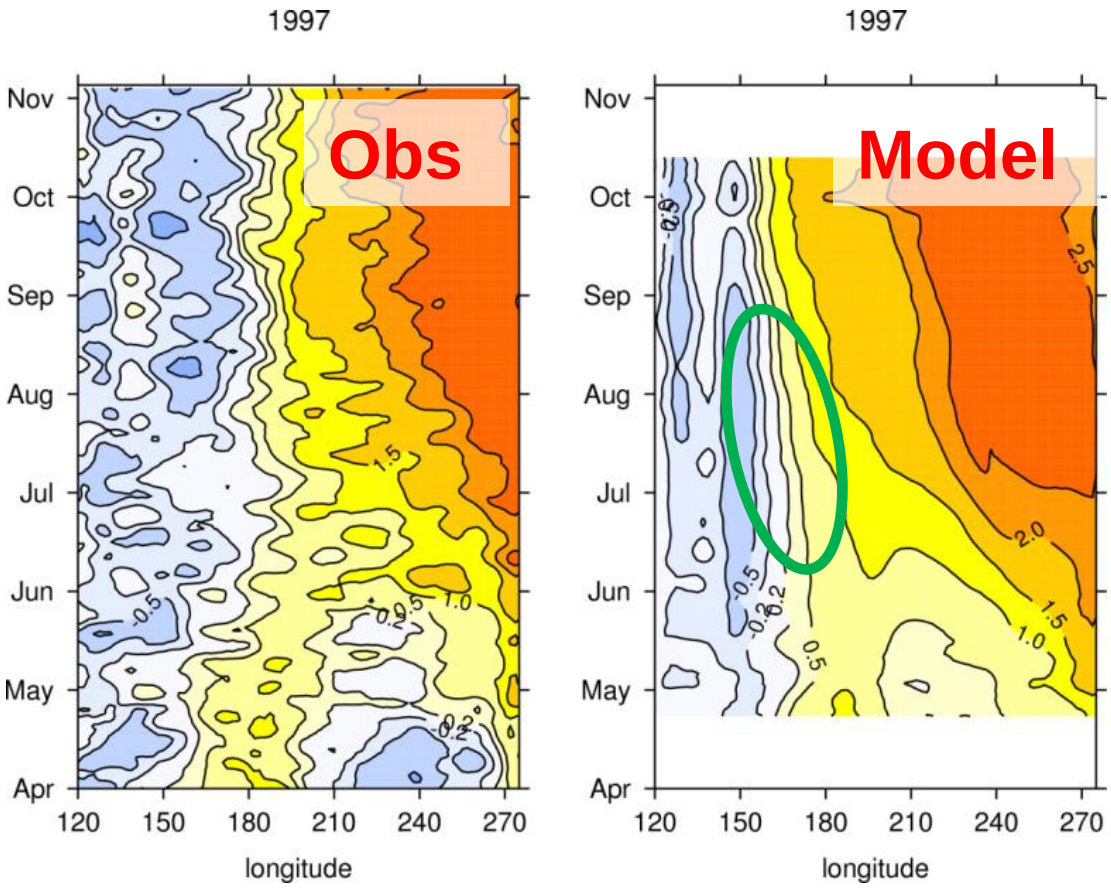
Rapid development of SST errors along the equator and in Niño region:



Following initialisation model shows rapid development of warm SST error west of the date line: but East Pacific cools quickly

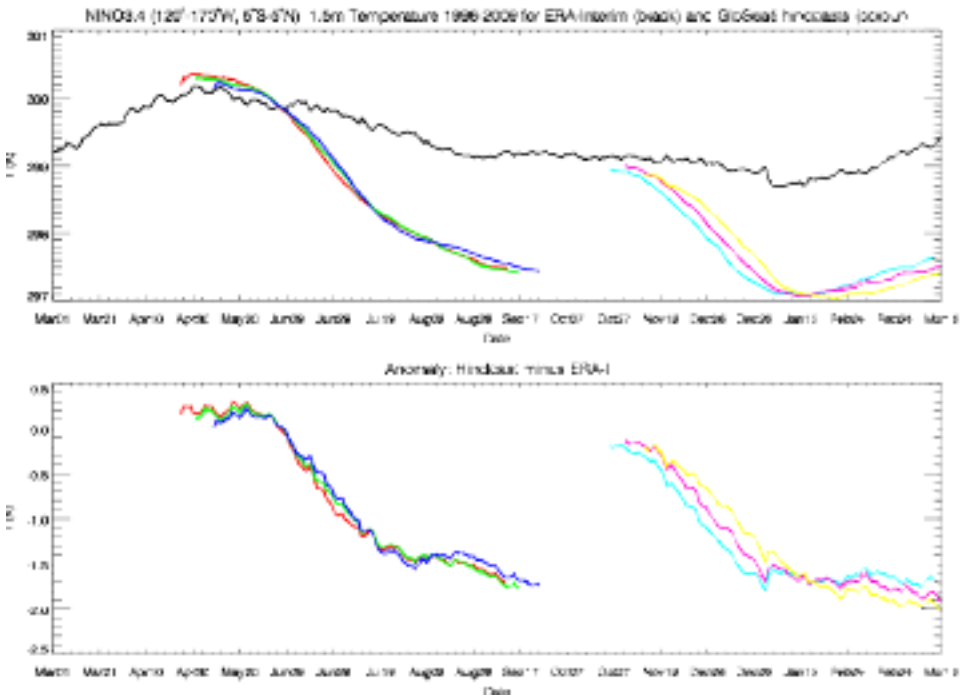


Figure from Keith Williams et al.
GC2 assessment © Met Office 2014 →

Prospects for the future – Indian Monsoon Mission

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- We are grateful to MoES/IITM Monsoon Mission Secretariat for approving our project *"Improved Indo-UK capability for seamless forecasting of monsoon rainfall: from days to the season".*
- 3-year project to begin in the next couple of months, collaboration between UoR (PI Turner, with S Woolnough & PDRA Stephanie Bush), UK Met Office team, NCMRWF (Rajagopal + visiting scientist exchange).

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Prospects for the future #2 – NERC/MoES Drivers of Variability in South Asia

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- Joint MoES funding round for field campaign and modelling work in India.
- Prospect of ground/ship-based field campaign in summer 2016, together with UK research aircraft.
- 3 bids, hopefully all funded.
- INCOMPASS (Interaction of Convective Organisation, Monsoon Precipitation, Atmosphere, Surface and Sea) including IISc (Bhat), Reading (Turner), NCMRWF, Leeds, Met Office, IIT-Kanpur, NAL.

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The end

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Thank you for your attention!

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Monsoon clouds: Marcel Costa
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