Decadal changes in the relationship between Indian and Australian summer monsoons

By

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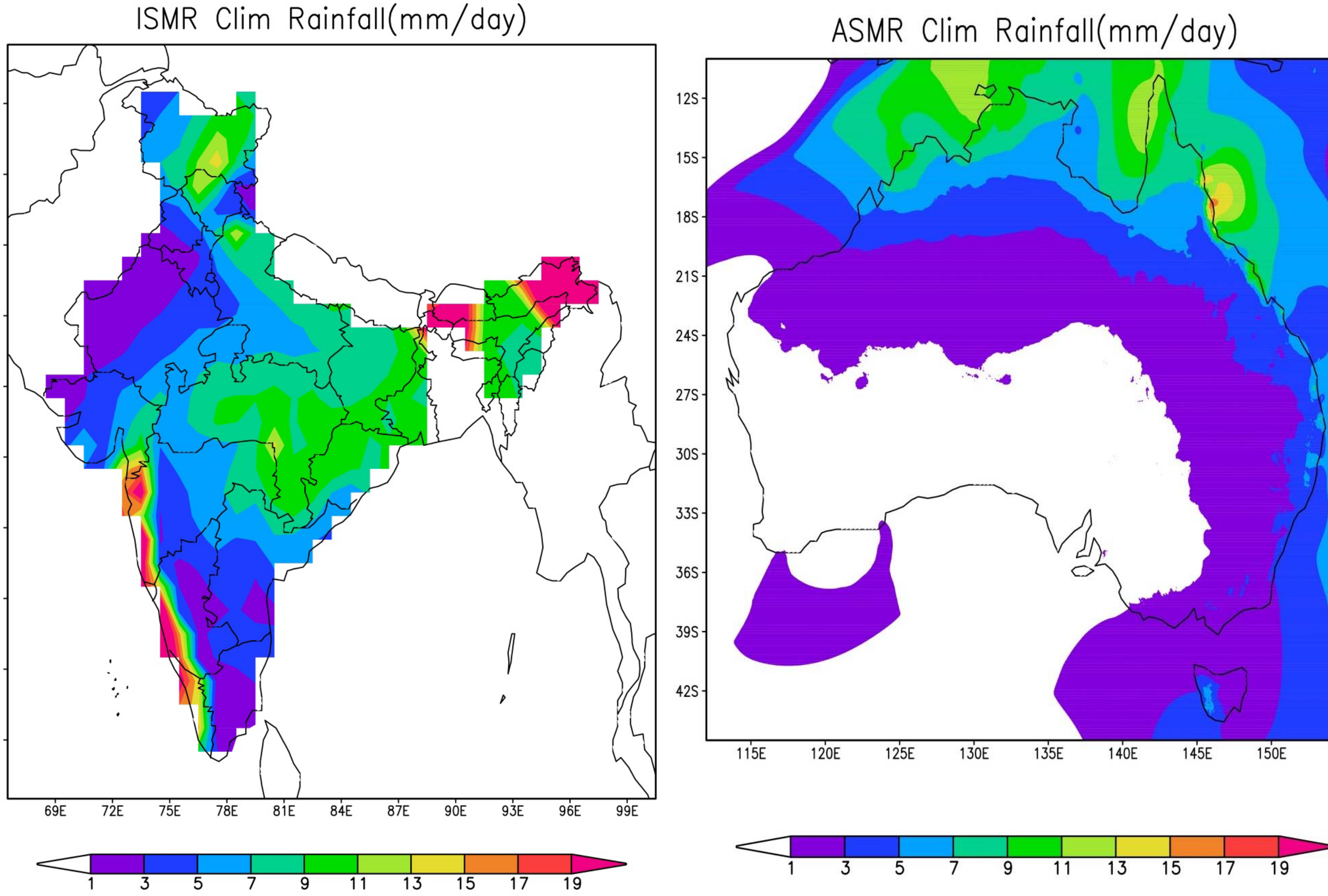
Outline of my talk

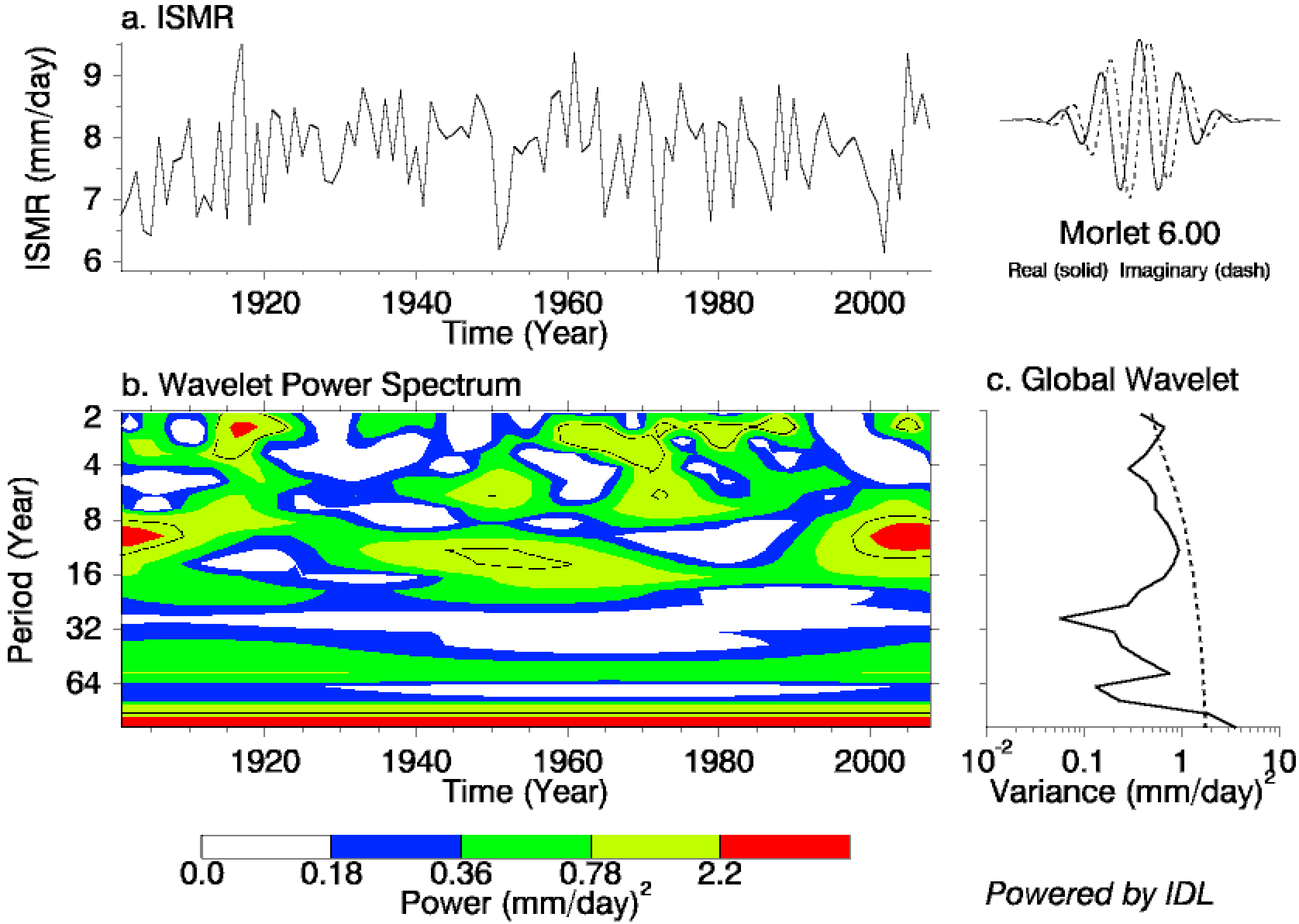
- Background of Monsoons
- Relation between ISMR & ASMR
- Decadal variability of ISMR –ASMR relation
- Role of tropical Indo-Pacific Climate drivers
- Summary

Background

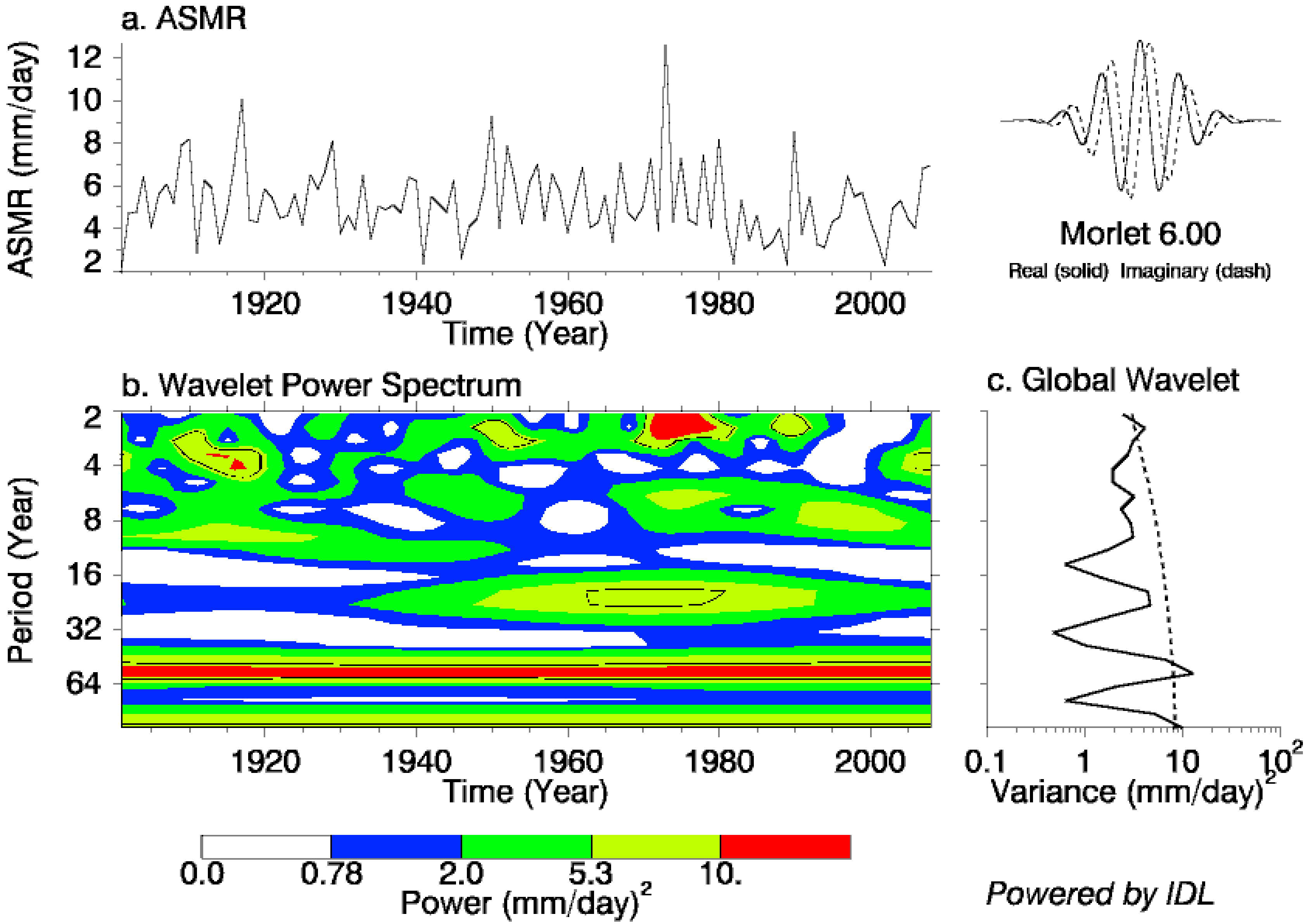
- India receives 80% of its annual rainfall during JJAS known as **I**ndian **S**ummer **M**onsoon **R**ainfall (ISMR).
- Indian Agriculture is highly dependent on ISMR.
- The Australian summer monsoon is traditionally referred to as the wet season in Northern Australia.
- Australia receives 75% of the annual rainfall during austral summer (i.e. December to following February) known as Australian Summer monsoon Rainfall (ASMR).



Homogeneous monsoon regions of India and Australia. ISMR calculated as area-averaged rainfall over the Indian land mass from June to September and ASMR calculated as area-averaged rainfall over the region 120ºE – 154ºE, 22ºS – 10ºS from December to following February of each year.



Black contour is the 10% significance level, using a red-noise (autoregressive lag1) background spectrum.

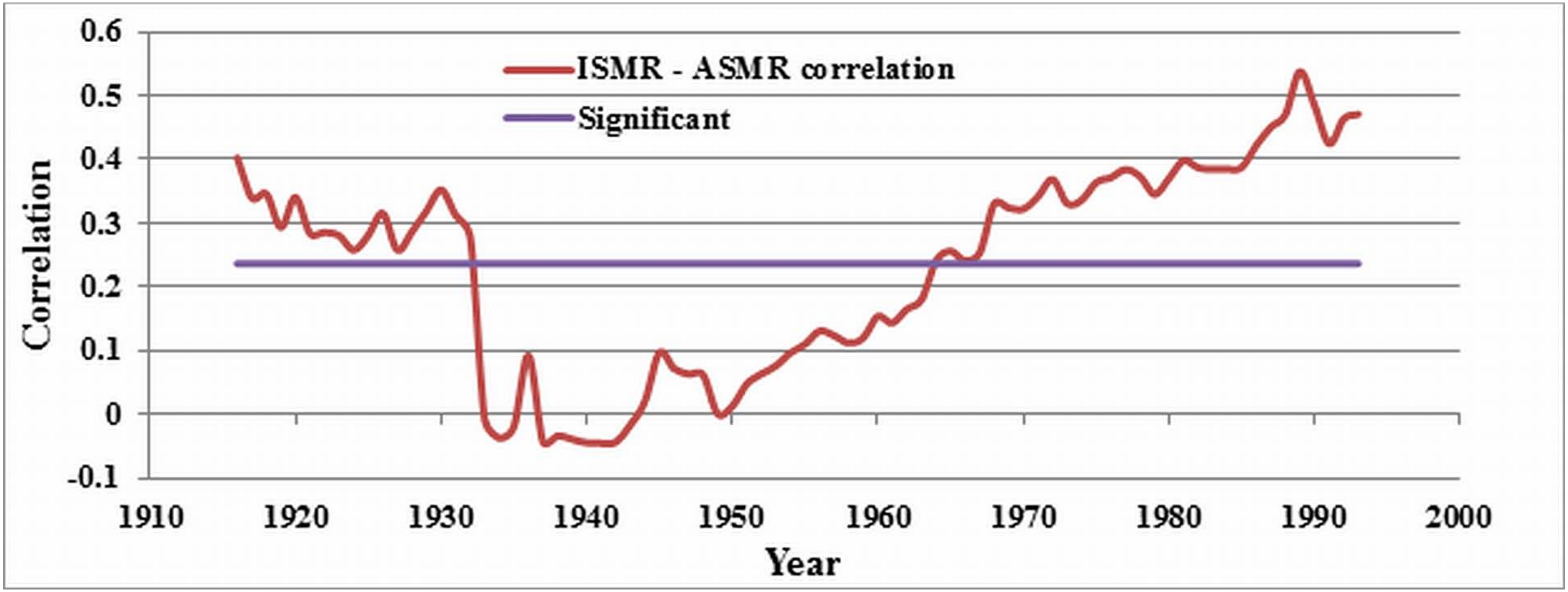


Black contour is the 10% significance level, using a red-noise (autoregressive lag1) background spectrum.

Relation between ISMR & ASMR

- Shukla and Paolino (1983) first noticed lead lag relation between Darwin pressure anomalies and ISMR and documented more fully by Meehl (1987).
- Joseph et al (1991) state that the relationship between the preceding ISMR and onset of the ASMR is very strong (strong ISMR is followed by early onset of ASM) and that this relationship is because of ENSO, statistically significant at 99% confidence level from a 2-tailed t-test.
- Meehl & Arblaster (2002) claimed that a stronger (weaker) than normal ISMR during the boreal summer is more likely to be followed by a stronger (weaker) than normal ASMR Known as Tropospheric Biennial Oscillation (TBO).
- Meehl and Arblaster (2002) portray the TBO as inherent biennial oscillation with the ISMR, ASMR, ENSO and Indian Ocean Dipole (IOD) playing important roles in the underlying mechanism
- Chang and Li (2000) portray the TBO is an emergent property that results from the interactions between the northern summer and winter monsoons and the tropical Indian and Pacific Oceans.

The Indian summer monsoon rainfall is correlated to the ASMR at r=0.3, for the period 1900 to 2009, significant at the 99% confidence level based on a 2-tailed Student's t-test.



31-year moving correlation between concurrent Indian Summer Monsoon Rainfall and Australian Summer Monsoon Rainfall

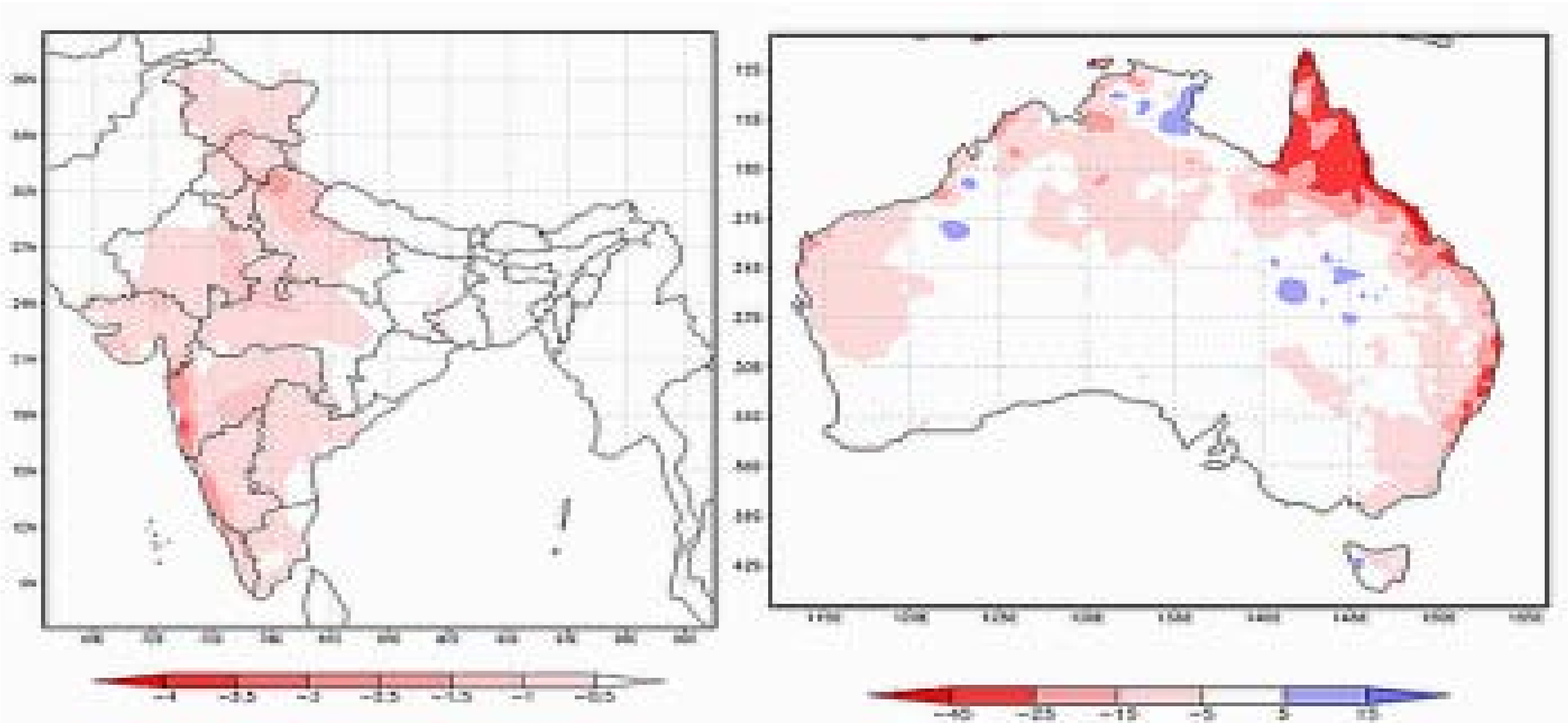
However, the correlation between the ASMR and following year ISMR (r= -0.15) is weak.

Interannual variability of ISMR & ASMR

Tropical Indo-Pacific Climate drivers such as

- El Niño Southern Oscillation (ENSO)
- Indian Ocean Diploe (IOD)
- El Niño Modoki
- Indian Ocean Basin-wide Warming (IOBW)

- ENSO is known to have a strong effect on both of the monsoons (Rasumusson and Carpenter 1982, Ropelewski and Halpert 1987). El Niño events typically result in anomalously low summer monsoon rainfall in many regions of India and Northeast Australia.



Rainfall anomaly composite during El Niño events from 1900 to 2009 over India (left) and Australia (right).

Background of IOD

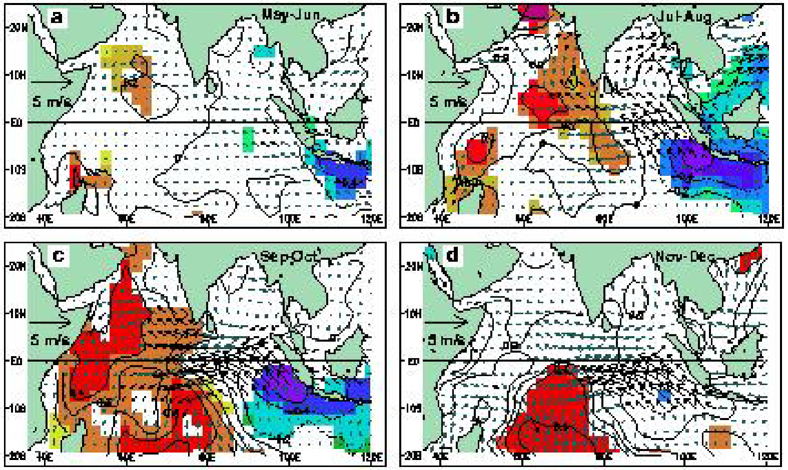
•Dipole like SST anomalies

•equatorial wind anomalies

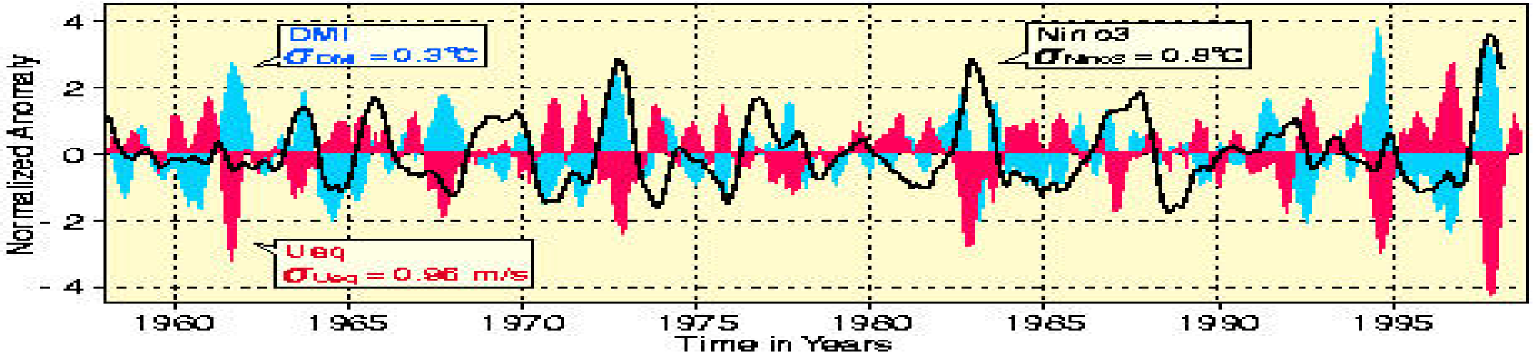
•sea level low(high) in the east(west)

•suppressed(enhanced) rain in the east(west)

•ocean dynamics may play a significant role

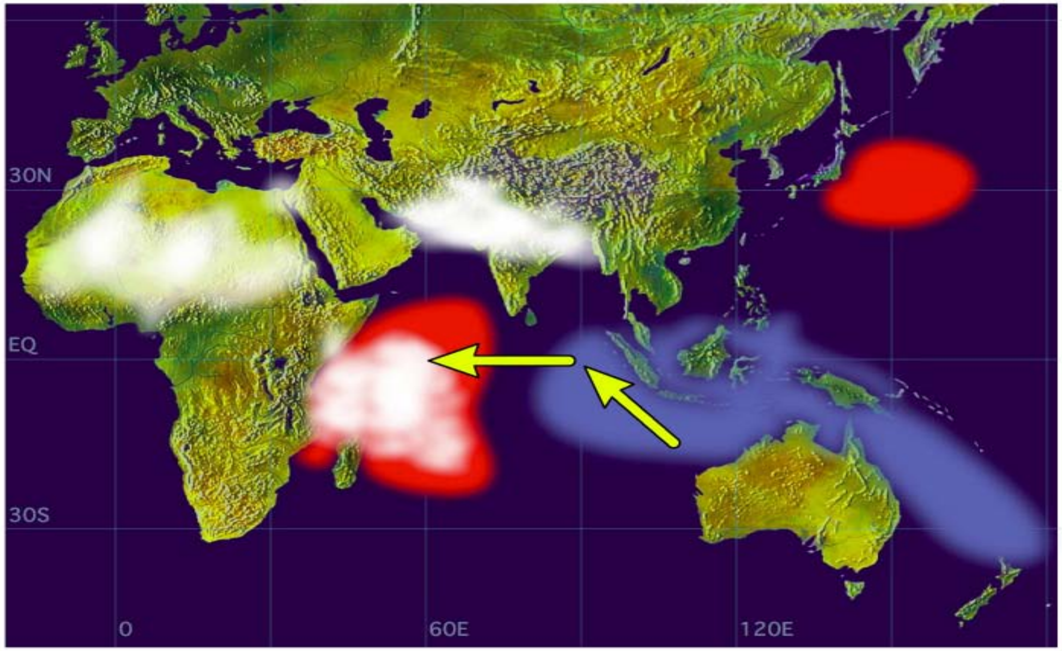


•strong cross correlation between all the variables mentioned above

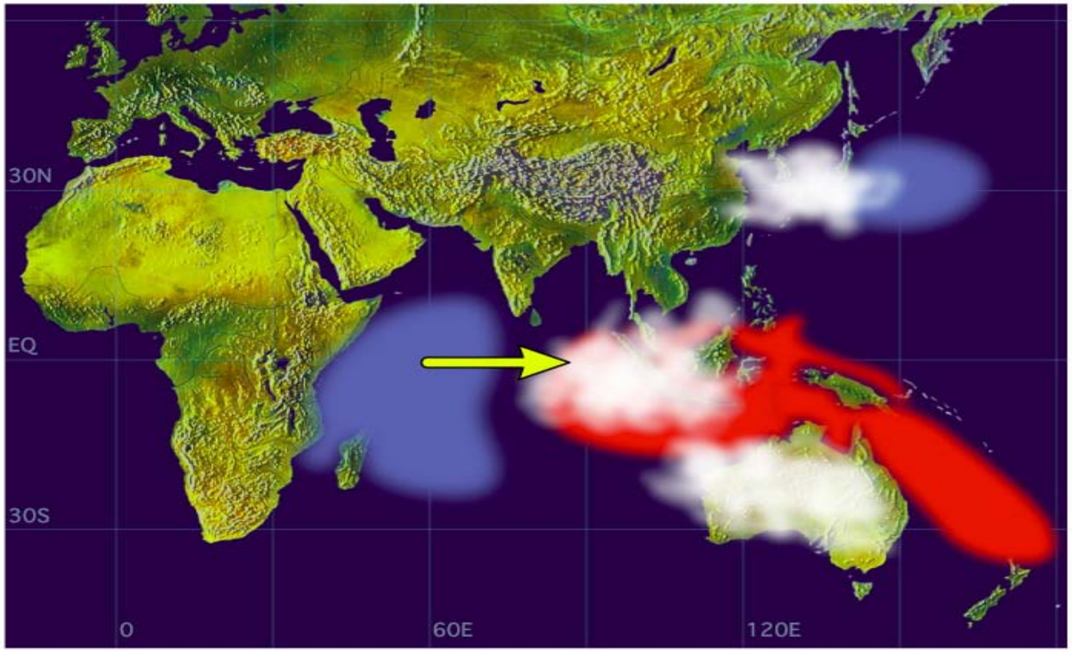


- *Saji et al. (2001)'s IODMI: SSTA(-10°S-10°N, 50°-70°E)-SSTA (10°S-Equator,90°E-110°E).*

Positive Dipole Mode



Negative Dipole Mode



- Ashok et al. (2001) identified influence of the Indian Ocean Dipole (IOD) on the interannual variability of the ISMR
- The IOD and the ENSO have complementarily affected the ISMR during the last four decades.
- Whenever the ENSO-ISMR correlation is low (high), the IOD-ISMR correlation is high (low).
- The IOD plays an important role as a modulator of the Indian monsoon rainfall and influences the correlation between the ISMR and ENSO.

Data sets

- India Meteorological Department $1^o x 1^o$ gridded rainfall data (Rajeevan et.al 2006)
- Area averaged homogeneous Indian Monthly Rainfall Data Set for the period 1888-2009 from IITM Pune (Parthasarathy et al. 1994).
- Australian gridded rainfall data at 0.05^o resolution from Australian Bureau of Meteorology (http://www.bom.gov.au/jsp/awap/rain/index.jsp, Lavery et al. 1997, Jones et al. 2009) for the period of 1900-2009 to compute the spatial correlations and composite analysis.
- HadiSST data for the period 1900-2009 (Rayner, et al. 2003) to calculate the indices El Niño, El Niño Modoki, IOBW and IOD.

Methodology

In our analysis we used

- Linear correlation
- moving correlations
- partial correlations and
- composite methods.

We classify an El Niño event as one in which the seasonally-averaged NINO3 index exceeds one standard deviation, derived for the climatology of the particular sub-period (of 3-4 decades) for the season specified.

- ISMR is calculated as an area-weighted seasonal rainfall averaged over the Indian land mass from June to September

- The ASMR is calculated as the area averaged rainfall over the region 120ºE – 154ºE, 22ºS – 10ºS from December to following February of each year.

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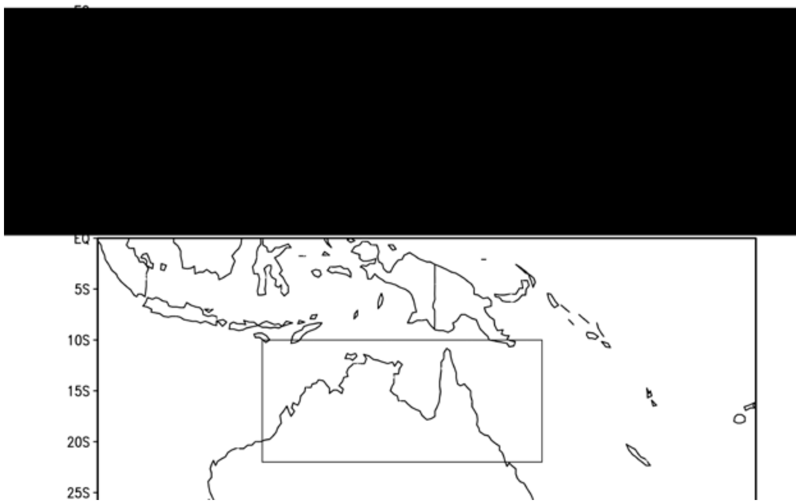
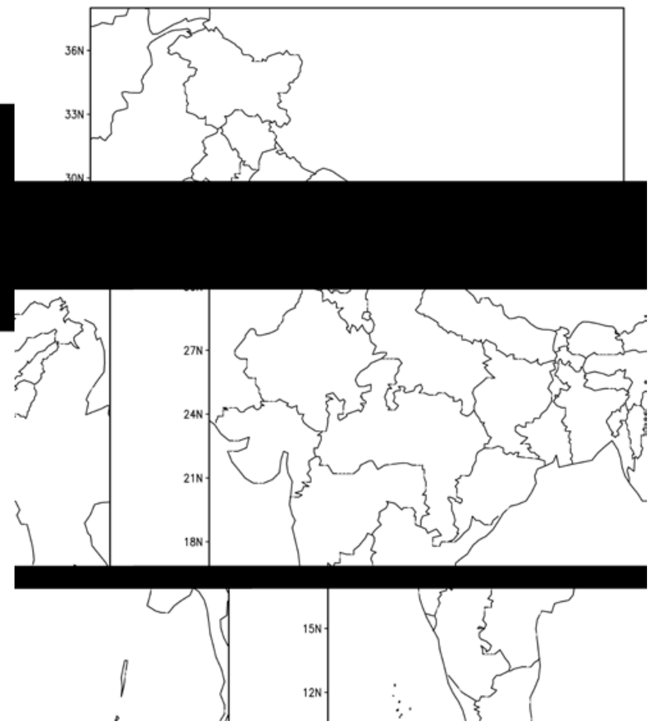
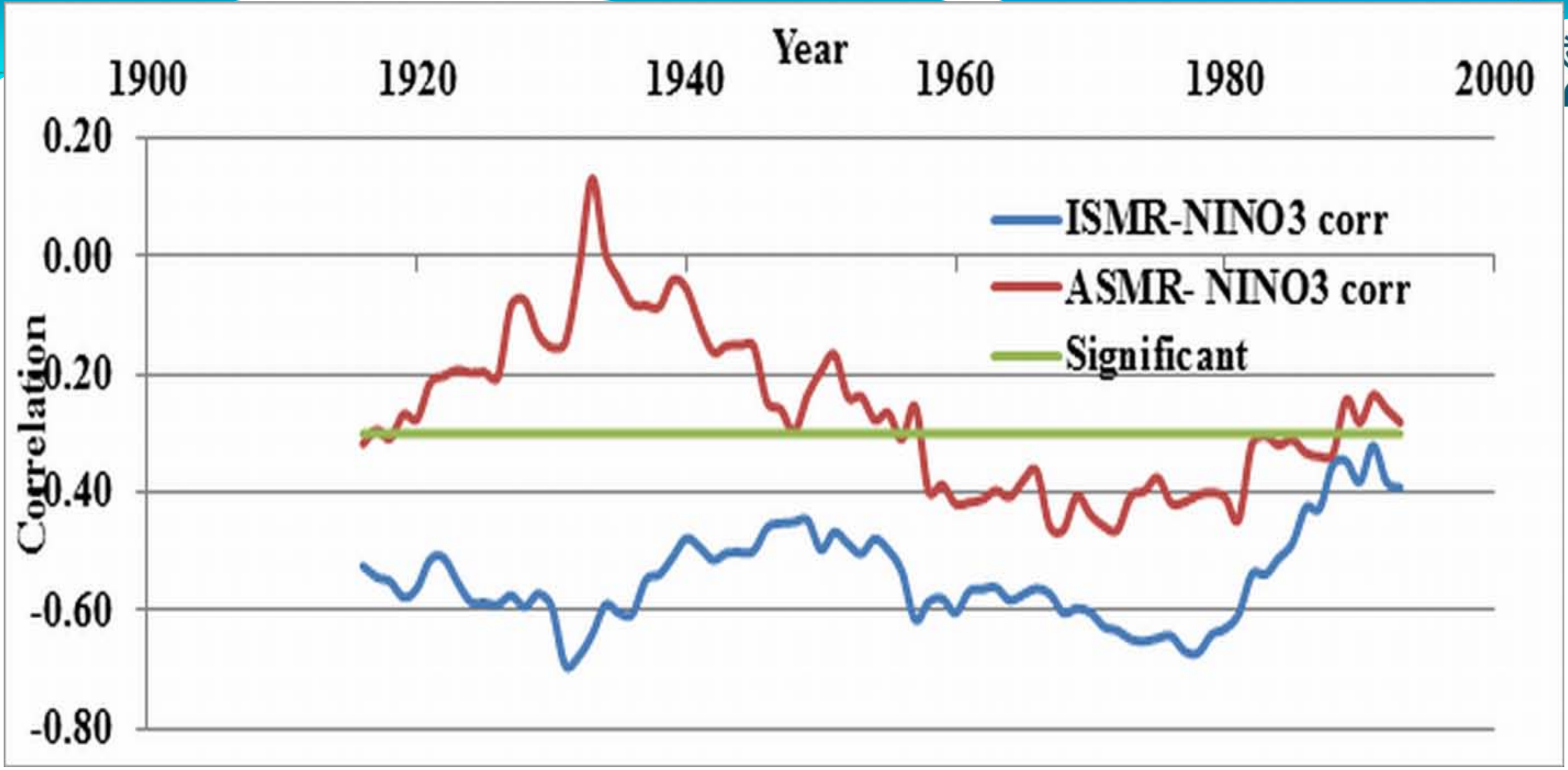


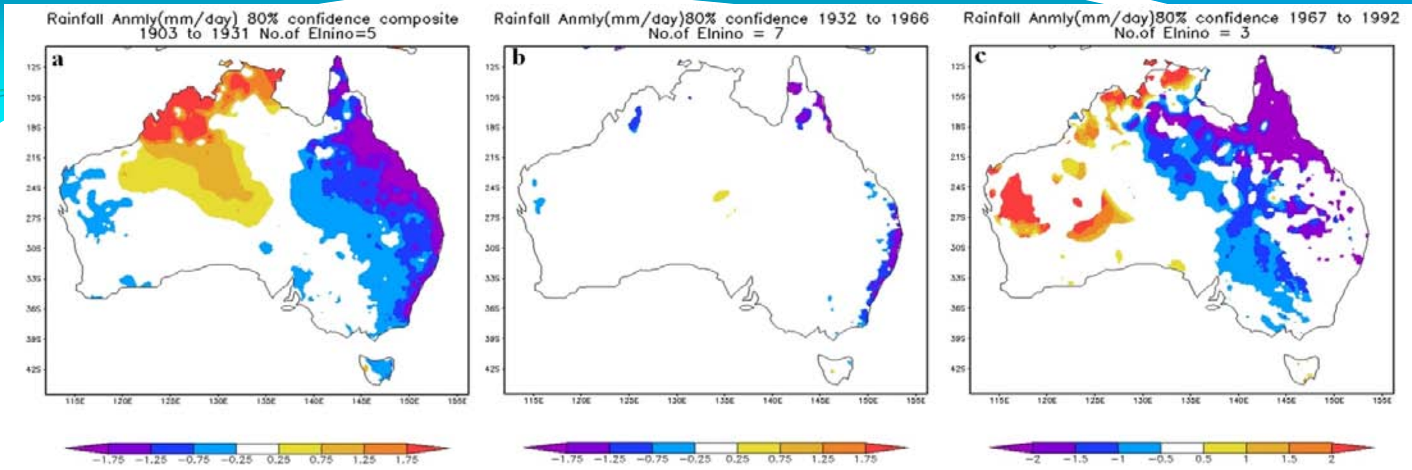


ENSO – ISMR and ENSO – ASMR relations



31-year moving correlation between ASMR and Nino3 SST anomalies (red) and between ISMR and Nino3 SST anomalies (blue), green line indicates 90% confidence level.

The ENSO –ASMR relation falls below the 90% confidence level during 1920-1960 whereas ENSO – ISMR relation remains statistically significant.



Composite Australian summer rainfall anomalies during El Nino events for 1903-1931 (left) 1932-1966 (middle) and 1967-1992 (right).

- During 1932-1966, the magnitude of the negative rainfall anomalies normally associated with the El Niños over the Northeastern Australia, is significantly weaker than during the other two sub-periods.

El Niño –ASMR relation

- Previous studies by Nicholls *et al.* 1982; McBride and Nicholls 1983 e.g., Nicholls 1981; Hendon 2003,2011,2012; Wu and Kirtman 2007, which suggests that the impact of El Niño on ASMR is much greater during the austral spring (September-November) and at the start of the austral summer season than during the summer season itself.
- The cause of the relatively weak relationship after the onset of summer monsoon is attributed to the positive (negative) feedback between the El Niño-associated anomalous circulation and local SST north of Australia (110ºE - 140ºE, 10ºS-Equator) that changes sign anomalously from cool in the pre-monsoon to warm after the monsoon onset.

Harry H. Hendon *et al.* 2011; The Global Monsoon System: Research and Forecast (2nd Edition)

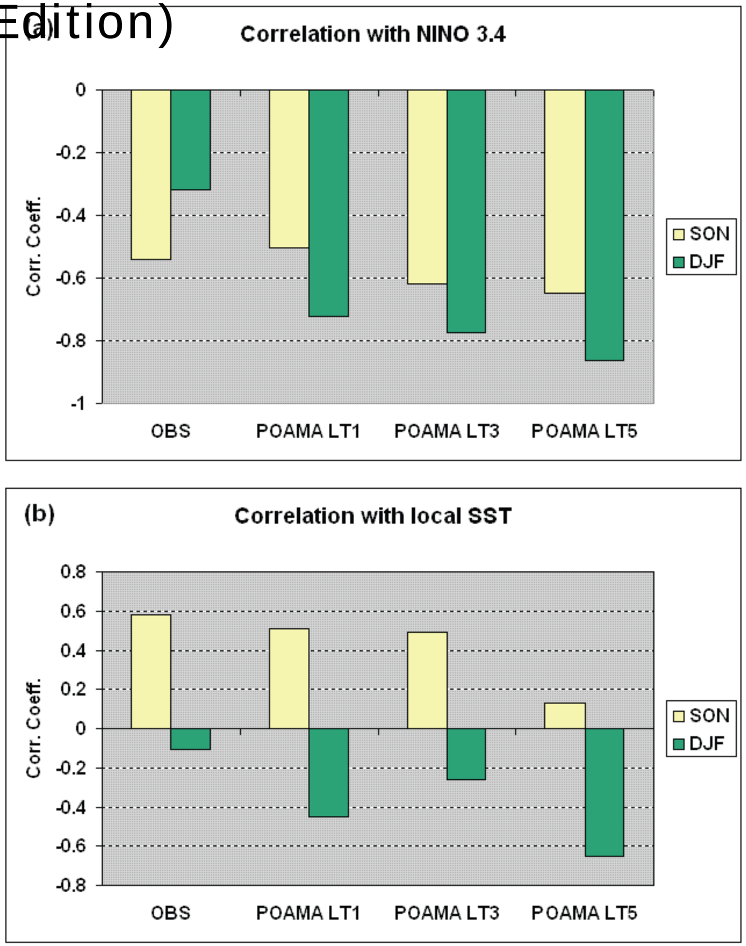
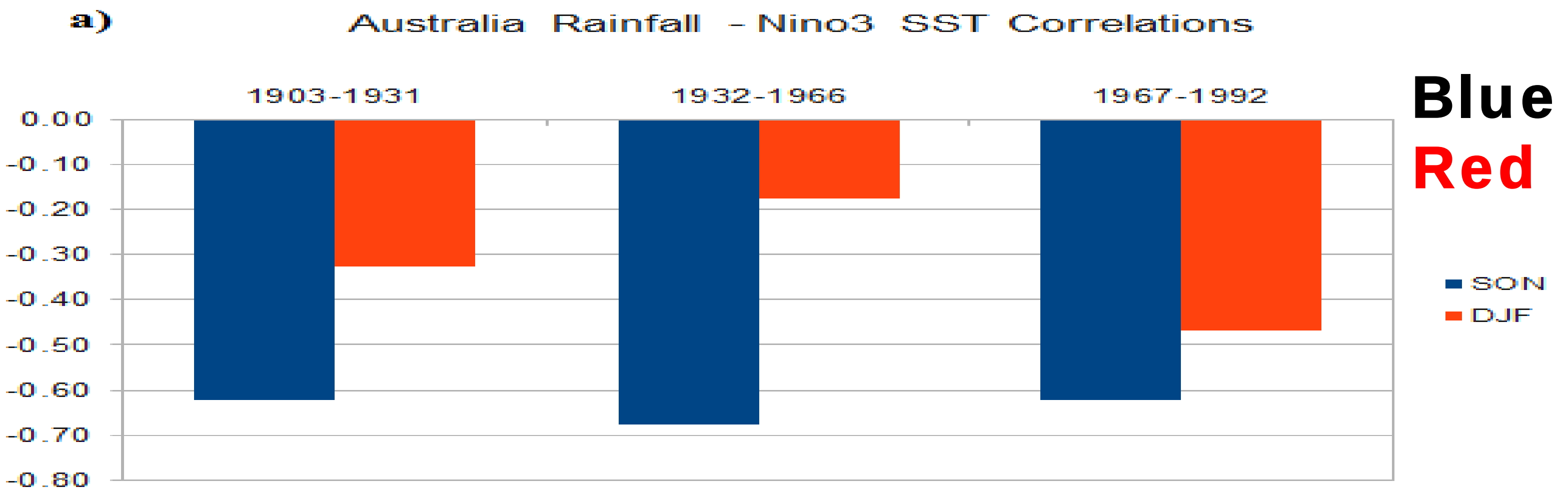
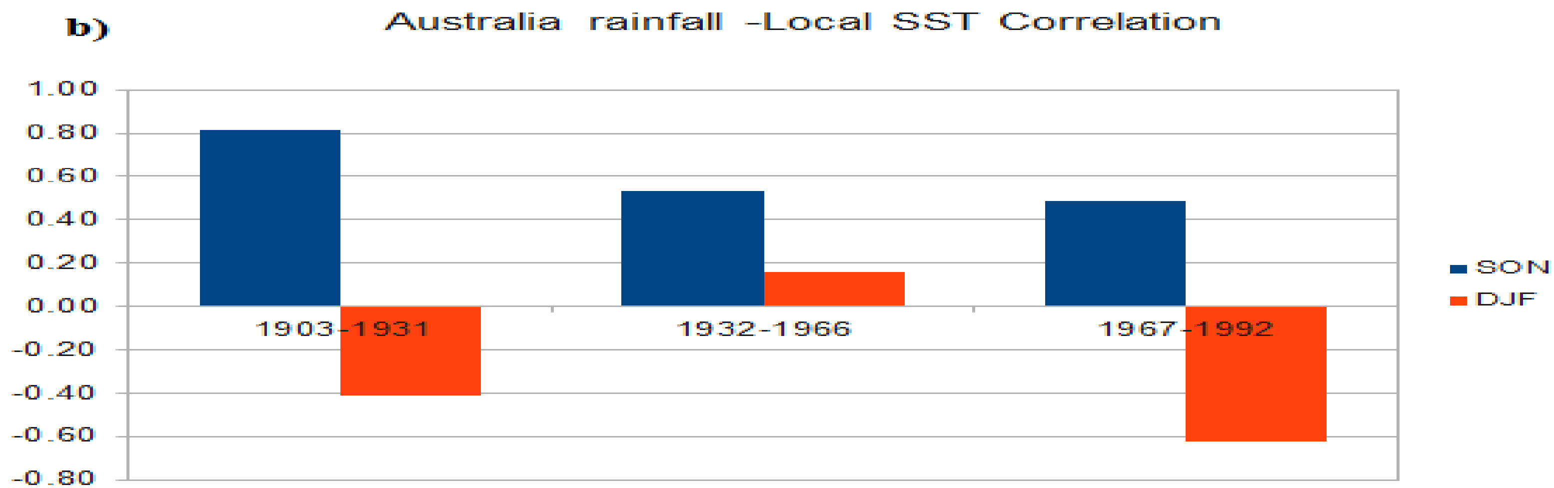


Figure 2. Correlation of Australian rainfall (north of 25°S) with (a) Nino-3.4 SST index, and (b) local SST, to north of Australia (10°S-Eq, 110°E-140°E) for DJF (monsoon season) and SON (pre-monsoon season). Observed relationships are on left. Predictions are at 1, 3, and 5 month lead time.

Blue SON
Red DJF



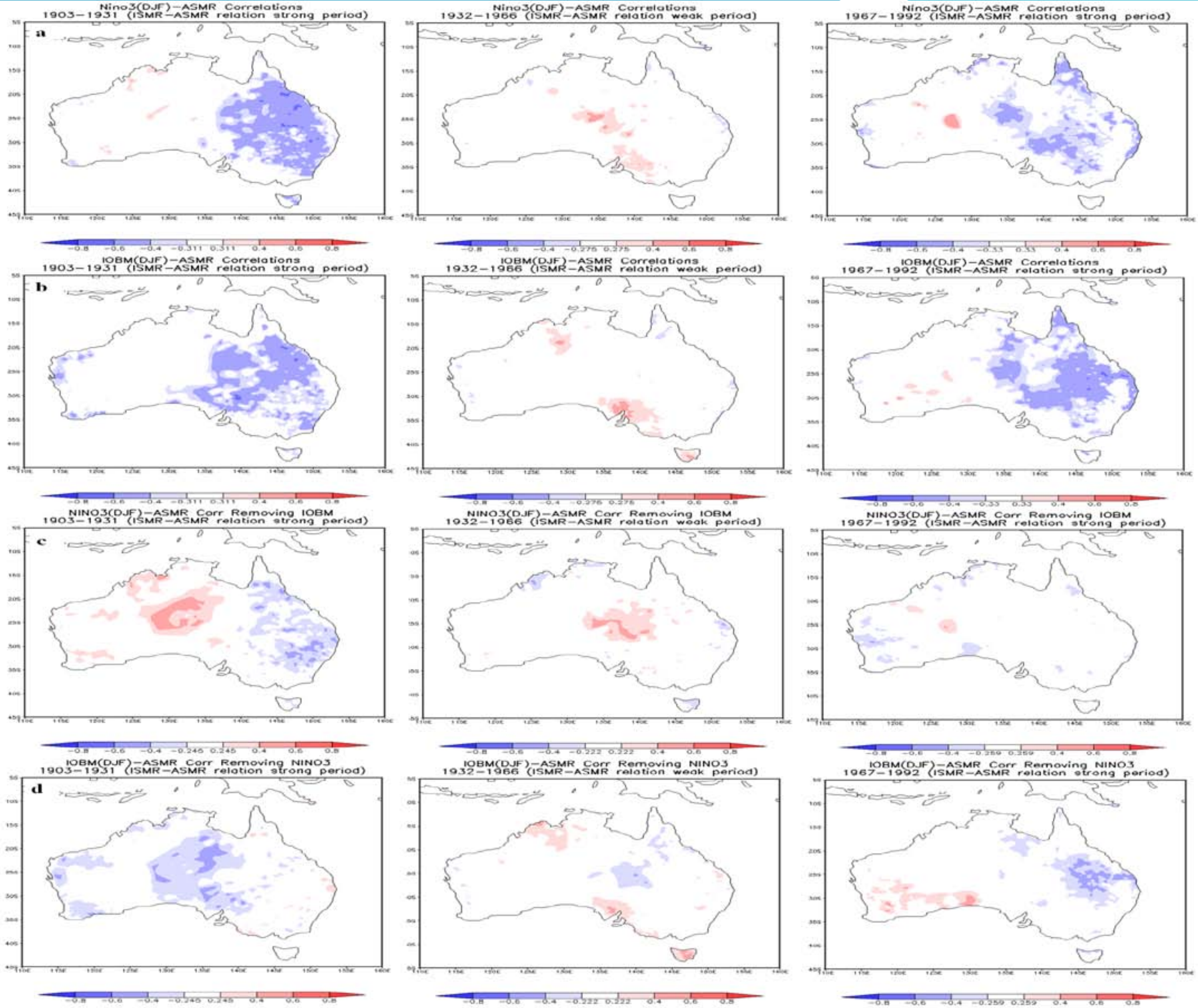


ASMR – NINO3 SST anomalies correlations (a) and ASMR – local SST correlations (b) during three sub periods.

- The impact of El Niño on ASMR is much greater during the austral spring
- The impact of El Niño on ASMR is relatively weak during austral summer
- The cause of the relatively weaker relationship after the onset of summer monsoon is attributed to the positive (negative) feedback between the El Niño-associated anomalous circulation and the local SST (north of Australia) anomaly that changes sign anomalously from cool in the pre- monsoon to warm after post the - monsoon onset.

- Another potential way the ENSO can influence the ASMR is through its ENSO signal in the Indian Ocean, namely the Indian Ocean Basin-wide Warming(IOBW).

- IOBW is essentially a manifestation of the ENSO in the tropical Indian Ocean (Saji et al., 2006, Tozuka et al., 2008, Taschetto et al. 2011)



NINO3 – ASMR corr.

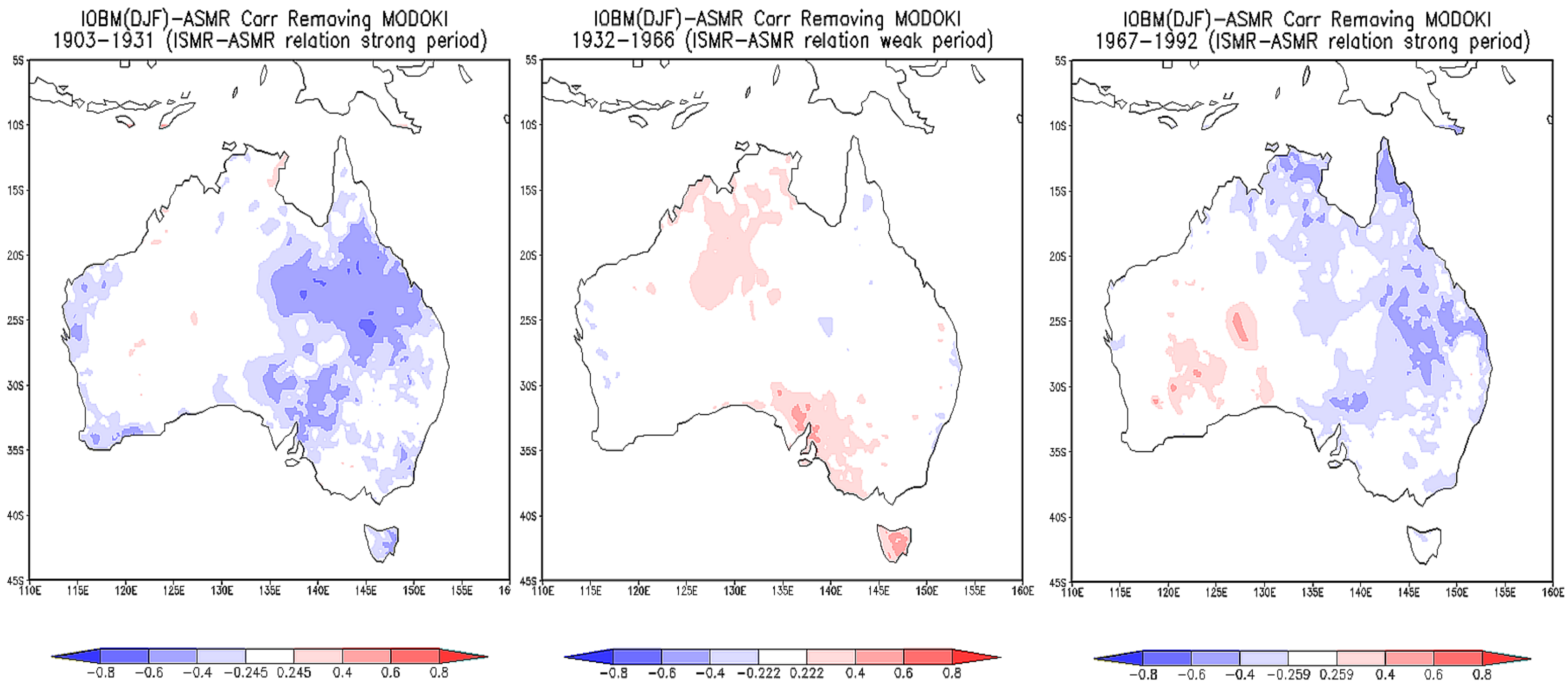
IOBW – ASMR corr.

NINO3 –ASMR (IOBM removed)

IOBW –ASMR (NINO3 removed)

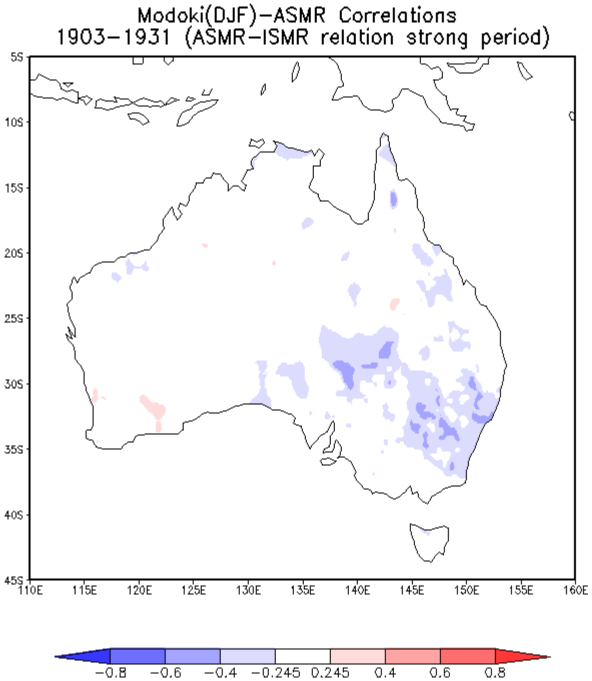
Correlation between (first row) NINO3 –ASMR; (second row) IOBM –ASMR; (third row) NINO3 –ASMR (with IOBM removed) and (fourth row) IOBM – ASMR (with NINO3 removed) for 1903-1931 (left) 1932-1966 (middle) and 1967-1992 (right).

1903 – 1931 1932-1966 1967 -1992

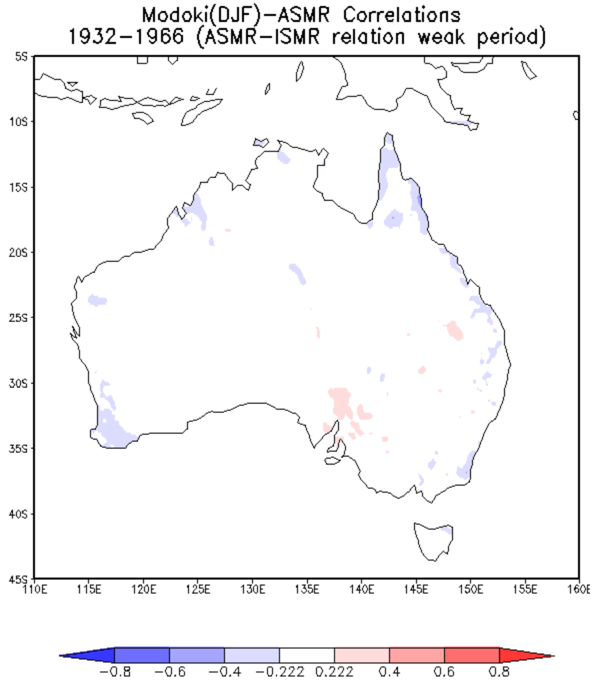


IOBM – ASMR correlations removing El Niño Modoki for sub period I (left), sub period II(middle) and sub period III(right).

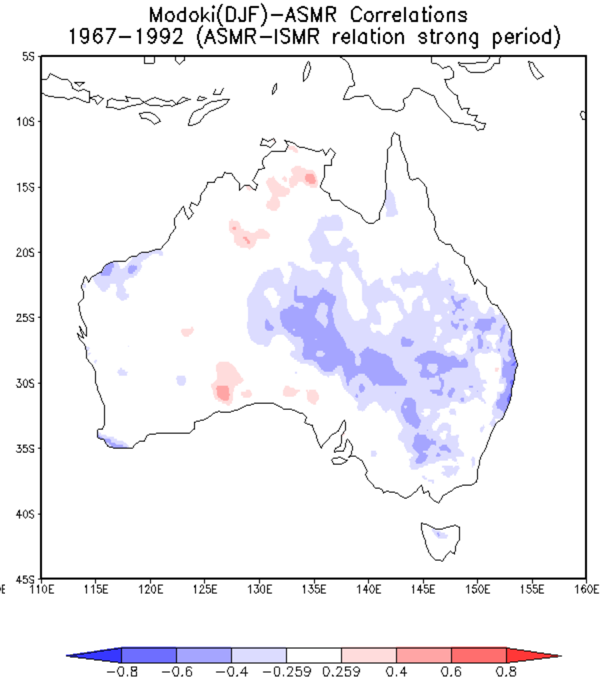
1903 – 1931



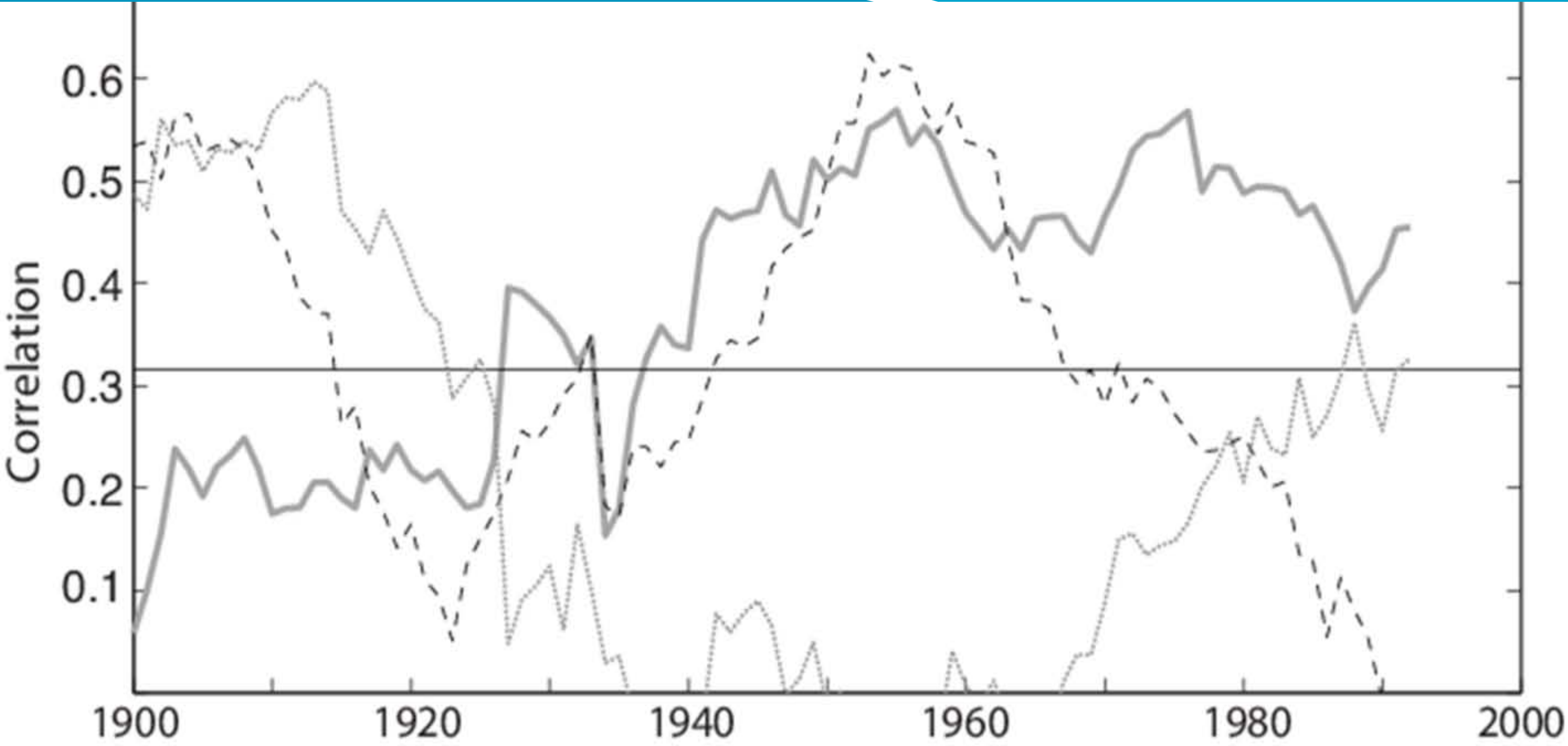
1932-1966



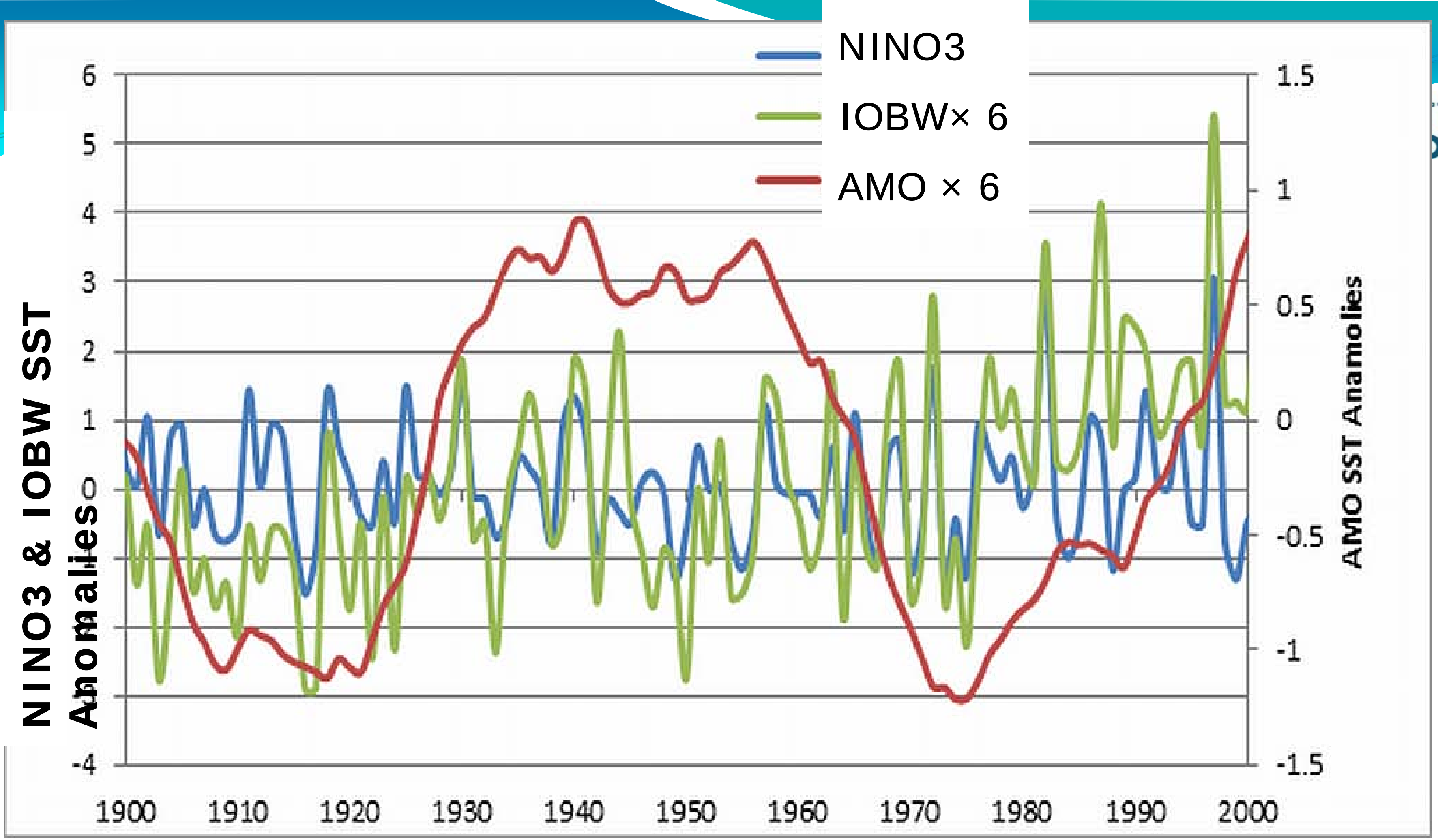
1967 -1992



El Nino Mdoki – ASMR correlations during three sub periods



31-year moving correlations between ISMR- and three synthetic time series that have a correlation with ISMR of r=0.31



Atlantic Multidecadal Oscillation (AMO), IOBW and NINO3 SST anomalies.

The apparent link between the phase of the Atlantic multidecadal oscillation (AMO) and the strengths of ENSO and IOBW

- The positive phase of the AMO is associated with a weakened concurrent ISMR-ASMR relationship, while its negative phase during the sub-periods of 1903-1931 and 1967-1992 indicates a typical TBO type of relationship.
- During positive phase of AMO, ENSO has low intensity and frequency

Summary

- ISMR – ASMR relationship waxes and wanes in an epochal fashion.
- The ISMR- ASMR association significantly weakens during the 1932-1966 period.
- The weakening of this relationship apparently related to the weak ENSO - ASMR relation during this period.
- The weak ENSO – ASMR relation probably due to the sign of the correlation between ASMR – local SST does not change to negative during the DJF season for the sub-period 1932-1966.
- This is possibly be associated with the weaker magnitude of ENSO during the DJF season in this sub-period .
- Apart from the local SST, the ENSO can influence the ASMR is through its ENSO signal in the Indian Ocean, namely the IOBW.
- Impact of IOBW on ASMR has little influence during 1903-1931 and 1932-1966.

- IOBW appears to play a relatively important role in driving ASMR changes in north central and north eastern regions during 1967-1992.
- The positive phase of the AMO is associated with a weakened ISMR-ASMR relationship.
- Studies [Folland et al., 1999; Kerr, 2000; Delworth and Mann, 2000; Kingtse et al. 2009] indicate that the AMO can influence the ENSO intensity and frequency.
- It is also hypothesized that changes in the north Atlantic can affect the ISMR (Goswami et al., 2006).

*Our results are subject to the limitation of the SST and Northern Australia Rainfall data quality of the earlier period.

However, the Indian rainfall data used here are considered to be relatively reliable for the whole period.

Thank you

This paper is in under review with Climate Dynamics

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