Decadal variability of Asian-Australian monsoon-ENSO-TBO relationships

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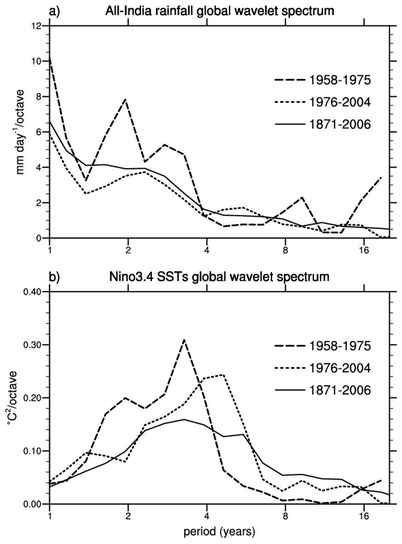
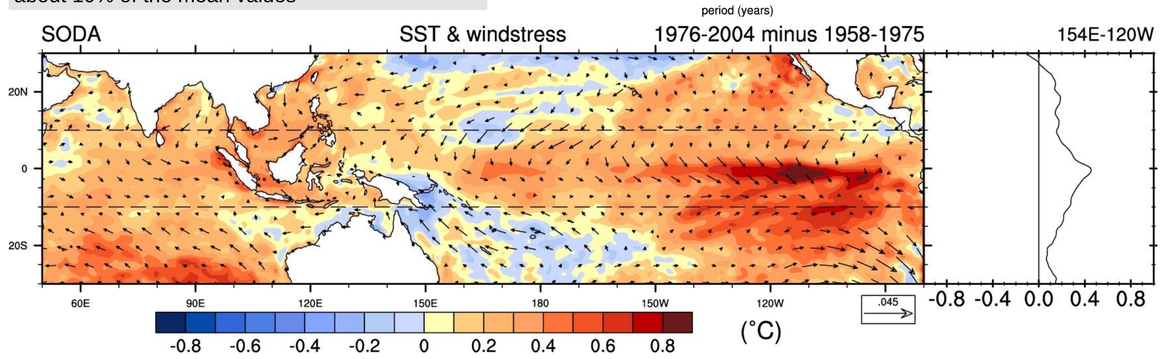
Objective

We focus on the effects of decadal SST variability in the tropical Pacific and the associated influences on Asian-Australian monsoon and Pacific SST connections.

SST differences, postshift minus preshift. Largest SST differences of are seen in the eastern equatorial Pacific, with considerably less warming and even some small amplitude cooling in the western equatorial Pacific. The Indian Ocean shows relatively larger warming than the western equatorial Pacific after the 1970s shift. Westerly windstress anomalies along the equator extend right across from the Indian Ocean to the Pacific, with largest wind stress anomalies in the eastern equatorial Pacific approaching 0.04 N m−2 or about 10% of the mean values



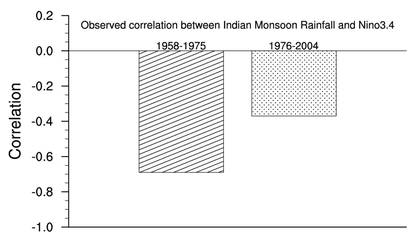
The amplitude of the wavelet spectrum power in the 2-year band is about half the amplitude in the post-1970s shift period compared to the pre-1970s shift era, for both Nino3.4 and All-India rainfall. The pre-1970s shift has greater power around the 5-yr band



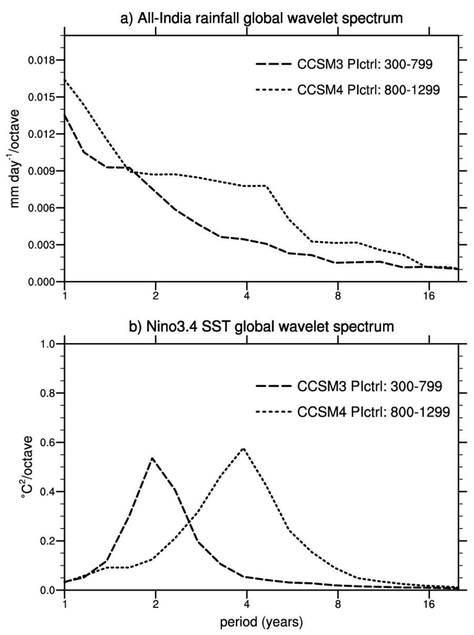
Approach

Two coupled models, CCSM3 & CCSM4, which have very different ENSO characteristics, illustrate how the mid-1970s shift-type changes in base state can make the Indo-Pacific monsoon-SST system less biennial.

Analysis of a long control run of CCSM4 shows how internally generated variability can modulate Indo-Pacific connections



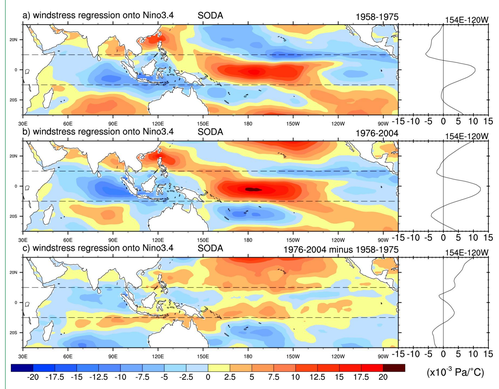
An eastward shift of the rising branch of the Walker circulation moves the center of upward motion away from the Australian–Asian region, and acts to isolate that area from its connection to the eastern tropical Pacific. This results in stronger negative correlations between Indian monsoon rainfall and Niño-3.4 SSTs in the preshift period compared to the postshift period.



The TBO is weaker in CCSM4 than in CCSM3 with greater power at periods greater than 2 yr in Indian monsoon rainfall and in Niño-3.4 SSTs in the Pacific

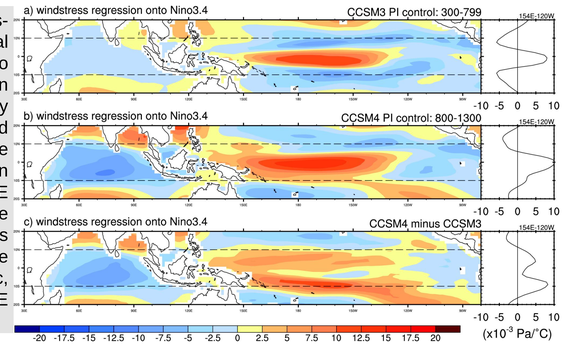
Reference: Meehl, G.A. and J.M. Arblaster 2011: Decadal variability of Asian-Australian monsoon-ENSO-TBO relationships. J. Climate, 24, 4925-4940, DOI: 10.1175/2011JCLI4015.1

A widening of the meridional domain of the trade wind anomalies in the post-shift compared to pre-shift period is found, consistent with wind-forced ocean Rossby waves forming farther poleward.

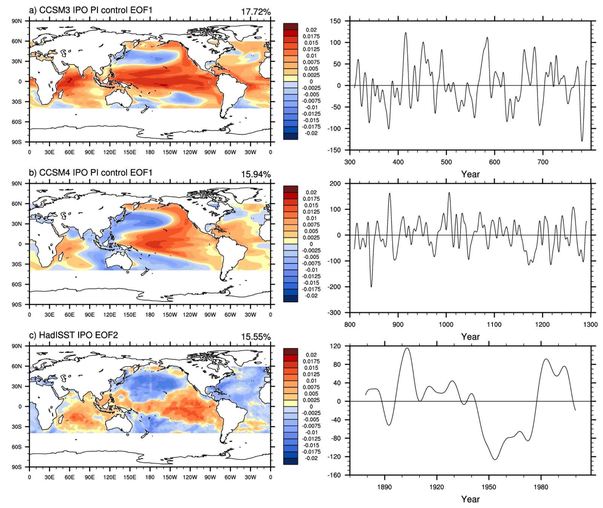


Associated with the decreased TBO in CCSM4, the domain of the zonal wind stress anomaly connections to Niño-3.4 SSTs is wider in latitude (positive anomalies near 10° N and 10° S in the differences, CCSM4 minus CCSM3

Regression of the bandpass-filtered (1–5 yr) zonal component of wind stress on to Niño-3.4 SSTs shows that when Niño-3.4 SSTs are anomalously warm, there are westerly wind stress anomalies (positive regression values) between about 130° W and 150° E roughly centered on the equator, with negative values east of around 130° W in the far eastern equatorial Pacific, and west of about 150° E across the Indian Ocean.



The time scale of the IPO in models and observations is in the multidecadal range and all have comparable patterns. However, the CCSM3 has more of a zonally uniform sign of SST anomalies across the Indian and Pacific in the IPO, while the CCSM4 has opposite-sign anomalies in the eastern Indian and western Pacific Oceans. The observations are somewhere in between the two model simulations



These differences in simulated IPO patterns produce a better connection of IPO variability with the TBO in CCSM4 compared to CCSM3.☐☐☐☐

Summary

A set of dynamically coupled ocean-atmosphere mechanisms previously has been proposed for the Asia-Pacific tropics to produce a dominant biennial component of interannual variability (the Tropospheric Biennial Oscillation or TBO). Namely, a strong Asian-Australian monsoon is often associated with negative SST anomalies in the equatorial eastern Pacific and a negative Indian Ocean Dipole in northern fall between the strong Indian monsoon and strong Australian monsoon, and tends to be followed by a weak monsoon and positive SST anomalies in the Pacific the following year and so on. These connections are communicated through the large-scale east-west (Walker) circulation that involves the full depth of the troposphere. However, the Asia-Pacific climate system is characterized by intermittent decadal fluctuations whereby the TBO during some time periods is more pronounced than others. Observations and models are analyzed to identify processes that make the system either more or less biennial at certain times due to one or some combination of:

1. increased latitudinal extent of Pacific trade winds and wider cold tongue
2. warmer tropical Pacific compared to tropical Indian Ocean that weakens trade winds and reduces coupling strength
3. eastward shift of the Walker circulation
4. reduced interannual variability of Pacific and/or Indian Ocean SST

Decadal timescale SST variability associated with the Interdecadal Pacific Oscillation (IPO) has been shown to alter the TBO over the Indo-Pacific region by contributing changes in either some or all of the four factors listed above. Analysis of a multi-century control run of CCSM4 shows that this decadal modulation of interannual variability is transferred via the Walker Circulation to the Asian-Australian monsoon region, thus affecting the TBO and monsoon-Pacific connections. Understanding these processes is important to be able to evaluate decadal predictions and longer term climate change in the Asia-Pacific region.