Warm Indian Ocean, Weak Asian Monsoon

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Summary

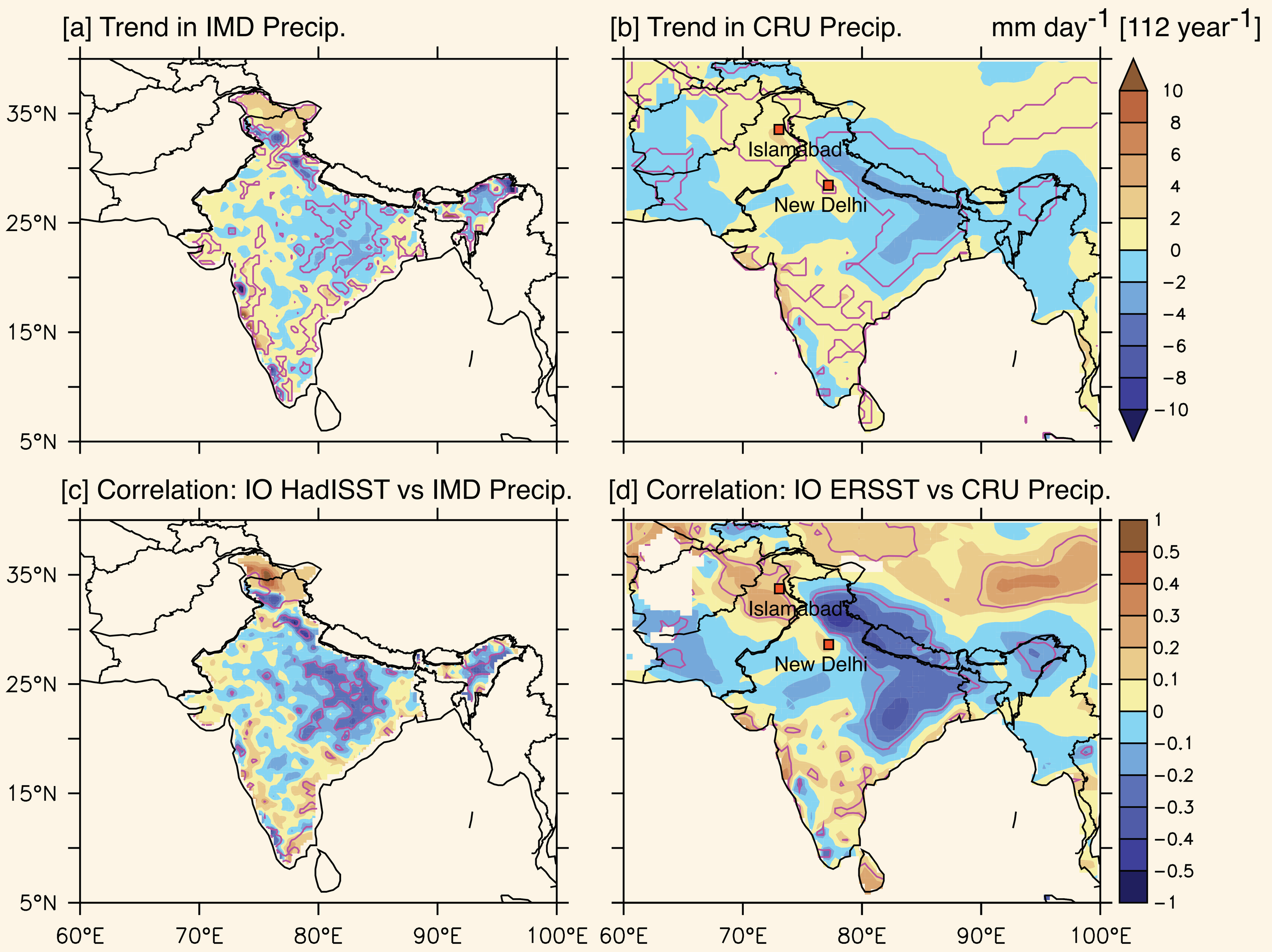
There are large uncertainties looming over the status and fate of the South Asian monsoon in a changing climate. Observations and climate models have suggested that anthropogenic warming in the past century has increased the moisture availability and the land-sea thermal contrast in the tropics, favoring an increase in monsoon rainfall. In contrast, we notice that South Asian subcontinent experienced a relatively subdued warming during this period. At the same time, the tropical Indian Ocean experienced a nearly monotonic warming, at a rate faster than the other tropical oceans.

Using long-term observations and coupled model experiments, we suggest that the enhanced Indian Ocean warming along with the suppressed warming of the subcontinent weaken the land-sea thermal contrast throughout the troposphere, dampen the monsoon Hadley circulation, and reduce the rainfall over South Asia. As a result, the summer monsoon rainfall during 1901-2012 shows a significant weakening trend over South Asia, extending from Pakistan through central India to Bangladesh.

1. Rainfall trends over South Asia and a warming Indian Ocean

The observed datasets [Fig.1a,b] show negative trends over South Asia, extending from Pakistan through central-eastern India to Bangladesh, in a horseshoe pattern with one of its arms placed on the foothills of the Himalayas, and the other obliquely along the central east coast of India. The reduction in summer rainfall over central-eastern India during the past century is about 10-20%. Correlation analyses [Fig.1c,d] with the Indian Ocean [IO] SST anomalies exhibit a similar horseshoe pattern, indicating that both the trends are associated.

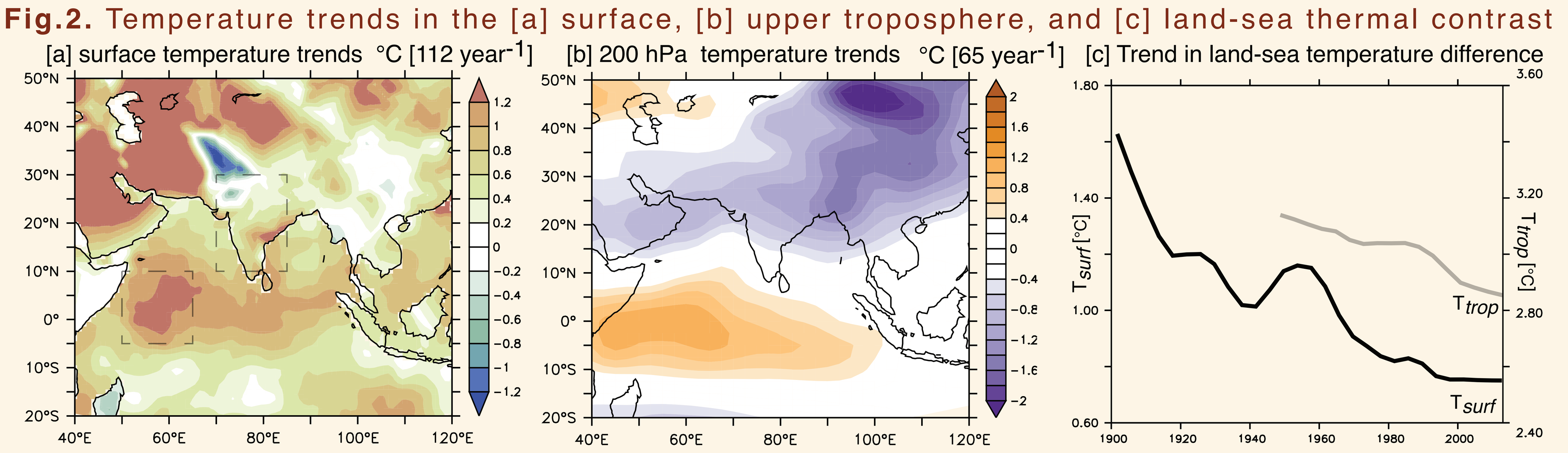
Fig.1. Precipitation [a,b] trends and [c,d] correlation with SST [June-Sept 1901-2012]



2. Indian Ocean warming weakens the land-sea thermal contrast

The monotonic warming trend over Indian Ocean is prominent, with the strongest warming over the west. At the same time the Indian subcontinent exhibits cooling during the past century. This implies a weakening meridional thermal gradient over the South Asian domain, in contrast with earlier studies which suggest a strengthening of the thermal gradient under a globally warming scenario. The decline in land-sea thermal contrast is evident in the surface [Fig.2a] as well as the whole troposphere [Fig.2b,2c]. Since land-sea thermal contrast is a driver of the monsoon circulation, a decrease in it indicates a weakened monsoon.

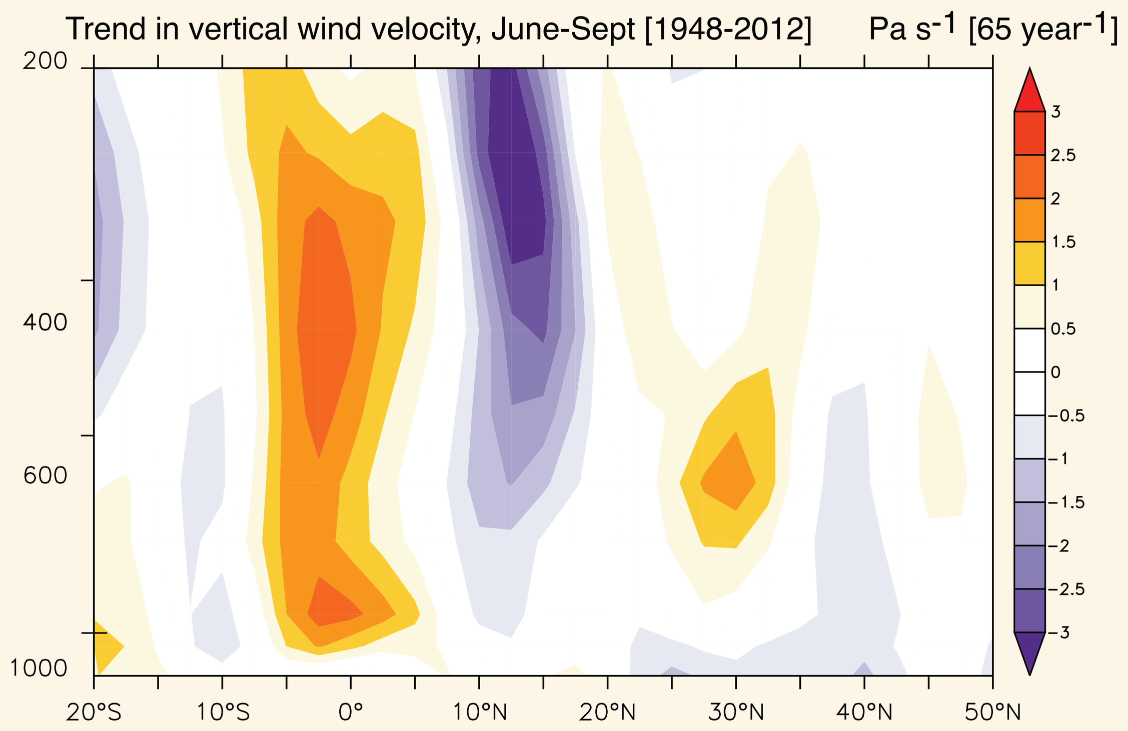
Fig.2. Temperature trends in the [a] surface, [b] upper troposphere, and [c] land-sea thermal contrast



3. Warming Indian Ocean dampens the monsoon Hadley circulation

A warm Indian Ocean enhances convective activity over ocean, but results in subsidence over the subcontinent, inhibiting convection and drying the landmass [Fig.3]. Such a modulation of the monsoon Hadley circulation builds up a competition between the land and oceanic rainfall.

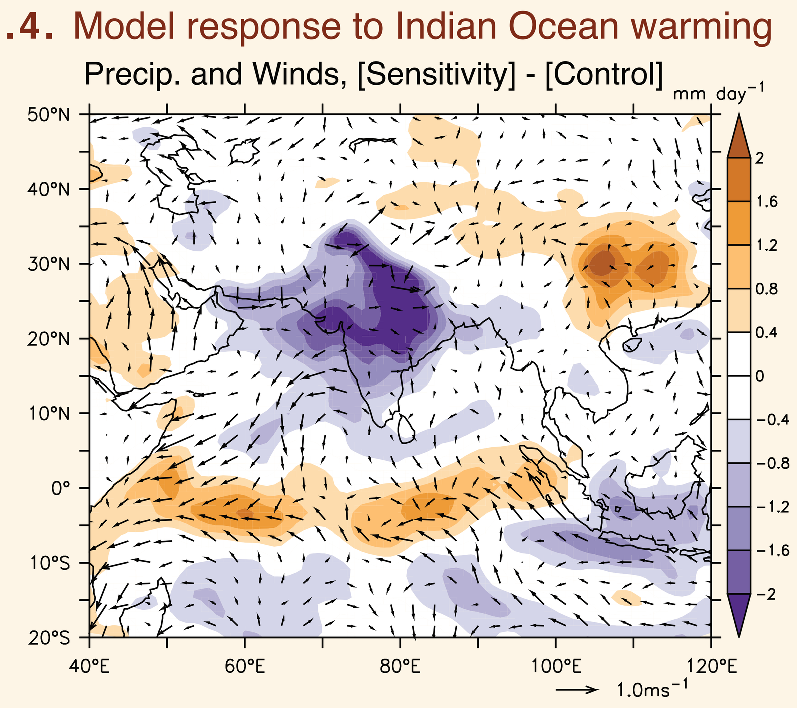
Fig.3. Trends in monsoon Hadley circulation



4. Climate model experiments

Model sensitivity experiments with simulated warming similar to observed trends indicate a weakening of the monsoon circulation, thereby weakening the precipitation over South Asia [Fig.4]. An interesting factor is the horseshoe pattern in negative precipitation anomalies, similar to the one in observed trends of precipitation, and in the correlation analyses [Fig.1].

Fig.4. Model response to Indian Ocean warming



5. Role of aerosols?

Aersols may have a potential role in cooling the South Asian subcontinent in recent decades. Hence they could be considered as the perfect partner in reducing the land-sea thermal contrast, along with a warming Indian Ocean. However, ambiguity still remains on the extent of cooling [or warming] induced by different types of aerosols.

Reference

Roxy M. K., K. Ritika, P. Terray, S. Masson, 2014: The curious case of Indian Ocean warming. *J.Climate*, 27, 22, 8501-8509.

Roxy M. K., K. Ritika, P. Terray, R. Murutugudde, K. Ashok and B. N. Goswami, 2014: Warm ocean, weak monsoon. *Nature Communications*, Revised.