Role of remote and regional SST boundary forcing in the evolution of the 2010 summer heavy rainfall event over northwest Indo-Pak region

Priya et al. (2015) Journal of climate

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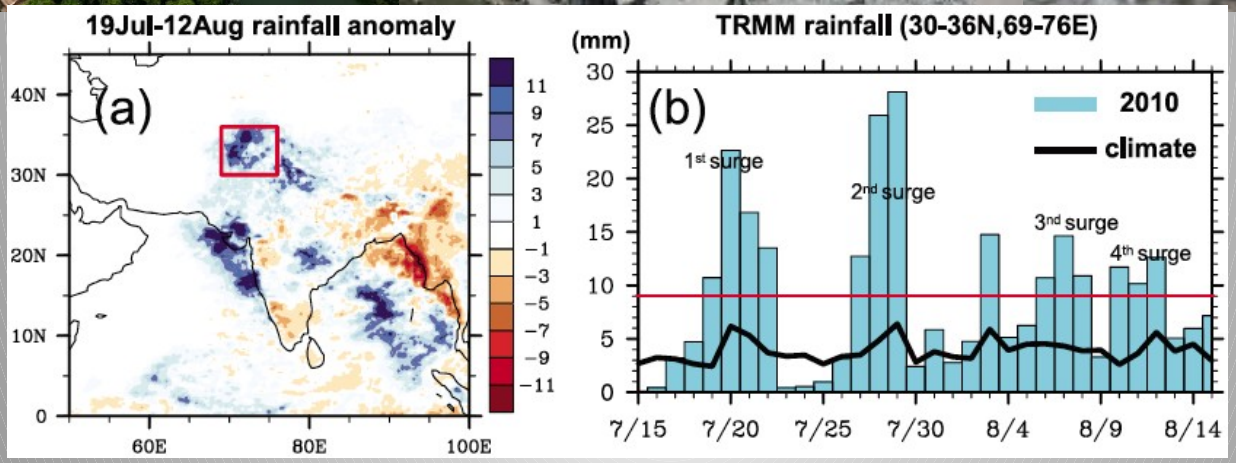
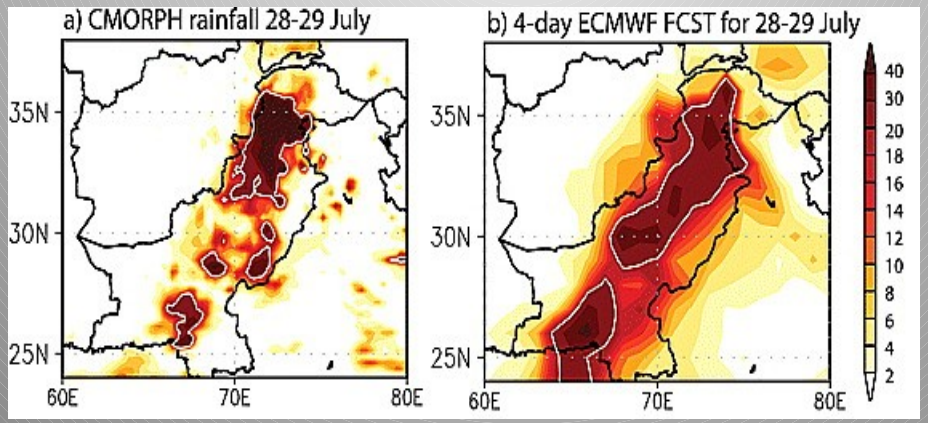
2010 Pakistan Floods

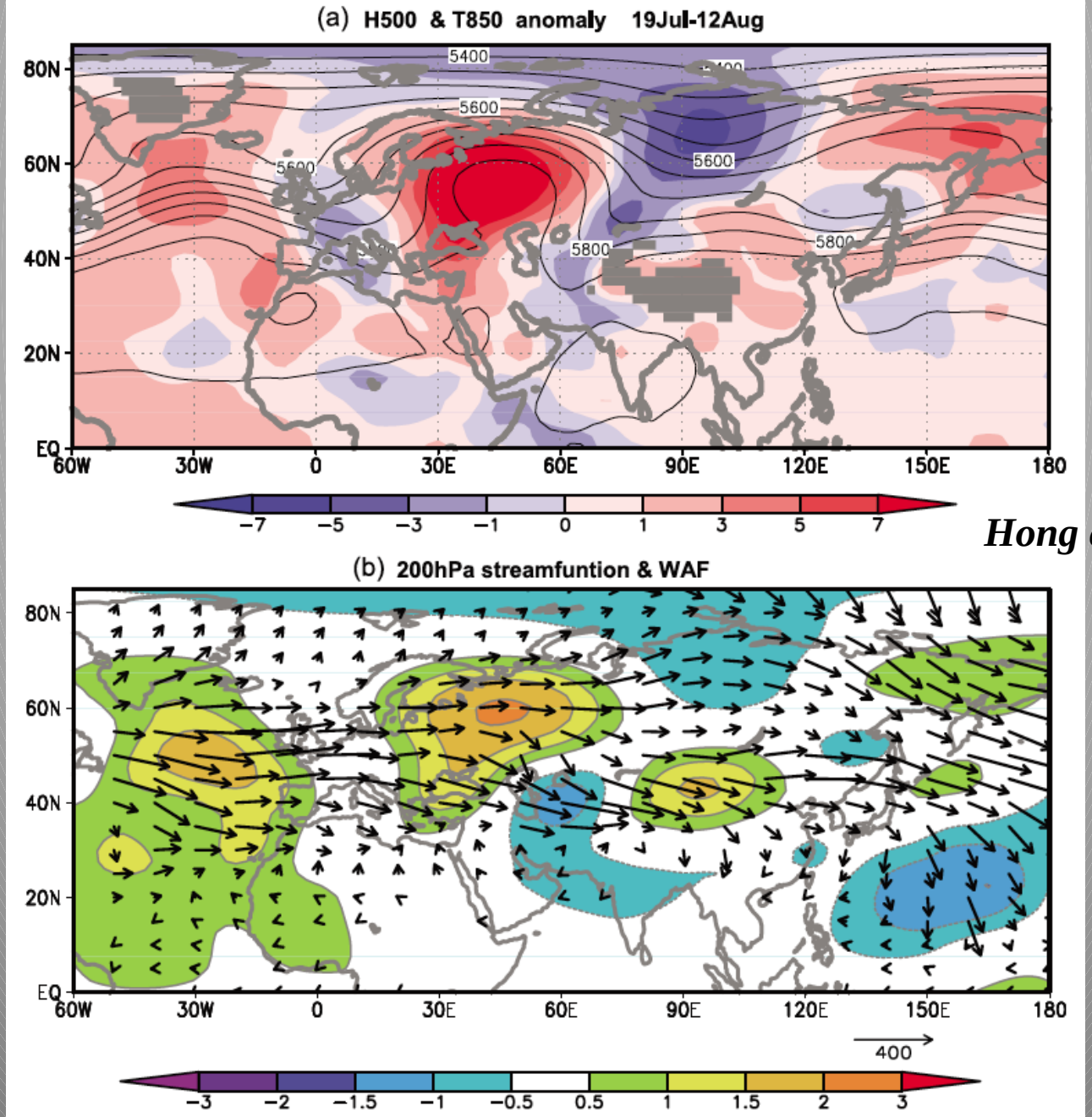


Hong et al (GRL,2011)



Webster et. al., (GRL,2011)

Figure 3. Anomalies during 19 July–12 August 2010: (a) 500 hPa height (interval 50 m) and 850 hPa temperature anomaly (shading), (b) 200 hPa stream function (shading, unit: 10^7 m^2 s^{-1}) and wave activity flux (unit: m^2 s^{-2}), and (c) the



Hong et al (GRL,2011

Severity of 2010 Flood – Global warming?

Pakistan: Humanitarian Snapshot - Floods (as of 2 Oct 2014)

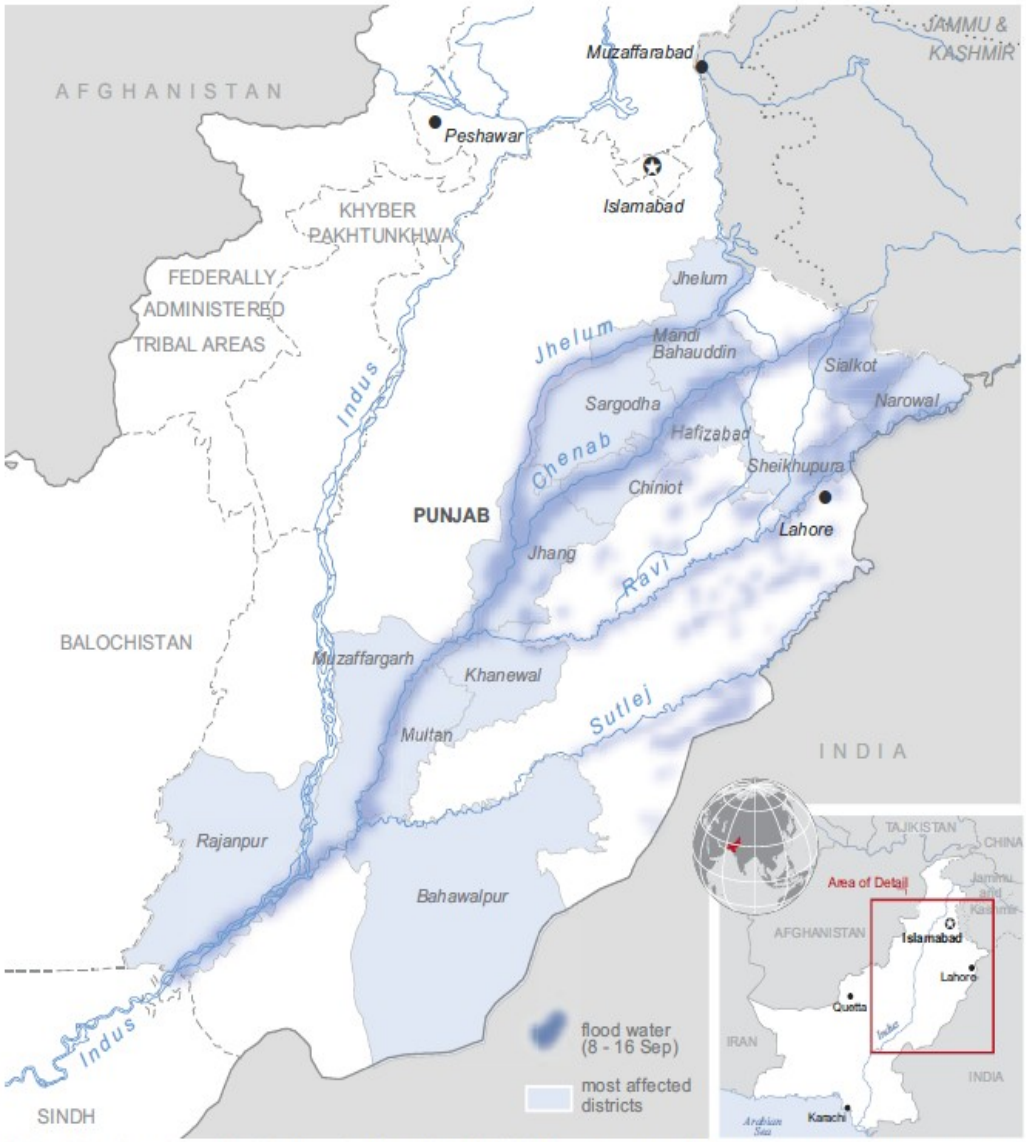
OCHA

FLOODS

Flash and urban floods ravaged north-eastern Pakistan and western India when late and concentrated monsoon rains started on 4 September. As of 2 October, the floods caused 364 deaths and affected approximately 2.5 million people in Pakistan. In addition to the loss of life and injury, there has been a social and economic cost: the partial and total loss of homes, significant loss of livestock and livelihoods and massive crop damage. Authorities set up 527 relief camps in affected areas to provide immediate health care services, referrals, cooked food, water, and non-food items, such as tents, blankets, soap, and sleeping mats.

KEY STATISTICS[1]

- 2.53 million people affected
- 107,000 houses damaged
- 2.4 million acres crops affected
- 527 Relief camps

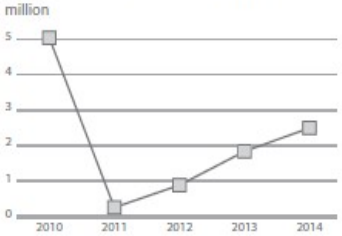


The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

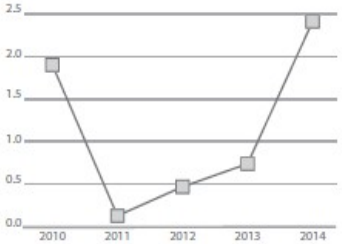
FLOOD HISTORY IN PUNJAB[2]

Recurrent monsoon floods over the last four years have affected more than 8 million people, many of them multiple times, leaving them vulnerable and in need of early recovery assistance.

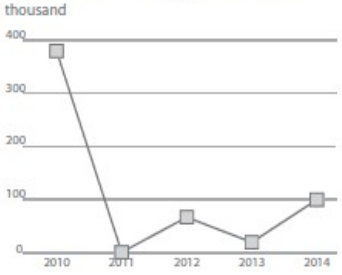
Number of affected people



Area of affected crop land



Number of damaged houses



Creation date: 2 Oct 2014 **Sources:** [1]NDMA Report - 2 Oct 2014. [2]PDMA Punjab OCHA Pakistan **Feedback:** ochapakistan@un.org **Web:** pak.humanitarianresponse.info

Motivations and questions

- The human disaster caused by the July–August 2010 flash floods over Pakistan called for a detailed scientific investigation in order to determine if such climate events can be anticipated and are linked to anthropogenic warming.

- Most of the previous investigations are based on observations or reanalyses. Only a few modeling efforts have been undertaken to delineate the factors leading to this disaster.

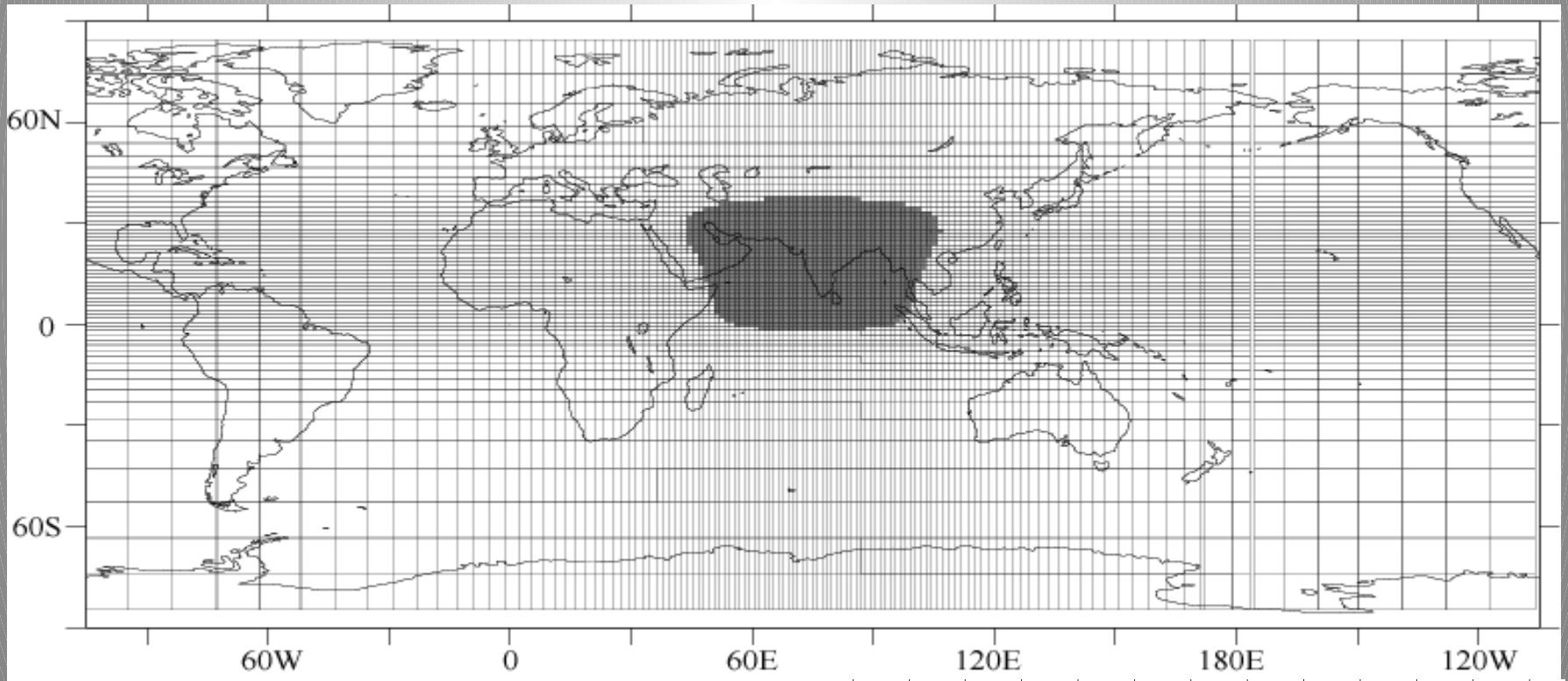
- Moreover, very few studies have focused on the relative impacts of the Indian and Pacific Oceans SST forcing relative to the mid-latitude atmospheric blocking/intrusions and their interactions with the monsoon surges for promoting the flood event.

Thus, a comprehensive (modeling) study focusing specifically on the role of Indo-Pacific SST forcing on the 2010 Pakistan floods is missing!

- These questions are tackled here in a modeling framework with the help of various sensitivity experiments performed with LMDZ.

- Interesting and challenging test of LMDZ for understanding extreme rainfall events, which are at the front of the scene now, especially in monsoon zone!

LMDZ (version 4) grid setup for CORDEX South Asia
shaded region has grid-size < 35 km (0-Equator, 45-110E)

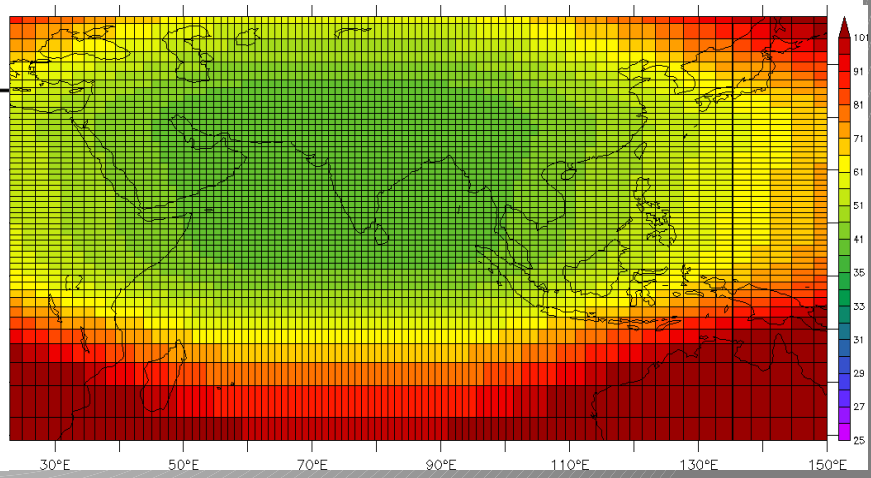


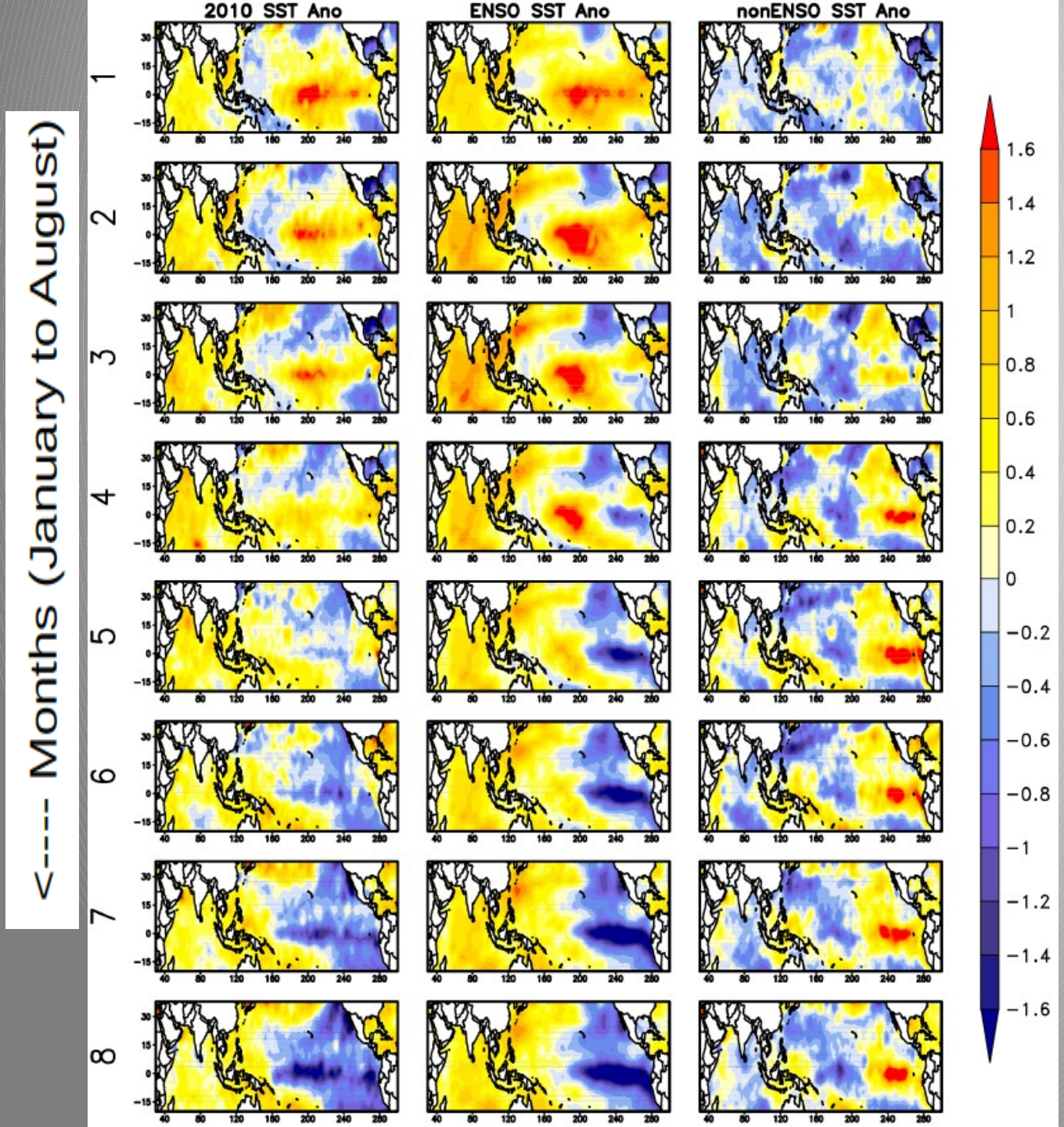
Clim Dyn
DOI 10.1007/s00382-012-1658-8

2012

High resolution simulation of the South Asian monsoon using a variable resolution global climate model

T. P Sabin · R. Krishnan · Josefine Ghattas · Sebastien Denvil · Jean-Louis Dufresne · Frederic Hourdin · Terray Pascal





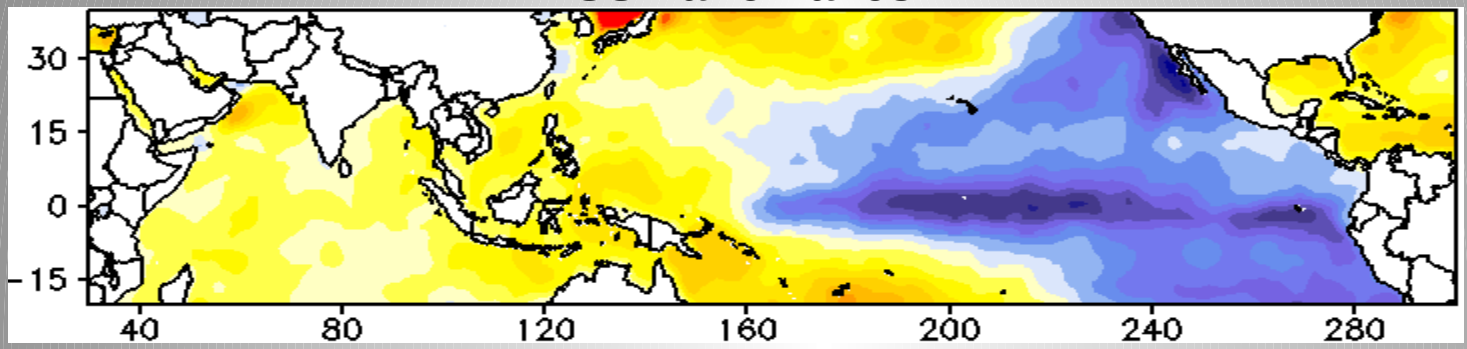
The ENSO and ENSO-unrelated components of monthly SST anomalies during 2010 were computed using a linear inverse modeling approach (Compo and Sardeshmukh, J. Climate, 2010)

This approach is one of the best methods currently available to isolate ENSO component in climate time series (see http://www.esrl.noaa.gov/psd/people/cecile.penland/pubs.html).

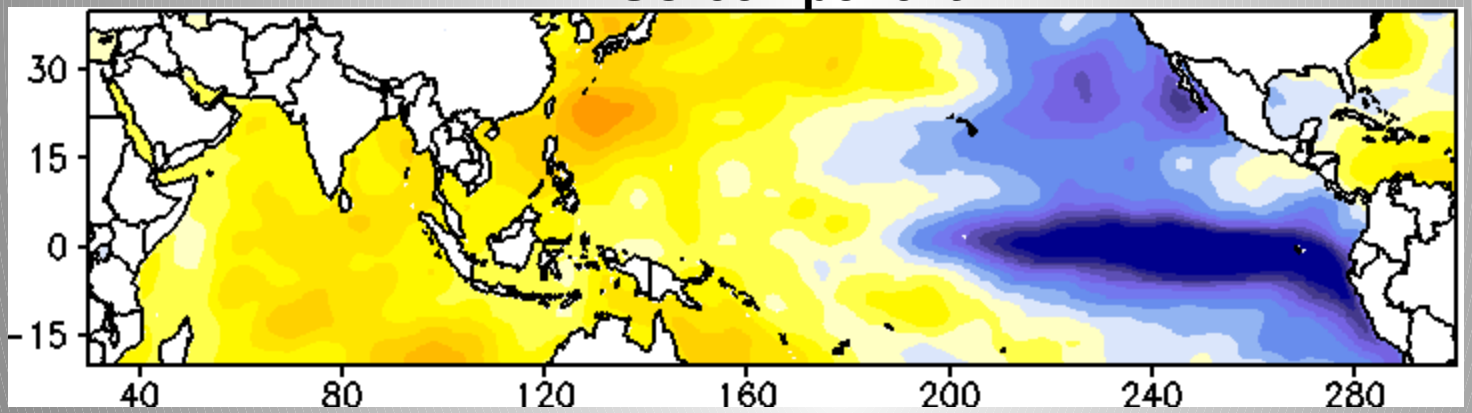
2010 JJAS

SST anomalies

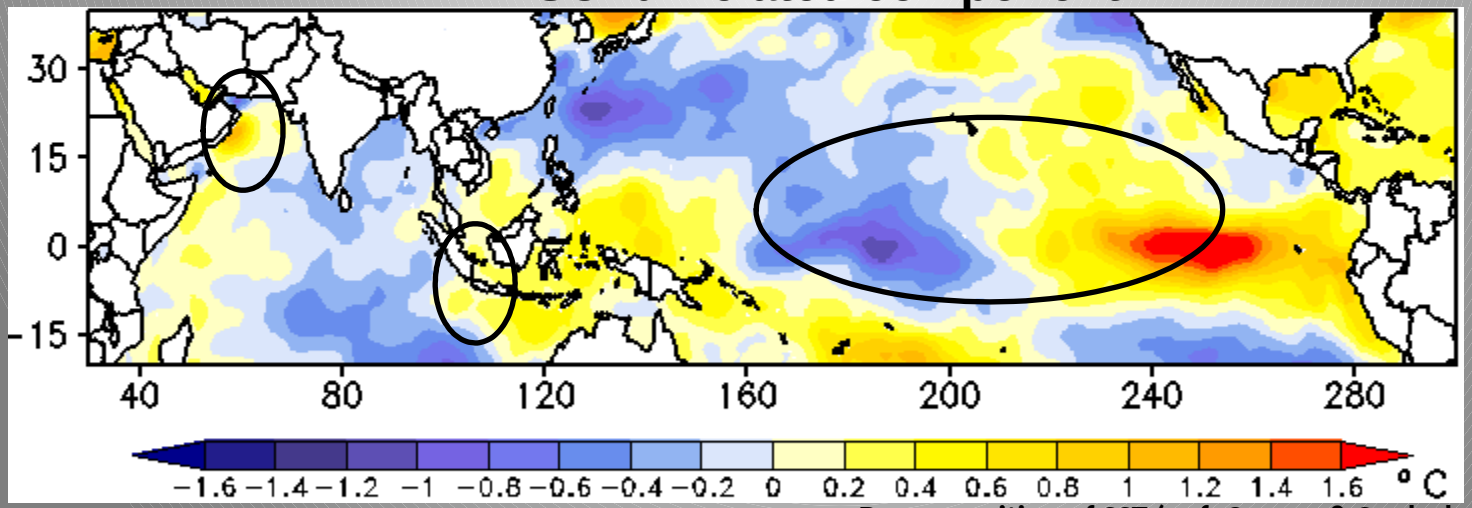
HadISST
Rayner et al. 2003



ENSO-component



ENSO- unrelated component



Decomposition of SST (ref: Compo & Sardeshmukh 2010)

Table 1: Acronyms and SST boundary forcings for the different sets of LMDZ simulation experiments.

Experiment	SST boundary condition
C-SST	Observed climatological SST
R-SST	Observed climatological SST + SST anomalies of 2010
E-SST	Observed climatological SST + ENSO related SST anomalies decomposed for 2010
NE-SST	Observed climatological SST + ENSO unrelated SST anomalies decomposed for 2010
NE-IO-SST	Observed climatological SST + ENSO unrelated SST anomalies over Indian Ocean decomposed for 2010

None of the simulations simulate the observed mid-latitude atmospheric blocking!

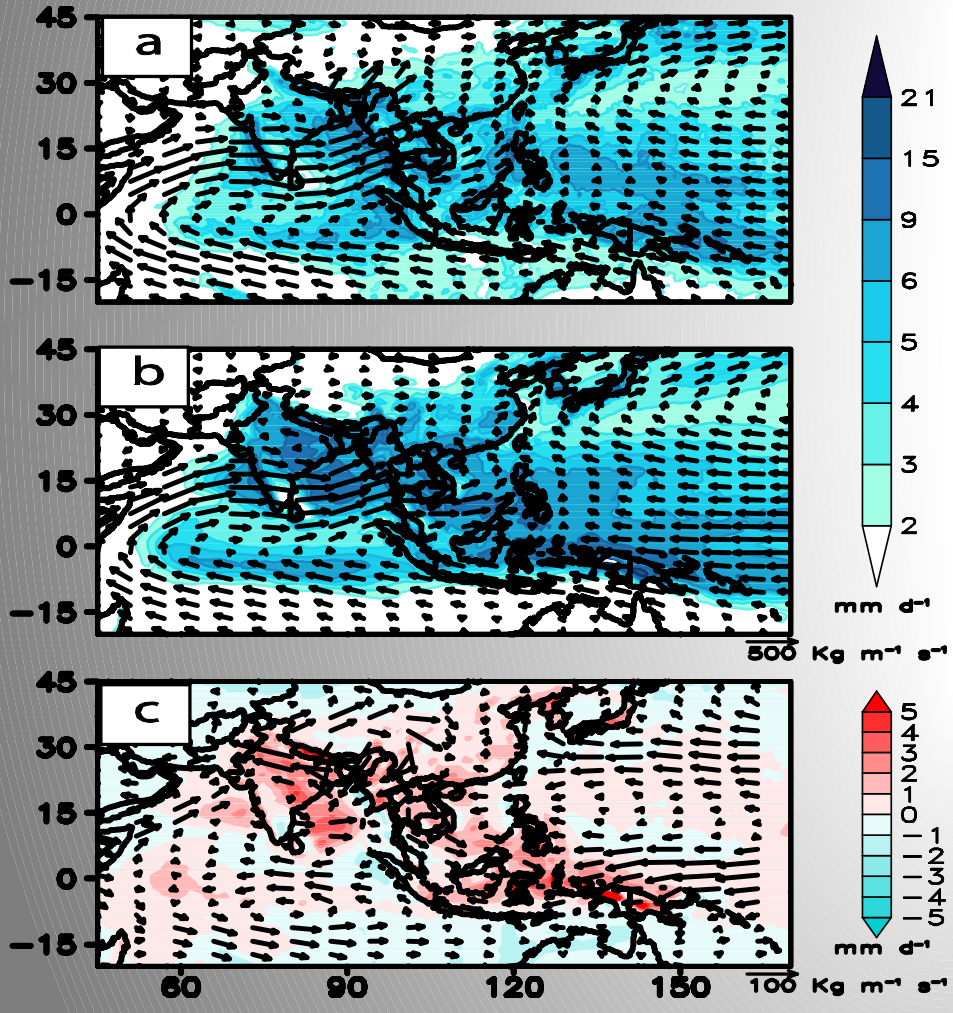
This blocking is not related to SST forcing, an expected result.

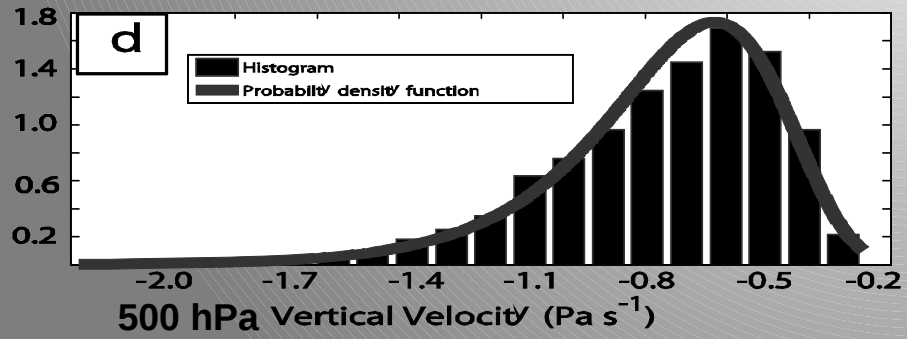
The time varying forcing agents (CO_2, CH_4, N_2O, …) are set to present values

10 members by experiment, all starting the 16^{th} May 2010

Perturbed initial conditions from ECMWF reanalysis

JJAS climatology Rainfall & Integrated moisture transport





Observation –TRMM (Rainfall) & NCEP (Moisture Transport)

Simulation – LMDZ – AGCM C-SST ensemble mean Highly realistic!!

Difference between C-SST simulations & observation

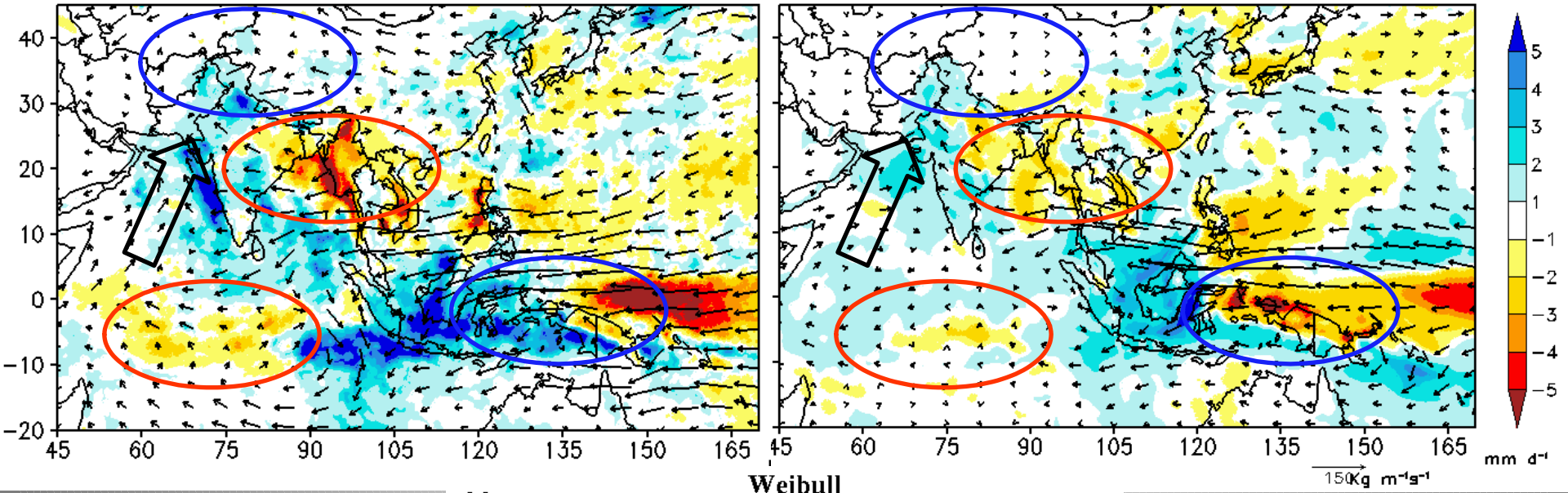
Histogram and fitted Weibull distribution for the daily minimum 500 hPa vertical velocity over NW Pakistan (70°-74°E;30°-36°E) and C-SST simulations during JJAS (122 days by 10 members)

shape and scale Weibull parameters estimated by the maximum likelihood method

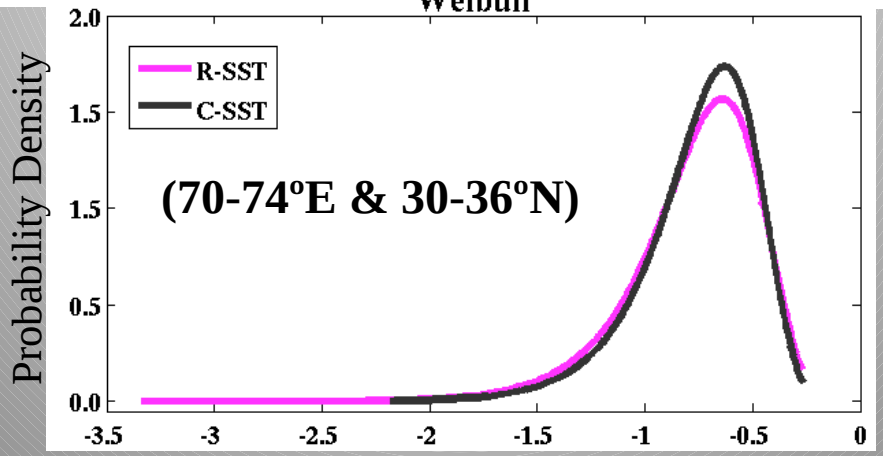
Rainfall and Moisture Transport Anomalies for JJAS 2010

Observation
TRMM (Rainfall) &
NCEP (Moisture Transport)

Simulation
LMDZ4 AGCM
R-SST ensemble mean

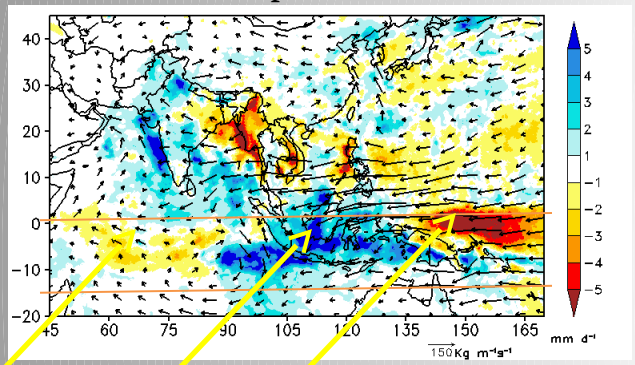


Weibull Distribution
&
Extreme Convection

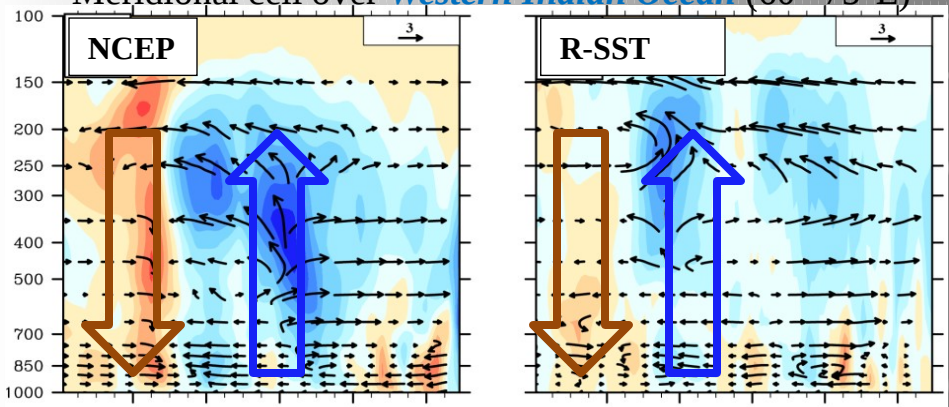


Meridional and zonal atmospheric cells over the Indian Ocean during JJAS 2010

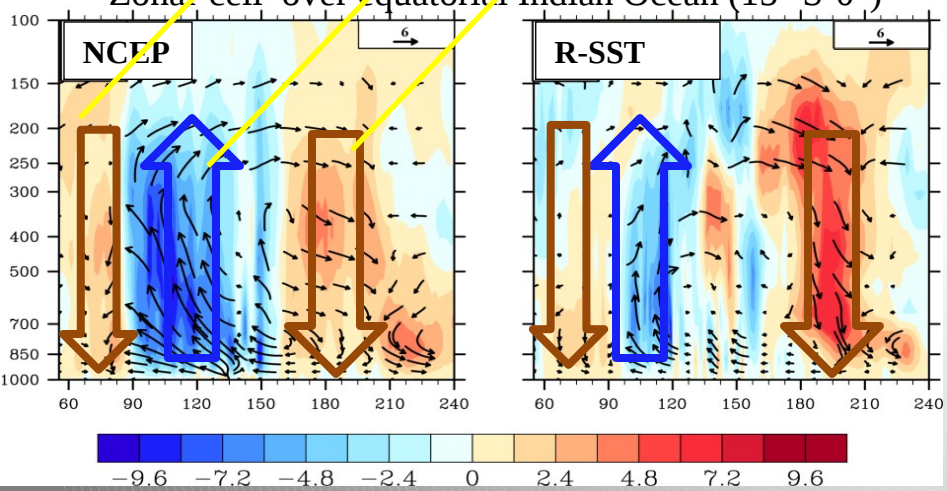
Rainfall and Moisture Transport Anomalies for JJAS 2010



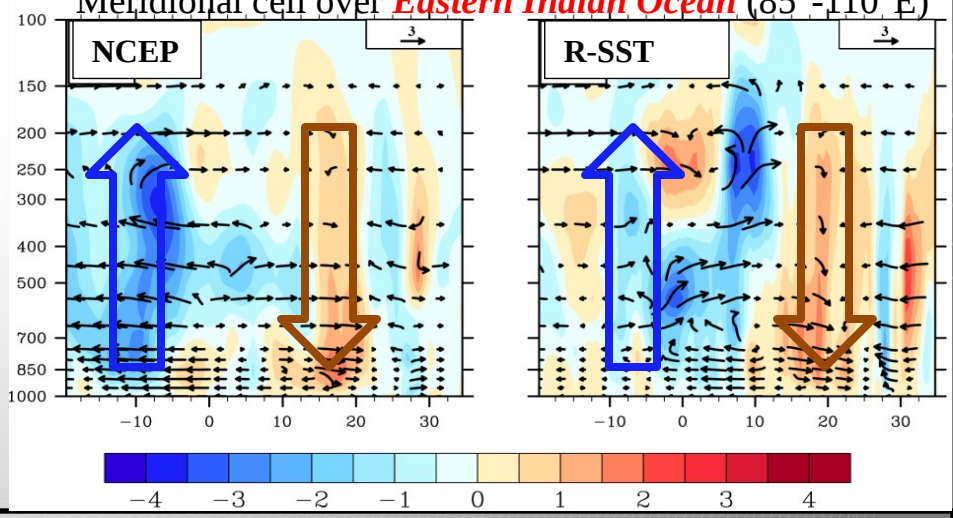
Meridional cell over *Western Indian Ocean* (60°-75°E)



Zonal-cell over equatorial Indian Ocean (15° S-0°)



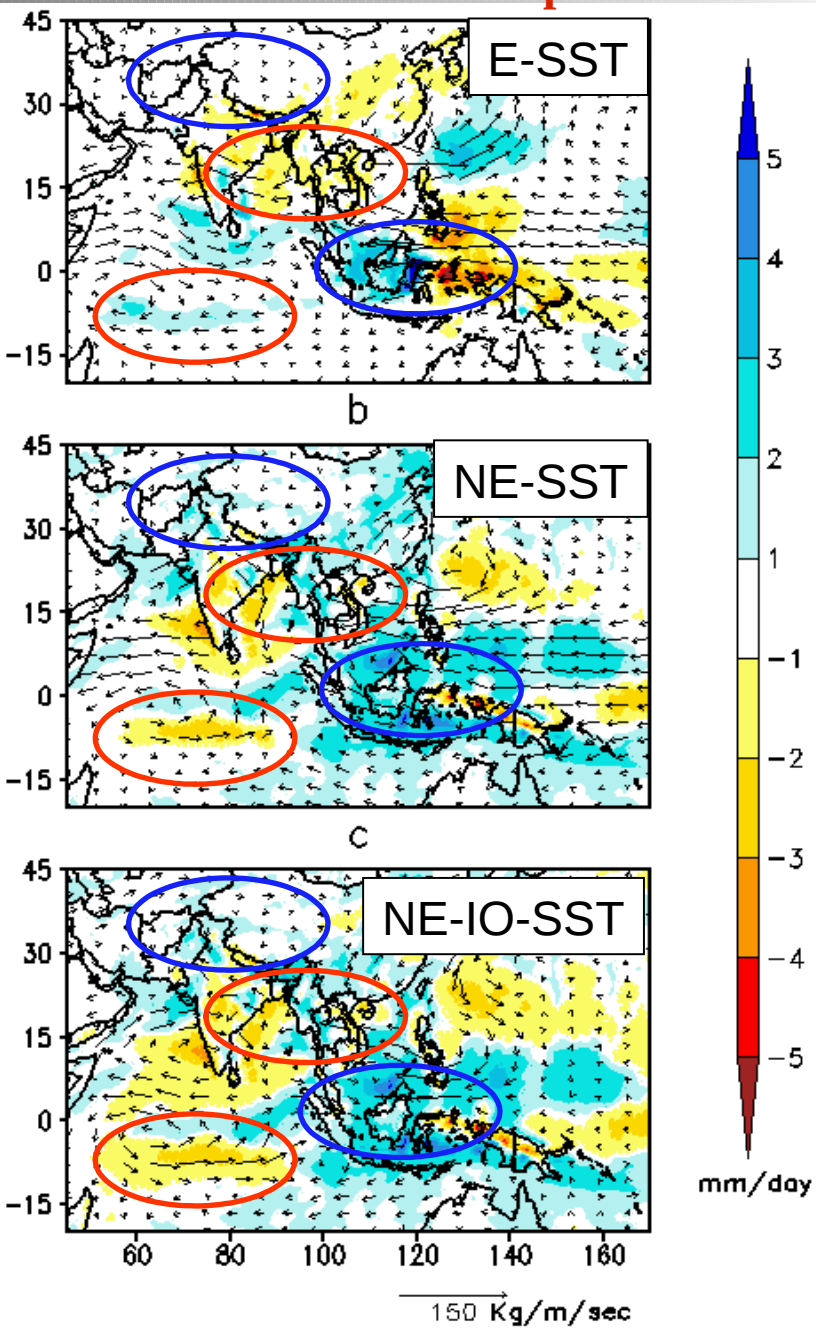
Meridional cell over *Eastern Indian Ocean* (85°-110°E)



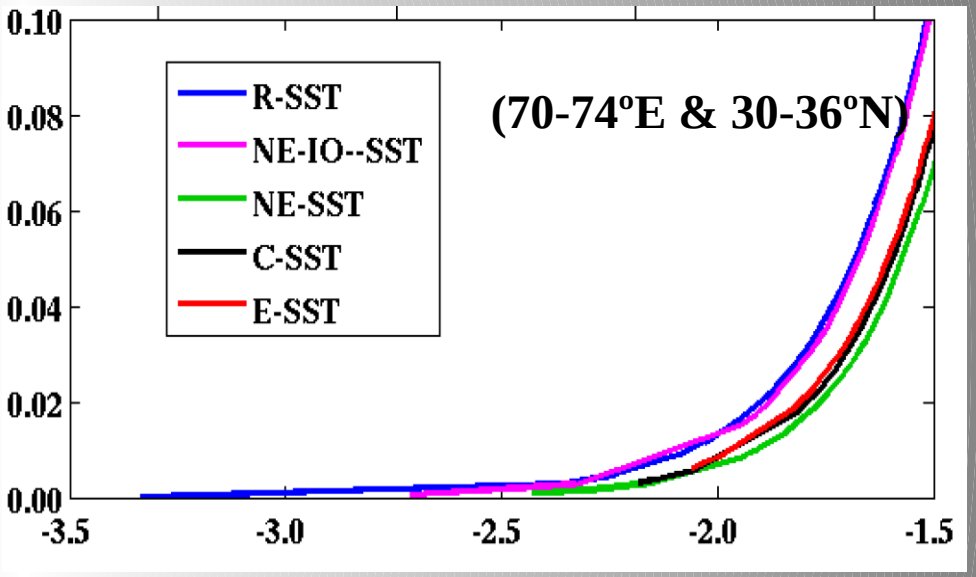
- **Realistic simulation of rainfall anomalies over the Indo-Pak region and atmospheric circulation observed during 2010 by the R-SST runs!**

What is the roles of ENSO and ENSO-unrelated SST patterns in modulating the northwest Indo-Pak rainfall and the observed/simulated atmospheric cells?

Rainfall and Moisture Transport Anomalies

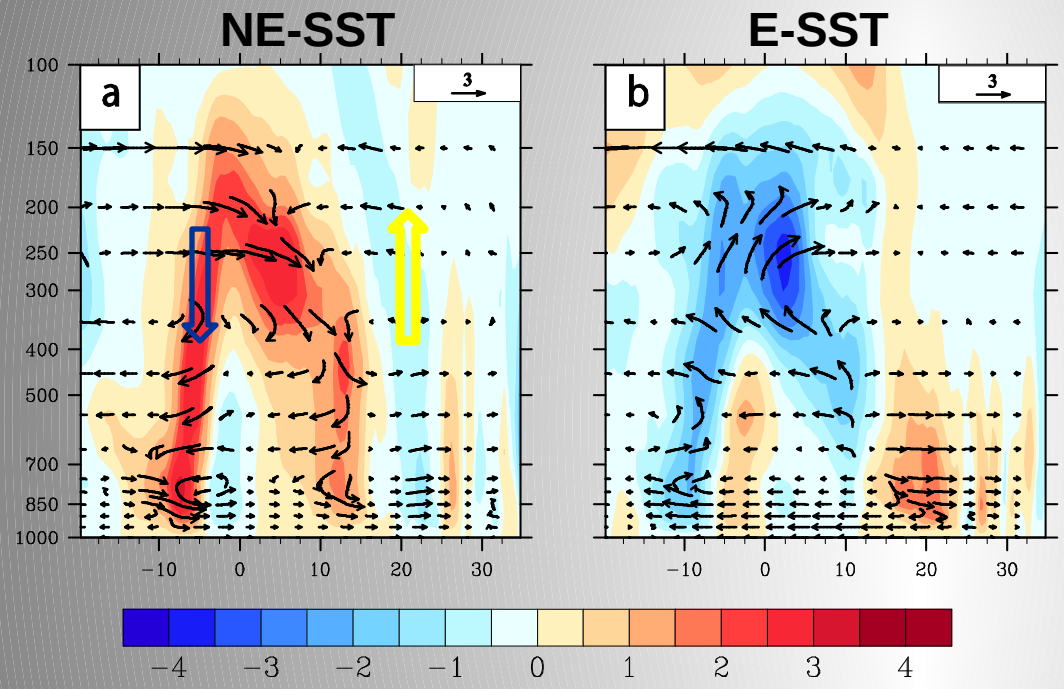


Weibull distribution tail



500 hPa Vertical Velocity (Pa s^{-1})

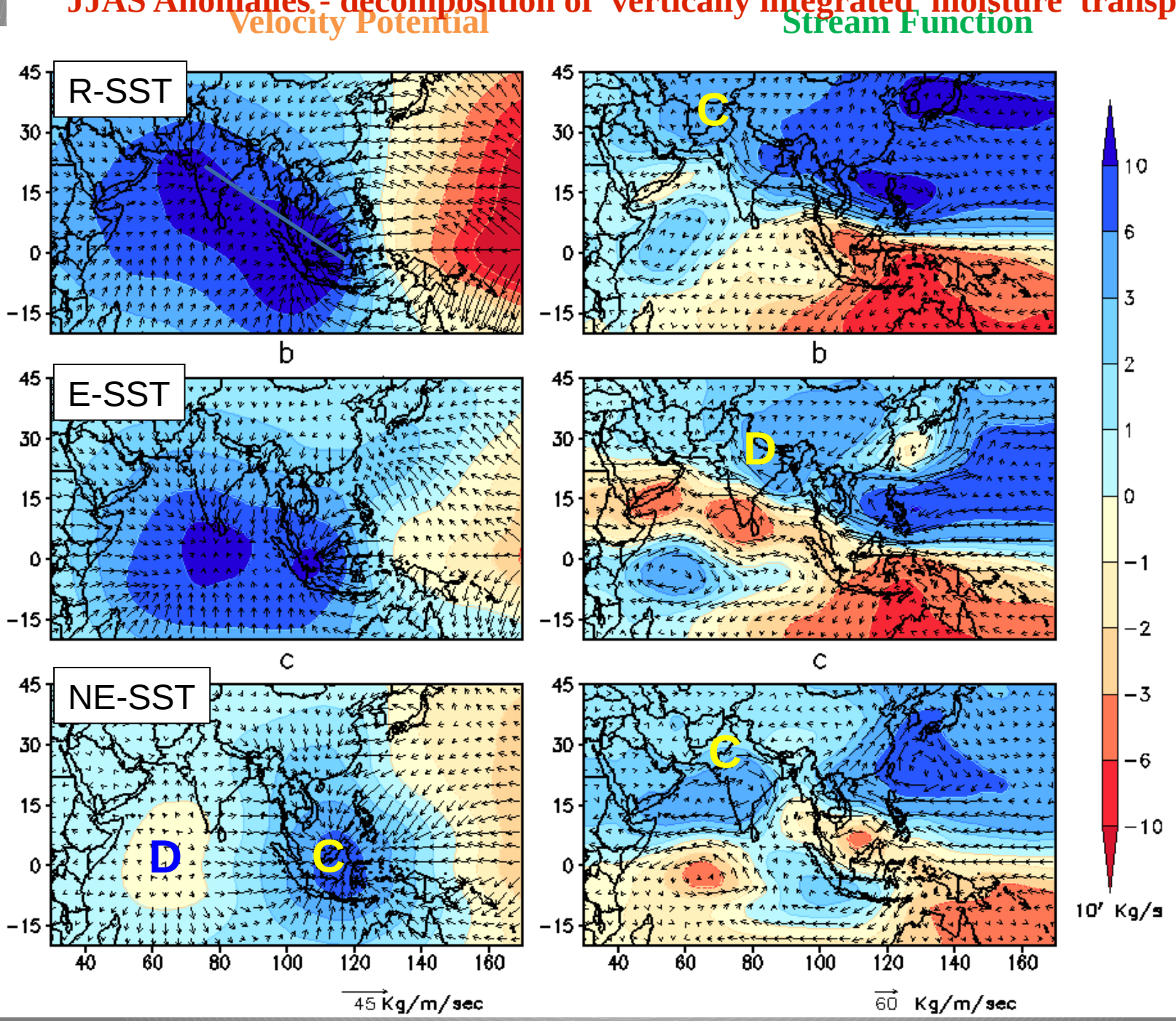
- Only NE-SST & NE-IO-SST runs could simulate extreme convective activity and anomalous positive rainfall over northwest India-Pakistan region during 2010!



Meridional-cell of zonaly averaged (60°-75°E) meridional and vertical wind

Zonal-cell of meridionaly averaged (15° S-0°) zonal and vertical wind

JJAS Anomalies - decomposition of vertically integrated moisture transport



CONCLUSIONS

None of the simulations simulate the observed mid-latitude atmospheric blocking, which was suggested as a key-trigger of the 2010 Indo-Pak flood event in past studies. This blocking is not related to SST forcing, an expected result.

However, interestingly:

- ENSO-related forcing seems to induce a modest westward shift of the large-scale monsoon circulation and significantly weakens the convection over Bay of Bengal, but is not sufficient for a realistic simulation of the flood event during 2010.

- Intensification of northward moisture transport from Arabian Sea into the subtropical Indo-Pak region leading to positive rainfall anomalies as observed in 2010 could be mostly attributed to ENSO-unrelated Indian SST forcing in addition to mid-latitude forcing.

- The warmer SST anomalies over the northwest and southeast Indian Ocean promotes northward moisture transport and enhanced convection over subtropical Indo-Pak region during 2010.

- This study highlights the intrinsic role of Indian Ocean SST in modulating regional scale heavy rainfall events. The in-situ observations over Indian Ocean may be crucial for better understanding and realistic prediction of such events.

Use of LMDZ at CCCR (IITM, Pune, India) and comments

- LMDZ4 is currently installed at CCCR (IITM, Pune, India) and is now heavily used in PhD thesis (3), publications (about 10 of rank A) and projects (CORDEX- Asia, Belmont Forum-PacMedy, national projects ...) But not at all the institution level (e.g. IITM), because it is not considered as a "MoES" model like CFS and GFS (e.g. NCEP models)!

- Good performance of LMDZ (however speed is a limiting factor) for the simulation of the mean Indian monsoon and extreme rainfall events in this study. Strong interest for the zooming capacity of LMDZ!

- The differences with coupled mode (e.g. IPSL model) is striking and raise many questions on how building a "realistic" coupled model for monsoon and more generally tropical variability!