IITM-ICTP Advanced School on Earth System Modelling (ESM) 18-27 July 2016

The variability of large scale circulation over the Indo-Pacific region

ENSO induced Pacific influence on Indian Ocean in the evolution Indo-Pak heavy rainfall

मिलिन्द मुजुमदार

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Centre for Climate Change Research (CCCR),

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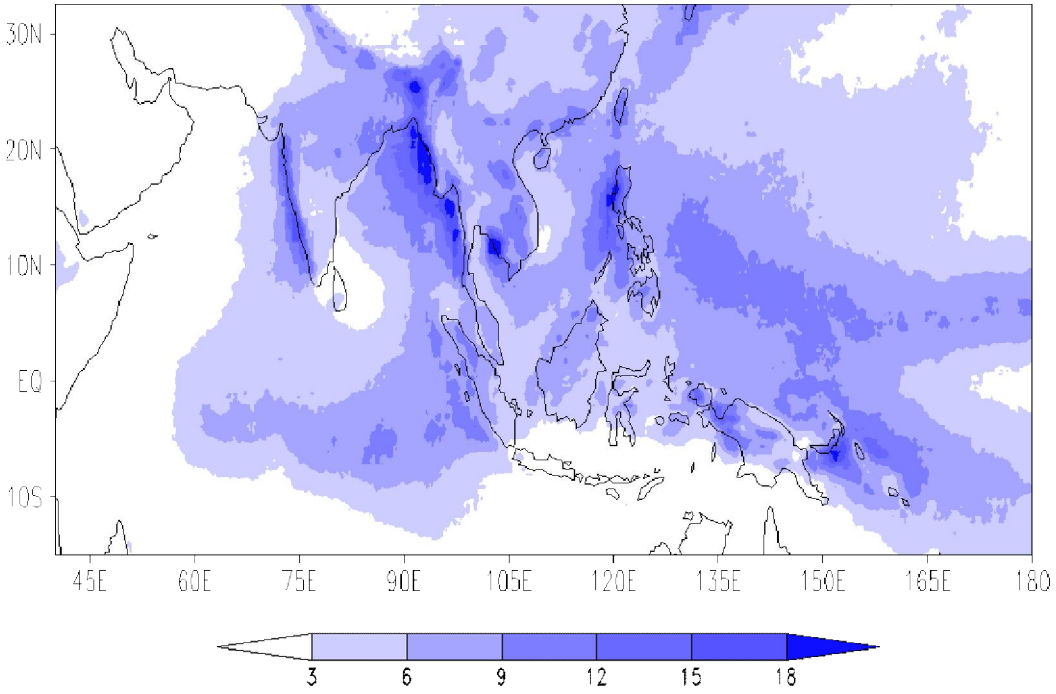
http://www.tropmet.res.in

Acknowledgements: **Director, IITM**
ICTP

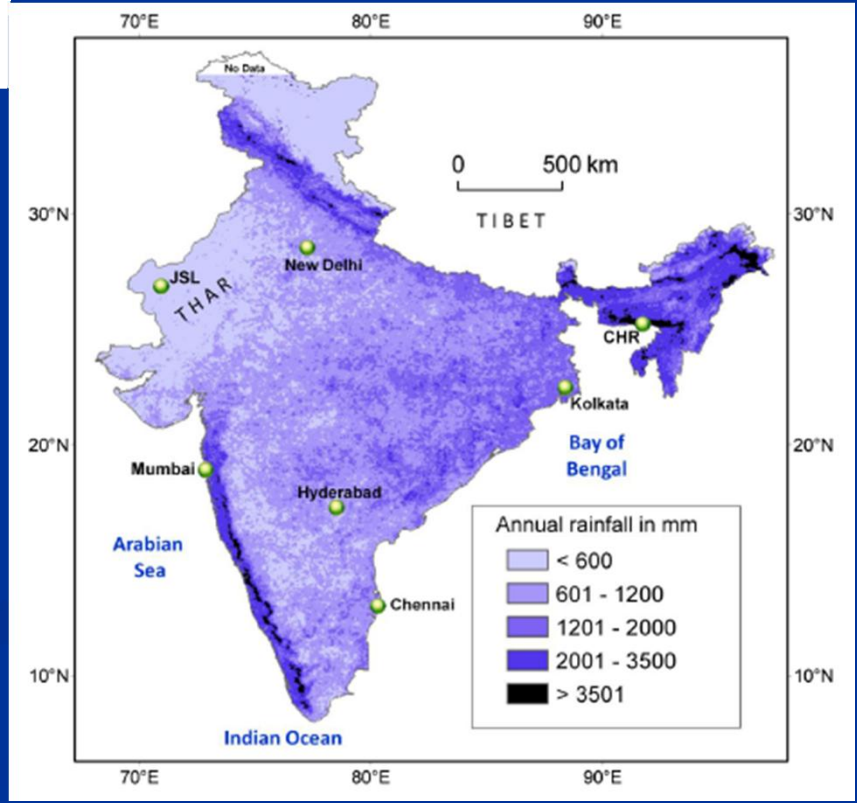


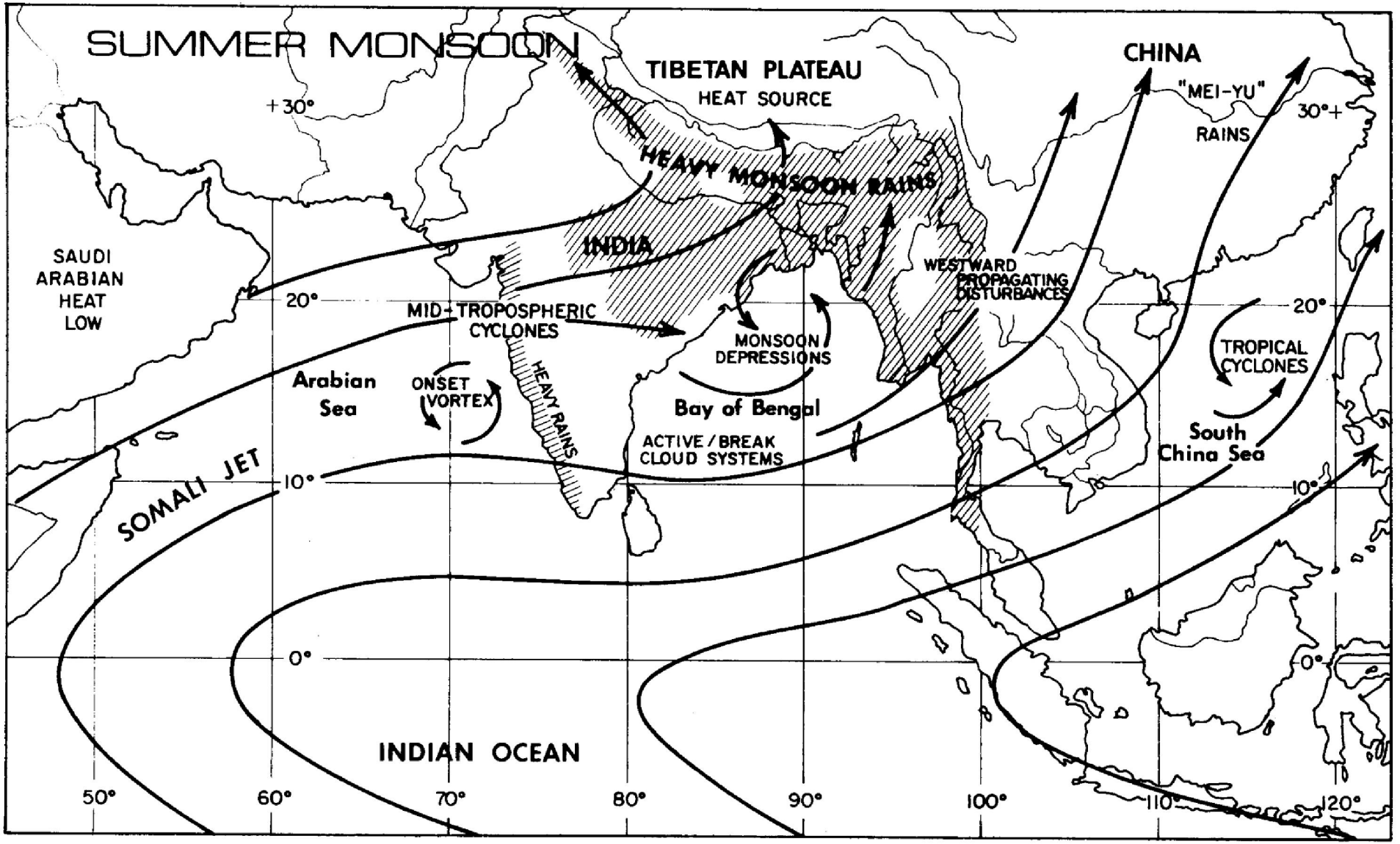
Spatial distribution of mean summer monsoon (JJAS) rainfall rate in mm day^{-1} based on TRMM 3B42

Rainfall from TRMM satellite. Data source: http://www.geog.ucsb.edu/~bodo/TRMM/)

A.K. Singhvi and R. Krishnan (2014): Chapter in book 'Landscapes and Landforms of India' – Springer Verlag

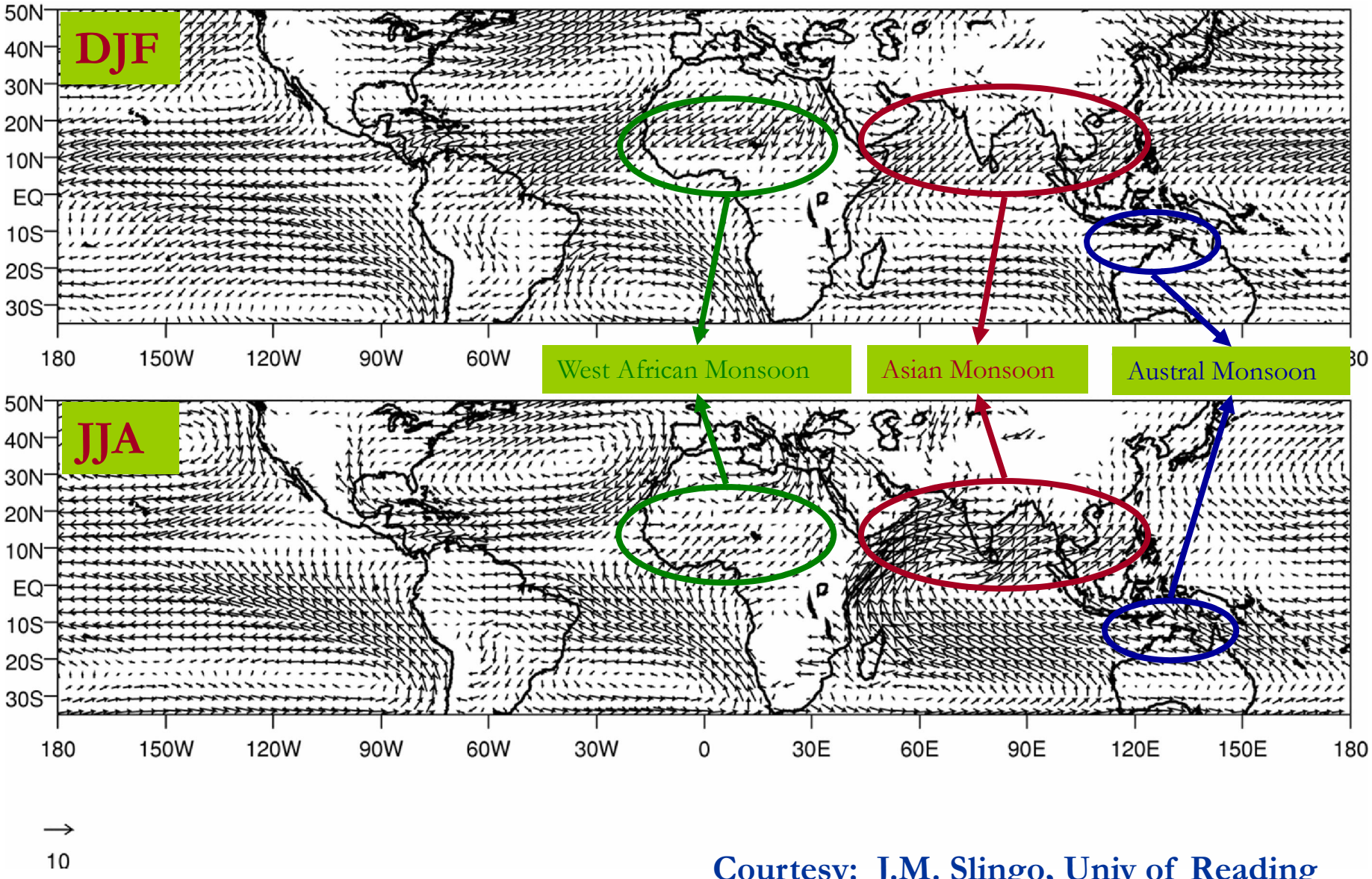
Annual rainfall over India in mm





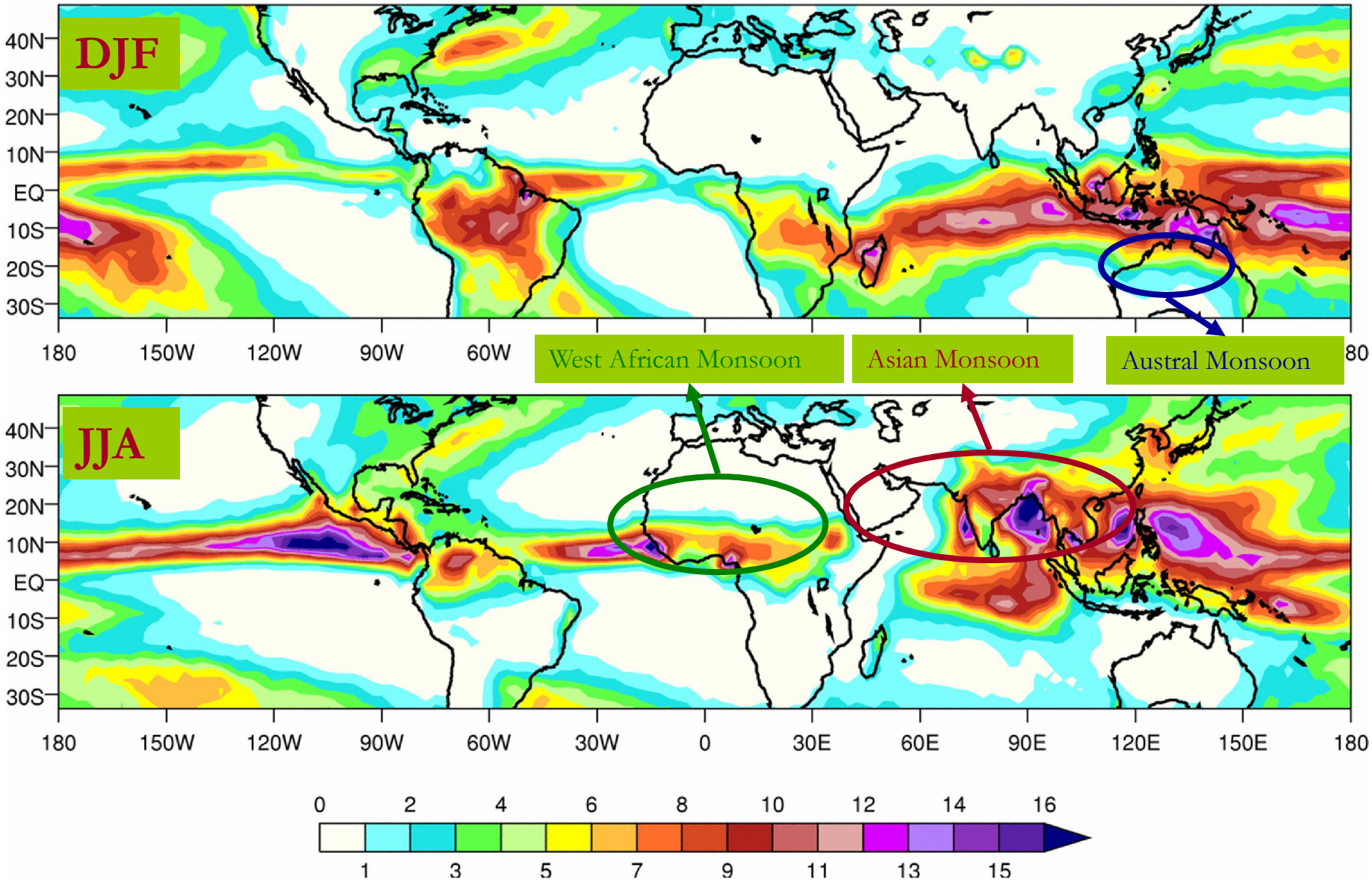
Primary synoptic and smaller-scale circulation features that affect cloudiness and precipitation in Summer monsoon region. Locations of June to September rainfall exceeding 100 cm over the land West of 100°E associated with the southwest monsoon are indicated (Rao, 1981). Those over water areas and east of 100°E are omitted.

Winds at 925hPa



Courtesy: J.M. Slingo, Univ of Reading

Rainfall (mm/day)



Courtesy: J.M. Slingo, Univ of Reading

Severity of 2010 Flood

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.

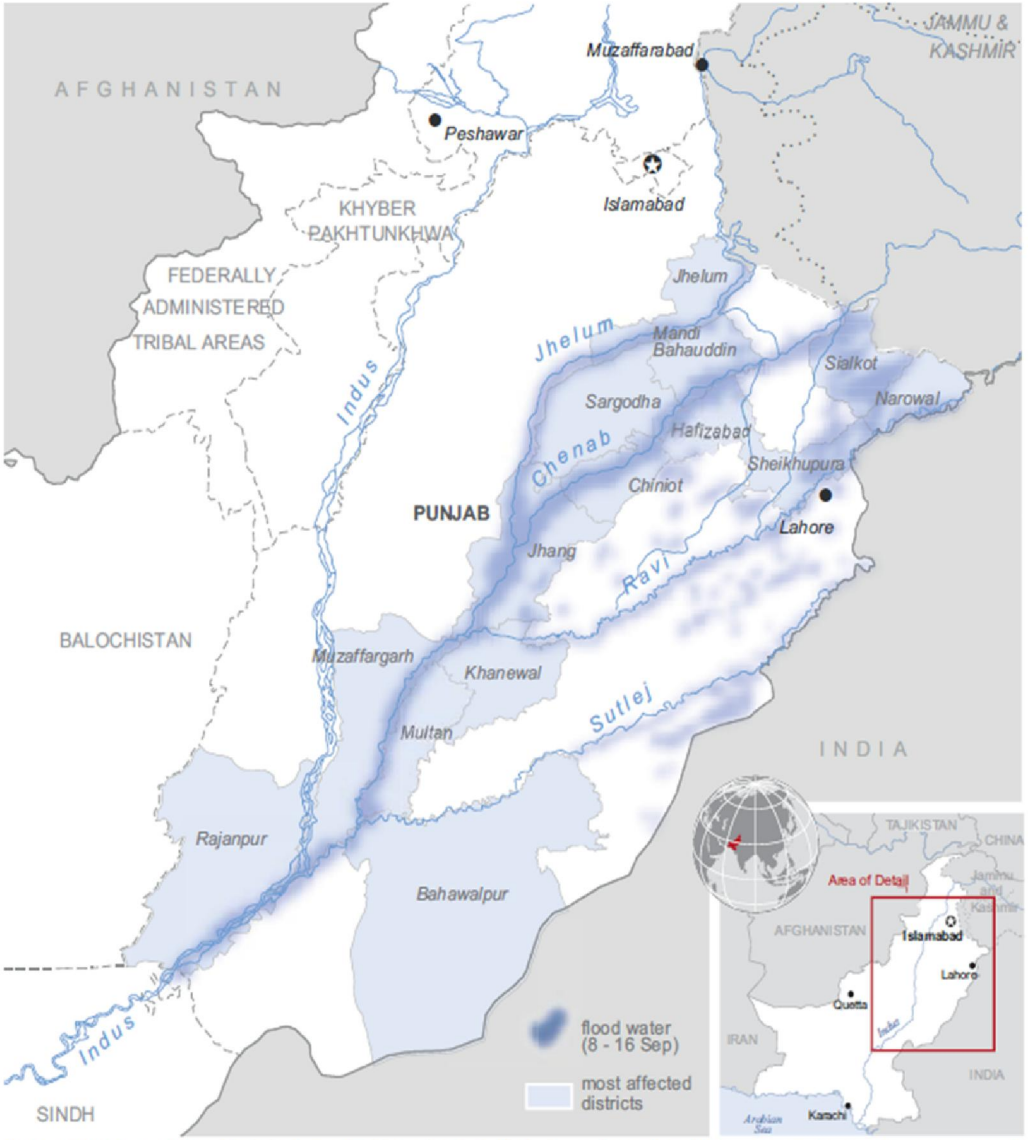
KEY STATISTICS[1]

2.53 million people affected

107,000 houses damaged

2.4 million acres crops affected

527 Relief camps

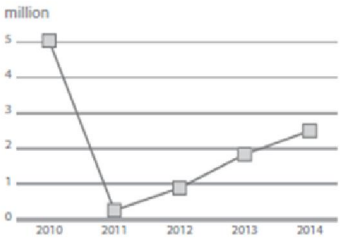


The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet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

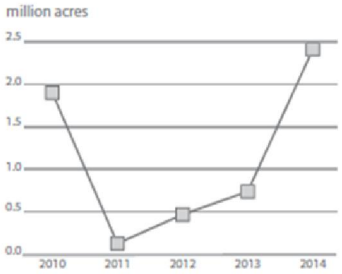
FLOOD HISTORY IN PUNJAB[2]

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.

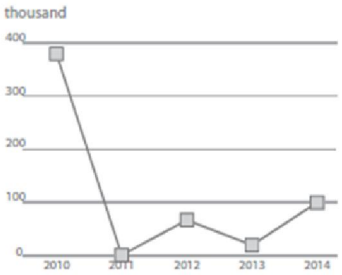
Number of affected people



Area of affected crop land

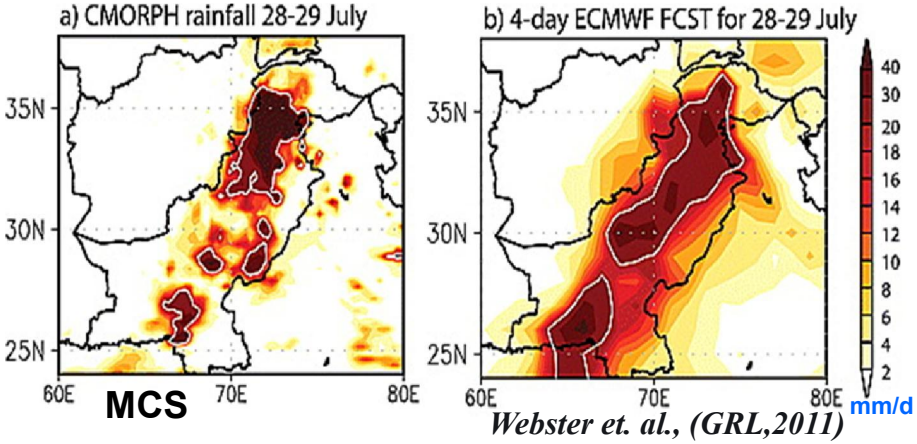


Number of damaged houses



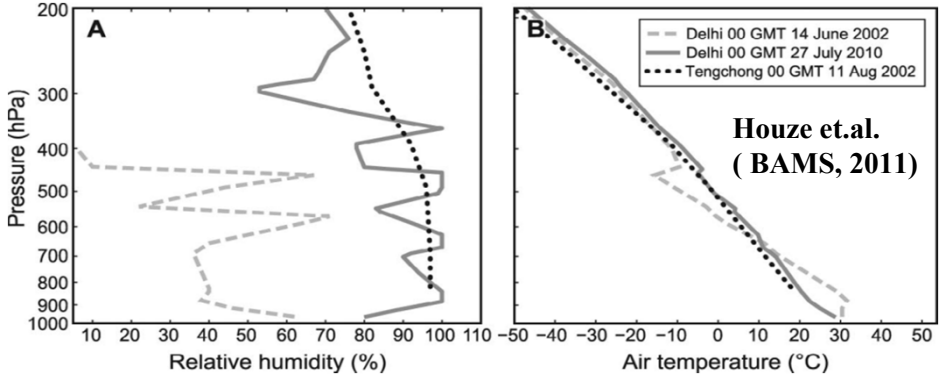
Creation date: 2 Oct 2014 **Sources:** [1]NDMA Report - 2 Oct 2014. [2]PDMA Punjab OCHA Pakistan **Feedback:** ochapakistan@un.org **Web:** pak.humanitarianresponse.info

2010 Pakistan Floods



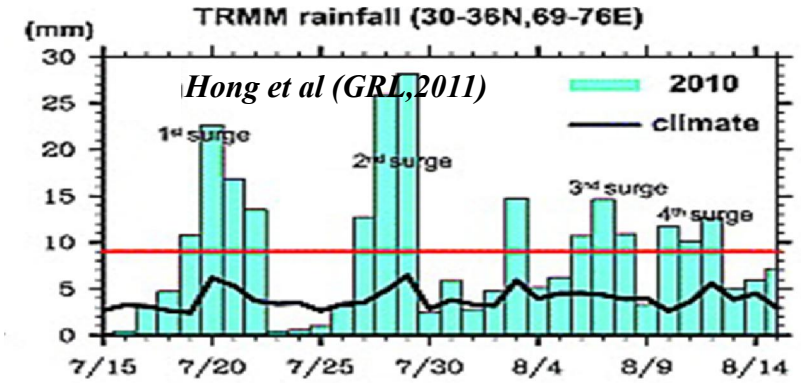
MCS

Webster et. al., (GRL,2011)



Houze et.al. (BAMS, 2011)

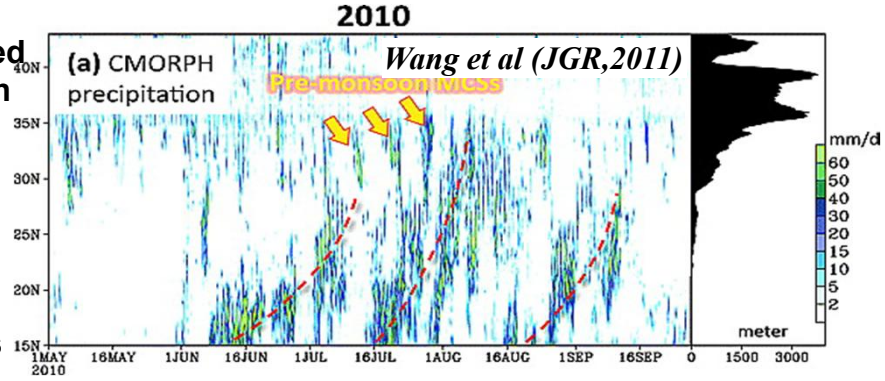
Convection of a more oceanic character in a high humid environment



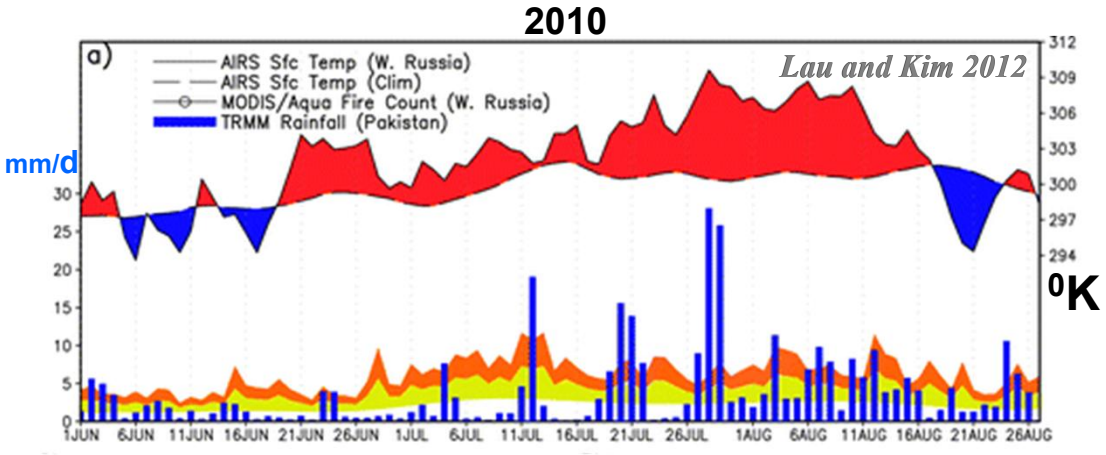
Hong et al (GRL,2011)

La Nina induced Teleconnection pattern

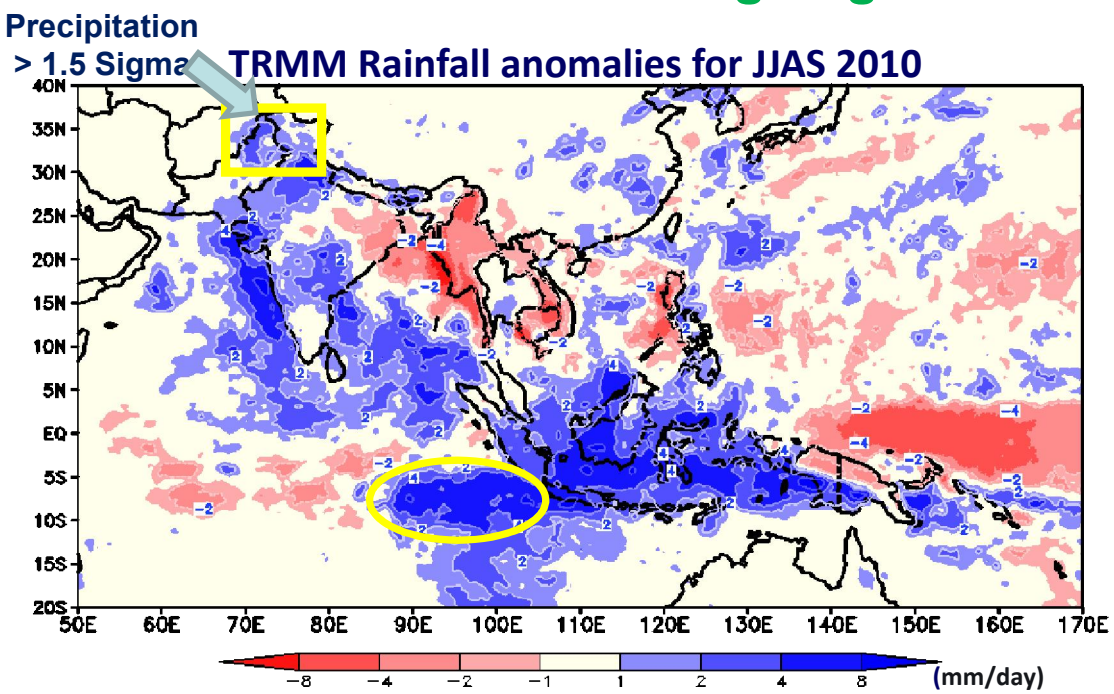
Persistent increase in conditional instabilities



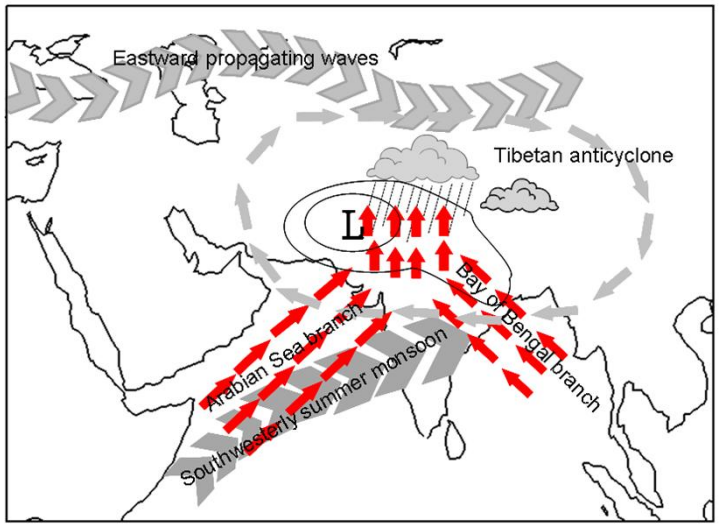
Wang et al (JGR,2011)



Persistence of synoptic and sub-synoptic Conditions are intriguing



Relative contribution of the mid-latitude circum global wave train (CGT) to the South Asian summer monsoon

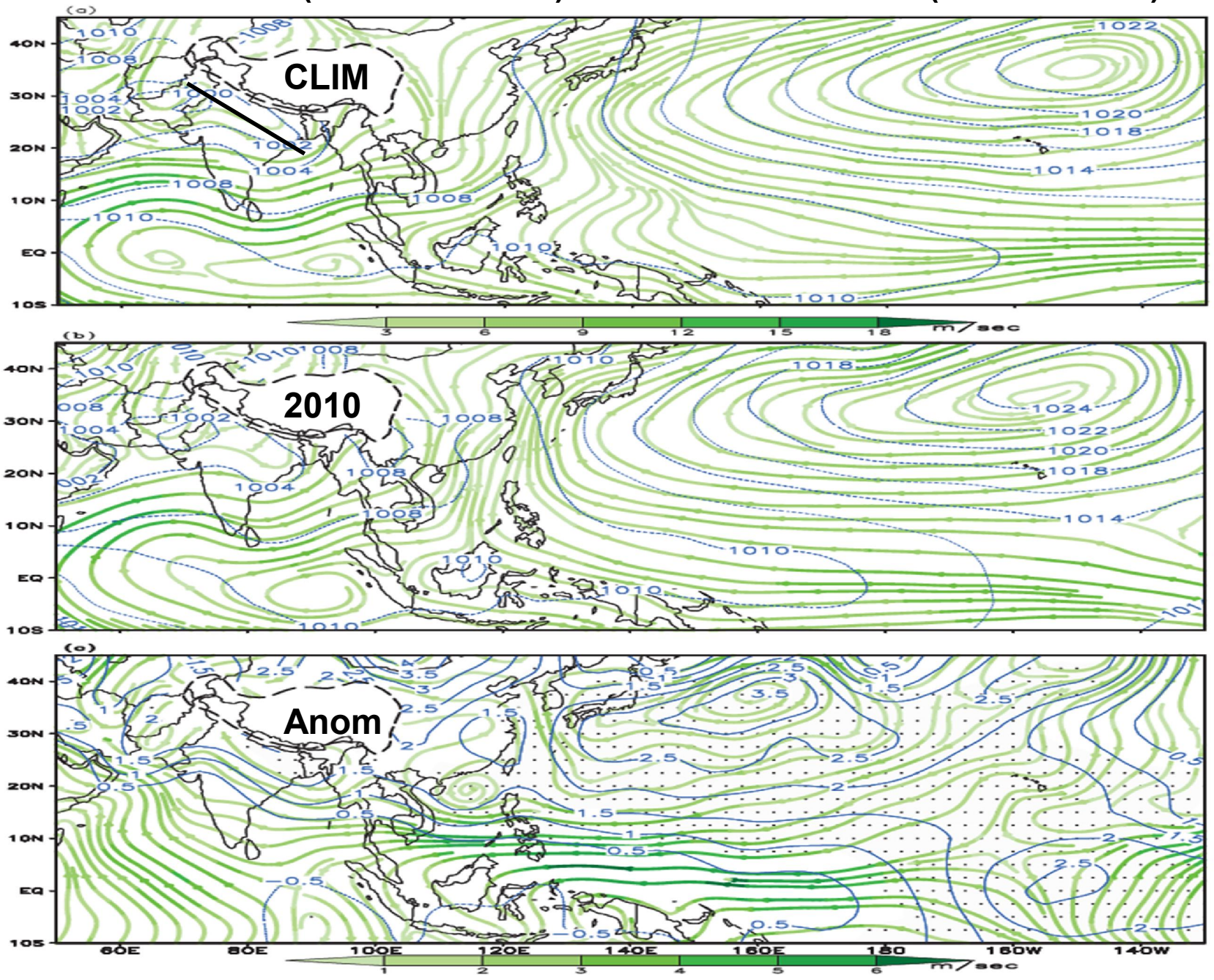


Saeed 2011

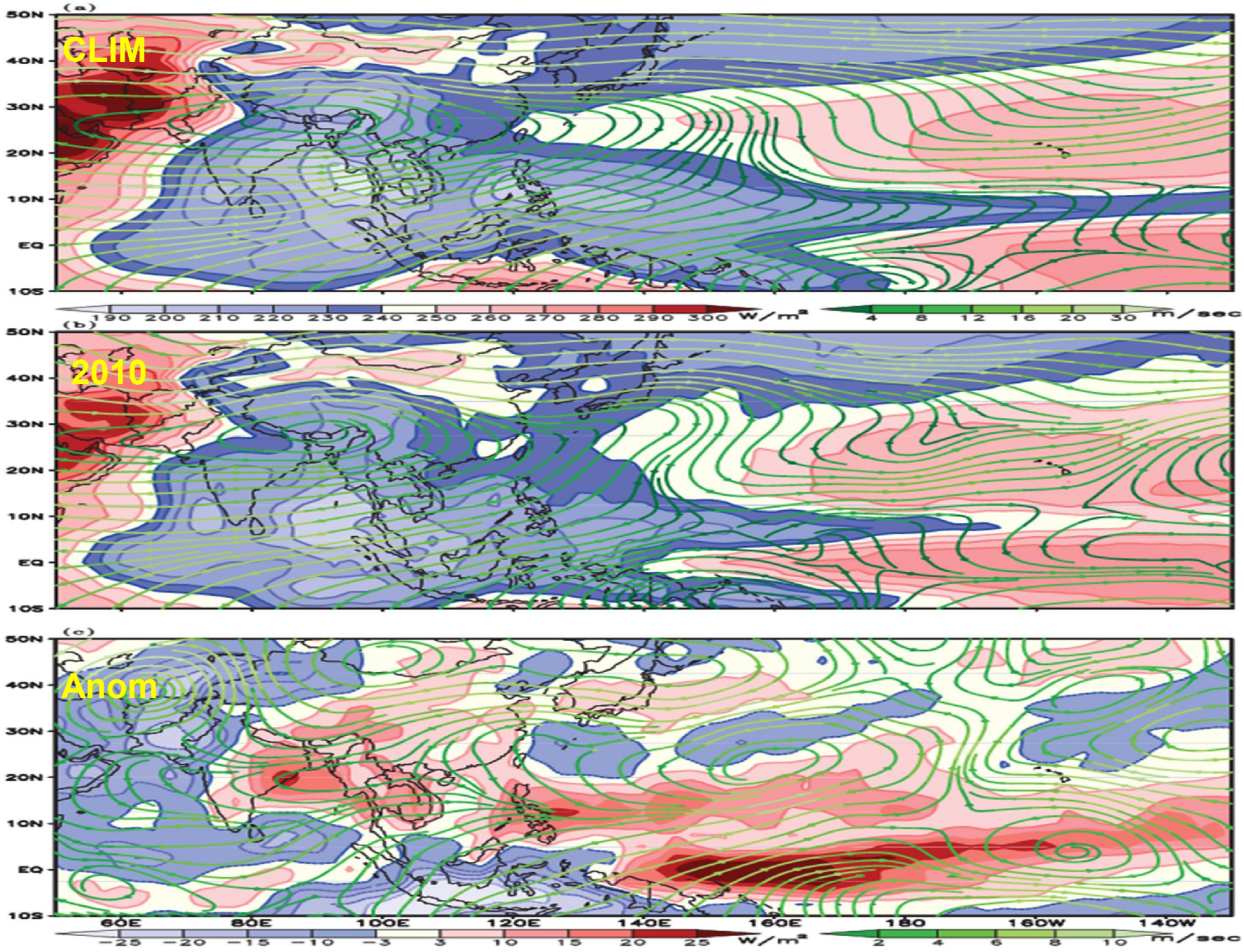
http://www.earthsystemschool.mpg.de

Milind Mujumdar, B. Preethi, T.P. Sabin, Karumari Ashok, Sajjad Saeed, D. S. Pai and R. Krishnan (2012) - Meteorological Applications 'Special issue on Asian summer monsoon'

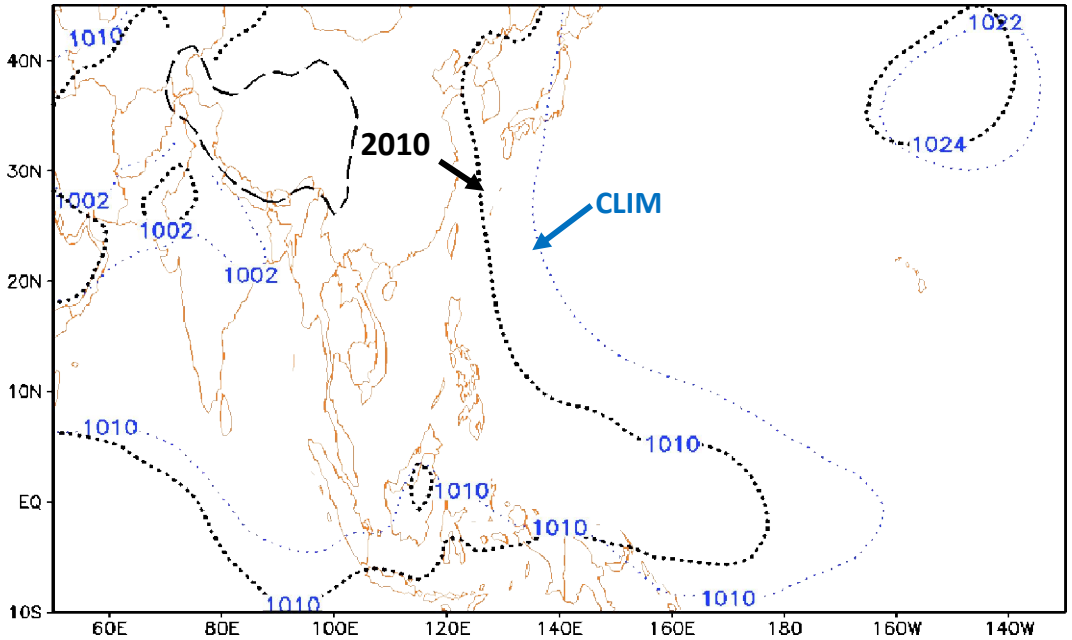
JJAS MSLP (blue contours) and Wind at 850 hPa (Stream-lines)



JJAS OLR(shading) and Wind at 200 hPa (Stream-lines)

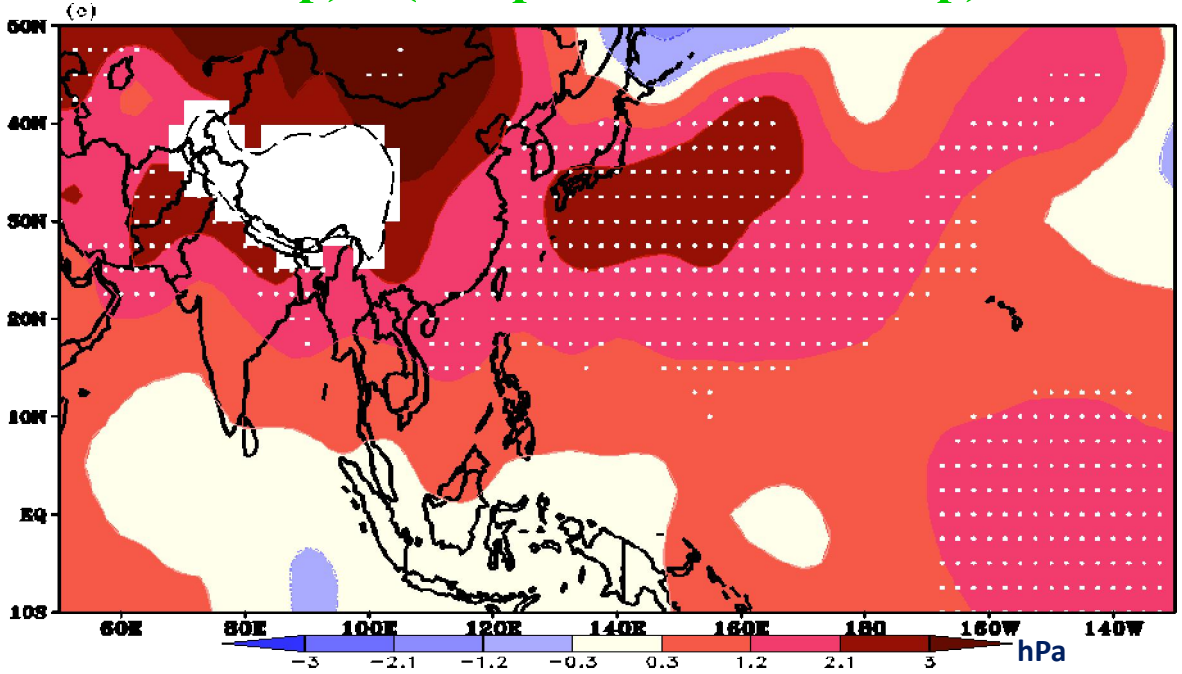


Mean sea level pressure (hPa) for JJAS 2010

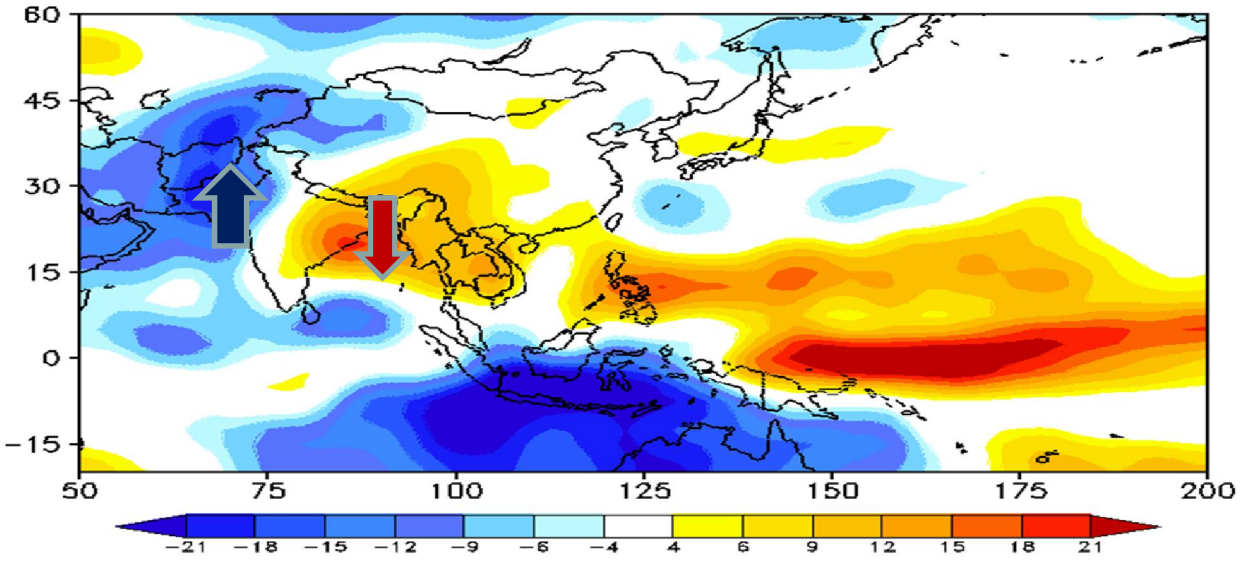


Mujumdar et al. (2012) - Meteorological Applications Special issue on Asian summer monsoon

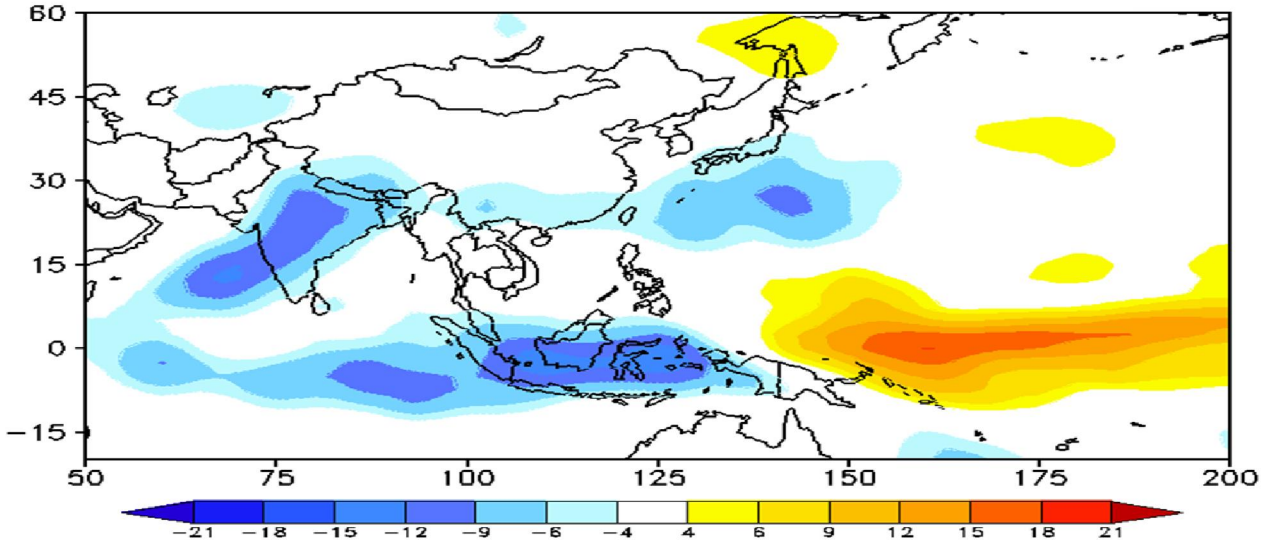
(2010 JJAS mslp) – (composite La Nina mslp) Anomalies



OLR Anomaly for JJAS 2010

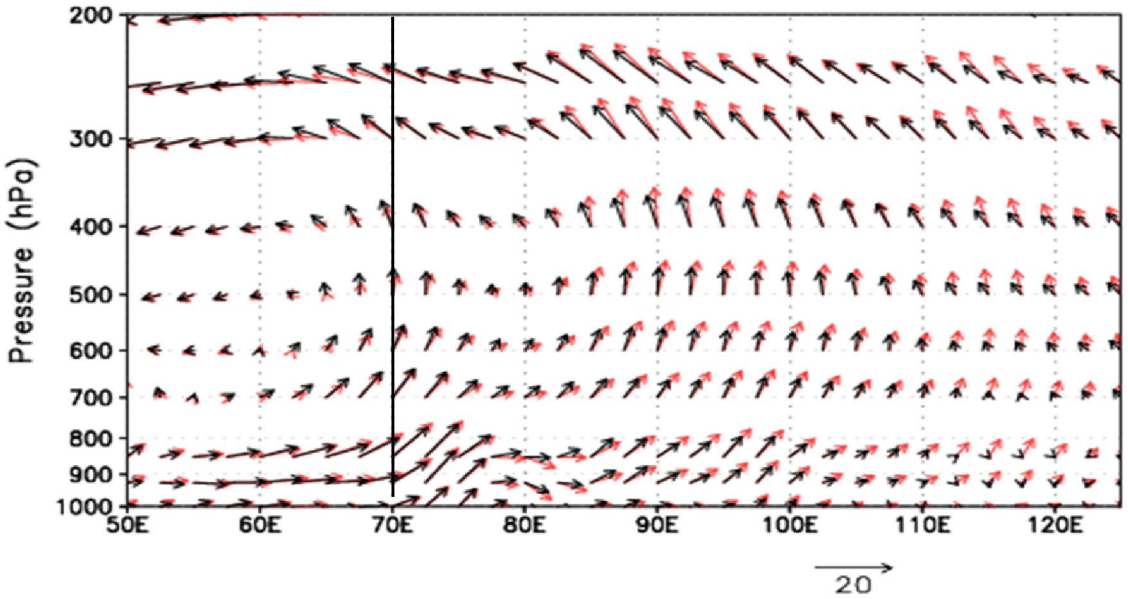


OLR Anomaly for (Composite La Nina Cases)



Modulation of convective zone

Zonal Circulation

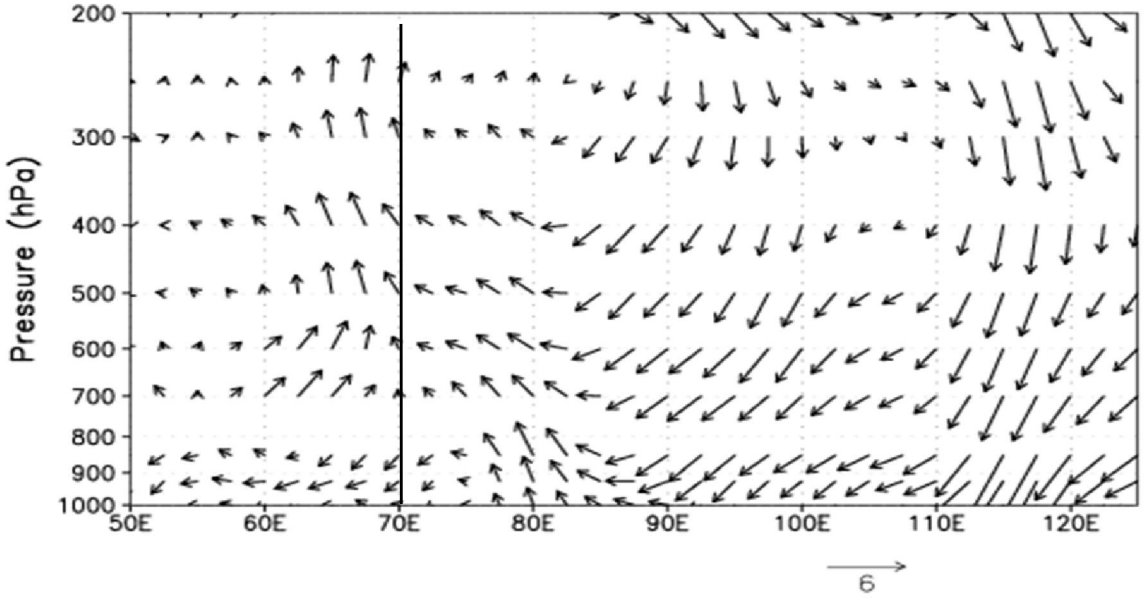


Red : Climatology

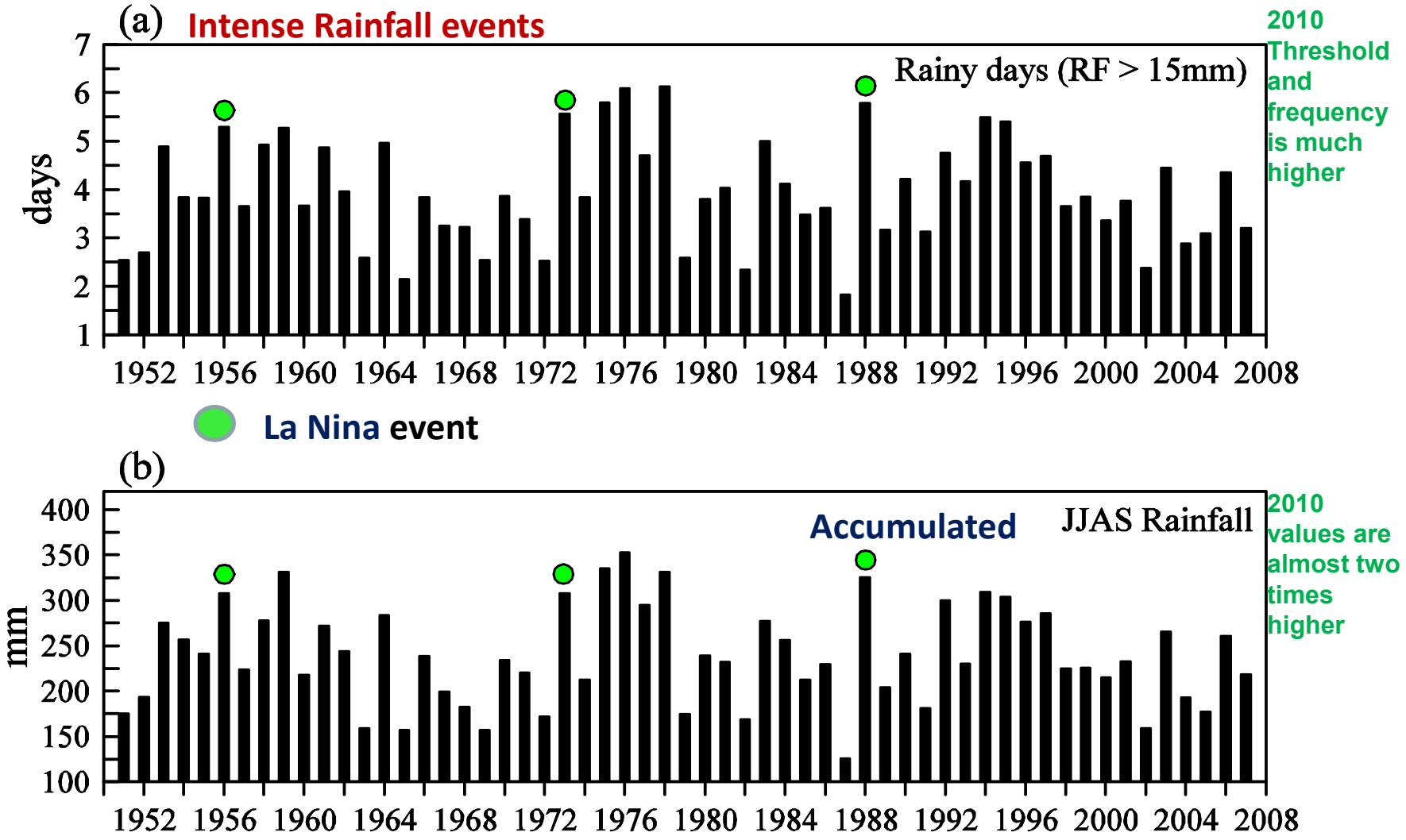
Black : 2010

Anomalous Zonal Circulation : 2010

Averaged over 10N-20N



Averaged Rainfall over Indo-Pak region (65-76 E; 28-36 N) during JJAS

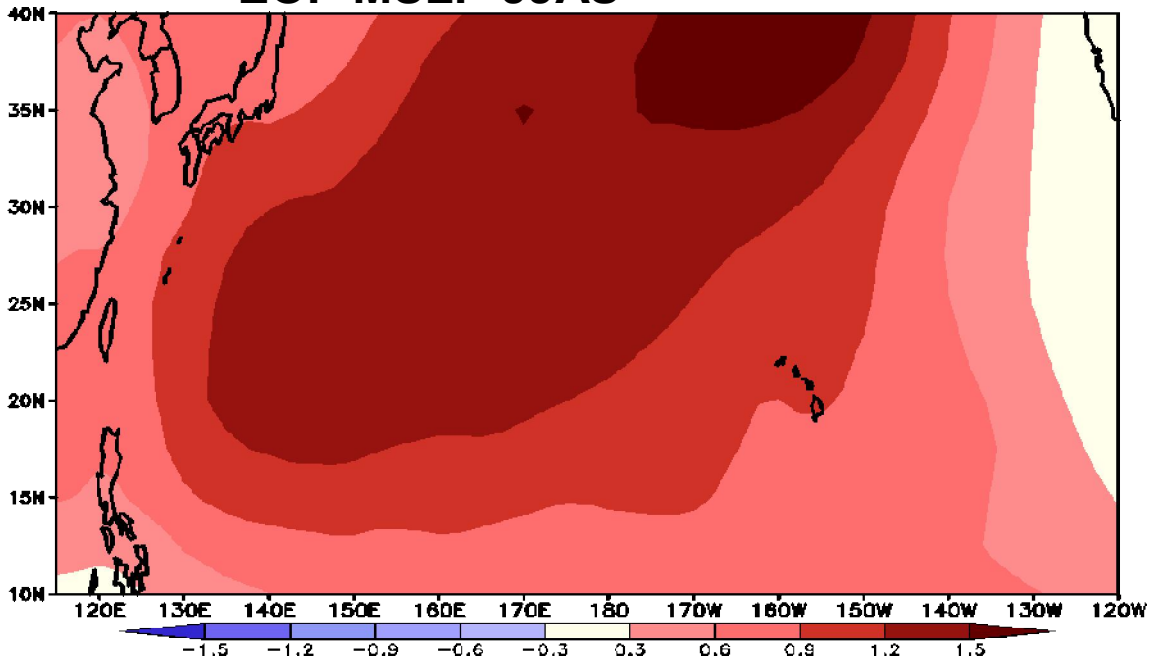


2010 Threshold and frequency is much higher

2010 values are almost two times higher

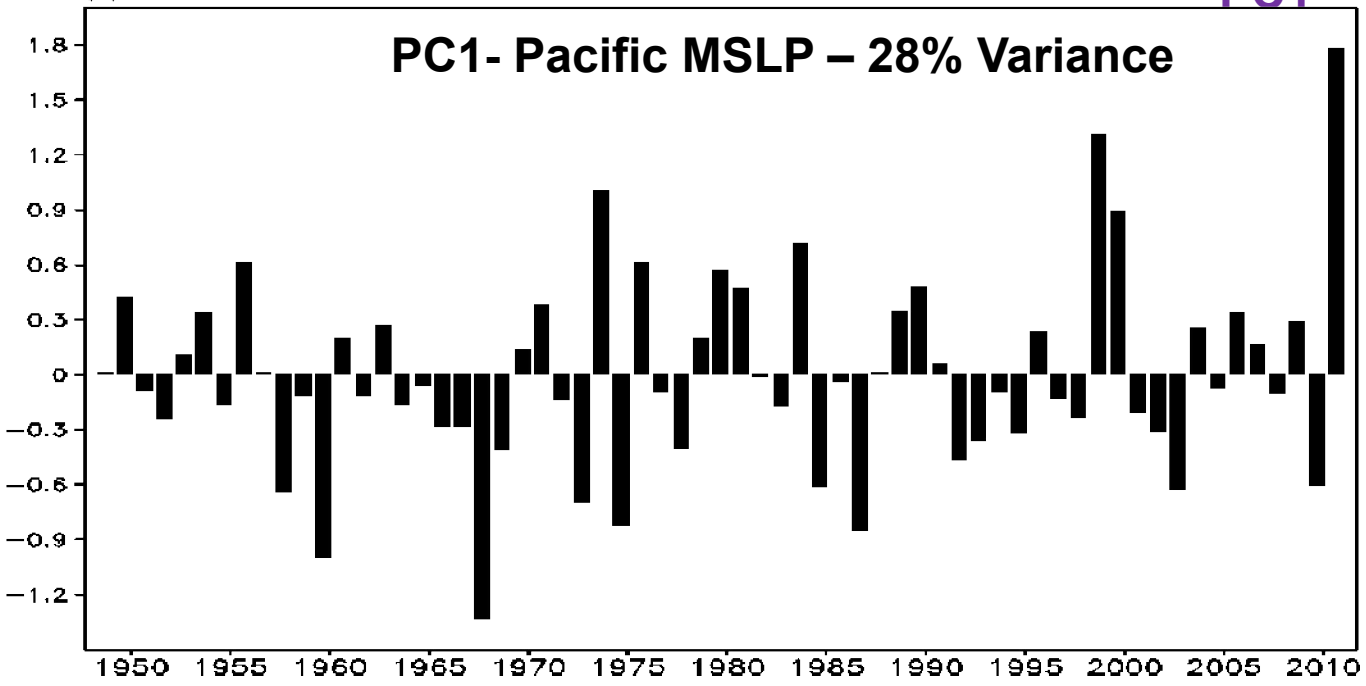
Mujumdar et al. (2012) - Meteorological Applications, Special issue on Asian summer monsoon

EOF-MSLP-JJAS

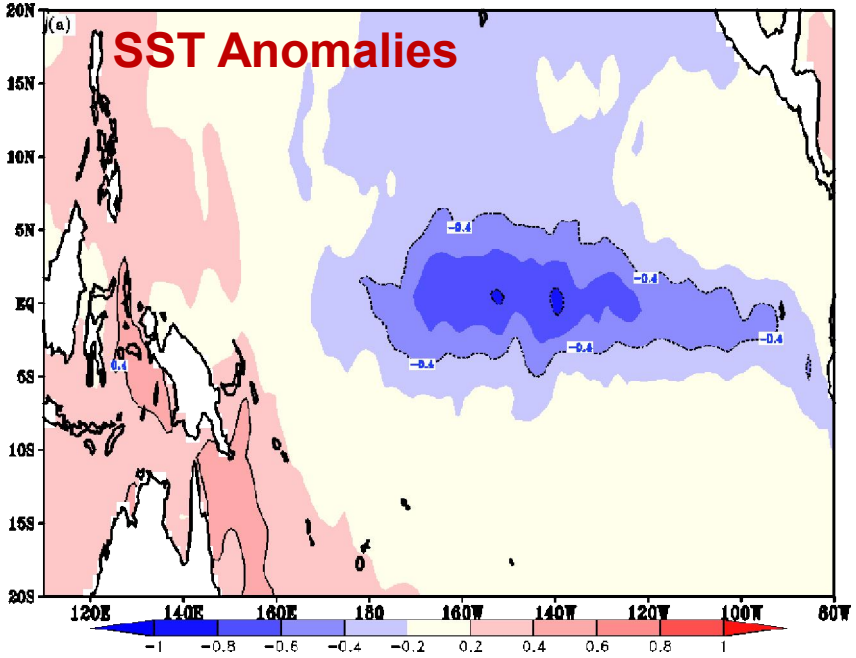


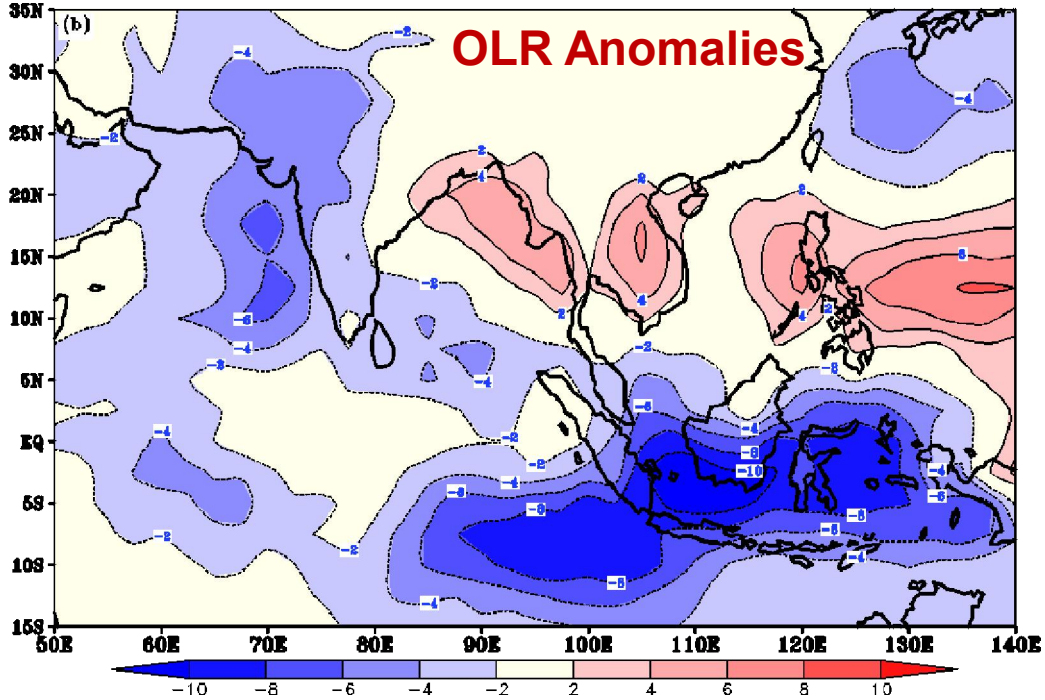
Quantitative assessment of the Large-scale circulation variability

PC1

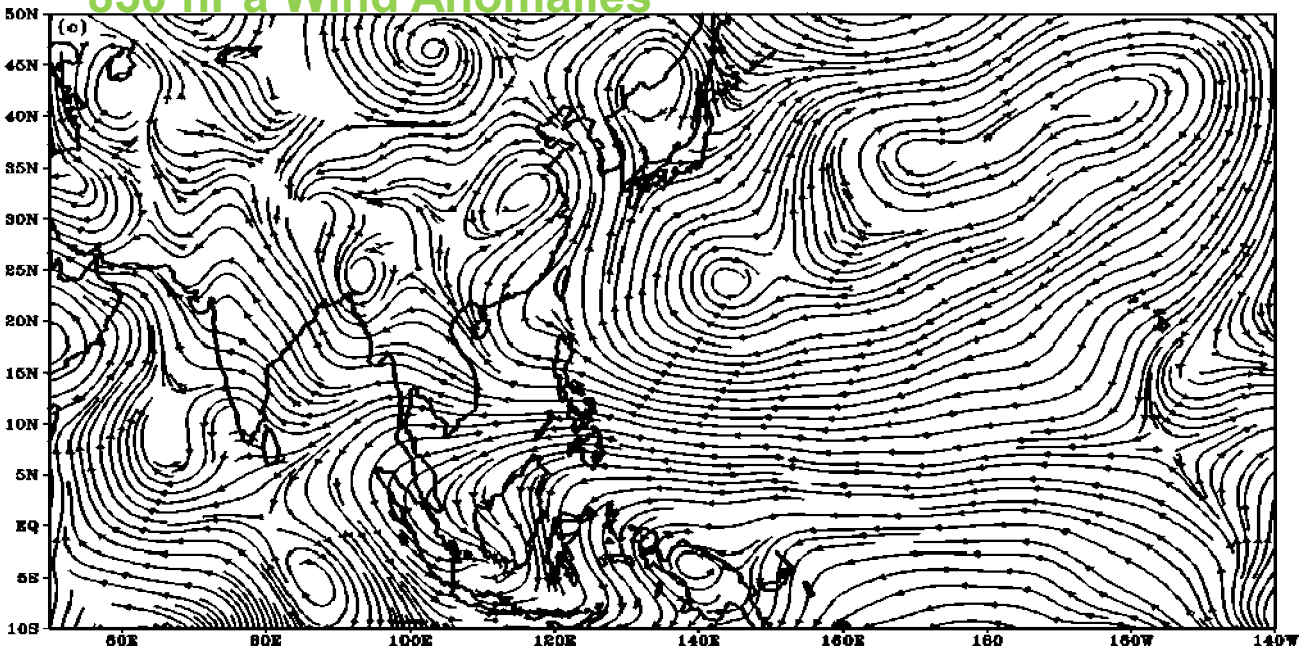


Regression on PC1

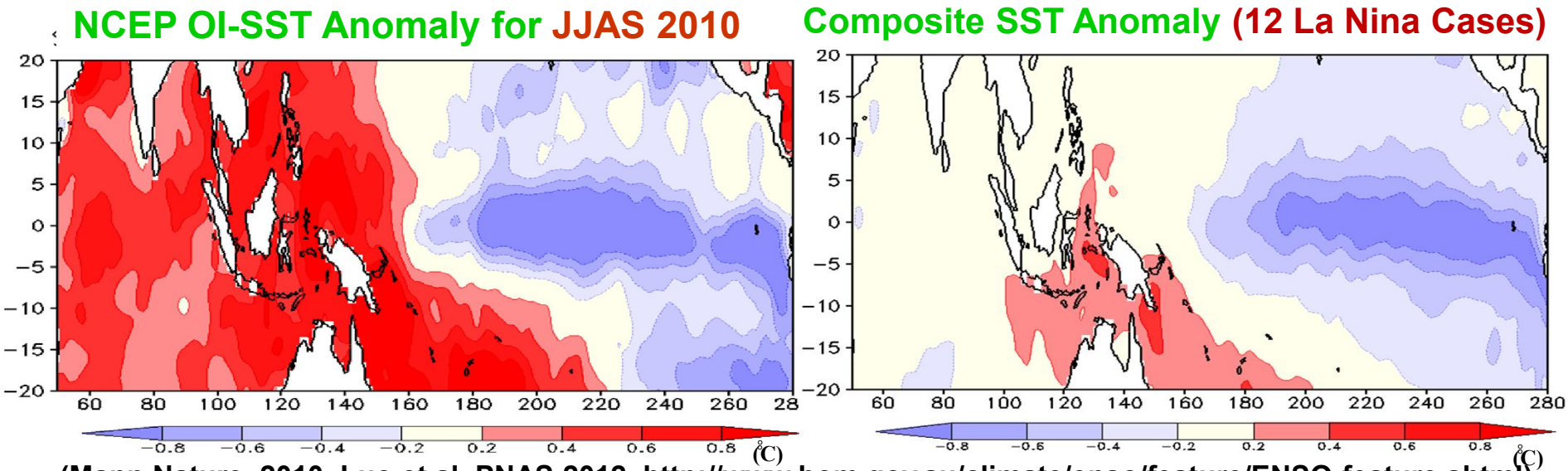




850 hPa Wind Anomalies



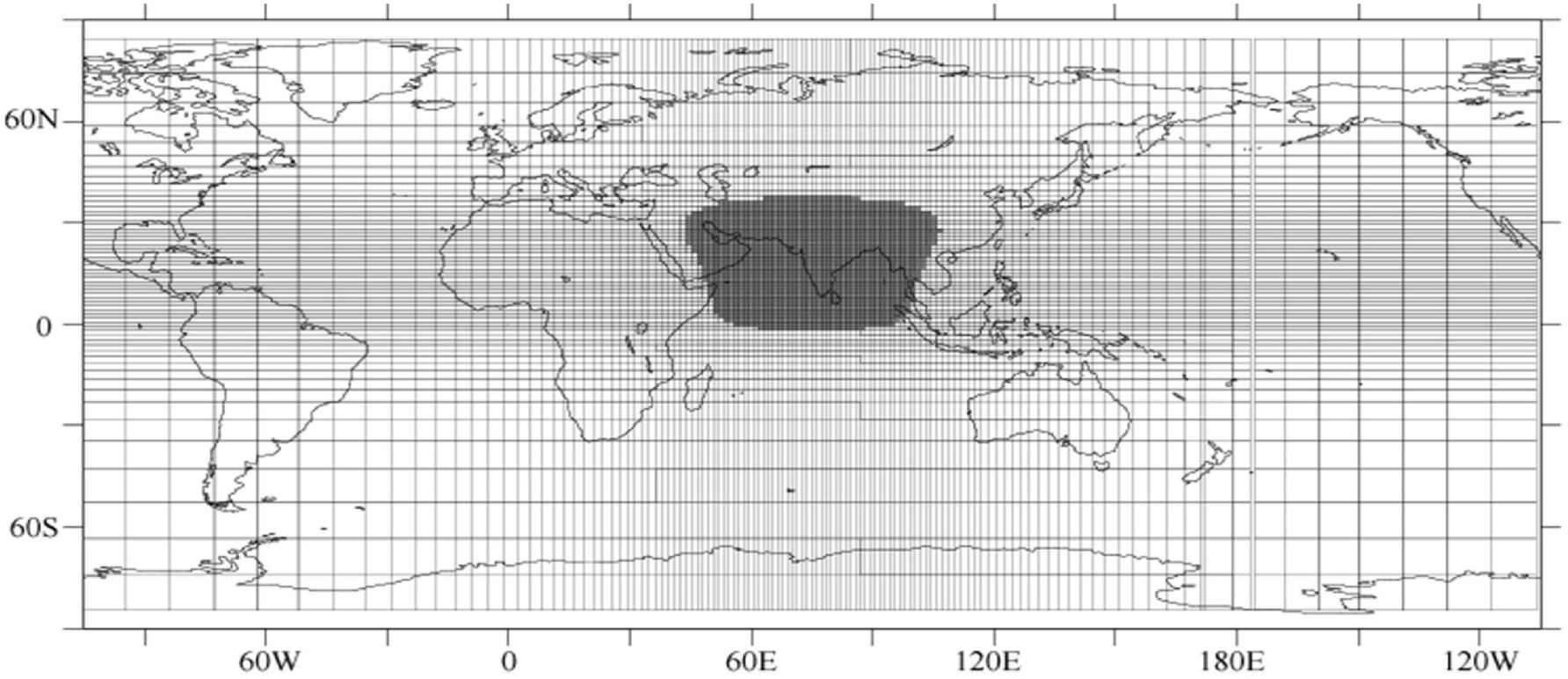
Asian summer monsoon response to La Nina events under warming climate



(Mann Nature, 2010, Luo et.al. PNAS 2012, http://www.bom.gov.au/climate/enso/feature/ENSO-feature.shtml).

12 La Nina cases – 1954, 1955, 1956, 1964, 1970, 1971, 1973, 1975, 1988, 1998, 1999, 2010

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

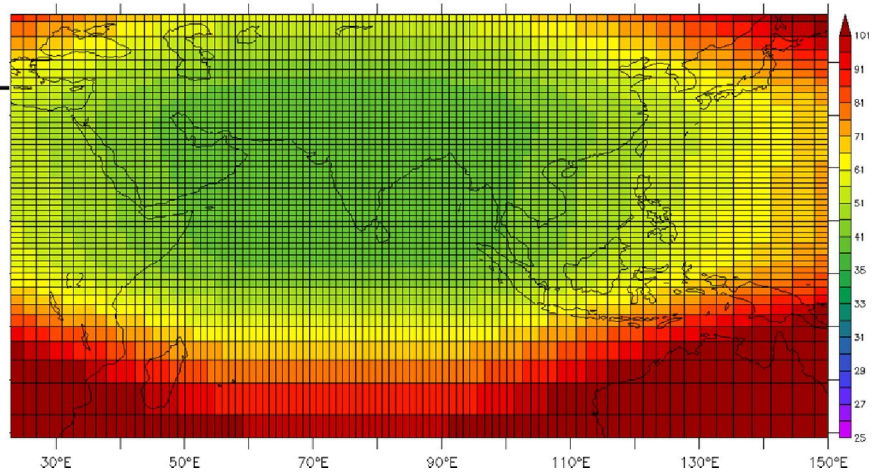


Clim Dyn
DOI 10.1007/s00382-012-1658-8

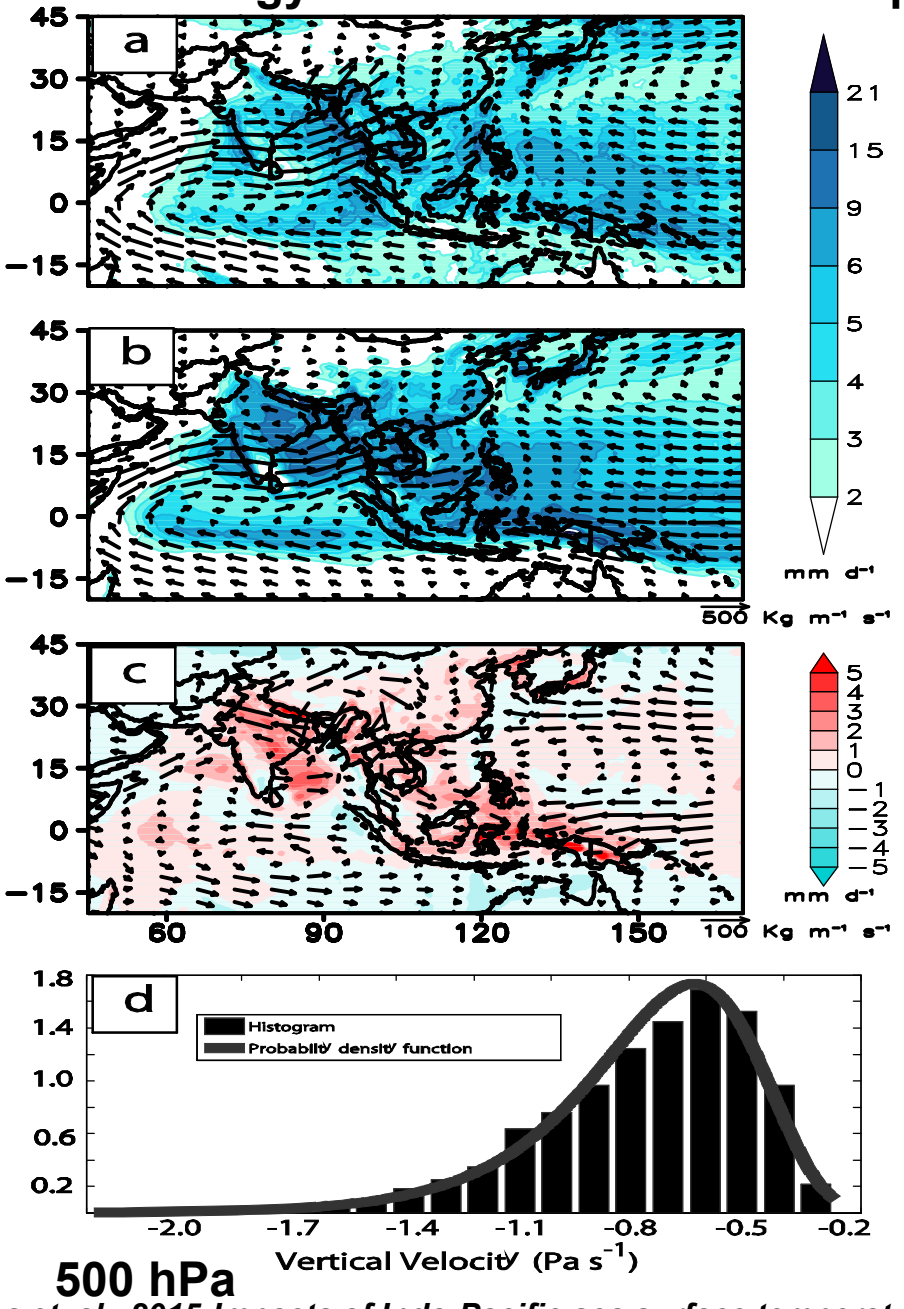
2012

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



JJAS climatology Rainfall & Moisture transport (integrated)



500 hPa

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

Simulation – LMDZ – AGCM C-SST ensemble mean

Difference between C-SST simulation & observation

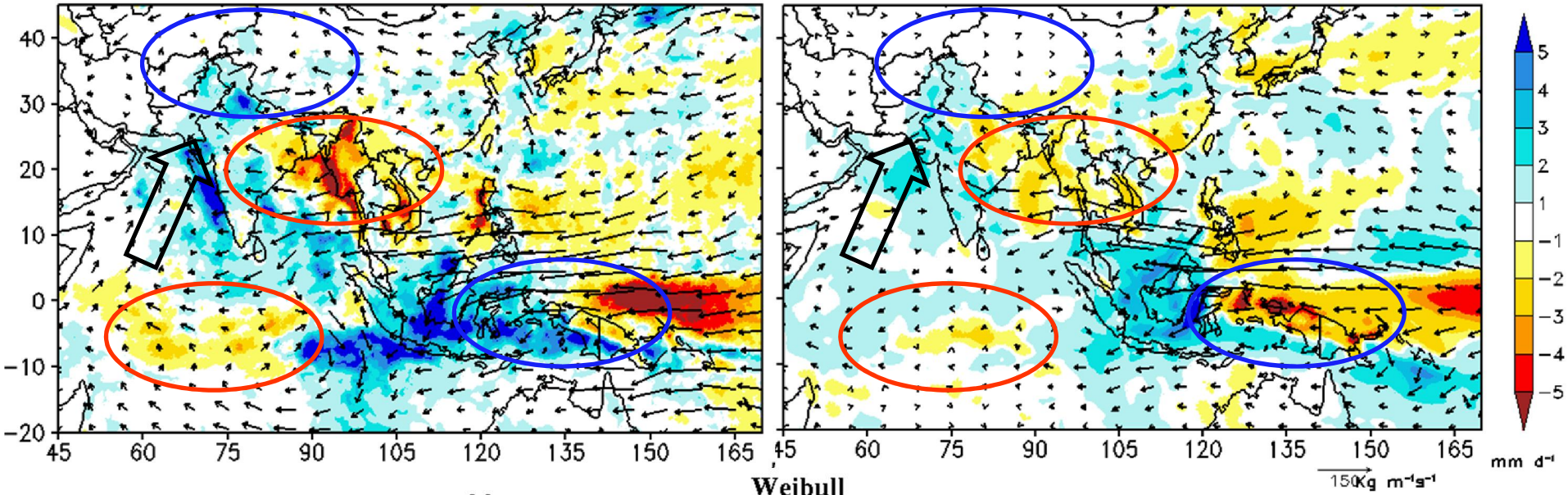
Historgram for C-SST simulation. shape and scale parameters

Priya et. al., 2015:Impacts of Indo-Pacific sea surface temperature anomalies on the summer monsoon circulation and heavy precipitation over northwest India-Pakistan region during 2010 (J. Clim, May 2015).

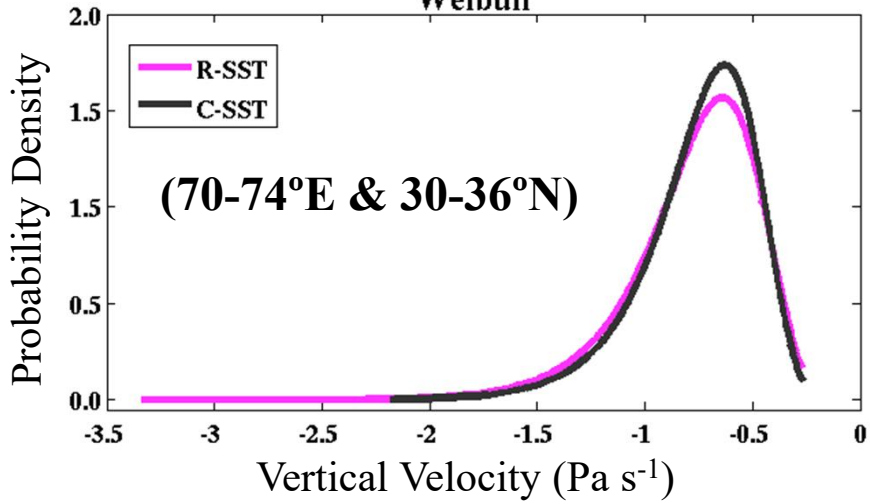
Rainfall and Moisture Transport Anomalies for JJAS 2010

Observation
TRMM (Rainfall) &
NCEP (Moisture Transport)

Simulation
LMDZ4 AGCM
R-SST ensemble mean



Weibull Distribution
&
Extreme Convection



Priya, ***Milind Mujumdar***, T.P. Sabin, Terray
R. Krishnan, *Journal of Climate* (2015)

**Fast transition of 2010 SST patterr
from preceding El Nino to followin
La Nina is explained by
Kim et. al. 2011**

The ENSO and ENSO-unrelated components of monthly SST anomalies during 2010, computed using linear inverse modelling approach of Compo and Sardeshmukh, (Climate Dynamics, 2009 and J. Climate, 2010), & were kindly provided by Dr. Compo through personal communication.

This approach is one of the best methods currently available to isolate ENSO component in climat time series as demonstrated by th work of Penland and coworkers during the last two decades (see http://www.esrl.noaa.gov/psd/peop e/cecile.penland/pubs.html).

Decomposition of SST (Ref.: Compo & Sardeshmukh, *Jclim*, 2010; Kim et. al., *GRL*, 2011; Kug and Kang, *Jclim*, 2006)

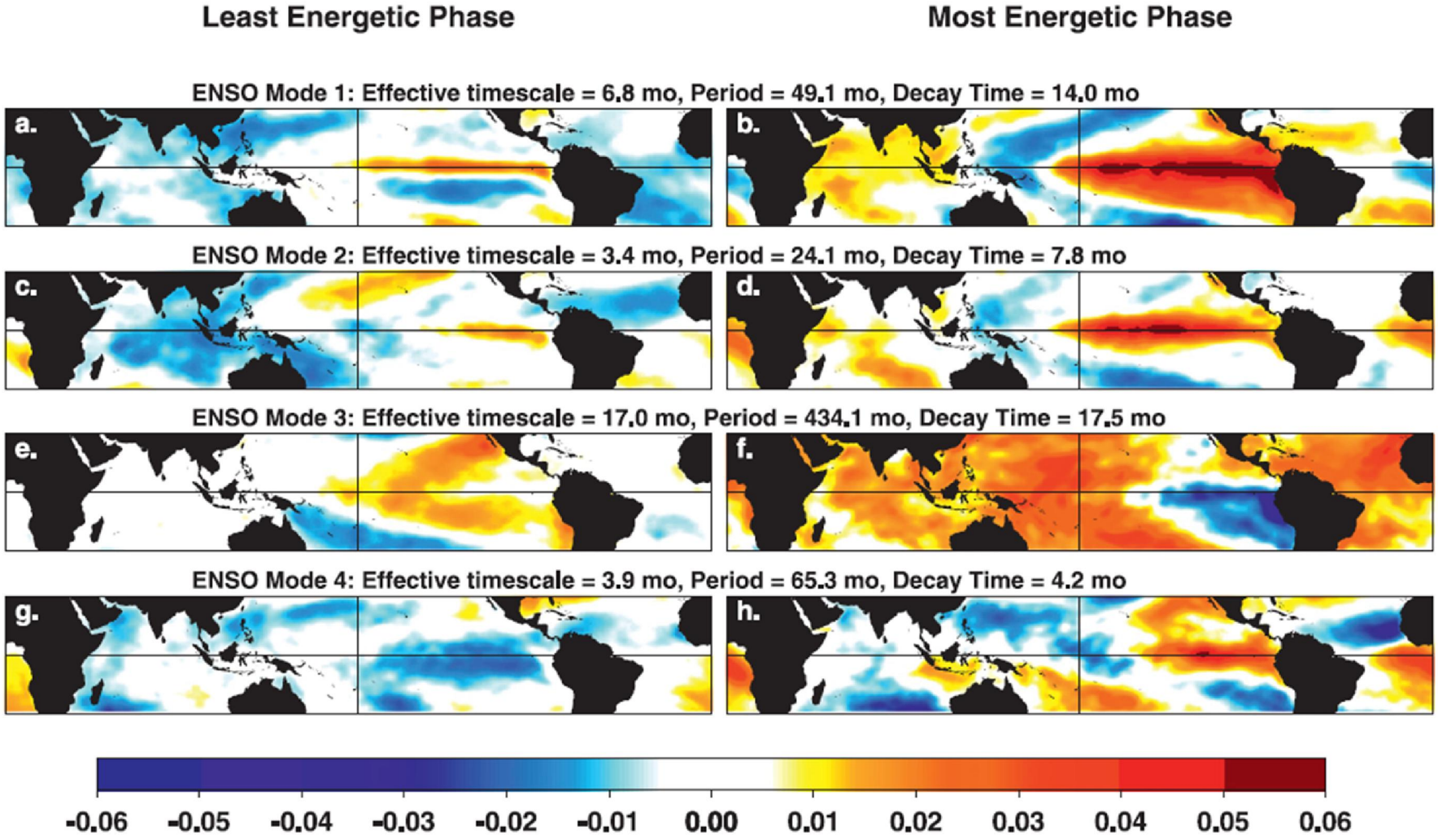


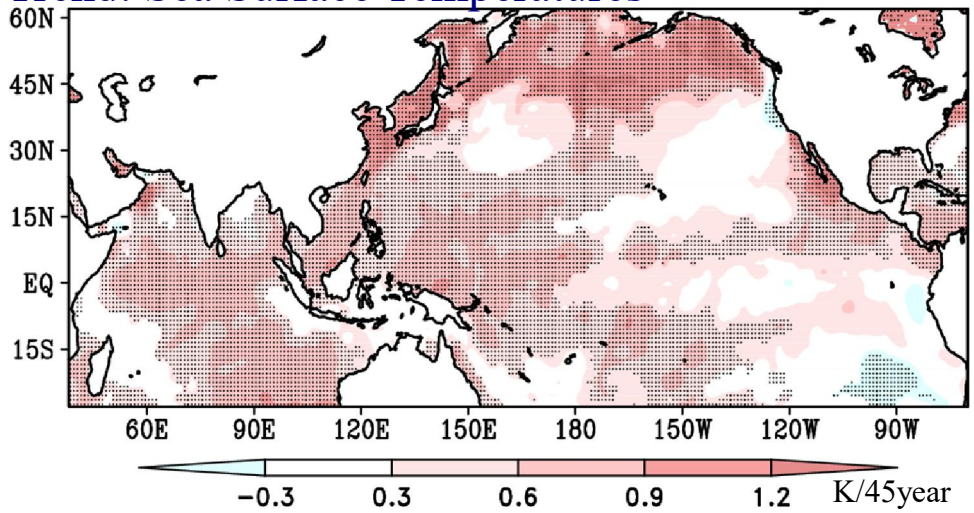
FIG. 4. (left) Least energetic and (right) most energetic phases of the four dynamical ENSO modes used for defining the ENSO-related tropical SST variations. The modes are ordered according to the projection of their adjoint onto the optimal initial structure shown in Fig. 3a. Each mode's effective time scale $1/|\beta|$ is indicated. Each mode evolves from (left) the least energetic phase **a** to (right) the most energetic phase **b**, then to $-\mathbf{a}$, and then to $-\mathbf{b}$ with the indicated period $2\pi/\omega$ while decaying with the indicated decay time scale $-1/\sigma$. The **a** phase is normalized to unity in the left panel. Note that the **a** and **b** phases of each mode are spatially orthogonal to each other by construction.

Compo and Sardeshmukh, J.Clim. 2010

Climate Dynamics 2016, B. Preethi, M. Mujumdar, R. H. Kripalani1, Amita Prabhu, R. Krishnan

Recent Trends and Teleconnections among South and East Asian summer monsoons in a warming environment

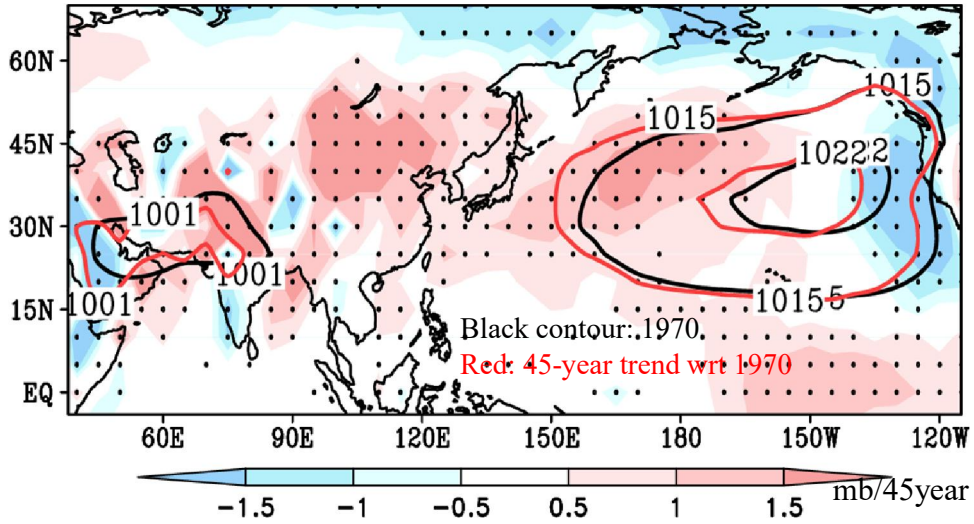
Trend: Sea Surface Temperatures



Recent Trends in Large-scale Circulation

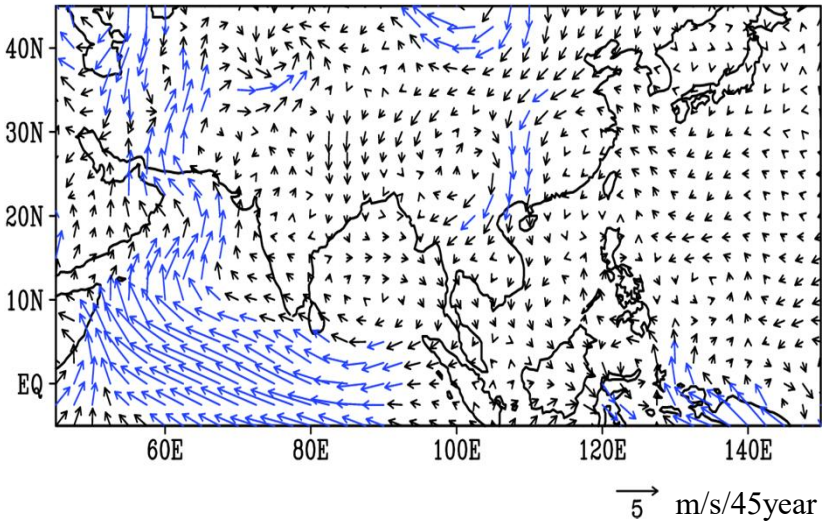
(1970-2014)

Trend: Mean Sea Level Pressure



Warmer SSTs over West Pacific and westward shift of NPSH could have resulted in transport of moisture to China-Korea-Japan, leading to increasing trend

Trend: Winds at 850 hPa



Southerly trend over the Arabian Sea and Weak anti-cyclonic circulation over BoB , suggestive of less moisture supply to Indian subcontinent, leading to drying trend.

Thank you