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 मुजुम्दार

Milind Mujumdar, mujum@tropmet.res.in
Associates: Priya P., Preethi, Roja CH, Sabin T.P., Pascal Terray and Krishnan R.

Centre for Climate Change Research (CCCR),
Indian Institute of Tropical Meteorology (IITM), Pune.
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.
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

FLOODS
Flesh 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

- 2.53 million people affected
- 107,000 houses damaged
- 2.4 million acres crops affected
- 527 Relief camps
2010 Pakistan Floods

Convection of a more oceanic character in a high humid environment

La Nina induced Teleconnection pattern

Persistent increase in conditional instabilities

Wang et al (JGR, 2011)

Houze et.al. (BAMS, 2011)
Relative contribution of the mid-latitude circum global wave train (CGT) to the South Asian summer monsoon

Persistence of synoptic and sub-synoptic Conditions are intriguing

Precipitation $> 1.5$ Sigma

TRMM Rainfall anomalies for JJAS 2010


http://www.earthsystemschool.mpg.de
JJAS MSLP (blue contours) and Wind at 850 hPa (Stream-lines)

CLIM

2010

Anom
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)**
Zonal Circulation

Red: Climatology
Black: 2010

Anomalous Zonal Circulation: 2010

Averaged over 10N-20N

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

Mujumdar et al. (2012) - Meteorological Applications, Special issue on Asian summer monsoon
Quantitative assessment of the Large-scale circulation variability

EOF-MSLP-JJAS

PC1- Pacific MSLP – 28% Variance
Regression on PC1

(a) SST Anomalies

(b) OLR Anomalies

(c) 850 hPa Wind Anomalies
Asian summer monsoon response to La Nina events under warming climate

NCEP OI-SST Anomaly for JJAS 2010

Composite SST Anomaly (12 La Nina Cases)


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

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)

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

Simulation –
LMDZ – AGCM C-SST ensemble mean

Difference between C-SST simulation & observation

Histogrm for C-SST simulation.
shape and scale parameters

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

(70-74ºE & 30-36ºN)
Fast transition of 2010 SST pattern from preceding El Nino to following 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 climate time series as demonstrated by the work of Penland and coworkers during the last two decades (see http://www.esrl.noaa.gov/psd/people/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 \(-a\), and then to \(-b\) 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.
Recent Trends and Teleconnections among South and East Asian summer monsoons in a warming environment

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: Sea Surface Temperatures

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.

Recent Trends in Large-scale Circulation (1970-2014)
Thank you