Impact of Climate Change on Northeast Monsoon System of India- Role of Siberian Teleconnection

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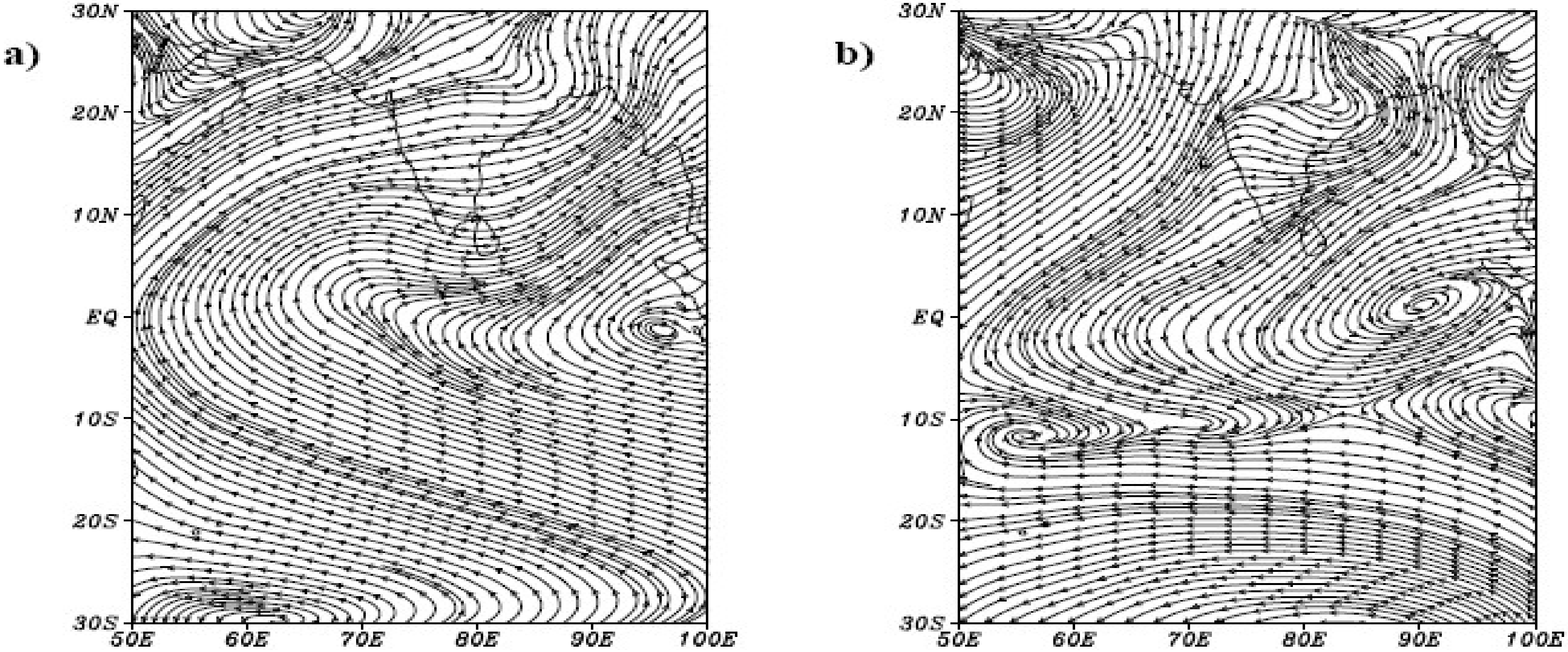
OUTLINE

- BACKGROUND
- OBJECTIVE
- RESULTS
- CONCLUSIONS

BACKGROUND

Climatological 925mb Streamlines for Asian Monsoon Region

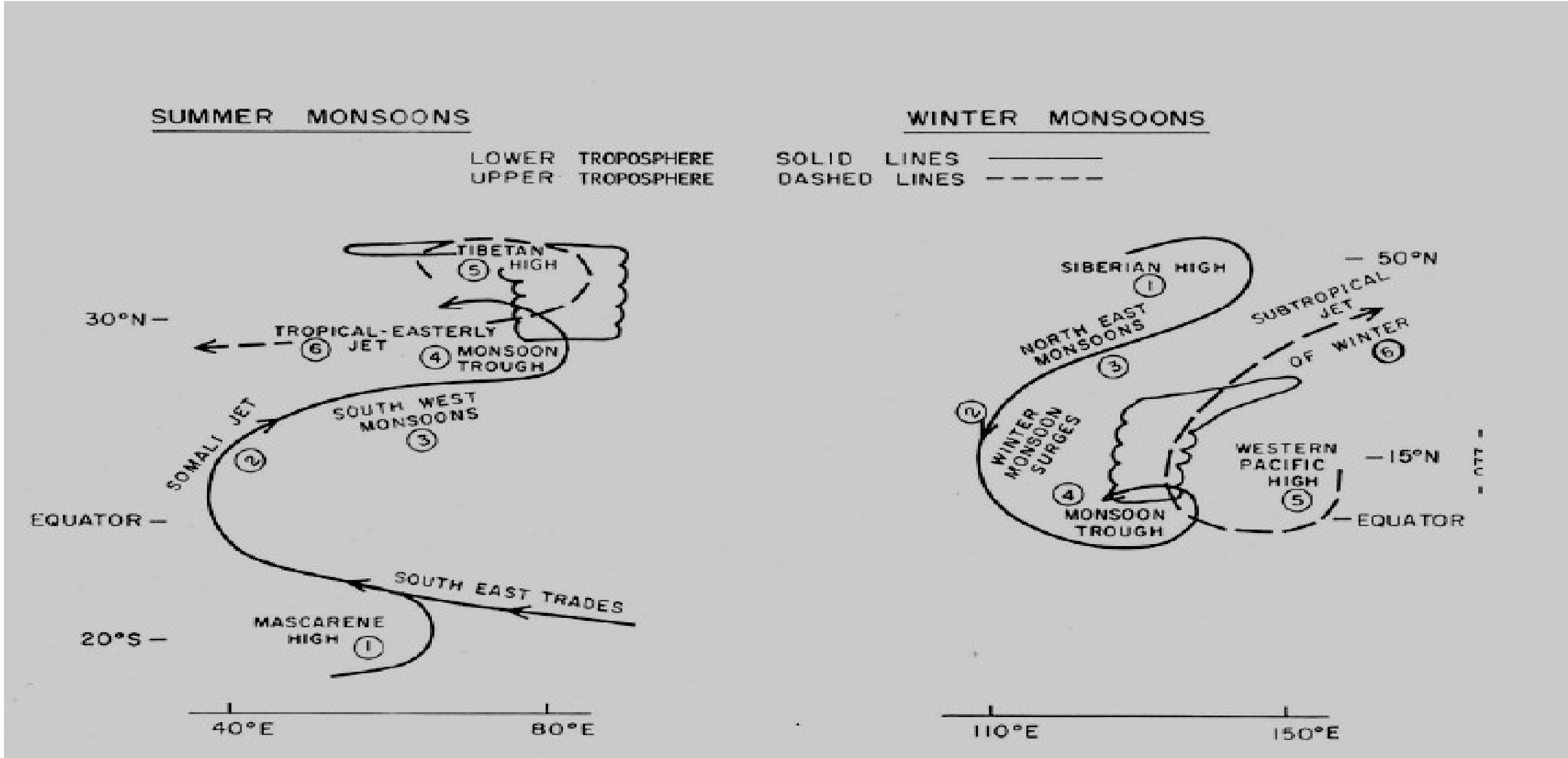


Summer Monsoon

Winter Monsoon

Courtesy: T.N. Krishnamurthy (‘An Introductory Course in Tropical Meteorology’)

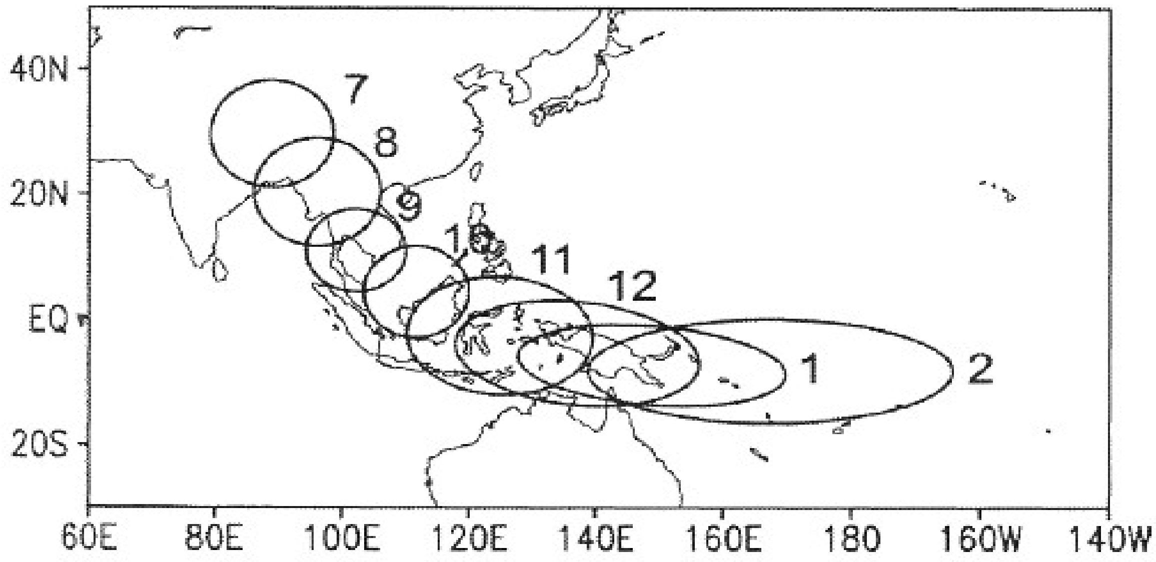
Asian Monsoon Dynamics



Key Elements	Asian Summer Monsoon	North-east Monsoon
(HEAT SOURCE)Q1	Tibetan High (TH)	West Pacific High(WPH)
(HEAT SINK)Q2	Mascarene High (MH)	Siberian High (SH)
WIND	SE trade wind	NE lower tropospheric flow
JET STREAM	Somali Jet, Tropical Easterly Jet (TEJ)	Winter Monsoon Surge, Subtropical Jet Stream of Winter (STJW)

Courtesy: T.N. Krishnamurthy (‘An Introductory Course in Tropical Meteorology’)

Principal Axis of Monsoon

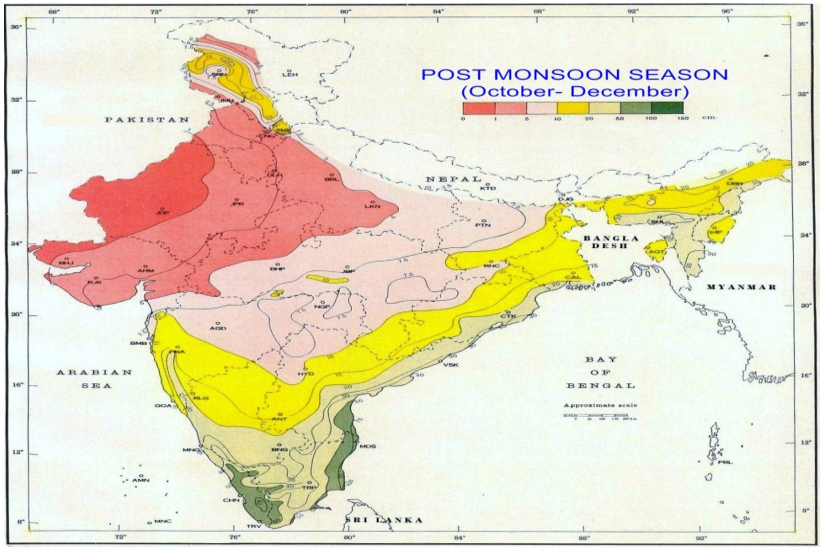


- Differential Heating is responsible for divergent vertical circulation with ascending lobes at Q1 (heat source) & descending lobes over Q2 (moisture sink)

- Seasonal propagation of Heat Source (Q1) associated with heavy Monsoonal precipitation between July & February. *The line described by the heat source locations in different months forms the principal axis of the Asian Monsoon*

Courtesy: T.N. Krishnamurthy ('An Introductory Course in Tropical Meteorology')

Northeast Monsoon



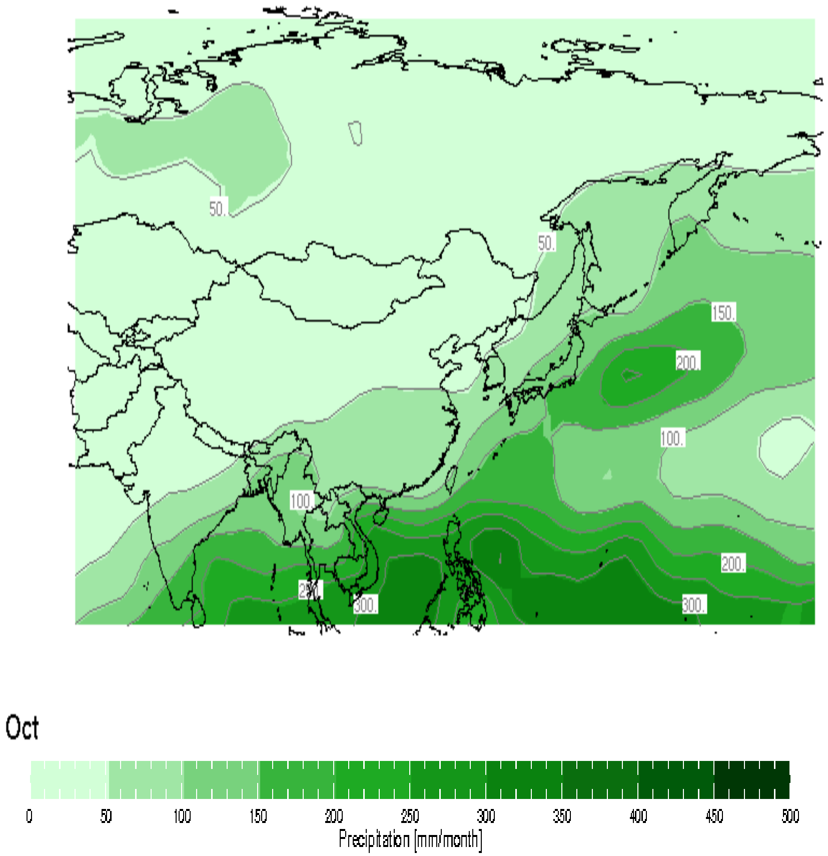
Source:
India Meteorological Department

•Northeast Monsoon season in India has deep impact on Seven meteorological stations of India

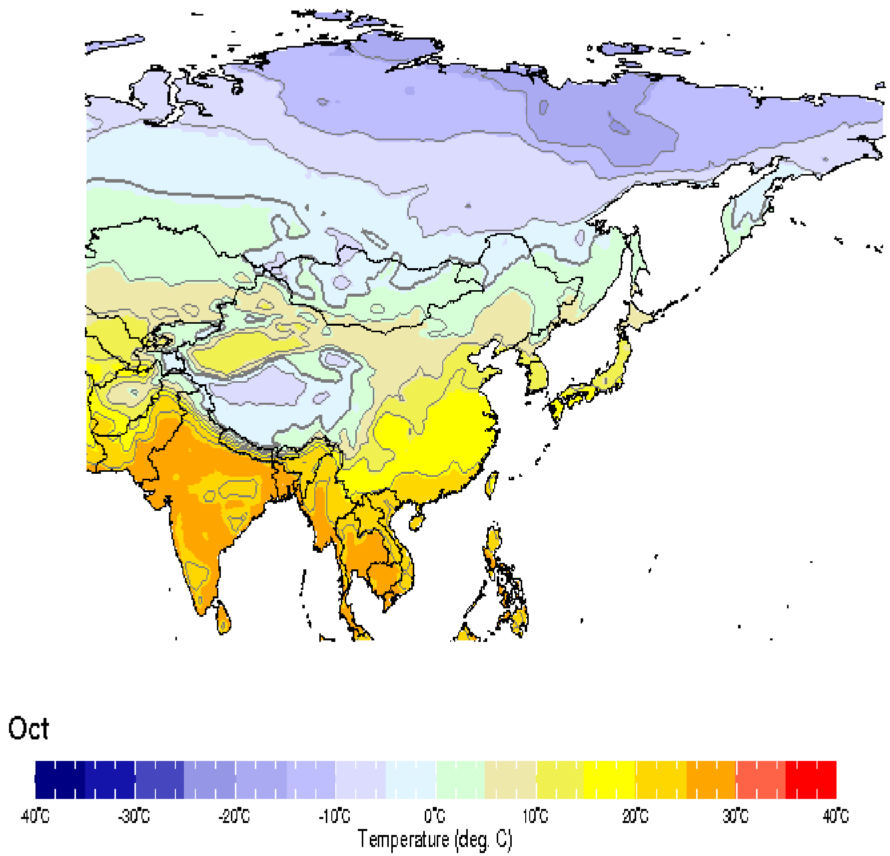
• Least study has been done on Northeast Monsoon (NEM)

• The changing pattern of relationship between NEM precipitation in India & its remote driver of dynamics i.e. Heat Source (Q1) & Heat Sink (Q2) regions have been least investigated

OND Monthly Precipitation & Surface Temperature Climatologies

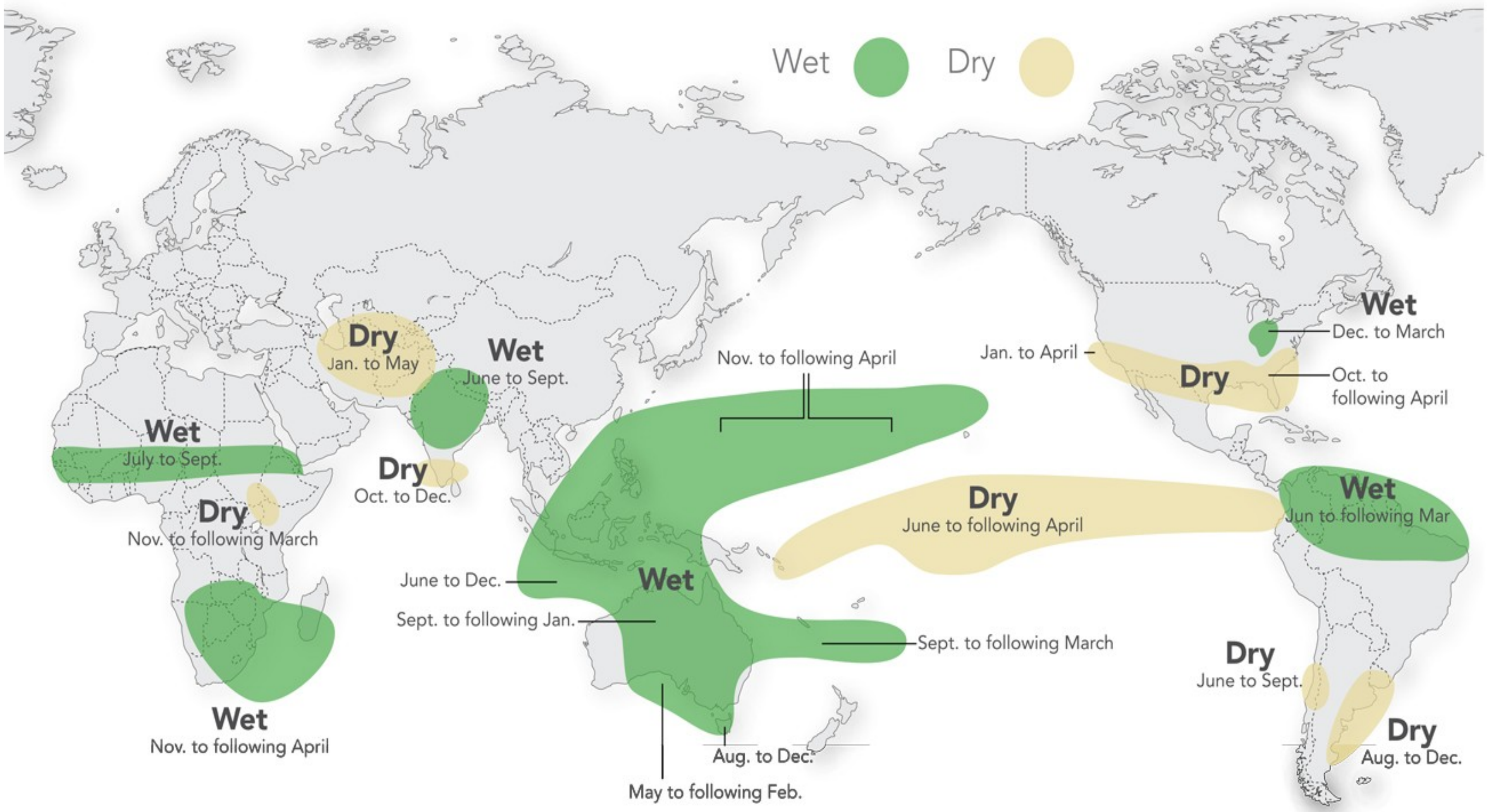


Source:
http://iridl.ldeo.columbia.edu/maproom/.Global/.Climatologies/.Precip_Loop.html
(CAMS_OPI monthly precipitation climatology (mm/month) for 1979-1995)



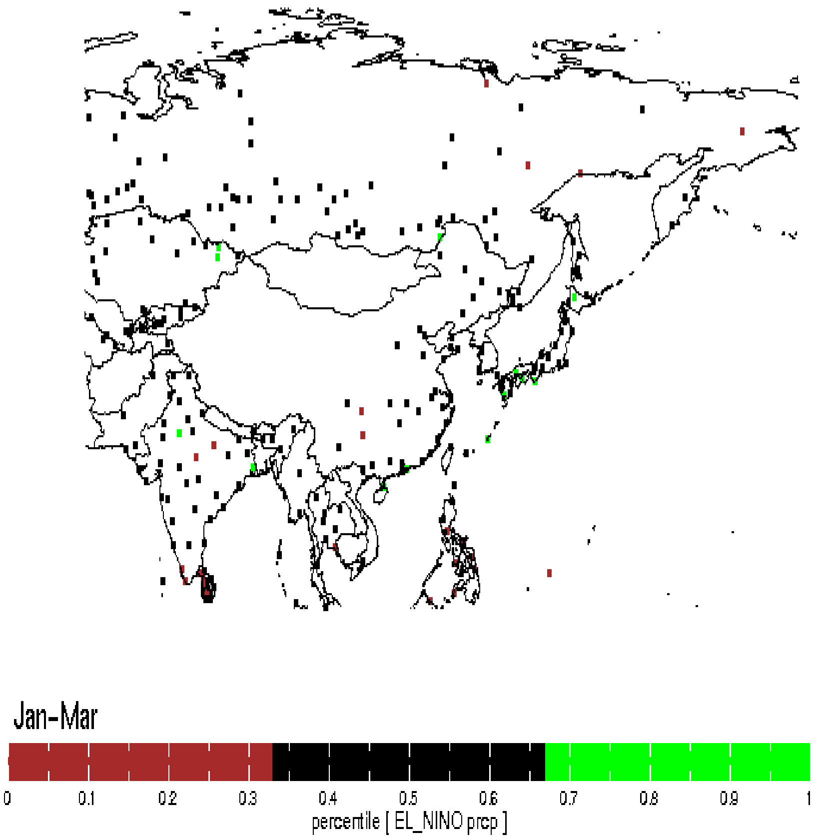
Source:
http://iridl.ldeo.columbia.edu/maproom/.Global/.Climatologies/.Temp_Loop.html
(Monthly surface air temperature (^{0}C) climatology of University of East Anglia for 1961-1990)

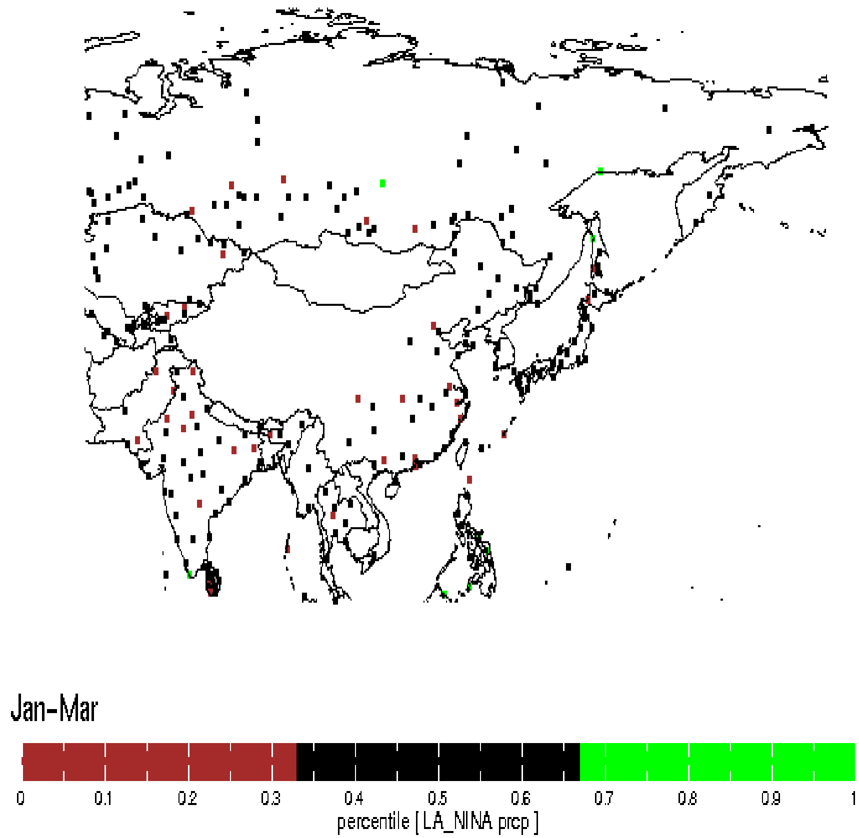
Effect of High ENSO Index on Global Precipitation Pattern



Source:
Ropelewski & Halpert, 1989

ENSO & Seasonal Precipitation





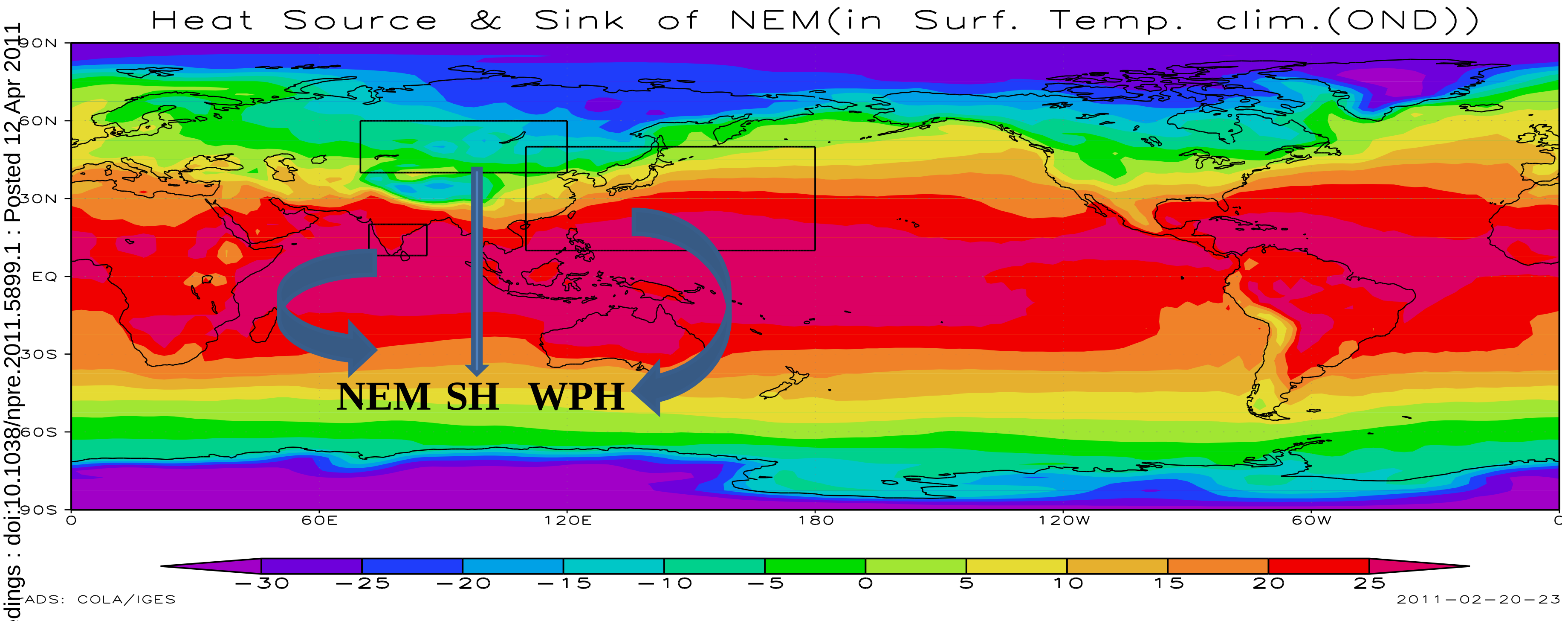
Source:
http://iridl.ldeo.columbia.edu/maproom/.ENSO/.Climate_Impacts/.Station_PRCP.html
(Long-term mean Seasonal precipitation tercile class for GCPS stations conditioned upon El Niño and La Niña occurrence)

OBJECTIVE

OBJECTIVE

- Trend analysis of climatic variables in Northeast monsoon precipitation zone and its heat sink & moisture source regions (viz., Siberian High (SH) & West Pacific High (WPH), respectively)
- Impact of El Nino & Southern Oscillation & Indian Ocean Dipole on Northeast Monsoon precipitation
- Decadal correlation of NEM precipitation with important climatic variables of the Heat Source & Moisture Sink of NEM

Domain of NEM & Heat Source & Sink



- *NE Monsoon domain in India(NEM): 8^0-20 ^{0}N, 72^0-86^0 E*
- *Siberian High(SH): 40^0-60^0N, 70^0-120^0E*
- *West Pacific High(WPH): 10^0-50^0N, 110^0-180^0E*
- Domain of Region of Interest: *5^0N-80^0N, 60^0N-180^0E*

Dataset used

- CRU TS3.0 Dataset for Precipitation & Temperature for the period from 1948 to 2006

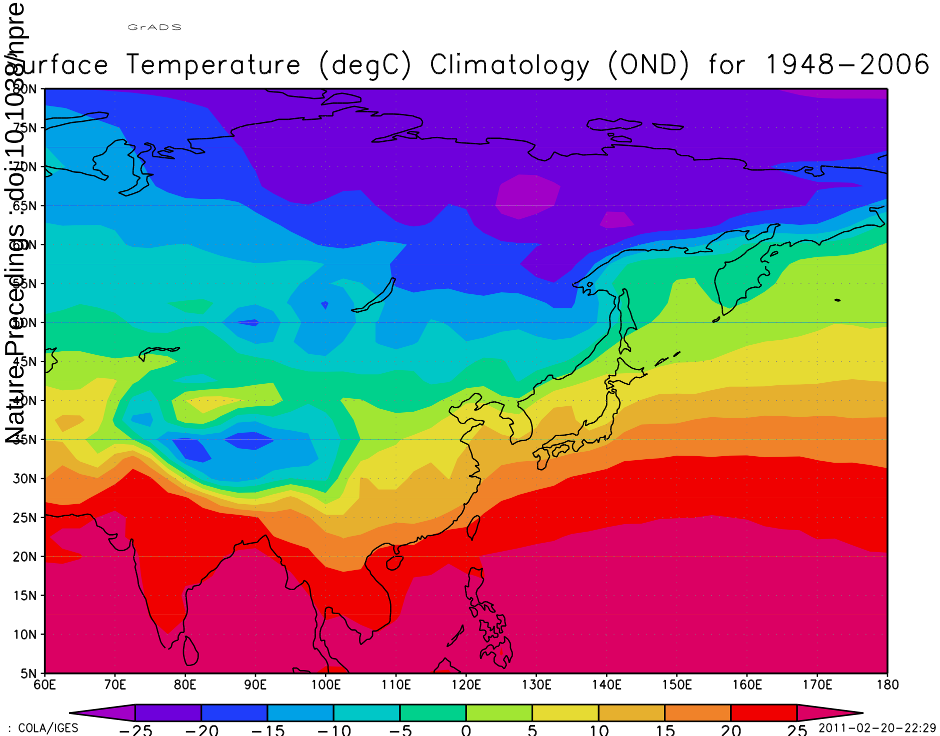
- NCEP REANALYSIS dataset for SH & WPH for climatic variable OLR, Surface Pressure & Surface Temperature for the period from 1948 to 2006 (http://www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl)

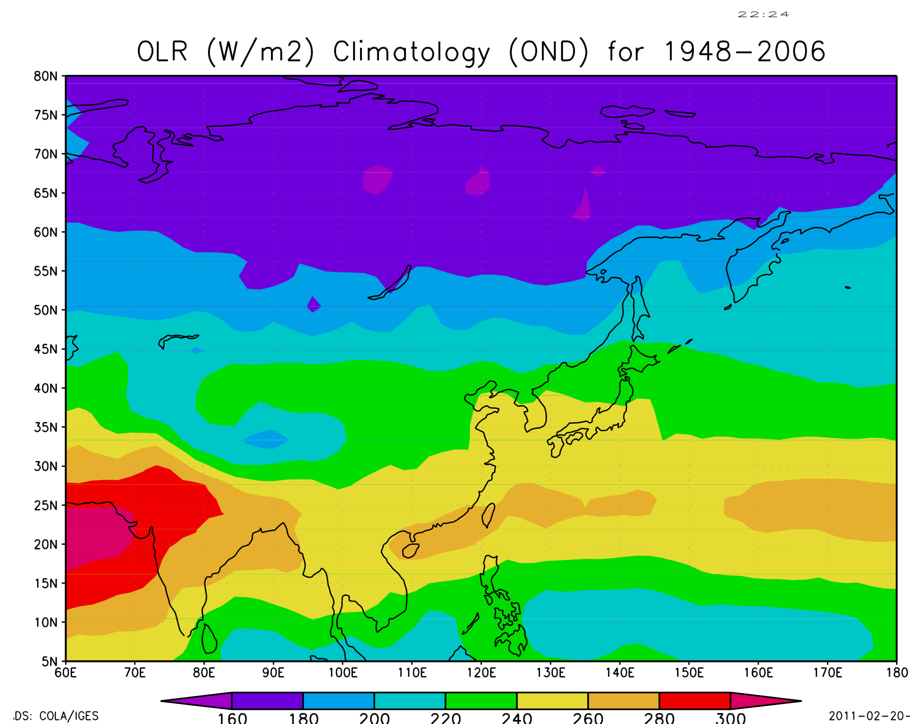
- Seasonal ENSO dataset(1950 to 2006) of NCEP

- Average (Jun to Nov) Dipole Mode Index (DMI) dataset (1958 to 2006) of JAMSTEC (

RESULTS

Climatology of OLR, Surface pressure & Surface Temperature





OBJECTIVE 1

Trend analysis of climatic variables in Northeast monsoon precipitation zone and its heat sink & moisture source regions (viz., Siberian High (SH) & West Pacific High (WPH), respectively)

MANN KENDAL TREND TEST STATISTICS

Let x_1 , x_2 , … x_n represent n data points where x_j represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

where

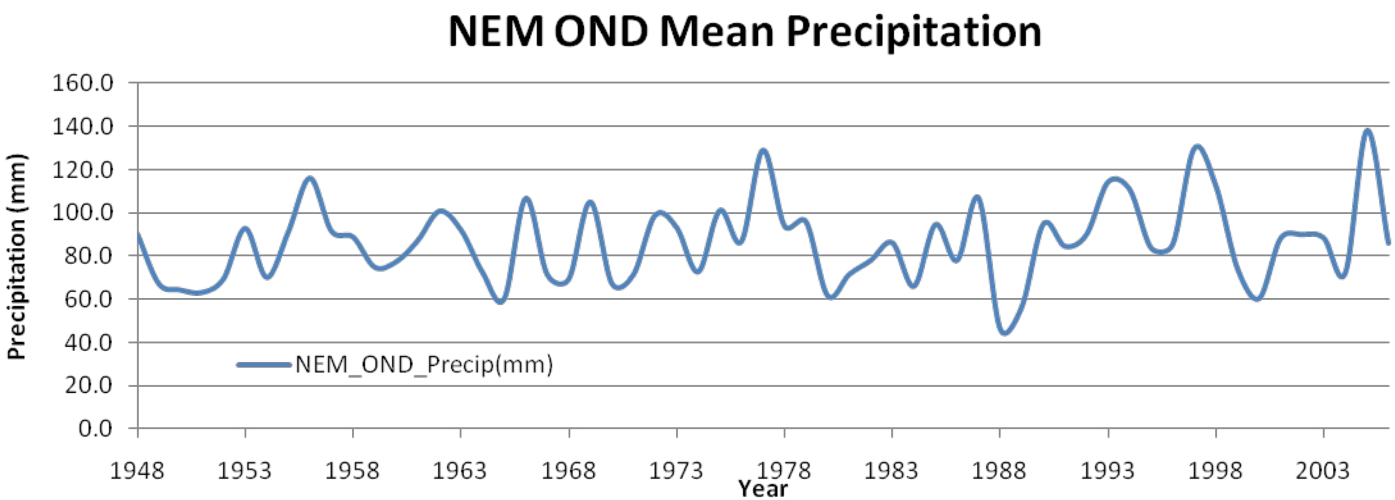
$$sign(x_j - x_k) = 1 \text{ if } x_j - x_k > 0$$
$$= 0 \text{ if } x_j - x_k = 0$$
$$= \text{-}1 \text{ if } x_j - x_k < 0$$

Climatic Variable	Tau corr. Coeff.	S value	Z value	P value	Intercept	Slope
NEM Precipitation	0.069	85	0.703	0.4822	-135.87	0.1125
NEM Temperature	0.243	298	2.494	0.0126	2.7832	0.0111
SH OLR	0.177	217	1.808	0.0706	89.568	0.0542
WPH OLR	0.367	450	3.757	0.0002	38.200	0.1000
SH Surface Pressure	0.377	462	3.865	0.124	834.11	0.0366
WPH Surface Pressure	0.100	123	1.023	0.3062	992.29	0.0056
SH Surface Temperature	0.238	291	2.428	0.0152	-74.511	0.0342
WPH Surface	0.386	473	3.979	0.0001	-6.0616	

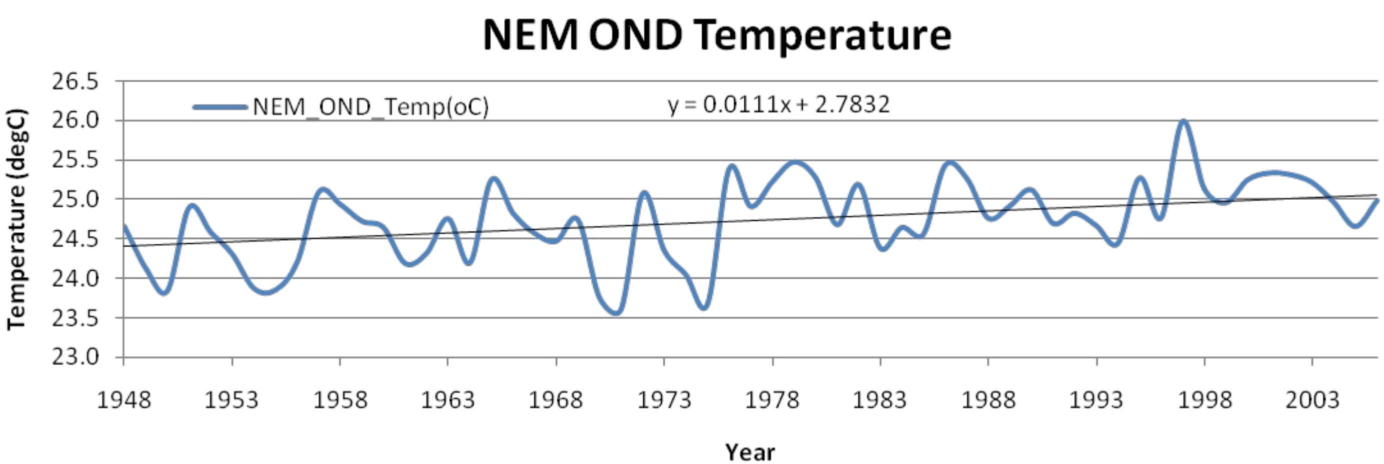
Significant (at 5 % level) trend

Non-significant (at 5 % level) trend

NEM Precipitation &Temperature Trend

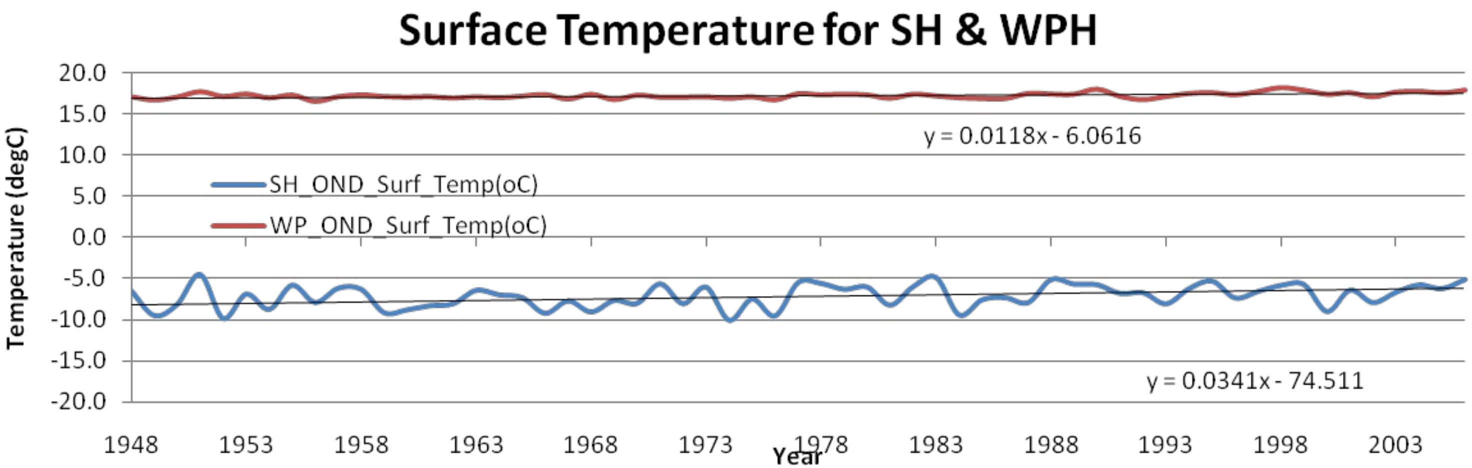


No Significant Trend

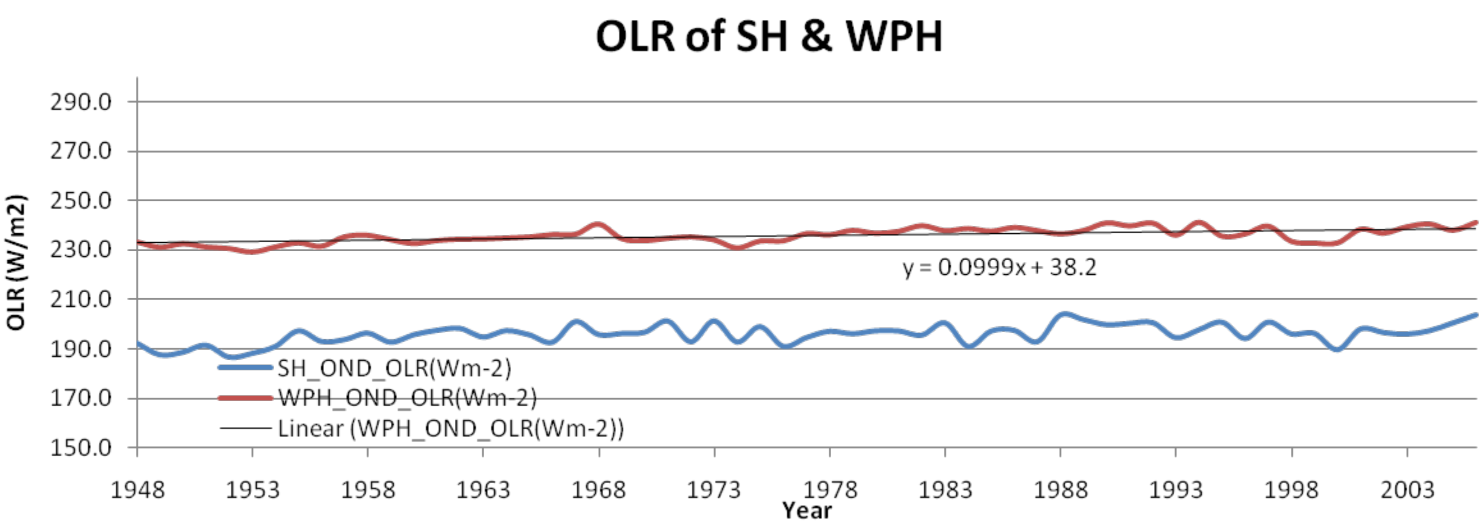


Significant Trend

Surface Temperature & OLR Trend for SH & WPH



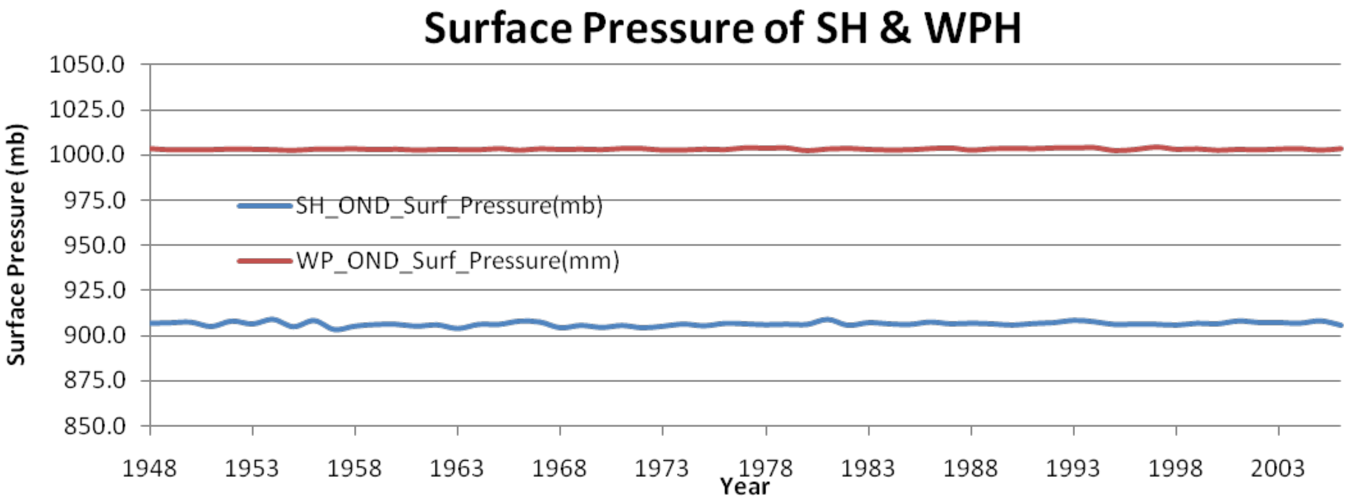
Significant Trend



Significant Trend

No Significant Trend

Surface Pressure Trend of SH & WPH



No
Significant Trend

RESULTS

- No significant trend in NEM precipitation in India whereas a significantly increasing trend in surface temperature prevails in India for the last 59 years(1948-2006) during NEM season

- Siberian High (SH) has no significant trend in OLR for the last 59 years (1948-2006) whereas the West Pacific High (WPH) has a significantly increasing trend in OLR during the NEM season

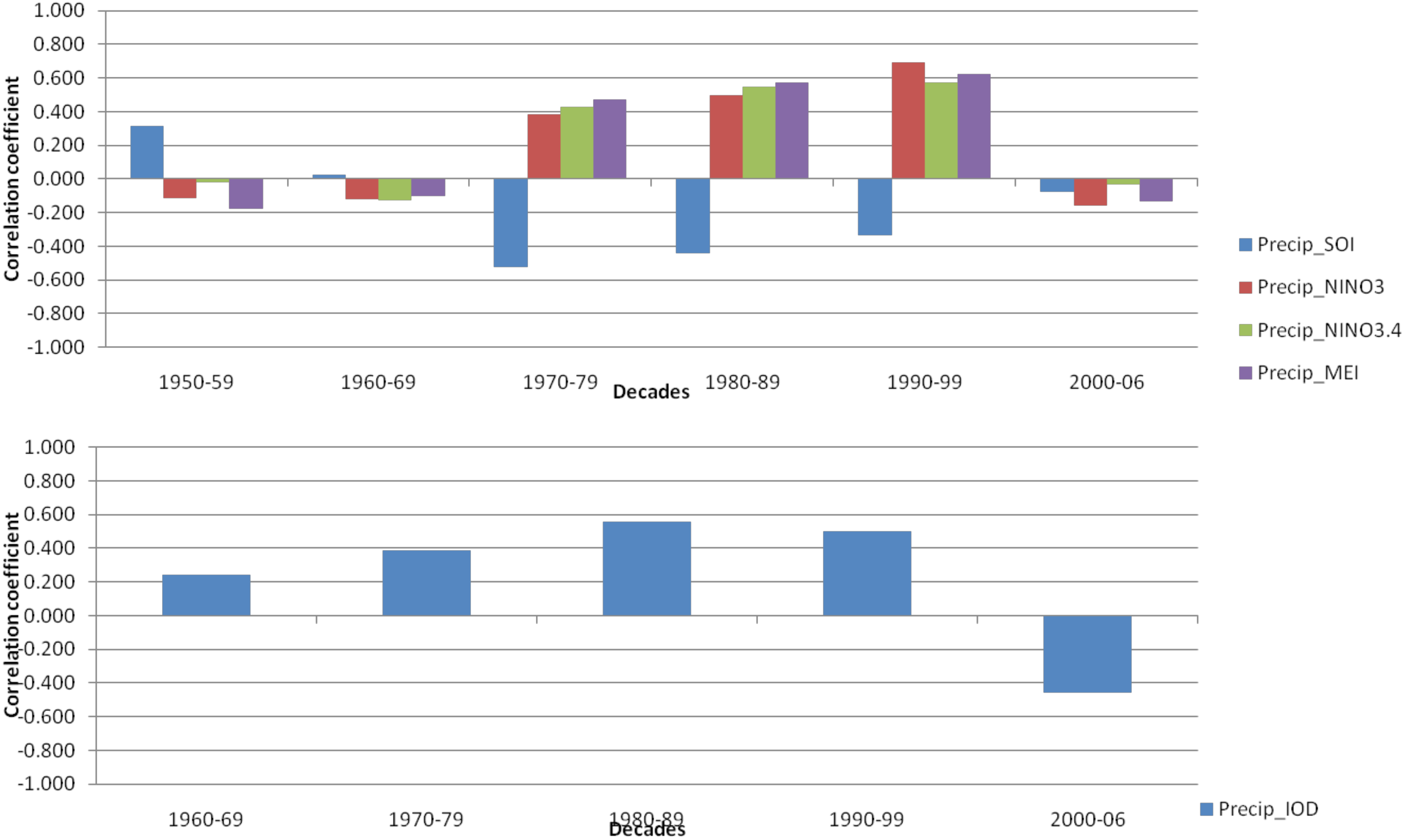
- Surface pressure over SH & WPH has no significant trend during the period

- Surface Temperature over SH & WPH has a significantly increasing trend for the last 59 years (1948-2006) during the NEM season

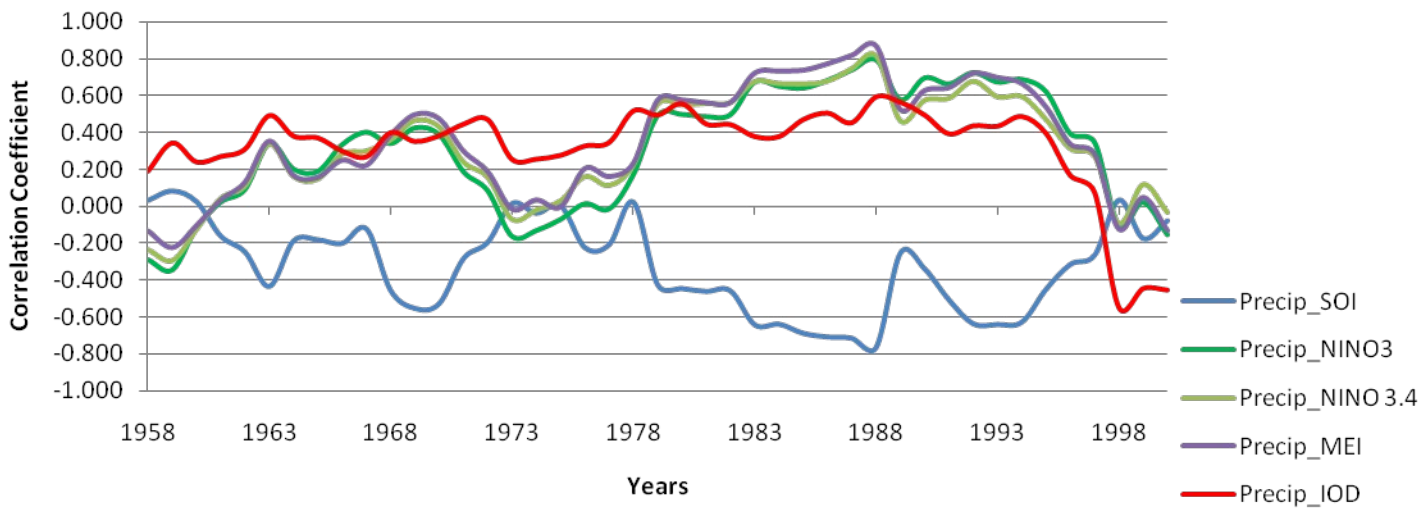
OBJECTIVE 2

Impact of El Nino & Southern Oscillation & Indian Ocean Dipole on Northeast Monsoon precipitation

Decadal Correlation of NEM Precipitation with ENSO (above) & IOD Indices (below)



Serial Correlation between NEM Precipitation and ENSO & IOD Indices



•Serial (10 year running window) correlation reveals that correlation of ENSO indices & DMI with NEM precipitation has increased between the period 1975-1998 and decreased at 1996

• Serial correlation of DMI & NEM precipitation remains less than that of ENSO & NEM precipitation during the period 1978-1996 whereas this relation is opposite during the period 1970-1978

Results

- Decadal correlation shows that decades prior to 1970's have on an average less correlation between NEM precipitation with ENSO & DMI and it increased after 1970s

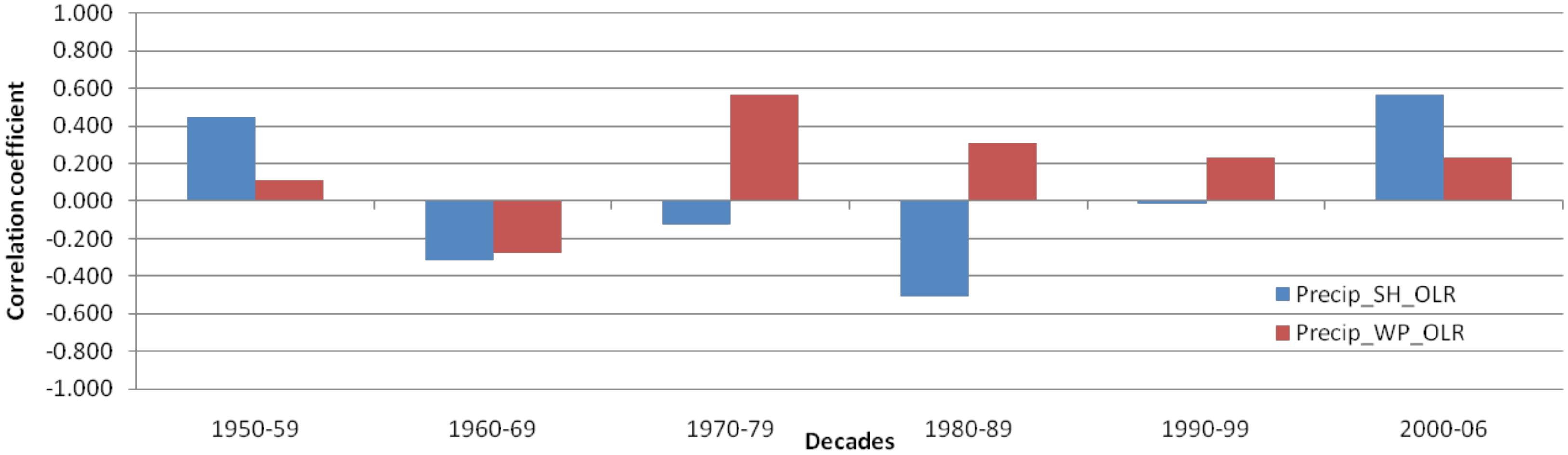
- Three decades from 1970-2000 has shown a positive & high correlation of NEM precipitation with ENSO & DMI. This correlation becomes negative & less in post 2000 decades

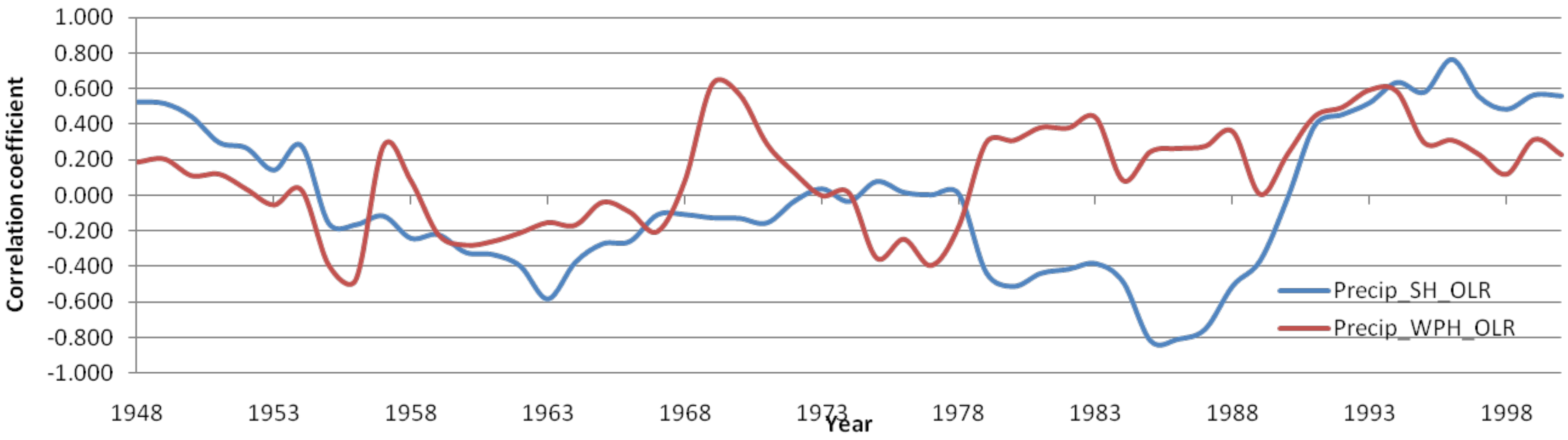
- The period during 2000-2006 has shown that the correlation of NEM precipitation with DMI is more than that with ENSO

OBJECTIVE 3

Decadal correlation of NEM precipitation with important climatic variables of the Heat Source & Moisture Sink of NEM

Serial (above) & Decadal (low) Correlation of NEM Precipitation with OLR of SH & WPH





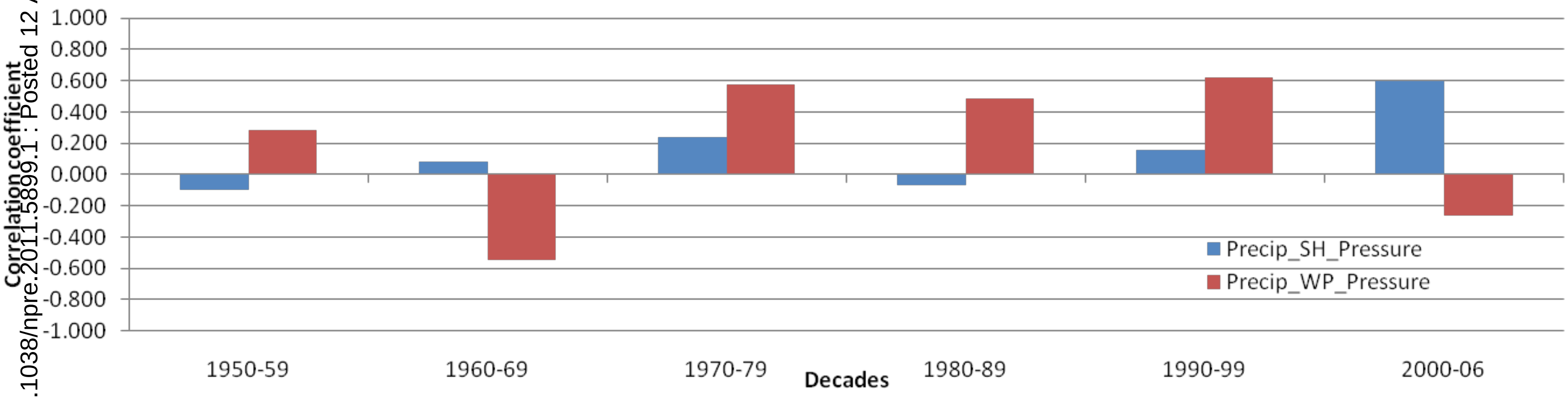
Results

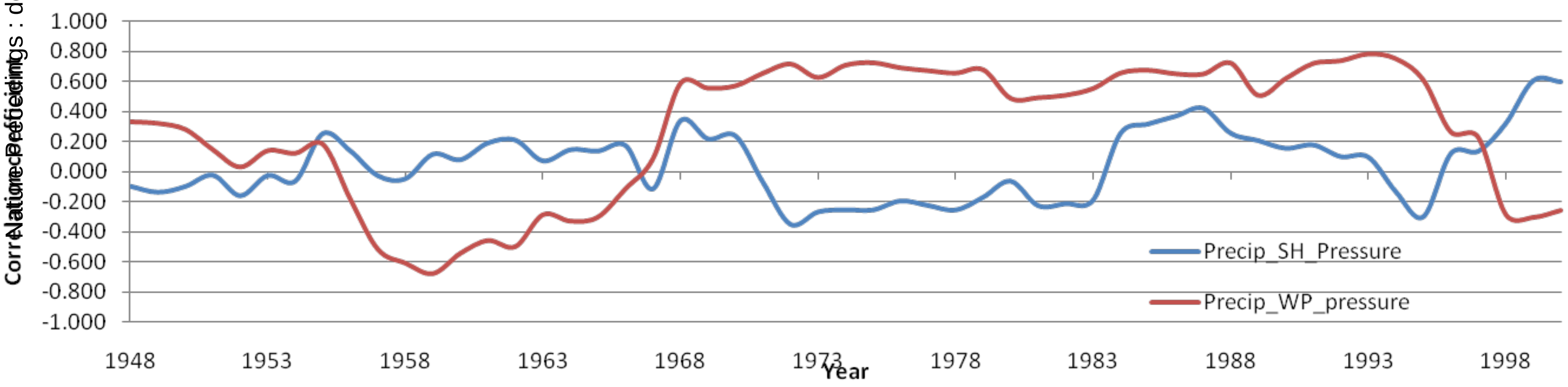
- Serial correlation of NEM precipitation with OLR of heat source & sink during the period 1978-1988 has shown a see-saw pattern between the correlation of NEM precipitation with both the OLR of SH & WPH

- The Decadal correlation shows that the correlation of NEM precipitation with the OLR of WPH has gradually decreases after 1970’s till 2006. But there is no such gradual increment of decrement of correlation for NEM precipitation & OLR of SH

- The decadal correlation of NEM precipitation & OLR of SH has shown high but negative correlation during the 1980-90’s and high but positive during 2000-2006

Serial (above) & Decadal (low) Correlation of NEM Precipitation with Surface Pressure of SH & WPH





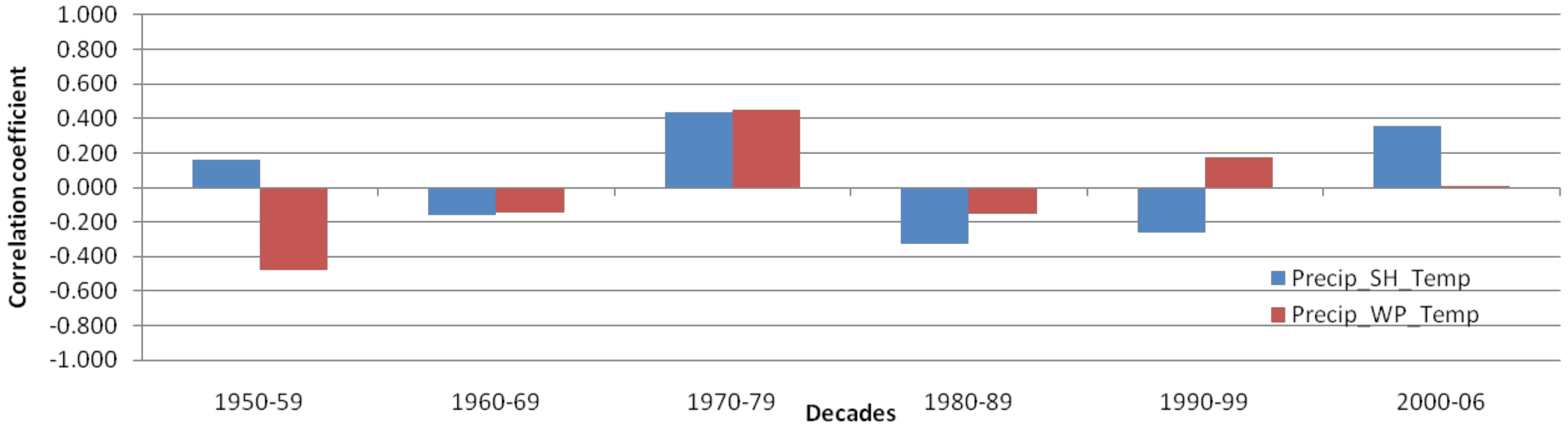
Results

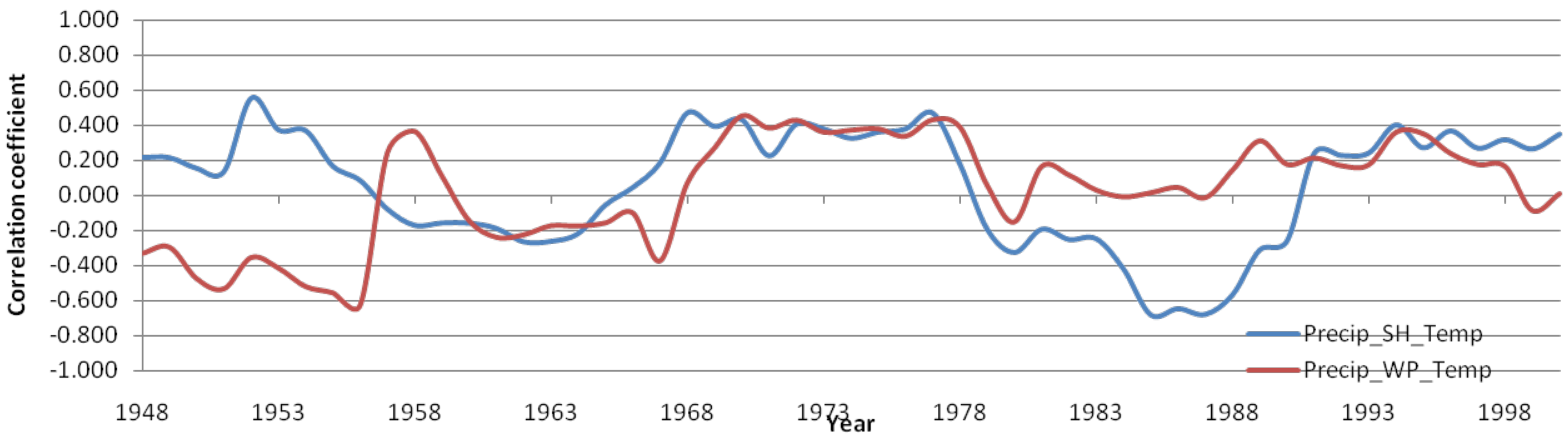
- Serial correlation of NEM precipitation & WPH surface pressure has shown a high & consistent correlation during the long period of 1968-1998. The same is not shown in case of SH surface pressure. The correlation reverses from negative to positive during 1983 between NEM precipitation & SH surface pressure

- Decadal correlation has also shown a consistent high & positive correlation between NEM precipitation & WPH surface pressure during three decades 1970-2000

- There is a negative & low correlation between NEM precipitation & WPH surface pressure while a positive & high correlation between NEM precipitation & SH surface pressure during 2000-2006

Serial (above) & Decadal (low) Correlation of NEM Precipitation with Surface Temperature of SH & WPH





Results

- Serial correlation of NEM precipitation and SH surface temperature reveals a wave-like correlation pattern with decadal reversal from positive to negative & *vice versa* during the period from 1948 to 1998. But there is no such vivid reversal of correlation for WPH surface temperature

- Decadal correlation also reveals that 1970-80 has the highest & positive correlation between NEM precipitation with SH & WPH surface temperature. The correlation decreases for NEM precipitation & WPH surface temperature during 2000-2006

CONCLUSIONS

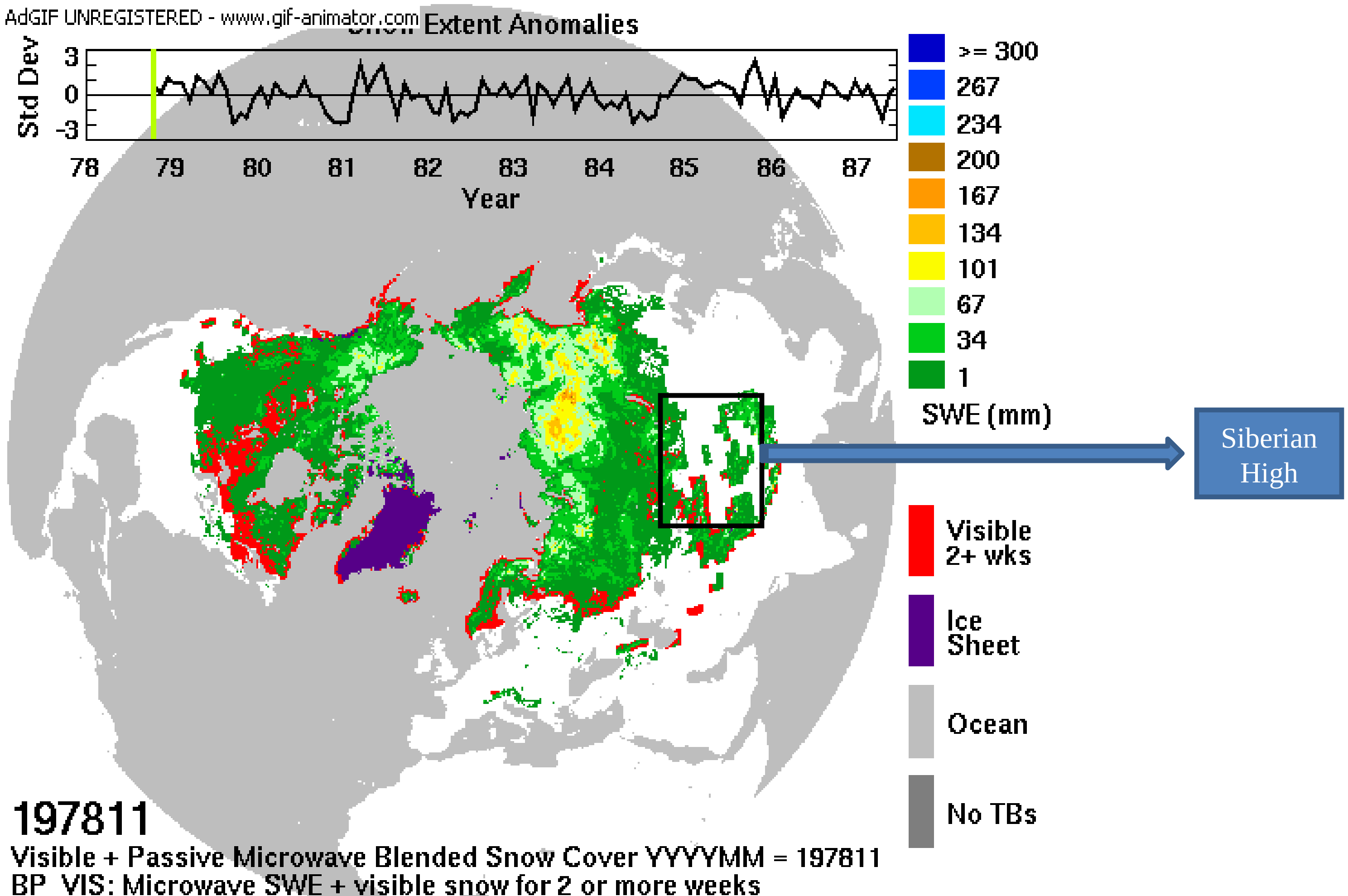
CONCLUSIONS

- There is no significant trend in NEM precipitation in Indian region. But the surface temperature has a significantly increasing trend over India during the NEM season
- There is a no significant trend in OLR of Siberian High (SH) West Pacific High (WPH) has an significantly increasing trend in OLR), surface pressure of both the SH & WPH has no significant trend for the last 59 years (1948-2006)
- Surface temperature over SH & WPH has a significantly increasing trend for the last 59 years (1948-2006)
- There is a high correlation of NEM precipitation with ENSO, IOD and OLR of WPH during the period 1970-2000. It signifies that convectional activity in the moisture source region of the NEM, warm SST in the western Indian ocean and the ENSO have a deep bearing on the NEM precipitation during the three decades 1970-2000

Contd. Conclusions

- The correlation of NEM precipitation with ENSO, IOD during the last period 2000-2006 has undergone changes where the NEM precipitation has shown a shift by negatively correlated with ENSO & IOD. The change is much more in IOD than ENSO which signifies that the conventional trend of bearing of warm or cold SST of west Indian ocean on NEM precipitation has decreased during this period of 2000-2006
- The correlation of NEM precipitation with the convectional activity of the moisture sink region of the NEM has been gradually on decrease since 1970s and the moisture source of NEM has a significantly decreasing convectional activity trend
- The correlation of NEM precipitation with all the three variables (OLR, surface pressure & surface temperature) has shown a comparatively much higher value for the heat sink regions (Siberian High) than that for the moisture source region (West Pacific High) during the period 2000-2006

Snow Extent for Oct.,Nov.,& Dec. for 1978-2007



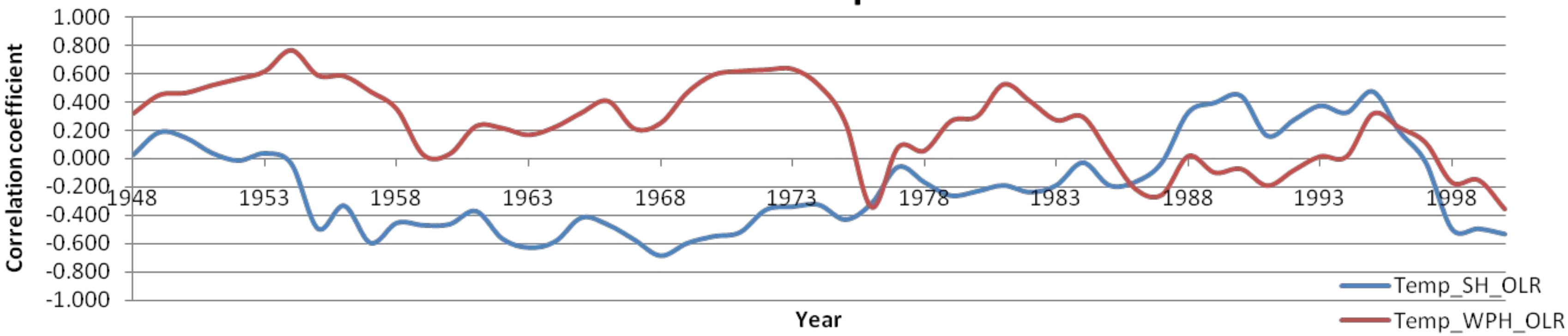
Source:
http://nsidc.org/data/docs/daac/nsidc0271_ease_grid_swe_climatology/browse/viewer.html
(**Armstrong, R. L., M. J. Brodzik, K. Knowles, and M. Savoie**. 2007. *Global monthly EASE-Grid snow water equivalent climatology*. Boulder, CO: National Snow and Ice Data Center. Digital media)

THANK YOU...

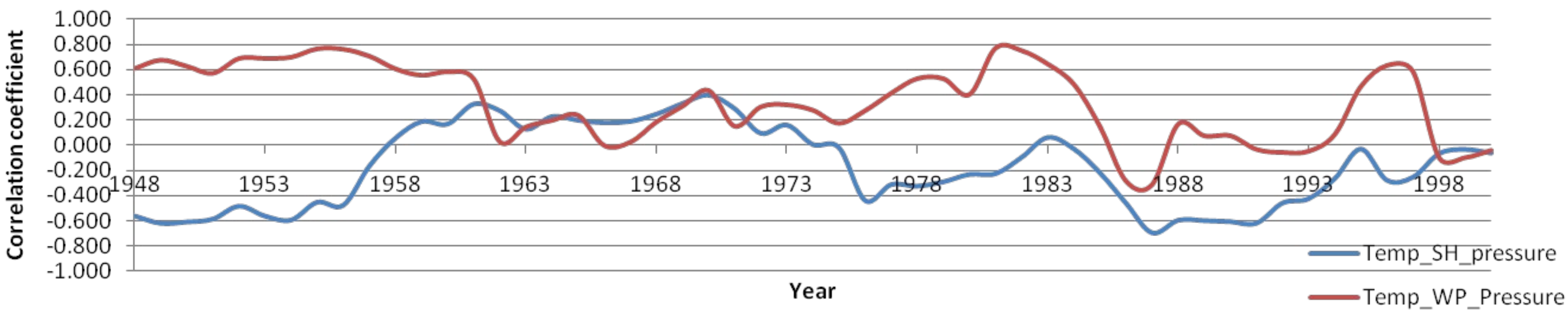
Others

Analysis with NEM Temperature & Other Variables

Serial Correlation between NEM Temperature & OLR of SH & WPH



Serial Correlation between NEM Temperature and Surface Pressure of SH & WPH



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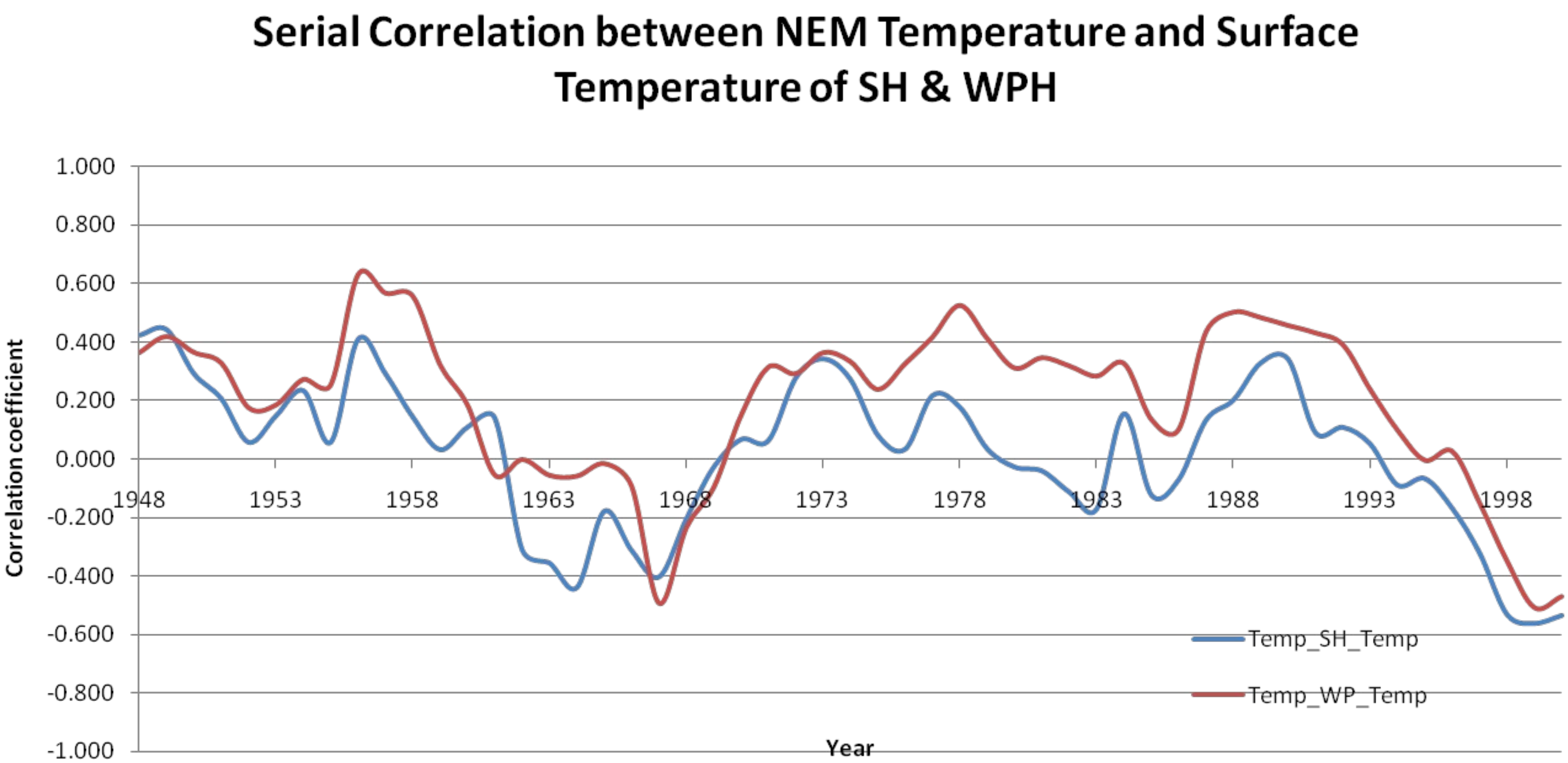

Serial Correlation between NEM Temperature and Surface Temperature of SH & WPH
1.000
0.800
0.600
0.400
0.200
0.000
-0.200
-0.400
-0.600
-0.800
-1.000
Correlation coefficient
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
Year
Temp_SH_Temp
Temp_WP_Temp

Correlation Matrices

Correlations

		NEM_OND_ Precip(mm)	NEM_OND_ Temp(oC)	SH_OND_ Surf_ Pressure(mb)	WP_OND_ Surf_ Pressure(mm)
NEM_OND_Precip(mm)	Pearson Correlation	1	.164	.059	.359**
	Sig. (2-tailed)		.215	.658	.005
	N	59	59	59	59
NEM_OND_Temp(oC)	Pearson Correlation	.164	1	.011	.342**
	Sig. (2-tailed)	.215		.935	.008
	N	59	59	59	59
SH_OND_Surf_ Pressure(mb)	Pearson Correlation	.059	.011	1	.089
	Sig. (2-tailed)	.658	.935		.503
	N	59	59	59	59
WP_OND_Surf_ Pressure(mm)	Pearson Correlation	.359**	.342**	.089	1
	Sig. (2-tailed)	.005	.008	.503	
	N	59	59	59	59

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		NEM_OND_ Precip(mm)	NEM_OND_ Temp(oC)	SH_OND_ Surf_ Temp(oC)	WP_OND_ Surf_ Temp(oC)
NEM_OND_Precip(mm)	Pearson Correlation	1	.164	.136	.143
	Sig. (2-tailed)		.215	.303	.280
	N	59	59	59	59
NEM_OND_Temp(oC)	Pearson Correlation	.164	1	.237	.410**
	Sig. (2-tailed)	.215		.071	.001
	N	59	59	59	59
SH_OND_Surf_ Temp(oC)	Pearson Correlation	.136	.237	1	.566**
	Sig. (2-tailed)	.303	.071		.000
	N	59	59	59	59
WP_OND_Surf_ Temp(oC)	Pearson Correlation	.143	.410**	.566**	1
	Sig. (2-tailed)	.280	.001	.000	
	N	59	59	59	59

**. Correlation is significant at the 0.01 level (2-tailed).

Contd.

Correlations

		NEM_OND_ Precip(mm)	NEM_OND_ Temp(oC)	SH_OND_ OLR(Wm-2)	WPH_OND_ OLR(Wm-2)
NEM_OND_Precip(mm)	Pearson Correlation	1	.164	.114	.172
	Sig. (2-tailed)		.215	.391	.194
	N	59	59	59	59
NEM_OND_Temp(oC)	Pearson Correlation	.164	1	.109	.463**
	Sig. (2-tailed)	.215		.413	.000
	N	59	59	59	59
SH_OND_OLR(Wm-2)	Pearson Correlation	.114	.109	1	.589**
	Sig. (2-tailed)	.391	.413		.000
	N	59	59	59	59
WPH_OND_OLR(Wm-2)	Pearson Correlation	.172	.463**	.589**	1
	Sig. (2-tailed)	.194	.000	.000	
	N	59	59	59	59

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		NEM_OND_ Precip(mm)	NEM_OND_ Temp(oC)	SOI_SOND	NINO3_OND	NINO3.4_ OND	MEI_SOND
NEM_OND_Precip(mm)	Pearson Correlation	1	.147	-.199	.258	.273*	.252
	Sig. (2-tailed)		.276	.138	.053	.040	.059
	N	57	57	57	57	57	57
NEM_OND_Temp(oC)	Pearson Correlation	.147	1	-.532**	.632**	.621**	.693**
	Sig. (2-tailed)	.276		.000	.000	.000	.000
	N	57	57	57	57	57	57
SOI_SOND	Pearson Correlation	-.199	-.532**	1	-.832**	-.882**	-.909**
	Sig. (2-tailed)	.138	.000		.000	.000	.000
	N	57	57	57	57	57	57
NINO3_OND	Pearson Correlation	.258	.632**	-.832**	1	.973**	.944**
	Sig. (2-tailed)	.053	.000	.000		.000	.000
	N	57	57	57	57	57	57
NINO3.4_OND	Pearson Correlation	.273*	.621**	-.882**	.973**	1	.960**
	Sig. (2-tailed)	.040	.000	.000	.000		.000
	N	57	57	57	57	57	57
MEI_SOND	Pearson Correlation	.252	.693**	-.909**	.944**	.960**	1
	Sig. (2-tailed)	.059	.000	.000	.000	.000	
	N	57	57	57	57	57	57

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Contd.

Correlations

		NEM_OND_ Precip(mm)	SOI_SOND	NINO3_OND	NINO3.4_ OND	MEI_SOND
NEM_OND_Precip(mm)	Pearson Correlation	1	-.199	.258	.273*	.252
	Sig. (2-tailed)		.138	.053	.040	.059
	N	57	57	57	57	57
SOI_SOND	Pearson Correlation	-.199	1	-.832**	-.882**	-.909**
	Sig. (2-tailed)	.138		.000	.000	.000
	N	57	57	57	57	57
NINO3_OND	Pearson Correlation	.258	-.832**	1	.973**	.944**
	Sig. (2-tailed)	.053	.000		.000	.000
	N	57	57	57	57	57
NINO3.4_OND	Pearson Correlation	.273*	-.882**	.973**	1	.960**
	Sig. (2-tailed)	.040	.000	.000		.000
	N	57	57	57	57	57
MEI_SOND	Pearson Correlation	.252	-.909**	.944**	.960**	1
	Sig. (2-tailed)	.059	.000	.000	.000	
	N	57	57	57	57	57

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		NEM_OND_ Precip(mm)	NEM_OND_ Temp(oC)	DMI
NEM_OND_Precip(mm)	Pearson Correlation	1	.147	.309*
	Sig. (2-tailed)		.314	.031
	N	49	49	49
NEM_OND_Temp(oC)	Pearson Correlation	.147	1	.293*
	Sig. (2-tailed)	.314		.041
	N	49	49	49
DMI	Pearson Correlation	.309*	.293*	1
	Sig. (2-tailed)	.031	.041	
	N	49	49	49

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		NEM_OND_ Precip(mm)	DMI
NEM_OND_Precip(mm)	Pearson Correlation	1	.309*
	Sig. (2-tailed)		.031
	N	49	49
DMI	Pearson Correlation	.309*	1
	Sig. (2-tailed)	.031	
	N	49	49

*. Correlation is significant at the 0.05 level (2-tailed).

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Apparent Heat Source & Moisture Sink

Apparent Heat Source (Q1) & Apparent Moisture Sink (Q2) are defined as

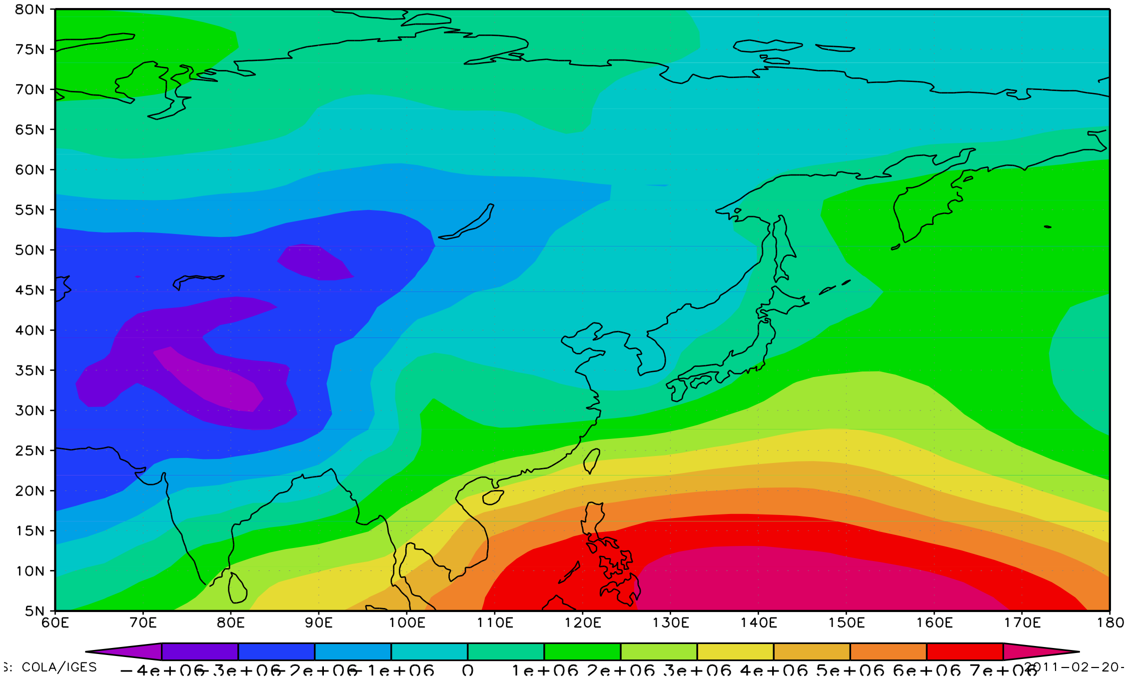
$$Q_1 = C_p\left(\frac{p}{p_0}\right)^{\kappa}\left(\frac{\partial\theta}{\partial t} + \mathbf{V}\cdot\boldsymbol{\nabla}\theta + \omega\frac{\partial\theta}{\partial p}\right) \quad \text{and} \qquad (1)$$

$$Q_2 = -L\left(\frac{\partial q}{\partial t} + \mathbf{V}\cdot\boldsymbol{\nabla}q + \omega\frac{\partial q}{\partial p}\right). \qquad (2)$$

In (1) and (2), θ is the potential temperature, q the mixing ratio of water vapor, $\mathbf{V}$ the horizontal velocity, ω the vertical p-velocity, and p the pressure. In the equation $\kappa = R/C_p$, R, and C_p are, respectively, the gas constant and the specific heat at constant pressure of dry air, $p_0 = 1000$ hPa, L is the latent heat of condensation, and $\boldsymbol{\nabla}$ is the isobaric gradient operator.

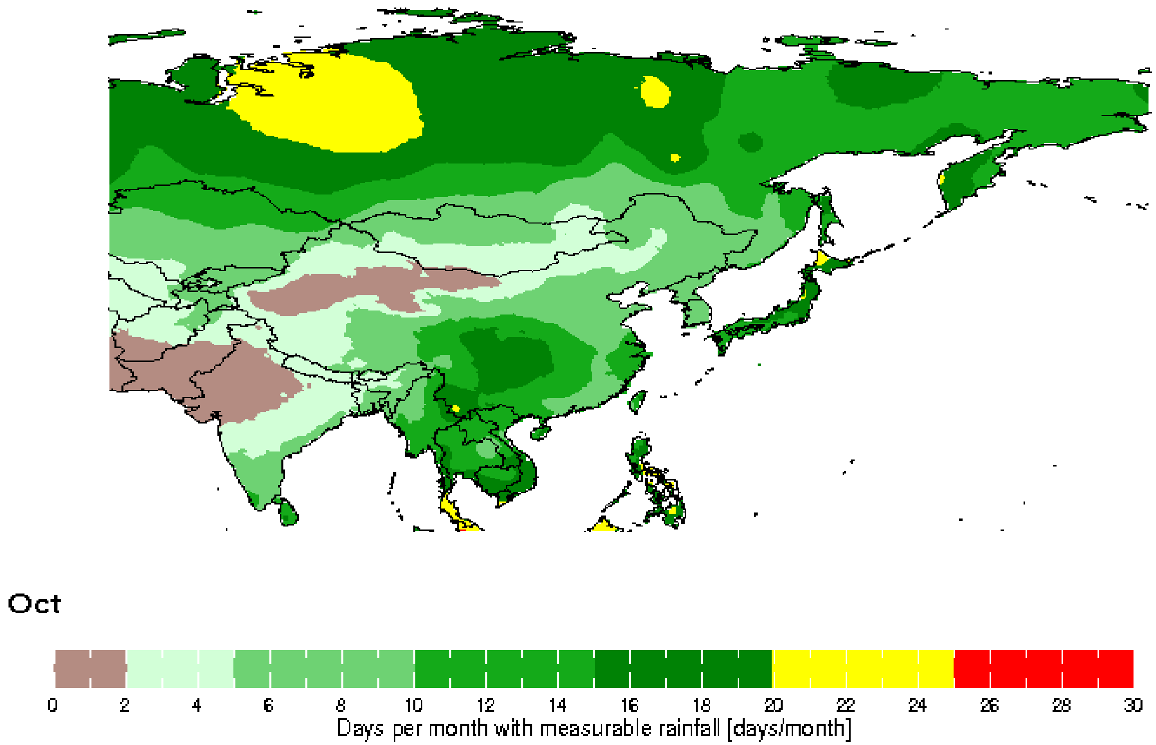
Source: Yanai & Tomita, 1998

Climatological (OND) Velocity Potential for 1948-2006



Source:
http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl

Climatological Precipitation Frequency



Source:
http://iridl.ldeo.columbia.edu/maproom/.Global/.Climatologies/.Prcp_Frequency.html
(Monthly precipitation frequency climatology of University of East Anglia for 1961-1990)

The End