Extreme Weather – The Flood and Drought Equation

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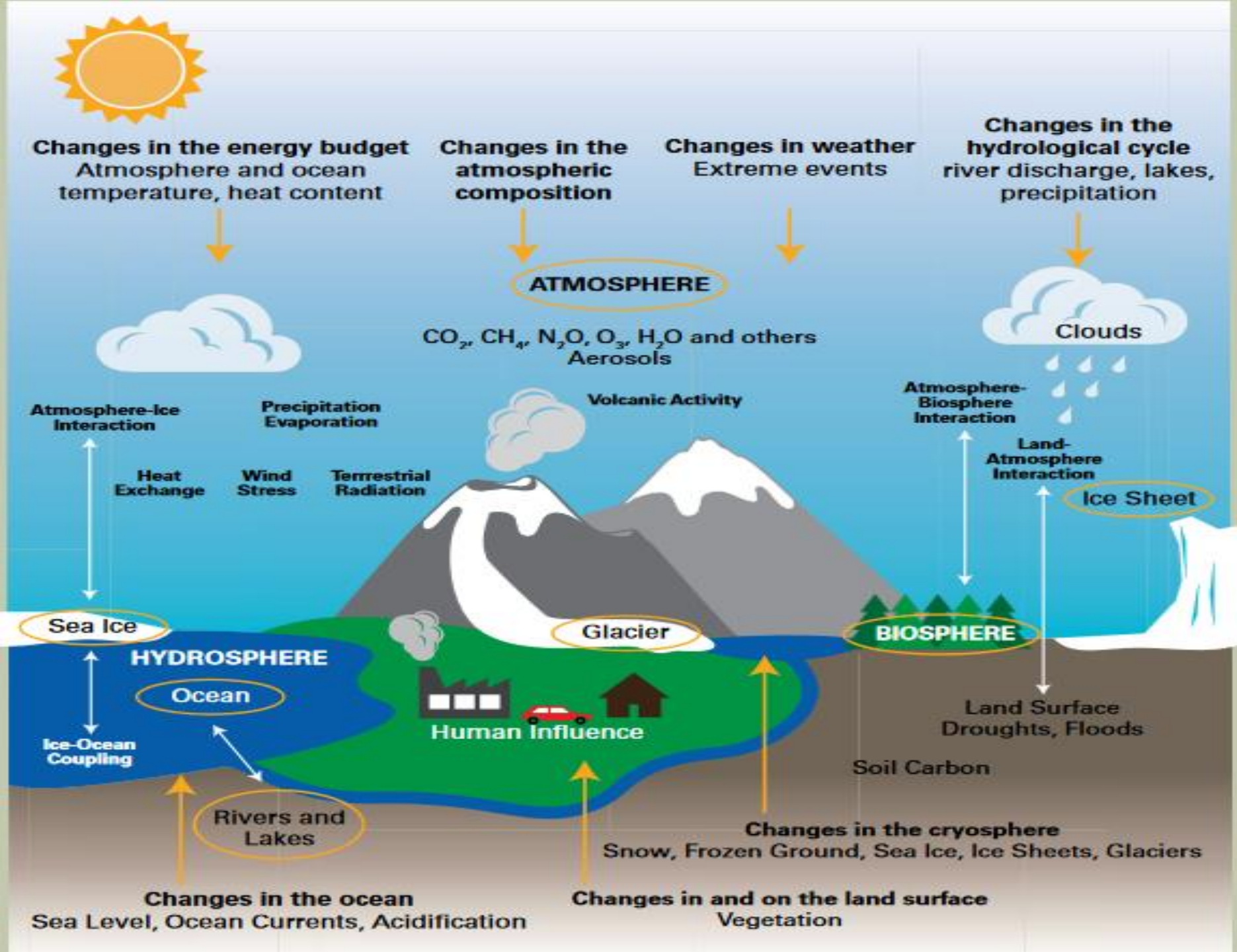
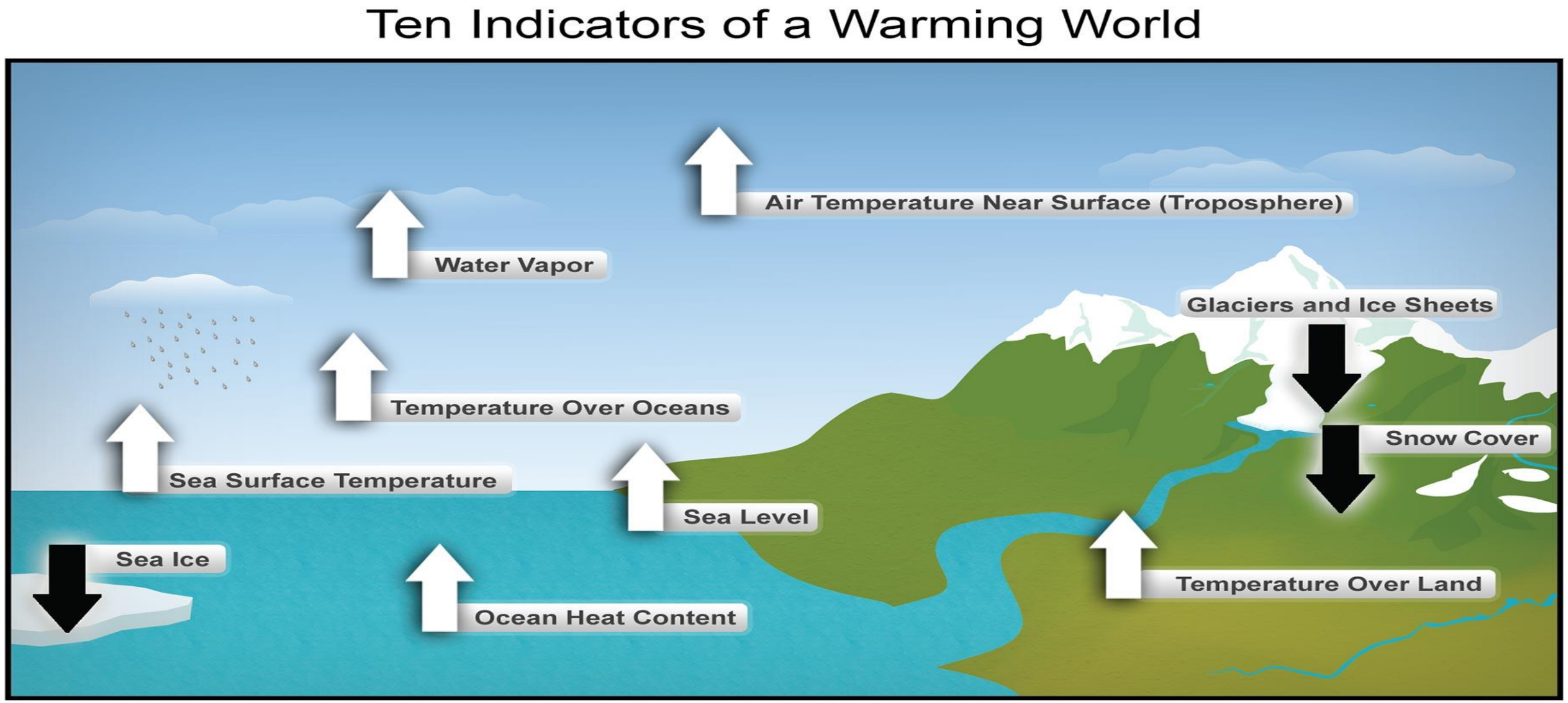
POINTS

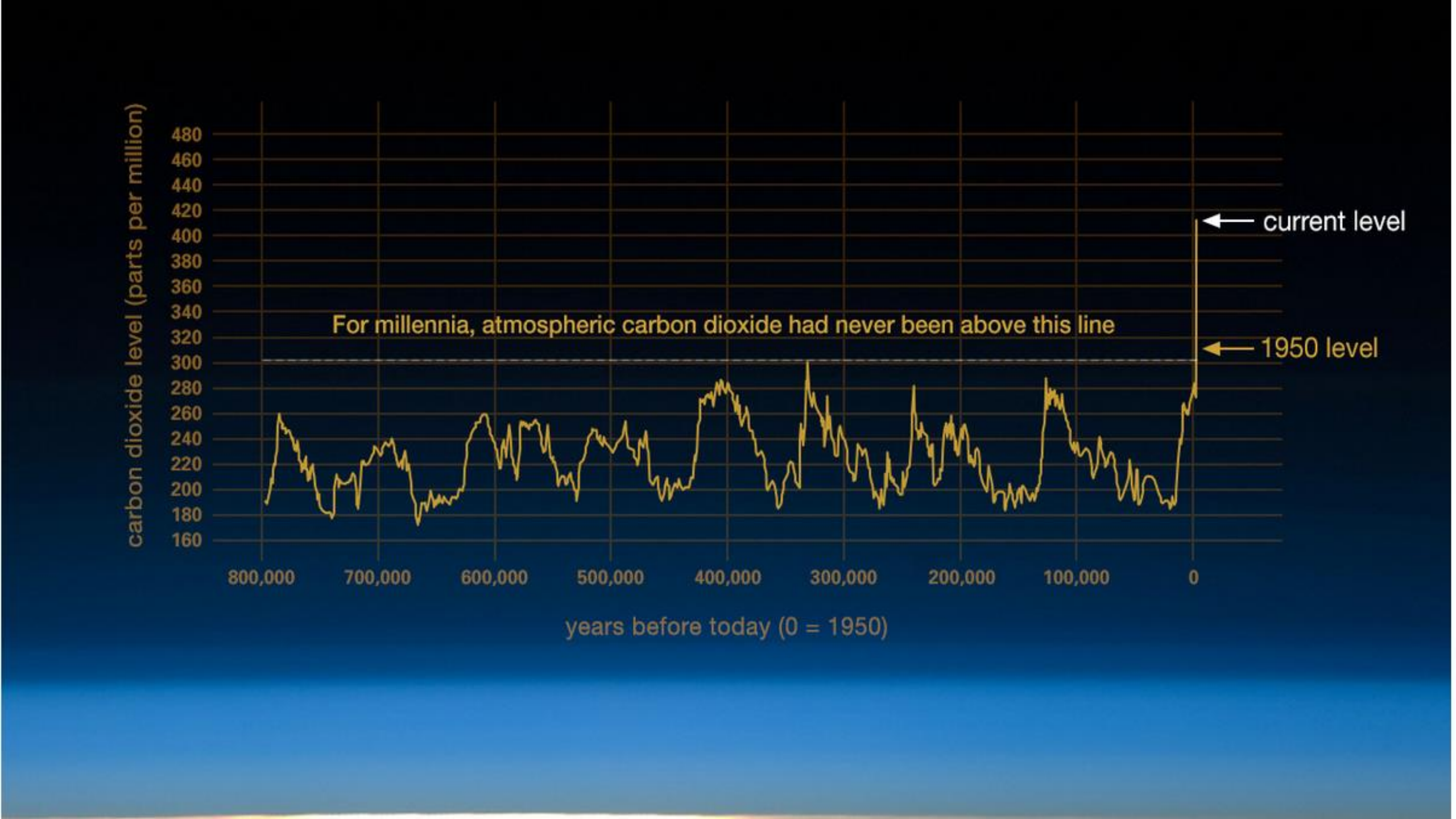
- Climate Change and Increasing Risk of Natural Disasters
- Integrated Modelling Efforts (INCOIS, NCCR)
- Ocean-Atmospheric Coupled Modelling - Extended Range and Seasonal Forecast
- Ocean-Atmospheric Hurricane WRF for Cyclone Prediction
- Warning Services For Coastal Region



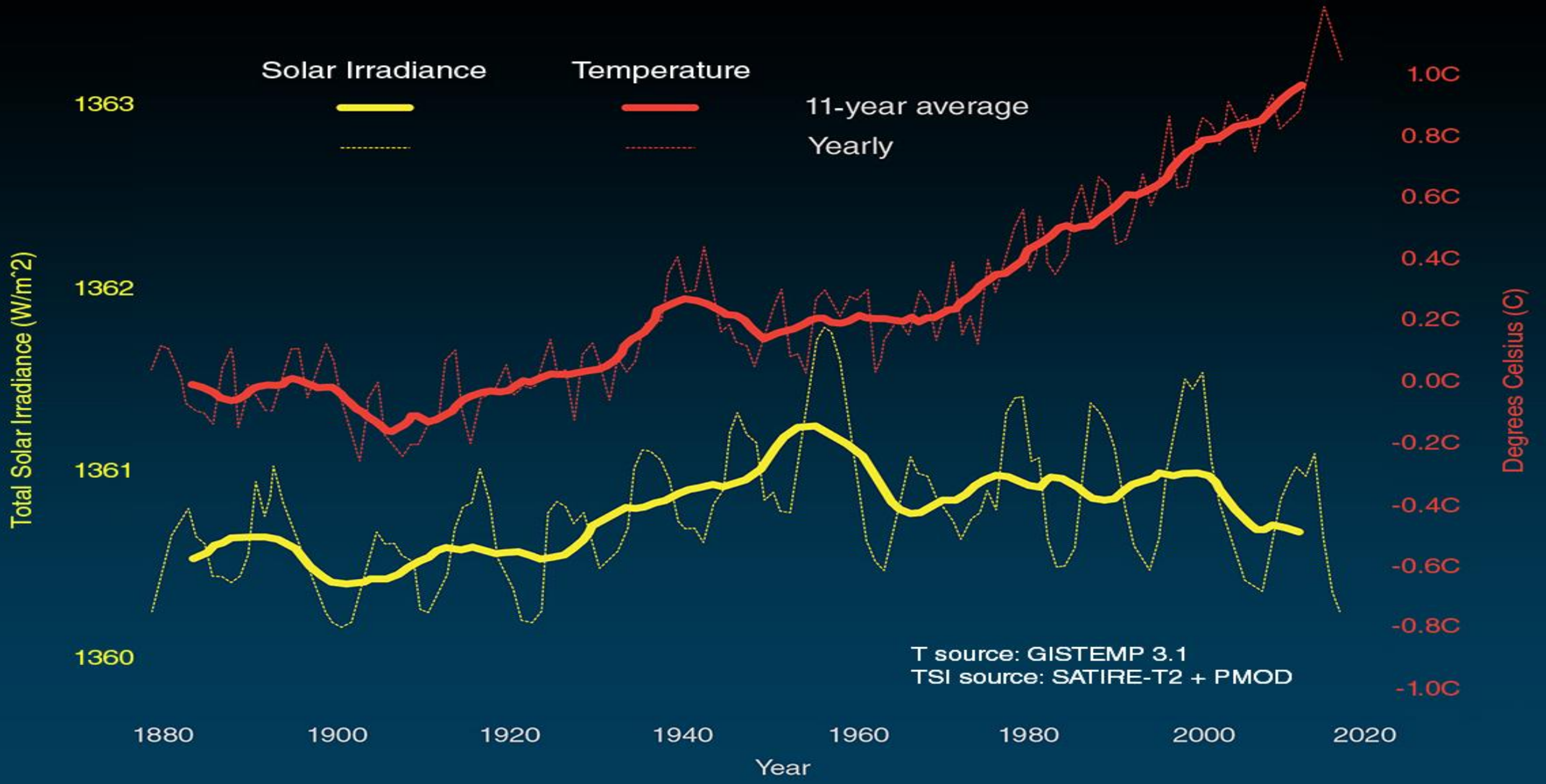
Key components of climate system and interactions: energy budget, atmospheric composition, weather, hydrological cycle, ocean and cryosphere.

Indicators measured globally over many decades that show that the Earth's Climate is Warming

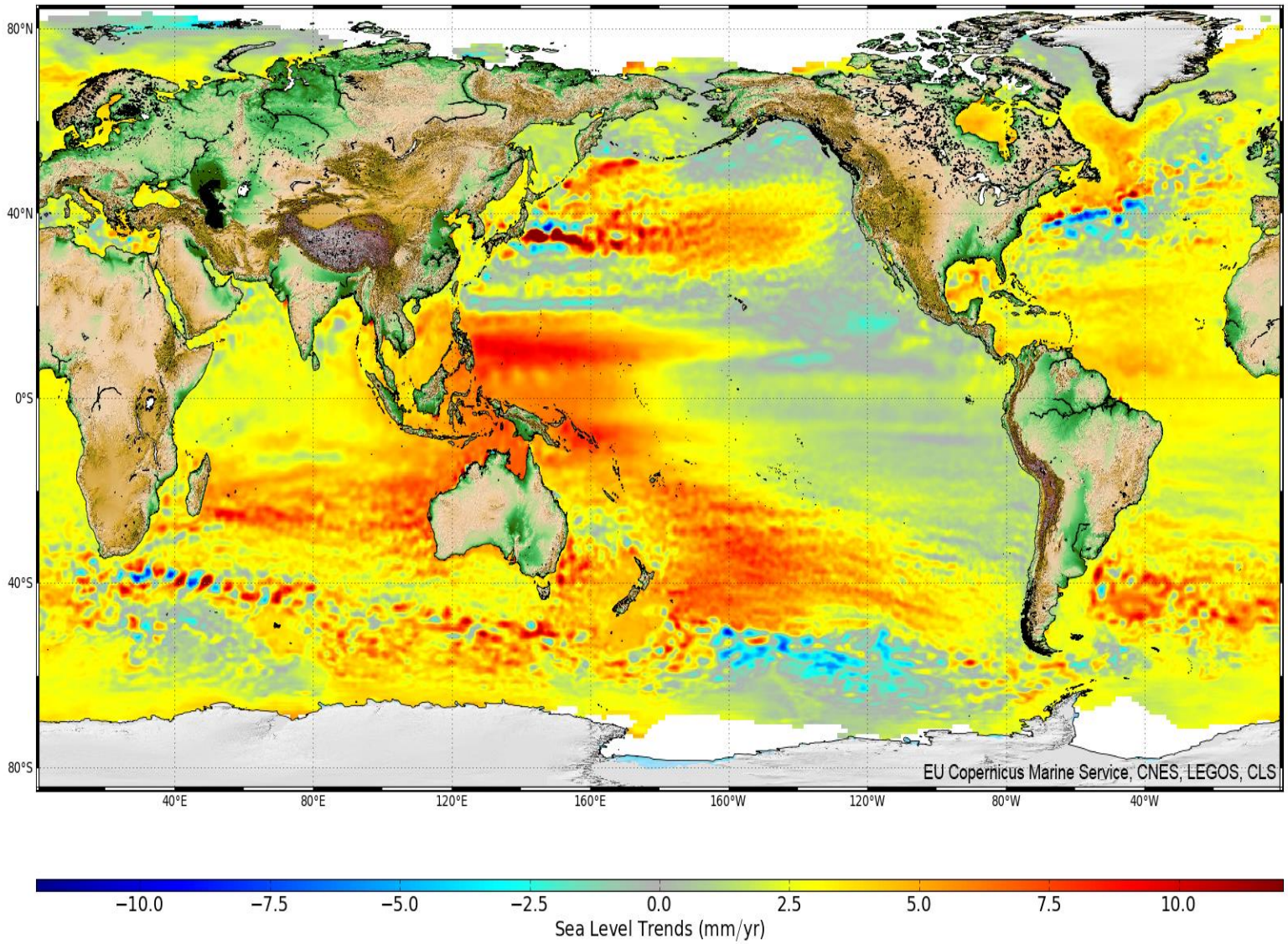



carbon dioxide level (parts per million)
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
For millennia, atmospheric carbon dioxide had never been above this line
current level
1950 level
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
years before today (0 = 1950)

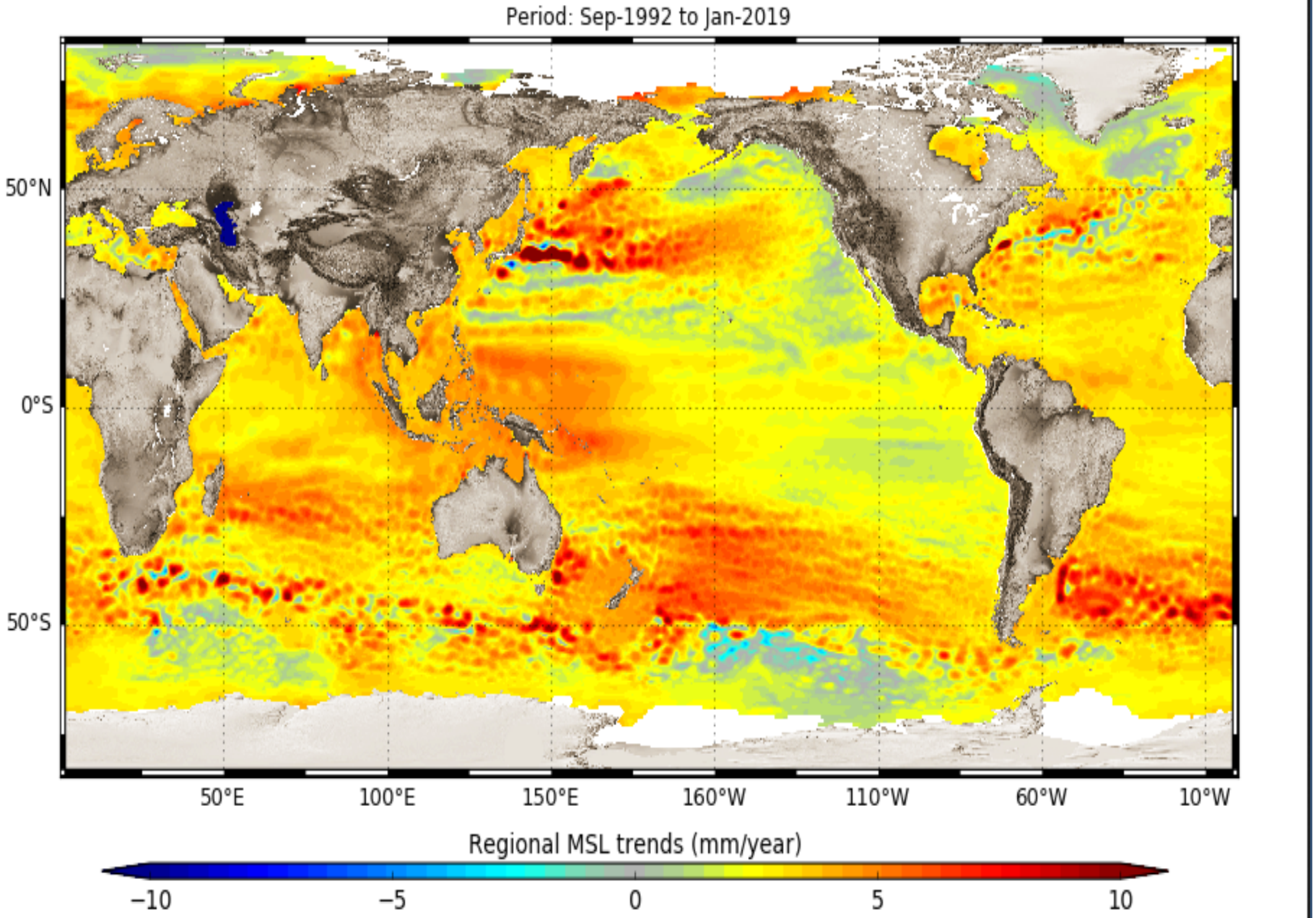
Temperature vs Solar Activity

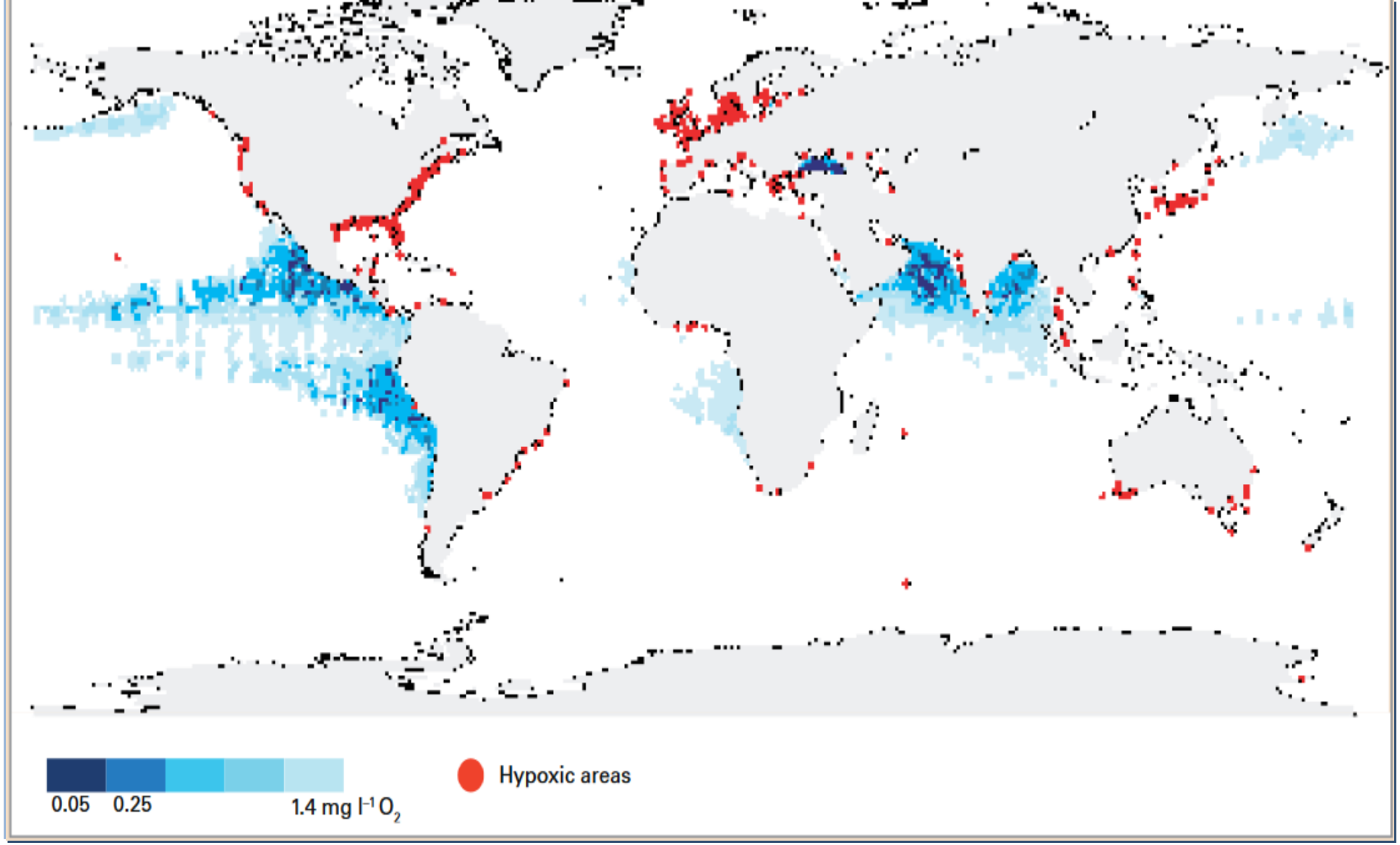


1992-2015


80°N
40°N
0°S
40°S
80°S
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
EU Copernicus Marine Service, CNES, LEGOS, CLS
−10.0
−7.5
−5.0
−2.5
0.0
2.5
5.0
7.5
10.0
Sea Level Trends (mm/yr)

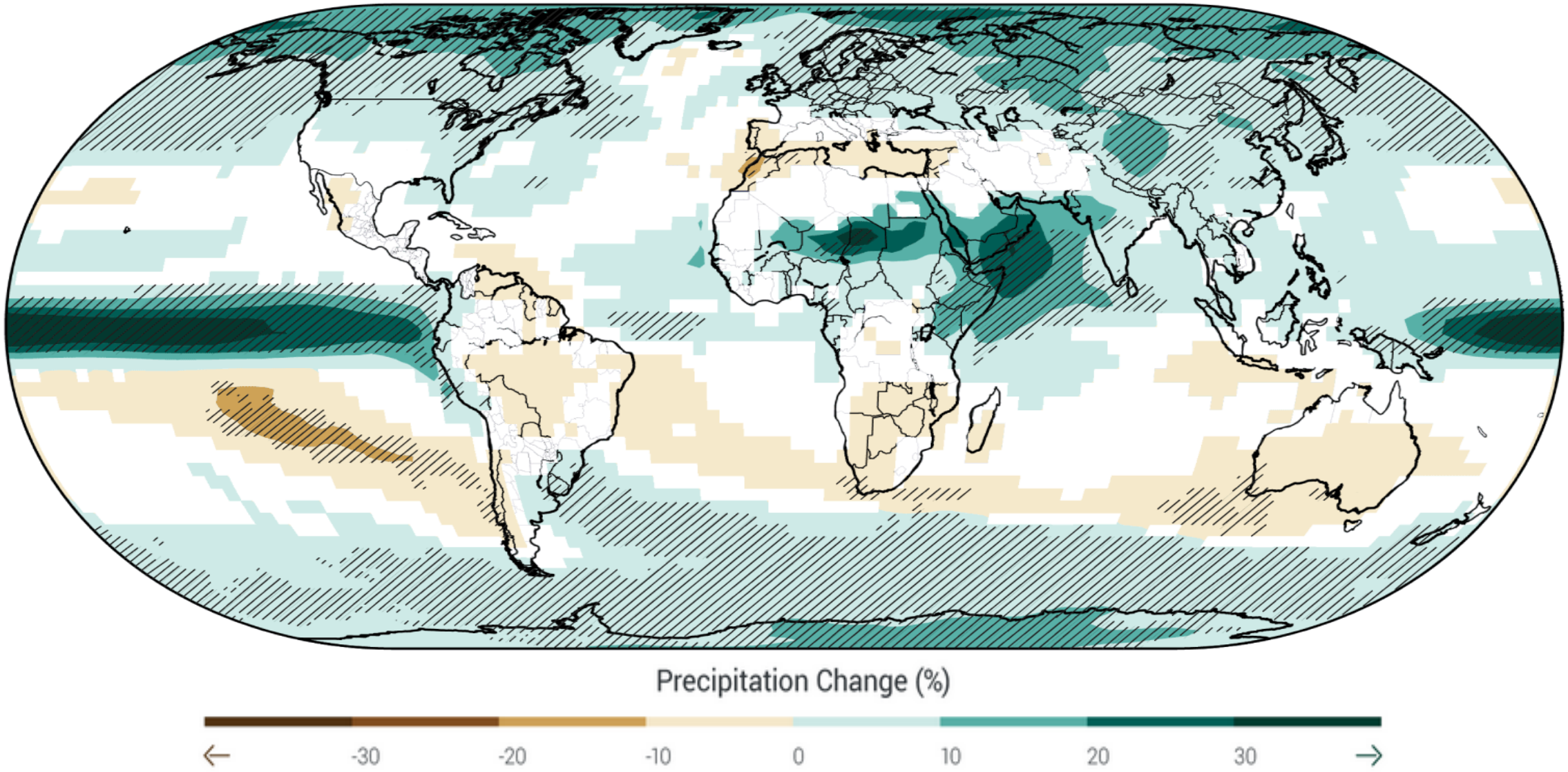
Multi-Mission Sea Level Trends



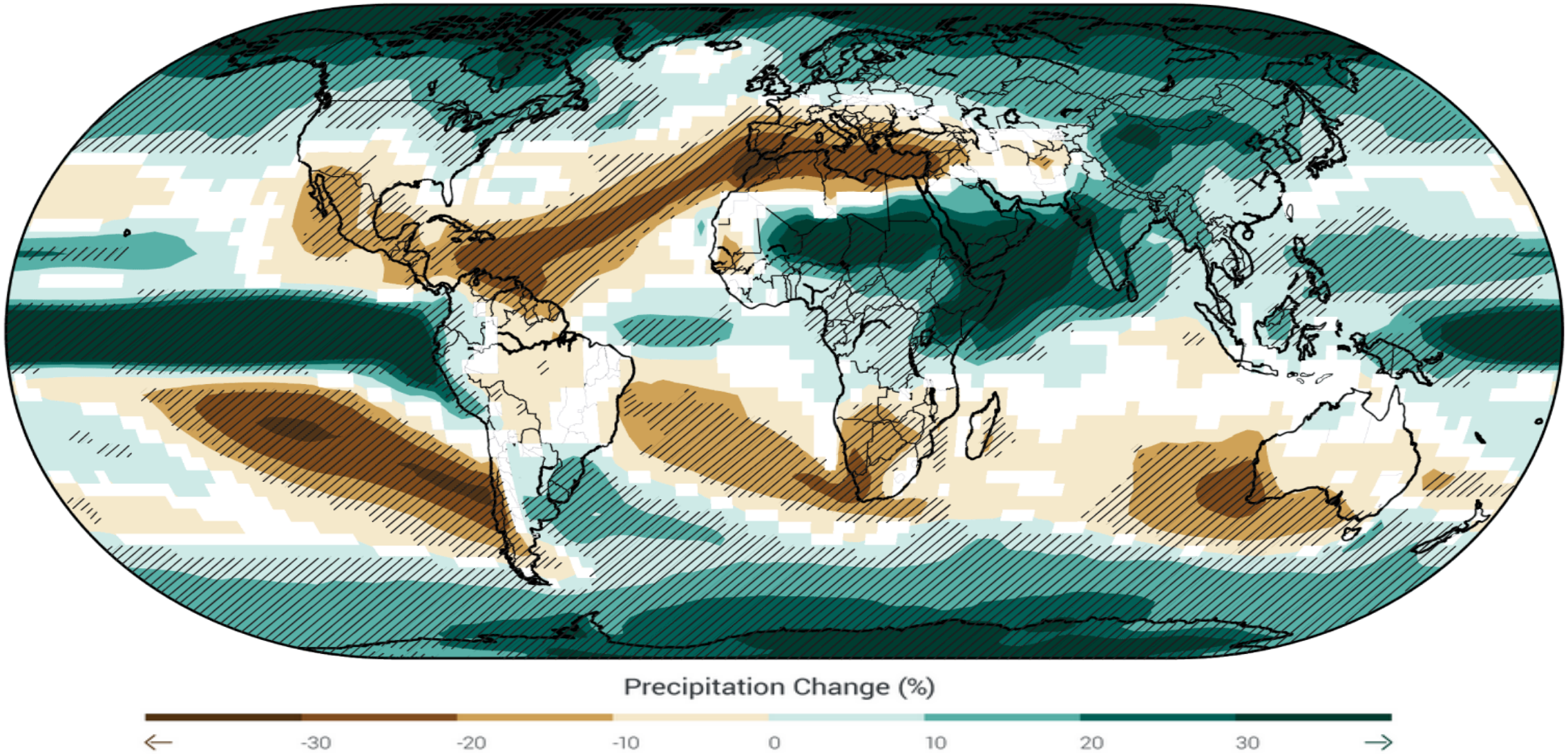


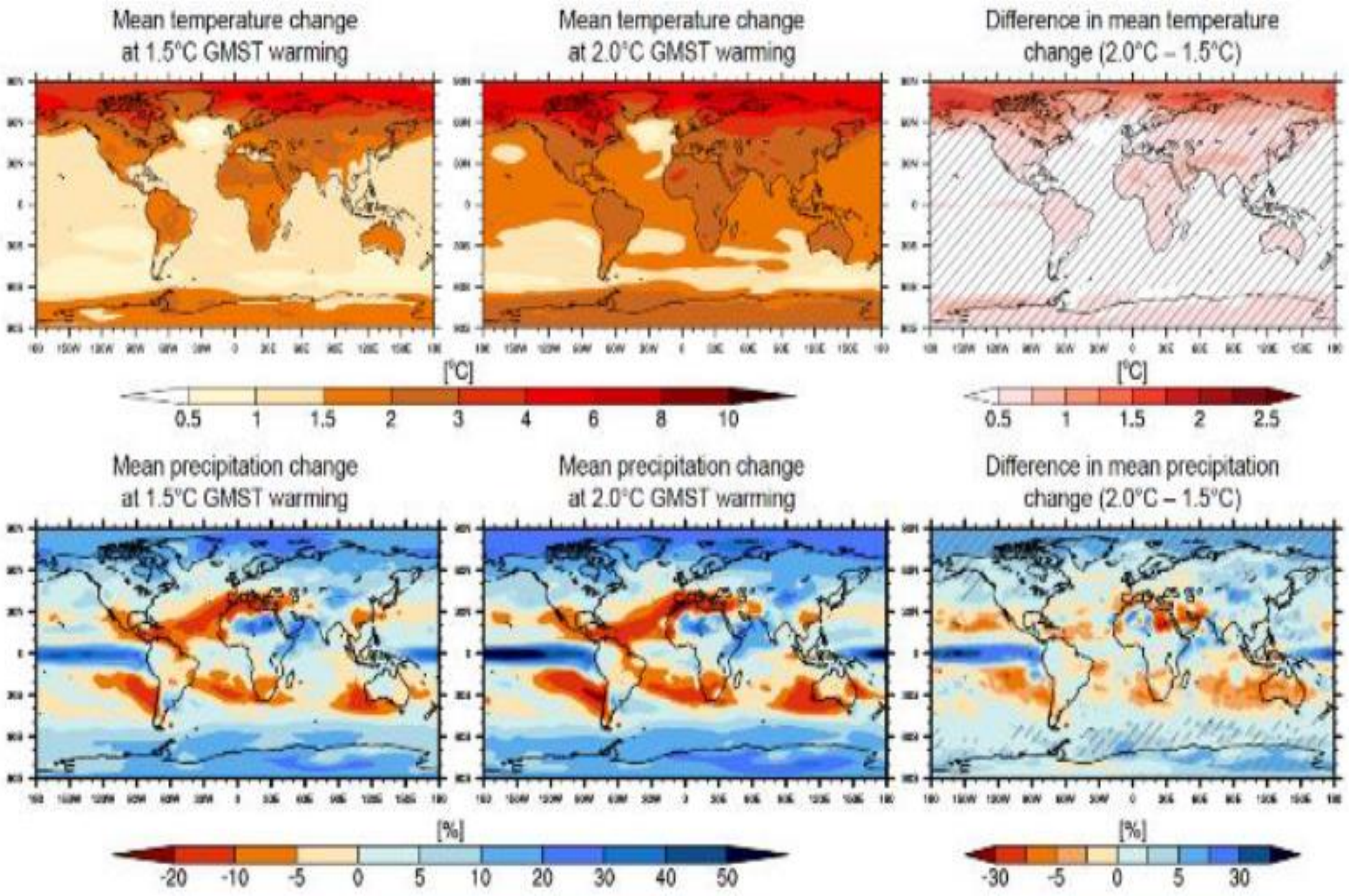
Oxygen minimum zones (blue) and areas with coastal hypoxia (red) in the world's oceans.
Coastal hypoxic sites mapped here are systems where oxygen concentrations of < 2 mg/L have been recorded and in which anthropogenic nutrients are a major cause of oxygen decline.

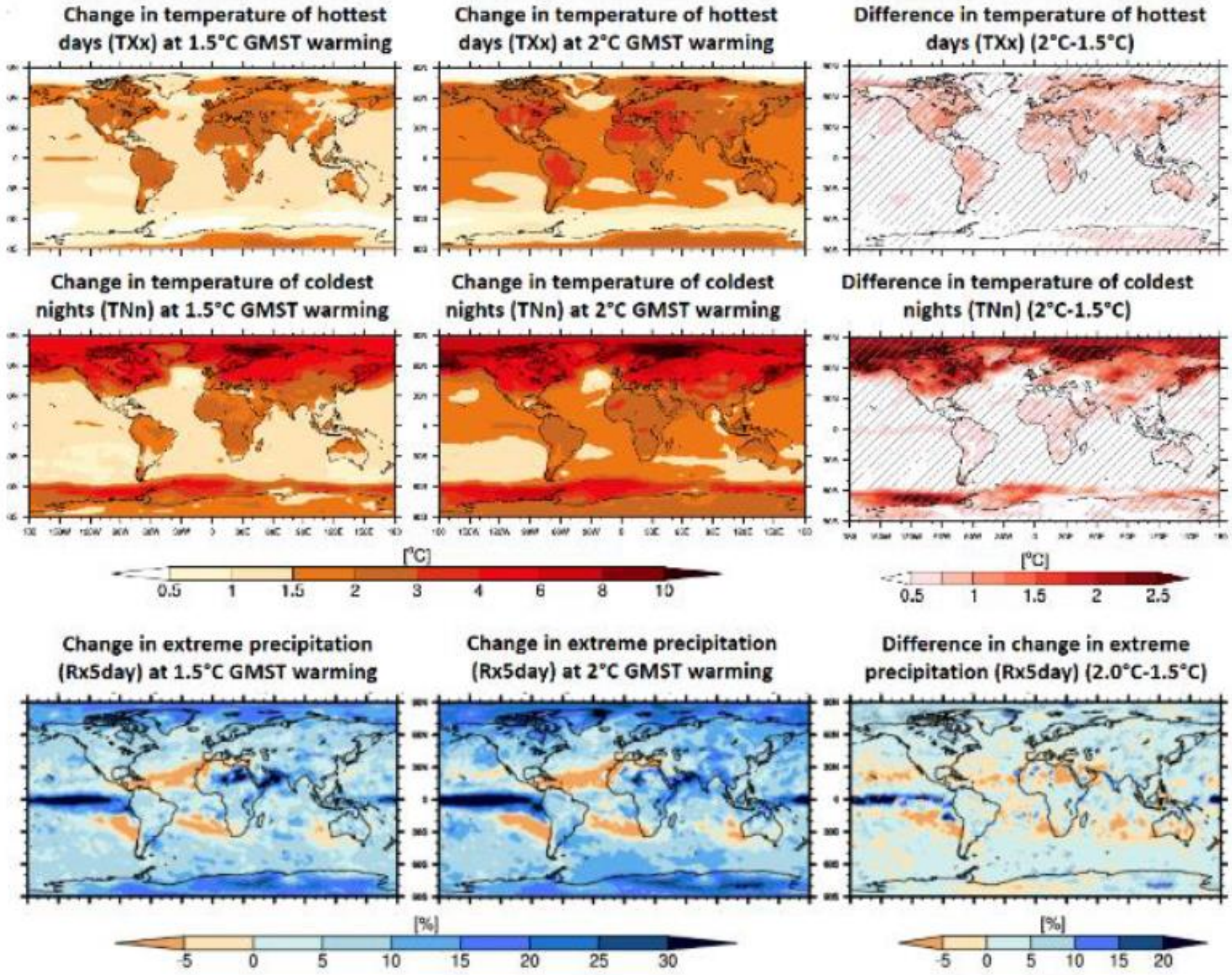
Rapid Emissions Reductions (RCP 2.6)



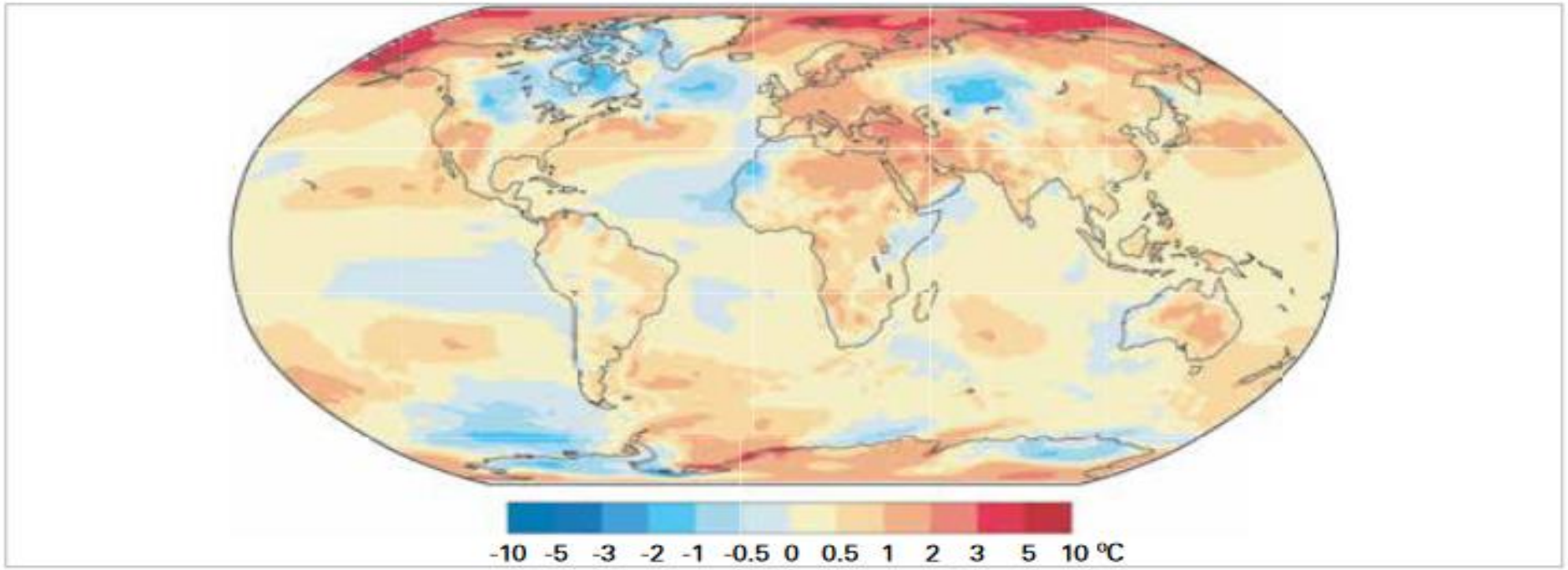
Continued Emissions Increases (RCP 8.5)




Mean temperature change
at 1.5°C GMST warming
Mean temperature change
at 2.0°C GMST warming
Difference in mean temperature
change (2.0°C – 1.5°C)
[°C]
0.5
1
1.5
2
3
4
6
8
10
[°C]
0.5
1
1.5
2
2.5
Mean precipitation change
at 1.5°C GMST warming
Mean precipitation change
at 2.0°C GMST warming
Difference in mean precipitation
change (2.0°C – 1.5°C)
[%]
-20
-10
-5
0
5
10
20
30
40
50
[%]
-30
-5
0
5
30


Change in temperature of hottest days (TXx) at 1.5°C GMST warming
Change in temperature of hottest days (TXx) at 2°C GMST warming
Difference in temperature of hottest days (TXx) (2°C-1.5°C)
Change in temperature of coldest nights (TNn) at 1.5°C GMST warming
Change in temperature of coldest nights (TNn) at 2°C GMST warming
Difference in temperature of coldest nights (TNn) (2°C-1.5°C)
[°C]
0.5 1 1.5 2 3 4 6 8 10
[°C]
0.5 1 1.5 2 2.5
Change in extreme precipitation (Rx5day) at 1.5°C GMST warming
Change in extreme precipitation (Rx5day) at 2°C GMST warming
Difference in change in extreme precipitation (Rx5day) (2.0°C-1.5°C)
[%]
-5 0 5 10 15 20 25 30
[%]
-5 0 5 10 15 20

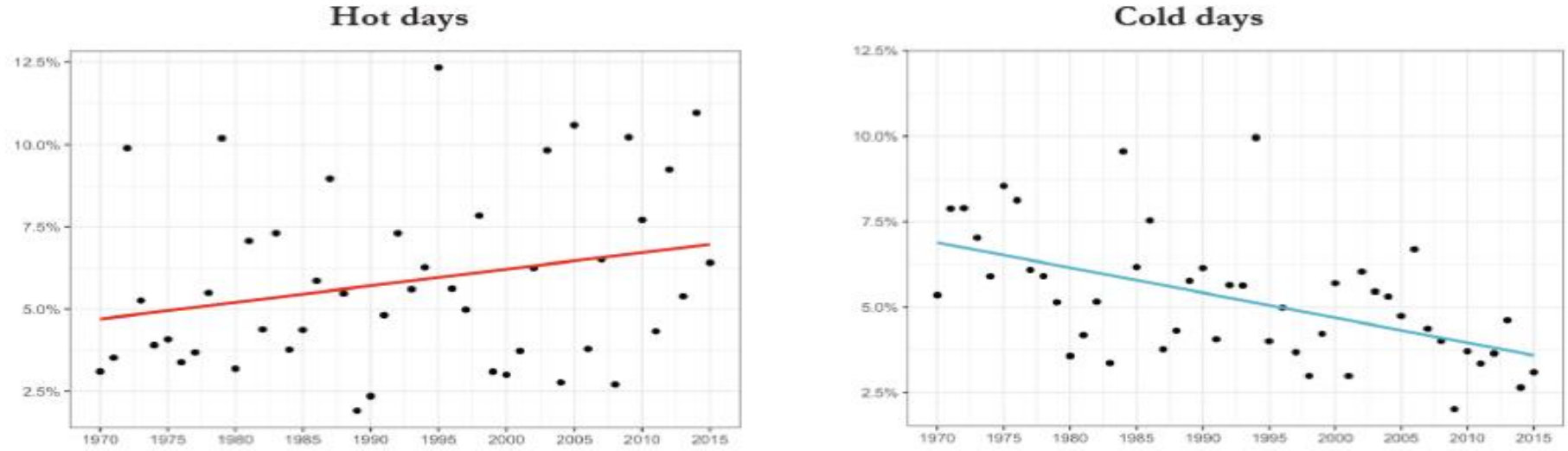
	Temperature and Energy	Atmospheric Composition	Ocean and Water	Cryosphere
Headline Indicators	Surface Temperature	Atmospheric CO_2	Ocean Acidification	Glacier Mass Balance
	Ocean Heat		Sea Level	Arctic and Antarctic Sea Ice Extent



Surface-air temperature anomaly for 2018 with respect to the 1981–2010 average. *Source: ECMWF ERA-Interim data, Copernicus Climate Change Service.*

Very Hot and Cold Days during the Monsoon

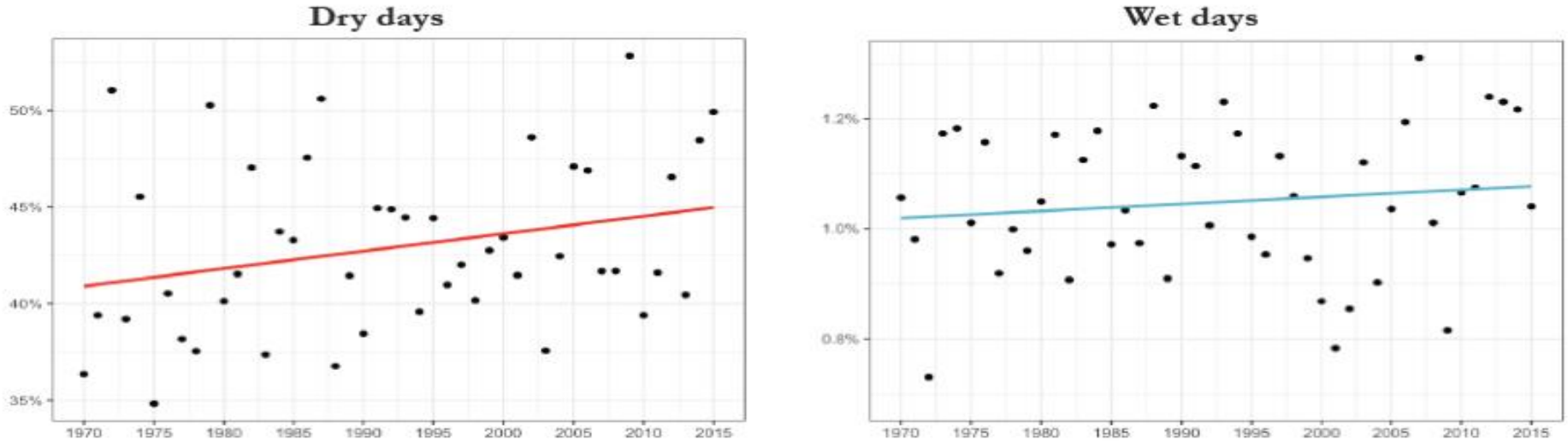
(percentage of total days)



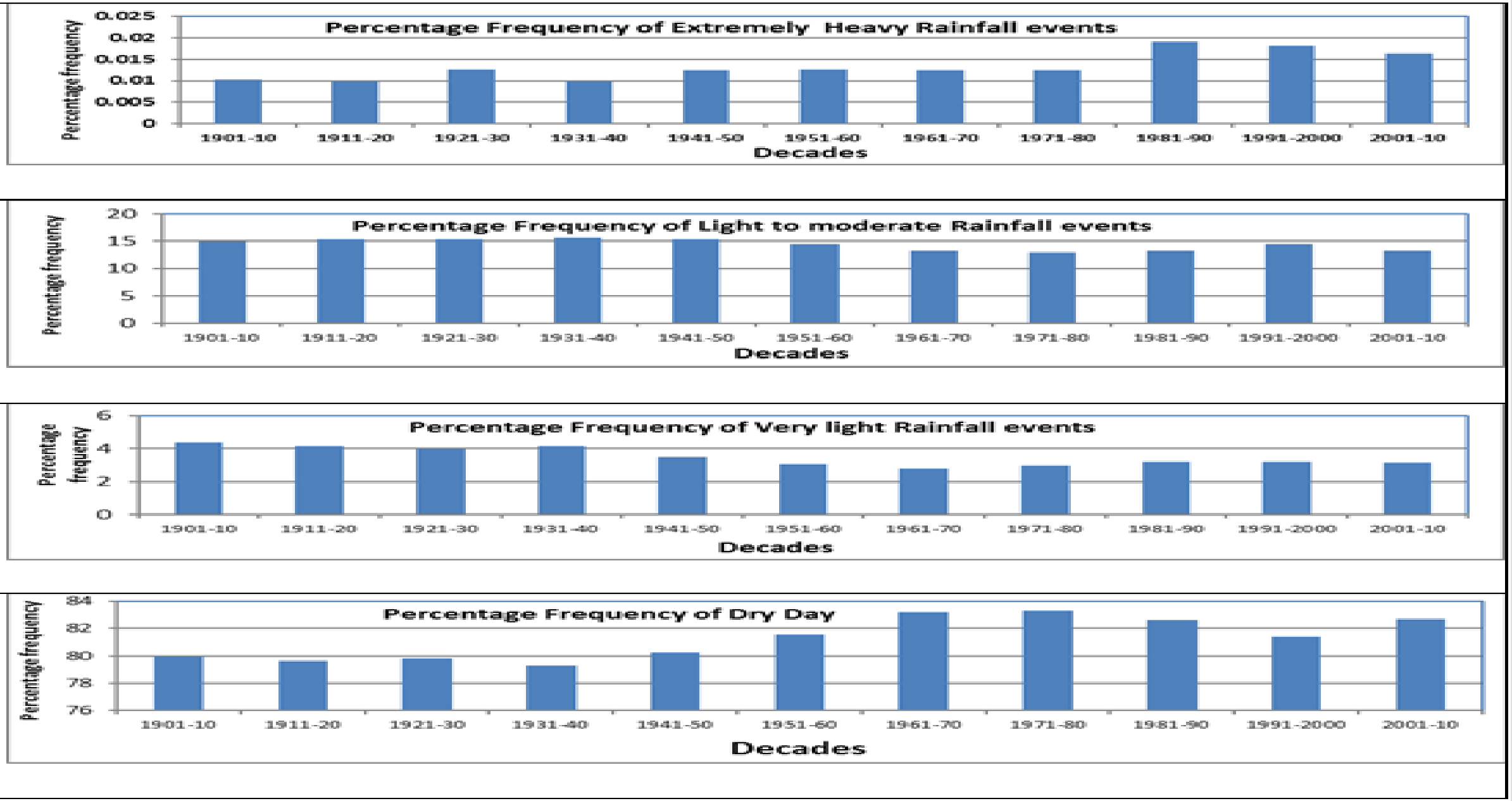
Source: Survey calculations from IMD data.

Dry and Wet Days during the Monsoon

(percentage of total days)



Source: Survey calculations from IMD data.



Decadal variability of annual frequencies of different rainfall events over India

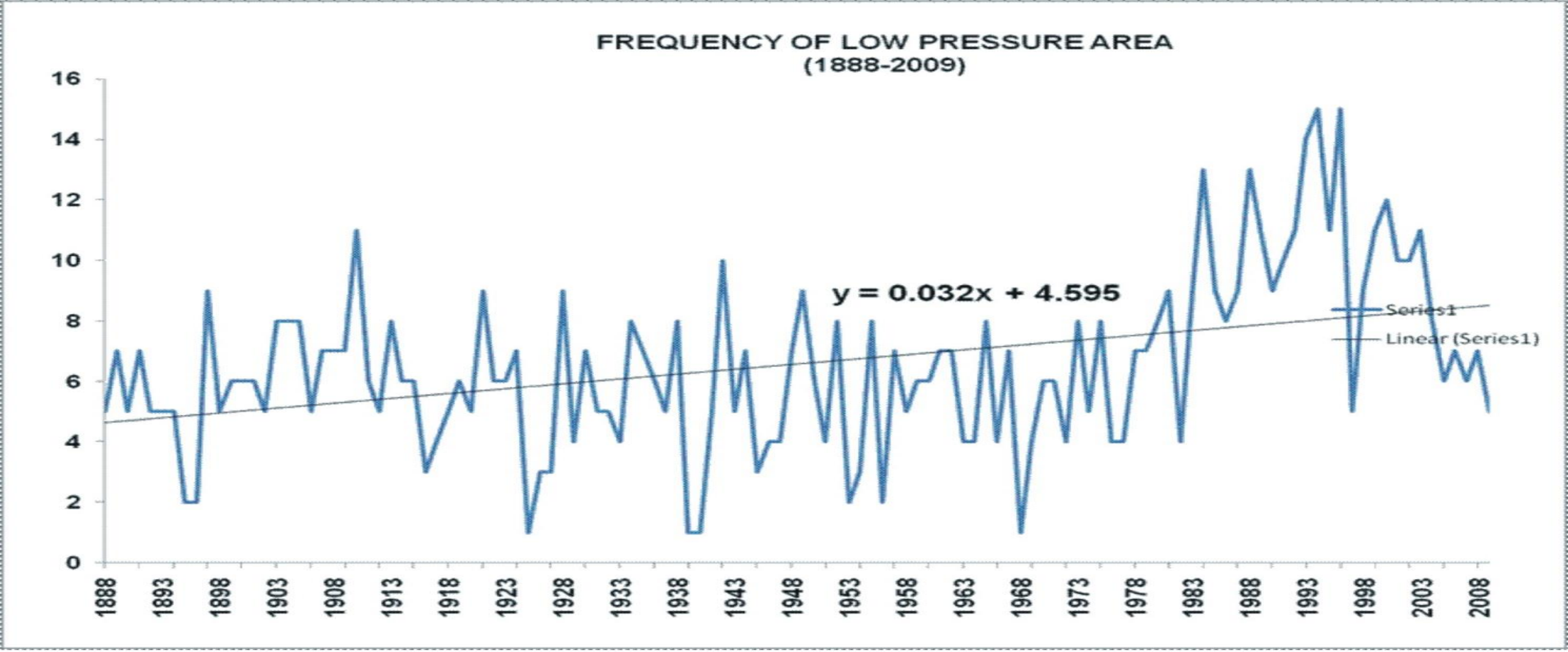
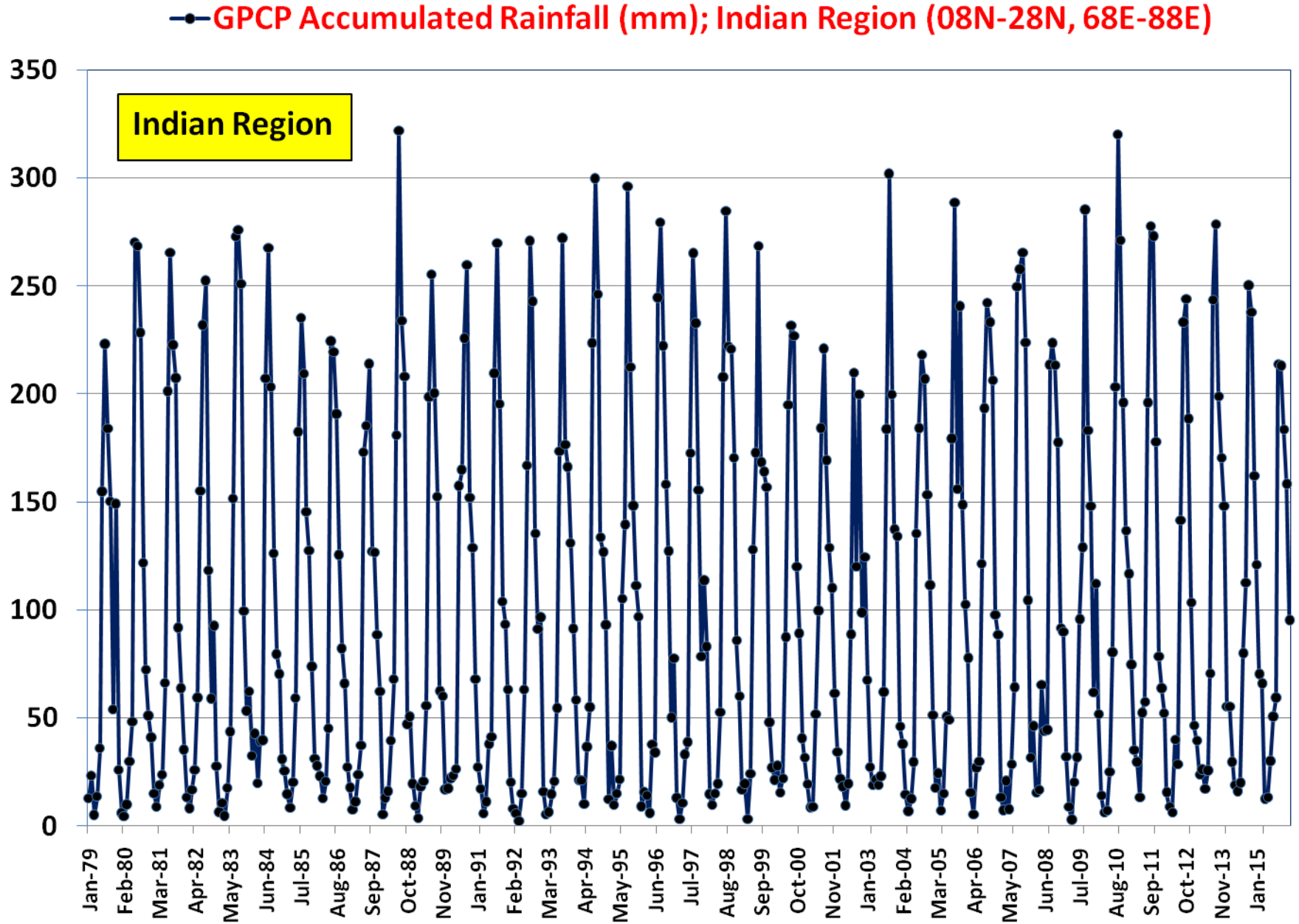


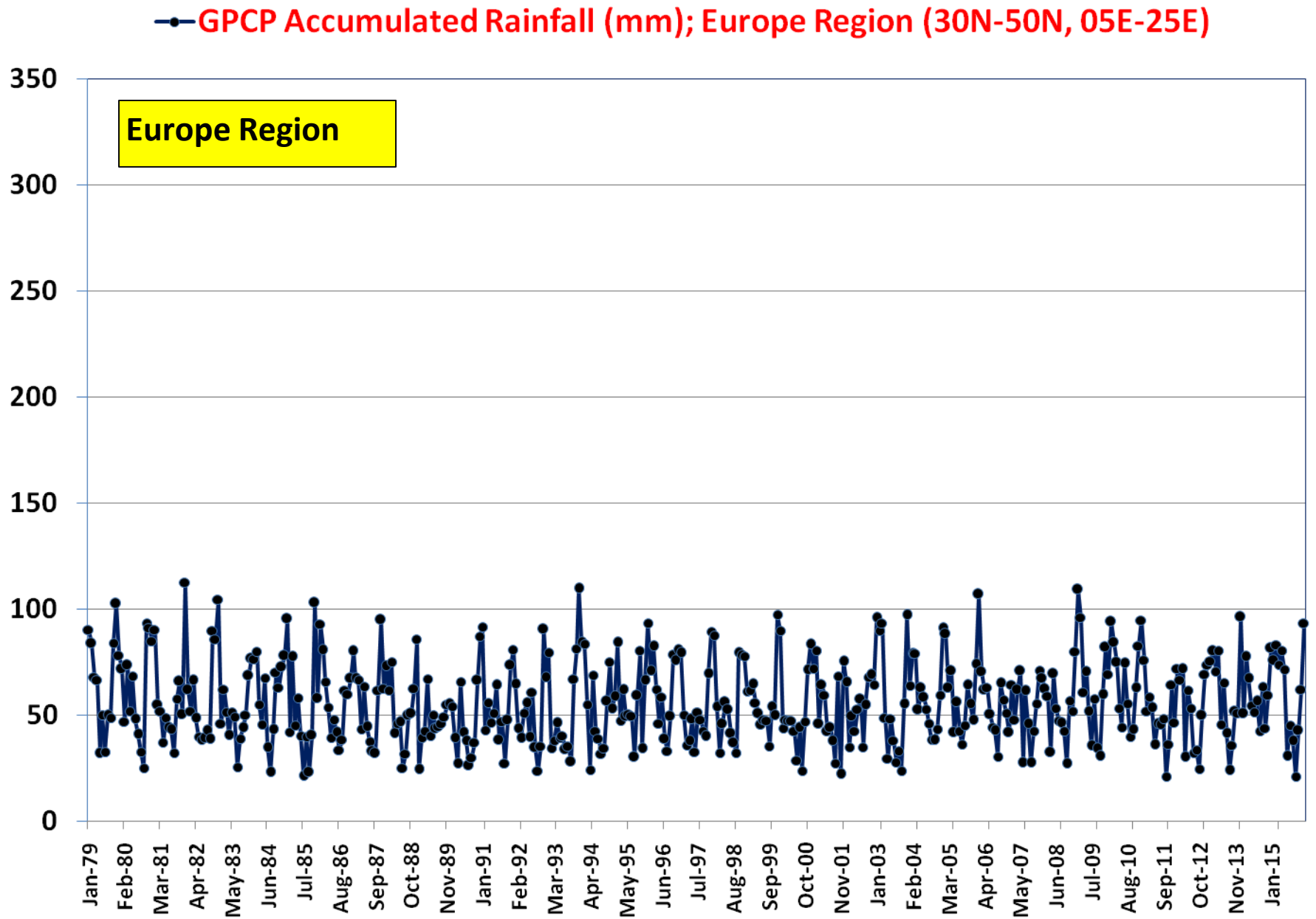
Fig. 4 Frequency of low pressure areas

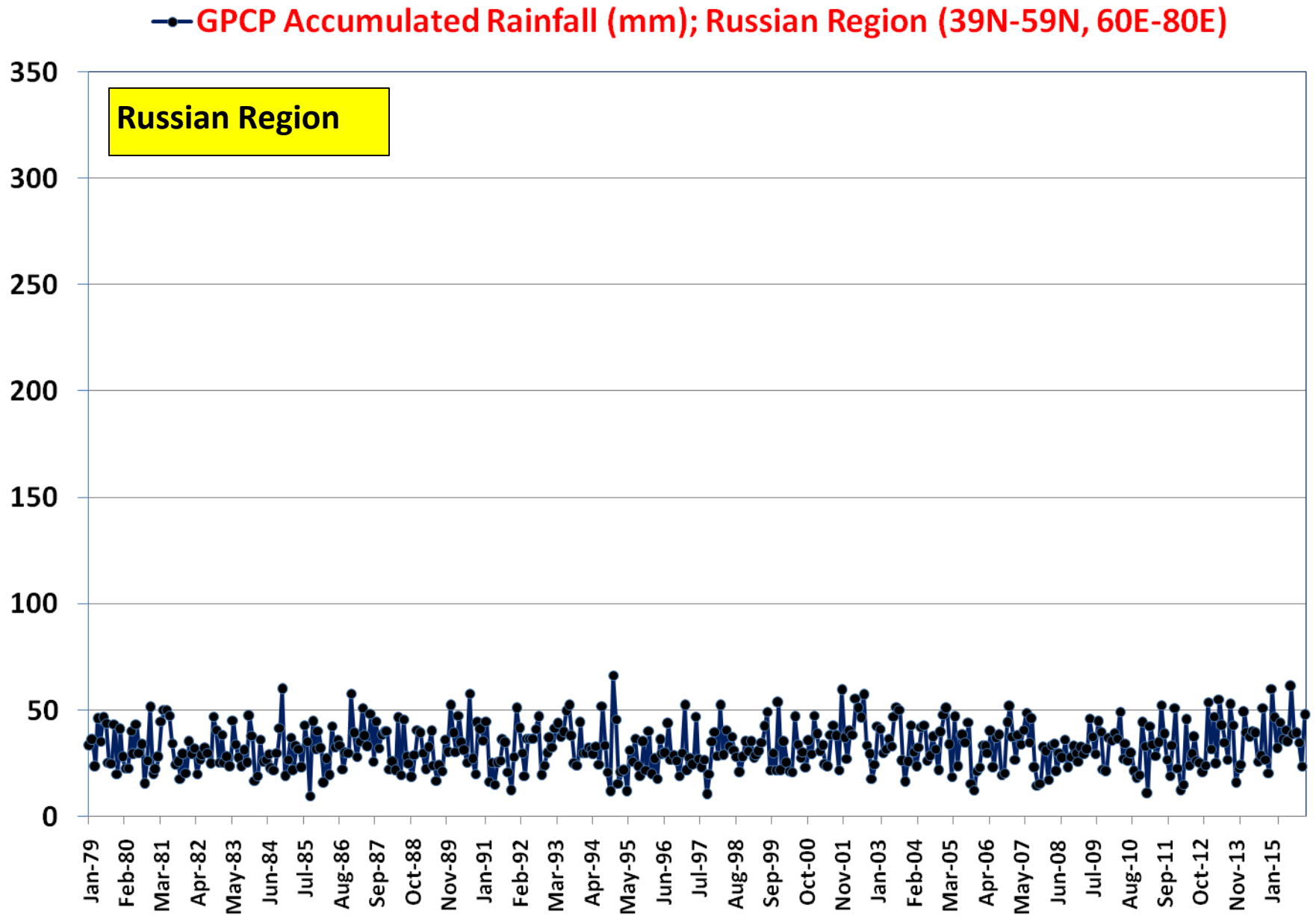
Accumulated Rainfall Variability over Different Geographical Regions

Based on GPCP Monthly Accumulated Rainfall (Jan 1979 to Oct- 2015)

- Indian Region
- Europe Region
- Russian Region
- USA East Coast


GPCP Accumulated Rainfall (mm); Indian Region (08N-28N, 68E-88E)
Indian Region
350
300
250
200
150
100
50
0
Jan-79
Feb-80
Mar-81
Apr-82
May-83
Jun-84
Jul-85
Aug-86
Sep-87
Oct-88
Nov-89
Jan-91
Feb-92
Mar-93
Apr-94
May-95
Jun-96
Jul-97
Aug-98
Sep-99
Oct-00
Nov-01
Jan-03
Feb-04
Mar-05
Apr-06
May-07
Jun-08
Jul-09
Aug-10
Sep-11
Oct-12
Nov-13
Jan-15


GPCP Accumulated Rainfall (mm); Europe Region (30N-50N, 05E-25E)
Europe Region
350
300
250
200
150
100
50
0
Jan-79
Feb-80
Mar-81
Apr-82
May-83
Jun-84
Jul-85
Aug-86
Sep-87
Oct-88
Nov-89
Jan-91
Feb-92
Mar-93
Apr-94
May-95
Jun-96
Jul-97
Aug-98
Sep-99
Oct-00
Nov-01
Jan-03
Feb-04
Mar-05
Apr-06
May-07
Jun-08
Jul-09
Aug-10
Sep-11
Oct-12
Nov-13
Jan-15


GPCP Accumulated Rainfall (mm); Russian Region (39N-59N, 60E-80E)
Russian Region
350
300
250
200
150
100
50
0
Jan-79
Feb-80
Mar-81
Apr-82
May-83
Jun-84
Jul-85
Aug-86
Sep-87
Oct-88
Nov-89
Jan-91
Feb-92
Mar-93
Apr-94
May-95
Jun-96
Jul-97
Aug-98
Sep-99
Oct-00
Nov-01
Jan-03
Feb-04
Mar-05
Apr-06
May-07
Jun-08
Jul-09
Aug-10
Sep-11
Oct-12
Nov-13
Jan-15

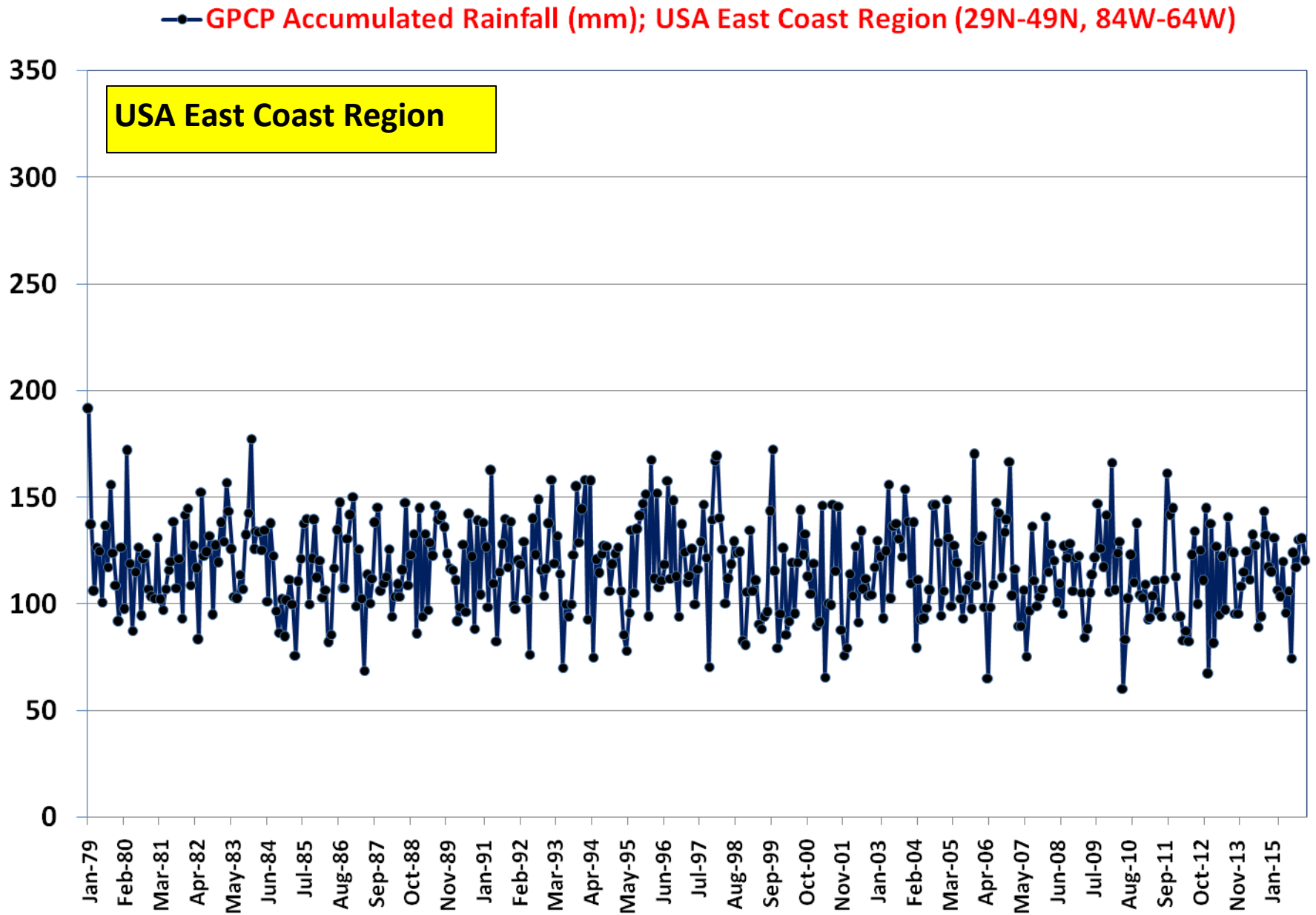

GPCP Accumulated Rainfall (mm); USA East Coast Region (29N-49N, 84W-64W)
USA East Coast Region
350
300
250
200
150
100
50
0
Jan-79
Feb-80
Mar-81
Apr-82
May-83
Jun-84
Jul-85
Aug-86
Sep-87
Oct-88
Nov-89
Jan-91
Feb-92
Mar-93
Apr-94
May-95
Jun-96
Jul-97
Aug-98
Sep-99
Oct-00
Nov-01
Jan-03
Feb-04
Mar-05
Apr-06
May-07
Jun-08
Jul-09
Aug-10
Sep-11
Oct-12
Nov-13
Jan-15

Table 4. Record rainfall (in 24 hrs.) during the monsoon season, 2010

S. No.	Station	Rainfall during past 24 hrs. (mm)	Date (June 10)	Previous record (mm)	Date of record	Year of record
1	N. Lakhimpur	207.8	16	183	22	1990
2	Osmanabad	111.2	23	68.2	3	2000
3	Thanjavur	61.0	11	55	12	1996
4	Cial Cochi	160.6	13	93.9	6	2004
			(July 10)			
1	Phoolbagh	146.2	21	123.6	11	2003
2	Damoh	253.6	26	225.1	18	1973
3	Okha	330.5	27	283.3	10	1973
4	Osmanabad	110	3	108.6	24	1979
5	Anantpur	123	11	114.8	17	1989
6	Kurnool	102	6	101.7	25	1983
7	Nandyal	143.2	11	116	16	1989
8	Dharmapuri	117	9	91.6	12	1989
9	Mandya	46.4	12	46.1	12	1978
			(Aug 10)			
1	Okha	226.5	3	119.8	11	1981
2	Bhira	380	30	350	23	1997
3	Osmanabad	149.8	22	85	21	2009
4	Narsapur	64.6	13	63.8	14	2001
5	Arogyavaram	111	21	90	9	1970
			(Sept 10)			
1	Ranchi AP	205.8	12	168.4	28	1963
2	Pant Nagar	117.2	7	105	10	1967
3	Bharatpur	107	4	91.8	17	1990
4	Gwalior	159.8	20	157.8	4	1995
5	Dhar	170.8	8	151	21	1973
6	Okha	91	10	74.5	12	1997
7	Vijaywada AP	132.4	4	127.6	19	1988
8	Narsapur	115.7	13	88.9	24	1997
9	Mangalore AP	150.2	24	125.5	6	1902
10	Panambur	125.2	24	113.6	26	1998
11	Belgaum (AP)	150	24	100.4	20	1981
12	Cochi AP	183.5	24	128	28	2009
13	Cial Cochi	108	24	77.4	18	2009

One–Day Extreme Rainfall Records During 2010

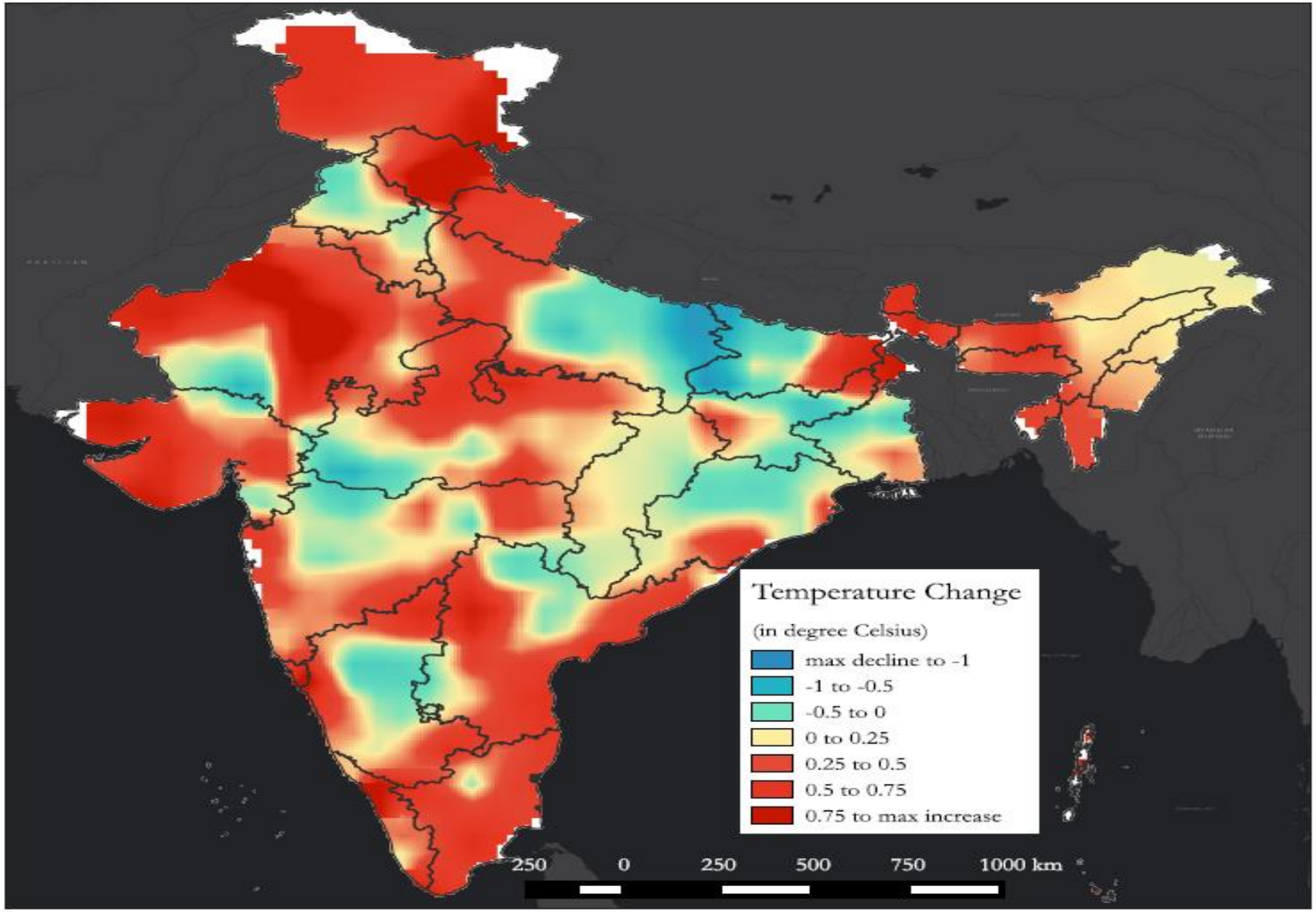
S.No.	Station	Rf mm. (New Record)	Date (Oct 10)	Previous Record	Date	Year
1	Pune	181.3	5	149.1	24	1892
2	Vijaywada ap	108.2	24	98.1	18	1980
3	Narsapur	124.6	31	101.3	30	1997
			(Nov. 10)			
1	Etawah	10.5	18	7.7	9	1982
2	Barmer	54.0	12	37.3	21	1976
3	Ajmer	46.0	24	42.4	29	1958
4	Jaipur ap	47.2	24	22.9	3	1981
5	Gwalior	24.3	25	15.1	13	2009
6	Datia	46.6	18	46.0	28	1979
7	Khandwa	101.0	18	84.8	10	1936
8	Rajkot	41.8	17	30.0	8	1982
9	Rajnandgaon	24.2	12	18.2	9	1998
10	Visakhapatnam	180.2	1	177.0	26	1992
11	Tun i	194.3	1	45.6	16	1998
12	Karwar	207.4	9	141.0	23	1948
			(Dec. 10)			
1	Churu	25.1	29	19	23	1967
2	Raipur	64.1	9	52.1	26	1909
3	Mana ap	29.9	9	26.8	14	1997
4	Kakinada	116.4	8	102.4	13	1969
5	Vijaywada ap	49.6	7	23.2	13	1988
6	Visakhapatnam	109.7	8	12.8	28	1989
7	Bapatla	104.2	7	83.8	16	2003
8	Narsapur	100.3	7	70.5	16	2003
9	Panambur	52.8	11	50.4	14	1998

2010

Death toll due to heavy rains / floods in different parts of the country, during the monsoon season >500
(mostly from northern and north-western parts).

Heavy rainfall events in November 2010 took a toll of more than 50 people from peninsular parts (AP, TN and Karnataka) of the country.

Spatial Changes in Temperature
(change in average temperature between the last decade and 1950-1980 period)



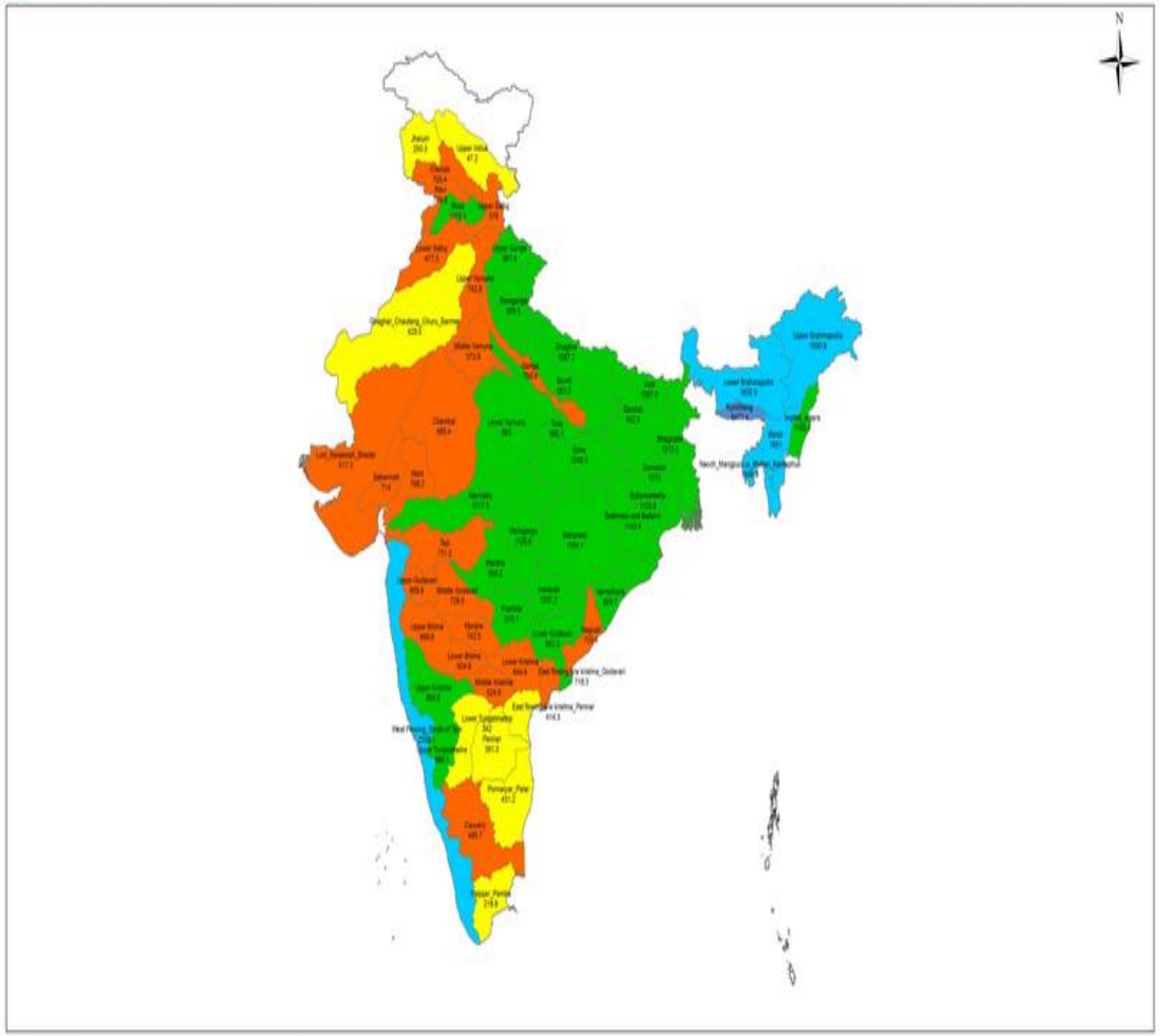
Source: Survey calculations from IMD data.[6] Red (blue) denotes rising (falling) temperature.

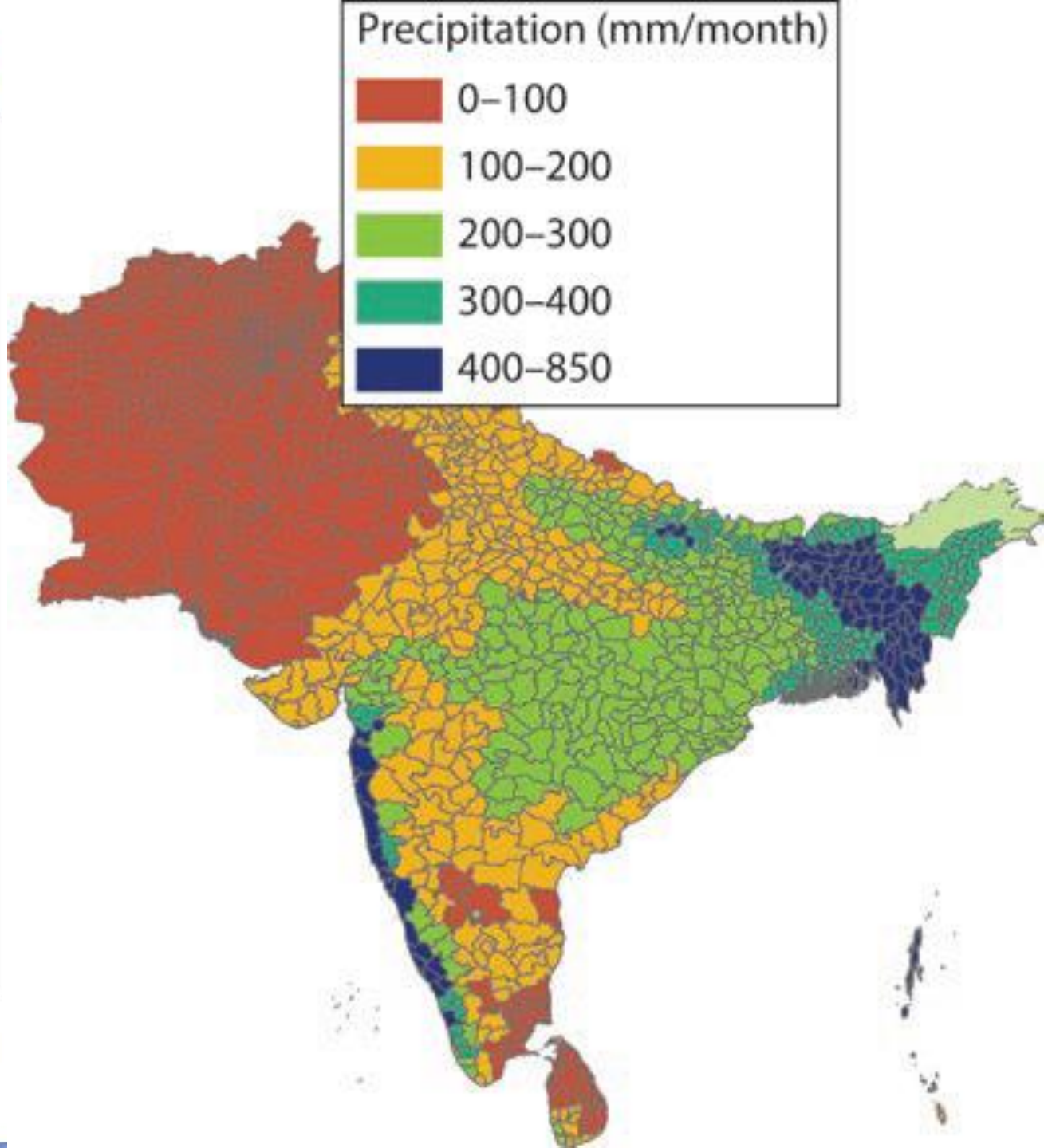
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

RIVER BASIN RAINFALL NORMALS (mm)

Monsoon Season(Jun-Sep)
1951 - 2000

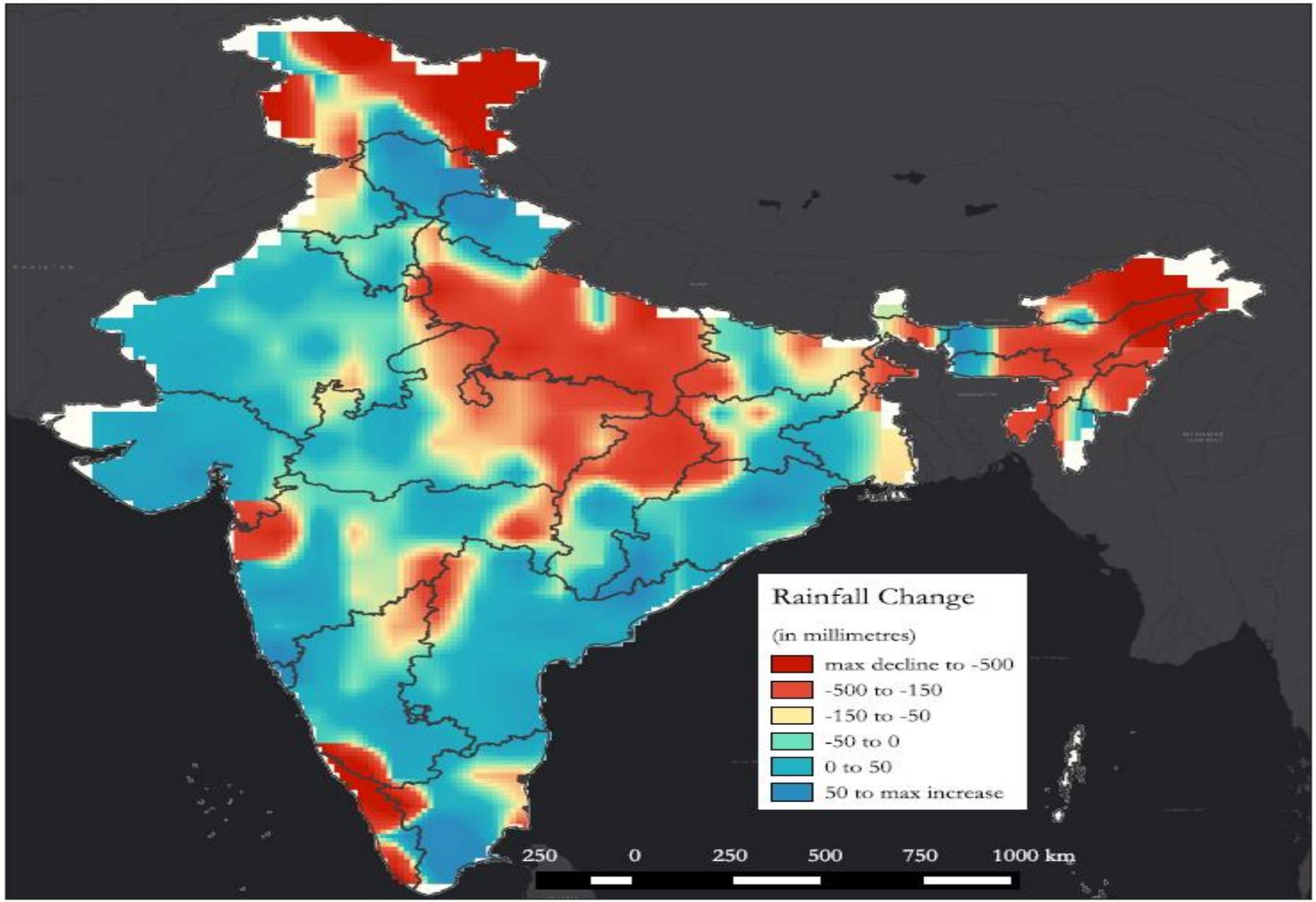
जल मौसम विज्ञान प्रभाग, नई दिल्ली
HYDROMET DIVISION, NEW DELHI



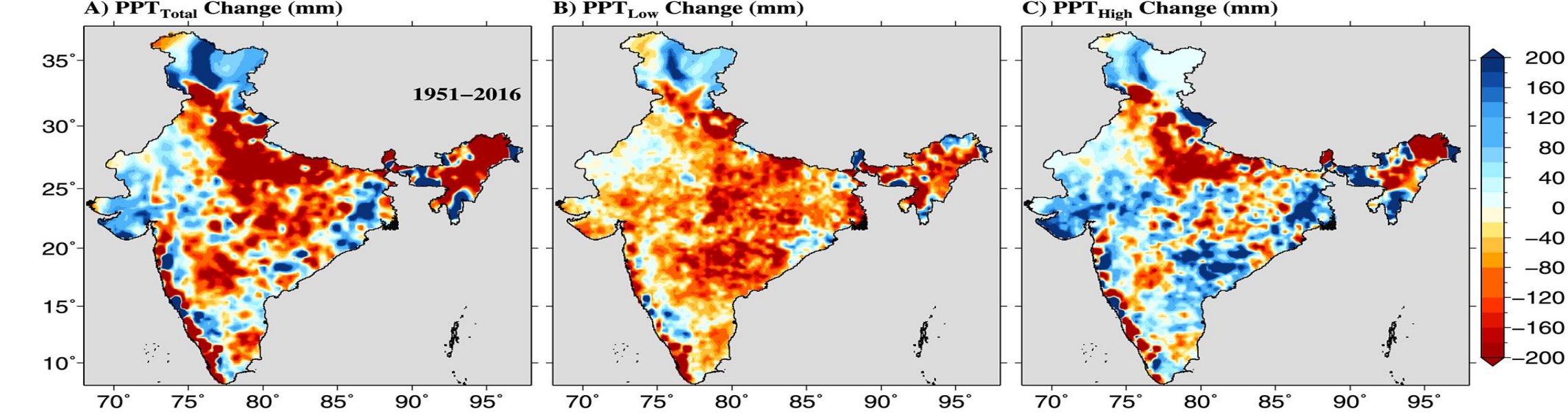


Spatial Changes in Rainfall

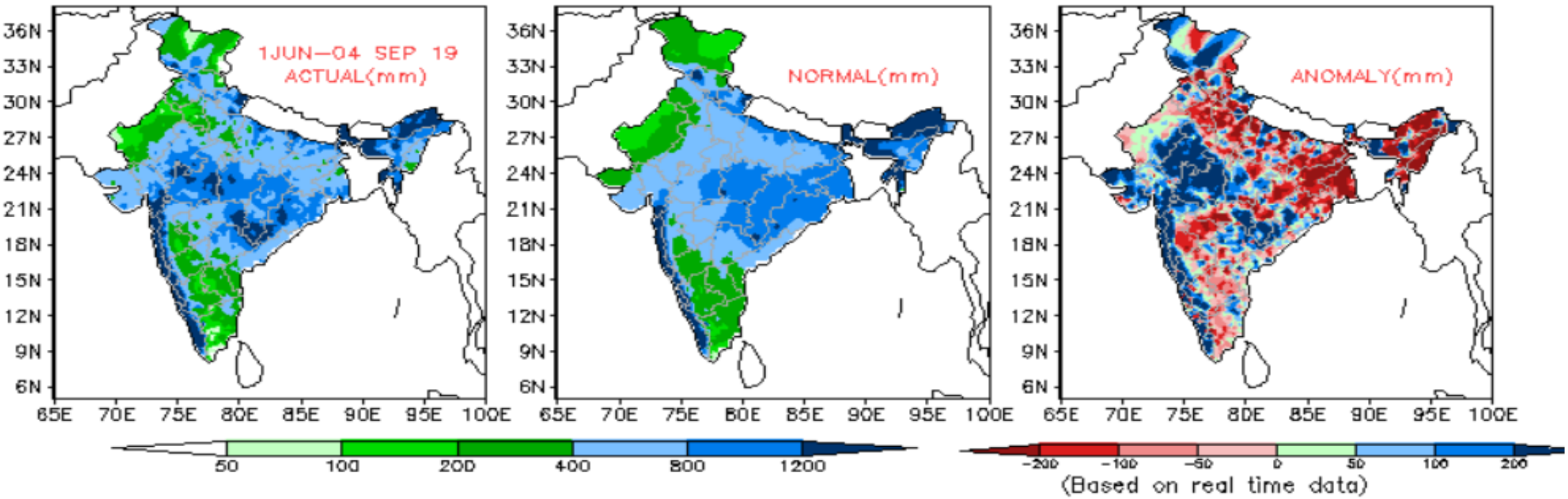
(change in average rainfall between the last decade and 1950-1980 period)

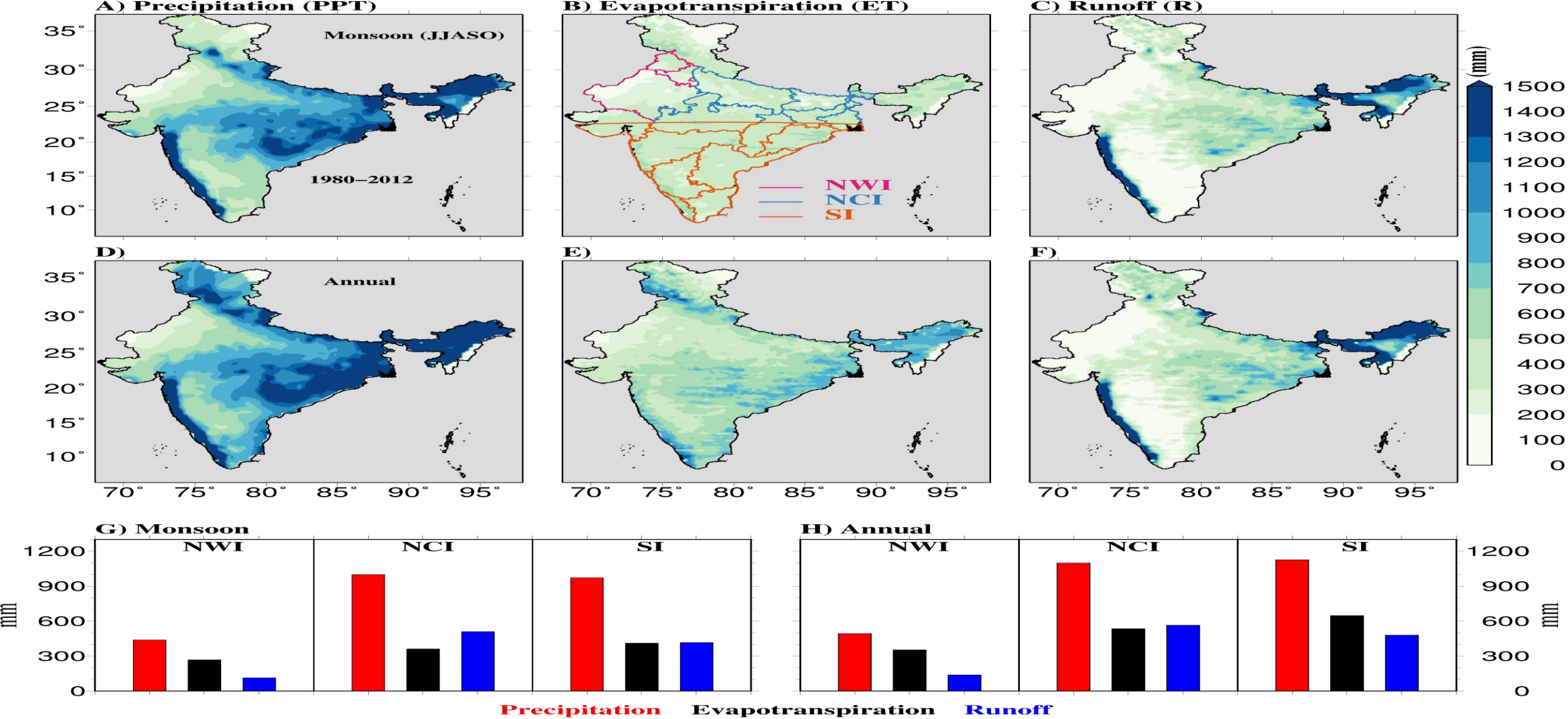


Source: Survey calculations from IMD data. Red (blue) denotes decreasing (increasing) rainfall.



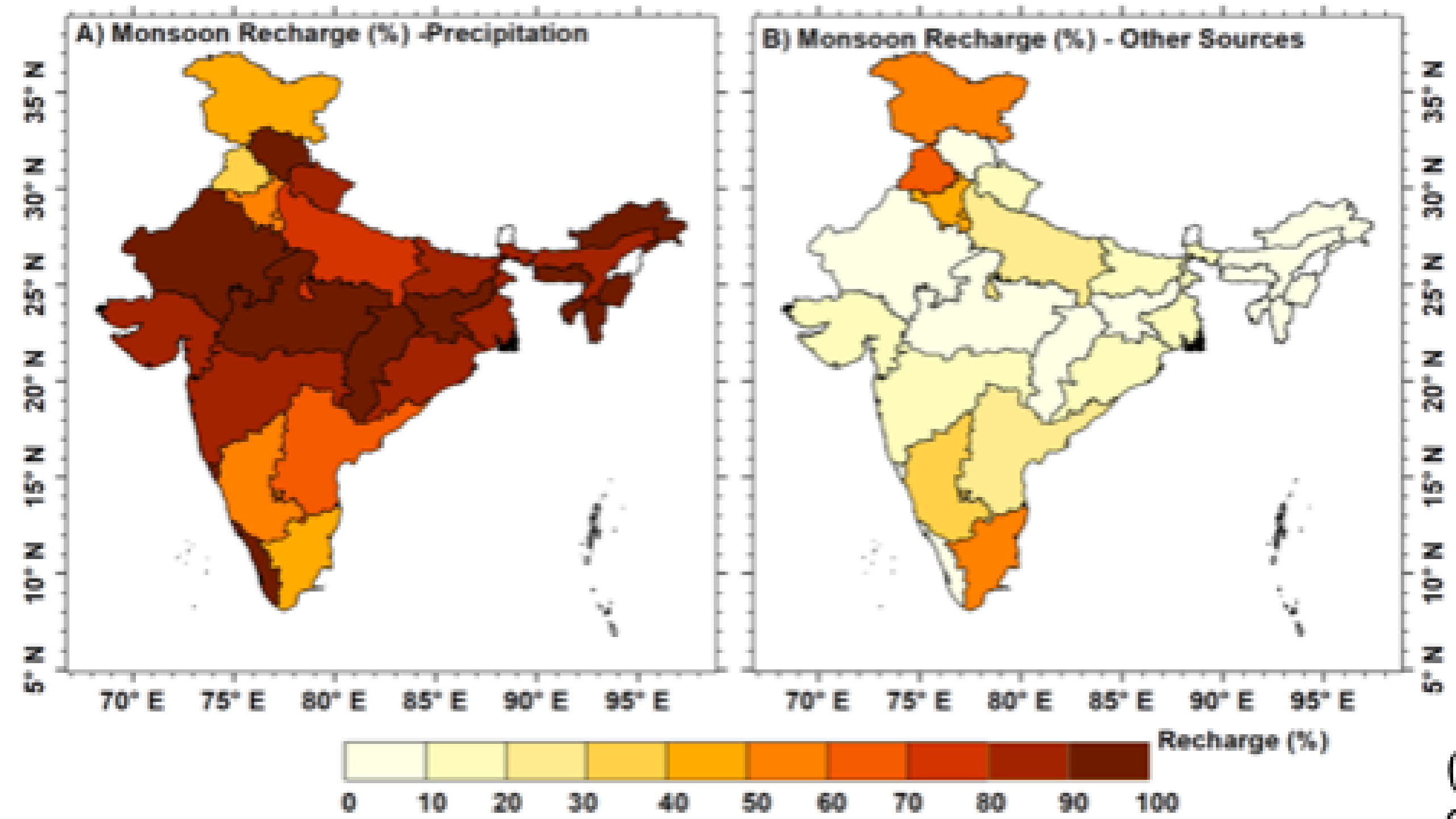
CLIMATE MONITORING AND ANALYSIS GROUP

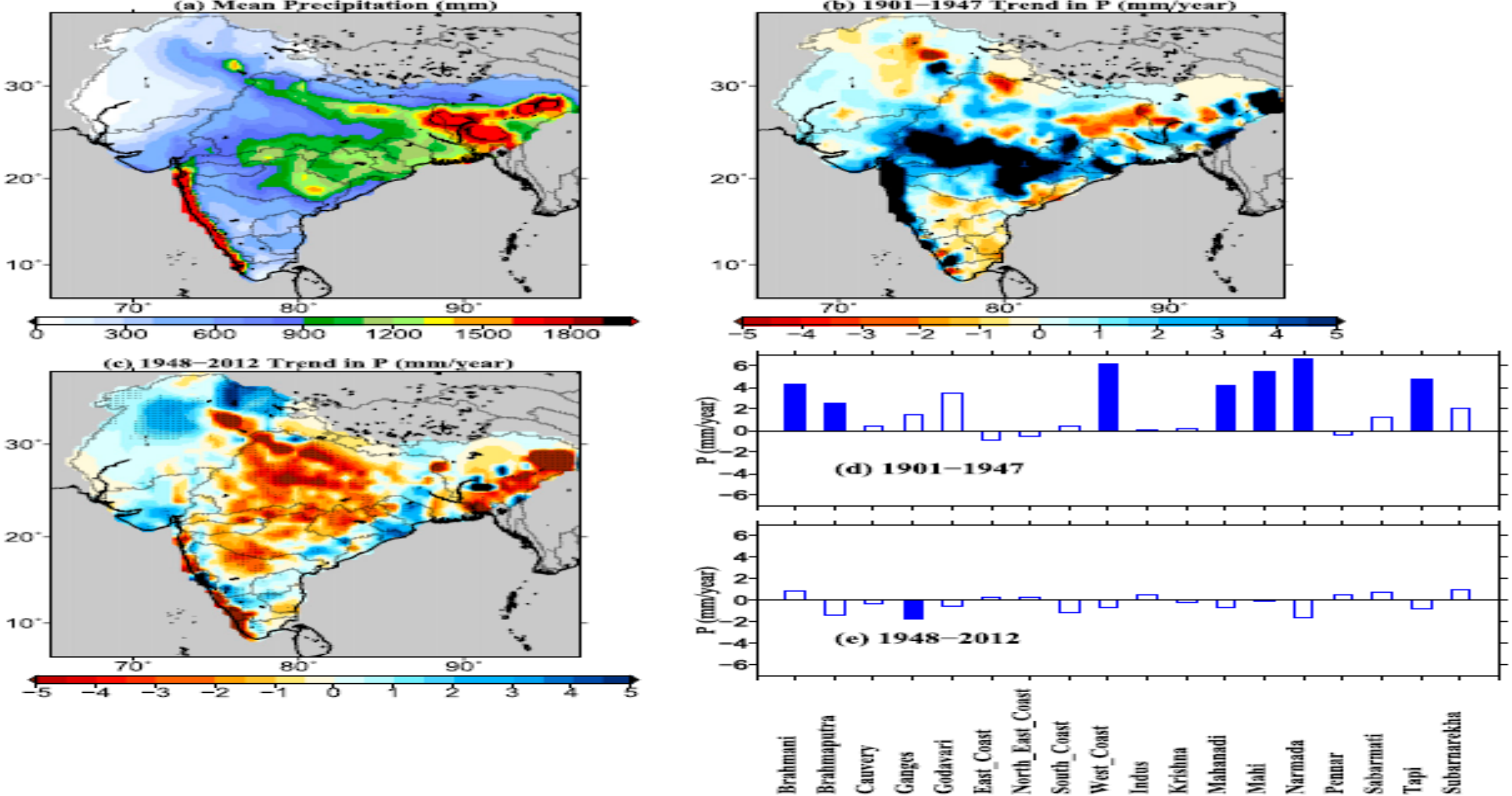




Water budget components (Precipitation, ET, and Total Runoff) from calibrated VIC model for 1980-2012 period for the monsoon season and annual time periods

Strong linkage between precipitation intensity and monsoon season groundwater recharge in India

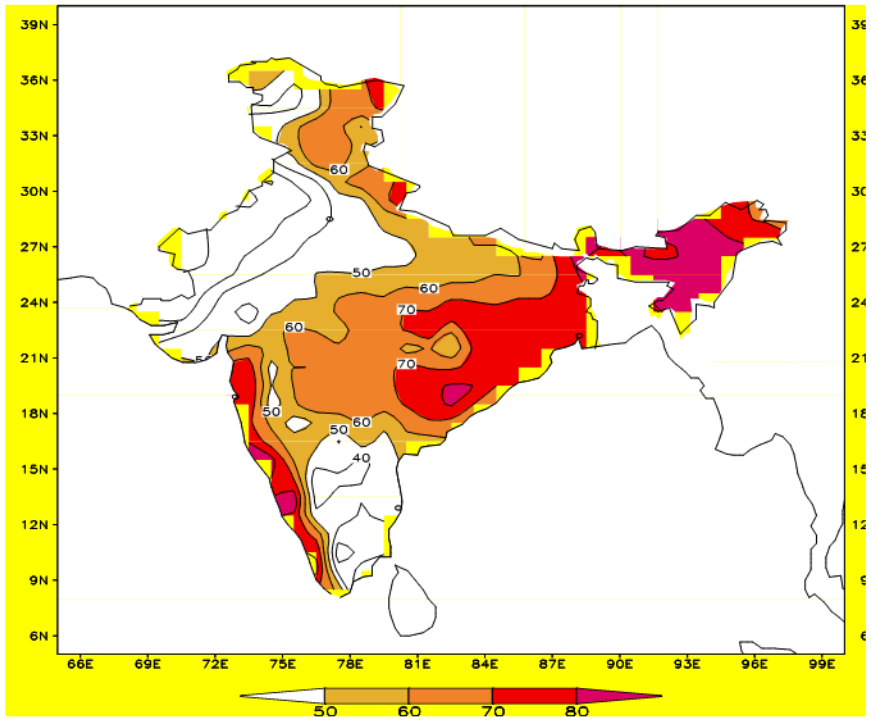

A) Monsoon Recharge (%) -Precipitation
B) Monsoon Recharge (%) - Other Sources
35° N
30° N
25° N
20° N
15° N
10° N
5° N
70° E
75° E
80° E
85° E
90° E
95° E
Recharge (%)
0
10
20
30
40
50
60
70
80
90
100



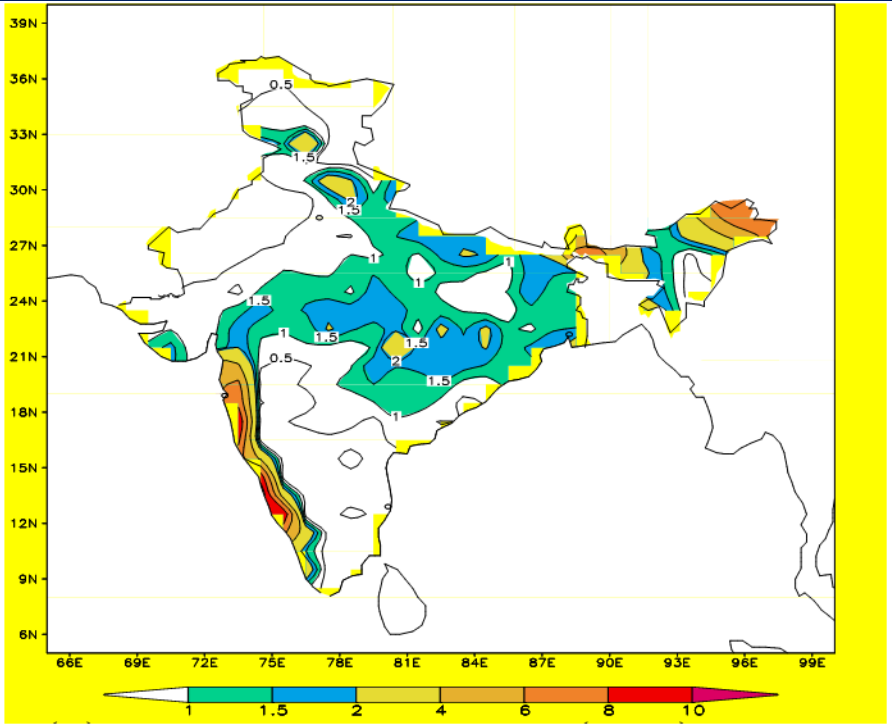
... (a) Mean P for the monsoon season during the period of 1971–2000; (b) trend in P (mm yr^{-1}) during the period of 1901–47 estimated using the Mann–Kendall test; and (c) as in (b), but for the period of 1948–2012. (d) Trend in the monsoon season P for the selected river basins for the period of 1901–47; and (e) as in (d), but for 1948–2012. Hollow bars in (d) and (e) show nonsignificant trends while solid bars represent significant trends for the selected periods of 1901–47 and 1948–2012. Long-term mean values for P are presented in Table 2.

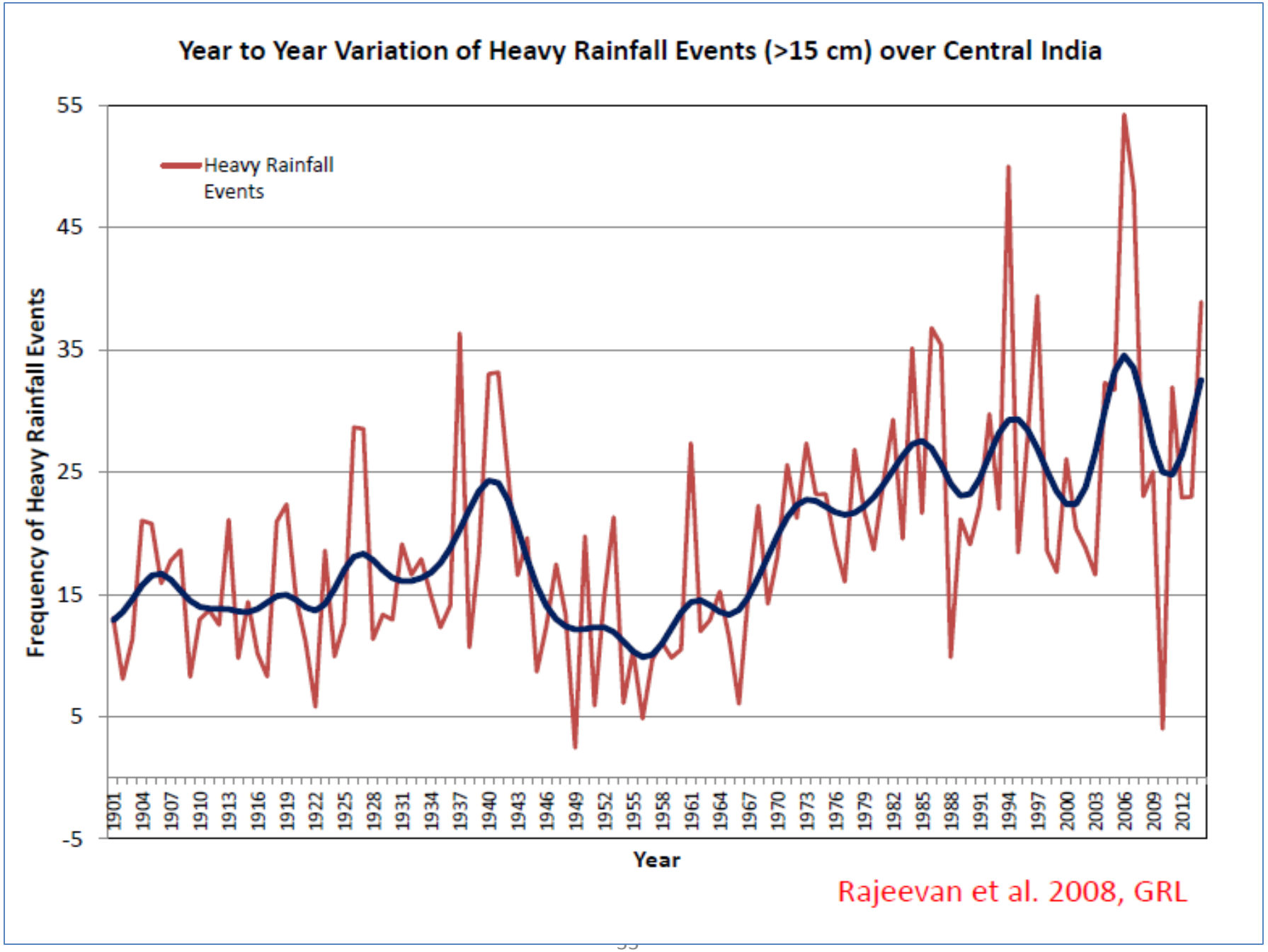
Indian Southwest Monsoon (June to September)

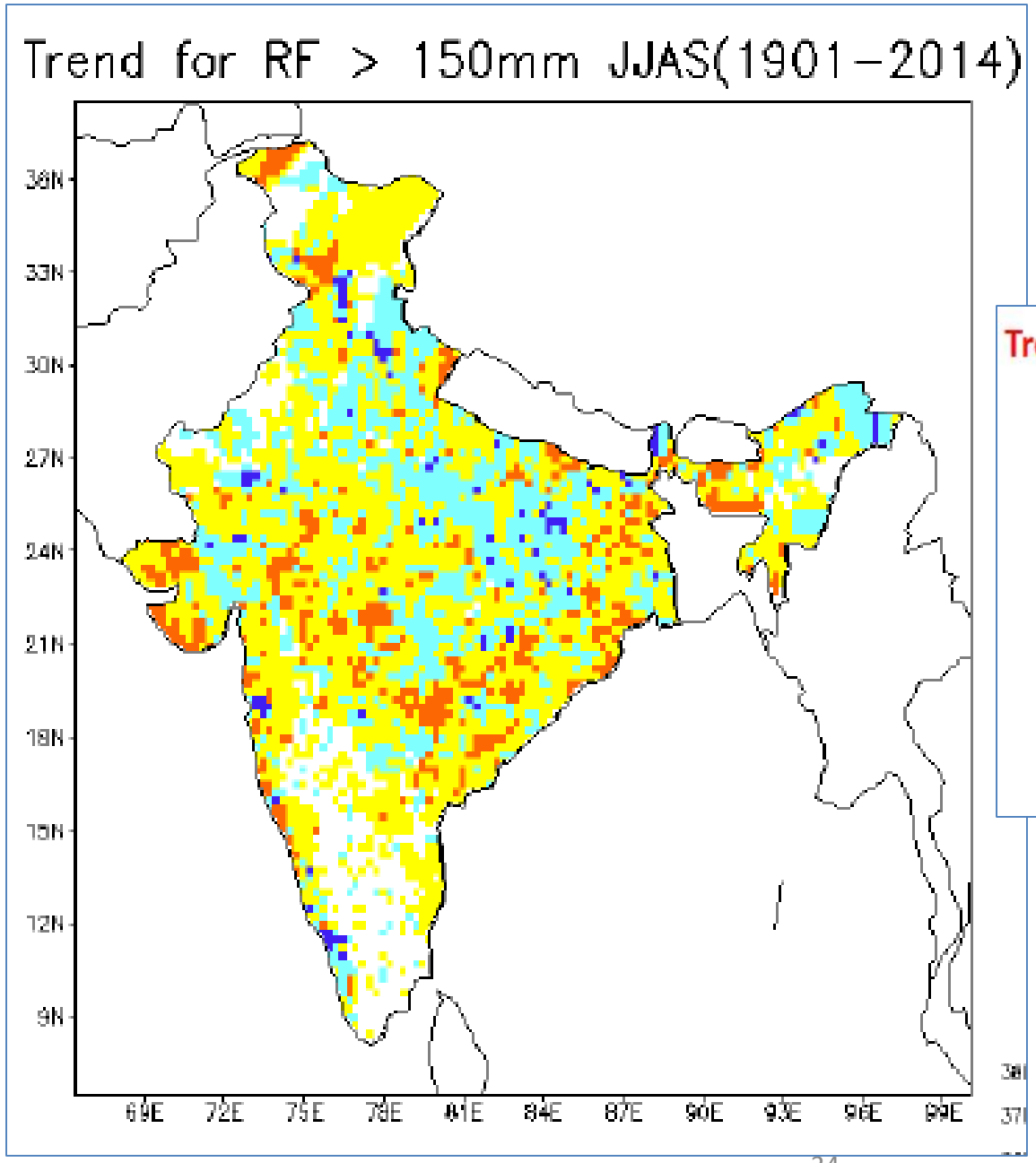
Mean % of Heavy rainfall days



Mean % of Very heavy rainfall days



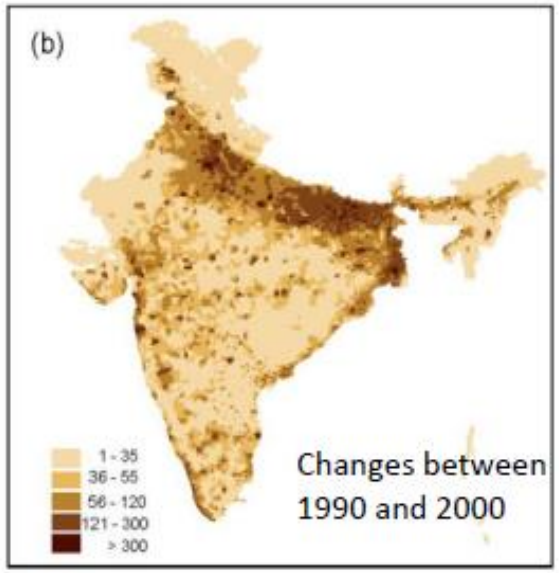

Year to Year Variation of Heavy Rainfall Events (>15 cm) over Central India
Heavy Rainfall Events
Frequency of Heavy Rainfall Events
55
45
35
25
15
5
-5
1901
1904
1907
1910
1913
1916
1919
1922
1925
1928
1931
1934
1937
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Year
Rajeevan et al. 2008, GRL

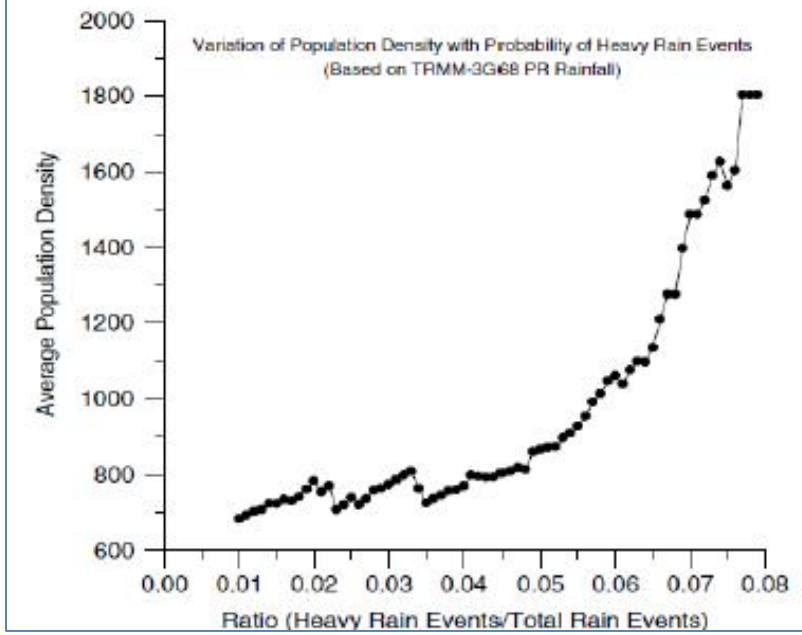


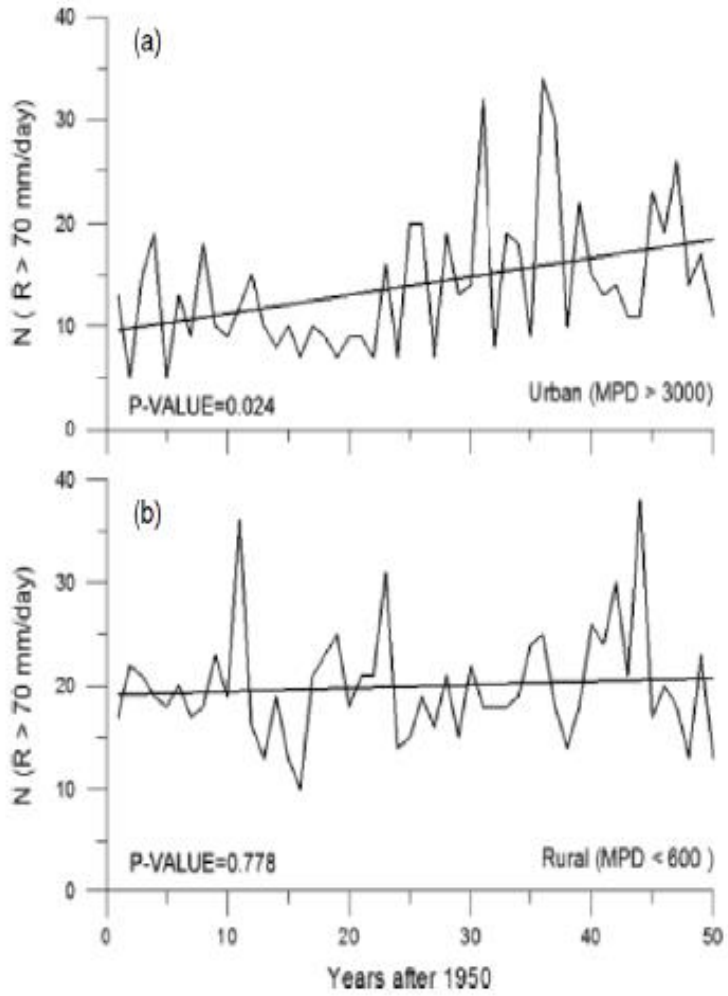
Trends in Heavy Rainfall Events: 1901-2014

- Increasing & Significant
- Increasing but not Significant
- Decreasing but not Significant
- Decreasing & Significant

Urban vs Rural Differences in Heavy Rainfall Events







Kishtawal et al. 2010, Int J Climatology

Pathway to Climate Risk Management

passes through

Disaster Risk Management

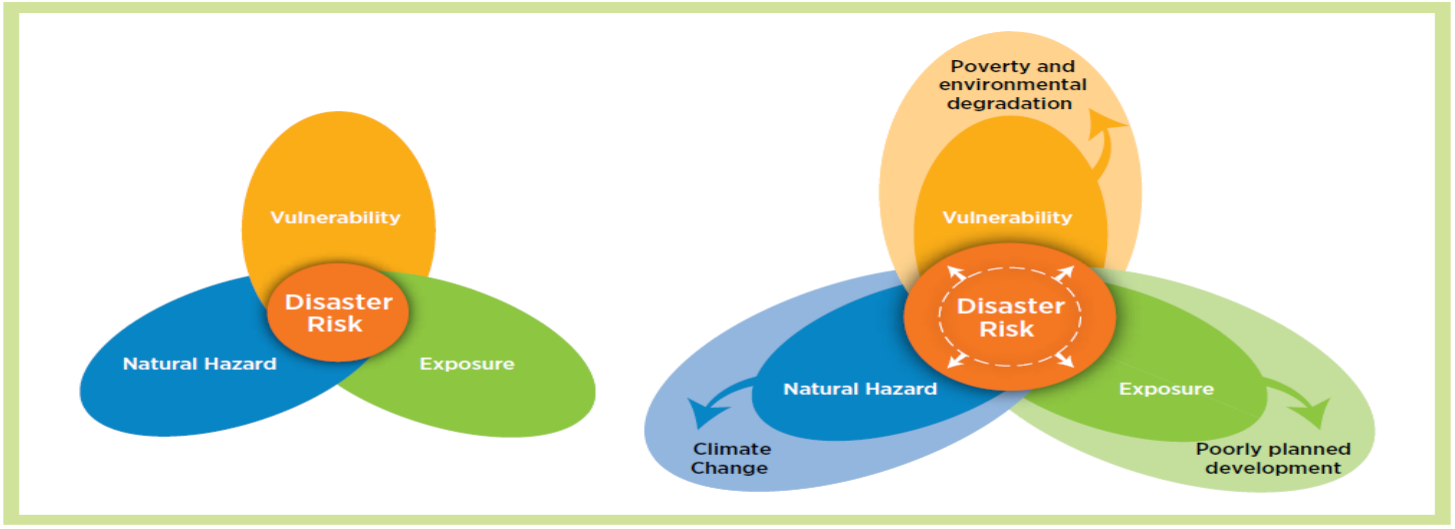
[as climate change brings additional degree of Vulnerability]

We need to migrate towards Impact based forecasting and Risk based Warning System

भारत मौसम विज्ञान विभाग

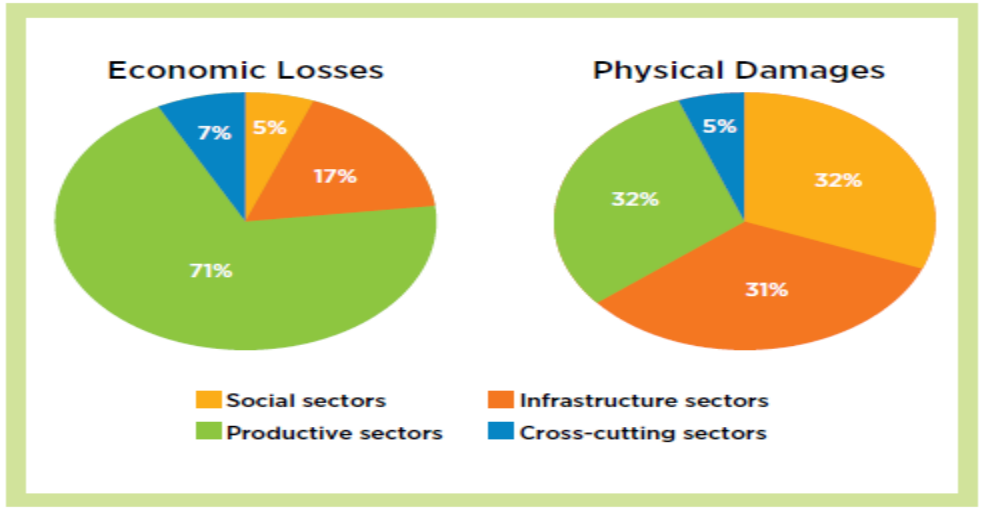
INDIA METEOROLOGICAL DEPARTMENT

Disaster and Climate Risk



Disaster risk is determined by the occurrence of a natural hazard (e.g., a cyclone), which may impact exposed populations and assets (e.g., houses located in the cyclone path). Vulnerability is the characteristic of the population or asset making it particularly susceptible to damaging effects (e.g., fragility of housing construction). Poorly planned development, poverty, environmental degradation and climate change are all drivers that can increase the magnitude of this interaction, leading to larger disasters.

Total loss and damage from hydro-meteorological disasters, by affected sector (1972–2013)



MoES Agencies dealing with various Hazards

HYDRO-METEOROLOGICAL HAZARDS – IMD, IITM and INCOIS

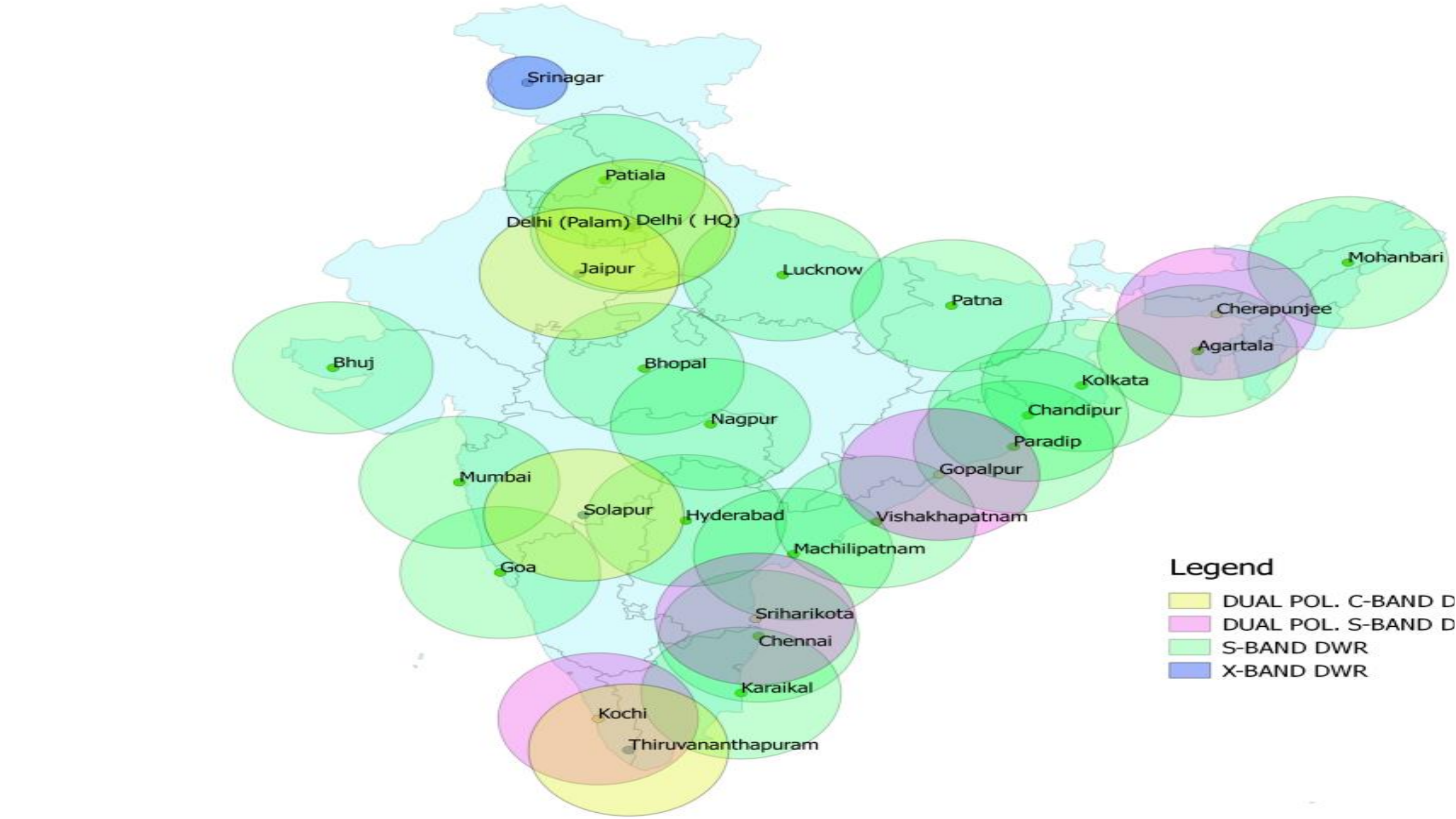
Tropical Cyclones, Local Severe Storms, Winter Systems.
[Support for Floods, Drought Snow Avalanches]
Climate change impacts on severe weather events (IITM and IMD)

ENVIRONMENTAL IMPACTS

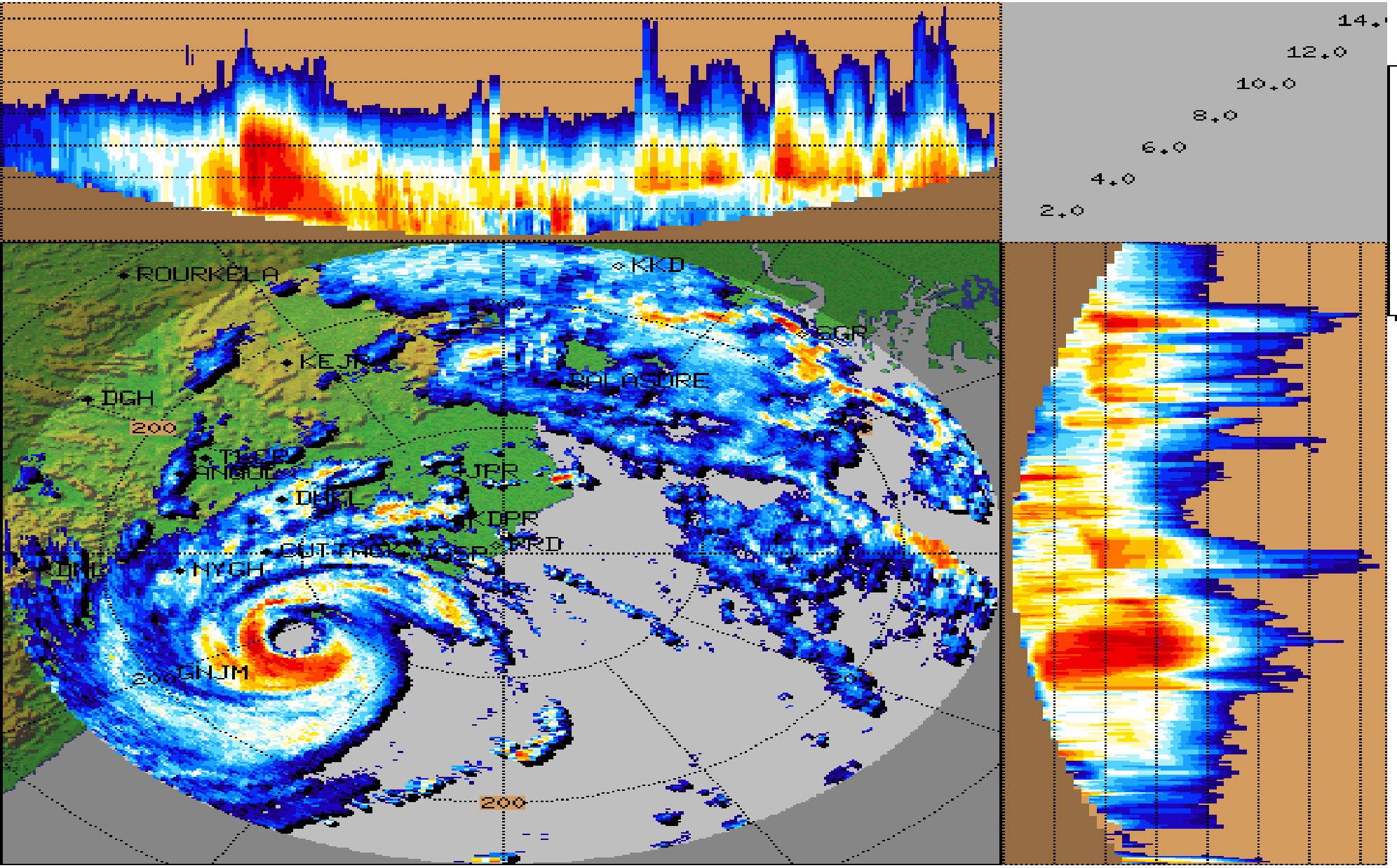
-Air pollution & Haze, FOG, Smog (IMD)
-Coastal Zone Management (NCCR)
-Coastal Erosion (NCCR)
-Eco-system monitoring/ modeling (IITM and IMD)

GEOLOGICAL HAZARDS

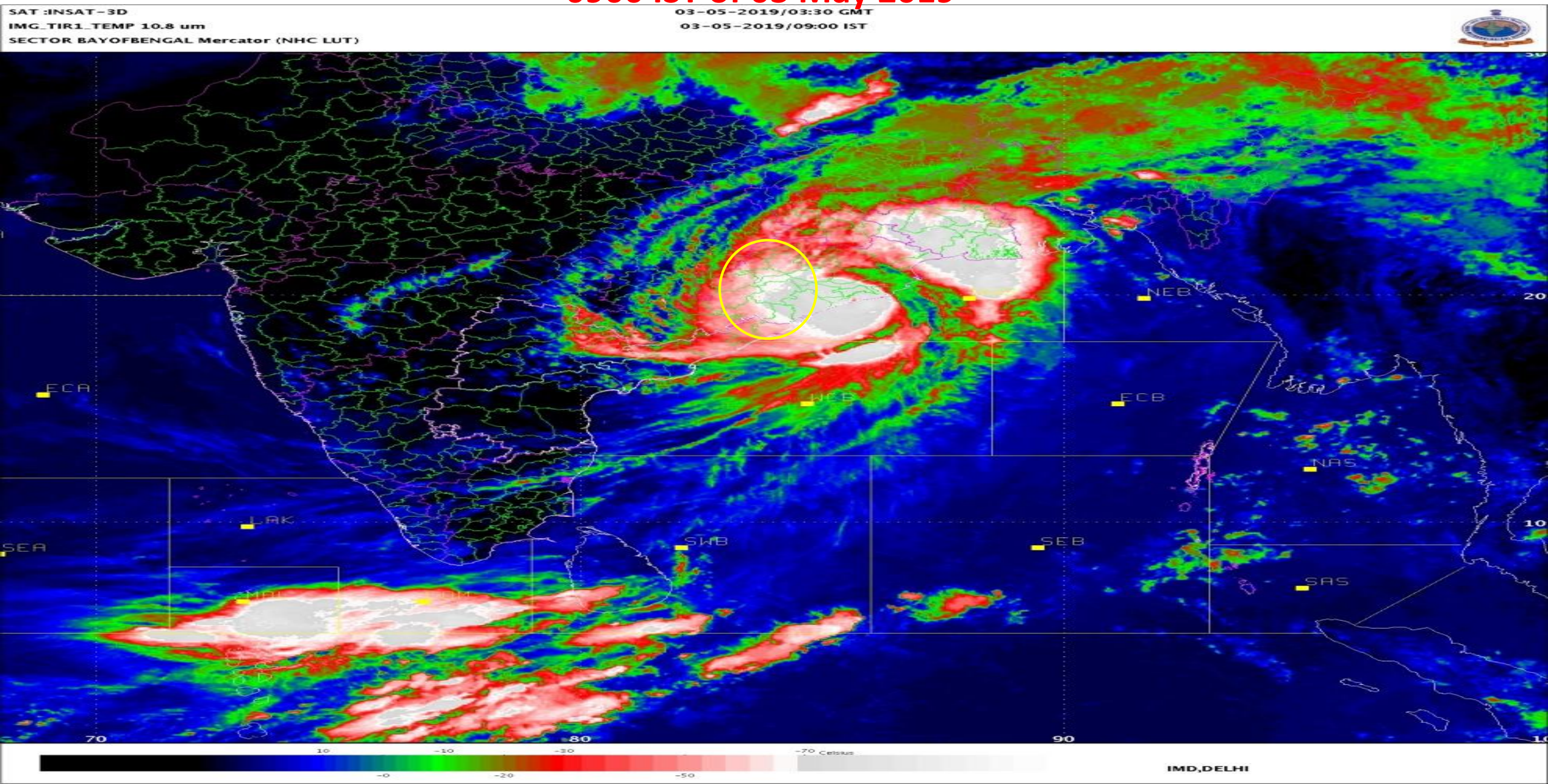
Earthquakes & Tsunamis (NCS and INCOIS)
[Support for Rain Induced Landslides/Mudslides (IMD)]


Srinagar
Patiala
Delhi (Palam)
Delhi (HQ)
Jaipur
Lucknow
Patna
Mohanbari
Cherapunjee
Agartala
Bhuj
Bhopal
Kolkata
Chandipur
Nagpur
Paradip
Gopalpur
Mumbai
Solapur
Hyderabad
Vishakhapatnam
Machilipatnam
Goa
Sriharikota
Chennai
Karaikal
Kochi
Thiruvananthapuram
Legend
DUAL POL. C-BAND D
DUAL POL. S-BAND D
S-BAND DWR
X-BAND DWR

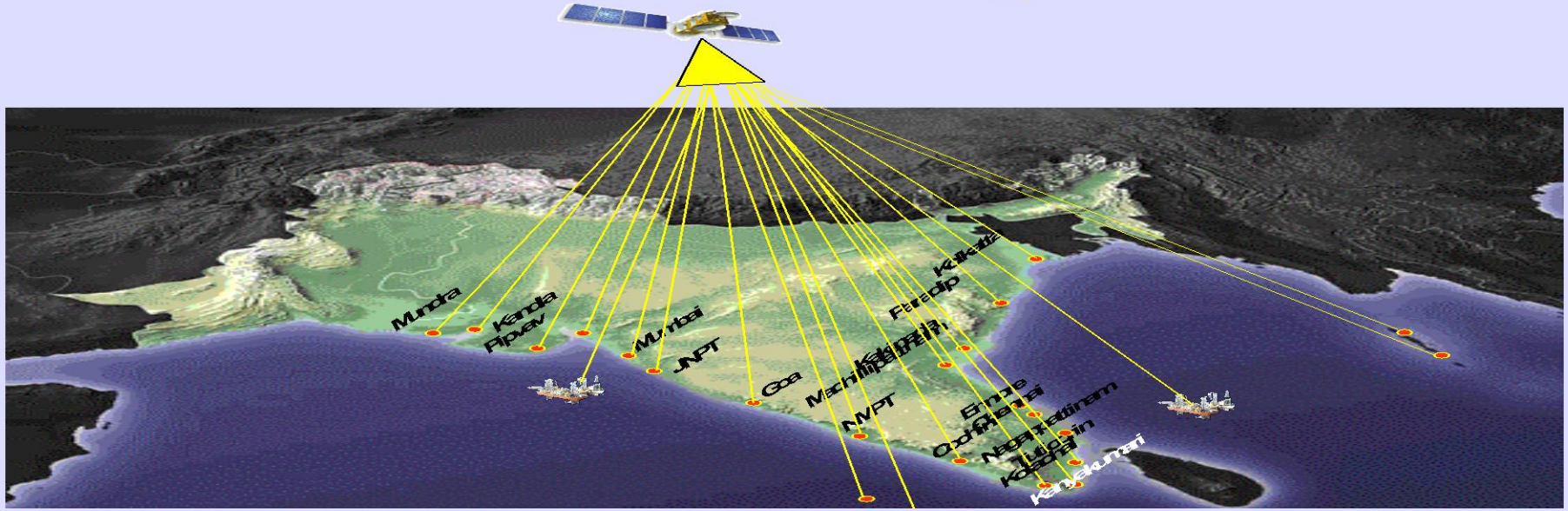
CDR PARADEEP AT THE TIME OF FANI CYCLONE CROSSING PURI



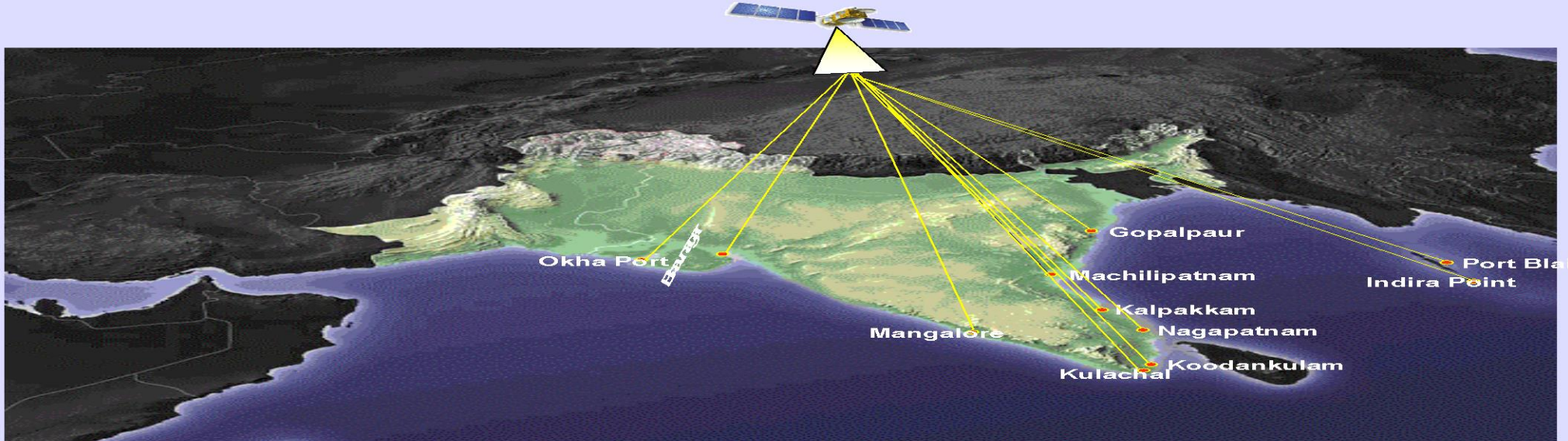
Extremely Severe Cyclonic Storm ‘FANI’ (19.6°N, 85.7°E)
0900 IST of 03 May 2019



Sea Level Monitoring Stations

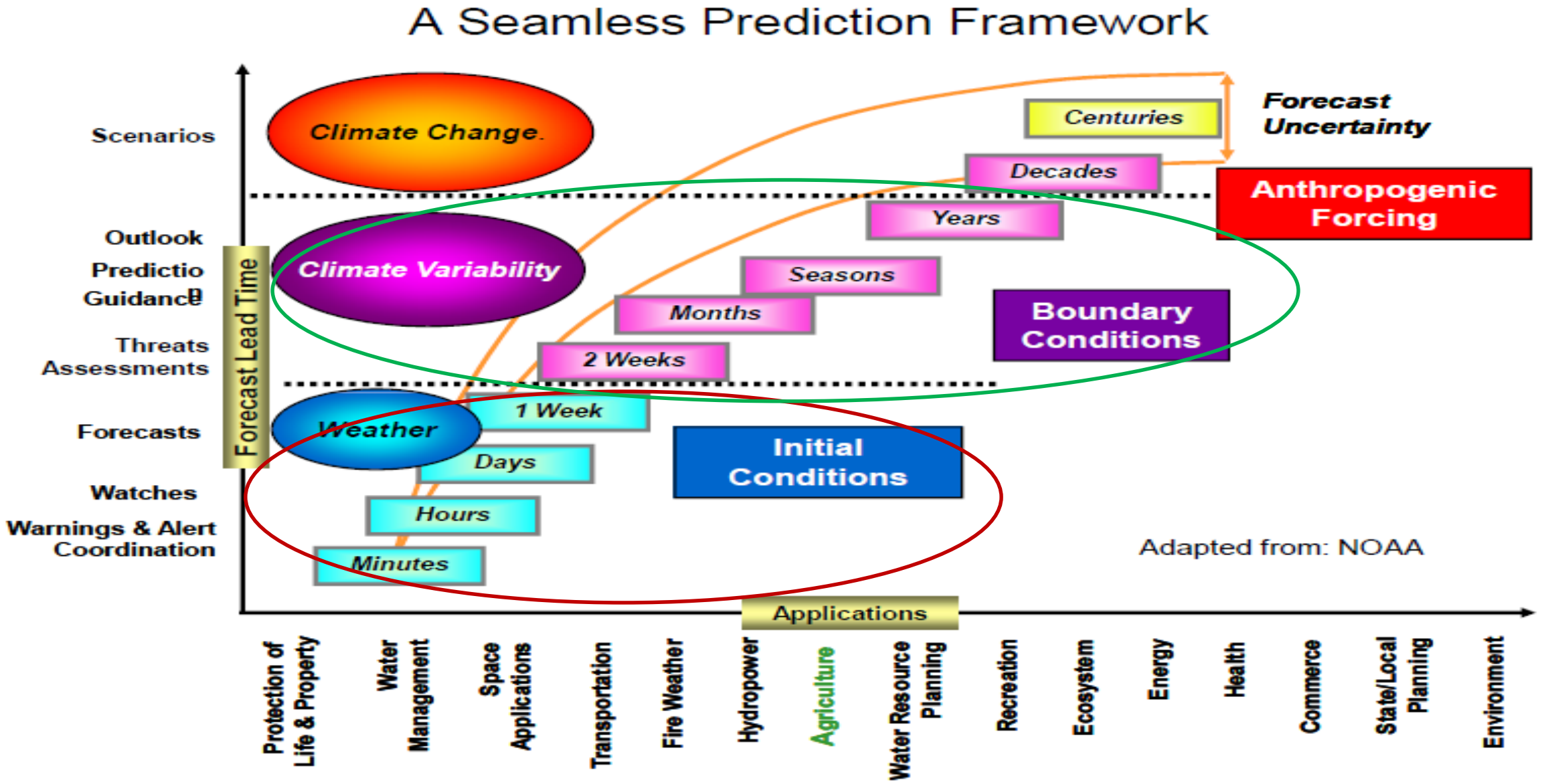


HF Radar-based Monitoring of Surface Current and Wave



Weather and Climate Prediction

Extended Range Prediction



A Few Points for Operational HWRF-HYCOM Modeling System

Atmospheric Model:

- Initialization for weaker storm (without any TCVITAL information)
- Improvement in rainfall prediction (rainfall over land region)
- Improvement in intensity prediction (reduction of overestimation)
- Physics to represent land-air-sea interactions at high-resolution

Atmospheric Data Assimilation:

- Start of cycling well ahead of the system to become cyclone
- Emphasis on non-conventional observations (i.e. radar radial wind, reflectivity and satellite radiances)
- Instead of global rather use of regional ensemble perturbations for EnVar

Ocean Coupling:

- Use of IMD-GFS for regional RTOFS of HYCOM model at INCOIS
- HYCOM coupling with HWRF well ahead of the system to become cyclone
- Effective coupling with shorter time interval preferably at every cycle

PHETHAI Cyclone
(13 – 18 December, 2018)

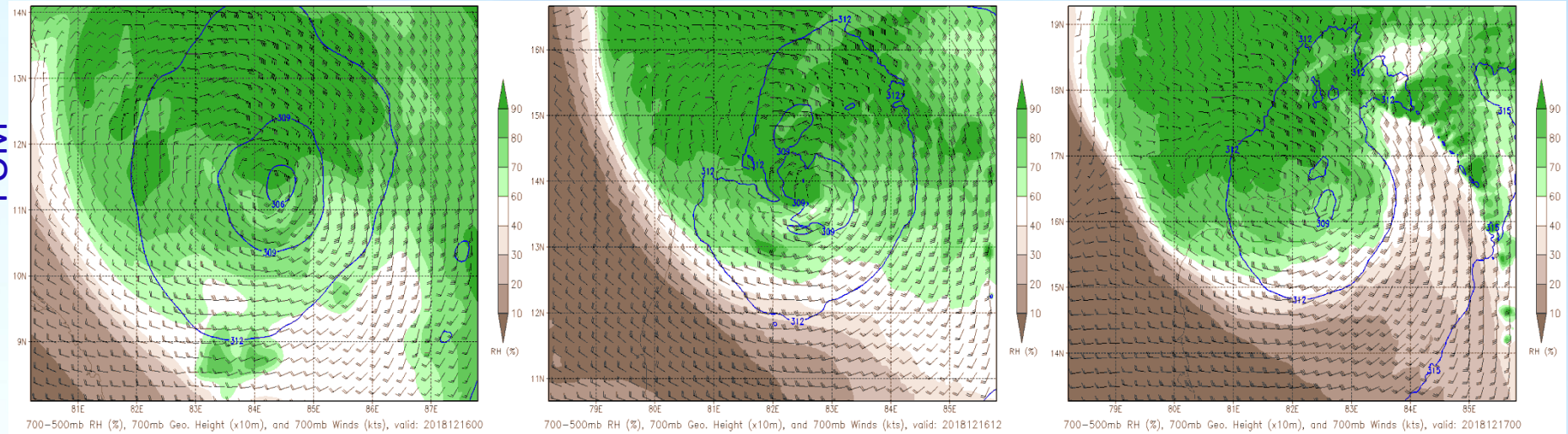
Structure of PHETHAI Cyclone

Initial Time
at 00 UTC 20181216

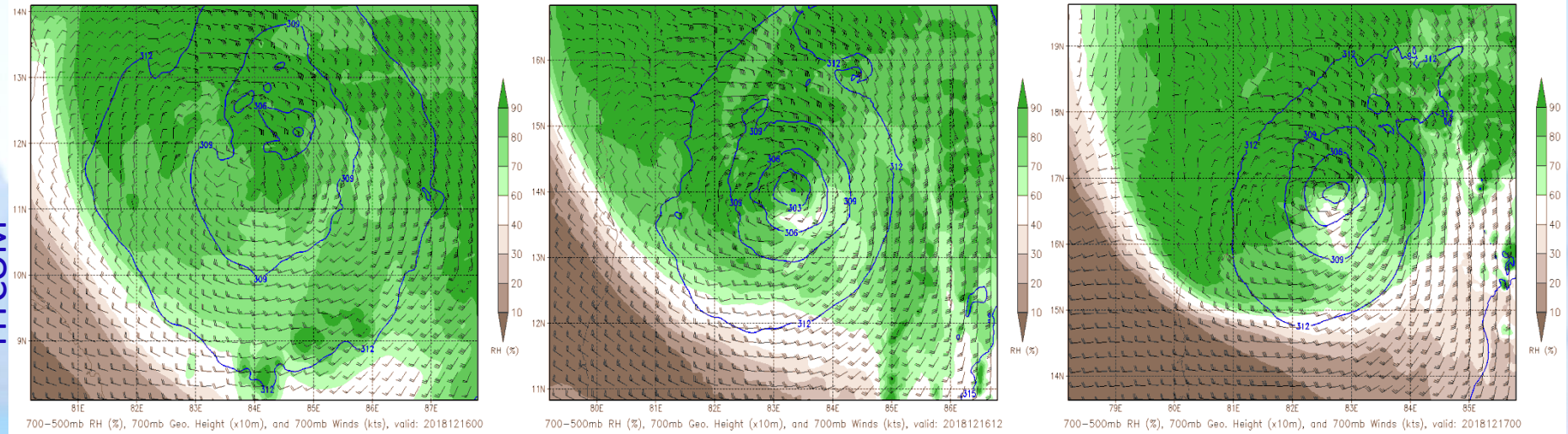
12 hours forecast
at 12 UTC 20181216

24 hours forecast
at 00 UTC 20181217

POM

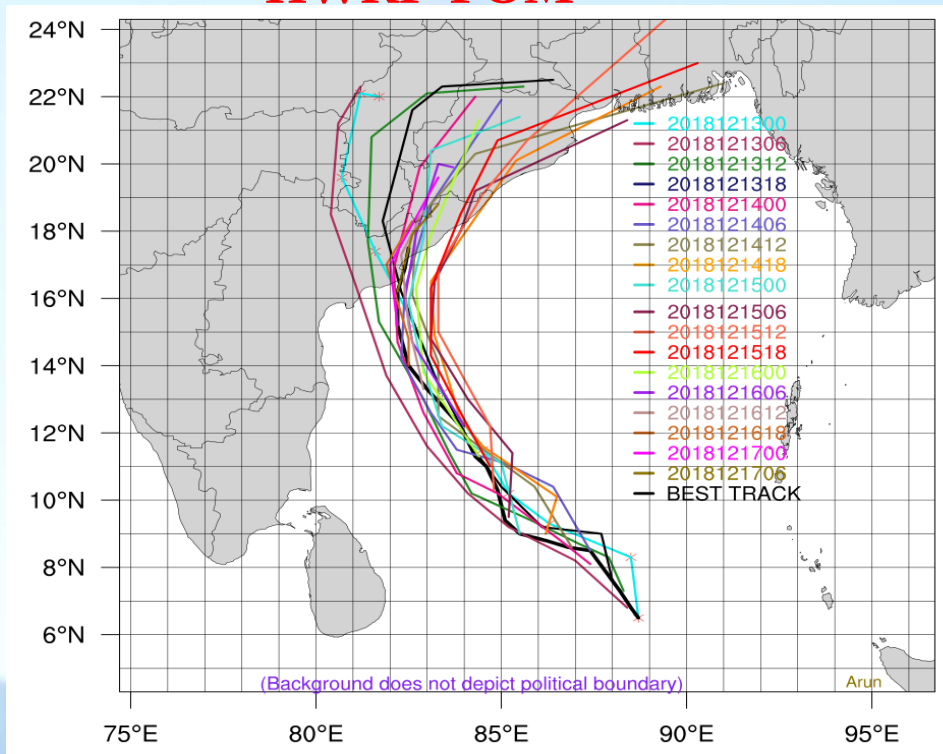


HYCOM

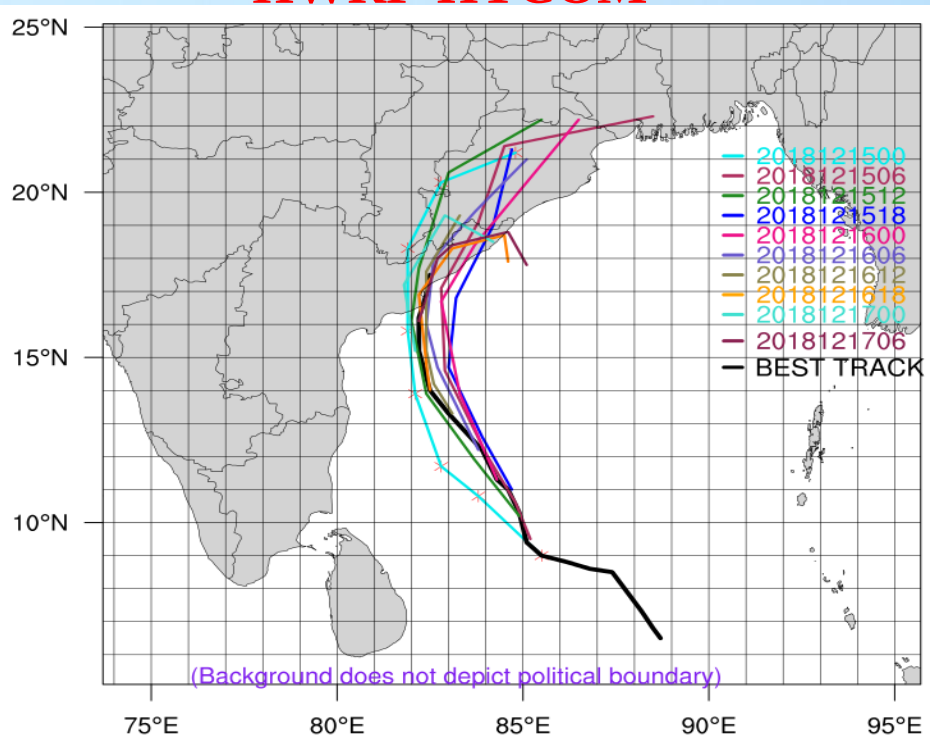


HWRF Forecast of PHETHAI Cyclone

HWRF-POM



HWRF-HYCOM



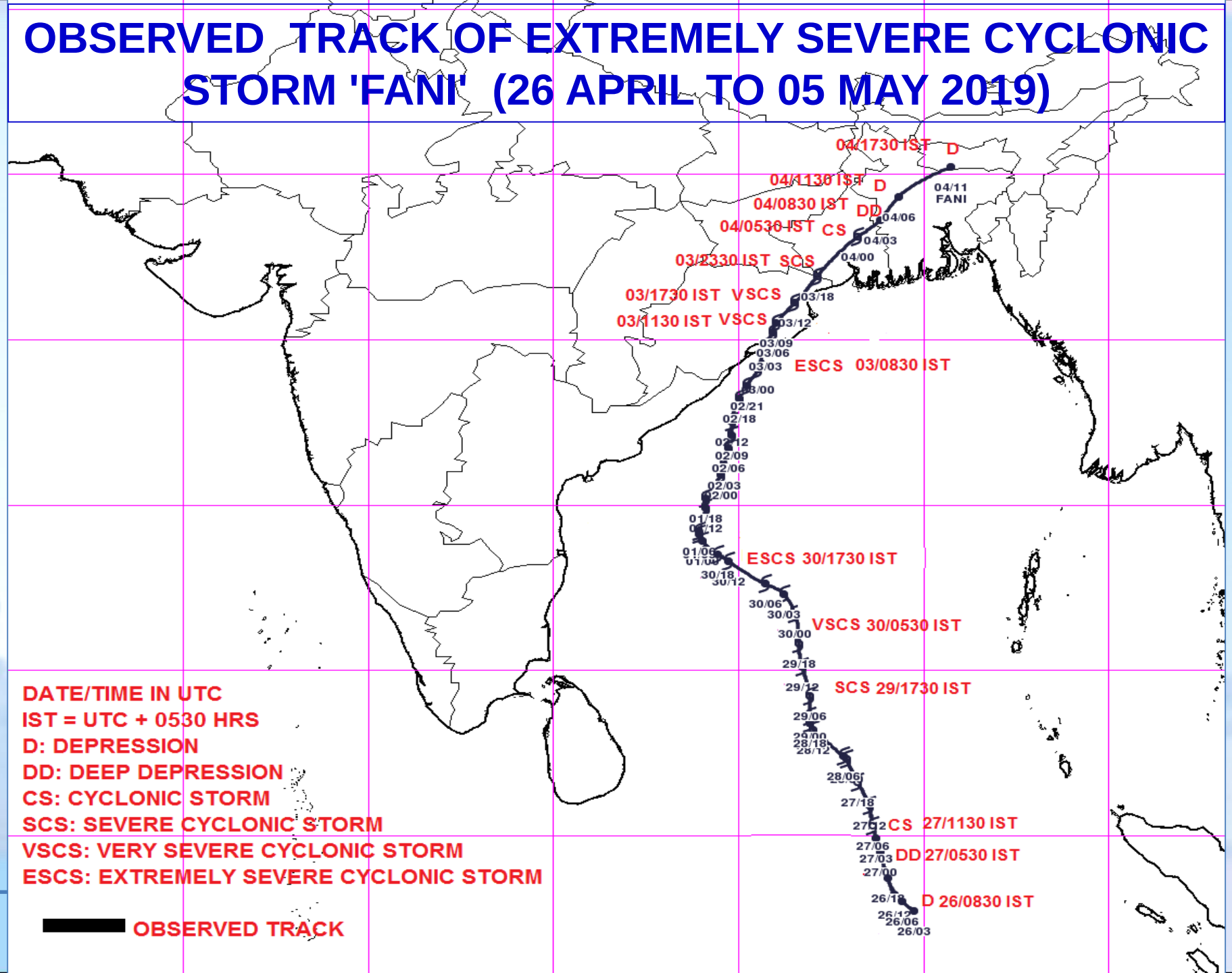
Average Track Forecast Error (Direct Position Error) in km

Lead Time	12 Hr	24 Hr	36 Hr	48 Hr	60 Hr	72 Hr
HWRF-POM	95(18)	142(16)	175(14)	208(12)	212(10)	287(8)
HWRF-HYCOM	83 (10)	123 (08)	195 (06)	187 (04)	219 (02)	283(1)

Root Mean Square (RMSE) (INTENSITY) errors in knots

Lead Time	12 Hr	24 Hr	36 Hr	48 Hr	60 Hr	72 Hr
HWRF-POM	11.6(18)	16.2(16)	17.7(14)	15.4(12)	13.4(10)	10.3(8)
HWRF-HYCOM	8.1 (10)	5.9 (08)	5.7 (06)	10.6 (04)	10 (02)	8.1 (1)

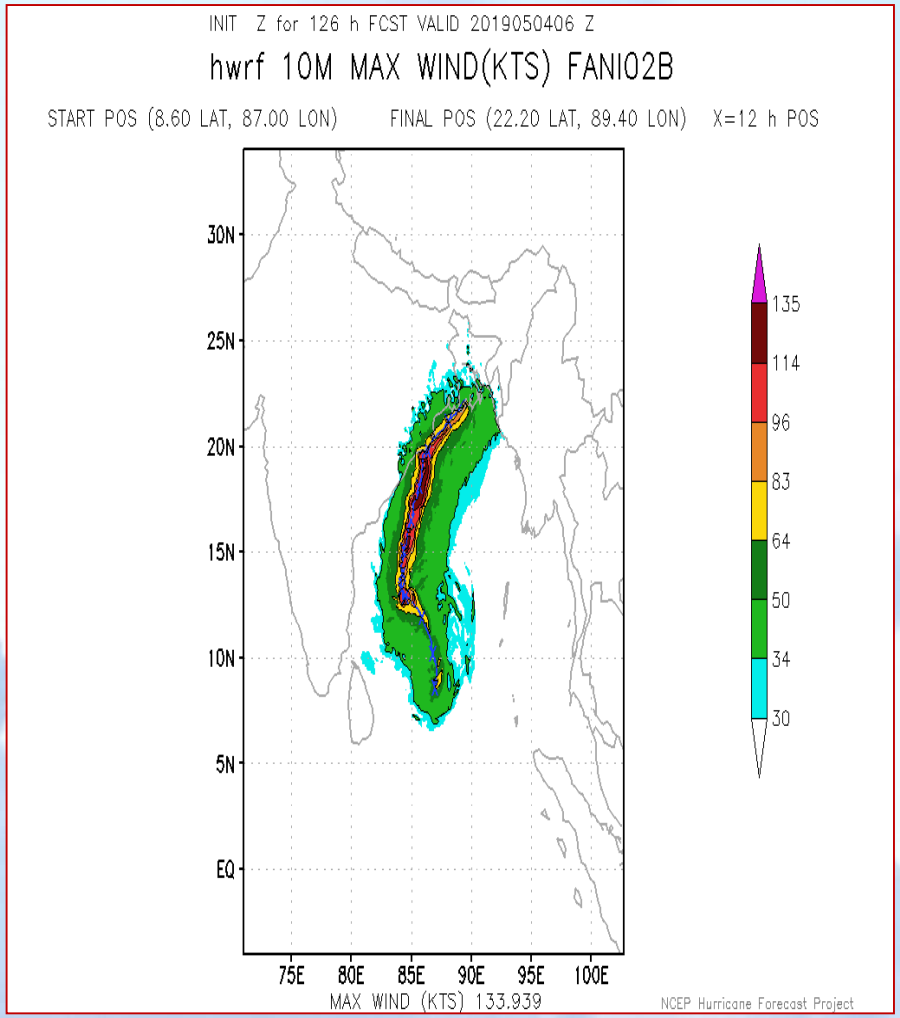
OBSERVED TRACK OF EXTREMELY SEVERE CYCLONIC STORM 'FANI' (26 APRIL TO 05 MAY 2019)

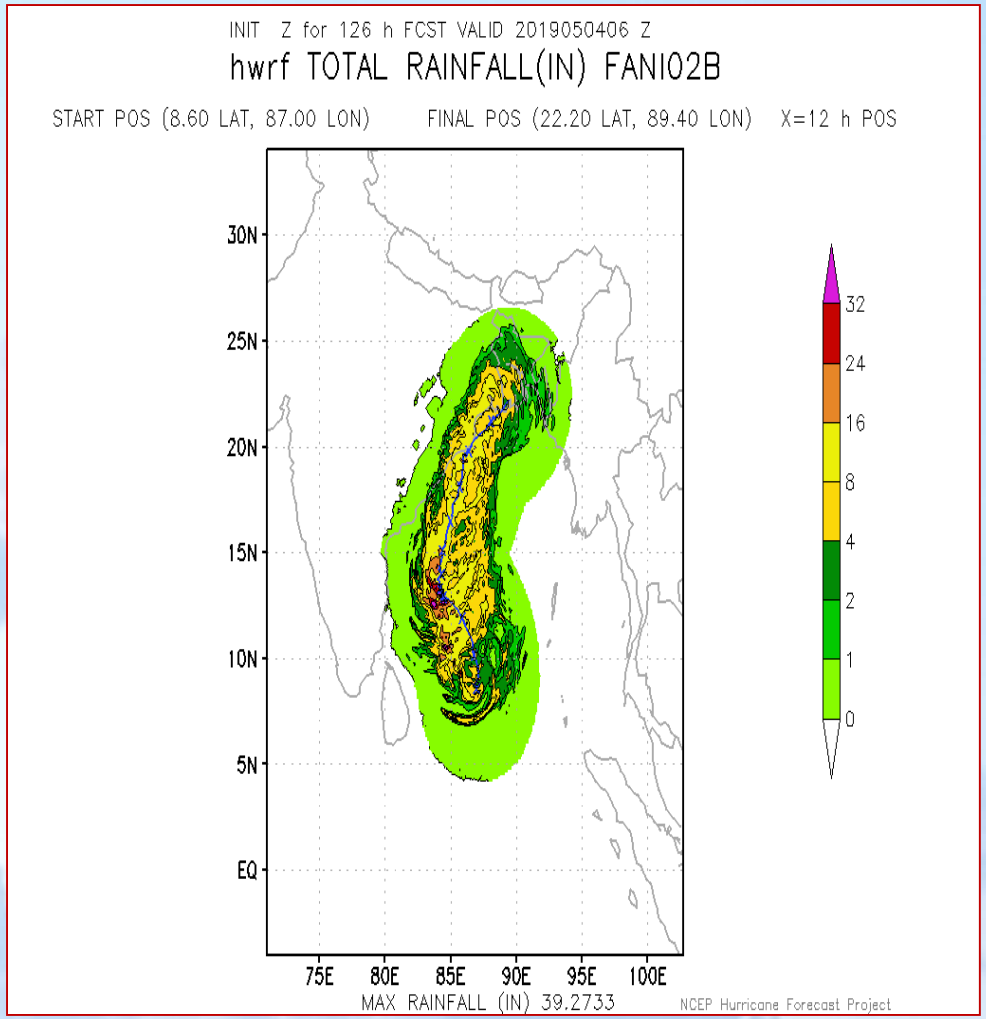


DATE/TIME IN UTC
IST = UTC + 0530 HRS
D: DEPRESSION
DD: DEEP DEPRESSION
CS: CYCLONIC STORM
SCS: SEVERE CYCLONIC STORM
VSCS: VERY SEVERE CYCLONIC STORM
ESCS: EXTREMELY SEVERE CYCLONIC STORM

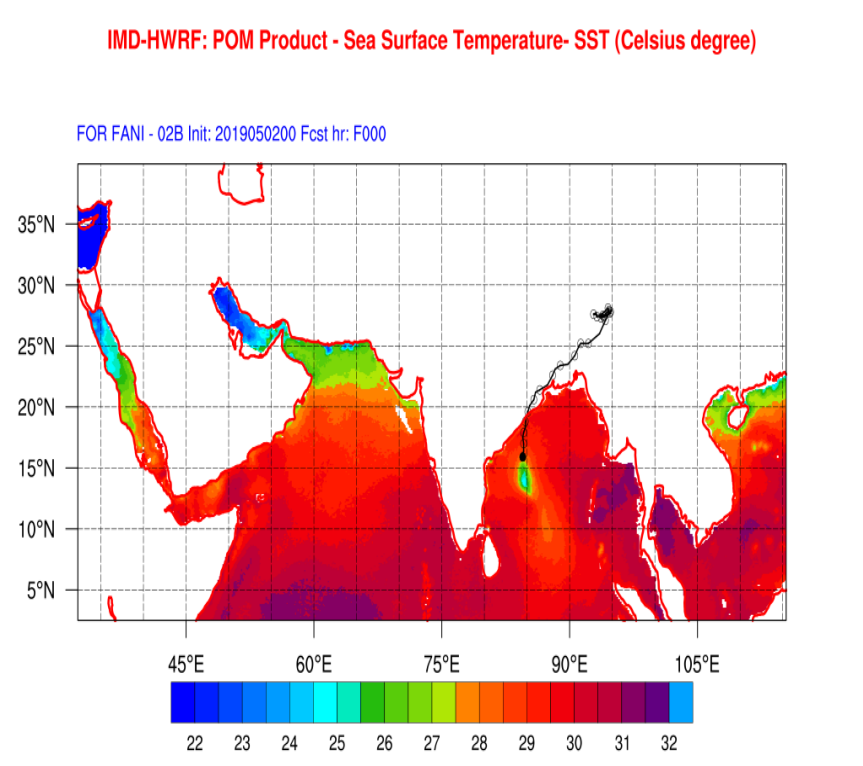
OBSERVED TRACK

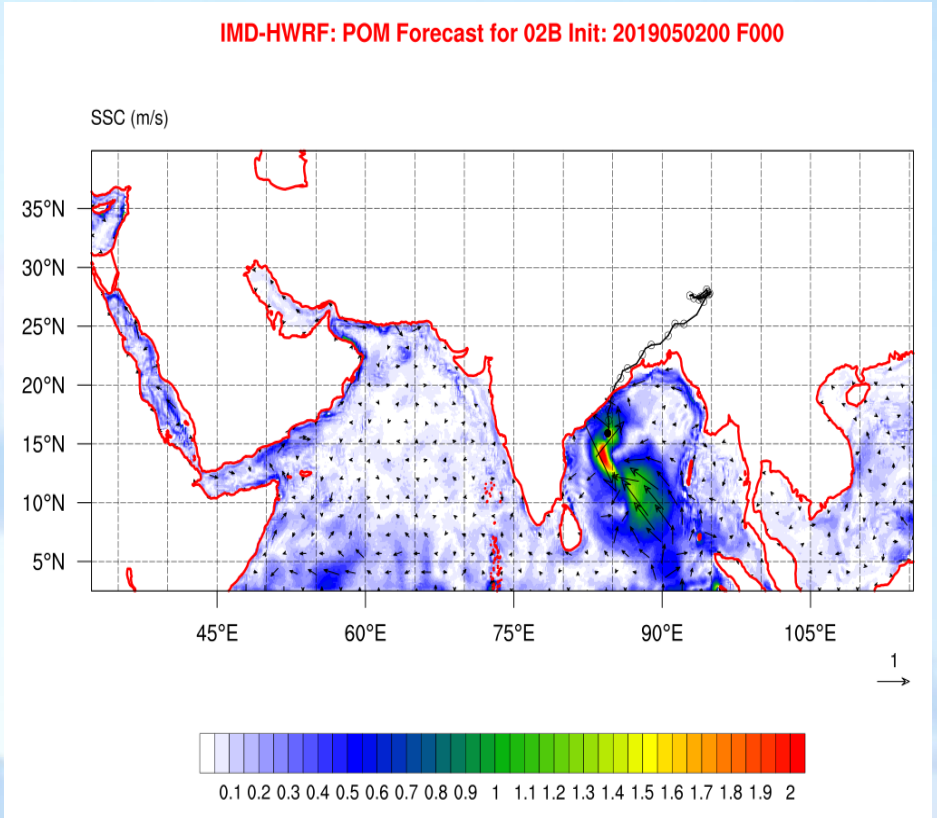
Wind & Rain Swath for recent Cyclone FANI from HWRF-POM coupled Model based on 29 April 00 UTC



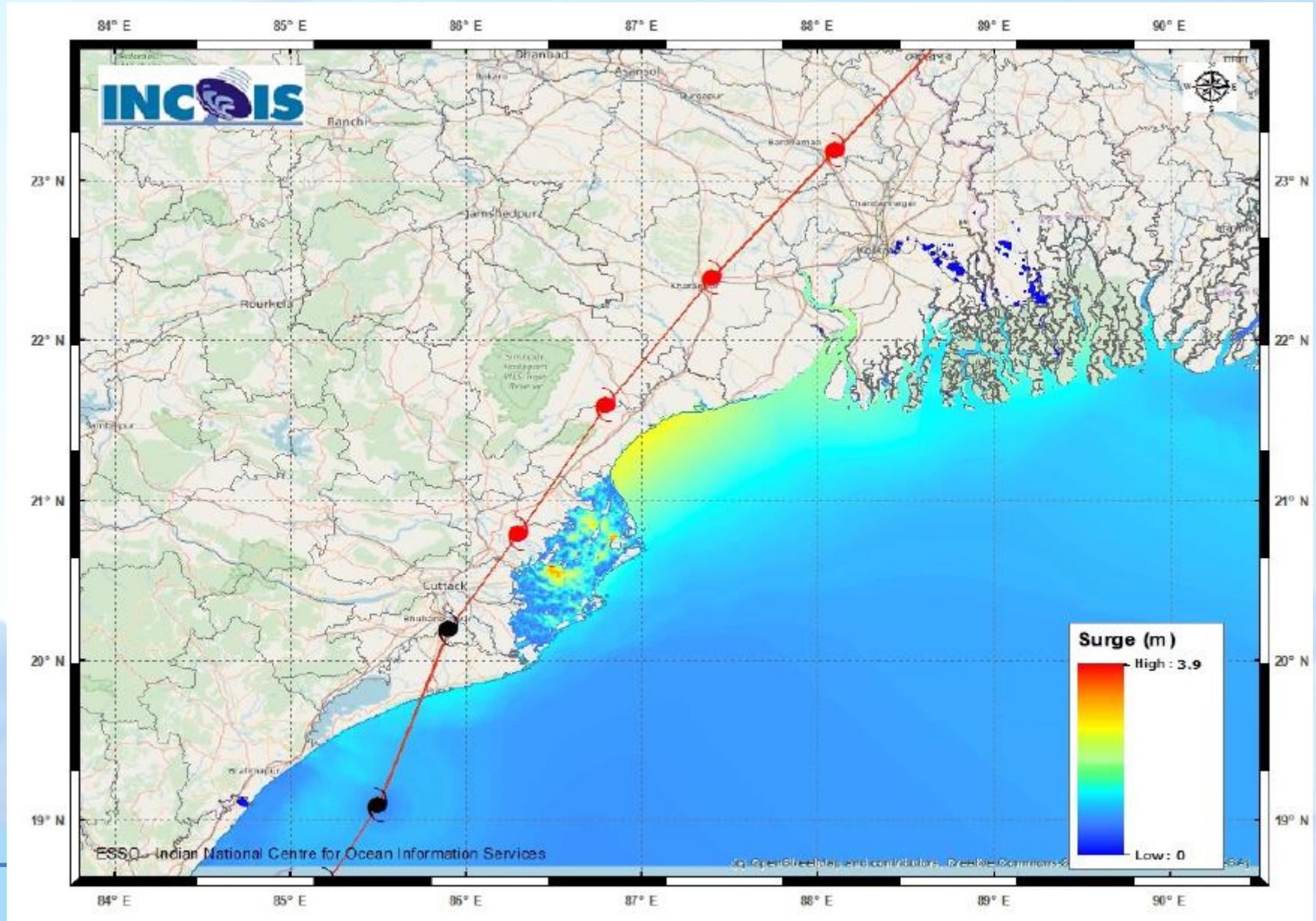


Sea Surface temperature and Sea Surface Current FANI from HWRF-POM coupled Model based on 02 May 00 UTC





STORM SURGE GUIDANCE



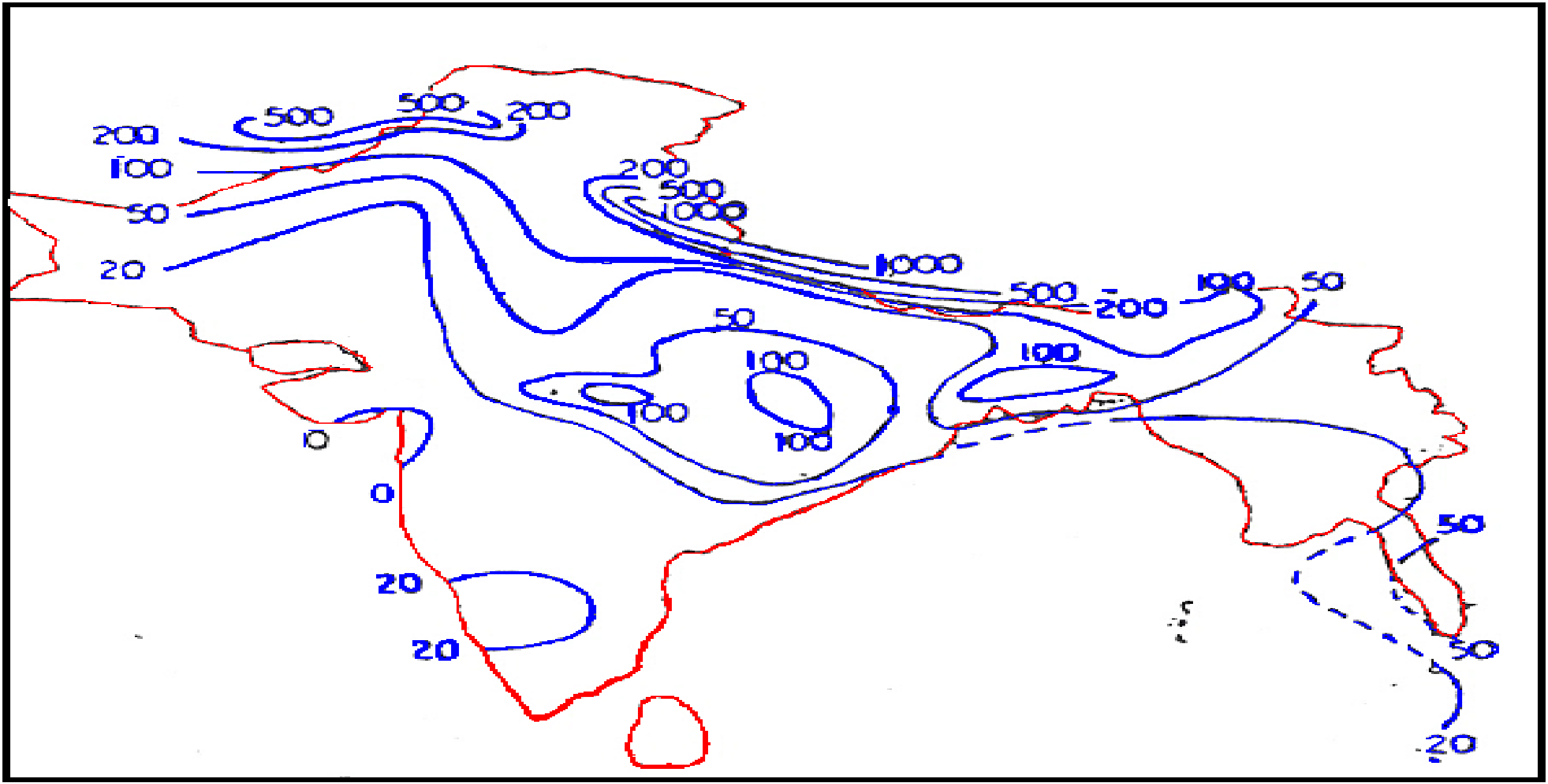
A Few Points for Future Operational Regional Coupled High-resolution Modeling System

Forecast verification:

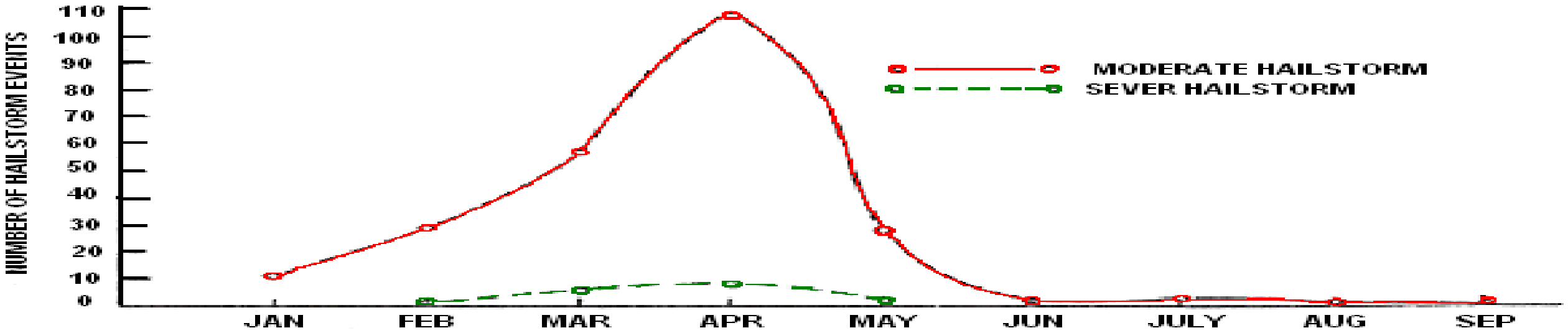
- Targeted verification at high-resolution with suitable methodology
- Need of higher resolution verification analyses and observations

Products for forecaster:

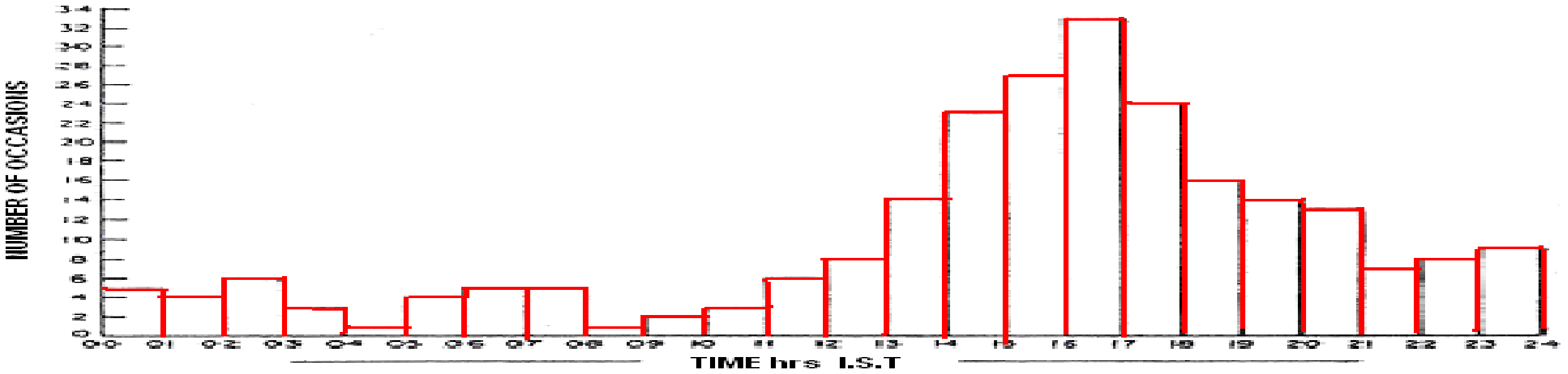
- Application to provide various categories of user specific products
- Impact assessment studies to assist forecaster in generating Impact Based Forecasts
- Robust operational system for timely and regular dissemination of forecasts up to end users



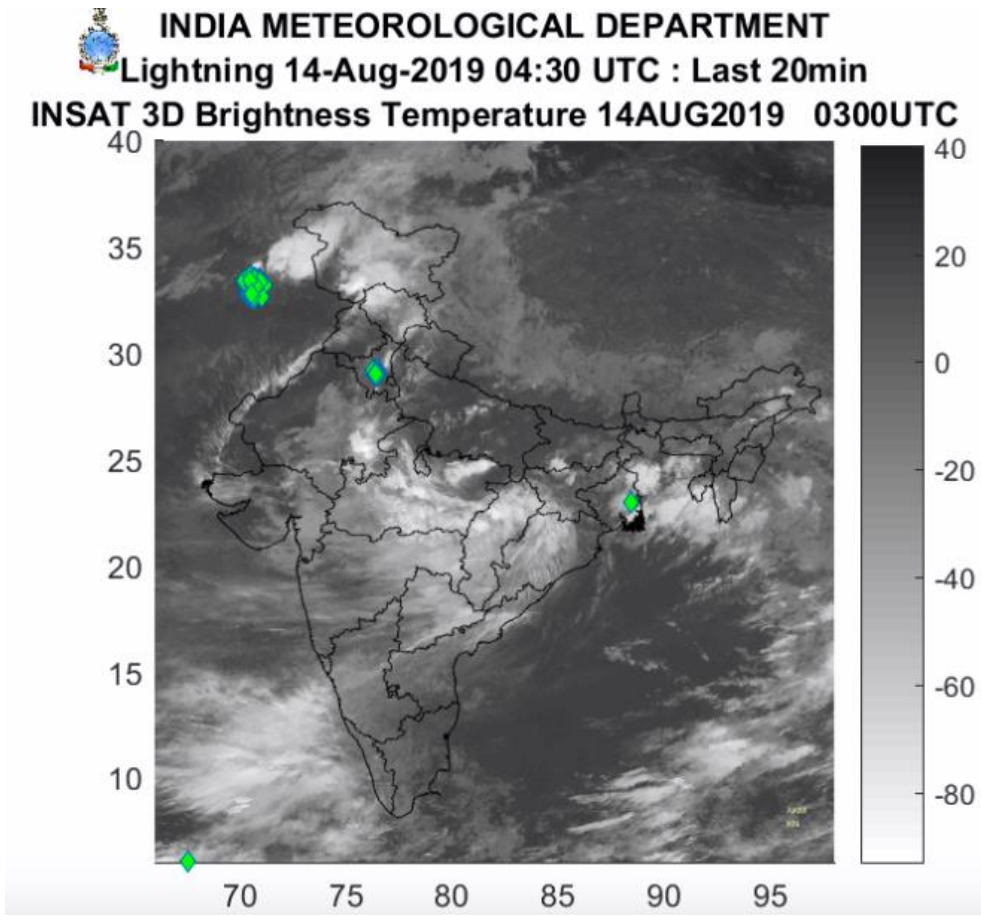
Hail occurrences during a hundred years

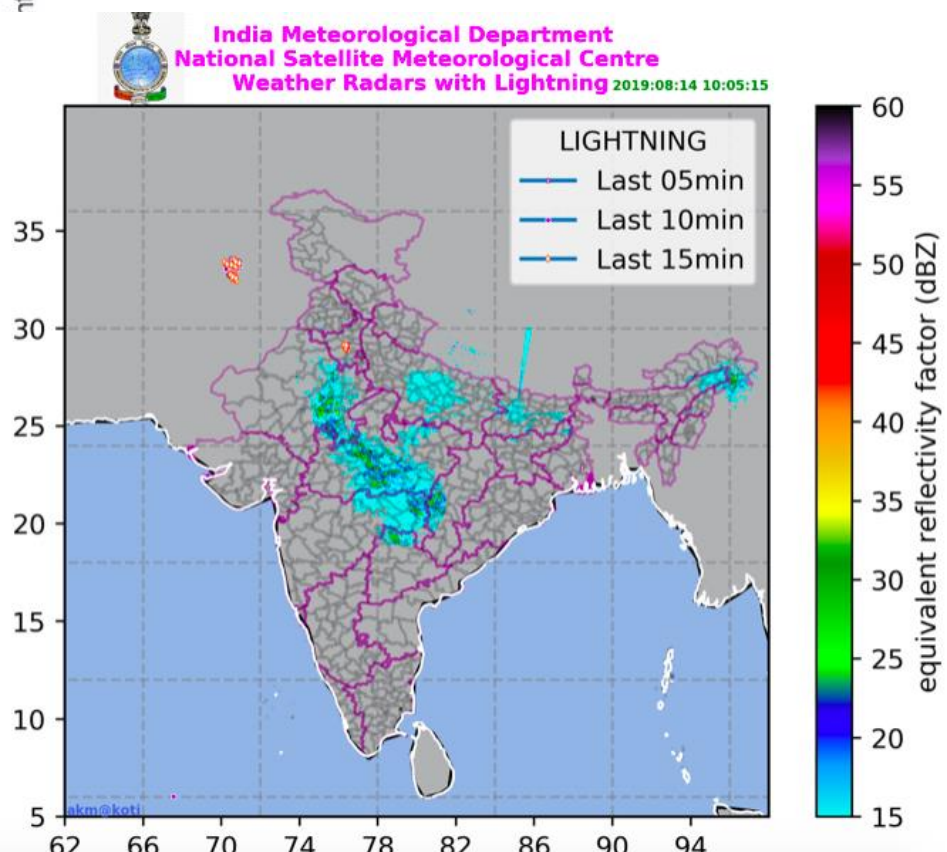


Monthly distribution of Hail storms in India



Diurnal variation of Hail storms in India

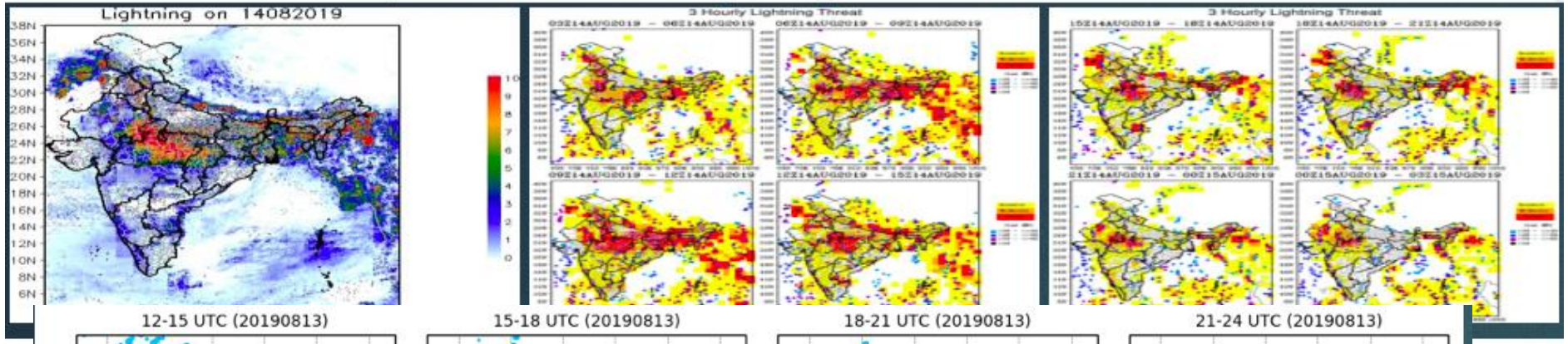

INDIA METEOROLOGICAL DEPARTMENT
Lightning 14-Aug-2019 04:30 UTC : Last 20min
INSAT 3D Brightness Temperature 14AUG2019 0300UTC
40
35
30
25
20
15
10
70
75
80
85
90
95
40
20
0
-20
-40
-60
-80

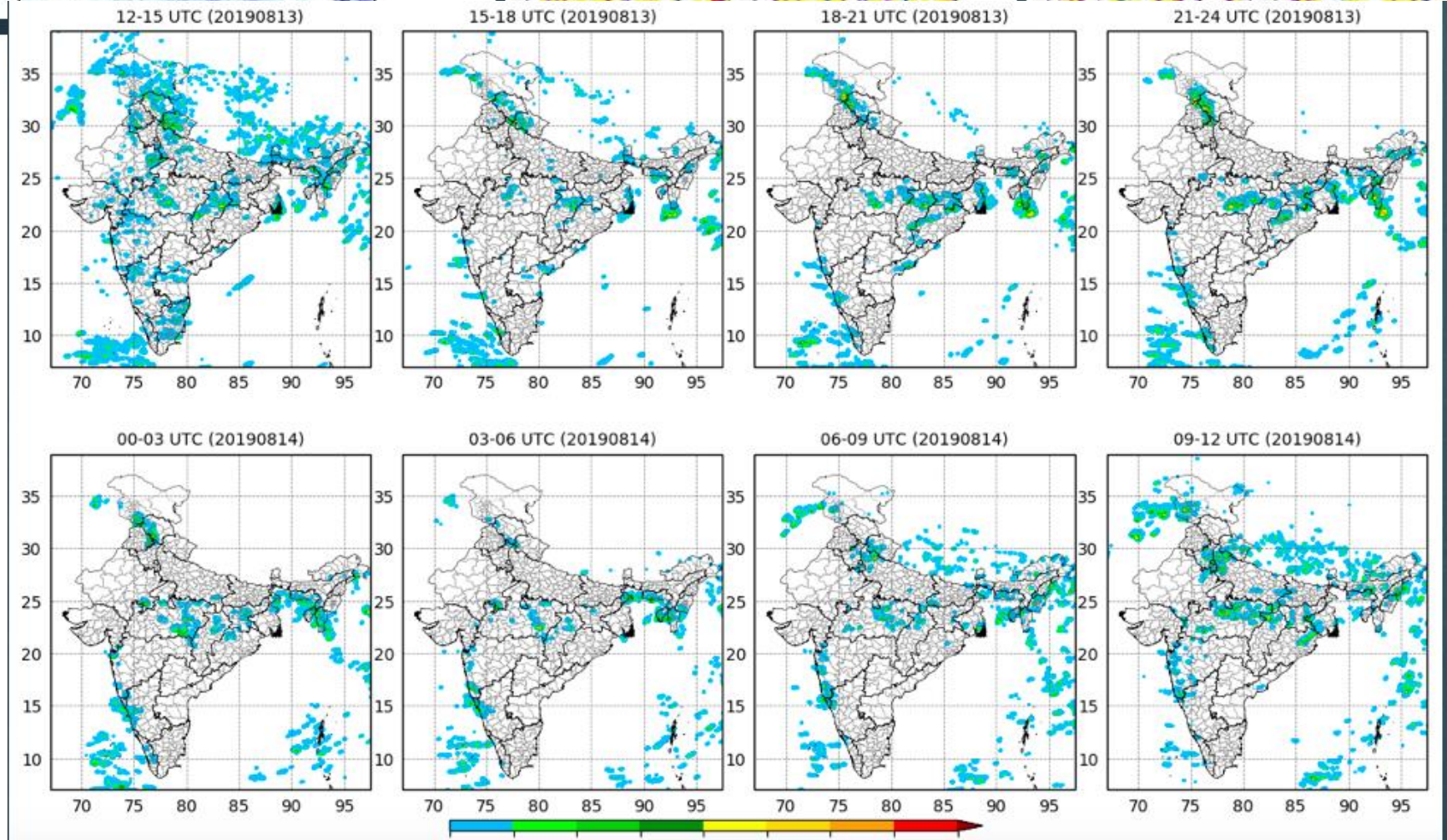

India Meteorological Department
National Satellite Meteorological Centre
Weather Radars with Lightning 2019:08:14 10:05:15
LIGHTNING
Last 05min
Last 10min
Last 15min
akm@koti
62
66
70
74
78
82
86
90
94
35
30
25
20
15
10
5
60
55
50
45
40
35
30
25
20
15
equivalent reflectivity factor (dBZ)

Real Time Forecast PPT

Dynamic Prediction of Lightning Flash Count

Archive View Details





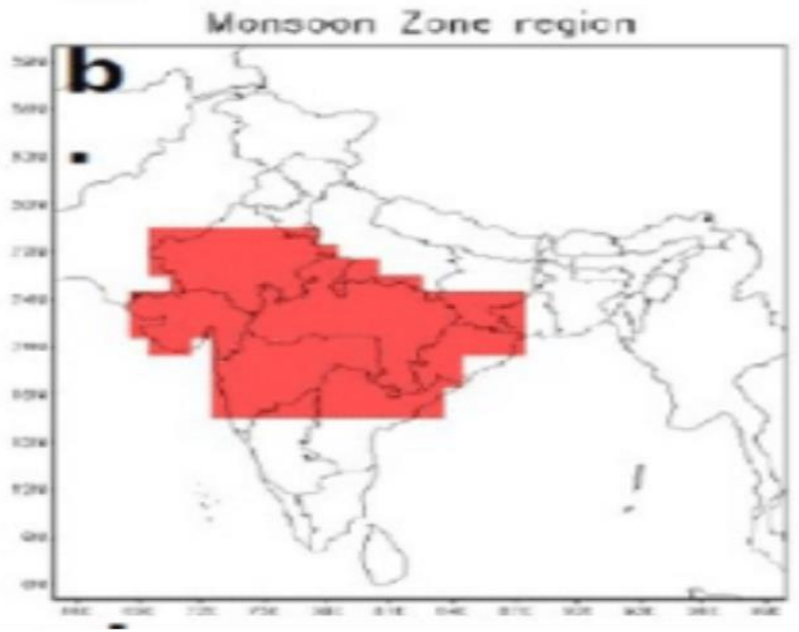
IMD's New ERF Operational System

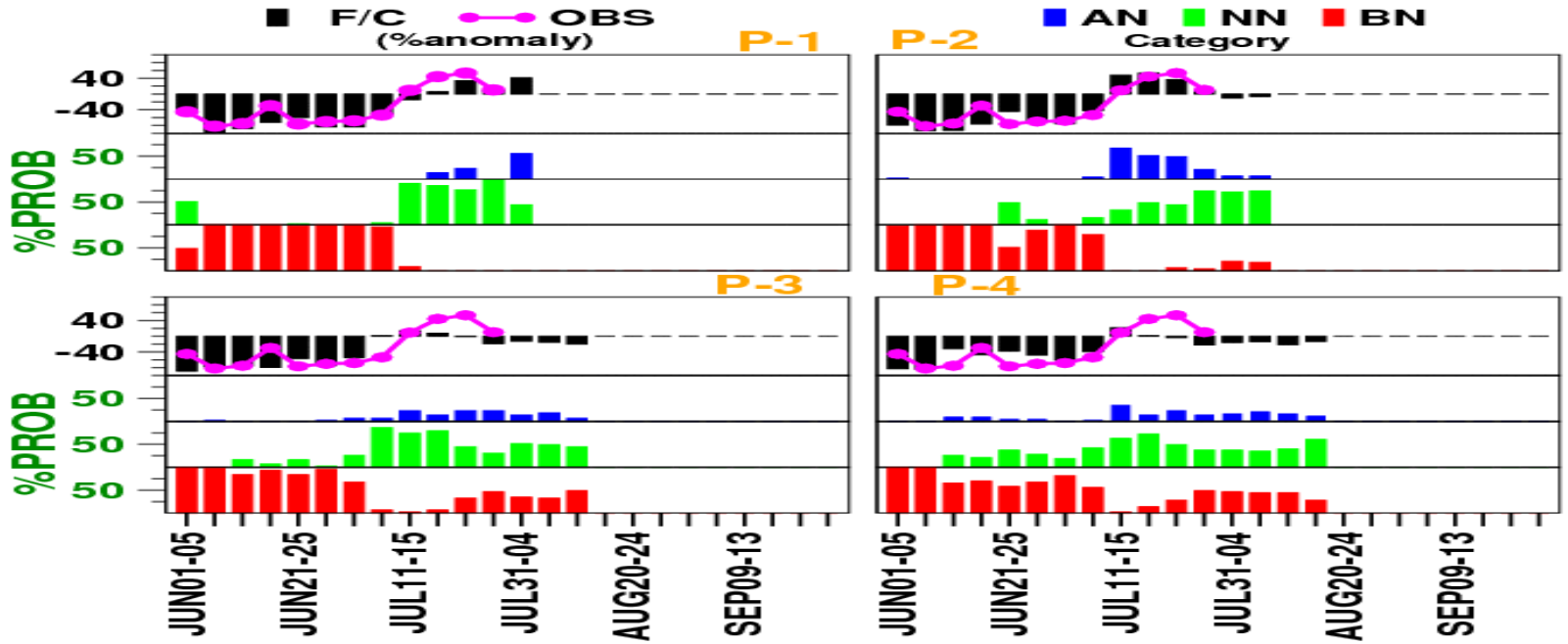
2008 : IMD started this activity using empirical and dynamical products.

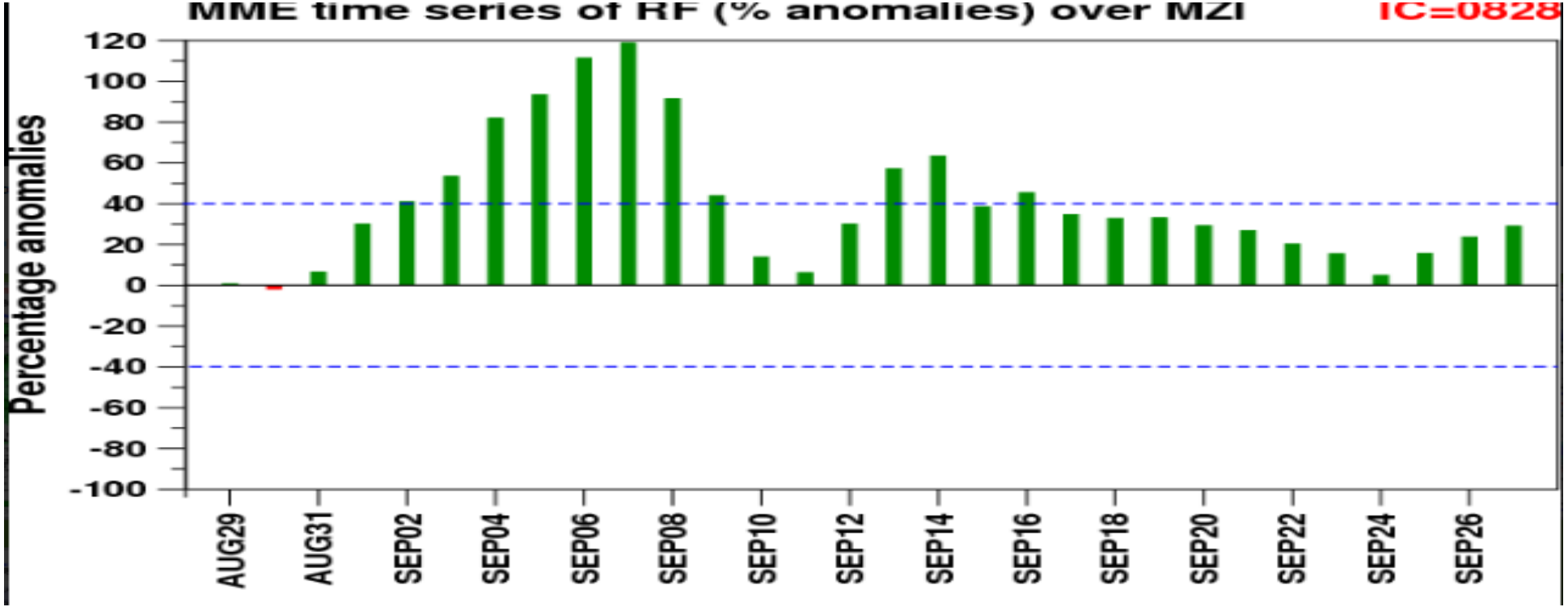
2008-2016 : Initially some empirical models (MJO forecasts, OLR anomalies based on empirical models) were used and subsequently previous versions of coupled models from NCEP, JMA , ECMWF were used for MME products.

- **2016 onwards : IMD is running coupled Ocean-Atmospheric model for operational ERF.**
- **IMD's current ERF system is rendered through joint collaboration of MoES institutions (IMD, IITM, NCMRWF and INCOIS).**
- **The system was developed at IITM and was transferred to IMD in July 2016.**

- ***Run operationally once in a week (Every Wednesday IC)***
- ***The atmospheric and oceanic initial conditions are used based on the analysis available from NCMRWF and INCOIS respectively.***
- *The UM model coupled model is also operationally running at NCMRWF.*

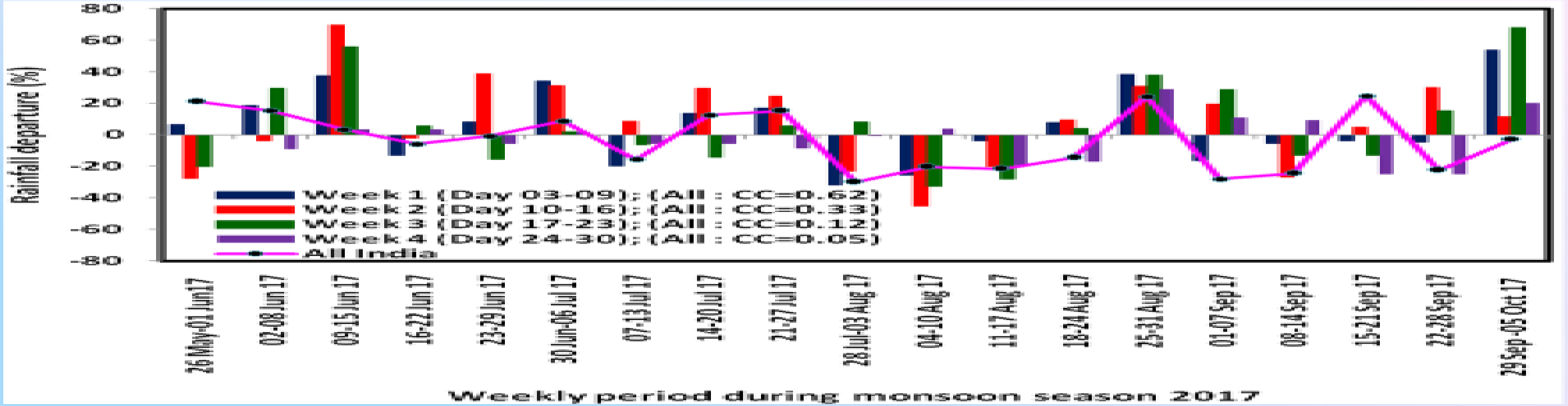

Monsoon Zone region
b


F/C
OBS
(%anomaly)
AN
NN
BN
Category
P-1
P-2
P-3
P-4
%PROB
40
-40
50
50
50
JUN01-05
JUN21-25
JUL11-15
JUL31-04
AUG20-24
SEP09-13

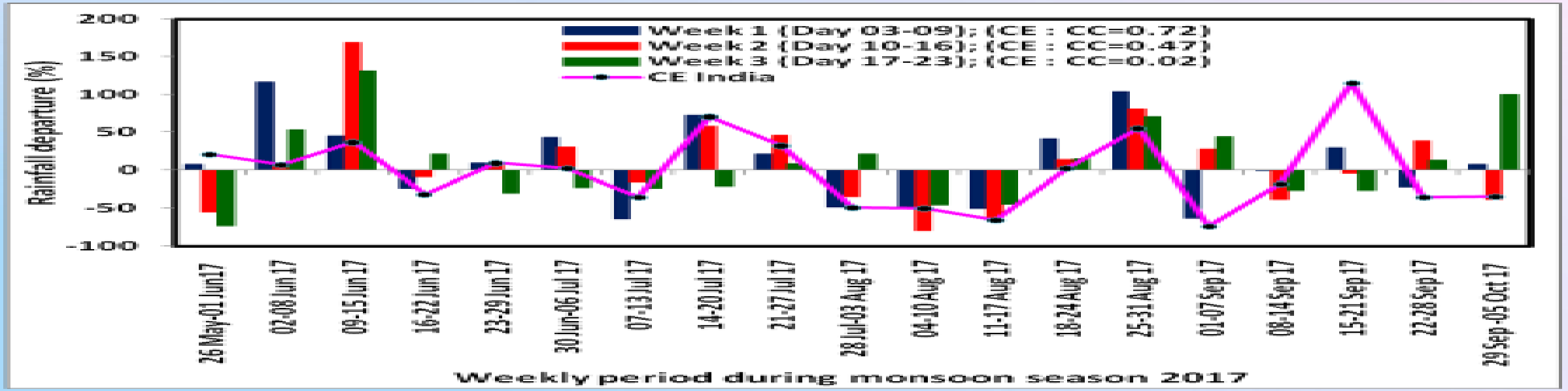

MME time series of RF (% anomalies) over MZI
IC=0828
Percentage anomalies
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
AUG29
AUG31
SEP02
SEP04
SEP06
SEP08
SEP10
SEP12
SEP14
SEP16
SEP18
SEP20
SEP22
SEP24
SEP26

Transition from Active to Weak Phase of Monsoon

Quantitative Forecast Skill, All India 2017

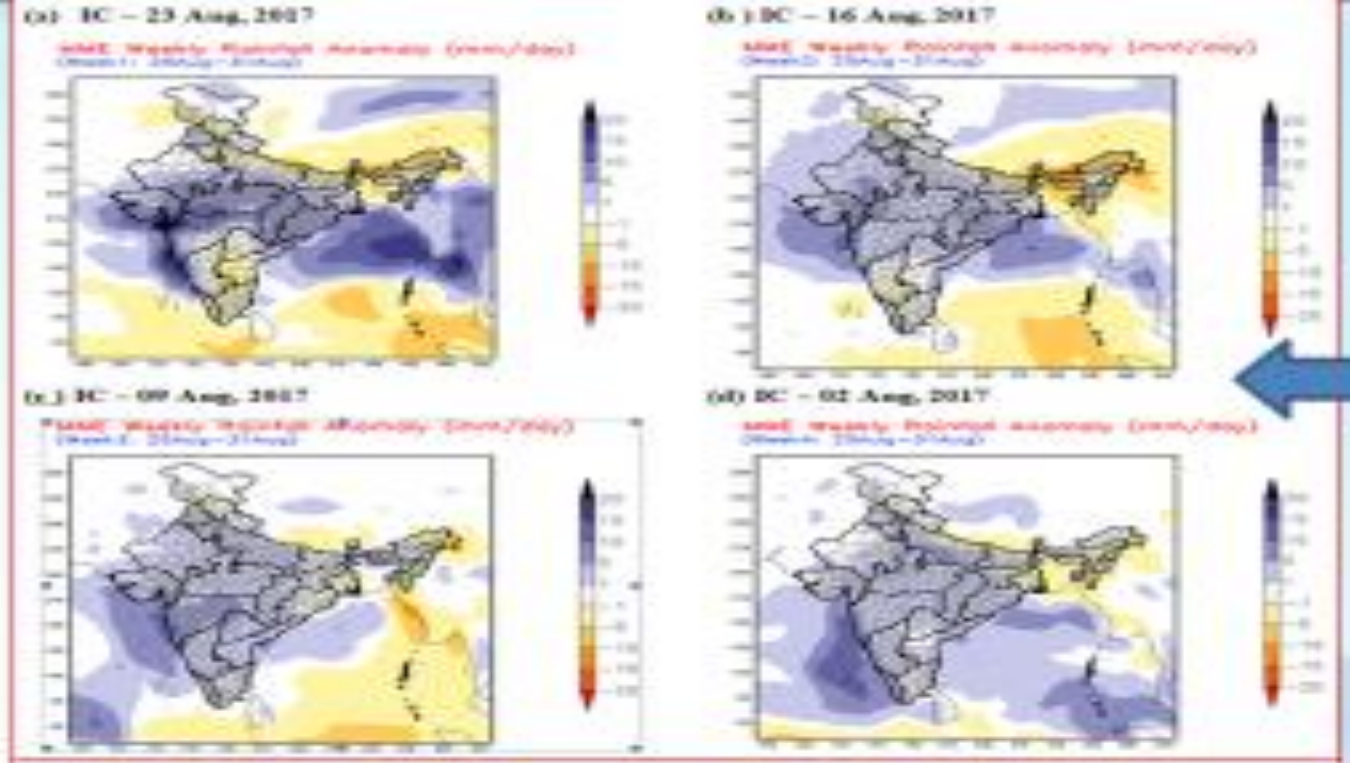


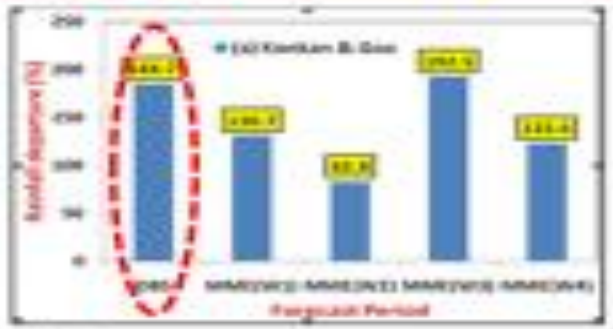
Quantitative Forecast Skill, CENTRAL REGION, 2017

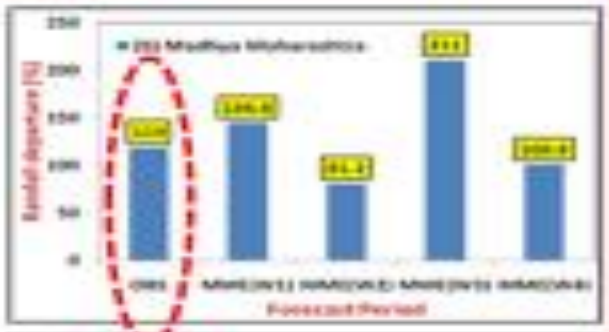


ERF for Hydrological applications

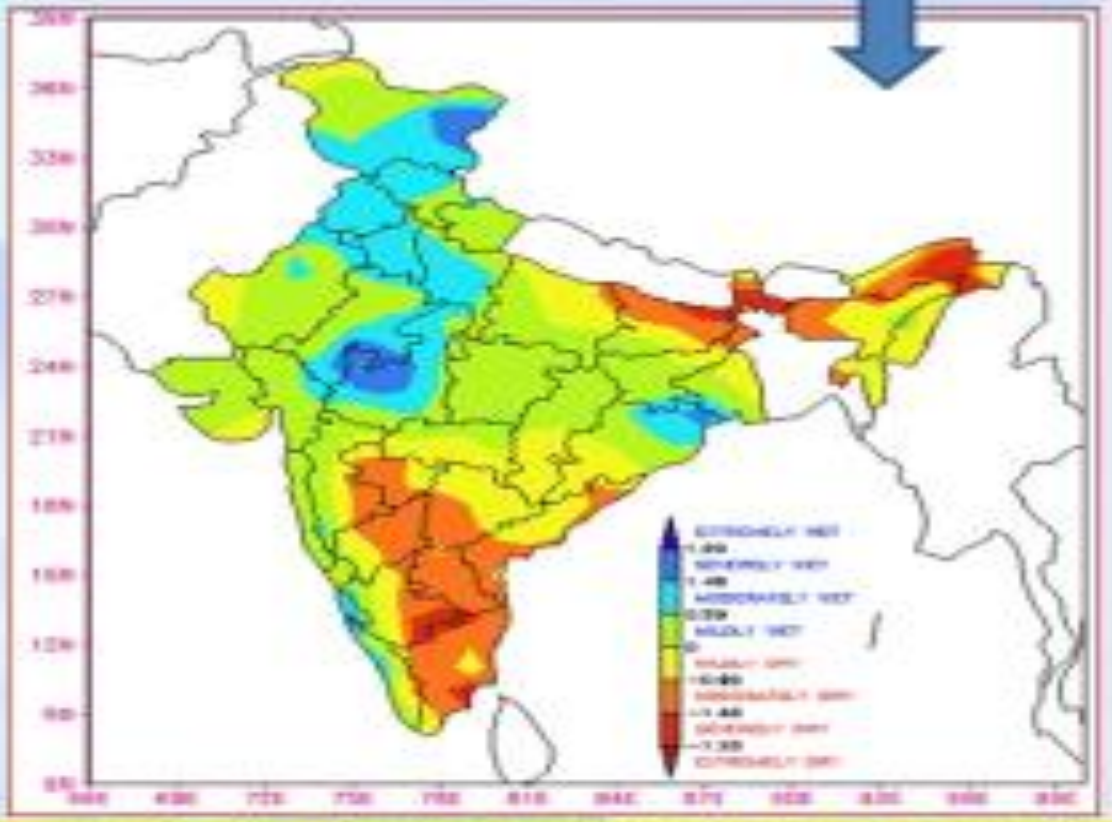
Heavy Rainfall Guidance for Flood, Reservoir Operation, Disaster Management





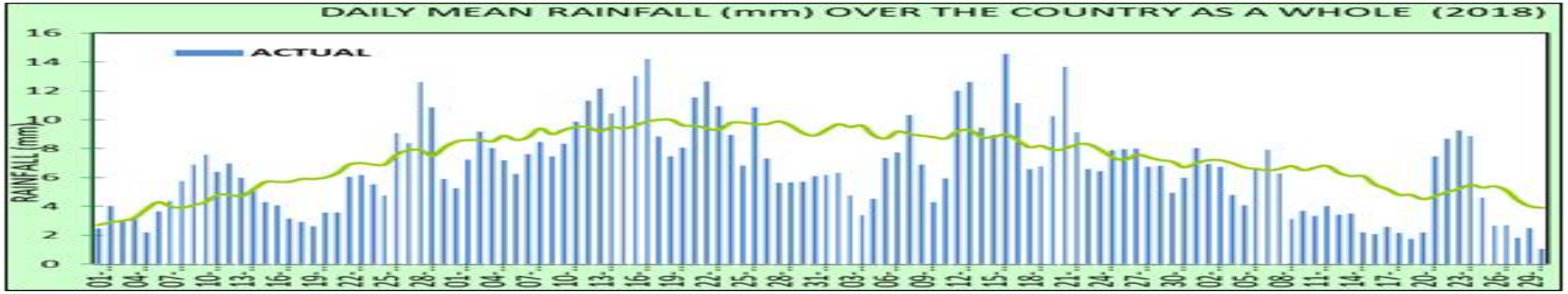


(25-31 August 2017); SPI



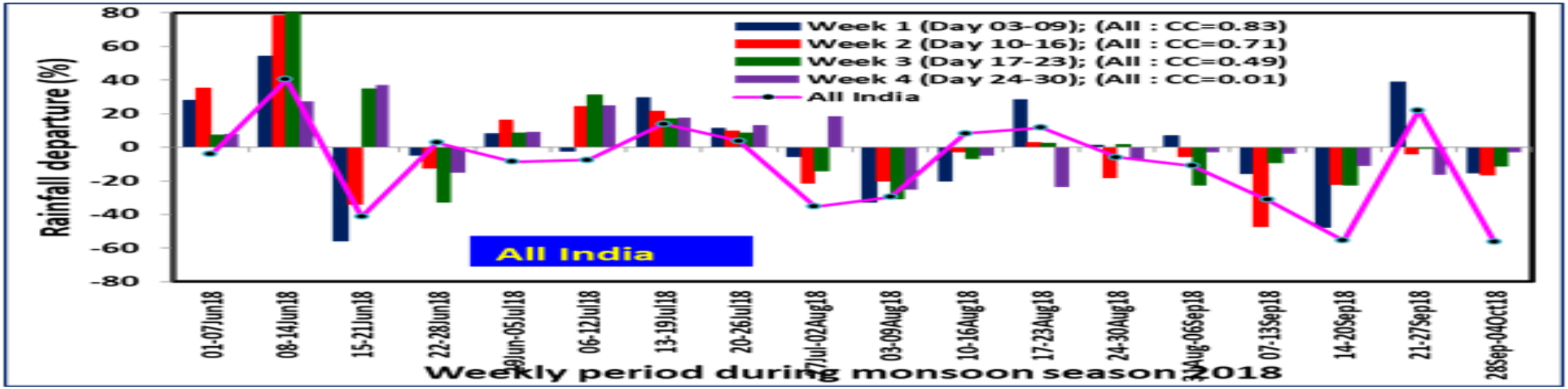
Standardized Precipitation Index (SPI) outlook based on the 4 weeks extended range forecast of 11 July, 2018 and valid for the period from 12 July to 8 August

All India and Monsoon Core Zone Rainfall During 2018 Monsoon

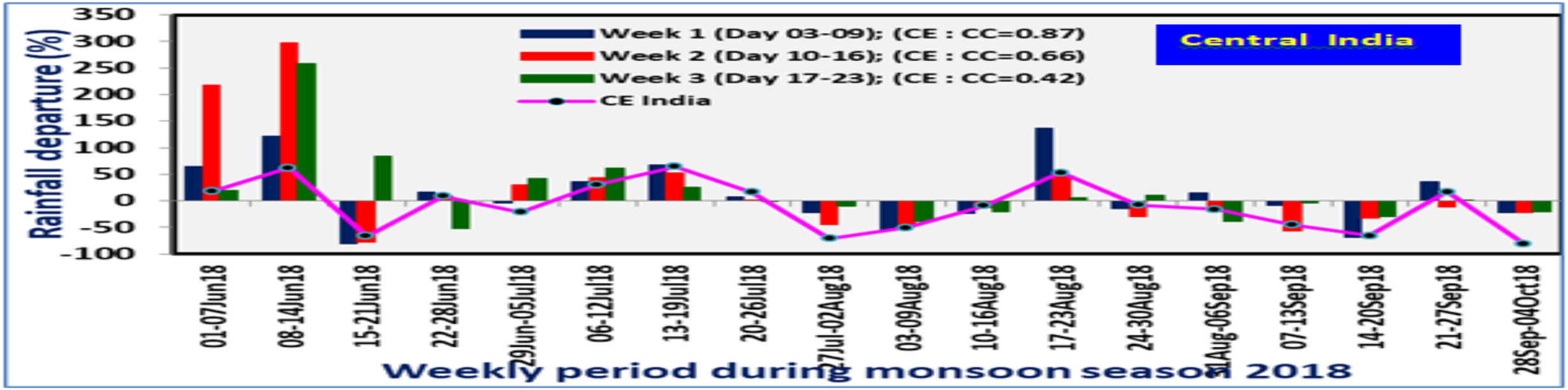


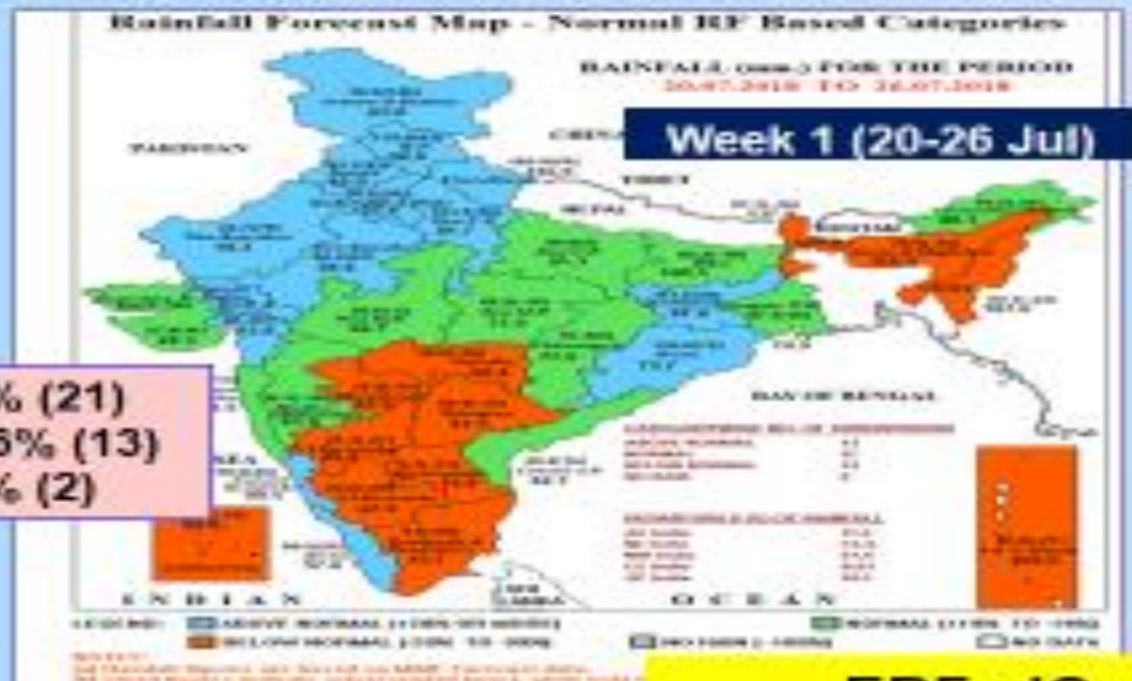
2018 ERF Monsoon Forecast Performance – All India and Central India

(a)



(b)



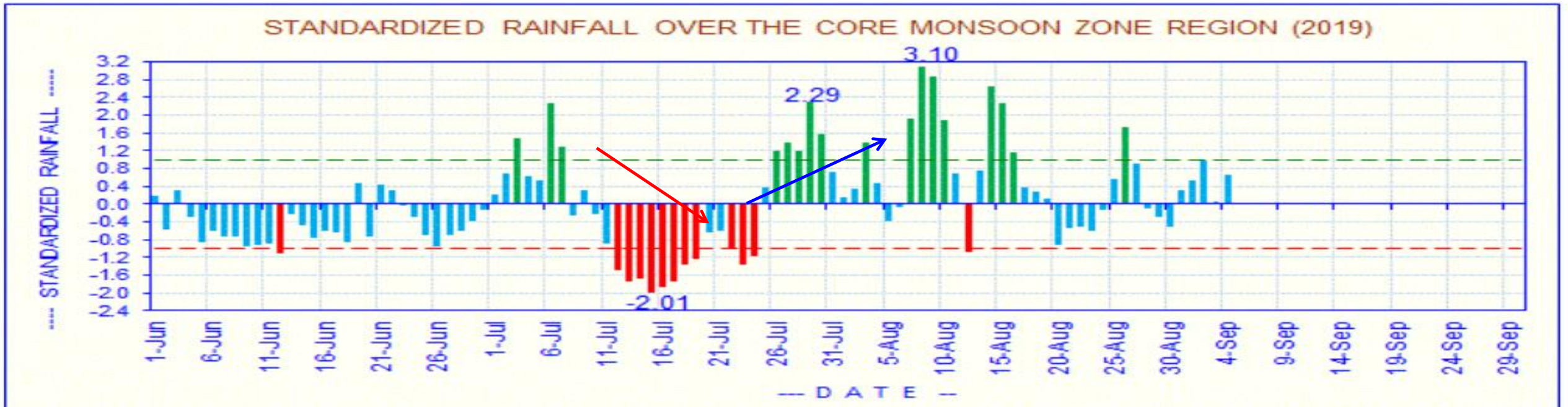


C =58% (21)
PC= 36% (13)
W = 6% (2)

C =72% (26)
PC= 20% (7)
W = 8% (3)

ERF : IC - 18 Jul, 2018

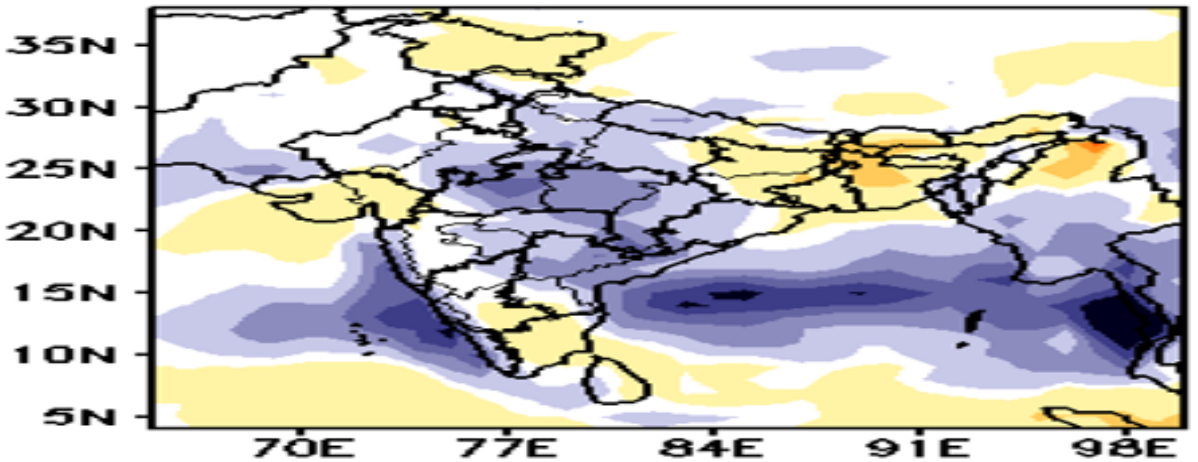
2019 Monsoon



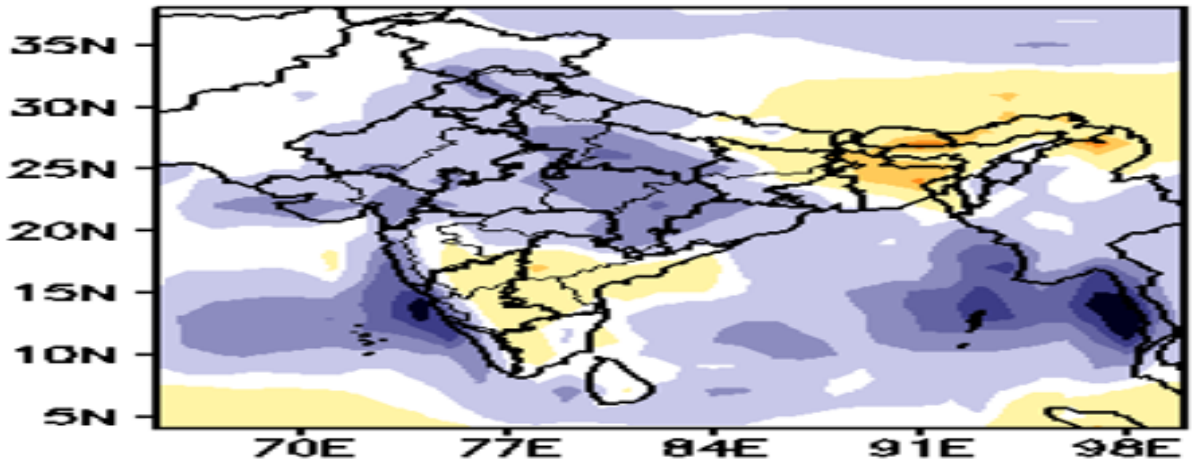
Predicted week wise weekly mean rainfall (MME) with % departure of rainfall over India as a whole and 4 homogeneous regions

Forecast Rainfall Anomaly (mm/day)

(Week1: 30Aug—05Sep)

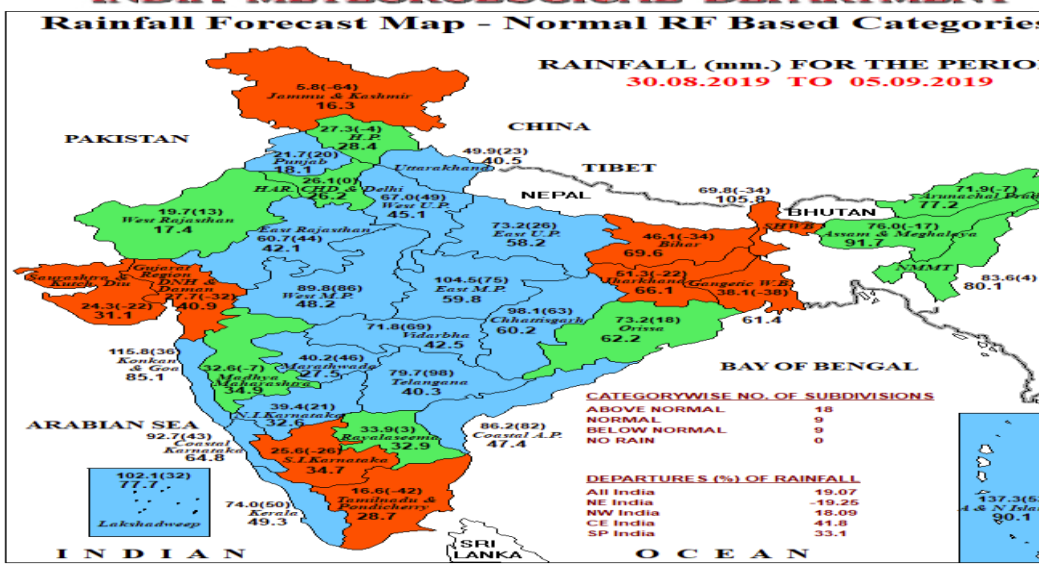


(Week2: 06Sep—12Sep)



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Rainfall Forecast Map - Normal RF Based Categories

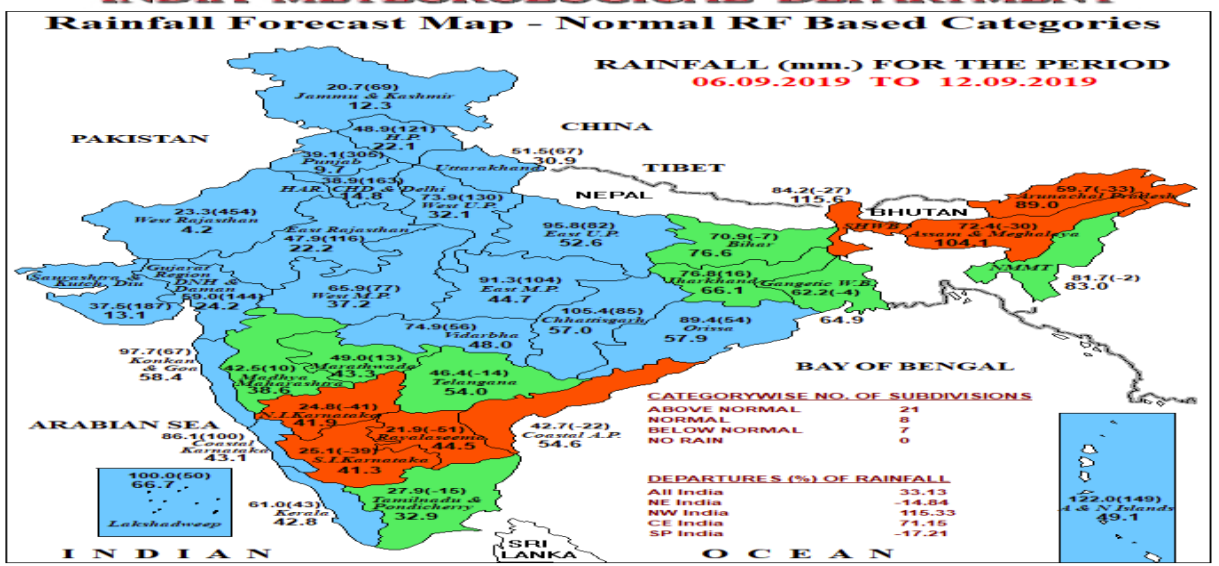


LEGEND: ABOVE NORMAL (+20% OR MORE) | NORMAL (+19% TO -19%) | BELOW NORMAL (-20% TO -99%) | NO RAIN (-100%) | NO DATA

NOTES:
(a) Rainfall figures are based on MME Forecast data.
(b) Small figures indicate actual rainfall (mm.), while bold figures indicate Normal rainfall (mm.)
Percentage Departures of Rainfall are shown in Brackets.

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Rainfall Forecast Map - Normal RF Based Categories



LEGEND: ABOVE NORMAL (+20% OR MORE) | NORMAL (+19% TO -19%) | BELOW NORMAL (-20% TO -99%) | NO RAIN (-100%) | NO DATA

NOTES:
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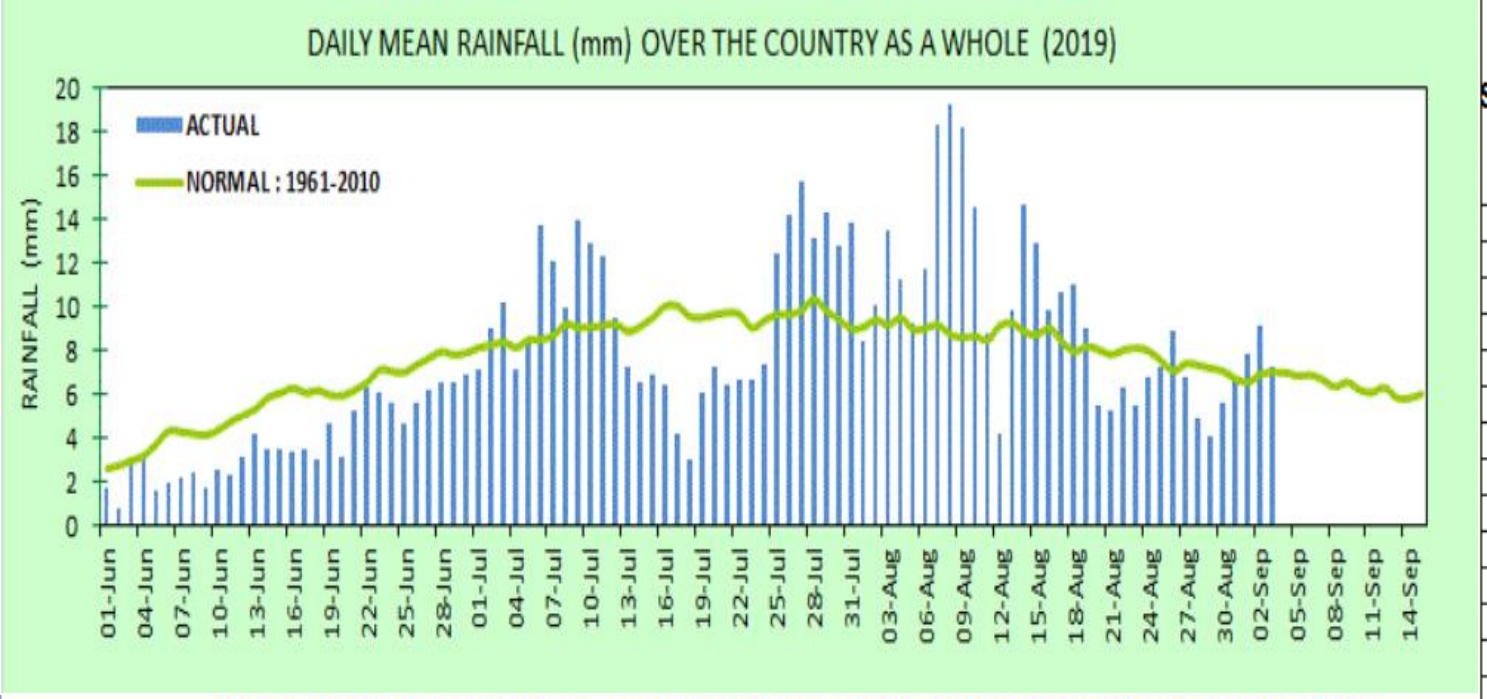
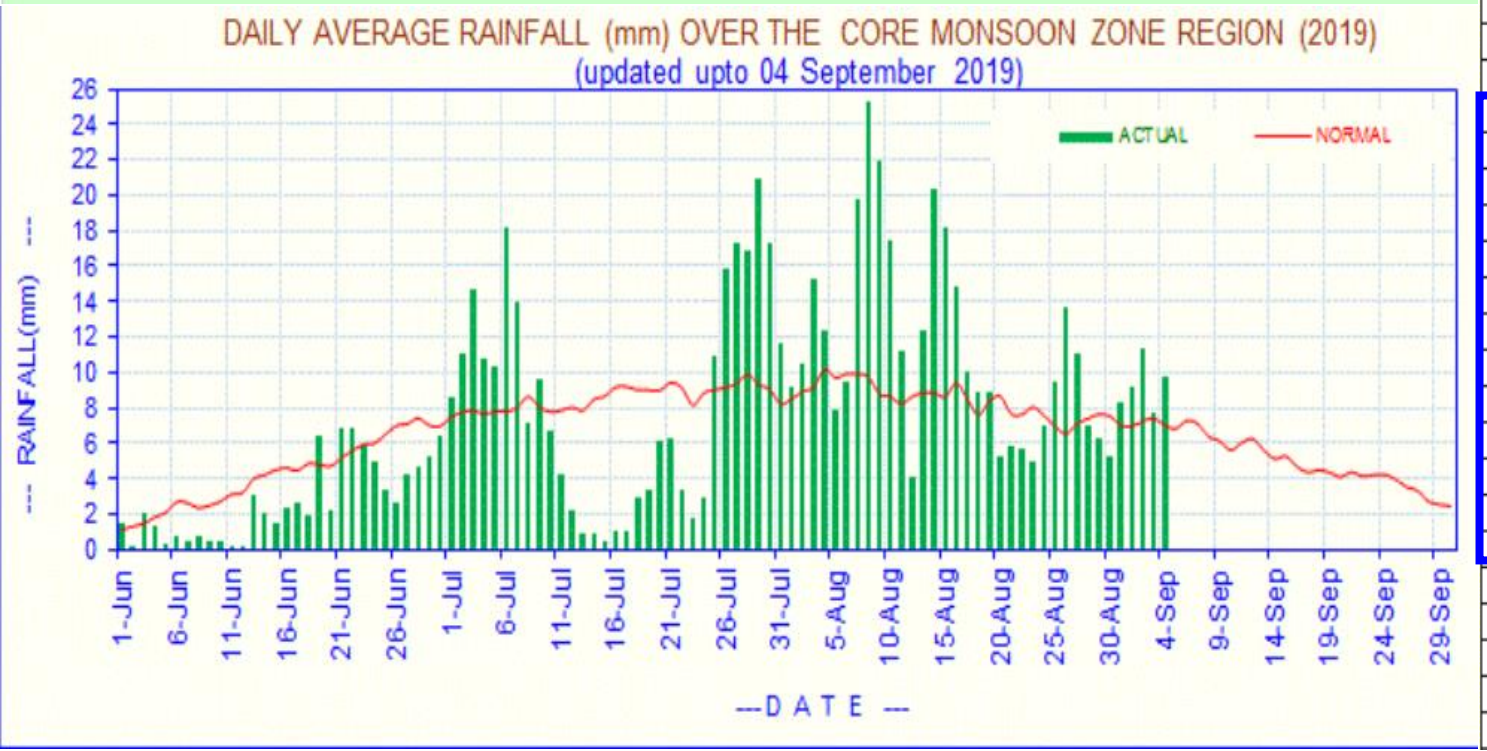
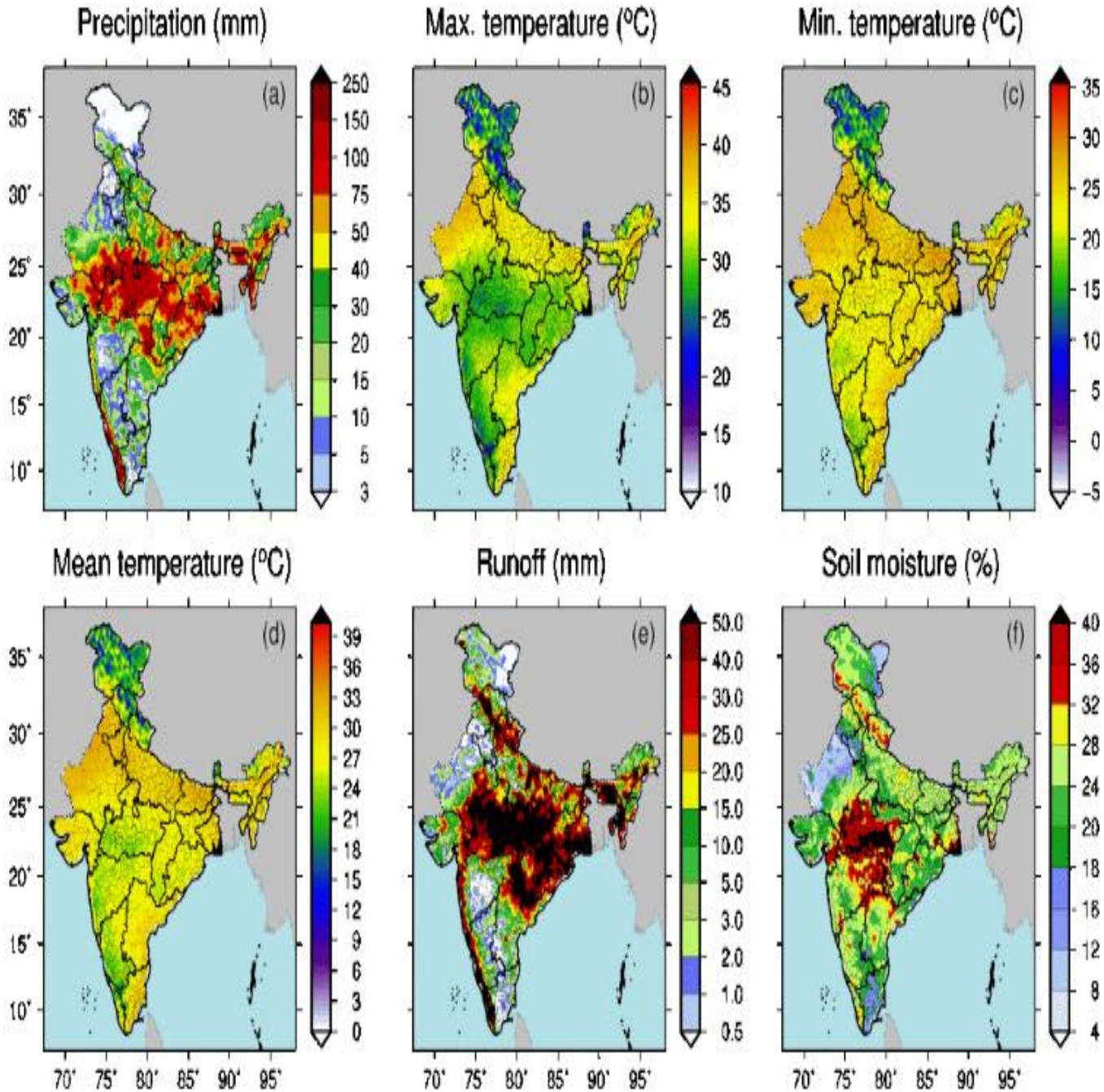


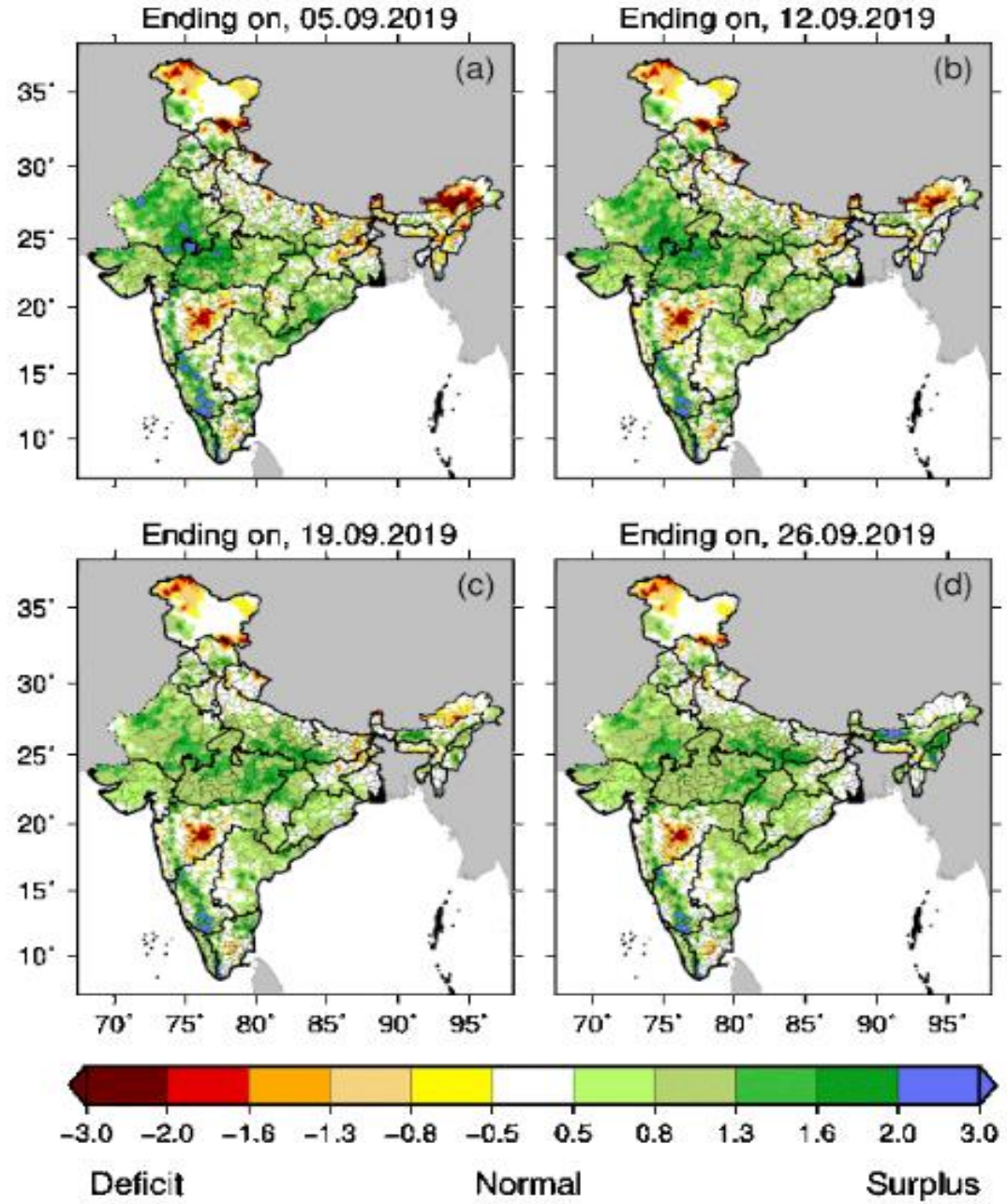


S.NO	MET.SUBDIVISION	WEEK ENDINGS																	
		5-Jun	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul	17-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug	28-Aug	4-Sep	11-Sep	18-Sep	25-Sep	30-Sep
1	A & N ISLANDS																		
2	ARUNACHAL PRADESH																		
3	ASSAM & MEGHALAYA																		
4	NAG.,MANI.,MIZO.& TRIPURA																		
5	S.H.W.B. & SIKKIM																		
6	GANGATIC W.B.																		
7	ODISHA																		
8	JHARKHAND																		
9	BIHAR																		
10	EAST U.P.																		
11	WEST U.P.																		
12	UTTARAKHAND																		
13	HAR., CHANDI.& DELHI																		
14	PUNJAB																		
15	HIMACHAL PRADESH																		
16	JAMMU & KASHMIR																		
17	WEST RAJASTHAN																		
18	EAST RAJASTHAN																		
19	WEST M.P.																		
20	EAST M.P.																		
21	GUJARAT REGION																		
22	SAURASHTRA & KUTCH																		
23	KONKAN & GOA																		
24	MADHYA M'RASHTRA																		
25	MARATHAWADA																		
26	VIDARBHA																		
27	CHATTISGARH																		
28	COASTAL A.P.																		
29	TELANGANA																		
30	RAYALASEEMA																		
31	TAMIL NADU																		
32	COASTAL KARNATAKA																		
33	N.I.KARNATAKA																		
34	S.I.KARNATAKA																		

23.8.2019–29.8.2019

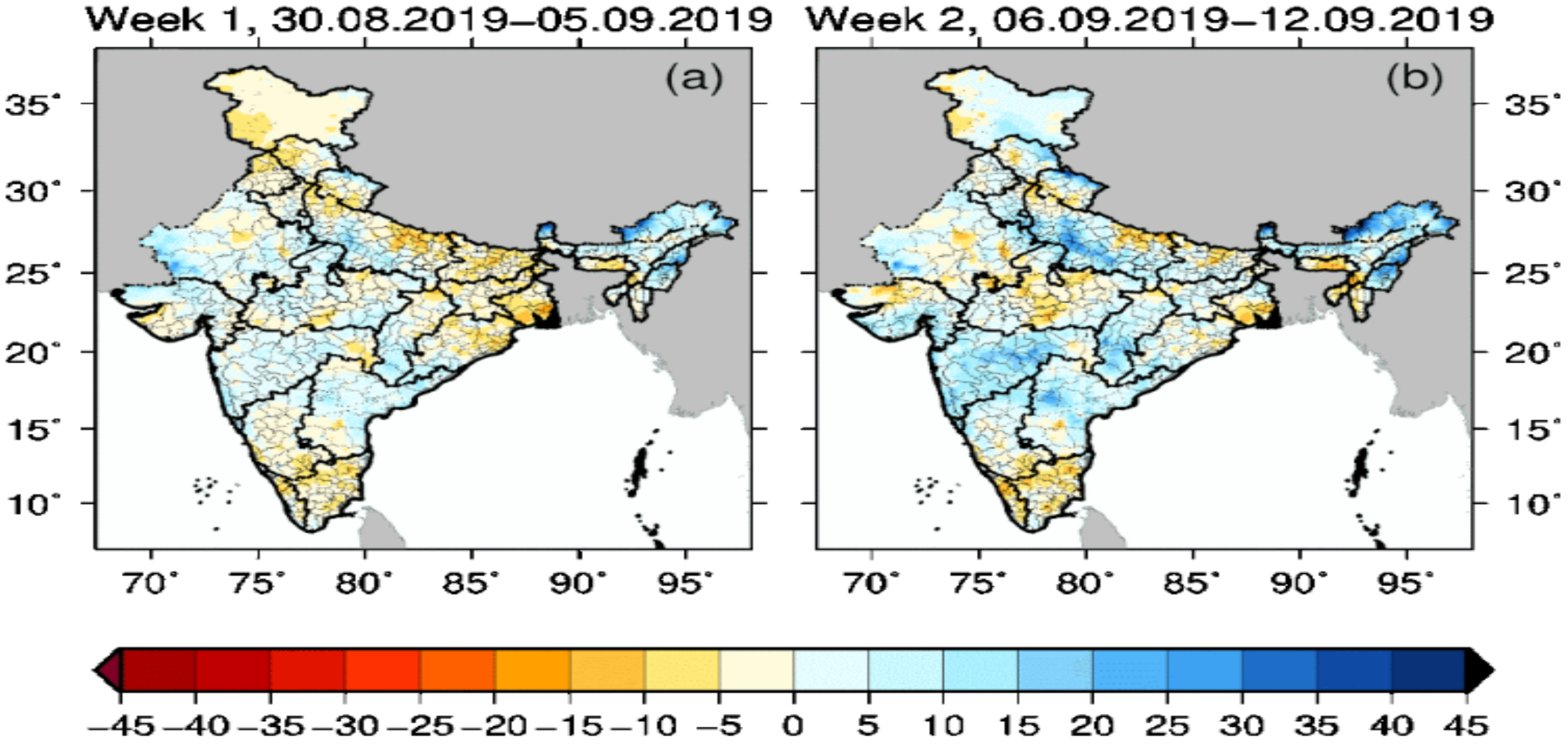


Standardized Soil Moisture Index
1 month SSI



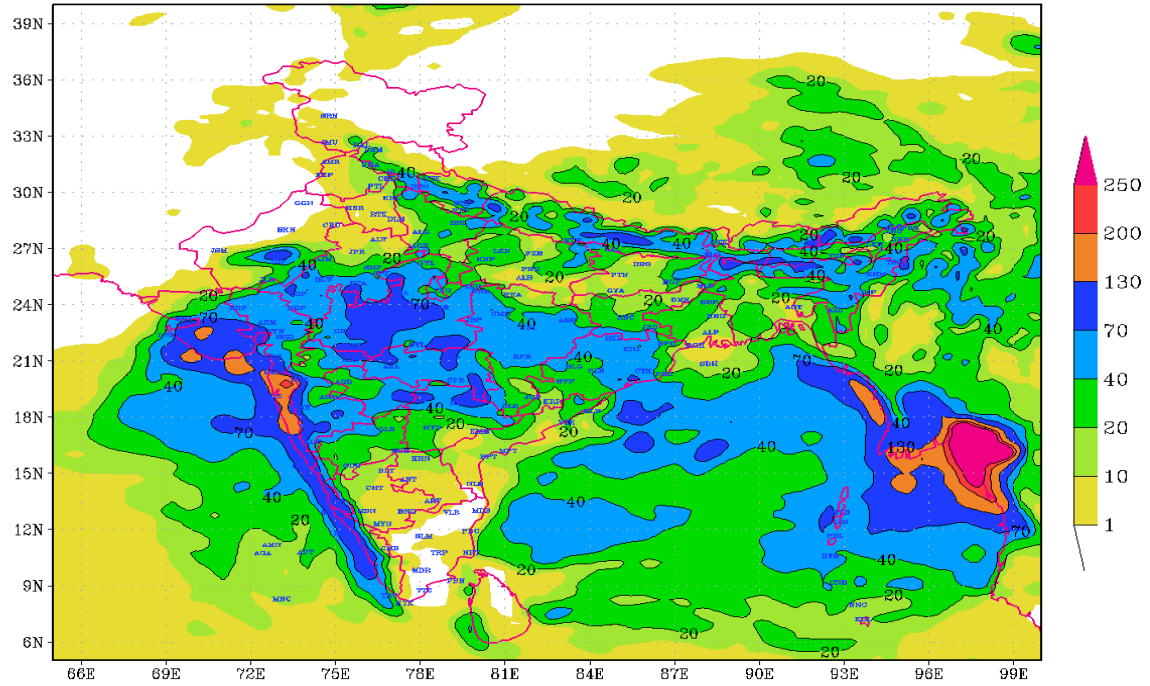
Anticipated weekly soil moisture change (mm)

w.r.t. previous week, 23.8.2019–29.8.2019



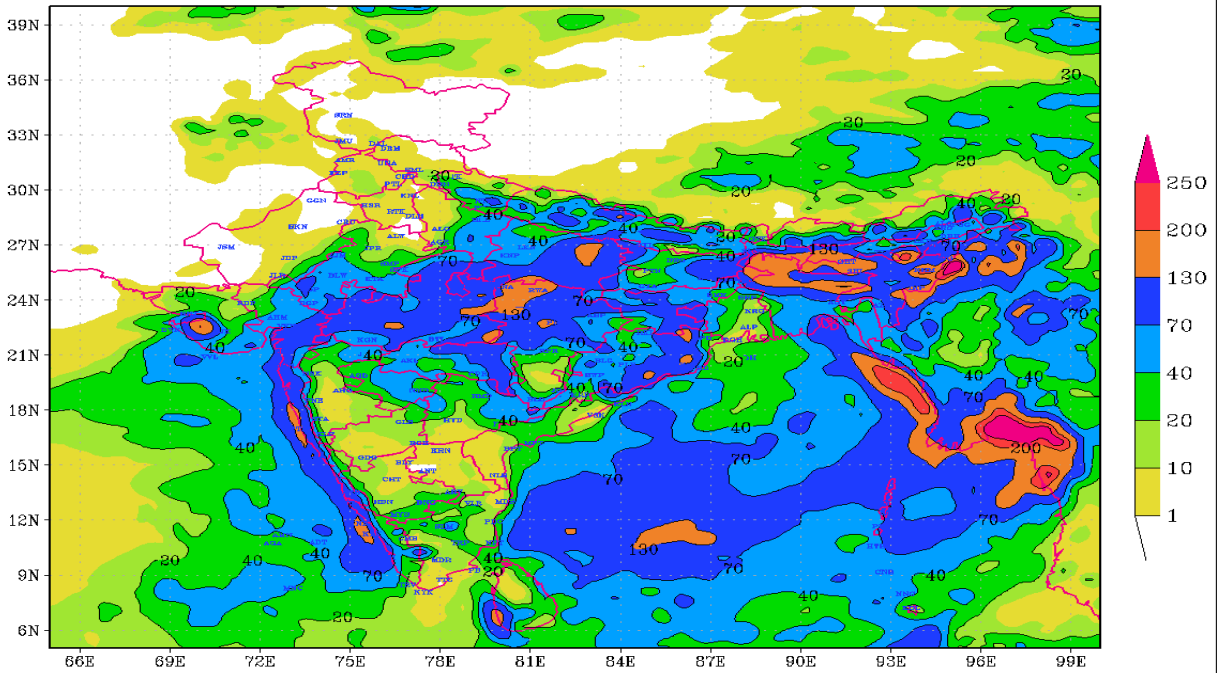
IMD:GFS MODEL(12 Km) CUM.RAINFALL (mm) FORECAST (Day1:Day3)

based on 00 UTC of 04-09-2019 valid for 03 UTC of 04-09-2019 to 07-09-2019



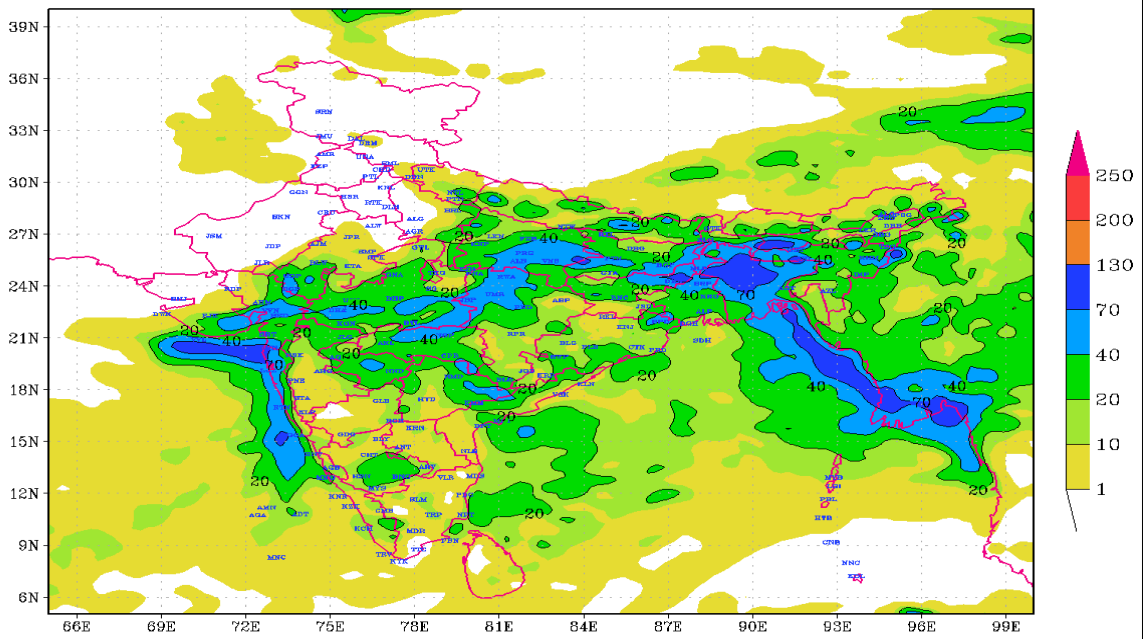
IMD:GFS MODEL(12 Km) CUM.RAINFALL (mm) FORECAST (Day4:Day8)

based on 00 UTC of 04-09-2019 valid for 03 UTC of 08-09-2019 to 12-09-2019



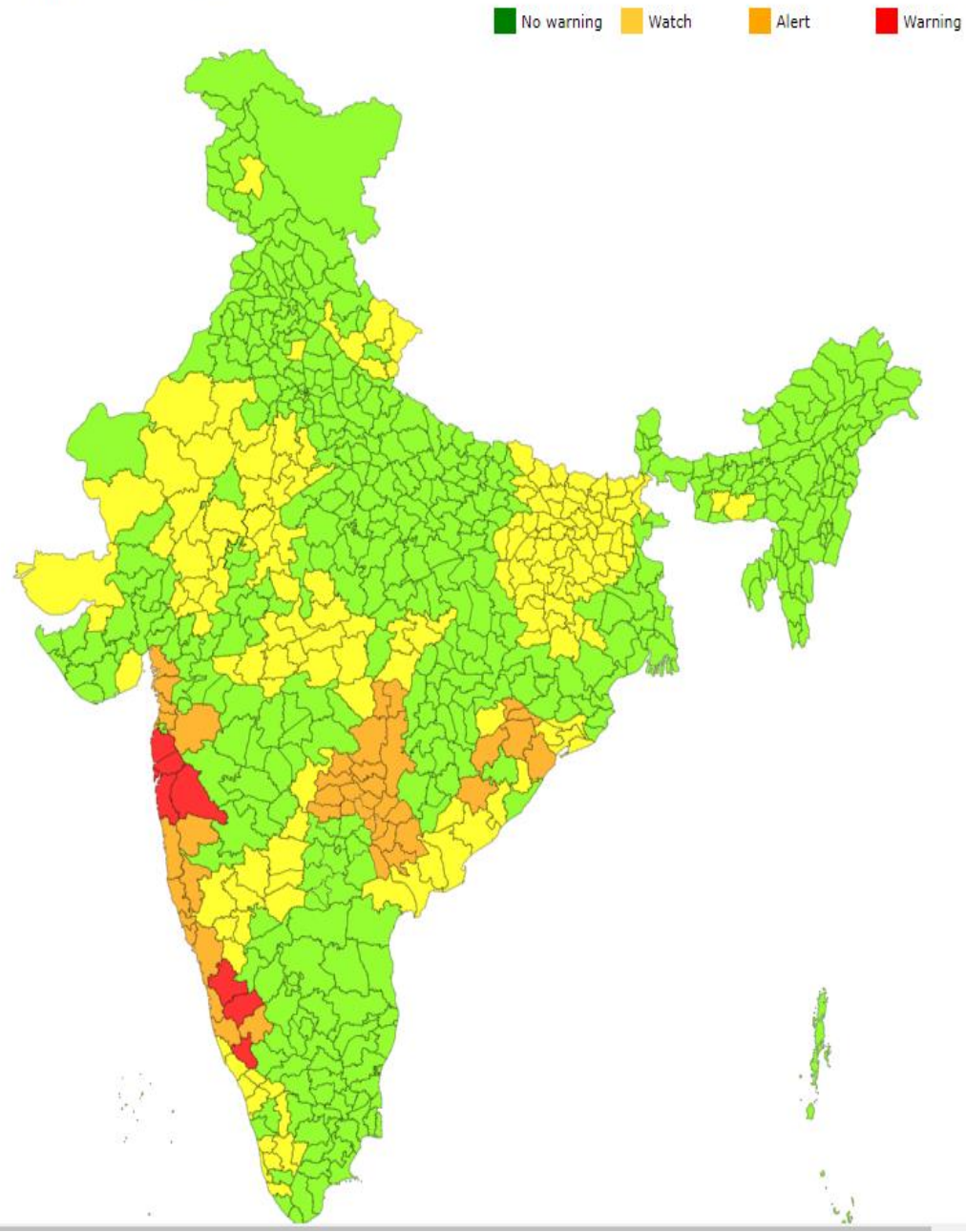
IMD:GFS MODEL(12 Km) CUM.RAINFALL (mm) FORECAST (Day9:Day10)

based on 00 UTC of 04-09-2019 valid for 03 UTC of 13-09-2019 to 14-09-2019

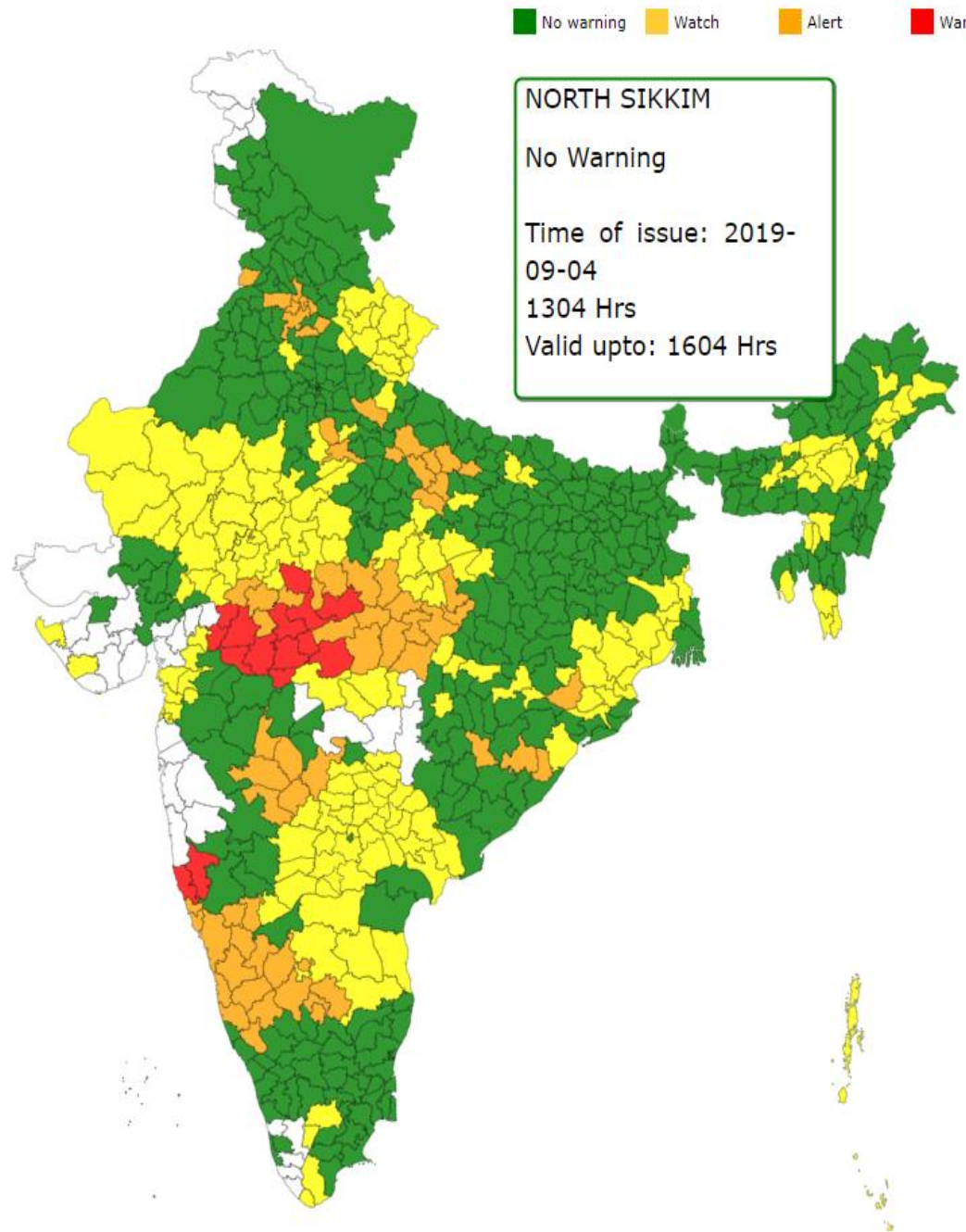


District-wise-warnings

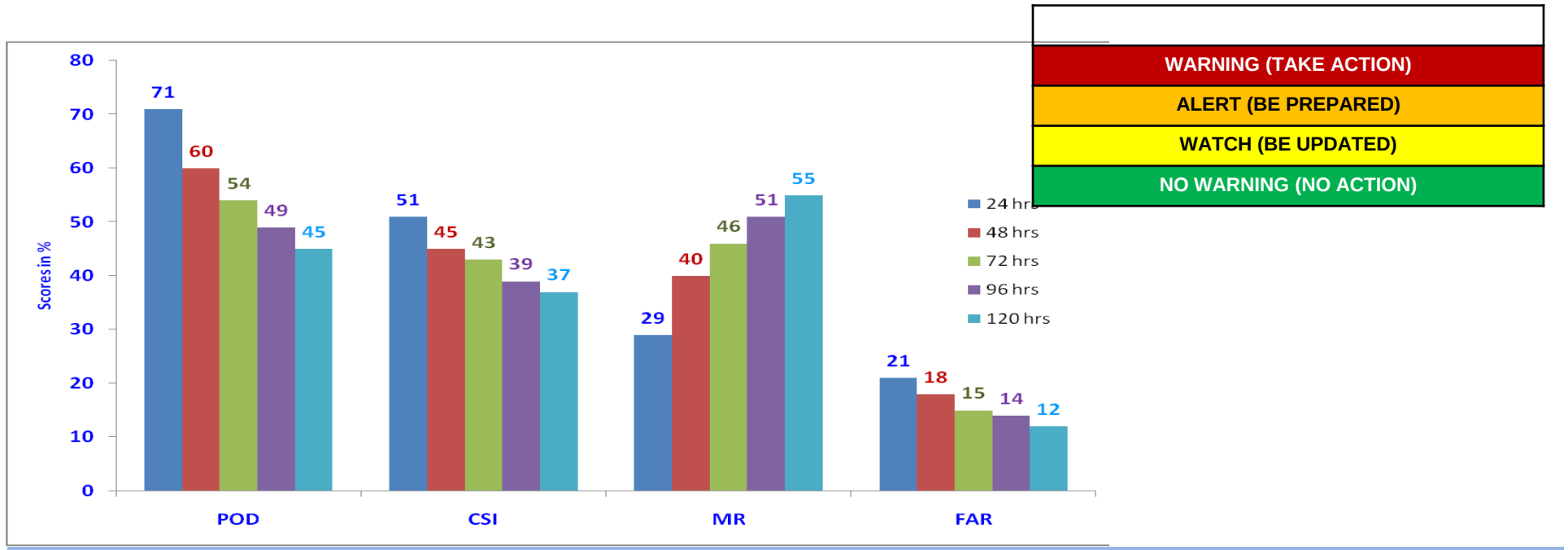
Day1 Day2 Day3 Day4 Day5



District wise Nowcast warnings



All India southwest Monsoon 2018 heavy rainfall warning skill (24, 48, 72, 96 & 120 hours)



WARNING (TAKE ACTION)
ALERT (BE PREPARED)
WATCH (BE UPDATED)
NO WARNING (NO ACTION)

- **Lead period of severe weather warning increased from 3 days to 5 days**
- **Colour coded meteorological subdivision and district level impact based warning issued across India**

Disasters 2018: Year in Review

Issue No. 54 | CRED Crunch | April 2019

315 Disaster Events (348*)

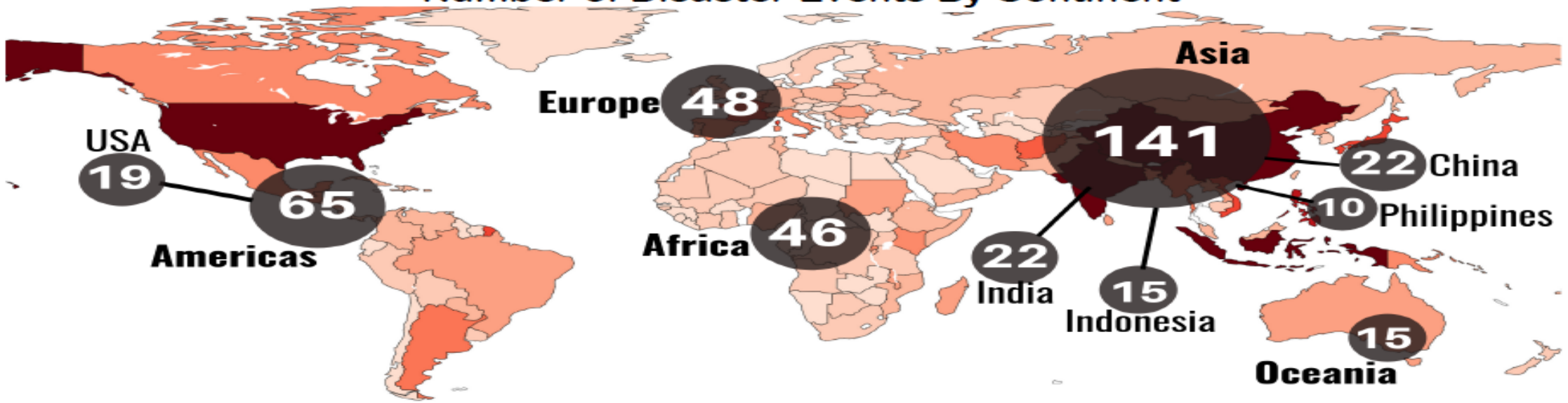
11,804 Deaths (67,572*)

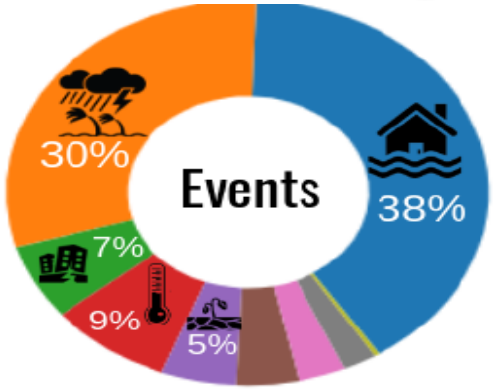
68.5 million Total Affected (198.8 million*)

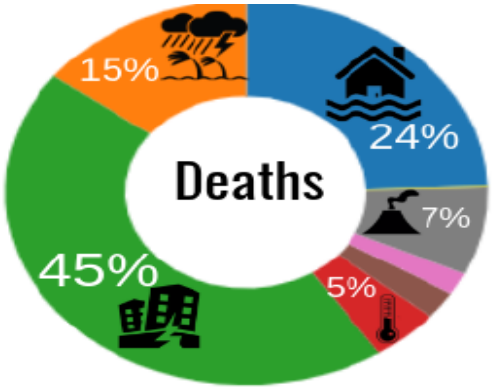
US$ 131.7 Billion Damages ($166.7 Billion*)

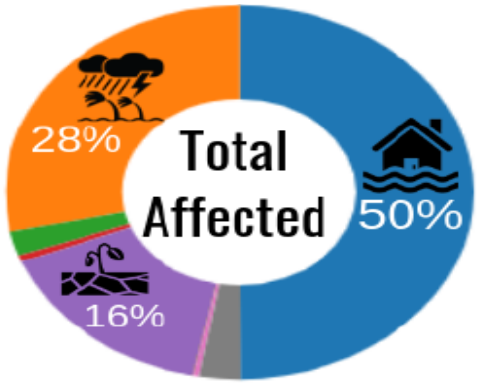
*2008-2017 Yearly Average

Number of Disaster Events By Continent

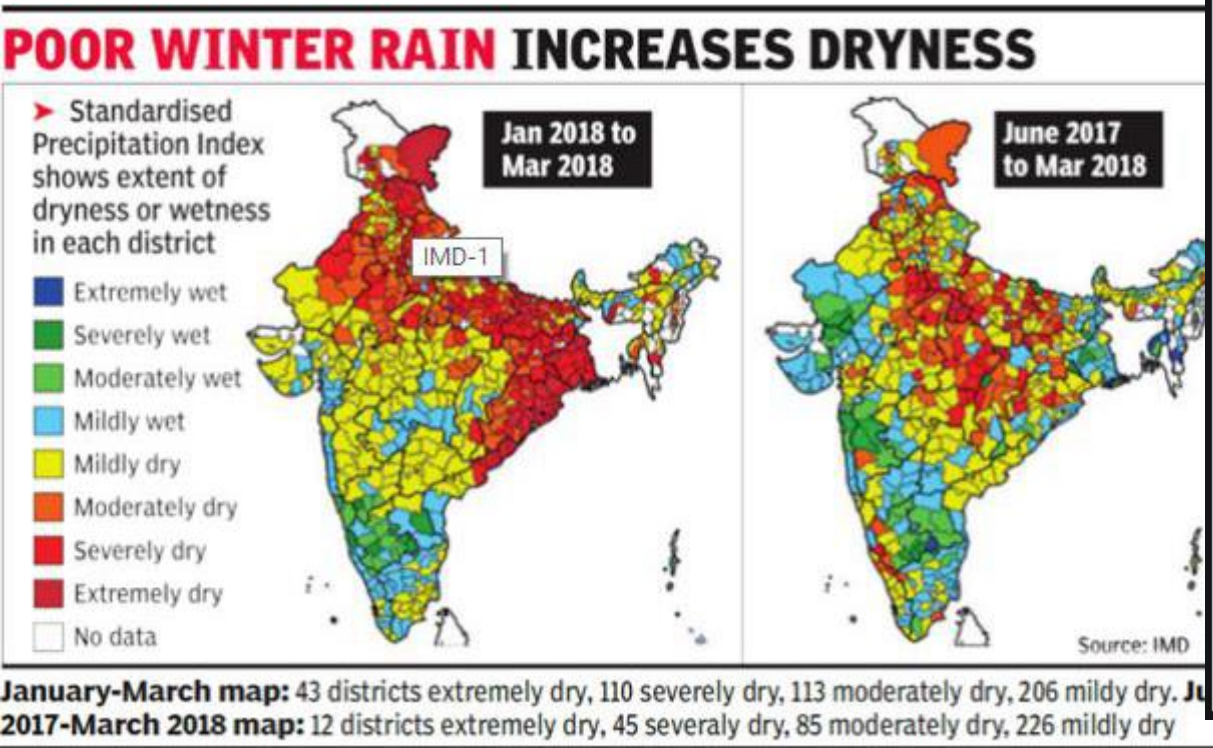


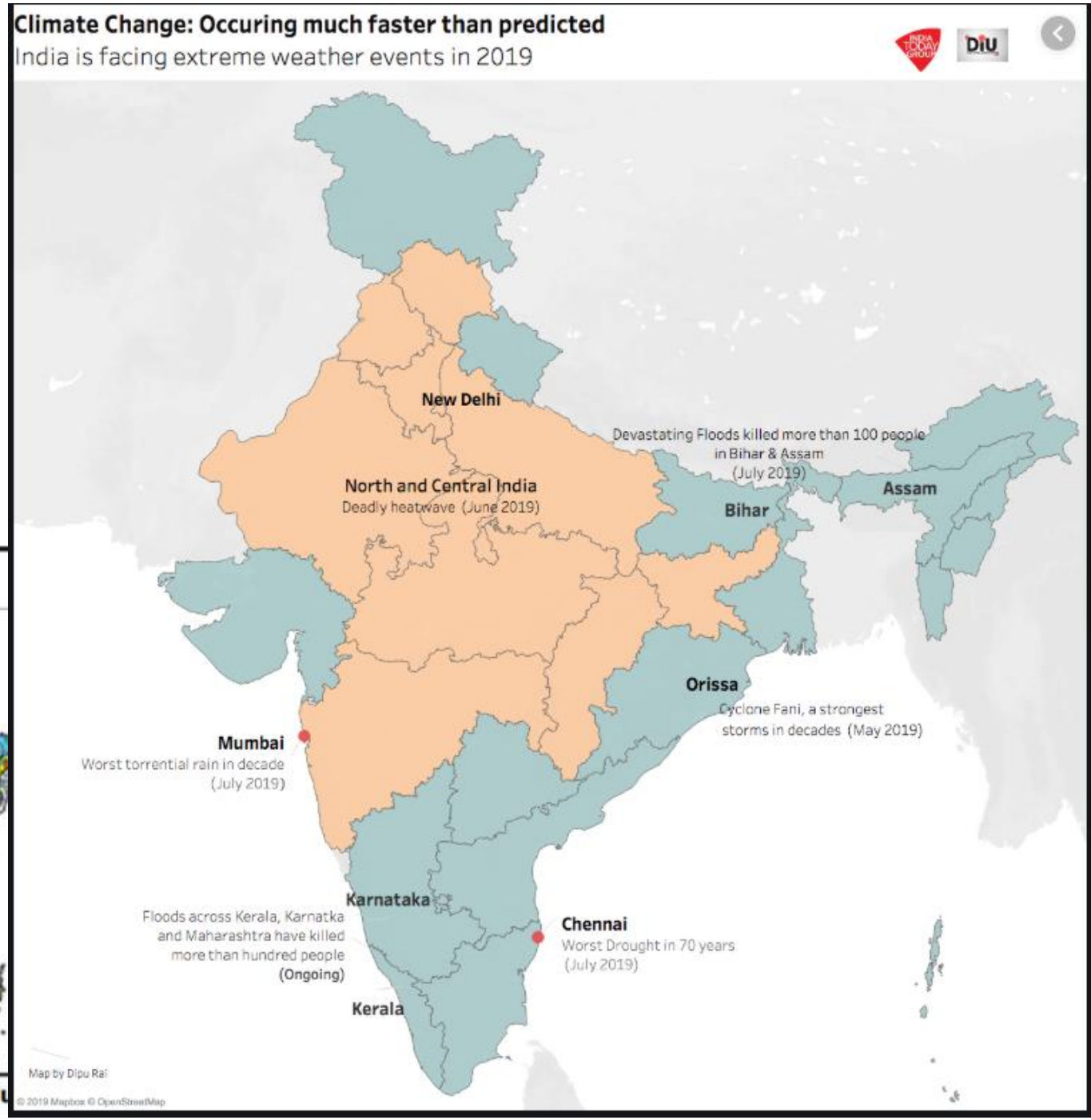






Ongoing situation: India in 2019





Ongoing situation

OCHA

SOUTH ASIA FLOODS
Humanitarian Snapshot

As of 25 July 2019

OVERVIEW

As a result of torrential monsoon rains mid July, over 25 million people have been affected by flooding in Bangladesh, India, Nepal and Myanmar. At least 600 people are known to have died and over half a million people have been displaced with homes, schools and hospitals damaged or destroyed. There is the possibility that the situation could deteriorate further as rains continue in many of the flood-affected areas.

The governments in all four countries are leading the response with support from in-country humanitarian agencies, national Red Cross/Red Crescent Societies, private sector and militaries.

BANGLADESH[1]

4,000,000 people affected

187,000 people displaced

Figures as of 21 July

INDIA[2]

20,800,000 people affected

428,000 people displaced

Figures are for Bihar and Assam states as of 22 July

MYANMAR[3]

78,000 people displaced

186 evacuation sites

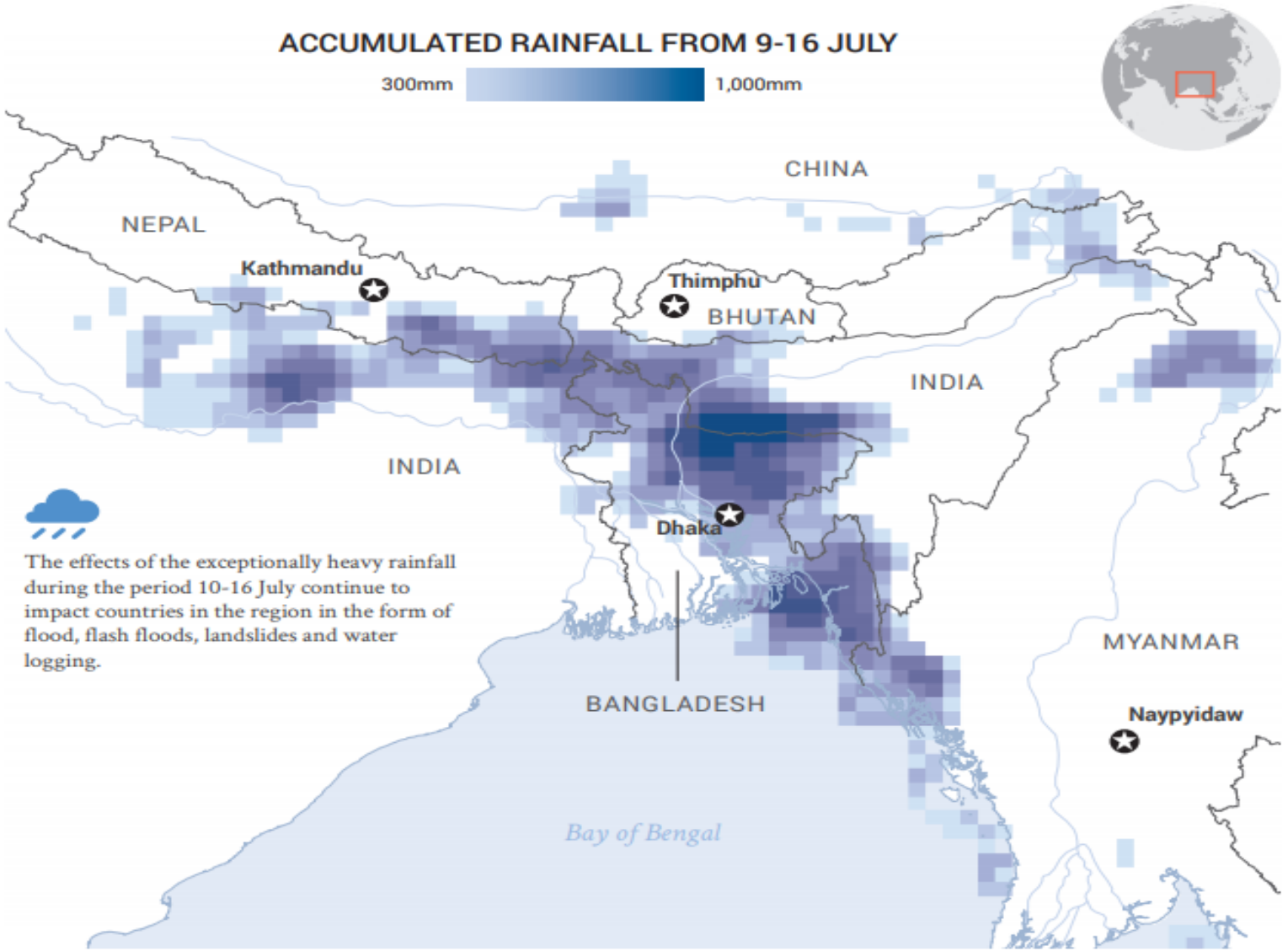
Figures as of 23 July

NEPAL[4]

375,000 people affected

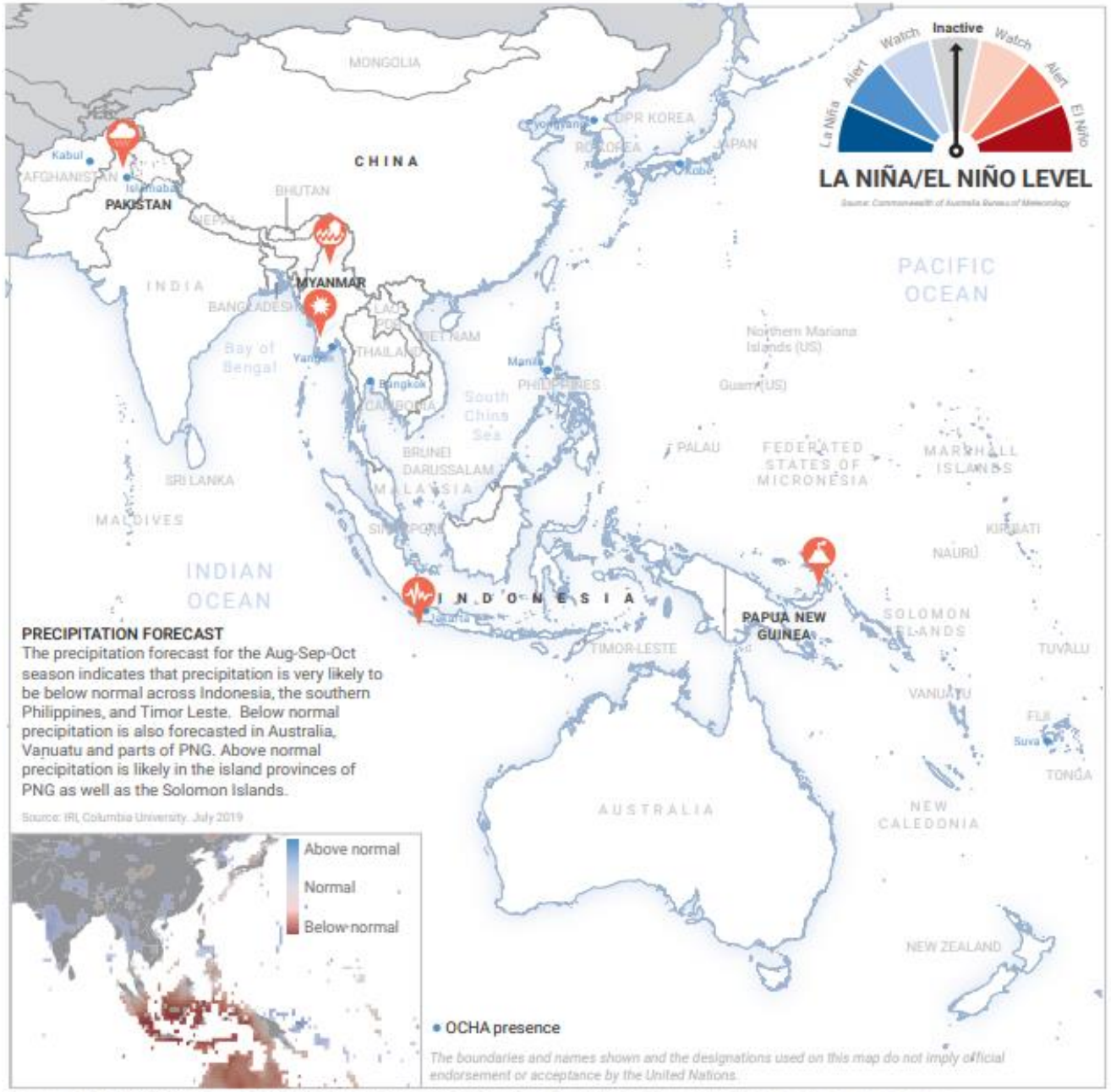
80,000 people displaced

Figures as of 21 July



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Creation date: 25 July 2019 **Sources:** Rainfall data: NASA, 1. Bangladesh RCO, 2. MoHA, 3 OCHA Myanmar, 4. Nepal Red Cross **Feedback:** marinosj@un.org www.unocha.org/roap www.reliefweb.int

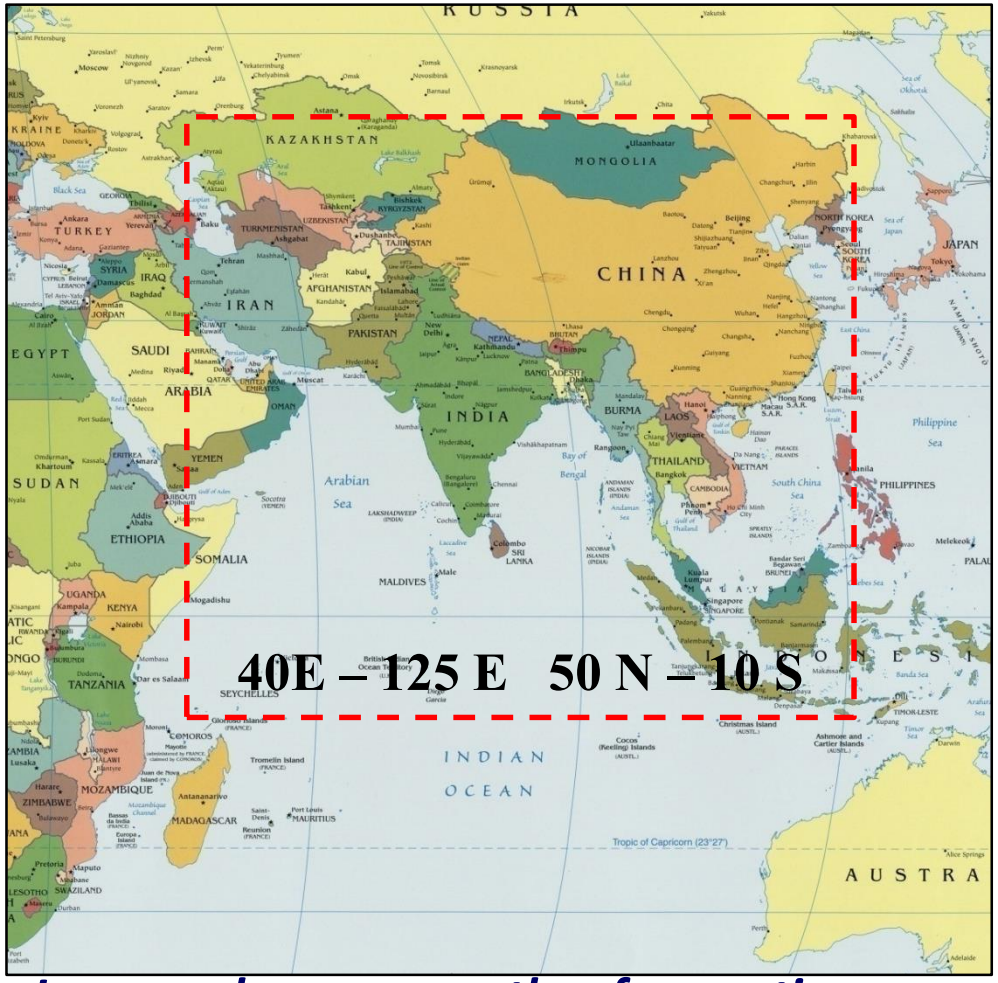


Ongoing situation

Pakistan

- As of July 25, 2019 104 people died from floods and extreme rain events in North Pakistan
- 1.2 million people in Sindh province suffering from droughts.

SWFDP – Bay of Bengal



- Bangladesh
- India
- Maldives
- Myanmar
- Sri Lanka
- Thailand
- Bhutan
- Nepal
- Afghanistan
- Pakistan

Severe Weather from TCs,
severe thunderstorms and monsoon:
Heavy precipitation, Strong winds
Large waves / swell, Storm Surge

Improved severe weather forecasting , warning services to disaster management (PWS) and other sectoral applications

Discussion

- Several lessons learned but still many gaps exist
- Good forecasts available but need to make maximum use of available information
- Extremes continue to surprise every year with new definition for extremes
- Changing dynamics of both nature and human dimensions – proactive institutional roles and dynamic risk assessment frameworks need to be developed
- Robust linkages between Science and Society
- More coordinated actions

What went wrong?

Available databases not sufficient

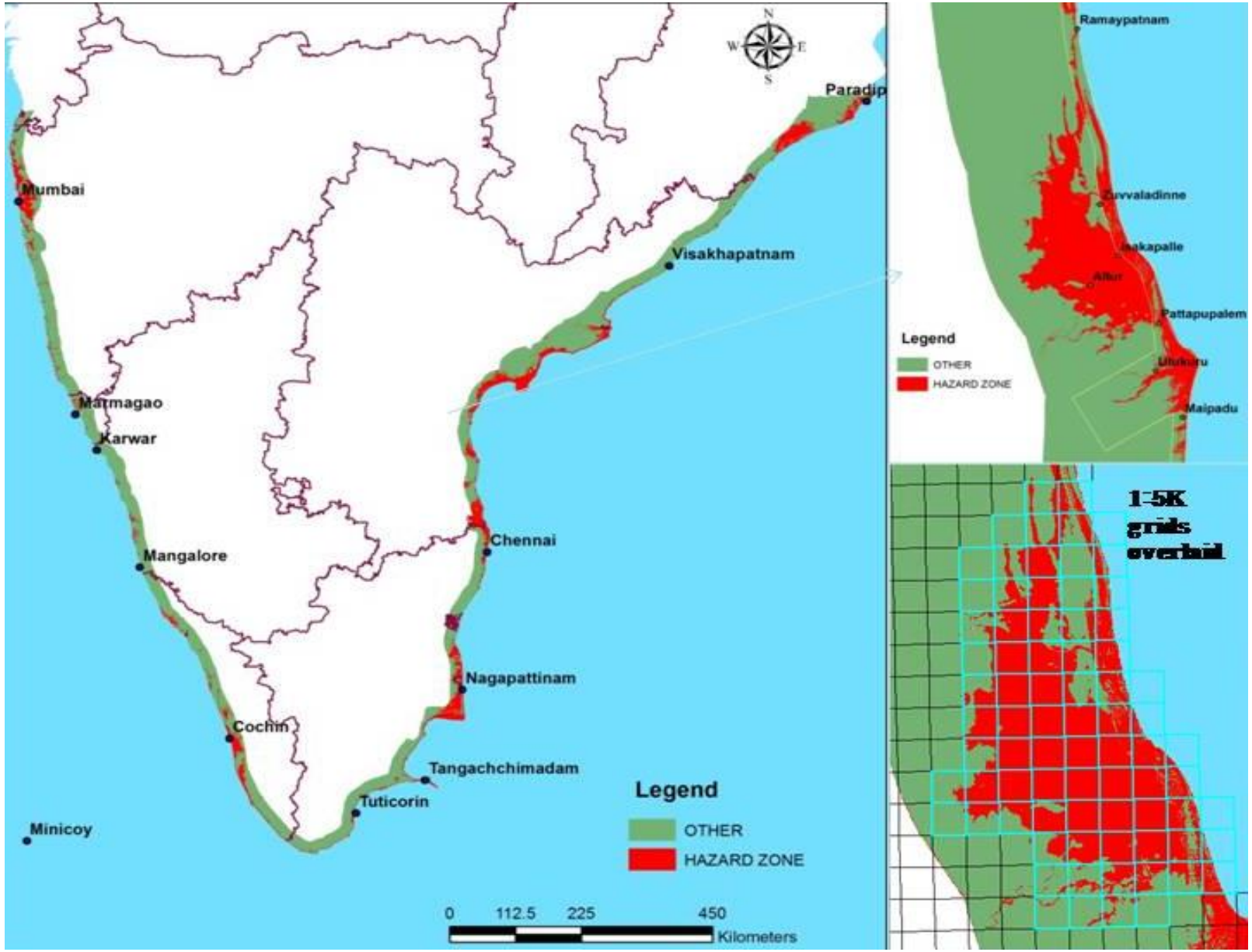
Forecast not reaching the last mile

Agencies not able to respond

Discussion

- We have achieved a lot in the past
- Need to appreciate the realities of 2018 and 2019
- Understand ground situation, requirements of society and how to collaborate locally **to overcome** the new challenges

Multi-Hazard Vulnerability



Thanks !