CEOP-AEGIS

Coordinated Asia-**E**uropean long-term **O**bserving system of Qinghai–Tibet **P**lateau hydro-meteorological processes and the **A**sian-monsoon syst**E**m with **G**round satellite **I**mage data and numerical **S**imulations

www.ceop-aegis.org

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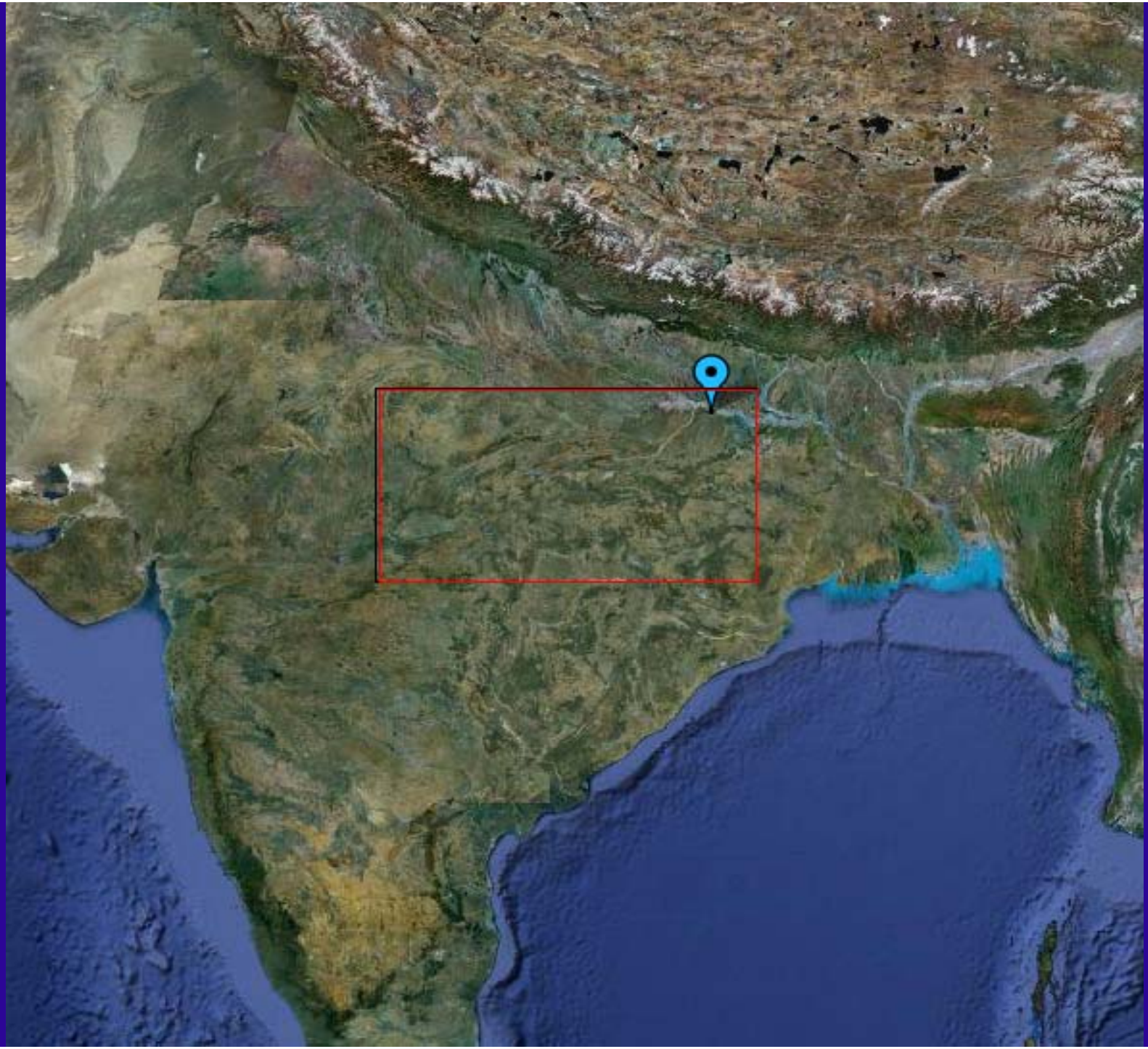
Delft University of Technology	Massimo Menenti	The Netherlands

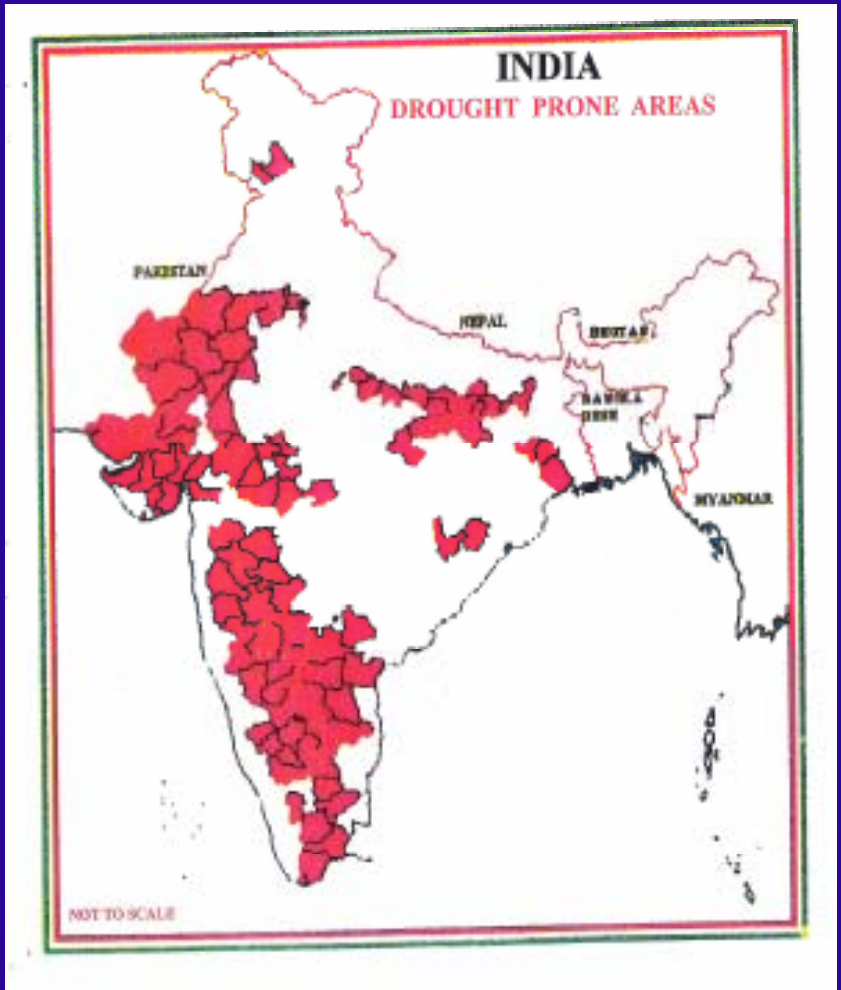
Work progress in WP 9 and achievements during May- September 2009

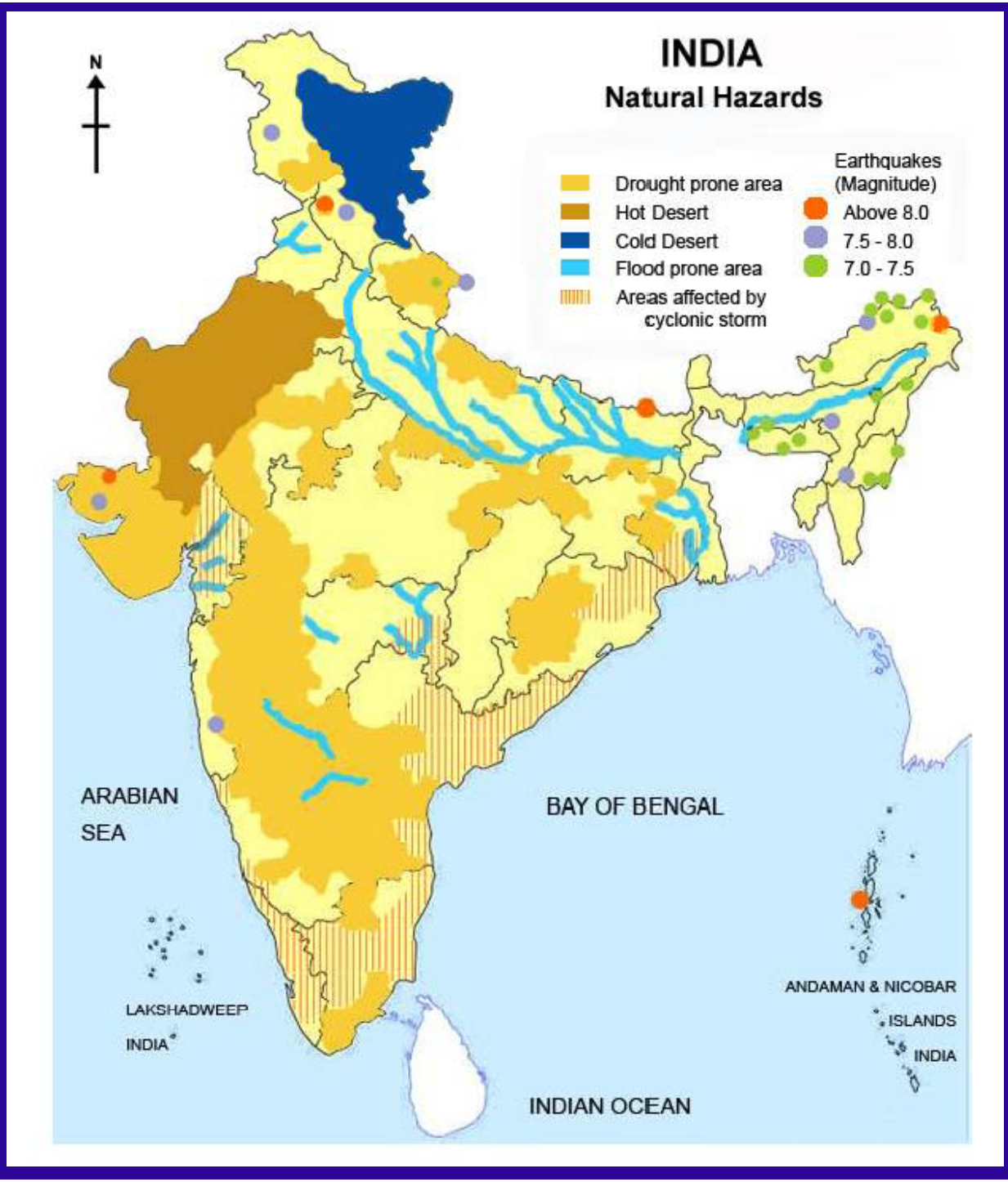


Preliminarily defined pilot areas in India:

- Betwa sub-basin of Yamuna Basin (Which is again a part of Ganga basin)
- Punpun sub-basin of Ganga basin
- Tel sub-basin of Mahanadi basin

DROUGHT PRONE AREAS OF INDIA




INDIA
Natural Hazards
N
Drought prone area
Hot Desert
Cold Desert
Flood prone area
Areas affected by cyclonic storm
Earthquakes (Magnitude)
Above 8.0
7.5 - 8.0
7.0 - 7.5
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
LAKSHADWEEP
INDIA
ANDAMAN & NICOBAR
ISLANDS
INDIA

CRITERIA OF METEOROLOGICAL DROUGHT in INDIA

- WHEN RAINFALL OF SOUTH WEST MONSOON SEASON IS LESS THAN 75% OF NORMAL RAINFALL FOR DISTRICT/MET sub DIVISION ,THAT AREA IS TAKEN TO BE UNDER DROUGHT CONDITION.

- WHEN RAINFALL IS IN BETWEEN 50 TO 74% OF NORMAL SEASONAL RAINFALL THE AREA IS UNDER MILD DROUGHT CONDITION.

- WHEN SAME RAJNFALL IS BELOW 50% OF NORMAL, AREA IS UNDER SEVERE DROUGHT CONDITION.

IMPORTANT DROUGHT EVENTS INDIA

- **THE DROUGHT YEARS that is WHEN 20% OR MORE AREA OF THE COUNTRY SUFFERED FROM DROUGHT(rainfall < 75% of normal) SINCE 1801 AD ARE**

1801, 1804, 1806, 1812, 1819, 1825, 1832, 1833, 1837, 1853, 1860, 1862, 1866, 1868, 1873, 1877, 1883, 1891, 1897, 1899, 1901, 1904, 1905, 1907, 1911, 1918, 1920, 1939, 1941, 1951, 1965, 1966, 1971, 1972, 1974, 1979, 1982, 1987 and 2002.

- THERE ARE 39 DROUGHT YEARS SINCE 1801 INDICATING RECCURANCE INTERVAL OF @ 5 YEARS.

- THERE ARE 4 OCCASSIONS WHEN DROUGHT CONTINUED FOR 2 YEARS AND 9 INSTANCES WHEN DROUGHT RECURRED IN ALTERNATE YEARS.

- THE AREA OF @ 511300 SQ. KMS IS DROUGHT PRONE.

Severe Drought Events in India

YEAR	% AREA AFFECTED	%DEPARTURE OF RAINFALL IN AFFECTED AREA
1918	71	- 49
1965	41	- 36
1972	47	-35
1979	45	-38
1987	50	-45
2002	29	-43

Recurrent Interval of Drought

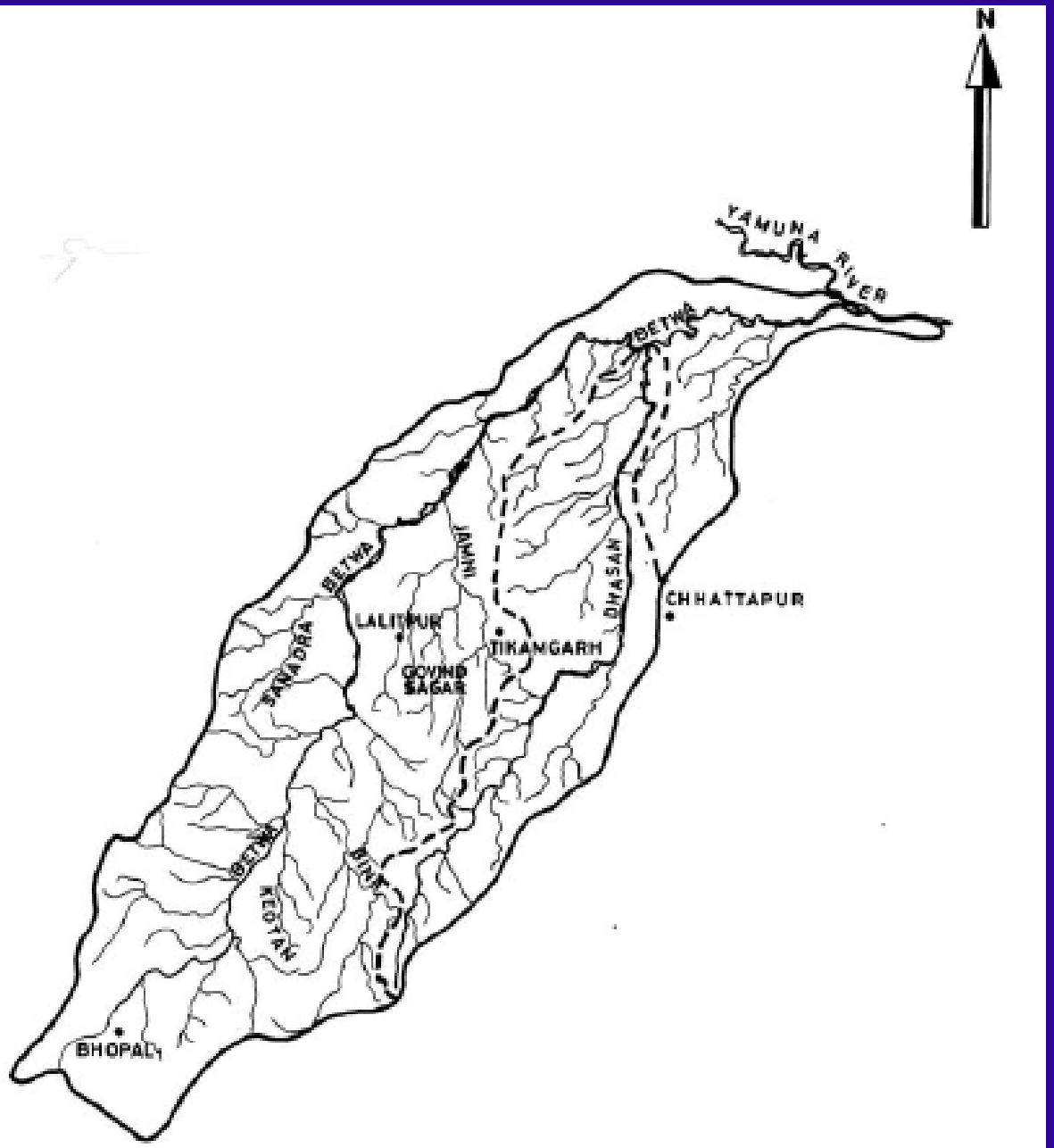
REURRENT INTERVAL	% AREA OF THE COUNTRY
< 5 YEARS	9
5 – 10 YEARS	47
10 – 15 YEARS	18
15 – 20 YEARS	13
VERY RARE	13

DATA COLLECTION & ANALYSIS

- HYDROLOGICAL DATA HAVE B EEN COLLECTED FROM BETWA RIVER BASIN(20-40 YEARS), TEL BASIN (7-10 YEARS) AND PUNPUN BASIN (5-7 YEARS).
- DATA ARE BEING COLLECTED FOR LONGER DURATION FROM TEL AND PUNPUN RIVER SYSTEMS
- METHODOLOGY HAS BEEN DEVELOPED (MAY BE MODIFIED AFTER DISCUSSIONS)
- CASE STUDY OF BEWA BASIN IS DISCUSSED

In India, rainy (or monsoon) season varies from 2–4 months in major part of the country, and the remaining 8–10 months are nearly dry, with very little or no rain. During lean (or non-rainy) period, the availability of water in streams, tanks, ponds, reservoirs etc. decreases sharply in drought prone areas of the country. Therefore, an appraisal of the available flows in rivers in both time and space becomes vital for year-plan formulation or modification of water uses comprising domestic/industrial water supply, irrigation scheduling, reservoir operation, in-stream flow maintenance, hydro-power generation etc., for sustainability of regional economic and ecological activities.

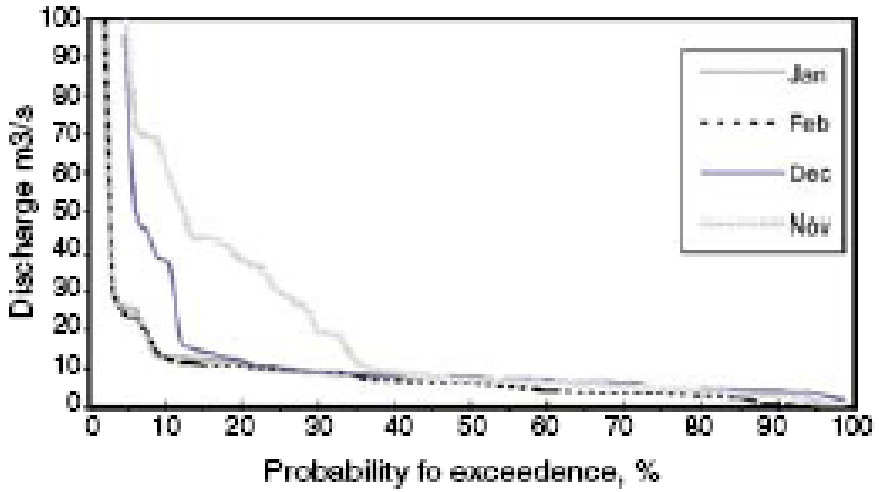
Abstract Streamflow appraisal in time and space particularly in semi arid and dry sub humid regions has vital importance in the formulation of round the year plan of water uses comprising domestic & industrial water supply, irrigation scheduling, reservoir operation, in-stream flow maintenance etc. Drought severity analysis including the estimation of flow availability, drought duration, and deficit volume etc. was carried out using the 20–42 years (1960–2001) 10-daily streamflow data of five sites on the Betwa River system and. independent streamflow drought events were described by pooling the data, and severity of an independent drought event classified using a new drought severity index (DSIe) defined as a function of (1) the ratio of deficit flow volume to corresponding volume at the truncation level and (2) the ratio of duration of deficit flow to the maximum possible duration of the independent streamflow drought event. The study found that the upper reaches of river course were more prone to severe droughts than were the lower reaches. The drought events starting during August−November were more likely to be severe drought events than those in the other months.

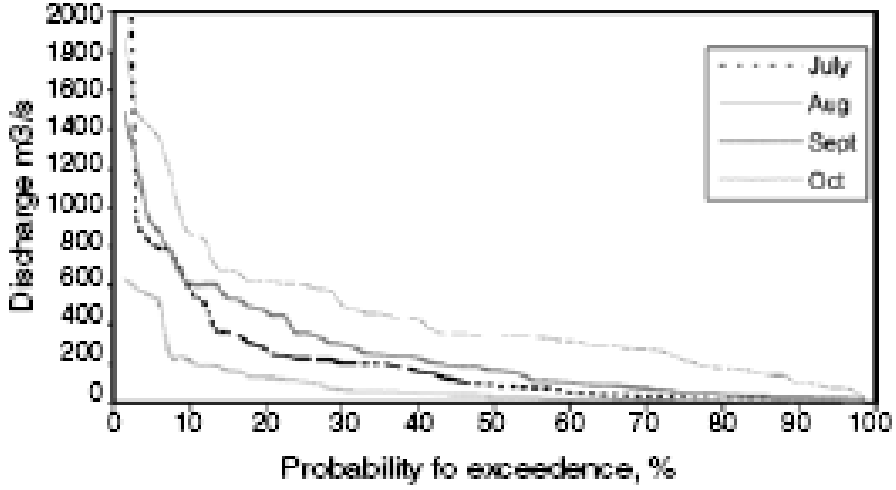


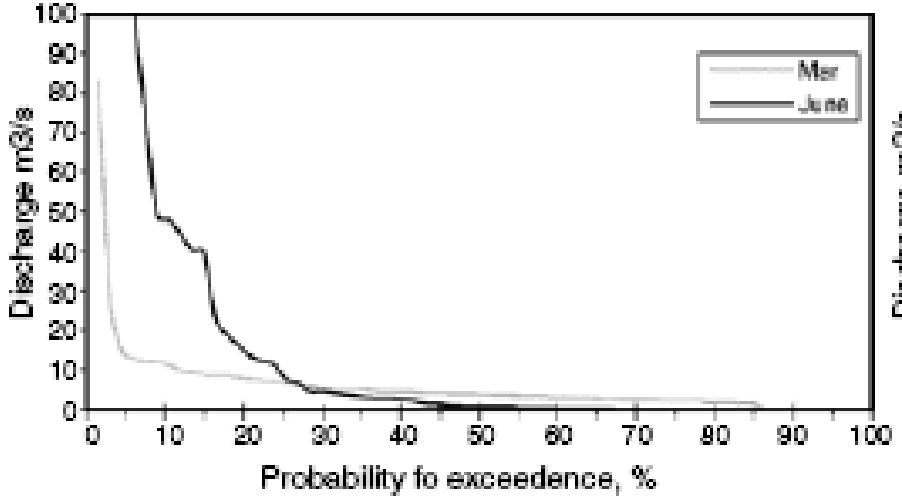
Index map of Betwa basin

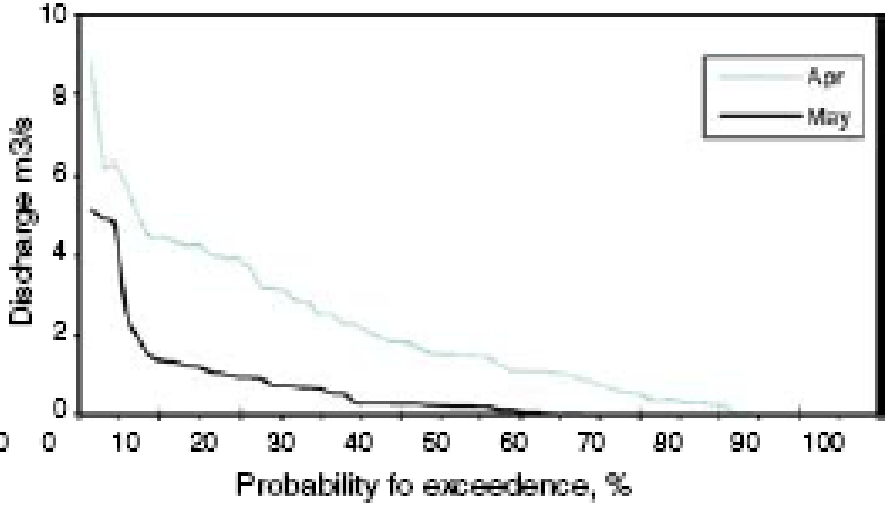
Table 1 Details of measurement sites and length of 10-daily discharge data

Sl No.	Gauge-discharge Site	Location	Catchment area (km^2)	Length of flow records (years)	Stream type
1.	Garauli on Dhasan	79° 18′ N 24° 38′ E	840	21 (1982–2002)	Intermittent
2.	Basoda on Betwa	77° 45′ N 23° 55′ E	7,525	22 (1980–2001)	Intermittent
3.	Rajghat on Betwa	78° 12′ N 24° 50′ E	16,540	23 (1971–1993)	Intermittent
4.	Mohna on Betwa	79° 22′ N 25° 42′ E	27,670	18 (1984–2001)	Perennial
5.	Shahjina on Betwa	79° 56′ N 25° 23′ E	44,023	22 (1980–2001)	Perennial









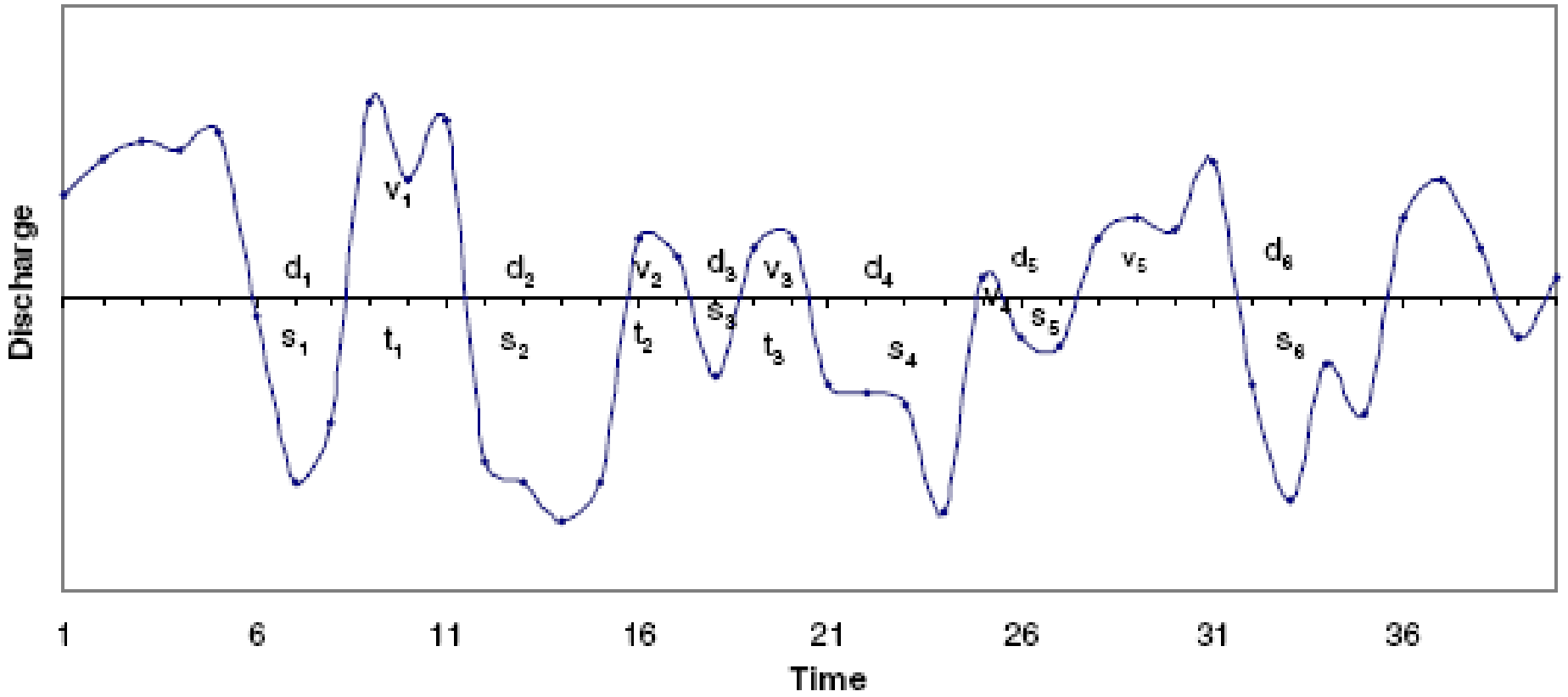
Monthly flow duration curve for Betwa River at Basoda Site

Estimation of Variable Truncation Level

A threshold can be chosen in a number of ways depending on the type of water deficit being studied. In some applications, it represents a well-defined flow quantity, such as reservoir specific yield, percentage of mean or a percentile flow. The selection of percentile relies on the hydrological regime. For perennial rivers, a low threshold ranging (Q_{70}, Q_{90}) can be considered reasonable (Hisdal et al. 2004; Meigh et al. 2002). For intermittent and ephemeral rivers with majority of zero flows, Q_{70} would be zero. For ephemeral rivers of South African region, mean flow can be taken as threshold (Meigh et al. 2002). Based on the eight streamflow records of the same region, Tate and Freeman (2000) used thresholds ranging ($Q_{12.5}$, Q_{90}) depending on the proportion of zero flows. As an alternative, Kjeldsen et al. (2000) suggested Q_{75} of monthly flow duration curve.

Table 2 Estimated values of truncation level for the Betwa and Dhasan at various sites at 75th percentile of flow duration curve (m^3/s)

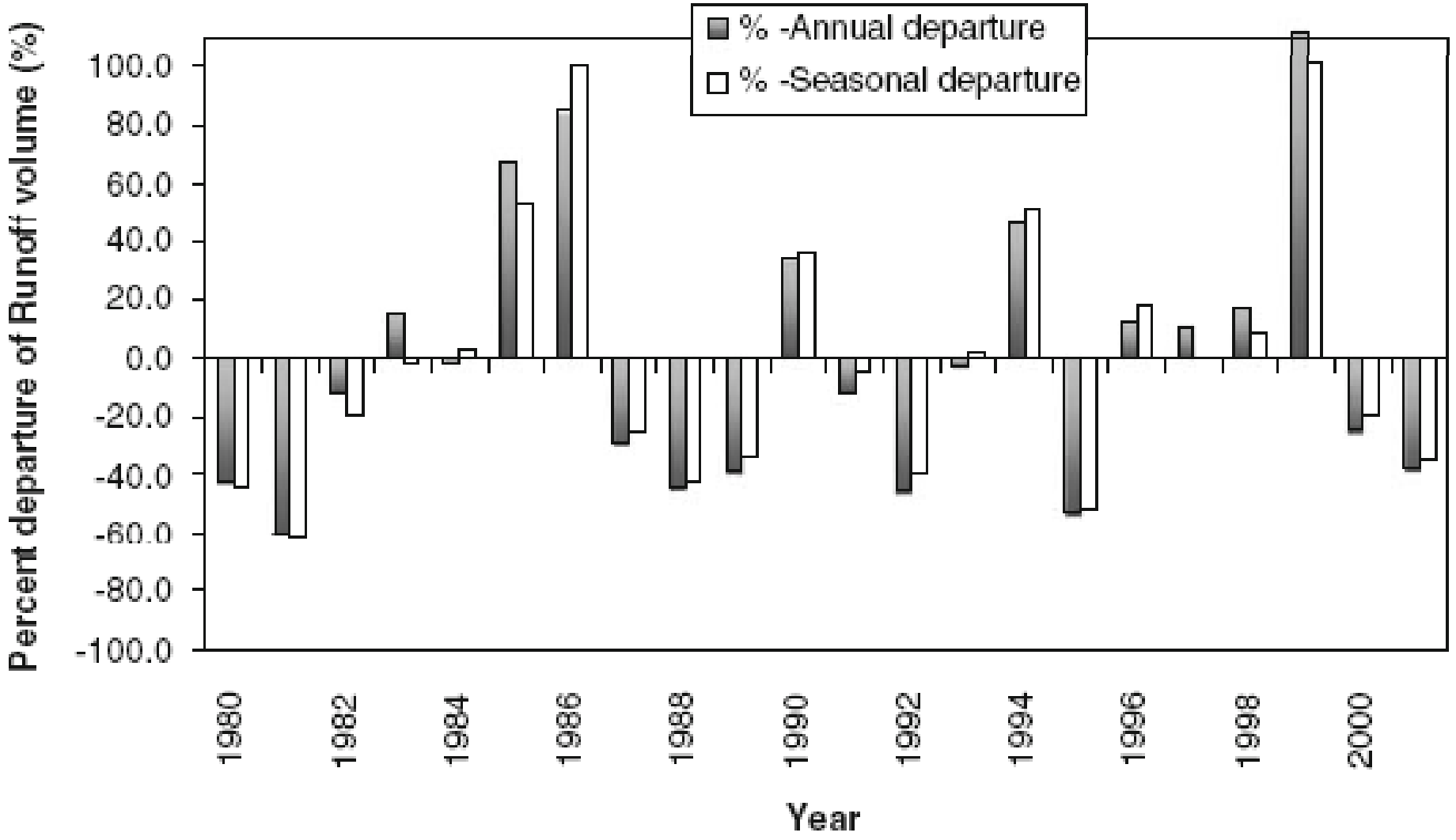
Month	Truncation level at 75^{th} percentile of flow duration curve (m^3/s) at sites				
	Betwa River				Dhasan River
	Basoda	Rajght	Mohna	Shahjina	Garauli
Jan	4.48	8.26	10.12	27.6	0.77
Feb	2.97	6.24	9.07	23.7	0.3
Mar	1.18	3.82	7.1	19.1	0
Apr	0	0.32	6.25	14.9	0
May	0	0	5.33	12.1	0
June	0	0	7.59	16.9	0
July	27.72	46.3	46.97	94.5	57.1
Aug	216.88	385.2	788.73	1,050.5	229.3
Sept	50.68	117.8	293.23	292.5	112.1
Oct	14.72	30.5	30.62	65.3	41.8
Nov	4.87	9.1	16.07	36.2	6.9
Dec	5.16	8.12	14.2	30.2	1.1



Q_j = truncation level
d_i = drought duration
s_i = deficit volume (severity)

t_i = inter-event time
v_i = inter-event volume

A definition sketch of drought events



Percentage departure of annual and monsoon runoff volume for Betwa at Basoda

Proposed Drought Severity Index

$$DSI_e = \frac{V_d}{V_{TL}} \frac{d_e}{d_m}$$

where V_d = deficit streamflow volume for the duration of drought event, V_{TL} = expected streamflow volume at truncation level flow for the duration of drought event, d_e = duration of independent drought event, and d_m = maximum duration of an independent drought

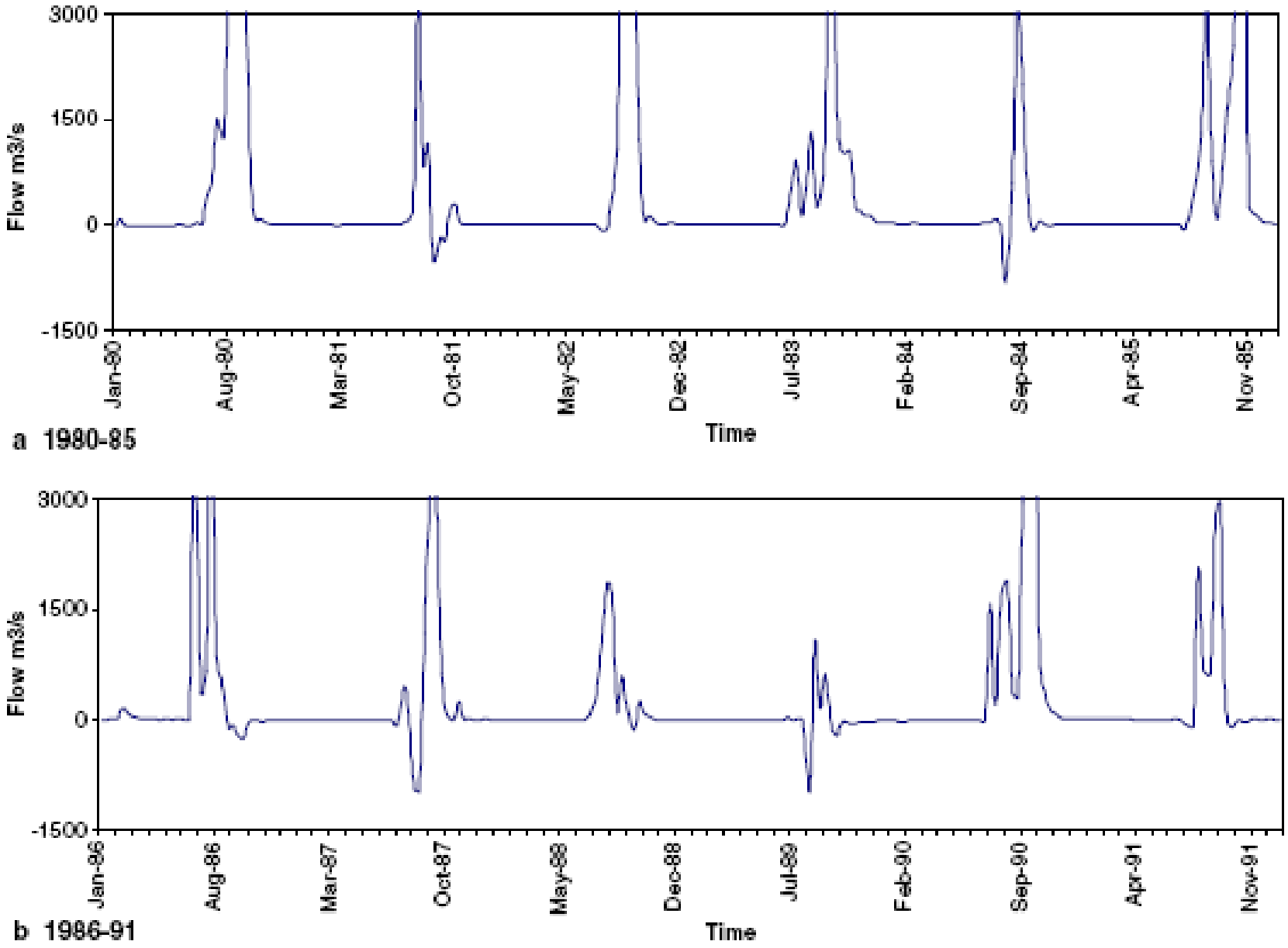


Fig. 5 Flow deviation with respect to the variable truncation level for Betwa at Shahjina for the years 1980–1985 and 1986–1991

Table 3 Streamflow drought events and their severity index for Betwa at Basoda site (1980–2001)

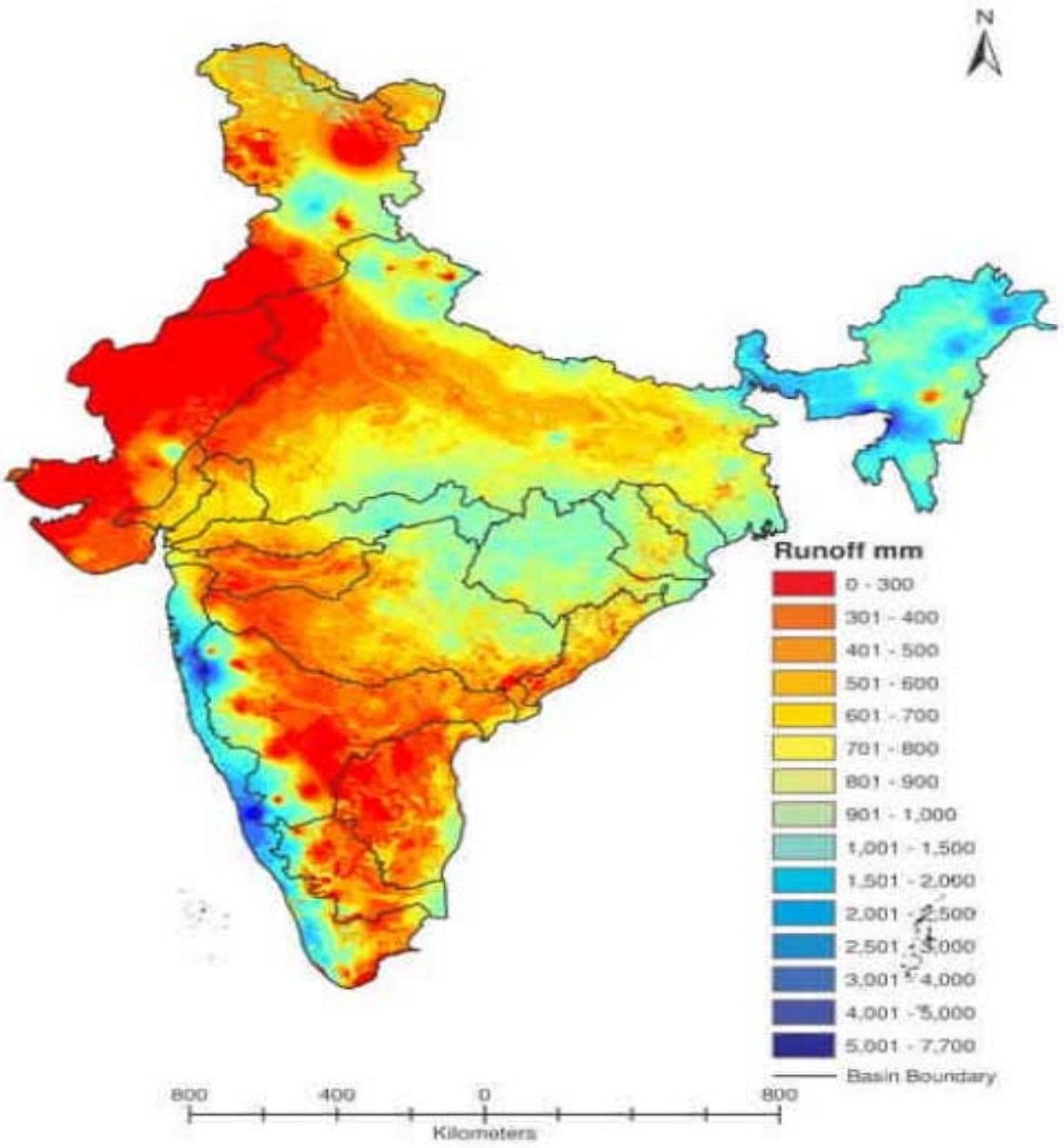
Sl. No.	Year of event	Onset date	Termination date	Duration	Severity (MCM)	Expected Runoff (MCM)	DSI_e	Category of drought severity
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	1980	Jan. 1, 1980	Jun. 10, 1980	160	−5.53	18	−0.12	Moderate
2	1981	Aug. 20, 1981	Dec. 20, 1981	120	−160	379	−0.14	Moderate
3	1984	Jul. 1, 1984	Jul. 30, 1984	30	−49	72	−0.06	Moderate
4	1986–1987	Sep. 1, 1986	Jan. 30, 1987	150	−115	207	−0.23	Severe
5	1988	Aug. 10, 1988	Sep. 20, 1988	50	−67	506	−0.02	Mild
6	1989–1990	Sep. 10, 1989	Jun. 30, 1990	270	−20	61	−0.25	Severe
7	1991	Sep., 20, 1991	Dec. 20, 1991	100	−34	147	−0.06	Moderate
8	1992–1993	Sep. 20, 1992	Jun. 30, 1993	260	−69	130	−0.37	Severe
9	2000–2001	Aug. 1, 2000	Jun. 30, 2001	310	−221	780	−0.24	Severe

THANK YOU

Work progress in WP 10 and achievements during May- September 2009

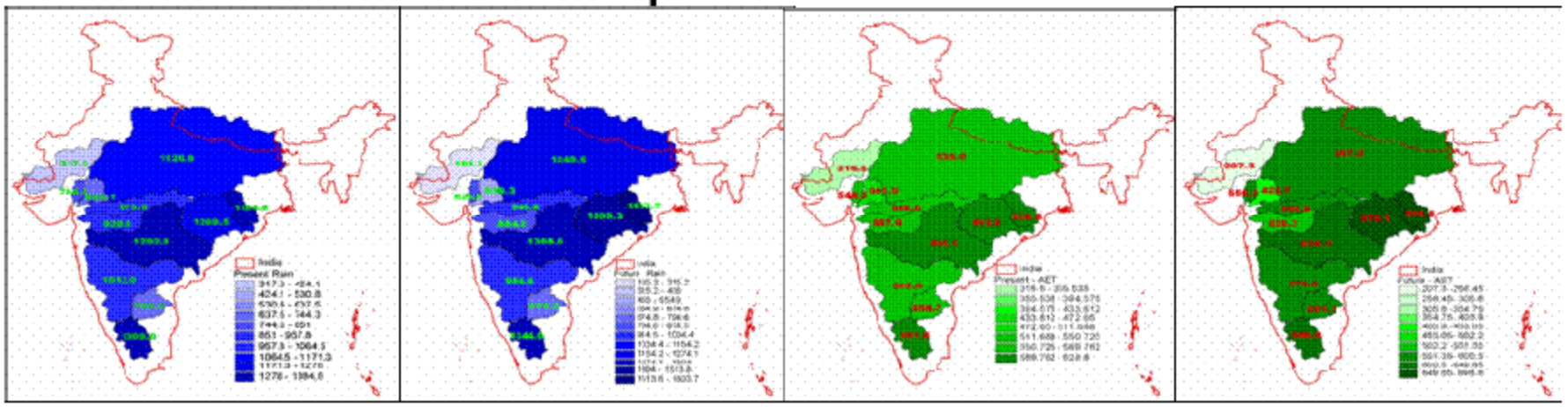
Objectives

- Monitor surface wetness and fraction of open water over large areas using passive and active microwave satellite data;
- Improve current tools for real time flood forecasting using the observations provided by the atmospheric-hydrologic network;
- Improve current methods for map and visualize flood inundation, flood risk using satellite data.



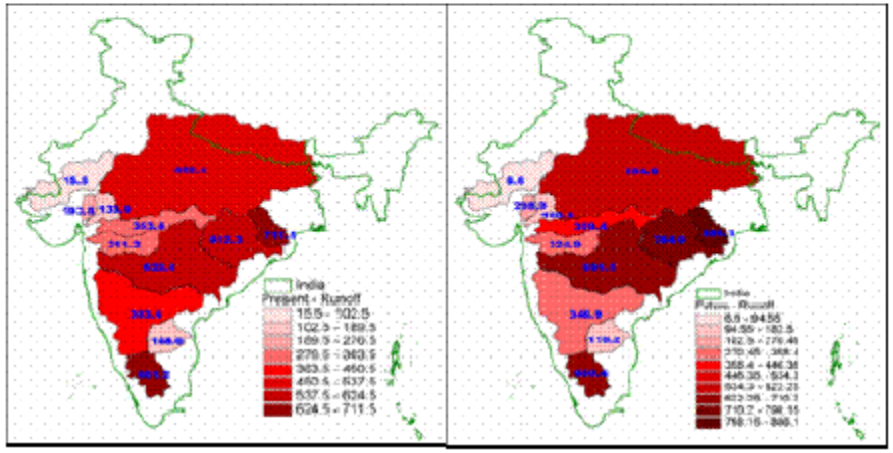
Annual runoff pattern map of India.

Composite Picture



Rainfall

Actual ET



Total Runoff

Preliminarily defined pilot areas in India:

- Upper Ganga basin up to Haridwar (part of Ganga basin)
- Gandak sub-basin of Ganga basin
- Bagmati sub-basin of of Ganga basin

Table . Area liable to floods (as per National Flood Commission) (in m. hac.)

State	Area liable to flood	Area protected by RBA	Area benefited
Bihar	4.26	1.566	2.949
Uttar Pradesh	7.34	0.739	1.5990
West Bengal	2.65	1.001	2.2005
Delhi	0.05	0.023	0.0780
Haryana	2.35	1.095	2.00
Total India	33.52	9.776	15.2925

Source: Central Water Commission

Table . Runoff and sediment load of the Ganga

River	Drainage area 10^6 Km^2	Runoff Km^3/yr	Sediment Load 10^6 tons/yr
Ganga	1.5	971	1670

Source: Data from Milliman and Meade, 1983 [11]; Van der Leeden et al., 1994 [12].

Ganges Basin is one of the largest in the world, covering a population of at least 600 million people.[2] Nevertheless, it is also comparatively one of the most under-utilised systems in the world. Its catchment area includes five countries (Bangladesh, Bhutan, India, Nepal and China), although the majority of the downstream sections of the basin are within Bangladesh and India. The Gangetic delta is also fed by the Indian states of Uttaranchal (part of Uttar Pradesh until 2000) and Sikkim (an independent nation-state until 1973) as well as the independent nation-states of Nepal and Bhutan.

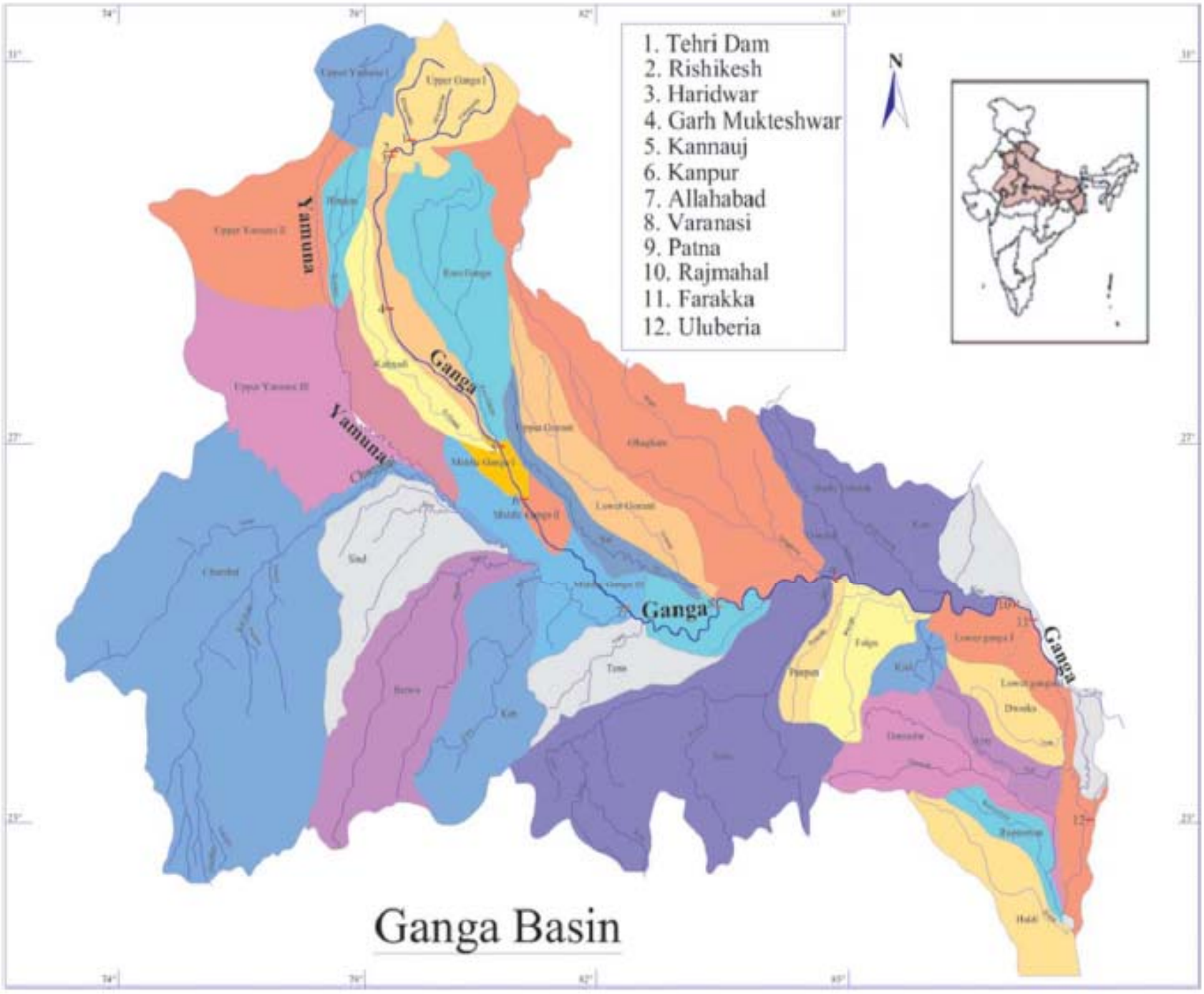

1. Tehri Dam
2. Rishikesh
3. Haridwar
4. Garh Mukteshwar
5. Kannauj
6. Kanpur
7. Allahabad
8. Varanasi
9. Patna
10. Rajmahal
11. Farakka
12. Uluberia
N
Yamuna
Ganga
Yamuna
Ganga
Ganga
Ganga Basin

Fig. 2 : Mean Discharge Seasonal

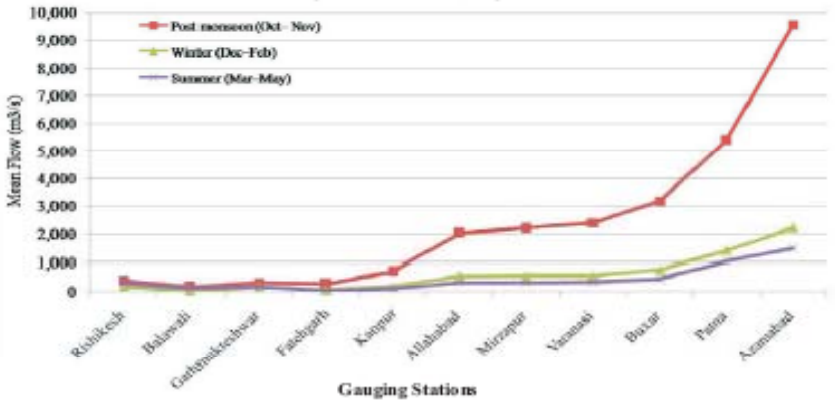


Fig. 3 : Seasonal Flow Variation

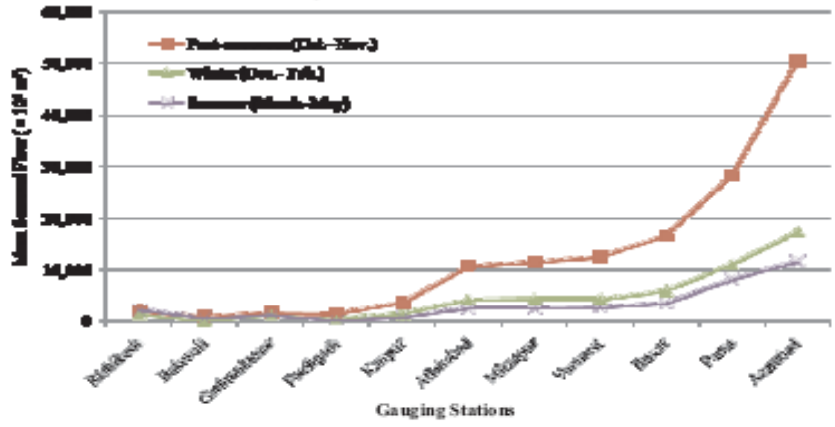
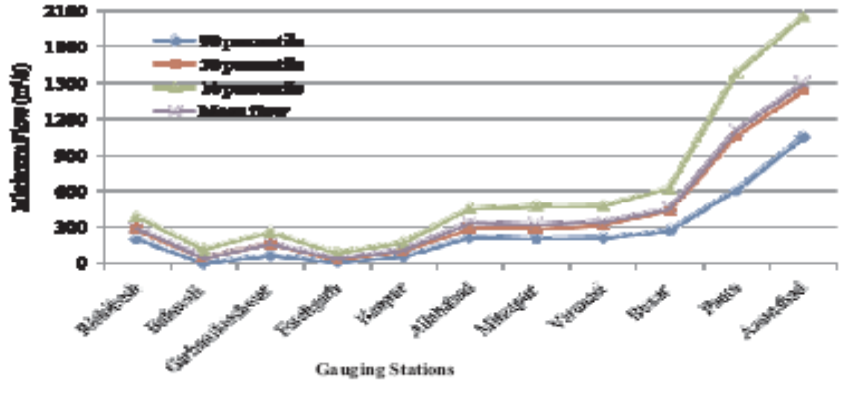
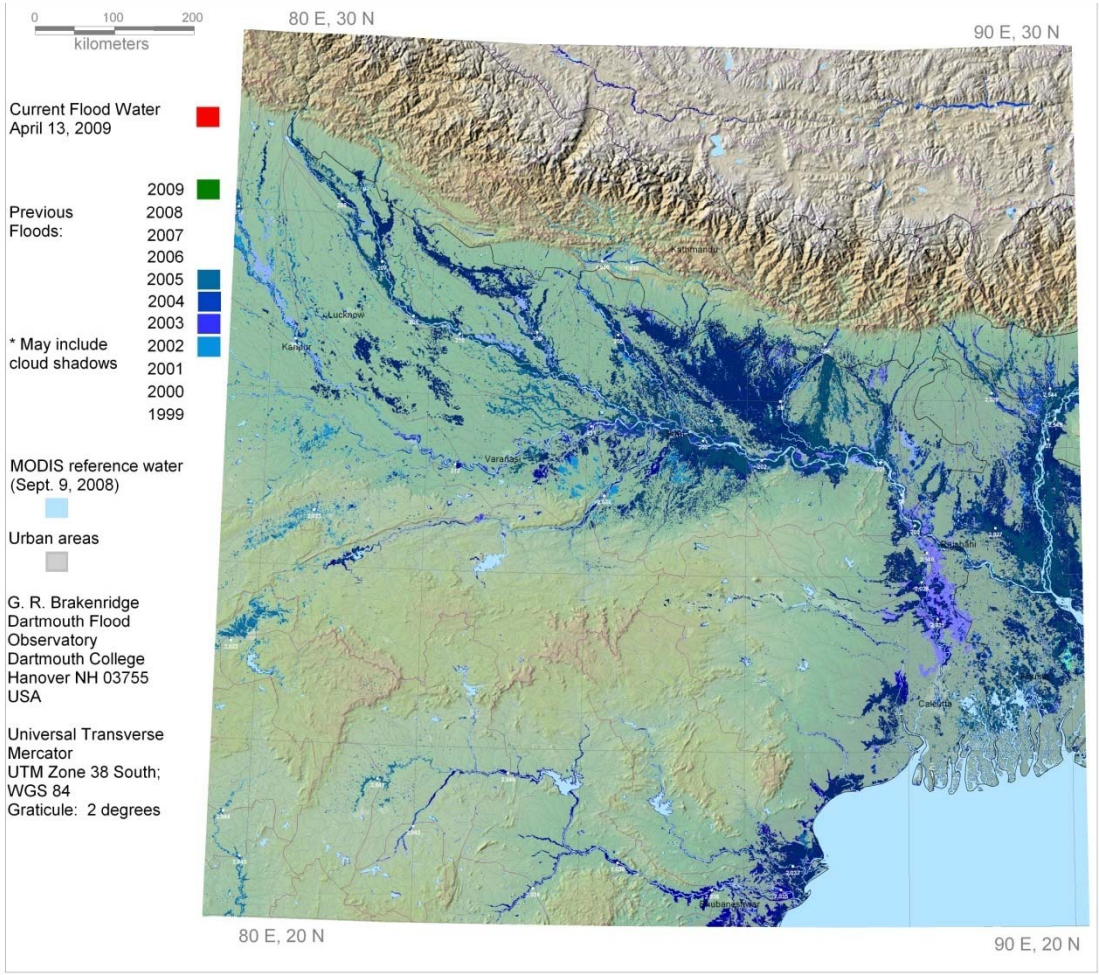
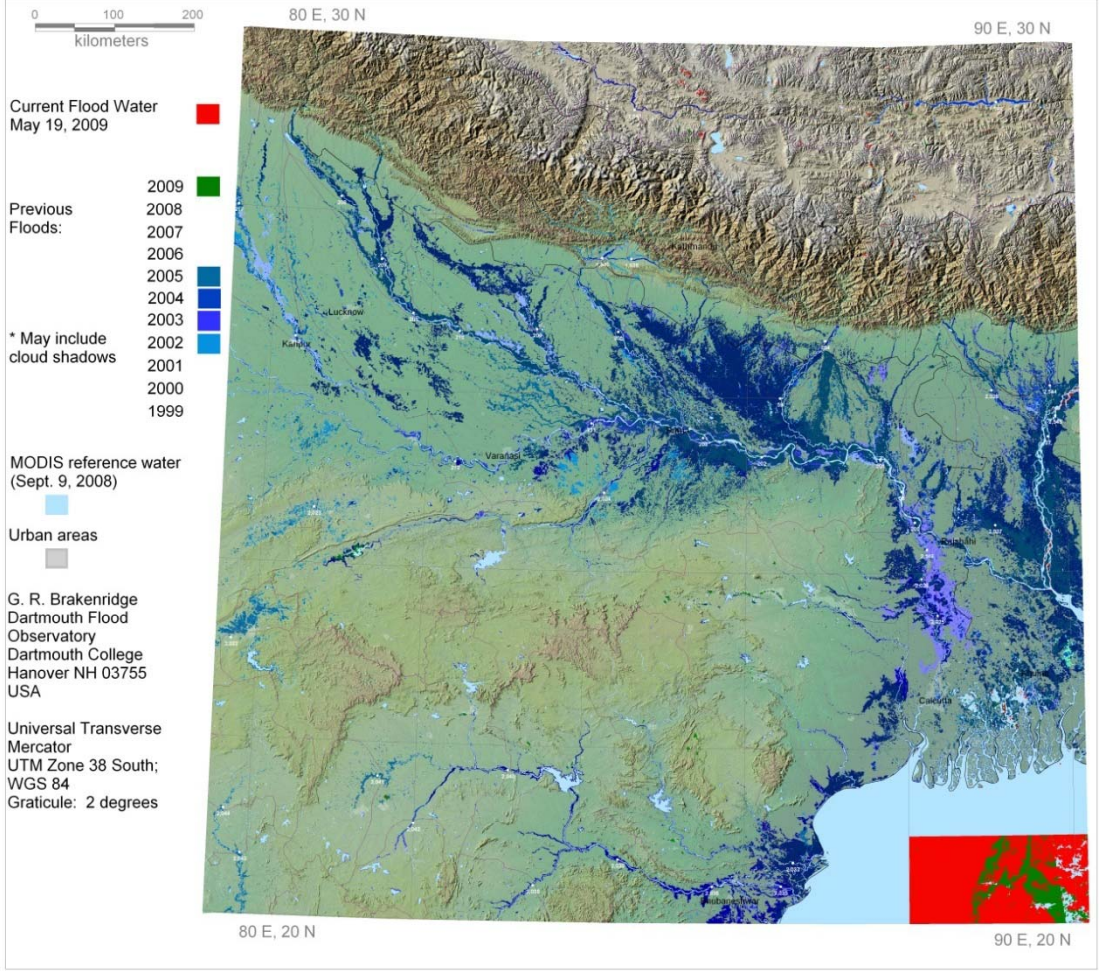
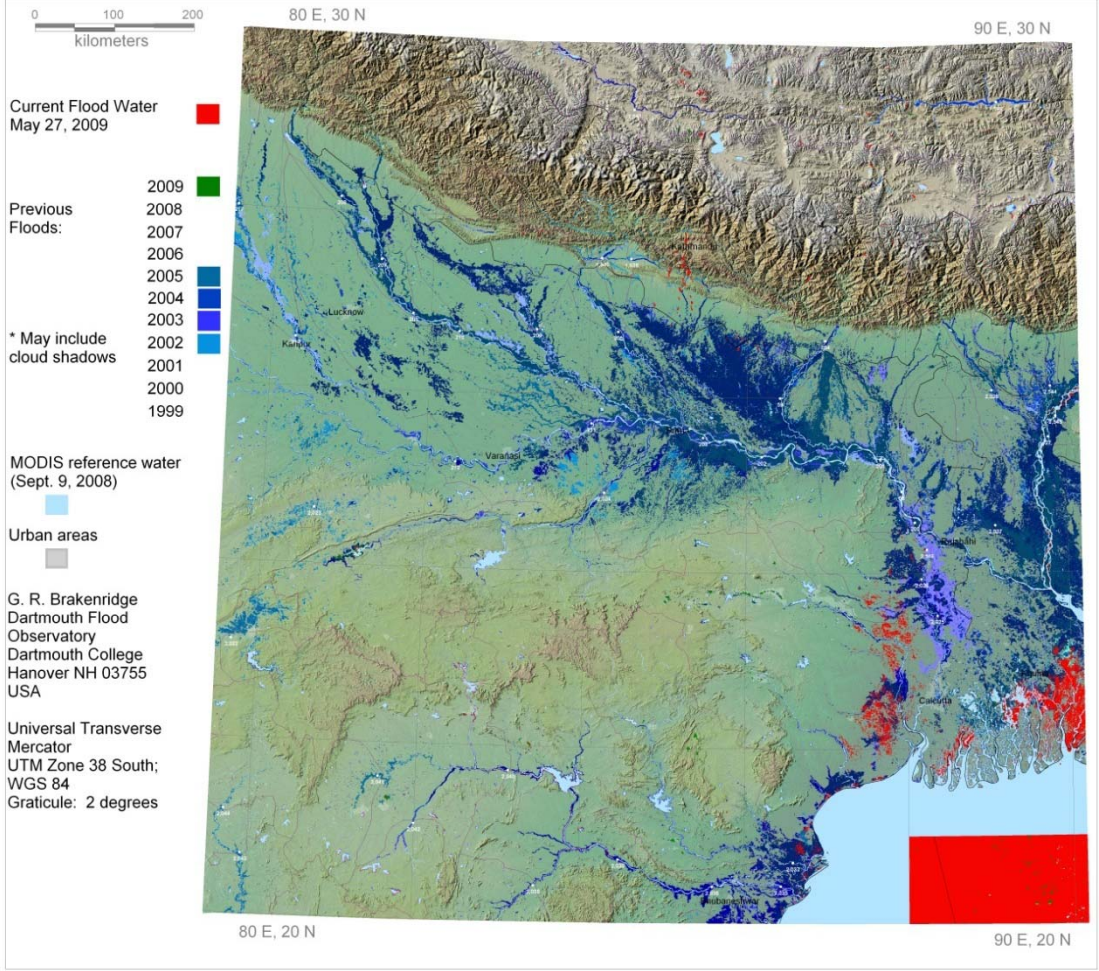


Fig. 4 : Lean Flow in Ganga during summers




0
100
200
kilometers
Current Flood Water
April 13, 2009
Previous
Floods:
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
* May include
cloud shadows
MODIS reference water
(Sept. 9, 2008)
Urban areas
G. R. Brakenridge
Dartmouth Flood
Observatory
Dartmouth College
Hanover NH 03755
USA
Universal Transverse
Mercator
UTM Zone 38 South;
WGS 84
Graticule: 2 degrees
80 E, 30 N
90 E, 30 N
Kathmandu
Lucknow
Kanpur
Varanasi
Calcutta
80 E, 20 N
90 E, 20 N


0 100 200
kilometers
Current Flood Water
May 19, 2009
Previous Floods:
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
* May include cloud shadows
MODIS reference water (Sept. 9, 2008)
Urban areas
G. R. Brakenridge
Dartmouth Flood Observatory
Dartmouth College
Hanover NH 03755
USA
Universal Transverse Mercator
UTM Zone 38 South;
WGS 84
Graticule: 2 degrees
80 E, 30 N
90 E, 30 N
Lucknow
Kanpur
Varanasi
Kolkata
80 E, 20 N
90 E, 20 N


0 100 200
kilometers
Current Flood Water
May 27, 2009
Previous Floods:
2009
2008
2007
2006
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2004
2003
2002
2001
2000
1999
* May include cloud shadows
MODIS reference water (Sept. 9, 2008)
Urban areas
G. R. Brakenridge
Dartmouth Flood Observatory
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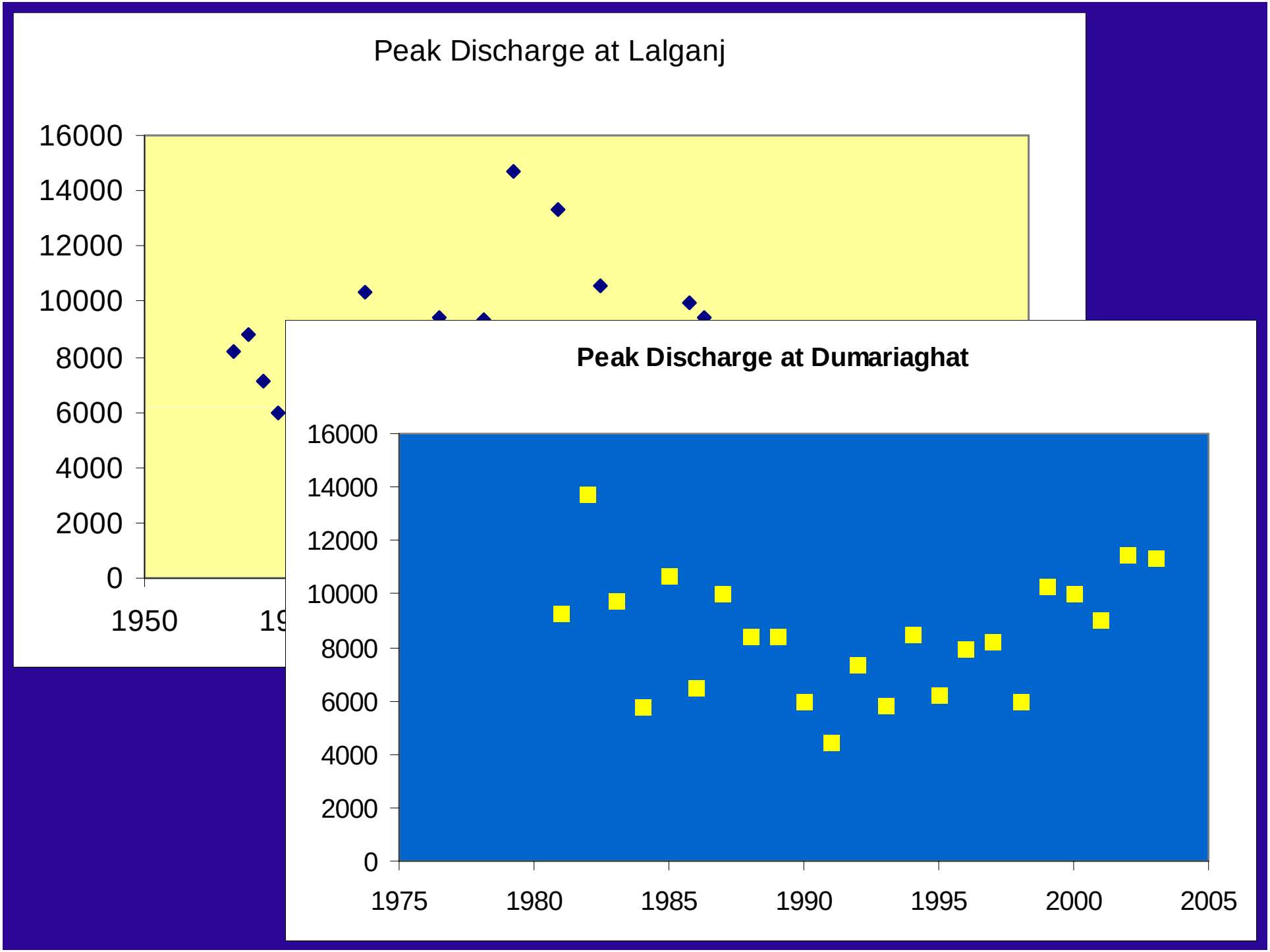
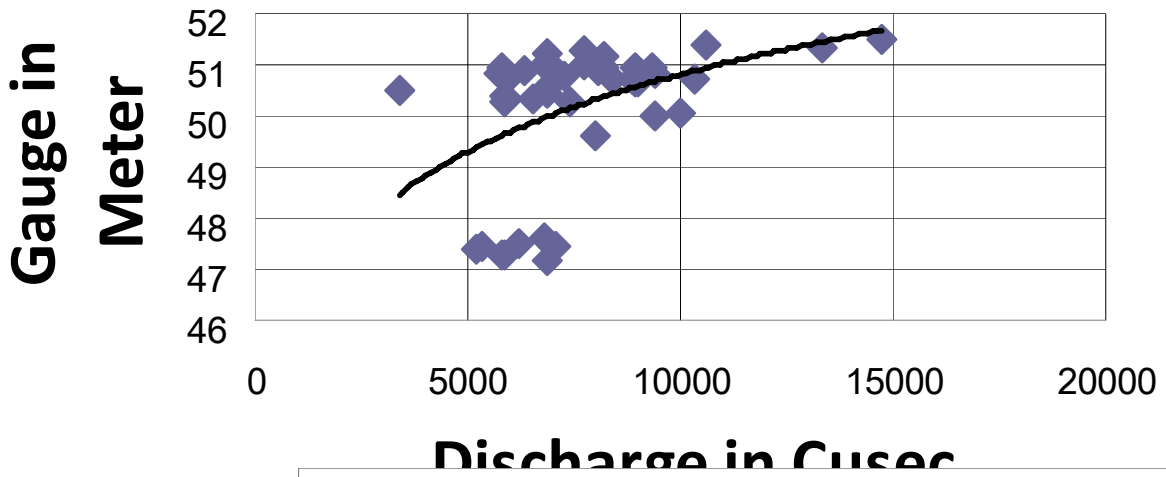
USA
Universal Transverse Mercator
UTM Zone 38 South;
WGS 84
Graticule: 2 degrees
80 E, 30 N
90 E, 30 N
Kathmandu
Lucknow
Kanpur
Varanasi
Kolkata
Chittagong
80 E, 20 N
90 E, 20 N

ANALYSIS TO BE CARRIED OUT

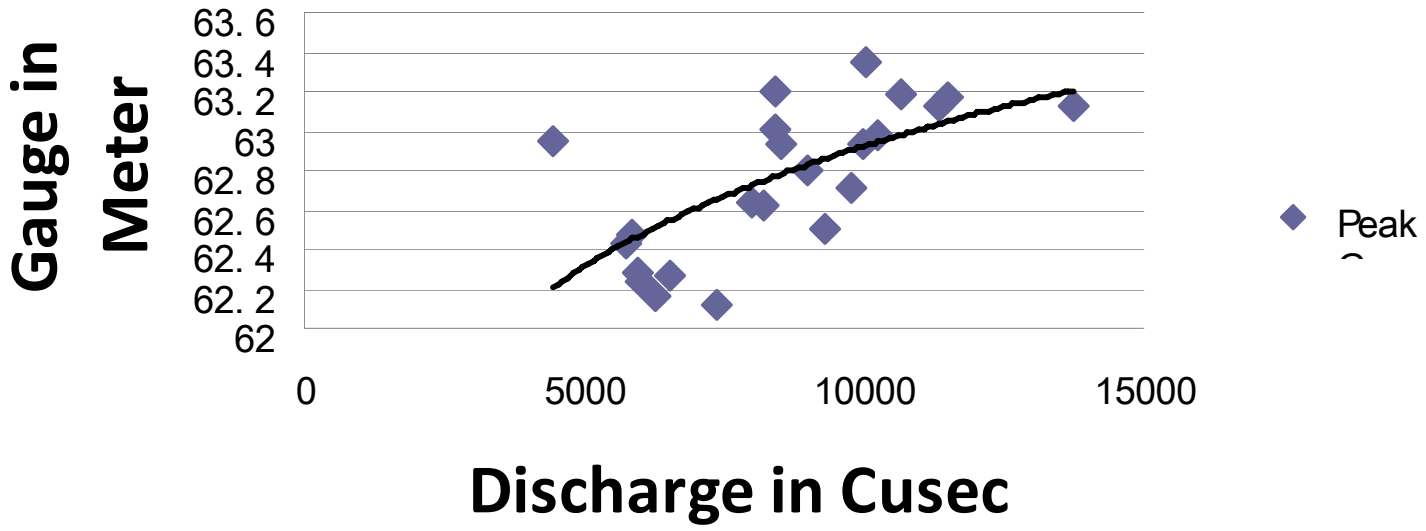
- Development of flood inundation maps w.r.t. different water level/discharges in sub-basins river Ganga (ESRI shape file).
- Water spread area of 2010 and before using satellite data (??AMSR-E and TRMM-water Watch) and contour maps(GTOPO30) for development of flood hazard maps for different return periods/water levels.
- Application of hydrological models to compute discharge based precipitation data and other satellite data and upstream discharge water level data. (HEC-RAS, HEC-HMS and SCS-CN)


Peak Discharge at Lalganj
16000
14000
12000
10000
8000
6000
4000
2000
0
1950
Peak Discharge at Dumariaghat
16000
14000
12000
10000
8000
6000
4000
2000
0
1975
1980
1985
1990
1995
2000
2005

Rating Curve of Lalganj



Rating Curve of Dumariaghat



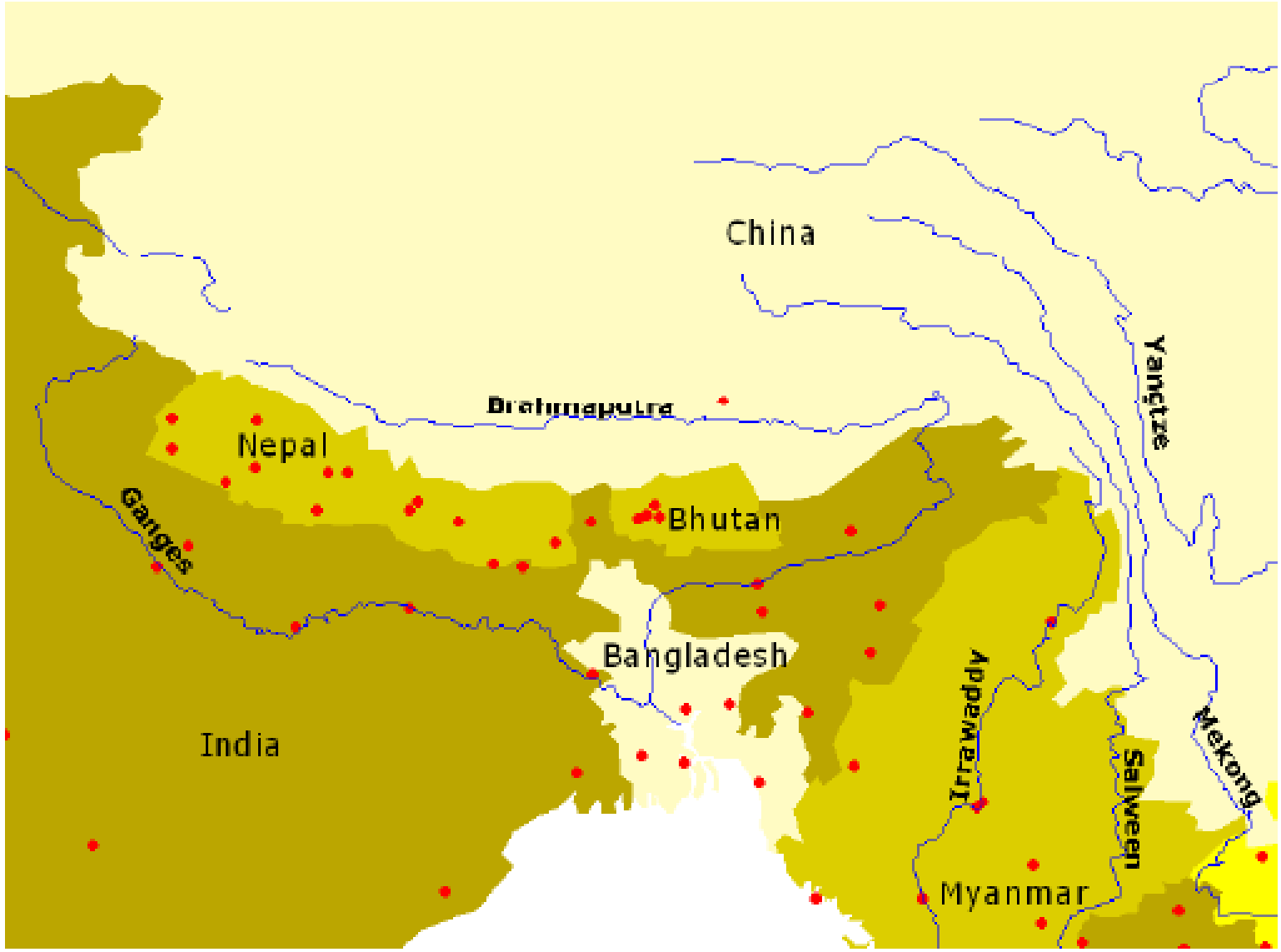


Figure 1 Study area with country limits, main rivers and main cities

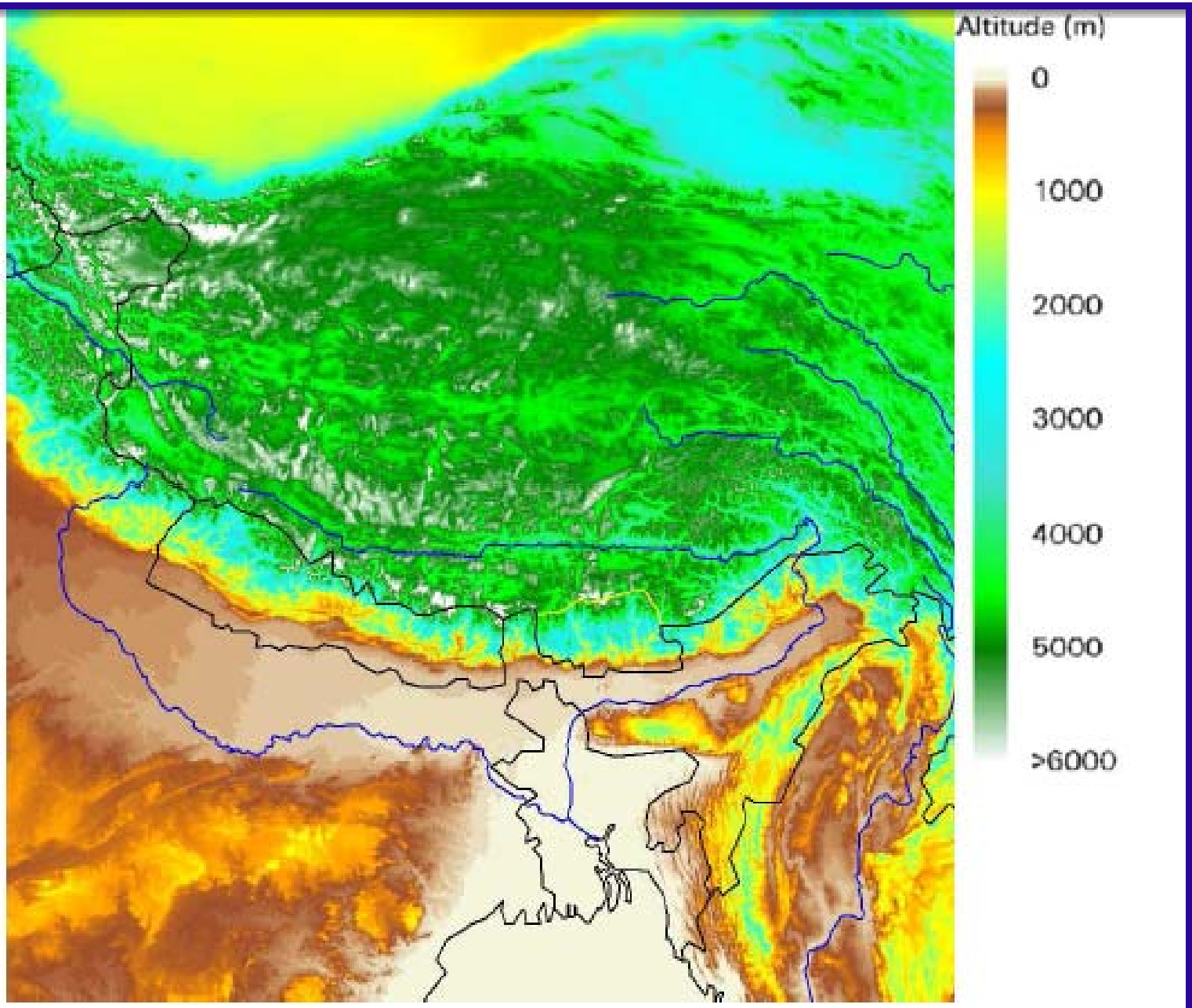


Figure 2 Digital elevation model of the area (source: SRTM)

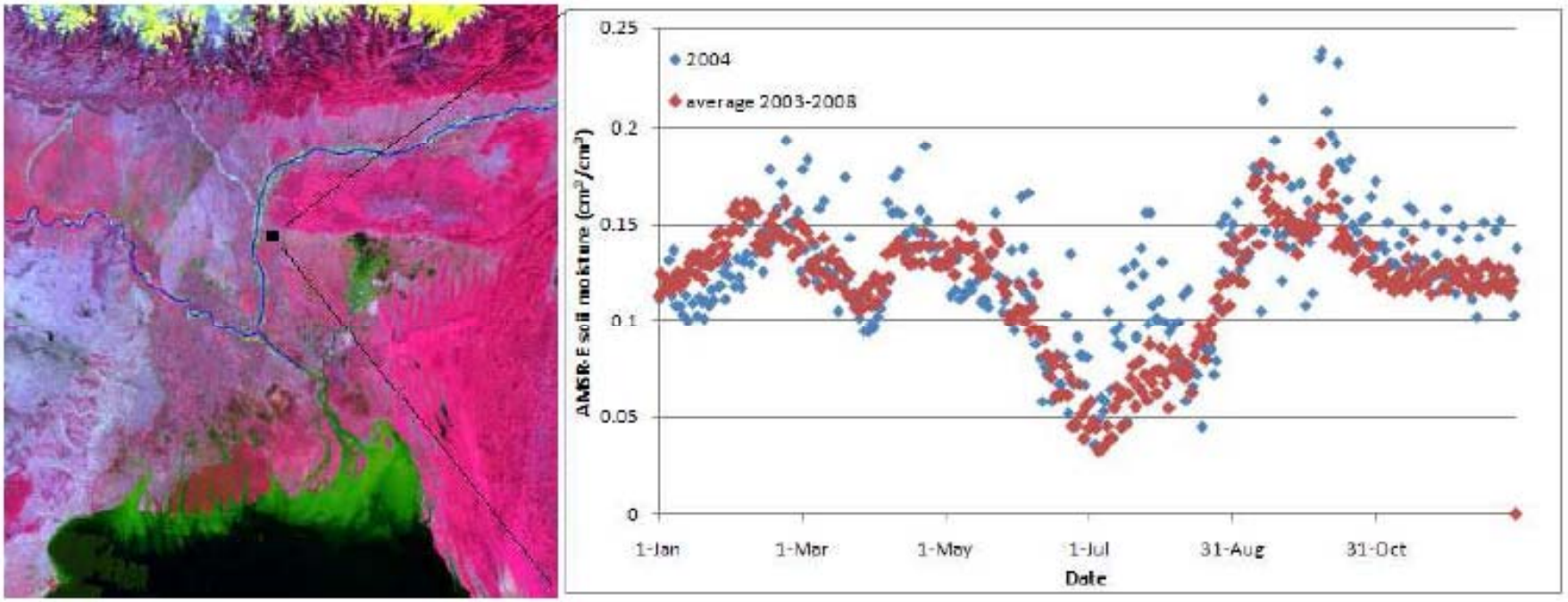


Figure 3 Daily AMSR-E soil moisture of 2004 and of 2003-2008 along the Brahmaputra river (longitude 89.875, latitude 25.125)

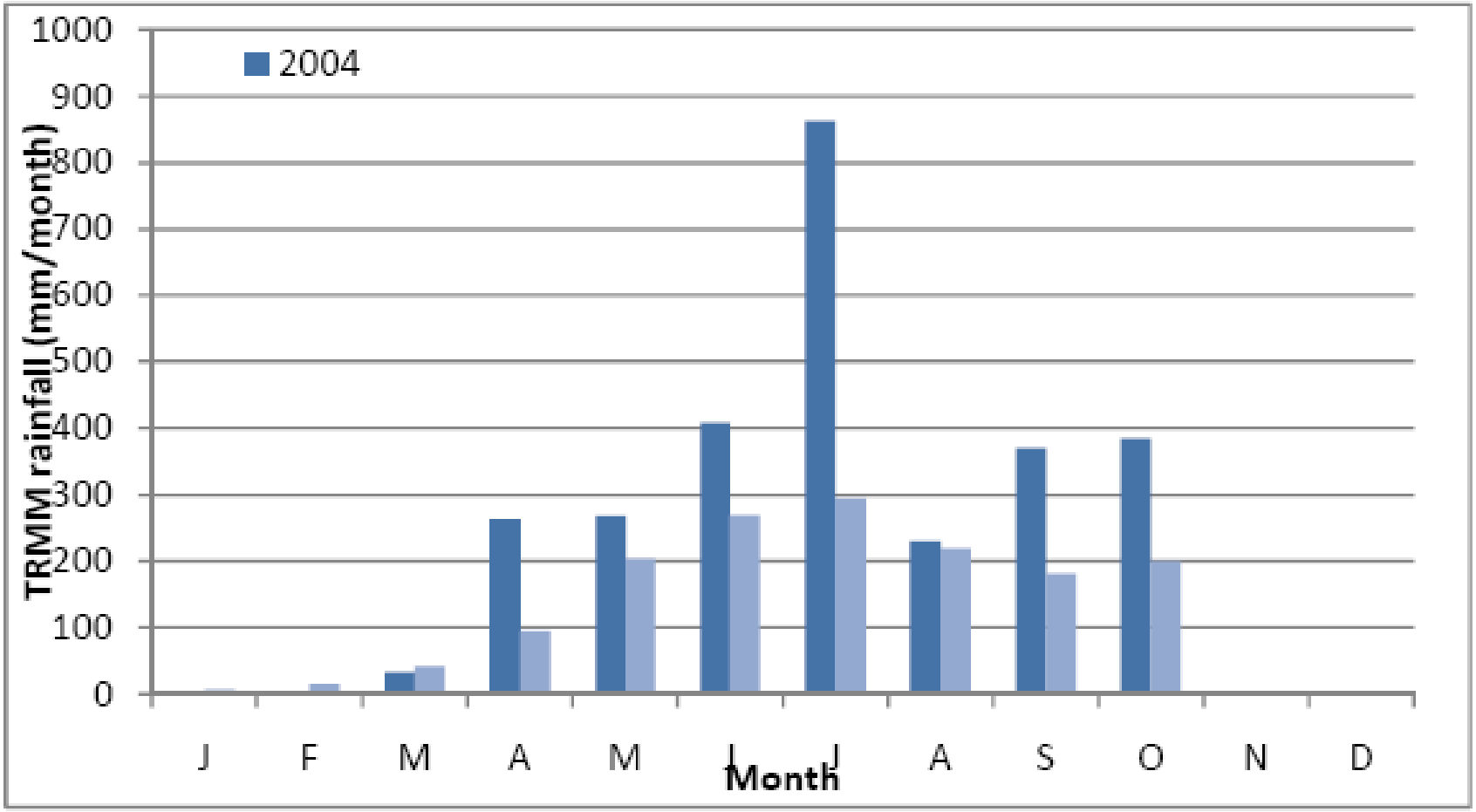


Figure 4 TRMM rainfall along the Brahmaputra river (see Figure 3)

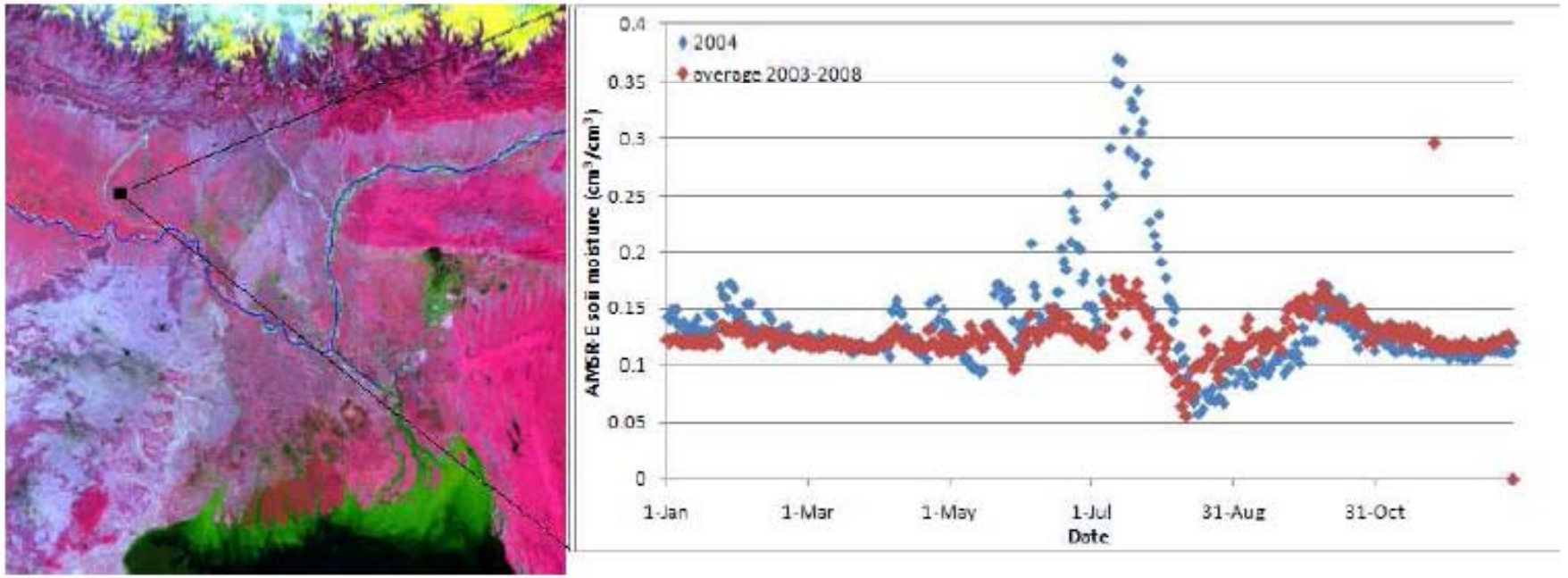


Figure 5 Daily AMSR-E soil moisture of 2004 and of 2003-2008 along the Ganges river (longitude 86.625, latitude 25.875)

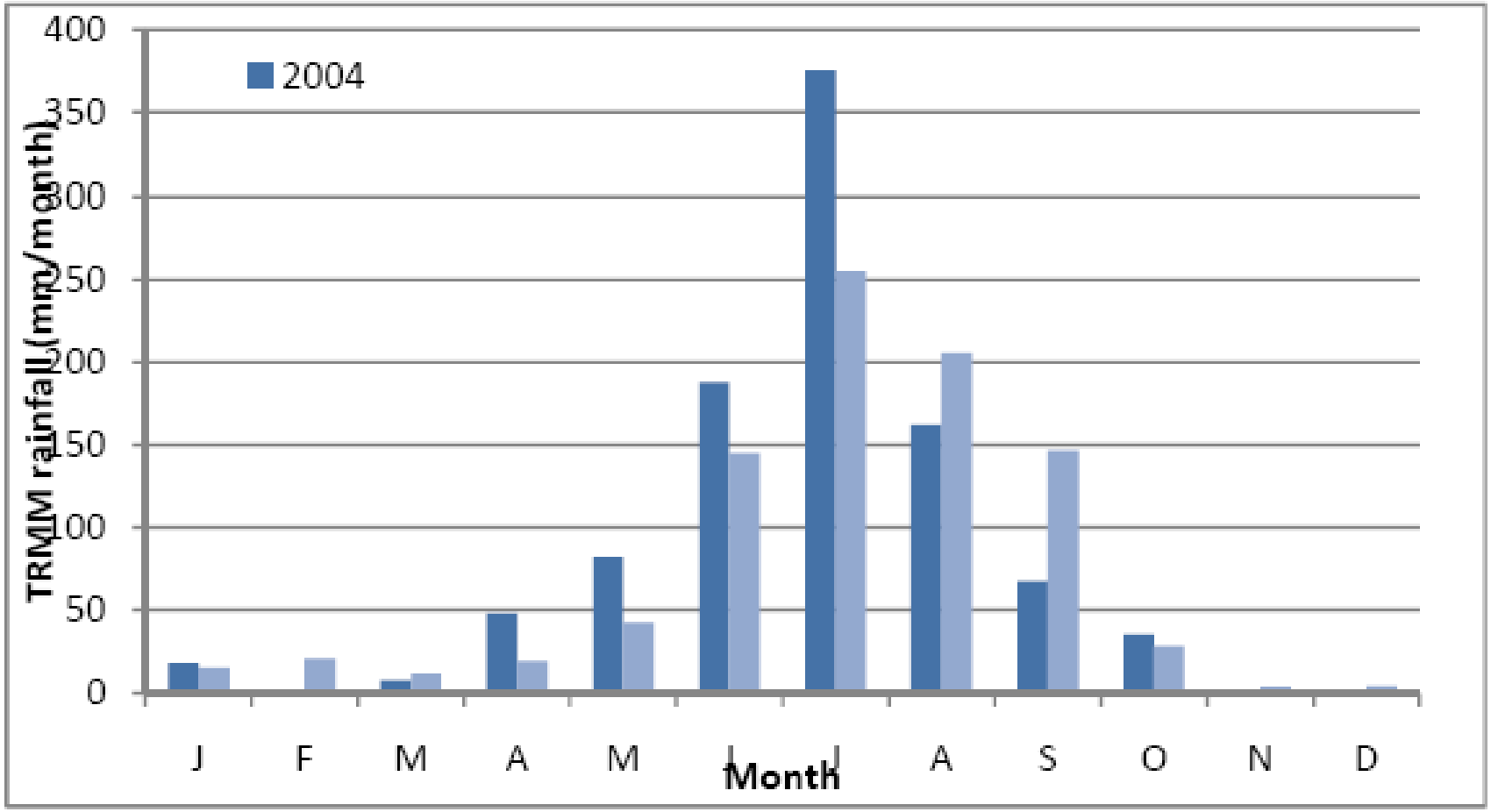


Figure 6 TRMM rainfall along the Ganges river (see Figure 5)

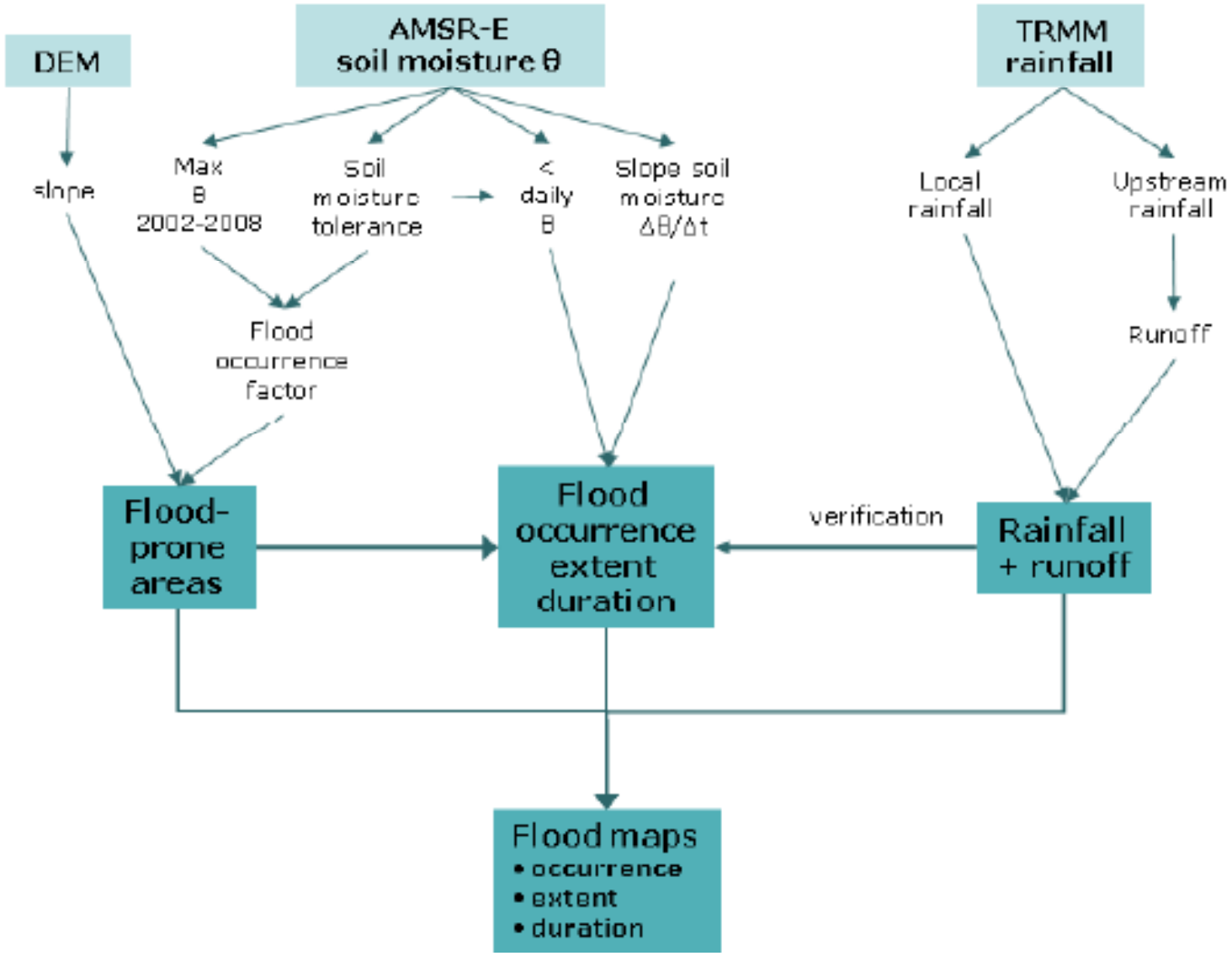


Figure 7 The flood model

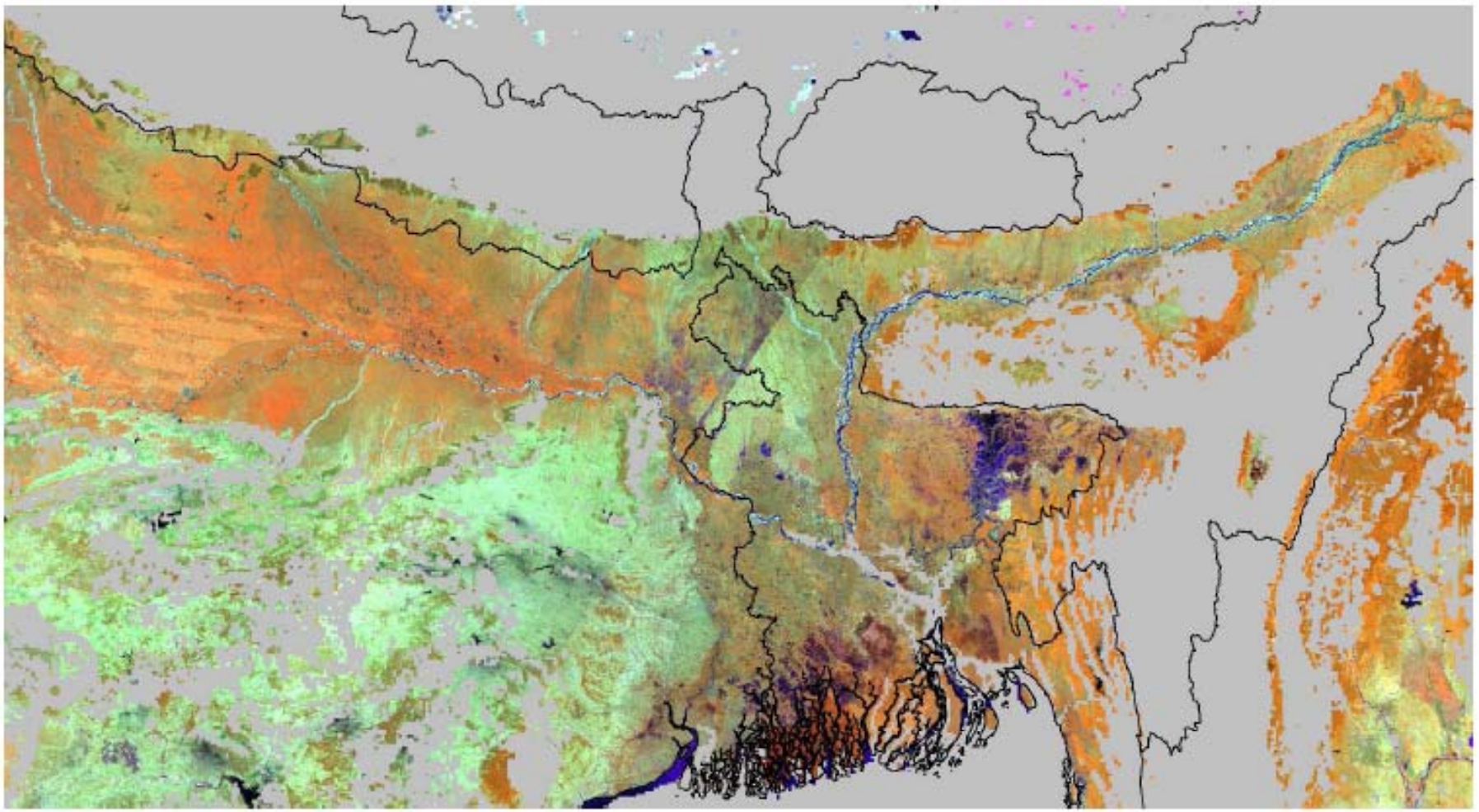


Figure 8 Selection of areas with a slope below one degree using the GTOPO30 DEM (areas with a slope above one degree area masked grey, background of MODIS image)

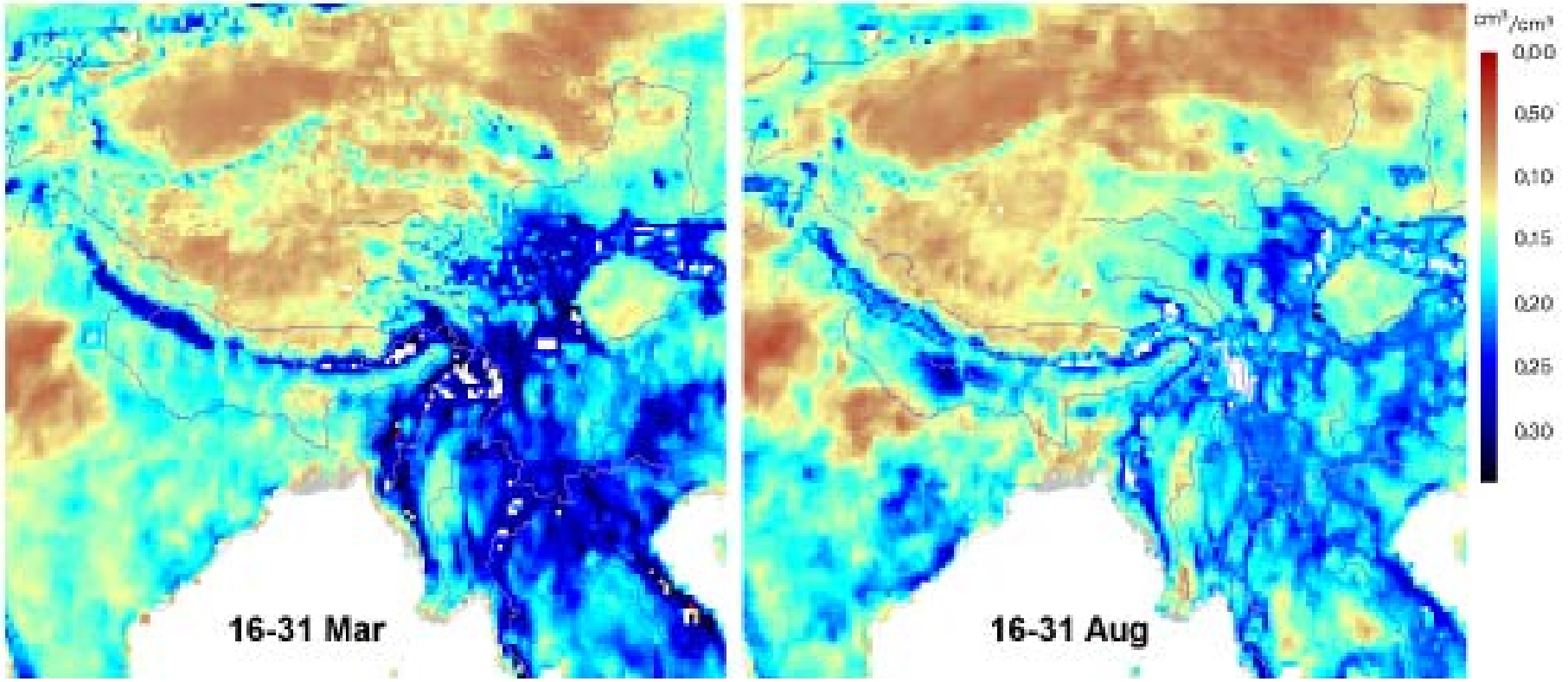


Figure 10 Bi-monthly soil moisture tolerance of two periods. When floods occur the absolute moisture values exceed these values.

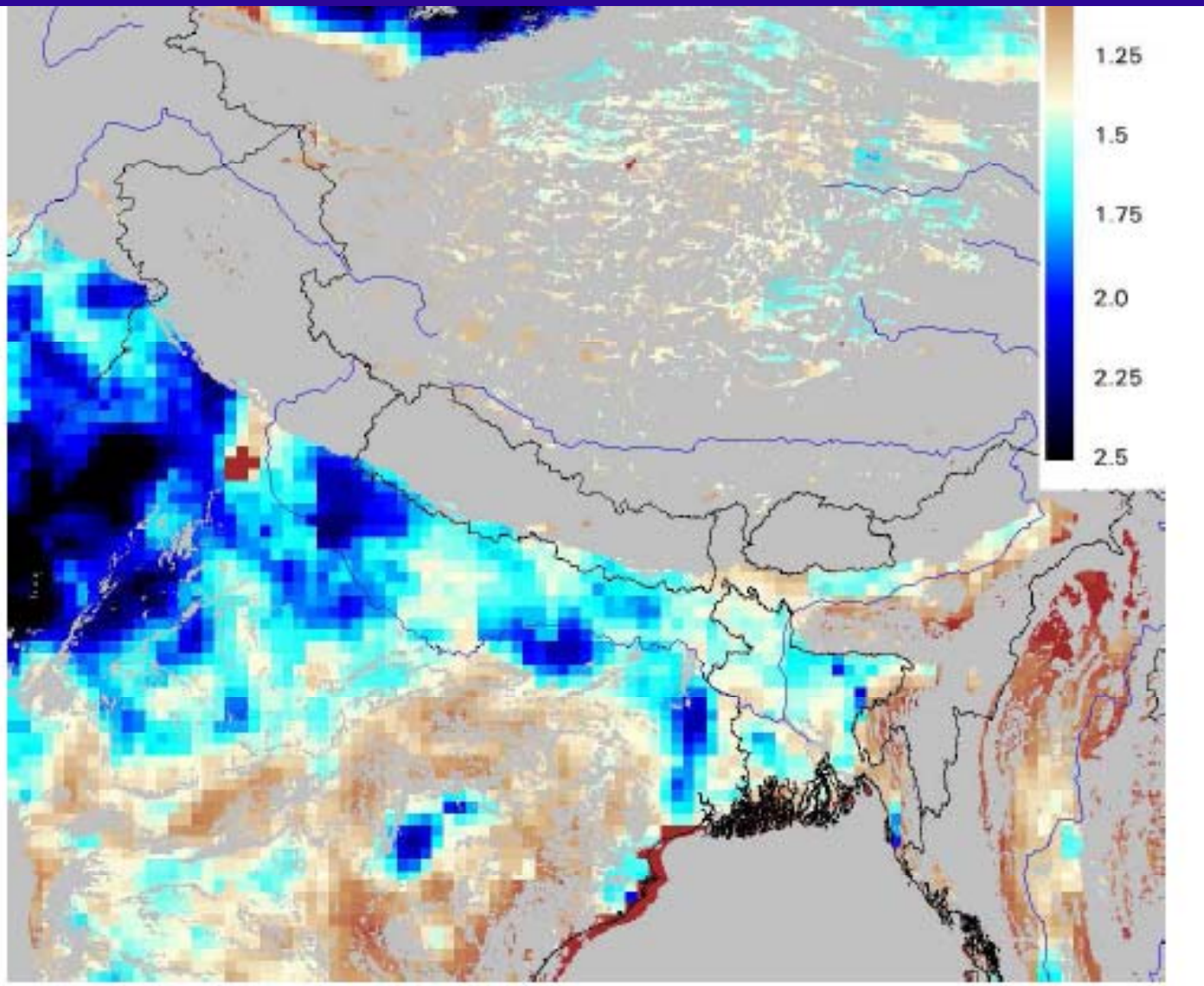


Figure 12 Maximal flood occurrence factor in all areas with a slope lower than 1 degree. The flood occurrence factor is the maximal soil moisture value divided by the soil moisture tolerance in all years measured (since 2002). High values indicate no flood occurrences.

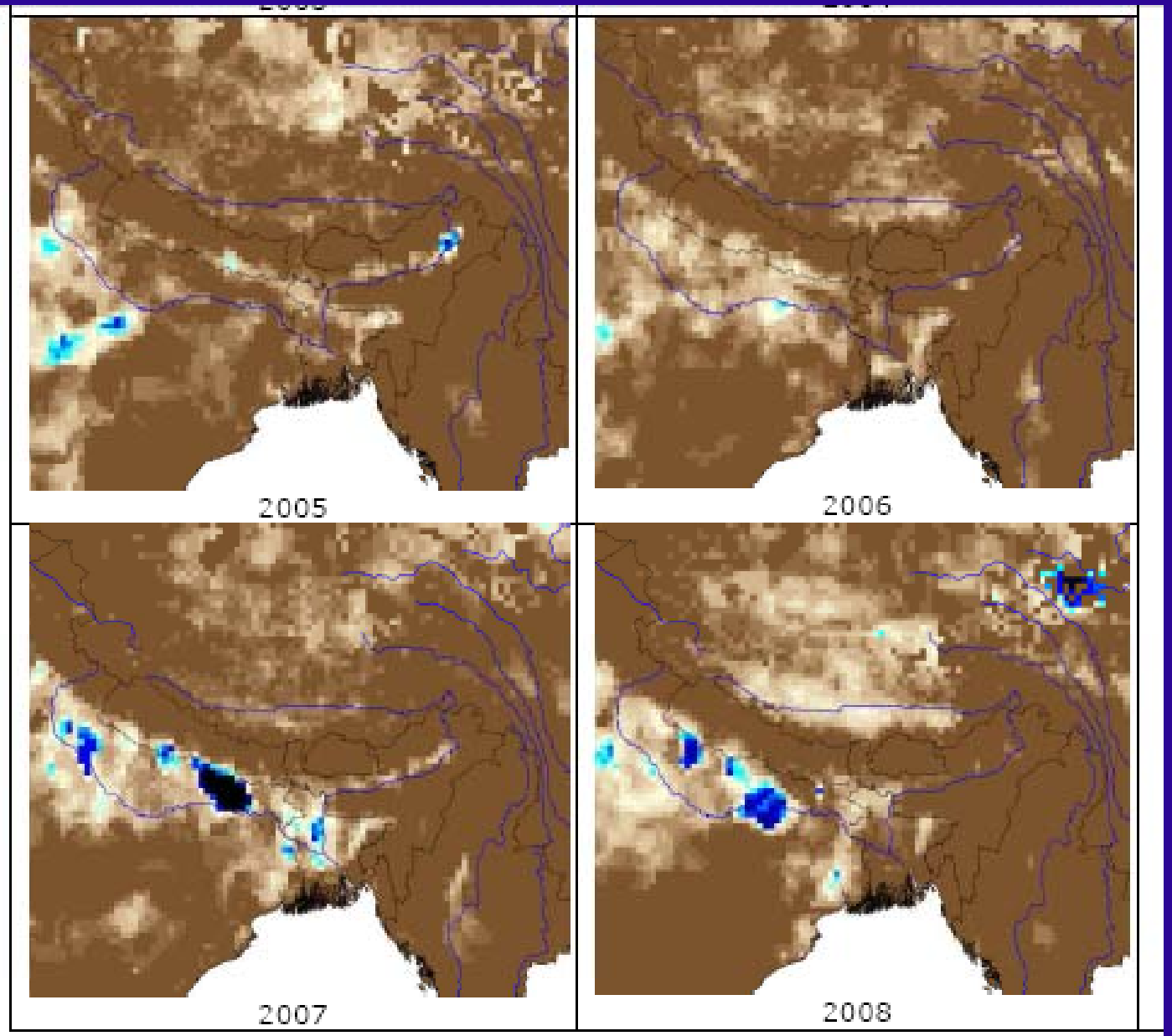


Figure 15 Flood frequency: the number of days flooded in a year

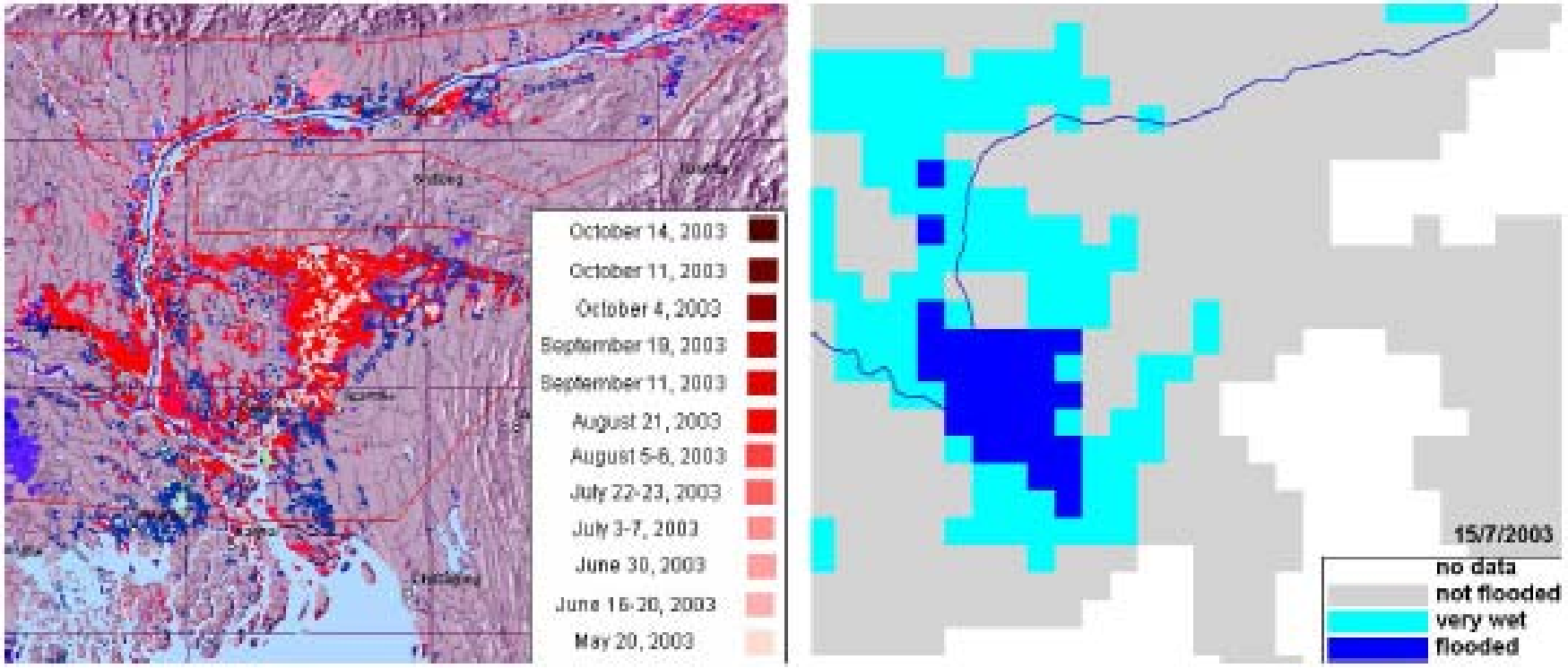


Figure 16 Dartmouth flood observations (DFO event #2003-134 Bangladesh and Northeast India) and flood detection using AMSR-E soil moisture data

THANK YOU