GFCS
GLOBAL FRAMEWORK FOR CLIMATE SERVICES

The GFCS Pillars: Developing climate services at the national level

Observations and Monitoring

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The Global Framework for Climate Services has four major components:

- Observation and Monitoring
- Research, Modelling and Prediction
- Climate Services Information System
- User Interface Programme

The Observations and Monitoring ensures that the climate observations and other data necessary (including socio-economic data) to meet the needs of end users are

- collected,
- managed, and
- disseminated, and are
- supported by relevant metadata

Key Challenges for the Himalayan Region

Due to rugged and inhomogeneous terrain;
High Topography (Highest Peaks of the World are in the Himalayas)
and the Himalayas extended over several Nations

- ❑ Establishment and Sustenance of observing network
- ❑ Collection of Socioeconomic Data
- ❑ Data Sharing and Data Exchange

Himalayan EcoSystem is Fragile nd needs Special Attaention

- ✓ The Observations and Monitoring Pillar is one of the foundational pillars of GFCS
- ✓ Need of Observations of appropriate types and of adequate quality and quantity.
- ✓ Observations availability at the right place and at the right time.
- ✓ Requirement of conventional data of the atmosphere (as needed for weather services) as well as variables needed to describe the climate system of the Third Pole including hydrologic and carbon cycles and the cryosphere.
- ✓ Remote Sensing data is Key in the Third Pole region where sustenance of ground-based observations is a challenge

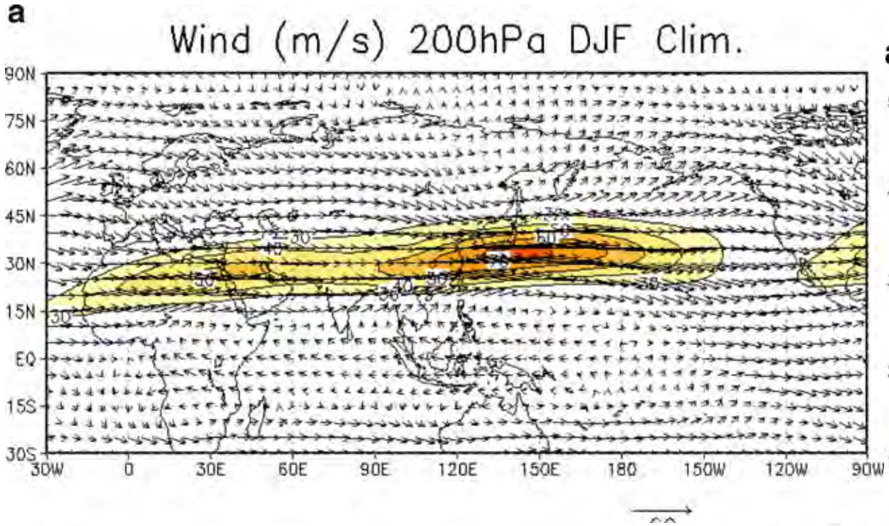
- Delivering useful climate services also requires the availability of socio-economic, biological, and environmental data, for national use in particular.

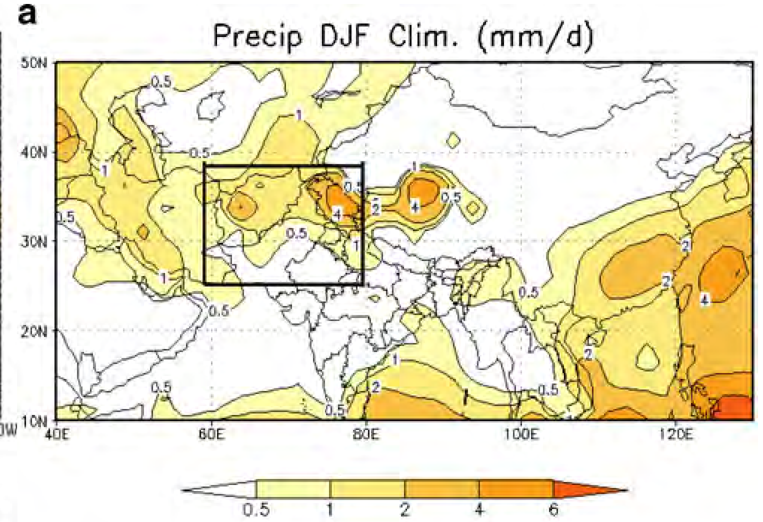
- Physical and chemical climate observations, along with complementary socio-economic and other data, must be effectively integrated to develop and provide users of climate services—farmers, public health officials, disaster risk reduction managers, water resources administrators etc

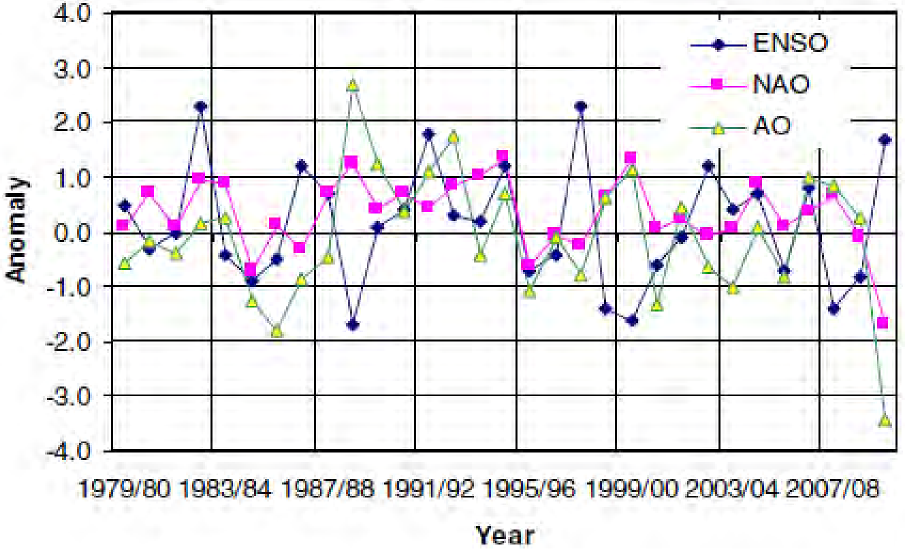
- with information that will help them minimize losses due to climate variability and change and to manage natural and human systems effectively.

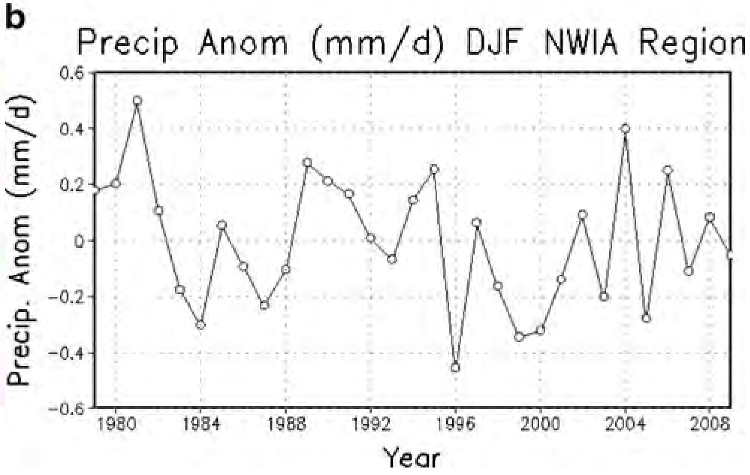
- Existing capabilities for climate observation and data exchange provide a strong basis for improving climate services.

- However, there are major gaps in climate observations (particularly in our context) over the Himalayas.









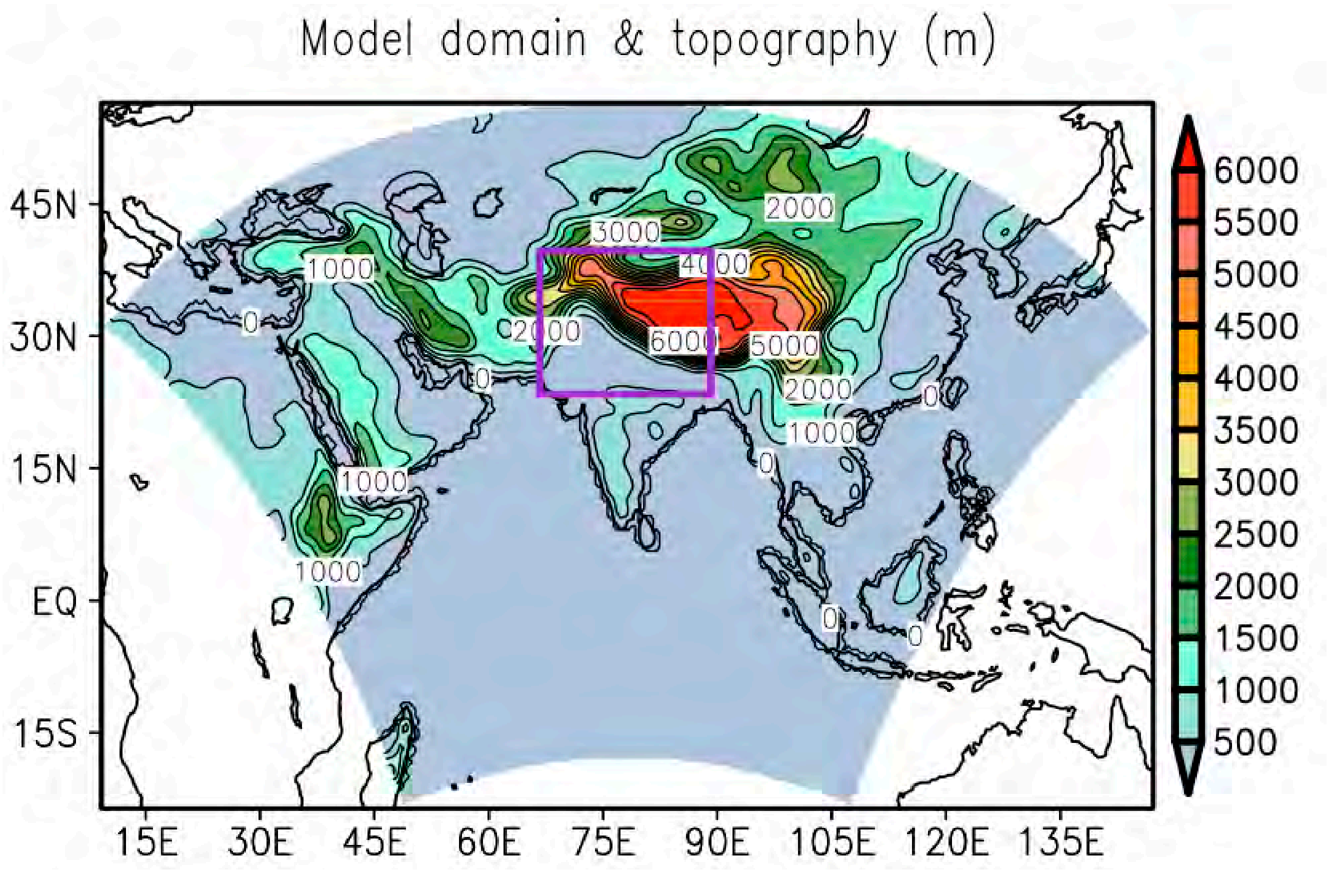
Importance of Himalayas on the Global Climate has been studied.

Few studies exist on the Influence of Global Climate on the Himalayan region (Yadav et al, Kar and Rana, Dimri etc

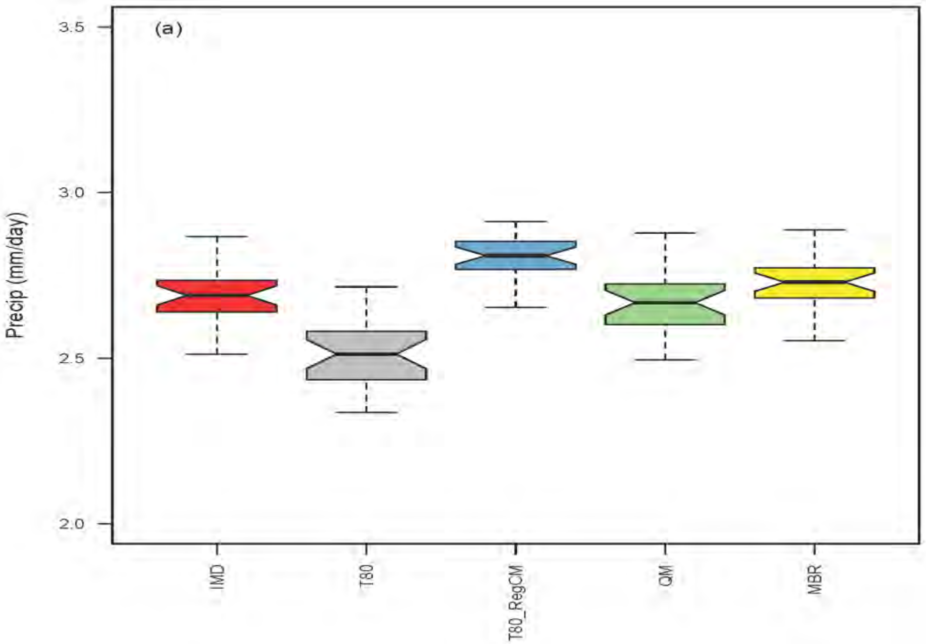
Climate Forcing such as ENSO, NAO and AO influence the climate o fthe Third Pole.

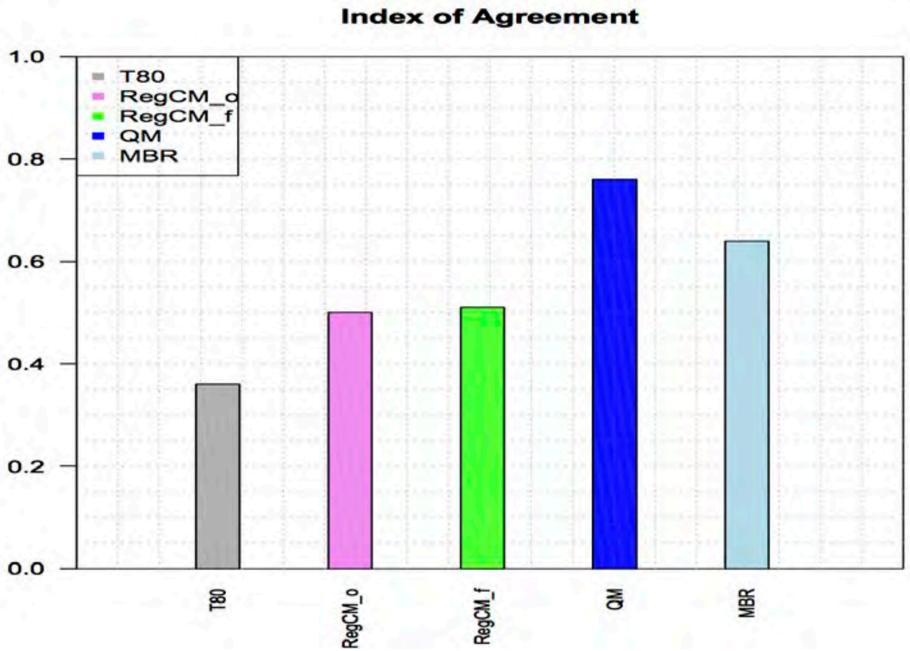
There exists a robust observation and monitoring system for ENSO, NAO, AO etc

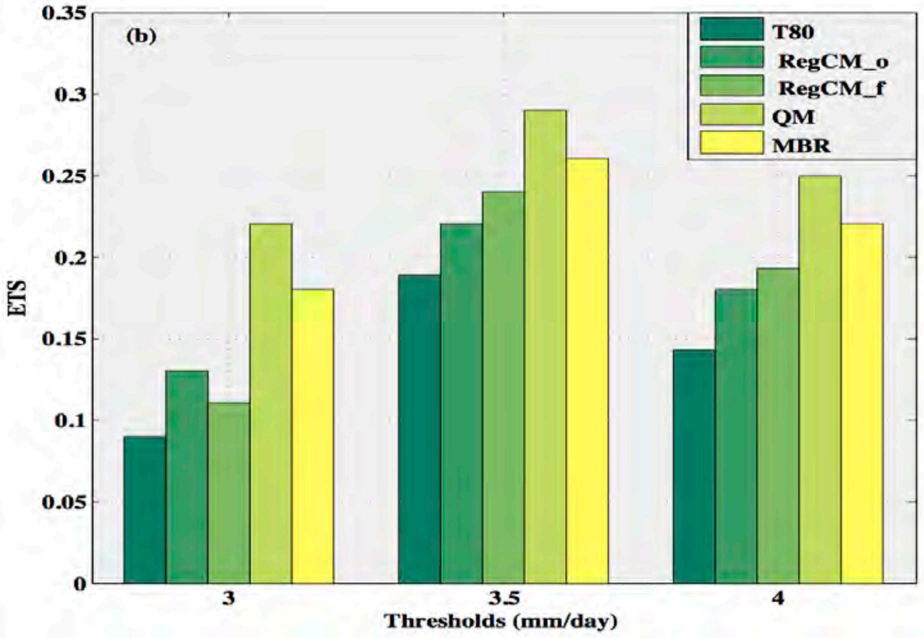
These parameters can be included in the development of climate service for the Third Pole



- ICTP Regional Climate Model (RegCM 4.1.1)
- Model domain and topography (in m)
- The region under the purple box shows the area of interest for which the results are analyzed
- Model domain and resolution 28^0 E - 128^0 E & 30^0 S - 56^0 N; 30km
- No. of grid points along x and y directions are 320 and 384 respectively
- Model time step 30 sec

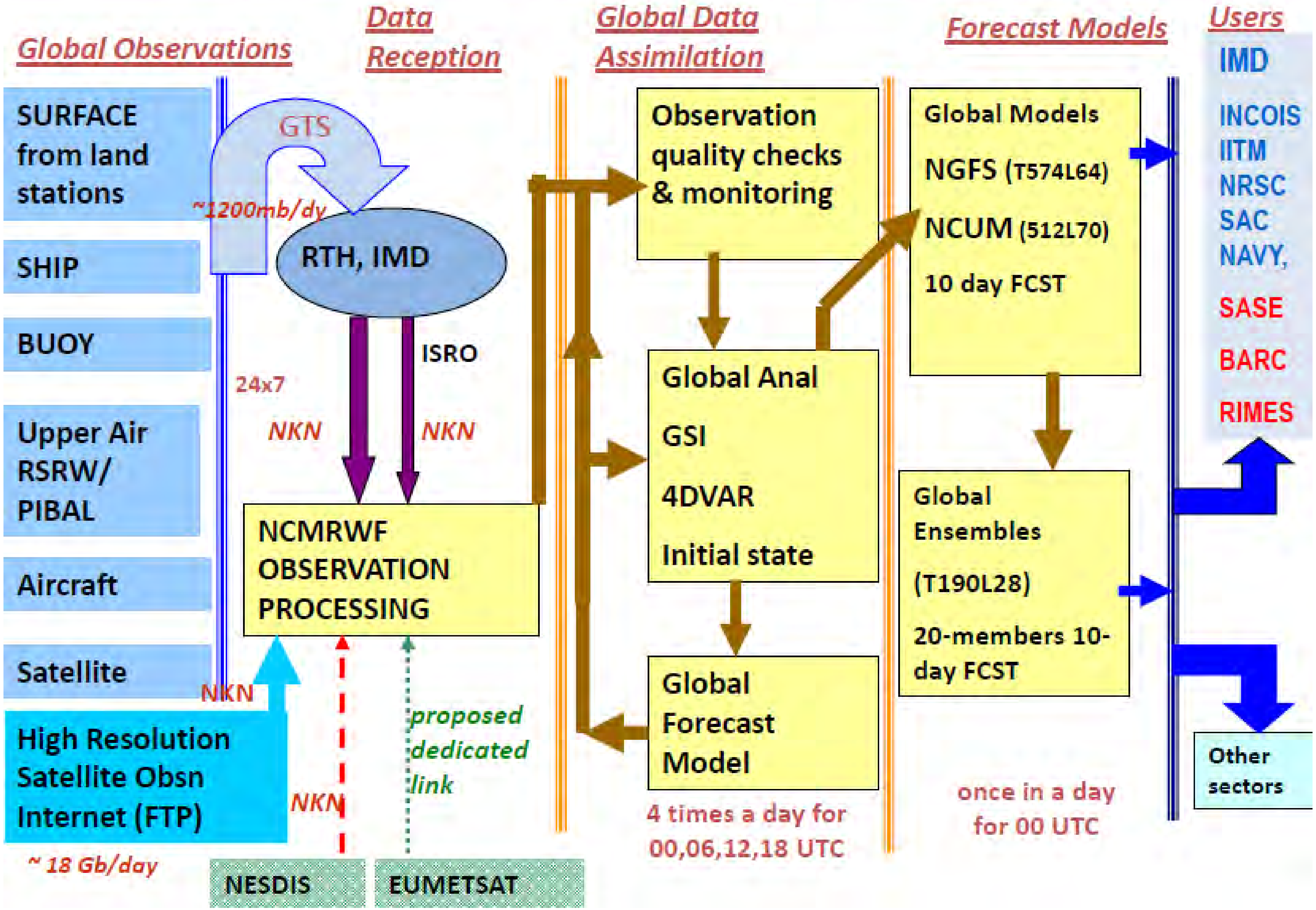


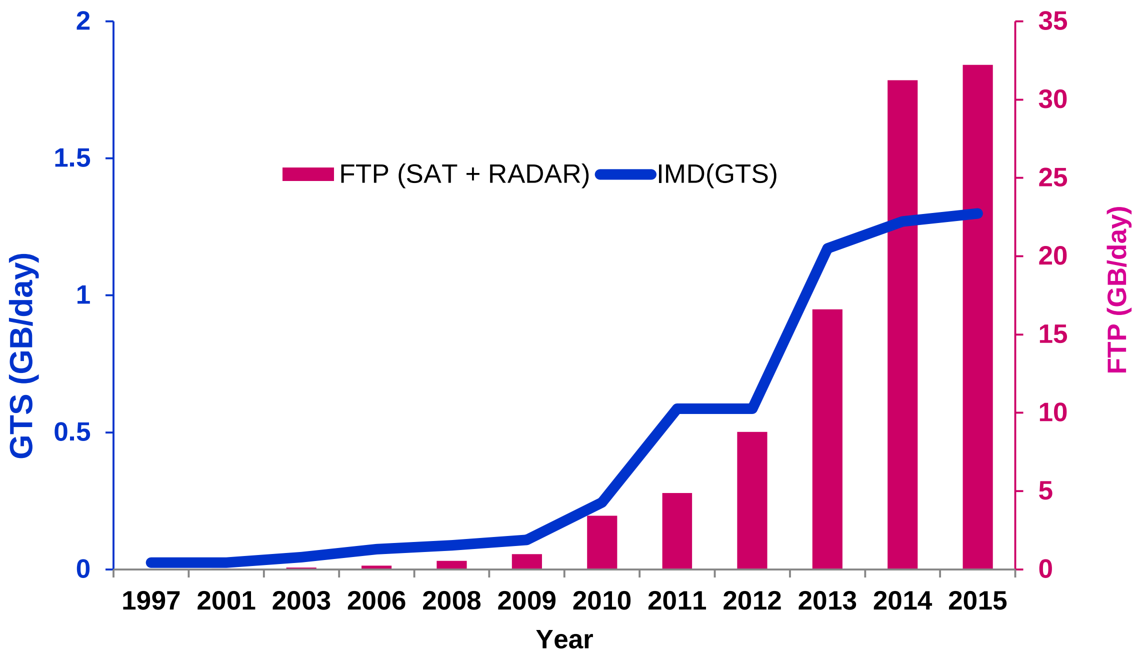




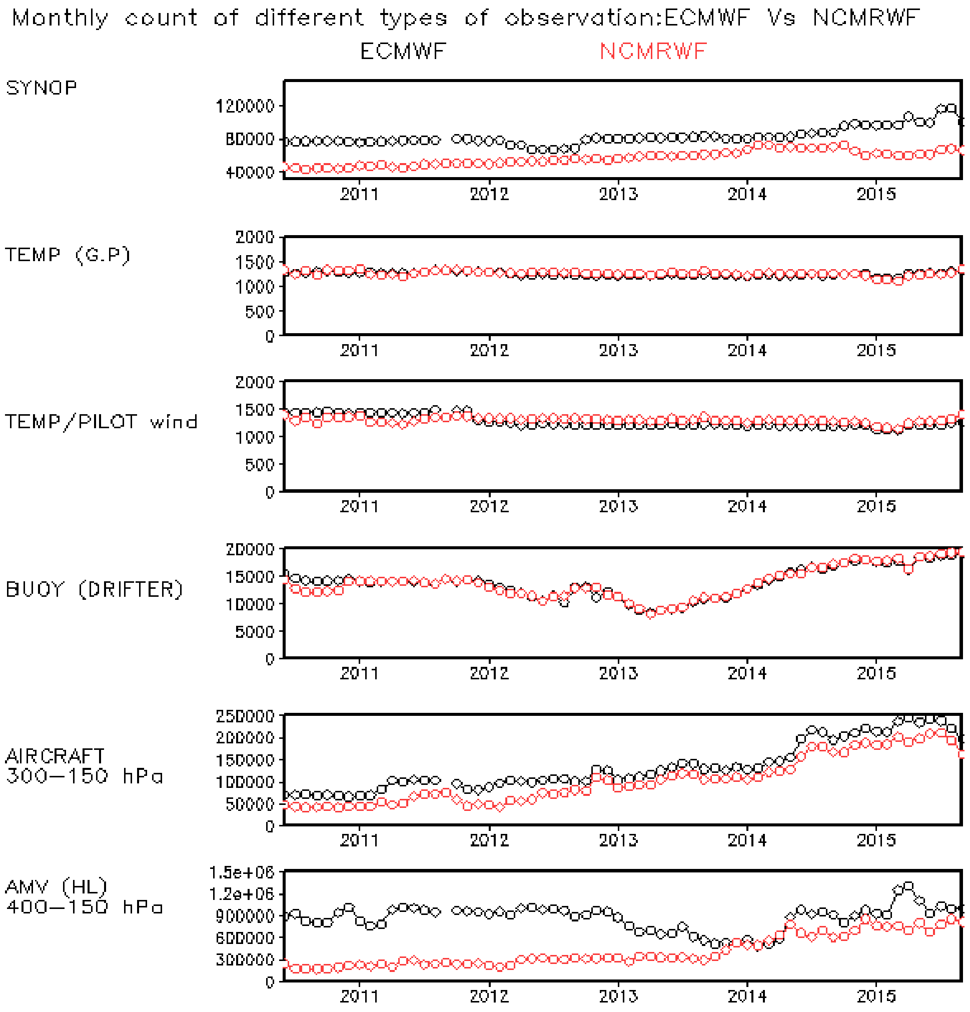
- **Box plot** suggests that the **distribution of QM values are closer** to the distribution of observed values compared to T80, RegCM model and MBR method
- **Index of Agreement** for **QM method is higher** compared to MBR, RegCM and T80
- **ETS** for three thresholds is computed and it shows that **QM** method has **highest** value

Numerical Weather Prediction System at NCMRWF





Year-wise increase in the volume of data reception



Current Operational Global Models

- NCMRWF Global Forecast System (NGFS) T574L64 with 3D-Var Data Assimilation
  - 10 day forecast – for 00 UTC
  - 3 day forecast -12 UTC for initializing RIMES 9-km WRF

- NCMRWF Global Ensemble Forecast System
  - NGEFS (T190L28/21 Members) -10 day ensemble forecasts

- 9km-WRF for RIMES domain – Daily running for 3 days with 12 UTC GFS inputs
- 3-km WRF runs for 8 NPCIL sites – IC & LBC from 9-km WRF runs from12 UTC GFS inputs

Seamless Prediction System

NCMRWF Unified Modelling System (NCUM)

- NCUM Global (17kmL70) with 4D-Var Data Assimilation
  - ➢10 day forecast

➢4-km NCUM-Regional (with explicit rain processes) running with NCUM-G inputs at 00 UTC for 72 hours

➢1.5-km NCUM-Regional (with explicit rain processes) trial runs with NCUM-G inputs for 72 hours

- Ensemble Prediction System

➢N400L70(33 km) 44 members

- Coupled ocean atmosphere system

Ensemble Prediction at NCMRWF

Model	No. of Members	Horizontal Resolution	Forecast Length
GEFS (T190L28) (Operational)	20 + 1	~70 km	10 Days
NEPS (N400L70) Based on NCUM	44 + 1	~33 km	10 Days (450 nodes/3.5 hrs)

- Long-term, well-calibrated, global observations of variables such as air temperature, rainfall, sea-level, and concentrations of greenhouse gases and aerosols are critical for defining the evolving state of the Earth's climate.

- Observations needed for providing climate services include precipitation, soil moisture, and surface air temperature, as well as observations of phenomena (e.g. thunderstorms, hail, fog, dust).

- The observational data is fundamental for defining the initial states for model runs (3-dimensional structure of the atmosphere), for validating the numerical models used for weather and short-term climate forecasting, and for longer-term scenario-based projections of climate change.

- At many NWP Centres world-wide including at NCMRWF and IMD, data received through GTS and satellite data are decoded, quality controlled and monitored routinely.

A Near-Real time Data decoding and monitoring system at NCMRWF

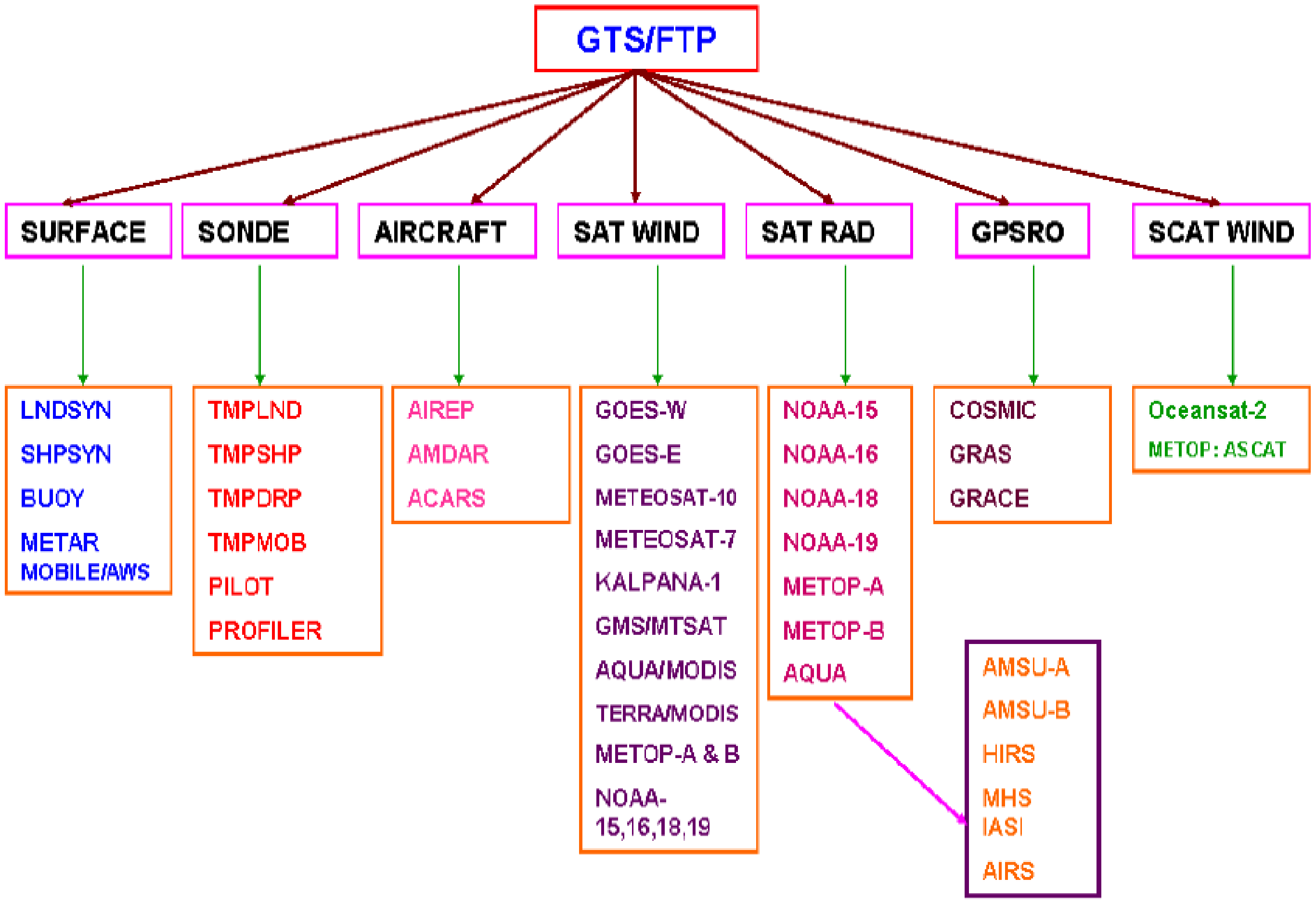


Figure 1: Near-real time global observations received at NCMRWF through GTS and Internet (ftp).

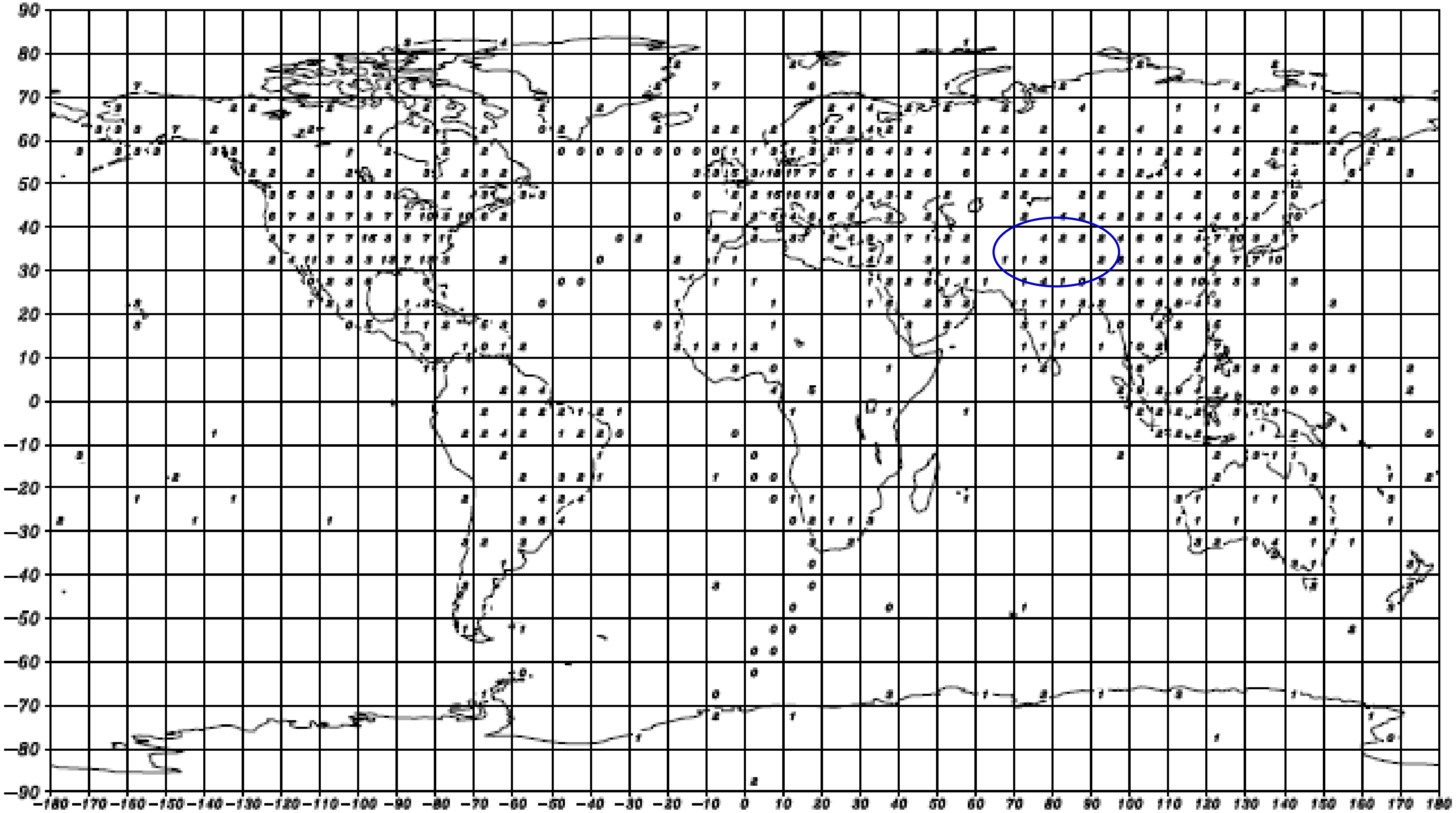
NCMRWF Monitoring Statistics 01 02 16 TO 29 02 16

Availability – TEMP 500 hPa geopotential

Average number of observations in 24 hours – 1560

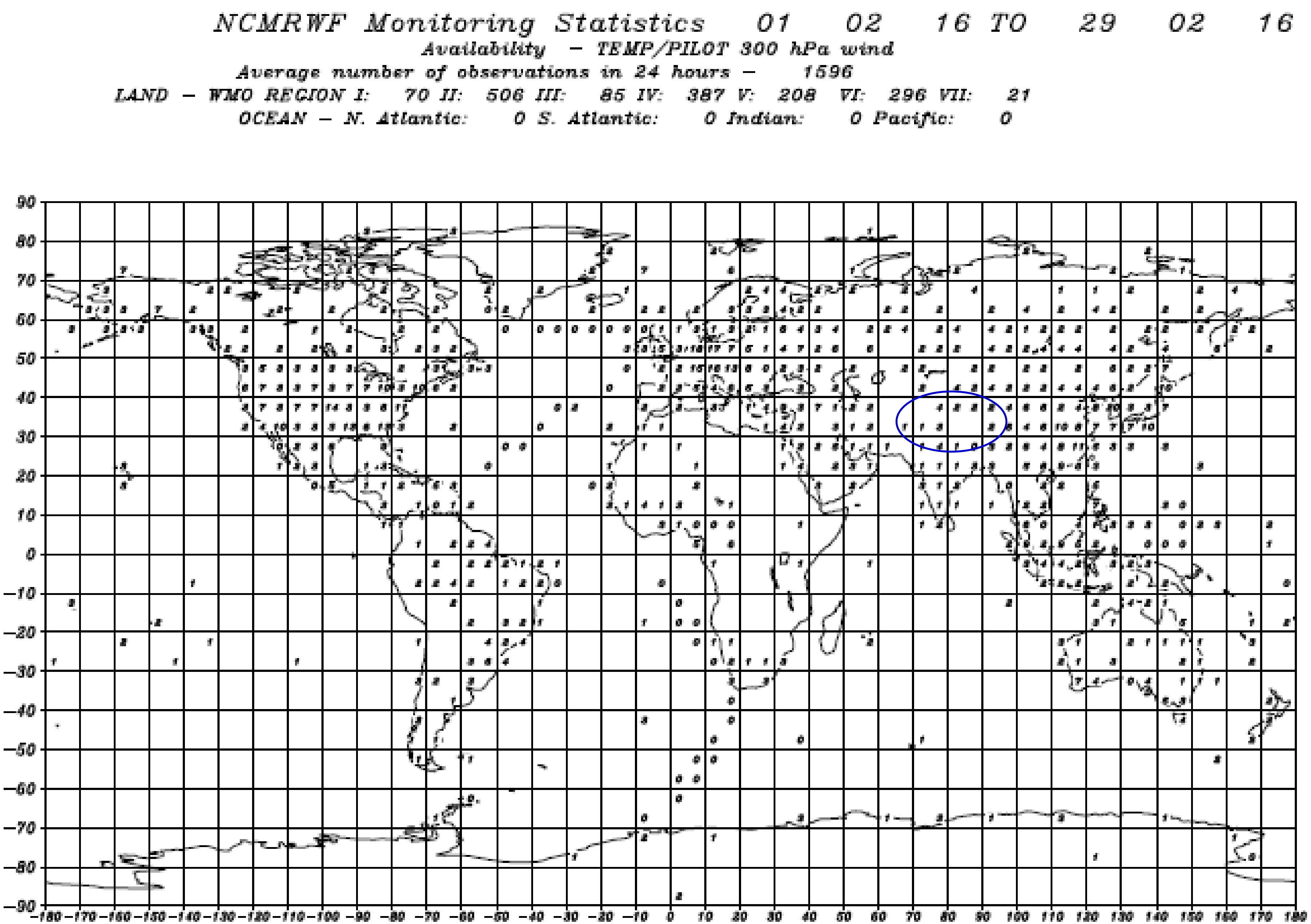
LAND – WMO REGION I: 65 II: 501 III: 85 IV: 392 V: 179 VI: 299 VII: 21

OCEAN – N. Atlantic: 0 S. Atlantic: 0 Indian: 0 Pacific: 0



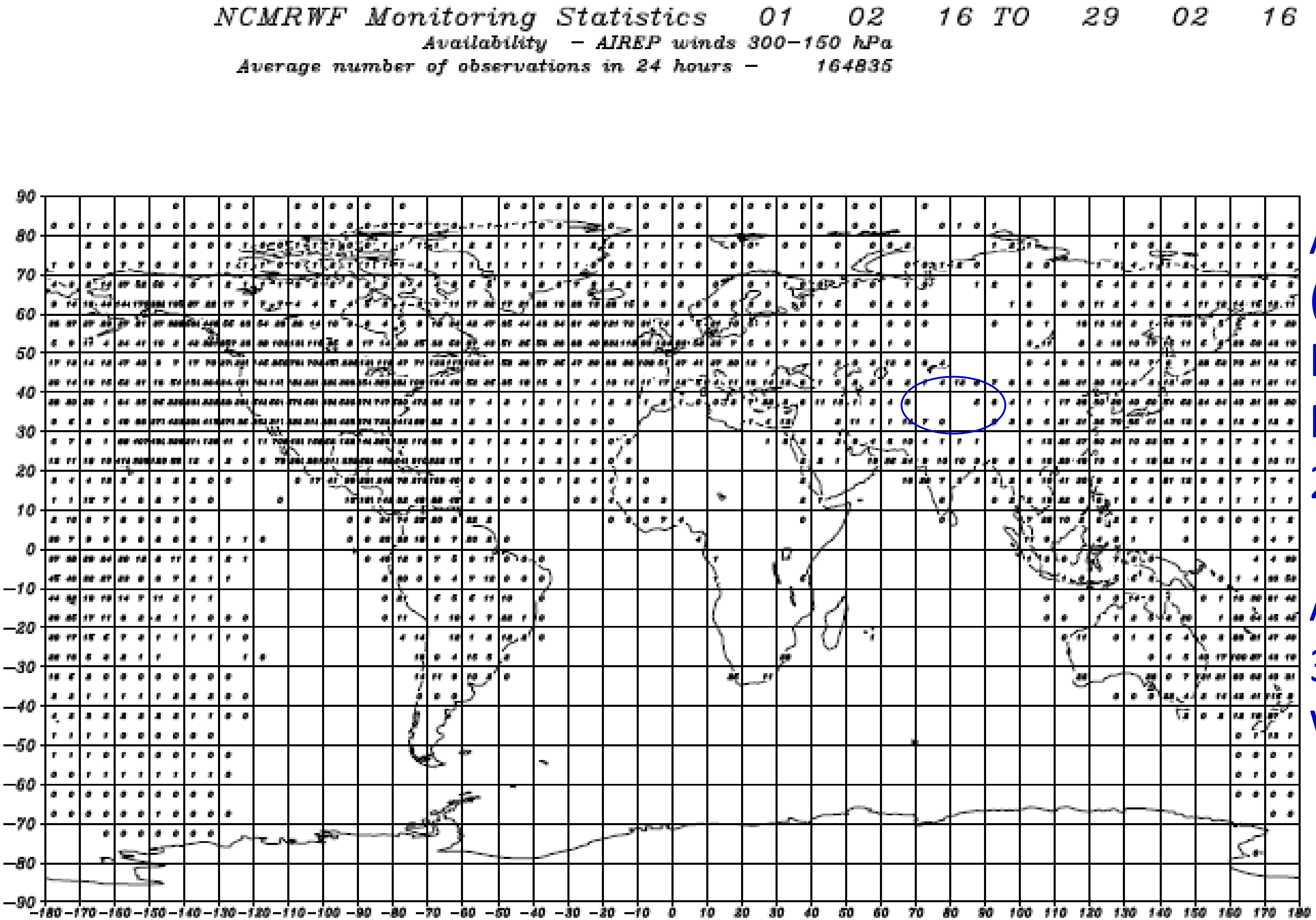
Average Number (per day) of Data Received at NCMRWF in Feb 2016

TEMP
500hPa Geop



Average Number (per day) of Data Received at NCMRWF in Feb 2016

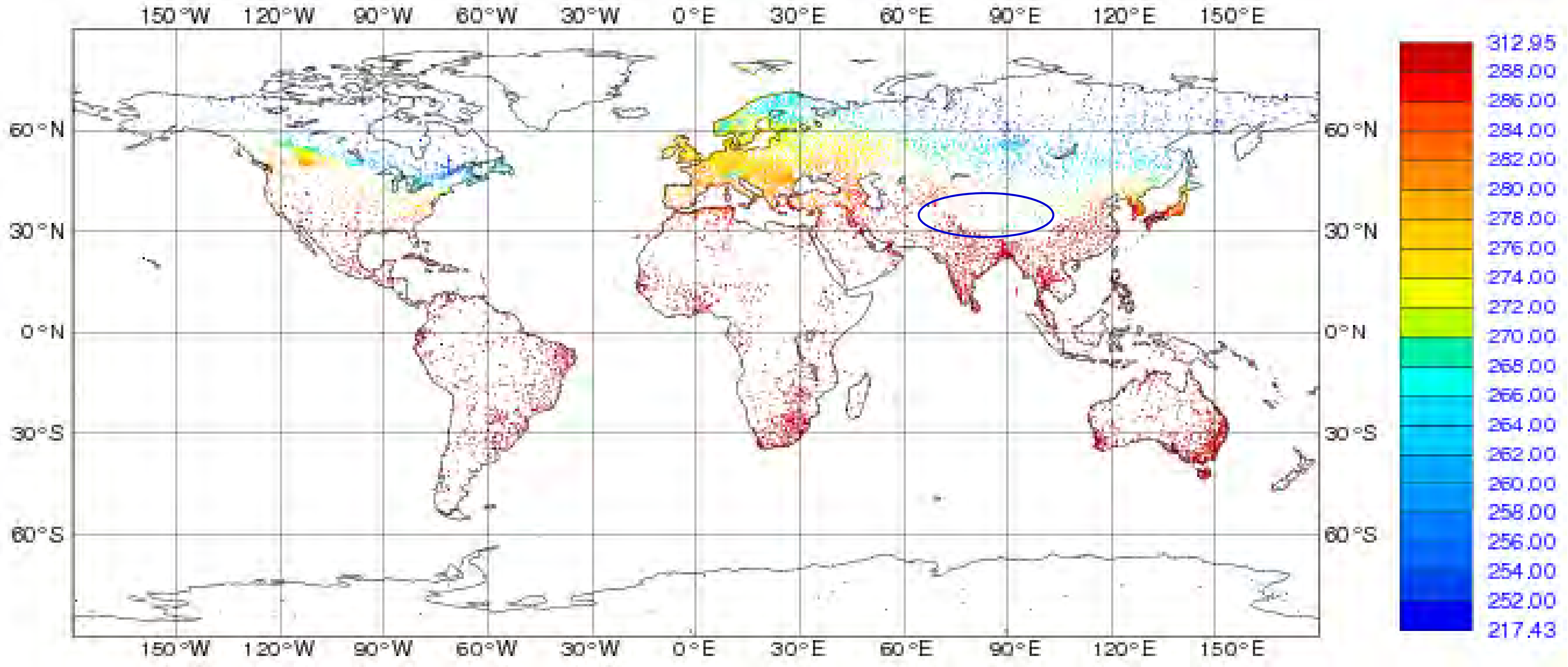
TEMP/PILOT 300hPa Winds



Average Number (per day) of Data Received at NCMRWF in Feb 2016

AIREP 300-100 hPa Winds

T2M FROM SYNOP
MEAN OBSERVATION [K] (USED)
DATA PERIOD = 2016-03-03 21 - 2016-03-05 09
EXP = 0001, CHANNEL = 1
Min: 219.433 Max: 310.951 Mean: 280.880
GRID: 0.50x 0.50



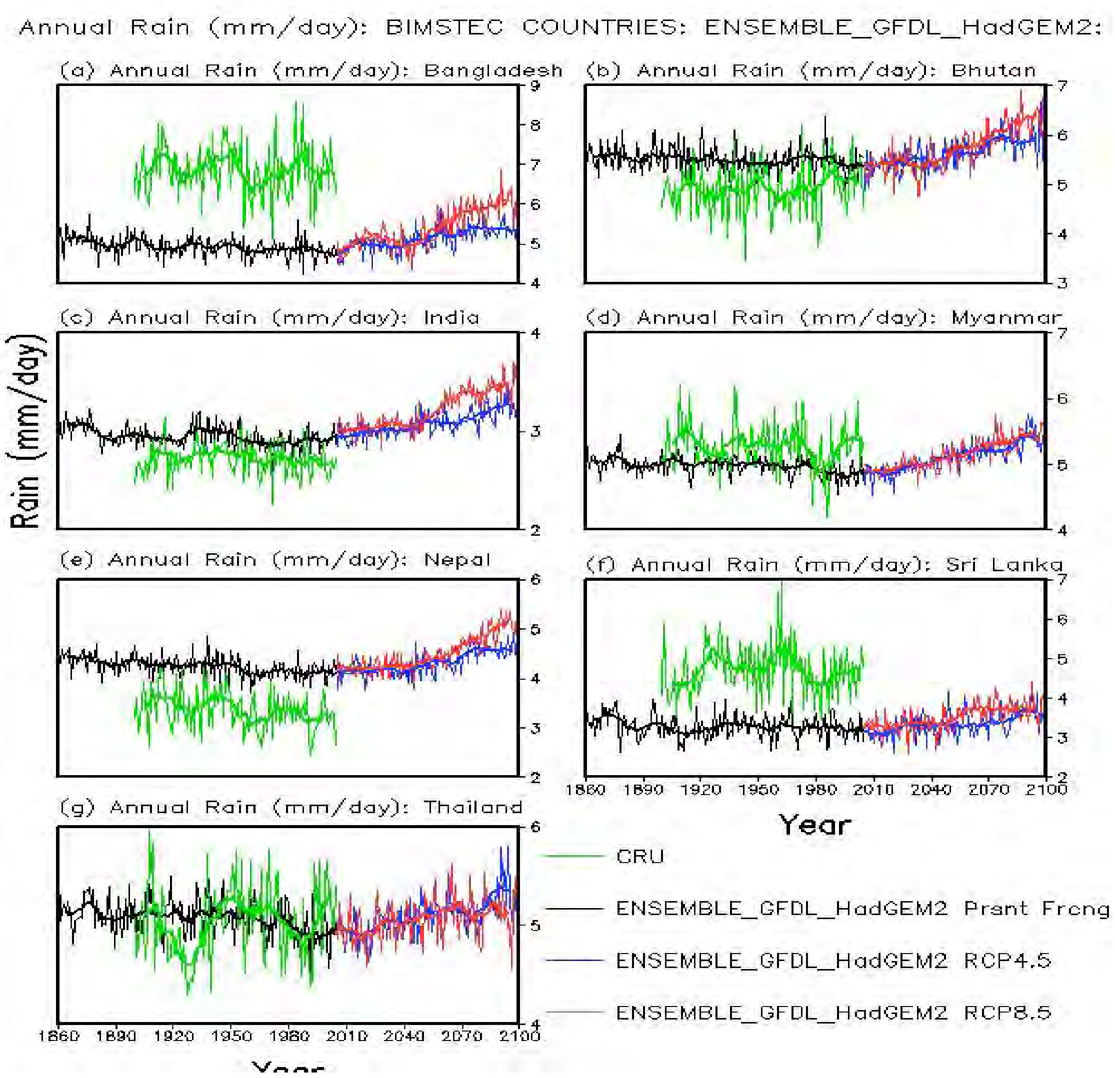
While there is steady progress in the observation and monitoring required for weather services, there is a big gap for such observing network for climate services

- Global parameters that influence the Third Pole
- Surface Conditions (both Remote sensing and In situ
- Land use / Land Cover, Snow, Glaciers, Soil Moisture
- 3-D structure of Atmosphere
- Aerosol
- Ecological Conditions
- Bio and Chemical state of atmosphere
- Hydrology
- Crop conditions

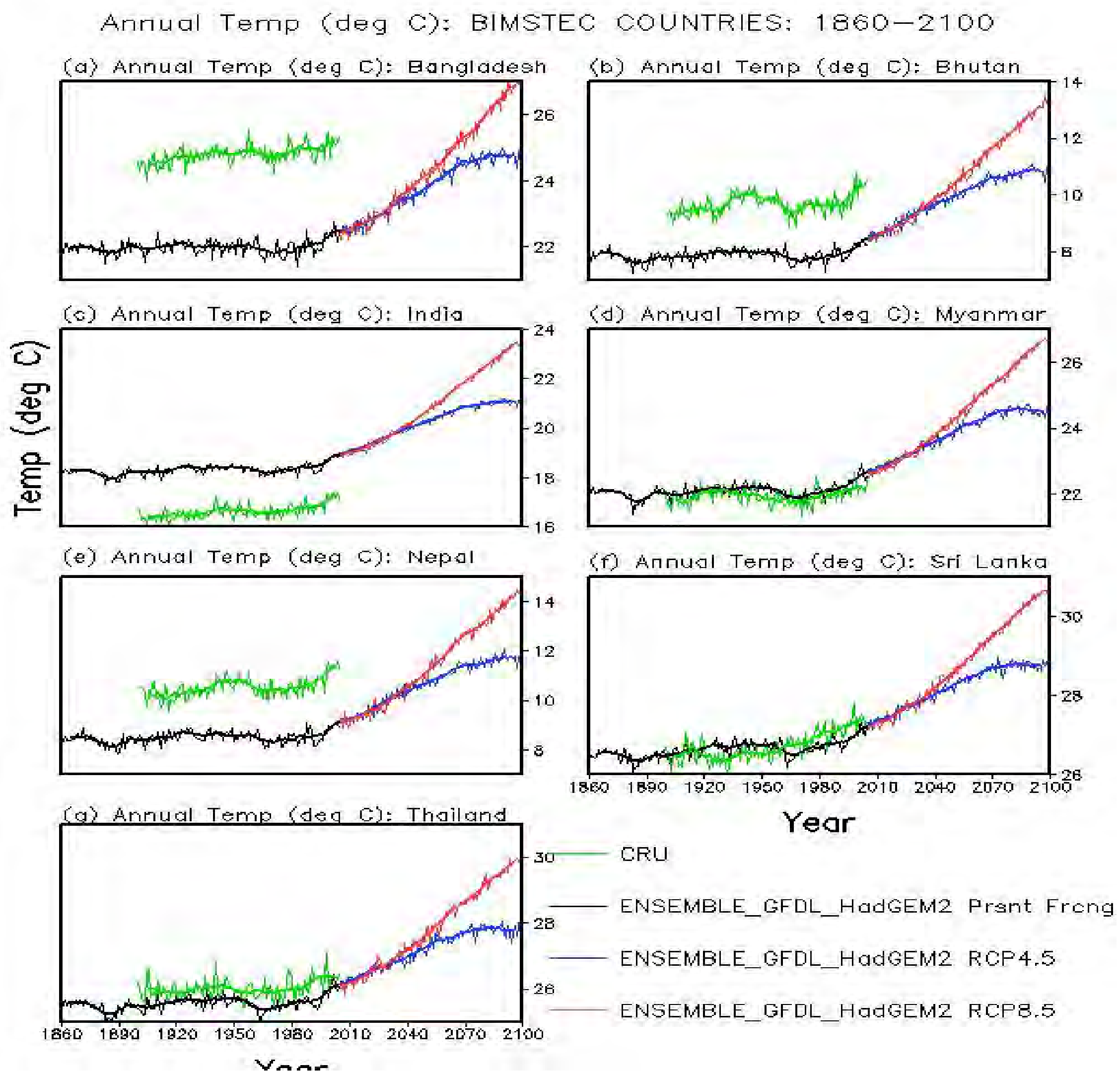
These go as input to Earth System Model, so essential for Climate Service

Climate Projections by GCMs for the BIMSTEC Countries

Rainfall



Temp



Constraints affecting climate and related data access and data exchange

- Major concern is the restrictive data policies of some data providers.
- Data Agencies for management and exchange of data have their own data policies, often based on national legislation.
- Therefore, many are not able to provide free and unrestricted access to their data.
- As a fundamental principle of data sharing within the GFCS, an open door policy should be pursued.
- Thus countries should continue to be encouraged to adopt free and unrestricted (non-discriminatory and without charge) international exchange of climate-related data and products.

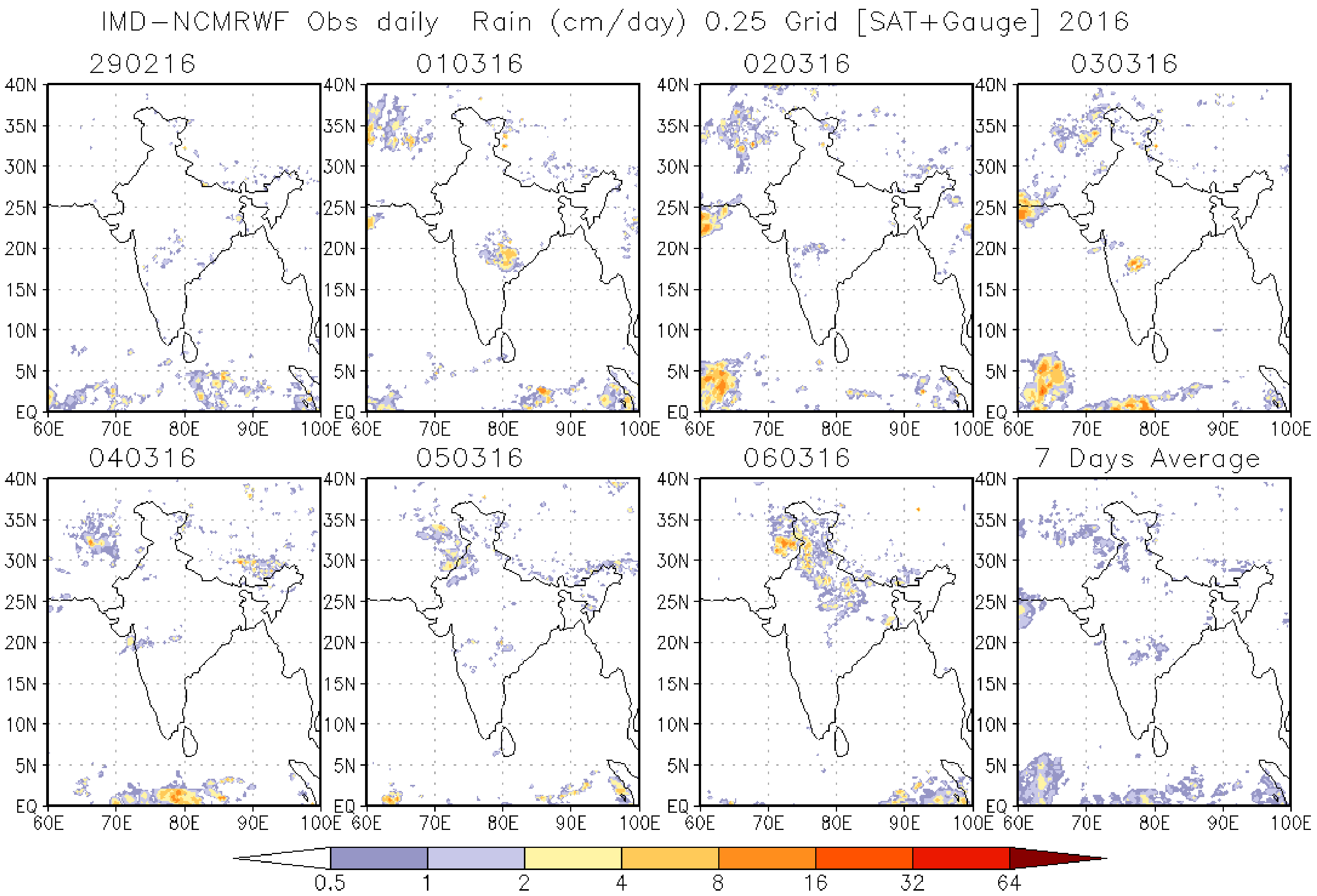
For Successful Implementation of the Observations and Monitoring Pillar

➢ all data needed by climate services be measured and available on a sustained basis.

depend on several factors:

❑ Agencies having observing networks (such as NMHSs, research institutes, universities, and the private sector) need to make their observations, data, and observational products available (including historical data and products);

❑ Technological developments and national, regional, or global economic circumstances must enable these entities to collect and deliver observations and data sustainably over the long term.



India's data sharing and accessibility policy is based on the principles :

- Openness,
- Flexibility,
- Transparency,
- Quality,
- Security and
- Machine-readable.

IMD-NCMRWF daily Gridded Merged (satellite and Gauge data) are available online and accessible by all

Addressing observing system gaps

- Effective engagement among entities operating or coordinating observing systems, including their users
- Implementing agreed observing standards and best practices
- Identifying data gaps and building of capacities and technical support to fill them;
- Providing adequate funding, human resources, and IT technology
- Implementing policies for open and broad access to all data needed for providing climate services at the frequencies required;
- Ensuring the relevance of observed variables and data to climate services required by users;

Modeling of Changing Water Cycle and Climate

A Project of the Ministry of Earth Sciences, Government of India
being implemented at NCMRWF and IMD

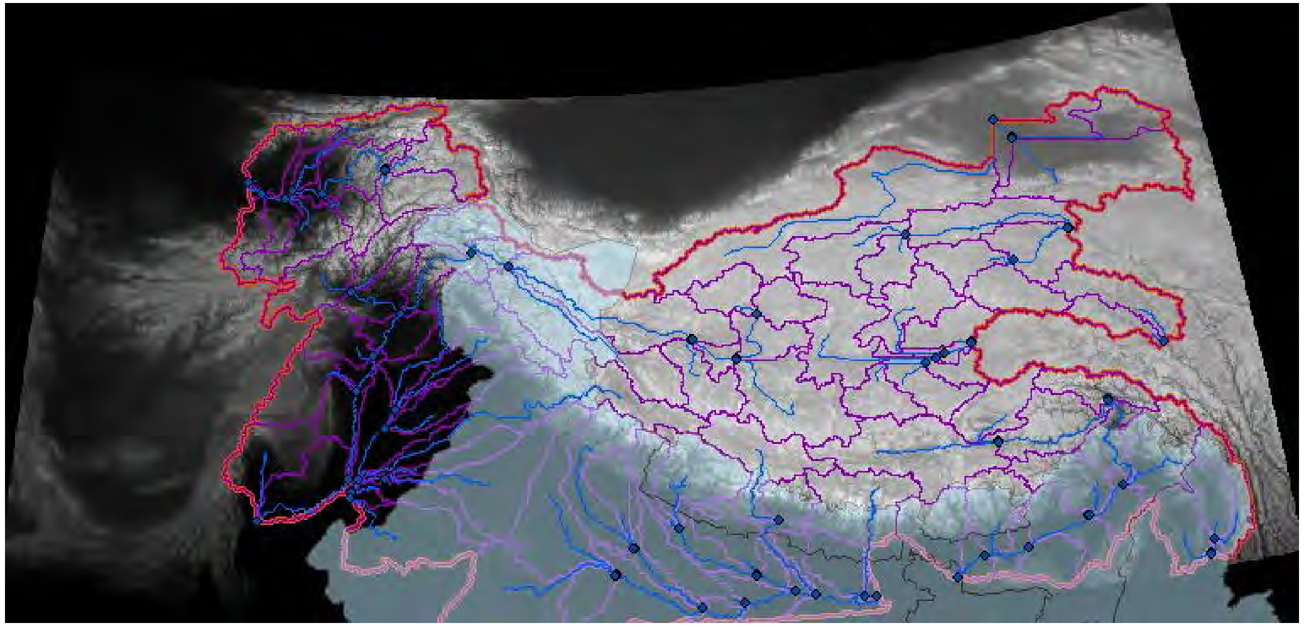
- India’s National Action Plan on Climate Change (NAPCC): Importance of climate variability and change on the water resources

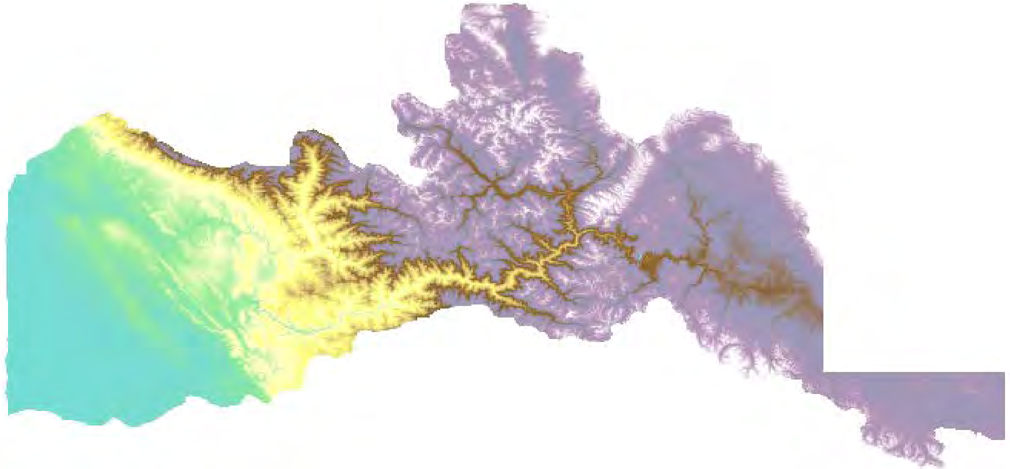
- The National Water Mission of the NAPCC recommends strategies to integrate climate information, water cycle and prediction methodologies.

- These strategies include establishment of additional automated stations for evaporation and rainfall data, strengthen monitoring of glacial and seasonal snow covers and assess the contribution of snowmelt to Indian rivers.

- For efficient use of water resources and for flood control, it is essential that weather and climate information are integrated into the water resource management programs.

River Systems in the Himalayas



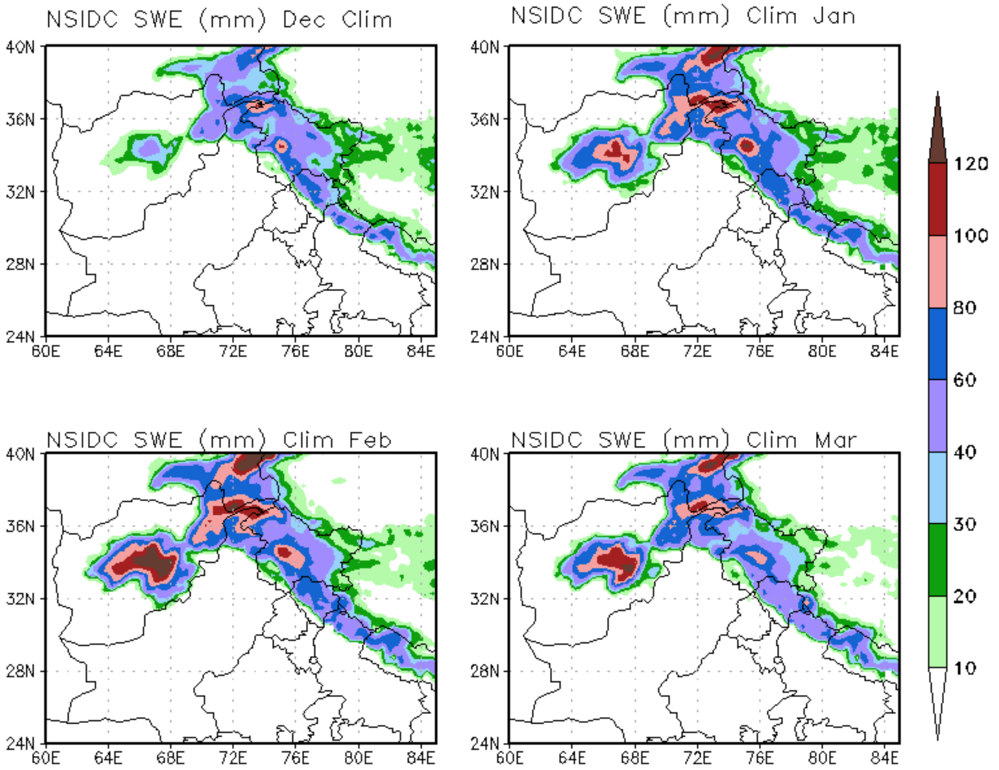


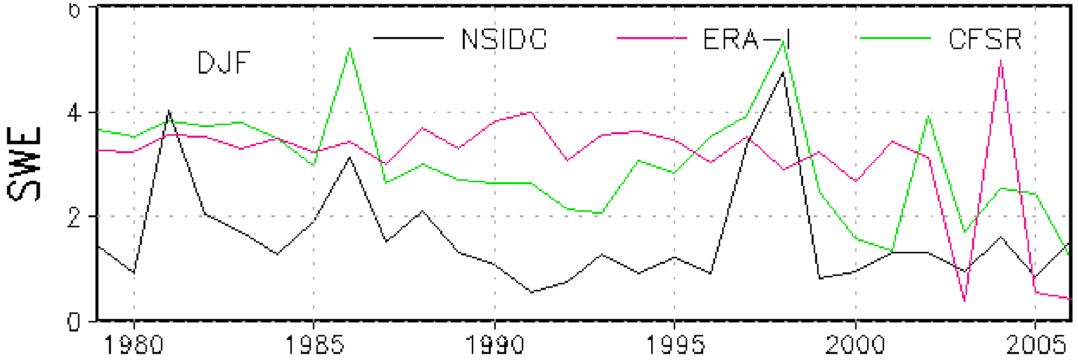
NRSC DEM- a part of basin is missing

Satluj River Basin

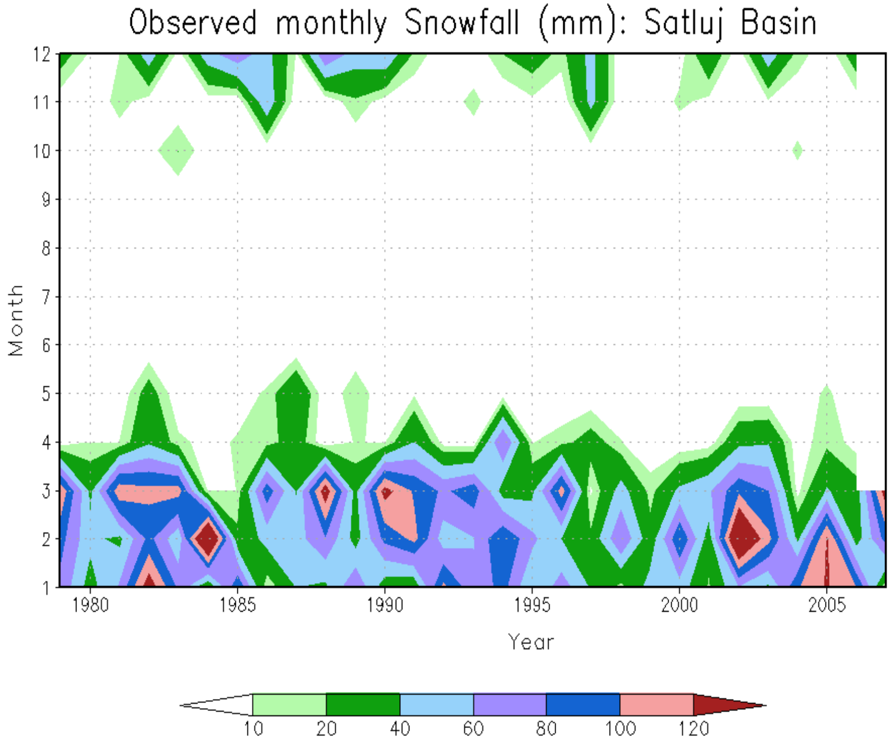
Snow Accumulation and Ablation Variability over Himalayas

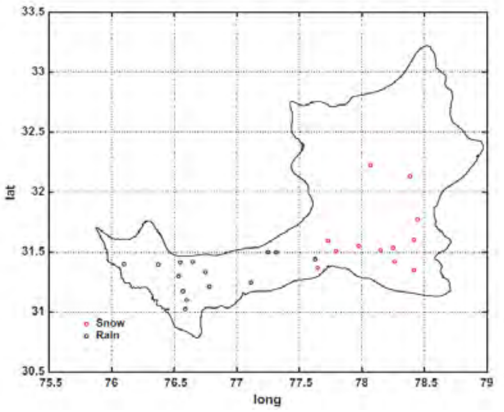
Climatology of Snow in Dec, Jan, Feb and Mar





Yearly Variation of Snow from NSIDC, CFSR and ERA-I

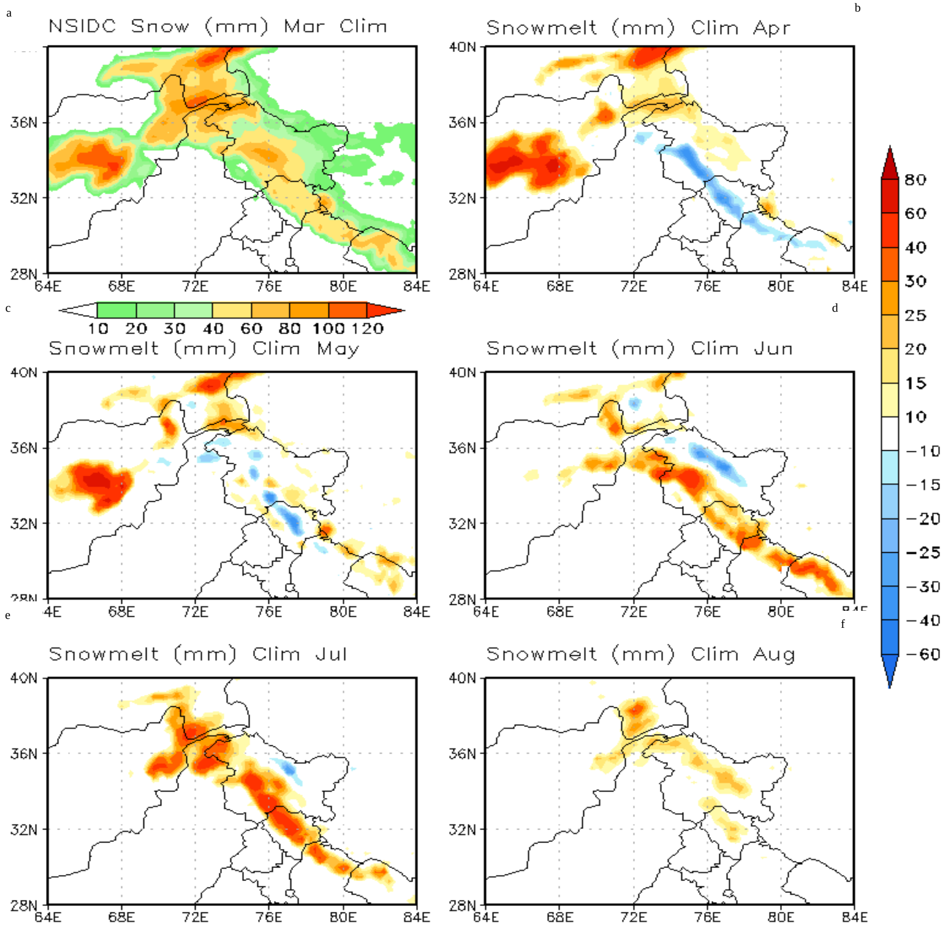




Observed Snowfall at BBMB stations in Satluj Basin

Remote Sensing data of snow accumulation and ablation (from National Snow and Ice Data Centre, NOAA) suggest large interannual variability over Himalayas. Mechanism of such variability has been examined using CFSR reanalysis upper-air data.

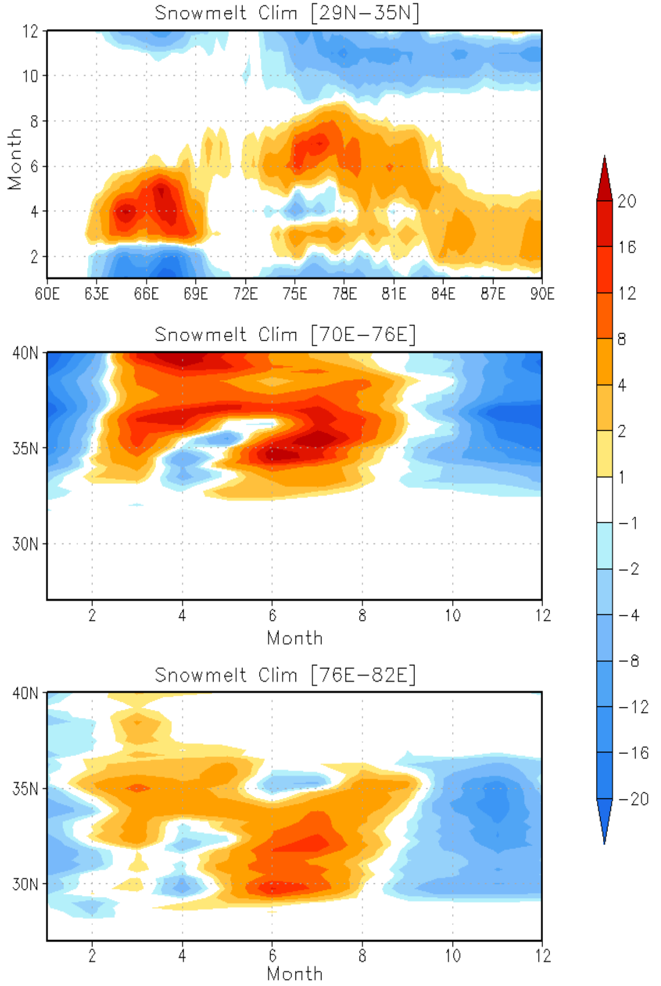
Spatial pattern of snowmelt (monthly) over the Himalayas



[29ºN-35ºN]

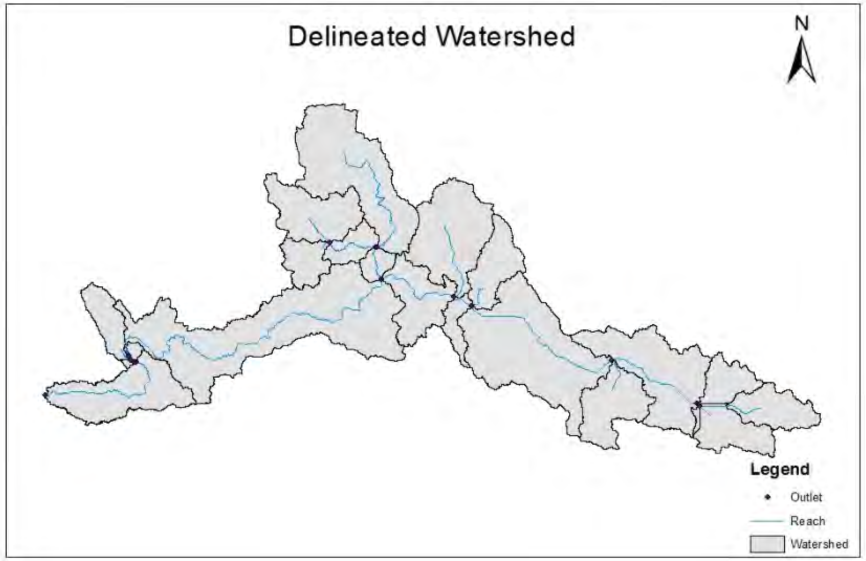
[70ºE-76ºE]

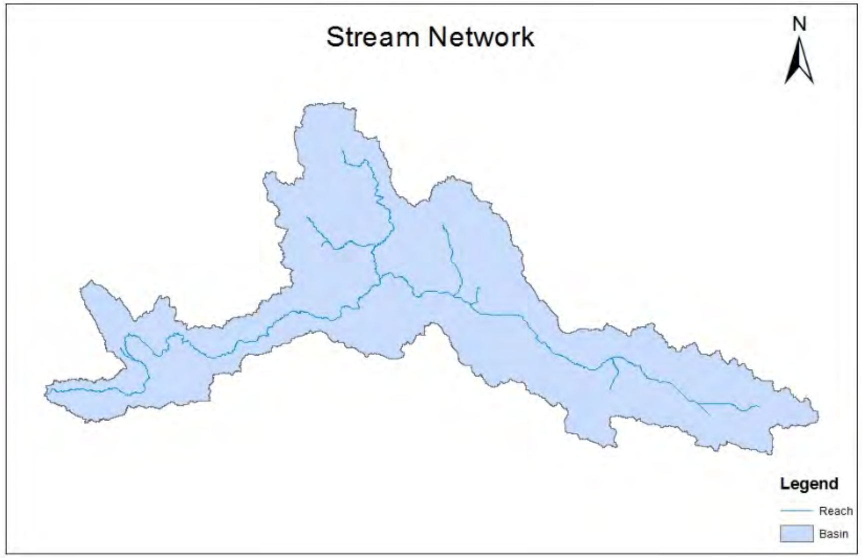
[76ºE-82ºE]

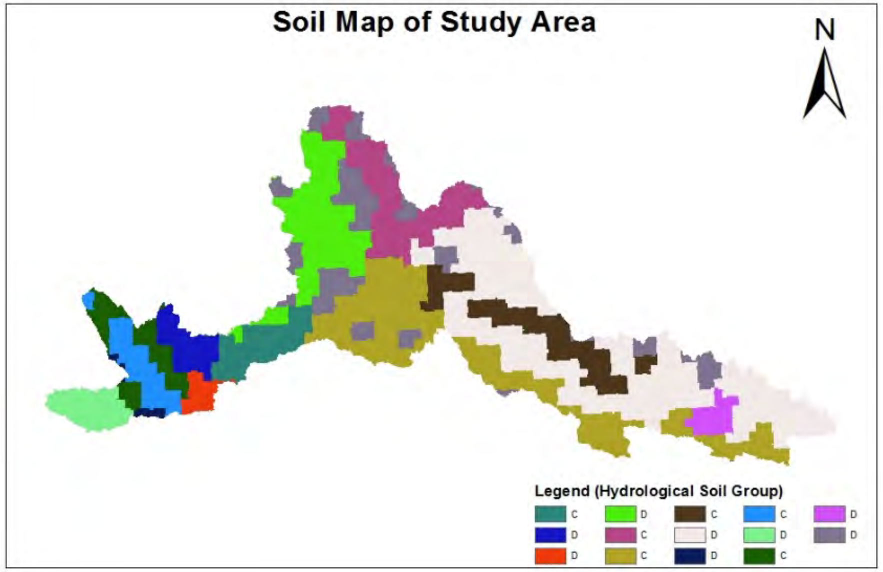


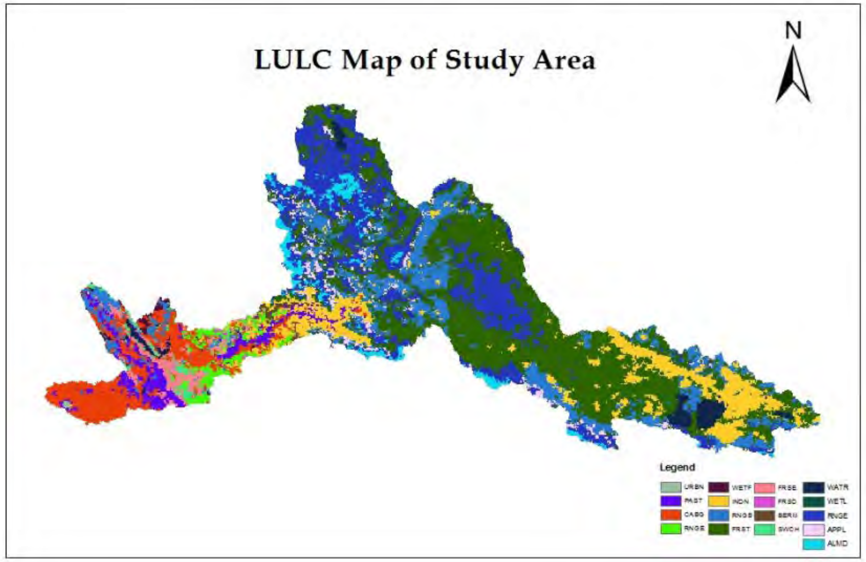
- In April, snowmelt mostly occurs in Afghanistan and northern parts of Jammu and Kashmir. Along the Pir Panjal range & Kashmir, snowfall continues in April.
- There is a north-west south-east band of additional snow covering J&K, Himachal and Uttarakhand.
- As the summer season progresses, the snowmelt contribution increases continuously. In June and July, most of the snow in the region melt and is available as snowmelt runoff.

Basin-wide physically based modeling for Satluj basin



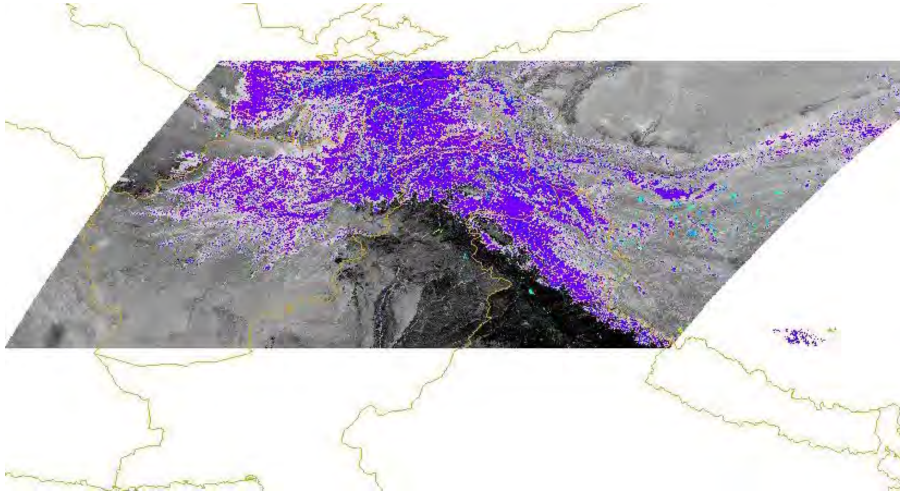




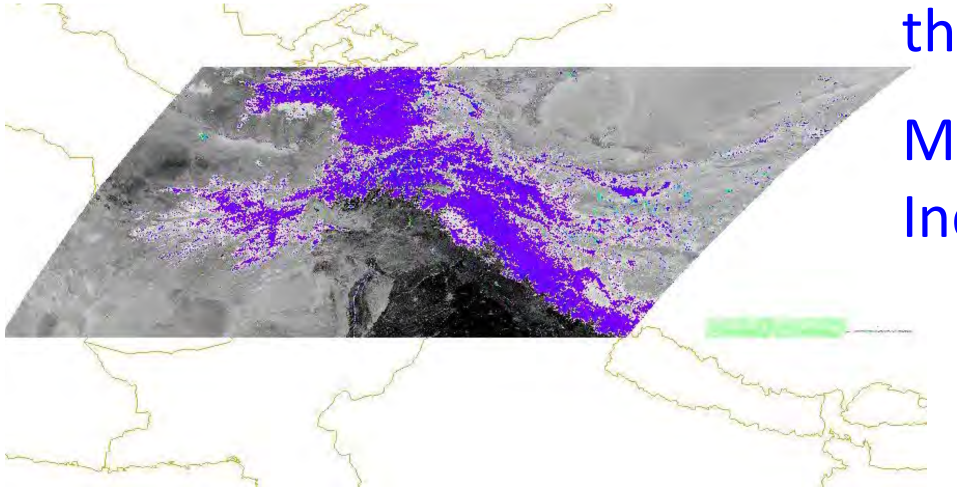


Normalized Difference Snow Index (NDSI)

End-Dec 2014



End-Jan 2015



The atmosphere is transparent at 0.66 and 1.6 µm wavelengths, while snow is very reflective at 0.66 mm and not reflective at 1.6 µm.

$$NDSI = (R_{0.66} - R_{1.66}) / (R_{0.66} + R_{1.66})$$

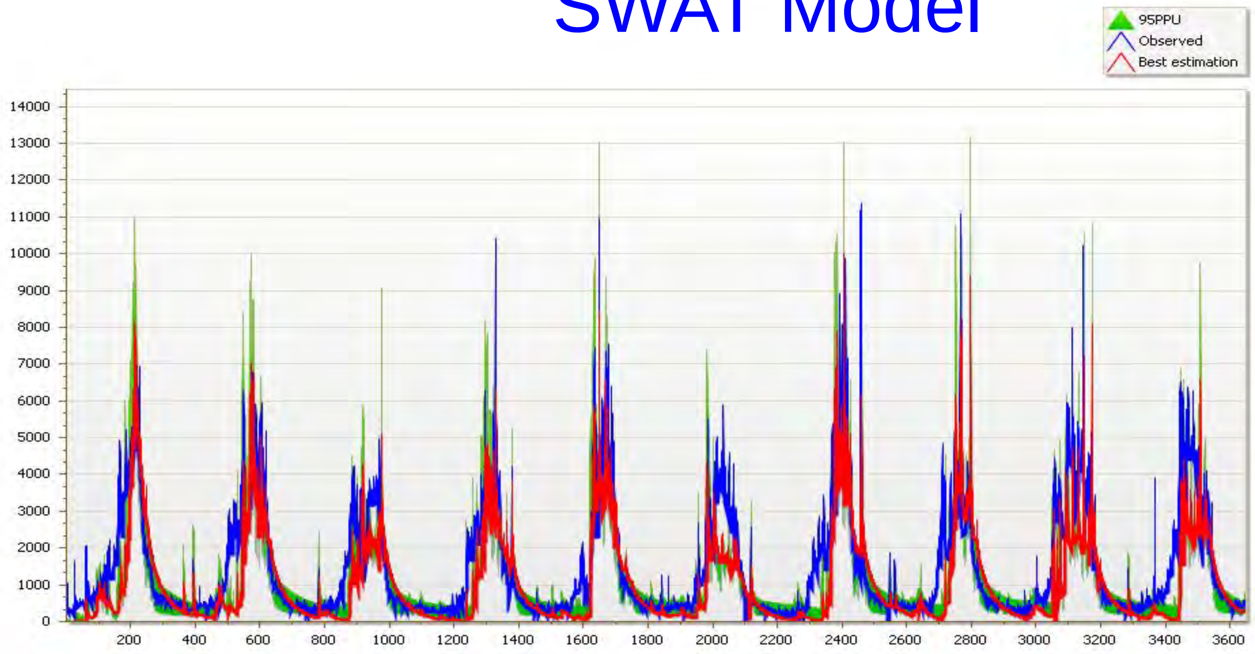
At visible wavelengths (e.g. 0.66 microns), snow cover is just as bright as clouds, and is therefore difficult to distinguish from cloud cover.

At 1.6 microns, snow absorbs sunlight appears much darker than clouds. So, snow cover and clouds can be separated.

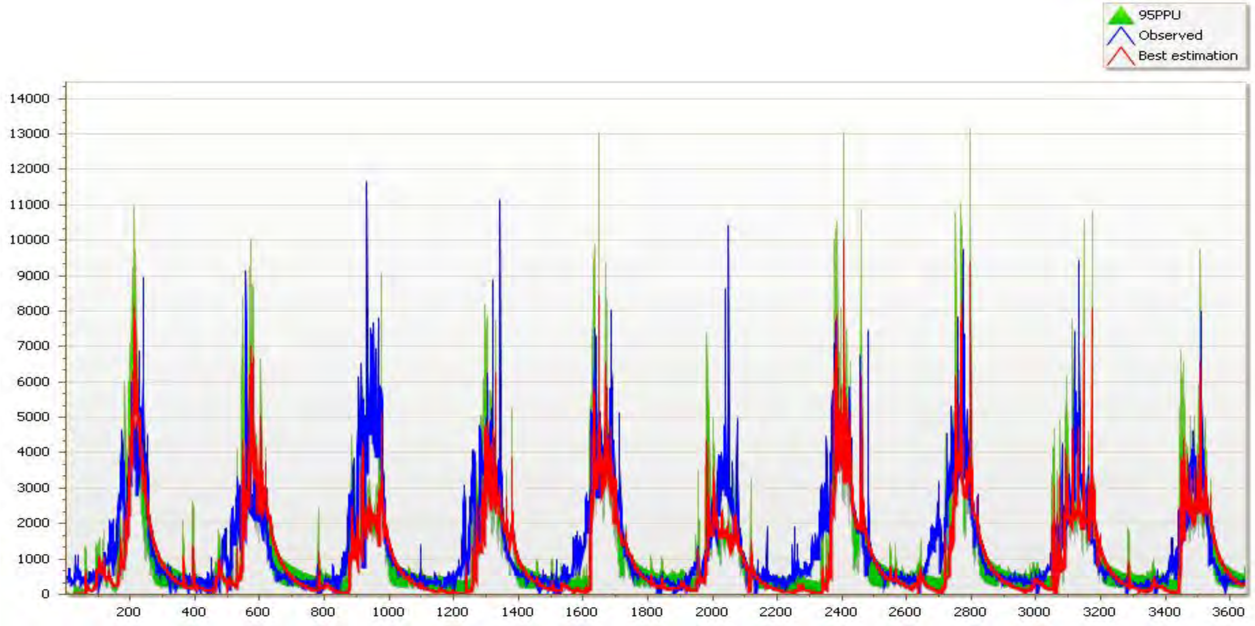
MODIS Reflectivity data has been used to compute Snow Index for the Himalayan region.

How to relate Snow Cover with the Snow Amount ??

Calibration and validation of Satluj Discharge using SWAT Model



Calibration 1982-1992



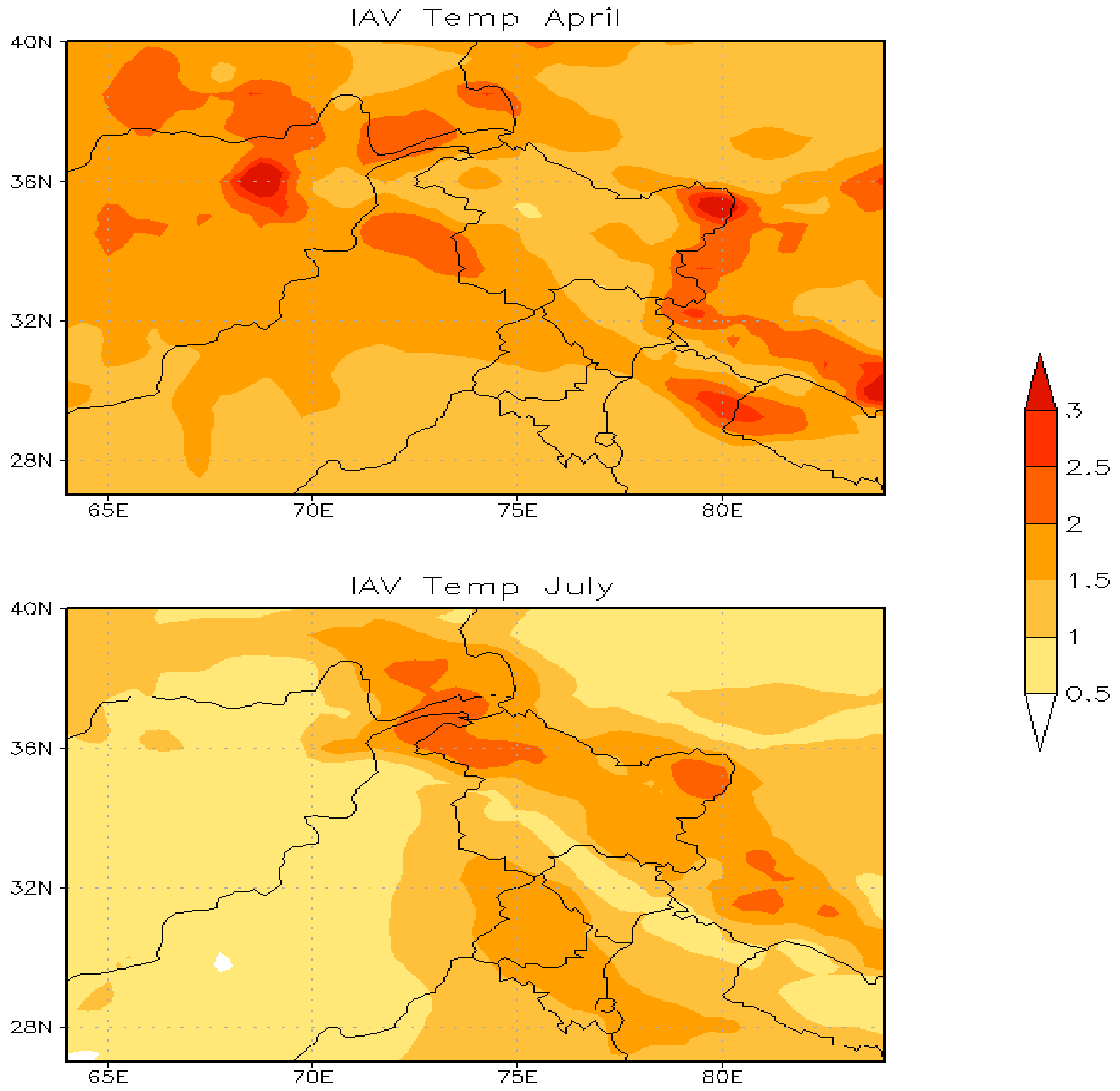
Validation 1993-2003

Interannual variability of monthly mean surface air Temp.

Modeling the snowmelt in a temperature index based model

April

July



Compared to July, in April, the interannual variation of temperature is too large.

Computed climatological DDF of April does not represent interannual variations of snowmelt processes in April.

So, the models do not capture the peaks of snowmelt in April

India's Cryosphere Research

The Himalaya forms the most important concentration of snow covered region outside the polar region.

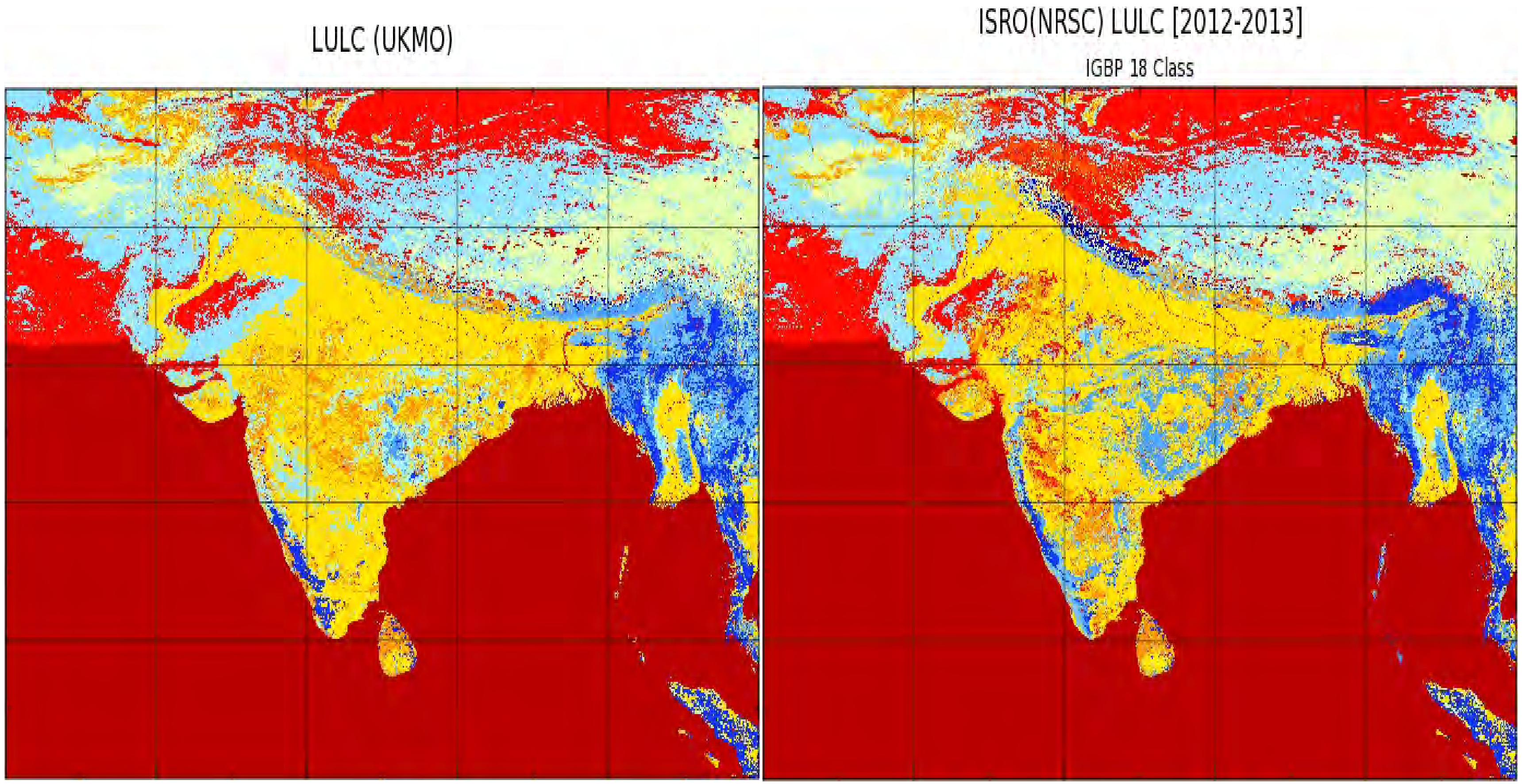
The Himalayan glaciers are highly sensitive to the on-going warming. The detailed glacier inventory of Indian Himalayas (GSI, SAC) indicates presence of 9579 glaciers in the Himalaya, some of which form the perennial source of major rivers.

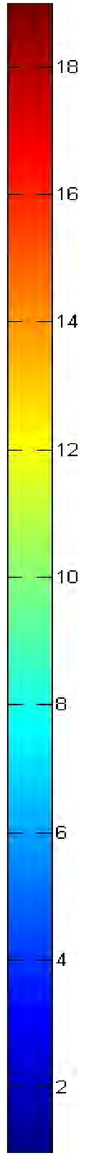
Changes in glaciers are one of the clearest indicators of alterations in regional climate, since they are governed by changes in accumulation (from snowfall) and ablation (by melting of ice).

The main objectives are

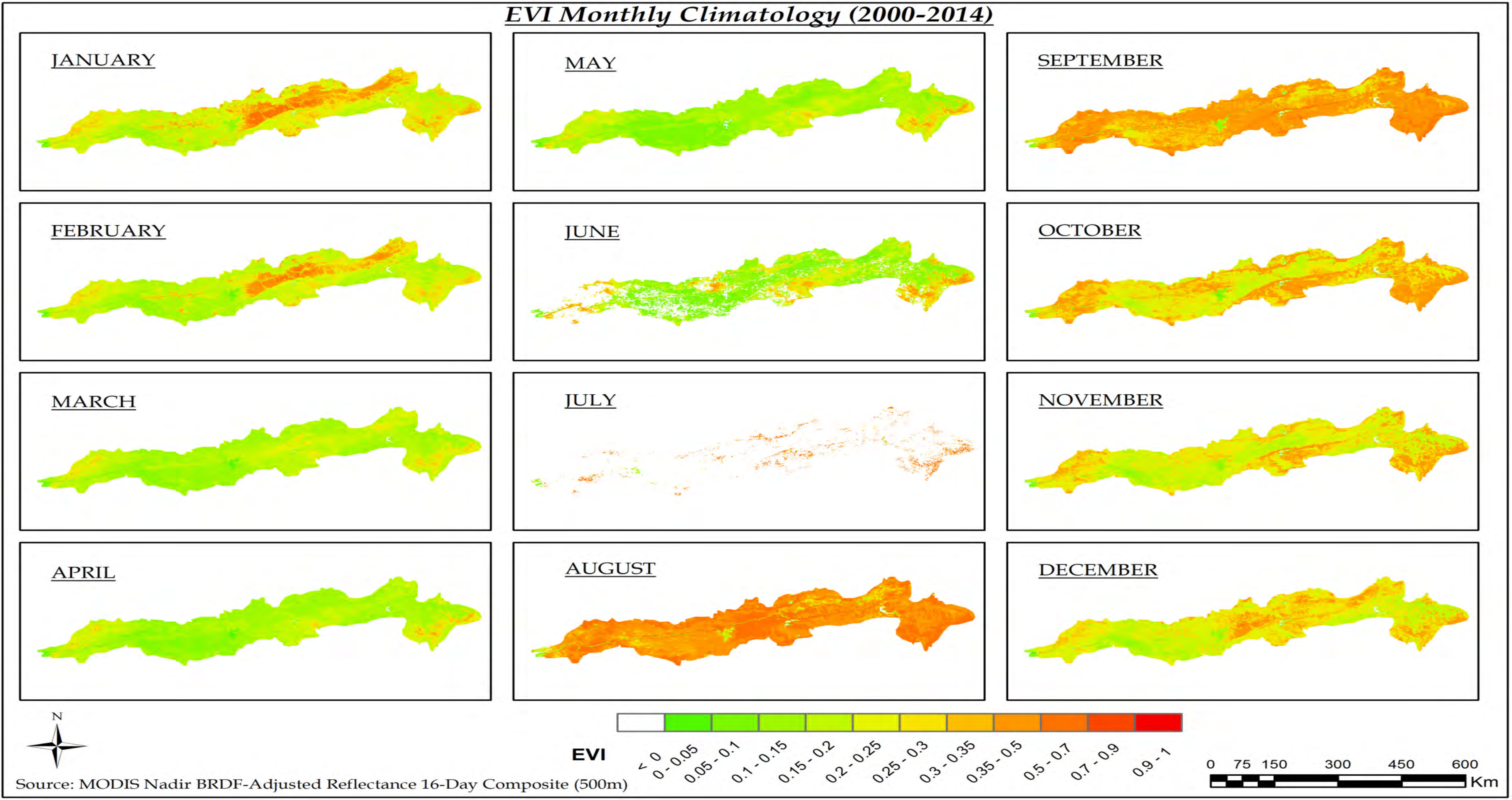
1. To study the dynamics and the rate of change in glaciers to understand its impact on hydrology, ecology and climate;
2. To assess the climate change using ice as an archive of information on past climate and its future implications.
3. To study the biogeochemical aspects of Himalayan ice and compare it with the polar environment.

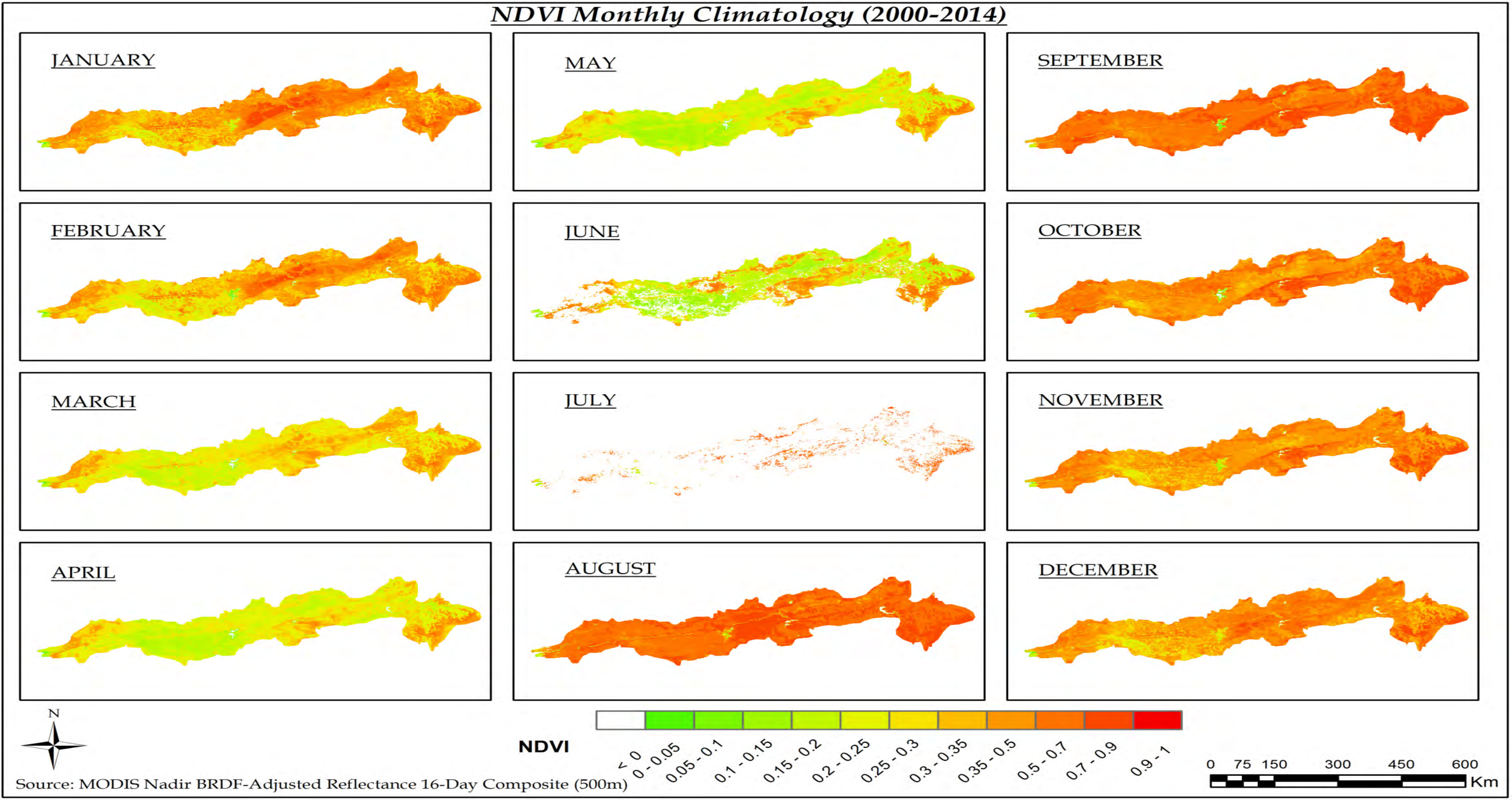
LuLc (UKMO & NRSC)





1	Evergreen needle leaf forest	10	Grassland
2	Evergreen broad leaf forest	11	Wetland
3	Deciduous needle leaf forest	12	Cropland
4	Deciduous broad leaf forest	13	Urban
5	Mixed forest	14	Mosaic
6	Closed shrub	15	Snow and ice
7	Open shrub	16	Barren
8	Woody Savannah	17	Water
9	Savannah	18	Open sea
		19	Missing data


EVI Monthly Climatology (2000-2014)
JANUARY
MAY
SEPTEMBER
FEBRUARY
JUNE
OCTOBER
MARCH
JULY
NOVEMBER
APRIL
AUGUST
DECEMBER
N
EVI
< 0
0 - 0.05
0.05 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.25
0.25 - 0.3
0.3 - 0.35
0.35 - 0.5
0.5 - 0.7
0.7 - 0.9
0.9 - 1
0 75 150 300 450 600
Km
Source: MODIS Nadir BRDF-Adjusted Reflectance 16-Day Composite (500m)


NDVI Monthly Climatology (2000-2014)
JANUARY
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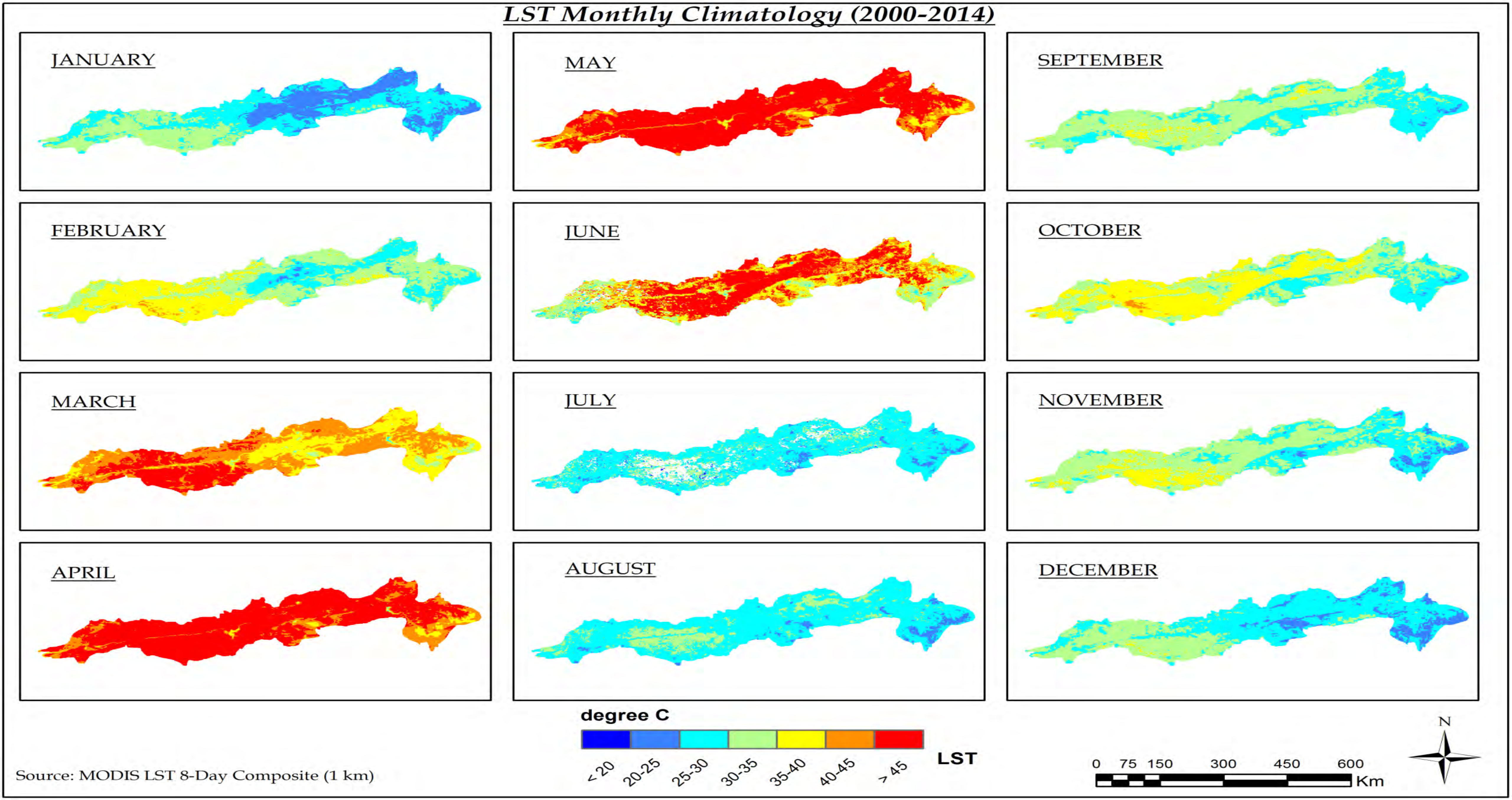
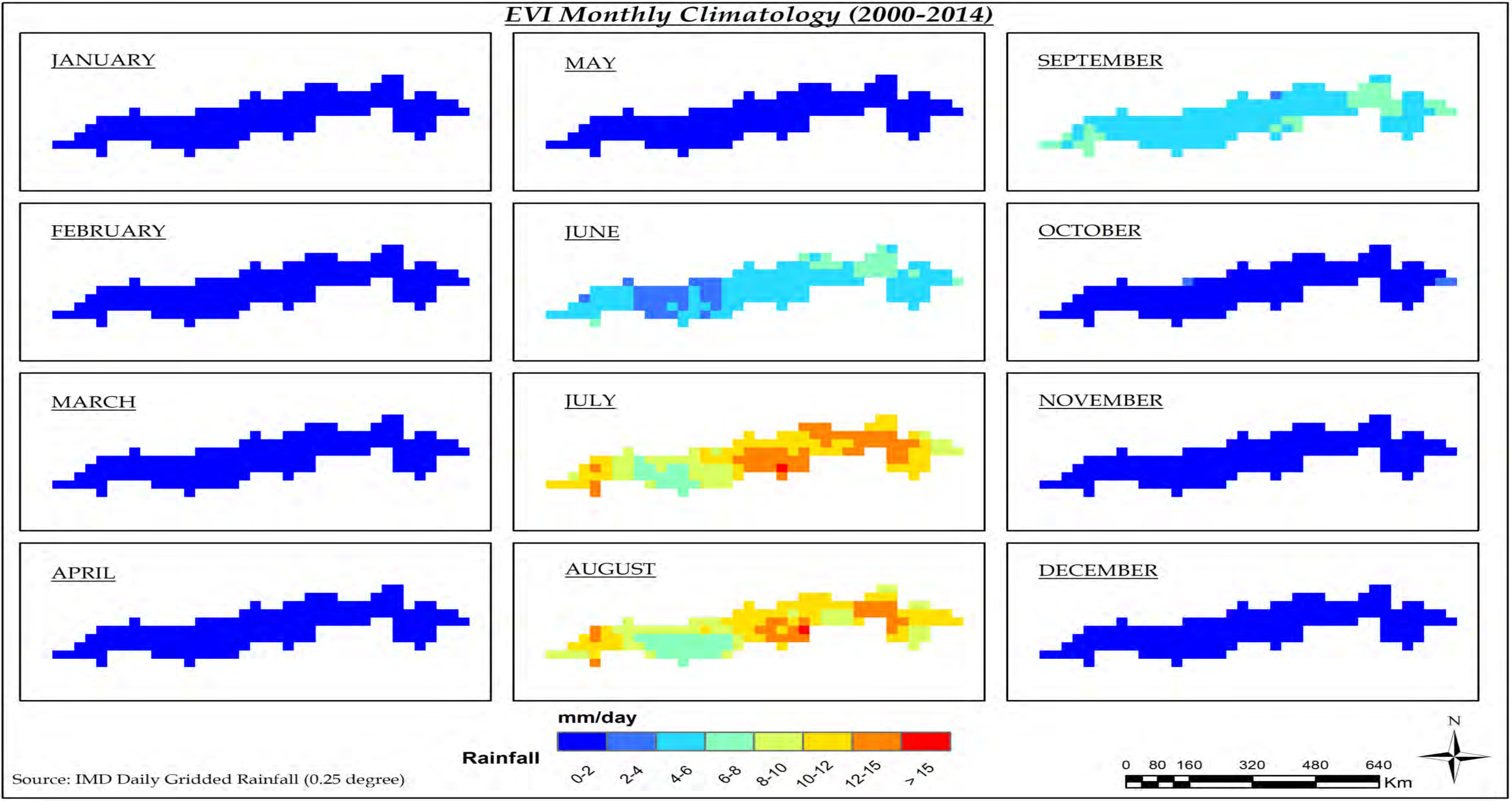
0.25 - 0.3
0.3 - 0.35
0.35 - 0.5
0.5 - 0.7
0.7 - 0.9
0.9 - 1
0 75 150 300 450 600
Km
Source: MODIS Nadir BRDF-Adjusted Reflectance 16-Day Composite (500m)


LST Monthly Climatology (2000-2014)
JANUARY
MAY
SEPTEMBER
FEBRUARY
JUNE
OCTOBER
MARCH
JULY
NOVEMBER
APRIL
AUGUST
DECEMBER
degree C
< 20
20-25
25-30
30-35
35-40
40-45
> 45
LST
Source: MODIS LST 8-Day Composite (1 km)
0 75 150 300 450 600
Km
N



EVI Monthly Climatology (2000-2014)
JANUARY
MAY
SEPTEMBER
FEBRUARY
JUNE
OCTOBER
MARCH
JULY
NOVEMBER
APRIL
AUGUST
DECEMBER
mm/day
Rainfall
0-2
2-4
4-6
6-8
8-10
10-12
12-15
> 15
Source: IMD Daily Gridded Rainfall (0.25 degree)
0 80 160 320 480 640
Km
N

India’s Integrated Himalayan Meteorology Programme

BACKGROUND:
A multi- agency national project named as PARWAT’ was initiated in 1999 by SASE, IMD, ARMY and NCMRWF to provide weather and avalanche forecasts for western Himalayas, mainly for meeting the strategic and operational requirement of ARMY.

Under this project, IMD had installed 26 AWS and 3 Upper Air Stations.

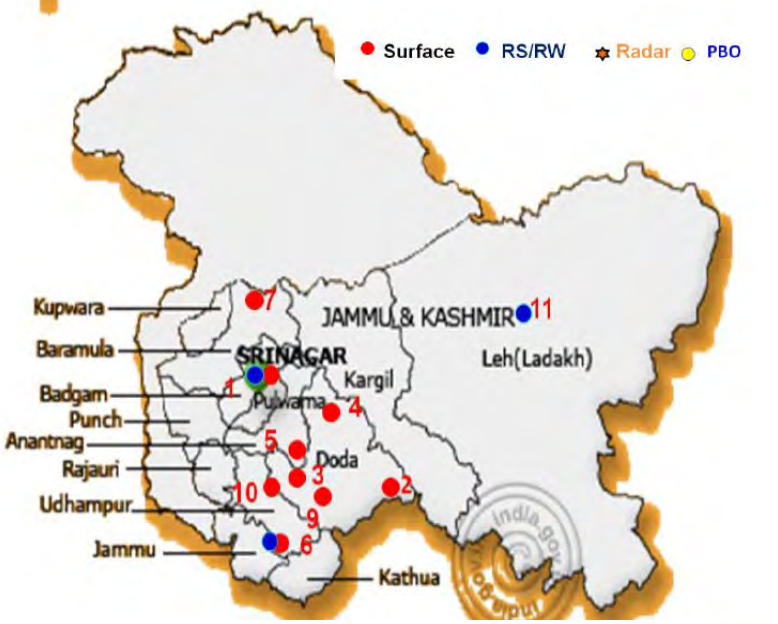
The data generated under the scheme have been archived.

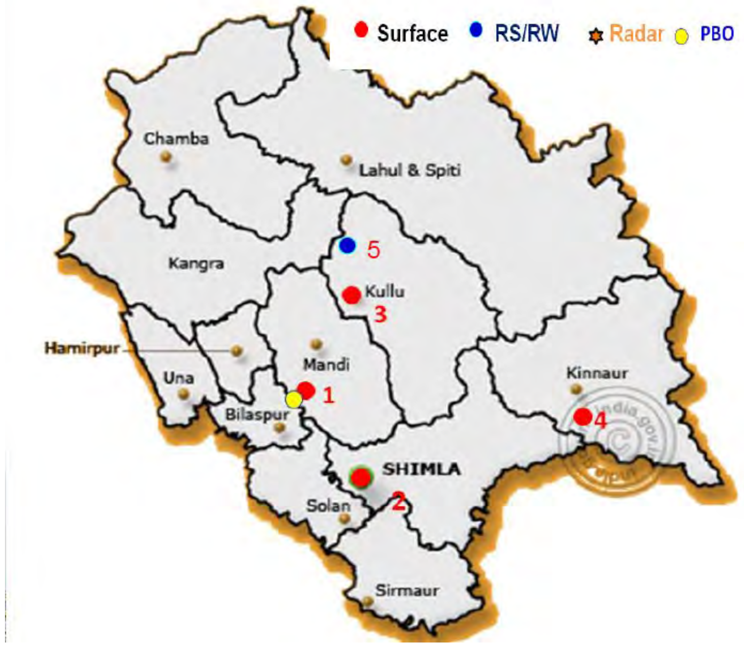
With the success of the f the project, Indian Army and other users desired to have similar facilities in the Central Himalayan region covering entire Himachal Pradesh and Uttaranchal for their strategic requirements.

Objectives of the India's Integrated Himalayan Meteorology Programme include

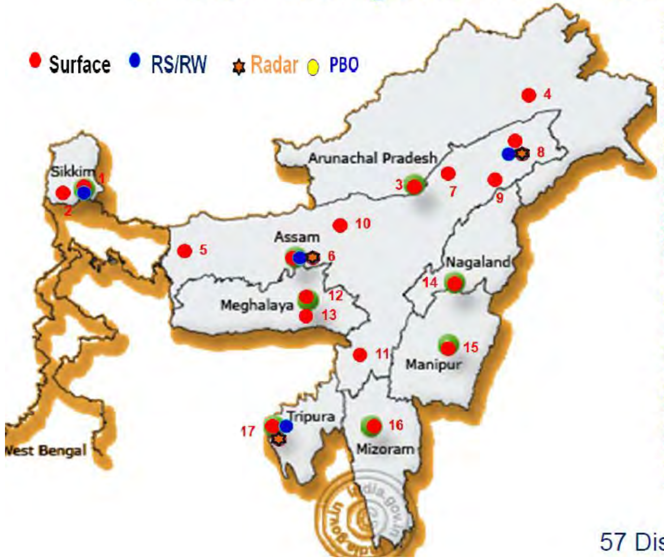
- To improve and upgrade mountain weather and climate monitoring and forecast services over the Himalayan region by establishing additional surface and upper air observatories.
- Interfacing the Indian side observational network for integration with those of neighboring countries in the Himalayan region.
- To establish a robust mechanism to exchange scientific analysis based meteorological information towards the holistic Himalayan development through customized weather, climate, hydrological, ecological and environmental services.
- To build enhanced understanding of weather and climate processes over complex Himalayan terrain and render quality forecasting services.
- To develop exclusive Himalayan climatology database for the region to capture the significant climate variability indices to meet the requirements of all users.
- To operate exclusive mountain meteorological services for the Himalayan states of India

Existing IMD Observing Systems in J&K, Himachal, Uttarakhand and NE States





NE states– Existing Observational Network



Sikkim
1. Gangtok
2. Tadong

Arunachal Pradesh
3. Itanagar
4. Passighat

Assam
5. Dhubri
6. Guwahati
7. North Lakhimpur
8. Mohanbari
9. Jorhat
10. Tezpur
11. Silchar

Meghalaya
12. Shillong (Barapani)
13. Cherrapunji

Nagaland
14. Dimapur

Manipur
15. Imphal

Mizoram
16. Lengpui

Tripura
17. Agartala

57 Districts

Existing IMD Observing Systems in J&K, Himachal, Uttarakhand and NE States

Type	JK	HP	UKD	ARP	NGL	MNP	MZR	TRP	ASM	MGL	SKM	Total
Surface	10	4	4	2	1	1	1	1	7	2	2	35
RS/RW	1+2	0+1	0	NIL	NIL	NIL	NIL	1	2	NIL	1	5+3
PBO	NIL	1	1	NIL	NIL	1	NIL	1	2	NIL	1	7
DWR	NIL	NIL	NIL	NIL	NIL	NIL	NIL	1	1	NIL	NIL	2
GPS	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Seismo	2	6	3	NIL	NIL	1	NIL	1	1	2	1	17
AMFU's	4	4	3	1	1	1	1	1	6	1	NIL	23

India has a massive plan to augment its observation Network in the Himalayan region Under Integrated Himalayan Meteorology Program

Observation and Monitoring of Natural Hazards in the Himalayas

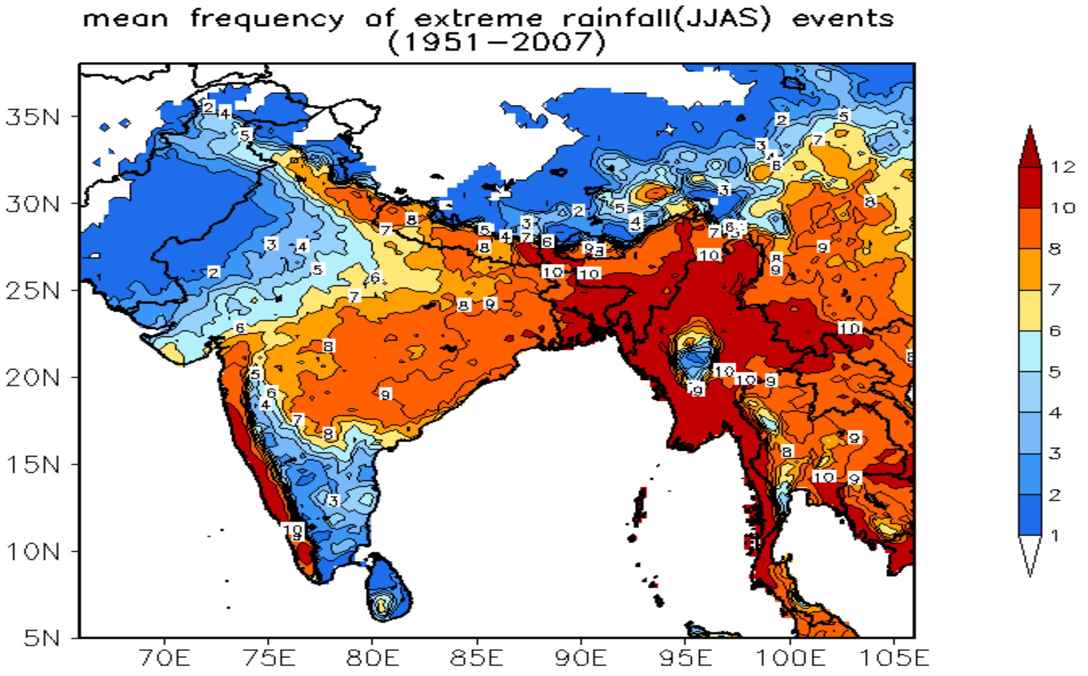
- Western Himalayas (Heavy snowfall, avalanche, flash flood, cloud burst, earthquake)
- Central Himalayas (Heavy snowfall, heavy rainfall, Landslide, avalanche, cloud burst, earthquake)
- Eastern Himalayas (Thunderstorm, heavy rainfall, Landslide, earthquake)

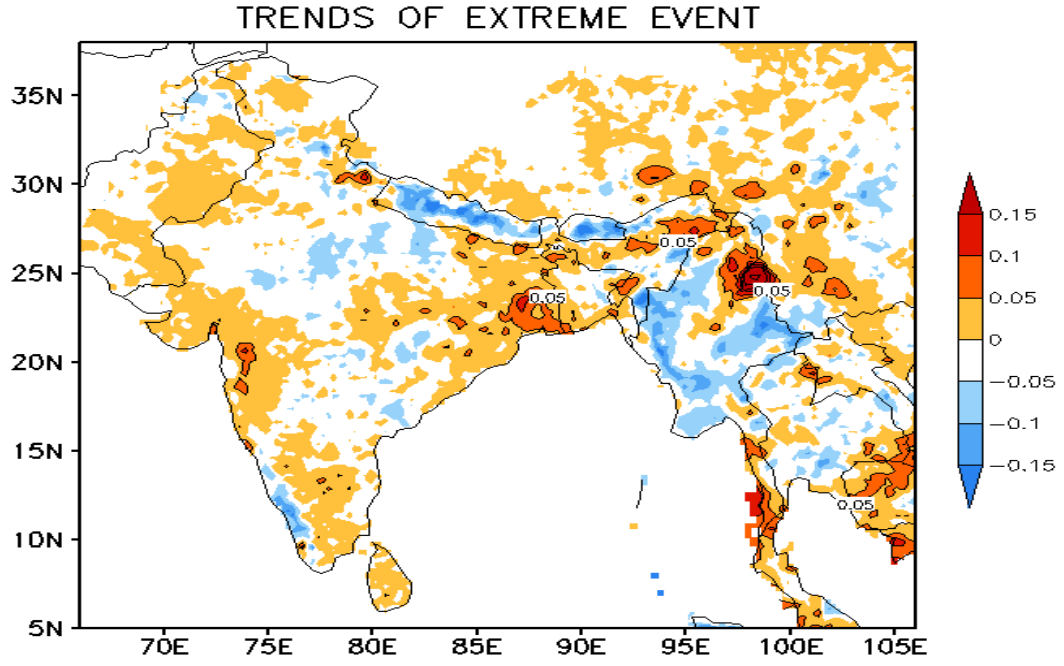
Observation and monitoring-related requirements for the Disaster Risk Reduction

- Historic and real-time hazard observational records at appropriate spatial and temporal resolution, including relevant metadata
- Observation and real-time monitoring of extreme events, including associated impacts;
- Interoperability of data across climate, health, socio-economic and biological observations.
- With risk knowledge, governments can manage risks through early warning systems and preparedness.

Monitoring & Prediction of Extreme Rainfall events

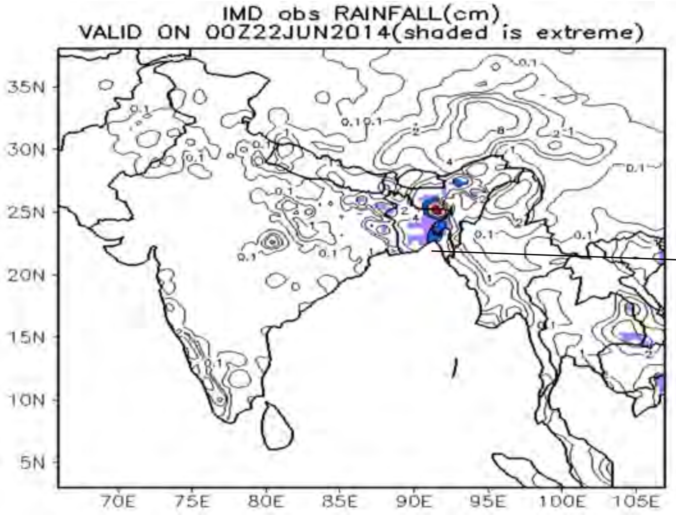
Mean frequencies(day/season) and tendencies(day/season) of the extreme rainfall events in the southwest monsoon season for the period 1951 to 2007 (above 90 percentile)

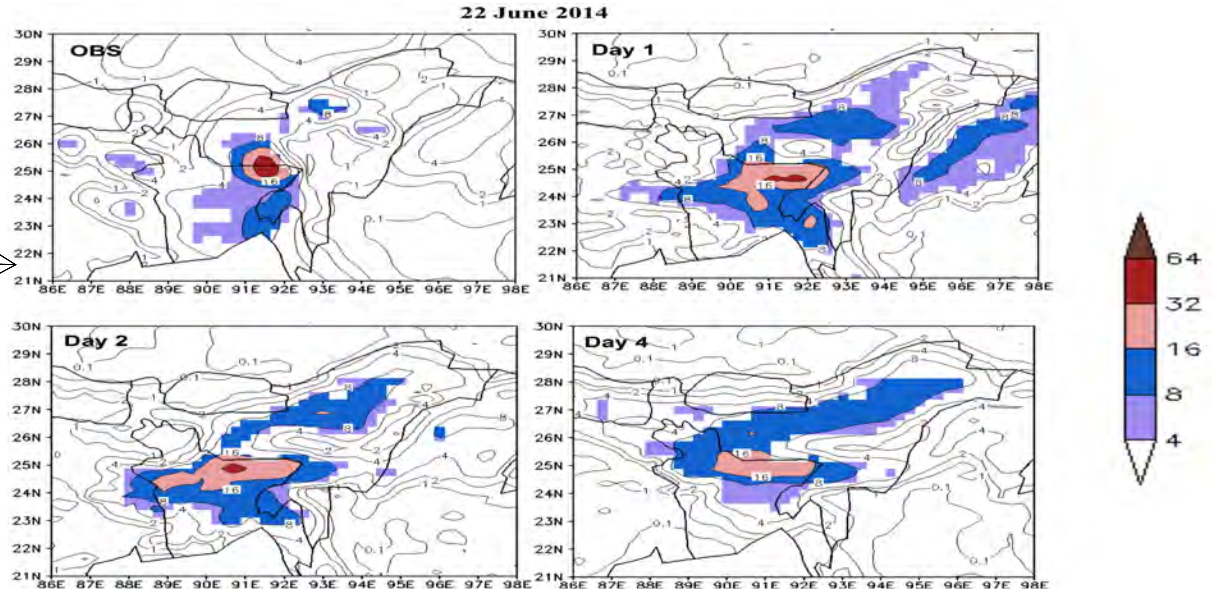




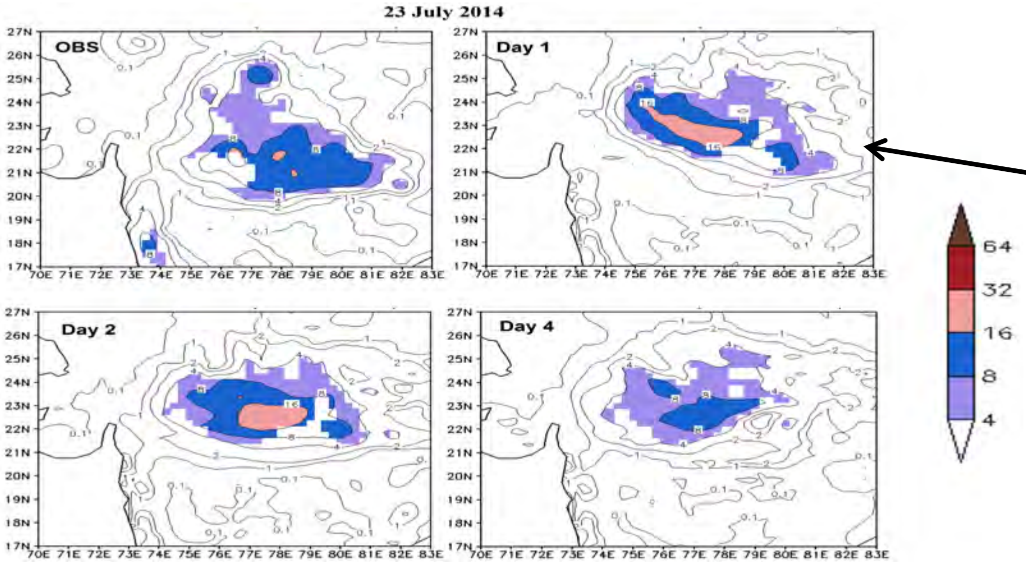
Real-time forecast of Extreme Rainfall

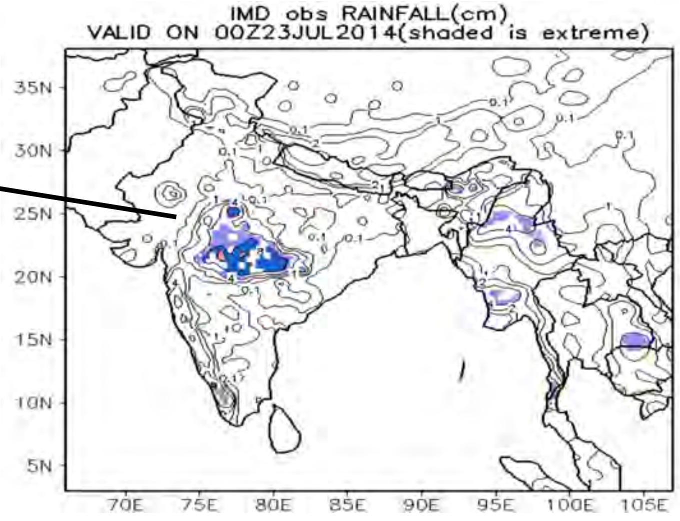
NCUM Real-time Forecasts in 2014





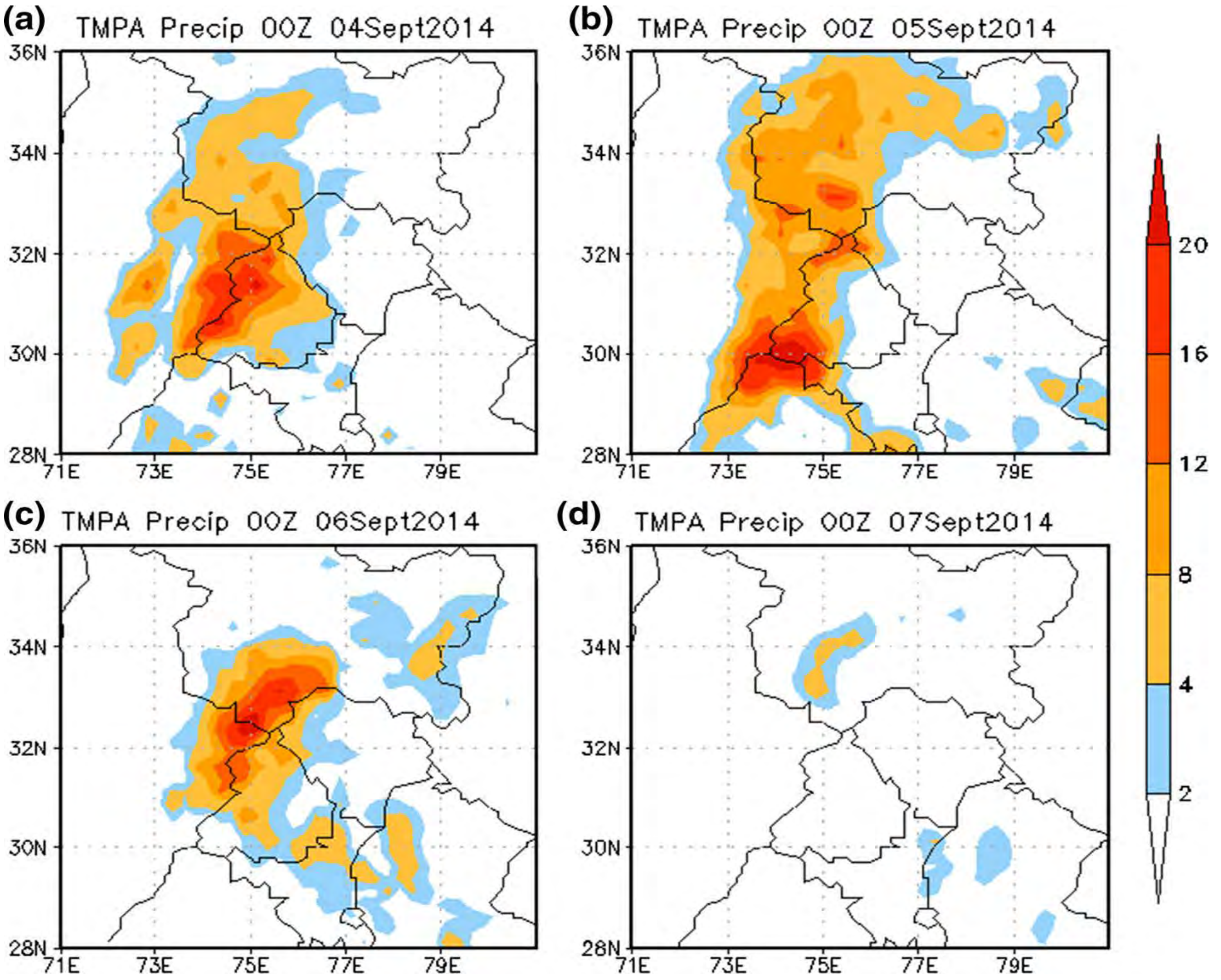
Extreme rainfall distribution on 22 June (Shaded values show above 90th percentile of climatology)





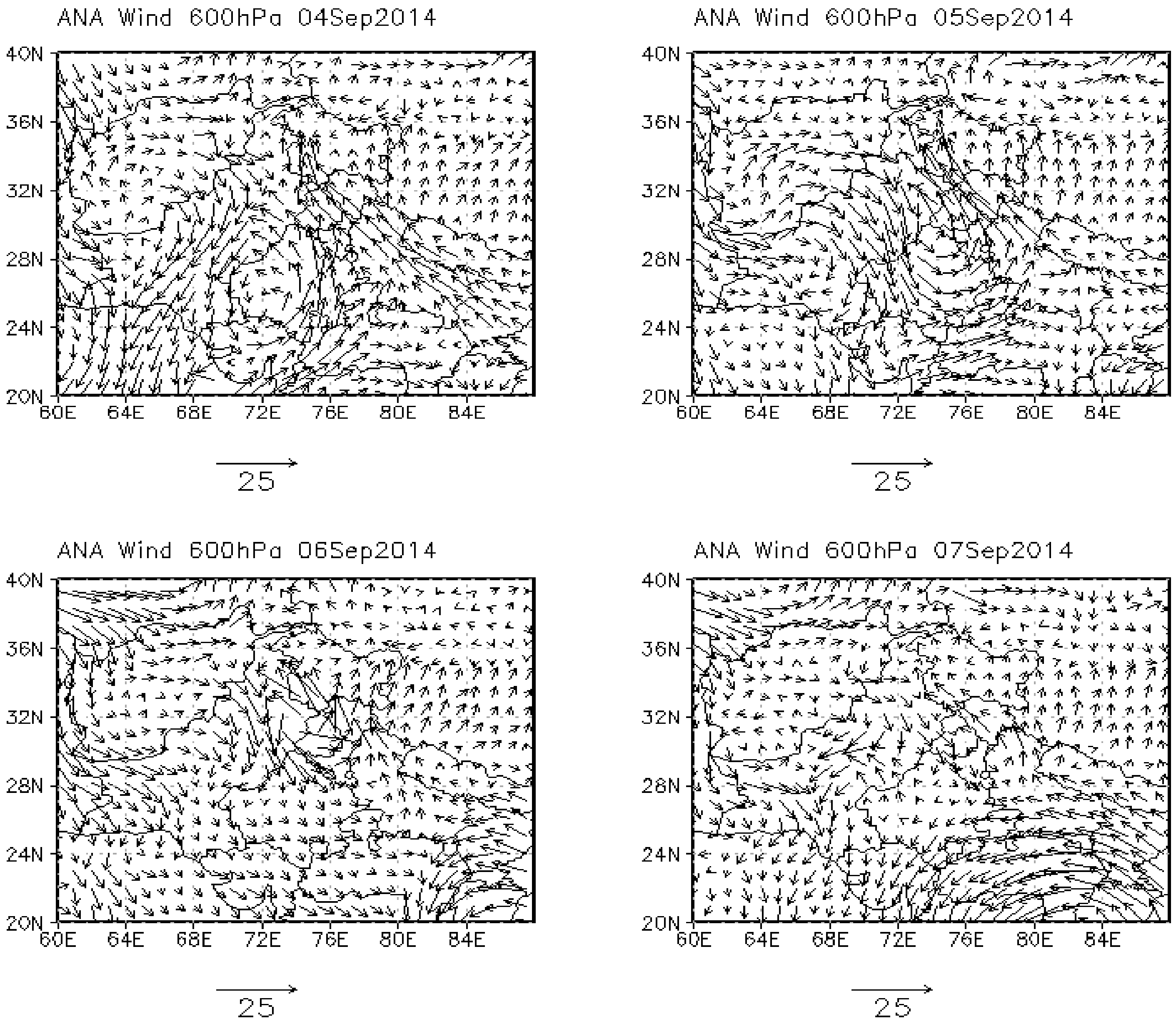
Extreme rainfall distribution on 23 July (Shaded values show above 90th percentile of climatology)

Studies on heavy rainfall in Kashmir- September 2014



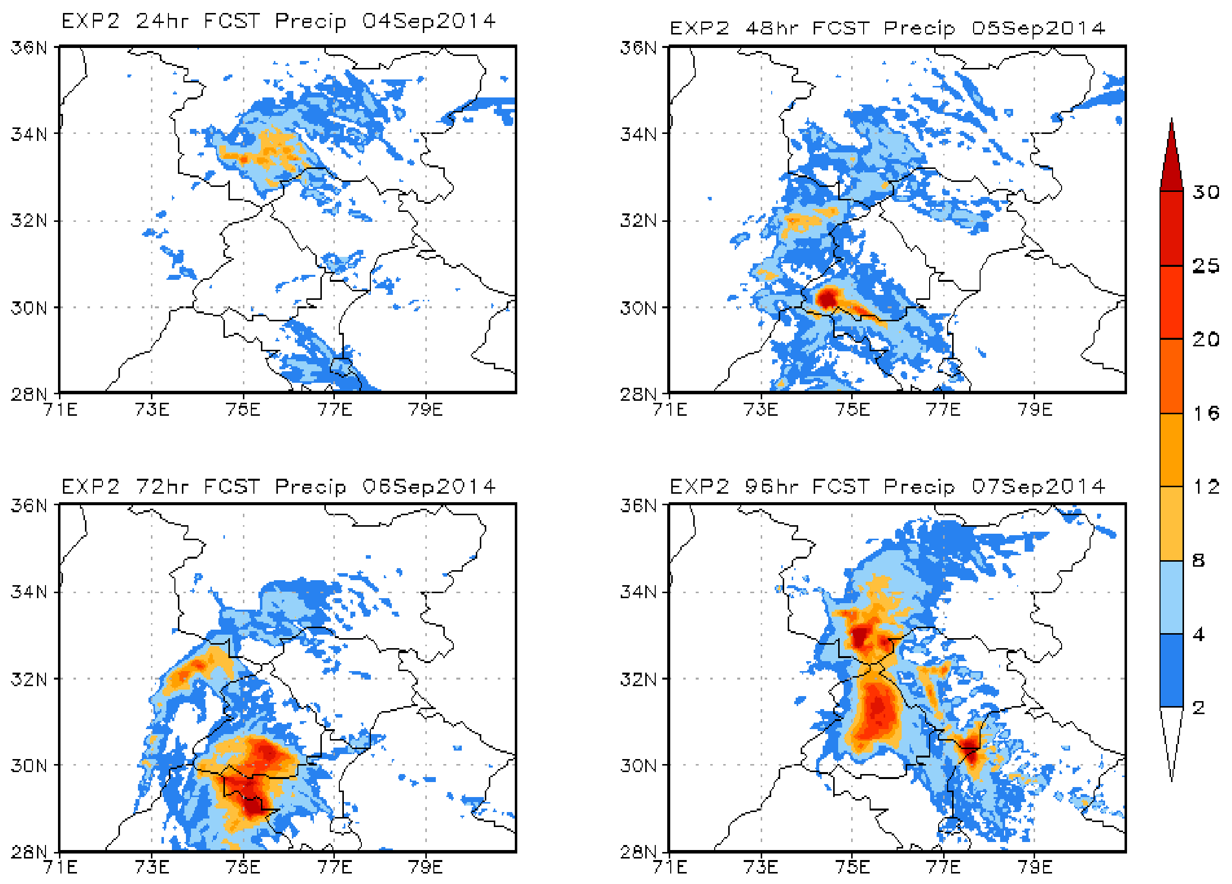
Studies on heavy rainfall in Kashmir- September 2014

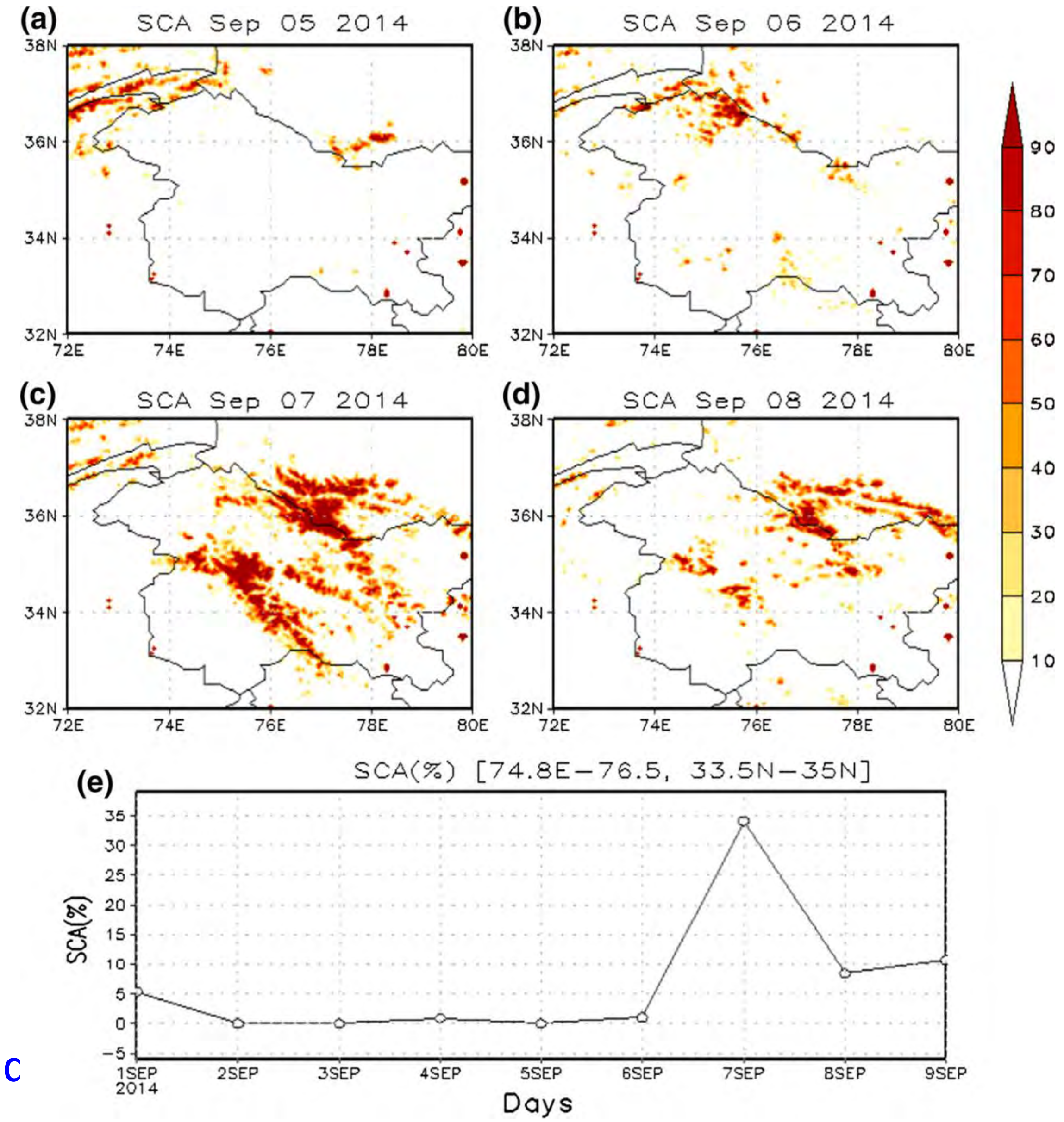
Winds at 600hPa from Global Analysis at NCMRWF



Global Model Rainfall Forecasts from 03 Sept and 04 Sept did not indicate very heavy rainfall

Precipitation from WRF





Experiments with high-resolution (6km) WRF model showec that when Graupels are considered in cloud microphysics, the rainfall amount enhanced

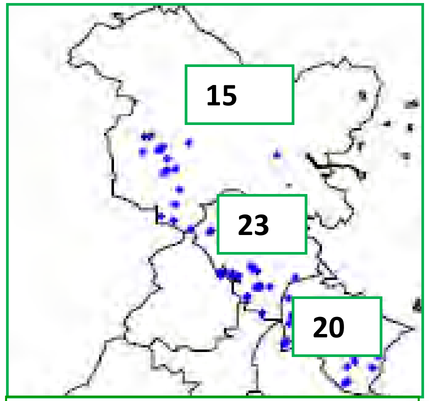
Integrated Himalayan Meteorology Programme

- Commissioning of 9 Doppler Weather Radars (DWRs)
- Commissioning 15 Micro Rain Radars (MRRs)
- Commissioning of 09 GPS based UA Systems along with GPS radiosonde
- Commissioning of 230 Surface Observing equipment consisting of Automatic Weather Stations, Automatic Rain Gauges & Snow Gauges
- Commissioning of 12 Compact Severe Weather Detection Radar Systems
- Commissioning of 9 Heliport Automated Weather Observation Systems (HAWOS)
- Commissioning of 3 Radiation Equipments.
- Procurement of mobile observing systems.
- Establishment of 15 Surface Field Observatories.

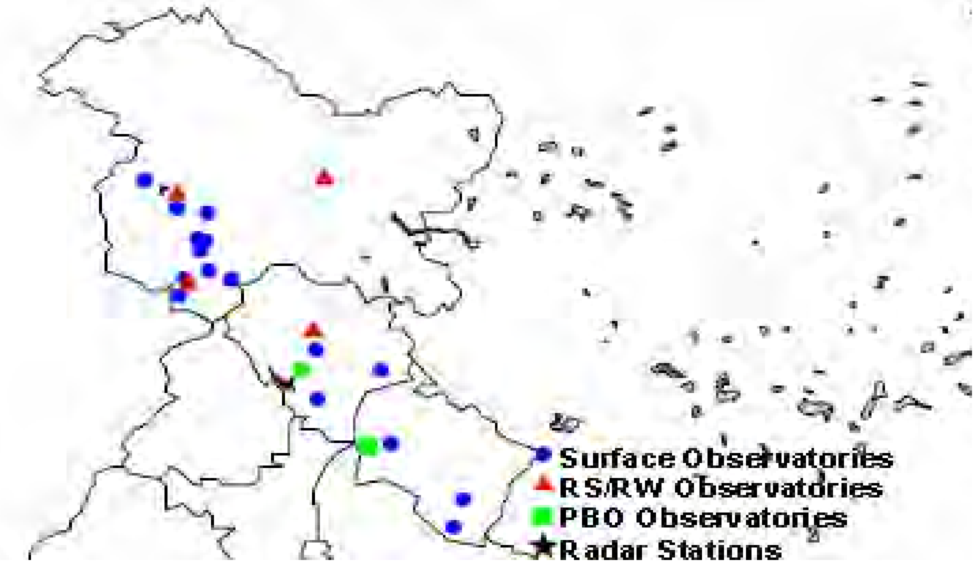
Proposed Locations of Snow Gauges in J&K, Himachal and Uttarakhand under Mountain Meteorology Program

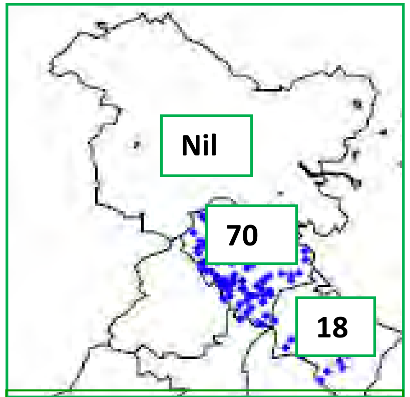
Integrated Himalayan Meteorology Programme

Existing IMD network in Western Himalayas



Existing AWS Network

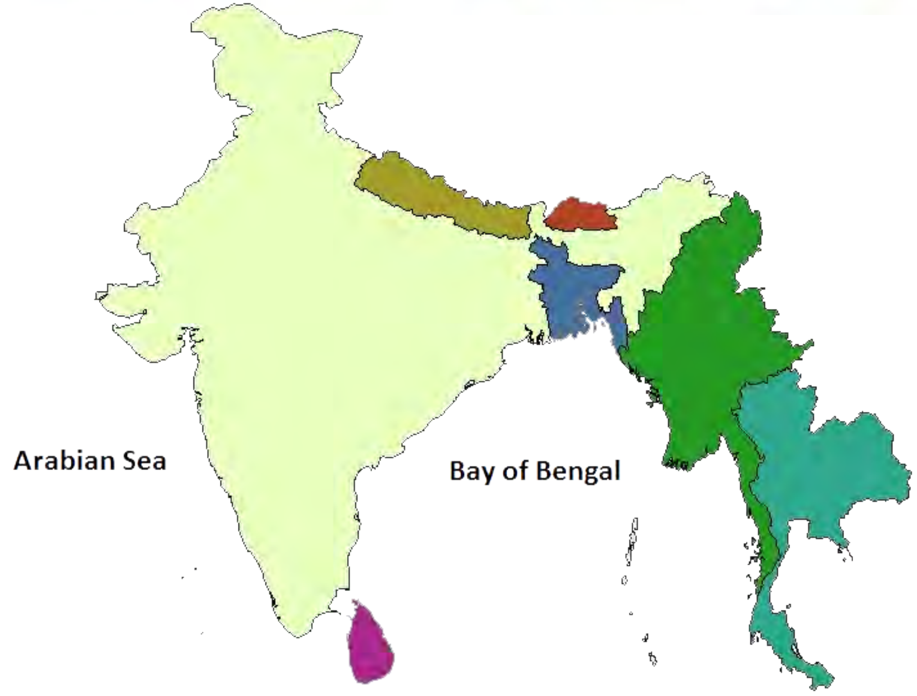




Existing ARG Network

Summary of Proposed Network

State	DWR	MRR	GPS Based Sonde	Compact System	HAWOS	AWS/ARG/SG	SFO
J & K	3	5	2	4	5	75	NIL
HP	3	5	2	4	0	65	NIL
UK	3	5	2	4	3	75	15
SHWB	NIL	3	1	NIL	1	15	NIL
TOTAL	09	18	07	12	09	230	15

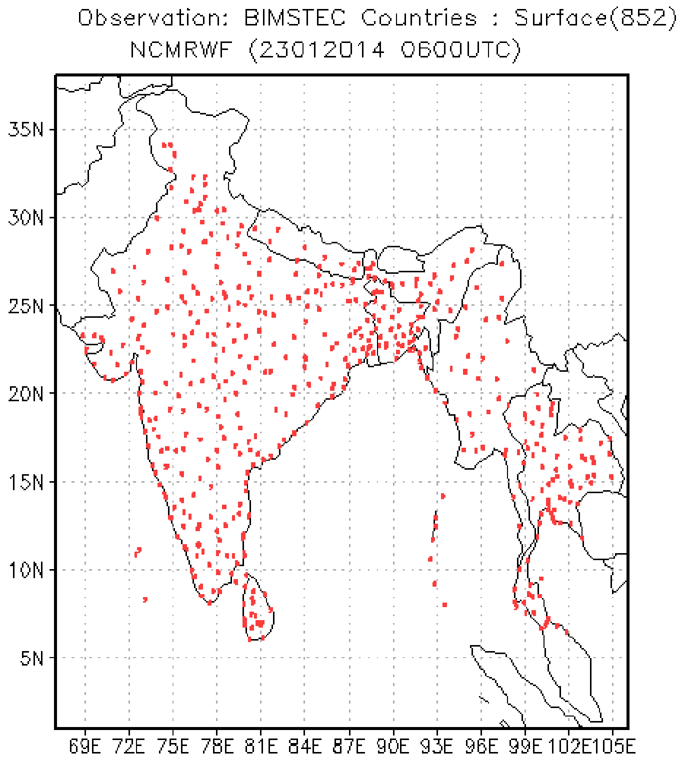


BIMSTEC Centre for Weather & Climate

To provide leadership in the weather and climate through improved specialized forecasts in the region

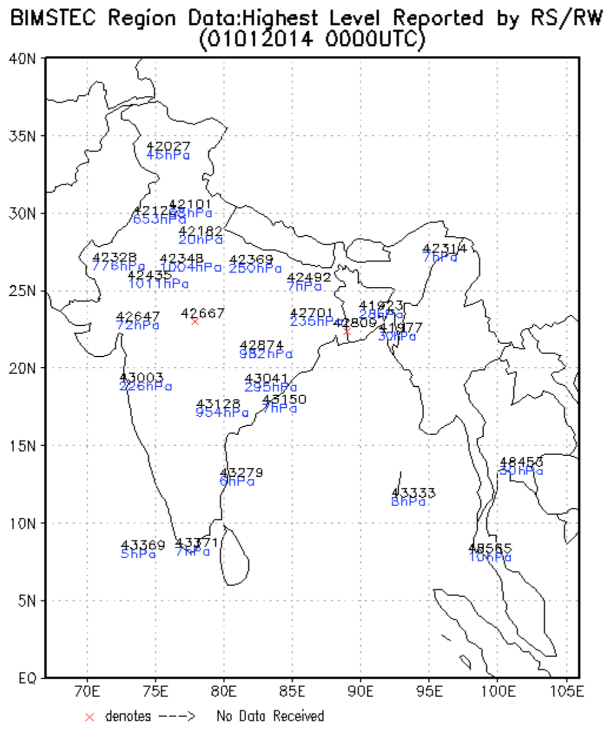
Total No. of Surface observations received in a typical month

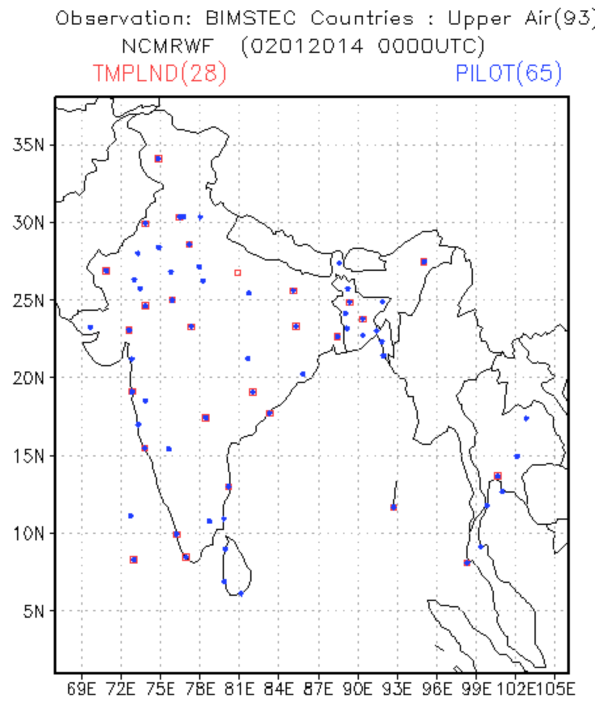
	00UTC	06UTC	12UTC	18UTC	Total
Bangladesh	1388	1689	1304	1013	5394
Myanmar	903	1959	1734	18	4614
Nepal	251	660	622	54	1587
Bhutan	0	0	0	0	0



Total No. of Radiosonde observations received in a typical month

	00UTC	06UTC	12UTC	18UTC	Total
Bangladesh	36 (20hPa)	0	24 (25hPa)	0	60
Myanmar	0	0	0	0	0
Nepal	0	0	0	0	0
Bhutan	0	0	0	0	0





Recovery of Climate Data of the Past

Large-scale data recovery, digitization, and homogenization of climate records

Use modern techniques, procedures, and tools to safeguard climate records risking damage or loss and to recover and digitize them.

Enhance the capacity of NMHSs and other climate data communities to accelerate the recovery, digitization, and homogenization of climate records, and to use modern data archiving and management tools

Need of High-Resolution Reanalysis of Climate System of the Himalayas

Partners could be all the stake holders including NMHSs, and of the application sectors: Agriculture, Water, health and Disaster etc

BIMSTEC Centre for Weather and Climate would be happy to be associated with all the stake holders for improving Climate Services over the Himalayan region

Thank You for Your Attention