Modelling and Management of Water in Future

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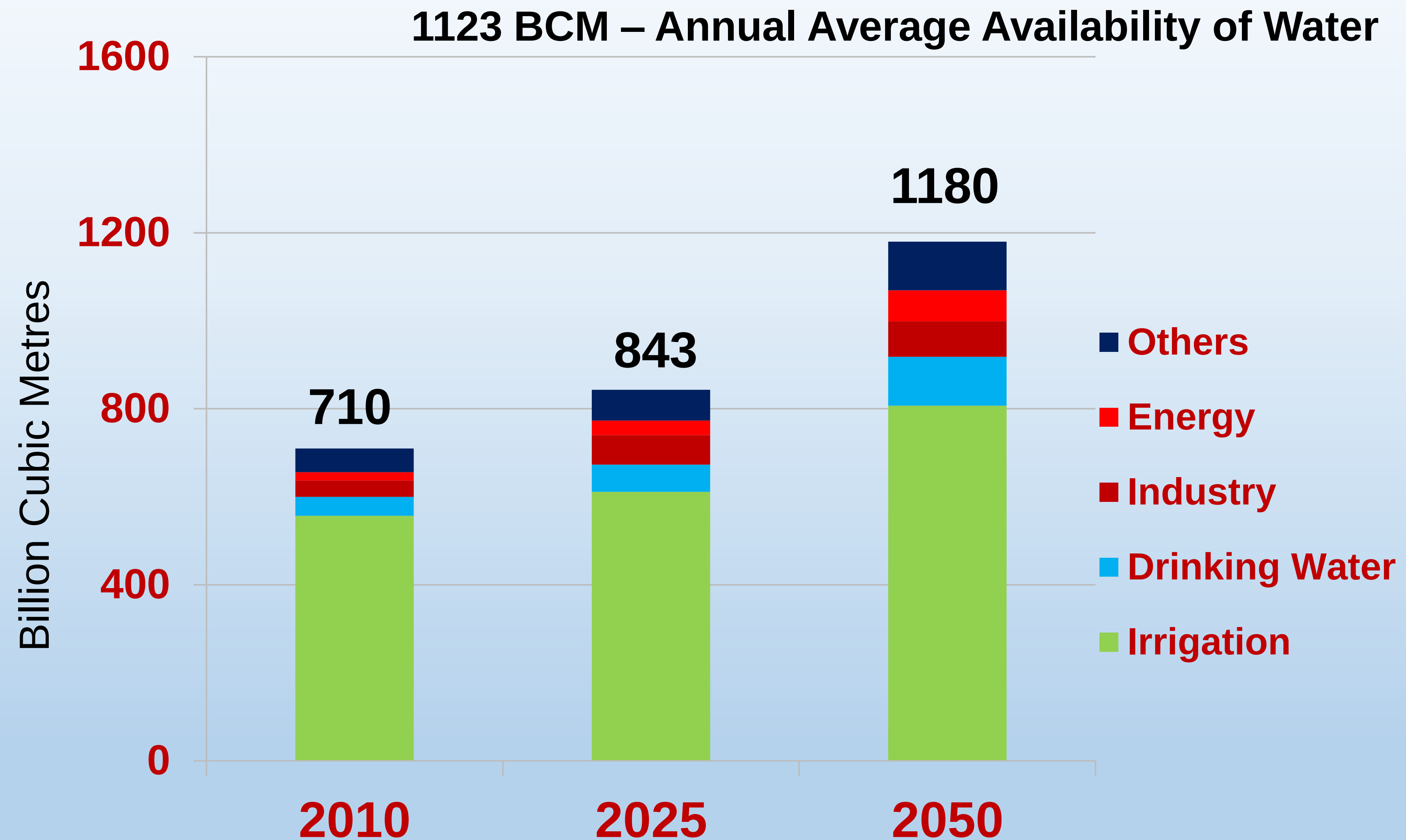
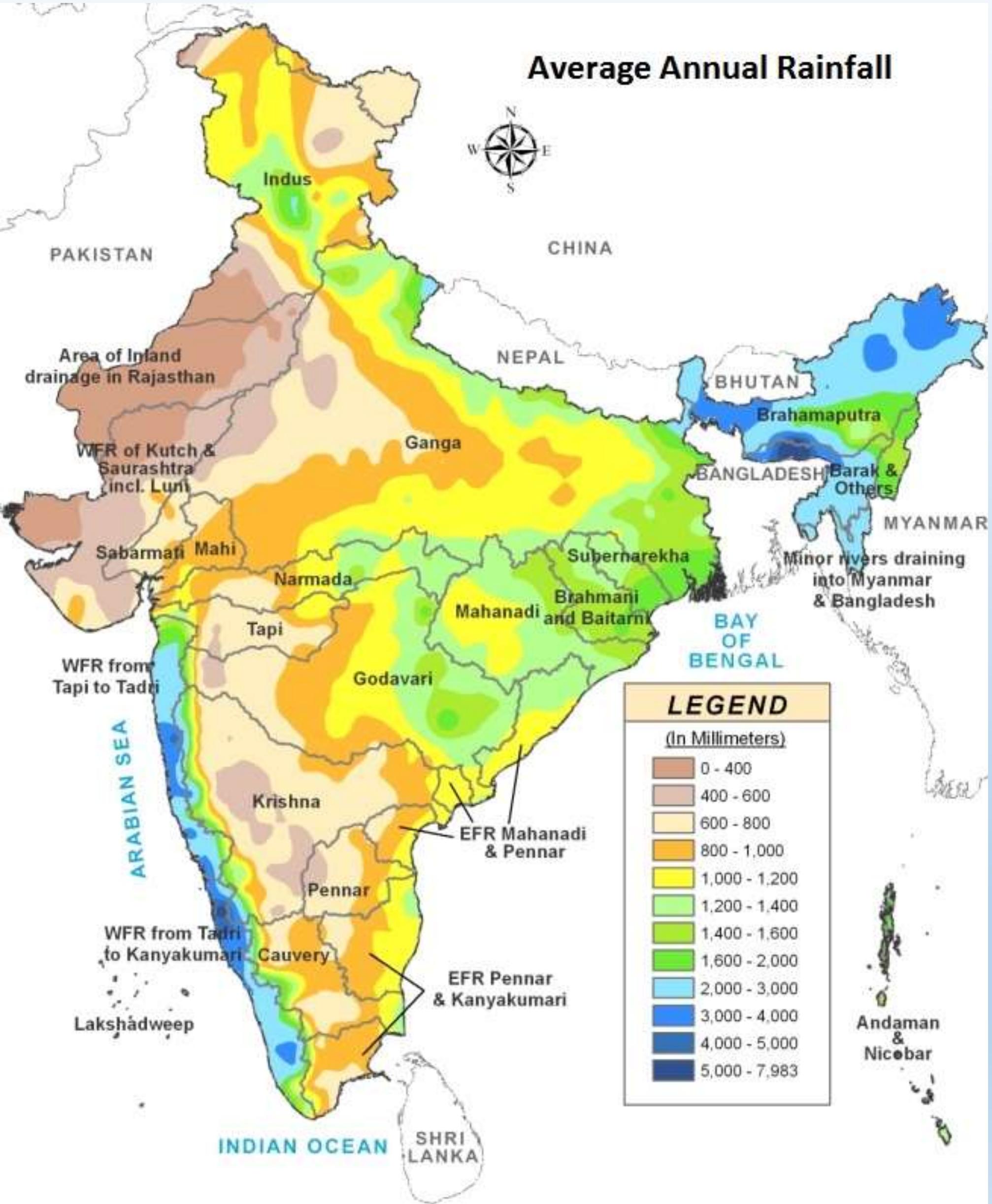
Water Scenarios in India



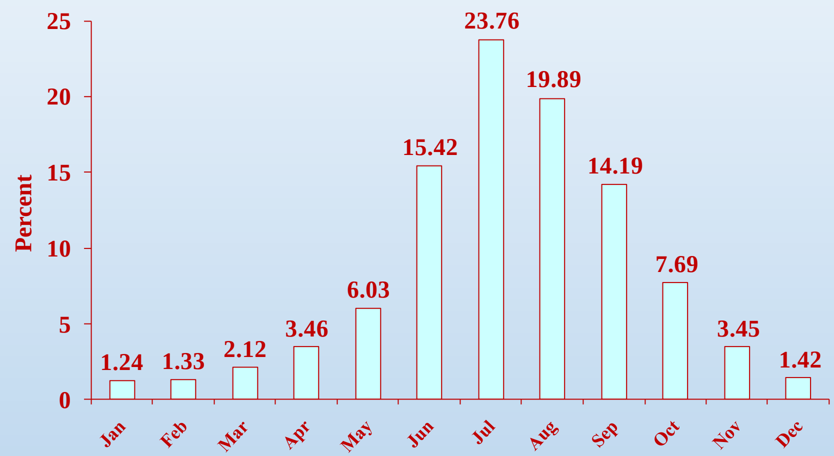
- **Water Use Efficiency low 35 - 45%**

against 50% - 60% in developed countries

Spatial & Temporal Variability of Rainfall



Annual precipitation : 4000 BCM, Summer monsoon: 75-80%; Rainy days: 5-150, most rain in 15 days, < 100 hrs



	Rainfall (mm)	
Average	1,170	World 1110 mm
Max.	11,000	Mawsynram, Meghalaya
Min.	150	Western Rajasthan

Water Demands

Rising temperatures and altered meteorological variables will also alter demand for most water uses. Utilization of water for numerous purposes need to be measured for optimal water resources utilization.

Water use in Agriculture

The changes in climate (mainly) in the form of precipitation, temperature, and radiation will affect the water availability and water demands for both irrigated and rainfed crops, crop growth and productivity.

Projected Water Demands as per National Commission for Integrated Water Resources Development Plan (NCIWRD)

Sector / Year	Water Requirement (BCM)	
	2025	2050
Irrigation	611	807
Drinking Water	62	111
Industry	67	81
Energy	33	70
Others	70	111
Total	843	1180

Water Demands

Water use in Energy Production

Climate change will have an impact on hydropower generation by altering the timing and amount of streamflow, increasing inter-annual variability of flows, changing the type and variation of demands, and altering evaporation from reservoirs and sediment fluxes.

Water for Environment

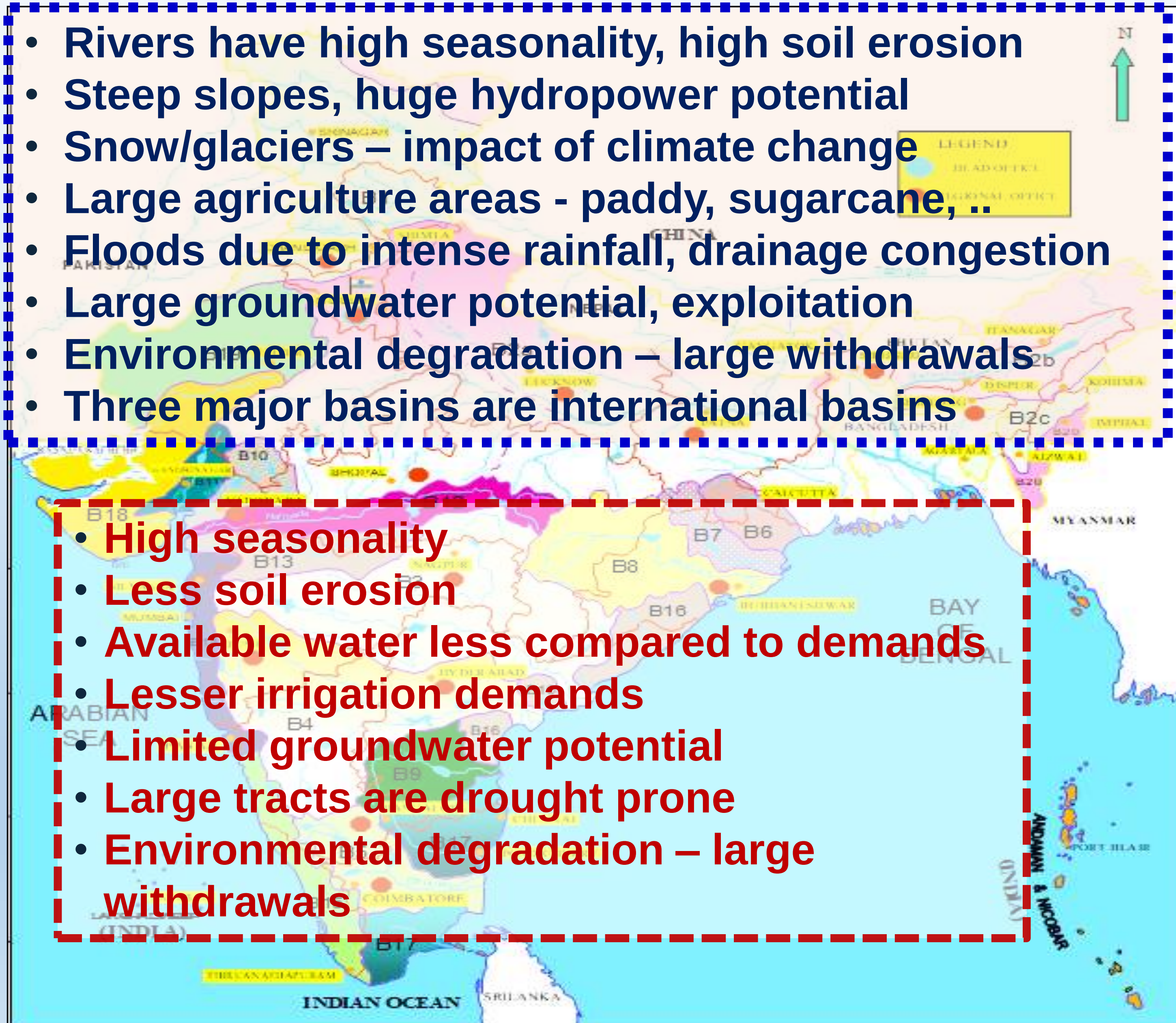
Climate change induced changes will likely increase the pressure for the regulation and use of water resources, increasing water scarcity and adversely impacting freshwater environments and ecosystem services (e.g. fisheries, water purification, tourism).

Consideration of environmental flow requirements (with increased temporal runoff variability due to climate change) may lead to further modification of reservoir operations to equitably address the different water sectors in India.

Issues and Challenges in WRD

- Rivers have high seasonality, high soil erosion
- Steep slopes, huge hydropower potential
- Snow/glaciers – impact of climate change
- Large agriculture areas - paddy, sugarcane, ..
- Floods due to intense rainfall, drainage congestion
- Large groundwater potential, exploitation
- Environmental degradation – large withdrawals
- Three major basins are international basins

- High seasonality
- Less soil erosion
- Available water less compared to demands
- Lesser irrigation demands
- Limited groundwater potential
- Large tracts are drought prone
- Environmental degradation – large withdrawals



Climate Change is any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or winds) sustained over several decades or longer.

Impact of Climate Change: Water Resources & Hydrologic Cycle

Cause	Impact
Increase in atmospheric water vapour content	➔ Increased precipitation
Change in precipitation patterns	➔ Increased risk of floods and droughts
Change in soil moisture and runoff	➔ Implications for agriculture and water supply
Ice melting and reduction in snow cover and glaciers	➔ Change in runoff pattern and GLOF
Sea level rise	➔ Increased seawater intrusion, Coastal population

AR6: Changes In Rainfall Pattern

- **AR6 considers real-world observations of changing rainfall patterns, as well as palaeoclimate evidence, reanalyses of data and model simulations.**

- **A phenomenon such as heavy rainfall over land, for instance, could be 10.5% wetter in a world warmer by 1.5°C, and occur 1.5 times more often, compared to the 1850-1900 period.**

- **At a global scale, extreme daily rainfall events would intensify by about 7% for each additional degree Celsius of global warming.**

- **The frequency and intensity of heavy precipitation events have increased since the 1950s over most land area.**

- **A warmer climate will intensify very wet and very dry weather and climate events and seasons, with implications for flooding or drought, but the location and frequency of these events depend on projected changes in regional atmospheric circulation.**

AR6: Asia Specific Observations

- **As per the recent historical observations, Heat extremes have increased while cold extremes have decreased, and these trends will continue over the coming decades.**

- **Mean surface wind speeds have decreased and will continue to decrease in central and northern parts of Asia.**

- **Glacier runoff in the Asian high mountains will increase up to mid-21st century, and subsequently runoff may decrease due to the loss of glacier storage.**

- **Relative sea level around Asia has increased faster than global average, with coastal area loss and shoreline retreat. Regional-mean sea level will continue to rise.**

- **The South and Southeast Asian monsoon has weakened in the second half of the 20th century due to the observed decrease of South and Southeast Asian monsoon precipitation and increase in anthropogenic aerosol forcing.**

AR 6 - India Specific Observations

- The average surface temperature of the Earth will cross 1.5 °C over pre-industrial levels in the next 20 years (By 2040) and 2°C by the middle of the century without sharp reduction of emissions.
- Global Warming will have a serious impact on mountain ranges across the world, including the Himalayas.
- Retreating snowlines and melting glaciers is a cause for alarm as this can cause a change in the water cycle, the precipitation patterns, increased floods as well as an increased scarcity of water in the future in the states across the Himalayas.
- The South West Monsoon has declined over the past few decades because of the increase of aerosols, but once this reduces, we will experience heavy monsoon rainfall.
- Changes in monsoon precipitation are also expected, with both annual and summer monsoon precipitation projected to increase.

Climate Change – Broad Picture

- Summer monsoon causes about 75-80 % of annual rainfall in India.
- Large inter-annual variability in monsoon precipitation and its patterns.
- Monsoon is likely to become less predictable.
- Major floods in the past decade, caused by intense rainfall — the “new normal” ?
- Extreme rainfall will continue to rise with temperatures.
- Significant warming is expected in Glacier and snow areas – impact on flows in Himalayan rivers

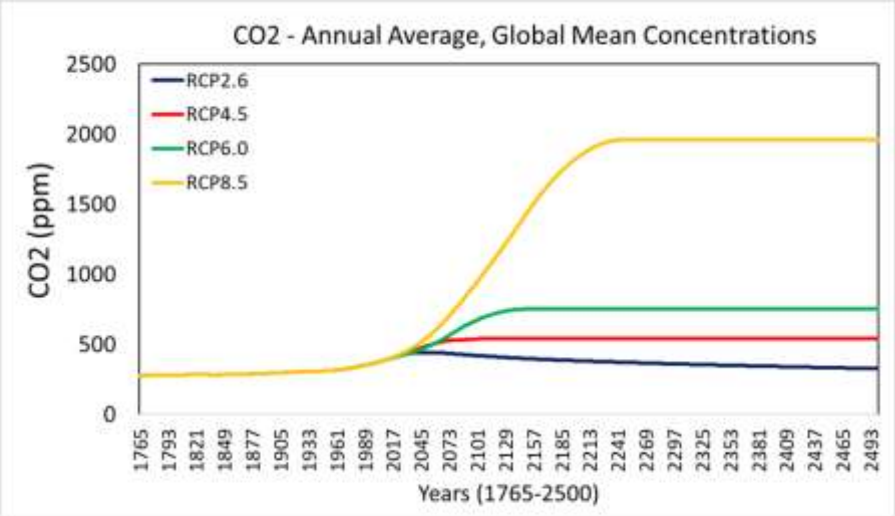
Climate Change – Broad Picture

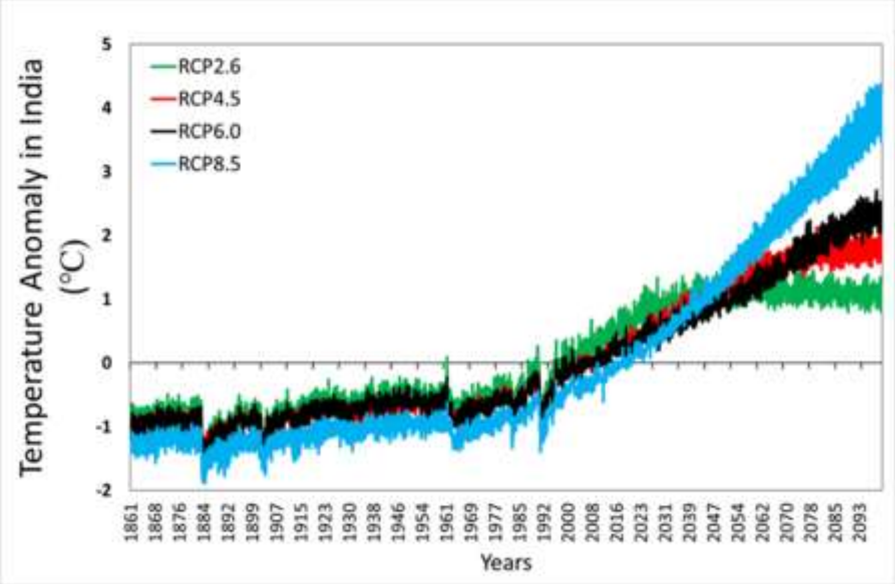
- Tendency to have more events of intense rainfall and longer dry spells; moderate rainfall events are reducing:
  - More flooding and droughts
  - More soil erosion
  - Less ground water recharge
- Flood damage in India is rising due to climate change, unwise urbanization, LULC changes, and environmental degradation. Many people are living in vulnerable areas.
- Development on floodplains are exacerbating risk, e.g., Kerala floods in 2018.
- Large uncertainties in climatic projections by different GCMs.
- Impact of human actions (LULC, …) on hydro-meteorologic extremes is not well known.

Scenarios for Future Projections

IPCC AR5 – Representation Concentration Pathway (RCP)

Description	IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 in 2100.
RCP6	Stabilization without overshoot pathway to 6 W/m^2 at stabilization after 2100
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m^2 at stabilization after 2100
RCP2.6	Peak in radiative forcing at ~ 3 W/m^2 before 2100 and decline



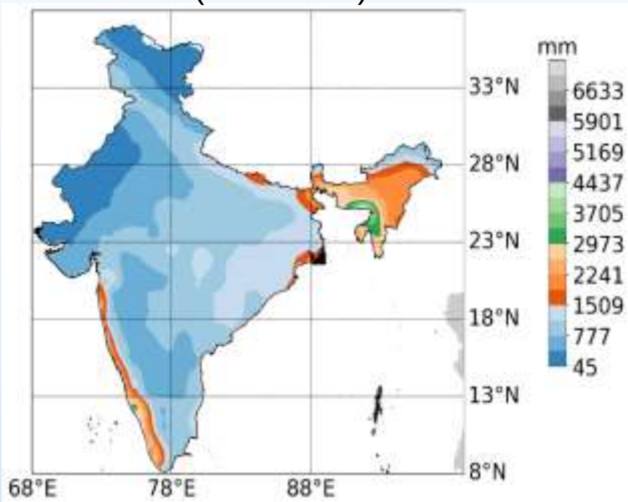


IPCC AR6: Socioeconomic development pathways.

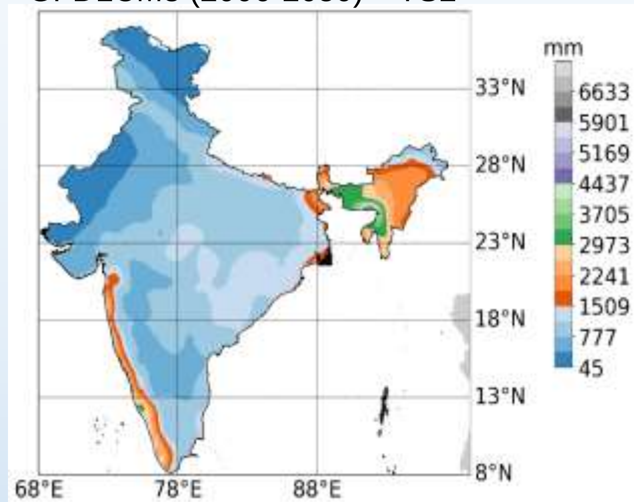
SSP	Scenario	Estimated Warming (2041-2060)	Estimated Warming (2081-2100)	Very Likely Range in ^{0}C (2081-2100)
SSP1-1.9	Very low GHG emission: CO_2 emissions cut to net zero around 2050	1.6^{0}C	1.4^{0}C	1.0 – 1.8
SSP1-2.6	Low GHC emissions: CO_2 emissions cut to net zero around 2075	1.7^{0}C	1.8^{0}C	1.3 – 2.4
SSP2-4.5	Intermediate GHG emission: CO_2 emissions around current level until 2050, then falling but not reaching net zero by 2100	2.0^{0}C	2.7^{0}C	2.1 – 3.5
SSP3-7.0	High GHG emissions: CO_2 emissions double by 2100	2.1^{0}C	3.6^{0}C	2.8 – 4.6
SSP5-8.5	Very high GHG emissions: CO_2 emissions triple by 2075	2.4^{0}C	4.4^{0}C	3.3 – 5.7

Spatio-Temporal Precipitation Variability - Historical vs Near Far Changes

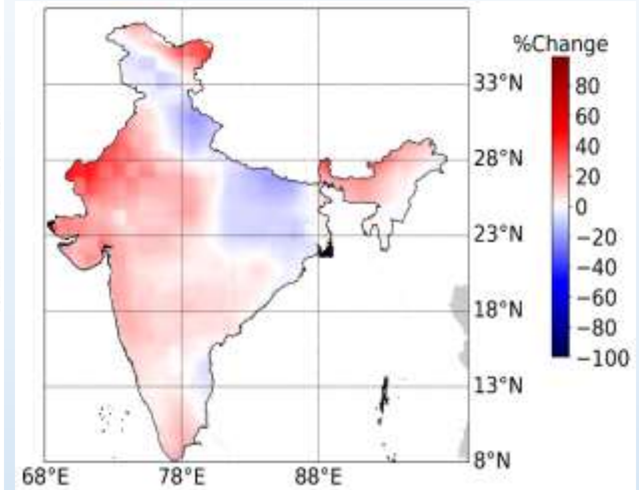
GFDLCM3 (1961-2005) – TS1



GFDLCM3 (2006-2050) – TS2

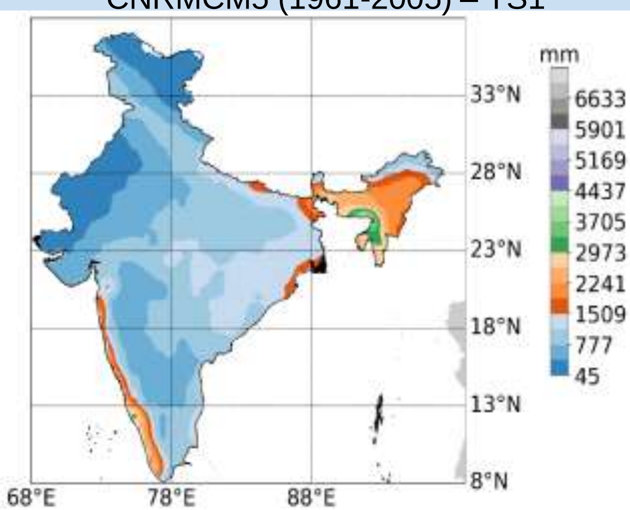


GFDLCM3 (TS1 vs TS2)

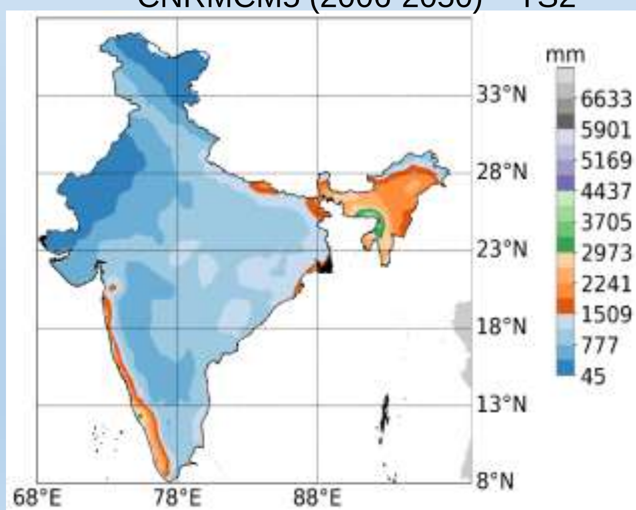


Precipitation difference (increase) is more pronounced in the Eastern, Western, and Southern parts of the country as compared to the states of UP, Bihar, Jharkhand, WB, Punjab and Haryana, excluding parts of Jammu and Kashmir.

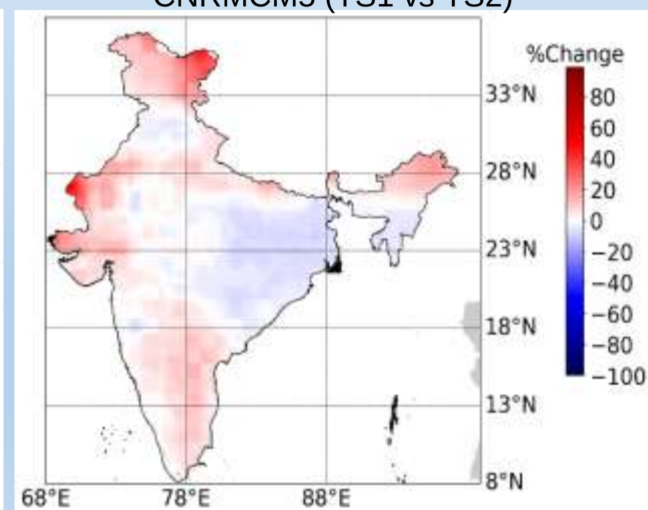
CNRMCM5 (1961-2005) – TS1



CNRMCM5 (2006-2050) – TS2



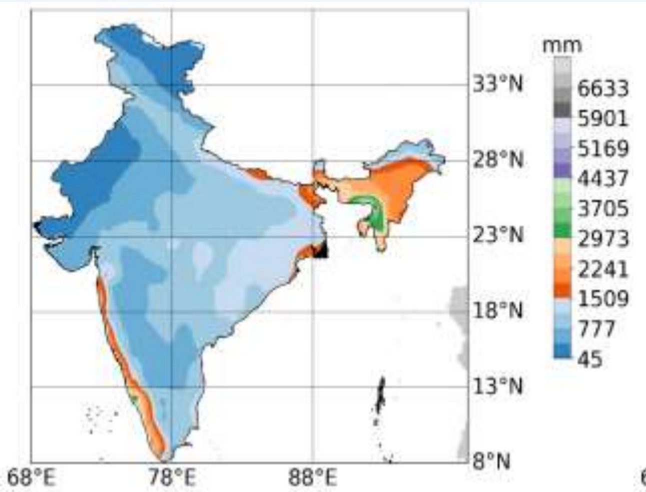
CNRMCM5 (TS1 vs TS2)



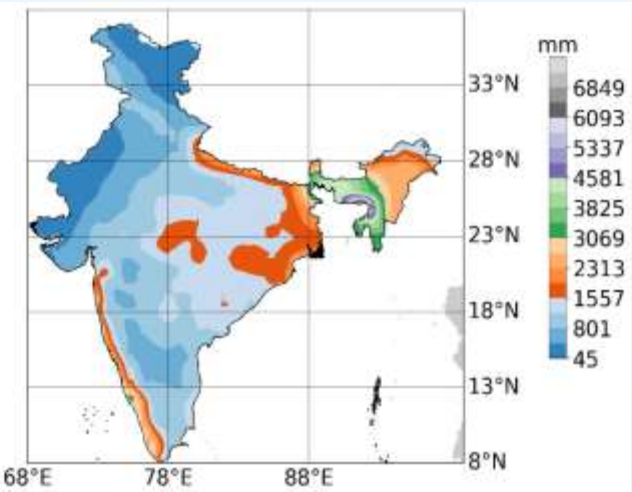
Precipitation difference (increase) is more pronounced in most parts of the country as compared to the parts of Central, SE and parts of NE states.

Spatio-Temporal Precipitation Variability - Historical vs Far Changes

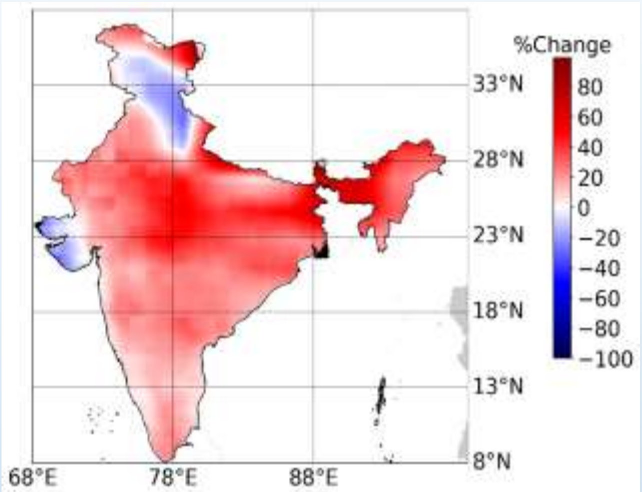
GFDLCM3 (1961-2005) – TS1



GFDLCM3 (2055-2100) – TS2

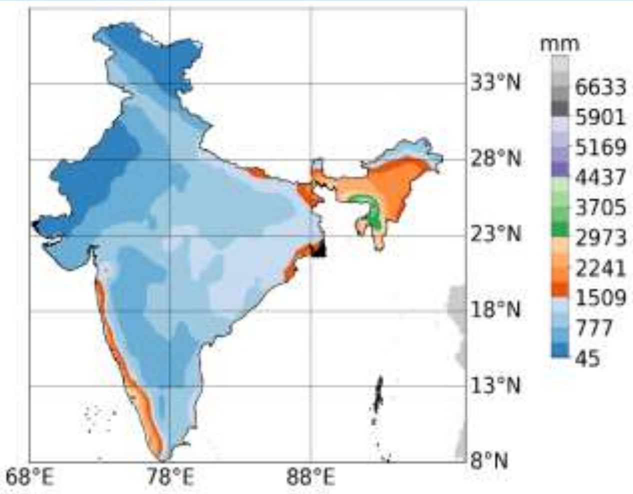


GFDLCM3 (TS1 vs TS3)

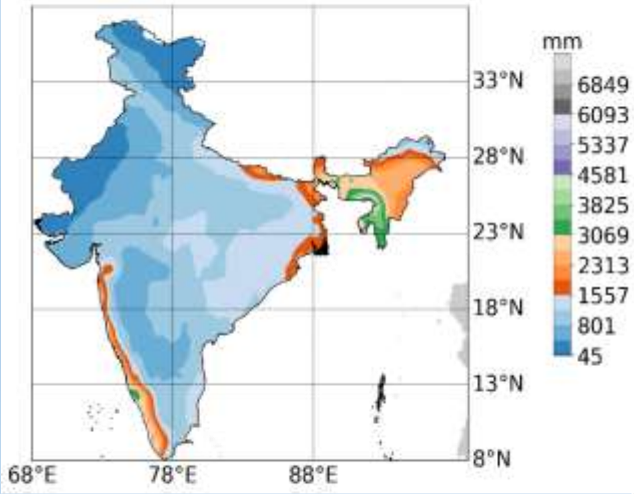


Precipitation difference (increase) is more pronounced in most part of the country, except Gujarat and parts of Hmachal and Jammu and Kashmir.

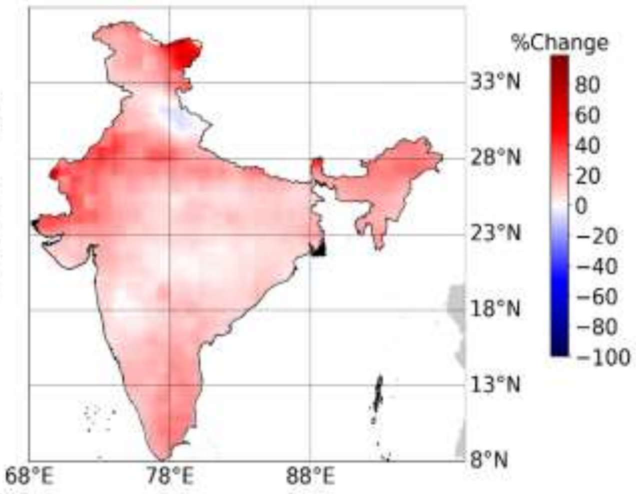
CNRMCM5 (1961-2005) – TS1



CNRMCM5 (2055-2100) – TS2



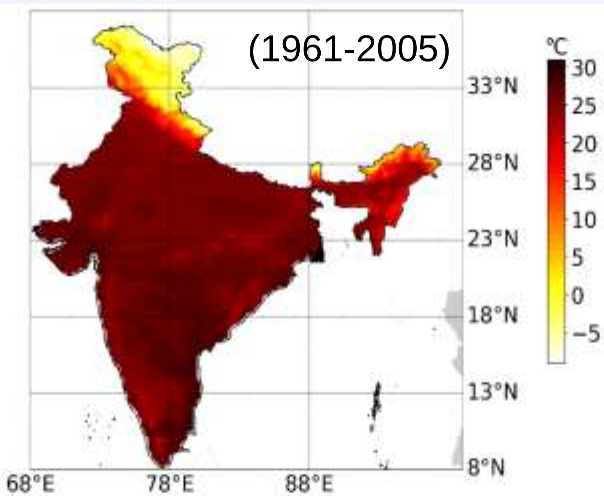
CNRMCM5 (TS1 vs TS3)



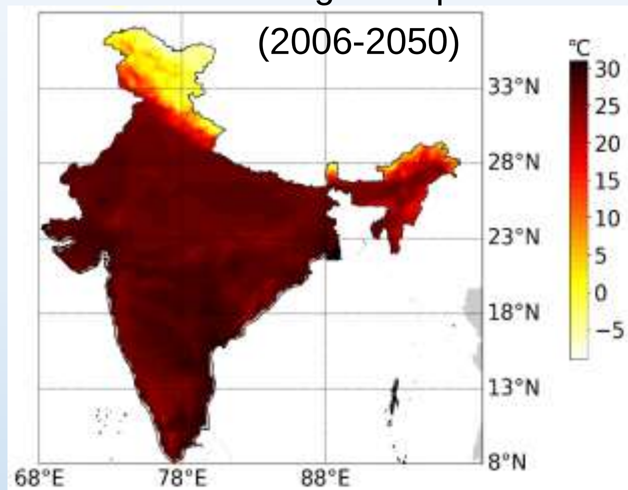
Precipitation difference (increase) is pronounced in most parts of the country.

Spatio-Temporal Temperature Variability - Historical vs Near Far Changes

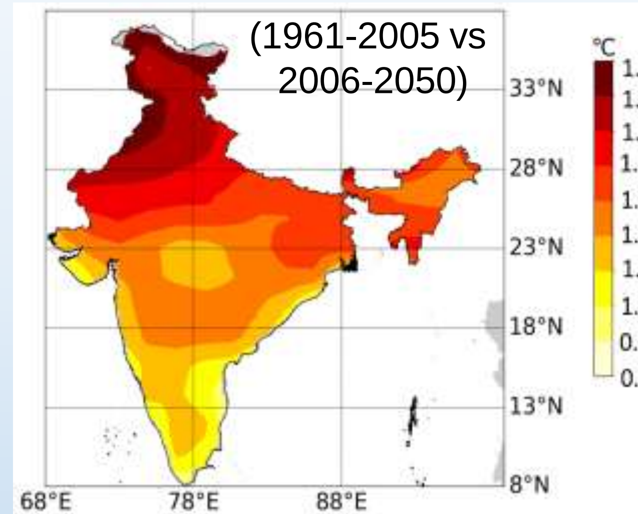
Annual Average Temp



Annual Average Temp

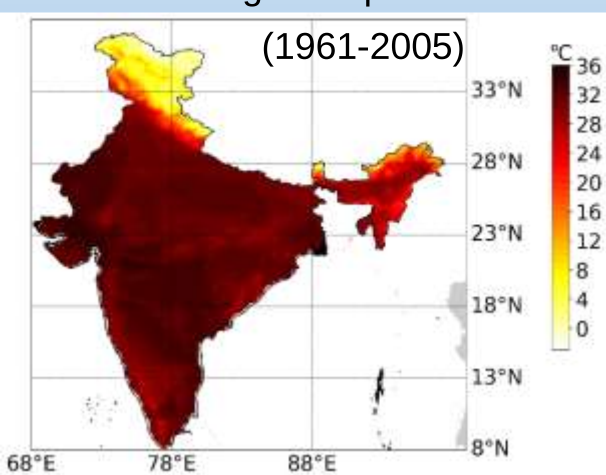


Change in Average Temp

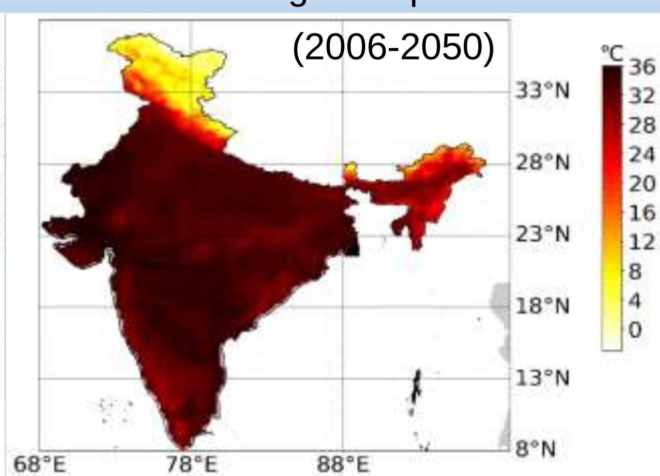


- ✓ Temperature difference (increase) is more pronounced in the northern parts as compared to the southern parts
- ✓ The warming trends are more pronounced in the WH region, NW and extreme Eastern parts.

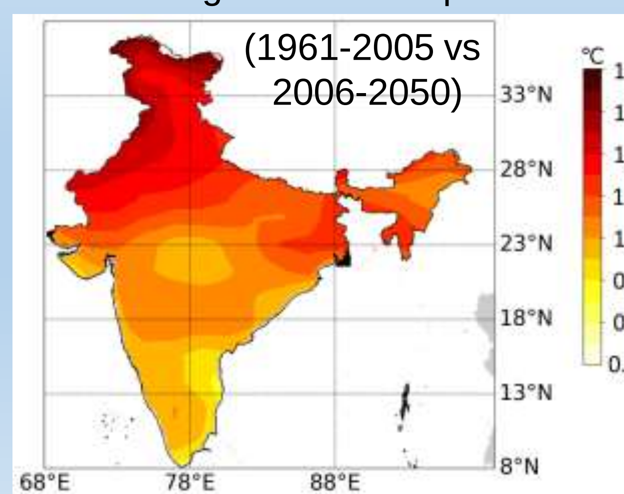
Annual Average Temp Max



Annual Average Temp Max

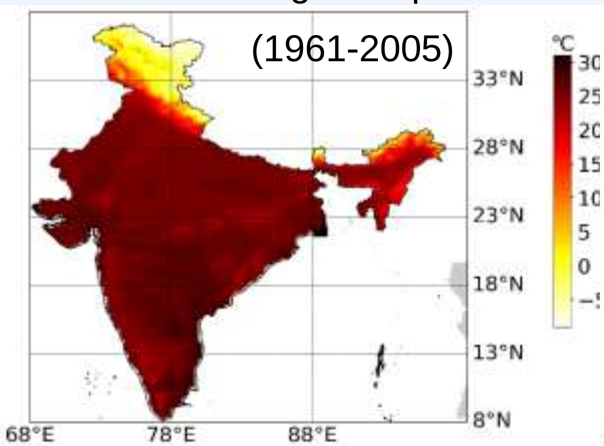


Change in Max Temp

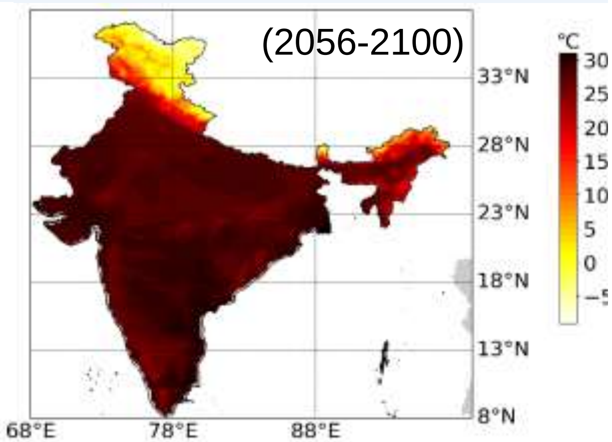


Spatio-Temporal Temperature Variability - Historical vs Far Changes

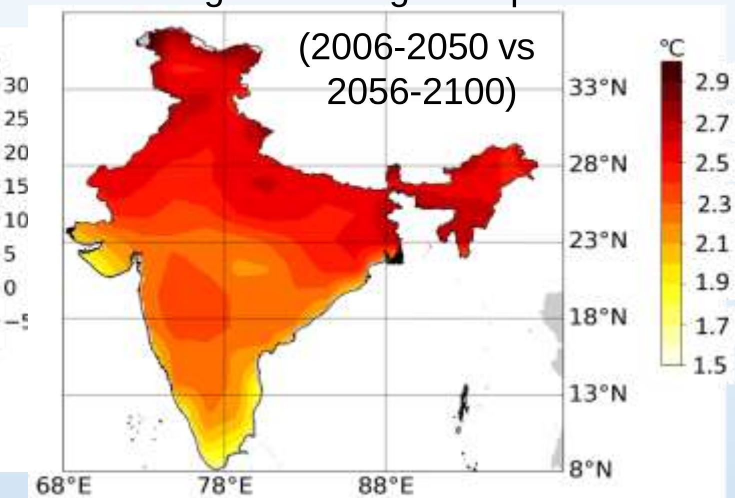
Annual Average Temp



Annual Average Temp

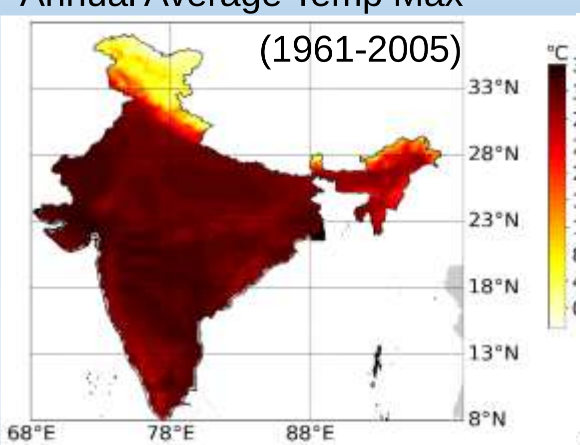


Change in Average Temp

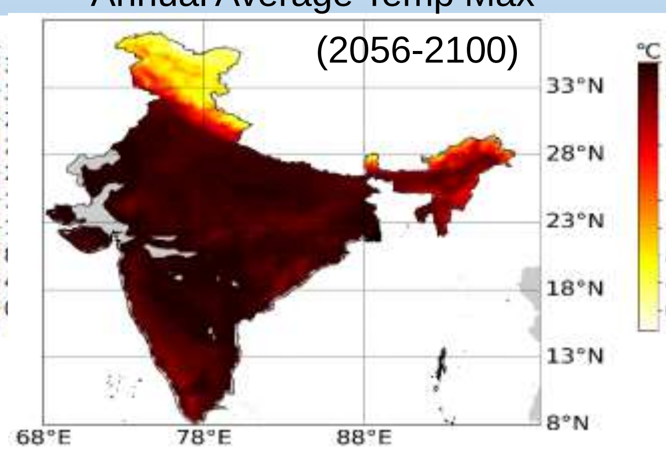


- ✓ Temperature difference (increase) is more pronounced in the N and NE parts as compared to the southern parts
- ✓ The warming trends are more pronounced in the WH region, NW and extreme Eastern parts.

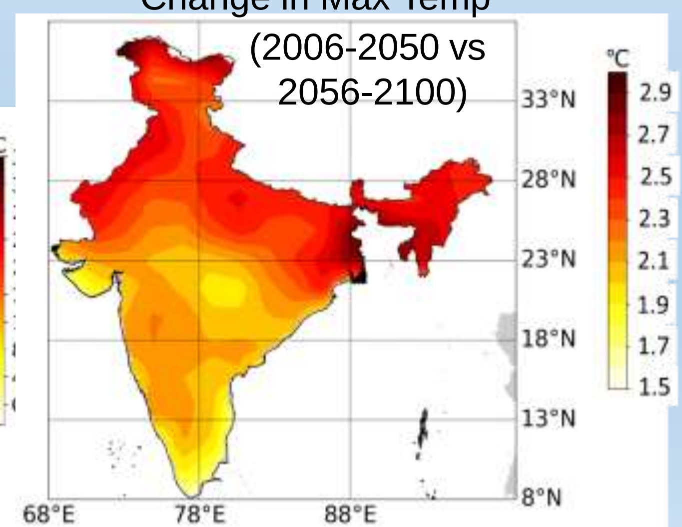
Annual Average Temp Max



Annual Average Temp Max

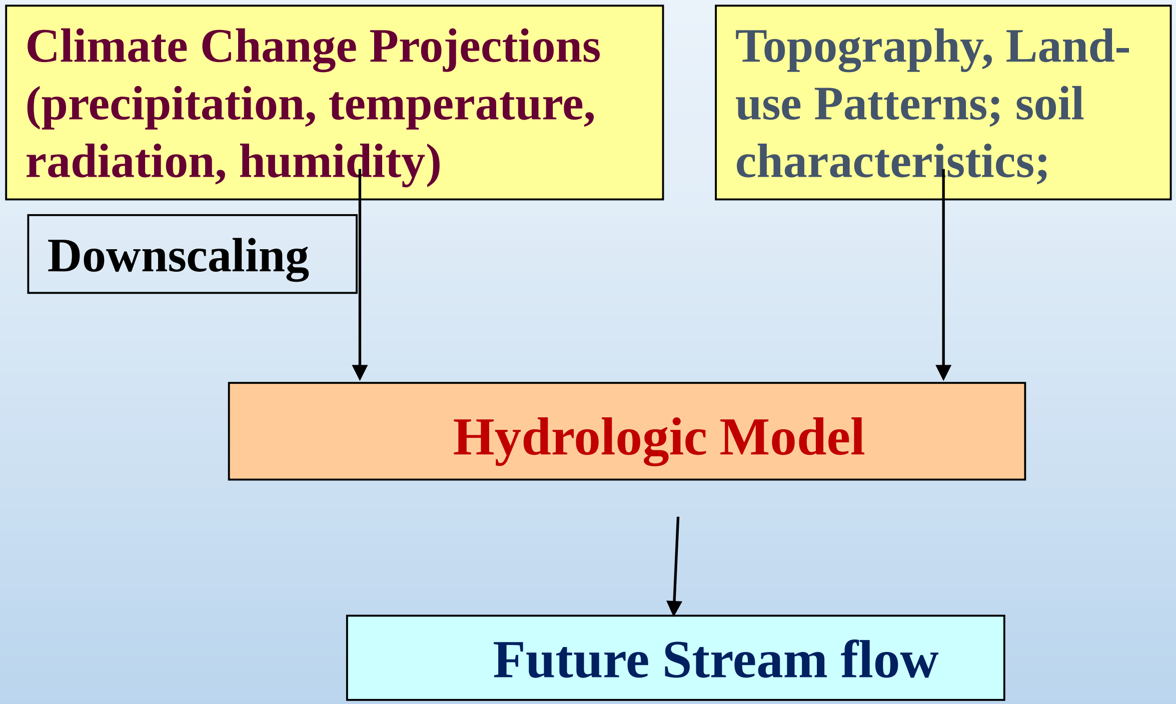


Change in Max Temp



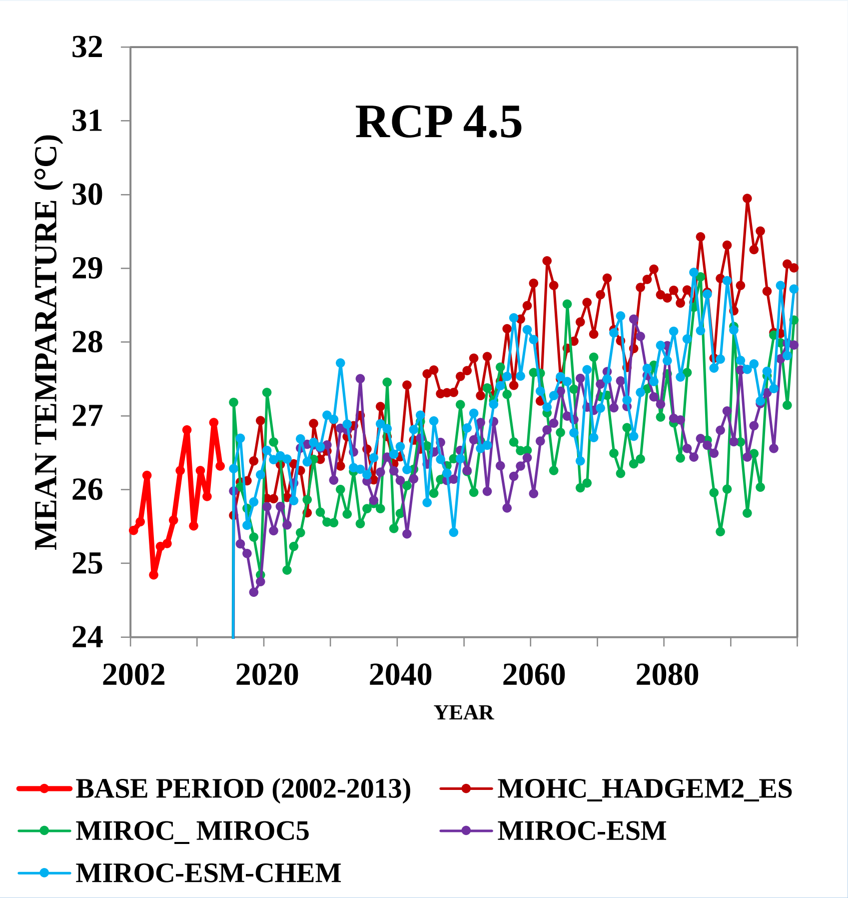
Impact of Climate Change on River runoff

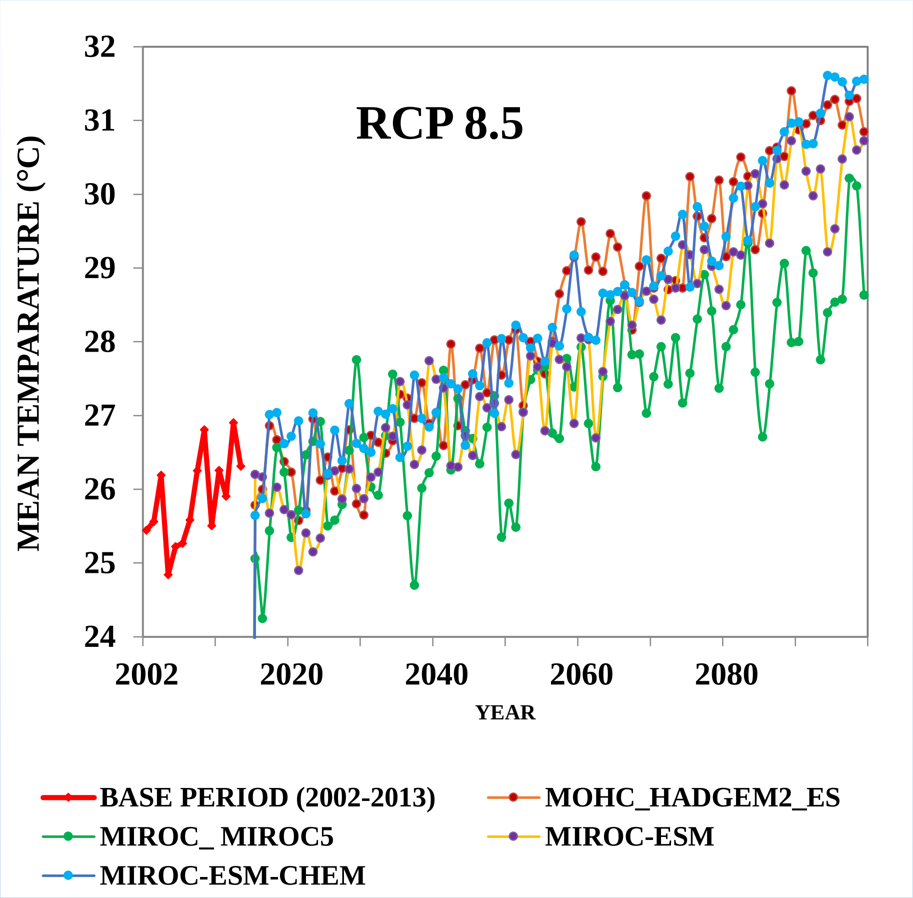
Climate change is causing and will continue to have a significant impact on the amount and the timing of river flows in different basins



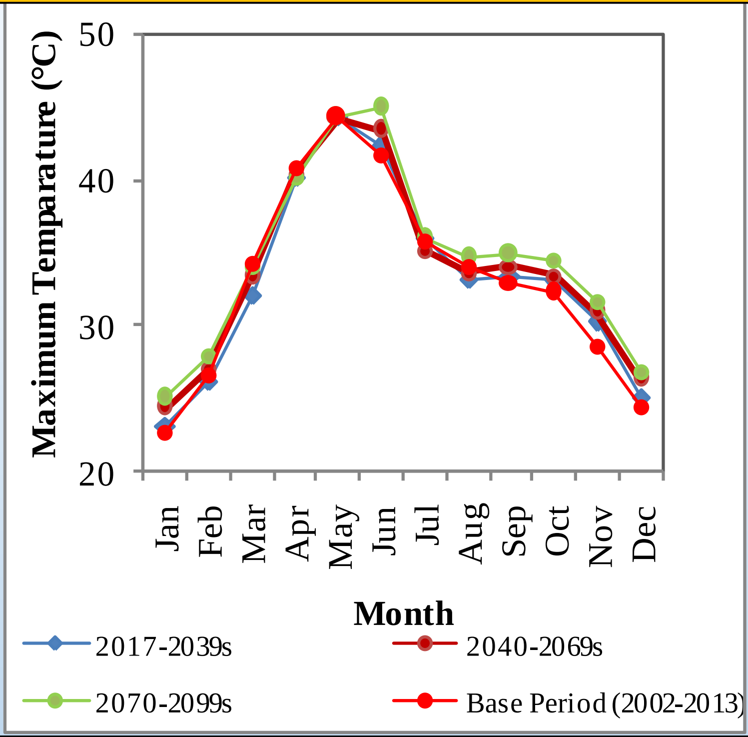
Climatic impact on river flows is more pronounced than the impact of land use change. It will result in increasing trend in river flows in higher latitudes regions and decreasing trend in mid and low-latitude regions.

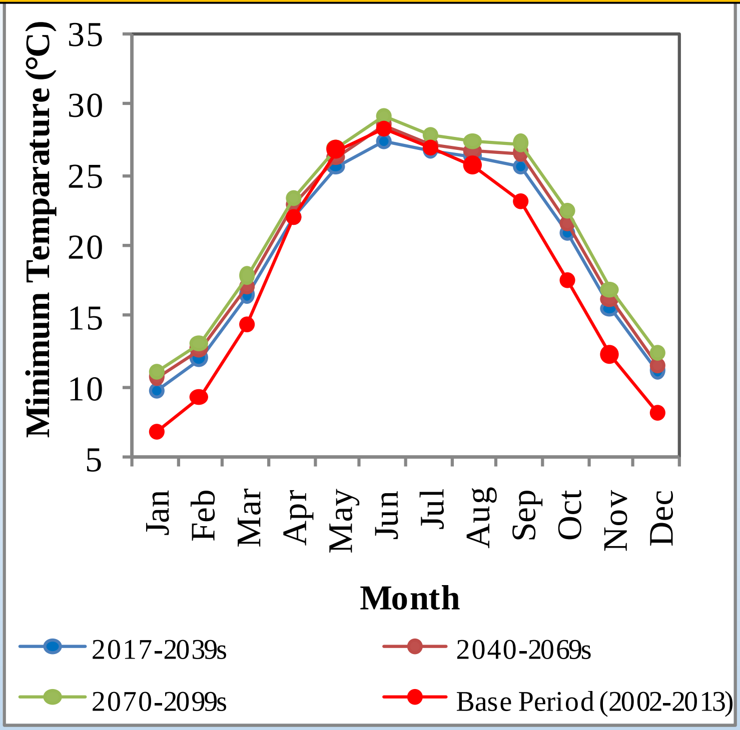
Projected Future Temperature (GOMTI BASIN)





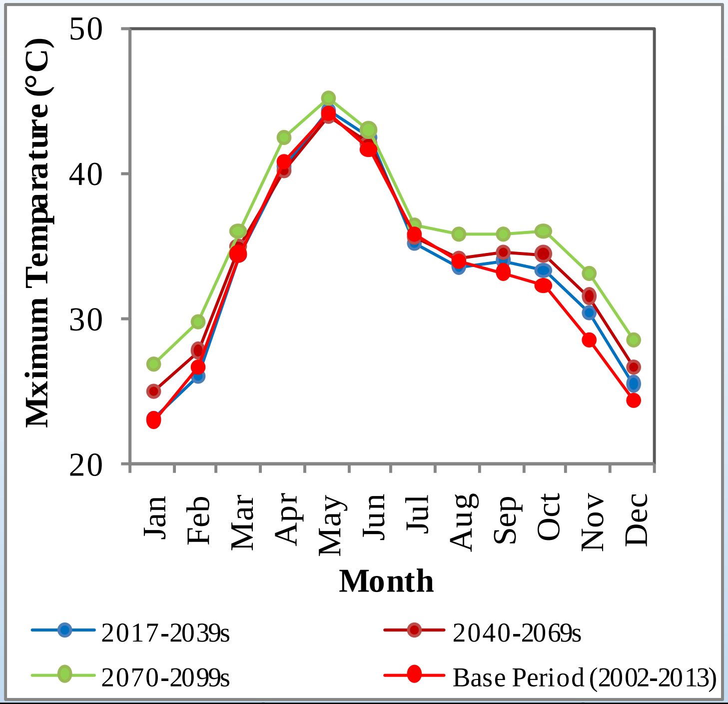
Monthly mean max-min temperature for the period of near, mid and end century of RCP 4.5

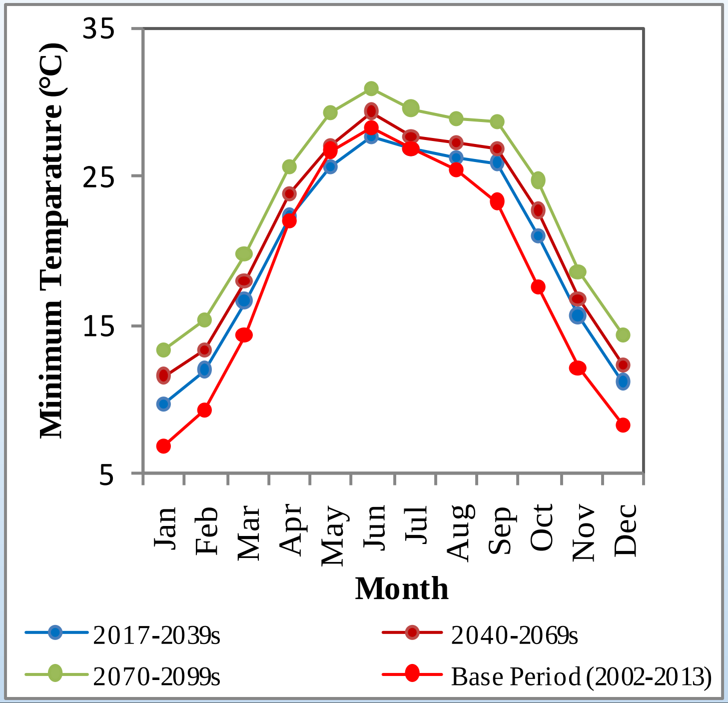




Parameters	Base Period	RCP 4.5 (% Change)		
	2002-2013	2017-2039s (Near Centaury)	2040-2069s (Mid Centaury)	2070-2099s (End Centaury)
Max Temp(°C)	33.21	+0.24	+2.80	+5.25
Min Temp (°C)	18.46	+8.07	+11.96	+15.70

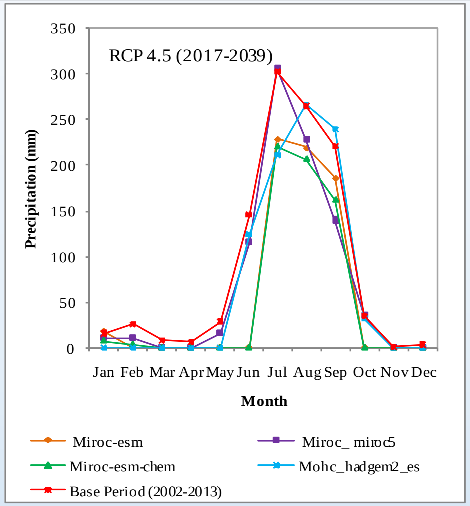
Monthly mean max-min temperature for the period of near, mid and end century of RCP 8.5

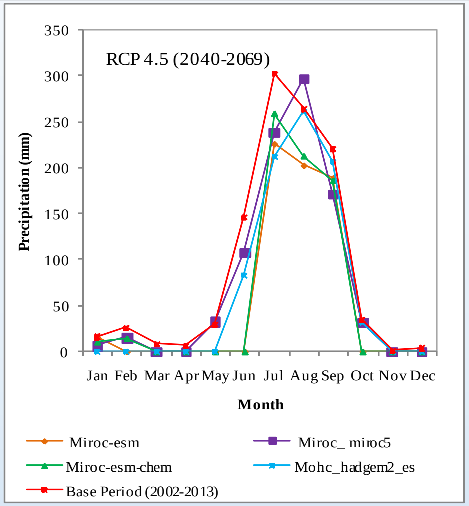


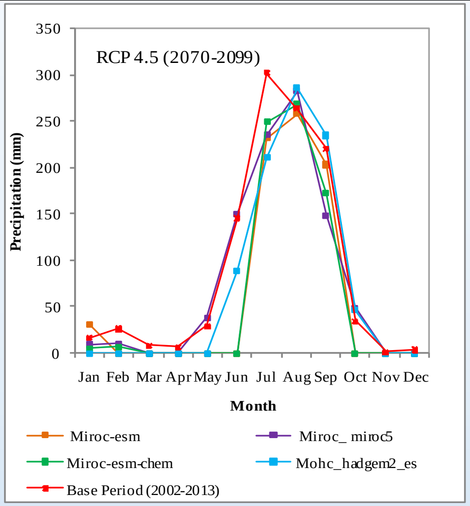


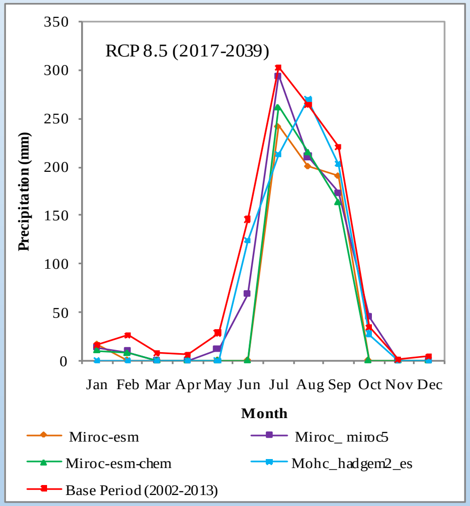
Parameters	Base Period	RCP 8.5 (% Change)		
	2002-2013	2017-2039s (Near Centaury)	2040-2069s (Mid Centaury)	2070-2099s (End Centaury)
Max Temp (°C)	33.21	+0.65	+4.62	+10.98
Min Temp (°C)	18.46	+8.75	+16.27	+26.39

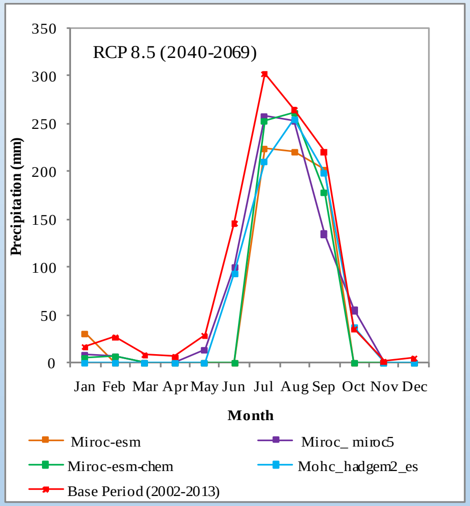
Projected Precipitation

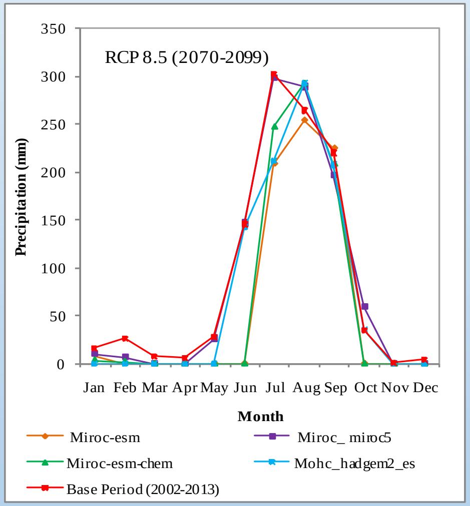






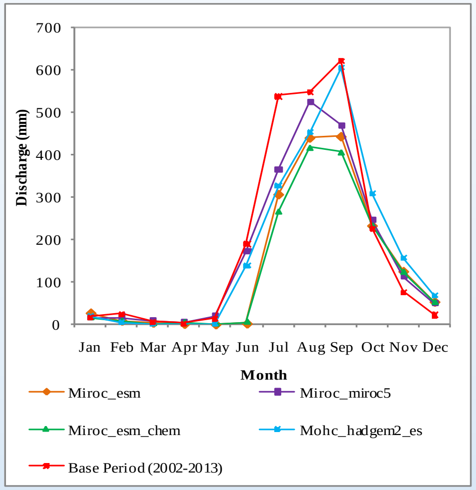


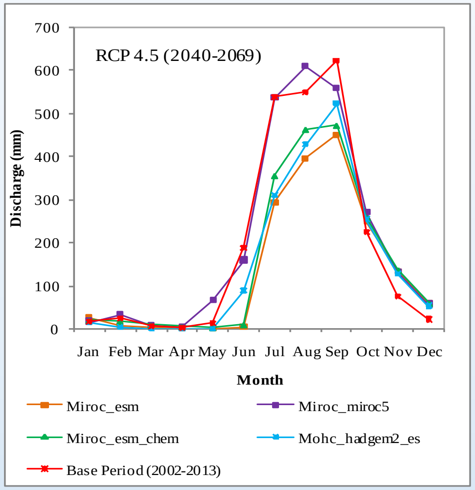


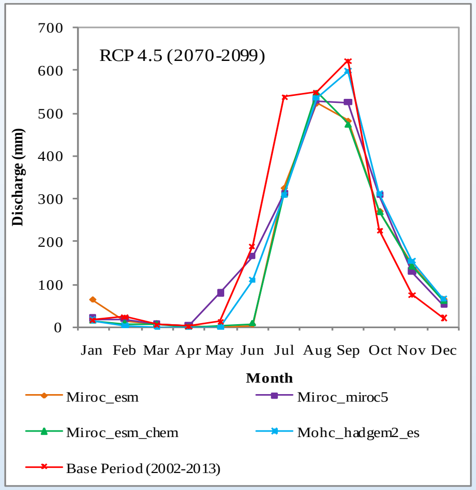


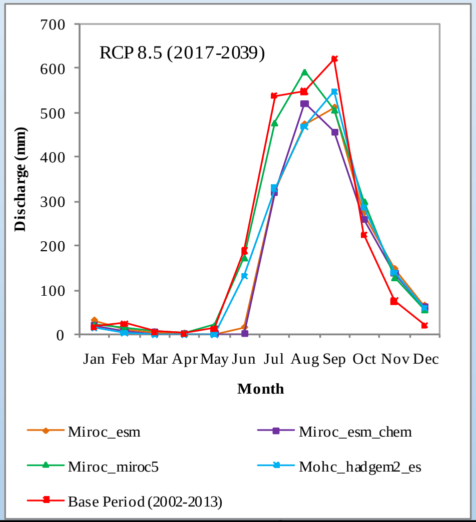
Parameter	Base Period	RCP 4.5 (% Change)			RCP 8.5 (% Change)		
	2002-2013	Near Centaury	Mid Centaury	End Centaury	Near Centaury	Mid Centaury	End Centaury
Precipitation (mm)	1055.98	-29.17	-28.69	-23.82	-29.65	-28.88	-24.87

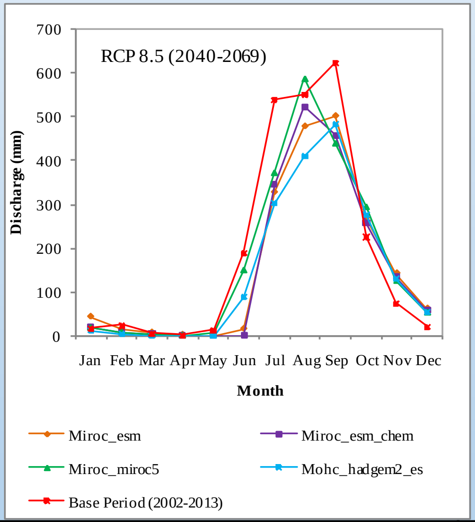
Projected Discharge

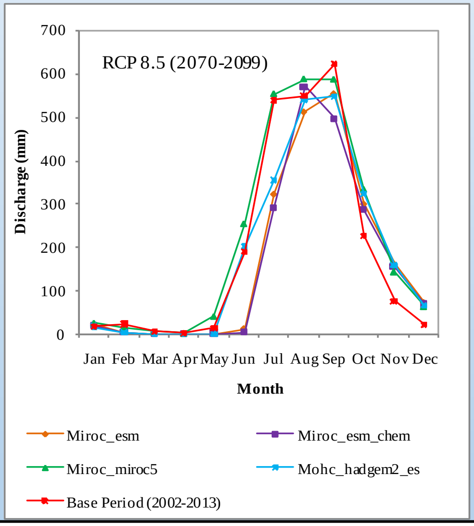






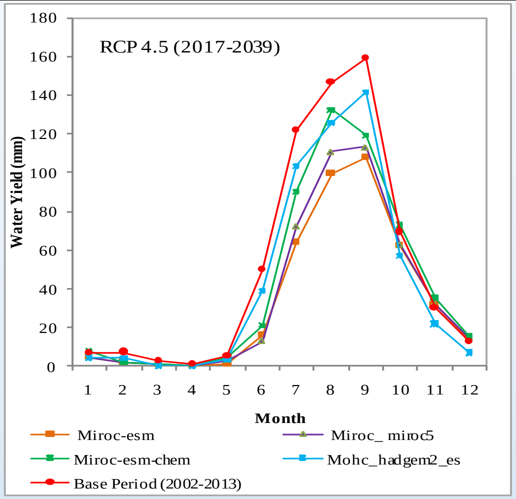


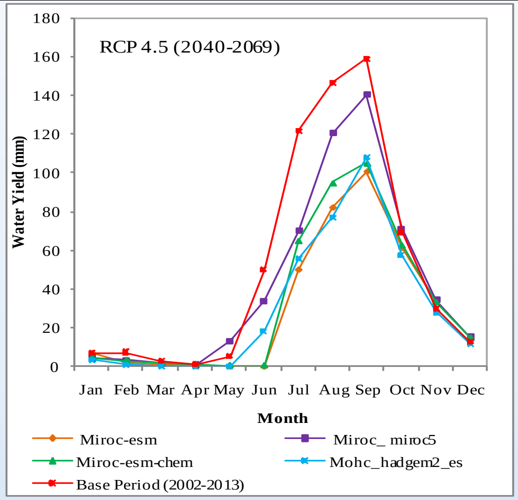


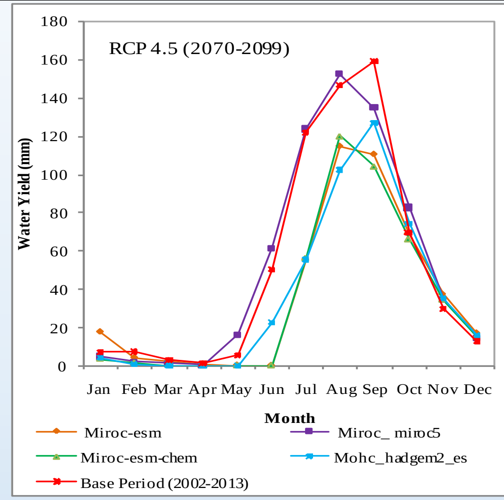


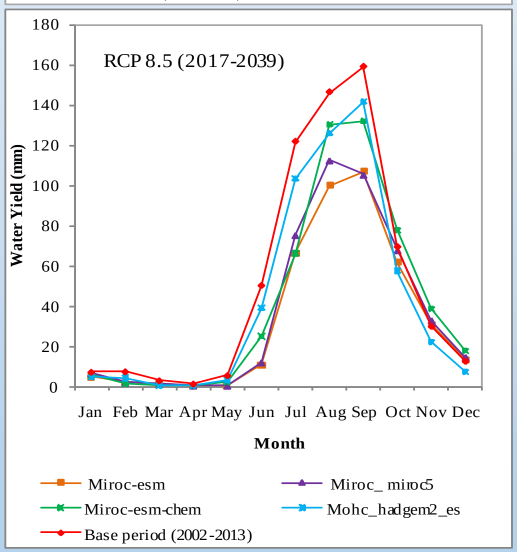
Parameter	Base Period	RCP 4.5 (% Change)			RCP 8.5 (% Change)		
	2002-2013	Near Centaury	Mid Centaury	End Centaury	Near Centaury	Mid Centaury	End Centaury
Discharge (m^3/sec)	2644.11	-31.27	-27.45	-24.30	-24.93	-28.96	-23.02

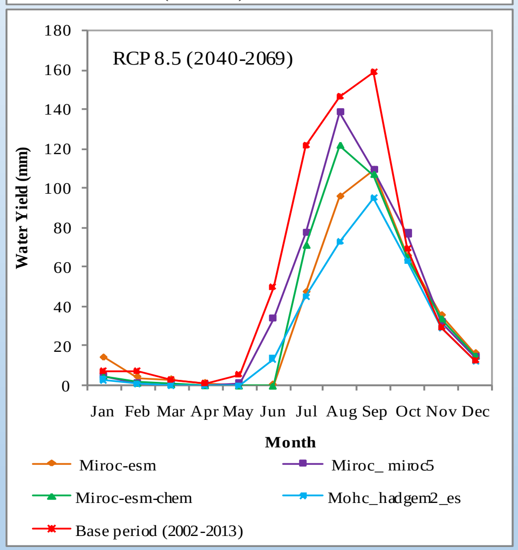
Projected Water Yield

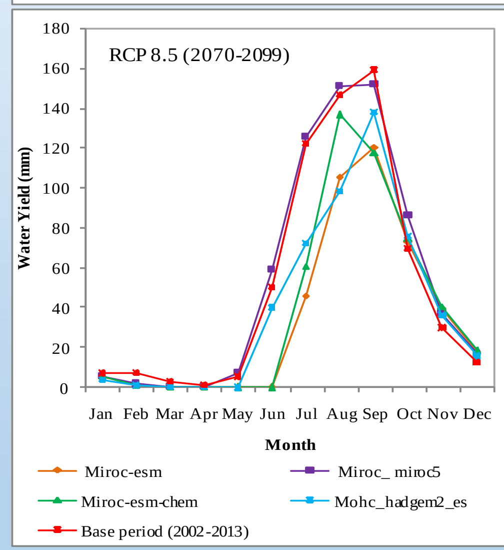






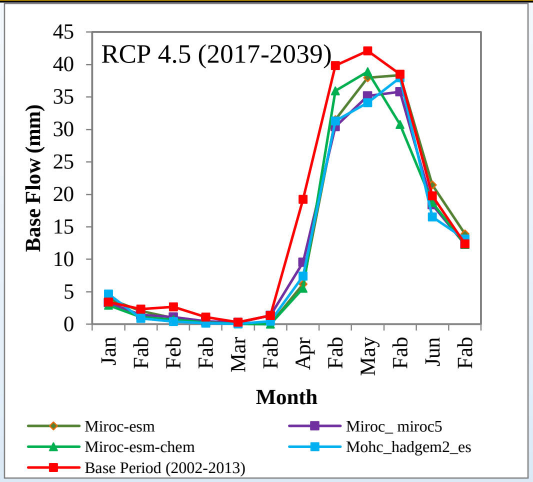


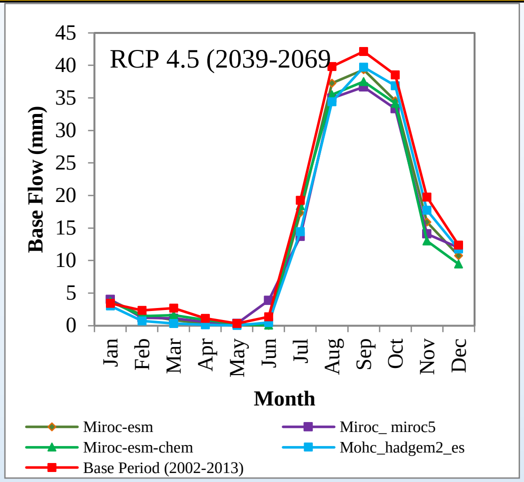


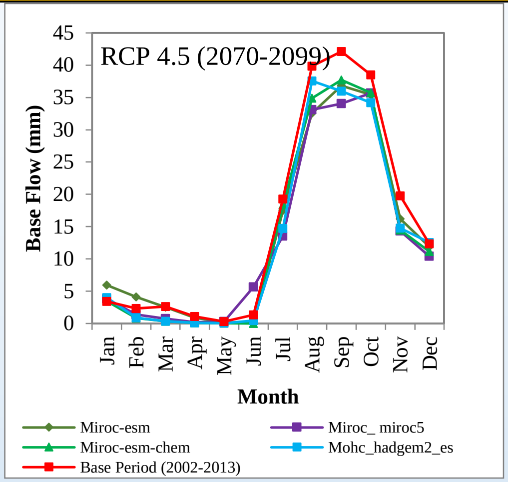


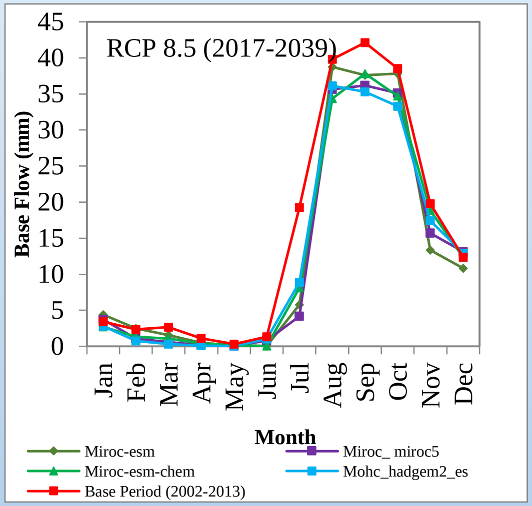
Parameter	Base Period	RCP 4.5 (% Change)			RCP 8.5 (% Change)		
	2002-2013	Near Centaury	Mid Centaury	End Centaury	Near Centaury)	Mid Centaury	End Centaury
Water Yield (mm)	613.49	-24.79	-34.66	-30.10	-25.33	-33.18	-27.26

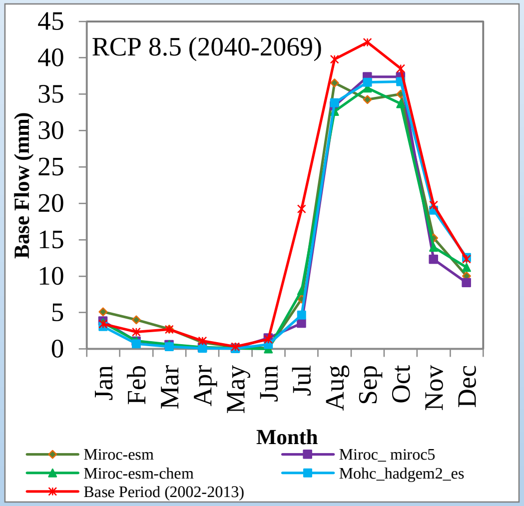
Projected Groundwater Recharge

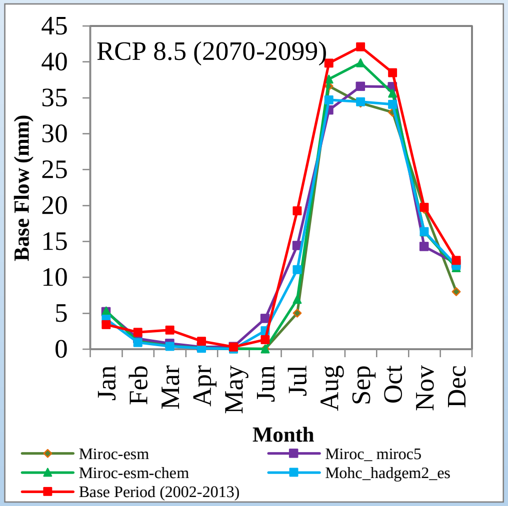












Parameter	Base Period	RCP 4.5 (% Change)			RCP 8.5 (% Change)		
	2002-2013	Near Centaury	Mid Centaury	End Centaury	Near Centaury	Mid Centaury	End Centaury
Recharge (mm)	183.08	-17.96	-18.96	-19.37	-20.72	-21.35	-21.77

Key Issues in Himalayan Region

1. Hydrological network and databases.
2. Trend of changes in snow cover over the Himalayas/basins.
3. Snow/glacier melt runoff contributions in Himalayan basins.
4. Why is glacier mass balance positive or negative for glaciers in similar regions?
5. Snow/glacier contributions in changing climate change?
6. Flash floods generated from Cloudburst, GLOF.
7. Dynamics and hazards of erosion, sedimentation and landscape processes.

IPCC AR6-Impacts On Himalaya's Ice/Glaciers

- **Snow cover will decline over most regions during the 21st century, in terms of water equivalent, extent and annual duration.**

- **Warming has occurred in the Himalayas, and has increased with altitude. Such elevation-dependent warming could lead to faster changes in the snowline, the glacier equilibrium-line altitude and the snow/rain transition height.**

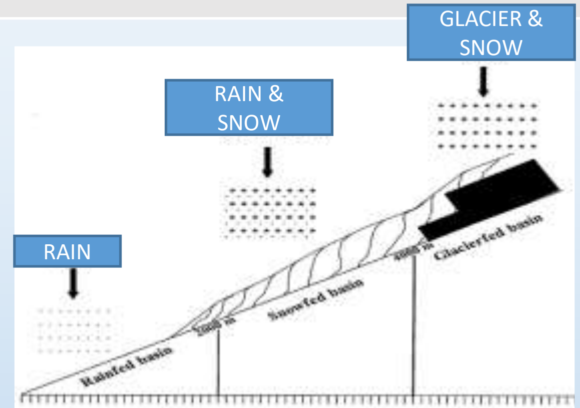
- **As per AR6, the projected runoff is typically decreased by contributions from small glaciers because of glacier mass loss, while runoff from larger glaciers will generally increase with increasing global warming levels until their mass becomes depleted.**

- **Himalayan glaciers will continue to shrink and permafrost to thaw in all regions where they are present. Glaciers are projected to lose more mass in higher greenhouse gas emissions scenario over the 21st century, as observed by SSP5-8.5 scenario.**

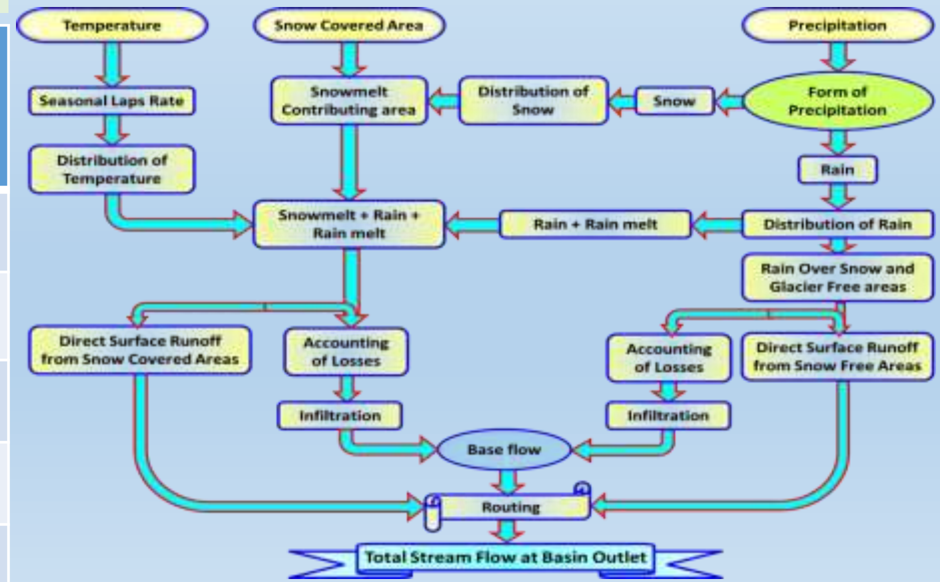
Snow/Glacier melt Runoff Studies

A snowmelt runoff Model (SNOWMOD) has been developed at NIH and applied for a number of Himalayan basins : Satluj, Chenab, Beas, Ganga, and Brahmputra basin.

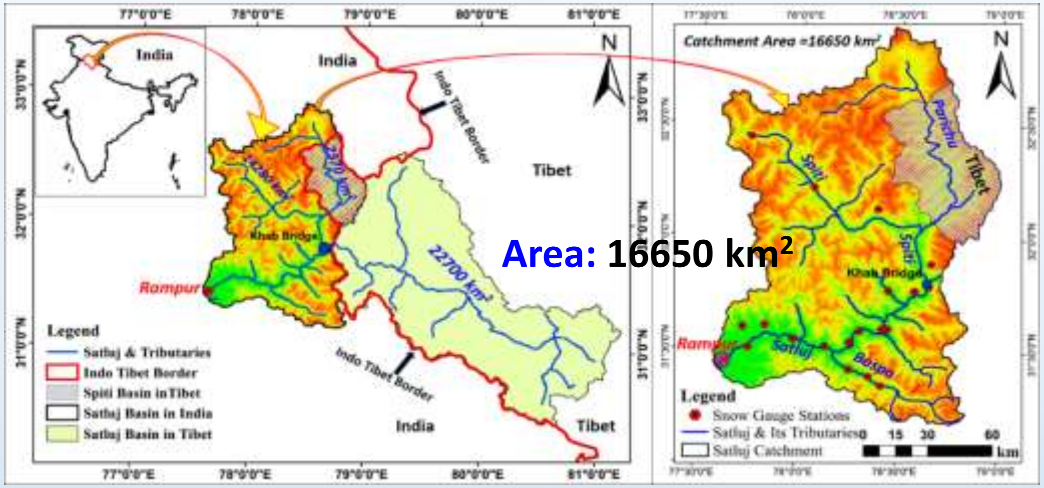
SNOWMOD: Temperature index model, which is designed to simulate daily stream flow for mountainous basins having contribution from both snowmelt and rainfall. Beside SNOWMOD other models such as SWAT, VIC, SPHY and SRM have also been used for streamflow modelling in Himalayan basins.

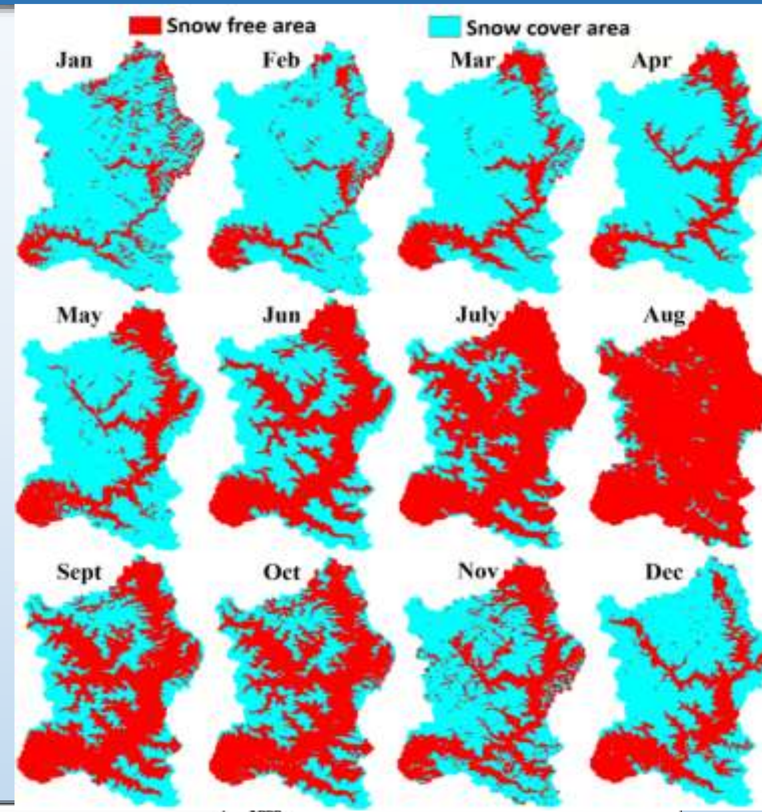


Basin	Site	Total Area (km^2)	Max. SCA (km^2)	Min. SCA (km^2)	Av. Snow & glaciers melt
Chenab	Akhnoor	22,200	15,590 (70%	5,400 (24%)	49%
Satluj	Bhakra Dam	22,275	14,498 (65%)	4,528 (20%)	60%
Beas	Pandoh Dam	5,278	2,700 (51%)	780 (14%)	35%
	Manali	204	173.4 (85%)	24.50 (12%)	54%
Ganga	Devprayag	19,700	9,080 (46%)	3,800 (19%)	28%



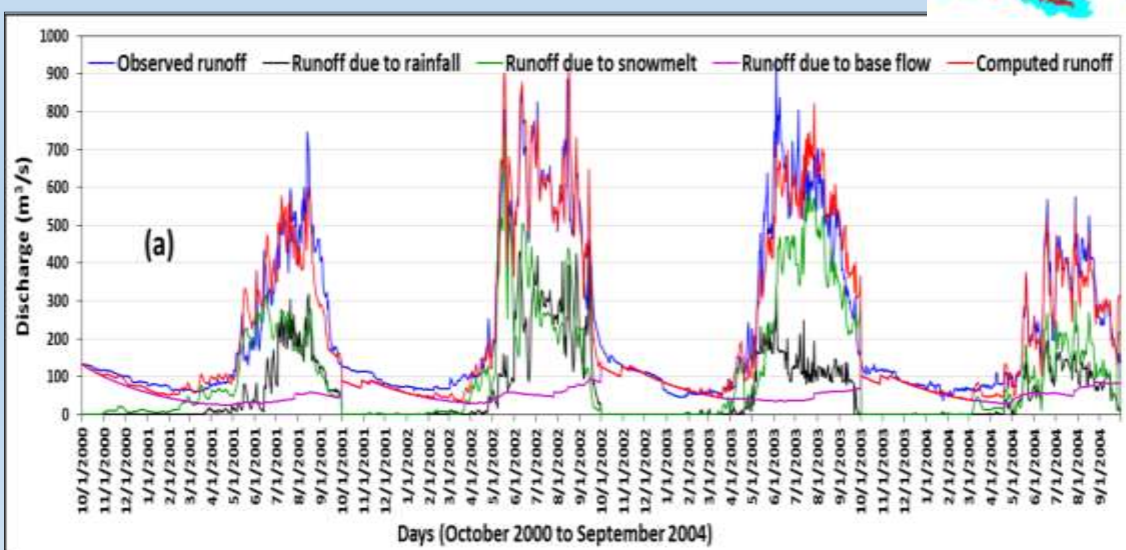
Snow/Glacier melt Runoff Studies

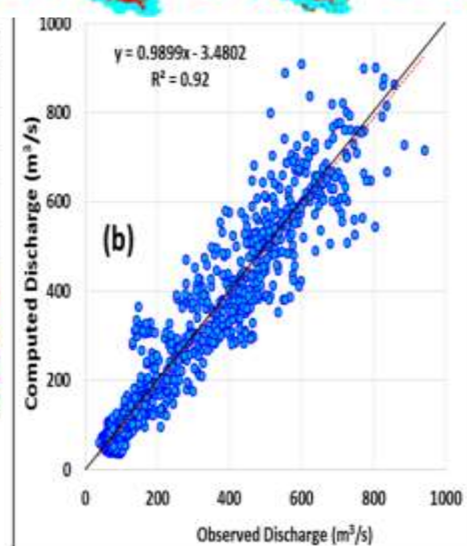




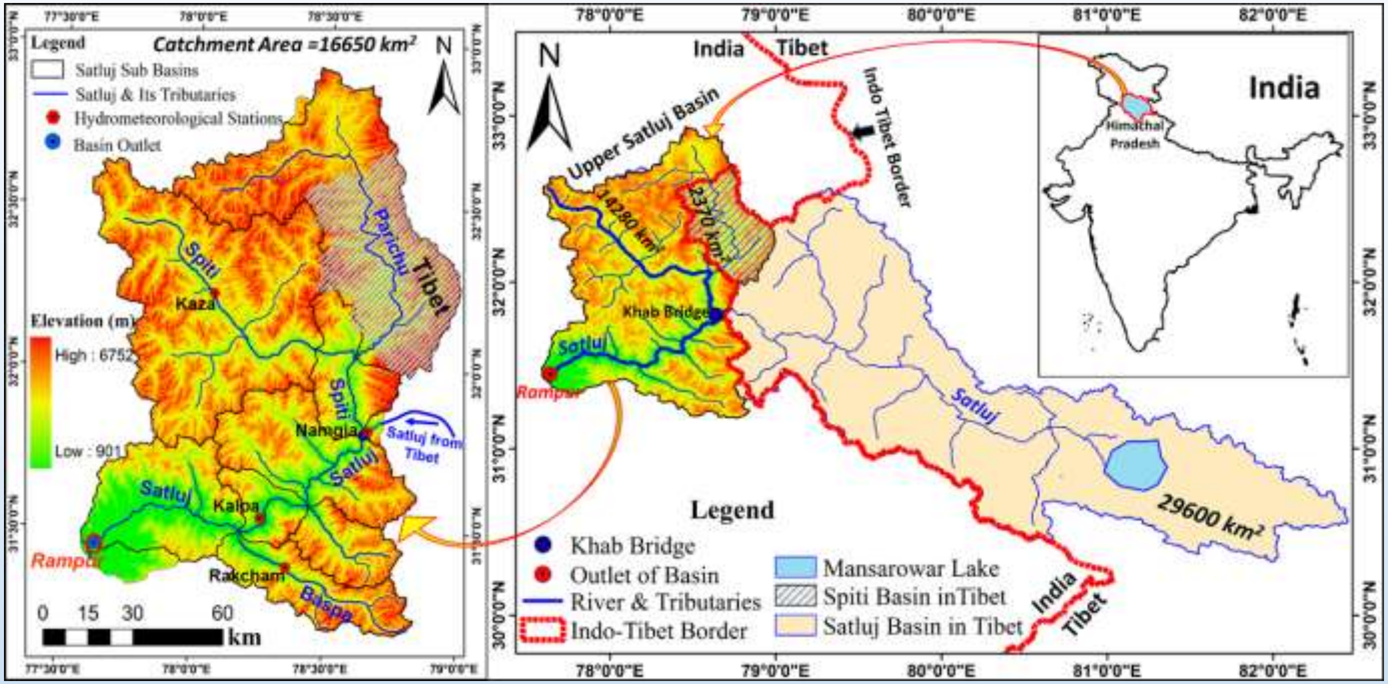
80% of the basin area is covered with seasonal snow during winters, whereas permanent snow occupies about 12% of the basin

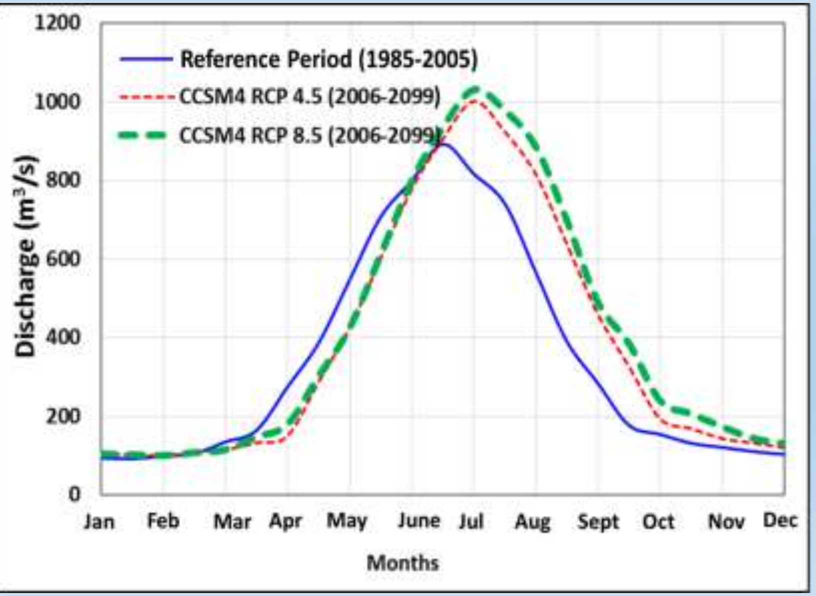
The snowmelt runoff contribution in total runoff Rampur 70%.





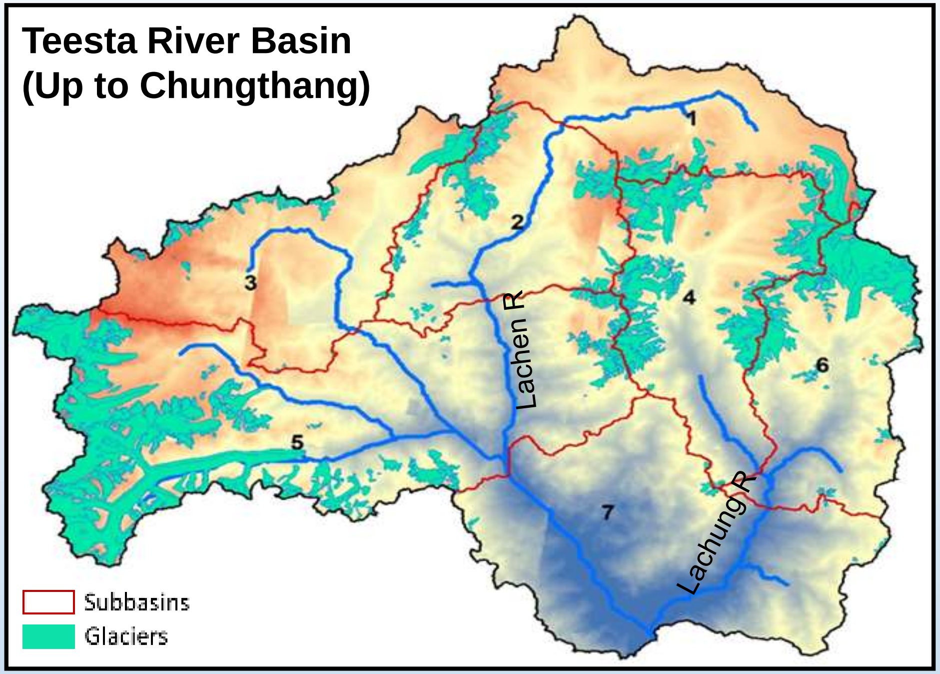
Snow/glacier melt runoff changes in Upper Satluj basin

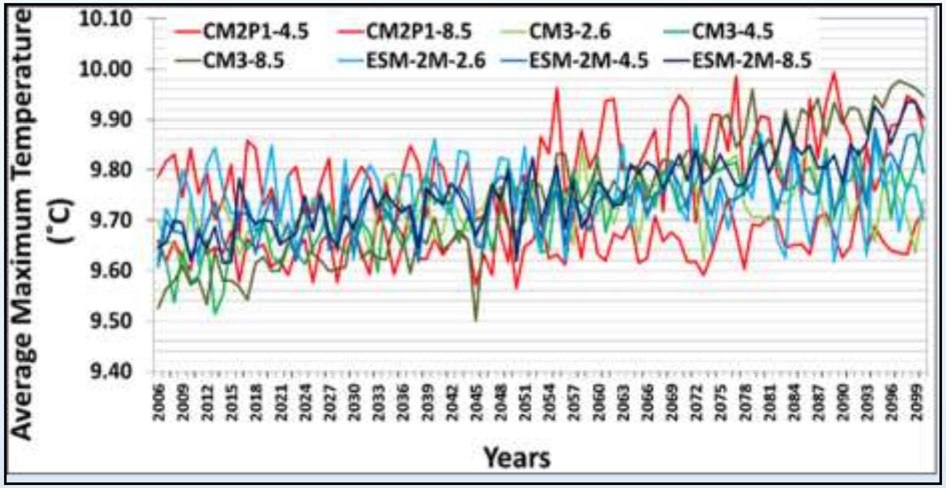


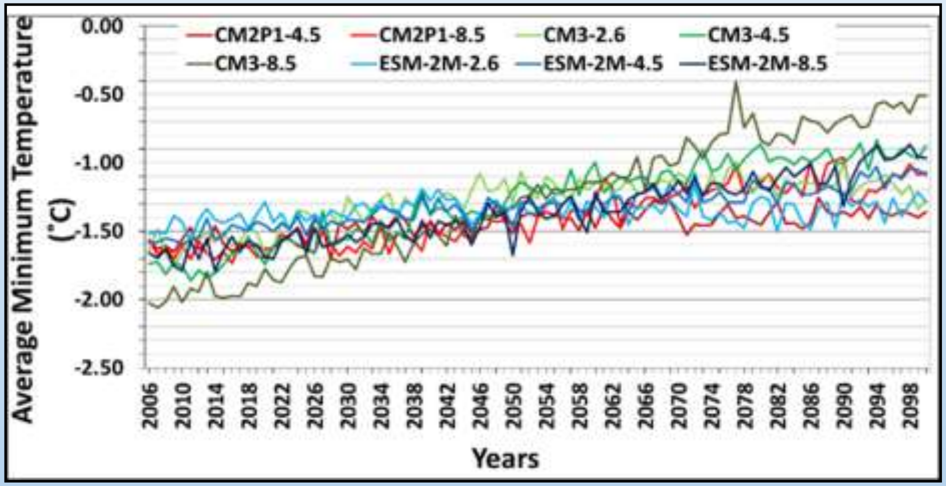


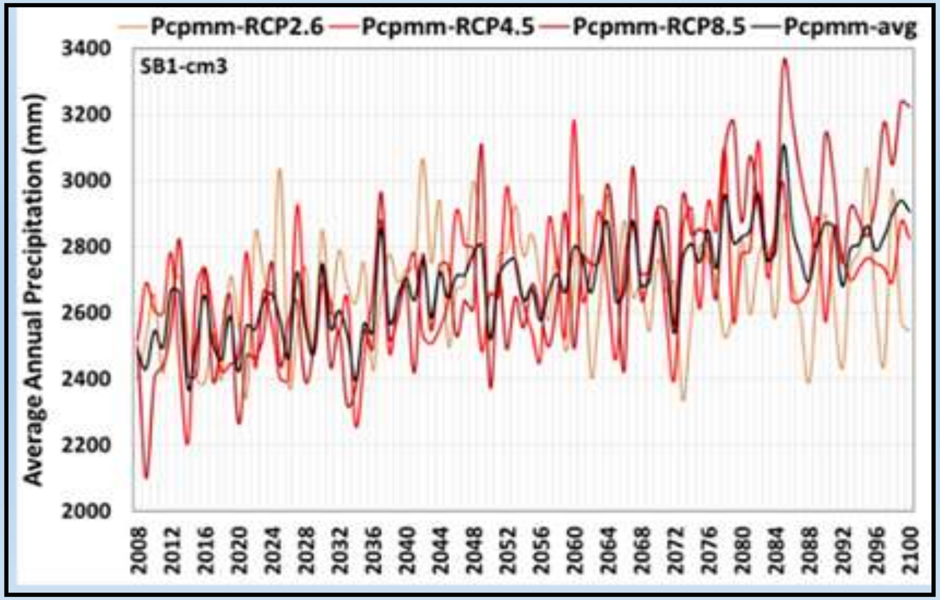
- **Annual precipitation will increase by 14% to 21% from the current average annual precipitation of about 420 mm and temperature will be increased by 2.18 °C to 5.71 °C by the end of the century.**
- **The converted future climatic change conditions into a possible range of stream flows shows a increase in streamflow by 11%–19% from the current average annual flow of about 333 m³/s by the end of the century.**

Snow/glacier melt runoff changes in Upper Teesta basin









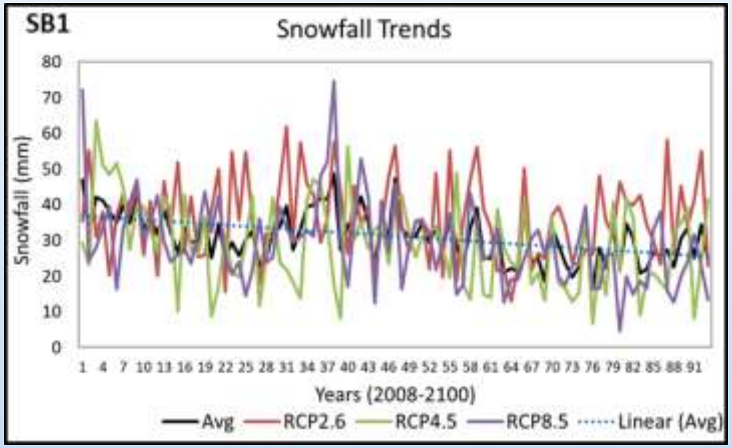
Precipitation change

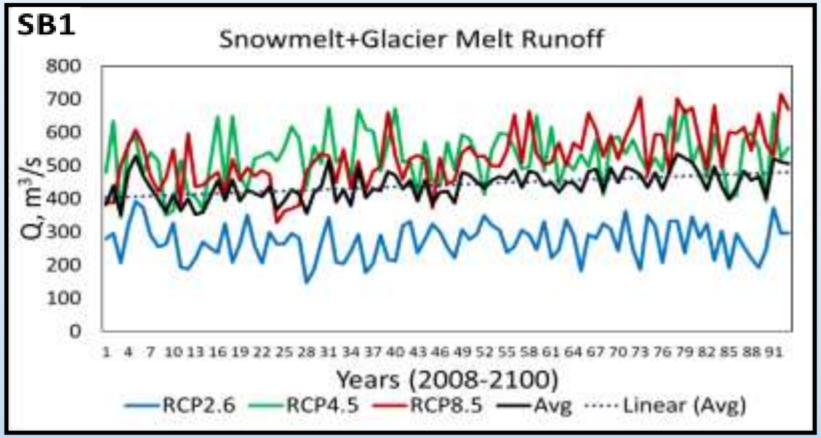
RCP 2.6	RCP 4.5	RCP8.5
5.37%	14.81%	26.95%

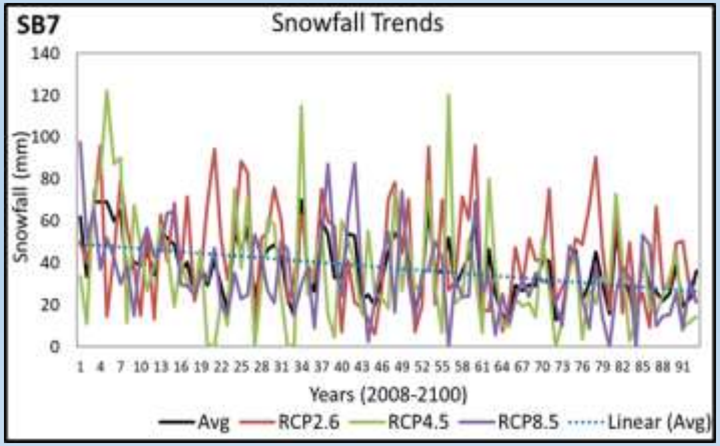
The average increase (for all models & RCPs) in maximum and minimum temperature is recorded around ~0.5°C and ~0.7°C, respectively.

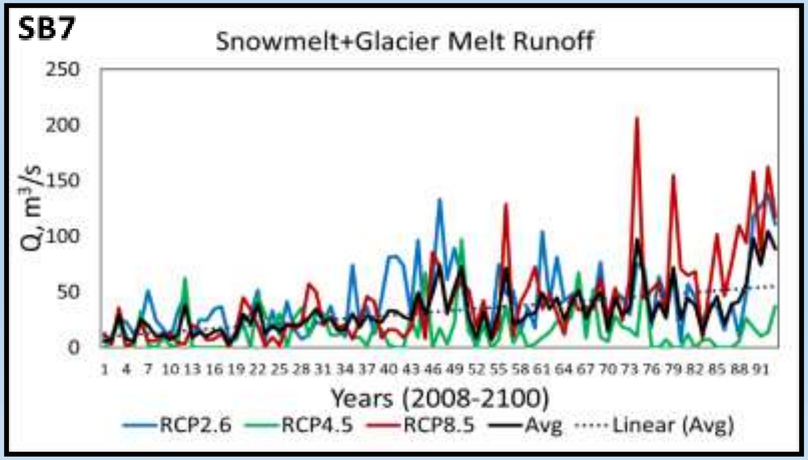
Snowfall and Snow/glacier melt runoff changes in Upper Teesta basin

Component	RCP2.6	RCP4.5	RCP8.5	Trend
% Change in Snowfall Amount	-3.01%	-3.94%	-4.7%	Decrease
% Change in Snowt+Glacier Melt Amount	0.68%	3.16%	8.59%	Increase

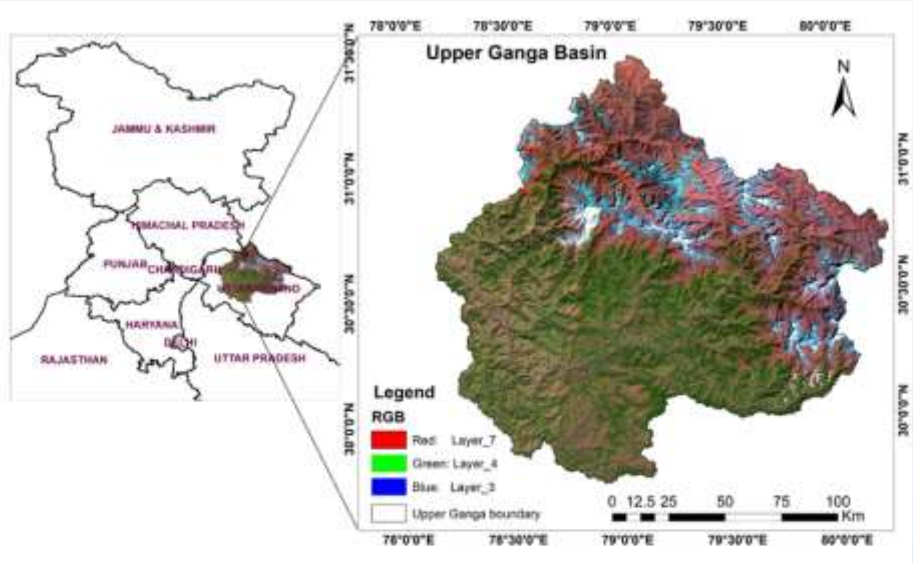


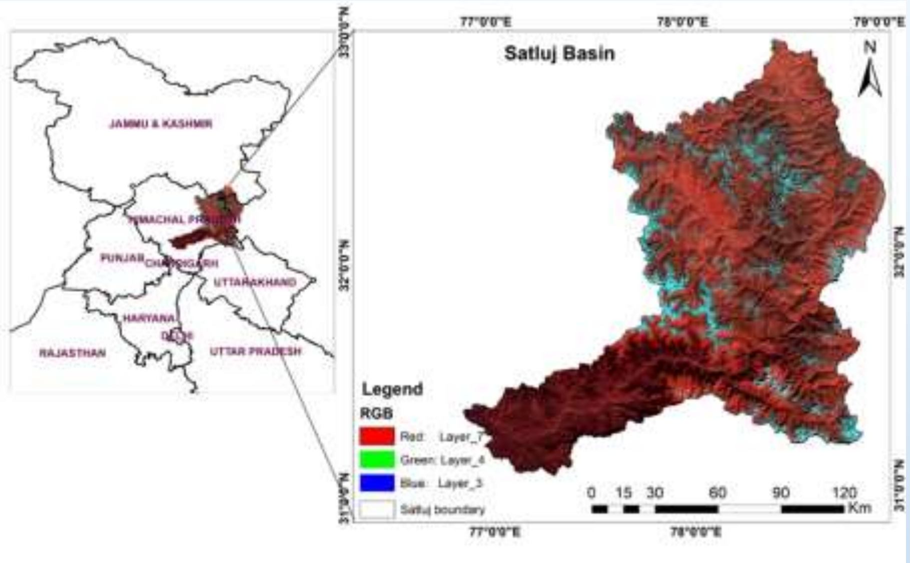


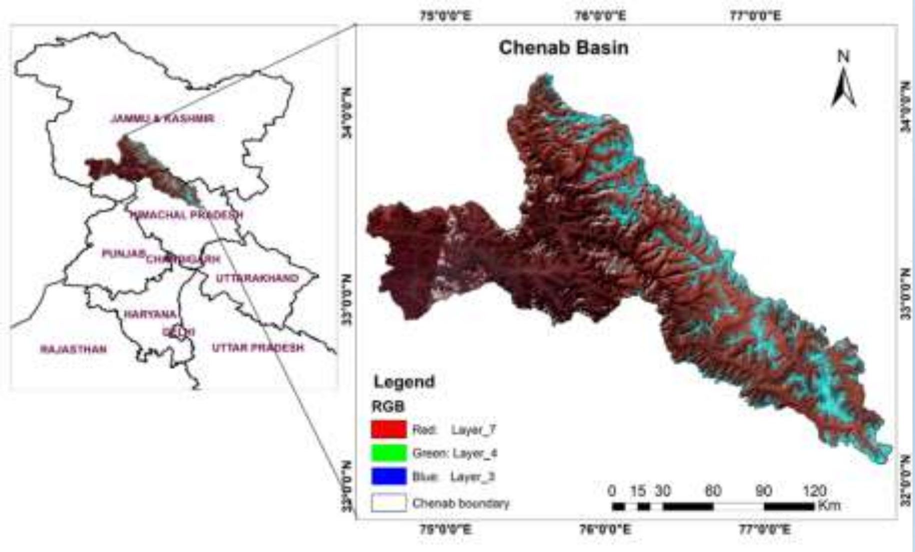


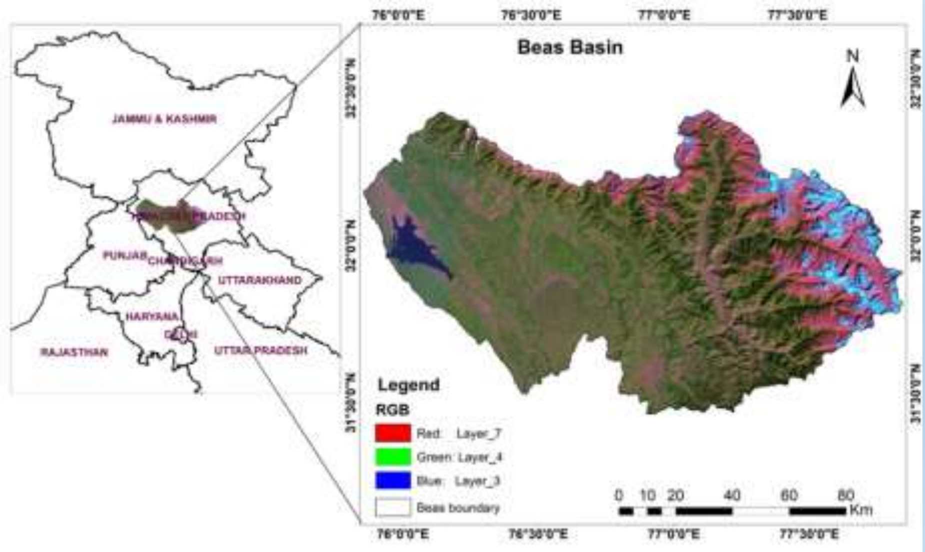


Glacier Change and Retreat



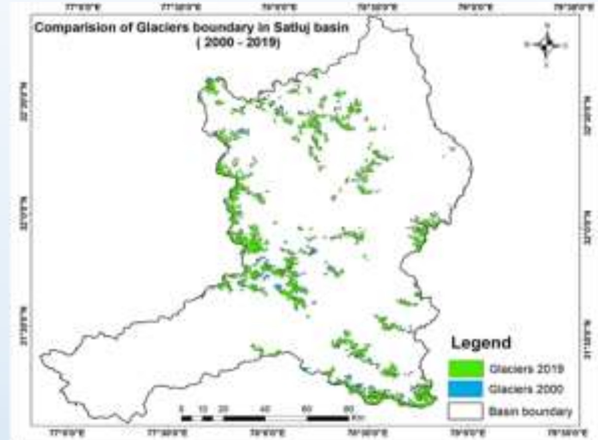




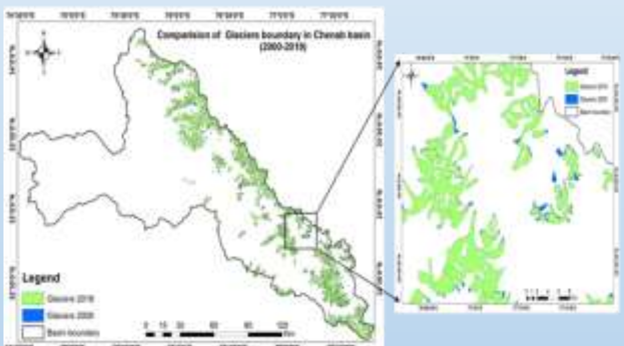


Identification of change in Glaciated areas

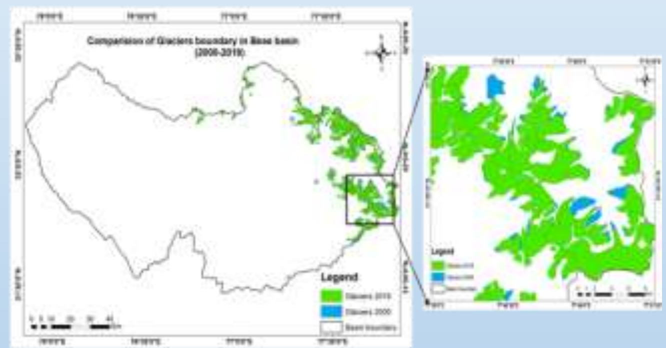
Upper Ganga basin



Satluj basin



Chenab basin



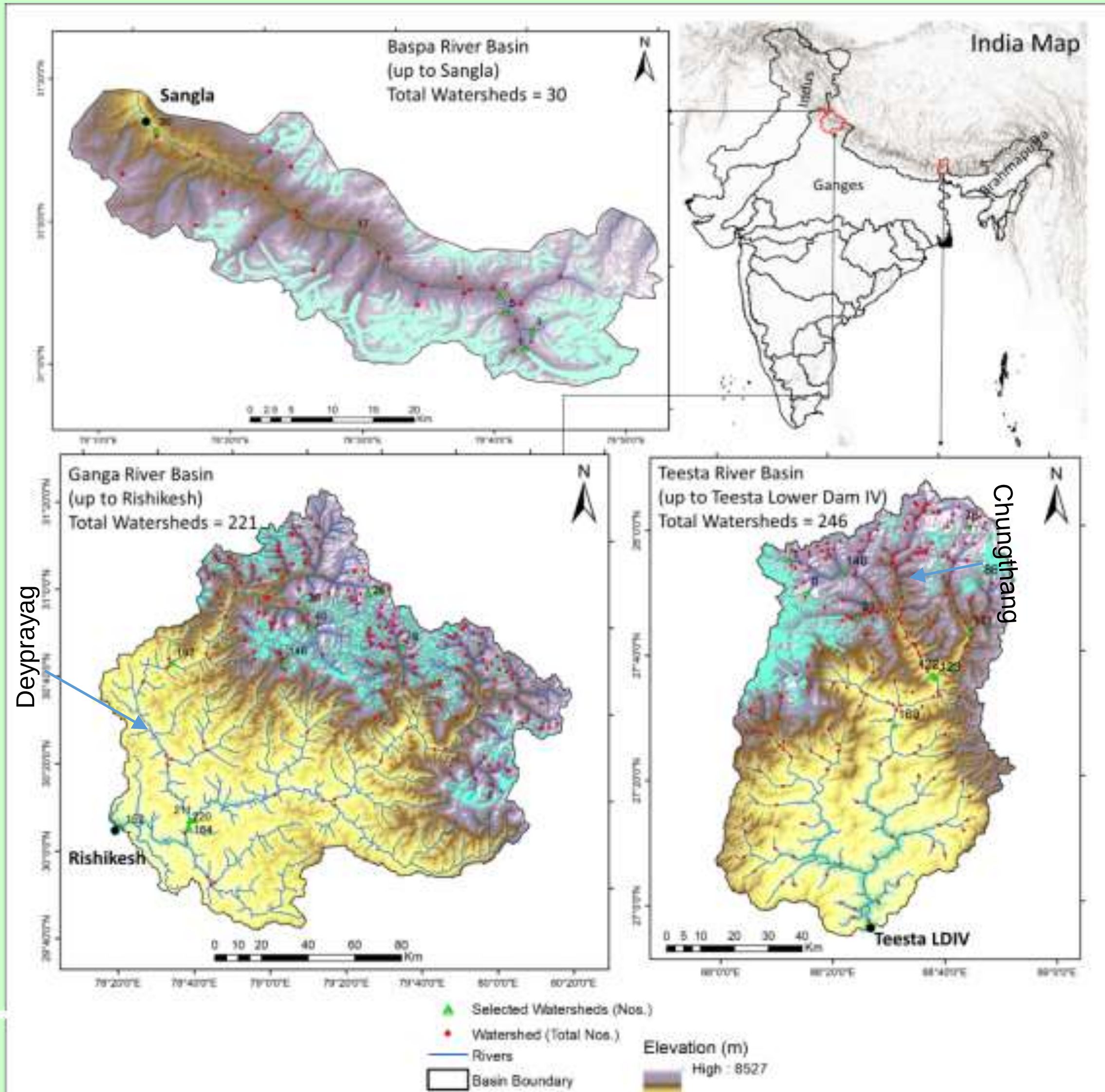
Beas basin

Year	UGB		Chenab basin		Satluj Basin		Beas Basin	
	No. of Glaciers	Area (sq. km)	No. of Glaciers	Area (sq. km)	No. of Glaciers	Area (sq. km)	No. of Glaciers	Area (sq. km)
2000	311	1918.4	403	2586	695	1263.15	218	649.505
2019	281	1756	395	2536	652	1163.45	208	628.192

Impacts of Glacier Change on the Runoff for three River Basins of Western & Eastern Himalayan Region

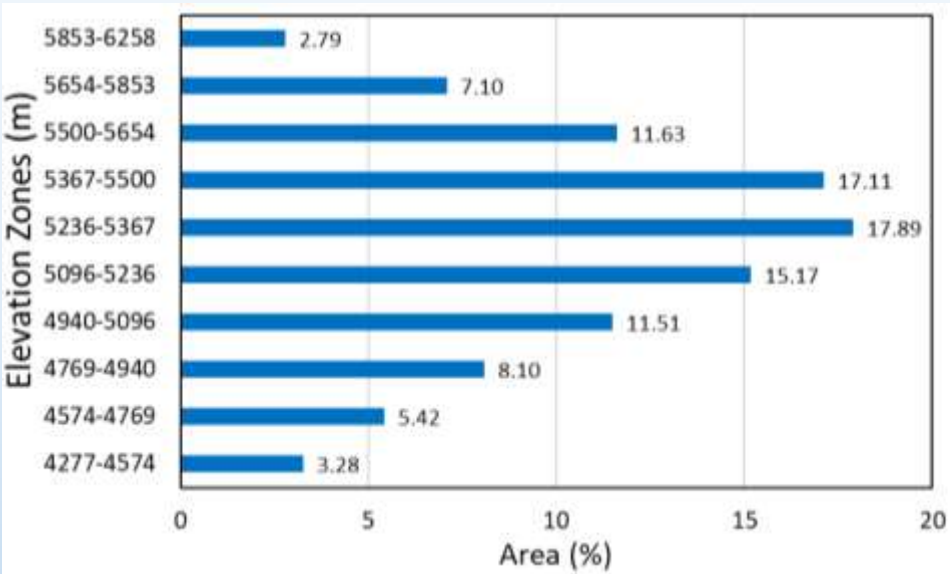
In the Himalayan region, the retreat of glaciers will have a large impact, as glaciers play an important role in river runoff

Characteristics	Baspa Basin	Upper Ganga Basin	Teesta River Basin
Study Area (Km2)	1100	21762	8132
Ele range (m)	6442-1742	7800-325	8022-142
No. of Glaciers	109	1536	398
Glacier Area (RGI)	230.74	1902.12	573.06
Glacier Area Years	221.17, 2000 176.96 2018	1890.94 2000 1875.15, 2010 1871.10, 2020	597.100 2000, 575.54 2020

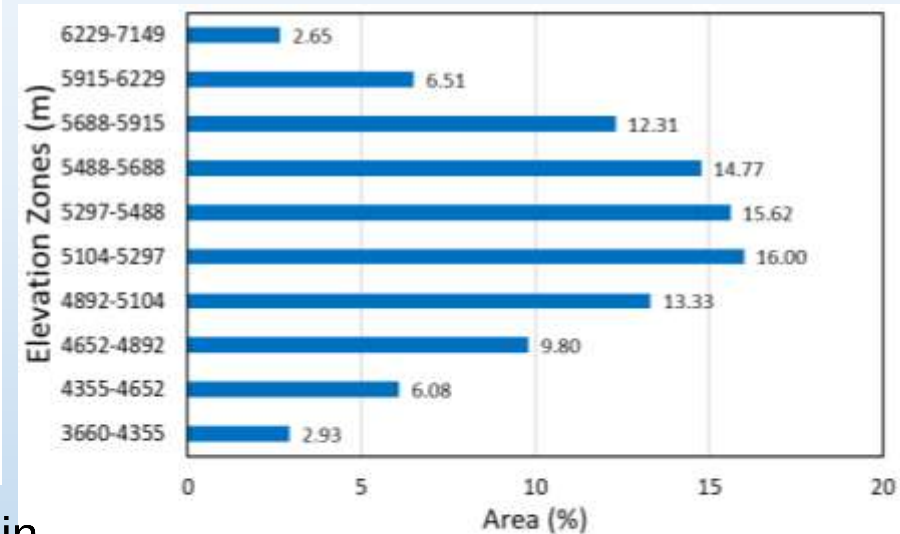


Glacier area and Elevation range of three River Basins of
Western & Eastern Himalayan Region

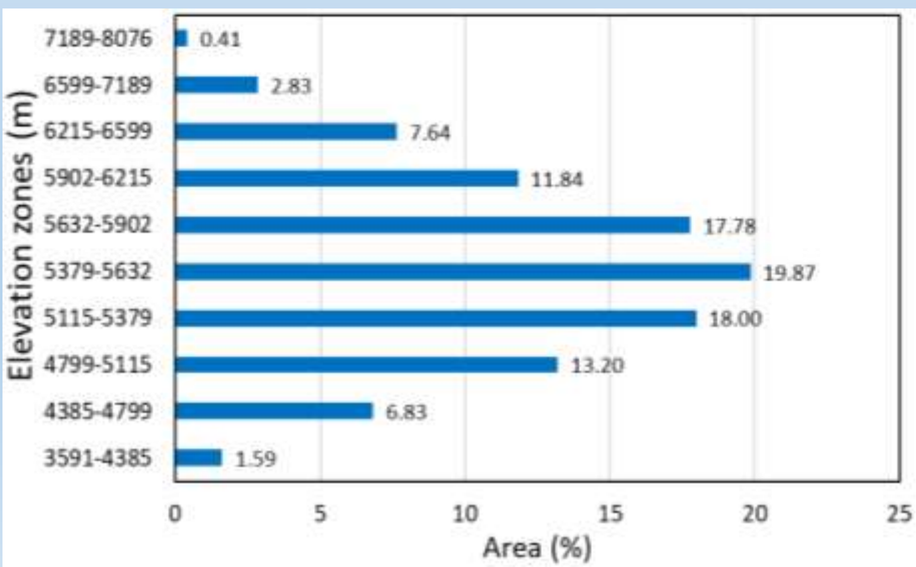
Baspa Basin



Ganga Basin



Teesta Basin



Snow and Glacier melt Runoff for three River Basins of Western & Eastern Himalayan Region

Baspa Basin

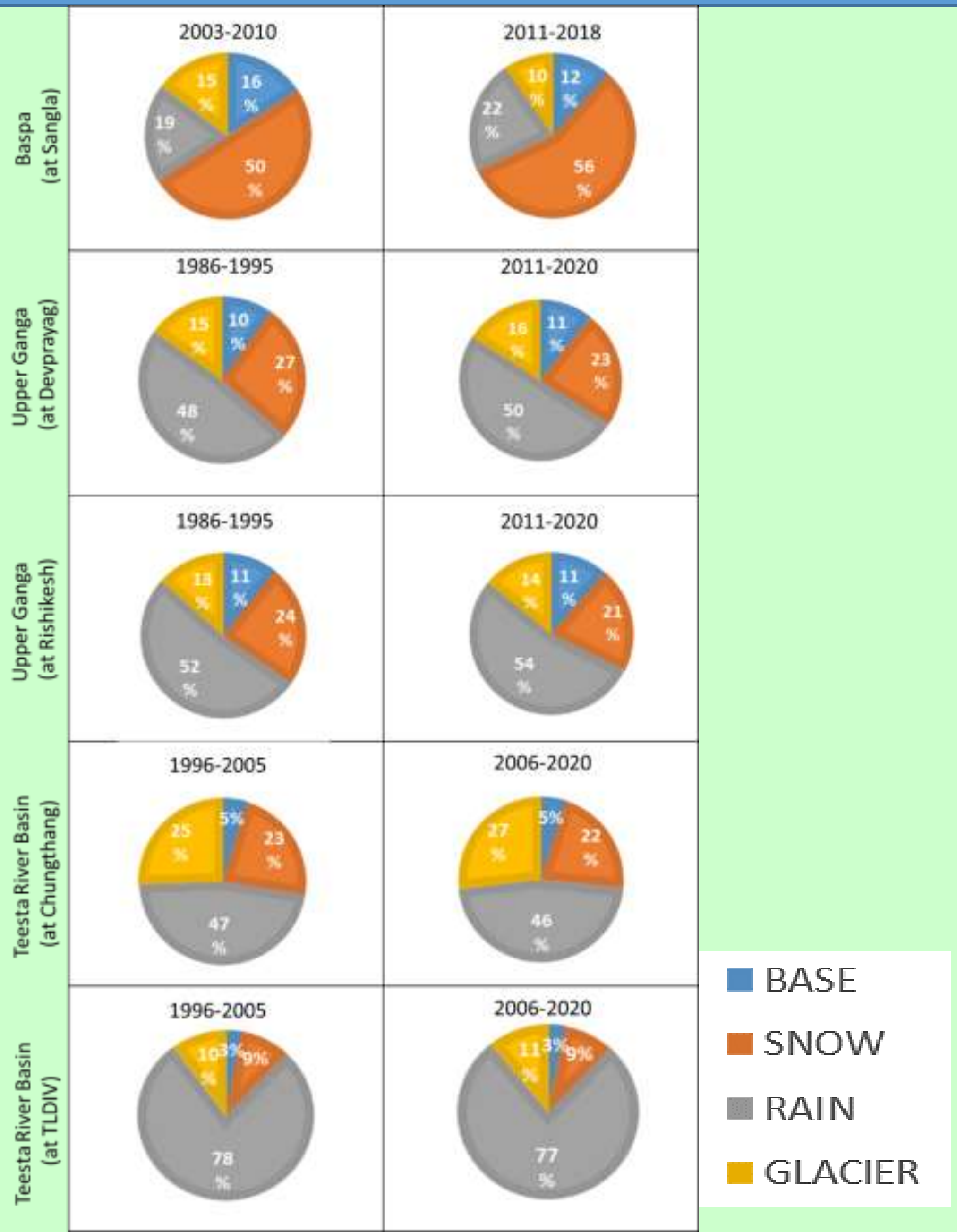
Glacier runoff 15% to 10%
Snowmelt runoff 50 to 56%

Ganga Basin
Upto Deyprayag
Glacier runoff 15% to 16%
Snowmelt runoff 27 to 23%

Upto Rishikesh
Glacier runoff 13% to 14%
Snowmelt runoff 24 to 21%

Teesta Basin
Upto Chungthang
Glacier runoff 25% to 27%
Snowmelt runoff 23% to 22%

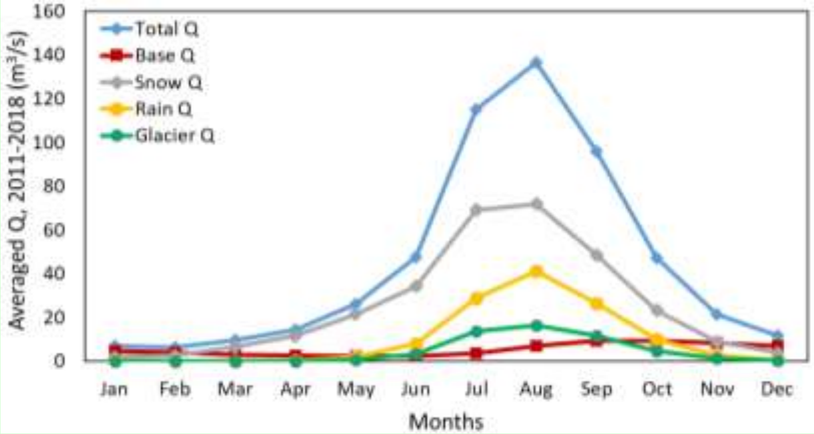
Upto TLD4
Glacier runoff 10% to 11%
Snowmelt runoff 09 to 09%



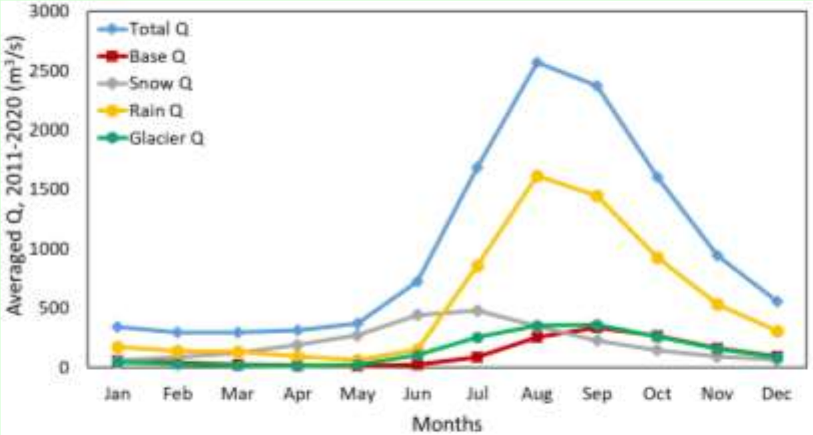
Impacts of Glacier Change on the Runoff for three River Basins of Western & Eastern Himalayan Region

As per AR6, the projected runoff is typically decreased by contributions from small glaciers because of glacier mass loss, while runoff from larger glaciers will generally increase with increasing global warming levels until their mass becomes depleted.

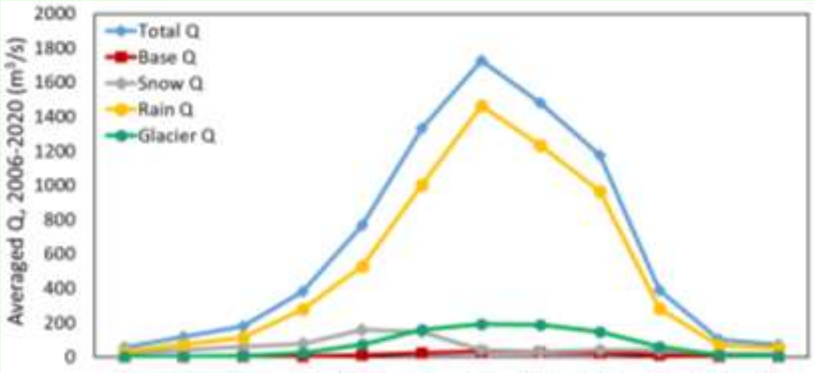
Baspa Basin



Ganga Basin



Teesta Basin

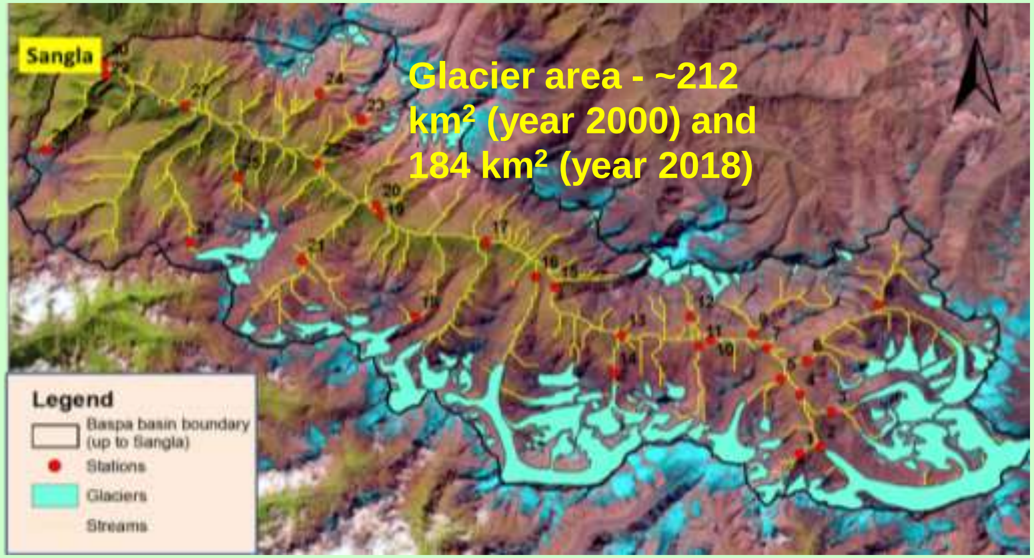


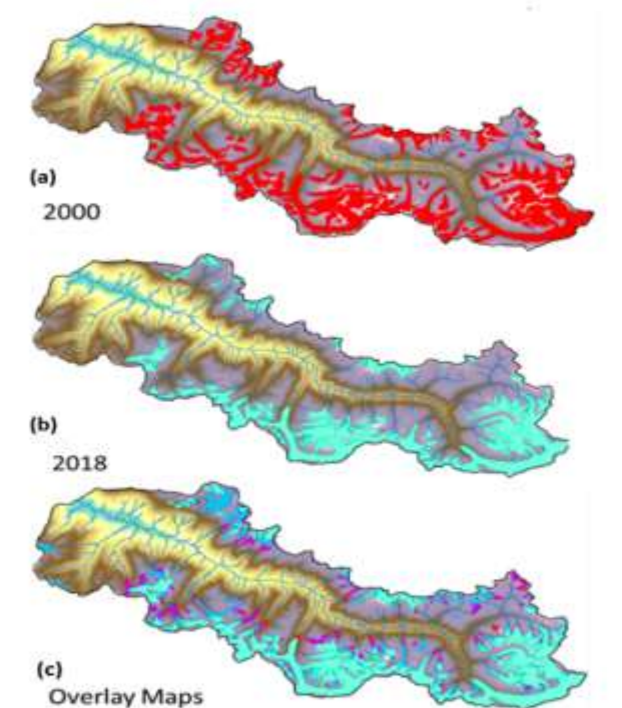
Impacts of Glacier Change on the Runoff for Baspa River Basin of Western Himalayan Region

Glacier & Non-glacier areas in Baspa

Study Area – 1100 km^2 , Elevations – 1800-6500 m

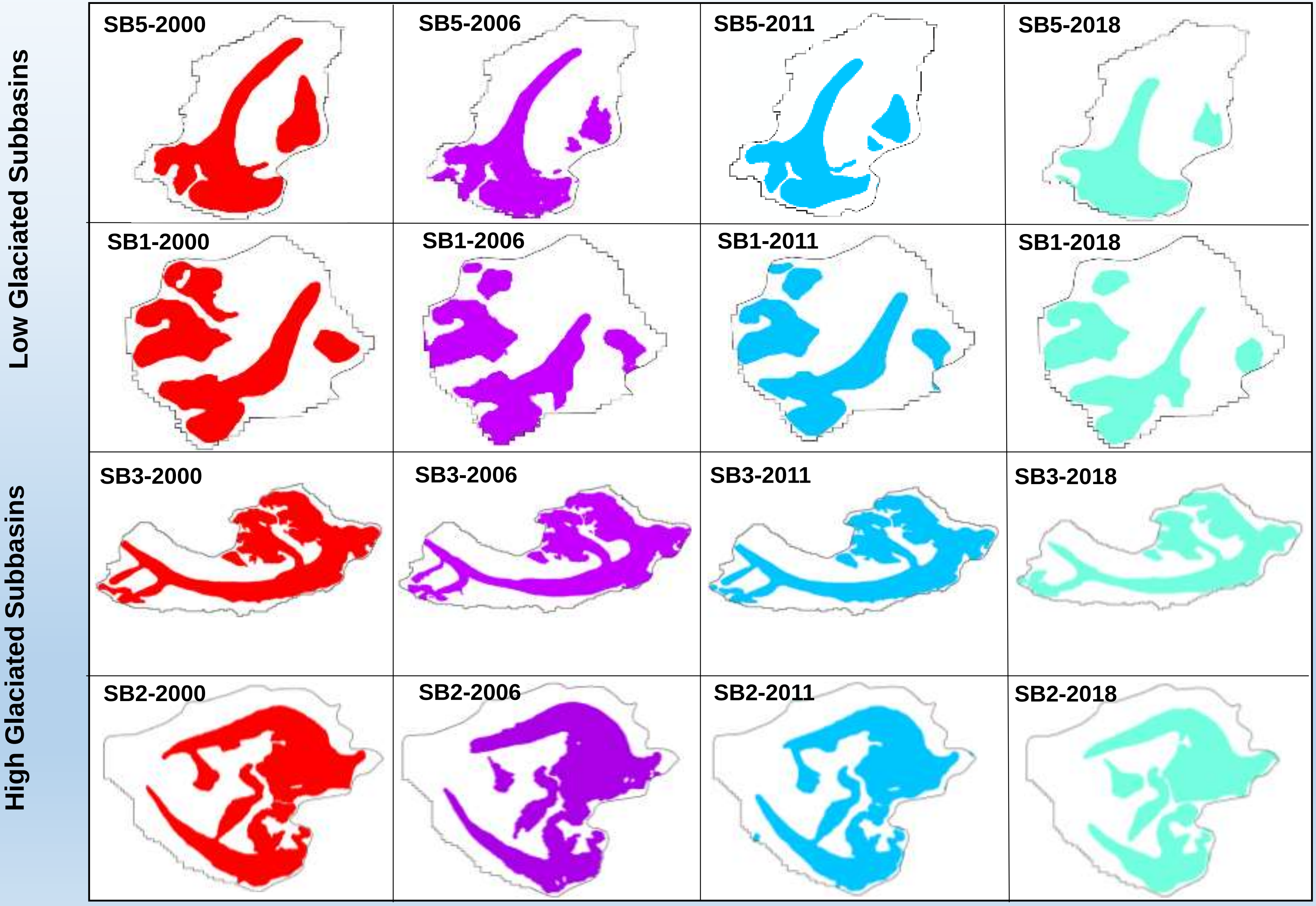
- Understanding of the local controls on the retreat of glaciers.
- Response of glacier is heterogeneous
- It is important because of hydropower projects in this basin



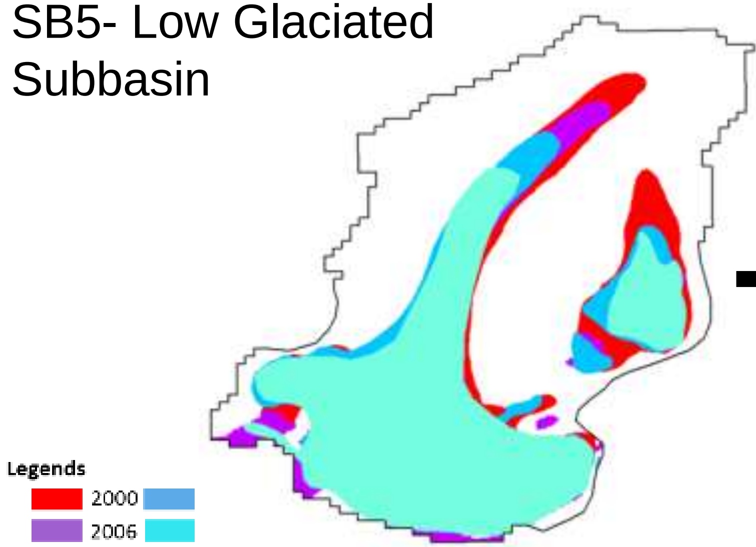


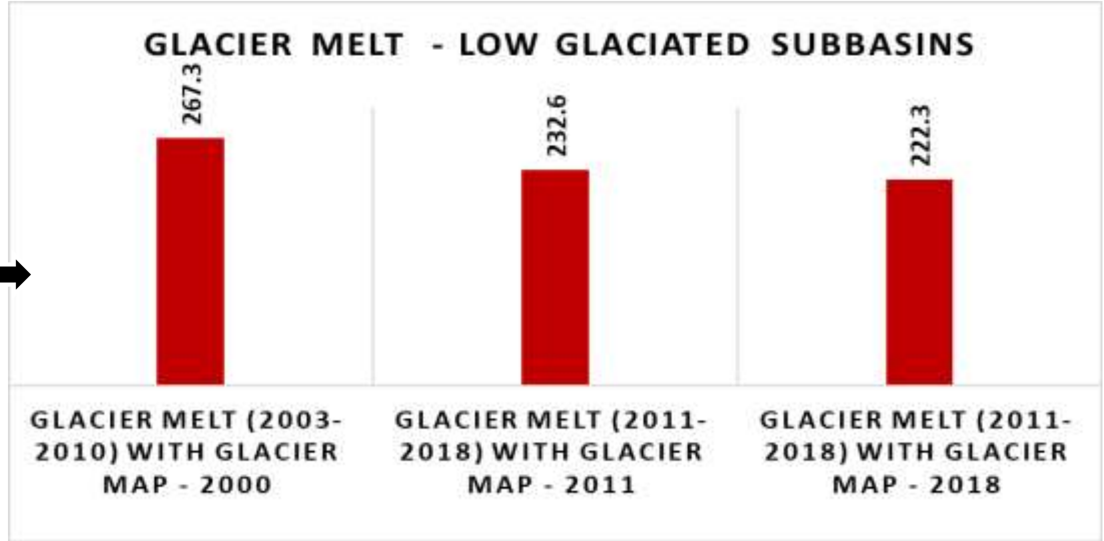
- **Glacier melt in glacier dominated watersheds is increasing while in other watersheds, it is reducing due to reduced glacier cover.**
- **The contribution from glacier melt runoff has been found to be reduced from 18 to 12% while snowmelt contribution increased from 58 to 64% from 2000 to 2018.**

Watersheds having different glacier cover

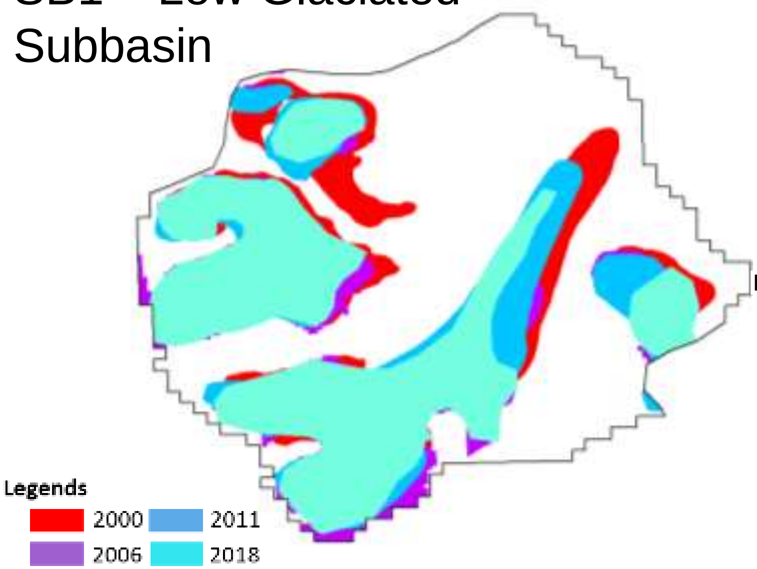


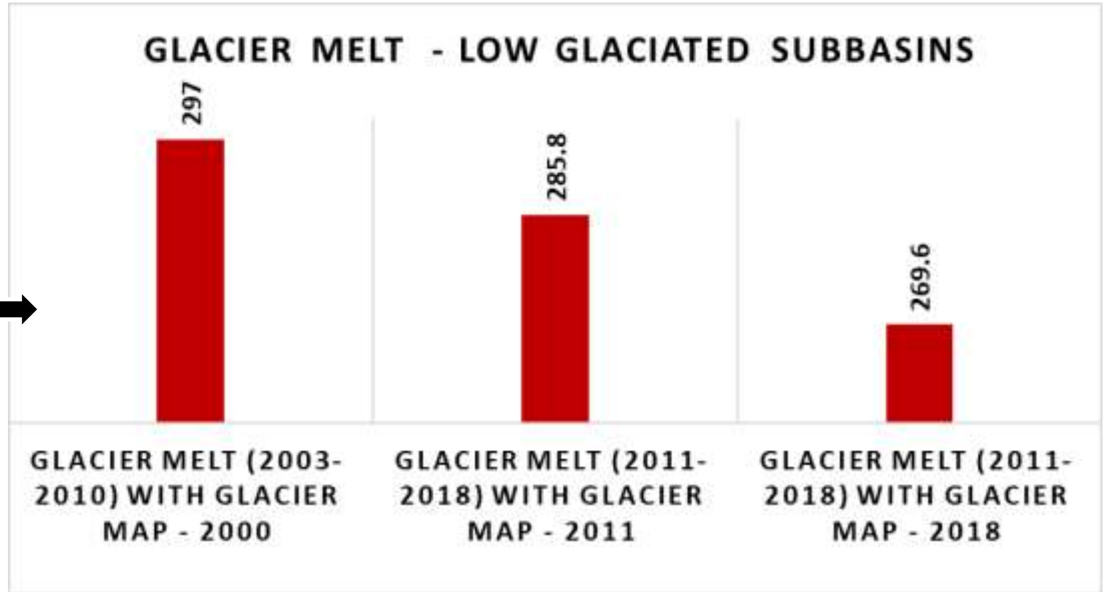
SB5- Low Glaciated Subbasin



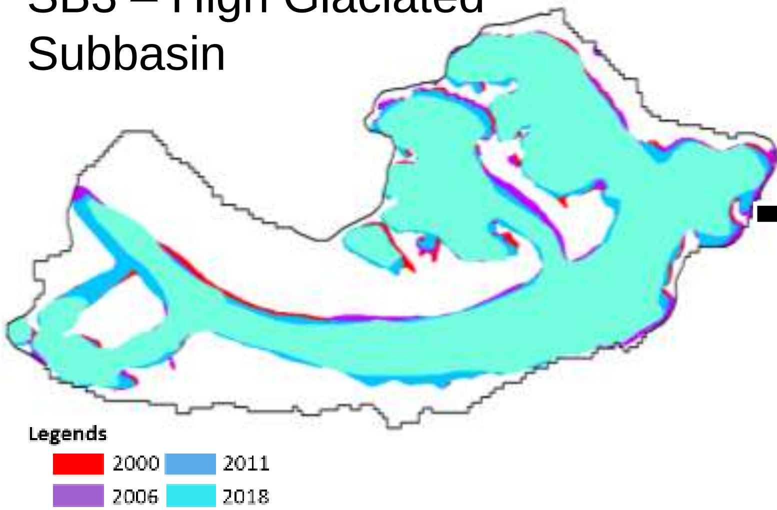


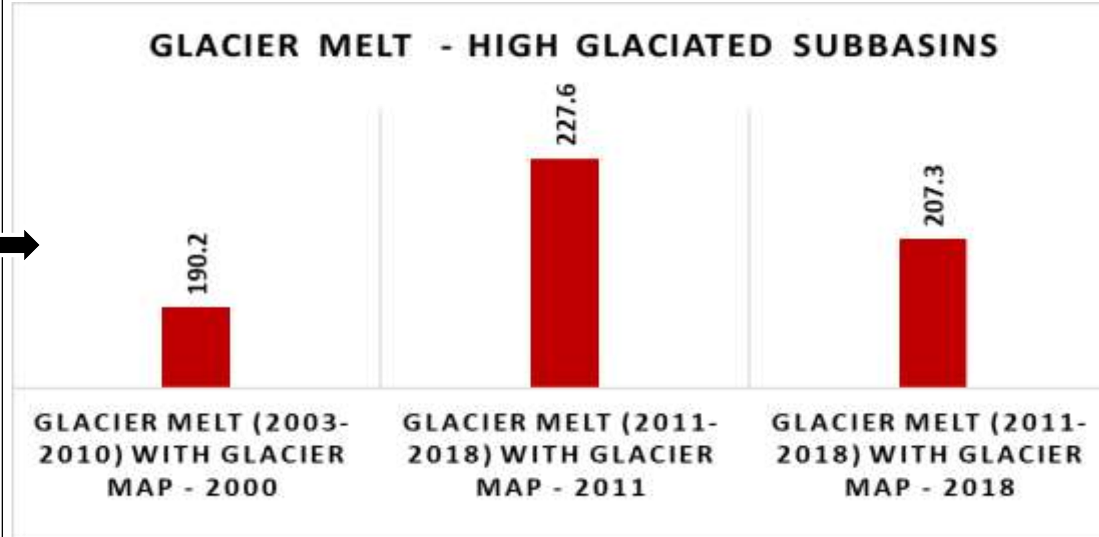
SB1 – Low Glaciated Subbasin



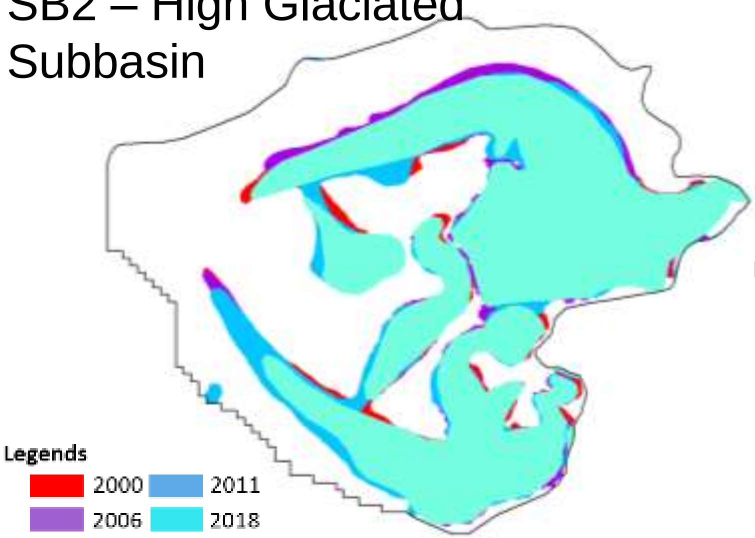


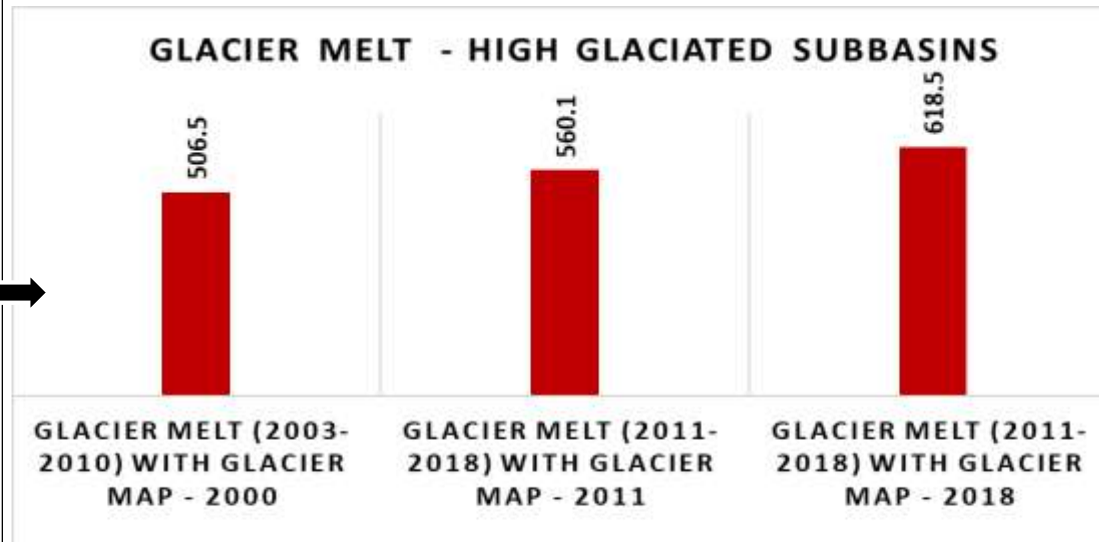
SB3 – High Glaciated Subbasin





SB2 – High Glaciated Subbasin





CHALLENGES

Assessment of Uncertainties in Projections

- The questions how to develop more reliable and regional scale projections so that they can be applied in hydrological modelling effectively.
- Uncertainty in future climate change presents a key challenge for adaptation planning.
- Customization of climate models for Indian conditions are required.

Managing for Climate Change Induced Migration

- In India, a very large populations live in the areas that are likely to get more floods and water stress.
- It may also lead to lower agriculture productivity therefore migration of people from these places is expected.
- In coastal areas also, due to coastal flooding, it is predicted that, by 2050, annual runoff in the Brahmaputra and Indus basins will decline substantially.
- In light of the dependence on agriculture for daily subsistence and livelihoods, more floods, landslides, droughts, and cyclones will increase vulnerability and lead to displacement.

CHALLENEGES

Management of Hydrological Extremes

- As the extreme events are going to be more frequent and intense, it will be necessary to develop and strengthen infrastructure (structural as well as non-structural for both, surface water and groundwater resources) to deal with increasing variability.

- We need to develop ways and means to store water made available during high flows to avoid damages and use it beneficially in dry periods.

- Regulation of urban development in flood-prone areas and flood plains.

- Preparation of Emergency Evacuation Plans (EAP) for the flood prone areas.

How to better manage water in the wake of climate change?

- A key is to understand the changing behavior of summer monsoon.
- LULC and climate triggered changes in weather and catchment response are going to be significant.
- Requires strengthening measurement networks.
- Require long-term climate change prediction at regional scale, and assessment of future water availability (with variability) and demands.
- Improved long-term weather forecasting at regional scale.
- Revision of procedures to estimate design floods for projects; consider GLOFs for Himalayan basins.

How to better manage water in the wake of climate change?

- Better sediment management in catchments, reservoirs and channels.
- Flood management by adopting all options: embankments, dams, forecasting, wetlands, ….
- Regulate development in floodplains and hills: Flood zone mapping and regulation.
- Consider entire ecosystem in water management - cities with wetlands, permeable surfaces, forests…
- Capacity building and governance.
- Build bridges with stakeholders and social systems.

How to better manage water in the wake of climate change?

- Consider non-stationarity of hydrologic data.
- Research on impacts of climate change on water quality in rivers and lakes, and treatment.
- Improve water and land productivity.
- Use every opportunity for water conservation at different scales for flood, drought and groundwater management.
- Revise performance norms to determine feasibility of projects.

How to better manage water in the wake of climate change?

Some of the studies requiring detailed scientific understanding of the causes and past trends behind climate change are:

- **To understand the impact of changing climate variables on crop water requirements and crop yields across various agro-climatic zones in the country.**
- **To understand the interaction between surface water and groundwater in different hydrogeological settings across the country and impact of climate change on such interaction. The outcome can be used to finalize sites for water harvesting and managed aquifer recharge to optimize groundwater resources.**
- **Specific studies to tackle urban flood management which have increased significantly in recent times.**
- **Further, there is need to tackle issue of encroachment and congestion of natural drainage.**
- **Assessment of Snow and glacier cover, their melt contribution and long-term impact of climate change on water contribution.**

CONCLUDING REMARKS

- **Effective and regular monitoring of data and web based information system**
- **Creation of additional storage and water transfer**
- **Rainwater harvesting and artificial recharge**
- **Adequate and effective regulation measures for water use allocation**
- **R&D Studies**
- **Integrated water resources planning, development and management**
- **The capacity building and awareness program**

THANKS