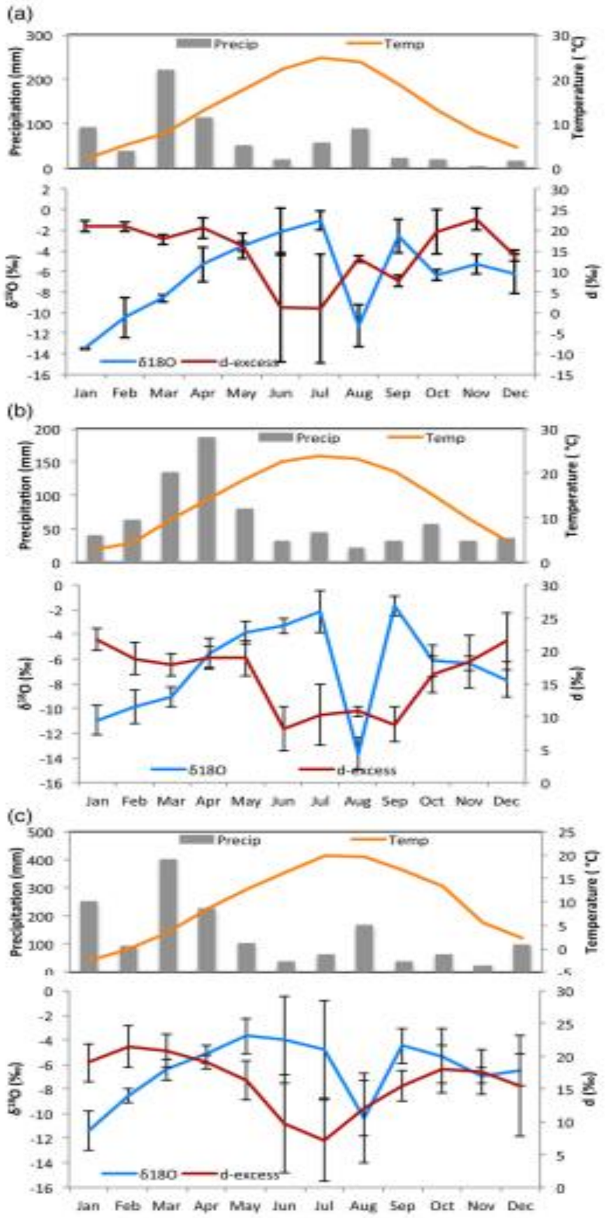
Upper Indus Basin Network

Country progress report

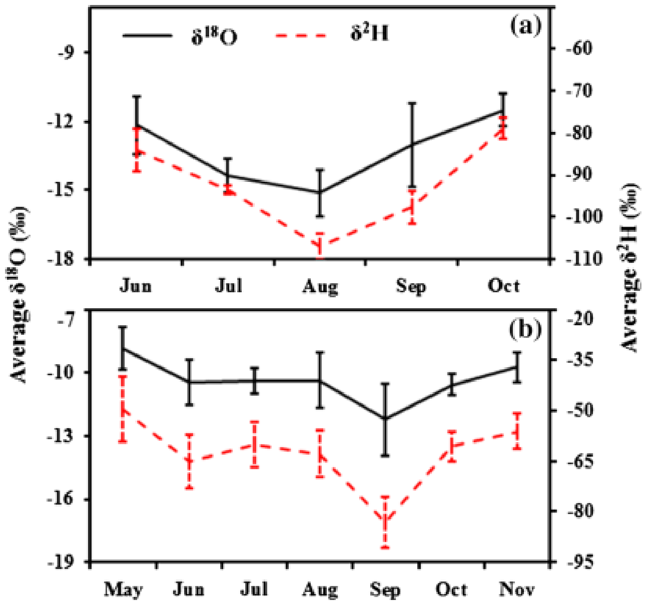
India

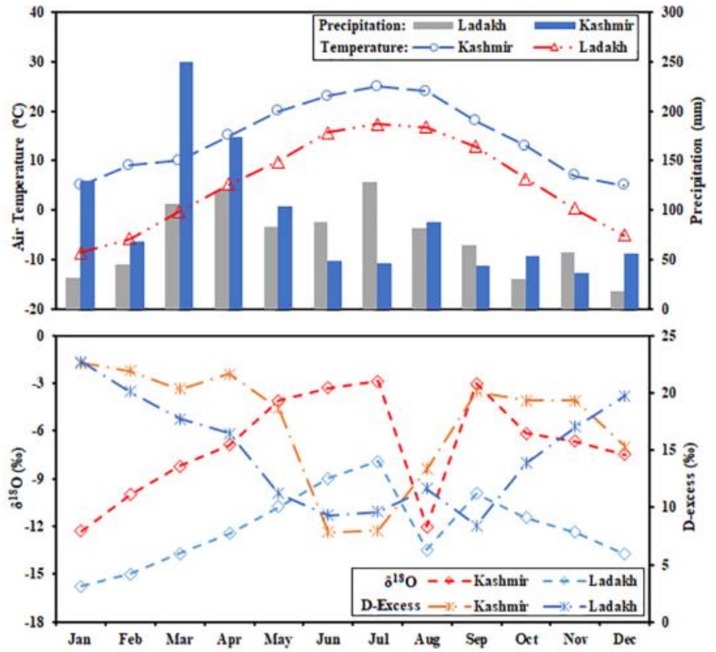
TWG1 : Framework of data collection, quality & standardization



1. MoES funded project "Groundwater security of Indus basin under climatic scenario" (Jeelani-PI)
2. NMHS funded project "Permafrost mapping and characterization in western Himalaya"(Jeelani-Co PI)
3. NIH, Roorkee funded Project "Snow/glacier cover (Jose-NIH)

✓ Variation of precipitation sources in Upper Indus River Basin from western disturbances and Indian Summer Monsoons and variation in glacier melt

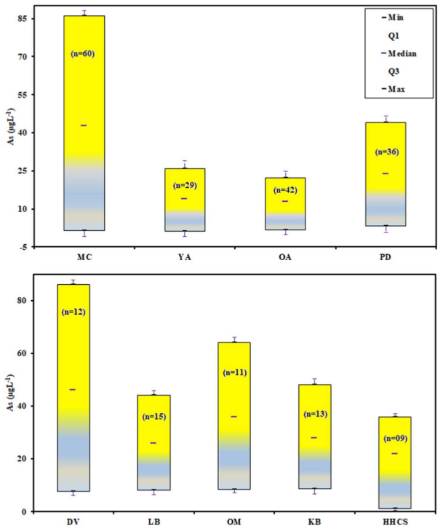




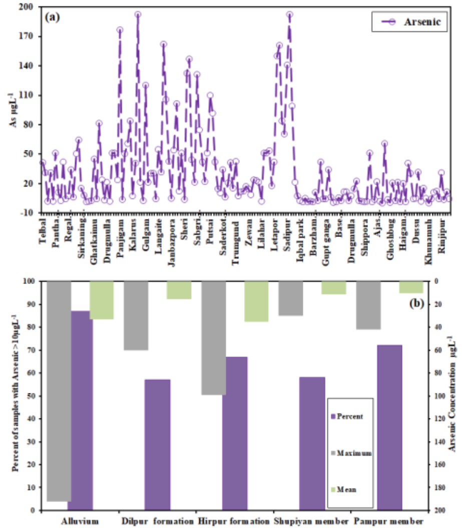
Jeelani et al.,2017 (JEHS)

Lone et al., 2017 (ATM RES)

Groundwater Quality –High Arsenic (As) in Ladakh & Kashmir

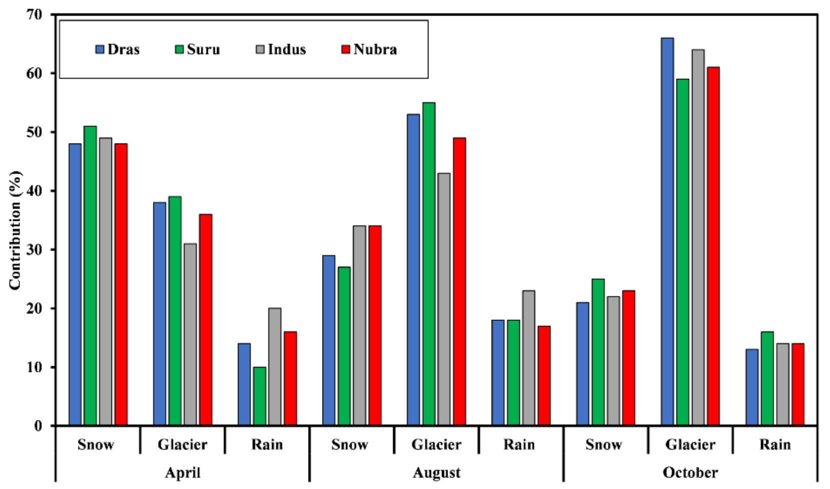


Lone et al., 2020 (AG)



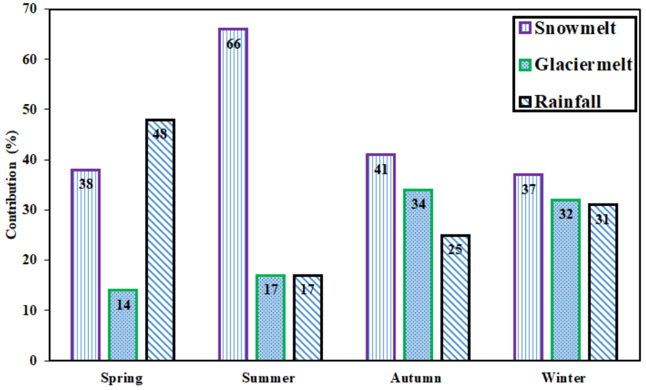
Jeelani et al.,2020 (JoH)

Contribution of melt water to groundwater in UIRB



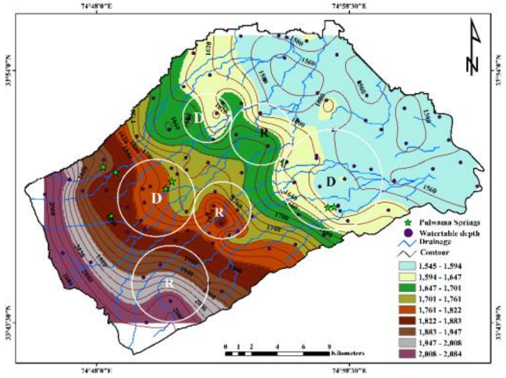
Lone et al., Under Review (STOTEN)

Contribution of melt water to groundwater in Jhelum basin



Lone et al., 2021 (HP)

Rejuvenation of Springs in Kashmir



Jeelani et al.,2021 (JGSD)

- ✓ Spring Rejuvenation
- ✓ Contribution of source waters to surface to water resources in UIRB, Ladakh………ongoing
- ✓ Isotopic characterization of permafrost …….on going

- Nonlinear recurrence quantification of the monsoon seasonal heavy rainy-days over northwest Himalaya: Status and future projections

  - Indian Summer Monsoon rainfall has characteristics of non-linear dynamical system, and the dynamical characteristics (such as predictability, determinism, etc.) of the nonlinear system are expected change under a warmer climate.

  - The modified state of ISMR is expected to impact the atmosphere-hydrosphere-cryosphere interactions of north-western Indian Himalayan region which has one of the highest concentrations of glaciers and snow covered area.

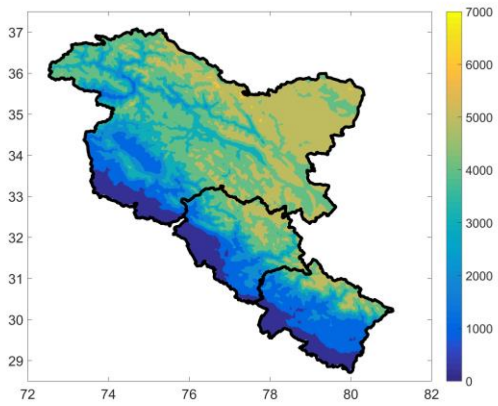
  - Hence, this study verifies the hypothesis that monsoon seasonal heavy rainy-day climatology over northwest Himalaya would exhibit certain degree of determinism for the baseline period (1970-2005), and expected to modify in its future state (2041-2099) due to warming.

  - Therefore, this study provides first time quantification of coherent structures and recurrences in the monsoon seasonal heavy rainy-day climatology using nonlinear time series analysis methods, particularly recurrence quantification analysis (RQA), for three administrative boundaries of the Indian Himalayan region, i.e. JKL, HP and UK.

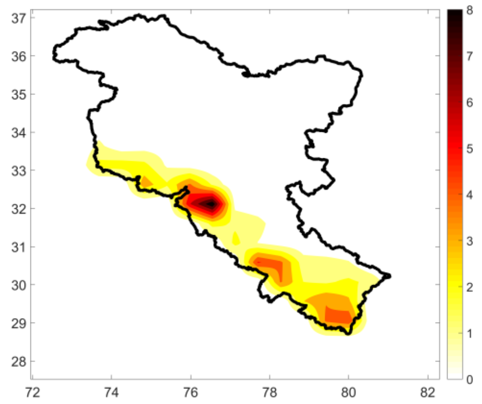
- Area averaged monsoon seasonal heavy rainy day (any day having rainfall > 35.5 mm) climatology were estimated for the baseline period (1970-2005) using APHRODITE (APHRO MA V1101R2) data over three administrative boundaries of the Indian Himalayan region, i.e. JKL, HP and UK.
- The future period (2041-2099) monsoon seasonal heavy rainy day climatology were estimated using CORDEX CSIRO-SA experiments for RCP 4.5 and 8.5 as follows:

Sl no.	Experiment	Short name	RCM description	GCM drivers	RCP
1	CSIRO-ACCESS-CCAM	ACCESS	Commonwealth Scientific and Industrial Research-Organization Conformal Cubic Atmospheric model (McGregor and Dix 2001)	ACCESS 1.0	4.5; 8.5
2	CSIRO-GFDL-CM3	GDLCM	Commonwealth Scientific and Industrial Research-Organization Conformal Cubic Atmospheric model (McGregor and Dix 2001)	GFDL-CM3	4.5; 8.5
3	CSIRO-NOREMS1	NorESM	Commonwealth Scientific and Industrial Research-Organization Conformal Cubic Atmospheric model (McGregor and Dix 2001)	NorESM-M	4.5; 8.5
4	CSIRO-CNRM-CM5	CNRM	Commonwealth Scientific and Industrial Research-Organization Conformal Cubic Atmospheric model (McGregor and Dix 2001)	CNRM-CM5	4.5; 8.5
5	MPI-EMS-LR-CSIRO	MPI	Commonwealth Scientific and Industrial Research-Organization Conformal Cubic Atmospheric model (McGregor and Dix 2001)	MPI-ESM-LR	4.5; 8.5

The CORDEX CSIRO-SA products were 'Delta' bias corrected for baseline and future periods and non-linear recurrences quantified.

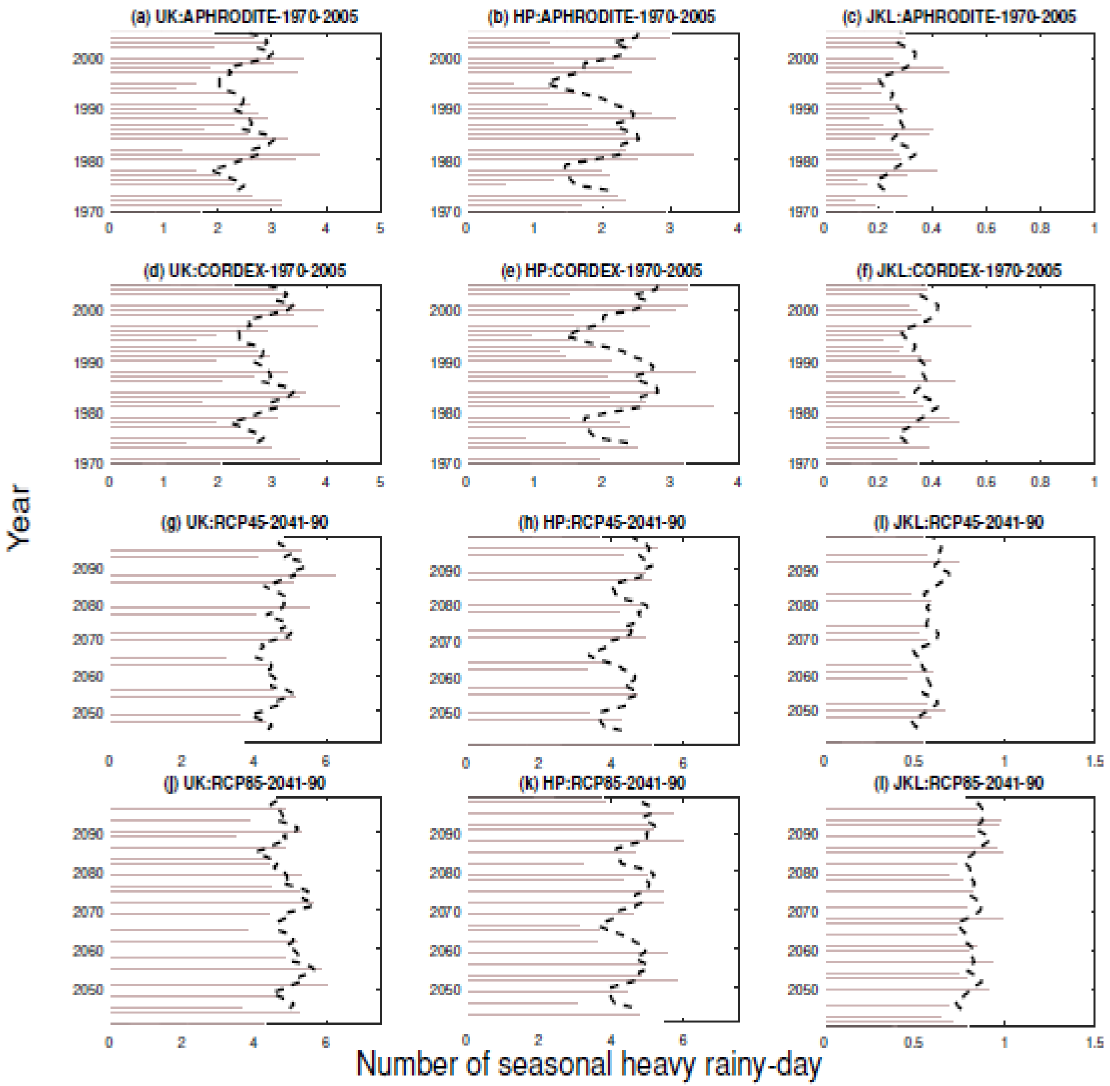


(a) Administrative boundaries of north-western Himalayan states



(b) APHRODITE: Heavy rainy day climatology (1970 - 2005)

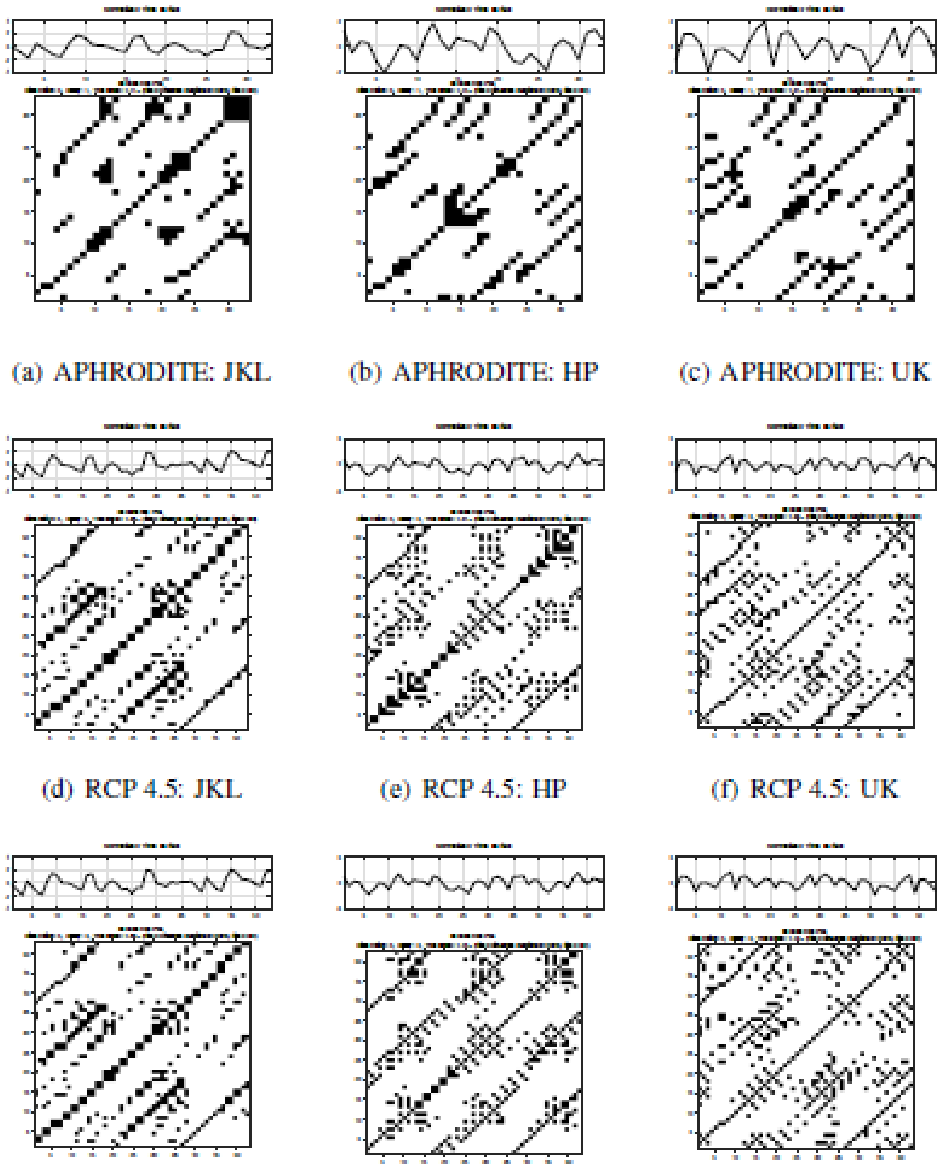
Results



- The average numbers of heavy rainy-day in a monsoon season over JKL, HP, and UK were noted to be 0.27 (0:09), 2.05 (0:73), 2.48 (0:72), respectively, during 1970-2005.
- The average heavy rainy-day climatologies, as obtained from the bias corrected ensemble CORDEX products, under RCP 4.5 over JKL, HP, and UK were noted to be 0.58 (0.09), 4.39 (0.73), and 4.65 (0.74), respectively.
- The same for RCP 8.5 were noted to be 0.82 (0.09), 4.60 (0.72), and 4.93 (0.75), respectively, indicating **an enhancement in the heavy rainy-day under warmer climate.**
- The monsoon heavy rainy-day climatology of 1970-2005 is noted to have an **average correlation dimension of 1.5, indicating fractal geometry of heavy rainy-day climatology,** which is not expected to change much under a warmer climate.

Results

Recurrence Plots as obtained from RQA



(a) APHRODITE: JKL (b) APHRODITE: HP (c) APHRODITE: UK

(d) RCP 4.5: JKL (e) RCP 4.5: HP (f) RCP 4.5: UK

(g) RCP 8.5: JKL (h) RCP 8.5: HP (i) RCP 8.5: UK

- The general signature of a deterministic nonlinear dynamical chaotic attractor is the diagonal lines parallel to the *Line of Identity*. As there are significant number of diagonals in recurrence plots of JKL, HP, and UK, it can be inferred that the **heavy rainy-day climatologies of study areas were governed by nonlinear deterministic systems.**
- The monsoon heavy rainy-day climatology of 1970-2005 has a **higher degree of determinism over HP**, whereas the **mean prediction time of the non-linear dynamical trajectories** controlling heavy rainy-day climatology is **higher over UK**.
- The monsoon heavy rainy-day climatology is expected to be **more fluctuating under the warmer climates of RCP 4.5 and 8.5 during 2041-2099**.
- The RQA patterns of monsoon heavy rainy-day climatology under the warmer climates of RCP 4.5 and 8.5 during 2041-2099 over **UK and JKL indicate gradual reduction in the deterministic structures in the phase space over these regions**.

Interim Conclusion

- This study provides first time quantification of coherent structures and recurrences in the monsoon seasonal heavy rainy-day climatology using nonlinear time series analysis methods, particularly RQA, for three administrative boundaries of the Indian Himalayan region, i.e. JKL, HP and UK.

- This study verifies that the monsoon seasonal heavy rainy-day climatology exhibited certain degree of determinism during baseline period of 1970-2005.

- Further, the non-liner dynamical system is expected to lose determinism over certain regions of northwestern Himalaya under warmer climates of RCP 4.5 and 8.5 leading to lesser predictability.

TWG2 : Climate Change over Indus basin in CMIP6 Model Simulations: Ashwini Kulkarni

Models simulations : Bias corrected high resolution (0.25 x 0.25 lon/lat)

-13 CMIP6 models (1995-2100)

Observed data : For model validation APHRODITE (1995-2014)

Variables : Daily Precipitation, Maximum and Minimum Temperature

Models

ACCESS-CM2
ACCESS-ESM1-5
BCC-CSM2-MR
CanESM5
EC-Earth3
EC-Earth3-Veg
INM-CM4-8
INM-CM5-0
MPI-ESM1-2-HR
MPI-ESM1-2-LR
MRI-ESM2-0
NorESM2-LM
NorESM2-MM

Scenarios

SSP245; SSP585

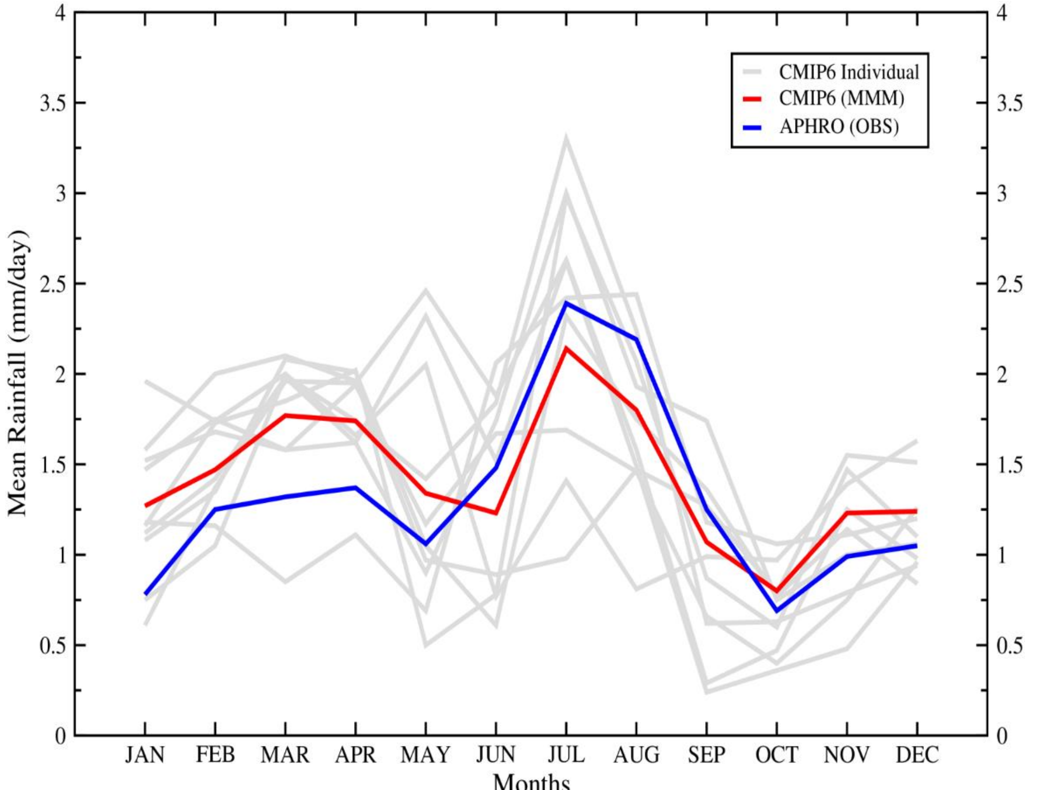
Time epochs

2030s : 2021-2040

2060s : 2051-2070

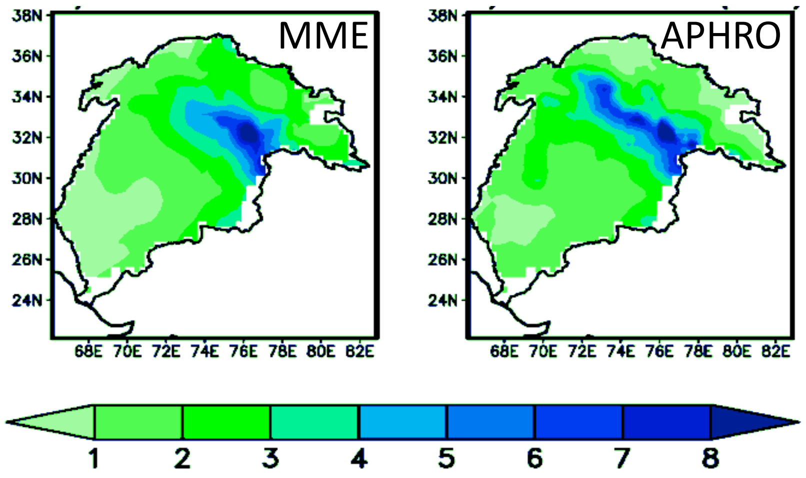
2090s : 2081-2100

Annual cycle of rainfall over Indus basin

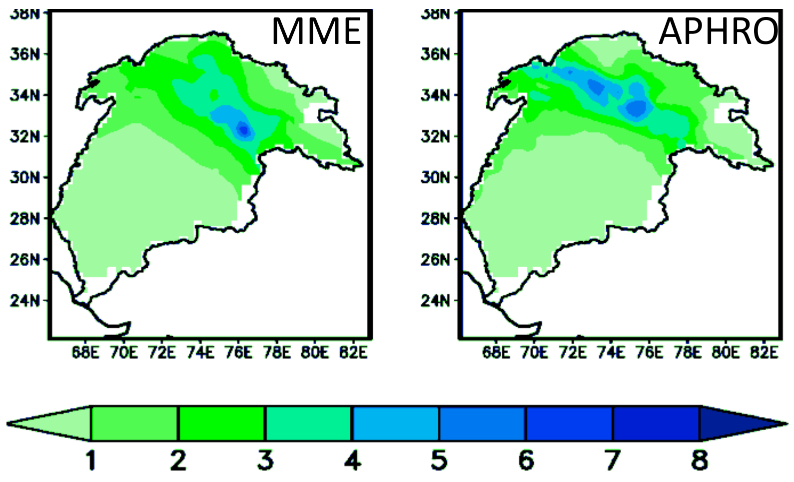


Mean precipitation (mm/day)multi model ensemble simulation compared with observed1995-2014

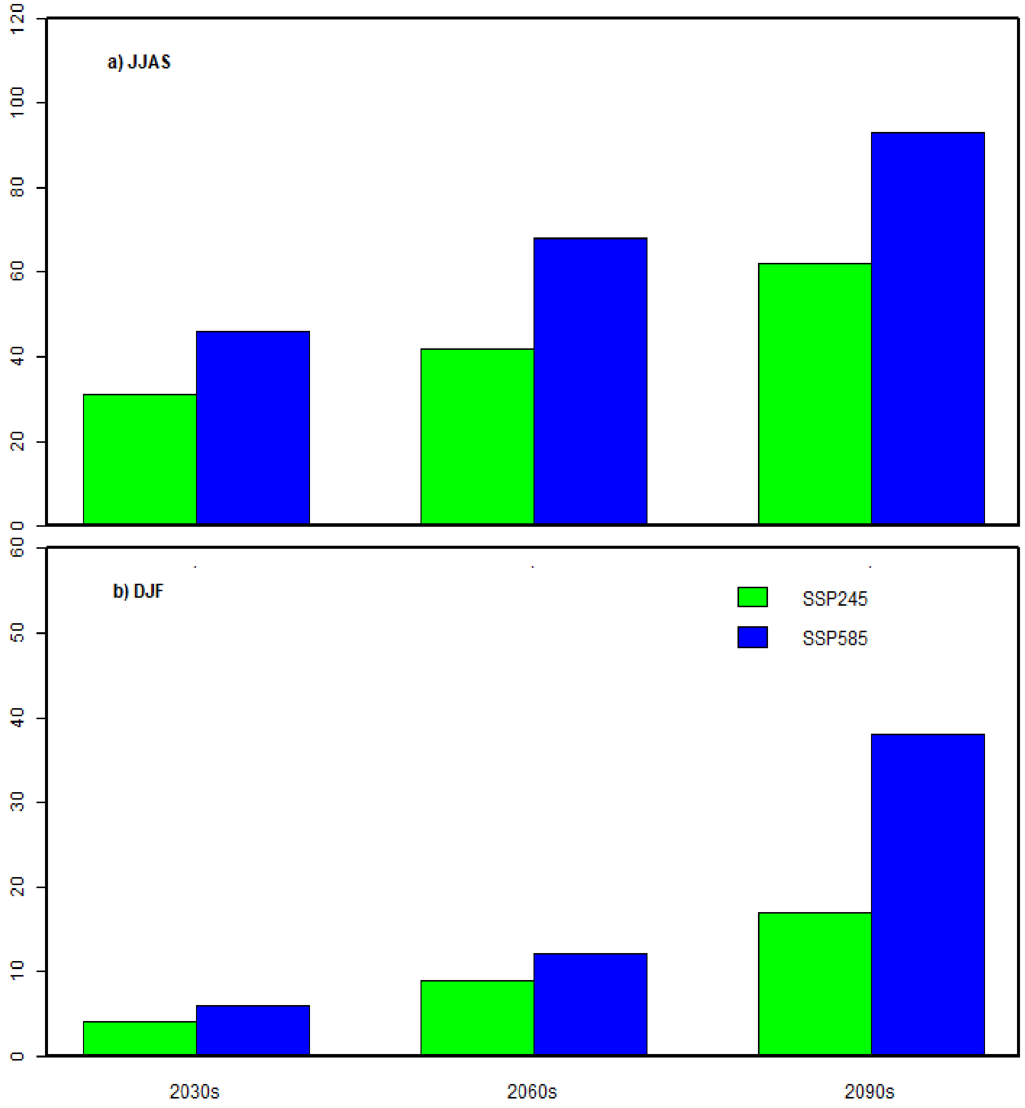
JJAS



DJF



Precipitation change (%) wrt 1995-2014



Air Quality Monitoring for Srinagar City (Lone et al, SKUAST-K)

- Concentrations of various pollutants on monthly basis showed that the lowest concentration of PM_1 was recorded in the month of April at Shalimar-SKUAST (15.10 µg/m^3).

- In case of $PM_{2.5}$ and PM_4, concentrations were found to be lowest at Shalimar-SKUAST (28.70 µg/m^3 and 44.50 µg/m^3 respectively) during April and the highest average concentrations at Dalgate (577.50 µg/m^3 and 780.87 µg/m^3, respectively) in December.

- Concentrations of PM_{10} and TSP were found to be at the minimum average for Shalimar (57.13 µg/m^3 and 77.7 µg/m^3 respectively) during the month of April and the maximum average value was recorded at Jehangir Chowk (1225.53 µg/m^3) 1410.27µg/m^3 respectively) in December.

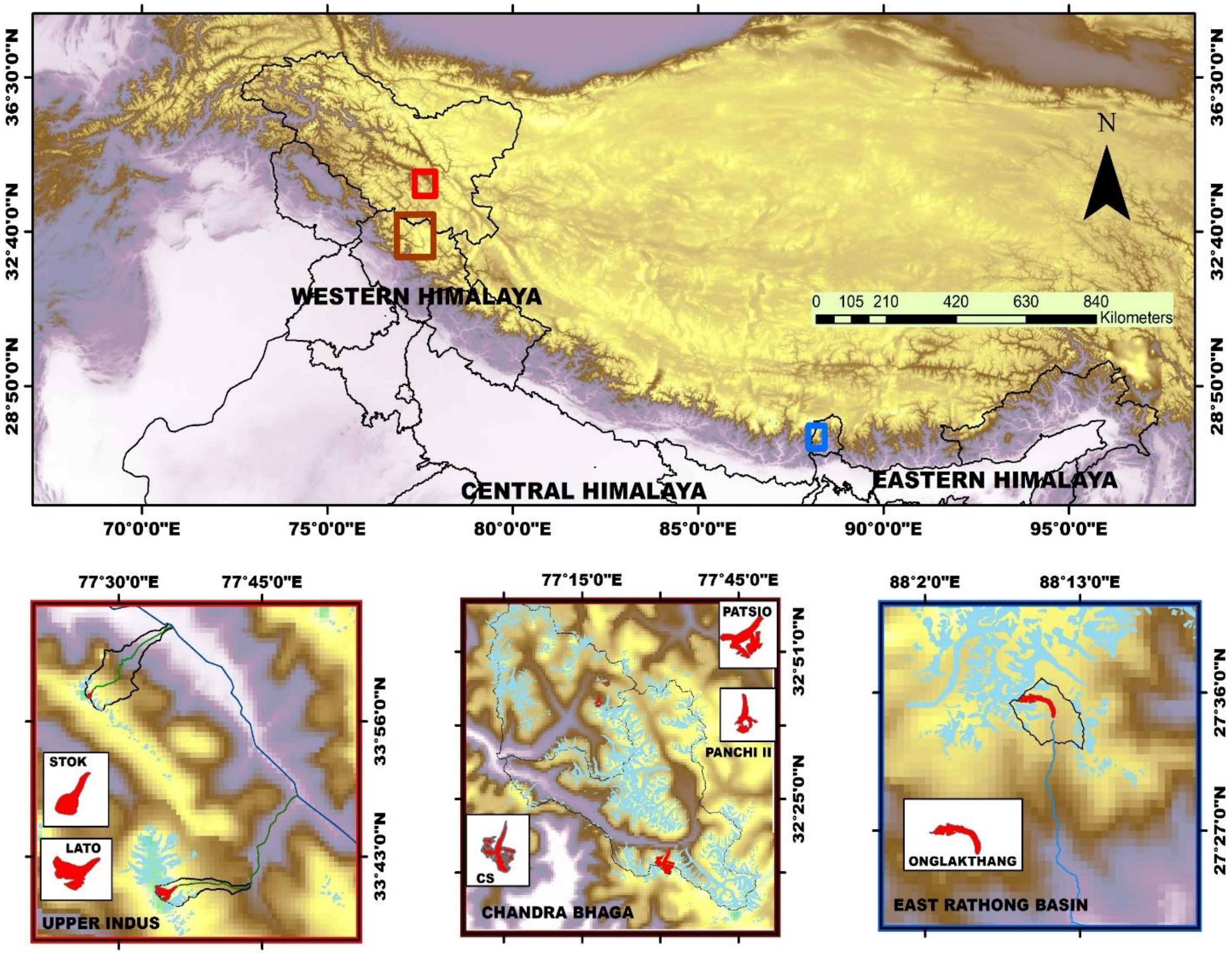
- CO_2 readings were at a minimum average of 332.43 ppm in July at Shalimar-SKUAST and the maximum average of 637.57 ppm during December which is due to the biomass burning in the fields.
- On Seasonal basis, Srinagar city had the pollutant concentrations low during the Spring season and highest during the Winter season.

- The lowest readings in the month of April 2020 for different locations were due to the Covid Pandemic lockdown with negligible transport and industrial activity.

TWG3 : Status of Cryosphere research and Future outlook : R Thayyen

Research Areas	Status	Gaps
Glacier Research	• NIH, JNU (Ladakh, Sutlej) • NCPOR (Chenab) • Wadia (Zanskar) • Kashmir univ (Kashmir/Drass) • SASE (Karakorum/ H.P) Focusing on small/medium sized glaciers.	• Studies on big glaciers • Climate forcing/dynamics of arid regimes • Improvement in Glacier inventory and volume estimation.
Snow cover	• NIH • Kashmir University • IIRS	• Snow amount in glacier elevations and MB controls • Orographic controls on snow distribution • Snow cover duration change, water/ permafrost • Albedo feedback and implications
Permafrost	• NIH, JNU, GBPINE, Kashmir Univ (Ladakh) • IIRS (Ladakh/ H.P)	• Extend and characteristics across UIB areas • Water/ disaster/ Water quality/ Micro-climate Linkages

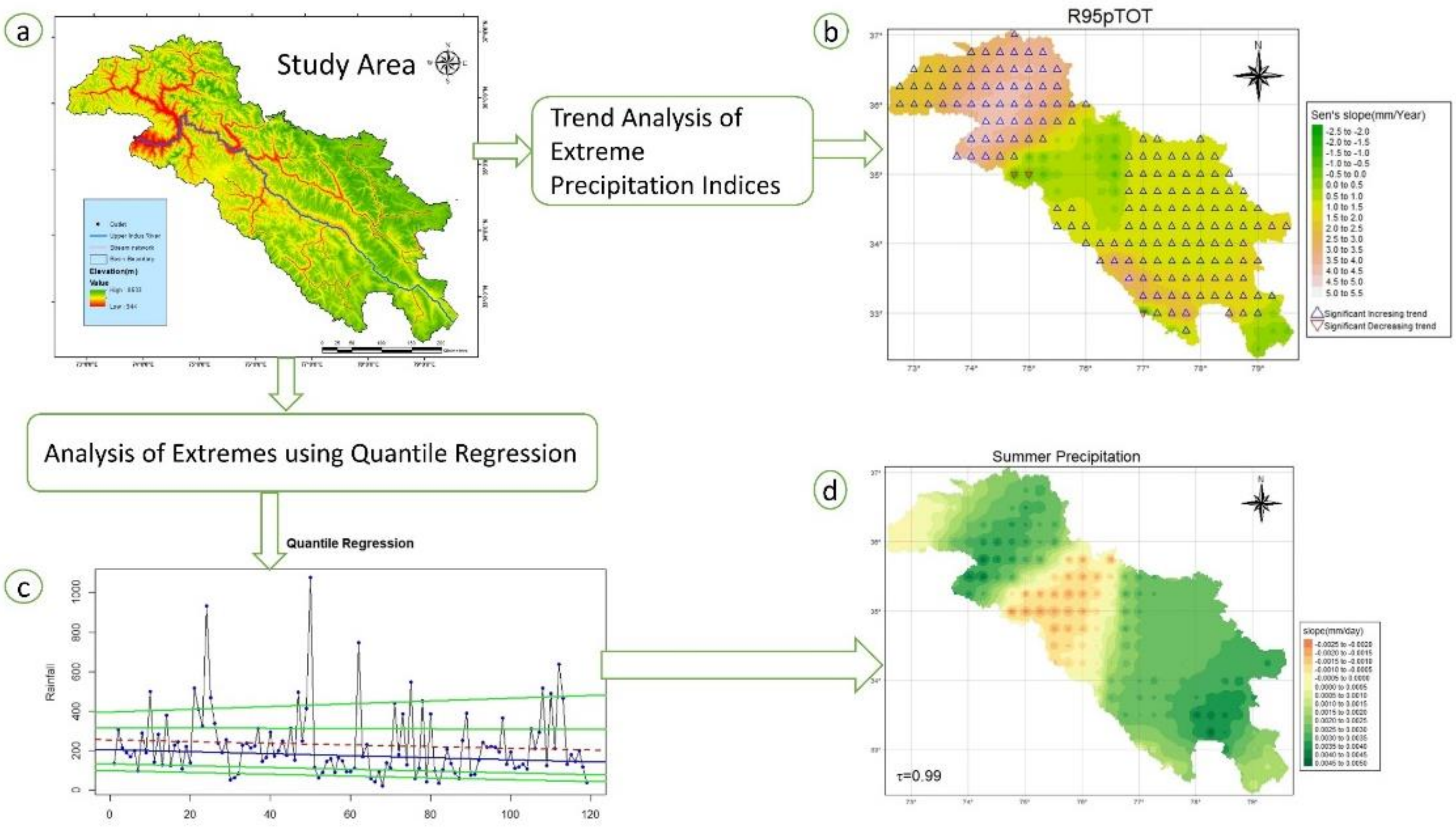
Glacier monitoring network in the Himalayas : Al. Ramanathan



- Intention: large ground-based network is to develop a robust-reliable dataset in the Himalaya, MB data available for 4-14yrs in these glaciers. This will reduce the uncertain estimates/computation of glacier change over complex topography
- In Chhota Shigri and Stok, it was observed that glaciers are quite more sensitive to year-to-year temperature variation with a sub-equal role of precipitation change.
- Overall results show that, in 2000s decade glaciers mass was significantly higher than the 2010s decade. This is based on three field-based studies and other available remotely sensed estimates

TWG4: Analysis of Precipitation Extremes *(DS Arya, AK Pandey)*

- Fig. (a) Calculation of ETCCD Indices of Precipitation (Rx1Day,Rx5Day,CDD,CWD, SDII,PRCPTOT,R10mm,R20mm,R95pTOT,R99pTOT) using IMD data with a spatial resolution of 0.25^{0} for 1901-2019.
- Fig. (b) Trends analysis using Sen's slope variation with significant locations of the index R95pTOT



- Fig. (c) Trend analysis of precipitation extremes(Daily and Monthly scale) shows the illustration of quantile regression method and
- Fig. (d) shows the spatial variation of trend in precipitation above 99th percentile quantile in summer season.

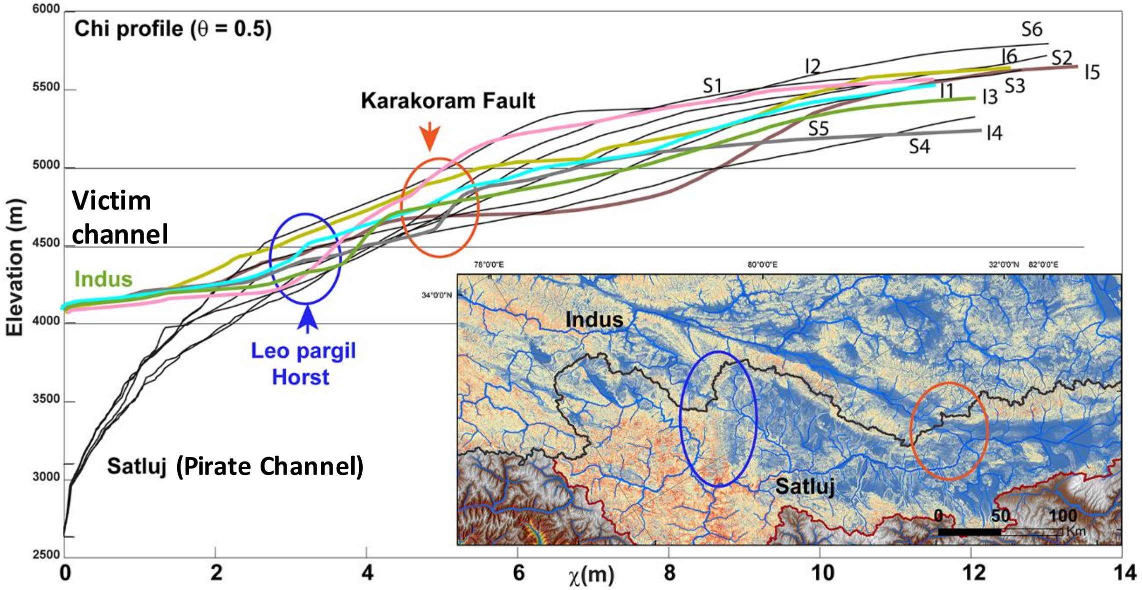
- ***Around 70% of the study area showing significant positive trends in all the extreme Indices except Consecutive Dry Days.***
- ***Grids in the north west part of the study area have higher rate of increase in all the indices.***
- ***Higher quantiles (>95th percentile) of precipitation on daily basis are increasing throughout the study area in summer monsoon.***
- ***In winter monsoon, higher quantiles are decreasing in the middle part of the study area on daily as well as monthly scale.***

Analysis under progress

- Statistical modelling of Extreme Precipitation using Extreme Value theory for both stationary and non-stationary approaches.
- Comparison of different data sets (IMD, HAR, APHRODITE) to study data scale impact
- Generation of Future precipitation using CMIP 6 GCM outputs for different SSP scenarios.
- Assessment of past and future water availability under different climate change scenarios

Role of tectonics -climate interaction in Drainage reorganization: Interaction of Indus- Upper Satluj valley

Upper Satluj valley was part of Indus catchment, which diverted to Himalayan terrain due to Karakoram Fault driven tectonics leading to river piracy during Pleistocene.



A collaborative activity of UIBN-IC

- Proposed a 'Short Term Course' on "Water Resources Assessment in Mountainous Region: A Climate Change Perspective" for the Officials of Afghanistan.
- Proposal submitted to ICIMOD

	Day 1 (Monday)	Day 2 (Tuesday)	Day 3 (Wednesday)	Day 4 (Thursday)	Day 5 (Friday)
0 - 11.00	@9.30 Registration @ 10.00 Introduction of Participants @ 10.00 Inaugural Function etc.	Hydrometric techniques for collection of hydrometeorological data {MKJ/DSA}{L}	Climate change and its impact on precipitation {APD}{L}	GCM and data downscaling {APD}{L}	Geological considerations in water resources assessment {AKP}{L}
	Bio-break and discussions with experts {over tea/coffee}				
15 - 1.00 PM	Course Overview {DSA} Global water resources, Hydrology, hydrological cycle and Processes {DSA}	Techniques for monitoring hydrological processes in a Mountainous watershed {SS}{L}	Weather system, monsoon and western disturbances in HKH region {DN}	Surface water Modelling tools and their scope – Overland flow commutations {DSA}	Water availability dynamics and its influence on livelihood options in HKH region {???} {L}*
	Lunch Break				
0 - 4.00 PM	Water balance studies {NKG}{L}	Deterministic processes used in surface water hydrology {NKG}{L}	Melt runoff estimation {RT}	Hydrograph separation using isotope technique {ASM}	Data types and open data sources {DSA/APD} {L}
	Bio-break and discussions with experts {over tea/coffee}				
5 – 5.45 PM	Groundwater hydrology and baseflow computation {BKY}{L}	DEM and catchment data delineation using GIS. {DSA}{LE}	Analysis of hydrological and climate data using excel {NKG}{LE}	Surface water Modelling tools and their scope – Stream flow modelling {DSA}	Feedback and Closing Session {APD/ DSA}

Water Supply and Demand Estimation in Jhelum River Basin

Bekele and Shaheen (SKUAST-Kashmir)

- Water budgeting in Jhelum river basin (Hydro-Economic WEAP Model).
- Water Supply Data: Jhelum river and tributaries discharge (1960-2020),
- Water Demand Data: Agriculture, Livestock, Domestic, Industrial, Commercial & Institutional, Env. Flow
- Climate Data: Temperature, Rainfall, RH, etc
- Study area will be Upper Jhelum river basin upto LOC.
- **Outcomes: Current & Future Water Demand & Supply (2021-2050)**

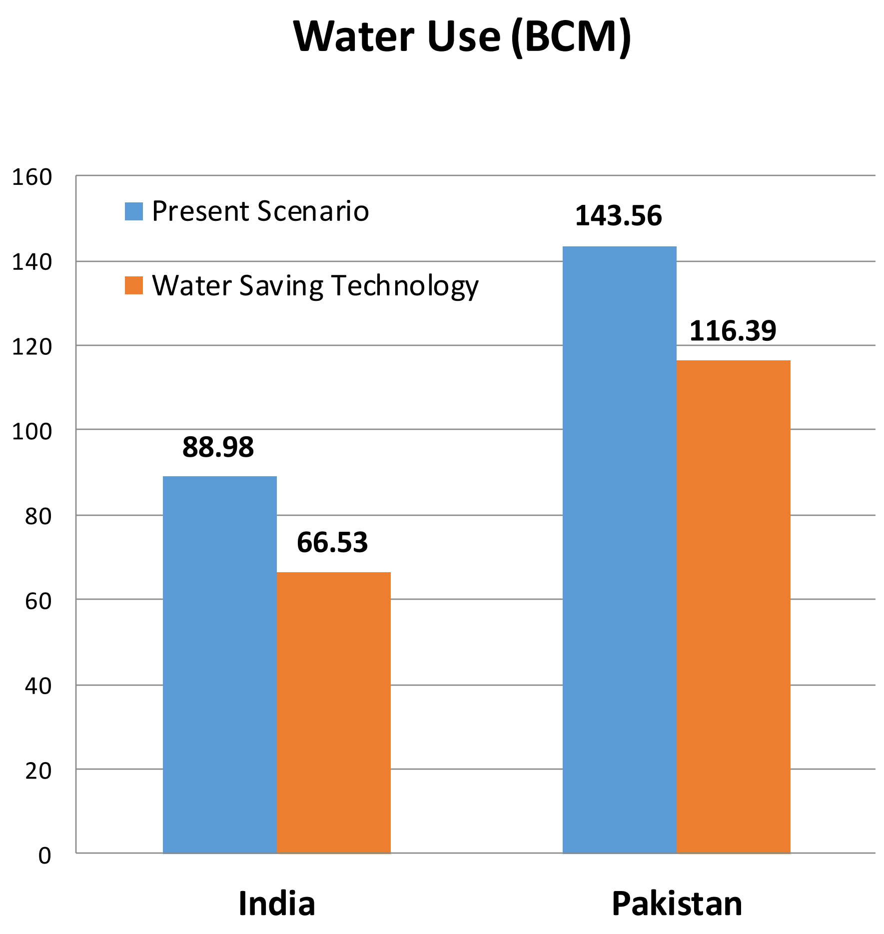
DEMAND SIDE AGRICULTURAL WATER MANAGEMENT- Technology & Policy

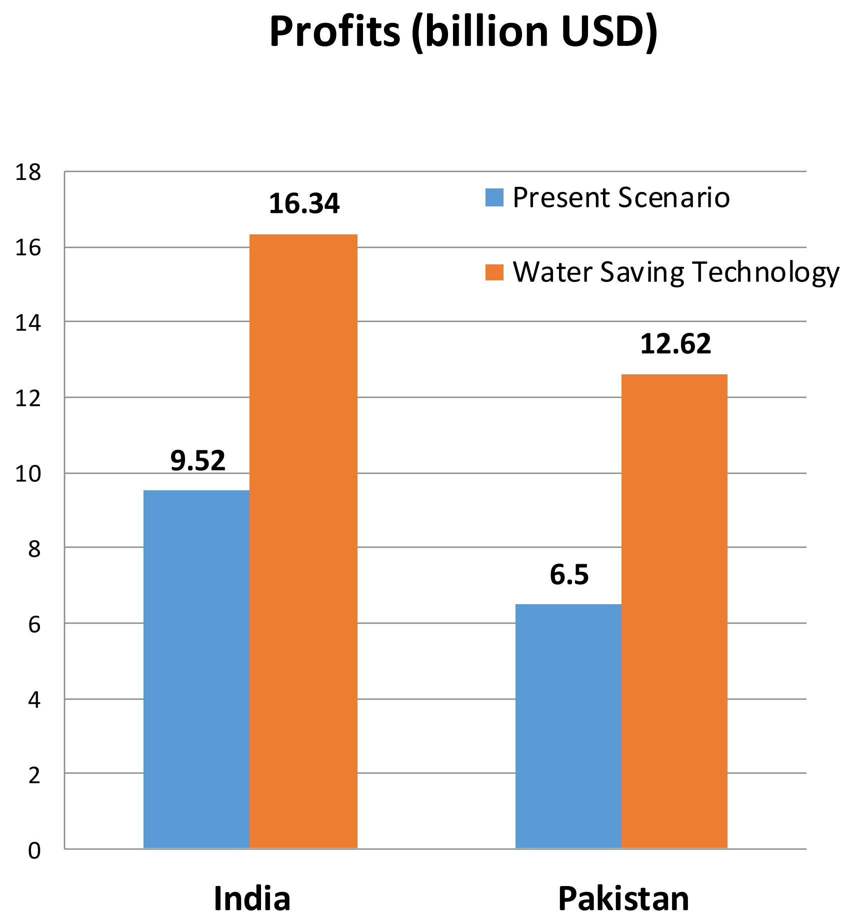
Profits and water use in agriculture from Indus Basin states

Country	Baseline		Water Saving Technology	
	Water use (BCM)	Profits (Billion USD)	Water use (BCM)	Net benefits (Billion USD)
INDIA	**88.98**	**9.52**	**66.53**	**16.34**
Punjab	47.74	2.84	36.21	4.03
Haryana	26.91	1.71	20.25	2.23
Rajasthan	7.41	0.92	5.92	2.03
Himachal Pradesh	1.95	1.55	1.02	2.07
J&K	4.97	2.5	3.13	5.98
PAKISTAN	**143.56**	**6.50**	**116.39**	**12.62**
Punjab	63.93	3.92	51.73	5.58
Sindh	53.2	1.15	42.21	2.57
KPK	17.35	0.85	13.37	1.97
Balochistan	7.85	0.41	7.85	1.53
J&K + Gilgit-Baltistan	1.23	0.17	1.23	0.97

Shaheen & Shah, 2017

Impact of Water Saving Policy: Ex-Ante Evaluation





Water saving of 50 BCM and profits up by 12.94 billion USD

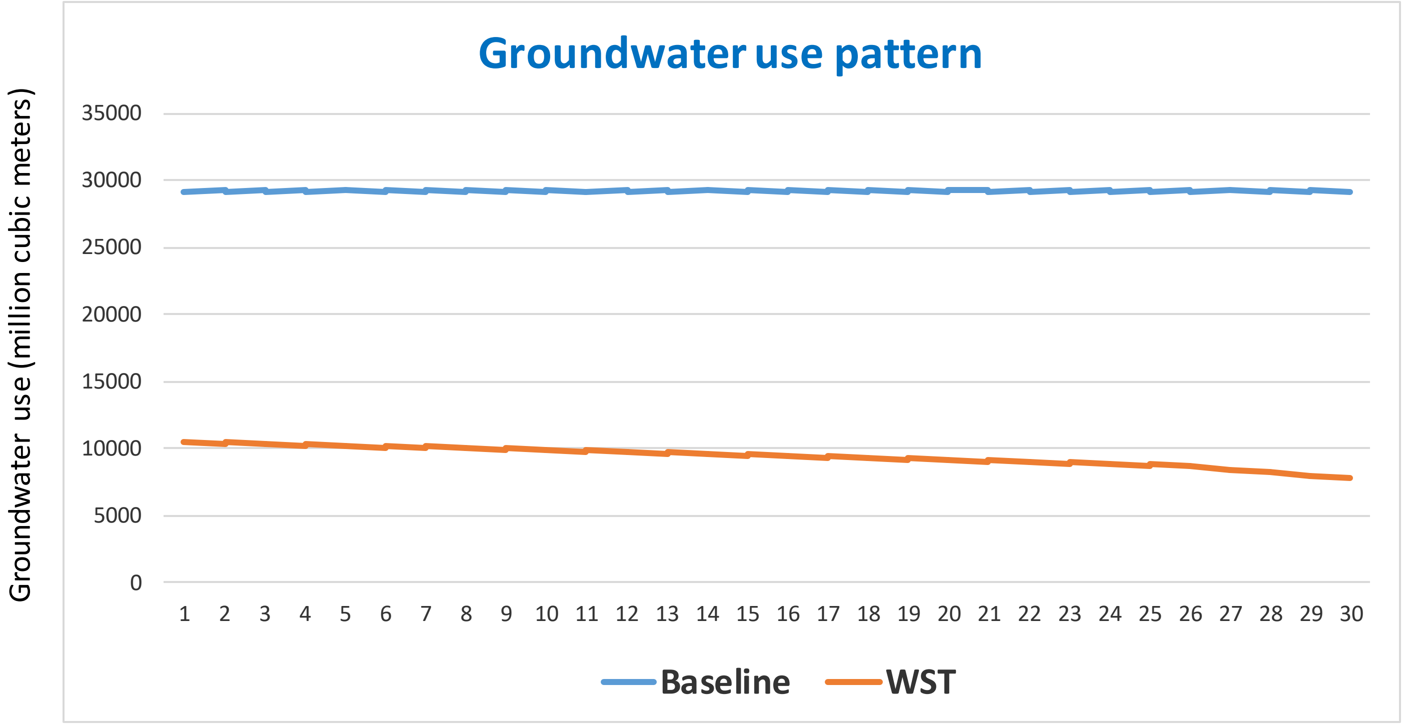
Shaheen & Shah, 2017

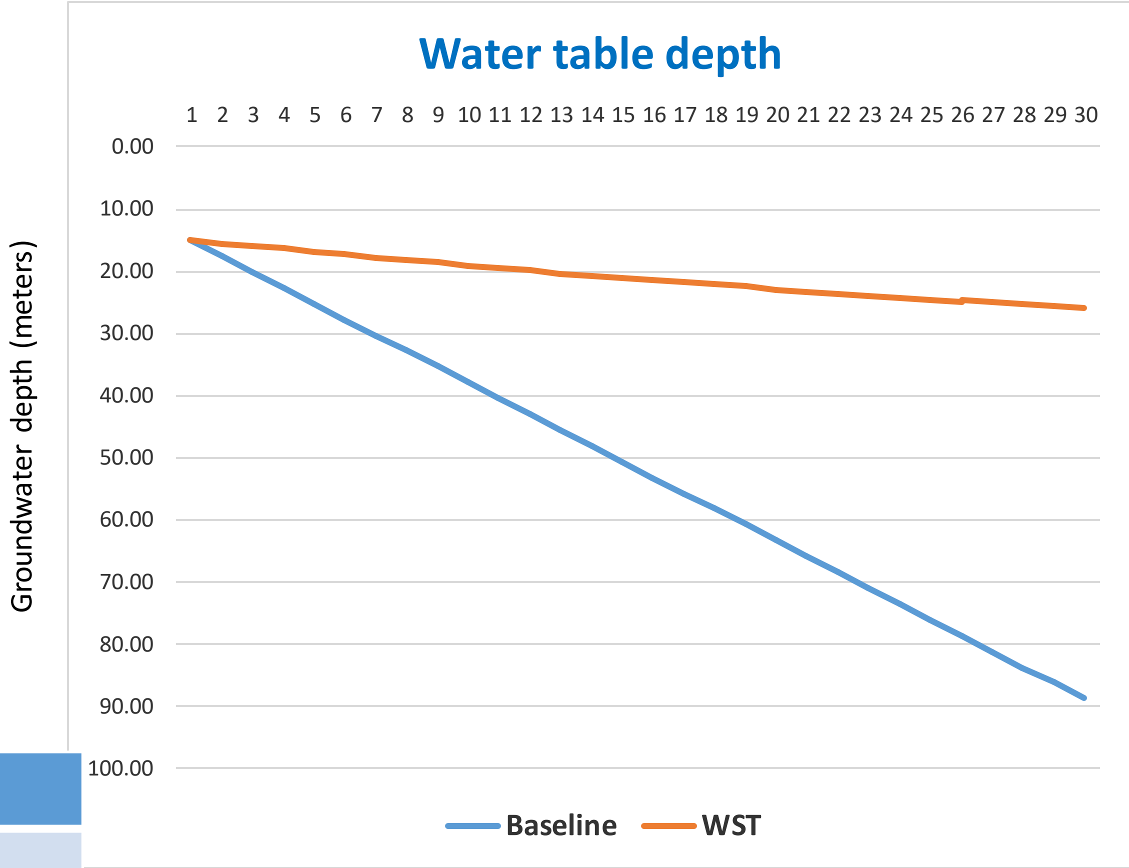
WST Subsidy – case of Indian Punjab

Particulars	Baseline	WST
Water Use (BCM)	47.74	27.51
Profits (billion USD)	2.84	4.62
Energy subsidy for GW (billion USD)	0.80	-
WST subsidy (billion USD)	-	0.45
Economic surplus to Farming community (billion USD)		**1.78**
Subsidy savings to Government (billion USD)		**0.45**
Net Economic surplus to Punjab State (billion USD)		**2.23**

Shaheen & Shah, 2017

Baseline Vs Water Saving Technology



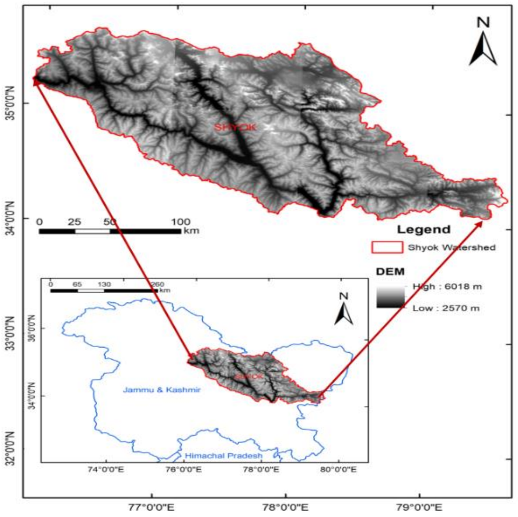


Particulars	Baseline	WST
Profits (billion USD)	43.82	41.93
Subsidy (Energy / WST) (in billion USD)	31.16	2.70
PVNB after internalizing subsidy (billion USD)	12.66	39.23
Net Economic gain to Farming community (billion USD)		1.89
Net savings to Government on cross subsidization (billion USD)		28.46
Total economic gain (billion USD)		30.35

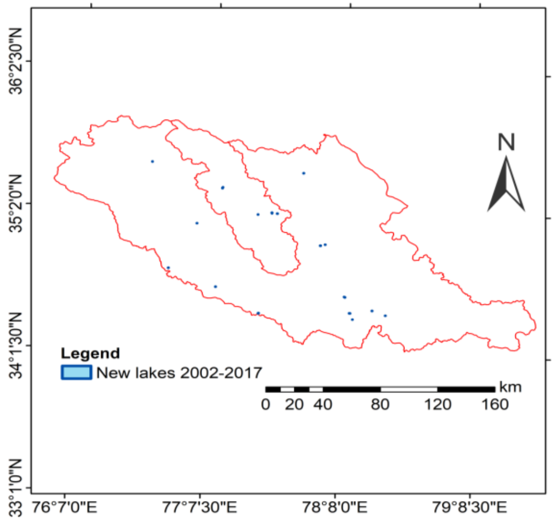
Shaheen & Shah, 2017

TWG5 : Lake Inventory and Evolution of Glacial Lakes in the Nubra - Shyok Basin of Karakoram Range: R. Kumar and R. Singh

Map Nubra-Shyok valley



New lakes formed from 2002 - 2017



The maximum concentration of lakes lies within an altitudinal range of 5000–5500 m asl and the rate of lake area change has increased during 2013 and 2017

Estimated water volume of water in the selective lakes in the Shyok basin during different years (Kumar et al., 2020)

		Year 2017		2013		2002	
Lake ID	Lake type	Area (in km^2)	Volume (in 10^6 m^3)	Area (in km^2)	Volume (in10^6 m^3)	Area (in km^2)	Volume (in 10^6 m^3)
67	MDL	0.222	8.79	0.219	8.72	0.218	8.71
1	MDL	0.223	8.93	------	-----	-----	-----
10	MDL	0.262	10.80	0.227	9.13	-----	-----
66	MDL	0.287	12.00	0.291	12.21	0.286	11.98
4	MDL	0.295	12.43	0.226	9.09	-----	-----
119	BDL	0.308	13.03	0.274	11.37	0.274	11.37
32	BDL	0.941	48.58	1.004	52.45	1.065	56.18
11	MDL	1.017	53.27	0.987	51.39	1.044	54.89
	Total		167.83		154.35		143.13

The increase in the area of the lake in the Shyok-Nubra basin is at a rate of 0.036, 0.477 and 0.151 km^2/year during (2002-13), (2013-2017), (2002-2017) respectively.

The increasing rate of the lake area in recent times may be interpreted as an influence of anthropogenic activities like the increasing temperature in the basin and may give rise to the potentiality of GLOF to some of the lakes.

TWG6- Adaptation: Gendered socio-economic impacts of and adaptation to CC- case study of Ladakh, India: (M. K. Mehra-JNU)

- Methods
  - Utilized **Principal Component Analysis (PCA)** to build climate risk indices (CRI) -- using data on variables for Hazard, Vulnerability, Exposure – block-wise analysis of Ladakh– years 2001 and 2011.
- Data
  - District Census Handbooks of Leh and Kargil (2001 and 2011) and Census website for most **vulnerability** indicators
  - For **exposure** category – data from Leh Disaster Management Plan of 2011-12 and Draft Report of Kargil Master Plan (2018)
  - For **hazard** -- data on precipitation and temperature variables

Findings

- There was substantial variation at block-level vulnerability and exposure and aggregate CRI for the region
- For most blocks for which CRI index was low in 2001, an increase was found in 2011
- For those blocks that displayed a relative fall in the index, level of CRI remained high, above 0.7 or 0.8 in general in the domain [0,1]
- **Gender dimension** emerging as an important determinant (role to be explored in future analyses)

- **Changing Vulnerabilities (Irtiqa et al, 2019 SKUAST-Kashmir)**
  - Shift of most vulnerable areas w.r.t climate change from traditional hotspots to newer areas

- **Kashmir valley Entangled in Anomaly of Climate Change (Shaheen et al, SKUAST)**

  - Last decade (2010-2020) experienced more severe climatic aberrations
  - 2014 floods in summer (5700 crore loss to agriculture and infrastructure)
  - Untimely snowfall (2nd Nov.) in 2019-huge loss to apple crop (1585 crore loss to apple fruit and trees)
  - 2020 drought – no rains for 45 days (huge loss to crops, particularly rainfed areas)
  - 2020 Severe winter (last 40 year period minimum temp. record break), frozen water bodies
  - Good snowfall in current winter (2020-21) with valley plains 2-3 ft snow while as hill stations about 7 ft.

- **Climate Resilience Research Program (SKUAST-Kashmir)**

  - Screening & breeding of drought tolerant verities of maize (Shalimar maize composite-8 with both heat & moisture tolerance); 25% less water requirement than normal/check varieties)
  - Bean variety in pipeline for drought tolerance
  - Screening of temperate fruits (apple and pear) w.r.t altitude and climate parameters (Lone et al)
  - Water Use efficiency, Organic agriculture etc

Thank You