Climate Change Research in Pakistan

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Major CC-related Concerns of Pakistan

- Increased variability of Monsoon;
- More rapid recession of HKH Glaciers threatening IRS Flows;
- Reduction in capacity of natural reservoirs due to rise in snowline;
- Increased risks of floods and droughts;

Major CC-related Concerns of Pakistan (contd.)

- Severe water-stressed conditions in arid and semi-arid regions;
- Food Insecurity due to reduced agriculture productivity;
- Upstream intrusion of saline water in the Indus delta; and risk to mangroves, coral reefs and breeding grounds of fish;

Some other CC-related Concerns of Pakistan

- Increase in Deforestation;
- Loss of Biodiversity;
- Increased Health Risks (Heat Strokes, Pneumonia, Malaria and other vector-borne diseases);
- Risk to Coastal Areas;
- Risk to Energy Supply facilities.

Climate Change Science Studies in Pakistan

- Climate Change research remained essentially neglected in Pakistan until recently;
- **May 2002:** Global Change Impact Studies Centre (GCISC) established with seed money provided by Ministry of Sc & Tech; GCISC now being supported by Planning Commission.
- **January 2005:** Prime Minister's Committee on Climate Change was established, with GCISC as its Secretariat.
- **Dec., 2006:** GCISC attached to National Centre for Physics as an autonomous organization.
- **Oct., 2008:** Planning Commission established a Task Force on Climate Change, with Exec. Dir., GCISC as its Member/ Secretary.

Research Focus of GCISC

- Climate Scenarios for Pakistan
- Impacts on Water Resources
- Impacts on Food Security
- Adaptation Measures

GCISC Research Activities

GCISC Approach for CC Research

Area of GCISC Activities at Present

Internal driving forces

External driving forces

Global Circulation Models (GCMs)

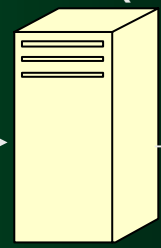
Super Computer

Anthropogenic Influences

Information at 300 km x 300 km level

Global Climate Scenarios

Regional Climate Models (RCMs)



Land use & Topographic data etc.

Regional Climate Scenarios

Information at 30 km x 30 km level

Impact Studies

Crop-growth Simulation Models

Adaptation Measures

Agriculture

Effects on Crop Yields

Mesoscale Climate Models (MMs)

Watershed Models

Effect on River inflows

Information at Sub-km level

Adaptation Measures

Future Activities

Health

Energy

Biodiversity

Simulation Models Currently in Use at GCISC

Regional Climate Models :

- RegCM3 (AS-ICTP, Italy)
- PRECIS (Hadley Centre, UK)
- WRF (NCAR, USA)

Watershed Models :

- DHSVM (Univ. of Washington, USA)
- UBC (Univ. of British Columbia, Canada)
- HEC-HMS (US Army Corps of Engineers)

Crop Simulation Models :

DSSAT: Decision Support System for Agro-technology Transfer (Univ. of Georgia, Griffin, USA) comprising several families of models:

- CERES (for cereals)
- CROPGRO (for grain legumes)
- CROPSIM (for root crops)
- Other Crops (for Tomato, Sunflower, Sugarcane, Pasture)

Environment:

- CALPUFF (Source: ASG, USA)

Salient Research Results Obtained by GCISC

Climate Trends (1951-2000)

Regions

I (a):
Greater Himalayas

I (b):
Sub-montane

II:
Western Highlands

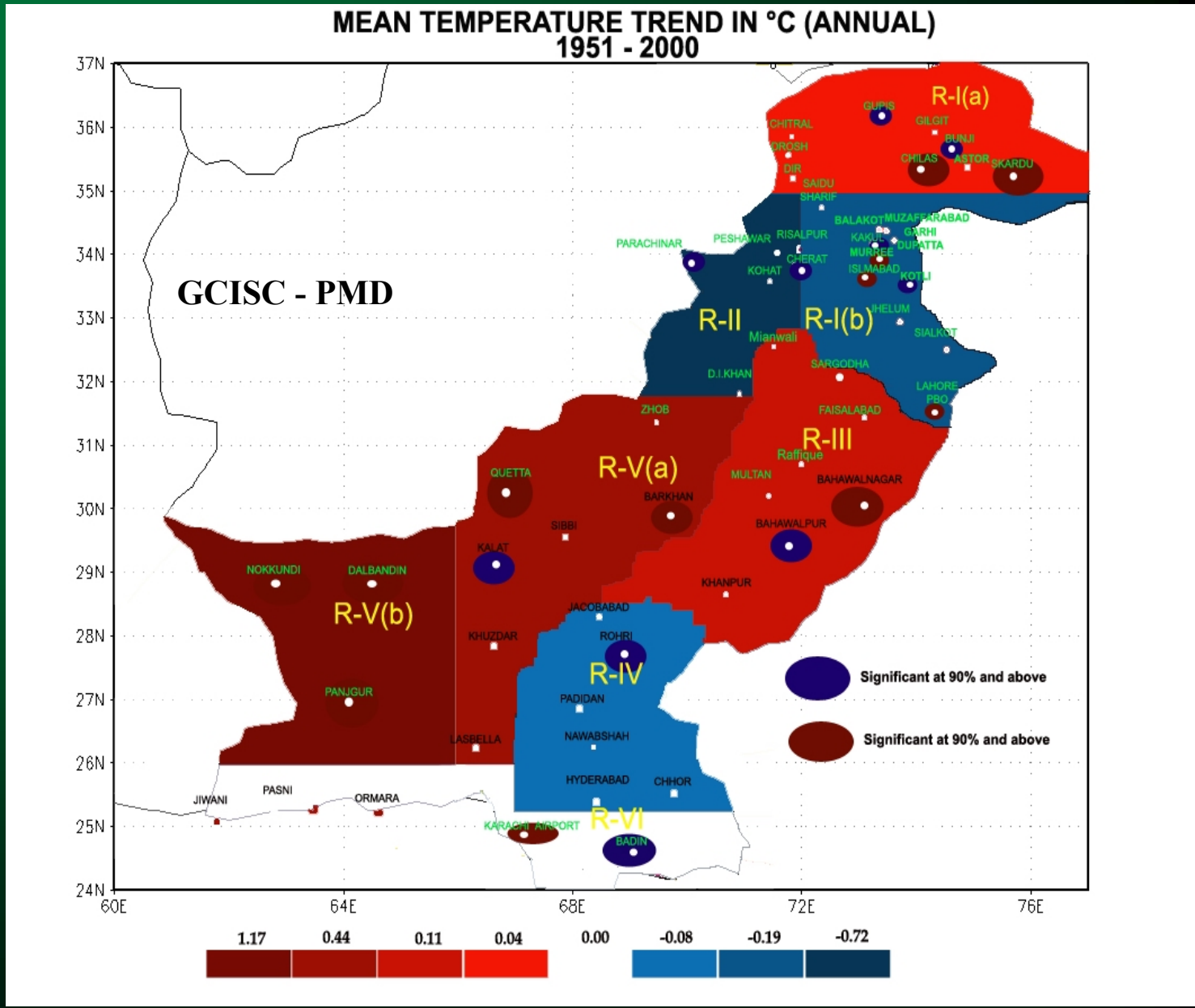
III
Central & Southern Punjab

IV
Lower Indus Plains

V (a)
Balochistan Plateau (East)

V (b)
Balochistan Plateau (West)

VI
Coastal Areas



Negative Trends in Region II, Ib and IV; Positive Trends in other regions

Precipitation Trend
(% Change per year, 1951 – 2000)

Regions

I (a):
Greater Himalayas

I (b):
Sub-montane

II:
Western Highlands

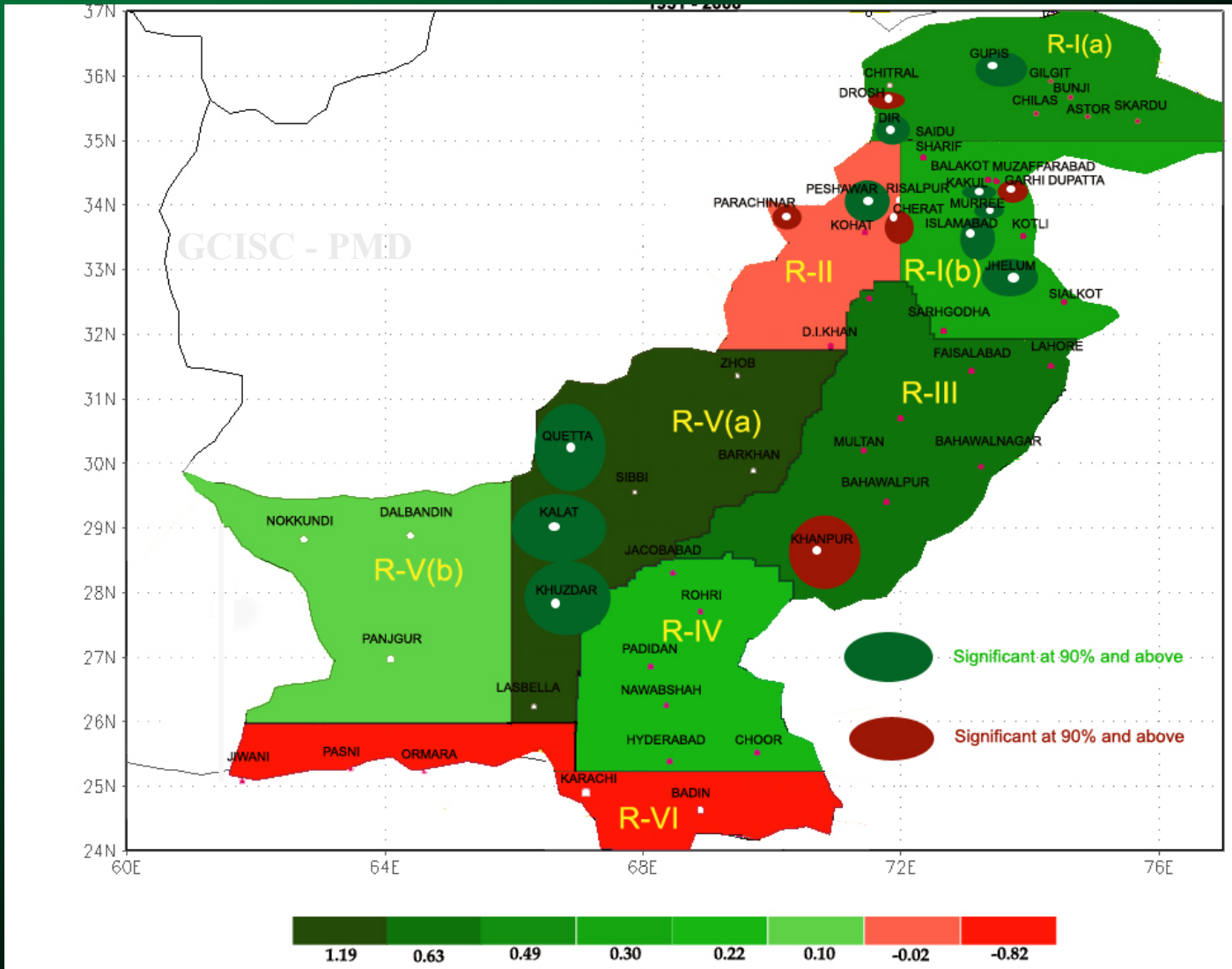
III
Central & Southern Punjab

IV
Lower Indus Plains

V (a)
Balochistan Plateau (East)

V (b)
Balochistan Plateau (West)

VI
Coastal Areas



Negative Trend in Region II and VI ; Positive Trends in other regions

Climate Change Projections

a) **Coarse resolution (~300 km x 300 km) projections using Outputs of 17 GCMs for A2 and A1B scenarios**

b) **Fine resolution (~50 km x 50 km) projections by dynamic downscaling of GCM outputs for A2 scenario using RCMs: RegCM3 and PRECIS**

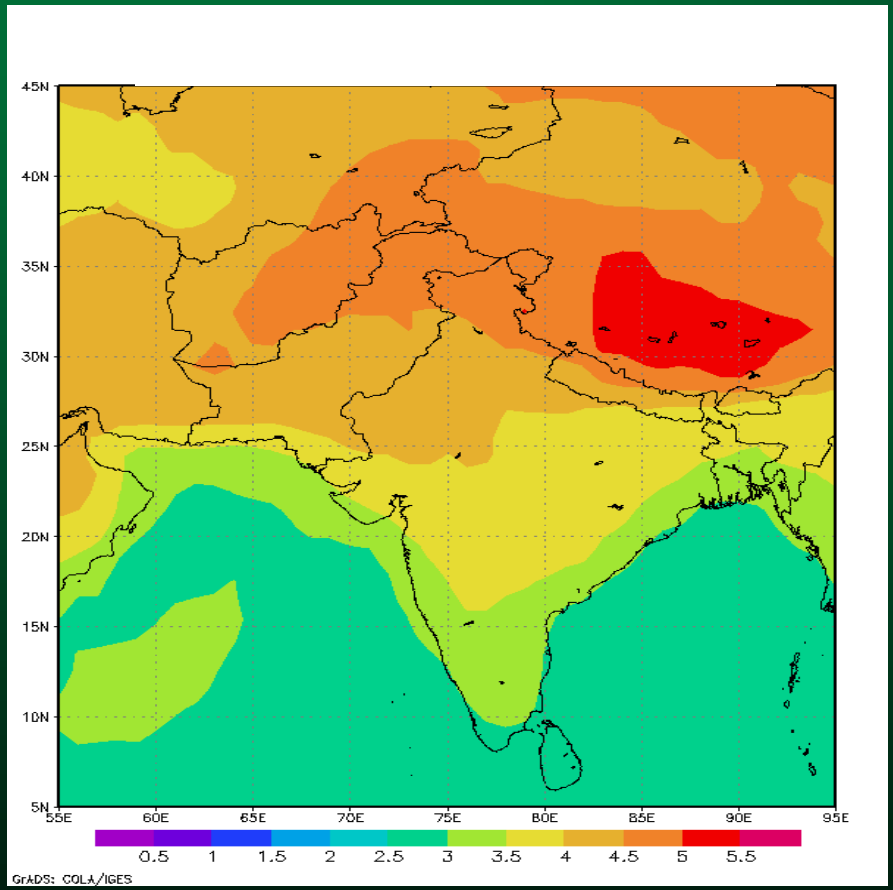
Base period: 1961 – 1990

Futures: **2020s** = 2010 – 2039

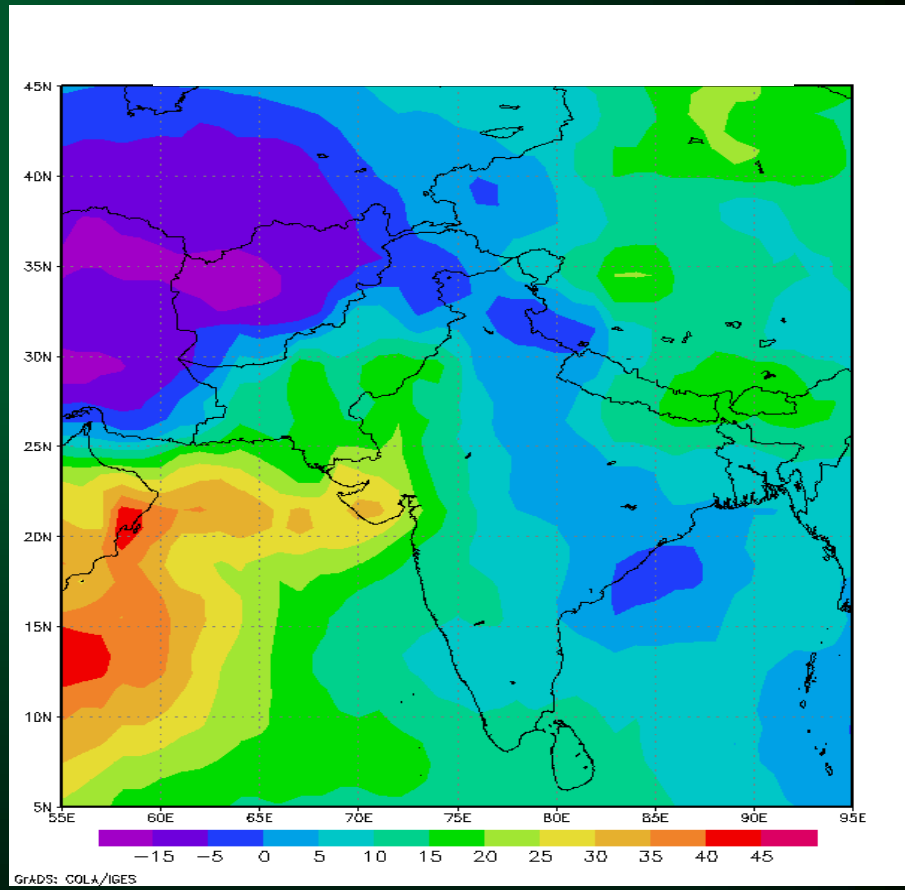
2050s = 2040 – 2069

2080s = 2070 – 2099

GCM-Ensemble based Projected Changes in Annual Average Temperature (°C) and Precipitation in 2080s (A2 Scenario)



Temperature Change (°C)

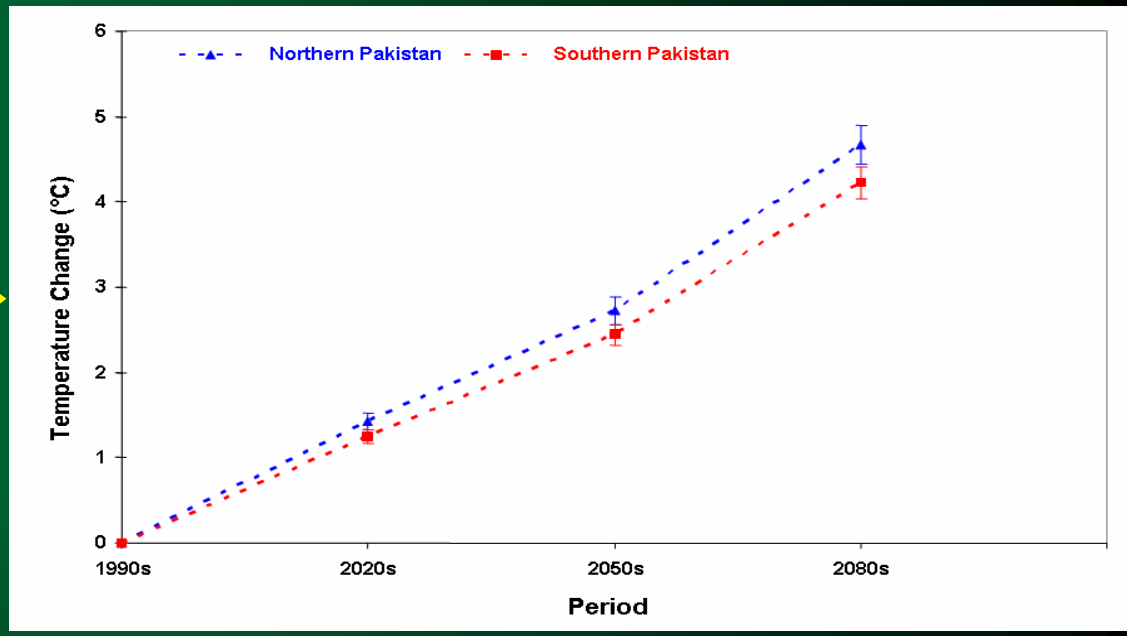


Precipitation Change (%)

Projected Changes in Average Temperature of Northern and Southern Pakistan

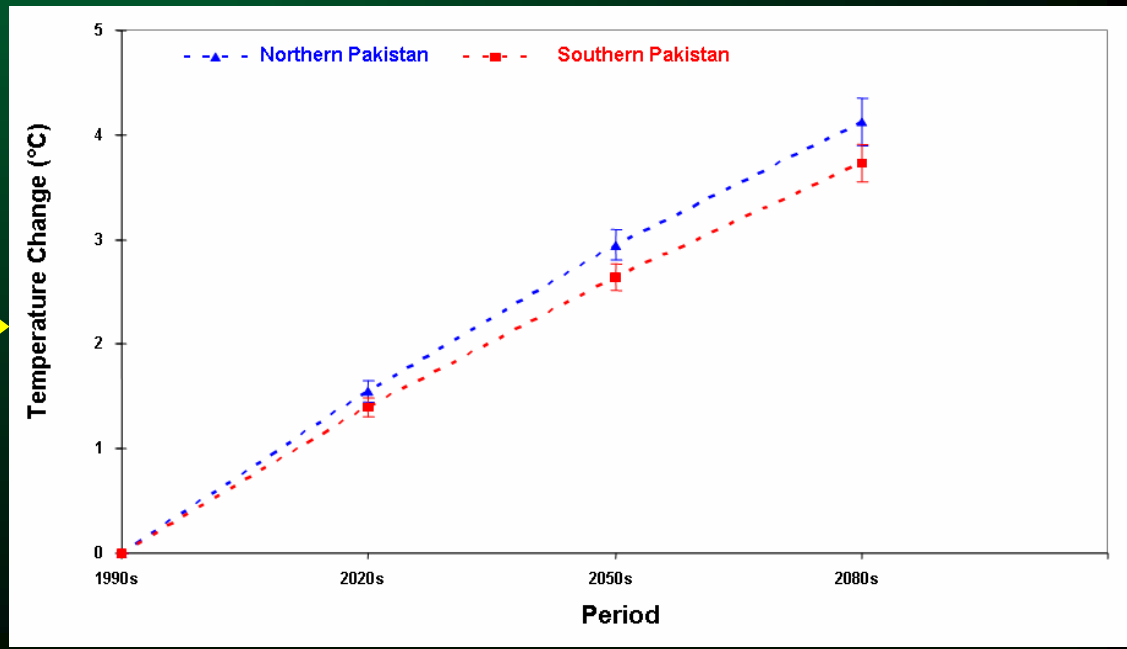
For A2 Scenario, based on Ensemble of 13 GCMs

(Global ΔT = 3.4 °C in 2100)

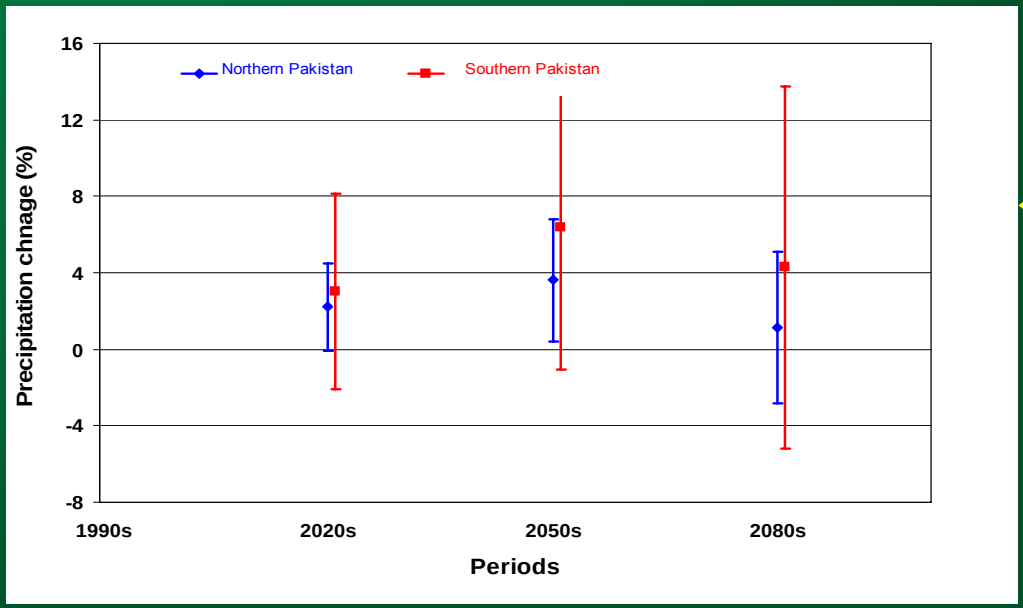


For A1B Scenario, based on Ensemble of 17 GCMs

(Global ΔT = 2.8 °C in 2100)

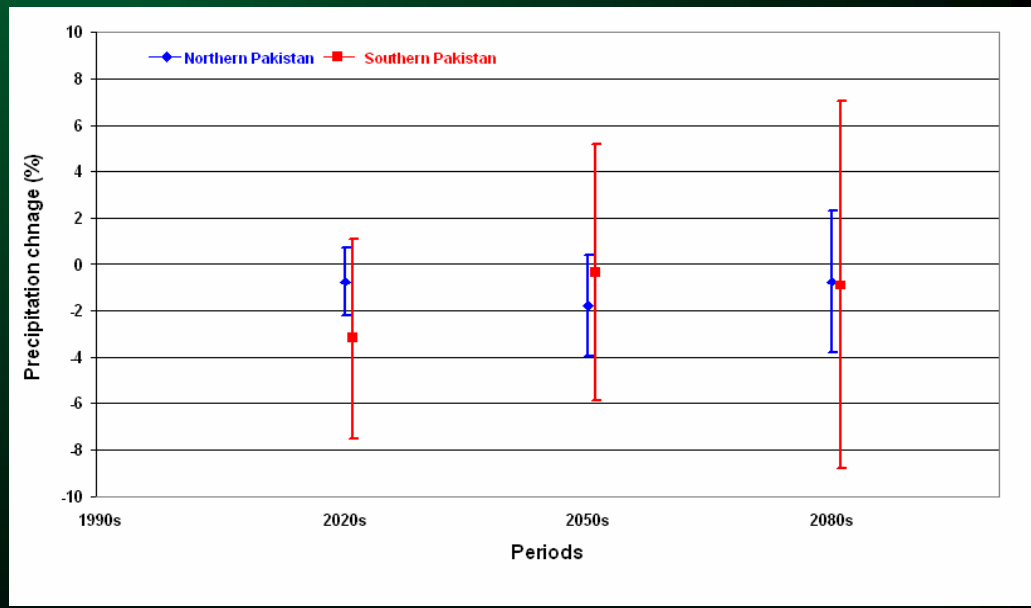


Projected Changes in Average Precipitation of Northern and Southern Pakistan



(Corresponding to IPCC A2 Scenario)
Based on Ensemble of 13 GCMs

(Corresponding to IPCC A1B Scenario)
Based on Ensemble of 17 GCMs



Projected Temperature Changes in 2080s, ΔT (°C) by GCM Ensemble for A2 Scenario

	Pakistan	Northern Pakistan	Southern Pakistan
Annual	4.38 ± 0.44	4.67 ± 0.23	4.22 ± 0.18
Summer	4.13 ± 0.26	4.56 ± 0.28	3.90 ± 0.26
Winter	4.47 ± 0.20	4.72 ± 0.24	4.33 ± 0.18

- Temperature increases in both summer and winter are higher in Northern Pakistan than in Southern Pakistan
- Temperature increases in Northern and Southern Pakistan are higher in winter than in summer

Projected Precipitation Changes in 2080s, ΔP (%) by GCM Ensemble for A2 Scenario

	Pakistan	Northern Pakistan	Southern Pakistan
Annual	3.48 ± 5.78	1.13 ± 3.95	4.28 ± 9.46
Summer	12.16 ± 8.91	7.08 ± 8.35	51.07 ± 39.78
Winter	-5.12 ± 4.78	-2.24 ± 4.10	-20.51 ± 9.05

- The rather large errors make it difficult to draw any definite conclusions about change in precipitation with time
- There is, however, some indication of precipitation increase in summer and precipitation decrease in winter in the Southern Pakistan

Dynamical Downscaling of GCM Scenarios using RCMs

- **Typical RCM Resolution: 50 km x 50 km**
- **Input: GCM output + Topography data + Land use and Land-Sea demarcation data**

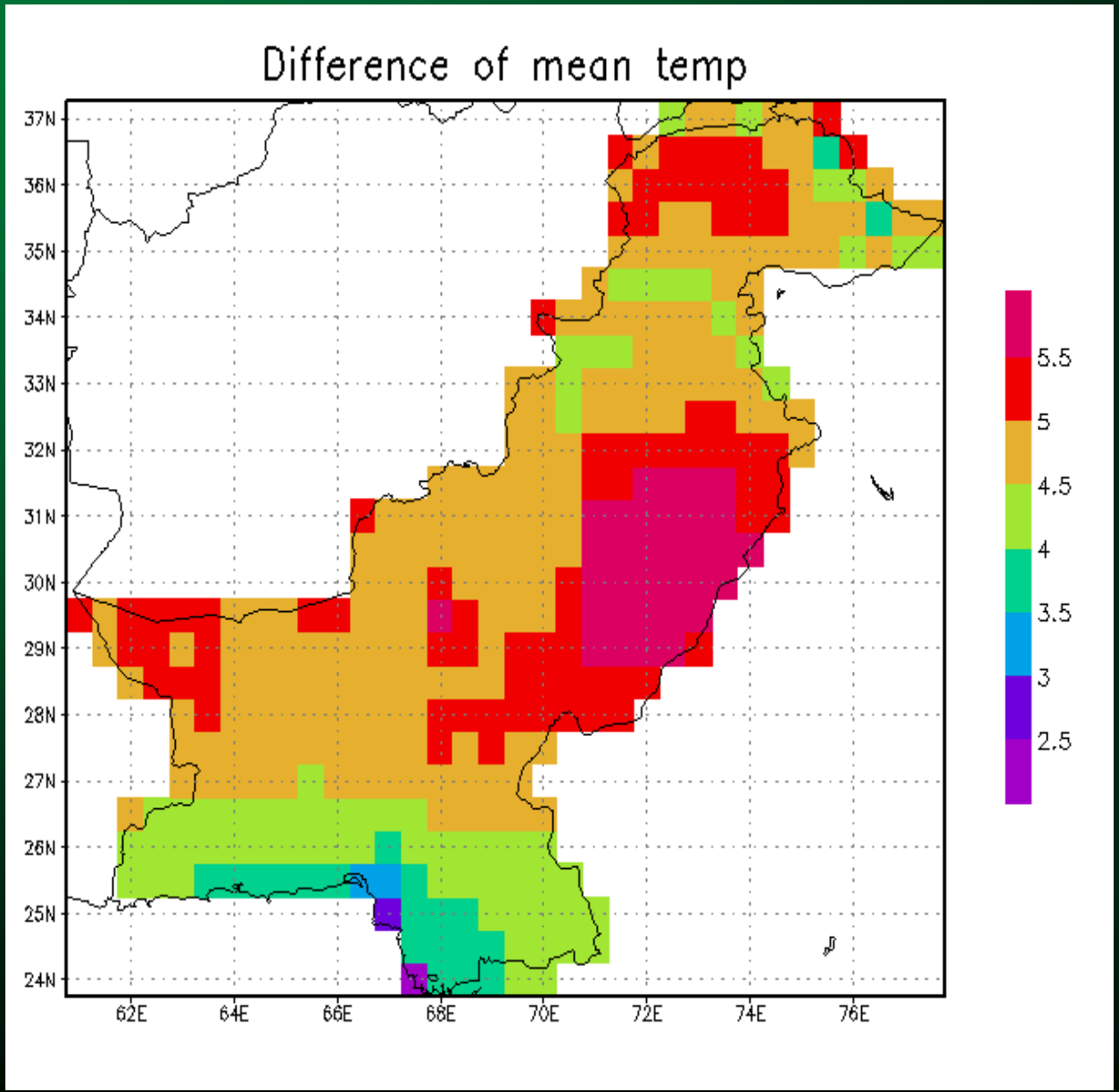
Models being used:

  - **PRECIS of Hadley Centre is used with HadAM3P (for 2080s only) and ECHAM4 of MPI, Germany (for 2020s, 2050s, 2080s)**
  - **RegCM3 of ICTP is used with FVGCM of NASA, USA (for 2080s only) and ECHAM5 of MPI (for 2050s, 2080s)**

- **Both PRECIS and RegCM3 have been validated over the whole South Asia as well as over different parts of Pakistan. These are found to reproduce well the observed climatology including extreme events.**

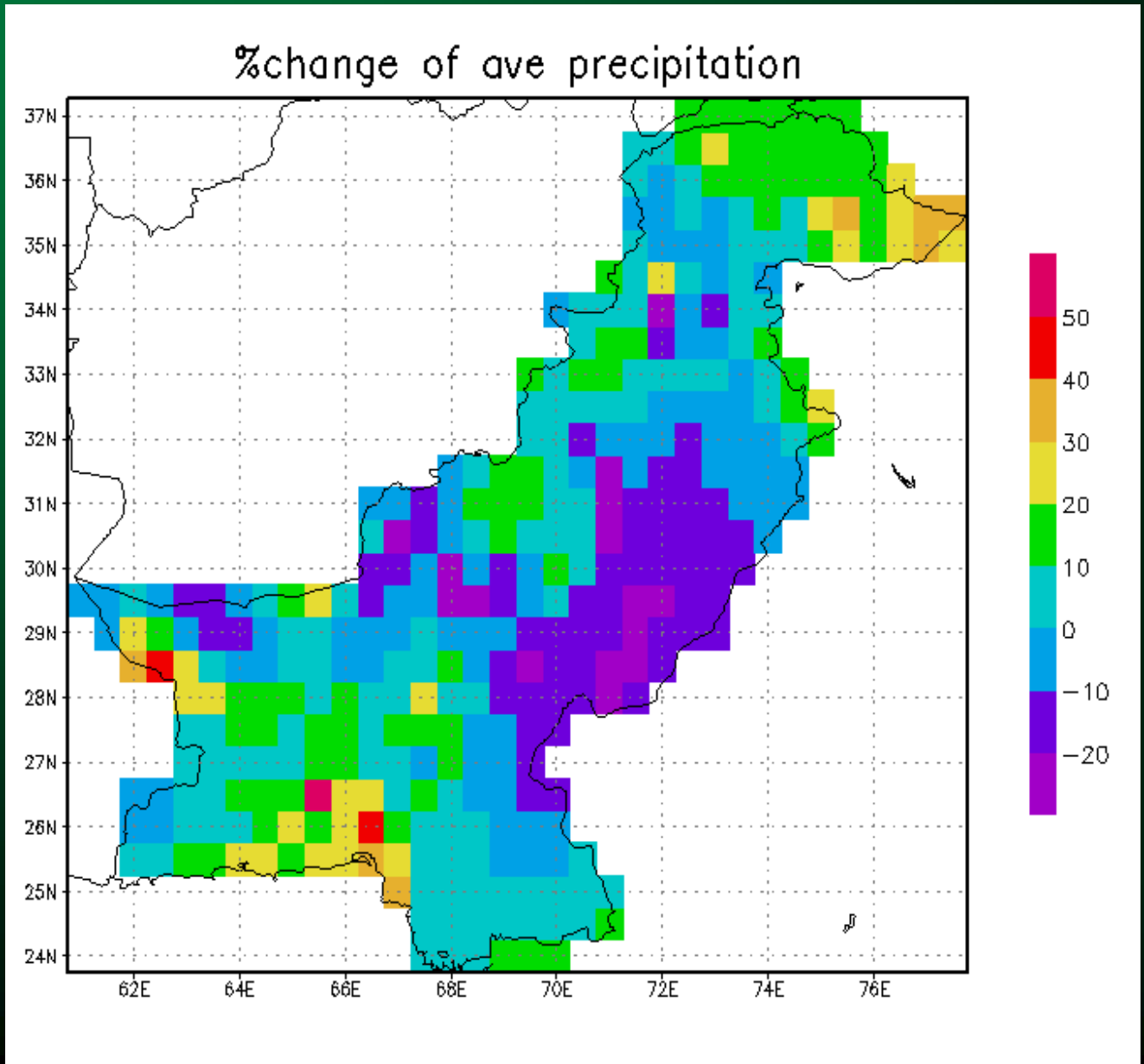
Projected Temperature Change (°C) for 2080s by PRECIS (A2 Scenario)

Pakistan



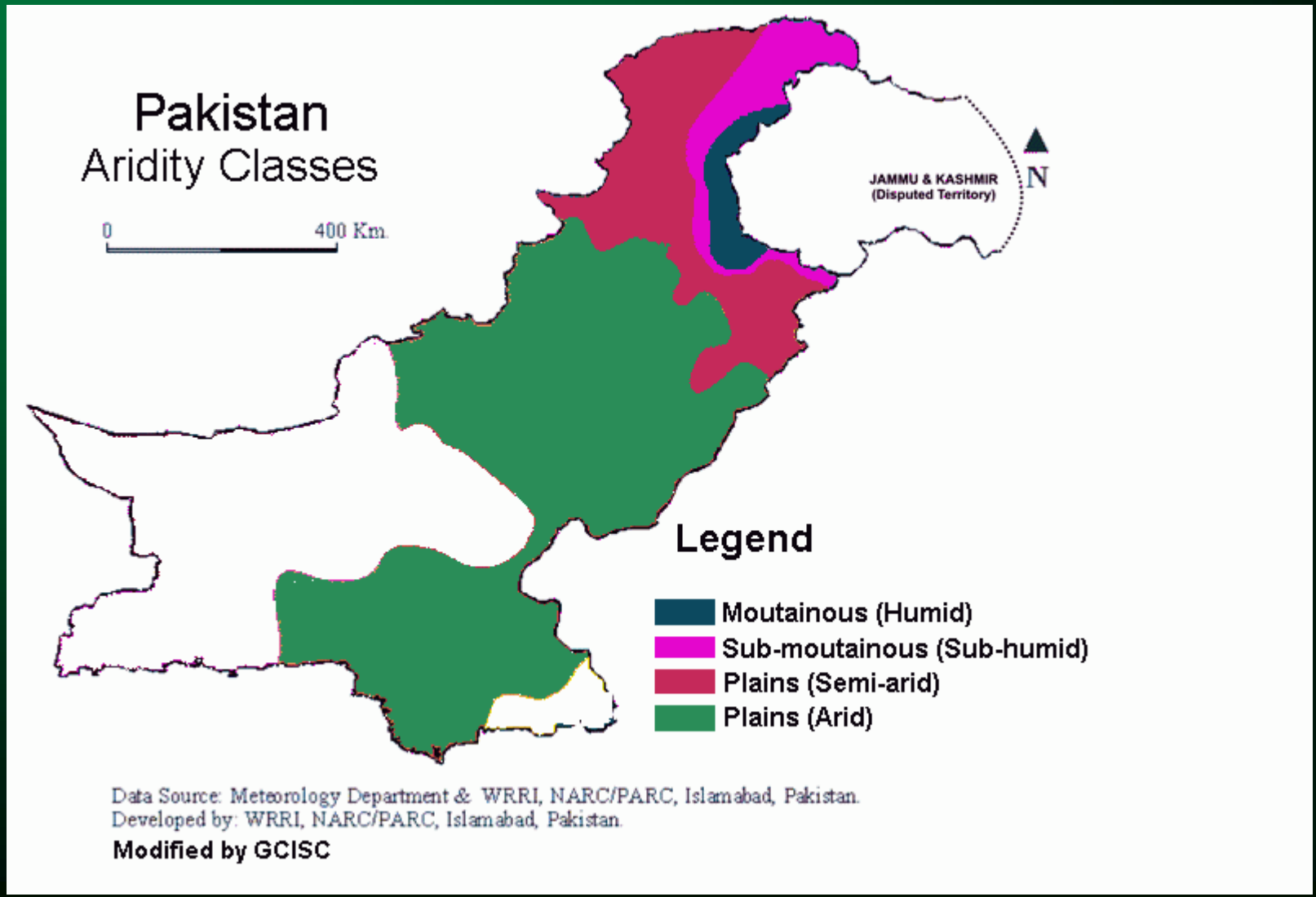
Projected Precipitation Change (%) for 2080s by PRECIS (A2 Scenario)

Pakistan



Impacts of Climate Change on Agriculture in Pakistan

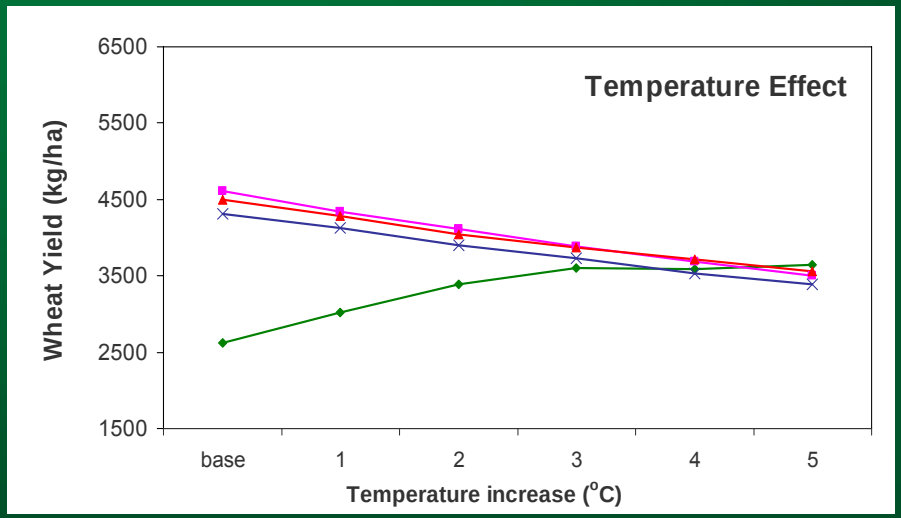
Agro-Climatic Zones Studied by GCISC

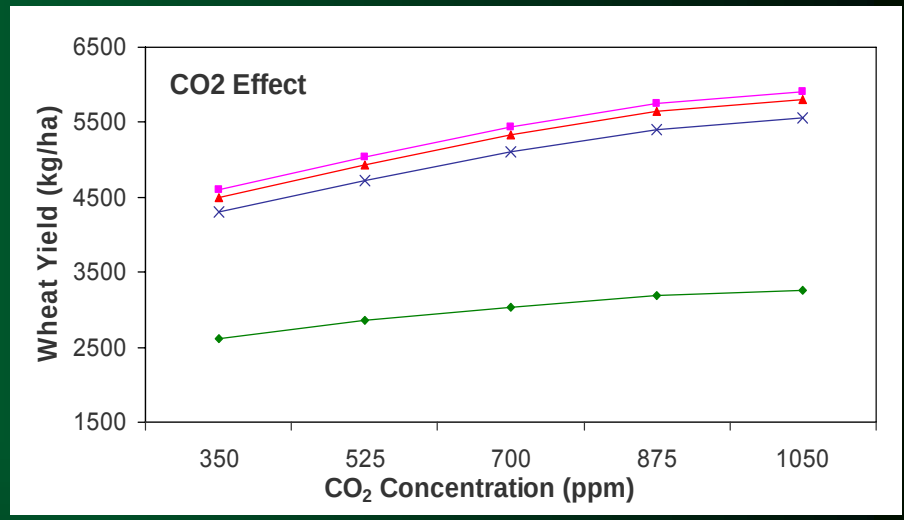


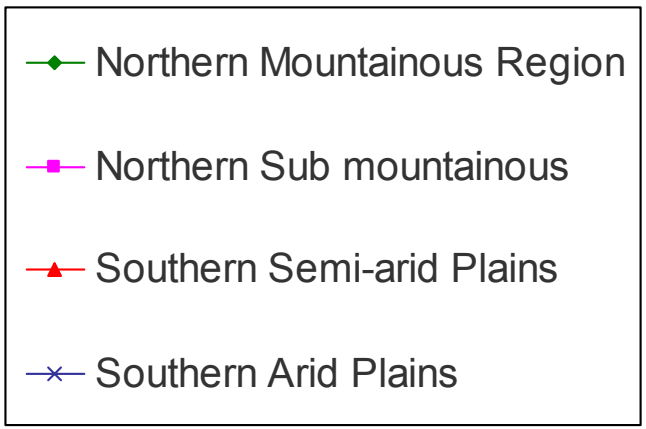
Impact of rise in temperature on wheat Growing Season Length in Northern and Southern parts of Pakistan

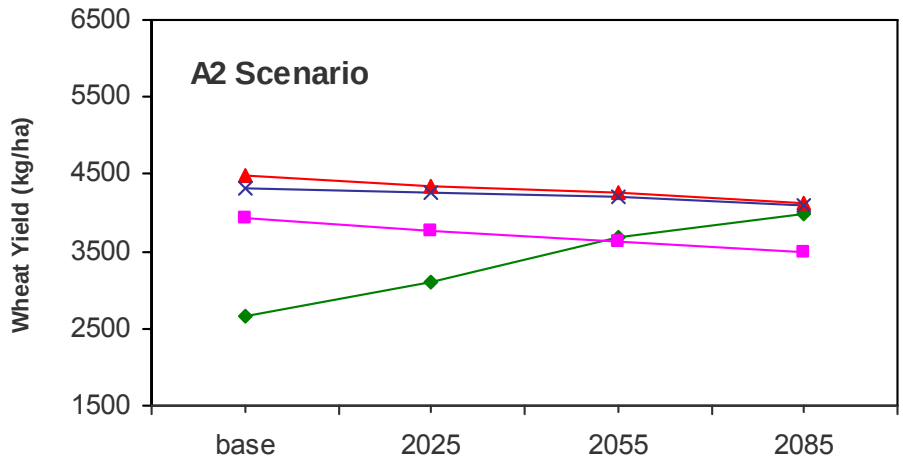
Temperature ˚C (increase over baseline)	Growing Season Length (Days)			
	Northern Pakistan		Southern Pakistan	
	Mountainous Region (Humid)	Sub-Mountainous Region (Sub-humid)	Plains (Semi-arid)	Plains (Arid)
Baseline	246	161	146	137
1	232	155	140	132
2	221	149	135	127
3	211	144	130	123
4	202	138	125	118
5	194	133	121	113

Change in Wheat Yield in Different Agro-climatic Zones of Pakistan with variation in Temperature, variation in CO_2 concentration, and for A2 Scenario









Climate Change Impact on Wheat Production in Pakistan by 2085 under A2 and B2 Scenarios

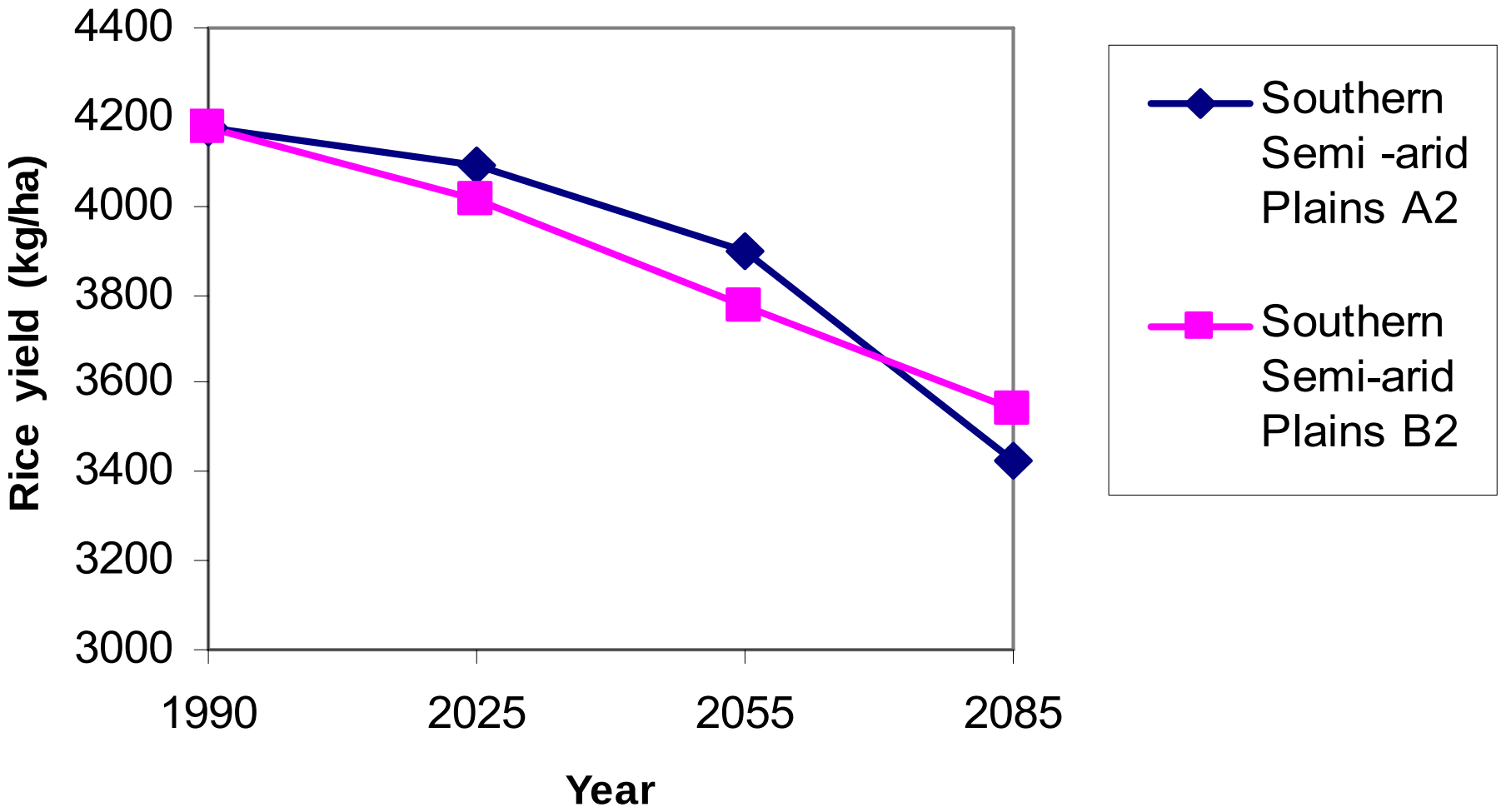
Region	% Share in National Production	Baseline Yield (kg ha^{-1})	% Change in yield in 2080	
			Scenario A2	Scenario B2
I (Northern Mountainous)	2	2658	+50	+40
II (Northern Sub-mountainous)	9	3933	-11	-11
III (Southern Semi arid Plain)	42	4306	-8	-8
IV (Southern Arid Plain)	47	4490	-5	-6
Total Country	**100**	**4326**	**-5.7**	**-6.4**

Effect of increase in Temperature on Growing Season Length of Rice in Semi arid areas of Punjab

(Cv. Basmati Super transplanted in 1st Week of July)

Temperature (°C)	Growing Season Length (Days)
Baseline	108
1 (increase over baseline)	102
2	100
3	98
4	92
5	89

Basmati Rice Yield in Southern Semi-arid Plains of Pakistan under A2 and B2 Scenarios



Yield decrease by 2085:18% in A2 and 15% in B2 Scenarios

Impacts of Climate Change on Water Resources of Pakistan

Melting of Glaciers in Pakistan

- Glaciers in Pakistan cover 13,680 sq. km which is 13% of mountain regions of the Upper Indus Basin (UIB). Melt water from these Glaciers contributes more than 60% to the flows from UIB.
- According to a 1999 report of *International Commission for Snow and Ice (ICSI)* "Glaciers in Himalayas are receding faster than in any other part of the world and, if the present rate continue, the likelihood of them disappearing by the year 2035 is very high".
- In 2005, Hewitt reported widespread evidence of glacier expansion in the late 1990s in the Central Karakoram, in contrast to a worldwide decline of mountain glaciers.
- These conflicting findings make the impact of climate change on Karakoram glaciers and Indus River flows very uncertain.

Some Projected Changes in River Flows due to Melting of HKH Glaciers

(As reported in recent studies)

World Bank (2006):

Western Himalayan glaciers will retreat for the next 50 years causing increase of Indus River flows. Then the glacier reservoirs will be empty, resulting in decrease of flows by up to 30% to 40% over the subsequent fifty years.

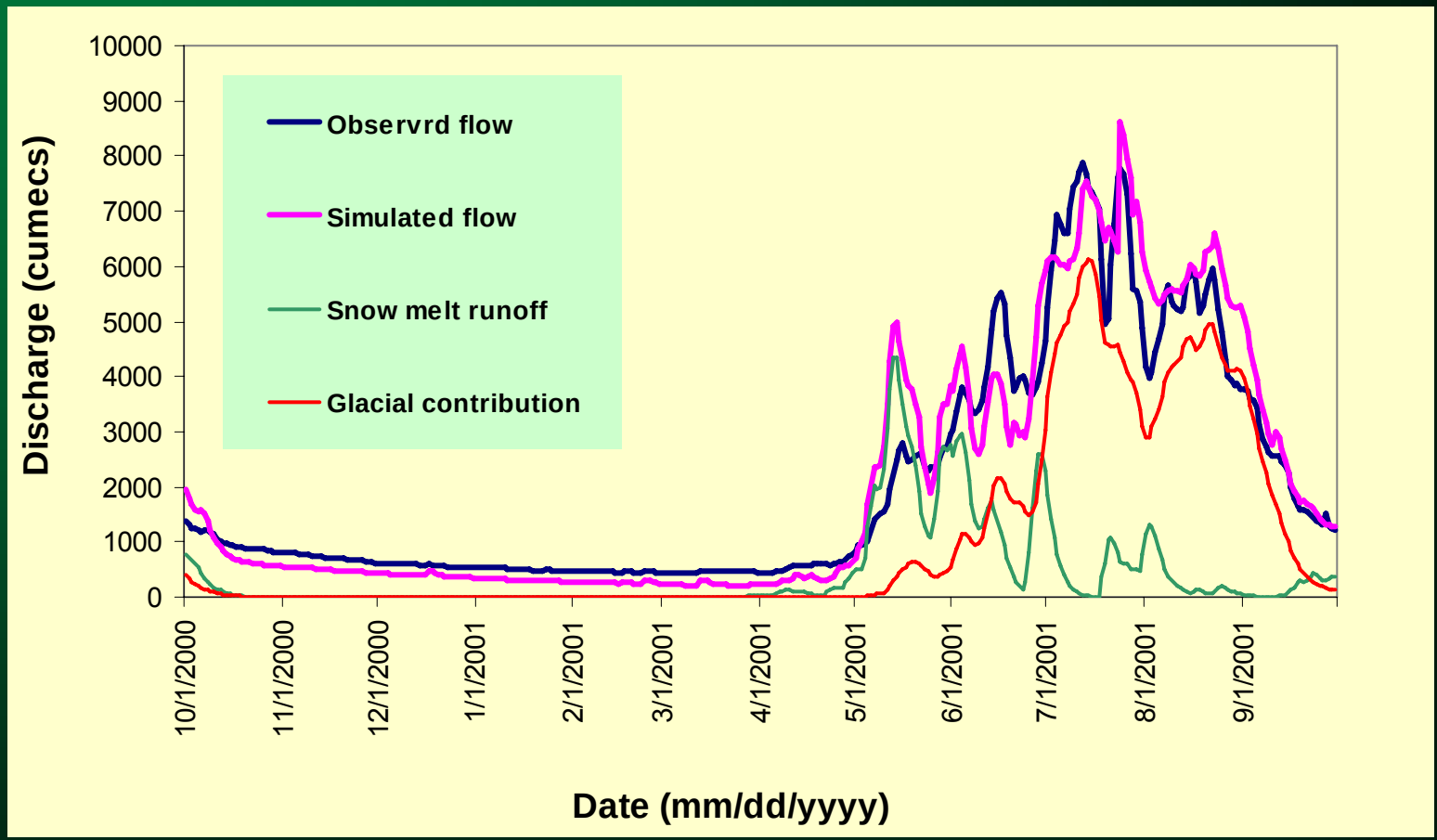
IPCC AR4 (2007):

Glacier melt in the Himalayas is projected to increase flooding within next two to three decades. This will be followed by decreased river flows as the glaciers recede.

GCISC Efforts to Assess the Impact of CC on Karakoram Glaciers and IRS Flows

- **In order to assess the impacts of Climate Change on Indus River flows, GCISC has:**
  - Joined hands with GLIMS (Global Land and Ice Measurement from Space) to study the Karakoram glaciers using satellite imagery
  - Validated and calibrated a semi distributed watershed model (UBC Model) to simulate month-wise Indus River flows; (Similar effort is now in progress on a fully distributed model, DHSVM) and
  - Using the UBC model, estimated the expected changes in Indus River flows for a hypothetical scenario which assumed average temperature increase by 3 ^{0}C and glacier area reduction by 50 %.

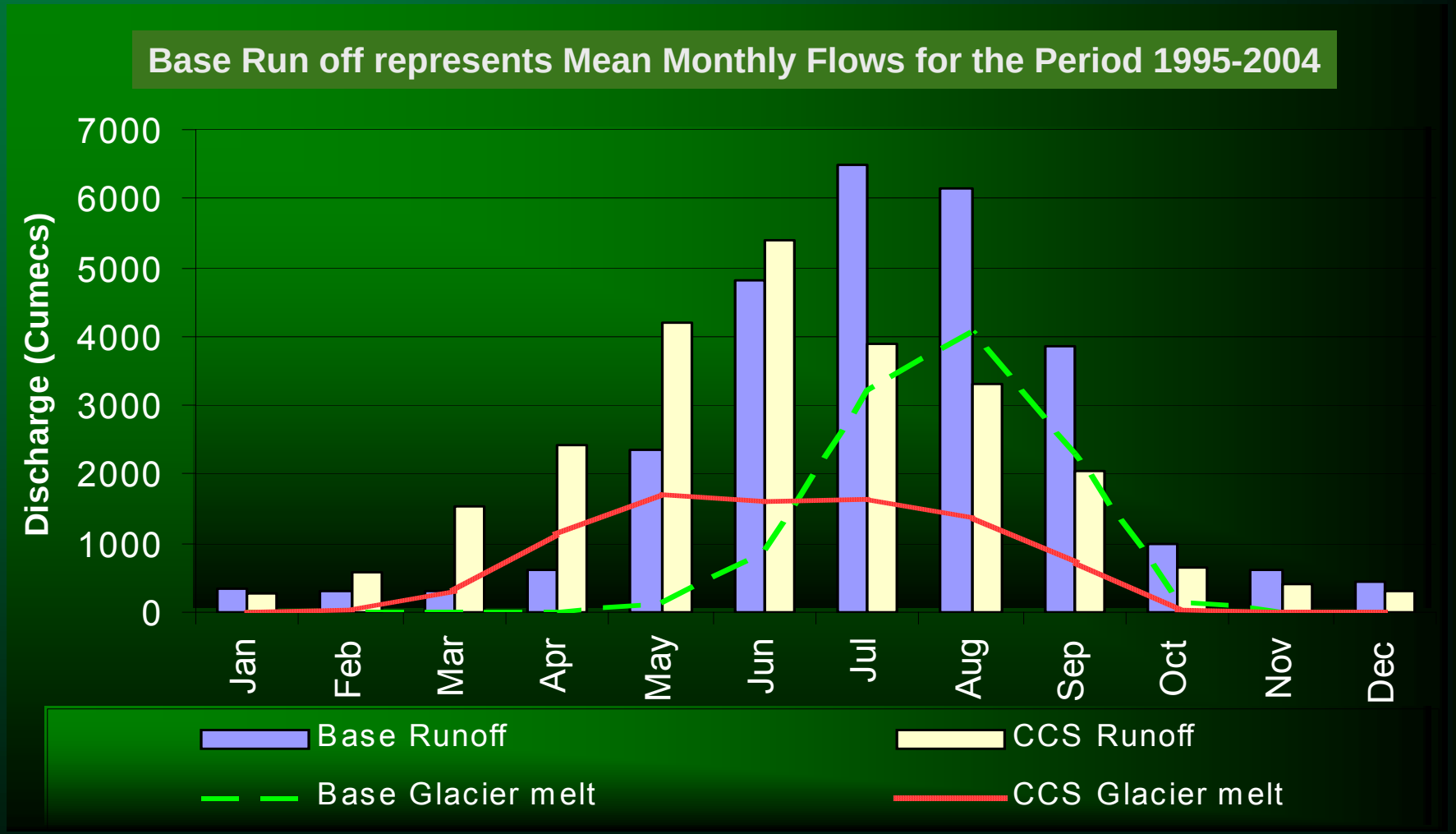
Indus River Flows at Bisham Qila
Simulated by UBC Watershed Model



	R^2	Eff.	% Vol. Diff.
Calibration (1999-2004)	*0.87*	*0.86*	*0.32*
Validation (1995-1999)	*0.87*	*0.87*	*-5.16*

Impact of Climate Change and Glacier retreat on Indus Flows

Assumed Climate Change Scenario (CCS):
Δ Temp: +3°C, Δ Glacier Area: - 50%



Main Results:
1. Annual flows reduced by 15%
2. Intra-Annual flow pattern considerably changed

Salient Research Results

- Expected temperature increase in Pakistan as whole higher than the expected global average increase.
- Projected temperature increase in the north is somewhat higher than in the south Pakistan.
- Projected temperature increase in winter is more than that in summer.
- As yet it is not possible to get a clear picture for precipitation change, due to large model uncertainties.
- The yields of both wheat and rice will decrease everywhere except in the Northern Mountainous areas where wheat yield will increase.
- The situation about the impacts of CC on Pakistan's water resources is unclear due to the uncertain behavior of Karakoram glaciers.

Thank You