

## PAKISTAN: RESEARCH ON IMPACTS OF CLIMATE CHANGE AND ADAPTATION STRATEGIES

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### ABSTRACT

Pakistan has a population of 170 million and is located in South-Asia between 24° and 37° N latitude and 61° and 75° longitude covering an area of 88.2 million hectares. It is endowed with diverse agro-climate, topography, and culture. Three of the major mountain ranges of the world, namely Himalaya, Karakoram, and Hindu-Kush (HKH), border the north followed by plateaus, plains and coastal areas in the south... The climatic variability is expressed by humid zones in the north-east to hyper-arid in the south-west and west. Major part of the agricultural and range lands lie in the arid to hyper-arid zones of the country.

The research on climate change in Pakistan is in its early stages with initial focus on studies relating to the potential impact of climate change on agriculture production and natural resource base. Several projects have been initiated in collaboration with international institutions like APN, ICIMOD, UNEP, START, etc. The focus of these initiatives is on the impact of climate change on the water resources (glacier melt, rainfall), temperature, agriculture, environment etc. Recently an inventory of glaciers and glacial lakes in the HKH region of Pakistan has been completed and a Global Change Impact Study Center established to undertake research on the impacts of climate change in a systematic manner.

The ongoing studies focus on resource inventories/vulnerability assessment and simulation modeling of the potential impacts on water resources, agriculture production, forest ecosystems and socioeconomic conditions. The major findings of these studies are summarized below.

There are strong indications that climate change is likely to impact Pakistan's agriculture in at least two ways. The Indus basin depends heavily on the glacier-melt that act as a reservoir, capturing snow and rains, holding water and releasing it into the rivers which feed the irrigation system. With the increase in global temperature there will be increase in the melting of glaciers for the next 50 years, during which time the flows in the rivers are expected to increase. Nine out of the ten General Circulation Models used by the IPCC indicate that precipitation during summer monsoon will increase substantially but is likely to be poorly distributed in time as well as in space; much of the additional rainfall is likely to be in high-intensity storms. The National Communication on Climate Change has projected the following major impacts on agriculture in Pakistan:

- a. Shift in Spatial Boundaries of Crop Potential Areas: The global climate change will affect the growing season length of crops due to higher temperature and reduced soil moisture; alter the stages of plant growth with accelerated growth early in the season, affecting the quantity and quality of biomass; affect crop pests and diseases; and entail spatial shifts in potential areas of agricultural crops.
- b. Changes in Productivity: The quality and quantity of crop yield will be affected by climate change in two ways: a) direct effects from changes in temperature, water balance, CO<sub>2</sub> concentrations and extreme events; and b) indirect effects through changes in distribution, frequency and severity of pest and disease outbreaks, incidence of fire, weed infestation, or through changes in soil properties;

- c. Changes in Water Availability: The increase in temperature has direct effect on crop evapotranspiration and loss of soil moisture. The increase in crop evapo-transpiration when combined with decrease in precipitation in the rain-fed environments resulted into decrease in crop evapo-transpiration due to limited availability and use of soil moisture by crops;
- d. Changes in Cropping Pattern: A rise in temperature and reduction in rainfall could increase the net irrigation water requirement of crops, thereby forcing farmers to make changes in cropping patterns to adjust to climate change.
- e. Changes in Land Use Pattern: The global warming, climatic extremes and CO<sub>2</sub> concentrations would lead towards changes in land use systems due to changes in the growing season of crops. The climatic changes in arid climates would result in increased salinity and/or water logging; which would certainly demand for integration of forestry and aquaculture with the crop based farming systems.

**KEYWORDS**

Research on Climate Change, Pakistan, APAARI/JIRCA Symposium

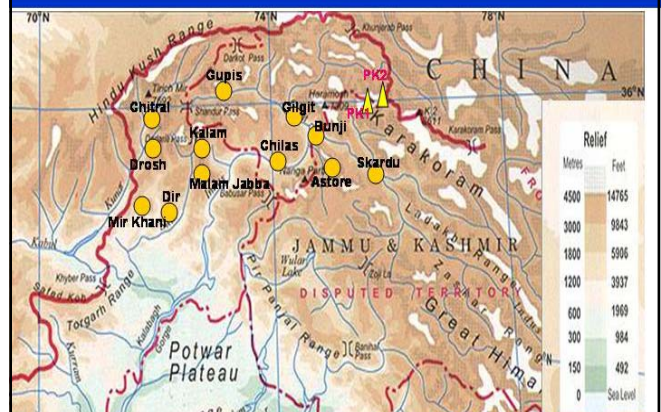
## Research Initiatives on Climate Change in Pakistan and Adaptation Strategies

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### Meteorological Stations located in Northern Pakistan



## Major Climate Change-related Concerns for Pakistan

- Recession of Hindu-Kush Himalaya glaciers threatening Indus River System flows
- Reduction in capacity of natural reservoirs (glacial lakes)
- Melting of glaciers due to global warming and its implications on river flows (seasonal, annual and inter-annual)

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### Cont...

- Increased variability of monsoon
- Changes in the quantity and pattern of precipitation, particularly in frequency and intensity of extreme events leading to floods and droughts
- Severe water-stressed conditions in arid and semi-arid regions
- Impact on agriculture productivity
- 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
- Risk to coastal areas

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## Institutions Involved in Research on Climate Change

- Global Change Impact Studies Center (GCISC)
  - Regional Climate Modeling
  - Crop Simulation Modeling
  - Watershed/Water Management Modeling
  - Human Resource Development
- Pakistan Meteorological Department (PMD)
  - Trend Analysis Using GCMs and RCMs
  - Potential Impacts on Agriculture and Natural Resources

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### Cont...

- Ministry of Environment
  - Implementation of UNFCCC in Pakistan
  - Education and Awareness
- Pakistan Agriculture Research Council (PARC)
  - Water Resources and Glaciers
- Space and Upper Atmosphere Research Commission
  - Water Resources
- WAPDA
  - Flood Forecasting and River Flows
- Educational Institutions
- Intern'l Institutions (e.g. APN, IUCN, ICIMOD, UNEP etc)

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## Glacier Research Activities

- Glaciers accumulation , movement, ablation, mass balance and runoff
- Effects of facets of debris covered glaciers on ablation
- Snow-melt runoff
- Hydro-meteorological variables and transient snowline retreat
- Relationships between topography, climate, snow-melt and snow-melt runoff
- Rock avalanches on selected glaciers
- Sedimentation yield of selected glaciers

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## Cont...

- Dammed lake and its potential hazards in selected basins
- Effect of monsoon air mass penetration in Upper Indus Basin
- Avalanches and their hazards in snow basins
- Flow forecasting for Jhelum River Basin using University of British Columbia Watershed Model

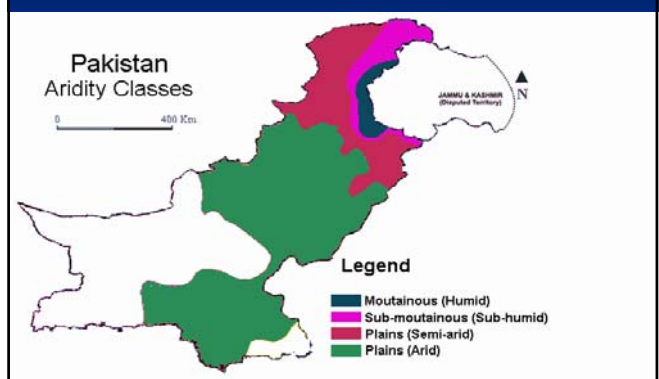
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## Crop Simulation Models

- CERES: Crop Environment Resource Synthesis (Rice & Wheat)
- CropGRO: Crop Growth (Cotton)
- Substor: Simulation of Underground Bulking Storage Organs (Potatoes)
- InfoCrop: Simulation Model (for Various Crops)
- Cotton GRO: Cotton Growth (Cotton)
- GCM: Global Circulation Model
- RCM: Regional Circulation Model

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## Agro-Climatic Zones Used by GCISC for Climate Change Impact Studies on Agriculture



## Results of Glaciers Research

### Eastern Karakoram Summer Flows

- Indus ( main) at Kachura Rising Trend

### Western Karakoram Summer Flows

- River Hunza at Dainyour Falling Trend
- River Gilgit at Alam Bridge Falling Trend

### Hindu-Kush Region

- River Chitral at Chitral Rising Trend

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## Cont...

- The summer flows trend from the Karakoram can serve as a good indicator of Temperature changes in the glaciers ablation zone
- Significant rising summer flows trend from the Karakoram eastern tributaries indicate warmer summers and glaciers recession in this region.
- Significant falling summer flows trend from the Karakoram western tributaries indicate cooling summers and stable or growing glaciers in this region.

Source: WAPDA, June 2008

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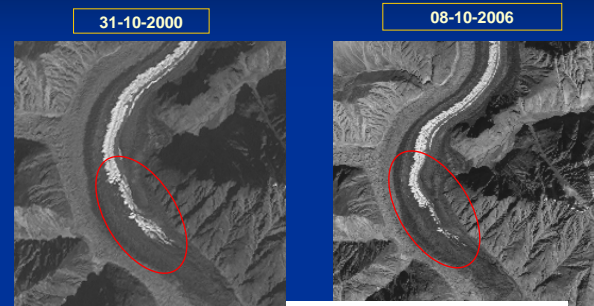
## Cont...

- In the last 25 years 0.3° C temperatures rise occurred
- Receding glaciers are signs of global climate change
- Due to glacier-melt there could be less amount of melt-water to sustain our agriculture and industrial activities in the next 50 years
- Water tables would continue to fall and the gross per capita water availability would decline
- Pakistan's agriculture, consequently economy that depends mainly on water from glacier melt would be severely affected

Source: SUPARCO, June 2008

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## Siachen Glacier Retreat

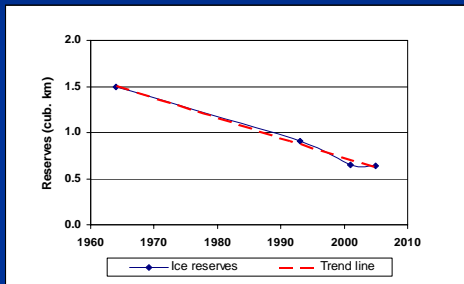


\* Siachen Glacier has been retreated about 1.8 Km in last 17 years

Source: PMD, June 2008

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## Trend Analysis of Glacier Ice Reserves



Source: PARC, 2008

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## Glaciers Inventory

- Total Number of Glaciers..... 5,218
- Total Glaciated Area..... 15041 Km<sup>2</sup>
- Est. Ice Reserves..... 2,738 Km<sup>3</sup>
- Glacial Lakes..... 2,420
- Major Lakes..... 1,328
- Potentially Dangerous Lakes..... 52

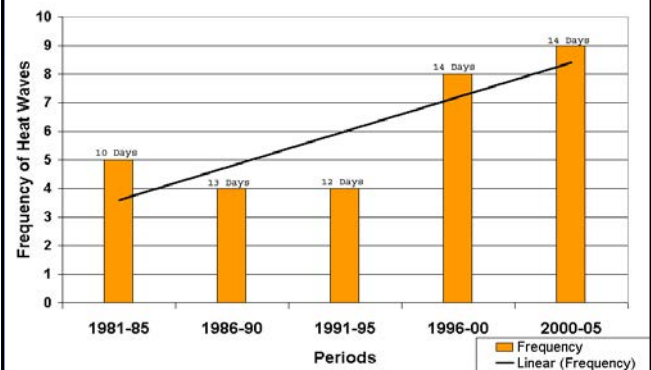
Source: PARC, 2008

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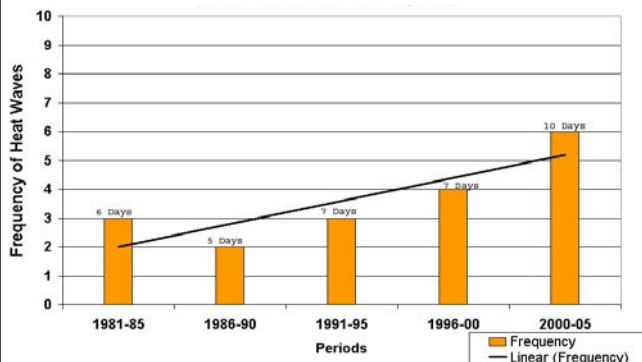
## Results of Climate Change Impact Studies On Agriculture

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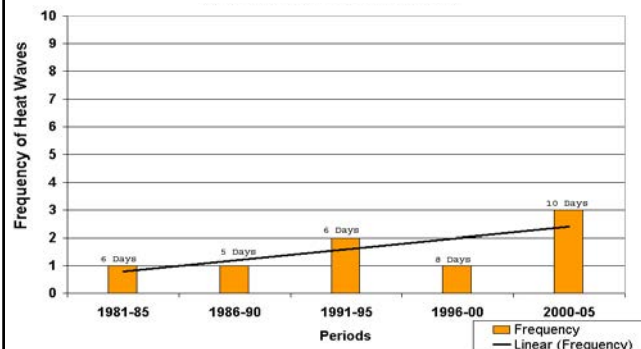
## Heat Waves over Northern Areas (April –June) When Max-Temperature > 30° C.



### Heat Waves over Northern Areas (April –June) When Max-Temperature > 35 ° C.



### Heat Waves over Northern Areas (April –June) When Max-Temperature > 40 ° C.



### 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

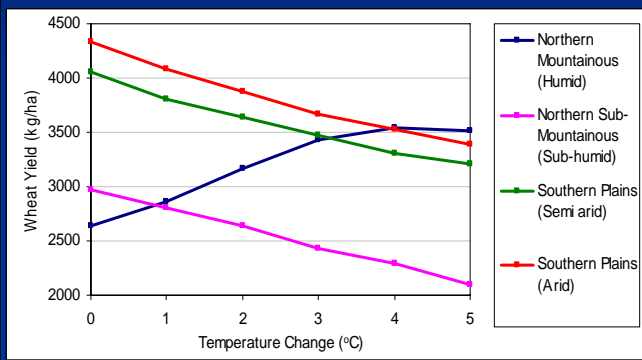
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### Impact of Rise in Temperature on Wheat Growing Season Length in Northern and Southern Parts of Pakistan

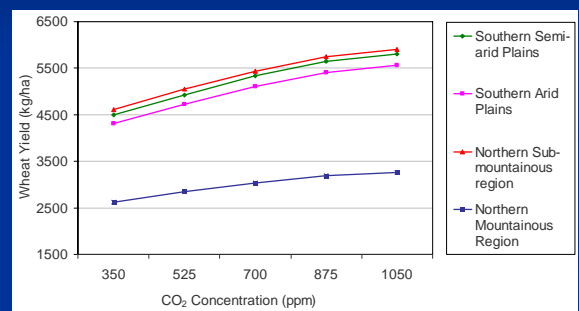
Temperature °C (increase over baseline)	Growing Season Length (Days)			
	Northern Pakistan		Southern Pakistan	
	Mountainous Region (Humid)	Sub-Mountainous Region (Sub-humid)	Plains (Semi-arid)	Plains (Arid)
Baseline	246	161	146	137
1	232	155	140	132
2	221	149	135	127
3	211	144	130	123
4	202	138	125	118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

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### Effect of Increase in Temperature on Wheat Yields in Different Agro-Climatic Zones of Pakistan (other factors remaining constant)

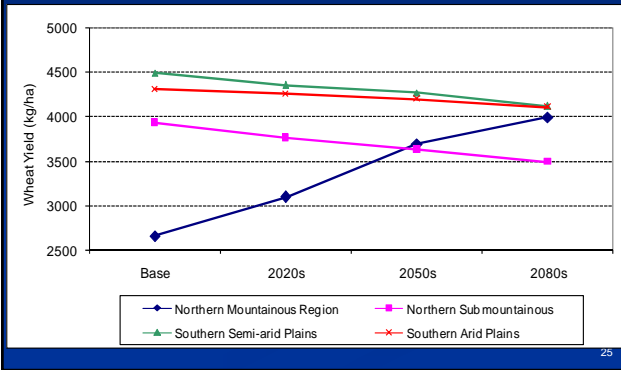


### Effect of Increase in CO<sub>2</sub> Concentration on Wheat Yield (other factors remaining constant)



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### Wheat Yield in Different Agro-Climatic Zones of Pakistan under A2 Scenarios



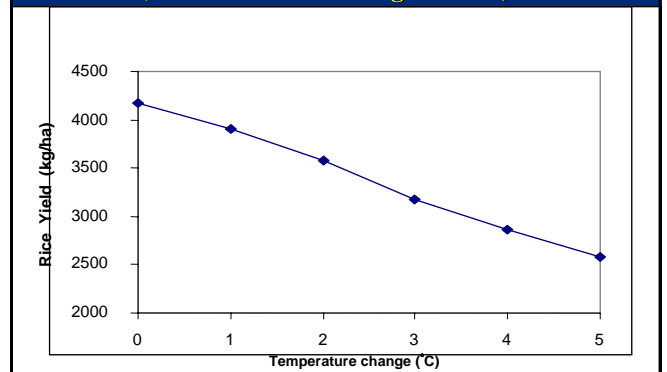
### Climate Change Impact on Wheat Production in Pakistan by 2085 under A2 and B2 Scenarios

Region	% Share in National Production	Baseline Yield (kg ha <sup>-1</sup> )	% Change in yield in 2080s	
			A2 Scenario	B2 Scenario
Northern Mountainous	2	2658	+50	+40
Northern Submountainous	9	3933	-11	-11
Southern Semi arid Plains	42	4306	-8	-8
Southern Arid Plains	47	4490	-5	-6
Pakistan	100	4326	-5.7	-6.4

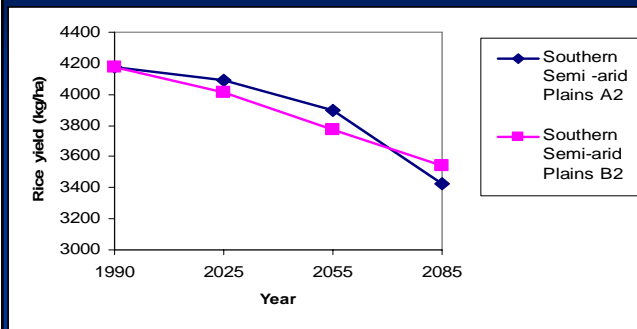
### Effect of Increase in Temperature on Growing Season Length of Rice in Semi arid areas of Punjab (Basmati Super transplanted in 1<sup>st</sup> Week of July)

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

### Effect of Increase in Temperature on Basmati Rice Yields in Southern Semi-arid Plains of Pakistan (other factors remaining constant)

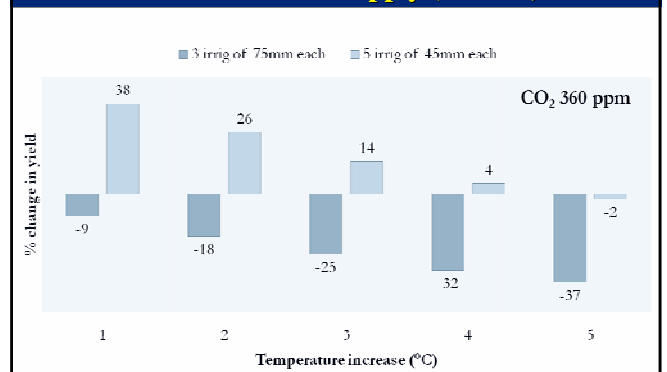


### Basmati Rice Yield in Southern Semi-arid Plains of Pakistan under A2 and B2 Scenarios

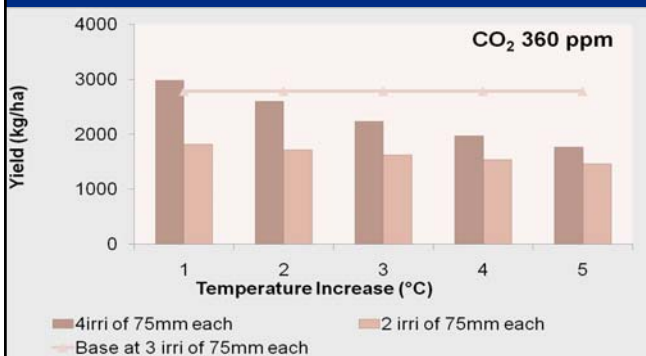


Yield decrease by 2085: 18% in A2 and 15% in B2 Scenarios

### % Change in Yield (in arid + semi-arid areas) by Changing the Irrigation Frequency with Constant Water Supply (225mm)



## Impact on Wheat Yield (in arid + semi-arid areas) due to Change in Temperature and Water Availability



## Summary of Results

- Pakistan will grow warmer by 1 ° C by 2030 and could even reach 4-5 ° C in the last 3 decades of this century.
- This would reduce yields of wheat, rice, sorghum and maize in the rain-fed areas
- Wetter monsoon zone by 12.6 %
- Monsoon shadow zone 17.5 % drier
- Shift in spatial boundaries of crop potential areas
- Changes in crop productivity
- Changes in water availability
- Changes in cropping pattern
- Changes in land use pattern

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## Adaptation Strategies

### WATER RESOURCES DEMAND MANAGEMENT

- Water metering system at watercourse heads
- Proper pricing and water market development
- Crop water requirement-based irrigation practices
- Use of resource conservation technologies i.e. adoption of high efficiency irrigation systems, raised bed technology, laser land leveling, and improved watercourses

### AGRICULTURE

- Adjustment of cropping calendar
- Development of heat tolerant wheat and rice varieties
- Advance seasonal weather forecasting
- Changes in Irrigation methods
- Changes in planting techniques for rice

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## The Way Forward

- Formulation of a national policy on climate change impacts on agriculture and adaptation strategies
- Extending the Meteorological Data Collection Network
- Joint study on climate change by key stakeholders at a national and regional level
- Formal coordination among all relevant planning, research, and implementation institutions
- Linkages with international organizations/Experts
- Collaborative research with international agencies
- Capacity building in climate change and its impact on agriculture

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## Abbreviations

- APN: Asia Pacific Network for Global Change Research
- UNEP: United Nations Environment Program
- ICIMOD: International Center for Integrated Mountain Development
- START: Global Change SysTEM for Analysis, Research and Training
- IPCC: Intergovernmental Panel on Climate Change

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## Models Abbreviations

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## IPCC Global Emissions Scenarios

- **A1:** Future world of rapid economic growth, global population peaks in mid-century and then declines and rapid introduction of new and more efficient technologies
- **A2:** one of the IPCC's two most commonly used global emissions scenarios. A2 assumes high population growth (15 billion by 2100) and energy use, slow technological progress, a regional focus, and moderate economic growth.
- **B1:** The same as A1 but with rapid change in economic structure towards a service & information economy and introduction of clean and resource-efficient technologies
- **B2:** B2 assumes moderate growth in population (10.4 billion in 2100) and energy use, moderately paced technological progress, a local focus and moderate economic growth.

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## Cont...

- Phase II (1991-1997) was initiated with the collaboration of British Columbia Hydro International and University of British Columbia Canada
- 20 Automated Data Collection Platforms (DCPs) were installed in the Upper Indus Basin (UIB)
- DCPs collect hydro-meteorological data within an elevation range of 2500-5500 meter above sea level (m.a.s.l) in the mountain ranges of the Hindu-Kush, Karakoram and Himalayas
- DCPs collect and transmit real-time hourly data on snow pack, precipitation, air temperature, humidity, wind and solar radiation.

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...ing are attributed to human activity and will affect the lives of human (IPCC 2007). Recent warmest year. The greatest warming over the next 100 years is expected to be at higher latitudes. Precipitation has been reasonably stable over the last 200 years. Pakistan will now see shift in both intensity and timing of precipitation. This could result in heavy losses to agriculture sector; Models revealed that Pests of course would appear earlier, requiring wholly different mitigation strategies. Climate change is likely to affect Pakistan in at least two ways. The Indus basin depends heavily on melting snow and rains, holding water and releasing it into the rivers which feed the irrigation system. There will be increase in the melting of glaciers for the next 50 years, during which time the models used by the IPCC project that precipitation during summer monsoon will increase substantially as well as in space; much of the additional rainfall is likely to be in high-intensity storms.

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