

# Glaciers and climate change in the Karakoram Himalaya: developments affecting water resources and environmental hazards

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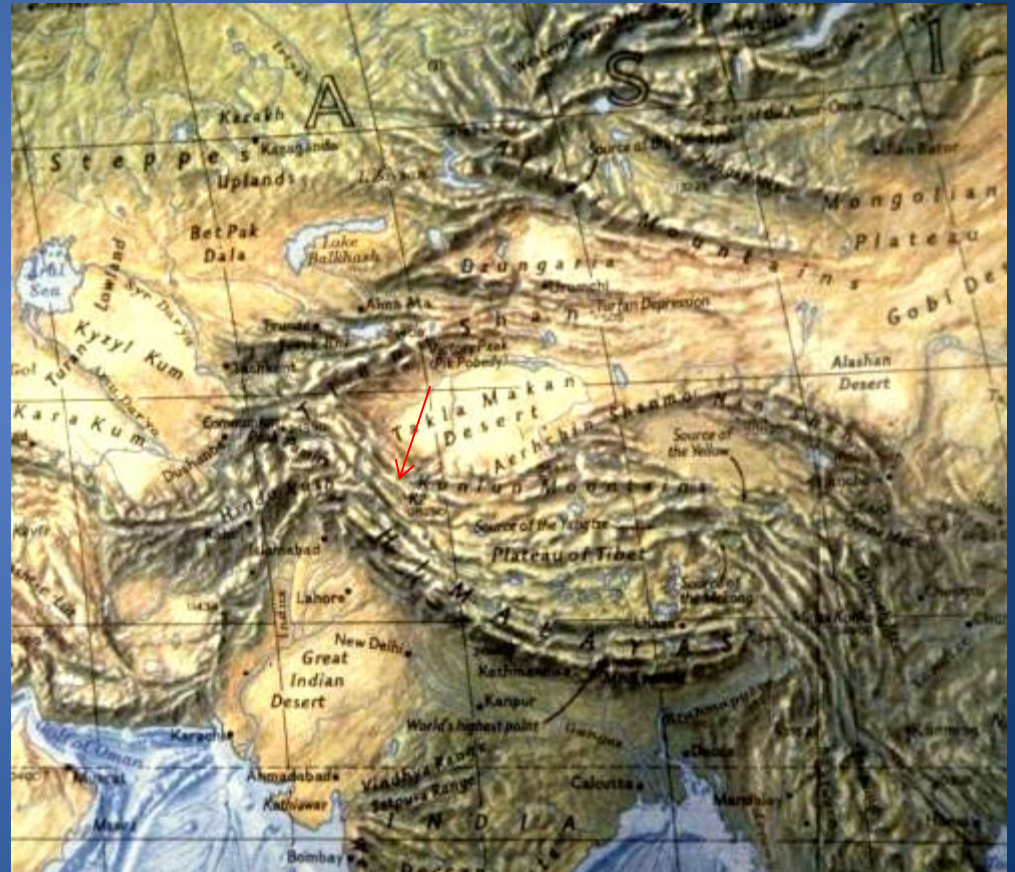
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# Glaciers and climate change in the Karakoram Himalaya

## OVERVIEW

- 1. Significance of the Karakoram glaciers
  - i) regionally and nationally
  - ii) for mountain people and habitat
- 2. Snow and ice covers
- 3. Recent changes in Karakoram glaciers
- 4. Context and key issues:
  - i) thinking vertically
  - ii) seasonal regimes
  - iii) avalanche-fed glaciers
  - iv) on-ice dust, dirt and debris
  - v) snow and ice temperatures
  - vi) shoulder seasons
- 5. Surging glaciers
- 6. Other glacial hazards:
  - i) GLOFs
  - ii) Glacier 'droughts'
  - iii) permafrost and rock glaciers
  - iv) rock avalanches and other geohazards
  - v) sediment yields and siltation



### 3. Glacier advances, thickening and surges in the Karakoram:

Why here?

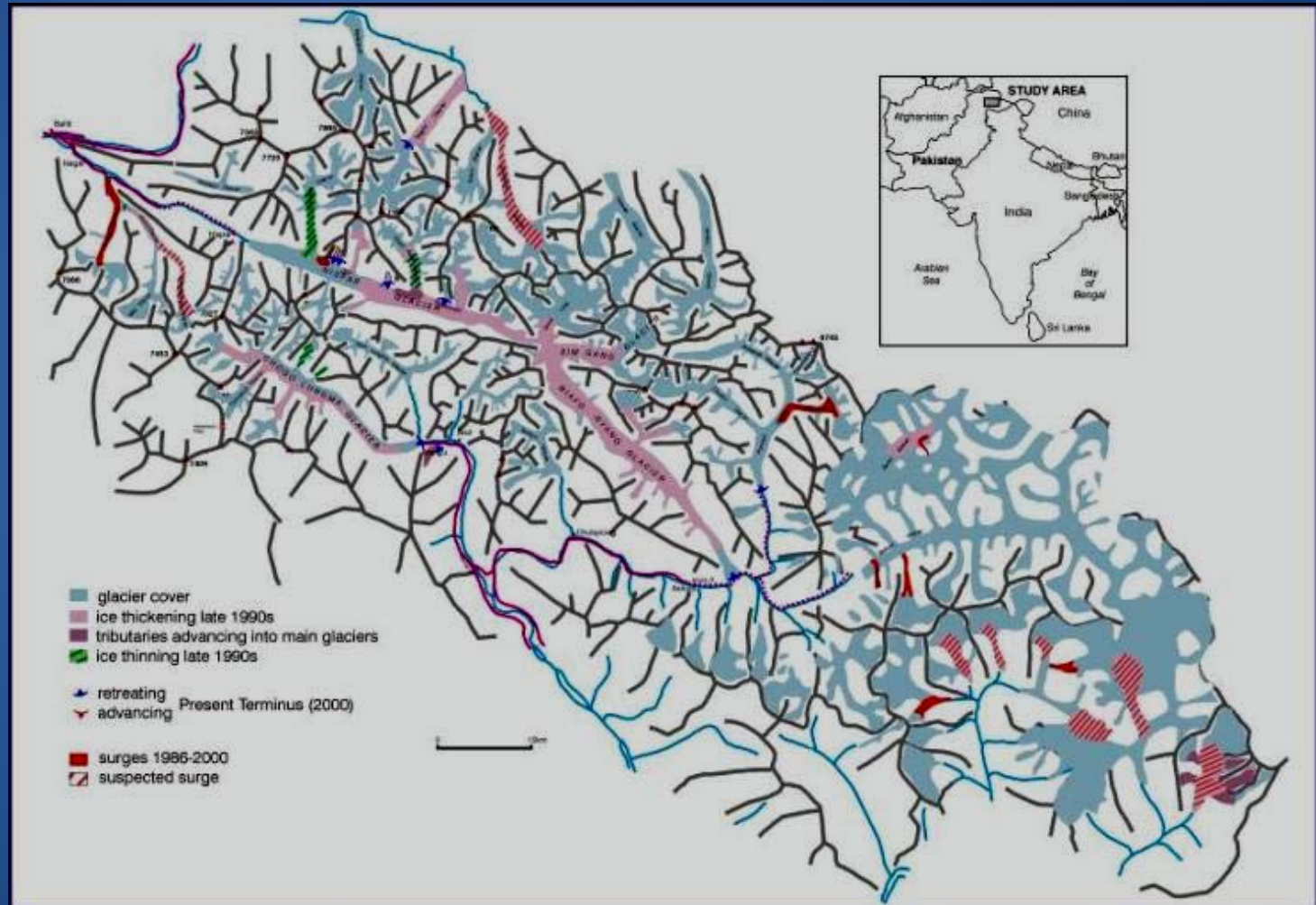
Why now?

Implications?

Most reports have mistakenly suggested that these glaciers are 'disappearing' (see below). Unlike the rest of the Himalaya and most Inner Asian ranges:

i) there has been no massive or even net reduction in the ice cover in the last three decades

ii) many glaciers have been retreating or thinned but, since 1995 I found more than 35 glaciers advancing, mid-glacier thickening in a dozen others, and a sudden increase in glacier surges



# Synopsis of recent glacier and climate change in the Karakoram

## Glaciers

- late 19<sup>th</sup>-early 20<sup>th</sup>  
Little Ice Age advances culminate
- 1920s-1970s  
General reduction by 10-15%
- mid-1970s  
Brief, minor advances
- late 1970s-mid-1990s  
Widespread, slow recession
- **mid-1990s to present**  
**Many advances and thickening**  
**Many more surges**

## Climate

- 19<sup>th</sup> C.  
Cooling, greater snowfall
- 20<sup>th</sup> C.  
Warming, summer drought
- **1960s to present**  
**Low ele.:**  
**winter warming, summer cooling**  
**High ele.:** warming?
- **1980s to present**  
**Increased summer storminess,**  
**upslope mov't rain/snow limits**



The Baltoro Glacier: best indicator or anomaly?  
It has advanced in most years since the 1950s



Some other advancing glaciers



Aling-Hushe (1997)



Chatteboi-Yarkhun (1998)

## Glacier thickening

The commonest, often the only form of glacier change reported, is terminus retreat.

However, that is usually much less significant for glacier survival, especially in the Karakoram, than changes in ice thickness.



BARPU GLACIER  
HUNZA-NAGYR  
1998

## Misleading assessments? (to date, no evidence to support these assertions )

**From: World Bank:** Report No. 34081-PK Pakistan Country Water Resources Assistance Strategy *Water Economy: Running Dry* November 14, 2005

p. xi Sobering Fact #7: Climate change. " The Indus basin depends heavily on the glaciers of the western Himalayas which act as a reservoir, capturing snow and rain, holding the water and releasing it into the rivers which feed the plain. It is now clear that climate change is **already affecting these western glaciers in a dramatic fashion (far more seriously, for example, than in the damper Eastern Himalayas)**....best estimates ....are that **there will be fifty years of glacial retreat**, during which time river flows will increase... But **then the glacial reservoirs will be empty**, and there are likely to be dramatic decreases in river flows—...conceivably by a terrifying 30% to 40% in the Indus basin in one hundred years time (Source: Rees, 2005)."

**From: The Economist, June 2008:** "...Mr Hasnain estimates that **Himalayan glaciers will be gone in 20-30 years**. That would leave many great rivers depending on seasonal rainfall. According to the IPCC, this may **be the fate of the Indus...by 2035...**"

The Guardian 2008 "...The problem is perhaps most acute in Asia, where glaciers are an important source for nine major rivers which run through land occupied by 2.4 billion people. In Pakistan, for example, 80 per cent of agricultural land is irrigated **by the Indus, which the WWF last year highlighted as one of the world's 10 big at-risk rivers because retreating glaciers provide 70-80 per cent of its flow...**"

**From: OXFAM, November 2007** "Over the past decade, the retreat of glaciers and the thawing of permafrost in the Himalayan highlands in north Asia have accelerated. Supplying seven of Asia's great rivers – the Ganges, **Indus**, Brahmaputra, Salween, Mekong, Yangtze and Huang He – the glaciers... **ensure a year-round supply of water to billions of people**. The impacts of glacial retreat range from increased risk of flooding in Himalayan catchment areas in the short-term, to reduced river flow in the long-term. Initially, accelerated Himalayan glacial runoff will increase the risk of lethal glacier lake outburst floods, flooding, avalanches and mud flows..."

**From: Asia Development Bank 2007** "...Rivers dependent on glacial melt from mountain ecosystems... **will be altered or dry up altogether.**"

**DFID 2004** "... Glaciers in the Himalayan mountain ranges will retreat further, as temperatures increase: **they have already retreated by 67% in the last decade**. Glacial melt would lead to increased summer river flow and floods over the next few decades, followed by a serious reduction in flows thereafter...."

However, while these changes are not (yet) happening in the Karakoram, that does not mean climate and glacier changes are not a problem! But, some of the main and newest problems are being missed or ignored.



## Where glacier melting actually happens:

Biafo Glacier and some dimensions (Hewitt et al,1989)



Length:	68 km
Area:	627 km sq
= appr. 4% Karakoram Indus ice	
Av. Width:	3 km
Max. depth	1.1 km
Av. ablation zone depth	c.400 m
Max. annual ablation	7 m
Av. Annual ablation (abl. Zone)	c.3 m

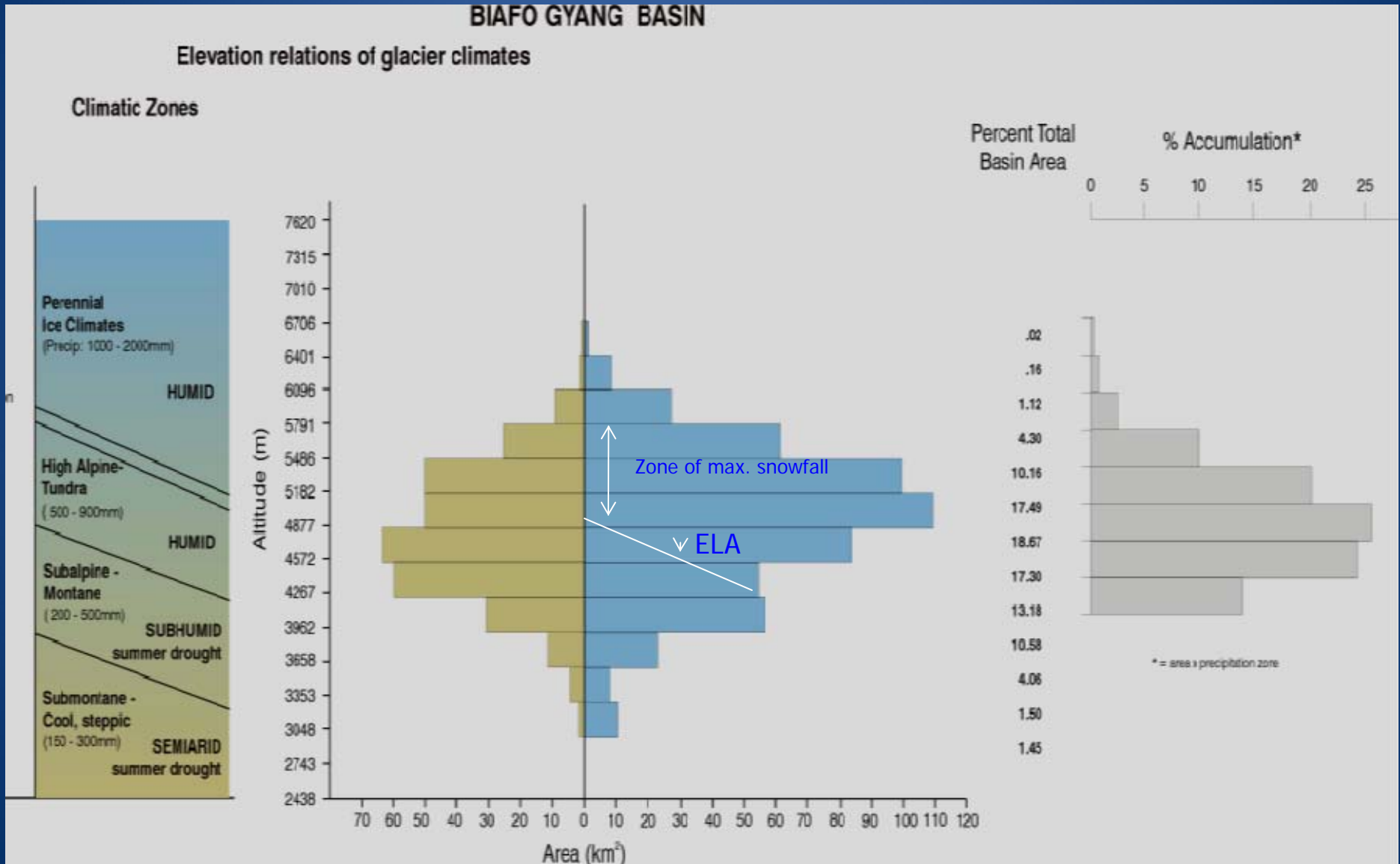


**The Biafo Accumulation Zone:**

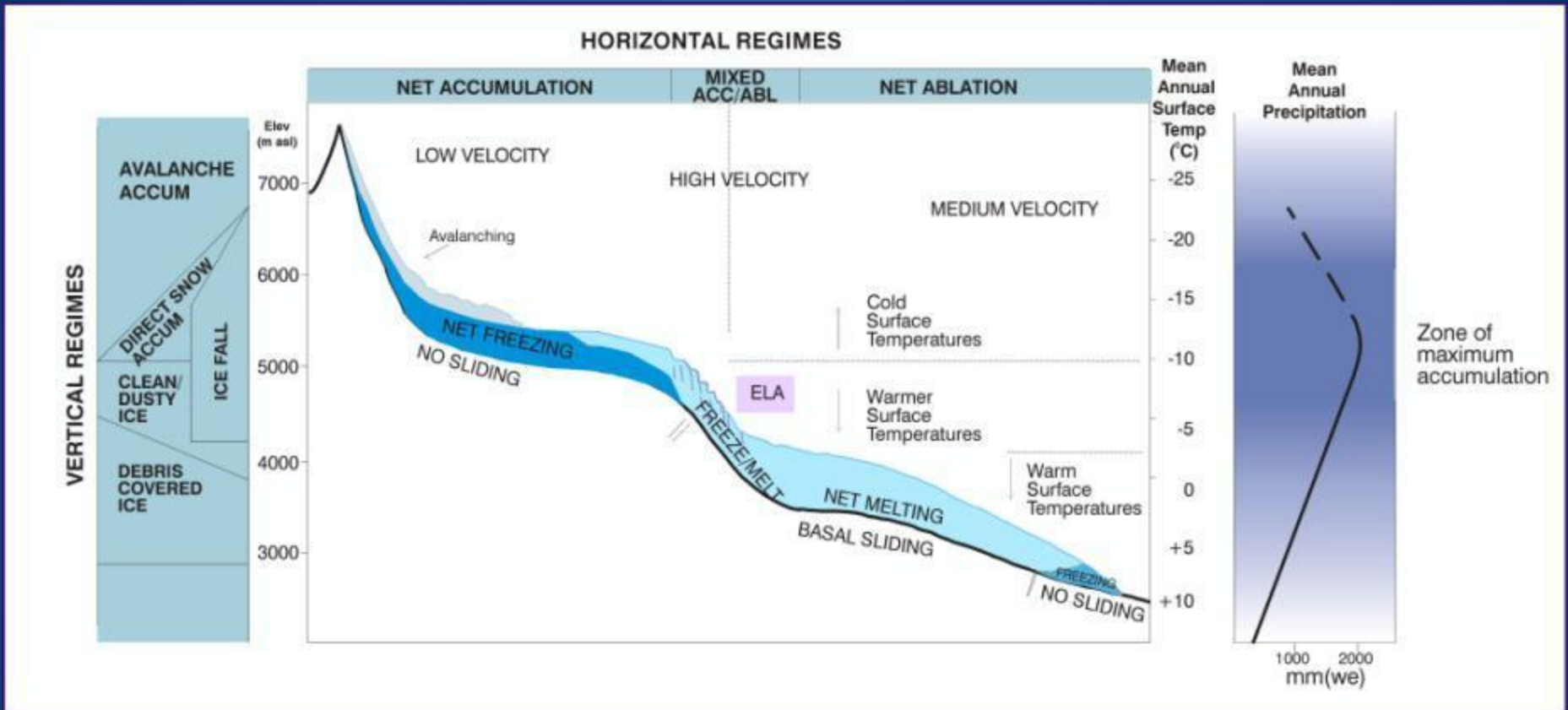
2/3rds of the glacier's area and at 4,800 - 7,300 m asl,  
Maximum snowfall in excess of 1,000 mm (water Equiv.) between 5,000-6,000 m asl



# 4. Thinking climate vertically is key! Area-altitude relations of climate and ice mass



Seeing climate vertically: glacier environments in the central Karakoram showing regime factors that control ice behaviour and responses to climate change.



Points to emphasise:

1. Zone of maximum precipitation, 5,000-6,000 m asl, **entirely within glacier accumulation zone** --- and 2,500 m or more higher than in eastern Greater Himalaya of Nepal
2. Snow avalanching and glacier nourishment : at all elevations but **prevailing in accumulation zones**
3. Predominance of **ablation-enhancing clean/dusty/dirty ice** in largest areas of ablation zone ice; heavy ablation-reducing debris covers in lower ablation zone
4. Altitude dependence of **ice thermal regimes**
5. Climatic change will primarily affect **the heights and vertical extent of controls** and glacier responses

## Thinking climate vertically

The accumulation zones and mid-, to upper-ablation zones above 3,800 m asl are the most critical for glacier survival and water supply



## Some basic considerations of snow and ice in water supply for Pakistan

Total snow and ice cover and melt water production are much less important than:

- i) the bulk of meltwater yields coincide with the Summer monsoon
- ii) 90% of glacier melt comes in about 2 months of the year (July-Aug.);  
90% of snow and glacier melting in about 3 months  
-- most of it goes to the sea!
- iii) variability of summer weather: huge ups and downs of water yield between sunny (high flows) and stormy (low flows) weather
- iv) in most years, less glacier melt means higher monsoon rains, but 'worst-case scenarios' are when both are high (major flood years), or both low (droughts)
- v) 'shoulder season' yields; critical for agriculture, hydropower, dam storage and cities -- NB: only snow melt involved in Spring, only glaciers in Fall
- vi) the history of natural hazards affecting water supply and infrastructure shows them to have been worst with greater snowfall (avalanching etc), cold (less melting and water availability, shorter summers in mts) and advancing glaciers (great ice dams, GLOFs, land loss in mts)
- vii) absent monitoring and poor forecasting capabilities for the glacial regions of the Upper Indus basin

# Some other concerns

- avalanche-fed glaciers
- on-ice dust, dirt and debris
- snow and ice temperatures
- seasonal regimes and 'shoulder seasons'
- glacier hazards
- catastrophic rockslides
- problems for large dam projects



### Avalanche-fed glaciers

As much as 80% of the ice in Karakoram glaciers has been avalanched through 1,000m+ before incorporation. Ice avalanches are also common.

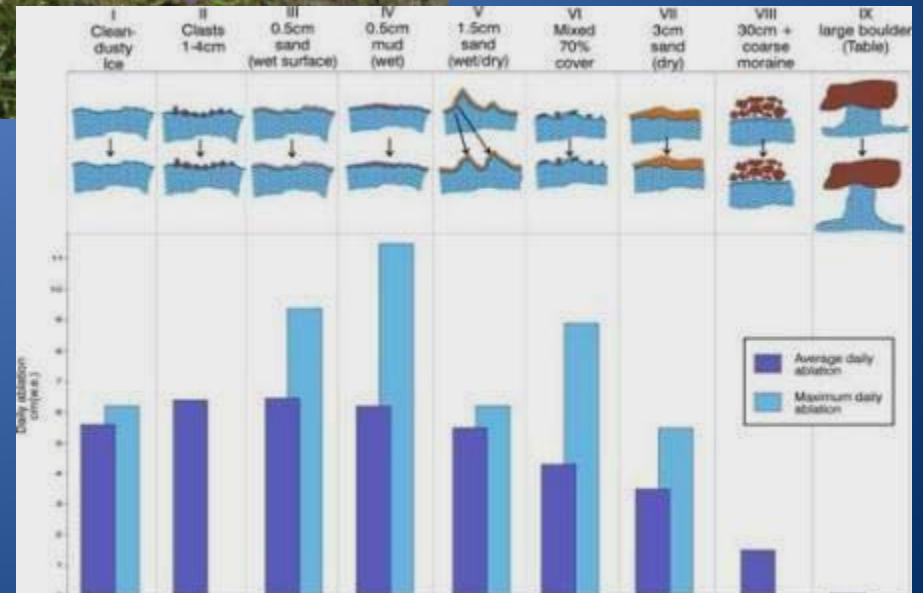






### Dirt and debris on ice:

- Major impacts on melting rates, water yields and responses to climate change.
- Dust and thin dirt enhance melting.
- Heavy debris on lower glacier protects ice in warming trend



## Glacial Lake Outburst Floods (GLOFs)



1. Small but locally severe GLOFs are the most widespread and frequent. They are the only ones reported in the UIB in the past several decades. All the known large events have occurred in periods of glacier advances.
2. More than 80 glaciers of intermediate-to-large size (10-65 km in length) have been, or could be, associated with large GLOFs, but are relatively rare.

Most large Karakoram ice dams and regionally disastrous GLOFs involve tributary glaciers entering main river valleys



Example: Yazghil Gl. Shimshal. (K.H. 1999)

Large GLOFs here differ from those associated with glacier retreat and recently emphasized elsewhere in the Himalaya and Inner Asian mountain ranges.

**NB: Only one reported major GLOF involved a moraine dam, and ALL involved glacier *advances*.**

## Glacier surges

1. In the past 150 years, 31 glacier surges are documented in the Karakoram involving 19 glaciers.
2. Many other glaciers have features associated with surge behaviour and may surge.
3. Since 1985, 15 surges have been recorded, more than in any comparable period since the 1850s. Twelve were high elevation, tributary glacier surges. (Hewitt, 1969; 1998; 2007).



## Catastrophic rockslide rock avalanches?

From: IPCC Climate Change Asia "...Glacier melt in the Himalayas is projected to increase flooding [and] **rock avalanches from destabilised slopes** ..."



## Rock avalanches in the Upper Indus basin

Inventory to date. 310 –

12 in last 150 years, only one in inhabited zone, 11 on glaciers



The 1986 Bualtar Glacier rock avalanches  
(viewed in 1987)

The range of glacier-related hazards: background to an 'all-hazards' approach.

Glacier hazards arise from advances and surges, retreats, sedimentation, GLOFs and meltwater floods, glacier-dependent 'droughts'.

Other hazards involve rainstorms, earthquakes, avalanches, catastrophic rockslides, debris flows, degrading permafrost and rock glaciers.

All these hazards are affected by climate change.

Of course, nothing has been as devastating or disruptive as the wars, refugee movements and social unrest.

As the map suggests some or all of these may be scattered along the same valleys.



#### The Karambar-Upper Yarkhun Example

At least nine glaciers have entered and blocked the Karambar River in the last 100 years. Those of the Karambar Glacier are indicated by known outburst floods in 1844, 1861, 1893, 1895 and 1905. This glacier also surged and interfered with the Karambar River in 1955 and 1993, without sealing a dam. Here, and other cases where the ice is back from the rivers, steep tip heaps of terminal or 'fan' moraine constrict the rivers and introduce large amounts of coarse sediment, affecting stream slope, sediment movement and storage.

# Climate change and dams built on the main Indus?

## Catastrophic rockslides and Diemer Basha dam.

### Project Description

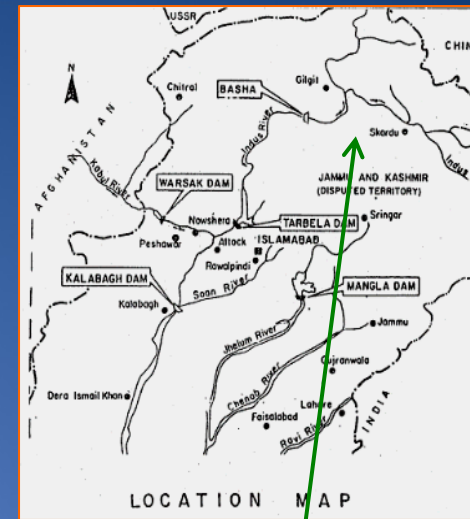
- Recommended after site and project assessment by Montreal Engineering, 1980s, with updates to design in early 2000s.
- The dam will impound a 100-km-long reservoir with a gross storage capacity of 7,3-million acre-feet of water covering an area of 110 km<sup>2</sup>.
- It will impound about 15% of the annual flow of the river.
- It will be the highest roller-compacted concrete type in the world, with an estimated lifespan of 100 years.
- The dam will also require the realignment of the Karakoram highway, a 100-km stretch, which will be submerged after the dam is filled.
- Once complete, the project will contribute more than 18 000 GWh/y to the national grid.

### Value

\$6,5-billion.

### Duration

The project is expected to be complete by 2016.



**The Lichar Landslide Complex, Indus Valley**  
- prehistoric and the only catastrophic landslide identified before the 1990s, but mistaken for the much smaller though disastrous 1841 event