BC and Climate Change at the Third Pole

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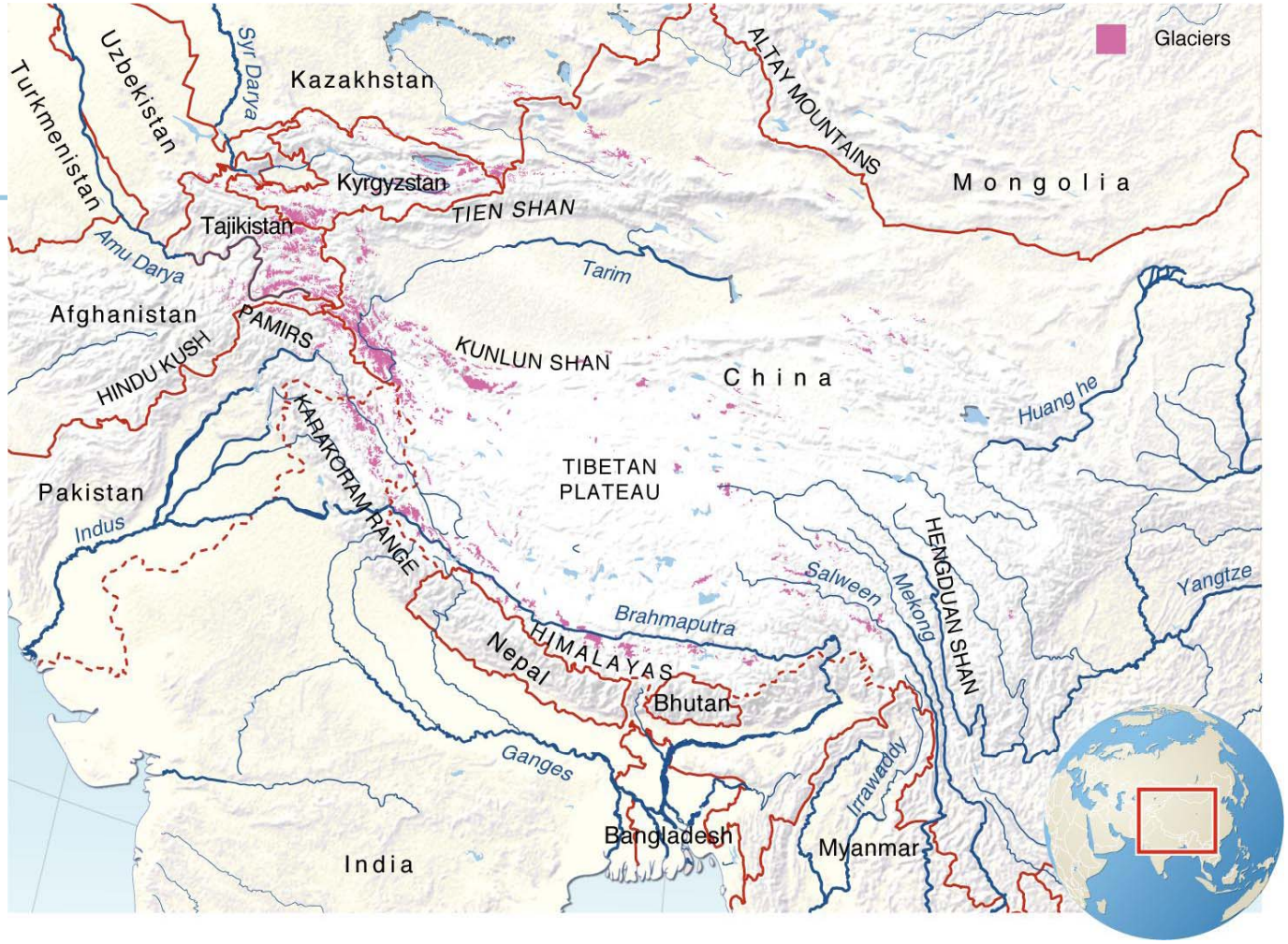
February 17, 2010



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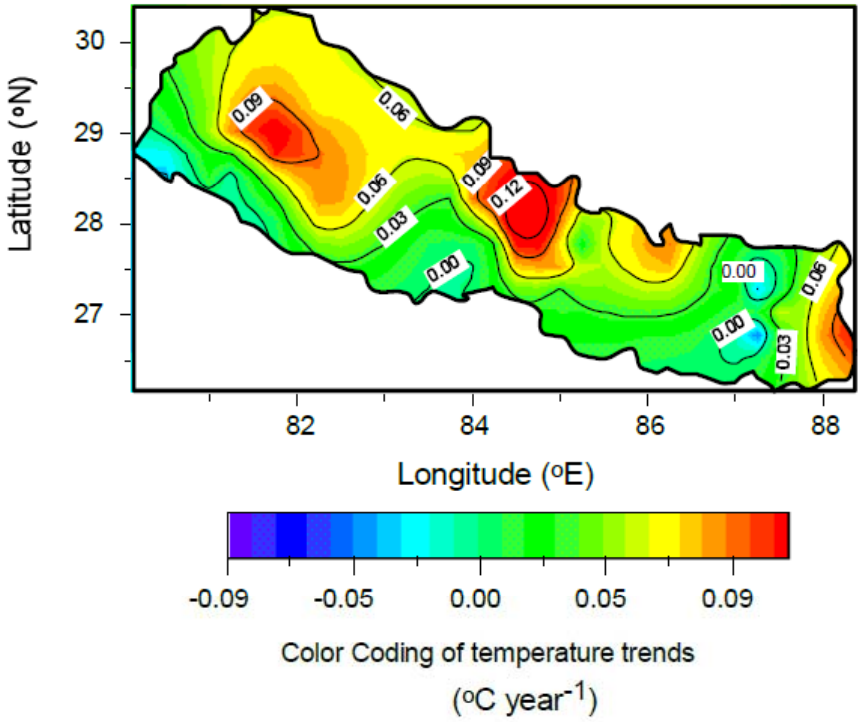
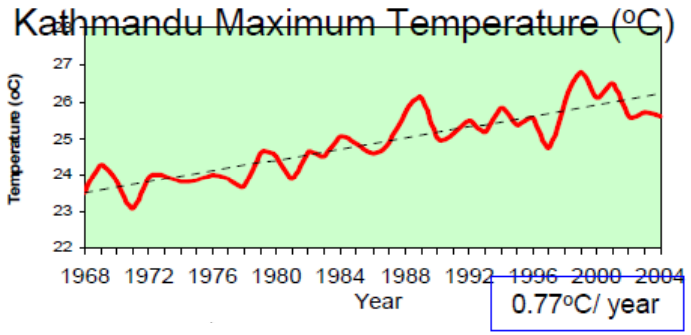
3rd Pole warming 3x faster than global average

Spatial Distribution of maximum temperature trends in Nepal for the period 1977 to 1994.



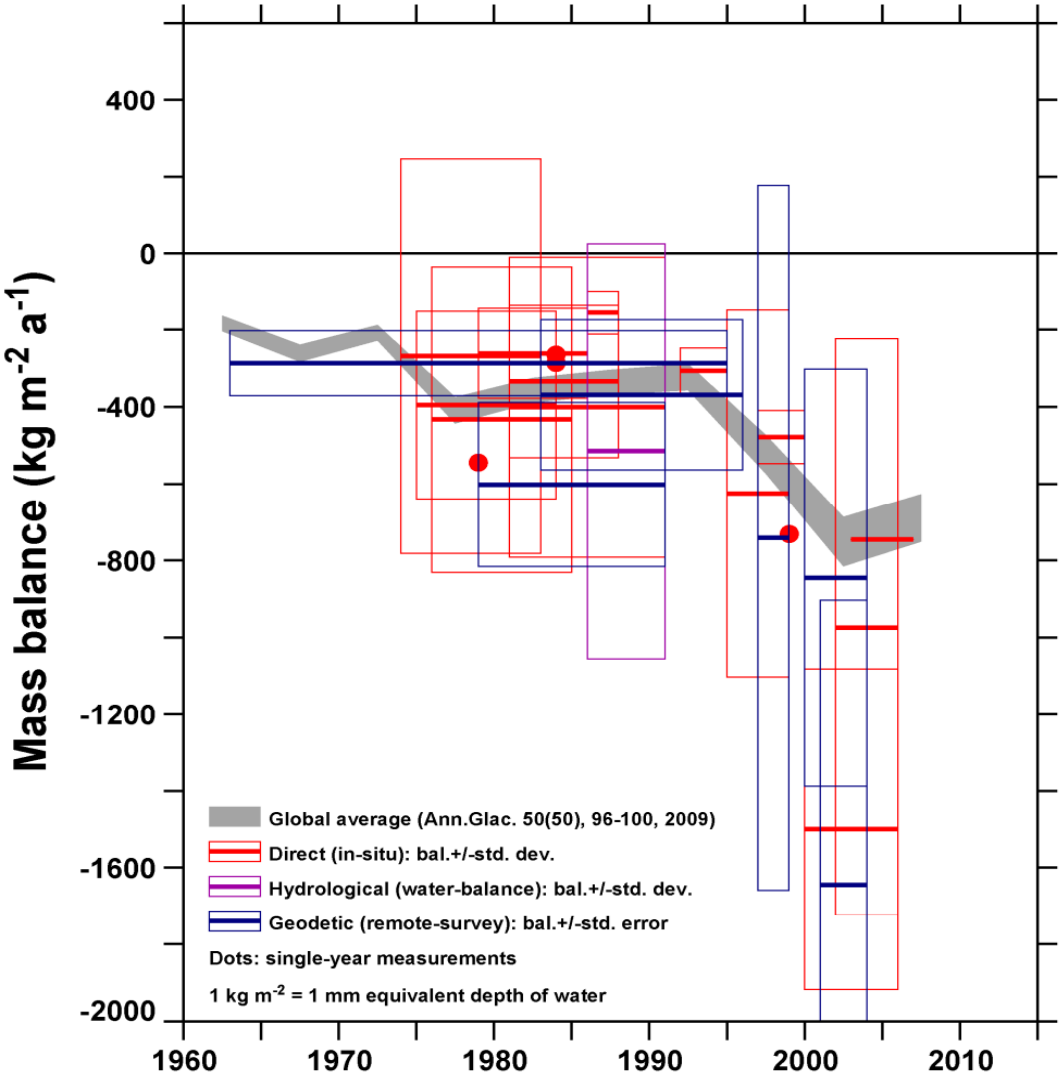


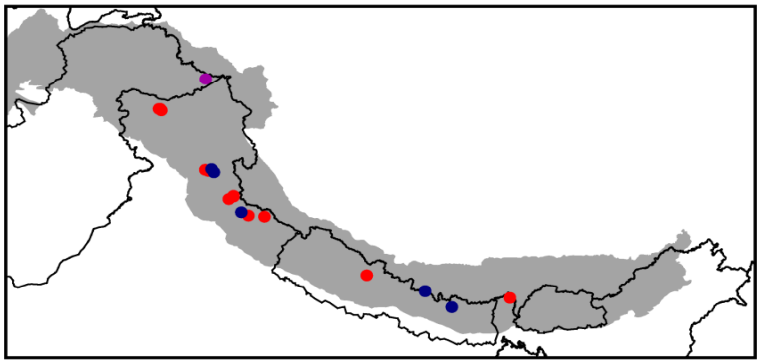
- Maximum temperatures in Nepal rising faster than region.
- Temperature increase greater with altitude.
- Winter temperature did not go below 0 °C in 2008-2009.

Courtesy of Dr. Madan Shrestha, DG, Met. Service, Nepal

NASA/GSFC

Himalayan glaciers = (-) mass balance





The graph shows all published Himalaya-Karakoram (HK) measurements; they are more negative after 1995 than before. The map shows where the measurement sites are.

Mass balance varies greatly year to year; these are series averages. Boxes suggest estimated uncertainty.

References: Kargel, Fujita

More than 80% of glaciers in Western China are retreating; areal decrease = 4.5% in 50 years

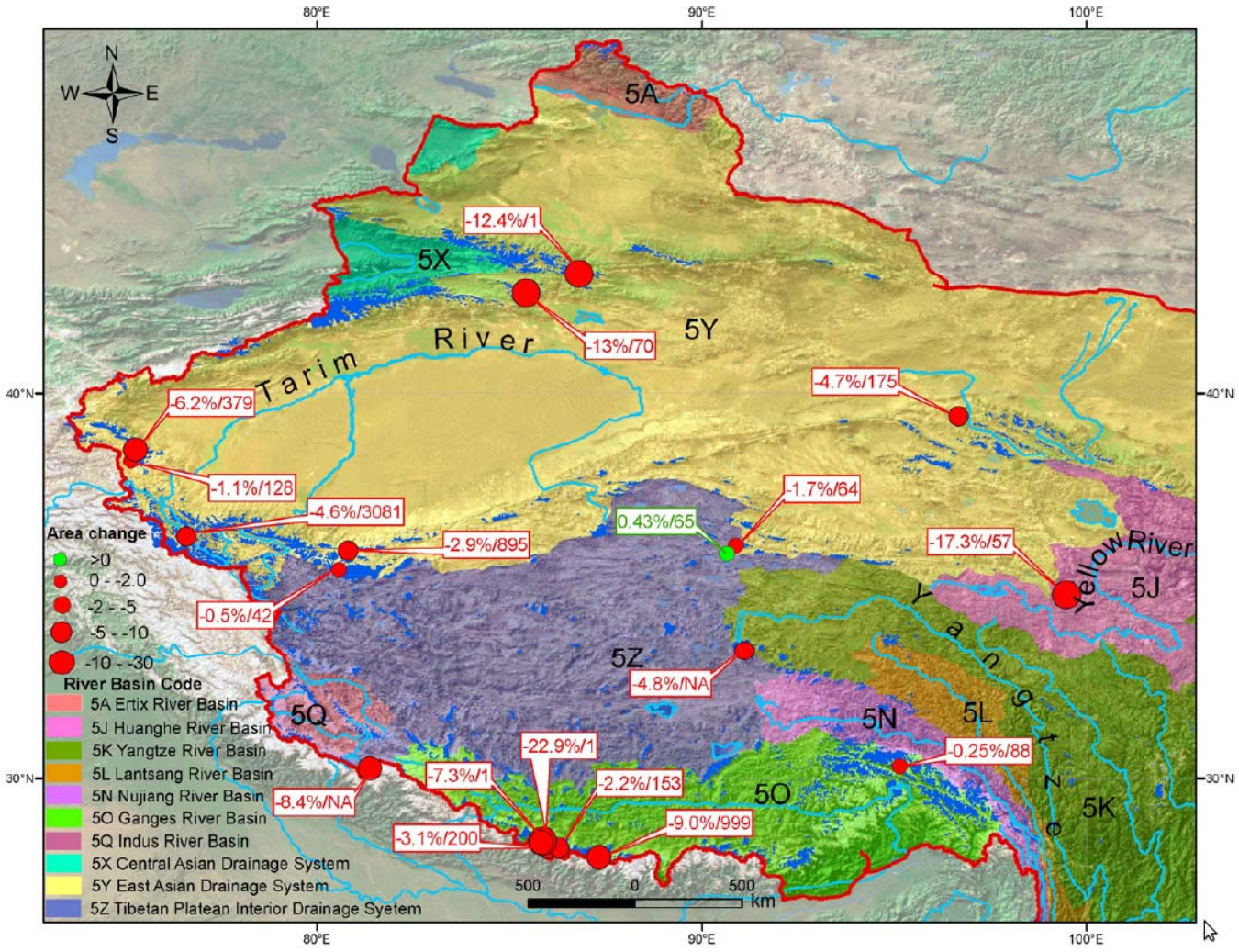


Fig. 4. Glacier change in China (The dot denotes the magnitude of change of glacier areal extent, the number with the dot shows the percentage of area change and number of glaciers that have been investigated).

Reference: Li, 2008

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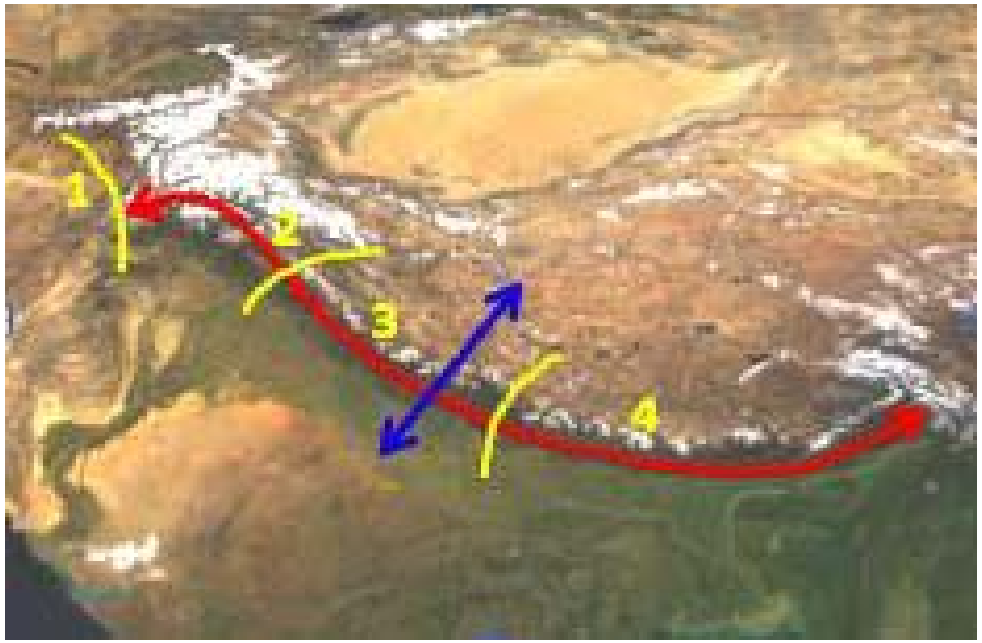
Glacial behavior is not uniform across the region



Greater Himalayan Range can be roughly divided into 4 'zones' based on differences in air currents, precipitation, glacier types, and sensitivity to warming.

1. Afghanistan relatively stable or slowly retreating
2. NW Himalayas & Karakoram very complex, includes surging/advancing, stable, and retreating glaciers
3. India, SW Tibet, W Nepal mainly stagnating, retreating with slower periods of in 20th & 21st
4. Nepal, Bhutan, Sikkim, SE Tibet rapid disintegration, many lake lakes forming, esp. since 1960s.
5 Central Tibetan glaciers are relatively stable, while surrounding ranges (Qilian, KunlanShan, TienShan) are experiencing extensive mass loss.

Reference: Kargel; Li, 2008

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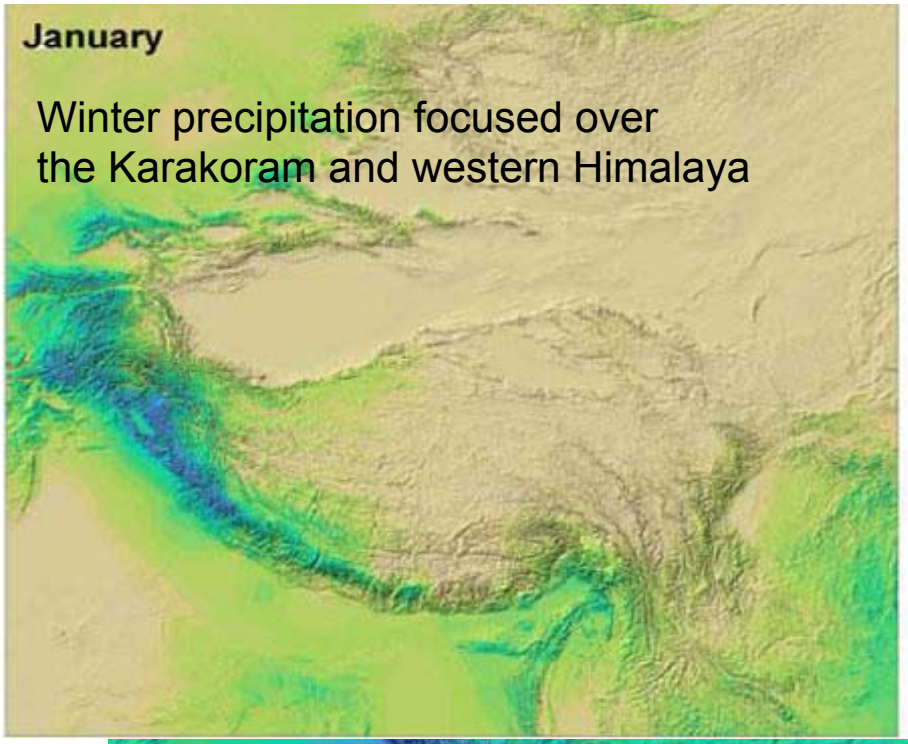
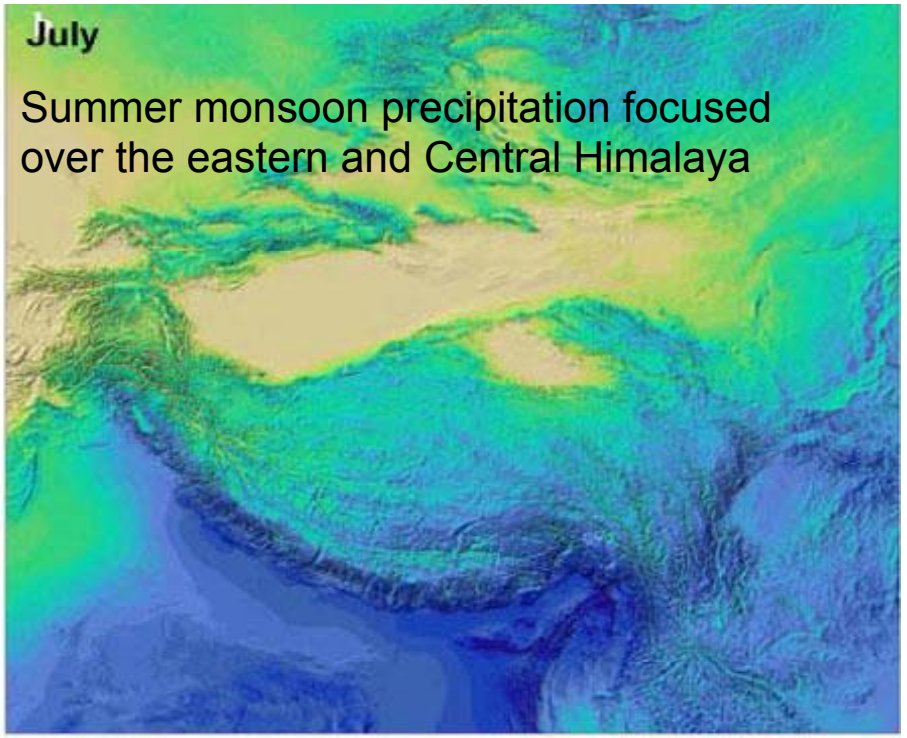
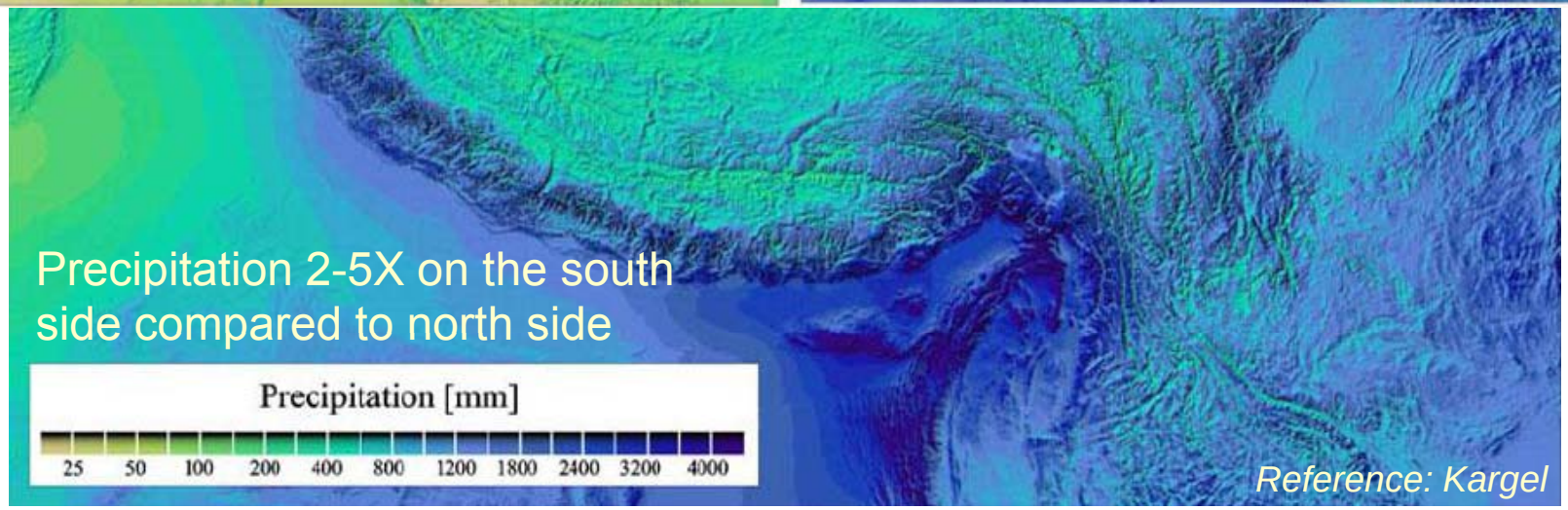
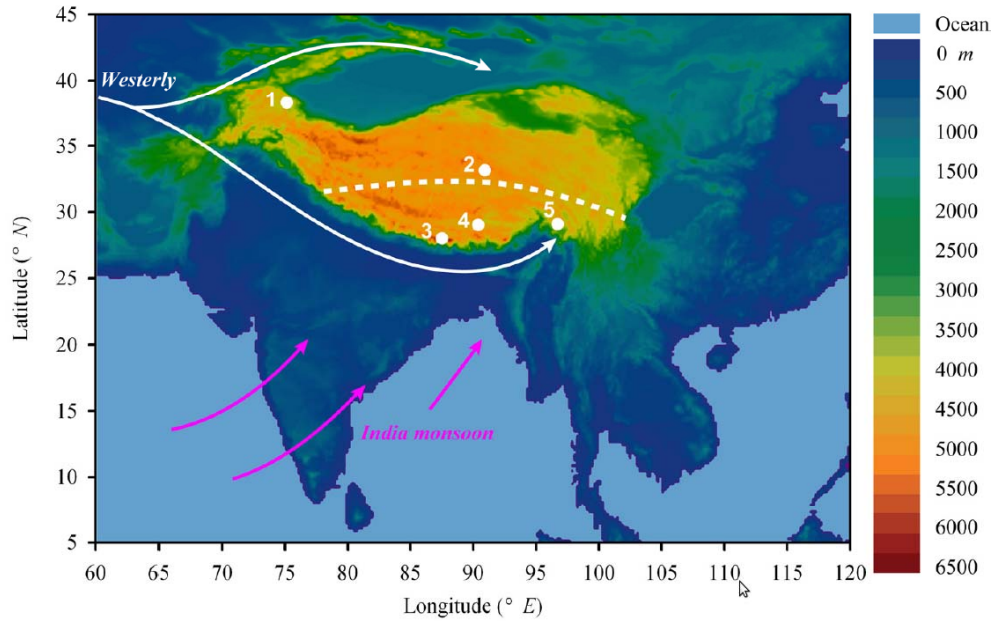
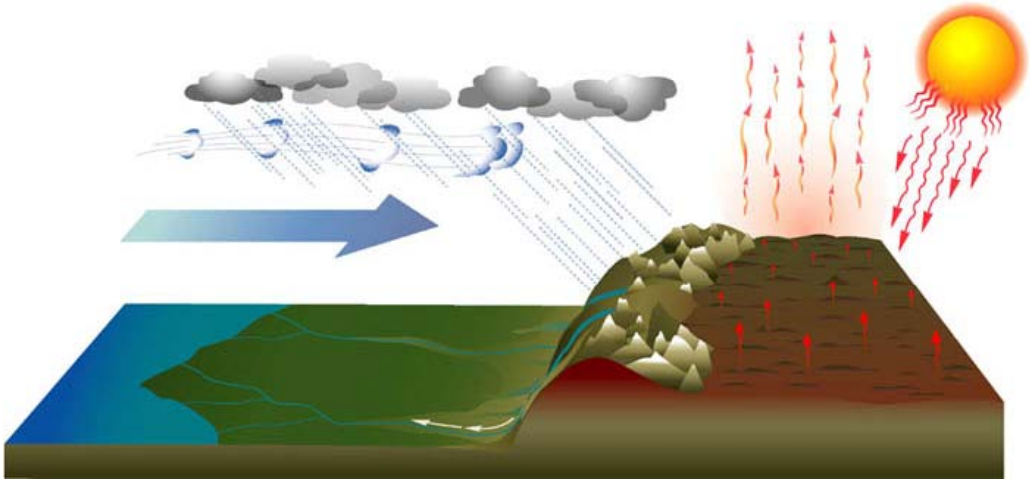


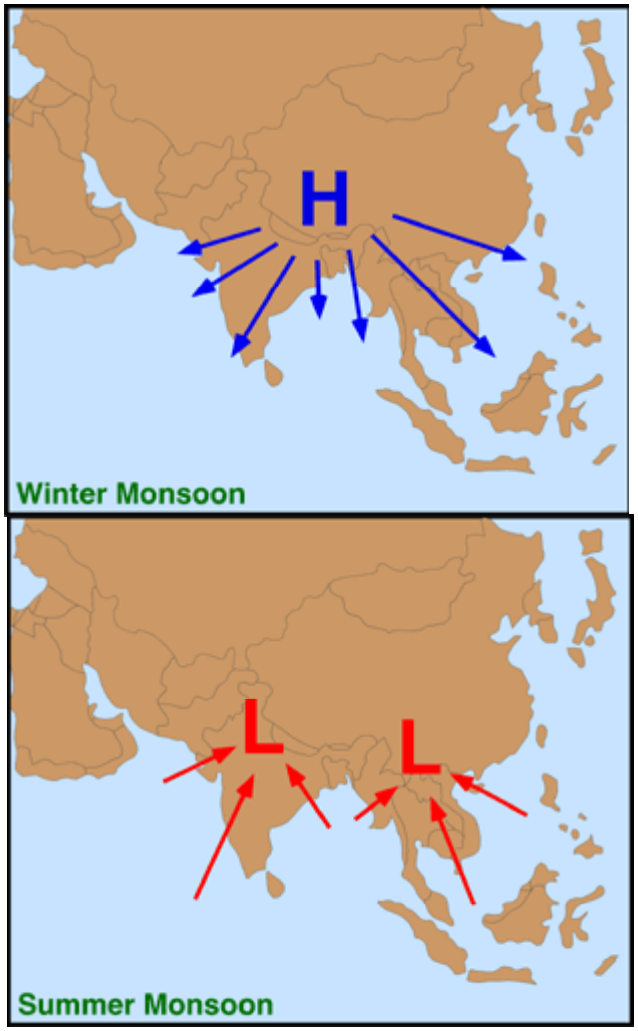




The monsoon is the foundation of the climate system – and economy – in this region.

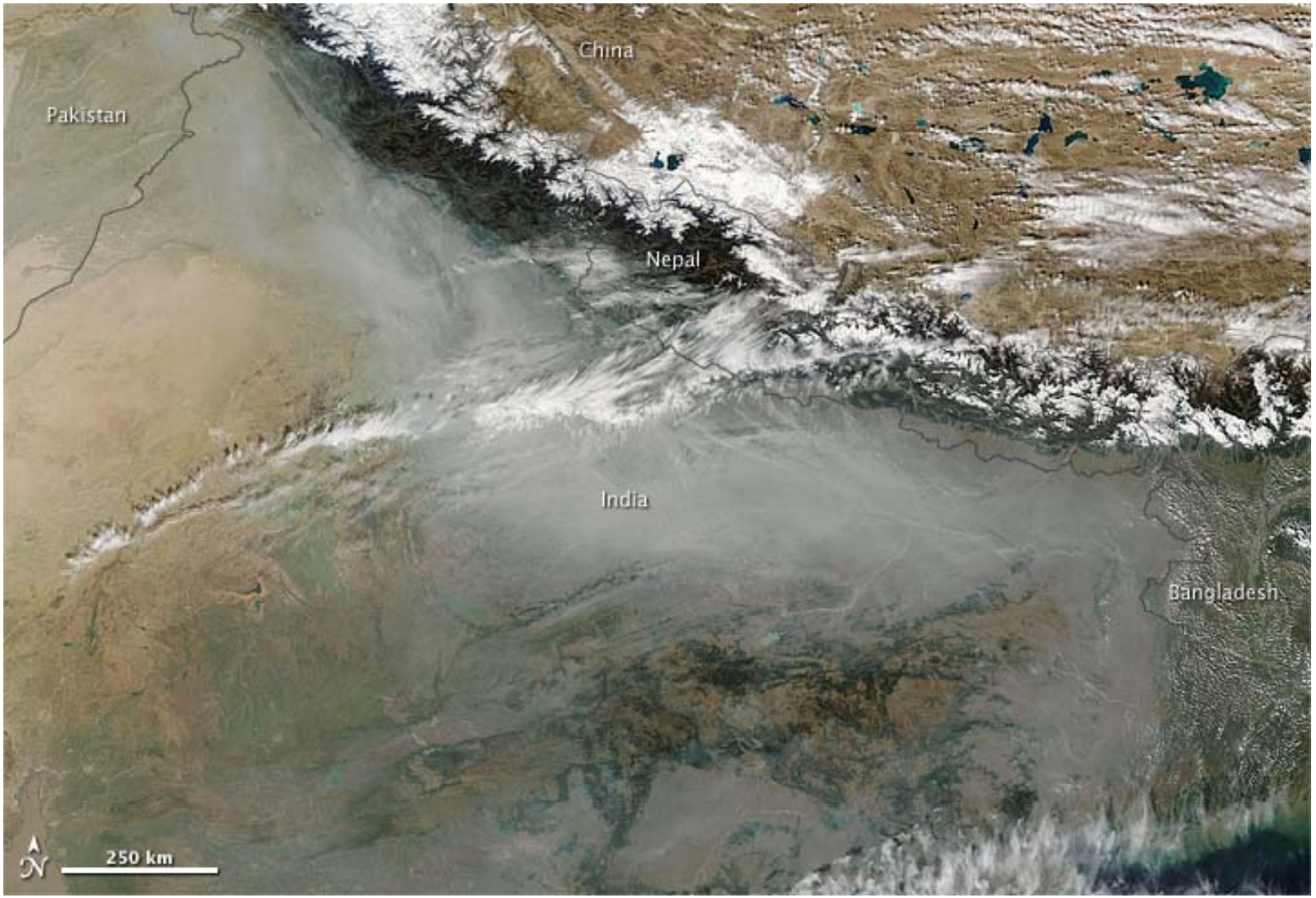






Reference: Xu, 2009

Atmospheric BC impacts climate at the 3rd Pole



Winter haze hugs the southern face of the Himalayas, causing health problems and warming the atmosphere. December 2, 2009. NASA

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seal2.jpg

Atmospheric Brown Clouds (a mixture of soot and other particles) are clearly visible looking south from a point near the crest of the Himalayas in Nepal. In contrast, the view to the North is relatively clear

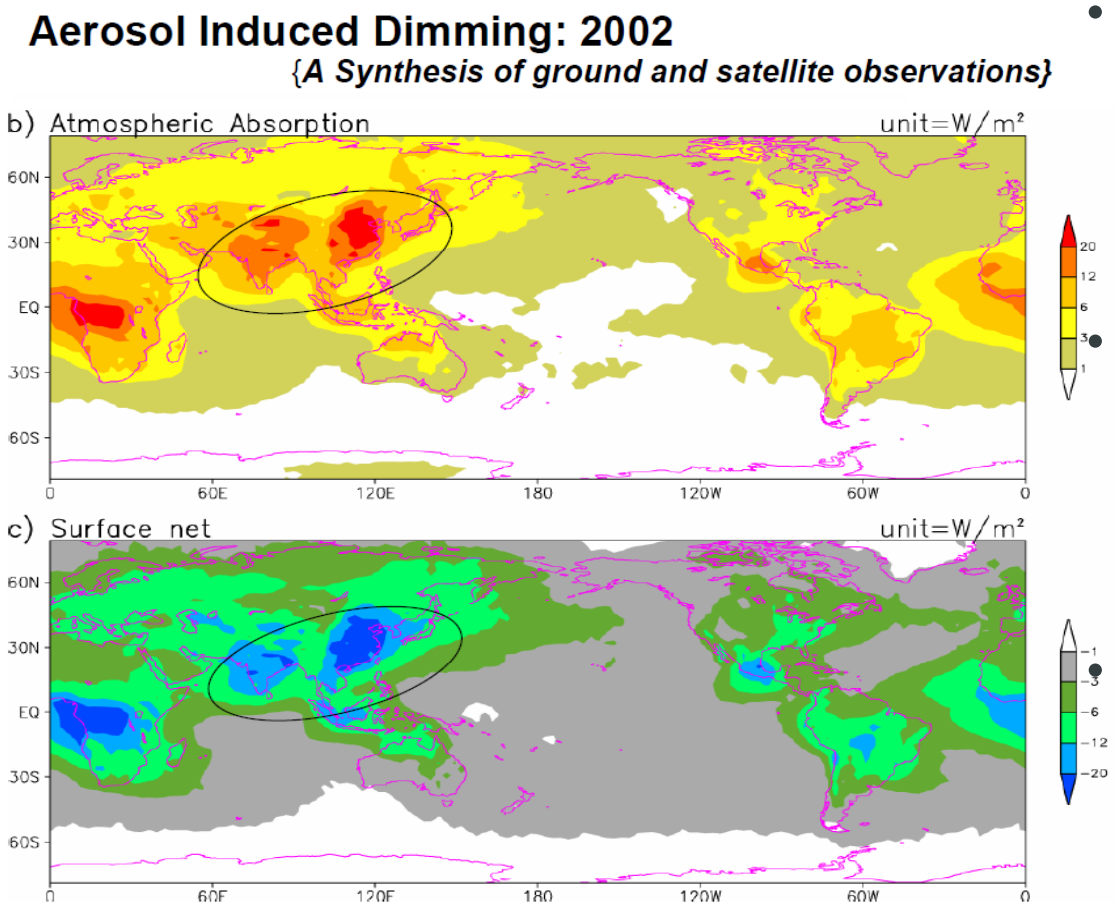
Looking South

Looking North (Mera Peak)

Inkhu Khola Valley, Solu-Khumbu, Nepal at ~4300m

Kaspari

Numerous studies predict that anthropogenic aerosols will impact Indian summer monsoon



Reference: Chung, Ramanathan, Kim, Podgorny, 2005

- Ramanathan's solar-dimming (SDM) theory focuses on Northern Indian Ocean - predicts monsoon will weaken.
- Lau's elevated heat pump (EHP) focuses on N India and Himalayan foothills - predicts monsoon will intensify and start earlier.
- Evidence suggests EHP enhances early monsoon rainfall (increases flooding), SDM leads to weakening of later monsoon (shorter, more droughts).

References: Ramanathan,Chung, Lau, Gautam

BC + dust aerosols enhance pre-monsoon warming south of the Himalayas

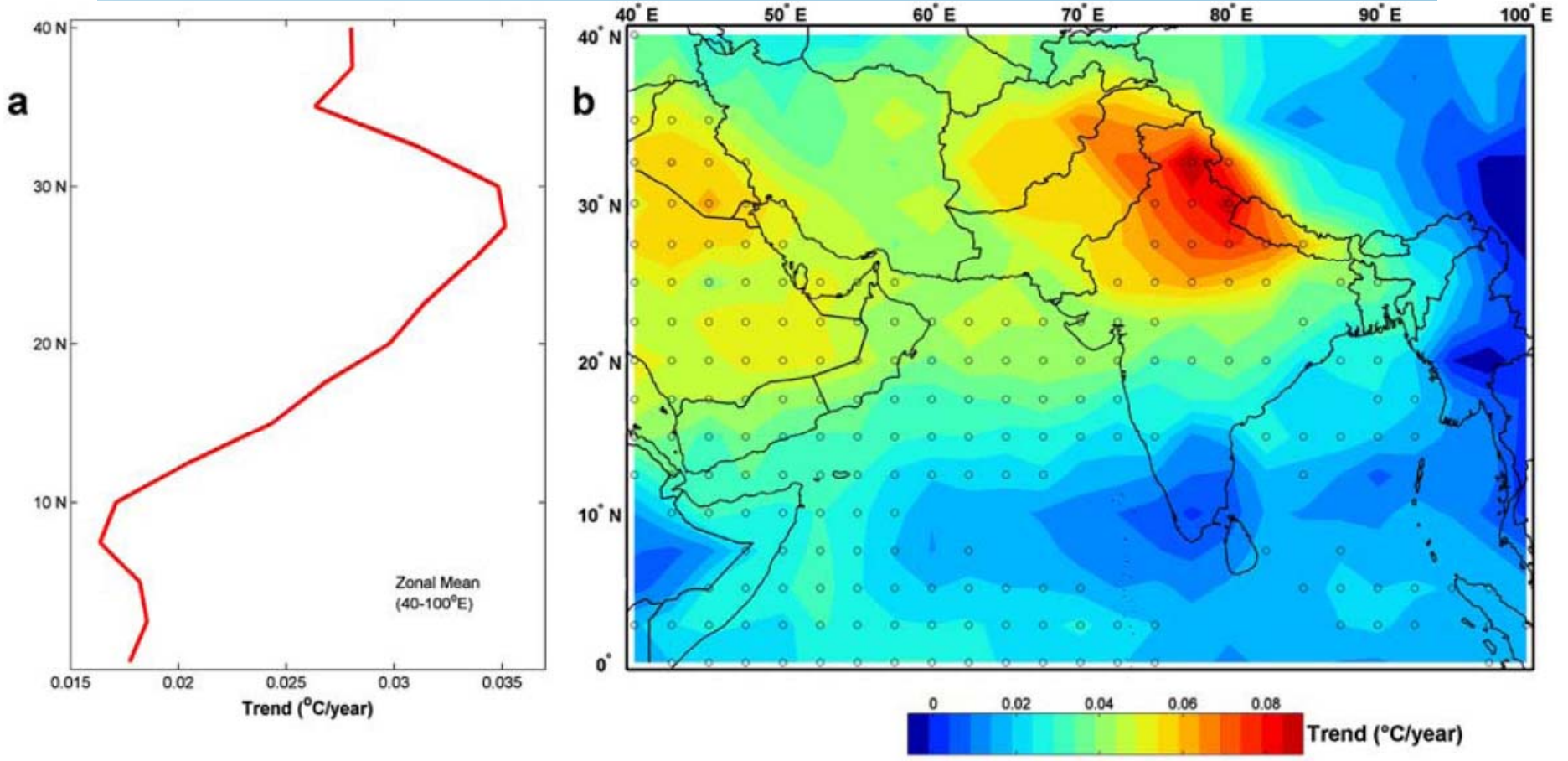


Figure 1. (a) Zonal mean (40–100 °E) latitudinal profile of mid-tropospheric temperature trend for the pre-monsoon season (March–April–May) from 1979 to 2007, and (b) spatial distribution of the mid-tropospheric temperature trend over the Indian Monsoon region in May. Open circles denote significance of linear trends at 95%.

Reference: Gautam, 2009

BC on snow causes heating and melting

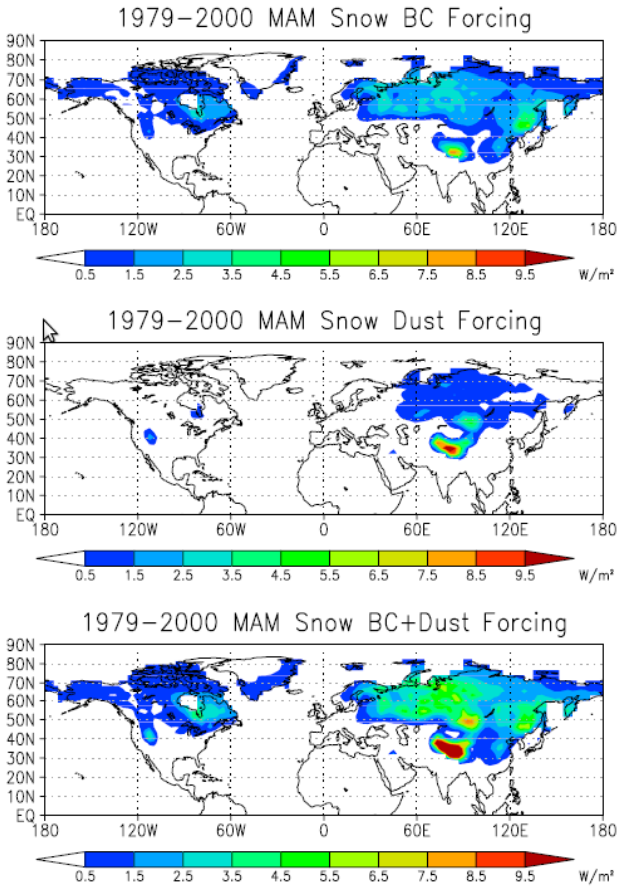


Fig. 7. March–May surface radiative forcing, averaged spatially and temporally only over snow, caused by (top) black carbon in snow, (middle) mineral dust in snow, and (bottom) both agents. Data are 1979–2000 ensemble means from experiment T2 (Table 1).

- Modeling studies predict that impact of BC on climate may be greatest at mid- low-latitudes in Asia because of BC-snow forcing.
- Forcing greatest in spring, during melt season.
- Melting increases BC concentration → positive feedback.
- During some spring months, BC-snow forcing exceeds 10 W m-2 over parts of E China and 20 W m-2 over the Tibetan Plateau.

Flanner, 2009

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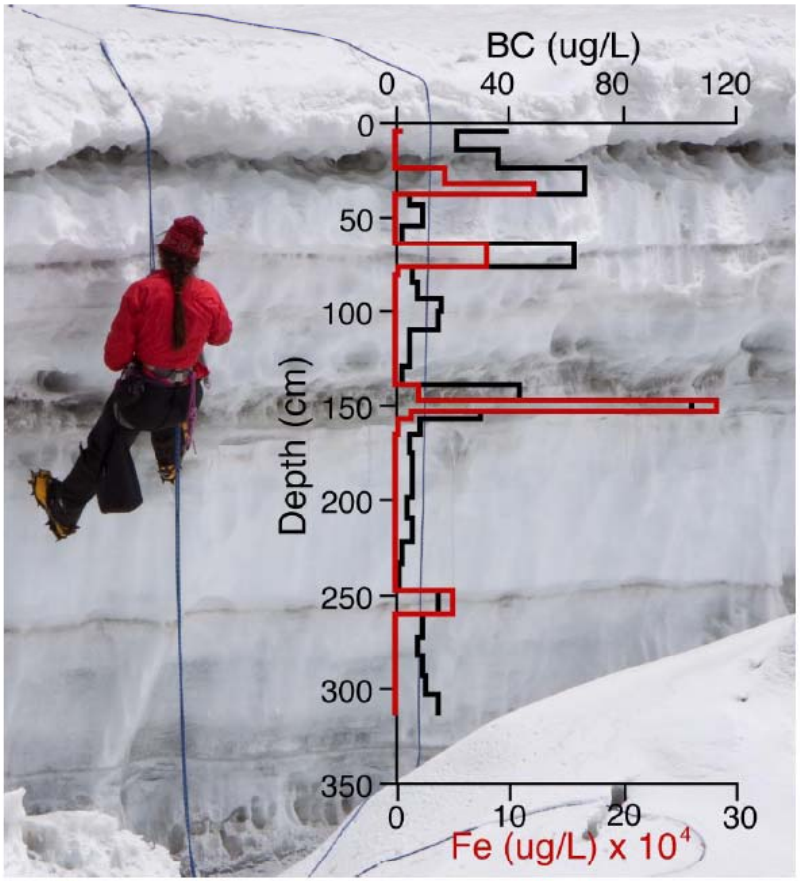
Impurities (Black Carbon and Dust) Deposited on Mera Glacier, Nepal in the Himalayas



Photographs by J. Cunningham

Kaspari

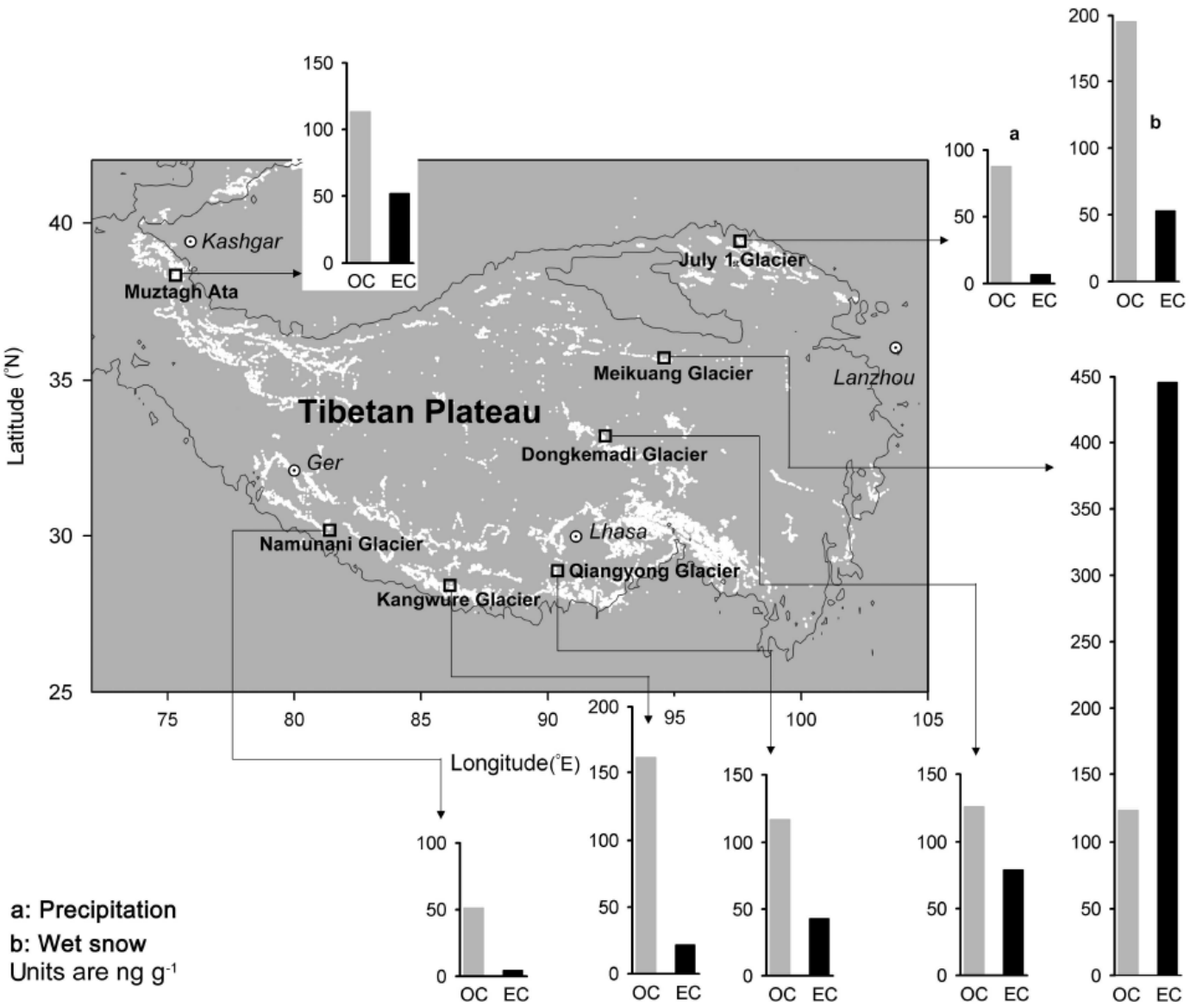
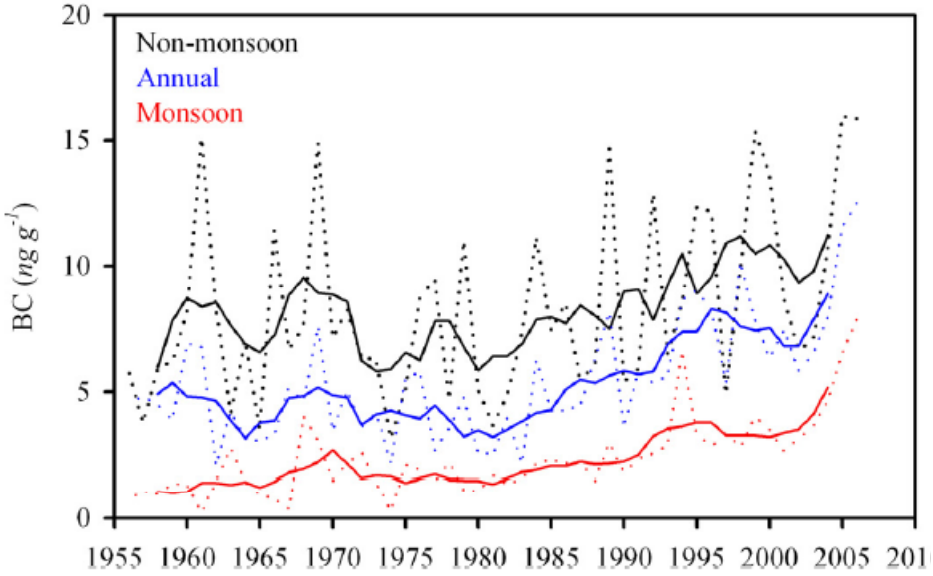
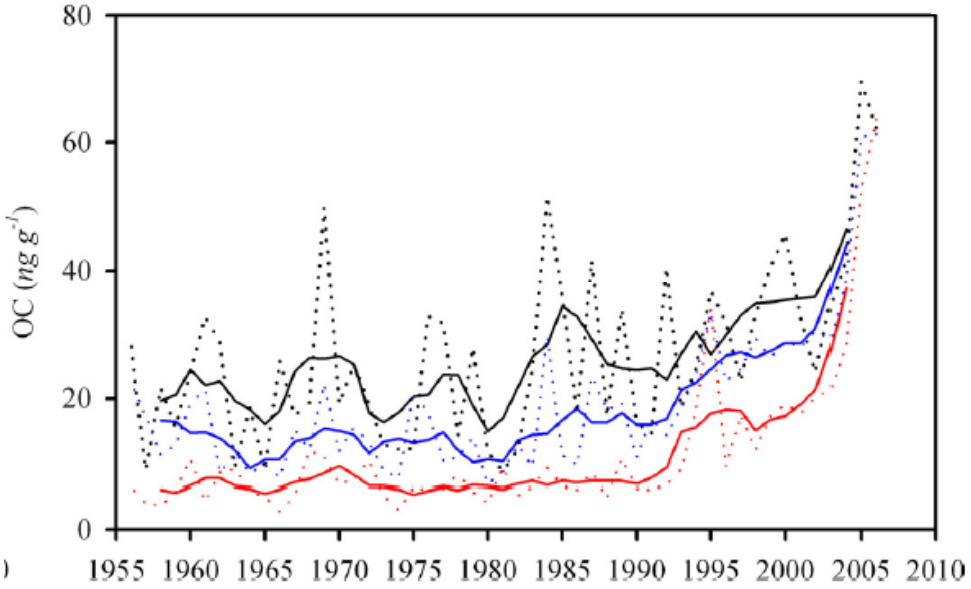
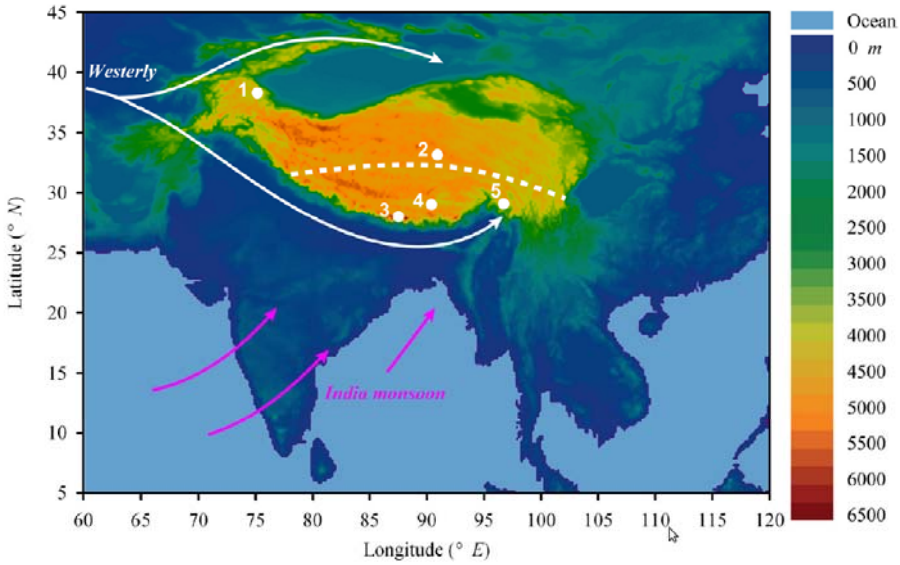


Fig. 2. Distribution of OC and EC concentrations in snow on the Tibetan Plateau.

Xu, 2006







- BC and OC concentrations from Zuoquipu glacier in SW Tibet.
- The data indicate an increasing Asian source since the 1990s, and especially in the last decade.
- Represents an increase of 30% in BC and OC from 1990-2003.

Reference: Xu, 2009

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3rd POLE: State of the Science

- Temperatures increasing faster in this region than globally
- The majority of glaciers are retreating, although behaviour is not uniform across region – reflects changing monsoon.
- Atmospheric BC warms the atmosphere & impacts the monsoon – shifting timing and intensity of rainfall, possible weakening it overall.
- Concentrations of BC in snow reflect increasing human activity – could have significant impacts on albedo, melting.
- This region is grossly under-monitored, although 20% of the world's population lives here.

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3rd POLE: State of the Politics

- Both India and China recognize that the region is vulnerable but are wary of Western data and claims.

- China has invested heavily in cryospheric research and concludes glaciers are melting. India has conducted less research and is wary of such claims

- There is growing interest in joint India-China initiatives but historical tension over the border makes this challenging.