Changes in climate over the last 3,000 years triggered marked changes in a Western Himalayan peatland, India

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1 ABSTRACT

The western **Himalaya** region of northern **India** is an important region for climatic studies as it is located within the Indian Ocean Monsoon (IOM) system. Glaciers are common at higher elevations and together with monsoon rains provide water to this densely populated region.

We provide **diatom** and **pollen**-based evidence from a **peat** deposit that the last three millennia oscillated between wet and dry periods. However, the abruptness and magnitude of change over the last **ca. 200 years** exceeded that of all previous intervals, with an **ecosystem turnover** to a much **wetter** state. This increase in moisture is likely a result of both direct and indirect associations with **global warming**.

2 STUDY SITE

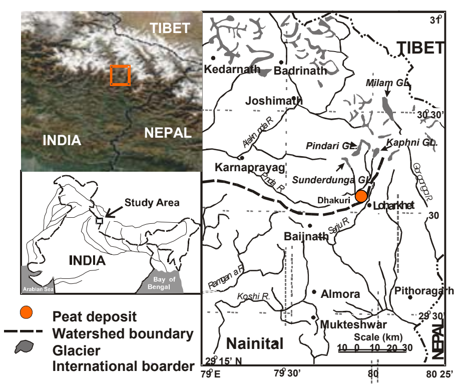


Figure 1.

The peat sequence was collected at an altitude of **2,650 m a.s.l**. from the Pinder Valley (30º 03' N, 79º 56' E) in the Kumaon Higher Himalayas, Northwest India.

3 ENVIRONMENTAL INDICATORS

Diatoms

Pollen

Phytoliths

- Magnetic Susceptibility
- Loss-On-Ignition

4 RESULTS & INTERPRETATION

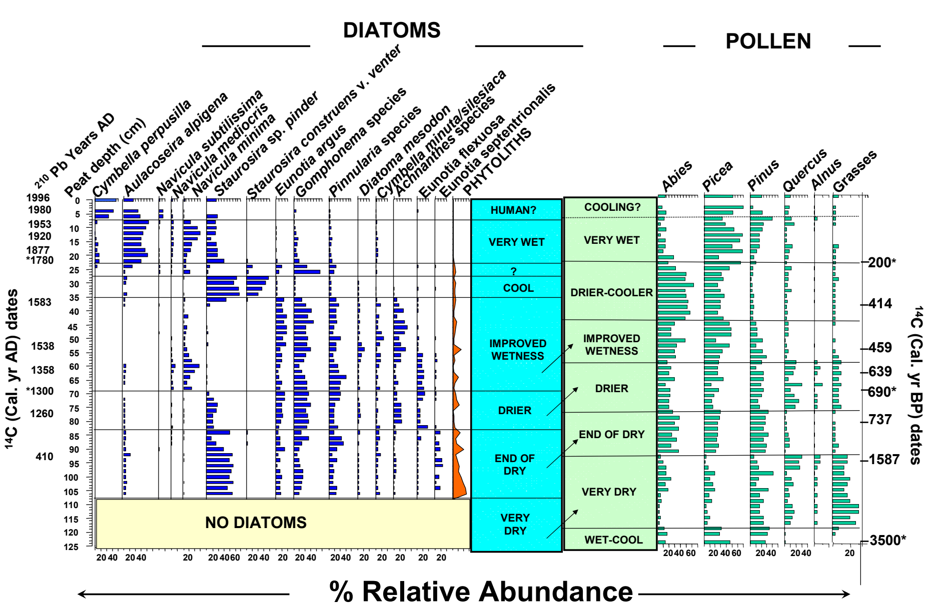


Figure 2. Diatom and pollen taxa are expressed in percent relative abundances. Phytolith relative abundances were calculated relative to the sum of all siliceous microfossils. Radiocarbon dates were calibrated with the standard data set INTCAL98. The scales of *Alnus* and grasses have been exaggerated 3X along the x-axis for purposes of clarity.

5 INTERPRETING BIOLOGICAL PROXIES

DIATOMS & PHYTOLITHS – local *in-situ* environment

Aulacoseira – free floating, open water diatom. Indicative of increased wetness in peatland

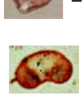
Benthic/epiphytic taxa typical of shallow environments

Grass phytoliths – *in situ* indicator of dry conditions

POLLEN – regional environment

Poaceae (grass) – grows in dry environments

Quercus (oak) – typical of dry environments

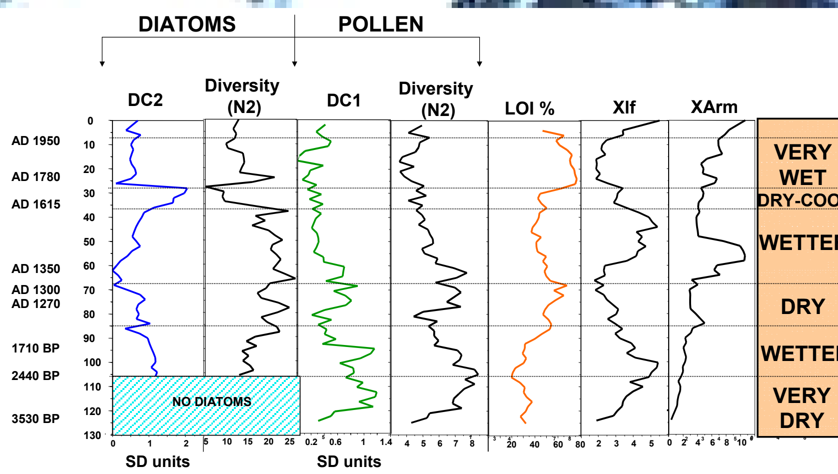


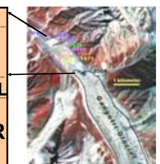
Picea (spruce) - prefers wetter conditions

Abies (fir) – prefers wetter conditions

Pinus (pine) –typical of wet nvironments

Alnus (alder) – grows in drier environments





ASTER image courtesy NASA EROS Data Center.

Figure 3. Data summarizing the main directions of change in our environmental proxies. DC1 and DC2 refer to trends in the detrended correspondence analysis for axes 1 and 2, respectively. Changes in the DC plots are given in standard deviation units (SD) and are indicative of the magnitude of species turnover through time. N2 is a measurement of species diversity. LOI (loss on ignition at 550ºC) estimates the % organic matter content in the sediment. Olf and O ARM are magnetic susceptibility measures.

Abrupt changes occurred within the last ca. 200 years (e.g. DC2 diatoms). The timing of these changes appear to correspond to accelerated melting of surrounding glaciers, particularly since the 1900's.

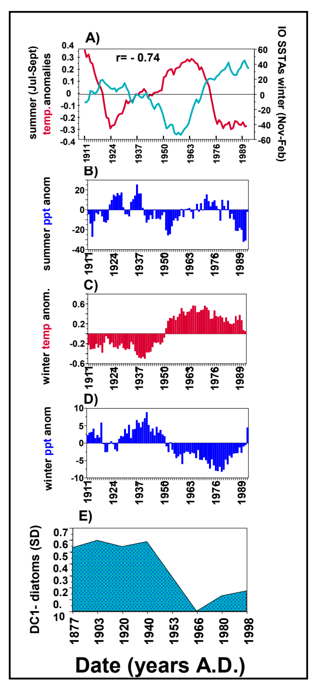


Figure 4. Seasonal climate anomalies (relative to the 1876 to 1995 monthly climatology mean) from the Mukteshwar station (29.47º N, 79.65ºE) and Indian Ocean Sea Surface Temperatures Anomalies (SSTAs) over the last ca. 100 years. A 15-year running mean was applied to all climate data. **A)** A comparison of winter Indian Ocean SSTs (1911 to 1995) trends with summer monsoon temperature anomalies. SSTAs are in hundredths of a degree Celsius. **B)** Summer monsoon precipitation anomalies. **C)** Winter (NDJF) temperature anomalies. **D)** Winter precipitation anomalies. **E)** Detrended correspondence analysis, axis 1 (DC1) for ditaoms as a summary of changes in diatoms for the last ca. 125 years.

- Last ca. 100 years of meteorological data and Indian Ocean Sea Surface Temperatures (IO SSTs) clearly show changes in summer monsoon intensity and its relation to IO SSTs
  - Positive IO SST = enhanced surface evaporation = increased moisture fluxes and monsoon rains
  - However monsoon precipitation data from the Mukteshwar station showed no relationship to IO SSTs (r =0.05).
  - Summaries of diatom and pollen data (DC1 and DC2) had weak and negative relationships to precipitation data.
  - However, there was a strong negative relationship between diatom DC1 and winter temperature (r = - 0.88) and a positive relationship with winter precipitation (r = + 0.54).
  - The amount of precipitation delivered in winter is much less than during the summer monsoon and therefore likely does not account for the magnitude of change recorded by our proxy indicators.

6 IMPLICATIONS AND CONCLUSIONS

- The ~3500 year Pinder Valley peat core records clear shifts between wet and dry periods
  - ca. 3500-2400 cal yr BP: Very Dry
  - ca. 2400-1100 cal yr BP (diatoms); ca. 1600-726 cal yr BP (pollen): Dry period ends
  - ca. AD 1300-1600 (diatoms); ca. AD 1350-1560 (pollen): Increased wetness. Changes are consistent with increase in monsoon strength (precipitation and wind strength).
  - ca. AD 1600-1700 (diatoms); ca. AD 1560-1780 (pollen): Drier and cooler
- ca. 200 yr cal BP – present – abrupt increase in wetness that is unmatched in previous intervals
  - 1st 2000 years – benthic diatoms
  - ca. AD 1780 – tychoplanktonic diatoms (*Aulacoeira*) (Fig. 2)
  - unequaled, abrupt change with DC2 diatom turnover (Fig. 3)
  - fir pollen replaced by Himalayan spruce (Fig. 2)
  - phytoliths disappear (Fig. 2)
  - rise in LOI and decrease in magnetic susceptibility (O lf) = more open water system
- Increases wetness not clearly linked to increased monsoon precipitation
  - strong *negative* correlation (r = -0.75) between our wetness indicators (e.g. *Aulacoseira*) and monsoon precipitation
  - strong *negative* correlation (r = -0.74) between monsoon temperatures and IO SSTAs (Fig. 4A)
    - i. Recent warming and accelerated melting of higher elevation glaciers = increased humidity, cooling in valley
    - ii. Changes in winter precipitation (snow) and temperature (snow melt) along valley slope (see Fig. 4 for correlations).
    - iii. Increased snow in the Tibetan Plateau or Eurasia may reduce land-sea temperature contrast = weakened monsoon circulation and vice-versa.
- Distinct changes in proxy indicators ca. AD 1950 to present
  - synchronous with changes in local meteorological trends (Fig. 4)
  - may be linked to atmospheric pollution
  - further increases in glacial meltwaters at higher elevations may indirectly cool temperatures downslope

7 THE BOTTOM LINE

- Peat deposits are sensitive recorders of shifts between wet and dry periods in this monsoon region
- Ecological repercussions of warming over last few centuries in Himalayas may be unexpected (e.g. increased wetness in valley etc.)
- Both local and larger-scale forcings must be considered when interpreting environmental change