Record of Quaternary Climatic Changes

---Land Record

---Marine Record

- The land-based evidence is less incomplete because successive glaciations may wipe out evidence of their predecessors.
- Ice cores from continental ice accumulations also provide a complete record, but do not go as far back in time as marine data. Eg. Vostok Ice core, Antarctica provides record of past 420,000 years.
- **The marine record preserves all the past glaciations.**

- **Marine isotope stages** (MIS), **marine oxygen-isotope stages**, or **oxygen isotope stages** (OIS), are alternating warm and cool periods in the Earth's paleoclimate, deduced from oxygen isotope data reflecting changes in temperature derived from data from deep sea core samples.
- Developed by successive and collaborative work by pioneer paleoclimatologists **Harold Urey, Cesare Emiliani, John Imbrie, Nicholas Shackleton** and a host of others.
- **MIS uses the balance of oxygen isotopes mainly from stacked fossil plankton (foraminifera) deposits on the bottom of the oceans to build an environmental history of our planet.** Pollen, sapropels* and other data that reflect historic climate are also used; these are called proxies
- *** Dark-coloured sediments that are rich in organic matter. Organic carbon concentrations in sapropels commonly exceed 2% in weight).**

- Marine Isotope Stages (MIS) provides a chronological listing of alternating cold and warm periods deduced from oxygen isotope data reflecting changes in temperature on our planet, going back to at least 2.6 million years.

- **Oxygen isotope ratio cycles**
- In oxygen isotope ratio analysis, variations in the ratio of O^{18} to O^{16} (two isotopes of oxygen) present in the calcite of oceanic core samples is used as a diagnostic of ancient ocean temperature change and therefore of climate change. Cold oceans are richer in O^{18}, which is included in the tests of the microorganisms (foraminifera) contributing the calcite.
- A more recent version of the sampling process makes use of modern glacial ice cores. Although less rich in O^{18} than sea water, the snow that fell on the glacier year by year nevertheless contained O^{18} and O^{16} in a ratio that depended on the mean annual temperature.

Connection between isotopes and temperature/weather

- ^{18}O is two neutrons heavier than ^{16}O and causes the water molecule in which it occurs to be heavier by that amount. The addition of more energy is required to vaporize $H_2{}^{18}O$ than $H_2{}^{16}O$, and $H_2{}^{18}O$ liberates more energy when it condenses. In addition, $H_2{}^{16}O$ tends to diffuse more rapidly.
- Because $H_2{}^{16}O$ requires less energy to vaporize, and is more likely to diffuse to the liquid surface, the first water vapour formed during evaporation of liquid water is enriched in $H_2{}^{16}O$, and the residual liquid is enriched in $H_2{}^{18}O$. When water vapour condenses into liquid, $H_2{}^{18}O$ preferentially enters the liquid, while $H_2{}^{16}O$ is concentrated in the remaining vapour.
- As an air mass moves from a warm region to a cold region, water vapour condenses and is removed as precipitation. The precipitation removes $H_2{}^{18}O$, leaving progressively more $H_2{}^{16}O$-rich water vapour. This distillation process causes precipitation to have lower $^{18}O/^{16}O$ as the temperature decreases.

- Due to the intense precipitation that occur in hurricanes, the $H_2{}^{18}O$ is exhausted relative to the $H_2{}^{16}O$, resulting in relatively low $^{18}O/^{16}O$ ratios. The subsequent uptake of hurricane rainfall in trees, creates a record of the passing of hurricanes that can be used to create a historical record in the absence of human records.

- **Connection between temperature and climate**
- The $^{18}O/^{16}O$ ratio provides a record of ancient water temperature. Water 10 to 15 degrees Celsius (18 to 27 degrees Fahrenheit) cooler than present represents glaciation. Precipitation and therefore **glacial ice contain water with a low ^{18}O content**. Since large amounts of ^{16}O water are being stored as glacial ice, **the ^{18}O content of oceanic water is high.**
- Water up to 5 degrees Celsius (9 °F) warmer than today represents an interglacial, when the **^{18}O content is lower in Oceanic water**. A plot of ancient water temperature over time indicates that climate has varied cyclically, with large cycles and harmonics, or smaller cycles, superimposed on the large ones. This technique has been especially valuable for identifying glacial maxima and minima in the Pleistocene.

- The following are the **start dates** of the most recent MIS, in thousands of years. **Glacials receive an even number; interglacials, odd**.
- **MIS 1:** 11 kya, end of the Younger Dryas marks the start of the Holocene, continuing to the present
- **MIS 2:** 24 (near Last Glacial Maximum)
- **MIS 3 :** 60
- **MIS 4** : 71 (74)
- **MIS 5** : 130
  - MIS 5a : 84.74
  - MIS 5b : 92.84
  - MIS 5c : 105.92
  - MIS 5d : 115.105
  - MIS 5e:- 130.115
- **MIS 6** 190
- **MIS 7** 244
- **MIS 8** 301
- **MIS 9** 334

- MIS 10 364
- MIS 11 427, the most similar to MIS 1.
- MIS 12 474
- MIS 13 528
- MIS 14 568
- MIS 15 621
- MIS 16 659
- MIS 17 712
- MIS 18 760
- MIS 19 787
- MIS 20 810
- MIS 21 865

- MIS 22 - 1.03 mya,
- MIS 62 - 1.75,
- MIS 103 - 2.588 (End of the Pliocene and start of the Pleistocene)

- Earth experienced 102 MIS stages beginning at about 2.588 MYA in the Early Pleistocene. Early Pleistocene stages were shallow and frequent. The latest were the most intense and most widely spaced.
- By convention, stages are numbered from the Holocene, which is MIS1. (**interglacials, odd receive an even number;**..
- The largest glacials were 2, 6, 12, and 16; the warmest interglacials, 1, 5, 9 and 11.
- Marine Isotope Stage 3 (MIS 3) – a period between 60 and 27 ka ago during the last glacial cycle – experienced several abrupt climatic warming phases (Dansgaard-Oeschger events).

Sudden climate jumps from the more distant past

- Climate instability on the timescale of tens of thousands of years has been found in deep ocean and lake cores going back more than 40 Myr.
- However, because these deeper records have a relatively poor time resolution, it is uncertain whether sudden decade-century timescale jumps in climate were common before the Quaternary Period.

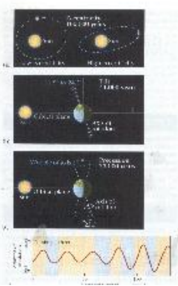
What causes glaciation / Climate Change?

- A number of Parameters seem to control the process of Glaciation and deglaciation

CAUSES OF GLOBAL CLIMATIC CHANGE

1. POSITION OF EARTH IN RELATION TO SUN

Milankovitch Cycle

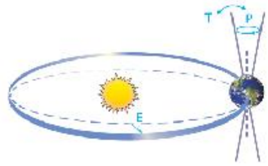


100, 000 Yr.
eccentricity

41,000 Yr.
tilt axis

25,000 Yr.
precession

Combined

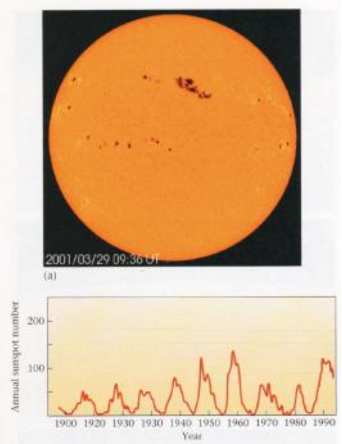


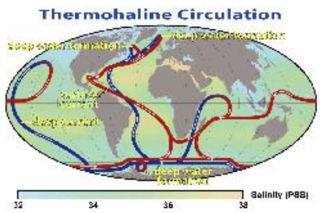
Sunspot Cycle or Fluctuation in solar radiation

Huge magnetic storms that show up as dark (cool) areas on the suns surface.

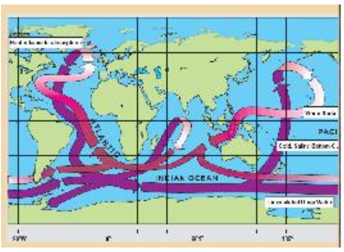
When there are more sunspots, the sun is emitting more energy, hence, the amount of energy incident on the earth increases.

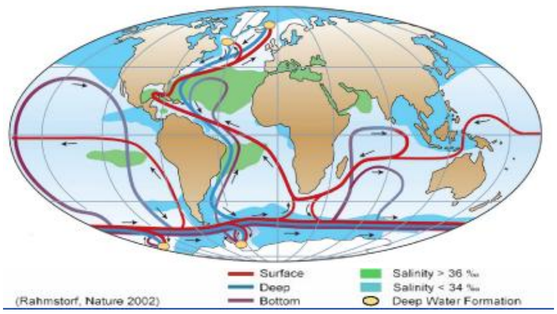
So, one could imagine warmer climate during a sun spot maximum and cooler climate during a minimum.



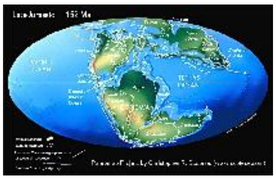


The term **thermohaline circulation** (**THC**) refers to the part of the large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes. The adjective thermohaline derives from *thermo-* referring to temperature and *-haline* referring to salt content, factors which together determine the density of sea water. It is the **driving mechanism** of large-scale "deep" ocean circulation

- Wind-driven surface currents (such as the Gulf Stream) head polewards from the equatorial Atlantic Ocean, cooling all the while and eventually sinking at high latitudes (forming North Atlantic Deep Water). This dense water then flows into the ocean basins. While the bulk of it upwells in the Southern Ocean, the oldest waters (with a transit time of around 1600 years) upwell in the North Pacific .
- 



Changes in Ocean currents

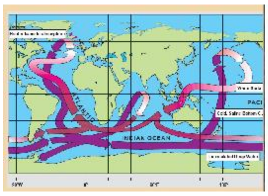


Relative Position of continents

Volcanic activity

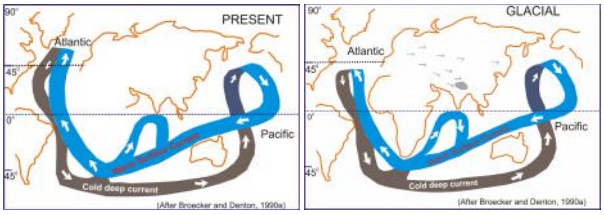
Albedo

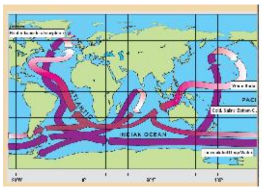
- Extensive mixing therefore takes place between the ocean basins, reducing differences between them and making the Earth's ocean a global system. On their journey, the water masses transport both energy (in the form of heat) and matter (solids, dissolved substances and gases) around the globe. **As such, the state of the circulation has a large impact on the climate of the Earth.**
- The thermohaline circulation is sometimes called the **ocean conveyor belt**, the **great ocean conveyor**, or the **global conveyor belt**. On occasion, it is used to refer to the **meridional overturning circulation** (often abbreviated as **MOC**).



- Changes in Thermohaline circulation

Ice calving in North Atlantic (Heinrich events) influenced the Thermohaline circulation





The **Gulf Stream**, together with its northern extension towards Europe, the North Atlantic Drift, is a powerful, warm, and swift Atlantic ocean current that originates at the tip of Florida, and follows the eastern coastlines of the United States and Newfoundland before crossing the Atlantic Ocean.

- At about 40°0′N 30°0′W / 40°N 30°W / 40; -30, it splits in two, with the northern stream crossing to northern Europe and the southern stream recirculating off West Africa.

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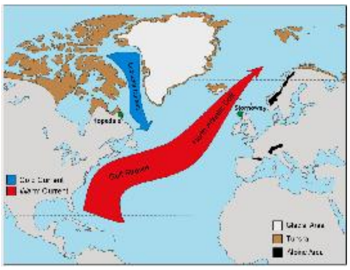
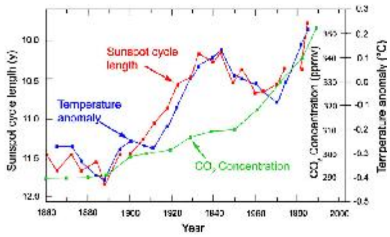


If anthropogenically produced CO2 is of such critical importance to climate change why was there a large temperature rise prior to the early 1940s when 80 percent of the human produced carbon dioxide was produced after World War II



Significance of Quaternary

- Flourishing and then extinction of many large mammals (Pleistocene megafauna)
- Evolution of anatomically modern humans.
- Modern humans migrated from Africa middle Palaeolithic, spreading all over the ice-free world during the late Pleistocene.
- Quaternary Ice Age continues with glaciations and interstadials (and the accompanying fluctuations from 100 to 300 ppm in atmospheric CO2 levels).
- The last glacial period ends; rise of human civilization. Quaternary Ice Age recedes, and the current interglacial begins.

- Younger Dryas cold spell occurs, agriculture begins, allowing humans to build cities. Paleolithic/Neolithic (Stone Age) cultures begin around 10000 BC, giving way to Copper Age (3500 BC) and Bronze Age (2500 BC).
- Cultures continue to grow in complexity and technical advancement through the Iron Age (1200 BC), giving rise to many pre-historic cultures throughout the world,
- Little Ice Age (stadial) causes brief cooling in Northern Hemisphere from 1400 to 1850.
- Following the Industrial Revolution, Atmospheric CO_2 levels rise from around 280 parts per million volume (ppmv) to the current level of 390 ppmv, due to anthropogenic emissions, very likely causing global warming and climate change.????

- The Quaternary period saw the extinctions of numerous predominantly larger, especially megafaunal, species, many of which occurred during the transition from the Pleistocene to the Holocene epoch. However, the extinction wave did not stop at the end of the Pleistocene, but continued especially on isolated Islands in Holocene extinctions.
- The **Holocene extinction event** is a name customarily given to the widespread, ongoing mass extinction of species during the modern Holocene epoch. The large number of extinctions span numerous families of plants and animals including mammals, birds, amphibians, reptiles and arthropods;

- A sizeable fraction of these extinctions are occurring in the rainforests. This extinction event is sometimes referred to as the **sixth extinction** following the previous five extinction events.
- Scientists estimate that the planet is undergoing the "largest mass extinction in 65 million years". (Sixth Extinction)
- Scientists forecast that up to five million species will be lost this century. It is said that "We are well into the opening phase of a mass extinction of species".
- There are about 10 million species on earth. If we carry on as we are, we could lose half of all those 10 million species

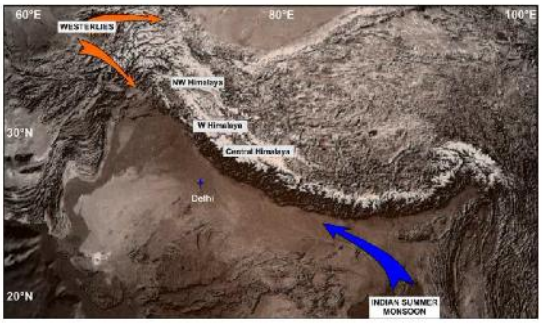
- With the present rate, the planet will continue to lose around 50 species per day compared to the natural extinction rate of one species every five years.
-

These extinctions, occurring near the Pleistocene / Holocene boundary, are sometimes referred to as the **Pleistocene extinction event** or Ice Age extinction event. However the Holocene extinction event continues through the events of the past several millennia and includes the present time.

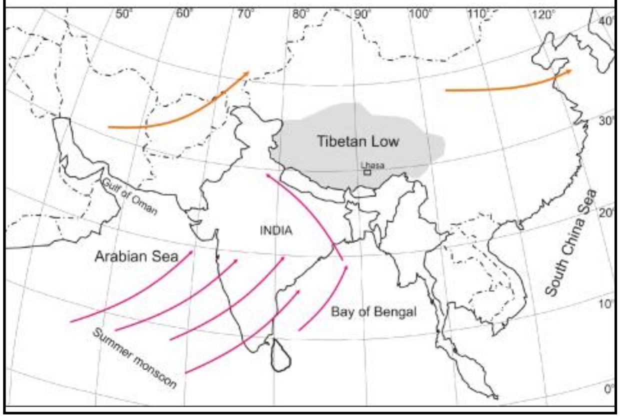
- Proxies used for evaluation of Quaternary palaeoclimate in Himalay
- Palynology
- Geochemistry
- Environmental magnetic
- Oxygen isotope
- Dendrochronology

Glaciation in Himalaya

The Himalayan region has one of the most spectacular valley glaciers of the World.



Summer



- It has been suggested that:
- The central Himalayan glacial valleys in the upper reaches have been subjected to multiple glaciations on the basis of present day disposition of the lateral moraines, recessional moraines and associated landforms.
- Chronologically constrained evidences of past glaciations in monsoon dominated Central Himalayan region are scanty (**Sharma and Owen, 1996; Pant et al., 2006; Nainwal et al., 2007, Juyal et al., 2009**). **These studies further suggest that during the late Quaternary, glaciers broadly responded to the changing Indian Summer Monsoon (ISM) intensities.**
- Thus it has been postulated that in the Central Himalaya, the snow precipitation/ accumulation is dominantly due to the ISM.
- As one moves towards the west, the role of ISM reduces and there is a gradual increase of the influence of winter precipitation due to the mid latitudel westerlies.

- Glacial chronologies from the Himalayan region indicate various degrees of asynchronous glacial behaviour. Part of this has been related to different sensitivities of glaciers situated in contrasting climatic compartments of the orogen.
- Glaciers in monsoon dominated regions in Himalaya appears to have responded synchronously during the late Quaternary.
- Whereas those located in the trajectory of mid-latitude westerlies advanced asynchronously relative to the monsoon influenced regions.
- It is further believed that these were in phase with the Northern Latitude cooling events. Glacier expansion is generally a response of lower temperature, but at high altitude it may be more sensitive to changes in moisture transport.
- It has been suggested that in humid regions, glaciers advanced due to changes in precipitation whereas in arid regions they are temperature driven

S. No.	Area	Established glacial chronology					OSL/ CRN	Ref.	Region
1	Zanskar Range		Chandra gl. Stage (No age)	Batal gl. Stage (~40-78 ka)	Kulti gl. Stage (~10-16 ka)	Sonapani gl. Stage (~LIA)	OSL	Taylor and Mitchell 2000	
2	Ladakh Range	Indus valley glacial stage (130 ka)	Leh glacial stage (Penultimate or older)	Kar gl. Stage (early part of last glacial cycle)	Bazgo gl. Stage (Middle of last glacial cycle)	Khalling gl. Stage (Early Holocene)	CRN	Owen et al. 2006	NW Himalaya
3	Nubra & Shyok valley			Deshkit 3 (~144 ka)	Deshkit 2 (~81 ka)	Deshkit 1 (~45 ka)	CRN	Dortch et al 2010	
4	Lahul Himalaya	Chandra gl. Stage (~43 ka)	Batal gl. Stage (~36 ka)	Kulti gl. Stage (~10-11.4 ka)	Sonapani-I (~Early mid Holocene)	Sonapani II (~LIA)	OSL	Owen et al. 1996	Western Himalaya
5				Chandra gl. Stage (No age)	Batal gl. Stage (~12-15.5 ka)	Kulti gl. Stage (~10-11.4 ka)	CRN	Owen et al. 2001	
6	Bhagirathi Valley			Bhagirathi stage (~63-5 ka)	Shivling stage (~5 ka)	Bhujbas stage (~LIA)	OSL	Sharma and Owen 1996	
7		Bhagirathi stage (~63-11 ka)	Kedar stage (~7 ka)	Shivling stage (~5 ka)	Gangotri Glacial stage (~1 ka)	Bhujbas stage (~200-300 yr BP)	CRN	Barnard et al 2004	
8	Alaknanda Valley		Alaknanda gl. advance	Alkapuri gl. Advance (~12 ka)	Satopanth gl. Advance (4.5 ka)	Recession of LIA (400 – 200 yr BP)	OSL	Nainwal et al 2007	Central Himalaya
9	Goriganga Valley			Glacial stage I	Glacial stage II	Glacial stage III	OSL	Pant et al 2006	
10	Chorabari glacier valley		Rambara Gl Stage (~13 ka)	Ghindurpani Gl Stage (~9 ka)	Garuriya Gl. Stage (~7 ka)	Kedarnath Gl Stage (~5 ka)	OSL	Mehta et al 2012	
11	Tons Valley	~16 ka	~11-12 ka	~8-9 ka	~5 ka	< 1 ka	CRN	Scherler et al 2010	