

Paleoclimate and Global warming

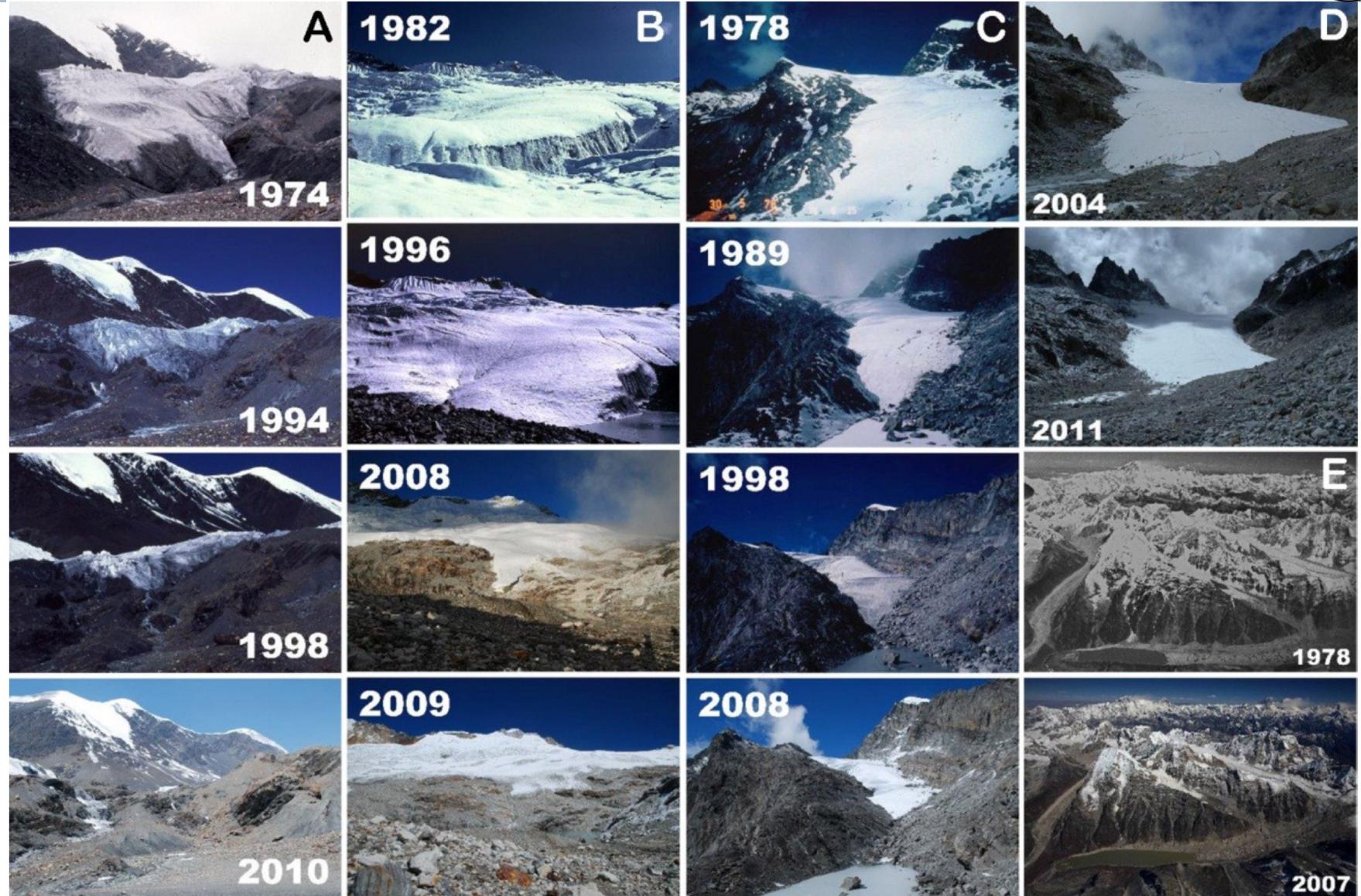
ESO 213



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Image: Indra Sen, Western Himalayas

Best evidence of global warming: The melting Himalayan Glaciers



Bolch et al., Science, 2012

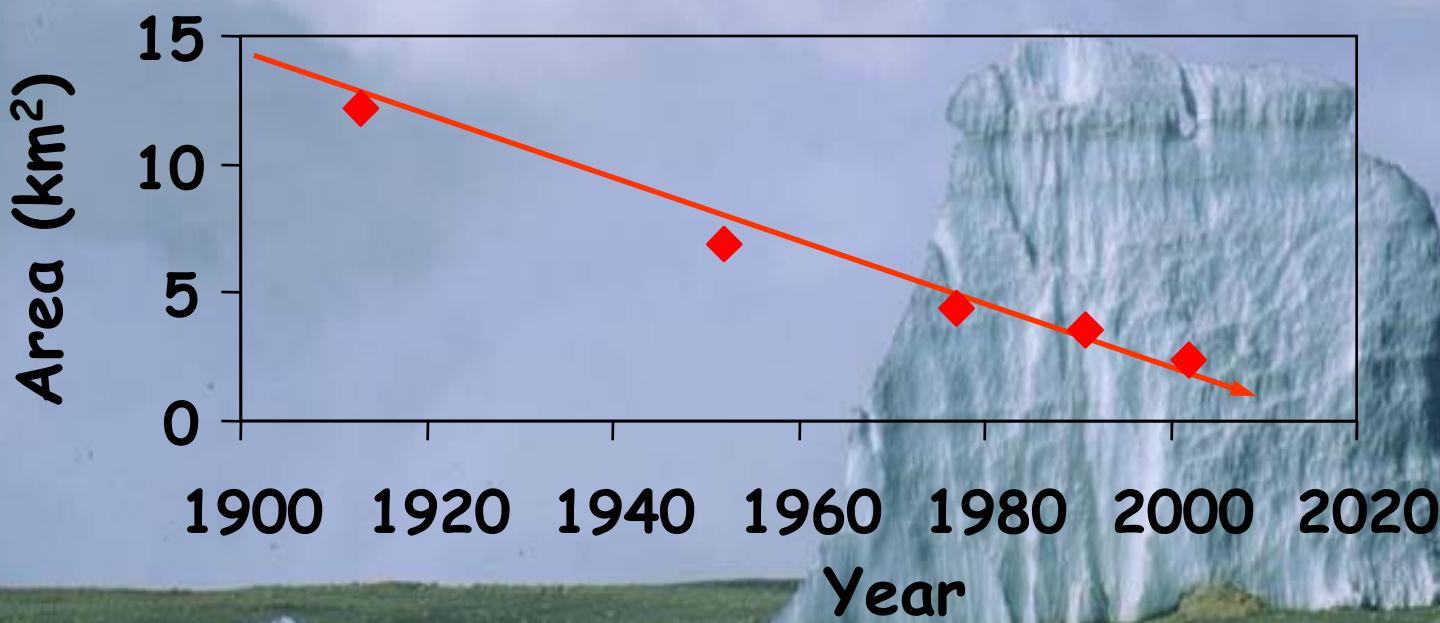
A photograph of Mount Kilimanjaro from a distance, showing its snow-capped peaks and surrounding vegetation. The year '1970' is printed in the top left corner.

1970

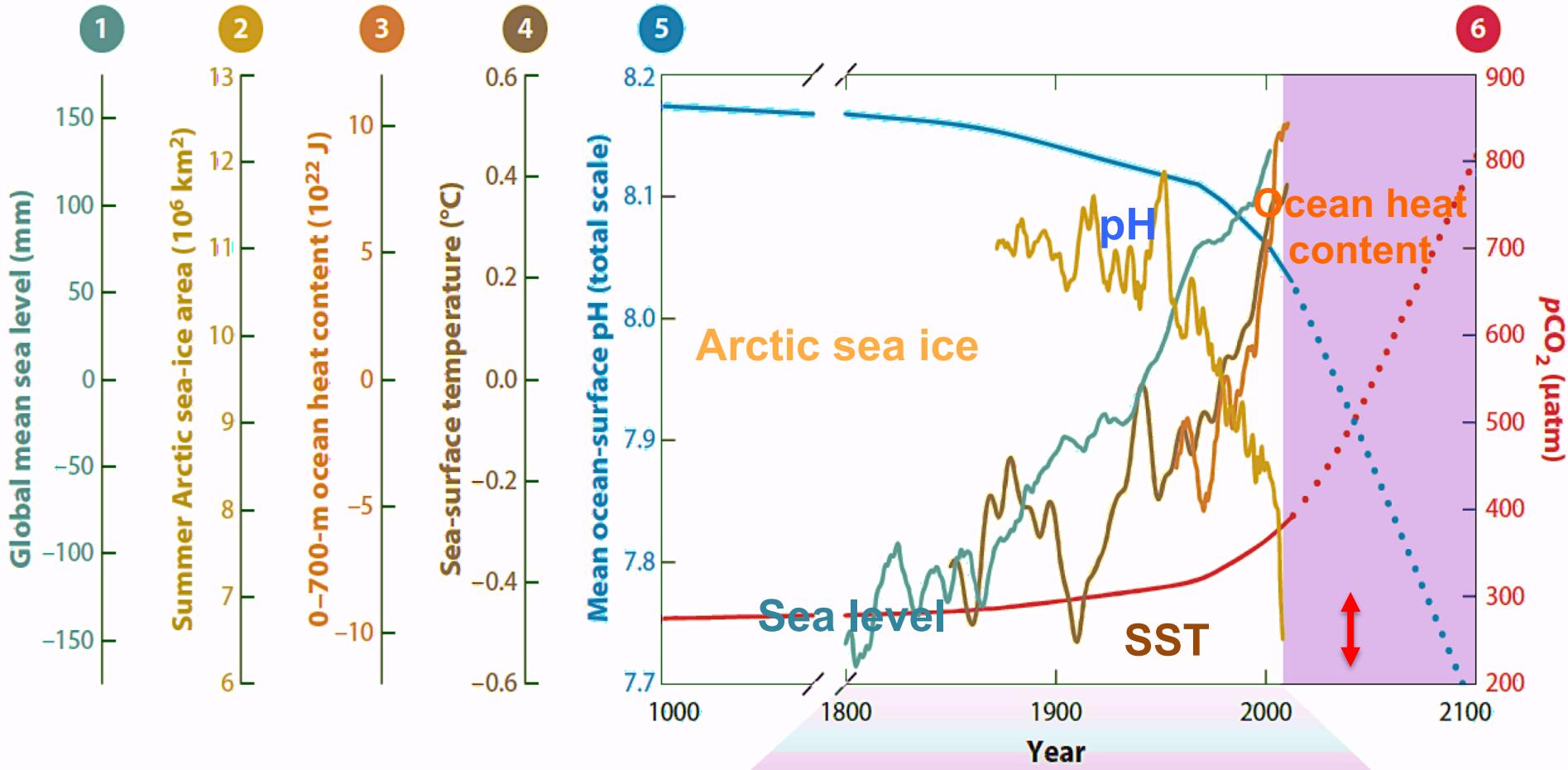
A photograph of Mount Kilimanjaro from a distance, showing its snow-capped peaks and surrounding vegetation. The year '2000' is printed in the top left corner.

2000

Ice on Mt. Kilimanjaro

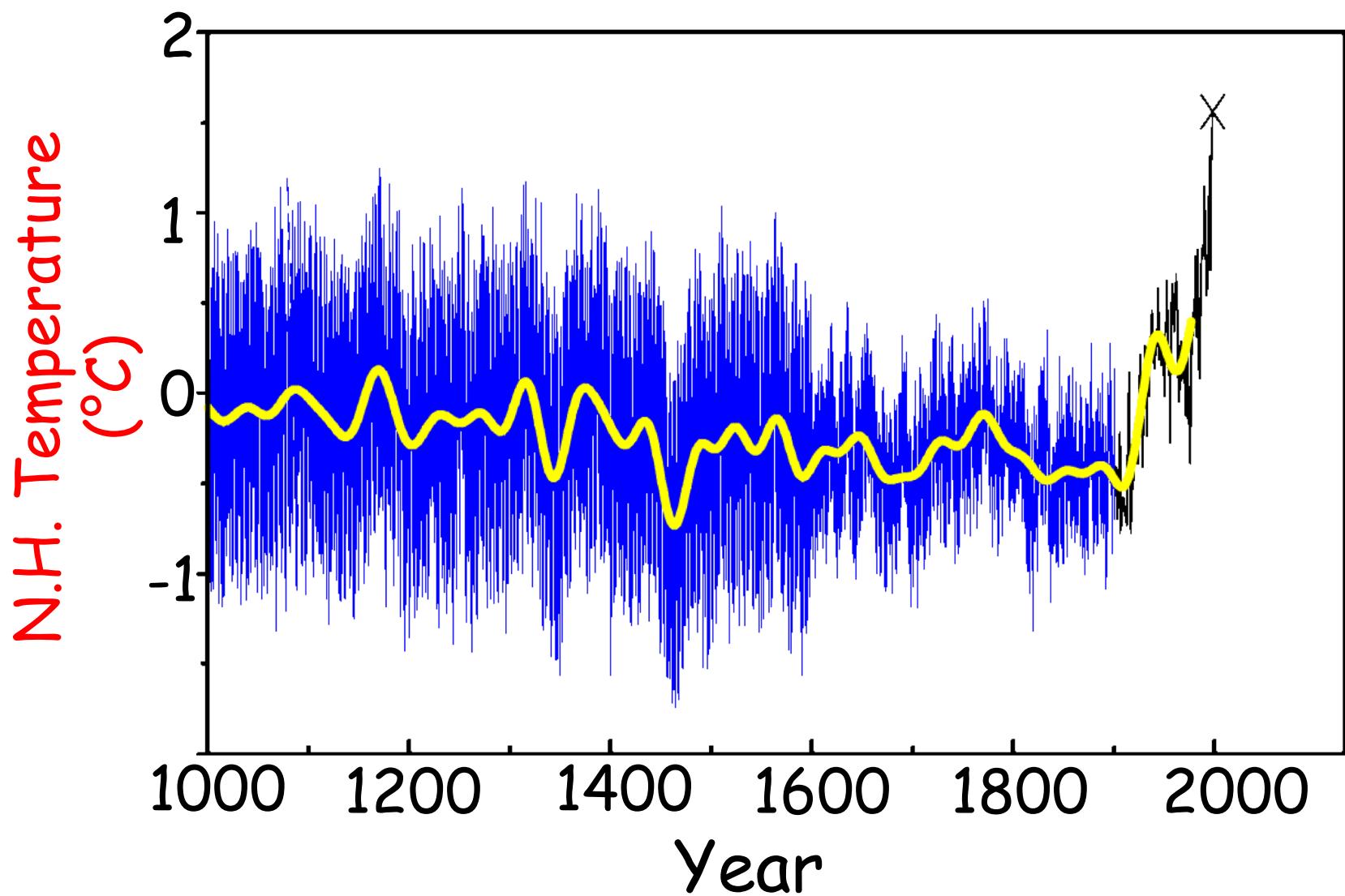


A period of unprecedented change in human history

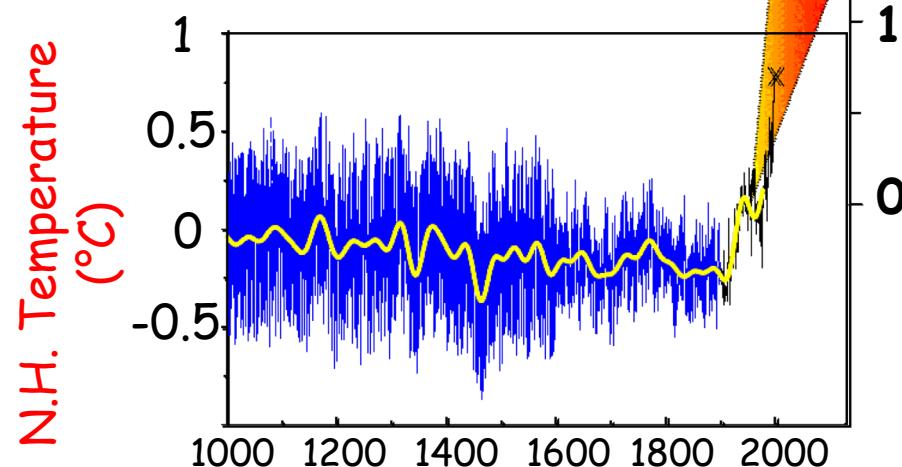


Doney et al. (2011)

"Recent" climate change and variability...



...provides
perspective on where
we are headed



IPCC Projections
to 2100

Greenhouse Gases

Carbon dioxide

combustion of solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products

Methane :

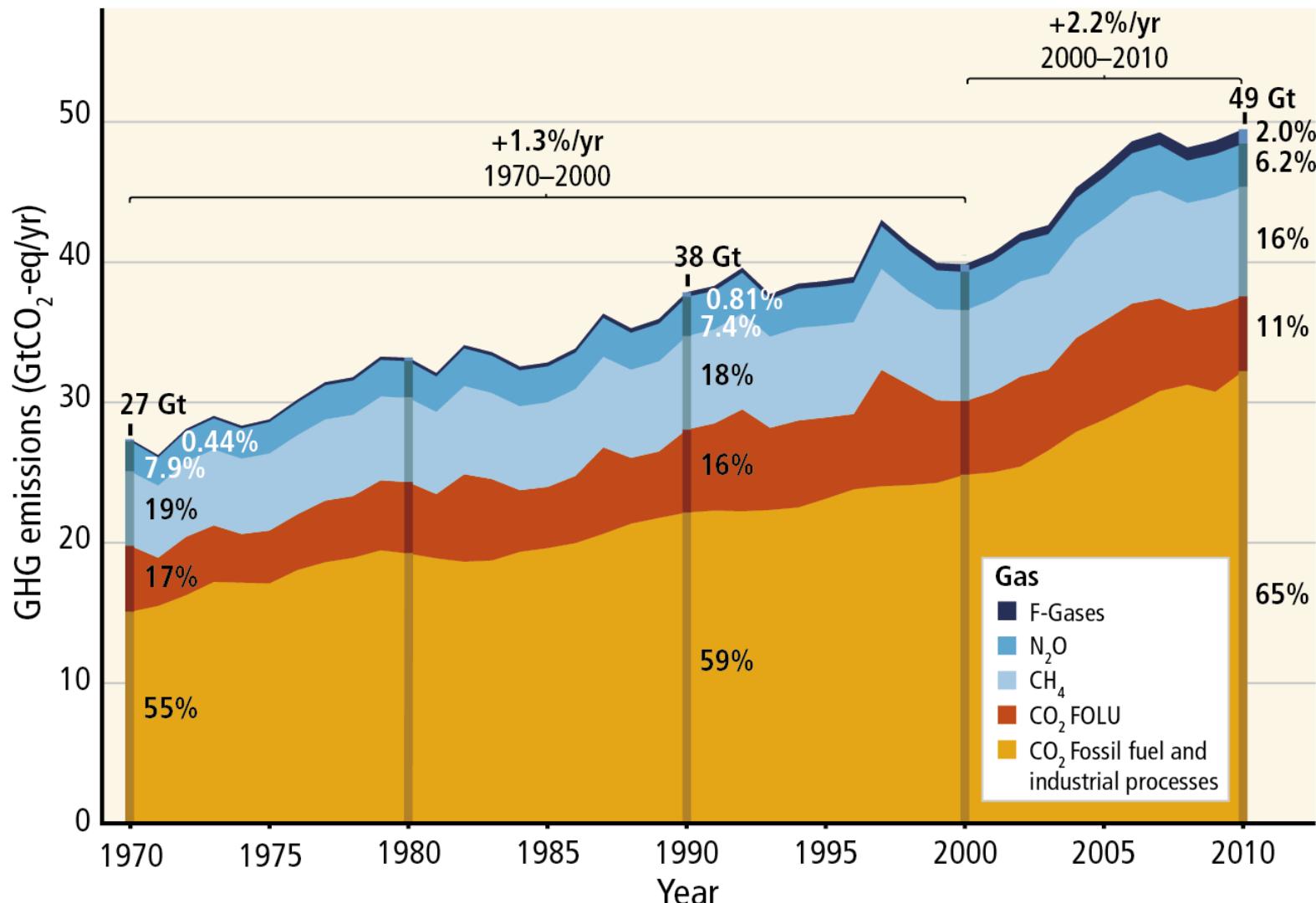
production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock.

Nitrous oxide

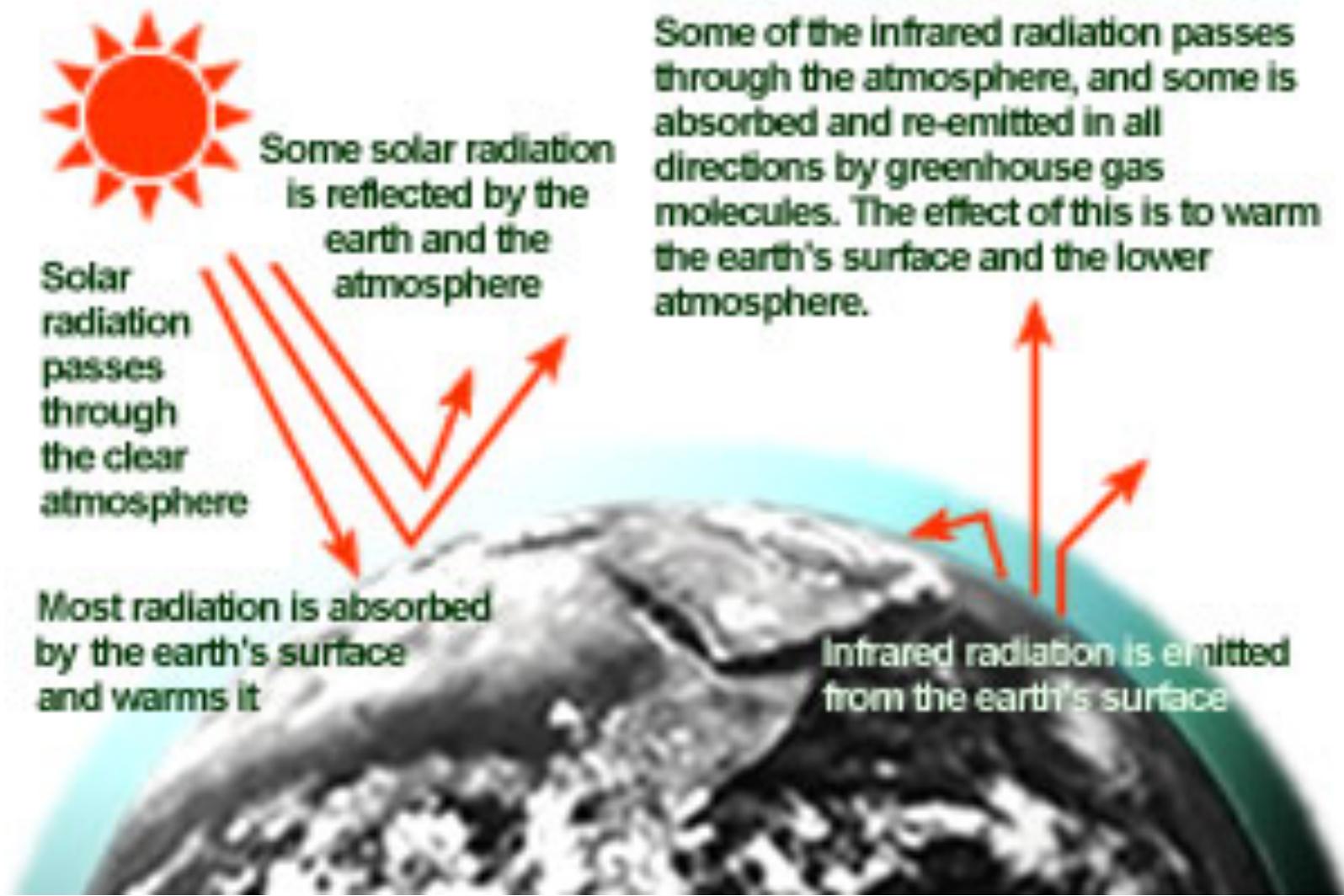
agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆),

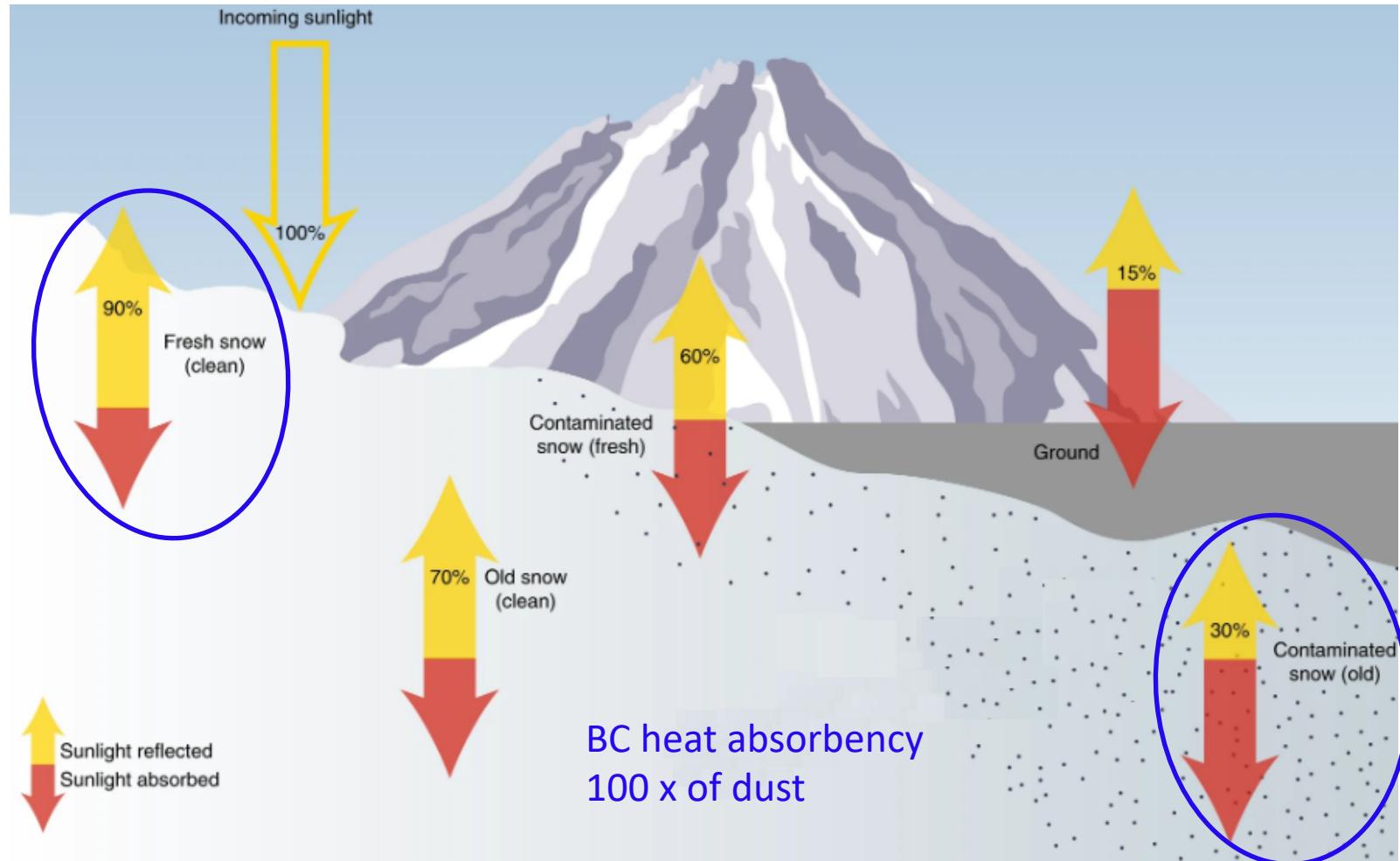
Total annual anthropogenic GHG emissions by gases 1970–2010



The Greenhouse Effect

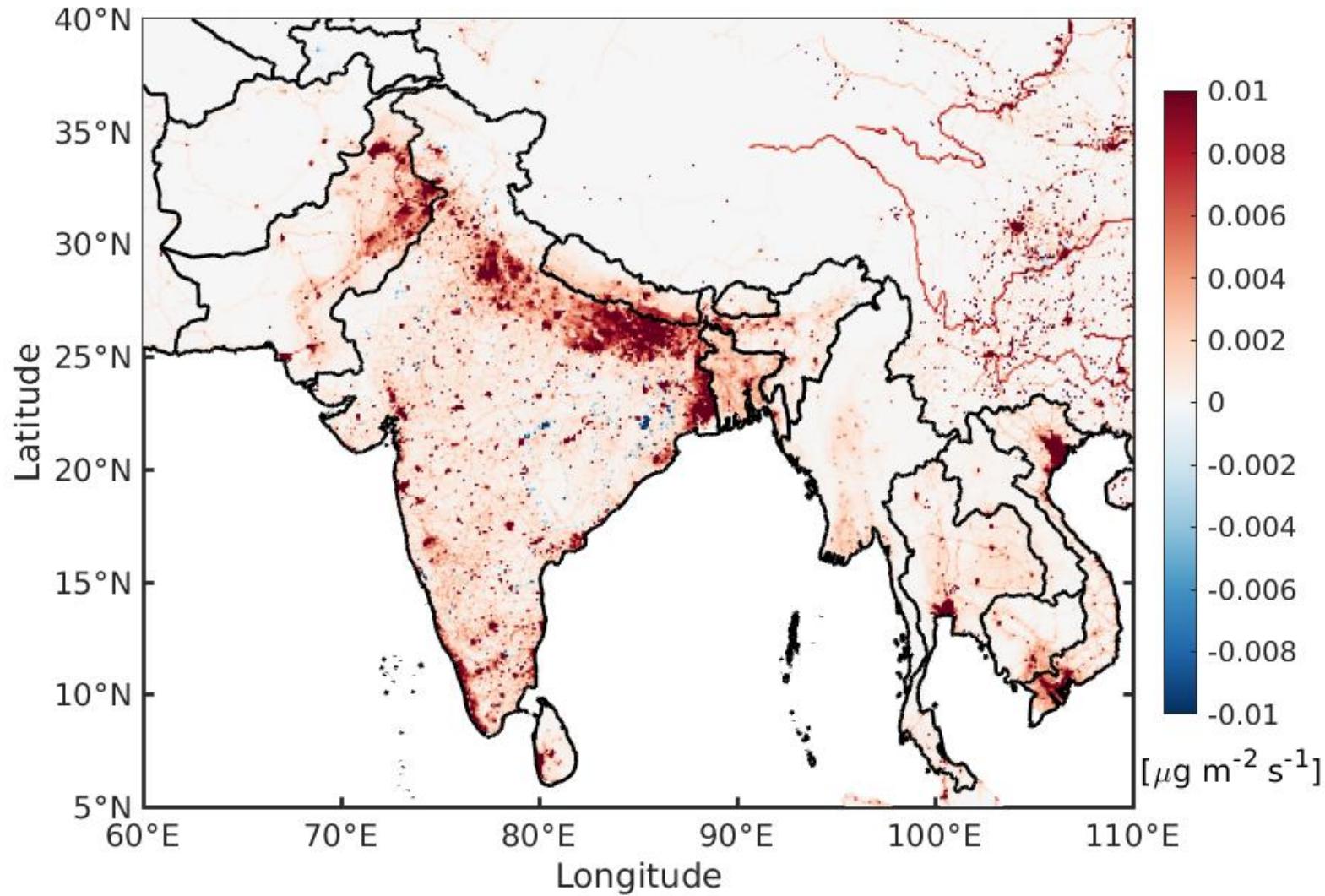


In addition to gases: particles are also released -Soot particles



Skiles et al. 2018

- Darken ice surface → Increase heat absorption → Enhance ice melting
- Serious concern for Himalaya: proximity to anthropogenic emission



The difference in carbonaceous aerosol emissions for sum of all aggregated emission sectors (energy, industry and processes, transport, residential, and agriculture) between the years 2012 and 1970. The Emissions Database for Global Atmospheric Research (EDGAR) version 4.3.2 for the years 1970 and 2012 (Sarwar et al., 2020, Environment Science and Technology)

Melting Himalayas due to impurities

Soot on Himalayan glaciers accelerates melting

by Rishika Pardikar | Mar 17, 2020

Recent research has shown once again that the many fires in the lower Himalayas and the foothills are forcing glaciers in the higher reaches to melt much faster



CLIMATE CHANGE

'Dirty Snow' Hastens Glacial Melt in Himalayas

By Bhrikuti Rai

Algae blooms to make glaciers melt faster than thought: scientists

New science on Himalayan glaciers shows debris fields to be a regulating factor in melting

Anthony Watts / January 27, 2011

South Asian soot drifts over Himalayas

by Aditi Gaddam | Apr 29, 2015

New study suggests pollution from South Asia's cooking stoves and forest fires drifts over the Himalayas, contributing to glacier melt on the Tibetan plateau, but more research needed to confirm how much



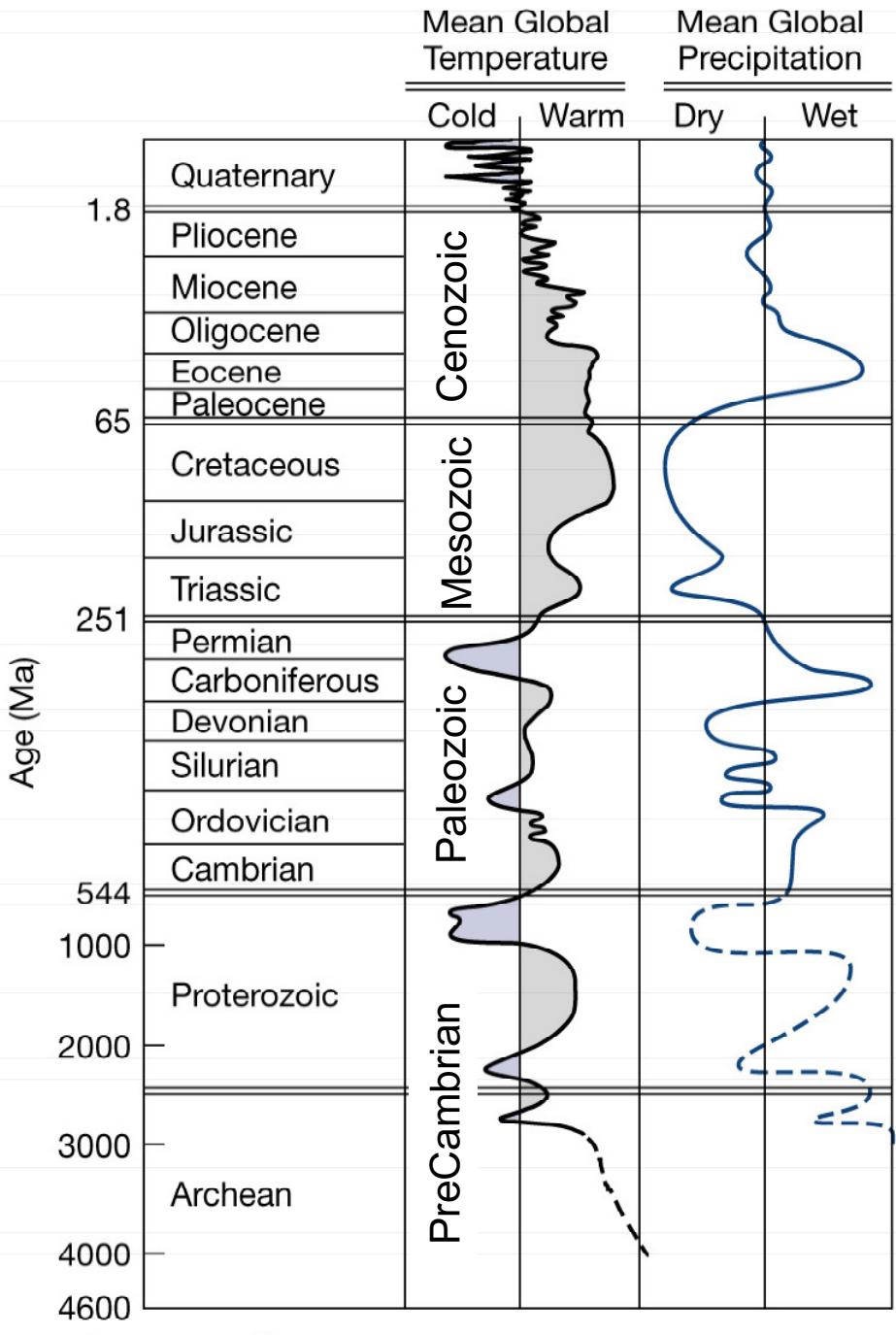
Photo Dumka et al. 2018

Past Climate

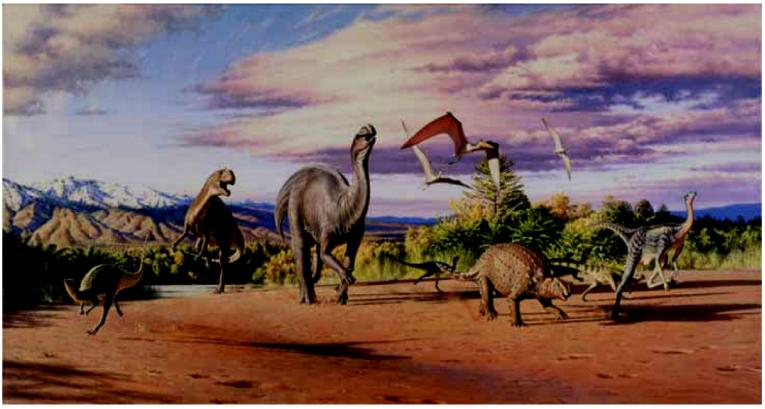
- **The statement "The present is the key to the past" was made by James Hutton, which is known as Uniformitarianism.**

Why past climate is important?

Ancient Climates



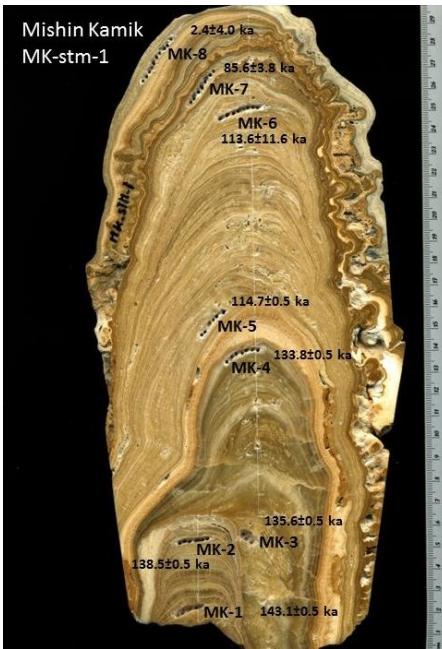
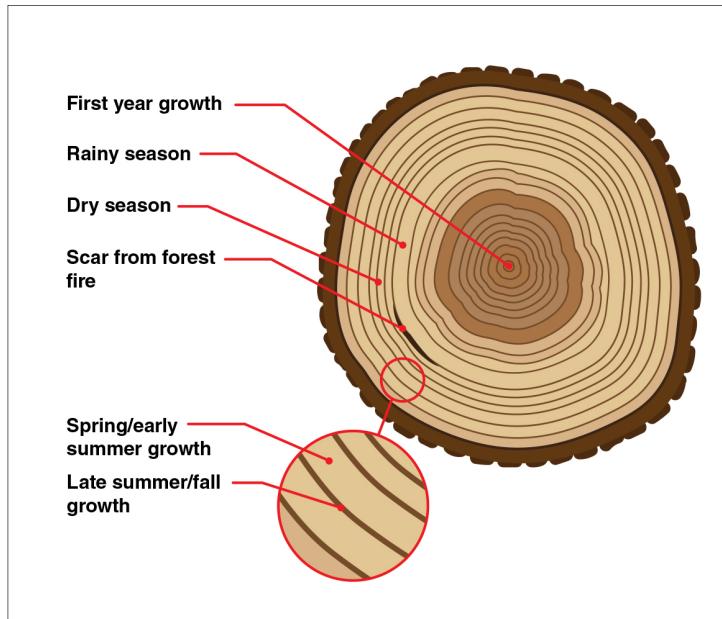
- Climate was **warm** during the Age of the Dinosaurs (the Mesozoic)
 - **Alligators** lived in Siberia!
 - **Dinosaurs** lived north of the Arctic Circle in Alaska!



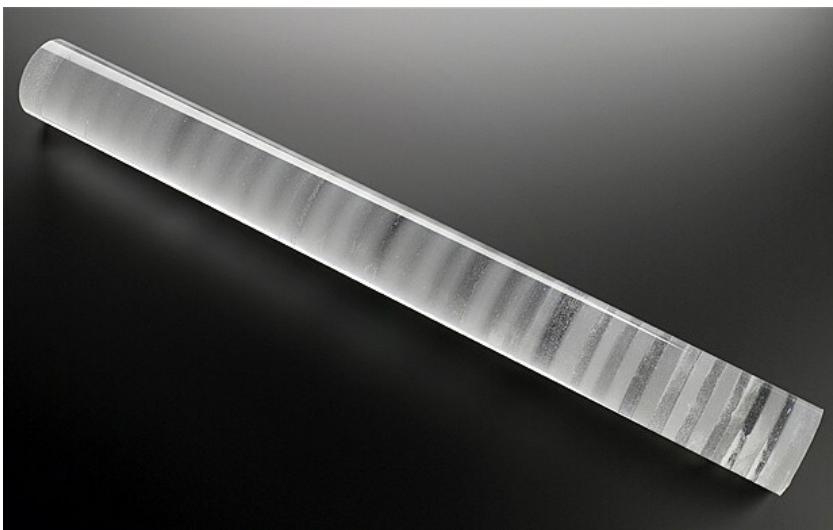
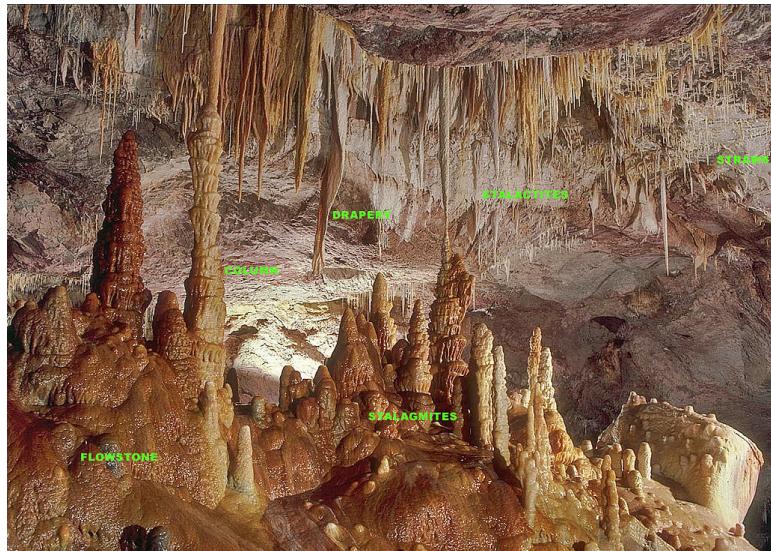
Methods to establish past climate

- **Isotopic Geochemical Studies:** the study of rock isotopic ratios, ice core bubbles, etc.
- **Dendochronology:** the study of tree rings
- **Pollen Distribution:** the study of plant types and prevalence (e.g., Europe's vegetation in the last ice age)
- **Lake Varves:** (like dendochronology, but with lake sediments)
- **Coral Bed Rings:** (like dendochronology, but with corals)
- **Fossils:** Studies of geological settings, etc.
- **Historical documents:** paintings of glaciers, etc.

Lets discuss: Various Proxies



Tree Ring
Speliothems,
Ice core,
Sediment
Core
Varve
deposit





Varve deposit
Ocean core



Some interesting environment to work



Exploratory Drilling Site: 4600 m

Some interesting environment to work

DRILL MACHINE
(ALTRENATE TO 4 STROKE
ENGINE)

OUR TEAM

PORATBLE 2 KW GENERATOR

HIGH ALTITUDE COLD
WEATHER CABLE

1.5 M LONG ICE CORER



DRILL HOLE: 9 CM DIAMETER





Some interesting environment to work

<https://www.youtube.com/watch?v=0nydKlpZdIU>

Oxygen isotopes and paleoclimate

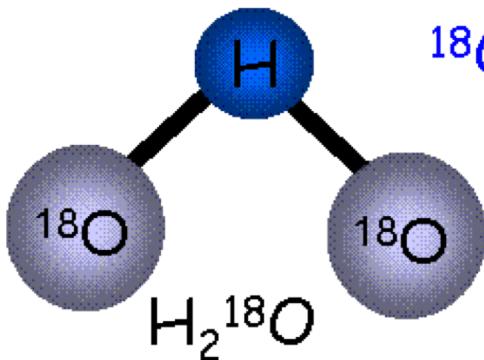
- Oxygen has three stable isotopes: ^{16}O , ^{17}O , and ^{18}O .
(We only care about ^{16}O and ^{18}O)
- ^{18}O is heavier than ^{16}O (it has 2 extra neutrons).
- The amount of ^{18}O compared to ^{16}O is expressed using "delta" notation - the unit is "per mil" (parts per thousand):
$$\delta^{18}\text{O} \text{ ‰} = \frac{{}^{18}\text{O}/{}^{16}\text{O} \text{ of sample} - {}^{18}\text{O}/{}^{16}\text{O} \text{ of standard}}{{}^{18}\text{O}/{}^{16}\text{O} \text{ of standard}} \times 1000$$

Fractionation:

Natural processes tend to preferentially take up the lighter isotope, and preferentially leave behind the heavier isotope.
For most chemistry, the isotopes behave the same.

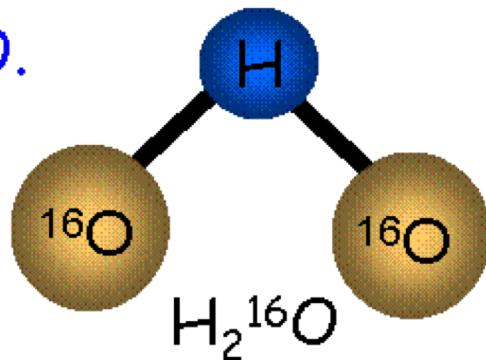
Isotope “fractionation”

- Oxygen isotopes are **fractionated** during evaporation and precipitation of H₂O
 - H₂¹⁶O evaporates more readily than H₂¹⁸O
 - H₂¹⁸O precipitates more readily than H₂¹⁶O



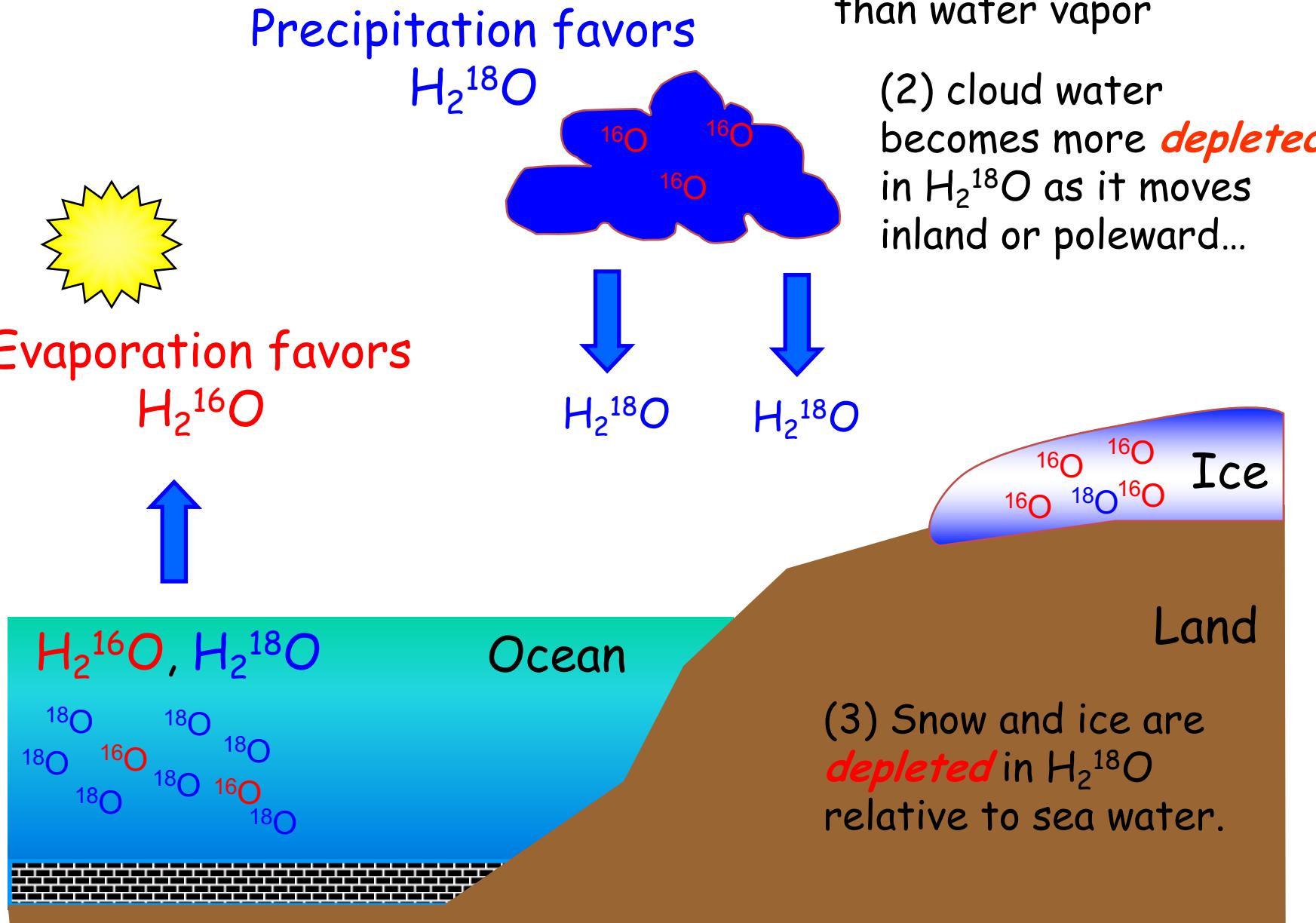
¹⁸O is heavier than ¹⁶O.

H₂¹⁸O is heavier than H₂¹⁶O.

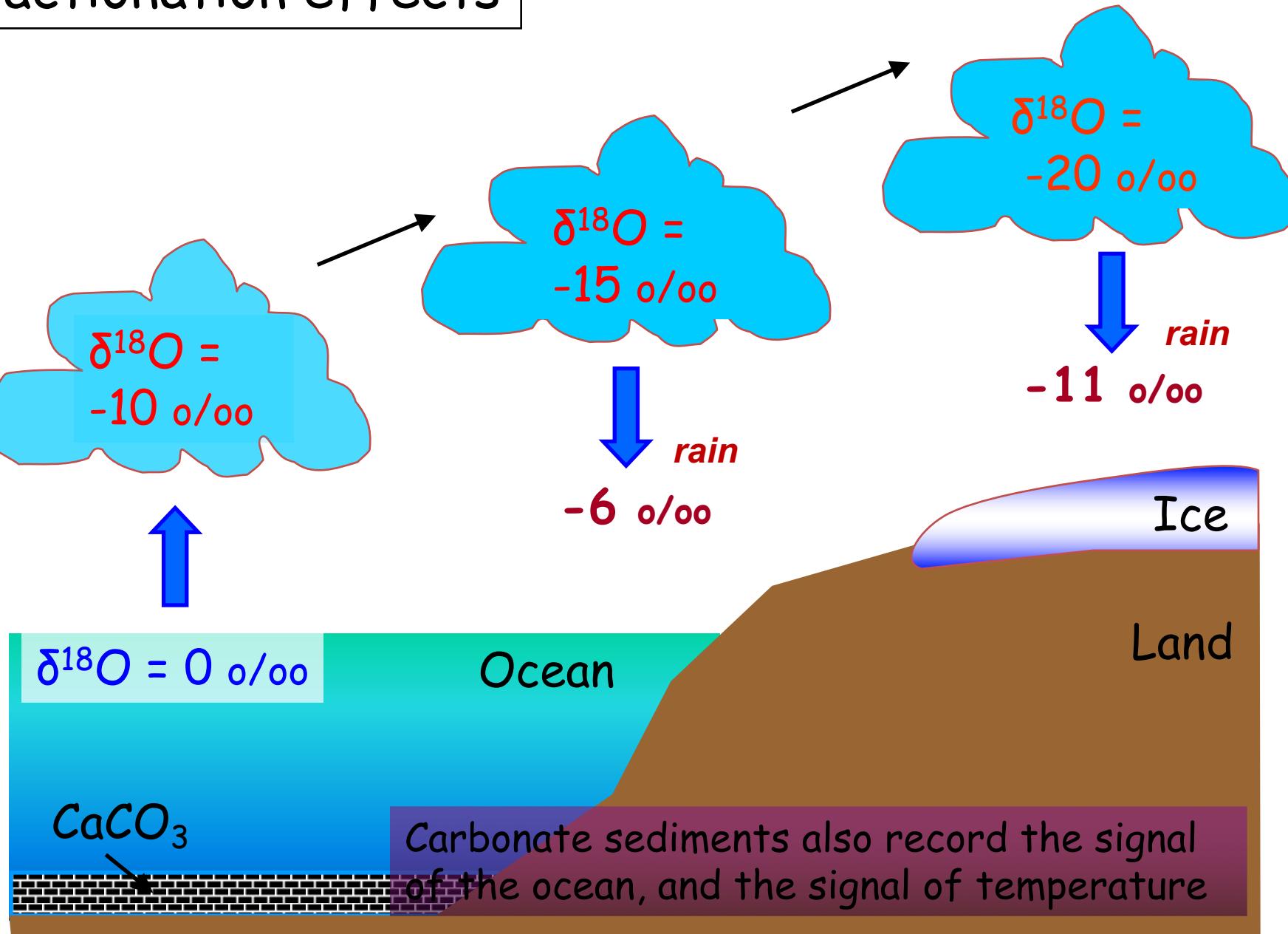


- Oxygen isotopes are also **fractionated** by marine organisms that secrete CaCO₃ shells. The organisms preferentially take up more ¹⁶O as temperature increases.

Fractionation effects



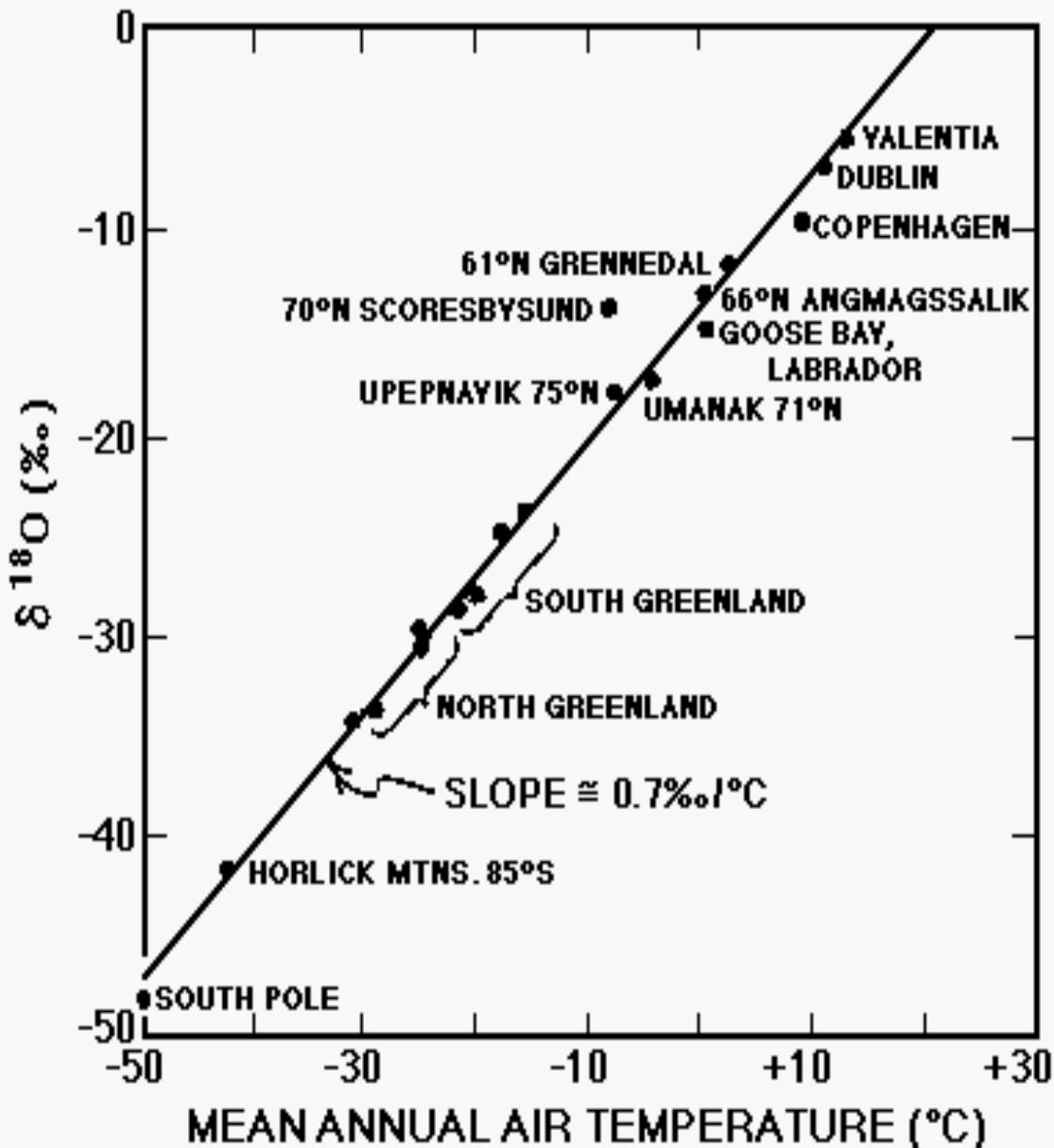
Fractionation effects



We can also show that the $\delta^{18}\text{O}$ of precipitation is well correlated with temperature!

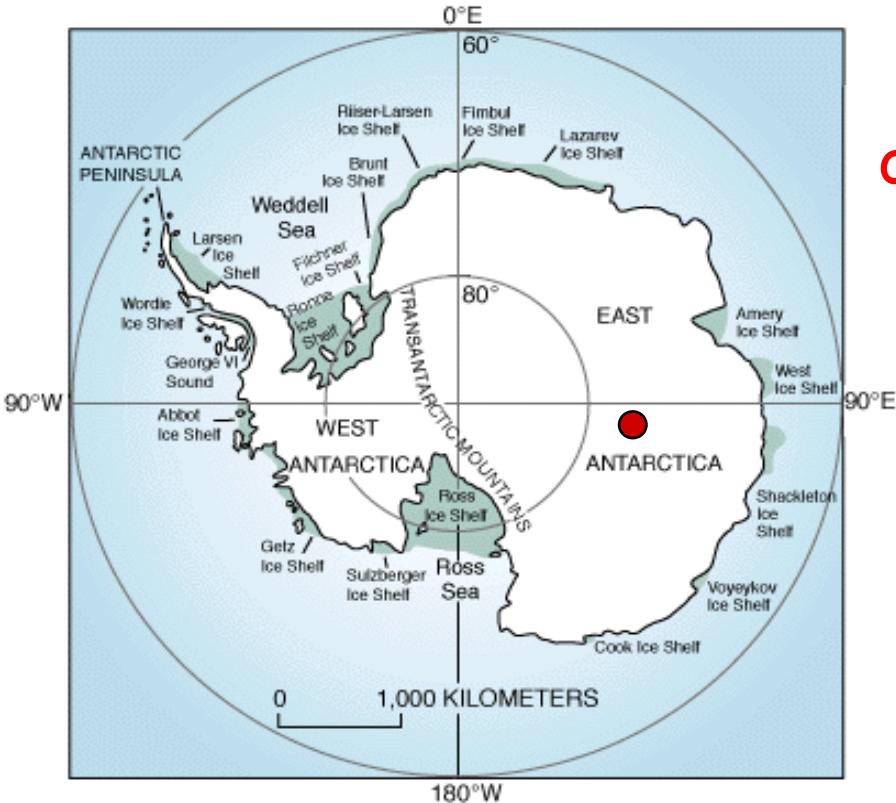
So, if we know the $\delta^{18}\text{O}$ of water or ice, we know what the air temperature was at that time.

(Note that hydrogen isotopes work the same way)



Observed $\delta^{18}\text{O}$ in average annual precipitation as a function of mean annual air temperature (Dansgaard, 1964). Note that all the points on this graph are for high latitudes ($>45^\circ$).

The Antarctic Ice Coring operation at Vostok station



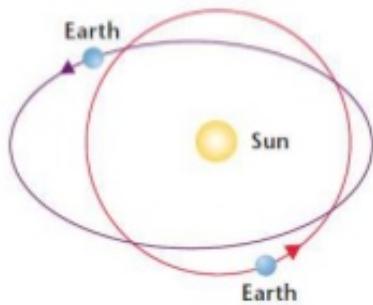
The Greenland Ice Coring operation at Summit station



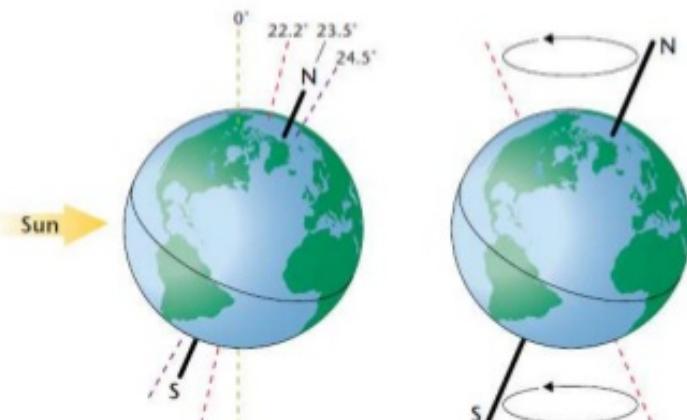
Dome GRIP
1990-1992

Some more thoughts? Can climate change be natural

Milankovitch Cycle

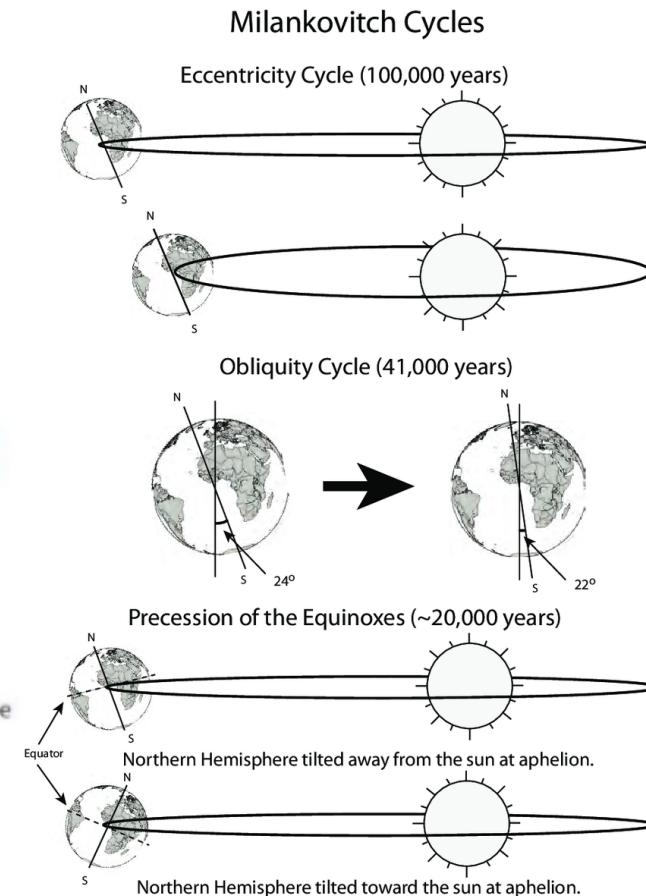


Eccentricity Earth encounters more variation in the energy that it receives from the sun when Earth's orbit is elongated than it does when Earth's orbit is more circular.



Tilt The tilt of Earth's axis varies between 22.2° and 24.5° . The greater the tilt angle is, the more solar energy the poles receive.

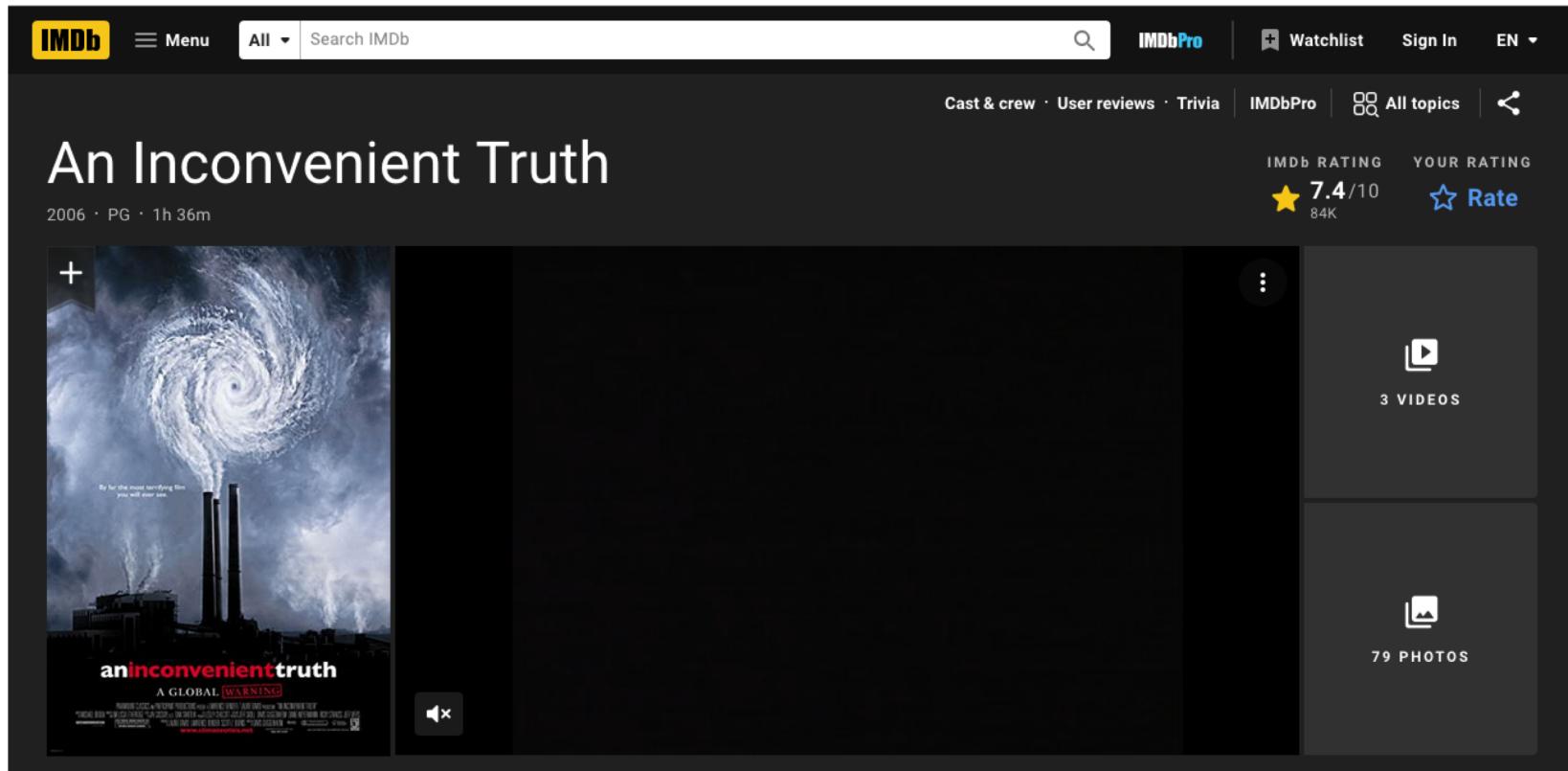
Precession A gradual change, or "wobble," in the orientation of Earth's axis affects the relationship between Earth's tilt and eccentricity.



Northern Hemisphere tilted away from the sun at aphelion.
Northern Hemisphere tilted toward the sun at aphelion.

Assignment

Watch this movie:



The image shows a screenshot of the IMDb website for the movie "An Inconvenient Truth". The page has a dark header with the IMDb logo, a search bar, and navigation links like "Menu", "All", "Search IMDb", "IMDbPro", "Watchlist", "Sign In", and "EN". Below the header, there's a navigation bar with links to "Cast & crew", "User reviews", "Trivia", "IMDbPro", "All topics", and a share icon. The main title "An Inconvenient Truth" is displayed prominently in large white text. Below it, the release year "2006", rating "PG", and runtime "1h 36m" are shown. To the right of the title, the IMDb rating is listed as "7.4/10" with "84K" reviews, and a "Rate" button. On the left, there's a large thumbnail image of the movie poster, which features a satellite view of a cyclone over a factory with smokestacks. A quote from the movie is visible on the poster: "By far the most terrifying film you will ever see." At the bottom of the poster, the title "aninconvenienttruth" and the subtitle "A GLOBAL WARNING" are printed. To the right of the poster, there are sections for "3 VIDEOS" and "79 PHOTOS". A volume icon with a 'x' is also present.

See you next class