Exercise 1 Due January 8, 10:00pm

Examine graphs of Davis' average temperatures from satellite and ground stations to determine whether there has been a climate change trend.

For Essay 1, you will compare Davis with a city of your choice.

Quiz 1 due Friday

Get help with the Exercise TONIGHT!

Enroll in **SAS 98 Section 002, CRN 40468** for **one unit credit**. This extra unit is for a discussion session that the TAs will stream live each Thursday nights at **7 PM** and will record that covers how to do the weekly assignment for SAS 25 & SAS 25v.

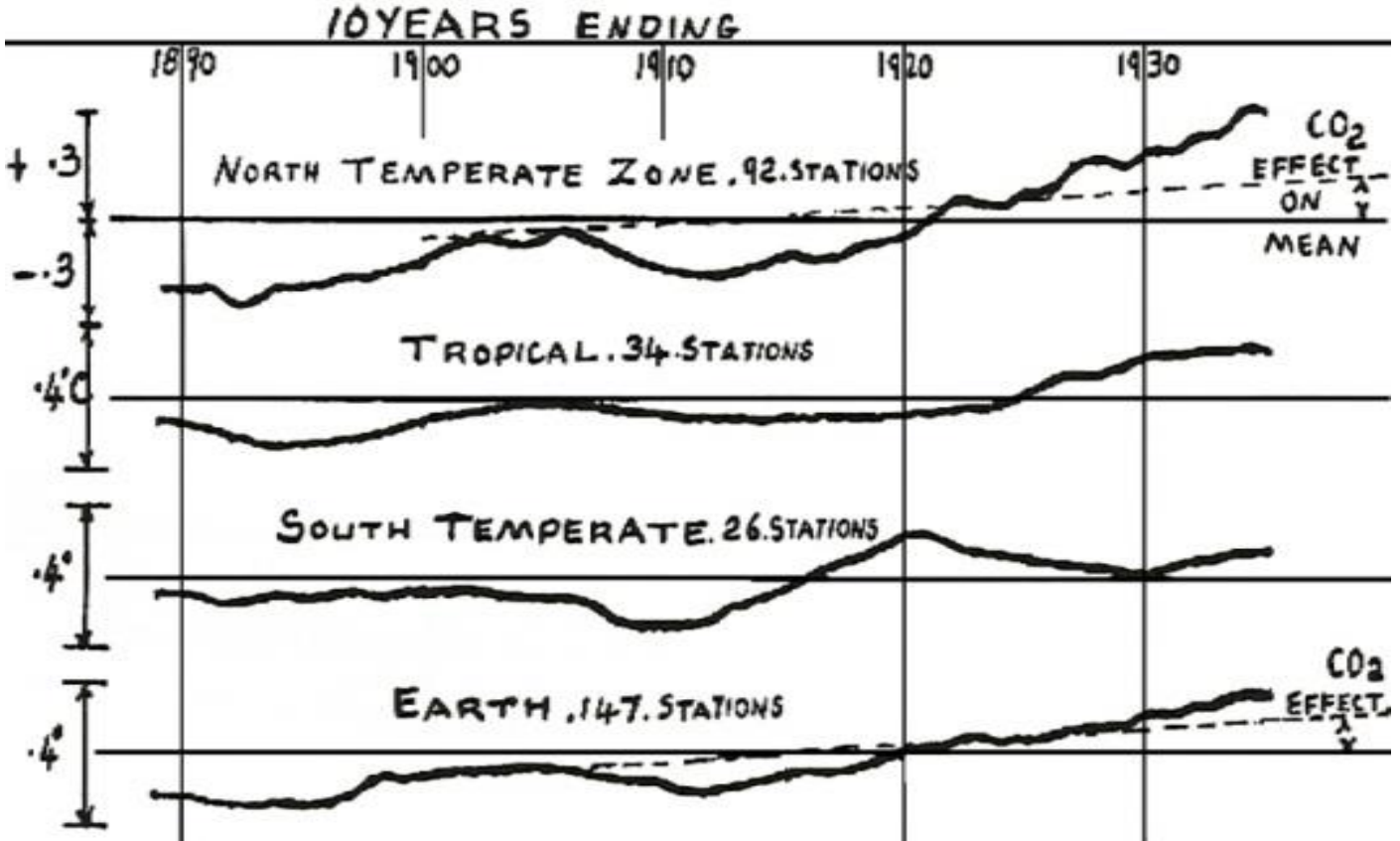
CRN	Day	Time	Online Discussion Room
40468	Thursday	7:10-8:00 PM	http://ucoe.adobeconnect.com/review/

Last Time…

- Climate vs weather
- History of climate change research
  - Guy Stewart Callendar
  - Roger Revelle and Hans Suess
  - David Keeling (Keeling Curve)

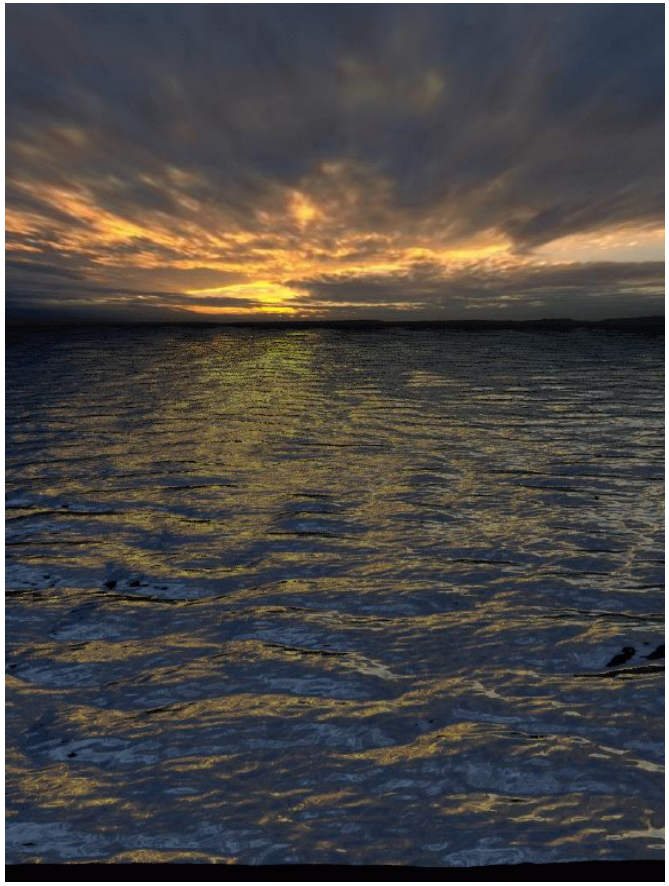
Weather Records

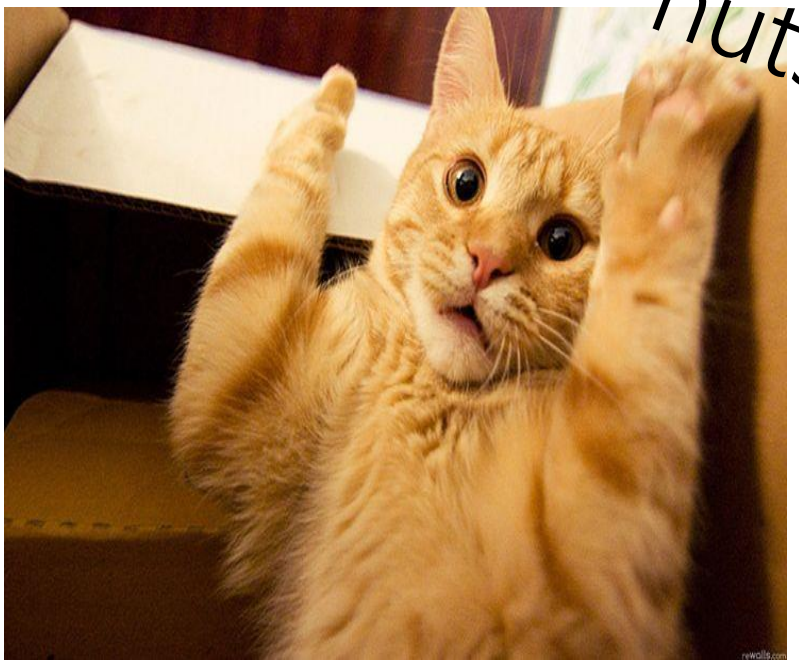
– **Guy Stewart** Callendar – 1st to discover recent warming trend and link it to fossil fuel emissions (1930s)



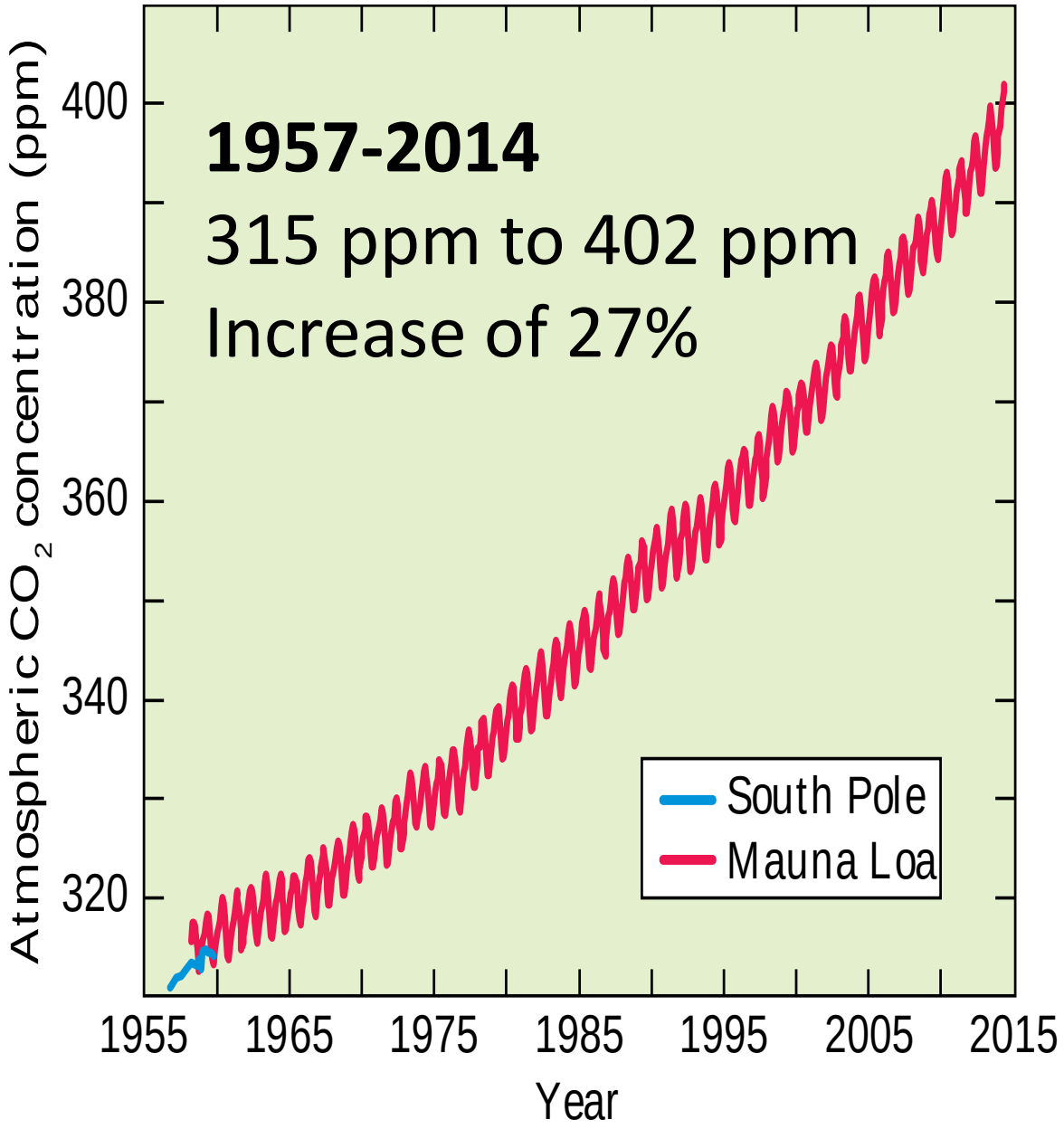
Roger Revelle and Hans Suess, 1957

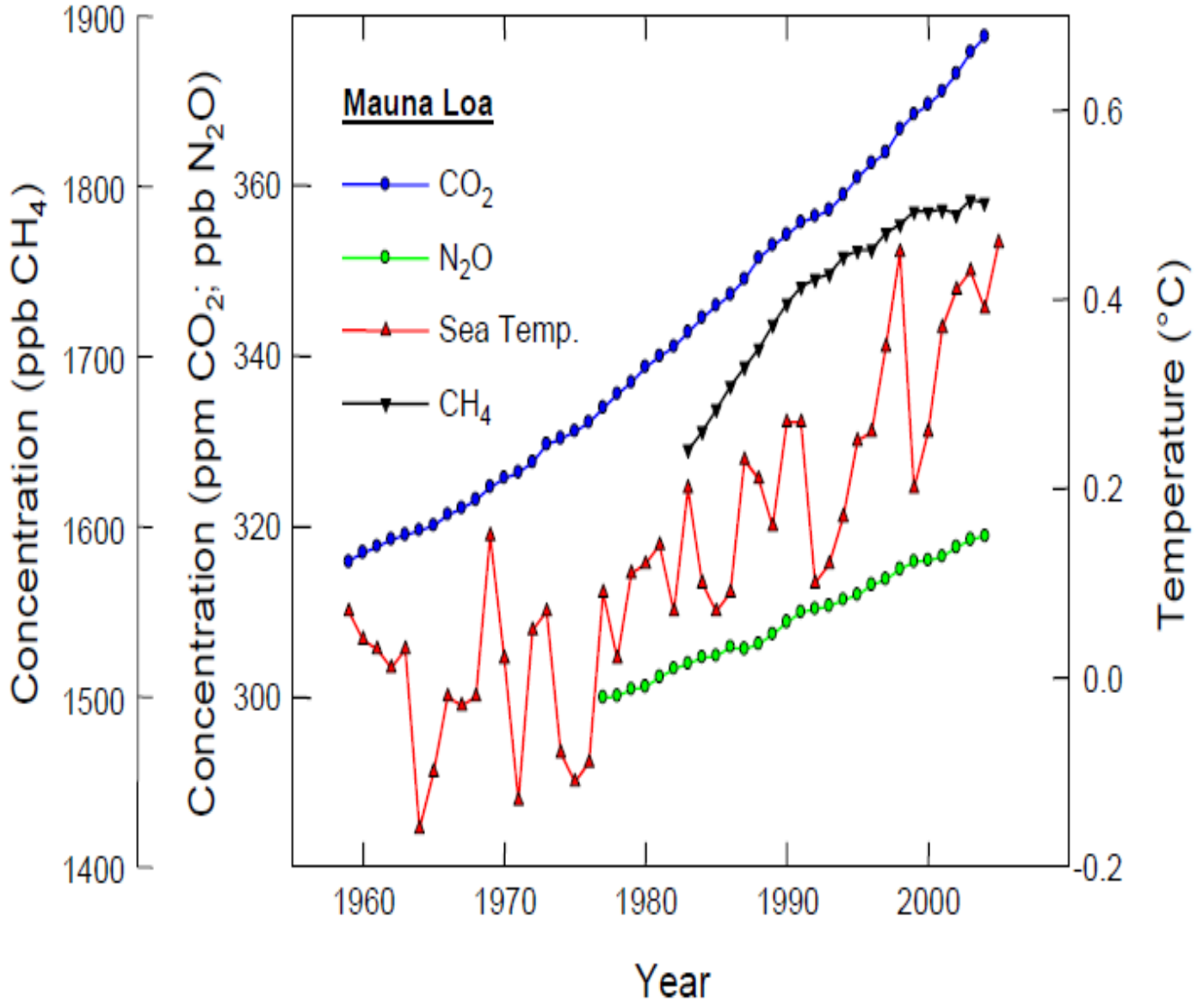
Discovered ocean is not a major sink for CO2





The Keeling Curve



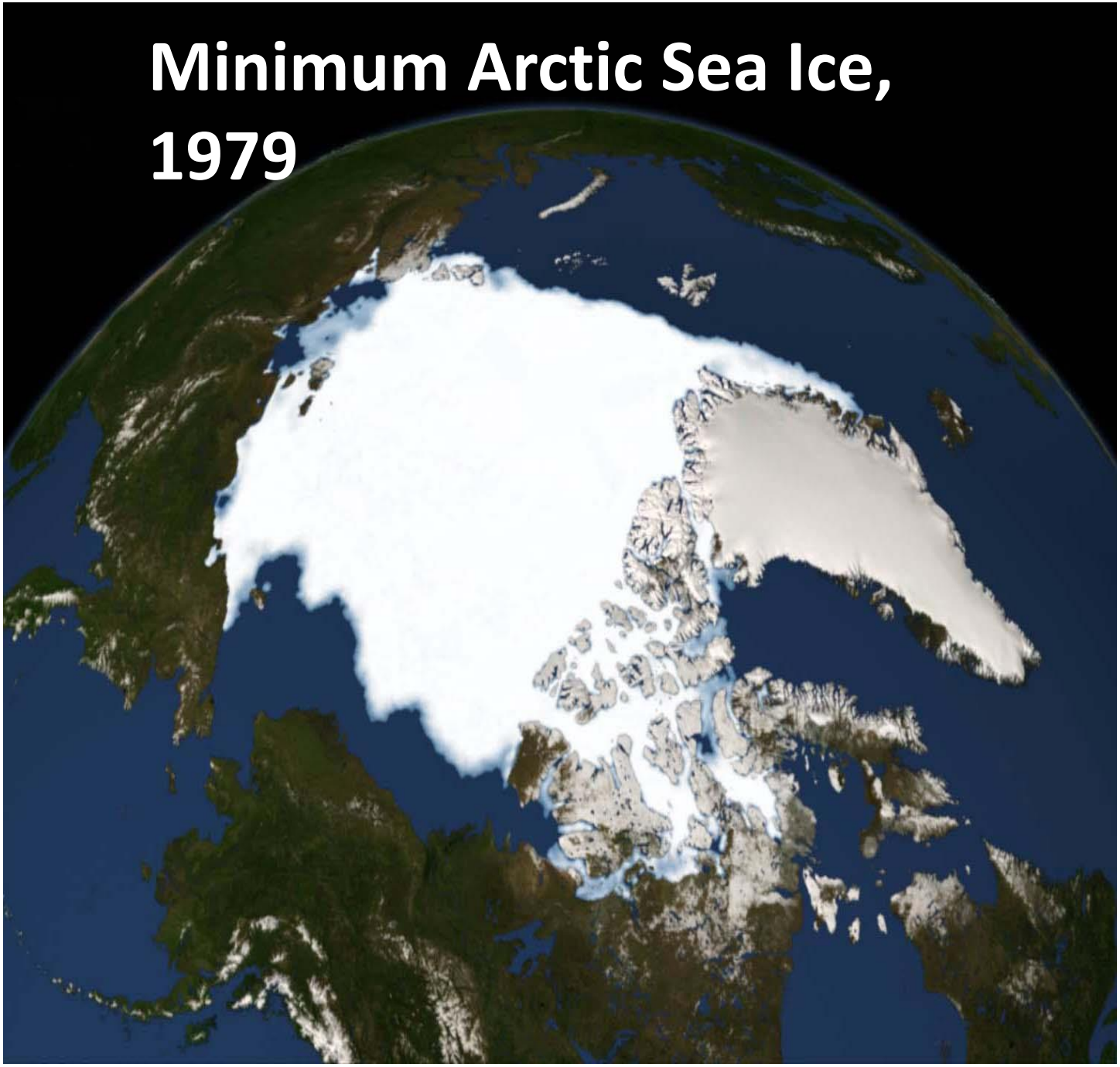

Mauna Loa
CO2
N2O
Sea Temp.
CH4
Concentration (ppb CH4)
Concentration (ppm CO2; ppb N2O)
Temperature (°C)
Year
1900
1800
1700
1600
1500
1400
360
340
320
300
0.6
0.4
0.2
0.0
-0.2
1960
1970
1980
1990
2000

Mt. Kilimanjaro on Feb. 17, 1993

Mt. Kilimanjaro on Feb. 21, 2000

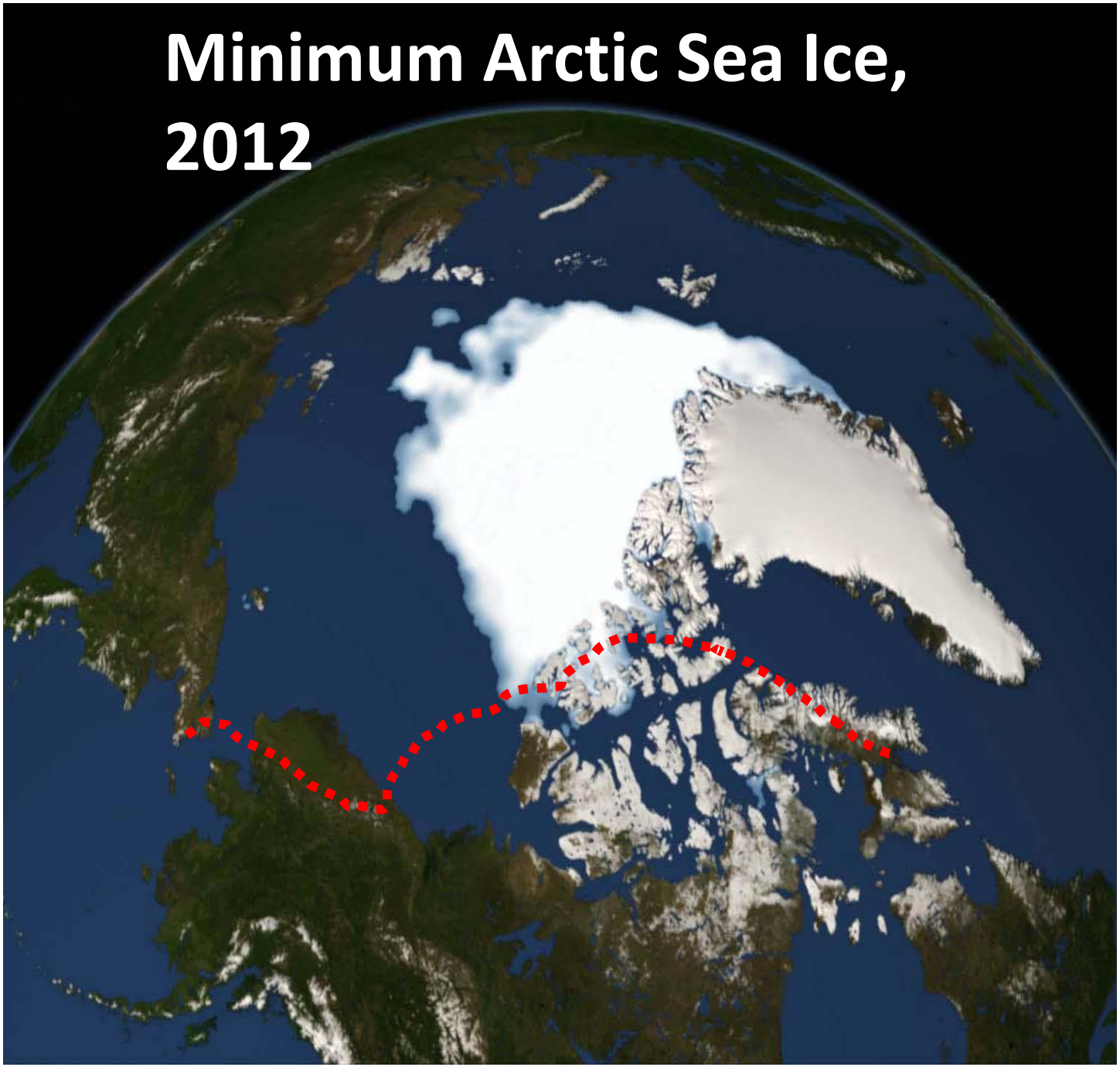
January-September, 2007

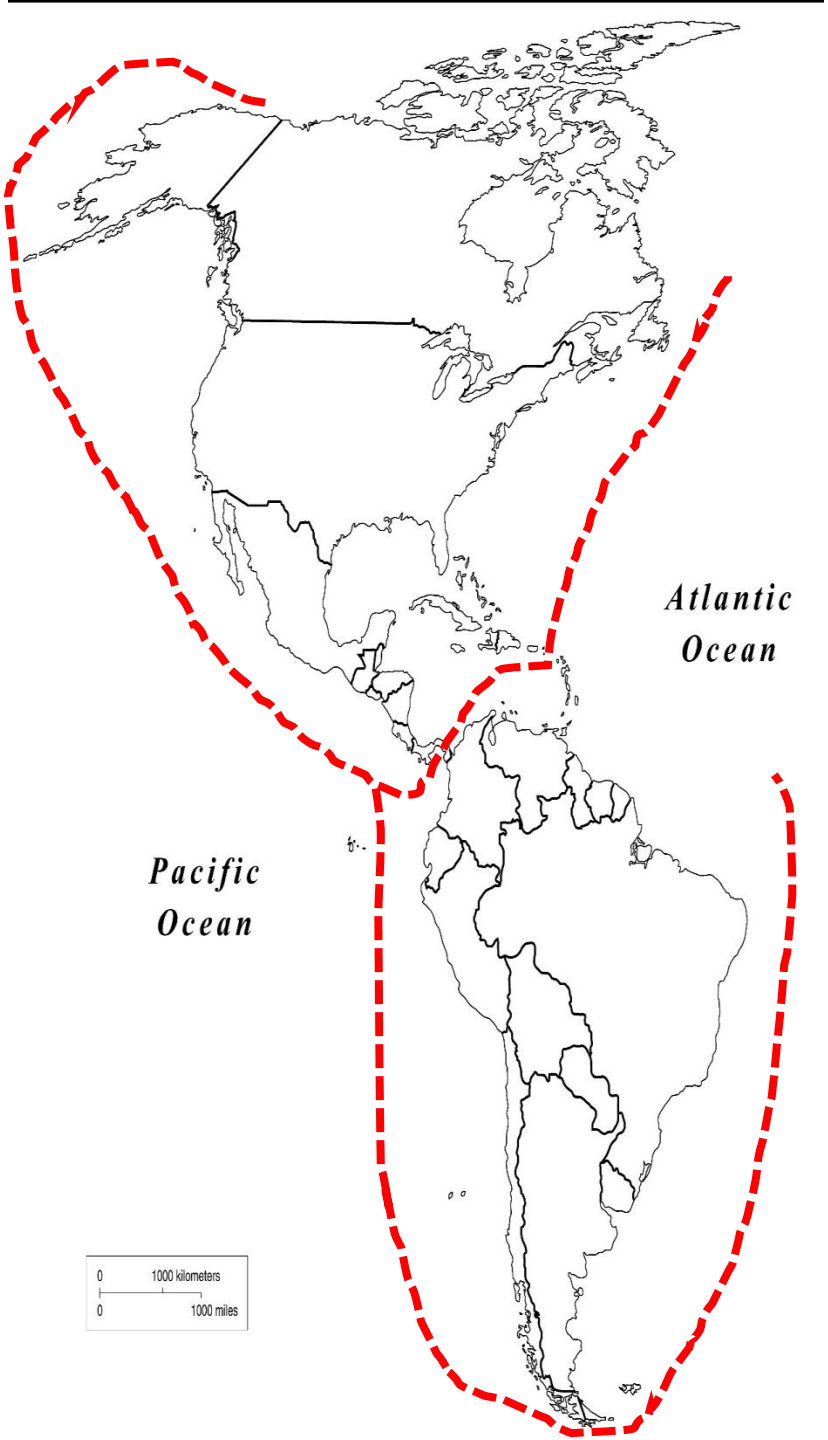
http://www.climatechangecourse.org/NW4Lg.mp4


Minimum Arctic Sea Ice,
1979

Became ice free for the first time in 2007

Navigated by a freighter in 2013




Atlantic
Ocean
Pacific
Ocean
0
1000 kilometers
0
1000 miles

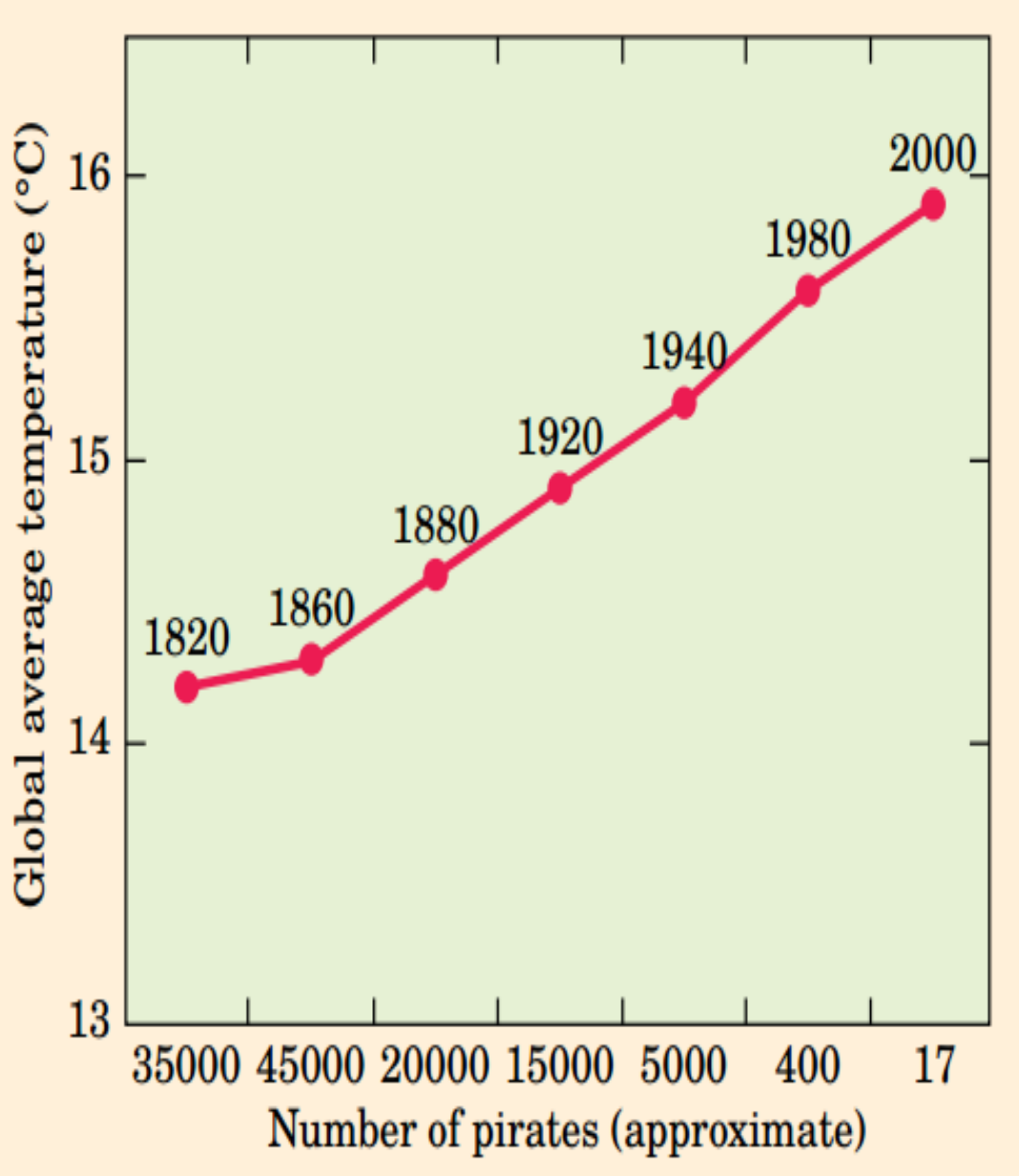
What Do We Know?

Global temperatures have warmed more than 0.6°C during the last 100 years

CO_2 concentrations have been increasing in correlation

Hottest Years on Record:	
2010	2011
1998	2004
2005	2001
2007	2002
2012	2003
2000	2013
2009	2006

Correlation Between CO_2 and Temp



Google Correlate

funny cat videos × Search correlations Enter your own data

Exclude terms containing **funny cat videos**

Compare US states
Compare weekly time series
Compare monthly time series

Shift series 0 weeks
Country:
United States

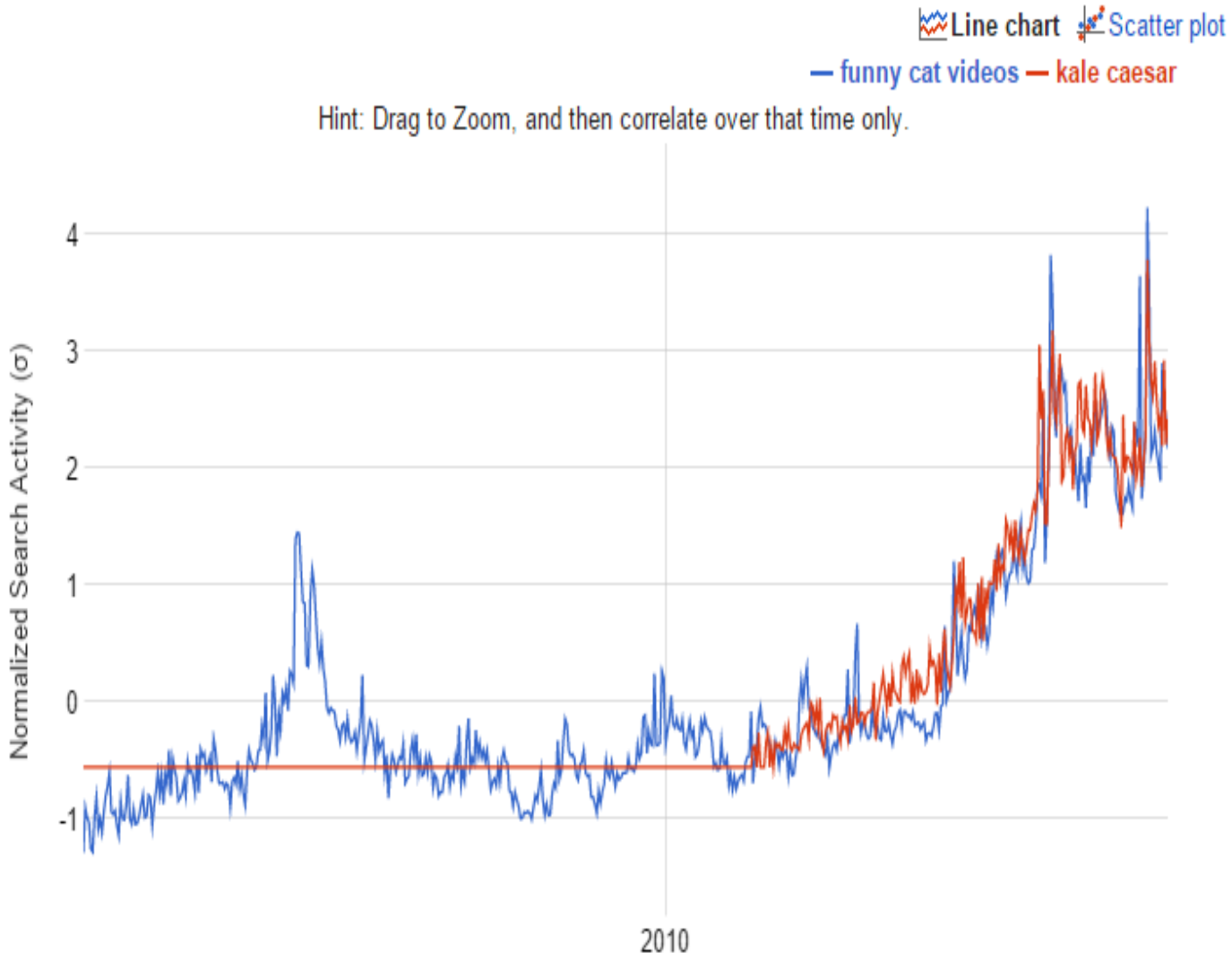
Documentation
Comic Book
FAQ
Tutorial
Whitepaper
Correlate Algorithm

Correlate Labs
Search by Drawing

Correlated with **funny cat videos**

0.9744 cat videos
0.9313 free minecraft games
0.9296 smart wifi
0.9291 pelicula completa en español
0.9286 completa en español
0.9283 pelicula completa español latino
0.9274 pelicula completa español
0.9270 little pony videos
0.9269 minecraft games
0.9267 pony videos
0.9264 full movie hd
0.9264 my little pony videos
0.9254 games for ios
0.9245 pelicula completa en español latino
0.9241 how do u screenshot
0.9239 star stable
0.9237 how to stream on twitch
0.9236 booty twerking
0.9235 ilysm
0.9234 philips smart tv
0.9234 stream on twitch
0.9230 modded apk
0.9227 youtube/pair

United States Web Search activity for **funny cat videos** and **kale caesar** (r=0.9198)



Global Warming

Are rising temperatures part of normal fluctuations?

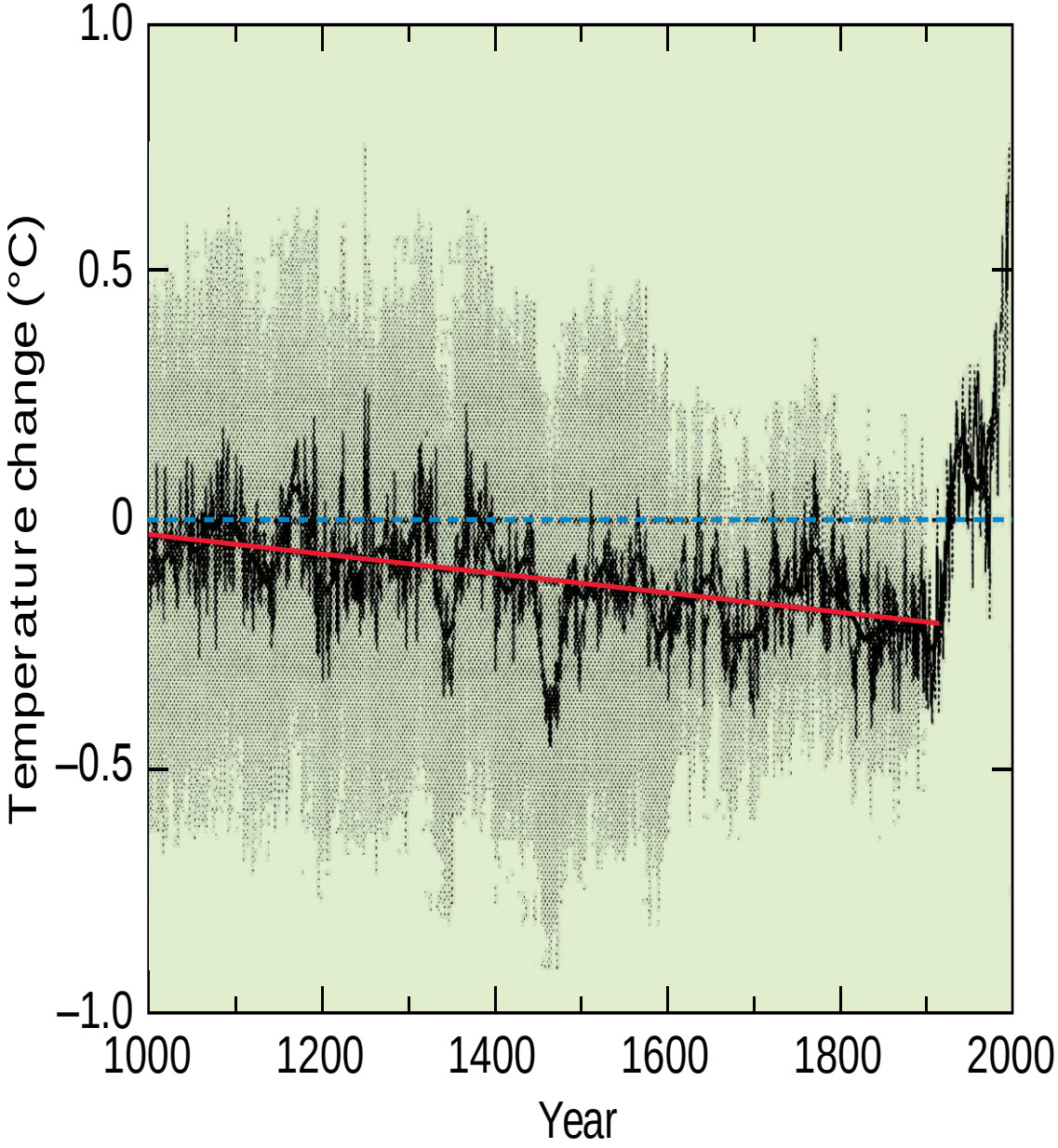
How important are human activities?

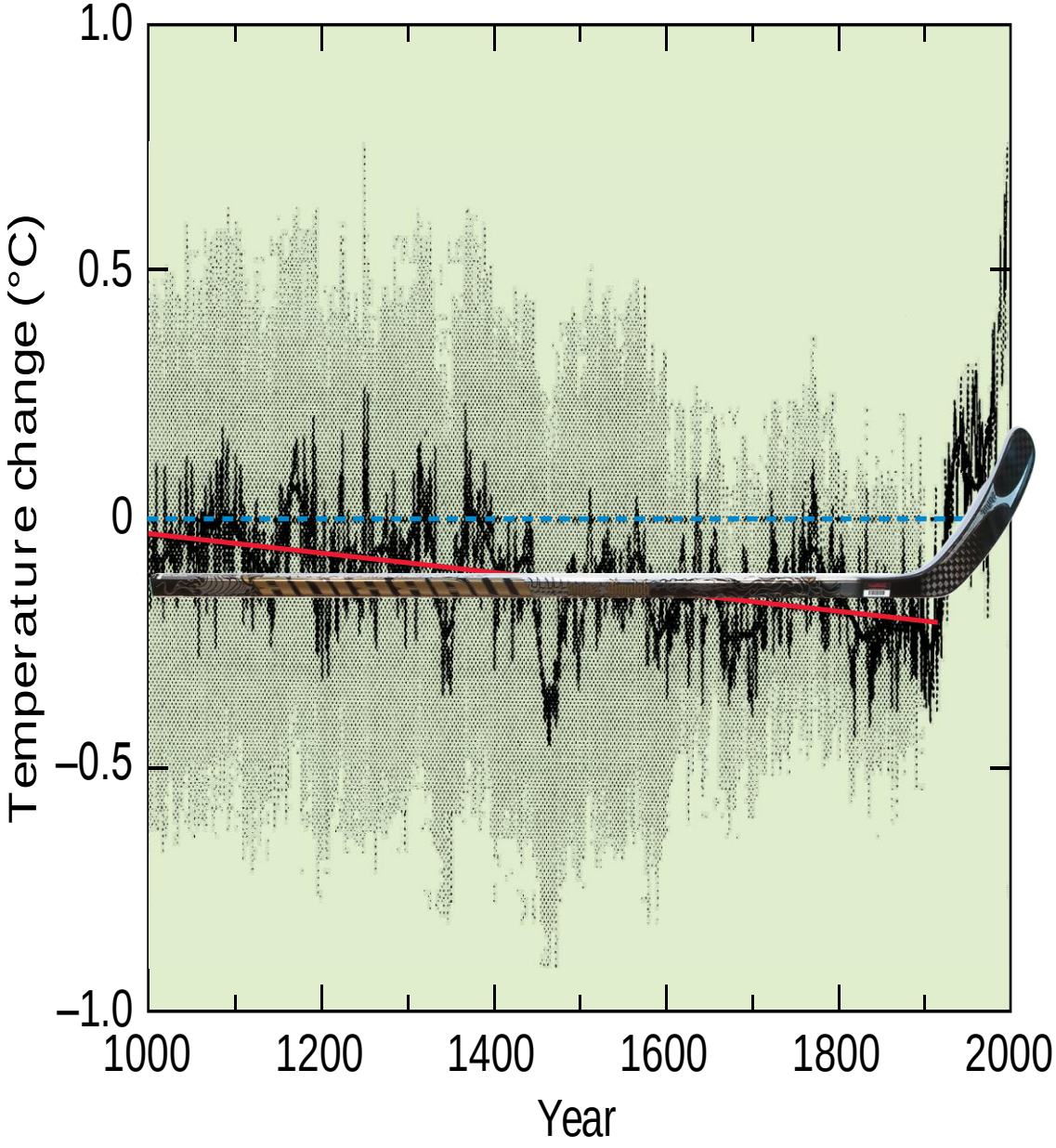
- Burning of fossil fuels
- Changes in land use

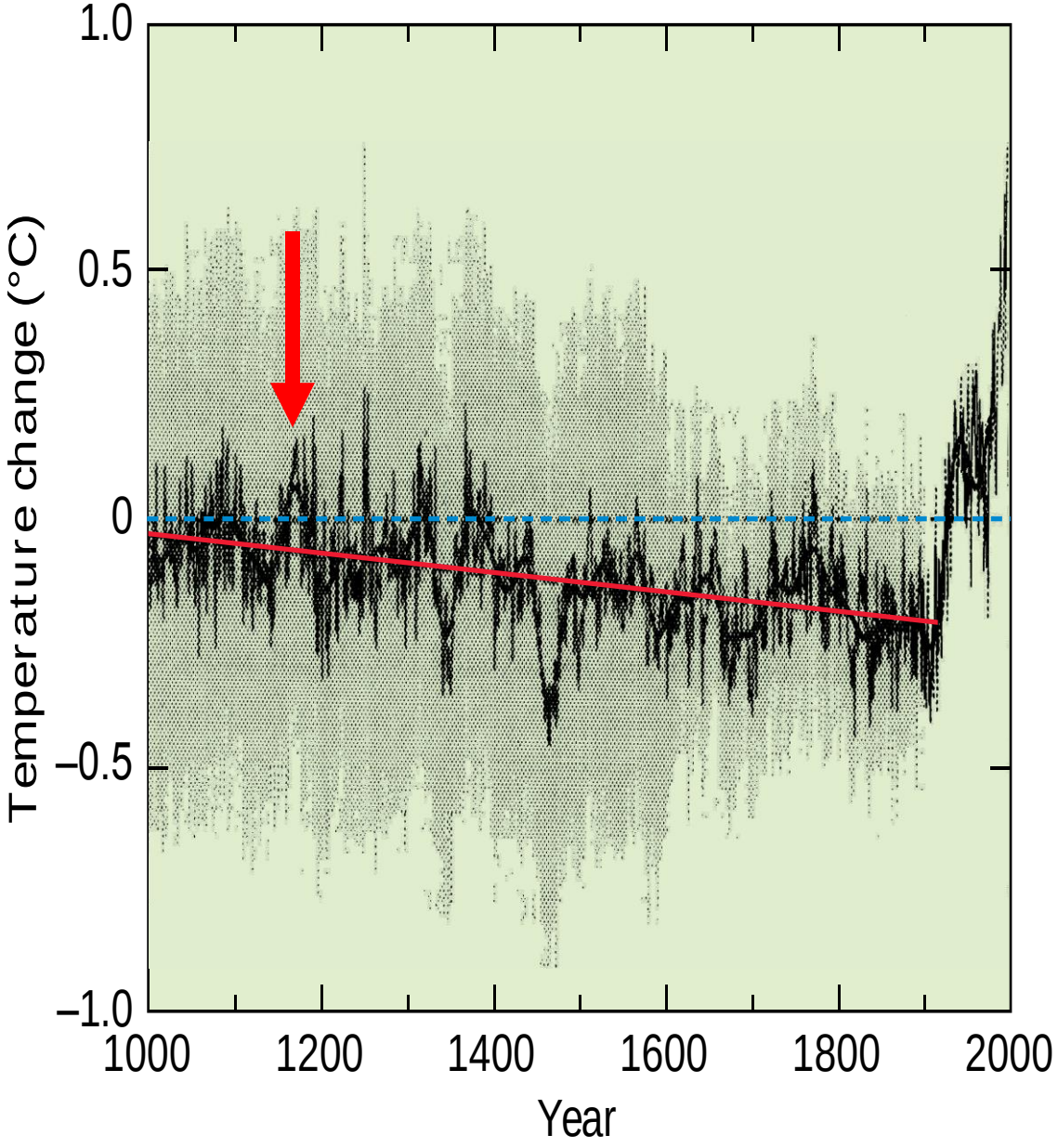
Clues:

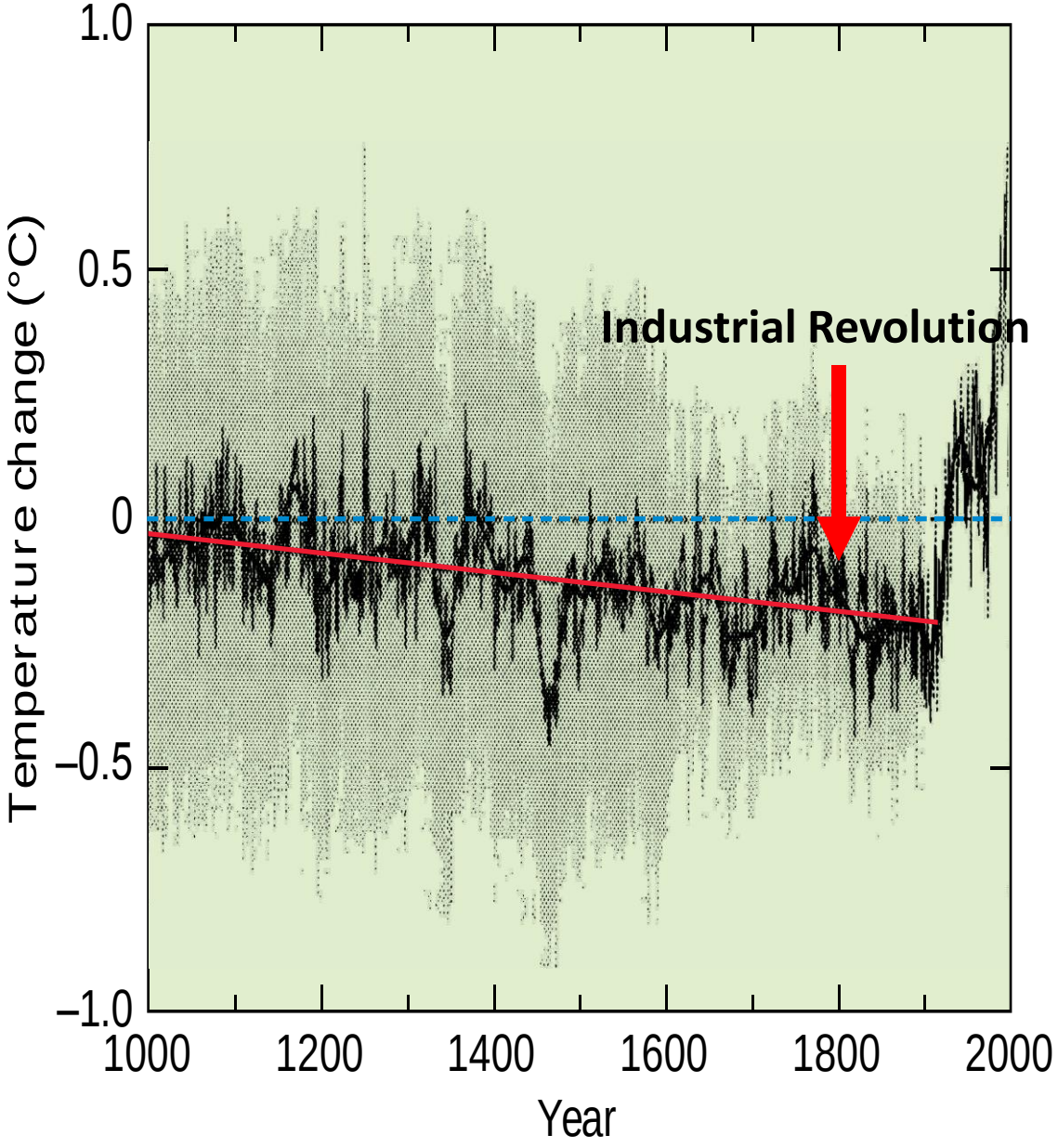
- How did climate vary before the Industrial Revolution?
- What other factors (non-human) influence climate?

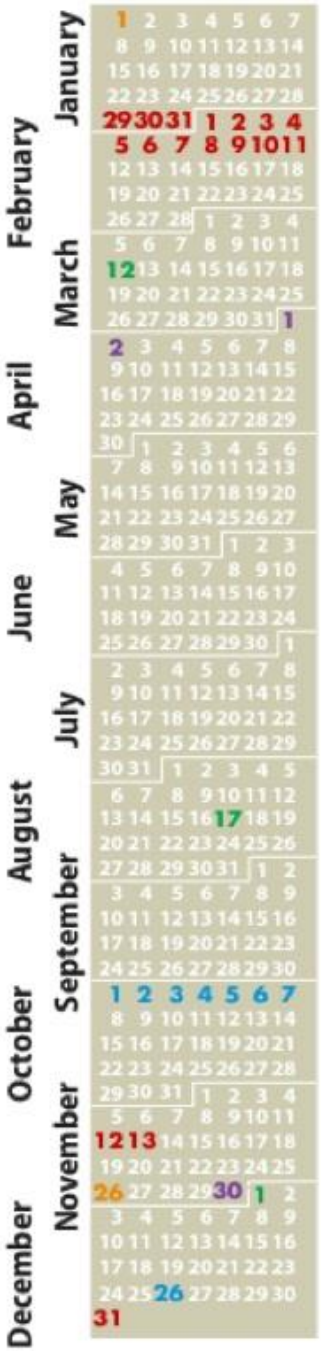
Direct measurements since 1861


1.0
0.5
0
–0.5
–1.0
Temperature change (°C)
1000
1200
1400
1600
1800
2000
Year


1.0
0.5
0
–0.5
–1.0
Temperature change (°C)
1000
1200
1400
1600
1800
2000
Year


1.0
0.5
0
–0.5
–1.0
Temperature change (°C)
1000
1200
1400
1600
1800
2000
Year


1.0
0.5
0
–0.5
–1.0
Temperature change (°C)
Industrial Revolution
1000
1200
1400
1600
1800
2000
Year



1: Earth forms

29–11: Oldest known rocks

12: Oldest chemical evidence of life

1–2: Oldest fossil cells

17: First eukaryotes

1–7: First multicellular organisms (algae)

12–13: First animals with shells and limbs

26: First animals with vertebrae

30: First land plants

1: First land animals

26: Extinction of dinosaurs

31: *Homo sapiens* appears one hour before midnight. Humans set foot on Moon $^{1}/_{4}$ second before midnight

1 day = 12.6 million years
1 second = 143 years

Earth's Past Climate

- The Earth is about 4.5 billion years old
- Eukaryotic life has been here for 2 billion years
- Humans have been here for 40,000 years
- We have direct weather records for the past 150 years

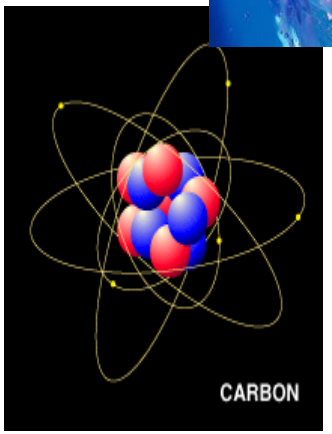
To learn about Earth's past, we have to use **Proxy Measures**

Proxy Measures of Climate

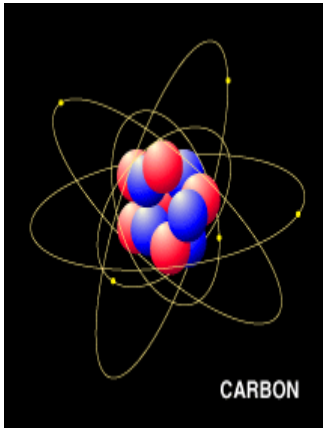
Proxy = surrogate or substitute

Proxy Measures:

- Ice Cores
- Tree Rings
- Glacial Extent
- Corral Reefs



Isotopes



A normal element has an equal number of neutrons and protons.

- Carbon (^{12}C) has 6 protons and 6 neutrons.

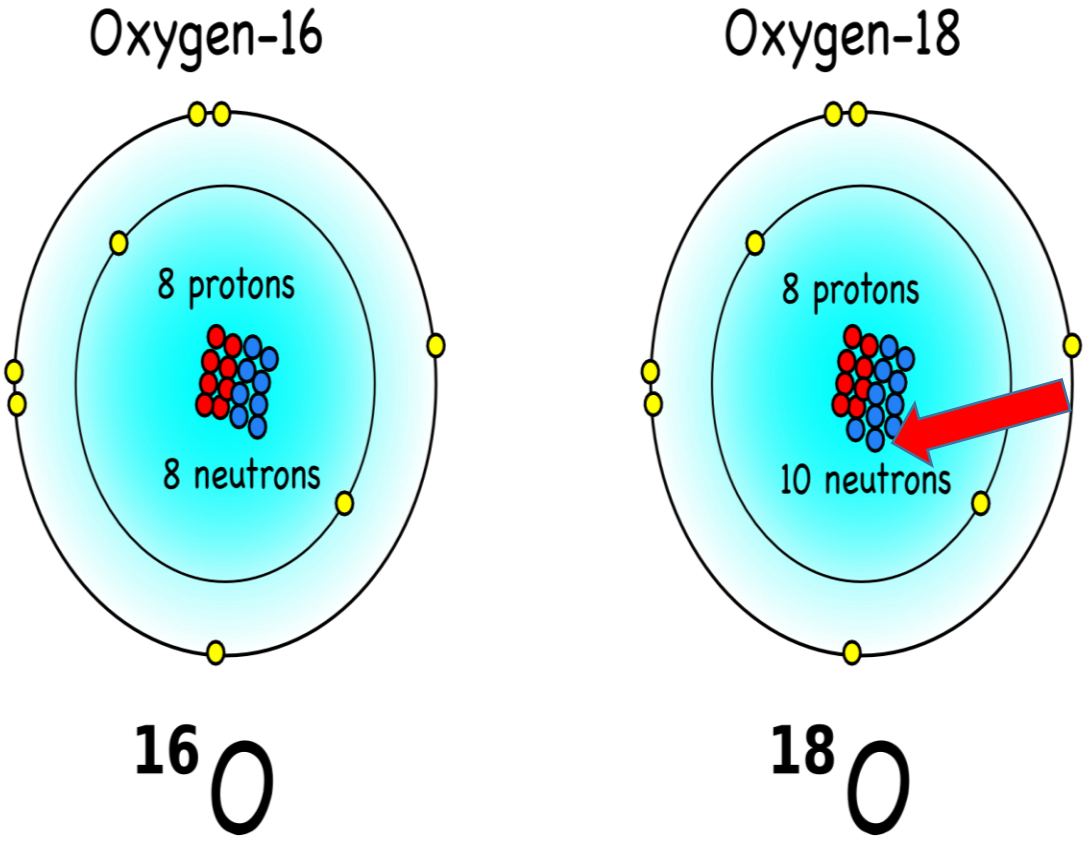
Carbon **always** has 6 protons

The number in front = the total number of protons and neutrons

Isotopes have different numbers of neutrons.

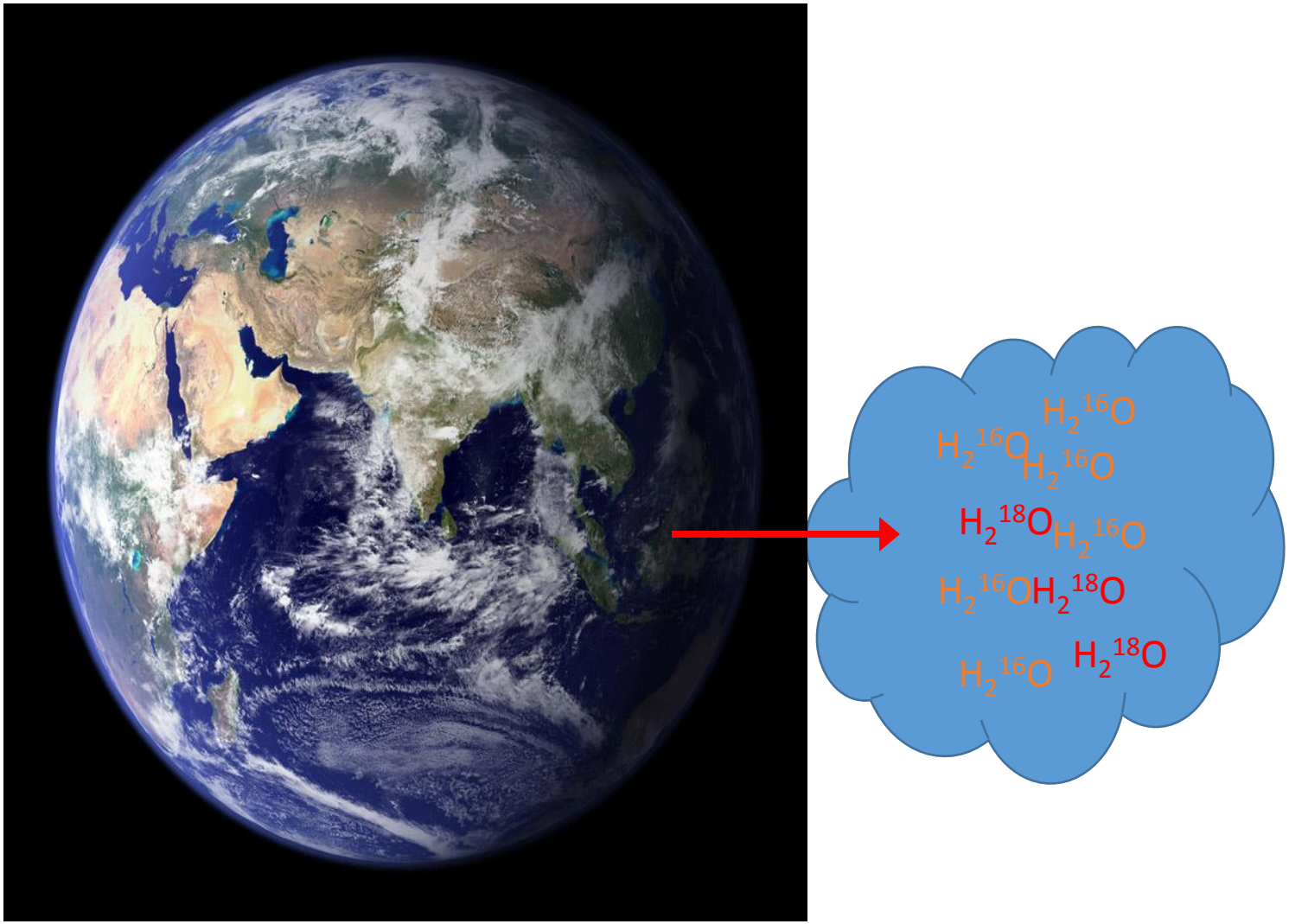
- Carbon has 14 isotopes, ranging from 2(^{8}C) to 16 (^{22}C) neutrons

Oxygen has 3 stable isotopes: ^{16}O, ^{17}O and ^{18}O

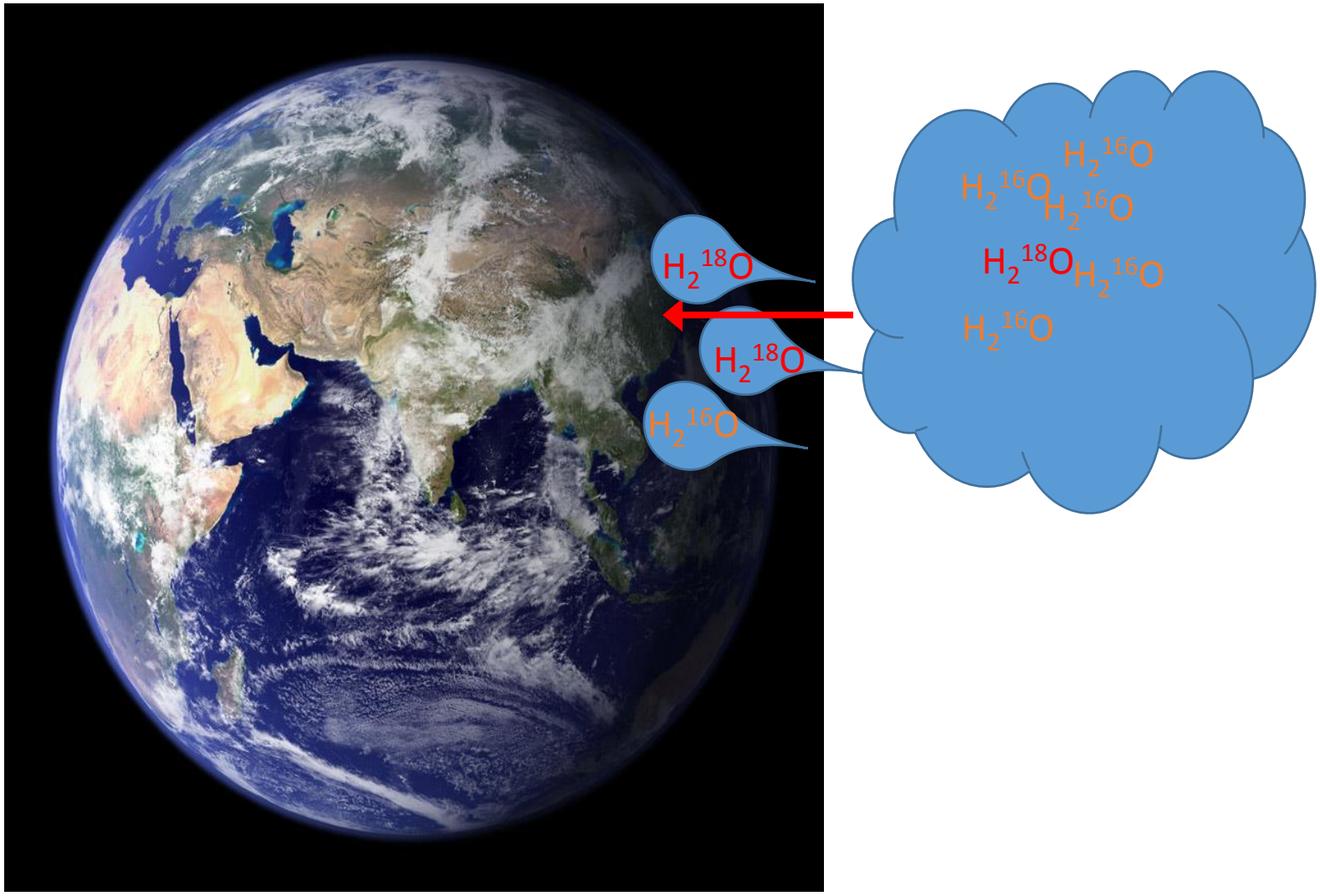


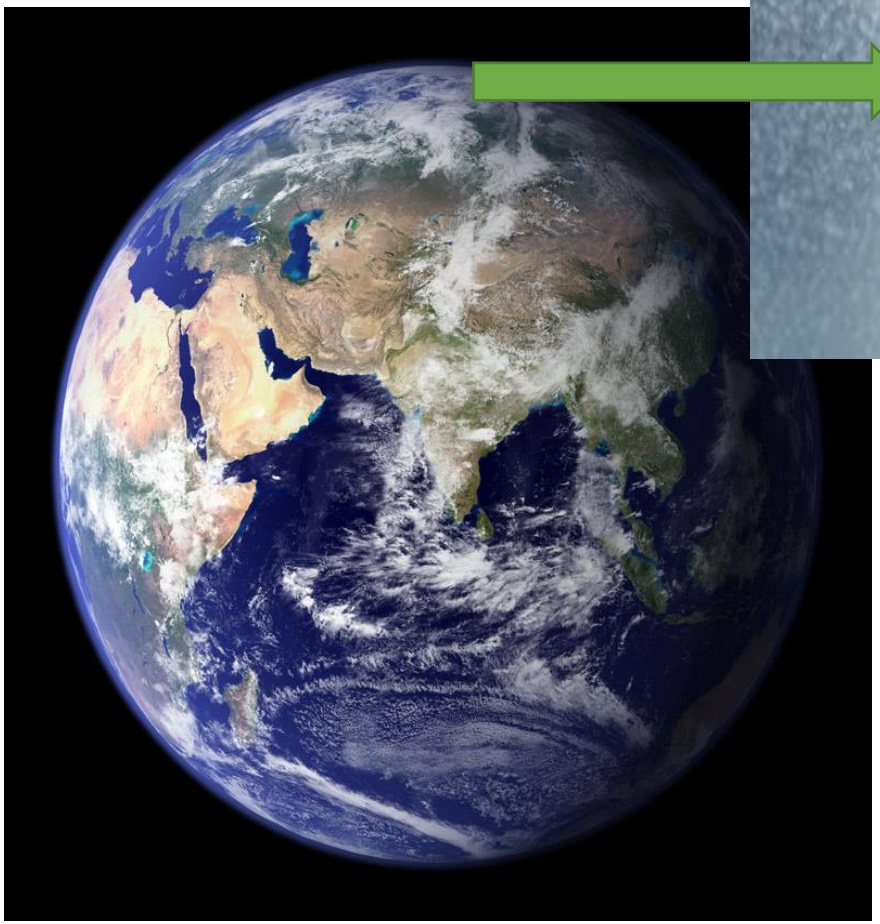
Forms LIGHT water **Forms HEAVY water**

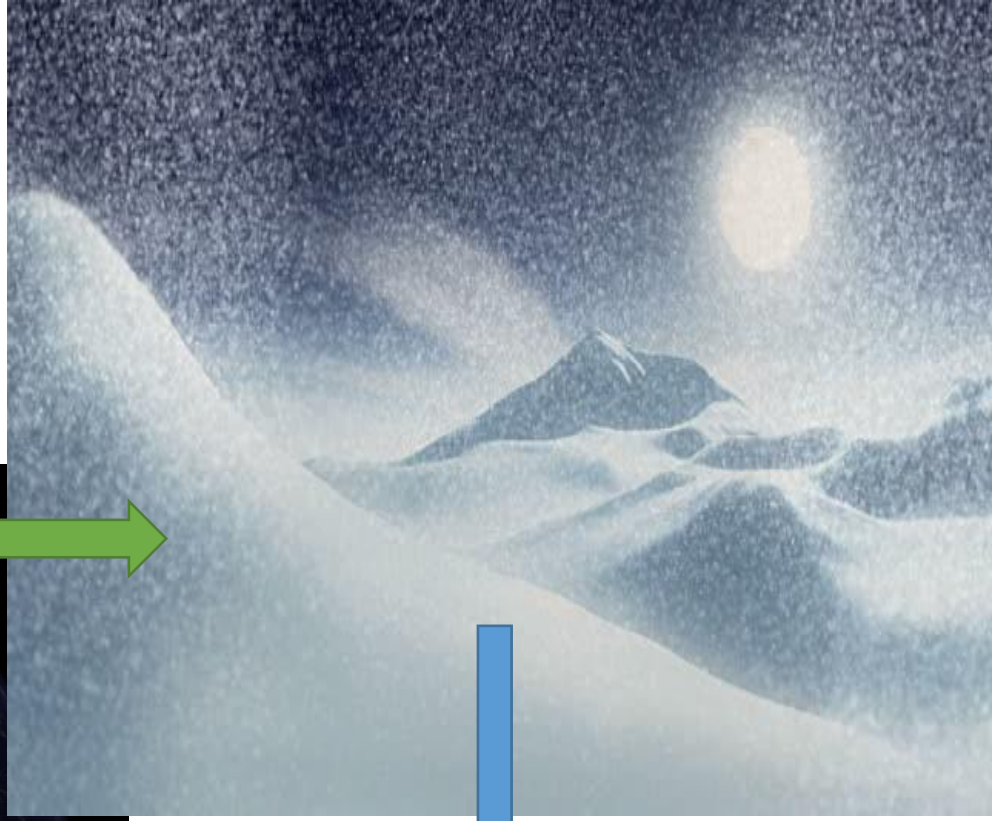
The Rainout Effect



The Rainout Effect





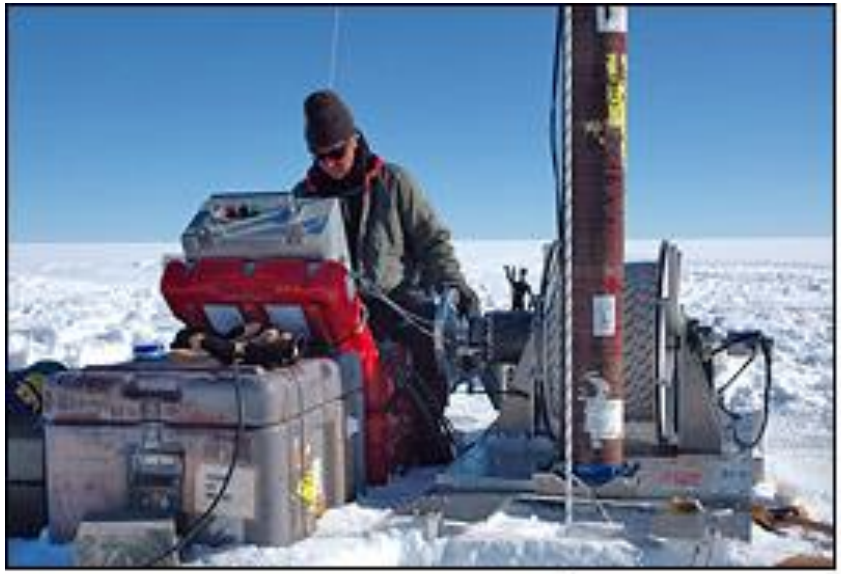


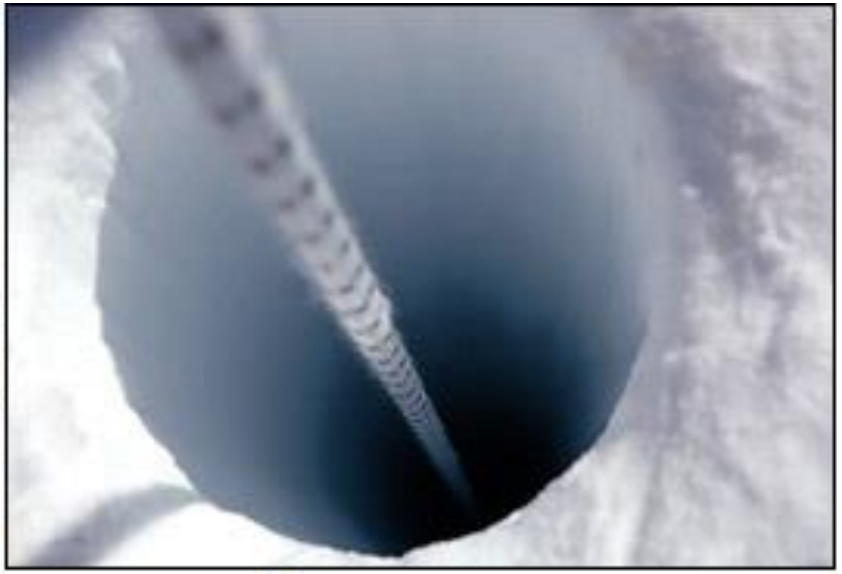
The Rainout Effect

- During a warm year, there will be a higher ratio of heavy water in the ice at the poles than during a cold year
- And, there will be a higher ratio of light water in the oceans at the equator than during a cold year.

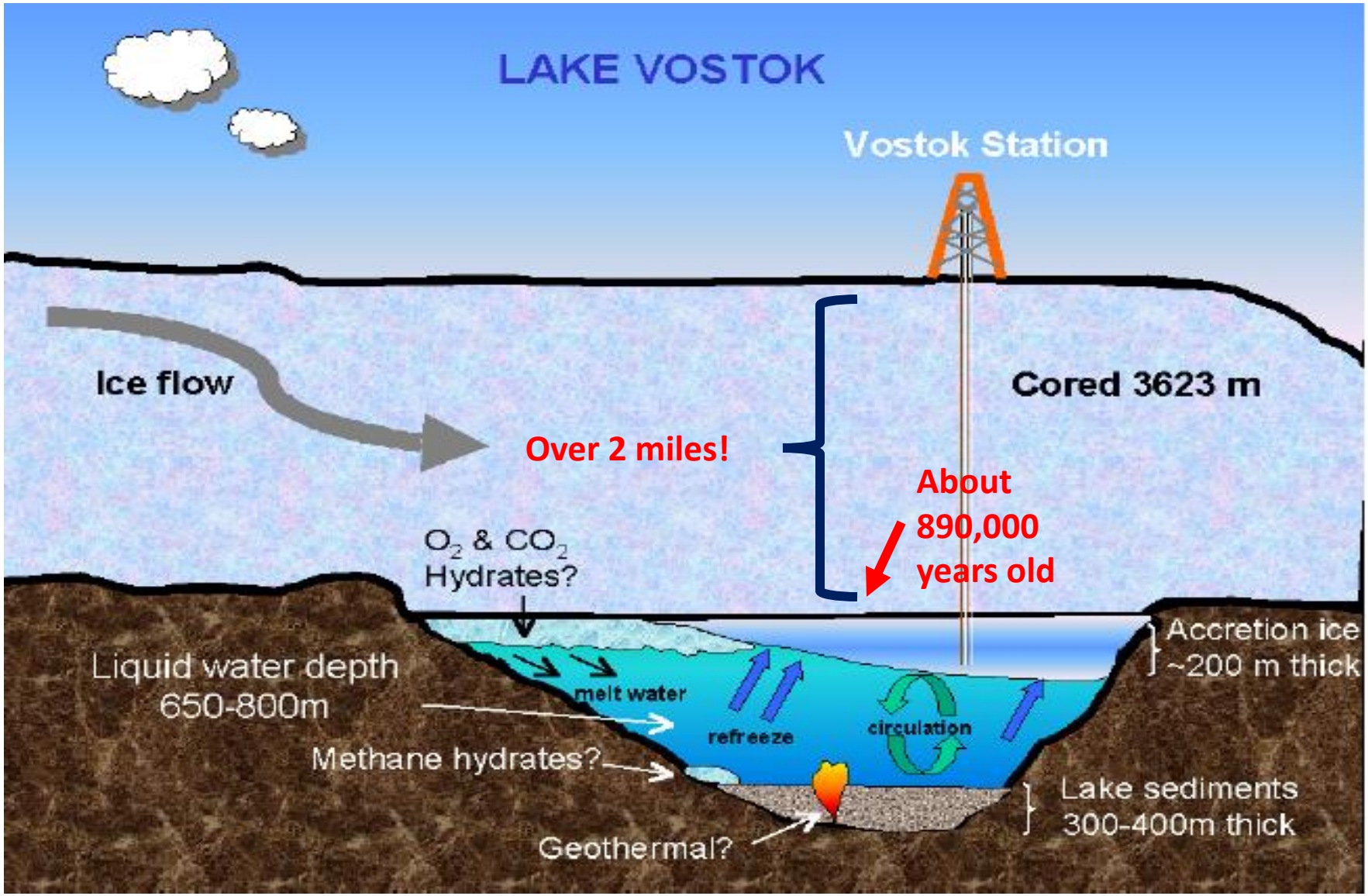
Ice Cores

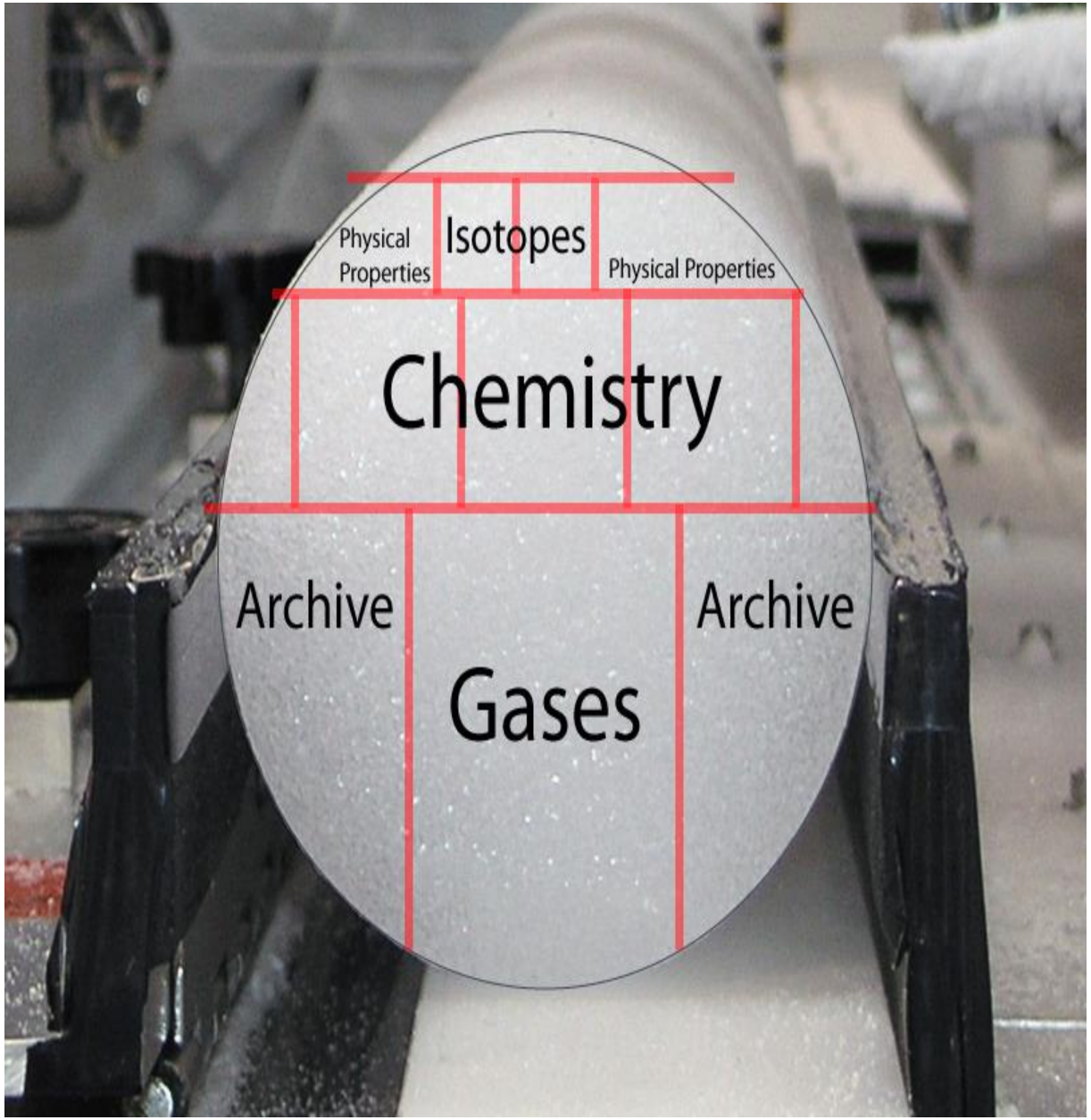
Ice Cores





Snow fall compacts into ice, air bubbles get trapped in the ice


LAKE VOSTOK
Vostok Station
Ice flow
Cored 3623 m
Over 2 miles!
About
890,000
years old
O_2 & CO_2
Hydrates?
Liquid water depth
650-800m
melt water
refreeze
circulation
Accretion ice
~200 m thick
Methane hydrates?
Lake sediments
300-400m thick
Geothermal?

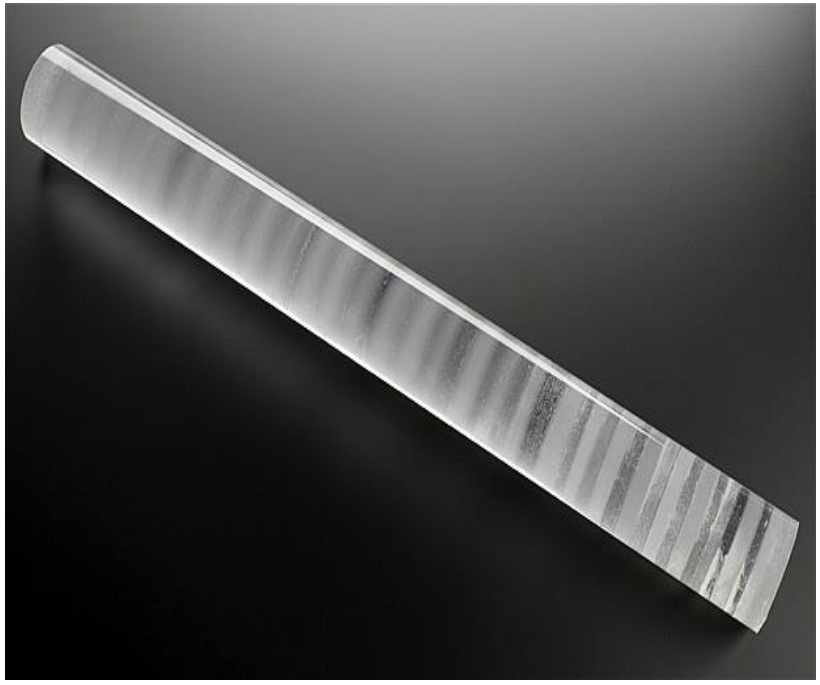

Physical Properties
Isotopes
Physical Properties
Chemistry
Archive
Gases
Archive

How do we know what time the air bubbles are from?

Annual layers created by:

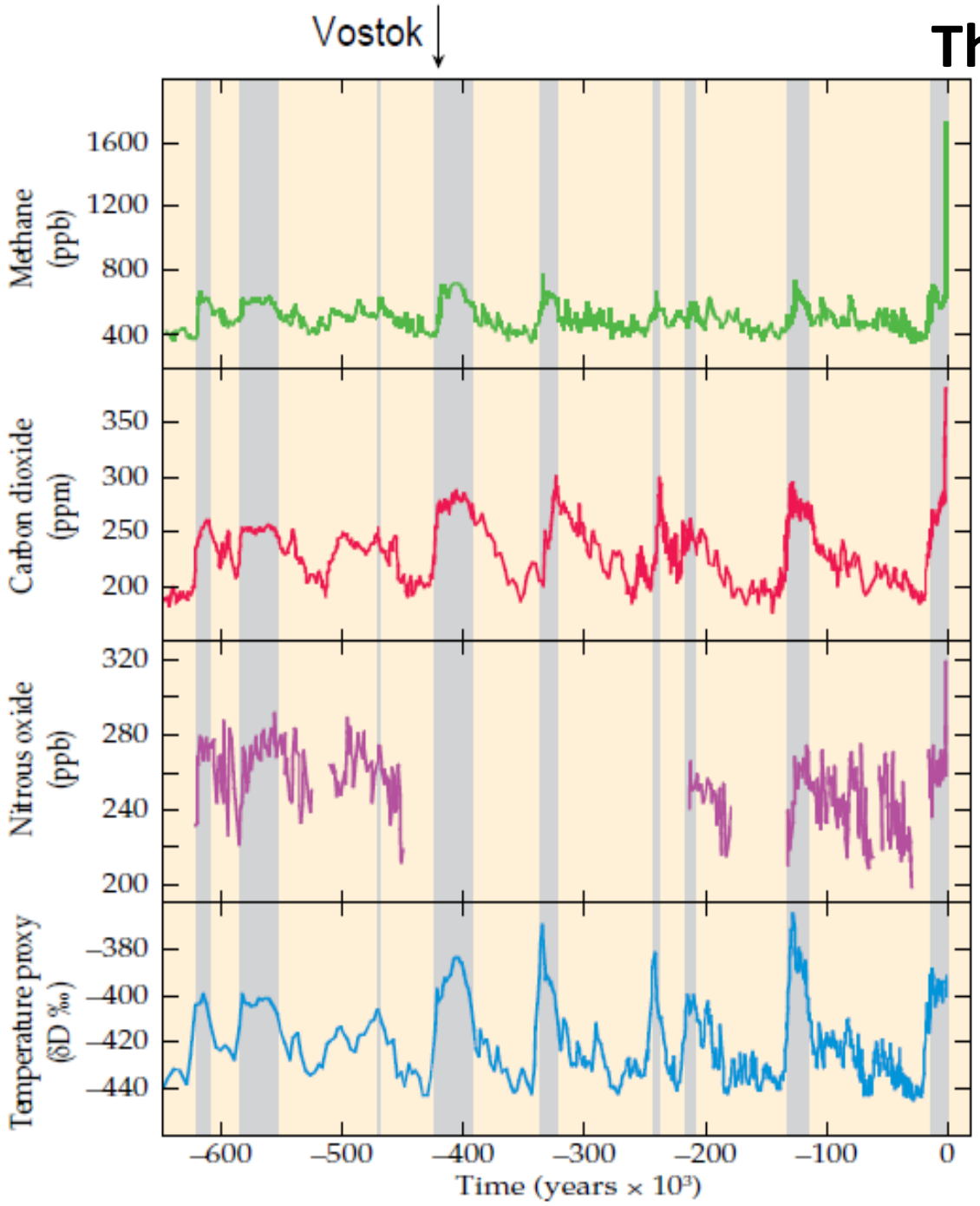
- Dust greater in summer
- Hydrogen peroxide greater in summer (UV)
- More heavy water during warm weather

Someone has to count the layers!



Parameter	Method	Certainty
CO_2	Direct analysis	More
Date	Relative $^{2}H_2{}^{18}O$ H_2O_2 dust	Some
Temperature	Absolute $^{2}H_2{}^{18}O$	Less

The Past 810,000 Years



Gray-shaded sections denote warm, interglacial periods.

Correlation between rise in temperature and concentration of greenhouse gases.