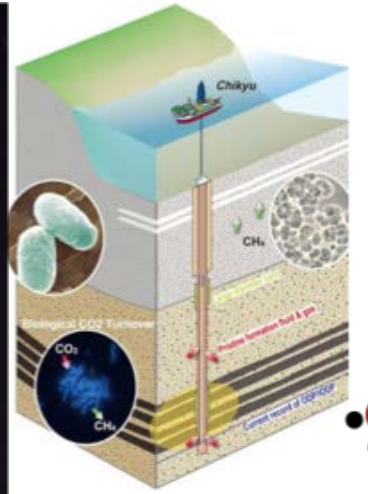
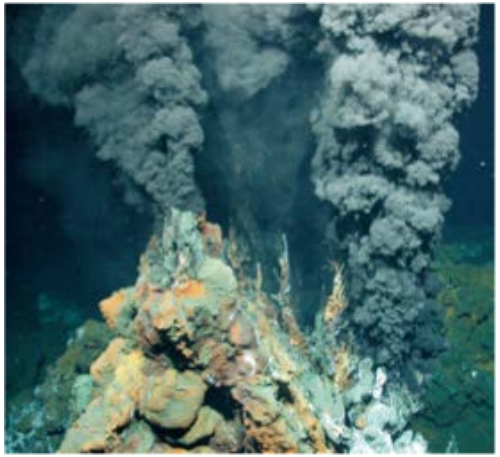
Climate Science 101: Warmer Things

Meghana Ranganathan and Ellen Lalk



Research: methane production by microbes kilometers below the ocean floor

hardcore stable isotope laboratory@MIT



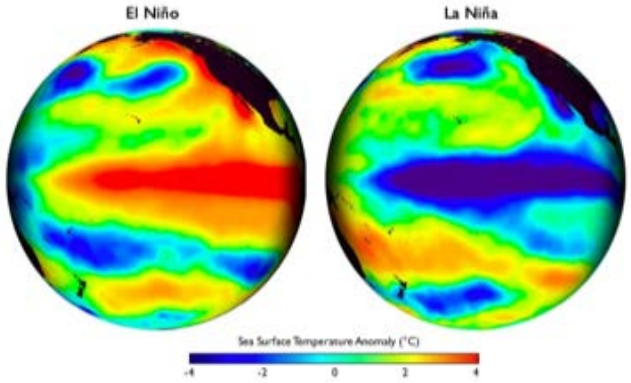
Introductions: Ellen Lalk

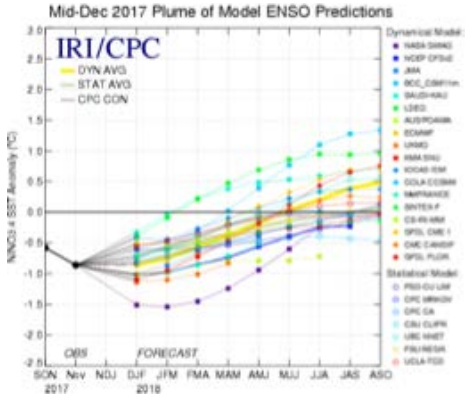
1st year PhD student in Chemical Oceanography

Penguin enthusiast

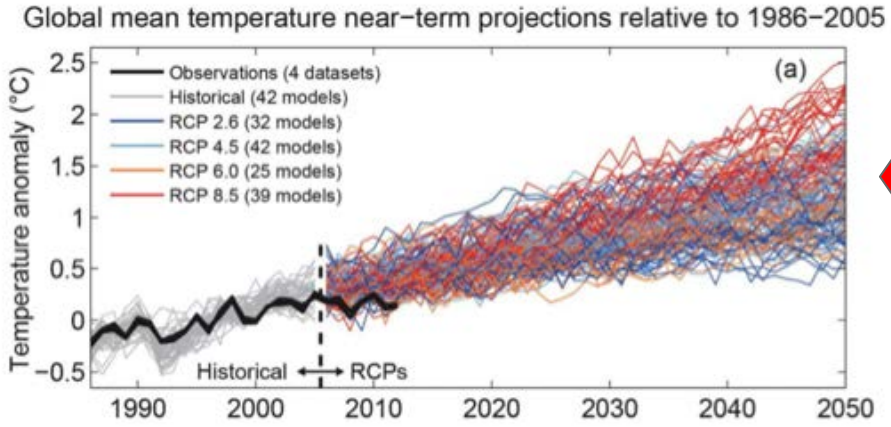
Previously studied Chemistry and Archaeology at WUSTL

Past Research: evaluating ENSO forecasts at Columbia/IRI





Introductions: Meghana Ranganathan



1st Year PhD Student in Atmospheric Science

Current research: using neural networks and machine learning to quantify climate uncertainty

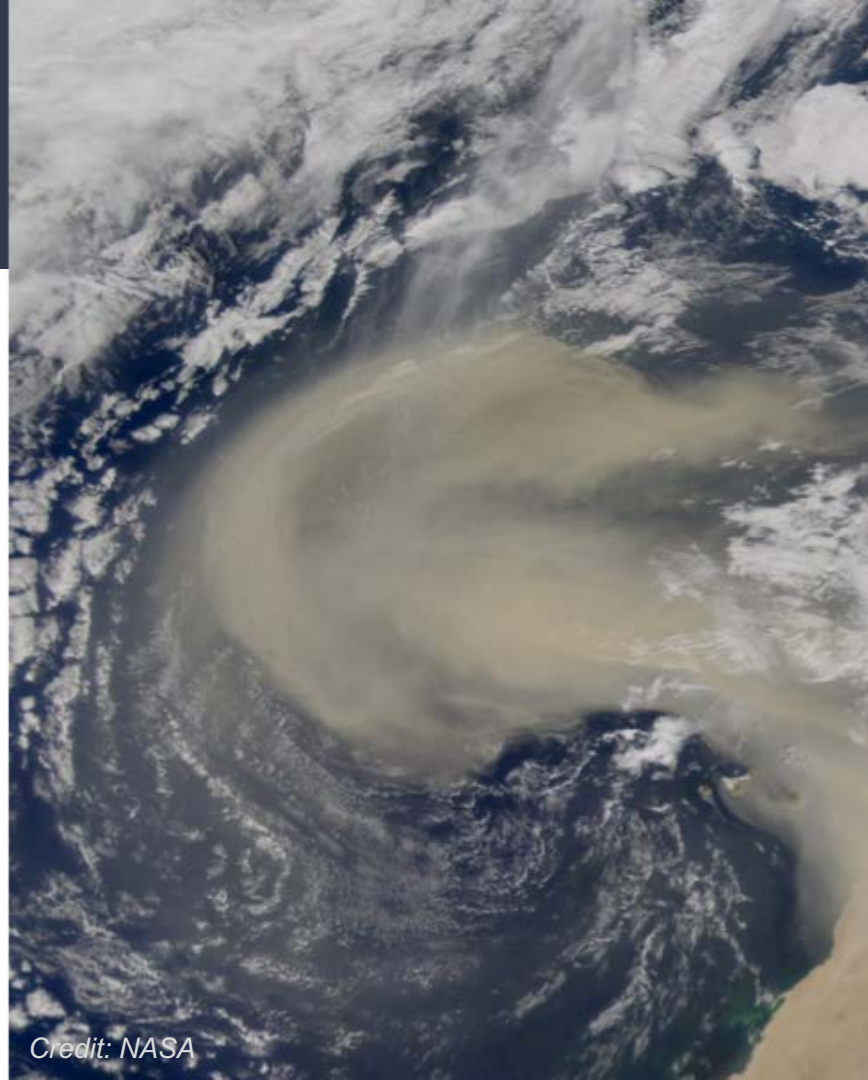
Images:
http://insideclimatenews.org/sites/default/files/styles/icn_full_wrap_wide/public/Climate%20chart_0.png?itok=GqFt5ALQ
https://iri.columbia.edu/wp-content/uploads/2017/12/figure4-1.gif
https://blog.wdtinc.com/hubfs/blog-files/elnino-vs-lanina-noaa.jpg?t=1513787240214

Topic Overview

1. What is “climate”
2. What Affects Earth’s Temperature
3. A Look Into Past Climate
4. Environmental Changes from Climate Change

Definitions

1. **Weather:** Things like precipitation, wind, and humidity that we experience at a given time in a specific location
2. **Climate:** average weather over a long period of time for a given region; the statistics of weather
3. **Climate Variability:** natural variation in climate that occurs over months or decades
4. **Climate Change:** a systematic change in long term state over multiple decades



Credit: NASA

The Climate System: Overview

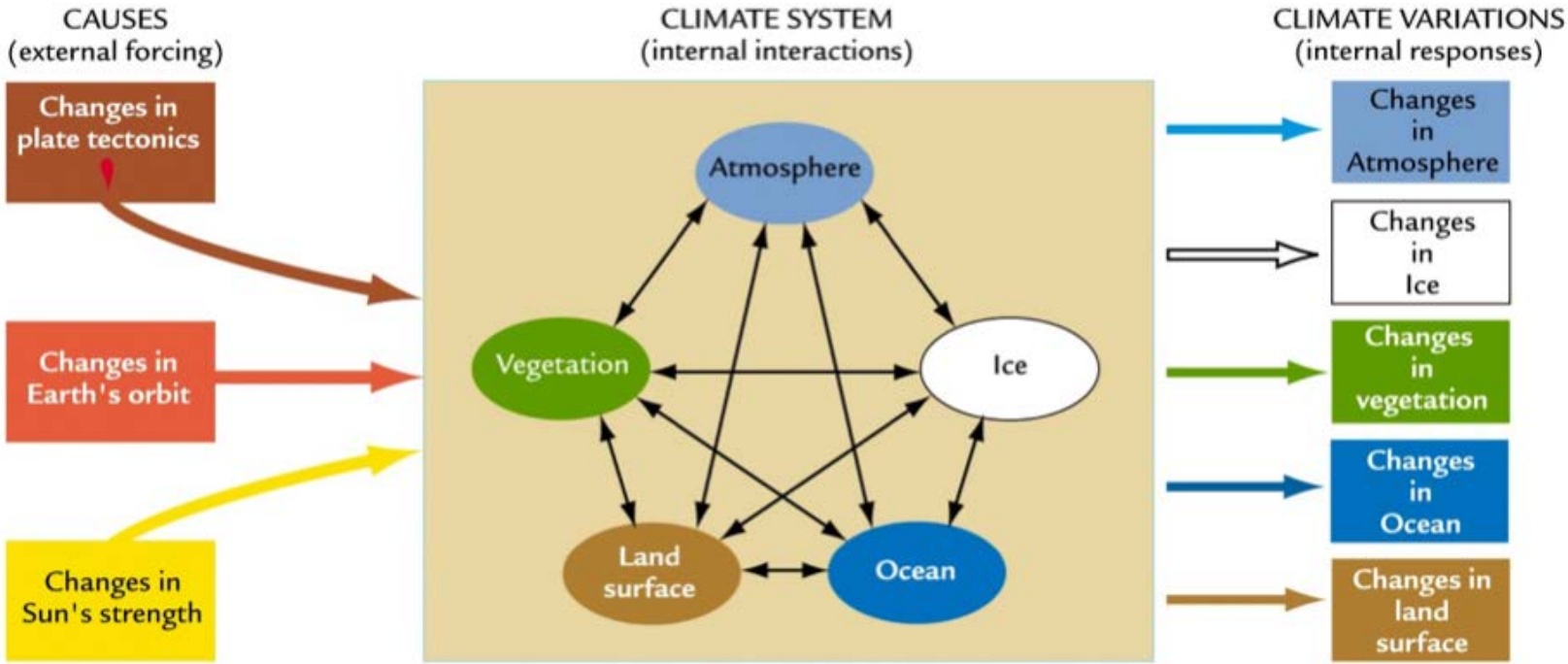
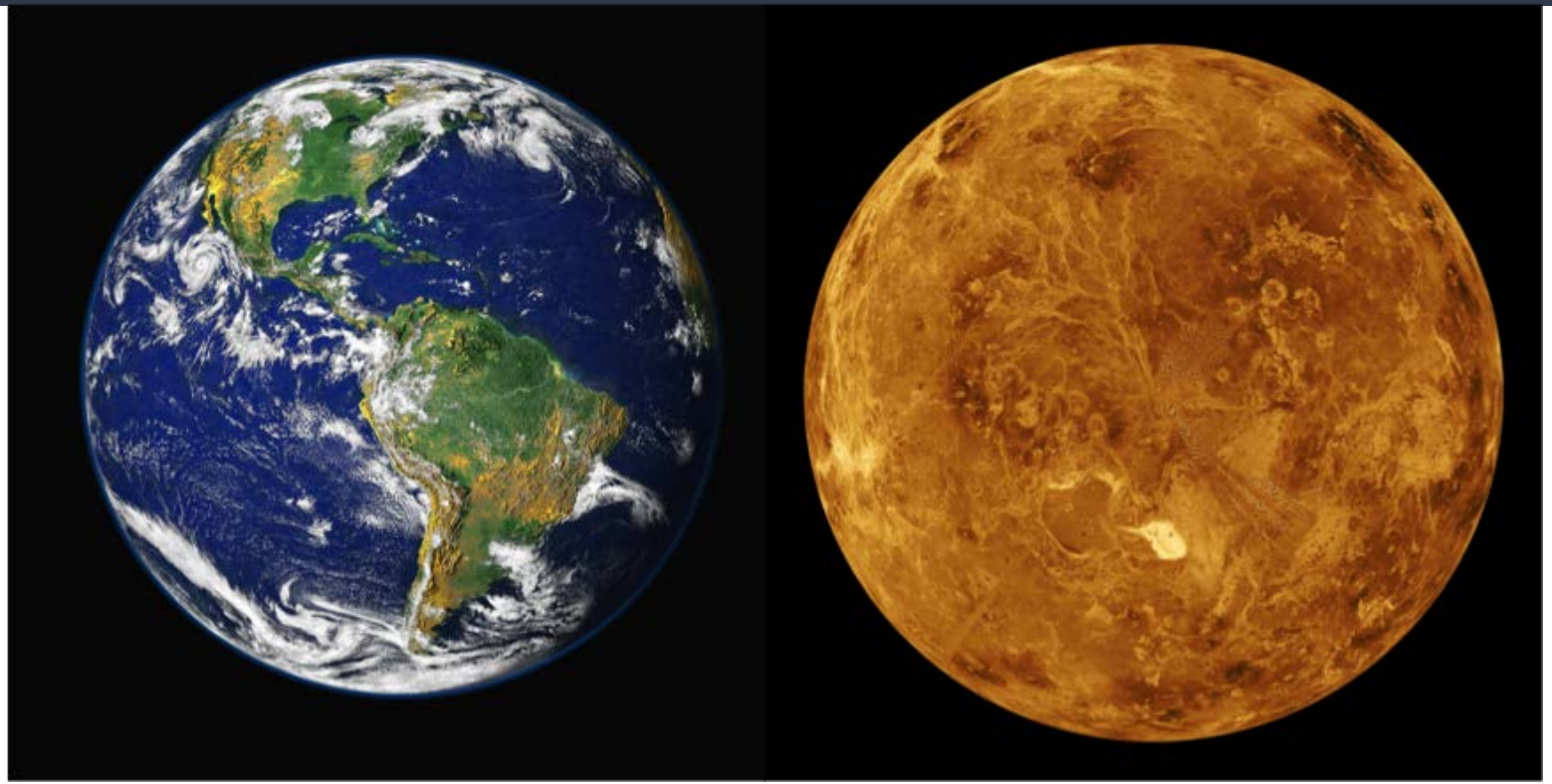


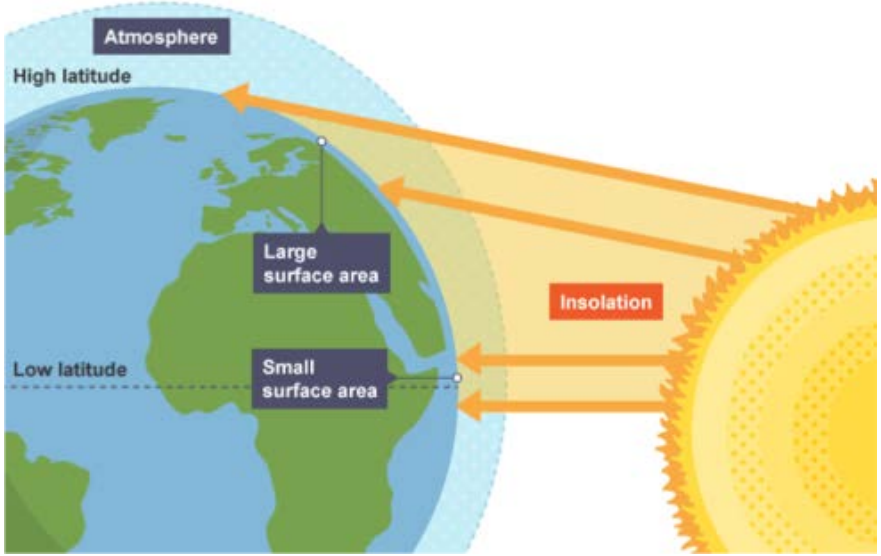
Image from: http://www.atmosedu.com/Geol390/figures/figure%2001-05-bottom.jpg

Sun: What Factors Affect Earth's Temperature?



Images:
https://static.pexels.com/photos/2422/sky-earth-galaxy-universe.jpg
https://www.nasa.gov/sites/default/files/thumbnails/image/pia00271.jpg

Factor 1: Insolation



$$\text{Flux} = \frac{\text{Energy}}{\text{Time} \times \text{Area}}$$

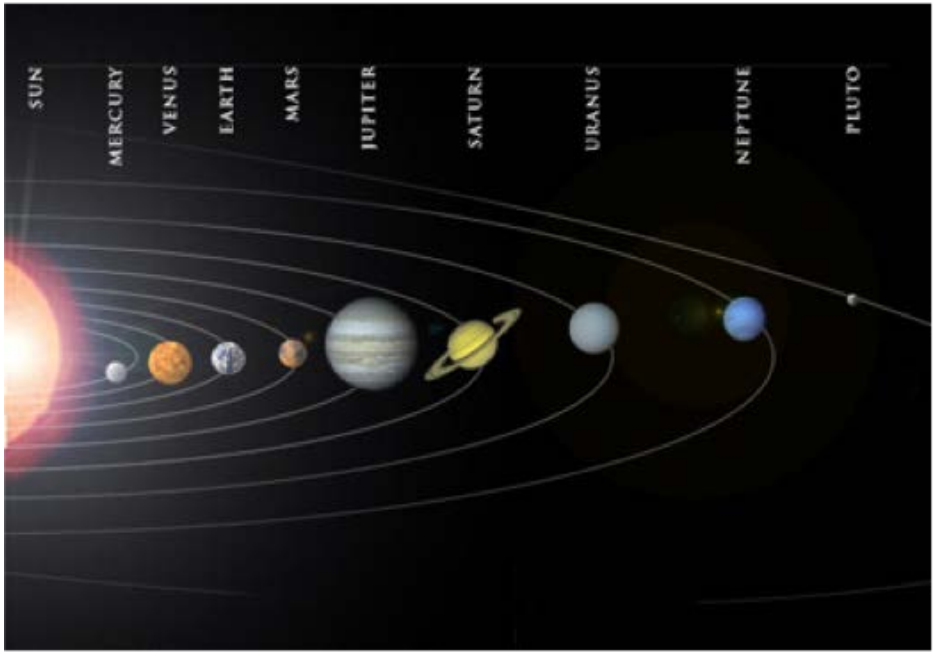


Image: https://bam.files.bbci.co.uk/bam/live/content/znyjtfr/large
http://easyscienceforkids.com/wp-content/uploads/2013/06/elliptical-orbits.jpg

Factor 2: Albedo

Grass: $\alpha = 0.20$

Antarctica: $\alpha = 0.81$

Clouds: $\alpha = 0.80 - 0.85$

Earth: $\alpha = 0.30$

Venus: $\alpha = 0.80$

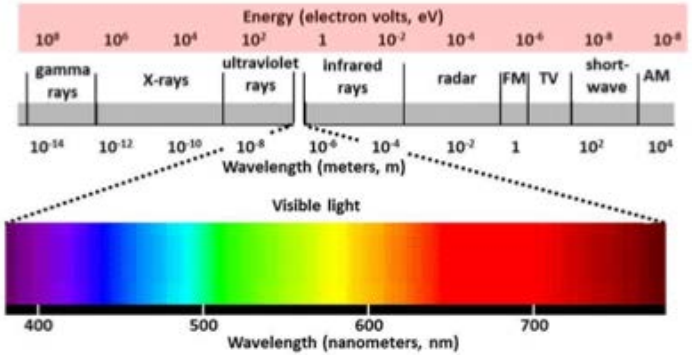
Albedo is α, where $0 < \alpha < 1$

Images: https://pmdvod.nationalgeographic.com/NG_Video/11/923/150827-nasa-mapping-greenland-ice-sheet-vin.jpg
https://www.nasa.gov/sites/default/files/thumbnails/image/pia00271.jpg

Factor 3: Atmosphere

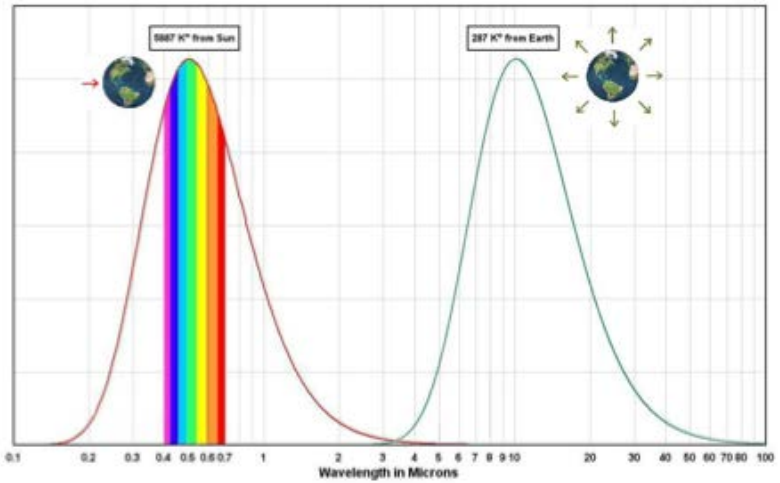
A **black body** absorbs all incoming radiation

$$F = \sigma T^4$$



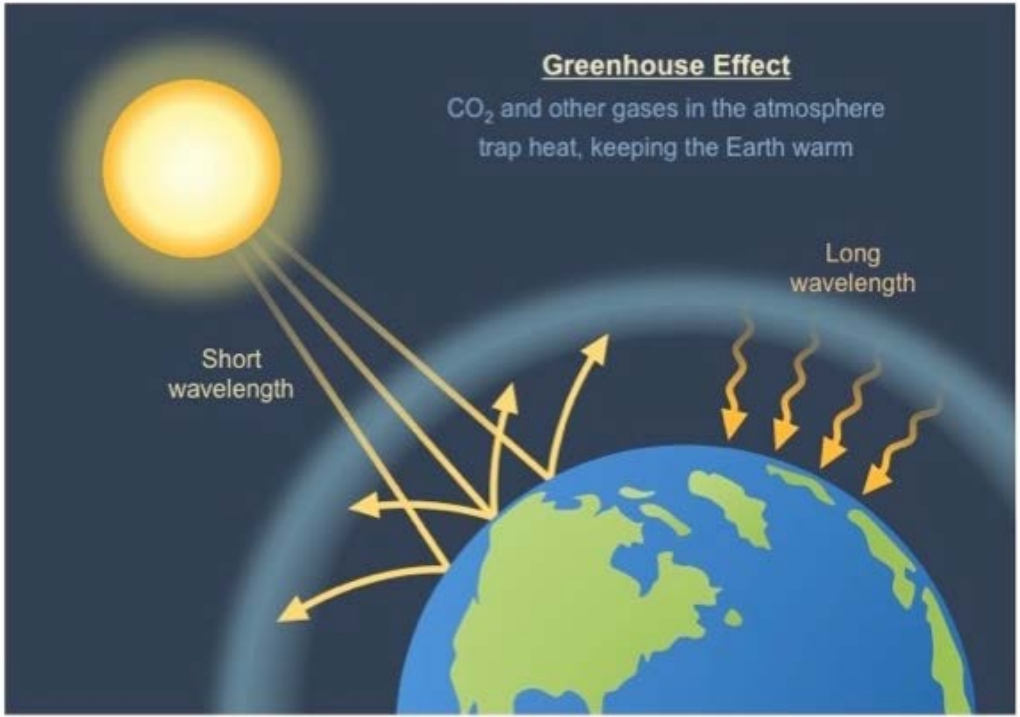
TRUE black bodies don't exist - instead they have albedo:

$$F = (1 - \alpha)\sigma T^4$$

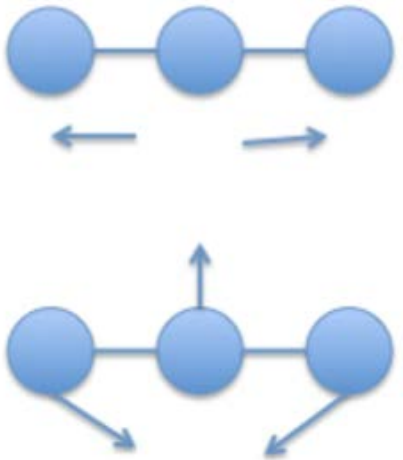


Images: http://ib.bioninja.com.au/_Media/greenhouse-effect_med.jpeg
http://planetforlife.com//images/blackbodyearth.jpg
http://ozonedepletiontheory.info/Images/electromagnetic-spectrum.jpg

Factor 3: Atmosphere



Some reflected energy gets trapped in the atmosphere by **greenhouse gases**. Why are some gases greenhouse gases?



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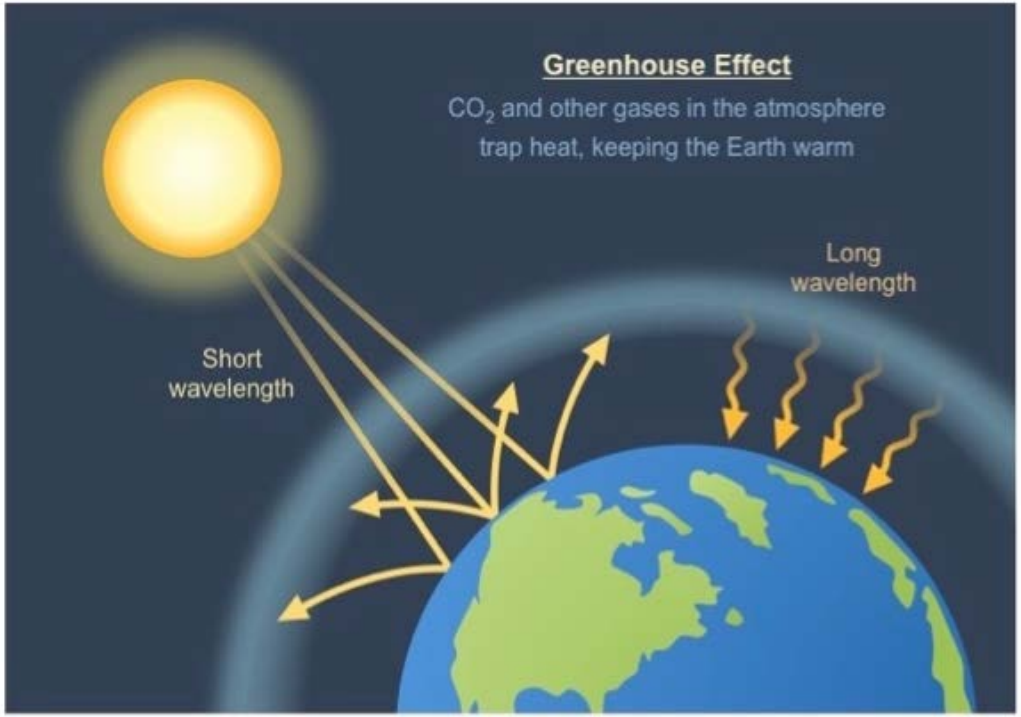
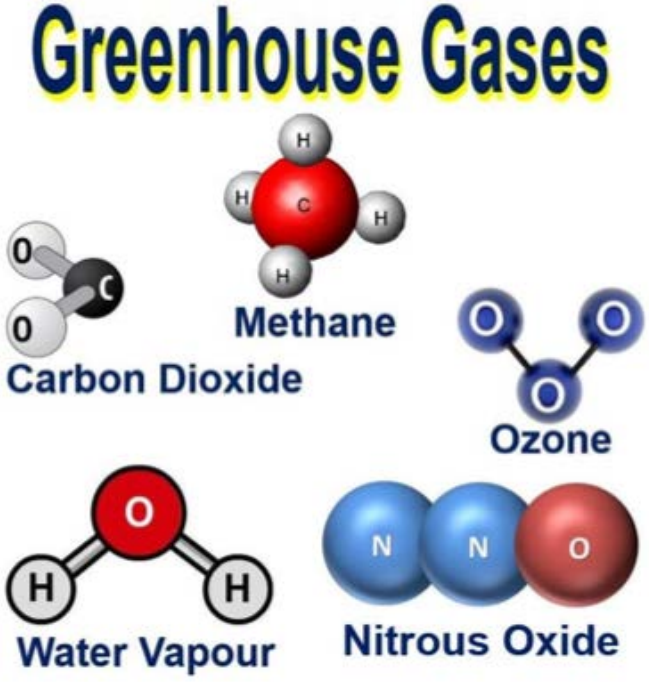
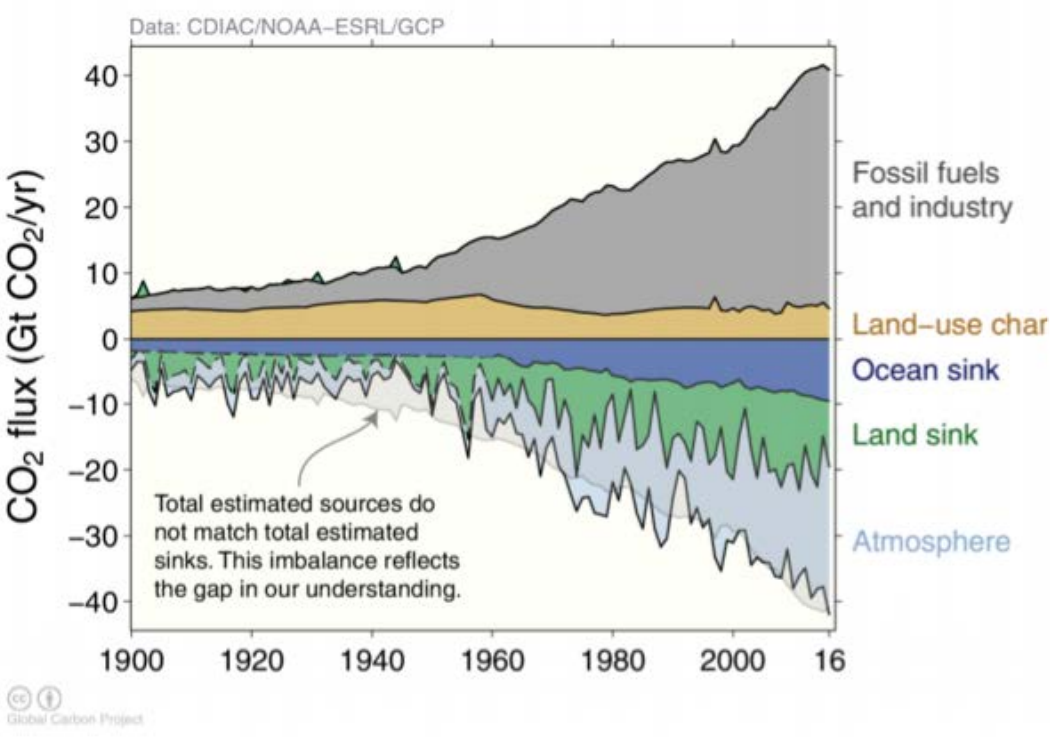
Factor 3: Atmosphere

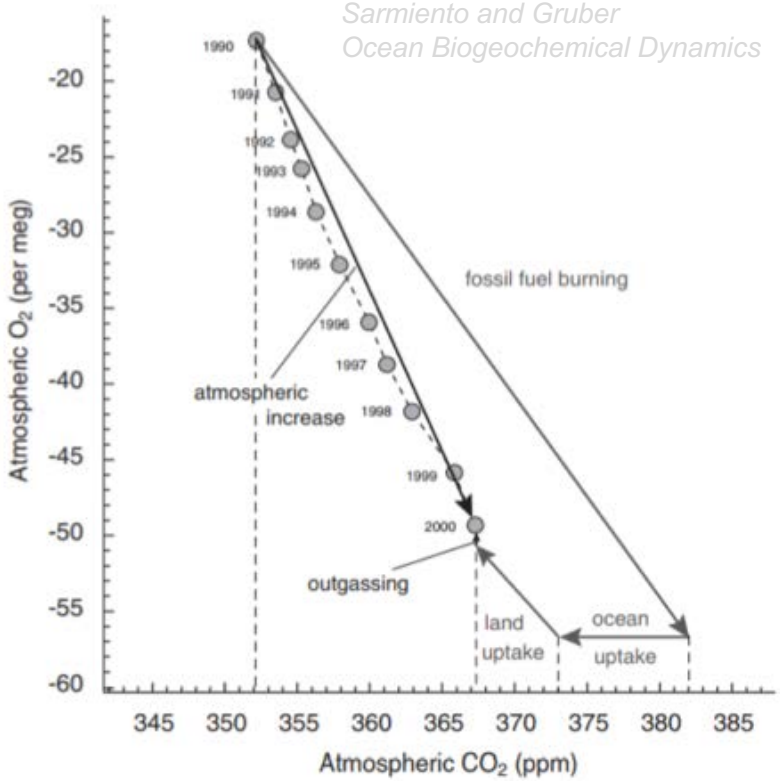




Images: http://ib.bioninja.com.au/_Media/greenhouse-effect_med.jpeg
http://marketbusinessnews.com/wp-content/uploads/2016/05/Greenhouse-gases-most-common.jpg

CO2 Sources and Sinks





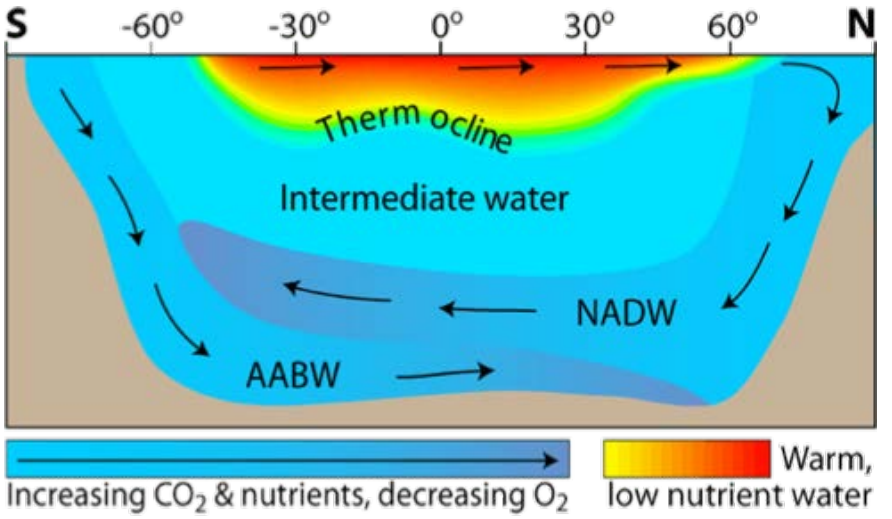
Factor 4: The Ocean

The ocean acts like a giant sponge, absorbing:

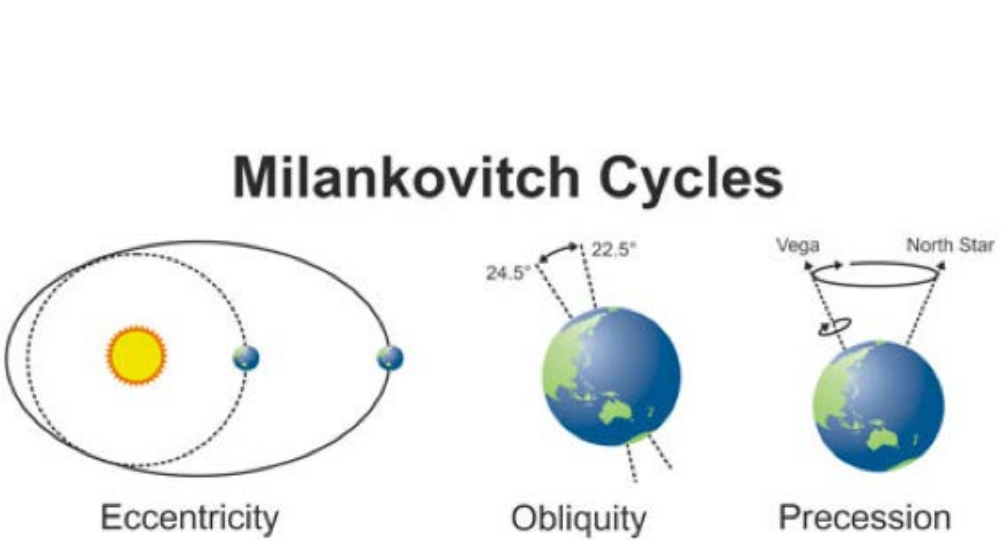
- ¼ of anthropogenic CO2 emission
- 90% of additional warming due to the greenhouse effect

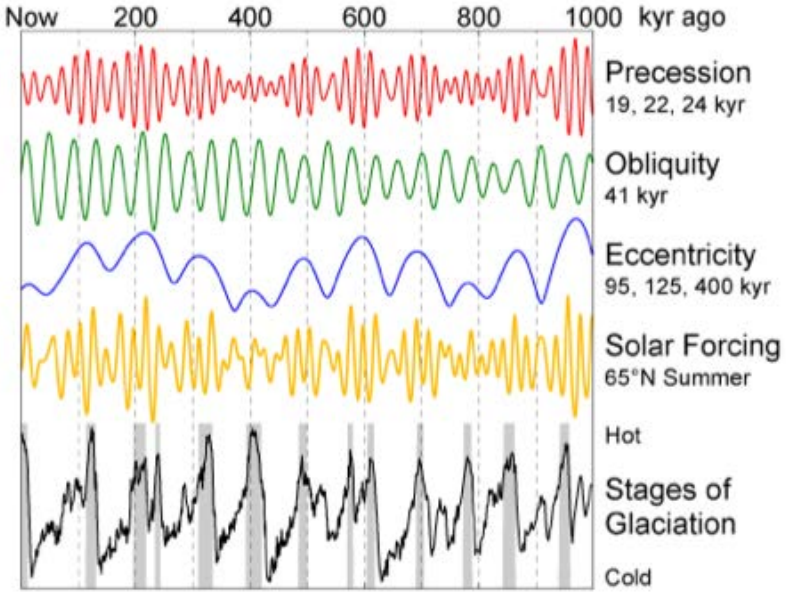
The surface ocean moves North, cool, traps more gas from the atmosphere, and then sinks to the deep

The ocean recirculates and eventually these buried emissions will resurface



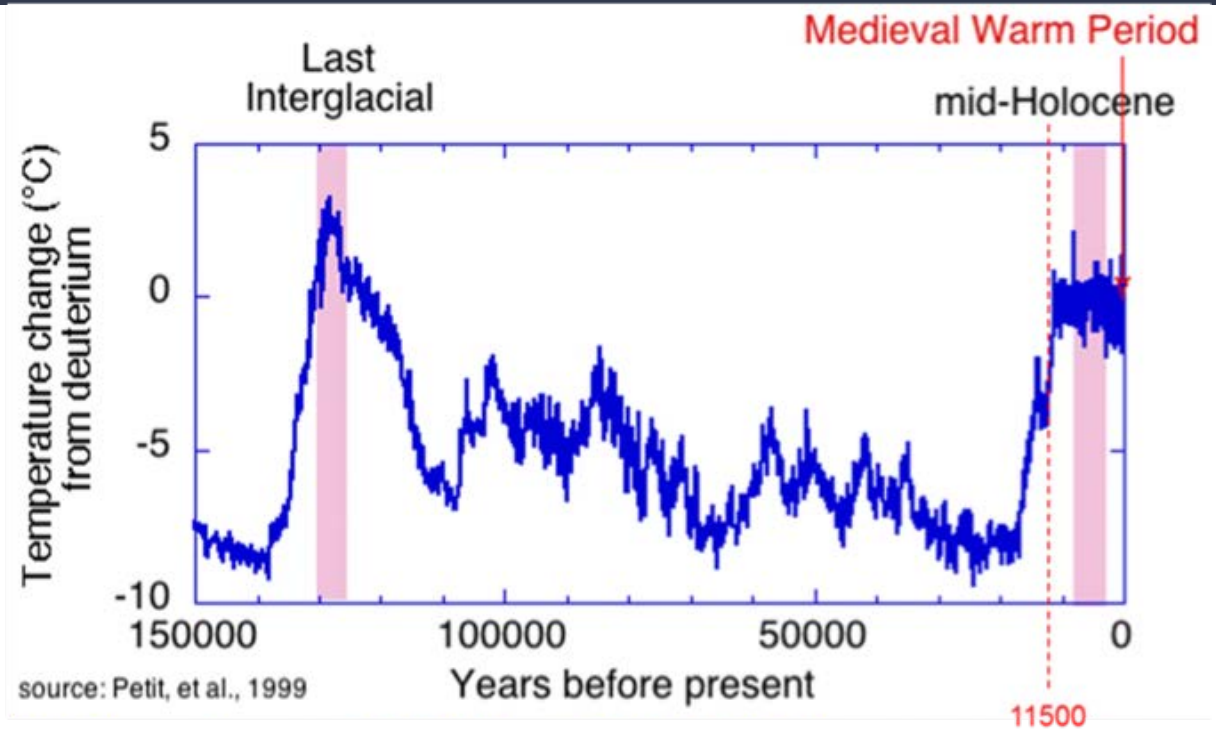
Factor 5: Orbital Changes (Milankovich Cycles)





Images: https://static.skepticalscience.com/images/Milankovitch_Cycles.jpg
https://www.periodni.com/gallery/milankovitch_cycle.png

Example: Eemian Period

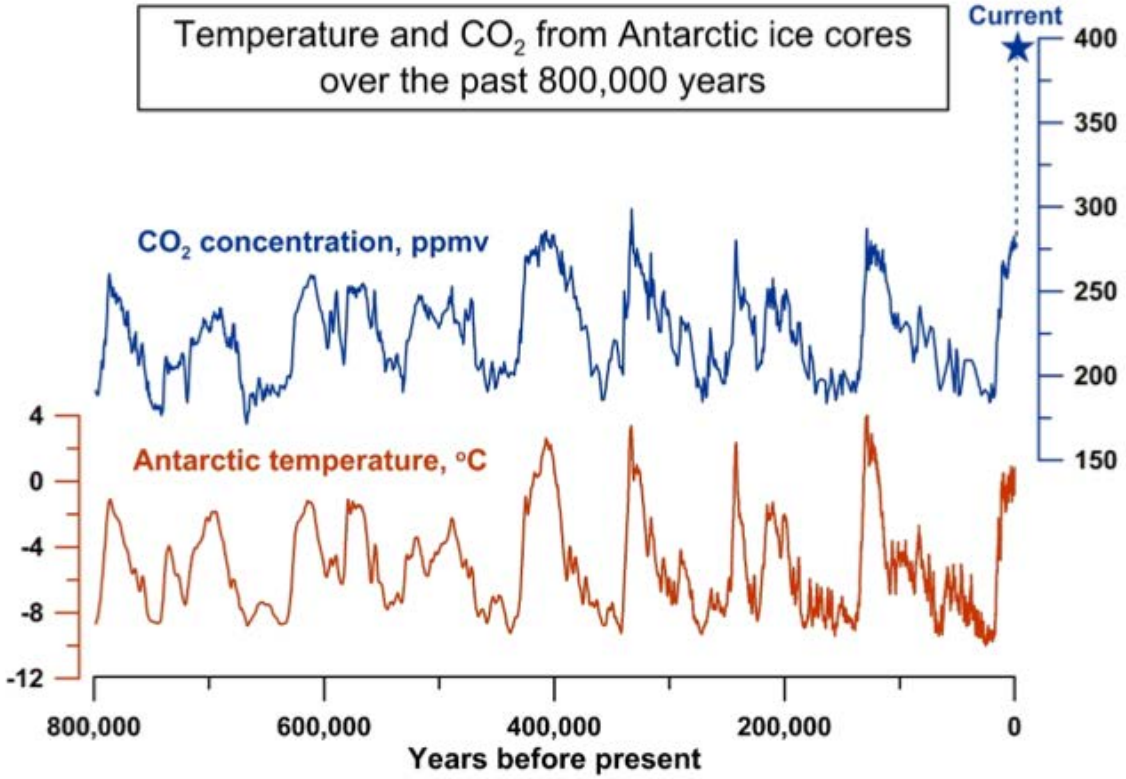


http://www.ncdc.noaa.gov/paleo/globalwarming/paleobefore.html

What made the Eemian period so much warmer than today?
-Milankovitch Cycles!
-Feedbacks!

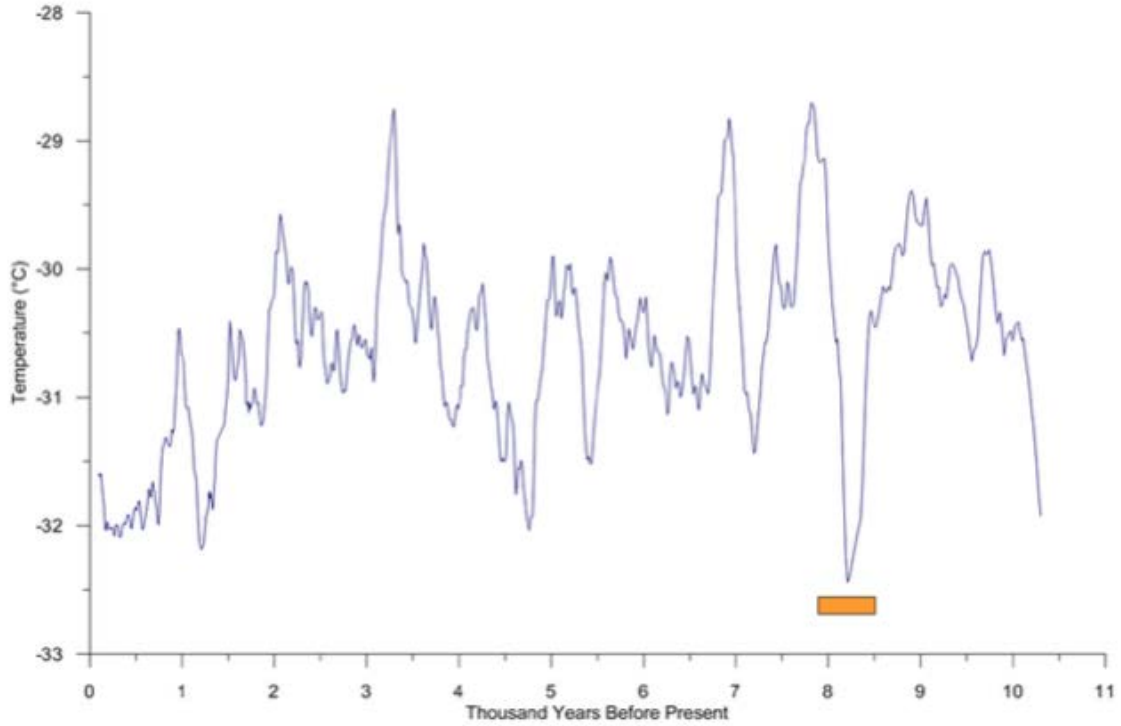
Images:
https://i.pinimg.com/originals/aa/1b/e9/aa1be9c5cba3b9a63979a3e4a2bfb6f4.jpg
https://6000generations.files.wordpress.com/2013/05/eemian-and-holocene-interglacials.png

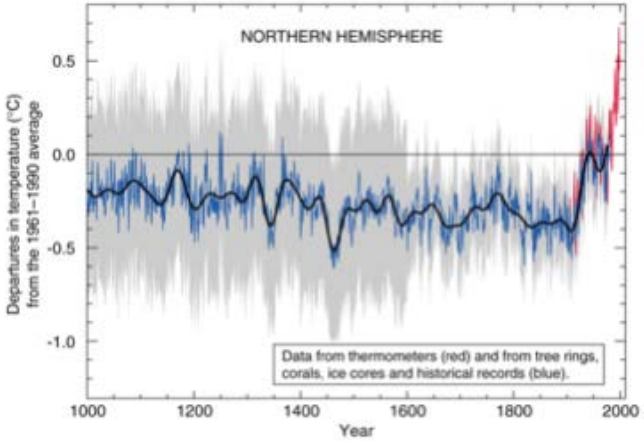
What does the past tell us?



Images: https://simpleclimate.files.wordpress.com/2012/04/edc.jpg
http://www.cosmographicresearch.org/Images/glacial_maximum_map2.jpg

Modern Climate: The Hockey Stick

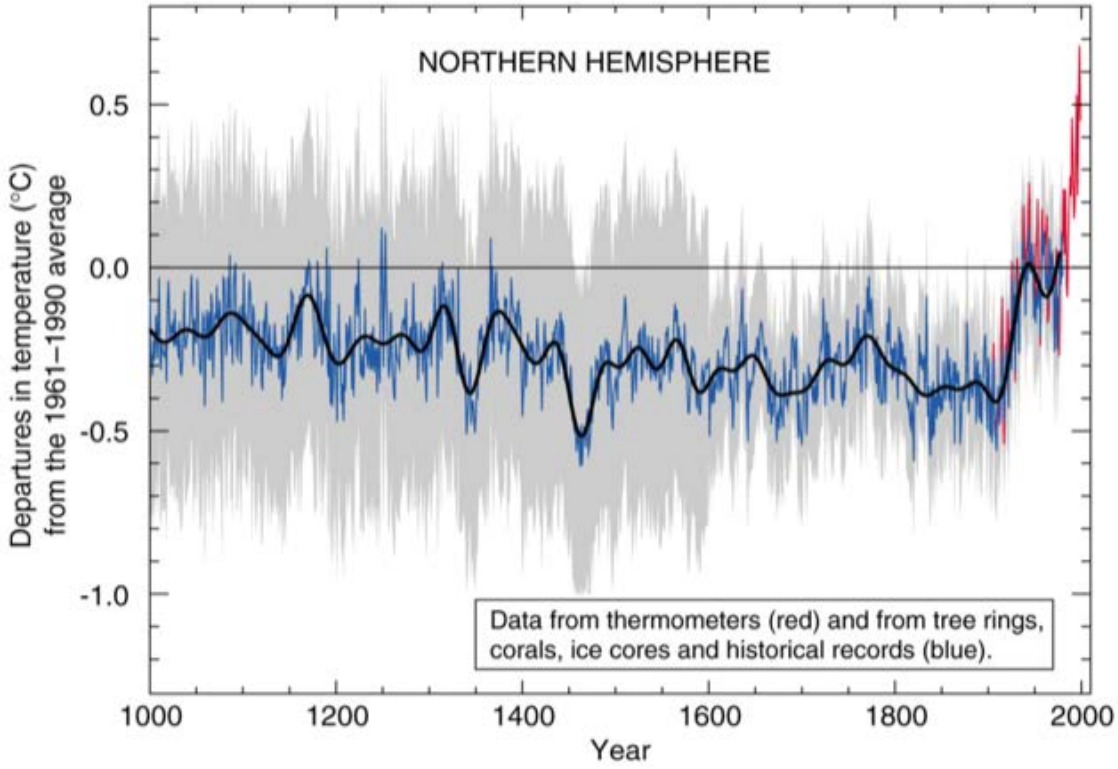


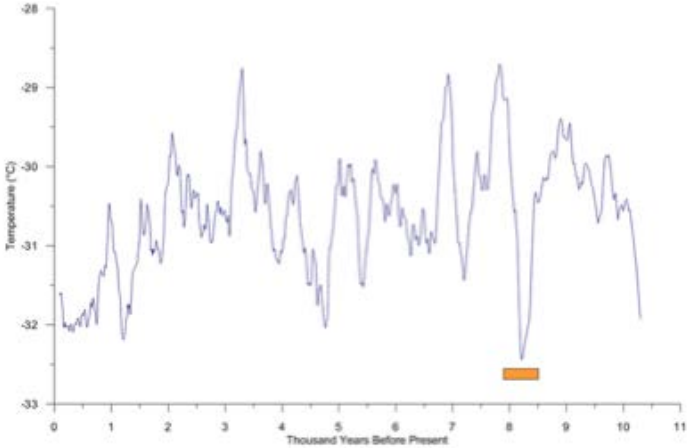


Is Earth more vulnerable to abrupt climate change now than before?

http://news.psu.edu/sites/default/files/styles/threshold-992/public/hockeystick.gif?itok=d3wvICuj
https://upload.wikimedia.org/wikipedia/commons/thumb/2/2d/Greenland_gisp2_alley.png/640px-Greenland_gisp2_alley.png

Modern Climate: The Hockey Stick





Is Earth more vulnerable to abrupt climate change now than before?

Images: http://news.psu.edu/sites/default/files/styles/threshold-992/public/hockeystick.gif?itok=d3wvlCuj
https://upload.wikimedia.org/wikipedia/commons/thumb/2/2d/Greenland_gisp2_alley.png/640px-Greenland_gisp2_alley.png

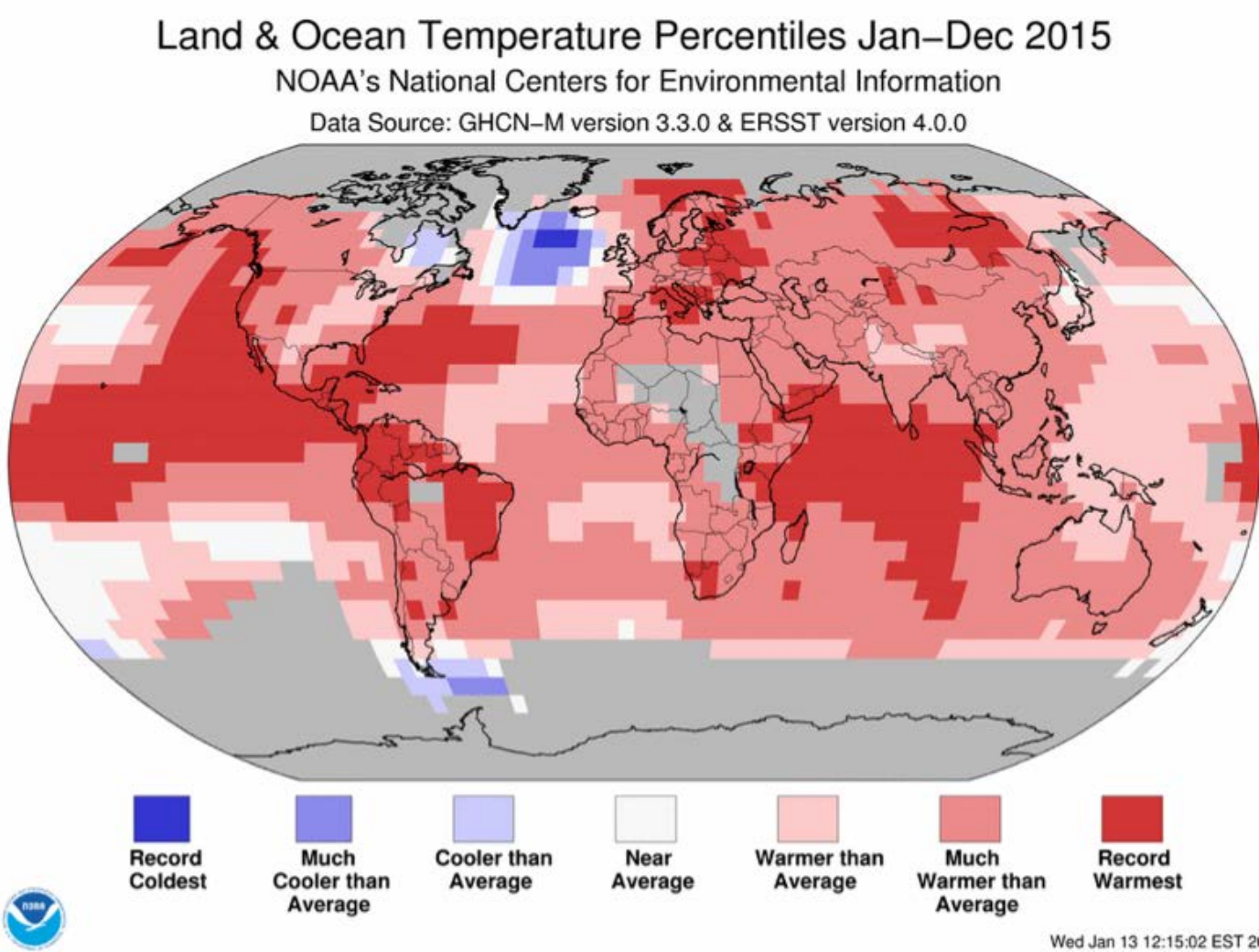
Climate change causes 5 critical environmental changes

1. Warming temperatures of the Earth's surface and oceans
2. Changes in the global water cycle
3. Declining glaciers and snowpack
4. Sea level rise
5. Ocean acidification

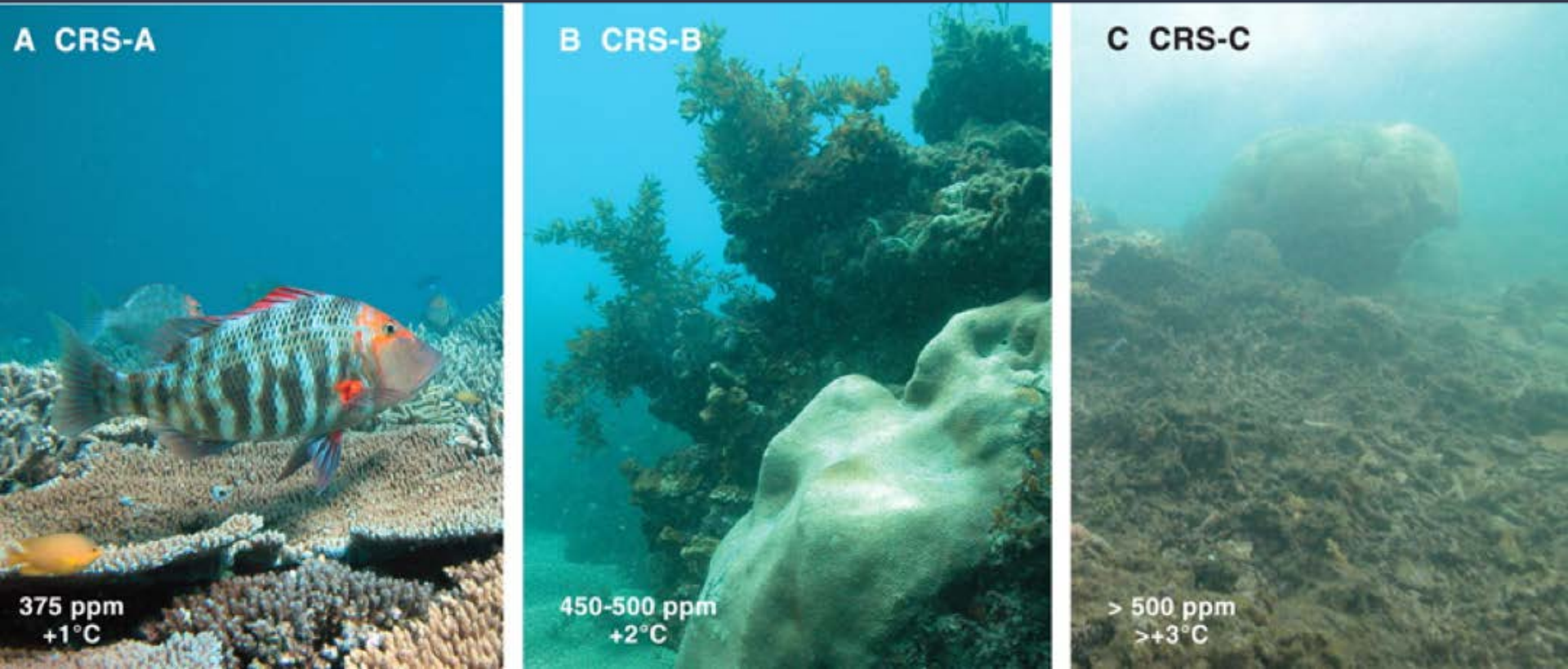
1.

Surface and Ocean Temperature Change

Warming is occurring almost twice as fast as the rate of warming in the previous century



Ocean Temperature and Coral Habitats

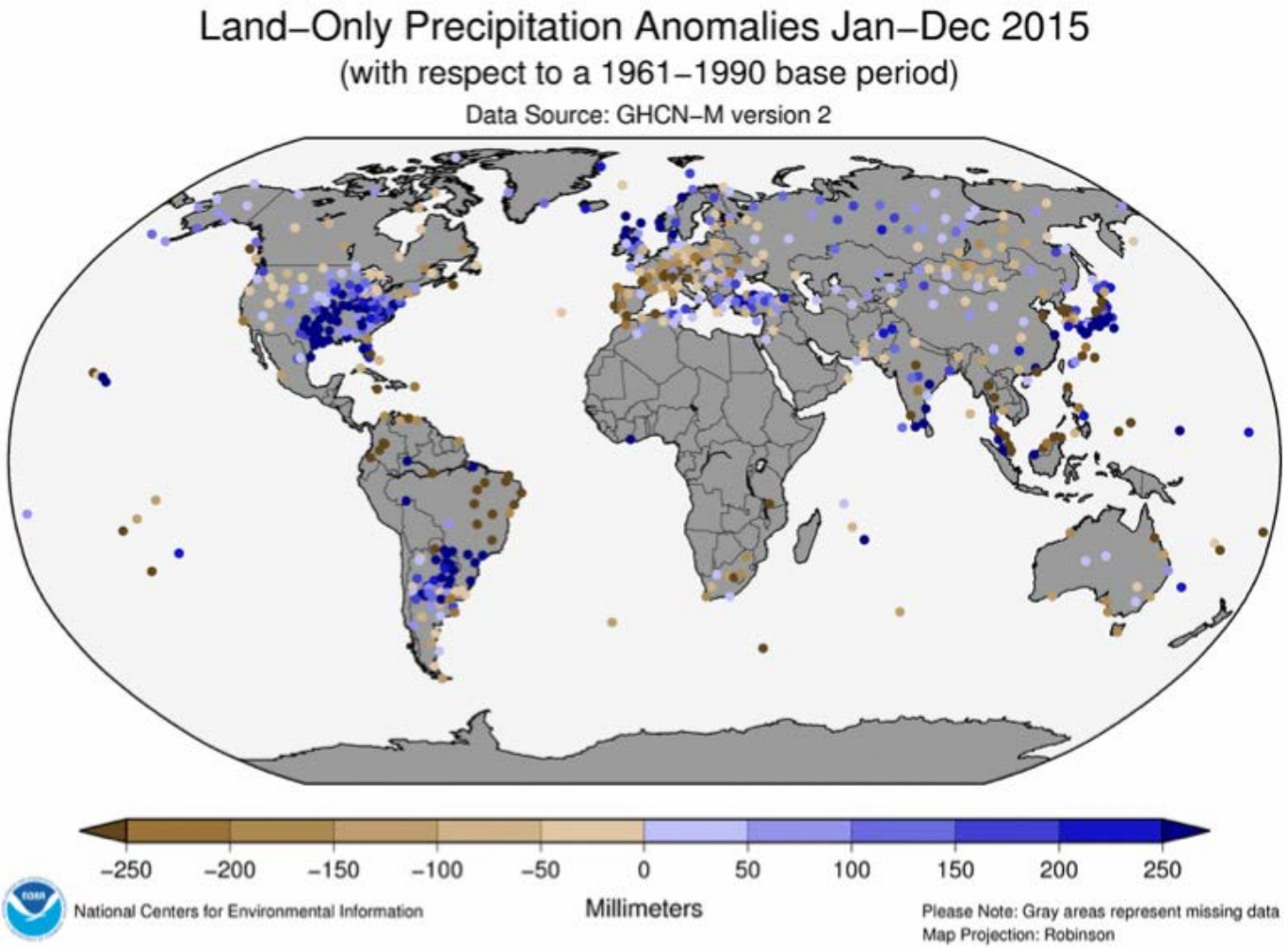


2.

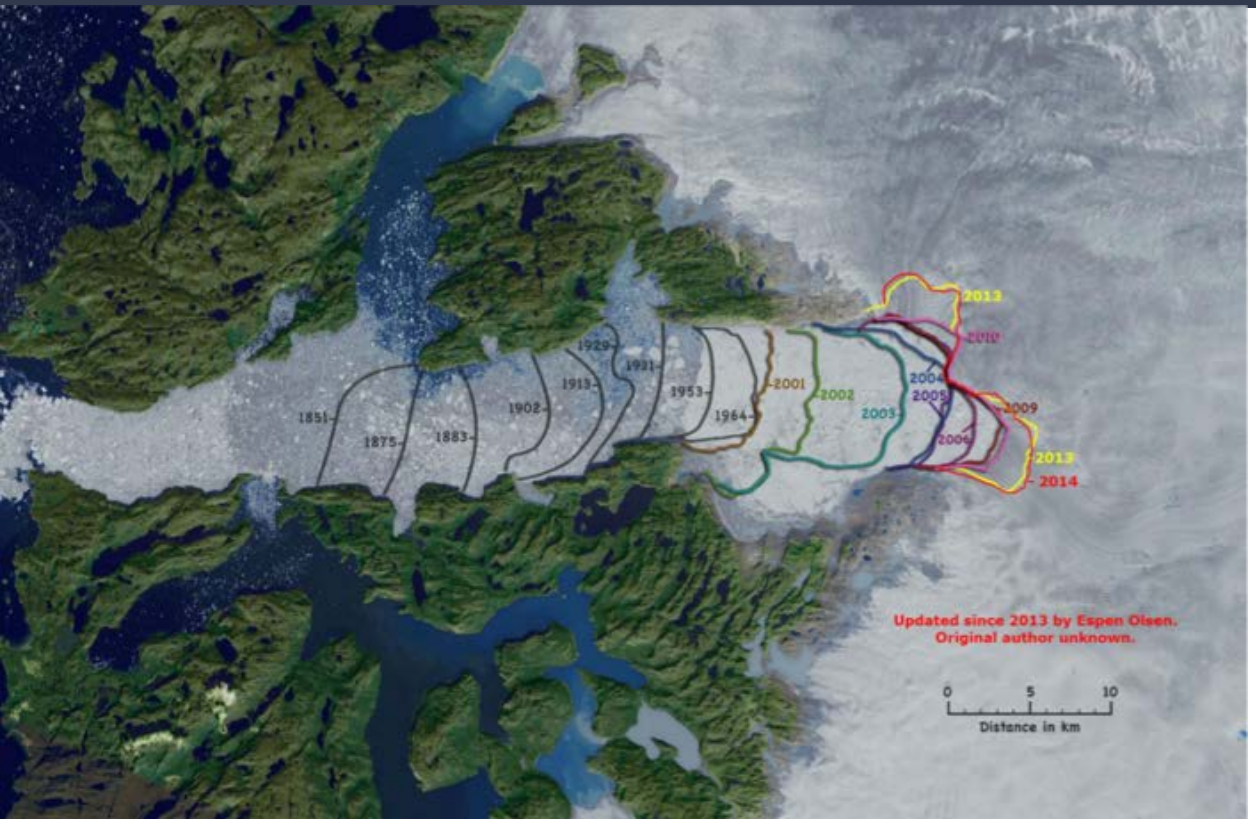
Changes in the Global Water Cycle

- As the atmosphere warms it is able to hold more water vapor

- The past century has experienced distinct geographical changes in total annual precipitation

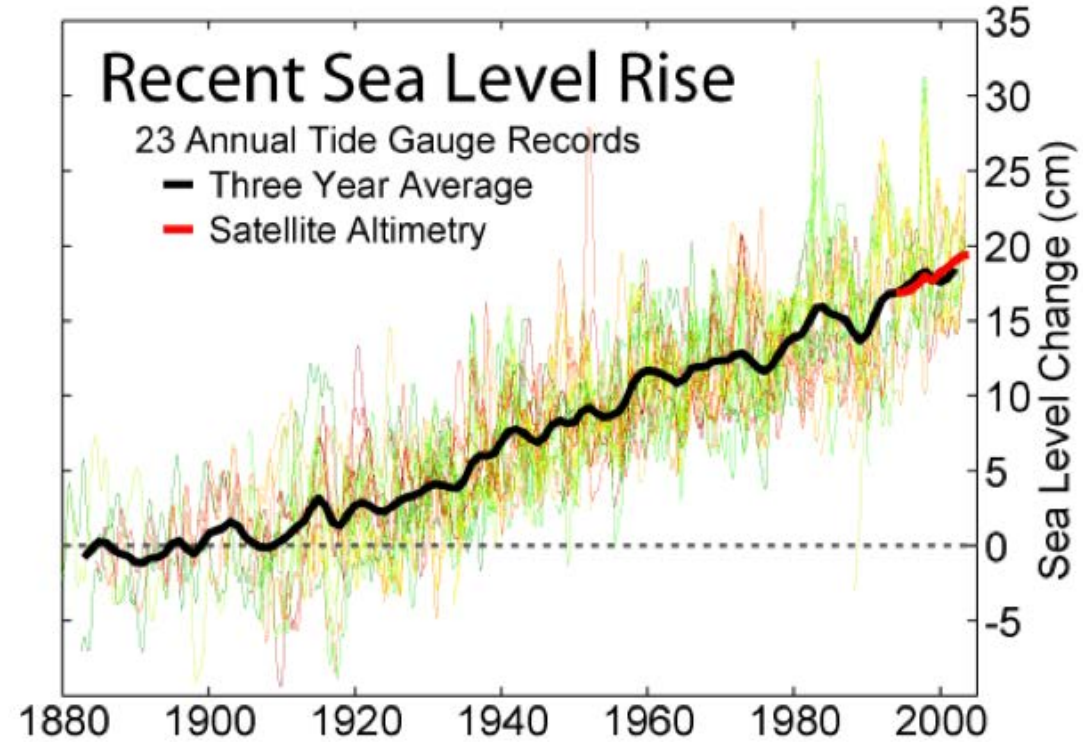


3. Glacier and Snowpack Decline



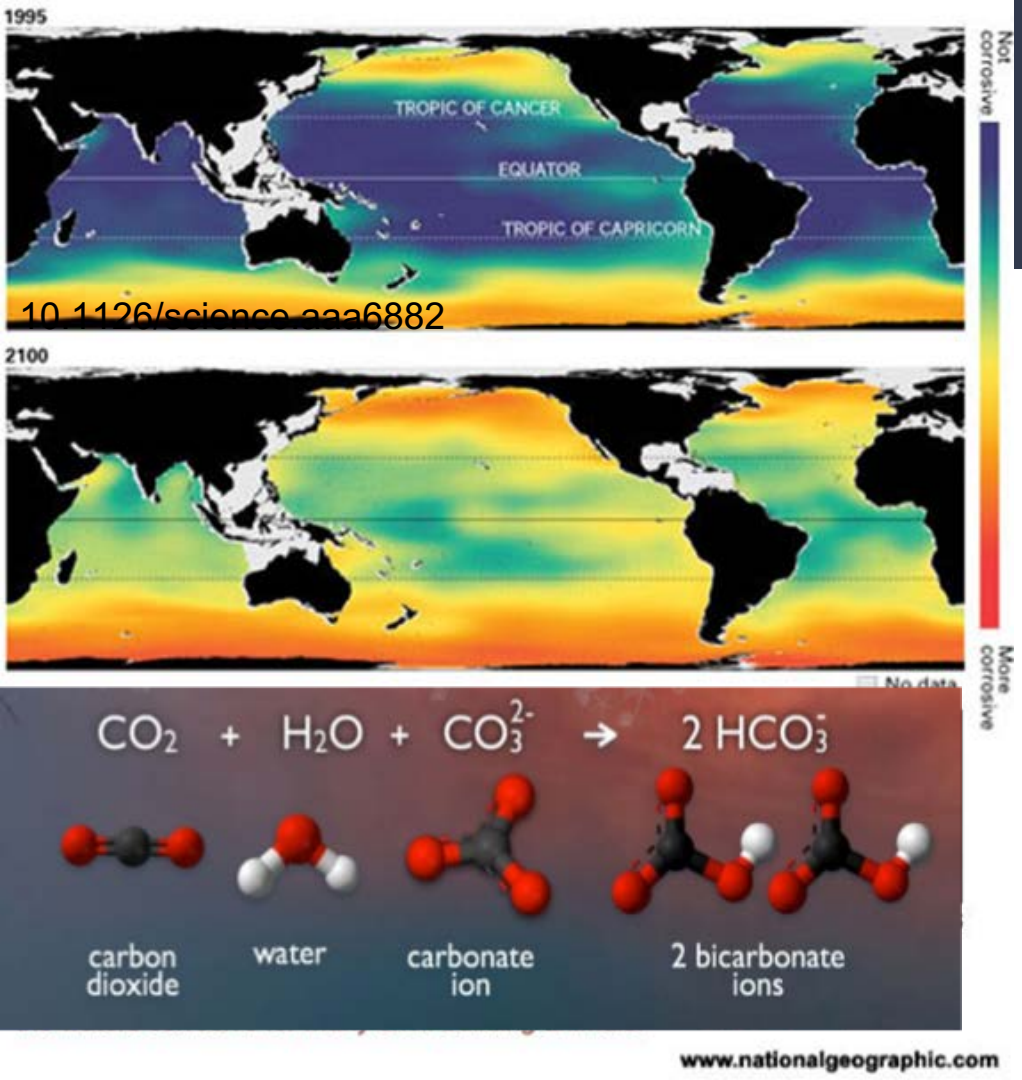
- Across the globe nearly all glaciers are decreasing in area
- Melt water affects seawater level and salinity
- Earlier spring runoff
- More frequent and severe flooding

4. Sea Level Rise



- Warmer water expands, so the ocean increases in volume
- Melting glaciers and snowpack
- A 2 m sea level rise would swamp 187 million people
  - This is an upper bound prediction for 2100

Sea Level Rise: Boston



5. Ocean Acidification

The surface ocean equilibrates with the atmosphere

Increase of pCO2 in the atmosphere consumes the carbonate ion, which decreases its saturation state

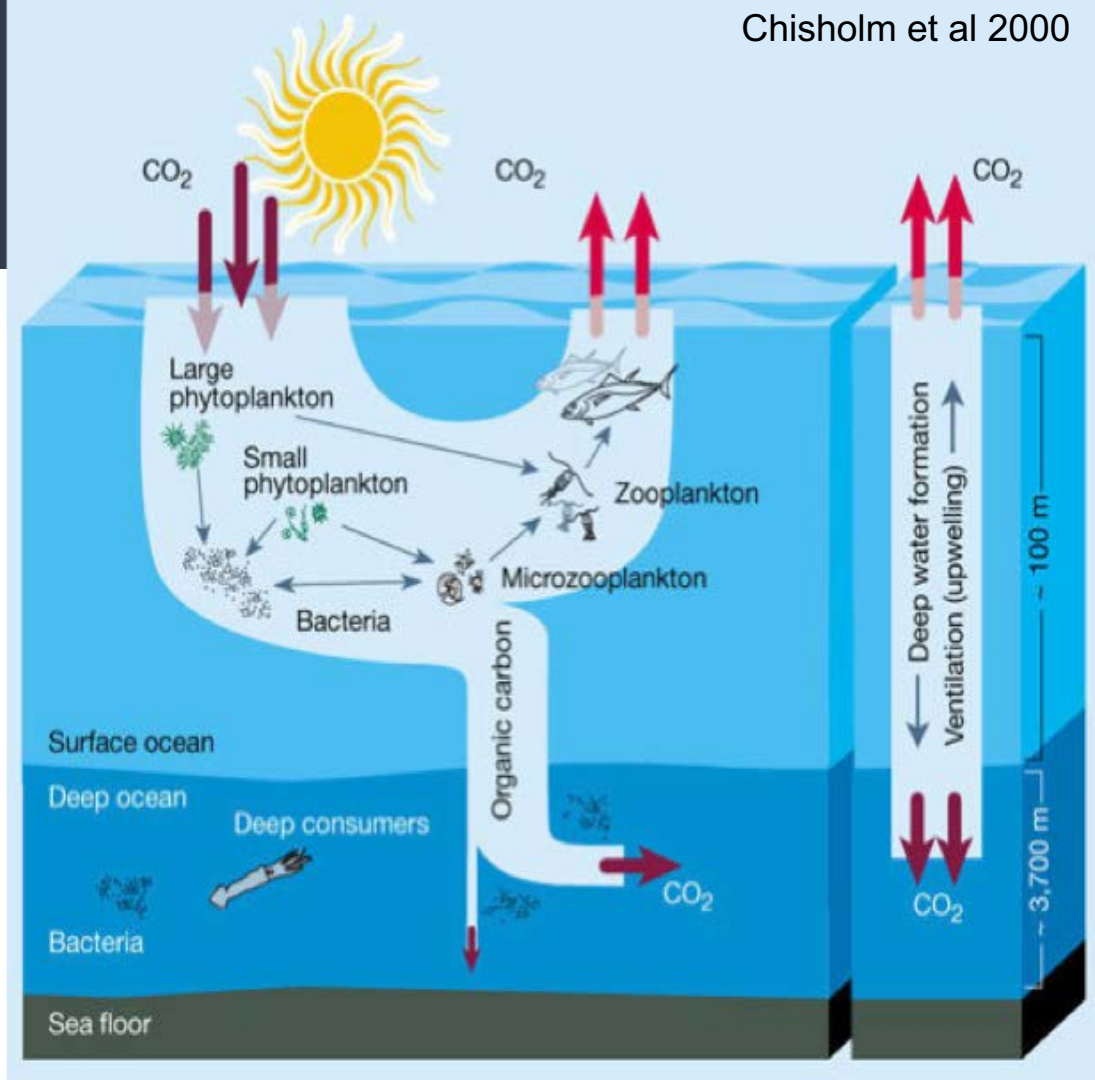
This impedes the effectiveness of the carbonate pump

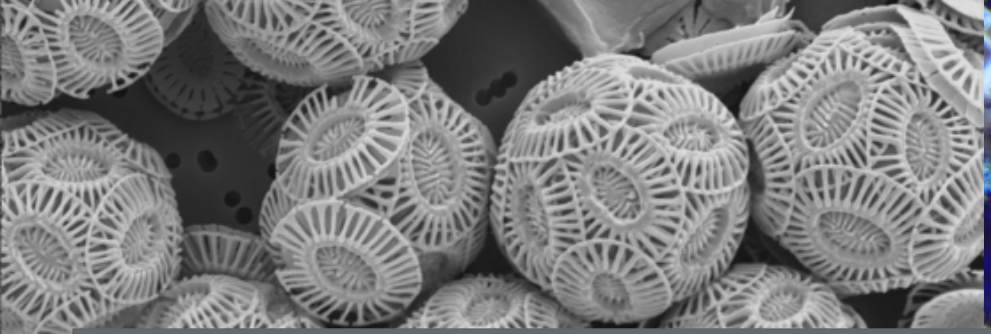
The Biological Pump

Contributors:

- Soft Tissue Pump
  - Organic matter formed by photosynthesis
  - Dead cells and fecal pellets aggregate and sink
- Carbonate Pump
  - CaCO3 shells formed by plankton and mollusks

Important sink of CO2 from the atmosphere!!!





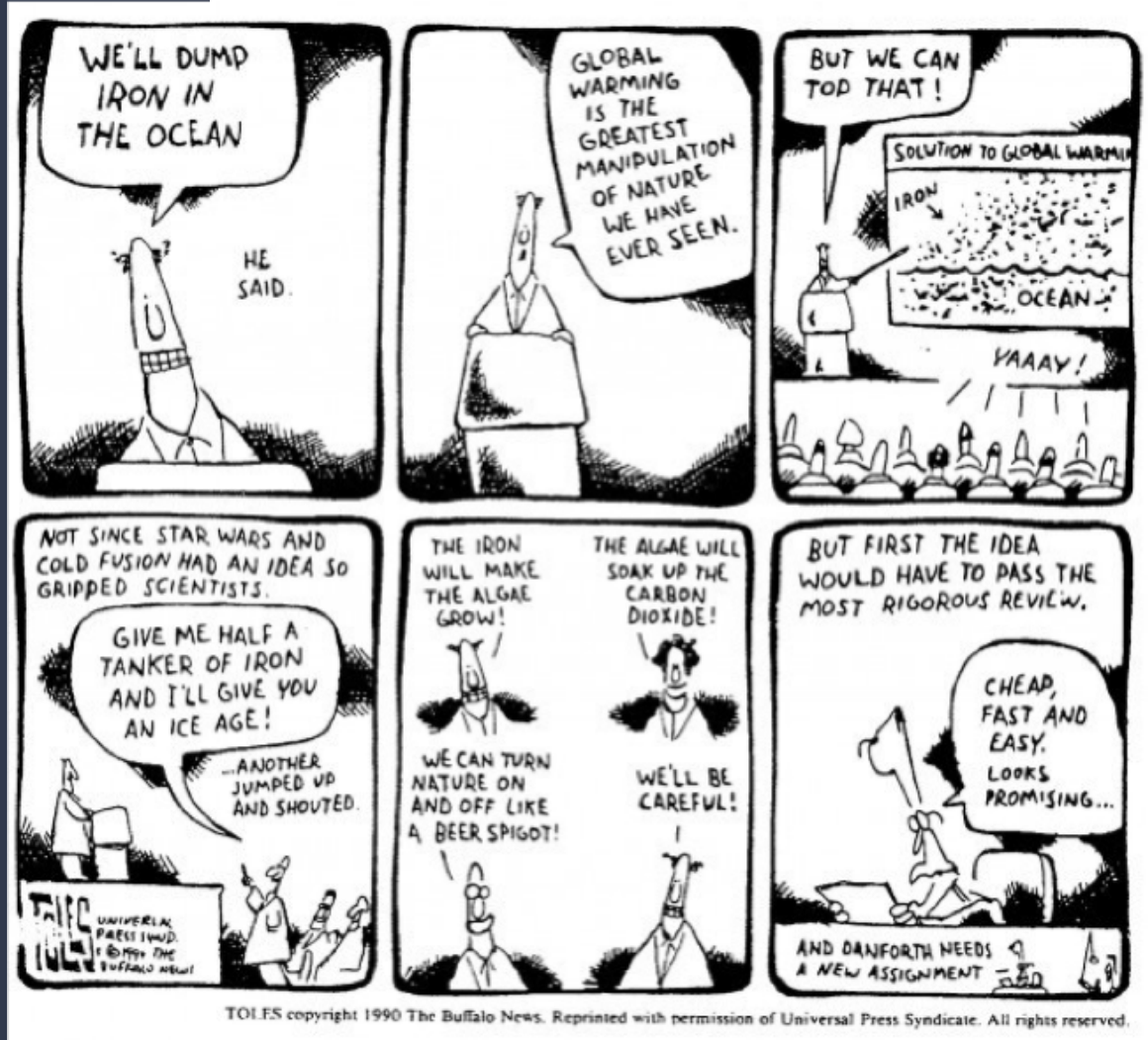
Ocean acidification= less carbonate formation
Dissolution of coral environments
Less Biodiversity

Potential Solutions to Ocean Acidification?

Geoengineering
- Iron Fertilization
- Adding alkalinity

These have significant economic and ecological costs.

Best solution:
Stop adding CO2 to the atmosphere



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The Aral Sea: anthropogenic environmental and climate change

Anthropogenic Impacts:

- Increases of agriculture in the 20th century used up all the water coming down the mountains before it could reach the sea
- Farmers grew water intensive crops
- Excessive use of agricultural pesticides
- Island in the center was used at a biological weapons development site (smallpox, plague, etc)

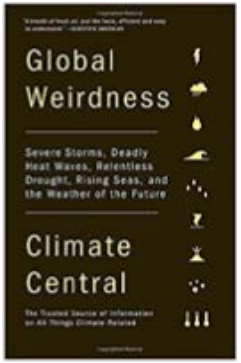
Climate Change Effects:

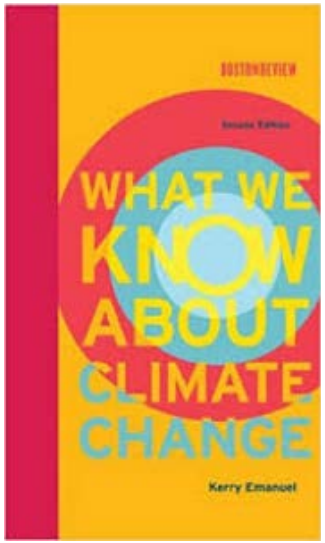
- Sea surface temperature (SST) changes
- Hotter summers, colder winters
- Exposed seabed results in dust storms
  - Issue for respiratory health
- Rising salinity kills fish
  - Decimates fishing villages
  - Destroys fishing and canning industry
  - Cultural loss of traditional food

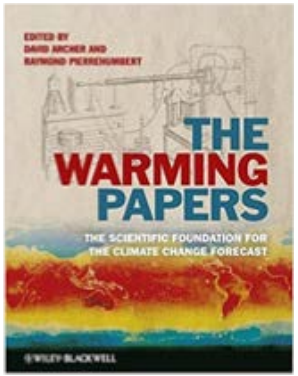
Books

Documentaries

Organizations







The Nature Conservancy

Protecting nature. Preserving life.

EARTHJUSTICE

WOODS HOLE OCEANOGRAPHIC INSTITUTION

1930

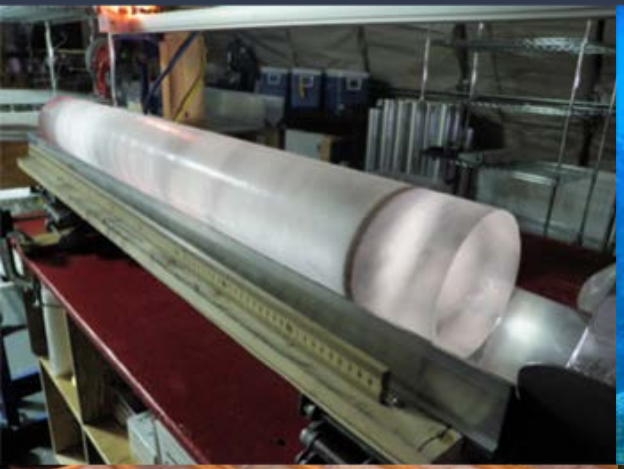
Union of Concerned Scientists

Science for a healthy planet and safer world

THESOLUTIONSPROJECT

EXTRA SLIDES

How Do We Know About Past Climates?



Images: https://climate.nasa.gov/internal_resources/1205/
https://upload.wikimedia.org/wikipedia/commons/thumb/2/2e/Coral_Outcrop_Flynn_Reef.jpg/1200px-Coral_Outcrop_Flynn_Reef.jpg
https://ldsmag.com/wp-content/uploads/2016/09/Tree-Rings.jpg
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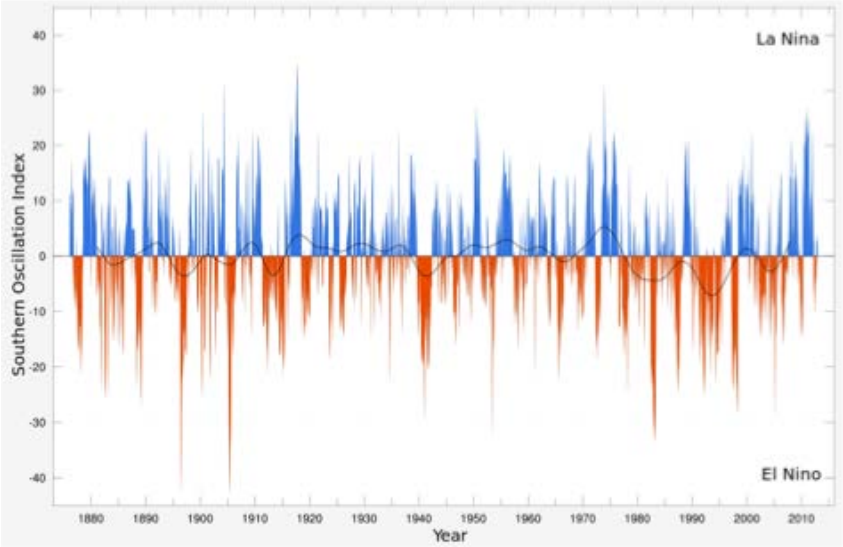
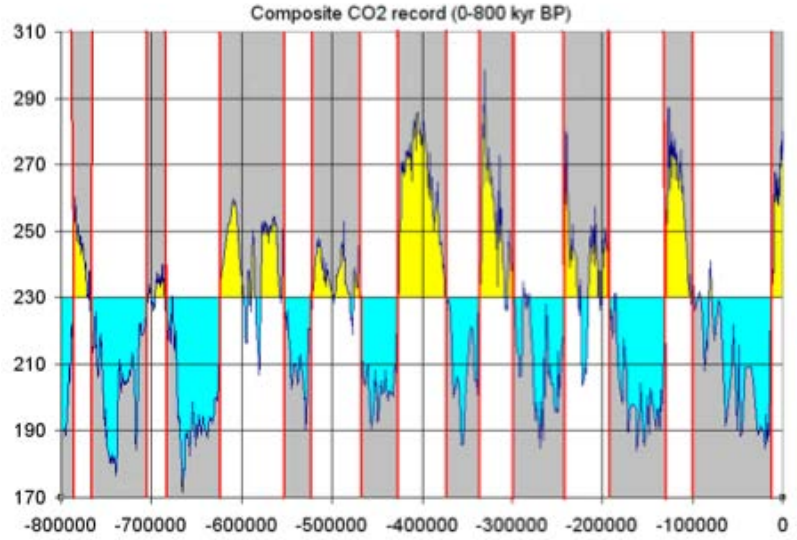
Climate Cycle Examples

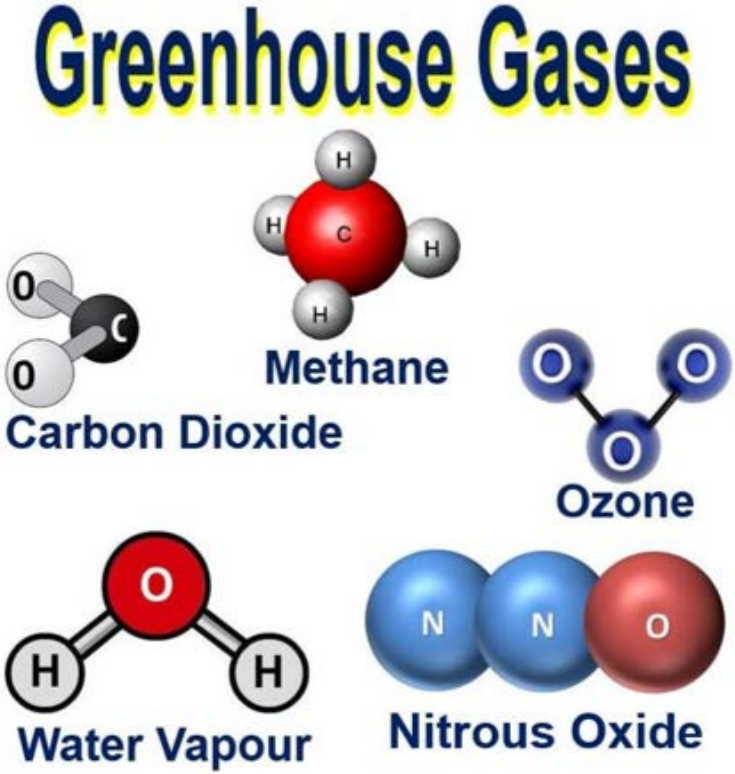


El Nino Southern Oscillation (ENSO)
Timescale of 2-4 years



Glacial-Interglacial Cycles
Timescale of 20,000 years

Factor 3: Atmosphere



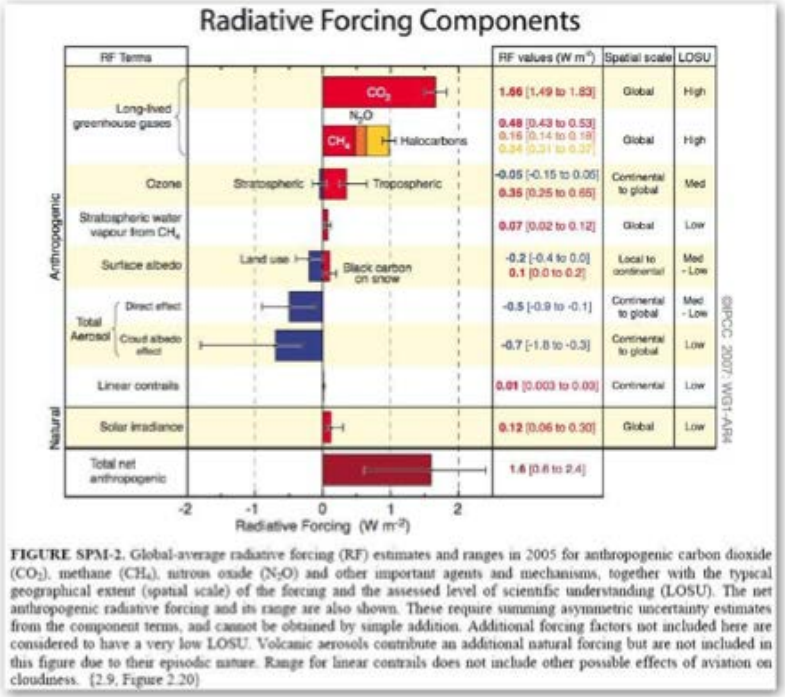


FIGURE SPM-2. Global-average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. Range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}

Imagse: https://d1o50x50snmhul.cloudfront.net/wp-content/uploads/2007/05/dn11639-1_767.jpg
http://marketbusinessnews.com/wp-content/uploads/2016/05/Greenhouse-gases-most-common.jpg