

# Climate Change: Mechanisms, Evidence and Their Impact on Health

An aerial view of Earth from space, showing a vast expanse of white and grey clouds over a dark blue ocean. The horizon is visible at the top of the frame, with a thin layer of atmosphere. The lighting suggests a low sun, creating long shadows and highlighting the texture of the clouds.

MPHP 441 Climate Change and Health  
February 3, 2021  
Mark E. Stewart, Ph.D.

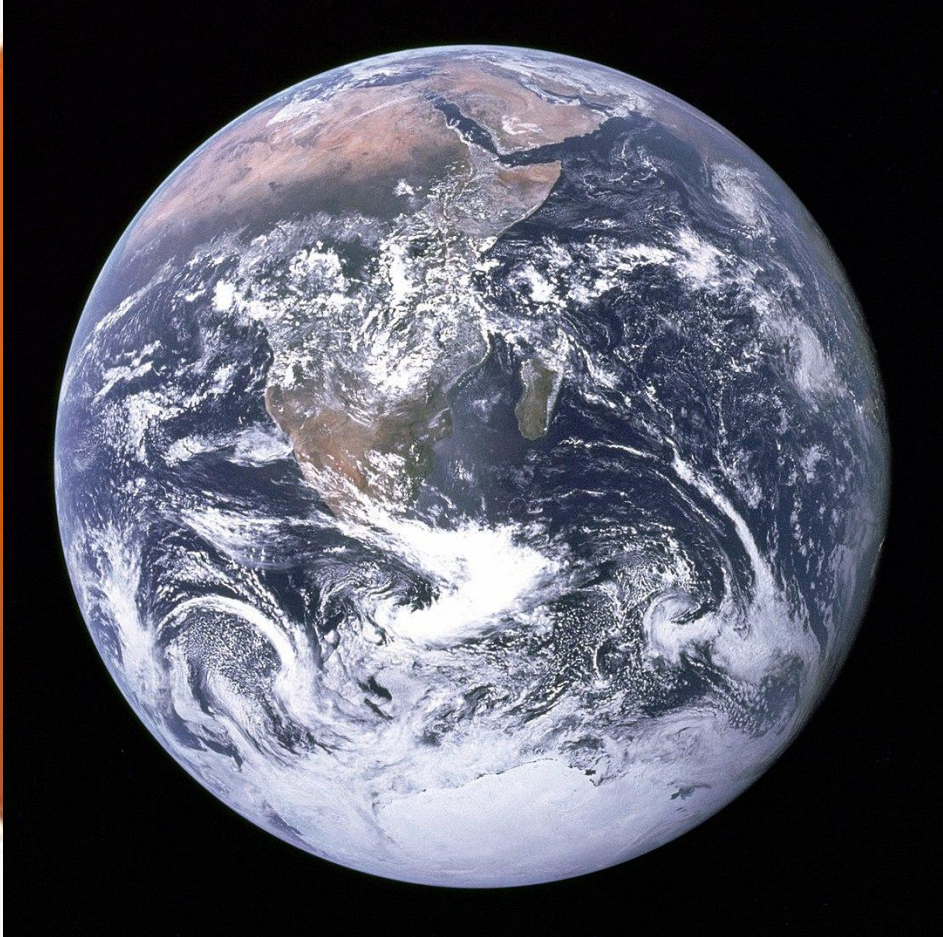
# Objectives

- Climate change,
  - The main ideas
  - The key mechanisms
  - The strong evidence
- Getting from climate science to health



# Outline

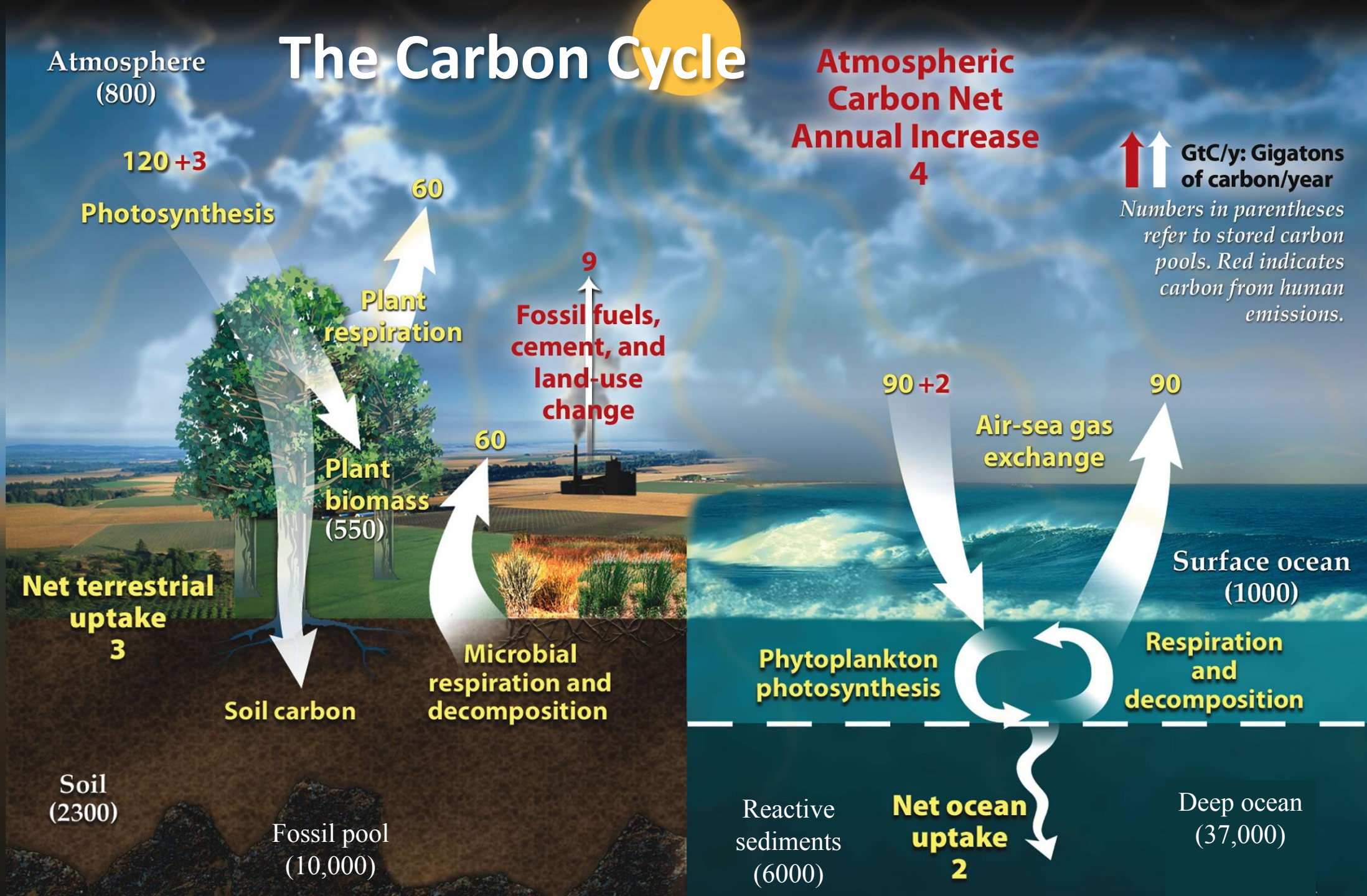
- Climate change, the main ideas
  - Yet, there are more details
- History
- Evidence, and weighing it
  - CO<sub>2</sub> measurements & ice cores
  - Changes in the average temperatures
  - Sensitive measures: glacier & sea ice extent
  - Extreme weather
  - Computer simulations
- Impact on health
  - Increased temperature
  - Water & food supply, migration & refugees
  - Air pollution
  - Extreme weather
- IPCC
- Social cost of carbon

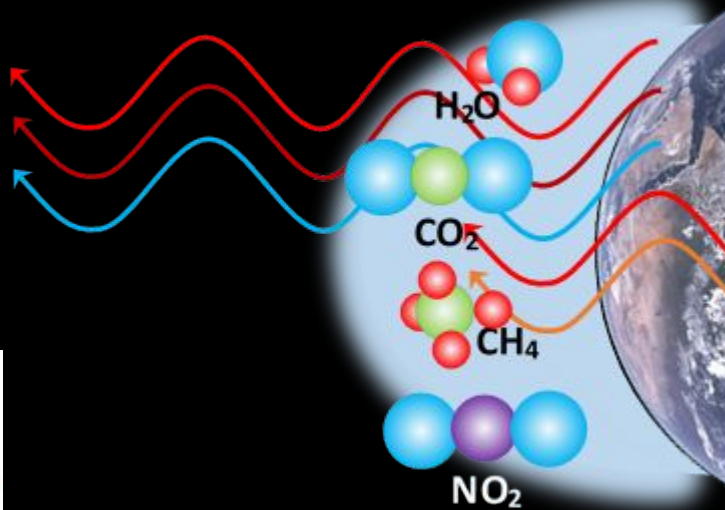
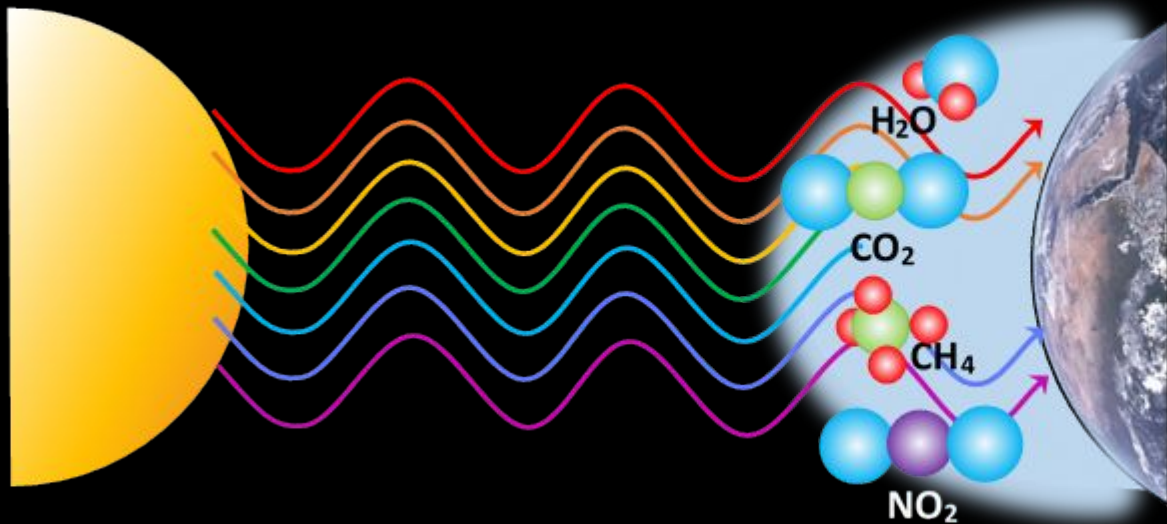


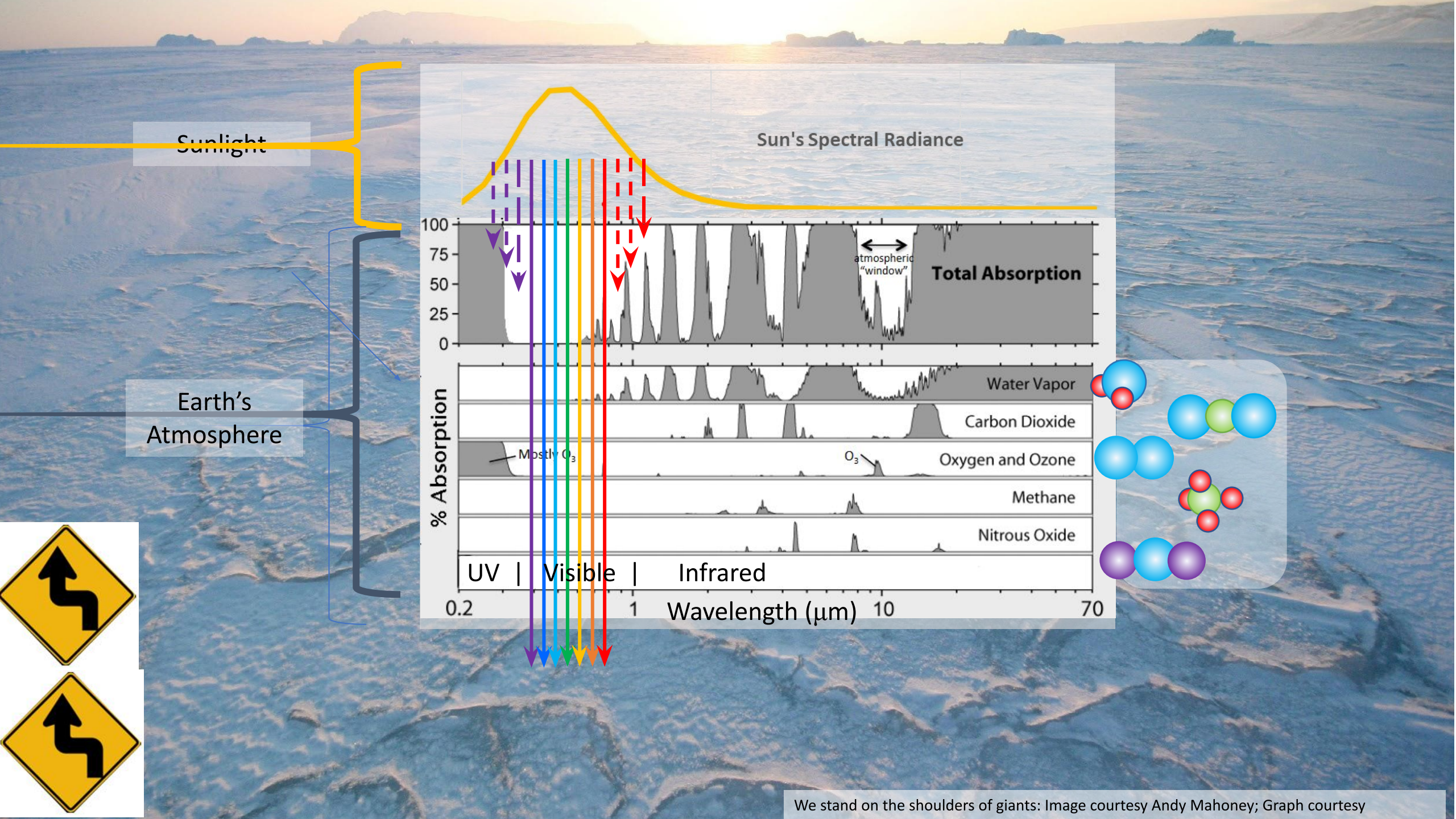
# Fast Facts

- The atmosphere is mainly nitrogen,  $N_2$ , 78%, and  $O_2$ , 21%
  - $CO_2$  is measured in ppm, 415 ppm, or 0.0415 %
  - $CH_4$  is 1.8 ppm, or 0.00018 % by volume
  - $H_2O$  vapor is up to 5%
- Nitrogen, argon are transparent to sunlight
- Greenhouse gases are long lived, centuries
  - PM2.5, smog, have shorter lifetimes
- Methane,  $CH_4$ , is 25 times the Global Warming Potential (GWP) of  $CO_2$ 
  - $N_2O$  is 289 times
  - GWP is over 100 year lifetime
  - CFCs, HFCs, HCFCs, PFCs,  $SF_6$  have GWPs of thousands or tens of thousands

# The Carbon Cycle

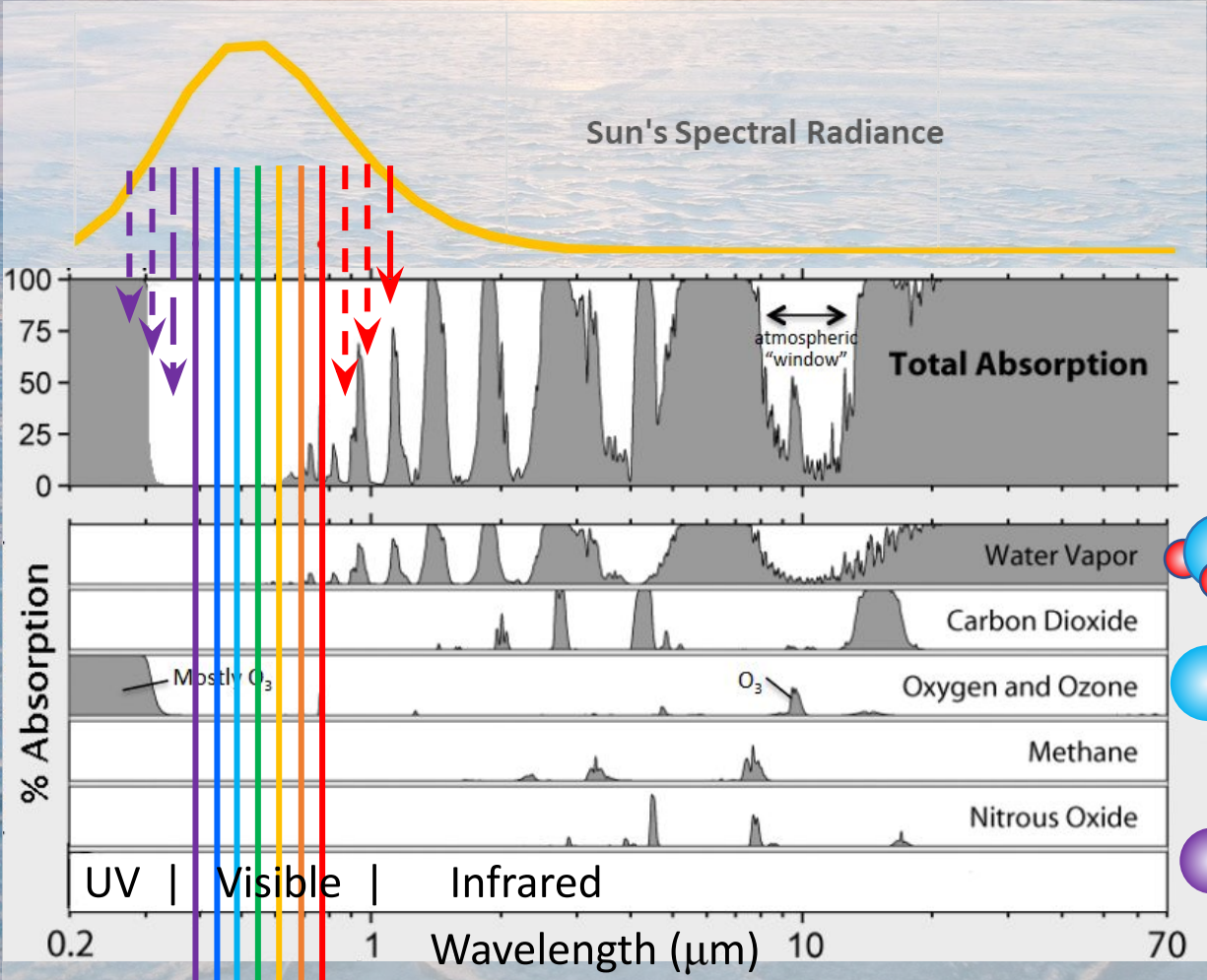




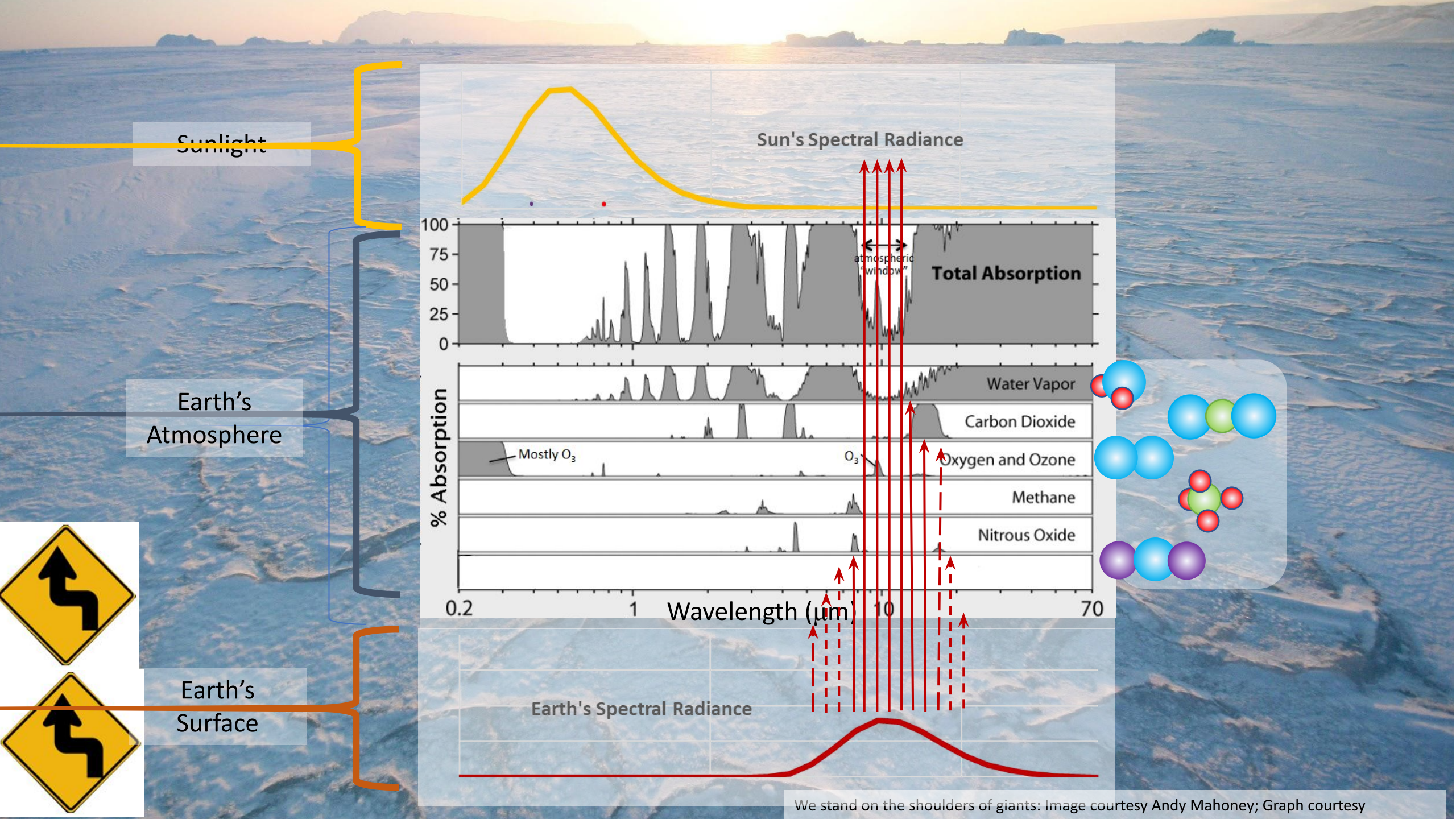


Sunlight

Earth's Atmosphere



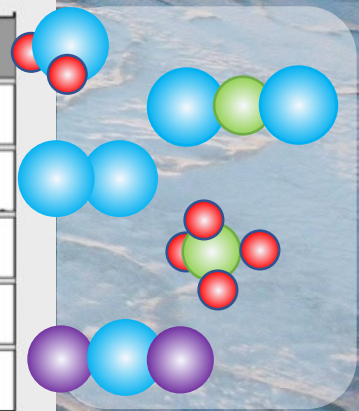
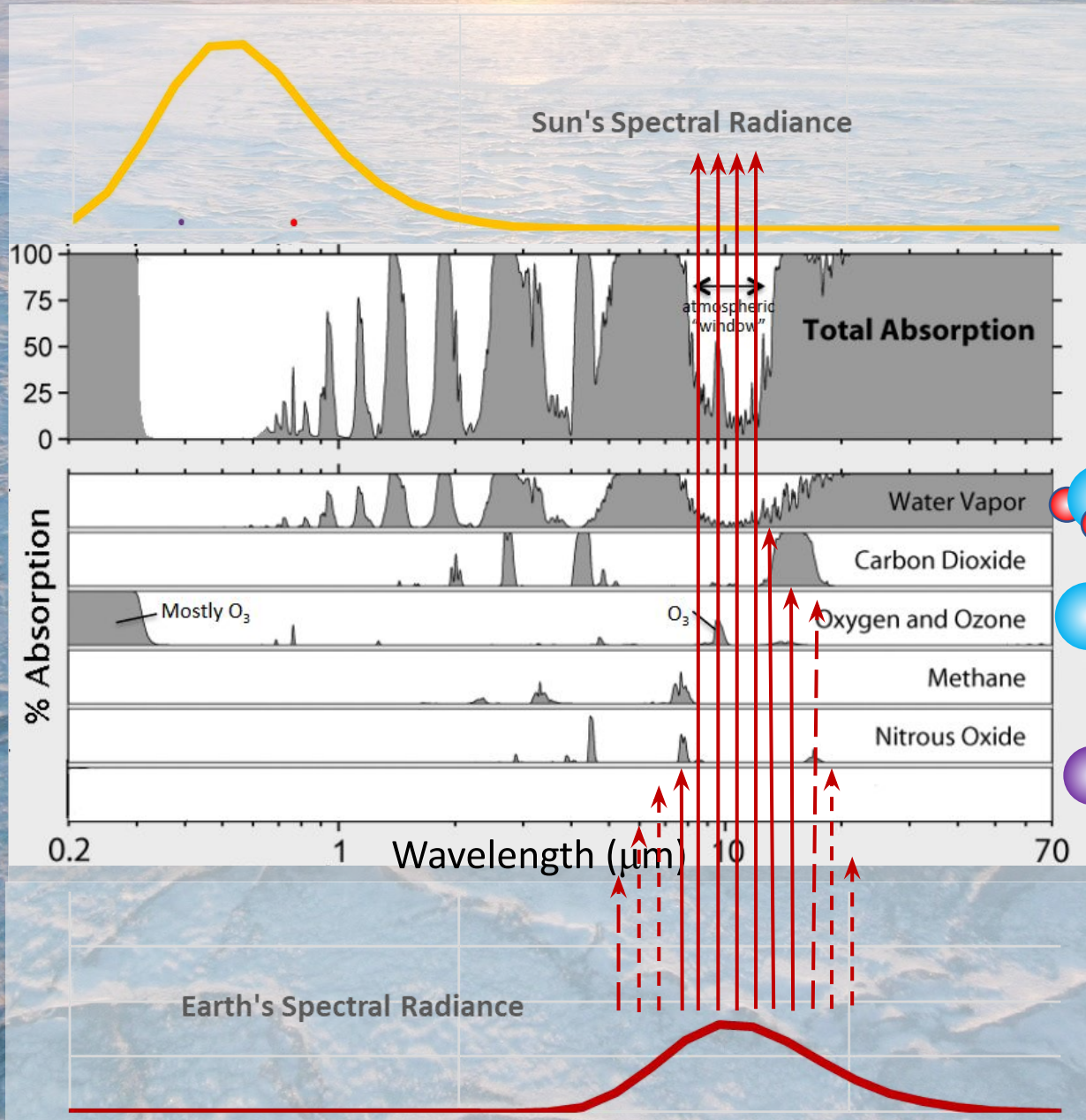




Sunlight

Earth's Atmosphere

Earth's Surface

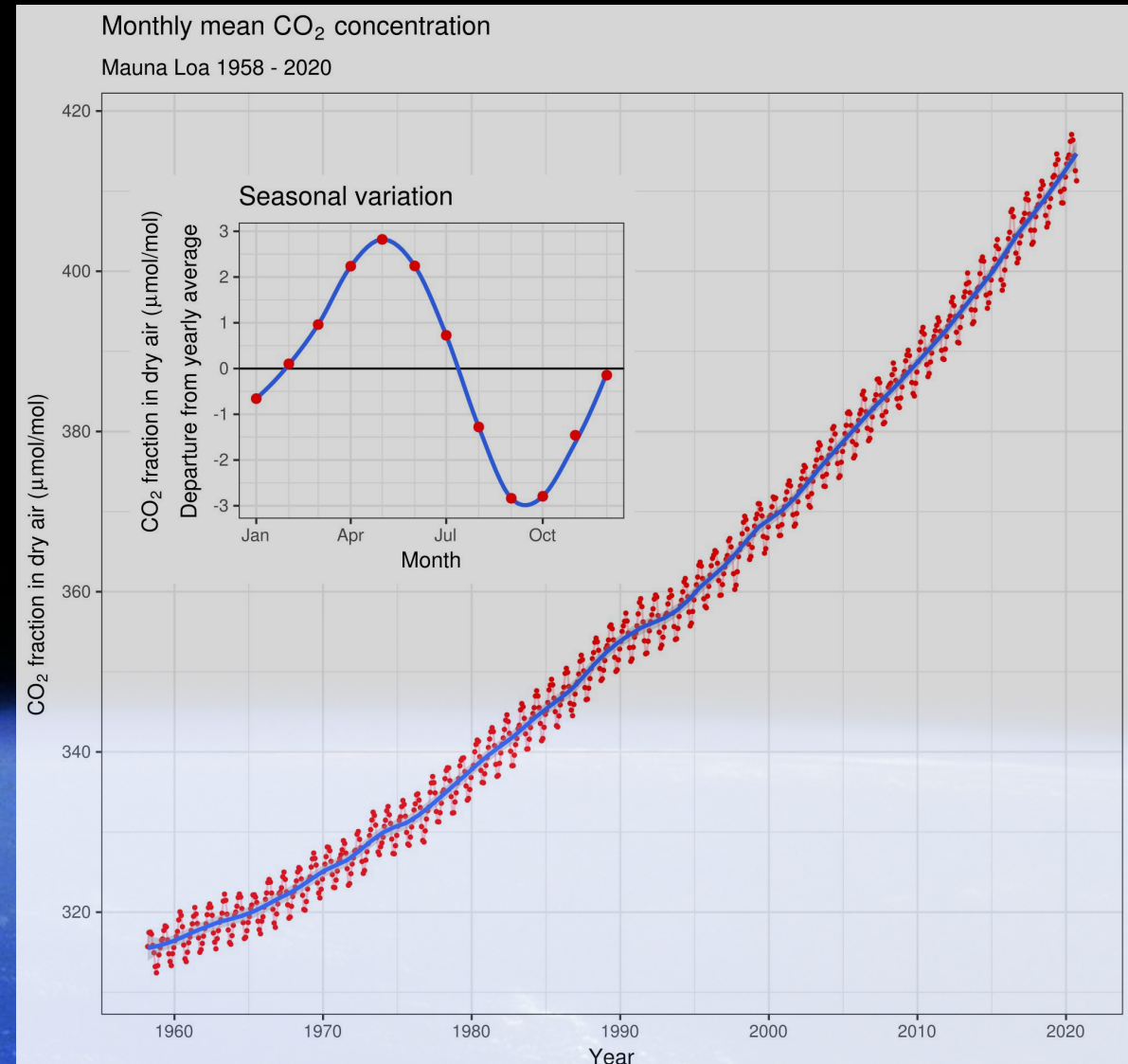


# History of the Greenhouse Effect

- CO<sub>2</sub> is a control knob for surface temperature, ice ages, climate change
- In the 1800's, scientists asked 'What caused multiple ice ages?'
  - Fossils indicate mass extinctions,
  - Geology indicates glaciation,
  - What determines the temperature of the Earth?
  - Plus, Industrial Revolution burned coal with prodigious CO<sub>2</sub> emissions
- Possible causes: variations in Earth's orbit? Brightness of the sun?
- In 1896, Svante Arrhenius predicted CO<sub>2</sub>'s role, plus mechanism
  - Arrhenius' predicted 11 °F to 14.5 °F warming if CO<sub>2</sub> doubled
  - Close to today's estimate of 5.5 °F to 9 °F (3 C to 5 C)

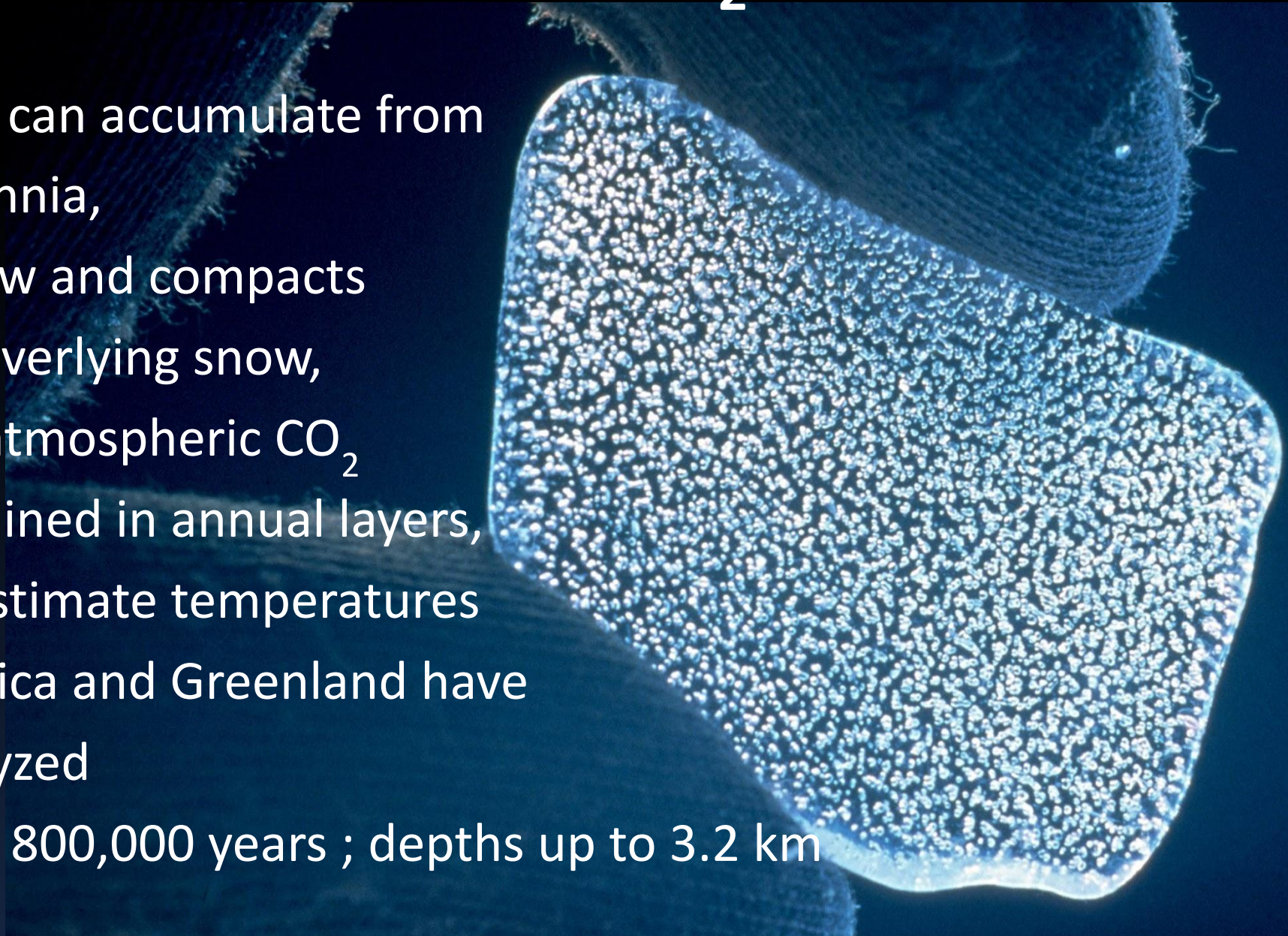
# Atmospheric CO<sub>2</sub> Concentration: Keeling Curve

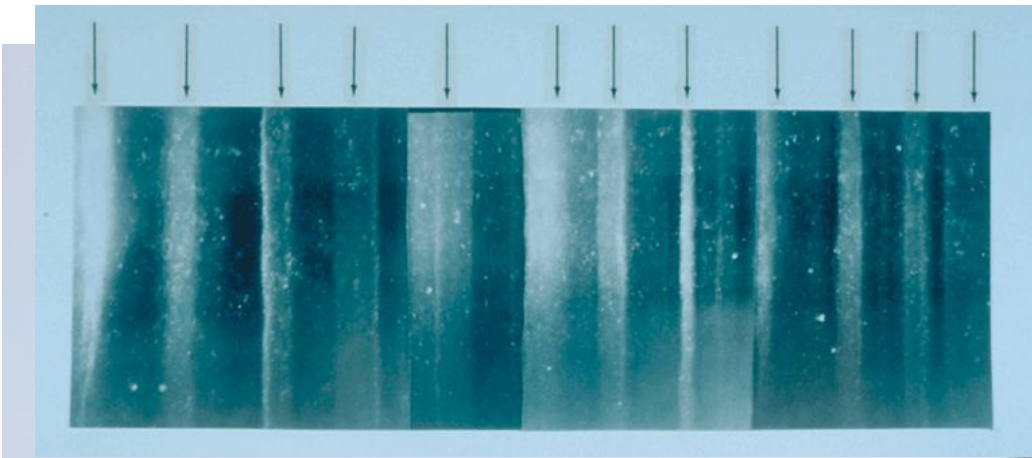
- In the 20<sup>th</sup> century, fossil fuel use raised concerns of CO<sub>2</sub> concentration
- In 1953-58, Keeling began atmospheric CO<sub>2</sub> measurements at Mauna Loa,
- A strong diurnal behavior—more CO<sub>2</sub> at night
- A strong annual behavior—maximum in May, minimum in October
- Shows a 30% increase over 60 years of continuous measurements



# Ice Cores: a Historical Record of CO<sub>2</sub> Concentration

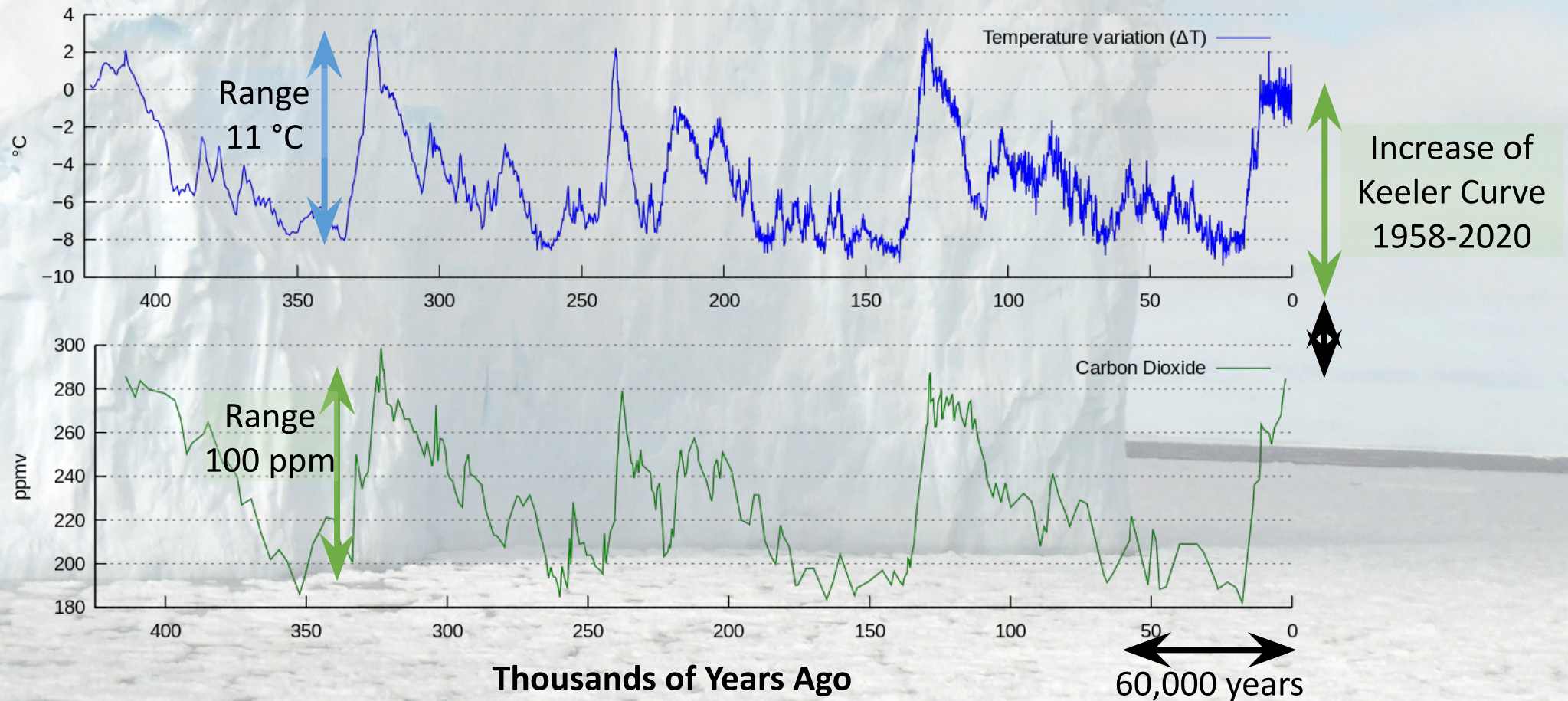
- In polar regions, snow can accumulate from year to year, for millennia,
- Air mixes with the snow and compacts under the weight of overlying snow,
- A historical record of atmospheric CO<sub>2</sub> concentration is contained in annual layers,
- Paleothermometers estimate temperatures
- Ice cores from Antarctica and Greenland have been drilled and analyzed
- Historical record up to 800,000 years ; depths up to 3.2 km





[https://en.wikipedia.org/wiki/Ice\\_core](https://en.wikipedia.org/wiki/Ice_core)

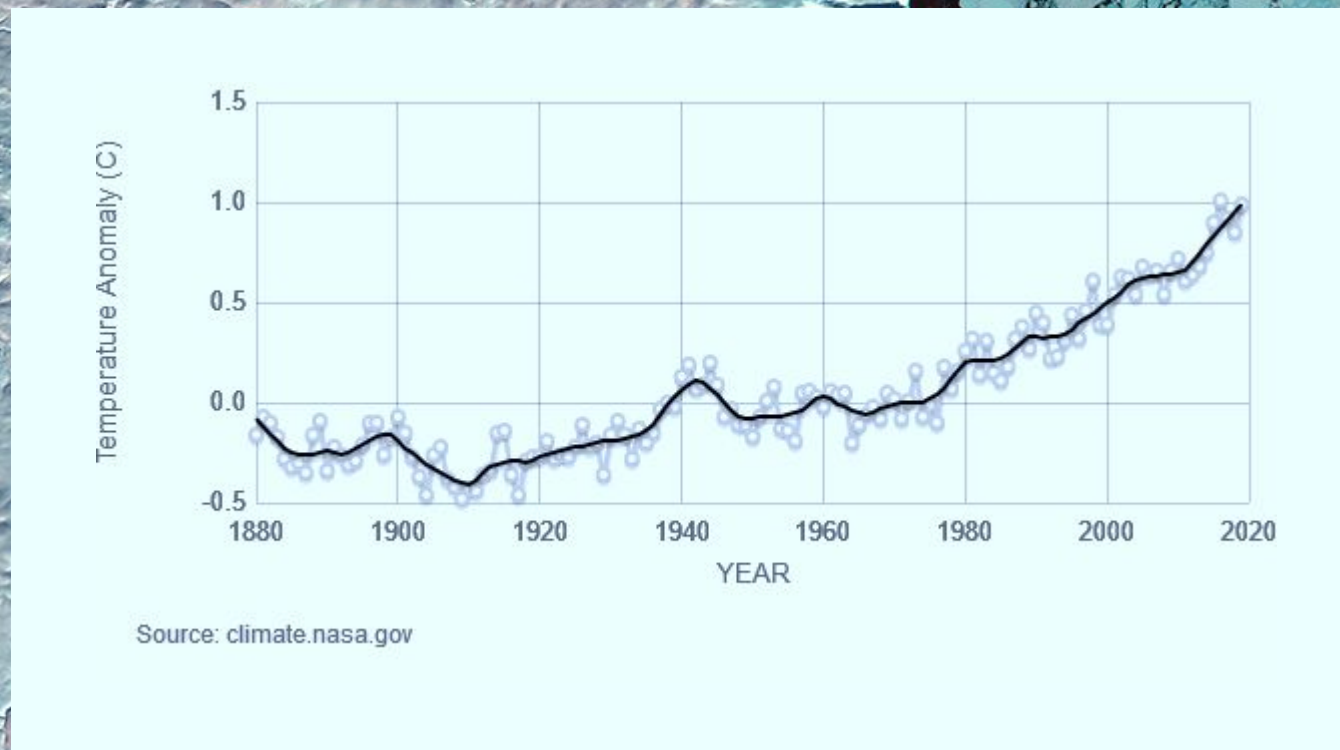
# Vostok ice core measurements, 400,000 year record



# Change in global surface temperature

(Annual Average Anomaly relative to 1951-1980)

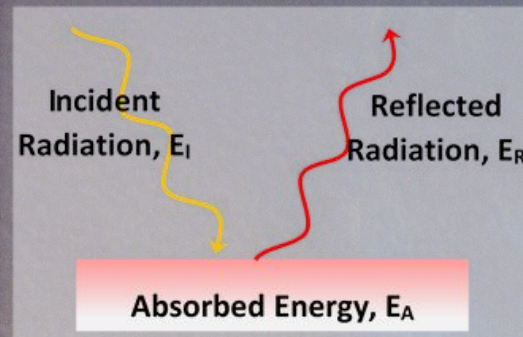
- 10 of the 20 warmest years all have occurred since 2001—excepting 1998



# A Sensitive Test for Climate Change

- Fifty years to wait for a 1 C temperature rise is a slow test
- Loss of snow and ice cover can give a clearer indicator
- Albedo,  $\alpha$ , ratio of reflected radiant energy,  $E_R$ , to incident radiant energy,  $E_I$ , on a body,

$$\alpha = E_R / E_I$$

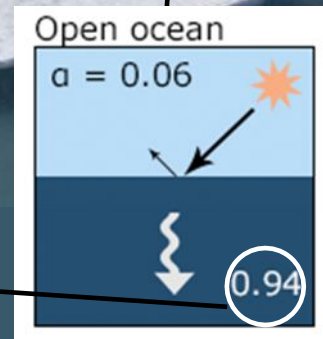
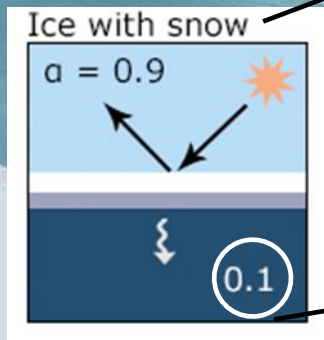
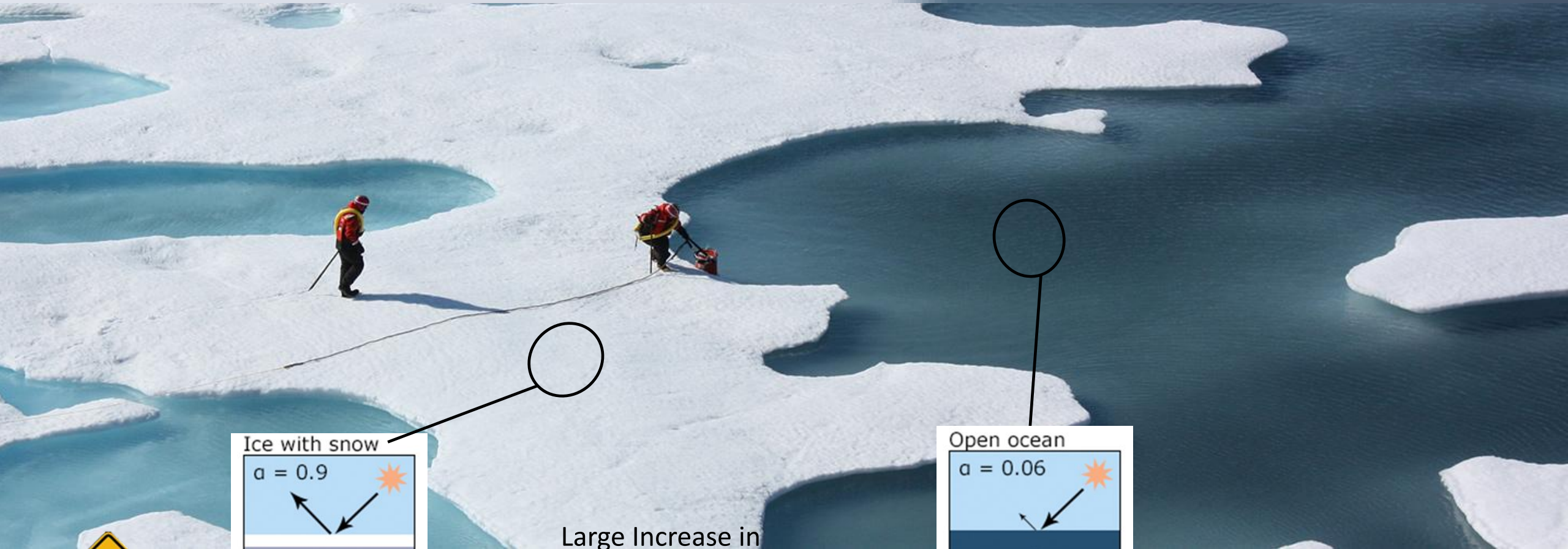


- Absorbed energy is the difference,  $E_A = E_I - E_R$ , and is large for open ocean or bare ground, but small for snow or ice





# Surface Change Accelerates Melting...

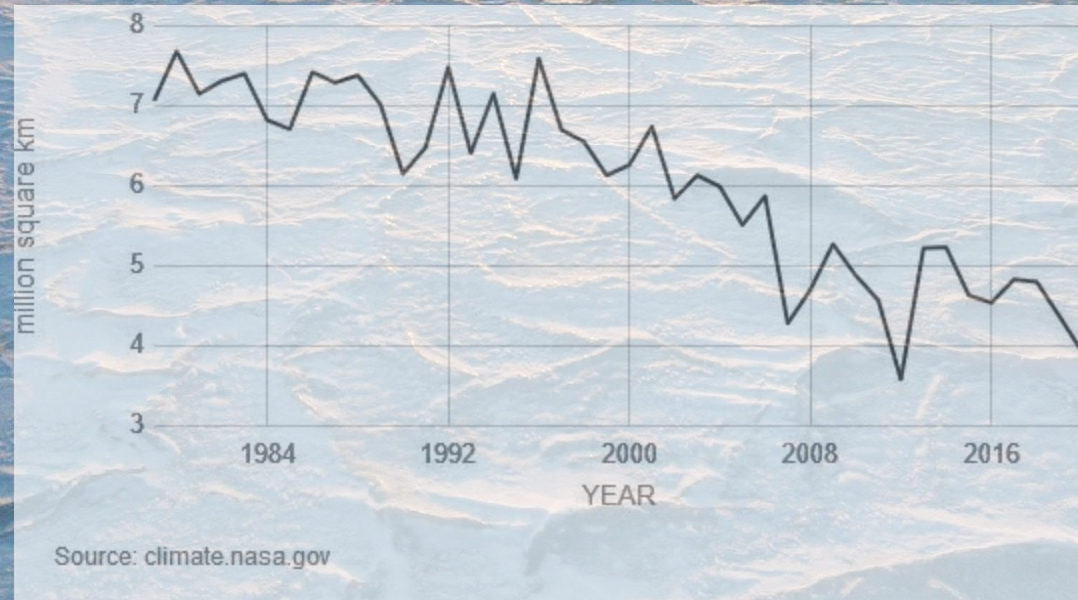


Large Increase in  
Surface Heating

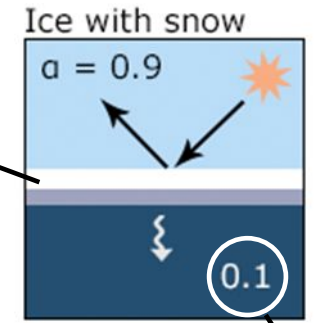


# Arctic Sea Ice Average September Minimum Extent

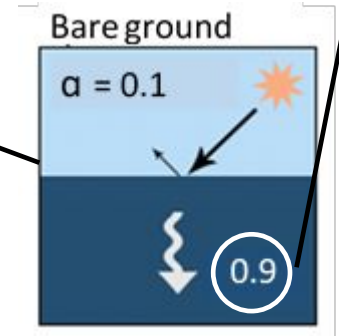
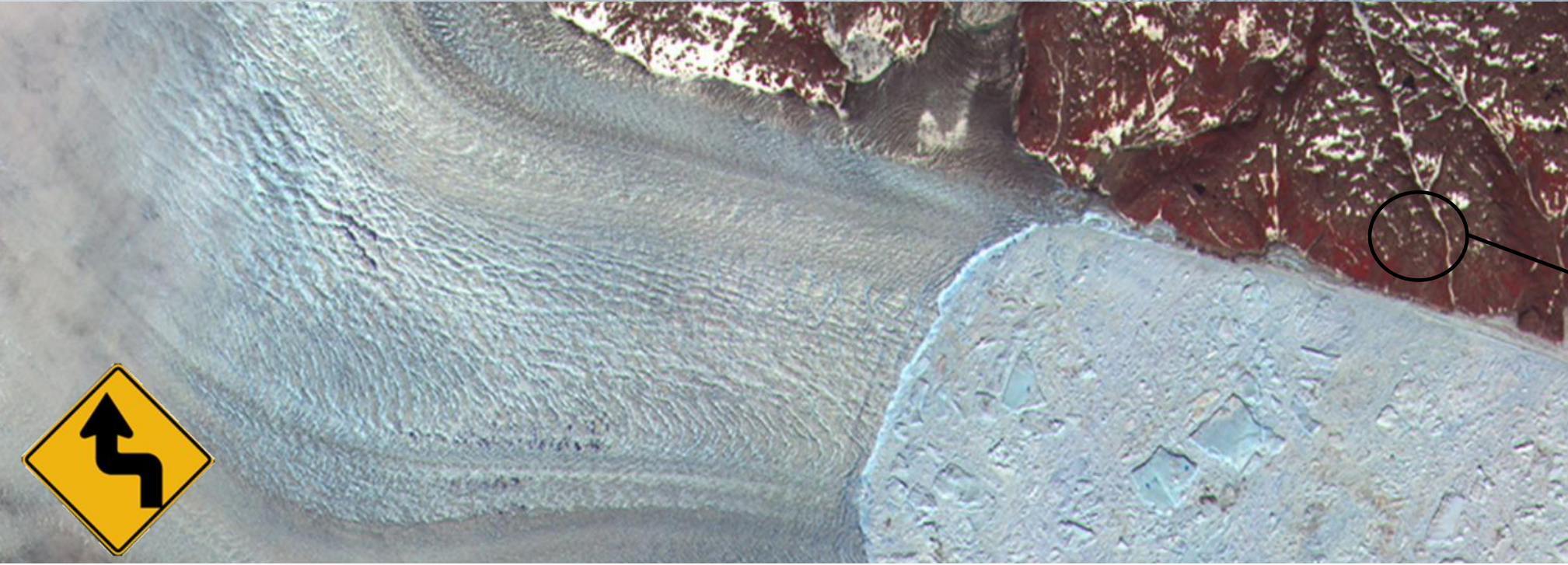
-13.1 % per decade



# Surface Change Accelerates Melting...



Large Increase in Surface Heating



# Ice Sheets: Greenland and Antarctica Mass Variation

Greenland 279.0 billion metric tons per year; Antarctica 149.0;

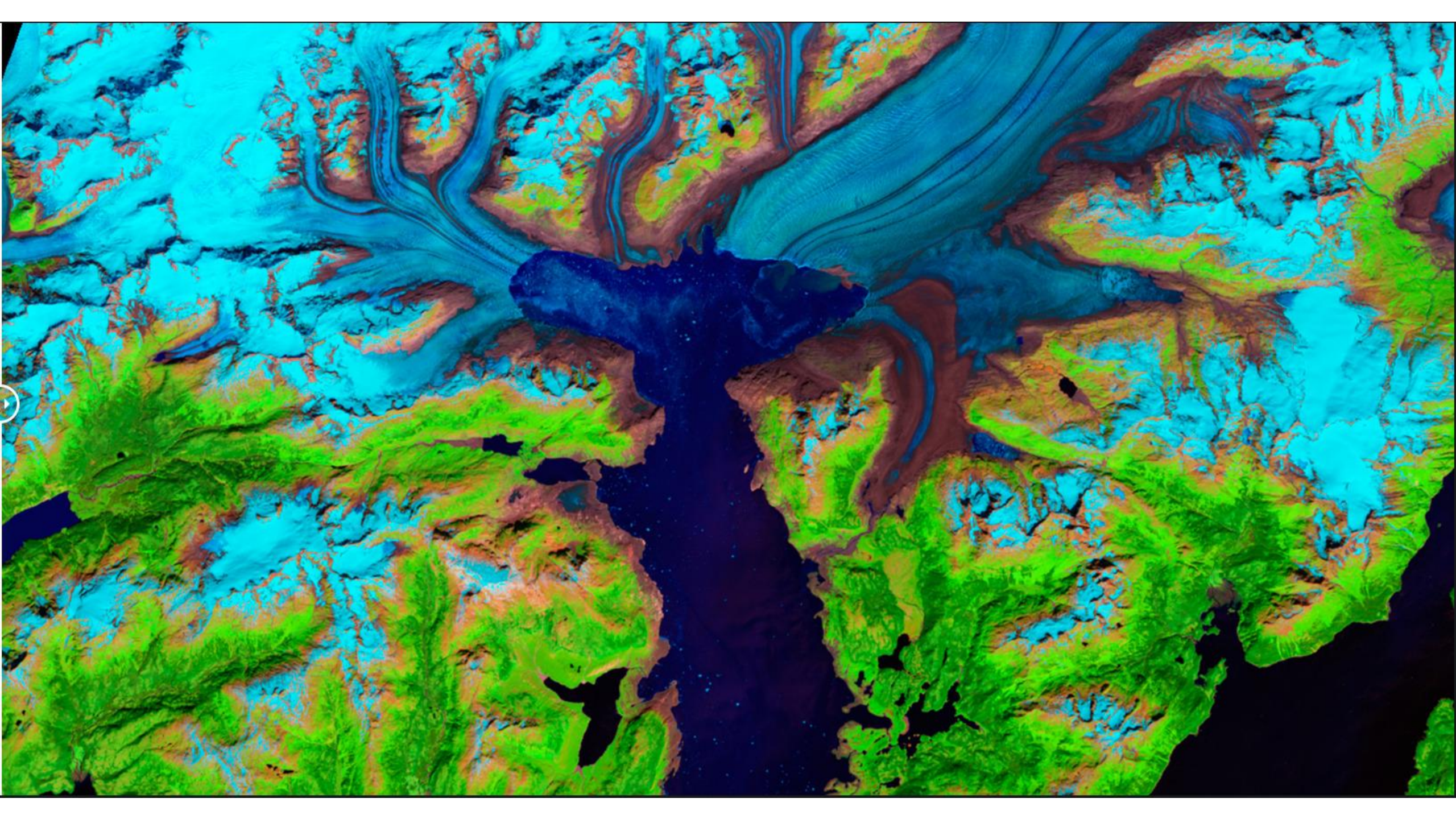




Maldives



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**Maldives**



# Northwestern Glacier, Alaska 1920s-1940s to August 2005





# Muir Glacier, Alaska Aug 12, 1941 to August 31, 2004



# Computer Simulations



- Supercomputer simulations are “fancy accounting”
- If half of global-warming emissions are not absorbed, how much CO<sub>2</sub>?

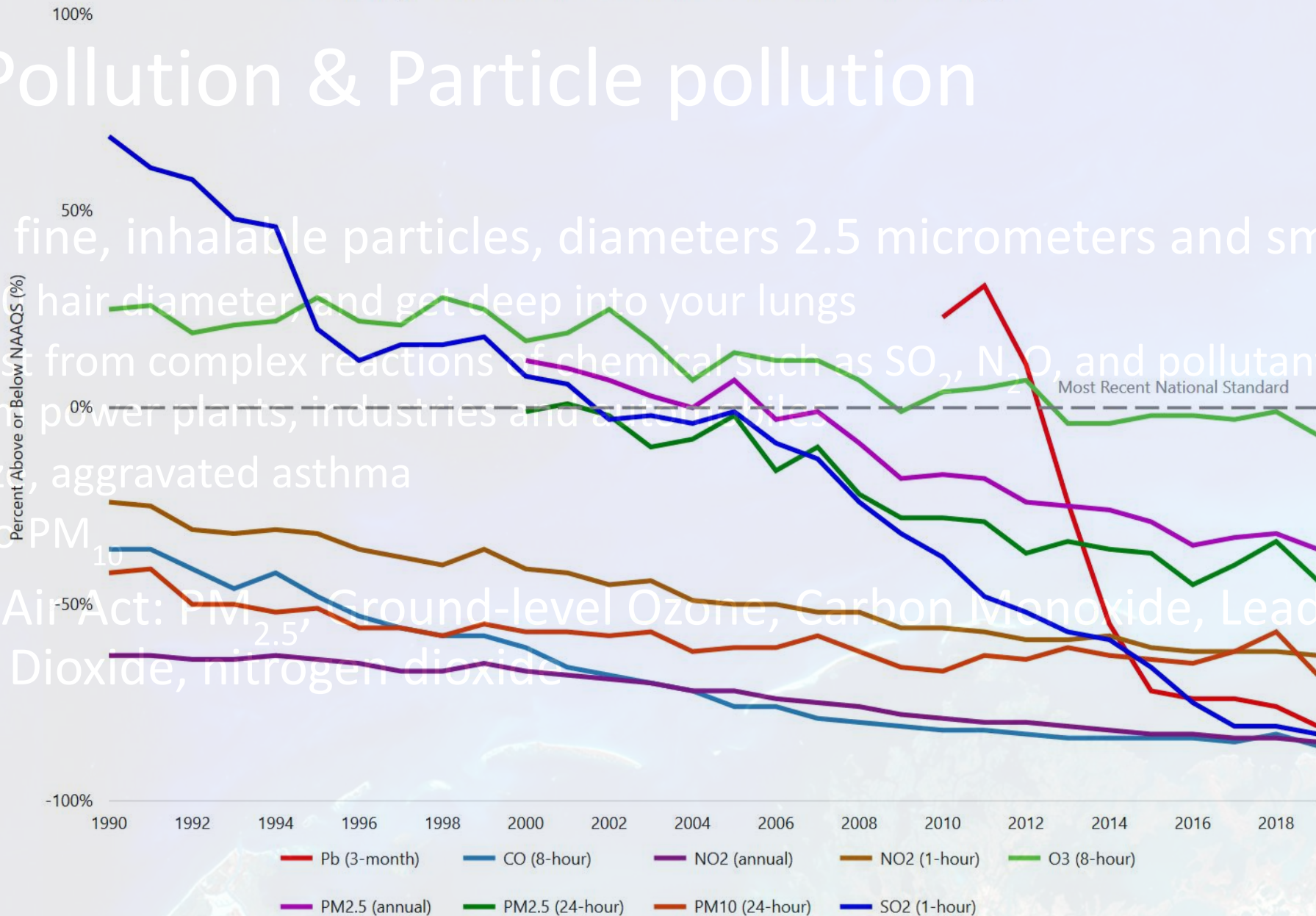
# Background and In Development



## Declining National Air Pollutant Concentration Averages

# Air Pollution & Particle pollution

- **PM<sub>2.5</sub>**: fine, inhalable particles, diameters 2.5 micrometers and smaller
  - 1/30 hair diameter, and get deep into your lungs
  - Most from complex reactions of chemical such as SO<sub>2</sub>, N<sub>2</sub>O, and pollutants from power plants, industries and automobiles
  - Hazardous, aggravated asthma
  - Also PM<sub>10</sub>
- Clean Air Act: PM<sub>2.5</sub>, Ground-level Ozone, Carbon Monoxide, Lead, Sulfur Dioxide, nitrogen dioxide



# Extreme Weather Change

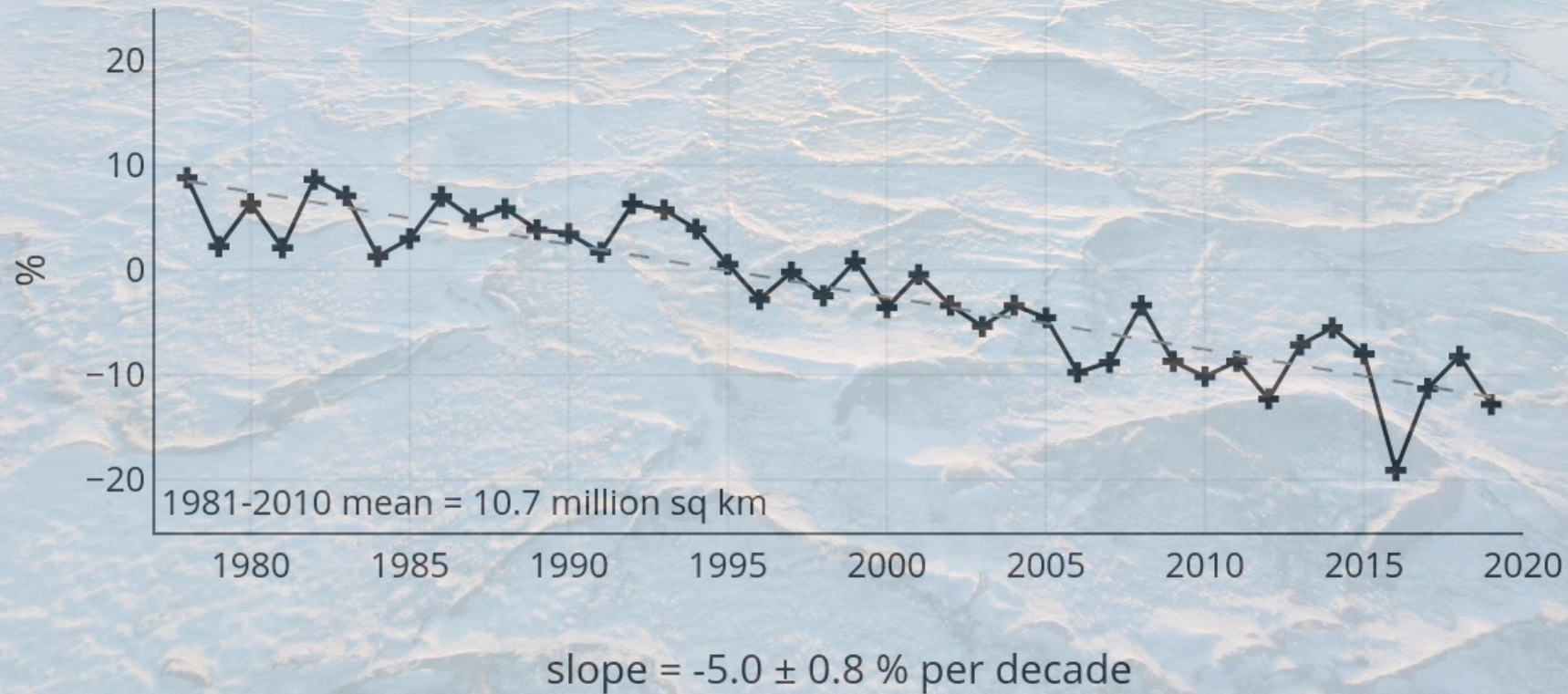
- Changes to Earth's climate results in “extreme weather” events
  - Heat Waves (Cold Waves)
  - Droughts & Floods
  - Tornadoes & Hurricanes
- <https://www.nytimes.com/2020/11/11/climate/hurricanes-climate-change-patterns.html?referringSource=articleShare>
- <https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather>

# IPCC: Intergovernmental Panel on Climate Change

- Changes to Earth's climate results in “extreme weather” events
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  - Tornadoes & Hurricanes

<https://nsidc.org/cryosphere/seaice/environment/trends.html>

Northern Hemisphere Extent Anomalies Nov 1978 - 2019

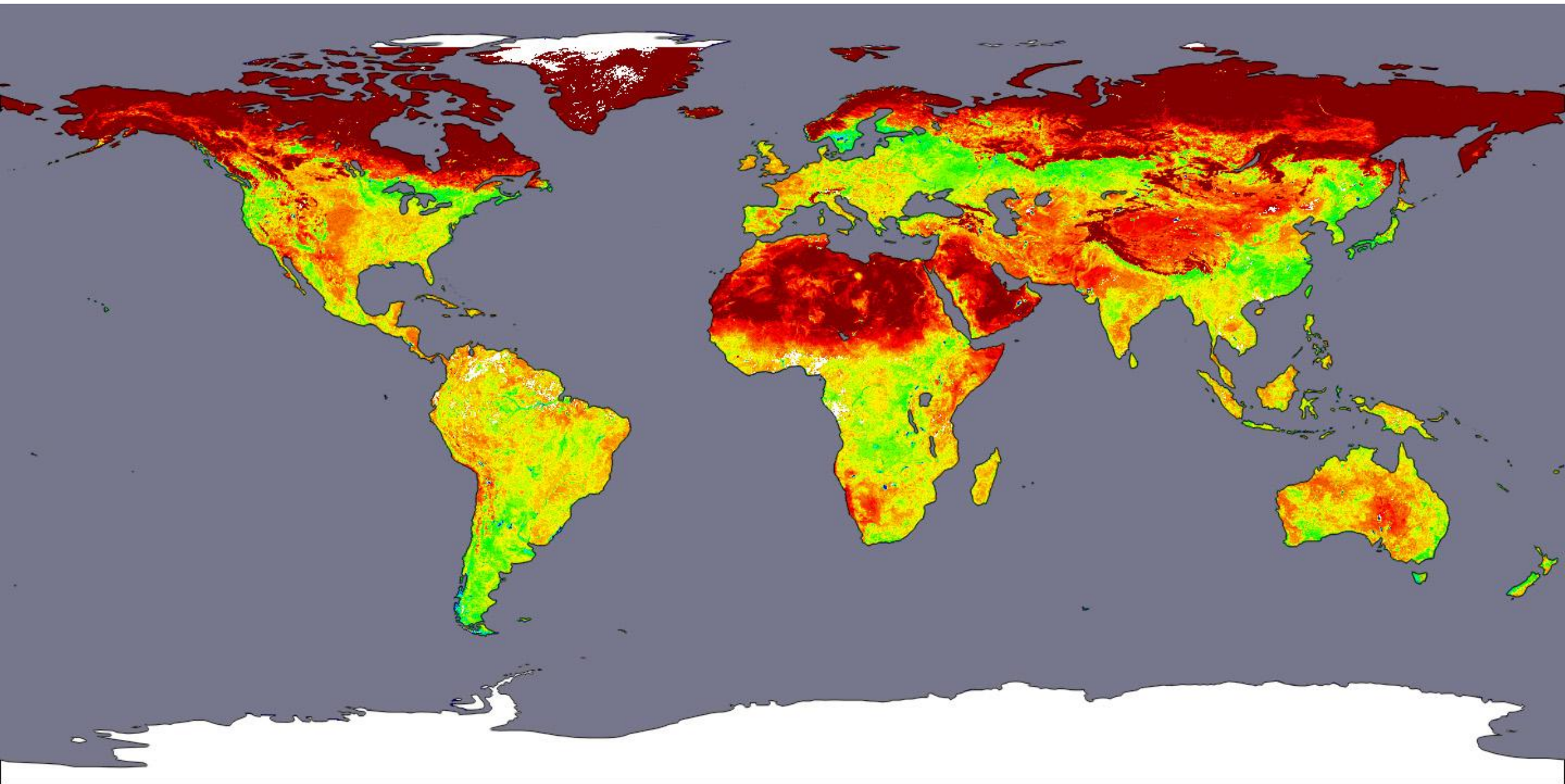


National Snow and Ice Data Center, University of Colorado, Boulder

# Migration of Animals—El Nino







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