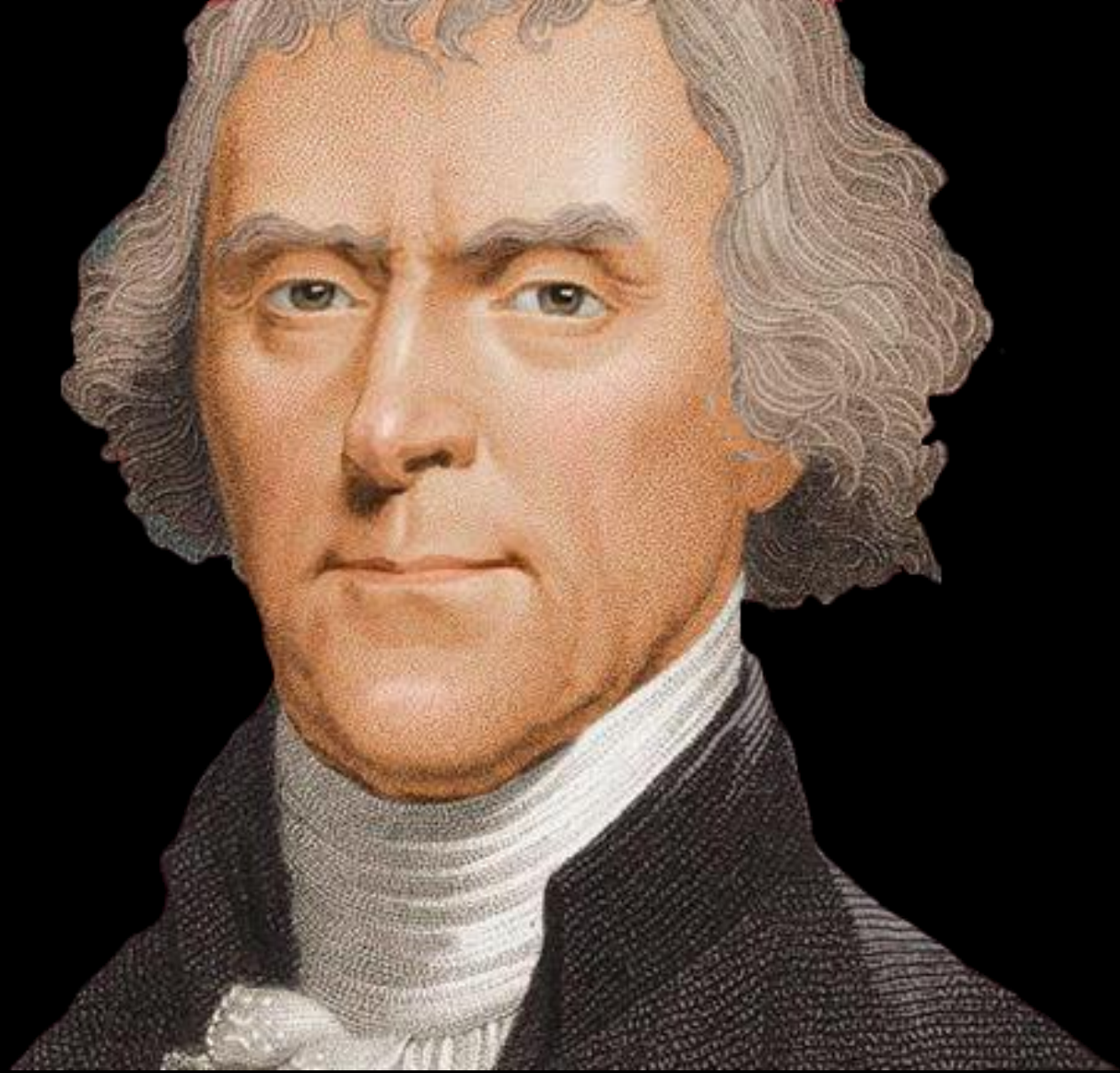


“If a nation expects to be ignorant and free in a state of civilization, it expects what never was and never will be.”

-Thomas Jefferson

January 1816



The Simple Science of Global Warming

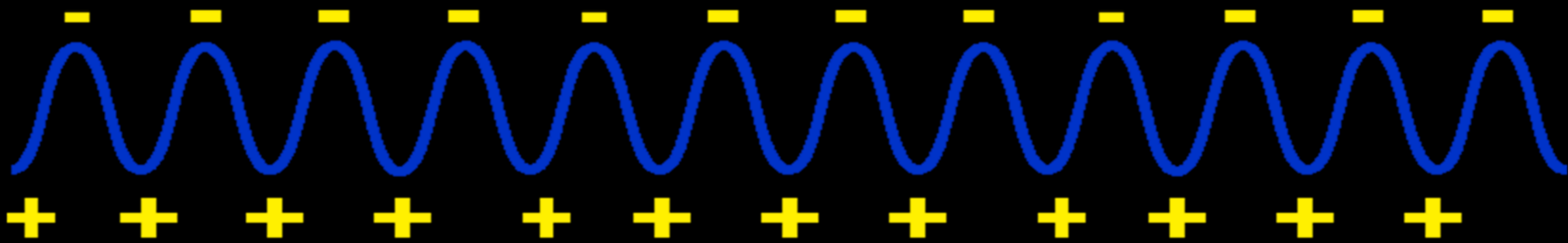
Why There **IS** an Overwhelming Consensus
that Humans are Driving Global Climate
to a Warmer, Less Friendly State

consensus

[kuh n-**sen**-suh s]

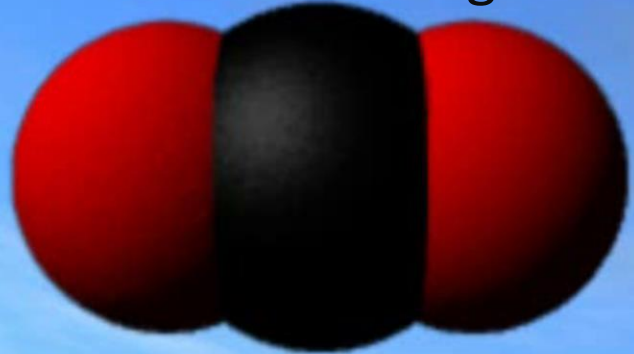
- noun, plural **consensuses**.
- 1. majority of opinion: *The consensus of the group was that they should meet twice a month.*
- 2. general agreement or concord; harmony.

Source: *dictionary.com*

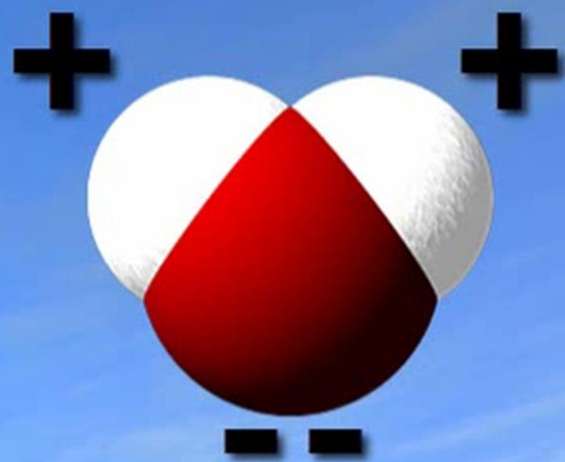


Typical Visible Light

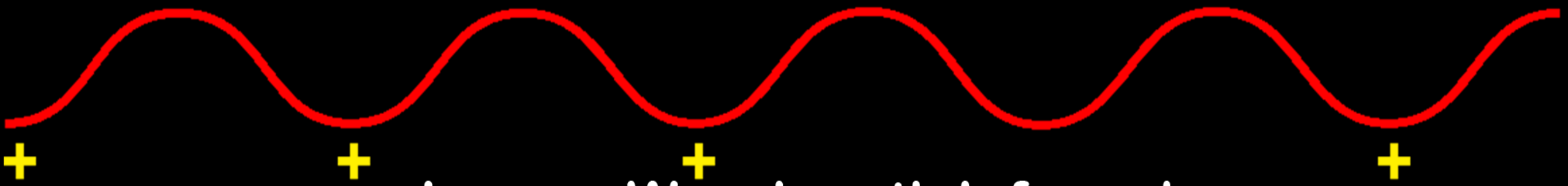
Molecules NOT oscillating with
Visible light



**Carbon
Dioxide**

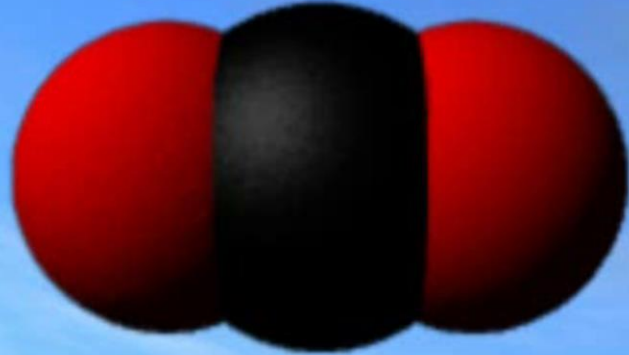


**Water
Vapor**

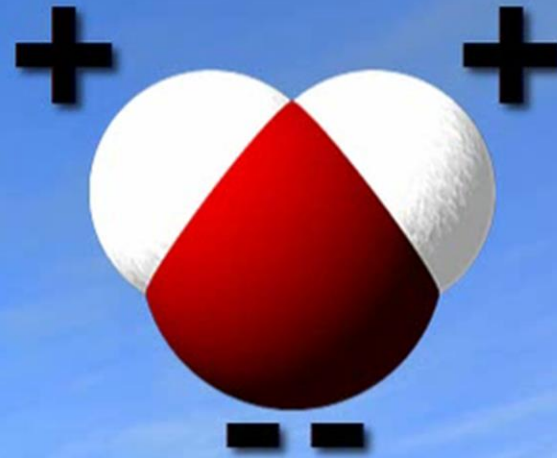


Longer Wavelength Infrared

Animation – not shown in PDF
Molecules oscillating.



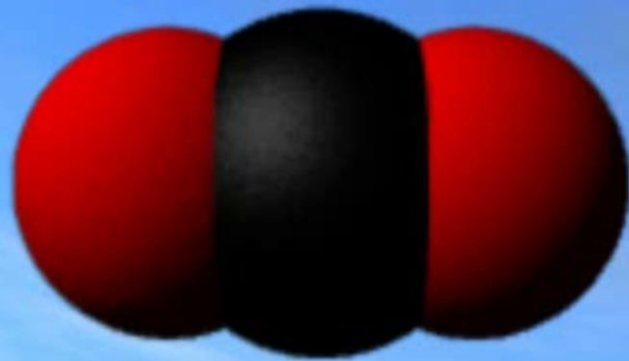
**Carbon
Dioxide**



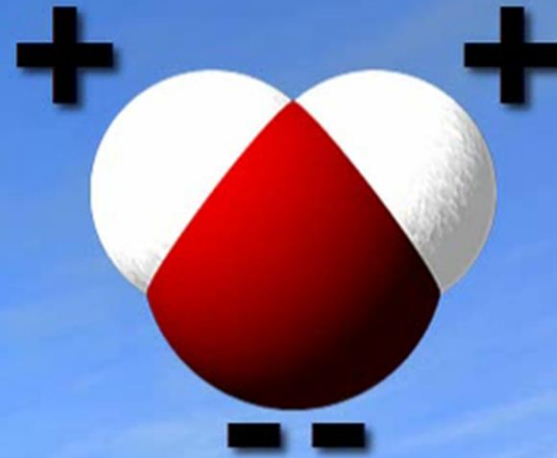
**Water
Vapor**

Animation – not shown in PDF –
Photons causing oscillations in greenhouse gas molecules
when absorbed and new photons being emitted.

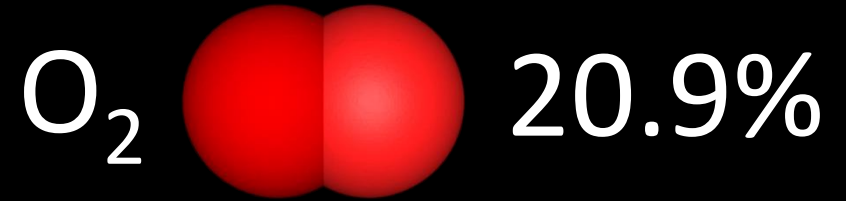
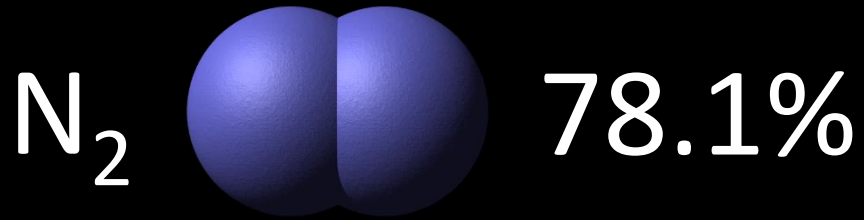
Photons and the Quantum Approach



**Carbon
Dioxide**



**Water
Vapor**



Permanent Gases

Neutral Charge

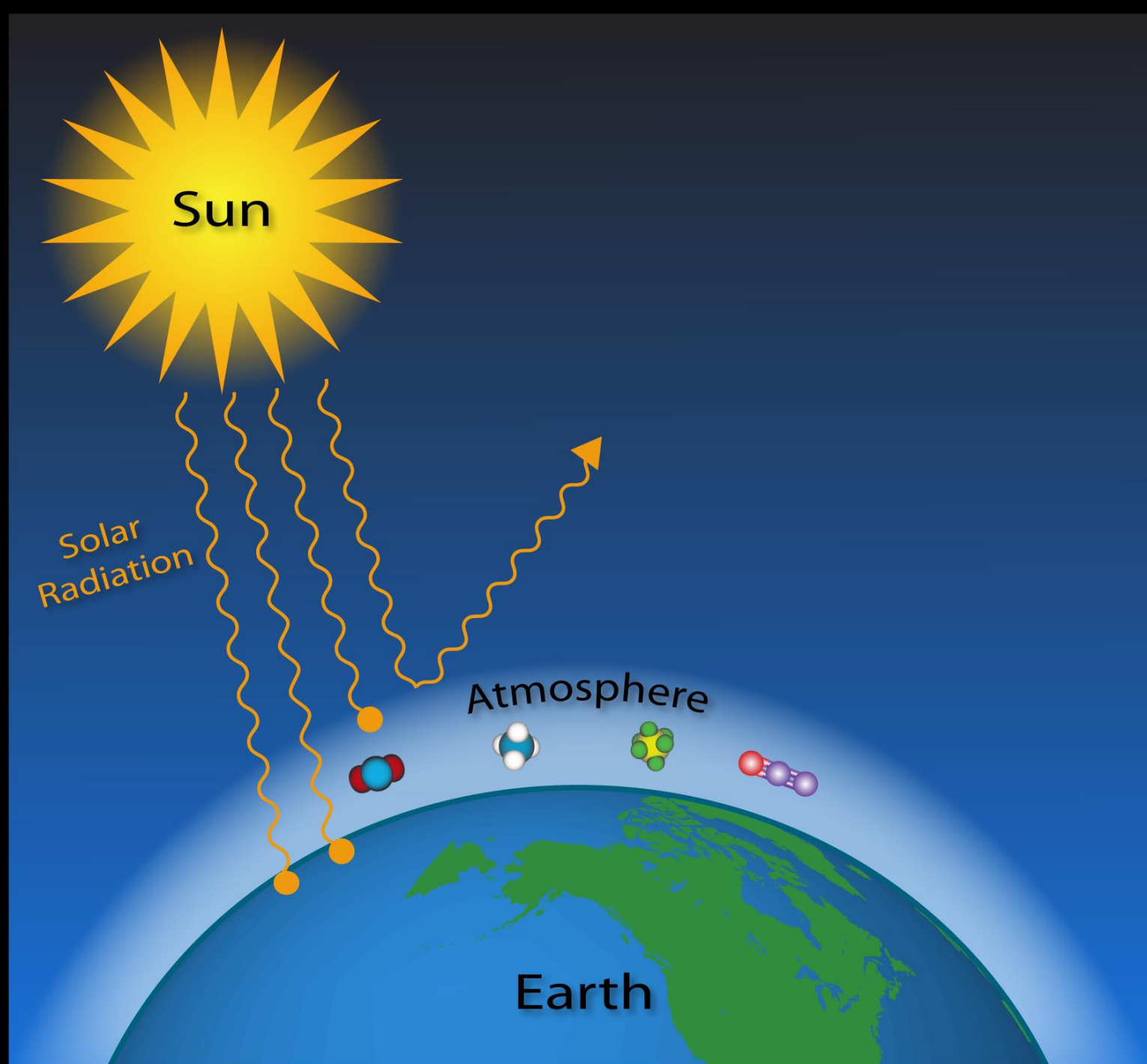
Cannot Bend to Create a Dipole

Virtually Transparent To
Visible and Infrared Radiation

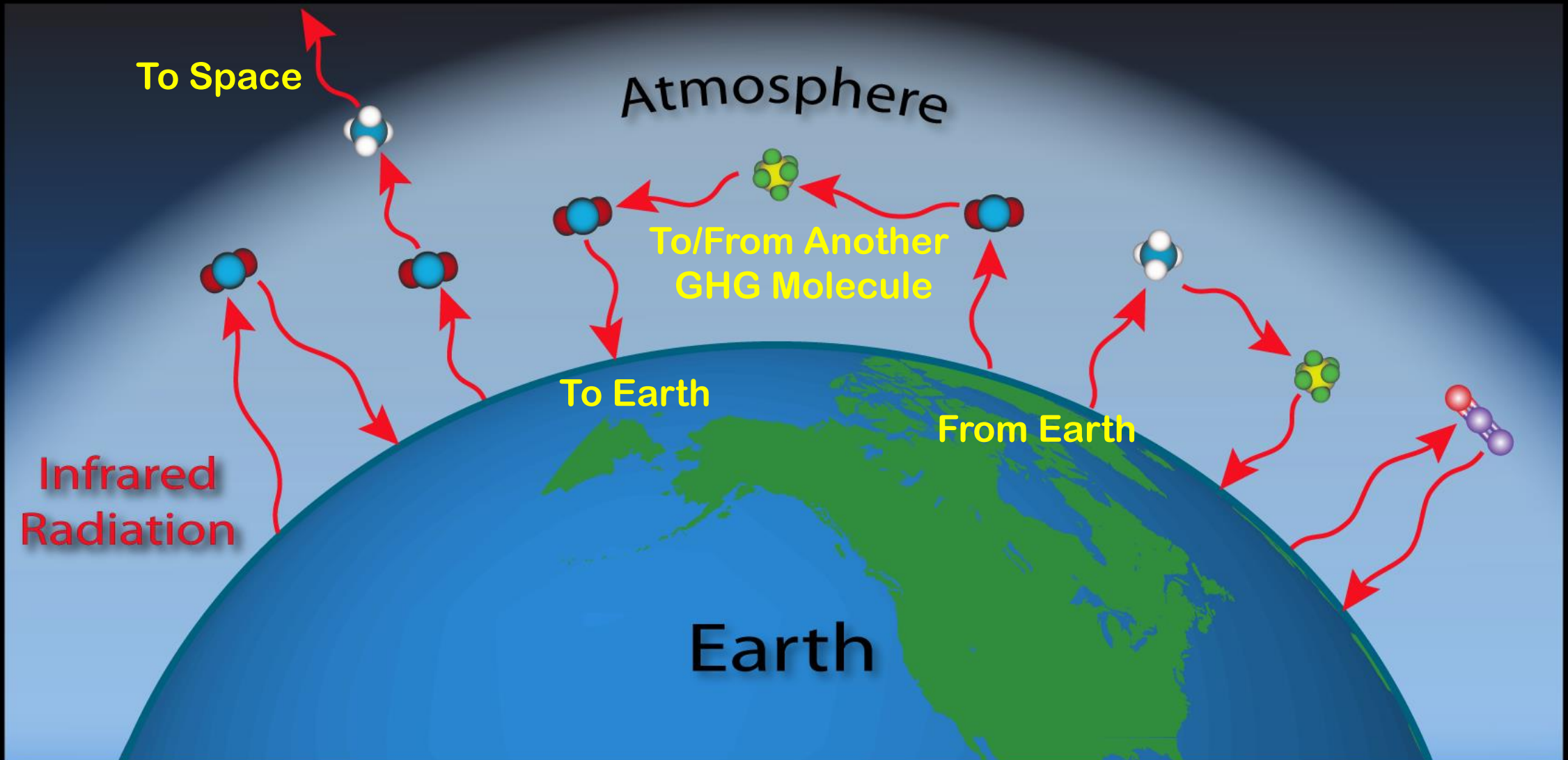
Simple Science:

Sun's radiant energy gets through the atmosphere,

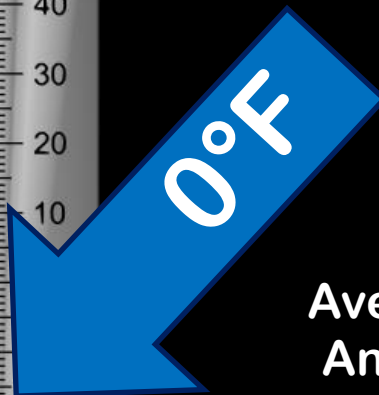
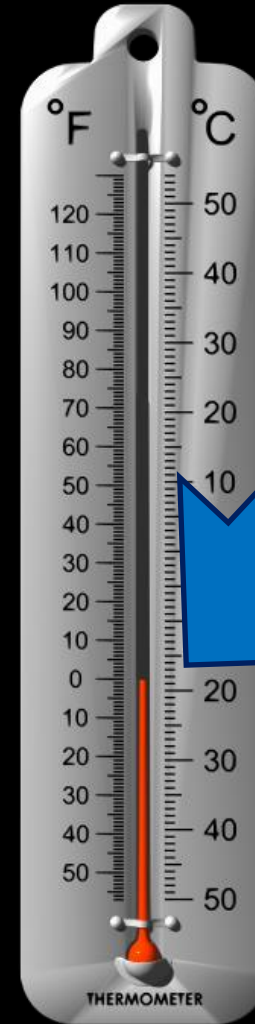
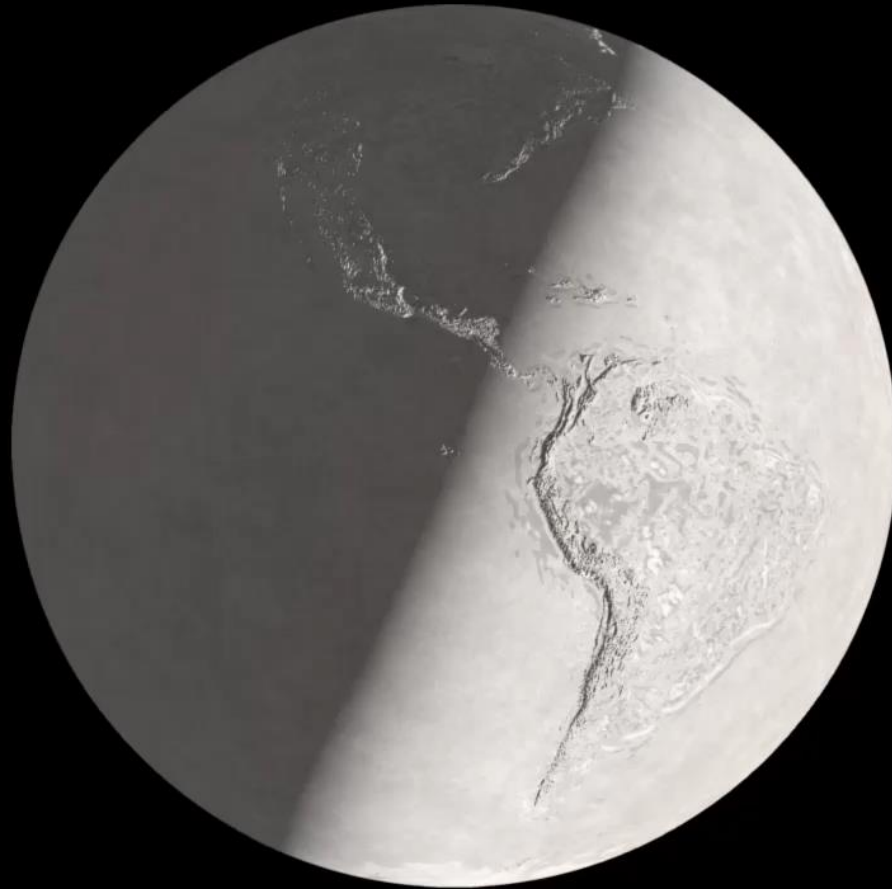
Earth's radiant energy is partially trapped.



Infrared energy is intercepted and re-emitted billions of times. Eventually some escapes to space.

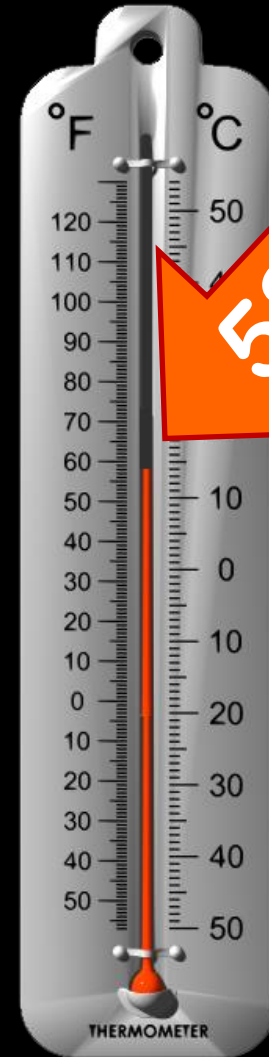


No Greenhouse Effect = Ice Covered Earth



Average
Annual
Global
Temperature

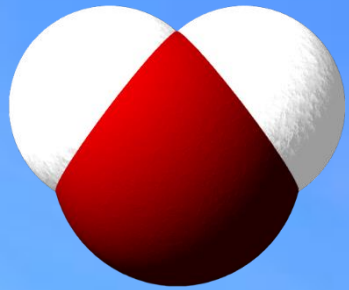
Greenhouse Effect = Habitable Earth



58.72°F

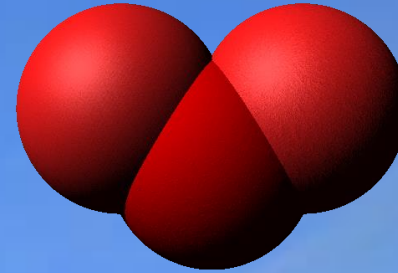
Average
Annual
Global
Temperature
For the Year
2013

The Main Greenhouse Gases



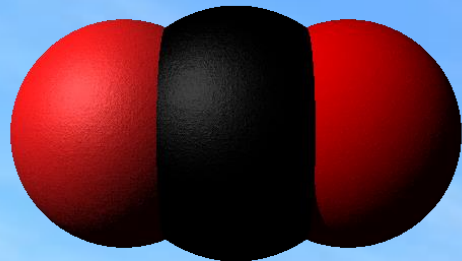
Water Vapor

H_2O
36% - 72%



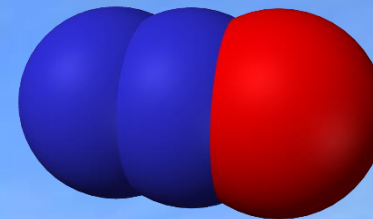
Ozone

O_3
3% - 7%
100 days?, GWP = xx



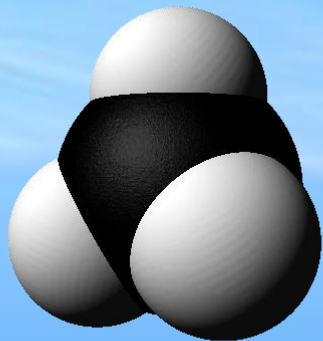
Carbon Dioxide

CO_2
9% - 26%
10 Yrs, GWP = 1



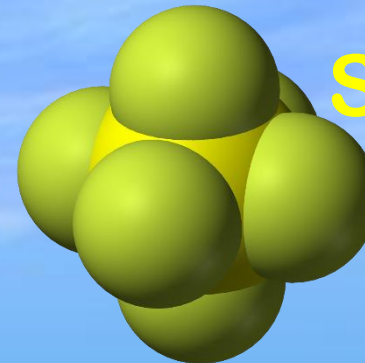
Nitrous Oxide

N_2O
~1%
121 Yrs, GWP = 310



Methane

CH_4
4% - 9%
12 Yrs, GWP = 25

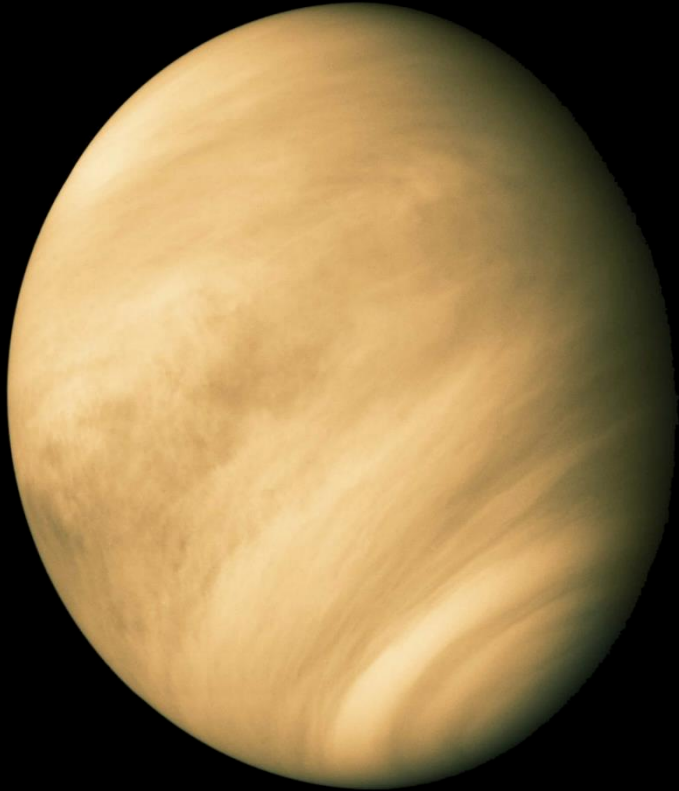


Sulfur Hexafluoride

SF_6
Negligible
3200 Yrs, GWP = 23,500

% = % of GH Effect, x Yrs = Average Residence Time in Atmosphere, GWP = 100 year global warming potential

Venus



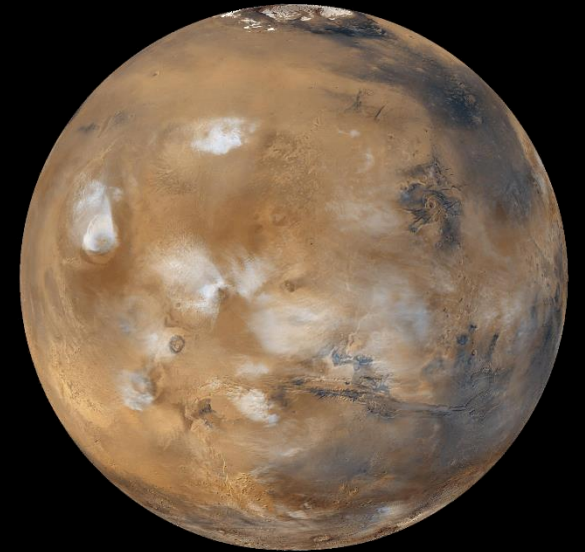
865°F

Earth



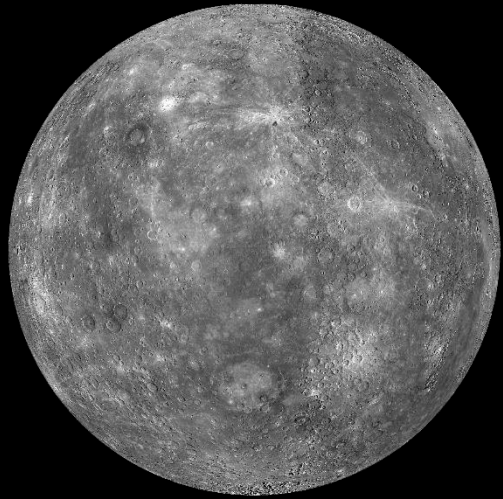
58.12°F

Mars



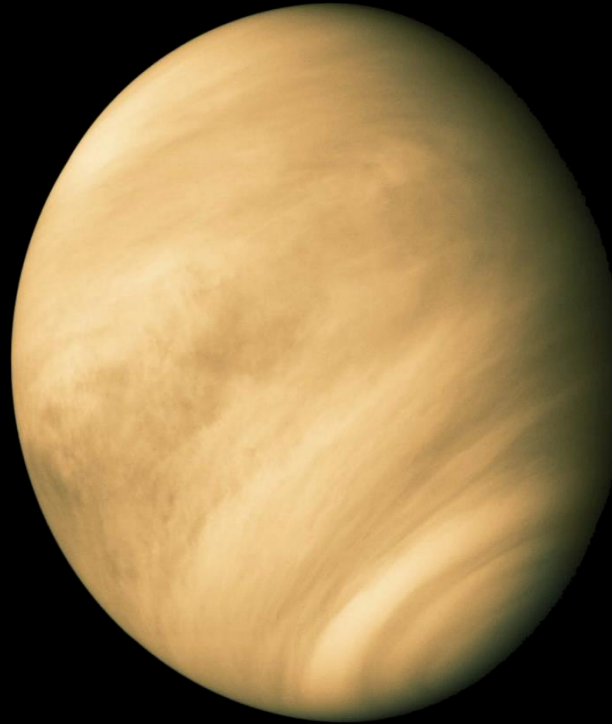
-67°F

Mercury



332°F

Venus



865°F

Earth



58.12°F

Mercury receives 3.5x more solar radiation than Venus.

A Timeline of Global Warning Science

1824 – Joseph Fourier realized atmospheric gases trap heat.

1850s – John Tyndall proved solar radiation passes through the atmosphere and greenhouse gases absorb enough Earth heat to account for Earth's climates.

A Timeline of Global Warning Science

1896 – Svante Arrhenius calculated that doubling atmospheric CO₂ could cause Earth's temperature to rise by 5° - 6°C (9° – 11°F).

He also calculated the ocean absorbed some of the CO₂ emitted.

A Timeline of Global Warning Science

1930s – Guy Stewart Callendar documented Earth's increasing temperature.

He blamed it on CO₂ from coal.

1955 – Hans Suess – fossil carbon, proved additional CO₂ was from fossil fuels.

A Timeline of Global Warning Science

1957 - Roger Revelle – ocean chemistry and CO₂ absorption

Charles David Keeling – Mauna Loa measuring CO₂ for 57 years.

.

A Timeline of Global Warning Science

- 1965** - **The President's Science Advisory Committee**, "... by the year 2000 there will be about 25% more CO₂ in our atmosphere than at present, [the increase] will modify the heat balance of the atmosphere to such an extent that marked changes in climate ... could occur."

**1 tonne =
2,200 pounds**

**Annual Emissions
Of CO₂:
82.72
trillion pounds**

82,720,000,000,000

Where humanity's CO₂ comes from

91% 33.4 billion metric tonnes



Fossil Fuels & Cement 2010

9% 3.3 billion metric tonnes



Land Use Change 2010

Where humanity's CO₂ goes

50% 18.4 billion metric tonnes



Atmosphere 2010

26% 9.5 billion metric tonnes



Land 2010

24% 8.8 billion metric tonnes

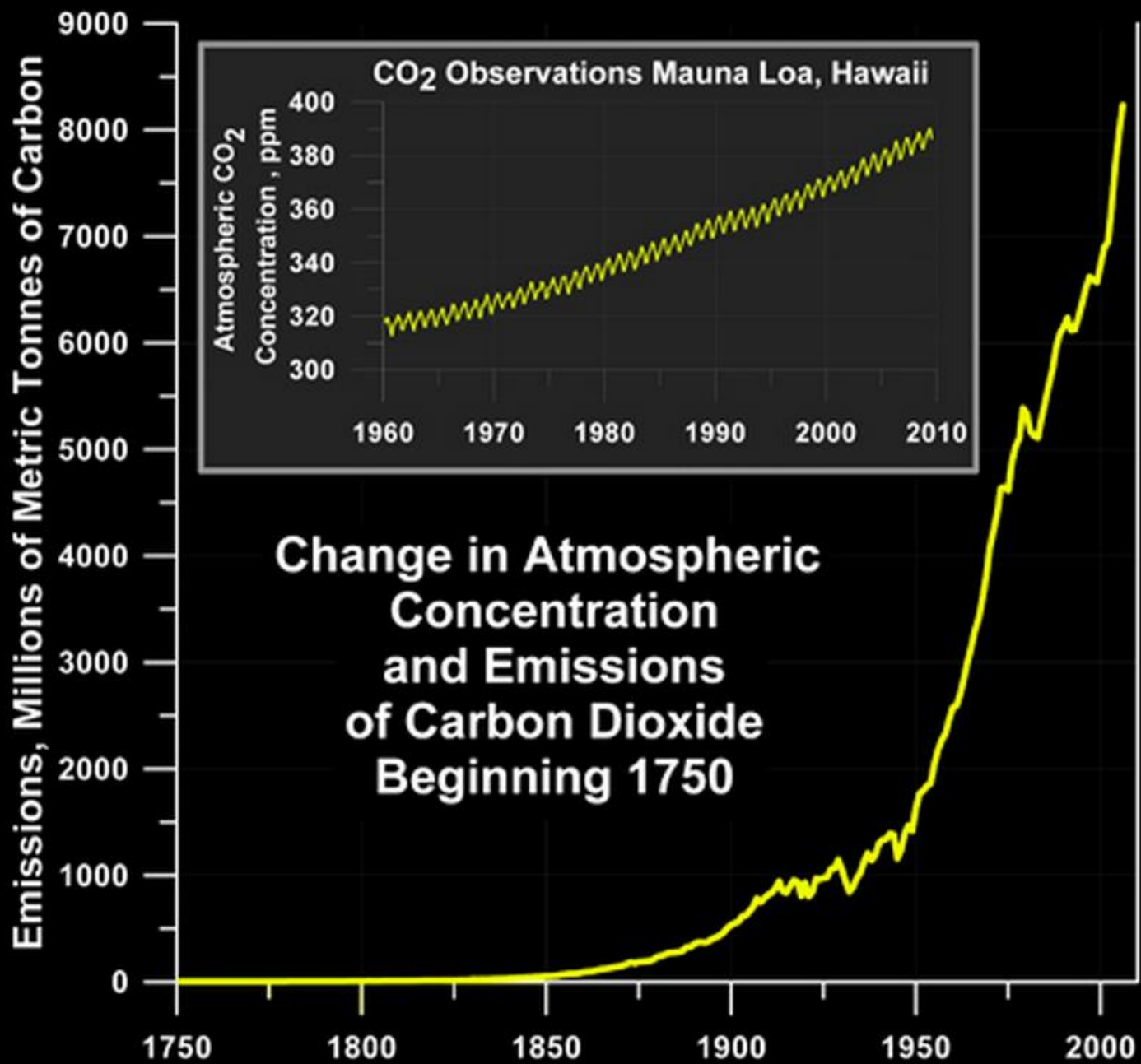


Oceans 2010

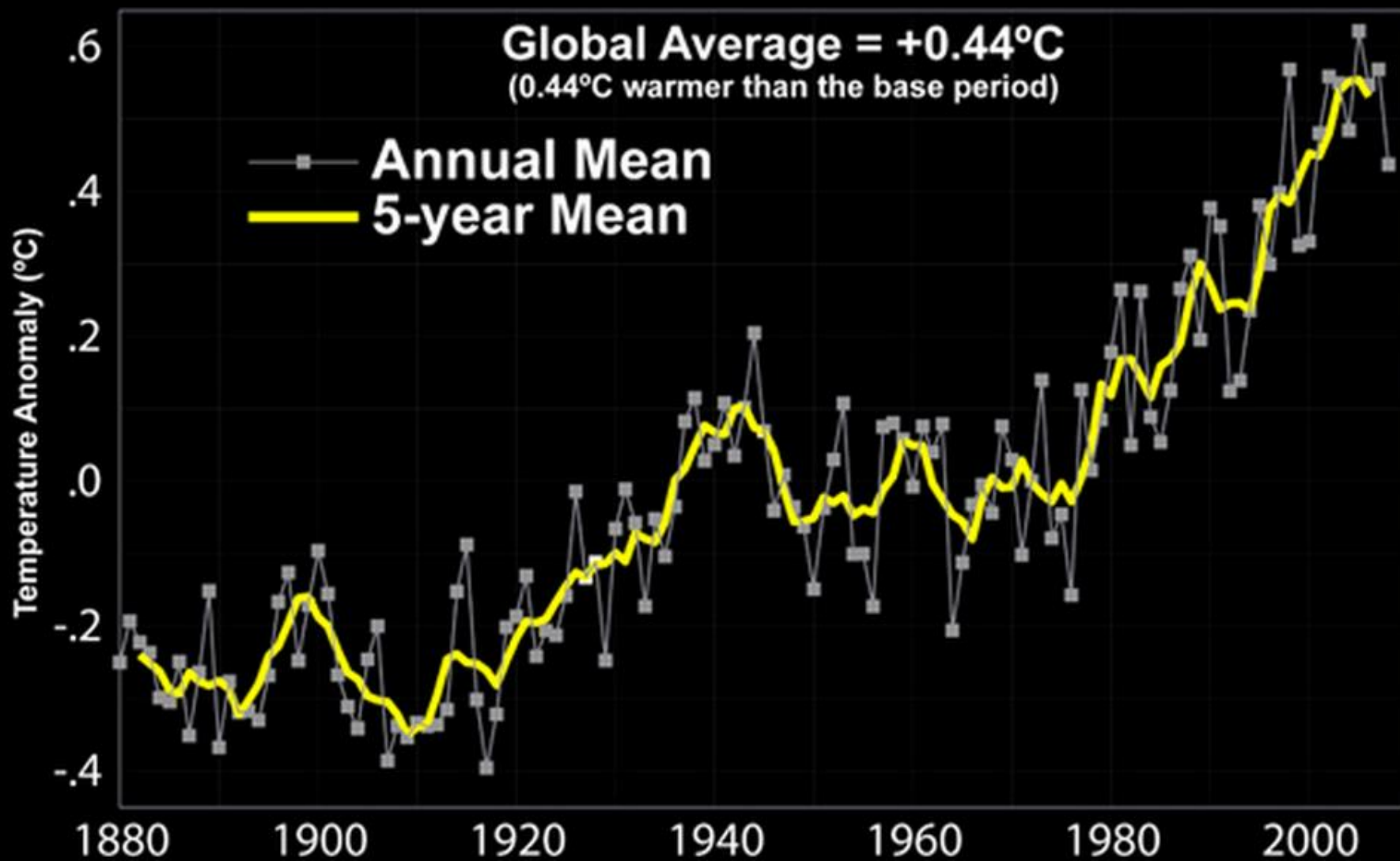


2010 data updated from:
Le Quéré et al. 2009, Nature Geoscience
Canadell et al. 2007, PNAS

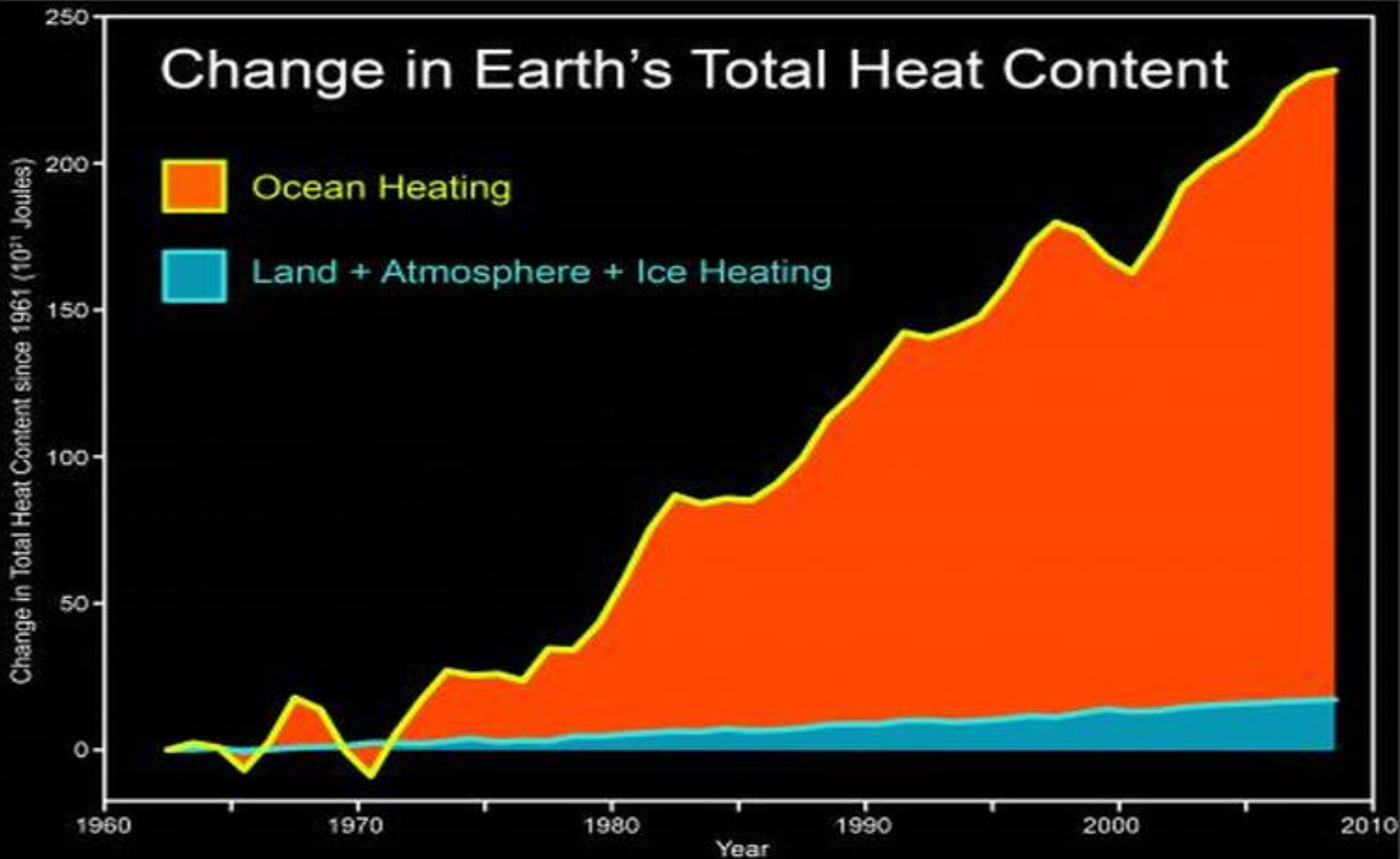
CO₂Now.org



Global Land + Ocean Temperature Anomaly (°C) Relative to the 1951 - 1980 Base Period



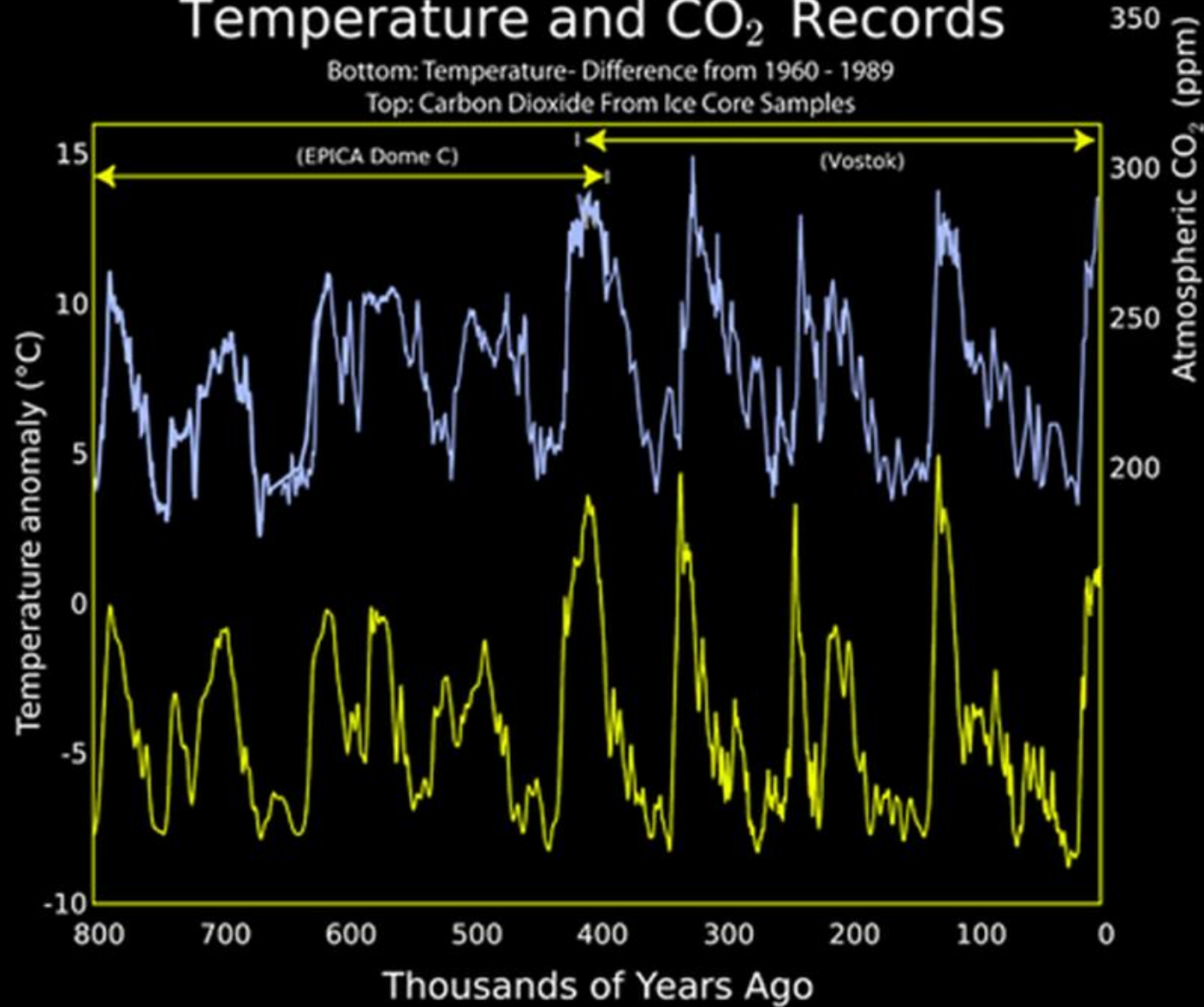
Change in Earth's Total Heat Content



387.27 ppm
Dec. 2009, Mauna Loa

Temperature and CO₂ Records

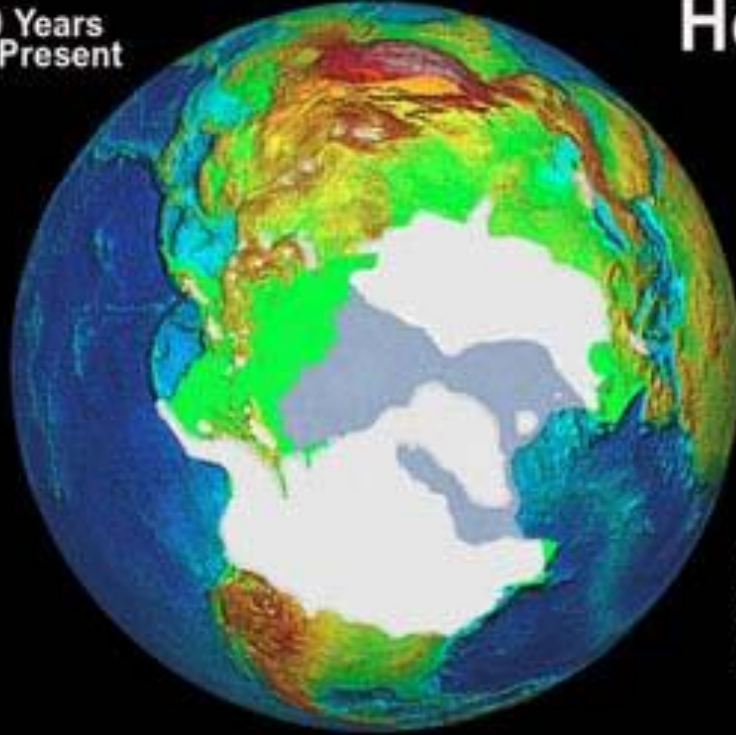
Bottom: Temperature- Difference from 1960 - 1989
Top: Carbon Dioxide From Ice Core Samples





Serbian РСД 2000 (dinar) Note
with Mulitin Milankovitch

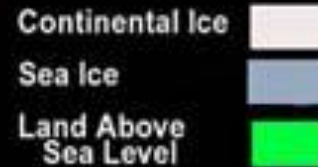
18,000 Years
Before Present



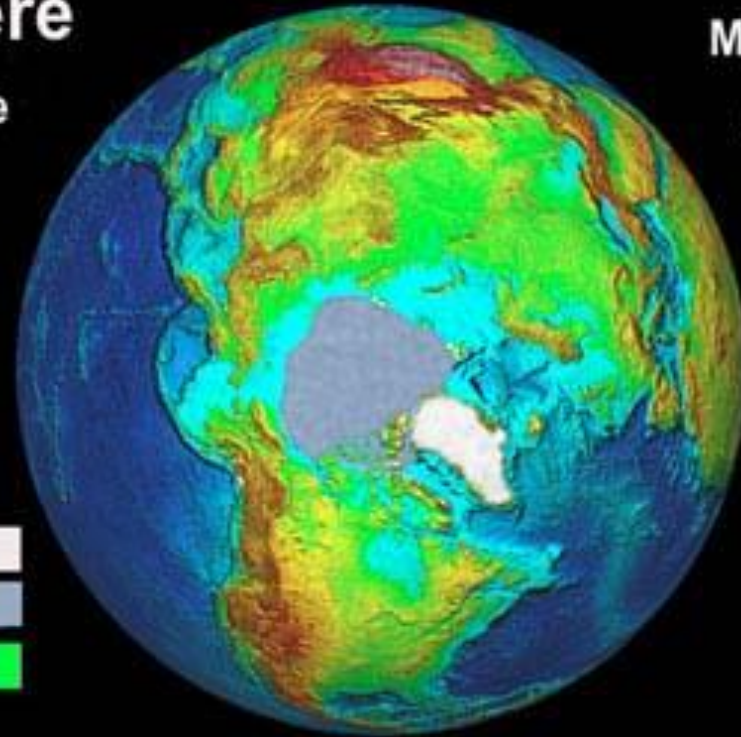
Northern Hemisphere

Ice Coverage

Legend



Modern Day
(August)

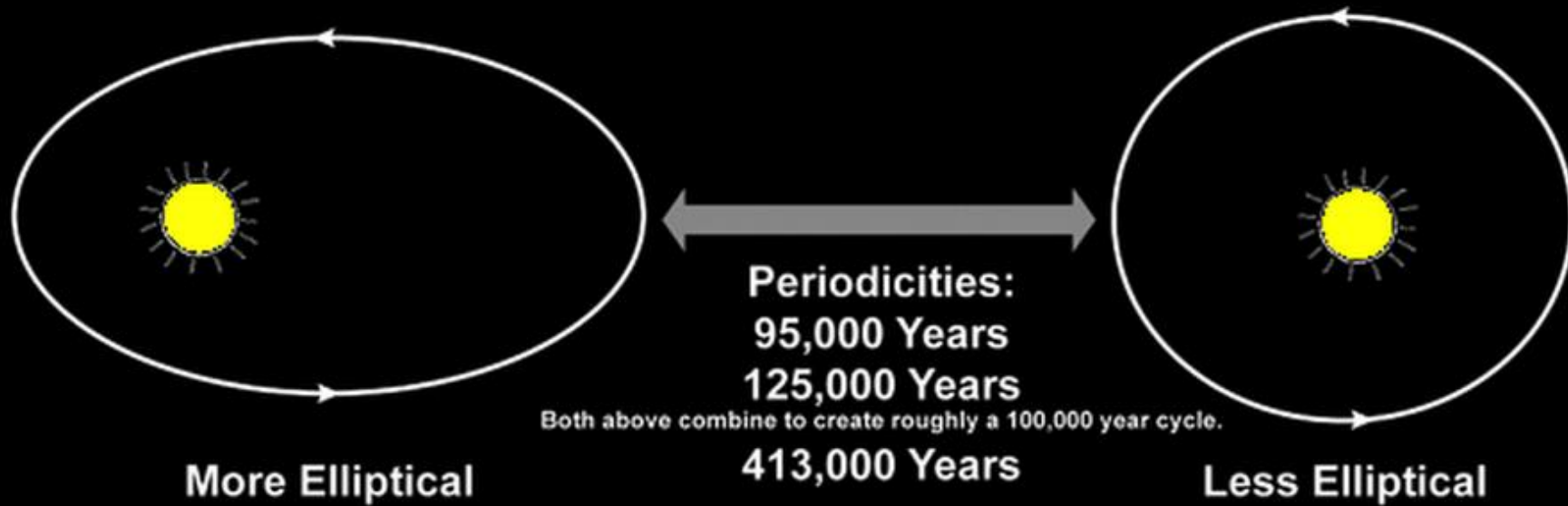


Note: Modern sea ice coverage represents summer months.

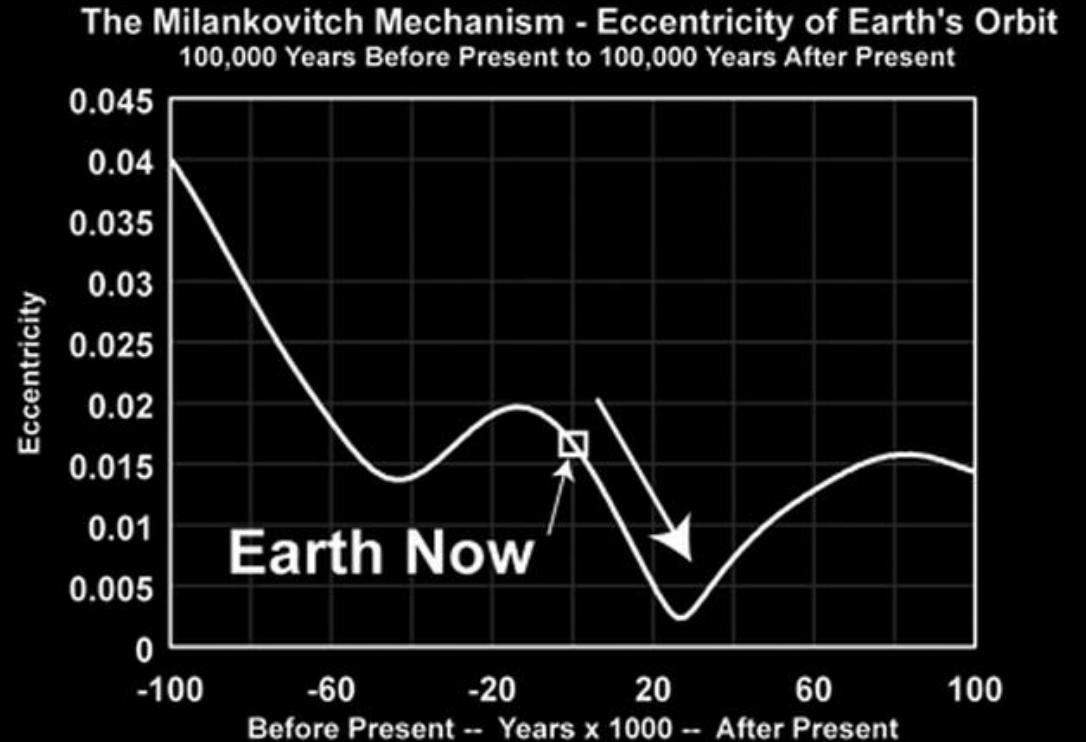


To grow, **ice sheets** needed large continental land masses

Growth would take place in the **high latitudes**



Milankovitch Mechanism
Eccentricity of Earth's Axis
 a.k.a. "Shape"
 Periodicities: 95k, 125k, 413k years

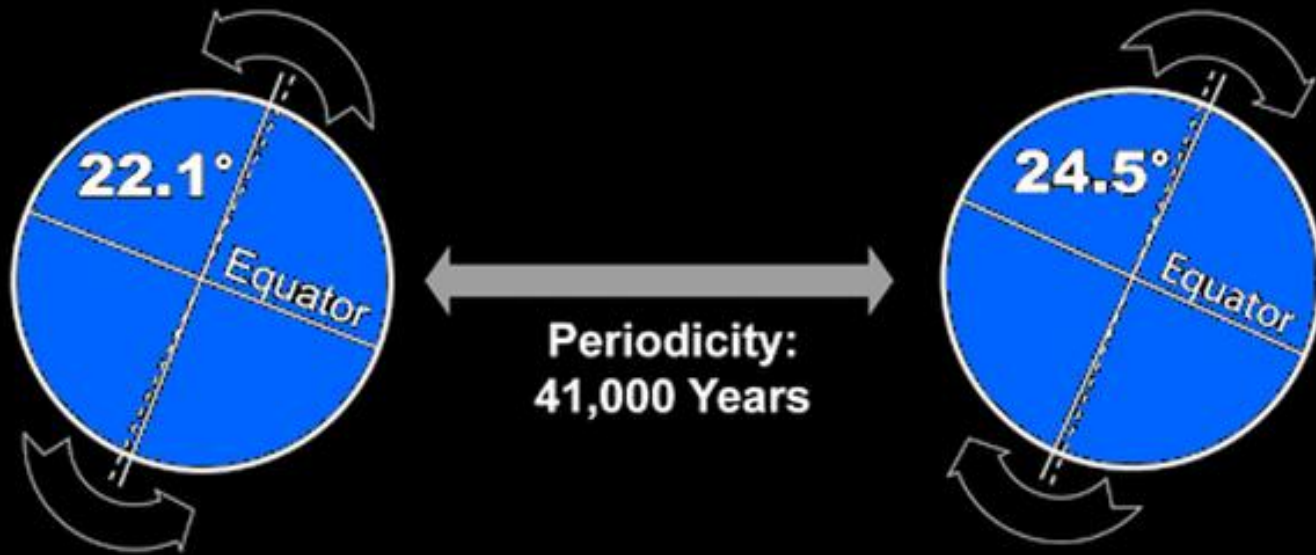


Milankovitch Mechanism

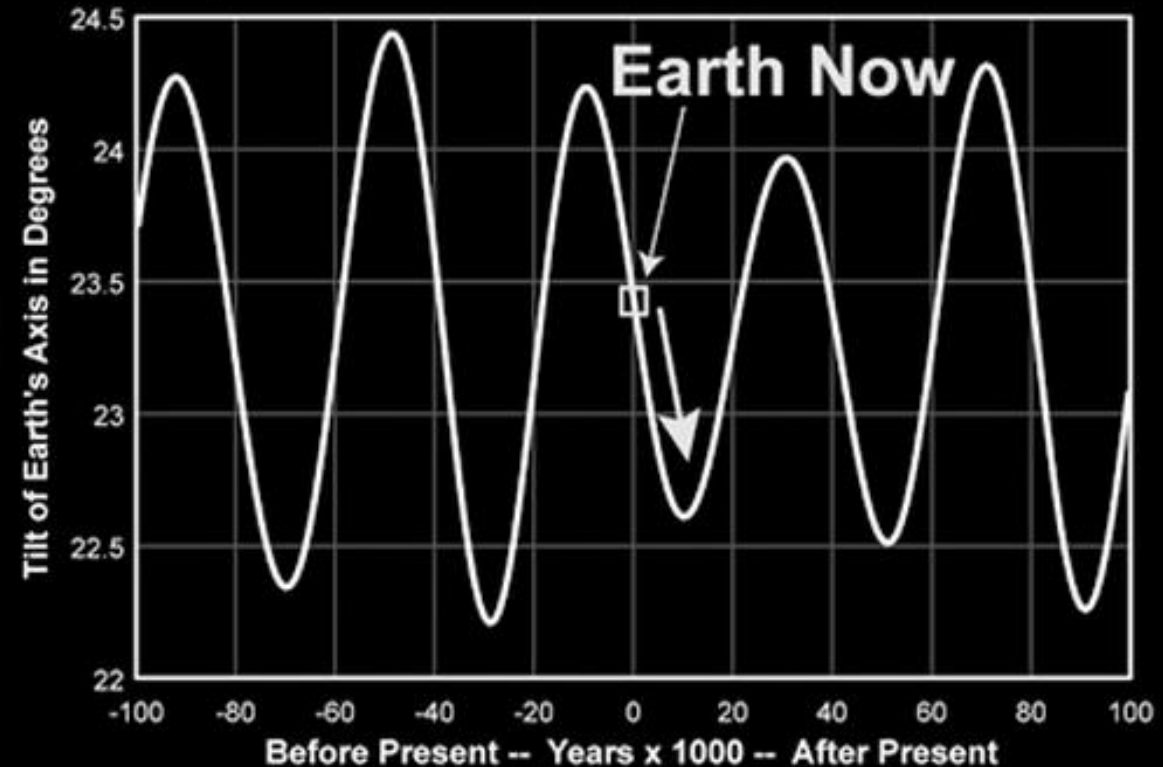
Obliquity of Earth's Axis

a.k.a. "Tilt"

Periodicity: 41k years



The Milankovitch Mechanism - Obliquity
100,000 Years Before Present to 100,000 Years After Present

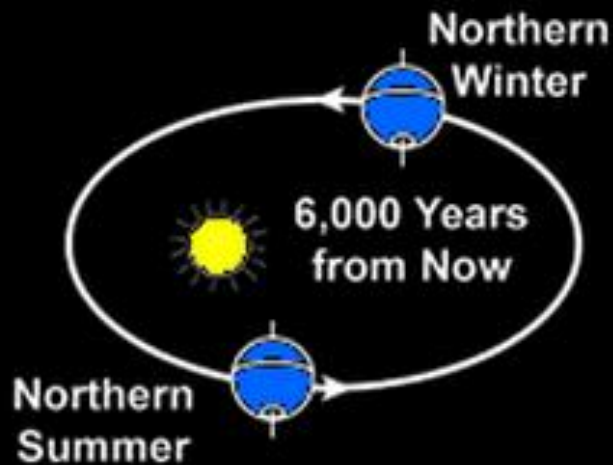
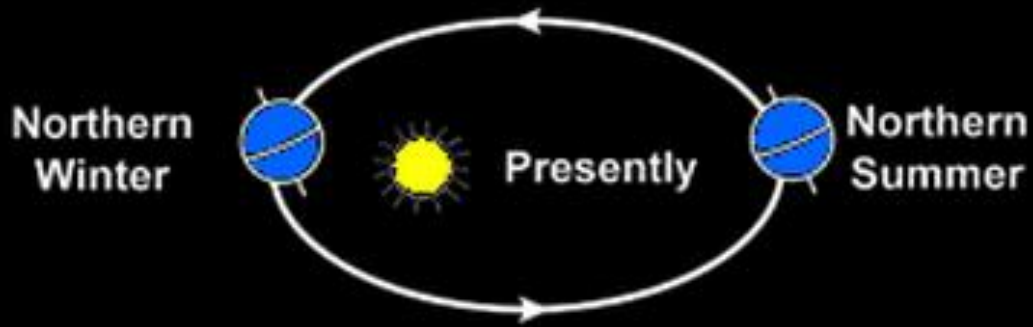


Milankovitch Mechanism

Precession of Earth's Axis

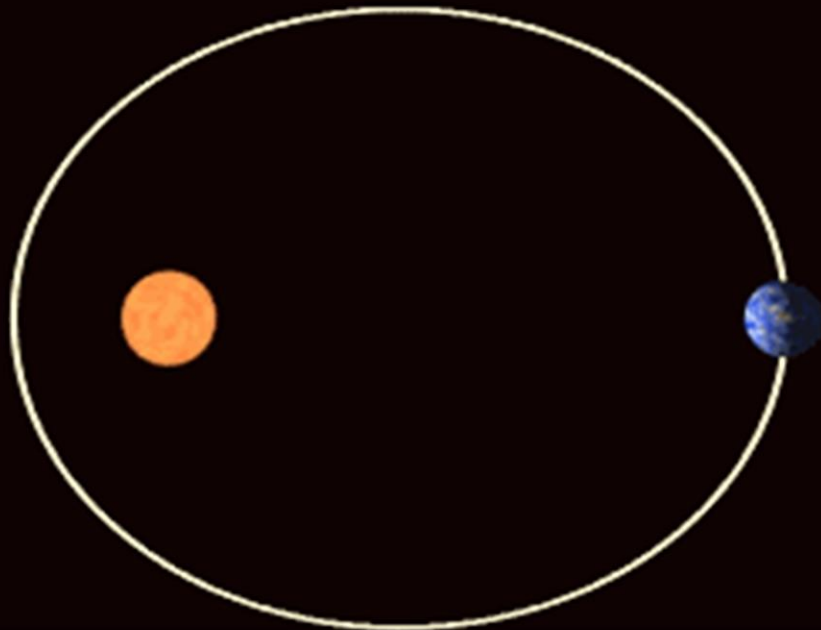
a.k.a. "Wobble"

Periodicities: 19k, 22k, 24k years



**Apsidal Precession
+
Axial Precession**

Periodicity: 21.6k years



**Milankovitch Mechanism
Apsidal Precession**

a.k.a. “”

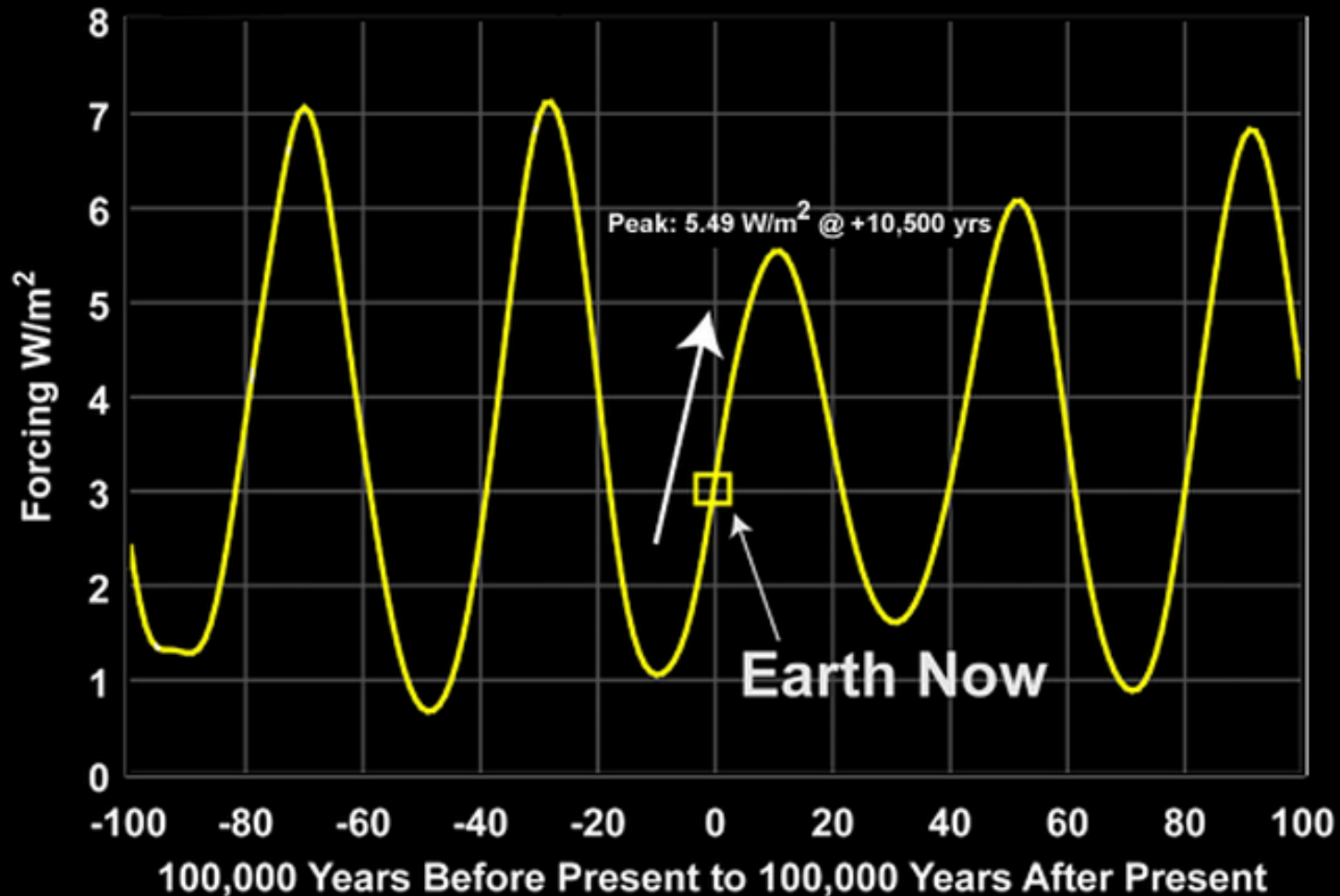
Periodicities: 134k years



Solar Forcing by the Milankovitch Mechanism

Mean Daily Insolation (W/m^2)

Nunavut, Canada, 65°N , 90°W , Northwest of Hudson Bay



Data: L'Institut de Mécanique céleste et de calcul des éphémérides (IMCCE), Paris, France.
Online calculator: <http://www.imcce.fr/Equipes/ASD/insola/earth/online/index.php>

OOPS!

THE NUMBERS DO NOT WORK!

When put to the test
forcing by the
Milankovitch Mechanism
does not provide enough warming
or cooling to account for
the observed changes.

Welcome to the World of Climate **Feedbacks**

There are two flavors:

Positive Feedback (**amplifying**)

and

Negative Feedback (**stabilizing**)

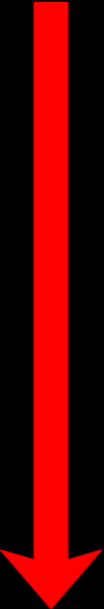
FORCING

Stabilizing (Negative) Water Vapor Feedback

WARMING



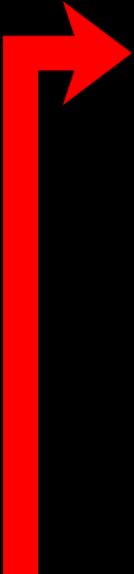
**EVAPORATION
INCREASES**



**LOW CLOUDS
INCREASE**



**ALBEDO
INCREASES**



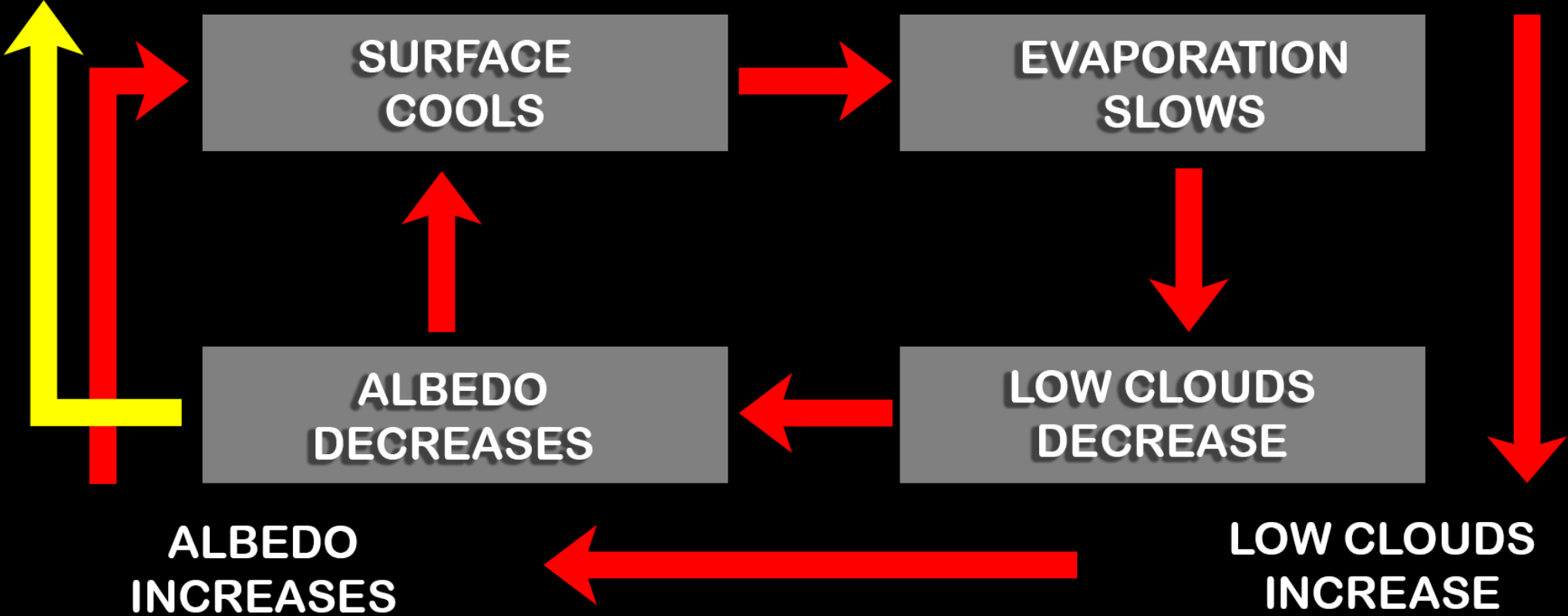
FORCING

Stabilizing (Negative) Water Vapor Feedback

WARMING



**EVAPORATION
INCREASES**



**SURFACE
COOLS**

**EVAPORATION
SLOWS**

**ALBEDO
DECREASES**

**LOW CLOUDS
DECREASE**

**ALBEDO
INCREASES**

**LOW CLOUDS
INCREASE**

FORCING

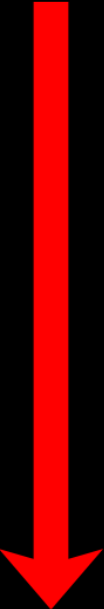
**Amplifying (Positive)
Ice-Albedo Feedback**

COOLING



**LESS
SNOWMELT**

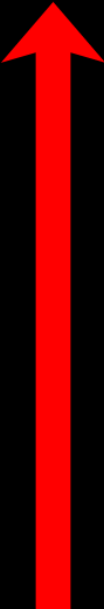
**NO SYSTEM CHECKS
COOLING ACCELERATES**



**GREAT AREA
WITH SNOW COVER**



**ALBEDO
INCREASES**



FORCING

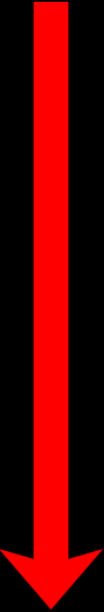
**Amplifying (Positive)
Ice-Albedo Feedback**

WARMING



**MORE
SNOWMELT**

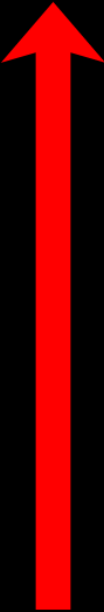
**NO SYSTEM CHECKS
WARMING ACCELERATES**



**SMALLER AREA
WITH SNOW COVER**



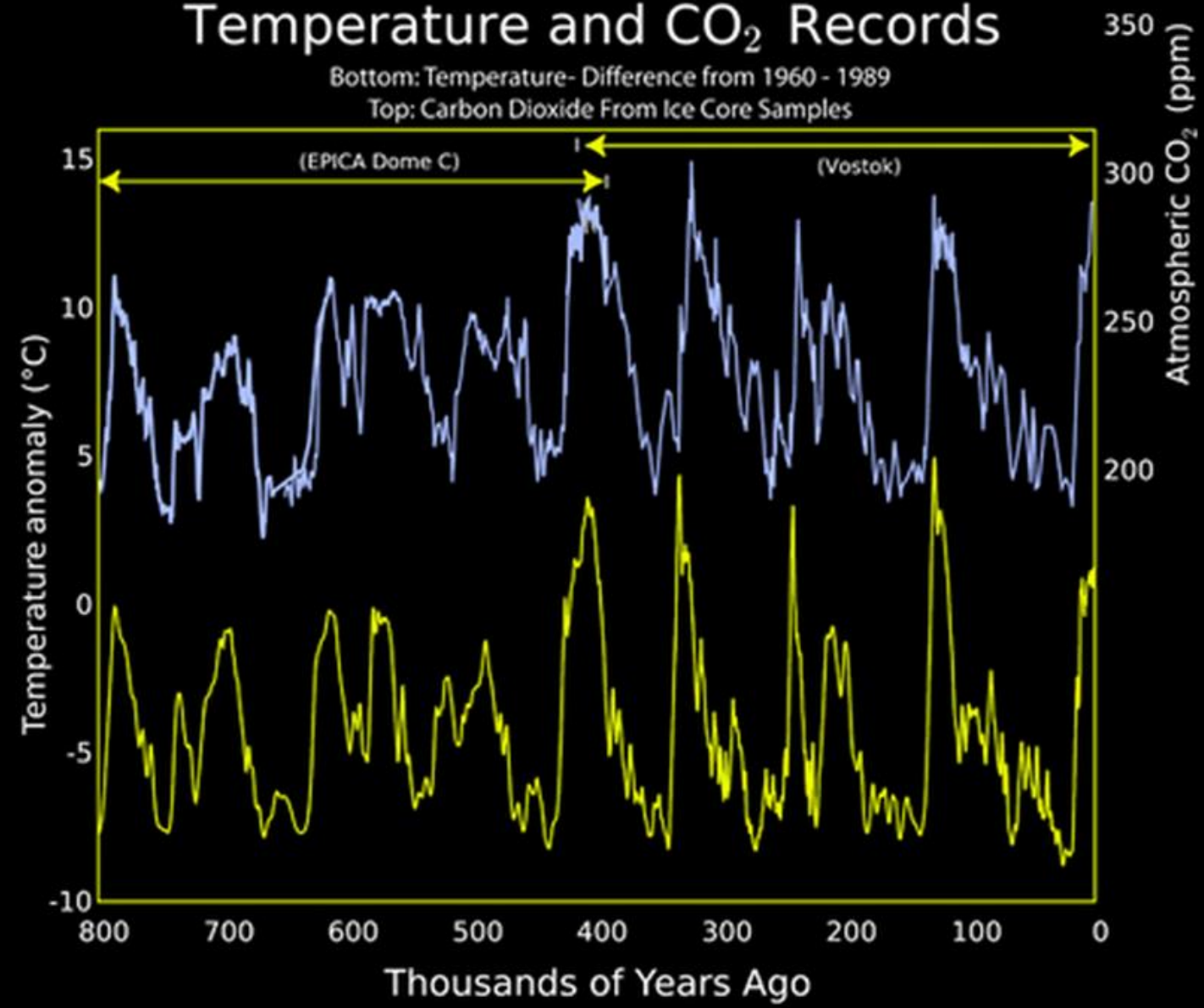
**ALBEDO
DECREASES**



387.27 ppm
Dec. 2009, Mauna Loa

Temperature and CO₂ Records

Bottom: Temperature- Difference from 1960 - 1989
Top: Carbon Dioxide From Ice Core Samples

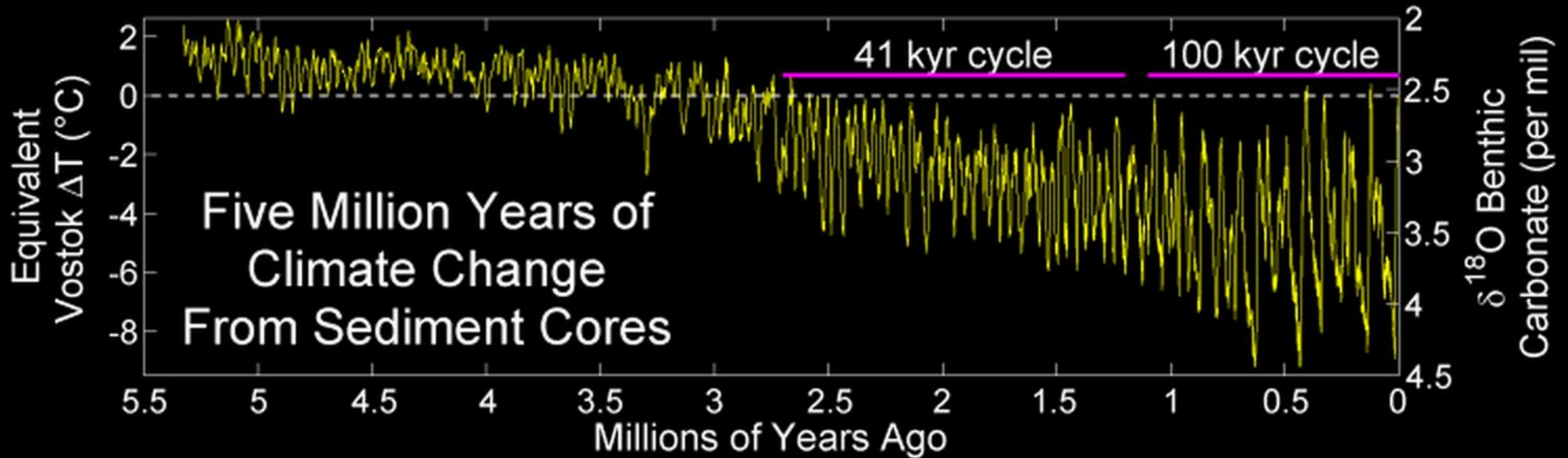


Ingredients of the Climate Change Recipe

**Greenhouse Gas Warming,
Milankovitch Forcing
&
System (Internal) Feedbacks**

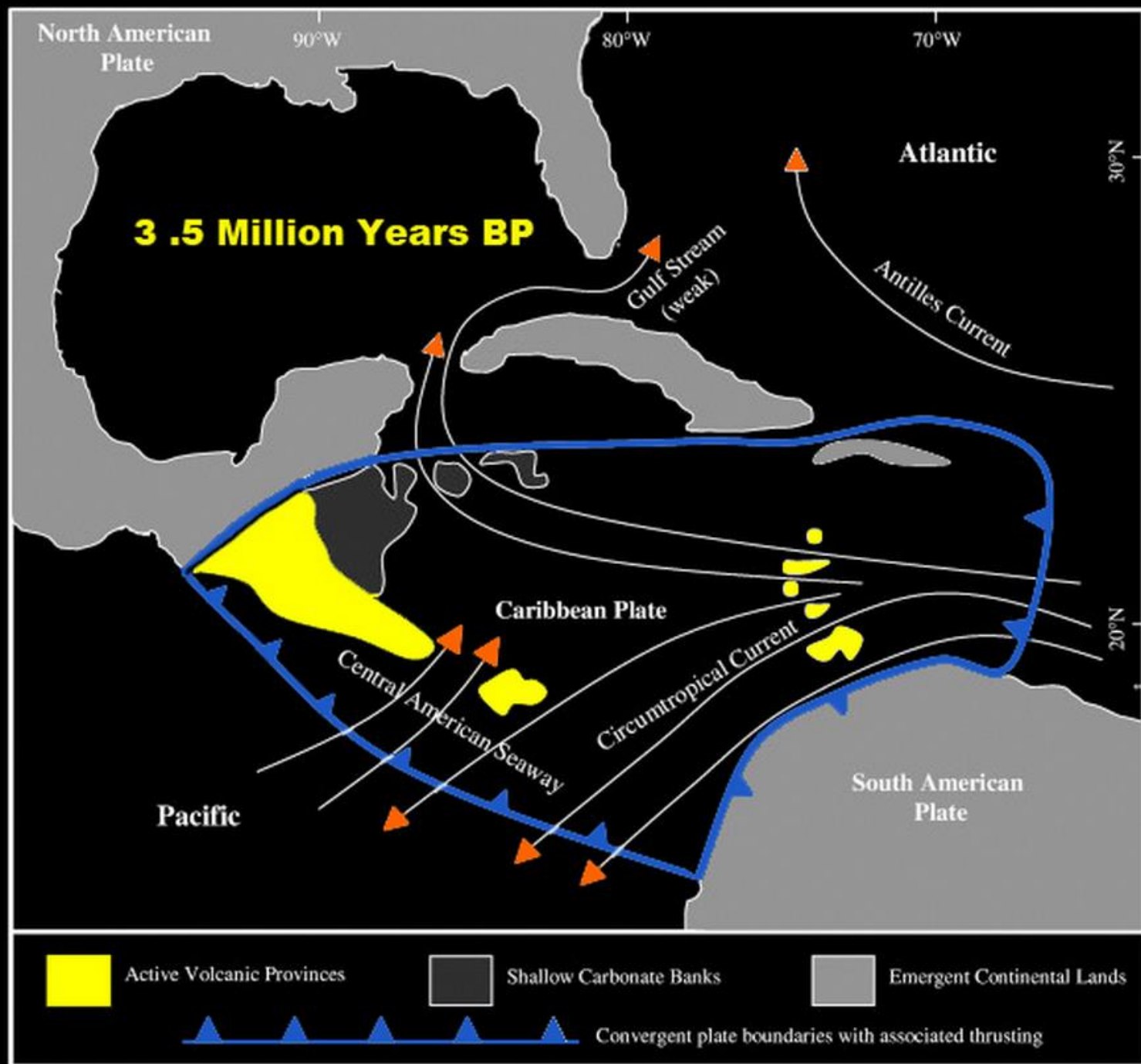
**But Wait
There's More**

5 Million Years of Climate Change

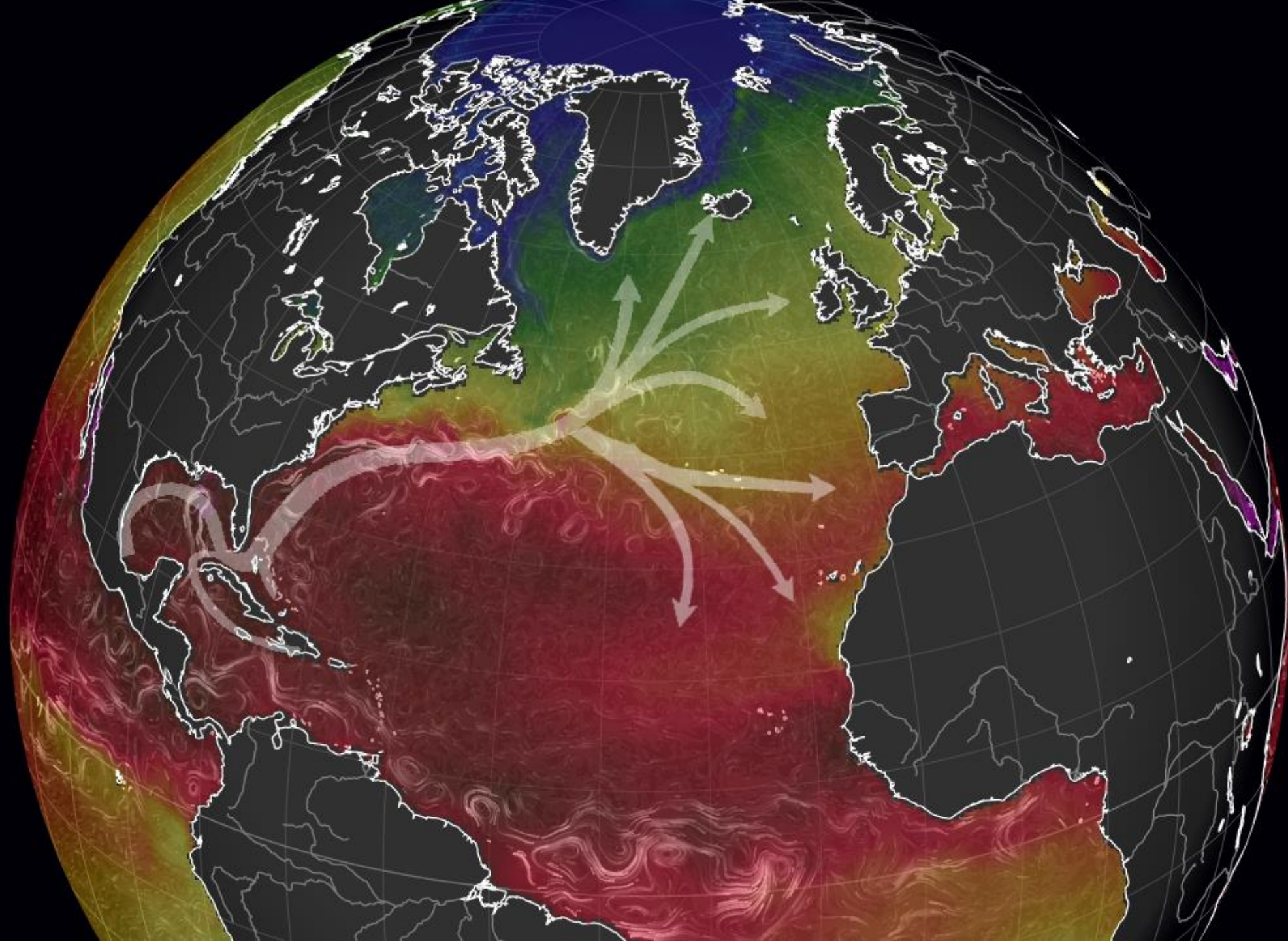


What Does Panama Have To Do With Glacial Cycles?

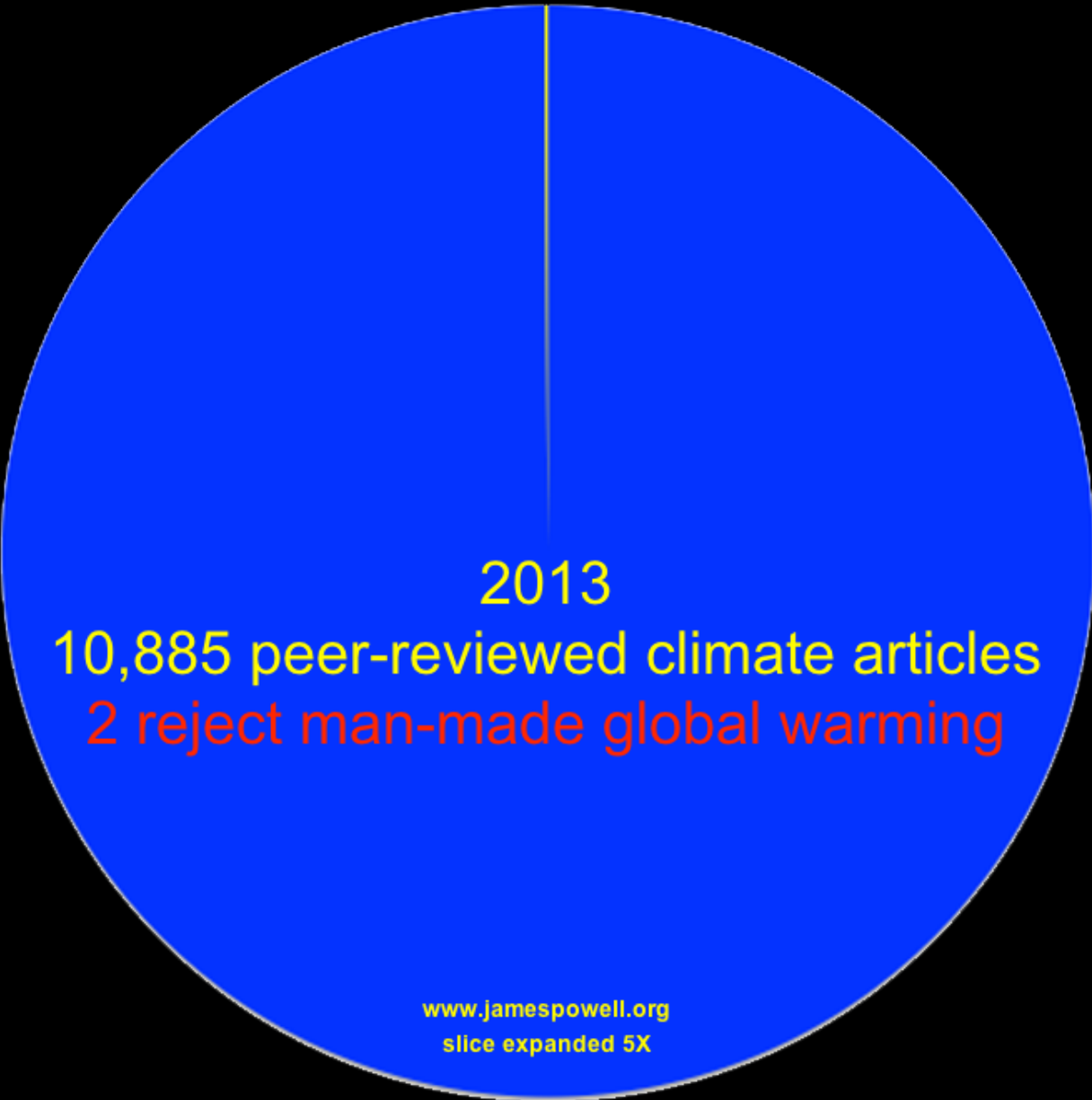






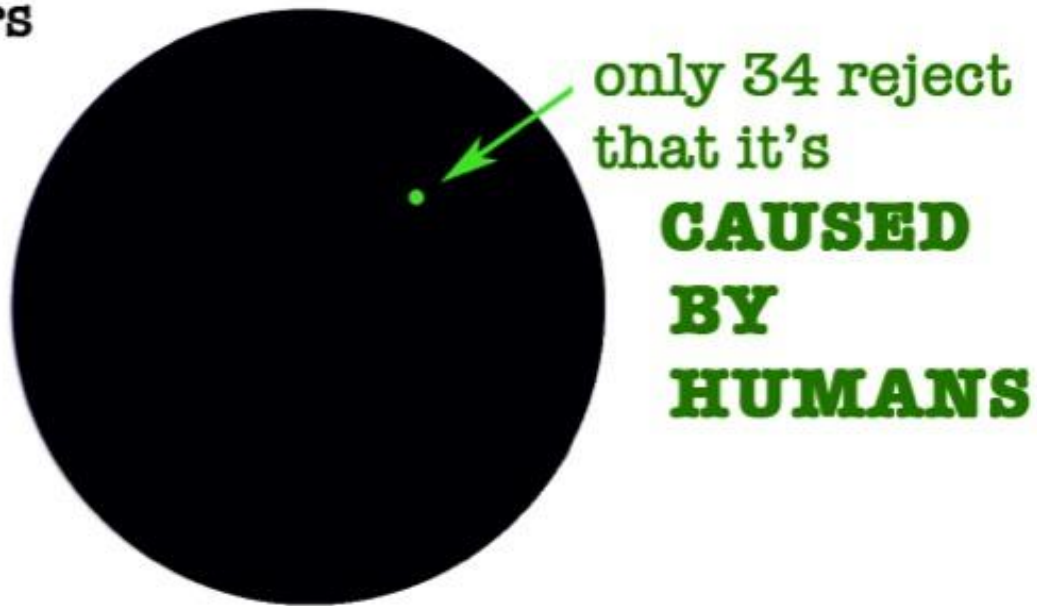



Consensus



Climate change is real.
But are humans causing it?

Of 33,700 authors
of peer-reviewed
CLIMATE CHANGE
papers





Thanks for inviting me!
Link to materials:
www.shorstmeyer.com