



Atmospheric CO₂ Buildup, Global Warming, Ocean Temperature Increase and Acidification

André W. Droxler

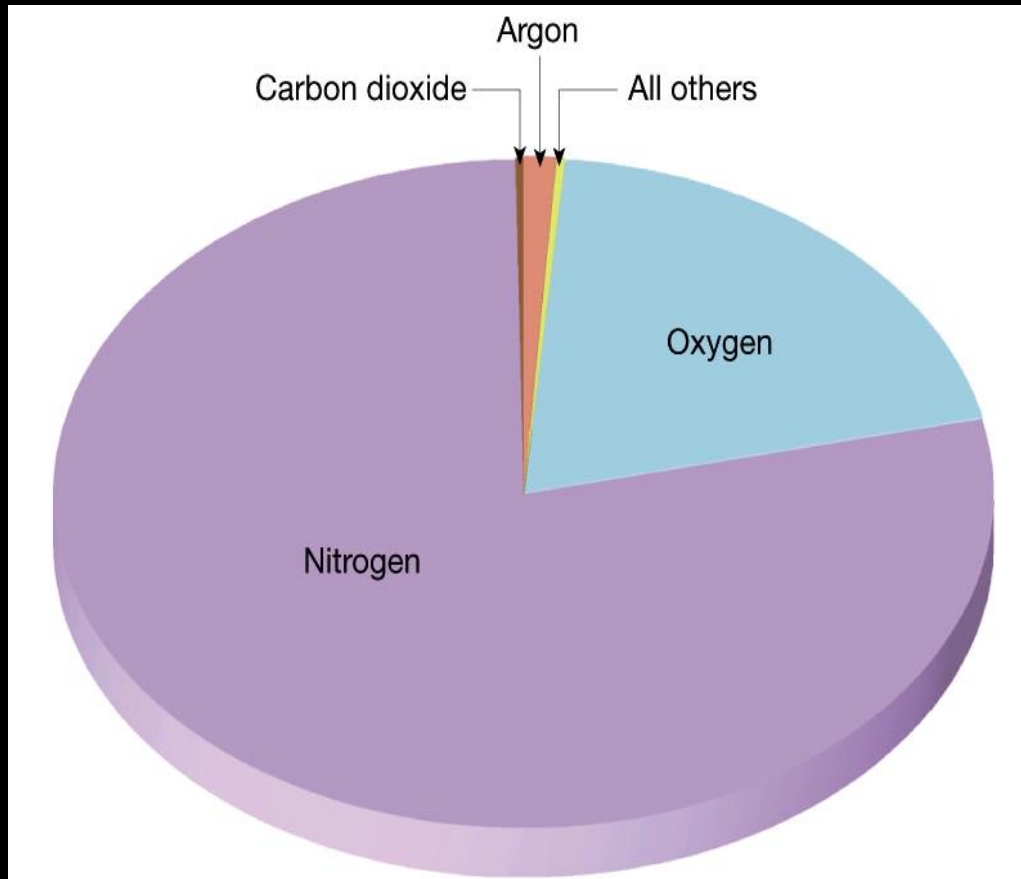
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Rice University**

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**The American Institute
of Aeronautics and
Astronautics (AIAA)**

May 5, 2017

<https://av8rdas.files.wordpress.com/2011/01/thin-blue-line1.jpg>



The gases in Earth's atmosphere include:

Nitrogen – 78 percent

Oxygen – 21 percent

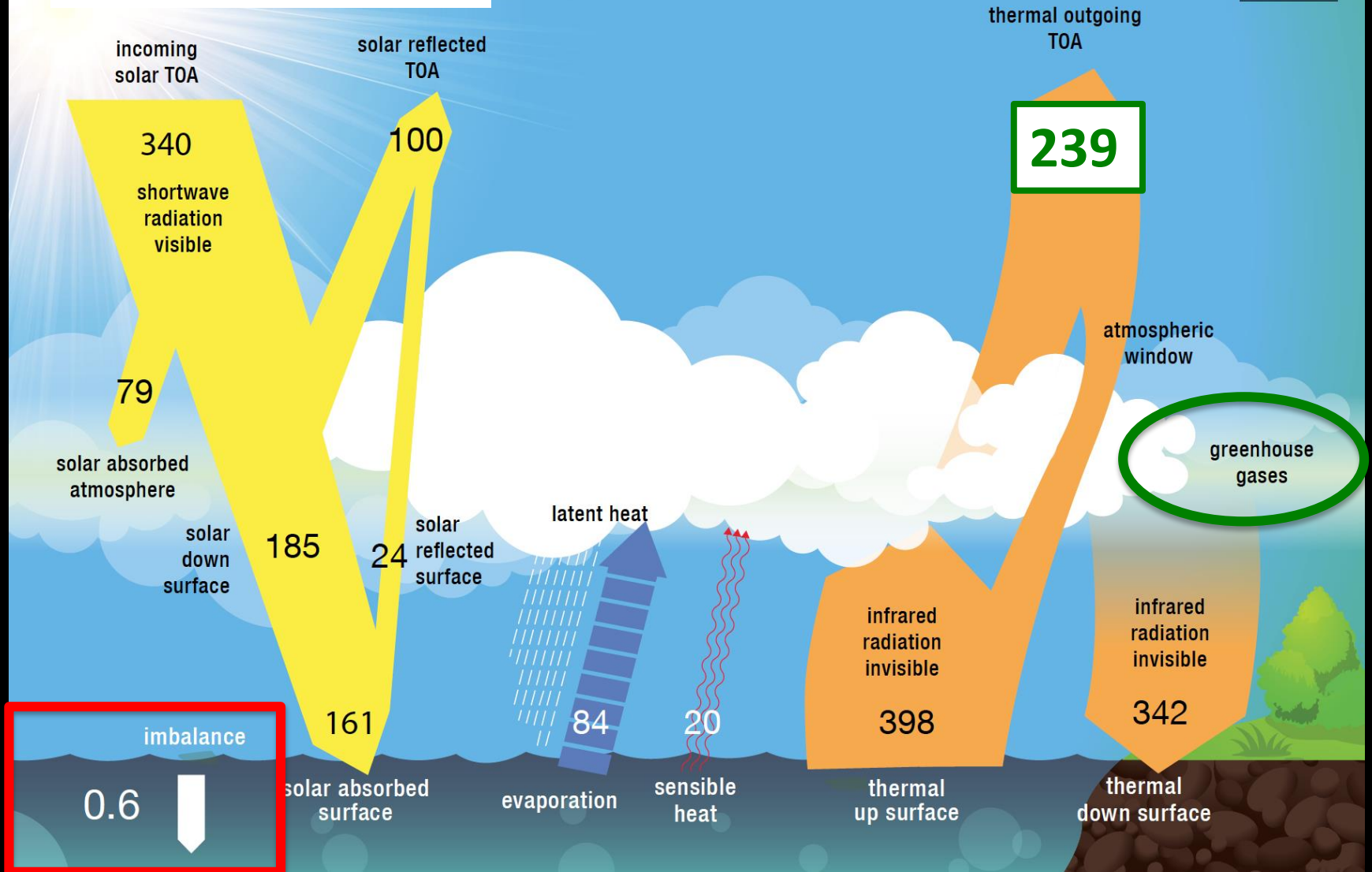
Argon – 0.93 percent

Carbon dioxide – 0.038 percent

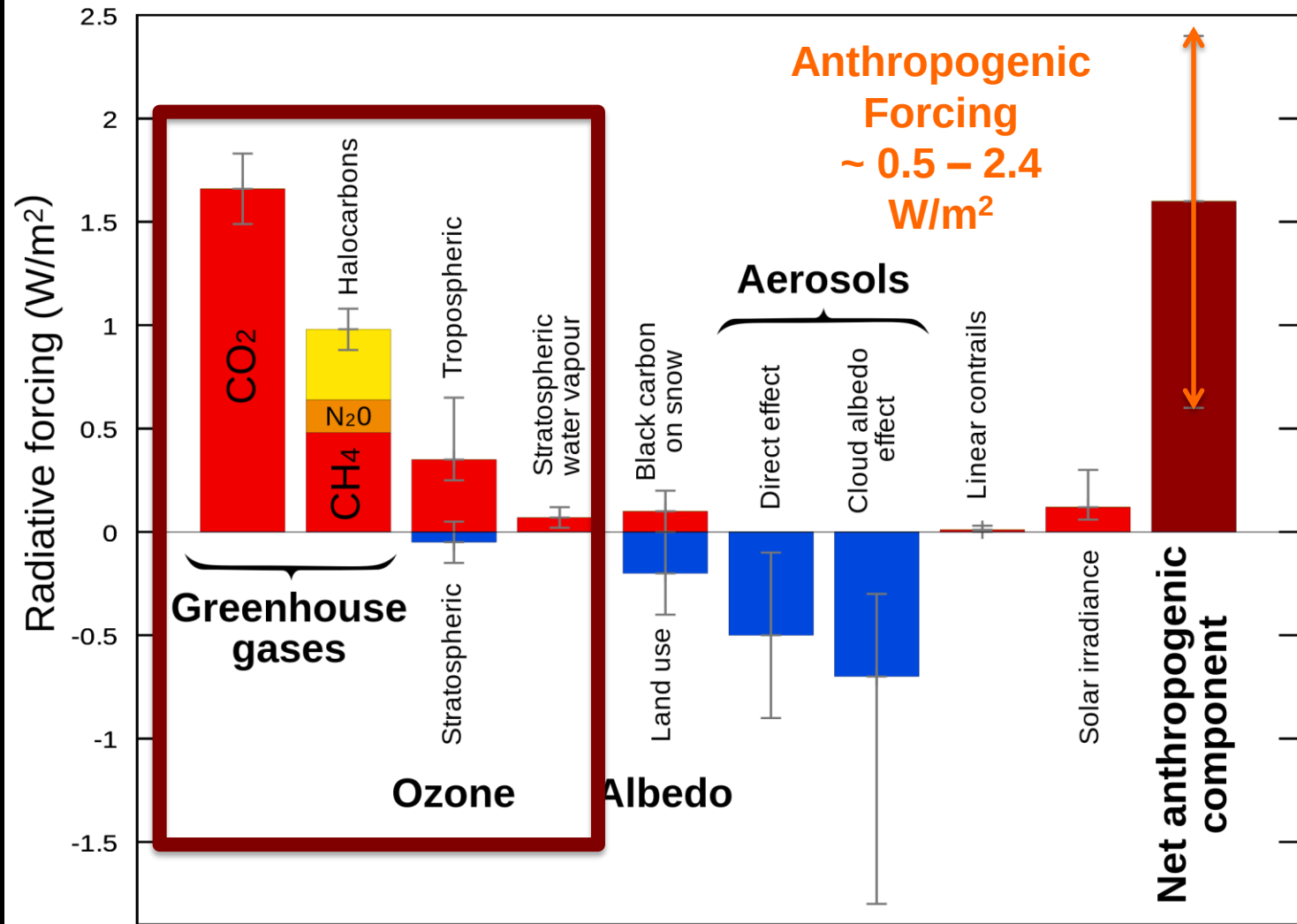
http://www.ux1.eiu.edu/~cfjps/1400/FIG01_010.JPG

$$340 - 100 = 240$$

Units
(Wm^2)



Radiative forcing components

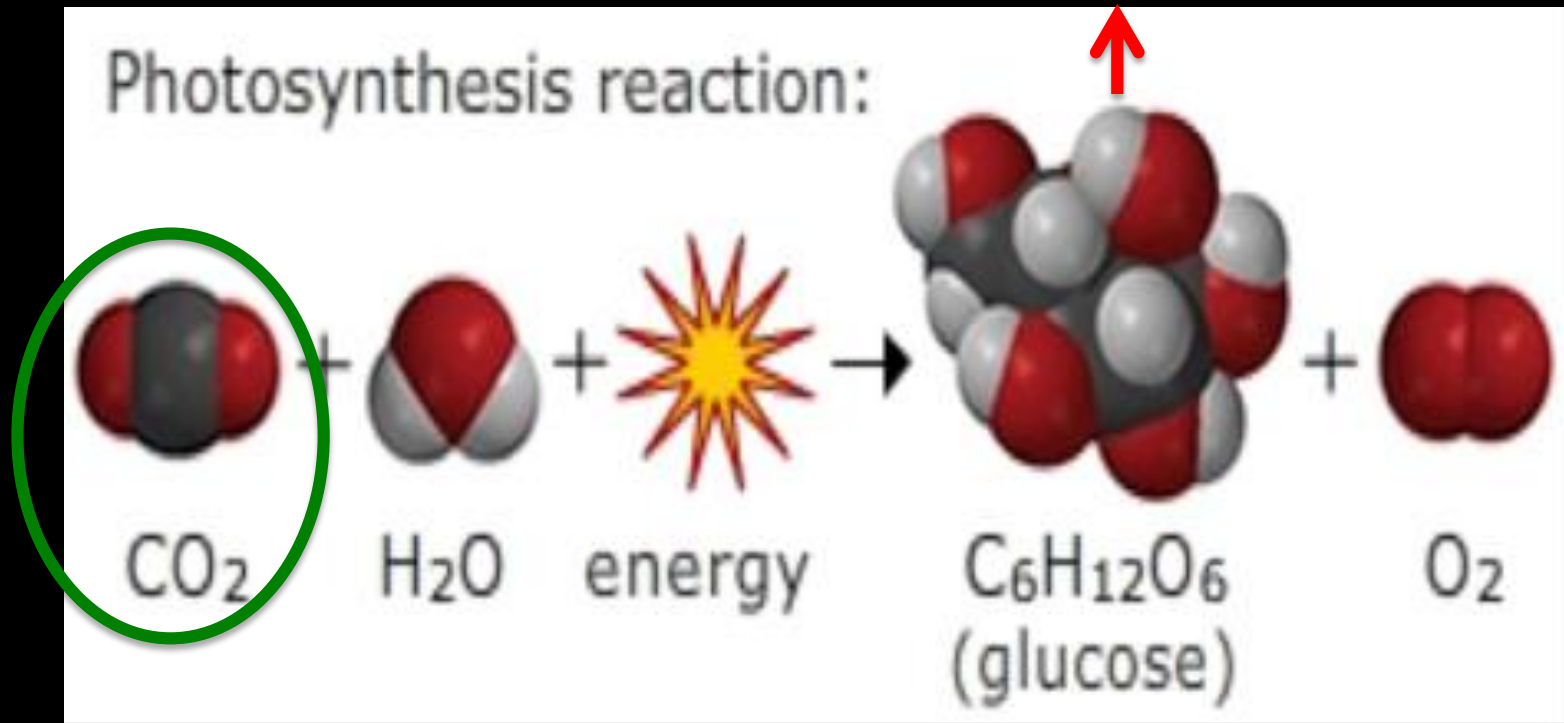


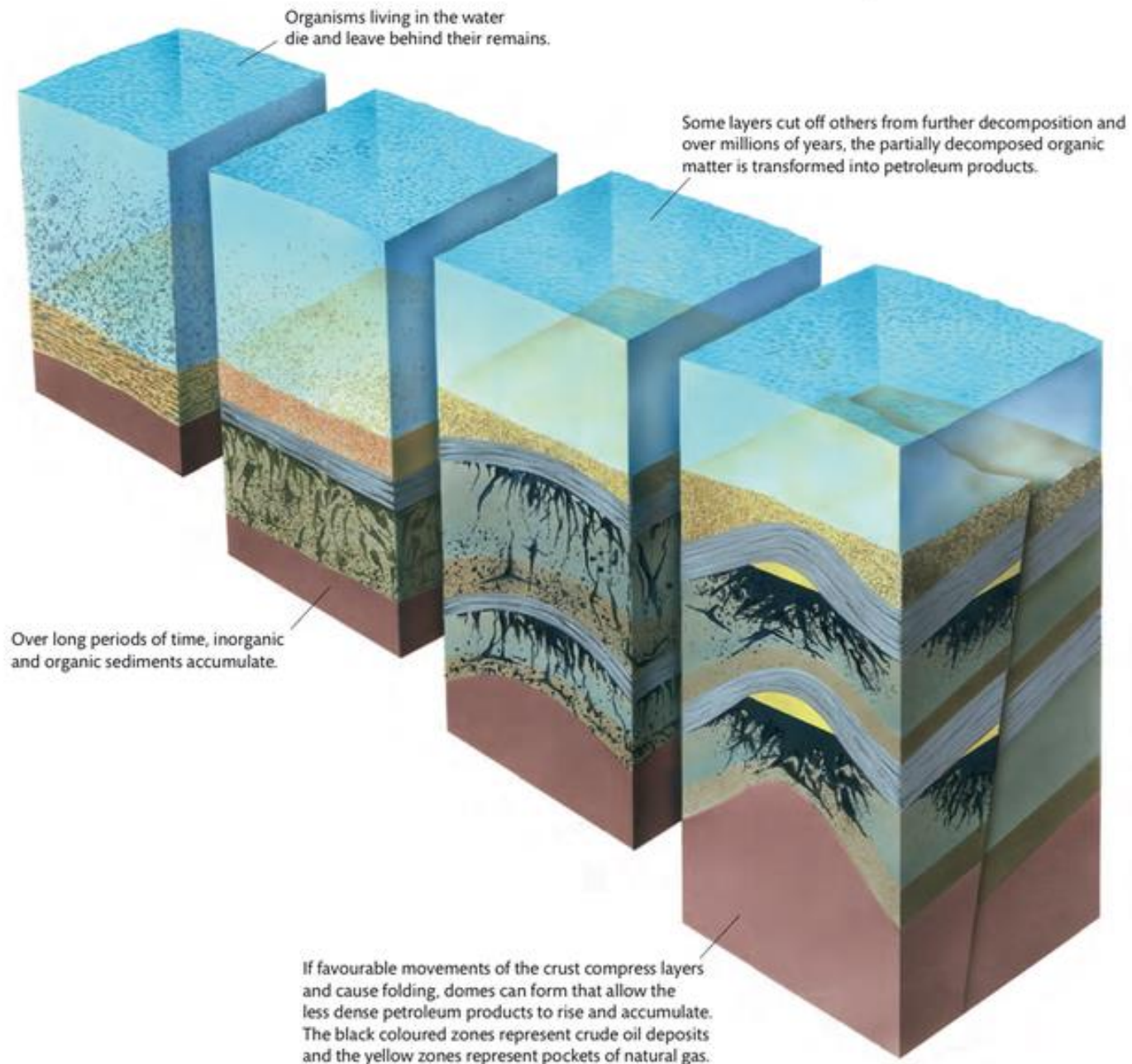
What happens when you burn gasoline?

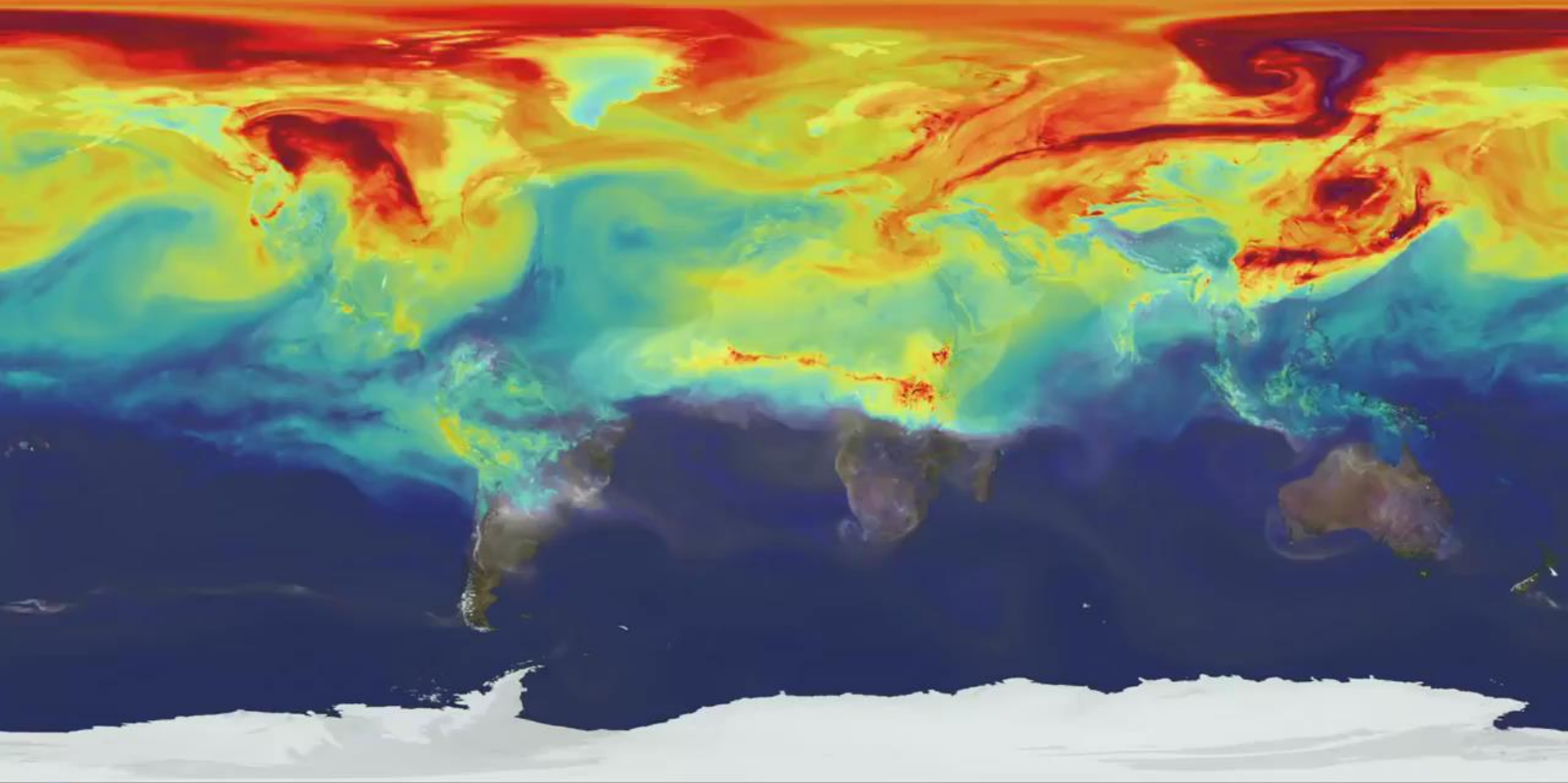


Earthguide <http://earthguide.ucsd.edu>
Memorie Yasuda

If organic tissues are preserved
and not rapidly recycled
Sink for CO₂
Potential Hydrocarbons,
Oil and Gas







2006 / 03 / 01

Global Modeling and Assimilation Office

Carbon Monoxide Column Abundance [1.0×10^{18} molec cm^{-2}]

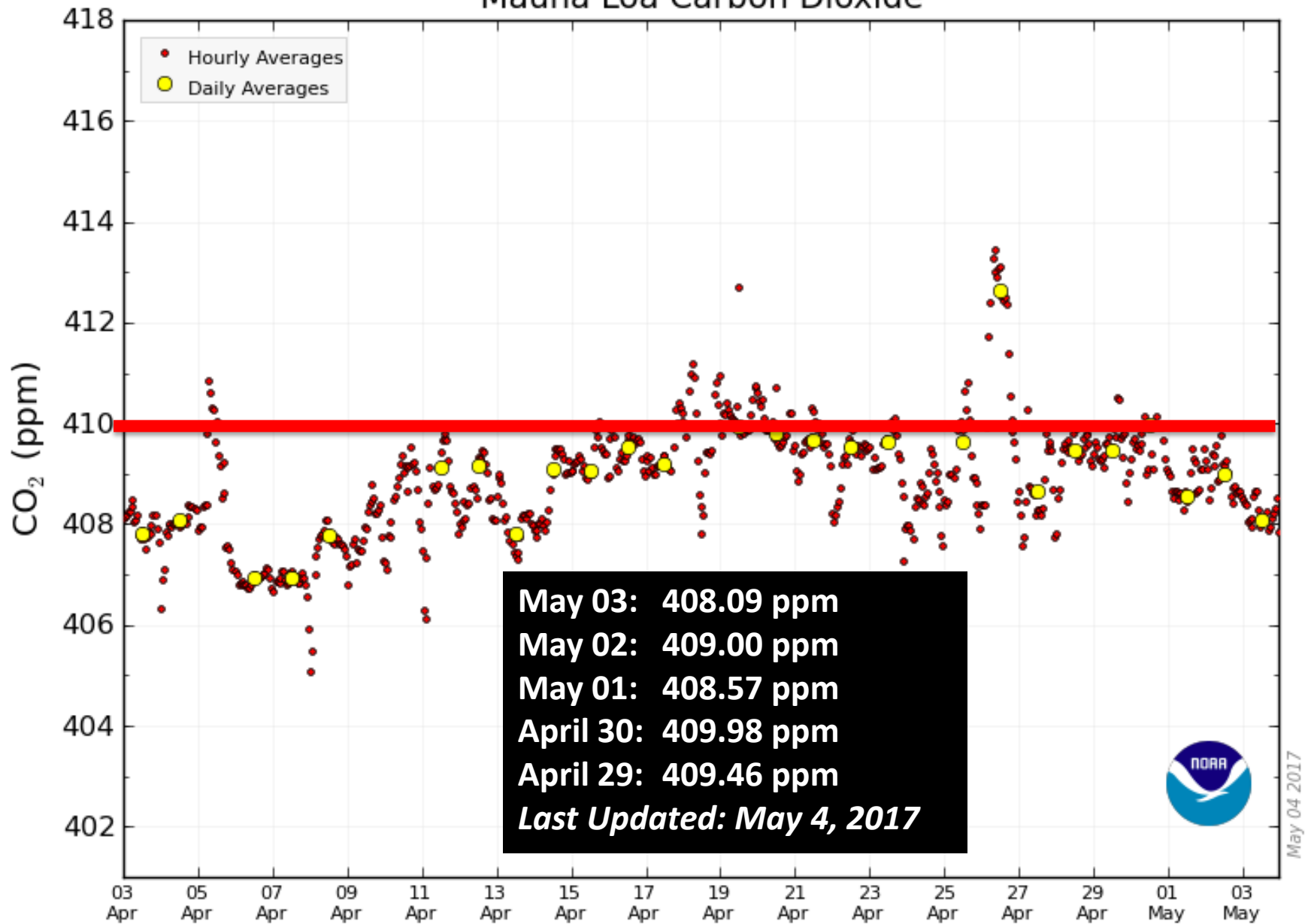
0.0 0.6 1.2 1.8 2.4 3.0 3.6 4.2 4.8 5.4 6.0

Carbon Dioxide Column Concentration [ppmv]

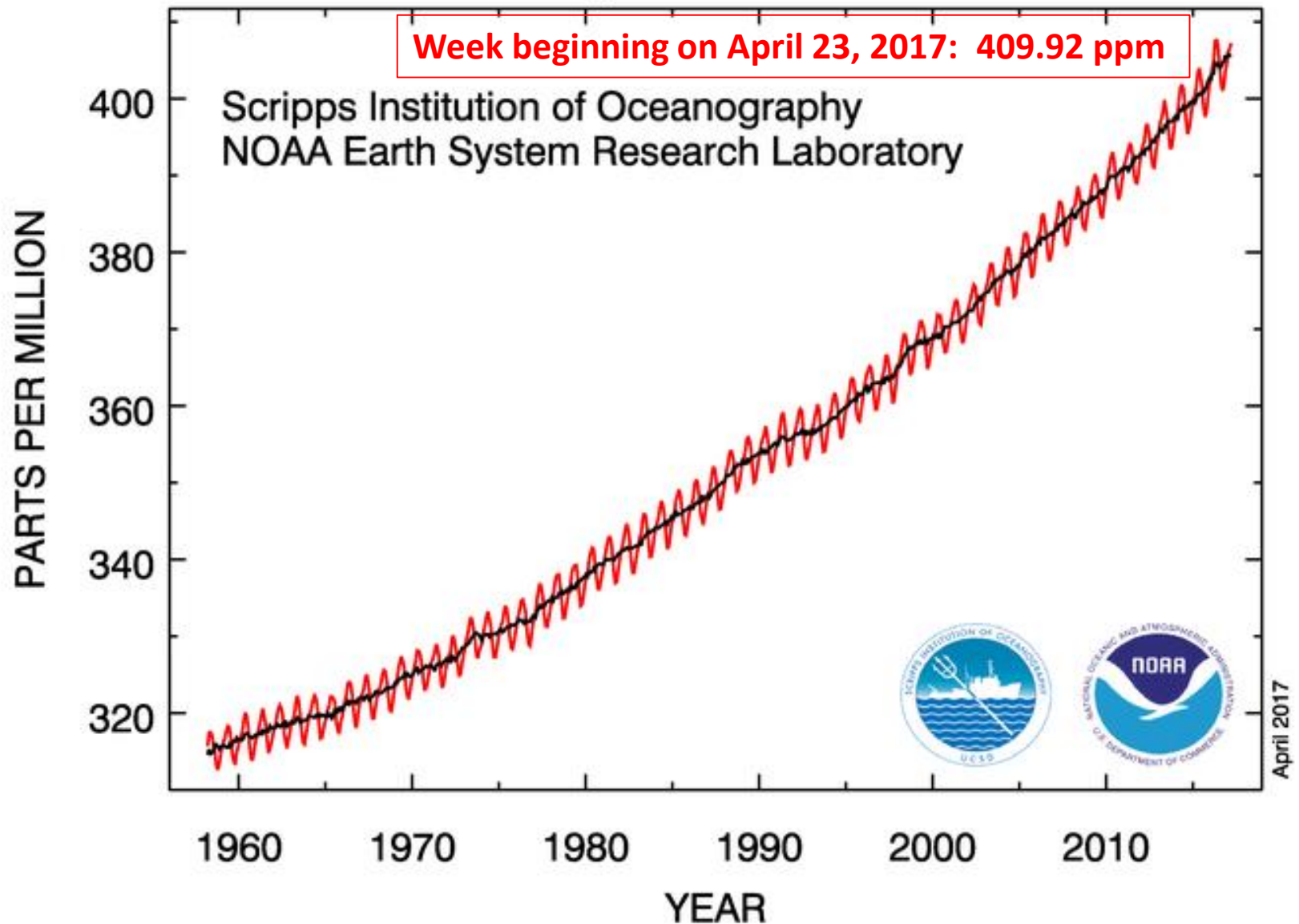
377 379 381 383 385 387 389 391 393 395

<https://gfycat.com/InexperiencedFalseGyps moth>

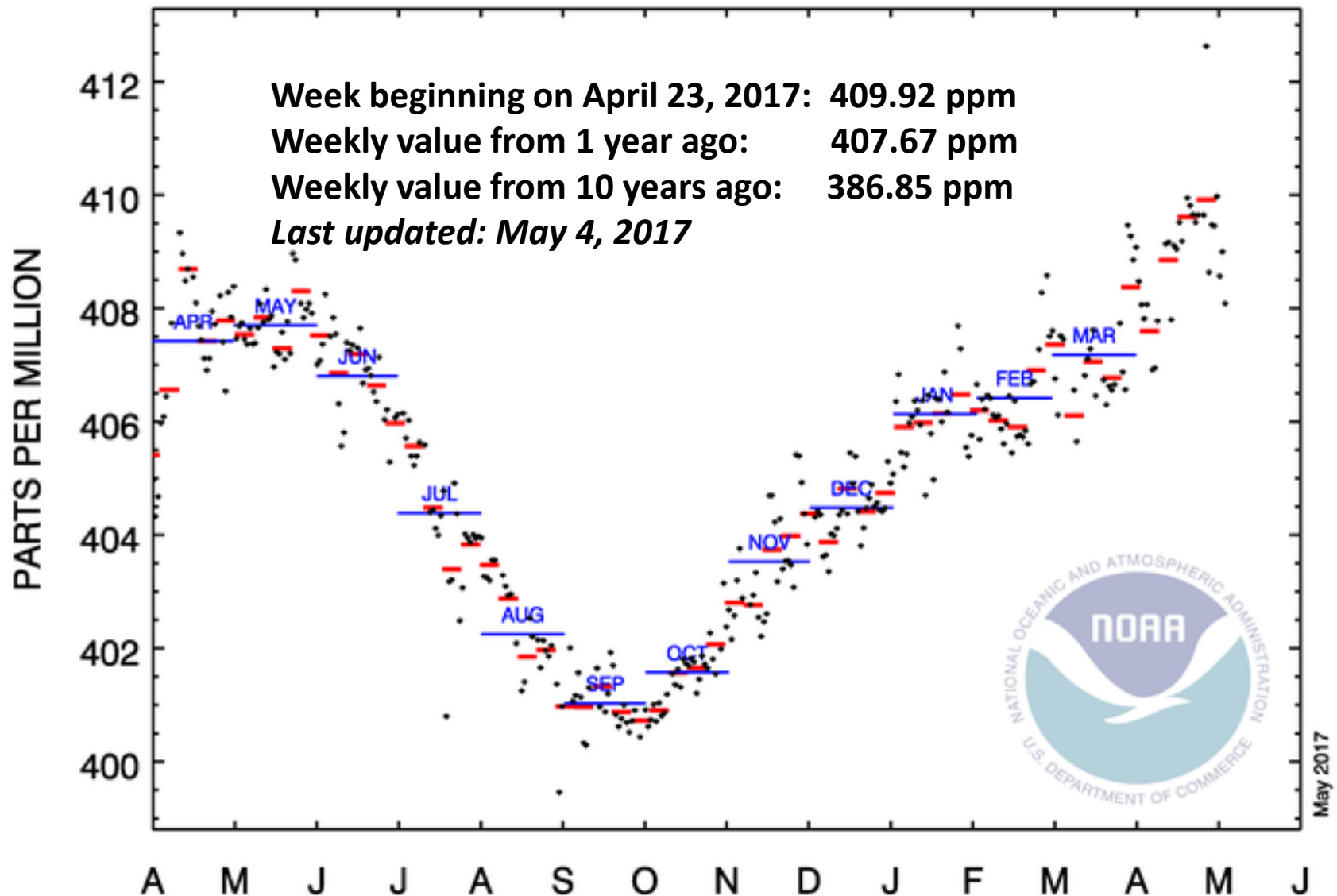
Mauna Loa Carbon Dioxide



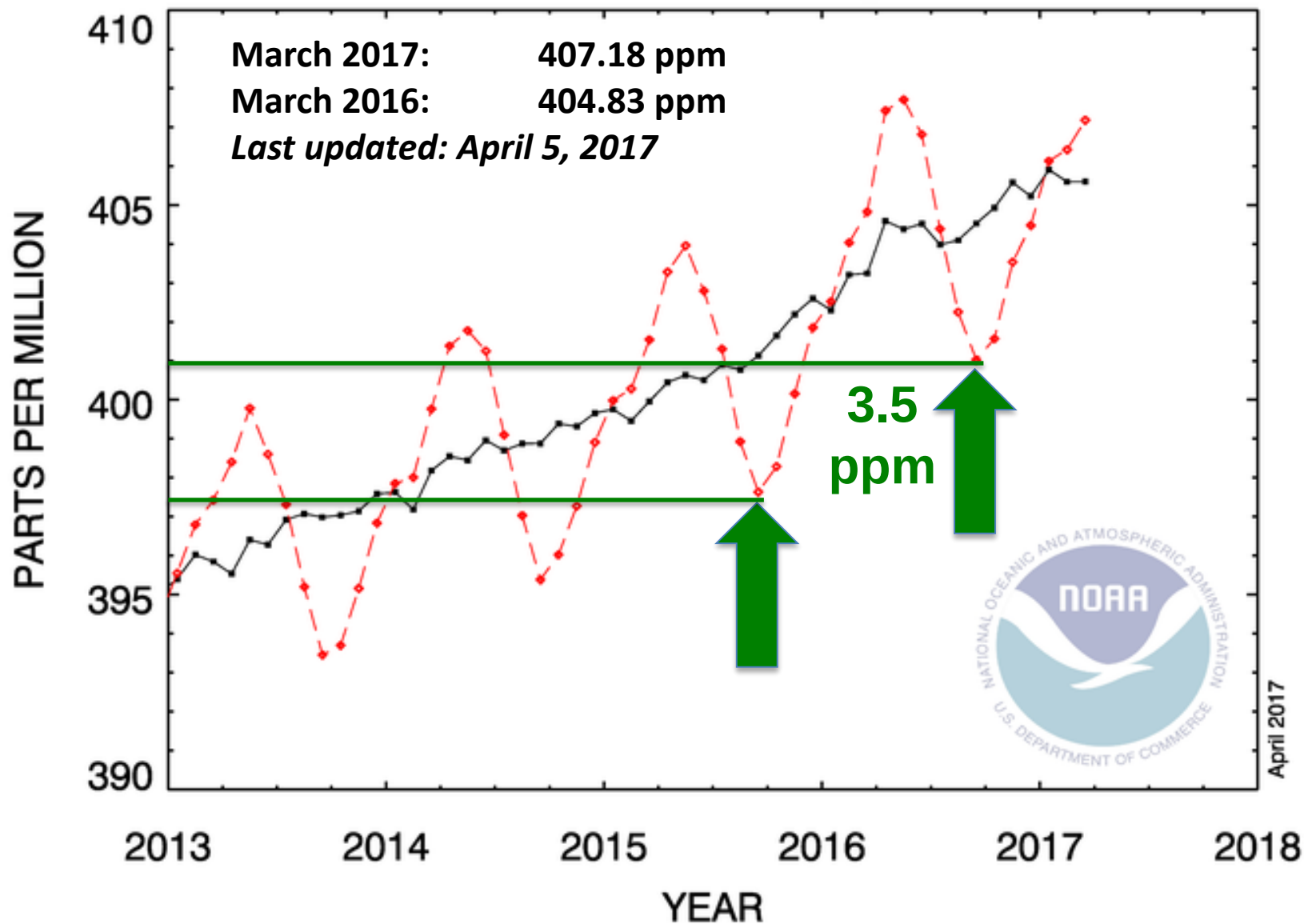
Atmospheric CO₂ at Mauna Loa Observatory



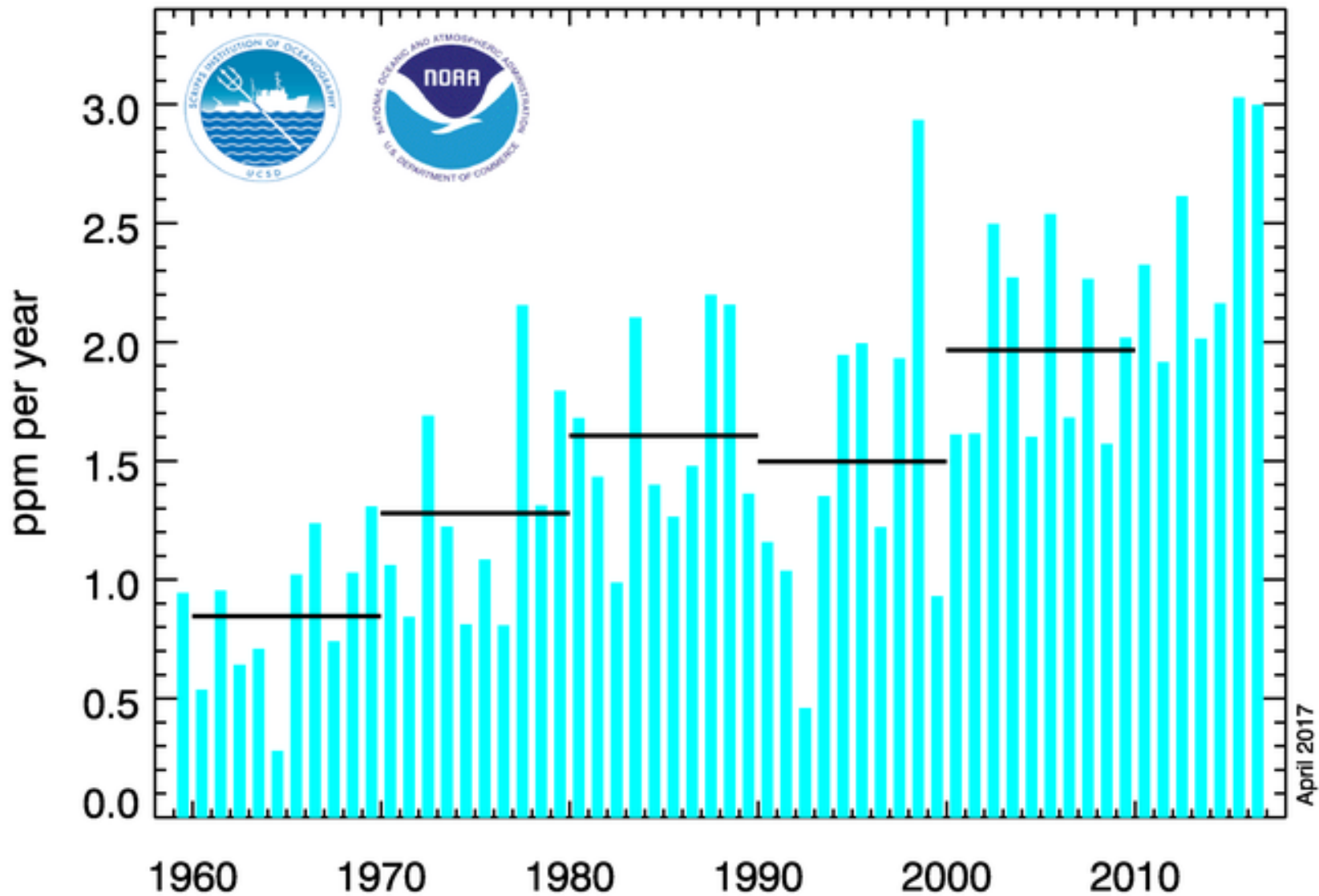
One year of CO₂ daily and weekly means at Mauna Loa

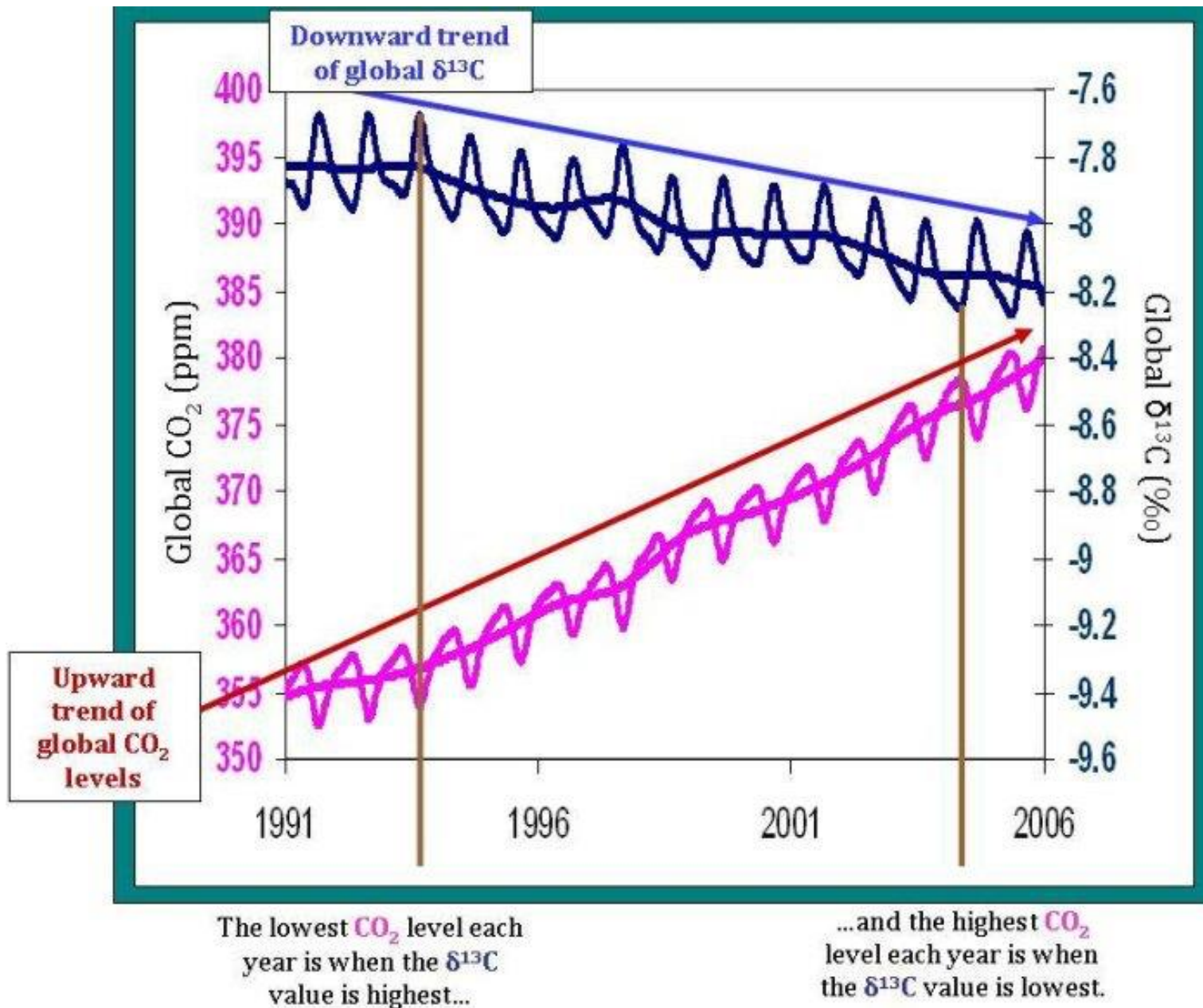


RECENT MONTHLY MEAN CO₂ AT MAUNA LOA

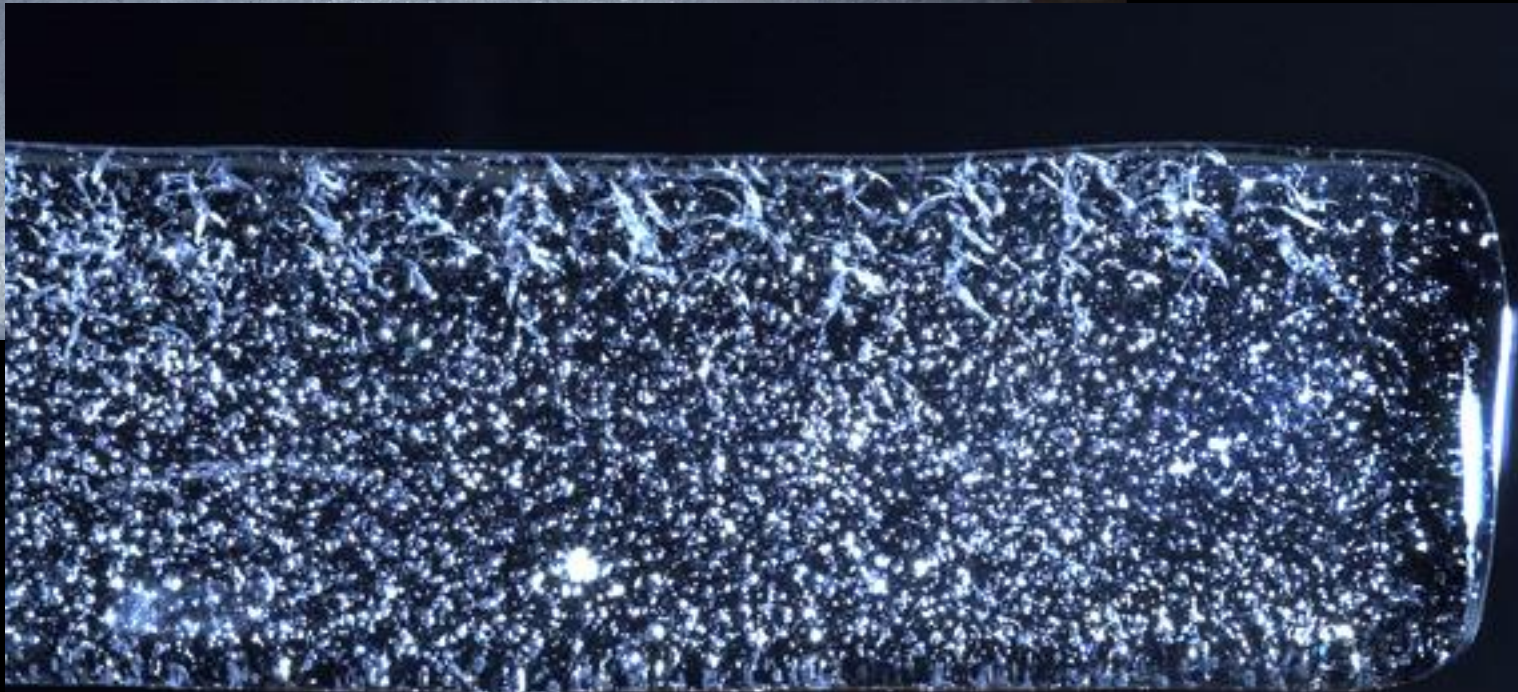
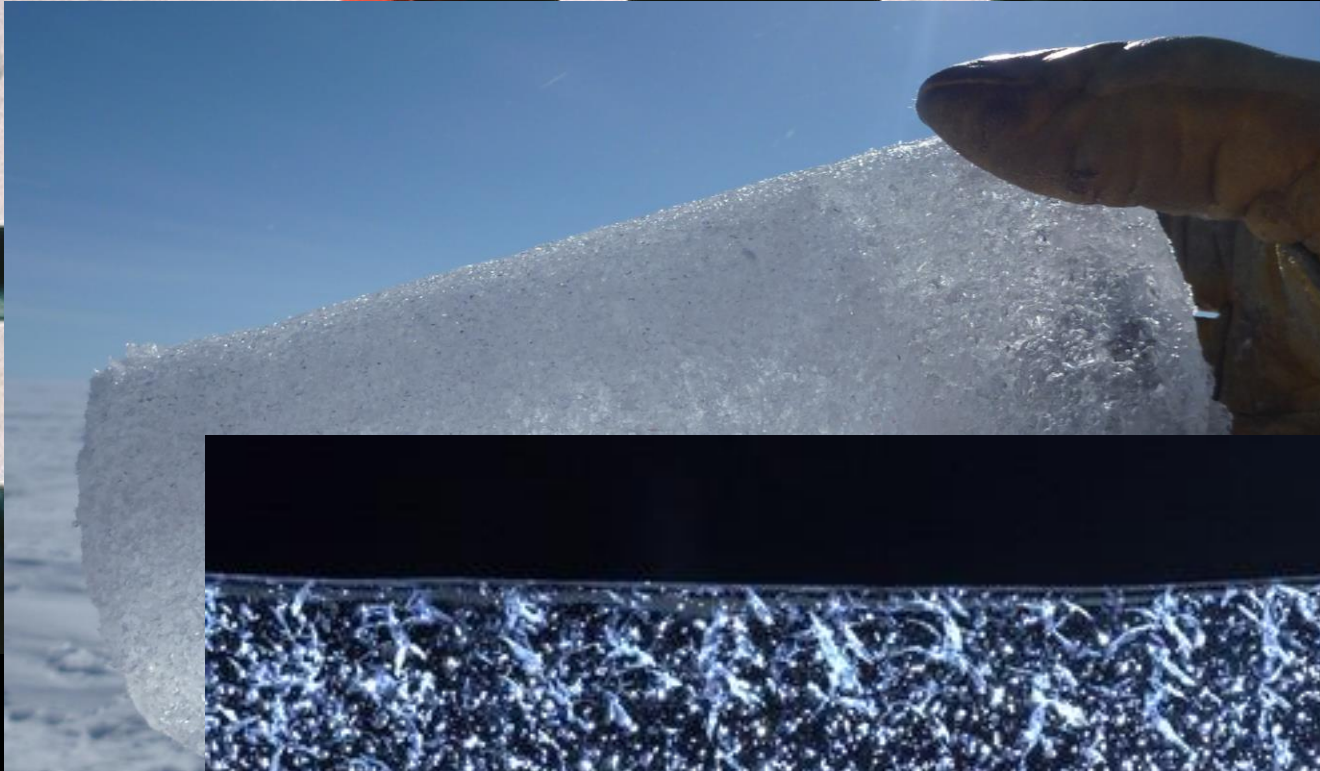


annual mean growth rate of CO₂ at Mauna Loa

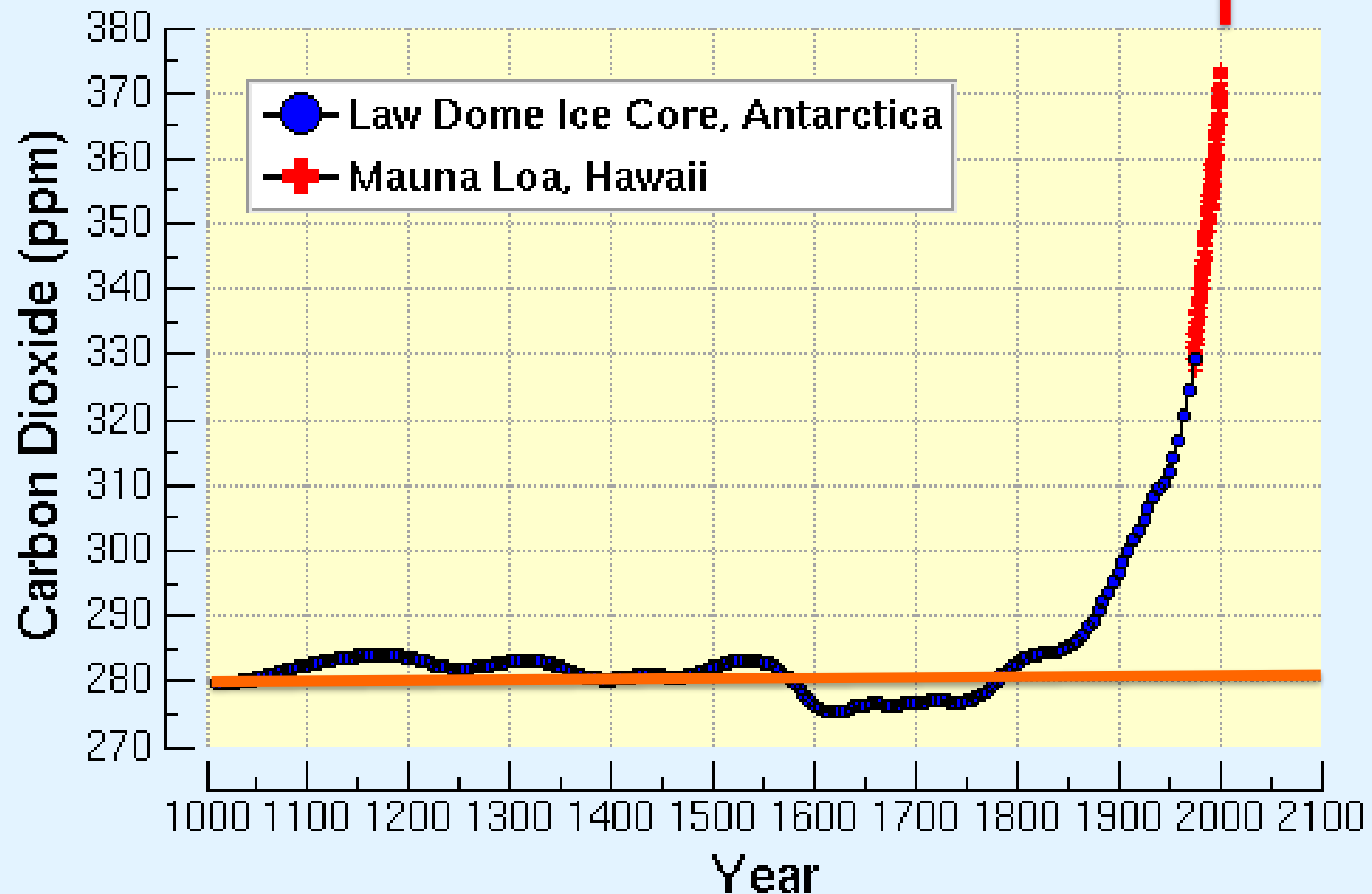








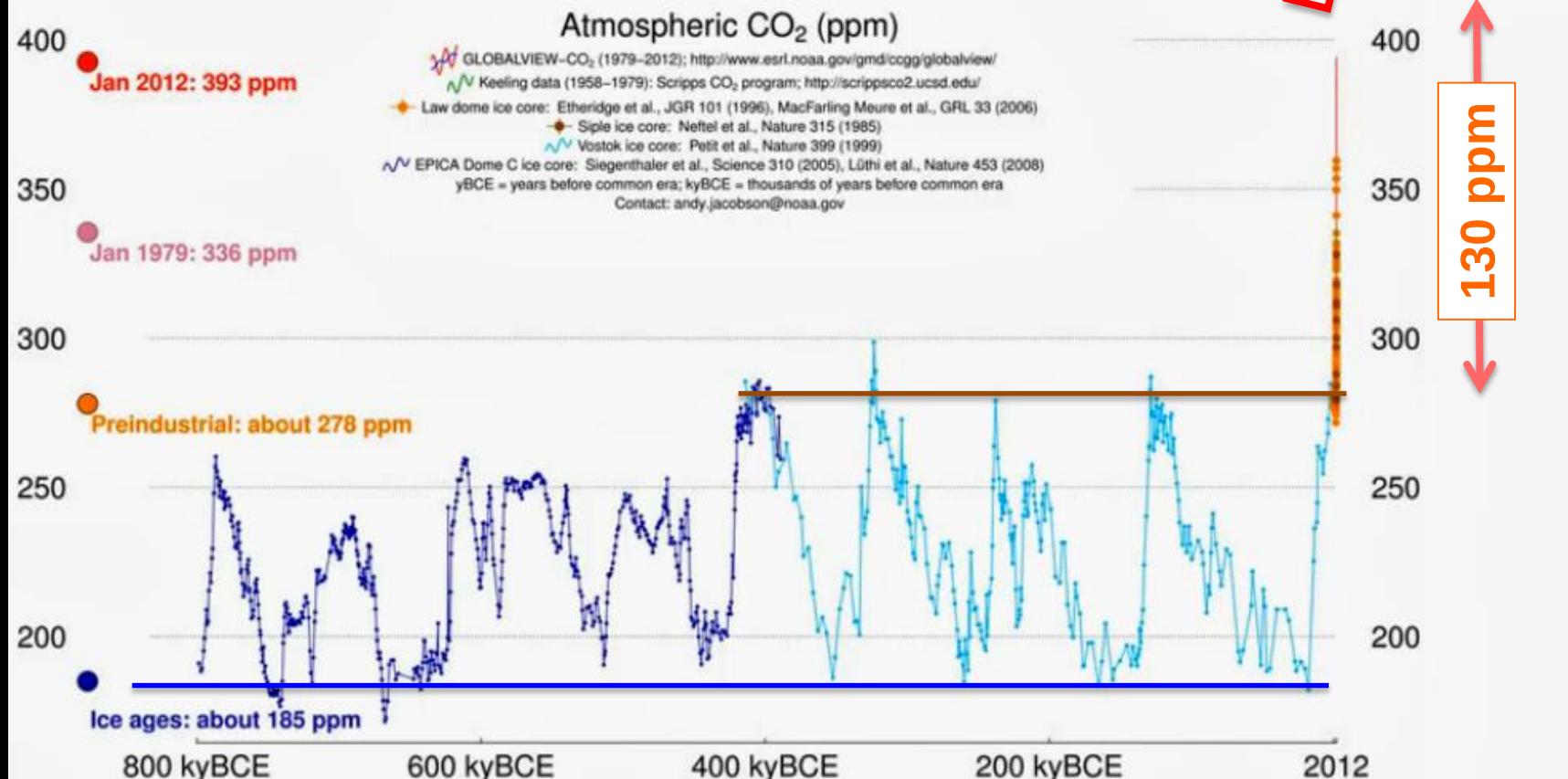
April 30 2017: 409.98 ppm

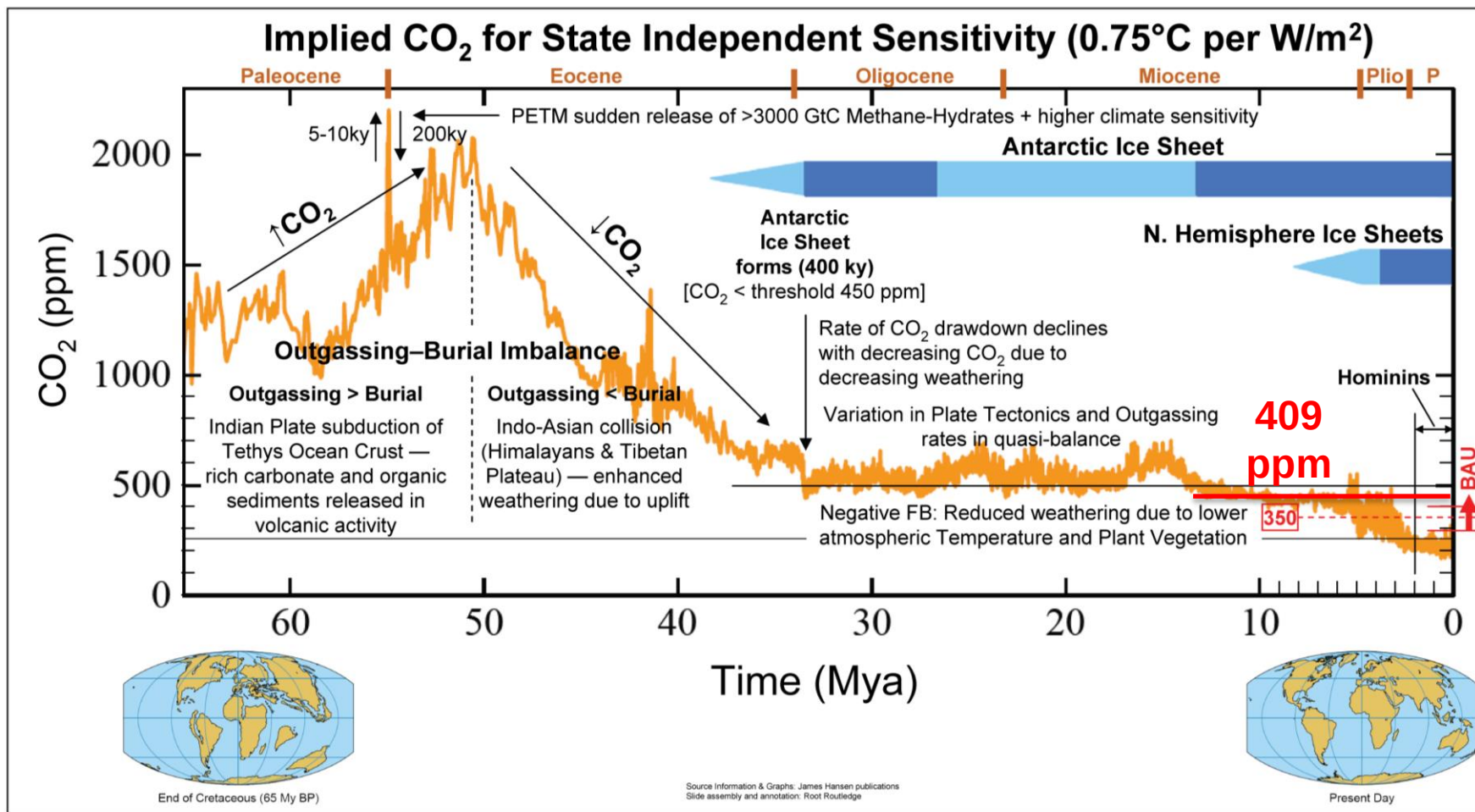




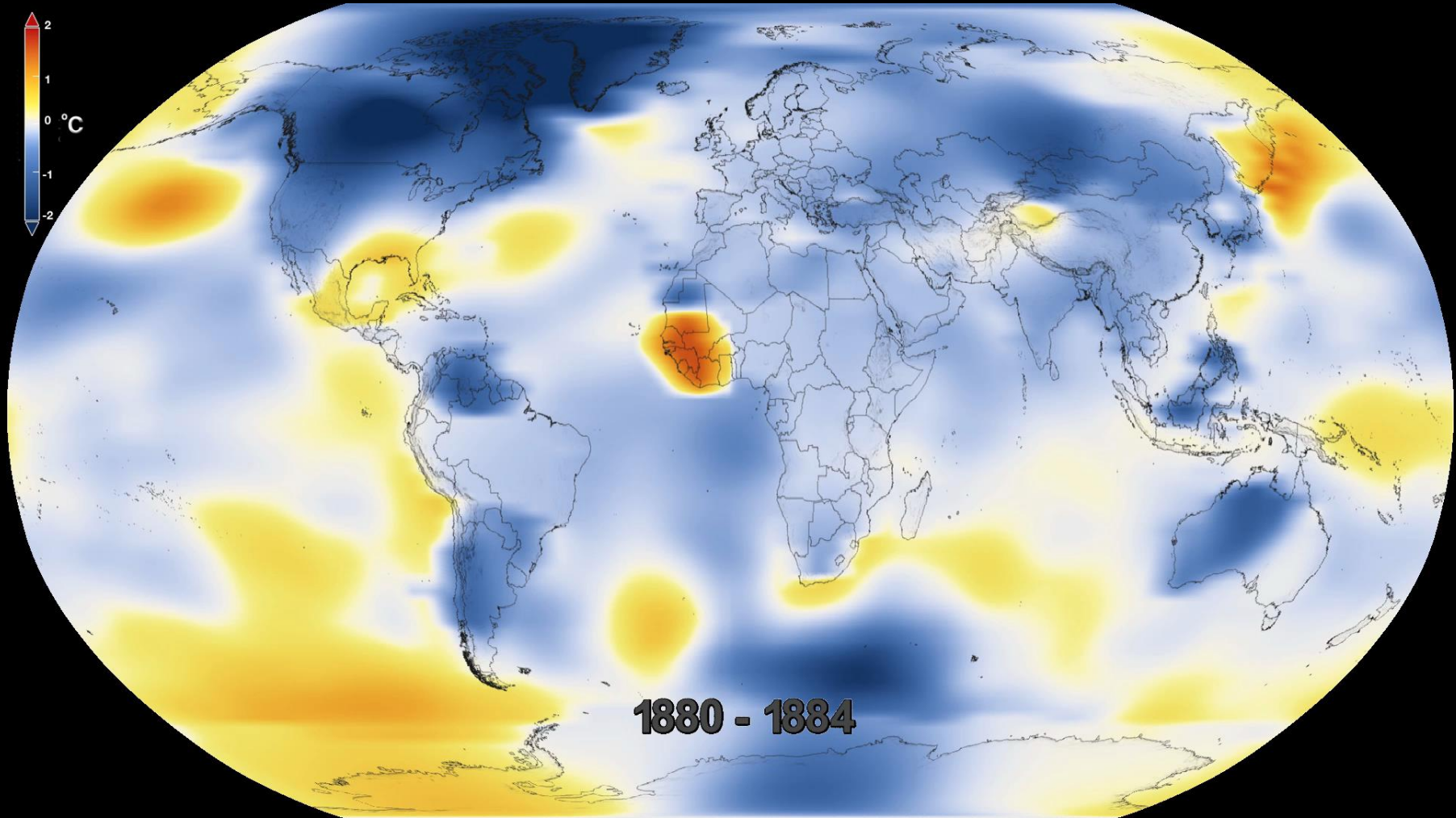
April 30 2017: 409.98 ppm

Time history of atmospheric carbon dioxide from 800,000 years ago until January, 2012.





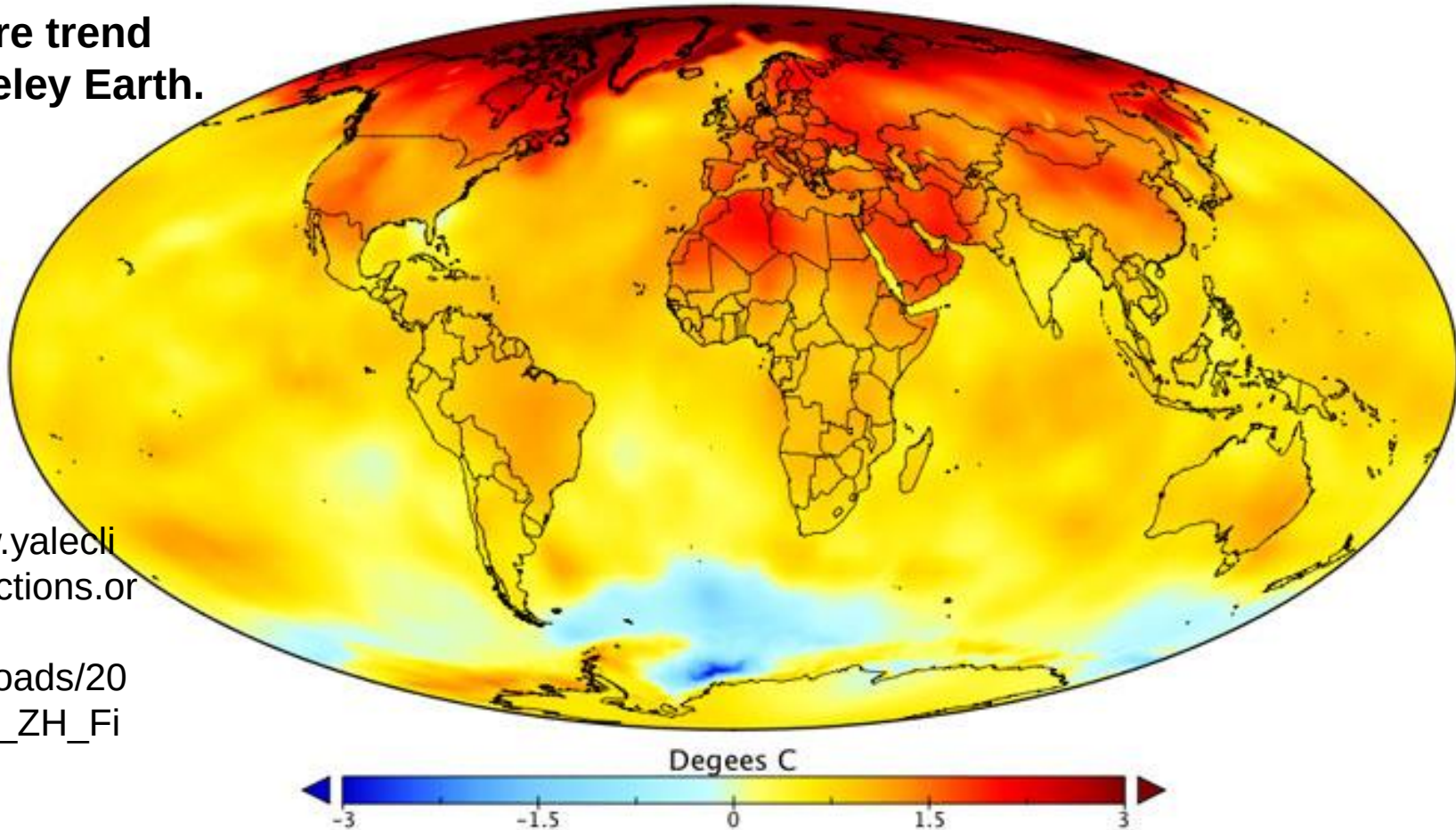
Earth Global Temperature Increase since 1880 (Temperature Anomaly in Deg. C)



https://svs.gsfc.nasa.gov/vis/a000000/a004500/a004546/gistemp2016_5year_full_record_celsius_30fps_1080p.mp4

**April 1970 through
March 2017
temperature trend
from Berkeley Earth.**

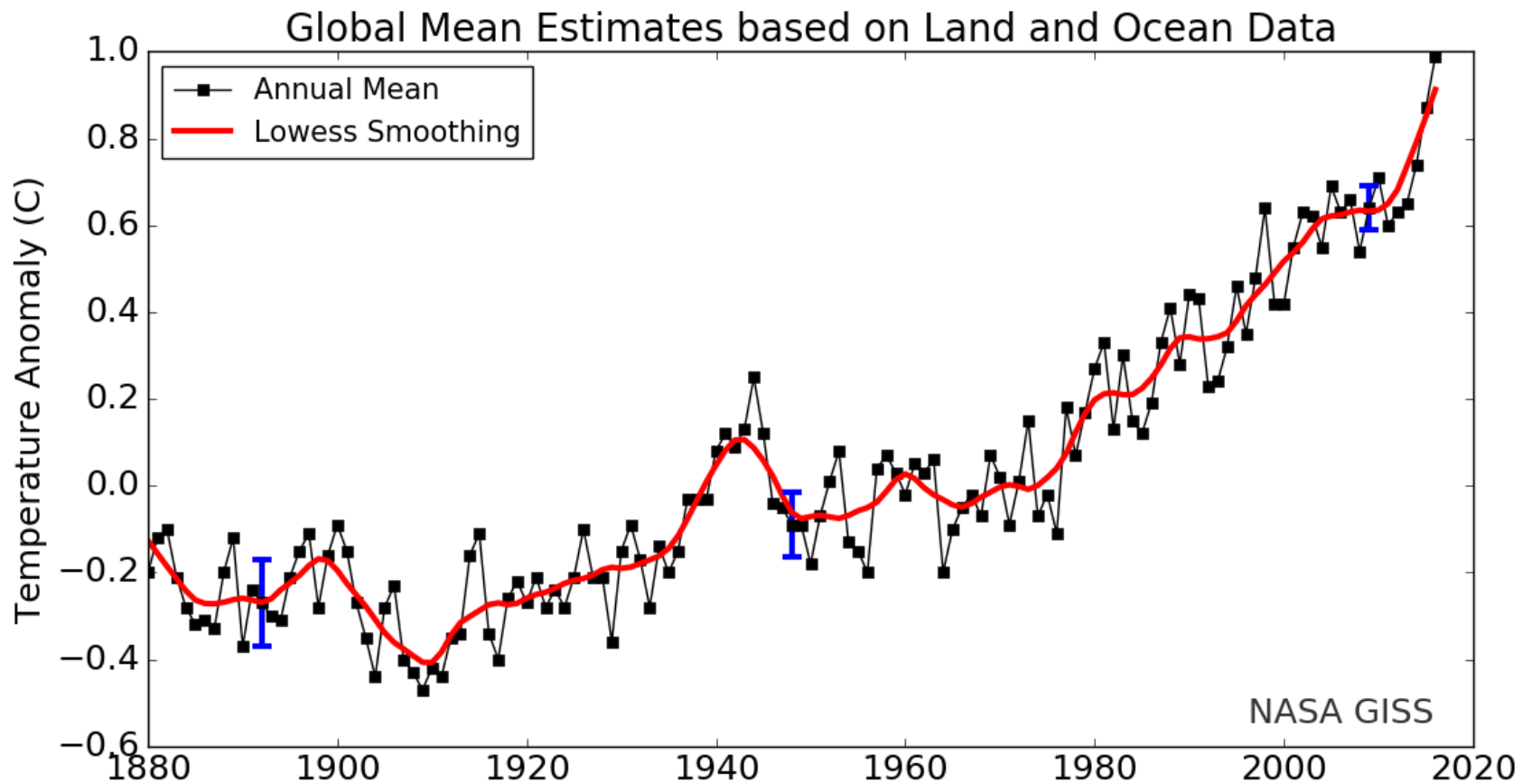
Global Temperature Change since Earth Day 1970



https://www.yaleclimateconnections.org/wp-content/uploads/2017/04/0417_ZH_Figure_5.jpg

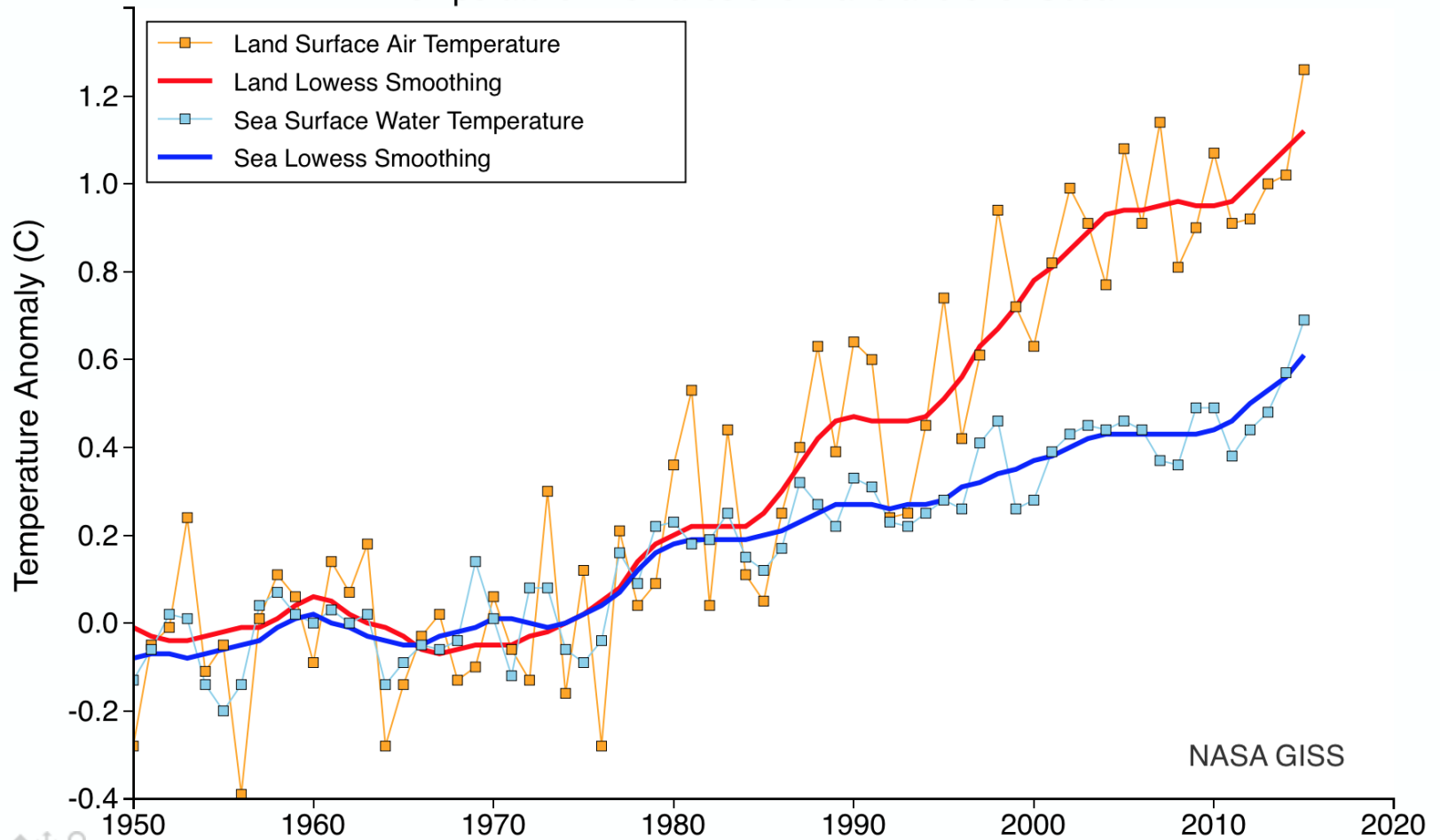
Since 1970:

- 1) global temperatures have increased by 0.86 degrees C (about 1.5 degrees F).**
- 2) Warming over land has increased more than over ocean, particularly in the high-latitude Arctic regions.**
- 3) Parts of the Arctic have warmed 3 degrees C (5.4 degrees F) just since 1970**



https://data.giss.nasa.gov/gistemp/graphs/graph_data/Global_Mean_Estimates_based_on_Land_and_Ocean_Data/graph.png

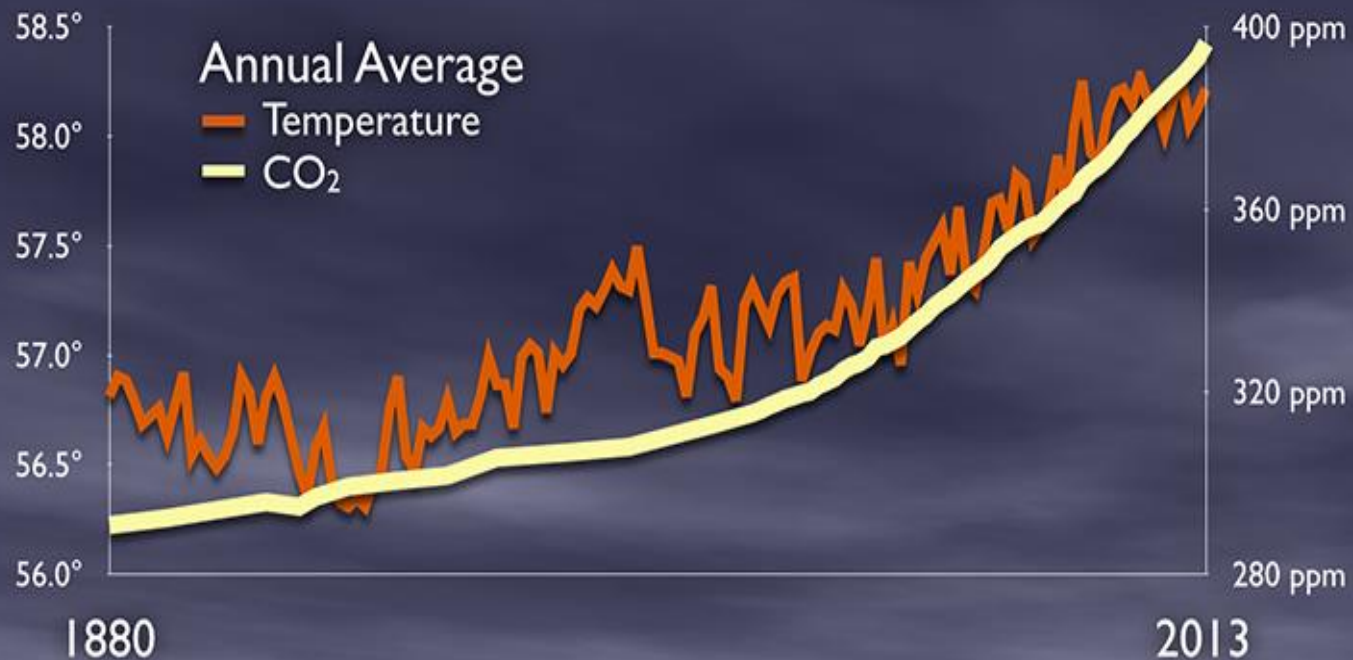
Temperature Anomalies over Land and over Ocean



NASA GISS

Annual (thin lines) and five-year lowess smooth (thick lines) for the temperature anomalies averaged over the Earth's land area and sea surface temperature anomalies averaged over the part of the ocean that is free of ice at all times (open ocean).

Global Temperature and CO₂



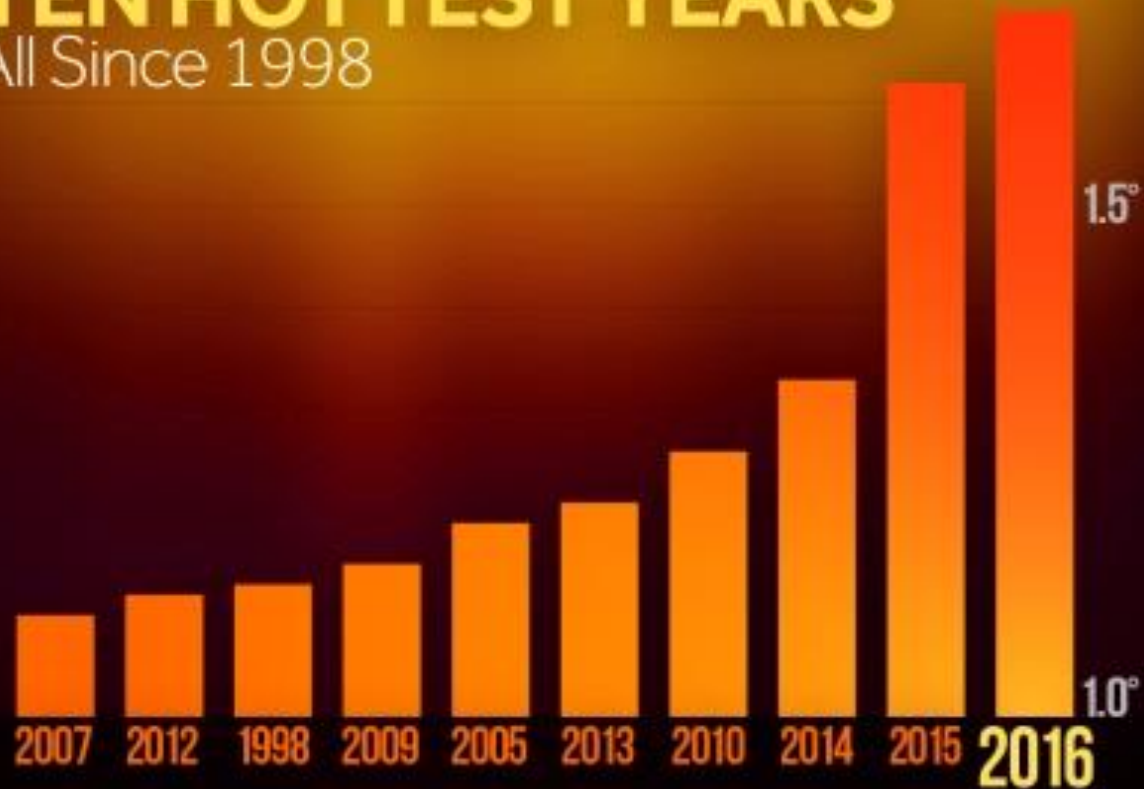
Source: National Climate Assessment 2014

CLIMATE  CENTRAL

http://assets.climatecentral.org/images/uploads/gallery/Global_Temp_and_CO2_400.jpg

TEN HOTTEST YEARS

All Since 1998



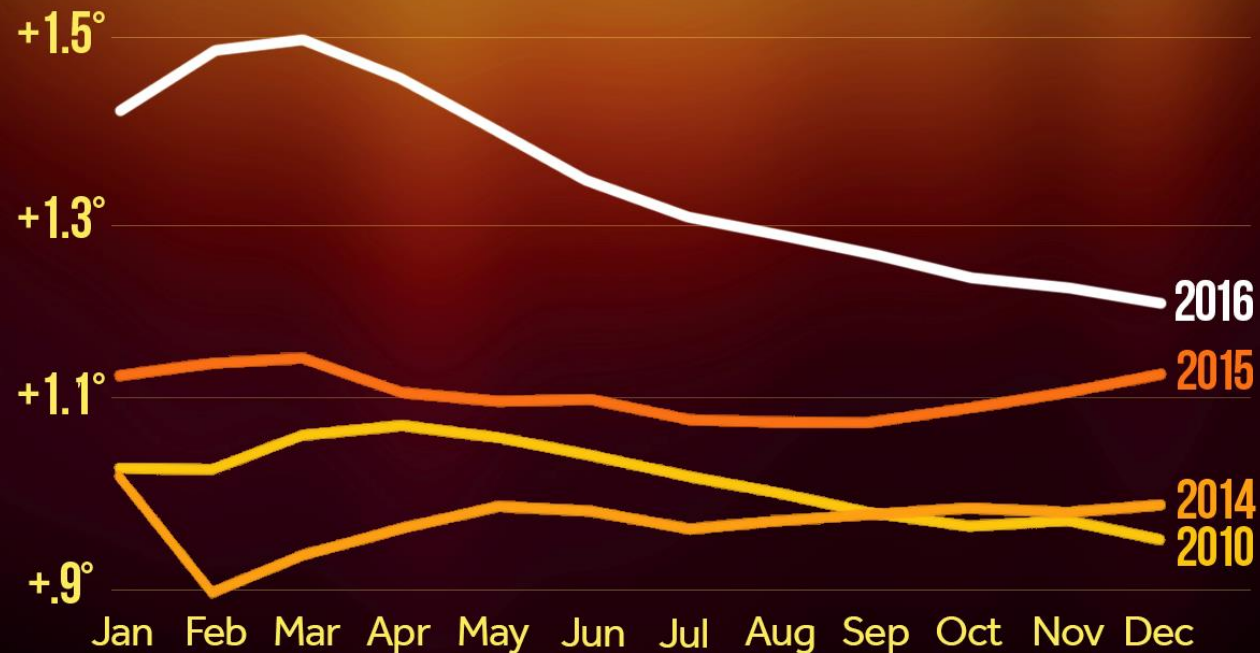
2007 and 2008 (not shown) tied with 2003. Columns represent difference from 20th-century average.
Data as of January 15, 2017. Subject to change based on RCEI revisions.
Source: NASA/NOAA

CLIMATE  CENTRAL

http://assets.climatecentral.org/images/uploads/gallery/2017HottestOnRecord_TopTen_en_title_lg.jpg

2016: HOTTEST START TO FINISH

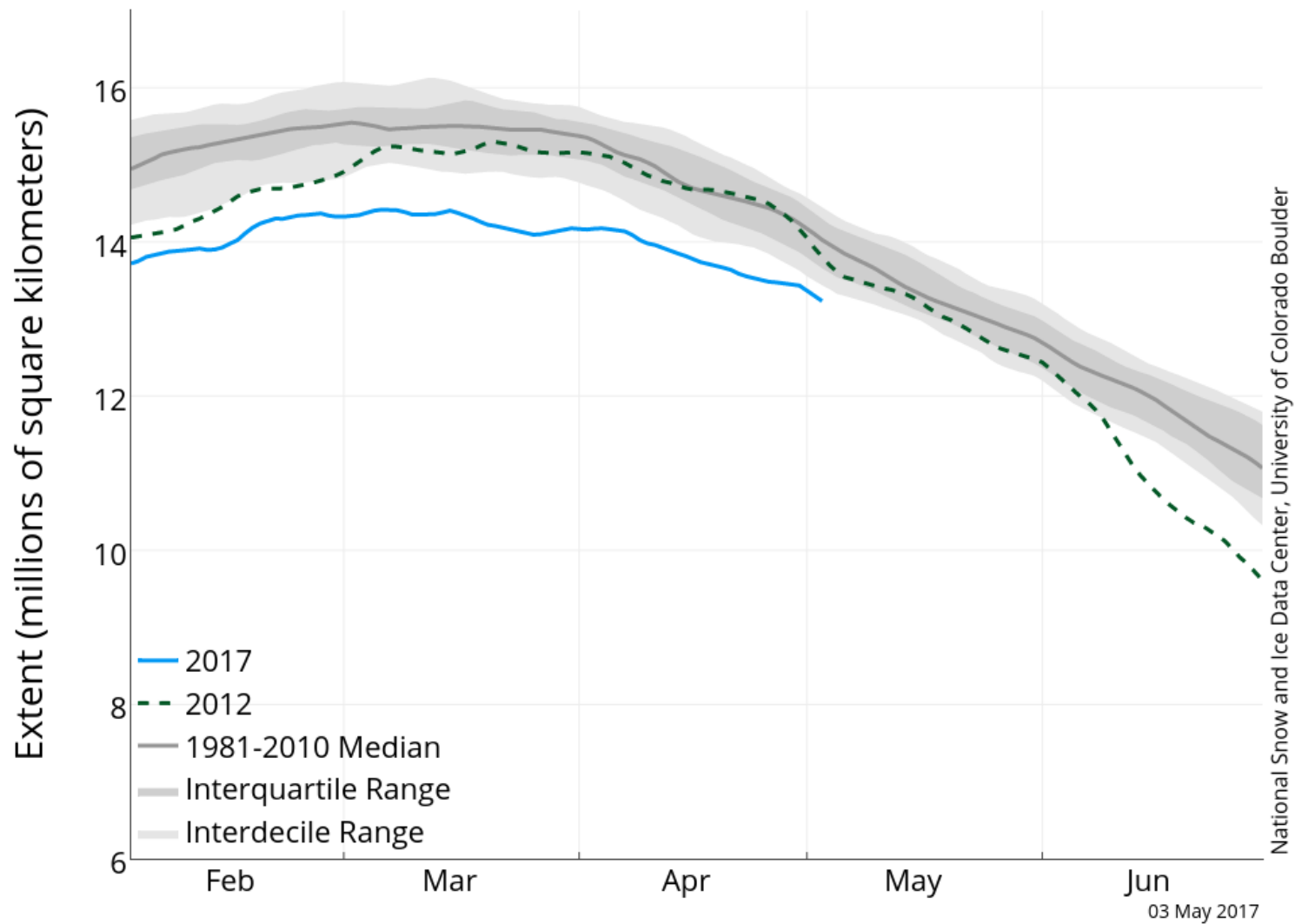
Global Year-to-Date Anomalies (°C) From 1881-1910



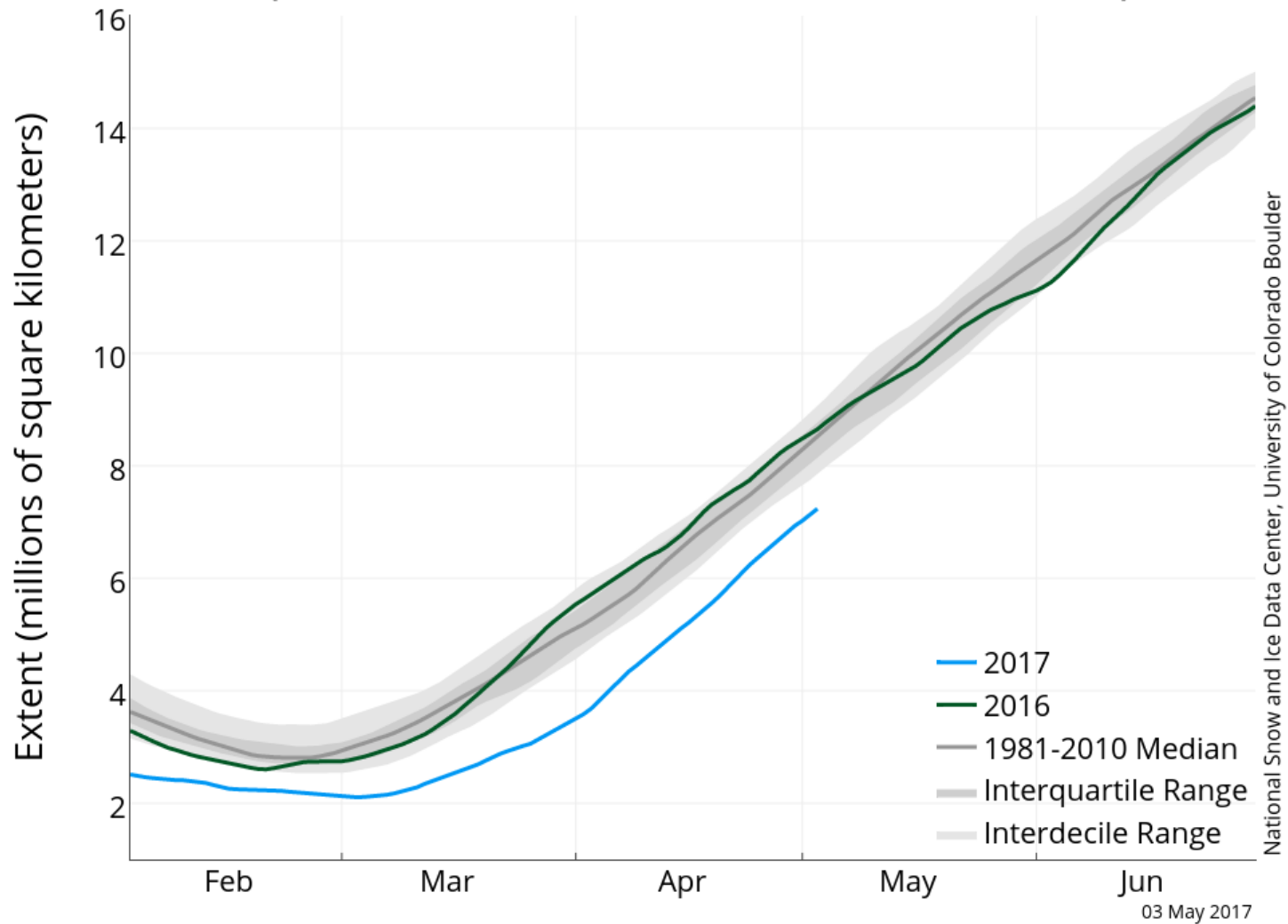
Source: NASA GISS and NOAA NCEI global temperature data averaged and adjusted to early industrial baseline (1881-1910). Data as of January 2017.

CLIMATE  CENTRAL

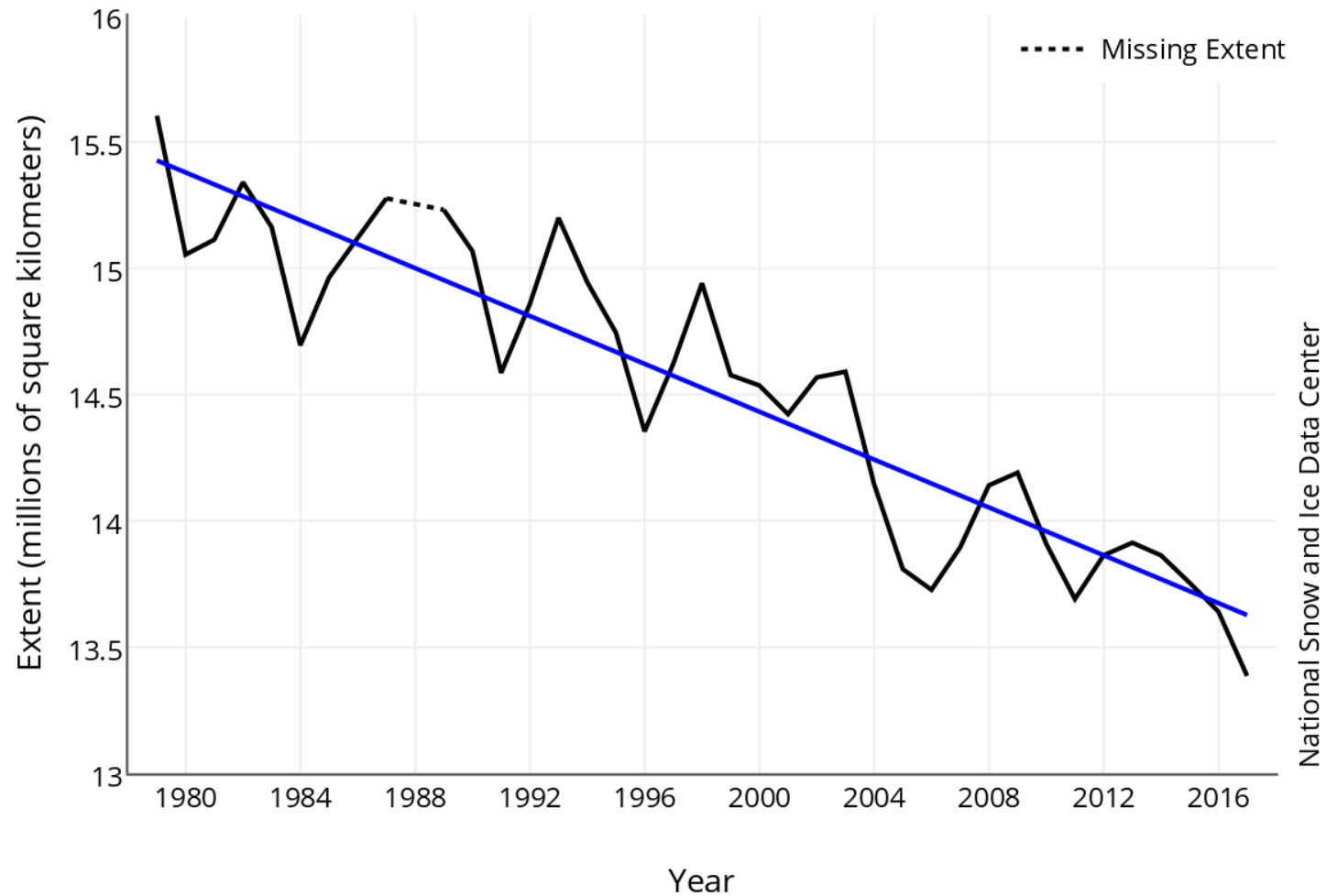
Arctic Sea Ice Extent (Area of ocean with at least 15% sea ice)

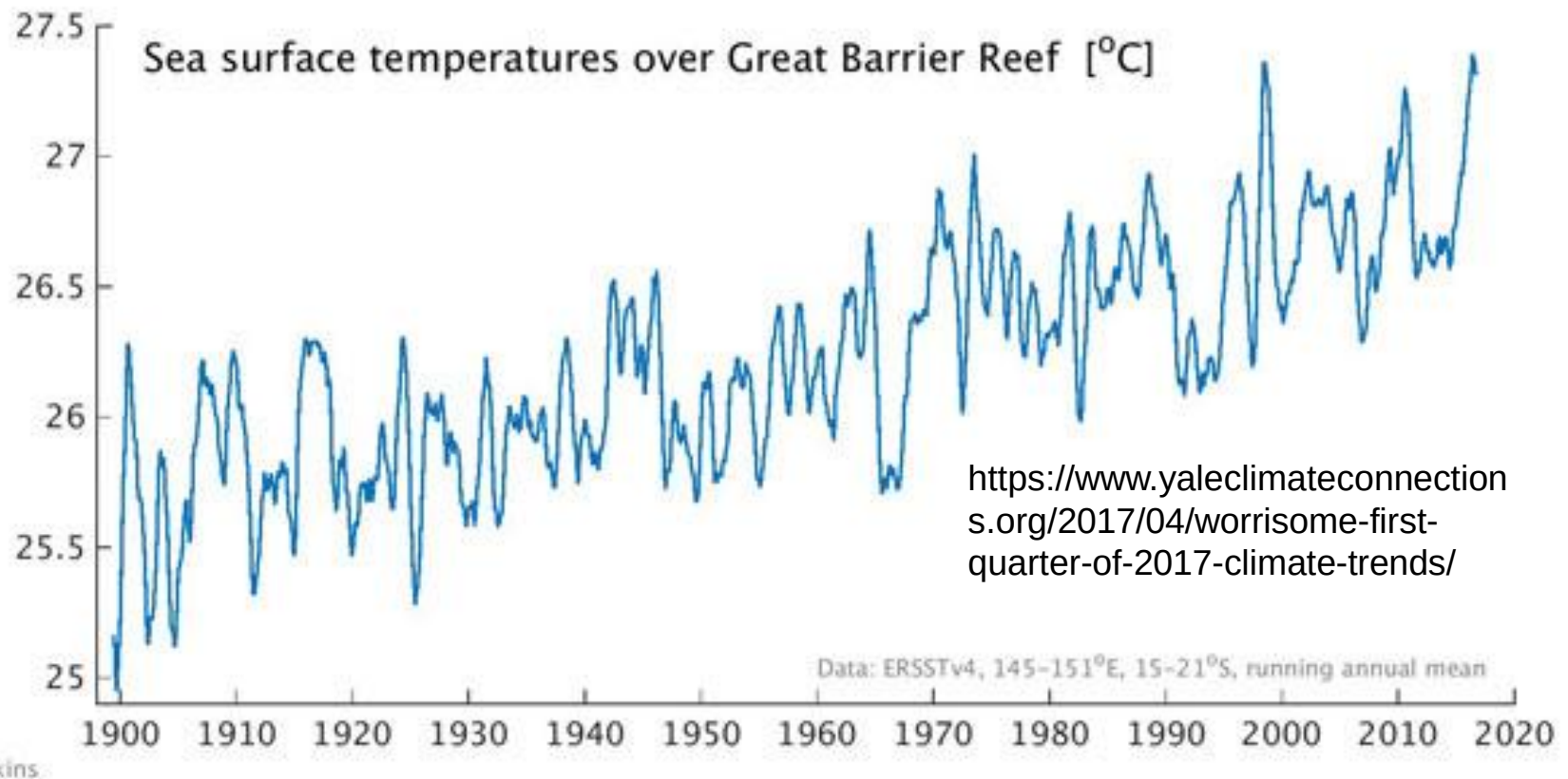


Antarctic Sea Ice Extent (Area of ocean with at least 15% sea ice)



Average Monthly Arctic Sea Ice Extent January 1979 - 2017





Coral bleaching events are driven primarily by high sea surface temperatures.

The oceans around northeast Australia have warmed nearly 1.5 degrees C (2.7 degrees F) since 1900, as shown in the figure above, and about 0.7 degrees C (1.2 degrees F) since 1979.

<https://www.theguardian.com/environment/2016/jun/07/the-great-barrier-reef-a-catastrophe-laid-bare>

Reef on the brink

The Great Barrier Reef: a catastrophe laid bare

Australia's natural wonder is in mortal danger. Bleaching caused by climate change has killed almost a quarter of its coral this year and many scientists believe it could be too late for the rest. Using exclusive photographs and new data, a Guardian special report investigates how the reef has been devastated - and what can be done to save it

by Michael Slezak

High Temperature > 29 deg. C Coral Reefs are bleaching

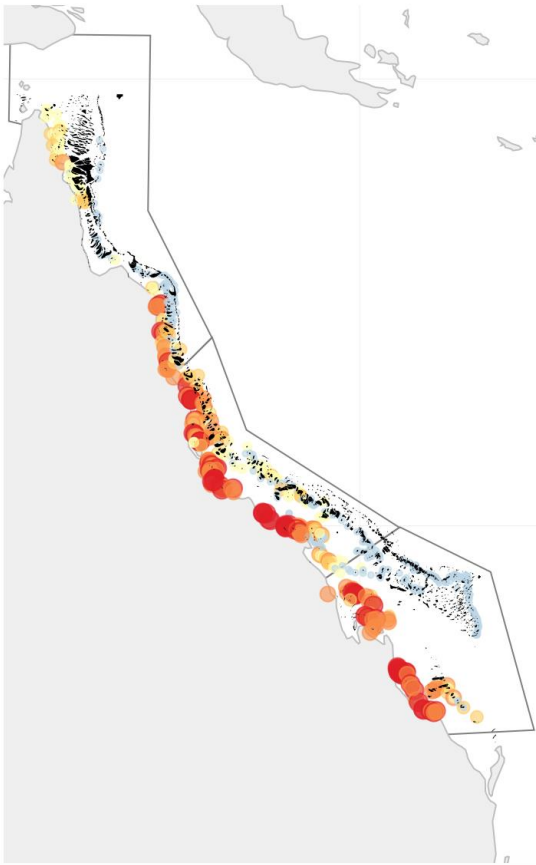


<http://news.medill.northwestern.edu/chicago/wp-content/uploads/sites/3/2016/03/American-Samoa-Before-During-After2.jpgcatastrophe>

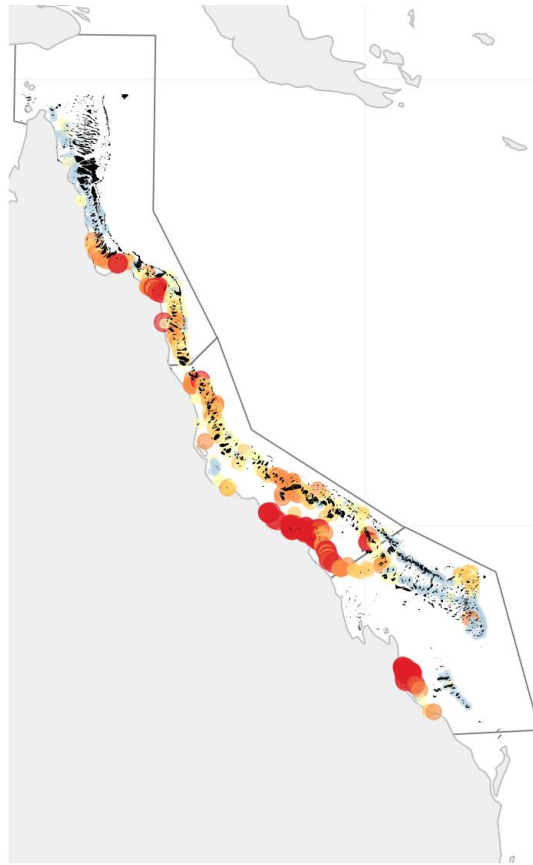
● >60% bleached ● 30-60% bleached ● 10-30% bleached ● 1-10% bleached ● <1% bleached

■ 81% severely bleached ■ 33% severely bleached ■ 1% severely bleached

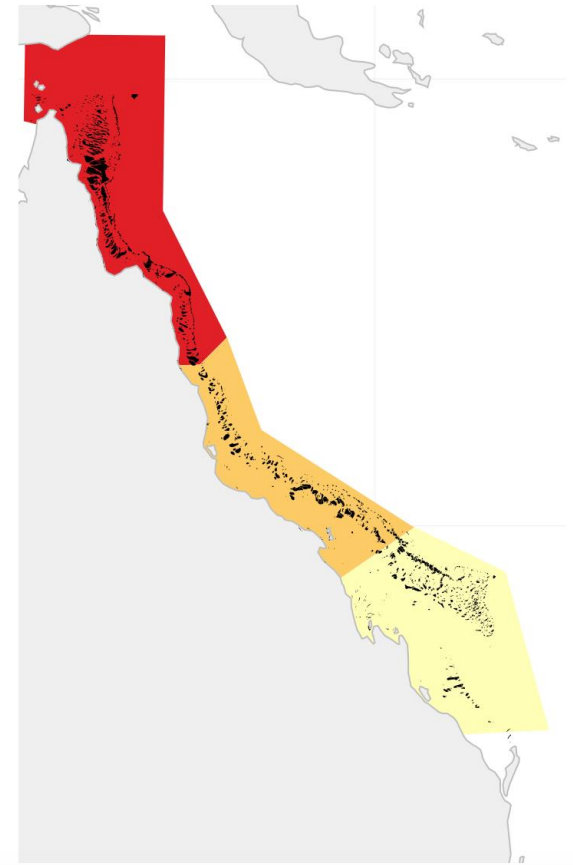
1998



2002

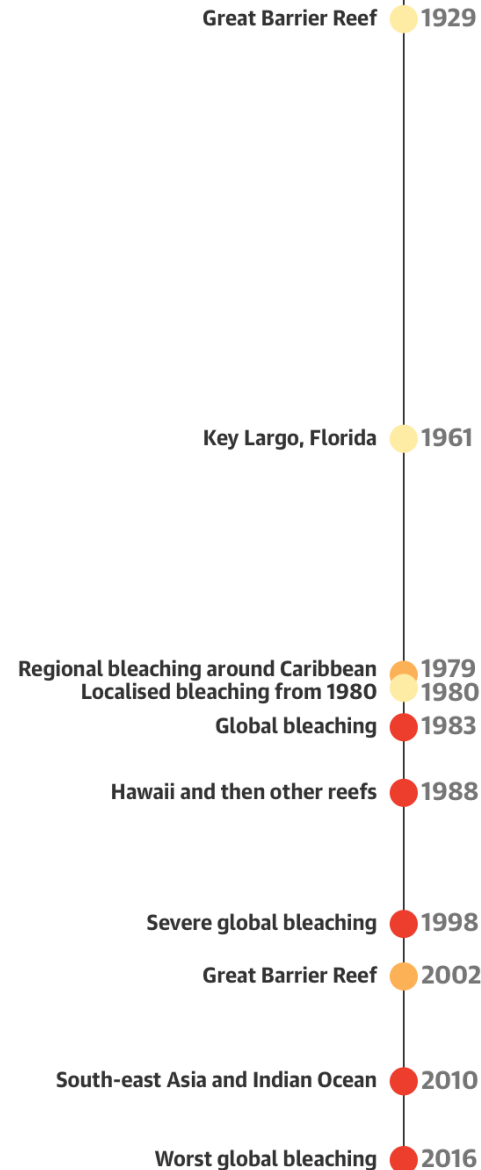
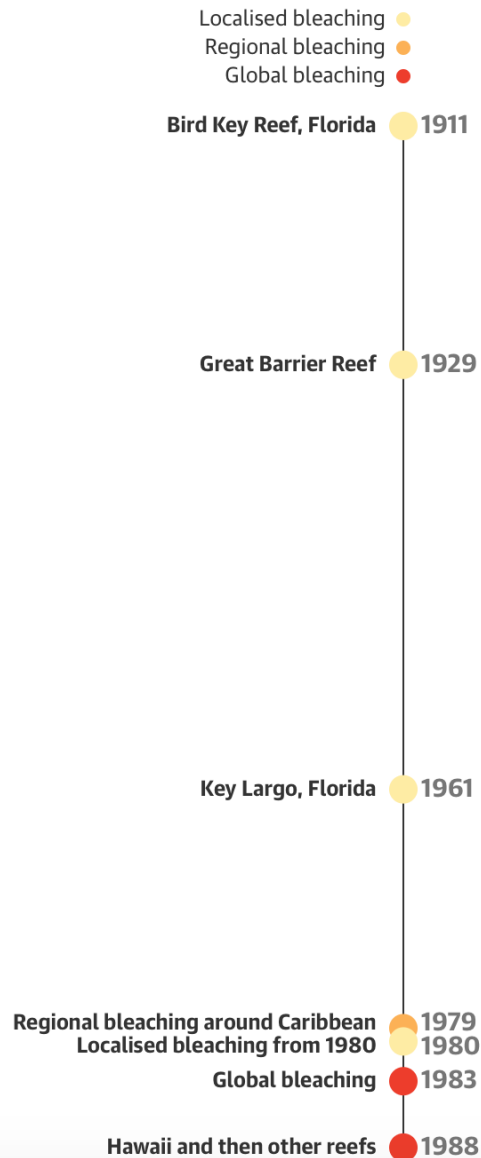


2016



Key bleaching events

Hover or tap on event for details



Sources: [Berkelmans et al \(2004\)](#), [Goreau and Hayes \(1994\)](#), [Williams and Bunkley-Williams \(1990\)](#)

<https://www.theguardian.com/environment/2016/jun/07/the-great-barrier-reef-a-catastrophe-laid-bare>

Australia's Great Barrier Reef was particularly hard hit by the 2016 bleaching event and now by the unexpected 2017 bleaching event, with the areas with severe bleaching shown in the figure below:

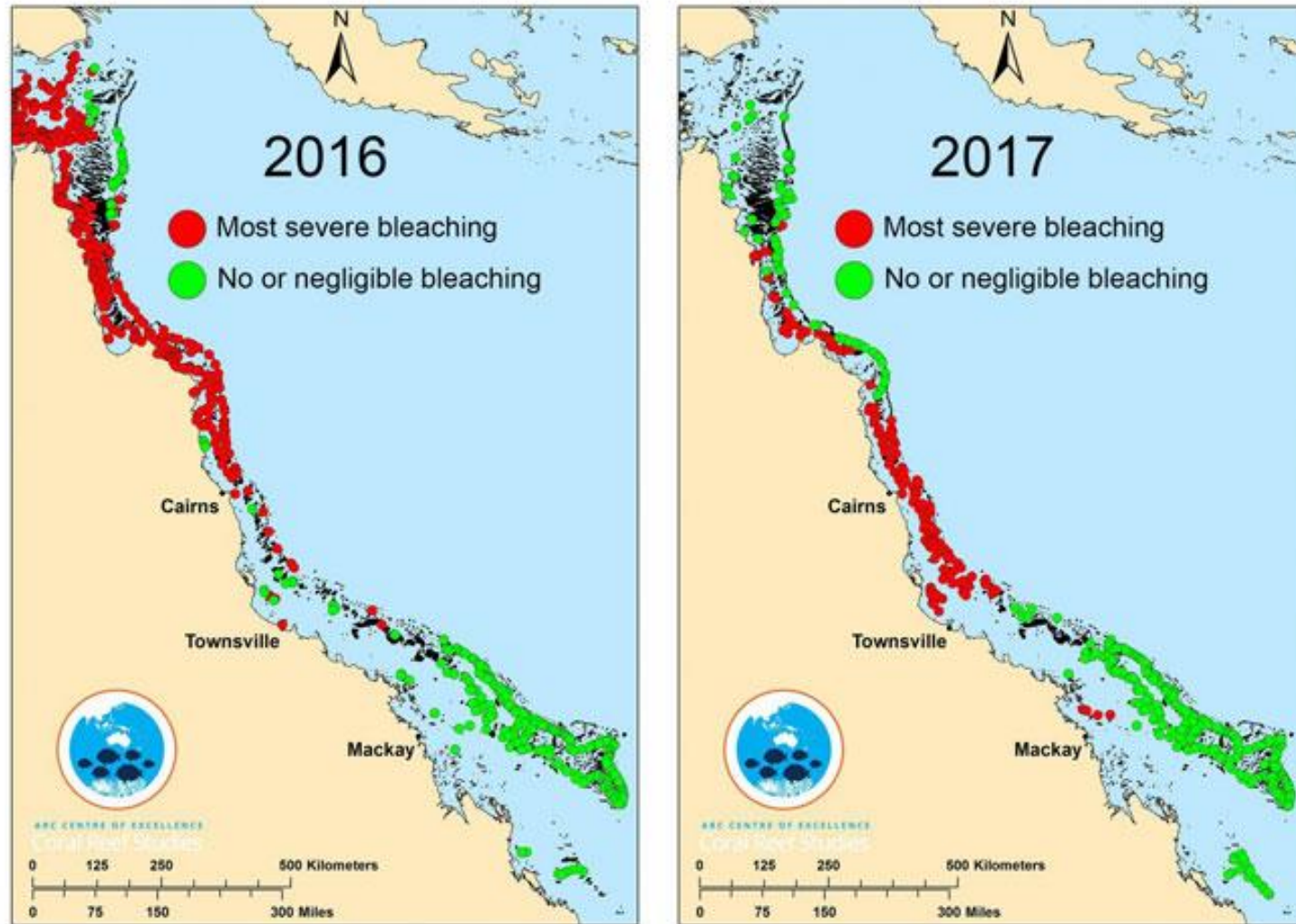
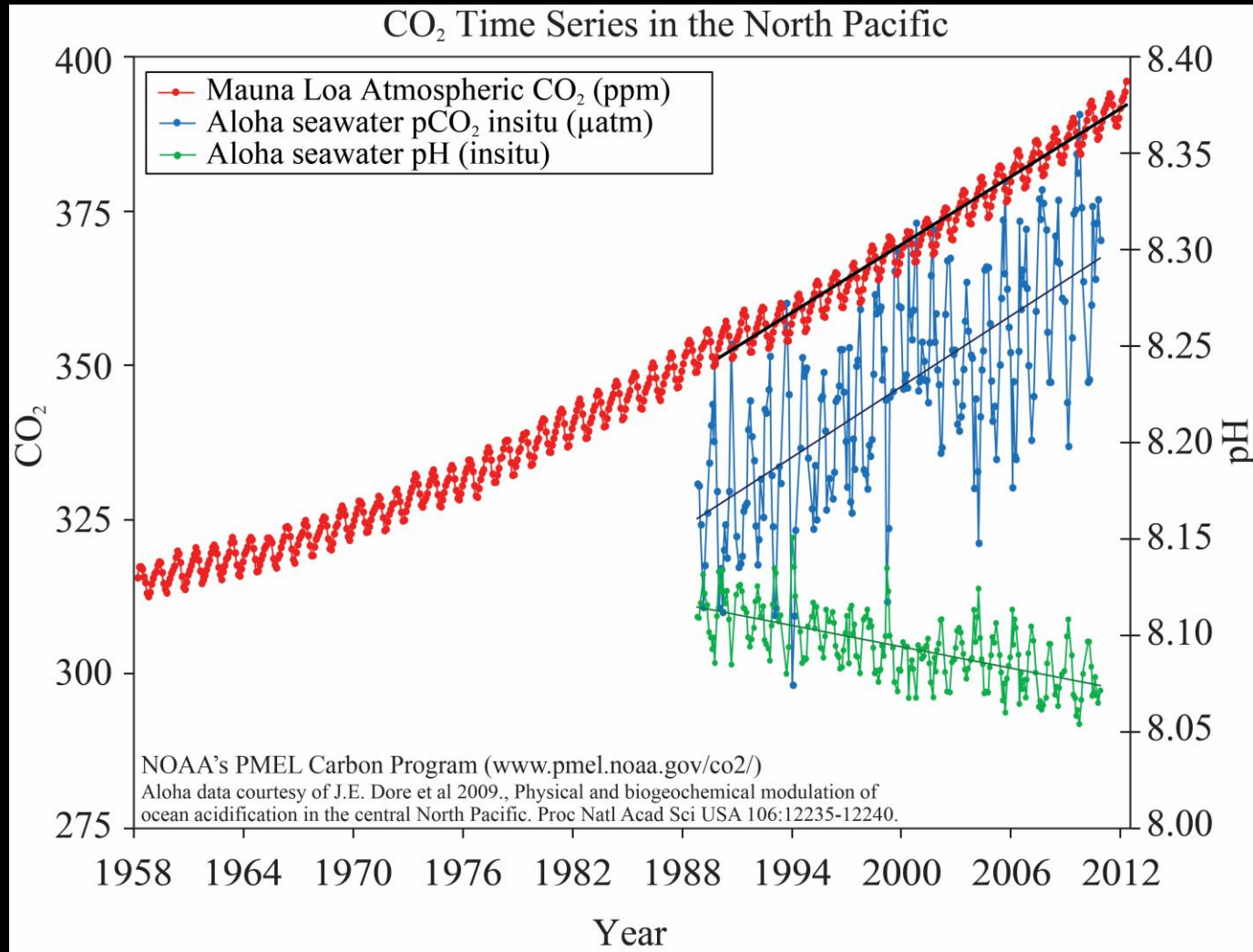


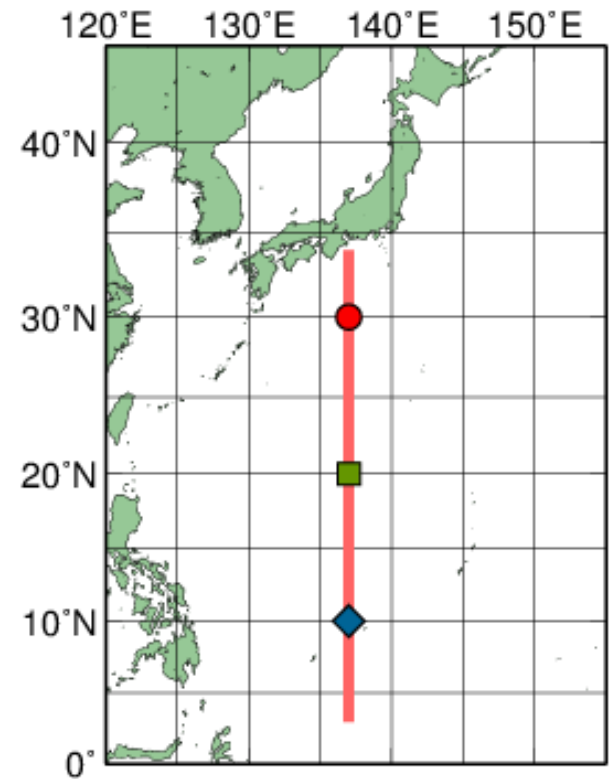
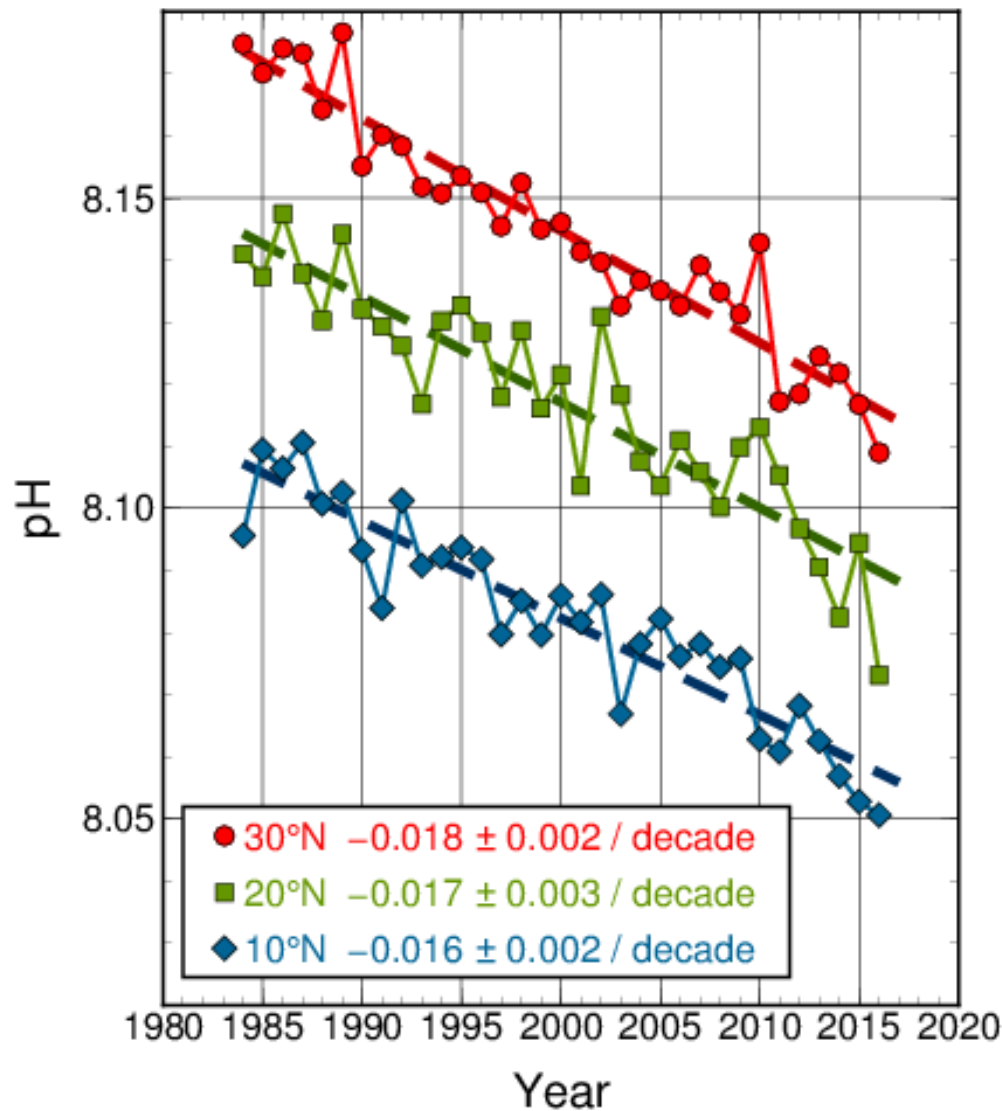
Figure from the ARC Centre of Excellence for Coral Reef Studies.

https://www.yaleclimateconnections.org/wp-content/uploads/2017/04/0417_ZH_Figure_8.jpg

High Atmospheric CO₂

Acidification of Upper Part of the Oceans





http://www.data.jma.go.jp/kaiyou/english/oa/oceanacidification_en.html

Values of pH in surface seawater have shown a clear long-term trend of decrease from 3°N and 34°N along the repeat hydrographic line at 137°E in winter (Jan. - Feb.) since 1984.

The rate of decrease is approximately 0.02 per decade at each latitude.

Ocean acidification slowing coral reef growth

Geochimica et Cosmochimica Acta 144 (2014) 72–81

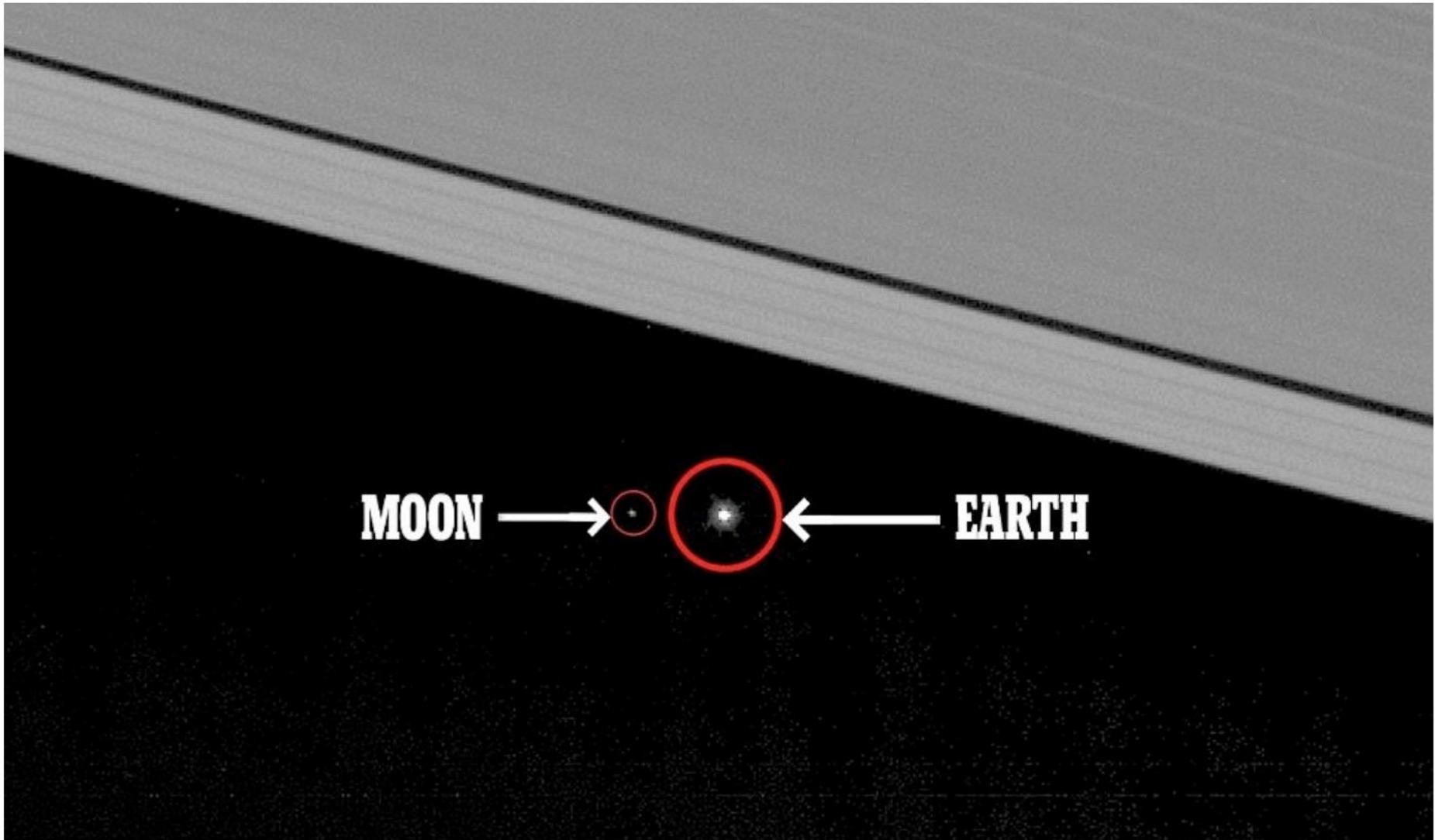
Community calcification in Lizard Island, Great Barrier Reef: A 33 year perspective

J. Silverman a,†, K. Schneider a, D.I. Kline b,c, T. Rivlin d,e, A. Rivlin d, S. Hamylton f, B. Lazar e, J. Erez e, K. Caldeira a

Measurements of community calcification (G_{net}) were made during September 2008 and October 2009 on a reef flat in Lizard Island, Great Barrier Reef, Australia, 33 years after the first measurements were made there by the LIMER expedition in 1975.

In 2008 and 2009, we measured $G_{\text{net}} = 61 \pm 12$ and 54 ± 13 mmol CaCO_3 $\text{m}^{-2} \cdot \text{day}^{-1}$, respectively.

These rates are 27–49% lower than those measured during the same season in 1975–76.



Cassini captured this extraordinary photo on April 12 at a distance of 1,400 million km from Earth. Image Credit: **NASA/JPL**



Thank You!

Tampering can be dangerous.
Nature can be vengeful.
We should have a great deal of

Respect

for the planet on which we live!

Rossby, 1956

What's Really Warming the World?

By Eric Roston and Blacki Migliozi | June 24, 2015

Skeptics of manmade climate change offer various natural causes to explain why the Earth has warmed 1.4 degrees Fahrenheit since 1880. But can these account for the planet's rising temperature? Scroll down to see how much different factors, both natural and industrial, contribute to global warming, based on findings from NASA's Goddard Institute for Space Studies.

