

Box 15.1 Climate Research: The Pioneers

The French mathematician Jean-Baptiste-Joseph de Fourier (1768-1830) suggested in 1827 that the atmosphere keeps the Earth warm by trapping heat as a plate of glass would. It is known today that the comparison of the atmosphere to a greenhouse is incorrect, but Fourier did suggest that the natural climate could be perturbed as a result of human activities. In 1859, the Irish physicist John Tyndall (1820-1893) measured the absorption of various gases, and established that water vapor, carbon dioxide, and methane were trapping infrared (terrestrial) radiation, while the most abundant atmospheric gases, nitrogen and oxygen, were not. He suggested that ice ages in the past could have been caused by changes in the atmospheric abundance of radiatively active gases.



Tyndall

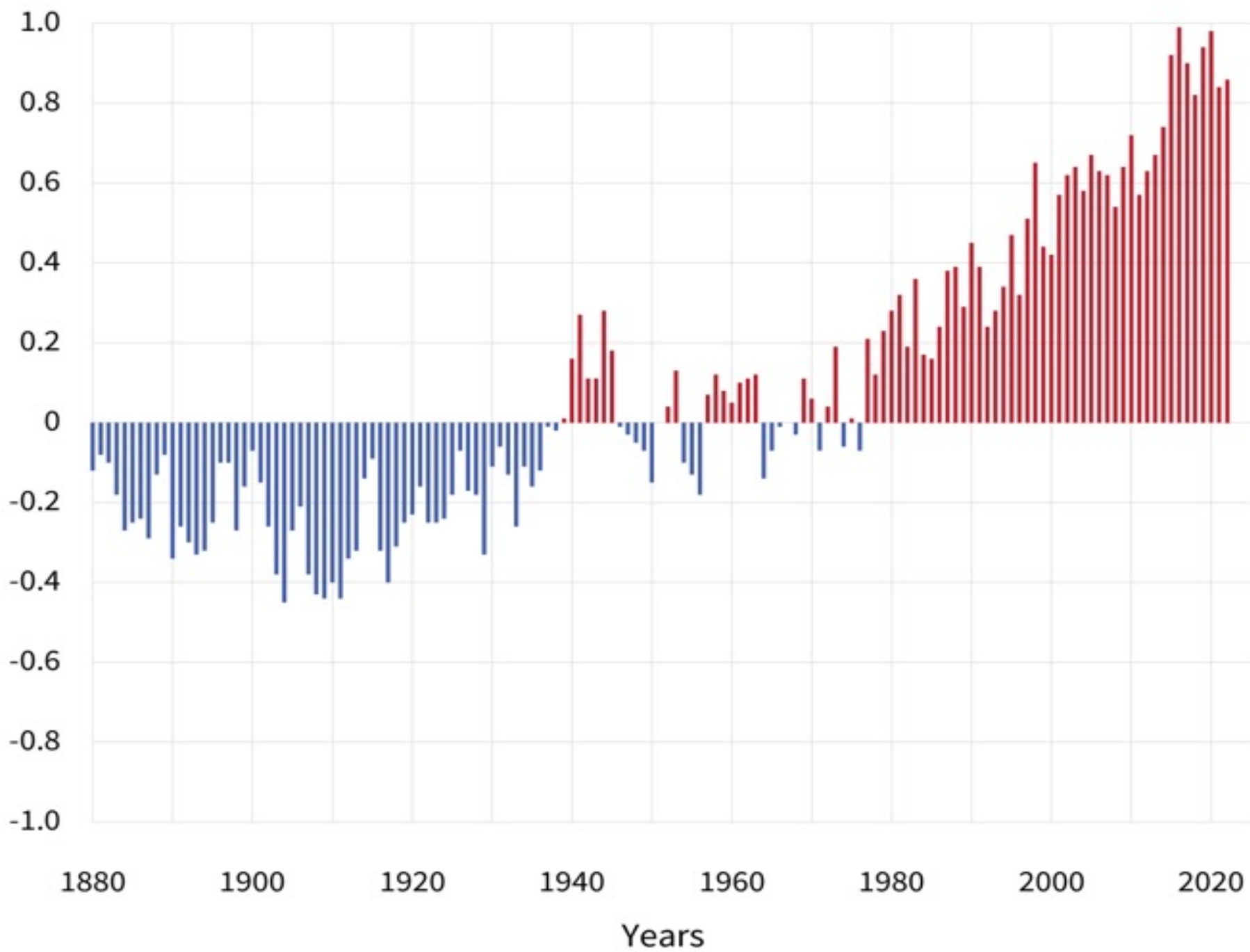


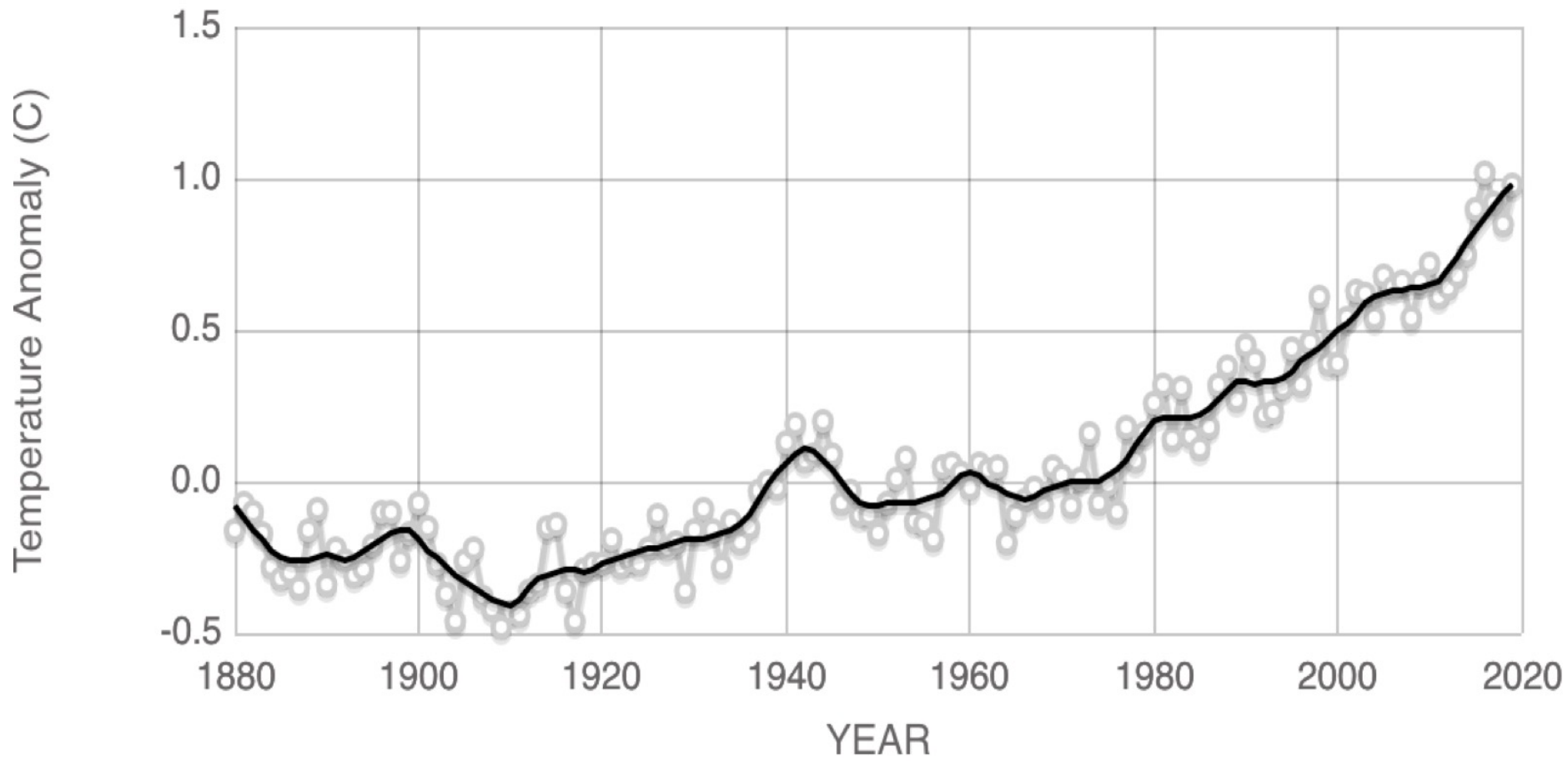
Arrhenius

In 1896 the Swedish scientist Svante Arrhenius (1859-1927), who was awarded the Nobel Prize for Chemistry in 1903, theorized that a doubling in the natural concentration of carbon dioxide in the air would increase the Earth's global mean temperature by 5-6 degrees Celsius. He pointed out that such a change was likely due to the rapid expansion of industry, and because, as he stated, "we are evaporating our coal mines into the air." In 1938 Guy Stewart Callendar, an engineer working for British Electrical Industries, noted that the level of CO₂ had increased by some 10 percent since the 1890s and that it could explain the rise in temperature recorded over the same period of time.

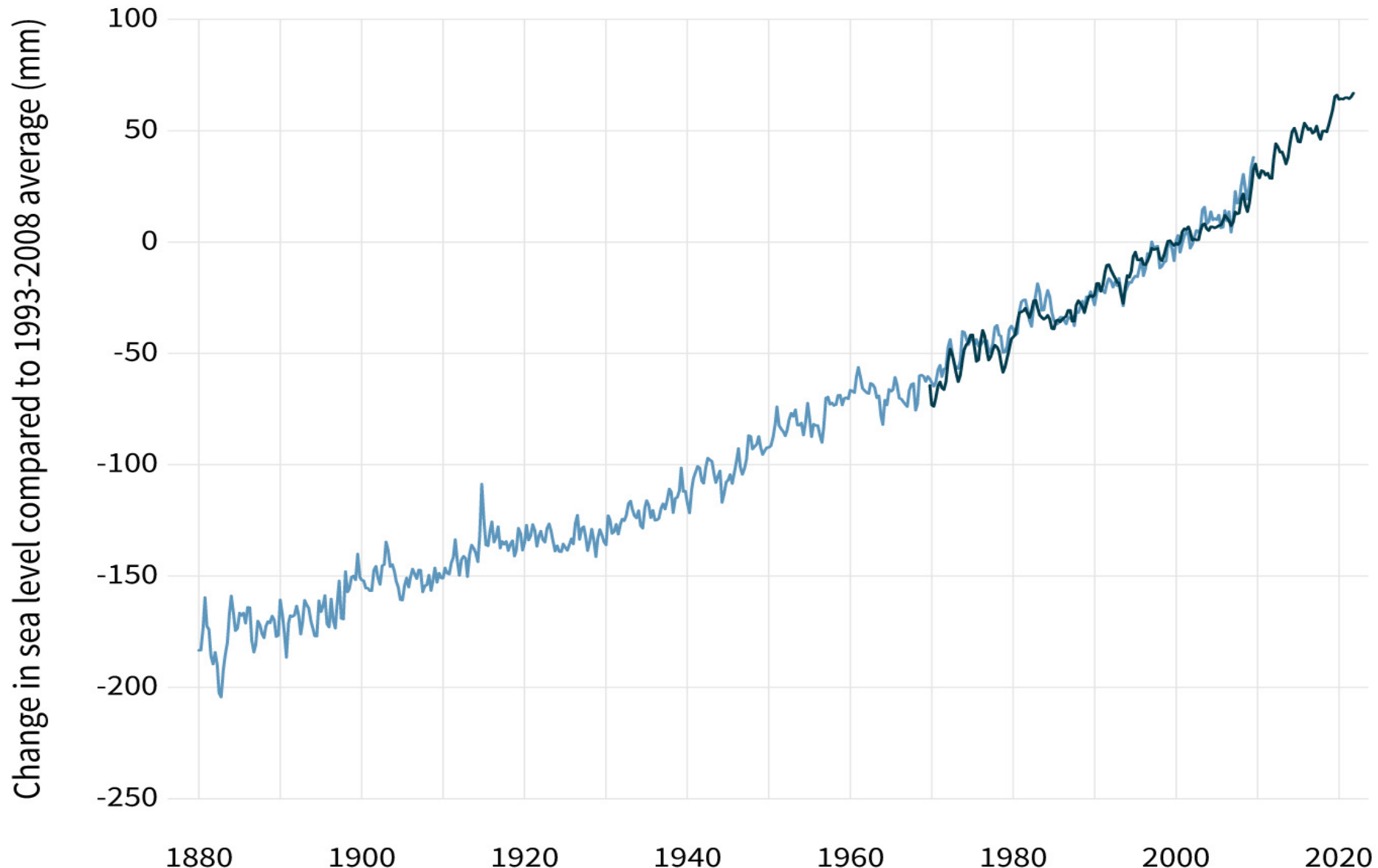
It was not, however, until the early 1960s that the potential importance of global warming was recognized after the American geochemist Charles D. Keeling reported a continuous increase in the abundance of CO₂ observed in a region as remote as the Mauna Loa Observatory in Hawaii. In the past decades, the question of global warming has led to much debate and even to controversies. The complexity of the problem, including the role played by atmospheric constituents other than CO₂, is taken into account in current studies.

Difference from 1901-2000 average ($^{\circ}\text{C}$)

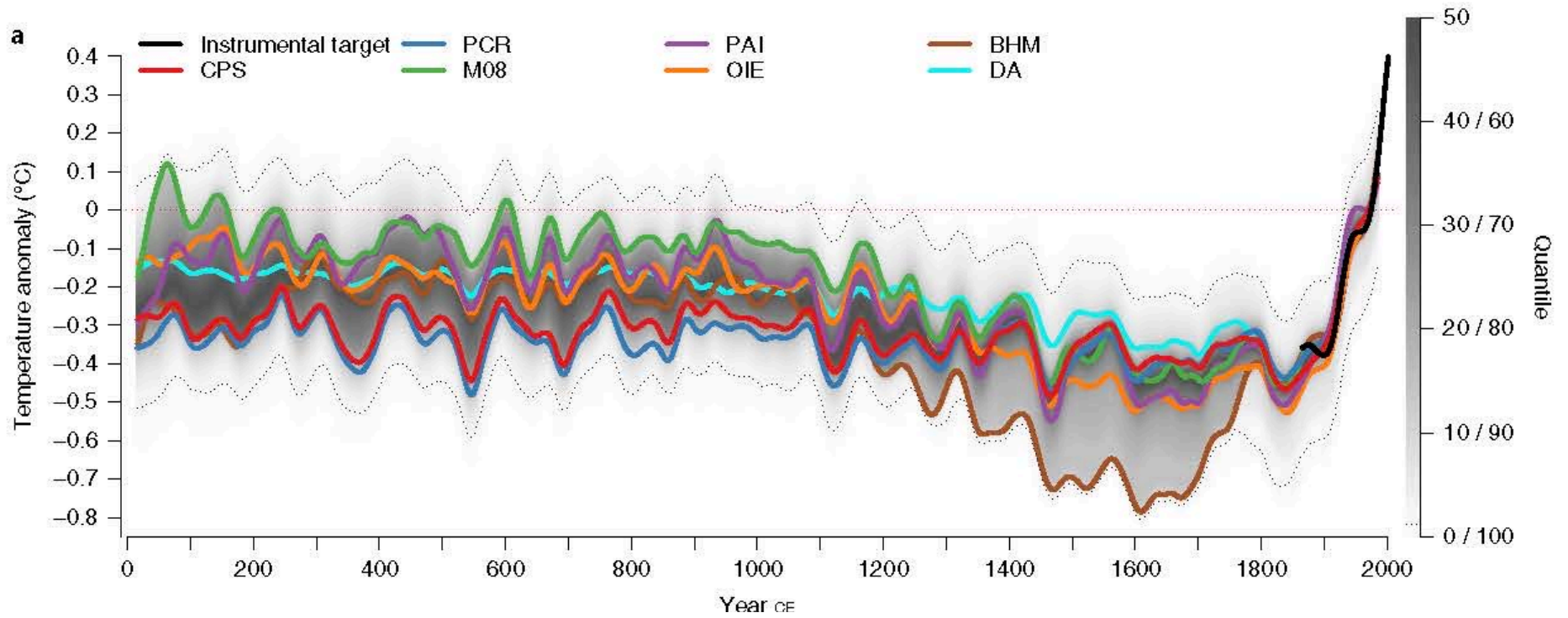




Source: climate.nasa.gov



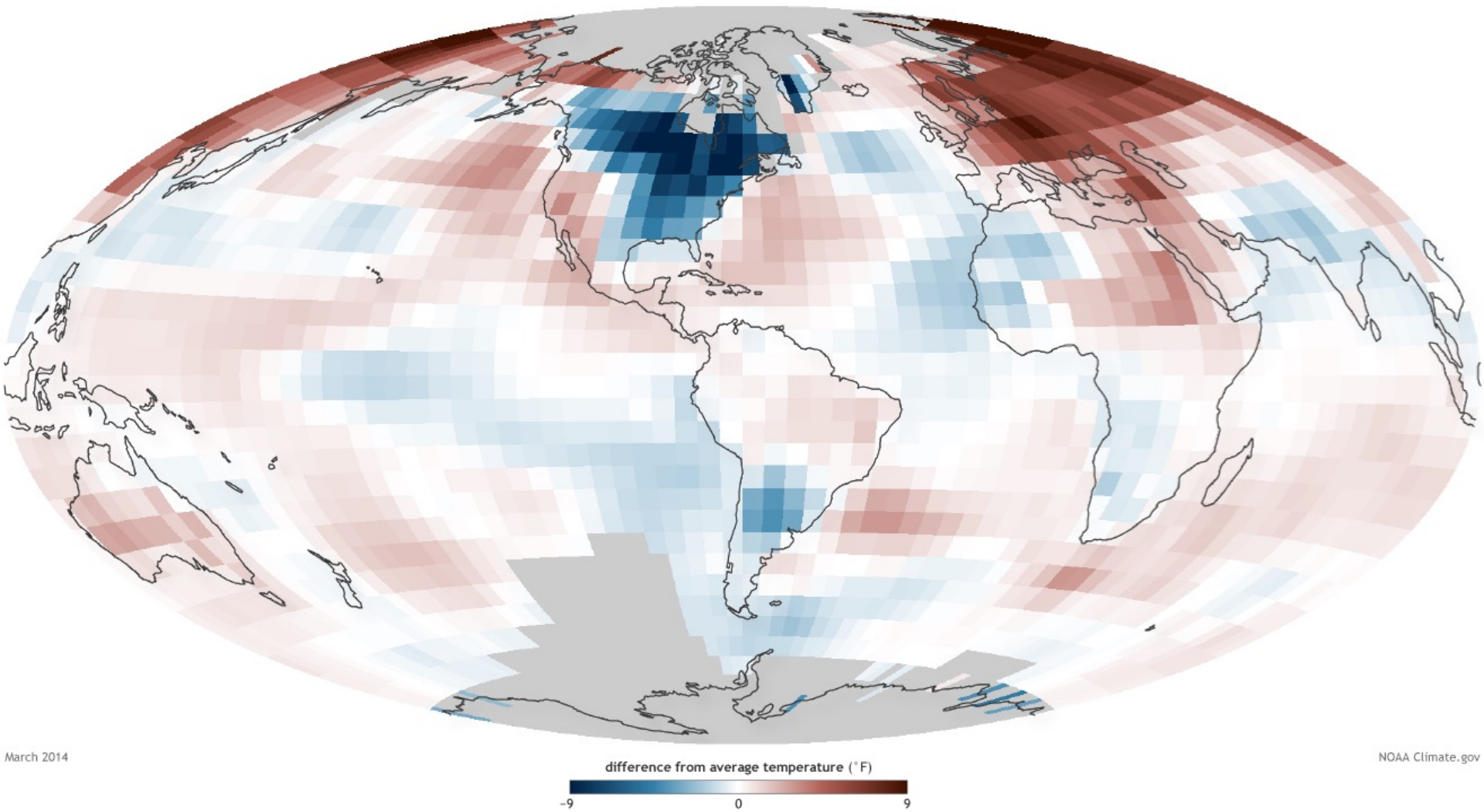
Seasonal (3-month) sea level estimates from Church and White (2011) (light blue line) and University of Hawaii Fast Delivery sea level data (dark blue). The values are shown as change in sea level in millimeters compared to the 1993-2008 average. NOAA Climate.gov image based on analysis and data from Philip Thompson, University of Hawaii Sea Level Center.

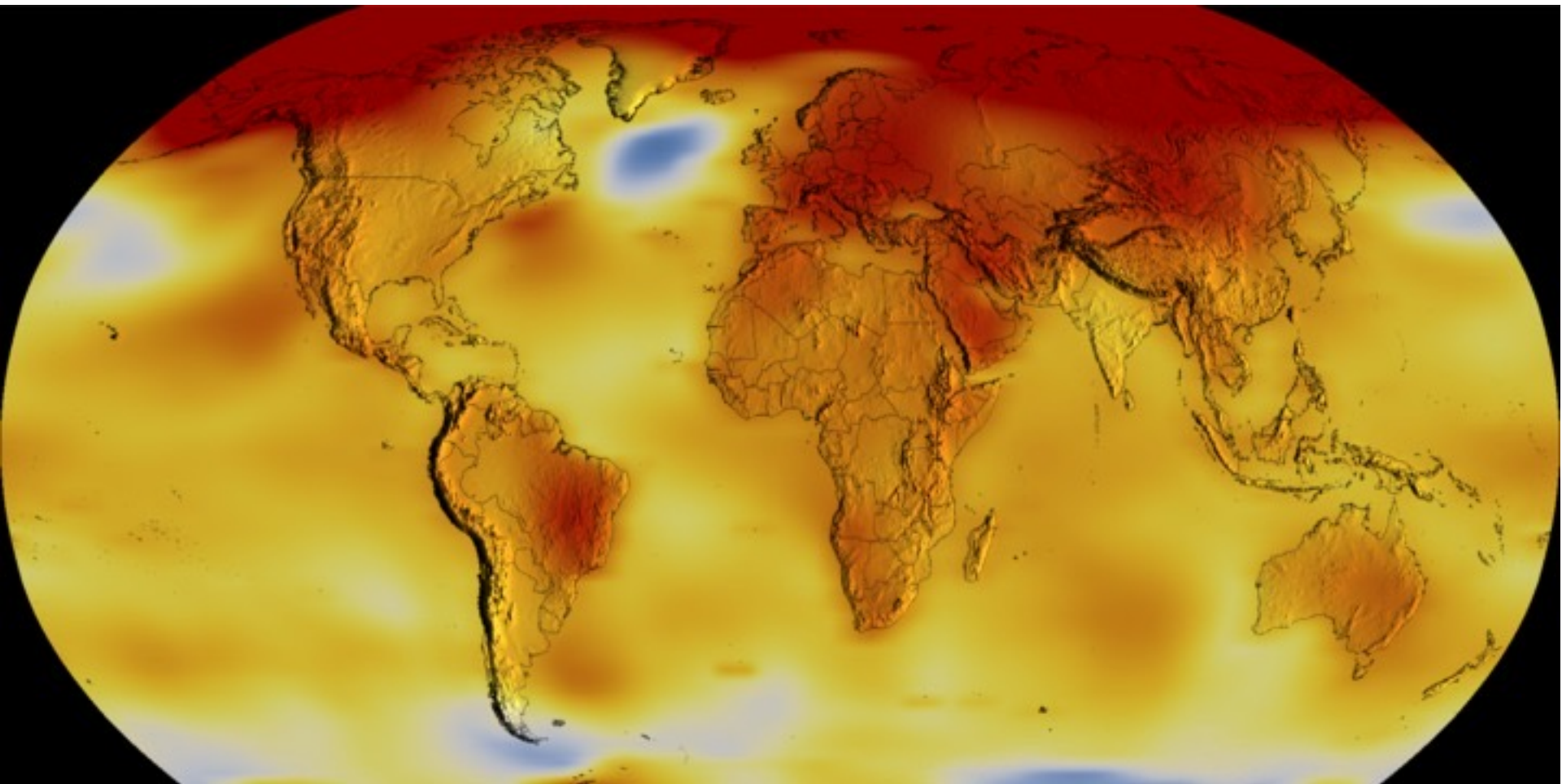


Newcom et al. 2019 NatureGeoscience

Departure of temperature from long term average (°F)

March 2014





January 2019 departure from 1880, color range -2 to +4F

<https://climate.nasa.gov/vital-signs/global-temperature/>





February 5 2020 Imperial Palace Kyoto



February 5 2020 Demachiyanagi



February 5 2020 Demachiyanaagi



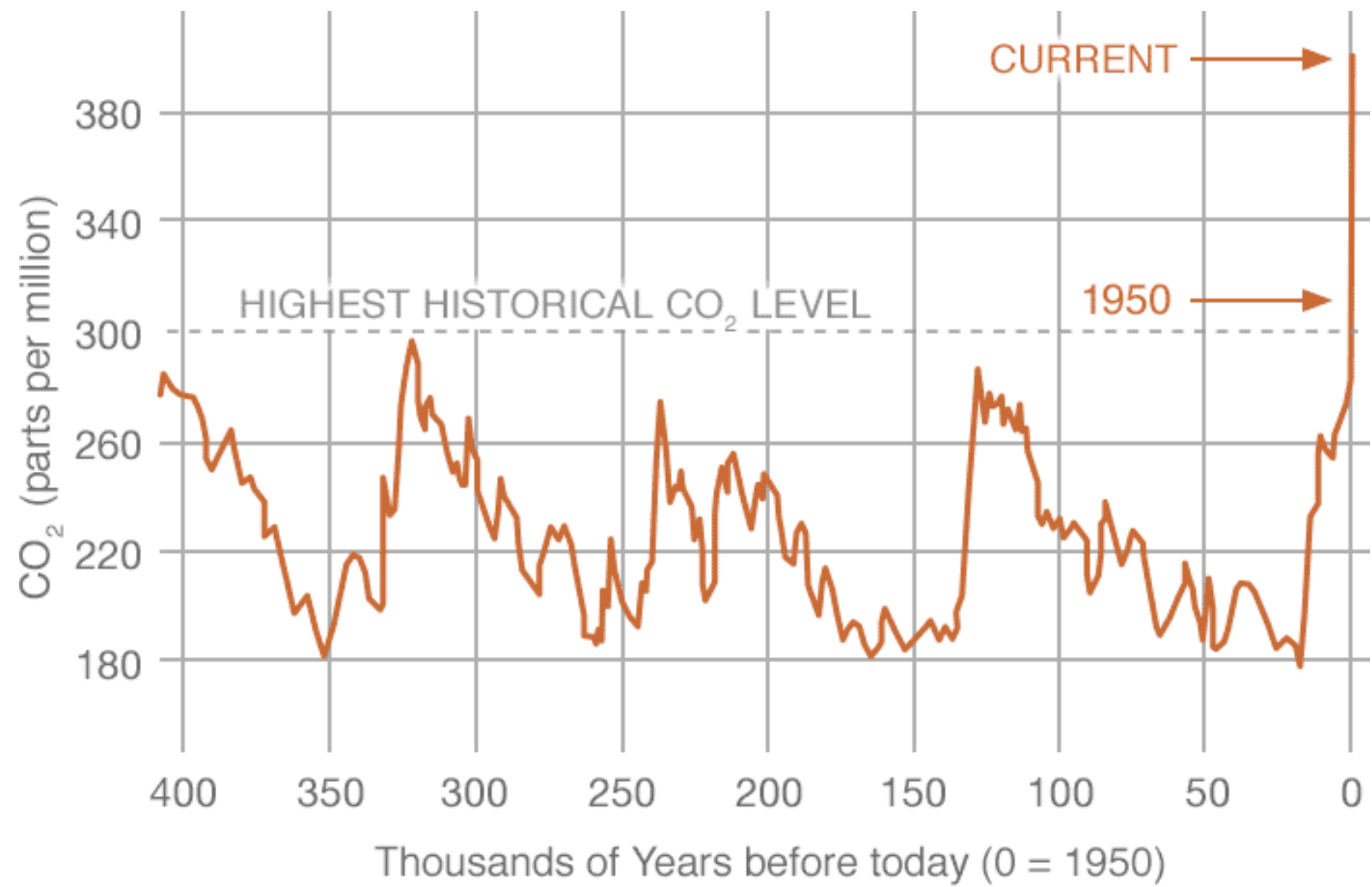
February 9 2020



February 9 2020



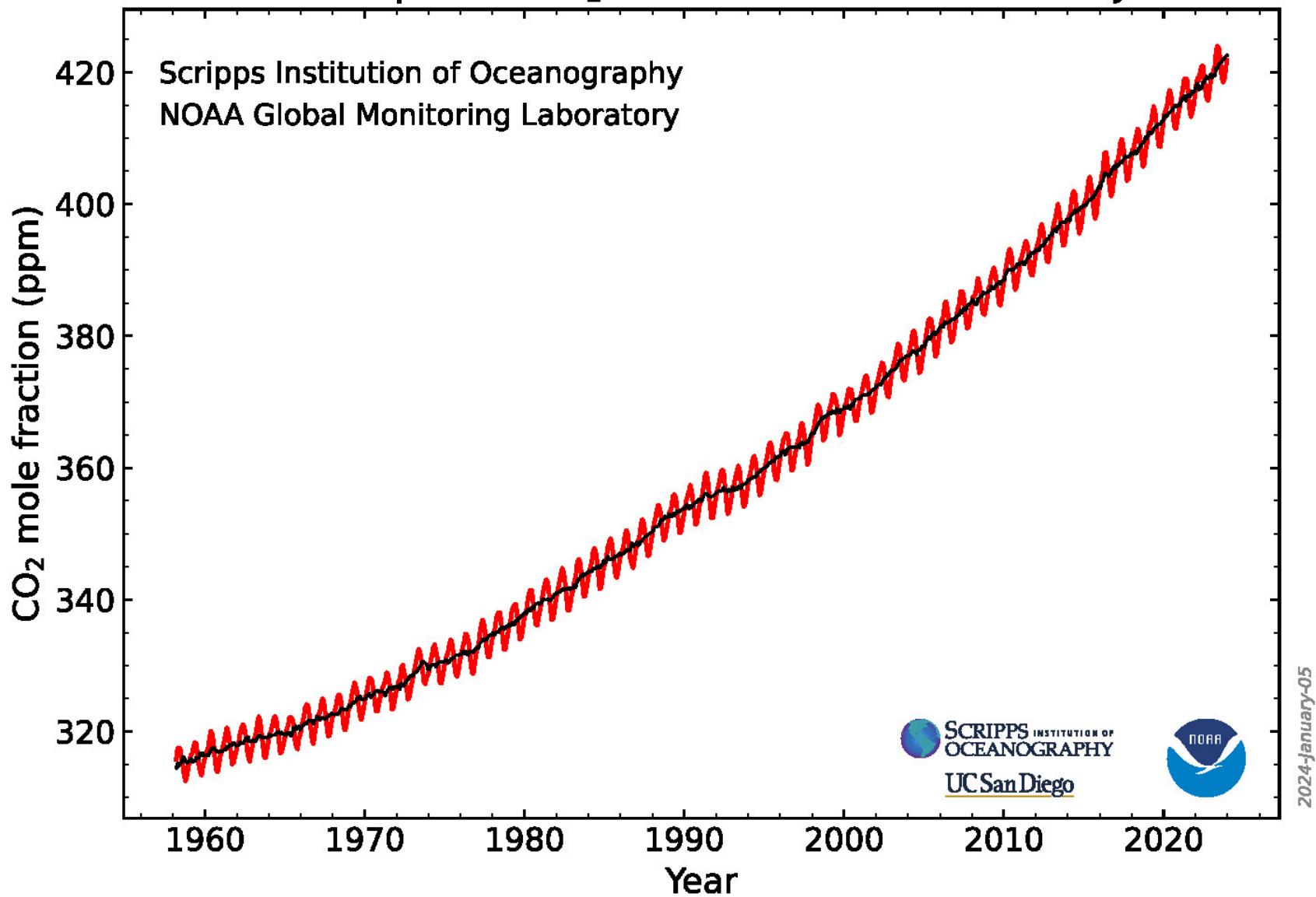
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NOAA

Atmospheric CO₂ at Mauna Loa Observatory



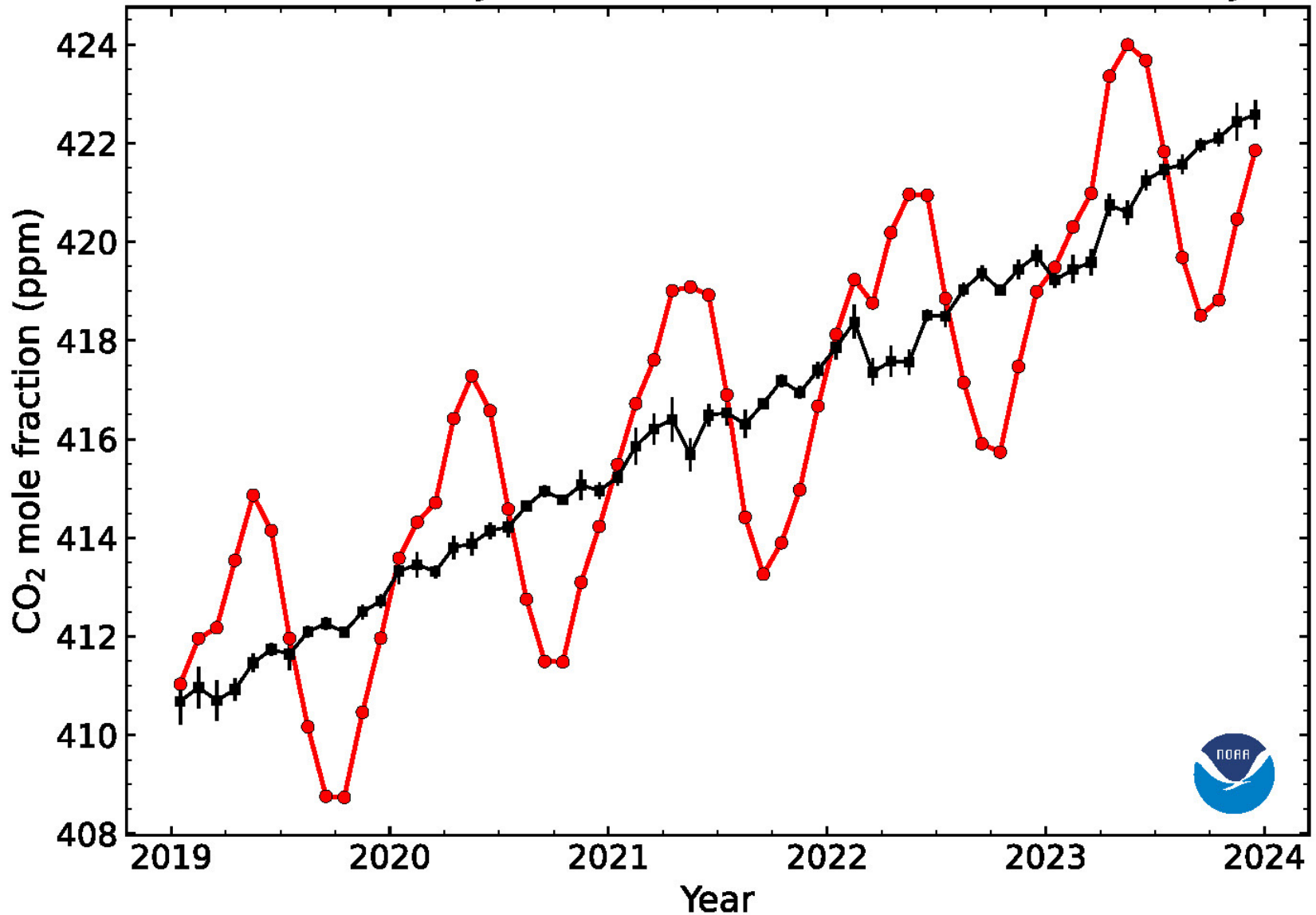
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory

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UC San Diego



2024-january-05

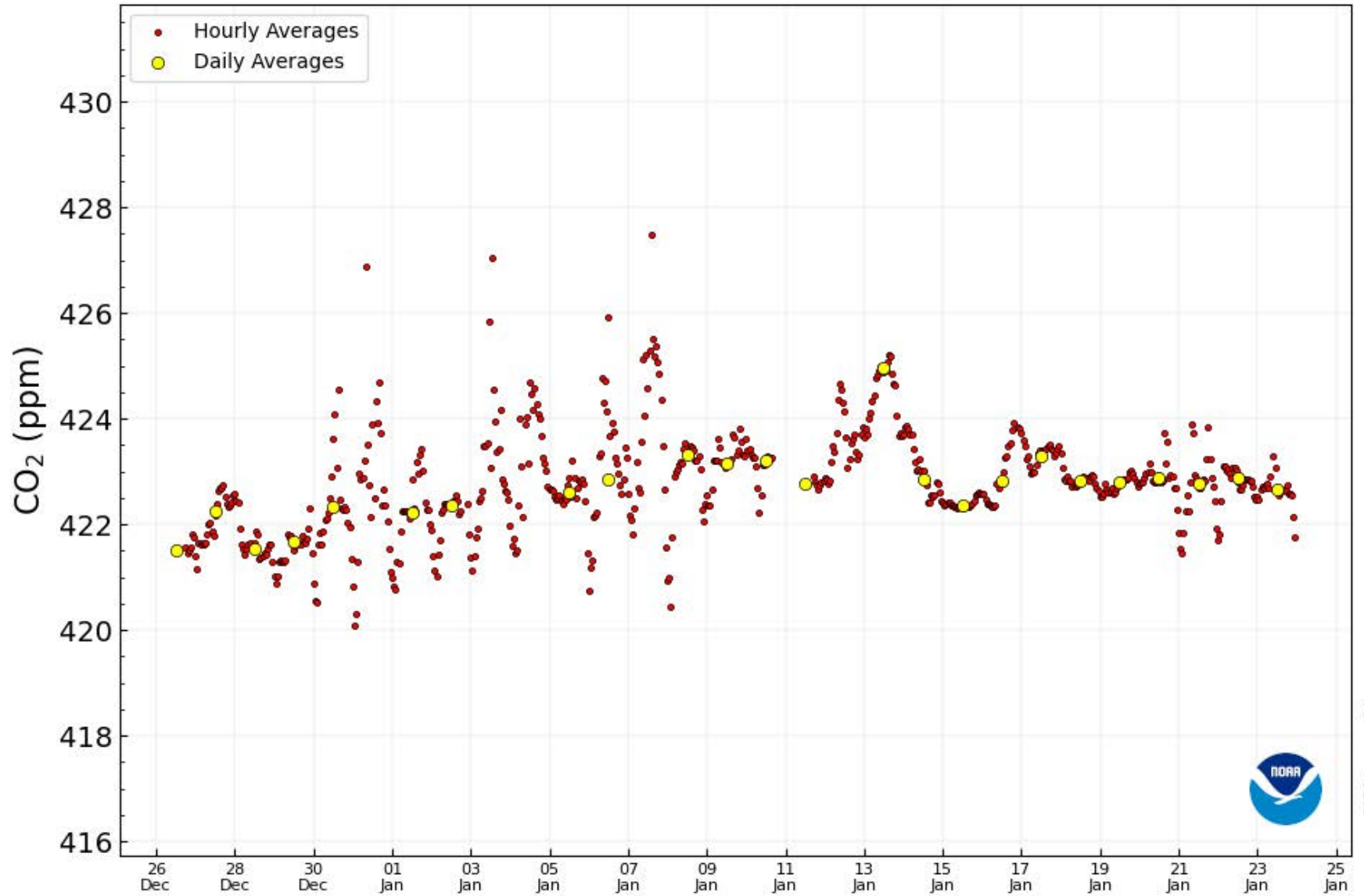
Recent Monthly Mean CO₂ at Mauna Loa Observatory



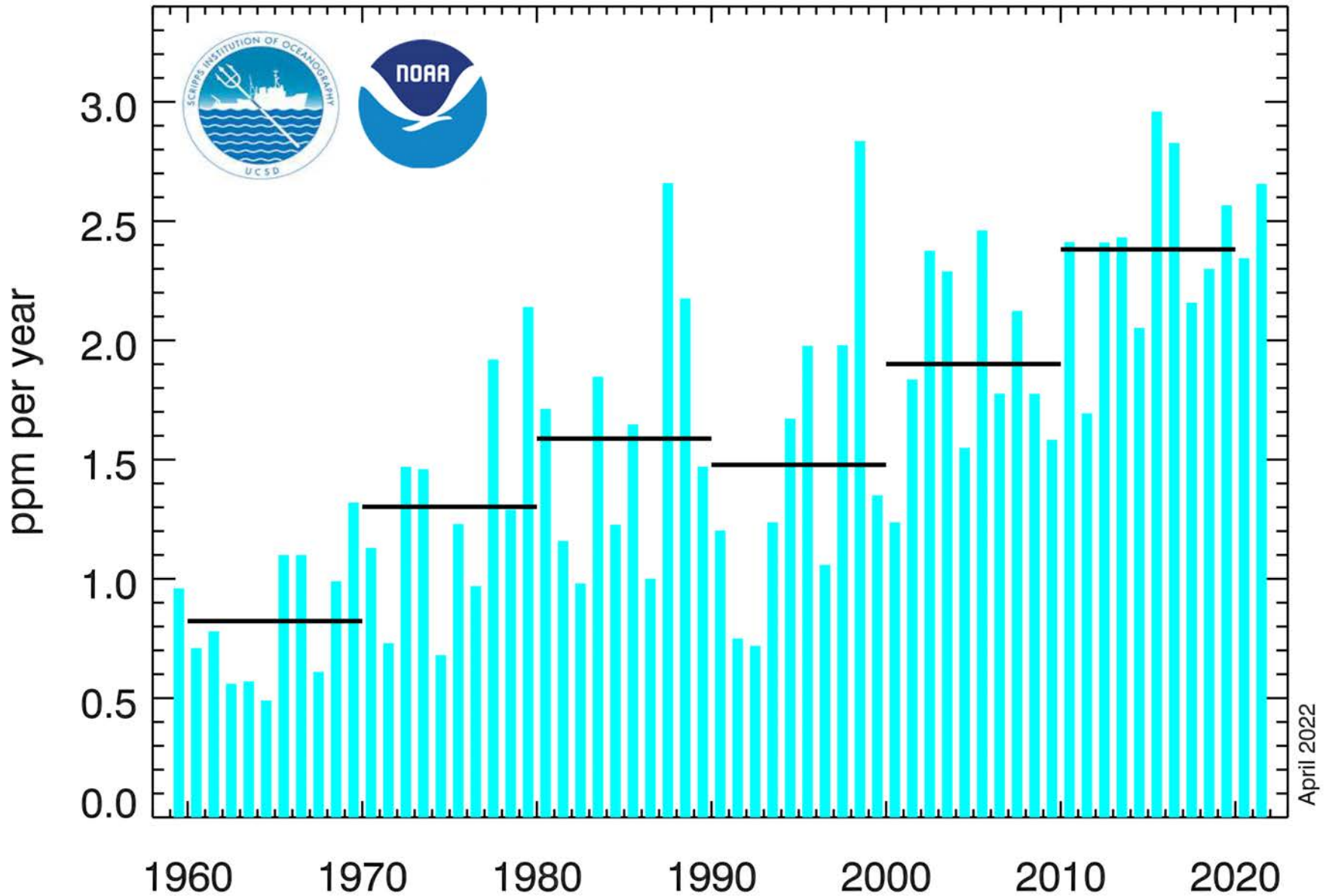
2024-January-05



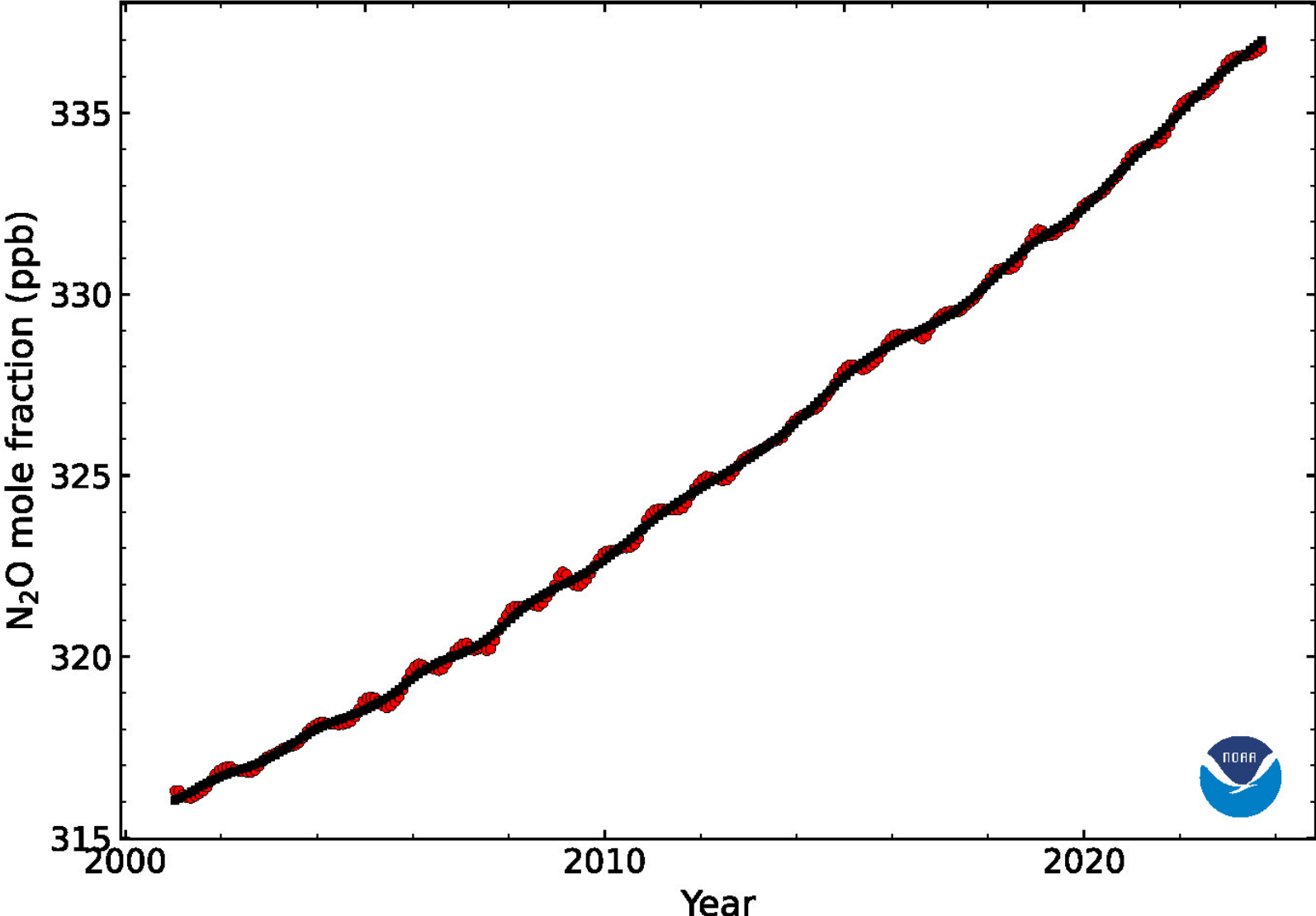
Mauna Loa Carbon Dioxide



Annual mean global growth rate of CO₂

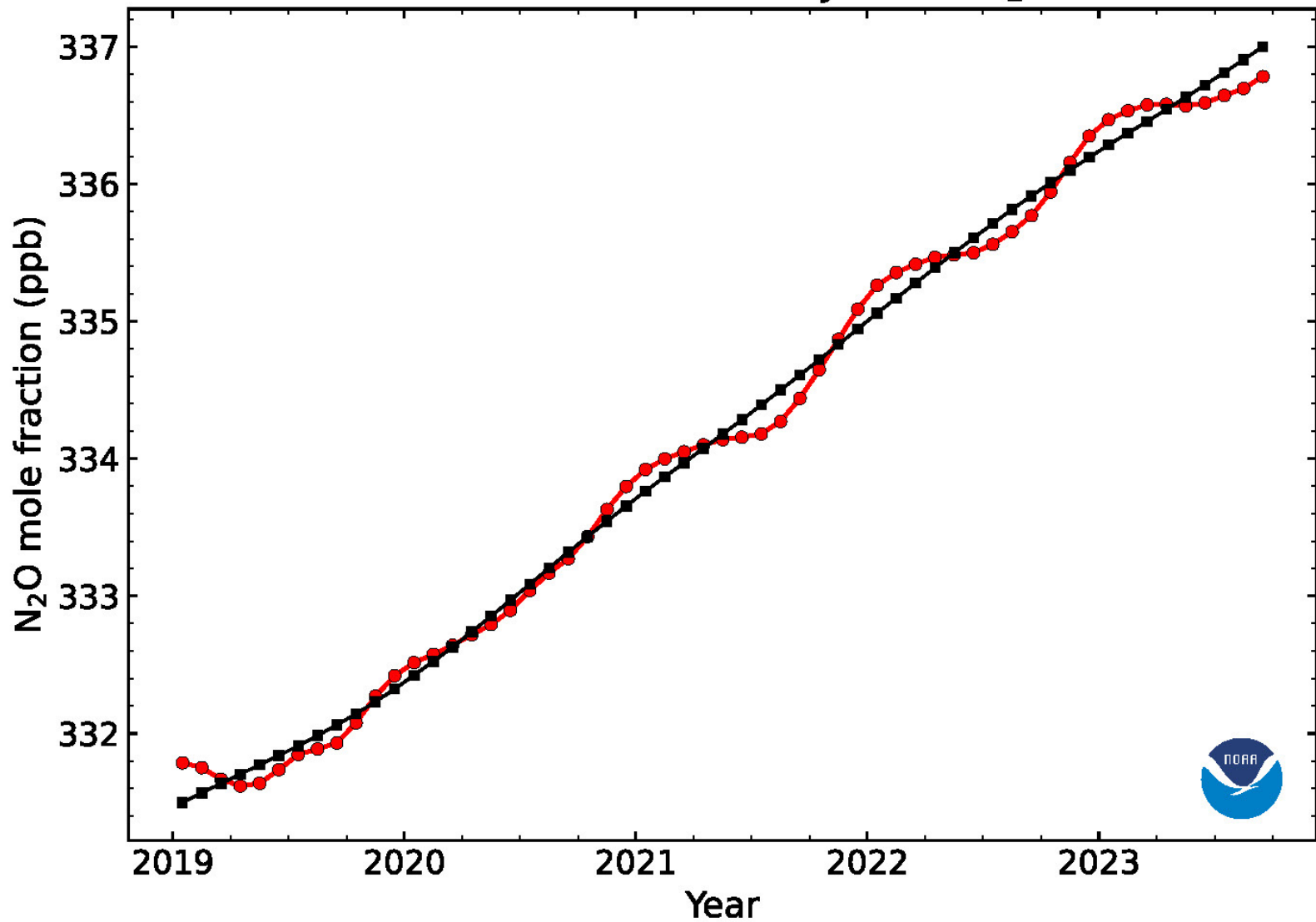


Global Monthly Mean N₂O



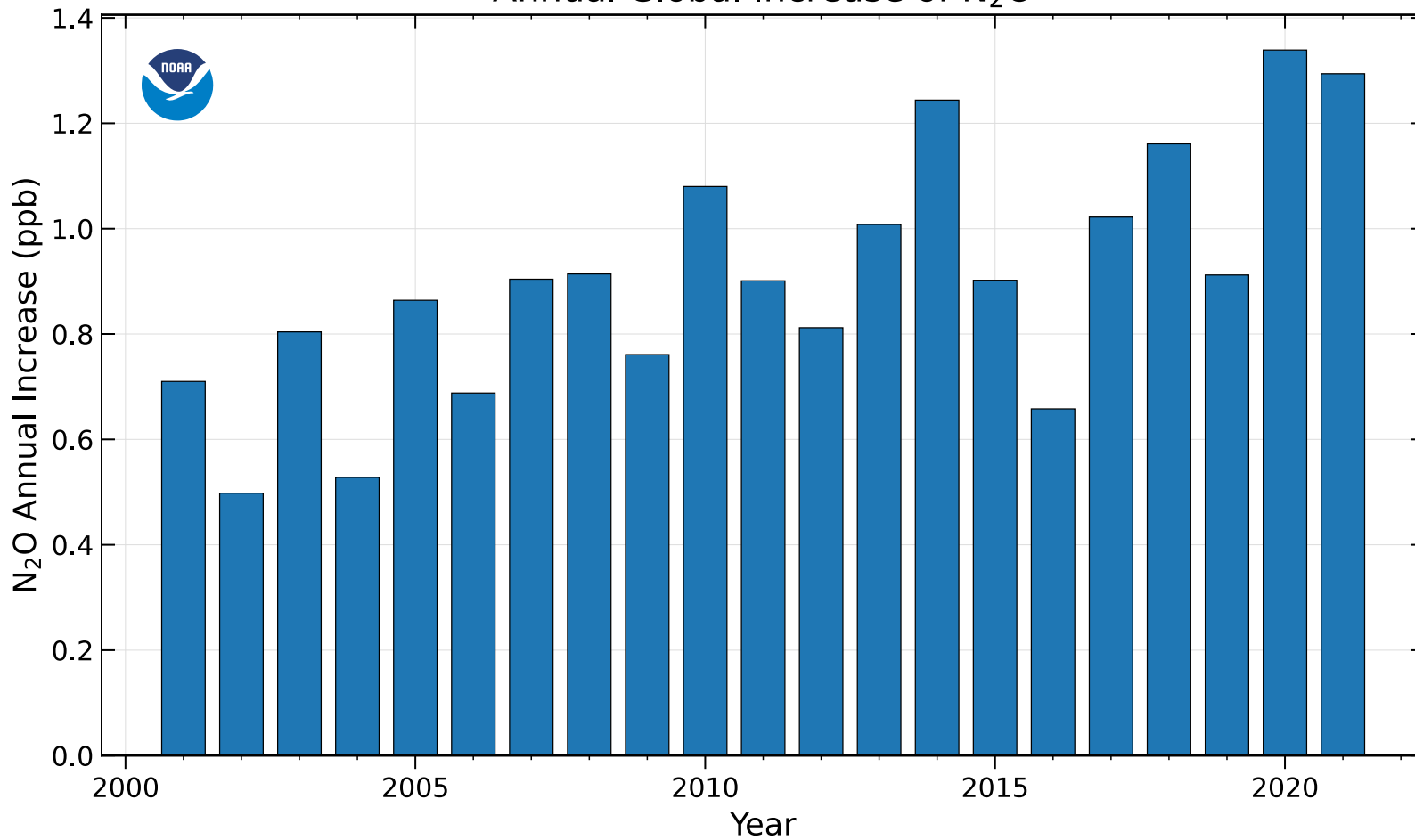
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Recent Global Monthly Mean N₂O



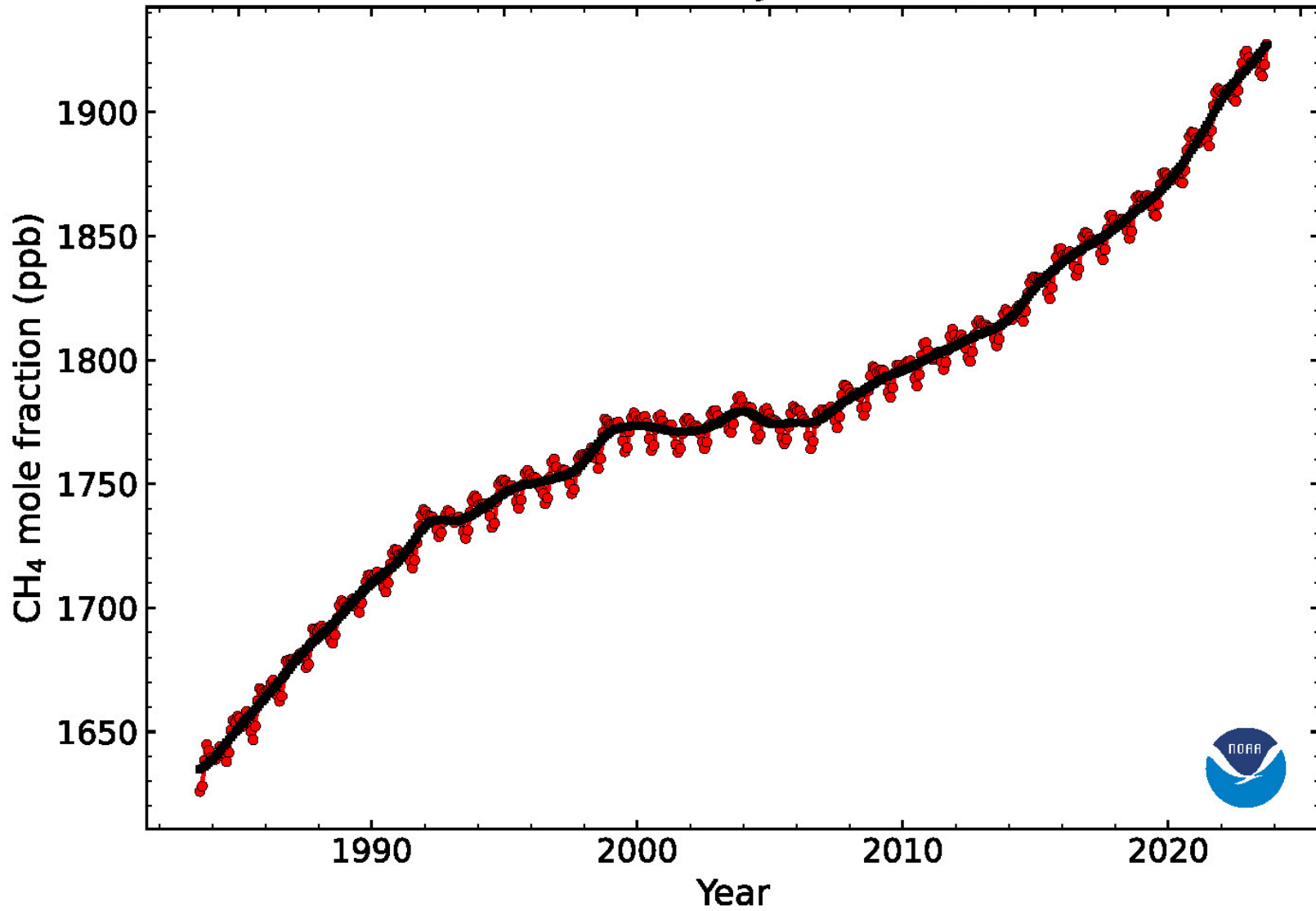
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Annual Global Increase of N₂O



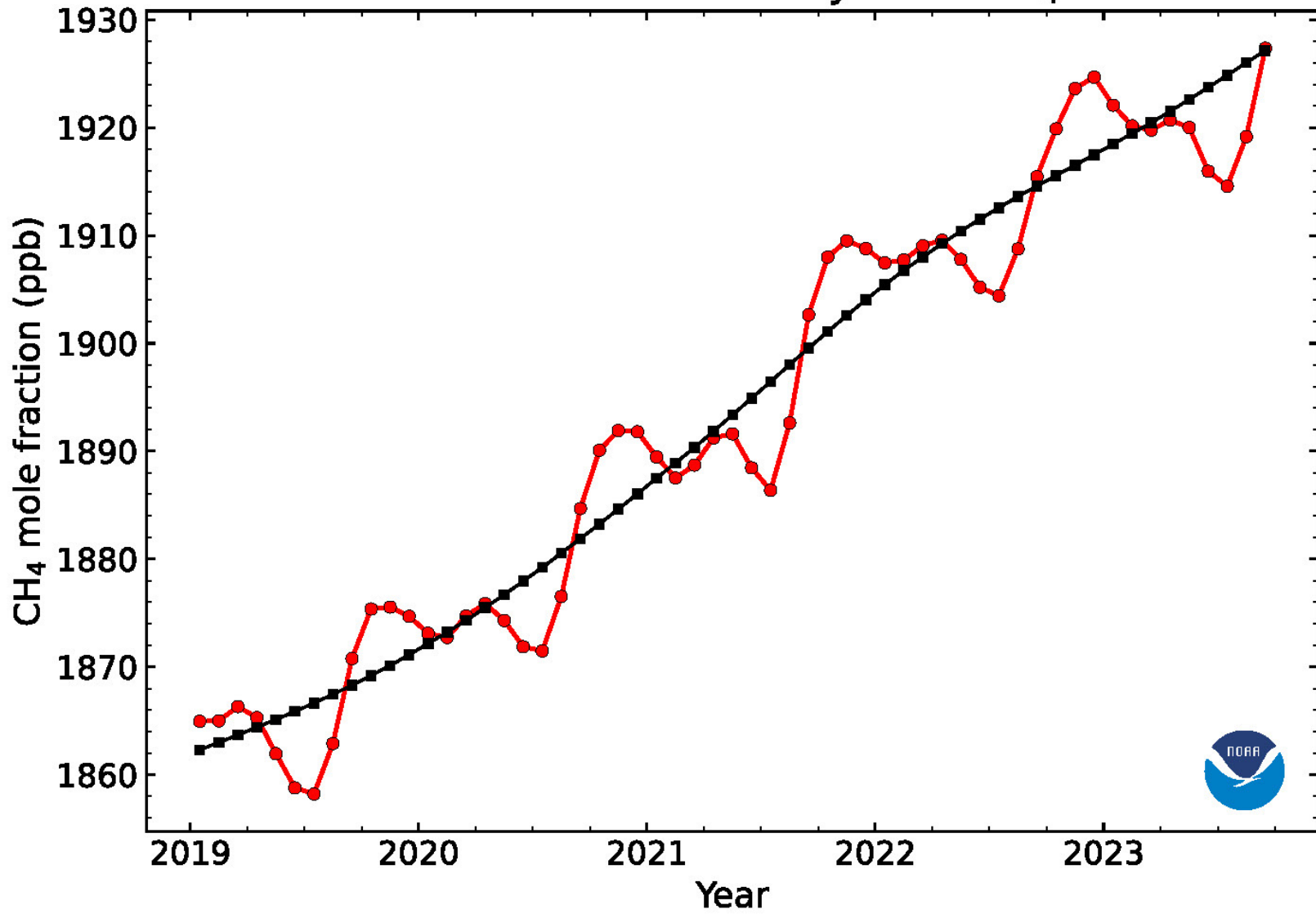
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Global Monthly Mean CH₄



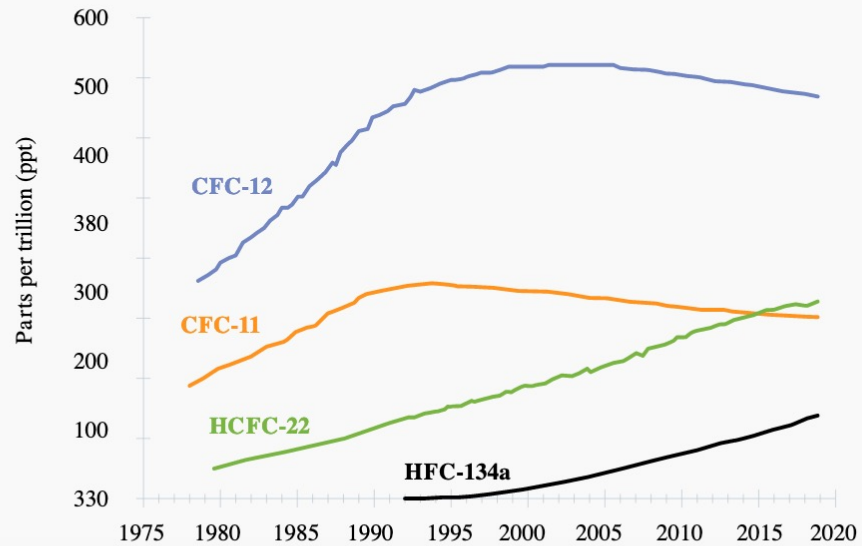
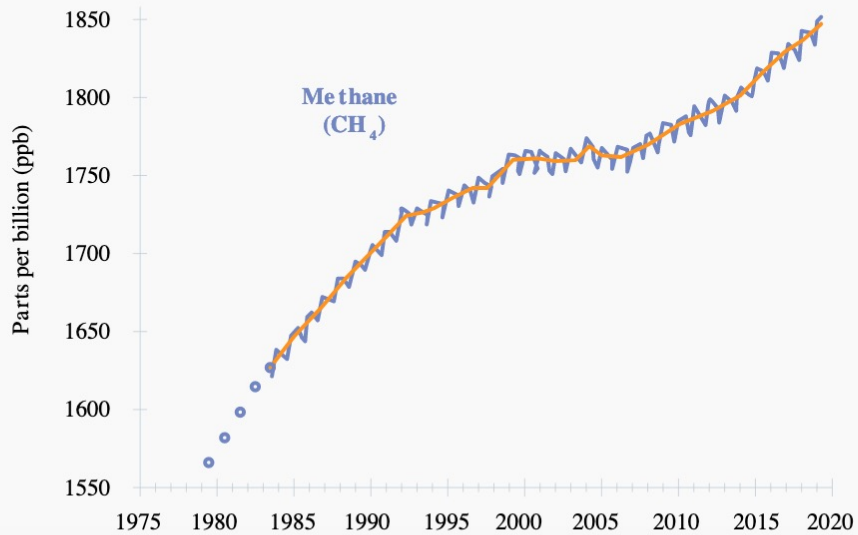
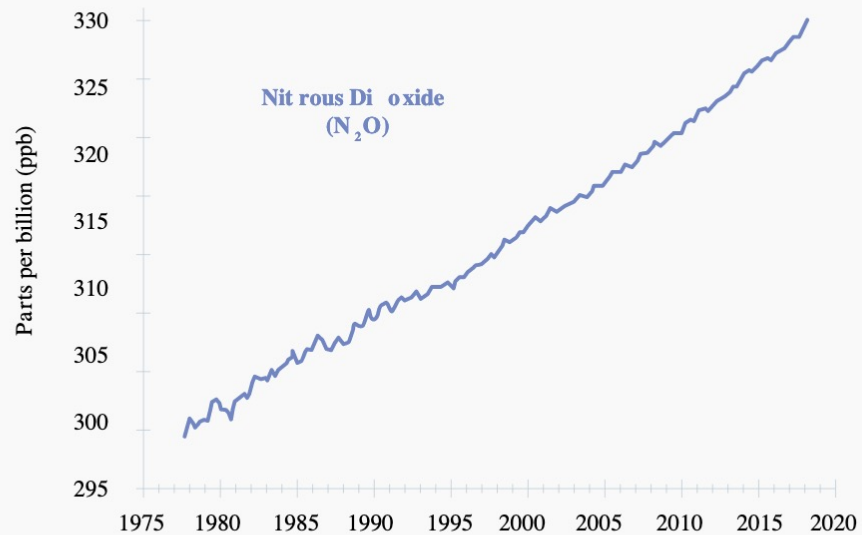
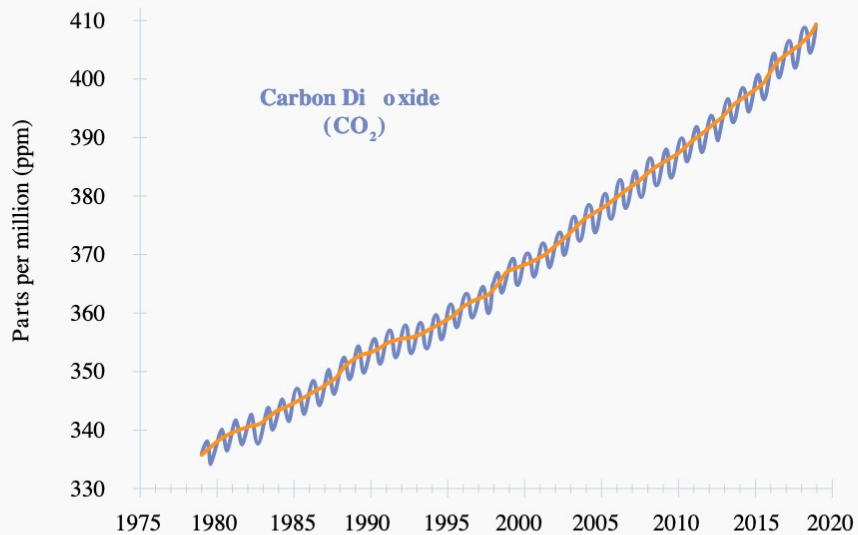
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Recent Global Monthly Mean CH₄

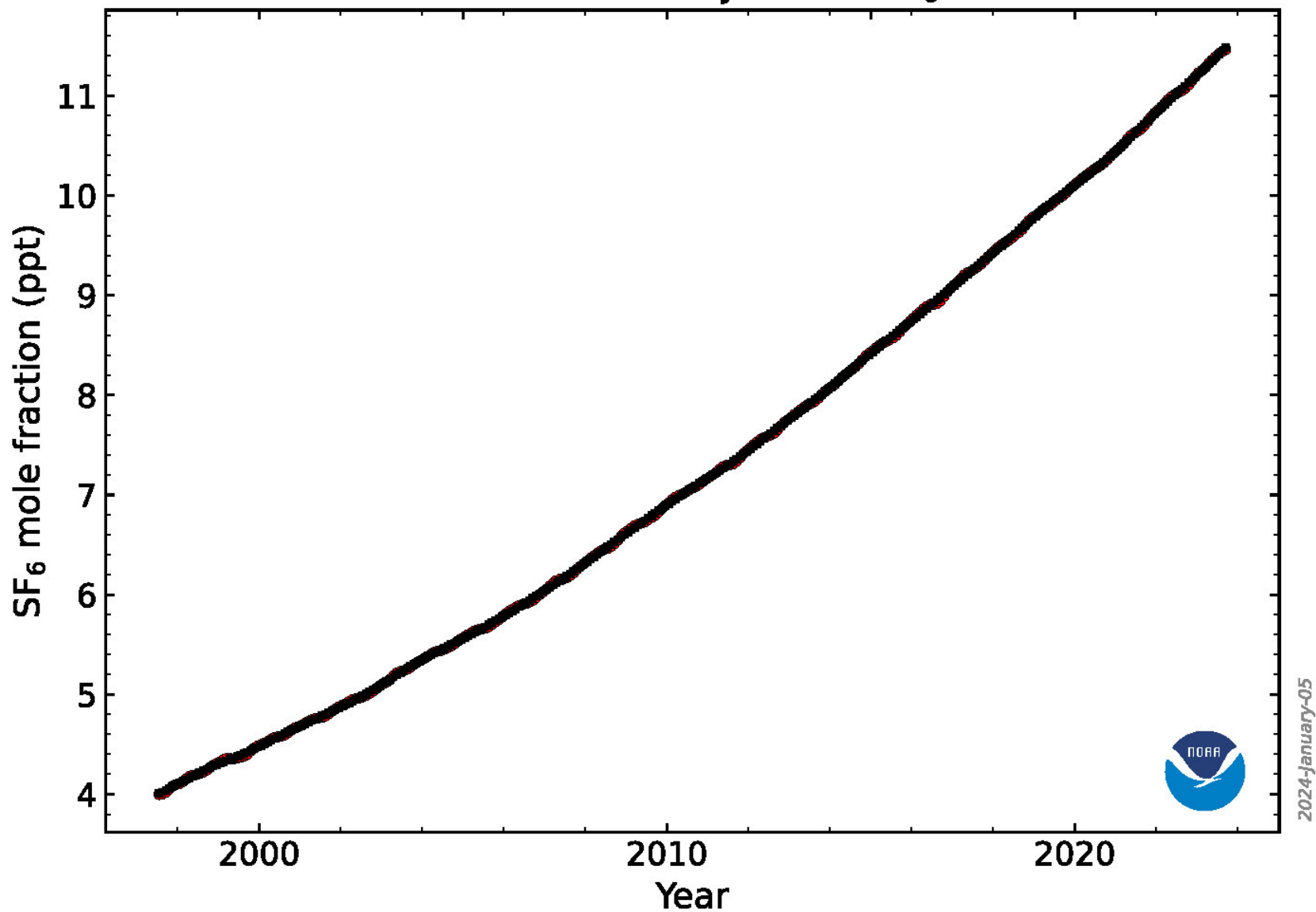


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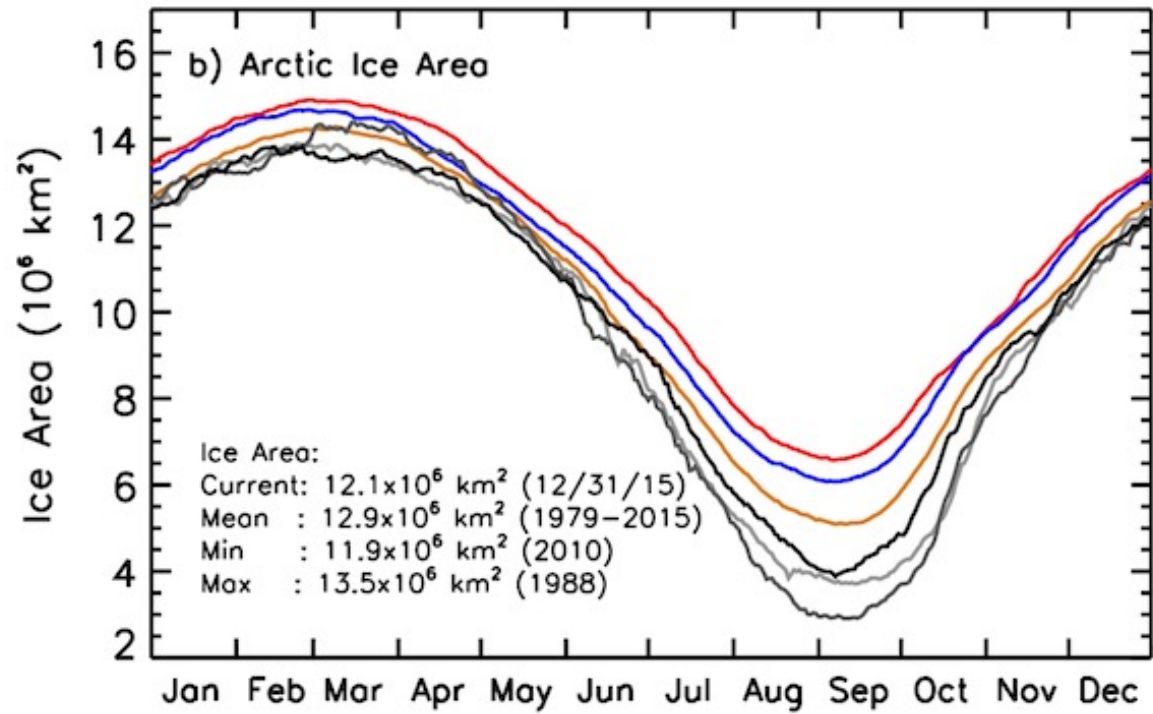
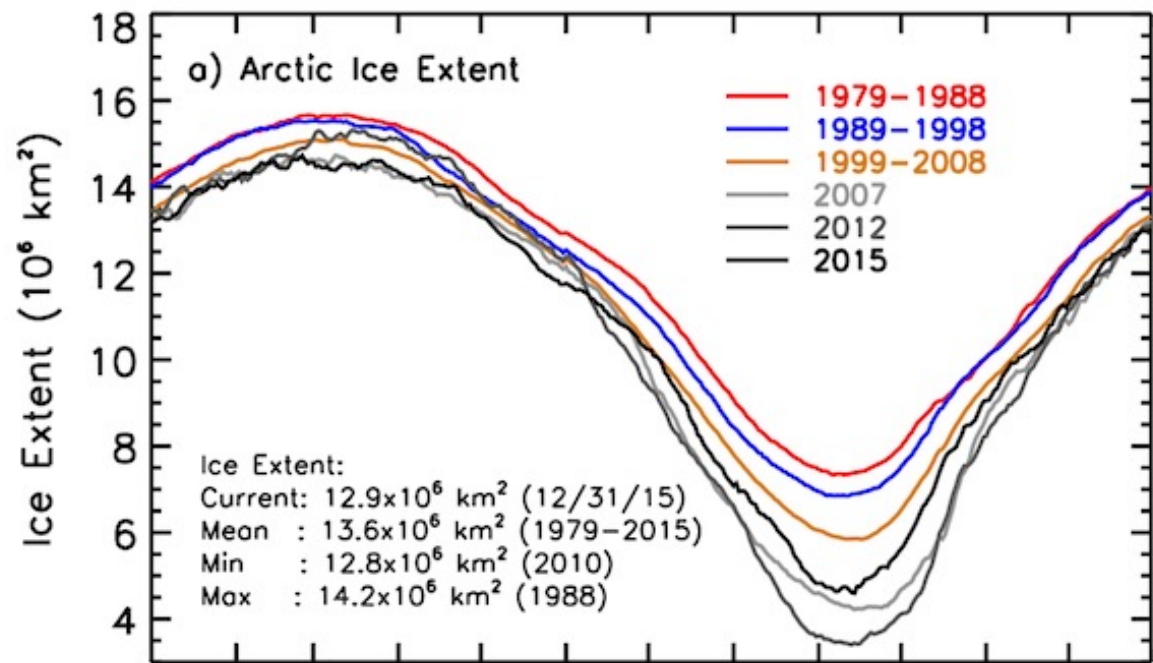


Global Monthly Mean SF₆

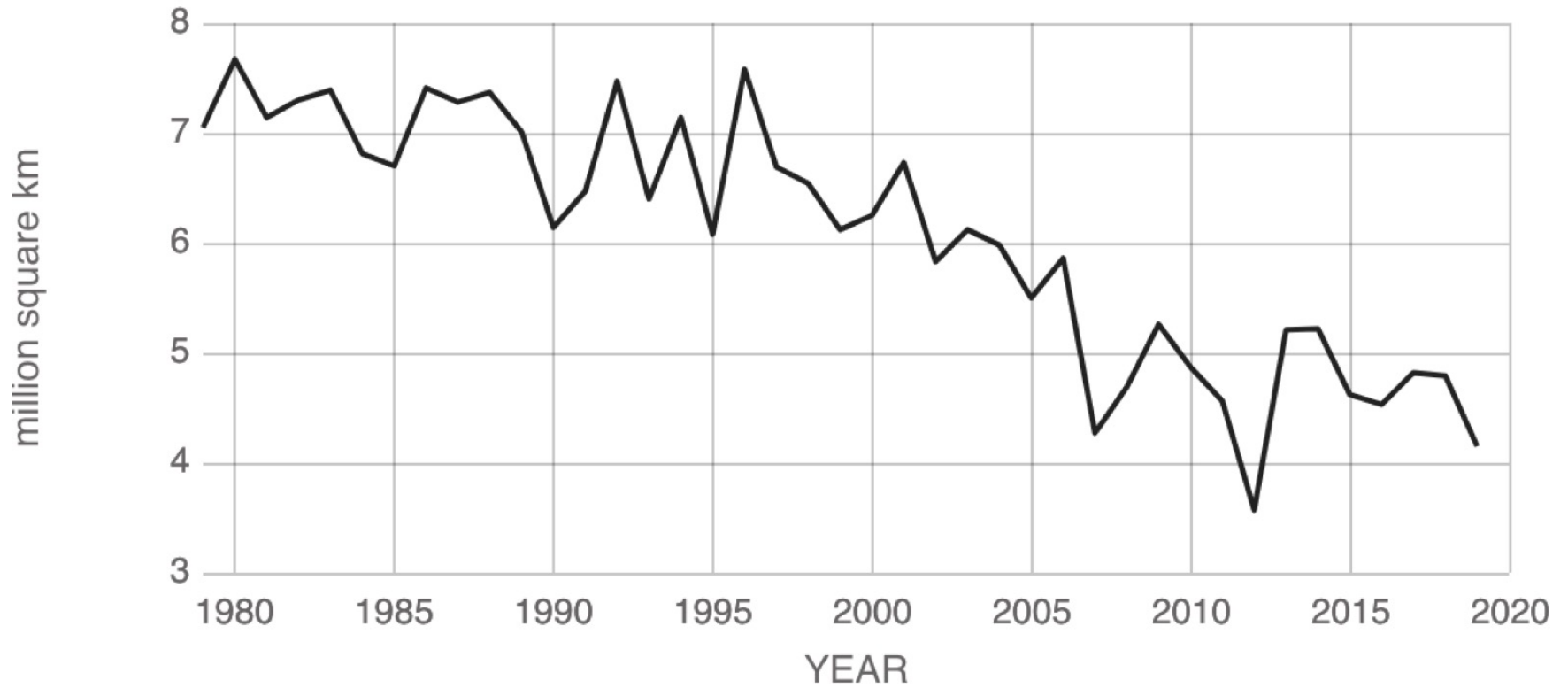


SF₆ “Sulfur hexafluoride”

- The lifetime of SF₆ in the atmosphere is ~ 580 years - 3,200 years.
- It is primarily used in electrical circuit breakers and high-voltage gas-insulated switchgear.
- On average, one SF₆ gas molecule traps 25,000 times more heat in the atmosphere than one CO₂ molecule, over a century-long time scale.
- Its emissions are likely to influence the Earth’s climate for thousands of years.
- Luckily, it is still in the parts per trillion category (parts per 10¹²).



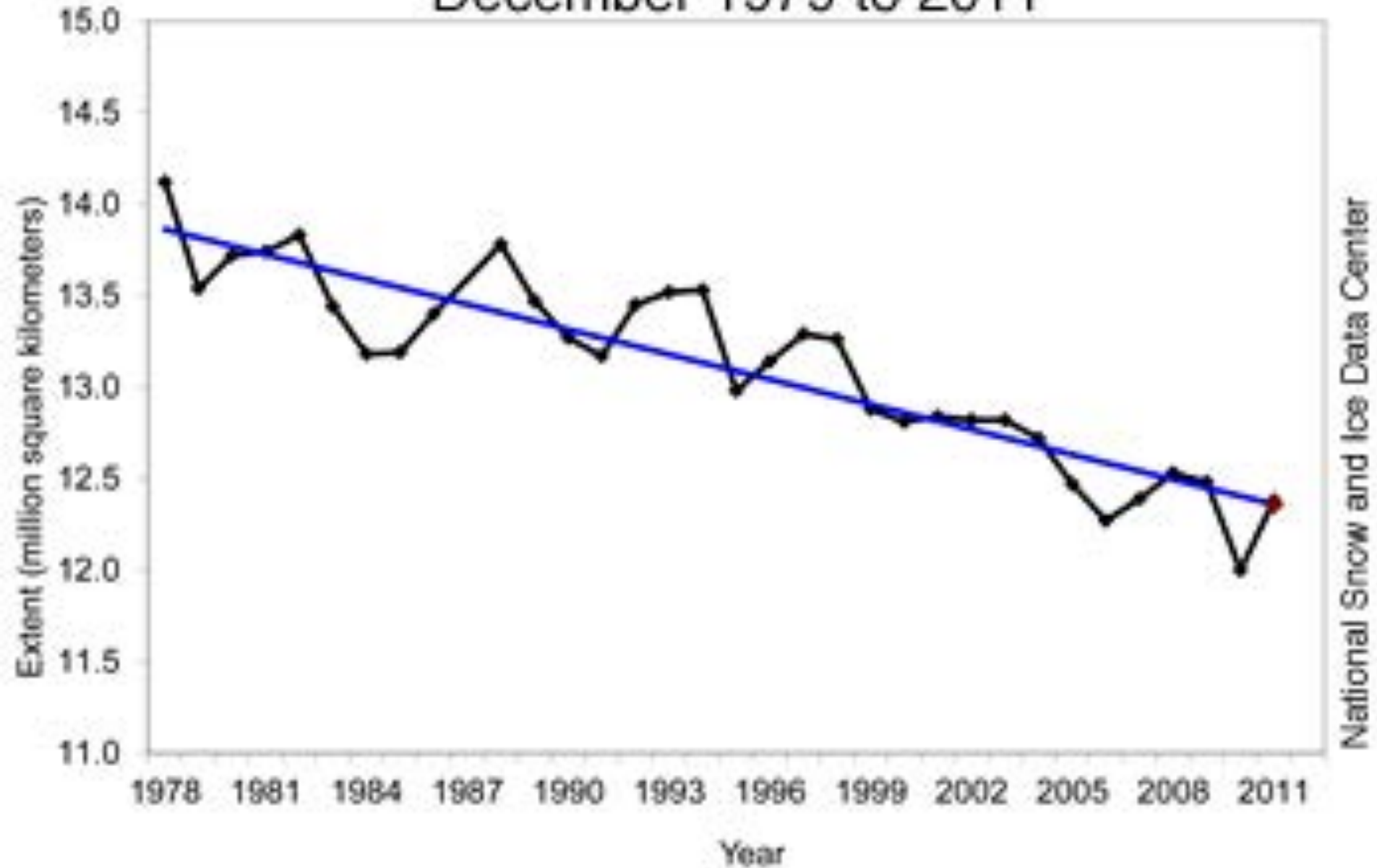
September Arctic Sea Ice Extent



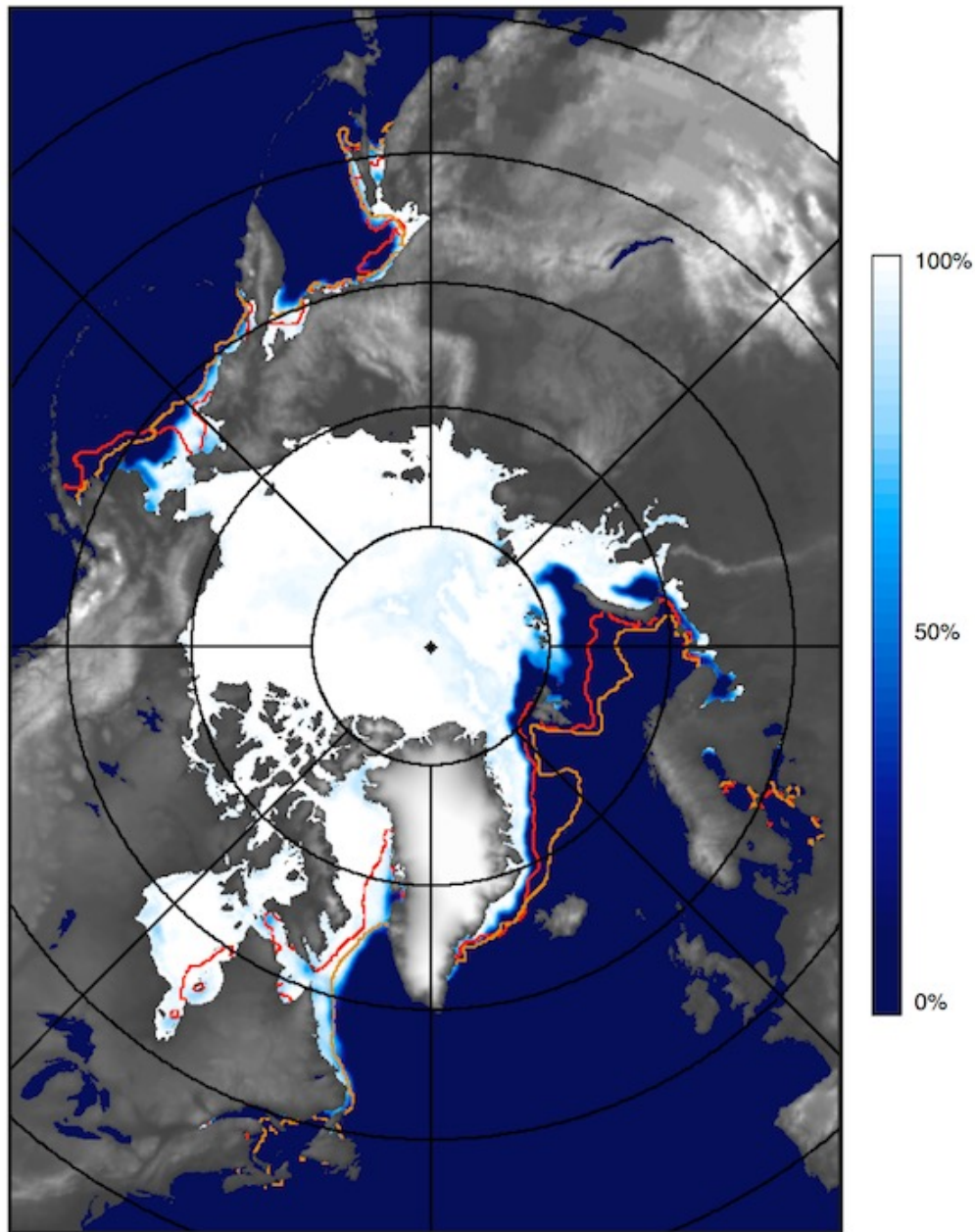
Source: climate.nasa.gov

<https://climate.nasa.gov/vital-signs/arctic-sea-ice/>

Average Monthly Arctic Sea Ice Extent December 1979 to 2011



Northern Hemisphere, December 31, 2015



Current Ice Extent: $12.9 \cdot 10^6 \text{ km}^2$

— Minimum 12/31 Extent Outline, 2010 ($12.8 \cdot 10^6 \text{ km}^2$)

— Maximum 12/31 Extent Outline, 1988 ($14.2 \cdot 10^6 \text{ km}^2$)



One Picture

Disappearing Act One of James Balog's most popular prints is this remarkable shot of a floating polar bear as seen above and below water. Photographed at the zoo in Portland, Oregon, with a battery of strobe lights placed at aquarium windows and on the ceiling, the bear "seems almost toylike and cuddly," Balog comments. "But you can sense its tremendous power." The picture, he adds, "also speaks to the global warming crisis and the knowledge that polar bears are losing their place on earth."

Facts: Insulated by two to six inches of fat against cold Arctic seas, polar bears can swim for hours without rest. Dog-paddling with their front paws and using their hind feet as rudders, they've been known to cross 100 to 150 miles of open water at a speed of 2 to 3 miles per hour. There are 19 subpopulations of polar bears scattered over the Arctic's vastness, and while the animals on Canada's western Hudson Bay, for one, have been well studied, other groups inhabit inaccessible areas. So scientists conjecture that the world's polar bear population might be 20,000 to 25,000 animals.

But polar bears depend on sea ice for their survival year-round, and summer sea ice is declining at a rate of about 8 percent per decade in the rapidly warming polar basin. Steven Amstrup, a wildlife biologist involved in an important new study on Alaska's Beaufort Sea that may produce bad news, puts it bluntly: "We know that the complete disappearance of sea ice would mean the end of polar bears."—*Les Line*

SPECIFICATIONS

Photographer: James Balog

Subject: Polar bear

Where: Oregon Zoo

Camera: Nikon F3 with

50mm lens

Film: Polaroid transparency





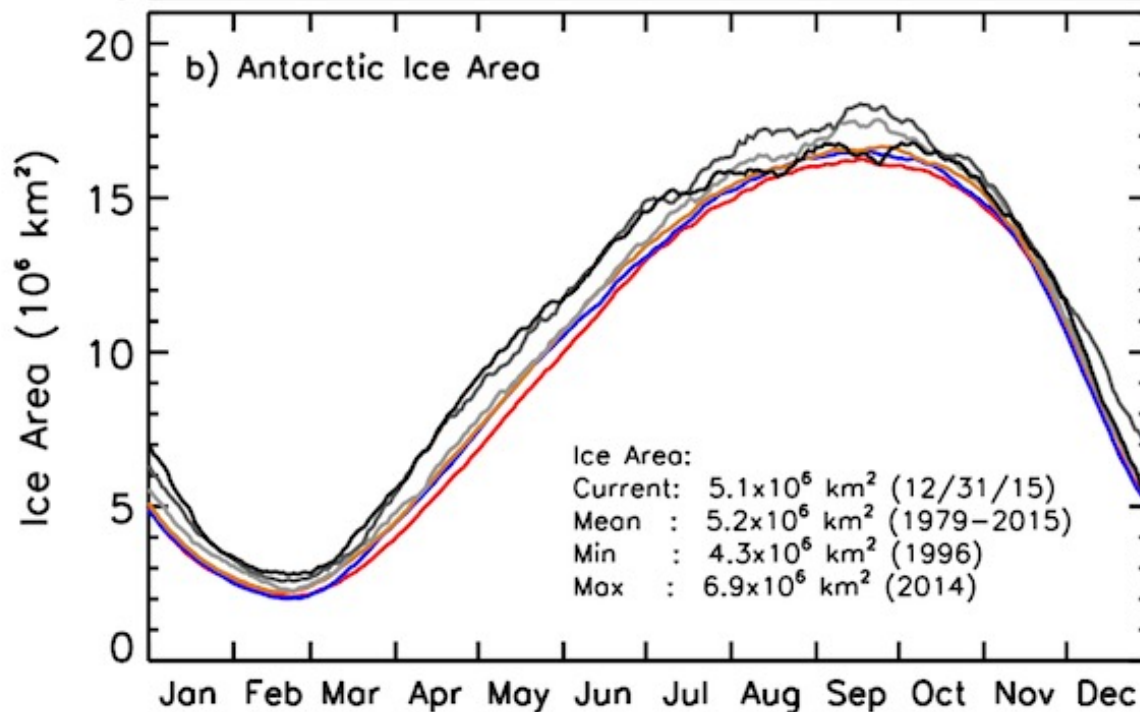
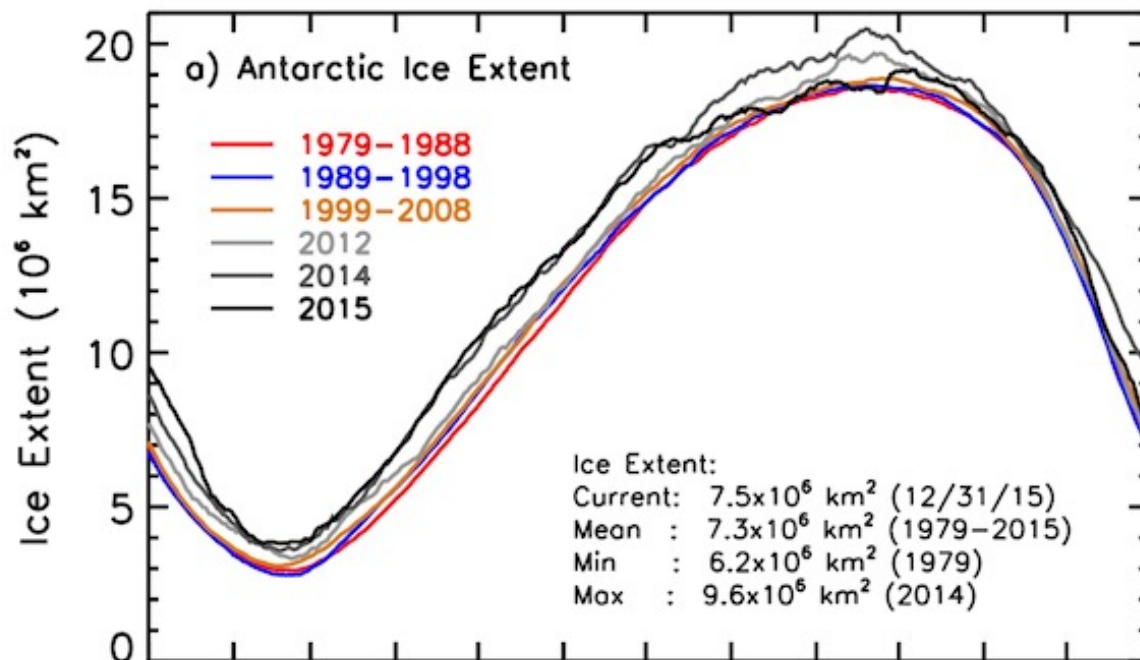




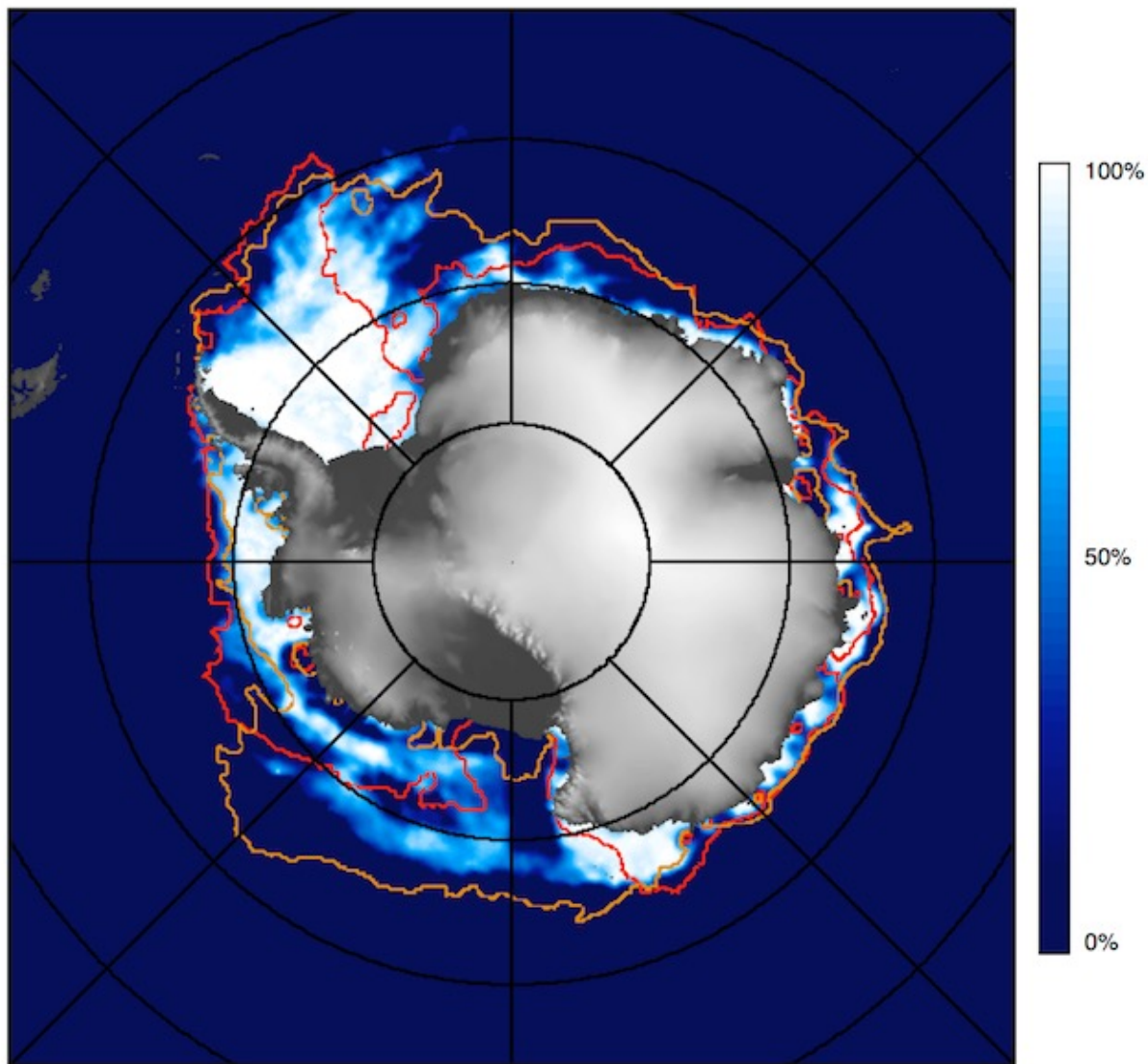








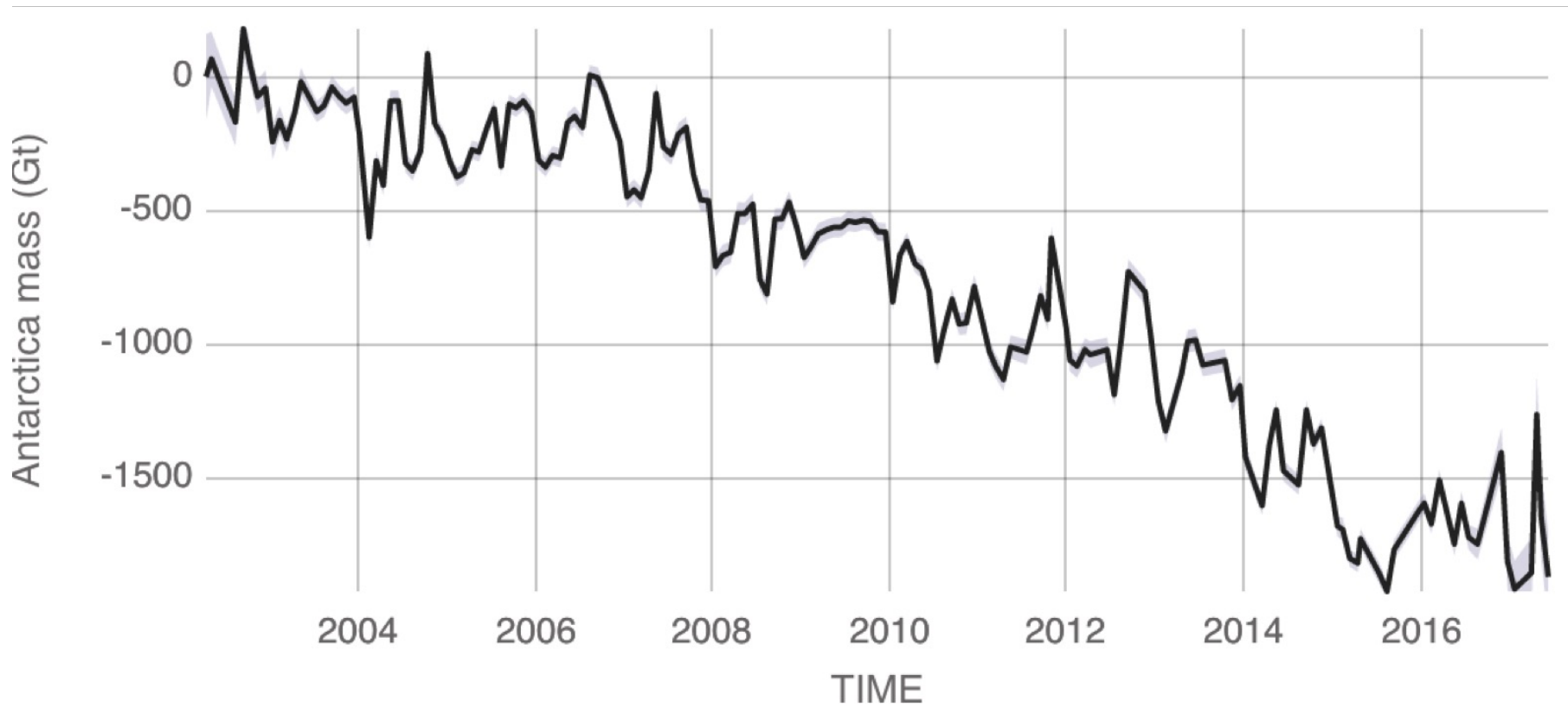
Southern Hemisphere, December 31, 2015



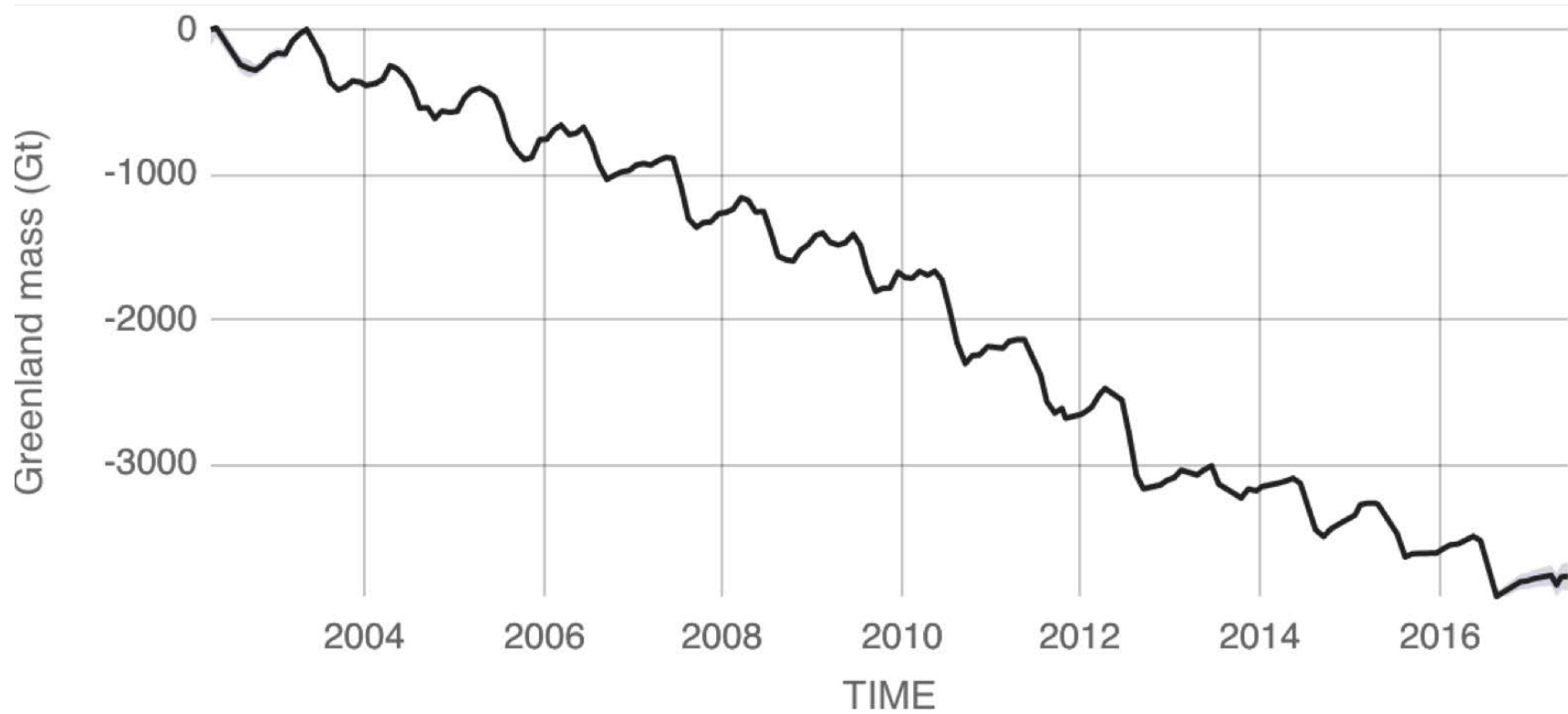
Current Ice Extent: $7.5 \cdot 10^6 \text{ km}^2$

— Minimum 12/31 Extent Outline, 1979 ($6.2 \cdot 10^6 \text{ km}^2$)

— Maximum 12/31 Extent Outline, 2014 ($9.6 \cdot 10^6 \text{ km}^2$)



Source: climate.nasa.gov

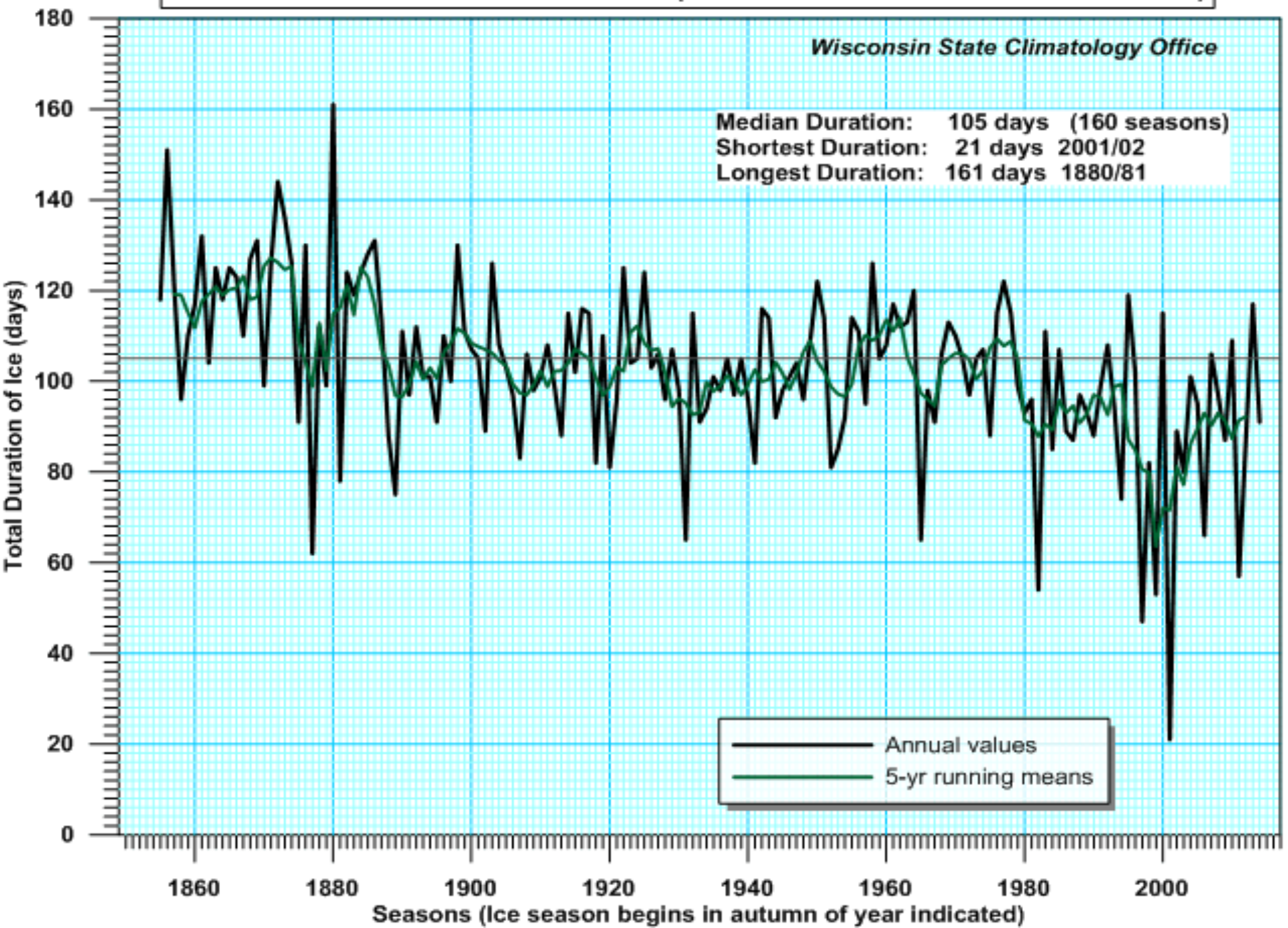


Source: climate.nasa.gov

Duration of Ice on Lake Mendota (1852/53 - 2014/15 Winter Seasons)

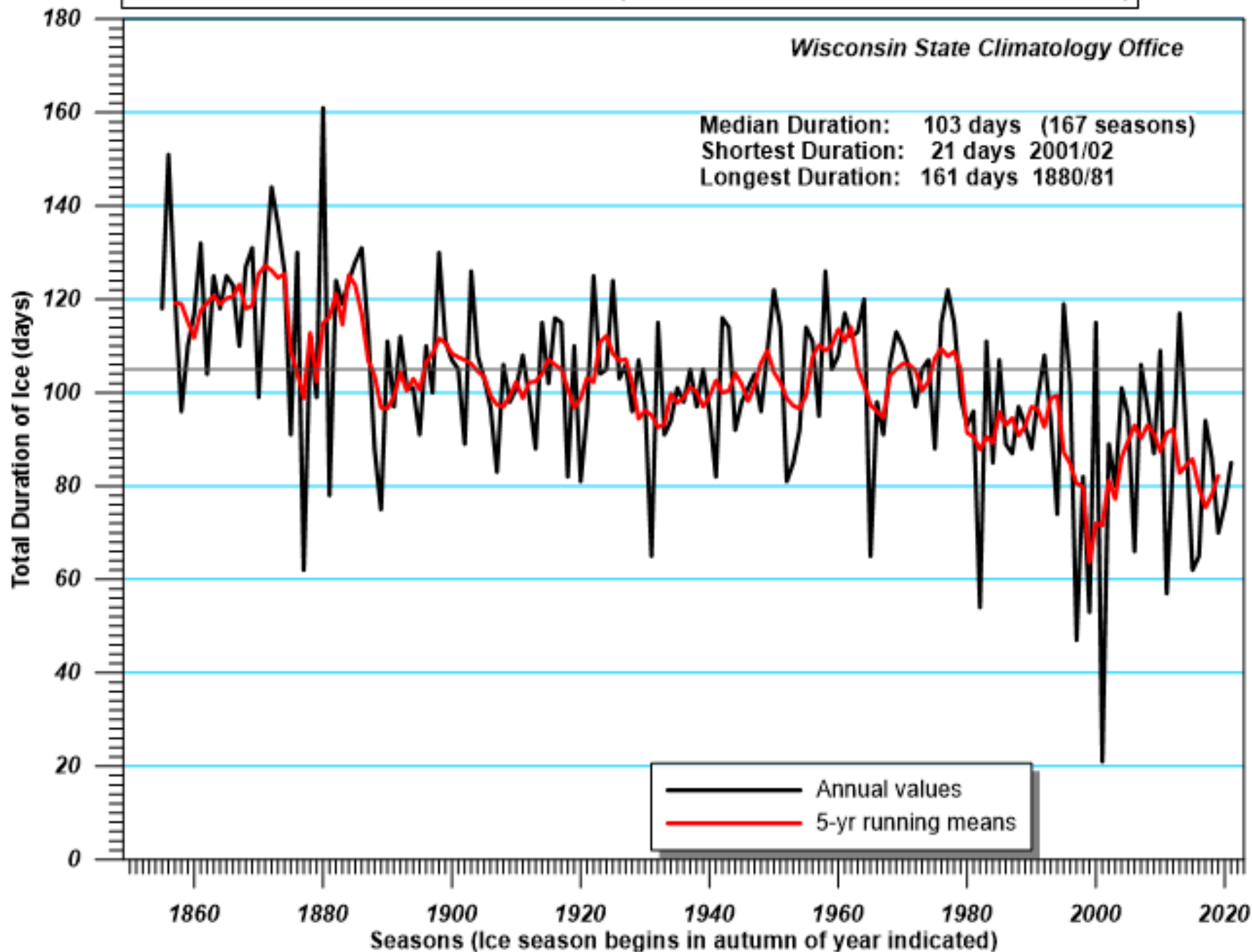
Wisconsin State Climatology Office

Median Duration: 105 days (160 seasons)
Shortest Duration: 21 days 2001/02
Longest Duration: 161 days 1880/81



Duration of Ice on Lake Mendota (1852/53 - 2021/22 Winter Seasons)

Wisconsin State Climatology Office



Summer Sea Surface Temperatures by Ocean Basin 1970-2005

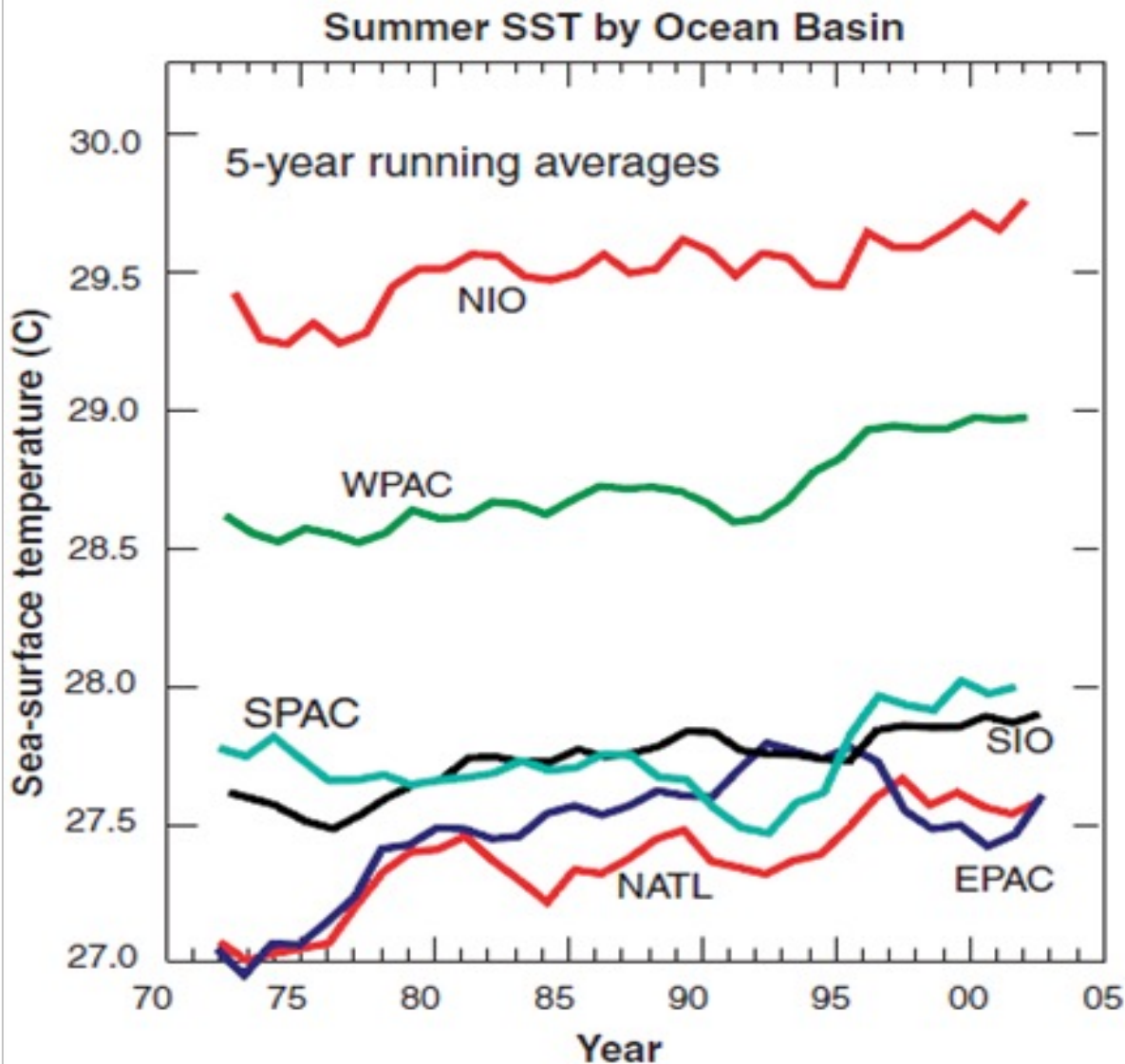


Fig. 1. Running 5-year mean of SST during the respective hurricane seasons for the principal ocean basins in which hurricanes occur: the North Atlantic Ocean (NATL: 90° to 20°E, 5° to 25°N, June-October), the Western Pacific Ocean (WPAC: 120° to 180°E, 5° to 20°N, May-December), the East Pacific Ocean (EPAC: 90° to 120°W, 5° to 20°N, June-October), the Southwest Pacific Ocean (SPAC: 155° to 180°E, 5° to 20°S, December-April), the North Indian Ocean (NIO: 55° to 90°E, 5° to 20°N, April-May and September-November), and the South Indian Ocean (SIO: 50° to 115°E, 5° to 20°S, November-April).

Global Tropical Cyclones 1970-2005

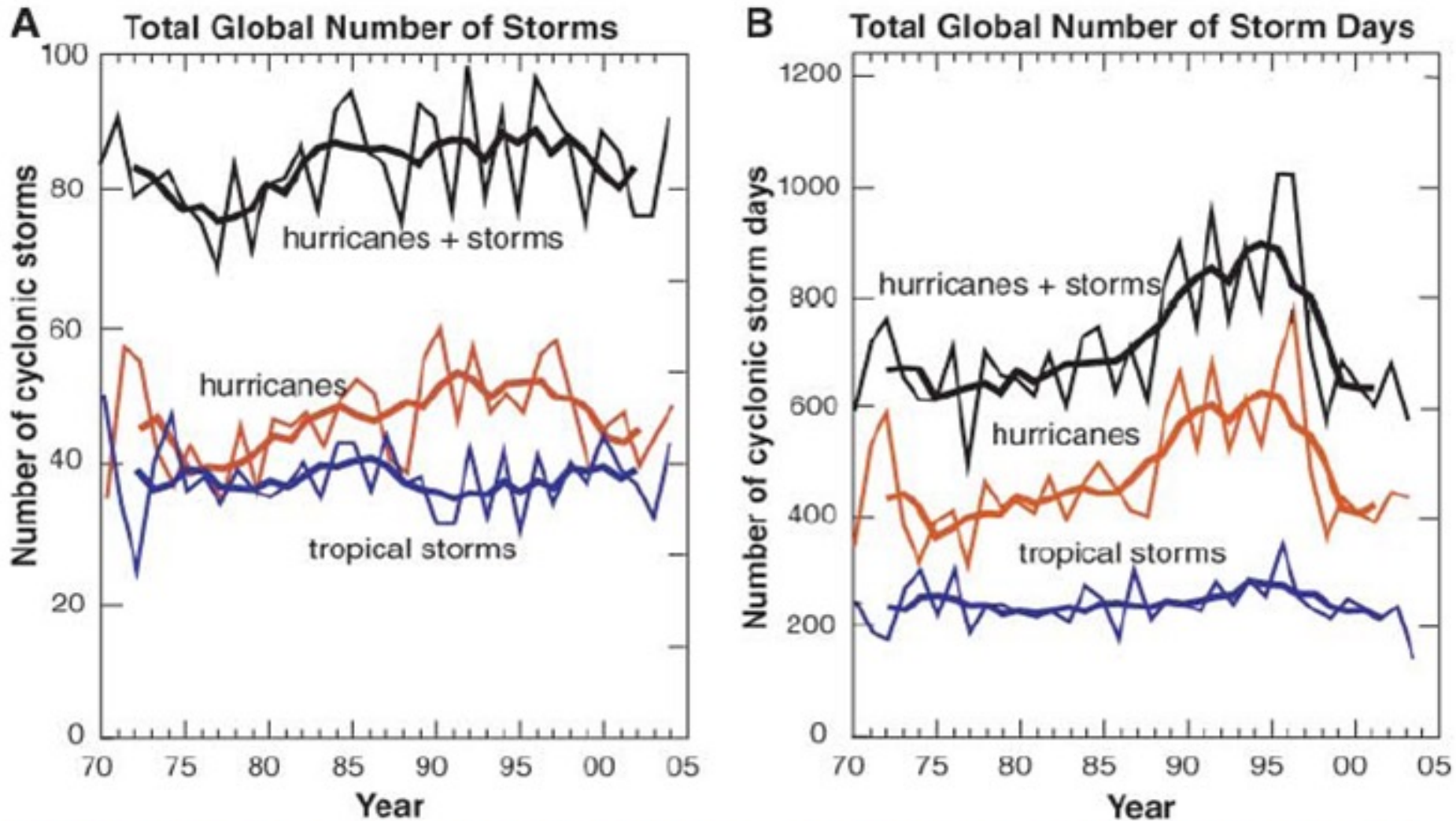
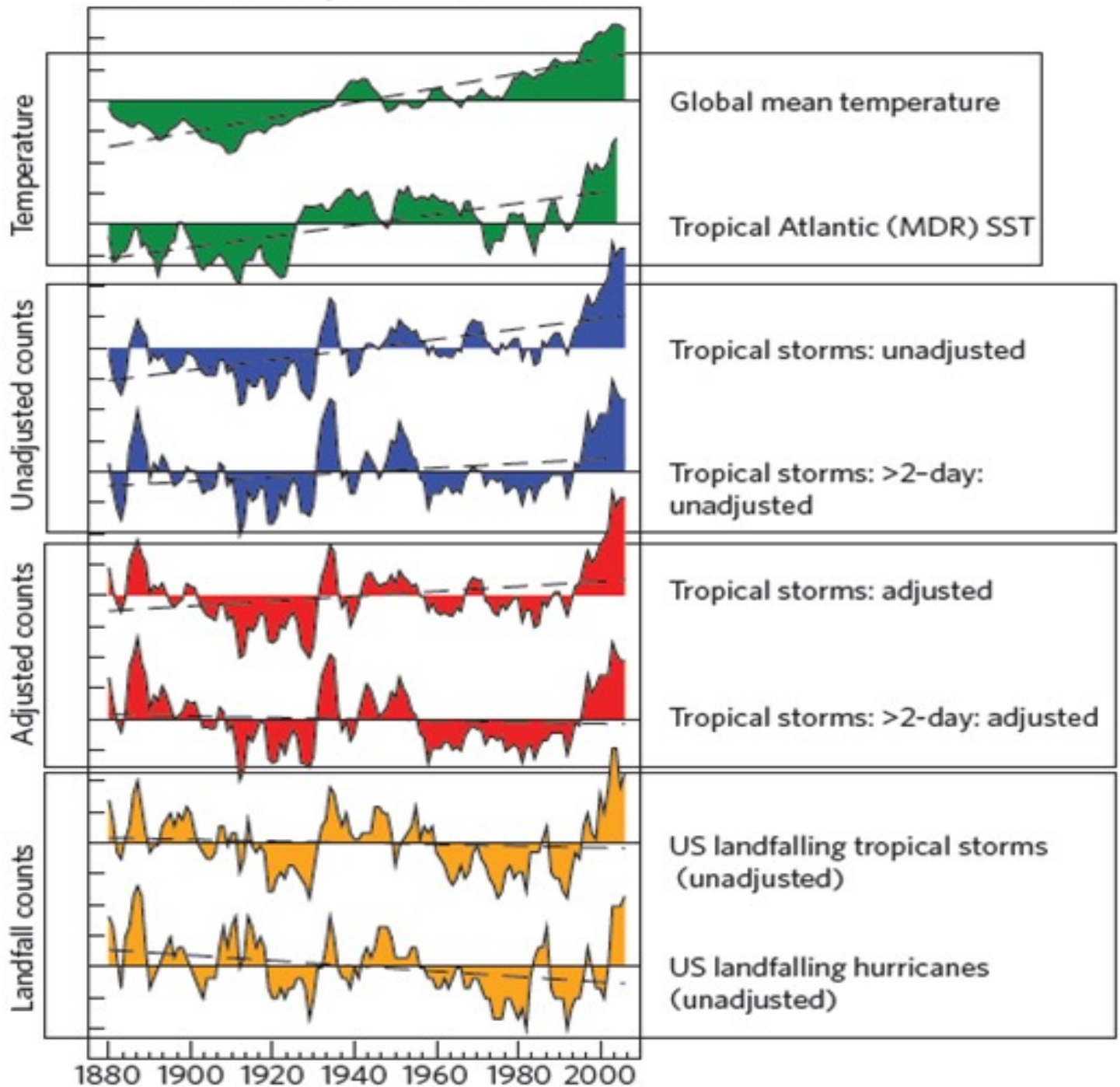


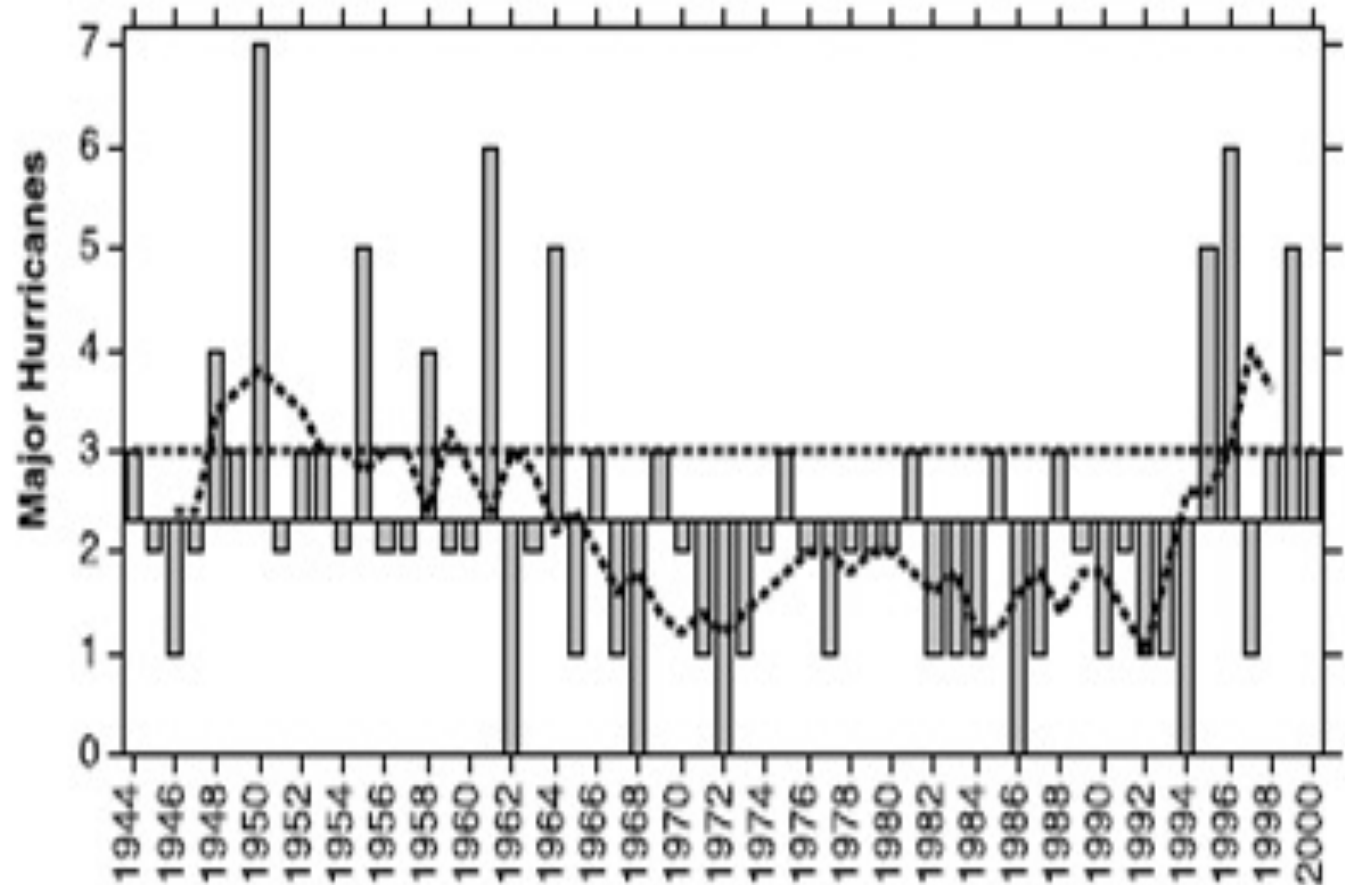
Fig. 2. Global time series for 1970–2004 of (A) number of storms and (B) number of storm days for tropical cyclones (hurricanes plus tropical storms; black curves), hurricanes (red curves), and tropical storms (blue curves). Contours indicate the year-by-year variability, and the bold curves show the 5-year running average.

Atlantic Tropical Cyclones 1880-2008



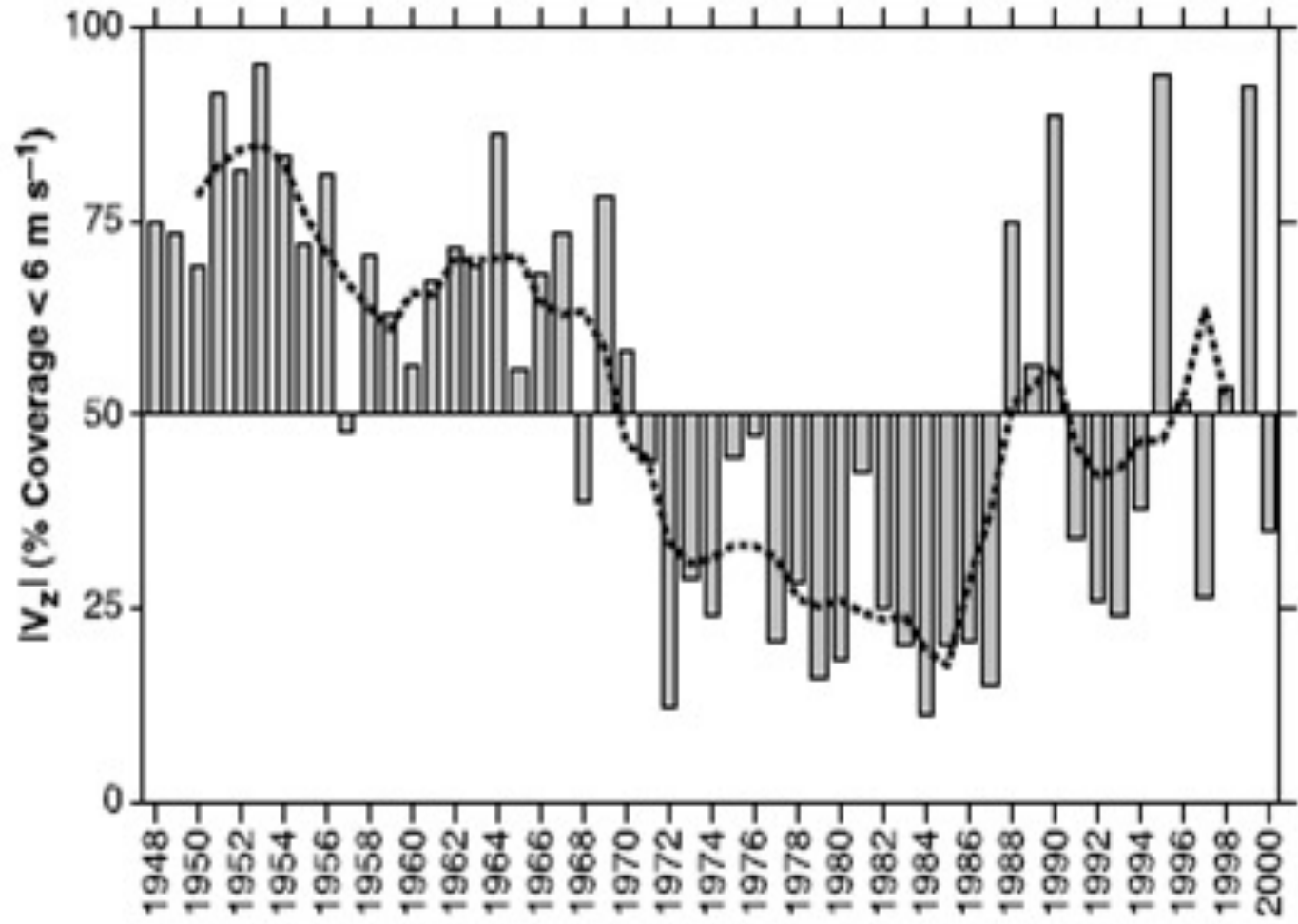
Major Atlantic Hurricanes 1944 - 2000

Fig. 1. Number of major hurricanes from 1944 through 2000 (32). Less reliable data before routine aircraft reconnaissance dictate caution in the use of these data before 1944 (33). Solid horizontal reference line corresponds to sample mean (2.3). Dashed curved line is 5-year running mean. Also shown is the threshold of three major hurricanes per year (dashed straight line).



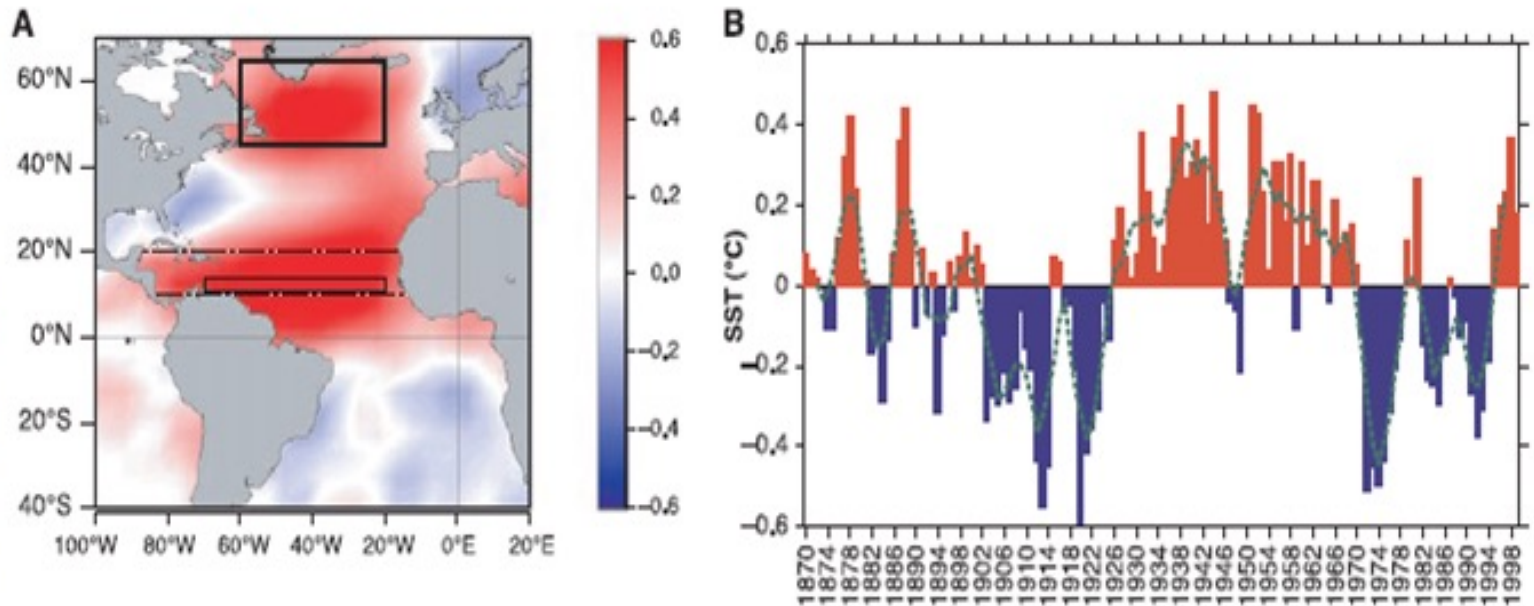
Tropical Atlantic SON Area with Weak Vertical Wind Shear 1944 - 2000

Fig. 3. Percentage of south-central portion (10°–14°N, 20°–70°W) of the main development region (see Fig. 2A) where $|V_z| < 6 \text{ m s}^{-1}$ (values extremely conducive for tropical cyclone development) for ASO. Dashed curved line is 5-year running mean. Higher and lower percentages indicate conditions that are more or less conducive to development, respectively.



Atlantic Meridional Mode Variation 1870 - 2000

Fig. 2. Atlantic sector of the first rotated EOF of non-ENSO global SST variability for 1870–2000 referred to as the "Atlantic multidecadal mode" (38, 39). (A) Spatial distribution of correlations between local monthly SST anomalies and the modal reconstruction over the indexed region (northern rectangle), the general area where the mode amplitude is the strongest. This distribution has a similar spatial structure to the actual rotated EOF and gives a measure of the local fractional variance (squared temporal correlation) accounted for at each grid point. Dashed lines give north and south boundaries of main development region (MDR) and box (10° to 14°N, 20° to 70°W) is region used to calculate data for Fig. 3. (B) Temporal reconstruction (annual means) of the mode-related variability averaged over the



rectangular areain (A). Dashed curved lines 5-year running mean. Although the signal is stronger in the North Atlantic, it is global in scope with positively correlated co-oscillations in parts of the North Pacific (55). For the multidecadal variations shown here, the coherence between the MDR and far North Atlantic is a robust feature. The SST fluctuations in the far North Atlantic could be used as a proxy for changes in the MDR.