Cryosphere

AOSC 680

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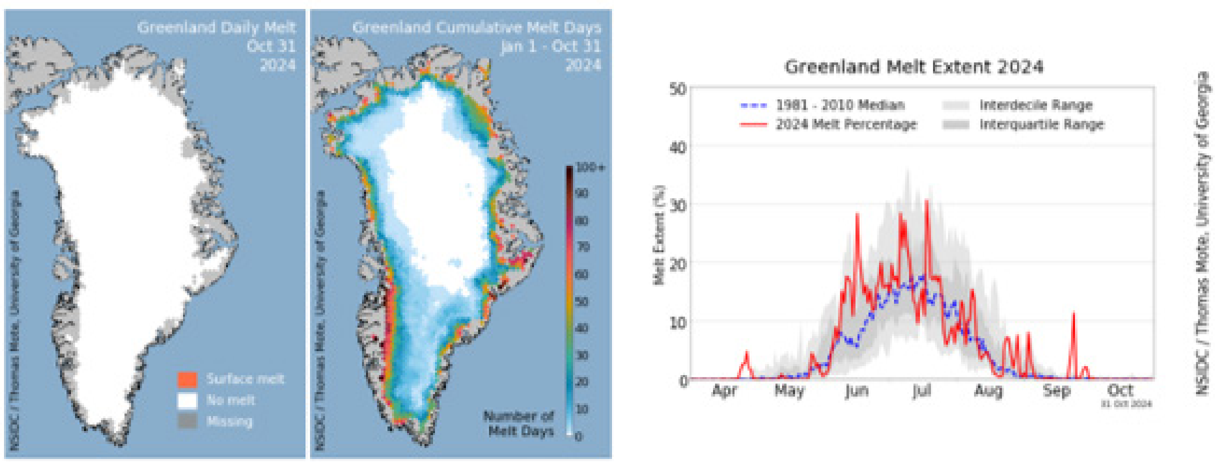
Class Web Sites:

http://www2.atmos.umd.edu/~rjs/class/fall2024
https://umd.instructure.com/courses/1367293

Greenland Daily Melt Images



About these images: These Greenland melt maps and graph dynamically update on a daily basis, with a one-day lag. On occasion, there is data delay which is usually resolved within a few days. Learn more about how to interpret the data and any known issues.

https://nsidc.org/learn/what-cryosphere
https://nsidc.org/ice-sheets-today

Lecture 19

7 November 2024

Announcement

11/07	Cryosphere	Chapters 1 and 9 of *The Cryosphere* by Shawn Marshall (30 pages)	AT 19	Lecture 19: **Hee-Sung** Ross Video
11/12	Ozone Layer	Chapter 8 of *Intro to Atmospheric Chemistry*, Jacob	AT 20	Lecture 20: **Julia**
11/14	Agriculture and Climate Change	AR6_WGII_Chap05.pdf (read Sects 5.2, 5.4,& 5.12) US_NCA_2023_Ch11 (read Intro & Sect 11.1) (42 pages)	AT 21	Lecture 21: **Dylan**
11/19	Wildfires and Climate Change	Pausas and Keeley, *Frontiers In Ecology and Envir*, 2021 Holden et al., *PNAS*, 2018 Virgilio et al., *GRL*, 2019 (23 pages of peer-reviewed literature)	AT 22	Lecture 22: **Shujun**
11/21	The End-Permian Mass Extinction	**Chapter 4** of *Ends of the World*, Brannen to be handed out in class 38 pages	AT 23	Lecture 23: **Sam**
11/26	The End-Ordovician Mass Extinction	**Chapter 2** of *Ends of the World*, Brannen to be handed out in class 44 pages	AT 24	Lecture 24: **Kyle**

Must use "atmchem" to open this reading

Ozone Hole and the Cryosphere

Changes in Lake, River, and Sea Ice

There is a detailed historical record of freeze-up and breakup of lake, river, and sea ice in many communities, particularly where ship navigation and ice roads are dependent on ice conditions. These observations are local and they often reflect near-shore conditions, so they may not be representative of regional or synoptic conditions. These are nevertheless valuable in documenting changes in ice cover during the past century, particularly for river and lake ice. In many freshwater ice settings, local observations are simpler to interpret, as water masses are limited in extent, there is less multiyear memory, and interannual variability in winds, pressure patterns, and currents have a minor influence compared with their impact on sea-ice conditions. Available river and lake records that are at least 150 years in length in the Northern Hemisphere point to shorter winters, with freeze-up occurring 8.7 ± 2.4 days later and breakup moving up by 9.8 ± 1.8 days over this 150-year period.

Over a shorter time frame, the last 30 to 70 years, regional compilations of the freshwater ice season indicate a large degree of variability. For recent decades, visible and microwave satellite imagery offer good discrimination between open water and ice conditions. Regional variations in the ice season are broadly consistent with temperature changes, with observations pointing to a shortening of the ice season by roughly 10 days per °C of warming. Changes in the snowpack can cause deviations from this relationship with temperature.

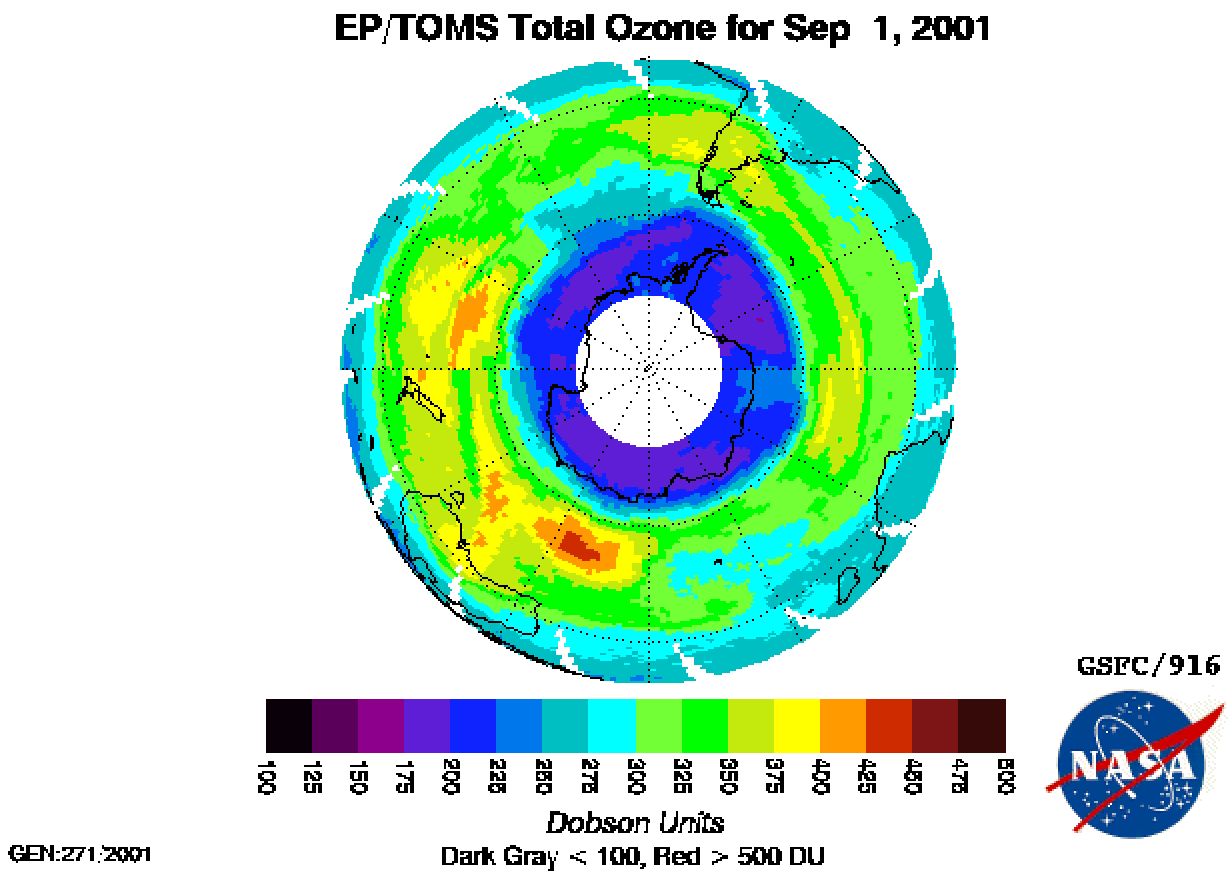
Microwave remote-sensing observations also provide a detailed view of changes in sea-ice cover since the late 1970s. Northern Hemisphere sea-ice cover has declined over this time in all seasons, with the strongest changes in late summer months. The March, annual, and September trends from 1979 to 2010 are −2.8%, −4.4%, and −12.4% per decade, respectively. In contrast, Antarctic sea ice has been stable over this period, with annual sea-ice extent in the Southern Hemisphere increasing by 1.3% per decade. This is consistent with observations of Antarctic cooling since the 1970s, attributed to the combined effects of stratospheric ozone depletion and strengthening of the Antarctic polar vortex, which helps to isolate Antarctica from meridional heat and moisture transport.

Chapter 9, *The Cryosphere*, Shawn Marshall

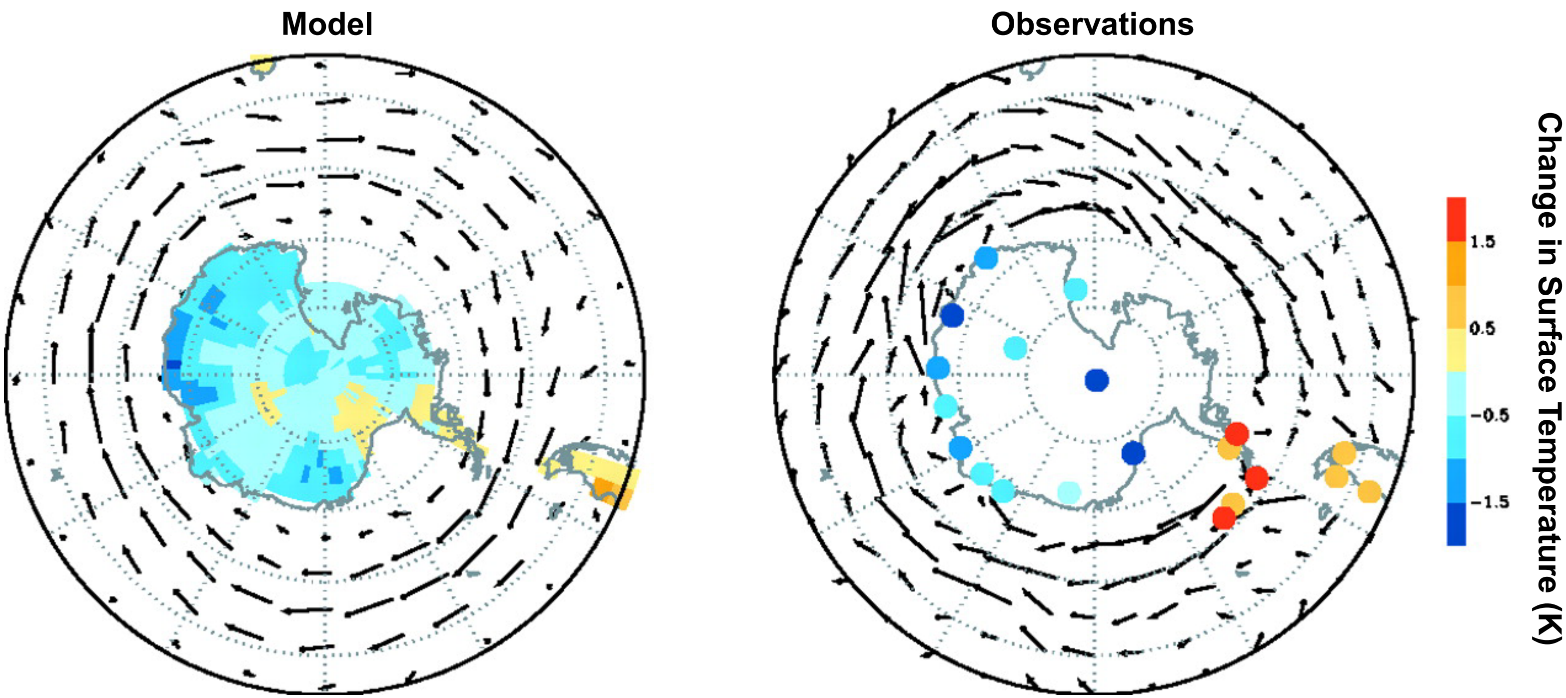
Polar Vortex Circulation

During winter:

- radiative cooling leads to cold air in polar stratosphere
- large scale low pressure region develops over pole
- strong “polar night jet” develops, isolating air at high latitudes from air at low latitudes
- T continues to fall in the “vortex like” circulation near the pole



The Ozone Hole may have shielded the Antarctic surface from warming!



Simulated and observed changes in surface temperature (K) and wind speed,1969 to 2000, averaged over December to May. The longest wind vector corresponds to 4 m/s.

Gillett and Thompson, *Science*, 2003

As ozone depletion occurs:

The positive phase of the southern annular mode (SAM) increases, causing Antarctic surface westerlies to intensify, resulting in cooling of Antarctic continent

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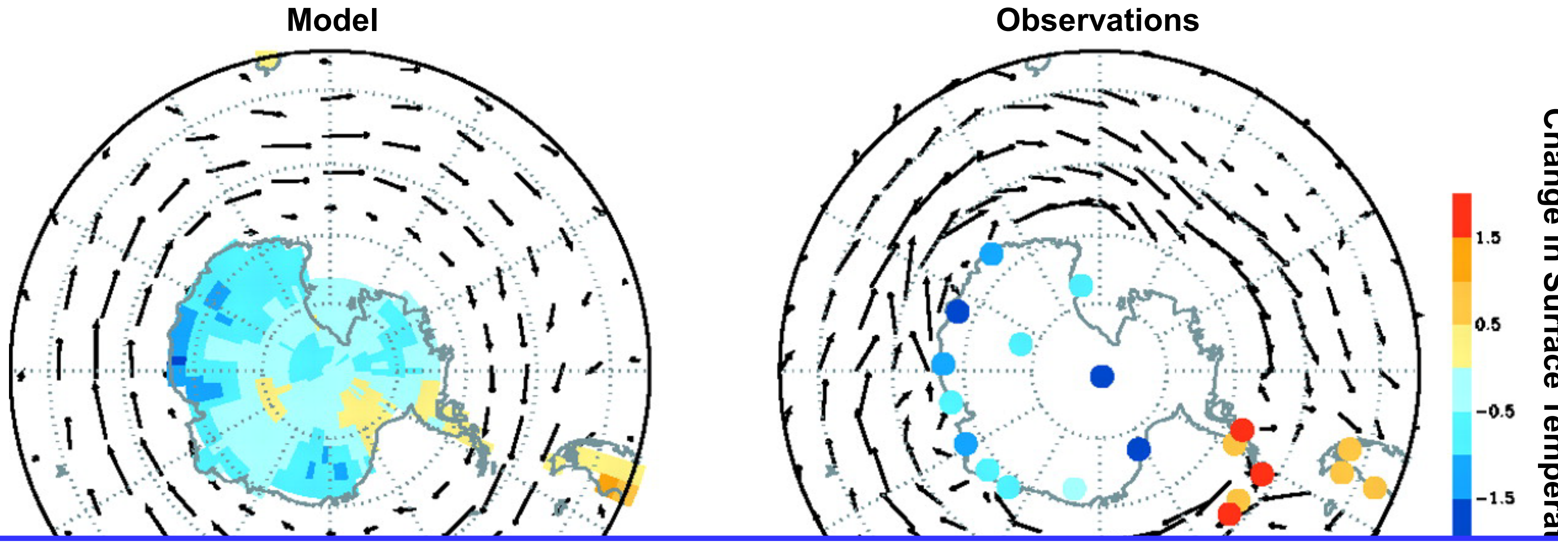

SAM: difference in zonal mean sea-level pressure between 40°S and 65°S. The pattern associated with SAM is a nearly annular pattern with a large low pressure anomaly centered on the South Pole and a ring of high pressure anomalies at mid-latitudes. The SAM effects storm tracks, precipitation patterns, etc.

http://www.climate.be/textbook/chapter5_node6.html

As ozone depletion occurs:

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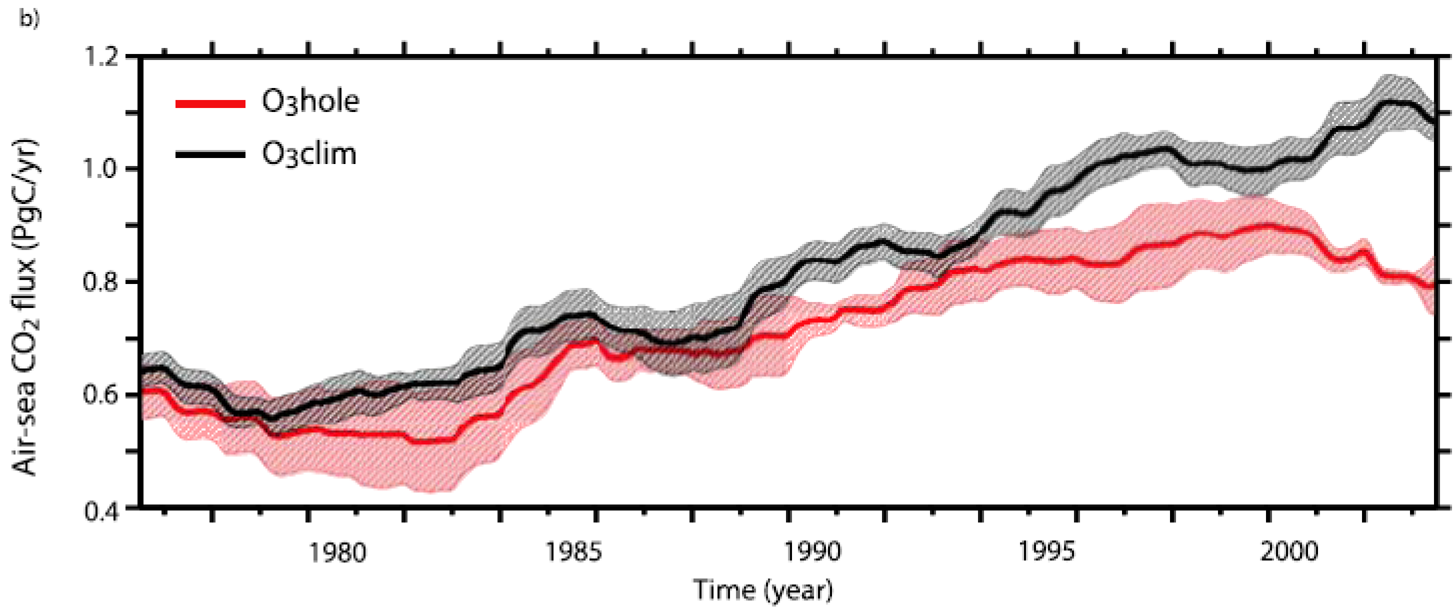
The Ozone Hole may have lead to increased ventilation of CO_2 from southern ocean



(b) Integrated air to sea CO_2 flux (south of 40°S) showing stratospheric ozone depletion (O_3hole) significantly reduces CO_2 uptake (relative to O_3clim), and is strongly correlated with changes in ΔpCO_2.

Lenton *et al.*,*GRL*, 2009

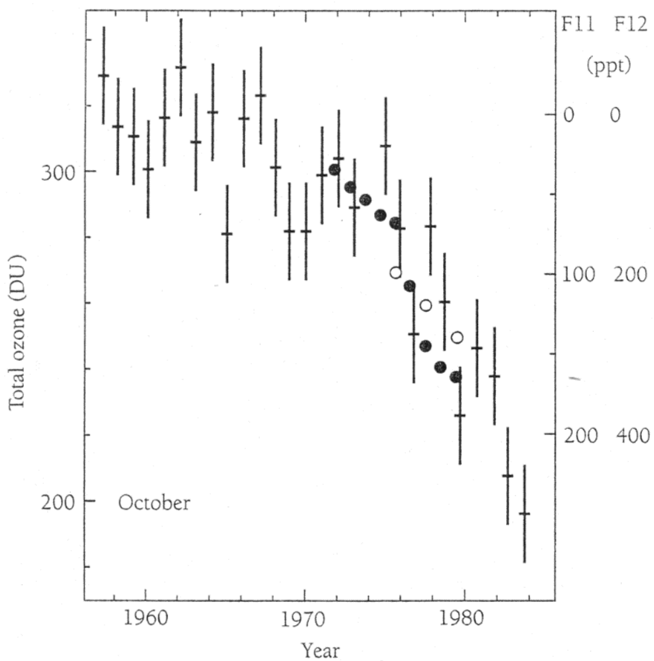
As ozone depletion occurs:

> **The positive phase of the southern annular mode (SAM) increases, causing Antarctic surface westerlies to intensify, resulting in increased ventilation of CO_2 from southern ocean**

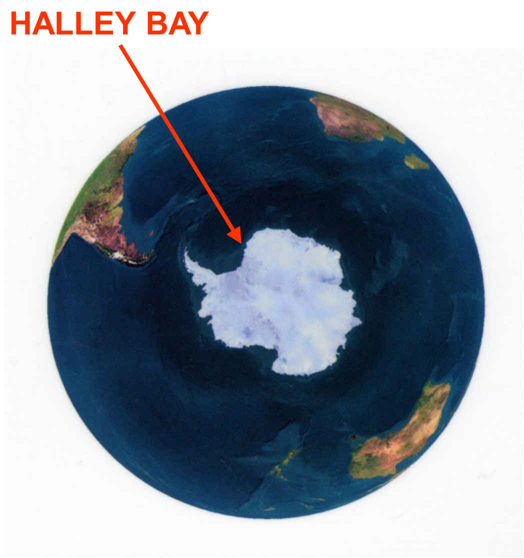
Polar Ozone Depletion

Discovery of the ozone hole:

Halley Bay (76°S)
October Mean



Farman *et al.*, Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction, *Nature, 315*, 207, 1985.



Southern Hemisphere

Polar Ozone Loss

- Cold Temperatures → Polar Stratospheric Clouds (**PSCs**)
- Reactions on PSC surfaces lead to elevated **ClO**

  $HCl + ClNO_3 \rightarrow Cl_2$ (gas) + HNO_3 (solid)

  $ClNO_3 + H_2O \rightarrow HOCl + HNO_3$

  Cl_2 + SUNLIGHT + $O_3 \rightarrow ClO$

  HOCl + SUNLIGHT + $O_3 \rightarrow ClO$

  HNO_3 SEDIMENTS (PSCs fall due to gravity)

- Elevated **ClO** + Sunlight destroys O_3
- BrO : Reaction Partner For ClO ⇒ Additional O_3 Loss


N817NA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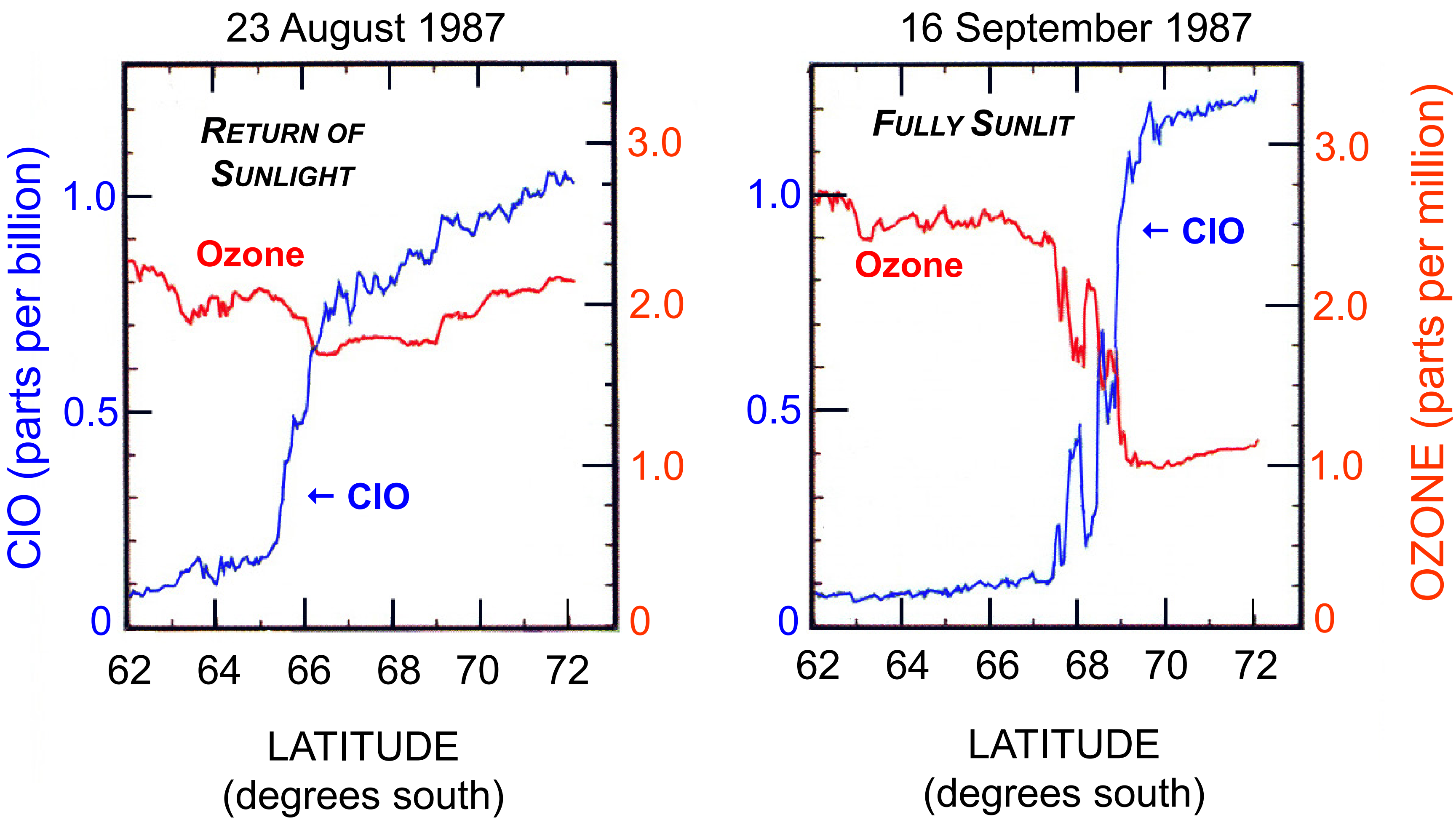
NASA

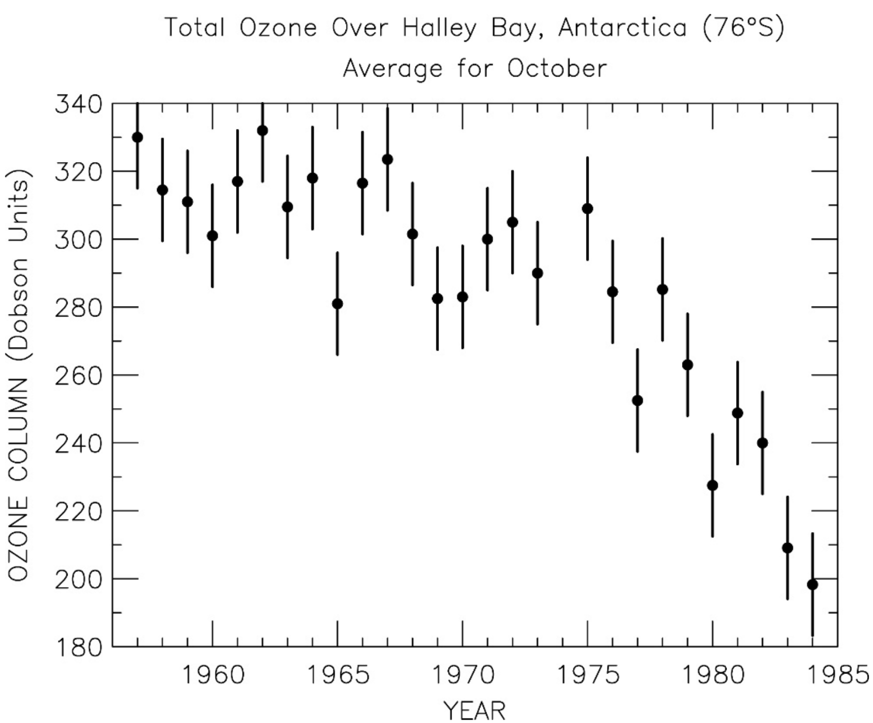
Airborne Antarctic Ozone Expedition: Punta Arenas, Chile,1987



Anderson et al., *Science*, 1991

Total Column Ozone over Halley Bay, Antarctica in October

From *Discovery of the Ozone Hole* paper:



After Farman *et al.*, Large losses of total ozone in Antarctica reveal Seasonal ClOx/NOx interaction, Nature, 315, 207, 1985.

Update: