

CHAPTER 8

Stratospheric Chemistry

From "Introduction to Atmospheric Chemistry" by Daniel J. Jacob

AOSC 680

Professor Ross Salawitch

Julia Feng-Bahns

Overview

01

Discovery of
the ozone layer

02

Chapman
mechanism

03

Catalytic
ozone loss

04

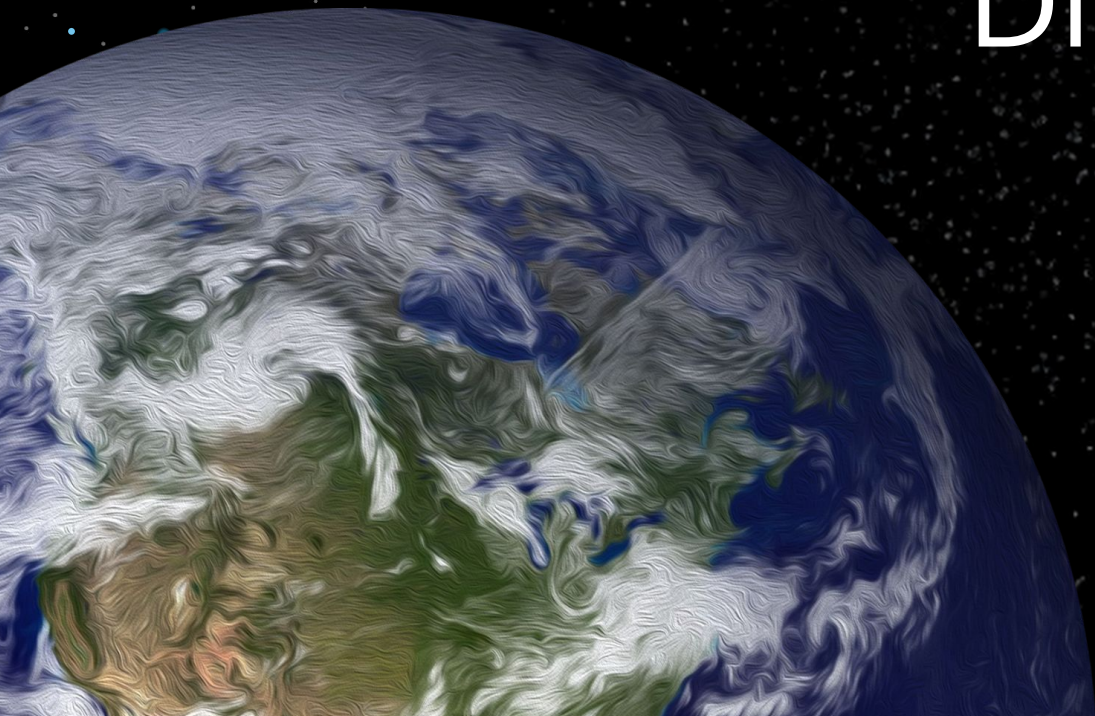
Antarctic
ozone hole

05

Aerosol-driven
ozone loss

01

Discovery of the ozone layer



How did we discover stratospheric ozone?

- Charles Fabry (1867 - 1945)
 - French physicist
- Ground-based measurements of solar __ radiation flux



Distribution of ozone in the ...?

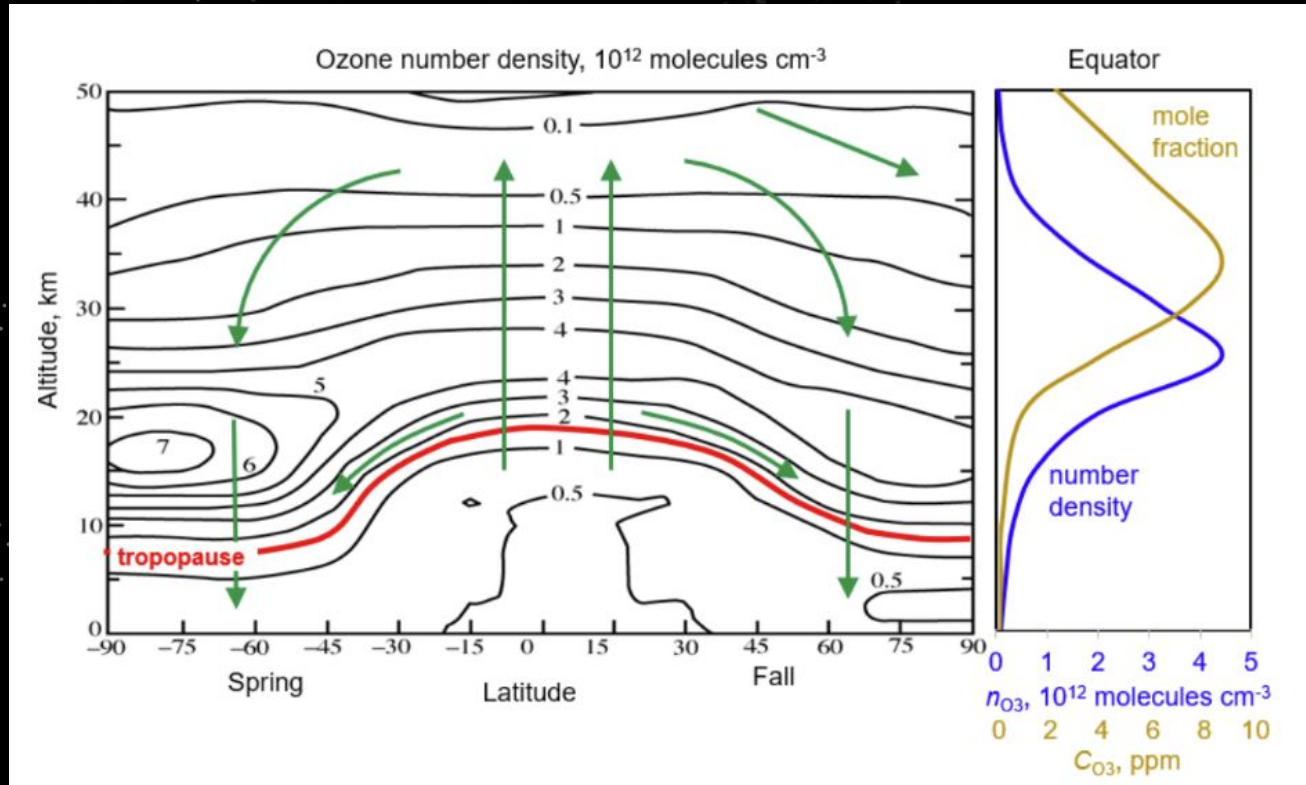
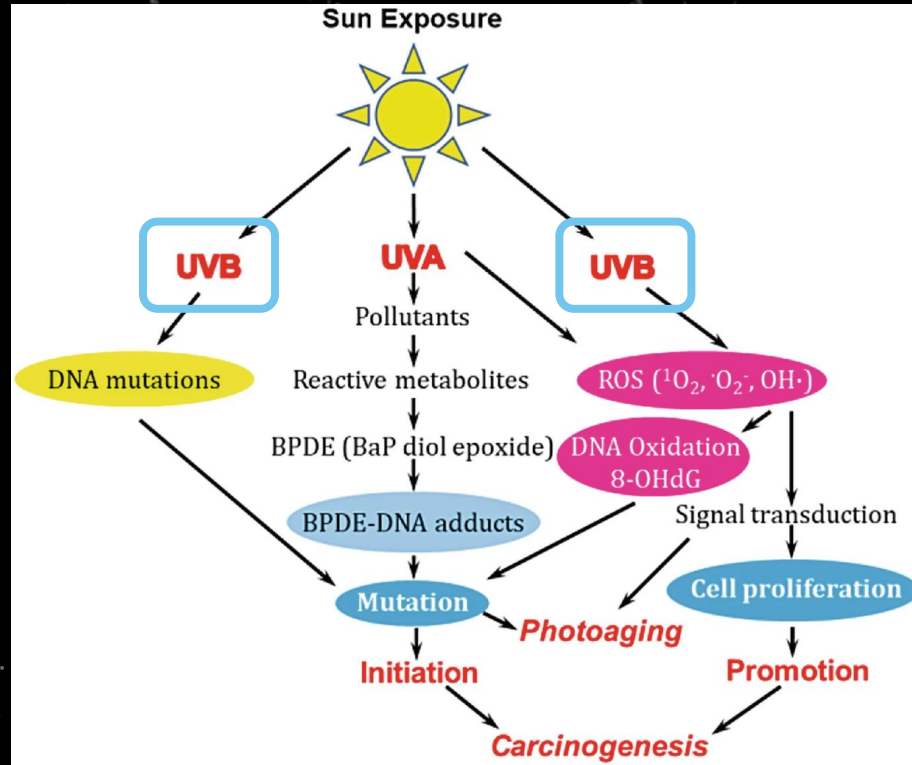


Figure 8-1 from Jacob

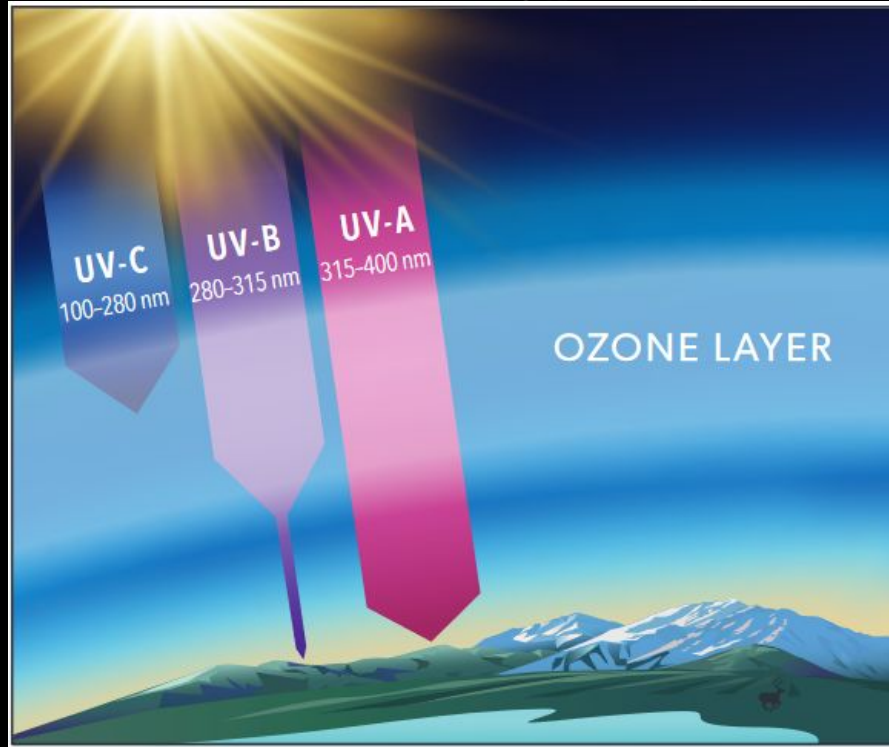
Why is the ozone layer so important??

Why is the ozone layer so important??



Skin Cancer Induced by Pollution-Mediated ROS (Burke 2022)

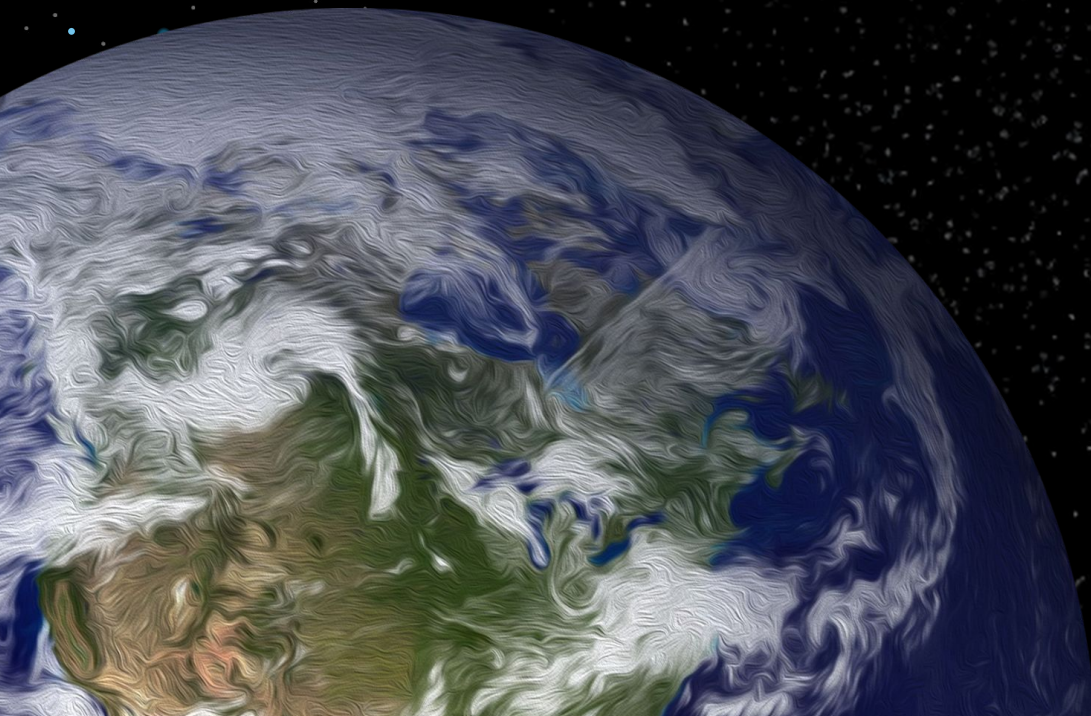
Why is the ozone layer so important??



"20 Questions and Answers about the Ozone Layer" (Salawitch et al.)

02

Chapman mechanism



Where does the ozone layer come from?

- Sydney Chapman (-)
 - British geophysicist
- Proposed a mechanism for the three-body collision of oxygen atoms



The Chapman mechanism

CHAPMAN MECHANISM FOR STRATOSPHERIC OZONE (1930)

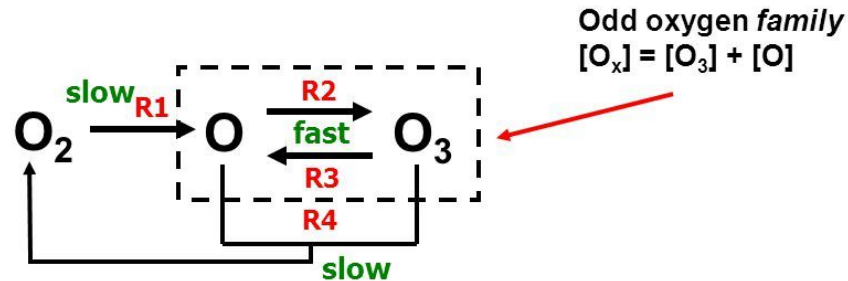
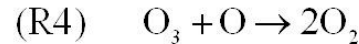
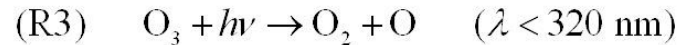
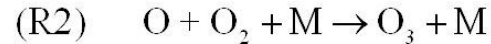
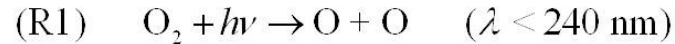


Figure 8-3 from Jacob

Sources of skepticism?

Distribution of ozone in the 1960s

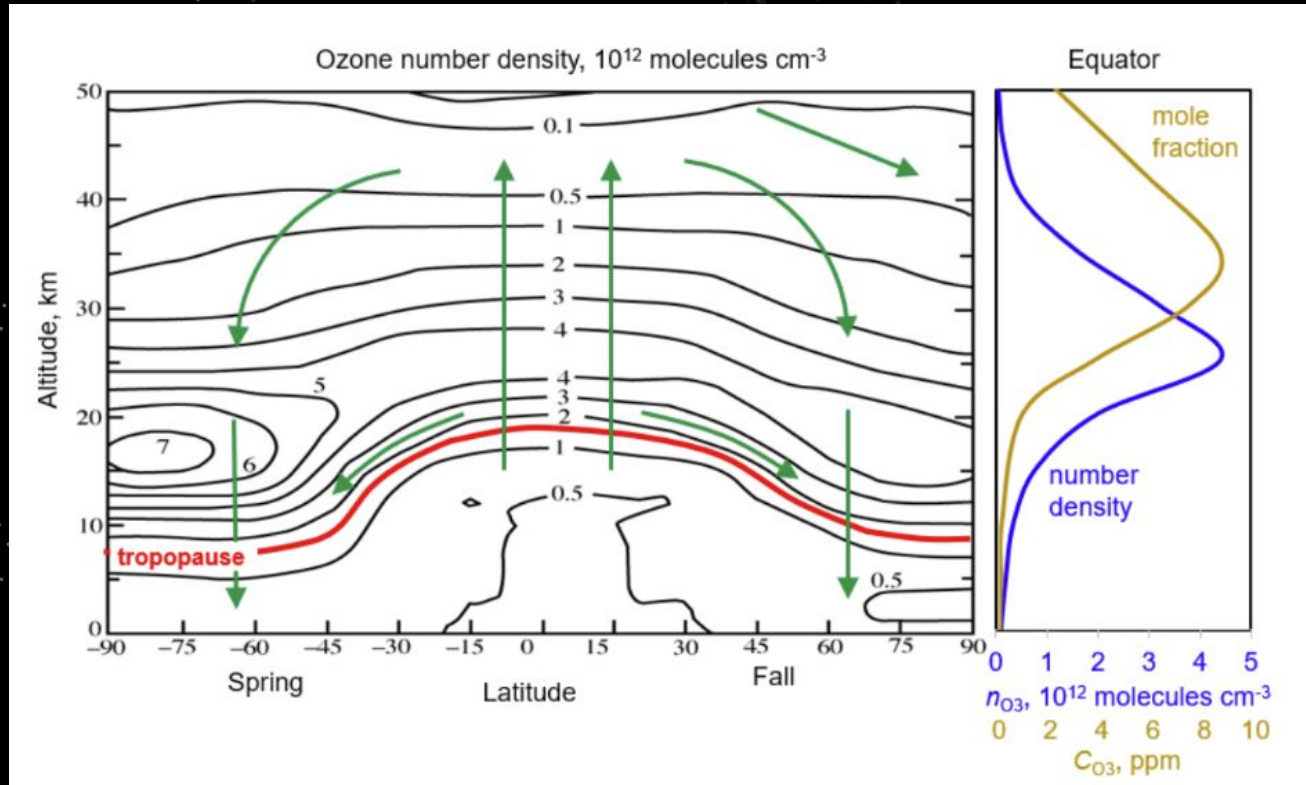


Figure 8-1 from Jacob

If the dominant source of ozone is O_2 photolysis due to the Chapman mechanism, why is it ozone concentration highest at high latitudes?

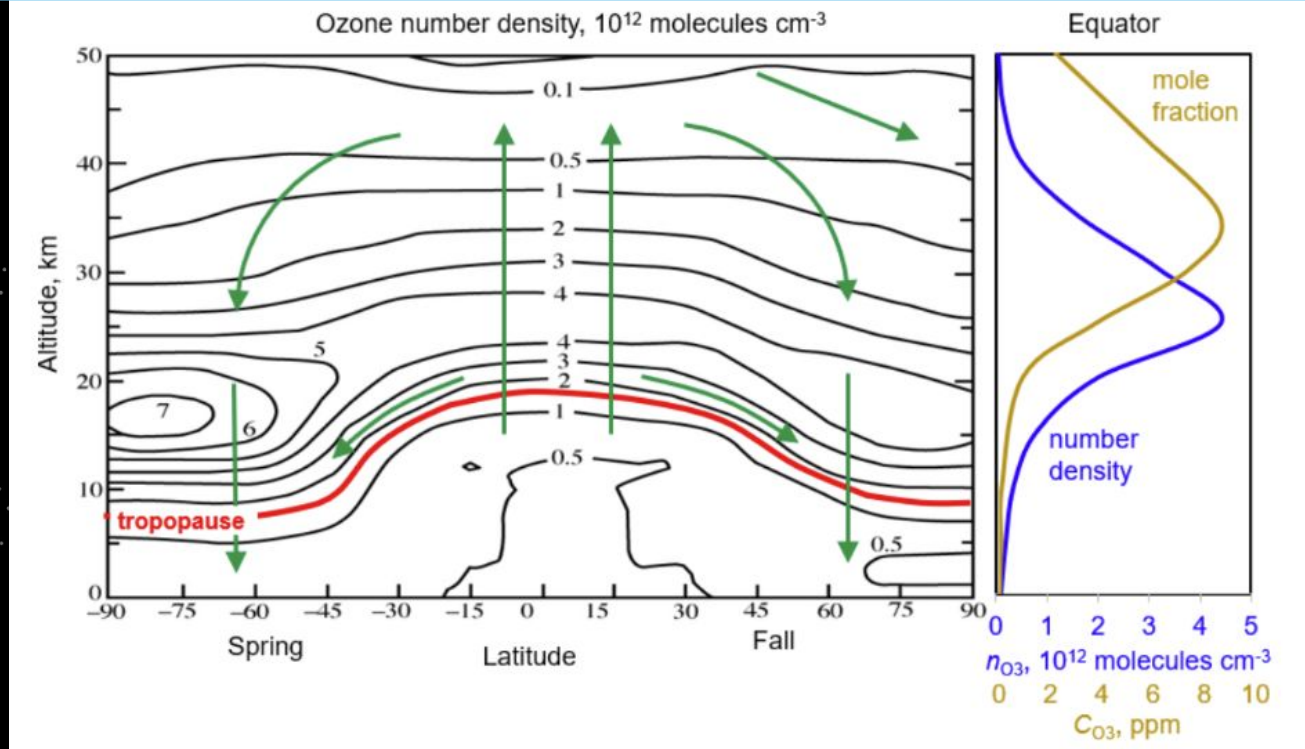


Figure 8-1 from Jacob

Distribution of ozone in the 1960s

- The green arrows represent **Brewer-Dobson circulation**
 - Thick ozone column at high latitudes

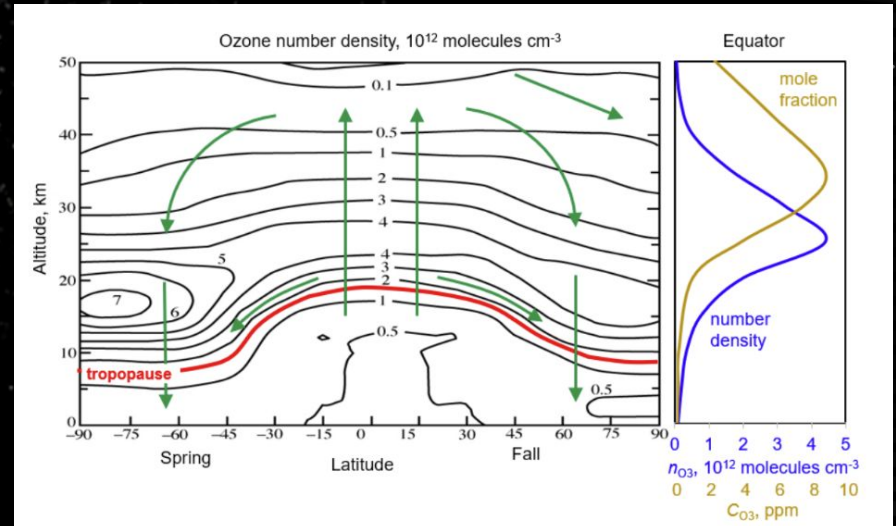
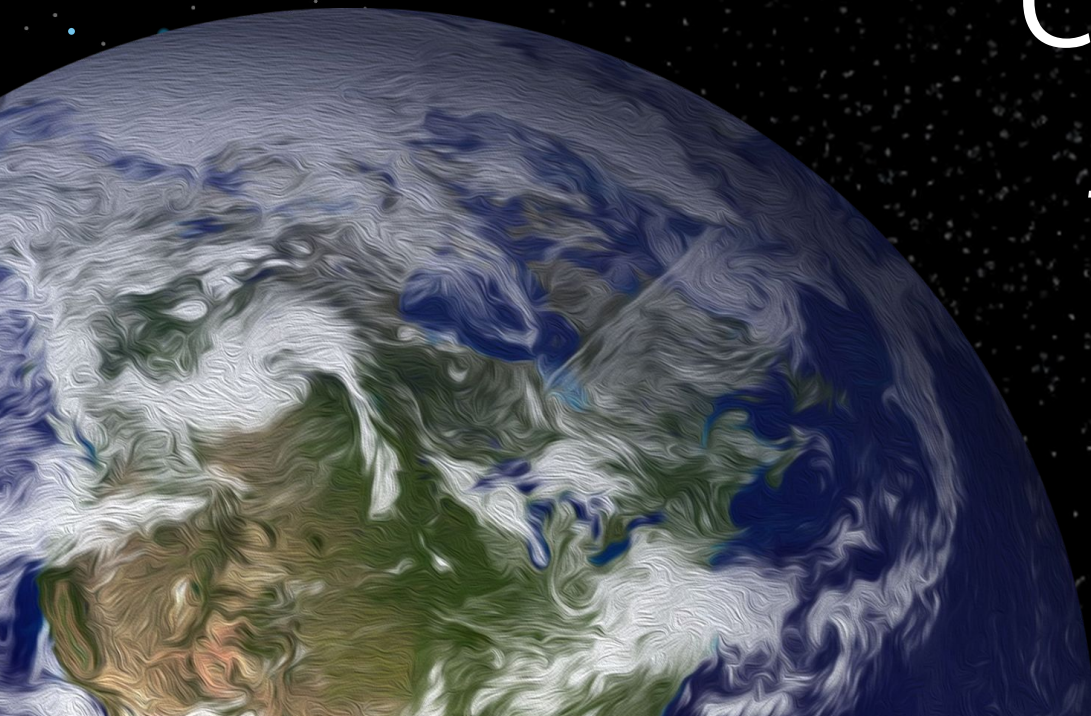


Figure 8-1 from Jacob

03

Catalytic cycles for ozone loss



Closing the ozone budget

So what is responsible, then, for the discrepancy between models based on the Chapman mechanism and actual ozone observations?

Nitrogen oxide cycling

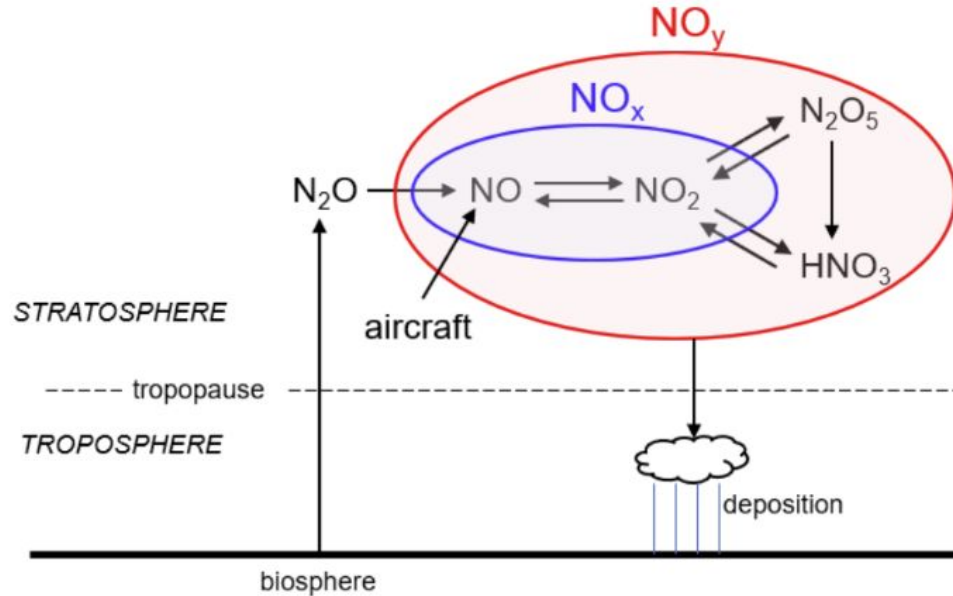


Figure 8-5. Cycling of nitrogen oxides in the stratosphere.

Figure 8-5 from Jacob

Closing the ozone budget

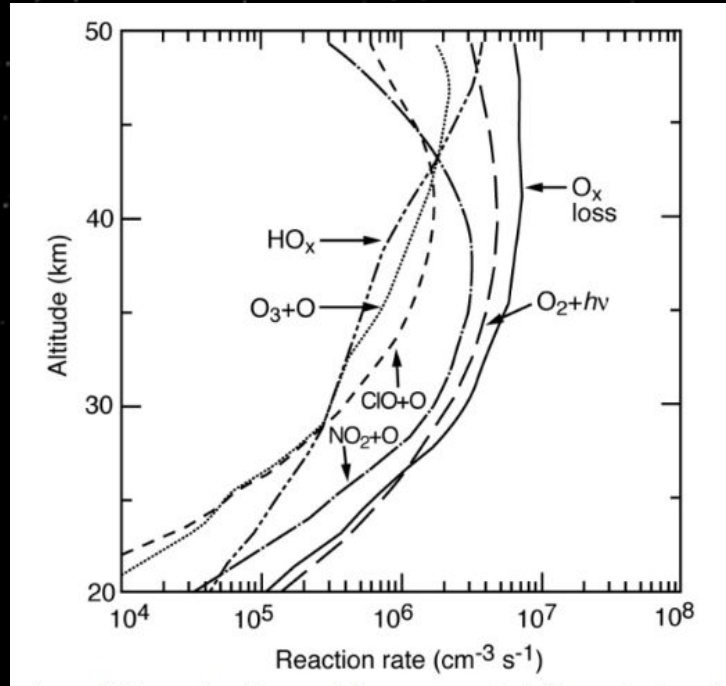
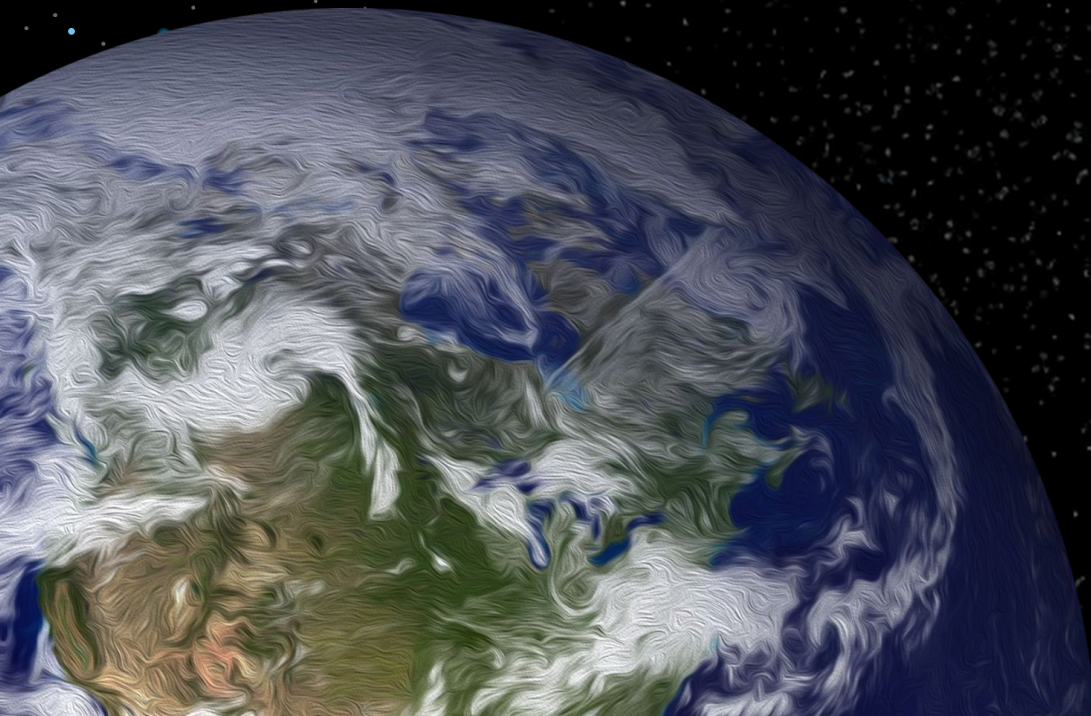


Figure 8-6 from Jacob
(McElroy, M.B., and R.J. Salawitch, *Science* 243, 763-770, 1989)

04

The Antarctic ozone hole



Structure of the ozone hole

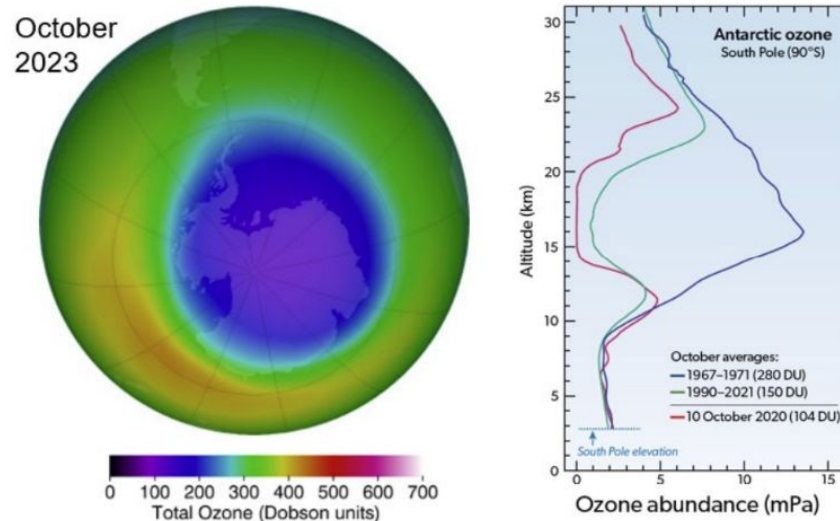


Figure 8-8. Structure of the Antarctic ozone hole. The left panel shows a circumpolar view of the mean ozone column in October 2023, a typical year. The right panel shows ozonesonde profiles at South Pole Station, comparing mean climatological profiles before the development of the ozone hole (1962-1971) versus when the ozone hole was fully developed (1990-2021). Also shown is an extreme profile featuring total ozone depletion in the lower stratosphere. From NASA Ozone Watch (<http://ozonewatch.gsfc.nasa.gov/>) and *Scientific Assessment of Ozone Depletion: 2022*, World Meteorological Organization (WMO) [2022].

What drove the formation of the Antarctic
ozone hole?

What drove the formation of the Antarctic ozone hole?

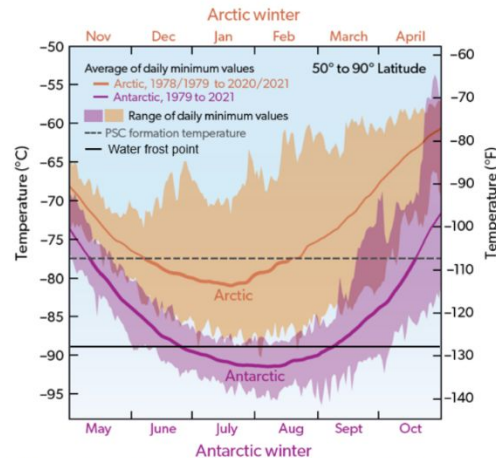


Figure 8-9. Seasonal evolution of minimum stratospheric temperatures in the Antarctic and Arctic from fall to spring. Formation of polar stratospheric clouds (PSCs) begins at -78°C . Water ice clouds form at -89°C . Adapted from *Scientific Assessment of Ozone Depletion: 2022*, World Meteorological Organization (WMO) [2022].

Chronology of the ozone hole

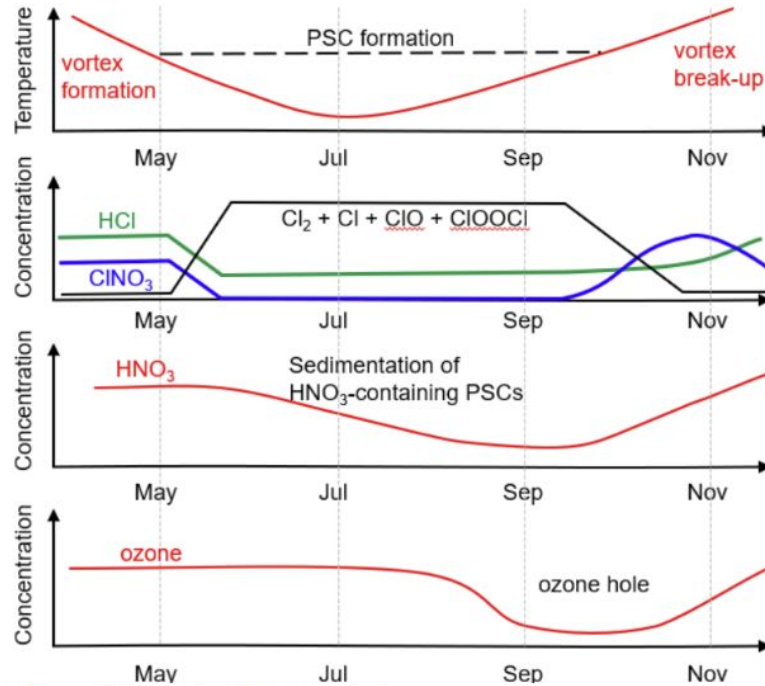
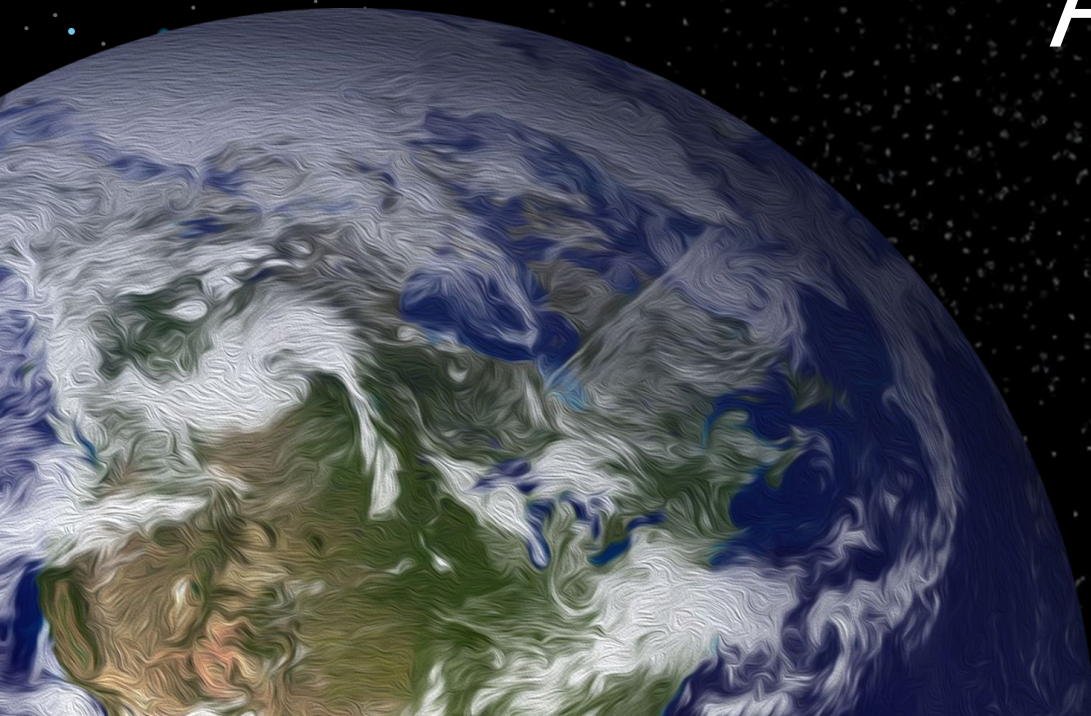


Figure 8-11. Chronology of the Antarctic ozone hole.

05

Aerosol-driven ozone loss



Stratospheric Aerosol Injection (SAI)

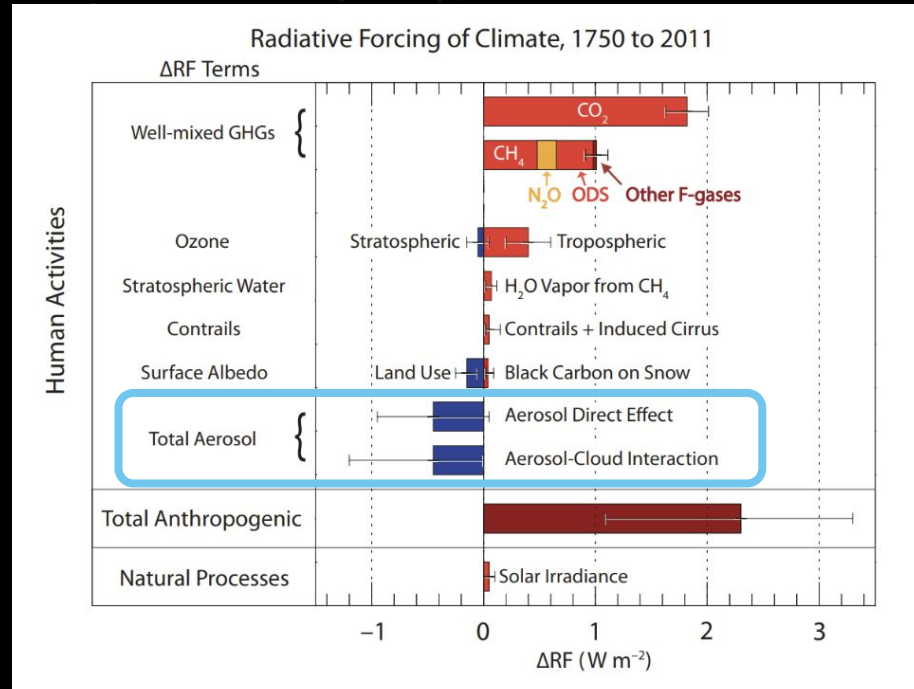


Figure 1.4 from *Paris Climate Agreement: Beacon of Hope*
(Salawitch, R.J.; Bennett, B.F.; Hope, A.P.; Tribett, W.R.; Canty, T.P.)

Stratospheric Aerosol Injection (SAI)

Why can't we just inject aerosols into the atmosphere to offset global warming?

<https://globalnews.ca/video/10445793/stratospheric-aerosol-injection-climate-scientists-divided-over-controversial-technology>

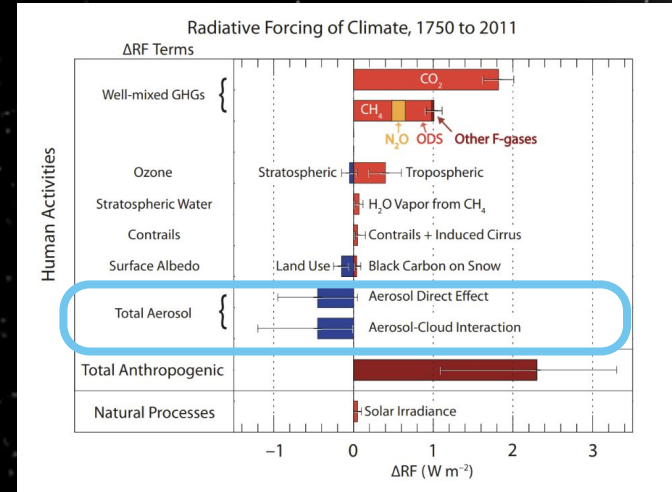


Figure 1.4 from *Paris Climate Agreement: Beacon of Hope*
(Salawitch, R.J.; Bennett, B.F.; Hope, A.P.; Tribett, W.R.; Canty, T.P.)