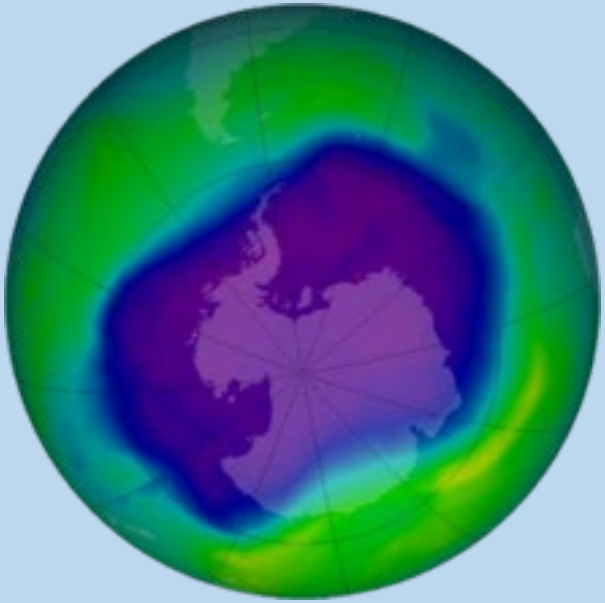
Space Science and Ozone

Began in 1957-1958 during the International Geophysical Year in Antarctica

Early studies concentrated on Earth's magnetic fields, cosmic rays, development of communication networks

Now have more complete understanding of the different atmospheric layers, interactions with solar events, etc.



Ozone 'hole', 2006

https://en.wikipedia.org/wiki/Ozone_depletion

International Geophysical Year
1957-1958

Important landmark for beginning of intense research in Antarctica, as well as other areas of the world and space science

Began at end of 'cold war', 67 countries participated but not China because Taiwan was included

First satellites launched (Sputnik 1) and knowledge of the magnetic field and interactions with cosmic rays and solar winds

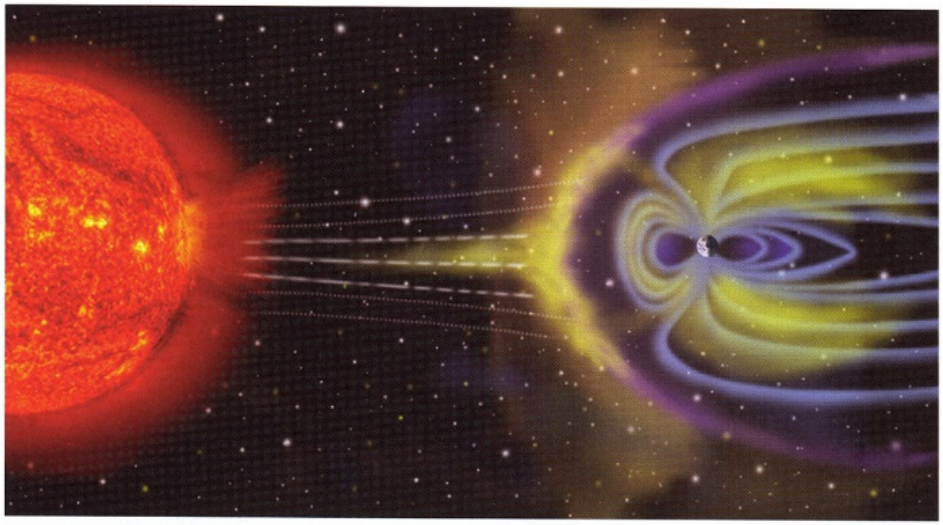
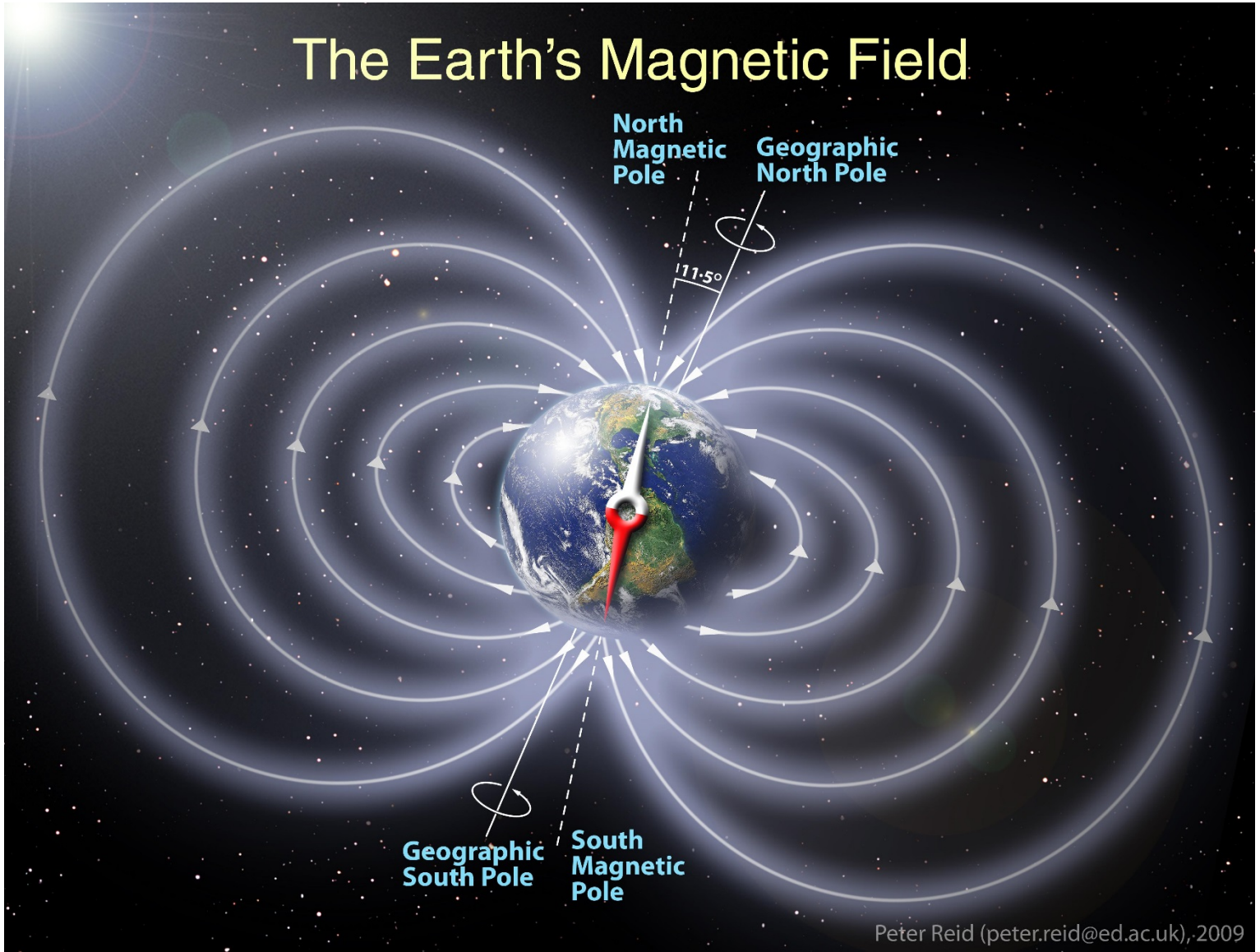


Figure 7.3 An artist's conception of the interaction between the solar wind and Earth's magnetic field. (Credit: NASA)

Fig. 7.3 in text

This field exists because of earth's solid iron core surrounded by liquid magma, creating a magnet-like effect. The magnetic poles have reversed themselves numerous times in earth's history, on average once every million years or so.



The magnetic poles also migrate, as movement of magma is constant (hence, plate tectonics)

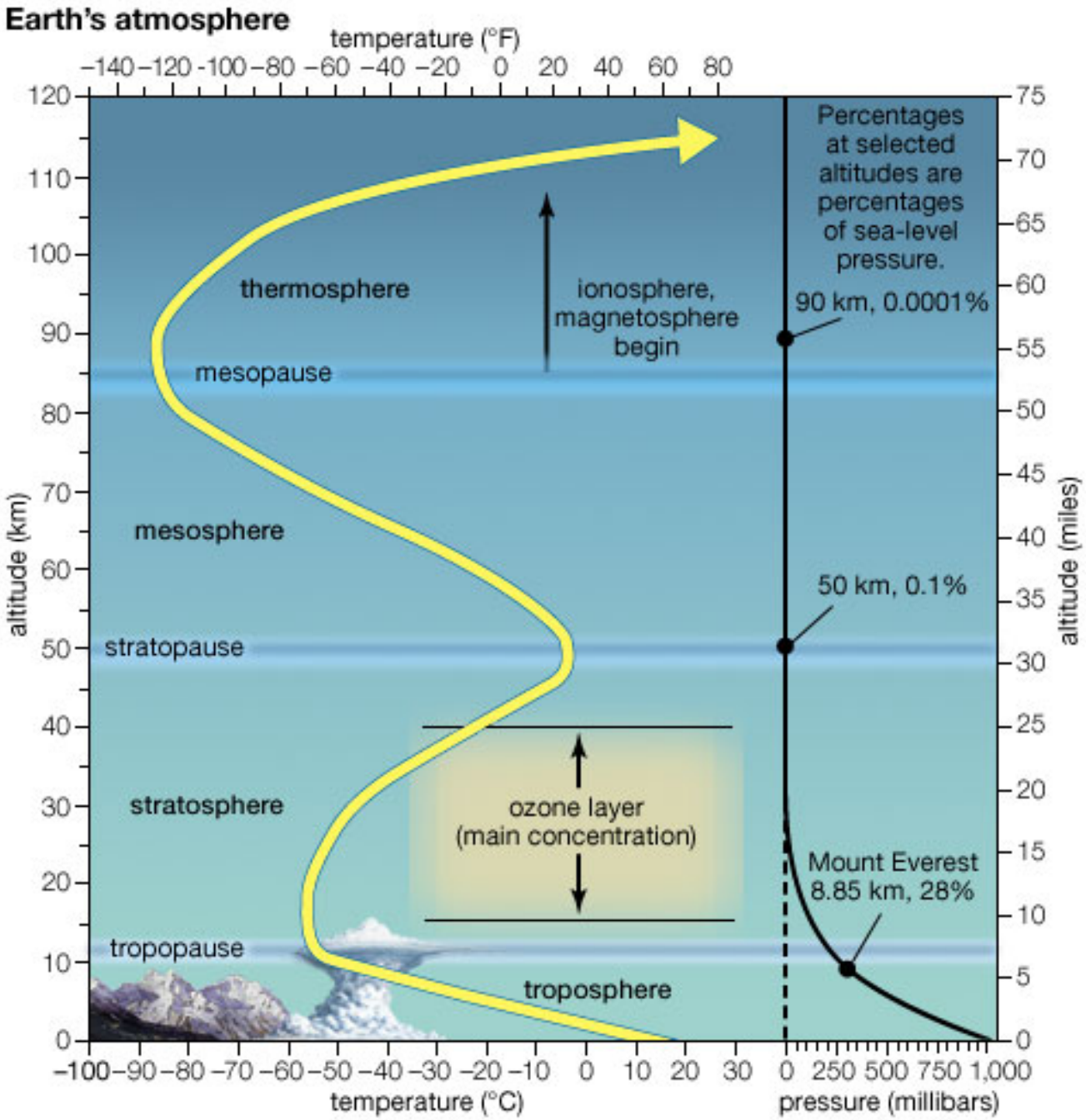
These poles can move up to 40 miles in a year, with the North Pole having moved ~600 miles northward since the early 1800s

Early interest in the magnetic poles for navigation at sea

Later, interests developed on radio waves for communication

Early voyages to Antarctic included scientific studies of the magnetic Pole and radio waves:

James Clark Ross, British, 1839-1843
Charles Wilkes, American, 1838-1842, U.S. Exploring Expedition
Dumont D'Urville, France, 1837-1840



Auroras occur here

Knowledge gained about space since IGY

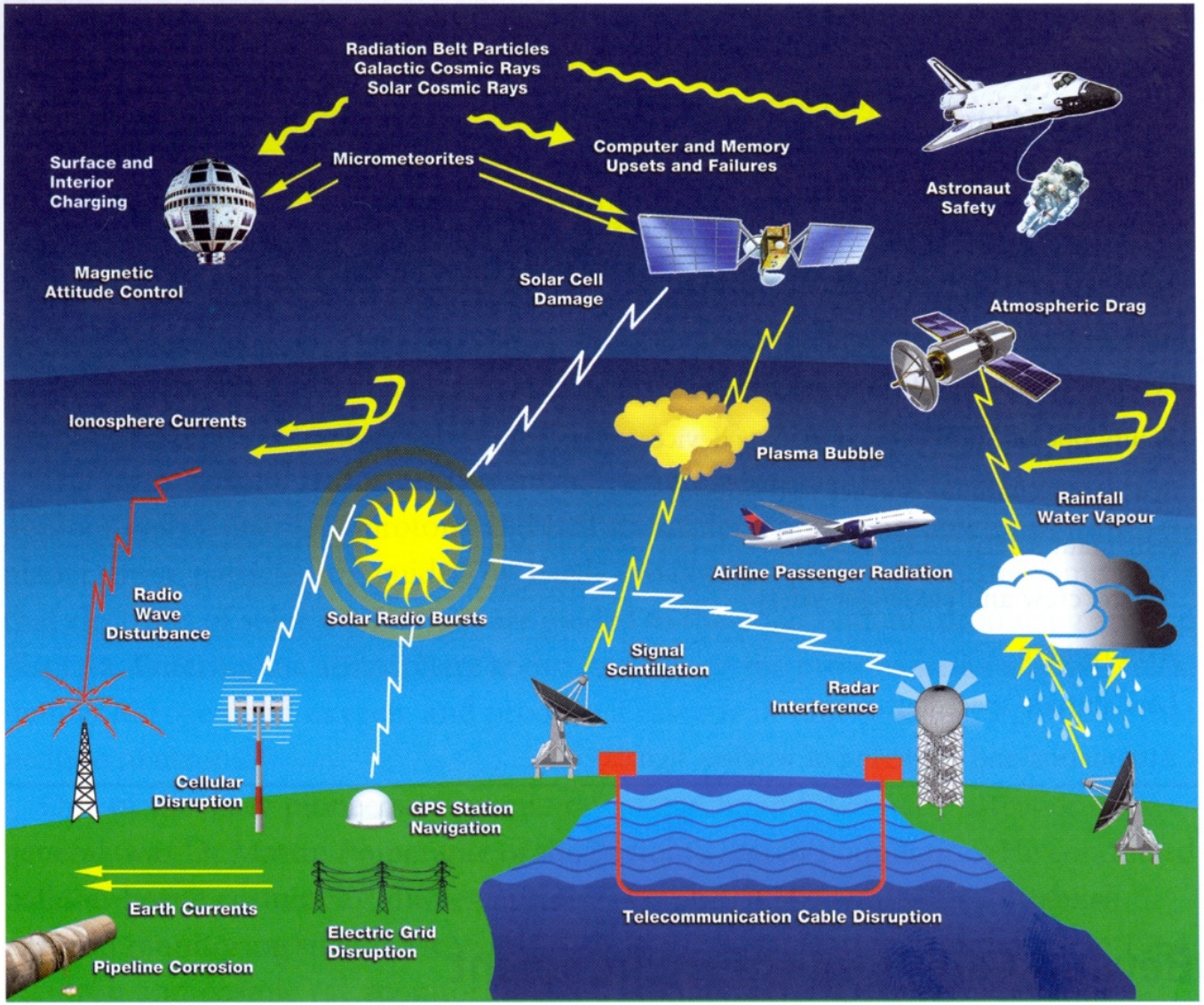


Figure 7.9 Space weather effects on technologies. (Credit: Alcatel-Lucent/New Versey Institute of Technology)

Fig. 7.9 in text

Astronomy in Antarctica

Ideal for space telescopes because of extreme cold

--prevents water vapor in air that would distort view
--reduced interference of infrared radiation from ground or from the scope itself
--reduced aerosols or pollutants
--no light pollution
--stable bedrock, little seismic activity

http://icestories.exploratorium.edu

Telescope at South Pole was first built in the 1970s

--has provided some of the best images of comets, solar events

--greater understanding of cosmic rays

Neutrinos

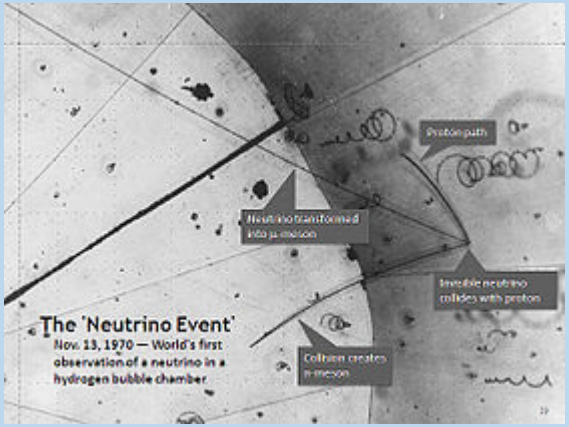
Neutrinos are neutral subatomic particles that originate with radioactive decay, or are emitted from nuclear reactions in the sun or from black holes in space

Billions pass through your body all the time

Hard to detect, only discovered in 1950s, but may interact with ice to for a blue flash, called Cherenkov radiation

Need a large array to detect these particles, Antarctic environment is ideal

Study of neutrinos helps us understand processes in the sun as well as the early universe after the Big Bang



The IceCube Telescope

Built between 2005 and 2010, at a cost of hundreds of millions of dollars, at the South Pole

Followed an earlier model, AMANDA, built in the 1990s

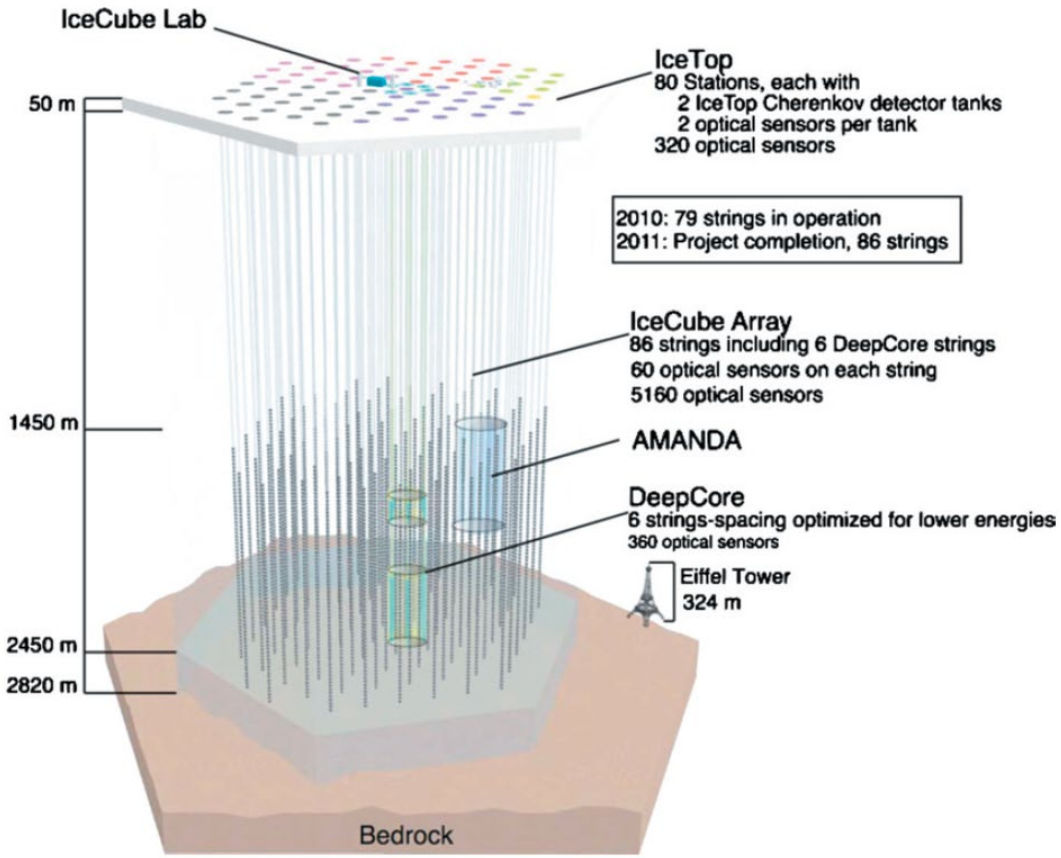
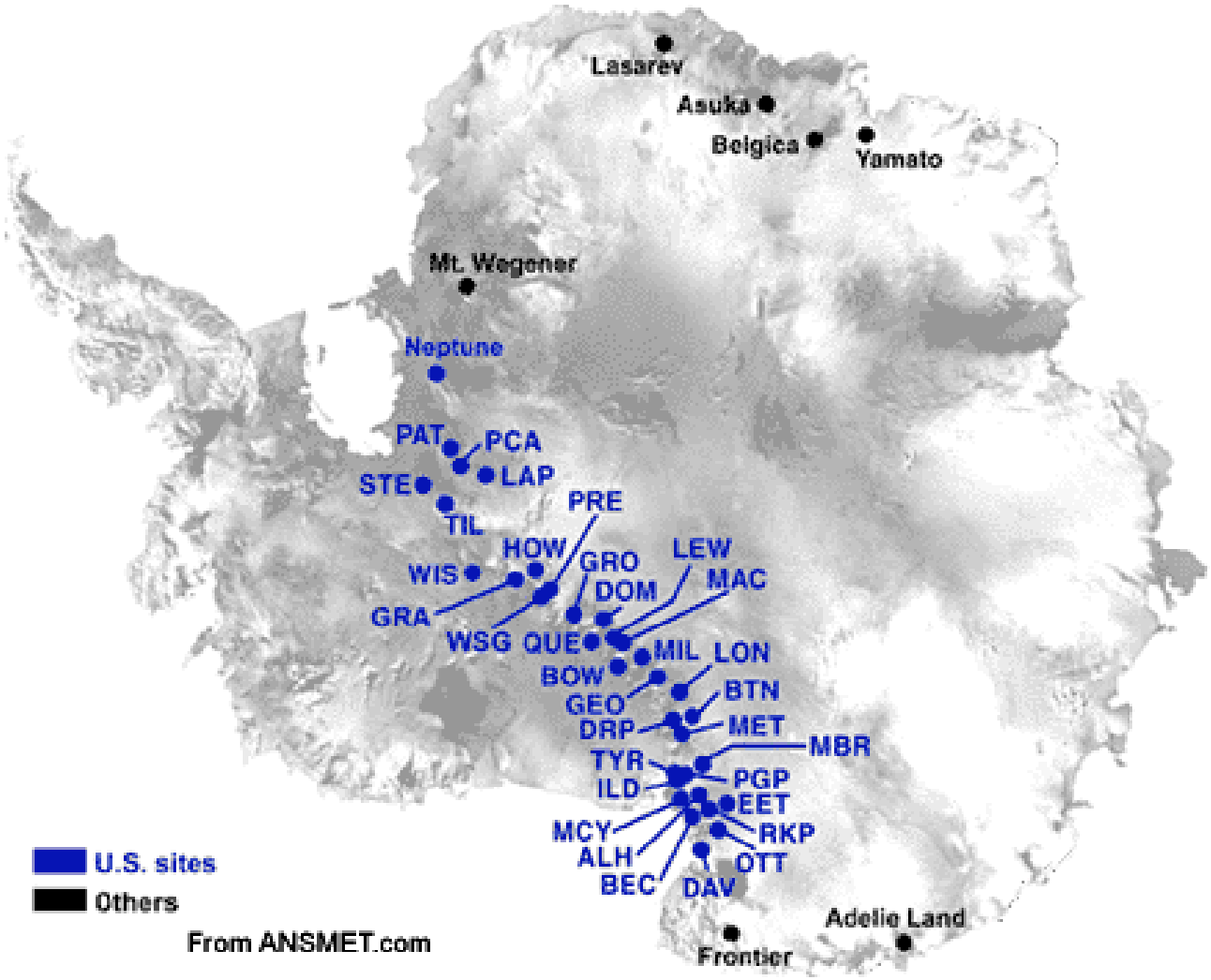


Fig. 7.12 in text

Good website for basic neutrino facts:

https://icecube.wisc.edu/info/neutrinos

Meteorites in Antarctica

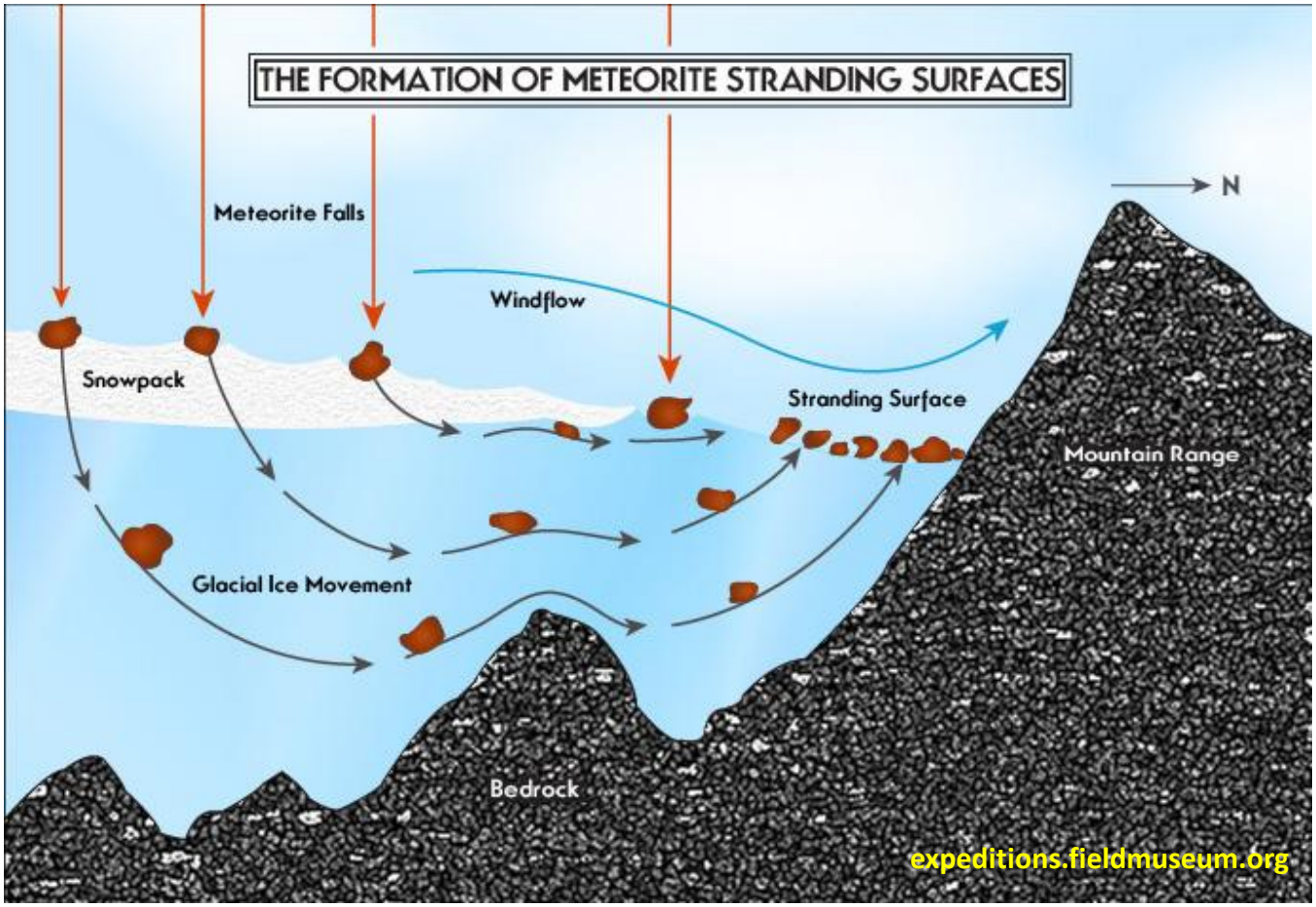


Antarctica: the perfect meteorite trap

Crash into ice, so less damage and more intact

Swept up by glacial movement to form meteorite fields

Stand out well on the white surface



First meteorite discovered in Antarctica in 1911 on Adelie Land coast

Over 17,500 have been recorded and collected since that time

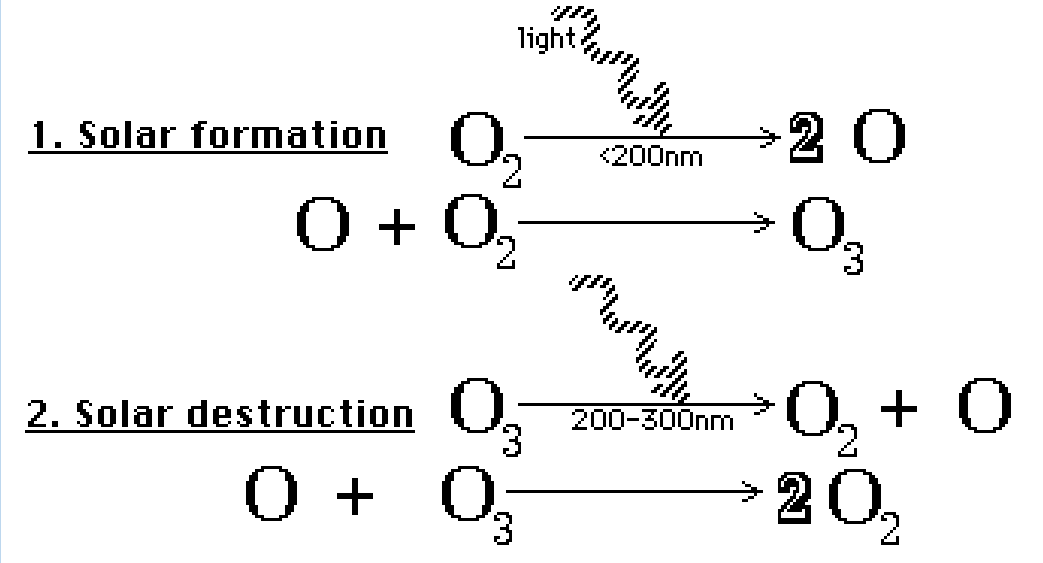
Have provided new information on the structure of the moon and mars, how asteroids form

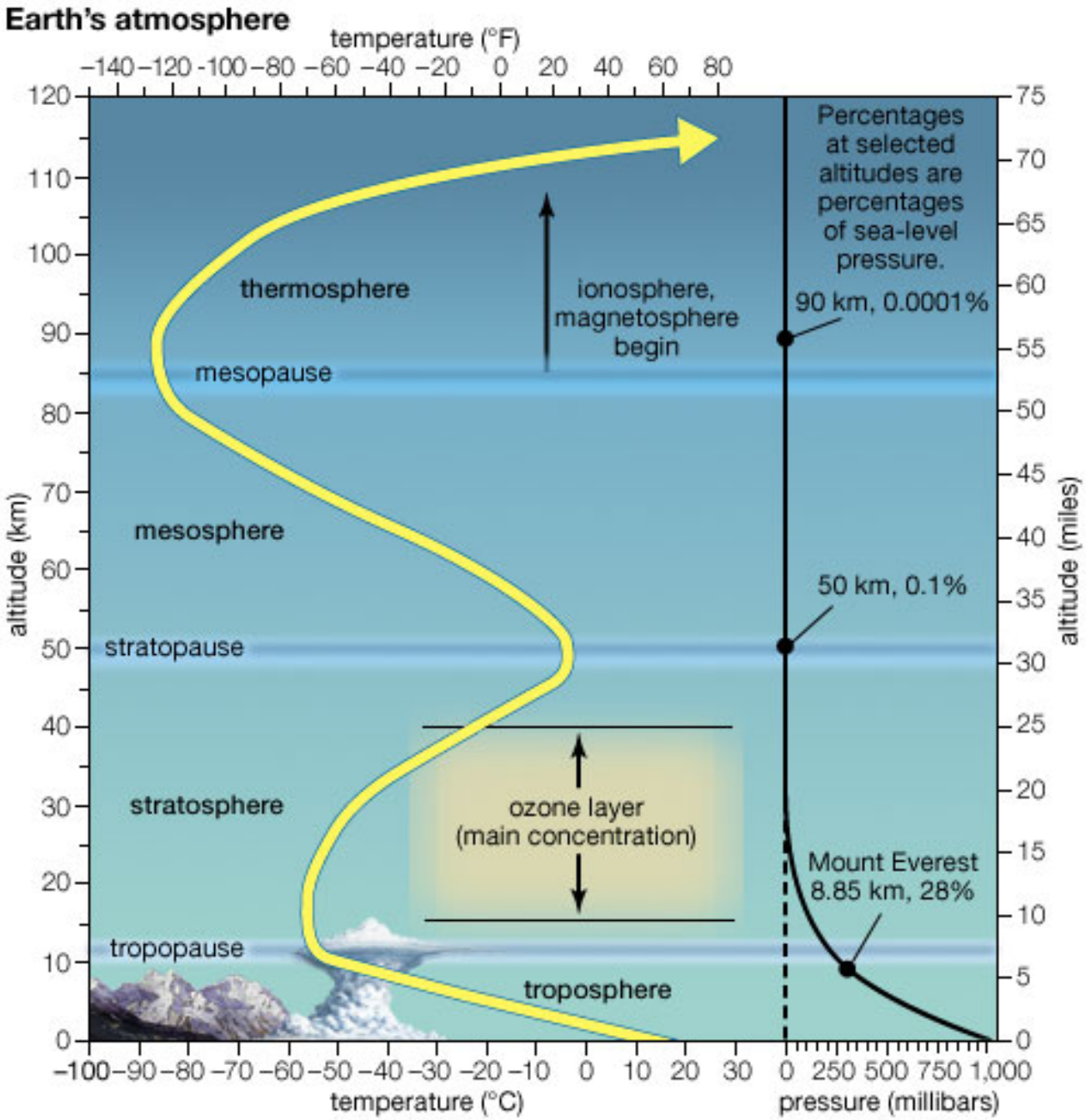
Ozone and the Antarctic Ozone Hole

Ozone is simply the O_3 molecule

Constantly forming or breaking apart in stratosphere, ~15-25 km above surface

React with UV light:





Auroras occur here

Early earth atmosphere did not have ozone

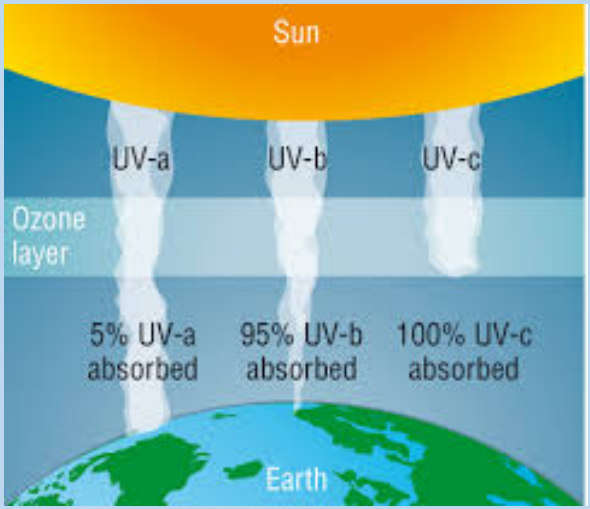
No protection on surface from UV light = no terrestrial life

Why life evolved first in the water, where UV light was reflected or absorbed

Once marine plants evolved ~3 billion yrs ago, photosynthesis produced O_2 and this in turn led to buildup of O_3

It took ~2.5 billion years for these plants to produce enough ozone for terrestrial life to evolve ~500 mya

Eventually, an equilibrium was reached in the atmosphere where the amount of O_3 being formed = amount destroyed by UV



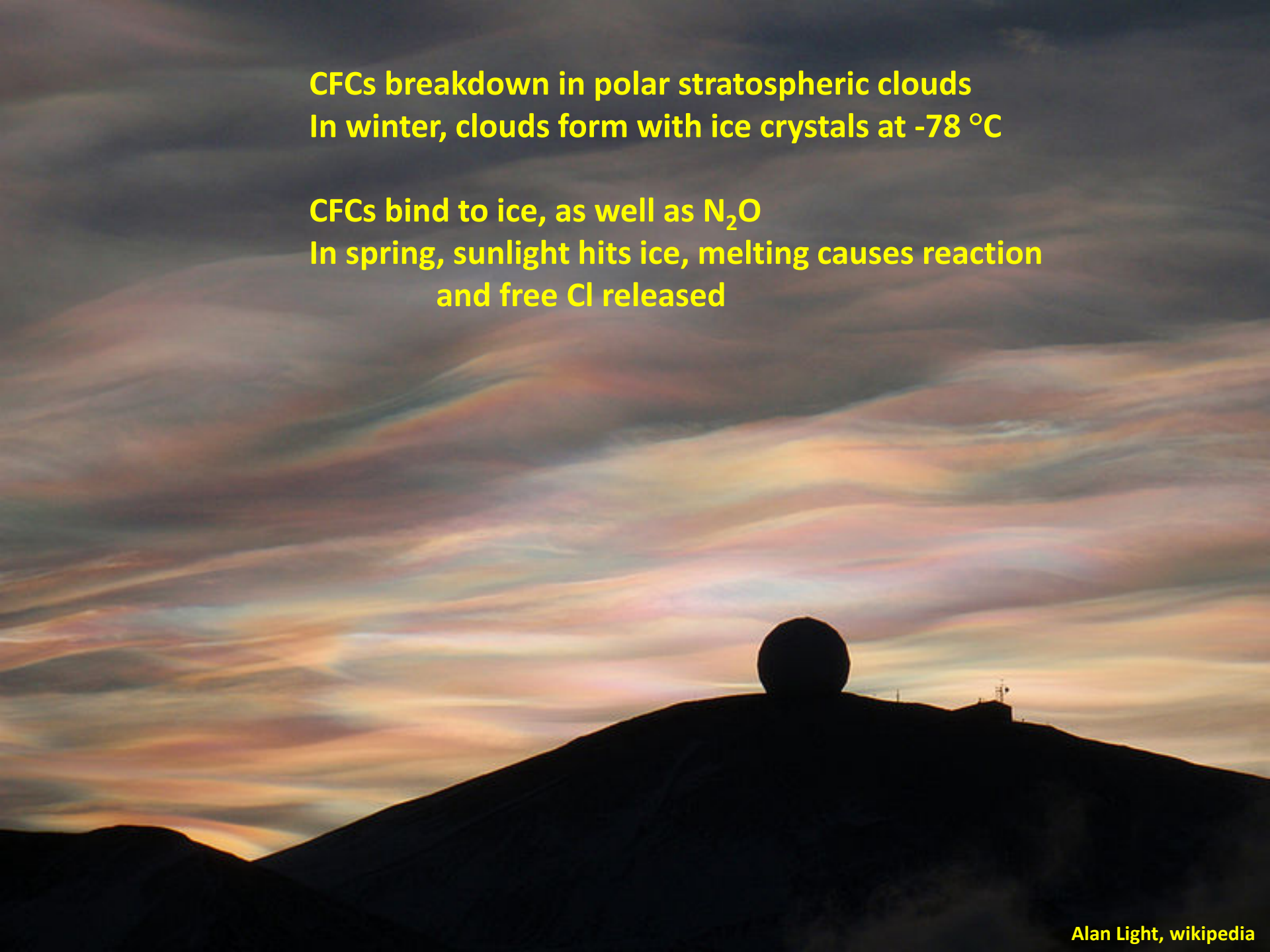
Ozone decline first reported at Halley Station (UK) in 1985

--station was founded in 1956 for IGY in 1957-1958

--conducting basic atmospheric studies, then saw decline was occurring since 1977

--further research indicated that Chlorine in the ozone hole was part of the problem

--Cl could only be in the atmosphere by artificial means, led to indication that CFCs were responsible


CFCs breakdown in polar stratospheric clouds
In winter, clouds form with ice crystals at -78 °C
CFCs bind to ice, as well as N_2O
In spring, sunlight hits ice, melting causes reaction
and free Cl released
Alan Light, wikipedia

Chlorofluorocarbons (CFCs)

--artificial compounds with chlorine and fluorine developed in the 1930 as coolants, solvents

--must break down to release Cl to be harmful to ozone

--break down with cold temperatures (ice particles) and light

$$Cl + O_3 \longrightarrow ClO + O_2$$

$$ClO + O_3 \longrightarrow Cl + 2O_2$$

$$\text{overall} \quad 2O_3 \longrightarrow 3O_2$$

Thus, one Cl atom can destroy 100,000 O_3 before washing out of the stratosphere

Antarctica is the ideal place for CFCs to break down

--every winter have extreme cold, formation of polar stratospheric clouds with ice crystals

--CFCs bind to crystals, then hit by light in spring and Cl released

--why the ozone hole forms every spring

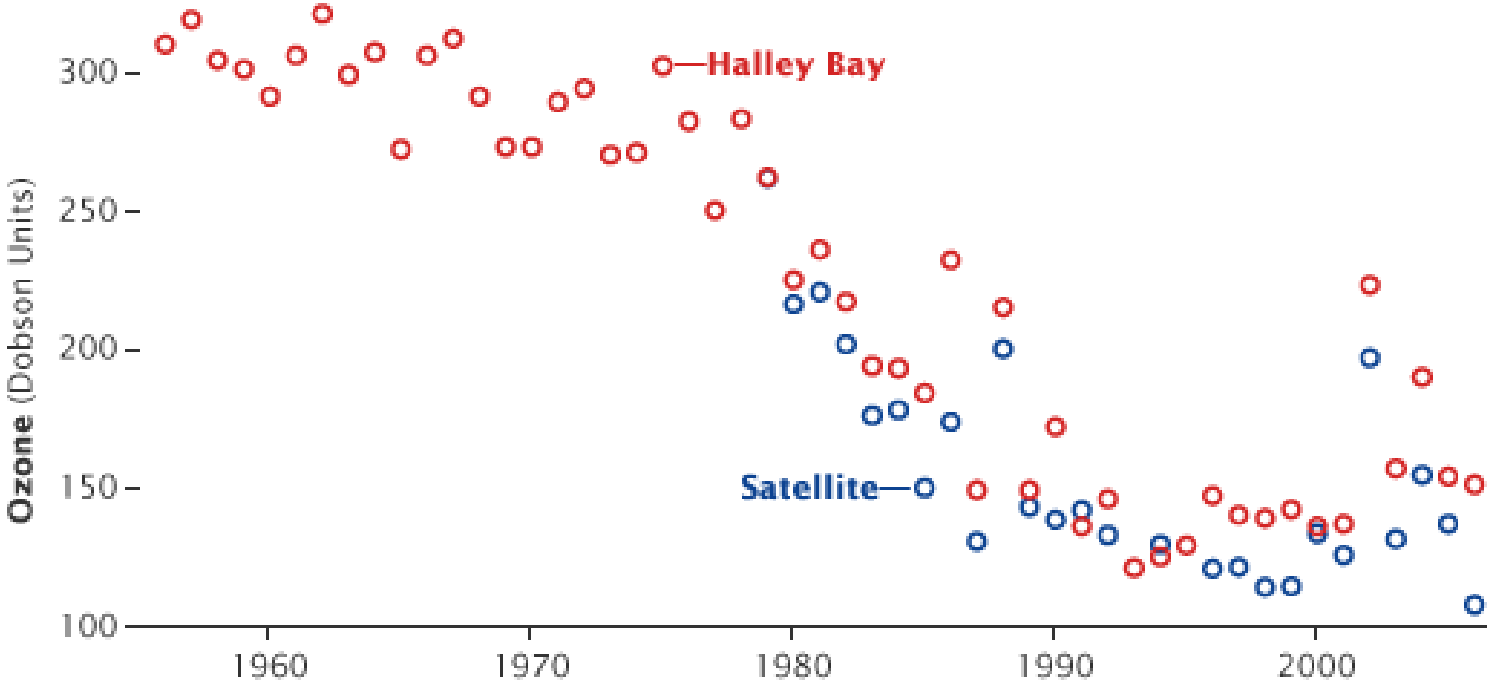
Ozone concentration measured in Dobson Units: 1 molecule of O_3 per billion of air

--in 1950s, normal level above Antarctica was 320 DU

--sharp declines began in mid 1970s

--by 1985, there was a 40% decline in previous equilibrium

--by 1994, 72% decline (only 91 DU)


Halley Bay
Satellite
Ozone (Dobson Units)
300
250
200
150
100
1960
1970
1980
1990
2000

Ozone hole, 1979-2013

https://www.youtube.com/watch?v=lBu3vltczRw

Quiz

1. What causes the earth's magnetic field and why do the magnetic poles migrate?

2. Why is Antarctica an ideal location for space telescopes?

3. What are neutrinos and why study them?

4. Why are there so many meteorites in Antarctica?

5. How does ozone form and how do CFCs cause an ozone hole?