Going to Work in Antarctica: Doing Science at the Bottom of the World

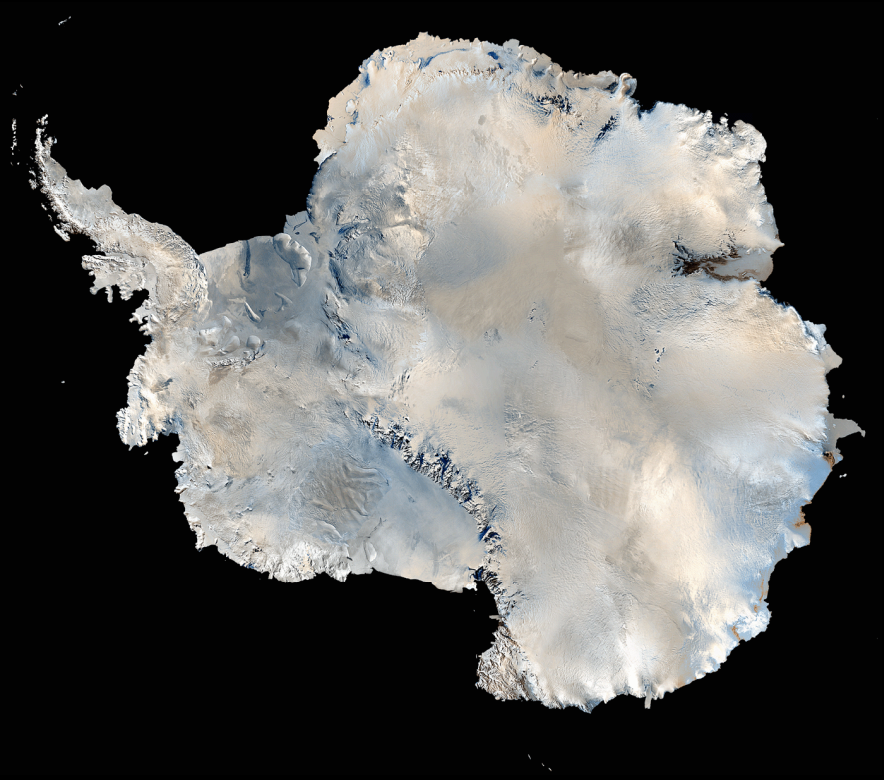
Susan Solomon Senior Scientist, NOAA Aeronomy Laboratory

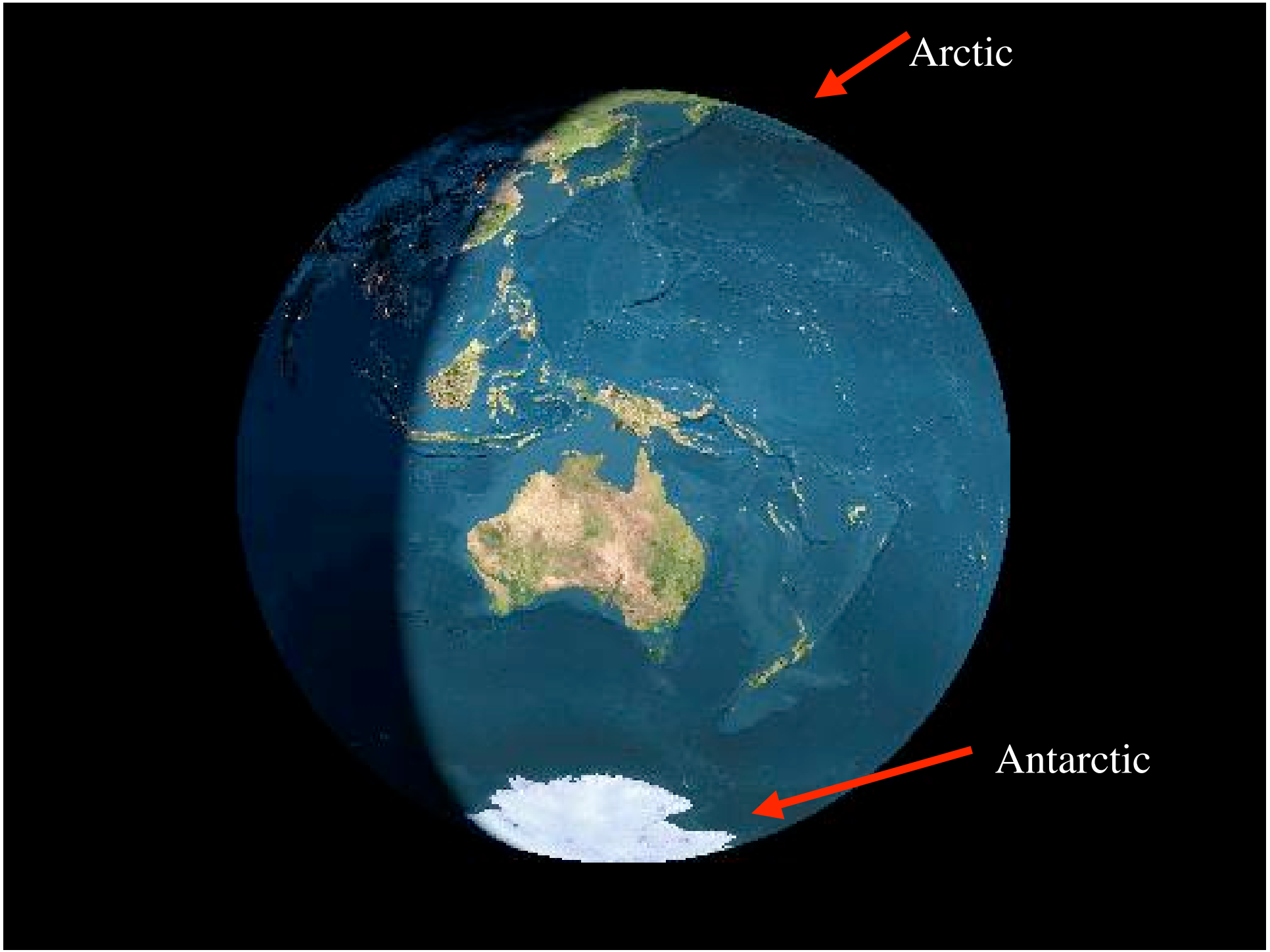
1) A Travelogue (because it was fun)

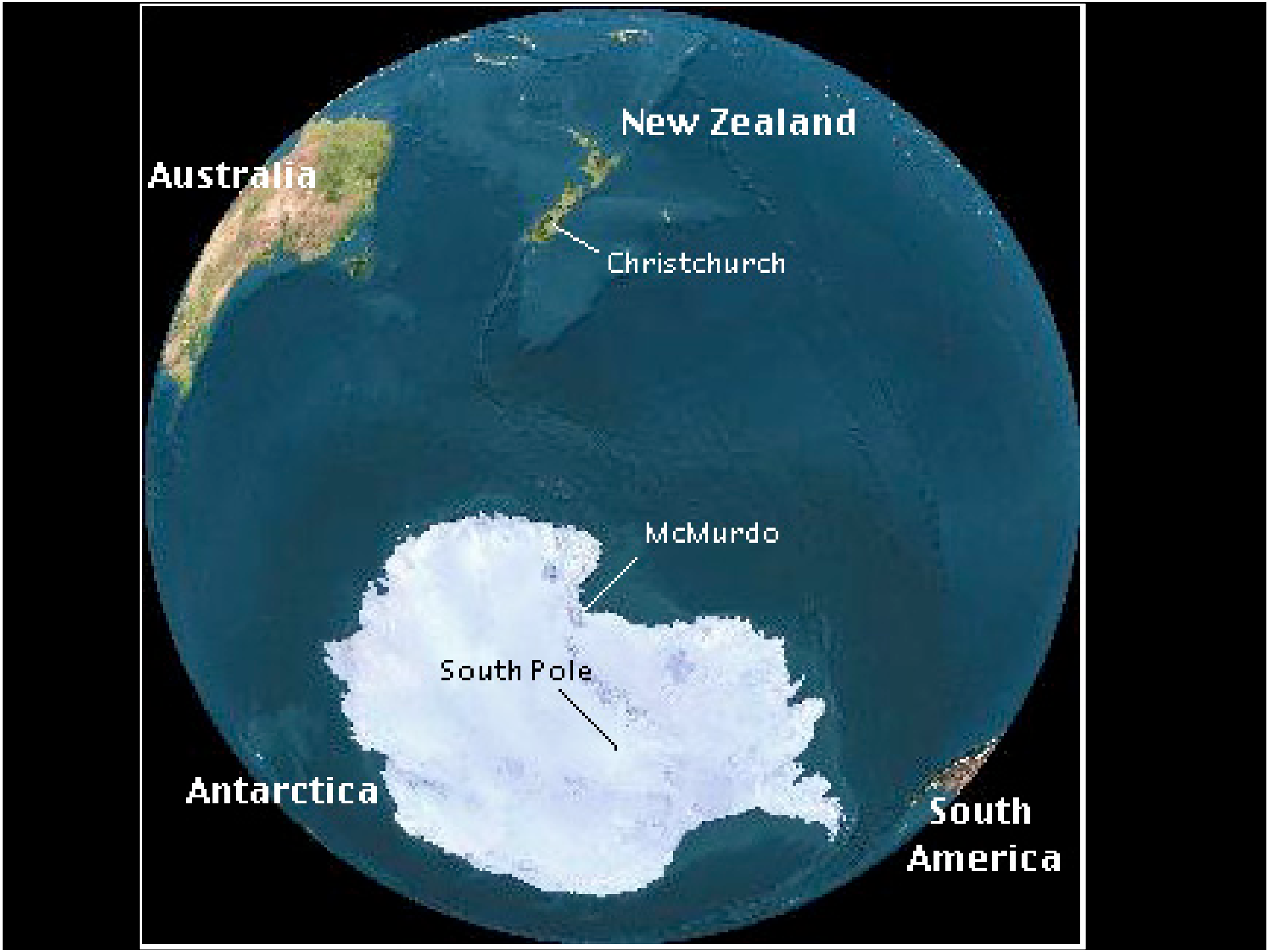
2) What I did there: The National Ozone Expedition 1986/7

3) Some of my other work (and all of it was fun)

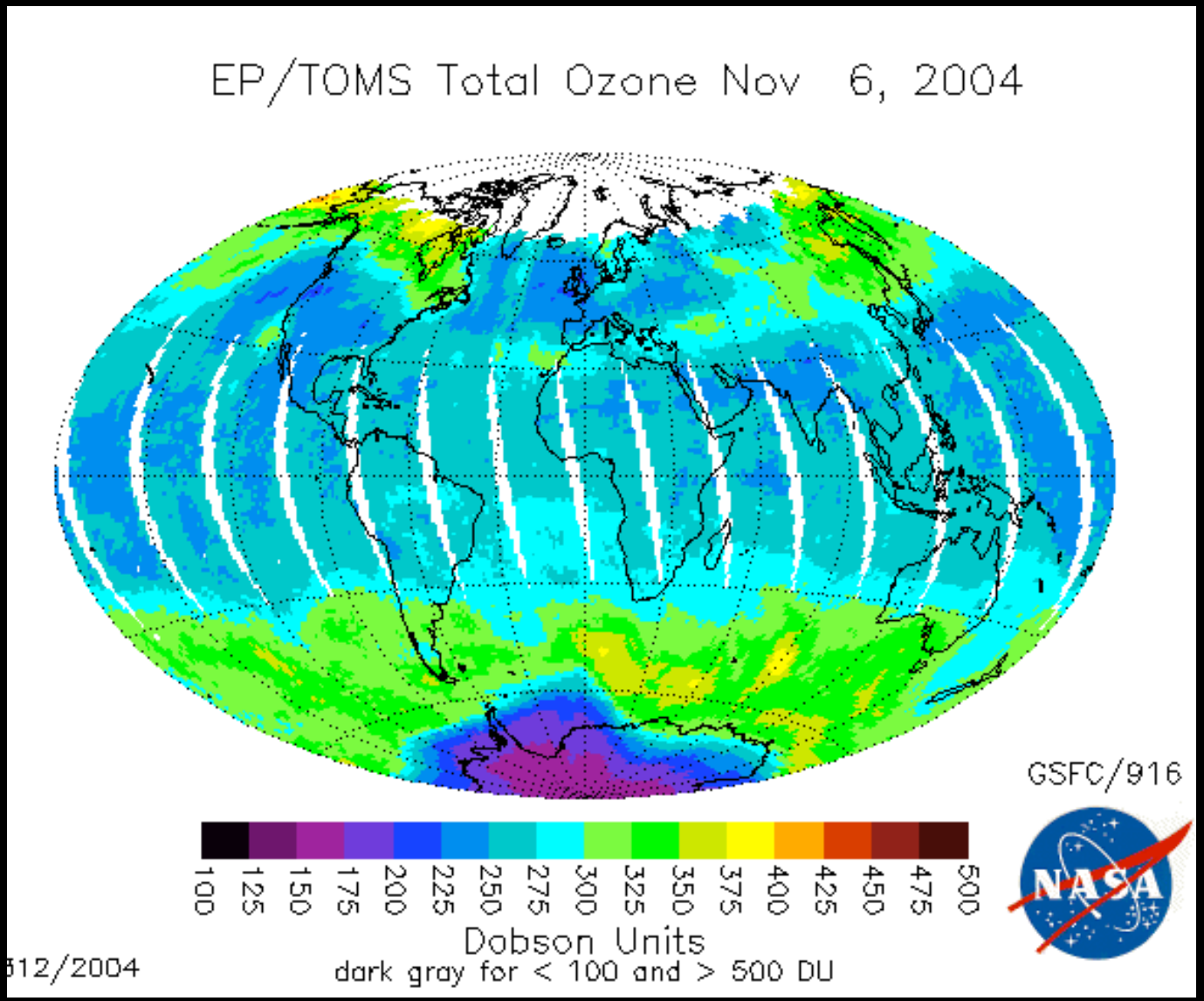
4) What other scientists do in Antarctica (because it is one of the greatest laboratories on Earth)



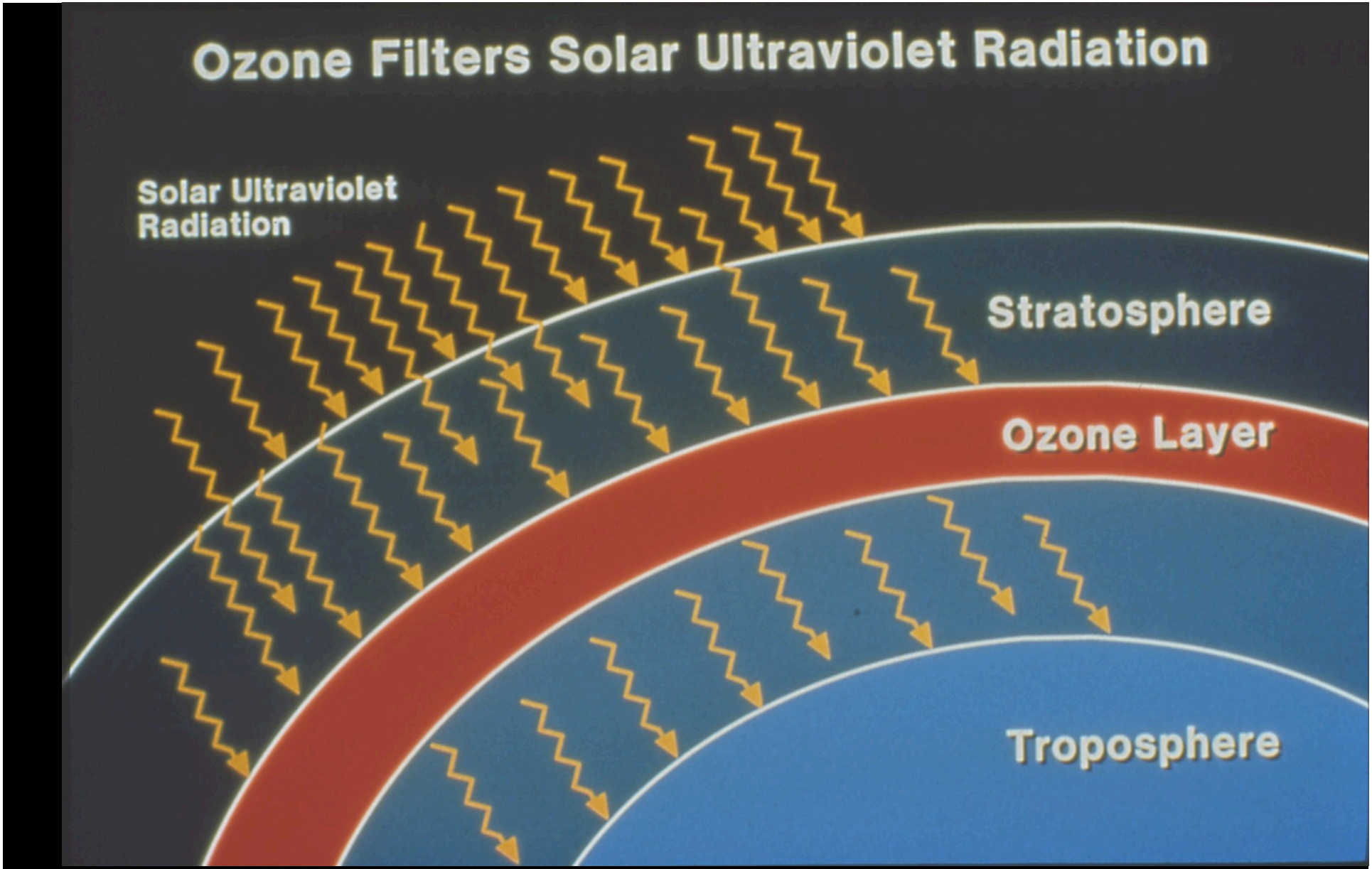

Arctic
Antarctic


New Zealand
Australia
Christchurch
McMurdo
South Pole
Antarctica
South America

There is a hole in our ozone layer over Antarctica every spring:



It was a shock to the world when it was discovered, and it changed my life.



Three kinds of ozone: good (stratosphere), bad (troposphere), and ugly (smog).

Plant grown in normal light

Plant grown in extra UV light

The National Ozone Expedition:

4 research groups, 16 scientists, 5000 kg equipment

On the tarmac in New Zealand
3:00 am August 23, 1986

A special polar airplane on skis

One aborted flight and nine hours later.

McMurdo Station, Antarctica: the Tokyo of Antarctica

Everything is recycled, very carefully.

There are some cool places nearby

All of Antarctica is a magnificent crystal palace

Stratospheric sink for chlorofluoromethanes : chlorine atomc-atalysed destruction of ozone

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Department of Chemistry, University of California, Irvine, California 92664

Chlorofluoromethanes are being added to the environment in steadily increasing amounts. These compounds are chemically inert and may remain in the atmosphere for 40–150 years, and concentrations can be expected to reach 10 to 30 times present levels. Photodissociation of the chlorofluoromethanes in the stratosphere produces significant amounts of chlorine atoms, and leads to the destruction of atmospheric ozone.

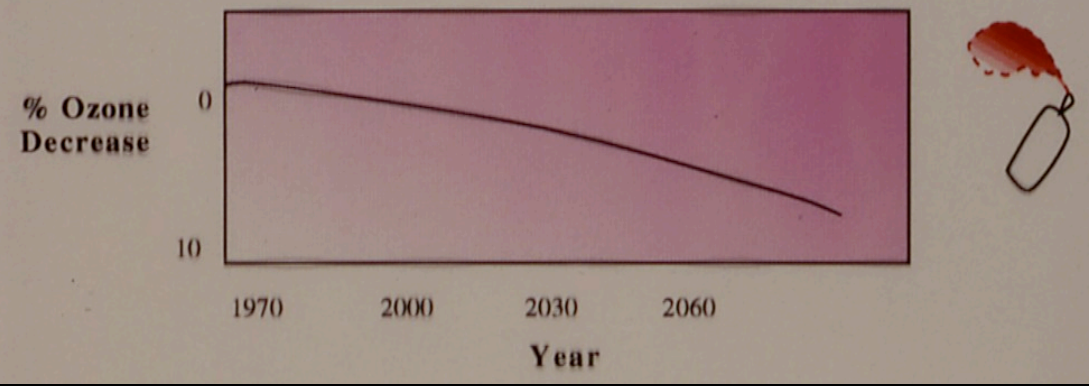
Reactions among gases only:

$$Cl + O_3 \rightarrow ClO + O_2$$

$$O + ClO \rightarrow Cl + O_2$$

Net: $O + O_3 \rightarrow 2O_2$

1975-1985. Expected that CFCs and Halons might deplete the ozone layer. Predicted 5-10% in 100 years.

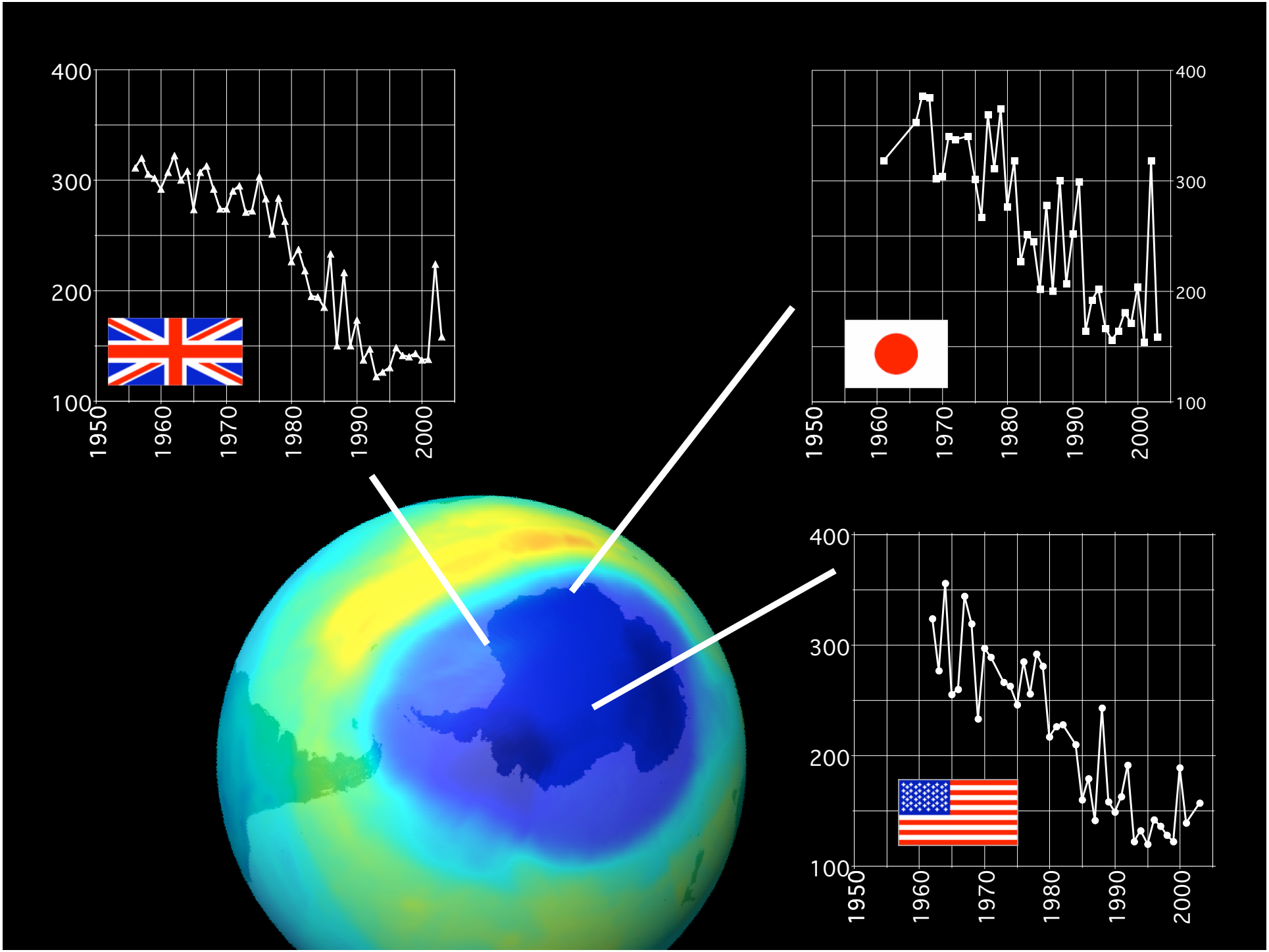


Risk of long-lasting effects…..

But only a theory….

A small effect….

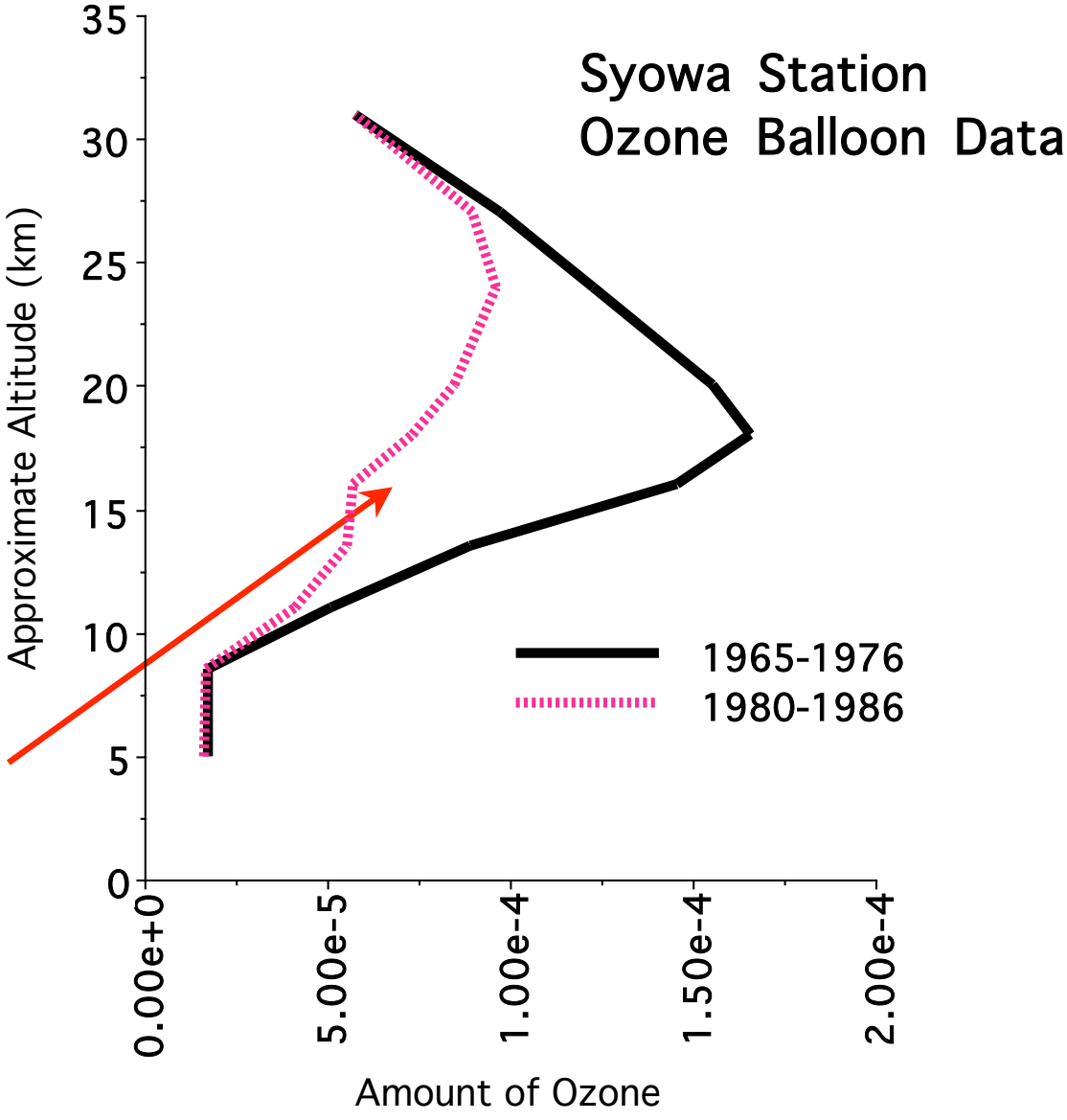
Far in the future…


400
300
200
100
1950
1960
1970
1980
1990
2000

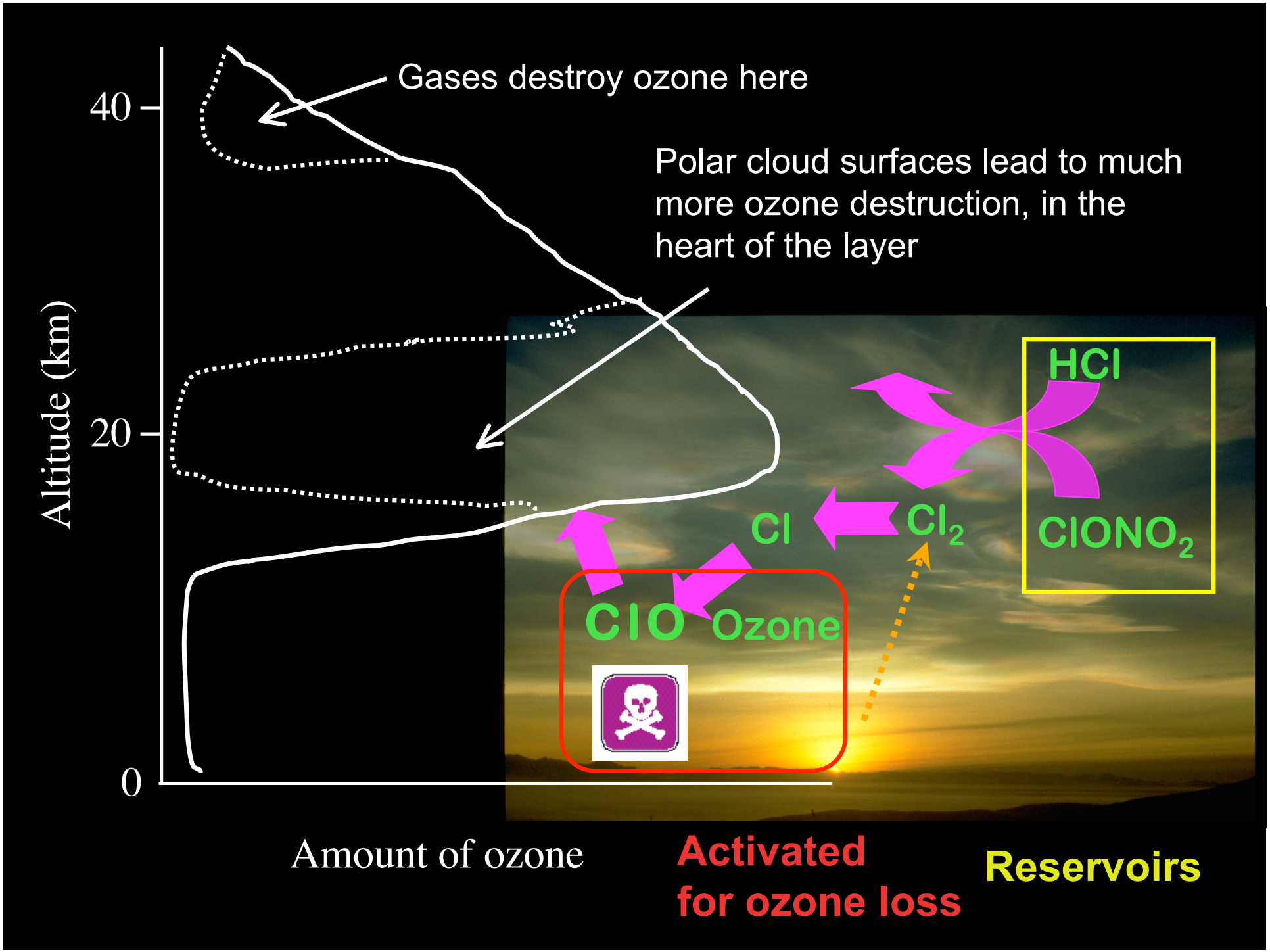
Launching ozone-measuring balloons

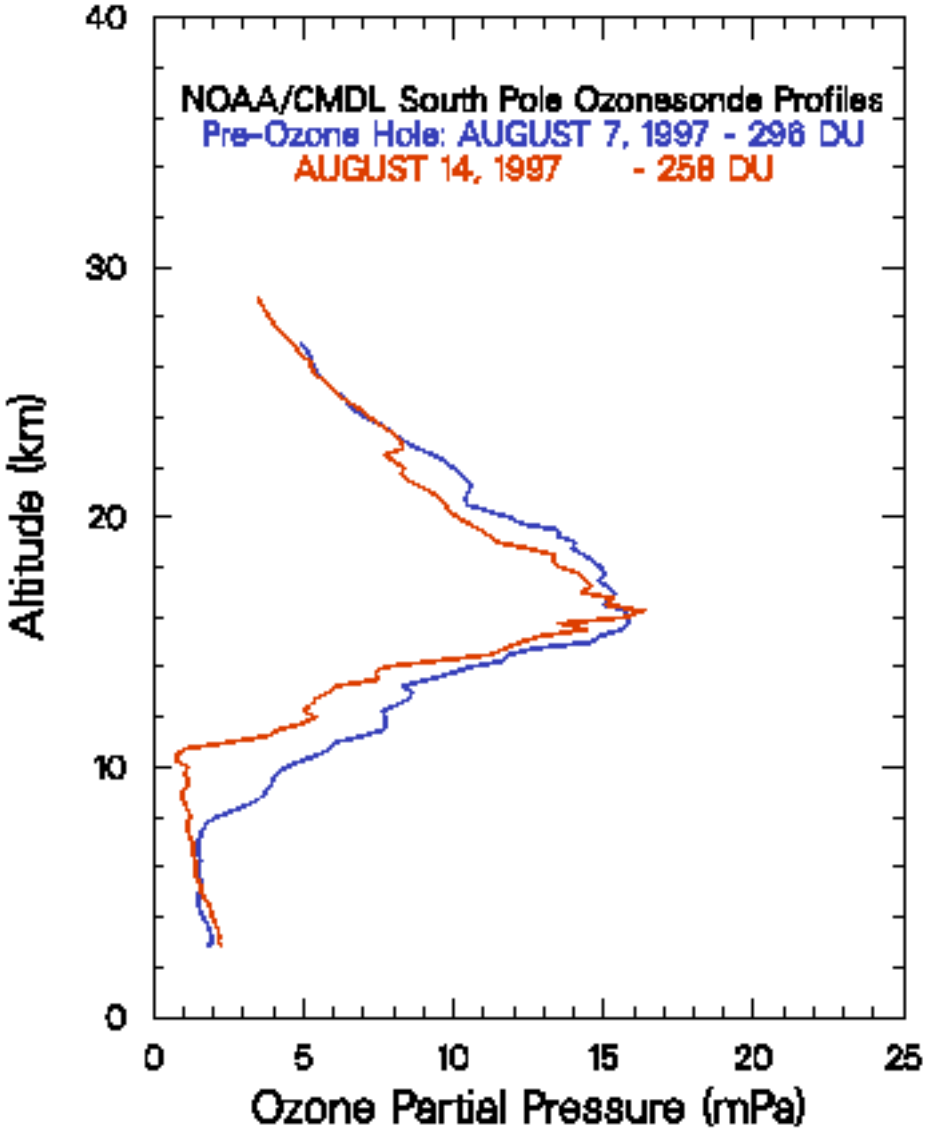
10-25 km, not 40 km as predicted from gas-phase chemistry. I am very grateful to Japanese scientists for this data.

Missing total ozone, but from WHERE in altitude? Only the Syowa data could tell us.



A new and different kind of ozone depletion.
Why only in Antarctica? Why in the spring?
Why at those altitudes, where it shouldn’t be?
Clouds.

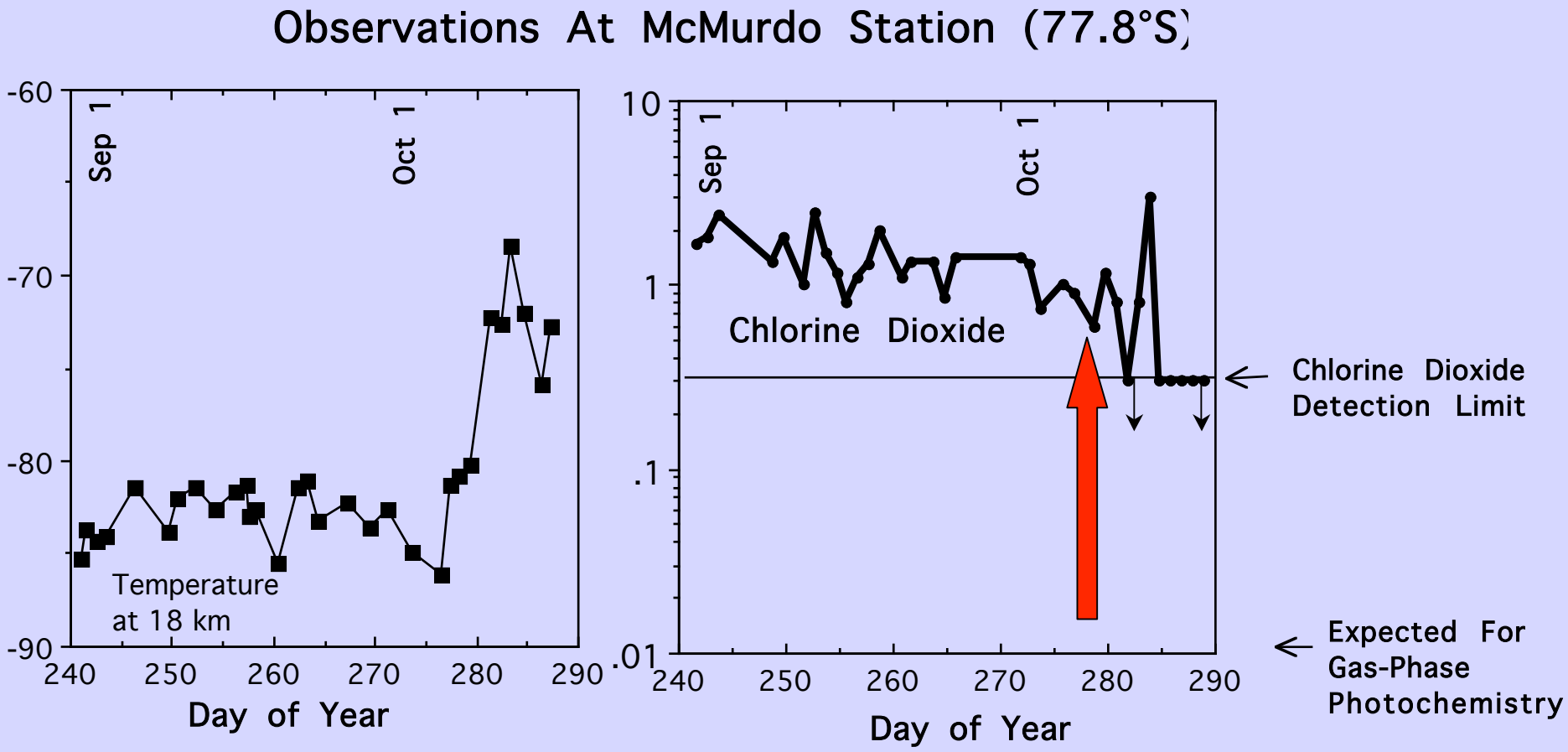

Gases destroy ozone here
Polar cloud surfaces lead to much more ozone destruction, in the heart of the layer
40
20
0
Altitude (km)
Amount of ozone
HCl
ClONO2
Cl
Cl2
ClO
Ozone
Activated for ozone loss
Reservoirs



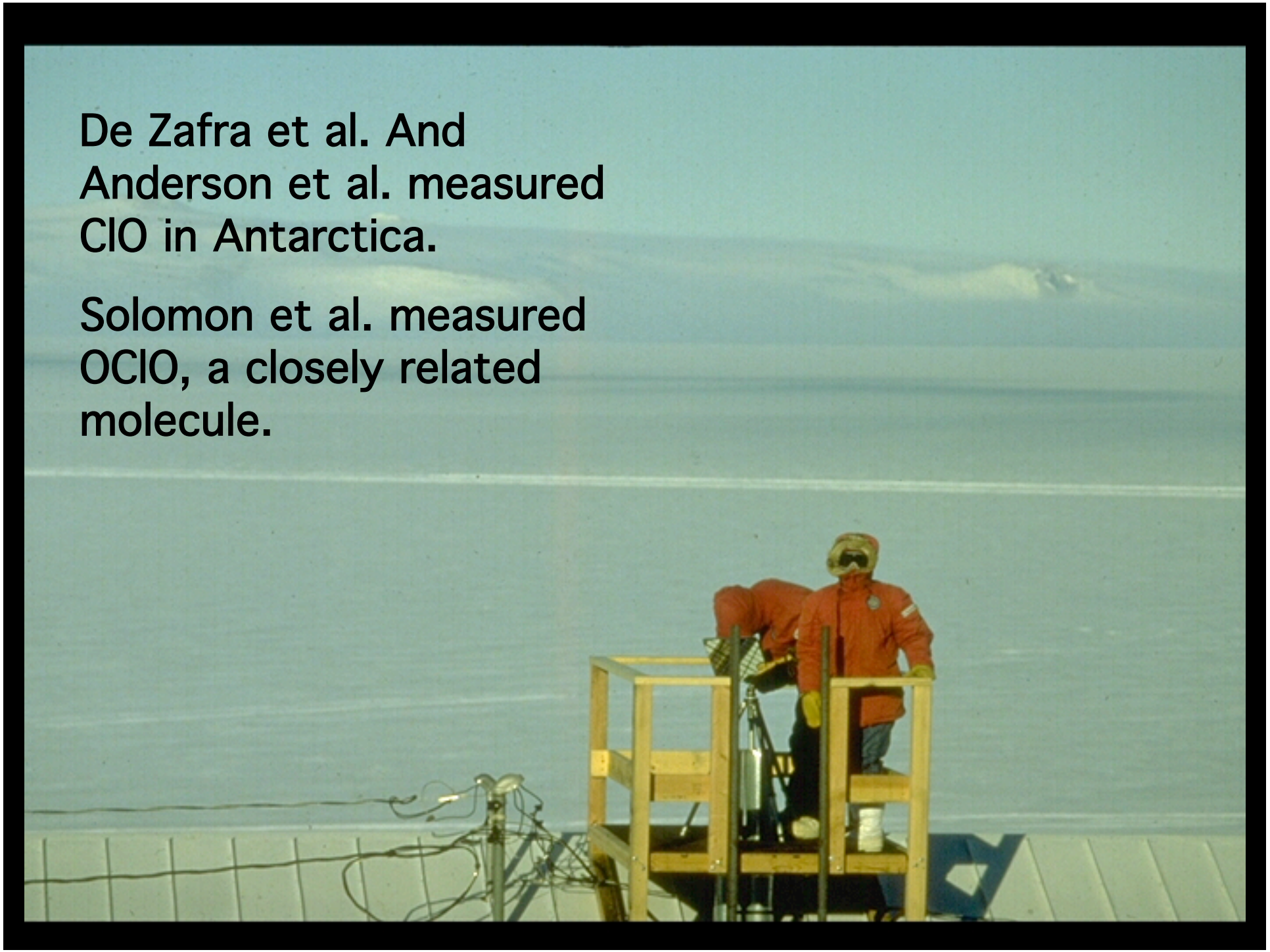
Chlorine teams up with two key factors: sunlight (spring) and icy cold surfaces (Antarctica)

Why is there an ozone hole over Antarctica? Only measurements could prove it.

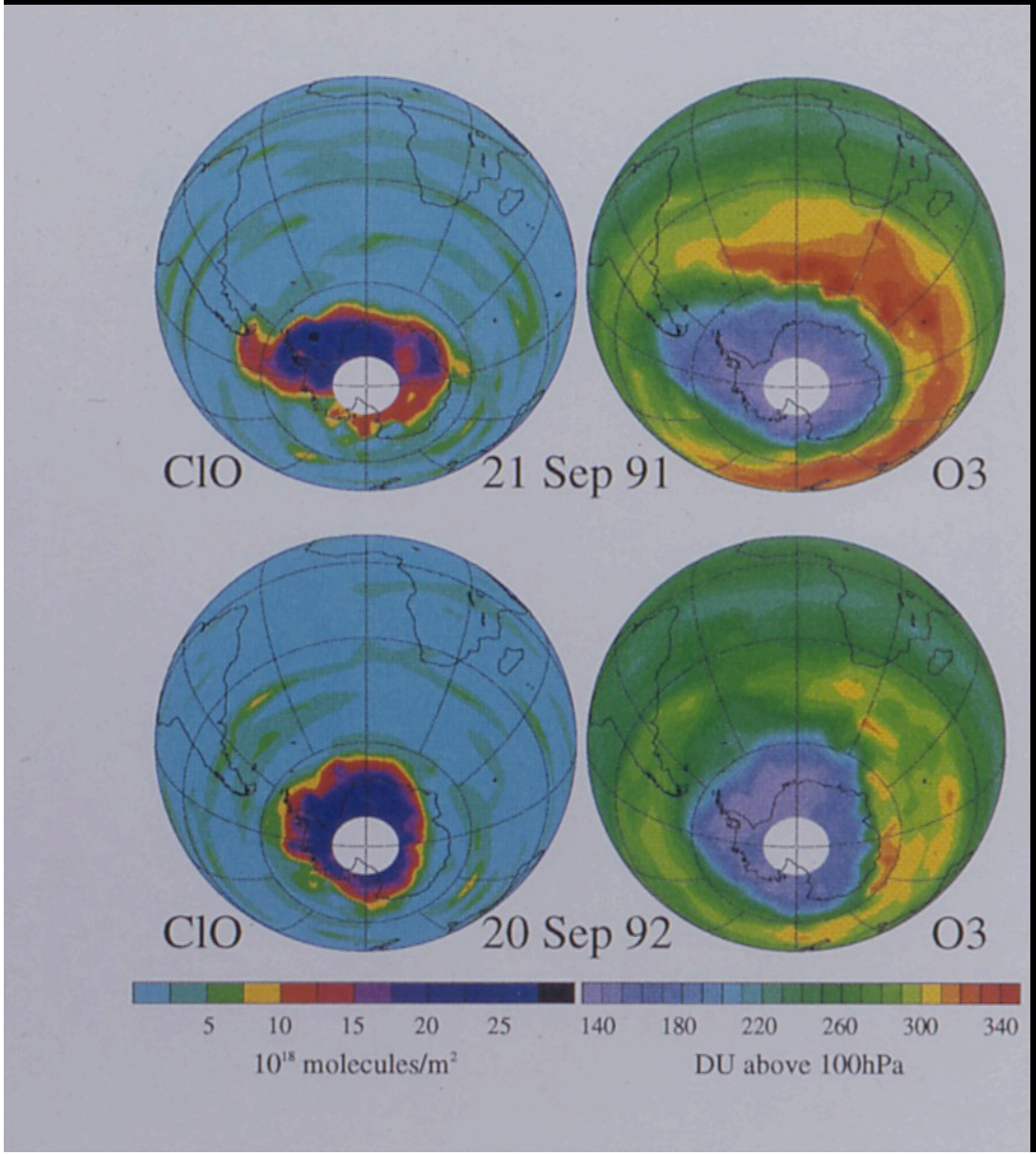
We could measure chlorine dioxide:



100x more OClO than there should have been: A fingerprint in seasonal behavior


De Zafra et al. And
Anderson et al. measured
ClO in Antarctica.
Solomon et al. measured
OClO, a closely related
molecule.

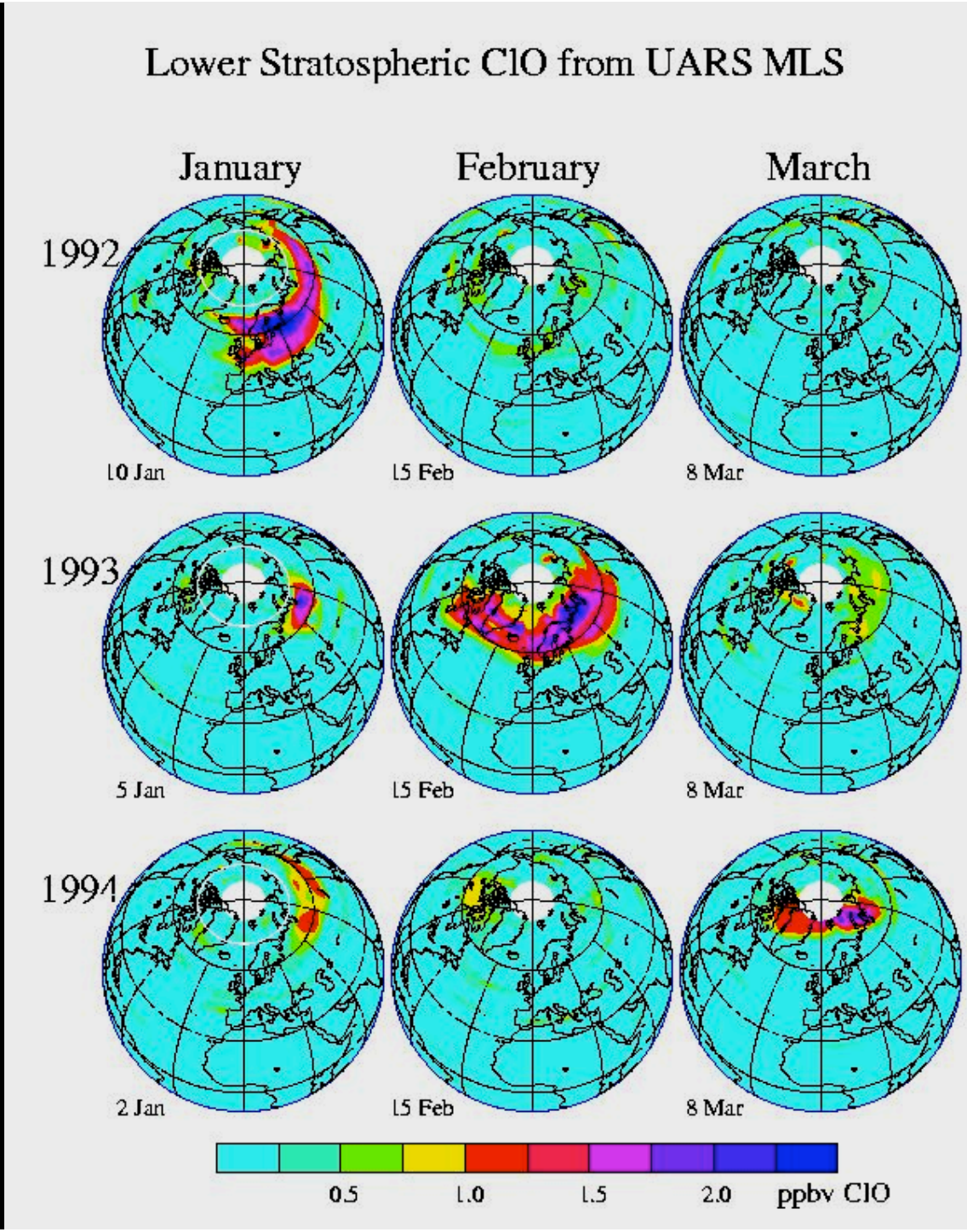
Now we have satellites for the bird's eye view….



Antarctica: cold nearly every year, with some variability

Ups and downs in Antarctic ozone depletion reflect cold and warm springs in the Antarctic stratosphere (not a recovery or a worsening).

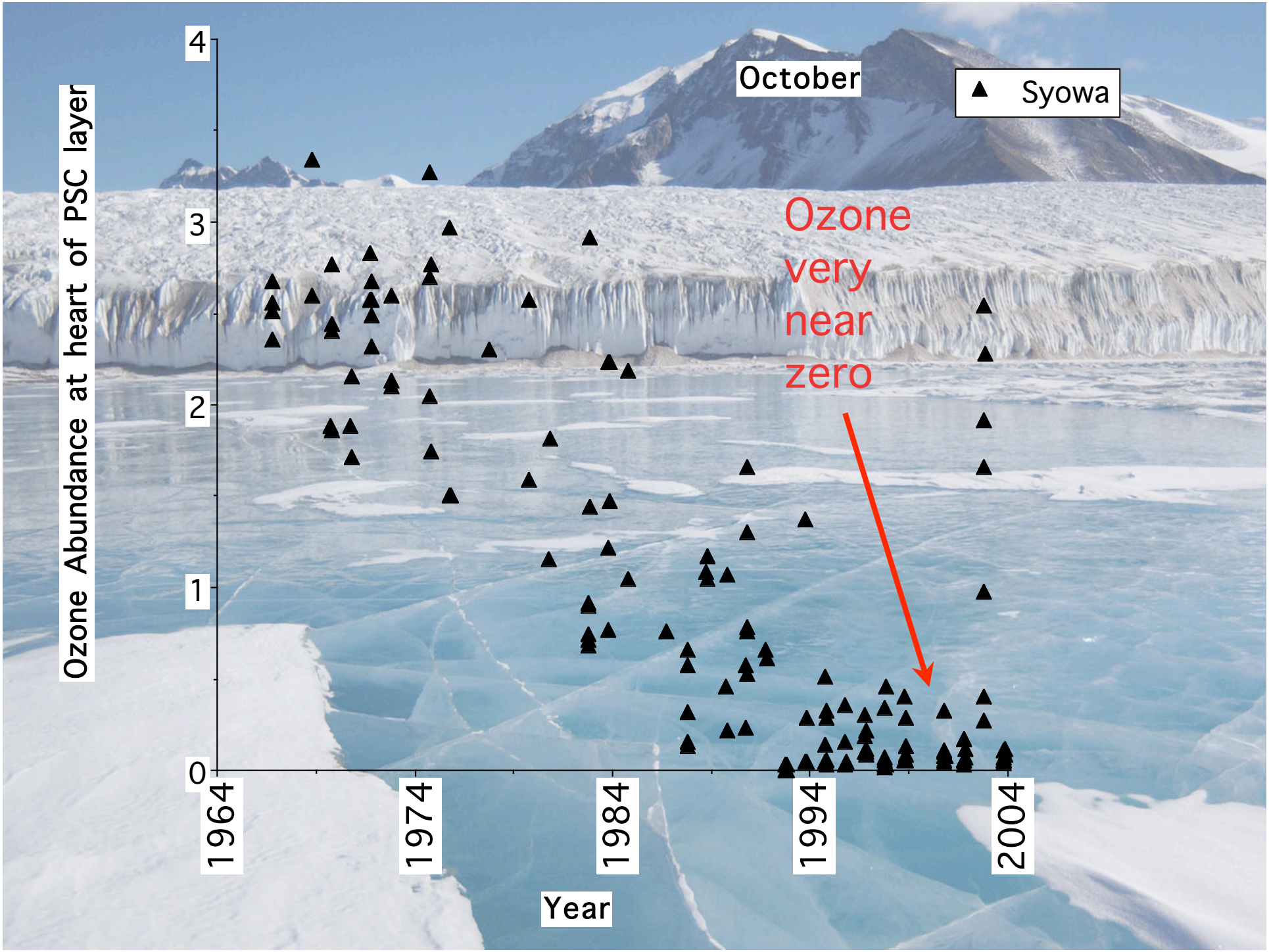
A very unusual warm Antarctic stratospheric spring occurred in 2002. But the ozone hole will be with us for decades.

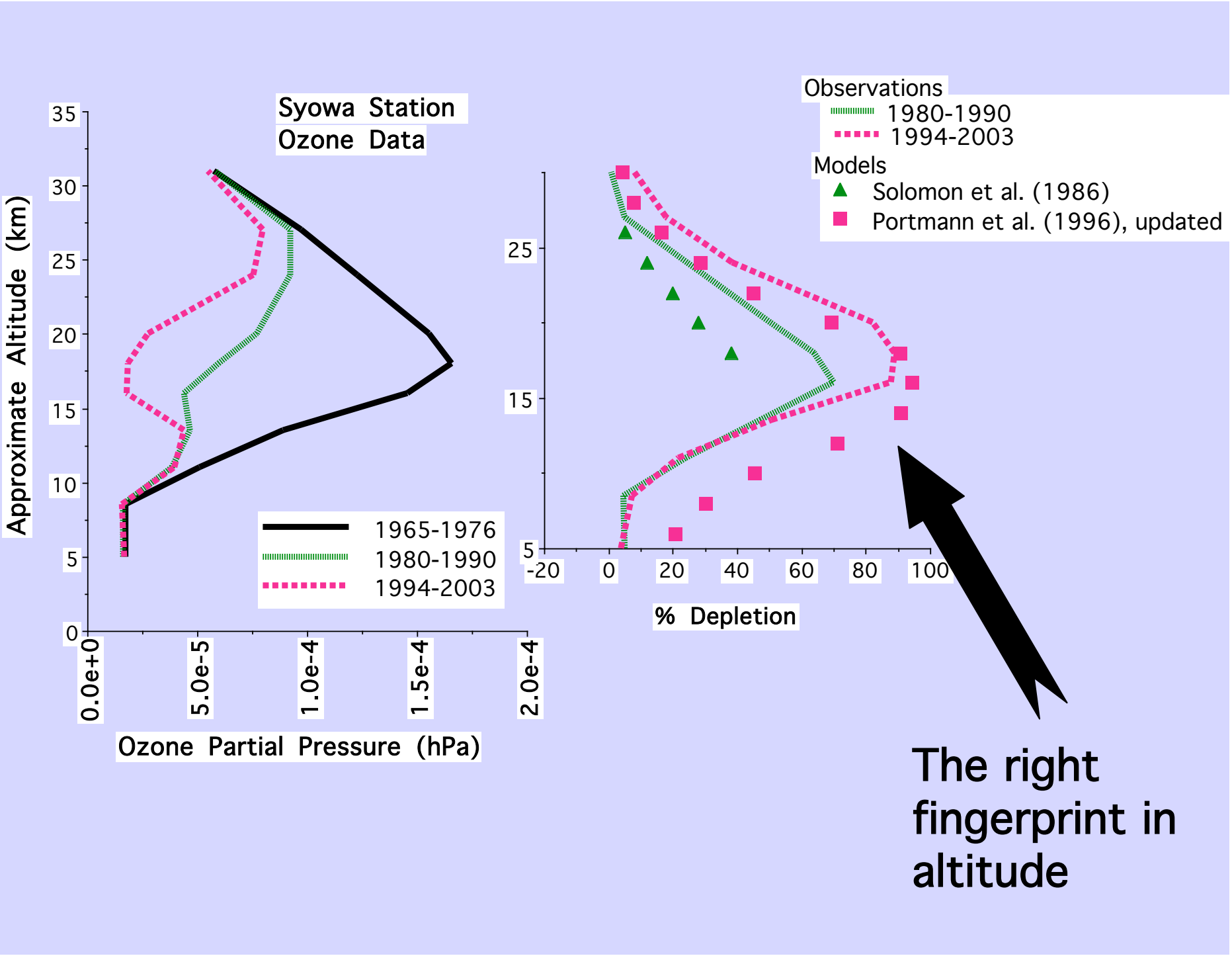


Arctic:

More variable but there is substantial ClO (and OClO) and some ozone depletion (up to about 25% in cold years)

Warms up earlier and ClO disappears sooner….note how much less ClO is present in March in the Arctic than the Antarctic in September.


October
Syowa
Ozone
very
near
zero
Ozone Abundance at heart of PSC layer
4
3
2
1
0
1964
1974
1984
1994
2004
Year


Syowa Station
Ozone Data
Approximate Altitude (km)
35
30
25
20
15
10
5
0
0.0e+0
5.0e-5
1.0e-4
1.5e-4
2.0e-4
Ozone Partial Pressure (hPa)
1965-1976
1980-1990
1994-2003
Observations
1980-1990
1994-2003
Models
Solomon et al. (1986)
Portmann et al. (1996), updated
25
15
5
-20
0
20
40
60
80
100
% Depletion
The right fingerprint in altitude

Where does the chlorine come from?

CH_3Cl - a "natural" chlorocarbon produced by the oceans. Only about 0.6 ppbv, no long term trend observed.

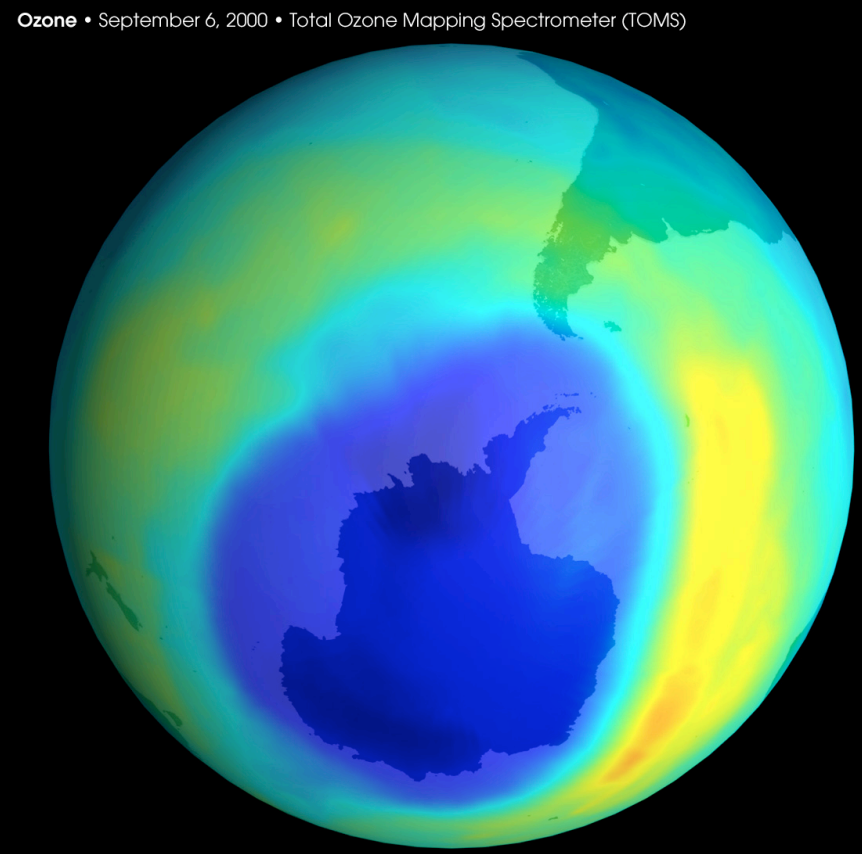
CFCs - CFC-11, CFC-12, CFC-113, etc. About 3.0 ppbv in today's atmosphere. Systematic long-term trends observed at many locations, consistent with KNOWN industrial release rates.

These are insoluble gases that can be transported from their source regions at the ground to the stratosphere, mainly via the tropical tropopause.

What about NaCl from the oceans? Highly soluble. Does not reach the stratosphere.

What about HCl from volcanoes? Highly soluble. Does not reach the stratosphere in significant amounts. Observed HCl at the base of the stratosphere is only 0.1 ppbv, compared to >3 from the CFCs and CH_3Cl.

There's a hole in Antarctica's ozone layer. It's due to the chlorine put into the atmosphere by people. The chlorine is more effective at destroying ozone where it's cold, due to reactions on polar stratospheric clouds inside the stratospheric vortex.



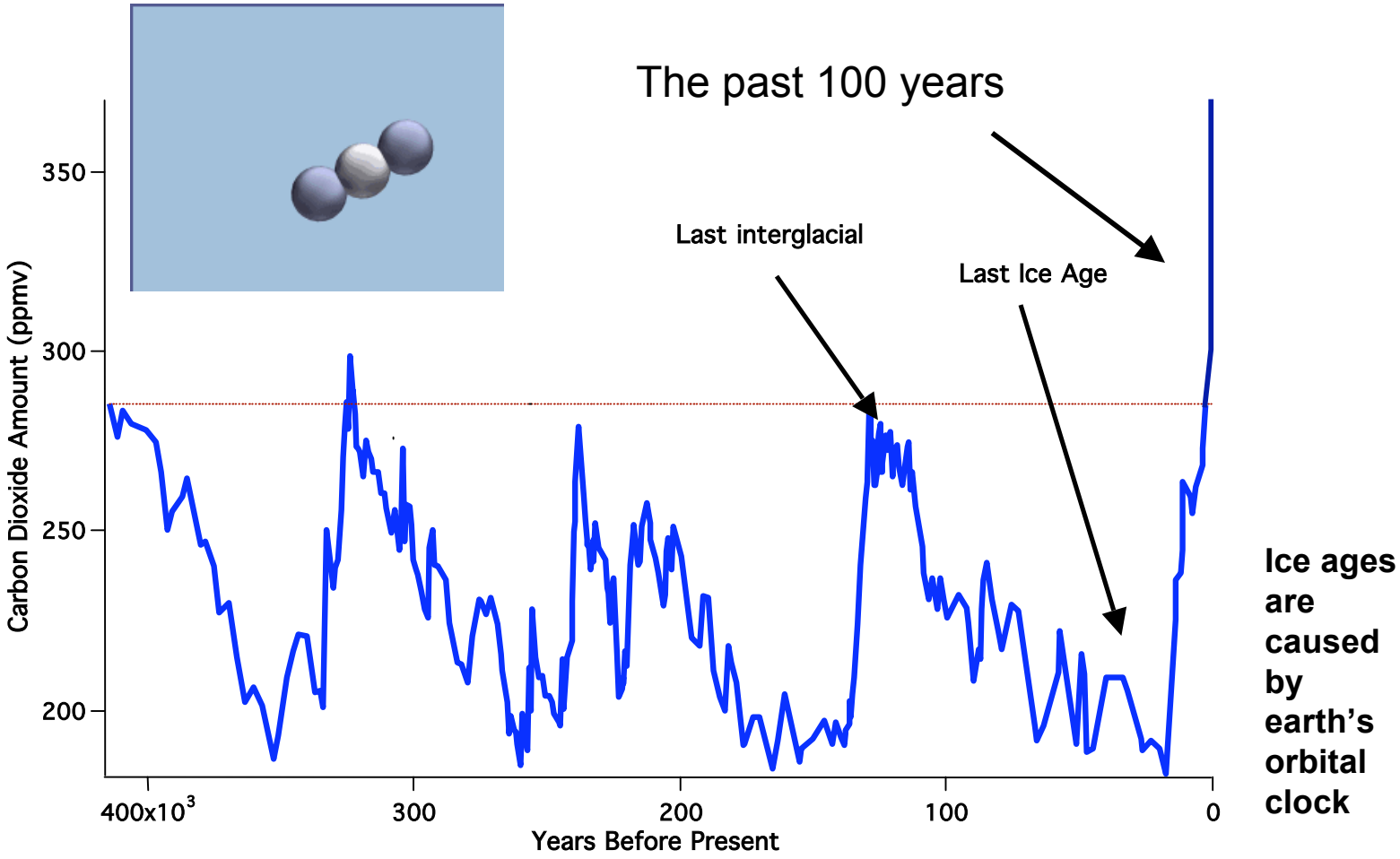
Antarctica is the coldest place on Earth, so it has more polar stratospheric clouds than the Arctic, and more ozone depletion.

Most scientists who work at McMurdo live in rooms like this

Some scientists live in field camps, studying the flow of ice….

Or digging up ice cores; bubbles in the ice show what the atmosphere was like up to about half a million years ago.

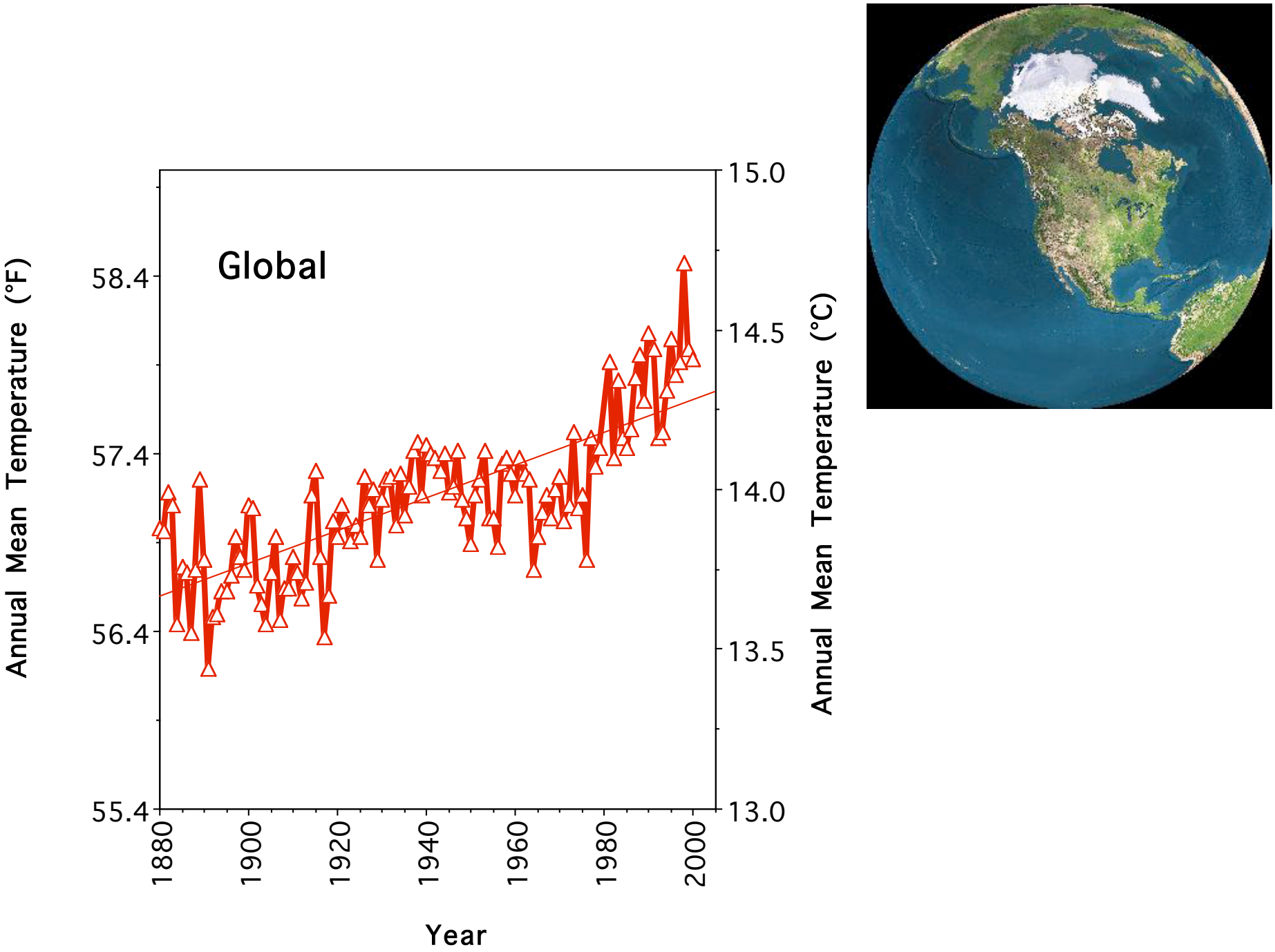
Some information about carbon dioxide changes through four past ice ages (from ice cores), and in the modern era (from global data)



Ice ages are caused by earth's orbital clock

It is well established that there is more carbon dioxide in the atmosphere today than there was in the past half million years - humans are 'forcing' the system in a new way.

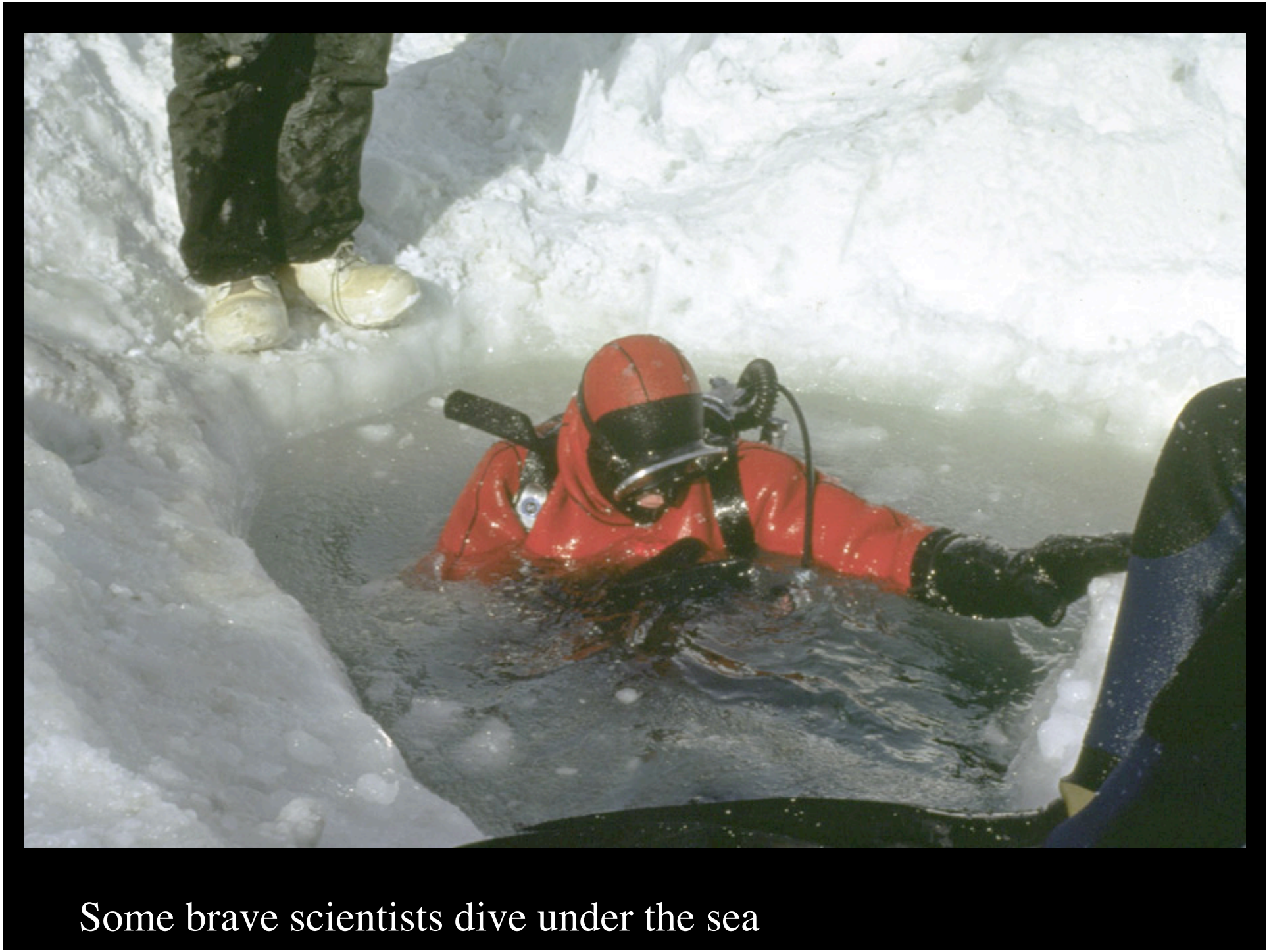
Antarctic weather instruments are part of the global climate network


Global
Annual Mean Temperature (°F)
Annual Mean Temperature (°C)
Year
58.4
57.4
56.4
55.4
15.0
14.5
14.0
13.5
13.0
1880
1900
1920
1940
1960
1980
2000

This is Antarctica’s only year-round resident

Rocks are of interest too

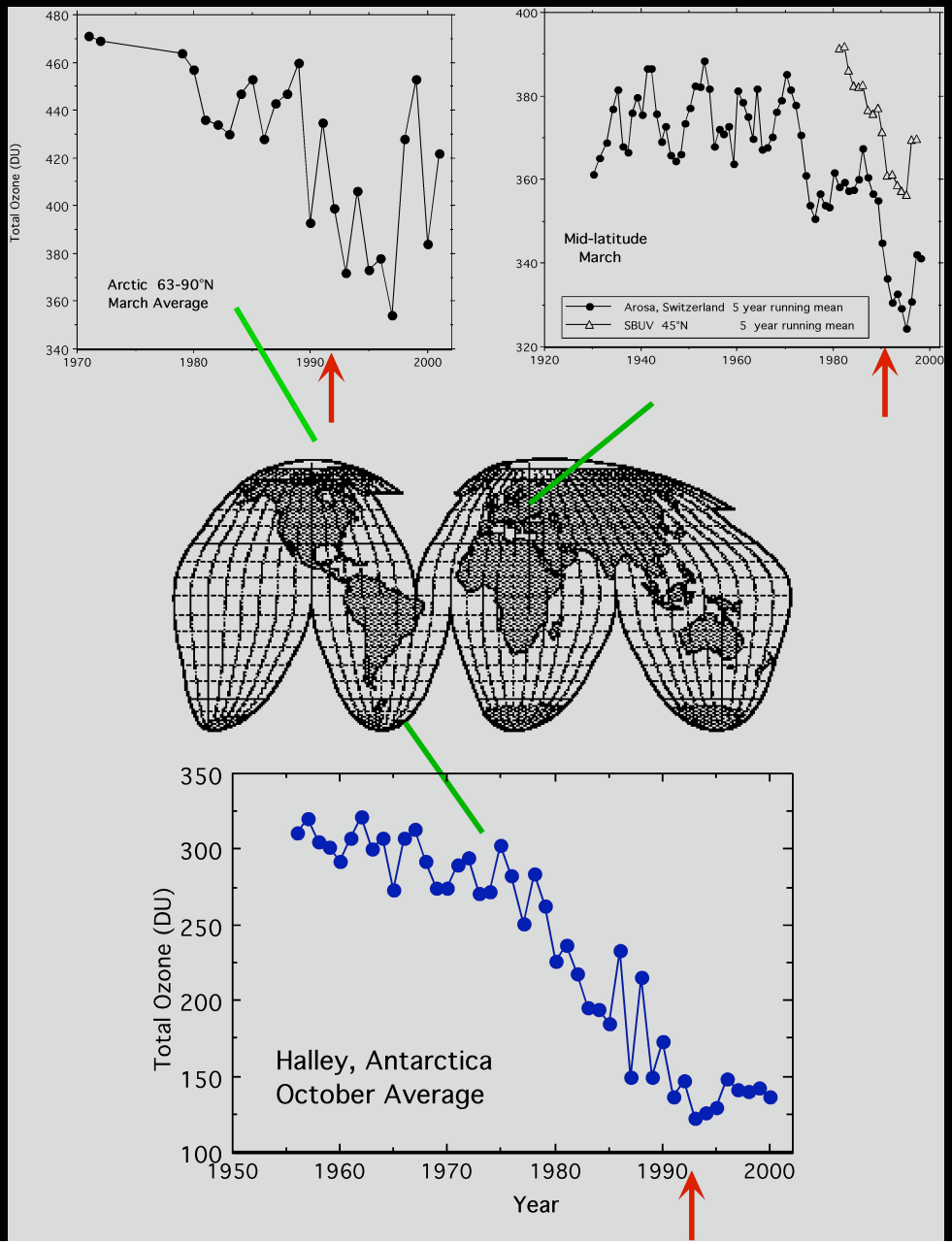
Some Antarctic rocks have living things under the surface - a form of algae. Could life on Mars be like this?



Some brave scientists dive under the sea

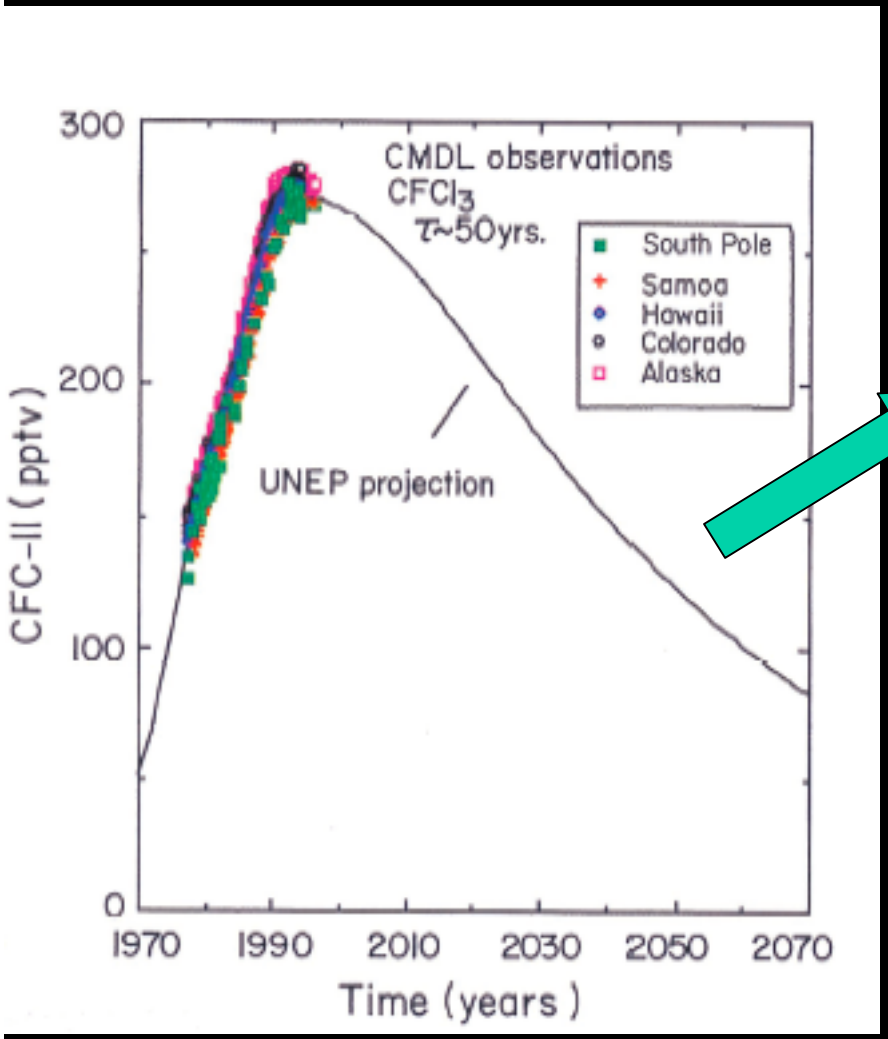
To study creatures like this shrimp-like animal

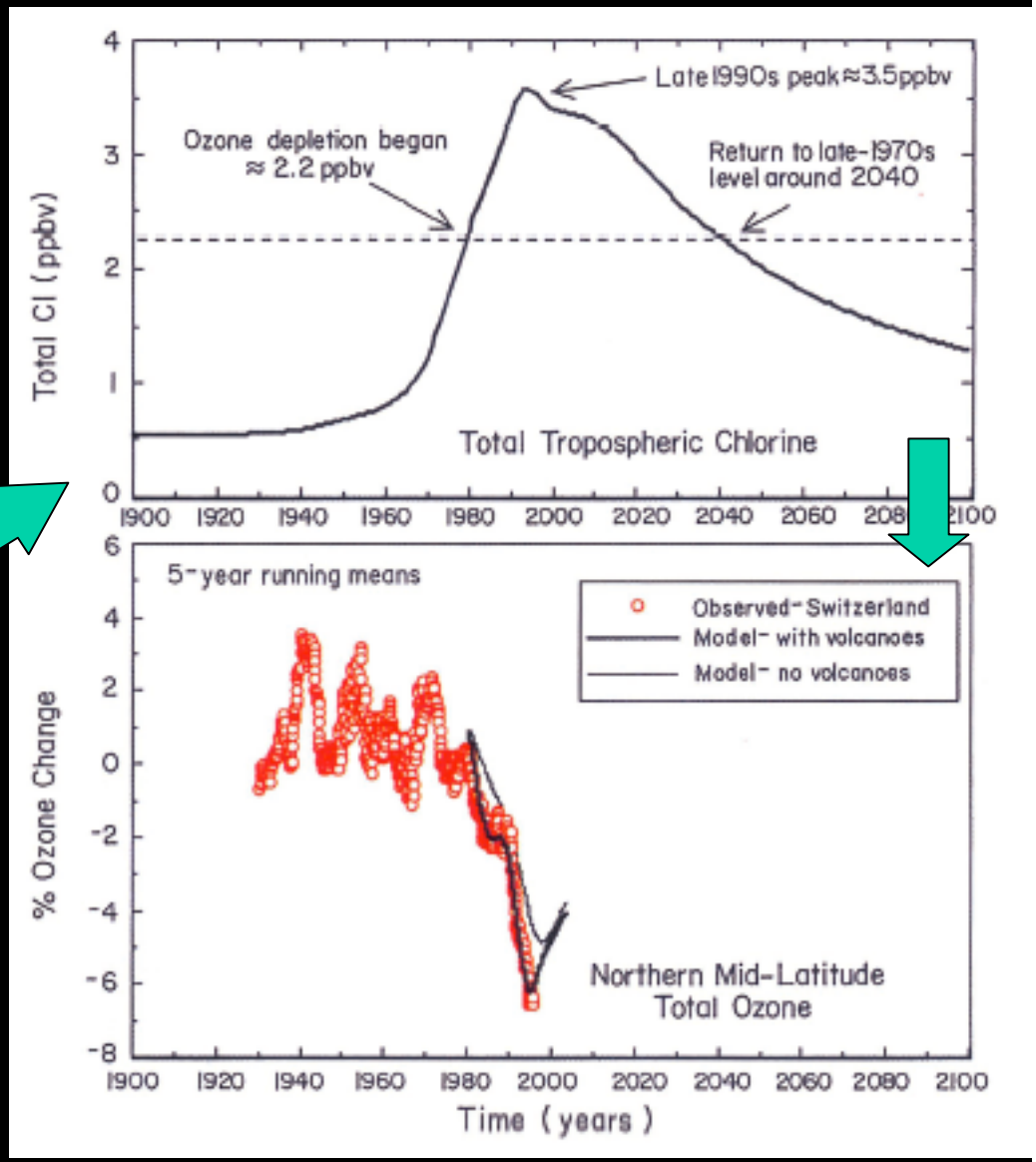
Ozone depletion from pole to pole, and in between:



When will the ozone layer recover?

A typical CFC:





I received the National Medal of Science in 2000 for my work explaining the ozone hole. It was a wonderful honor. The Blue Planet Prize is an international honor that also humbles me.

And a great privilege was going to Antarctica and doing the work, together with wonderful colleagues.

Do I look happy?


Thanks for your attention.....