ESRL Serving Society: The Ozone Layer Yesterday, Today, and Tomorrow

Susan Solomon, Senior Scientist, ESRL

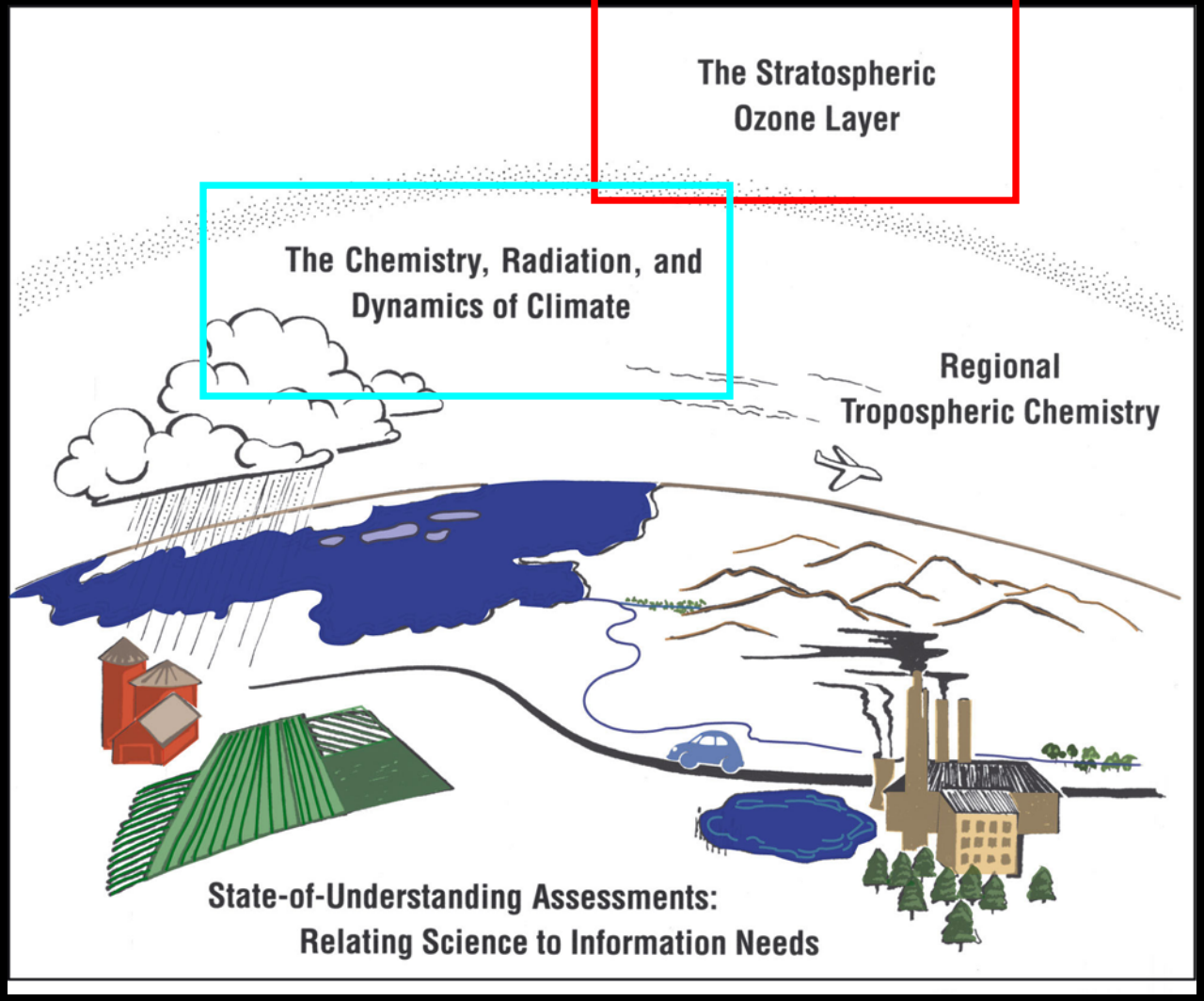
1) Yesterday: A story that stretches from pole to pole

2) Today: Is the ozone layer recovering?

3) Tomorrow: How can we best serve a changing issue?

4) New Connections and Closing Thoughts

ESRL roles in a range of challenges in different periods of ozone as an environmental issue



1) Credibility: how well do we understand the science?

2) Practicality: science input to what options are available.

3) Accountability: are actions working?

4) Connectability: to other issues

Three kinds of ozone: good (stratosphere), bad (troposphere), and ugly (smog). Ozone depletion is not the primary cause of surface climate change. It is our planet's key protection from UV.

Ancient ozone history…..

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

Mario J. Molina & F. S. Rowland

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.

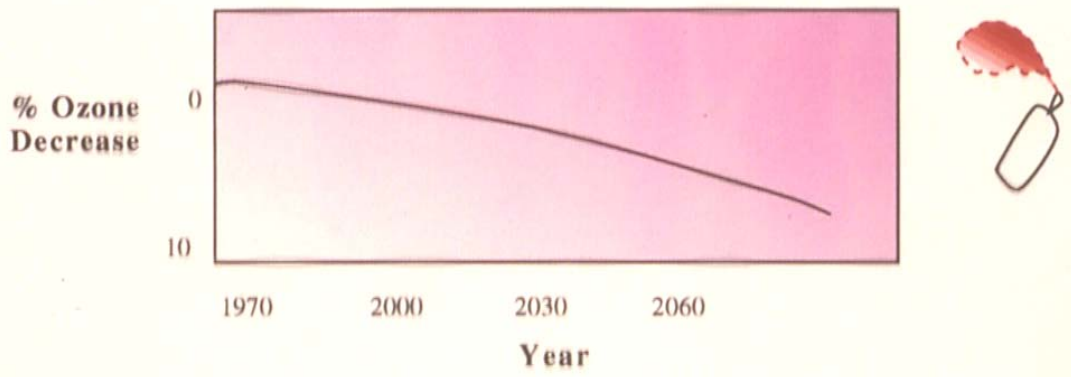
$$Cl + O_3 \rightarrow ClO + O_2$$

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

Reactions among gases only:

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.



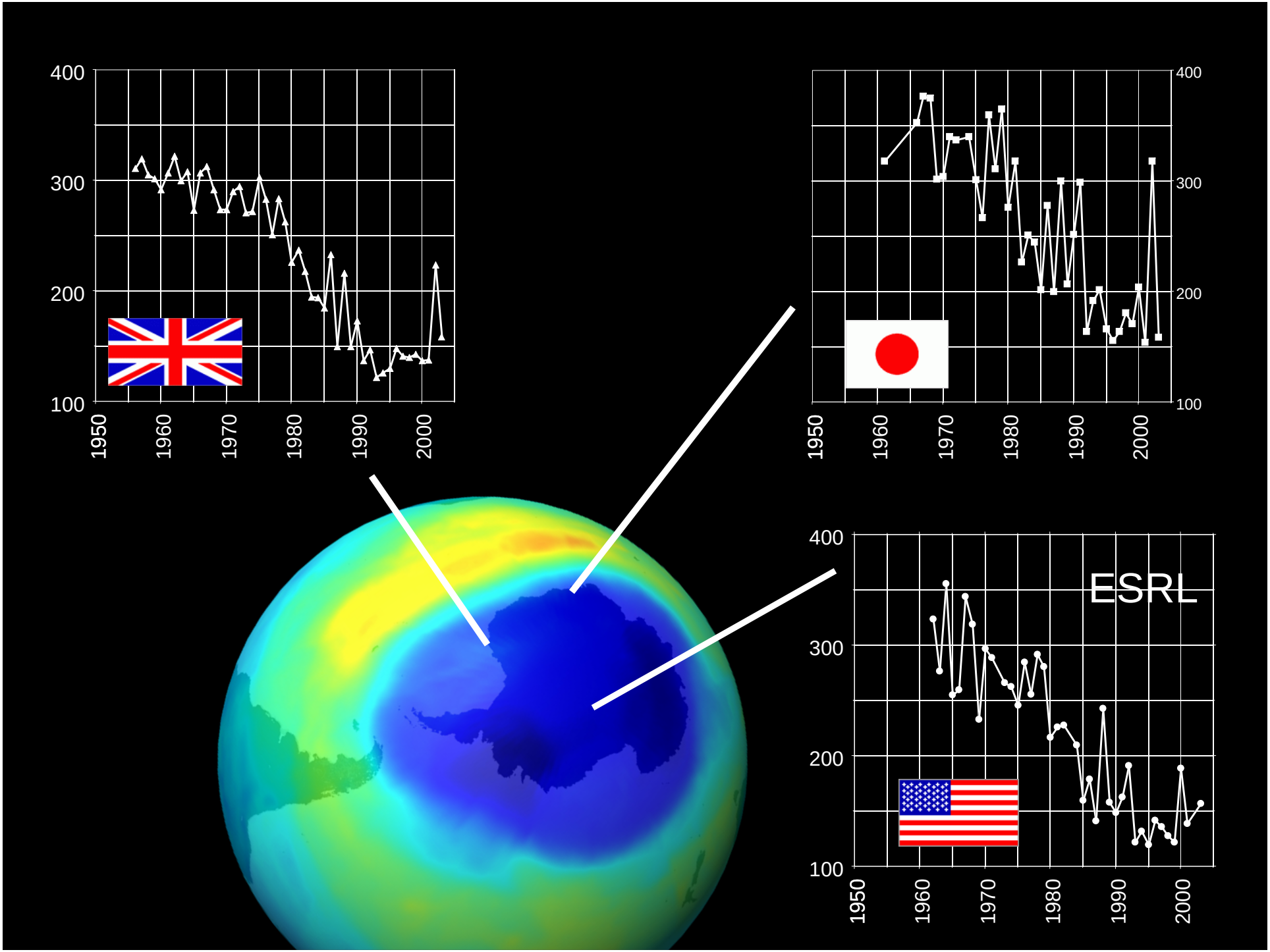
Risk of long-lasting effects…..

But only a theory….

A small effect….

Far in the future…

But then…an ozone surprise!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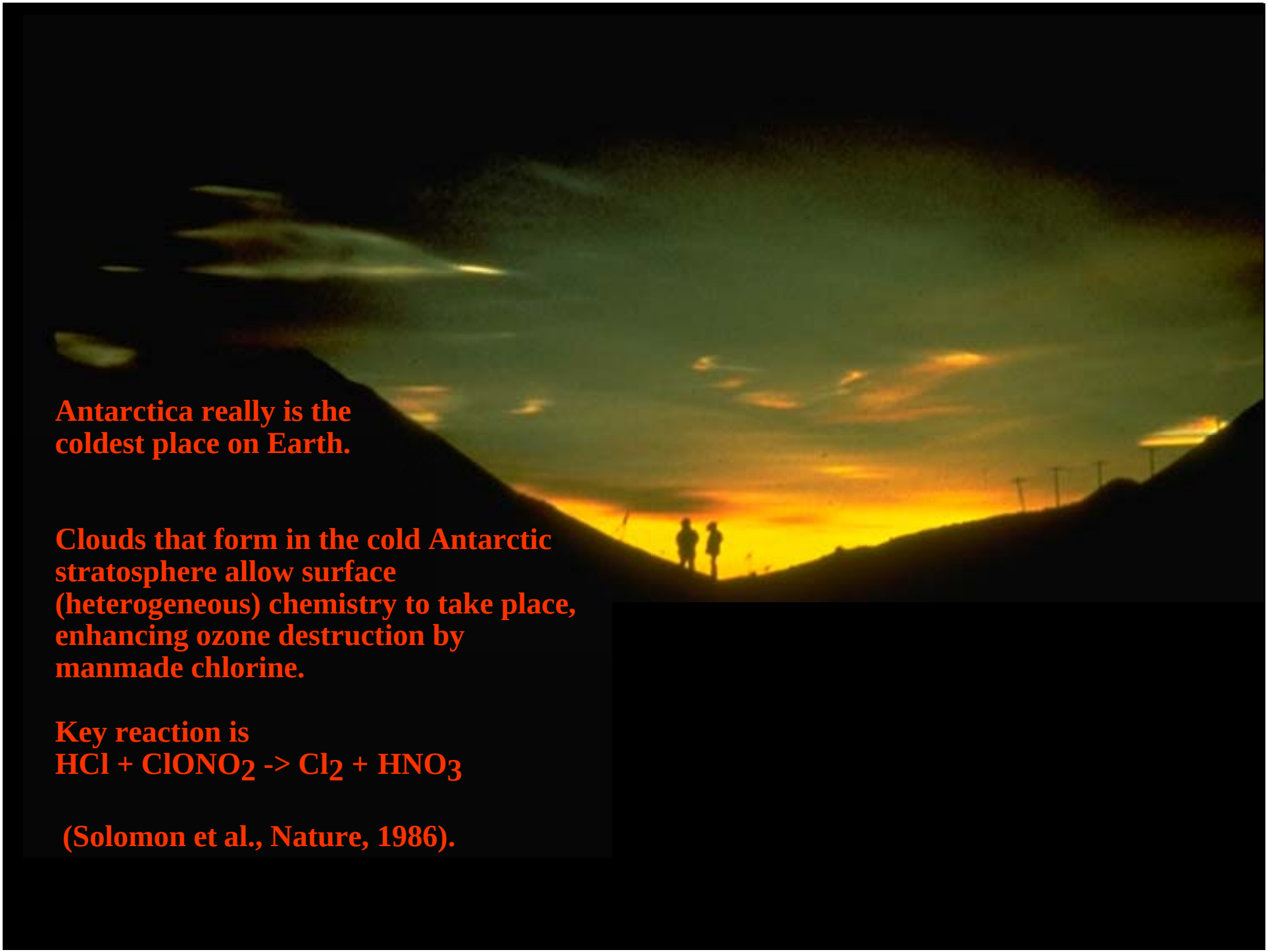

Antarctica really is the coldest place on Earth.

Clouds that form in the cold Antarctic stratosphere allow surface (heterogeneous) chemistry to take place, enhancing ozone destruction by manmade chlorine.

Key reaction is
$HCl + ClONO_2 \rightarrow Cl_2 + HNO_3$

(Solomon et al., Nature, 1986).

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

Normal layer

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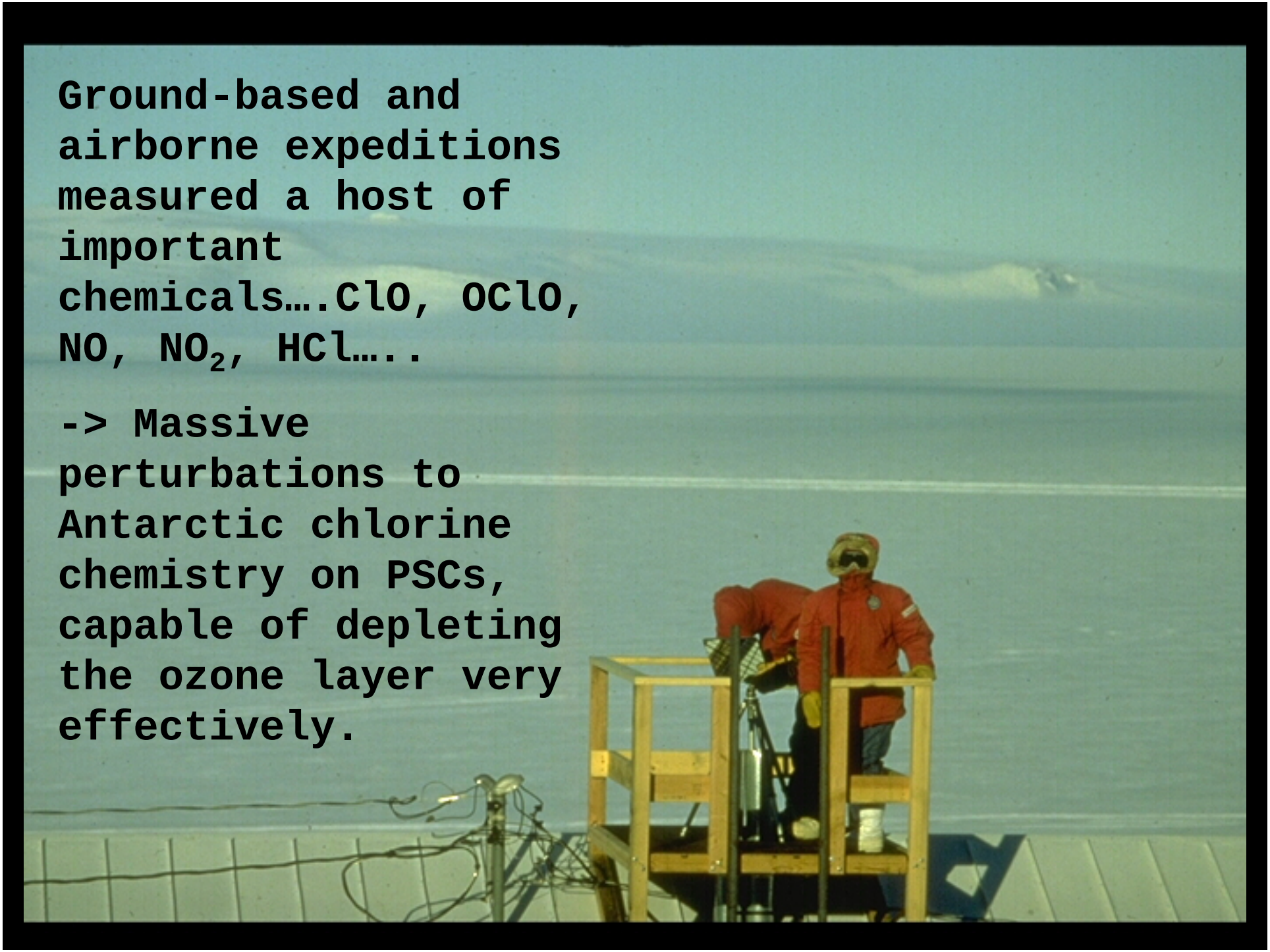
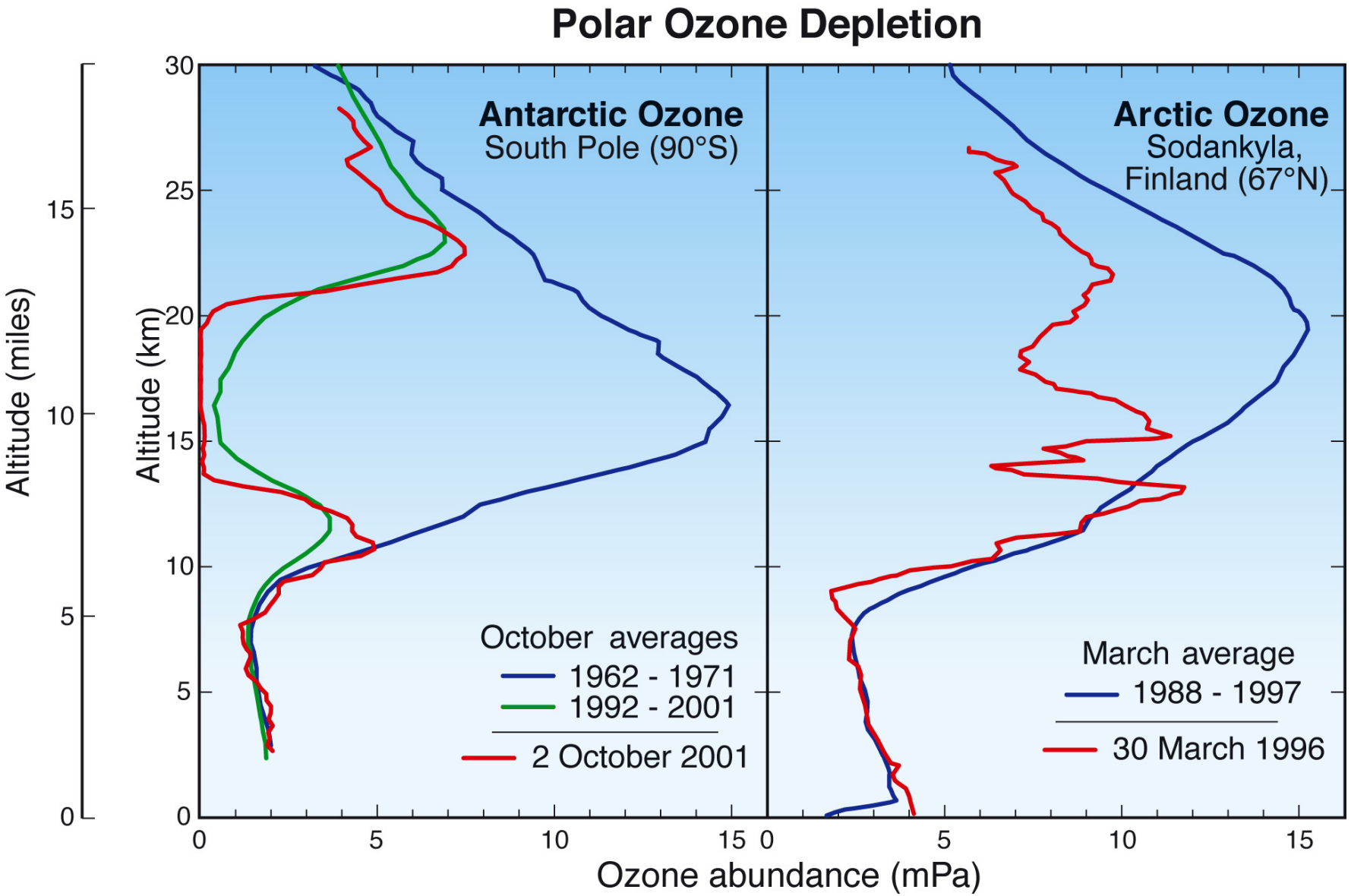
ESRL balloons

Airborne measurements in the Antarctic and Arctic: Key ESRL participation with chemical instruments and mission leaders.



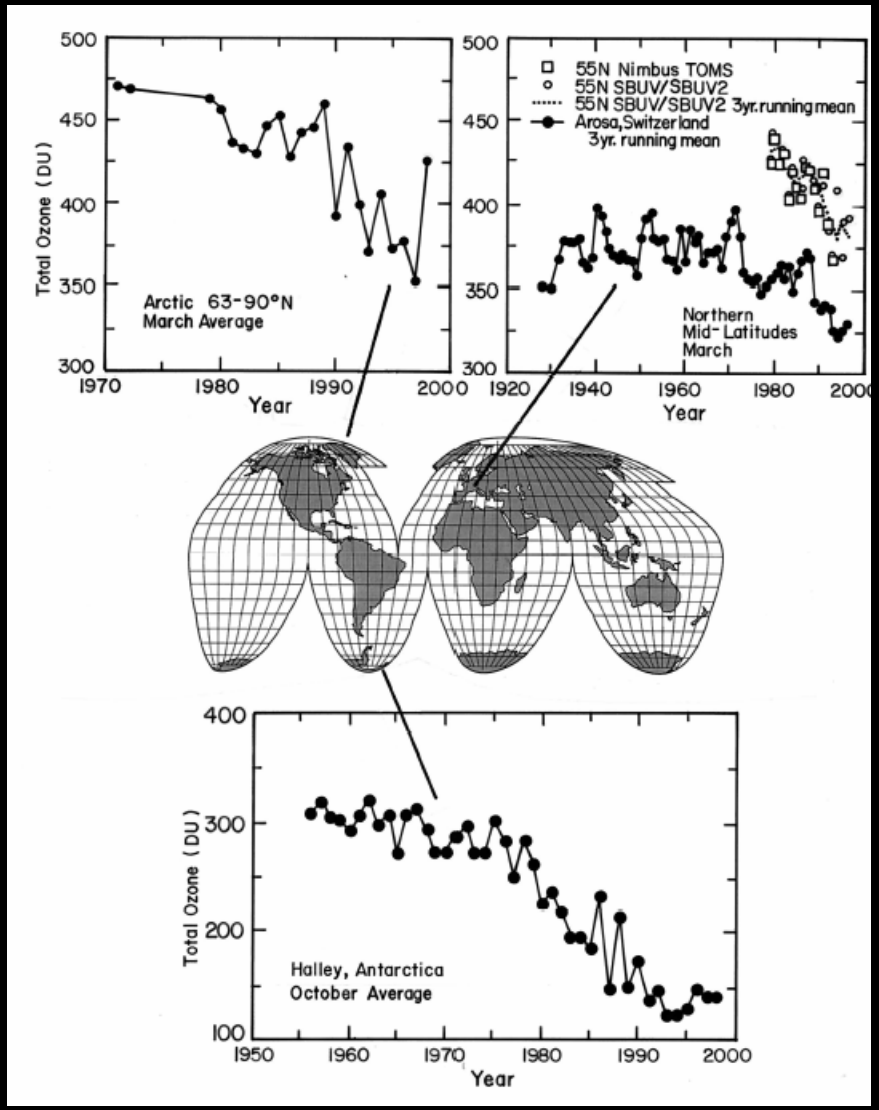
Ground-based and airborne expeditions measured a host of important chemicals….ClO, OClO, NO, NO_2, HCl…..

-> Massive perturbations to Antarctic chlorine chemistry on PSCs, capable of depleting the ozone layer very effectively.



The Arctic is warmer and displays some ozone depletion……but not as much as Antarctica

Stages of Environmental Issues



Credibility: Is the change real? How confident can we be about the role of humans?

ESRL contributions:

-ozone hole mechanism proposed

-observations clinched it

-other latitudes including Arctic and mid-latitudes

What to do? How about perfluorocarbons (PFCs)?

No ozone depletion……but verrrry long lifetimes….and related implications for climate effects…

CF_4 - Lives about 50,000 years. If cavemen could have made it, some would still be around.

C_3F_8 - Lives more than 2000 years. If the ancient Romans could have made it, some would still be around.

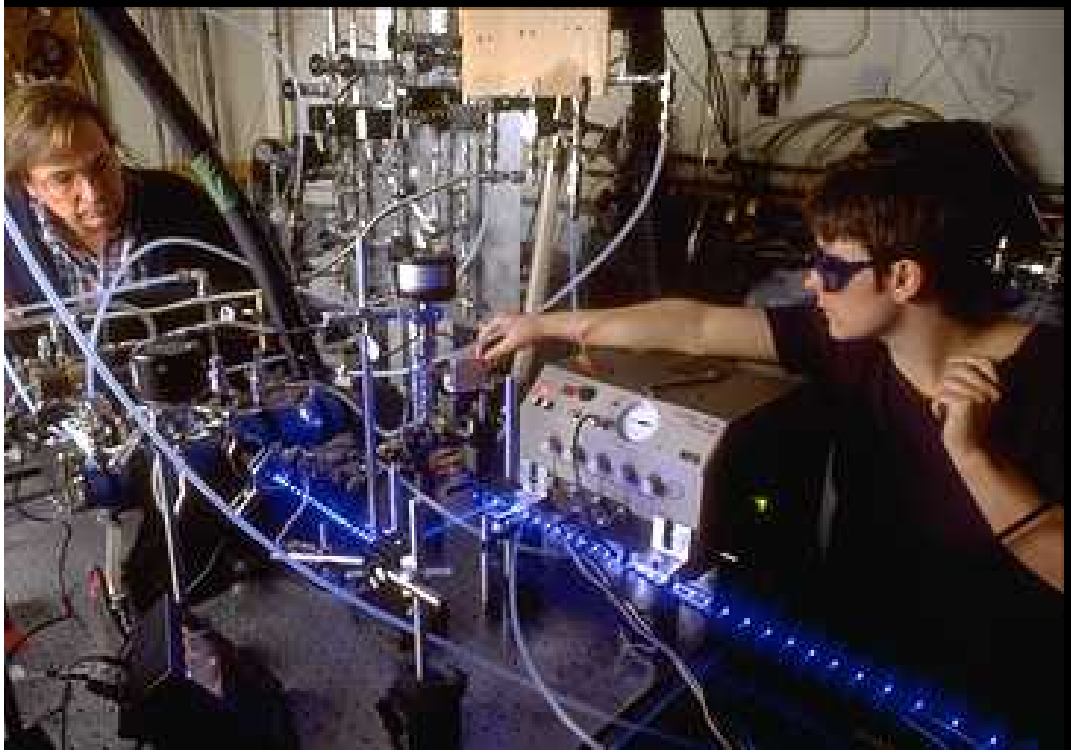
Per molecule: 5700 times more climate bang than CO2

Per molecule: 8600 times more climate bang than CO2

Do Hydrofluorocarbons Destroy Stratospheric Ozone?

Table 1. The reactions and their rate coefficients important in chemistry of CF_3 in the stratosphere and used for modeling the effect of CF_3 on the ODP of HFCs. For the model calculations, the rate coefficients and reaction products are selected so as to maximize the estimated ozone depletion.

Reaction	Rate constant (cm^3 $molecule^{-1}$ s^{-1})	Comments
1. $CF_3O + O_3 \rightarrow CF_3O_2 + O_2$	$<4 \times 10^{-14}$	This work, upper limit
2. $CF_3O_2 + O_3 \rightarrow CF_3O + 2O_2$	$<3 \times 10^{-15}$	This work, upper limit
3. $CF_3O + NO \rightarrow CF_2O + FNO$	6×10^{-11}*	This work, 298 K. Higher at lower T
4. $CF_3O + CH_4 \rightarrow CF_3OH + CH_3$	$>2 \times 10^{-15}$	This work, extrapolated to low T



The bottom line:

ESRL laboratory work established that HFCs don't destroy ozone at a key time in the search for substitutes

Stages of Environmental Issues

HFC-134a

HCFC-141b

HCFC-22

PFCs

HFC-123

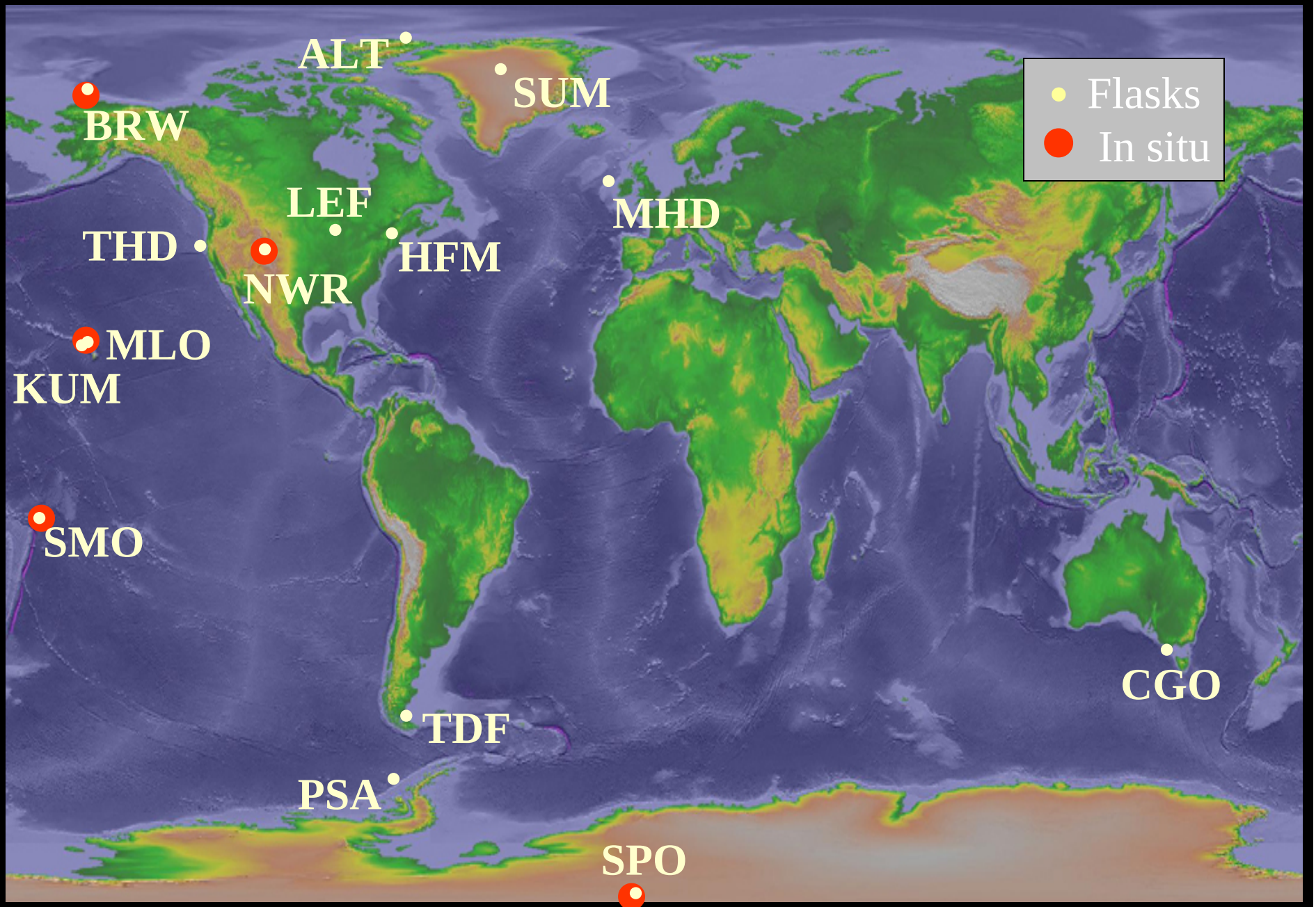
HFC-125

Practicality: What are the options? What substitute chemicals are available, and how might they affect the environment?

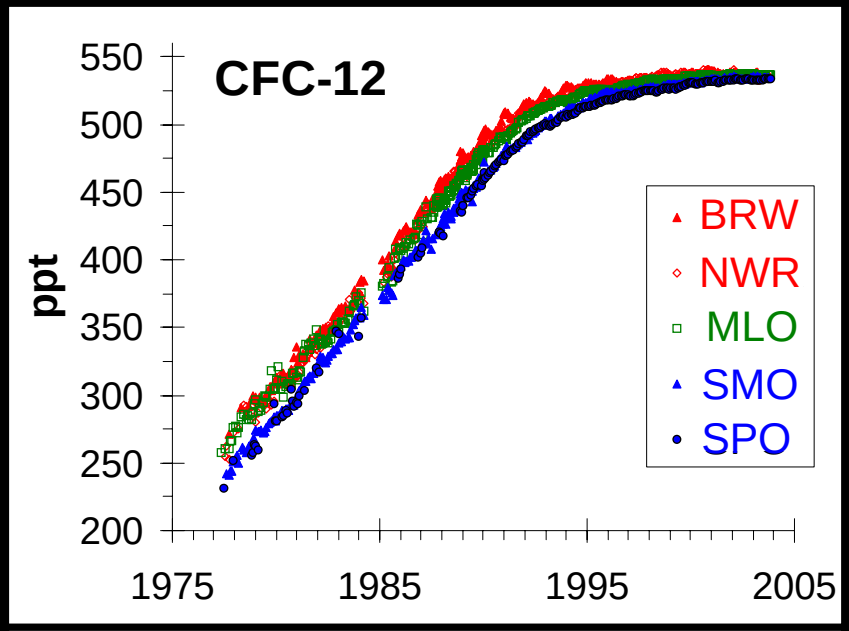
ESRL contributions:

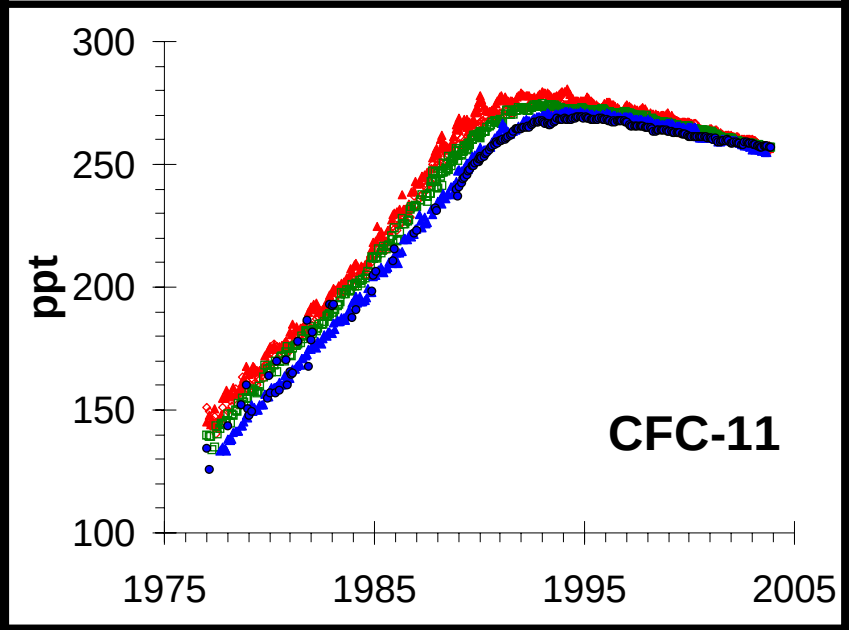
-laboratory work to understand how safe a host of proposed substitute chemicals are for ozone, for climate, and for society.

NOAA ESRL halocarbon sampling network



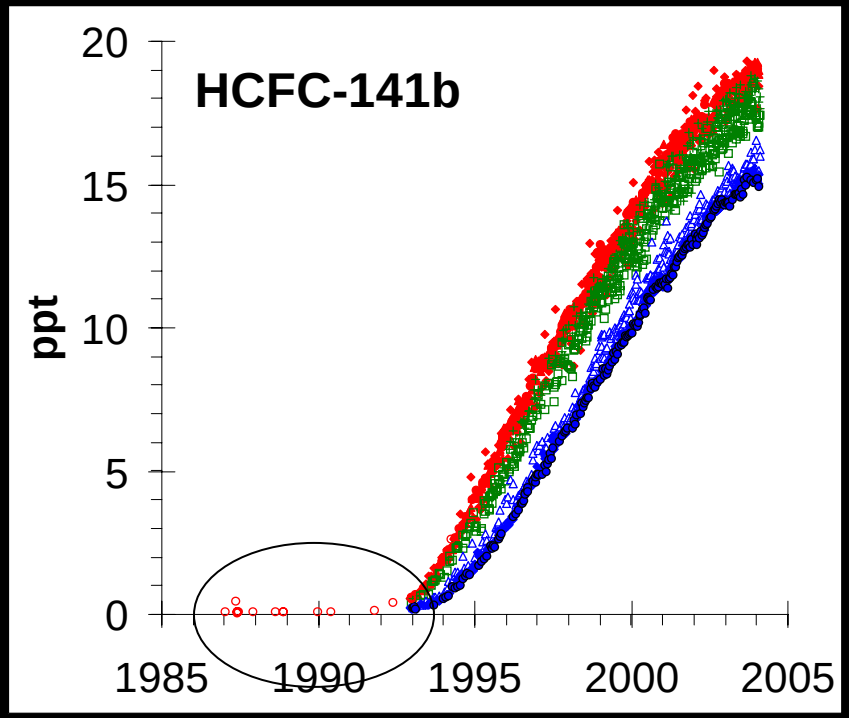
Demonstrated Success of the Montreal Protocol



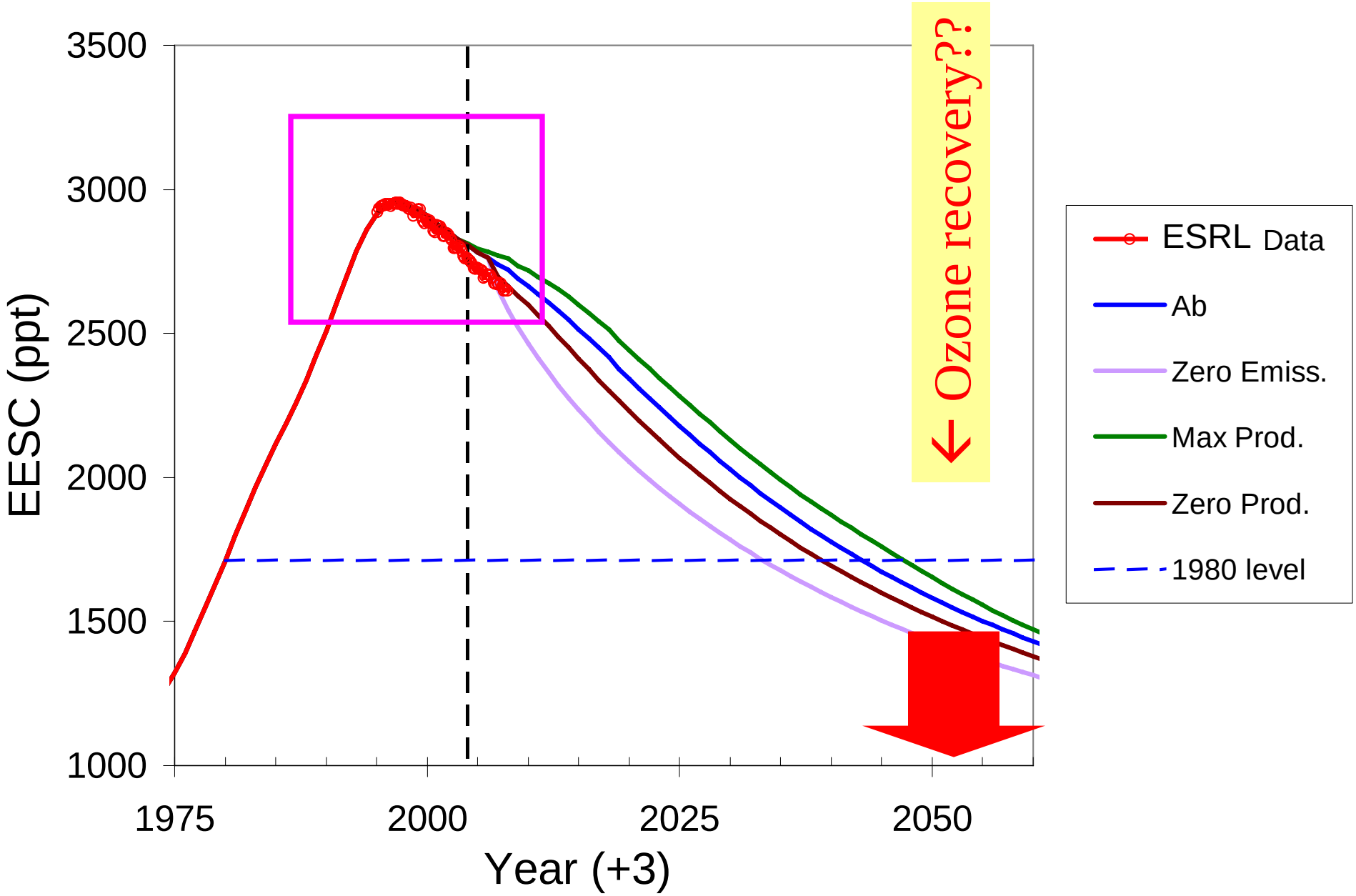


CFC growth slowed in the 1990s and now these gases are declining (but very slowly because of long lifetimes).

Substitutes are growing but much more slowly.



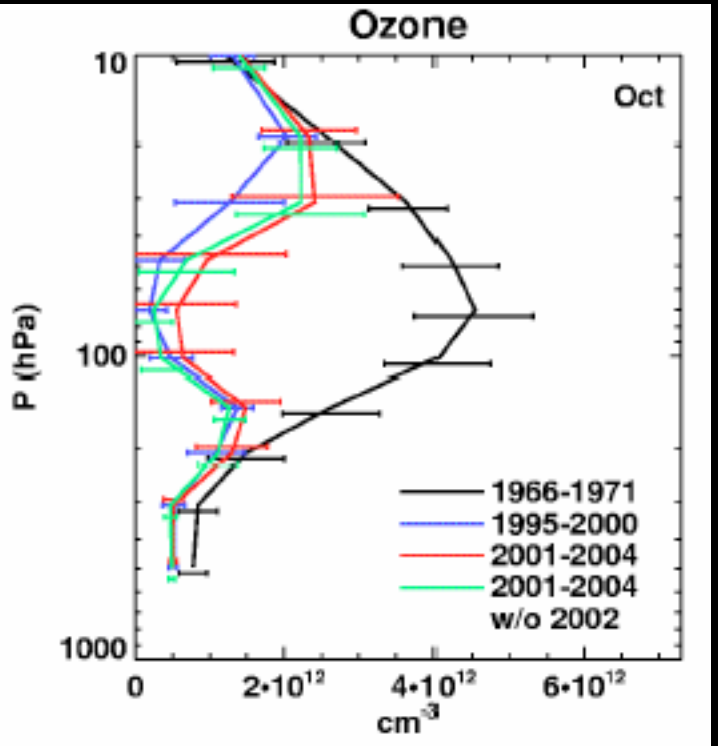
EESC—An estimate of total ozone-depleting halogen



Is ozone recovery beginning?

Challenge: separate other factors from those of CFCs (e.g., variability in stratospheric 'weather' …)

Stages of Environmental Issues



South Pole ozone in recent years

Accountability: Have actions taken been effective?

ESRL contributions

-Showing that CFCs are going down under the Montreal Protocol but….

- Evaluating ozone recovery

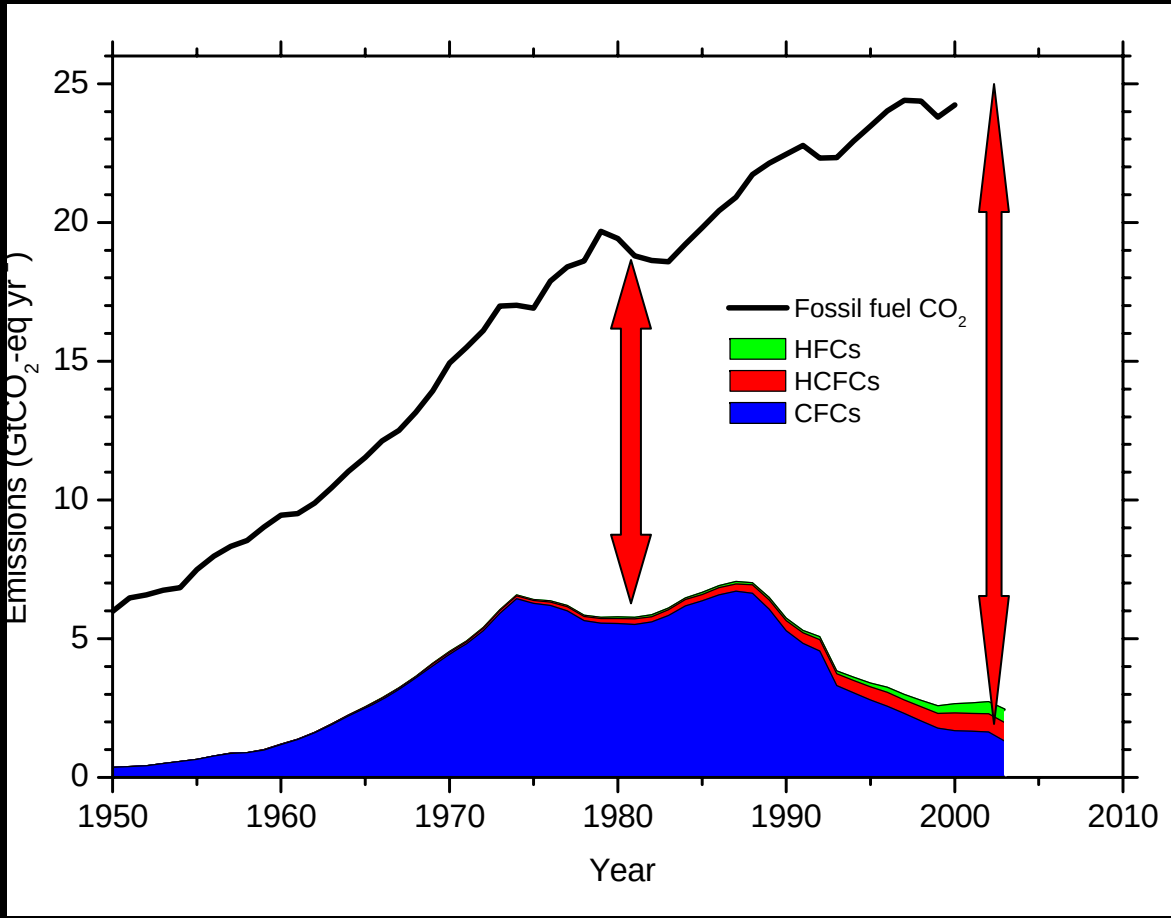
- End-to-end information on the state of understanding and assessment

Halocarbon are greenhouse gases

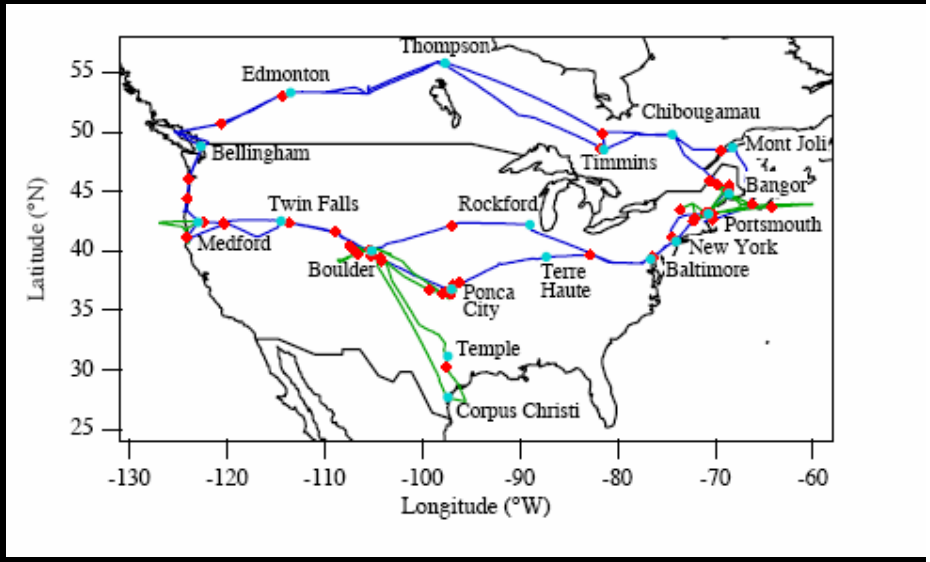
Montreal protocol has helped reduce climate change, too!

~7.5 Gt near 1990, about 33% of that year's CO_2 emissions from global fossil fuel burning

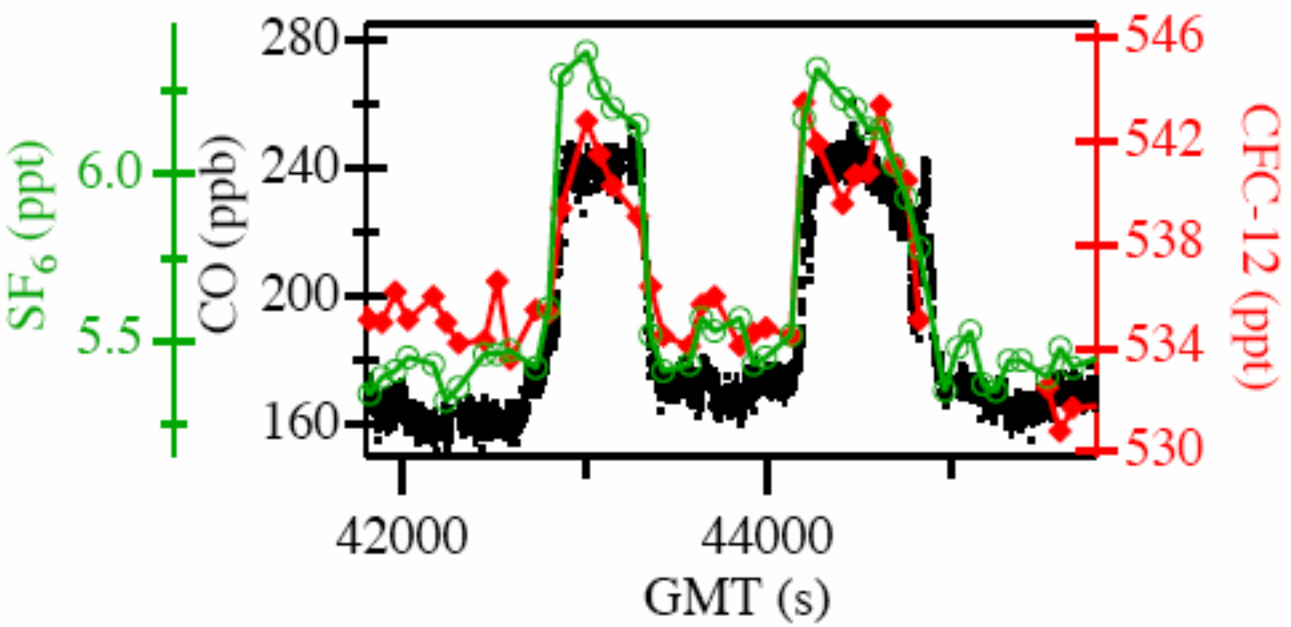
~2.5 Gt near 2000, about 10% of that year's CO_2 emissions from global fossil fuel burning



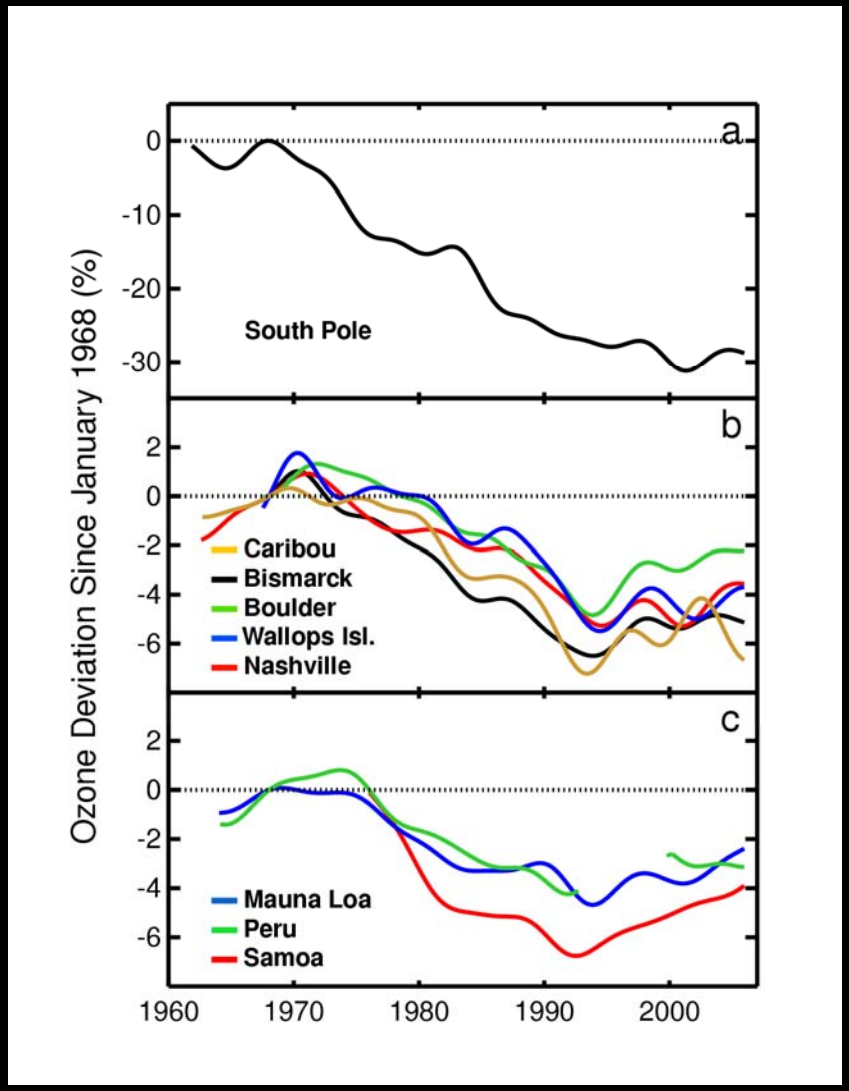
Good news: new systems with HFCs and HCFCs are 'tighter' and their contribution is smaller



Plumes of CFC-12 were still coming out of US cities in 2003 - leaking out of old systems. Better recycling?



Key Issues on the Horizon



ESRL contributions:

-Role of CFCs and substitutes for surface climate change: leakage, tightness, new chemicals….

-How will ozone and UV change in a changing climate? Poles to tropics…..

-Ozone depletion has a cooling effect. Need to explain temperature changes all the way from the bottom to the top of the atmosphere.

Ozone is linked to practicality and accountability in climate change


Thank you for your attention