New Results From

Inside the Ozone Hole

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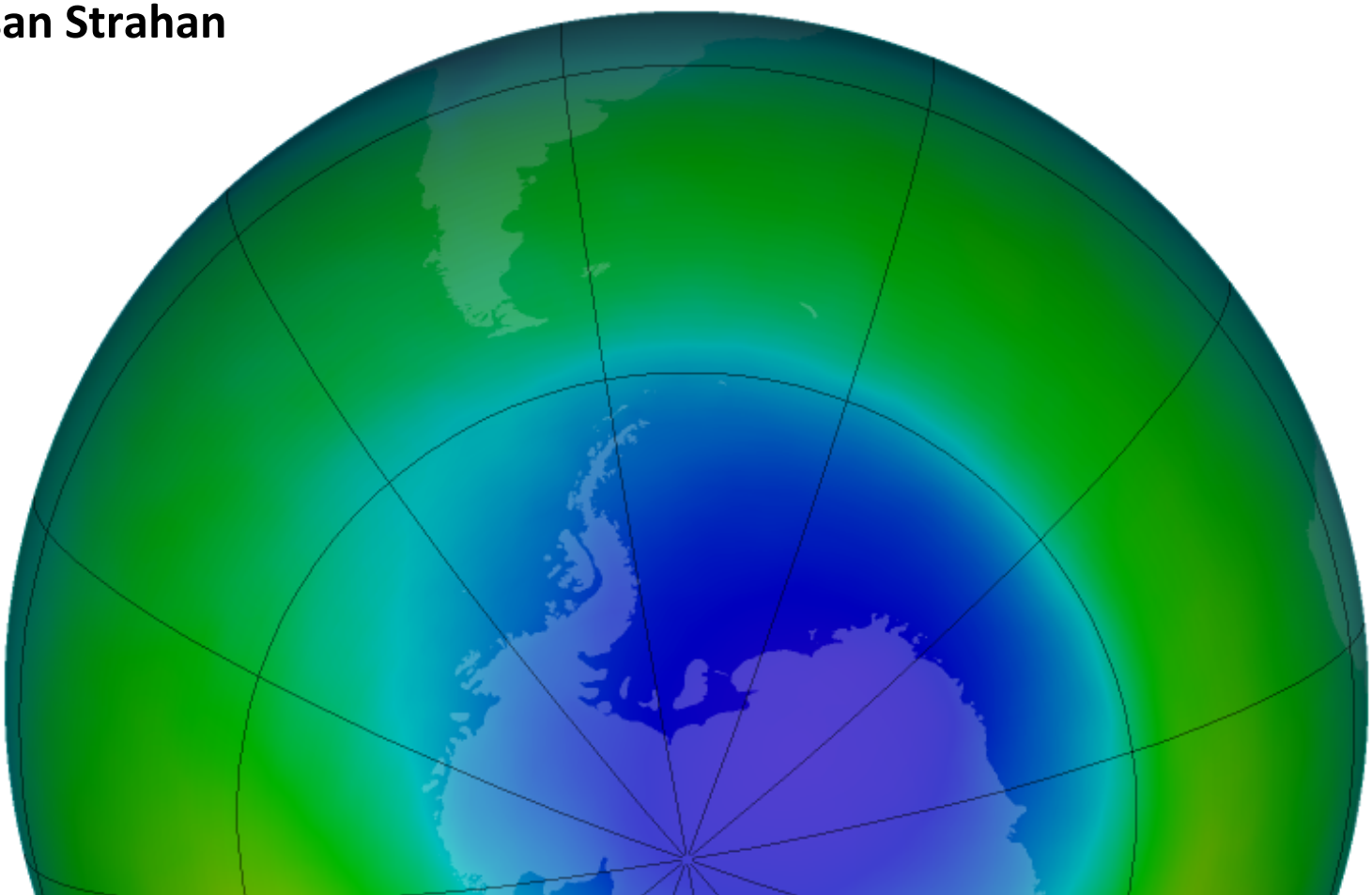
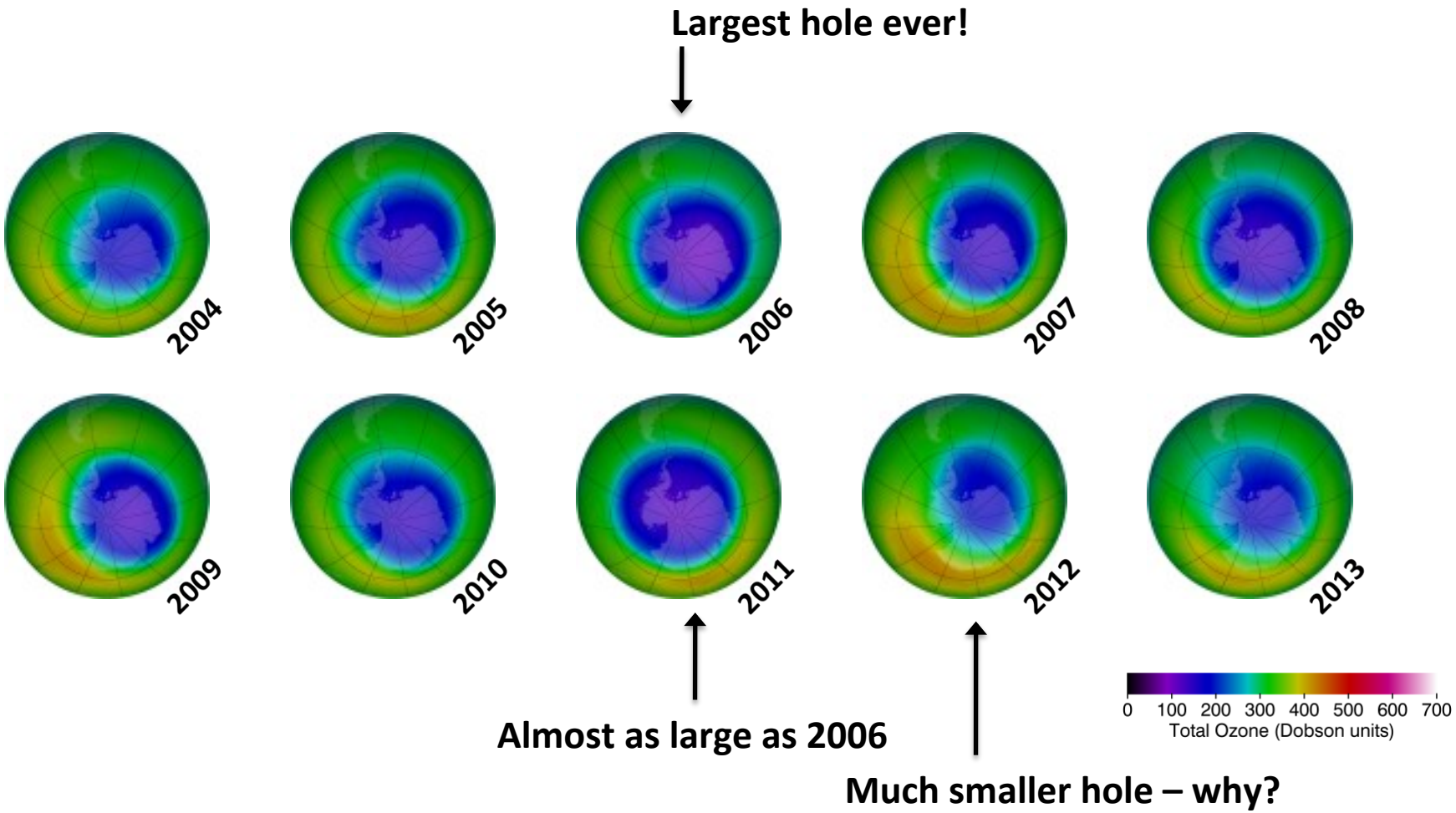


Is the Stratospheric Ozone Hole Recovering?



Bottom Line: We're not there yet

Legacy of Metrics from Space

1975 1980 1985 1990 1995 2000 2005 2010 2015

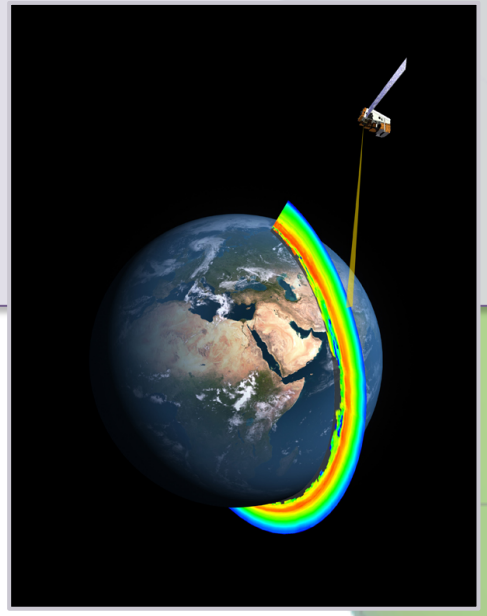
Nimbus 7 – TOMS
10/78 6/93

Meteor 3 – TOMS
8/91-12/94

Earth Probe – TOMS
7/96 12/05

Aura – OMI
(ongoing)
7/04

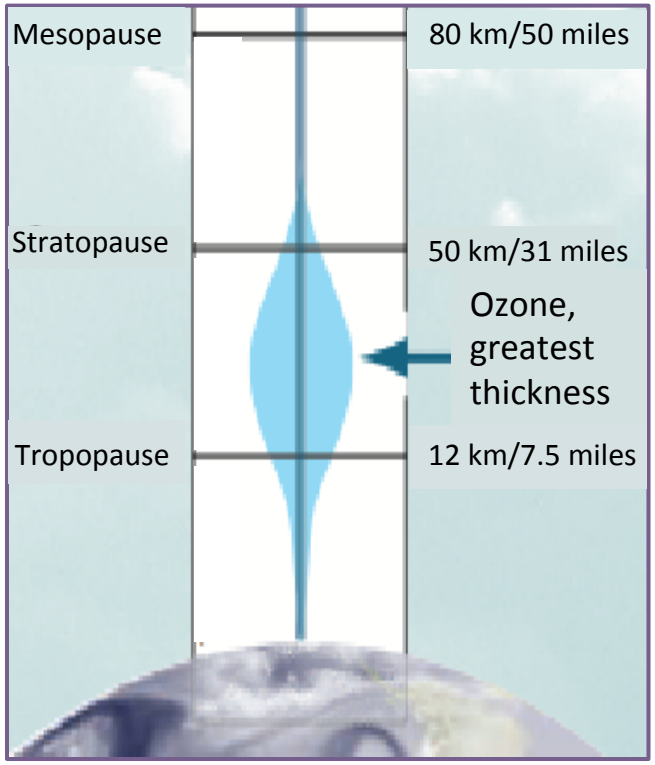
Suomi NPP – OMPS
(ongoing)
10/11



Suomi NPP

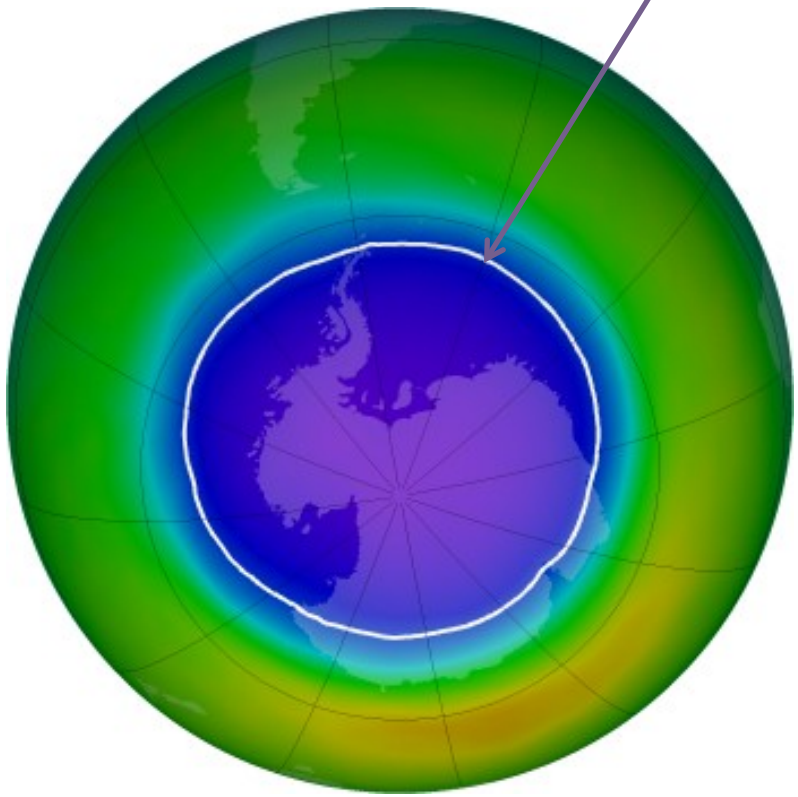
Classic Metrics …

… used to describe the Ozone Hole are obtained from Total Column Ozone. These metrics place each year in the context of the long observational record.



Total Column Ozone

A classic ozone hole's metric – the Antarctic area with total ozone column below 220 DU.



Limitation: No vertical information

New Metrics …

… have been derived from instruments looking inside the ozone hole, revealing processes invisible in the column but must be accounted for to isolate the impact of decreased chlorine.

Satellite: Aura (3rd of the large EOS observatories)

Date: July 15, 2004 – present

Instrument: Microwave Limb Sounder
Profiles of O_3 and HCl, N_2O, ClO

Satellite: Suomi National Polar-orbiting Partnership (NPP)

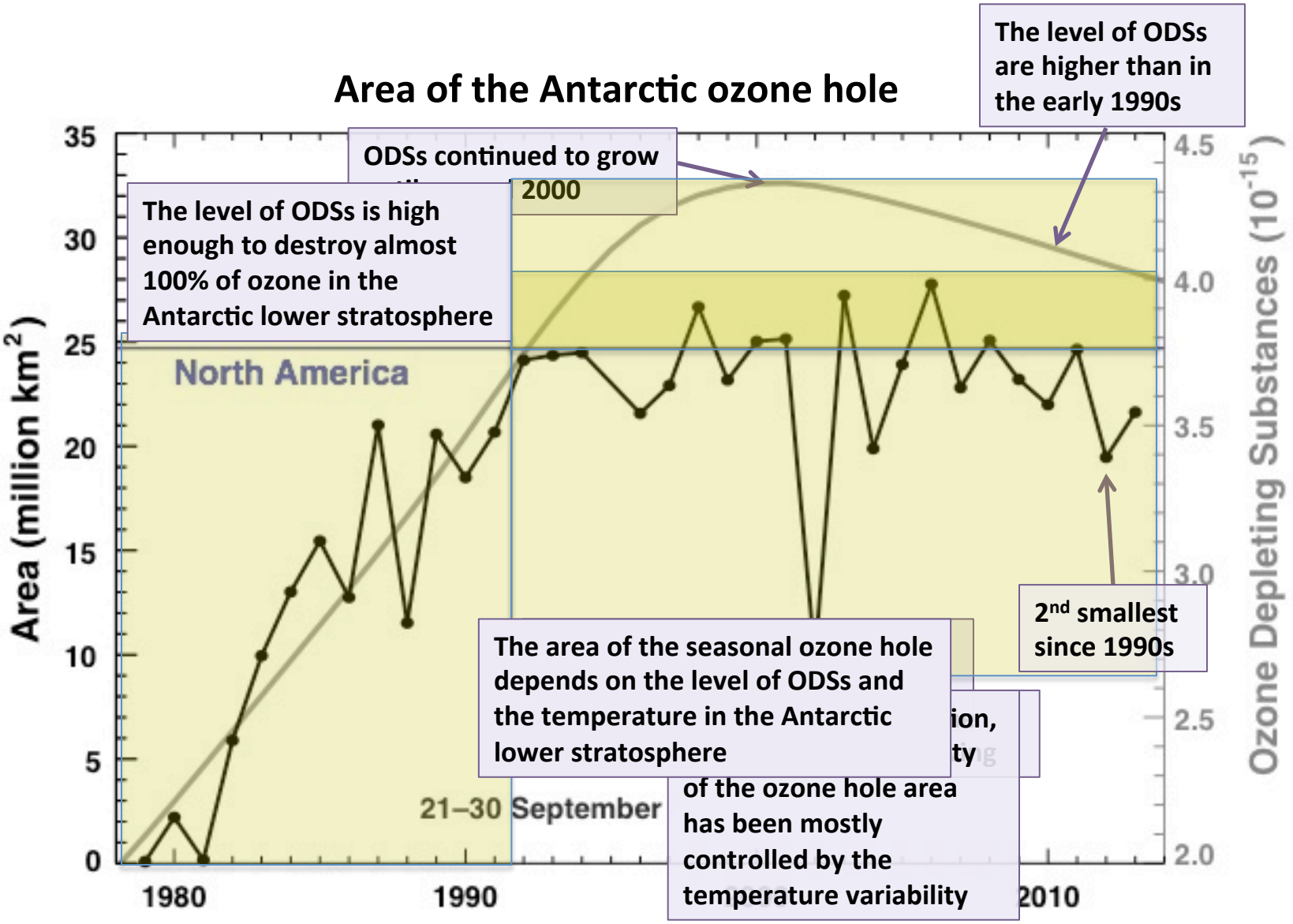
Date: October 28, 2011

Instrument: Ozone Mapping Profiler Suite (OMPS)

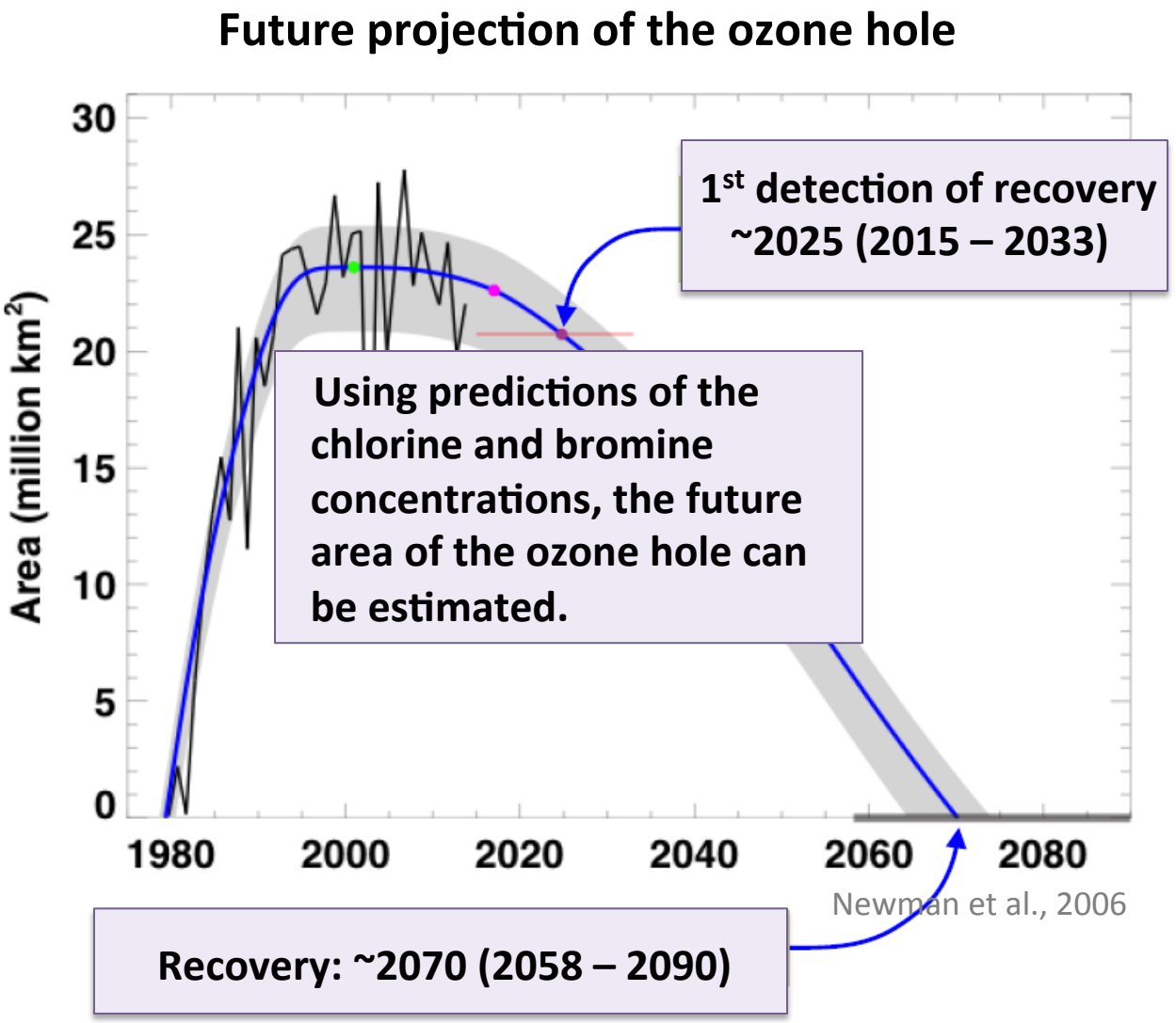
Questions:

- **Why is the 2012 Ozone Hole the second smallest since the late 1980's?**
- **Why do column measurements in 2011 and 2006 appear the same?**

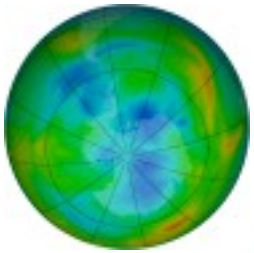
Is the Antarctic ozone hole recovering?



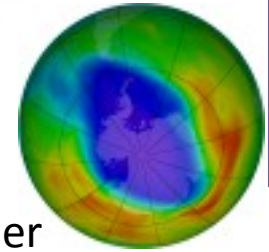
Is the Antarctic ozone hole recovering?



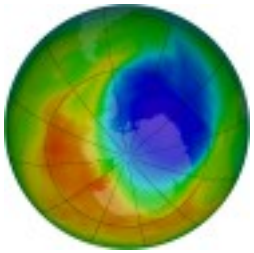
Evolution of the 2012 ozone hole



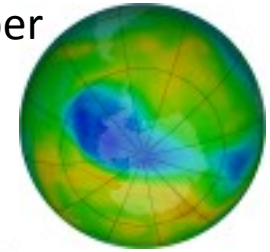
1 August



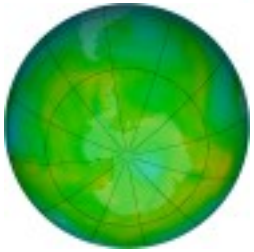
4 October



19 October



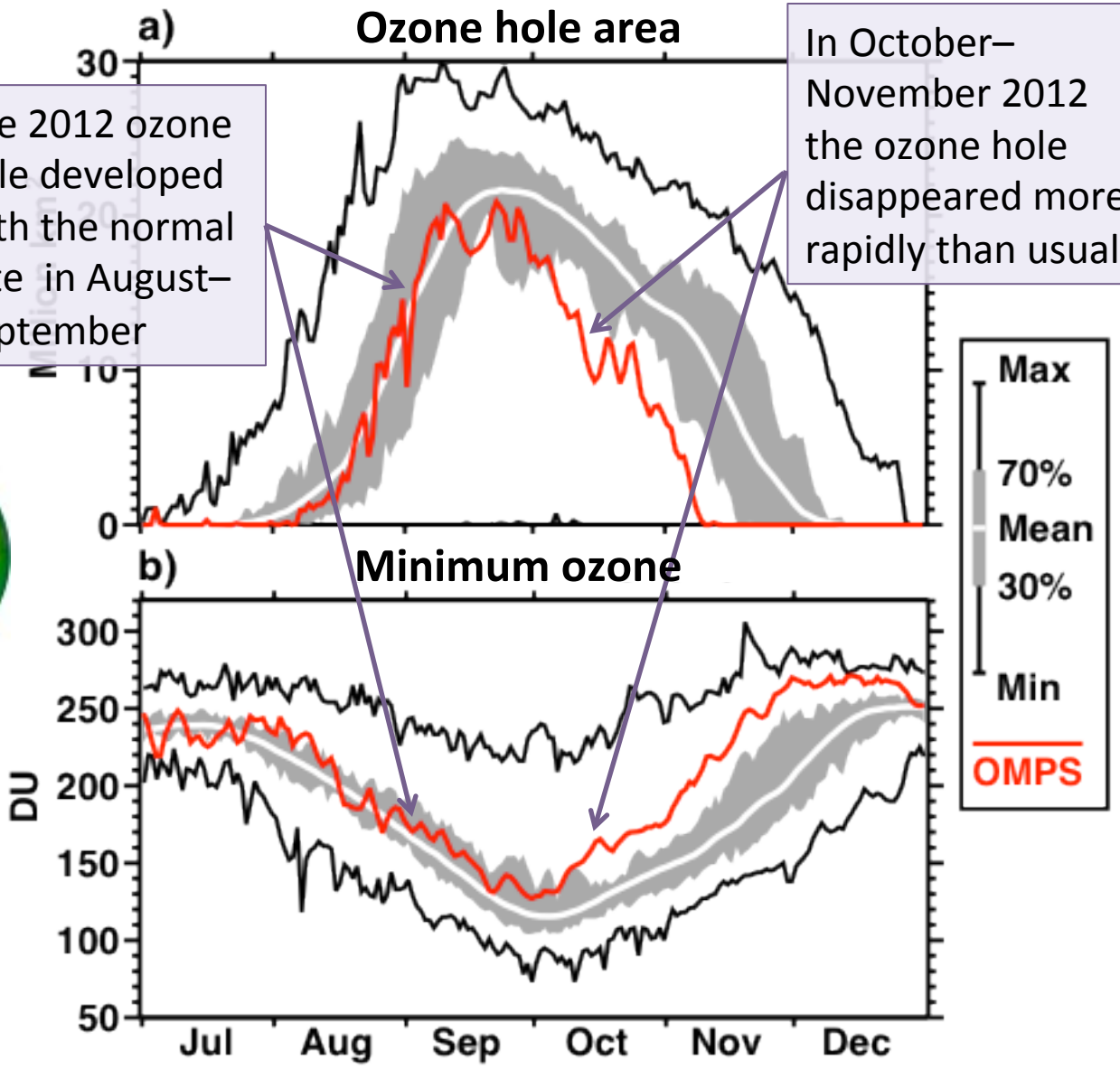
7 November



1 December

The 2012 ozone hole developed with the normal rate in August–September

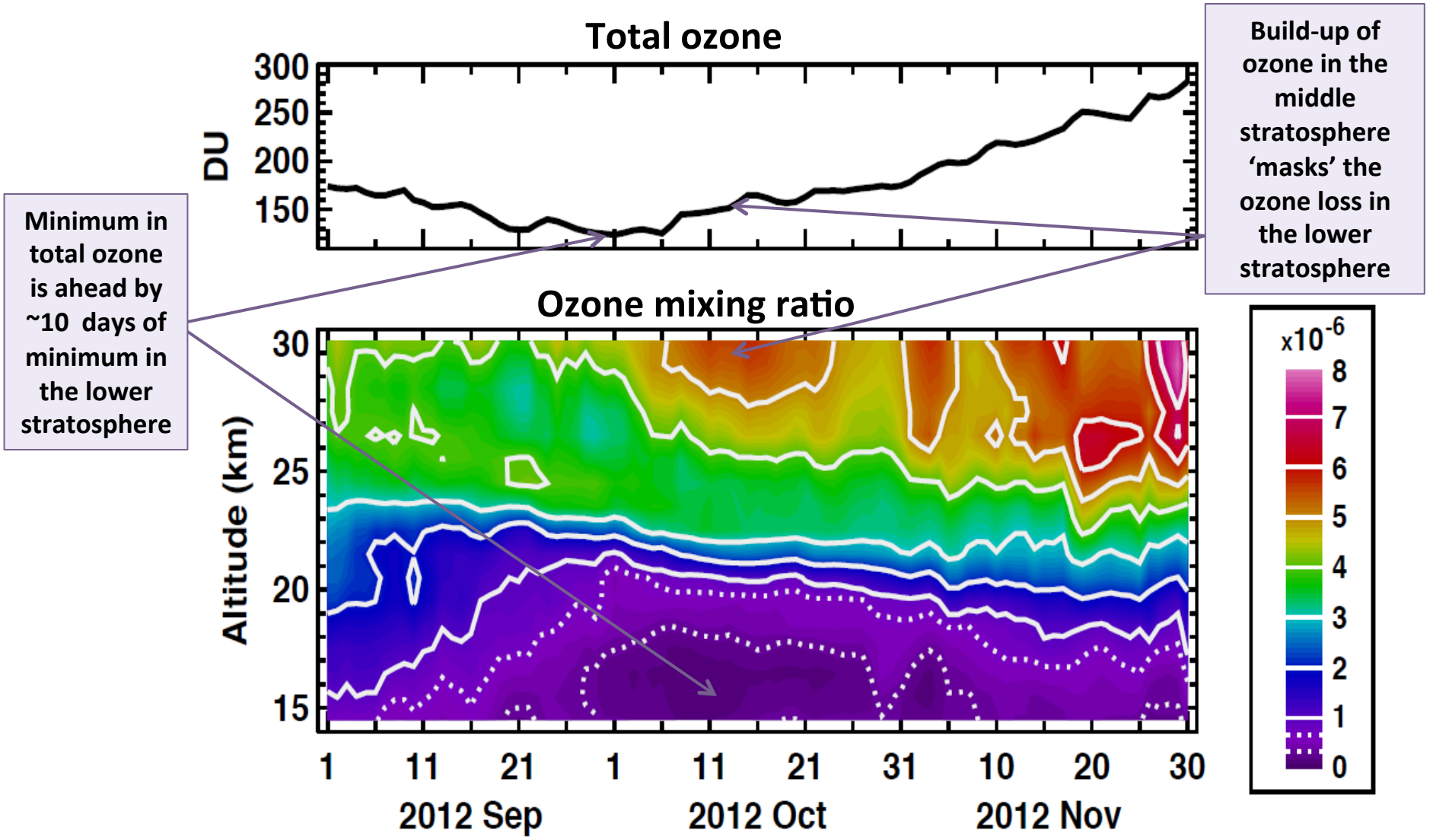
In October–November 2012 the ozone hole disappeared more rapidly than usual



http://ozonewatch.gsfc.nasa.gov

First look inside the hole

with the Ozone Mapper and Profiler Suite (OMPS)



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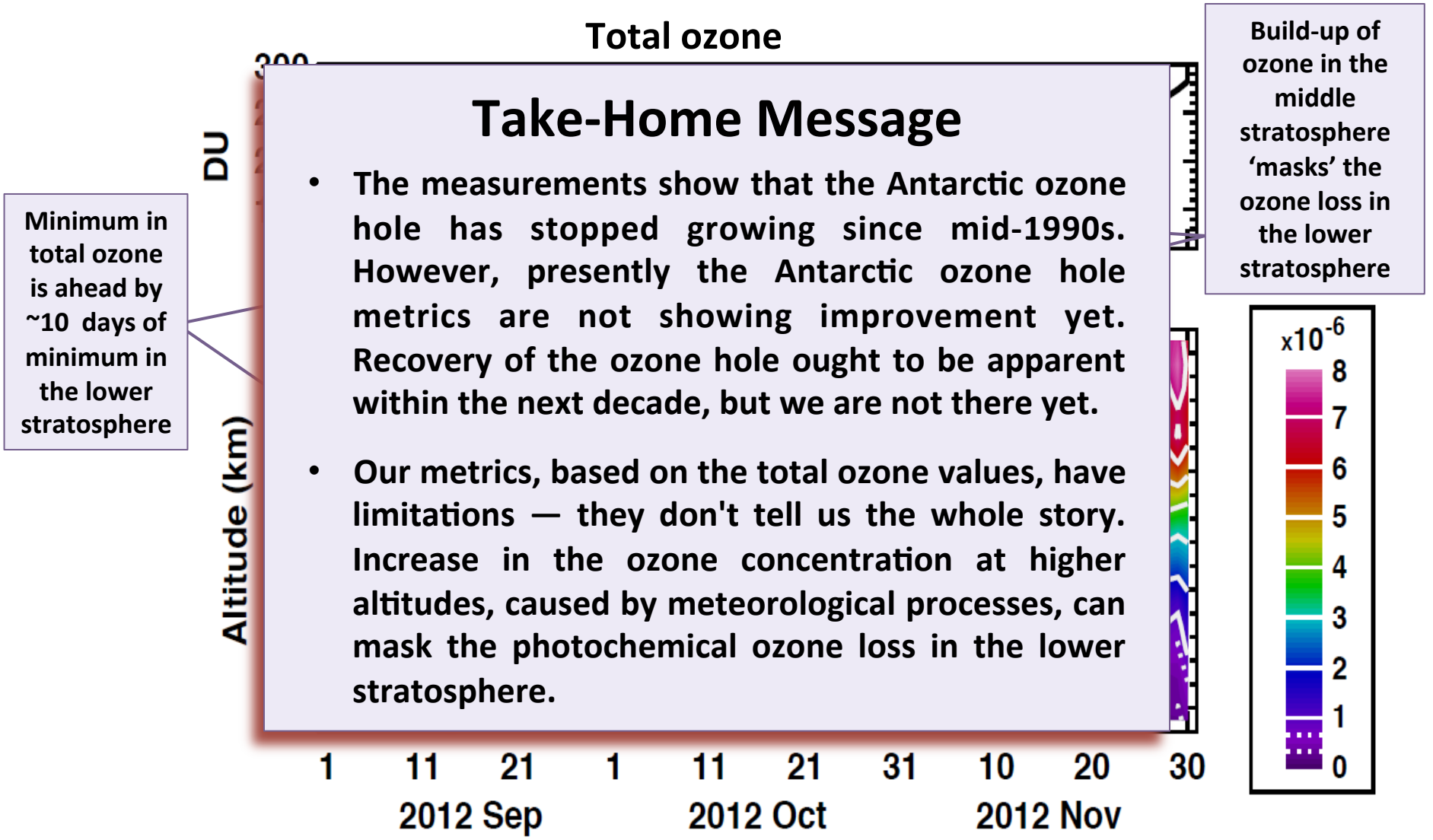


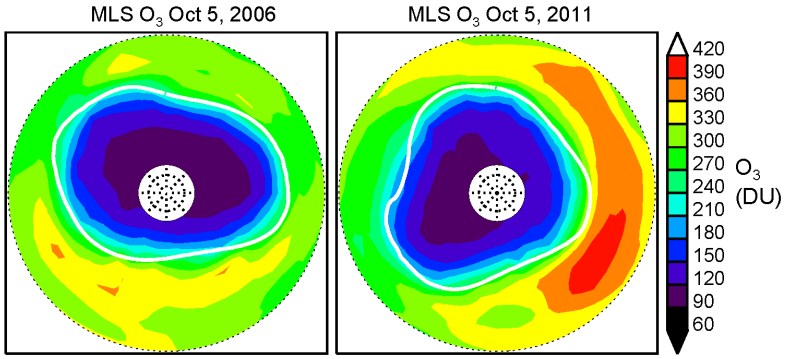
Take-Home Message

- The measurements show that the Antarctic ozone hole has stopped growing since mid-1990s. However, presently the Antarctic ozone hole metrics are not showing improvement yet. Recovery of the ozone hole ought to be apparent within the next decade, but we are not there yet.
- Our metrics, based on the total ozone values, have limitations — they don't tell us the whole story. Increase in the ozone concentration at higher altitudes, caused by meteorological processes, can mask the photochemical ozone loss in the lower stratosphere.

A look inside the 2006 and 2011 holes

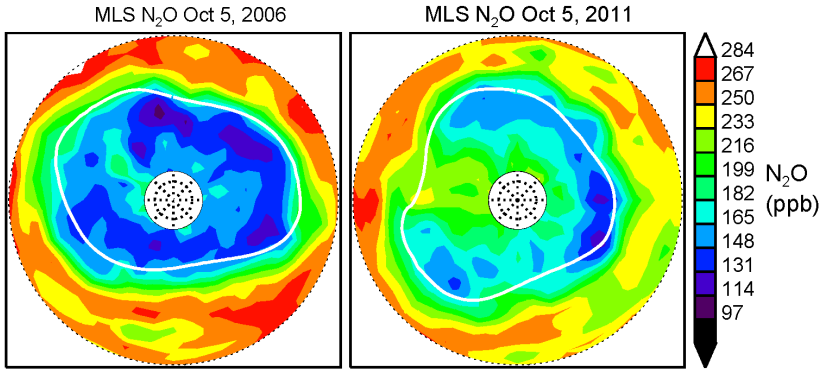
with Aura's Microwave Limb Sounder

The 2006 and 2011 ozone holes were very similar



2006 and 2011 were two of the largest and deepest ozone holes of the past decade. Ozone in both years is near its minimum on this date.

Inside the ozone hole, other chemical species were very different – Why?

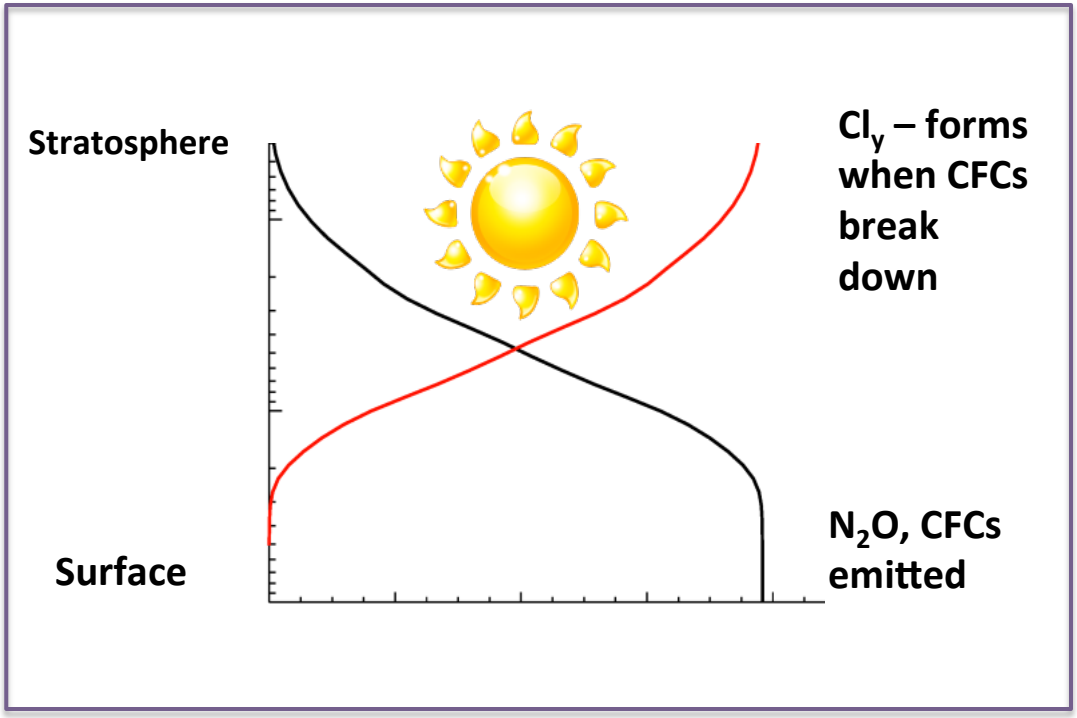


Nitrous oxide (N_2O) is also measured by MLS.

There was a lot more of it in 2011 than in 2006.

The amount of N_2O tells us about the journey this air mass has taken through the atmosphere.

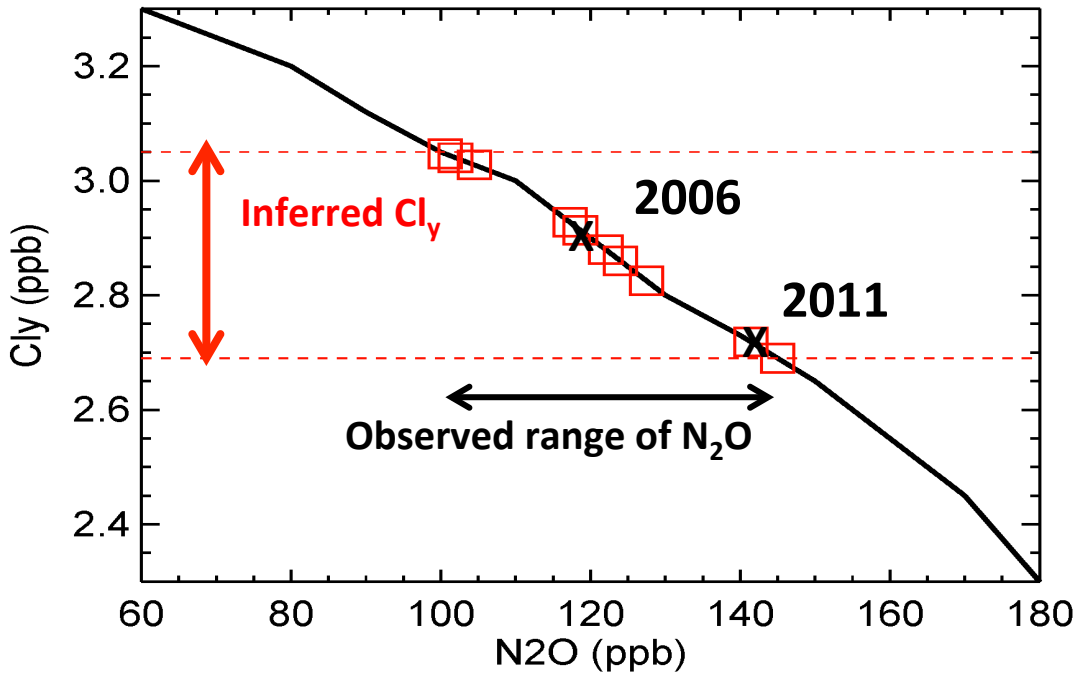
The Chlorine and Nitrous Oxide Relationship



- N_2O and CFCs are emitted at the surface.
- Inorganic chlorine (Cl_y) forms when CFCs breakdown.
- When chlorine is high, N_2O is low and vice versa.

- **We use N_2O to tell us about chlorine (Cl_y) inside the ozone hole.**
- **Chlorine affects how much ozone depletion occurs, but we don't have measurements to see how much is there.**

Chlorine in the ozone holes: 2004-2013

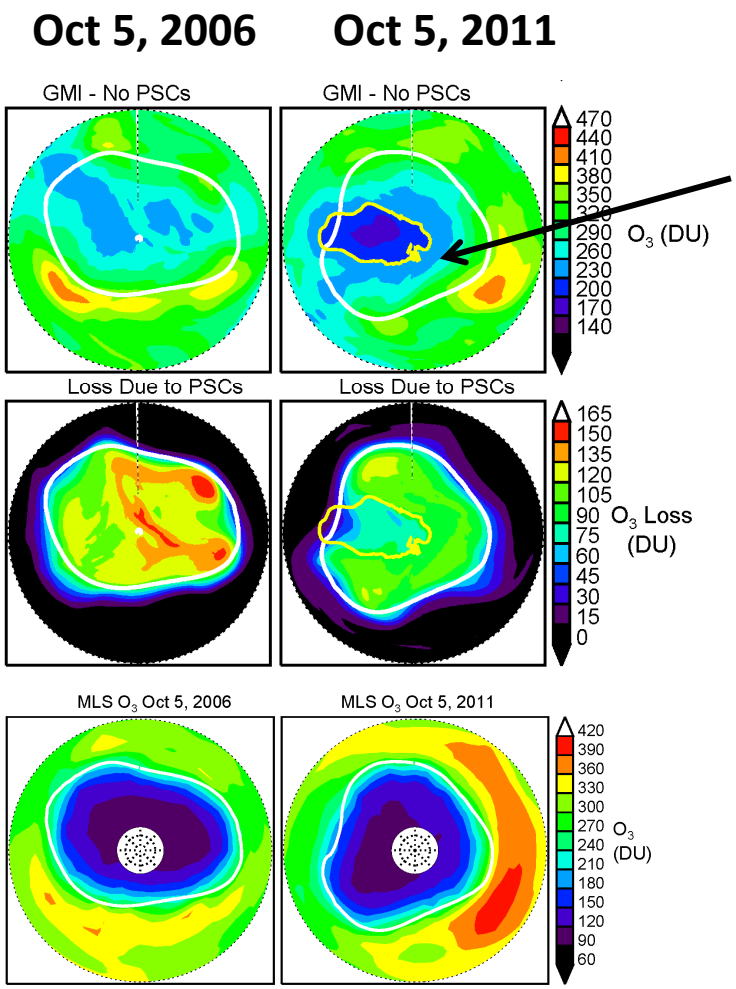


Solid line = nitrous oxide and chlorine relationship derived from observations [Schauffler et al., 2003].

- Nitrous oxide (N_2O) variations measured inside the ozone hole (red boxes) imply chlorine (Cl_y) variations of about 10 percent (~300 ppt).
- Chlorine is expected to decrease by ~5% during this decade due to the Montreal Protocol, but we find variations of ±5% EACH year!
- **2011 had less chlorine than 2006. Why was the 2011 ozone hole as severe as 2006?**

Why was the 2011 ozone hole as severe as 2006?

To answer 'why', we use a model that realistically simulates the chemistry and meteorology of the stratosphere.



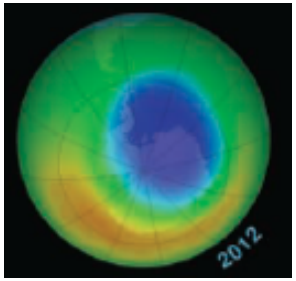
When ozone-destroying reactions are turned off in the model, we see the 2011 Antarctic had less ozone than 2006. This is a meteorological, not chemical effect.

Model calculations also show there was less ozone depletion in 2011 than 2006.

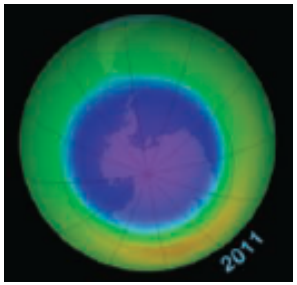
- **Chemical loss can vary significantly without obvious impact on column ozone because the winds bringing O_3 to the pole vary too.**
- **Column ozone metrics don't reveal what's going on inside the ozone hole.**

To summarize …

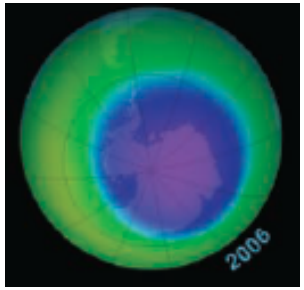
- **We've known for a long time the chlorine and temperature matter to the ozone hole.**
- **Our two studies find that what also matters are the winds that bring ozone to the Antarctic at and above the levels where ozone depletion occurs.**



2012: Severe ozone depletion occurred at lower levels while winds brought more ozone to the Antarctic at higher levels. **The net result was a smaller than usual ozone hole.**



2011: Winds brought less ozone to the Antarctic and there less ozone depletion than in 2006. **The net result was an ozone hole that was larger and deeper than most holes in the past decade.**



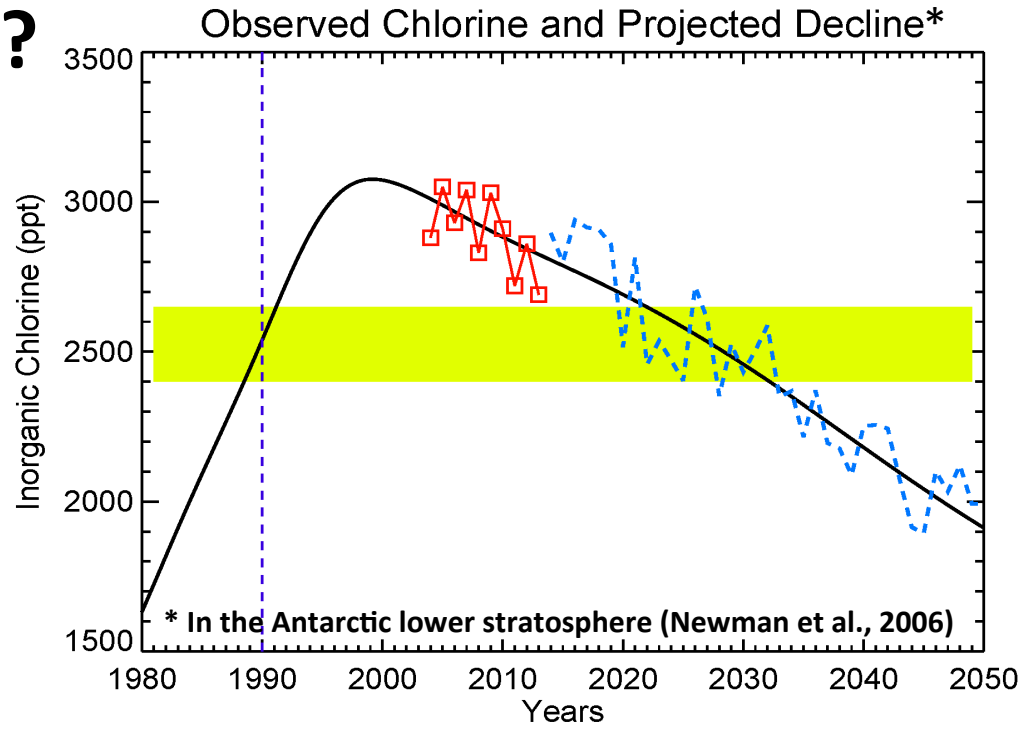
2006: The largest observed ozone hole.

The ozone classic metrics do not reveal what's going on 'under the hood' of the ozone hole. You have to look under the hood to see why the ozone hole varies.

When will the ozone hole respond to declining chlorine?

High Chlorine: Hole area depends on temperature and winds, not chlorine variations

Low chlorine: Hole area grows when chlorine increases (and vice versa)



Before the 1990s: hole area increased as chlorine increased

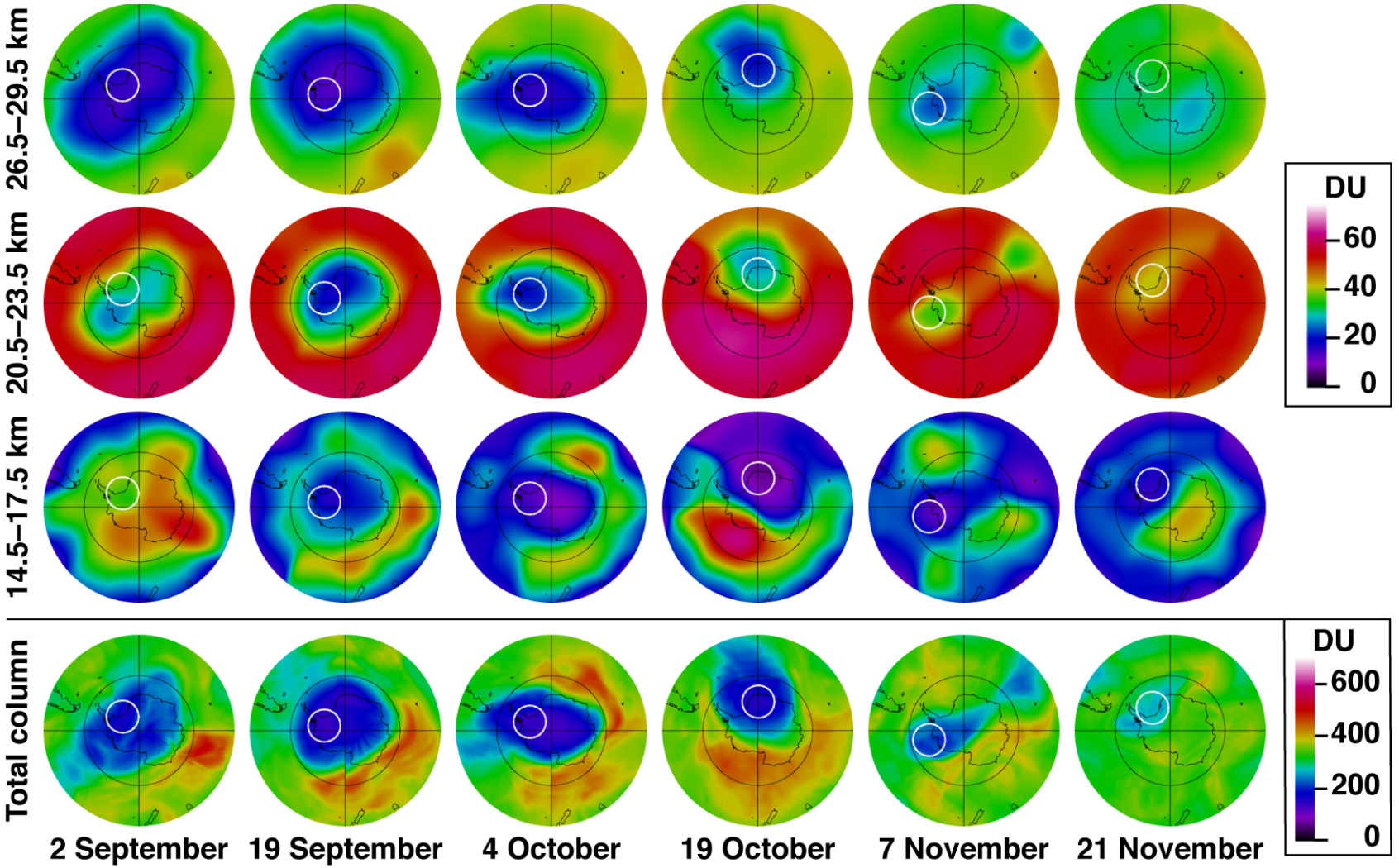
~1990-2015: Large hole area that varies with temperature and winds

About 2015-2033: Some years will have smaller area due to chlorine decline

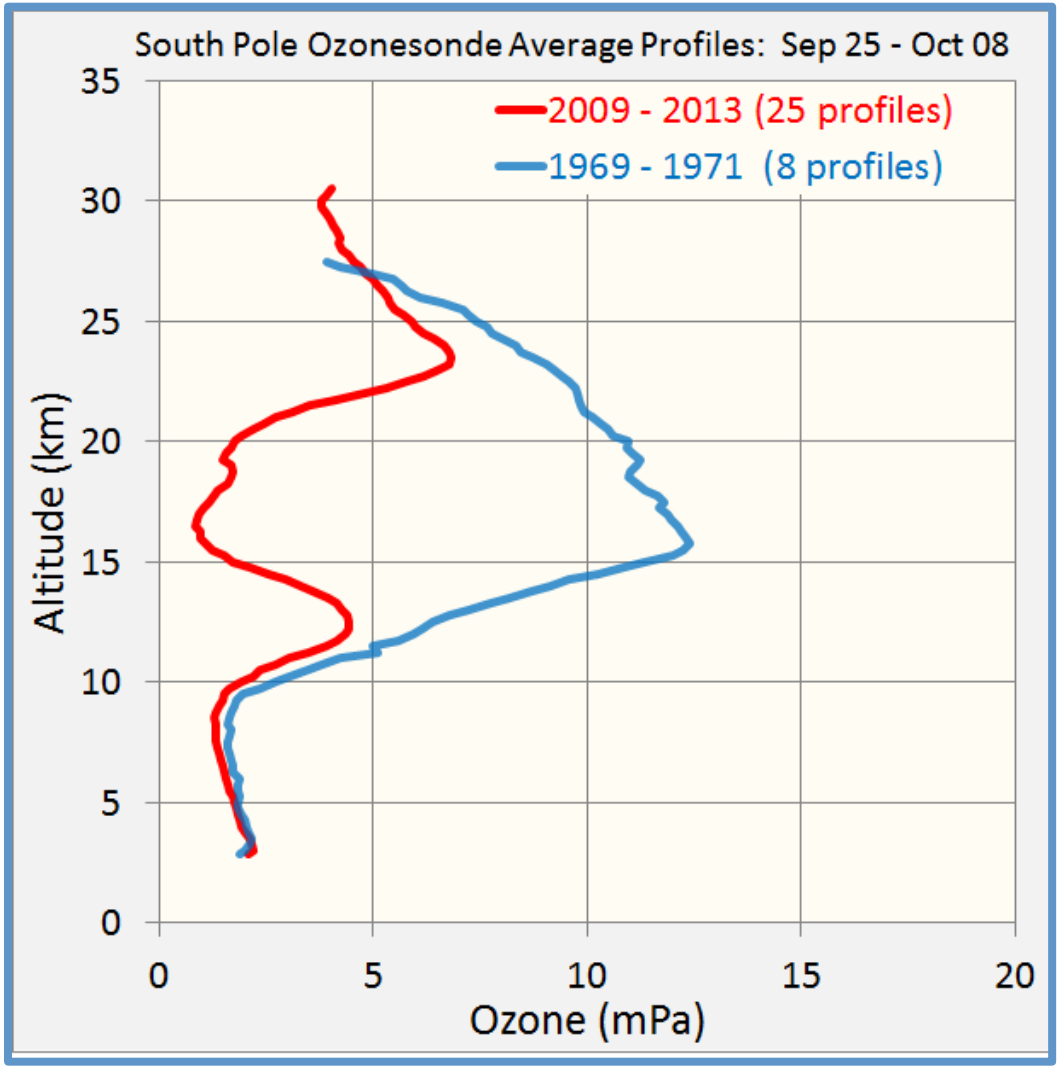
Beyond the mid-2030's: Lower chlorine produces smaller ozone holes than today. Full recovery around 2070.

Back up slides

Inside the 2012 Antarctic ozone hole



Ozone profiles over Antarctica



This figure is courtesy of Bryan Johnson, NOAA