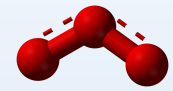
Aura and Stratospheric Ozone

Richard S. Stolarski
Johns Hopkins University
Baltimore, MD

(Emeritus at GSFC)

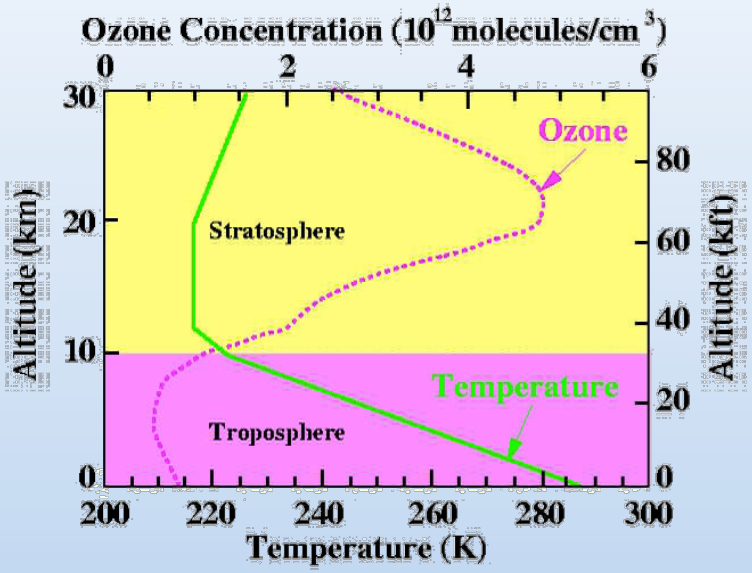
Stratospheric Ozone

- Ozone is a tri-atomic form of oxygen, O_3 
- Ozone is produced by ultraviolet radiation from the sun
- Ozone is destroyed by chemical reactions that recombine ozone to molecular oxygen

  $(O + O_3 \rightarrow O_2 + O_2)$
- Ozone is a "renewable resource": its concentration is determined by a balance of production and loss

Stratospheric Ozone

- Ozone forms a layer in the stratosphere



- Ozone layer shields the surface from UV radiation

The Fluorocarbon-Ozone Problem

- Ozone destruction can be enhanced by catalytic reactions of the oxides of chlorine, bromine, nitrogen, and hydrogen

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

$$\text{net: } O + O_3 \rightarrow O_2 + O_2$$

- Most chlorine compounds are soluble and do not reach the stratosphere

The Fluorocarbon-Ozone Problem

- Chlorofluorocarbons (CFCs) are industrially-produced chemicals that were used in refrigeration, aerosol sprays, foam-blowing, etc

$$\text{CFC-11} = CFCl_3$$

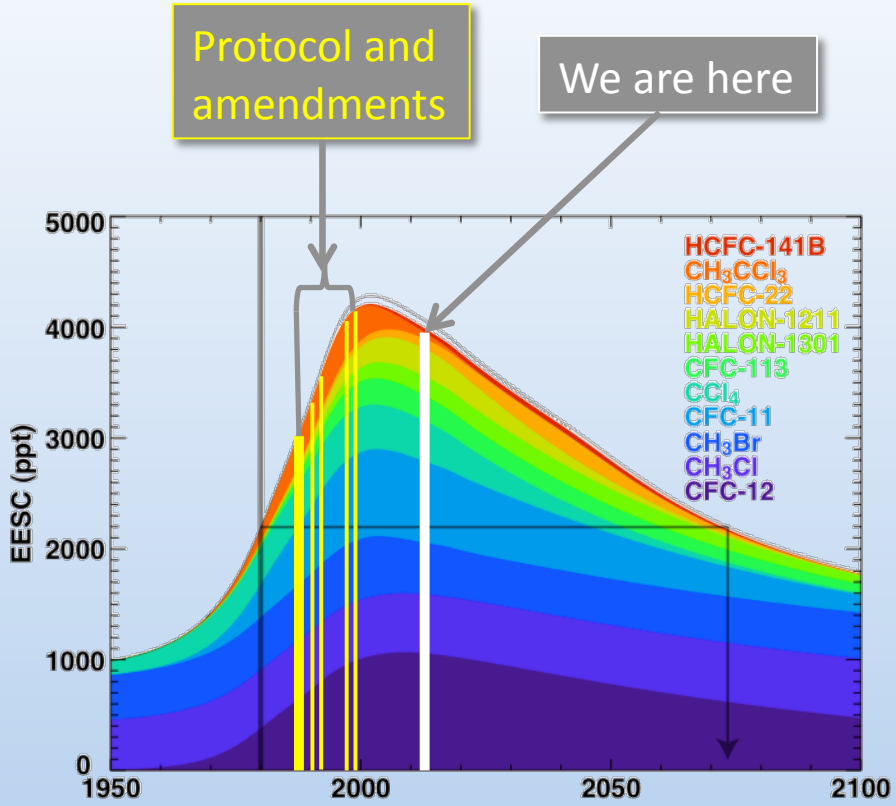
$$\text{CFC-12} = CF_2Cl_2$$

$$\text{CFC-113} = C_2F_3Cl_3$$

- They are insoluble, unreactive, and non-absorbing of visible radiation; they can reach the stratosphere where UV radiation releases the chlorine

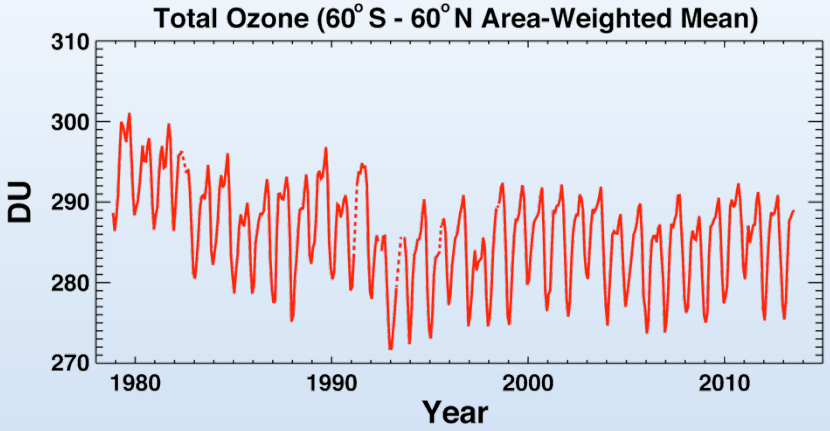
The Fluorocarbon-Ozone Problem

- Fluorocarbons emissions were growing rapidly in the 1970s and 1980s
- The Montreal Protocol (1987) and its amendments (1990, 1992, 1997, 1999) began limiting production
- Chlorine levels are declining



How does Aura enter this picture?

- Ozone concentrations were decreasing
- They appear to have leveled off
- Was this because of the Montreal Protocol?
- What will happen in the future?

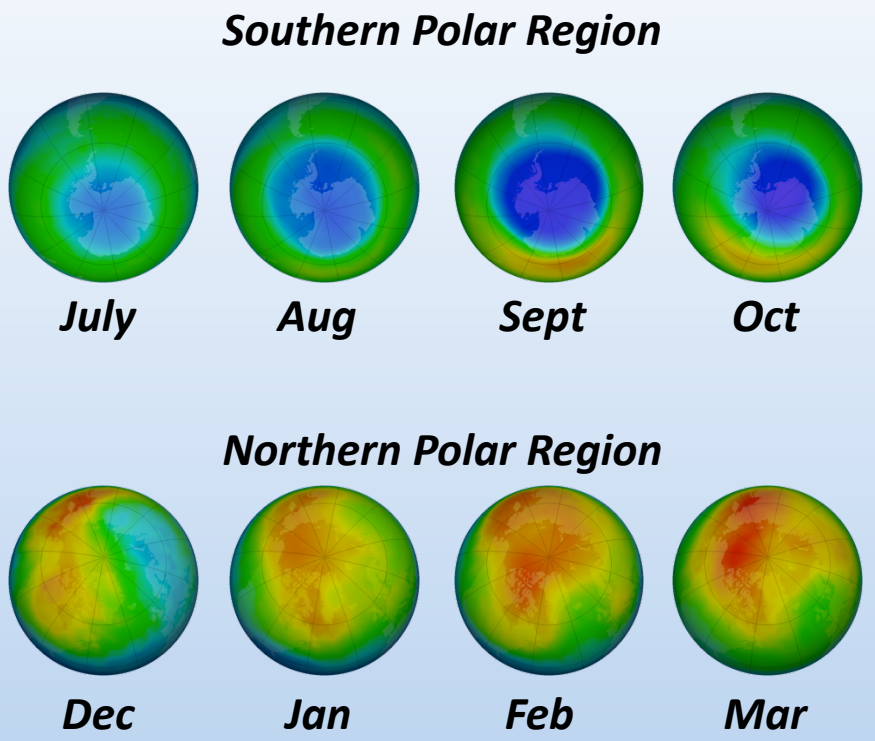


Data from the NASA/NOAA SBUV series of instruments

Can we explain the general shape of this curve? Can we explain the deviations from this shape?

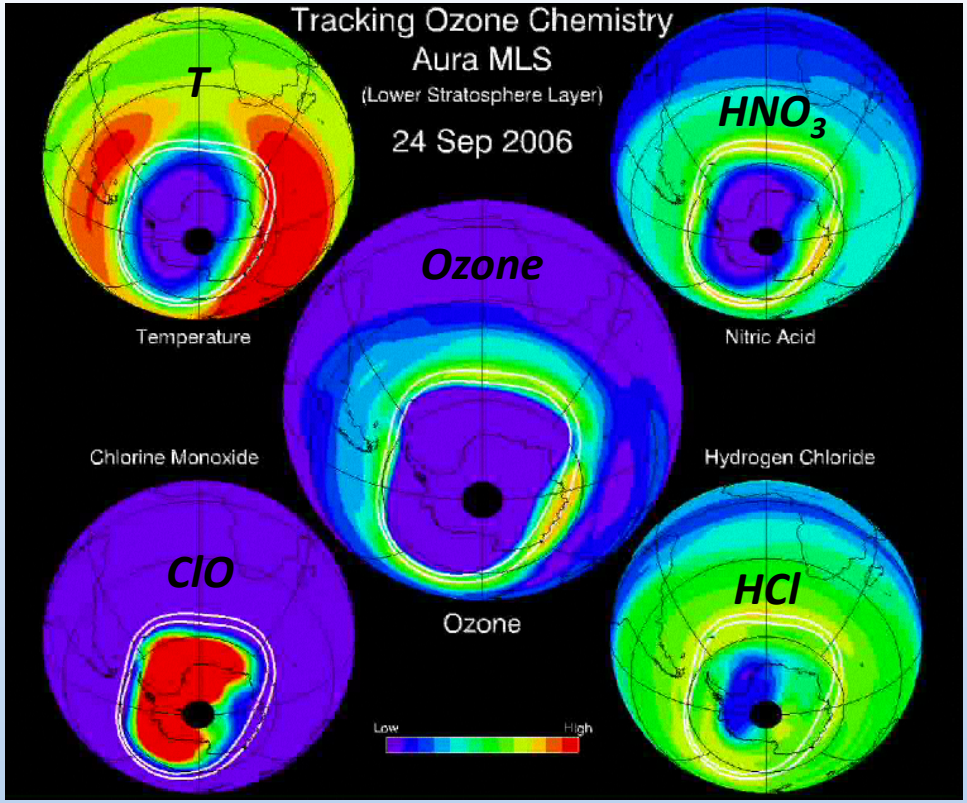
How does Aura enter this picture?

- "Ozone hole" observed in southern polar spring
- Very different behavior in north polar region
- What causes difference?
- What causes year-to-year variation, particularly in NH?



Graphics from ozonewatch.gsfc.nasa.gov

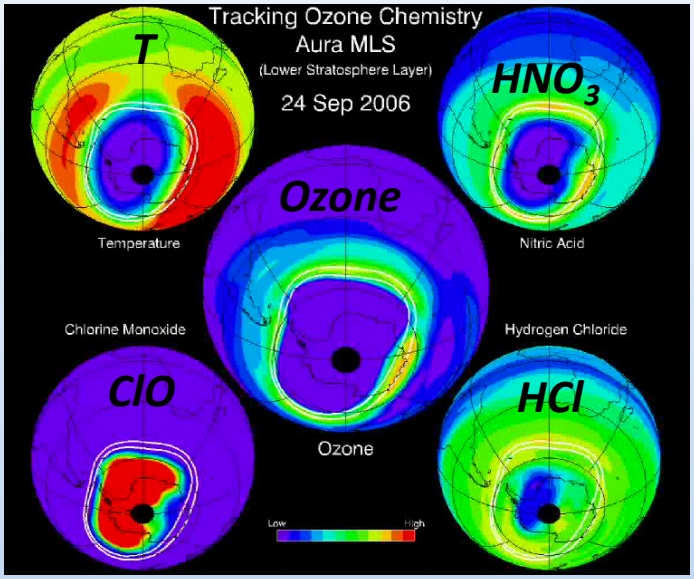
Aura MLS Measures Ozone and the Chemicals that Determine its Concentration



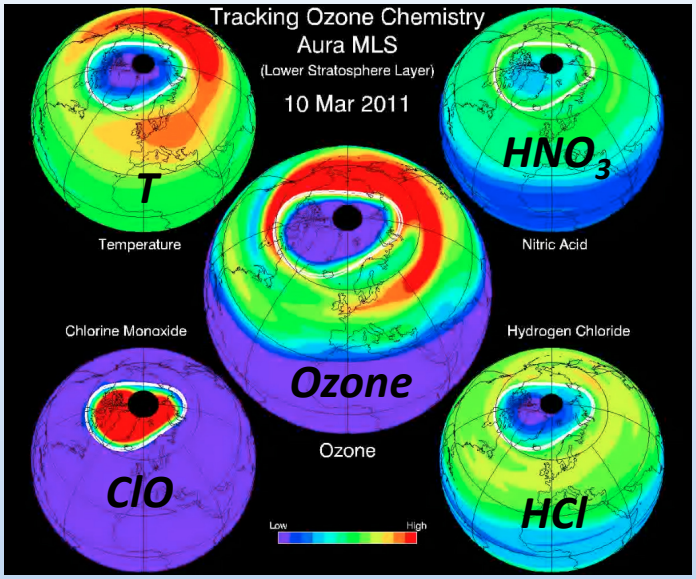
South Polar 24 September 2006

- *Temperature: cold T results in PSCs*
- *Nitric acid: HNO_3 removed by PSCs*
- *HCl: reservoir for chlorine*
- *ClO: active form of chlorine for catalysis*
- *Ozone: reduced by chlorine catalysis*

We can contrast the northern and southern polar regions

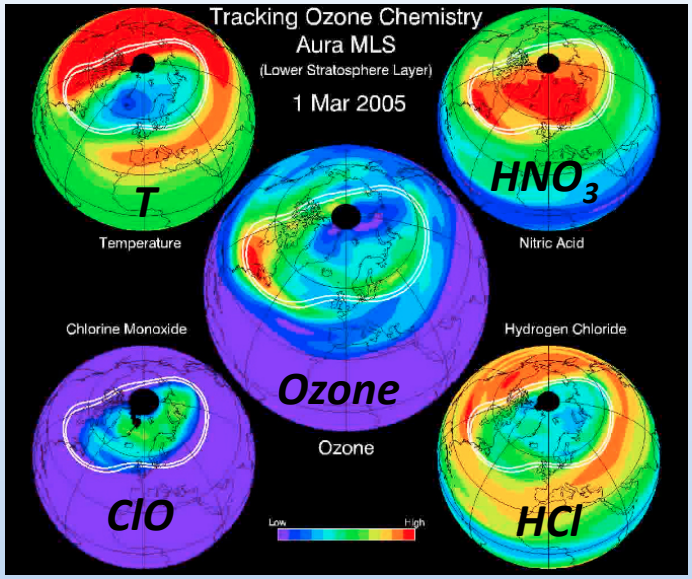


South Polar 24 September 2006

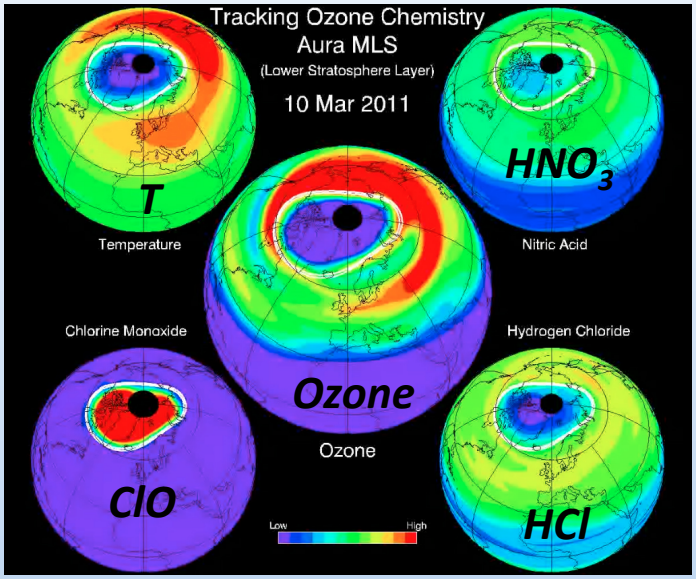


North Polar 10 March 2011

We can observe radically different northern polar winters



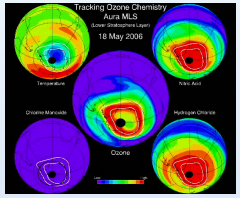
North Polar 1 March 2005



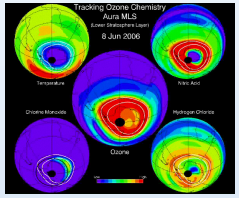
North Polar 10 March 2011

Aura
atmospheric chemistry
climate • pollution • ozone • clouds • aerosols

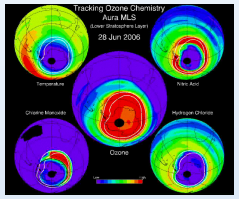
We can observe a daily sequence over an entire polar winter



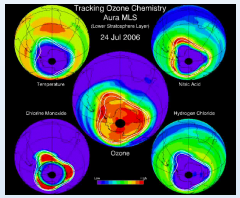
18 May



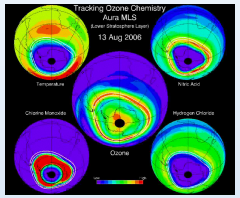
8 June



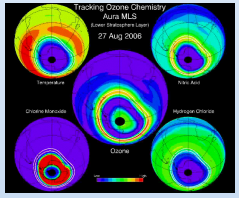
28 June



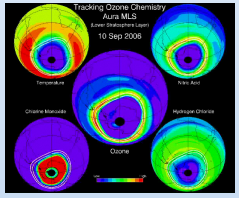
24 July



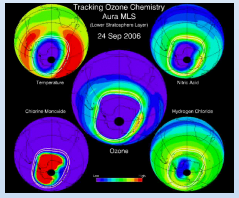
13 Aug



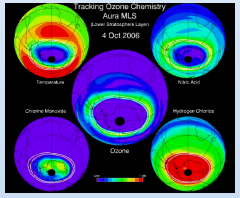
27 Aug



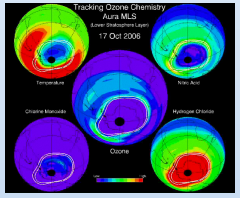
10 Sept



24 Sept

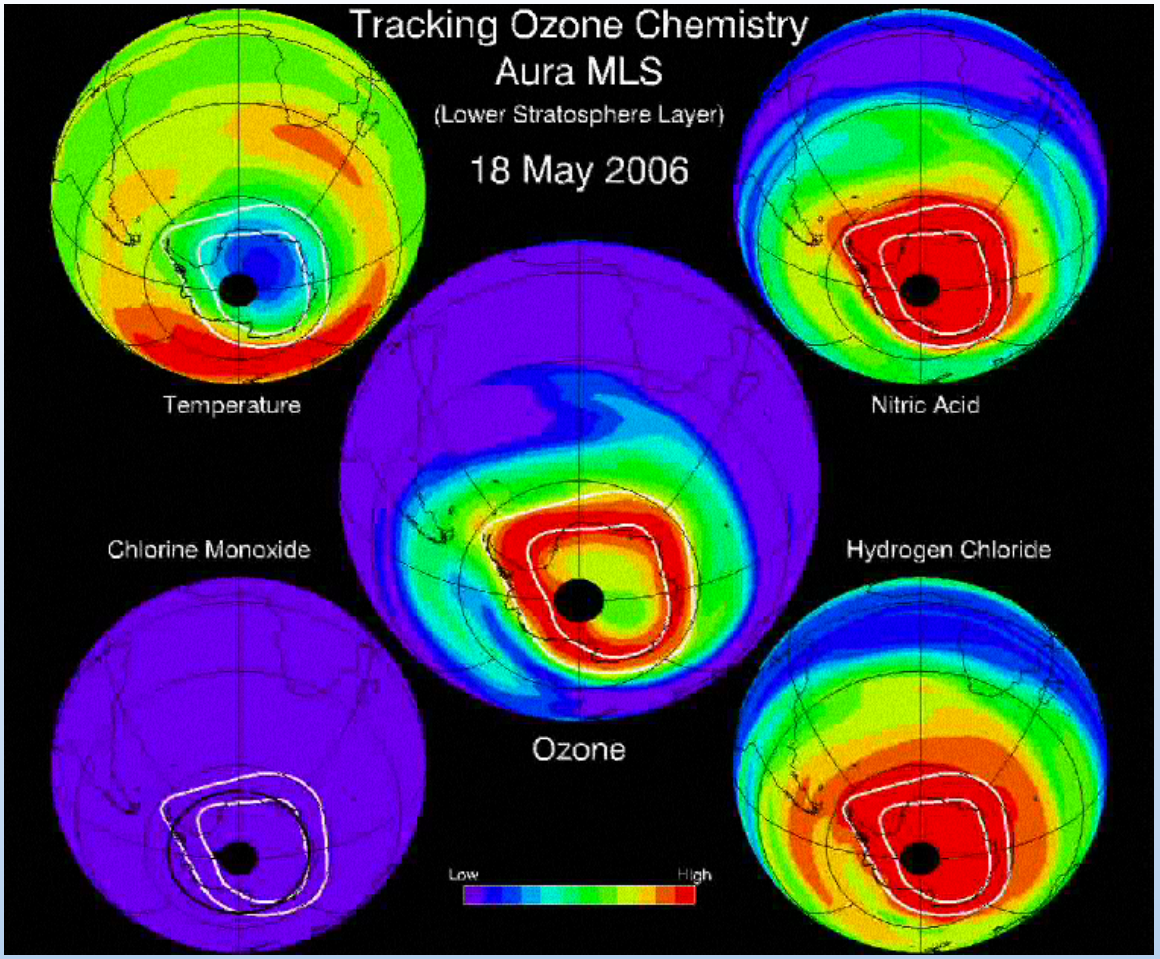


4 Oct



17 Oct

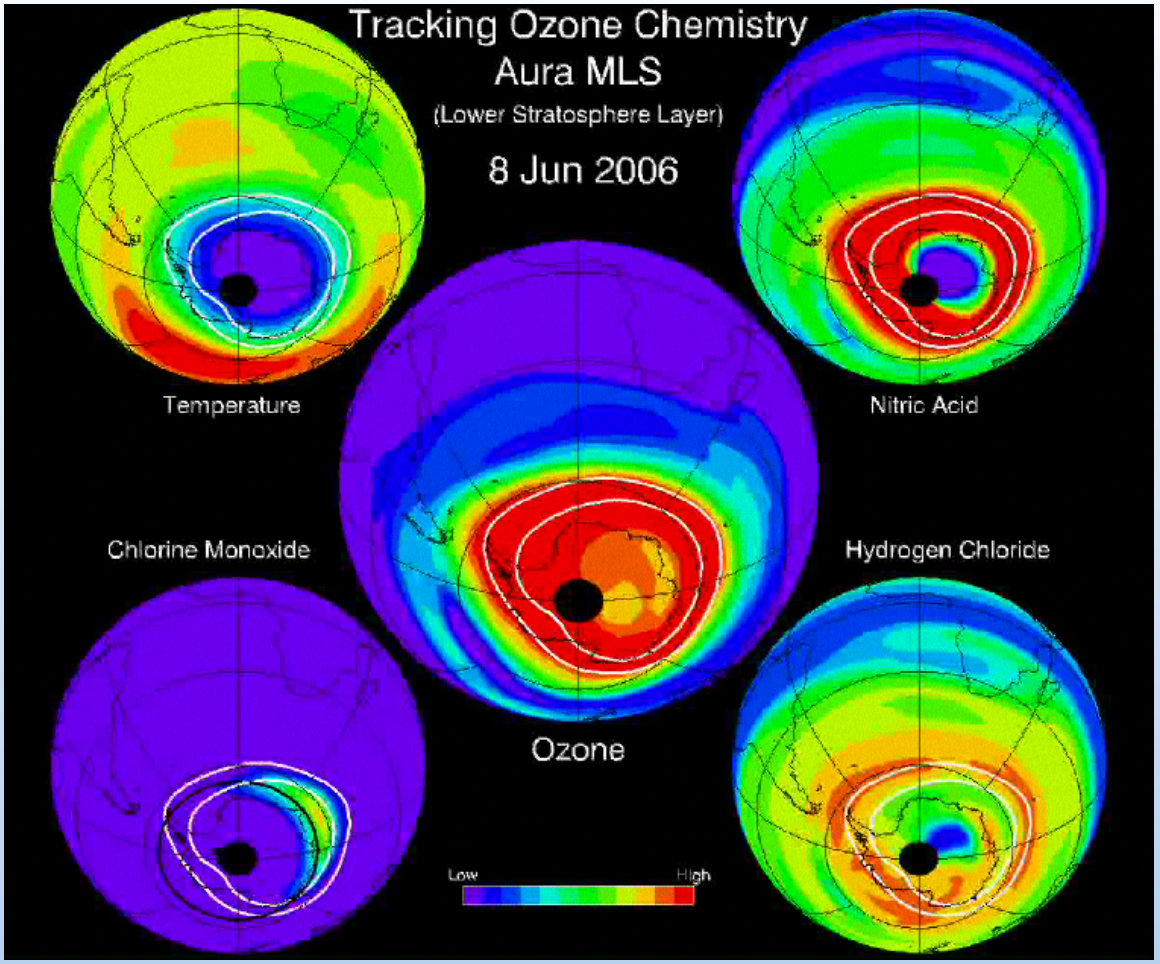
Next 10 slides will show this sequence for the south polar region



Aura

atmospheric chemistry

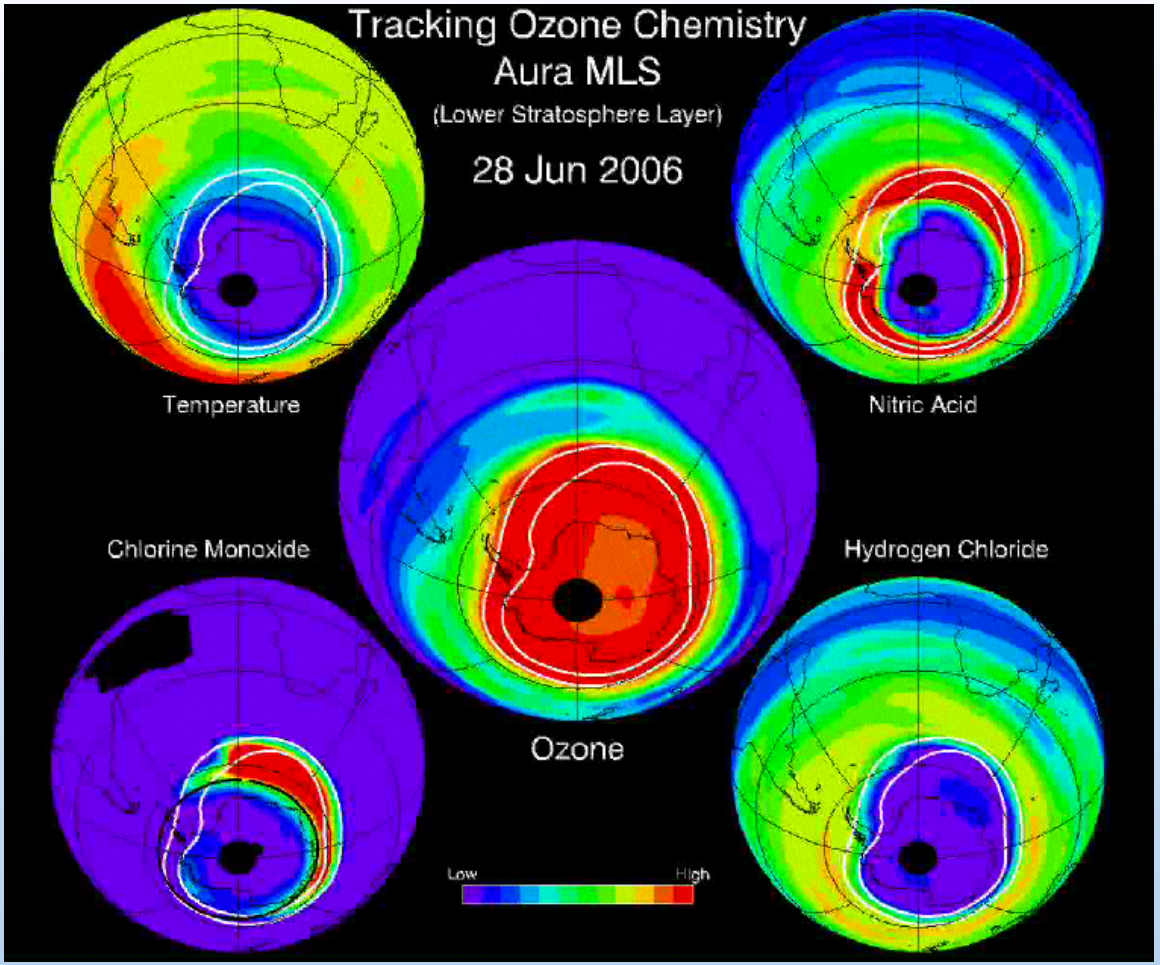
climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

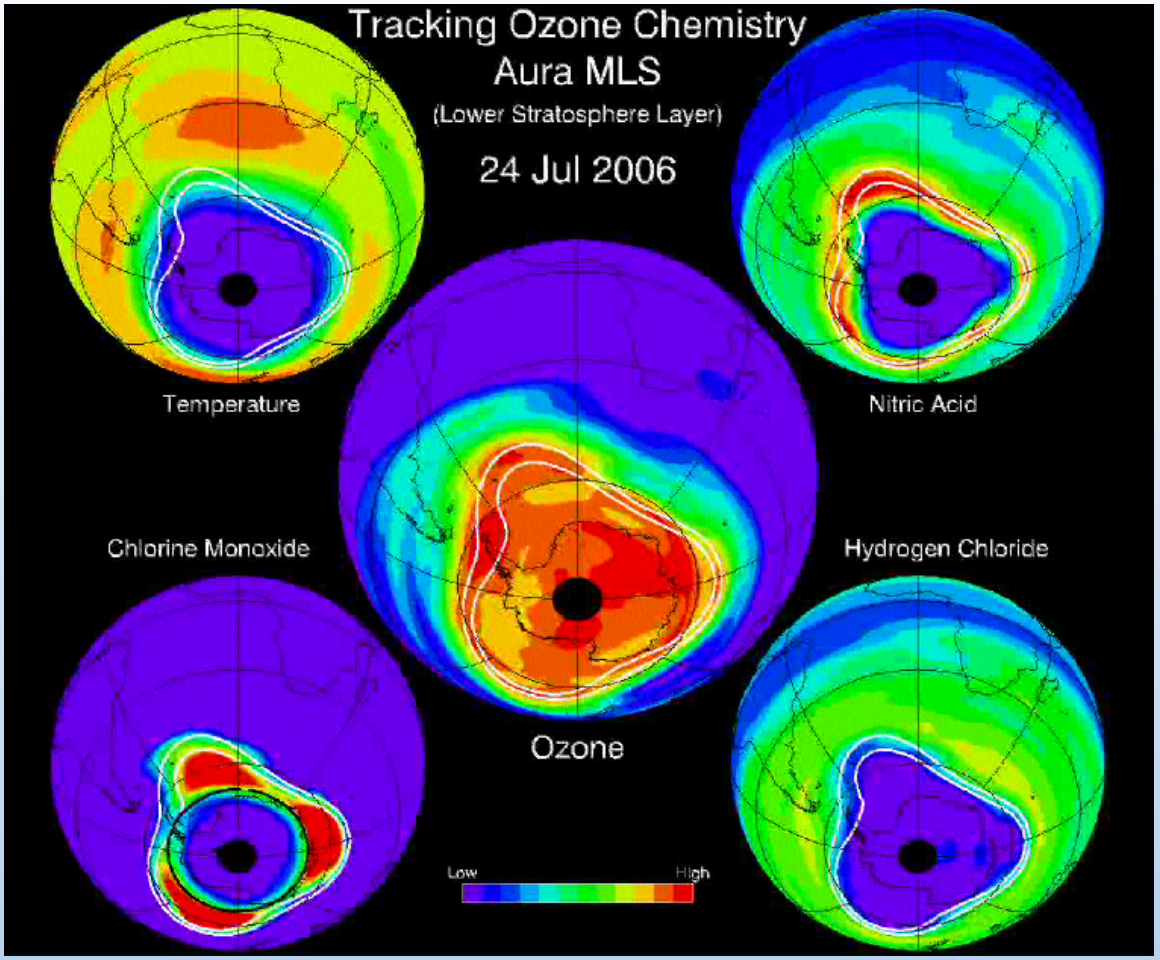
climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

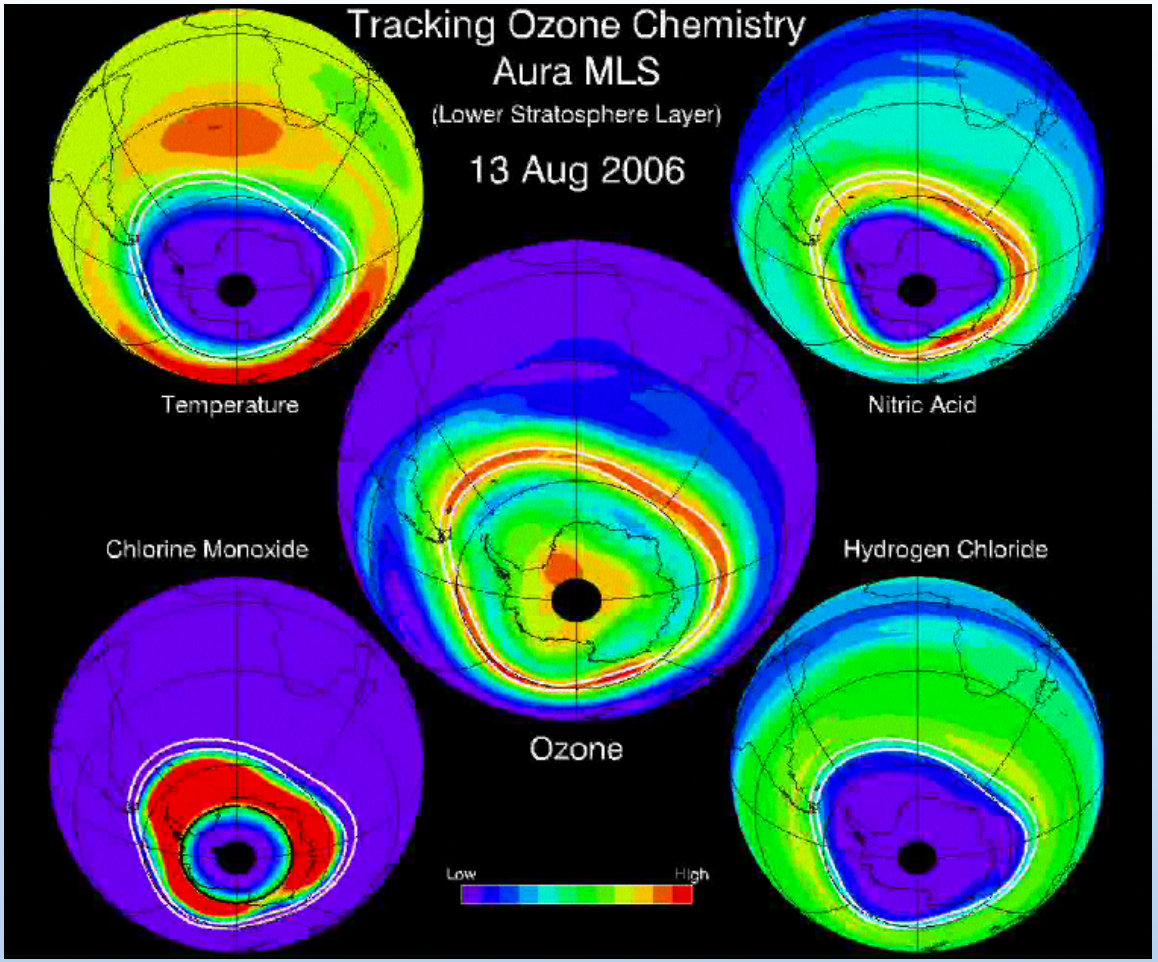
climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

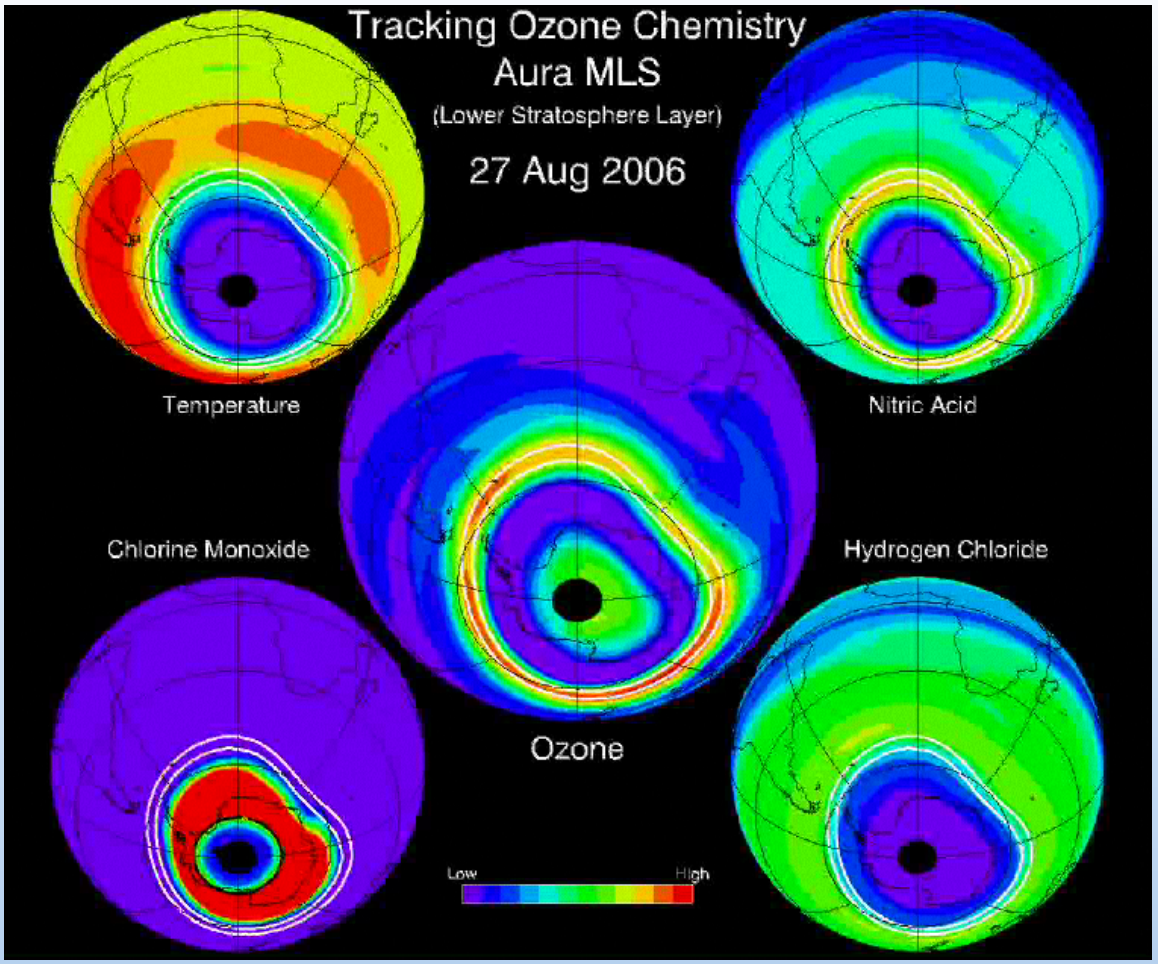
climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

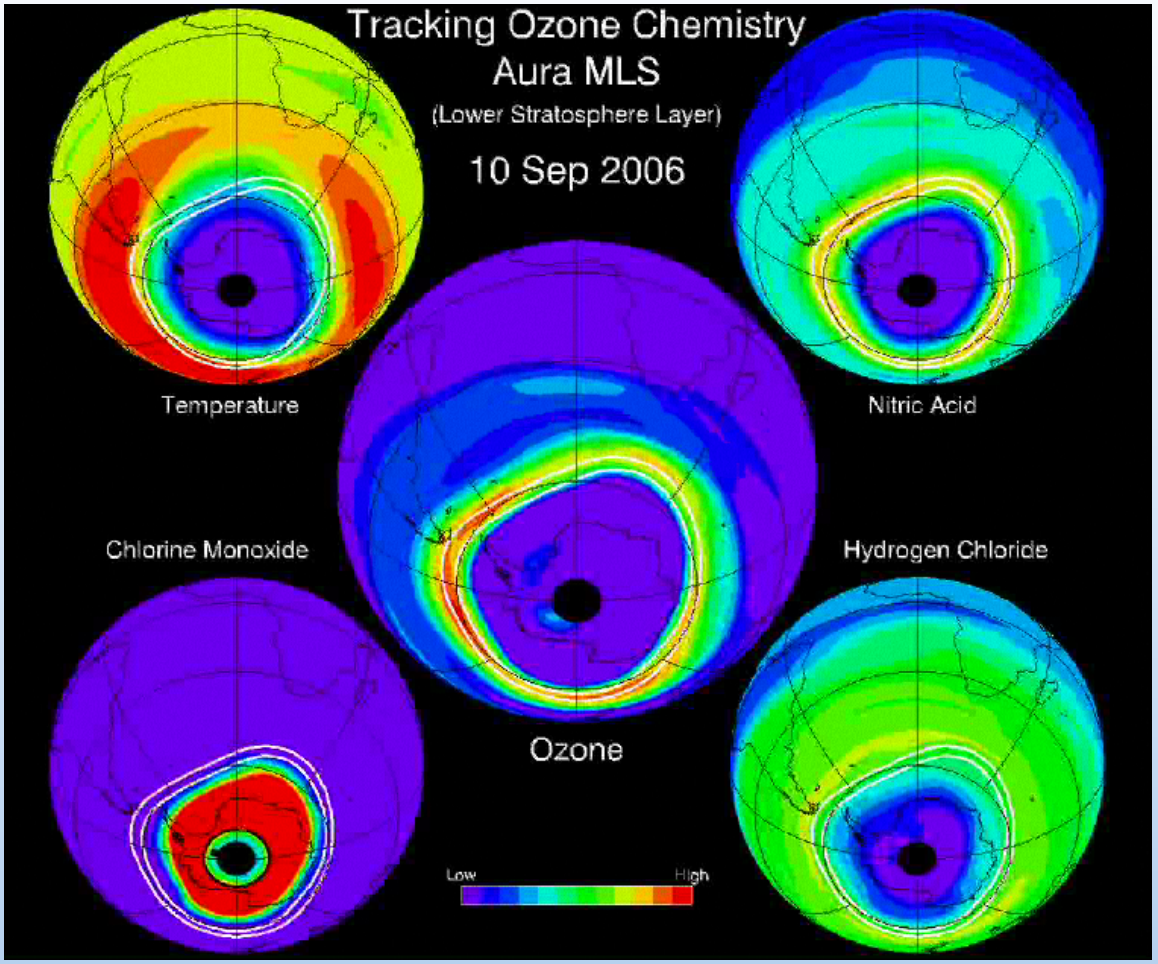
climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

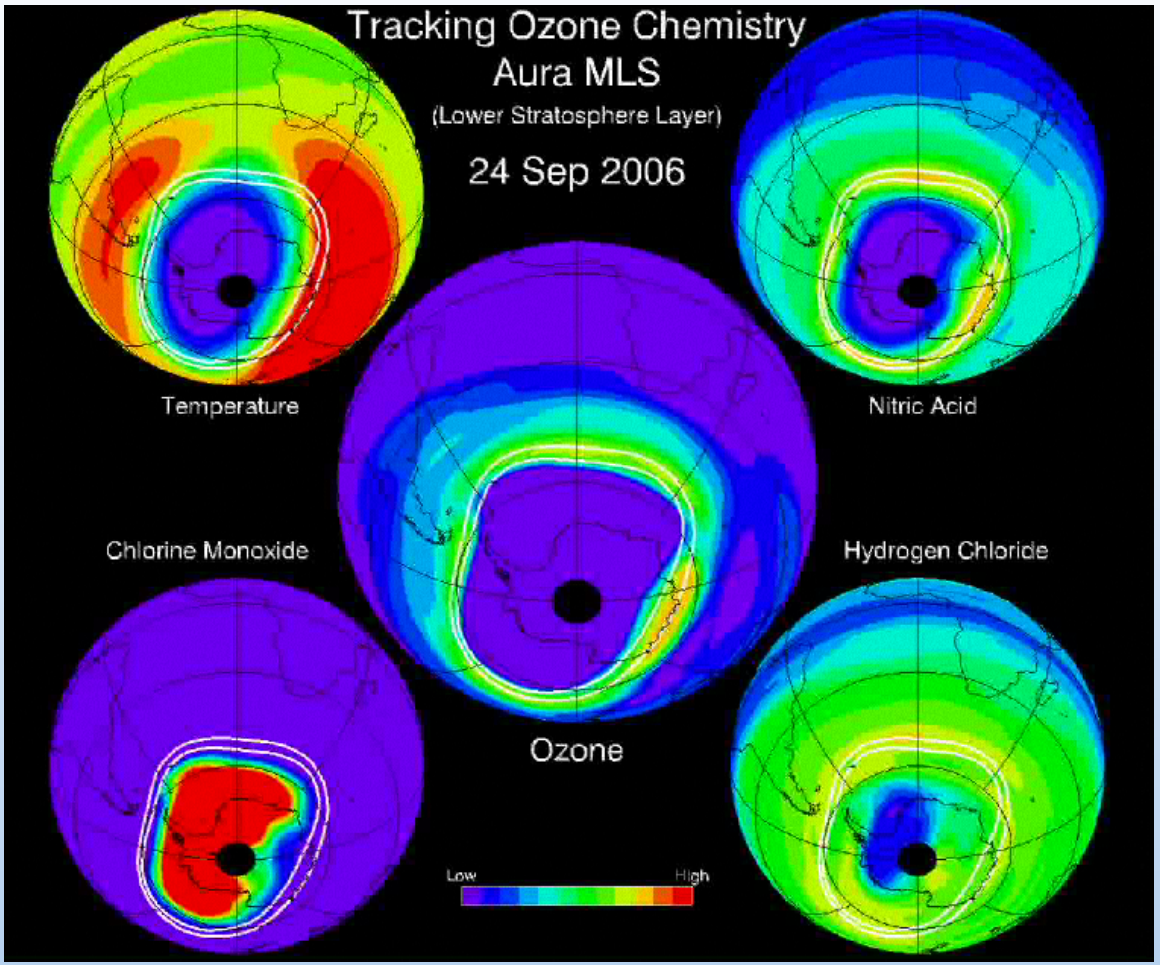
climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

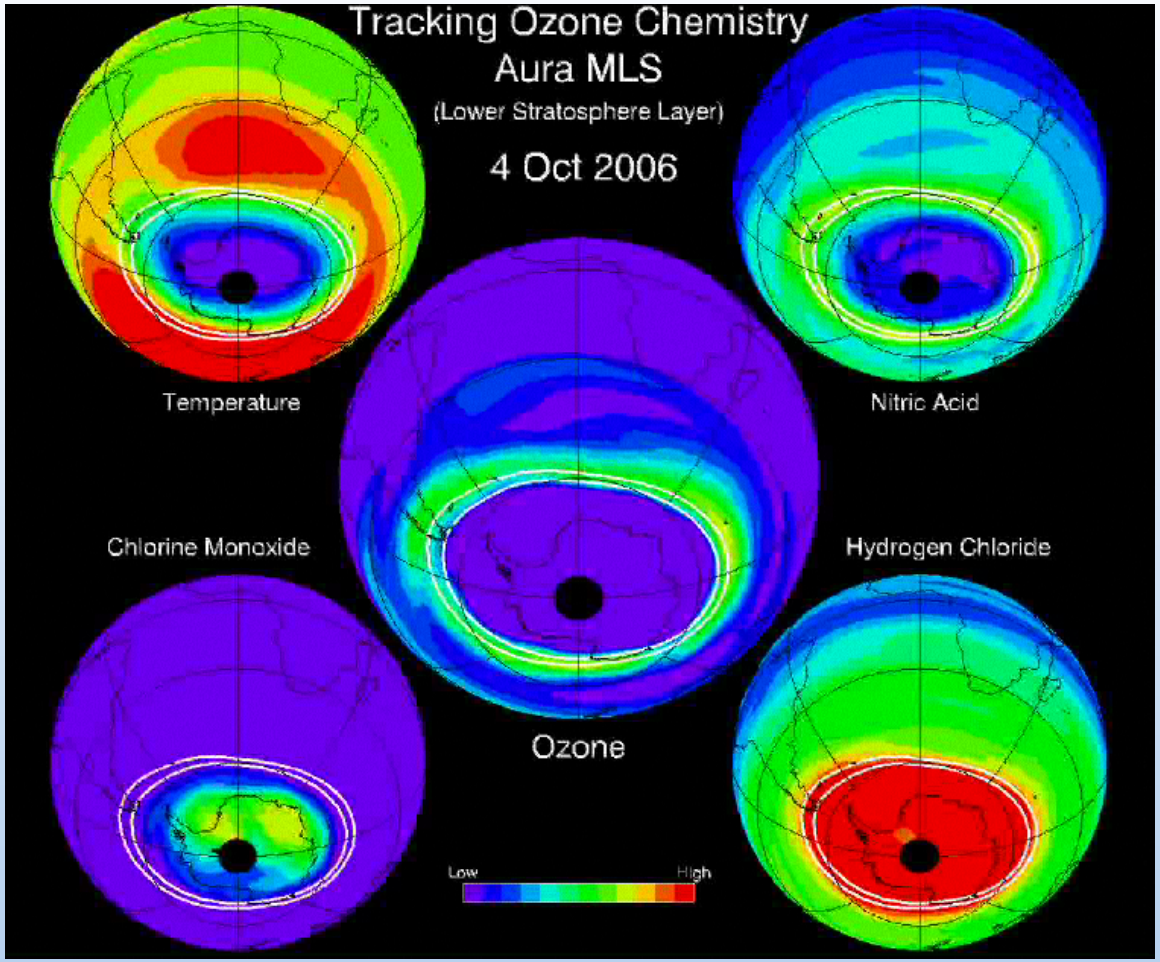
climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

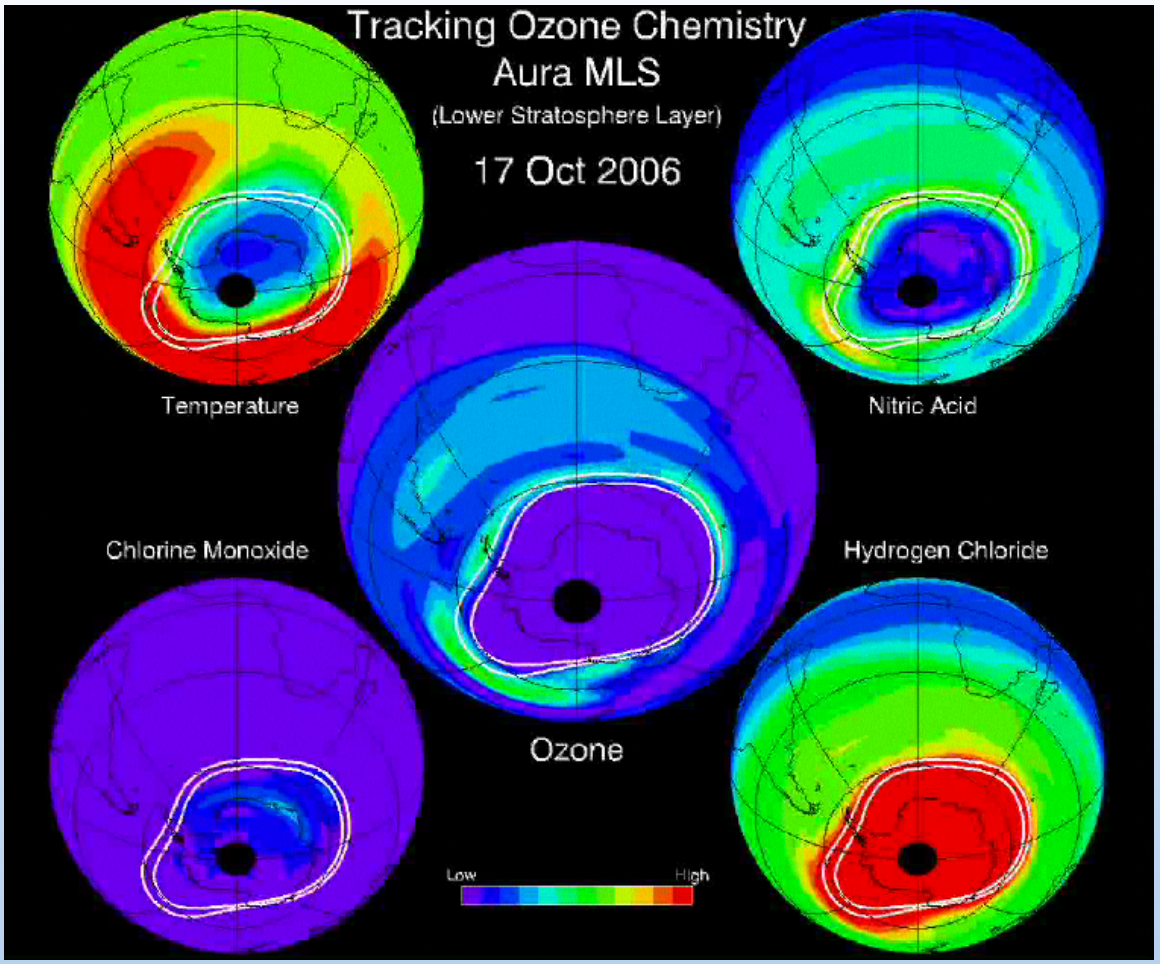
climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

climate • pollution • ozone • clouds • aerosols



Aura

atmospheric chemistry

climate • pollution • ozone • clouds • aerosols

Attribution and future prediction

- With Aura we have been able to observe the interaction of chemistry with the motions of the stratosphere over the entire globe under a wide variety of conditions
- We can use models, together with Aura data to attribute variations in ozone to cause
- We thus have the tools to make future predictions of ozone with a greater degree of confidence due to the measurements on Aura
- If future ozone deviates from expectation, we have the capability to diagnose the cause