Arguably the most dramatic example of an anthropogenic effect on the atmosphere is the Antarctic ozone hole. The ozone hole is a severe chemical depletion of the stratospheric ozone layer that is directly attributable to anthropogenic chlorine and bromine. However, the anomalous chemistry leading to the ozone hole depends on dynamic conditions; in particular, it requires the right combination of low temperature and sunlight, which is found extensively and persistently only over the Antarctic during spring. (While anthropogenically induced ozone depletion occurs at other times and in other parts of the stratosphere, including the Arctic, it is not nearly as severe as in the Antarctic spring.) A further ingredient is the dynamical confinement of the polar air mass, so that individual air parcels can undergo severe ozone depletion. The low temperature that is characteristic of the Antarctic vortex is associated with a strong vortex, providing the necessary confinement. The ozone hole is shown in late September of 2001 in the left side of Fig. 1.

During the first two-thirds of September 2002, the Antarctic ozone hole developed much as it had done every austral spring since the mid-1980s, when the phenomenon was first detected. But over a period of a few days in late September, the ozone hole was observed to split in two (middle of Fig. 1). This was such a remarkable and surprising event that it made it to the front page of newspapers worldwide. Any atmospheric scientist with a knowledge of stratospheric dynamics immediately recognized that a split ozone hole meant a split vortex, and thus a stratospheric sudden warming.

Stratospheric sudden warmings occur regularly in the Arctic (though not every year), and have been studied for many decades. They are produced by the dynamical momentum forcing resulting from the breaking and dissipation of planetary-scale Rossby waves in the stratosphere. The distortion of the vortex and the warming go hand in hand, and are essentially two sides of the same coin. Prior to 2002, no stratospheric sudden warming had ever been observed in the Antarctic, at least since regular observations began there in 1957, and it was widely believed that it was not possible in today’s climate given the comparatively weak levels of planetary wave forcing in the Southern Hemisphere (which is why the Antarctic winter-spring temperatures are so low compared to the Arctic).

This special issue arose from a request by several scientists, in order to motivate detailed analyses of this unprecedented event and have them published together. A call for papers was broadcast, and this collection is the result. I am indebted to Alan Plumb and Steve Wofsy for helping with the editing, and to some particularly dedicated reviewers who helped bring closure at the end. The papers cover both dynamical and chemical aspects of the event, including:

- characterization of the unusual nature of the event, and whether a sudden warming might have happened in the past (Hió and Yoden, Roscoe et al., Naujokat and Roscoe, Kushner and Polvani);
- synoptic description, and comparison with sudden warmings in the Arctic (Charlton et al., Krueger et al.);
- attempts to explain, through diagnostic analyses, why the event occurred (Newman and Nash, Scaife et al., Harnik et al., Gray et al.);
- the predictability of the event (Simmons et al., Manney et al.);
- connections to climate through stratosphere-troposphere coupling (Thompson et al.);
- characterization of the event through measurements of various chemical species, including ozone (Stolarski et al., von Savigny et al., Orsolini et al., Randell et al., Freiss et al., Richter et al., Glatthor et al., Kondragunta et al.);
- predictability and modeling studies of ozone evolution during the event (Eskes et al., Feng et al., Siegmund et al.); and
- impact on chemical ozone loss and its midlatitude consequences (Konopka et al., Grooss et al., Marchand et al.).

In the end, no cause-and-effect “explanation” of why the Antarctic stratosphere vortex and ozone hole split in two in September of 2002 has been established. Indeed there may well have been no identifiable external cause: it may simply be best just to regard it as a random event, associated with the chaotic nature of atmosphere dynamics. In particular, there seems to be no evidence that the event reflects some kind of climate change. However it does underscore the difficulty (and importance) of adequately characterizing natural variability, in order to distinguish such variability from long-term changes. It further illustrates how the atmosphere is capable of dramatic shifts that can confound conventional wisdom. Such dramatic events need to be understood in order to determine whether they are random flukes or precursors of future climate change.
Moreover, the split ozone hole was in no way indicative of ozone recovery. The anthropogenic chlorine and bromine that is depleting stratospheric ozone has a long lifetime, and despite the reduction in emissions due to the Montreal Protocol and its amendments and adjustments, halogen loading is not expected to return to pre-1980 levels until 2050 or so. Model predictions suggest that the ozone hole will recover over the same time scale (WMO 2003). Indeed, in 2003 the ozone hole was back to normal (right side of Fig. 1). Yet the split ozone hole of 2002, and its contrast with other years, underscores the way in which dynamics and chemistry act in a coupled manner to determine the impact of anthropogenic perturbations on the atmosphere.

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