ATMOSPHERIC SCIENCE

Raising the roof

The atmosphere's lowermost 10 km have long been assumed to be almost solely responsible for weather and climate on Earth. Emerging evidence points to the layer above as an important influence on surface winds and temperatures on seasonal to decadal timescales.

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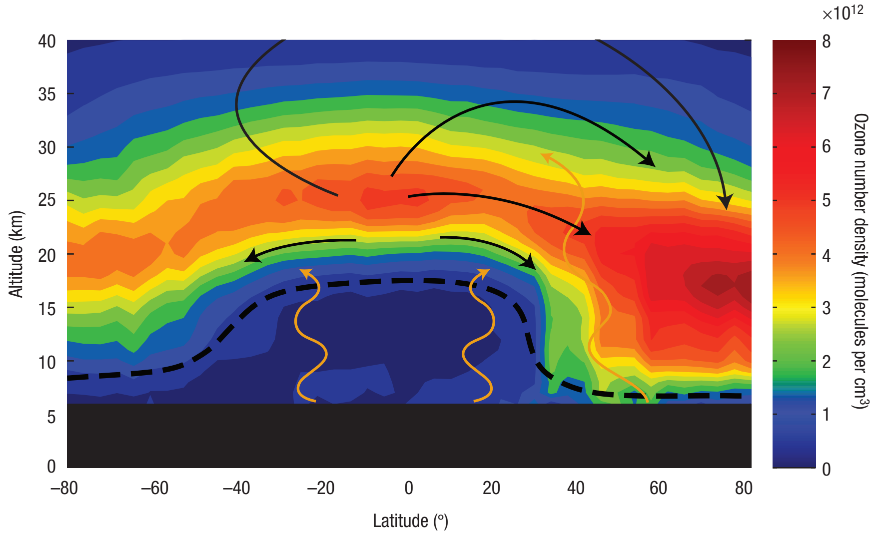

Figure 1 Brewer–Dobson circulation and stratospheric ozone. A longitudinally averaged cross-section of the atmosphere shows a schematic of the stratospheric global circulation, or Brewer–Dobson circulation (black arrows), and the ozone distribution as measured by the OSIRIS satellite instrument in March 2004. The circulation is forced by waves propagating up from the troposphere (orange wiggly arrows), especially in the winter hemisphere, and it strongly shapes the distribution of ozone by transporting it from its source region in the tropical upper stratosphere to the high-latitude lower stratosphere. The dashed line represents the tropopause, or the boundary between the troposphere and stratosphere. Copyright OSIRIS Science Team.

The traditional view of the atmosphere holds that the troposphere, which extends from the Earth's surface to an altitude of about 10 km, is the main 'weather layer'. However, in recent years, weather forecasting centres around the world have realized that in order to improve their forecasts, they need to raise the lids on their models to fully represent the atmospheric layer between heights of about 10 and 50 km — that is, the stratosphere. Climate modellers, too, are moving towards a full representation of the stratosphere, for distinct but related reasons — partly to include stratospheric influences such as ozone depletion (and recovery) and the effects of solar variability on tropospheric climate, and partly to more accurately simulate the atmospheric response to tropospheric perturbations. The links between these two layers of the Earth's atmosphere that affect both weather forecasts and climate predictions were the focus of the recent AGU Chapman Conference, *The Role of the Stratosphere in Climate and Climate Change*, held in Santorini, Greece in September[1]. A unique aspect of the workshop was the range of sessions spanning the timescales of both weather and climate.

On seasonal timescales, observational studies show that knowledge of stratospheric wind or temperature anomalies may enhance seasonal predictability in the troposphere[2,3]. Such anomalies generally originate in the troposphere and propogate up into the stratosphere. However, the timescale in which they return back down depends on the altitude they are returned from, which depends on the state of the stratosphere[4]. Through this mechanism, the state of the stratosphere affects the seasonal cycle, seen, for example, in the modelled response of wintertime Arctic surface circulation to Siberian snow-cover anomalies in autumn (C. G. Fletcher, Univ. of Toronto, Canada). Operational seasonal prediction systems are now reaching the point where the role of the stratosphere in seasonal weather predictability can be assessed quantitatively, and some preliminary results were presented at the meeting (Y. Kuroda, Meteorological Research Institute, Japan; B. Christiansen, Danish Meteorological Institute, Denmark).

On decadal timescales, the absorption of incoming solar radiation by stratospheric ozone varies owing to changes in stratospheric ozone levels and solar variability. These only marginally affect the global energy balance at the Earth's surface, but accompanying changes in the atmospheric circulation could amplify their regional influences[5,6]. It is important to understand the effects of past ozone depletion and the expected future recovery of stratospheric ozone levels on the troposphere in order to distinguish them from those of climate change[7]. With respect to the 11-year solar cycle, the most convincing evidence found so far for a mechanism producing a tropospheric response comes from a modelling study forced by lower stratospheric temperature anomalies derived from observations (I. Simpson, Imperial College London, UK).

The study highlighted the role of changes in the tropospheric Hadley circulation and midlatitude jet stream as the mechanism for propagating the solar-cycle signal to the surface.

An earlier modelling study suggested that the stratospheric Brewer–Dobson circulation (see Fig. 1) could be strengthening in response to a changing climate[8]. This circulation shapes the global stratospheric ozone distribution as well as climatic features such as the height and temperature of the boundary between the troposphere and stratosphere, known as the tropopause. There is now a growing consensus amongst models that the effect of climate change on the strength of the Brewer–Dobson circulation is robust (N. Butchart, Met Office, UK), but the mechanisms involved remain controversial. New observational and modelling results point to a previously unrecognized contribution to the forcing of the circulation — that of waves in the tropics forced by convection (W. J. Randel, National Center for Atmospheric Research, USA).

No one would question the benefit of a full representation of the stratosphere in an atmospheric model. But given limited computational resources, modellers have to decide whether to invest in an improved representation of the stratosphere versus other processes, such as ocean circulation. A recent modelling study suggests that the inability of current climate models to reproduce the Arctic circulation trend over the past 40 years is largely a result of the lack of representation of observed stratospheric circulation trends[9]. This highlights the need to quantify the benefits of a full representation of the stratosphere in a systematic fashion. To do so, a natural approach is to compare models with and without stratospheric representation, termed ‘high-top’ and ‘low-top’ models, respectively. Preliminary comparisons have revealed significant differences in the impact of El Niño on the tropospheric high-latitude circulation, with high-top models better able to represent the spatial structure of the observed tropospheric response (S. Ineson, Met Office, UK; C. Cagnazzo, INGV Bologna, Italy; C. Bell, Univ. of Reading, UK).

The question of the stratospheric influence on tropospheric weather and climate has been growing in importance for some time[10]. Tools such as seasonal prediction systems and low/high-top model comparisons are finally in place for a systematic study of this issue. The meeting in Greece showed the increasing potential of these approaches and the growing importance of studying the role of the stratosphere in weather and climate research.

References

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ENVIRONMENTAL BIOLOGY

Trees of extremes

Tierra del Fuego — the windswept hook of rugged land stretching towards Antarctica at the southernmost point of South America — is not known for its hospitable climate. When visiting the area in the southern summer of 1832, Charles Darwin wrote “the atmosphere, likewise, in this climate, where gale succeeds gale, with rain, hail, and sleet, seems blacker than anywhere else” (C. Darwin, *The Voyage of the Beagle*; 1839). The presence at the timberline of gnarled and dwarfed trees, as seen in this image, seems testament to the harsh weather of the region. But Hector D’Antoni at NASA and colleagues have found that it’s not the weather that makes the environment extreme: the area is subject to high levels of ultraviolet radiation (*Geophys. Res. Lett.* **34,** L22704; 2007).

The researchers measured a number of environmental parameters on vertical transects of the steep slopes forming the northern shore of the Beagle Channel near Ushuaia, Tierra del Fuego. They found that although the temperature, moisture, acidity and nutrient content of the soils were not unusual for the region, levels of ultraviolet solar radiation were sufficiently high to classify the upper timberline environment as extreme. As ultraviolet radiation is dangerous to life — it damages important biological molecules like proteins and DNA — trees growing under these conditions must have evolved strategies for coping with such high levels in order to survive.

Previous work showed that leaves from the dominant tree genus in the area — the beech *Nothofagus* — contain glycoside compounds, which protect the leaf by absorbing the ultraviolet radiation. The local evergreen *N. betuloides* contains higher concentrations of these protector compounds than the two deciduous species, *N. antarctica* and *N. pumilio*. D’Antoni and colleagues suggest that the leaf shape of these trees, with a rippled profile and glossy surface, may have evolved to maximize the reflection of ultraviolet radiation.

Studies of extreme environments may help understand the conditions in which the early stages of life have evolved, for example high temperature,

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pressure or salinity. The high elevation forests on Tierra del Fuego broaden the repertoire by adding high ultraviolet solar radiation.

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