Clearly, climate–chemistry feedbacks and tropospheric ozone trends must be better understood to guide the implementation of policies aimed at limiting any detrimental impacts of climate change. For example, if the influx of stratospheric ozone to the troposphere does increase with climate change, and background tropospheric ozone levels rise, then increasingly stringent ozone pollution control policies will be needed to attain the air quality standards required to protect the biosphere. A key step will be the development and application of climate models that resolve, in sufficient detail, the dynamics and chemistry of both the troposphere and stratosphere — these models are in their infancy at present.

David S. Stevenson is in the School of GeoSciences, University of Edinburgh, Edinburgh EH9 3JN, UK.
e-mail: david.s.stevenson@ed.ac.uk

References

1. Tourpali, K. *et al. Atmos. Chem. Phys.* **9,** 1165–1172 (2009).
2. Gauss, M. *et al. Atmos. Chem. Phys.* **6,** 575–599 (2006).
3. Fiore, A. M. *et al. J. Geophys. Res.* **114,** D04301 (2009).
4. Hegglin, M. I. & Shepherd, T. G. *Nature Geosci.* **2,** 687–691 (2009).
5. McLandress, C. & Shepherd, T. G. *J. Clim.* **22,** 1516–1540 (2009).
6. Butchart, N. *et al. Clim. Dynam.* **27,** 727–741 (2006).
7. Engel, A. *Nature Geosci.* **2,** 28–31 (2009).
8. Ordóñez, C. *et al. Geophys. Res. Lett.* **34,** L07805 (2007).
9. Parrish, D. D., Millet, D. B. & Goldstein, A. H. *Atmos. Chem. Phys.* **9,** 1303–1323 (2009).
10. Stevenson, D. S. *et al. J. Geophys. Res.* **111,** D08301 (2006).
11. Jacob, D. J. & Winner, D. A. *Atmos. Environ.* **43,** 51–63 (2009).
12. Cordero, E., Newman, P. A., Weaver, C. & Fleming, E. in *Stratospheric Ozone: An Electronic Textbook* (ed. Todaro, R. M.) Ch. 6 (NASA, 2000); available at <http://www.ccpo.odu.edu/SEES/ozone/class/Chap_6/.>

PAUL G. SILVER

Earth deformation, writ large

Deformation in the Earth is the story of patterns — patterns of convective flow in the mantle, tectonic plate motions, seismicity, and stress and strain along major fault zones. Over a career spanning three decades, Paul Silver taught us how to read the chapters in that story, until he was killed tragically on 7 August in an automobile accident that also took the life of his 22-year-old daughter, Celine.

Born in Los Angeles in 1948, Silver received a BA in psychology from the University of California, Los Angeles. He pursued a brief career in music before returning to college for a BA in geology from Berkeley. His appetite for Earth science whetted, Silver accepted a graduate school offer from Tom Jordan at the Scripps Institution of Oceanography. He completed a thesis on the aspherical seismic velocity structure of the mantle and new methods for quantifying earthquake sources, topics that strongly influenced later work by others. With his PhD in hand, Silver moved in 1982 to the Carnegie Institution's Department of Terrestrial Magnetism, his professional home thereafter.

In 1989, Silver and colleagues carried out the first modern portable broadband seismic experiment, targeting the deep structure of the North American continental interior. That experiment led to one of his most important contributions: the development of methods to recover the anisotropy, or directional dependence, of mantle seismic velocity from observations of shear-wave birefringence. Silver was the first to apply shear-wave splitting measurements on the scale of continents and plates, and he was a leader in the use of such observations to constrain three-dimensional patterns of upper-mantle convection and the mechanisms of continental assembly revealed by fossil anisotropy in now-cooled continental mantle roots.


NATHALIE VALETTE-SILVER

Another of Silver's seismic experiments captured, at close range, the largest-known deep earthquake. Silver showed that the source dimensions of that event were too large for the then-leading explanation for deep earthquakes: phase changes within a wedge of metastable olivine in cold subducted lithosphere. Silver championed the alternative idea — backed by seismic and laboratory observations he helped amass — that deep earthquakes instead occur on inherited fault structures reactivated at depth by slab dehydration.

Gregarious, jovial and generous, Silver readily built research partnerships around the globe. He was particularly inspirational to the Carnegie Institution's younger scientists, more than 30 of whom began working with him while postdoctoral fellows. Many continued this collaboration long after moving to more senior positions at other institutions. Silver's passion for music continued, too, as a drummer in a jazz trio that played throughout the Washington DC area.

Silver's love of a good argument drew him to one of the most controversial topics in seismology today: whether earthquakes have recognizable precursors. Together with his wife Nathalie Valette-Silver, he showed that geyser eruption intervals in hydrothermal areas change in advance of nearby large earthquakes. He discovered an annual periodicity in the seismicity of hydrothermal areas triggered by the 1992 Landers earthquake, and his proposal that annual variations in atmospheric pressure were the cause implies that very small changes in stress can affect earthquake occurrence. Recent work by Silver and colleagues on the San Andreas fault suggests that a large earthquake anywhere can affect worldwide the strength of fault zones and thus the likelihood of new earthquakes.

To improve our ability to understand the workings of major fault zones, Silver conceived and spearheaded the push, more than a decade ago, for a Plate Boundary Observatory of seismic and geodetic instruments across western North America to monitor time-dependent deformation in unprecedented detail. That facility, now operational as part of the EarthScope project of the US National Science Foundation, is one of Silver's most lasting legacies.

SEAN C. SOLOMON