Introduction. Progress in Earth science and climate studies

By J. Michael T. Thompson*

Department of Applied Mathematics and Theoretical Physics, Centre for Mathematical Sciences, University of Cambridge, Wilberforce Road, Cambridge CB3 0WA, UK

In this introductory paper, I review the ‘visions of the future’ articles prepared by top young scientists for the second of the two Christmas 2008 Triennial Issues of Phil. Trans. R. Soc. A, devoted respectively to astronomy and Earth science. Topics covered in the Earth science issue include: trace gases in the atmosphere; dynamics of the Antarctic circumpolar current; a study of the boundary between the Earth’s rocky mantle and its iron core; and two studies of volcanoes and their plumes. A final section devoted to ecology and climate covers: the mathematical modelling of plant–soil interactions; the effects of the boreal forests on the Earth’s climate; the role of the past palaeoclimate in testing and calibrating today’s numerical climate models; and the evaluation of these models including the quantification of their uncertainties.

Keywords: atmosphere and oceans; Earth’s mantle; volcanoes; ecology; climate change

By virtue of the three-yearly cycling through the physical sciences established in 2002 (table 1), the collection of articles by young scientists for Christmas 2008 is devoted to astronomy and Earth science. This year, these are spread between two issues of the Philosophical Transactions of the Royal Society A to reflect the higher frequency of the journal that increased from 12 to 24 issues per year in January 2008.

The present paper introduces the second of these two issues devoted to Earth science. The first three papers are devoted to the Earth’s atmosphere, oceans and mantle. First, Palmer (2008) looks at the quantification of the sources and sinks of trace gases in the atmosphere using space-borne measurements. He describes how new technology is now allowing us to observe surface air pollutants and climate-relevant trace gases in the lower troposphere, where we live and breathe. He reviews the techniques for measuring the atmosphere from space, and how the measurements can be used to infer the surface sources and sinks. This knowledge improves our fundamental understanding of the Earth’s climate system and aids the mitigation of surface air pollution and greenhouse gases. Next, Thompson (2008) examines eddies and jets in the Antarctic circumpolar current (ACC). This is the longest and strongest oceanic current on Earth, but...
remains one of the most poorly represented components of global climate models. Difficulties are associated with the role of mesoscale eddies and jets, the oceanic equivalents of atmospheric storms. Moreover, the dynamics of energetic eddies and topographically steered jets may both temper and enhance the sensitivity of different aspects of the ACC’s circulation to the changes in climate. In the last of the opening papers, Wookey & Dobson (2008) explore the boundary between the Earth’s rocky mantle and iron core. Lying almost 2900 km below the surface, this is physically the most significant region in the Earth’s interior. It may be the terminus for subducted surface material, the source of mantle plumes and a controller of the Earth’s magnetic field. It also has a great significance for the evolution of the solid Earth and its seismic activity. The authors describe how a diamond anvil cell, reproducing core–mantle pressures and temperatures, has allowed laboratory experiments on a new phase of ‘post-perovskite’ material. Backed by theoretical studies, these findings are helping to improve dynamic simulations of the deep Earth.

There follows a two-paper section devoted to volcanoes. Edmonds (2008) presents new geochemical insights into magma degassing, which plays a fundamental role in controlling whether a volcanic eruption is explosive or effusive. This distinction can be a matter of life or death for the approximately 500 million people worldwide, who live in the shadow of a hazardous volcano. The author explains how the composition of volcanic gases is dependent on a number of factors, the most important being magma composition and the depth of gas–melt segregation prior to eruption. The latter parameter has proved difficult to constrain in the past, but is arguably the most critical for controlling eruptive style. Mather (2008) looks at the interactions between volcanism and atmospheric chemistry. Here, recent measurements of trace gas species in volcanic plumes are offering intriguing hints of the chemical activity in the hot environment at volcanic vents. This shows that the vents should not only be regarded as passive sources of volcanic gases, but also as ‘reaction vessels’ that unlock otherwise inert volcanic and atmospheric gas species. Rapid cooling of this mixture allows these species to persist into the environment with important consequences for gas plume chemistry and impacts. These effects have important consequences in terms of the evolution of the nitrogen cycle and the role of particles in modulating the Earth’s climate.

Table 1. Millennium and Triennial statistics. (Here, M denotes Millennium and T denotes Triennial. Under issue is given the publication number. Pprs signifies the number of contributed papers. The authors column gives the number of authors, including co-authors, followed in brackets by the number of female authors. Age denotes the average age of the corresponding authors in years.)

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The last four papers of the issue are devoted to inter-related aspects of ecology and climate change. Roose & Schnepf (2008) discuss how mathematical modelling could, and should, be applied to plant–soil interactions. Their aim is to persuade members of the biological and mathematical communities of the need to collaborate in developing quantitative mechanistic models. These models will aid the basic science of plants and should help with real-world problems, such as food shortages and global warming. The paper reviews, in particular, the mathematical models that have been developed to describe nutrient and water uptake by the roots. The ultimate aim is to develop a valid quantitative whole-plant model within a soil–plant–atmosphere continuum. Next, Spracklen et al. (2008) study the effects of the boreal forests on the climate. Previous work had concluded that the net effect of these northern forests was to warm the Earth. This was based on the idea that the cooling from storage of carbon in vegetation and soils was less than the warming due to the absorption of the Sun’s rays by the dark forest canopy. The authors suggest, however, that these studies ignored the impacts of forests on atmospheric aerosols. They use an atmospheric model to show that through emission of organic vapours and the resulting condensation of newly formed particles, boreal forests double the regional cloud condensation nuclei. Based on this, they propose that the combination of climate forcings related to boreal forests may result in a significant global homeostasis. In cold conditions, the snow–vegetation albedo effect is dominant and the forests have a warming action. Meanwhile, in warm conditions, they may emit sufficient organic vapour to modify the cloud albedo and have a cooling action. Skinner (2008) points to the relevance of the past in contemplating future climate change. He admits that from social and economic perspectives, the ‘sharp end’ of climate research is very much about looking forward in time: we need to know as accurately as possible what to expect and when to expect it. However, there are two ways in which knowledge of the past affects our approach to present-day climate change. First, our grasp of past climate behaviour (roughly speaking ‘what we know is possible’) affects how we build our climate models, whether these are ‘intuitive’ models in the minds of the public or highly complex numerical models inside supercomputers. Second, the past palaeoclimate provides a means of directly testing and calibrating our numerical climate models. So climate models should be given credence to the extent that they are compatible with an increasingly rich tapestry of past climatic behaviour. In the last paper of the collection, Knutti (2008) also addresses the accuracy and reliability of climate modelling. Predictions of future climate are based on elaborate numerical computer models, so as computational capacity increases and better observations become available, one would expect the model predictions to get more reliable. His article discusses how climate models are evaluated and how uncertainty in predictions can be quantified. It outlines some strategies that the climate modelling community may employ to help provide useful information to the public and policymakers.

A number of previous ‘young scientist’ collections, from which the present one is historically derived, might be of interest to today’s readers. The first such collection, assembled to celebrate the new Millennium, appeared as three special issues of Phil. Trans. R. Soc. A. The first of these issues was devoted to astronomy and Earth sciences and appeared as issue number 1763 on 15 December 1999: details can be found in Thompson (1999). The three Millennium
issues of the journal formed the basis of three popular paperbacked books published by Cambridge University Press, the first being likewise devoted to astronomy and Earth science (Thompson 2001).

The popularity of these collections triggered the present series of Triennial Christmas issues, which now form a three-year *triennial* cycle as shown in Table 1.

As can be seen in the table, the previous Triennial Issues devoted to astronomy and Earth science appeared in 2002 and 2005; details of the emerging series and its contents are given by Thompson (2002) and Thompson & Wang (2005). The interest of the Research Councils is mirrored by Morgan & Thompson (2002). Finally, a selection from the triennial papers in Earth science, together with some additional contributions, appears in the second book of a series published by Imperial College Press (Sammonds & Thompson 2007).

**References**


J. Michael T. Thompson FRS was born in Cottingham, Yorkshire, in 1937, and attended Hull Grammar School. He graduated from the University of Cambridge with first class honours in mechanical sciences in 1958, winning the three top prizes of the Engineering Department. One of these was the prestigious Rex Moir Prize. He was later awarded two Cambridge doctorates, a PhD in 1962 and an ScD in 1977. Recently, in 2004, he received an honorary DSc from the University of Aberdeen.

While a postdoctoral research fellow at Peterhouse, he spent a year as a Fulbright visitor in the Department of Aeronautics and Astronautics at Stanford University in California. Joining University College London (UCL) in 1964, he was appointed as a professor in 1977, and subsequently the Director of the Centre for Nonlinear Dynamics in 1991.

Based on his research into elastic buckling phenomena, he published three books on instabilities, bifurcations and catastrophes. A fourth book published in 1986 is now in its second edition as Nonlinear Dynamics and Chaos (Wiley, 2002). Over 14,000 copies of this seminal work have been sold worldwide, and it has been translated into Japanese and Italian.

Michael was elected a Fellow of the Royal Society in 1985, and served on the Council of the Society. He won the OMAE Award of the American Society of Mechanical Engineers in 1985 in recognition of his outstanding originality and significance. Seven years later, in 1992, he was awarded the James Alfred Ewing Medal on the joint nomination of the presidents of the Institution of Civil Engineers and the Royal Society. The award, founded in memory of Sir Alfred Ewing, is made for special meritorious contributions to the science of engineering in the field of research. He was a senior fellow of the Science and Engineering Research Council from 1988 to 1993.

From 1998 to 2007, Michael was the editor of the Philosophical Transactions of the Royal Society A, the world’s longest running scientific journal. His special Millennium Issues of the journal, in which young scientists were invited to give their visions of the future, were re-published as three popular paperback books by Cambridge University Press in 2001. As a follow-up to this successful venture,
Michael has created a running programme of Christmas Issues, which he is using as the basis of his new Royal Society Series on Advances in Science. The first book in the series is *Advances in Astronomy: from the Big Bang to the Solar System* (ed. J. M. T. Thompson, Imperial College Press, 2005). The second is *Advances in Earth science: from Earthquakes to Global Warming* (eds P. R. Sammonds & J. M. T. Thompson), and the third is *Advances in Nanoengineering: Electronics, Materials and Assembly* (eds A. G. Davies & J. M. T. Thompson).

Michael is now Emeritus Professor of Nonlinear Dynamics at UCL, and an Honorary Fellow at the Department of Applied Mathematics and Theoretical Physics (DAMTP) of the University of Cambridge. He is active in promoting a greater understanding of science and mathematics among the general public. Two popular lectures in the Millennium Mathematics Project, delivered at DAMTP, are now streamed from the web, and also available on DVD. In 2004, Michael was awarded a Gold Medal by the Institute of Mathematics and its Applications (IMA) at their 40th anniversary meeting for his lifetime contributions to mathematics.

In April 2006, Michael was appointed, part-time, as a distinguished Sixth Century Professor in Theoretical and Applied Dynamics at the University of Aberdeen. Married with 2 children and 10 grandchildren, his recreations include astronomy with his grandchildren, wildlife photography, badminton and tennis. He is pictured with his wife Margaret.