

crucial anchor point because the melting curve of the core-forming alloy at 330 gigapascals would provide an upper bound and a lower bound of the temperature for the inner core and outer core, respectively. Following the adiabatic temperature distribution of the outer core as rationalized from its thermal conduction and convection behavior, the temperature at the top of the outer core and the thermal gradient across the core-mantle boundary can then be evaluated together with the lower-mantle temperature profile.

At the conditions of the inner and outer core, the only experiments possible at the moment are by dynamic shock wave techniques. Step by step, static diamond-cell experiments have reached to more than 200 gigapascals and high temperatures, but the detection of melting onset at such extreme conditions remains highly debated. The extrapolation of these results gives 5000–7000 K on the melting of iron at 330 gigapascals (Figure 2), with different theoretical calculations supporting different experimental estimates. Such a discrepancy of approximately 2000 K translates into drastic uncertainty in evaluating the thermal history and heat budget of the core and the core-mantle boundary. The melting temperature depression and subsolidus phase relations in iron/nickel/light element alloys at the Earth's core conditions add further uncertainties in estimating its thermal structure.

#### Future Missions

The mineral physics quest to the Earth's core falls largely on stably creating and

simultaneously measuring pressure-temperature conditions of the subjected candidate iron alloys. Though measuring physical properties at the core conditions remains extremely difficult, as the typical sample size is only of the order of a few tens of micrometers, ongoing collaborative efforts by mineral physicists in the past decade have made it possible to directly probe some of these properties in situ statically using advanced synchrotron light sources and detecting techniques. Scientists are also gearing up in building new facilities that will help couple dynamic shock wave techniques with synchrotron light sources so as to allow in situ probing of these properties under extreme dynamic conditions. Efforts to search for and develop universal pressure and temperature scales are also under way to establish consistent results for a coherent picture of the core. The expectation of mineral physicists involved with these efforts is that within a decade, these mineral physics missions to the Earth's core will provide crucial information to greatly enhance our understanding of the nature of the core.

#### Acknowledgments

We acknowledge S. D. Jacobsen for constructive comments. Leonid Dubrovinsky is supported by Deutsche Forschungsgemeinschaft (DFG) and European Science Foundation EuroMinSci programs. Jung-Fu Lin is supported by the U.S. National Science Foundation Geophysics Directorate (EAR-0838221), Carnegie/Department of Energy Alliance Center (CDAC), and

Consortium of Materials Properties Research in Earth Sciences (COMPRES).

#### References

- Antonangeli, D., F. Occelli, H. Requardt, J. Badro, G. Fiquet, and M. Krisch (2004), Elastic anisotropy in textured hcp-iron to 112 GPa from sound wave propagation measurements, *Earth Planet. Sci. Lett.*, *225*(1-2), 243–251.
- Badro, J., G. Fiquet, F. Guyot, E. Gregoryanz, F. Occelli, D. Antonangeli, and M. d'Astuto (2007), Effect of light elements on the sound velocities in solid iron: Implications for the composition of Earth's core, *Earth Planet. Sci. Lett.*, *254*(1-2), 233–238.
- Belonoshko, A. B., N. V. Skorodumova, A. Rosengren, and B. Johansson (2008), Elastic anisotropy of Earth's inner core, *Science*, *319*(5864), 797–800.
- Dubrovinsky, L., et al. (2007), Body-centered cubic iron-nickel alloy in Earth's core, *Science*, *316*(5833), 1880–1883.
- Lin, J.-F., W. Sturhahn, J. Zhao, G. Shen, H.-K. Mao, and R. J. Hemley (2005), Sound velocities of hot dense iron: Birch's law revisited, *Science*, *308*(5730), 1892–1894.
- Vočadlo, L. (2007), Ab initio calculations of the elasticity of iron and iron alloys at inner core conditions: Evidence for a partially molten inner core?, *Earth Planet. Sci. Lett.*, *254*(1-2), 227–232.
- Vočadlo, L., D. Alfè, M. J. Gillan, I. G. Wood, J. P. Brodholt, and G. D. Price (2003), Possible thermal and chemical stabilization of body-centred-cubic iron in the Earth's core, *Nature*, *424*(6948), 536–539.

#### Author Information

Leonid Dubrovinsky, University of Bayreuth, Bayreuth, Germany; E-mail: Leonid.Dubrovinsky@uni-bayreuth.de; and Jung-Fu Lin, University of Texas at Austin

## Examining the Scientific Consensus on Climate Change

PAGES 22–23

Fifty-two percent of Americans think most climate scientists agree that the Earth has been warming in recent years, and 47% think climate scientists agree (i.e., that there is a scientific consensus) that human activities are a major cause of that warming, according to recent polling (see <http://www.pollingreport.com/enviro.htm>). However, attempts to quantify the scientific consensus on anthropogenic warming have met with criticism. For instance, Oreskes [2004] reviewed 928 abstracts from peer-reviewed research papers and found that more than 75% either explicitly or implicitly accepted the consensus view that Earth's climate is being affected by human activities. Yet Oreskes's approach has been criticized for overstating the level of consensus acceptance within the examined abstracts [Peiser, 2005] and for not capturing the full diversity of scientific opinion [Pielke, 2005]. A review of previous attempts at quantifying the consensus and

criticisms is provided by Kendall Zimmerman [2008]. The objective of our study presented here is to assess the scientific consensus on climate change through an unbiased survey of a large and broad group of Earth scientists.

An invitation to participate in the survey was sent to 10,257 Earth scientists. The database was built from Keane and Martinez [2007], which lists all geosciences faculty at reporting academic institutions, along with researchers at state geologic surveys associated with local universities, and researchers at U.S. federal research facilities (e.g., U.S. Geological Survey, NASA, and NOAA (U.S. National Oceanic and Atmospheric Administration) facilities; U.S. Department of Energy national laboratories; and so forth). To maximize the response rate, the survey was designed to take less than 2 minutes to complete, and it was administered by a professional online survey site (<http://www.questionpro.com>) that allowed one-time participation by those who received the invitation.

This brief report addresses the two primary questions of the survey, which contained up to nine questions (the full study is given by Kendall Zimmerman [2008]):

1. When compared with pre-1800s levels, do you think that mean global temperatures have generally risen, fallen, or remained relatively constant?
2. Do you think human activity is a significant contributing factor in changing mean global temperatures?

With 3146 individuals completing the survey, the participant response rate for the survey was 30.7%. This is a typical response rate for Web-based surveys [Cook et al., 2000; Kaplowitz et al., 2004]. Of our survey participants, 90% were from U.S. institutions and 6% were from Canadian institutions; the remaining 4% were from institutions in 21 other nations. More than 90% of participants had Ph.D.s, and 7% had master's degrees. With survey participants asked to select a single category, the most common areas of expertise reported were geochemistry (15.5%), geophysics (12%), and oceanography (10.5%). General geology, hydrology/hydrogeology, and paleontology each accounted for 5–7% of the total respondents. Approximately 5% of the respondents were climate

scientists, and 8.5% of the respondents indicated that more than 50% of their peer-reviewed publications in the past 5 years have been on the subject of climate change. While respondents' names are kept private, the authors noted that the survey included participants with well-documented dissenting opinions on global warming theory.

Results show that overall, 90% of participants answered "risen" to question 1 and 82% answered yes to question 2. In general, as the level of active research and specialization in climate science increases, so does agreement with the two primary questions (Figure 1). In our survey, the most specialized and knowledgeable respondents (with regard to climate change) are those who listed climate science as their area of expertise and who also have published more than 50% of their recent peer-reviewed papers on the subject of climate change (79 individuals in total). Of these specialists, 96.2% (76 of 79) answered "risen" to question 1 and 97.4% (75 of 77) answered yes to question 2. This is in contrast to results of a recent Gallup poll (see <http://www.gallup.com/poll/1615/Environment.aspx>) that suggests that only 58% of the general public would answer yes to our question 2. The two areas of expertise in the survey with the smallest percentage of participants answering yes to question 2 were economic geology with 47% (48 of 103) and meteorology with 64% (23 of 36).

It seems that the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances

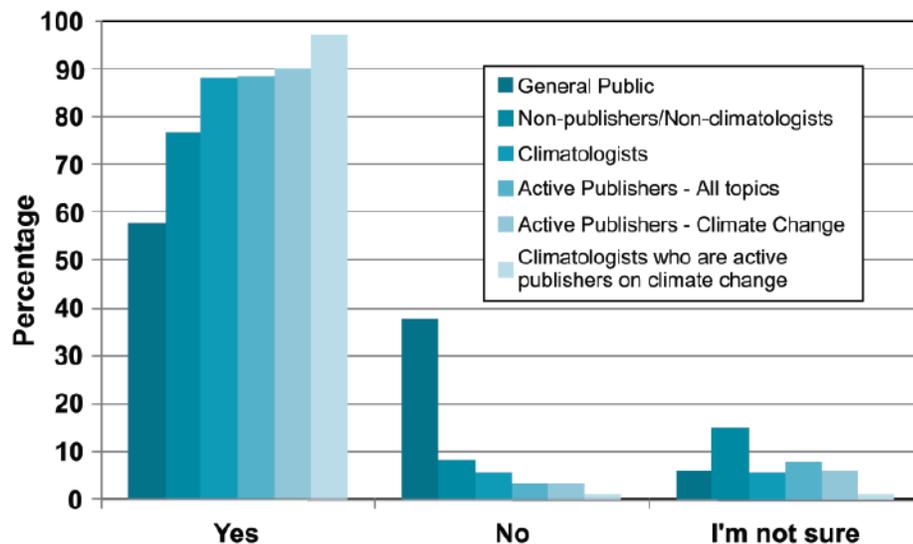


Fig. 1. Response distribution to our survey question 2. The general public data come from a 2008 Gallup poll (see <http://www.gallup.com/poll/1615/Environment.aspx>).

and scientific basis of long-term climate processes. The challenge, rather, appears to be how to effectively communicate this fact to policy makers and to a public that continues to mistakenly perceive debate among scientists.

#### References

- Cook, C., F. Heath, and R. Thompson (2000), A meta-analysis of response rates in Web- or Internet-based surveys, *Educ. Psychol. Meas.*, 60, 821–836.
- Kaplowitz, M., T. Hadlock, and R. Levine (2004), A comparison of Web and mail survey response rates, *Public Opin. Q.*, 68, 94–101.
- Keane, C. M., and C. M. Martinez (Eds.) (2007), *Directory of Geoscience Departments 2007*, 45th ed., Am. Geol. Inst., Alexandria, Va.
- Kendall Zimmerman, M. (2008), The consensus on the consensus: An opinion survey of Earth scientists on global climate change, 250 pp., Univ. of Ill. at Chicago.
- Oreskes, N. (2004), Beyond the ivory tower: The scientific consensus on climate change, *Science*, 306, 1686–1686.
- Peiser, B. J. (2005), The dangers of consensus science, *Can. Natl. Post*, 17 May.
- Pielke, R. A. (2005), Consensus about climate change?, *Science*, 308, 952–953.

—PETER T. DORAN and MAGGIE KENDALL ZIMMERMAN, Earth and Environmental Sciences, University of Illinois at Chicago; E-mail: pdoran@uic.edu

## GEOPHYSICISTS

### Honors

PAGE 23

AGU executive director **Fred Spilhaus** and **Joseph Burns**, Cornell University, Ithaca, N. Y., have been made honorary fellows of the Royal Astronomical Society (RAS), a U.K. society for professional

astronomers and geophysicists. The Society, on 9 January, also honored other AGU members: **Eric Priest** of the University of St. Andrews, United Kingdom, received the Gold Medal for Geophysics for his work in the fields of solar and solar-terrestrial physics. **Malcolm Sambridge** of the Australian National University, Canberra, received the Price Medal for his major contribution to algorithms in geophysics. In honoring **David Kerridge** of the British Geological Survey in Edinburgh with the Award for Services to Geophysics, RAS noted the Survey's effort

at leading a multiagency study to assess the tsunami risk to the United Kingdom.

**Wallace Broecker** of Columbia University's Lamont-Doherty Earth Observatory, Palisades, N. Y., has received the 2008 BBVA Foundation Frontiers of Knowledge Award in the climate change category. The award certificate notes that Broecker's research into the oceans' biological and chemical processes "pioneered the development of Earth system science as the basis for understanding global climate change, both past and present."