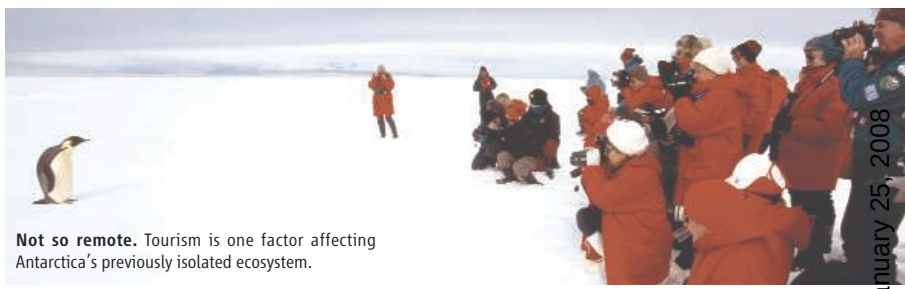
LETTERS

edited by Jennifer Sills

Antarctica Invaded



Not so remote. Tourism is one factor affecting Antarctica's previously isolated ecosystem.

THE PERSPECTIVE "ANTARCTIC BIODIVERSITY" (P. CONVEY and M. I. Stevens, 28 September 2007, p. 1877) highlights endemic fauna and flora on the south polar continent that have persisted through glacial cycles and remained geographically isolated for millions of years. However, this ancient biota is no longer isolated. Despite being surrounded by a vast ocean, Antarctica's isolation has diminished rapidly for a variety of reasons: a burgeoning tourist industry that produces tens of thousands of visitors each year; scientific exploration; increased accessibility by air and by sea; and global warming, which is removing physiological barriers to colonization by species that previously could not survive the inhospitable climate (*1*, *2*).

Human activity in Antarctica is taking its toll. In one alarming example, poultry viruses and *Salmonella* have been found in penguins (*3*). This discovery garnered media attention, but invasions by many other organisms have occurred with less fanfare. Nearly 200 alien species of fungi, terrestrial plants, invertebrates, and vertebrates have colonized the Antarctic continent and its surrounding islands within just the past two centuries (*1*), an astonishing rate for this once intensely remote region. On Gough Island, for example, the modern rate of invasion may be as much as 20,000 times higher than the prehistoric rate (*4*). Although their effects have been poorly studied to date, alien species have already reduced populations of native plants, invertebrates, and seabirds (*5*–*7*), and they have had direct and indirect effects on ecosystem processes (*1*, *8*). The dramatic effects that alien species have had in insular endemically rich regions elsewhere (*9*–*11*) warn that they could play a major role in reshaping Antarctica's diversity.

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References

1. Y. Frenot *et al.*, *Biol. Rev.* **80**, 45 (2005).
2. D. K. A. Barnes *et al.*, *Global Ecol. Biogeogr.* **5**, 121 (2006).
3. H. Gardner *et al.*, *Nature* **387**, 245 (1997).
4. K. J. Gaston *et al.*, *Proc. R. Soc. London* **270**, 1091 (2003).
5. M. Pascal, *Mammalia* **44**, 171 (1980).
6. G. Ernsting *et al.*, *Oecologia* **103**, 34 (1995).
7. J. L. Chapuis *et al.*, *Biol. Conserv.* **67**, 97 (1994).
8. C. Hänel, S. L. Chown, *Polar Biol.* **20**, 99 (1998).
9. F. Witte *et al.*, *Env. Biol. Fishes.* **34**, 1 (1992).
10. T. H. Fritz, G. H. Rodda, *Annu. Rev. Ecol. Syst.* **29**, 113 (1998).
11. J. Short *et al.*, *Biol. Conserv.* **103**, 283 (2002).

A Closer Look at the IPCC Report

IN THEIR POLICY FORUM ("THE LIMITS OF consensus," 14 September 2007, p. 1505), M. Oppenheimer *et al*. make several misleading statements. They suggest that a premature drive for consensus led Working Group I to understate the risk of large future sea-level rise in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (WGI-AR4). They assert that the "Summary for Policymakers" (SPM) of the WGI-AR4 did not properly consider increasing contributions from rapid dynamical changes in the ice sheets of Greenland and West Antarctica (WAIS). However, in quoting the SPM discussion of sea-level rise, they ignore its explicit statements on the subject, such as "dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise"; the model projections "[do not] include the full effect of ice sheet flow because a basis in published literature is lacking"; and, crucially, "larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise" (*1*).

We agree with Oppenheimer *et al*. that paleoclimatic observations should be considered in assessing possible long-term future sea-level rise and polar ice sheet changes, but dispute their inference that the SPM omitted the available information. The SPM explicitly noted that "global average sea level in the last interglacial period (about 125,000 years ago) was likely 4 to 6 m higher than during the 20th century, mainly due to the retreat of polar ice" from Greenland and possibly Antarctica as well. The SPM refers to the whole of Antarctica because of the possibility of differing behavior for the East Antarctic Ice Sheet (for which there is currently some evidence for mass gain, as opposed to mass loss of WAIS), in order to communicate with policymakers whose interest lies in understanding the total contribution to sea-level rise.

Oppenheimer *et al*. offer a number of suggestions for handling uncertainty, but they do not address the fact that quantitative model projections of ice-sheet dynamical changes cannot yet be made because of the

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inadequacy of current scientific knowledge. Observations do not presently offer a clear way to progress past these model limitations, in part because of discrepancies among published studies: Whereas some suggest that currently observed flows in outlet glaciers may be transient and thus have limited implications for long-term sea-level rise, others suggest the opposite.

IPCC assesses the literature; it does not conduct new research. In our view, providing numerical estimates of potential sea-level rise due to processes not yet quantified in the literature (whether by expert elicitation, as suggested by Oppenheimer *et al*., or by another process) would lead to inappropriate "anchoring around numerical values" of exactly the type that Oppenheimer *et al*. warn against. Far from minimizing structural uncertainties, or driving for a "premature consensus," as Oppenheimer *et al*. suggest, the SPM text of the WGI-AR4 appropriately does the exact opposite by explicitly stating that "understanding of these processes is limited and there is no consensus on their magnitude."

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Reference

1. IPCC, Summary for Policymakers (SPM), in *Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon *et al*., Eds. (Cambridge Univ. Press, New York, 2007).

Response

We disagree with Solomon *et al*. that our Policy Forum was misleading. We correctly noted that model-based numerical ranges for 21st-century sea-level rise presented in the WGI SPM (Table SPM-3) did not account for the uncertainty resulting from potential increases in the rapid dynamical response of ice sheets. Solomon *et al*. challenge this assertion by pointing instead to qualitative statements in the SPM, implying that the latter provide a satisfactory accounting of uncertainty. But the distinction between numerical values highlighted in a prominent table and narrative qualifications of such numbers is critically important. Numbers are powerful, grabbing the readers' attention, whereas qualifications are often ignored. For example, the tabular values, indicating a maximum sea-level rise of 59 cm during the 21st century, are cited frequently in the public discussion absent any qualification.

We did not imply, as Solomon *et al*. argue, that the WGI SPM omitted information from paleoclimate studies in evaluating uncertainty in sea-level rise beyond the 21st century. We suggested that it gave too much credence to ice-sheet models compared with other sources of information. For example, in reporting only a model-based estimate for the time scale of a long-term contribution (from Greenland), the WGI SPM gives short shrift to the implications of observations of fast responses in both Greenland and WAIS, narrative qualifications to the contrary notwithstanding. Such an approach understates the range of opinion in the relevant expert community on the potential magnitude and rate of the ice-sheet contribution as indicated by studies reviewed during AR4 (*1*). Further perspective on this question is provided by the AR4 Synthesis Report (*2*).

Finally, contrary to Solomon *et al*.'s assertion, our suggestions for improving the treatment of uncertainty were made specifically with the shortcomings of ice-sheet modeling in mind. It makes little sense to highlight model-based projections of sea-level rise when models that are supposed to account for the ice-sheet component have failed the test against reality. Other approaches provide important additional perspectives. For example, the fact that two independent semi-empirical analyses estimating uncertainties in future sea-level rise have been published recently (*3*, *4*) suggests that observation-based methods yield important insights where models are deficient.

We do not propose that IPCC "conduct new research." Rather, we argue that it take full advantage of what has already been produced. IPCC also has the flexibility to fill gaps in modeling and analysis where the completeness of assessment calls for it, and has done so many times. In anticipation of a Fifth Assessment, and realizing that ice-sheet models may not improve rapidly, IPCC should encourage the development of a more comprehensive approach to uncertainty. As it has done for other arenas, such as emissions scenarios or abrupt climate change, IPCC could spur research into empirical approaches, formalized expert elicitation, and comprehensive analysis of paleo-ice extent and sea level, each carried out with a specific view toward informing quantitative judgments on the range of future sea level. Holding workshops on this problem over the next few years would fit neatly into IPCC tradition.

Three of us are authors of AR4, well aware of the difficulty of assessment. A premise of our Policy Forum is that IPCC has done a superb job of establishing the scientific consensus. But in a high-stakes problem like global warming, governments need to calibrate policy to the full range of plausible outcomes, for sea-level rise and for all other key uncertainties.

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References

1. G. A. Meehl *et al*., *Global Climate Projections*, in *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon *et al.*, Eds. (Cambridge Univ. Press, Cambridge, 2007).
2. IPCC, *Fourth Assessment Report, Climate Change 2007: Synthesis Report*, available at www.ipcc.ch/ipccreports/ar4-syr.htm.
3. M. F. Meier *et al*., *Science* **317**, 1064 (2007).
4. S. Rahmstorf, *Science* **315**, 368 (2007).

CORRECTIONS AND CLARIFICATIONS

News Focus: "Gunning for the Ivy League," by H. Xin and D. Normile (11 January, p. 148). In the chart titled "Higher Education in China," the unit label for the *y* axis should have been thousands, not millions.

Special Issue on The Cosmic Web: News: "Untangling the celestial strings," by A. Cho (4 January, p. 47). The first Pan-STARRS telescope is located at Haleakala Observatories, Maui, not on Mauna Kea as the article stated.

Policy Forum: "Implementation science" by T. Madon *et al*. (14 December 2007, p. 1728). The authors' affiliation is The John E. Fogarty International Center at NIH; the division name is incorrect and should have been removed.

Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 3 months or issues of general interest. They can be submitted through the Web (www.submit2science.org) or by regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.

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