Introduction

Julio L. Betancourt

In 1984, a workshop was held on "Climatic variability of the eastern North Pacific and western North America". From it has emerged an annual series of workshops held each spring at the Asilomar Conference Center, Monterey Peninsula, California (Mooers and others 1986). These annual gatherings have come to be called PACLIM (Pacific Climate) Workshops, reflecting broad interests in the climatologies associated with the Pacific Ocean. Participants in the seven workshops that have convened since 1984 have included atmospheric scientists, hydrologists, geologists, glaciologists, oceanographers, limnologists, and both marine and terrestrial biologists. A collective goal of PACLIM is to connect these various interests with common targets. One such target is the climate system associated with El Niño-Southern Oscillation (ENSO) and its physical and biological manifestations. Another is the behavior of this system on the scale of decades, centuries and millennia, as recorded in high-resolution proxy data (*i.e.*, annual ice layers, corals, sediment varves and tree rings). Multidisciplinary collaborations fostered by previous PACLIM workshops are illustrated in Peterson (1989) and Betancourt and MacKay (1990).

PACLIM Workshops have been sponsored largely by the U.S. Geological Survey in cooperation with other federal and state agencies, as well as private institutions. PACLIM 90, which led to publication of this proceedings, was sponsored by USGS, NOAA-National Geophysical Data Center, NOAA-Climate Analysis Center, the National Park Service-Global Change Program, the American Geophysical Union, Southern California Edison, and the California Department of Water Resources.

On behalf of the sponsors, we extend our thanks to those individuals responsible for organizing and planning PACLIM 90. Ana MacKay, National Research Program, Water Resources Division, USGS, wore many hats and single-handedly made PACLIM 90 a success. Paul Weiss, comptroller at the American Geophysical Union, was incredibly efficient in managing funds from private sources. AGU's role is critical to PACLIM, both in disseminating information about the workshop and in banking funds. Merilee Bennett, USGS, made transferring funds across federal agencies look easy.

PACLIM 90 Theme: Comparison of Observations vs. Simulations of GCMs

Less than two years into LBJ's presidency, in the midst of the Da Nang offensive, the President's Science Advisory Council prophesied that general circulation models would be able to predict the climatic effects of increasing atmospheric CO_2 concentrations (Revelle *et al.* 1965). For those on the sidelines, this surely meant we would be able to anticipate more or less flow in the overcommitted Colorado River or the relative success of our harvests in the Nation's Breadbasket, the Midwest.

In the quarter-century since then, GCMs have evolved in tandem with our computer technology and alongside an explosion of knowledge about how the Earth's climate system works. Despite our growing sophistication, if we are now sure of anything, it is that significant uncertainties exist. To wit, the greenhouse effect apparently has warmed the

Earth no more than the 0.5 $\pm$ 0.2 K observed in the instrumental record (Jones and others 1986) and far less than the 2.5 to 4.5 K predicted from doubled-CO_2 GCM experiments. Members of the 1965 President's Science Advisory Council would have been miffed to find that in 1991, the North American continent would be but a small region in a global GCM, inappropriately scaled to capture what is a complex mosaic of hydroclimatic, ecological, and economic diversity. They would also be surprised at how difficult it has been to statistically measure goodness-of-fit between GCM simulations of present climate and actual observations thereof (Livezey 1985; Katz 1988; Moss 1992). Moreover, despite the considerable efforts of a proficient and well-funded climate modeling community, GCM characterizations are not yet capable of driving policy that anticipates the future of our energy, food, and water resources.

In setting the theme for the Seventh Annual Pacific Climate (PACLIM) Workshop, "Comparison of observations vs. simulations of GCMs", it was not our intent to dwell on inadequacies of the models. Since its inception in 1984, PACLIM has favored empirical data sets, and the focus seldom has been on numerical models, that is until Hugh Elsaesser's (1989) keynote address at PACLIM 89. Participants took to heart Elsaesser's comments about the turf factor, that the CO_2 problem had become the sole province of radiation transport specialists with little input from other relevant disciplines, such as those represented at PACLIM. If the PACLIM group has an inclination, it is that there is no substitute for well-resolved time-series observations in geophysical research, and that such time series are essential for constructing and verifying conceptual and numerical models, be they geophysical or biological (Cayan *et al.* 1989)

The response to Elsaesser, then, was a conscious effort to recruit participation in PACLIM by the climate modeling community. A PACLIM workshop is a somewhat informal affair held in full view of Monterey Bay, where a glacialogist can walk the beach with a phytoplankton ecologist. If PACLIM is anything, it is an opportunity to talk across disciplines. So in part, PACLIM 90 was designed as a chance for the empiricist to get to know the modeler and vice-versa.

Stanley Grotch's keynote address, which opens the Proceedings, is related to a recently published critique of the use of GCMs to predict regional climate change (Grotch and MacCracken 1991). For seven GCMs, Grotch compared model gridpoint reconstructions with historical data for current surface air temperature and precipitation. The good news is that the models and historical data closely agree on seasonally-averaged and area-weighted global average temperatures. The bad news is illustrated by discordance in the latitudinal distribution of seasonal temperature and precipitation. For winter temperatures, simulations and observations diverge the most at high latitudes, and for winter precipitation the disagreement is 100 percent at some latitudes. Other studies have shown that even greater discrepancies, in this case between the various models, occur in longitudinal profiles of seasonal precipitation, specifically in the subtropics (Neilson *et al.* 1990). The comparison among the different models points up the advantage that several competing models have over a single "definitive" supermodel, a controversy that raged in budget meetings for fiscal year 1992 (Kerr 1990). The disparity between the various models probably stems from how well (or poorly) the models simulate present climate. Further improvement of sensitivity estimates will be bounded by the theoretical limits, both in time and space, of climate predictability (Grotch and MacCracken 1991).

No doubt, climate modeling stands to benefit from the kinds of studies that make up these proceedings: better integration of surface hydrology in the form of submodels (Dickinson and Kennedy; Roads and others; Neilson and others); validation from operational weather forecasting using GCMs (Mo); synoptic studies and in-depth analyses of the instrumental record (Wade and Redmond; Redmond; Riddle and others; Cayan; Goodridge); development of proxy records for times and places for which we have no instrumental record (Anderson; Thompson; Holdsworth; Schimmelmann and Tegner; Dunbar and others; Meko; Dean and others); and an understanding of how global climates might drive local and regional ecosystems (Ware; Ainley and others). Four papers in the volume (Ebbesmeyer and others; Linsley; de Menocal and Bloemendal; Quade and Cerling) remind us that, at various times (the late 1970s, the Younger Dryas, the onset of the Pleistocene 2.4 Myr, and 7.3 Myr, when conditions for the Asian Monsoon apparently began), the Earth's climate shifts mode, producing step-like changes in both the geologic and instrumental record. The ability of GCM models to reproduce such abrupt and directional changes offers a compelling opportunity to validate such models.

References

Betancourt, J.L., and A.M. MacKay, eds., 1990. *Proceedings of the Sixth Annual Pacific Climate (PACLIM) Workshop, March 5-8, 1989*. California Department of Water Resources, Interagency Ecological Studies Program Technical Report 23.

Cayan, D.R., J.V. Gardner, J.M. Landwehr, J. Namias, and D.H. Peterson, 1989. in D.H. Peterson, ed., "Aspects of Climatic Variability in the Pacific and the western Americas". *American Geophysical Union Monograph* 55, pp. xiii-xvi.

Elsaesser, H.W. 1990. "Atmospheric carbon dioxide and the climatic record". In J.L. Betancourt and A.M. MacKay, eds., *Proceedings of the Sixth Annual Pacific Climate (PACLIM) Workshop, March 5-8, 1989*. California Department of Water Resources, Interagency Ecological Studies Program Technical Report 23, pp. 5-18.

Grotch, S.L., and M.C. MacCracken, 1991. "The use of general circulation models to predict regional climatic change". *Journal of Climate* 4:286-303.

Jones, P.D., S.C.B. Raper, R.S. Bradley, H.F. Diaz, P.M. Kelly, and T.M.L. Wigley, 1986. "Northern Hemisphere surface air temperature variations, 1851-1984". *Journal of Climate and Applied Meteorology* 25:161-179.

Katz, R.W. 1988. "Statistical procedures for making inferences about changes in climatic variability". *Journal of Climate* 1:1057-1068.

Kerr, R.A. 1990. "Climatologists debate how to model the world". *Science* 250:1082-1083.

Mooers, C.N.K., D.H. Peterson, and D.R. Cayan, 1986. "The Pacific Climate Workshops": *EOS* 67:1404-1405.

Livezey, R.E. 1985. "Statistical analysis of general circulation model climate simulations: Sensitivity and prediction experiments". *Journal of Atmospheric Sciences* 42:1139-1149.

Moss, M.E. 1992. "Bayesian relative information measure: A tool for analyzing the outputs of general circulation models". *Journal of Geophysical Research* (in press).

Neilson, R.P., G.A. King, J. Lenihan, and R.L. DeVelice, 1990. "The annual course of precipitation over much of the United States: Observed versus GCM simulation". In J.L. Betancourt. and A.M. MacKay, eds., *Proceedings of the Sixth Annual Pacific Climate (PACLIM) Workshop, March 5-8, 1989.* California Department of Water Resources, Interagency Ecological Studies Program Technical Report 23, pp. 19-26.

Peterson, D.H., ed., "Aspects of Climatic Variability in the Pacific and the western Americas". *American Geophysical Union Monograph* 55

Revelle, R., W. Broecker, H. Craig, C.D. Keeling, and J. Smagorinsky, 1965. Appendix Y4, "Atmospheric carbon dioxide". In *Restoring the quality of our Environment, Report of the Environmental Pollution Panel*, President's Science Advisory Committee, Washington, DC.