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Diagnostic Studies of Climate Variability

Annual Report to the U.S. Department of Energy
for the period December 1, 1992 - November 30, 1993

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Diagnostic Studies of Climate Variability

Research Objectives for 1992-1993

Research in 1992-93, the second year of the project, involved, *inter alia*, the following topics (completed publications [listed in **Appendix 1**] are indicated in parentheses, where appropriate):

1. Continuation of studies of proxy climatic records to try to extend the record of large-scale climatic conditions back into previous centuries, and to determine if there are reliable regional analogs for larger scale climatic fluctuations (Bradley & Jones, 1993; Diaz and Pulwarty, 1993; Hughes and Diaz, 1993);
2. Examination of indices of long-term climatic variability to determine if climate has become more, or less, variable over time. This involves studies of both instrumental and proxy data sets for sites throughout the world (Diaz and Bradley, 1993);
3. Continuation of studies of mid-winter polar boundary layer climate as a possible indicator of greenhouse gas-induced climate changes (Bradley et al, 1992, 1993a);
4. Documentation of the linkages between observed temperature and precipitation changes on regional space scales (Bradley et al., 1993b) and changes in large-scale atmospheric circulation patterns (Diaz and Kiladis, 1993; Diaz and Markgraf, 1993);
5. Regridding of global temperature anomalies using an equidistant grid, optimal interpolation scheme, and stratification of data by extent of urbanization at each station, then recomputation of regional and hemispheric temperature trends

Significant progress has been made in all of these areas. In the following section we summarize results of the work accomplished.

1. Extending the Climate Record back in time and examining changes in Climate Variability

All hemispheric or global records of temperature, on which the debate over global warming rests, begin in the mid- to late 19th century. We have attempted to extend these records back in time to provide a longer-term perspective on instrumentally-recorded temperature variations of the last 100-140 years. Using proxy records which record the same seasonal signal of temperature, a 400-500 year perspective is obtained (Bradley and Jones, 1993). Although the records do not cover the entire earth, the regions from which records are available do capture most of the variance of hemispheric temperature on the decadal timescale. The reconstructed record of hemispheric temperature enables two alternative interpretations to be made. Either temperatures began to increase several hundred years ago, and have fluctuated around a slowly

increasing average (Figure 1a) or temperatures have been generally cooler (on average by 0.2-0.3°C) and have undergone a unique increase in the last few decades (Figure 1b). In the first interpretation, "global warming" could not be ascribed solely to anthropogenic increases in greenhouse gases, since the increase in temperature began long before such gases began to rise dramatically. However, with the second interpretation, the recent warming could be viewed as clearly diagnostic of the unique contributions of greenhouse gases to the global energy balance. Our analysis does not yet permit us to favor one interpretation over the other, though we note that the most recent decades are exceptional under either interpretation. However, other factors (particularly the unusual ENSO conditions of the past 20 years) may have played a role in producing this recent anomaly (cf. Diaz and Pulwarty, 1993). Further research is needed to compare temperature variability in both hemispheres over long time periods, where possible extending the record back over the last 1000 years (Diaz and Bradley, 1993). A special issue of the journal *Climatic Change*, arising from a conference (organised by H.Diaz and M.Hughes) will focus more attention on this matter (Diaz and Hughes, 1993). The available records must also be examined in relation to forcing factors which may have been important over the last few centuries, such as solar variability and explosive volcanism. Comparison of records from each hemisphere can help to resolve which of these factors has been of most importance over the last millennium.

2. Polar boundary layer in winter

Low level temperature conditions in the polar mid-winter provide a unique test of greenhouse gas effects on the long-wave radiation balance of the earth. Our research shows that over a wide sector of the Arctic, and over parts of the Antarctic, surface temperatures have increased and inversion depths have decreased, perhaps as a result of increased greenhouse gases (Bradley et al., 1992; Bradley et al, 1993a,b). Preliminary studies of Siberian data suggest similar changes have occurred there also, but data are sparse and documentation is poor. We are consulting with Russian colleagues to obtain quality-controlled radiosonde data from the interior of Arctic Russia to extend our analysis in this region.

3. Links between Temperature and Precipitation Changes

The debate over potential impacts of climate change generally revolves around temperature changes, yet precipitation changes are likely to have an equally if not more profound economic and social impact. To examine the relationship between temperature, precipitation and pressure anomalies we have produced a computer-based atlas of climate anomalies covering the entire period of instrumental records (Bradley et al., 1993c). This atlas will be available on CD-ROM for display on a

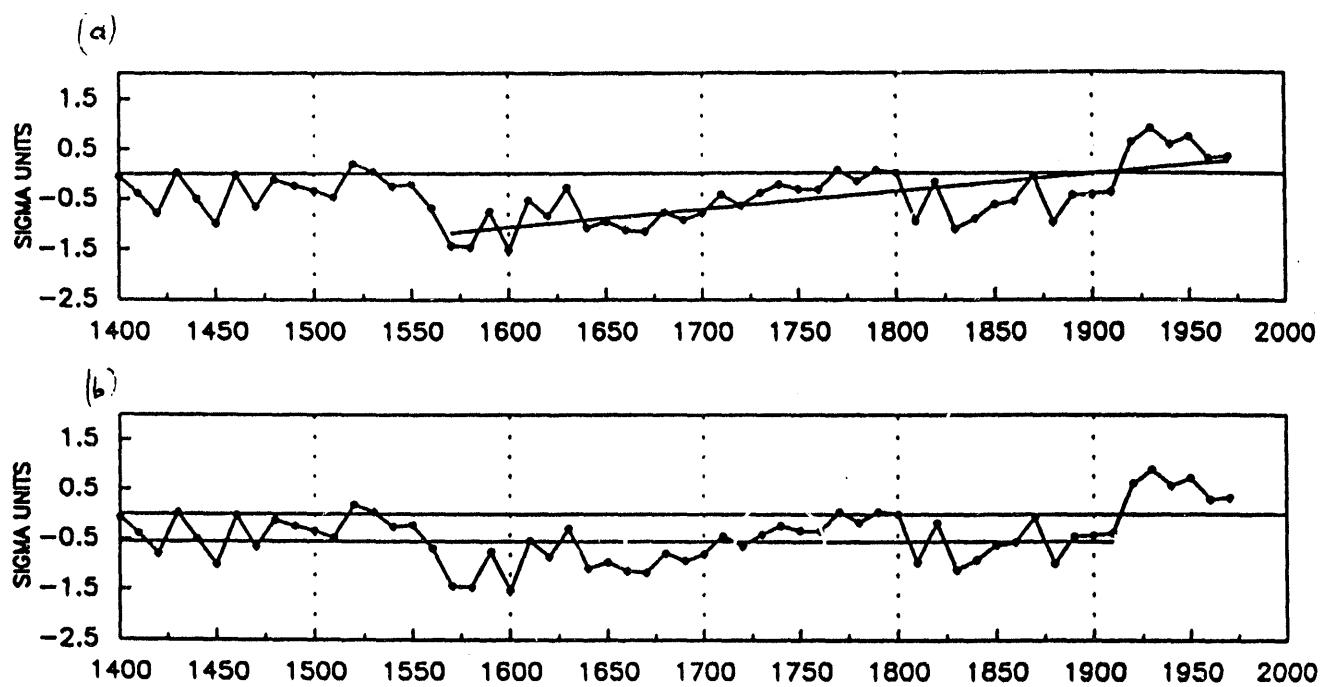


Figure 1. Alternative views of the "northern hemisphere" normalised summer temperature anomaly reconstruction for the last ~600 years (see text for discussion).

variety of computer platforms, including IBM PC, Macintosh and workstations such as SUN and Silicon Graphics (with X-windows). Studies have also continued to document the relationships between ENSOs and extra-tropical circulation anomalies (Diaz and Kiladis, 1993). A major book on the long-term record of ENSOs was produced in 1993, which provides an important perspective on recent ENSO variability (Diaz and Markgraf, 1993). In particular, it shows that the recent persistence of negative SOIs (i.e. ENSO-like conditions lasting for almost 2 decades) is extremely unusual in the context of the last few centuries.

4. Temperature change and Urbanization

The debate over how much of the observed temperature change of the last century has been due to urbanization continues to exercise the press, though most climatologists do not believe it is of great significance on a global scale. As a further contribution to this debate we are utilising a satellite-derived GIS-based classification of the extent of urbanization of the earth. Station records are classified as to the extent of local urbanization so that the available data can be stratified into urban and non-urban sets, and the large-scale temperature changes derived from each set can then be compared. Results to date show that the number of "urban" records used in compiling hemispheric average temperature changes is small, though of increasing importance over long periods of time. In another approach, we have compiled a set of high elevation data from around the world to compare unequivocally non-urban sites with their lowland counterparts where urban influences may have been of some significance.

This re-analysis also involves comparing the results of gridding with an "equidistant" system, versus the traditional 5°x5° latitude/longitude system. Important differences are apparent, though we do not yet know to what extent these result from improvements we have made in data coverage within our data bank.

A number of papers describing these results in more detail are listed in **Appendix 1**, either published or in press. In addition we note the following activities, involving invitations and presentations of our research results at national and international meetings:

Bradley: *Workshop on the Climate of the Maunder Minimum*, European Science Foundation, Bern Switzerland, September, 1992 (invited).

Bradley: *Special Session on The Little Ice Age*, American Association for the Advancement of Science, Boston, Massachusetts, February 1993. (invited).

Bradley: *NATO Symposium on The Solar Engine and its Influence on Climate*, Paris, France, October, 1993 (invited).

Diaz and Bradley: *Climate Variations on the Decade to Century Timescale*, National Academy of Sciences, Irvine, California, September, 1992 (invited).

Diaz: *8th American Meteorological Society Conference on Applied Meteorology*, Anaheim, California, January, 1993. Assessing global climate trends using multi-response permutation procedures (with T.J. Brown and P.W.Mielke).

Diaz: *4th Symposium on Global Change Studies*, Anaheim, California, January 1993. Climate Variations in the Rocky Mountain West (with T.J. Brown).

Diaz: *International Conference on Climate Variability, Global Change and their Impacts in Latin America and the Caribbean*. San Jose, Costa Rica, March 1993. La influencia del Fenomeno "El Niño-Oscilación Sur" sobre el Clima de la Región tropical de América. (invited)

Diaz: *NATO Symposium on Global Precipitation Variability and Change*, Toulon, France, September 1993. Approaches to the regionalisation of precipitation climates in the context of global climate change monitoring. (invited).

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} **Appendix 2** is a description of the proposed research in 1993-4, and a proposed budget.

Appendix 1

Publications Arising from the Research Grant in 1992-93

Bradley, R.S., F.T. Keimig, and H.F. Diaz, 1992: Climatology of surface-based inversions in the North American Arctic. **J. Geophysical Research-Atmospheres**, 97, D14, 15,699-15,712.

Bradley, R.S., F.T. Keimig, and H.F. Diaz, 1993a: Recent changes in the North American Arctic boundary layer in winter. **J. Geophysical Research-Atmospheres**, 97, D5, 8851-8858.

Bradley, R.S., F.T. Keimig, and H.F. Diaz, 1993b: Recent changes in Arctic Temperature Inversions. **DoE Research Summary No. 25**. Carbon Dioxide Information Analysis Center, Oak Ridge, Tennessee, 4pp.

Diaz, H.F. and V. Markgraf (eds.) **El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation**. Cambridge University Press, 476pp.

Diaz, H.F. and G.N. Kiladis, 1992: Atmospheric teleconnections associated with the extreme phases of the Southern Oscillation. In: Diaz, H.F. and V. Markgraf, *op. cit.*, pp. 175-192.

Diaz, H.F. and R.S. Pulwarty, 1992: A comparison of Southern Oscillation and El Niño signals in the tropics. In: Diaz, H.F. and V. Markgraf, *op. cit.*, pp. 175-192.

Papers in Press

Bradley, R.S., L. Ahern and F.T. Keimig, 1993c: A computer-based atlas of global climate variations. **Bulletin of the American Meteorological Society** (in press).

Bradley, R.S. and Jones, P.D., 1993: Little Ice Age summer temperature variations: their nature and relevance to recent global warming trends. **The Holocene** (in press).

Diaz, H.F. and R.S. Bradley, 1993: Documenting natural climatic variations: how different is the climate of the 20th century from that of previous centuries? In: **Climate Variability on Decade to Century Timescales**. National Academy of Sciences, Washington D.C. (in press).

Diaz, H.F. and R.S. Pulwarty, 1993: An analysis of the timescales of variability in centuries-long ENSO-sensitive records of the last 1000 years. **Climatic Change** (in press).

Hughes, M.K. and H.F. Diaz, 1993: Was there a Medieval Warm Period, and if so, where and when? **Climatic Change** (in press).

A high-contrast, black and white image showing three distinct horizontal bands. The top band consists of two vertical rectangles, one black and one white, side-by-side. The middle band is a single, thick, black horizontal bar. The bottom band is a single, thick, black horizontal bar, positioned lower than the middle one. The entire image is set against a white background.

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