4.1 MAXIMUM AND MINIMUM TEMPERATURE TRENDS FOR THE GLOBE: AN UPDATE THROUGH 2004

Russell S. Vose*, David R. Easterling, and Byron Gleason
NOAA National Climatic Data Center, Asheville, North Carolina

1. INTRODUCTION

Minimum temperature increased about twice as fast as maximum temperature over global land areas since 1950, resulting in a broad decline in the diurnal temperature range (DTR; Folland et al., 2001). Changes in cloud cover, precipitation, soil moisture, and atmospheric circulation likely accounted for much of the trend differential during the period (e.g., Dai et al., 1999; Przybylak, 2000; Braganza et al., 2004). Changes in land use also impacted the DTR in some areas (e.g., Balling et al., 1998; Bonan, 1999; Small et al., 2001). Unfortunately, data constraints have historically limited global-scale analyses of DTR trends and their causes; in particular, the most recent global assessment (Easterling et al., 1997) only covered about half of the land surface and ended in 1993. Consequently, in this study we use new data acquisitions to expand spatial coverage and update global trends in maximum temperature, minimum temperature, and the DTR through the period 1950-2004. For consistency with the IPCC Fourth Assessment Report, trends during the satellite era (1979-2004) are also discussed.

2. DATA

Data for this study were compiled from 20 source datasets. The primary sources were the Global Historical Climatology Network (Peterson and Vose, 1997) monthly and daily databases (which contain most of the data used in Easterling et al.), and two editions of World Weather Records (1981-1990 and 1991-2000). These global datasets were supplemented with acquisitions from Argentina, Australia, Brazil, Chile, Cuba, Greece, Iran, New Zealand, and South Africa. CLIMAT reports were used to update about 20% of the stations after 1994. In addition, high-quality synoptic reports were included to fill recent gaps in about 10% of the stations (provided digital and manual checks indicated that the synoptic data closely matched historical monthly time series during periods of overlaps).

The source data were quality assured using methods described in Peterson et al. (1998). The approach of Menne and Williams (2005) was then employed to produce adjustments for undocumented changes in station location, instrumentation, and observing practice. Unlike Easterling et al. (1997), the final adjusted dataset was not stratified into urban and rural subnetworks because urban warming does not appear to significantly bias multidecadal trends over large areas.

3. METHODS

The climate anomaly method (Jones and Moberg, 2003) was used to develop global, hemispheric, and grid-box time series for the period 1950-2004. The first step involved excluding stations that had less than 21 years of data during a base period of 1961-1990 and less than 4 years of data in each decade during that 30-year span. Base-period normals were then computed by month for the remaining 4280 maximum, 4284 minimum, and 4157 DTR stations. Next, each monthly temperature at each station was converted to an anomaly from its base-period mean. The station-based anomalies were then averaged into 5° by 5° latitude-longitude grid boxes for each year/month from 1950-2004. Finally, global and hemispheric means were computed by area-weighting each grid box by the cosine of the central latitude and averaging all of the weighted grid-box values in the given year/month. On average, the resulting dataset covers the equivalent of 71% of the total global land area, 17% more than in previous studies.

The climate anomaly method was also used to develop global, hemispheric, and grid-box time series for the satellite era. To maximize spatial coverage, a base period of 1979-2004 was used instead of 1961-1990 because the latter results in grid-box trend maps that cover 12% less of the land surface. (In general, the two base periods yield comparable results at large spatial scales; for instance, their global DTR trends for 1950-2004 differ by only 0.0013°C dec^{-1}). A total of 3588 maximum, 3565 minimum, and 3360 DTR stations each have at least 21 years of data during the satellite period. On average, the resulting dataset covers the equivalent of 71% of the land surface.

* *Corresponding author address:* Russell S. Vose, NOAA National Climatic Data Center, 151 Patton Ave, Asheville, NC 28801; e-mail: Russell.Vose@noaa.gov.

4. 1950-2004 TRENDS

Figure 1 depicts the global annual time series for each variable for the period 1950-2004. In general, both maximum and minimum temperature increase from about the mid-1970s to present, with warming in the minimum during the 1950s as well. The DTR generally decreases during the period, though much of the change occurs in two periods (the 1950s and the early-1970s to early 1980s). From 1950-2004, the least-squares regression trend in annual maximum temperature is 0.141°C dec^{-1}, in minimum temperature is 0.204°C dec^{-1}, and in DTR is -0.066°C dec^{-1}. The trends in maximum and minimum temperature exceed those in Easterling et al. (1997) by 0.050 and 0.018°C dec^{-1}, respectively, whereas the DTR trend is less by 0.018°C dec^{-1}. The larger maximum and minimum trends are generally consistent with the large positive global temperature anomalies observed in most years since 1993 (Levinson et al., 2005) while the smaller DTR trend likely reflects the accelerated rate of warming in the maximum.

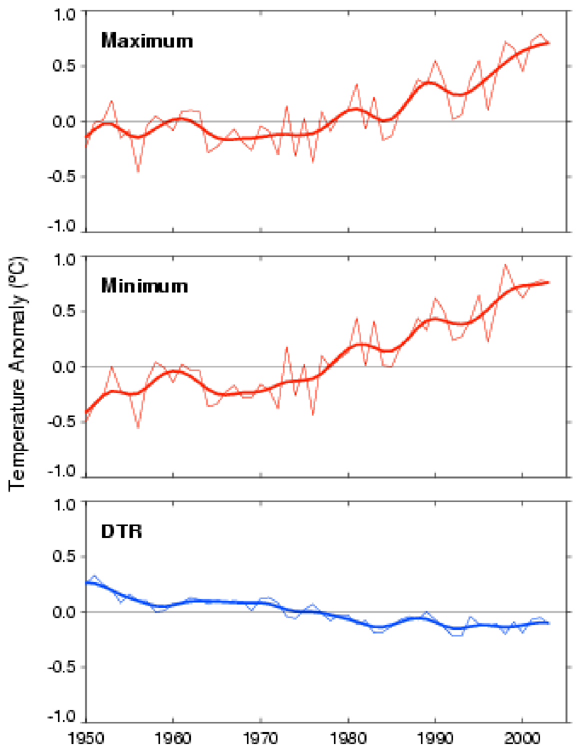

Figure 1. Anomaly time series for global land areas over the period 1950-2004.

5. 1979-2004 TRENDS

Both maximum and minimum temperature increases from 1979-2004 whereas the DTR is basically trendless. The maximum and minimum temperature trends are nearly identical (0.287 versus 0.295°C dec^{-1}), and both are comparable to the mean temperature trend over global land areas for the period (0.296 °C dec^{-1}) as derived from the Global Historical Climatology Network database (J. Lawrimore, pers. comm., 2005). Given the similarity between maximum and minimum temperature, the trend in the DTR (-0.001 °C dec^{-1}) is not statistically significant at the 5% level.

Figure 2 depicts the annual trend for each variable in each 5° by 5° grid box during the period 1979-2004. Boxes having less than 21 years of data (80% completeness) were excluded from the analysis. In general, maximum temperature increased in most regions except northern Peru, northern Argentina, northwestern Australia, and parts of the north Pacific Ocean. Minimum temperature increased in virtually all areas except southern Argentina, western Australia, and parts of the western Pacific Ocean. The DTR pattern was far less consistent, with increases in some areas (e.g., western North America, northern Eurasia) and decreases in others (e.g., northeastern Canada, the southeastern United States).

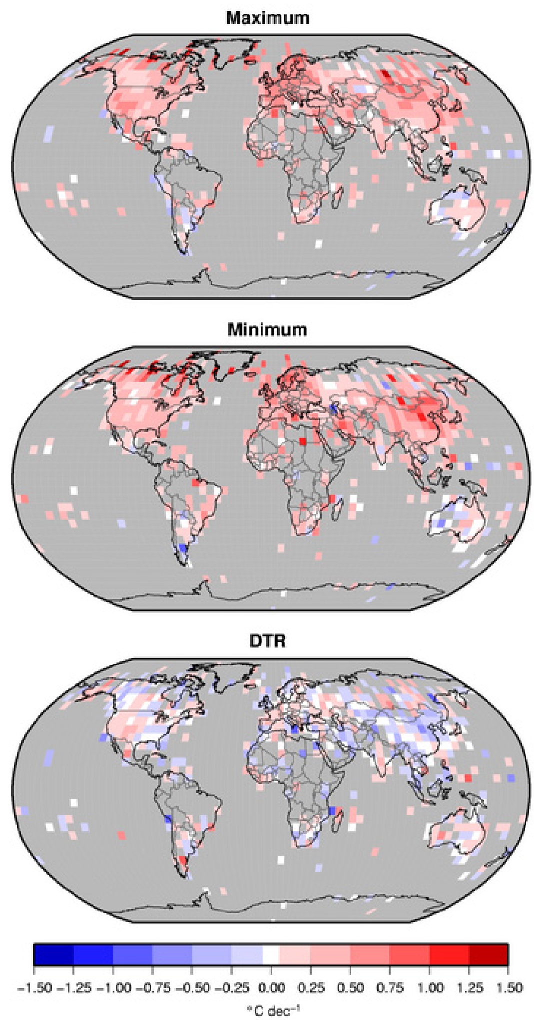

Figure 2. Least-squares trends in 5° by 5° grid boxes for the period 1979-2004.

6. CONCLUSIONS

This study used a suite of new data acquisitions to examine recent global trends in maximum temperature, minimum temperature, and the DTR. Consistent with Easterling et al. (1997), minimum temperature increased at a faster rate than maximum temperature during the latter half of the 20th century, resulting in a significant decrease in the DTR for this period. In contrast, maximum and minimum temperature increases were roughly comparable during the satellite era, muting recent changes in the DTR. Maximum and minimum temperature increased in almost all parts of the globe during both periods, whereas a widespread decrease in the DTR was only evident from 1950-1980.

A more detailed assessment of these trends has been accepted for publication by *Geophysical Research Letters.*

7. REFERENCES

Balling, R.C., Jr., J.M. Klopatek, M.L. Hildebrandt, C.K. Moritz, and C.J. Watts, Impacts of land degradation on historical temperature records from the Sonoran Desert, *Clim. Change,* **40**, 669-681, 1998.

Bonan, G.B., Observational evidence for reduction of daily maximum temperature by croplands in the midwest United States, *J. Clim.,* **14**, 2430-2442, 2001.

Braganza, K., D.J. Karoly, and J.M. Arblaster, Diurnal temperature range as an index of global climate change during the 20th century, *Geophys. Res. Lett.,* **31**, 10.1029/2004GL019998, 2004.

Dai, A., K.E. Trenberth, and T.R. Karl, Effects of clouds, soil moisture, precipitation, and water vapor on diurnal temperature range, *J. Clim.,* **12**, 2451-2473, 1999.

Easterling, D.R., B. Horton, P.D. Jones, T.C. Peterson, R.R. Karl, D.E. Parker, M.J. Salinger, V. Razuvayev, N. Plummer, P. Jamason, and C.K. Folland, Maximum and minimum temperature trends for the globe, *Science*, **277**, 364-367, 1997.

Folland, C.K. and others, Observed Climate Variability and Change, in *Climate Change 2001: The Scientific Basis,* pp. 108-109, Cambridge University Press, Cambridge, 2001.

Jones, P.D. and A. Moberg, Hemispheric and large-scale surface air temperature variations: An extensive revision and an update to 2001, *J. Clim.,* **16**, 206-223, 2003.

Levinson, D.H. and others, State of the climate in 2004, *Bull. Amer. Meteor. Soc.*, **86**, S1-S86, 2005.

Menne, M.J. and C.W. Williams, Jr., Detection of undocumented change points: On the use of multiple test statistics and composite reference series, *J. Clim.* (in press).

Peterson, T.C. and R.S. Vose, An overview of the Global Historical Climatology Network temperature database, *Bull. Amer. Meteor. Soc.*, **78**, 2837-2849, 1997.

Peterson, T.C., R.S. Vose, V.N. Razuvaev, and R.L. Schmoyer, Global Historical Climatology Network (GHCN) quality control of monthly temperature data, *Int. J. Climatol.,* **18**, 1169-1179, 1998.

Przybylak, R., Diurnal temperature range in the Arctic and its relation to hemispheric and Arctic circulation patterns, *Int. J. Climatol.,* **20**, 231-253, 2000.

Small, E.E., L.C. Sloan, and R. Nychka, Changes in surface air temperature caused by desiccation of the Aral Sea, *J. Clim.,* **14**, 284-299, 2001.