Final Report
Data Preparation and Analysis for Annex III, USA/PRC Cooperation in the Field of
Atmospheric Trace Gases
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Introduction.

The National Climatic Data Center (NCDC) has been a long-time and very active participant in the joint research program on the Greenhouse Effect created by the bilateral agreement Annex III to the Protocol on Fossil Energy Research and Development on Cooperation in the Field of Atmospheric Trace Gases. This agreement between the United States Department of Energy (DOE) and the People's Republic of China (PRC) Chinese Academy of Sciences (CAS) has fostered a large amount of data set development and research (Riches et al., 1992) as well as science exchange between the two countries. Within the agreement there have been four basic tasks: 1) to analyze general circulation models, 2) to prepare, validate, and analyze data, 3) analyze the relationship between large scale and local climate, and 4) atmospheric trace gas measurements, particularly methane (Riches et al. 1992). Within this framework the NCDC has had two basic tasks in this program: to develop, validate, analyze and exchange long-term climate data sets suitable for analyzing past climate change, and to perform research into past climate change and

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linking large-scale and regional climates. Following is a brief review of NCDC's accomplishments in the project.

Task 2: Prepare, Validate, and Analyze Data.

The NCDC is the world's largest active archive of climate data and one of the primary functions of the Center is to develop high-quality, long-term climate data sets useful both for analyzing the past climate, and providing validation for climate model simulations. The activities at NCDC for Task 2 can be further divided into two basic components: (1) developing data sets through data compilation and developing new and innovative techniques to improve the quality of the data; and (2) analyzing these data for evidence of trends and fluctuations on both a global and regional basis.

Data Set Development.

The NCDC has developed a number of high-quality data sets under auspices of this project. Many of these data sets have been forwarded to the Carbon Dioxide Information and Analysis Center (CDIAC) at Oak Ridge National Laboratory where they have been distributed as a part of their Numerical Data Package series. The initial data set developed was the United States Historical Climatology Network data set (USHCN, Karl et al. 1990, Easterling et al 1996a). This is a high-quality data set of monthly averaged maximum, minimum, and mean temperature, and total precipitation for 1200 observing stations in the continental United States for the general period of record 1900-1997. The stations in this data set are from the U.S. Cooperative Network operated by the U.S. National Weather Service and were chosen from approximately 7,000 to represent the highest quality data available. Stations were chosen based on length of record, a low percentage of missing data, and as few changes as possible that could potentially affect the

homogeneity of the station's data record. Once the network was established, techniques to assess and, where possible, adjust the data for potential inhomogeneities were developed. The basic adjustment steps are outlined in Easterling, et al. (1996b), and include adjustments for the time-of-observation bias problem (Karl, et al. 1986), changes from liquid-in-glass (LIG) temperature sensors to thermistor-based systems (Quayle, et al. 1991), random station changes such as station moves (Karl and Williams 1987), and the urban heat island effect (Karl, et al. 1988). This data set is updated annually and provided to the research community both by the Carbon Dioxide Information and Analysis Center (CDIAC) at Oak Ridge National Laboratory and the NCDC. A daily version of this data set is also available, but for a smaller network of 137 stations (Hughes, et al. 1992) however, it is also currently being updated with data for 1000 stations for the period 1948-1997. Furthermore, the NCDC also has a data rescue project underway that will provide digital data for these and additional U.S. cooperative stations for the pre-1948 period. In some cases data will be available well back into the 19th century. These data will be incorporated into an update version of the daily USHCN data set.

Another high-quality data set developed at the NCDC is the Global Historical Climatology Network (GHCN, Vose et al. 1992, Peterson and Vose 1997). This data set consists of monthly data from 7,500 monthly averaged temperature, over 20,000 precipitation, and 2,500 sea-level pressure stations. Also monthly averaged maximum and minimum temperature is available for a sub-set of the temperature stations covering approximately 50% of the global landmass. These data have been subjected to rigorous quality control methods developed specifically for this data set (Peterson et al. 1998a). Furthermore, special homogeneity methods were developed and applied to this data set

that operate in the absence of station history information (Peterson and Easterling 1994; Easterling and Peterson 1995; Peterson, et al. 1998b). The development of GHCN has included data from a number of unique sources. For example, one source of late 19th and early 20th century African data has been from colonial archive data from European countries that maintained colonies on the continent (Peterson and Griffiths 1997). The GHCN is automatically updated whenever new source data such as CLIMAT messages are available which is approximately 20 times a month.

Upper-air data is a critical element in establishing whether long-term climate change has occurred. The Comprehensive Aerological Reference Data Set (CARDS; Eskridge et al. 1995) has been a long-term data set development project at the NCDC that is currently coming to fruition. This data set consists of millions of radiosonde soundings from around the world and is designed to provide a daily data set of upper-air soundings suitable for evaluating climate models and long-term climate change. This data set has been subjected to a complex quality control system developed specifically for this project (Eskridge et al. 1995). Also, methods to adjust data for specific changes in radiosonde instrumentation have been developed (Luers and Eskridge 1998). These methods are unique since they are physically based and model heat transfer processes to adjust temperatures instead of the more usual statistical approaches used in surface data sets such as those discussed above.

Other long-term data sets developed as a part of this project include a cloud/sunshine data set for the United States (Steurer and Karl 1991) and daily snowdepth for 195 stations in the United States (Easterling, et al. 1997b).

Climate Analysis.

Another major part of the NCDC activities on this project has been to analyze the climate for past fluctuations and changes on both a regional and global basis. Since there has been a large amount of research associated with this project at the NCDC, only a number of relevant examples are discussed here.

It is critical for climate change detection and attribution issues that the types of data sets discussed above are used to establish changes that may be occurring both on a regional and global basis. The NCDC has focused on this task by analyzing data for the U.S., PRC, and other parts of the world as well as providing global analyses. One area of research has been trend analysis in temperature and precipitation. It is well established that the annual global temperature has risen by approximately 0.6 Deg C over the 20th century. The robustness of this signal, however, has been the subject of some debate. One area of research at NCDC has been to develop new methods to determine the globally averaged surface temperature. Recently a new method was introduced by Peterson et al. (1998c) designed to allow the inclusion of data for more stations around the globe than was previously possible. This method allows the inclusion of stations with periods of record too short to use in older anomaly-based methods by utilizing the annual year-to-year temperature change in place of anomalies. The method is more robust, particularly in data-poor areas. A second area of concern in examining globally-averaged surface temperatures is the extent to which the observed warming over the 20th century (0.6 Deg C) is affected by urbanization. This is a recurring concern (see Karl et al. 1988, Wang et al. 1990) and earlier studies have shown that urban warming accounts for only approximately 0.1 Deg C of the observed warming over the 20th century. A recent study at NCDC that is the most comprehensive yet undertaken addressing the urban problem

(Peterson, et al., 1999) has shown that the global temperature signal is only minimally affected by increased urbanization and that it is truly representative of large-scale surface climate warming (Figure 1).

It is clear from the preceding discussion that the global surface climate has warmed, but it is also evident that most of this warming has occurred due to an asymmetric warming of the maximum and minimum temperatures. Karl et al (1984) for examined this possibility in the U.S. showing that for most areas the trend in the minimum temperature exceeds the trend of maximum temperature resulting in a decreased diurnal temperature range (DTR). This was examined on a more global basis in a series of three papers where each succeeding analysis included more of the global landmass. In all three analyses (Karl et al. 1991; Karl et al. 1993; Easterling et al. 1997a) most of the additional areas of the world showed trends consistent with the notion that most of the warming is concentrated in the minimum temperature (Figures 2 and 3). There have been a number of forcing mechanisms proposed to help explain these trends, one of which is increasing cloud cover which was investigated by Karl and Steurer (1990).

Another area of increasing concern in examining climate change is the extent to which there have been changes in the incidence of extreme events. Karl et al. (1996) found evidence of an increase in heavy precipitation events (exceeding 2 inches per day) in the U.S. A subsequent analysis found increasing trends in the contribution of the highest tenth percentile amounts to the annual precipitation total (Karl and Knight 1997). This results both from an increase in intensity and an increase in the total number of raindays over the U.S. Similar results were found for the PRC, Australia, and the former Soviet Union. Kunkel et al. (1999) also examined heavy precipitation trends in the U.S. and

found that heavy multi-day (7-day) precipitation events are also increasing. Extreme temperature events are also an area of concern and Easterling (1999b) found evidence of changes in the occurrences of days above and below specific threshold temperatures. He found decreases in the number of days below freezing for the 20th century over the entire U.S., and regionally found the strongest decreases in the West and Northwest regions, with increases occurring in the Southeast U.S. Trends in days above 90F were found to be largely affected by the Dust Bowl era droughts of the 1930s which lead to an overall decreasing trend over the country. However, the West and Northwest regions show evidence of increases while the Central and Southeast regions show evidence of decreases. These patterns are largely consistent with the patterns of annual temperature changes in the U.S. with most of the country showing warming over the 20th century, but the Southeast U.S. having a cooling trend (Karl et al. 1996).

A final area of research discussed here is best categorized under Task 3.

Downscaling is a term that refers to a suite of techniques designed to provide higher resolution output than the climate simulation input. Karl, et al. (1990) introduced a method that develops transfer functions between free-atmosphere data and surface data, then applies these transfer functions using free-atmosphere data using a general circulation model simulation to project surface variables such as temperature and precipitation. Easterling (1999a) has taken this methodology and extended it using surface data for a number of observing stations to develop regional climate change scenarios for use in climate impacts work.

Concluding Remarks.

The NCDC has had a long and productive experience in this project which has allowed us to develop a number of unique high quality climate data sets that have been used extensively by both researchers on this project, and by the larger research community. Lastly, this project has provided critical support for the development of these types of data sets at the NCDC and allowed researchers here to address issues of climate change through the identification of significant long-term climate trends and fluctuations.

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