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RECENT CHANGES OF WEATHER PATTERNS IN NORTH AMERICA

Summary Report for Period

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Principal Investigator

George J. Kukla

Lamont-Doherty Earth Observatory

Palisades, New York 10964

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The research performed under contracts DE-FG02-85-ER60372-A through E, has been carried out as a cooperative study by George Kukla (Columbia University) and Thomas Karl (National Climatic Data Center). The focus of the research effort has been, in combination with climate models, to understand the nature of the ongoing climate change primarily over the North America continent and the surrounding oceans. Our goal has been to identify to what degree the ongoing global climate change is attributable to natural as opposed to man made causes (MacCracken and Kukla, 1985). The following presents a brief overview of our results.

Several unique, quality adjusted data bases containing maximum and minimum surface air temperatures, the diurnal range, precipitation and cloud observations as well as upper air observations have been compiled over the course of this research. They have been made available through the National Climate Data Center (NCDC) as well as CDIAC of the Oak Ridge National Laboratory. The data for the Historical Climatology Network (HCN) for example, has been adjusted taking into account changes in station locations, instrument height, observing times (Karl et al., 1986a; Karl et al., 1986b; Karl and Williams, 1987). Increases in urbanization have also been addressed (Kukla et al., 1985; Kukla et al., 1986; Karl et al., 1988; Jones et al., 1989).

The decreasing diurnal temperature range especially in summer and autumn between 1941-1980, was first observed from stations in North America (Karl et al., 1984; Karl et al., 1985). Subsequently, a decrease in the range has also been reported for the former USSR and China (Karl et al., 1991; Kukla and Karl, 1992a; Kukla and Karl, 1992b; Kukla and Karl, 1993; Kukla et al., 1994). In these two regions there was also found to be substantial decrease in the seasonal and annual temperature extremes. Additional analysis for other countries covering 50% of the Northern Hemisphere and 10% of the Southern Hemisphere land masses have shown that minimum temperature increased at a rate three times that of the maximum over 1951-1990 (Karl et al., 1993).

Earlier work (Kukla et al., 1985; Karl et al., 1986a) pointed to factors other than precipitation contributing to the decrease in the range. Daily temperatures stratified by cloud amount, dew point and wind direction were analysed for 14 U.S. stations (Karl et al., 1987). The data show that between 1948-1983 minimum temperatures and the temperature range increased under overcast conditions. The results are unrelated to humidity or wind direction and pointed to the complex role clouds have in the climate system. The decrease in the temperature range over the contiguous U.S. was later found to be statistically related to increasing cloud cover (Kukla and Riches, 1989; Plantico et al., 1990). The increase in cloud cover was associated with lower cloud ceilings. The decrease in the temperature range appears to be related in part, to an observed increase in cloudiness but has also been shown to be sensitive to snow cover, thermal advection, surface stability, global radiation and relative humidity (Karl et al., 1995a). The ultimate cause for the change in the temperature range however, still remains unknown.

An international Minimax Workshop (27-30 September 1993, College Park, Maryland) was convened (Kukla et al., 1994; 1995a) to study various aspects of the changing diurnal range on a global scale. This effort initiated widespread effort in developing relevant time series covering additional geographic locations which continues today (Weber et al., 1994; Kumar et al., 1994; Turkes et al., 1996; Xie and Cao, 1996; Onate and Pou, 1996; Brazdil et al., 1996; Przybylak, 1997; Sun et al., 1999).

We compared temperature observations of maximum, minimum and the range in three regions of the U.S. with the control runs of three GCM's. Overall the models simulate a considerably smaller diurnal temperature range (Kukla et al., 1995b). Several models, for example, (Cao et al., 1992, Rind et al., 1989a) have simulated the projected change in the DTR to be a very small decrease relative to the large mean temperature increase for doubled CO₂. As yet current model and observational deficiencies make this a difficult problem to resolve. Recent work by Groisman et al., in

press indicates that large discrepancies between observations and GCM simulations of the diurnal cloud/temperature associations are found in some models particularly in the warm season.

When analyzing the trends of the surface air maximum and minimum temperature in North America between 1950 and 1990 we noted an inverse correlation between trends of temperature and industrial emissions of SO₂ which enabled an empirical estimate to be made of the impact of aerosols on air temperature (Karl et al. 1995b; Ramaswamy et al. 1995). In cooperation with climatologist J. Dessens we further tested whether a similar feature is also present in Europe. Using a limited amount of stations we found that the maximum daily temperatures in France were lower during the times of high industrial sulfur emissions than during intervals of moderate emissions.

Trends of seasonal surface air temperature compared with those of the free atmosphere between the 500 and 850 mb level in several geographic regions of the contiguous United States over the 1948-86 interval showed a slight relative warming of the mid troposphere with respect to the surface in winter. Relative cooling of the upper air was found in the West in summer and slight warming in the East. No differences in trends were noted between the upper air and surface temperature for the transitional seasons (Gavin et al., 1989).

Because of the discrepancy between the GISS general circulation model results on the onset of the last glaciation compared with the paleoclimate evidence (Rind et al., 1989b), we paid increased attention to the climatology of the precipitable water over the globe particularly in the vicinity of North America. We found that the concentration of atmospheric water vapor has a pronounced seasonal cycle which is significantly delayed behind the insolation forcing. Using dew point temperatures at the 850 mb level as a proxy for the precipitable water cycle, we found that the seasonal cycle of the water vapor greenhouse forcing shows intriguing relationships with the orbital changes over the past 150 millennia and we concluded that the greenhouse cycle plays a significant feedback

reinforcement of orbital changes in the Pleistocene climate variations (Kukla and Karl, 1991).

In order to make comparisons with the expected impacts of CO₂ we have analysed the latitudinal temperature trends over periods of various lengths as limited by reasonably complete available observational data (Kukla et al., 1998). This updates our earlier study (Kukla et al., 1992; Kukla, 1993) showing a meridional temperature gradient between the low and the high latitudes (cf. also Angell, 1991) and an oscillatory increase of the temperature gradient between the relatively warm springs and relatively cool autumns. The meridional temperature gradient increased especially in boreal autumn between 1920-1994 and 1945-1994. Available evidence suggests that precipitation decreased in the low latitudes but increased in the northern high latitudes especially in late autumn and winter (1945-93). The average annual mean global temperature increased during the same time periods but the warming is not uniform, resulting in the increase of the boreal temperature gradient in autumn. Increased storminess and the increased transport of water vapor from the low latitudes to the high latitudes observed by others may be related to the increased gradient.

Some of these observations are at variance with the predicted impact of increasing CO₂ as simulated by atmospheric climate models. However, several features of the ongoing climate change are not inconsistent with the hypothetical climate scenario of the late part of the last interglacial (Kukla et al., 1992). As recently shown (Kukla, 1997 and Kukla et al., 1997) the last interglacial environments in the middle latitudes lasted considerably longer than the elapsed part of the Holocene. This has important repercussions for understanding the mechanism for climate change. It has been convincingly shown that the climate settings are developing in response to Milankovitch forcing. These are currently similar to those of the declining phases of last interglacial (Kukla, 1991; Kukla and Went, 1992). During the late last interglacial, the insolation to the top of the atmosphere (TOA) decreased at high and increased at low latitudes. It decreased in boreal autumn and increased

in spring. The equator to poles insolation gradient decreased in spring but increased greatly in autumn. Such a shift could lead to warming of the low latitudes and cooling of the high latitudes, enhancing the temperature gradient and leading to increased precipitation in the Arctic in autumn and winter (Kukla and Gavin, 1992; Kukla, 1993). As similar, slow insolation redistribution is taking place currently, we are concentrating on the further analysis of the atmospheric and oceanic changes in the North Atlantic area and their potential link to insolation.

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