DOE/ER/60372--7

DE92 014342

DOE/ER/60372D-1

DOE/ER/60372-7

RECENT CHANGES OF WEATHER PATTERNS IN NORTH AMERICA

PROGRESS REPORT FOR PERIOD

8/15/91 - 4/1/92

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April 1992

Prepared for

The U.S. Department of Energy

Carbon Dioxide Research Division

AGREEMENT NO. DE-FG02-85-ER60372

OBJECTIVES

1) To analyze the time related changes and variability in the property and frequency of air masses and the weather extremes over North America.

2) To determine to what degree the observed changes agree with the predictions based on climate models.

RATIONALE

Climate models predict a general increase of surface air temperature and drought over parts of the North American continent due to increased CO_2 concentrations. Regional climate change results in part from the changed frequency of the atmospheric and oceanic circulation patterns and partly from the changed properties of the different air mass types.

We plan to investigate the changing frequency and properties of the air mass types focusing on moisture dependent variables and comparing the findings with the results of numerical climate models.

DATA BASES

In the current first year of the project we have worked on the data selection and quality checks of the combined United States-Canadian upper air data set. Out of a considerably larger data base we are now estimating that data for approximately 70 stations will be sufficiently complete. The file contains twice-a-day information on key upper air atmospheric parameters at several pressure levels and is merged with daily surface data. Most records begin in the second half of the 1940's. We plan to have the data base ready for analysis and delivery to the Oak Ridge data depository by the end of the current funding period.

RESULTS TO DATE

We have continued with the study of the decreasing diurnal temperature range which is a dominant trend observed in the stations not only in North America but also in the former USSR and in China (Karl et al., 1991; Kukla and Karl, 1991).

We have compared the mean daily minimum and maximum temperatures simulated by an atmospheric general circulation mixed layer ocean model with the observed seasonal temperatures in the northern and southern Great Plains, eastern midwest and Great Lakes in the United States. The observations are based on mostly rural stations from the HCN network. We found that the simulated mean daily maxima over all regions and seasons averaged 1.6°C lower than those observed during the 1966-1975 decade. This decade was selected for comparison because the CO_2 concentrations as recorded at the Mauna Loa station during this period were closest to the 326 ppmv used in the model's 1 x CO_2 run. The largest difference occurs in spring, with the maximum temperature colder by to 4.2°C in the simulation. However, the model minima are about 5-7°C higher than those observed. The underestimation of mean maxima and overestimation of the minima gives a diurnal temperature range that is about 5°C smaller than the observed one. This points to a potential problem in the construction of the model, especially with respect to its handling of atmospheric water vapor. Another factor contributing to the observed difference could be the impact of tropospheric aerosols which may cool the surface, especially in summer. The impact of aerosols was not included in this model.

Both the recently observed temperature trends as well as the 2 x CO_2 minus 1 x CO_2 show a decrease of the diurnal temperature range. The observed rate of the decrease over time however, is considerably larger than the corresponding portion of the 2 x CO_2 minus 1 x CO_2 difference (Kukla et al., in print (a)).

The conclusion has to be drawn that either the current temperature change is to a large degree caused by variables other than CO_2, or the models incompletely portray some of the feedback mechanisms which could augment the CO_2 impact (such as e.g. the cloud feedbacks). Another possibility is that an increase in cloud condensation nuclei due to the industrial sulphur emissions may lead to thicker cloud cover resulting in the reduction of the daily maxima and increase of daily minima. We are further investigating potential causes of the discrepancy. We are also expanding the study to include other models which have the diurnal temperature cycle.

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., 1989), we have 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 seasonal insolation forcing. Using dew point temperatures at the 850 mb level as a proxy for the precipitable water cycle, we found that the cycle of the water vapor greenhouse forcing shows intriguing relationships with the orbital changes over the past 150 millenia and we concluded that the greenhouse cycle had at least a contributory role in the Pleistocene climate variations (Kukla and Karl, 1991).

When analyzing the geographic pattern of the current 1945-1986 surface air temperature trends over USA and the rest of the globe, we noted a qualitative resemblance to some aspects of the ongoing insolation shifts. However, the insolation changes are in quantitative terms negligible and can not have caused the recently observed trends which are instead understood as reflections of the oscillations of the atmospheric and oceanic circulation along a stationary long term mean. However, in the long run the interference of the small insolation trends with random internal climate oscillations could eventually move the system into a different mode of operation (Kukla et al., in print (b)).

In our ongoing work we are concentrating on the CO_2 impact on the North American continent, assuming that the increasing greenhouse forcing will affect both the general circulation of the atmosphere, as well as the air mass properties.

RESULTING PUBLICATIONS

Karl, T., G. Kukla, V.N. Razuvayev, M.J. Changery, R.G. Quayle, R.R. Heim, Jr., D.R. Easterling and C.B. Fu. 1991. Global Warming: Evidence for asymmetric diurnal temperature change. Geophys. Res. Lett. 18: 2253-2256.

Kukla, G., and T. Karl. 1991. Seasonal cycle of insolation and climate change. Proceedings of the Sixteenth Annual Climate Diagnostics Workshop, National Oceanic and Atmospheric Administration, Univ. of California, Los Angeles, October 28-November 1, 1991, P. 215-222.

Kukla, G., J. Gavin, T. Karl, and M. Schlesinger. (in print (a)). Comparison of simulated and observed temperatures over regions of the United States. Abstract. Second International Conference on Modeling of Global Climate Change, Hamburg, 1992.

Kukla, G., R. Knight, J. Gavin, and T. Karl. (in print (b)). Recent temperature trends: Are they reinformced by insolation. NATO ARW, Springer-Verlag.

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Rind, D., D. Peteet, and G. Kukla. 1989. Can Milankovitch orbital variations initiate the growth of ice sheets in a general circulation model? J. Geophys. Res. 94: 12851-12871.

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