METEOROLOGY

Solar Activity and the Weather

from a Correspondent

A SYMPOSIUM on "Possible Relationships Between Solar Activity and Meteorological Phenomena" was held at the Goddard Space Flight Center (GSFC) on November 7–8, sponsored by NASA, in cooperation with the University Corporation for Atmospheric Research (UCAR) and the American Meteorological Society. In his welcome and opening remarks, J. C. Fletcher (NASA) dedicated the symposium to C. G. Abbot for his pre-eminent pioneering work in the measurement of the solar constant and the search for solar–meteorological relationships. Dr Abbot, who in 1972 celebrated his one hundredth birthday, was present in the audience.

In the two opening papers W. O. Roberts (UCAR) and J. Wilcox (Stanford University) reviewed some of the statistical evidence to suggest a meteorological and climatic response to variations in solar activity. The statistical evidence presented includes:

(1) The recurrence of droughts in the high plains of the United States related to the double sunspot cycle of 22 yr.

(2) An increase in meridional circulations and blocking patterns at high and intermediate latitudes, especially in winter, generally related to high solar activity.

(3) Glacier advances and other indicators of cold climate in late glacial and post-glacial time occurred during intervals of weak solar activity, and a similar percentage of glacier recessions and warm climate indicators occurred with high solar activity.

(4) In some regions of the globe the atmospheric pressure increases after geomagnetic storms, whereas in other places the pressure decreases. The reaction time is about 3 d and tends to increase with decreasing latitude.

(5) High latitudes show higher average pressures at sunspot maximum than at minimum and at high solar activity there is a mass displacement of air toward high latitudes.

(6) Developing 300 mbar low pressure trough systems entering or forming in the Gulf of Alaska 2 to 4 d after a sharp rise in geomagnetic activity tend to be larger than average size, and the vorticity area index of these trough systems reaches a maximum about 1 d after the passing of a solar magnetic sector boundary, followed by an increase of magnitude approximately 10% during the next 2 or 3 d.

(7) The mean change in height of atmospheric constant pressure levels during the first 24 h after a flare is greater than may be expected from mere random fluctuations in height.

(8) Significant increases in westerly winds at the 700 mbar level in the longitude belt from 90° W to 180° occur ~3 or 4 d after magnetic storms.

(9) Thunderstorm activity has been correlated with the Earth's position in a solar magnetic sector and solar hydrogen-α flare activity.

A. J. Dessler (Rice University) discussed some problems in coupling solar activity to meteorological responses since most geophysical phenomena have a high intrinsic noise level and there is no acceptable mechanism to help organise the data into a manageable search. The energy provided by meteorological phenomena is (essentially) entirely provided by sunlight. The solar constant is about 10^6 erg cm^{-2} s^{-1}. The available energy flux to the atmosphere of the solar wind and the interplanetary magnetic field for undisturbed conditions is less than one millionth of that of the solar constant, and the meteorological response, related to solar activity energy variations, of less than 0.1 to at most 10^3 erg cm^{-2} s^{-1}. So a 'trigger mechanism' is envisioned since brute force will not work. Dessler discussed the hypothesis of C. O. Hines (University of Toronto) whereby magnetospheric convective motions, which are intensified during magnetic storms, change the vorticity of the lower atmosphere at or near auroral latitudes by viscous coupling. Dessler concluded that there seems to be enough power within the magnetosphere to cause such changes in vorticity, if the power can be directed and coupled effectively.

Another mechanism discussed by Dessler is heating accomplished by direct particle bombardment in the auroral zone. An outstanding intense auroral beam has an energy flux less than 10^{-3} that of sunlight. The heat capacity of the upper atmosphere is so small that the effect of absorbing this energy flux is profound. But the upper atmosphere is thermally isolated from the lower atmosphere by two temperature minima—at the tropopause (15 km) and at the mesopause (80 km). Energy may be converted to forms that can penetrate through these temperature minima to the troposphere, such as infrared radiation and infrasonic waves. But with a power input of only 10^{-3} that of sunlight, Dessler believes it is hard to imagine that the small fraction of this energy that would go into either component would provide a sensible perturbation to the tropospheric system. Roberts believes that a promising trigger mechanism involves the modification of the atmospheric radiation budget through the sudden formation of cirrus clouds at the tropopause following solar activity.

R. C. J. Somerville reported on numerical experiments on short-term meteorological effects of solar variability performed at the NASA Goddard Institute for Space Studies directed by R. Jastrow. The GISS group carried out a set of numerical experiments to test the short-range sensitivity of a large atmospheric general circulation model to changes in solar constant and ozone amount. On the basis of the results of 12-d integrations with very large variations in these parameters, it was concluded that realistic variations would produce insignificant meteorological effects. The GISS study also concluded that any causal relationships between solar variability and weather, for time scales of 2 weeks or less, will have to rely on changes in parameters other than solar constant or ozone amounts, or upon mechanisms not yet incorporated in the model.

W. W. Kellogg (National Center for Atmospheric Research, Boulder) discussed needed measurements and observations including:

- Continuous monitoring of the energy and pitch angle distribution of geomagnetically trapped electrons and protons in order to determine when they are precipitated into the lower ionosphere.
- Monitoring from balloons in the region of the tropopause the incidence of ionising radiation and any accompanying changes of temperature, conductivity, ozone amount or ultraviolet flux.
- Continuous monitoring from a satellite of absolute solar flux in the near ultraviolet, between 2,000 and 3,000 Å.
- Monitoring global ozone distribution in the region above 30 km.
- Observations of wind systems in the mesosphere and lower thermosphere.
- Detection of high latitude cirrus cloud formation through optical techniques or through the effect of a cirrus deck on the upward infrared radiation in the atmospheric window.
- Satellite optical and radio monitoring of global thunderstorm activity.

In his symposium summary S. I. Rasool (NASA) cautioned against the current practice of correlating solar variations with localised, isolated weather effects instead of global responses. He stressed the importance of the stratosphere as a buffer for solar-meteorological responses and commented that due to its tremendous inertia the relaxation time of the troposphere is so large that short-term tropospheric responses to solar variations cannot be easily identified.