INFLUENCE OF SOLAR WIND VARIABILITY ON THE RECURRENCE OF DROUGHTS

(Research Note)

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Abstract. The observed effects of solar flares and interplanetary sector crossings seem to indicate that particle precipitation in the Earth's upper atmosphere decreases cyclonic activity in the troposphere. As an extrapolation to longer term effects, it is suggested that the recurrence of prolonged periods of enhanced solar wind particle precipitation in the upper atmosphere during alternate solar minima could cause the recurrence of extreme droughts.

There is at present evidence of a 22-year rhythm of drought in the western United States, that is related to the Hale solar cycle since the 17th century (Mitchell *et al.*, 1979). In this note, a plausible physical reason for such a relation is suggested, whereby solar wind particle precipitation influences the tropospheric circulation in such a manner as to encourage the onset of droughts.

Significant solar cycle variability is manifested in the ultraviolet component of solar radiation (Heath and Thekaekara, 1977), as well as in the solar wind (Feldman *et al.*, 1978) and magnetic field (Babcock, 1961). All of these could possibly influence the dynamics of the terrestrial atmosphere. Variation in UV radiation occurs with a 11-year periodicity and hence cannot be a reason for the 22-year periodicity of droughts. Though the structure of the solar wind also varies with a 11-year period (Hundhausen, 1977) the combination of such a variability with the 22-year periodicity in the orientation of the interplanetary magnetic field (IMF) (Svalgaard and Wilcox, 1976) may well produce a net 22-year periodicity in the amount of solar wind particle energy penetrating into the upper atmosphere of the Earth. The 22-year periodicity seen in geomagnetic activity (Chernosky, 1966; Svalgaard, 1977) could be considered as evidence for such an effect. Let us, therefore, examine the influence of both, particle precipitation and magnetic field, in more detail.

It would be instructive to look at the effect of upper atmospheric particle precipitation on the circulation of the troposphere, occurring on short time scales. Solar flares, for example, do seem to induce changes in the pattern of tropospheric circulation both as early effects (6 hr after flare out burst) and delayed effects, e.g. a decrease in the vorticity area index (VAI), 3 to 4 days after the flare (Olson *et al.*, 1975). The physical processes responsible for these phenomena are not well understood. Schuurmans (1979) has, however, suggested that solar flare particles penetrating the atmosphere might create heat sinks and cause mass flow around such sites. According to him, the delayed effects

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might be a result of increased short wavelength baroclinic stability consequent to the onset of flows around the heat sinks. Such increased stability quenches the development of short wave extra-tropical cyclones and may be a reason for the decrease in VAI. The net effect of particle deposition thus seems to be the creation of anticyclonic patterns in the troposphere and the increase of short wavelength stability of the atmosphere. The early effect of a flare is seen to attain a maximum about 6 hr after the flare (Schuurmans, 1979), whereas the arrival time of flare generated shock waves and enhanced magnetic fields is between 20 hr to 55 hr (Hundhausen, 1972). Hence the relative importance of the role of the magnetic field enhancement in producing the effect mentioned above, as compared to that of particle deposition does seem to be small. It must be mentioned that flares as such cannot produce long term effects since they are not frequent enough (Livingston, 1979). However, observing the effect of flares can help in understanding the effects of particle precipitation.

Yet another phenomenon that occurs on a short time scale and produces significant effects on tropospheric circulation is the passage of interplanetary magnetic sector boundaries across the Earth. It is now well established that the VAI computed for each hemisphere reaches a minimum one day after a passage (Hines and Halevy, 1977; Roberts, 1979; Wilcox, 1979). Sectors are often accompanied by high speed solar wind streams (Hundhausen, 1977) which possess larger kinetic and total energy flux than the normal solar wind (Feldman *et al.*, 1978). Therefore, even in the case of sector passage, the observed decrease in VAI can be attributed to the Schuurmans mechanism. The possibility of magnetic influence cannot be ruled out since sectors accompanied by enhanced IMF seemed to produce twice the average effect (Wilcox, 1979). However, the fact that sector crossings unaccompanied by any significant IMF enhancements also produced the effect on VAI somewhat weakens the case for a predominantly magnetic influence.

These short term effects thus clearly illustrate the manner by which particle precipitation can influence tropospheric circulation. On a larger time scale, the solar wind structure does seem to change from a disorganised state at solar maximum to a highly organised one consisting of a stable pattern of high-speed streams at solar minimum (Hundhausen, 1977). The width of high-speed streams increases during minimum resulting in the Earth being submerged within high speed streams for 50% of the 27-day solar rotation period during minimum as compared to less than 10% during maximum. The kinetic energy and total energy flux of the solar wind at 1 AU are also larger by a factor of 1.5 during minimum (Feldman *et al.*, 1978). Such a recurrence of larger durations of enhanced particle precipitation would induce the troposphere to be organised into anticyclonic patterns to a larger extent. The creation of anticyclonic patterns over large areas is precisely the condition necessary for the onset of major continental droughts (Namias, 1979). The role of the IMF could then be to allow more precipitation when it is pointing away from the Sun than when it is pointing towards the Sun. The effect of IMF orientation is seen in the case of short-term effects for example from the observation that the area of troughs over the Gulf of Alaska is more when the IMF is away as compared to the area when it is towards the Sun (Wilcox, 1979). Also, more solar electrons were seen to penetrate the atmosphere when the IMF was pointing away from the Sun (Yeager and Frank, 1976).

If particle precipitation indeed had a significant influence, then other terrestrial effects related to the recurrence of enhanced particle precipitation ought to be highly correlated with the recurrence of droughts. In fact, Sargent (1979) found that the duration of high amplitudes of the geomagnetic recurrence index had a 22-year periodicity. Moreover, the epochs of extended duration were found to match well with those of extreme drought. Sargent (1979) advocated a search for a physical explanation for the fact that the presence of the prolonged periods of organised solar wind is related to the presence of prolonged periods of well-ordered tropospheric circulation characteristic of droughts. The enhanced particle energy flux and the extended duration of this flux in the solar wind during minima, coupled with the 22-year modulation in particle penetration caused by the IMF could well produce a modulation in the Schuurmans mechanism leading to a corresponding periodicity in the probability for droughts.

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