for 1882–1973 shows a marked peak near 11 years. The 23-year peak may well be related to the double sunspot cycle.

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551.521.14 : 551.577.38 : 551.585.53

Comment on the Paper 'Dynamics of Deserts and Drought in the Sahel' by J. G. Charney

By E. A. Ripley

The idea that the recent drought in the Sahelian zone of Africa can be at least partially blamed on overgrazing of the area by sheep and goats (Charney 1975) is an attractive one. If proven, the hypothesis could lead to the inclusion of these animals in man’s arsenal of weather modification weapons. However, before carrying out a general slaughter of these ubiquitous creatures throughout the Sahel and persuading their former owners to lend their hands to the green revolution, perhaps this hypothesis should be examined more carefully.

Charney’s argument seems to be that vegetation absorbs more solar radiation than desert, thus becoming hotter during the day, resulting in enhanced convection, and hence greater rainfall, over the vegetated areas.

If my interpretation is correct, the above hypothesis appears to be inconsistent even with Charney’s own observation that ‘Desert surfaces are hotter than surrounding regions’. Anyone who has walked barefoot on a beach on a sunny day knows that dry sand, in spite of its higher albedo, is much hotter than wet sand.

Those working in the surface boundary layer have found that vegetated areas are indeed cooler
than adjacent non-vegetated areas, under sunny conditions, even if the two have similar albedos. The explanation lies in the conversion of a considerable part of the available energy to a latent form, by the evaporation of water from the vegetated surface. In order to support the vegetation, needed by Charney to effect the albedo change, a considerable amount of water is also required, the evaporation of which would consume a large fraction of the available energy.

It is fortunate that this is so, as most plants are unable to tolerate temperatures as high as those found on desert surfaces during the day. For instance, Geiger (1965) has reported desert surface temperatures in excess of 50°C. Even the remarkable Tidestromia oblongifolia Wats (Standl.), a herb native to Death Valley, California, is forced to reduce its photosynthetic rate considerably at temperatures above 50°C (Björkman et al. 1972). This temperature is close to the upper limit of plant survival, as higher temperatures result in enzyme denaturation (Salisbury and Ross 1969).

Charney has proposed that the lower net radiation, which is even negative (Charney, Fig. 1) on average for most of the Sahel in July, requires a reduction in sensible heat flux from the surface to the air, resulting in suppression of convection and associated precipitation. While a reduction in sensible heat flux may be found on the average over a 24-hour period, during the daytime, the warmer desert surface probably transfers more heat to the air than its vegetated counterpart. This warming is apparently more than compensated for, on a diurnal basis, by the night-time cooling. Davies (1967) found that the relationship between daytime net radiation and solar radiation was similar for a sand surface at Dakar and grass surfaces in southern Nigeria.

Many investigators (for example, Van Bavel and Fritschen 1965 and McCulloch et al. 1965) have compared wet, or vegetated, surfaces with adjacent dry surfaces and found that in spite of greater net radiation over the wet or vegetated surfaces, daytime sensible heat flux to the atmosphere was greater for the dry surfaces. In a comparison of adjacent grazed and ungrazed areas in northeastern Uganda, McCulloch et al. (1965) measured albedos of 0.20 and 0.15 for the grazed and ungrazed area, respectively. Daytime net radiation average (over 4 days) 1256J cm⁻² for the grazed area compared with 1549J cm⁻² for the ungrazed area. In spite of the lower net radiation, the grazed area had a mean effective radiative surface temperature of 34-7°C compared with 29-2°C for the ungrazed area.

Thus, on the bases of actual measurements and energy-balance considerations, including evaporation, one should expect enhanced daytime convection over desert areas compared with adjacent vegetated areas, i.e. a negative rather than a positive feedback effect as was proposed by Charney. Other aspects of this work have been discussed in a comment by Ripley (1975) on a paper by Charney, Stone, and Quirk (1975).

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Department of Plant Ecology, University of Saskatchewan, Saskatoon, Canada.
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Professor Ripley's criticism is based on a misunderstanding. I have nowhere argued, as he maintains in the second paragraph of his comments, that because vegetation absorbs more solar radiation than desert, it necessarily becomes hotter during the day. What I did say in my Q.J. article is that a decrease of albedo due to an increase of desert vegetation will result in a net heating of the desert air relative to its surroundings. I believe this to be true whether or not evaporation occurs, but I do not disagree with his assertion that if an increase of vegetation decreases the albedo, increased evapotranspiration can more than absorb the increase of solar radiation and thereby cause the surface temperature to decrease. The essential point is that the total energy, sensible \((e_p T)\) plus latent \((Lq)\), will still increase. This will cause a steepening of the lapse-rate of moist static energy, \(e_pT + Lq + gz\), and an increase of convective cloud and precipitation. The solar energy used for evaporation will then be released as sensible heat and the mean air temperature will increase. In the general circulation model used for our numerical simulations, the time constants for moist convection were so small and the air so wet and unstable that the condensed vapour did fall out as precipitation.

The above considerations apply to the moist atmosphere simulations reported in the second part of my article, not to the theoretical model calculations discussed in the first part. Ripley's misunderstanding may have arisen from the fact that the latter model applies only to a dry desert atmosphere in which an increase of albedo does result in a decrease of both surface and upper air temperature. In constructing this model I was concerned only to show that a high desert albedo implies relative cooling, sinking and drying of the air, and to resolve the paradox that the air aloft can sink relative to its surroundings even though the desert surface is hotter than its surroundings. The resolution comes from just the consideration that the surroundings are wet, so that solar radiation is used to evaporate moisture as much as to heat the surface, and that when this moisture later condenses as convective precipitation, it releases latent heat to the atmosphere, not to the ground, and thus maintains the approximately moist-adiabatic vertical temperature distribution which is prescribed at the desert boundaries of my model. In consequence, the dry desert air with its more nearly dry-adiabatic low-level lapse-rate becomes hotter than the boundaries at low levels but colder aloft, and the lower air rises while the upper air sinks.

The simplified theoretical model does not suffice to determine the detailed effects of changes in albedo in the marginal areas because it does not provide for the moisture intermediary in distributing the solar energy. Thus, as Ripley states, it does not determine the correct surface temperatures. But it remains the case that an increase of albedo causes net cooling and a reduction of vertical velocity and precipitation, in both the theoretical model and the simulations with a quite sophisticated general circulation model.

A somewhat more detailed statement has been sent to Science in reply to similar comments by Professor Ripley on the paper by Charney, Stone and Quirk.

Department of Meteorology,  
Massachusetts Institute of Technology,  
Cambridge,  
Massachusetts 02139,  
5 November 1975