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**Comments on "Spatial Variation of Net Radiation, Albedo and  
Surface Temperature of Forests"**

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Federer (1968) has demonstrated that spatial variation need not be of major concern in sampling net radiation over uniform plant canopies. During his discussion of radiative exchange, however, he estimated albedo and net infrared radiation through an erroneous interpretation of the linear regression used to relate net

radiation  $R_n$  to downward solar radiation  $R_{sd}$ . The resulting error may illustrate the problems encountered in attempting to represent a process by means of an inadequate statistical model. This comment will evaluate the errors involved in Federer's method of estimating albedo and net infrared flux, and will demonstrate that the errors can be serious under certain conditions.

Federer pooled summer, fall and winter radiation observations over a deciduous forest to calculate the regression of  $R_n$  on  $R_{sd}$  as

$$R_n = 0.83R_{sd} - 0.13, \quad (1)$$

with a standard error of  $0.032 \text{ ly min}^{-1}$ . He also cited the accepted definition of  $R_n$  in terms of its radiative components, i.e.,

$$R_n = (1-a)R_{sd} + R_{id} - R_{iu}, \quad (2)$$

where  $a$  is the surface albedo, and  $R_{id}$  and  $R_{iu}$  are the downward and upward infrared flux, respectively, over the surface. Since the two equations bear an apparent similarity, Federer interpreted the "converse of the slope" in (1) as a mean albedo of 0.17. However, this actually gives the unity complement of the slope, or  $1-0.83$ . He further estimated a mean net infrared flux of  $-0.13 \text{ ly min}^{-1}$  from the constant term in (1). Although Federer qualified these approximations by pointing out that " $R_{sd}$  and  $R_{iu}$  are correlated, i.e., as solar radiation increases, surface temperature also increases," his final summary reports the mean albedo to be 0.17 and the mean net infrared flux to be  $-0.13 \text{ ly min}^{-1}$ .

Such estimates of mean albedo and mean net infrared radiation are in error if the net infrared radiation varies during the averaging period. Since the net infrared flux is related to surface temperature, it will vary over any surface, such as bare dry soil, that exhibits large temperature fluctuations. Significant changes in the infrared exchange can also occur over vegetated surfaces. An analysis of the errors introduced by neglecting the change in net infrared radiation will demonstrate the problems that could result from a general application of this approximation technique to other data.

The error involved in estimating  $a$  as  $(1-A)$  from a regression of the form

$$R_n = AR_{sd} + B, \quad (3)$$

can be determined by equating (2) and (3) and solving for the albedo

$$a = (1-A) + (R_{id} - R_{iu} - B)R_{sd}^{-1}. \quad (4)$$

The second term in (4),  $(R_{id} - R_{iu} - B)R_{sd}^{-1}$ , is the error that is introduced into the estimate of albedo by treating the net infrared flux as a constant. Similarly, a solu-

tion of (2) and (3) for the net infrared flux yields

$$R_{id} - R_{iu} = B + (A + a - 1)R_{sd}, \quad (5)$$

where the error involved in estimating the net infrared flux from  $B$  in (3) is given by the second term in (5), or  $(A + a - 1)R_{sd}$ . Since these errors are systematic rather than random, they may be reduced but not eliminated by averaging over longer periods of time.

Federer does not tabulate the data needed to solve (4) and (5) in order to compute the magnitude of the errors associated with application of his approximation. Although of interest, the magnitudes of his errors are not of major importance. What does merit our consideration, however, are the errors that may result from the application of Federer's interpretation to regressions developed in more extreme environments.

Let us, for example, examine the data available from Fritschen's (1967) investigation of the radiation exchange characteristics of six irrigated crops during clear summer days near Phoenix, Ariz. Individual crop responses varied from that of alfalfa, which maintained a rather constant net infrared flux, to that of barley which showed a large diurnal change. The summer season regression over barley, in  $\text{ly min}^{-1}$ , was

$$R_n = 0.655R_{sd} - 0.120. \quad (6)$$

The estimated barley albedo would be 0.345 if calculated after Federer from the unity complement of 0.655. This is quite different from the measured mean albedo of 0.23 reported by Fritschen.

It is not possible to check the net infrared estimate directly, as was done for the albedo, because Fritschen did not tabulate the data upon which (6) is based. However, (5) can be solved for  $R_{id} - R_{iu}$  if a reasonable value is assumed for  $R_{sd}$ . A summer clear weather  $R_{sd}$  average of  $600 \text{ ly per 12-hr day}$  is a conservative estimate for the Phoenix area; the exact value is not critical since it will become apparent that the choice of either  $500$  or  $700 \text{ ly day}^{-1}$  would still yield the same conclusion. If  $R_{sd}$  is  $600 \text{ ly (12 hr)}^{-1}$ , or  $0.833 \text{ ly min}^{-1}$ , then (5) yields a mean net infrared flux of  $-0.20 \text{ ly min}^{-1}$  over the barley. This compares with the  $-0.12 \text{ ly min}^{-1}$  derived after Federer from the  $B$  term in (6).

It can thus be concluded that large errors may be involved if the albedo and net infrared flux are estimated from the respective  $A$  and  $B$  constants of regression model (3). This confirms that the simple regression model, although it may be suited for prediction purposes, does not adequately represent the complex radiation exchange process.

#### REFERENCES

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