Albedo of an Old-Growth Coniferous Forest

J. Wade-Murphy,
Kyaw Tha Paw U and Matthias Falk
University of California, Davis

Purpose

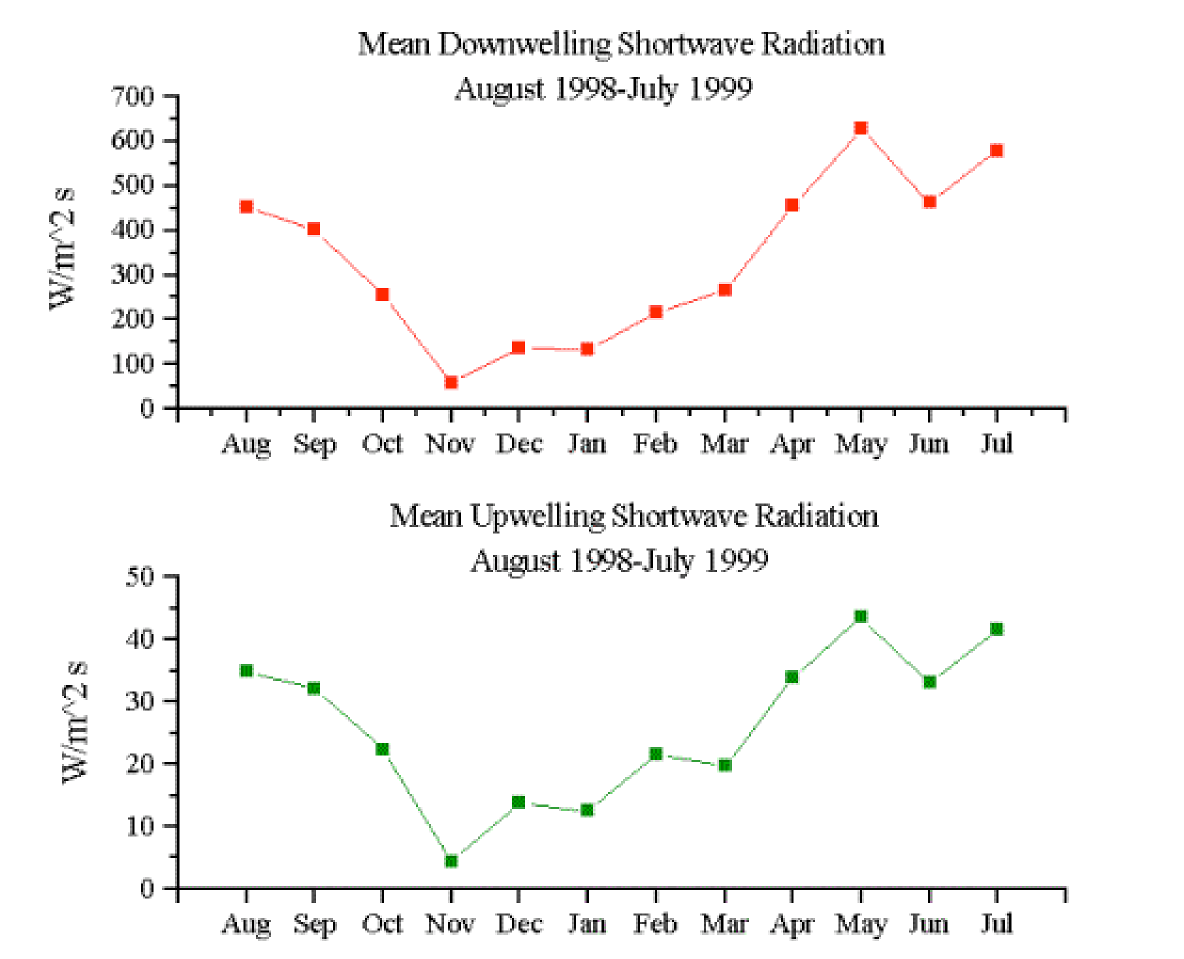
The intent was to calculate albedo in order to more fully understand the microclimatological situation of an old-growth, 65 m tall Douglas Fir and Western Hemlock forest canopy. Albedo illustrates the amount of energy that a forest uses by describing the amount of shortwave radiation that it absorbs and reflects.

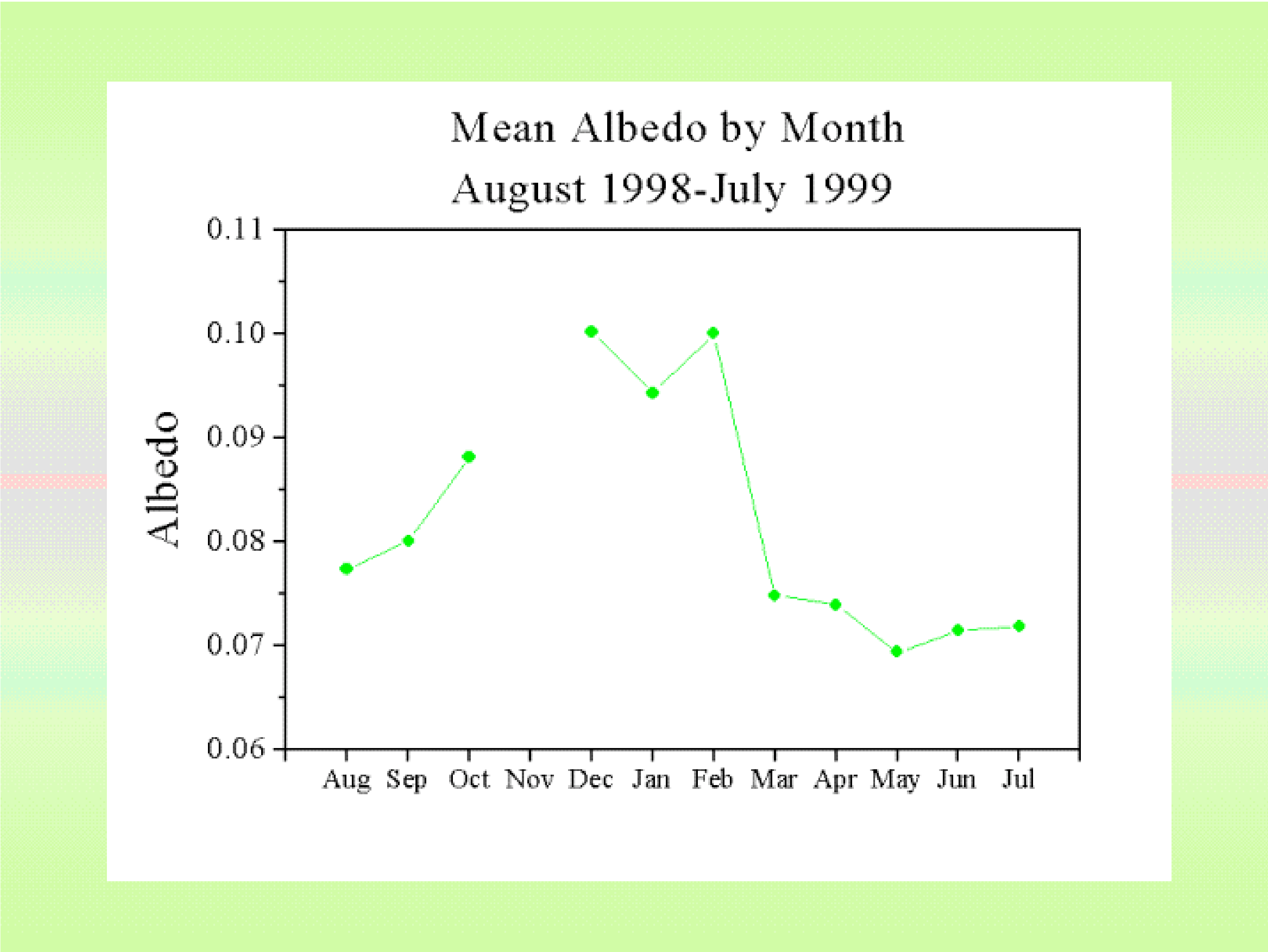
At this time, it is difficult to reconcile the energy budget of especially old-growth stands, so understanding the forest's use of shortwave radiative energy could be useful in attempts to do so.

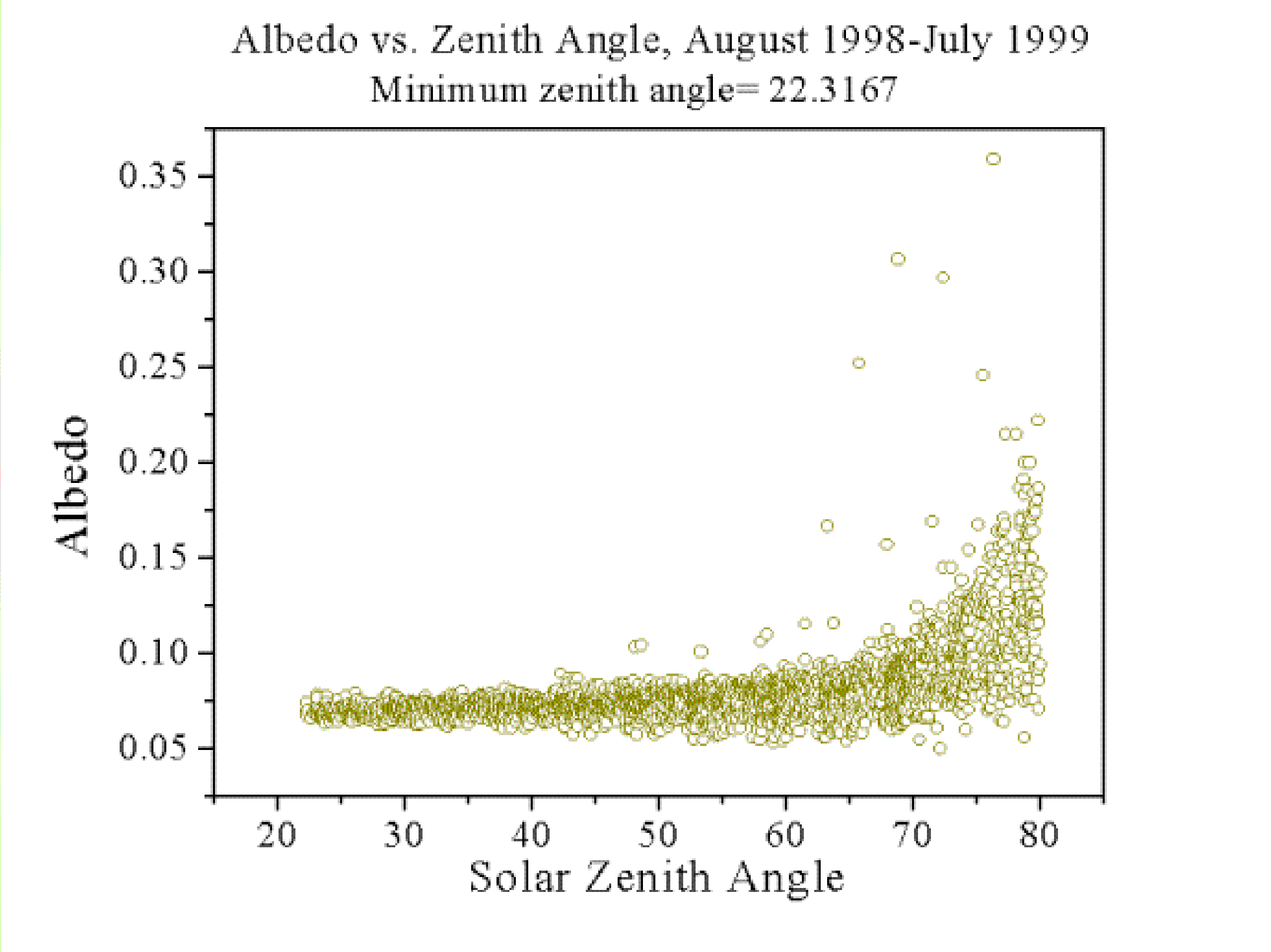
Plan

Albedo is calculated by finding the amount of shortwave radiation (0.3-3 μm) reflected by the forest in relation to how much shortwave radiation is being directed into the forest. Albedo, then is the amount of upwelling shortwave radiation divided by the amount of downwelling. Radiation measurements were made by a Kipp & Zonen CNR 1 Net Radiometer mounted on the arm of the 82 m crane at the Wind River Canopy Crane Research Facility in southwestern Washington, at 45°49′N, 121°58′ W. Measurements are long-term and continuous, and those used in the albedo calculation are from the annual period of August 1998 through July 1999.

The mean albedo was calculated by dividing the average downwelling radiation for the time period by the average upwelling. This method is modeled after Betts and Ball (1997). In calculating these means, measurements from days with precipitation were removed from the data set to exclude variables like snow reflectivity.


Mean Downwelling Shortwave Radiation
August 1998-July 1999
W/m^2 s
0
100
200
300
400
500
600
700
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Mean Upwelling Shortwave Radiation
August 1998-July 1999
W/m^2 s
0
10
20
30
40
50
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul


Mean Albedo by Month
August 1998-July 1999
Albedo
0.11
0.10
0.09
0.08
0.07
0.06
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul

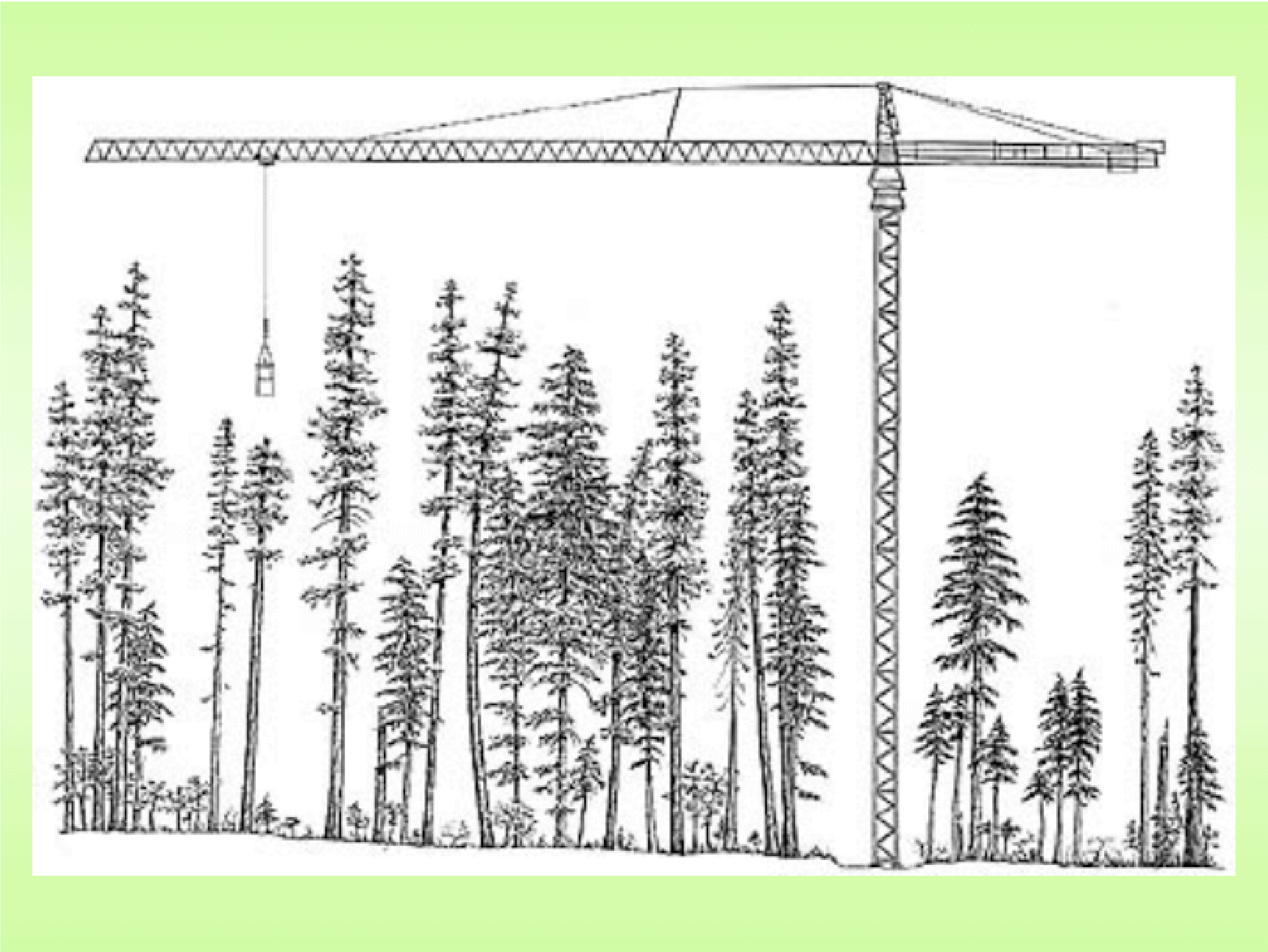


Albedo vs. Zenith Angle, August 1998-July 1999
Minimum zenith angle= 22.3167
Albedo
0.05
0.10
0.15
0.20
0.25
0.30
0.35
20
30
40
50
60
70
80
Solar Zenith Angle

(above) These graphs show the mean amount of shortwave radiation that enters and leaves the forest canopy during the day from August 1998 through July 1999. This data is for days without precipitation.

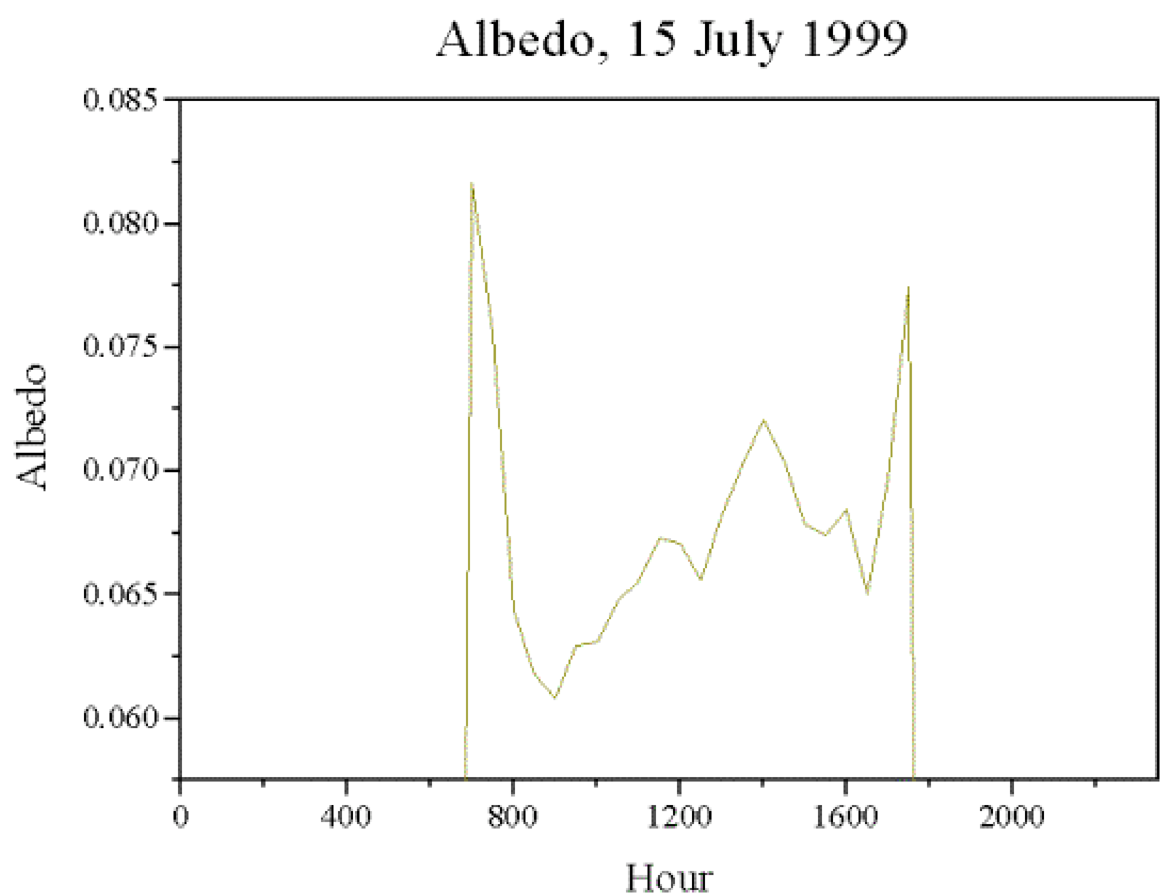
(right) This graph shows the mean albedo by month. The mean albedo for the year period from August 1998 through July 1999 was 7.54%, the lowest published albedo that we know of for long-term, continuous measurements.

(below) For the tall, coniferous forest, greater solar zenith angles lead to higher albedo, meaning that albedo is higher in winter than during the summer. Scatter at high zenith angles may be an artifact of the radiometer's measuring device, or a result of downwelling radiation mistakenly being measured as upwelling due to a slight tilt of the radiometer.



(above) The net radiometer is fixed to an arm that extends horizontally from the highest point of the crane, 20 m above the canopy. It moves with the jib, thereby sampling in all directions, but doing so arbitrarily.

(below) The diurnal cycle of albedo shows that albedo peaks during the time of the sun's greatest solar zenith angles. This may be due to the canopy structure, if it is less able to repel rays that enter perpendicularly. From the morning high, it drops as low as 6.08% during this summer day without water stress conditions.


Albedo, 15 July 1999
0.085
0.080
0.075
0.070
0.065
0.060
Albedo
0
400
800
1200
1600
2000
Hour

Results

The mean albedo for August 1998 through July 1999 was 7.54%, the lowest published albedo encountered for long-term, continuous measurements (see Mukammal 1971, Stewart 1971, Tajchman 1972, Betts and Ball 1997, Ni and Woodcock 2000). The month of May had the lowest mean albedo, 6.9%, while December and February had the highest with 10%. Larger solar zenith angles corresponded to higher albedo.

Conclusions

The extremely low albedo calculated for the Wind River old-growth Douglas Fir and Western Hemlock stand might be due to the height of the canopy. At 65 m, it corresponds well with Stanhill's (1976) description of the relationship between mean albedo and canopy height. Alternately, the rough geometry and topography of the canopy, the dark green color of its needles, and a very high leaf area index may contribute. It would be interesting to make similar measurements at the 40, 20 and 10 year old Douglas Fir stands near the old-growth site to see how the reflectance of shallower, denser stands compare.

References

Betts, A.K., and J.H. Ball, 1997. Albedo over the boreal forest. J. Geophys. Res. 102D: 28,901-28,909.

Mukammal, E.K., 1971. Some aspects of radiant energy in a pine forest. Arch. Met. Geoph. Biokl. Ser. B 19:29-52.

Ni, W. and C.E. Woodcock, 2000. Effect of canopy structure and the presence of snow on the albedo of boreal conifer forests. J. Geophys. Res. 105D: 11,879-11,888.

Stanhill, G., 1970. Some results of helcopter measurements of albedo. Solar Energy 13:69-66.

Stewart, J.B., 1971. The albedo of a pine forest. Quart. J. Royal Meteorol. Soc. 97:561-564.

Tajchman, S.J., 1972. The radiation and energy balances of coniferous and deciduous forests. J. Appl. Ecol. 9:359-375.