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A 24-hour radiation budget at a high-grass marsh in early winter

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A 24-HOUR RADIATION BUDGET AT A HIGH-GRASS MARSH IN EARLY WINTER

INTRODUCTION As with others of the numerous physical factors forming the nonliving environment of terrestrial ecosystems, the upward and downward exchanges of the fluxes of solar (short-wave) and terrestrial (long-wave) radiation often appear in the literature as yearly, seasonal, or monthly averages. Because these tend to present a misleading or incomplete picture of environmental conditions, a 24-hour series of measurements is presented here.

A series of radiation measurements was taken on November 25th and 26th, 1967, at the UWM Cedar-Sauk Field Station (43° 23' N. Lat., 88° 01' W. Long.) to determine the radiation budget at a high-grass marsh in early winter. The marsh in which the measurements were taken is located east of the Field Station laboratory building, occupying a shallow depression which is surrounded by low, wooded hills on the north, south and west, and an elevated roadbed on the east. The ground in the marsh was saturated and unfrozen at the time of the observations and the sedge grass vegetation was three to four feet high, dry, and light in color.

During the observation period, a complete weather system passed over the Field Station. Observations were taken under a variety of sky-cover conditions, from clear to completely overcast and back to clear. They also included periods of light and moderate rain and light snow. The sky was completely overcast from 1430 hours to 2130 hours on November 25th, although initial observations at 1200 hours had been under clear sky conditions. Moderate to light rain fell intermittently between 1430 hours and 1800 hours. Clear sky conditions were observed between 2130 hours on November 25th and 1100 hours on November 26th. From 1100 hours to 1200 hours on the 26th, the sky became overcast again and the observation period ended during a snow-shower. The temperature declined steadily from an initial reading of 9.0 C. (taken 2 meters above the soil surface) to -2.8 C. at 0600 hours on the 26th. After a slight mid-morning increase, it dropped to 0.5 C. at the final reading at noon on the 26th.

Two types of instruments were used to obtain all four fluxes of upward and downward radiation. A Kipp and Zonen pyranometer measured the fluxes of upward and downward short-wave radiation, and a Schulze radiometer measured the fluxes of upward and downward all-wave (short-wave plus long-wave) radiation. Both instruments were read every half-hour during daylight hours while the Schulze radiometer only was read hourly during the period of darkness.

SHORT-WAVE RADIATION Downward short-wave radiation is composed of both the direct solar component and the diffused component, which is the portion of the solar beam scattered by molecules in the atmosphere and reaching the ground from the whole sky. (See Fig. 1)

Upward short-wave radiation is that part of the downward short-wave flux that is reflected from the surface of the earth. The degree of reflection, or albedo, is governed by several factors, the most important being surface texture and color.

Short-wave radiation, which occurs only during the daylight hours, was found to fluctuate over a wide range of values, depending on the amount and density of the cloud-cover. A maximum value of 0.6 ly min^{-1}** was measured for downward short-wave radiation at 1200 hours, November 25th, when the sun was nearest the zenith (zenith angle was 61°). The total downward short-wave flux over the 24-hour observation period was 173 langleys. This value is considerably higher than a 17-year average figure for this season of the year of 112 ly day^{-1} at Madison, Wisconsin, but less than the Madison average for cloudless sky conditions of 196 ly day^{-1} (Piipo, 1929). Various cloud-cover regimes over stations at comparable latitudes have produced daily intensities of 136 ly day^{-1} at Karadag in the Crimean Peninsula (44° 30' N.) and 190 ly day^{-1} at Vladivostok (43° 15' N.), according to observations by Barashkova (1959).

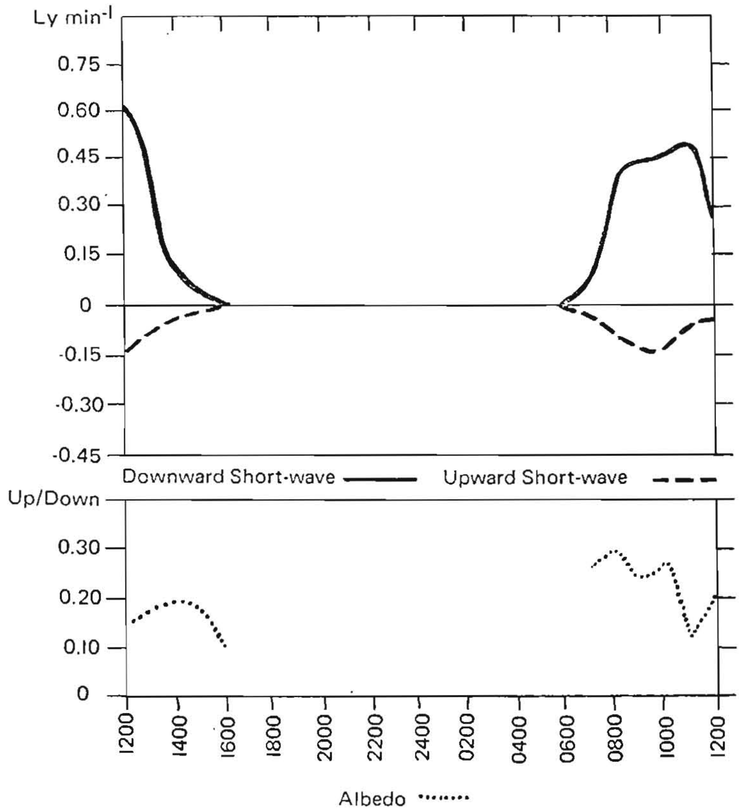
By comparing measurements under clear-sky conditions, latitudinal similarities become more apparent:

Time	*Cedar-Sauk*	*Odessa* (46° 28' N.)
0930	0.47 ly min^{-1}	0.45 ly min^{-1}
1230	0.61 ly min^{-1}	0.64 ly min^{-1}
1530	0.04 ly min^{-1} (complete overcast)	0.20 ly min^{-1}

(Odessa data from Pivovarova-November mean)

**ly or langley: an energy unit equivalent to one 15° C gram-calorie per square centimeter per unit of time, in this case, minute.

Figure 1. Short-Wave Fluxes and Albedo



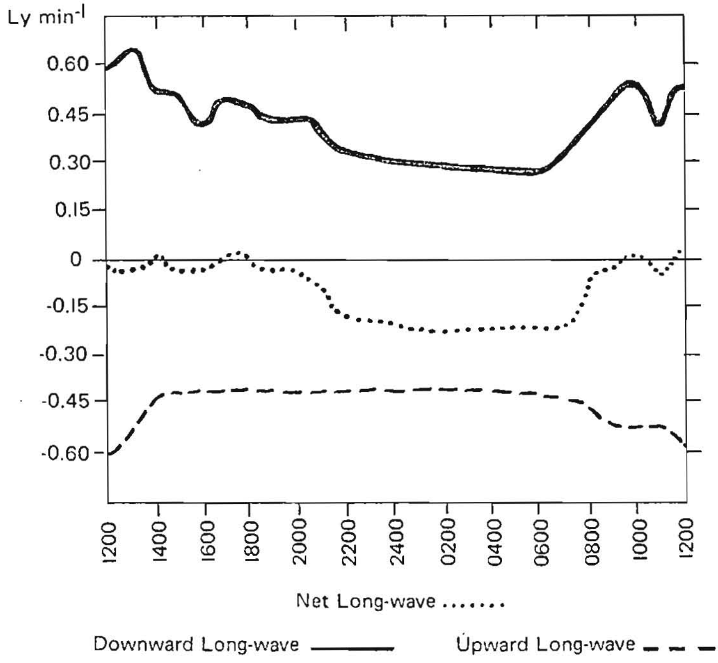
The shape of the curve of upward short-wave radiation is similar to the curve of the downward flux, except on the morning of November 26th, when frost on the grass increased the albedo. Total upward short-wave radiation during the observation period was 38 langleys. The albedo, averaged over the entire period, was 0.22 (the downward short-wave flux divided into the upward short-wave flux= 38/173). This value is in agreement with reported albedos of 0.19 for dry grass (Kondratyev, 1965) and 0.24 for a short clover-grass mixture (Aslyng, 1960). Net short-wave radiation absorbed by the vegetation and soil surface during the observation period was 135 langleys (173 - 38).

LONG-WAVE RADIATION The downward and upward fluxes of long-wave radiation were obtained by subtracting the fluxes of short-wave radiation from the respective all-wave fluxes measured with the Schulze radiometer.

As the energy of long-wave radiation is derived from molecular kinetic energy, all matter having temperatures above absolute zero becomes a source of long-wave radiation. Long-wave radiation is emitted from atmospheric water vapor, ozone and carbon dioxide, and especially from clouds having high liquid-water content. The downward component of this radiation arrived at the earth's surface, during the observation period, in amounts that ranged from 0.65 ly min^{-1} to 0.23 ly min^{-1}. The total flux of downward long-wave radiation during the observation period was 587 langleys.

While passing cloud sheets restrict the descent of downward short-wave radiation, they also act as sources of long-wave radiation. A comparison of the graphs of short-wave radiation (Fig. 1) and long-wave radiation (Fig. 2) shows the increase in downward long-wave radiation during the passing of cloud sheets while downward short-wave radiation is being restricted.

Figure 2. Long-wave Fluxes and Net Long-wave



Upward long-wave radiation originates at the earth's surface, where it is emitted from the soil, vegetation and all other matter, natural and manmade. The upward long-wave radiation flux exhibited the smallest fluctuation of all four fluxes during the observation period. Observations during daylight hours indicated an upward flux of 0.50 to 0.60 ly min^{-1}, and observations during the night were nearly constant at 0.44 ly min^{-1}. This uniformity indicates that there was little nocturnal temperature change at soil and vegetative surfaces. The total flux of upward long-wave radiation during the observation period was 718 langleys.

Combining the downward and upward fluxes of long-wave radiation results in a net long-wave deficit of 131 langleys during the observation period. We may compare this value with similar data calculated for three places in Japan; the long-wave deficit averages -108 ly day^{-1} at Niigata on the cloudy west coast, -150 ly day^{-1} at Sendai and -145 ly day^{-1} at Tokyo (Kondo, 1967).

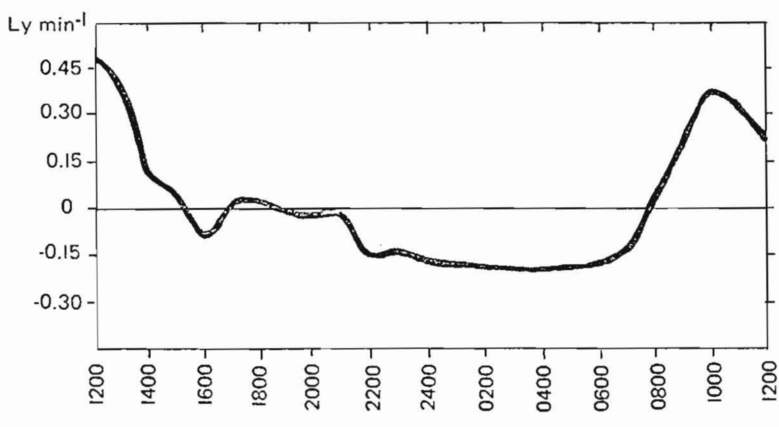
Air temperatures at 10 cm and 200 cm above the soil surface were converted into long-wave radiation values by the Stefan-Boltzmann formula. The calculated values agree with the measured values during periods of darkness or heavy cloud cover, but are much lower than measured values during periods of sunshine when downward short-wave radiation is abundant. As the downward short-wave radiation impinges on the vegetation, the surface temperature is increased far above that of the surrounding air. The long-wave radiation emitted from the vegetation becomes greater than the amount that would be emitted from surfaces at the temperature of the air. In the absence of short-wave radiation, the temperature of the vegetation and surrounding air attains equilibrium and the calculated long-wave values approach the measured values.

RESULTANT WHOLE-SPECTRUM RADIATION The radiation budget of the high-grass marsh for the 24-hour observation period is illustrated by the following diagram:

	Short-wave	Long-wave	Total
Down	173 ly	587 ly	760 ly
Up	- 38 ly	- 718 ly	- 756 ly
Net	135 ly	- 131 ly	4 ly

Figure 3 shows the hour to hour changes in the net or resultant radiation, which totals 4 langleys over the 24-hour period.

Figure 3. Net All-wave Radiation



CONCLUSION A 24-hour radiation budget for a high-grass marsh in early winter has been presented. While a positive radiation balance in early winter is not unusual, the factors producing it can be isolated and examined from measurements taken during the observation period.

A strong flux of downward short-wave radiation between 1200 hours and 1330 hours on November 25th, under clear skies, and again between 0900 hours and 1130 hours on November 26th, provided a large daytime all-wave surplus. The heavy cloud cover between 1400 hours and 2100 hours on November 25th produced a large downward flux of long-wave radiation, helping to maintain a positive all-wave balance as late as 1800 hours on November 25th. The combined fluxes of downward short-wave radiation under clear skies and downward long-wave radiation under heavy cloud cover were sufficient to produce a small positive radiation balance over the 24-hour period.

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UWM'S FIRST PH.D. IN BOTANY AWARDED FOR STUDY OF CEDARBURG BOG

ANOTHER MILESTONE in the development of UWM and the Field Station was passed this January when Thomas F. Grittinger was granted the first Ph.D. in Botany on our campus. Tom had, of course, used the Field Station as a base of operation during the three years of his field study which encompassed the whole bog area. His thesis, entitled "Vegetational Patterns and Edaphic Relationships in Cedarburg Bog," summarized the results of many strenuous days of work at all seasons which he spent traversing his sample lines. He collected not only a tremendous amount of data and many voucher specimens of plants, but also countless mosquito bites, frost bite, soaked clothing and sumac poisoning (to which he became increasingly sensitive with prolonged exposure and which nearly forced him to abandon the study). But all's well that ends well and we are, of course, very proud of Tom's achievement.

For the first time we now have a large amount of information about the variety and detailed composition of the vegetation within the bog, together with related factors such as peat depth and water quality. The vegetation types were objectively analyzed, described, and mapped, then related to site factors and history of distrubance. A copy of the thesis will be filed at the Field Station, where it will be invaluable as background material for future studies in the bog area or similar sites in southeastern Wisconsin.

Several important conclusions of Tom's study are of general interest. One of the most interesting is that some fairly large areas in the remote central part of the bog are of a "string bog" type, considered to be distinctly northern and not previously reported nearer than Seney in Upper Michigan. These areas consist of open, very soft and wet floating mats dominated by small sedges (*Rhynchospora* spp.) and herbs, interspersed by more or less parallel small ridges supporting bog shrubs, pitcher plant and very stunted trees of tamarack and cedar. There is a gentle slope in the string bog of from 1.5 to 3.5 feet per mile generally from north to south, but flow of water through the peat is evidently very slow and the water therefore is very low in oxygen and in available nutrients. String bogs have been reported