**P1.3** THE SURFACE ENERGY BUDGET OF A MOUNTAIN REGION

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## 1. INTRODUCTION

During the summer of 2002, a joint research team comprising students from Scotland and the United States conducted research in the Cloud Peak Wilderness area of the Bighorn Mountains in Wyoming. One of the studies conducted concerned the meteorological characteristics of the region as they applied to the overall environment. Given the limited time frame and available equipment we were unable to study long-term climatological quantities directly. Limitation of this study included using independent meteorological stations to collect data for specific localities and in turn apply it to the site to determine an overall heat budget.

## 2. RATIONALE

The study of the energy or heat budget refers to a method used to estimate the exchange of total energy between a site and the overlying atmosphere. By measuring the net radiation and other energy variables, one can find the heat budget of the region. Through application of the data collected from the surrounding lakes (Ringbone Lake in particular), a relationship can be established between the heat budget and evaporation rates.

**Figure 1: NOAA Station Site**

## 3. STUDY SITE

Research was conducted in a mountain region in the Cloud Peak Wilderness Area. The NOAA weather station site was on a moraine that bisected Ringbone Lake into two larger regions connected by a narrower channel. The sparse vegetation on the moraine, combined with the elevated location of the station above the lake surface created adequate fetch and ample access to solar radiation. The station was at an altitude 2744 m of above sea level and had a location of 44° 16' 17.043"N and 107°01' 36.413"W.

## 4. INSTRUMENTATION

To record meteorological and physical aspects of the atmosphere, Dr. Jeff Hare from CIRES assisted in operation of the NOAA weather station (Figures 2 and 3).

**Figure 2: Dr. Jeff Hare supervising use of NOAA station.**

This weather station held instruments necessary in recording data pertaining to the surrounding environment. It consisted of a set of several instruments attached to a 3-meter-high tripod. Included in this set of instruments were two R.M. Young prop and vane anemometers, set at the surface and at 3 meters. At each of those heights, Vaisala HM45C temperature and relative humidity sensors were also employed. In addition, a Campbell Scientific net radiometer measured downward- and upward-traveling photons to determine net radiation flux. An Eppley PSP pyranometer, was utilized to measure incoming solar radiation. Finally, two Eppley PIR pyrgeometers were mounted on a metal plate. One facing upward and another downward, they

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measured incoming and outgoing infrared radiation, respectively.

**Figure 3: NOAA Station.**

A Campbell 21x datalogger was used to record the information from the measuring devices into a memory canister. To ensure validity and quality of data, the two memory canisters were exchanged every three to four days. These canisters were downloaded into laptops at base camp. The files were readable by Microsoft Excel, a program that was also used as a data analysis tool for this study. Fourteen consecutive days of data were successfully recorded.

## 5. APPLICATIONS

In contrast with high-technology methods used in recording the atmospheric data, simple yet effective methods were used to obtain lake depth and inflow data. Scaled measuring poles were fixed vertically and used to measure changes in depth over time. Pigmy meters were used to determine the flow of Oliver Creek, the stream that flows into and out of the lake. Given various data sets and observations, the research team condensed the possible relationship of the diminishment in lake depth with atmospheric conditions. From the data made available by the NOAA station, the potential evaporation rate can be computed.

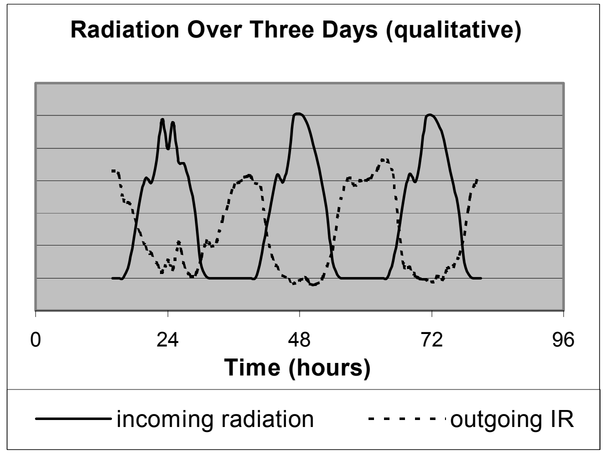
### 5.1 *Radiation and Energy*

As seen in Figure 4, incoming solar radiation of all wavelengths affects outgoing infrared radiation, with a slight time delay. This is only one portion of the energy budget, the overall picture of energy transfers in an environment. To assist in analysis of the budget, the equation

$$Q_N = Q_H + Q_E + Q_S + Q_M \qquad \textit{Equation 1}$$

can be used, where $Q_N$ is net radiation flux (in Watts per square meter), $Q_H$ is sensible heat flux, $Q_E$ is latent heat flux, $Q_S$ is storage, and $Q_M$ is molecular flux. This and other relations have been and will further be applied to the data gathered.

**Figure 4: Outgoing and incoming energy comparison (IR data rescaled to highlight relations between data sets)**




### 5.2 *Applications in Hydrology*

Significant variations in lake depth were observed over the study period. These changes in depth were particularly curious. Therefore, the solar radiation, net radiation, and incoming and outgoing infrared radiation were of particular interest. The net radiation in particular, in combination with temperature, wind speed, and dew point (derived from relative humidity, figure 5, and temperature), can be used to determine evaporation rates, as explained in Monteith (1990).

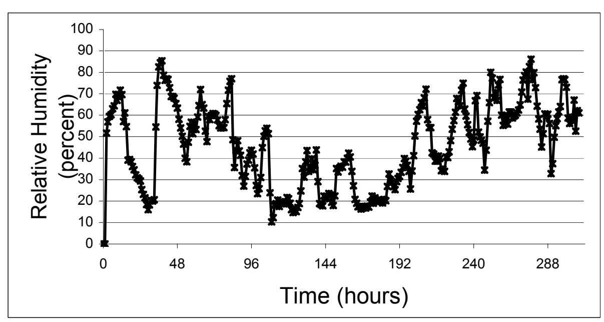



**Figure 5: Relative humidity data**

## 6. Summary

While in Wyoming, data pertinent to the environment of the Cloud Peak Wilderness were collected. Although small amounts of preliminary analysis were performed on site, most of the on-site work involved data collection.

At present, the solar radiation, temperature, and humidity data are being further analyzed in relation to hydrological data. An overall understanding of some major factors affecting the lakes and surrounding atmosphere, especially in regards to evaporation, should result.

## 7. REFERENCES

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## 8. ACKNOWLEDGEMENTS

Dr. Thomas C. Arnold of State College High School.

Dr. Jeff Hare, of the Cooperative Institute for Research in Environmental Science (CIRES) at University of Colorado with NOAA, for being an advisor and for his supervision of the use of NOAA equipment.

Dr. Dennis Thomson of the Pennsylvania State University.