RED DUST LAYER SURFACE EFFECTS ON SNOWPACK TEMPERATURE GRADIENTS, SUBALPINE FOREST, NIWOT RIDGE, COLORADO

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Introduction

Dust that fell with snow on February 15th, 2006 (Photo 1) may have caused some of the largest rate increases in snow temperature ever reported. At our C1 site (3030m), after a few warm days, and on the first day that the minimum temperature was above 0 C, snow temperatures increased from -4 C to 0 C (isothermal) in less than 24 hours on February 28th, when the red dust layer was near, but below, the surface. Later, at the Soddie site (3300m), there was release of snowpack meltwater into snow lysimeters on about March 6th as that site briefly became isothermal when the red layer was about 20 cm below the surface following three warm, clear days. New snowfall occurred and snow pack temperatures again decreased below 0 C. On April 4th, the entire Soddie snow pack temperature increased from -4 C to 0 C in less than one hour, the beginning of consistent meltwater flow a month earlier than the seven-year average. This rapid temperature response does not appear to be explained by extremes in air temperatures or solar radiation. However, the light sensor at the red dust layer, about 30 cm below the snow surface, suggests radiative activation of the red dust layer at this time.

Photo 1: Dust Layer on Feb. 18th, 2006 at Loveland Pass, CO

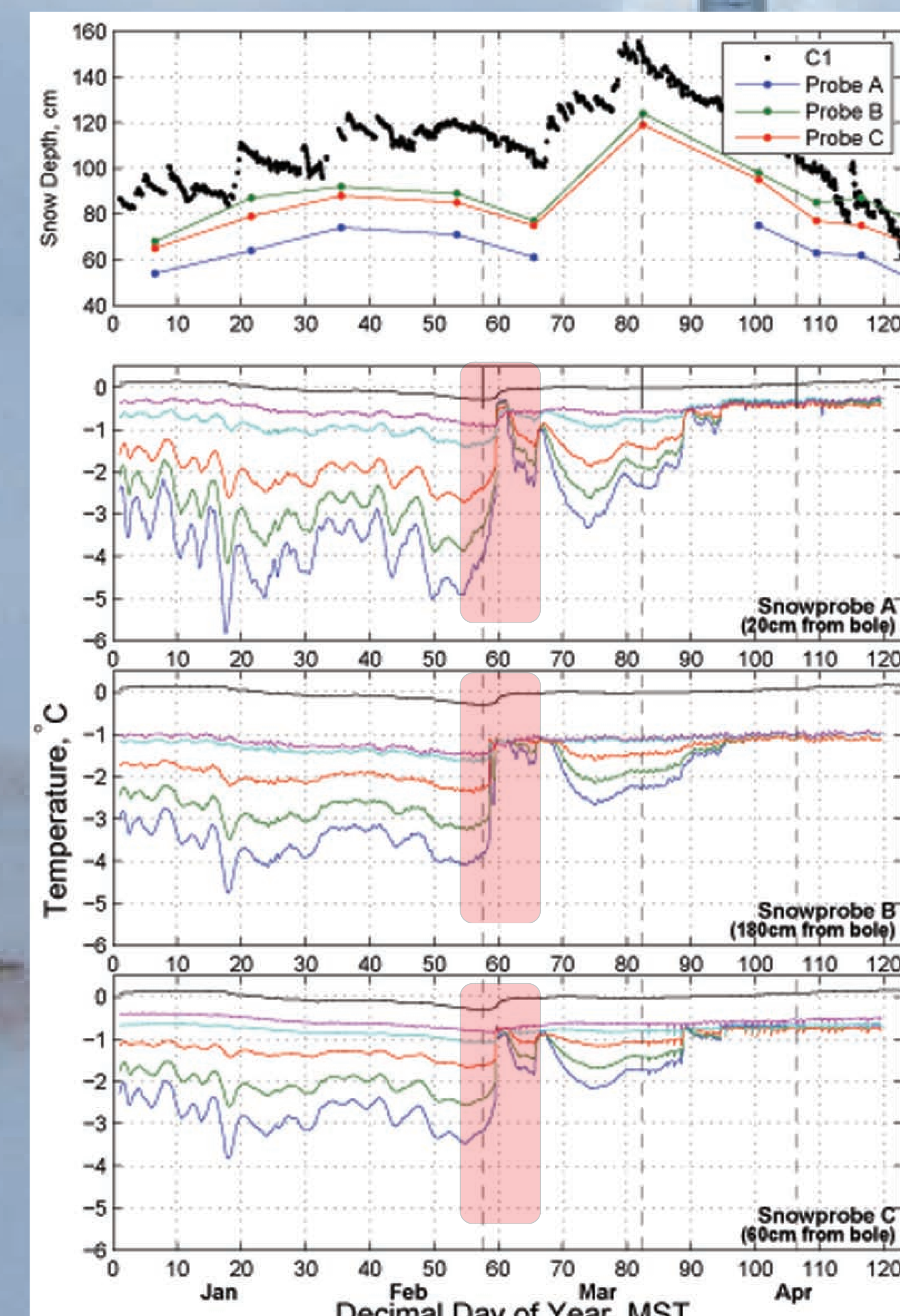

Figure 1. C1 Snow Depth and Temperature

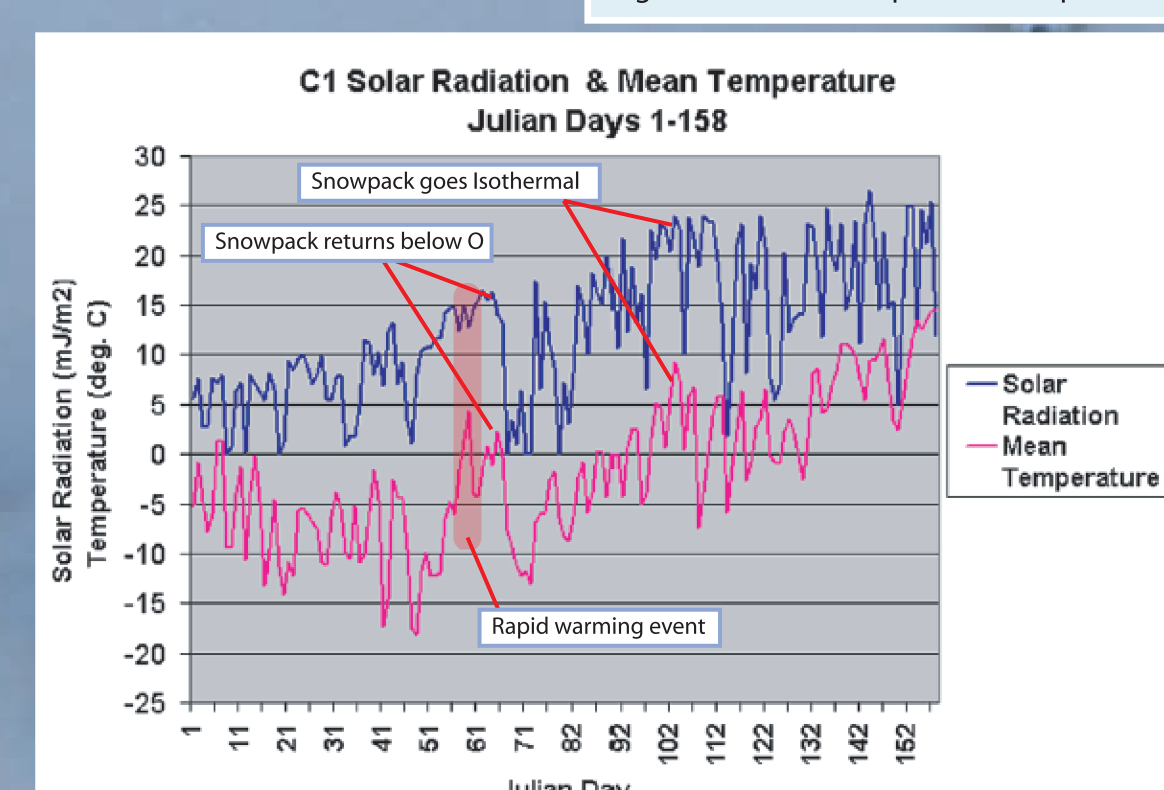

Figure 2. C1 Solar Radiation and Average Temperature

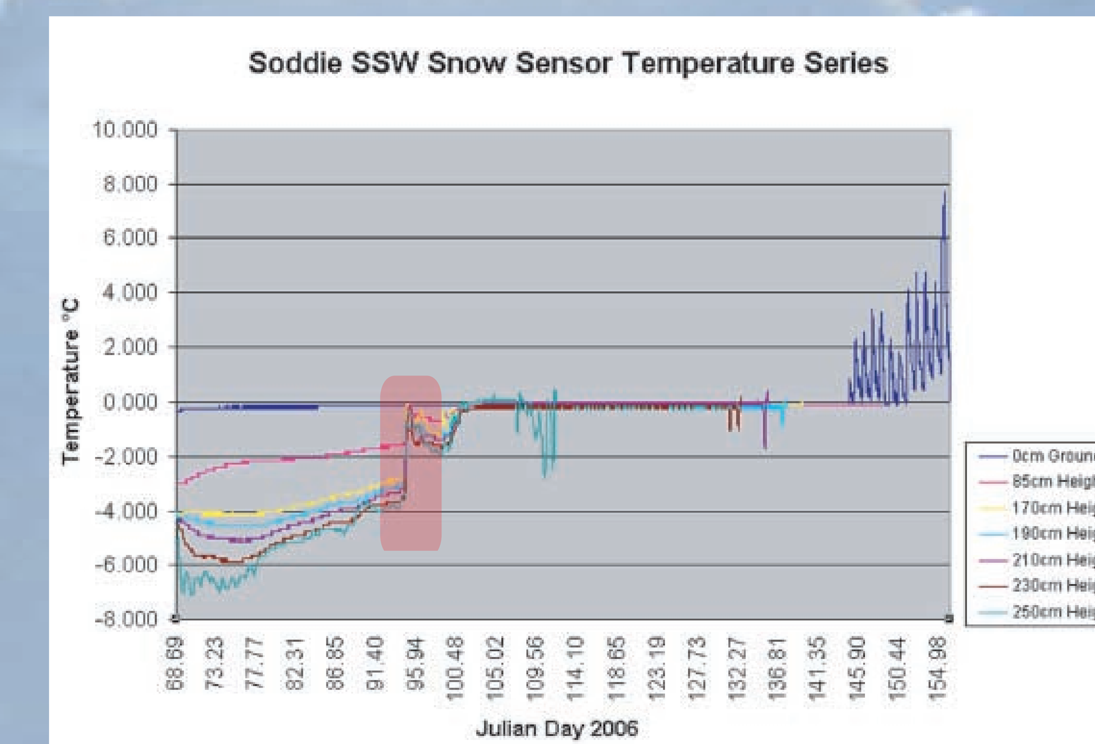

Figure 3. Soddie SSW Snow Temperatures

Photo 2: Sensor Installation at Soddie SSW

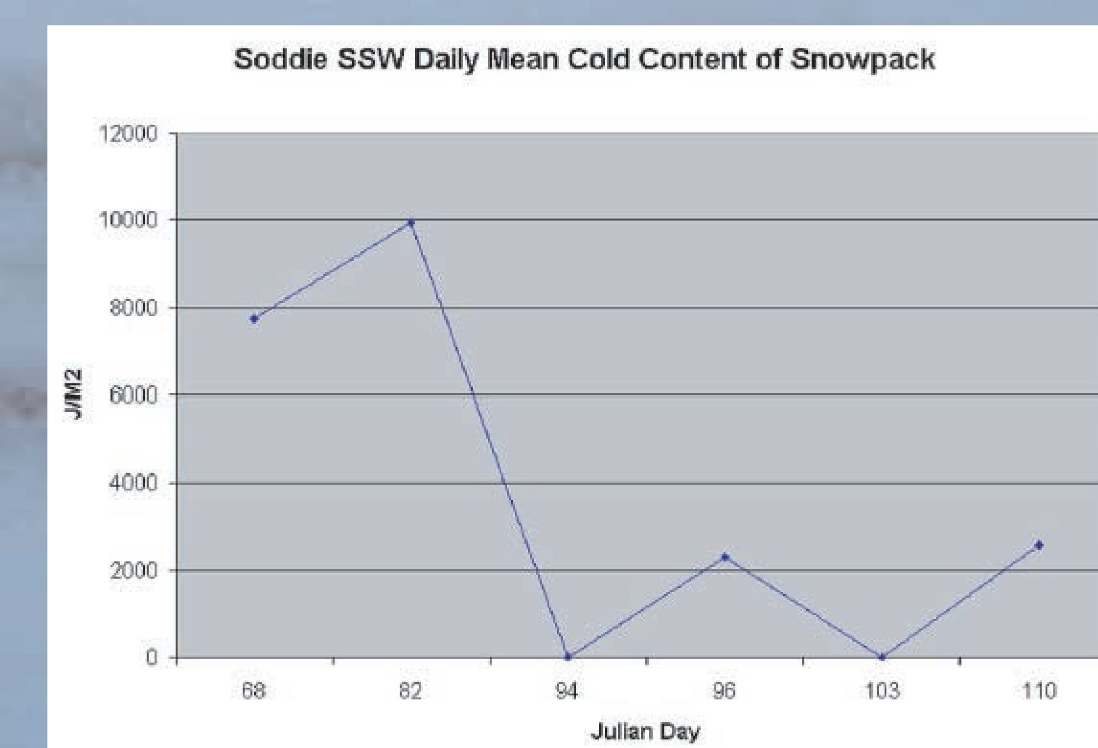

Figure 4. Soddie SSW Cold Content

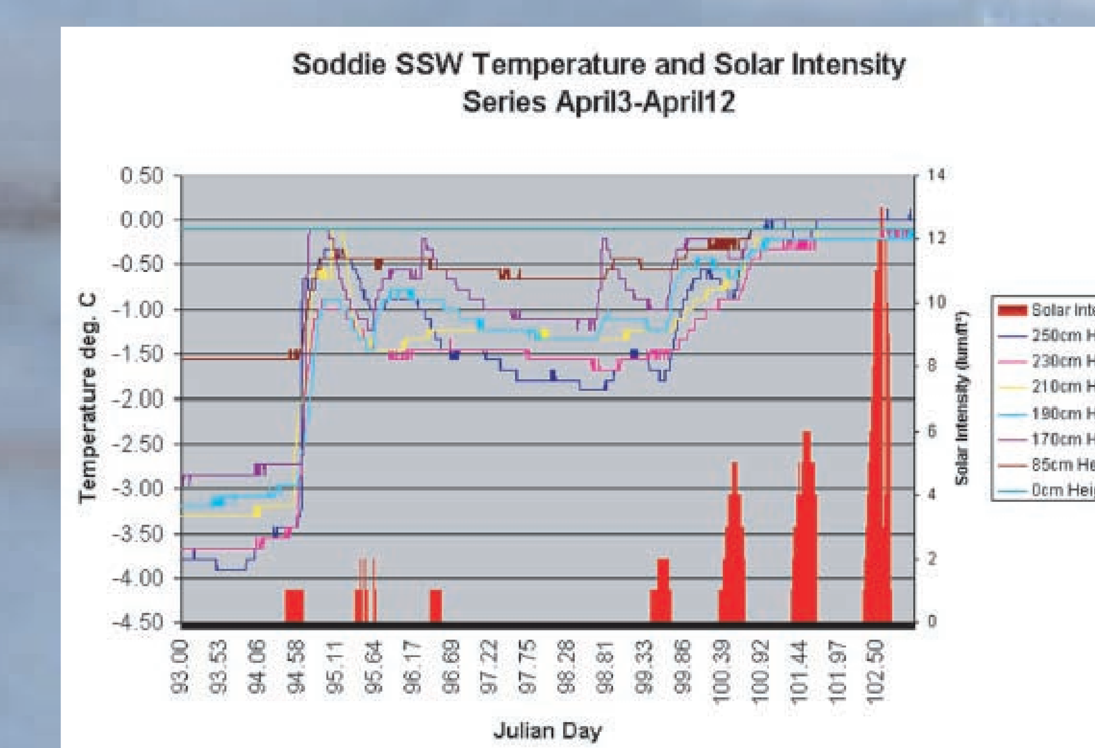

Figure 5. Soddie SSW Solar Intensity and Temperature

Discussion

Extremely rapid increases in snow temperatures are presented for two sites on Niwot Ridge, Colorado. The existing data suggests these increases were triggered by a red dust layer a few tens of centimeters below the snow surface. At the lower site, C1, on February 28th, the snowpack temperatures rose from -3 C to 0 C in less than a day (Figure 1). Energy fluxes at three locations in the area range from 9.2 to 15.3 Joules per meter squared (J/m^2) per minute. Subsequent snowfall, reduced solar radiation, and decreased air temperatures correspond to a return to below zero snowpack temperatures after March 3rd (Figure 2). Uninterrupted meltout began on March 31st, without unusual temperature or solar radiation forcing.

In response to this uncharacteristic rapid increase at C1, temperature and light sensors were installed in a high-resolution vertical array on March 9, 2006 at the Soddie site to quantify the rate of future snowpack warming (Photo 2). Data from this array show that on April 4th the two and one half meter snowpack temperature rose from -3.3 C to 0 C in one hour (Figure 3), an energy flux of 112 J/m^2 per minute. Figure 4 shows the mean cold content of the entire snowpack dropping from 9,947J/m^2 on March 23rd to zero on April 4th. This corresponds to the time when solar radiation penetrated to the red dust layer, 30 cm below the surface (Figure 5).

Summary

Our data suggest that dust layers in snowpacks can spawn very high energy fluxes throughout the entire snowpack in a very short time period bringing the snowpack to the melting point in one hour. Furthermore, the dust layer does not have to be at the surface to trigger the shift from cold to isothermal; this can occur at depths of 20-30 cm. Due to the obvious hydrological and ecological impacts of early snowpack melt-off, increased air-born dust in winter should be considered in future climate change scenarios. Runoff from the Colorado River basin could be particularly effected by a dustier southwestern US, coupled with vigorous frontal passages.

FUTURE STUDY

High resolution light and temperature arrays in snowpacks with and without dust layers can more firmly quantify the effect of dust layers on critical snowpack issues, such as the initiation of melt events, the rate of melt, and seasonality of meltout.