

THE SPATIAL DISTRIBUTION AND IMPACT ON AVALANCHE CONDITION OF A DUST-ON-SNOW EVENT IN THE COLOADO ROCKY MOUNTAINS

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Abstract

On the afternoon of February 14th, and continuing into the morning of February 16th, 2006, strong winds across the desert southwest of the United States picked up significant dust and dirt, depositing it across the mountain ranges of Colorado. This weather system also deposited snow throughout Colorado, which contributed to avalanche activity during and shortly after the storm. The dust-on-snow event created a layer within the snowpack that played a role in a number of individual avalanches and avalanche cycles throughout the rest of the 2006 avalanche season.

KEYWORDS: dust-on-snow, avalanche cycle, case study

1. Weather

The 2005-2006 winter brought a severe drought to the desert southwest. The National Weather Service recorded 143 consecutive days with no measurable precipitation from October 18 through March 12 (Hogan, 2006). On February 14th a cold polar air mass caused the jet stream to move southward over the Four Corners region of the U.S. (Figure 1). This area was especially dry this day with surface dew point temperatures in the single digits and dew point depression between 5 and 10 °C (~10 to 20 °F) (Figure 2). As strong surface winds, associated with the upper-level jet, moved over southern Utah and Arizona, they picked up an enormous amount of dust and dirt. The jet and associated snow storm then spread the dirt across Colorado along with several inches of new snow (Figure 3).

The new snow layer accumulated on a layer of faceted snow that formed during the preceding period of calm weather. Wind speeds during the snow storm averaged in the 20 m/s (~40 mi/hr) range with gusts over 35 m/s (~80 mi/hr) from the San Juan Mountains north to the Cameron Pass area (just south of the Wyoming border). By the afternoon of February 15 winds pegged the anemometer at 45 m/s (~100 mi/hr) near Red Mountain Pass in southwest Colorado.

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The strong winds, new snow and dust left the snow surface with a "Pintoed look" (Figure 4).

On the front lines I just happened to be teaching a field session of the National Avalanche School in Telluride on February 14th. As the storm approached, the LaSalle Mountains in Utah became more obscured from the dust stirred up in northern Arizona. By "sweep time" the LaSalles had become totally obscured behind a dark wall of dust, dirt and cloud. I remember the distinct feel of grit in my teeth as I skied to the base area for a cold dark beer at the world

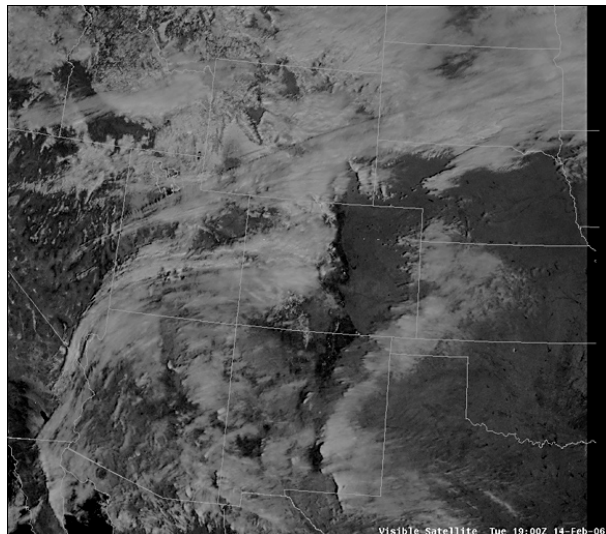


Figure 1: A satellite image from the visible band on the morning of February 14th, 2006. The first jet streak of the system is located to the northwest of Colorado.

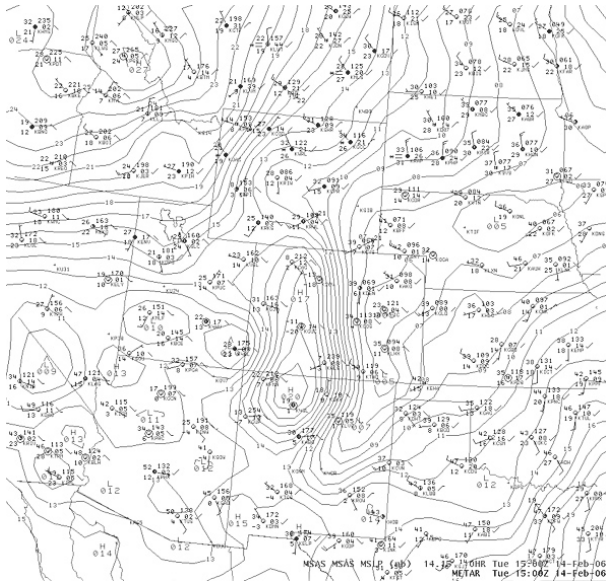


Figure 2: Surface pressure analysis and observations from the morning of February 14, 2006.

famous “Lizard Lounge”.

Snowfall dropped to below normal in March and April across the north and central mountains, while in the southern mountains March was a banner month. As a result of the dust layer remained within top 20-50 cm (8 - 20 in) of the snowpack for the rest of the winter. Only in wind loaded areas did the dust become deeper than a meter (~3 ft).

2. Distribution of the dust layer

By the morning of February 15th, the dust layer had been observed from across the San Juan Mountains (including Wolf Creek, Red

Mountain and Lizard Head Passes). However, the dust also made it into the central and even northern portions of the State. The Colorado Avalanche Information Center (CAIC) received reports of dust across Monarch Pass and in the Aspen, Grand Mesa and McClure Pass areas. Dust in snow was noted across Summit County, Loveland and Berthoud Passes (Figure 5). The strong winds even moved dust onto the Front Range of the Colorado mountains with accumulations in Boulder and Jefferson Counties. To a lesser extent the dust was noted in the Steamboat and Cameron Pass areas, just south of the Wyoming border.

3. Snowpack

The February 14th snow storm was preceded by two days of mild temperatures and mostly clear skies. These conditions promote the growth of faceted snow crystals near the surface of the snowpack (Birkeland et al., 1998). Prior to the dust-on-snow event, near surface facets (NSF) had been observed in several portions of the Colorado mountains.

Very cold air moved into the state as soon as the storm exited eastward. Sunny skies allowed large solar input into the snowpack. Our typical February snowpack reflects much of the income solar radiation. However, with a dark layer at or near the snow surface the snow was able to absorb more solar radiation than normal. This combination, enhanced solar gains and very cold air temperatures, created a temperature gradient within the snowpack and helped form weak faceted snow directly above and below the dust layer. These faceted layers of snow acted as weak layers for many avalanches. In addition, daytime temperature near the dust layer rose

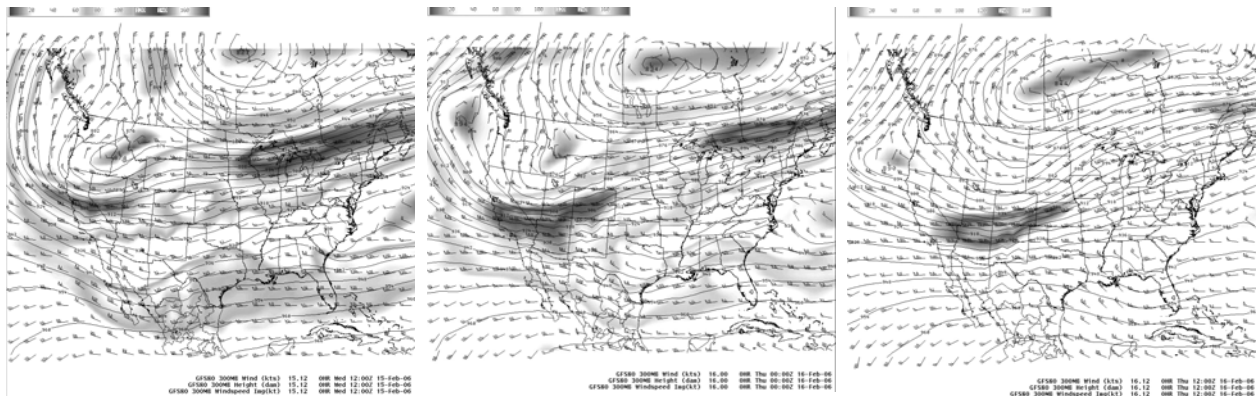


Figure 3: Upper-level flow (300 mb) as depicted by the Global Forecast System (GFS) model. The wind barbs are 10 knots each (flags are 50 knots), the contour lines are in dekameters and the color contours are wind speed in knots).



Figure 4: Portions of the dust layer were on the snow surface for the rest of the winter and often gave the snowpack a “Pintoed” look.

above 0 °C (32 °F) forming a hard melt freeze crust. As noted earlier, snow fall averages decreased across the north and central mountains of Colorado and the dust layer remained a half meter or less below the surface in most places. As we moved later into the spring, the brown dust layer and associated melt freeze crust helped heat from solar insolation to penetrate deeper into the snowpack. By May there was an increase in wet slab and wet loose activity, generally just above or just below the dust layer crust.

4. Avalanche cycles

Some avalanche activity was reported during the initial wind and snow cycle, but

generally the winds were so strong that it scoured away the snow and did not deposit it into avalanche path start zones. The initial storm left a mix of wind hardened snow and red desert dust near the surface and three months remaining in the avalanche season.

The first wet cycle of the season struck the mountains of Colorado at the end of February. Warm overnight temperatures on February 27th helped spur a fairly active cycle on the 28th. Colorado Highways 91 on Fremont Pass, 40 over Berthoud Pass, and Interstate 70 west of both Vail Pass and the Eisenhower Tunnel all had short closure periods due to avalanche debris onto at least one lane. Highway 50 over Monarch Pass was closed in both directions for a time due to several wet slides burying the pavement with several feet of wet snow. Most of these slides were shallow and did not entrain a great deal of snow, so CDOT crews were quickly able to re-open roads. The biggest slide of the cycle, running out of an infrequent path known as the Finger, closed both lanes of Highway 6 on the west side of Loveland Pass. The last time an avalanche from this path hit the road was 1978. Many of these slides resulted from the combination of the mid-month dust event and the warm temperatures in the days before the cycle.

Shallow avalanche activity (with a few exceptions, Figures 6) became the norm in March and April. Many of the slabs broke at the dust layer (Figure 7). In May, every snow event produced some avalanche activity. Rapid warming stressed weak layers almost

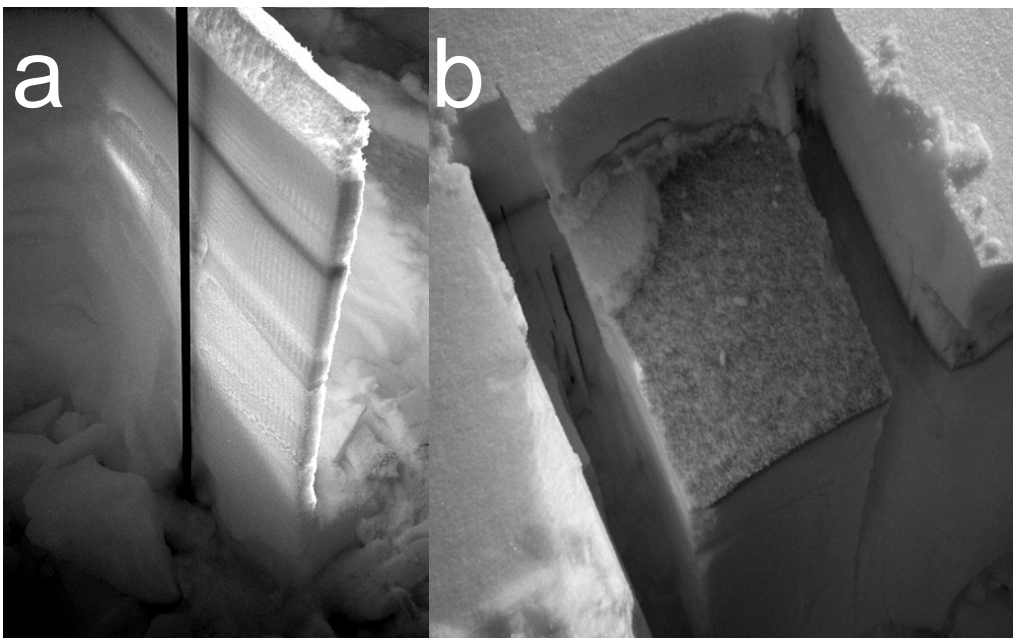


Figure 5: In many areas the dust layer was buried during the initial snow storm, but remained near the snow surface. The layer was evident in snow profiles (a) and in shear tests (b).



Figure 6: A wet avalanche released by explosives during avalanche hazard reduction work in May of 2006. (Photograph by Robby Scribner).

immediately after each storm cycle. Wet slide activity was reported from across the Summit, Eagle and Clear Creek Counties almost daily during the month. As our season ended, May turned out to be one of the busiest avalanche months of our 2005-2006 season.

5. Conclusions

- Dust-on-snow events in Colorado can be expected for as long as the drought persists in the desert southwest.
 - A layer of deposited dust and dirt on top of the snowpack may reduce the length of time that seasonal snow remains on the ground.
 - Once buried, the dust layer can impact future avalanche formation and release, especially for wet avalanches.
- If the melt freeze crust becomes sufficiently thick, it may act to cap any buried weaknesses.

6. A little speculation

Dust-on-snow events across the San Juan Mountains have increased over the last few years. They could also be increasing in the north and central ranges as well. This will be something we will need to monitor over the next several years. On May 18th, 1980 Mt St Helens erupted and spread ash eastward at least as far as Arapahoe Basin, where I was working as a ski patroller. Within just a couple weeks we went from a great winter to an abrupt end of skiing due almost exclusively to the layer of ash which blanketed our snowpack. We can safely assume that one apparent result of larger and more frequent dust-on-snow events is that the season

of snow on the ground will shorten. If melt freeze crusts form around future dust layers we should expect to see similar avalanche activity to what was reported during the last three months of the 2005-2006 season. Generally most of these were not large avalanches, and involved only snow above and just below the melt freeze dust layer of mid-February. The larger events were quite large and could easily have affected life and property. These dust layers (we would think) would do a couple things. They would create a melt freeze crust containing the dust layer. If dust events occur during the colder months, we could expect to see faceting processes develop weak layers around the dust layer as it develops into a melt freeze crust. The 2005-2006 season ended on a busy avalanche note. Even though field observations had almost ceased, over 100 avalanches were reported in May from the Summit, Clear Creek and Eagle County area.

7. References

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Figure 7: This avalanche left the dust layer exposed on the bed surface.