ABSTRACT: There are very few well-documented cases of dry snow avalanches being triggered by warming. This study was originally presented at the Utah Snow and Avalanche Workshop in November of 2012. Synopsis - Case study of Sunday March 4, 2012. All the natural and human triggered slides that stemmed from Heat/Solar Radiation-induced deformation on a conditionally unstable snowpack. A powerful Pacific storm shook the Wasatch over the last days of February and early March of 2012. A number of naturals (10) and human triggered slides - many remote - went reported to the Utah Avalanche Center on Friday March 2nd - the day that the storm was winding down. It was the end of the avalanche cycle. Or was it? The next day offered warming temps and overcast skies - some would use the term “green-housing.” More human triggered slides, no naturals. The next day dawned clear with temperatures spiking into the 40s; incoming solar radiation skyrocketed above 900 W/m^2 (net 250 W/m^2). The house fell apart. Creep rates went through the roof, clearly exceeding the ductile to brittle threshold, with stresses concentrated along weak interfaces formed mid-February. By the end of the day, over 35 size 2 and 3 naturals went reported to the Utah Avalanche Center.

KEYWORDS: solar radiation, avalanche cycle, creep rate, deformation

1. INTRODUCTION

Most natural avalanche cycles in a cold dry snowpack typically stem from direct loading from wind or precipitation events. Lacking these weather events, a very few occur under the influence of dramatic spikes of temperature and solar radiation. This phenomenon is not well understood with very few case studies representing these events. This case study from early March 2012 in the Wasatch Mountains of Utah may help describe this phenomenon and offer some forecasting tips for the future.

2. BACKGROUND

Others have looked at temperature effects on snow stability with an emphasis on slab stiffness/tensile strength and both the vertical (settlement) and slope parallel (creep) deformation rates. Exner/Jamieson, 2009 (1), measured slope parallel speeds of .9-1.5mm/hr (roughly before their toothpicks melted out at 0930 hrs). Conway (2) and others have measured rates of 10^{-6} m/s. Reiweger and Schweizer, 2010 (3), found brittle behavior at strain rates faster than 10^{-3} m/s which agrees with previous measurements on the ductile to brittle transition. Habermann, 2007 (4), demonstrated that stress concentration at interfaces typically result in higher shear rates. Reiweger and Schweizer, 2010 in lab experiments found that different kind of weak layers show that 90% or more of the deformation is concentrated within the weak layer, leading to strain rates 100-1000 times the global strain rates. I suspect that our March 4 event had both things going on – with slab stiffness perhaps primarily complicit in the human triggered slides while creep rate differential
(as implied by the measured settlement rates at the Alta Guard Station) sparked the natural cycle.

3. THE STRUCTURE
On Sunday, March 4th 2012, two days after a classic 30-50" (75-125cm) Wasatch storm, the sun came out and the house fell apart. Over 35 size 2 and 3 cold dry slab natural avalanches were reported to us at the Utah Avalanche Center. How many more went unseen or unreported? The story begins in February when two clear spells each produced a radiation-recrystallized facet-crust structure with subsequent snowfalls blanketing and preserving the weaknesses (Fig 1). Not long after, a powerful Pacific storm then shook the Wasatch over the last days of February and early March. Storm totals from February 27-March 2 recorded at the Alta Guard Station (8800'/2680m asl) in Little Cottonwood Canyon totaled 39.5"/2.44" SWE (100.3cm/62.0mm SWE). What happened after the storm is the subject of this paper.

4. THE THREE DAYS OF AVALANCE ACTIVITY

**Friday March 2** – The storm was winding down. 10 size 2 or 3 naturals went reported to us. Skin-nning along a ridgeline, my own touring party remotely triggered a size 2 avalanche along the February 8 radiation recrystallization (RR) facet/crust interface in Silver Fork drainage. Nine other similar human triggered slides were reported that day.

**Saturday March 3** – Zero naturals. Ten size 2 or 3 human triggered avalanches reported to the UAC.

**Sunday March 4** – Numerous human triggered slides. But here’s the kicker – 35 size 2 and 3 naturals reported to the Utah Avalanche Center (Fig. 2). Photo of representative natural from that day (Fig. 3 – photo by Bill Nalli).

5. THE WEATHER

The weather graph speaks for itself (Fig. 4). But a couple take-home points – note how the snow temperatures initially spiked on Saturday when we had warming, but overcast skies. Temperatures
jumped from highs Saturday of 23 F (-5C) to 42 (+5.5C) degrees on Sunday. Solar radiation input jumped from 428 W/m² on Saturday (at 1430 hrs) to 913 W/m² on Sunday (at 1300 hrs). Net solar (input minus reflected solar) for the two days was 71 W/m² on Saturday and 270 W/m² on Sunday. Note how the vertical deformation – or settlement rates – skyrocketed from Saturday’s 5.6% to Sunday’s 36%. The rate was 5 times what it was on the previous, overcast – but warm -- day...36 hours after the last snowflake hit the ground! What was the pattern? All of these failed on a facet/crust interface buried 2-4’ (.6-1.2m) deep on aspects primarily ranging from east-northeast to southeast to south. These were all cold dry slabs where the warming affected the mechanics of the slab but did not penetrate down to the weak layer. Winds at a representative weather station at 10,400’ (3170m asl) were less than 20mph (9 m/s). (All the weather data were gathered from the National Weather Service in Salt Lake City and the Alta Guard/Kowplot weather station in Little Cottonwood Canyon 8800’ (2680m asl).

Fig 4: Cloud cover, temps, settlement, solar radiation for the three days

6. IMPLICATIONS FOR FORECASTING

Take home points for me are outlined in the checklist. In a nutshell, temperature and solar radiation are critical in and of themselves, but change in same may be more so. Having the structured snow pack was also fundamental. I suspect that had the same weather parameters affected a homogenous un-layered snowpack and storm, natural activity may have been at a minimum. It also seemed key that the upper portion of snow affected was low-density powder snow that is more susceptible to deformation than higher density snow (or slabs). Last, but not least, perhaps snow temperature spikes may not be as crucial as the other factors (Fig 5). Certainly more research is needed.

Fig 5: Forecasting Considerations

7. REFERENCES