GRAUPEL AS A PERSISTENT WEAK LAYER IN A MARITIME SNOW CLIMATE

Steve A. Reynaud

Sierra Avalanche Center
Tahoe National Forest Avalanche Forecasting Program
Truckee, CA, USA

Abstract: Graupel is a common and, normally, short lived weak layer in maritime snow climates. Graupel forms during storms from strong convective activity and can be caused by the passage of a cold front or during springtime convective shower activity. Graupel looks like a pile of ball bearings and is heavily rimed new snow. Most literature and research within North America, including educational material from the American Avalanche Association and Avalanche Canada, points to graupel being a non-persistent weak layer that should stabilize quickly. Can graupel layers persist for longer periods of time than previously thought?

Keywords: Graupel, Persistent Weak Layer, Persistent Slab, Storm Snow Instabilities.

Introduction:

During the winter of 2017-2018 in the greater Lake Tahoe area, a graupel layer was buried. This layer resulted in many natural and human triggered avalanches over an 8-day period. These avalanches exhibited the characteristics of a persistent weak layer with a long duration of avalanche activity, remote triggering, wide propagation, and consistent unstable snowpack test results.

Snowpack Structure and Weather Events:

On March 13, a graupel layer was deposited during a small storm event that had high elevation rain up to 2750m (9000'). Above this elevation, around 1cm of graupel was deposited on a variety of existing snow surfaces. Melt freeze crusts had existed on E-SE-S-SW-W aspects due to warm temperatures with NW-N-NE aspects remaining soft unconsolidated snow. Two days after the graupel was buried, with continuing rapid loading, avalanches started occuring with an avalanche cycle that lasted for 8 days between March 15 through March 22.

During this period we received 1-2m of snow during the March 13 - March 17 period and another warmer atmospheric river storm March 21 – March 22 that deposited between 10-22cm of rain up to 2440m with 1-1.5m of heavy wet snow above that. This timeframe turned out to be the most active avalanche period of our winter with another, more widespread, deep slab avalanche cycle occurring at the same time. During this period we had 3 Moderate avalanche rated danger days, 4 Considerable danger days, and 3 high avalanche danger days. Avalanche problems ranged from wind slabs, storm slabs, multiple deep slab issues, wet loose, and wet slabs.

We investigated and/or received information on 7 different avalanches related to this buried graupel weak layer over this 8 day period. 4 natural avalanches and 3 human triggered, including 1 remotely triggered avalanche. All of these avalanches were on E aspects, above 2750m and all were in the greater Mt. Rose area. The Mt. Rose area is in the NE portion of our forecast region located in the Carson Range of Nevada. It is a higher elevation range from 2600m to 3285m with a dryer and colder climate compared to our forecast area within the Sierra Nevada mountain range. It can exhibit characteristics of an intermountain region as well as a maritime climate. While this graupel/crust combination was found in other areas of the forecast region, no known avalanches were thought to have occurred outside of the Mt. Rose area. The melt freeze crust/graupel combination seemed to be the most important factor in this weak layer persisting for an extended period. This graupel layer was not producing avalanches on

Steve Reynaud
Avalanche Forecaster
Tahoe National Forest/Sierra Avalanche Center
PO Box 1976, Truckee, CA 96160
steve@sierraavalanchecenter.org

southerly aspects where the crusts would have also existed which was thought due to a lack of a consistent snowpack on SE/S/SW aspects from a very dry winter until the beginning of March. Temperatures were moderate with some high elevation rain and heavy loading. The graupel layer was deposited when it was warm and wet which could have allowed the graupel to initially bond well to the existing melt freeze crust. This winter we had several examples of poorly developed weak layers becoming reactive during large loading events, mostly attributed to large atmospheric river storms.

Snowpack and Avalanche Events

Tuesday March 13, 2018.

Observations from Slab Cliffs in the Mt. Rose area showed rain overnight and into the morning with a thin rain crust observed up to 2750m. 1cm of new snow overnight above 2750m which was mostly made up of graupel. The old snow surface was made up of wet snow below 2600m with melt freeze crusts and soft snow on northerly aspects above 2750m. This rain crust had graupel imbedded into the upper part of the crust-see figure 1.

Fig. 1-Graupel on rain crust. Photo: Steve Reynaud

March 16, 2018-Natural Deep Slab Avalanche-SE Relay Peak.

Avalanche crown and debris covered by additional storm snow. Debris up to 2m deep with some broken small trees up to 15cm in diameter. Fig. 2, D3 R5 natural avalanche. Fig. 5, is the snow profile from Monday, March 19 when the avalanche was investigated. Figure 3 shows the graupel weak layer on a melt freeze crust.

Fig. 2-Large Crown across slope. Photo: Steve Reynaud

Fig. 3- Melt freeze crust with graupel above. Photo: Steve Reynaud

Saturday March 17, 2018

This avalanche was skier triggered by the 7th person to ski the slope. The person was carried by the avalanche and lost skis and poles. When the slide stopped moving the person ended up only partially buried and was able to self-rescue, see Figure 4. The avalanche failed on the graupel layer above a melt freeze crust buried 70cm deep.

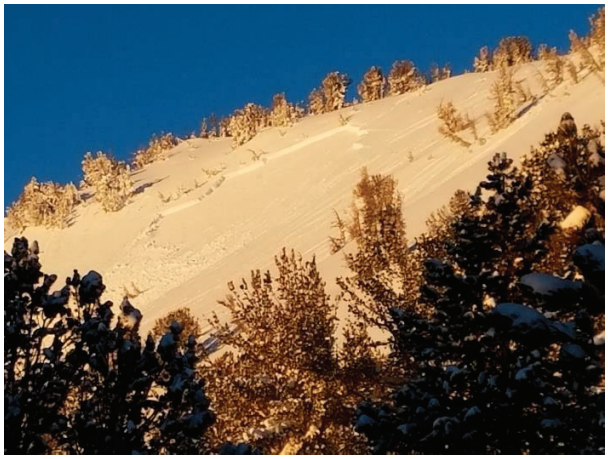

Fig. 4 – Skier triggered avalanche.

Sunday March 18, 2018:

Remotely triggered deep slab avalanche failing on graupel layer. 3108m, E aspect, 1.2m crown, crust visible on bed surface-Fig. 5.

Public Observation: "Three of us skied over from the peak of Mt Houghton to the east bowl (facing Mt Rose) and stopped above the bowl and at least 15 meters above the start of the roll over. Suddenly we all felt the snow collapse. It felt like it dropped about 5cm. No whumpfing sound and no cracks that we could see, just the collapse. We skied down, above the bowl a bit more, so we could look into it and saw the crown below the rocks on skiers left. We suspect there was a sun crust that it slid on."

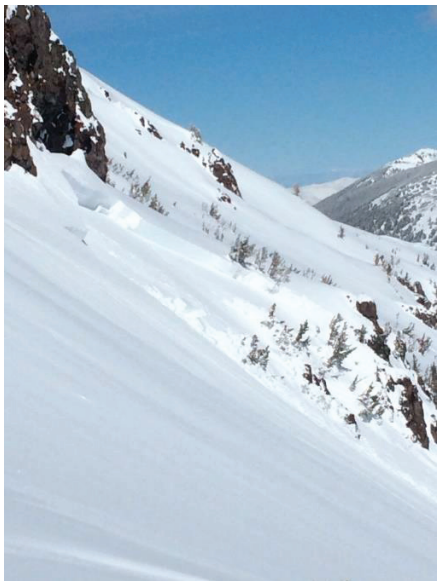

Fig. 5 – Remotely triggered slab avalanche.

Monday March 19 SAC Observation:

This natural deep slab avalanche was thought to have occurred on Friday during the last storm cycle on a high avalanche danger day. Several things were learned after researching the avalanche and doing a crown line profile-see snow pit. On last Tuesday rain was observed up to around 2750m throughout the forecast area. In the Mt. Rose area, graupel was seen above the rain line-see observation from Incline Lake Peak/Slab Cliffs from Tuesday 3/13. This graupel fell throughout the area early Tuesday and then the larger storm began later that night and into Wednesday. The graupel layer was deposited on top of firm melt freeze crusts on many aspects that formed during the warm up over the previous weekend on E-SE-S-SW-W aspects. Areas below 2750m are thought to have had rain on last Tuesday with no graupel layer and aspects more northerly did not have the melt freeze crusts and have bonded better to the old snow and newer storm snow. The combination of the graupel layer with the firm melt freeze crust bed surface seem to be the main ingredients for these deep slab avalanches.

4 avalanches have occurred from this graupel layer that we know about and all have been in the Mt. Rose area on E aspects above 2750m. 2 natural avalanches and 2 skier triggered avalanches. Snowpack tests on the crown line of this avalanche indicate that this layer remains weak and that propagation is likely if failure can be initiated. This specific avalanche had very wide propagation taking out some trees with areas of deep debris-D3 avalanche.

Thursday March 22, Natural D3 Deep Slab on Proletariate Bowl

D3, R4, 240m wide and 200m length. See Figure 6 SnowPilot profile.

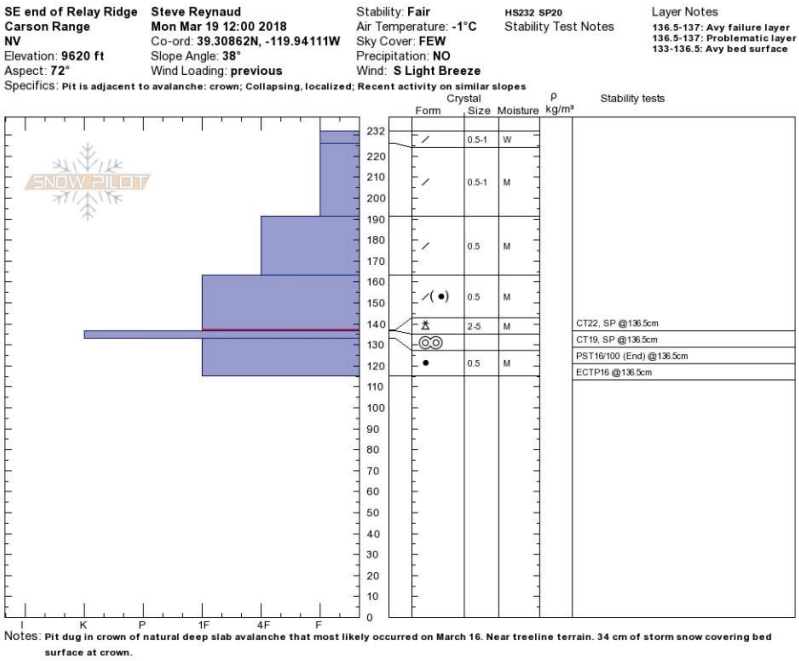

Fig. 5. SnowPilot profile by Steve Reynaud

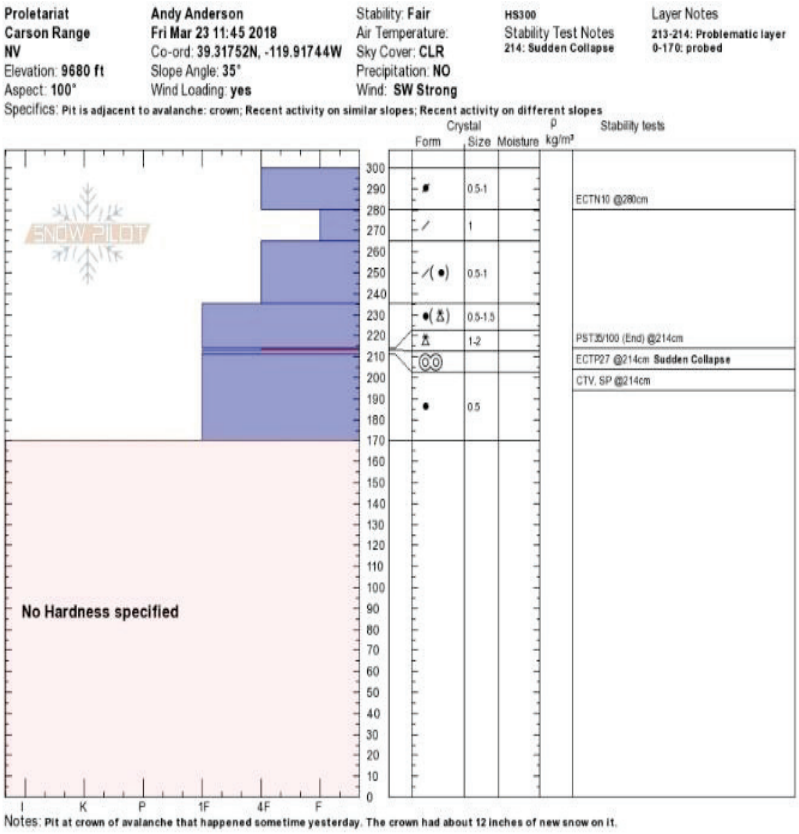

Fig. 6. SnowPilot profile by Andy Anderson.

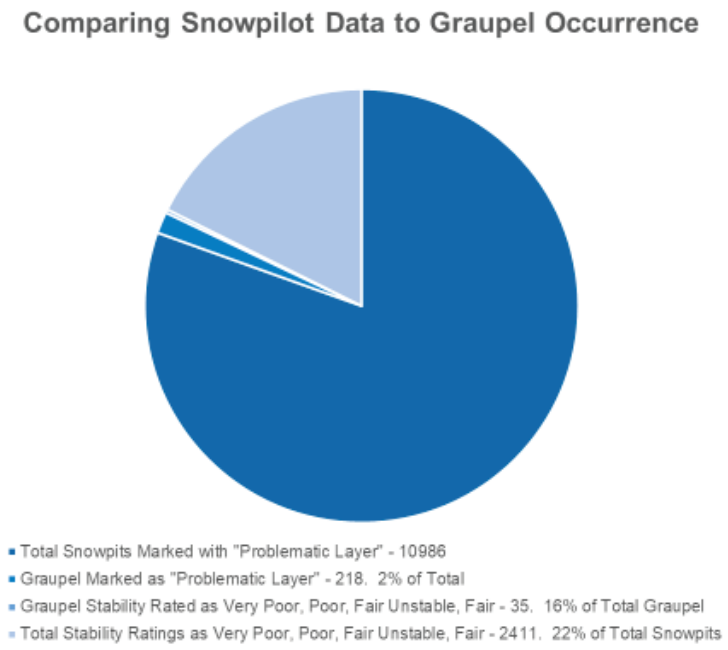

Fig. 7. SnowPilot Data

SnowPilot Data

Figure 7 shows graupel represents a very small amount of the "problematic layers" reported to the SnowPilot database at 2% of the total snow pits. Within those numbers, graupel layers are less reactive than other problematic layers as ranked by stability ratings as a total percentage (stability ratings of very poor, poor, fair unstable, and fair). Out of the 35 graupel pits rated VP, P, FU, and F, 3 of those are from this graupel event on Mt. Rose. There is a possibility that graupel has been underreported over the years and just grouped into storm snow instabilities. While this is a possibility and could have occurred in the past when avalanche fatalities were not as routinely investigated, in areas without avalanche centers, or during poor visibility storm events, it is probably not widespread.

Little is also known about avalanche fatalities from graupel. After looking at the data, this is probably because graupel does not account for as many avalanches as other weak layers. Locally, in the Sierra Nevada, we have had avalanches resulting from graupel weak layers. One of note was during the winter of 2004-2005 resulting in a widespread avalanche cycle with an incident that killed 1 backcountry skier and partially buried 2 others on Mt. Anderson. Field observations from that time indicated that the graupel was non-reactive within 12-24 hours.

Conclusion

Graupel is very common in our maritime snow climate. The combination of graupel and melt freeze crusts interact with each other from year to year with, for the most part, short lived avalanche instabilities. At this point, I could not find any other data to show that a graupel layer has ever persisted for more than a couple days. The SnowPilot data points to graupel as being a relatively safe layer with lower occurrence and less unstable stability ratings compared to other weak layers. This graupel event in March 2018 seems to be a rare occurrence. Though it has occurred and should be added as one more variable that is possible to affect snow stability.

Acknowledgements: Special thanks to Sierra Avalanche Center forecasters Brandon Schwartz and Andy Anderson for their forecasts, observations, and reports. Many thanks to the crew at SnowPilot for detailed information about the subject matter.