The Avalanche Weather Triangle

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Abstract: Fredston and Fesler (1994) used a triangle as a graphic organizer to represent three factors that produce avalanche instability: terrain, snowpack and weather. When people are placed in the middle of this triangle we now have a hazard. This has aided thousands of students to clearly understand what produces avalanches. The weather side of the triangle is often the least understood by participants in avalanche courses. This poster carries the triangle graph a step further to aid students in understanding the important weather factors in avalanche formation. The three primary weather factors are presented as parts of a triangle graphic organizer. These factors – precipitation, wind, and temperature - are each broken down into three more subcategories. This graph of three triangles arranged into one aids students to remember nine important weather factors.

Keyword: Weather education, avalanche education, avalanche factors, weather observations, graphic organizer.

1. Introduction

Fredston and Fesler (1994) have presented a simple way to understand avalanche formation. The concept of weather, snowpack and terrain being important in the creation of instability is not new. Putting it all together into the Hazard Triangle is an clear, concise way of relating this information. Many avalanche courses use this triangle graphic organizer.

Graphic organizers are used extensively in education. Diagrams, such as the Hazard Triangle, aid the spatial reasoning portion of our brain to remember concepts. Elementary teachers diagram stories and sentences. Fire environment weather is explained to firefighters as a triangle consisting of weather, topography, and fuels (Whiteman 2000). Emergency medical instructors use a three triangle graphic organizer to assist First Responders and EMT's in understanding the patient assessment system (Morrissey 2000).

Relating complex information into a triangle format is advantageous to the instructor and the student. It forces educators to distill a complex concept to its bare essence. A triangle demonstrates to the student the interdependence of components, and it is a powerful memory tool.

Fredston and Fesler presented weather, snowpack and terrain as the three instability factors that can create an avalanche hazard when people are present. Of these, weather is often the most difficult to present to students. This is unfortunate as weather is the architect of snowpack structure and often the trigger (or a contributor) for slides.

2. Weather graphic organizer

Wind, precipitation, and temperature are critical weather factors leading to instability. These three factors are listed as topics to be covered by the American Avalanche Association in the level-1 course guidelines (1999). Other factors - such as relative humidity - play a role in avalanche formation, but not as dominant a role as the big three. Wait! Did I say three weather factors? Well, three makes a triangle.

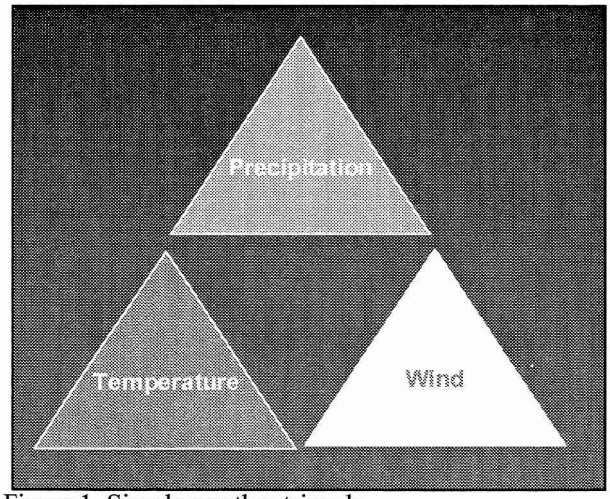

Figure 1. Simple weather triangle

Now, how do we relate these even further without confusing our students? Unfortunately, avalanche

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formation is not as simple as saying, "yes, we had wind." Each factor must be analyzed further. Precipitation, wind, and temperature each have three subcategories that are important in the formation of avalanches.

2.1 Precipitation:

We want to know the type of precipitation. Snow and rain have different effects on the snowpack. The rate, or precipitation intensity, is a contributing factor in avalanche formation. Given enough time snow can adjust to many loads. We know that a rapid change in any weather factors magnifies stress on the snowpack.

> KEY CONCEPT: visco-elastic snow adjusts well if slowly deformed. Rapid change in any weather triangle factor results in quick deformation and increase stress on the snowpack. (Tremper, 2001)

Discussing rate is a great time to introduce students to this general concept. The total amount of precipitation delivered during a storm is an important observation, and must be compared with the students' 'feeling' about the total strength of the snowpack.

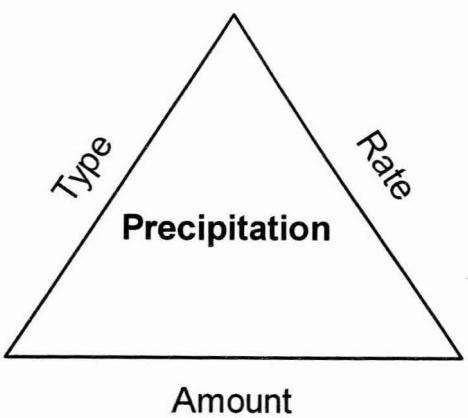

Figure 2. Subcategories of precipitation

2.2 Wind:

Wind speeds of 5 to 22m/second (10 to 50mph) are excellent at transporting snow, depending on density (Tremper, 2001). The duration, when factored with amount of snow available for transport, tells us how much load has been applied to lee slopes. And, we do not know which slopes have been loaded and which have been scoured without knowing the direction.

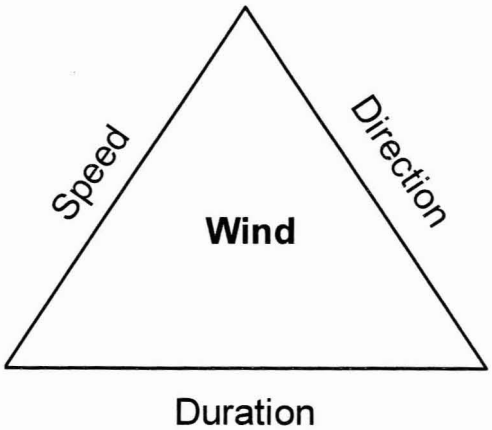

Figure 3. Subcategories of wind

2.3 Temperature:

Temperatures at or above freezing weaken grain bonds and produce loose snow slides as well as dry and wet slabs. This is a convenient place to calculate if freezing levels will reach up into areas you will be forecasting for. It is helpful to teach students how to estimate freezing levels to determine which elevation will have high hazards. The temperature trend is especially important while it is snowing. Warming trends during a storm tends to create slab conditions - an upside down cake (Tremper 2001). Solar radiation can create densification, and slabs, in the upper snowpack. The sun also drives the formation of persistent layers on the surface and near surface as well as crusts. The lack of sun (clouds) can hold heat in the atmosphere, warming the snowpack.

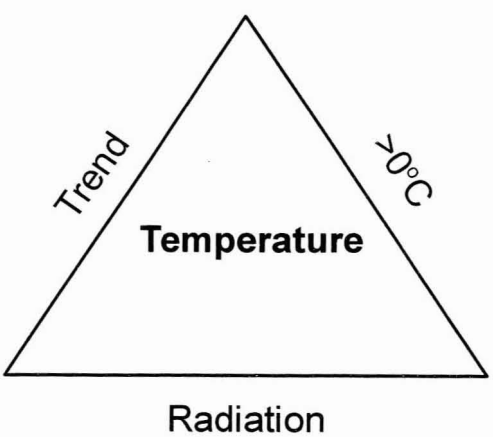

Figure 4. Subcategories of temperature

A complete weather graphic organizer with all its critical observations listed would look like figure 5.

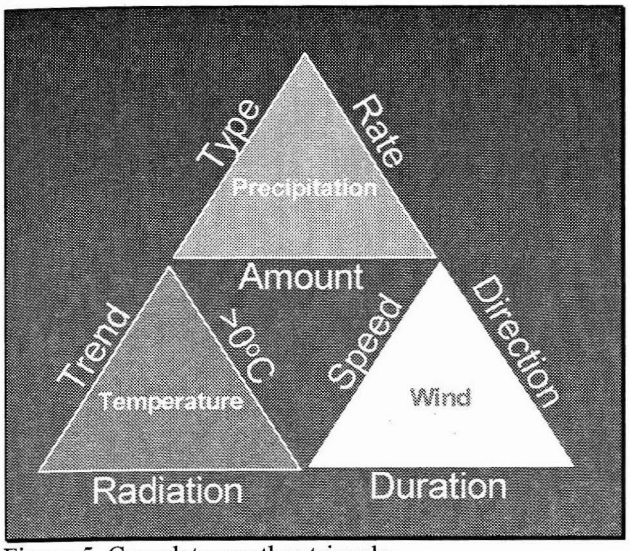

Figure 5. Complete weather triangle

3. Weather: Separate entities functioning in combination

These nine factors are not a laundry list, but an interconnected process. For example, a cooling trend may negate the effect of a high precipitation rate, reducing instability. Wind velocity of 10m/second after a storm producing 15cm (six inches) of total snow will increase stress on lee slopes. All weather factors are tied to terrain and snowpack to determine stability.

Critical threshold values have been developed for many weather parameters. The first, known as the Ten Contributory Factors, were postulated by Montgomery Atwater (1953). Some aspects of this list have fallen out of favor with educators. Mr. Atwater's preamble, however, is true without question and applies to this system: "In order to discuss these contributory factors coherently, it is necessary to identify and discuss each as if it were a separate entity. [In] nature they are not separated, but function as a combination." It is helpful to relate threshold values to students, but with caution. Students should view these threshold values as imprecise warnings – such as 2.5cm/hr snow = red flag (McClung 1993). These values are not absolute, but are related to general concepts (i.e. slabs are unstable when rapidly loaded and deformed). The most important lesson is the interrelation of all nine factors in the development of a weather related avalanche hazard forecast. A triangle is a great graphic organizer for relating all nine critical weather variables as interrelated, and assisting the student to remember all factors.

4. Conclusion

Wind, precipitation and temperature are the primary weather factors that contribute to avalanche formation. Each of these factors has three subcategories that aid the student in understanding avalanche formation. By observing nine pieces of data we get a better picture of how the weather is constructing our snowpack, causing instability, or improving recreational opportunities.

Using this Weather Triangle graphic organizer has been helpful in the creation of a PowerPoint Presentation and an avalanche weather game for training courses. The Triangle serves as an outline for presenting weather as a contributing factor in the formation of avalanches, and as a memory tool.

5. Reference

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