<u>A Brief Analysis of Hillside Wind Gusts</u>

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Anyone who has lived on the Hillside or east Anchorage for any length of time knows that strong winds are a fairly common occurrence during the cooler months of the year. From time-to-time wind speeds can be strong enough to topple trees, lift roofs and create general mayhem. These episodes are associated with downslope windstorms during which air is initially over the Gulf of Alaska, flows down the western slopes of the Chugach Mountains. Wind speeds during these events are highly variable in both time and space; at any given location speeds can increase or decrease significantly over the span over a few seconds. In addition, locations a mile or two apart can experience drastically different speeds.

The National Weather Service has operated a wind sensor (anemometer) in Glen Alps for several decades. The data displayed on the Mesonet webpage for example gives the one minute average during the observation period as well as the fastest one second wind (gusts) during that same period. The peak gusts is the fastest one second gust over the previous one hour period; which is why the gusts and the peak gusts frequently do not agree. Although speeds are sampled every second by the instrument, due to the large volume of data only on rare occasions is the one second data archived. A few examples of one second wind data is presented below.

Figure 1 displays a two and one-half minute window of strong winds (mph) during the January 22, 2008 storm. The red line which is the one second data shows high frequency variations and ranges from 8 to 84 mph. The dark green line is the one minute average (running mean) which for this example is starts off around 30 mph but then increases to +40 mph. Notice that lulls in the wind speed are common as well. There are times at the start or conclusion of a wind event during which the speeds are calm, however during the peak of the event calm winds are rare. The overall impression is that wind speeds on the one second time scale rise and fall like a roller-coaster.

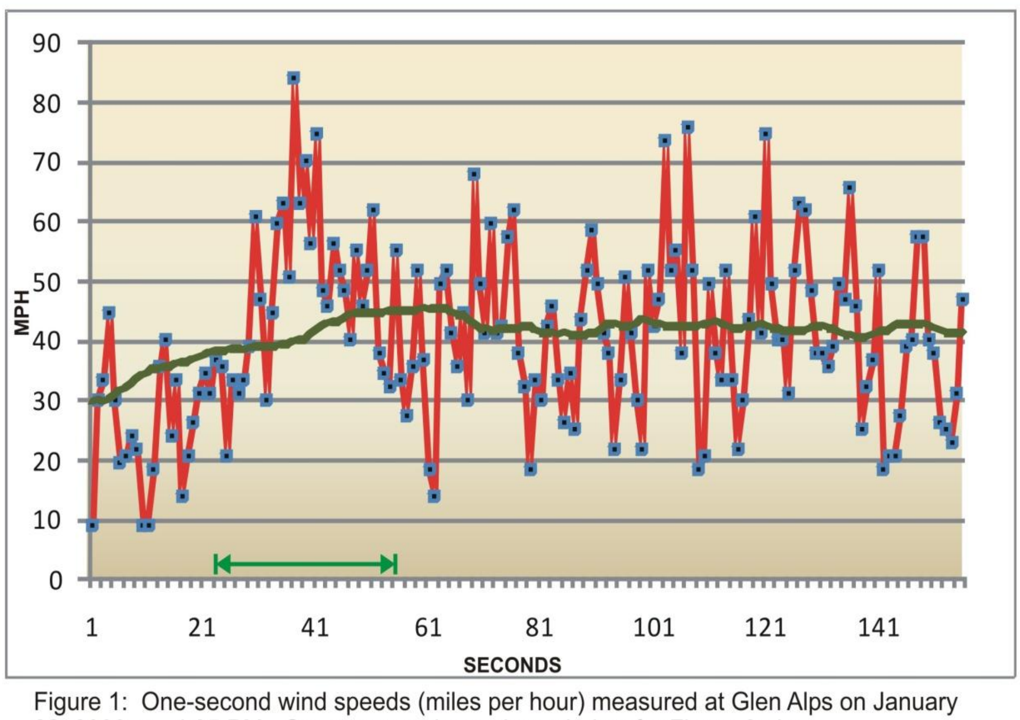

Figure 1: One-second wind speeds (miles per hour) measured at Glen Alps on January 22, 2008 at ~4:35 PM. Green arrow shows time window for Figure 2 plot.

Figure 2 is an expanded view of the time period highlighted by the light green arrow seen in the bottom left of Figure 1. The purple arrow indicates an increase from 50 mph to 84 mph in one second. The orange arrows show that at certain times the speeds tend to be ‘clustered’; three to five second intervals during which the speeds are <u>nearly</u> constant.

The best way to understand these wind regimes is to separate the observed wind into two components: the first part is a relatively steady flow that moves down the mountain slopes in layers, effectively ‘hugging’ the terrain. This air tends to be produced by the pressure difference that exists across the mountains: higher pressure over the northern Gulf of Alaska with lower pressure in northern Cook Inlet (air flows from high to low pressure). The second component which is superimposed on the steady flow is the highly turbulent (gusty) part which is produced above the mountains. Air movement several thousand feet above the mountains is at certain times highly turbulent because it moves in a wave pattern. When the height of these waves becomes large they tend to curl over like an ocean wave breaking as it moves toward the beach. This wave breaking action generates zones or eddies of highly turbulent air. The air beneath the eddy (steady component) as a consequence is forced toward the ground and accelerates. The result is that observed wind speeds increase dramatically. Wave breaking in the atmosphere is not continuous and hence speeds in the air above the ground tend to pulsate. Lulls or short periods of weak winds may represent an eddy which has reached the ground, or through some other process, weakens the steady flow (our understanding of this is far from complete).

The two aforementioned components when combined produce the red line pattern of Figure 1 while the steady component is fairly well represented by the dark green line. Although Glen Alps is the only location at which continuous one second wind data is available, it is clear to residents that gusts and lulls are pretty localized- they in general do not appear to travel down the Hillside from summit to base. Computer model simulations as well as observations from various locations around the world that experience downslope windstorms, indicate that the strongest winds are often found along the mid-point of a mountain slope. In reality the Glen Alps site is about half-way down the lee slope of the western Chugach even though it is referred to as 'upper Hillside'. The pattern of tree and structural damage varies from one event to the next, with some events producing the strongest winds on the Hillside and others in east Anchorage. In other words these wind storms are not identical in their nature; there is a lot of uncertainty (predictability) in where the gusts and lulls will be produced as well as the maximum speed. During the October 2008 wind storm there was significant tree damage around the Hilltop Ski Area but almost no tree damage at Campbell Airstrip locate one and three quarter miles downstream; this is a good example of the spatial variability of the strongest gusts.

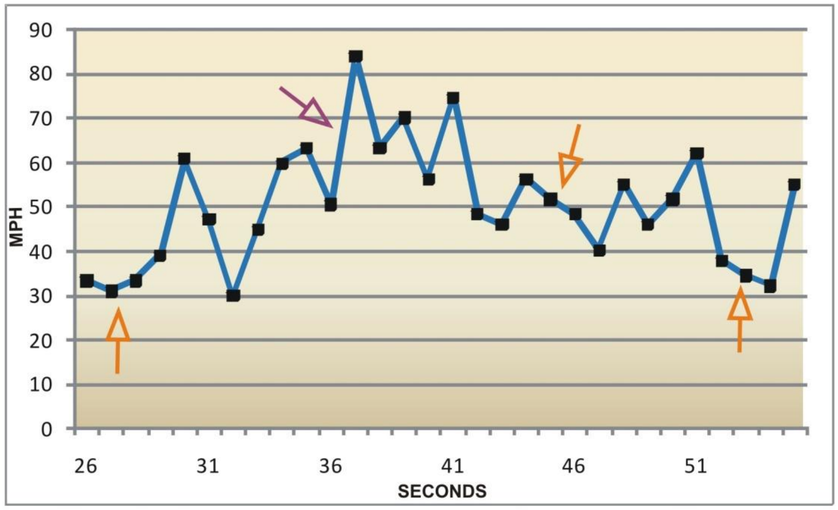

Figure 2: One second wind speeds (mph) from window of figure 1.

Figure 3 shows one second wind speeds at the beginning of the February 20, 2008 event. The blue arrow highlights a forty second period during which the speeds were +200% of the steady winds. During the onset and conclusion of wind events the steady wind speeds are typically lower compared to those that occur during the peak. In addition the duration of the steady winds tend to be longer as well, in other words the frequency of the gusts is not as high at the beginning and conclusion of an event compared to the peak period. This is probably due to the fact that at the beginning of an event the flow over the mountains is just beginning to form high amplitude breaking mountain waves, while at the conclusion of an event wave breaking is starting to weaken and become less frequent. During the peak of the event although wave breaking is not continuous (at least as observed from any given point), it tends to be stronger and more frequent then at the start and conclusion.

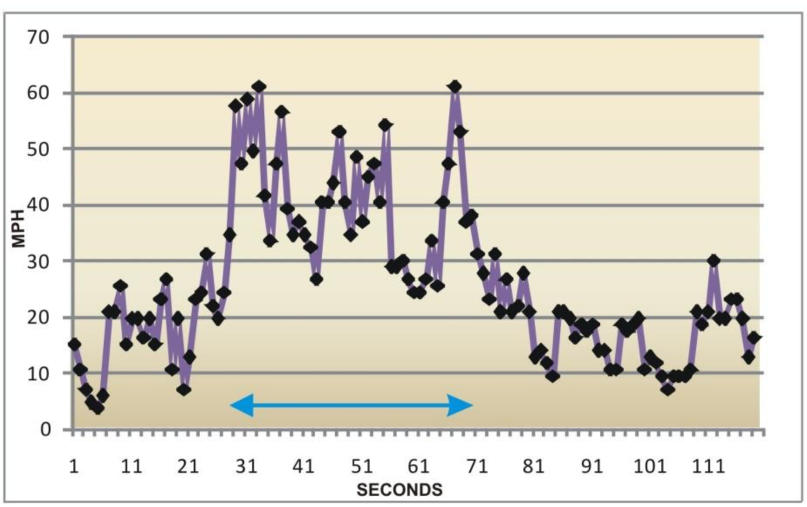

Figure 3: One second wind speeds (mph) for February 20, 2008 event.

Another common observation during strong events is that the wind direction at any given location on the Hillside or east Anchorage does not necessarily remain steady. Although the primarily direction is for the winds to blow out of the east or southeast there are times when the direction is radically different. Northeast to northwest flow is not uncommon because of the formation of larger eddies that form at the base of the Chugach Mountains and interact with the pressure field in northern Cook Inlet. On the smaller scale, it is possible that eddies (and maybe rotors) generated in the wave breaking zone above the mountains reach the ground. In that case the highly turbulent air can create small zones where the wind direction is different from the steady flow. There is some speculation that the local terrain (canyons, gaps between the higher summits) enhances wind speeds during downslope wind events, but this has not been proven by systematic observations or modeling studies. It is clear however that the strong winds frequently observed in the Bear Valley area are closely related to the flow in Turnagain Arm; Turnagain Arm which is of course a gap in barrier of the Western Chugach provides a channel for strong winds. At times the winds several thousand feet above sea-level moving through the gap move over the ridge and accelerate as it moves down into Bear Valley. Hence there are times when the winds in Turnagain Arm and Bear Valley are significantly stronger than what the wind sensor measures at Glen Alps.

General Characteristics:

1. The strongest gusts often exceed the one minute average by 200% and in some cases as high as 300%. For example, if the one minute average is 30 mph then a one second gust of around 60 mph can be expected. At times however gusts to of 70-100 mph do occur. This rule of thumb does not work at lower speeds where the difference between the steady wind and gusts can be much greater.
2. In the seconds prior to a very strong gust the speeds can either successively increase ('ramp-up') or be characterized by an abrupt increase ('jump'). Both characteristics are common.
3. The strongest gusts tend to have a duration of up to 3-sec and occasionally 5-sec. Fortunately these strong gusts do not last longer than a few seconds otherwise damage would be considerably more extensive.
4. The strongest gusts do not seem to move down the length of the Hillside- they appear in an area and they weaken over a fairly short distance (several miles).

Further Reading:

For a more in depth study of Turnagain Arm winds read: *The Nature of Gap Winds through the Western Chugach Mountains*. http://pafc.noaa.gov/papers/papers.php (under Research Papers on main web page)

For a more detailed look at downslope winds in Anchorage read: *Analysis of Anchorage Downslope Windstorms*. http://pafc.noaa.gov/papers/papers.php (under Research Papers on main web page)