14A.2 WIND PROFILER PERFORMANCE IN COMPLEX TERRAIN: JUNEAU, ALASKA

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1. INTRODUCTION

Juneau, Alaska is located in complex, mountainous terrain with nearby peaks rising steeply from sea level to over 1 km. In addition, because of its coastal location between the Coast mountain range and the Alexander Archipelago, Juneau's weather is strongly influenced by both moist maritime air masses and cold dry continental air masses (Colman, 1986). The Aleutian low in the Gulf of Alaska guides storms with strong pressure gradients on shore, and the interaction of these storms with the precipitous terrain generates strong local flows. Dry continental air traverses the Coast range to reach Juneau and arrives as strong NE winds from density currents known as Gap flow or down slope windstorms from amplified mountain waves knows locally as the "Taku" (Dierking, 1998; Colman and Dierking, 1992).

Since 1998 three radar wind profilers and numerous anemometers have been collecting data near Juneau as part of an aviation safety project. The locations of these wind sensors expose each of them to different flows around this dramatic terrain. Wind profilers are often affected by ground clutter when sited in mountainous terrain so, while they have been used to study deep flows affected by large scale terrain, for example mesoscale circulations and atmospheric waves, they have seldom been used to study smaller scale flows around terrain.

In this paper, the wind profiler and anemometer data set is used to reveal local flows. This is possible because the dataset has been processed using the NIMA/NWCA algorithms described in Morse et al. (2002), Goodrich et al. (2002) and Cohn et al. (2001) greatly reducing contamination by ground clutter, and because a statistical approach is used. The flows are studied using probability density functions of measured wind directions, and using wind rose histograms (a statistical composite of wind speed and direction occurrences) for each site. The wind rose histogram can show dominant directions of flow as well as the dominant wind speeds from each direction. Less frequent phenomena also appear in these plots. Finally, diurnal effects are presented from anemometer data, with examination of similar effects from the wind profilers left for future work.

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2. THE ROLE OF TERRAIN

The terrain surrounding Juneau is divided by the Gastineau Channel, which runs from NW to SE between the mainland and Douglas Island (Figure 1).

The orientation of this channel plays a role in flow characteristics both when flow is from the Gulf of Alaska to the west, and when it comes over the Taku glacier to the northeast. On both sides of the Channel the terrain rises steeply. On the NE side there are several ridges and peaks separated by creek drainages. These drainages are important in the case of Taku flow. To the northeast of these ridges and valleys are the Juneau ice fields and Taku glacier.

We present results primarily from the South Douglas wind profiler, located near sea level on the SW side of the Channel and indicated by "SD" in Fig. 1. At heights below the nearby peaks, this profiler is exposed to the channel restricted flow. It is also exposed to Taku direction winds associated with Gap flow and mountain waves. The two other wind profilers are located at North Douglas (ND) and Lemon Creek (LC). Other locations indicated in Fig. 1 correspond to anemometer sites further described in Cohn (2003).

3. WINDS IN THE GASTINEAU CHANNEL

Figure 2 shows wind direction and wind rose histograms for seven altitude layers from the South Douglas wind profiler. Logarithmic shading is used. Although measurements were collected with 60 m altitude resolution, data has been grouped into 300 m layers for clarity. Each plot in this figure includes about 4×10^6 30-second wind measurements. Only high quality (high NWCA confidence) data is included. The plots illustrate the observed pattern of winds around Juneau and trends with increasing altitude.

In the lowest altitude plot, covering an altitude range of 120 m (the lowest available wind profiler measurement) to 300 m, the direction distribution is similar to that seen by a co-located anemometer at the surface (not shown) although the observed wind speeds are greater. One noticeable difference is that the NE flow direction (from about 50°) is much less distinct than in the anemometer distribution. Taku and Gap flow winds will often have low NWCA confidence compared with many other situations because the continental air is dry and cold leading to

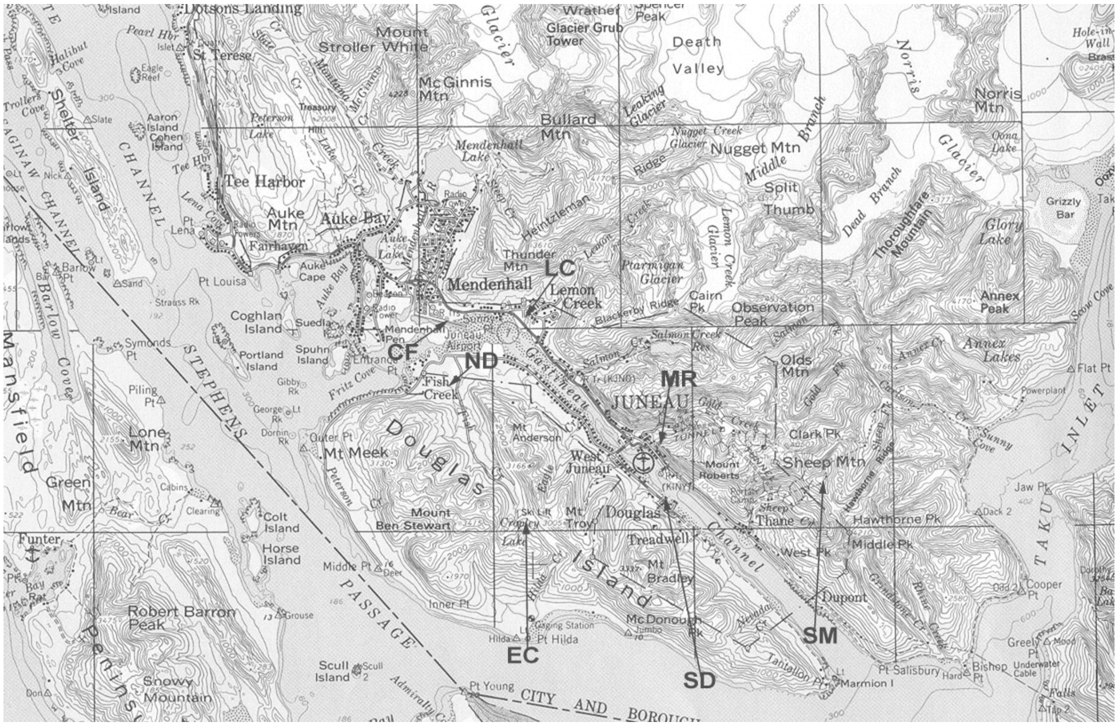

Figure 1: Map of Juneau and Southeast Alaska. SD, ND, and LC are locations of radar wind profilers with collocated anemometers; SM, MR, and EC are locations of mountaintop anemometers; and CF is an anemometer at the Juneau airport (center field).

weaker backscatter, and because the strong winds generate ground clutter in the lower range gates. The NE winds will be seen more clearly at higher altitudes where ground clutter is less severe. Another difference is that the down-channel mode (from about 315^{o}) does not show a skewness introduced by flow out of the Bear Creek valley (just west of SD), which has been observed with the surface anemometer. This suggests that the Bear Creek outflow events are shallow. The dominant flow directions, closely aligned with the channel, show little variation in direction. Winds are deflected to flow along the channel from either the northwest or southeast, depending on the synoptic wind direction. The channel is steep and narrow so it produces a classic channelized flow. flow. Since the dominant incident wind direction above the terrain is from the south-southwest, there are many more occurrences of SE then NW flow in the channel. The wind profiler captures this, even though it is at low altitude and near many ground clutter targets.

In the next altitude layer, between 300-600 m and roughly 600 m below the mountain ridges, there is even less variation in direction than in the 120-300 m layer, but this may be because the data is less affected by ground clutter. Higher wind speeds are measured in this layer, a trend which will continue with increasing altitude.

The next higher layer, between 600-900 m, has similar features but is less restricted by the channel. The dominant up-channel direction rotates clockwise, to more southerly, and the NE mode becomes clearly visible.

In the wind rose histogram covering 900-1200 m (near the height of the local mountain ridges) a NE direction mode has become clearly visible in the wind rose histogram with a concentration of measurements from the northeast occurs more frequently and a new mode begins to emerge. The new mode, from about 220 degrees, represents winds observed from the synoptic direction above the influence of the Channel. This measurement layer is at an altitude where the channelized flow below transitions to free atmospheric flow above, which is less directly influenced by the terrain

In the two highest layers, 1500-1800 m and 1800-2100 m, a broad range of directions from the south and west begin to dominate. This is more representative of the prevailing wind above local terrain. Although there are still many observations aligned with the channel (including some down-channel) direction winds, the influence of the Gastineau Channel is least here, and the main surface effects will be through friction and waves. In these layers the Taku or Gap flow wind direction is most clearly identified and from about 50 degrees.

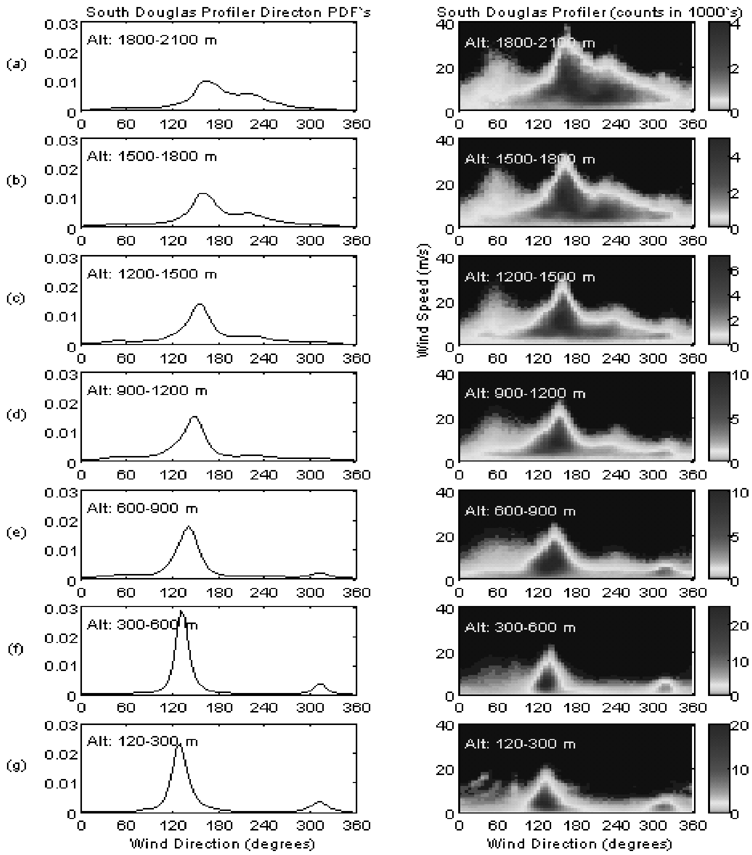

Figure 2: Wind direction probability density functions (PDF, left column) and wind rose histograms (right column) for seven altitude ranges from the South Douglas wind profiler (SD).

Overall, the South Douglas wind profiler wind rose histogram documents the local wind patterns around Juneau very well. Near the surface the winds are parallel to the Gastineau channel from the northwest or southeast. The strongest winds are from the southeast direction. The NE wind mode is seen at all altitudes but is most visible at or above 900-1200 m. South to southwest winds are evident, occurring most at the highest levels of data, as is expected as one moves farther above the influences of the Gastineau Channel. Wind speeds are the highest and observations most frequent from these directions.

3. DIURNAL EFFECTS

As described in Cohn (2003), the anemometer data shows many examples of a diurnal pattern in the observed wind directions.

Diurnal flows are considered in detail in, for example, Whiteman (2000), and generally occur where there is differential heating or cooling creating a temperature gradient. Nocturnal drainage flows in valleys are common, occurring as elevated valley walls radiate heat more effectively than lower surfaces. Diurnal flows generated by daytime temperature differences caused by differential solar heating are also seen when the terrain geometry is favorable.

Figure 3 shows the diurnal distribution of 1-minute winds from various direction sectors around the SD, ND, and LC anemometers, as a function of local time. Both daytime and nocturnal flows are seen. Although nocturnal drainage flows are expected to be shallow, the daytime circulations may be deeper, especially within the LC valley. Future analysis of the wind profiler observations will use used to investigate the vertical structure of these flows.

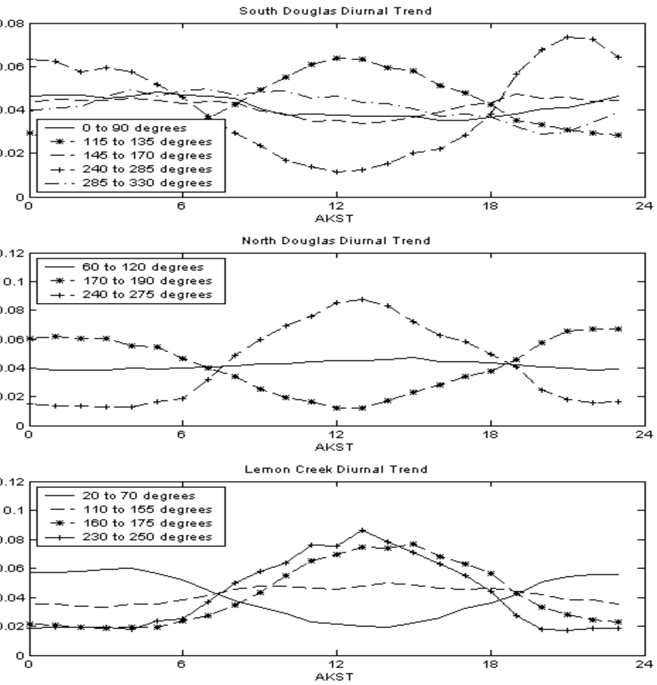

Figure 3: Probability density functions, as a function of local standard time, for various wind direction sectors from the SD, ND, and LC anemometers. PDF with a daytime minimum are expected from valley drainage flows; those with a daytime maximum are expected from up-valley or cross-valley flows; and those with no diurnal variation are expected from synoptic or other non-diurnal flows.

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