4.2 WEATHER PATTERNS OF JUNEAU ALASKA AND THEIR RELATIONSHIP TO AIRCRAFT HAZARDS

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1. INTRODUCTION

Juneau is located on the coast of Southeast Alaska. On its landward side, the Coast mountain range influences weather with nearby peaks rising steeply from sea level to over 1 km. On the Gulf of Alaska side are the islands of the Alexander Archipelago. Local weather is strongly influenced by flows from both sides – moist maritime air masses of strong low pressure systems from the Gulf of Alaska, and cold, dry continental air masses from interior Canada (Colman, 1986). The synoptic patterns and mesoscale systems interact with local terrain to generate strong and complex local flows. These include gap flows through the many local valleys and passes, "Taku" flow which is the local name of amplified mountain wave events, and strong channeled flow through the Gastineau and other local channels (Dierking, 1998; Colman and Dierking, 1992). More detail on these and other observations around Juneau are presented in Cohn (2004).

Juneau's flows and terrain interactions generate strong mechanical turbulence and wind shears, both of which represent hazards to aviation. Understanding these weather patterns, terrain interactions, and the hazards that result is necessary as part of the development of JWHAS, an alert system for local aviators. JWHAS, the Juneau Wind Hazard Alert System, is described in Barron and Yates (2004), Morse et al. (2004), and Fowler et al. (2004).

2. JUNEAU TERRAIN

The terrain surrounding Juneau is divided by the Gastineau Channel, which runs from NW to SE between the mainland and Douglas Island (Fig. 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 and gap flows. Valleys on this NE side are associated (from N to S) with Lemon Creek, Salmon Creek, Gold Creek, and Sheep Creek. The up-valley ends of the Lemon and Salmon Creek valleys are more enclosed than Gold Creek and Sheep Creek, so gap flows are less common. The Gold Creek valley includes downtown Juneau. To the northeast of these valleys and ridges are the Juneau ice fields and Taku glacier.

On the west side of the Gastineau Channel, high mountains on Douglas Island also play a role in the weather. Douglas Island is partially divided by the Fish Creek valley, which is approximately parallel to the Gastineau Channel. On the east side, near the Channel, Mt. Anderson, Mt. Troy, and Mt. Bradley perturb flow from the south and east. On the west side of the island, Mt. Meek and Mt. Ben Stewart protrude into westerly and southerly flows.

3. WEATHER PATTERNS

While the large scale flows are well described as maritime land-falling lows from the Gulf or Canadian highs forcing gap flow, the local flows are also tied to the terrain. For our purposes, the following general classifications are useful, merging vernacular of the Juneau forecasters and others. Specific threshold wind speeds and precise wind directions are not specified.

1. *Southeast Flow*: Winds aloft are strong and from the southeast to west. Within the Gastineau Channel, winds rotate to be from the southeast and can accelerate. This flow direction is a result of the synoptic pressure gradient along the Gastineau Channel and restriction of coriolis turning by the channel "walls". Similarly an accelerated southeast flow is sometimes

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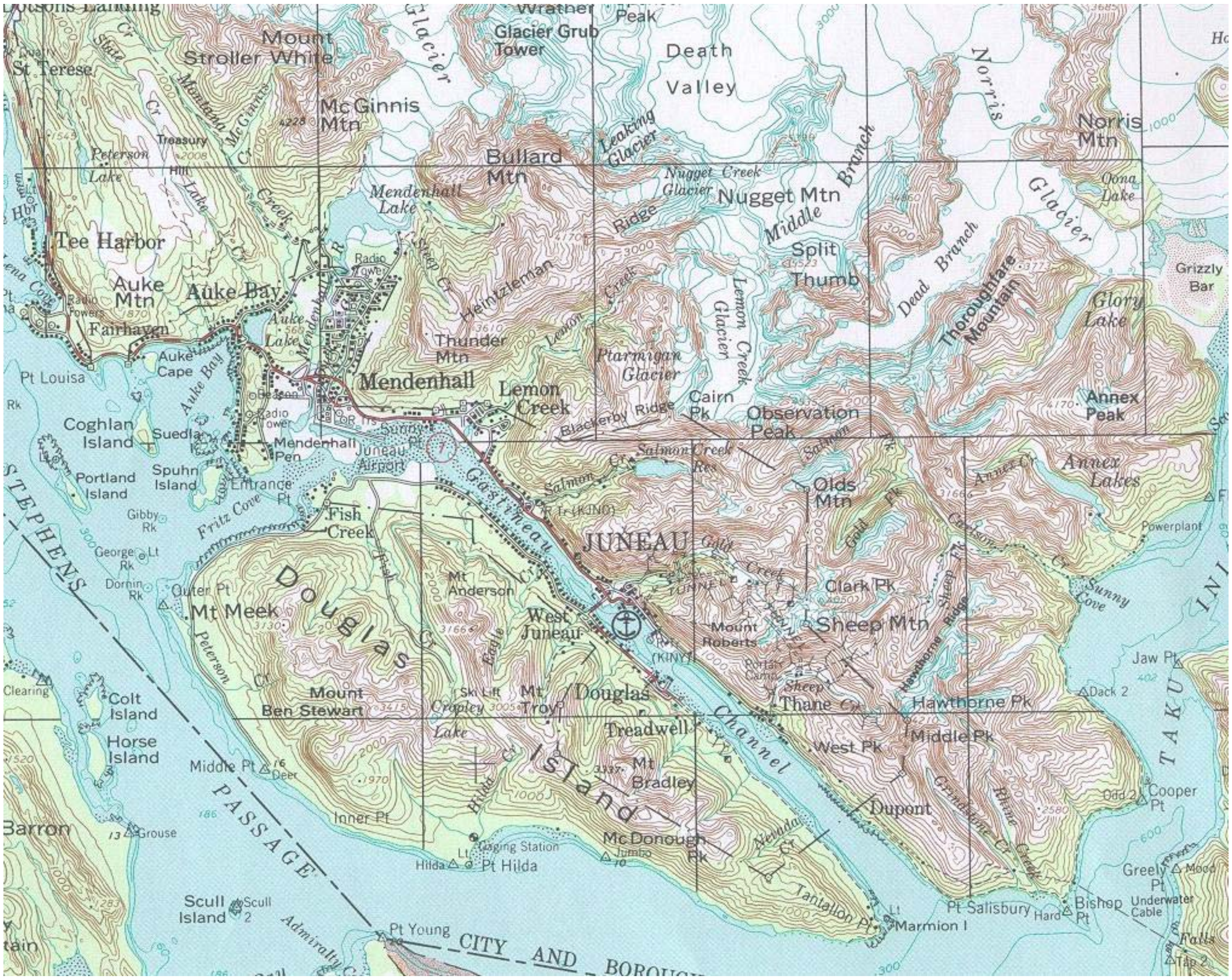

Figure 1. Map of Juneau and Southeast Alaska. SD, ND, and LC are the locations of radar wind profilers with collocated anemometer and the South Douglas, North Douglas, and Lemon Creek sites.

observed in the Fish Creek valley on Douglas Island.

2. *Taku Flow*: Winds are strong and from the north or northeast. Flow over the mountains upwind of Juneau creates mountain waves (stationary phase gravity waves). A critical layer is present aloft which traps this wave energy, allowing the waves to amplify. This wave activity generates strong winds, wind gusts, and turbulence within the Gastineau Channel.

3. *Gap Flow*: This is a similar condition to the Taku flow, except a critical layer is not present so mountain waves are not amplified. Often gap flow will occur when a shallow layer of cold air at the surface, dammed behind the high peaks, becomes deep enough to spill through mountain passes. This air will accelerate as a drainage flow down the creek valleys on the northeast side of the Gastineau Channel, generating localized turbulence. Flow will sometimes also occur over the Salisbury ridge in the southern part of the Gastineau Channel. Gap flow is driven by a pressure gradient across mountain passes. It can also result from an approaching low from the Gulf.

4. *Mixed Flow*: This refers to a regime similar to a gap flow, but having only a shallow flow from the north and flow aloft characteristic of a Southeast flow. In this situation aviation hazards may be similar to both gap and southeast flow.

These regimes represent only strong wind cases, and fall within the regimes of Colman (1986), with the gap flow and mixed flow both belonging to his "transition" flow regime. In addition to

Figure 2. Downtown Juneau and the southern half of the Gastineau Channel. Flow from the Gold Creek valley passes over downtown. Farther down the Channel are Sheep Creek, Salisbury Ridge, and at its southern end the Channel meets the Taku Inlet.

these four regimes, there are flows with lighter winds (from any direction).

Figure 2 shows the Gold Creek valley and downtown Juneau, about half way down the Gastineau Channel, in mixed flow conditions. Westerly flow aloft is bringing moisture and overcast skies, but gap flow is seen by the perturbed water surface at the outflows of Gold Creek and Sheep Creek (farther south in the Channel).

The distinct Taku and Southeast flow regimes are illustrated by the wind rose histogram of Fig. 3. This figure, made using a database of 1-min resolution data from the anemometer atop Sheep Mountain, shows the frequency of occurrence of wind speed and wind direction accumulated in bins 1 m s^{-1} by 5 degrees. The color scale was chosen to emphasize the less

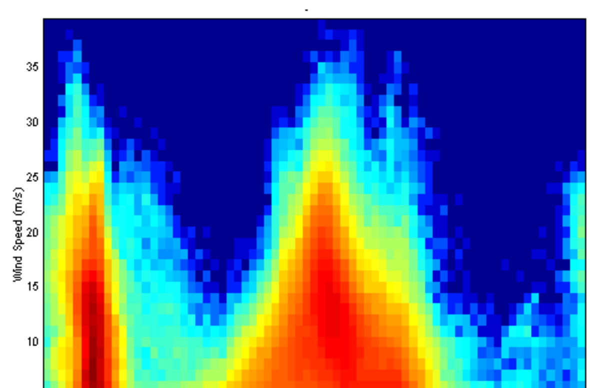

Figure 3: Wind rose histogram for the anemometer atop Sheep Mountain. The wind rose color axis is nonlinear to emphasize smaller values. Following the meteorological convention, wind directions are clockwise from true north.

frequent modes. This depiction is useful because it shows the directions of the highest wind speeds even if these directions are rare. From the figure, it is clear that strong winds will come from either the Taku direction (about 45 degrees) over the inland mountains and glacier or from the “southeast” direction with winds from south through west which generate SE winds in the Channel.

4. HAZARDS

Aircraft measurements of hazards were made during three JWHAS field projects. The data collection is described in Cohn et al. (2004). Measured hazards are EDR, defined as the cube root of eddy dissipation rate, and wind shear. These calculations are described in Gilbert et al. (2004) and Wilson et al. (2004) respectively. We will focus on EDR. Our analysis was done using an older version of the EDR dataset, with a few known errors, but this will not affect our conclusions. Figures 4-6 show composites of all aircraft measurements of EDR in three geographic regions around Juneau.

Figure 4 shows EDR values in the Lemon Creek vicinity. The lower plot shows a plan view and the upper plot shows a view of the same data projected against the vertical plane. In all the plots shown, larger values are plotted on top of smaller values so they are not masked. This also means that large values will be most visible. The color scale is EDR in cgs units. From this plot it appears that the strongest EDR values occur deeper in the Lemon Creek valley. From the plan view it is clear that this region includes a small part of the Fox departure flight path. The terrain profile plotted in the projection view is the terrain height along the line in the lower plot. This plot appears to show that the stronger EDR generally occurs lower in the valley. The highest EDR values in red occur along a small number of flight legs, and these flights were in strong southeast flow.

The next figure (Fig. 5) shows the plan and projection views of EDR measured within the Gastineau Channel. The data shown here is only from the FY2000 field season. There is good correlation between locations of strong turbulence and the creek outflows along the Channel. In particular there is strong turbulence at the outflow of Gold Creek near downtown Juneau, Sheep Creek southeast of downtown,

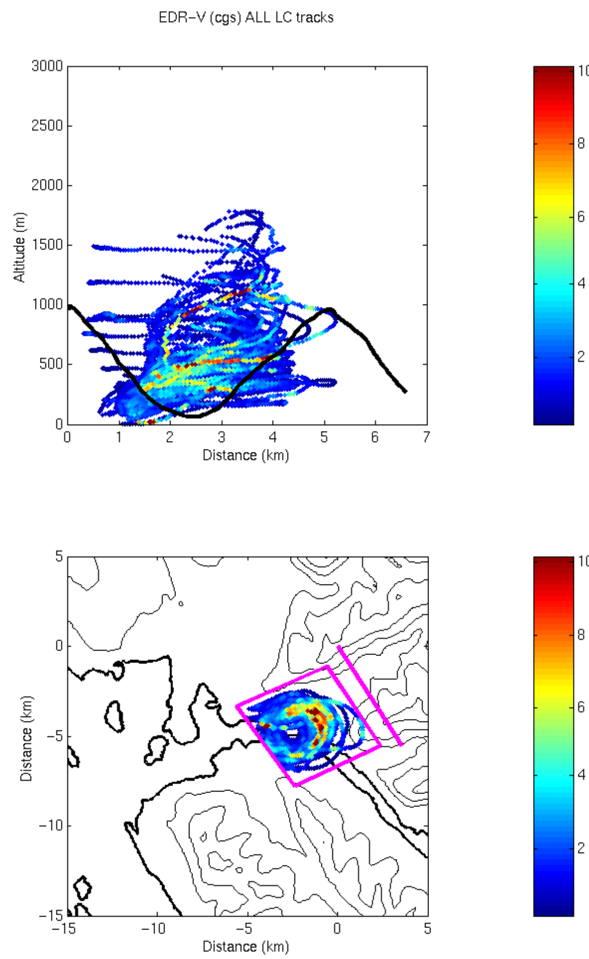

Figure 4: Spatial distribution of aircraft EDR (cgs units) measurements near Lemon Creek, including all measurements which passed quality control. Larger values are plotted over smaller values so they are most prominent. The lower plot is a plan view. The upper plot is the projection of the same data onto a vertical plane indicated by the line shown in the lower plot.

and over Salisbury ridge near the southeast end of the Channel.

The projection view shows the distribution with altitude of these stronger EDR measurements. The creek drainages appear clearly in the terrain plot. From left to right the creek drainages are Lemon Creek, Salmon Creek, Gold Creek, Sheep Creek, and at the extreme right is the Taku inlet. The terrain profile shown is the terrain height under the line indicated in the plan view, and does not directly indicate the relative height or depth of the drainages. Various flight

Correlation of the strong EDR flights with weather shows that turbulence associated with the creek drainages occurs during gap flow and Taku flow.

Figure 6 shows the plan and projection views of EDR measured along tracks in the airport basin north of Douglas Island. The terrain on Douglas Island is dominated by two groups of mountains separated by the Fish Creek valley. The plan view shows that two areas of larger values of EDR are seen to the northwest of two mountain ridge lines. In SE conditions this would be downwind of the highest peaks. Depending on the actual wind direction, the eastern region of high EDR could also be downwind of the Fish Creek valley.

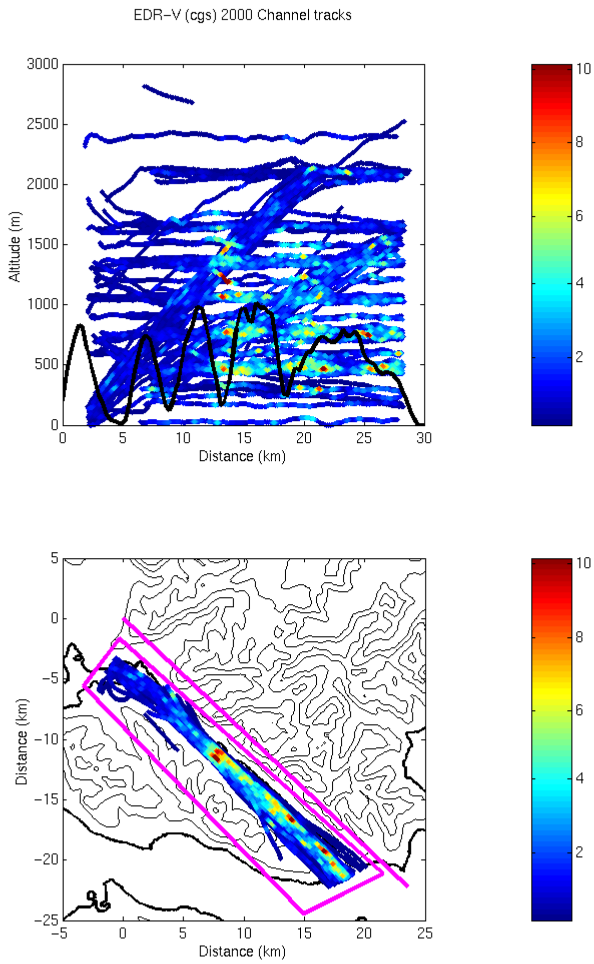

Figure 5: Spatial distribution of aircraft EDR (cgs units) measurements in the Gastineau Channel. The format is the same as Fig. 4.

paths can be identified in this plot. The horizontal legs are the "stacks" where tracks were flown along the Channel at a constant altitude; the steep tracks beginning to the left of Lemon Creek and climbing past Mt. Juneau (just left of Gold Creek) are tracks following the departure path, and the more shallow paths descending from right to left are tracks following the arrival procedure.

This figure shows that very few large EDR values were observed at the Salmon Creek outflow or well in front of the Lemon Creek basin. Turbulence at the Gold creek outflow appears stronger and perhaps broader at lower altitudes, although some large values are seen at higher altitudes. Similar patterns are seen at the Sheep Creek outflow and over Salisbury ridge.

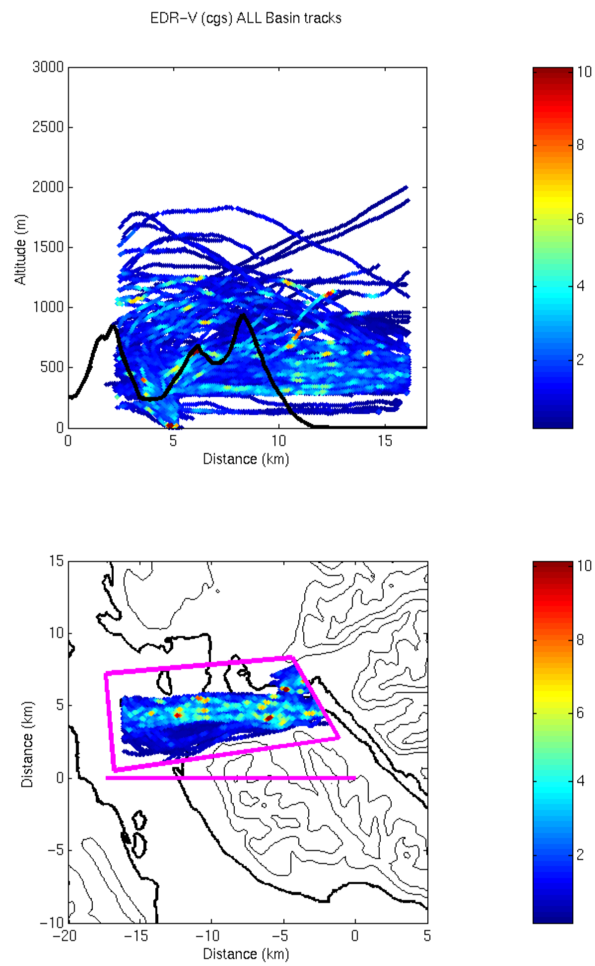

Figure 6: Spatial distribution of aircraft EDR (cgs units) measurements in the airport basin north of Douglas Island. The format is the same as Fig. 4.

The projection view is the projection of this data looking to the south. The two ridges are visible with the left ridge corresponding to the mountains on the east side of Douglas Island, and the right ridge corresponding to the west-side Douglas Island mountains. The valley between is the Fish Creek valley. In this plot, level flight tracks are during “stacks” within the airport basin, and tracks increasing in altitude from left to right are Lemon Creek or Fox departure patterns.

It is interesting to note that the strong EDR values downwind of the eastern ridge were clearly seen during the 1998 field project, while the strong EDR downwind of the western ridge were primarily seen in the winter 1999-2000 dataset. The data in this figure includes both data sets.

5. DISCUSSION

Understanding the weather patterns and air flows around Juneau, and the relationship between these flows, the local terrain, and aviation hazards, is essential to development of JWHAS. It is clear that hazard locations depend critically on the synoptic scale flow regime which drives the local flows. In its prototype form, the JWHAS algorithm uses a wind regime algorithm, tailoring its warning calculation to the type of local flow (Taku, Southeast, Mixed, and calm).

A second direct use of this analysis occurred when choosing the JWHAS warning areas. Hazard calculations are specific to the “hot spots” identified by this analysis. Analysis domains and warning areas were chosen based on these hot spots.

The locations of strong turbulence and aviation hazards make physical sense. Turbulence is found downwind of mountain peaks exposed to high winds (e.g. Mt Meek in SE condifions), at locations where high winds flow around barriers (e.g. from southeast flow around Blackerby ridge into Lemon Creek), within cold drainage flows and at their intersection with dissimilar flows (e.g. drainage outflow of Gold Creek), and in mountain wave conditions (in the Channel during Taku events)..

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