P4.4 FIELD PROGRAMS TO INVESTIGATE HAZARDS TO AVIATION IN JUNEAU, ALASKA

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1. INTRODUCTION

Data collected during three field projects were central to development of an automated turbulence and wind shear alert system at the Juneau International Airport. The Juneau Wind Hazard Alert System (JWHAS) is described in several companion papers in these proceedings (Barron and Yates, 2004; Fowler et al., 2004; Morse et al., 2004; Mueller el al., 2004; Braid et al, 2004). This paper describes the purpose and planning of these data collection exercises, the strengths and limitations of the sensors used, and discusses lessons learned which may be applicable to future aviation related field studies.

Base data for JWHAS consists of winds and derived fields from three boundary layer wind profilers and from a network of anemometers. This data is collected continuously and will be used to generate aviation alerts. During the field projects additional data were collected *in situ* using instrumented aircraft, and at various times using scanning radar and lidar remote sensors.

The weather patterns of Juneau and their relationship to aviation hazards are discussed more fully in Cohn et al., 2004. Juneau is located in complex, mountainous terrain with nearby peaks rising steeply from sea level to over 1 km. It is a coastal city, with the Gulf of Alaska and Alexander Archipelago to the west and the Coast mountain range to the east. Juneau's weather is strongly influenced by both moist maritime air masses and cold dry continental air masses (Colman, 1986). Low pressure systems originating in the Gulf of Alaska and down slope windstorms both result in strong turbulence and wind shear as they flow around the local peaks. These local mountains and valleys, as well as the long narrow Gastineau Channel exert great influence on the location and strength of aviation hazards. Fig. 1 shows a view of Juneau looking toward the southeast. The airport is in the foreground, the city is tucked behind Mt. Juneau in the Gold Creek valley. The Gastineau Channel separates the mainland (left side) from Douglas Island (right) both of which have high peaks.

Field experiments were needed at several stages in the JWHAS development, and each addressed multiple goals. At the start of the project, aviation hazards were generally known through anecdotal reports, primarily by local commercial and private pilots. These reports gave a rough expectation of turbulence or wind shear under weather conditions linked to a mountaintop wind measurement. For example, it is expected that during strong flow from the SE within the Gastineau Channel pilots would experience some wind shear when ascending or descending through about 3000 feet out of or into the Channel. It was also expected that turbulence would be encountered when flying within the Channel during downslope flow or "Taku" flow (the local name for trapped mountain wave events). However, to build a robust system we need to understand the flows more precisely. How strong are the wind shears? What flow regimes result in strong shear? Where, specifically, is turbulence expected? How strong is it? Under what wind conditions (specific threshold of speed and range of directions)? How often do hazards occur? ***GOAL 1: "collect data to understand the meteorology, air flows, hazard locations and climatology of hazards around Juneau".***

As is described in the companion paper by Morse et al. (2004), the design of the JWHAS system relies upon correlations between measurements with the system anemometers and wind profilers, and observed hazards. Development of the system required a "training" data set to quantify these correlations. Sufficient "truth" data were needed to establish these correlations at many locations, and under varied weather (wind) conditions. ***GOAL 2: "collect data to train the warning system".***

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Figure 1: Juneau, Alaska looking to the southeast. The Juneau International Airport is in the foreground. The Gastineau channel (center) separates the mainland (left) from Douglas Island (right). Downtown Juneau is about half-way down the Channel, on the mainland side.

By the third field deployment a prototype of the warning system was in place. Although it was not trained using a vetted data set, this was an opportunity to collect a data set which could be used in a verification exercise desired by the sponsoring agency. While the data collected in this field season continued to contribute to other goals, its primary design criteria was ***GOAL 3: "collect data to verify the warning system".*** The verification exercise is described in Fowler et al. (2004).

Another goal specific to the third field project involved the use of two aircraft. Because of the vastly different weight and measurement equipment of the participating aircraft, a requirement was ***GOAL 4: calibrate the eddy dissipation rate (turbulence) and shear measurements of each aircraft and establish the level of turbulence experienced with an operational airframe.*** Measurement and airframe effects of turbulence and wind shear for the JWHAS development are discussed in Gilbert et al. (2004) and Wilson et al. (2004).

A final objective of the field observation periods was to evaluate the base measurements collected as the driving input for the JWHAS system. Corroborating measurements by the aircraft, and close scrutiny by on-site staff are used to verify the performance of the wind profiler and anemometer measurements and their quality control algorithms. ***GOAL 5: Evaluate the base wind profiler and anemometer measurements.***

2. FIELD COLLECTION SUMMARY

The field project data collection goals were primarily addressed by collecting high-rate aircraft measurements of wind speed. From these turbulence and wind shear can be derived. Details on these calculations, and the difficulties encountered can be found in the companion papers (Gilbert et al., 2004 and Wilson et al., 2004).

a. Base measurements

The JWHAS area of coverage includes the area surrounding the runway and typical commercial aircraft departure and approach paths. Generally,

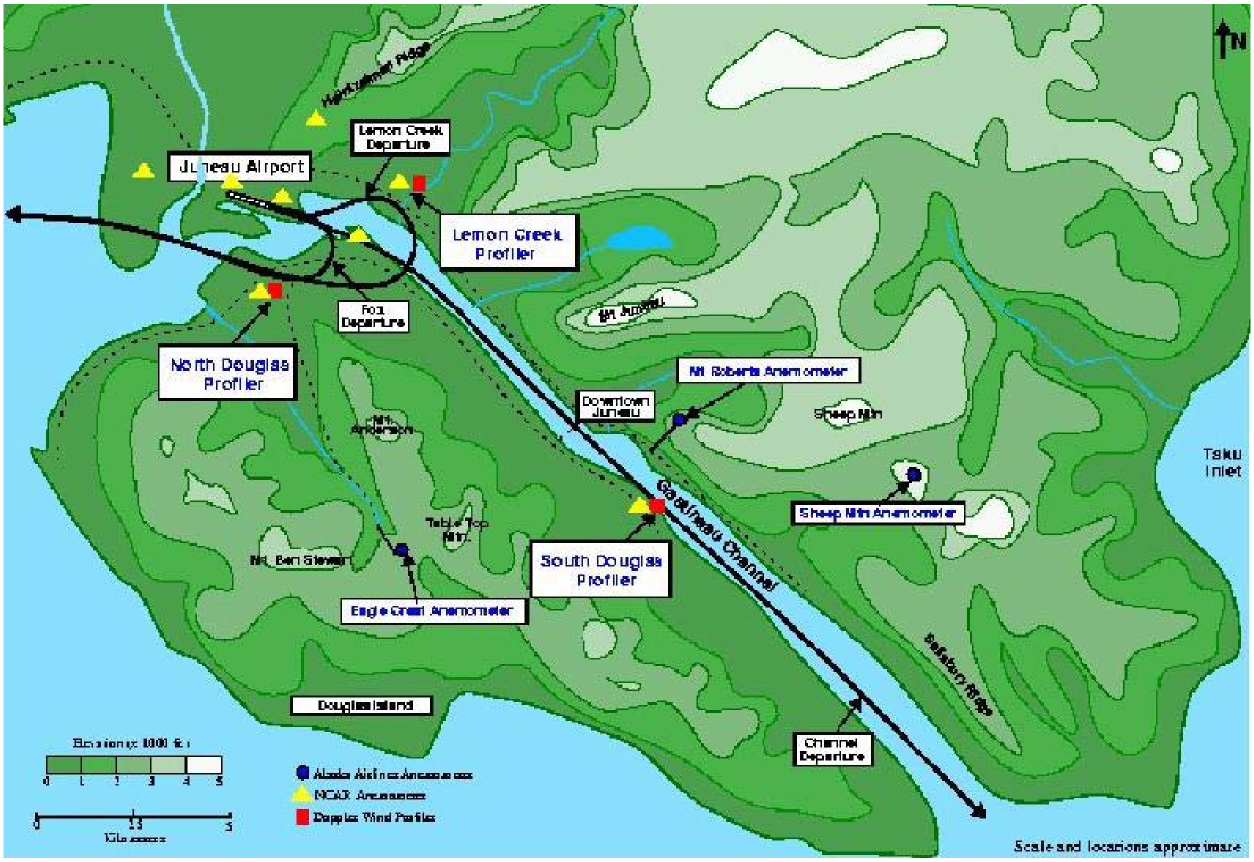

Figure 2: Departures from Runway 08 (Lemon Creek departure, Fox departure, Channel Departure), and locations of anemometers and wind profilers.

the airport basin and the Gastineau Channel are covered. Fig. 2 shows the three departures of interest, all of which use runway 08. Departures to the west (runway 26) do not fly close to terrain and are not expected to encounter terrain induced hazards. From runway 08 departing commercial aircraft may do a “Channel” departure, banking right and climbing while proceeding down the Gastineau Channel. They may do a “Lemon Creek” departure, banking left from the runway to enter a wide right turn through the Lemon Creek valley (visible as the broad valley in Fig. 1) and departing over the northern edge of Douglas Island. Or they may do a “Fox” departure, making a tight right turn off the runway and again departing the area over the northern edge of Douglas Island. As seen in Fig. 2, each of these departures flies over at least one of the wind profilers which provide base measurements for JWHAS. The South Douglas wind profiler is on a pier within the Gastineau Channel under the “Channel” departure path. Its wind measurements can diagnose the strength of southeast flows within the channel and synoptically driven winds above. The Lemon Creek wind profiler is directly under the Lemon Creek departure path. The North Douglas wind profiler is on the downwind sections of both the Fox and Lemon Creek departures. In addition, the JWHAS system relies on anemometer measurements from three mountaintops. The Eagle Crest anemometer is on a high peak on Douglas Island, the Sheep Mountain anemometer is in a saddle high up on the mainland, and the Mt. Roberts anemometer is also on the mainland but close to the Channel. Anemometers near sea level on Pederson Hill just west of the airport, and on the airport grounds provide additional base input for JWHAS. The locations of each of these sensors are indicated on Fig. 2.

b. Field support infrastructure

The operating environment for the JWHAS base instruments and for aircraft in Juneau is at times inhospitable. The mountaintop anemometers are exposed to severe icing conditions (Fig. 3), and the wind profilers are located near mountains and can face strong ground clutter. In addition to the turbulence and wind

Figure 3: The Sheep Mountain anemometer tower shows buildup of rime ice. The anemometers are headed to protect from this vulnerability (courtesy Al Yates).

shear being studied, aircraft can face rapidly changing weather leading to reduced visibility and ceilings which fall below the surrounding terrain height. During the field projects, decisions for flight operations depended on forecasts made with the assistance of the Juneau Forecast Office of the NWS. The forecasts also depended on observations of the base data making use of custom real-time displays, on local observations (out-the-window and using camera images from a tower on Pederson Hill), and on weather information such as satellite images available on the internet. One key to success of the field projects was a well connected operations center. From this center, we could evaluate the base data, communicate with the NWS forecast office via telephone, talk to the aircraft via radio, and track weather conditions on the internet. Fig. 4 shows the operations center. Science and Engineering stations are on the left. The other workstations, routers, and supporting devices monitor or

Figure 4: The Juneau Operations Center and analysis laboratory

support parts of JWHAS.

c. FY 1998 Data Collection

From February 11 through April 10, 1998 the University of North Dakota Cessna Citation research aircraft conducted flights in the Juneau vicinity to investigate the locations and strength of turbulence (Fig. 5). Flight tracks includes standard approach and departure patterns, a series of constant altitude stacks up and down the Channel incremented by 500 ft, and a constant altitude racetrack pattern around the airport basin, again incremented by 500 ft. A total of 32 research flight hours were conducted.

A Doppler lidar was deployed by Coherent Technologies, Inc. at no charge to the project. This lidar measures radial velocity using backscatter from aerosols.

Figure 5: The Univ. of North Dakota Citation II research aircraft (http://www.aero.und.edu/ats/citation.htm#)

d. FY 2000 data collection
The second field project took place over the Millennium transition, from December 1 1999 through March 31 2000. The University of Wyoming King Air research aircraft flew 74 research hours, following much the same flight patterns as in the first field project (Fig. 6).

The Doppler on Wheels (DOW) scanning weather radar was also used during this field project (Fig. 7). The DOW is a mobile X-band scanning radar constructed jointly by the University of Oklahoma and NCAR. It was designed with storm chasing in mind and can quickly move between locations. A description and analysis of the DOW data are presented in the companion paper by Mueller et al. (2004).

Figure 6: The Univ. of Wyoming Kingair research aircraft outside its hanger in Juneau.

Figure 7: The Univ. of Oklahoma/NCAR Doppler on Wheels mobile scanning X-band weather radar.

e. FY 2003 data collection
The third field project took place from October 15, 2002 through January 20, 2003. Considered the final opportunity for data collection, this project again used the King Air and the DOW, and a chartered Boeing 737-400 participated. This 737 (Fig. 8) was equipped with a Quick Access Recorder (QAR) to measure winds from which turbulence and wind shear could be calculated. The advantage of this aircraft is that it is certified to operate in the Gastineau Channel during periods of low ceiling and visibility typical during southeast flow, and is the same type as flown commercially into the Juneau airport. Prior field data had not been collected in these conditions because of safety and flight regulations. Additional flight patterns were constructed to safely coordinate dual-aircraft flights. The FY 2003 project also aggressively collected data in quiescent conditions to be sure we had enough “null” cases to train the warning system.

Figure 8: The chartered Alaska Airlines Boeing 737-400 departing the Juneau airport.

f. A typical day of field operations
A typical day in the field project proceeds as follows:

- Review NWS forecast FAX every morning. Usually follow-up with a phone call to discuss forecast.
- Compare expected weather with “tick list”. Decide if flight or DOW operations should be conducted in 12-36 hour window. Update crews and project phone message.
- Plan detailed DOW operations, including sequence of operation sites, and scan sequence from each site.
- Plan aircraft use (both aircraft). Decide priorities but maintain flexibility because of traffic, changes in weather, etc.

- Pre-flight briefing with aircraft crews; pre-deployment briefing with DOW crew.
- DOW deploys following detailed plan. Occasional phone contact to discuss observations and weather.
- Aircraft flights begin. Communication with Ops Director (in lab) using VHF radio.
- Aircraft provide pilot reports of turbulence along each flight leg. Ops Director records along with base wind information.
- Ops Director coordinates next flight leg with pilots on-the-fly. Modified as traffic allows.
- After landing, short post-flight discussion/review.
- Update “tick-list” count of flight legs and weather encountered.
- Review base data (wind profiler and anemometer) for the day.
- Prepare flight summary, DOW summary, and daily summary (email logs).
- Phone NWS for weather briefing/update
- Plan next day’s possible activities. Give crews a head-up. Update project phone message.
- Head for home.

3. LESSONS LEARNED

The lessons learned during each field season improved planning for the next. But also each season was different so new challenges were faced, mistakes were made, and lessons were learned.

- ***Good logistics are essential.*** The central lab space provided access to information including realtime and recent past displays of the wind profiler and anemometer winds; output of the “Op Spec” guidance for flight operations; web based weather products including NWS published forecasts, satellite maps, model output, surface and sounding station data, etc.; a diagnostic display of all instrument status; telephone and fax contact with the local NWS forecast office for weather discussions; telephone contact with the DOW operating crew; VHF radio communication with the aircraft and listen-only communication with the tower and flight operations center. With each field project, more access was added, improving our ability to conduct operations.
- ***Project pre-planning must be comprehensive.*** This will take as much effort as the data collection. In addition to the basics, such as contracting with aircraft, renting hangers, coordinating with air traffic controllers, etc., preparation included charting the number of observations (aircraft flight legs and DOW scans) needed for specific locations and weather conditions, creating and installing display software, planning daily interactions with the NWS and with each group participating, etc.
- ***Have flexibility and backup plans.*** While some observations are critical, any field project using sophisticated systems will have missed opportunities because of equipment problems, unexpected weather, or miscommunication. During the FY03 deployment, the engine of the DOW truck failed. While waiting for a new engine to arrive by barge, DOW was moved from site-to-site using a tow truck.
- ***Communicate early and often.*** Everyone wants or needs to know the project status. A daily status update was issued with a heads-up for future flights or DOW deployments; voice messaging was used to distribute the latest updates; the Operations Center and DOW crew communicated often by cell phone during deployments; VHF radios linked the Ops Center with the aircraft in-flight, and during dual aircraft flights the aircraft were able to communicate directly with one another.
- ***Test and understand instruments early.*** As described in Gilbert et al. (2004) and Wilson et al. (2004), accurately measuring in situ turbulence and wind shear with aircraft is not an easy or routine task. In fact, wind measurements during turns, climbs, or other accelerated flight can have significant errors. Problems were found in turbulence measurements from all aircraft data streams (Citation, Kingair, chartered 737) which required huge efforts to resolve. In the case of the 737 data system the basic measurement resolution was too coarse, and the data were not as useful as expected.

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