Ensuring operational safety through real-time current data collection in Port of Juneau, Alaska, USA

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Abstract
This work describes the use of real-time current monitoring systems at the Port of Juneau, Alaska, USA, to manage better the risks presented by increasingly larger cruise ships navigating a confined waterway. The system described provides pilots and vessels' masters real-time tidal current information obtained from sensors located at critical navigational points via the port's Automatic Identification System (AIS). The system consists of a 400 kHz, 2D side-looking acoustic Doppler profiler that is connected via a cable to a shore-based cellular modem, that relays the data to the Marine Exchange of Alaska, which in turn transmits the data to vessel operators and others via AIS and the internet. Currents are measured as far away as 100m from the dock extending into the area where vessel operators commence their turn for approaching the docks or anchorage area. Examples of the current data, along with a discussion of the installation and system requirements, are presented in this report.

Keywords: Currents, Real-Time, ADCP, Operational Safety.

1. Introduction

Vessel docking operations can be challenging endeavors even under normal conditions, and are especially complicated by strong local currents. Information on the velocity and direction of current prior to a vessel being affected by the forces is valuable to mariners when deciding how to maneuver the vessel in confined waters. As the economic value of real-time oceanographic data has been well documented [6], this present work describes the use of real-time current monitoring systems at the Port of Juneau, Alaska, USA, in order to mitigate the hazards presented in navigating and mooring large vessels in the Port's confined waters.

2. The Port of Juneau

The City and Borough of Juneau is the capital of the US state of Alaska. It is located along the Gastineau Channel (Figure 1) and has a population of over 31,000 people. Tourism is a key contributor to the local economy, especially during summer months (May-September). The Port of Juneau is the largest cruise ship port in Alaska with over 500 vessel port calls a year bringing over 1 million passengers to this picturesque community [2][4]. There are four docking facilities in the port where large cruise ships can moor. At times one or two additional cruise ships are anchored in the harbor making maneuvering of vessels to and from their berths even more challenging. Information on the velocity and direction of currents as they enter the port aids pilots and masters in making critical maneuvering decisions.

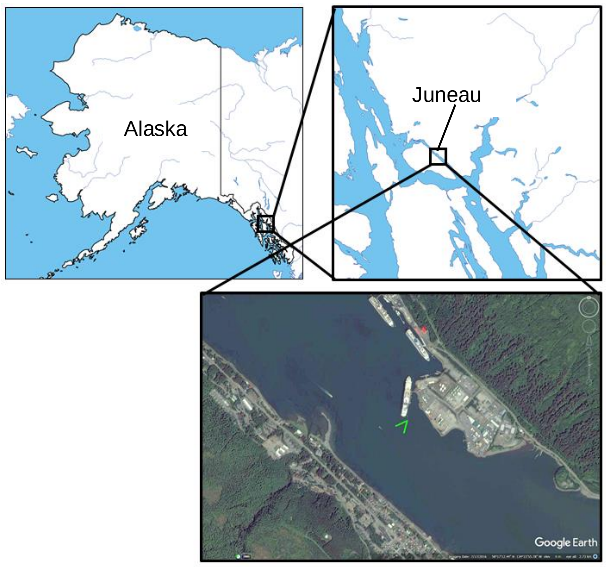

Figure 1 Location of AJ Port south of the town of Juneau, where the system is installed. The width of Gastineau Channel where the dock is located is approximately 700 m. The two green lines in bottom map represent the exact location of the beam paths from the profiler's transducers (each path is 101 m long).

The Port of Juneau is a physically small port with increasingly larger cruise ships calling at this port due to the natural beauty of Alaska. The increasingly larger cruise ships arriving at the Port of Juneau required the construction of larger docks to provide adequate moorage. In doing so, the new docks further restricted the open water where vessels maneuver when arriving and departing the port making it more challenging to safely navigate ships in the physically restricted waters. Prior to installing the real-time current monitoring system, pilots and masters had to rely on tidal current predictions which do not take into account other factors impacting currents in the port, such as glacier run off and wind. The Marine Exchange of Alaska, has installed and operates AIS stations and weather sensors at over 140 locations throughout coastal Alaska. To evaluate and mitigate the navigational challenges presented by the new larger docks, the Port of Juneau hired the Marine Exchange to work with pilots and masters to assess the navigational hazards and install current and weather sensors in strategic locations.

3. System Description

The real-time current monitoring system installed at the Port of Juneau consists of the following components:

- Nortek 400 kHz 2D Profiler
- Online Cable
- Cellular Modem
- Back-up power system

The primary component of the system is the Nortek 2D Profiler, which is a side-looking Acoustic Doppler Current Profiler (ADCP). The use of side-looking current profiling systems for real-time port and harbor operations has been in place for nearly 20 years [1]. They operate by transmitting relatively short pulses of sound which then scatter off the particles in the water and each pulse's reflection (echo) is detected back at the system. Each echo is Doppler-shifted, with the shift proportional to the speed of the water [5]. The instrument used in this specific work is pictured on Figure 2.

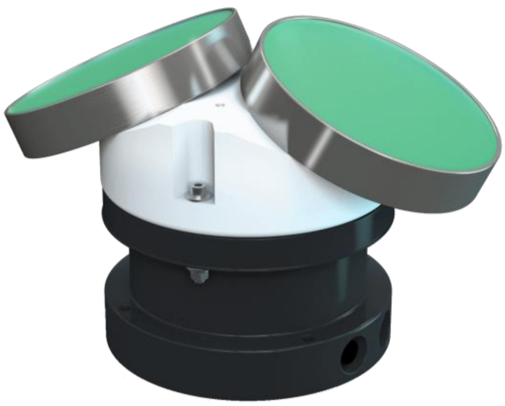

Figure 2 The Nortek 400 kHz 2D Profiler. The two green urethane covered transducers can be readily seen.

Each of the two transducer elements on the instrument are installed such that they point horizontally and away from the instrument. To provide 2D current information, both transducers are tilted away from the instrument's vertical center line by an angle of 25°. The acoustic pulse generated by the transducers can reach a maximum range of 100-130m in front of the instrument, with the actual usable range being a function of the amount of suspended particles in the water and the water depth at the installation site (Figure 3).

Current speed and direction data are measured and recorded inside horizontal cells of configurable size and location away from the instrument. How often the instrument samples is also user-configurable. For the system described here, a total of 12 horizontal cells were used, each 8 m long, and data recorded at an interval of 15 minutes with a 2 minute averaging period. Ancillary data such as water temperature, pressure (a proxy for tide elevation) and input voltage is also recorded. The 2D Profiler is installed at a depth of 6.1 m below MLLW and is oriented at a heading of 220° true North. Figure 4 shows the actual pier where 2D profiler is installed.

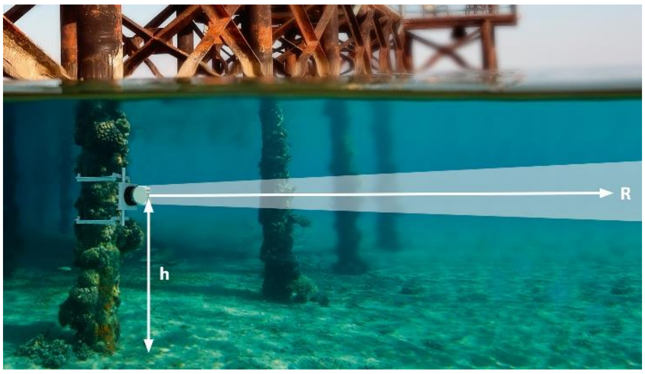

Figure 3 Conceptual illustration of a typical installation on a pier piling. The maximum profiling range, R, can be estimated as $R < 15 \times h$, where h is the distance from the instrument to the bottom.

Fabrication of the instrument's mounting bracket was done in a local workshop and divers were used for the installation (Figure 5). Shore power is used to power the instrument and cellular modem, but is unavailable during winter. So a wind turbine, charging regulator and batteries were installed to provide power during that period. In addition to providing current data, the station also provides basic meteorological data, such as wind, barometric pressure, air temperature and relative humidity.

Figure 4 The Nortek 400 kHz 2D Profiler is installed on one of the pilings at the end of the pier. A cruise ship can be seen in the foreground.

Figure 5 Photo of diver during installation procedure. The specially-designed (green) online cable can be seen coiled up in the bottom right.

4. Data Review

Summary current speed and direction data from July-September, 2016, is presented in Figures 6-8.

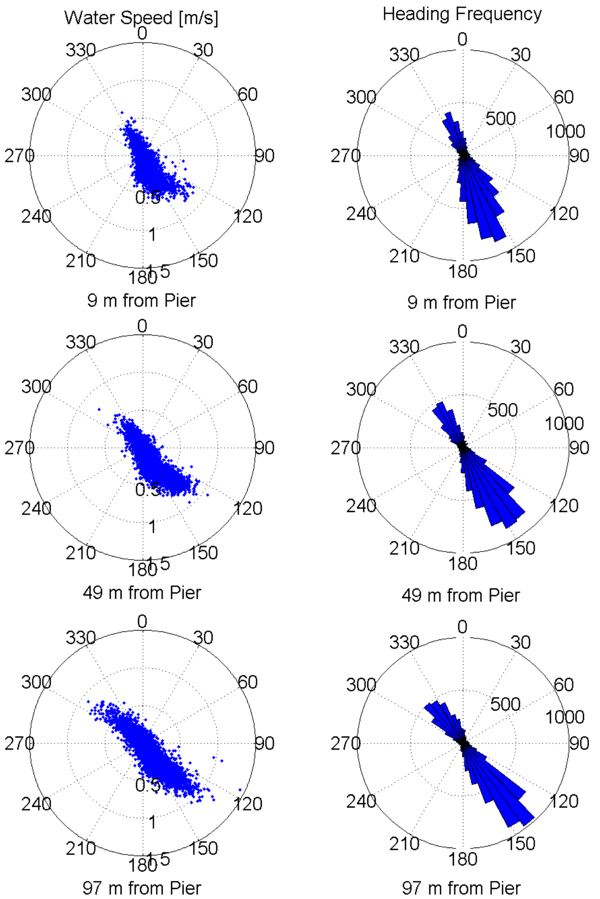

Figure 6 Polar plots of current speed (left) and frequency of occurrence for different current heading directions (right). Top two graphs are for Cell 1, centered 9 m away from the sensor/pier, middle graphs are Cell 6 (49 m) and bottom graphs are Cell 12 (97 m). Plots cover entire data set from 2 July through 30 September, 2016. 0° is True North.

Although this study covers only data from (mostly) summer months, the strong seasonality of current regimes in this part of Alaska has been documented before [3]. The data presented here clearly show the tidal influence in the distribution of current speed and direction during this period. Figure 6 shows ebb and flood direction follow the channel's alignment, with ebb currents centered around 150° and flood around 330° true north. Current speeds reach a maximum of about 1.2 m/s during ebb period and around 0.8 m/s during flood.

Flood currents persist well past the tidal peak, indicating relying on tidal elevation alone would provide limited (perhaps even misleading) information to pilots and masters during docking procedures. This asymmetry is more pronounced in the occurrence frequency, with ebb currents lasting nearly twice as long as flood currents (Figure 6). Current directionality also varied with distance away from the pier, which is of particular interest for navigation safety as vessels may be subject to currents of different magnitude and direction at the same time. This can be observed during the Spring tide period (Figure 7) but also at the weaker current periods during Neap tide (Figure 8).

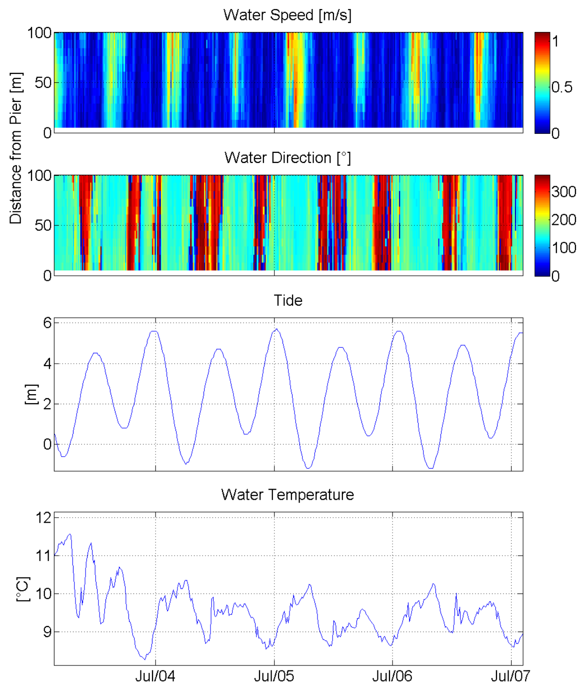

Figure 7 Water speed, direction, tide elevation and water temperature centered on the July Spring tide (5 July). Water speed and direction are shown as color contours away from the pier against time. Tide elevation is referenced to MLLW.

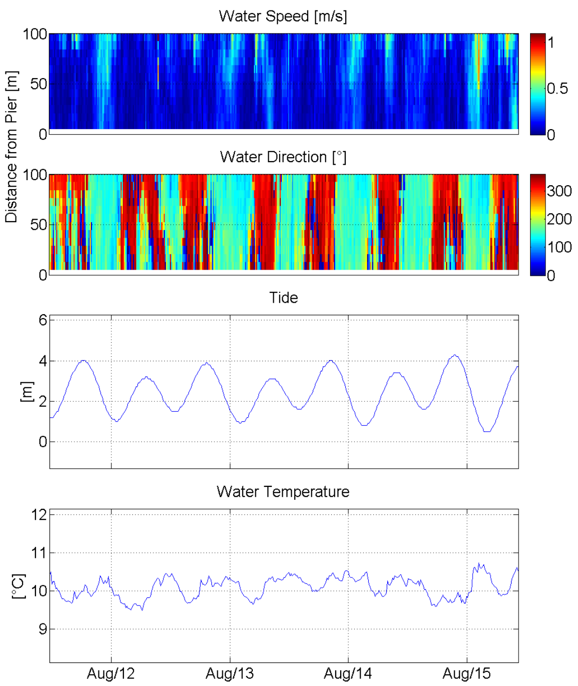

Figure 8 Water speed, direction, tide elevation and water temperature centered on the August Neap tide (13 Aug). Water speed and direction are shown as color contours away from the pier versus time. Tide elevation is referenced to MLLW.

Although the site observes a well-defined mixed semidiurnal tidal cycle, the currents are clearly asymmetrical, with ebb currents occurring more often and having higher magnitude than flood currents. This is important for vessel traffic managers and ship captains alike, as tidal elevations cannot be used as a direct proxy to current speeds, and only paint a partial picture of the site's flow regime at any given time.

The real-time data collected by the 2D Profiler is shared with the public via the Marine Exchange of Alaska's specially designed website (Figure 9). Tide and meteorological information is also available via the Automatic Identification System (AIS). Because of the successful implementation of this system, the Port of Juneau will be installing two more real-time current monitoring systems in 2017 as part of the planned Phase II expansion of the port.

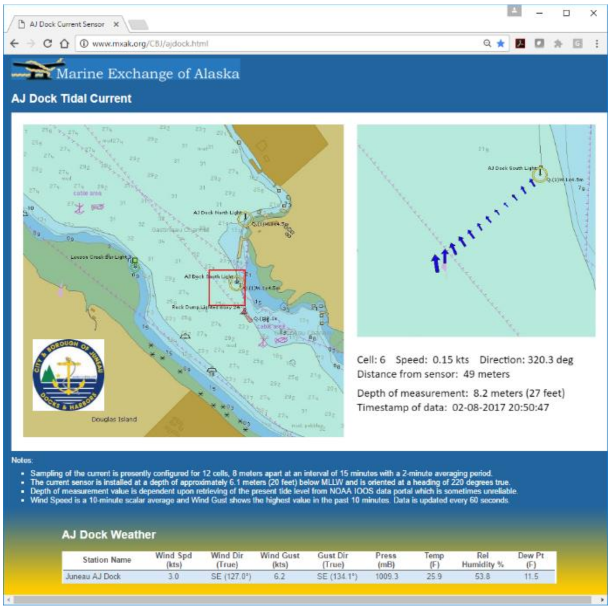

Figure 9 Marine Exchange of Alaska website for AJ Dock, showing real-time current speed, direction, tidal and meteorological information for public access. Arrows on right side indicate current speed and direction in front of the Nortek 400 kHz 2D Profiler. Arrows are centered on each of the Profiler's 12 user-defined cells.

5. Conclusion

The Marine Exchange of Alaska operates a real-time current monitoring system, based on the Nortek 400 kHz 2D Profiler. The data generated by this sensor is provided to the public via the Exchange's website. Review of data from summer months in 2016 show a clear asymmetry between tidal elevations and current speed and direction occurrence and the variability in current direction and velocity as a function of distance away from the pier. Real-time dissemination of this information is aiding safe operation of vessels in the port that receives over a million cruise ship visitors a year. Prior to the installation of this system, ship pilots and harbor masters had to rely solely on tidal predictions and experience during docking operations and vessel maneuvering in these physically restricted waters. The success of this current sensor has led to the decision by the Port to install two more sensors in 2017 when Phase II of the Port of Juneau's expansion is completed.

6. References

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