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Continuous monitoring of river surface ice during freeze-up using upward looking sonar

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ABSTRACT

This paper describes an algorithm that has been developed to process field data from two upward looking sonars, one high (546 kHz) and one low (235 kHz) frequency, a 2 MHz current profiler and a monitoring station, to measure surface ice characteristics on the North Saskatchewan River in the north east of Edmonton, AB, Canada, during the 2009/2010 freeze-up season. The algorithm used to calculate pans/rafts drafts and lengths, and the surface ice concentration is described. The validity and the accuracy of this technique were tested and computed surface ice conditions are presented. For the purpose of examining the effects of hydro-meteorological conditions on measured pan characteristics, the freeze-up period was divided into three distinct stages depending on the measured surface ice concentration. Pan/raft drafts were found to range from 0.1 to 1.0 m and pan/raft lengths from 0.6 to 8.0 m. The sonar proved to be very accurate in detecting the exact surface ice conditions locally above the sonar beam. However, interpretation of the results can sometimes be challenging, especially when physical processes such as bridging affect local ice conditions. Therefore, additional visual observations (e.g. time lapse photography) of surface ice conditions are recommended to aid in the interpretation of sonar measurements.

1. Introduction

A variety of methods have been developed to monitor surface ice conditions in rivers (i.e. pan concentrations, pan sizes and ice cover formation) during freeze-up such as: observations by personnel (Calkins and Gooch, 1982; Michel, 1984; Osterkamp and Gosink, 1982, 1983), satellite remote sensing, such as RADARSAT (Tracy and Daly, 2003; Unterschultz et al., 2009; Weber et al., 2003), aerial photographs (Daly et al., 1986; Erb, 1986), and web-based cameras (Vuyovich et al., 2009). However, each method has its limitations: the observations by personnel may be quite accurate but very costly and in most cases the sites are in remote areas that are very hard to access; satellite remote sensing using high resolution Synthetic Aperture Radar (e.g. RADARSAT 2) has the potential to provide accurate data on surface ice concentrations, however this application has not yet been explored extensively; photographic methods are hampered by fog, snow or condensation on the camera lenses and these are a common problem in winter. However, none of these methods provide complete monitoring of freeze-up processes, since none measure ice thicknesses. Accurate and continuous measurements of surface ice characteristics (e.g. pan characteristics) are needed both for model validation, and to advance our fundamental understanding of river ice processes (Shen, 2010).

Recently, an upward looking sonar, the Shallow Water Ice Profiling Sonar (SWIPS) [ASL Environmental Sciences Inc., Canada] has been developed to measure ice drafts in rivers. A detailed description of the specifications and principle of operation of these ice profiling sonars was reported by Ghobrial et al. (2012). These sonar instruments have been deployed successfully in the Peace River, Alberta since 2004 and the field tests on the Peace River, reported by Jasek et al. (2005) and Marko and Jasek (2010a,b), have shown that these sonar instruments can detect floating frazil pans as well as suspended frazil particles. Richard and Morse (2008) used the deep water Ice Profiling Sonar (IPS) to monitor surface ice conditions on the St Lawrence River, Quebec.

The primary objective of this study was to use sonar data to provide continuous measurements of surface ice properties (i.e. surface ice concentration, pan drafts and pan lengths). To accomplish this, an algorithm was developed that uses sonar data to estimate surface ice properties. Jasek et al. (2011) applied this algorithm to sonar data gathered on the Peace River, AB, Canada and found that surface ice properties computed from sonar data were in good agreement with predictions made using the CRISSP model. In this study, field measurements were gathered on the North Saskatchewan River in Edmonton, AB, Canada using two upward looking sonars, a current profiler, an environmental monitoring station and time lapse photography during freeze-up from 15-Oct-09 to 13-Jan-10. A detailed description of the algorithm is presented, its accuracy is assessed and

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time series of surface ice properties are used to investigate pan evolution during the freeze-up season. Preliminary results from this study were reported by Ghobrial et al. (2010).

2. Site description

The North Saskatchewan River, Canada, (length ~1300 km; mean discharge of 245 m^3/s measured at Water Survey of Canada gage ID# 05DF001 at Edmonton) is a glacier-fed, regulated river that flows east from the Canadian Rockies (1800 m above sea level) across Alberta (720 m above sea level at Edmonton), to central Saskatchewan (Kellerhals et al., 1972). The winter discharge is largely controlled by the outflows from the Bighorn and Brazeau dams in the upper part of the basin (Hicks, 1997). The river is a shallow meandering river of 1 to 3 m in depth, and 100 to 200 m in width. Upstream of Edmonton, the river has numerous islands and through Edmonton, the river has an average slope of 0.00035 (Gerard and Andres, 1982), and is irregularly meandering (see Fig. 1) with many point bars and side channel bars.

The instrument deployment location was in northeast Edmonton, AB (Fig. 1) at EPCOR's Clover Bar Power Generating Station (53°35′15″ N; 113°22′50″ W). The river at this location is approximately 120 m wide and has an average depth of about 1.9 m at low flow. A detailed bathymetric survey was conducted to identify a sufficiently deep and level spot on the river bed for placement of the instrument platform. Fig. 2 shows a plan view of the study site, the water depths (at the mean daily discharge of 130 m^3/s) in the deployment reach, and the locations of the instruments' platform. The thermal regime of the river at this location is influenced by discharges from the city's Gold Bar Waste Water Treatment Plant (*WWTP*) approximately 6 km upstream (Fig. 1) and locally from the power plant cooling water outfall located on the east bank ~50 m upstream of the platform location (Fig. 2). These warm water discharges caused the local water temperature to fluctuate by several degrees periodically during the freeze-up period. The thermal energy associated with these temperature fluctuations affected the freeze-up regime and the duration for which a complete ice cover was present at the site.

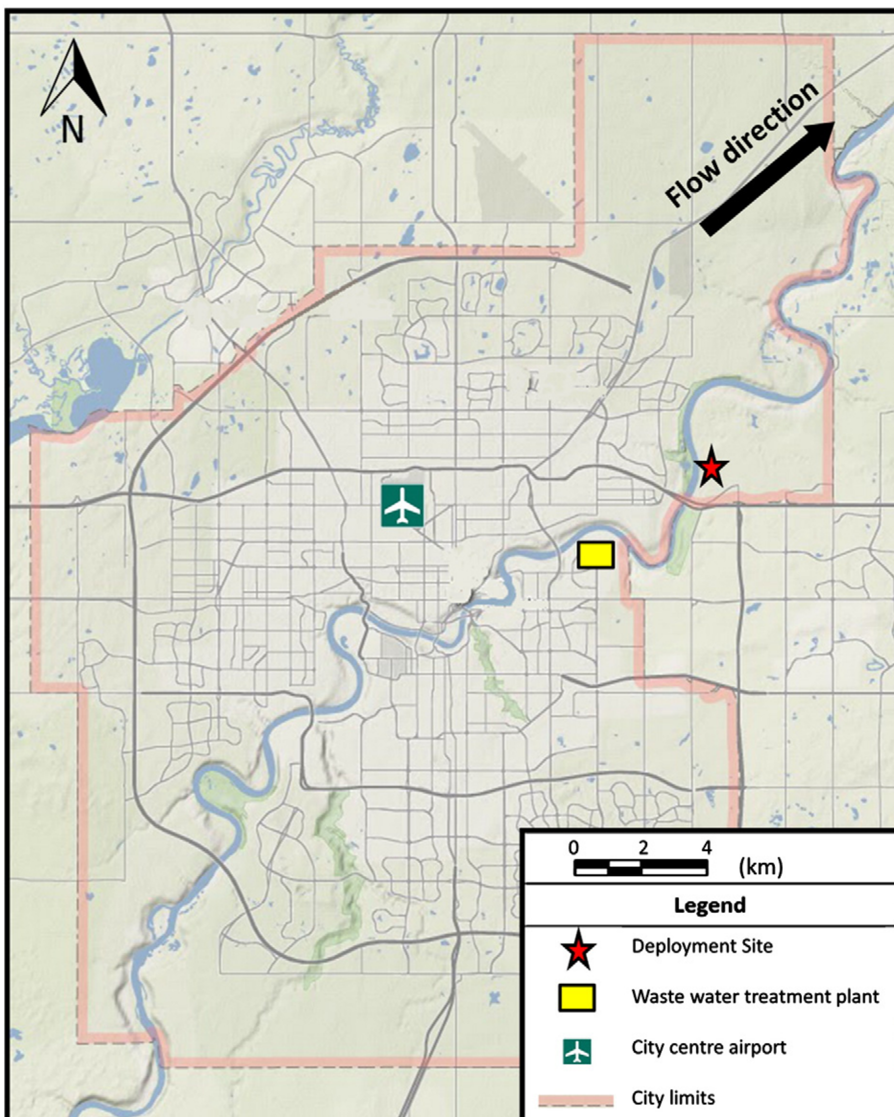

Fig. 1. Satellite Google® Map of the North Saskatchewan River in the vicinity of Edmonton showing: the deployment site, the city center airport, and the city Gold Bar waste water treatment plant.