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Influence of Mackenzie Delta Breakup on the Timing and Duration of Water Overflow on the Outer Delta Sea Ice Surface

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EXTENDED ABSTRACT

In winter, the shallow water depth regions of the outer Mackenzie Delta freeze to the bed thus forming bottomfast ice. During breakup, fresh water quickly floods the outer delta ice surface. This overflow is caused by a rapidly increasing water discharge from the upstream rivers, combined with an insufficient under-ice flow capacity in the outer delta. This overflow phenomenon is not only interesting from a sea ice perspective, but is also important in terms of defining boundary conditions in our numerical models of the Mackenzie Delta, during the ice breakup period. In an attempt to predict the duration and the timing of this overflow, to aid in planning field observations, our investigations revealed that the overflow duration is highly dependent on the type of breakup (thermal versus dynamic) that occurs in the upper delta. Furthermore, it appears that the timing of the overflow can be predicted from the water level in the Mackenzie River at Arctic Red River (MARR). This poster describes our efforts in developing an understanding of what leads the Mackenzie Delta to breakup thermally versus dynamically, and describes a means by which we can predict the timing and duration of this overflow phenomenon.

Figure 1 shows a map of the Mackenzie Delta including the key location used in this study. The nature of breakup at MARR was determined by examining both the water level gauge at this site (Water Survey of Canada (WSC), 2009) and high-resolution Landsat satellite images (U.S. Geological Survey, 2009) as illustrated in Figure 2. WSC data from 2002 to 2008 suggests that the water level at MARR, referenced to the Geodetic Survey of Canada datum, stays under 10m during thermal breakup years (2003 and 2007) and peaks above 12 m during the years where dynamic breakup occurs. A water level of about 10 m at MARR appears to be the transition threshold, since an intact ice cover was observed at a water level of 10.4 m in 2008, and a dynamic breakup was observed at a water level of 9.9 m in 2002. Furthermore, the study showed that a small freeze-up ice jam with a maximum peak water level of 5.5 m and a pre-breakup water level less than 3.2 m at MARR might predict that the subsequent breakup will be thermal.

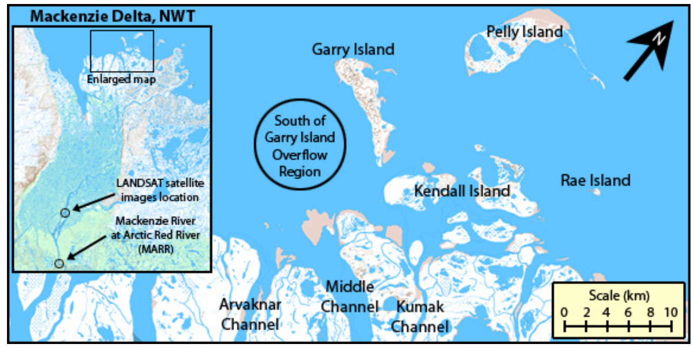

Figure 1: Map of the Mackenzie Delta, NWT. (Natural Resources Canada, 2009)

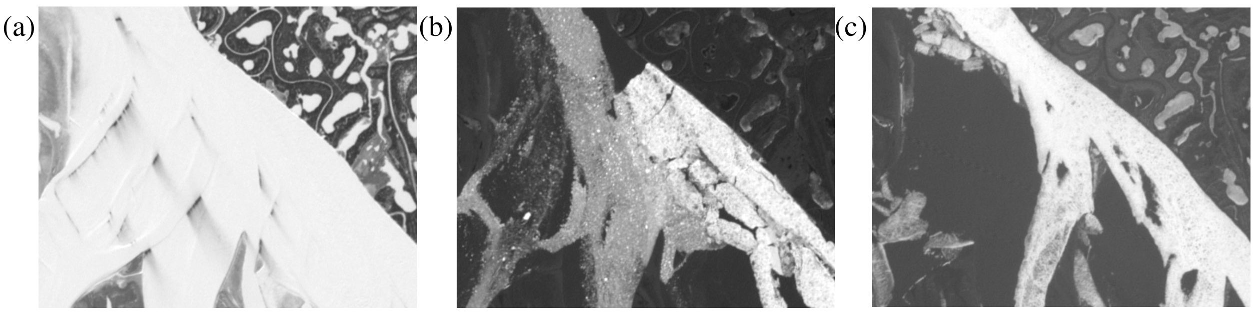

Figure 2: Landsat satellite images of the Mackenzie Delta 58km downstream of MARR showing (a) typical pre-breakup ice condition on April 22, 2002, (b) dynamic breakup on May 24, 2002, and (c) thermal breakup on May 27, 2003.

As verified some years ago, the bottomfast ice of the outer Mackenzie Delta can be identified using a Synthetic Aperture Radar (SAR). Using ENVISAT ASAR images (European Space Agency, 2009) in combination with MODIS satellite images (University of Alaska, 2009), the bottomfast ice was outlined and four stages of water overflow were identified as presented in Figure 3 for the 2008 overflow event. An overflow analysis south of Garry Island from 2005 to 2008 suggests that, on average: the first overflow on bottomfast ice occurs on May 14th; the first overflow on floating ice occurs on May 18th; the floating ice overflow peaks on May 20th; and the floating ice is drained on May 25th.

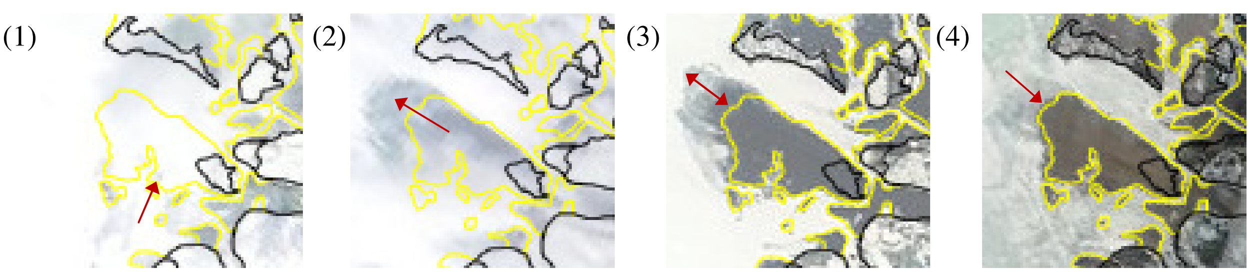

Figure 3: Overflow south of Garry Island in 2008 at (1) first overflow on bottomfast ice: May 16th, (2) first overflow on floating ice: May 20th, (3) maximum overflow on floating ice: May 22nd, and (4) drained floating ice: May 25th. The yellow border outlines the bottomfast ice location.

The overflow stages usually last for a shorter duration in years when breakup at MARR is dynamic, compared to years when it is thermal. For example, south of the Garry Island region, the four stages of overflow were completed in only 6 days in 2006 (dynamic breakup at MARR) whereas they took 18 days to complete during 2007 (thermal breakup at MARR).

The number of days it took for the overflow stages to occur south of Garry Island following a known water level increase at MARR is summarized in Table 1. In this table, the 0.3 m/d water level rise (WL rise) refers to the first date when the water level at MARR increased by 0.3 m in a day. Also, the 2 m difference in water level (ΔWL) refers to the first date when the water level at MARR increased by 2 m with respect to its pre-breakup level. The data correlates very well from year to year thus providing a confident overflow prediction. Water level data at MARR from 2002 to 2008 suggests that, on average, the 0.3 m/d water level rise occurs on May 10th and the 2.0 m cumulative water level increase happens on May 12th.

Table 1: Number of days the different stages of overflow south of Garry Island happened following a given water level event in the Mackenzie River at Arctic Red River (MARR) from 2005 to 2008.

Overflow Stage and Description	Days since WL rise > 0.3m/d	Days since ΔWL > 2m	Days since WL is declining
Stage 1 - First overflow on bottomfast ice	5 to 8	3 to 6	
Stage 2 - First overflow on floating ice	9 to 10	7 to 8	
Stage 3 - Maximum overflow on floating ice	11 to 13	9 to 12	
Stage 4 - Drained floating ice			1 to 4

This investigation showed that the overflow of the outer Mackenzie Delta is predictable and is related to a rapid increase in discharge which can be observed from the water level at MARR. As observed from satellite images, the nature of the breakup in the upper delta, which controls the duration of the outer delta overflow, seems to be thermal when the freeze-up ice jam and the pre-breakup water level are lower than average at MARR. The overflow duration lasts for a much longer period of time when thermal breakup occurs compared to a dynamic breakup. Additional studies concerning the nature of breakup at MARR would provide us with more confident and precise results which would then supply more accurate boundary conditions for the numerical model of the Mackenzie Delta. These studies would also be useful to improve predictions for the timing and the duration of the overflow which are valuable for field observations.

Acknowledgments

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