Seasonal development in the Canadian Beaufort Shelf during 2009

The MALINA expedition was conducted from 31 July to 24 August 2009 in the southeastern Beaufort Sea onboard the research icebreaker *CCGS Amundsen* (Figure 1). This supplementary section briefly describes the seasonal development leading up to the MALINA expedition.

The southeastern Beaufort Sea was fully ice covered from the end of November 2008 to mid-May 2009 when the flaw lead, called Cape Bathurst Polynya, began to open up along the mouth of Amundsen Gulf. By June 2009, the Cape Bathurst Polynya had formed into an open water strip between the landfast ice and the offshore pack ice, which extended the full length of the Canadian Beaufort Sea shelf. This is a feature that reoccurs each year but displays considerable temporal variability (Galley et al., 2008). The annual peak of river discharge (>25000 $m^3 s^{-1}$ measured at the Arctic Red River location) in early June was extensively hindered from entering offshore waters by the solid landfast ice cover and its thick, deformed border, the Stamukhi zone. MODIS satellite images (Figures S1 and S2) show that ice break-up occurred progressively towards east in Amundsen Gulf during the first half of June and ice floes moved westward partly covering the shelf in response to sustained easterly winds. In fact, easterly along-shelf winds persisted throughout June (see Figure 8a). The landfast ice along the river delta, however, remained fast. The MODIS satellite images also reveal a river plume that extended from the landfast ice edge in Mackenzie Bay (westernmost part of the shelf) northwest into the pack ice (see Figure S2).

Mackenzie River water began overflowing the landfast ice cover by mid-June. The landfast ice cover gradually broke up during the latter part of June 2009 starting from Mackenzie Bay in the west and moving east. During this time, satellite imagery revealed large turbid surface plumes that extended northwest into the pack ice. In early July, only a section of possibly grounded landfast ice remained north of Beluga Bay and numerous ice floes were scattered over the shelf.

Wind direction changed to northwesterly in July, and wind speeds decreased markedly by the end of the month. Consequently, the river plume changed direction to flow east along the coast. Satellite images of the period reveal a surface plume extending north of Cape Bathurst into

Amundsen Gulf. Such eastward flow is a typical response of the river outflow in the absence of winds (e.g., Carmack and Macdonald, 2002). Weak winds also kept the broken-up landfast ice floes on the shelf and the Beaufort Sea pack ice margin extended further south compared to previous and following years.

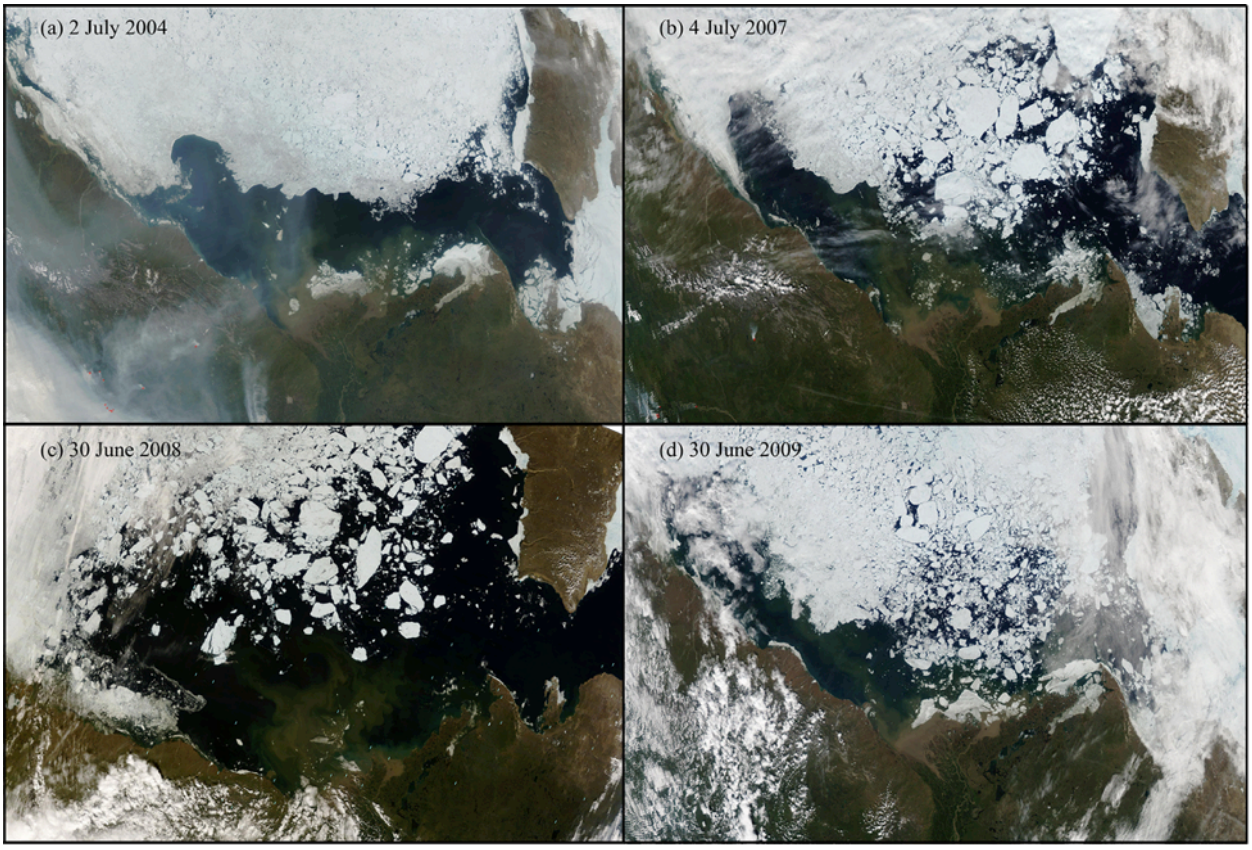

Figure S1. MODIS true-color images of the surface conditions in southern Beaufort Sea during the June to July cross-over during four years.

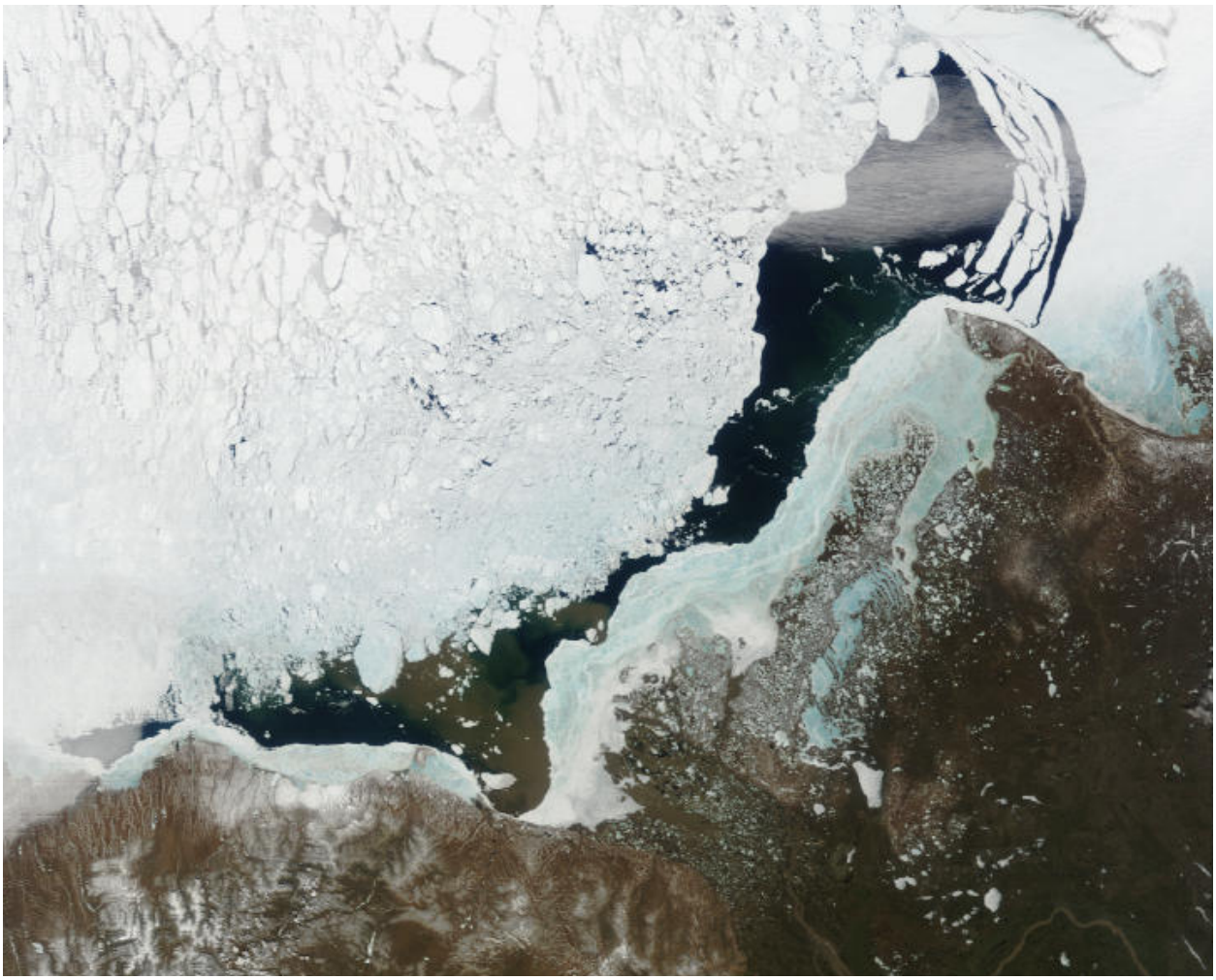

Figure S2. Cut out of study region from MODIS truecolor image (crefl1_143.A2009156205000-2009156205500.1km.jpg) for yearday 156 (June 4) in 2009. A sediment-laden plume is seen extending northwestward from the landfast ice edge to the pack ice.

Examples of river plume inertia

Figure S3 shows MODIS imagery of sea-surface temperature that highlights the effects of river plume inertia. Figure S3a shows how the invading plume reached northwest past the ice edge (located at about 71°N) creating a 130 km long and 80 km wide ice-free area and apparently affecting the surface temperature of the ice field for an additional 250 km. Thus, the plume may have extended more than 650 km from the river mouth and affected the sea ice cover over a distance of 380 km. At the same time of the 2009 season (Figure S3b), the plume did not appear to have an effect on ice surface temperatures (mainly thicker multi-year ice) past the ice edge located about 260 km from the river mouth.

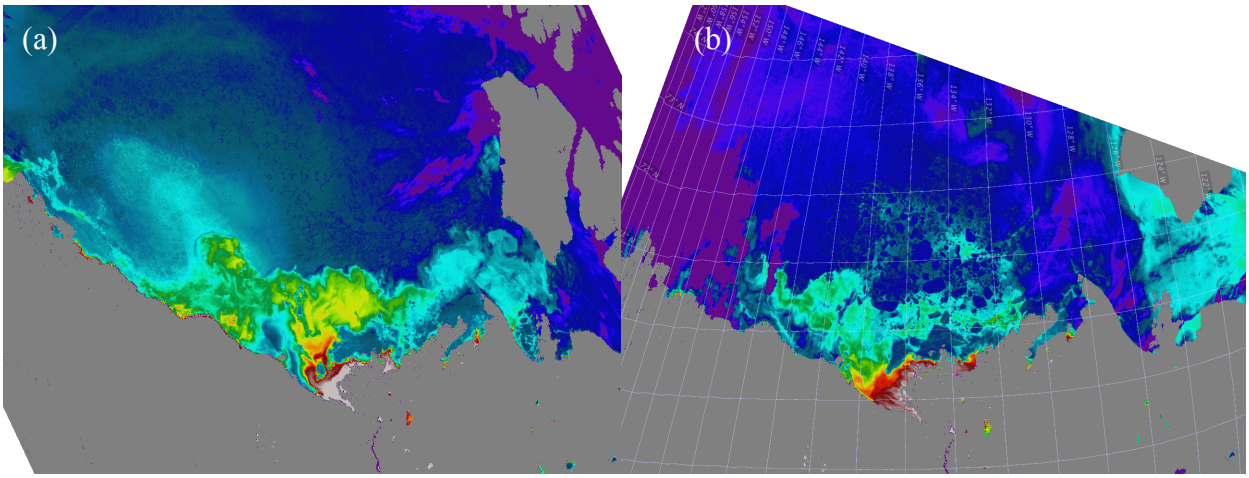

Figure S3. MODIS sea surface temperature scenes for the Beaufort Sea. Temperature scale is linear from –1°C (purple) to 14°C (dark red). Scene (a) was taken on 2 July 2004, while the scene in (b) was taken on 30 June 2009.