Examining the Effects of Arctic Warming on Coastal Landforms and Estuarine Ecosystems

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We examined how climate change over the last few millennia has impacted coastal landforms in coastal Alaska in an effort to inform how current Arctic warming might drive geomorphic change. The results suggest that current barrier spit landforms formed during the Medieval Warm Period between 1000 and 500 years ago during an interval of heightened storm activity and reduced sea ice.

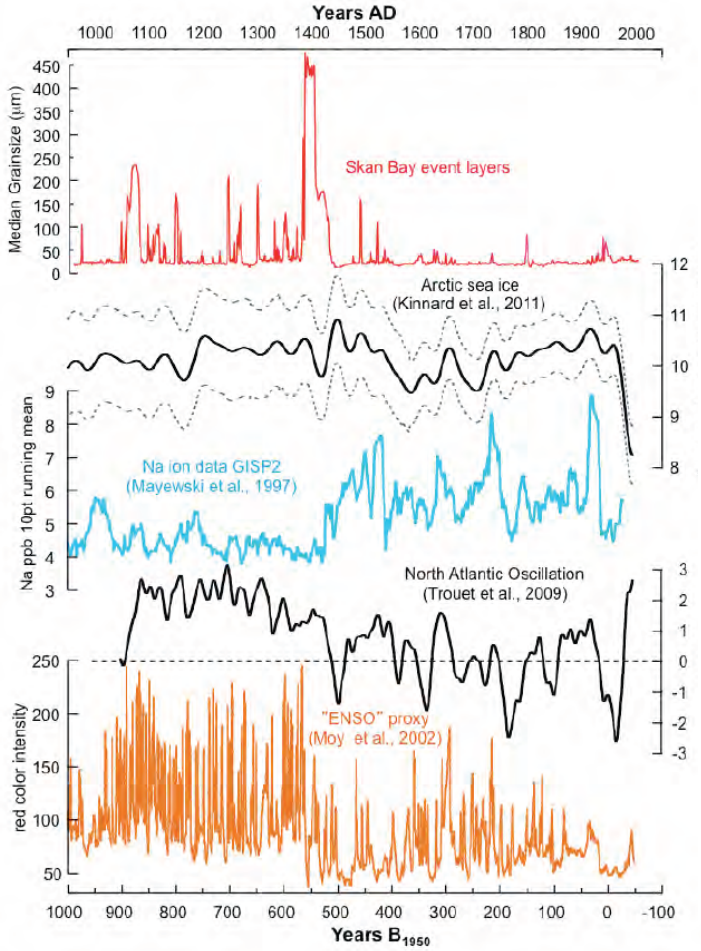

Figure 1 - a) Median grain size for core VC3 at Skan Bay plotted with time. Note the significantly larger and more frequent coarse-grained layers between AD 1000 and AD 1500 (950-450 years B1950). b) Forty-year smoothed Arctic sea ice proxy record with 95% confidence interval (from Kinnard et al., 2011). c) Na ion data from the GISP2 ice core (Mayewski et al., 1997). Increases in Na ions preserved in the ice is thought to represent increased storminess in the North Atlantic. c) Winter North Atlantic Oscillation (NAO) proxy record (Trouet et al., 2009) indicates a persistent positive NAO between ~AD 1100 and AD 1400 (900-550 years B1950). e) Red color intensity of a sediment core from Laguna Pallcacocha, southern Ecuador (Moy et al., 2002) that is thought to record El Nino influenced rainfall events (i.e. red layers, or spikes in red color intensity, are a proxy for past El Nino-like events).

We collected a series of cores from Skan Bay, Unalaska, a 65 m deep salinity stratified fjord basin with a -10 m bedrock sill, which provide an exceptionally high-resolution record of storm-induced deposition. Core VC3 provides a high-resolution record of sedimentation in Skan Bay during the last 1000 years, accumulating nearly nine meters of sediment in that time. Numerous coarse grained layers are preserved in the fine grained sediment accumulation in Skan Bay. The grain size data and our preliminary age model, derived from four radiocarbon dates and Cs-137 and Pb-210 activity, reveal that the bay experienced frequent episodic deposition of sand (Fig. 1), suggest that the interval of frequent episodic storm-induced deposition, or active interval, during the Medieval Warm Period (MWP; ~950 to ~450 years ago). This active interval of storms was followed be an interval of relative quiescence during the Little Ice Age (LIA) through to the modern interval of warming (~450 years ago to present).

One possible explanation for the temporal variability in storm-induced deposition at Skan Bay might be that sea ice was less extensive in the MWP, which allowed more wave action from winter storms to transport coarse grained sediment into the bay. However, the recent sea ice reconstruction of

Kinnard et al. (2011) does not indicate any dramatic increases in sea ice during the LIA (Fig. 1). If anything, the reconstruction suggests there may have been a modest reduction in sea ice at this time. Thus the Skan record likely represents a change in extreme storminess and not simple changes in sea ice extent that regulates how storms waves interact with the coast and mobilize sediment.

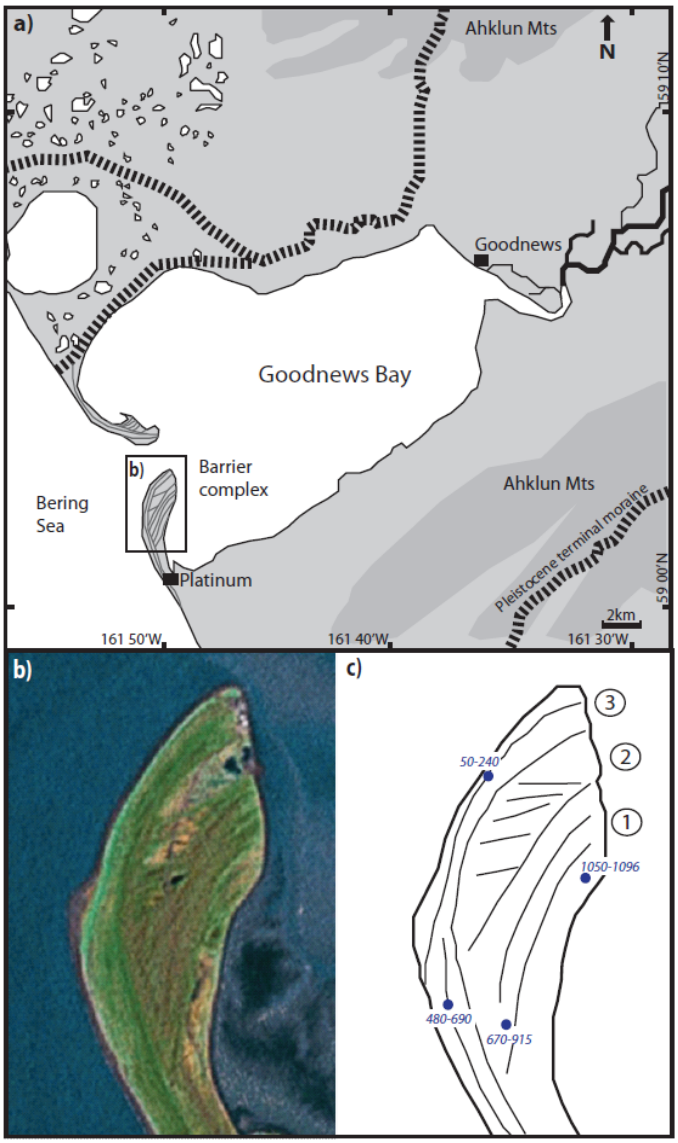

Figure 2 - a) Site map of Goodnews Bay area showing locations of Pleistocene terminal moraines, the base of the Ahklun Mountains and the Goodnews Bay barrier complex. b) Inset from a) showing close-up of barrier complex. c) Schematic outline of at least three variations in the angle of ridge orientation with radiocarbon ages (blue).

The pattern of storminess inferred from our preliminary data at Skan Bay appear to be out of phase with Na and K ion based reconstructions of storminess from the GISP2 ice core (Fig. 1). This may indicate a seesaw pattern of storminess between the North Atlantic and Bering Sea over the last millennia, which might be tied to large scale circulation changes and ocean/atmosphere teleconnections. This hypothesis is in part supported by other paleoclimate data (Fig. 1) that indicate large reductions in El Nino-like behavior at the transition between the MWP and the LIA (Moy et al., 2002) and a switch from a persistent positive North Atlantic Oscillation (NAO) state during the MWP to a more negative and fluctuating NAO after AD 1500.

We conducted a field survey at the southern Goodnews Bay Spit (Fig. 2). Along the barrier complex a dozen pits were dug and sampled for radiocarbon dating with the goal of understanding the chronological development of the barrier. Results indicate that the entire southern barrier was constructed in less than 1100 yrs, with the oldest ridge on the bayside and youngest on the oceanside. The southern spit is large, at over 5 km long and 1 km wide, and interpretations from satellite images (Fig 2b) show at least four phases of changing ridge orientation. The oldest ridge set strikes approximately northeast-southwest and contains some 8-10 ridges and developed between 1200 and 600 years ago. A second ridge set with ~6 ridges lies between the oldest and youngest ridge sets and strikes almost east-west. The next youngest ridge set was constructed by about 500 years ago. One final ridge has been built in between 50 and 240 years ago.

What is striking is the youth of the entire barrier complex and associated dramatic changes in ridge orientation. The initiation of the barrier complex coincides with the end of a cold period between AD 400-800 and the beginning of the Medieval Warm Period (AD 1000-1500) in which the Bering, Chukchi, and Beaufort Seas were seasonally ice-free. This decrease in sea ice and longer period of open-

ocean (increased fetch, increased storminess) likely resulted in barrier initiation and development. Barrier development slowed or ceased through the Little Ice Age (AD 1400-1800) when persistent sea ice was present at Goodnew Bay. The youngest ridge set may reflect a return to warmer, more or less ice free conditions, with a similar orientation to the oldest ridge set.

This work has demonstrated that past warm intervals in the Artic have likely played a key role in the building of coastal barrier landforms. Further the results suggest that barrier landforms have begun to grow once again over the last century or so in response to recent climate warming. These results have profound implications for how coastal landforms may transform in the future given current and projected future warming. We are still working up manuscripts for publication, but have already used the preliminary data collected with ARI support as the basis for a National Science Foundation proposal.