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Interactive comment on "The effect of changing sea ice on the vulnerability of Arctic coasts" *by* K. R. Barnhart et al.

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General Comments:

This paper is a welcome addition to the literature on the changing environmental drivers of Arctic coastal erosion. It reports on a pan-Arctic analysis of coastal sea-ice concentration as derived from the 1979-2012 satellite record. This unique and valuable circumpolar synthesis is the major contribution of the paper. On this basis, the authors observe a 1.5- to 3-fold increase in the median length of the open-water season over 34 years, with large regional variance. The paper reviews pertinent literature on multi-temporal analyses of trends in shoreline retreat rates from a wide range of sites across the Arctic, finding that most studies reveal no clear correlation between erosion rates and the length of the open-water season, despite the theoretical expectation that

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a shorter duration of ice against the coast, particularly in more stormy seasons, should increase the probability of elevated water levels and storm wave impacts on the coast. This provides a strong quantitative foundation for assessing the lack of correlation between climate change and coastal erosion rates on many high-latitude coasts (e.g. Forbes and Hansom 2012) and studies cited in this paper (Vasiliev, 2005; Solomon, 2005; Lantuit and Pollard, 2008; St-Hilaire-Gravel et al., 2012; among others). Nevertheless, an increase in shore retreat rates has been clearly documented on some ice-rich permafrost coasts developed in unlithified sediments, both in Siberia (Günther et al., 2013) and Alaska (e.g. Mars & Houseknecht, 2009; Jones et al., 2009). The authors of the paper under review present a detailed analysis of changes in open-water season, ice-free fetch, and coastal forcing of water level and waves in the nearshore zone for a study site at Drew Point, Alaska, where Mars and Houseknecht (op. cit.) documented more than a doubling of coastal land-loss rates between 1955-1985 and 1985-2005. They demonstrate a clear increase in extreme values of water level ('set-up') and increasing fetch at Drew Point from 1979 to 2012, consistent with the observed acceleration of erosion rates. In a supplementary analysis of first and last days of open water from 6 of 7 coastal sectors in the Arctic Ocean, they document the geographic variability and differential effects of earlier breakup and later freeze-up on coastal forcing and erosion potential. This paper does not directly assess links between open water, forcing, and coastal erosion (for which see Barnhart et al., 2014), rather it clarifies the implications of changing ice concentration on a variety of processes affecting shoreline stability.

Specific Comments:

I have some misgivings about the use of 'vulnerability' in the title, as the paper deals primarily with aspects of exposure and forcing. In the authors' definition of vulnerability (page 2279, line 10), there is a component of 'capacity to resist change' which is not captured in this paper. 'Vulnerability' has a wide range of interpretations in the coastal literature, from purely physical responses to transdisciplinary analyses involving human

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activities and adaptive capacity. I would suggest at least to add the adjective 'physical' and alternatively to consider use of a different term.

With respect to the whole-Arctic analysis of the ice-free season ('sea-ice-free season' seems unnecessarily cumbersome – an initial explanation would suffice), I am curious about the apparent absence of data along some coasts in Figures 1 and 2 (notably Canadian Beaufort Sea, Amundsen Gulf, Banks Island, parts of northern Greenland, and southwestern Novaya Zemlya). Does this relate to ice mobility that prevents the algorithm from recognizing fast ice along these coasts? In some cases, there may be a narrow band of landfast ice that is not recognized at the scale of the 25 km cells. Some clarification would be helpful. It would also be helpful to give the cell size when first introduced (p. 2285, line 14).

With respect to Mackenzie River discharge (p. 2289, lines 25-27), studies of ice-affected peak discharge at the head of the delta (e.g. Beltaos, 2012), since the work of Overeem and Syvitski (2010), have resulted in revised discharge values that show no significant trend in total annual discharge (Lesack et al., 2013). Lesack et al. (2013, 2014) have shown, however, that despite no change in the date of freshet initiation, breakup in the Mackenzie Delta is occurring earlier.

The authors have reasonably excluded the Canadian Arctic Archipelago (CAA) from their analysis in Figure 16 (p. 2301, lines 27-28 & p. 2302, line 1). However their statement about sea ice persisting in the CAA throughout the summer season is misleading and applies only to the northwestern sector. Open water is extensively and increasingly prevalent throughout the rest of the region, including the Northwest Passage.

Figure 5 presents the pan-Arctic distribution of coastal erosion rates (Lantuit et al., 2012) in a different and useful way. However the caption for Figure 5 states that "deposition occurs primarily in deltaic regions, for example the McKenzie [sic] delta in the Beaufort Sea." Apart from the misspelling ('Mackenzie' is correct), this overlooks the fact that the delta is transgressive and retreating across almost its entire front

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(Solomon, 2005; Forbes and Hansom, 2012). Zones of local progradation along the Beaufort Sea coast occur on coastal barriers, spits, and forelands west of the delta. However, in the original published map (Lantuit et al., 2012, figure 6), the areas of progradation are plotted west of Herschel Island along the Alaska coast and may relate to delta aggradation at the mouths of North Slope rivers from the Colville east.

The results of this paper have great value, but it is important to recognize that the erosion processes operating at Drew Point are particular to low, ice-rich permafrost bluffs in ice-bonded but otherwise unlithified sediments, as found on the Arctic coastal plain in Siberia, Alaska, and northwestern Canada, but are not universally applicable across the Arctic. As they state in their conclusions (p. 2303, line 13), coastal erosion is affected "by lithology, geomorphology, and ice content" to which we might add orientation and exposure, storm climate, ice dynamics, relative sea-level trend, and sediment supply, among other factors.

The paper is well written and very clean, with few errors and mostly good figures. I am not convinced that panels B-E of Figure 9 are necessary and Figure 16 was extremely difficult to work out. Panels F-H of Figure 12 are missing and some captions refer to left and right panels when they appear one above the other.

Technical Corrections: [page,line(s)]: correction

[2277]: See comment above re title. [2278,2]: 'Shorefast' is not essential to this statement and it is generally not shorefast ice that governs the open-water fetch. Simplest solution here is to omit the first word 'shorefast'. [2278,4]: Delete comma after 'duration' and 'the' before 'summertime'. [2278,13]: Hyphenation ('sea ice free' not hyphenated here, hyphenated above on line 4). Note my comment above suggesting the simpler phrase 'ice-free' (or use 'open-water'). [2278,14]: Change 'has' to 'have'. [2278,16]: In my experience, notch (or 'niche') incision is not submarine (although it may occur when the base of the beach is submerged in a storm surge) – e.g. Forbes et al. (2014, Figure 16c,d) show good examples of notching from Tuktoyaktuk Island in the Canadian Beaufort, photographed after the storm event and exposed at the back of the low-tide beach. [2279,8]: Fix punctuation for IPCC reference. [2281,14]: Delete 'the' before 'vulnerability' and add 'of' to read "... and increasing vulnerability of Arctic ..." [2282,1]: Should 'blocks' be 'bluffs'? – I know we are talking about block failure, but it seems inappropriate here. [2284,7]: Add semicolon after 'trations' and delete 'and' to read "sea ice concentrations; meteorology from ..." [2286,25]: Change first 'an' to 'a'. [2286,26]: Change 'varies' to 'vary'. [2288, 6]: Change 'storms' to 'storm'. [2288,15]: Change 'between' to 'for' – usage "between 1984-2002" equates to 'between ... to ...', whereas it should be 'from ... to ...' or 'between ... and ...' [2288,16]: Delete 'between'. [2288,19]: Delete 'between'. [2288,25]: Change dash to ' and '. [2289,5]: Ditto. [2289,24]: Change 'Canada' to 'Canadian'. [2290,1]: Delete second 'are'. [2290,11]: Delete 'is'. [2290,24]: I assume 'following' should be 'preceding'. [2291,7]: Delete 'what' and change 'once' to 'one'. [2291,9]: Change 'made' to 'determined' or 'averaged'. [2291,15]: Add 'that' to read "... it is the passage of storms that does ..." [2294,10]: The Atmospheric Environment Service is now the Meteorological Service of Canada. It would be appropriate here to refer to "Canadian Ice Service charts ..." [2298,11]: Note panel 'f' missing. [2298,12]: Change 'also' to 'did'. [2299,10]: Add comma after 'storm' and change "wind-based definition of a storm" to 'latter'. [2299,21]: Add word 'at' before 'Barrow'. [2299,23]: Delete 'to' before 'Barrow'. [2303,2]: Fix punctuation for Barnhart et al. reference. [2306,6-12]: Delete duplicate reference to Lantuit et al. 2012. [2317,caption]: Fix Fig. 5 caption as noted above. [2318,caption]: Delete duplicate 'the' in line 2 of Fig. 6 caption. [2322,caption]: The "white" lines appear yellow to me. Note upper and lower panels are referred to a left and right. [2325,caption]: Add missing panels or delete last 3 lines. [2326,caption]: Reference to Fig. 12c and f needs to be fixed depending on whether F-H in Fig. 12 are added or not. [2327,Fig.14]: Typo in legend of panel A – 'Positive cet up'

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