RELATIVE SEA LEVEL CHANGE IN WESTERN ALASKA AS CONSTRUCTED FROM REPEAT TIDE GAUGE AND GPS MEASUREMENTS

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Summary

Western Alaska, as referred to here, is composed of the coastal margin from north of the Seward Peninsula around Kotzebue, extending south to the Alaskan Peninsula and Port Heiden. This is an environmentally active region with very sparse data coverage both in the areas of geophysics and oceanography. Current changes in climate have accelerated in recent years and are now adversely affecting the local communities (Figure 1.), so that damage occurs yearly in Western Alaska and extreme measures such as village relocation are now being considered (Forbes, 2011). In order to make the most informed decisions regarding community planning a map of relative sea level (RSL) change in Western Alaska is needed and the preliminary steps that are being taken towards such a product are presented here.

Figure 1. House in the abandoned village of Meshik, where erosion of the beach cliffs has forced inhabitants to relocate to Port Heiden.

In the summer of 2013 a campaign of 32 tidal and geodetic benchmarks was conducted. This first season of field work was focused on the Seward Peninsula. Funding through the DGGS Coastal Program, provided by the Western Alaska Lanscape Conservation Coopertive provided an an opportunity to travel to Port Heiden for the installation of a tide gauge allowed for an opportunity to obtain measurements on the Alaskan Peninsula. A vertical velocity model has been constructed that incorporates the field work done in 2013. This model (Figure 2.) reflects 2-4 mm/yr of subsidence that is occurring in Western Alaska, and can be seen in contrast to the subduction-driven uplift taking place along the Aleutians and southern coast of Alaska.

Onshore Component

The tectonic environment of Western Alaska is believed to be the Bering Plate/North American Plate boundary (Figure 3.). In 2005, a campaign was conducted by Ryan Cross (UAF) to occupy geodetic benchmarks in Western Alaska and the Aleutians in order to quantify the horizontal motions of the Bering plate with emphasis on being able to define the plate boundaries. His findings suggest a clockwise rotation of a plate defined on its southern extent by the Aleutian islands, Eastern Russia and the Kamchatka Peninsula for the western boundary, while the Seward peninsula down to the Alaska Peninsula compose the eastern contact of the Bering plate with the North American plate boundary. This Bering plate is not well understood and the available data is limited in the region of study (Cross, 2007).

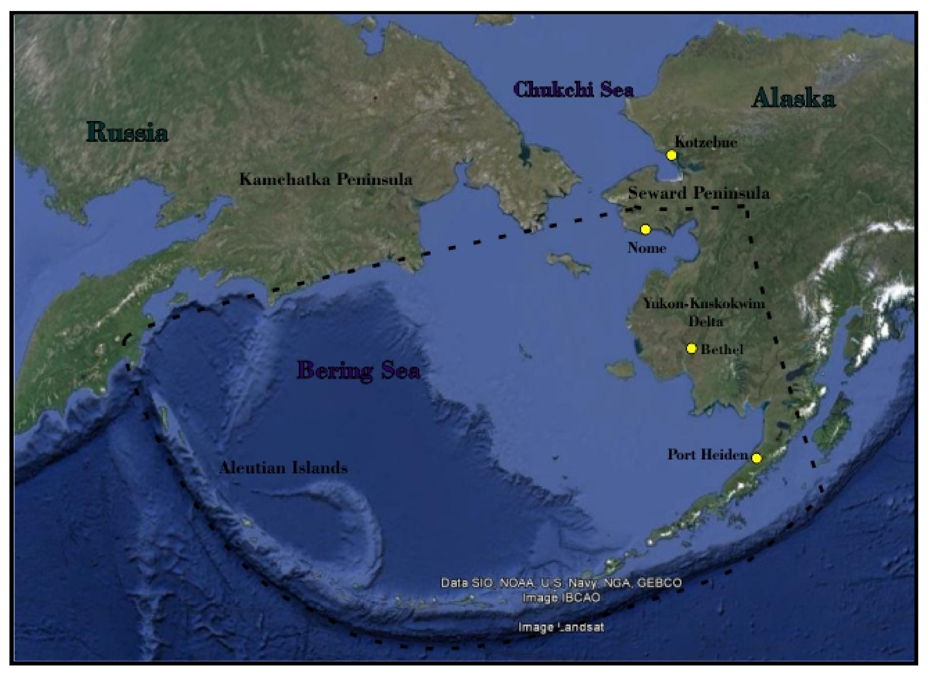


Figure 3. Proposed Bering plate of Cross et al. (2007) is outlined in black dashed lines. Large cities in Western Alaska are indicated with yellow circles and represent the extent of the region.

The remote and less populated Western Alaska has not been a priority for data collection, so in many places this study will be contributing the third data point to velocity models, significantly improving the determination of a trend line (Figure 4.). GPS data consists of campaigns (Figure 5.) of static observations of both geodetic and tidal benchmarks for a minimum of 3 days, as well as available data from continuous sites in the region that are maintained as part of Earth Scope's Plate Boundary Observatory project. The data obtained from both campaign and continuous sites is then analyzed using the GIPSY/OASIS II software goa-5.0, developed by the Jet Propulsion Laboratory in Pasadena, California. Our preliminary vertical velocity model of Western Alaska defines the contrast between the uplift of the Aleutian Islands and Southern Alaska due to subduction processes with the subsidence of Western Alaska.

Figure 5. Campaign GPS station set up in Golovin, AK summer of 2013.

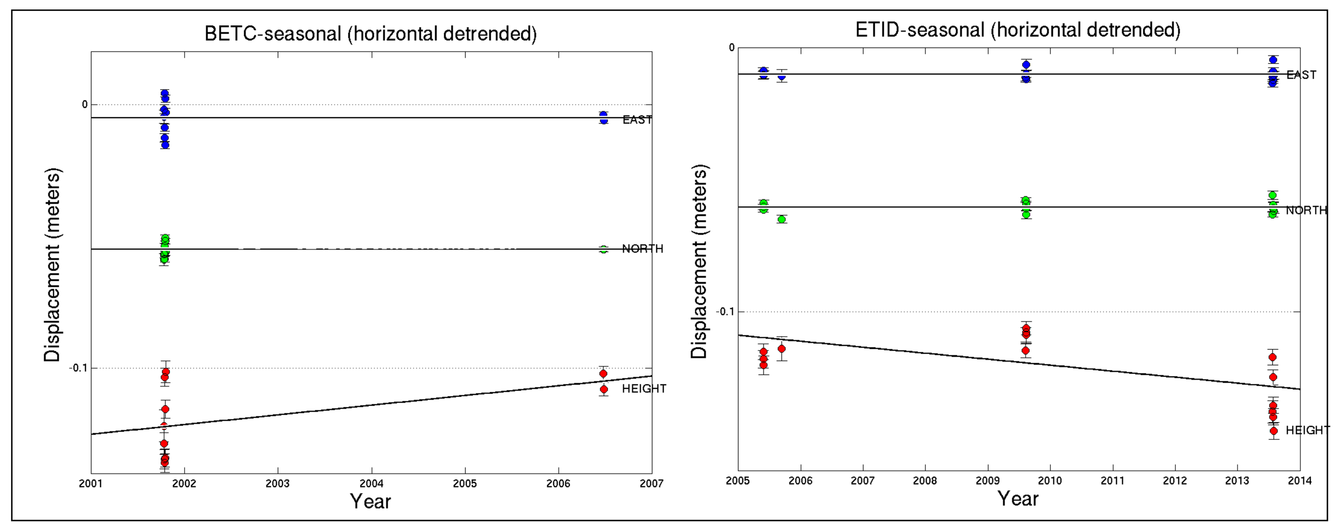


Figure 4. Timeseries of campaign stations BETC (left) from Bethel, Alaska and ETID (right), from Elim, Alaska . BETC infers a positive trend in the vertical velocity (bottom line), but the trendline is constructed only through two points. ETID was occupied during the summer of 2013 field season which redirected the trendline from a positive slope to a negative slope. BETC is planned to be occupied in the upcoming season.

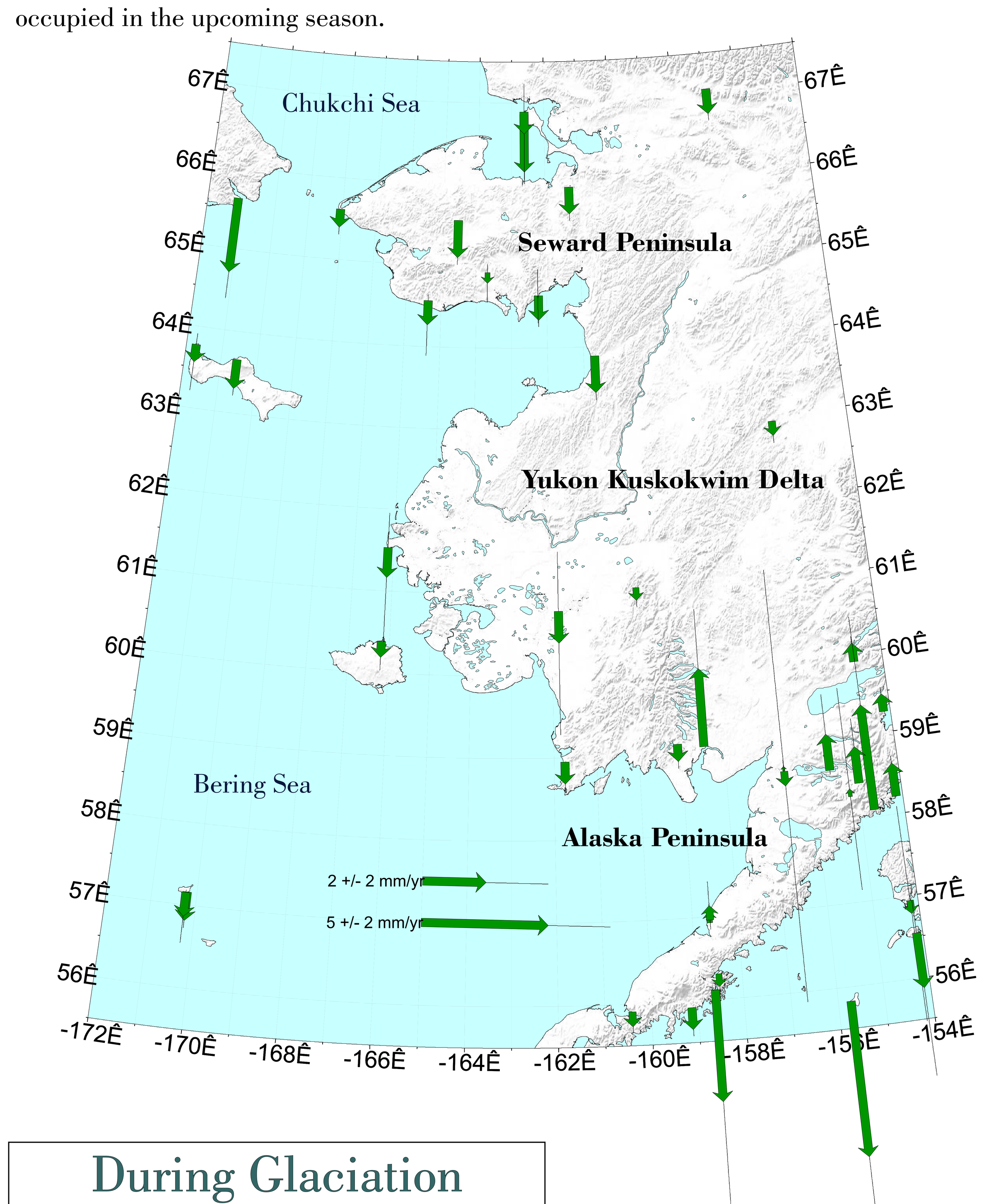


Figure 2. (Above) Preliminary vertical velocity map of Western Alaska. Measured benchmarks are located at the base of the velocity arrows, bars coming off of the arrows represent vertical error at that station. The summer of 2013 succeeded in the occupation of the Seward Peninsula and Alaska Peninsula. The summer of 2014 will be spent on the Yukon-Kuskokwim Delta.

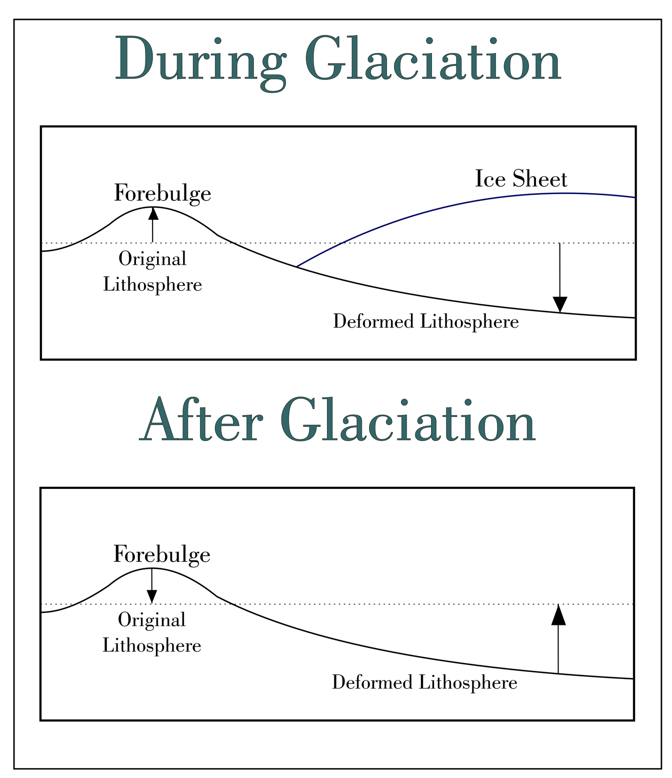
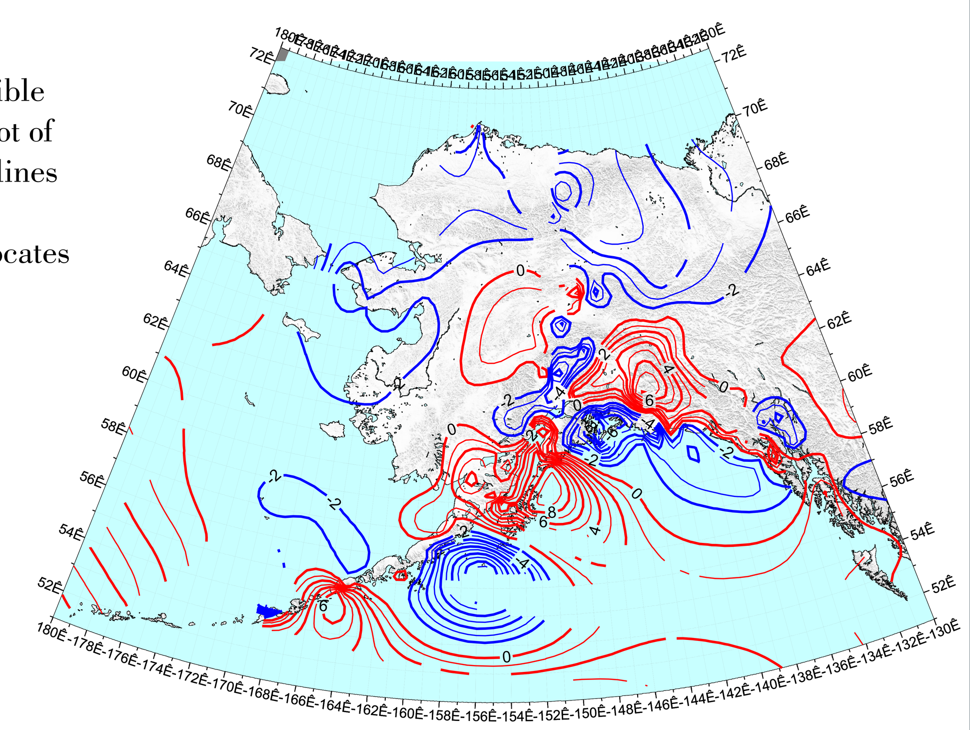


Figure 7. (Left) Diagram of the development and subsidence of a forbulge resulting from ice sheet loading.

Figure 8. (Right) One possible vertical velocity contour plot of GIA effects in Alaska, red lines indicate uplift and blue, subsidence. This version locates the forebulge collapse of -2 mm/yr over the Seward Peninsula and northern Yukon-Kuskokwim Delta.

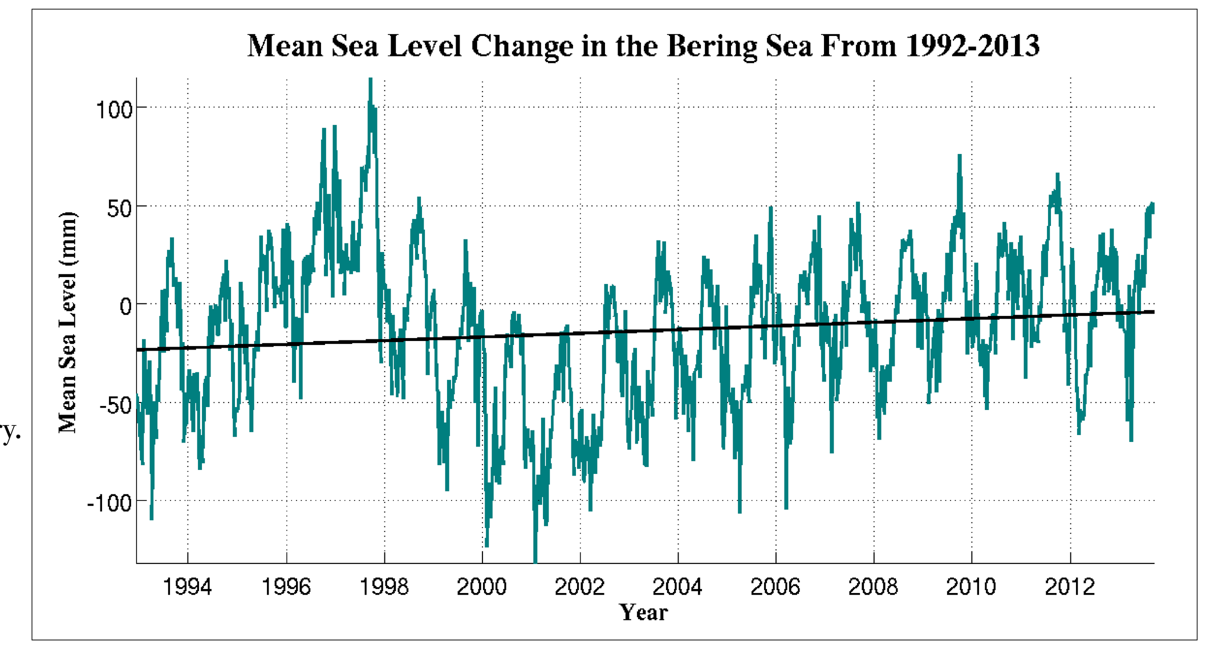


Offshore Component

The offshore component of this study involves the mean sea level (MSL) change in the Bering Sea, which is bordered in the north by the Chukchi Sea and in the south by the Pacific Ocean. The Bering Sea is, for the most part, a shallow continental shelf environment so geometry and dynamics of the smaller bodies of water such as Norton Sound and Bristol Bay can play significant roles when trying to observe local sea level trends through a regional tidal context. The challenges in data availability extend to the offshore component of this study as well. Tidal datums do exist, but are stored by a variety of private, public, and government organizations. These datums span from the early 1900s to the present, and pose many challenges relating to accuracy, error and lack of a known control.

In many of the communities in Western Alaska tidal prediction are not even available and the local fishermen and residents have adapted by adding or subtracting hours from the tidal predictions of other more populated communities. With the complicated shapes of the shallow bays and sounds in Western Alaska this still leads to inaccurate estimates. Currently eustatic MSL for the Bering Sea is exhibiting an increase of approximately + 2.6 mm/yr based on the model produced by the CU Sea Level Research group (Figure 6.)(Nerem et al., 2013).

Figure 6. Mean sea level change in the Bering Sea from 1992-2013 as modeled by Nerem et al. (2013) from satellite altimetry.



Future Research

Onshore Component

To isolate the driving forces of the observed subsidence in Western Alaska, more time needs to be spent investigating the effects of glacial isostatic adjustment (GIA) and delta subsidence in this region. The influence of the GIA involves the subsidence of the fore bulge from the Cordilleran and Laurentide ice sheets of the Pleistocene (Figure 7.). The model ICE-3G is being used to analyze the predicted location of the fore bulge. There are two current possibilities (Figure 8.) based upon different mantle viscosities used in the model (Tushingham et al., 1991), and our preliminary data indicates the model that predicts the location of the fore bulge to be in the vicinity of the Seward Peninsula as opposed to a farther east location. More work with both the velocity model and the ICE-3G model will help to further define this relationship. To analyze the potential influence of deltaic sediment loading on the vertical velocity of the Bering plate delta subsidence models are being researched. There is no established model that can be applied to the area, but with sediment flux data for the Yukon and Kuskokwim Rivers we feel it is possible to modify the ICE-3G model for water and sediment parameters so that we could estimate the effect a subsiding delta would have on the Bering Plate. Much more research and modeling time will be required before any conclusions about the effect of delta sediment deposition on tectonic vertical velocity can be surmised.

Offshore Component

Tide gauge records and satellite altimetry data still needs to be compiled and analyzed in order to establish an accurate MSL trend for the region, and then tie the onshore and offshore components together to arrive at estimates of RSL change

References

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