Toward a Predictive Model of Arctic Coastal Retreat in a Warming Climate, Beaufort Sea, Alaska

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LONG-TERM GOALS

The long-term goal of this project is to quantify the environmental drivers of rapid coastal erosion in the Arctic, and to begin developing predictive models of future rates of coastal erosion resulting from climate change. Our study is focused on the Beaufort Sea coast within the National Petroleum Reserve – Alaska (NPR-A), approximately halfway between Barrow and Prudhoe Bay. We are focusing our efforts on collecting empirical data that will help us to develop process-based models of coastal change.

OBJECTIVES

Our main scientific objective is to understand and quantify the relative roles of thermal and mechanical (wave) energy in driving coastal erosion in the Arctic. We are combining high-resolution observations of coastline retreat with meteorological and oceanic monitoring programs. Our completed field data collection over 2007-2012 includes: 1) measurement of bluff substrate properties including ice content, ice-wedge polygon spacing, and the thermal properties of bluff materials; 2) time-lapse photography to observe coastal erosion processes in real-time; 3) establishment of a meteorological monitoring network to summarize the climatic forcings on the system; and 4) monitoring of offshore conditions including bathymetry, wave fields, and sea surface temperatures. By synthesizing these field observations and remote sensing observations into process-based numerical models, we anticipate that we will be able to predict future patterns of Arctic landscape change in the face of changing climatic

APPROACH AND WORK PLAN

Our technical approach includes direct observation of coastal erosion using time-lapse photography; collection of relevant field data including coastal bluff composition, wave and sea surface temperature records, and meteorological records; and modeling of relevant thermal and mechanical processes.

The personnel involved in these activities are as follows: Analyses of time-lapse photography and meteorological records is being undertaken by Dr. Wobus. Sea ice analyses and wave and surge modeling have been conducted by Dr. Overeem with contributions from undergraduate student Cori Holmes. Masters student Nora Matell developed thermal models of lake erosion, and compiled remote sensing datasets from the NPR-A. Numerical models and data mining code have been developed by Drs. Anderson, Wobus and Overeem collaboratively. USGS scientists Clow, Urban and Jones assisted with retrieval of sensors during the 2008-2012 summer seasons. Wave sensors were built by collaborator Tim Stanton at the Naval Postgraduate School in Monterey, and were deployed during the summer field season in 2009, and again in late summer 2010. Higher resolution time-lapse cameras were deployed in collaboration with the Extreme Ice Survey in summer 2010. Graduate student Katy Barnhart was employed starting in July 2010 and thereafter to assess the time-lapse imagery and to generate a numerical model of the coastal erosion process, and individual environmental components (e.g., wave field, water level) based upon all measurements.

WORK COMPLETED

Over the past reporting year we presented one poster at the AGU annual meeting 2011 and one poster at a local symposium. Additional research will be presented at the upcoming AGU meeting (2012). We currently have two papers in preparation that we aim to submit to peer reviewed journals by the end of the calendar year. During the summer 2012 field season, our USGS colleagues serviced our two meteorological stations; re-measured coastal position relative to the benchmarks established in 2007, 2008, 2010, and 2011; retrieved levelogger pressure transducers and hunting cameras used to monitor lake shore erosion and lake levels; and continued collection of soil and lake temperature histories. Investigator Anderson and graduate student Barnhart are co-conveners of a session at the upcoming AGU meeting entitled "Thermal Control on Weathering, Erosion and Landscape Evolution". Graduate student Barnhart applied for and was awarded a NASA Earth and Space Science Fellowship. Her proposal, entitled "Flexible Heat Flow Models of the Active Layer and Conductive Permafrost: Thermal State from Field Measurements and Satellite-Derived Skin Temperature", will allow for continued work in this environment, integration of ground based observations and remotely sensed datasets, and further collaboration with the USGS.

The research effort over the last year has focused on constructing models for the environmental conditions that drive coastal change, investigation into the influence of the distance to the sea ice edge on nearshore hydrodynamic conditions, GIS analysis of coastal change detected through remotely sensed imagery and field surveys, and initial coastal erosion model runs for the period 1979-2012. At present, we are setting up final modeling runs.

RESULTS

One of our major goals for this project was to use our time-lapse imagery to quantify the relative roles of warming surface waters and wave energy from storms in driving coastal erosion. Toward this end, we have leveraged a time-lapse sequence documenting shoreline erosion along an inland lake where we have simultaneous water temperature measurements. Since wave energy is limited in this lake environment, this record has allowed us to calibrate a model of purely thermal erosion along a permafrost coastline. Our simple model suggests that previously published models of bluff erosion predict observed erosion rates quite well.

The next step is to take these models to the Beaufort Sea coastline over three main time periods (hindcast from 1979-2012, observation time period in 2010, and the future). The rapid retreat of the Beaufort coastline after the last appearance of sea ice – even in the absence of substantial wave energy – strongly implicates a thermal driver for the coastal erosion that we have observed (Figure 1). In the laboratory, we measured the ice content of seventeen composite samples collected from bluffs at Drew Point. Ice contents (by mass) ranged from 25-95%, with most of the samples having ice contents in excess of 50%. Combined, these data suggest that thermal processes may be more important than mechanical processes in eroding this coastline. A corollary to this is that continued increases in sea surface temperatures could directly influence erosion rates into the future.

Thus far, we have used remotely sensed records from the MODIS satellite to reconstruct time series of sea surface temperature and to evaluate the total thermal erosion potential in this setting. Comparisons of these coarse-resolution data with observations of coastal erosion rates from repeat measurements of onshore benchmarks also indicate that thermal processes could account for the majority of erosion that we have observed over two summers of monitoring.

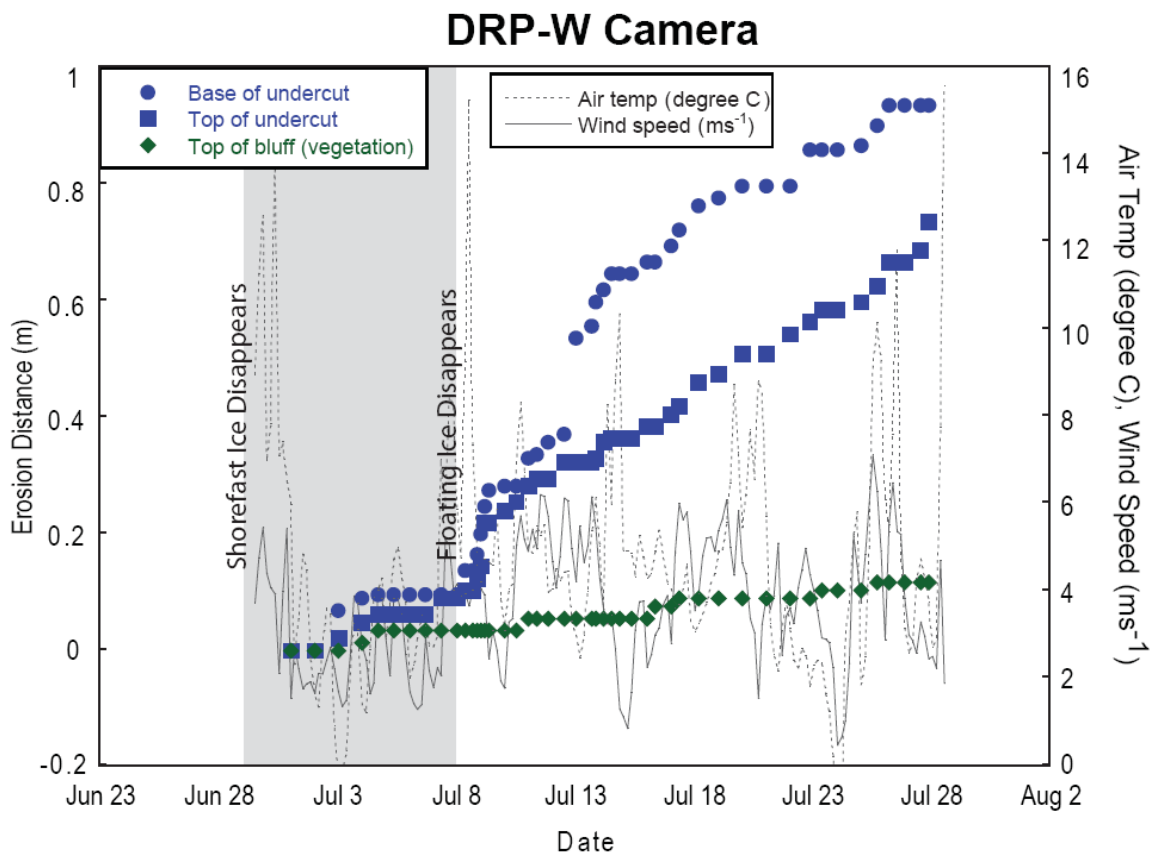

Figure 1. Rate of coastal erosion over July 2008 as reconstructed from time-lapse imagery at Drew Point. Erosion accelerates following retreat of sea ice, and is ongoing even in relatively calm wind conditions.

In Spring and Summer 2012 we expanded our GIS analysis of coastal erosion rate to include field surveys of coast position in Summers 2008, 2011, and 2012, as well as Landsat Imagery from 1979, 1985, 1992, 2002, and 2006 (Figure 2). We are using this dataset to explore the spatial variability of the coastal erosion rate and to provide a benchmark with which we can assess the success of our hindcast modeling effort. In addition to this dataset, we will use all published records and studies of the coastal erosion rate to assess the success of long term modeling runs of coastal erosion.

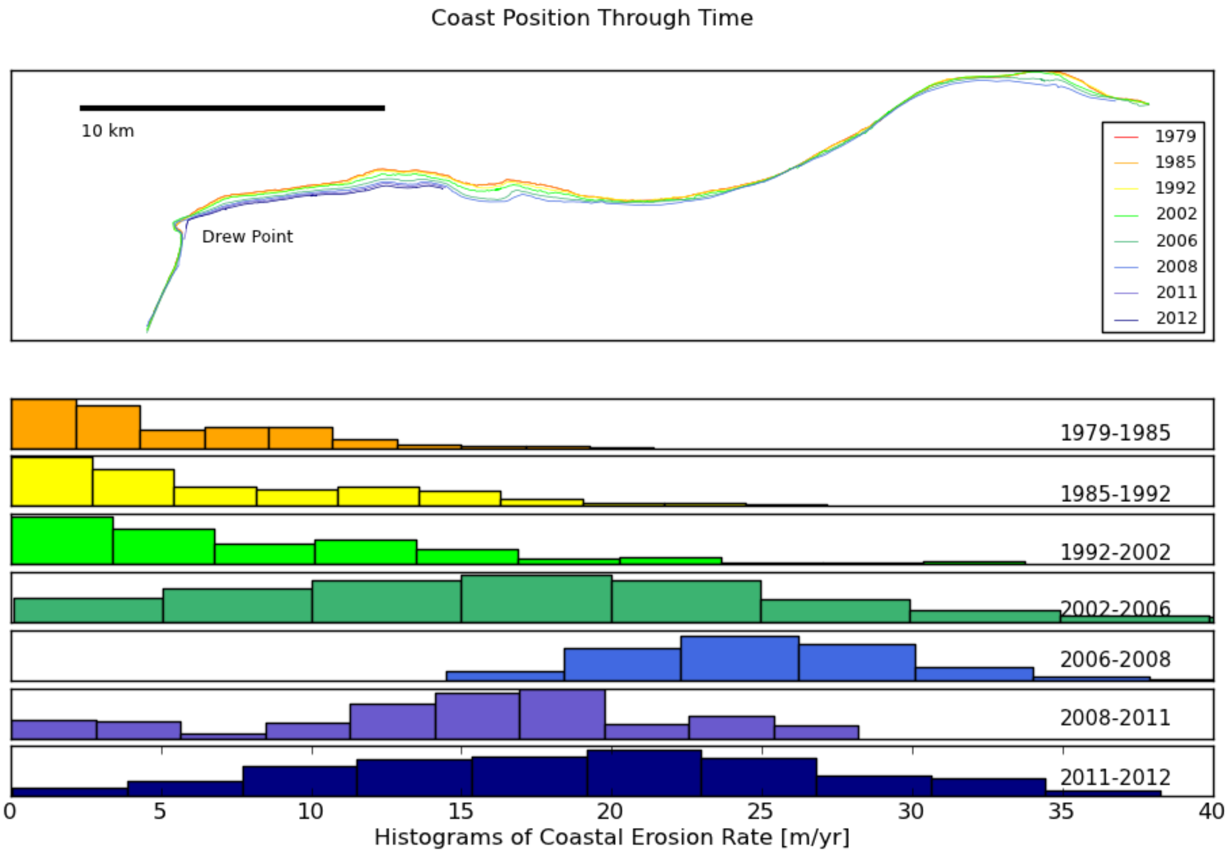

Figure 2. Map of the coast position in the Drew Point area over the period 1979-2012 based on a combination of field surveys and remotely sensed datasets. The lower panel shows histograms of the rate of coastal erosion between each observation period.

We used Nimbus 7-SMMR /SSM/I and DMSP SSMI Passive Microwave data to assess sea ice concentration around the Drew Point coast. This dataset runs from 1978 to the present at daily or two-daily time resolution, but has a low spatial resolution (~25 by 25km gridcells).

To address whether this data is adequate in the nearshore we extensively validated the low-resolution data against more detailed operational ice charts. These charts are drawn by analysts based on satellite data from a number of instruments as well as ship-based and aerial surveys.

Whereas previous validations have been concerned with the regional ice extent, such comparisons have not focused on the near-shore zone specifically. We cross-evaluated the passive microwave SSM/I sea ice concentration in the nearshore zone of the Drew Point coast along the Beaufort Sea against high-resolution NIC operational data, and MODIS remote-sensing imagery. We focused on the 2008 open water season, the comparison confirmed the accuracy of the estimated first-day of open water based on the passive microwave data. It also told us that the window of ice retreat in the nearshore zone (4km) is within 3 days of the estimated date of break-up derived from the passive microwave instruments for the larger 25km nearshore region.

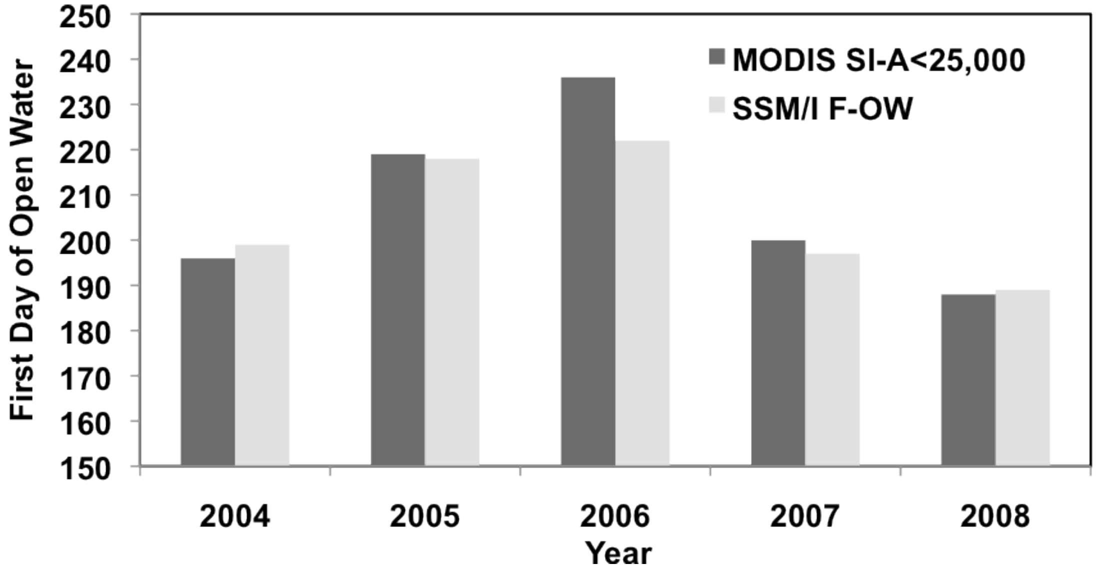

Figure 3. First-day of open water as retrieved from SSM/I signal sea ice concentration <15% corresponds with first day that sea ice area on the high-resolution MODIS imagery falls below 25,0000 km2 for 2004-2008.

Consequently, cross-evaluation of sea ice concentrations retrieved from passive microwave signal (SSM/I) against high-resolution IMS data and MODIS imagery for 2004-2008, shows that the use of SSM/I in the nearshore zone of the Drew Point area along the Beaufort Sea is adequate for assessment of the longterm trends in break-up and freeze-up days.

We evaluated the effects of increased fetch on coastal erosion by wave energy. We analyzed the data to determine ‘open-water distance’, the distance from a coastal cell towards the sea ice margin where concentration rises above a wave damping threshold (we used >50% ice). This allows us to show how fetch develops over the year and how it is related to the 20-year average fetch (Figure 5).

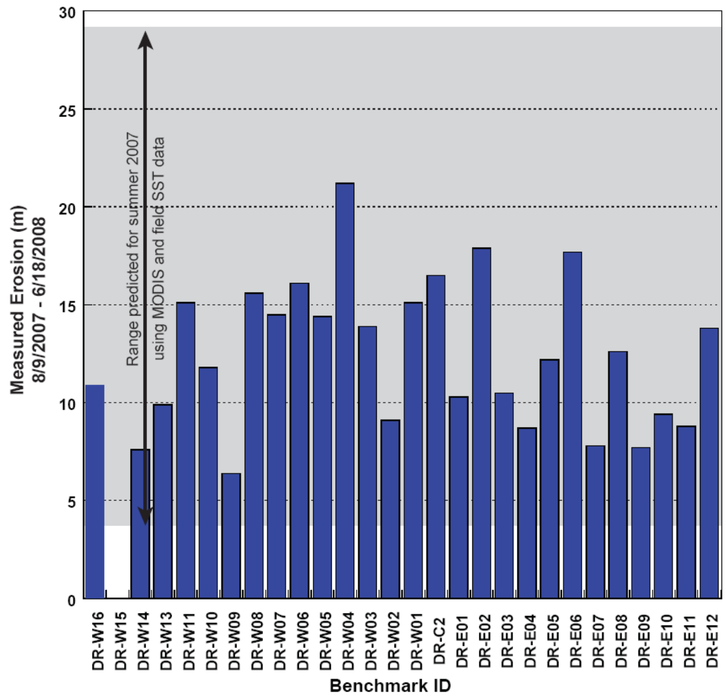

Figure 4 Integrated coastal erosion over an entire season (9th of August 2007- 18th of June 2008) as reconstructed from repeat survey transect along Drew Point. Total loss is consistent with thermal erosion potential modeled from MODIS.

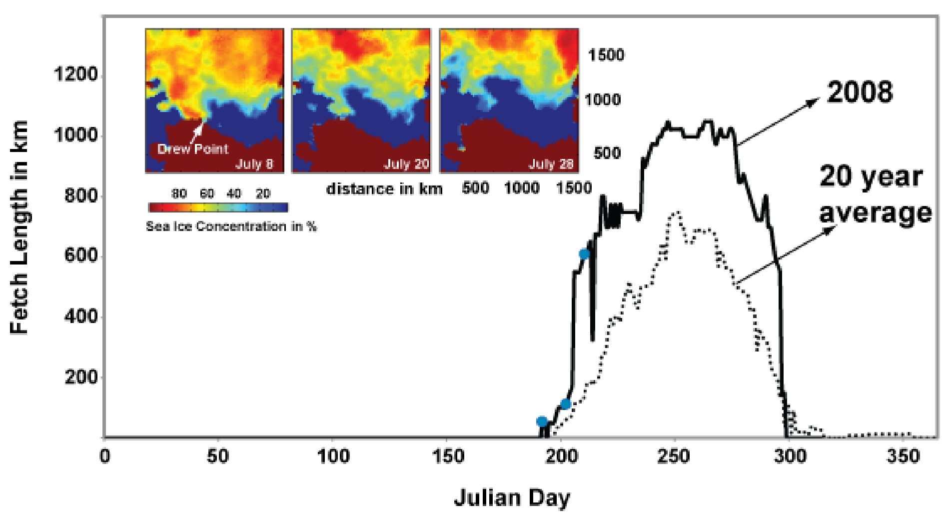

Figure 5. Fetch Length at Drew Point for different stages over the summer season 2008 is reconstructed from Nimbus-7 Passive microwave data, 2008 has open water distances that are 100's of km longer than the 20 year average conditions.

From summer 2009 wave buoy data and the thermal loggers we had deployed with these sensors, we have extracted information about the role of storms in local mixing of shelf waters. The highest ocean temperatures adjacent to the coastal bluffs occur not long after sea ice detaches from the coastline. A single storm event thoroughly mixes the shelf waters over a reach of shelf that is at least 10 km in width normal to the coastline, and they remain well mixed through the remainder of the summer except for several discrete events, all associated with storms.

We have now carefully analyzed the sea ice records from 1979 to present, as this sets the context for coastal erosion. An important result is the lengthening of the sea ice-free period of the summer. We show that for our reach of coastline, the sea ice-free period has lengthened considerably, resulting in roughly 2.5-fold increase in exposure to melt by seawater. This expansion of ice-free conditions is asymmetrical, with the majority of the lengthening being into the fall season (0.9 days/yr), and smaller expansion into the mid-summer (0.7 days/yr) (Figure 5). This reduces the leverage of the expansion on acceleration of coastal bluff retreat, as the sea surface temperatures in the fall are declining due to decline in direct insolation.

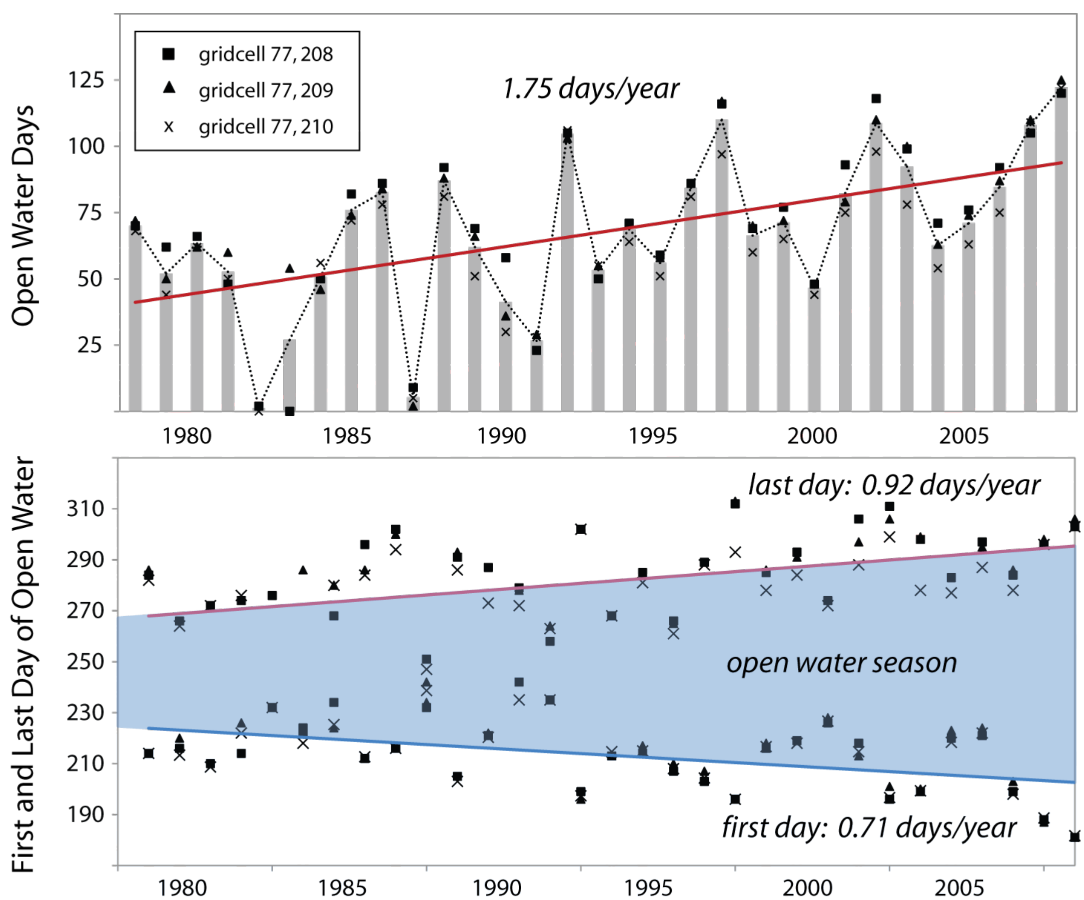

Figure 6. History of sea-ice free conditions (open water) in 3 adjacent cells along Beaufort Sea coastline, centered on our research site.

Our offshore work during the summer of 2009 gave us our first look at the detailed bathymetry in the shallow Beaufort Sea. One hypothesis to be tested is that if coastal erosion rates have in fact accelerated over the past century, there should be an inflection in the bathymetry that reflects this acceleration. There are suggestions from our bathymetric surveys that such an inflection exists in the nearshore environment which would be consistent with the idea that coastal erosion rates have accelerated in the recent past.

Summer 2010 field effort and data analysis
The summer 2010 field effort netted us time series of wave level (including contributions from waves, surge and tides), water temperature at several near-shore sites, and coastal erosion patterns from time-lapse photography. We had deployed four cameras, two high-end cameras one on land the other attached to a pole embedded in the subsea permafrost; and two lower resolution cameras (hunting cameras) of the sort we have deployed in previous summers. We used image feature tracking analysis to quantify coastal bluff demise. The data analysis of the August 13th-Sept 11th period, the water temperatures were remarkably homogenized in the near-shore zone. Water level shows clearly the role of surge set-up in modulating the location of the water impact with the cliff face, resulting in bluff retreat and block melt rates that vary significantly on short timescales. The demise of the toppled coastal bluff blocks is revealed by the offshore camera. It is noteworthy that the pattern is best explained by our algorihms that combine SST, significant wave height and water level. This provides a validation data set for our numerical models of this process. The retreat observed in this one-month interval was of the order of 10 m, much of a year's worth of retreat according to our pin-flag measurements from the last two summers.

Summer 2011 Field Effort
From July 29th through and August 10th 2011 graduate student Katy Barnhart visited the Drew Point, Lake 31, Lake 145, and East Lake Teshekpuk field sites while working with USGS collaborators. The aim of the field season was to repeat mapping of the coast location, continue data collection of soil and lake temperatures, install two additional cameras, and install Levelogger pressure transducers to monitor water level in two lakes. Below is a brief description of the specific tasks accomplished during this field season.

At Drew Point Barnhart re-walked the full 7 km stretch of coast with a GPS, made measurements of the thermal state of the coastal bluffs, recovered soil temperature sensors deployed in Summer 2010, and re-deployed temperature sensors. At Lake 31, she assisted in maintaining the meterological station, installed a Levelogger pressure transducer specially outfitted to survive freezing overwinter, re-measured the shoreline pin-flag transect, downloaded the timelapse camera, recover temperature sensors deployed in Summer 2010 from both the lake and the soil, re-deployed temperature sensors in both the lake and the soil, made measurements of the thermal state of the lakeshore, and deployed an additional hunting camera. At Lake 145 she installed temperature sensors in the lake. At East Lake Teshekpuk, she installed another specially outfitted Levelogger pressure transducer, deployed a hunting camera, and took a near-shore bathymetric profile.

Summer 2012 Field Effort
Our USGS collaborators Gary Clow, Frank Urban, and Gene Ellis were in the field in August 2012. In addition to their USGS work, they maintained the meteorological stations at Lake 31 and Drew Point. They recovered hunting cameras and sensors deployed in Summer 2012. Ellis re-walked the full 7 km stretch of coast at Drew Point.

Models
The work of Masters student Nora Matell was published in *Computers in Geosciences*. In this paper we introduce our model of the thermal impact of thaw lakes on the permafrost of the North Slope. This model is now stored in the model repository on the CSDMS site.

Graduate student Katy Barnhart has continued her work (started in 2010) on the development of numerical models of coastal bluff retreat. The physics embedded in this model includes the growth of a coastal notch by melt, toppling of the block when a torque condition is exceeded, and subsequent melting of the failed blocks. Melting is accomplished by both air and water. Water level is modulated of the water level by waves and surge and tide. Melt rate is governed by an empirically based iceberg melting algorithm that includes explicitly the roles of wave height, wave period, and water temperature.

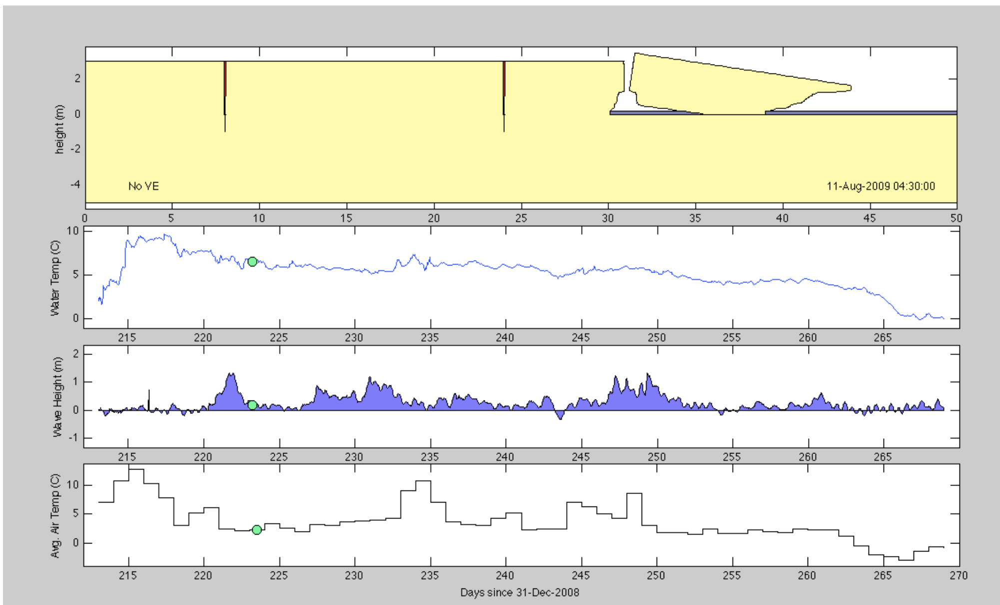

Figure 7. Screenshot of model result from coastal bluff retreat numerical model. Top: coastal bluff in cross-section, showing recently toppled bluff block. Failure occurs on ice wedges. Time series of water temperature, wave height and air temperature. Green dots display where the model is in time, JD 223.

As our goal is to place the coastal retreat problem in a quantitative, even predictive framework, we aim to exercise the model in the following ways. First we will use Summers 2009 and 2010 direct observations to refine the model to our particular coastal conditions and establish that the model can reproduce rates similar to those observed. Second, we will attempt to reproduce the rates of coastal retreat over the period for which we have both sea-ice and meteorological constraints (1979-2012). Finally, we will use the insight gained from these two exercises to explore the influence of anticipated changes to the arctic system under the expected range of future climate scenarios (see section on Models of Environmental Conditions).

In order to establish applicability of the erosion rules we employ, we are currently working to compare proxies for short time-scale erosion rate and the instantaneous erosion rate predicted for the same time period from our measurements of air temperature, water height, and wave characteristics (See Section on Extracting Erosion Rate Proxies From Time lapse Imagery). Our aim is not to "fit" the model to the known rates, but to demonstrate that the rules we use capture the process correctly.

In this endeavor we will mine not only the sea ice data sets, but those of the terrestrial meterological stations maintained by our USGS colleagues. As an example of the weather data now available, we display here a stack of time series of downwelling solar radiation at Drew Point, with air temperatures at the same met station. The pattern shows nicely both the solar-driven direct radiation, but variations about it that reflect both diffuse radiation and storm-driven cloud events. The air temperatures distinctly lag the insolation pattern, as the presence or absence of sea ice governs the continentality of the site (note high variation in air temperatures occurs in the time window outside the open water season in Fig 8).

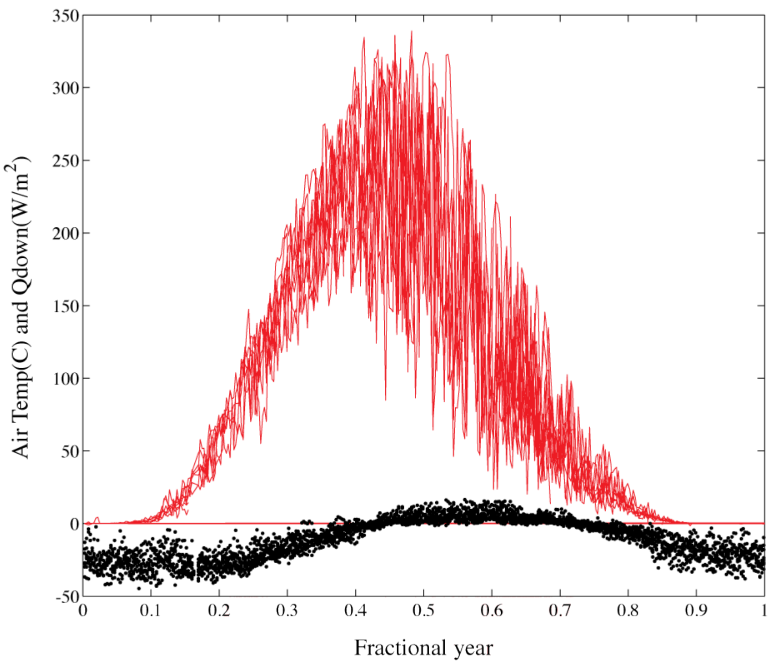

Figure 8. Stacked met records form the Drew Point met station, covering 12 years of record. Red lines = downwelling solar radiation; black dots = air temperature.

Extracting Erosion Rate Proxies From Timelapse Imagery

In order to evaluate the applicability of potential erosion rules to use in numerical modeling efforts we have developed erosion rate proxies from the timelapse imagery. Figure 9 outlines the method used to extract these proxies from the imagery collected during Summer 2010. Graduate student Katy Barnhart wrote code to automatically extract the cross sectional area of degrading blocks from the images. Barnhart worked with staff at the Extreme Ice Survey and other researchers at INSTAAR to try and develop an automatic method to detect the location of the block. However, she determined that there is little to automatically distinguish the block from the surrounding landscape in the images. In order to extract the block size, red dots must be placed on the image in order to identify the location of the block. Figure 9E shows the resulting block size history from the marine camera. Barnhart is currently exploring the relationship between the rate of block degradation, air temperature, water temperature, and wave characteristics. and calculated erosion rates from established thermal and mechanical erosion rules. She presented the results of this work at the CSDMS conference in late October 2011 and at AGU in early December 2011.

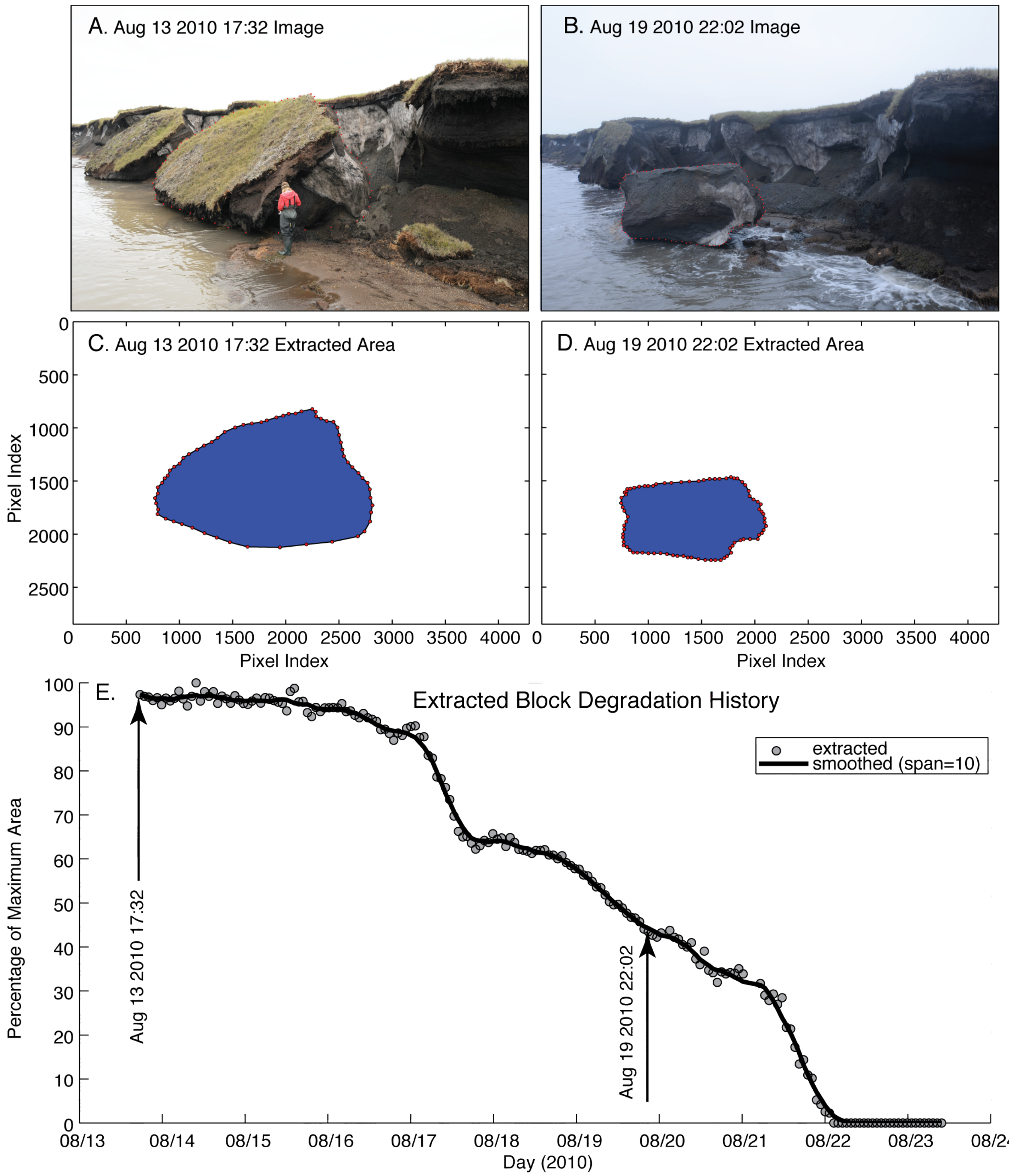

Figure 9. Overview of method used for erosion rate proxy extraction from time lapse imagery. Images A and B taken from timelapse record. Red dots are manually placed on block. Block cross sectional area is then automatically extracted from images using MATLAB (C and D). Part E shows the block size history from Summer 2010 using every 5th image (1.25 hr interval).

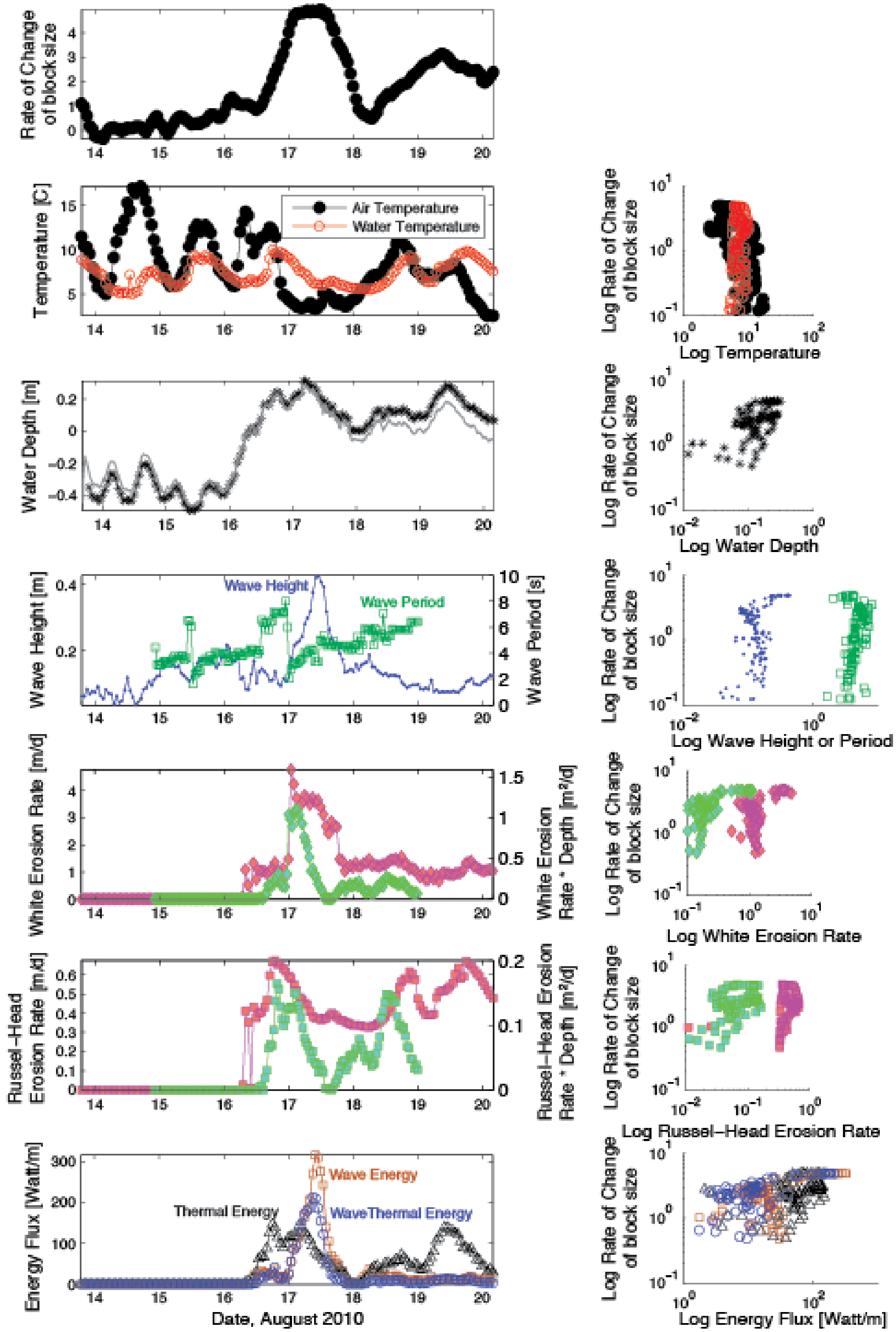

Figure 10. Comparison of the rate of change of apparent area of the block shown in Figure 9 with all observed environmental conditions (air temperature, water temperature, water level, wave height, wave period), and theoretical rules for instantaneous submarine erosion rate (White, Russell-Head, Wave Energy, Thermal Energy).

The air temperature, water temperature, water depth, wave height, and wave period are all environmental factors that could influence the rate of block degradation. Air temperature controls the rate of the less efficient subaerial erosion process, while the difference between the water temperature and the temperature of the eroding block, and the wave field characteristics likley influence the rate of heat transfer to melt the interstitial ice, and the water depth controls the portion of the block that is exposed to subaqueous erosion.

We compare environmental conditions and theoretical rules for instantaneous submarine erosion rate with the record of the rate of change of block size. The examination of enviornmental conditions, modified iceberg melting rules, and energy fluxes to the coast establish that water depth, water temperature and wave height are the most significant environmental conditions to the instantaneous rate of coastal erosion. The two most important environmental factors that influence the rate of coastal erosion in ice rich permafrost are the water depth and the wave height. We are not able to fully explore the influence of water temperature as it does not change significantly while the eroding block is exposed to water. We suspect that the water temperature is significant in that it must be greater than zero.

WRF MODELING

We colloborate with Dr. Clow , USGS to further explore regional climate controls on the local meteorological and oceanographic conditions. We use the Weather Research and Forecasting Model (WRF-model) to simulate atmospheric conditions over the time periods of observation, e.g. August-September 2010 when we have a complete data record of both local meteorology, bluff retreat, sea water level fluctuation, SST and significant wave height. The WRF-model is a mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs. It features multiple dynamical cores, a software architecture allowing for computational parallelism. These simulations have been set up to run in parallel on the High Performance Computing System of CSDMS.

It appears that periods of rapid erosion can coincide with relatively quiescence atmospheric conditions. We are presently correlating these simulations with water level data to explore the controlling factors on storm setup and surge.

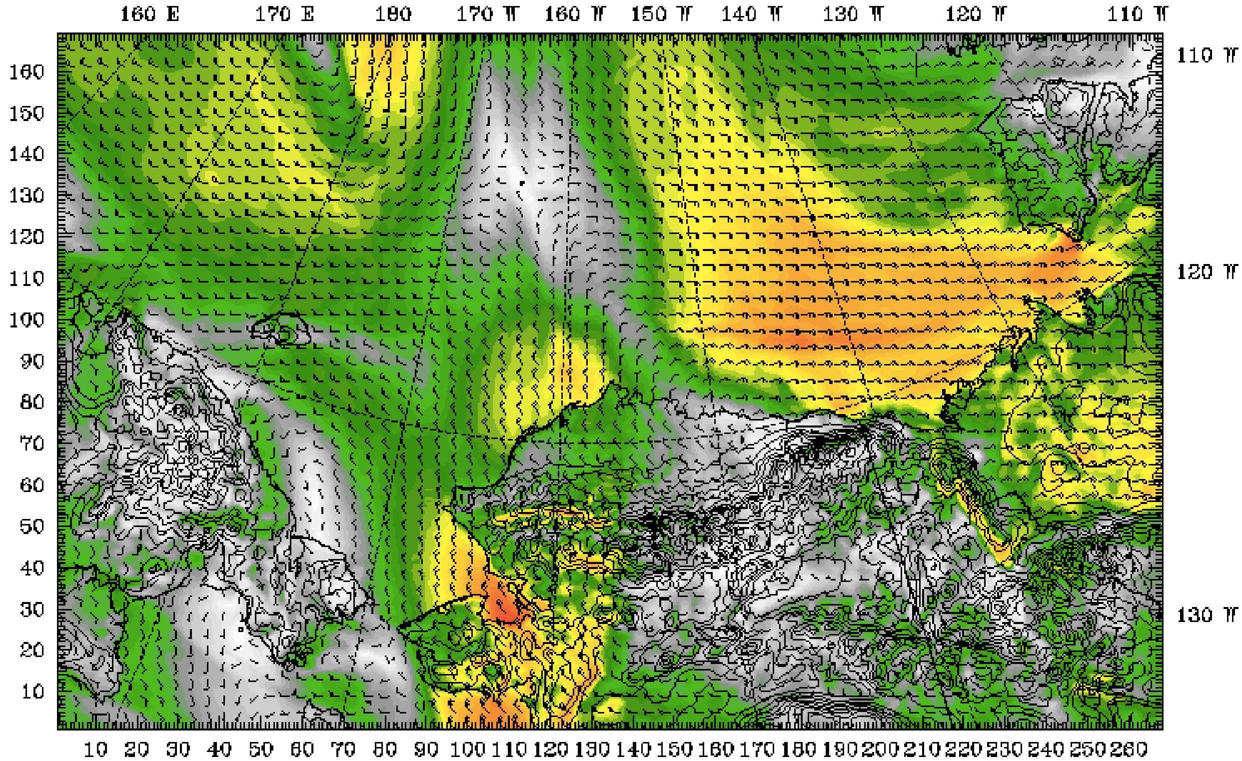

Figure 11. WRF snapshot of August 17th, 2011. Analysis of time-lapse imagery shows rapid block melt during these conditions. However the wind velocity predictions predicted with WRF are 4-8m/s along the Drew Point Coast. The storm system appears to be of modest intensity, however winds are variable and changed to a direction over the course of the day, which perhaps contributed to higher set-up.

MODELING OF ENVIRONMENTAL DRIVERS

In order to undertake hindcast model runs for the period 1979-2012, we need timeseries of environmental conditions for that period. We use the wind speed and direction measured at Barrow to determine wind set up and wave field (wave height and period). We model wind driven setup using the bathystrophic storm surge model and model the wave field was calculated using equations outlined in the Shore Protection Manual (1984) for fetch-limited waves in shallow water. We find that we are able to reproduce the observed water level and wavefield for the periods of time in 2009 and 2010 that field instruments were deployed (Figure 12).

We use the timing of sea ice retreat from the Drew Point area and a model of water temperature change based on a radiation balance at the ocean-air interface to predict water temperatures for the hindcast period. We find that we are able to capture the seasonal and daily cycles of heating and cooling well. As expected we are not able to capture the details of storm related water temperature changes using this simple model.

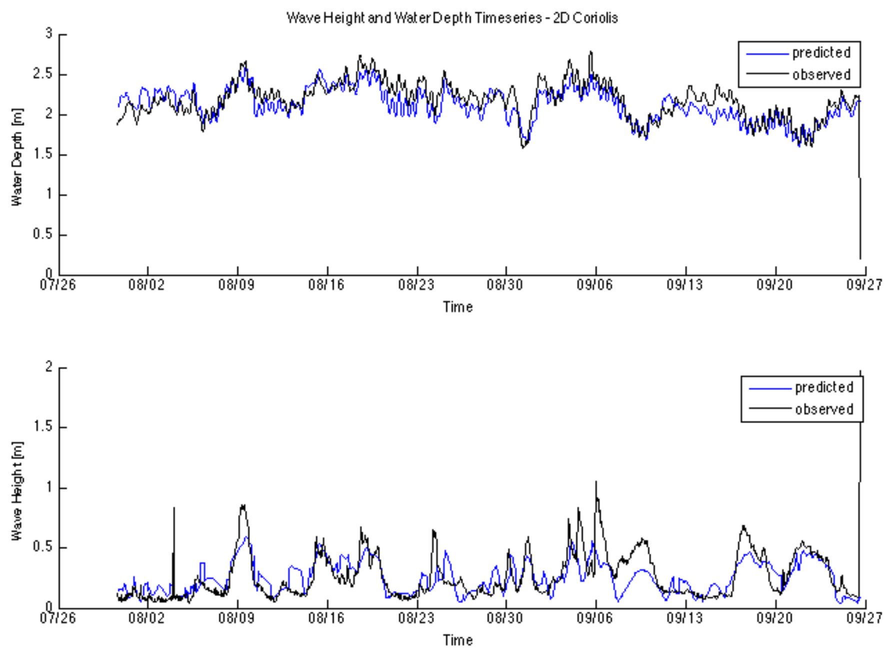

Figure 12 Observed and predicted timeseries of water depth and wave height from summer 2009. Modeled timeseries will be constructed for the timeperiod 1979-2012 and used as drivers for hindcast model runs.

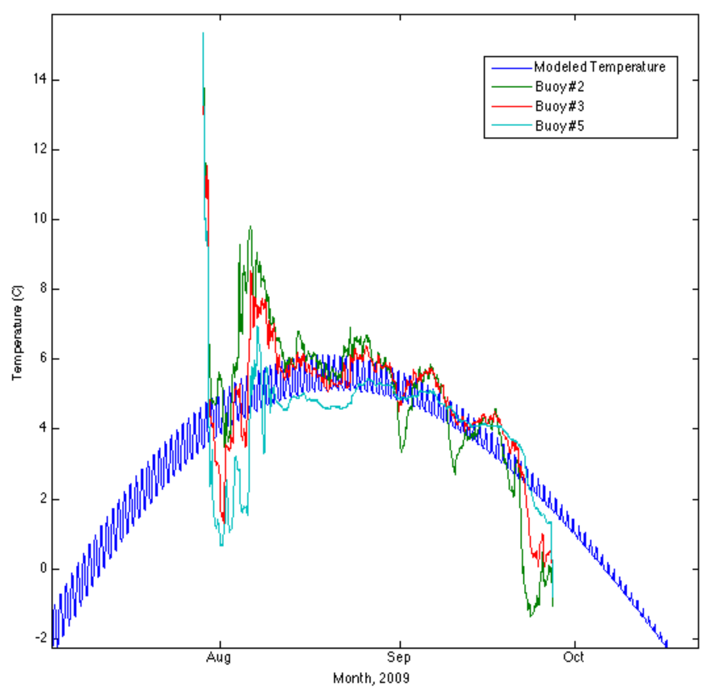

Figure 12. Modeled and measured (at 3 locations) water temperature from summer 2009. Water temperature model captures the seasonal and daily cycles of water temperature but does not capture variations in water temperature associated with passing storms (few day-week time scale).

IMPACT AND APPLICATIONS

Science Education and Communication

In Fall 2008 we produced a video from our time-lapse photography which was posted on the New York Times "Dot Earth" website. The video, entitled 'Alaska's Eroding Coast', shows the dramatic loss of coastline during a period of relatively calm weather over the middle of the summer of 2007. This video has been viewed more than 36,000 times. In the summer of 2008 we participated in an IPY "Dispatches from the field" event, in which we communicated our daily science activities to a global community of science educators via satellite telephone hookup.

TRANSITIONS

Science Education and Communication

Our work has been disseminated among other researchers studying Arctic climate change and coastal processes. Our project was featured as an example on 'Modeling Arctic Coastal Erosion' in the policy document 'Arctic Coasts 2009 – a Circumpolar Review' that has been published by IASC-LOICZ-AMAP. Our coastal erosion video was also shown at the large plenary closing ceremony of the International Polar Year (IPY) in Geneva, Switzerland.

As listed in the end of this report, in FY2010 as well as FY2011 we were involved in press conferences, television and newspaper interviews, and have given several talks at both local and national venues. These interviews contributed to a feature article in ScienceNews, July 16th 2011, Collapsing Coastlines-How Arctic shores are pulled a-sea, by D. Strain.

Overeem and Barnhart met in December 2011 and July 2012 with ARCADIS coastal engineer John Atkinson to discuss potential implications of our findings for coastal dynamics near Wainwright along the Chuckchi Coast in reference to ARCADIS' exploratory consulting project for Royal Dutch Shell. USGS scientists Clow and Urban had meetings with Shell representatives during their 2012 field period in Inigok, Alaska.

RELATED PROJECTS

PI Anderson and co-PI Overeem are both members of the Community Surface Dynamics Modeling System (CSDMS) terrestrial working group (http://csdms.colorado.edu/index.html). We anticipate that our project will tap the broader expertise of the CSDMS consortium as we move into the modeling component of our study. Photos and movies of the eroding permafrost coast, as well as thawing lake shores at our field site have been added to the Educational Gallery of the CSDMS:
http://csdms.colorado.edu/wiki/index.php/Coastal_GL4

The model for 'Lake-Permafrost with Subsidence' developed by graduate student Nora Matell has been added to the Model repository of CSDMS and is now available as open-source code for interested earth scientist worldwide.
http://csdms.colorado.edu/wiki/Model:ThawLake1D

PIs Wobus and Anderson are both involved in an NSF-sponsored project to understand weathering in alpine environments. Thermal models of ground temperatures as well as technologies developed for monitoring weather conditions, collecting time-lapse photographs, and deploying self-contained temperature probes are creating synergies between these two projects.

Graduate student Barnhart was selected in June 2012 as a recipient of a NASA Earth and Space Science Fellowship. Her proposal, entitled "Flexible Heat Flow Models of the Active Layer and Conductive Permafrost: Thermal State from Field Measurements and Satellite-Derived Skin Temperature", will allow for continued work in this environment and collaboration with the USGS. This project will integrate remotely sensed surface temperature, vegetation, and snow cover with near surface and deep borehole observations, with the intention of constraining the spatial and temporal record of the energy flux into the permafrost over the observation period on a regional scale, while identifying the surface processes responsible for that flux.

NOPP Award 2010, July 2009

Our project was chosen to receive the National Oceanographic Partnership Program 2010 Award for Excellence in partnering and outreach. The award was presented to Cameron Wobus at the annual ORRAP meeting in Seward, Alaska, in July of 2010.

PUBLICATIONS

Overeem, I., R. S. Anderson, C. Wobus, G. D. Clow, F. E. Urban, N. Matell, 2011, Quantifying the Role of Sea Ice Loss on Arctic Coastal Erosion, *Geophysical Research Letters*

Wobus, C., I. Overeem, N. Matell, and R.S. Anderson, 2011, Thermal erosion of a permafrost coastline: Improving process-based models using time-lapse photography, *Arctic Alpine Antarctic Research* 43(3): 474-484. (includes cover photo of this issue)

Matell, N., R. S. Anderson, I. Overeem, C. Wobus, F. E. Urban, and G. D. Clow, 2011, Modeling the subsurface thermal impact of Arctic thaw lakes in a warming climate. *Computers & Geosciences* (2011), doi:10.1016/j.cageo.2011.08.028

Other Contributions

Overeem, I., 2010. Arctic Coastal Erosion along the Beaufort Sea. Contribution to "A Science Plan for Regional Arctic System Modeling". In: Roberts et al., (eds.), 2010. A report by the Arctic Research Community for the National Science Foundation Office of Polar Programs.

THESES

Matell, N., 2009. Shoreline erosion and thermal impact of thaw lakes in a warming landscape, Arctic Coastal Plain, Alaska. M.Sc. thesis project, Department of Geology, University of Colorado, Boulder.

Holmes, C., 2009. "Focused Temporal and Spatial Study on Sea Ice Location in the Beaufort Sea, Alaska, and its Role in Coastal Erosion". Honors BSc thesis. University of Colorado, Boulder.

ABSTRACTS

2008 AGU

Matell, N., R. S. Anderson, C. Wobus, I. Overeem, F. Urban, and G. Clow, 2008, "Thinking along 2 axes: Lakeshore erosion and subsurface effects of thaw lakes along Alaska's Arctic Coastal Plain", AGU Fall Meeting

Wobus, C., R.S. Anderson, I. Overeem, N. Matell, F. Urban, G. Clow, B. Jones, and C. Holmes, 2008, "Monitoring coastal erosion on the Beaufort Sea coast: Erosion process and the relative roles of thermal and wave energy". AGU Fall Meeting.

Peckham, S., Overeem, I., 2008, Sediment Transport in a Changing Arctic: River Plumes, Longshore Transport and Coastal Erosion. Arctic Change Meeting, December 10th, 2008. Quebec, Canada.

2009 AGU

Overeem was a Session chair "Arctic Coasts at Risk", AGU Annual Meeting 2009.

Overeem, I., Wobus, C.W., Anderson, R. S., Clow, G.D., Urban, F.E., Stanton, T. P., 2009.Quantifying Sea-Ice Loss as a Driver of Arctic Coastal Erosion. AGU Fall Meeting, San Francisco, December 2009.

Wobus, C.W., Anderson, R. S., Overeem, I., Clow, G.D., Urban, F.E., 2009. Calibrating thermal erosion models along an Arctic coastline. (Invited) AGU Fall Meeting, San Francisco, December 2009.

Overeem, I., Wobus, C.W., Anderson, R. S., Clow, G.D., Urban, F.E., Stanton, T. P., 2009. Quantifying Sea-Ice Loss as a Driver of Arctic Coastal Erosion. AGU Fall Meeting, San Francisco, December 2009.

Anderson, R. S., Wobus, C.W., Overeem, I., Clow, G.D., Urban, F.E., Stanton, T. P., 2009. Rapid coastal erosion on the Beaufort Sea coast: A triple whammy induced by climate change (Invited), AGU Fall Meeting, San Francisco, December 2009.

2010 AGU

Barnhart, K. R., R. S. Anderson, I. Overeem, C. Wobus, G. D. Clow, F. E. Urban, and T. Stanton, 2010, Modeling the rate and style of Arctic coastal retreat along the Beaufort Sea, Alaska, Abstract, AGU Fall meeting 2010

Overeem, I., R. S. Anderson, C. Wobus, N. Matell, G. D. Clow, F. E. Urban, and T. Stanton, 2010, The impact of sea ice loss on wave dynamics and coastal erosion along the Arctic Coast, Abstract, AGU Fall meeting 2010

Wobus, C., R. S. Anderson, I. Overeem, T. Stanton, G. D. Clow, F. E. Urban, 2010, The role of summertime storms in thermoabrasion of a permafrost coast, Abstract, AGU Fall meeting 2010

2011 AGU

Barnhart, K., R. S. Anderson, I. Overeem, C. Wobus, G. D. Clow, F. Urban, A. LeWinter, T. Stanton, 2011, Modeling the rate and style of Arctic coastal retreat along the Beaufort Sea, Alaska, AGU Annual Meeting 2011

2012 AGU

Barnhart, K., R. S. Anderson, I. Overeem, C. Wobus, G. D. Clow, F. Urban, A. LeWinter, T. Stanton, 2012, Relationship between environmental conditions and rates of coastal erosion in Arctic Alaska, AGU Annual Meeting 2012

2010 State of the Arctic Conference

Wobus, C. W., R. S. Anderson, I. Overeem, G. Clow, F. Urban, and T. Stanton. Thermal erosion of an Arctic Coastline: Field observations and Model development. State of the Arctic Conference, Miami, FL, March 17, 2010.

2010 ONR Coastal Geosciences review in Chicago

Wobus, C. W., R. S. Anderson, I. Overeem, G. Clow, F. Urban, and T. Stanton. Thermal erosion of an Arctic Coastline: Field observations and Model development. 2010 ONR Coastal Geosciences review meeting, June 4 2010.

2010 Polar Society

Overeem, I., 2010, Sea Ice Loss Induces Arctic Coastal Erosion. Program and Abstracts of the American Polar Society Meeting 2010, Institute of Arctic and Alpine research (INSTAAR), Univ. of Colorado at Boulder. (Invited talk)

2010 NSIDC

Anderson, R. S., 2010, The triple whammy of sea ice loss on coastal erosion, National Snow and Ice Data Center (NSIDC), University of Colorado at Boulder.

2011 National Park Service

Anderson, R.S., July 20th 2011, webinar to the NPS titled: “Rapid erosion of a frozen Arctic coast: dominance of thermal processes and their likely acceleration along Alaska’s Beaufort Sea coast” given at local headquarters in Lakewood, CO, and broadcast nationally

2011 INSTAAR Seminar

Overeem, I., March 2011. The Impact of Sea-Ice Loss on Wave Dynamics and Coastal Erosion Along the Arctic Coast.

CONFERENCE SESSIONS

2012 AGU

R. S. Anderson, Crosby, B., Barnhart, K.R., Barnhart T.B., conveners. “Session EP35: Thermal Control on Weathering, Erosion and Landscape Evolution”, Earth and Planetary Surface Processes Focus group, AGU Annual Meeting, 2012

OUTREACH TO GENERAL PUBLIC

Bob Anderson was invited to participate in AGU Press Conference--Climate change discussion for science journalists, organized during Fall AGU 2009 Meeting. The news conference was held with a panel of 3 other Arctic scientists.

Interviews with two national papers on “Eroding Coast of Northern Alaska”. Video footage of interviews and supplementary photographic material are posted as well.

University of Colorado Press Announcement in December 2009 resulted in publications in Science Daily, Alaskan News Reader, Hindu Times.

Interview in May 2010, contributed photos to article for Anchore Press: “A fragile past - Archaeologists are scrambling as accelerated erosion sweeps away artifacts on Alaska's Arctic coast”

Overeem gave an interview to be used in a documentary about “Climate Change and its Impacts”. The working title of the documentary is 7th Generation.

Overeem contributed to a feature article in ScienceNews, July 16th 2011, Collapsing Coastlines-How Arctic shores are pulled a-sea, by D. Strain.

DATA SHARING

Our USGS collaborators Frank Urban and Gary Clow are sharing the data streams from our met stations on the North Slope through the Climate and Permafrost Network.
http://data.usgs.gov/climateMonitoring/region/show?region=alaska