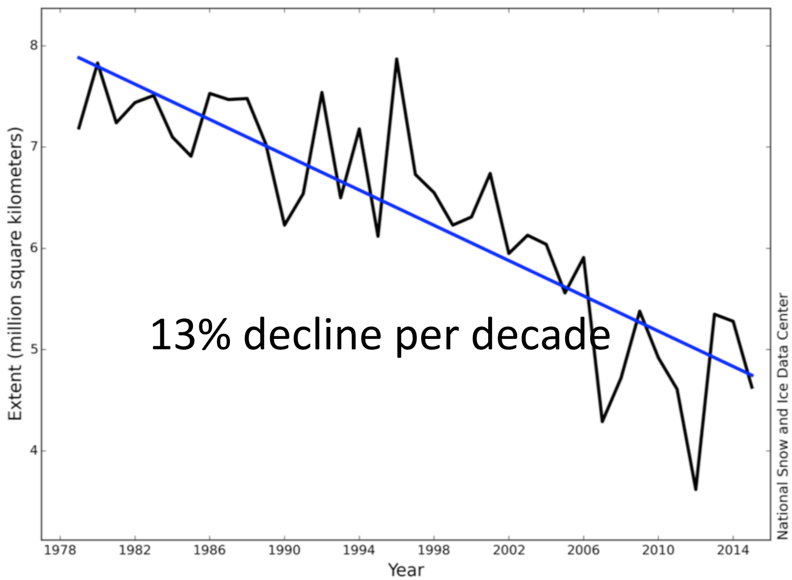
What is New in the Arctic Coastal Zone?

Irina Overeem

CSDMS, INSTAAR, University of Colorado at Boulder, CO

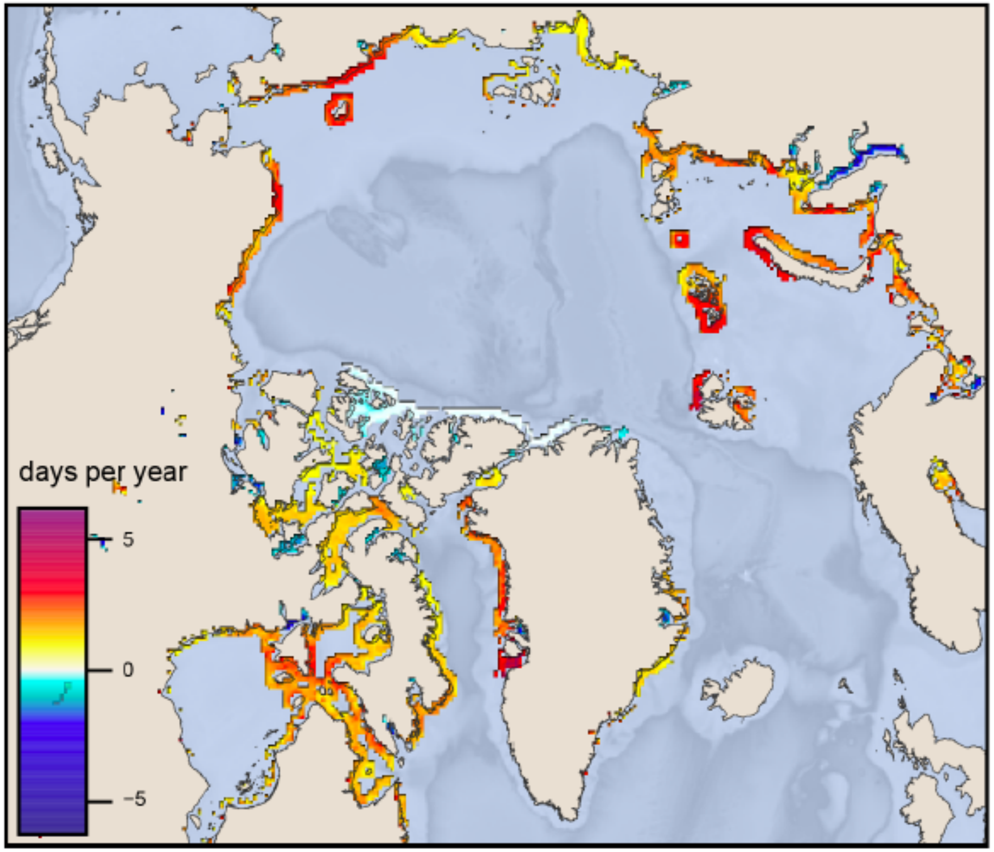
Sea Ice Decline

Monthly Sea Ice Extent 1979-2015



From: NSIDC, november 2015

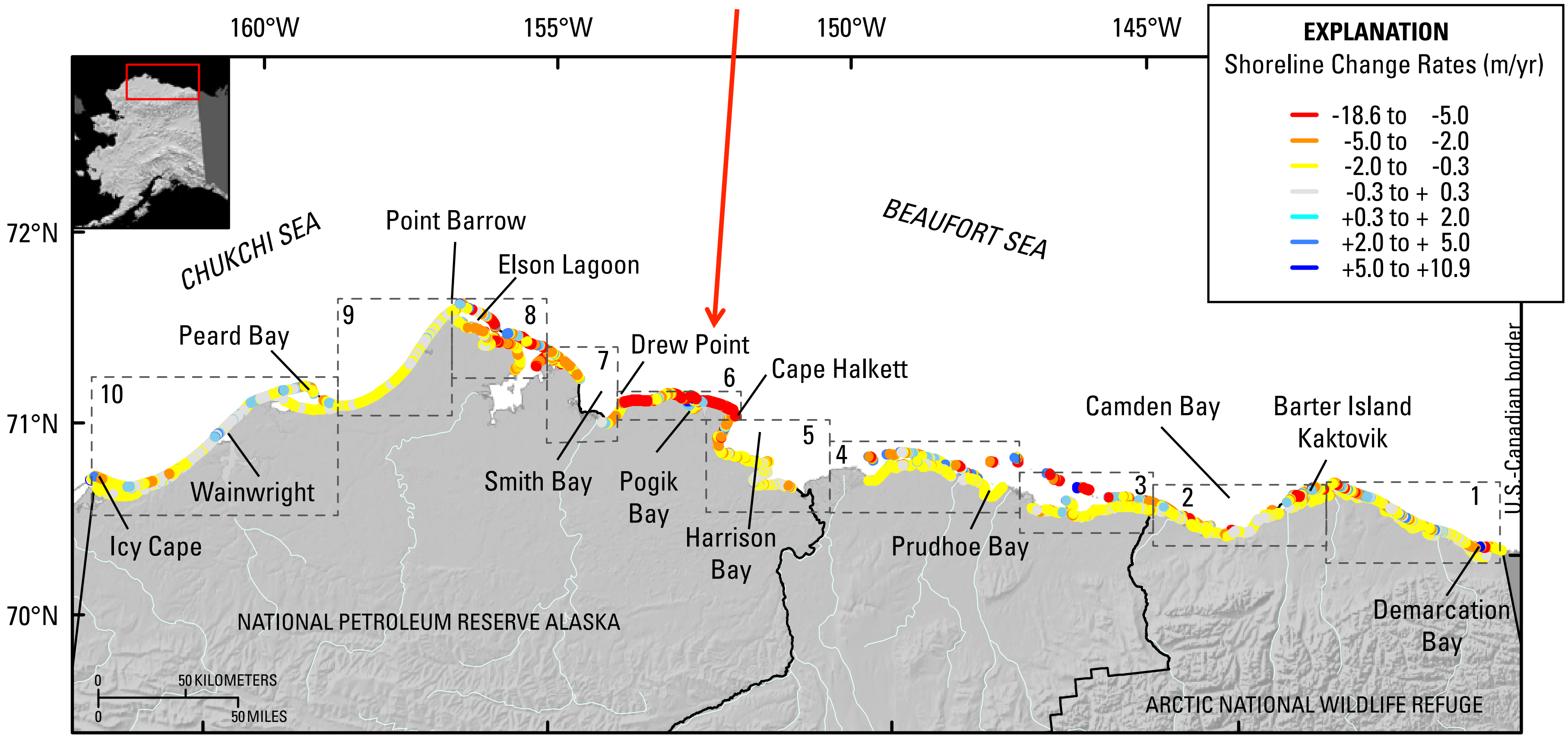
Rate of Change in Open Water Days 1979-2012



Over last 30 years, length of open water expanded 1,5-3 times (Barnhart et al., 2014)

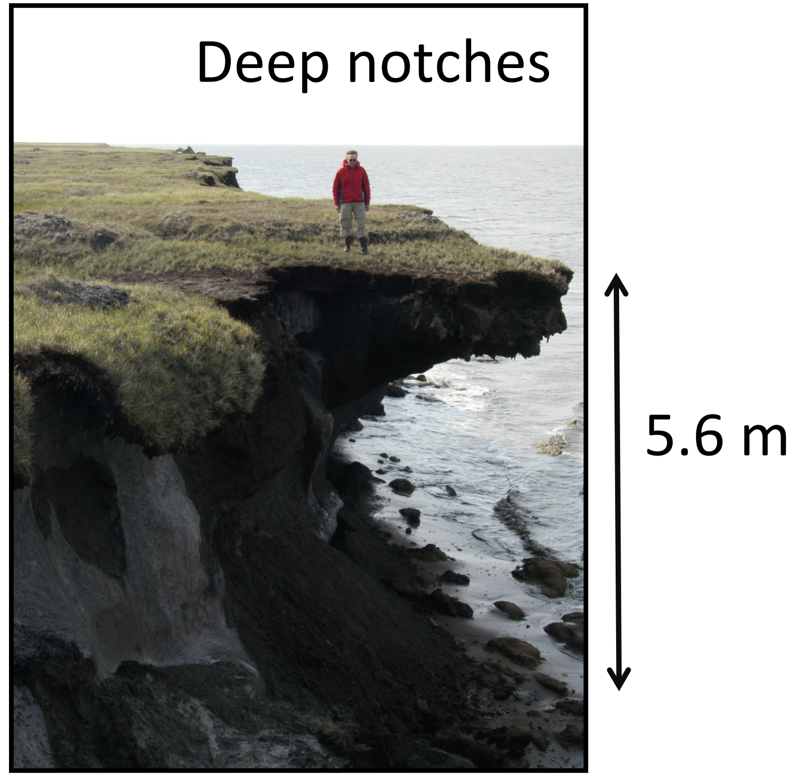
Regional Coastal Retreat

Erosion hotspot Drew Point



(From Gibbs and Richmond, 2015; USGS Open File Report 1048)


Bluffs are 4-5 m high


Deep notches
5.6 m


Ice Content 64%

Why is Coastal Erosion Important?

Shisharef, Alaska
565 people need to relocate

Photo: Shismaref Erosion and Relocation Committee

Oil and gas infrastructure
Mitigation of several wells

Photos: Gary Clow, USGS & S. Flora, BLM

Research Questions

Arctic-wide warming and decline in sea ice extent occur concurrently with increase in erosion; this suggests a causal relationship.

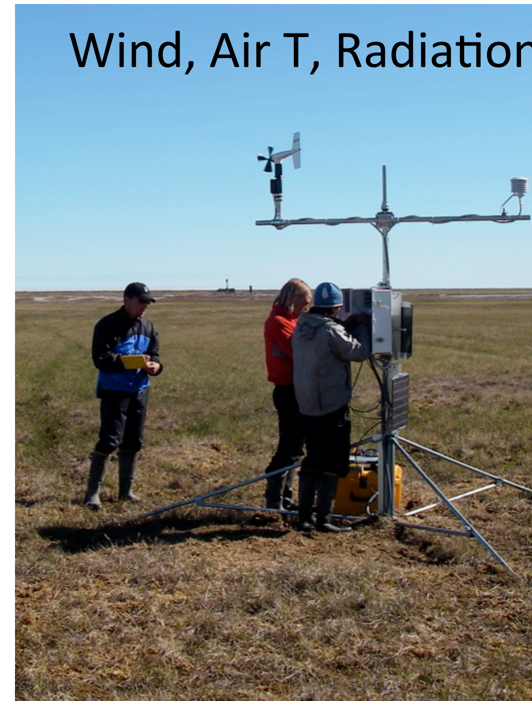
- Can we quantify the erosion processes?
- Are there any non-linear feedbacks?

Aim to model the erosion process to ultimately make predictions into next 50 years.

Field Observations 2007-2011

Sea Surface Temperature
and Water Level

Bathymetry and Waves



Wind, Air T, Radiation

Permafrost Temperature

Coastal Erosion Mechanisms

Sea Ice needs to be gone before sea water temperature starts increasing, and waves start bathing icy bluffs.

Sea Ice Season versus Open Water Season = limiting factor

Quantify erosion (Ew) with iceberg melt model

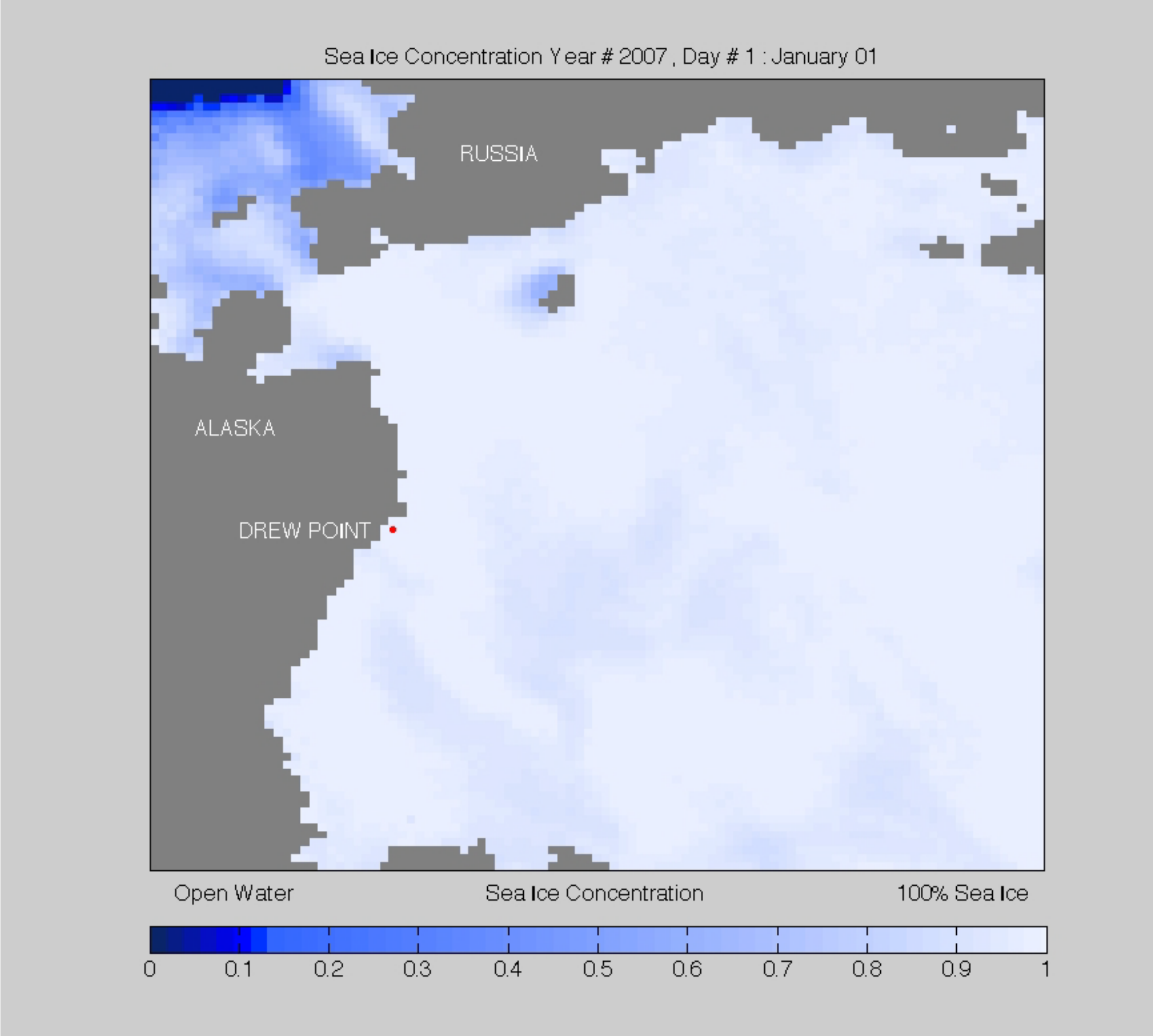
$$E_w = 0.000146\lambda\left(\frac{R}{\tau}\right)^{0.2}\left(\frac{H}{\tau}\right)^{0.8}(T_w - \delta_w)$$

High sea water temperature forces rapid erosion

(White et al., 1980; Kubat et al., 2007; Wobus et al., 2010; Barnhart et al., 2014.)

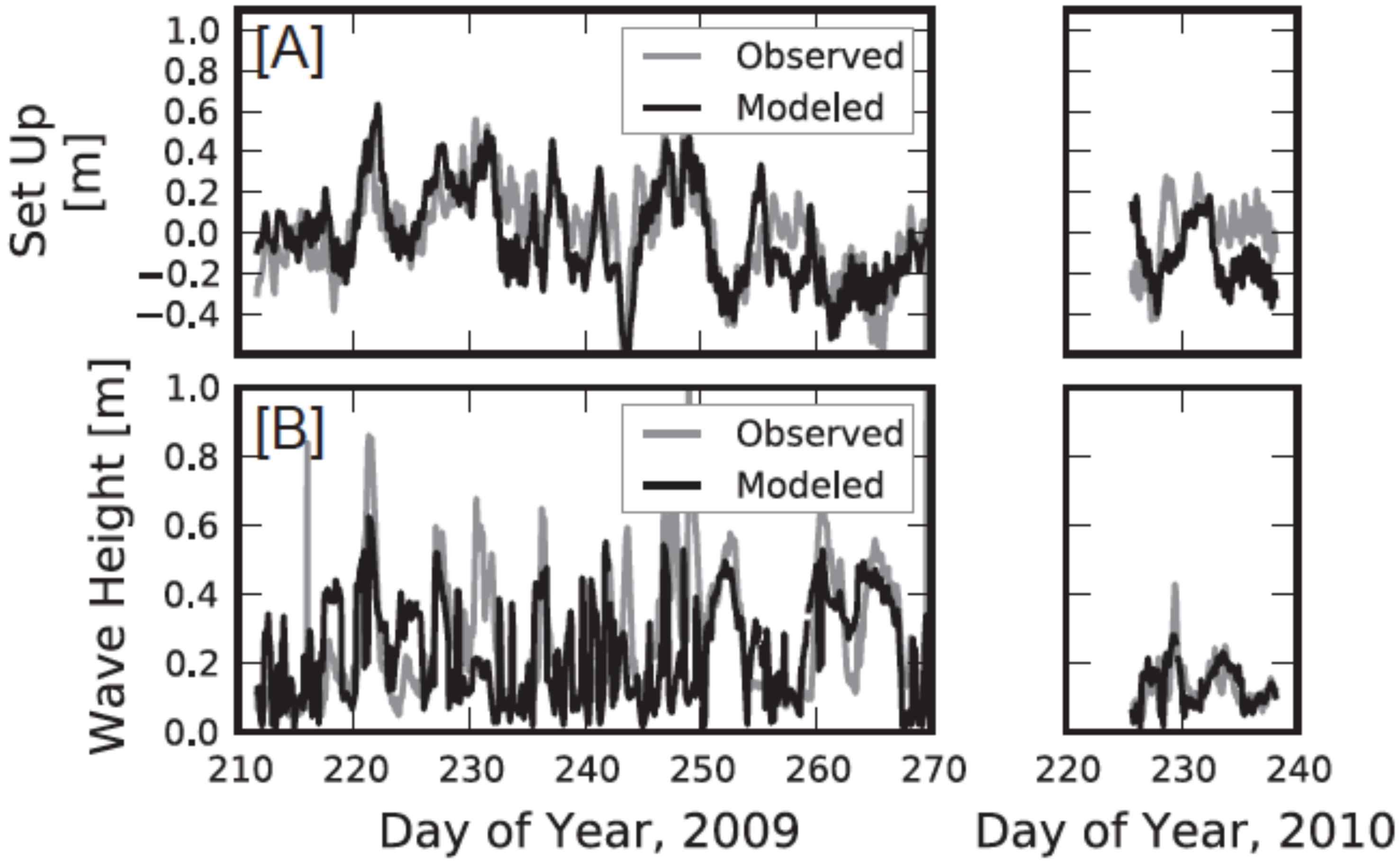
Time-lapse camera August 13th-August 21th, 2010

Wind, Sea-Ice and Fetch Model

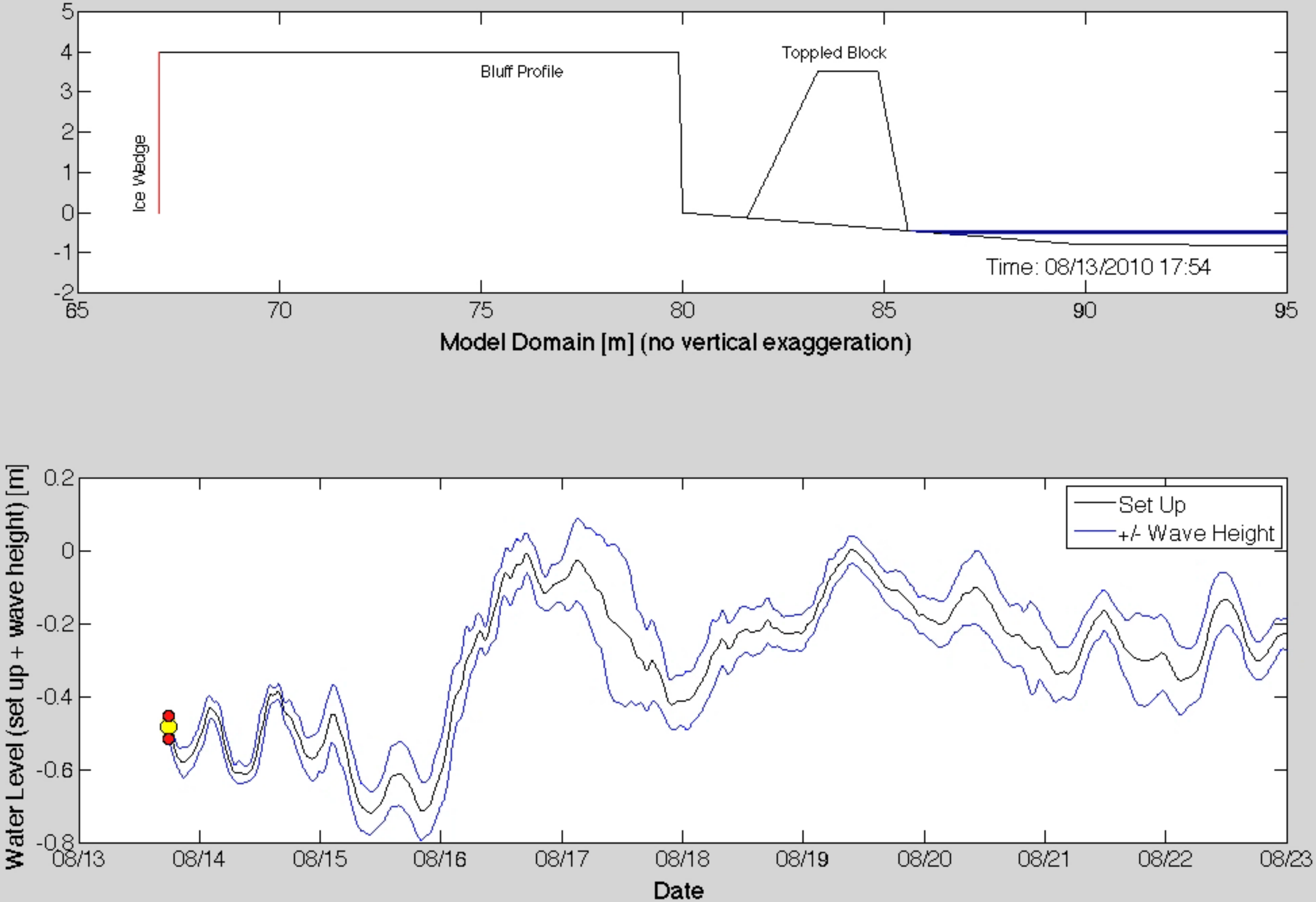


al., GRL, 2011)

Water level and Wave Predictions

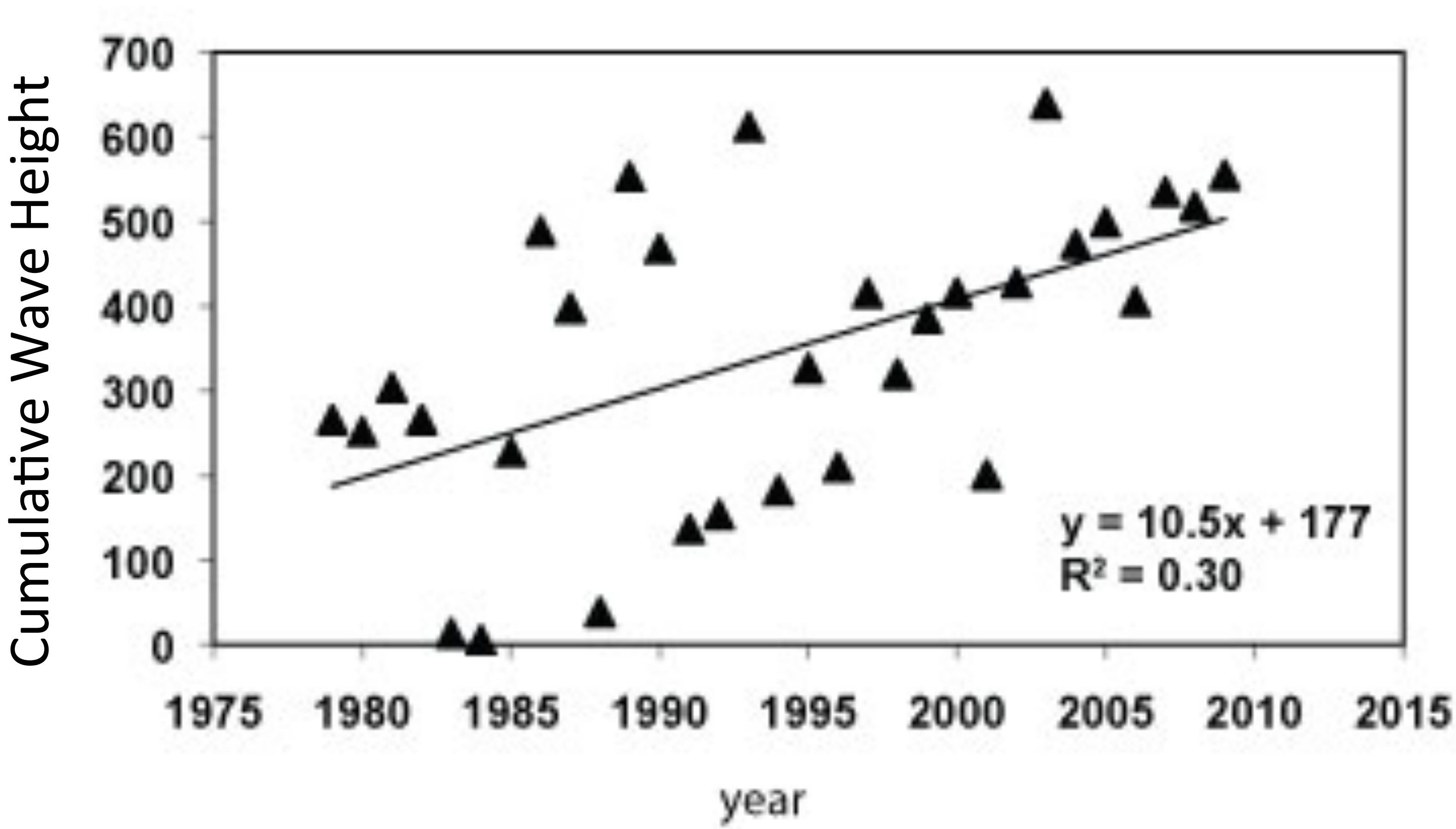


Good match between observed and predicted set up and wave heights



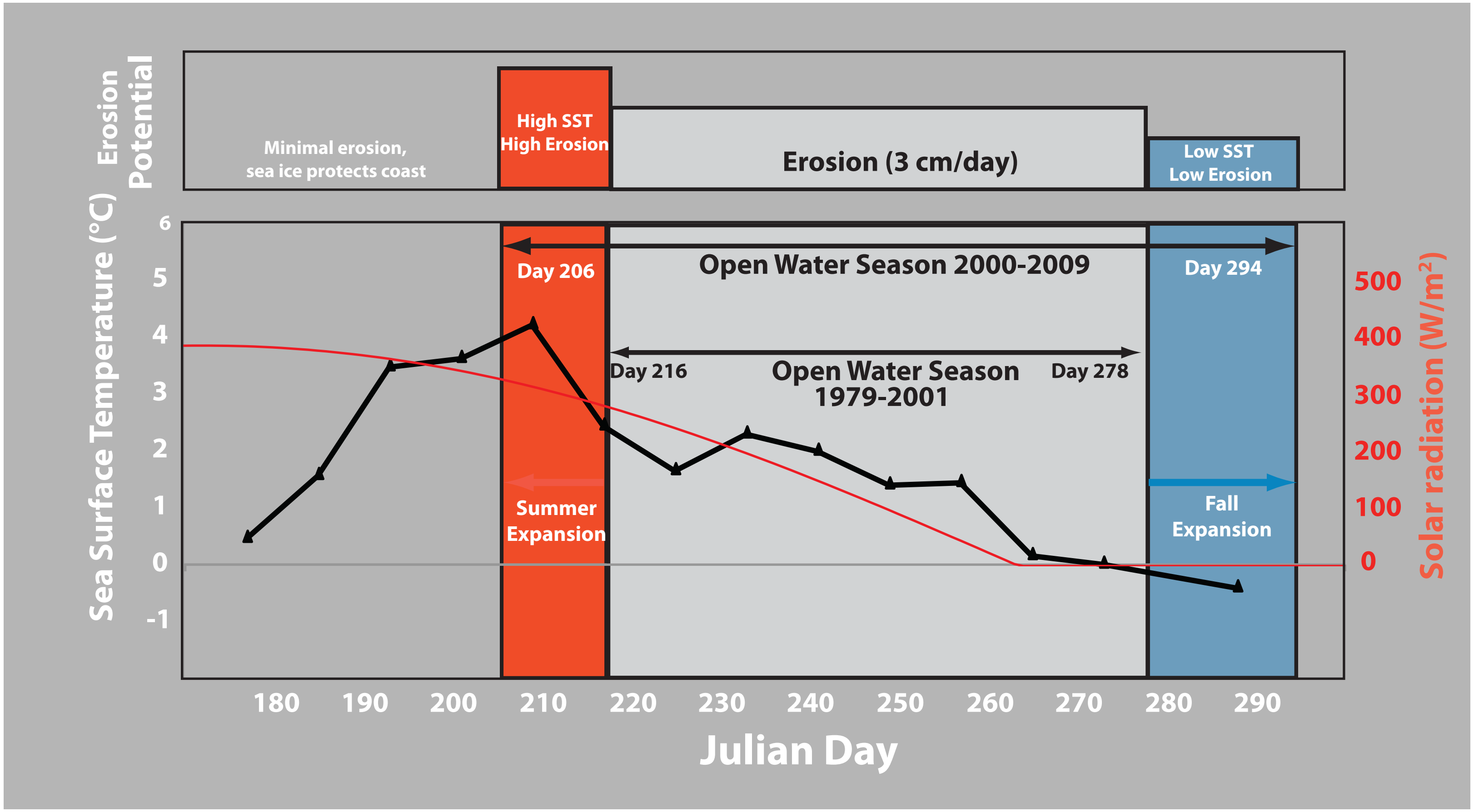
Ice Wedge
Bluff Profile
Toppled Block
Time: 08/13/2010 17:54
Model Domain [m] (no vertical exaggeration)
Water Level (set up + wave height) [m]
Set Up
+/- Wave Height
Date

Thirty Years of Wave Exposure



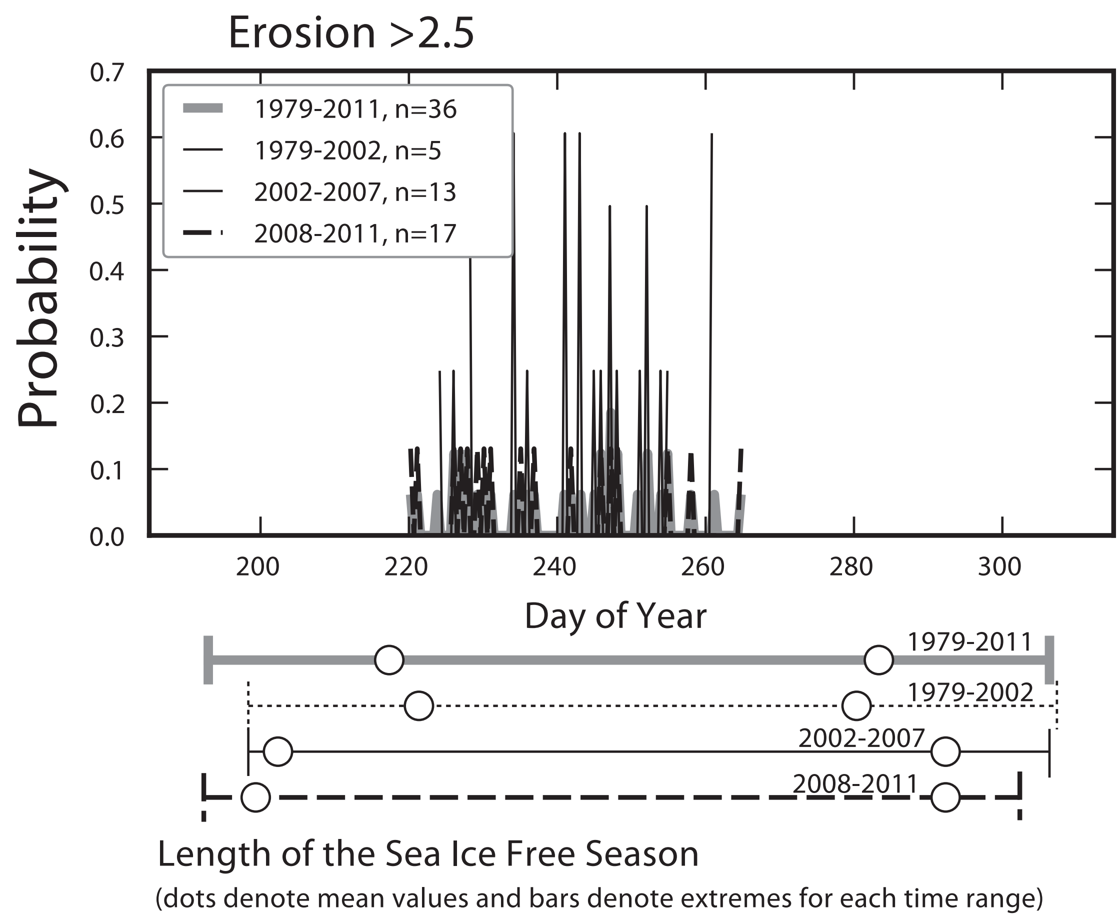
Cumulative wave height increases 2,5 times over last 30 years (Overeem et al., 2011)

Dampening Mechanism?



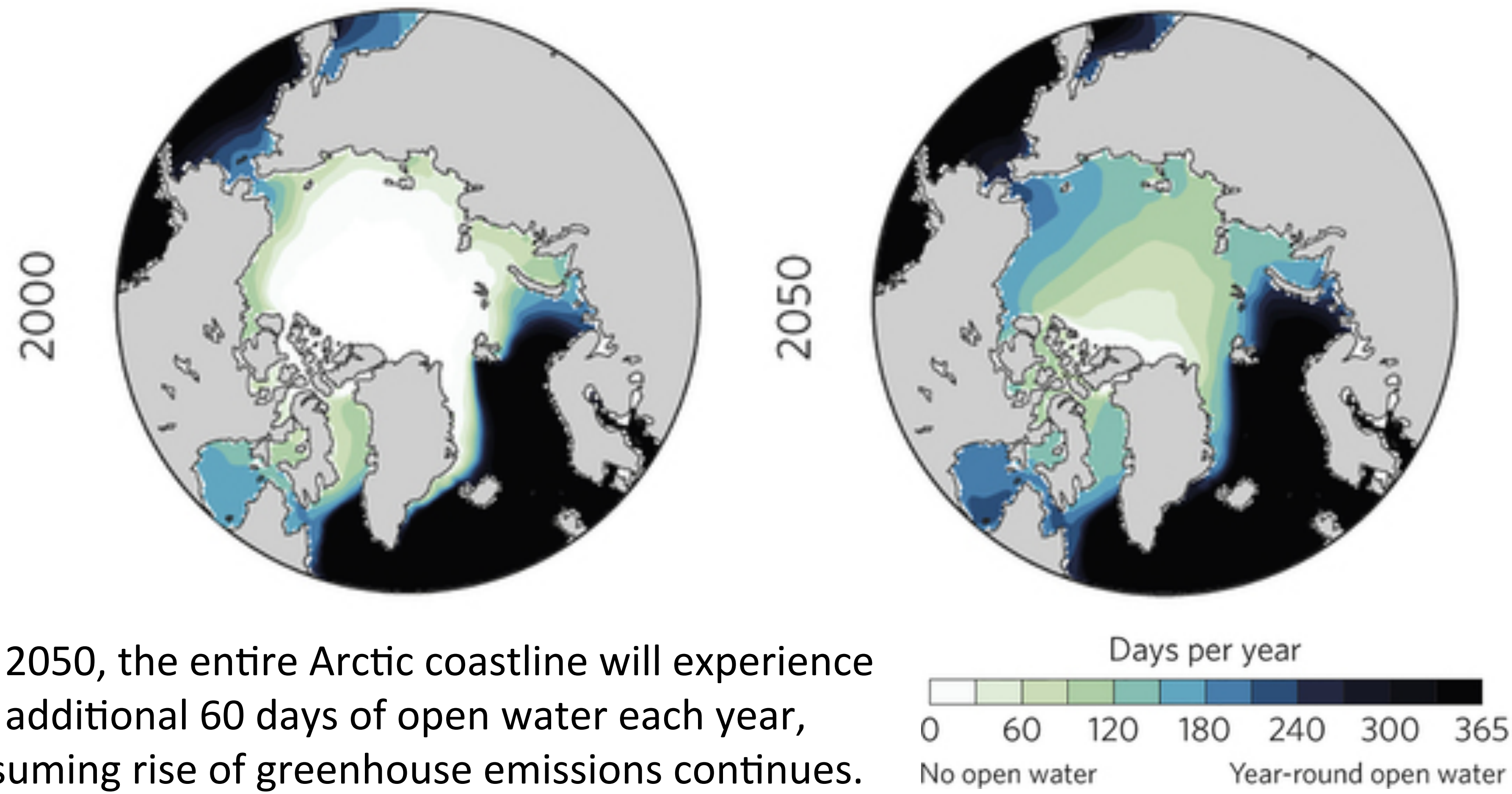
Hypothesis: erosion from fall storms is less efficient due to lower SST. (Overeem et al., 2011).

Modeled Largest Erosion Events



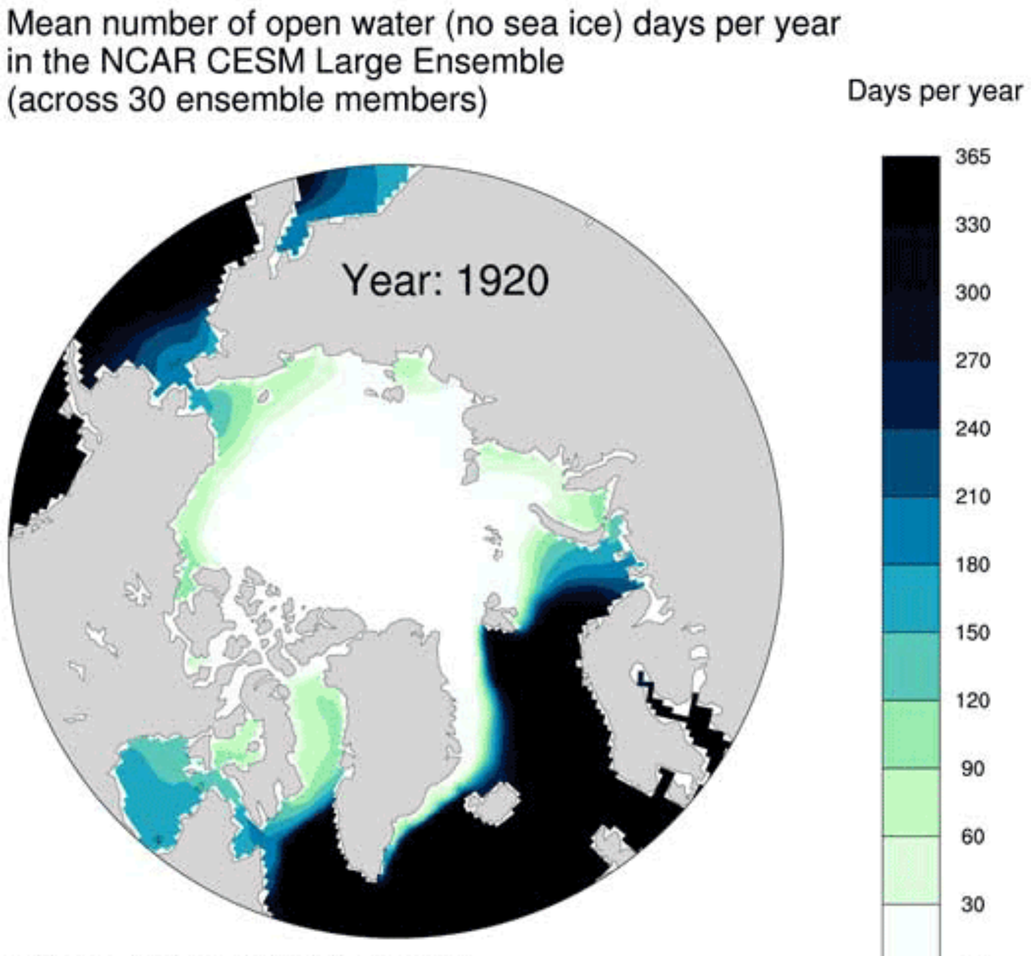
Model: large erosion events over last 30 years have not occurred beyond ~Sept 15. Coastal flooding can still occur.

CESM Future Open Water



By 2050, the entire Arctic coastline will experience an additional 60 days of open water each year, assuming rise of greenhouse emissions continues. (Barnhart et al., Nature Climate Change, 2015)

CESM Open Water 1920-2100



Barnhart, K. R., Miller, C. R., Overeem, I., & Kay, J. E. (2015). Mapping the future of Arctic open water. Nature Climate Change. http://doi.org/doi:10.1038/nclimate2848

Conclusions

- Erosion is widespread, 84% of Chukchi and Beaufort Coast sees erosion. Erosion is controlled by expanding open water season.
- Wave exposure and storm surges increased. Erosion of the icy bluffs is largely a thermal process, sea water temperatures dominate rates.
- Postulated dampening mechanism is corroborated by modeling; erosion is less efficient in Fall season.

New Challenges

- Understanding of sea ice and coastal dynamics near major rivers, i.e. the Yukon and Mackenzie Rivers. Dire need of observations of heat, chemical, physical interactions during river spring flood and summer ice break-up conditions.
- Understanding of coastal system for extreme events, i.e. during Arctic Cyclones. Focus on storm surges and barrier island and spit dynamics.
- Assessing the land-ocean exchange of carbon and nutrient fluxes to nearshore system associated with coastal erosion, river dynamics. Need for nearshore observations during transition times, observations on biochemistry. (ARCTIC_COLORS).