Thermal Erosion of an Arctic Coastline

Field Observations and Model Calibration

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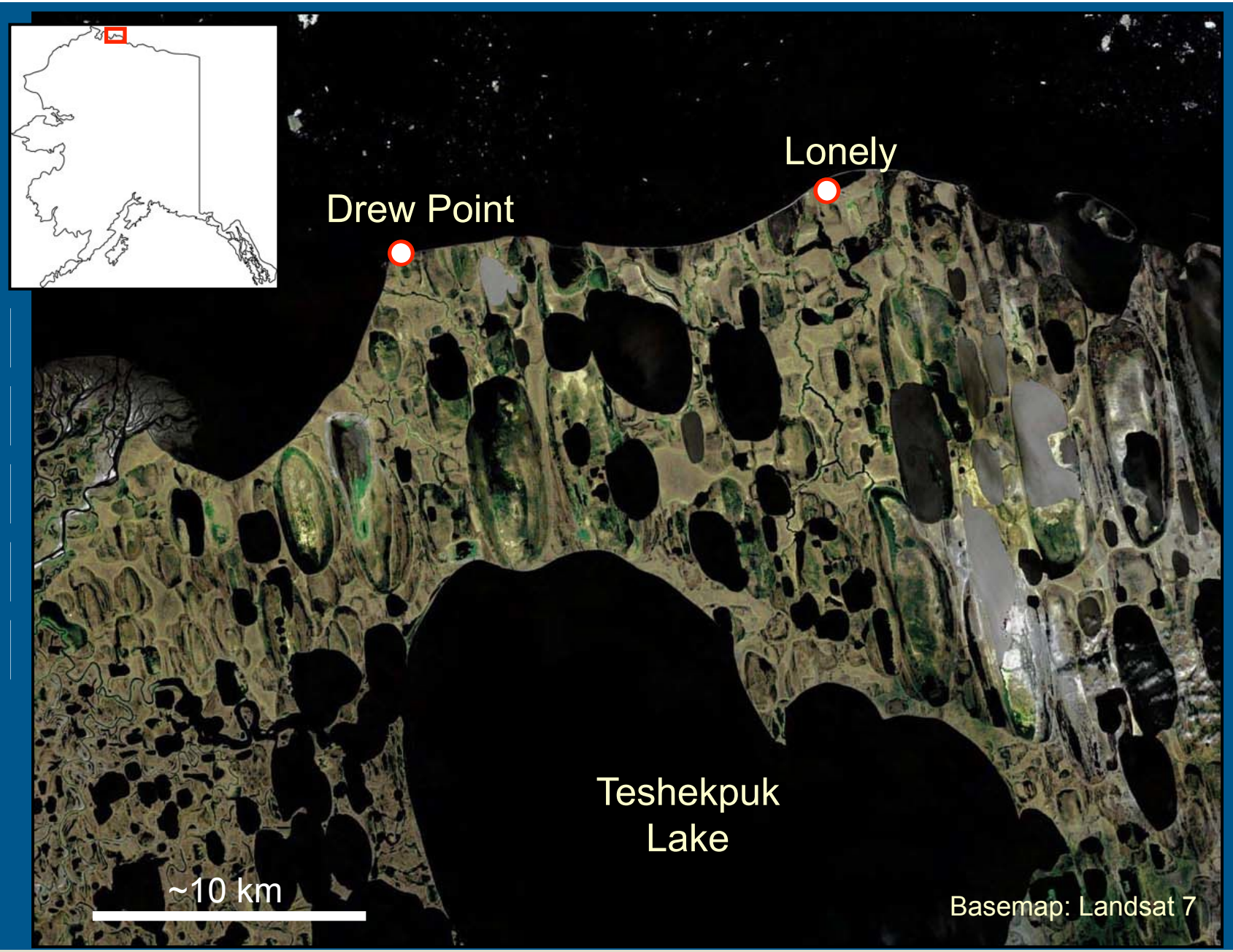
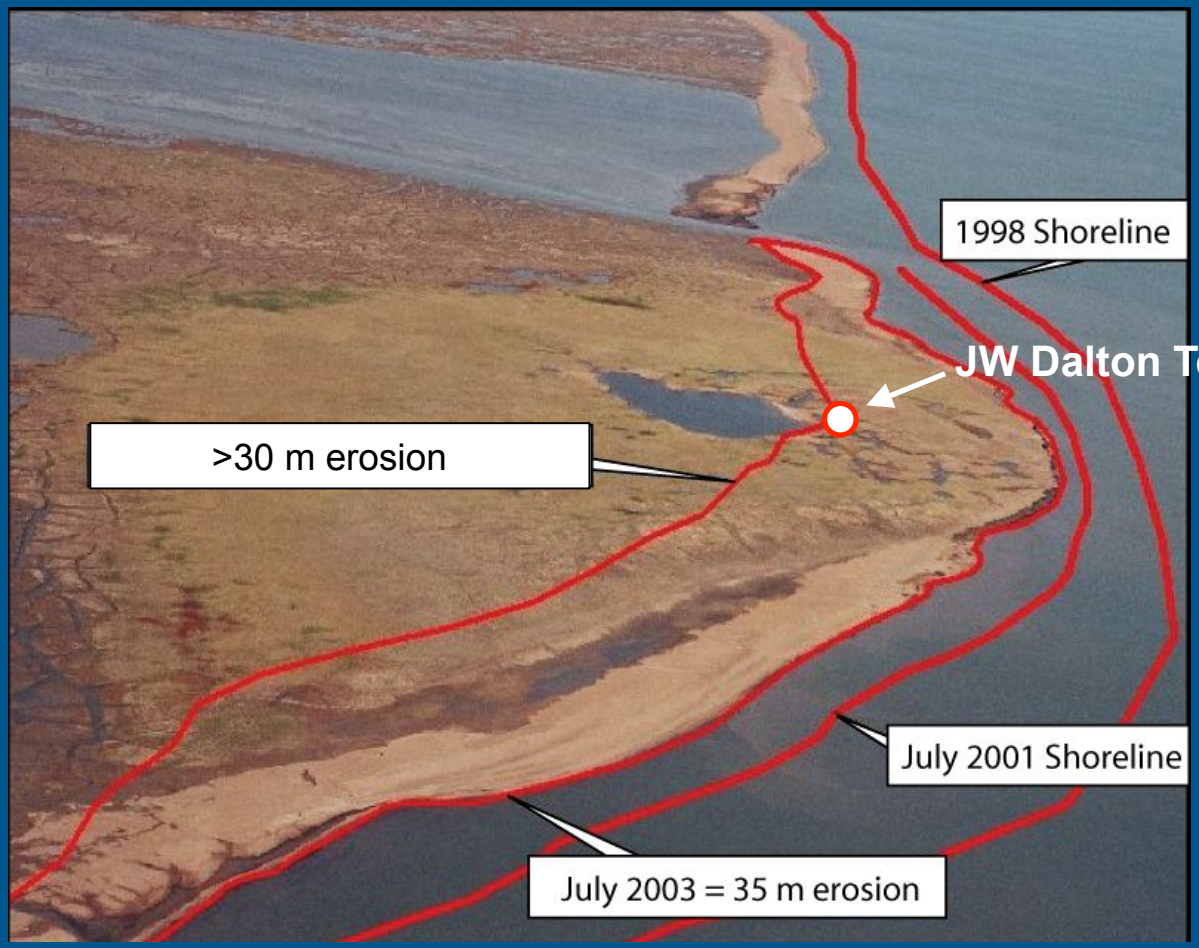
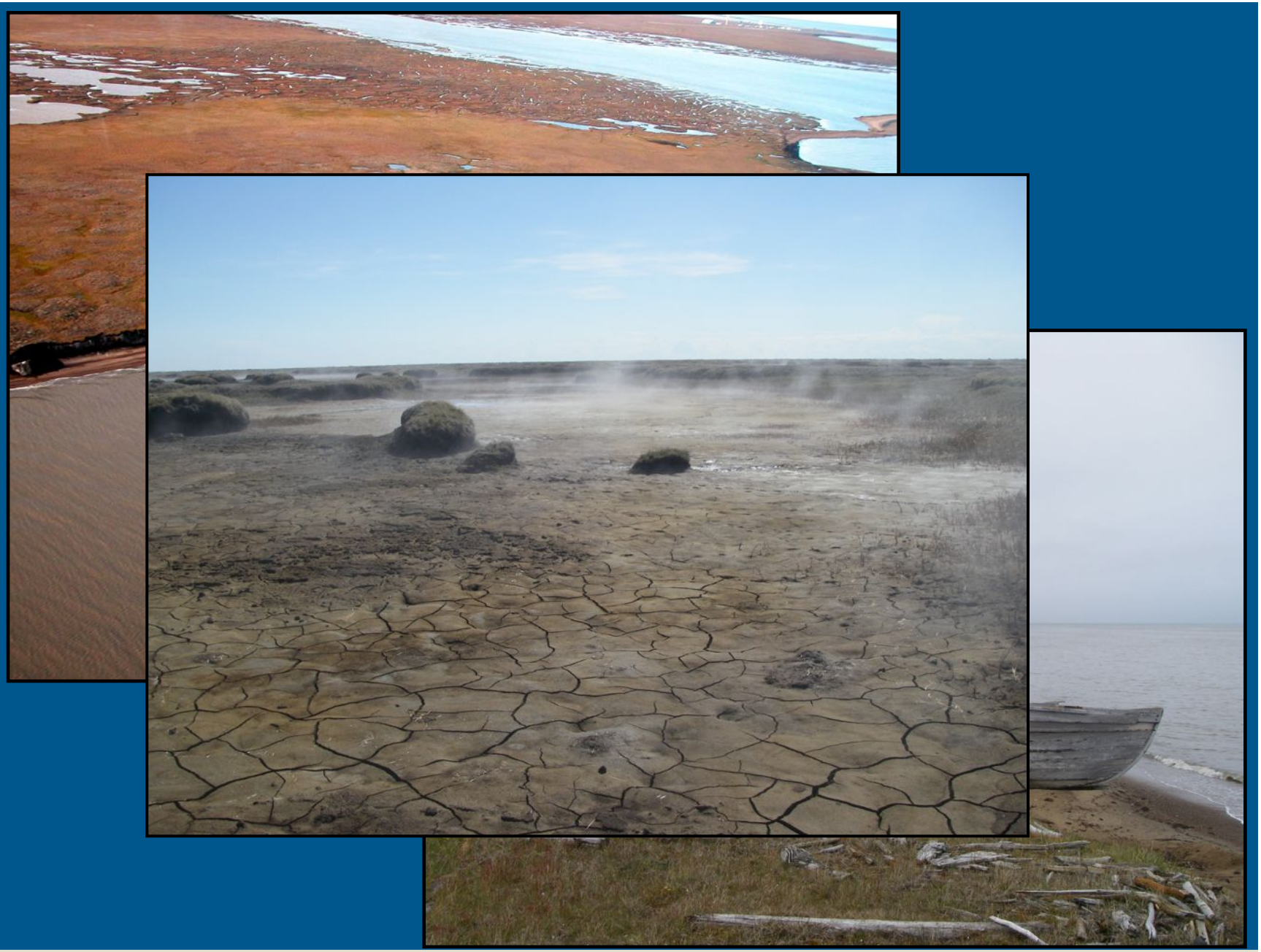
National Oceanographic Partnership Program
Promoting Partnerships for the Future of Oceanography


Lonely
Drew Point
Teshekpuk
Lake
~10 km
Basemap: Landsat 7

Motivation: >30m erosion in one calm (but warm) summer





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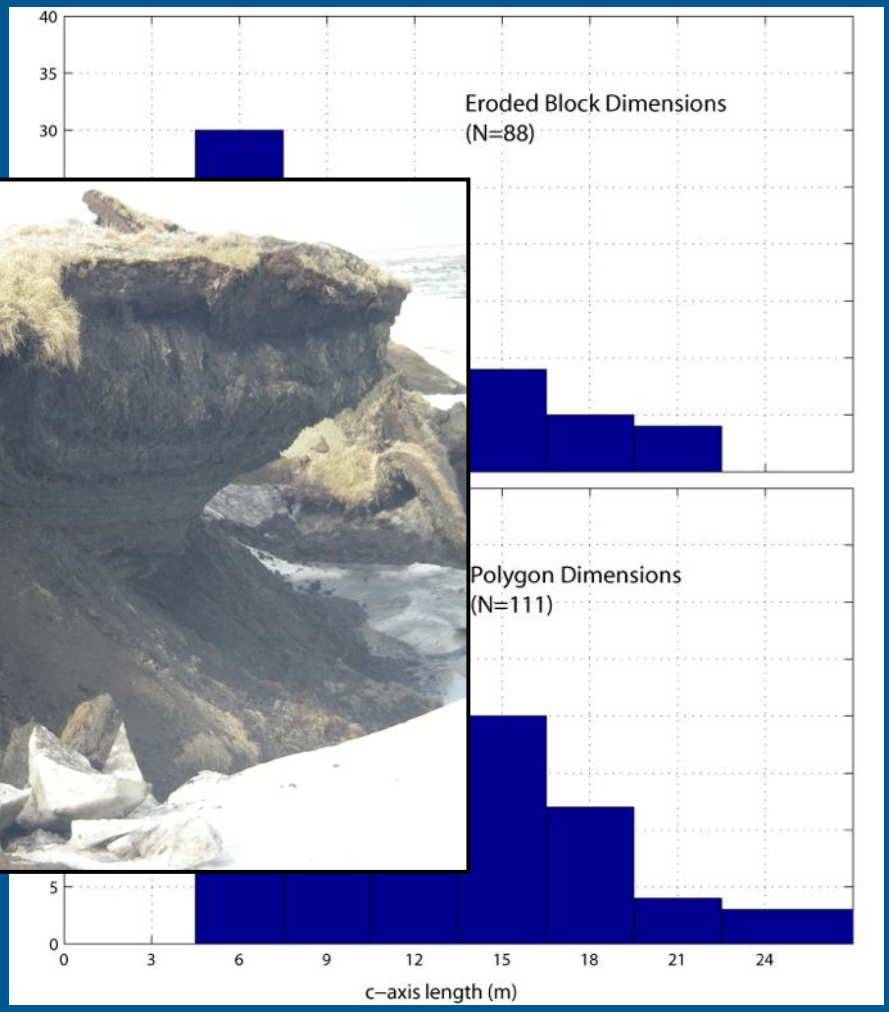
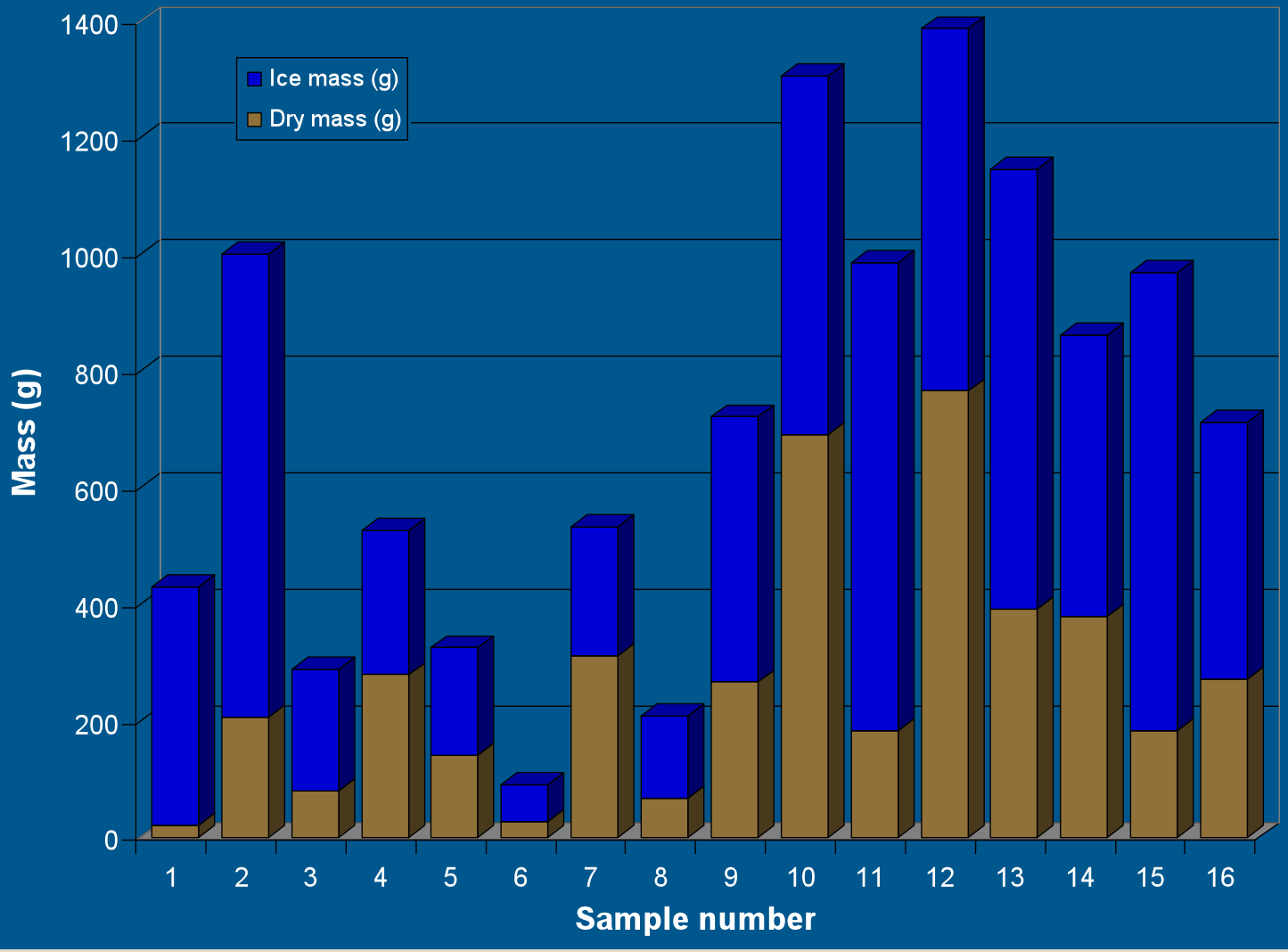
Outline

- Empirical observations
  - Bluff failure mechanisms
  - Bluff material properties
  - Measured erosion rates
  - Time-lapse photography
- Modeling thermal erosion potential
  - Short-term observations
  - Scaling up to seasonal erosion
- The role of sea ice

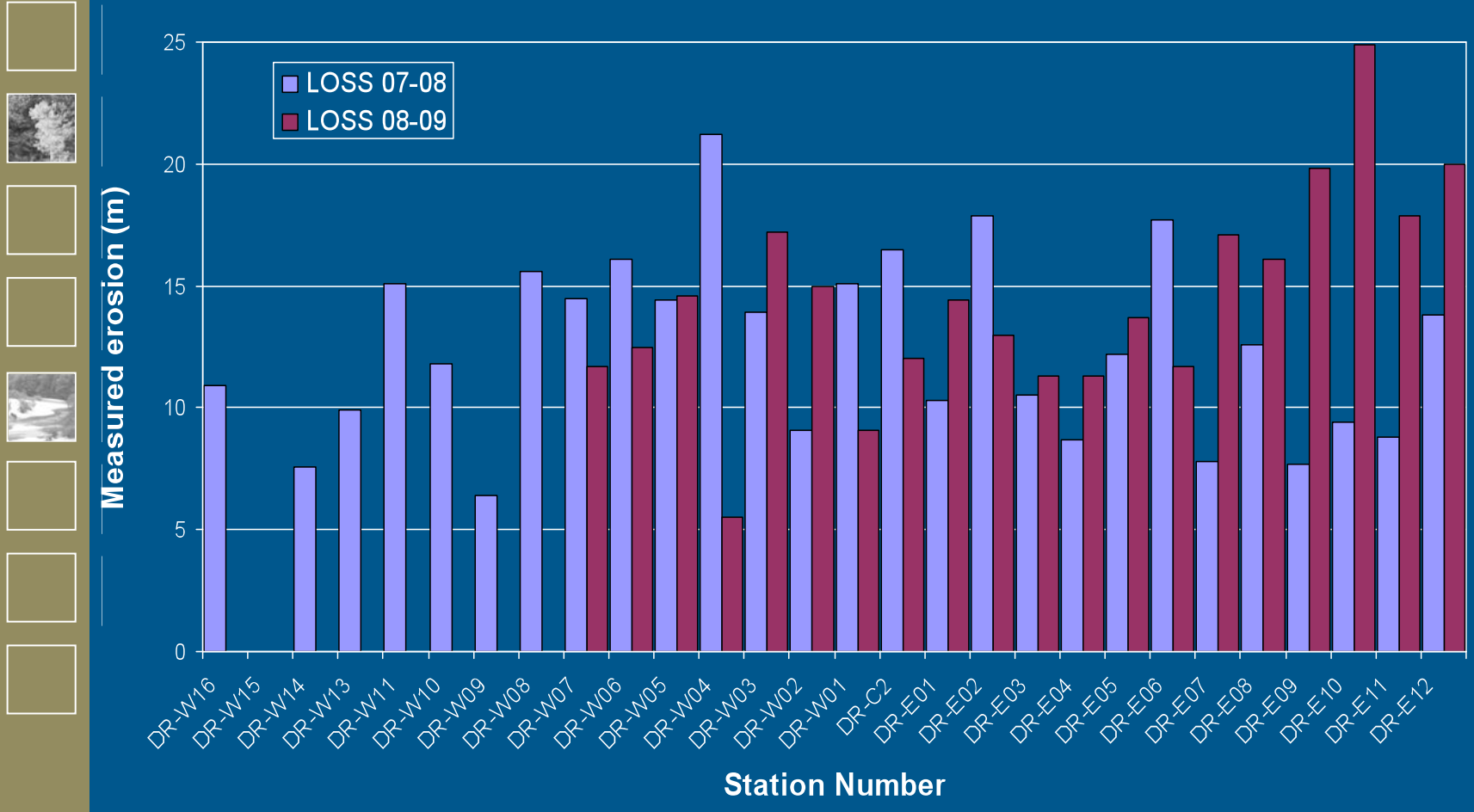
Bluff Properties (1): Eroded blocks are controlled by ice wedges



Bluff Properties (2): Mechanically strong; samples average 65% ice by mass



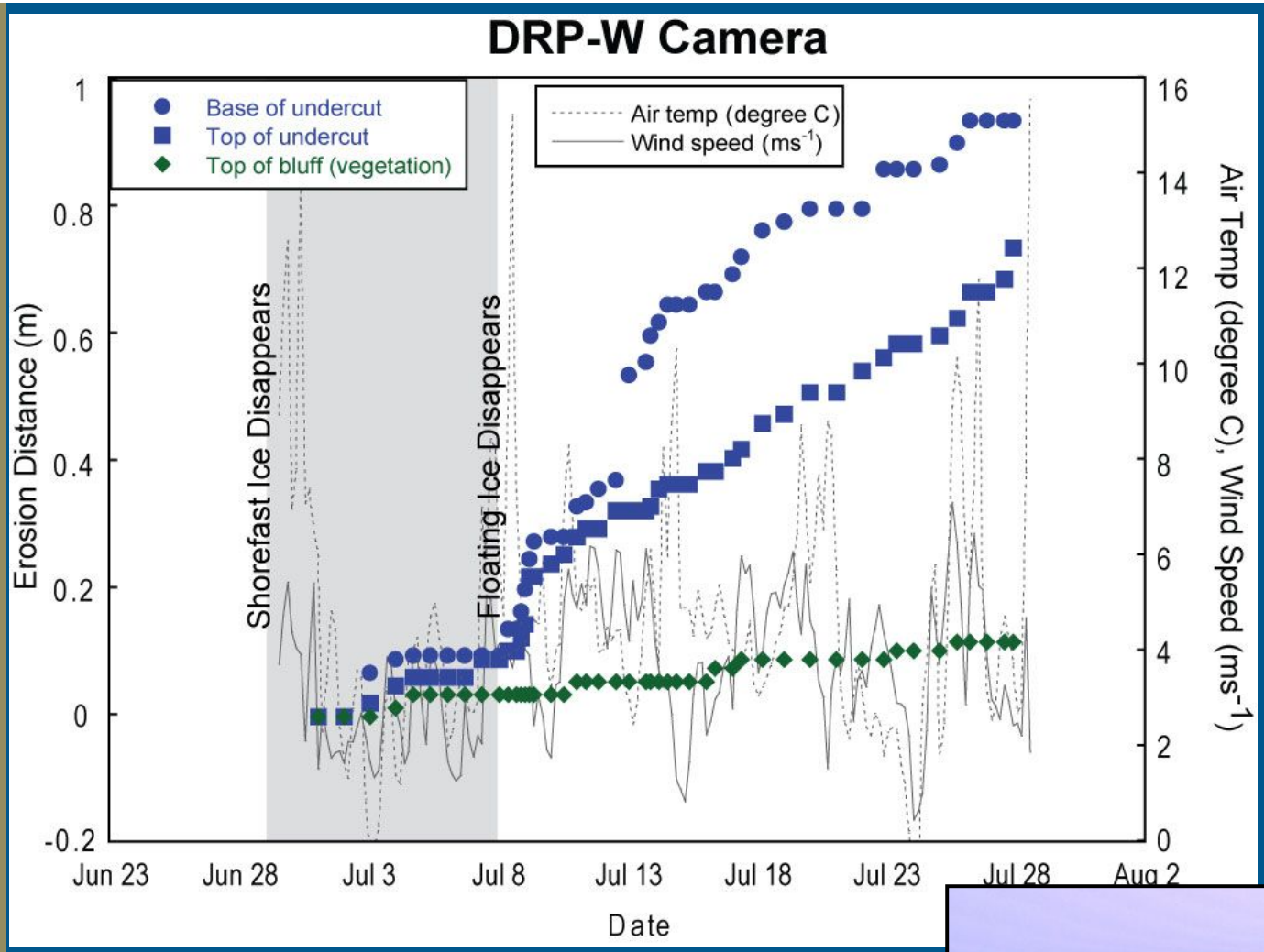
Erosion rates from repeat surveys

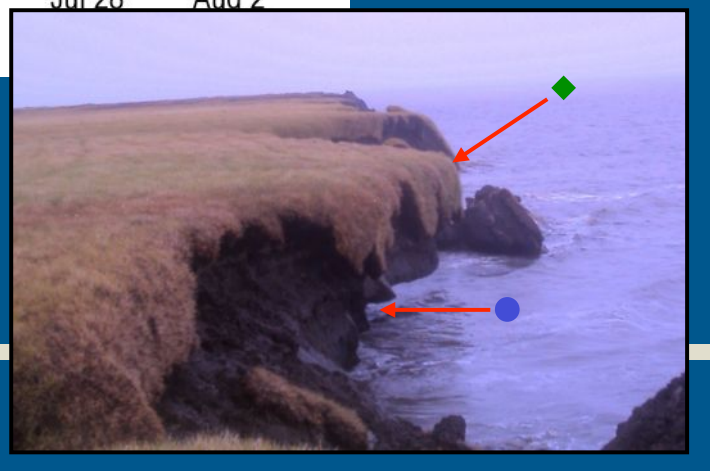


10-15 cm/day over open water season

Time-lapse Photography – 1 (Jun 27 – Jul 28, 2008)

Time-lapse Photography – 2 (Jul 21 – Jul 28, 2008)


DRP-W Camera
Base of undercut
Top of undercut
Top of bluff (vegetation)
Air temp (degree C)
Wind speed (ms-1)
Shorefast Ice Disappears
Floating Ice Disappears
Erosion Distance (m)
Air Temp (degree C), Wind Speed (ms-1)
1
0.8
0.6
0.4
0.2
0
-0.2
16
14
12
10
8
6
4
2
0
Jun 23
Jun 28
Jul 3
Jul 8
Jul 13
Jul 18
Jul 23
Jul 28
Aug 2
Date



Russell-Head (1980): Iceberg Melting

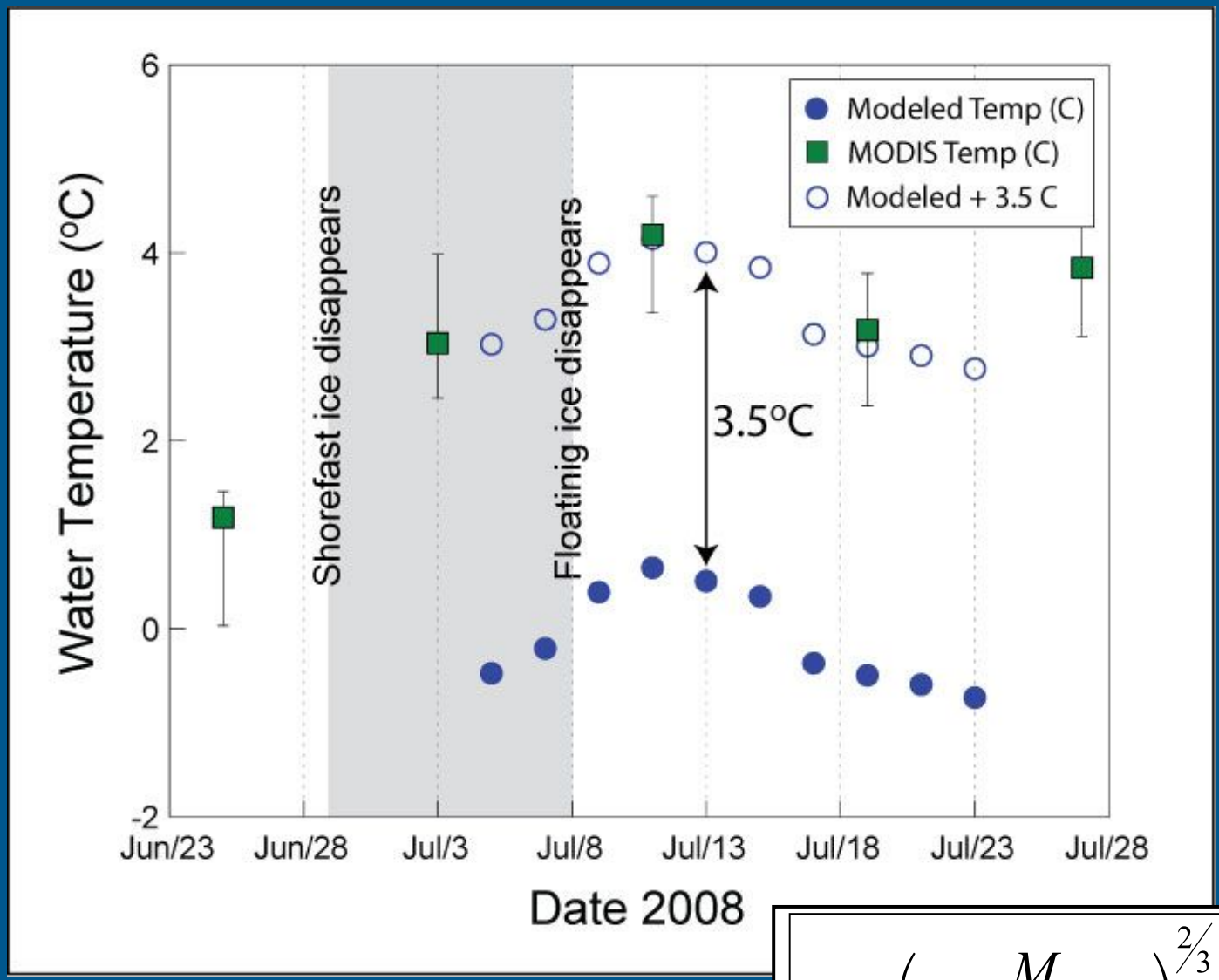
- Empirically derived formula for melting ice in a seawater bath
- Starting point for modeling the thawing of ice-rich bluffs at Drew Point

$$M = 2.08x10^{-7}\left(T_s + 1.8\right)^{1.5}$$

M is melt rate in m/s; T_s is water temperature in °C

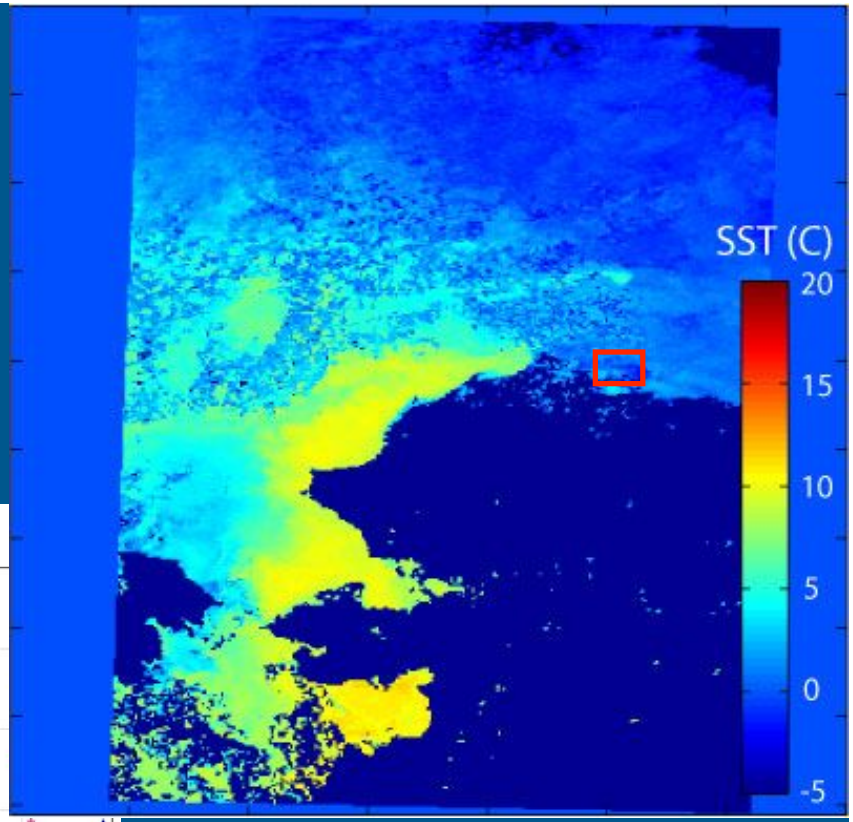
Russell-Head, D. D. (1980), The melting of free-drifting icebergs, *Annals of Glaciology*, *1*, 119-122

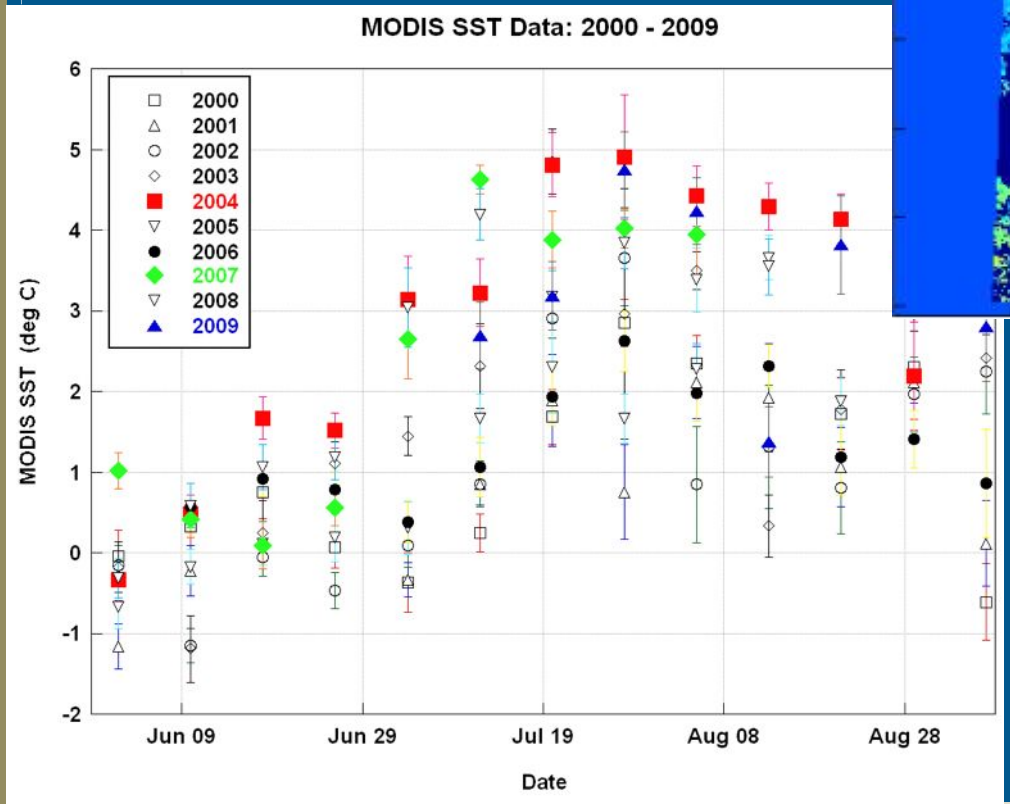
Inversion of erosion rate for temperature



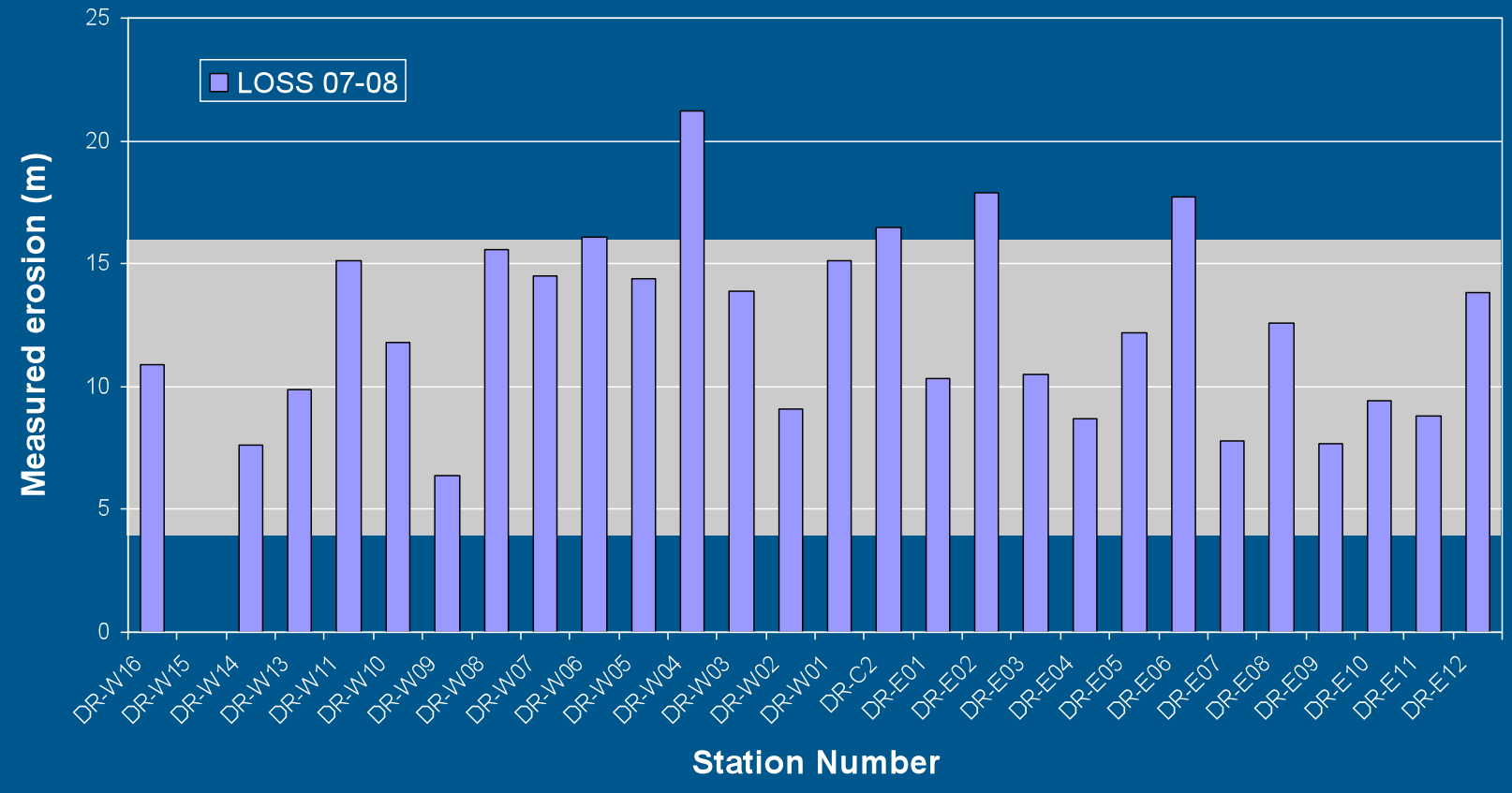
$$T_s = \left(\frac{M}{2.08x10^{-7}} \right)^{2/3} - 1.8$$

Leverage MODIS SST dataset to estimate thermal erosion through time





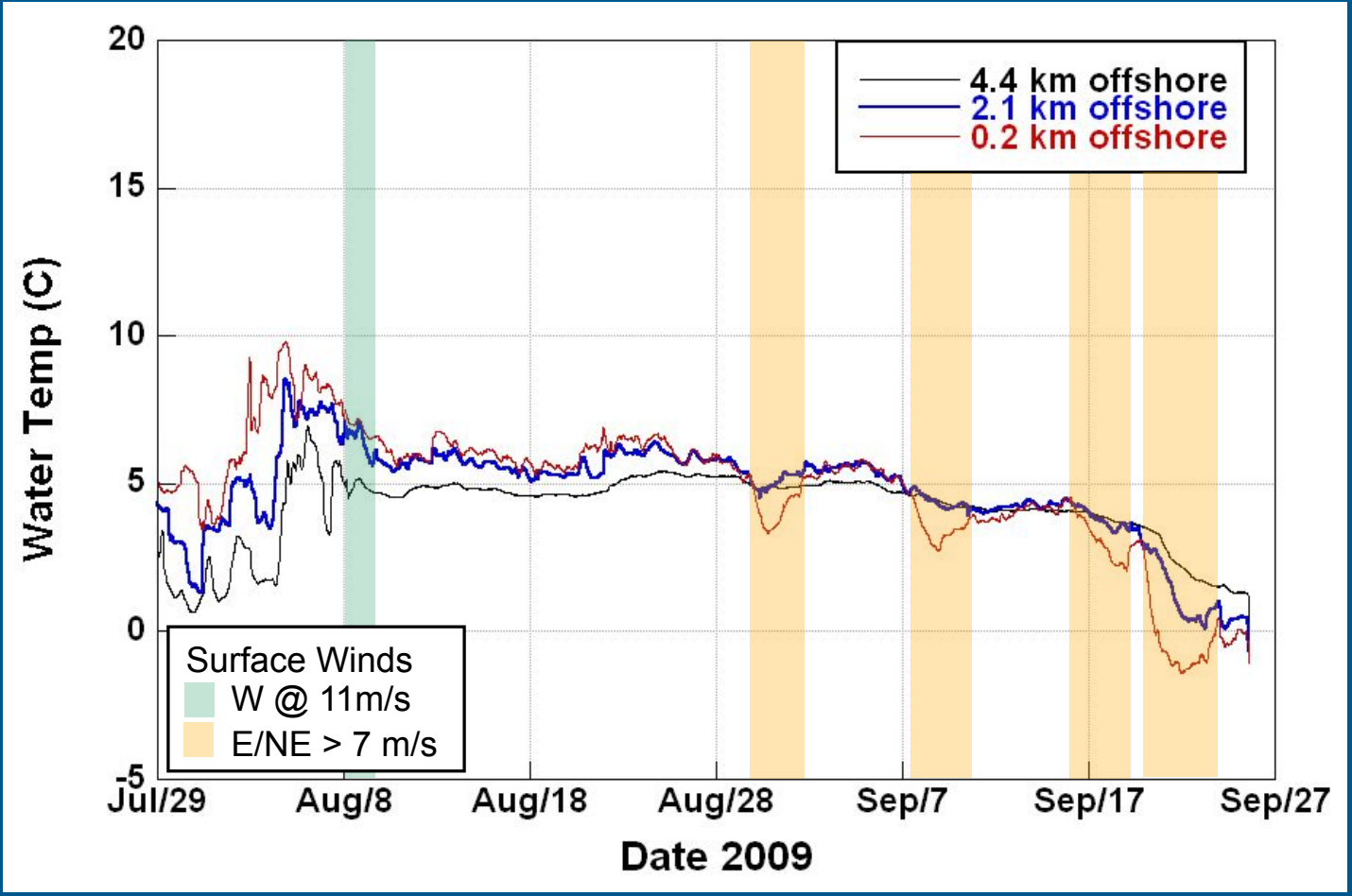
MODIS data predict the right magnitude of thermal erosion



= Predicted seasonal erosion from MODIS SST

The role of storms

1. Ocean mixing and heat transport



The role of storms

2. Surface setup - Bathes more of the bluff face in warm water

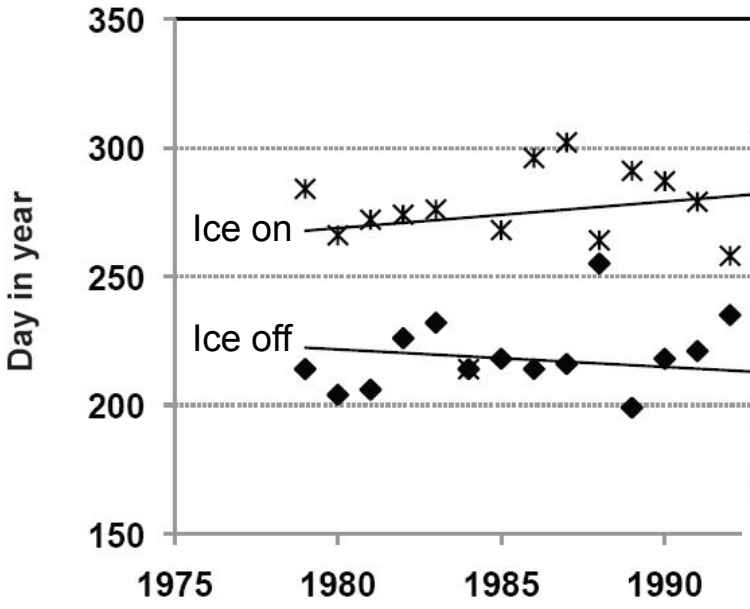
7/17/08, 0600: Wind 4.3 m/s from NE

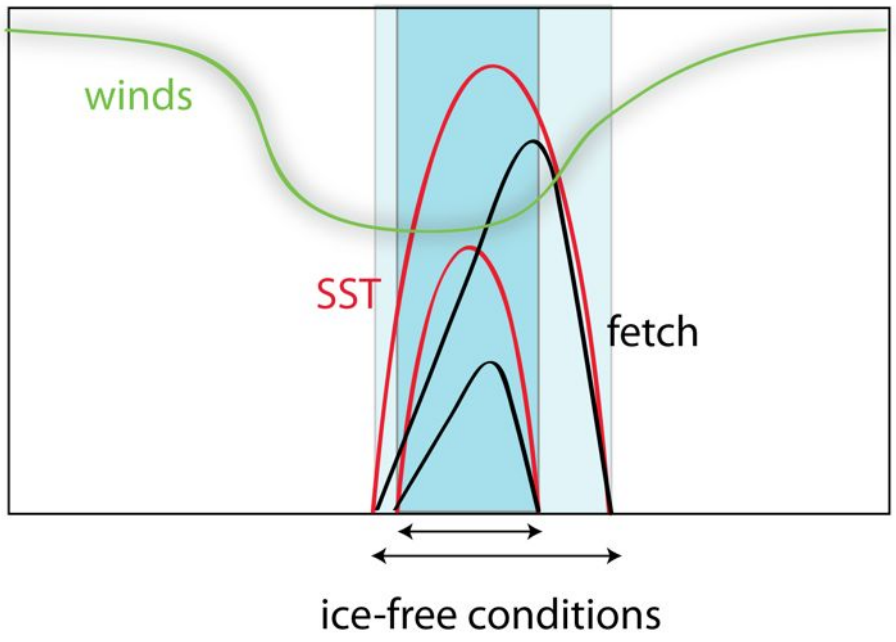
7/18/08, 0600: Wind 4.3 m/s from E

Average open water season is getting longer

1979-2001: 63 open water days

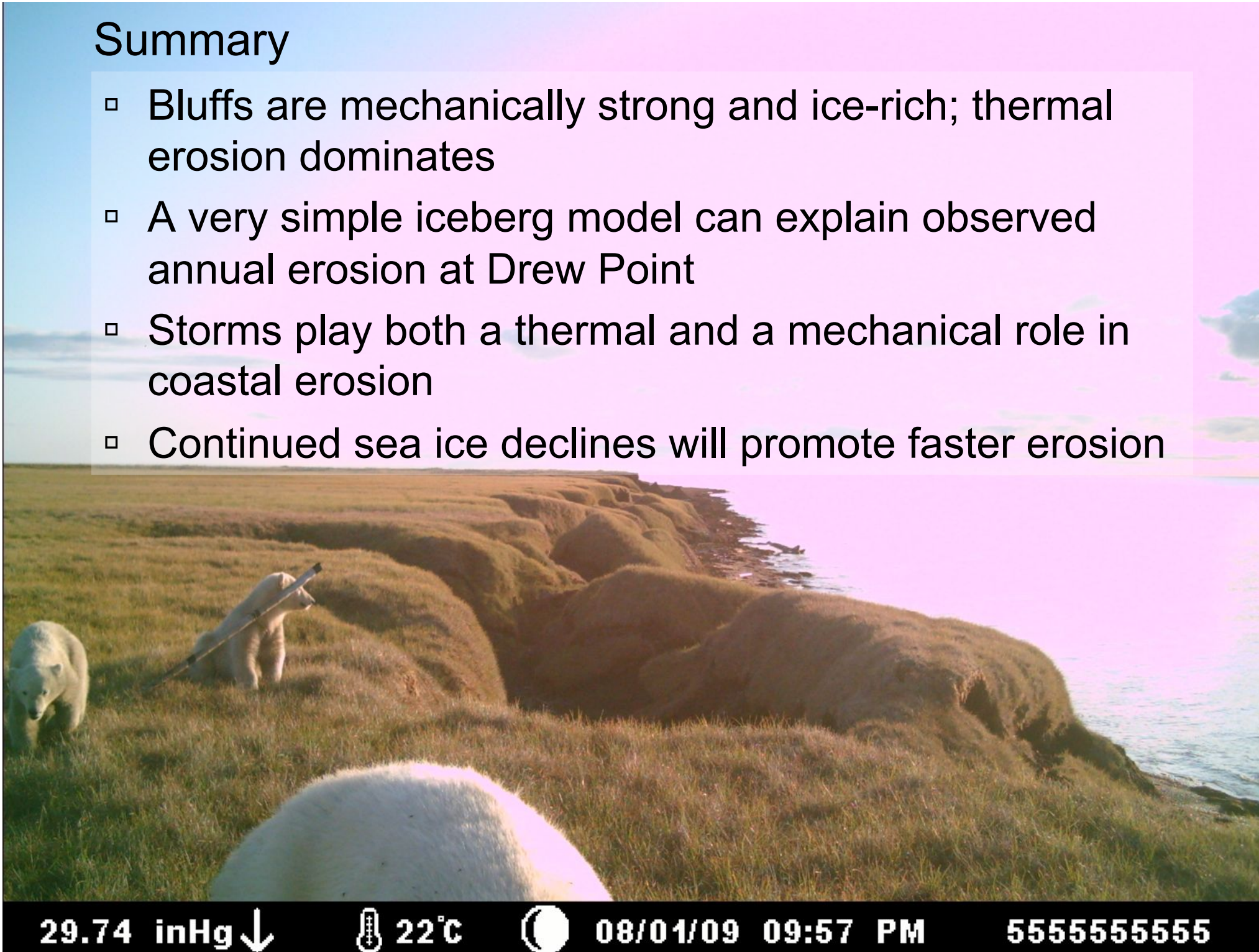
2002-2008: 96 open water days





Summary

- Bluffs are mechanically strong and ice-rich; thermal erosion dominates
- A very simple iceberg model can explain observed annual erosion at Drew Point
- Storms play both a thermal and a mechanical role in coastal erosion
- Continued sea ice declines will promote faster erosion



Acknowledgements

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Ben Jones, US Geological Survey

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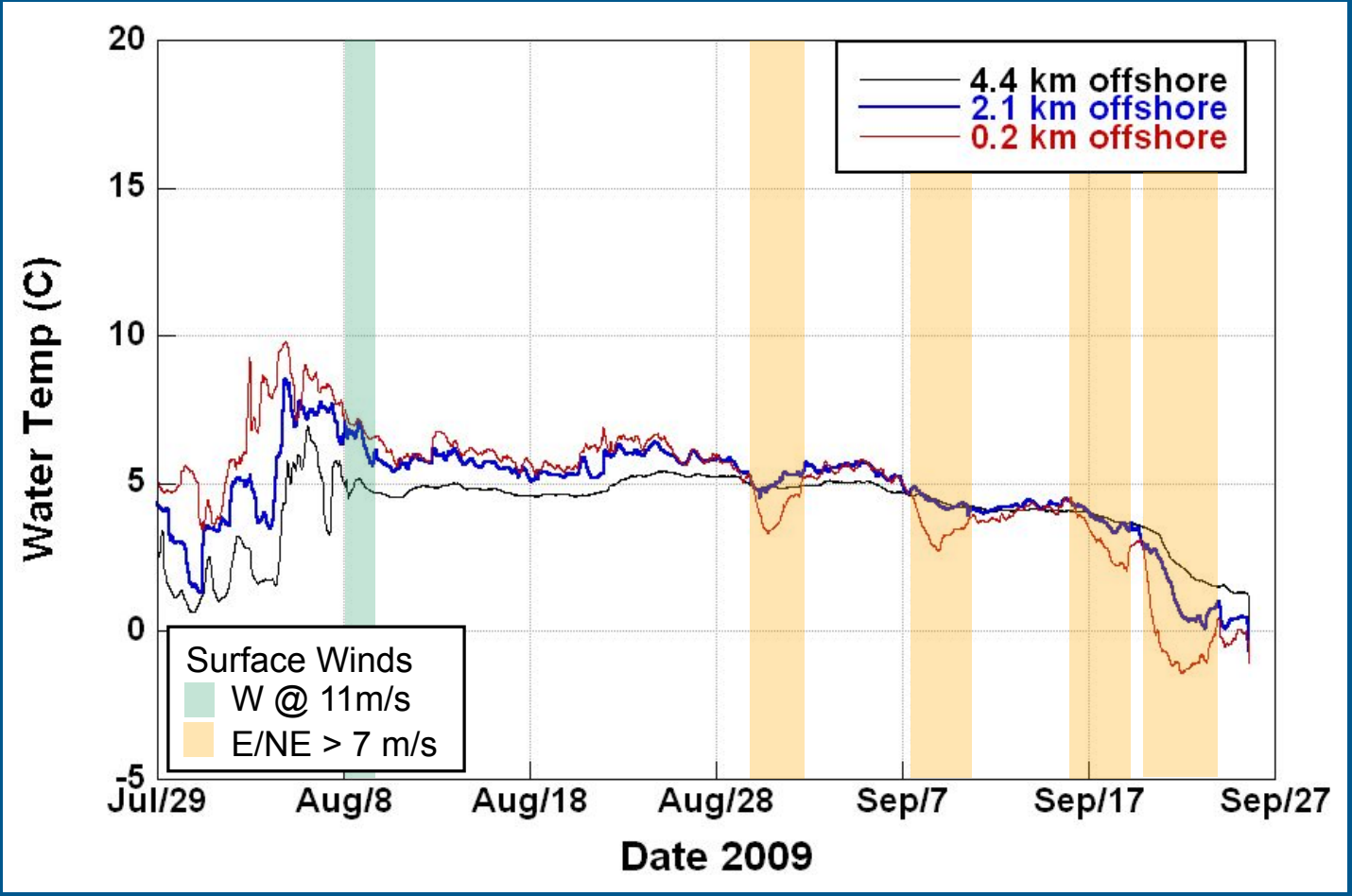

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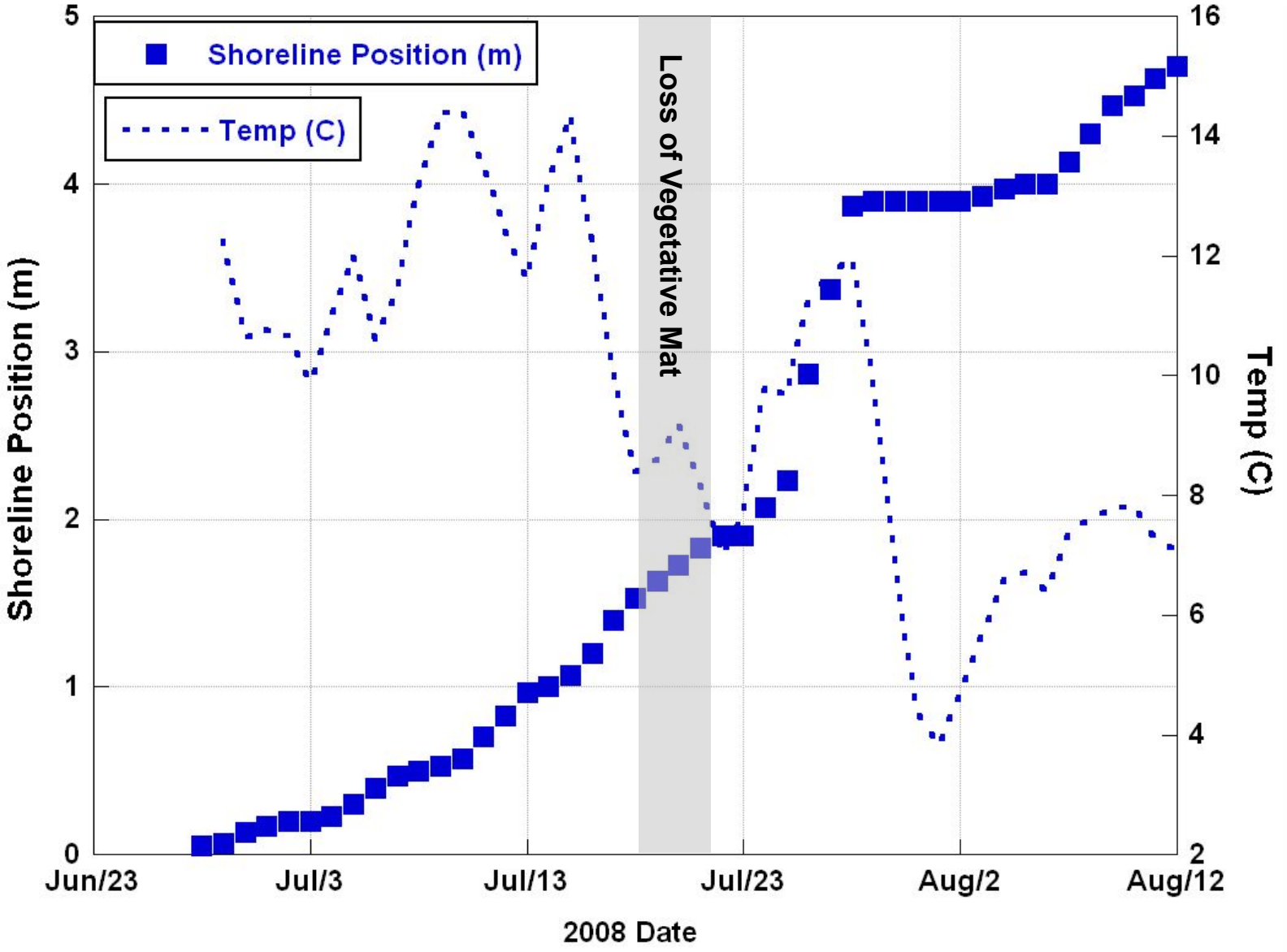
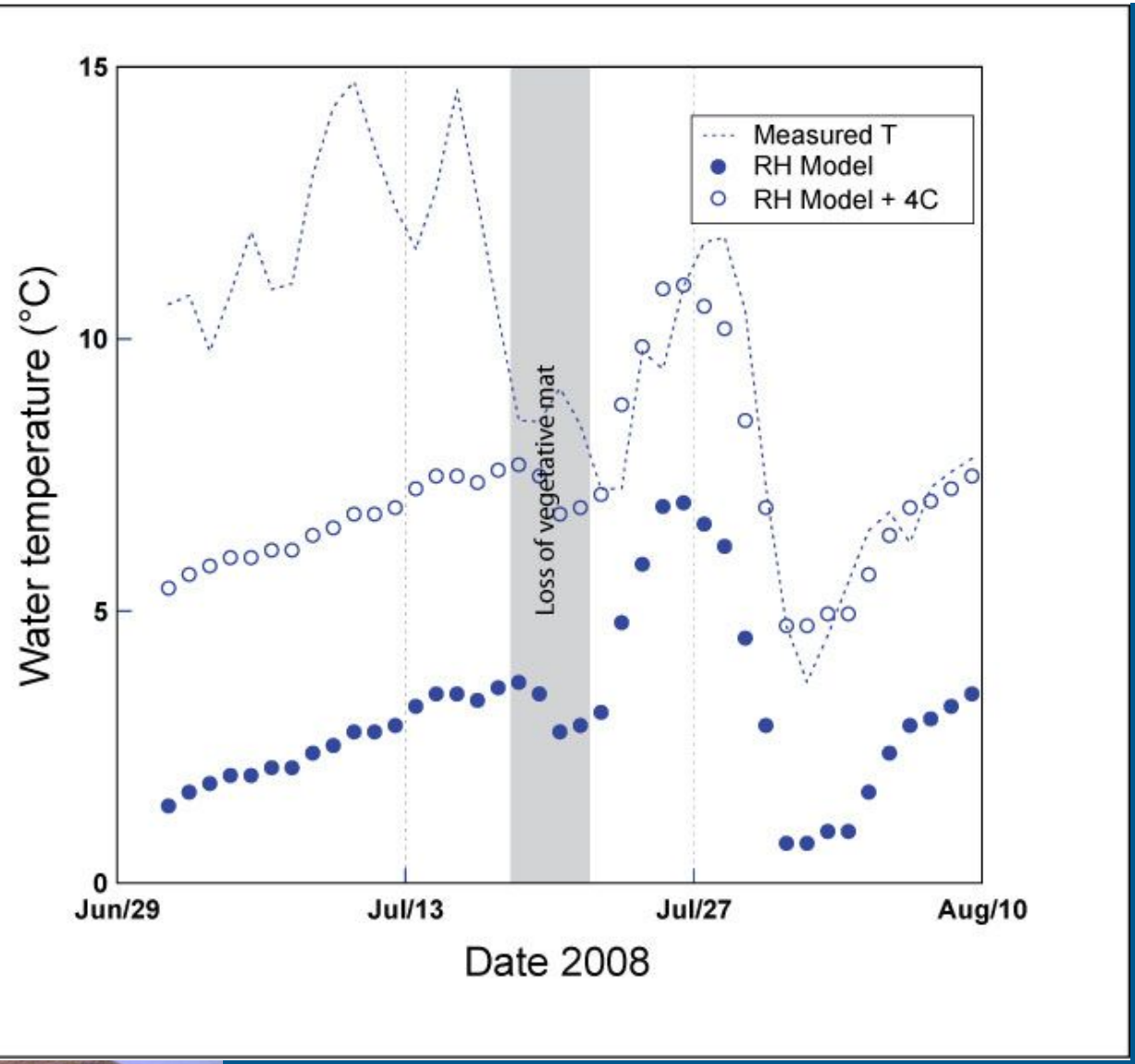
Lake 31 Time Lapse

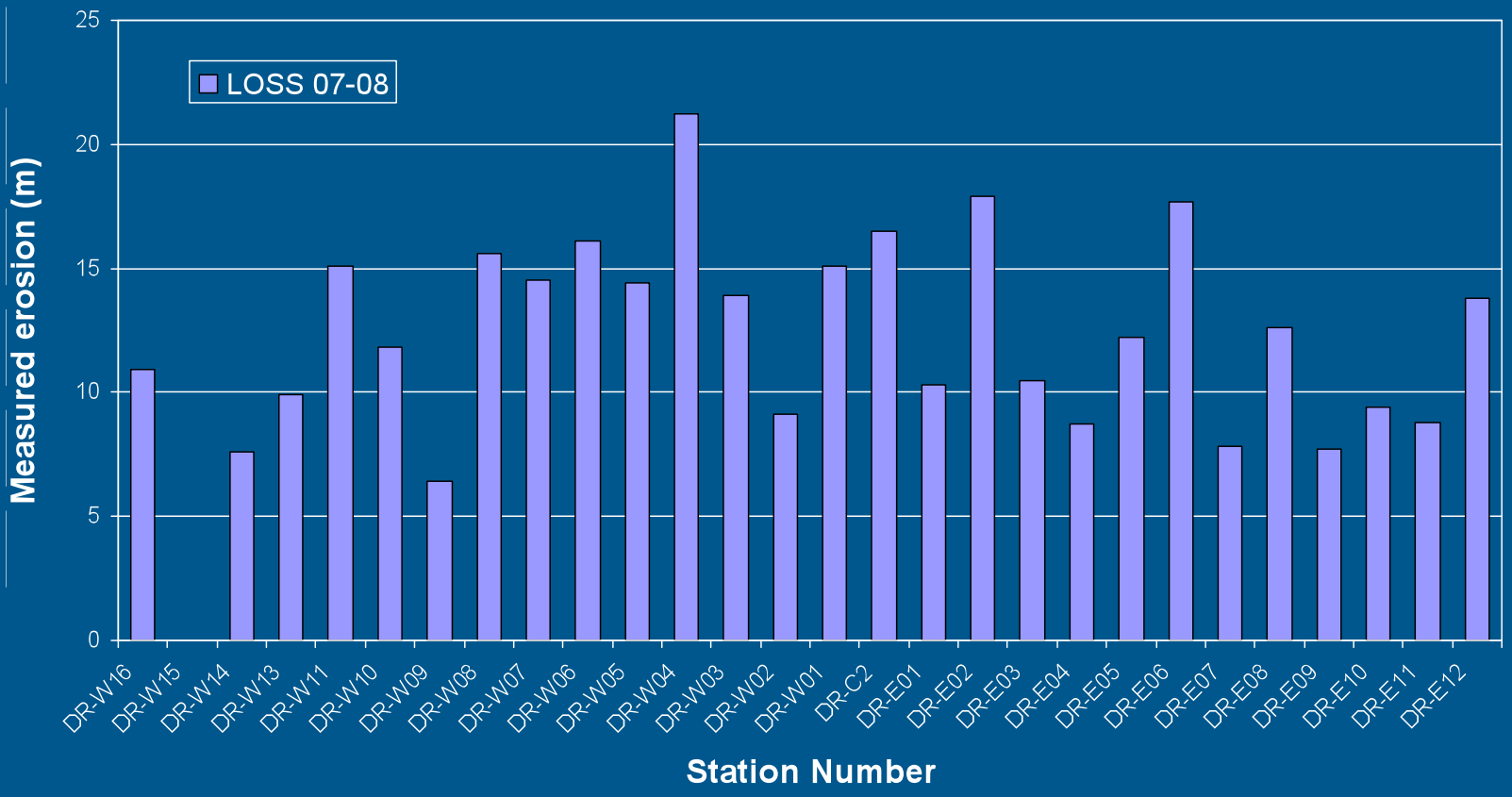
Lake 31 Timelapse



7/14/08 4:00 PM
Cuddleback


Water temperature (°C)
15
10
5
0
Jun/29
Jul/13
Jul/27
Aug/10
Date 2008
Measured T
RH Model
RH Model + 4C
Loss of vegetative mat

Erosion Rates (1) Seasonal erosion rates



Average Loss August 2007 – June 2008: 12.4 m
(0.15 m/day over 81 days of open water)

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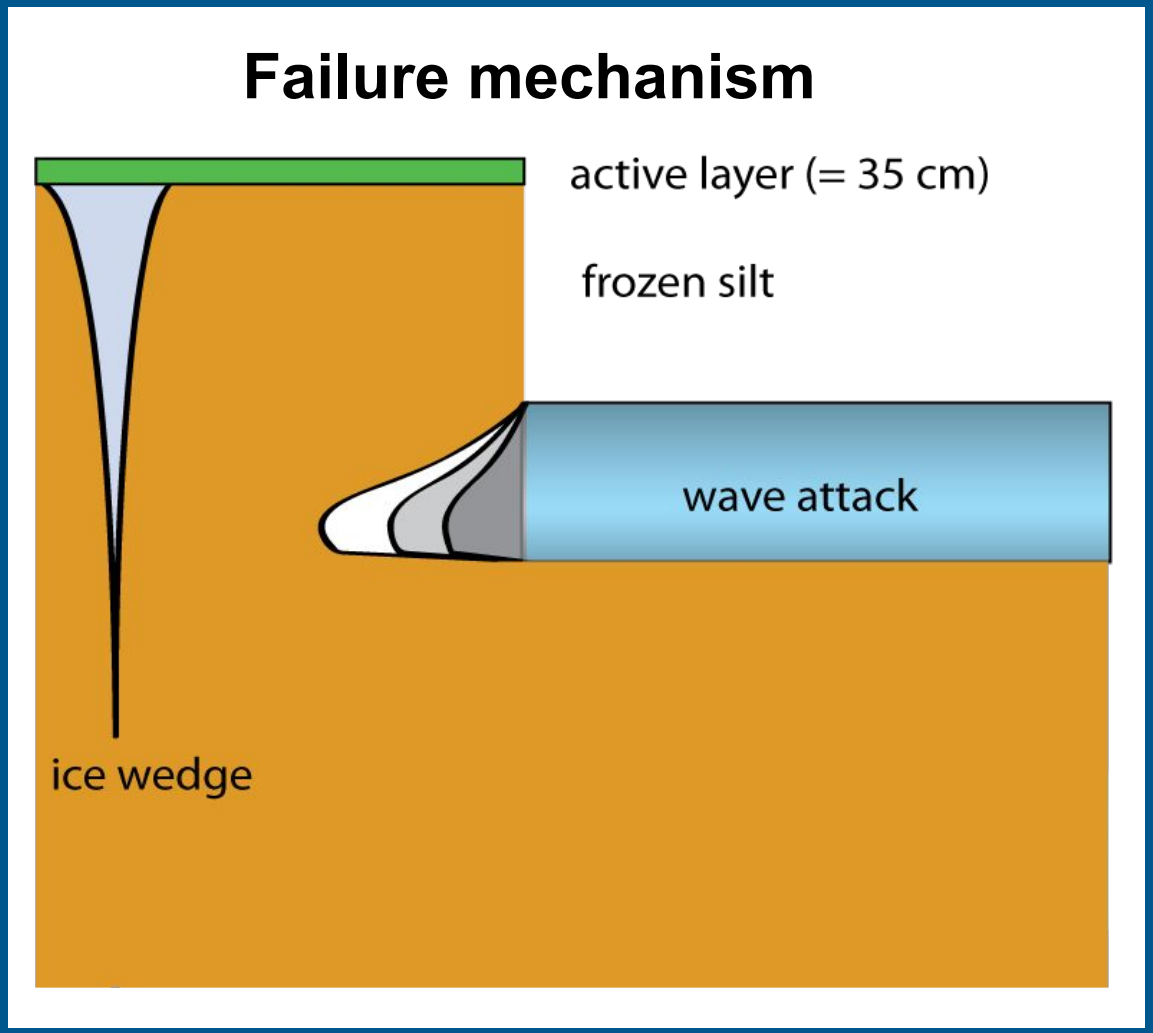
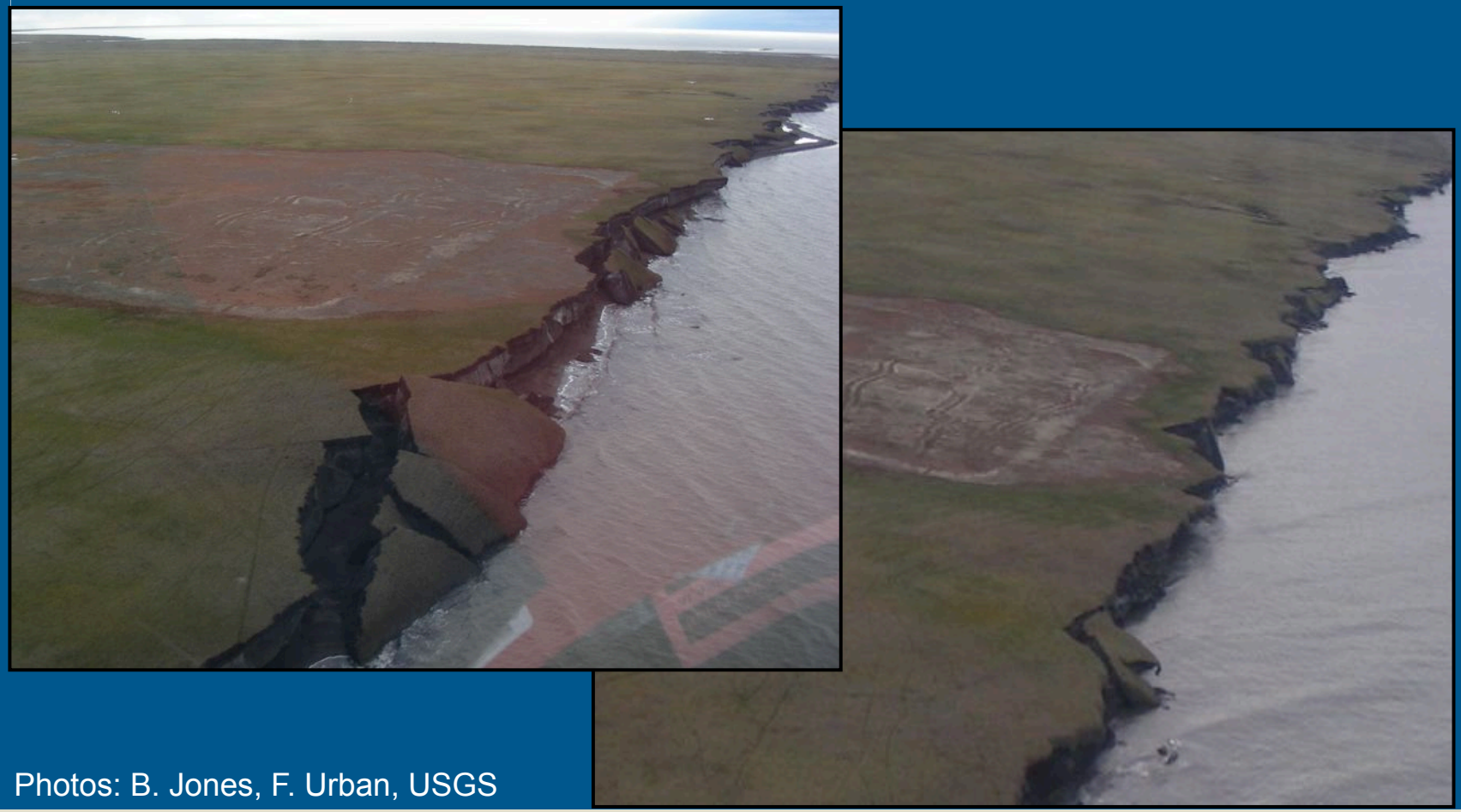
Conceptual Model: Eroded blocks are controlled by ice wedges



The dual role of storms

2. Shaking thermally prepared blocks free



Photos: B. Jones, F. Urban, USGS