



The Hydrology and Ice-cover of Teshekpuk Lake in a Changing Arctic Climate

Christopher D. Arp
Water and Environmental Research Center,
University of Alaska Fairbanks

Benjamin M. Jones
Alaska Science Center, U.S. Geological Survey
Geophysical Institute, University of Alaska, Fairbanks

W A T E R R E S O U R C E S

IMPACT

January 2010 | Volume 12 | Number 1

THE VALUE OF
GIS FOR WATER
RESOURCES

AWRA

Community, Conversation, Connections

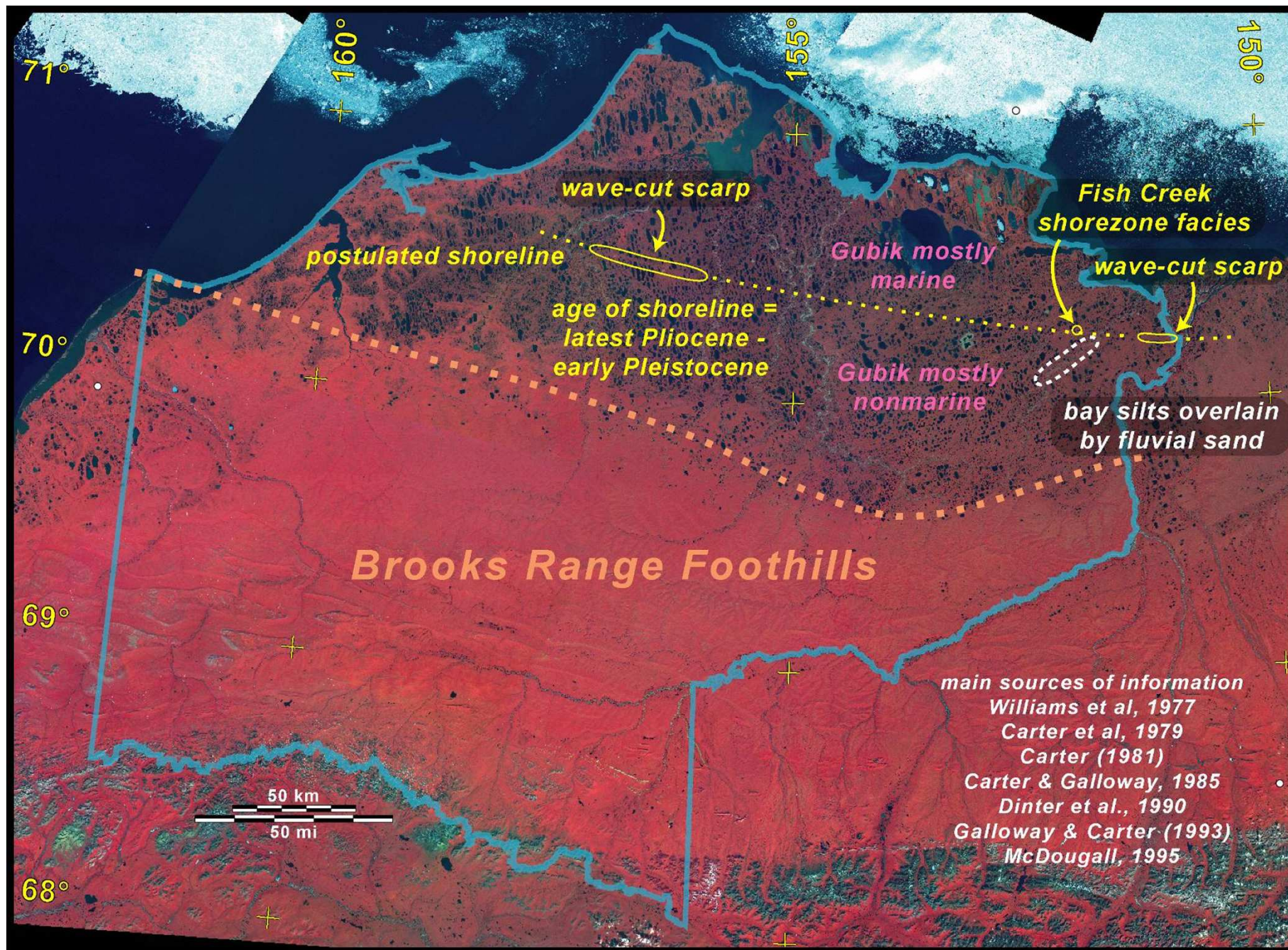
AMERICAN WATER RESOURCES ASSOCIATION

Talk Outline

1. Natural history of Teshekpuk Lake
2. Thermokarst lake hydrology & ice dynamics
3. Methods for reconstructing ice records
4. Teshekpuk Lake ice cover history
5. Climate conditions leading short and long open-water seasons
6. Impacts on hydrology and ecology

Natural History of Teshekpuk Lake

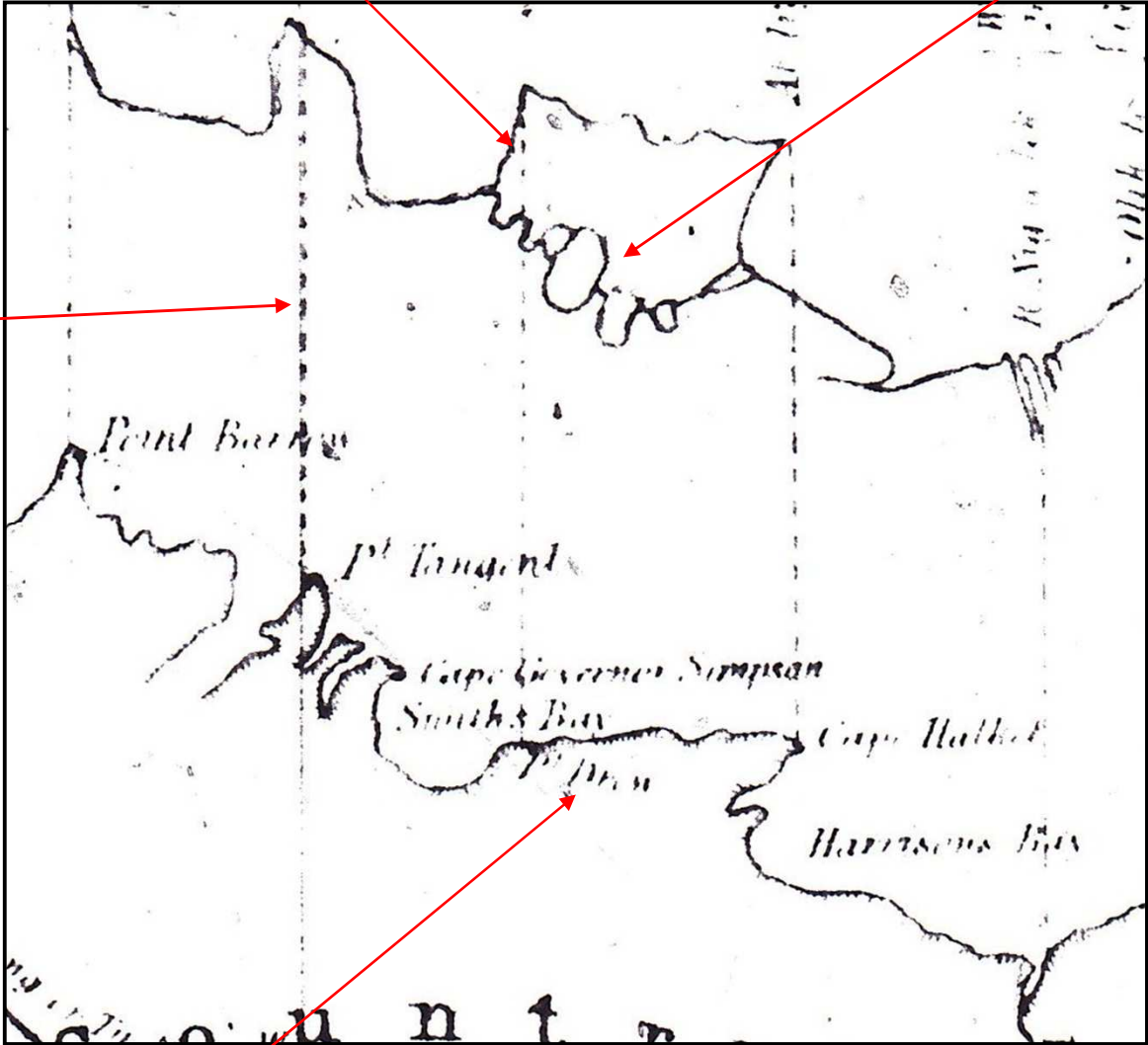




Native map dating to early-1800s

Teshkepkuk

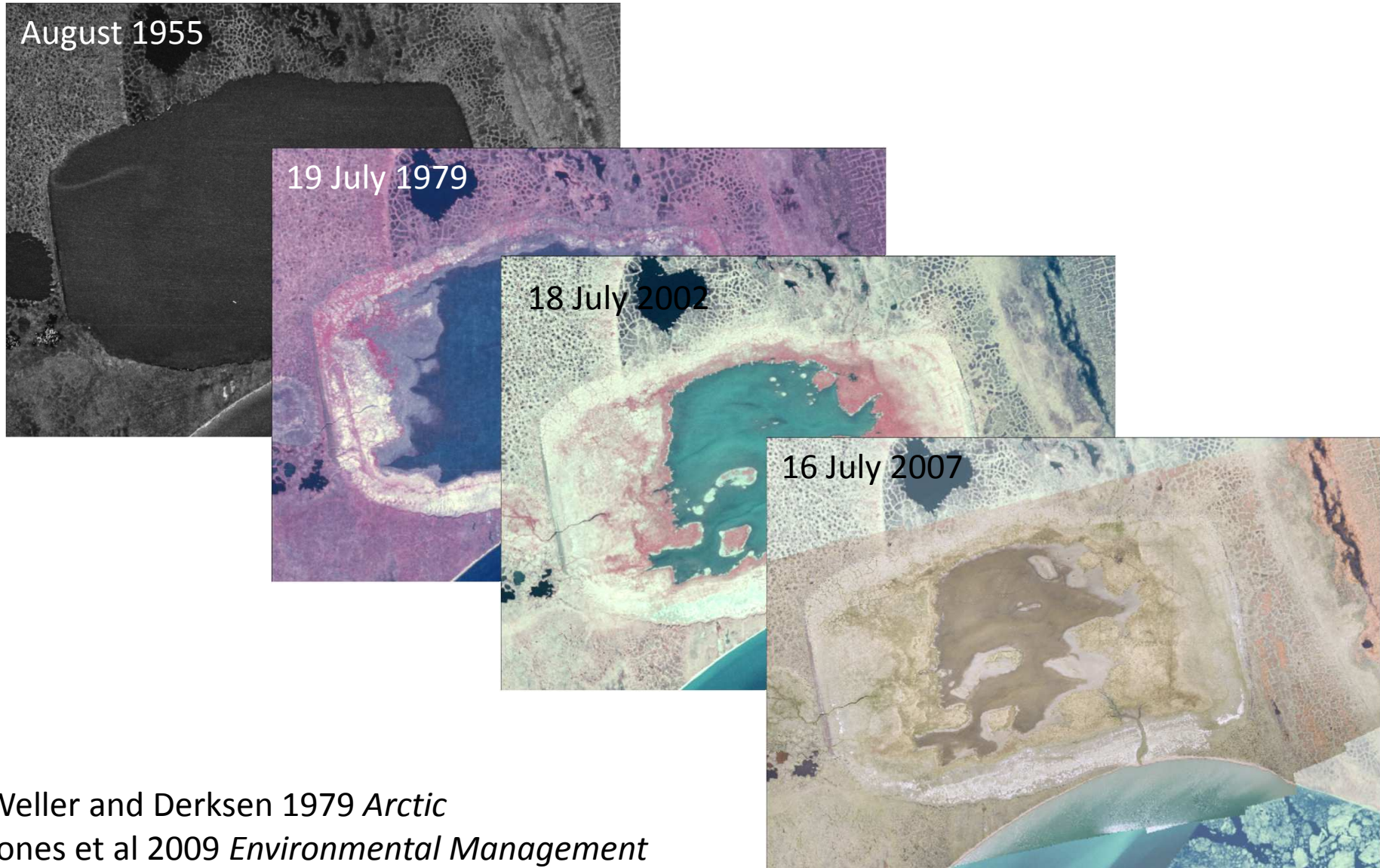
Dashed lines show agreement between native map and explorers map



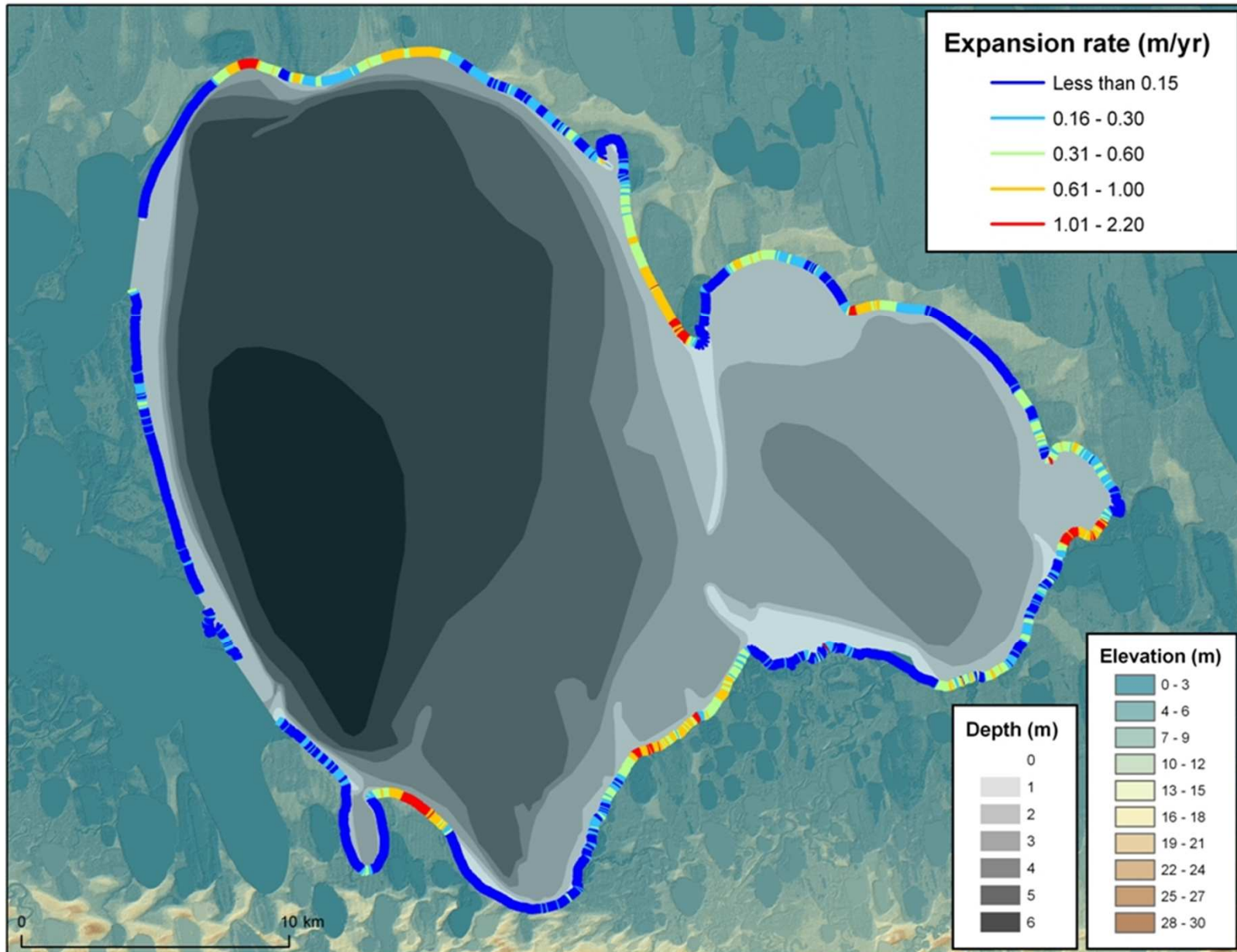
Early explorers map dating to 1830s

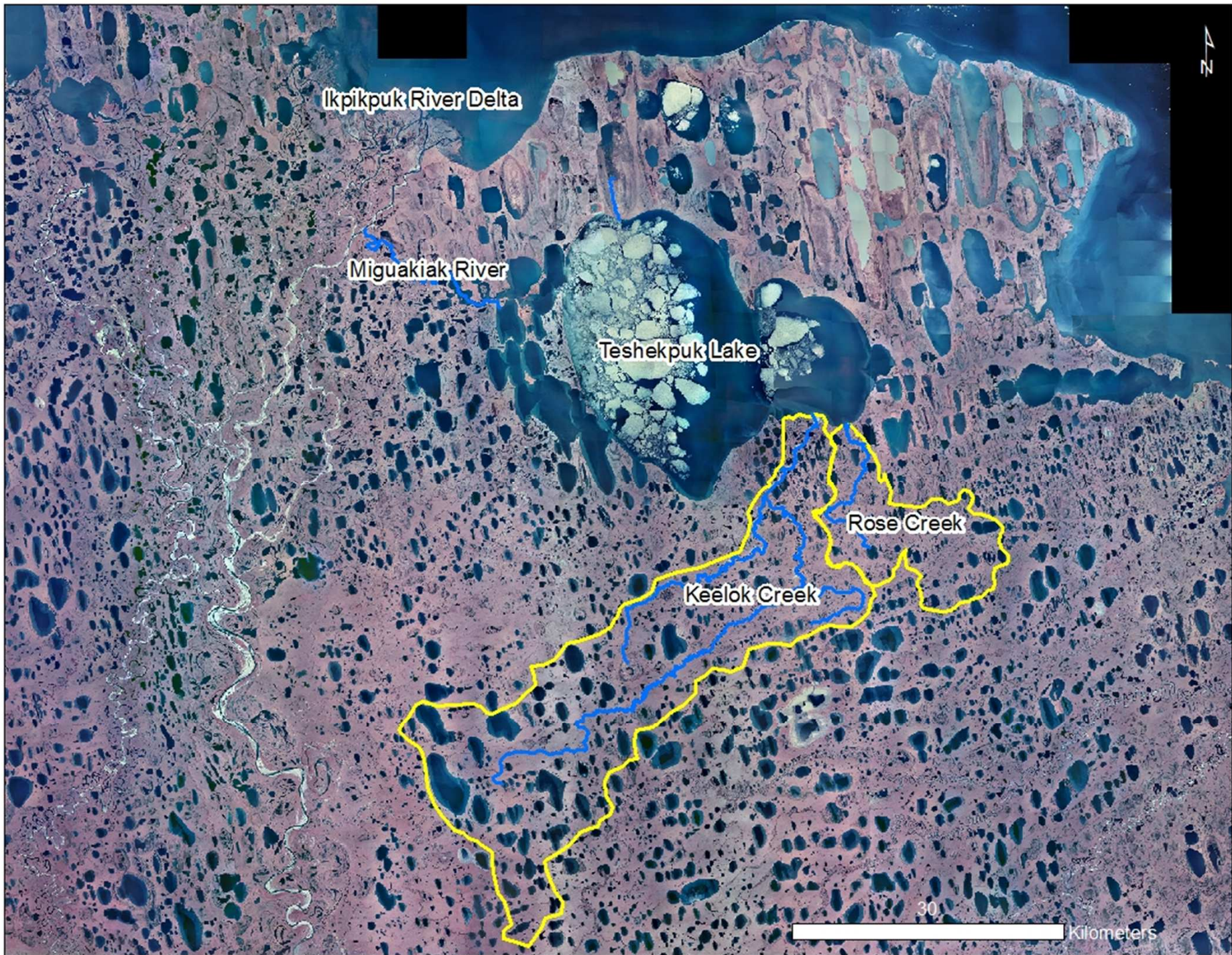
*note Tesh as separate lakes

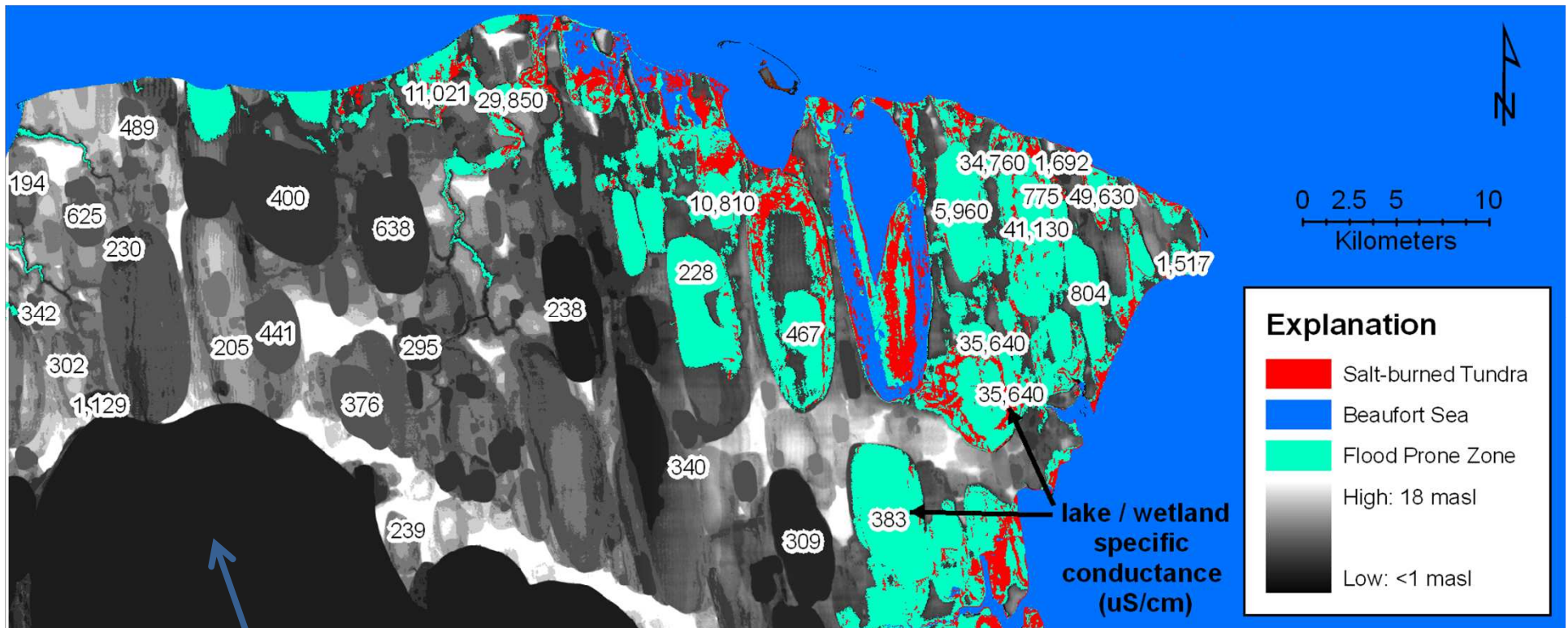
North Lake/Derksen Basin



Modern day expansion rates







Teshekpuk Lake is very fresh!
 Specific Conductance ranges from 250 – 350 uS/cm

Wildlife - Caribou



Person et al 2007 *Arctic*

Wildlife - Fish



Species	1990-92	2003-05
Broad whitefish	X	X
Humpback whitefish	X	X
Least cisco	X	X
Round whitefish	X	X
Bering cisco	X	X
Arctic grayling	X	X
Pink salmon	X	
Arctic char		X
Lake trout		X
Burbot	X	X
Northern pike	X	X
Slimy sculpin		X
Alaska blackfish		X
Threespine stickelback		X
Ninespine stickelback	X	X

Moulton et al 2007

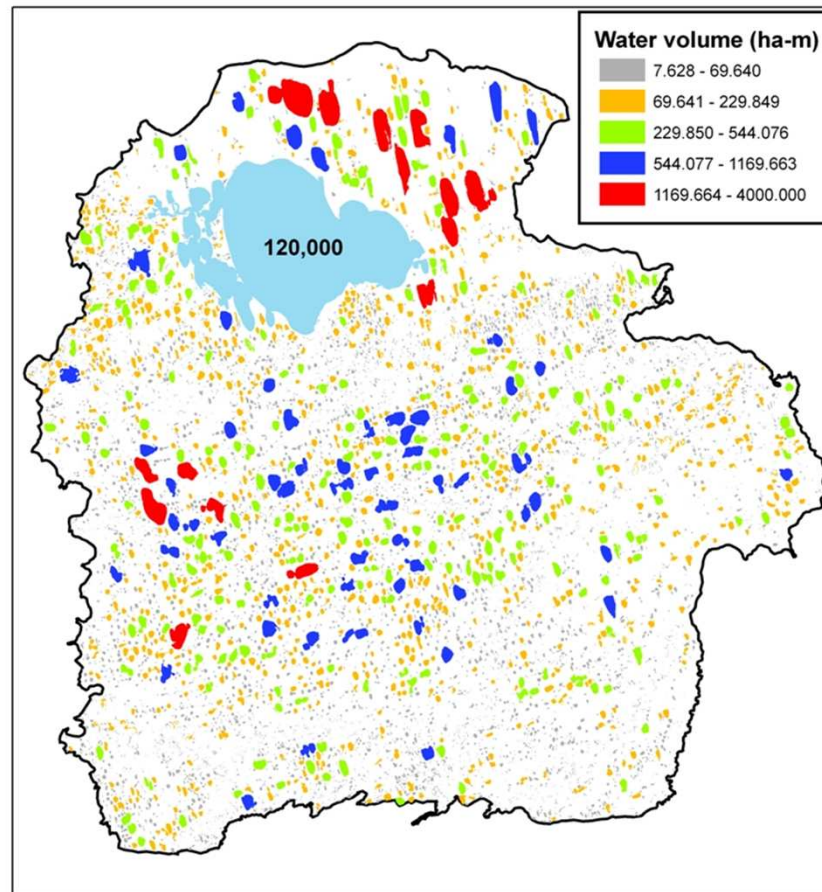
Wildlife - Invertebrates



Mesidotea entomon teshpuki (?)
B. Jones

First estimate of lake surface water storage

Based on surface area to volume relationship for three lake types



Lake Type	Total Volume (ha-m)	Percent of Area
Thaw	98173	16.9
Depression	312951	53.9
Riverine	50023	8.6
Teshekpuk	120000	20.6

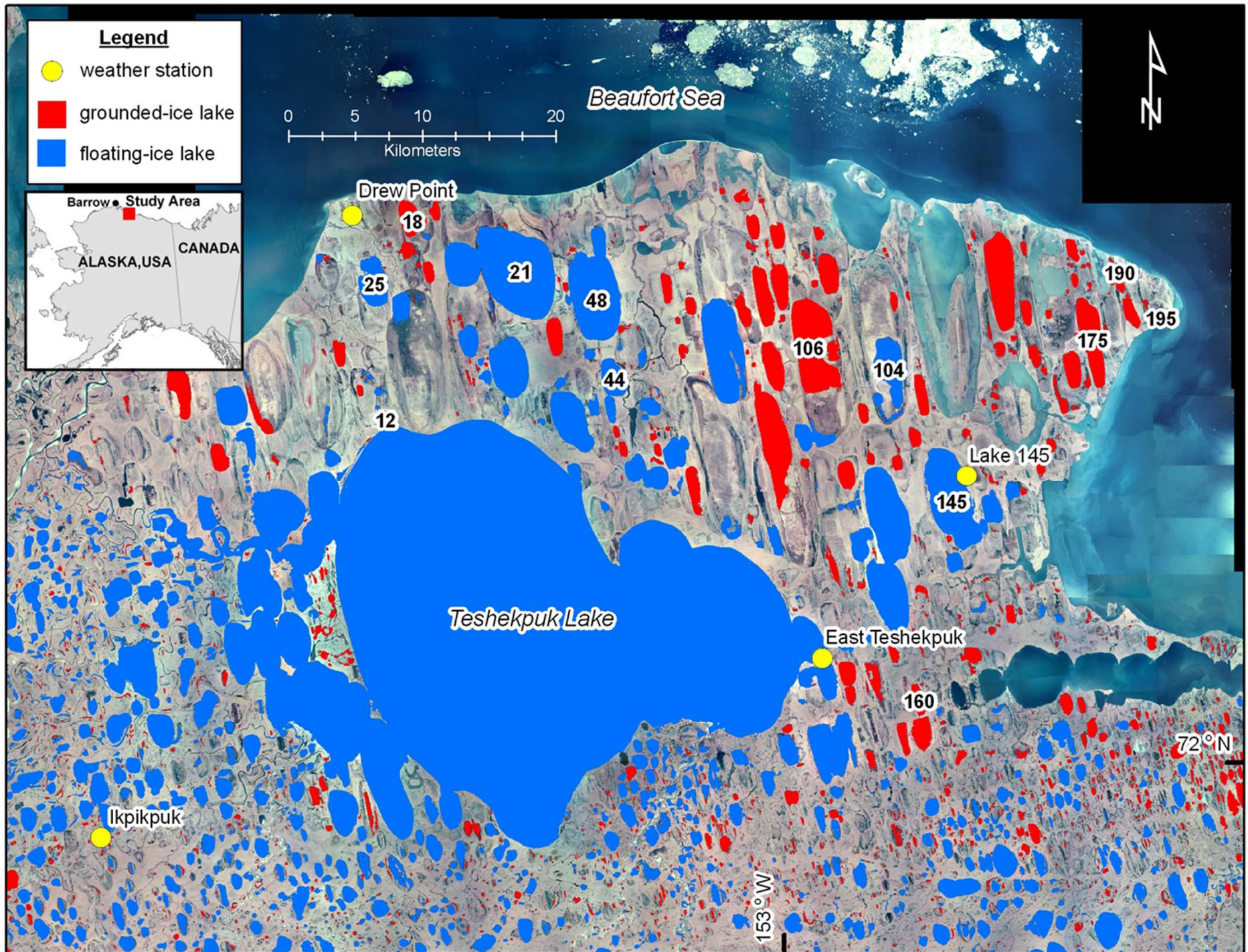


Thermokarst Lake Hydrologic & Ice Regimes

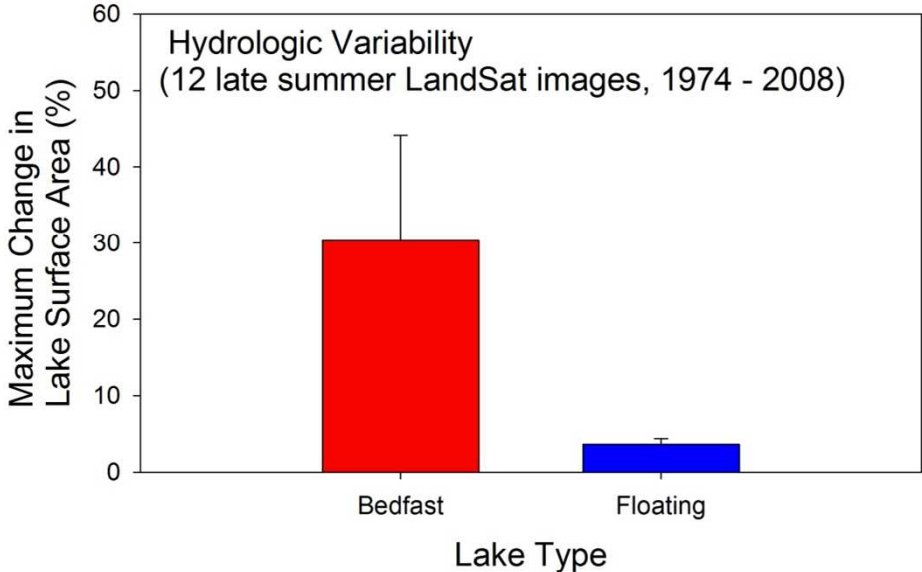
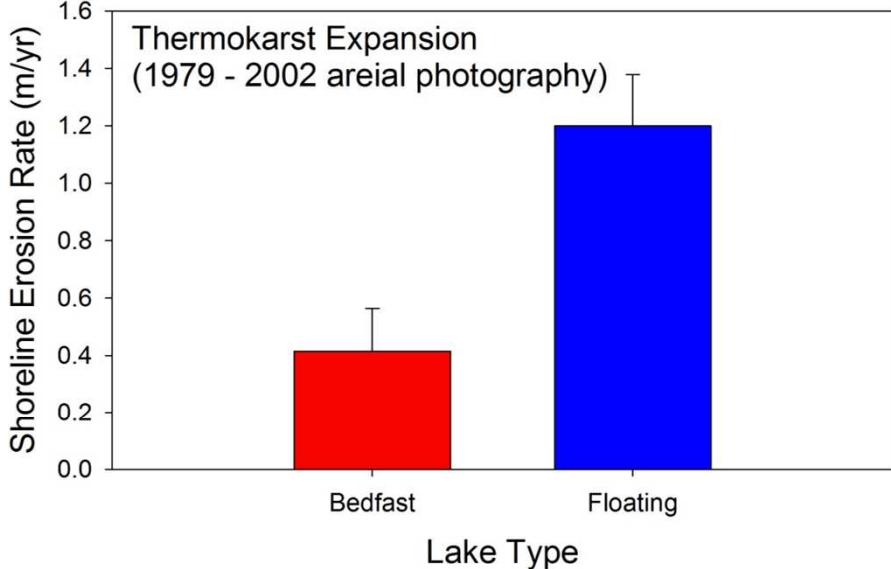


Arctic Lake Change Questions

1. What are the processes underlying observed changes in lakes across permafrost zones?
2. What are the relative roles of lake expansion by thermokarst erosion vs. variation in water balance?
3. Do lakes respond to climate change uniformly within a region?
4. What is the role of lake bathymetry and ice phenology in geomorphic and hydrologic processes?



Comparing Lake Change Mechanisms between Grounded-ice and Floating-ice Lakes



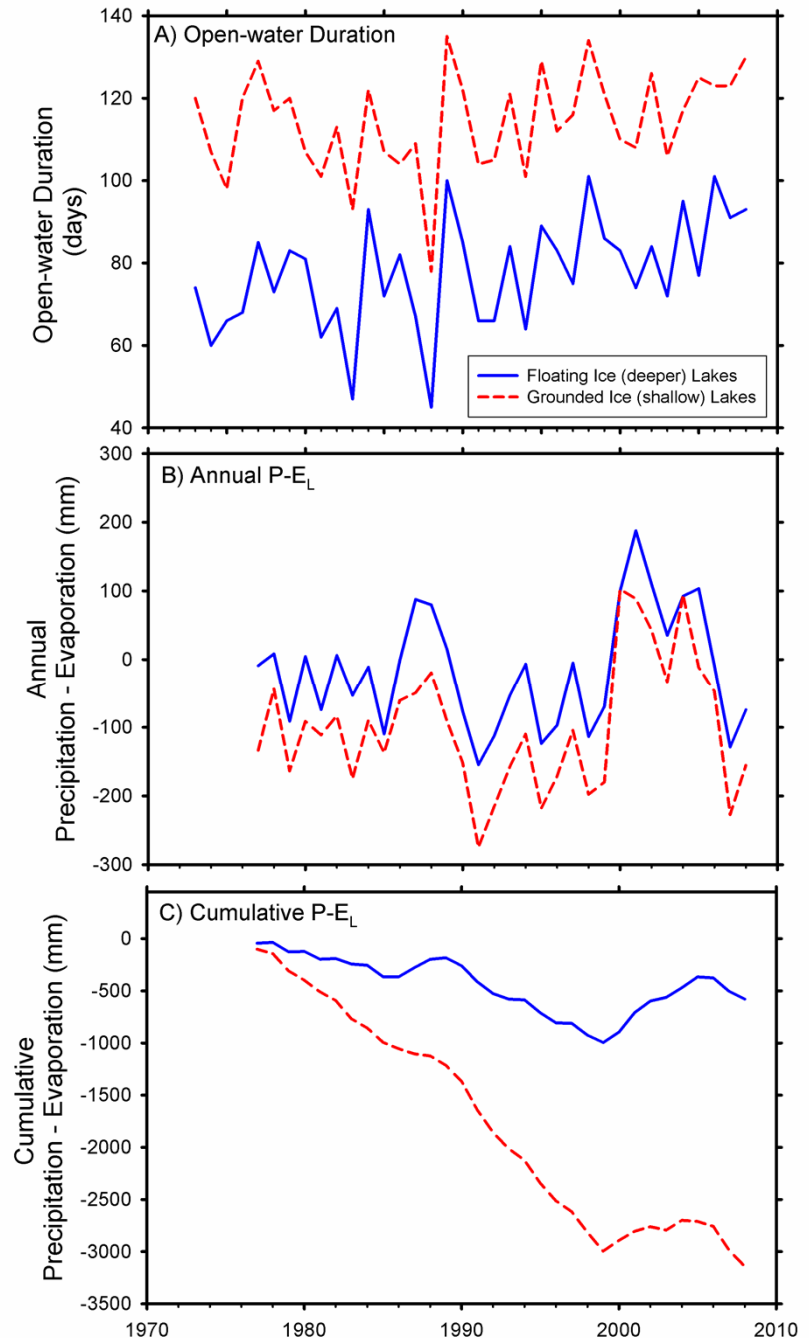
Divergent Hydrologic Behavior between Grounded-ice and Floating-ice Lakes

Longer open-water
period for grounded
ice lakes

More positive water
balance for floating ice
lakes

Potentially different long term
water balance in lakes...

...but depends on runoff
contributions, lake storage, and
outlet discharge

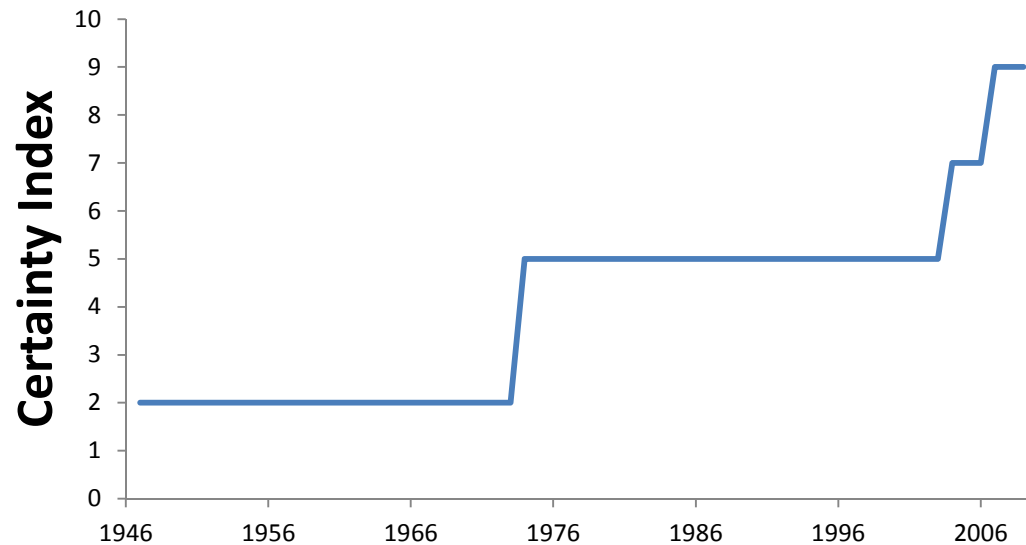


Methods for Reconstructing Ice Regimes

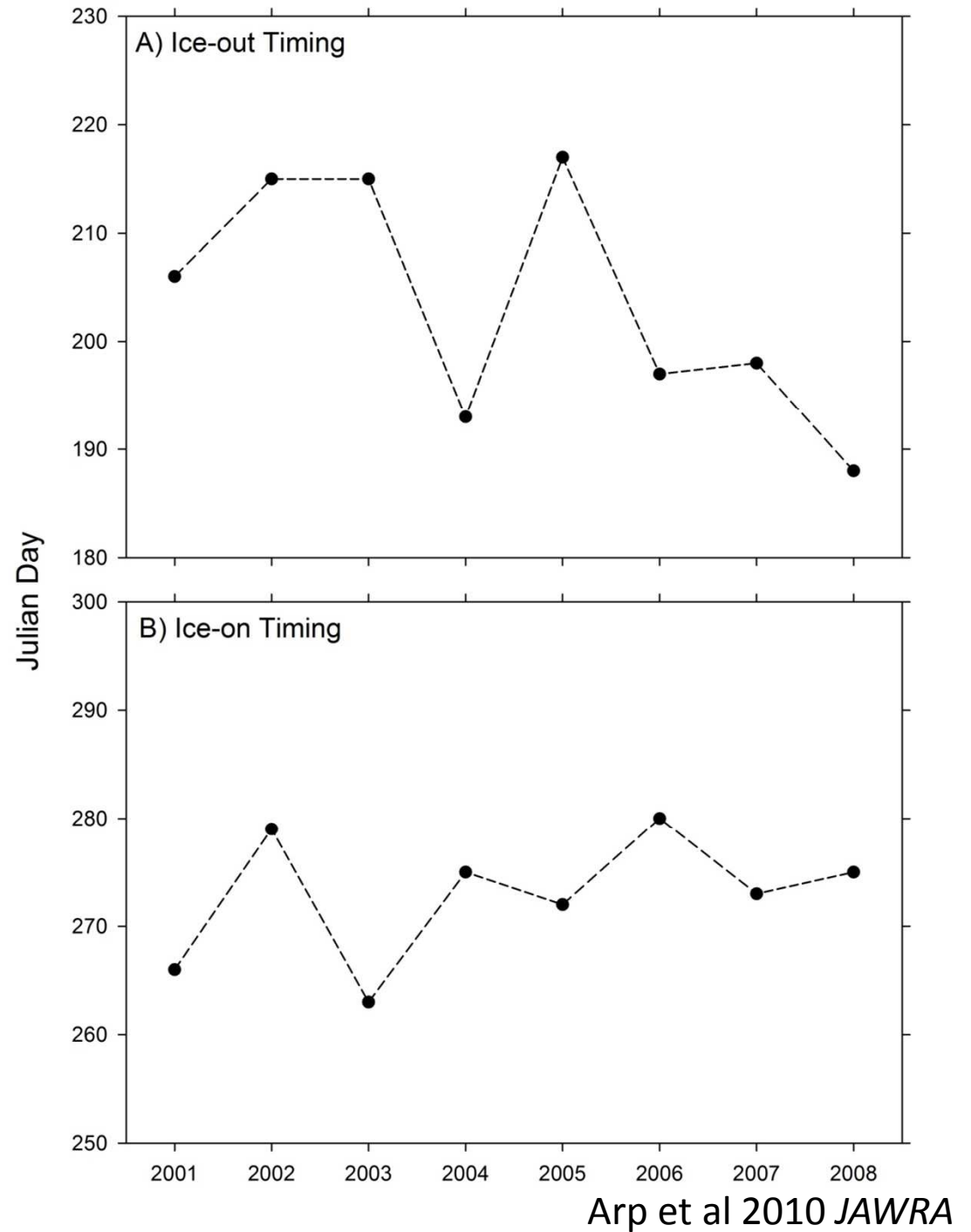


Integrated Monitoring, Remote Sensing, and Modeling

- Temperature sensors (2007-09) – detect ice out and ice formation (high resolution, short period)
- MODIS (2004-08, Arp et al 2010 JAWRA) and Landsat (1974-2009, this study) – bracket ice out and ice formation (low resolution, moderate period)
- Ice growth model (modified Stefan equation based on FDD) and ice decay model (Belillo et al 1964 based on TDD) both driven by air temperature from TLSA (1998-2009) and Barrow (1947 – 2009)



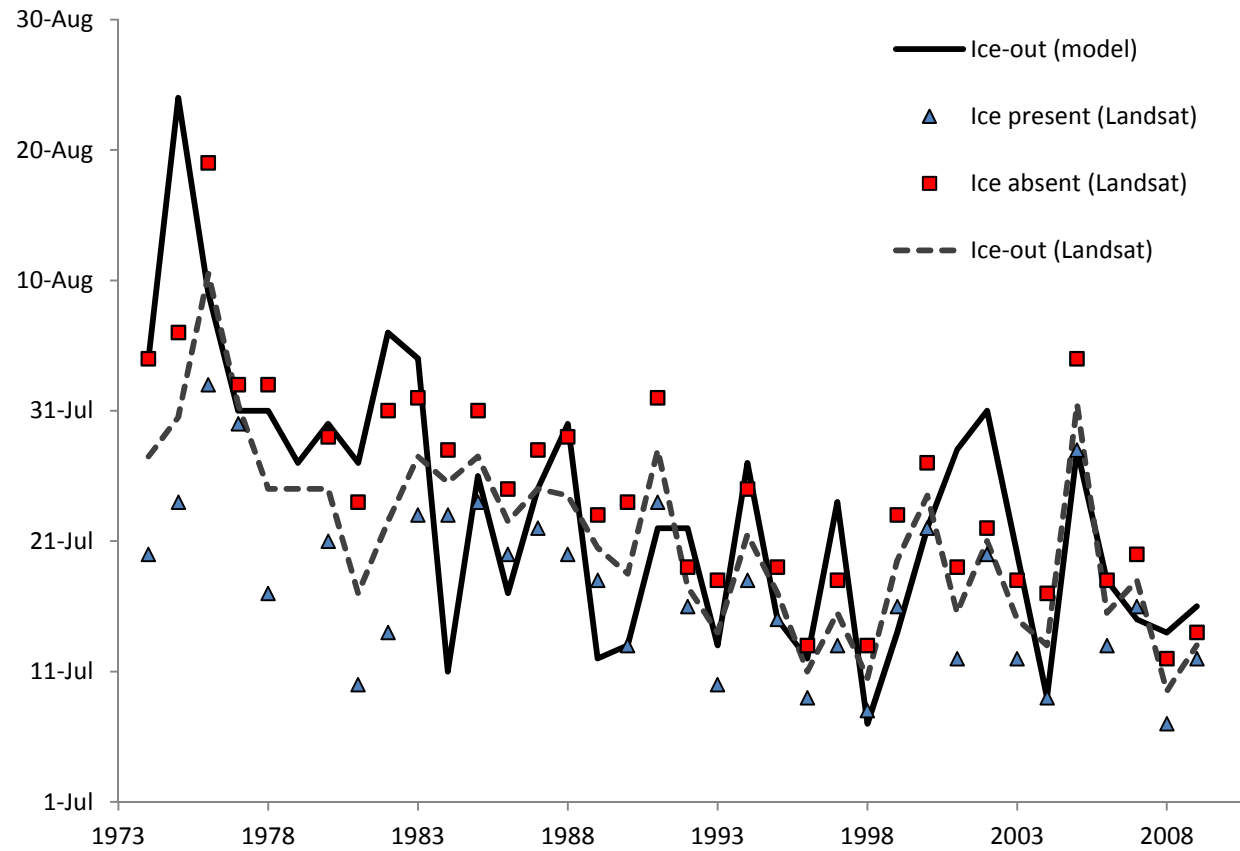
Results from Previous Work and Evaluation of Certainty



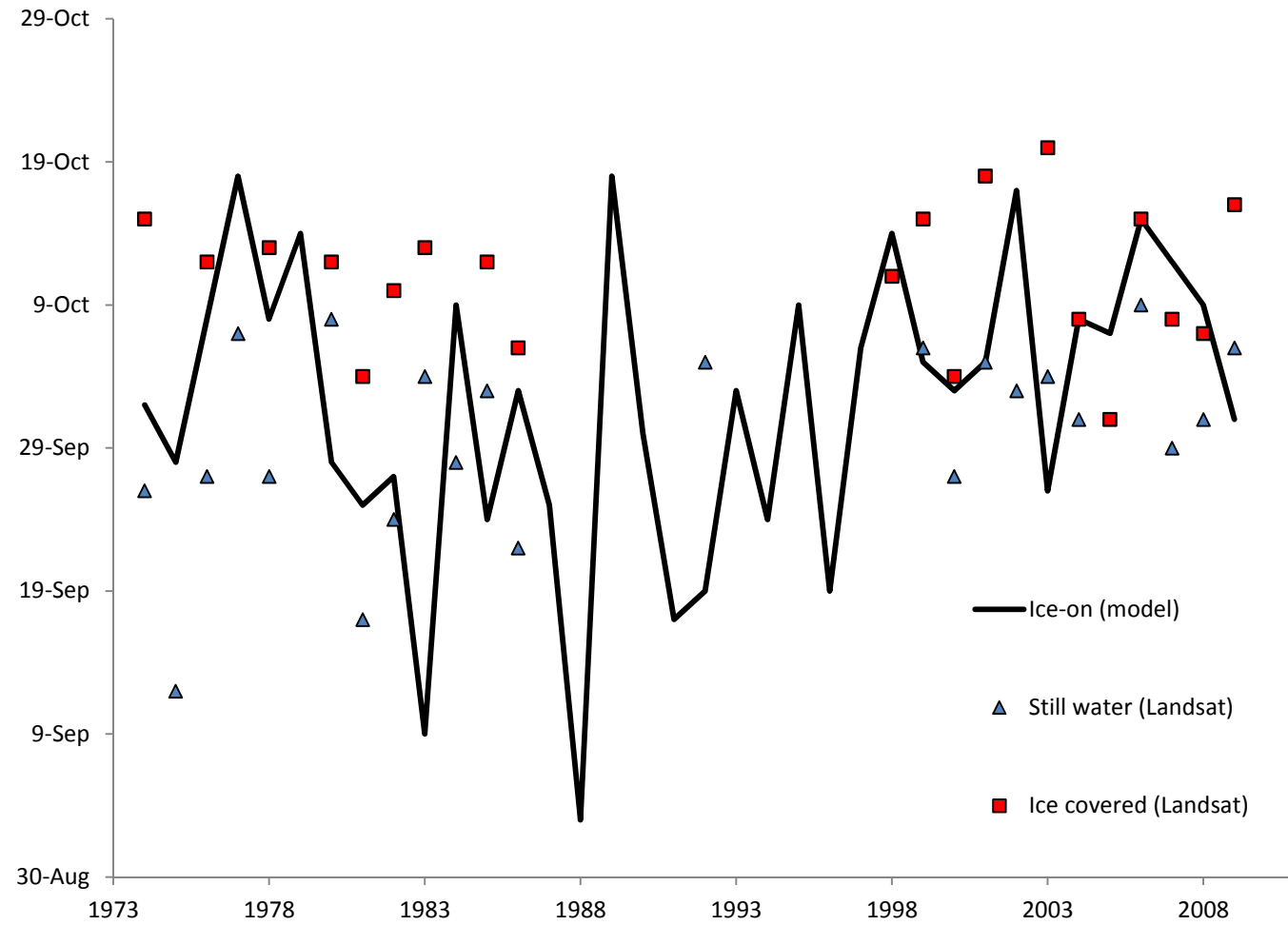
Teshekpuk Lake ice cover history



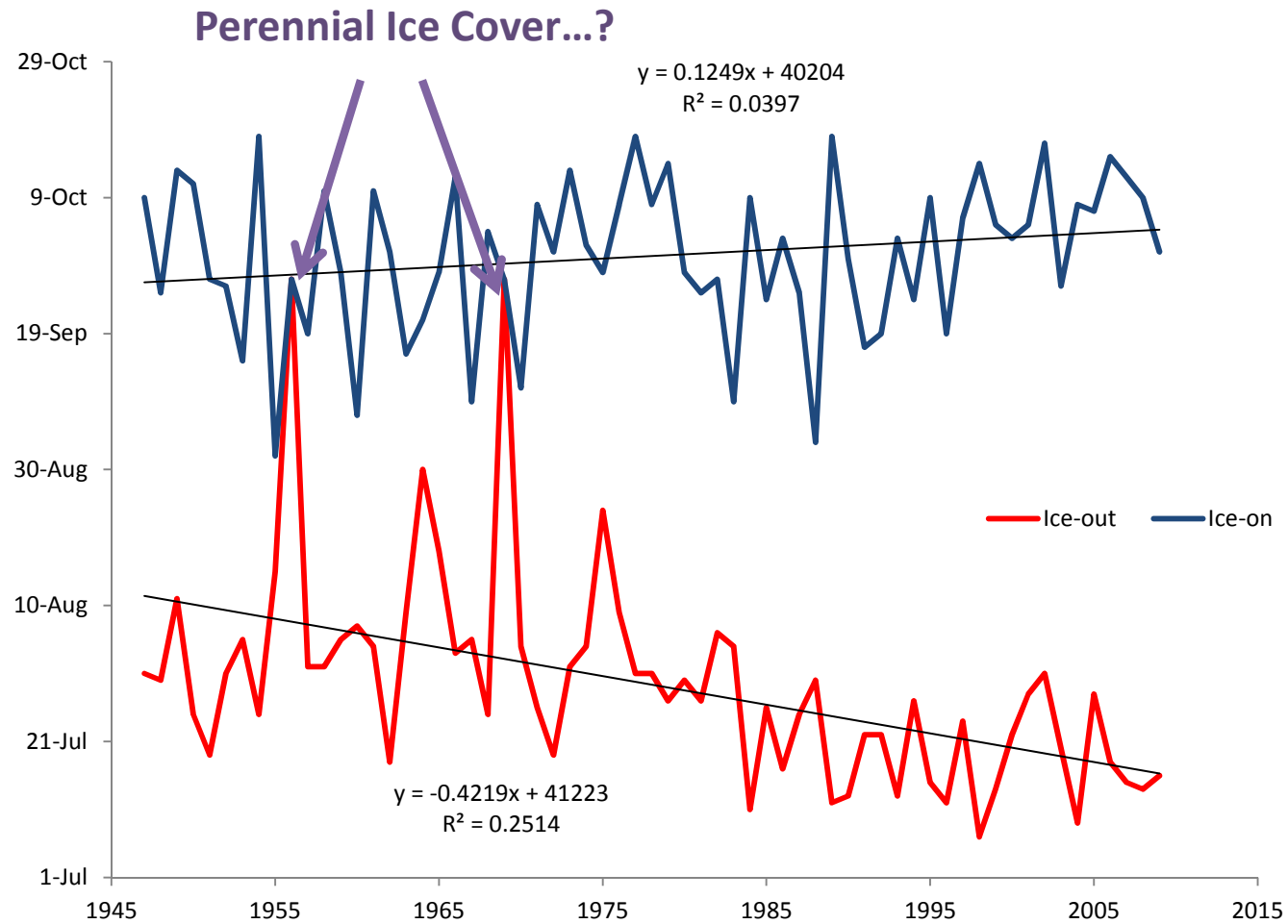
Ice-out Timing Analysis (1974 – 2009)



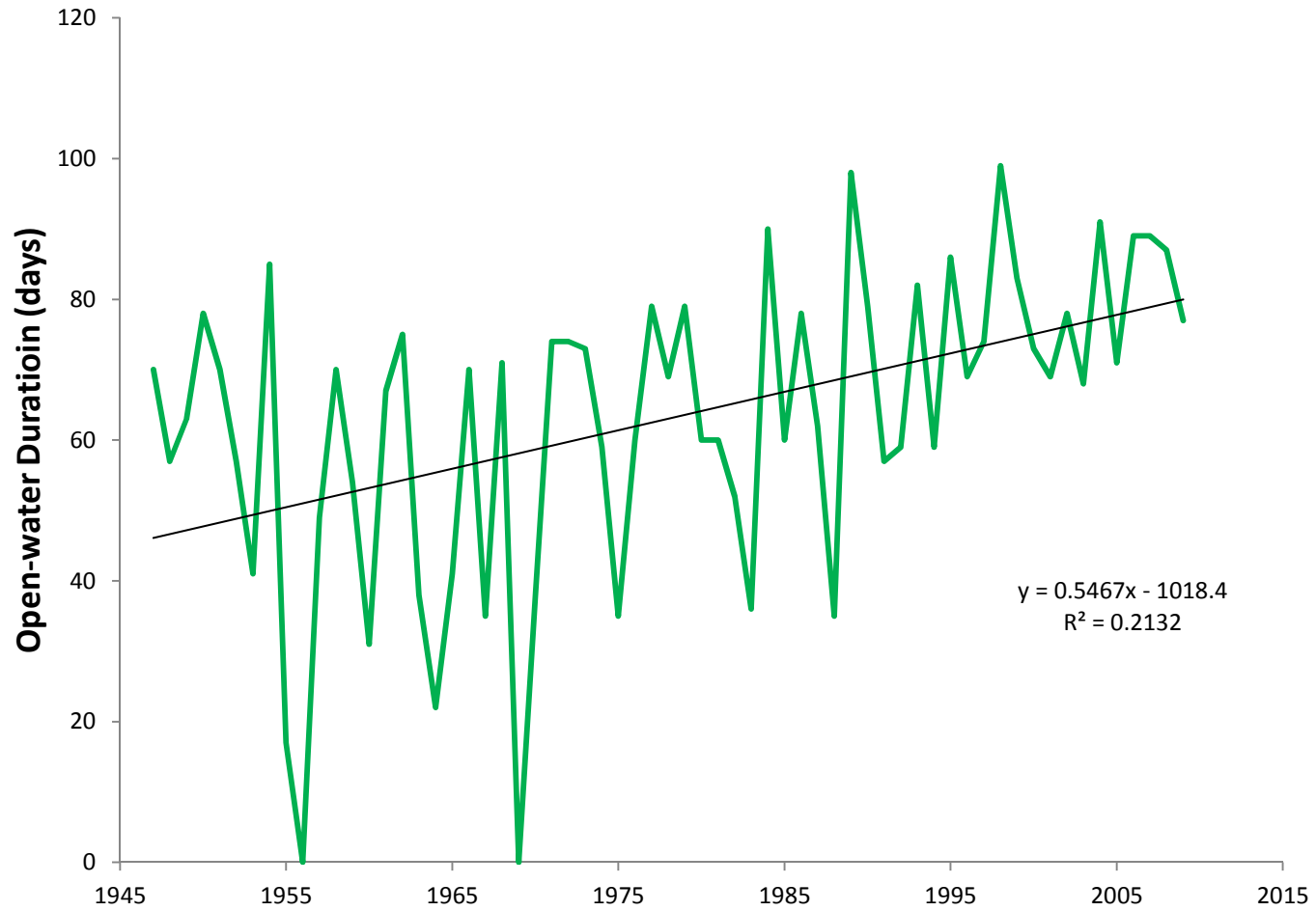
Ice-on Timing Analysis (1974 – 2009)



Ice-out and Ice-on Timing (1947 – 2009)



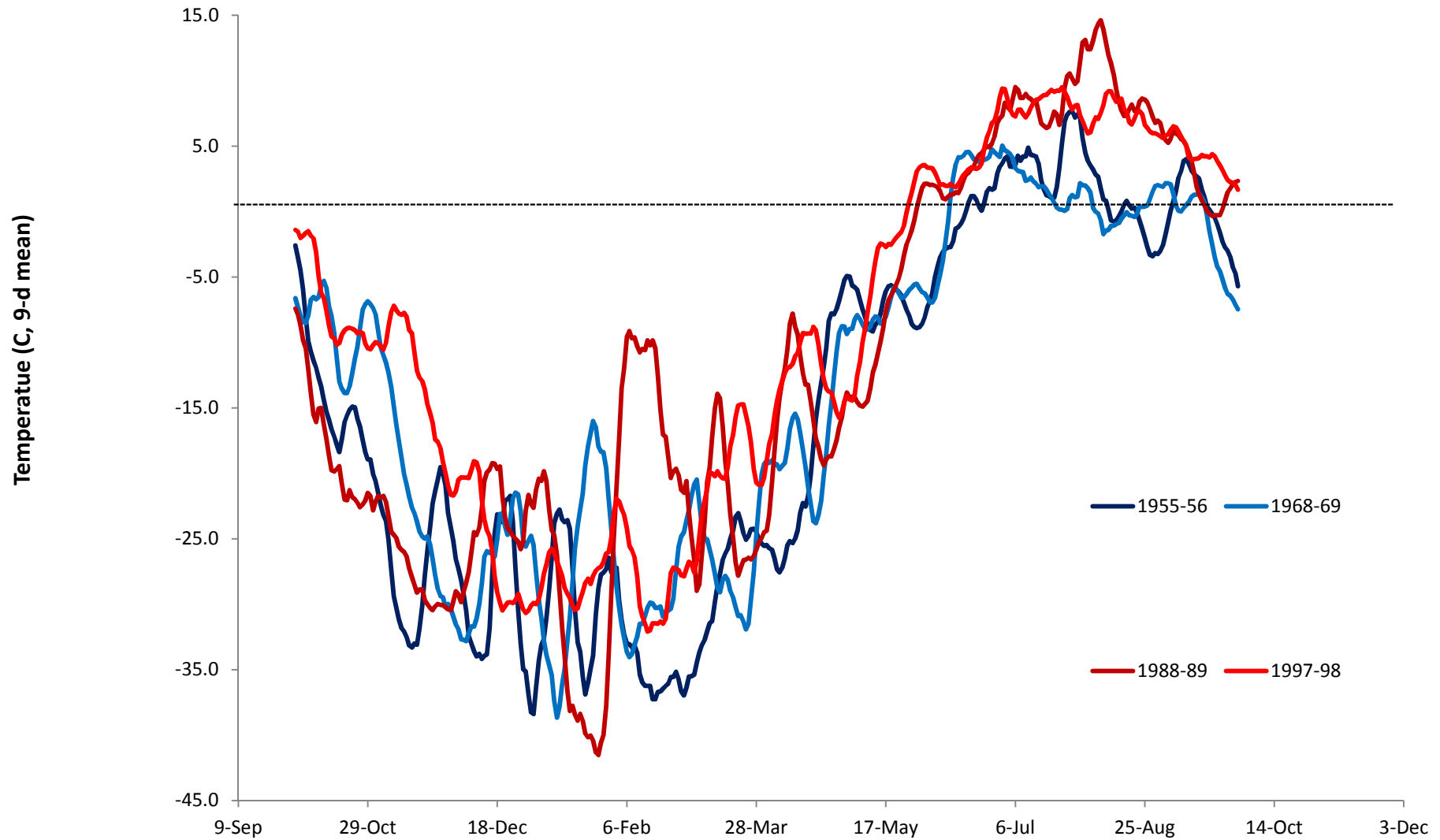
Ice Free Duration (1947 – 2009)



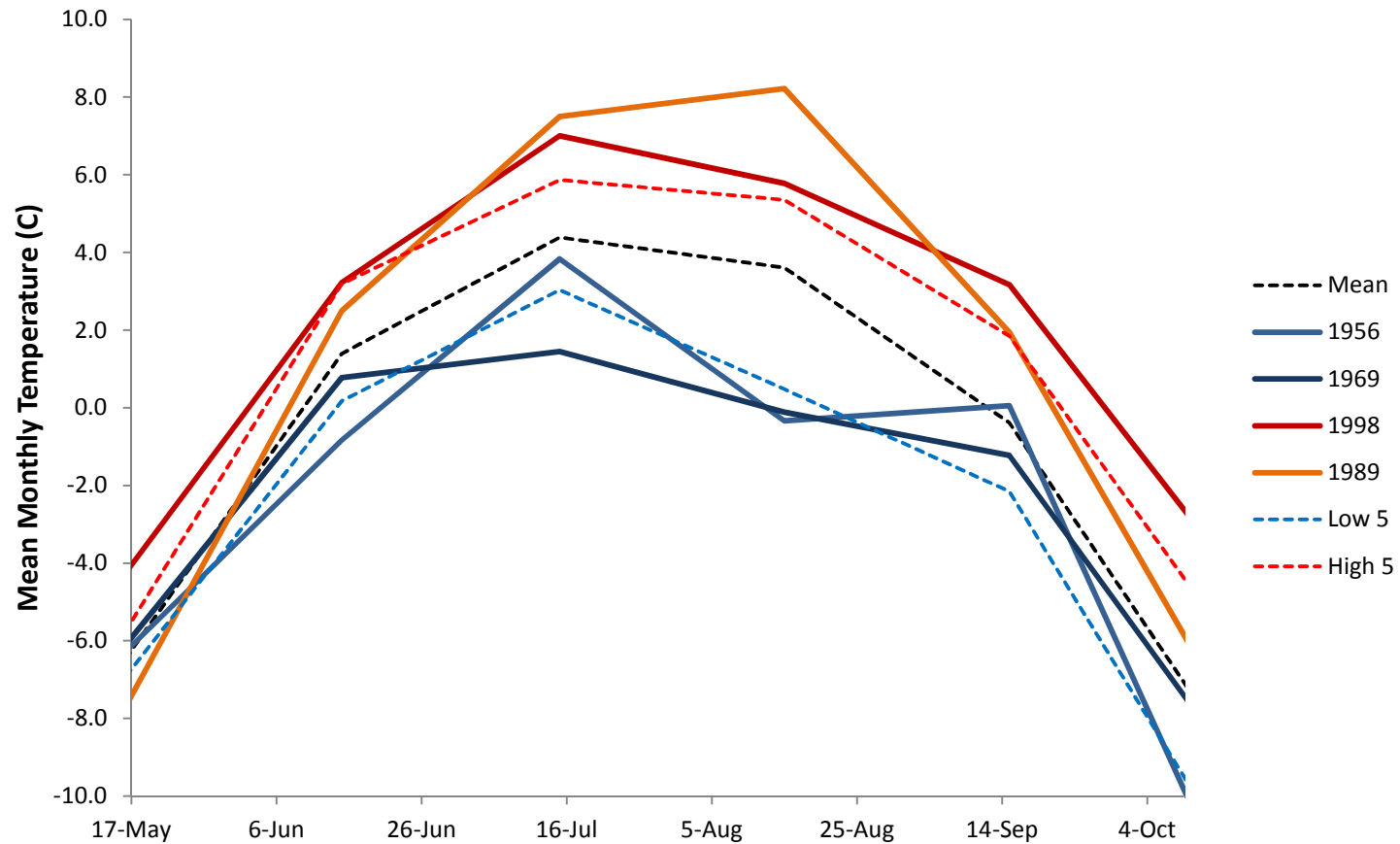
Climate Conditions leading to Short and Long Open-water Periods on Teshekpuk



Temperature Regimes of Perennial Ice Cover Years (blue) vs. Longest Ice-Free Duration Years (red)



Closer Look at Average (black), Long (red), and Short (blue) Ice Free Periods



Effects of Air Temperature considered major driver of Ice Formation and Decay

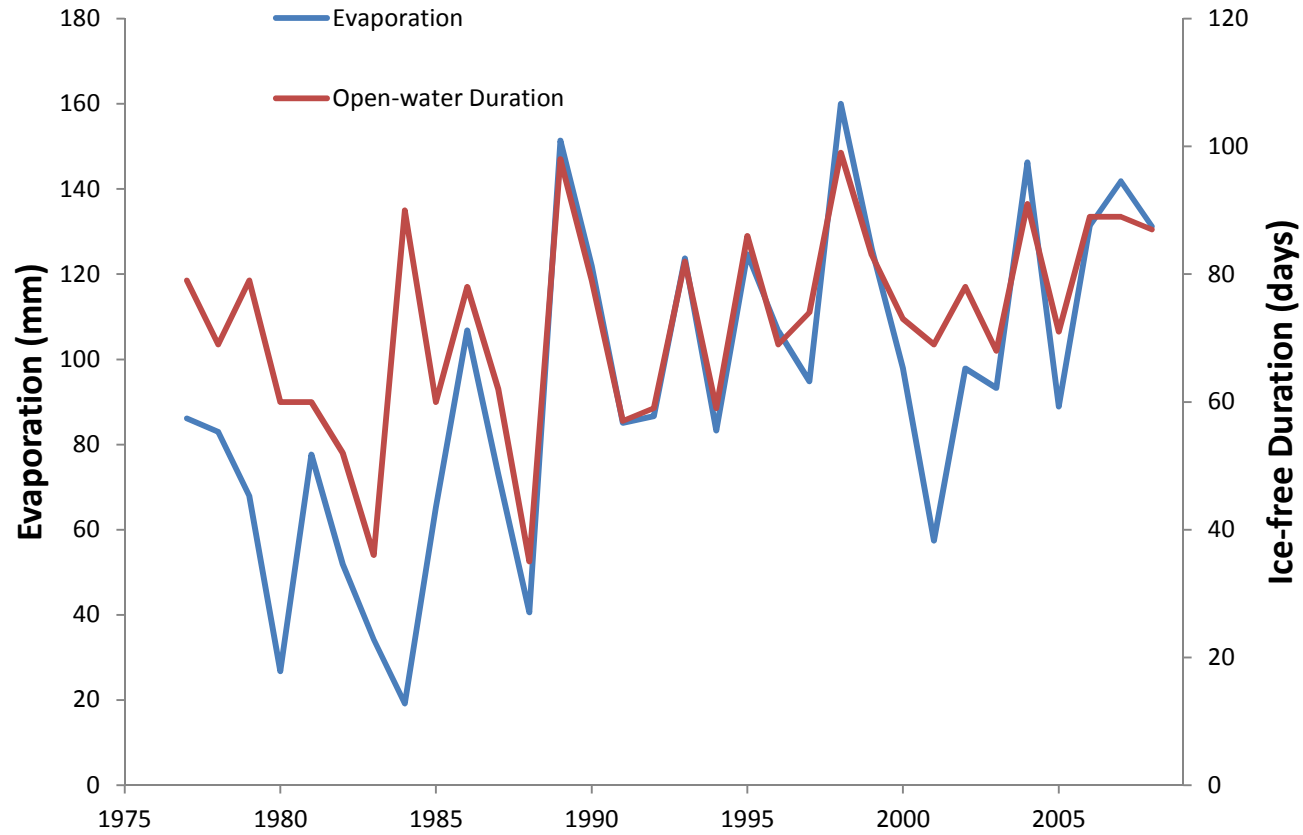
Other Drivers of Lake Ice Dynamics

1. Snow
2. Wind
3. Solar Radiation
4. Lake morphometry

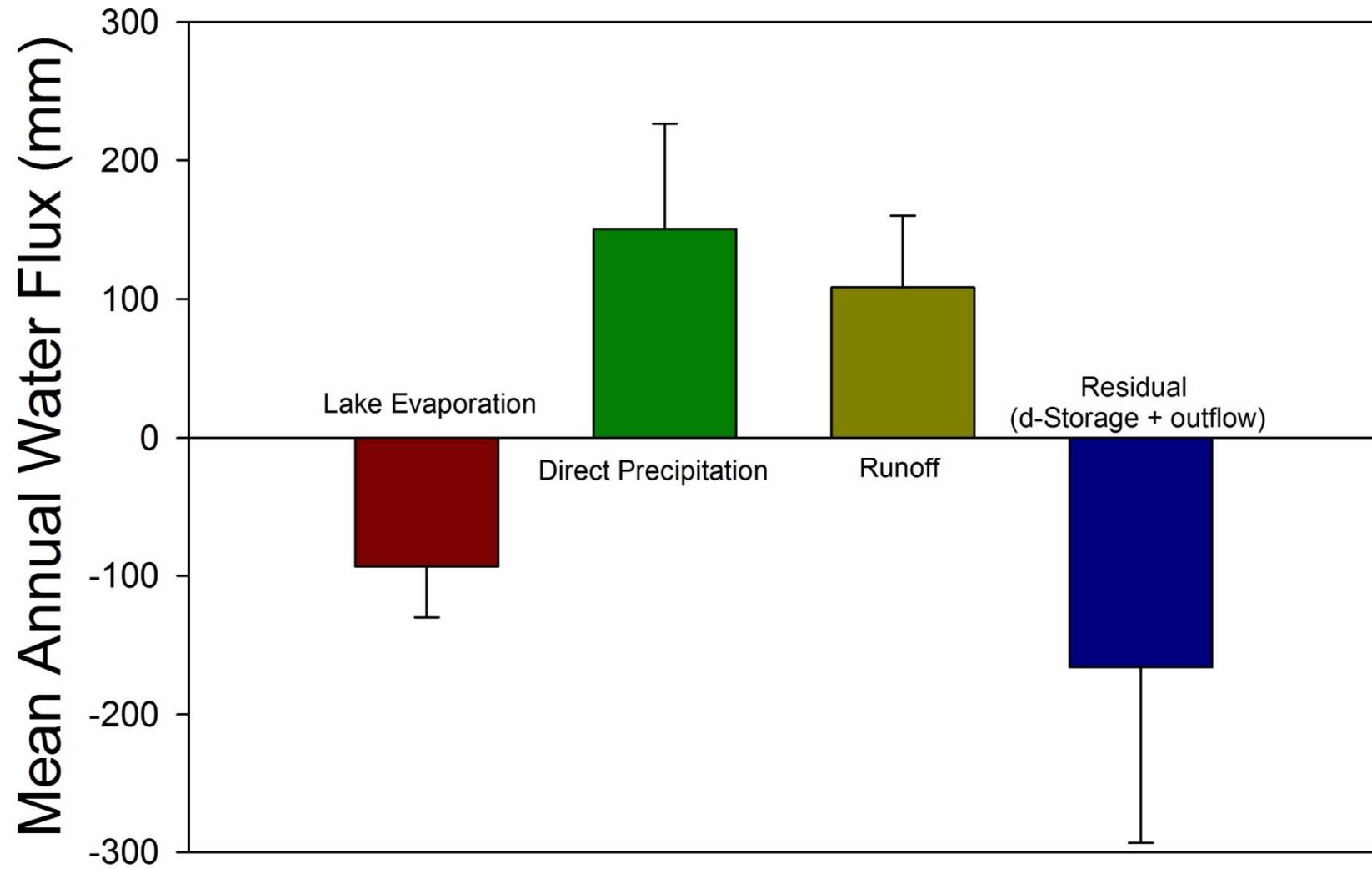
Impact of Ice-cover on Hydrology



The role of Ice Cover and Dynamics on Lake Hydrology and other Processes

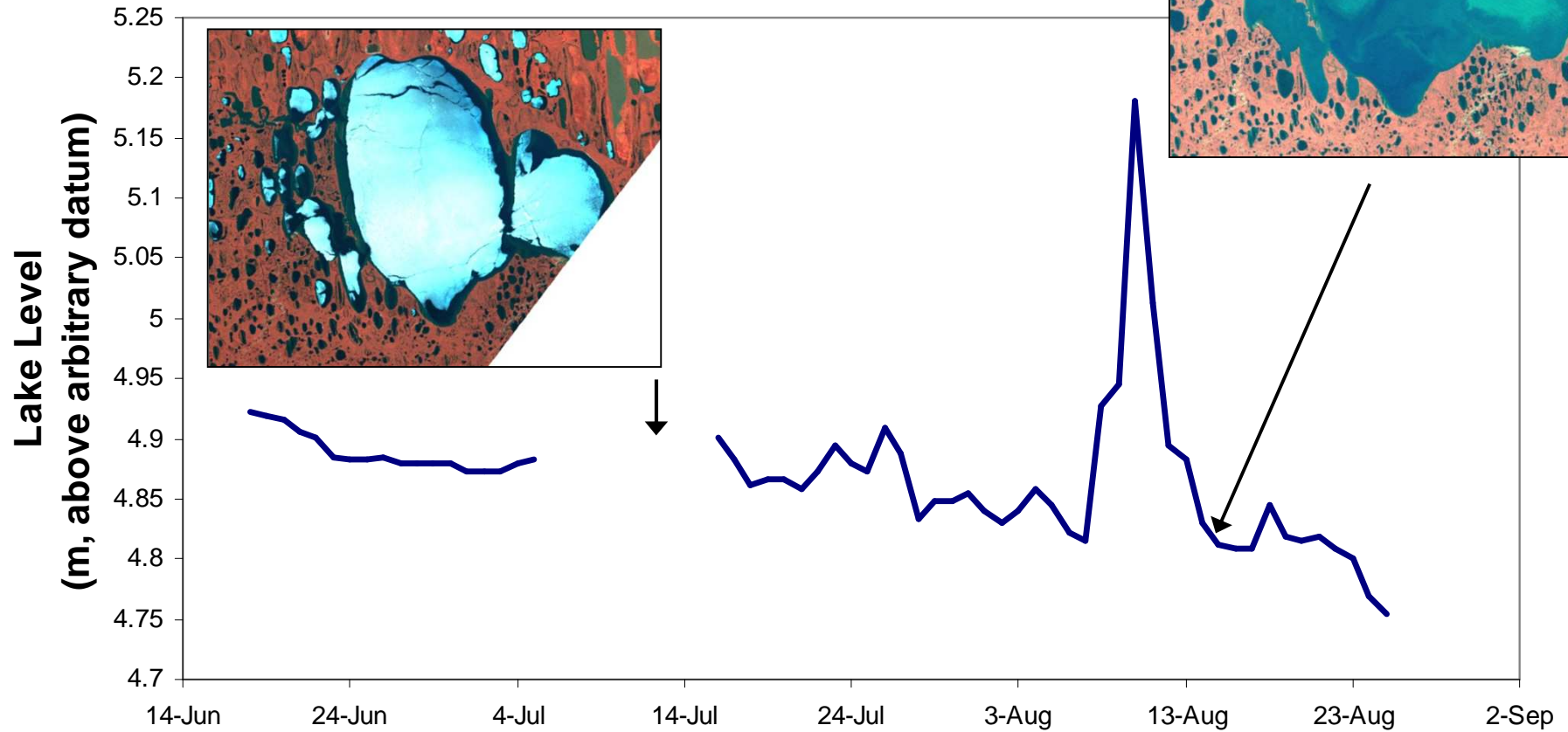


Rough Estimate of Teshekpuk Lake Water Balance (1977 – 2008)

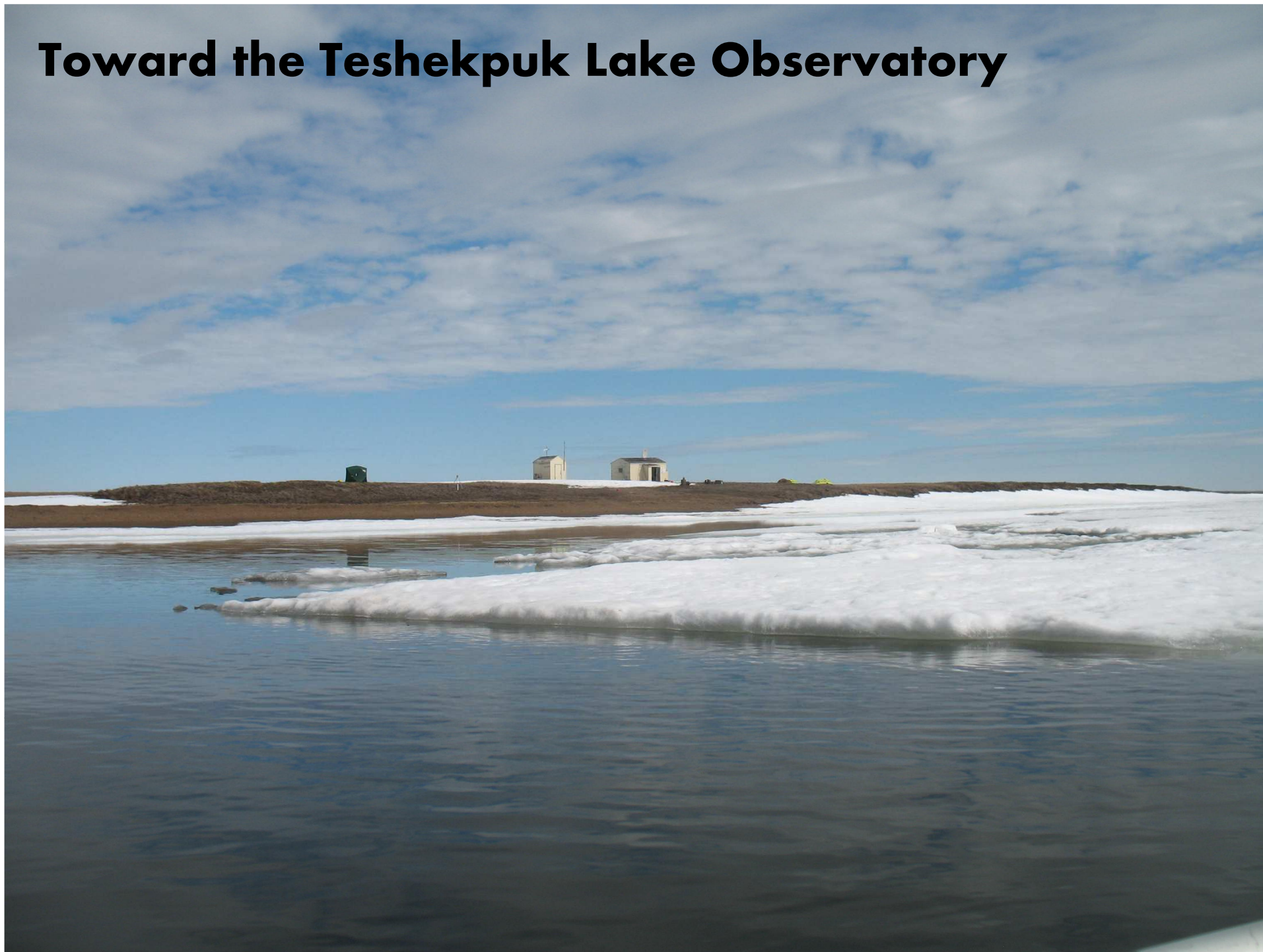


Teshekpuk Lake - Ice jams, wind, and outflow

Teshekpuk Lake - 1977



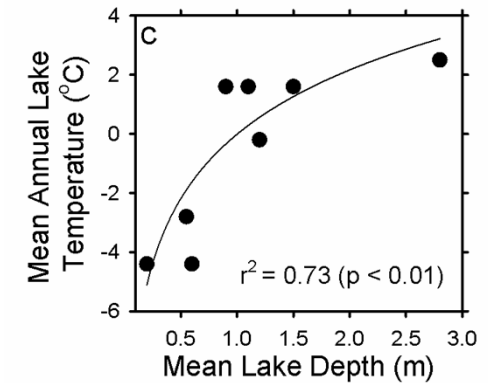
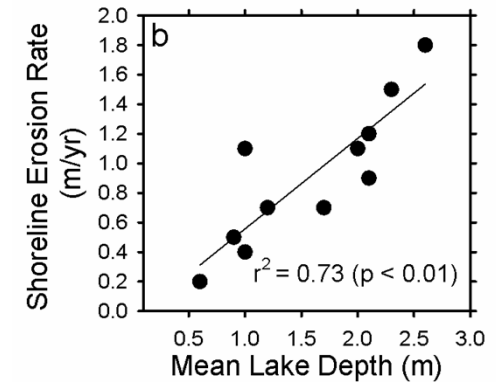
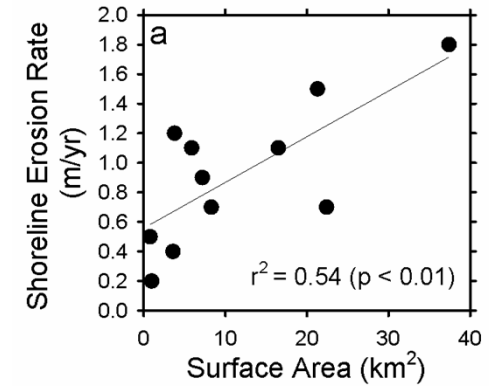
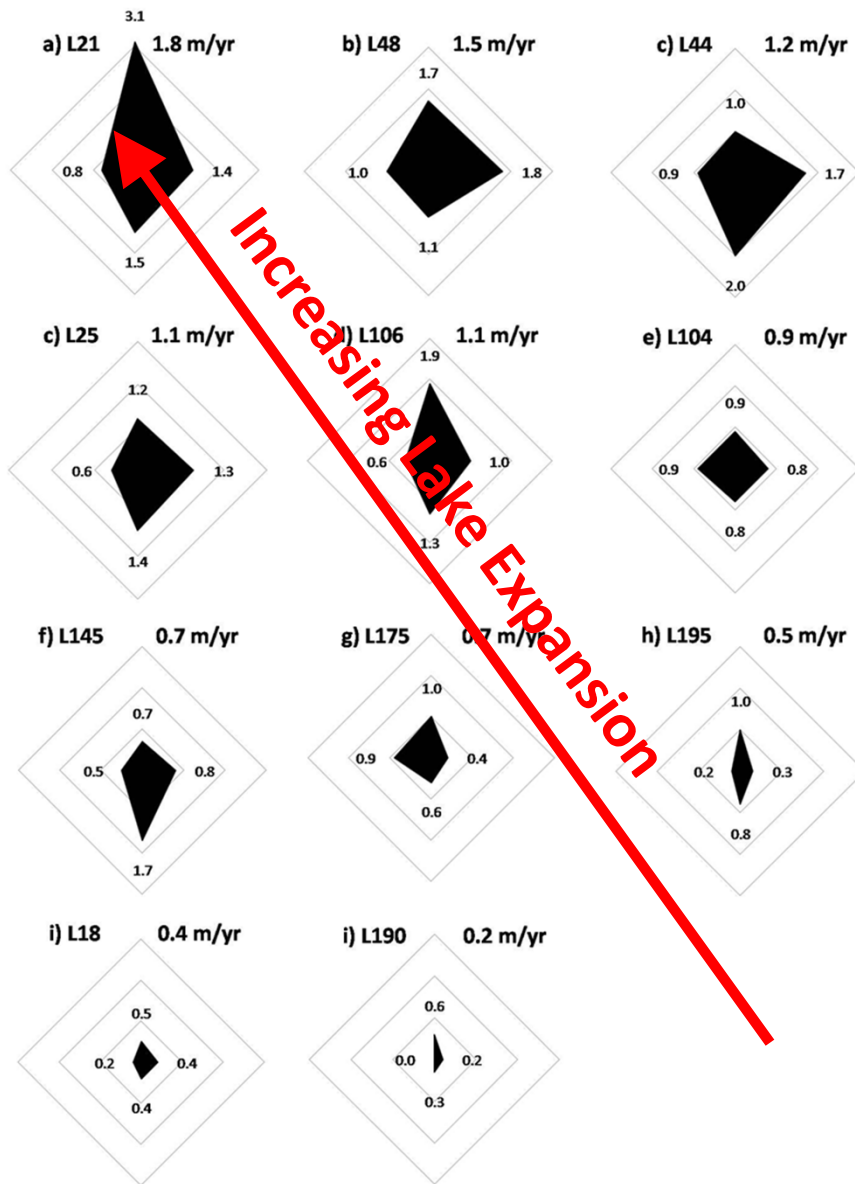
Toward the Teshekpuk Lake Observatory



Conclusions



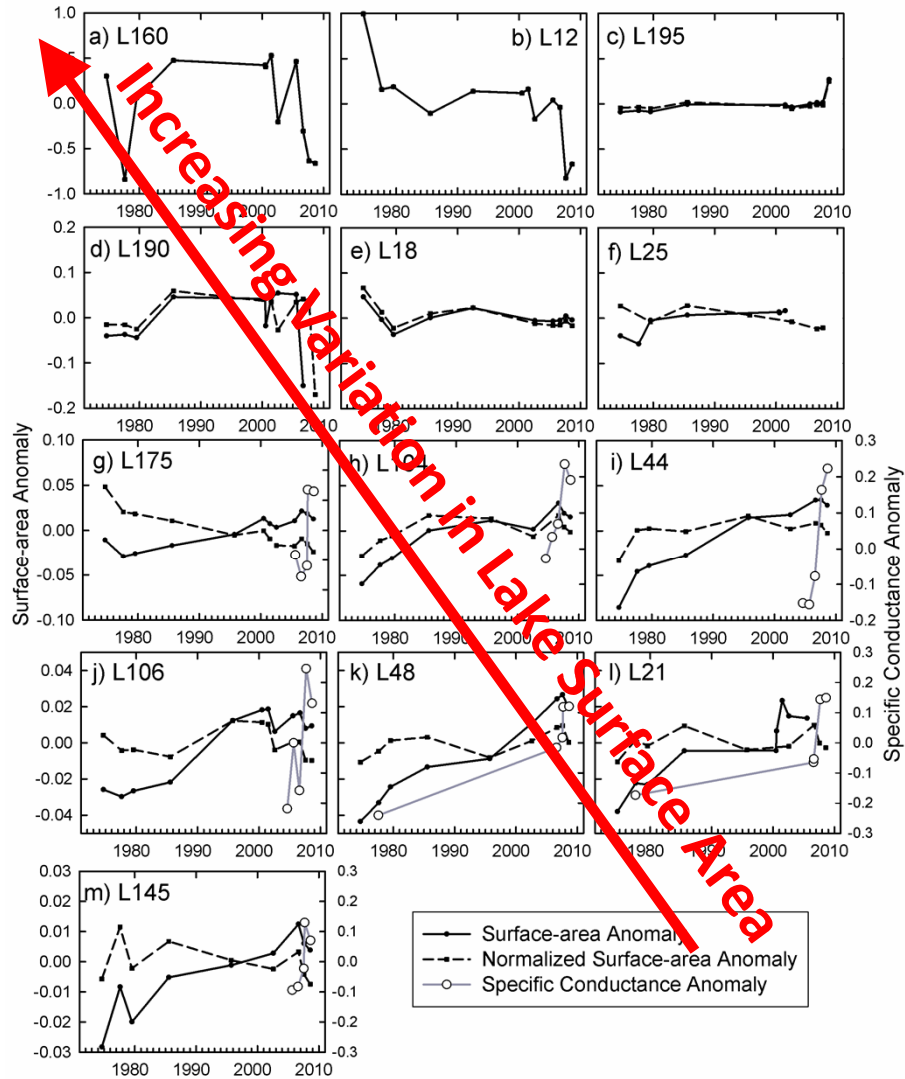
Geomorphic Processes – Thermokarst Erosion



**Deeper lakes
have higher
erosion rates**

**Deeper lakes
are warmer
with greater
potential for
thermal
erosion**

Hydrologic Processes – Water Balance



**Deep lake
with late
(July)
ice-out**

**Shallow lake
with early
(June)
ice-out**

**Very shallow
lake with
very early
(May)
ice-out**

