

# Sea-ice change around Alaska & Impacts on Human Activities



Hajo Eicken

Geophysical Institute

University of Alaska Fairbanks,

[hajo.eicken@gi.alaska.edu](mailto:hajo.eicken@gi.alaska.edu)

- Introduction
- The Arctic sea-ice cover: Observations & predictions
- Alaska sea-ice change
- Impacts
- Conclusions

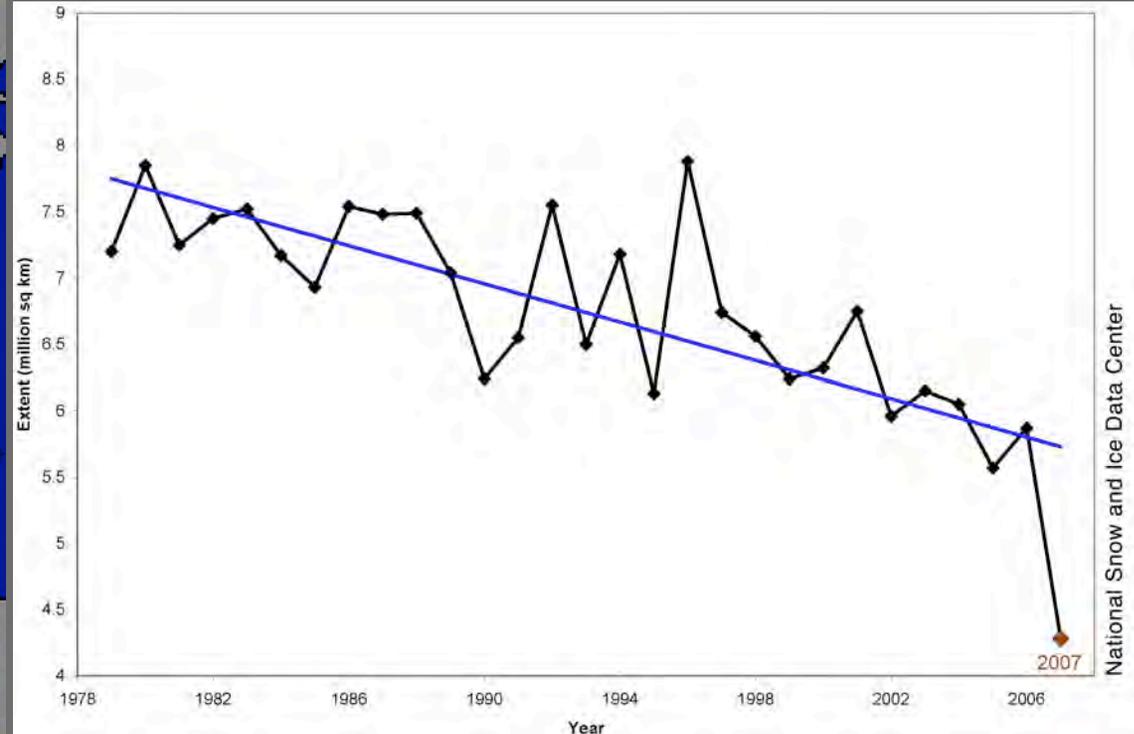
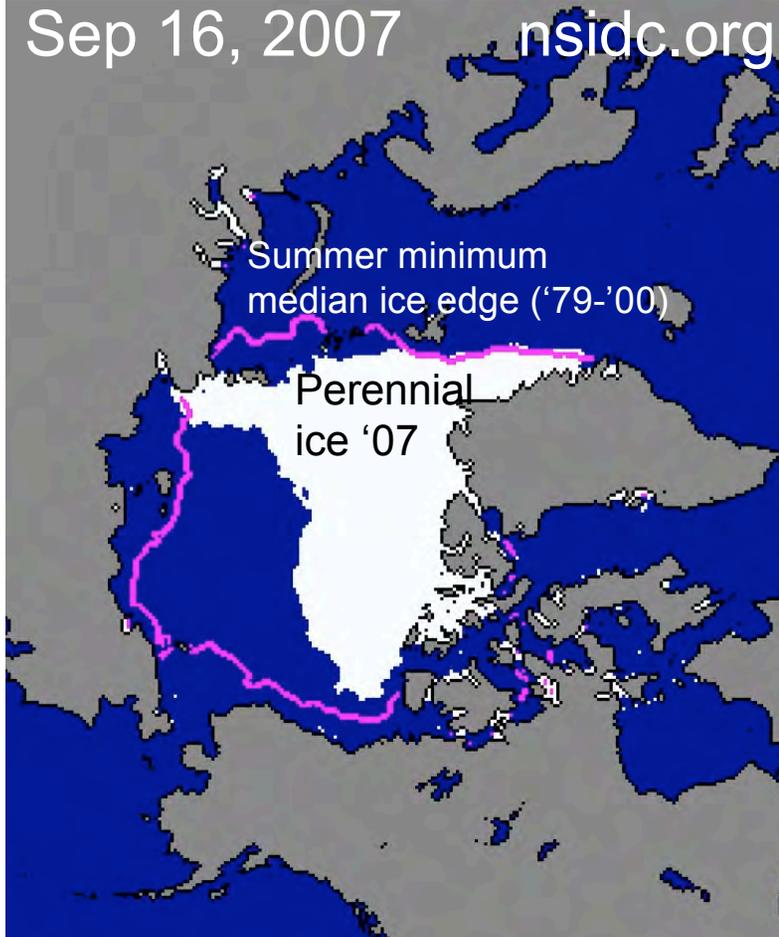
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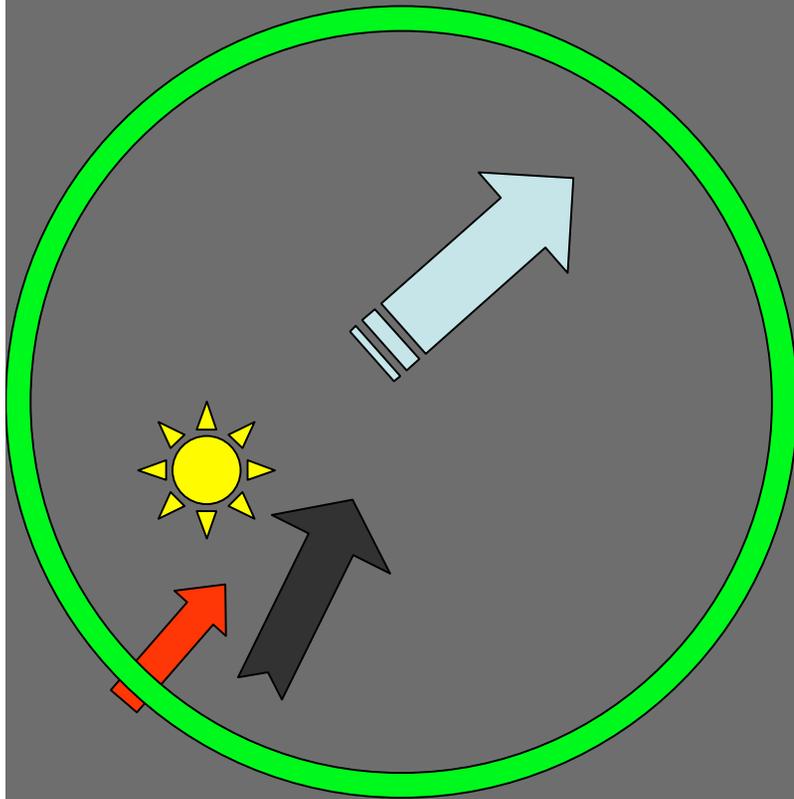
# Arctic sea-ice summer extent

Sep 16, 2007 nsidc.org



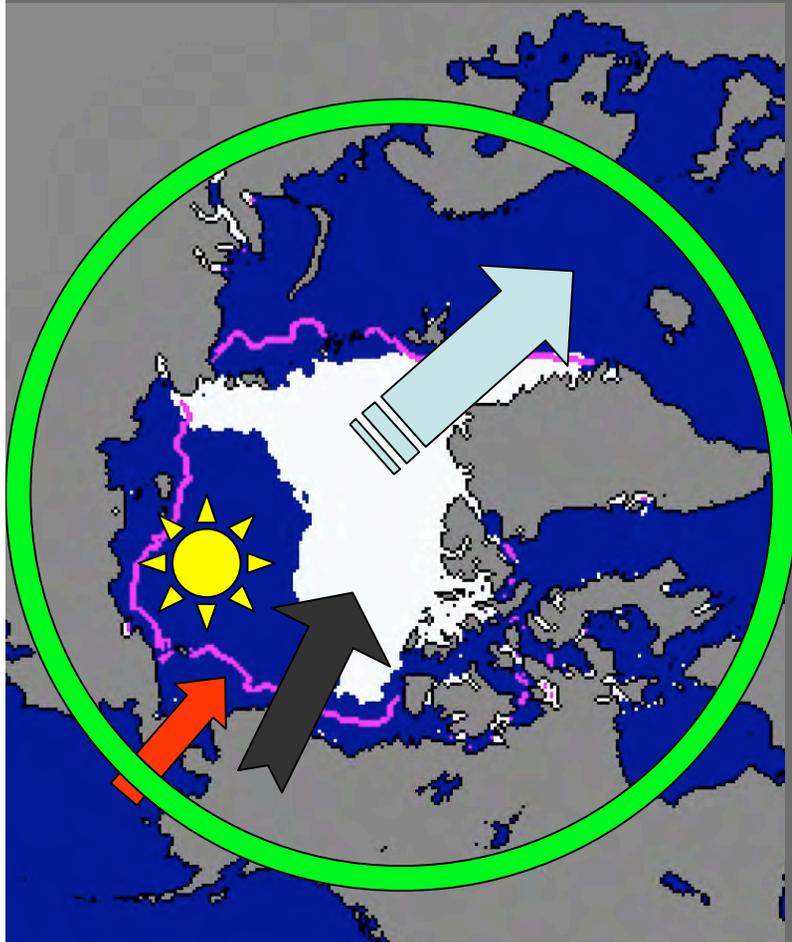
- 2007 record sea-ice minimum, almost one quarter less in extent than previous record minimum in 2005
- Winter ice extent is decreasing but at much slower rate: More seasonal ice!

# The 2007 record minimum Arctic sea-ice summer extent: Possible explanations



- (1) Longer-term retreat pattern roughly in line with what is predicted as result of global warming
- (2) Thinner, younger, more mobile ice moves & retreats more quickly in summer
- (3) Southerly winds brought warm air and moved ice towards North Pole in 2007
- (4) Warm inflow of water through Bering Strait (?)
- (5) Warming of water north of Alaska as a result of thinned & reduced ice cover melts back ice from below in summer (>7 feet of summer bottom melt north of Alaska!)

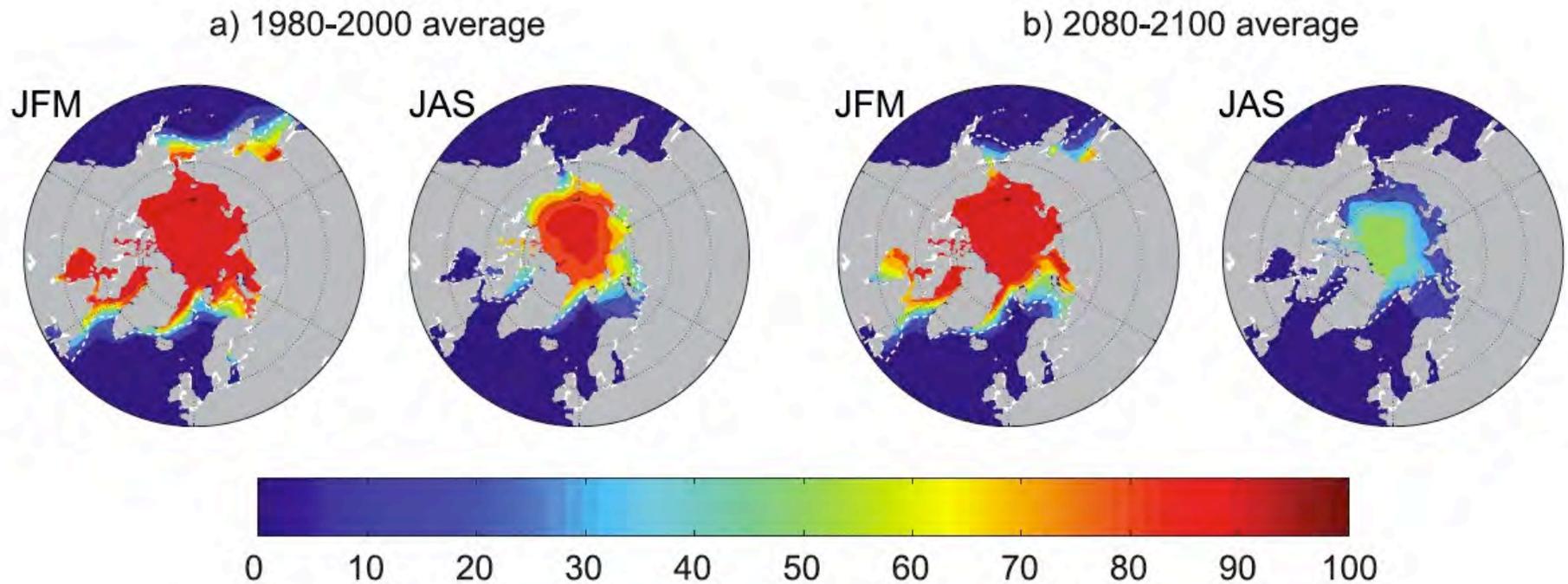
# The 2007 record minimum Arctic sea-ice summer extent: Possible explanations



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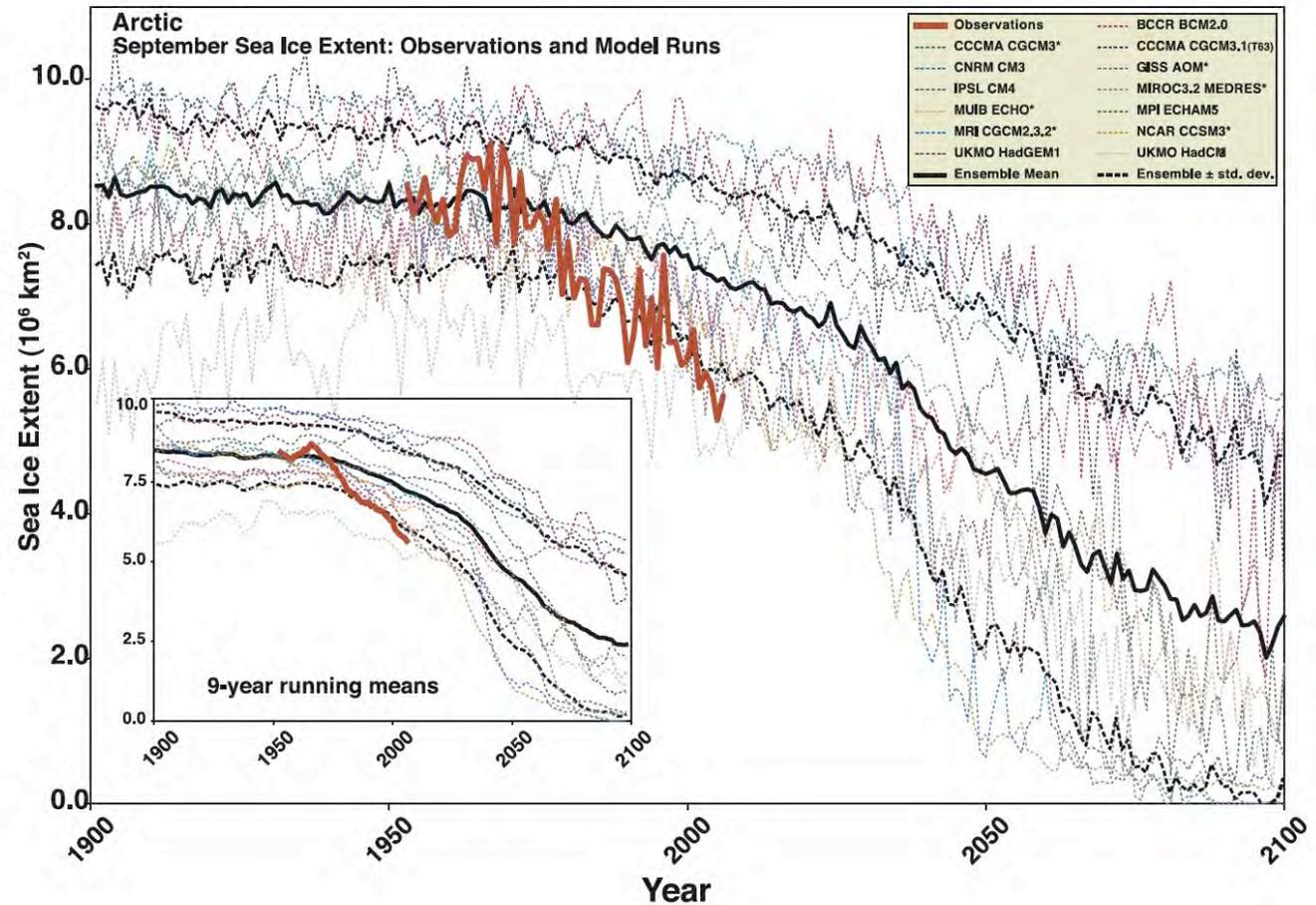
# The Arctic sea-ice cover: Model projections

Meehl et al., 2007



# The Arctic sea-ice cover: Model projections

- Recent summer reductions somewhat faster than models predict
- Several plausible explanations, related to how albedo, ice thickness and other factors are simulated



Stroeve et al., 2007

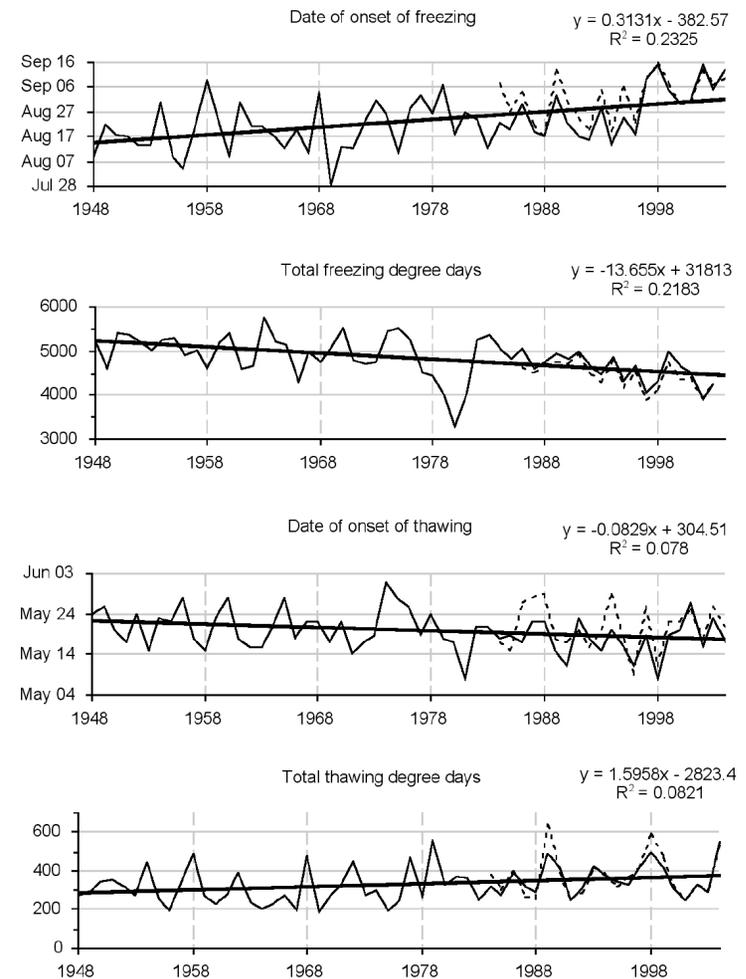
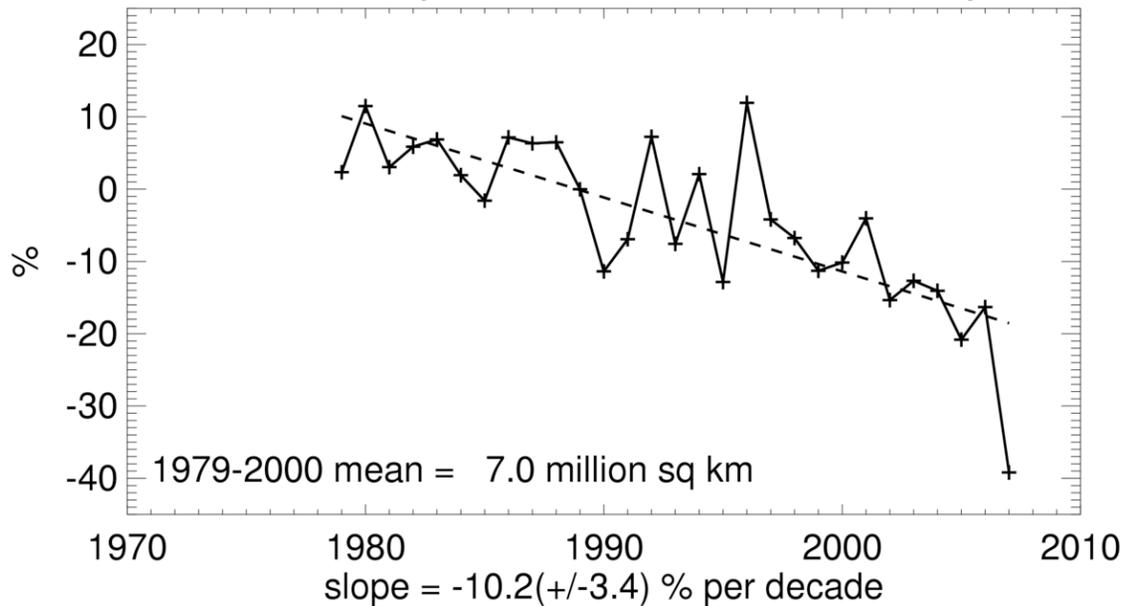
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# Minimum ice extent anomalies, onset of freezing/melt, freezing/thawing degree-days

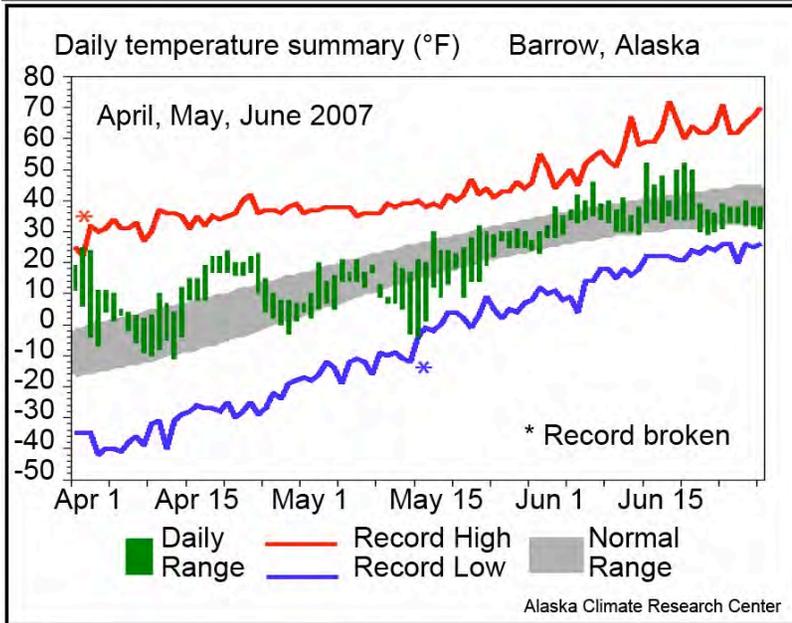
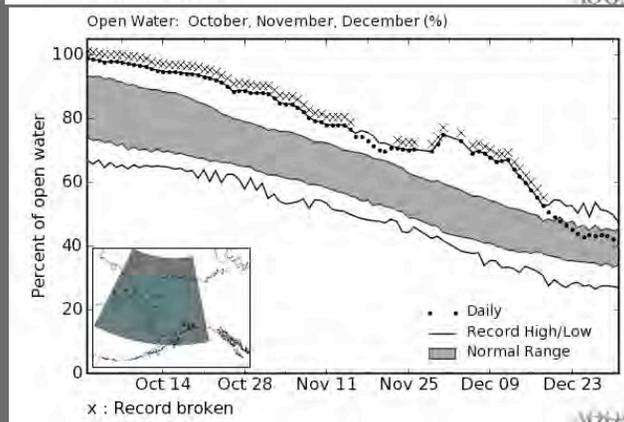
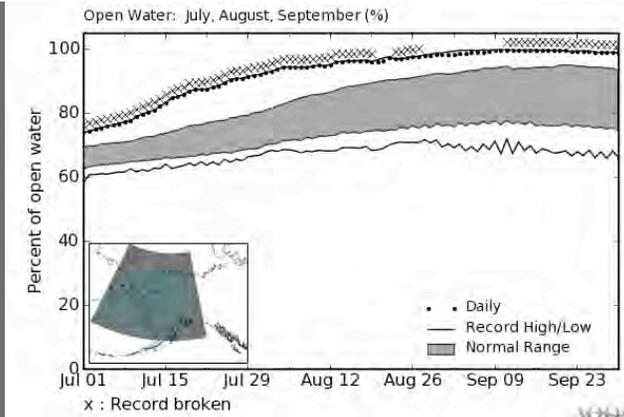
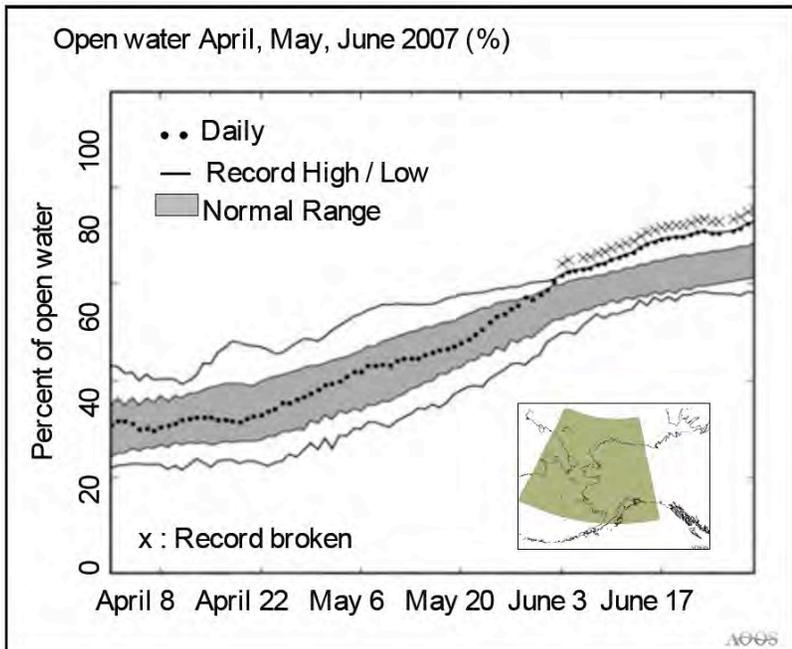
Northern Hemisphere Extent Anomalies Sep 2007



NSIDC (2007)

- Reduction in summer ice
- Beaufort/Chukchi Seas: Later freeze-up, reduced freezing degree-days

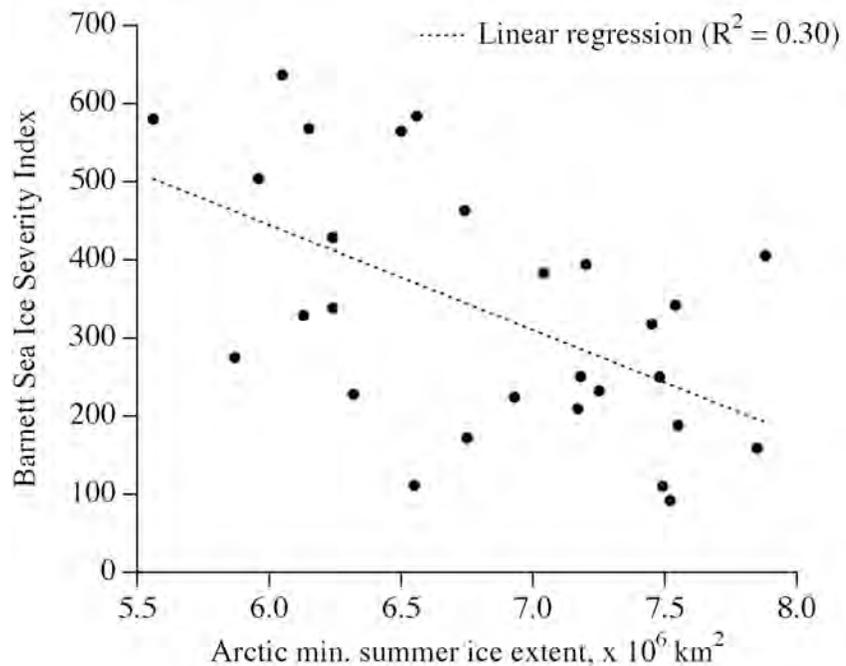
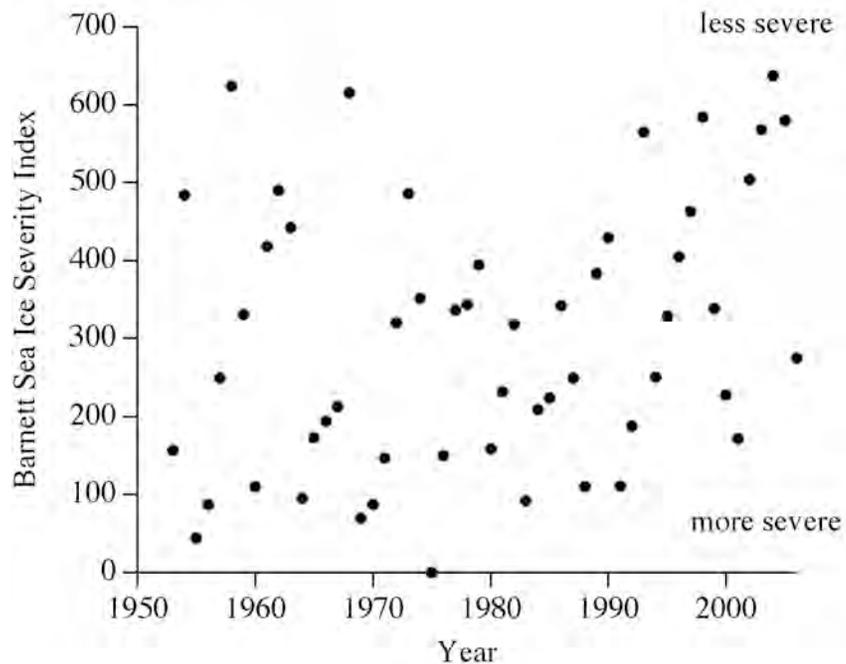
Mahoney et al. (2007)



2007:  
Record  
ice year  
in Alaska?

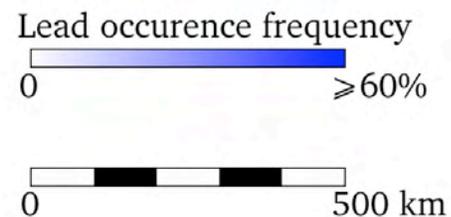
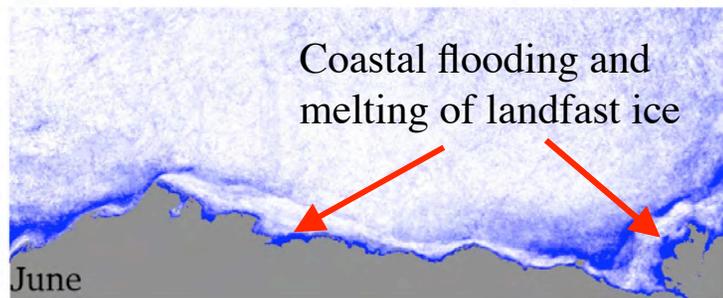
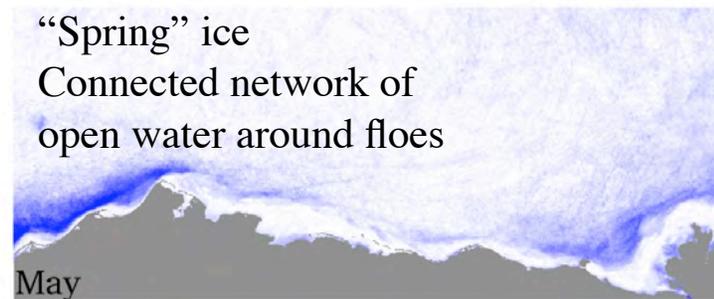
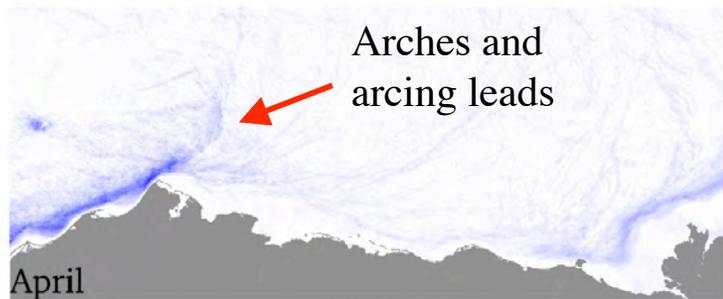
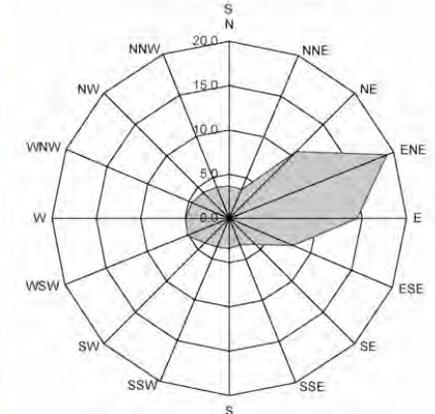
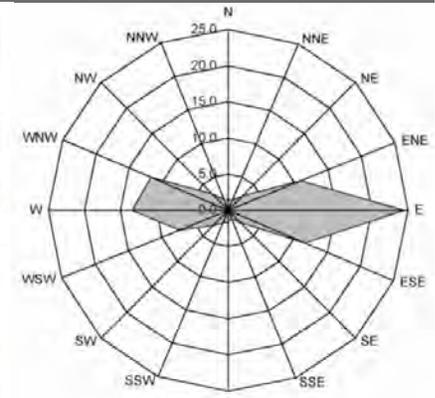
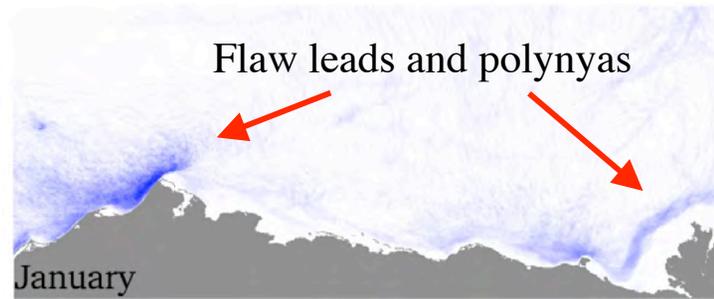
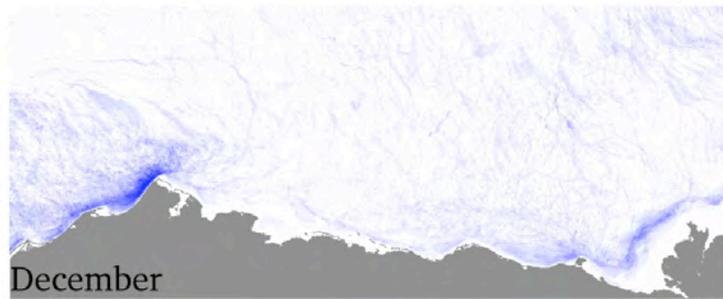
- From June 2007, amount of open water at record high through Nov
- Barrow air temperature normal in early summer, above-normal (records broken on 5 days) in late summer

# Summer ice variability: Regional ice regime vs. Arctic ice regime



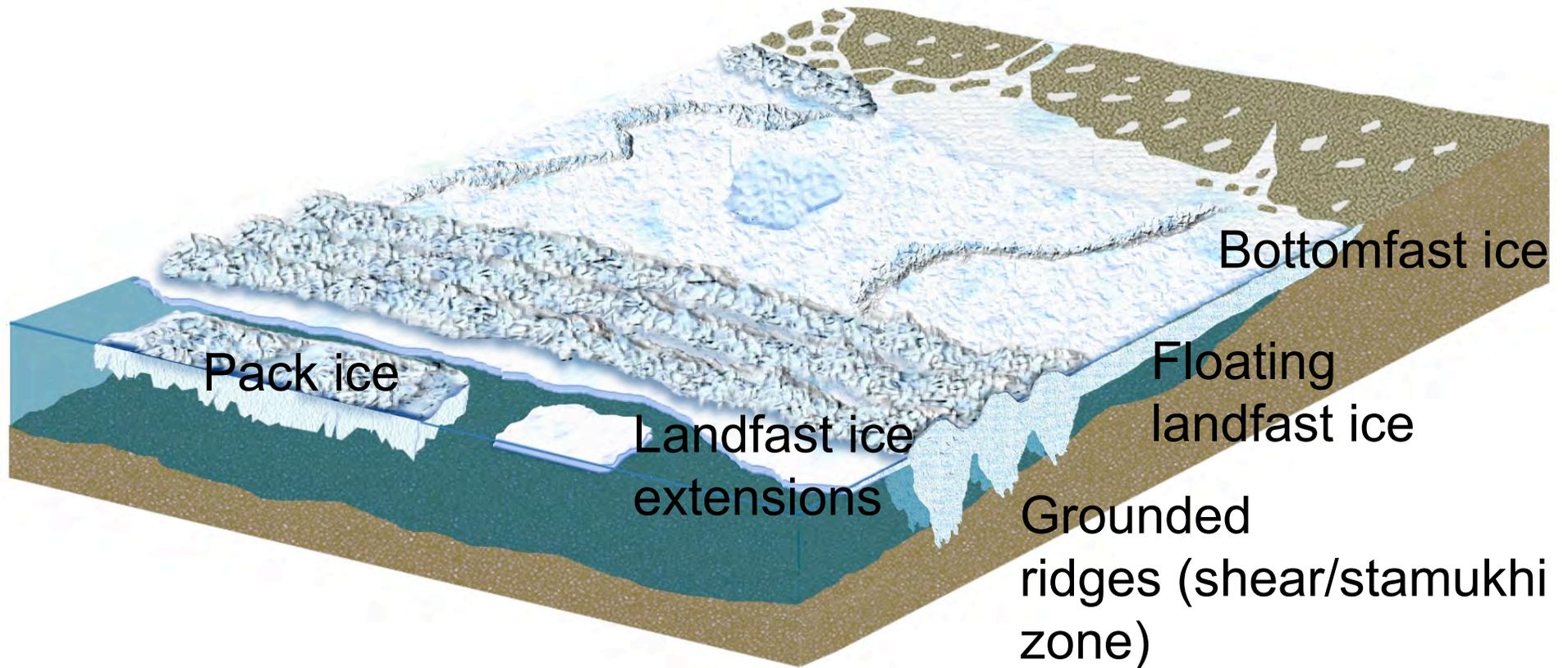
- Length of Barrow-Prudhoe navigation season, severity of ice in coastal Chukchi-Beaufort Sea in August-September (computed by National Ice Center)
- Resolution/accuracy of remote sensing data
- Interannual & local variability
- Summer ice incursions

# Lead occurrence patterns (1993-2004)

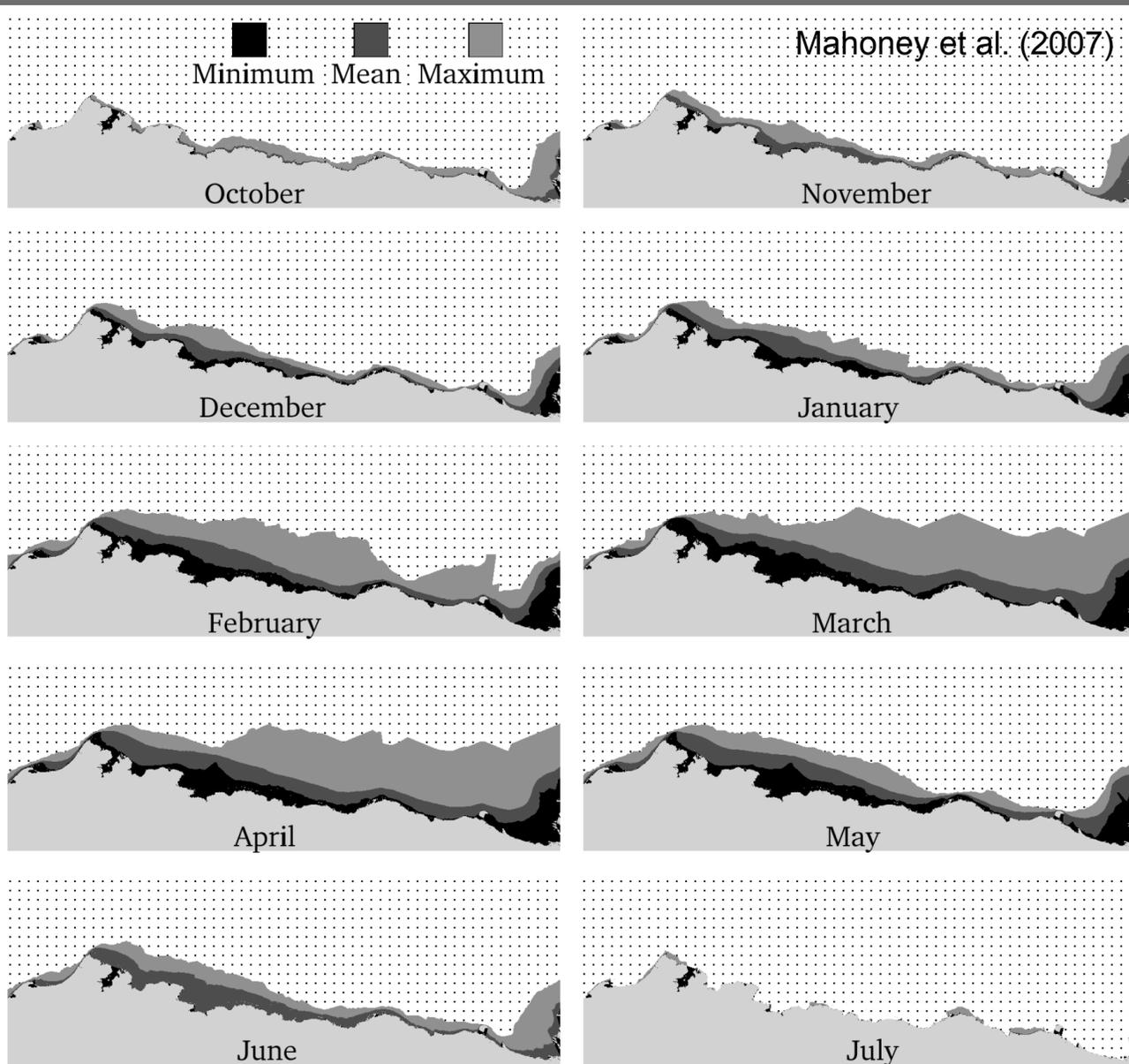


- Winds mostly from ENE (Barrow, 1971-2000) or E (Barter Island, 1971-1988)

# Landfast ice zone



# Seasonal cycle of landfast ice extent



- Mean controlled by bathymetry
- Maximum controlled by pack/landfast ice interaction (stable extension)
- Minimum controlled by break-out events
- Iñupiaq ice experts: Break-outs much more frequent since early 1990s

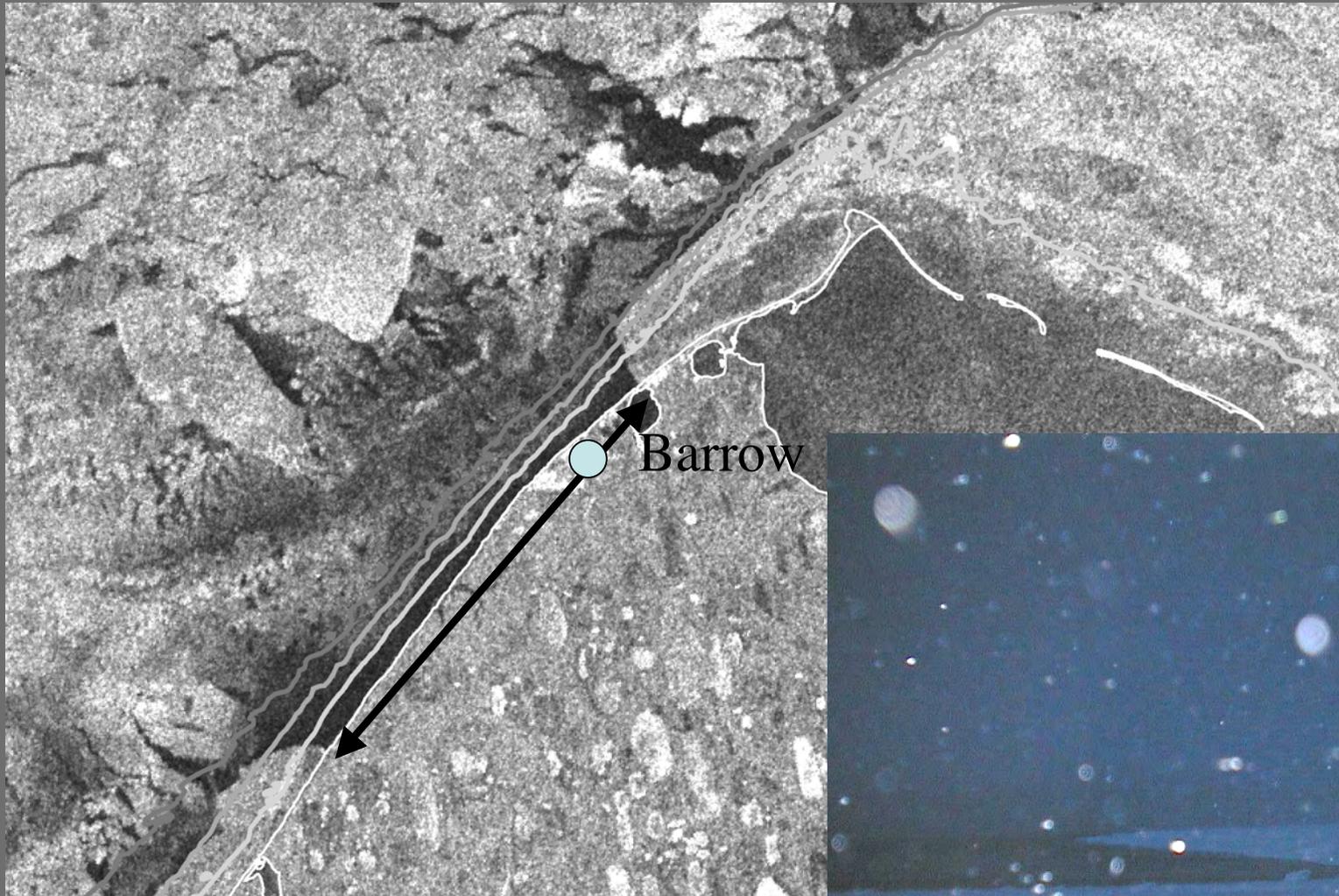
1996-2004: E Chuk West Centr East Beauf Barry et al. (1979a)

		Zone 1	Zone 2	Zone 3	Zone 4	All zones	Central Chukchi	Central Beaufort	
<b>First Ice*</b>	<b>Mean</b>	Dec 01	Oct 25	Nov 04	Nov 9	Nov 7	Early November	Mid October	<b>First continuous fast ice</b>
	$\sigma'$	31.8	9.6	11.4	17.5	16.4			
<b>Stable Ice</b>	<b>Mean</b>	Feb 23	Jan 22	Jan 28	Jan 27	Feb 01	Feb	Jan/Feb	<b>Stable ice inside of 15 m isobath</b>
	$\sigma'$	41.9	30.1	32.6	34.9	34.1			
<b>Break up</b>	<b>Mean</b>	Jun 04	Jun 11	Jun 04	May 26	Jun 06	Jun 10	Jun 30	<b>First openings and movement</b>
	$\sigma'$	13.9	14.2	13.7	12.6	14.6			
<b>Ice Free</b>	<b>Mean</b>	Jun 18	Jun 24	Jun 24	Jun 06	Jun 18	Jul 05	Aug 01	<b>Nearshore largely free of fast ice</b>
	$\sigma'$	12.7	8.4	12.6	10.2	10.4			

\*1996-1998 omitted from analysis

Mahoney et al. (2007)

# Winter sea-ice break-out events



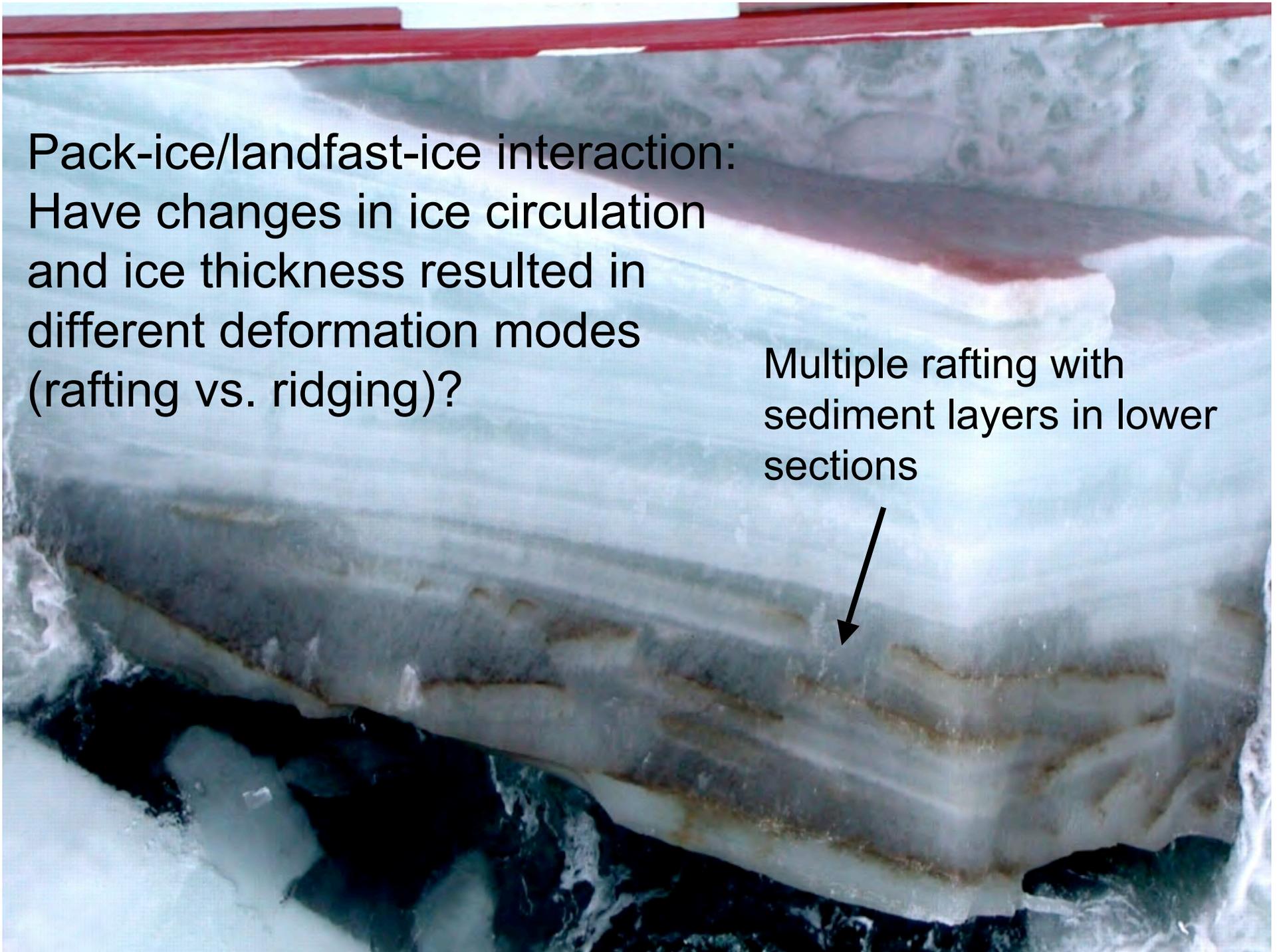
December 13, 2001: Ice breaks out from stretch of coastline SW of Barrow past NARL (>15 km)



Photo: Craig George

Pack-ice/landfast-ice interaction:  
Have changes in ice circulation  
and ice thickness resulted in  
different deformation modes  
(rafting vs. ridging)?

Multiple rafting with  
sediment layers in lower  
sections



# Ice Push events (ivu)

Photo: A. Jensen



Fbks Daily News-Miner  
Jan 25, 2006

The voice of Interior Alaska since 1903  
WEDNESDAY, JANUARY 25, 2006

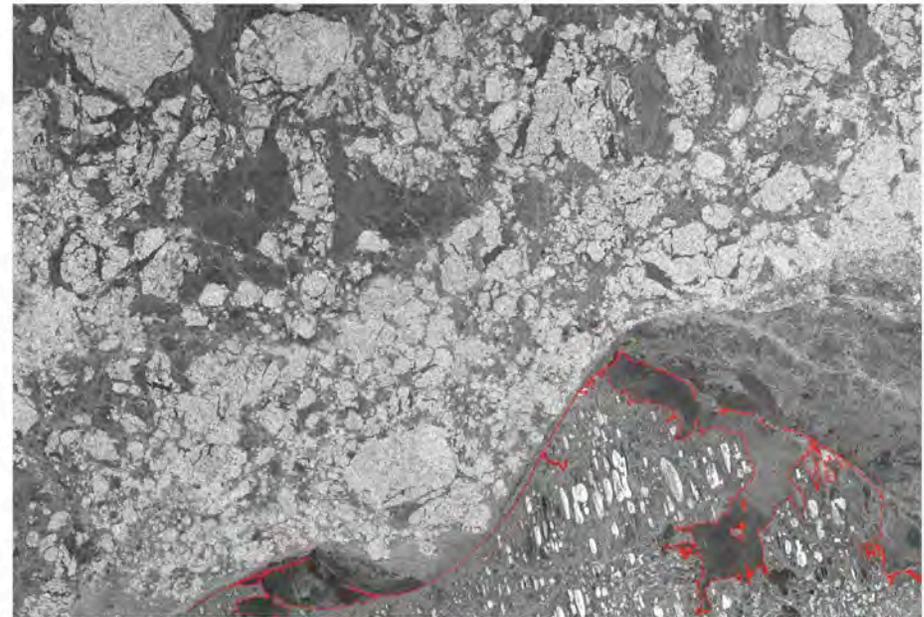
www.newsminer.com



John Tidwell photo

**SEA ICE**—Heavy equipment operators clear Arctic Ocean ice from Stevenson Street in Barrow on Tuesday after winds and currents carried it ashore. No structures or utilities were damaged when the ice began rolling ashore around 5:30 a.m., catching residents and Barrow officials by surprise.

## Ice ashore



RADARSAT ScansAR Wide Beam 20060123 GMT: 17:12:34

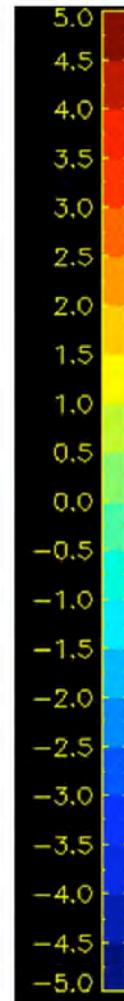
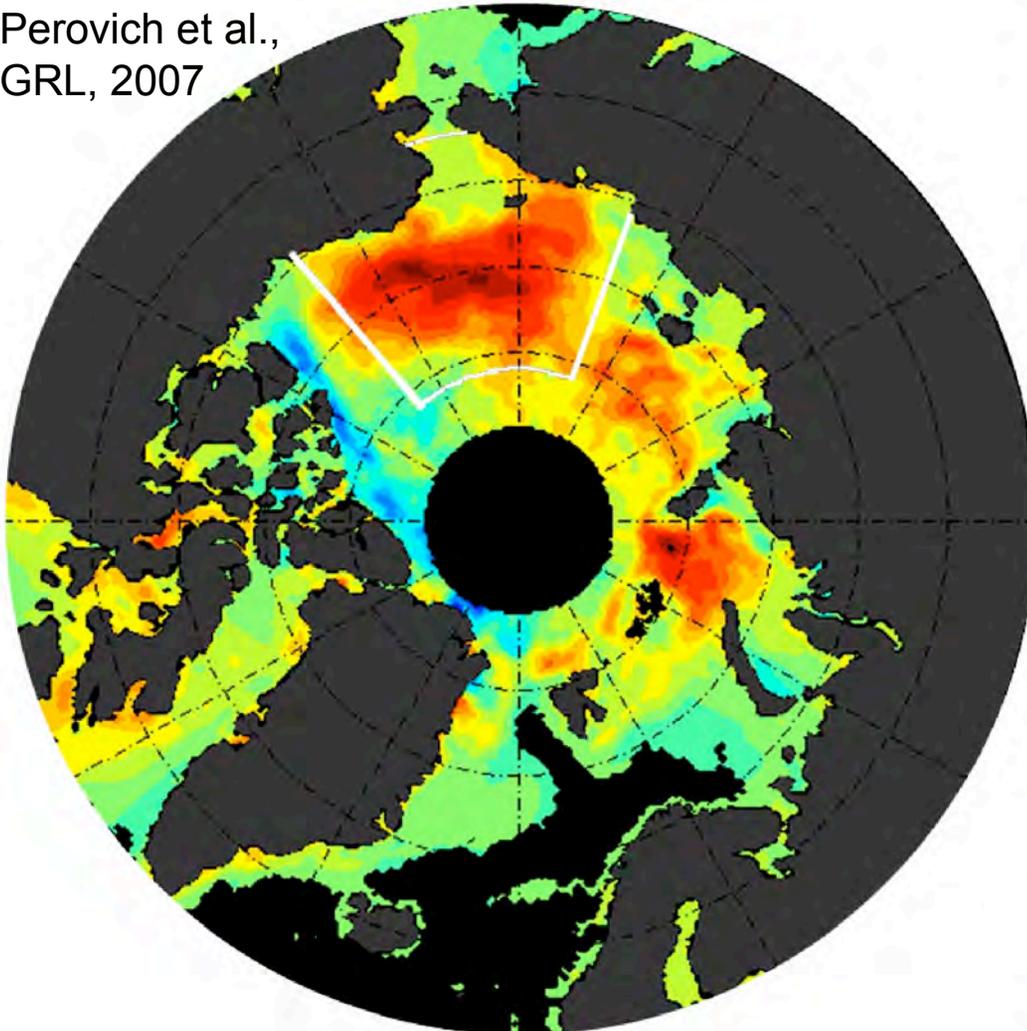
0 10 20 30 40 50 Kilometers

Source: Canadian Space Agency downlinked by the Alaska Satellite Facility. Processed by Allison Gaylord, Nuna Technologies.

# Solar heating of surface waters in pack ice

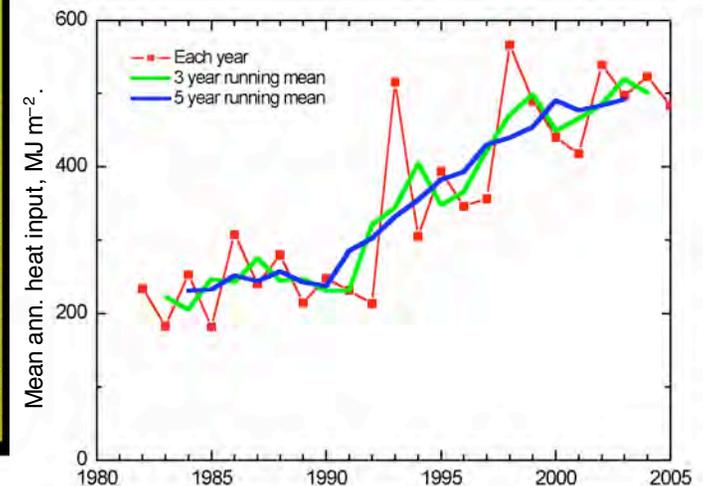
Solar heating linear trend ( $\% \text{ yr}^{-1}$ )

Perovich et al.,  
GRL, 2007



- Oceans north of Alaska have received at least twice as much heat from sun in recent years compared to 1980s

Solar heat input at  
 $75^\circ \text{N } 165^\circ \text{W}$



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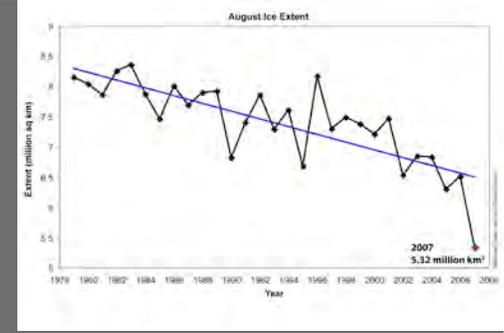
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Barrow Whaling camp  
(Photo: Bill Hess)

# A changing North

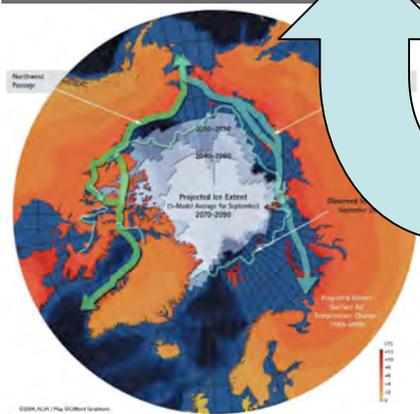
Regime shifts in climate and the environment that are about to exceed range of past variability and change



NSIDC

Sweeping impacts of change on Northern populations and cultures

ACIA



Increasing inter-dependence between the Arctic region and global processes

Expansion of global geopolitical and economic interests into the North

AK Sea Ice Change & Impacts on Human Activities

BP Northstar  
Photo: BP



# Sea-ice system services

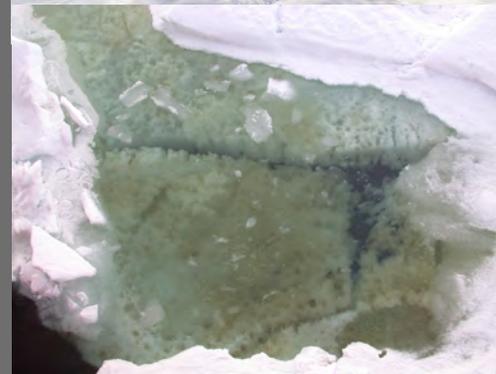
- Regulating
  - Climate regulator
  - Marine & coastal hazard
  - Stabilizing element in coastal zone
  - Geologic agent (ice rafting of sediments, bottom interaction)
- Provisioning
  - Transportation corridor
  - Platform (industry & subsistence)
  - Freshwater source
  - Source of food
- Cultural
  - Subsistence activities
  - Ice as part of cultural & spiritual landscape (incl. tourism)
- Supporting
  - Ice-based foodwebs
  - Reservoir and driver of biological diversity (e.g., extremophiles)



(1) Icescape



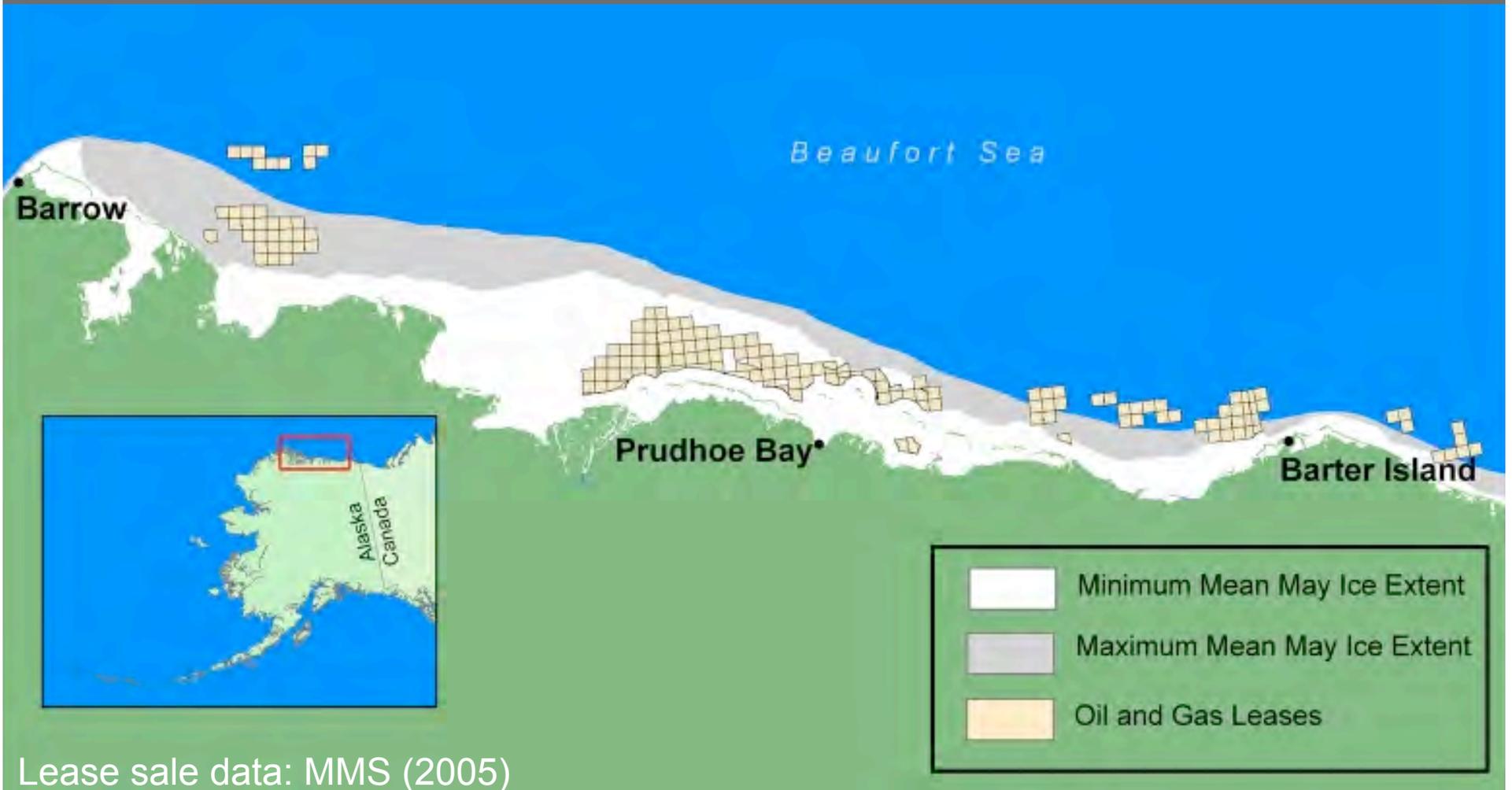
(2) Platform & Hazard

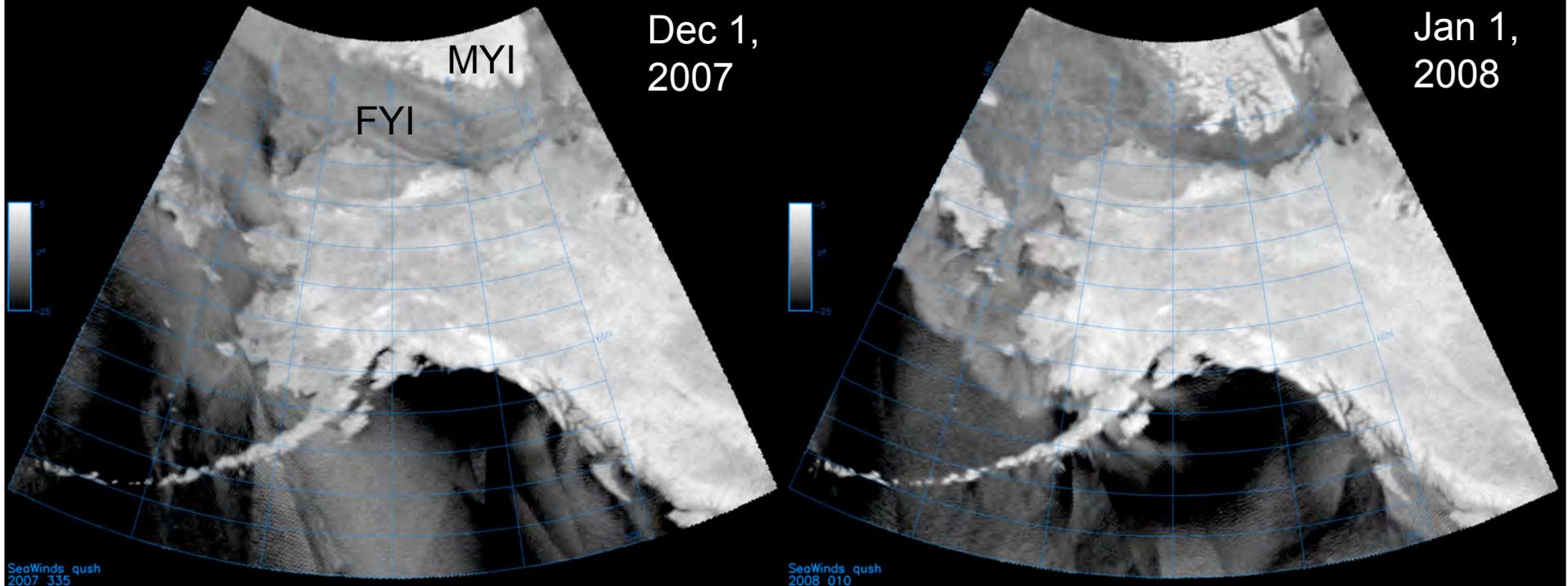


(3) Habitat



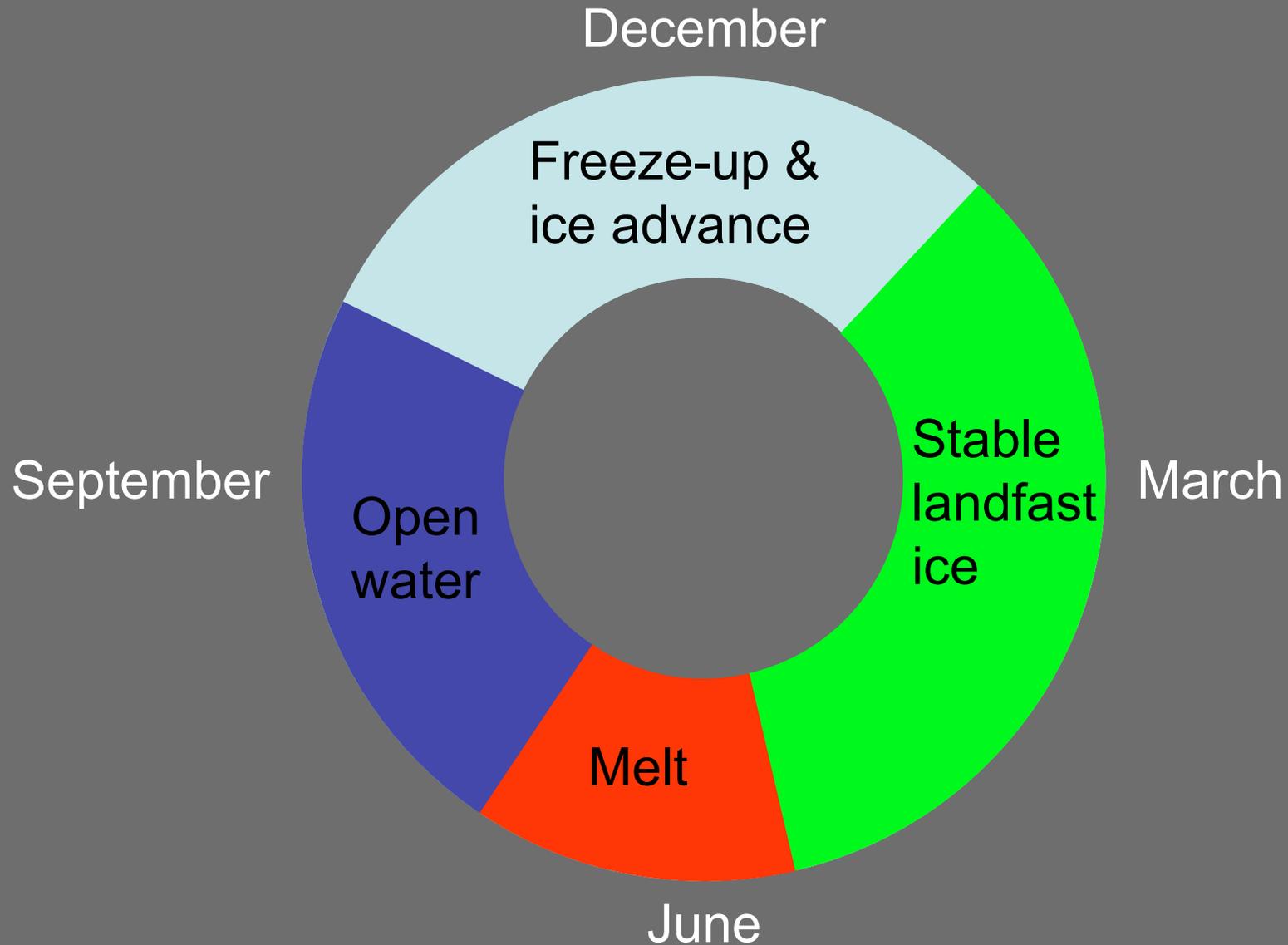
# Lease areas in relation to ice conditions



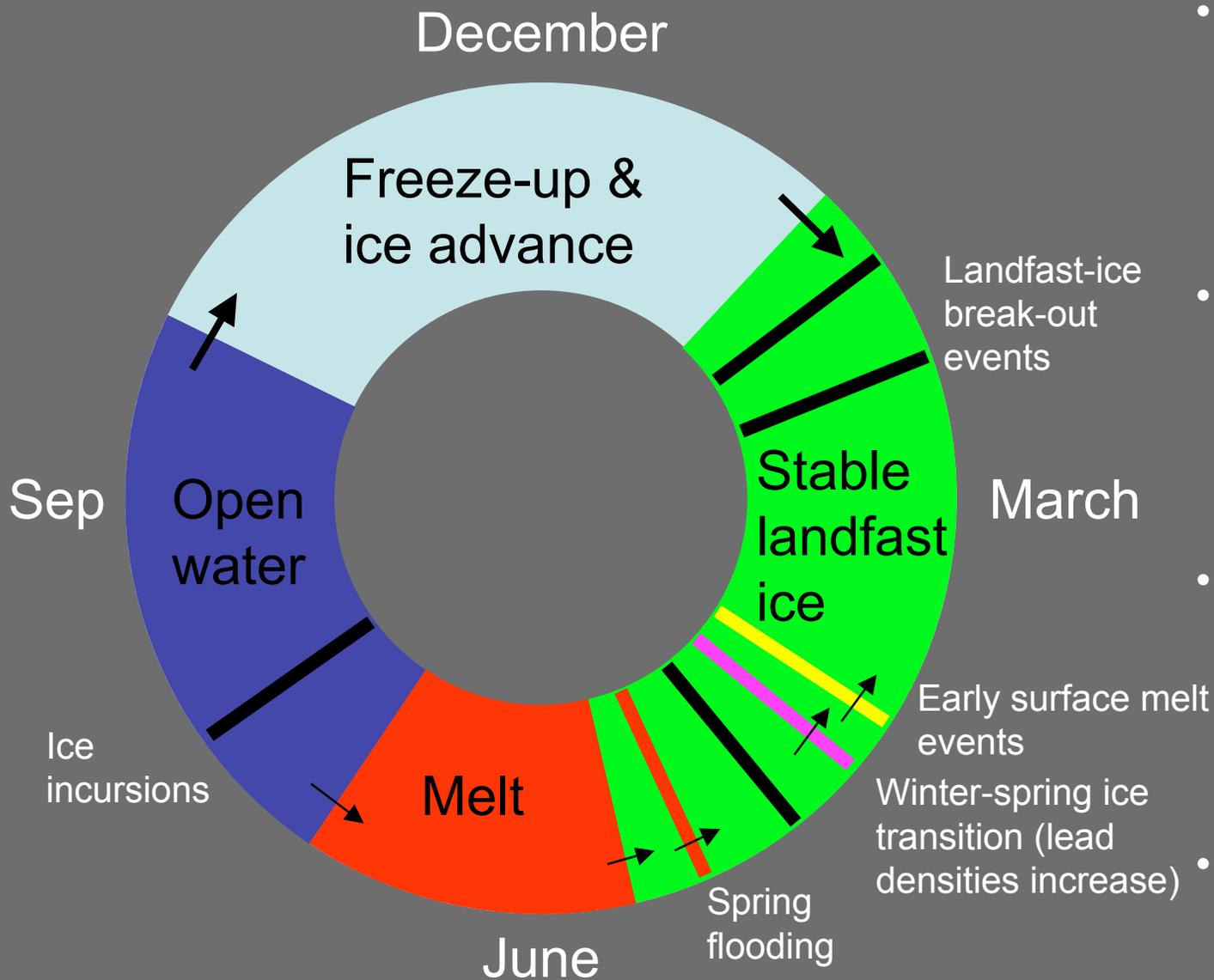


- Ice circulation patterns help bring old (multiyear) ice to Beaufort Sea coast
- If normal ice drift pattern persists, multiyear ice likely to arrive at Barrow by mid/late spring

# Annual sea-ice cycle & operational windows



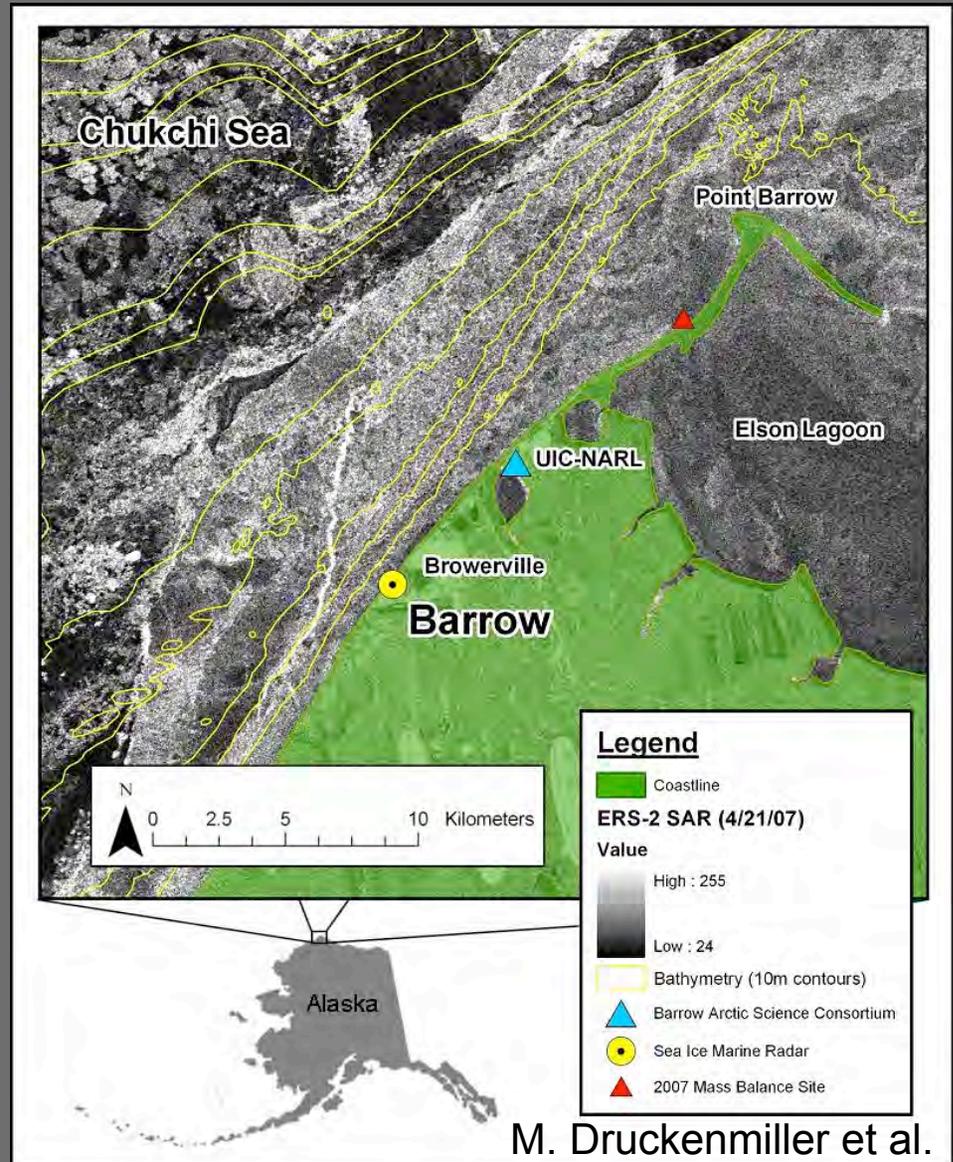
# Annual sea-ice cycle & operational windows



- Open-water operations regime longer, potential for ice incursions
- Landfast-ice operations regime shorter, potential for break-outs
- Coastal & offshore ice regime more variable in time & space
- Highly specific to a given location

# The value of integrated sea-ice observations

- *Remote sensing* (km-scale): Ice extent and evolution
- *Coastal radar* (sub-km scale): Ice dynamics and evolution
- *EM thickness and DGPS topography* surveys (sub-km scale)
- *Ice mass-balance* site (10s m-scale): sealevel , water temperature, ice & snow thickness & temperature
- *Local ice observations* (J. Leavitt, A. Brower Sr. and others): Iñupiaq expertise & ice use, annual cycle
- Seasonal Ice Zone Observing Network (SIZONet) IPY Project



# IPY-1 at Barrow: US Signal Corps Station

- Observation Hut (parts in all likelihood still on site)



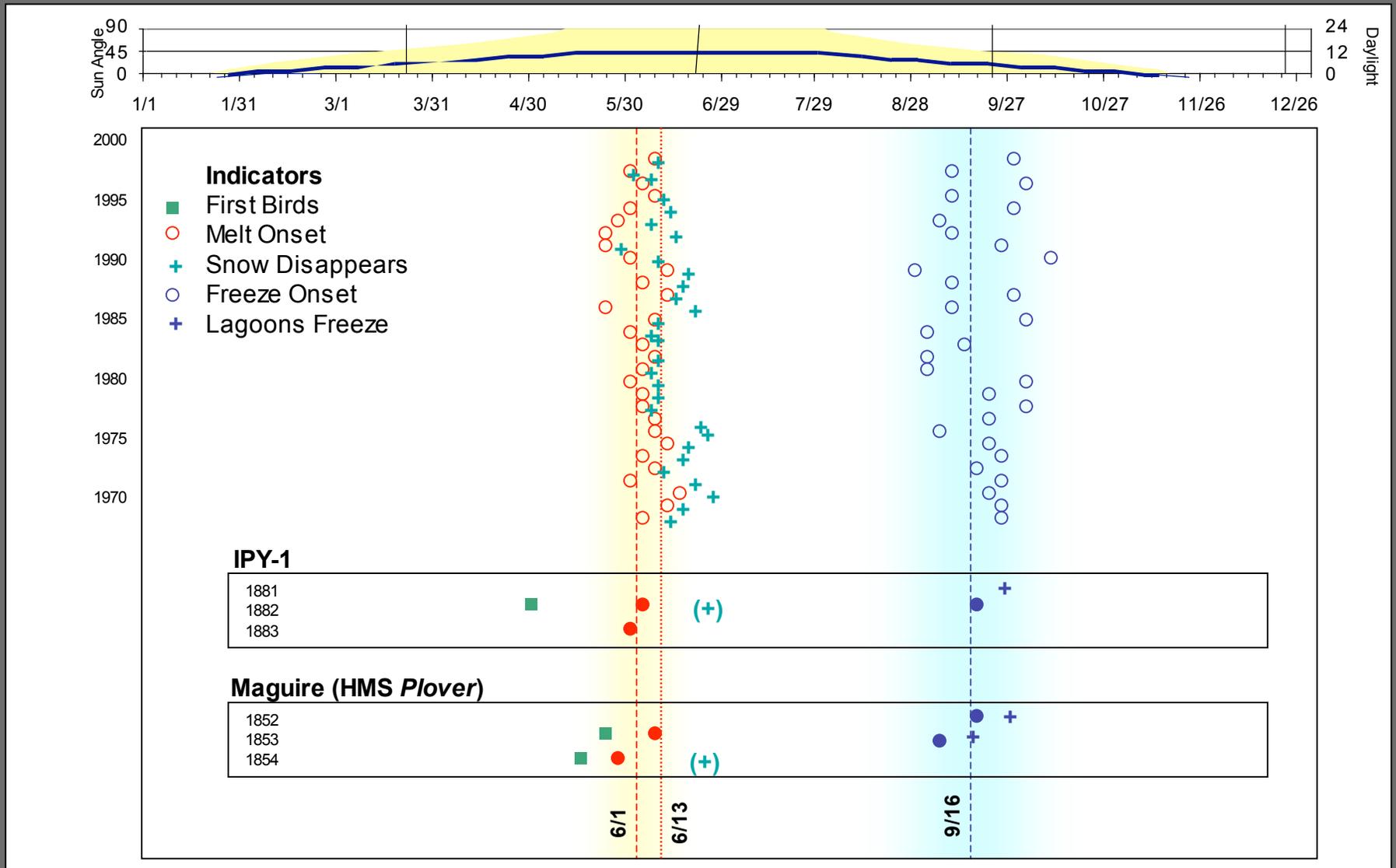
FRONT VIEW OF MAIN BUILDING, UNITED STATES SIGNAL STATION.  
POINT BARROW, ALASKA.

- Grounded ice off the beach in August 1883



ARCTIC OCEAN FROM THE STATION, AUGUST, 1883.

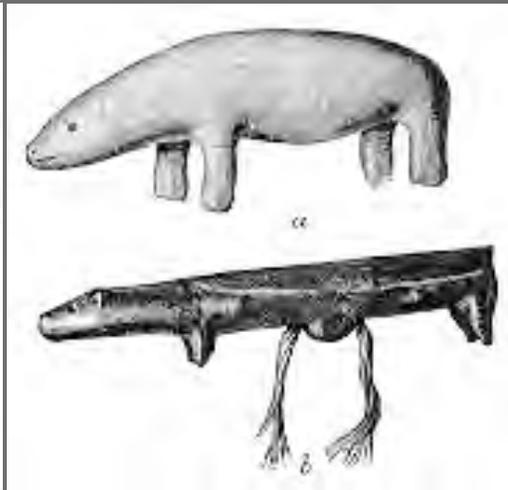
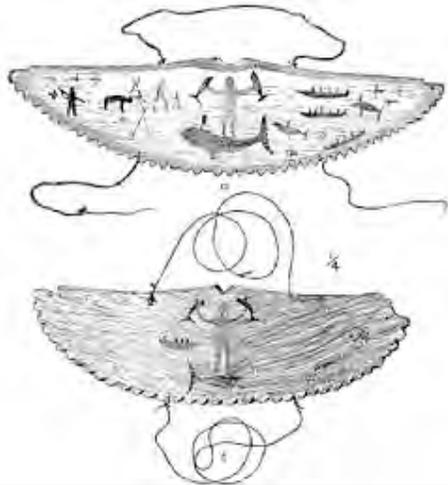
# IPY 1882/83 in context: Melt/Freeze at Barrow (K. Wood, 2004)



Data sources: US Naval Observatory, Astronomical Applications. NOAA NCDC. R. Stone, NOAA CMDL (Snowmelt). P. Ray, Report of the Point Barrow Exp. R. Maguire, Journal

# Advice & guidance from Iñupiat experts

- Murdoch, John. *Ethnological Results of the Point Barrow Expedition*. Washington, D.C.: Smithsonian Institution Press, 1988. Reprint. Originally published: 1892.



**Erk-sing-ra: source of local knowledge recorded by Capt. Maguire at Point Barrow in the 1850s. “[We] had worse seasons before the Ship came...”**

*Journal of Rochefort Maguire.*  
Photo: *US National Archives.*

# Conclusions

- Open water season: longer, potential for ice incursions (ice detection)
- Landfast ice: extent little changed, less stable (lack of grounded ridges and stabilizing factors)
- Coastal zone: Change in ice dynamics (rafting, sediment entrainment, break-outs)?
- Multi-year ice reservoir remains in Canadian Arctic with overall thinner ice: More variability
- Role of local expertise in responding and adapting to changing conditions

## Resources:

### **AOOS:**

[ak.aos.org](http://ak.aos.org)

### ***NWS Anchorage Ice Desk:***

[pafc.arh.noaa.gov/ice.php](http://pafc.arh.noaa.gov/ice.php)

### ***National Snow & Ice Data Center:***

[nsidc.org](http://nsidc.org)

### ***Barrow/Wales Ice Observatory***

[www.gi.alaska.edu/BRWICE](http://www.gi.alaska.edu/BRWICE)

[www.gi.alaska.edu/WLSICE](http://www.gi.alaska.edu/WLSICE)

### ***University of Alaska IPY Initiatives***

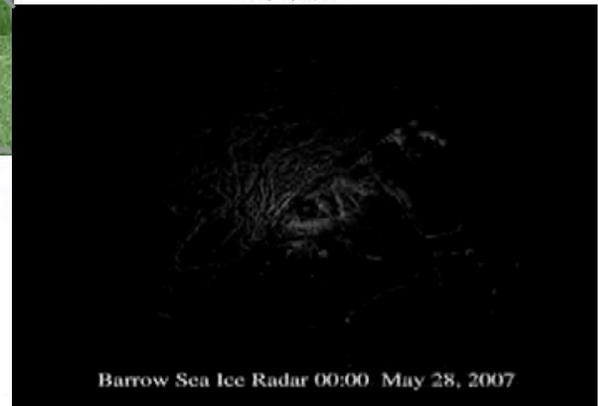
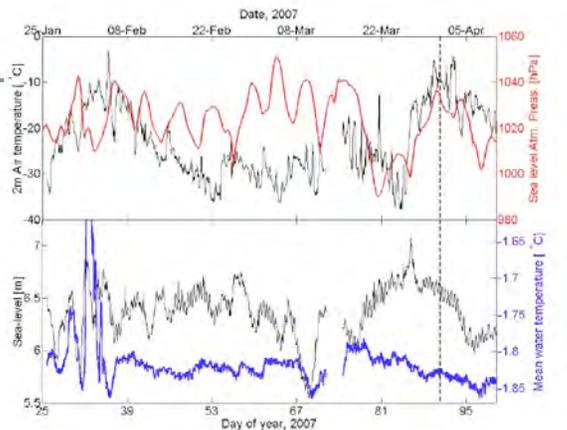
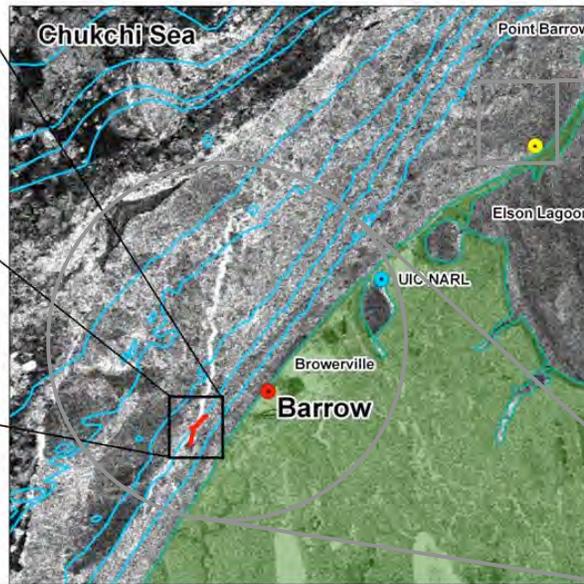
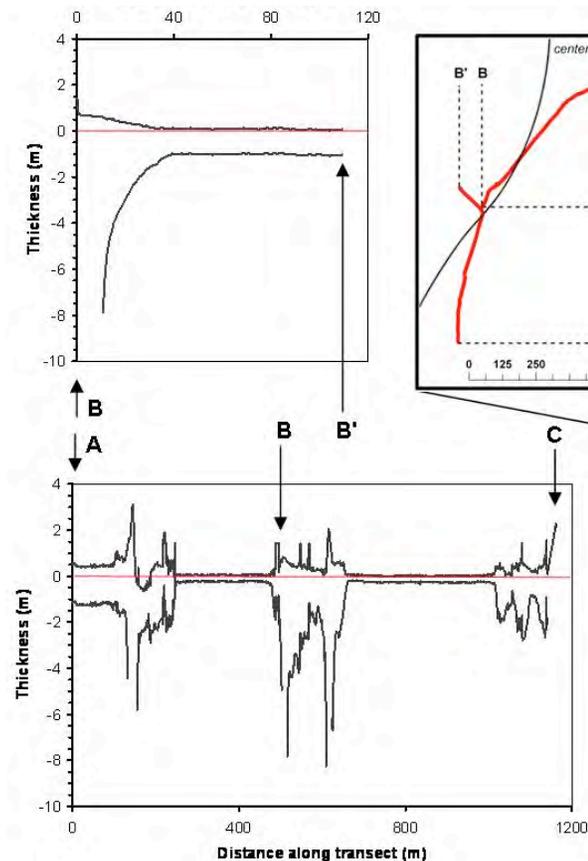
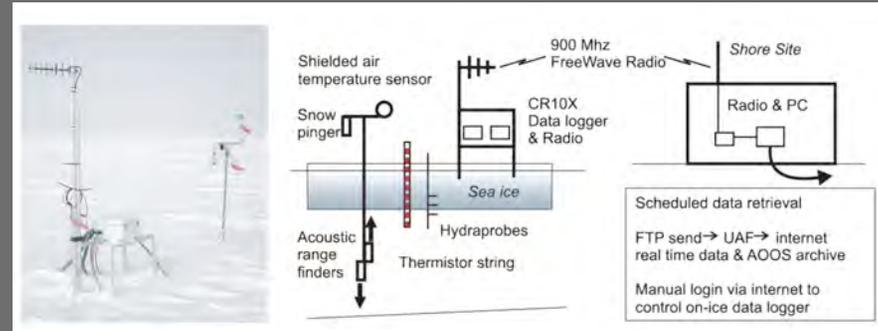
[www.alaska.edu/ipy](http://www.alaska.edu/ipy)

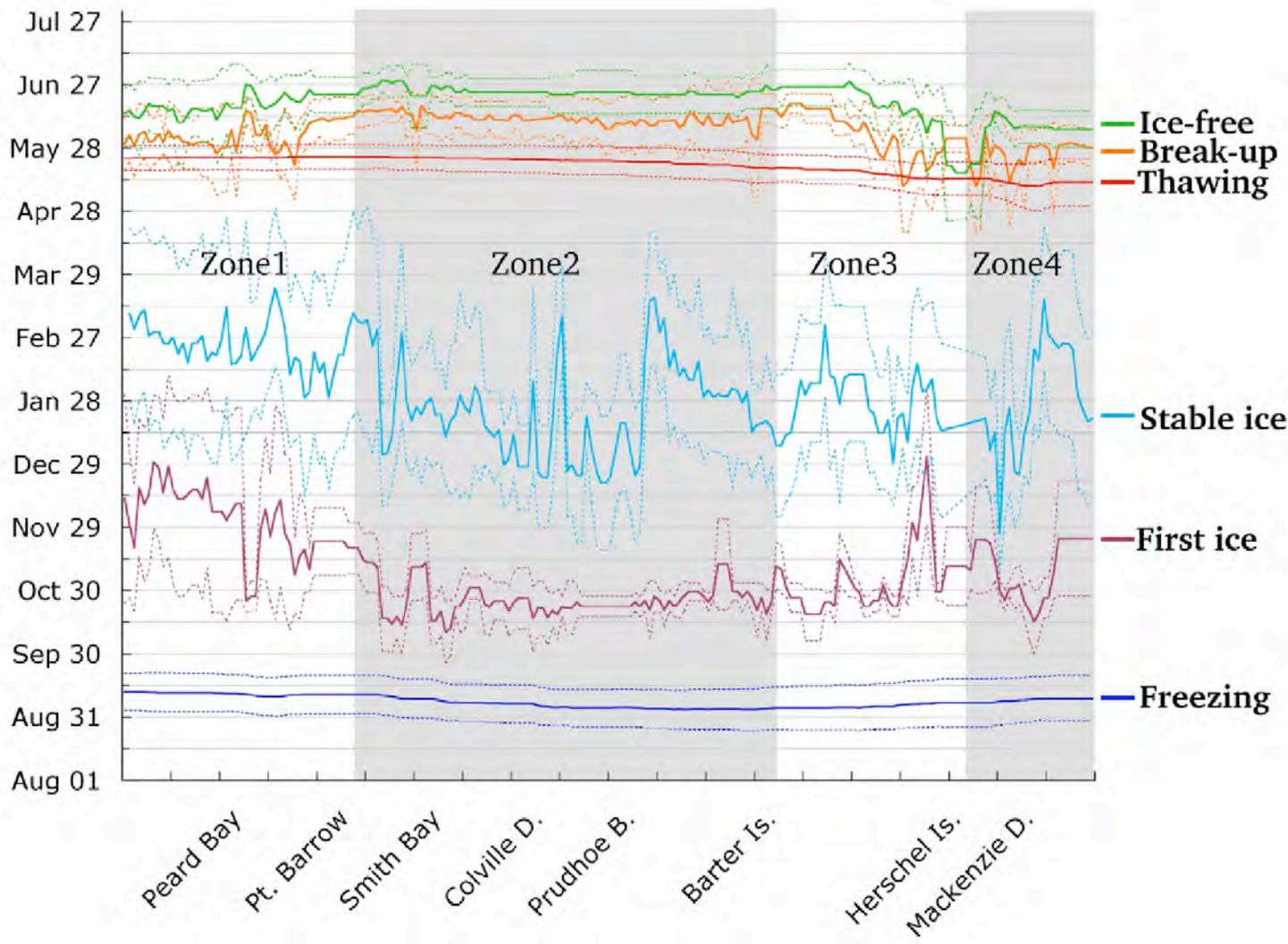
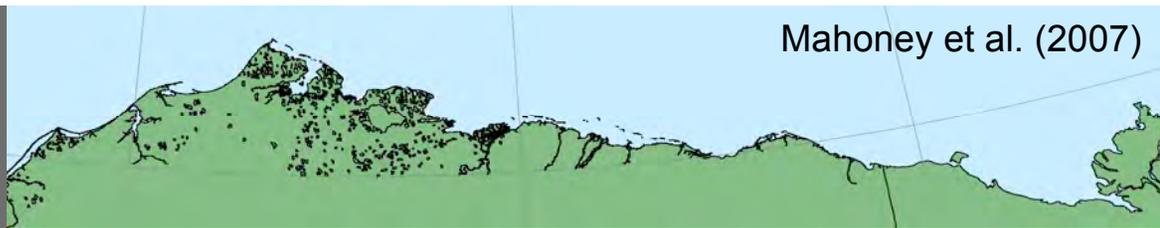
“North by 2020 - Forum for local and global perspectives on the North”

# Case study: Breakout event April 1 & May 28, 2007

No.	Event	Source
1	Few ridges were formed in the landfast ice region off Barrow due to a lack of a west wind.	Leavitt 2007b
2	There was a lack of multiyear ice incorporated into the landfast ice. Whaling crews had to haul freshwater to their camps as opposed to melting multiyear ice.	Brower, H. 2007
3	There was "low-profile" multiyear ice in the landfast ice off Barrow, as opposed to the "high-profile smooth hills of old ice" that people are used to seeing.	Brower, A. 2007b
4	There was an "instability" in the landfast ice due to "young ice forming later in winter." Also, the pressure ridges were smaller.	Aiken 2007
5	"Climate change will bring new ice conditions to the Chukchi [Sea]—young ice will pile up in a new way, even if thick heavy multiyear ice is not around."	Brower, H. 2006

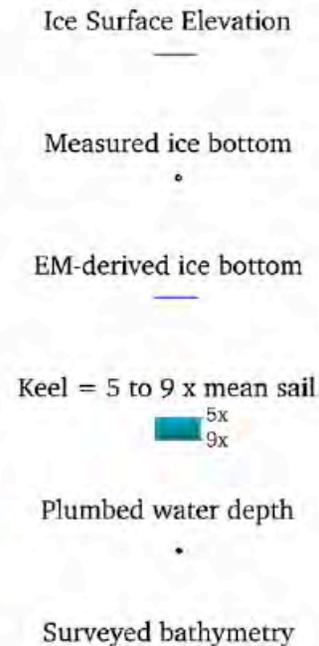
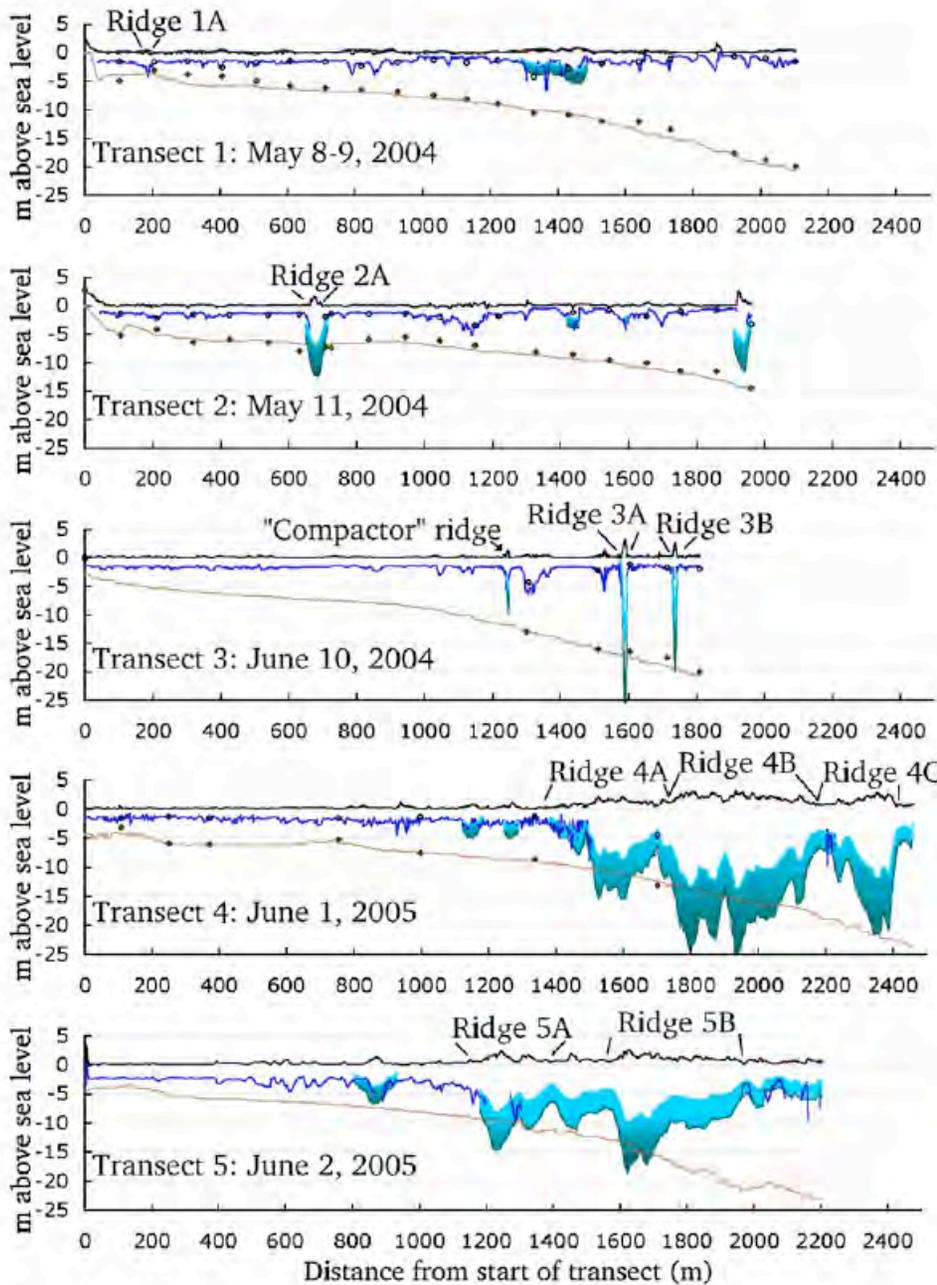
[www.gi.alaska.edu/BRWICE](http://www.gi.alaska.edu/BRWICE)





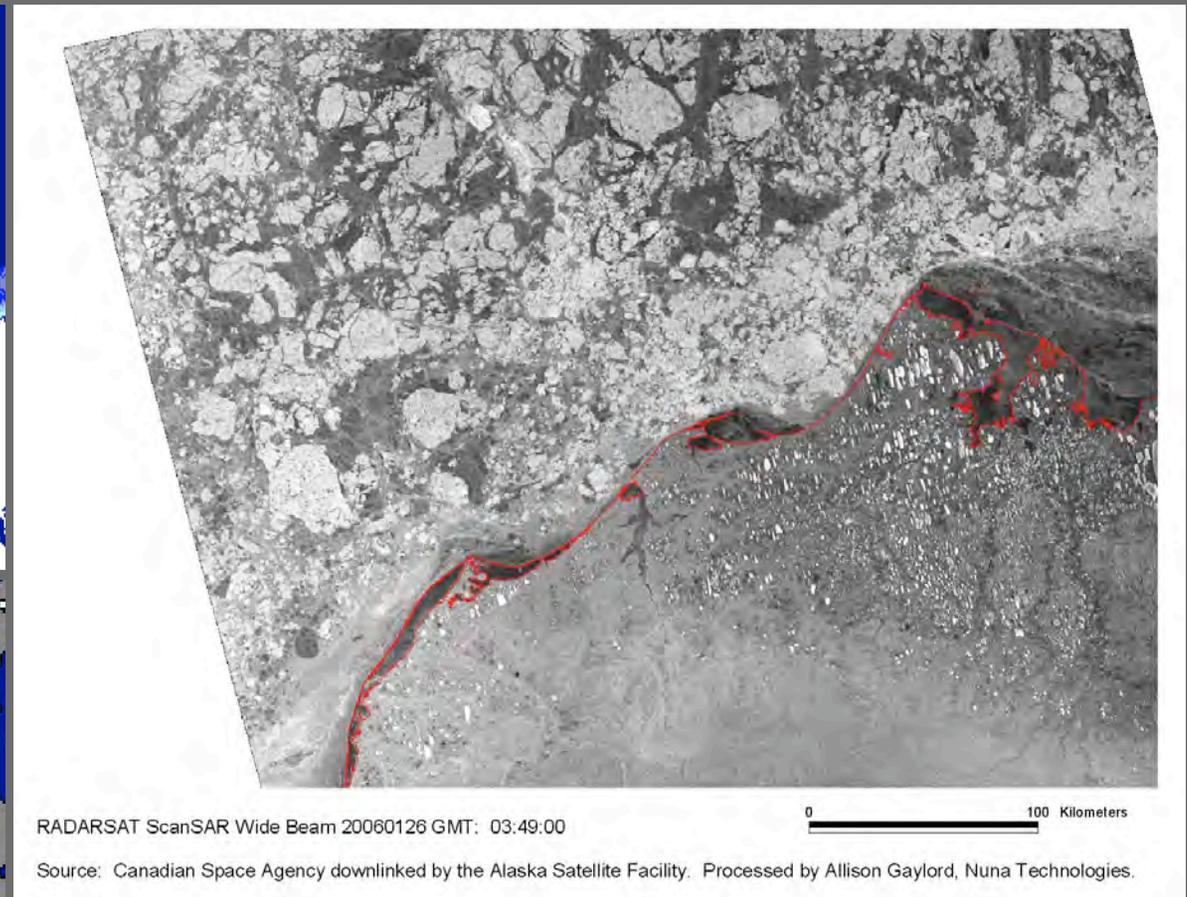
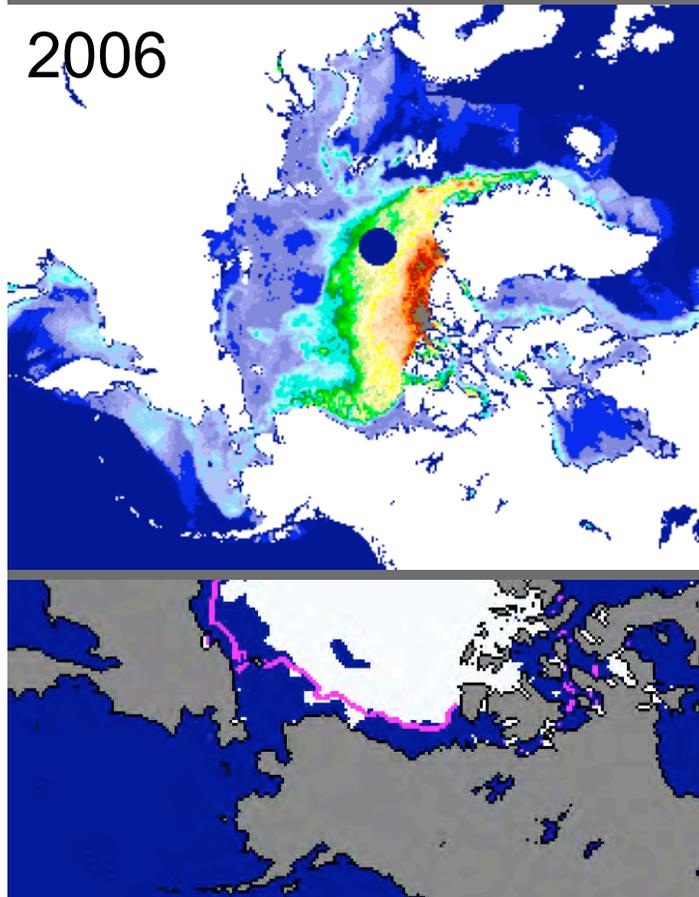
- Spatial and temporal variability in key seasonal events
- Early onset (e.g. Prudhoe Bay) vs. late onset (e.g., Point Barrow)
- Stable vs. variable ice regimes
- Importance of local conditions

# Ice morphology



- Potential lack of grounded ridges as factor in reduced ice stability
- Impact of ice morphology on under-ice currents and potential oil dispersal

# Multi-year ice incursions



- Reservoir of MY ice north of Canada: Delay of seasonal ice retreat, summer & winter ice hazard, variability in summer ice conditions over shelf