

Beaufort Sea-Ice Zones & Implications for Spill Scenarios



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- Introduction: Zonation & operational windows
- Landfast ice, pack ice and the flaw zone
- Implications for oil-spill scenarios
- Conclusions

Beaufort Sea-Ice Zones & Implications for Spill Scenarios



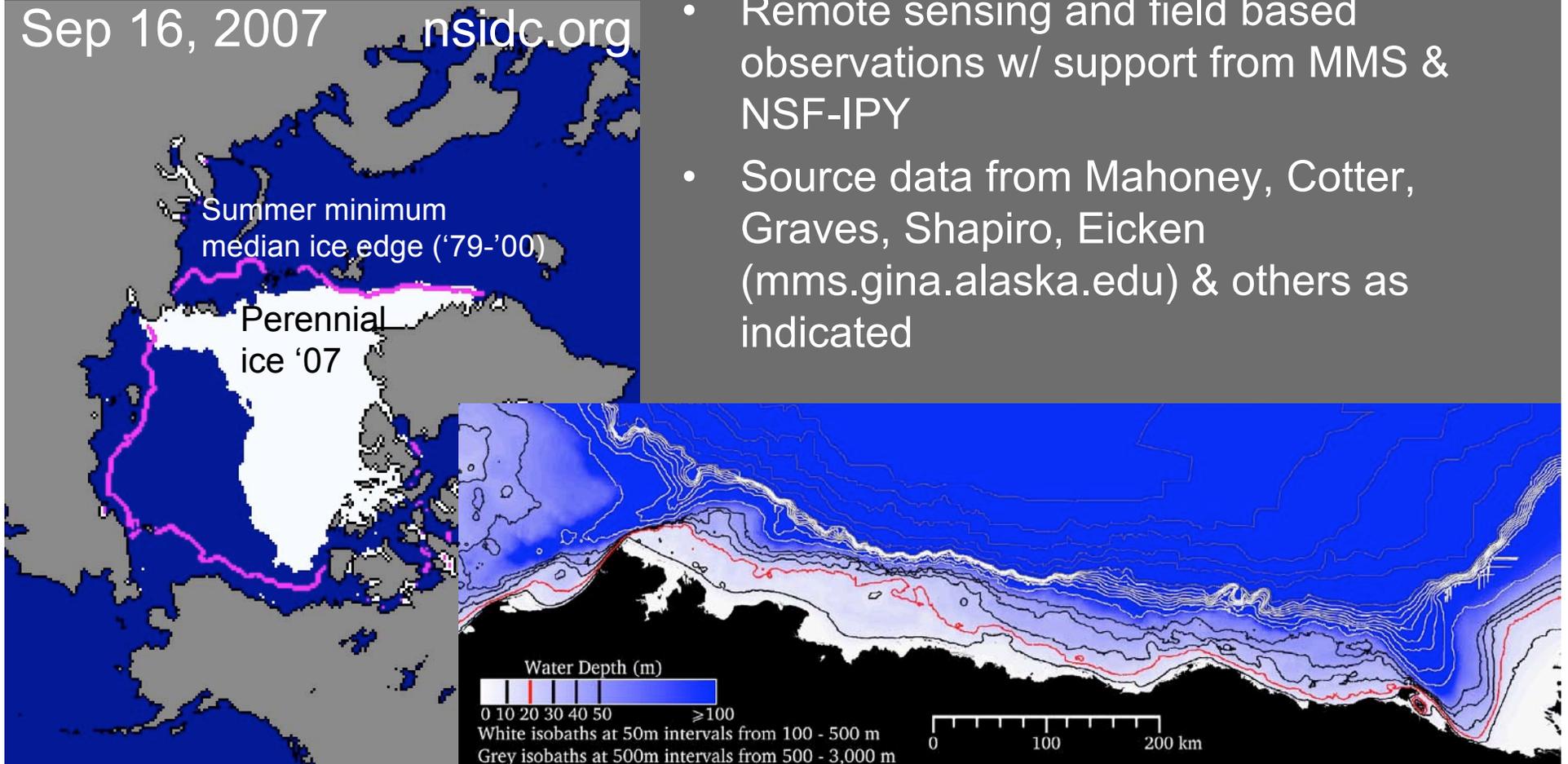
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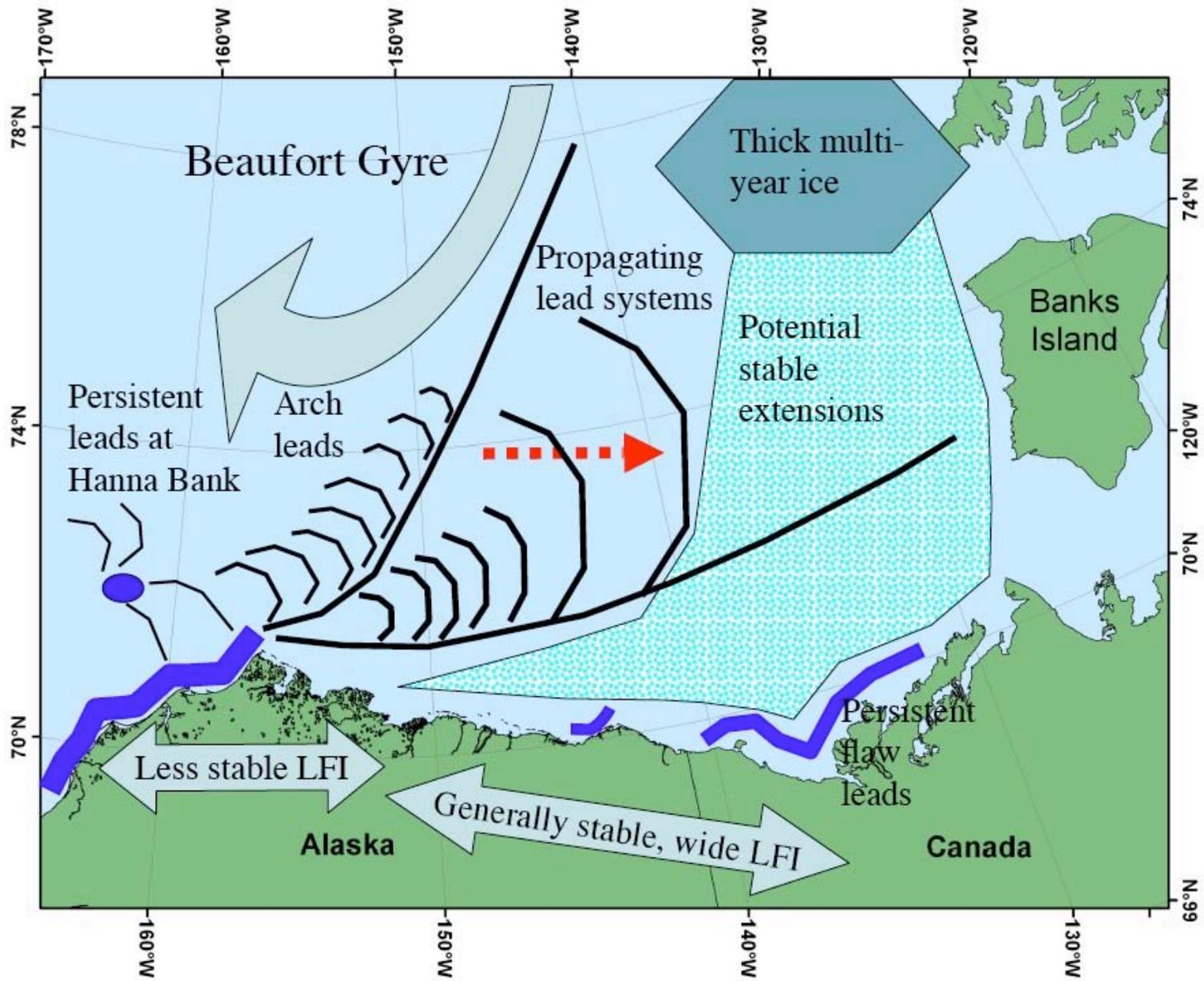
The Beaufort Sea ice cover in context

Sep 16, 2007

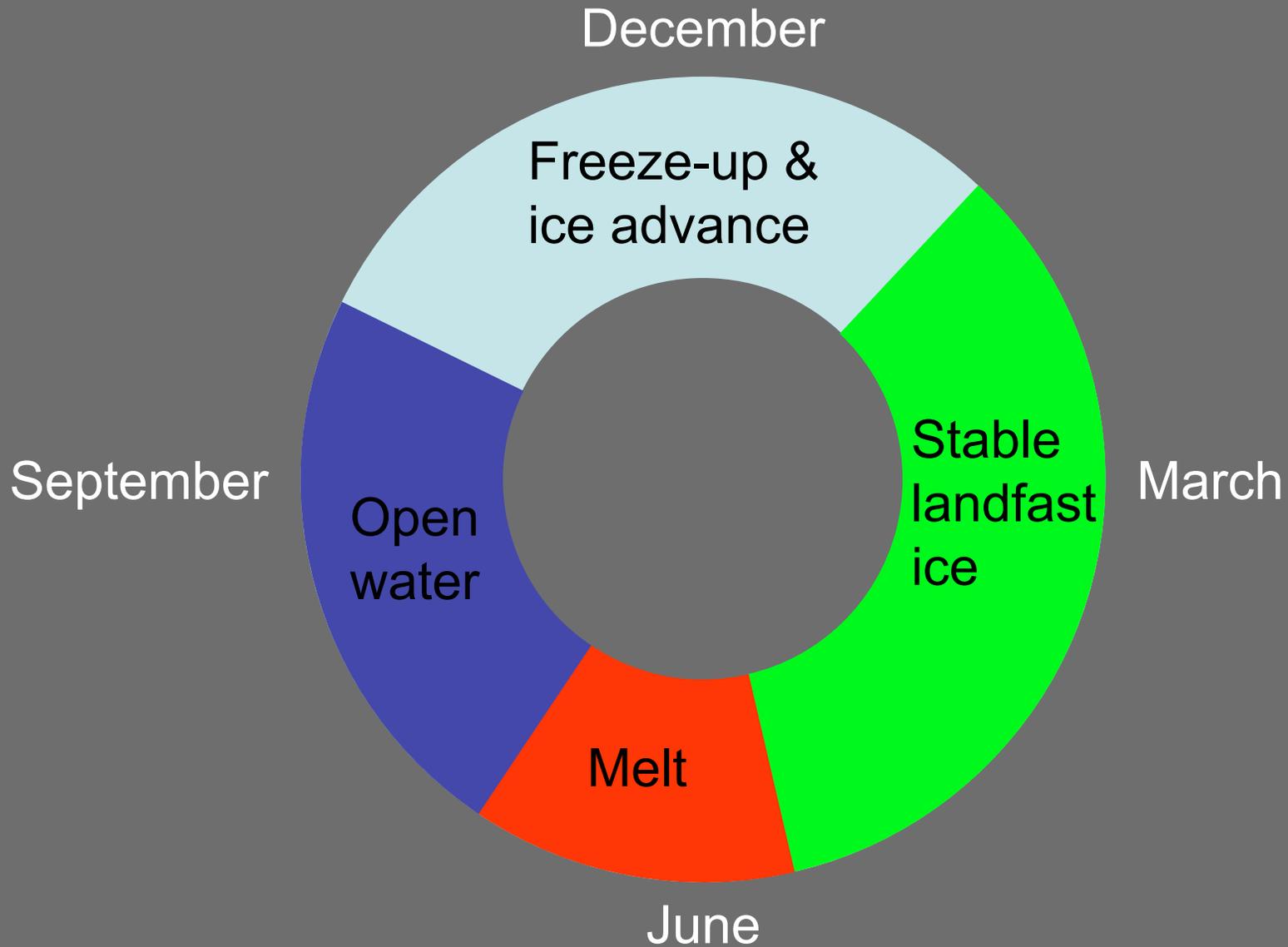
nsidc.org

- Remote sensing and field based observations w/ support from MMS & NSF-IPY
- Source data from Mahoney, Cotter, Graves, Shapiro, Eicken (mms.gina.alaska.edu) & others as indicated



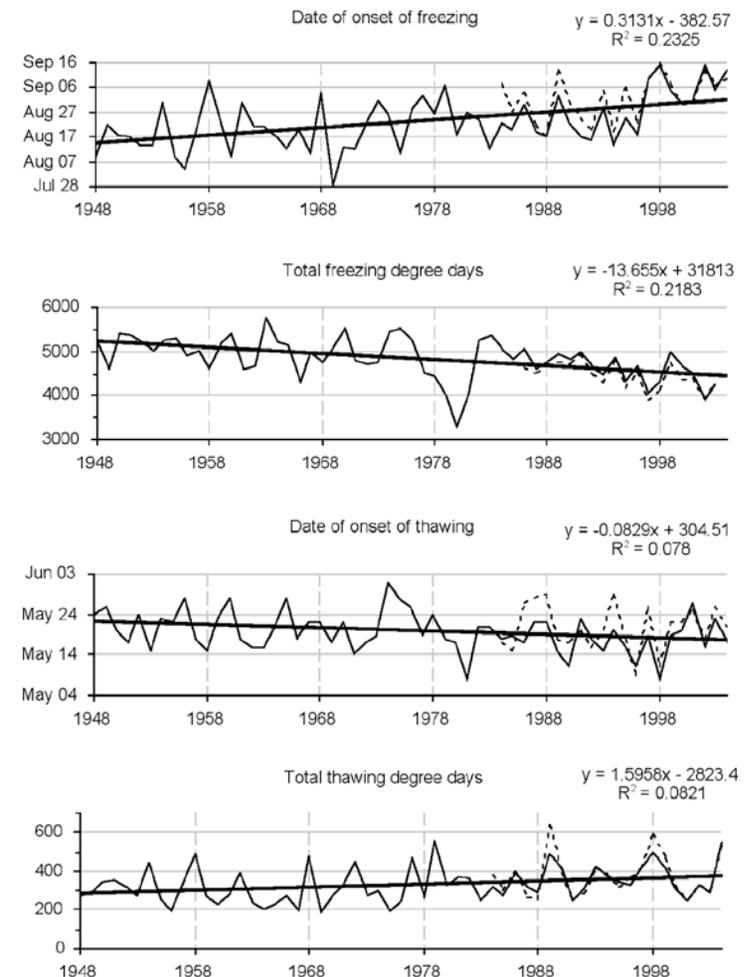
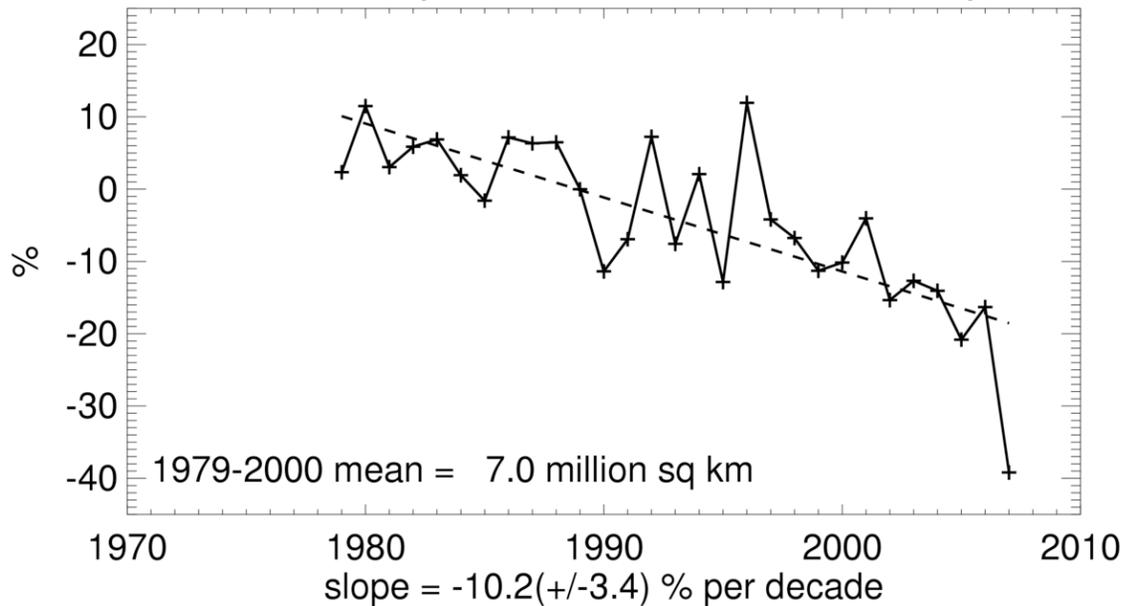


Annual sea-ice cycle & operational windows



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

Northern Hemisphere Extent Anomalies Sep 2007

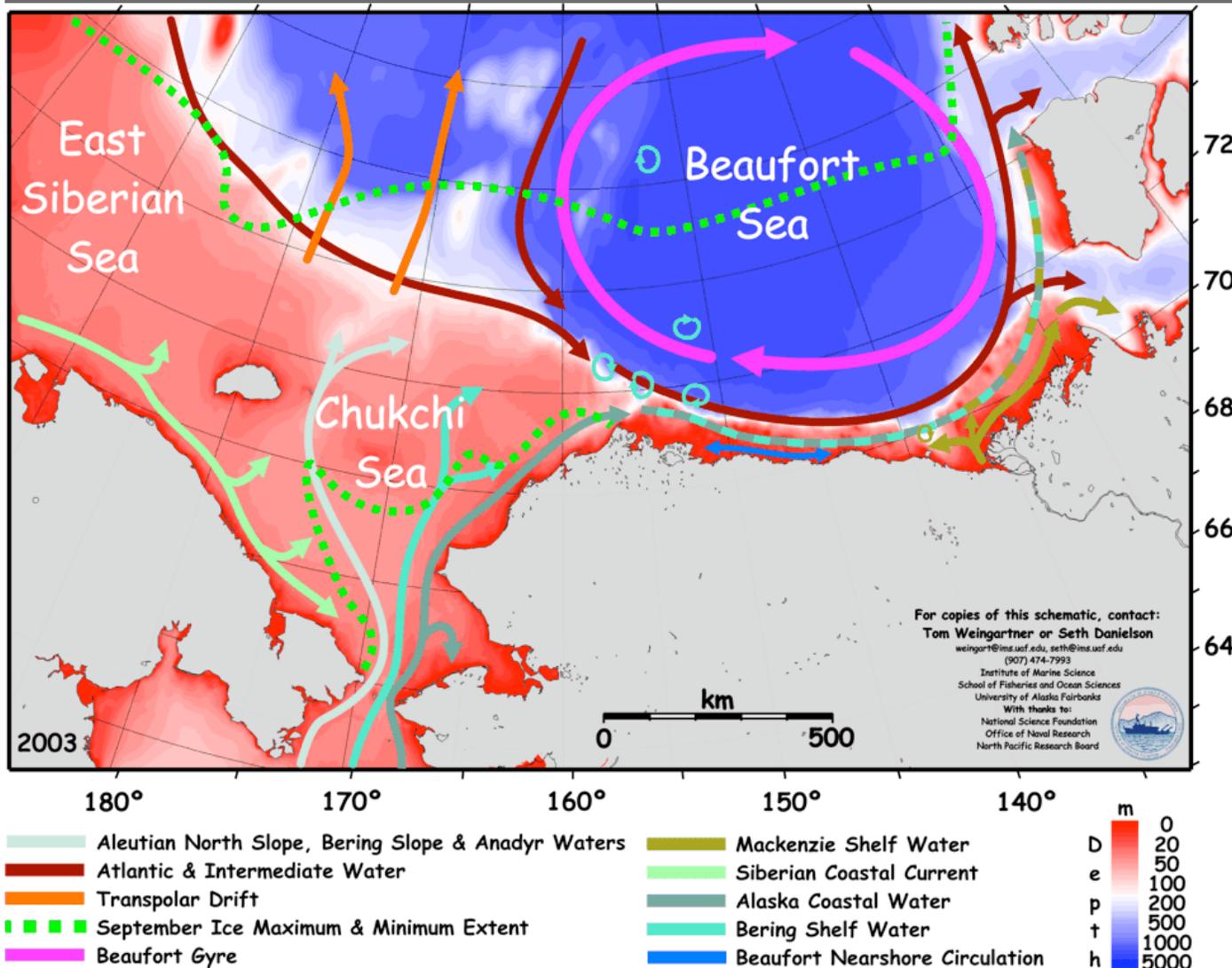


NSIDC (2007)

- Reduction in summer ice
- Beaufort/Chukchi: Earlier melt, reduced freezing degree-days

Mahoney et al. (2007)

The open water season



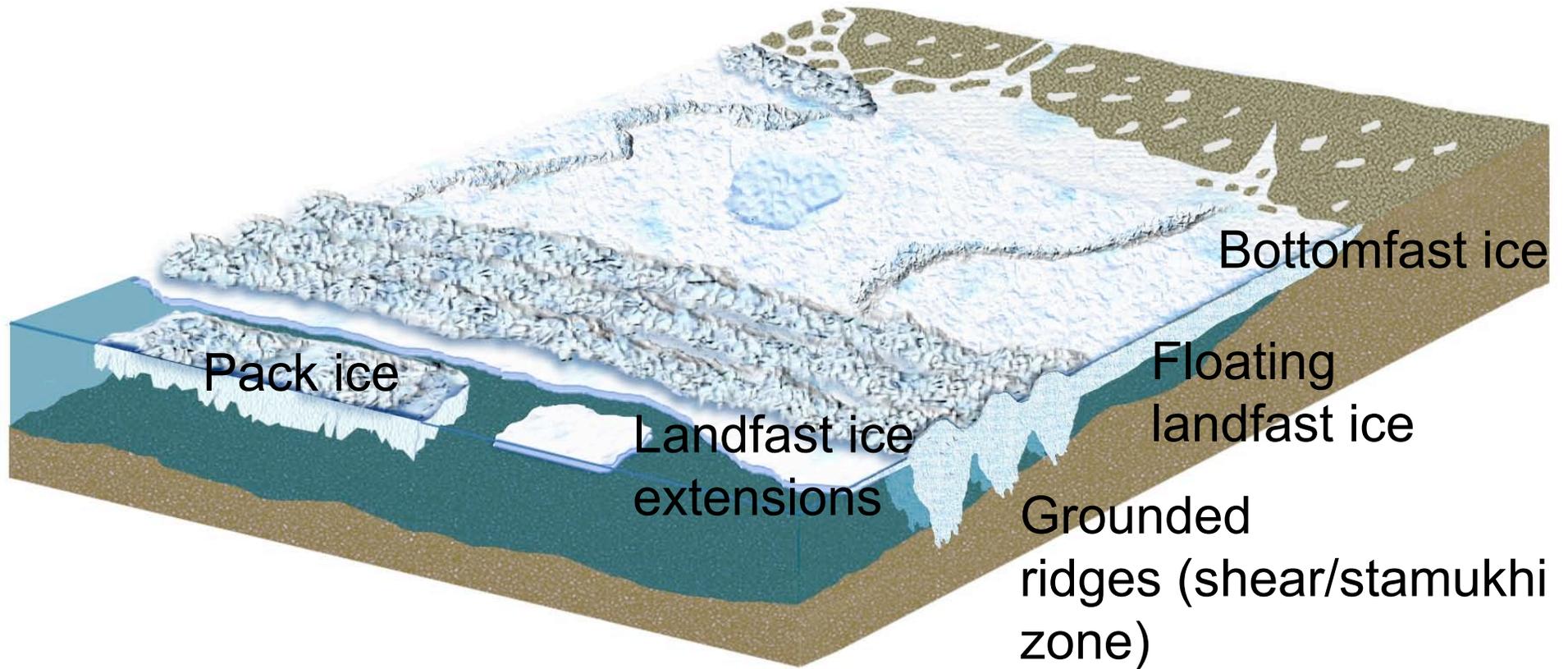
- Surface ocean circulation & potential open-water oil dispersal patterns (Weingartner & Danielson, www.ims.uaf.edu/u/beaufort/)
- Coastal current & nearshore circulation: Complicate ice drift & deformation patterns

Beaufort Sea-Ice Zones & Implications for Spill Scenarios

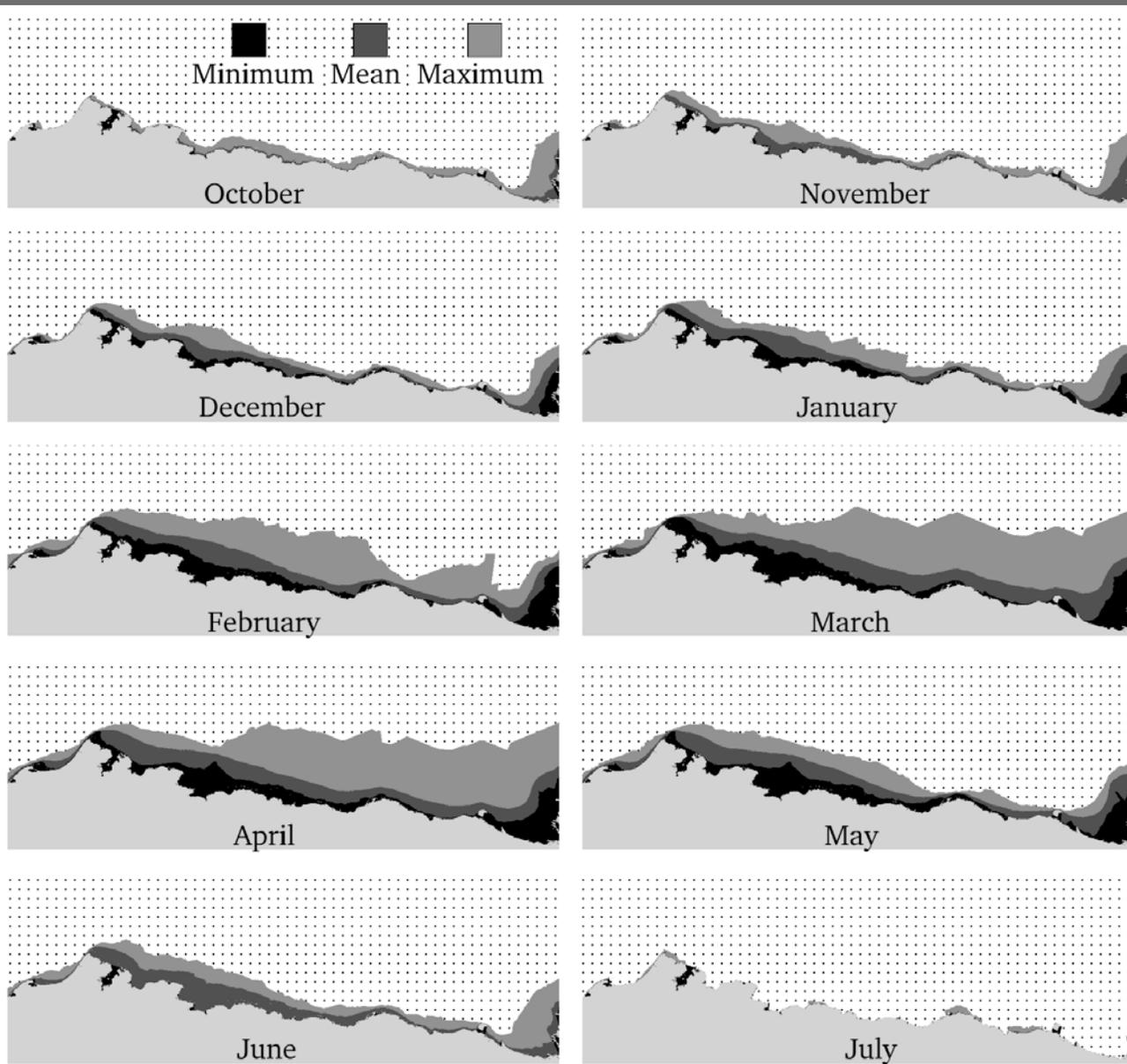


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Landfast ice zone



Seasonal cycle of landfast ice extent



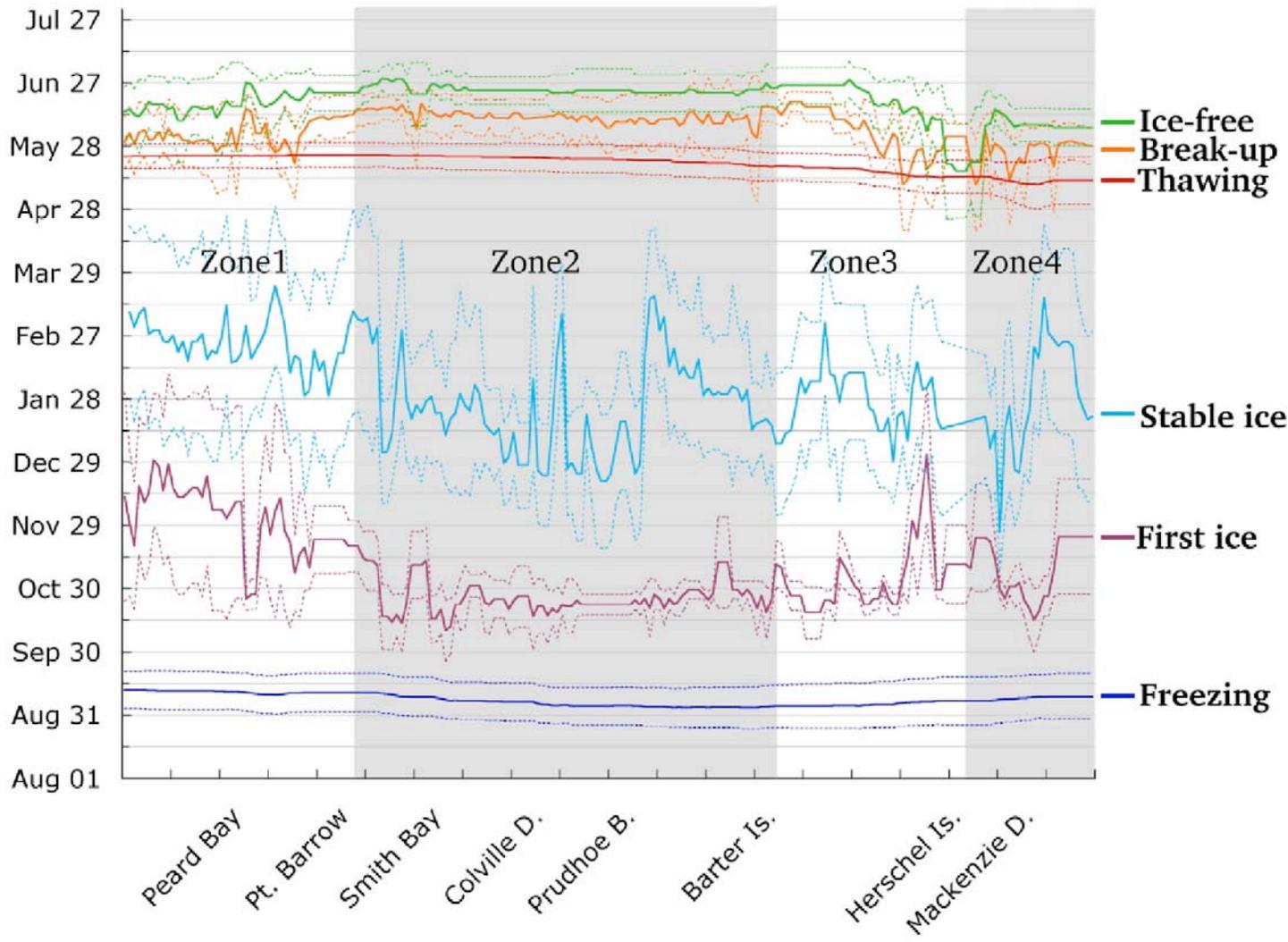
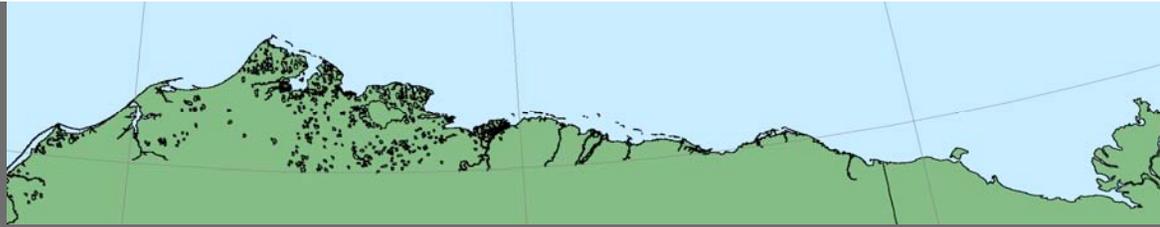
- Mean controlled by bathymetry
- Maximum controlled by pack/landfast ice interaction (stable extension)
- Minimum controlled by break-out events
- Iñupiaq ice experts: Break-outs much more frequent since early 1990s

This study

Barry et al. (1979a)

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

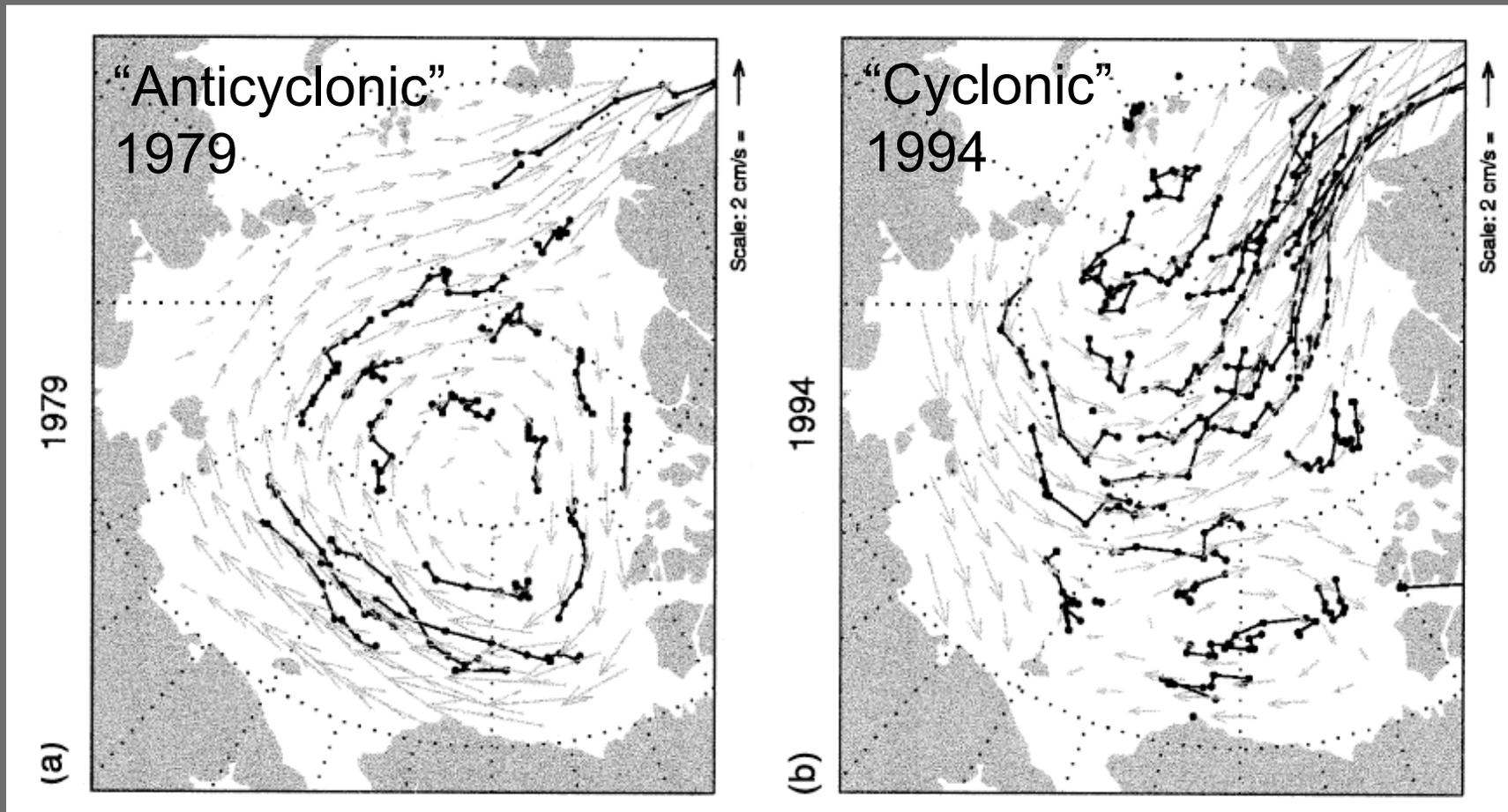
*1996-1998 omitted from analysis



- 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

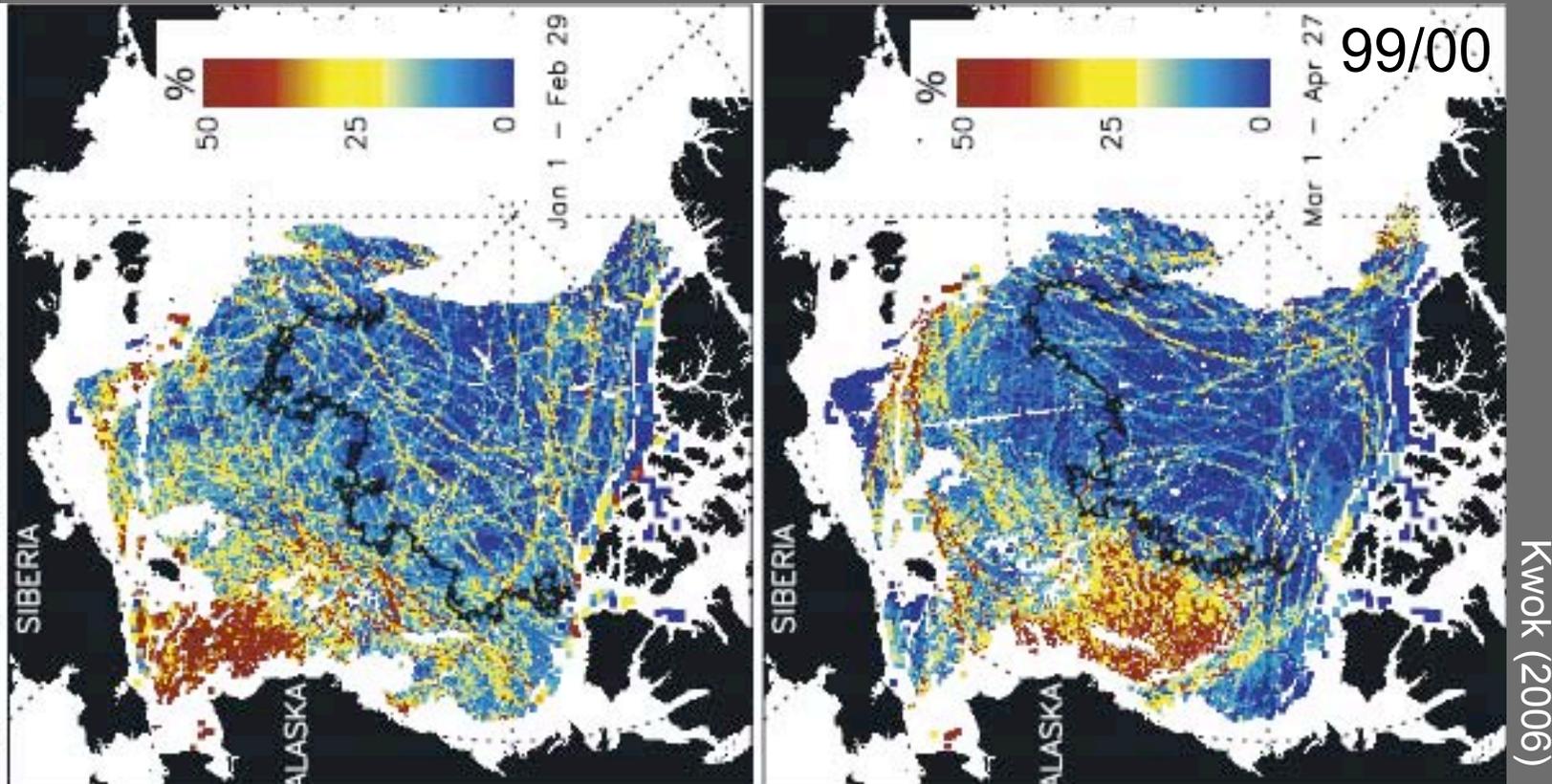
Pack-ice movement

- Lower atmospheric pressure favors “cyclonic” circulation:
 - Faster export of ice
 - Transpolar Drift expanded, Beaufort Gyre reduced in extent



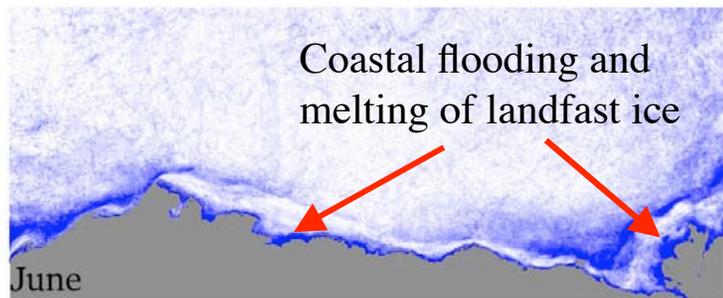
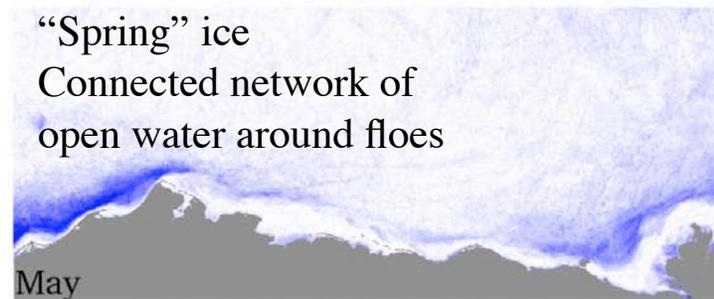
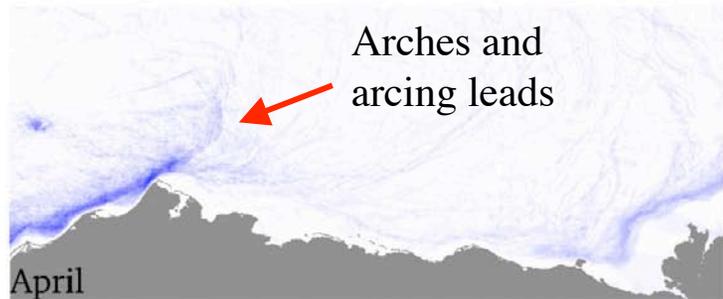
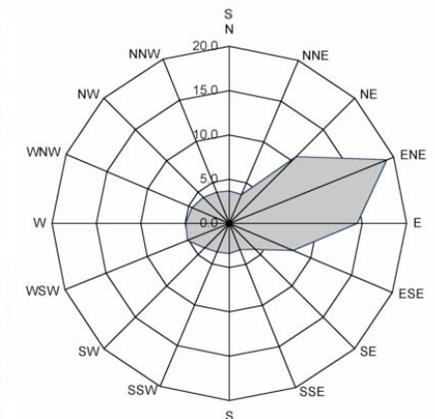
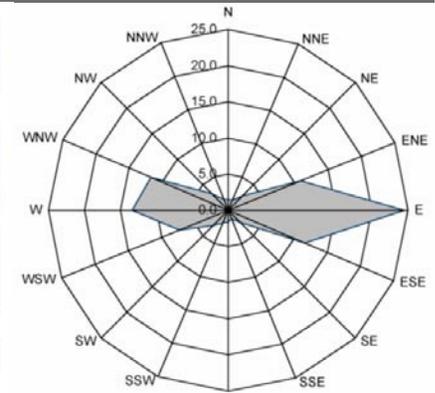
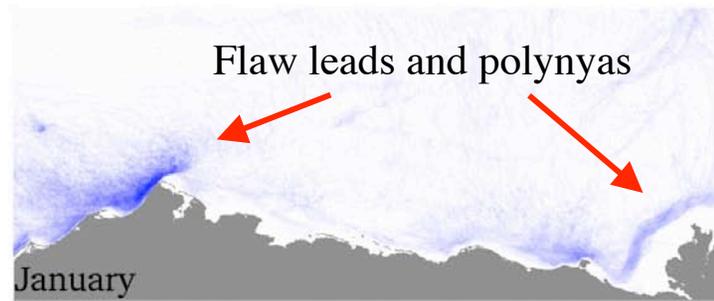
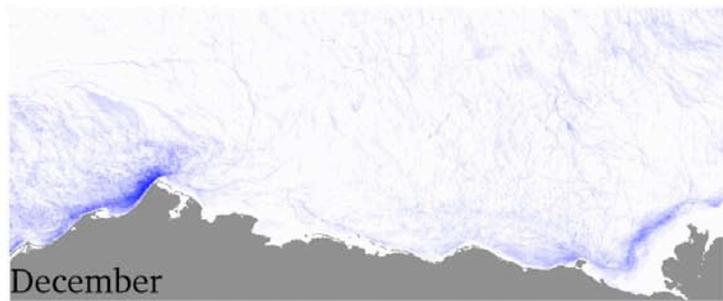
Rigor et al. (2002)

Divergence & shear between pack & landfast ice



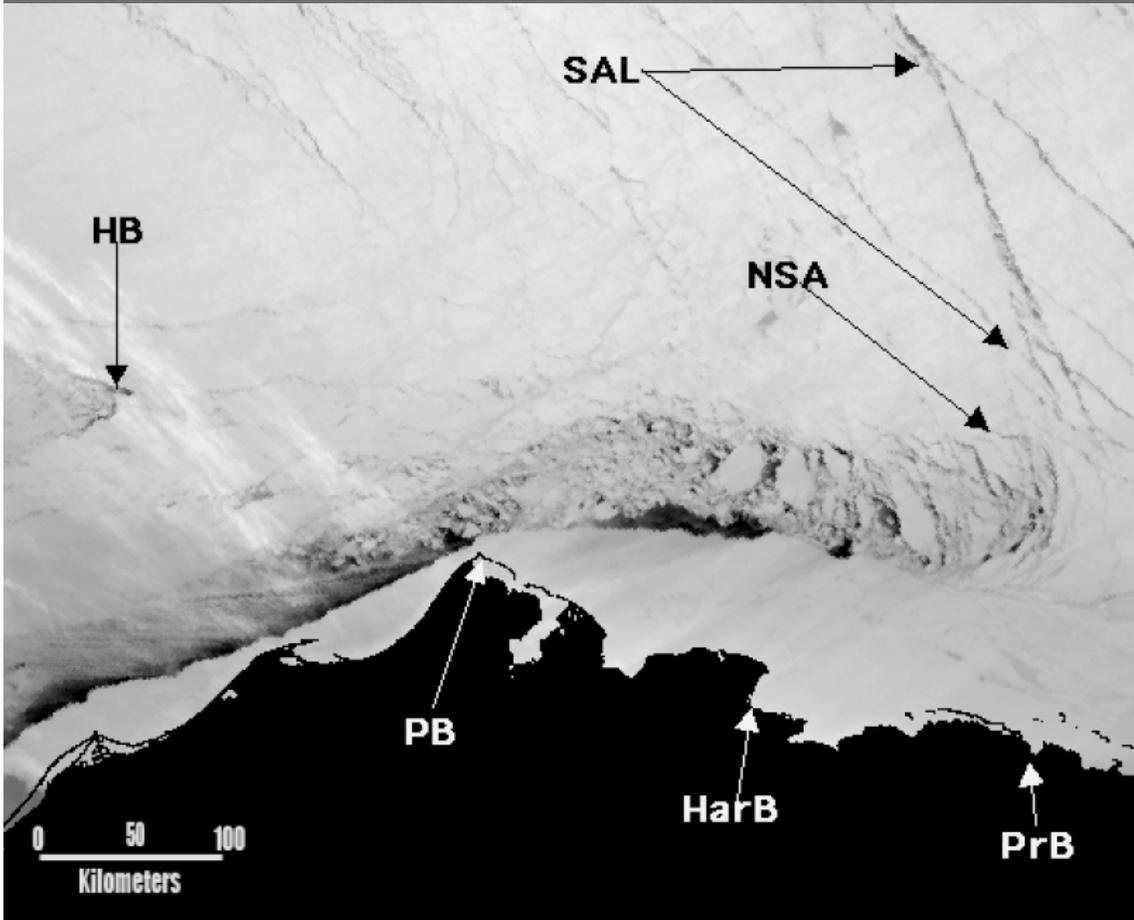
- Time fraction that ice is “active”: $\text{div} > 0.02/\text{day}$, $\text{shear} > 0.03/\text{day}$
- Lack of data over shelves and in coastal regions

Lead occurrence patterns (1993-2004)



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

The Flaw Zone



- Flaw zone:
 - few km to >100 km wide
 - Separates landfast from pack ice
 - Shear/rotation of floes, propagation of cracks
 - Few data on ice motion and deformation in flaw zone

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Movement & mobilization of oil in sea ice

AMAP
Assessment
Report (1998)

Less multi-
year ice

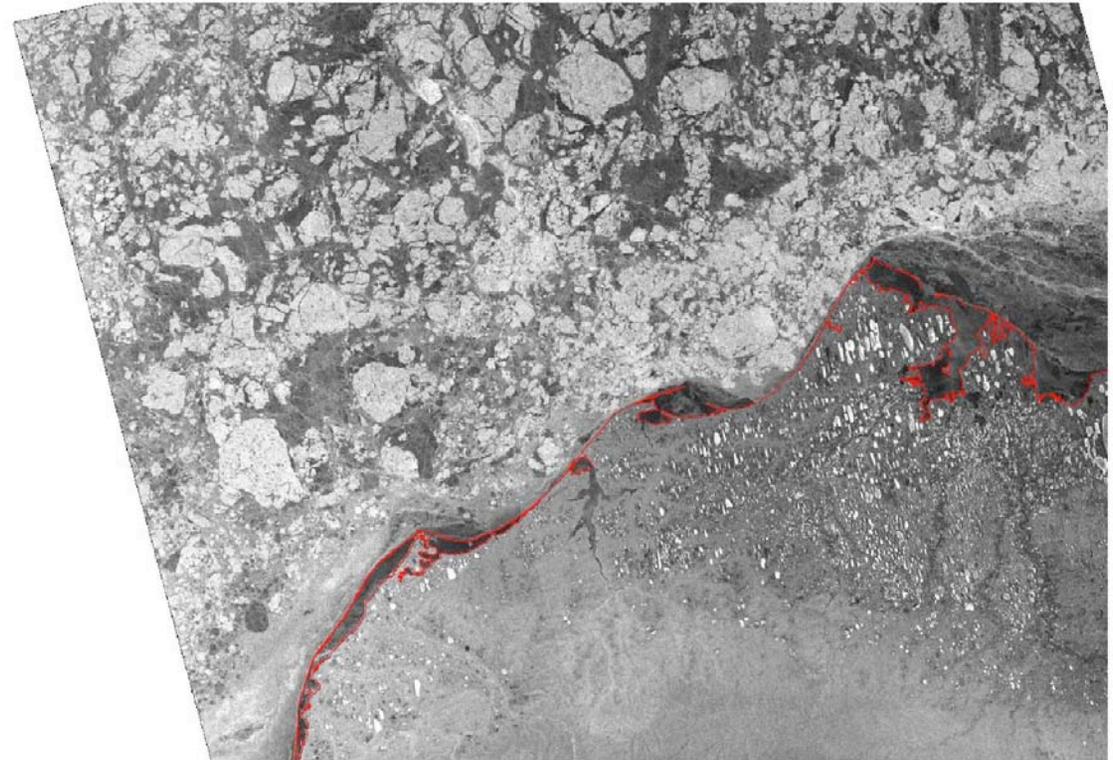
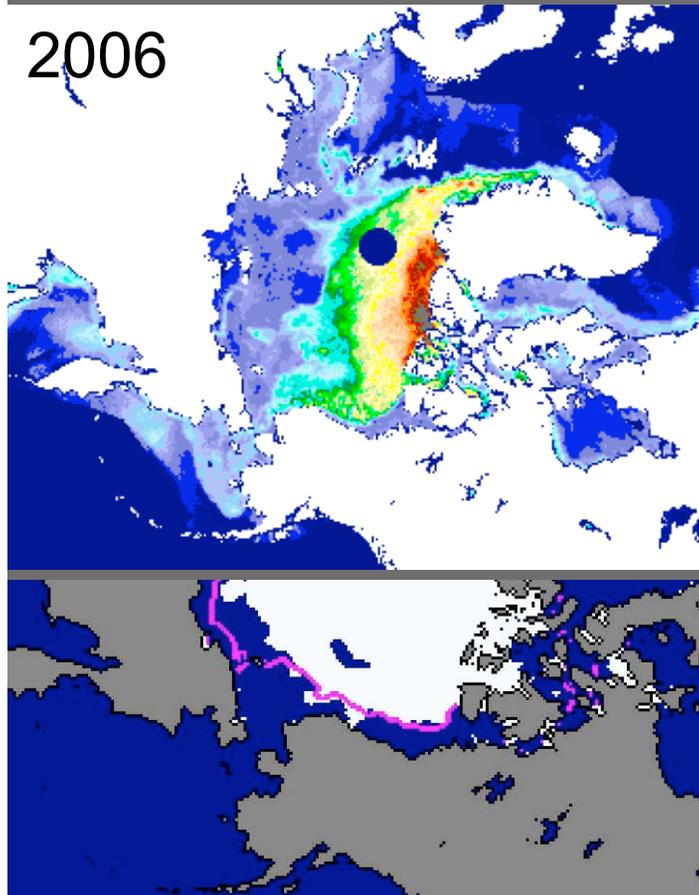
More first-year ice, greater spatial & temporal variability in ice conditions

Increased oil mobility (permeability & melt)



- Release into open water and leads
- Trapping in rubble, rough ice & frazil (potential for sediment-oil interaction)
- Movement with drift ice vs. local confinement in landfast ice
- Upward percolation in spring: Earlier onset of warming & melt, more permeable ice cover?

Multi-year ice incursions



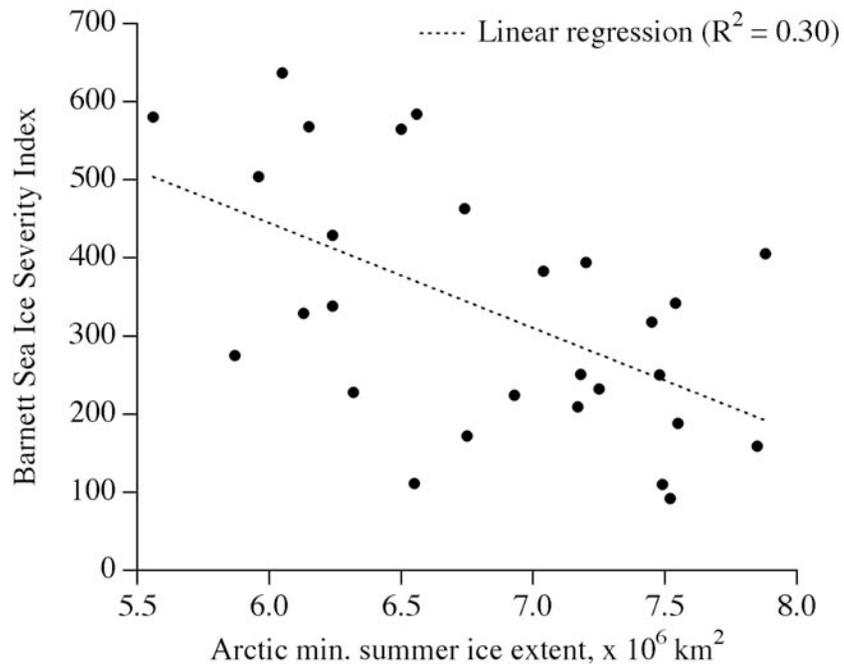
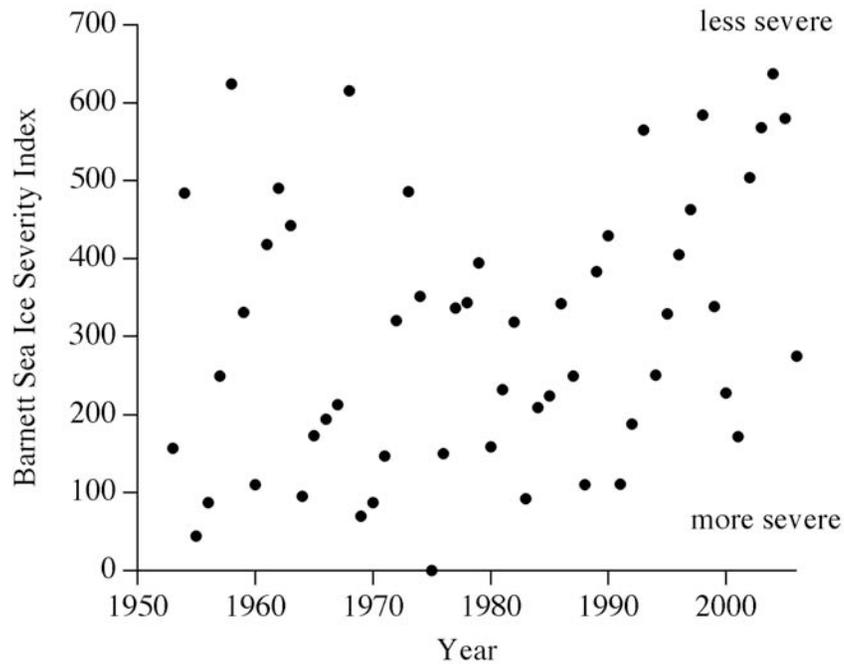
RADARSAT ScanSAR Wide Beam 20060126 GMT: 03:49:00

0 100 Kilometers

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

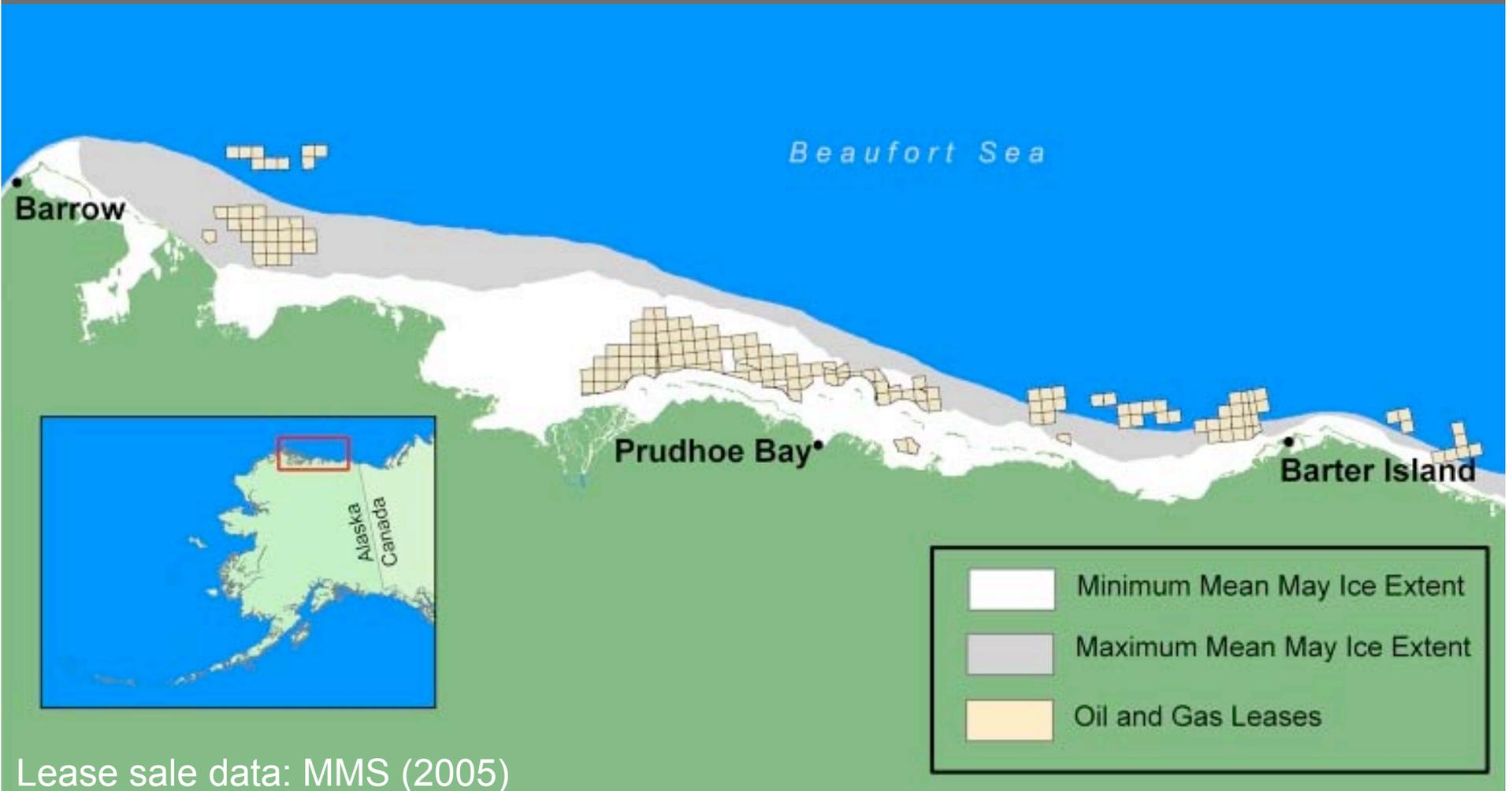
- Reservoir of MY ice north of Canada: Delay of seasonal ice retreat, summer & winter ice hazard, variability in summer ice conditions over shelf

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

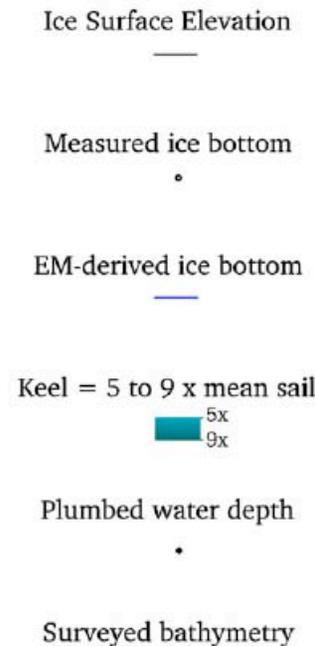
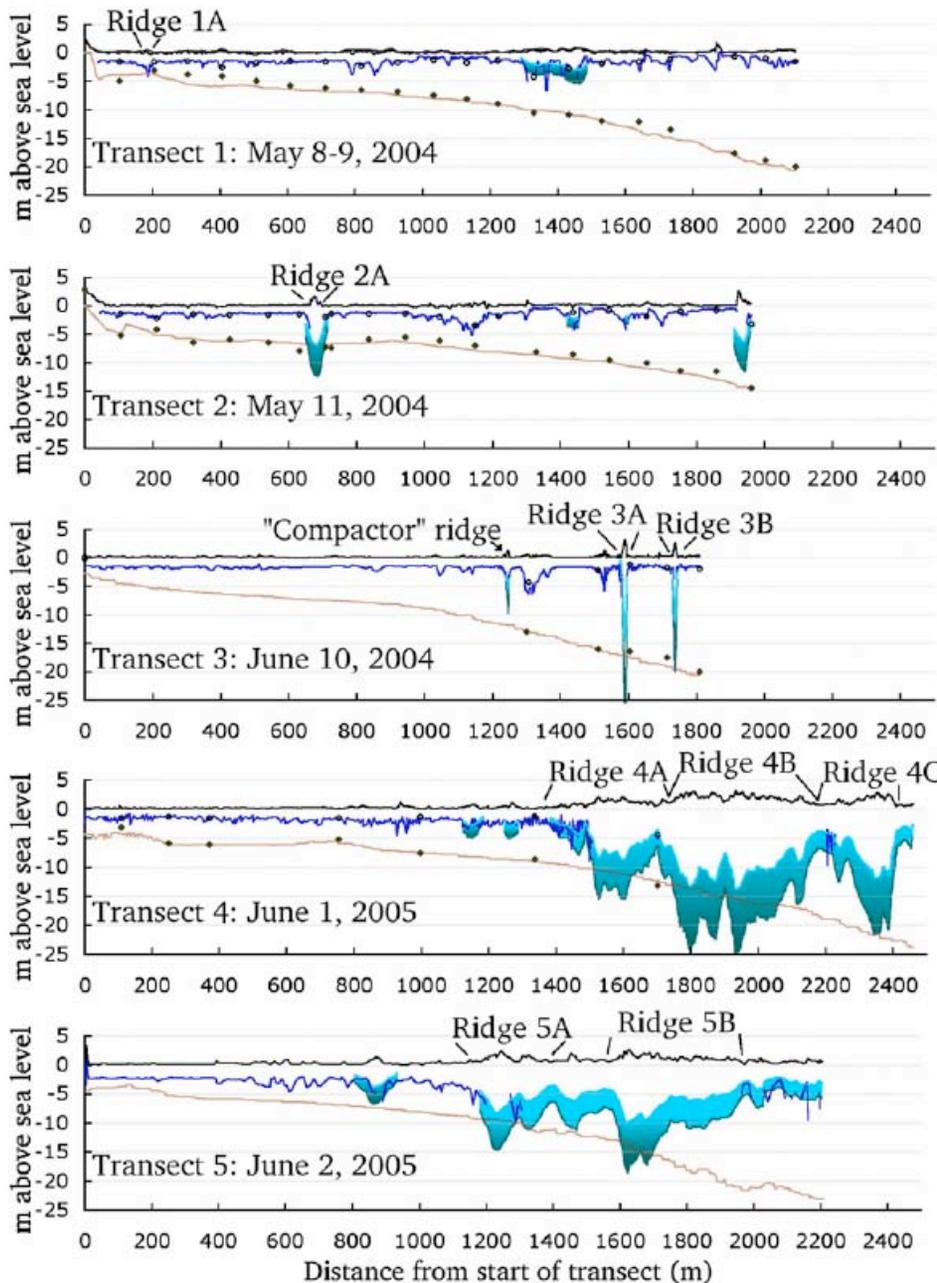


- Length of Barrow-Prudhoe navigation season, severity of ice in coastal Chukchi-Beaufort Sea in August-September (computed by National Ice Center)
- Resolution/accuracy of remote sensing data
- Interannual & local variability
- Summer ice incursions

Lease areas in relation to ice conditions

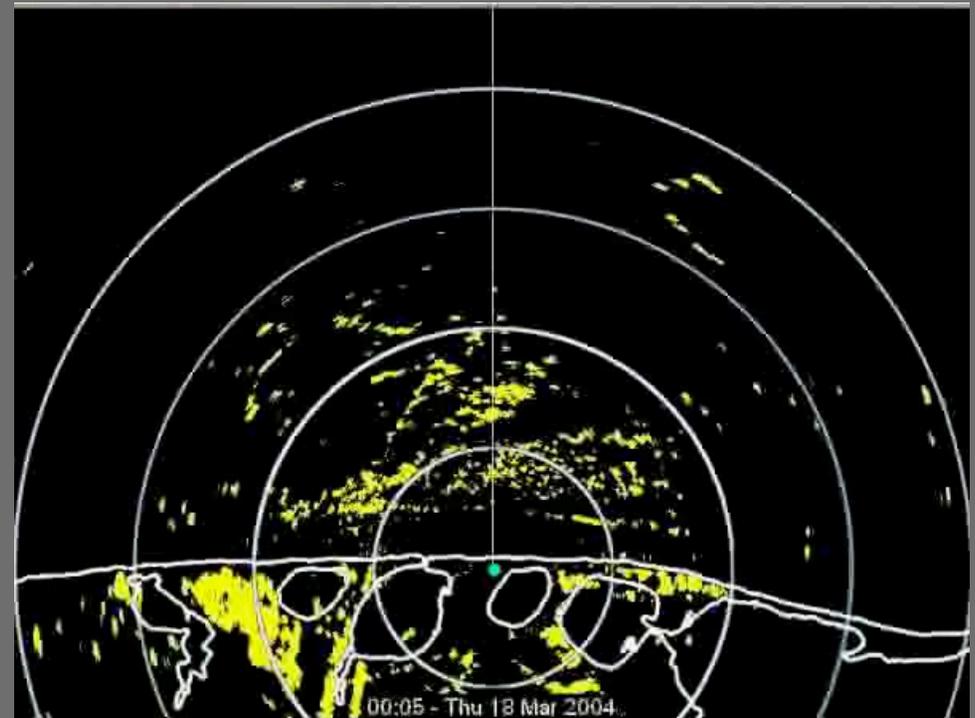
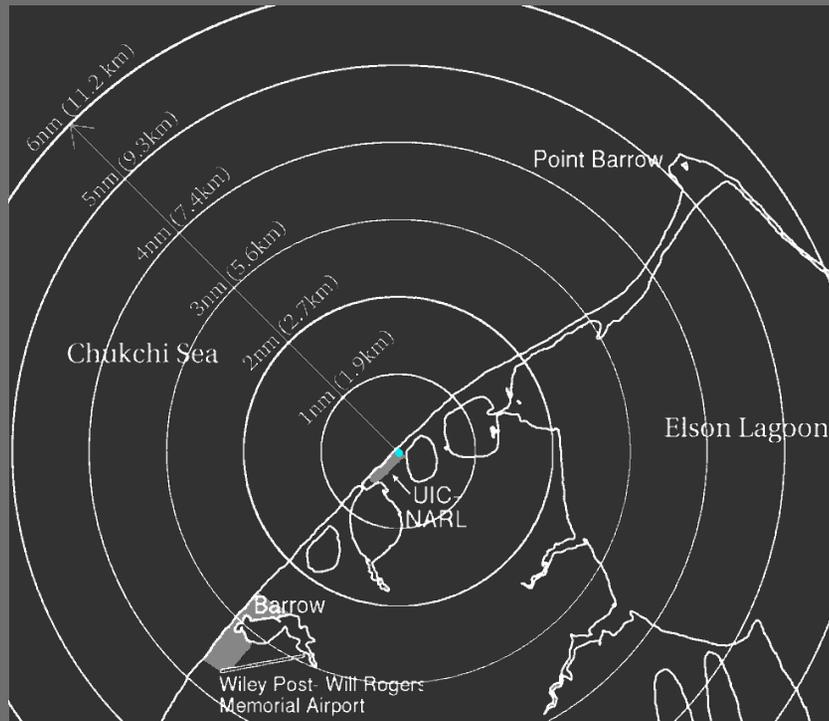


Ice morphology



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

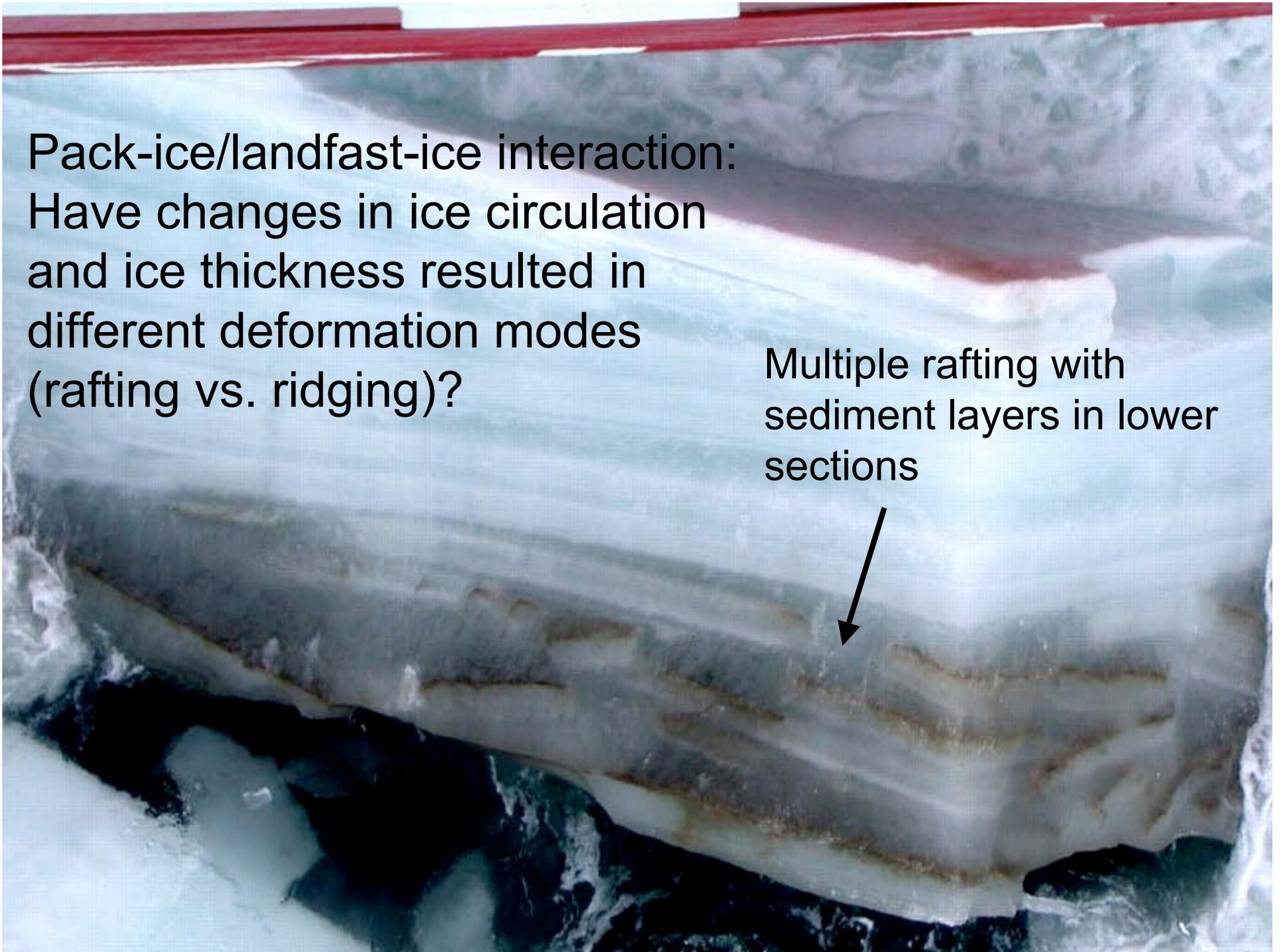
Dynamics of the flaw zone



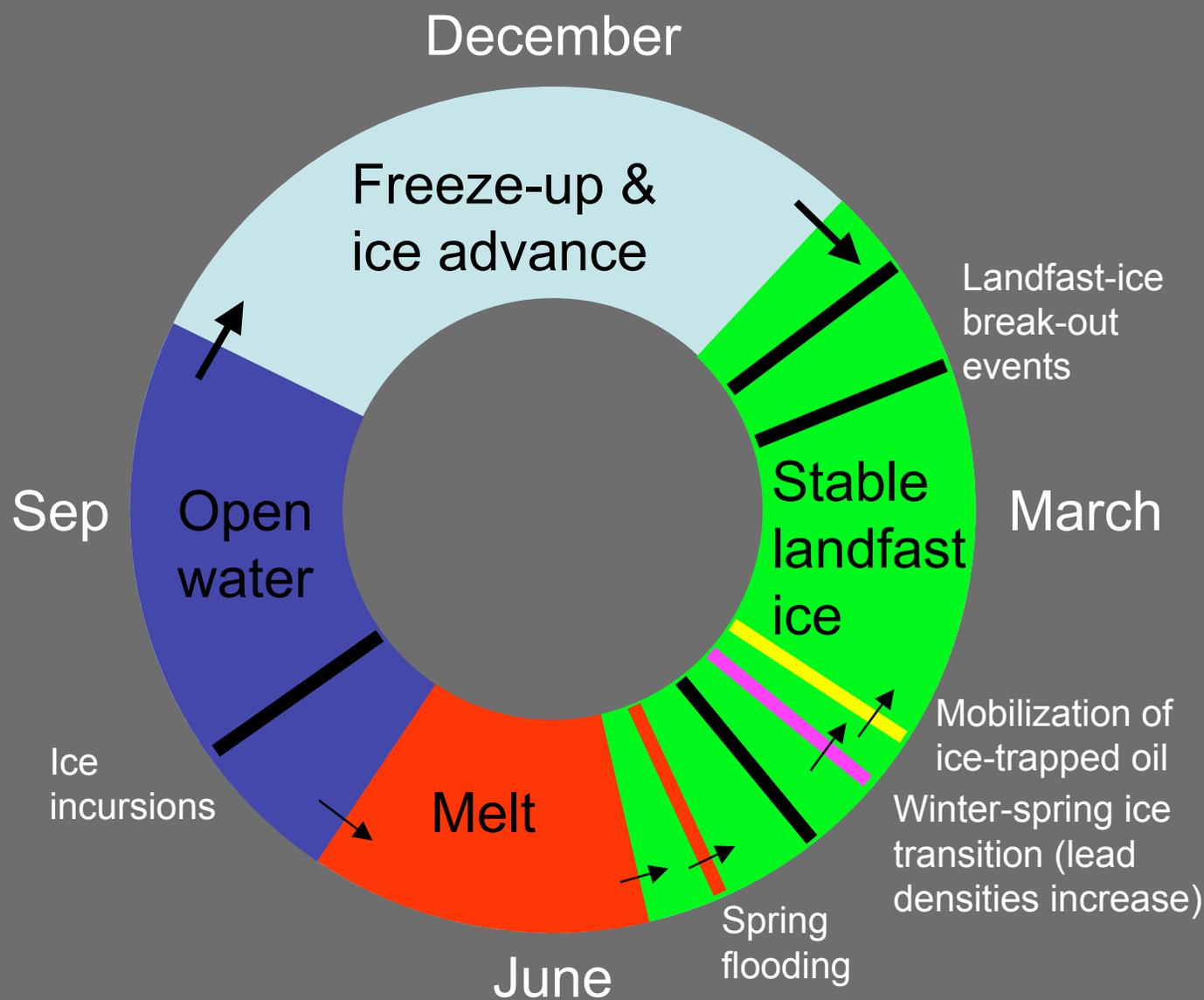
- Coastal marine radar at Barrow provides glimpse of key processes in flaw zone and landfast/pack-ice interaction
- More details in Mahoney et al. (CRST, 2007) & at www.gi.alaska.edu/snowice/sea-lake-ice/data.html

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



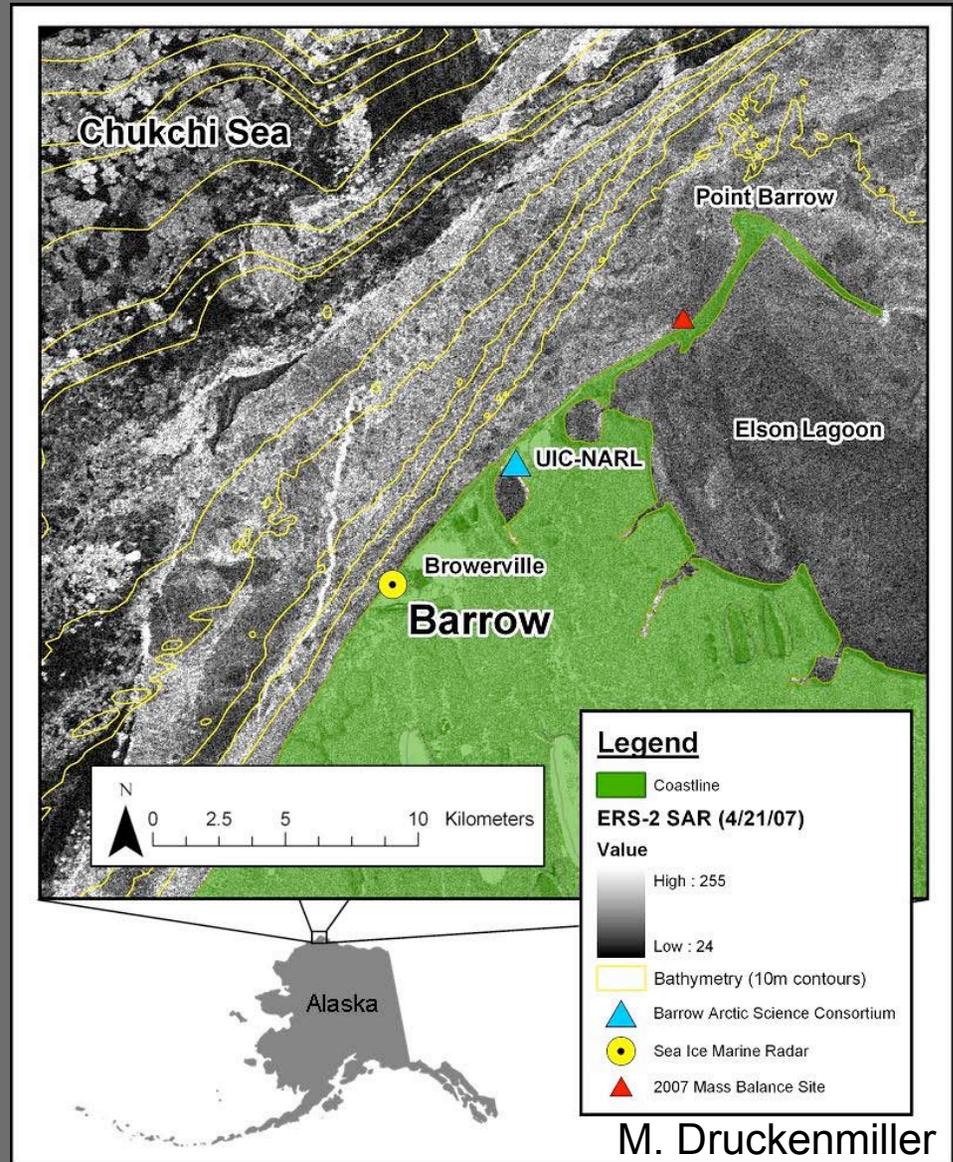
Annual sea-ice cycle & operational windows



- Open-water operations regime longer, potential for ice incursions
- Landfast-ice operations regime shorter, potential for break-outs
- Flaw-zone regime more variable in time & space
- Highly specific to particular 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



Conclusions



Data exchange meeting
Thursday 4-6pm
1007 W 3rd Ave, #100
Flyers & white paper
outside meeting hall

- Open water season: longer, potential for ice incursions (ice detection)
- Landfast ice: extent little changed, less stable (lack of grounded ridges and stabilizing factors)
- Ice morphology & under-ice currents
- Flaw zone: Change in ice dynamics (rafting, sediment entrainment, break-outs)? Need for quantitative information
- Multi-year ice reservoir remains in Canadian Arctic
- Role of local expertise in integrated observations and spill response