



Engineering in Canada's Northern Oceans

Research and Strategies for Development
A Study for the Canadian Academy of Engineering

Project Team

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THE CANADIAN ACADEMY
OF ENGINEERING

*Leadership in Engineering Advice
for Canada*



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*Chef de file en matière d'expertise-conseil
en génie pour le Canada*

Presentations

1. Ian. Introduction; brief reviews of past reports case studies of Beaufort and E coast Canada, Caspian and Barents Seas; review of climate change literature
2. Bob. Further case studies: Voisey's bay; Arctic Islands; Arctic Pilot Project; Canadian Centres; codes and standards, review of mineral resources, ports infrastructure. Gaps in knowledge.
3. Peter. Shipping in the Arctic; sovereignty, patrol vessels, icebreakers; engineering and technology gaps; recommendations on R&D strategies; universities and colleges in north; new ventures.

Contents

- 1. Introduction**
- 2. Review of Recent Reports, Climate Change**
- 3. Canadian Activities and Engineering in Northern Oceans**
 - 3.1 Inventory of Canadian Centres oriented towards Northern Research
 - 3.2 Codes and Standards
 - 3.3 Canadian Expertise on Northern Engineering
- 4. Canadian Engineering Projects for Northern Oceans**
 - 4.1 Introduction
 - 4.2 Case Studies showing Canadian Experience
- 5. Inventory of Mineral Resources**

6. Ships and Shipping in the North

6.1 North West Passages

6.2 1970s A Zenith of Canadian Icebreaker
Design & Construction

6.3 Arctic Evacuation, Escape and Rescue, EER

6.4 Current Northern Waters Shipping Activities

7. Sovereignty

8. Conceptual Visionary Projects and Programs

8.1 IAOSSES

8.2 Arctic LNG – Clean Green Fuel for the North

8.3 Mobile Arctic Engineering Research Platform

8.4 Canadian Arctic Railway

9. The Aging of Experienced Arctic Engineers

10. Barriers to Arctic Developments

11. Recommendations

Present status



Canada's northern waters. Source: <http://atlas.gc.ca/>

Regions of Activity

Caspian



Recent Reports

Selected Highlights and Conclusions

- Centre for the North (CFN). Changing tides: Economic Development in Canada's Northern Marine Waters
- CFN: Northern Assets. Transportation Infrastructure in Remote Communities
- CARD (C-CORE). Arctic Development Roadmap

Changing tides: Economic
Development in Canada's Northern
Marine Waters

Development will hinge on four factors

- Climate change
- Infrastructure
- Emergency response & SAR
- Commodity prices

Climate change

- The report considers that this will improve the accessibility of northern marine waters.
- It does emphasize spatial and temporal variation of temperature changes.
- The average increase in temperature in Canada has been above global averages.
- The strongest warming trends between were in the far North of Canada. These were the Arctic Tundra, Arctic Mountains and Fjords, Mackenzie District, and Yukon and North British Columbia climatic regions. Some areas saw little increase in temperature.

Exhibit 1
Climatic Regions



Source: Environment Canada, Atmospheric Environment Service, Climate Research Branch, 1998, *Climate Trends and Variations Bulletin for Canada*, Ottawa.

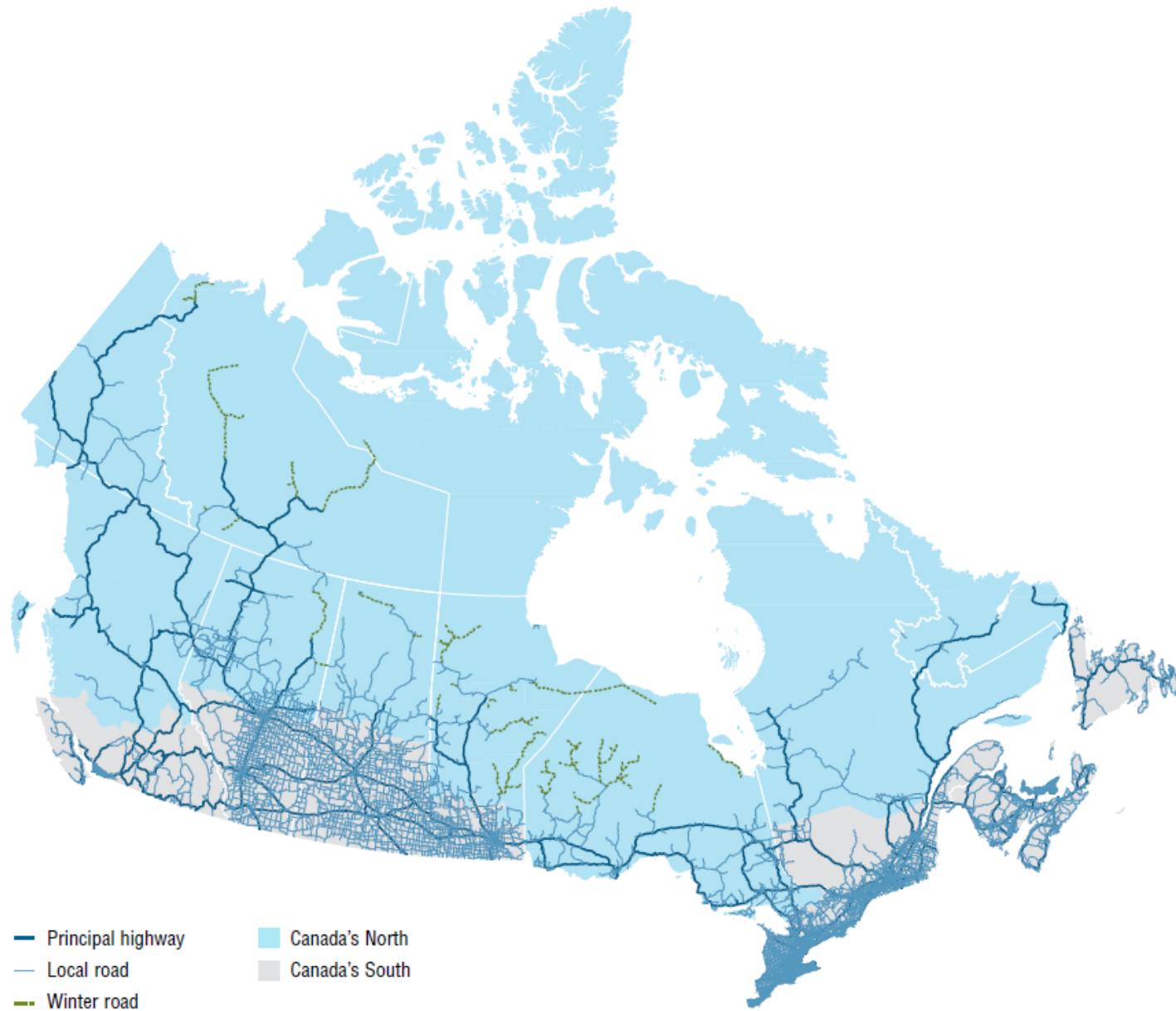
- An increase in shipping is possible but there are complicating factors
- Permafrost reduction
- The way that the risks and benefits of economic development are weighted and managed must make sense to Northerners, keep their interests front and centre, and effectively capture the Northern context
- Public-private cooperation and partnerships
- “Boom-bust” issues

CFN: Northern Assets.
Transportation Infrastructure in
Remote Communities

Highlights

- Transportation infrastructure in Northern communities is significantly more expensive to develop than in the South
- Transportation infrastructure in Canada's North is sparse.
- Climate change; warming, permafrost degradation, declining viability of winter roads Must be taken into account in new designs
- Importance of marine transportation
- Operational deepwater port at Churchill, Manitoba
- (Note plans for Nanisivik)
- Benefit-cost analyses for these projects must capture a full range of economic and social benefits unique to Northern communities
- Leveraging public and private interests

Exhibit 1
Road Infrastructure in Canada



Sources: Golder Associates; The Conference Board of Canada.

CARD Arctic Development Roadmap

Arctic Development Roadmap

- Focussed on oil and gas development
- Interviews with major oil and gas operators
- Includes discussion of worldwide possible developments
- Issues
 - Environmental protection
 - Ice management
 - Ice mechanics and loading
 - Station-keeping in ice
 - Environmental Characterization

Exhibit 2

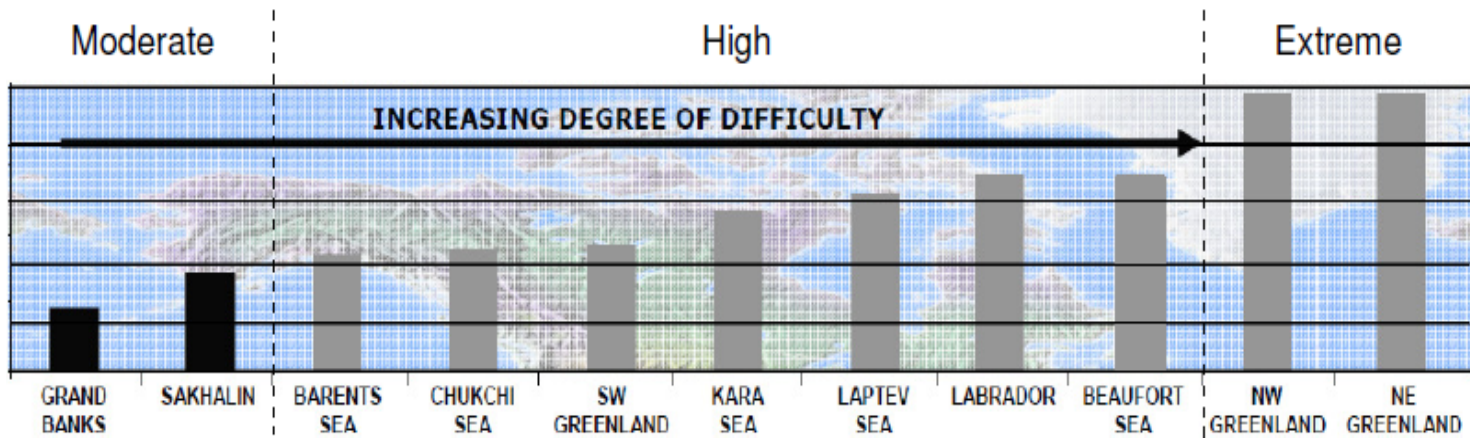
Oil and Gas Dispositions as of December 31, 2012, In and Around Canada's Territorial Waters



Oil and Gas Dispositions as of December 31, 2012

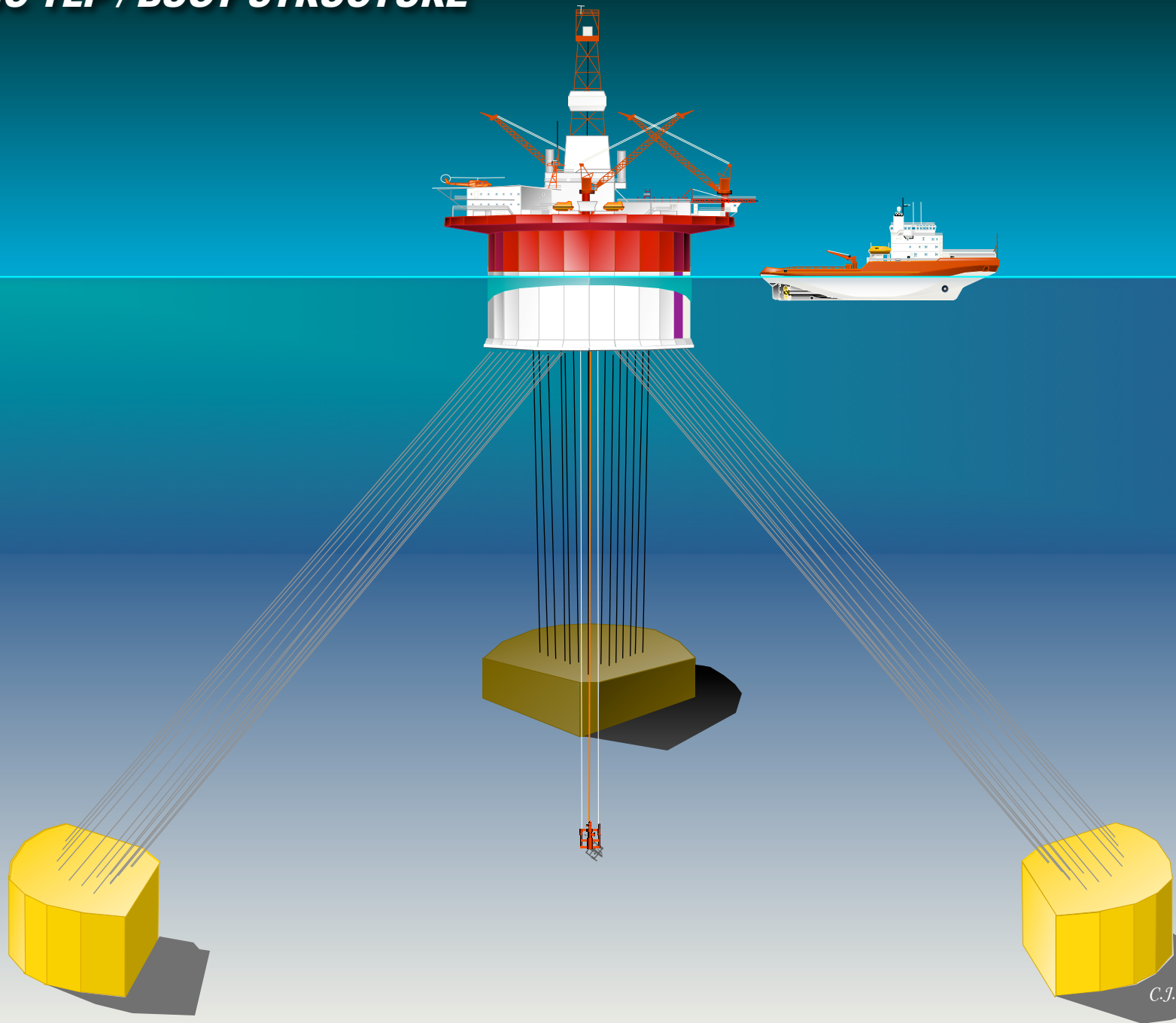
- Significant discovery licences
- Licence issued in 2012
- Licence issued per *Canada Petroleum Resources Act*, para 17(f)(b)
- Area subject to work prohibition
- Licence under work prohibition order
- Exploration licence
- Production licence

Sources: Aboriginal Affairs and Northern Development Canada; The Conference Board of Canada.



Relative degree of difficulty of various Arctic oil and gas development scenarios (Scott, 2009)

ARCTIC TLP / BUOY STRUCTURE



*J.C. I.A.
for
C.J.K. Engineering
Aug. 2005*

Case studies of Canadian Involvement in Northern Engineering

Some Examples

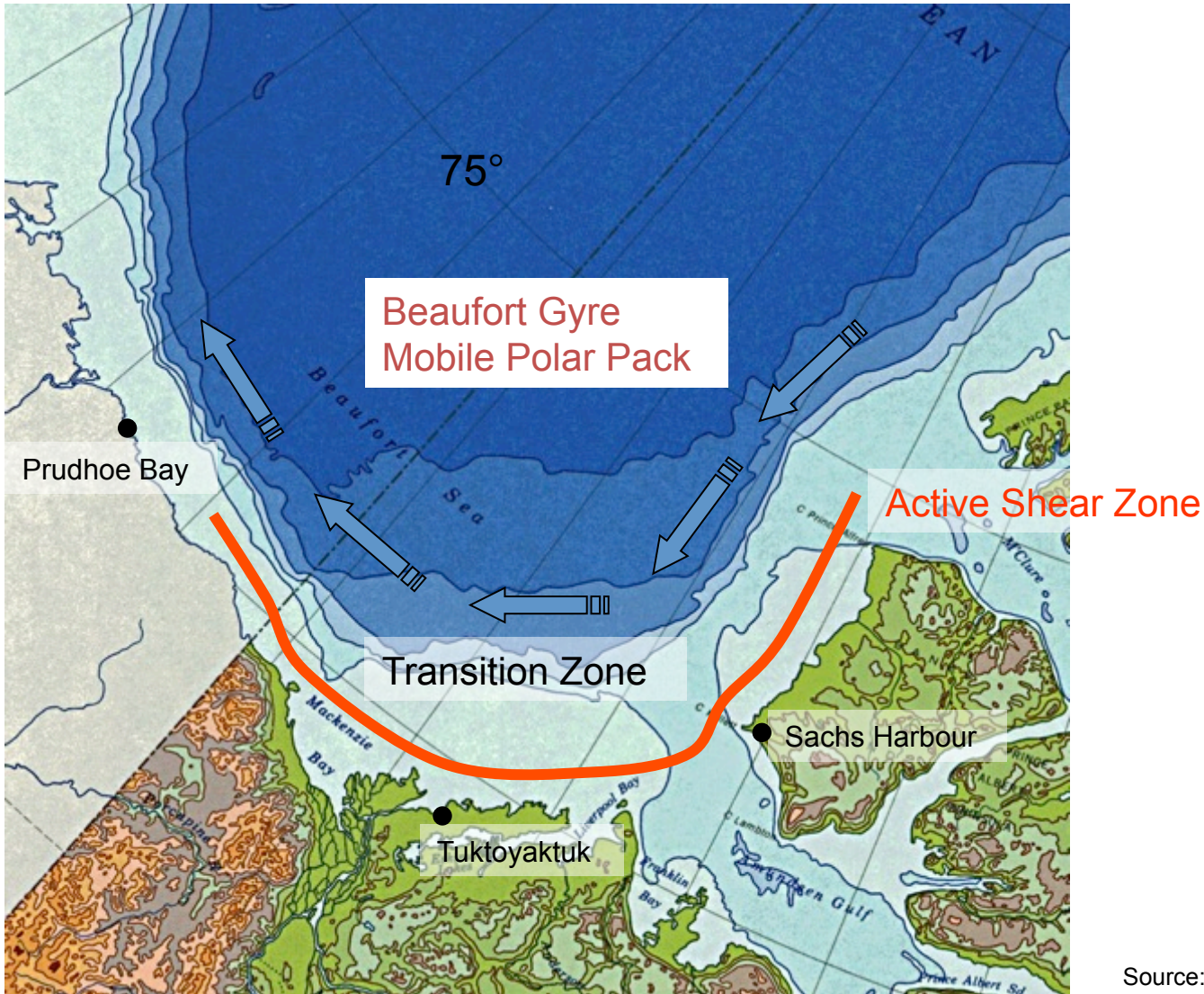
- Beaufort Sea
- East Coast
- Caspian Sea
- Barents Sea

Work characterized by innovations and creativity

Beaufort Sea

- Imperial Oil Research Lab in Calgary (1969) to investigate ice effects on offshore platforms in the Beaufort Sea. They initiated research on the crushing strength of Arctic ice and field programmes to look at ice movement, ice thickness and morphology in the immediate area of interest
- APOA 1 Nutcracker ice tests

Environmental Forces



Source: After, Environment Canada

- Ice Islands
 - Grounded
 - Floating



Mars Ice Island



Ice Island Construction

- Artificial Islands
 - Non Retained Island (NRI)
 - Sandbag or Rock Retained Gravel Island



Island Construction



Esso Kugmallit Island

- Caisson Retained Islands (CRI)
 - Canmar CRI
 - Esso CRI
 - Molikpaq



Esso CRI



Molikpaq

Early production

- In 1974 Panarctic discovered the Bent Horn oil field on Cameron Banks Island.
- In 1985 the first shipment of 100,000 barrels was made by the MV Arctic to a refinery in Montreal.
- These shipments continued until the late 1990s.



SSDC

Molikpaq Structure (showing production of particles of crushed ice)





Hans island

- Floating Structures
 - Northern Explorer I, II, III & IV
 - Kulluk



Explorer III

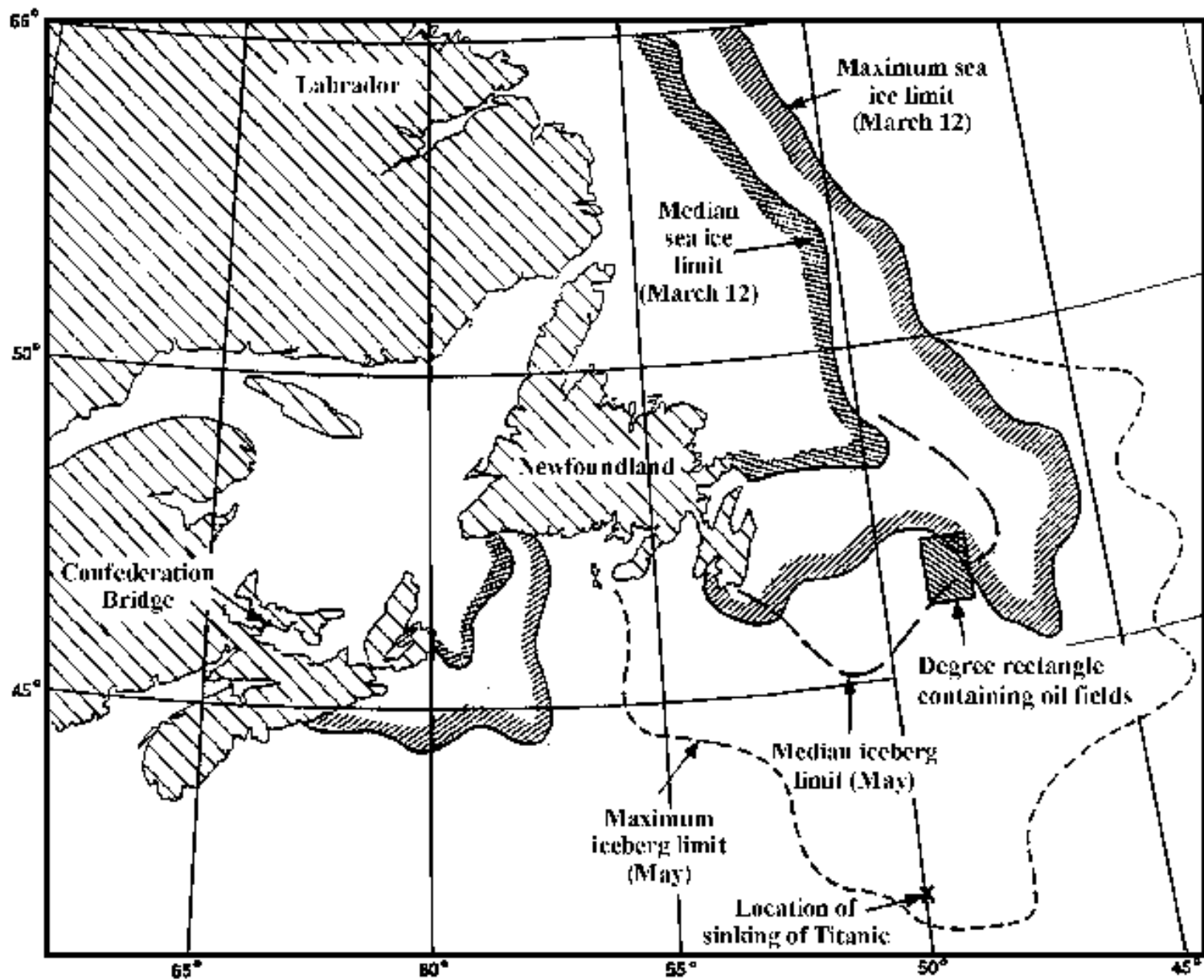


Kulluk

Conclude

- Successful designs of exploration structures for waters up to 30-40m
- Imaginative experiments
- Very important findings on design and ice loads
 - Local and global ice pressures
 - Scale effect

Grand Banks



The Titanic on her maiden voyage

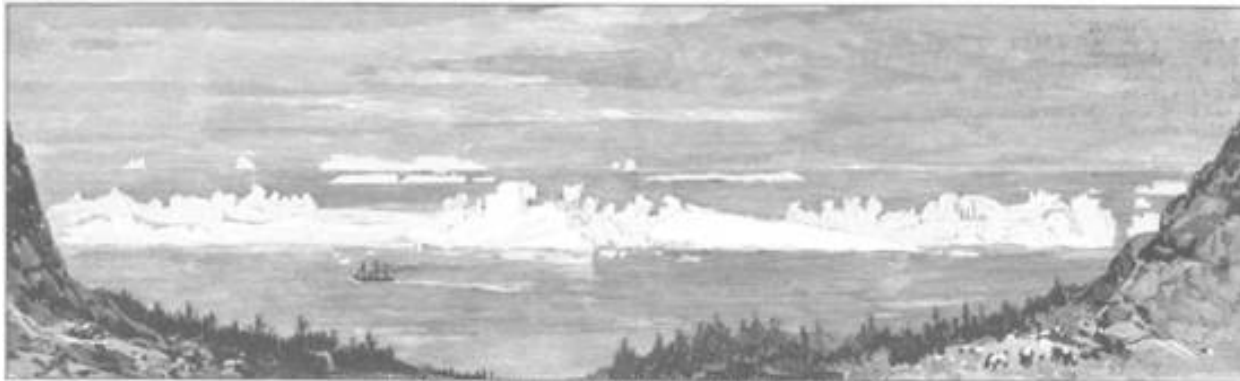


http://www.maritimequest.com/liners/titanic_art_page_3.htm
<http://www.kenmarschall.com/>



Close-up of bow,
Canadian Bulker

What size? Ice islands 10 km long have been observed, once near St John's (Harpers Weekly 1884)



ISLAND OF ICE COMPUTED TO BE FROM 8 TO 9 MILES IN LENGTH



ICEBERGS OFF THE HARBOR OF ST. JOHN'S, NEWFOUNDLAND.—FROM SKETCHES BY J. W. HAYWARD.—

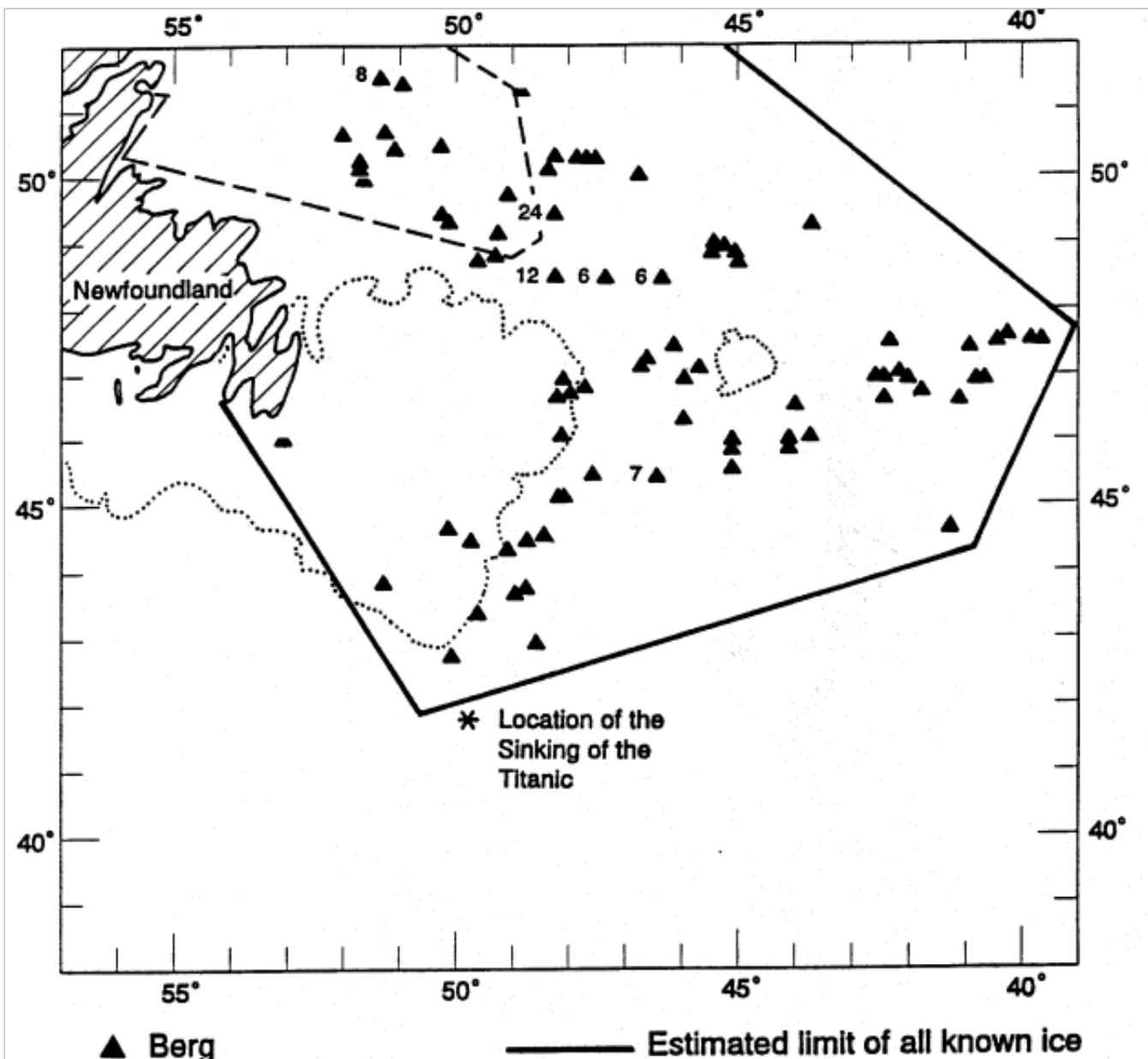
From a sketch by J. W. Hayward for *Harper's Weekly*, October 4, 1884.

Recently



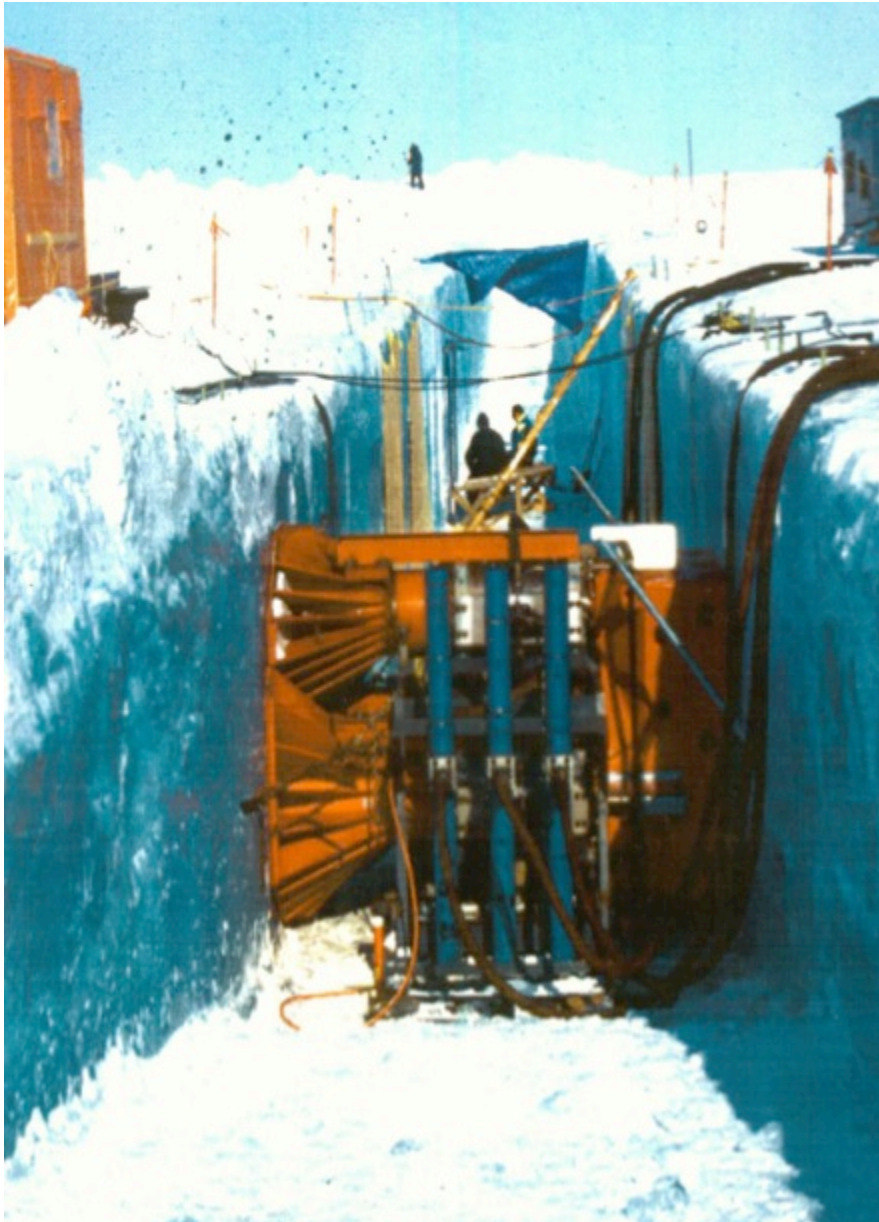
Approach using probabilities and risk

- Number of potential impacts
- Size distribution of icebergs
- Iceberg shape
- Velocity distribution
- Ice strength





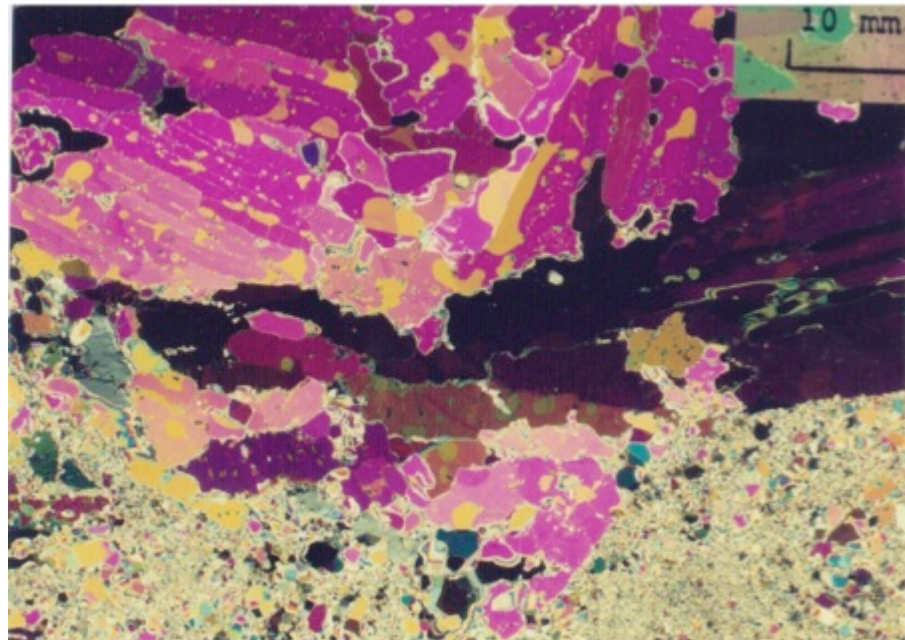
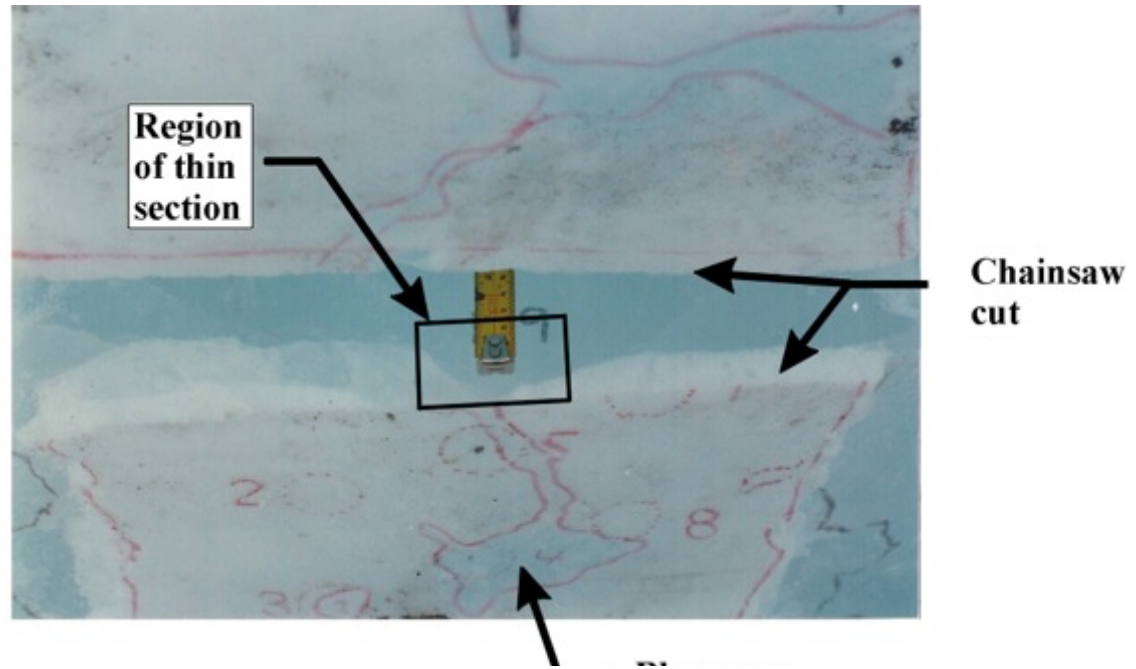
Hibernia GBS

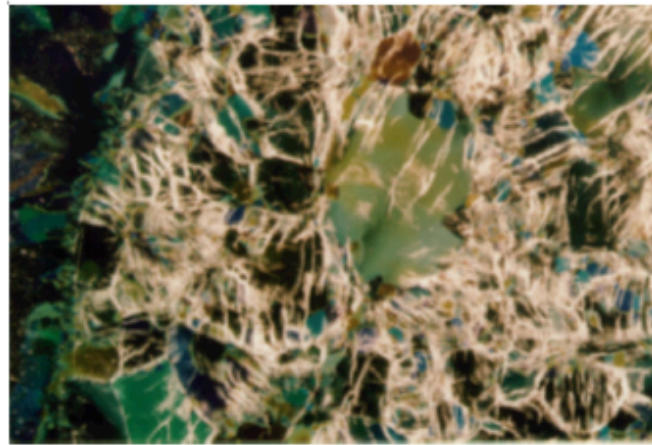


Hobson's Choice Ice Experiments

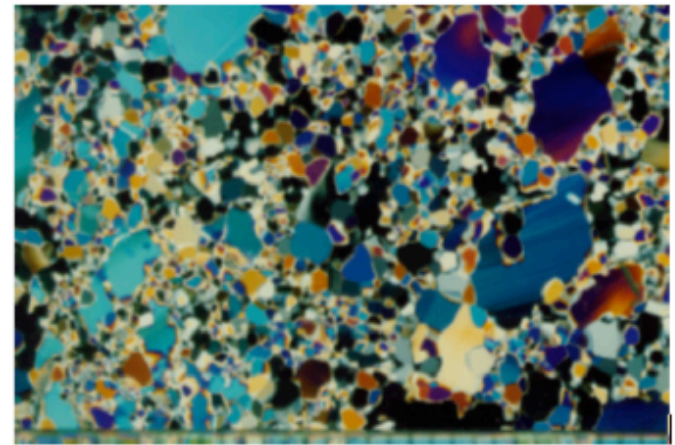
Following Pond Inlet

Deformation in a layer





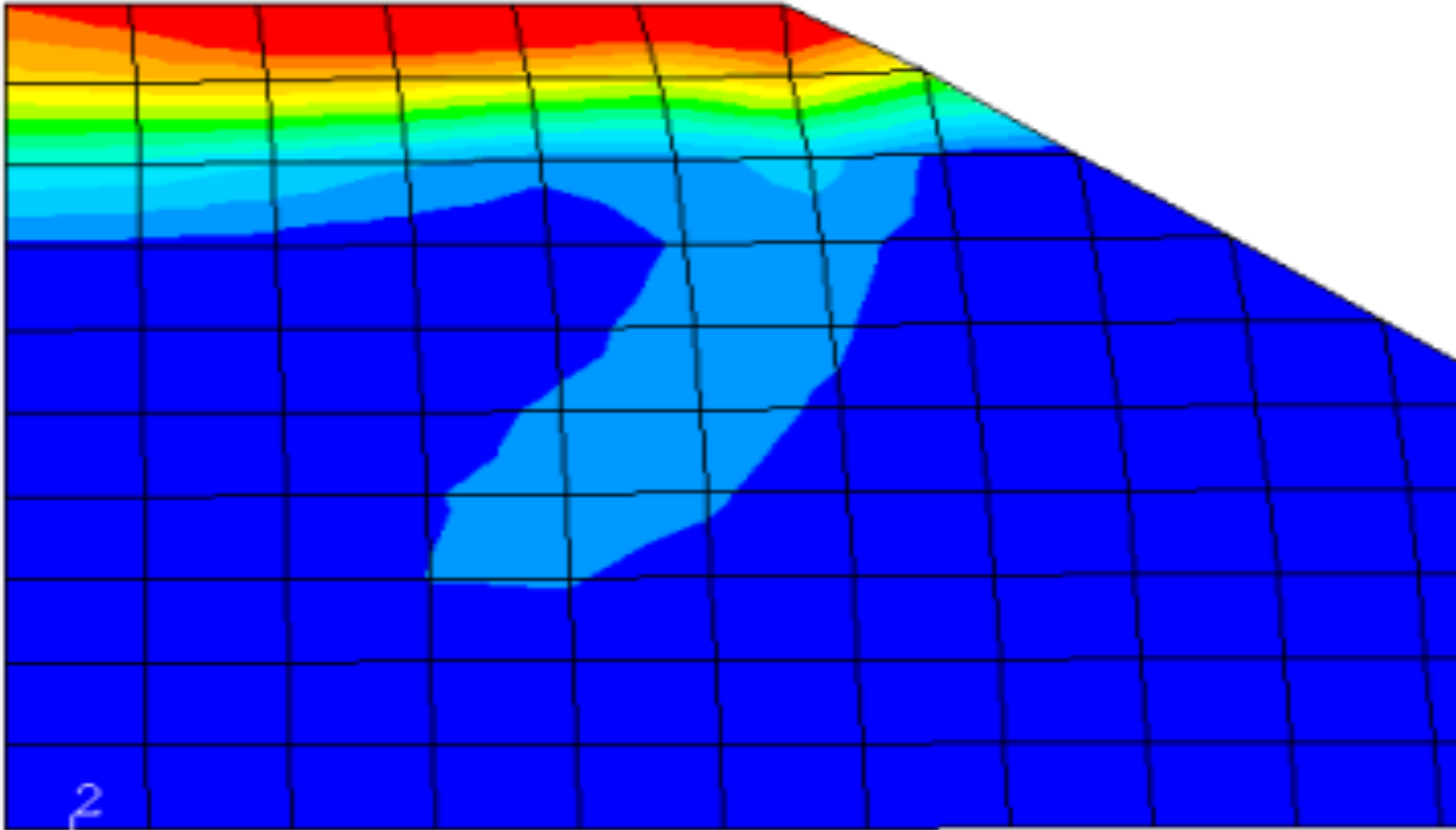
$p_c = 5 \text{ MPa}$, $s = 15 \text{ MPa}$



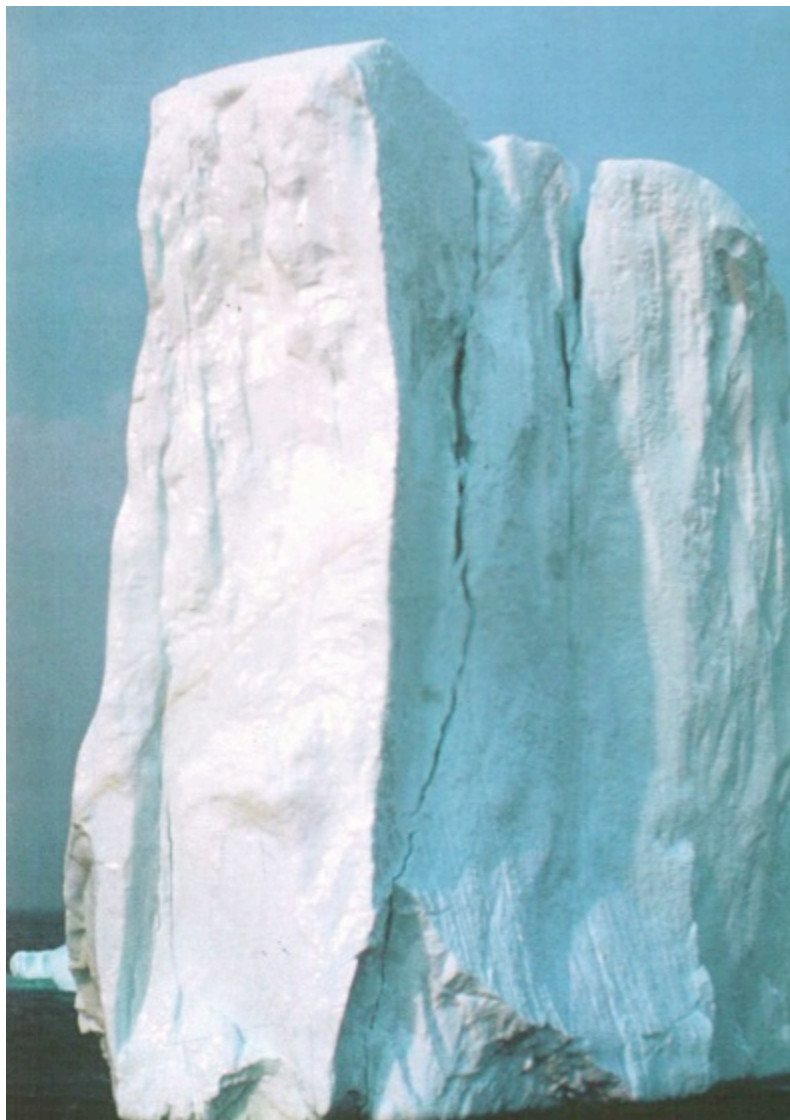
$p_c = 60 \text{ MPa}$, $s = 15 \text{ MPa}$, $\epsilon = 44\%$

Thin sections viewed through crossed polarized filters with side lighting

ABAQUS UMAT



Icebergs also fail!





Petro-Canada Terra Nova Project



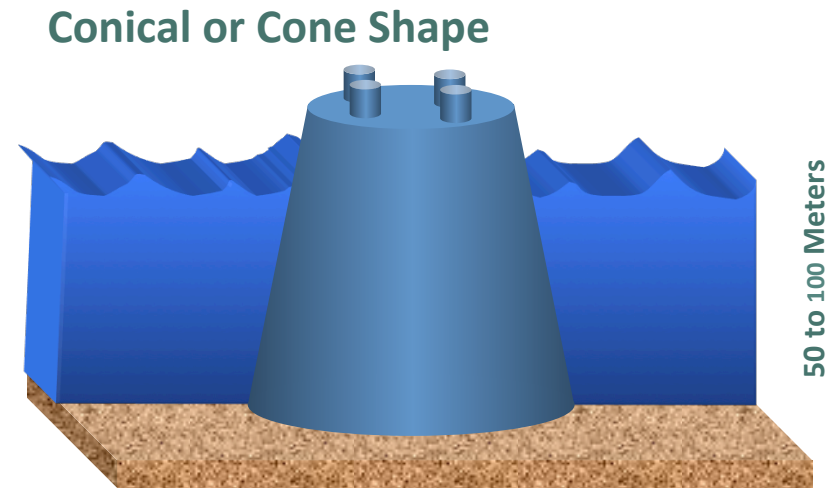
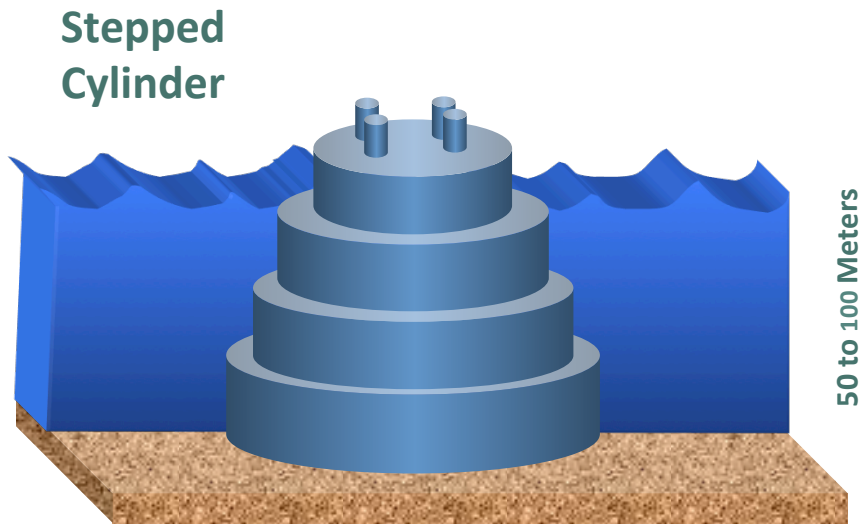
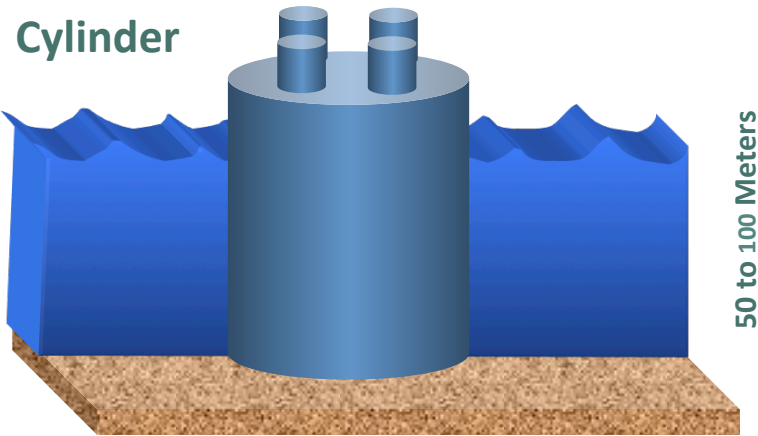
Husky White Rose Project





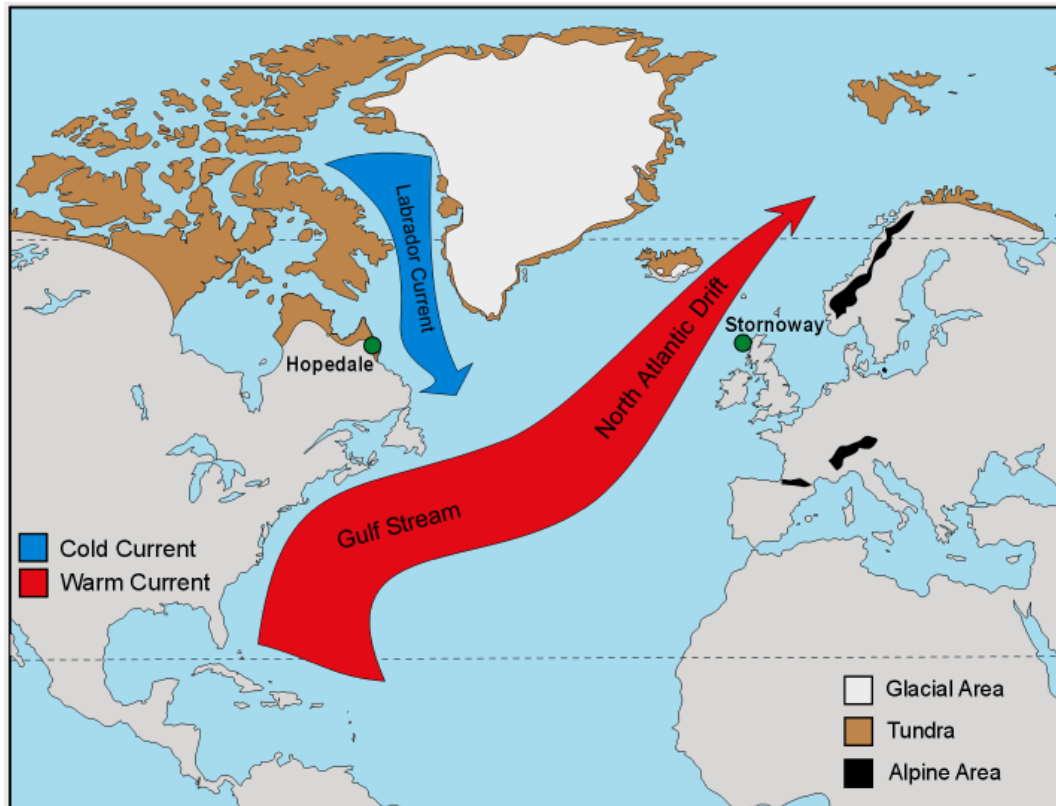


Basic GBS shapes



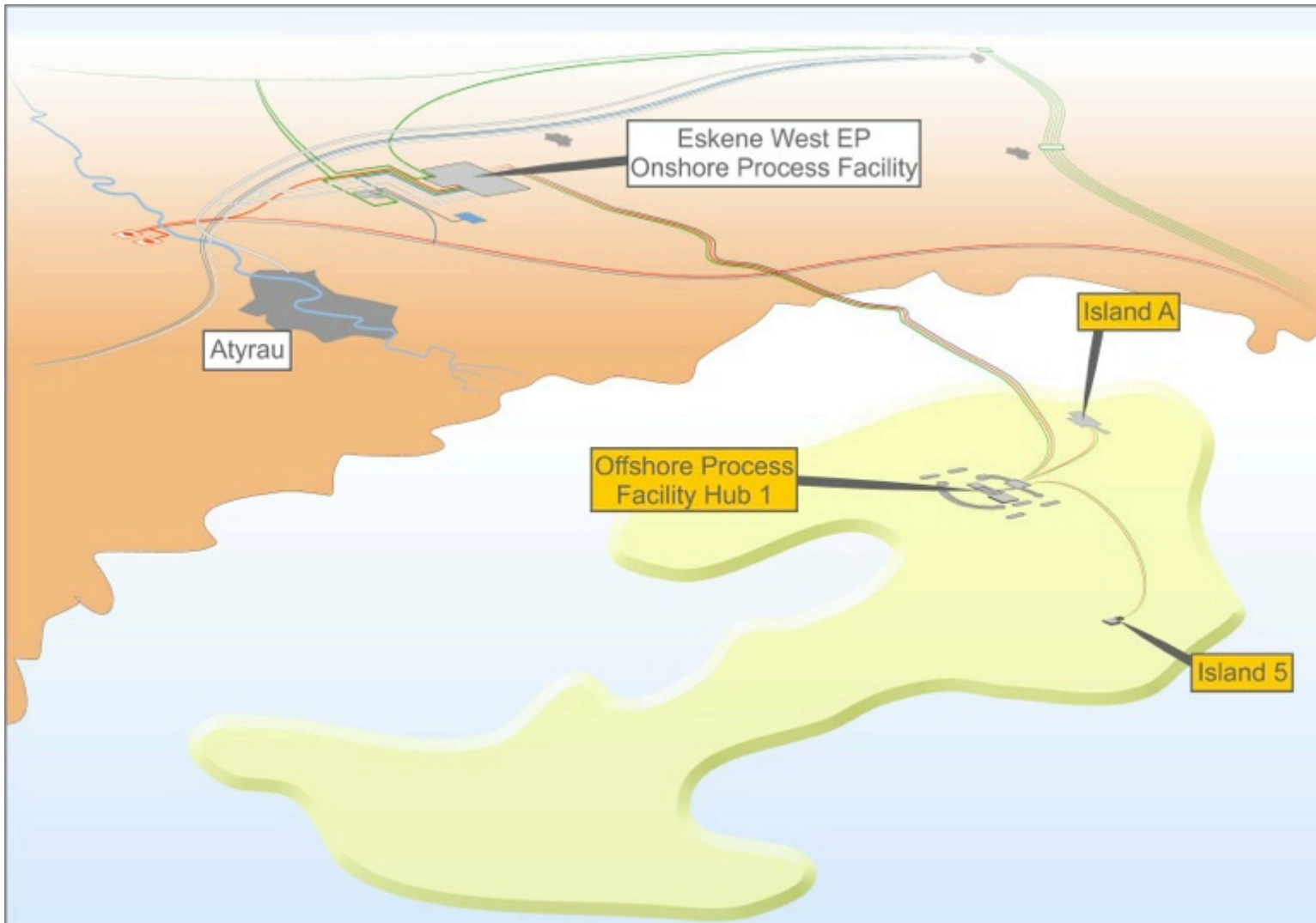
Overview of Environmental Conditions

- Sea ice and icebergs are driven by wind and by currents
- In the Barents Sea often sea ice and icebergs are found together with icebergs embedded in sea ice
- The Gulf Stream enters the area bringing warm currents into the sea
- Contrast to Hibernia & White Rose



Caspian Sea

(Shallow water)



EP Tranche 3

Stamukhi

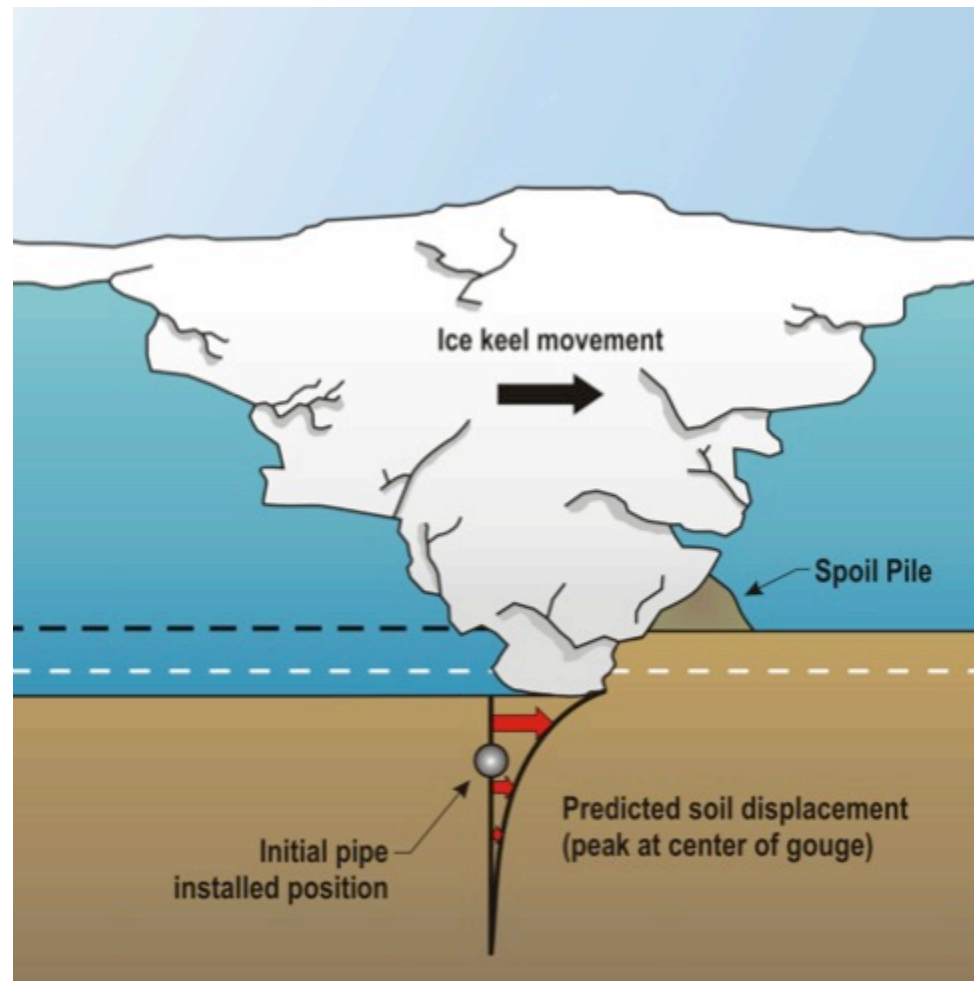


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- Pipeline Ice Risk Assessment & Mitigation



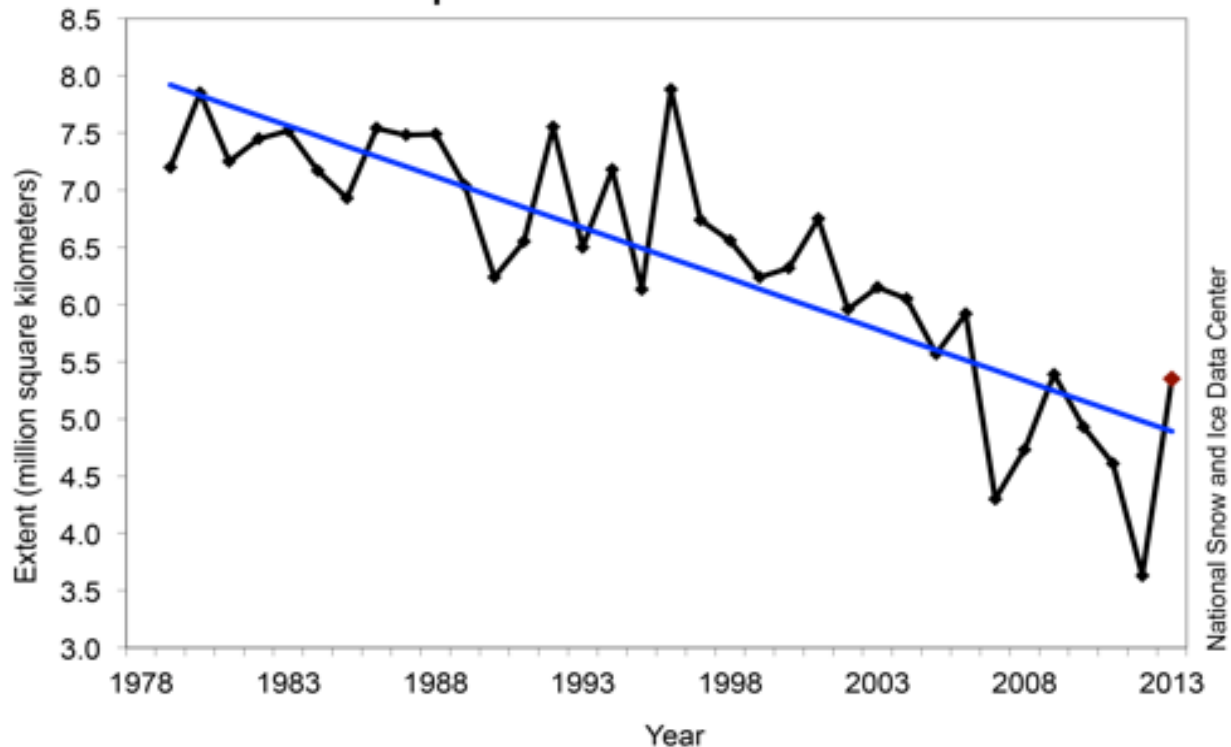
Climate Change

IPCC Fifth Assessment Report (IPCC, 2013)

- Warming of the climate system is unequivocal, and since the 1950s.
- The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.

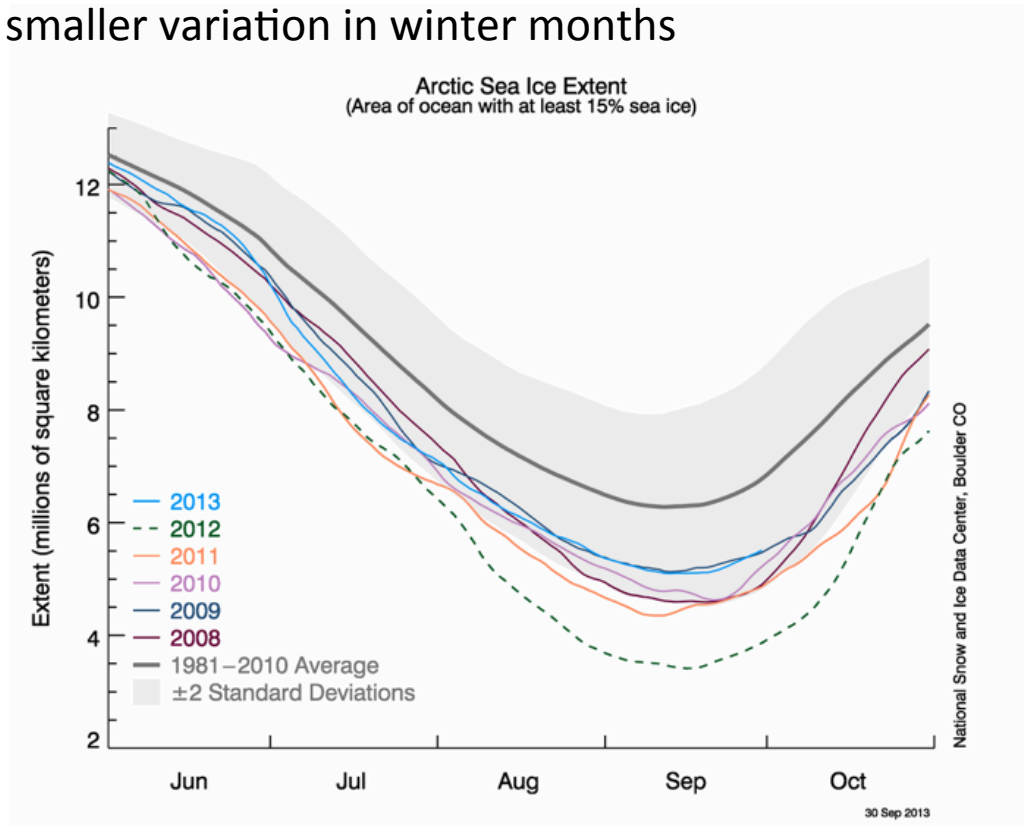
Sea Ice and Forecasts

Average Monthly Arctic Sea Ice Extent
September 1979 - 2013



<http://nsidc.org/arcticseaicenews/2013/10/a-better-year-for-the-cryosphere/>:

Note smaller variation in winter months



Arctic sea ice extent as of September 30, 2013,
with daily ice extent data for the previous five years.

The gray area around the average line shows the two standard deviation range of the

<http://nsidc.org/arcticseaicenews/2013/10/a-better-year-for-the-cryosphere/>:



Sea ice extent



Iceberg sources

- Major
- Minor

→ Common iceberg tracks

Smedsrud et al. (2011)

“The high sea ice area export must have been a significant contributor to the low September sea ice covers observed in recent years. The sea ice area export in 2009 and 2010 was lower than for the previous years, 2005, 2006, 2007 and 2008, perhaps indicating that the sea ice export may return to more moderate levels again soon.”

Uncertainties

- IPCC is accepted but interpretation in Arctic is far from straightforward
- Highly variable ice conditions
- Variability in forecasts (Stroeve et al. (2014) and Wilson et al. (2004))
- Flux through Fram Strait
- Pack ice is present within the Canadian Arctic Archipelago throughout the year.
- Multiyear ice is formed in the zone of heavy ridging along the periphery of the Beaufort gyre
- In a warmer climate, the ice bridges that ring the Sverdrup Basin will be weaker, and heavy ice will move more quickly through the Basin (Melling)

Ice between the arctic islands

- Wilson et al. consider the Northwest Passage (NWP) shipping route. Sea ice predictions were considered to be less dependable and indeed inadequate for the Canadian Arctic Archipelago and the passageways between the islands

- Howell et al. (2013) confirmed that the presence of MY ice in the Canadian Arctic Archipelago originating from the Arctic Ocean has been maintained and increased since 2005, attributed to increased open water area within the Canadian Arctic Archipelago that have provided more leeway for inflow to occur.

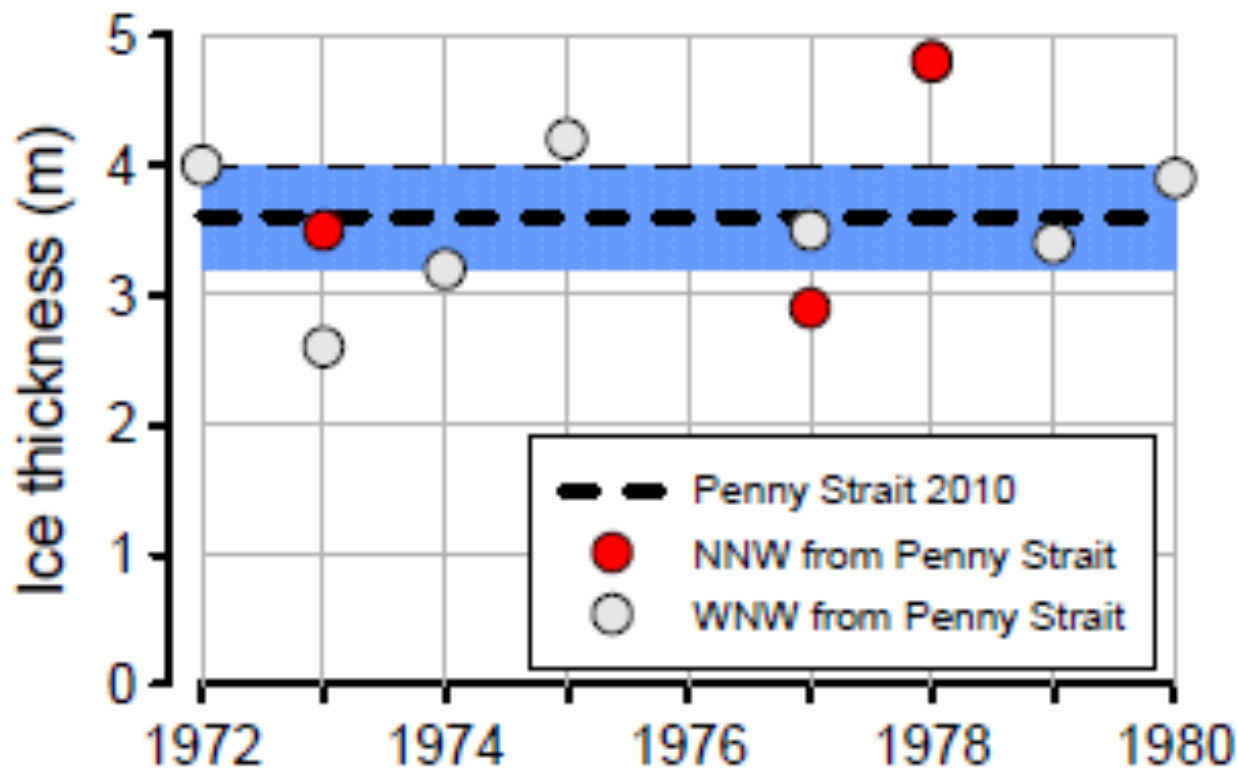


Figure 25. Track-mean ice thickness from drill-hole surveys north-west of Penny Strait during late winter in the 1970s, compared with values based on 2009 data (shaded band is $\pm\sigma$).



http://en.wikipedia.org/wiki/Northwest_Passage

Other climate impacts

- Drilling season could be increased in length if warming persists
- Warming of permafrost leads to shorter season for winter roads
- New design require consideration of discontinuous permafrost

Uncertainties

- Future ice conditions
- Interannual variability
- Need to account for in design and planning

Recommendations

- Our recommendations are primarily dealt with in the presentation by Peter Noble
- Here it is noted that improved access to educational facilities by northerners is seen as a priority, and we advocate the commencement of instruction in engineering and technology at CHARs linked to expertise in other Universities in Canada, for example Memorial University



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