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Changing sea ice in the Canadian Arctic

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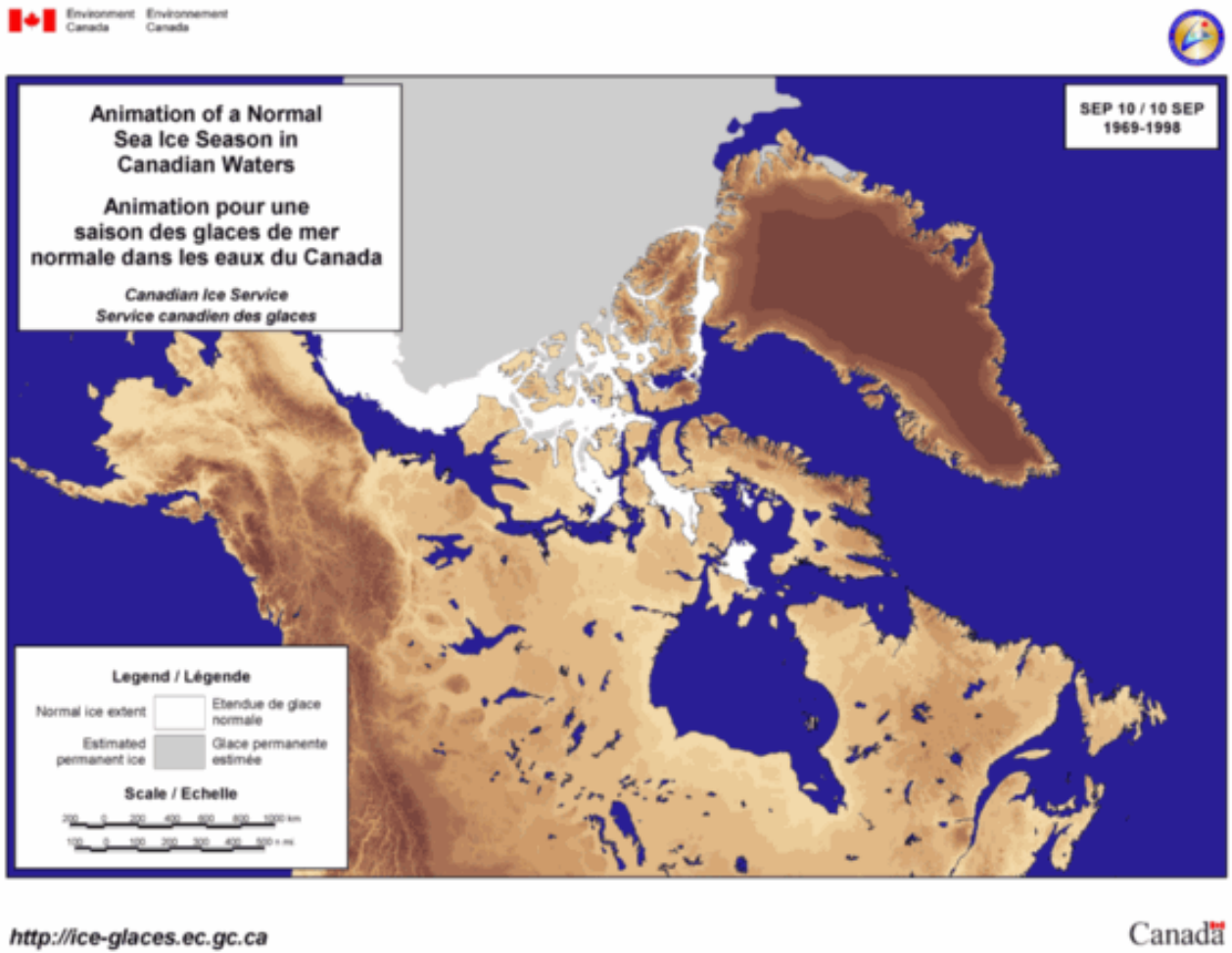
Environment and Climate Change Canada

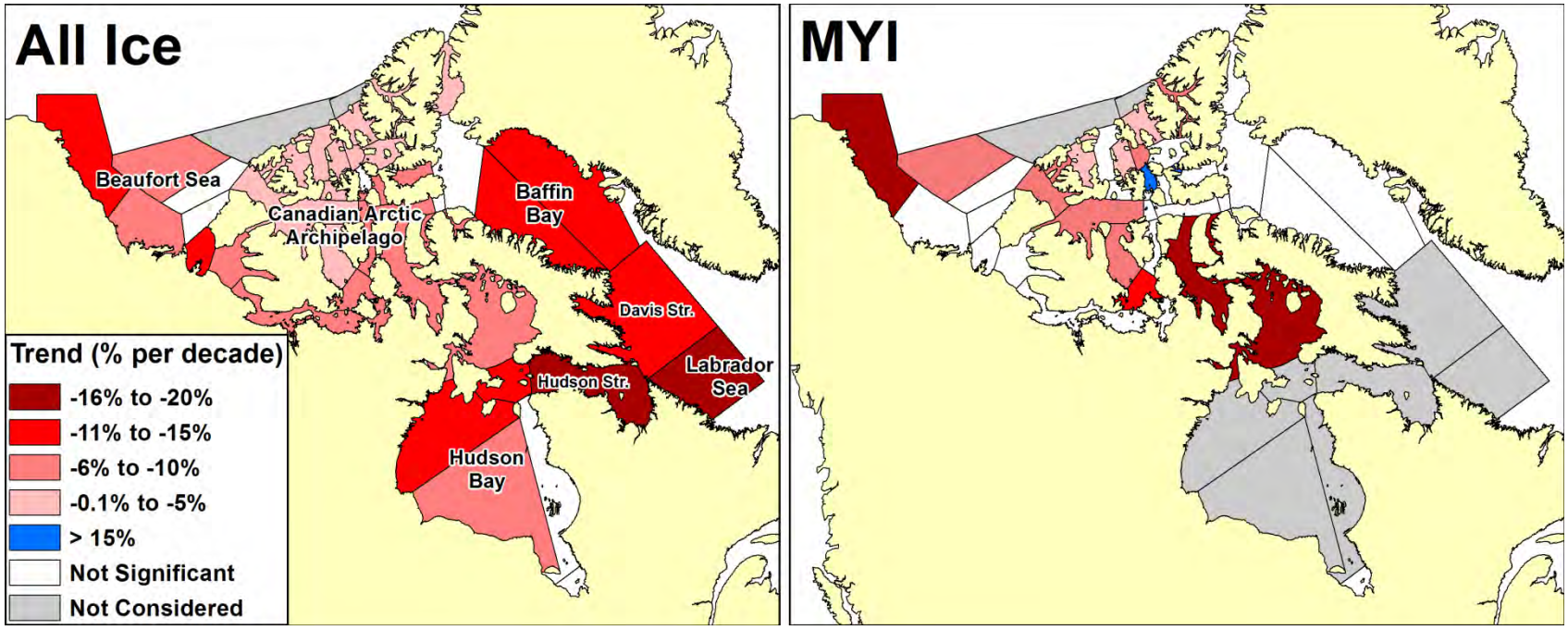
July 21, 2017

Outline

- Trends
- Canadian Arctic Archipelago
- Northwest Passage
- Beaufort Sea



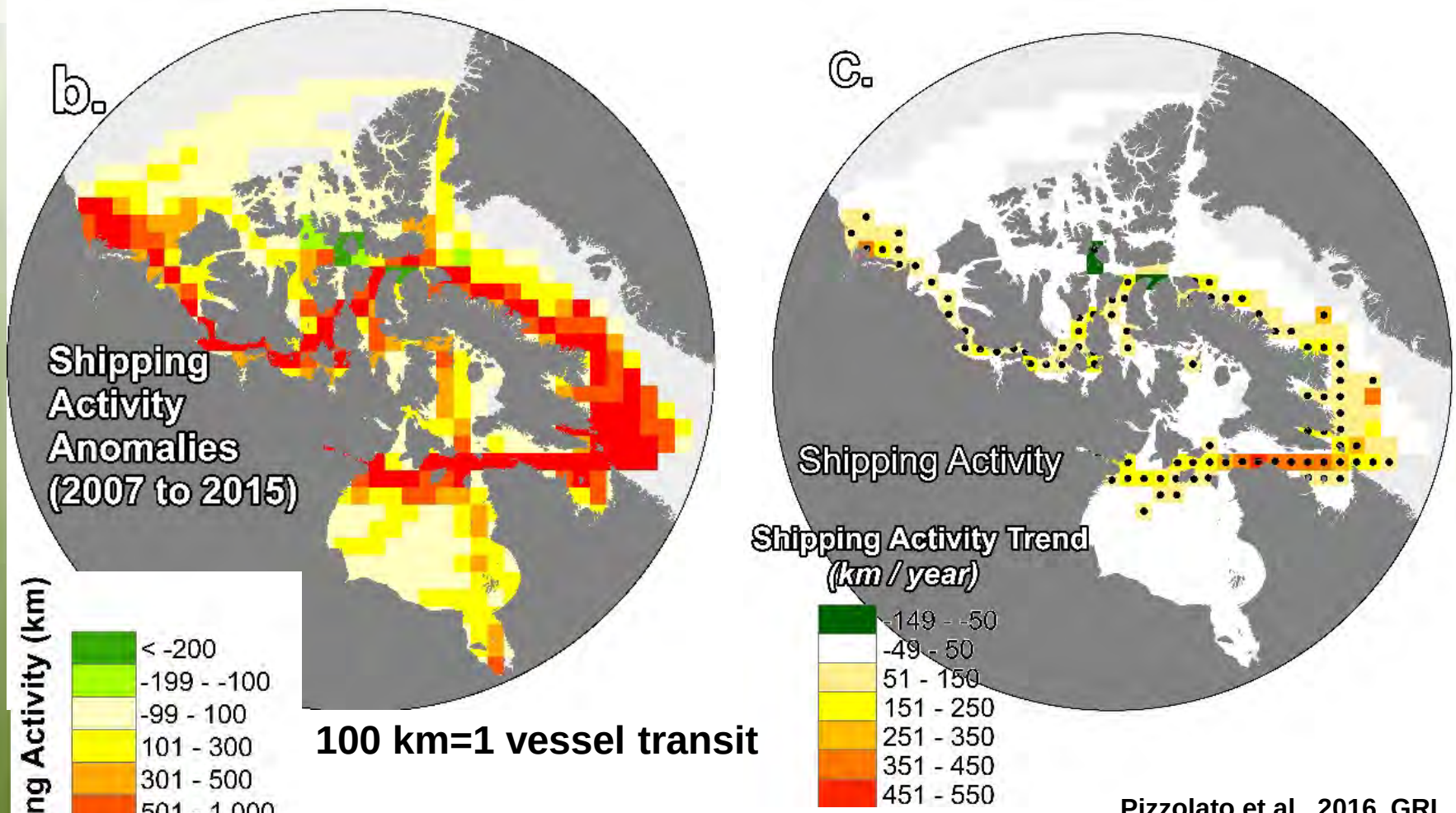
Summer sea ice trends in the Canadian Arctic, 1968-2016



Tivy et al., 2011, updated

- Almost all regions in the Canadian Arctic are experiencing decreases in total ice.
- Multi-year ice (MYI) decreases are not as wide-spread as total ice.
  - in the last 10 years the MYI trend has doubled.

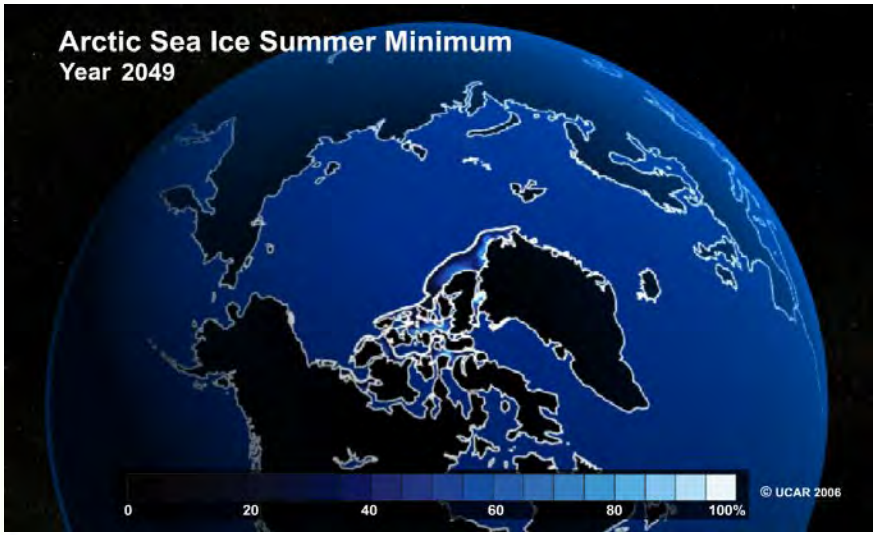
Canadian Arctic shipping activity anomalies and trends, 1990-2015

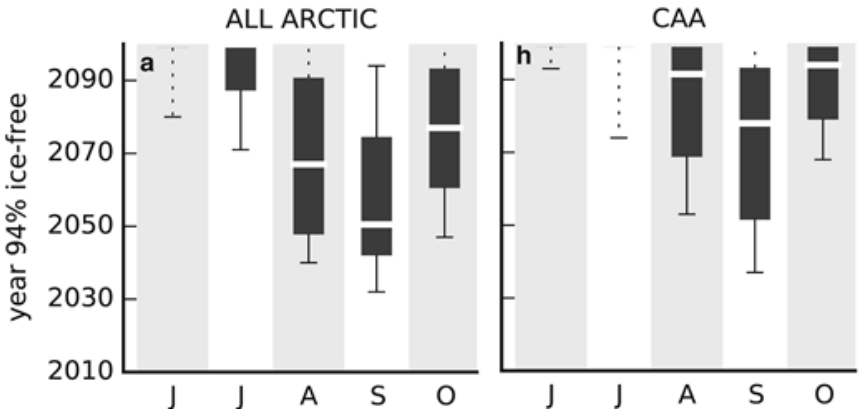


Pizzolato et al., 2016, GRL

Canadian Arctic Archipelago

Sea ice loss in the CAA will lag the Arctic Ocean

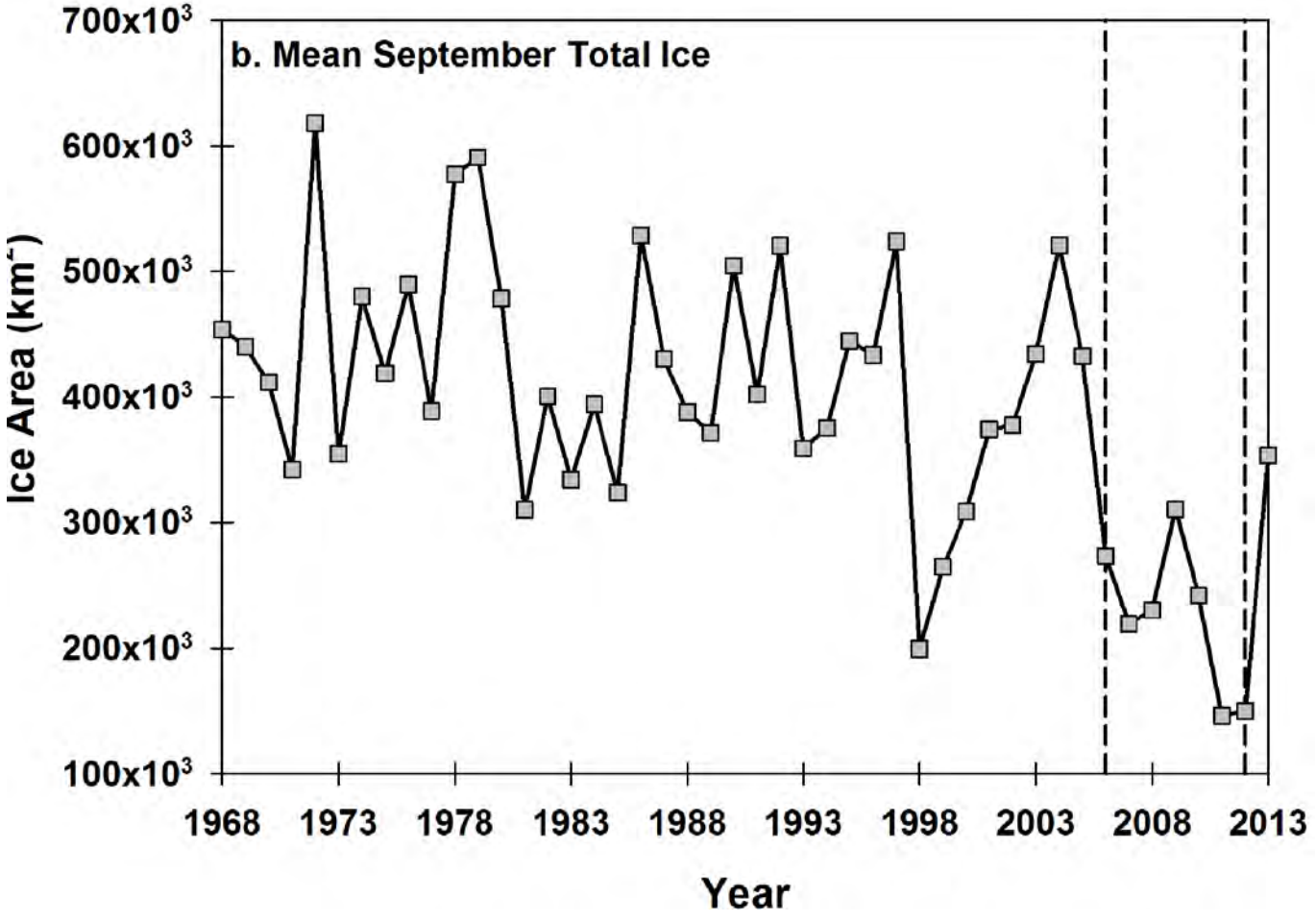




- Arctic sea ice-free ~2050 versus CAA (Northwest Passage) not ice free until ~2070.
- Observed and predicted changes vary from region to region and one cannot extrapolate evidence for change in one region to the next.
- How is sea ice in Canadian Arctic Archipelago responding to change?

Holland et al., 2006; Laliberte et al., 2015

Record light ice year of 1998!



Howell et al., 2010

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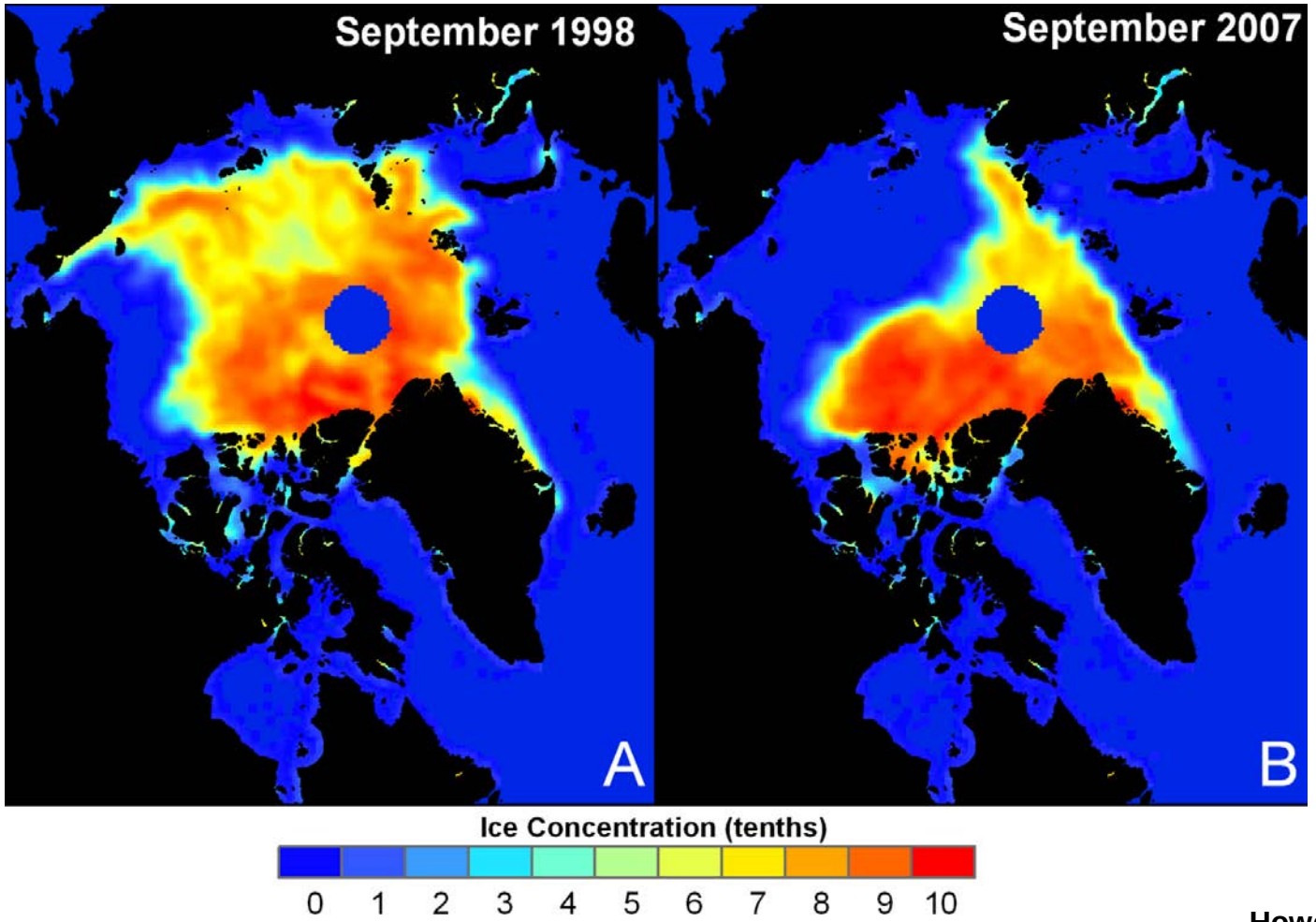
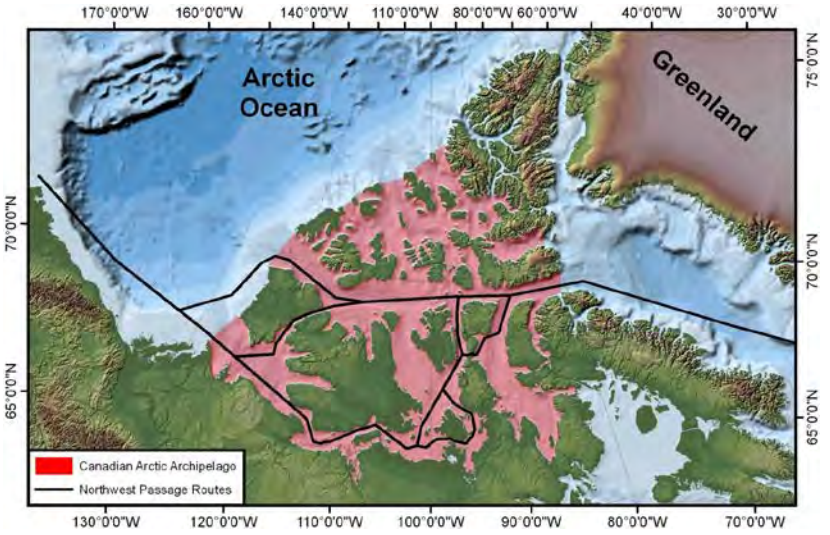
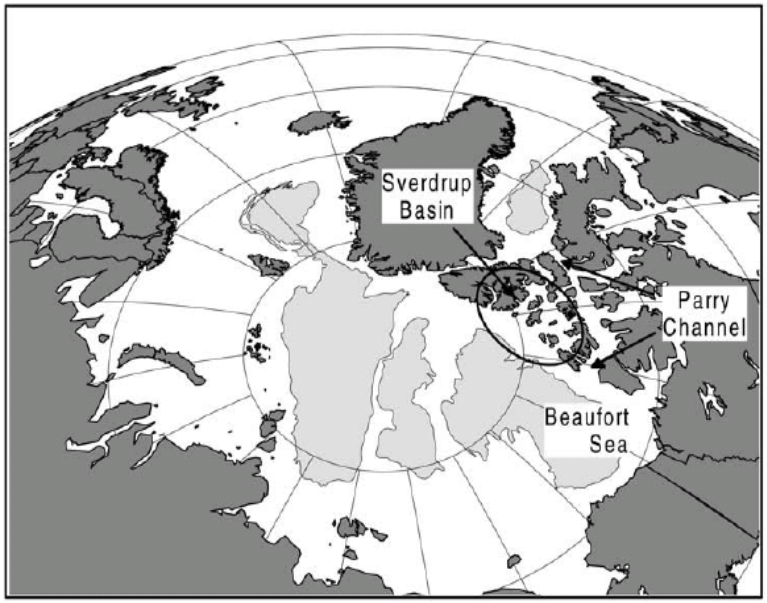


Howell et al., 2010

Different ice regime compared to the Arctic Ocean

- i) Landfast (immobile) for 6 to 8 months of the year.
  - *Negates influence of winter-time changes in atmospheric circulation.*
- ii) Wind driven sea ice movement is restricted because of numerous narrow water channels.
- iii) Ice thickness is controlled by more by thermodynamics than dynamics (ridging) in the CAA.
- iv) Exchange of ice between the CAA and the Arctic Ocean.
- v) Often ~50% mix of seasonal first-year ice and multi-year ice.

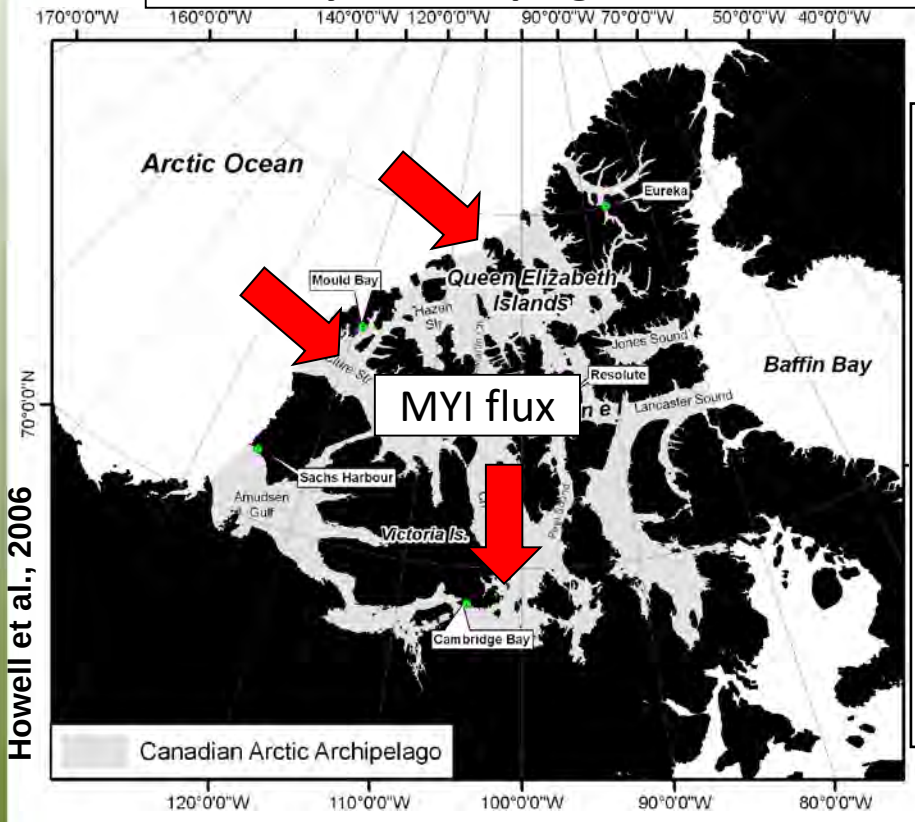




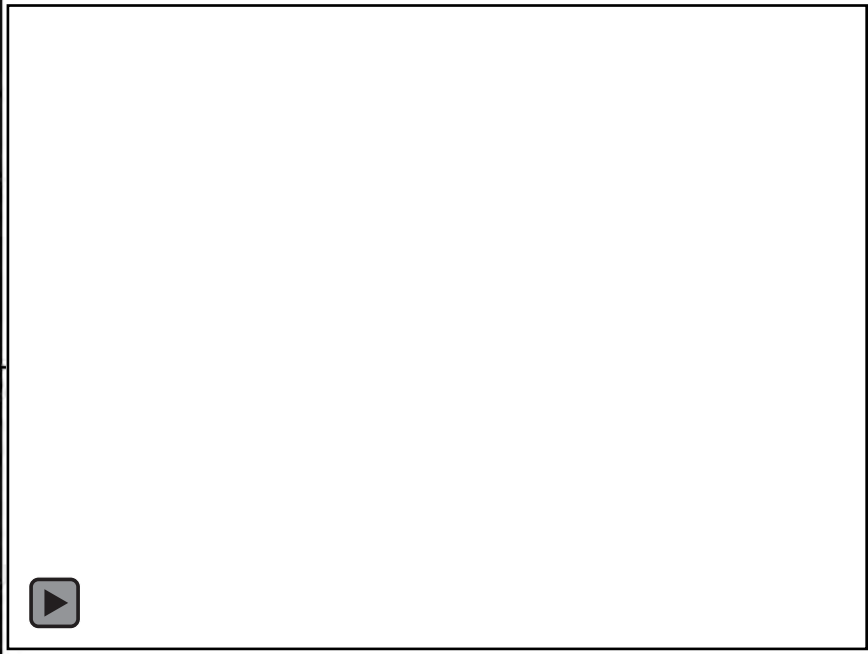
Melling, 2002

The sea ice “drain-trap” mechanism

Large-scale atmospheric circulation continuously forces multi-year ice up against the north face of the CAA



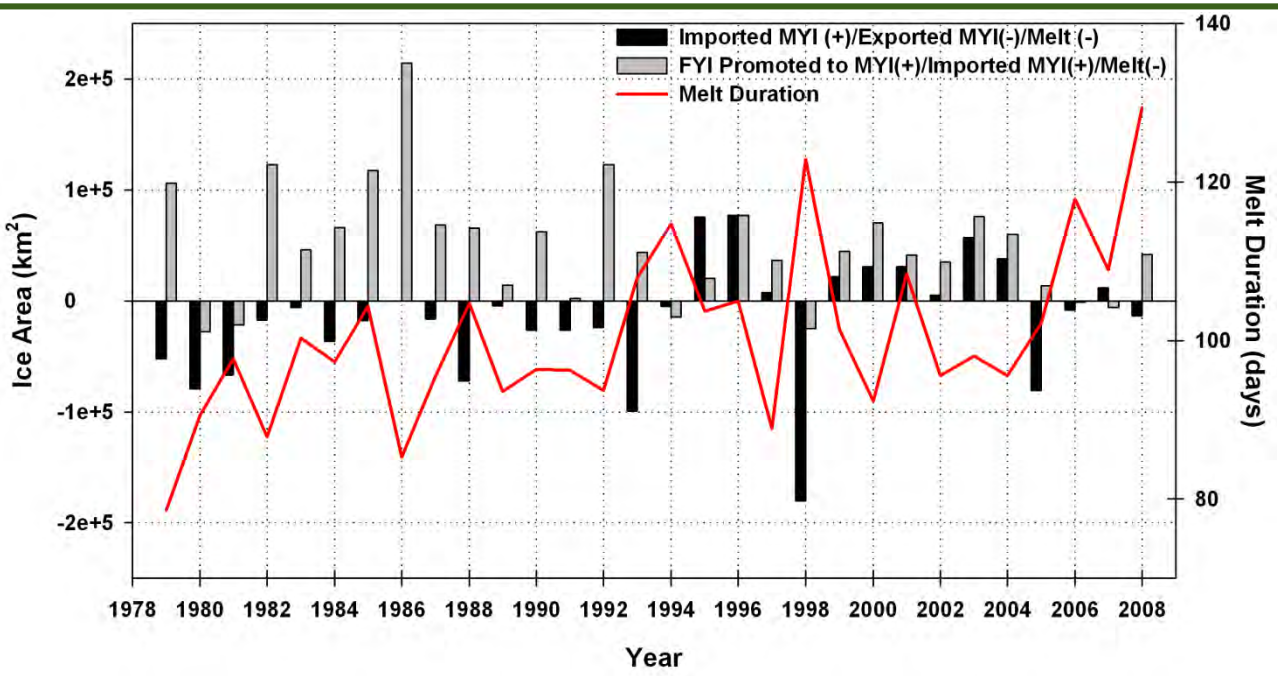
Howell et al., 2006



Howell et al., 2006

- Helps facilitate heavy sea ice conditions within the CAA.
- Also, facilitates “recovery” from light ice years.

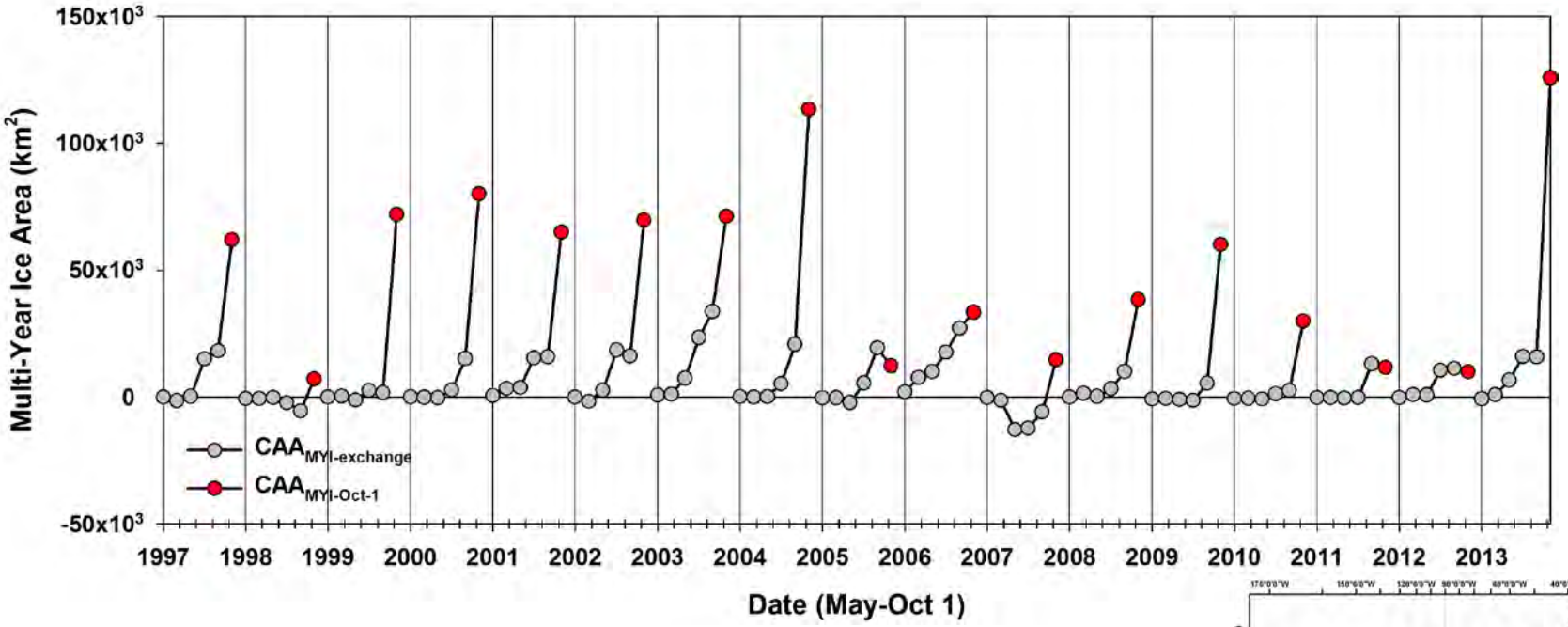
Changing source of multi-year ice in the CAA



- FYI aging was the dominant contribution to the CAA's MYI inventory up until 1994 when the source changed to more Arctic Ocean MYI import.
- Longer/warmer melt seasons → increased open water → more opportunity for Arctic Ocean MYI import.

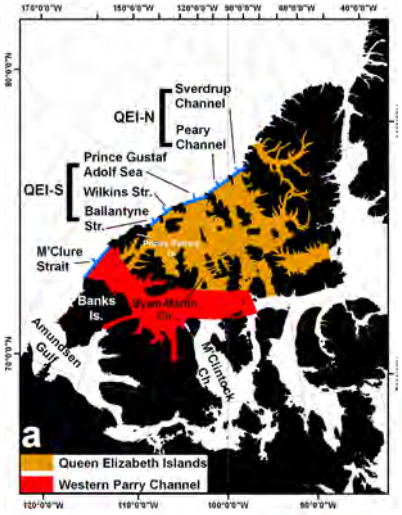
Howell et al., 2009

Changing source of multi-year ice in the CAA

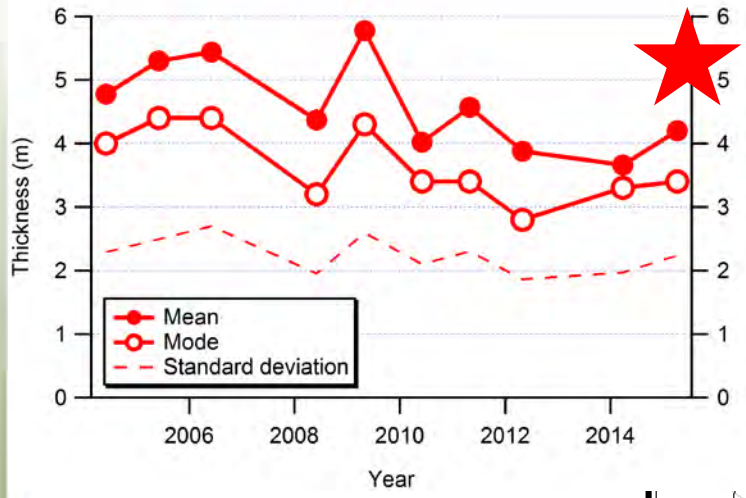


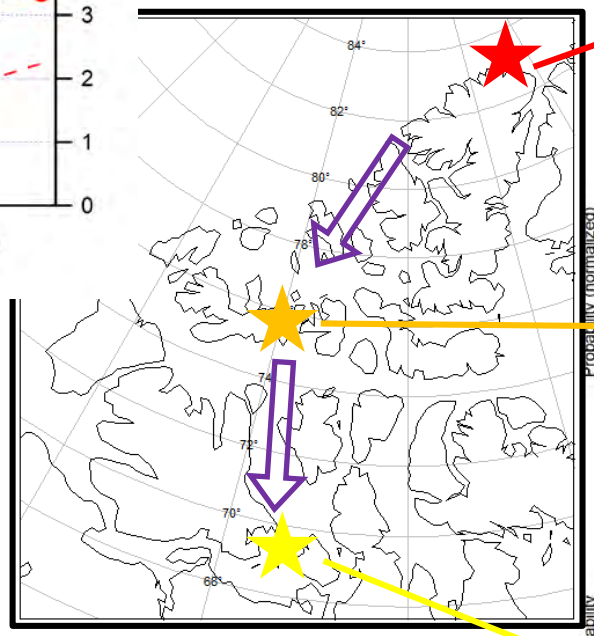
Howell et al., 2015

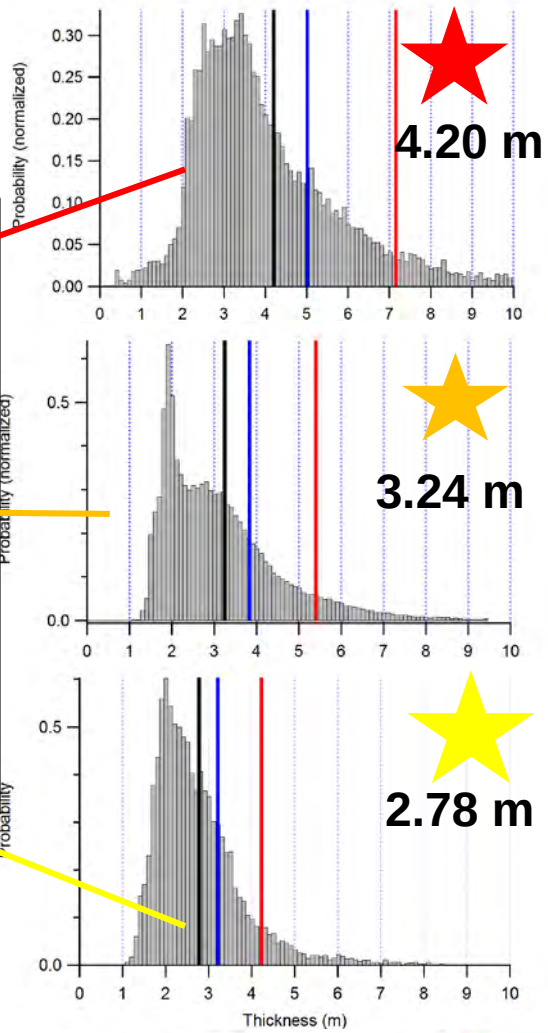
- FYI aging is the primary source (80%) of CAA MYI
- Arctic Ocean MYI inflow is the secondary source (20%)
- Low period of MYI Replenishment from 2005-2012



Ice thickness in the CAA



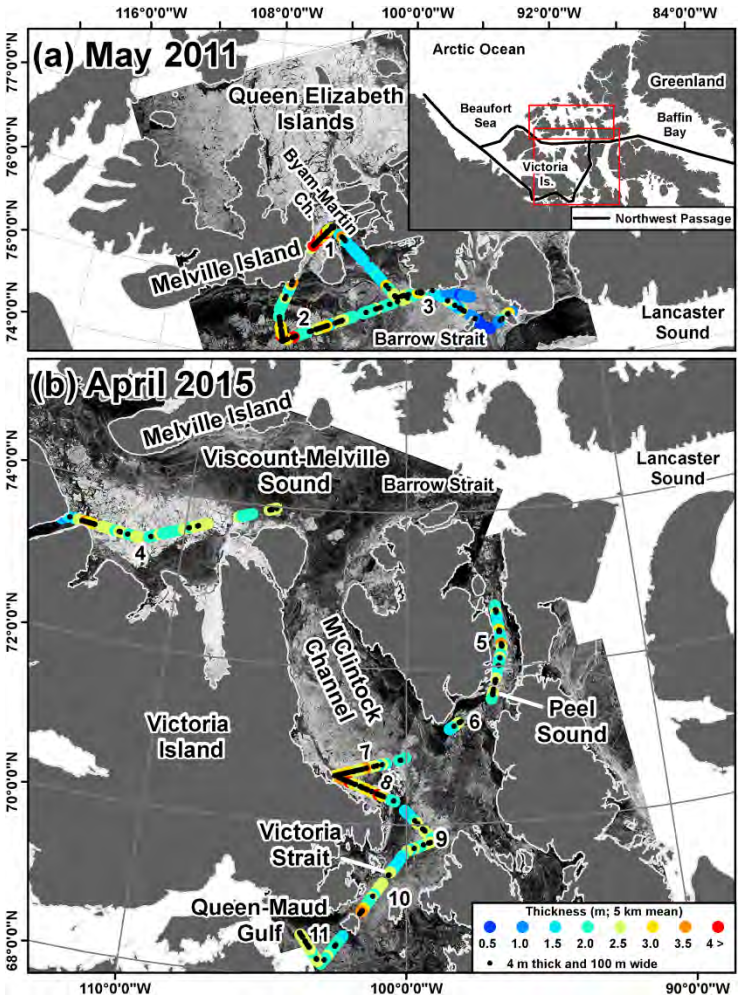




- Strong thinning during multiyear southward drift
- Emergence of 2 m thick FYI mixed into MYI

C. Haas

Ice thickness in the CAA



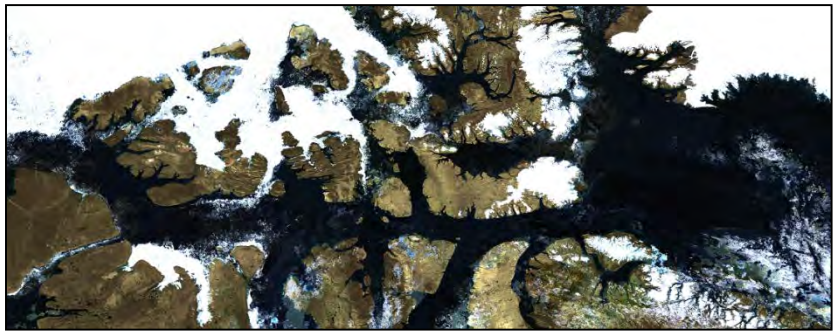
- Thicker MYI from the Arctic Ocean can transit more quickly through the CAA.
- Even in today's climate ice is still very thick (3-4 m) and potentially hazardous.
- Thick ice features more than 100 m wide and thicker than 4 m occur frequently.

Haas and Howell, 2015

The Northwest Passage

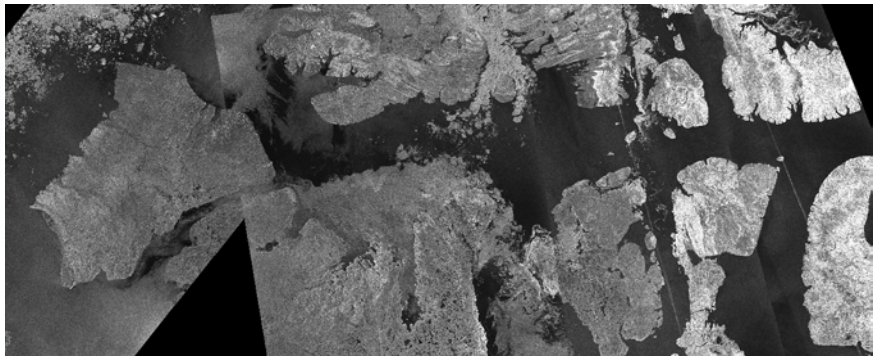
The clearing of the Northwest Passage

2007 – August 21



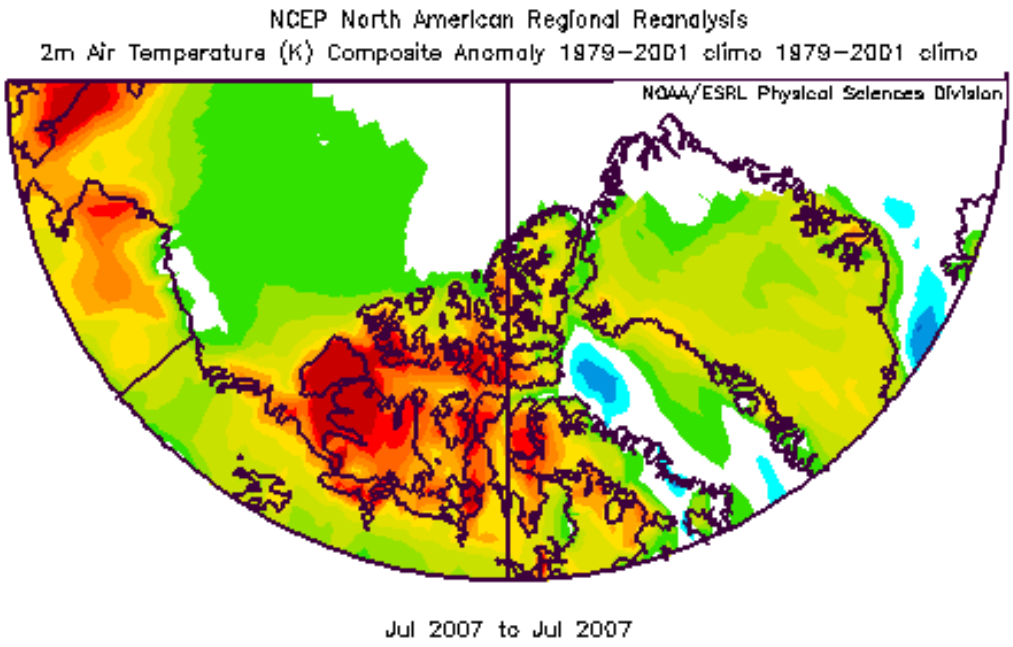
2015 – September 26

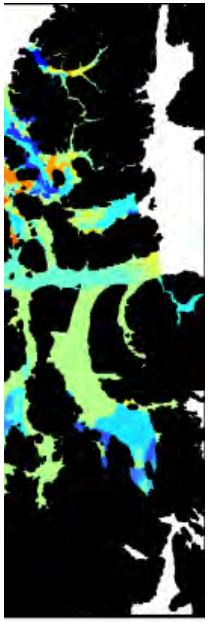
1999 – September 3



What caused the Northwest Passage to clear in 2007?

- The following sequence of events:
  - i) minimal MYI in the region.
  - ii) anomalous warm temperatures facilitating rapid melt.





vell et al., 2009

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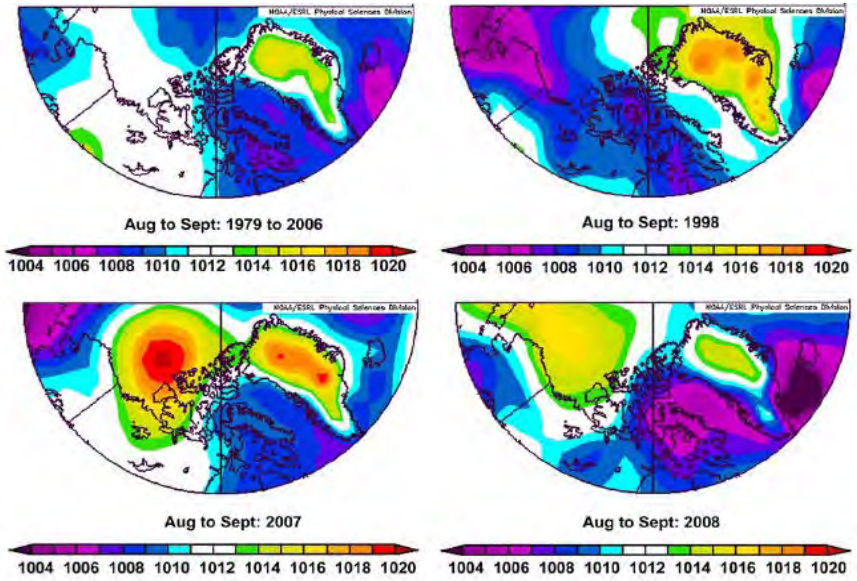
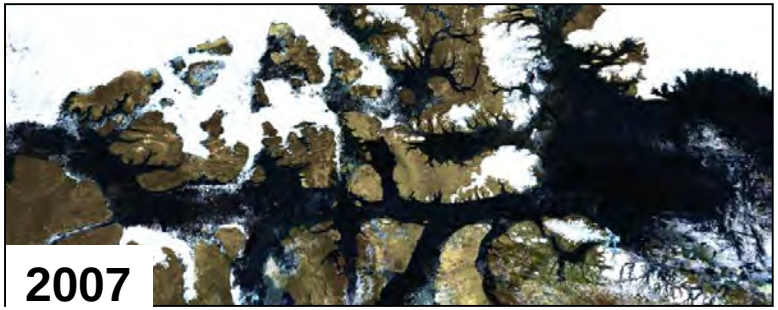
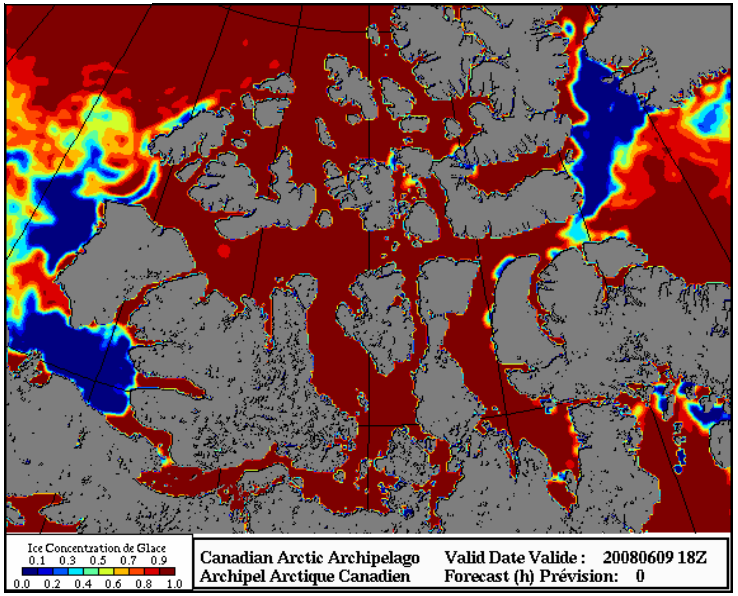
What caused the Northwest Passage to clear in 2007?



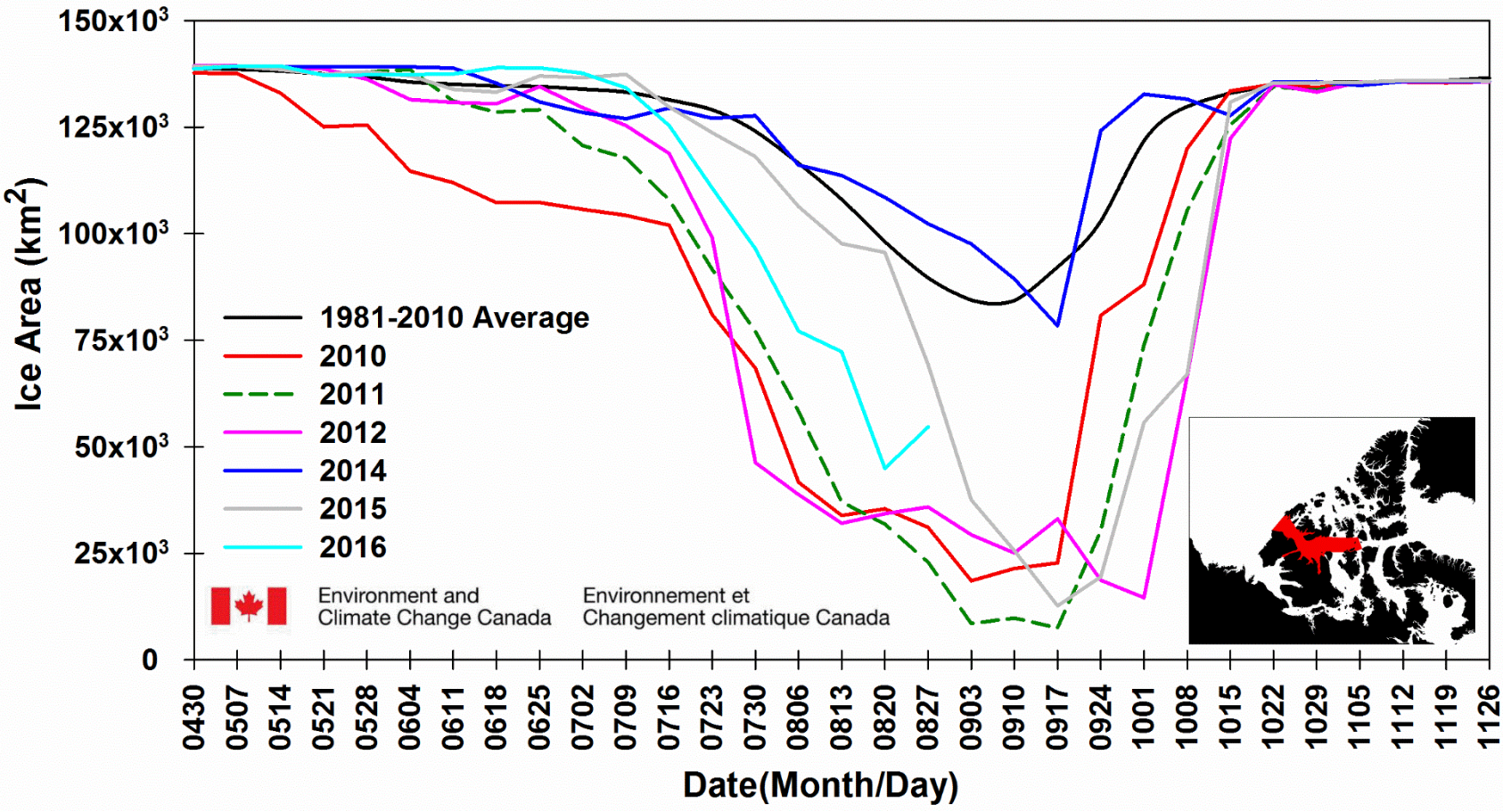


2008

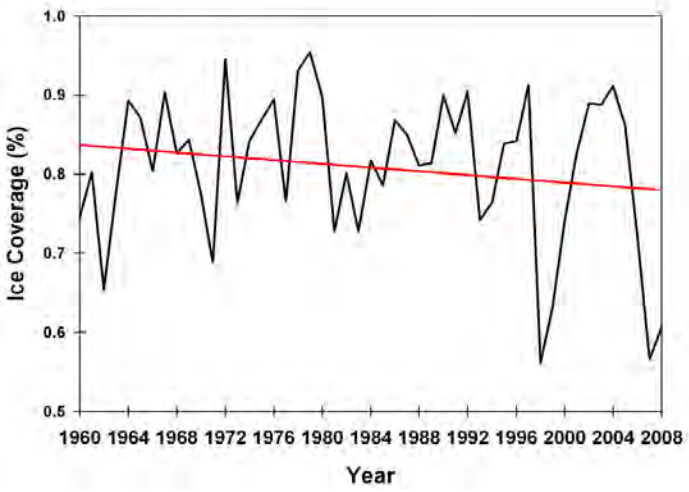


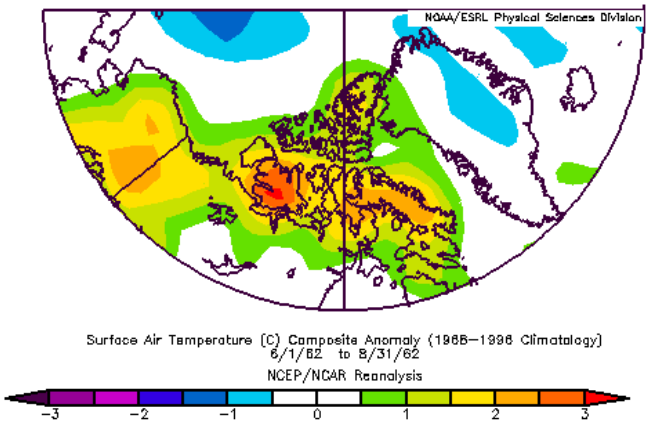
- Atmospheric circulation forces ice along Melville Island.
- 2008 continuous flow across Parry Channel – a long melt season is not enough.
  - 2008 longest melt season on record

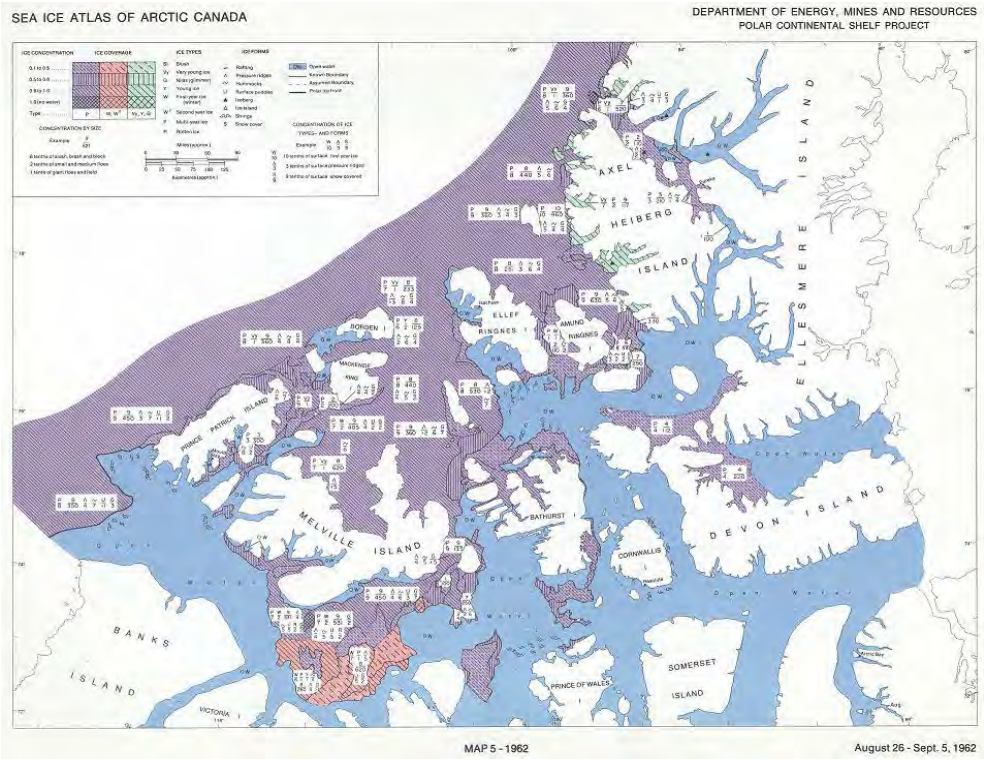
Clearing more common in recent years



Northwest Passage almost completely cleared 50+ years ago in 1962







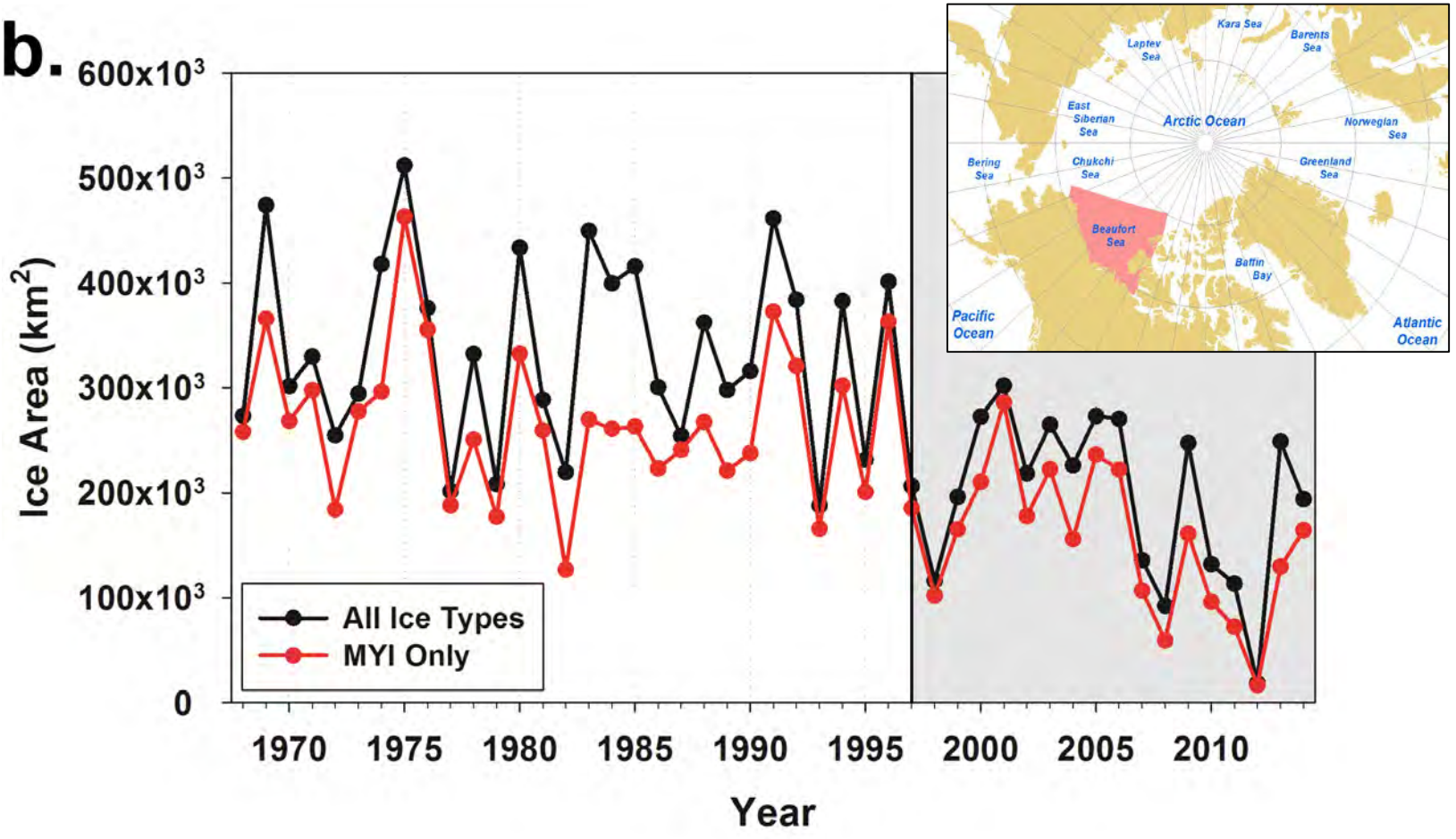
Tivy et al., 2011

Beaufort Sea

Sea ice circulation in the Beaufort Sea

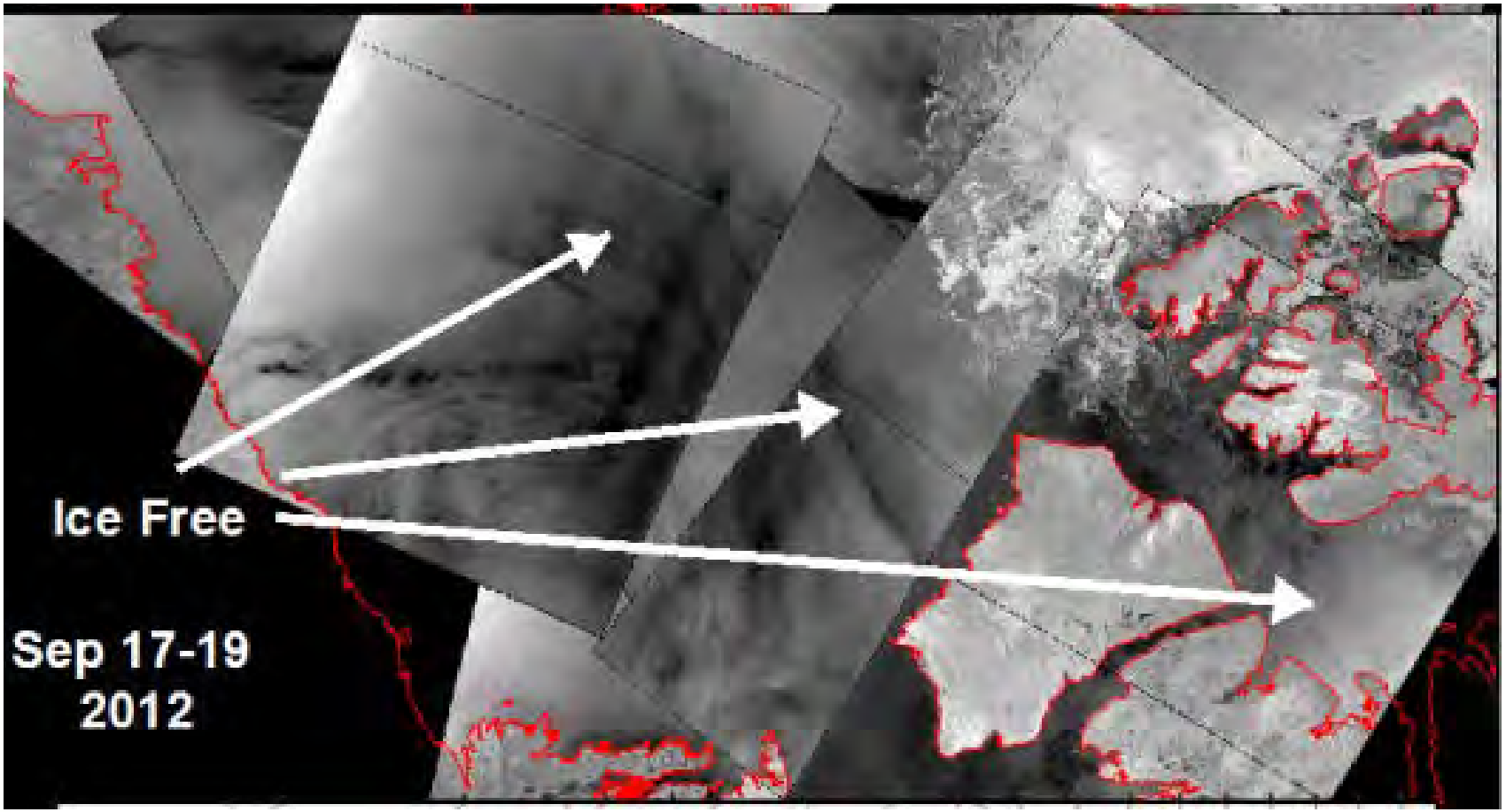
- Ice can circulate in the Beaufort Gyre for 7-10 years.
- Historically a region where ice would age and thicken before being re-circulated in the Arctic.
- Region has experienced dramatic changes in recent years.

Average September sea ice area



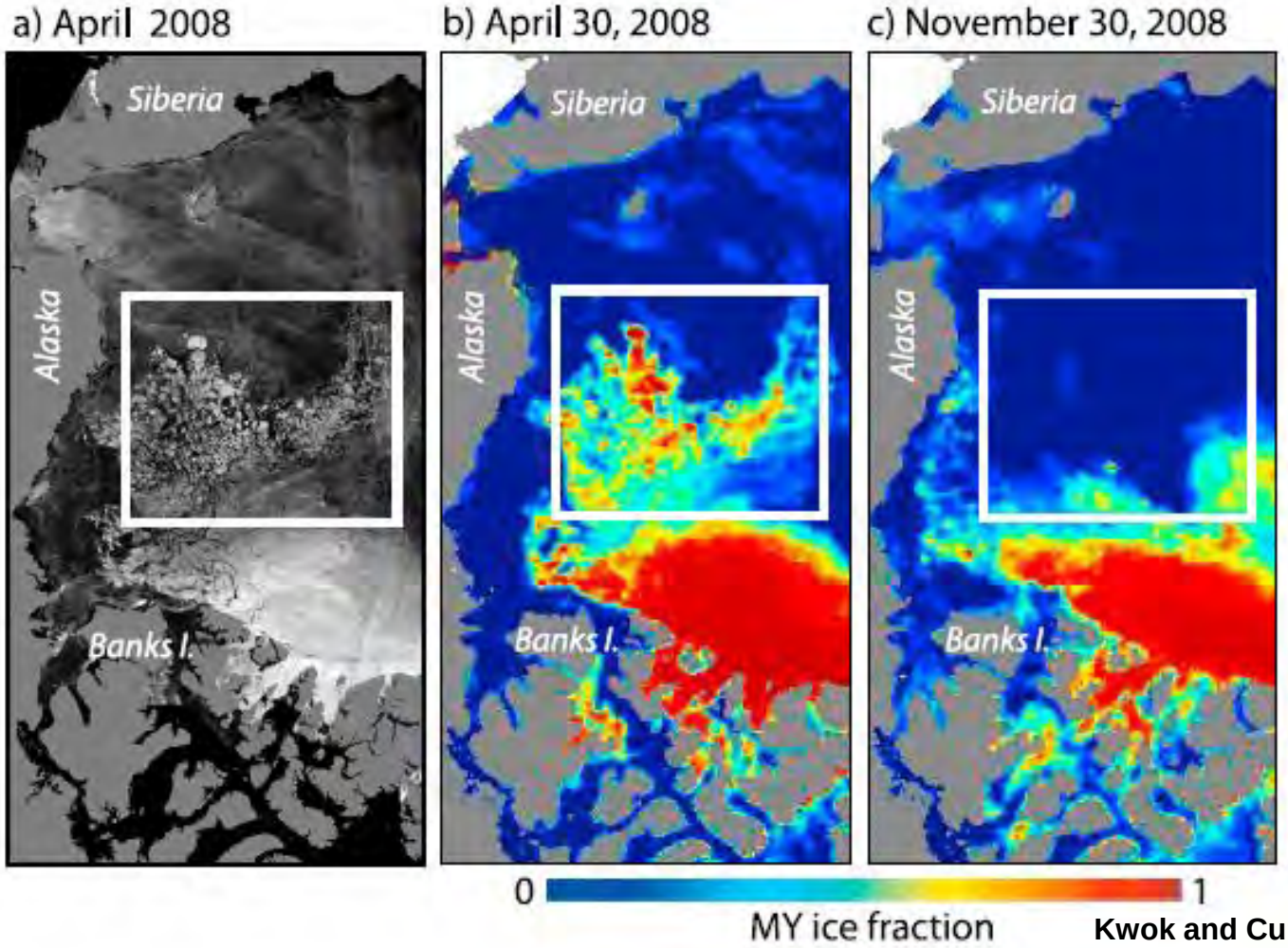
Howell et al., 2016

Virtually sea ice-free in 2012



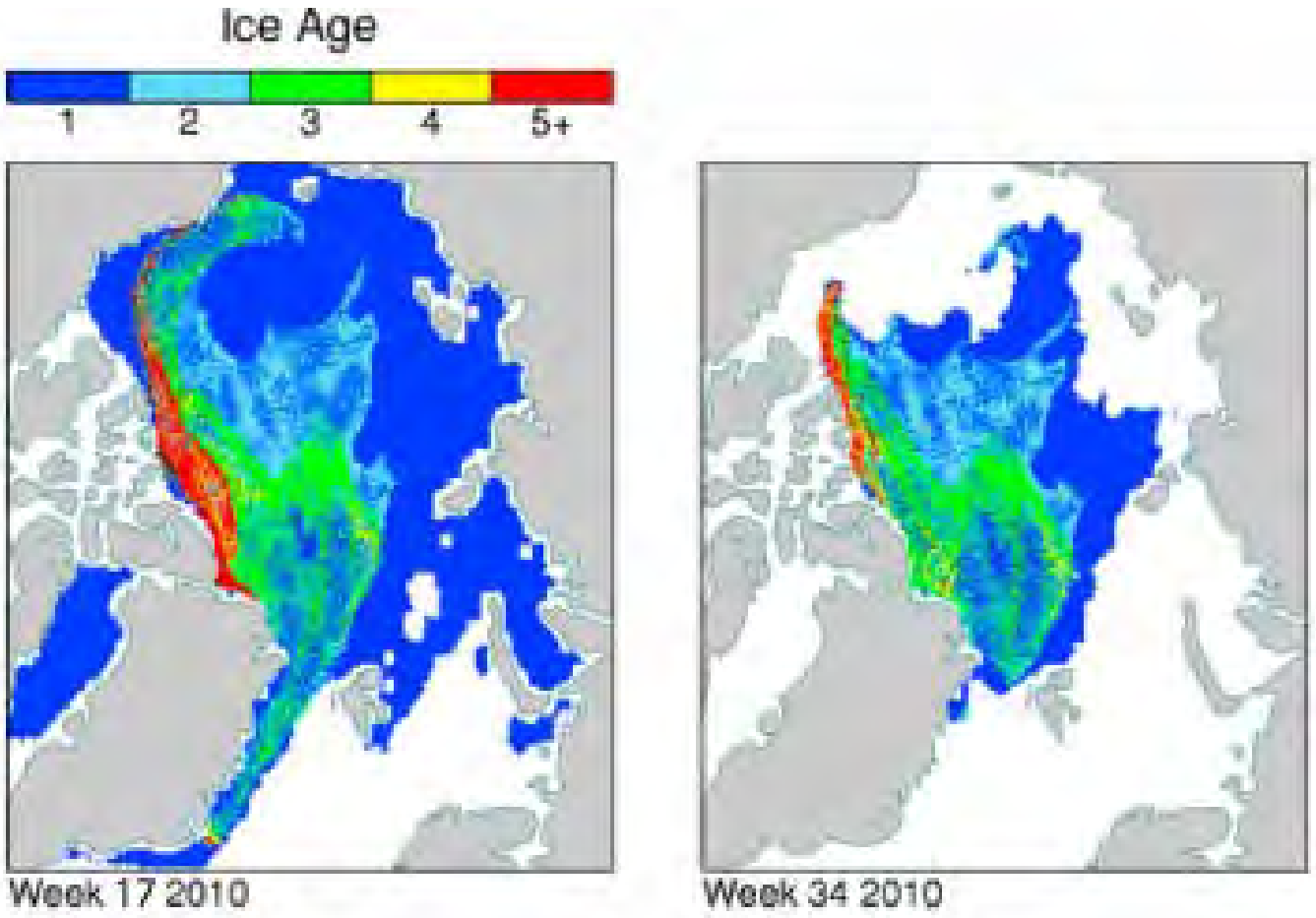
Howell et al., 2009

Increased melt in 2008



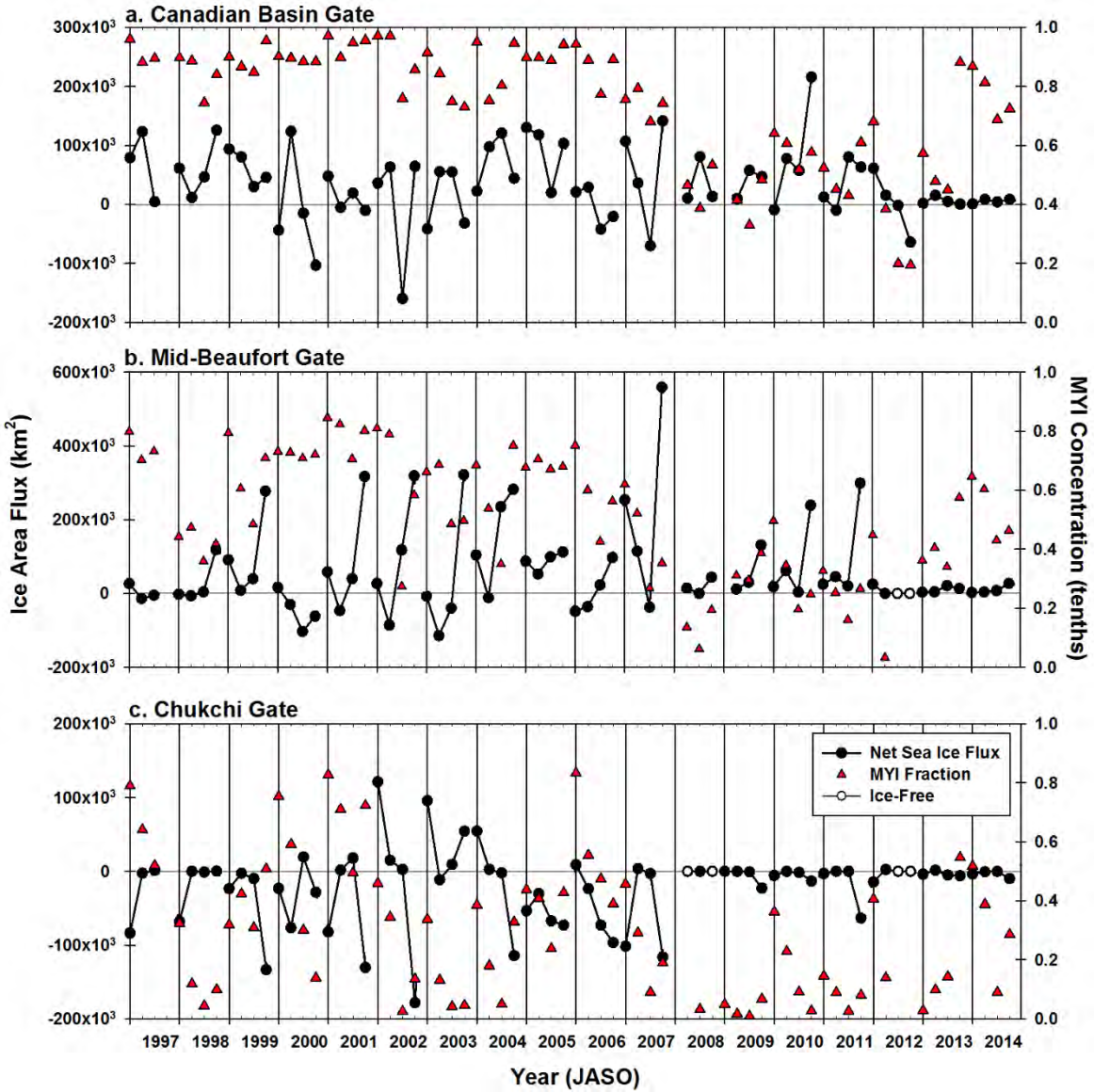
Kwok and Cunningham, 2010

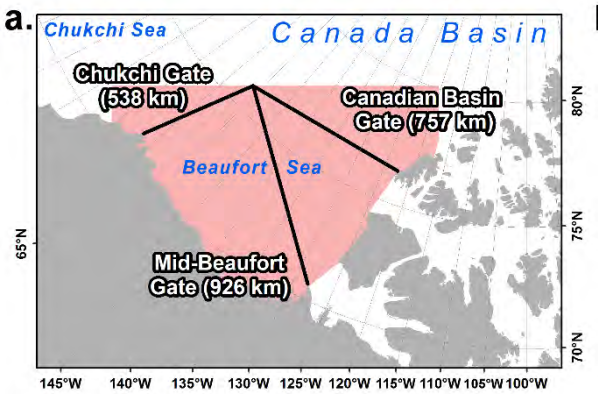
Increased melt in 2010



Stroeve et al., 2010

Quantifying ice transport through the Beaufort Sea





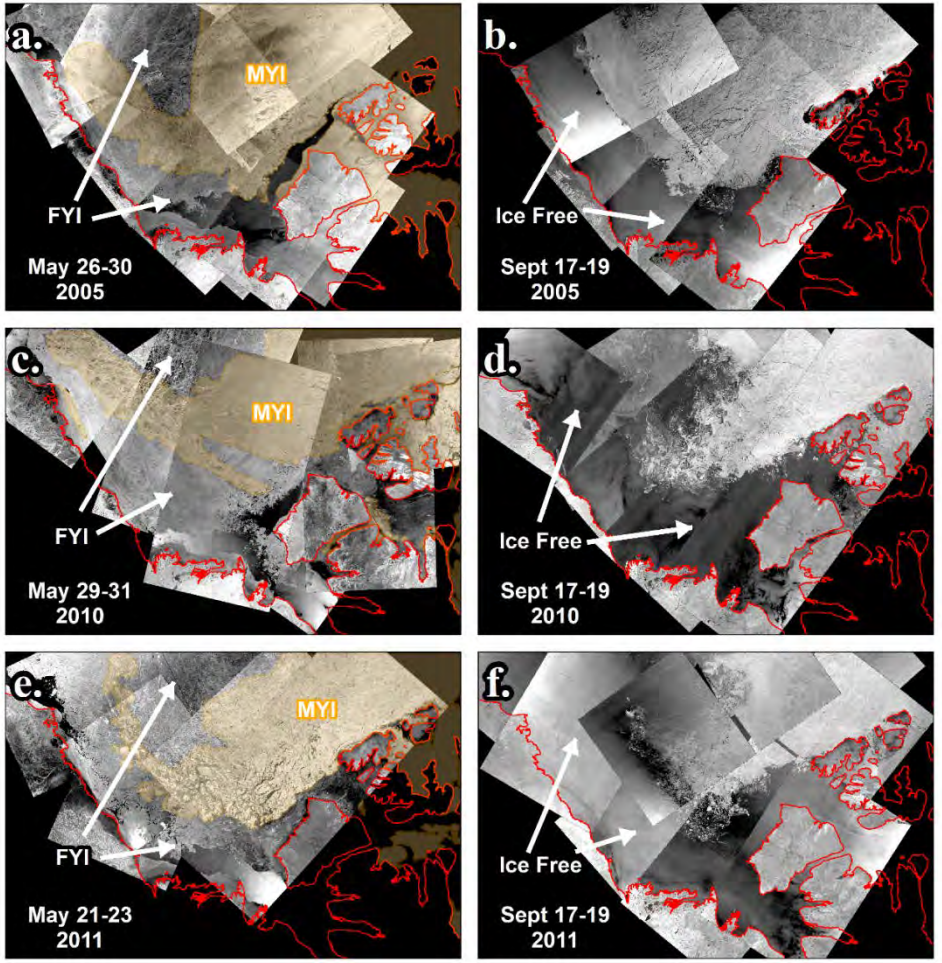
- No flux at the Chukchi gate since 2008
- No flux at the Canadian Basin and Mid-Beaufort gate since 2012

Howell et al., 2016

Canada

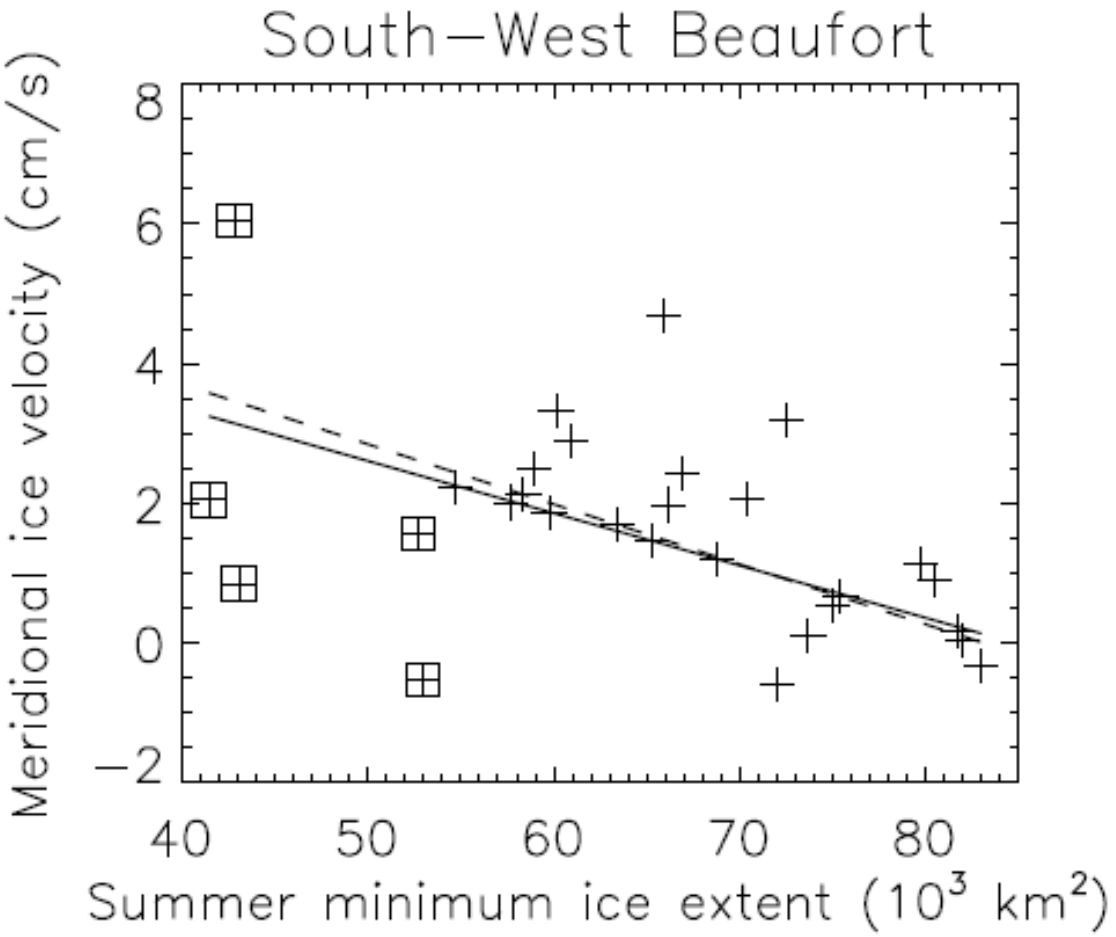
Quantifying ice transport through the Beaufort Sea

- MYI appears more “healthier” in the Beaufort Sea in 2005.
- Notice the heavily decayed MYI in the Beaufort Sea in 2010 and 2011.
- Unable to survive the complete transit through the Beaufort Sea.
- MYI cemetery.



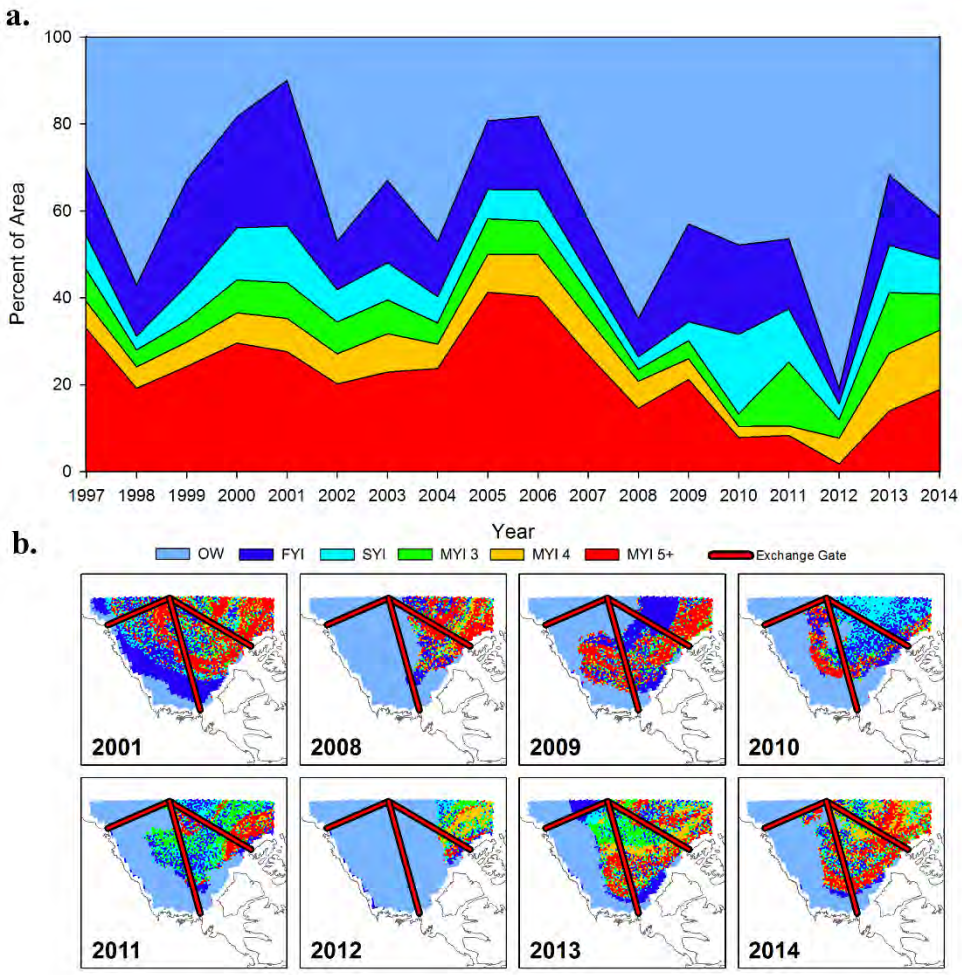
Howell et al., 2016

Light years not related to northward ice drift in summer



Hutchings and Rigor, 2012

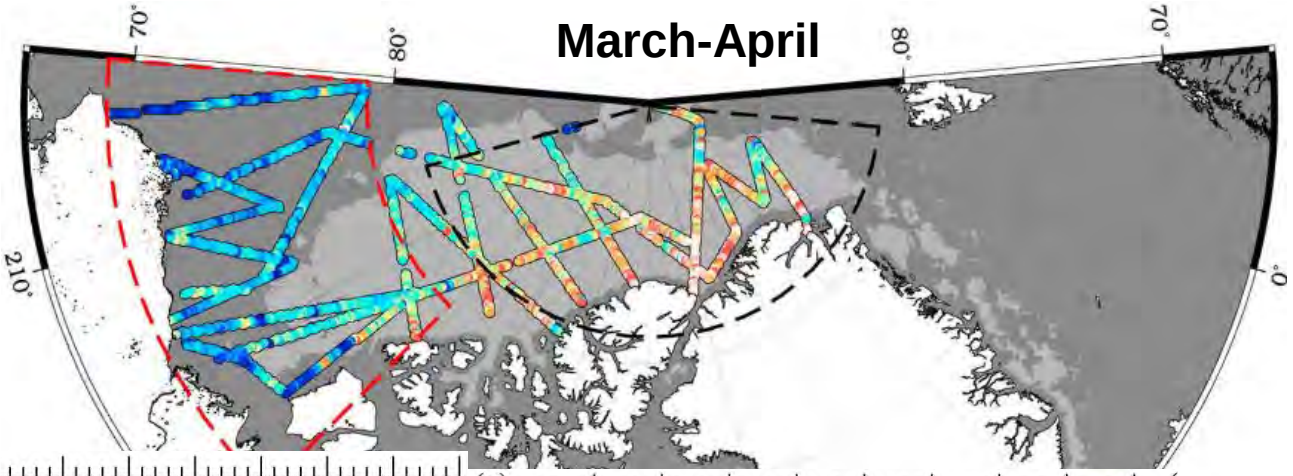
Why is MYI melting in transit?

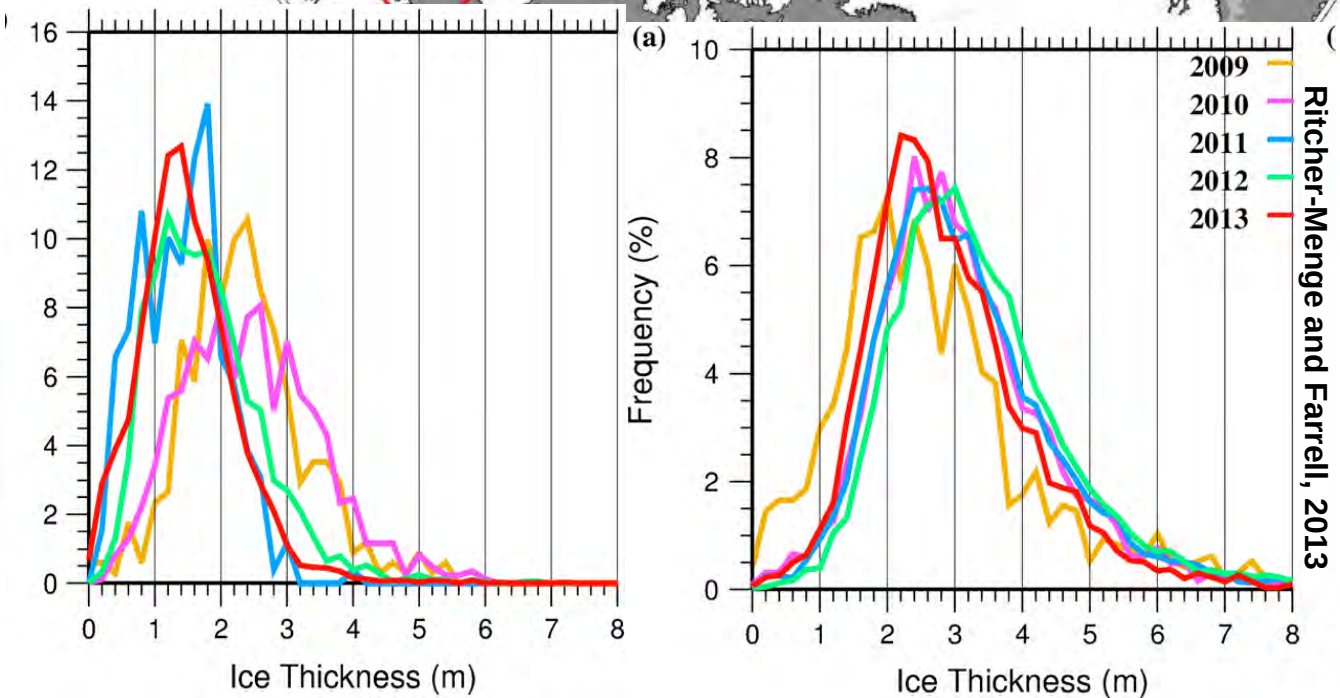


- Younger and thinner ice since 2008
- Thinner ice, easier to melt, more absorption of solar radiation → amplified the sea ice-albedo feedback

Howell et al., 2016

Thinner ice in the Beaufort prior to melt





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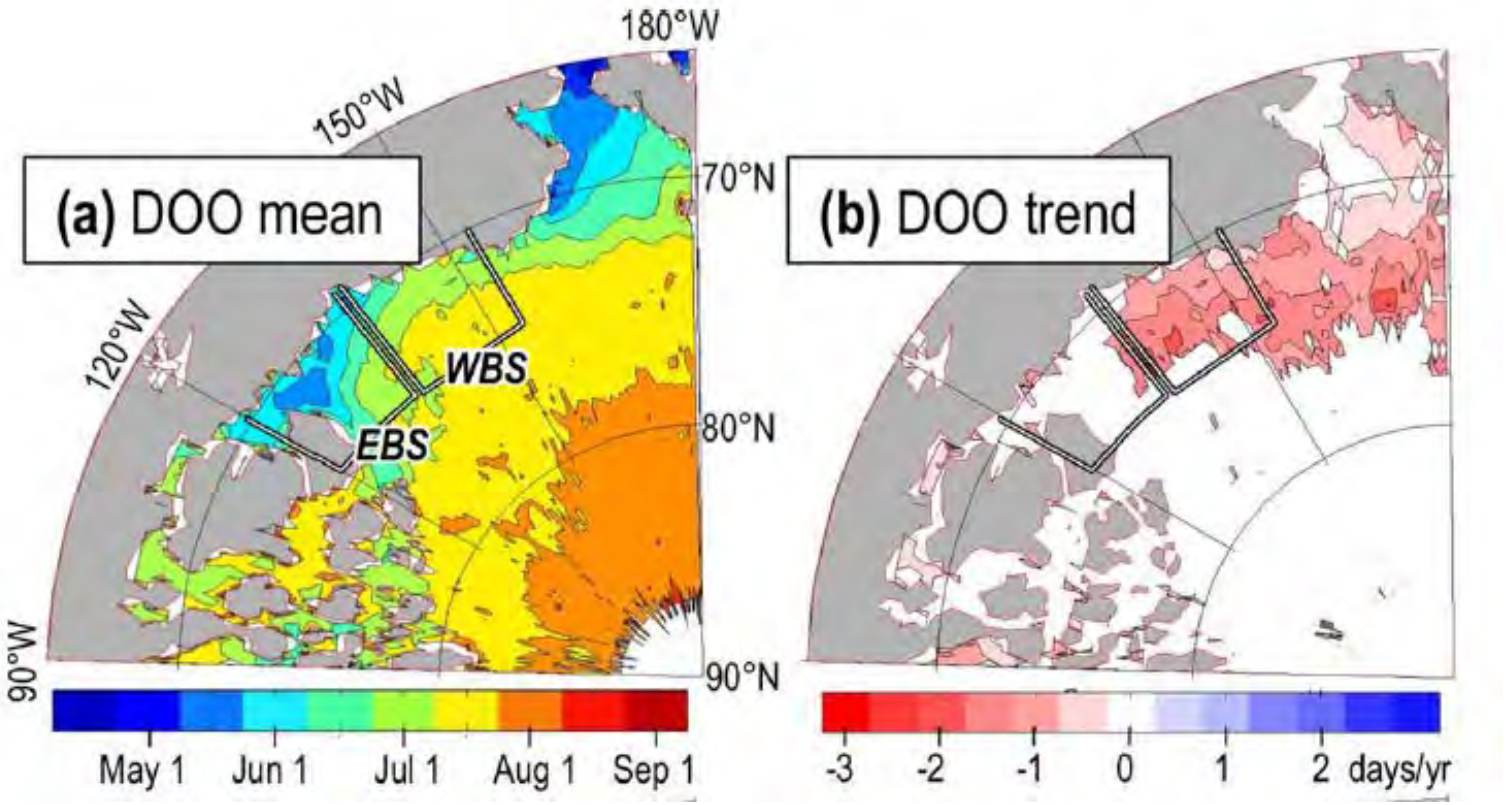
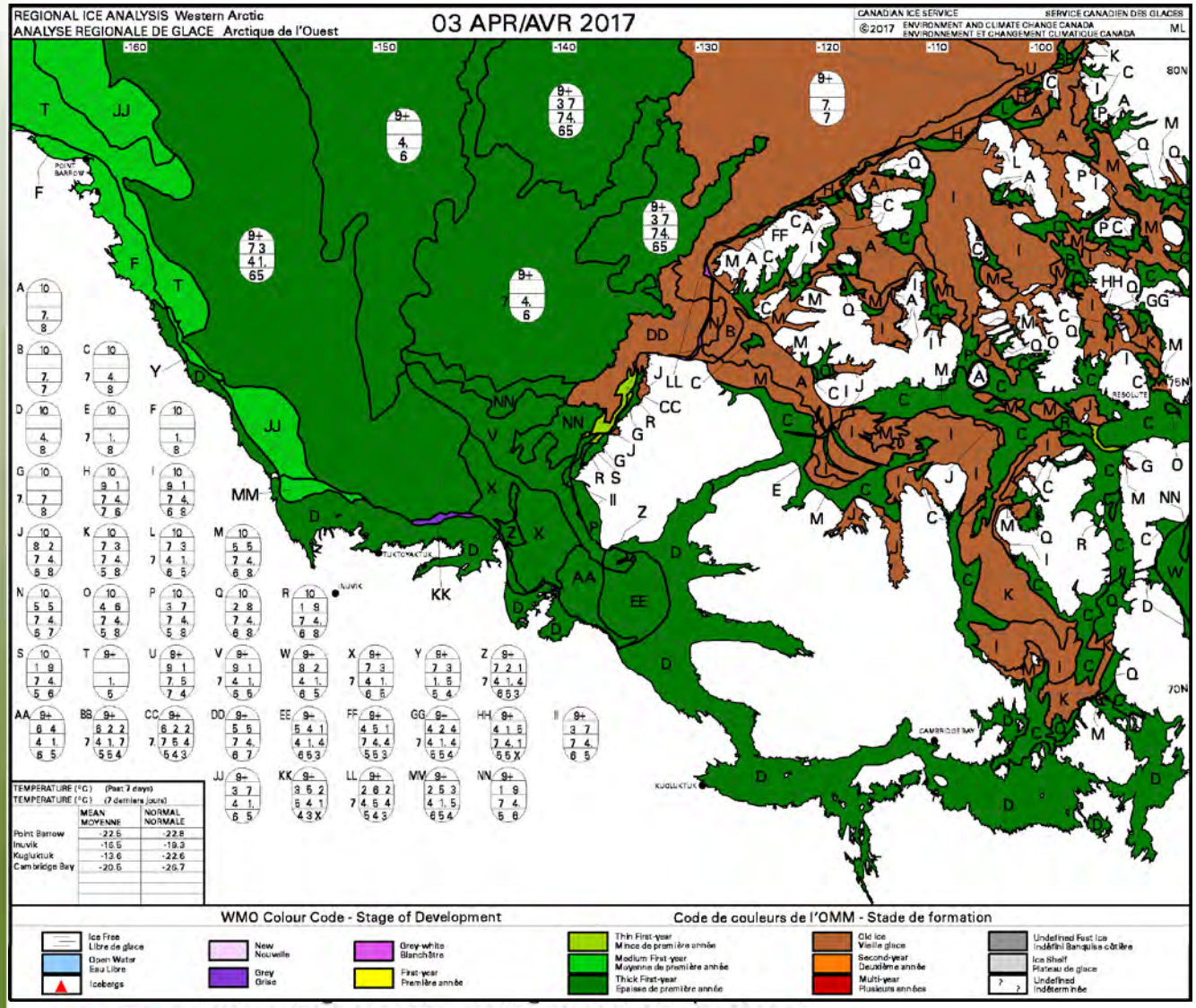
Earlier ice break-up

- Date of Opening (DOO)



Steele et al., 2015

MYI distribution prior to 2017 melt season



- Lots in the CAA ☺
- Minimal in the Beaufort ☹

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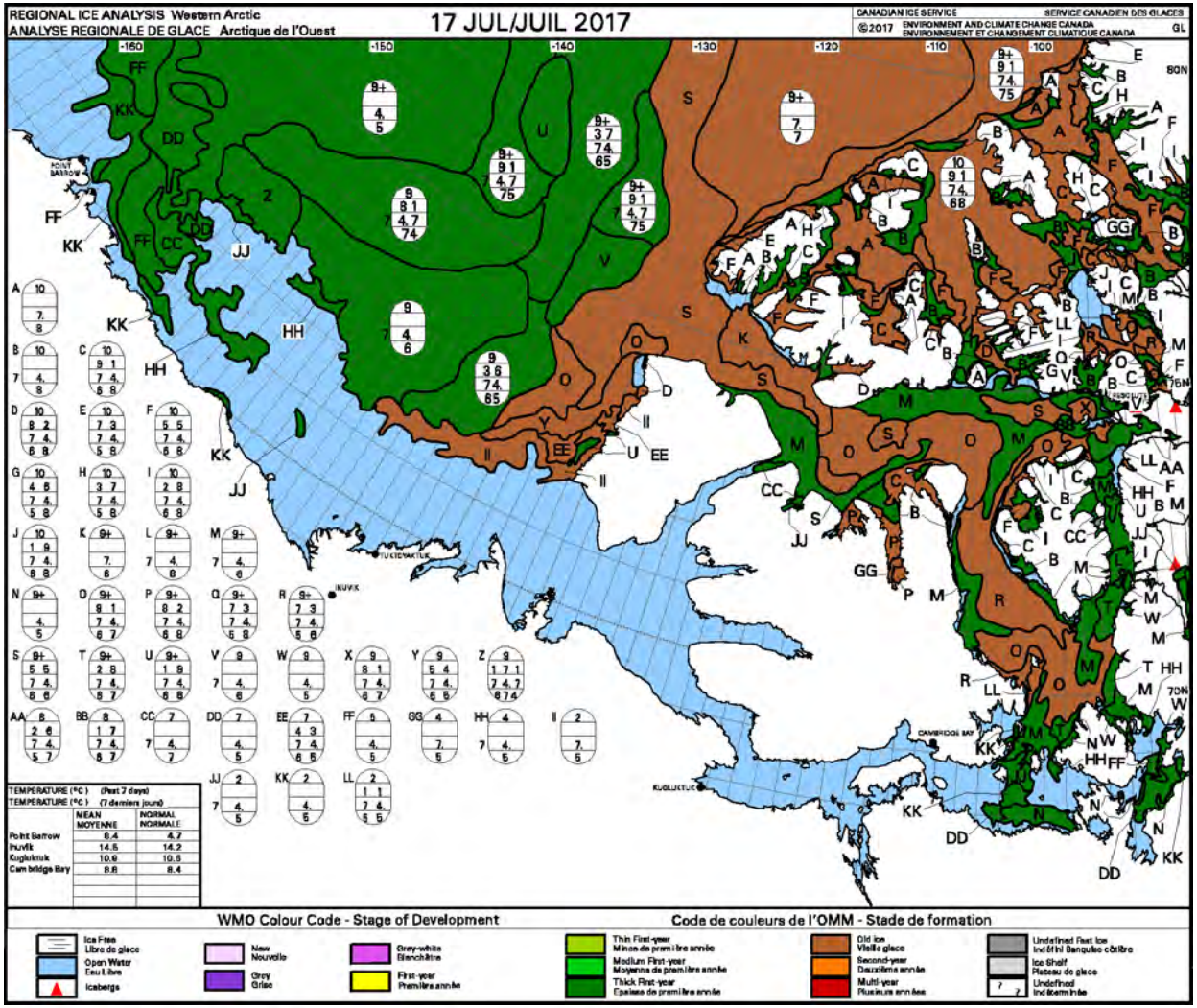
MYI distribution prior to 2017 melt season



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