

# *Loitering*

## *of the Retreating Sea Ice Edge in the Arctic Seas*

***Michael Steele & Wendy Ermold***

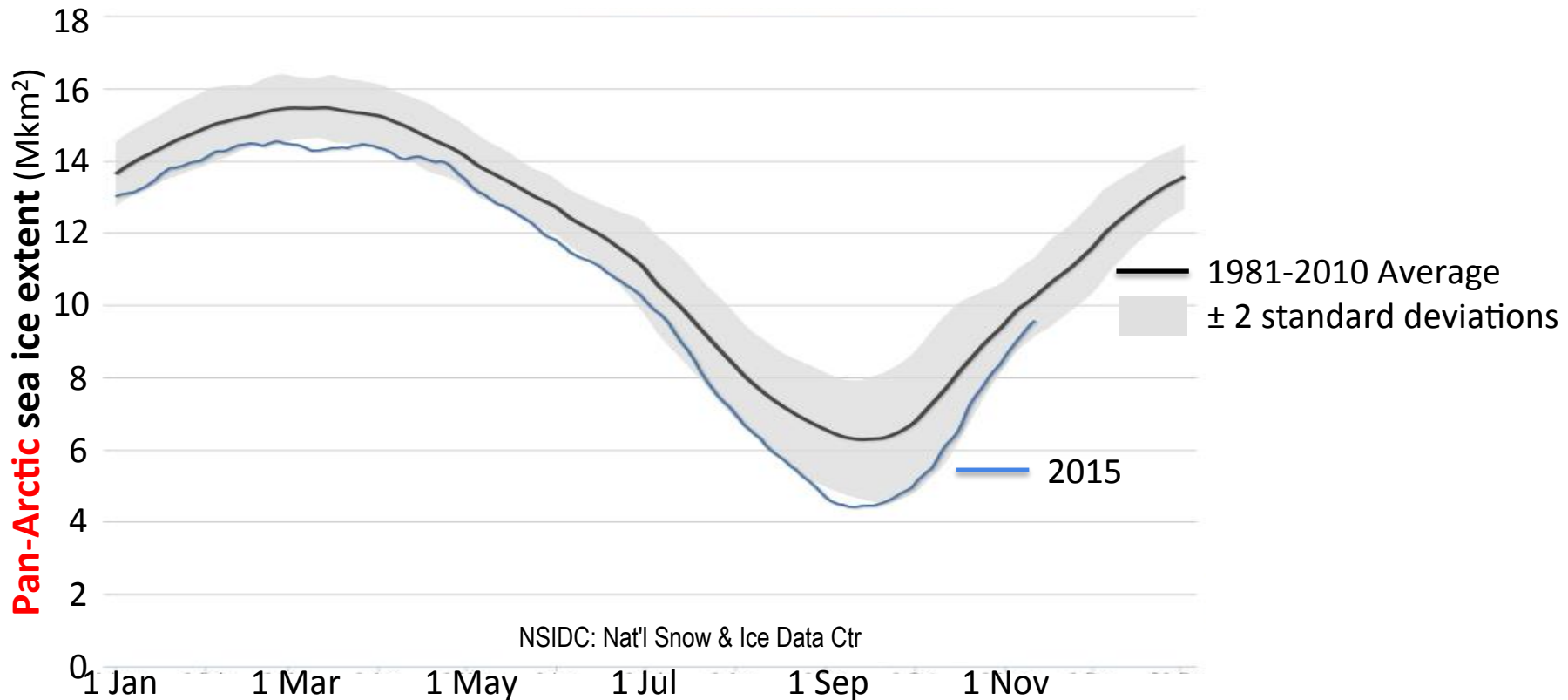
*Polar Science Center, Applied Physics Laboratory*

*University of Washington*

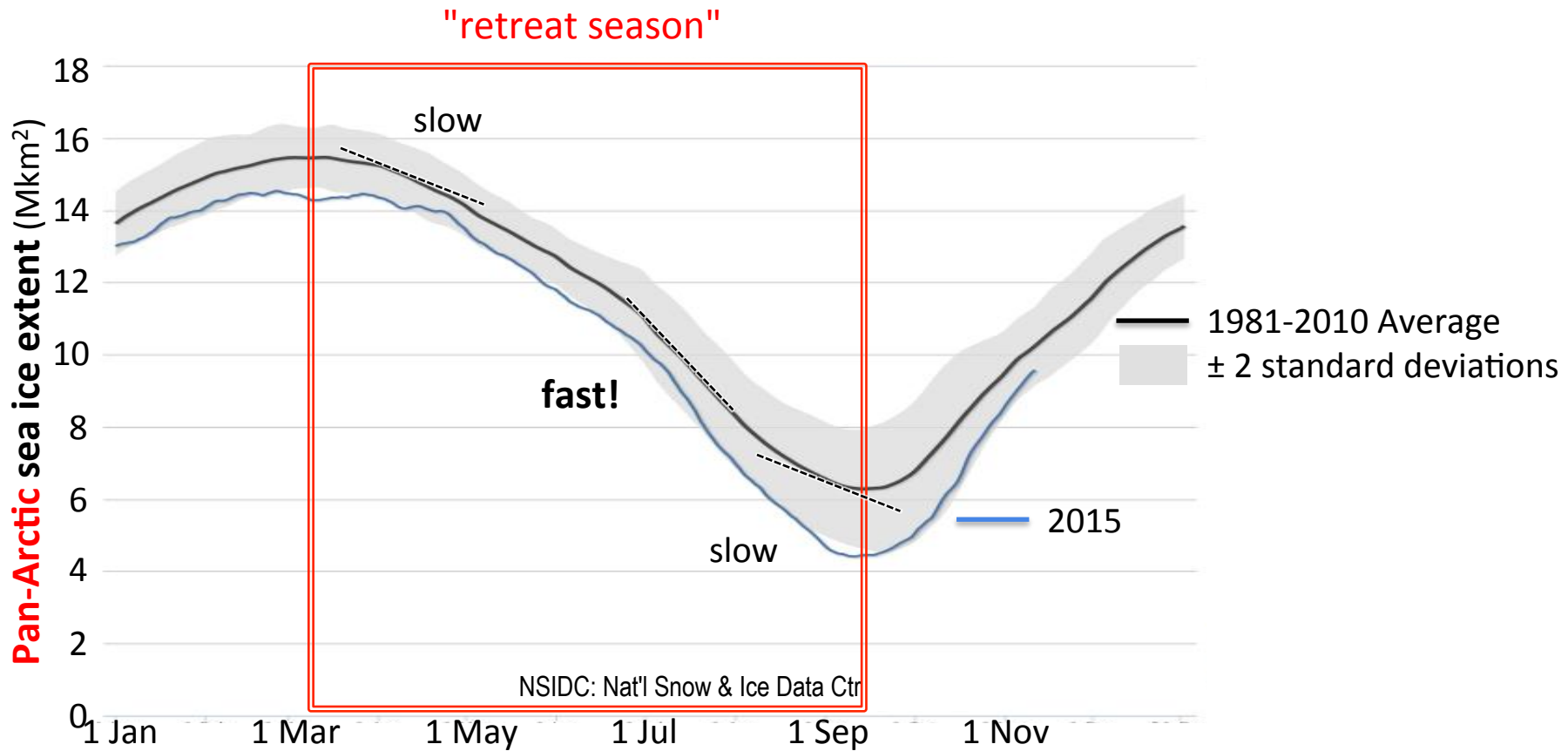
*Seattle, WA USA*

Steele, M. & W. Ermold, "Loitering of the retreating sea ice edge  
in the Arctic Seas," *JGR*, in press, 2015.

# How fast does arctic sea ice retreat?

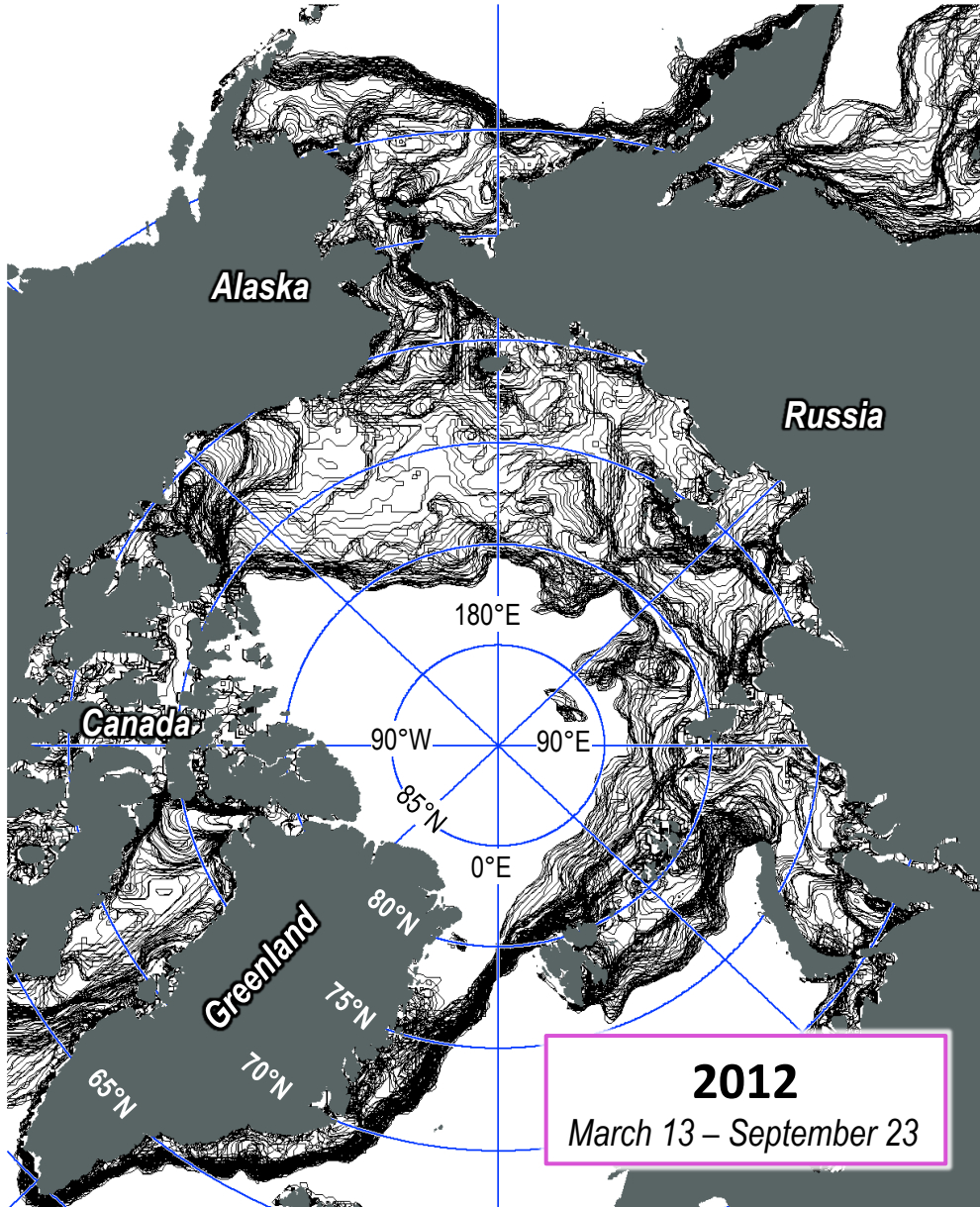


# How fast does arctic sea ice retreat?





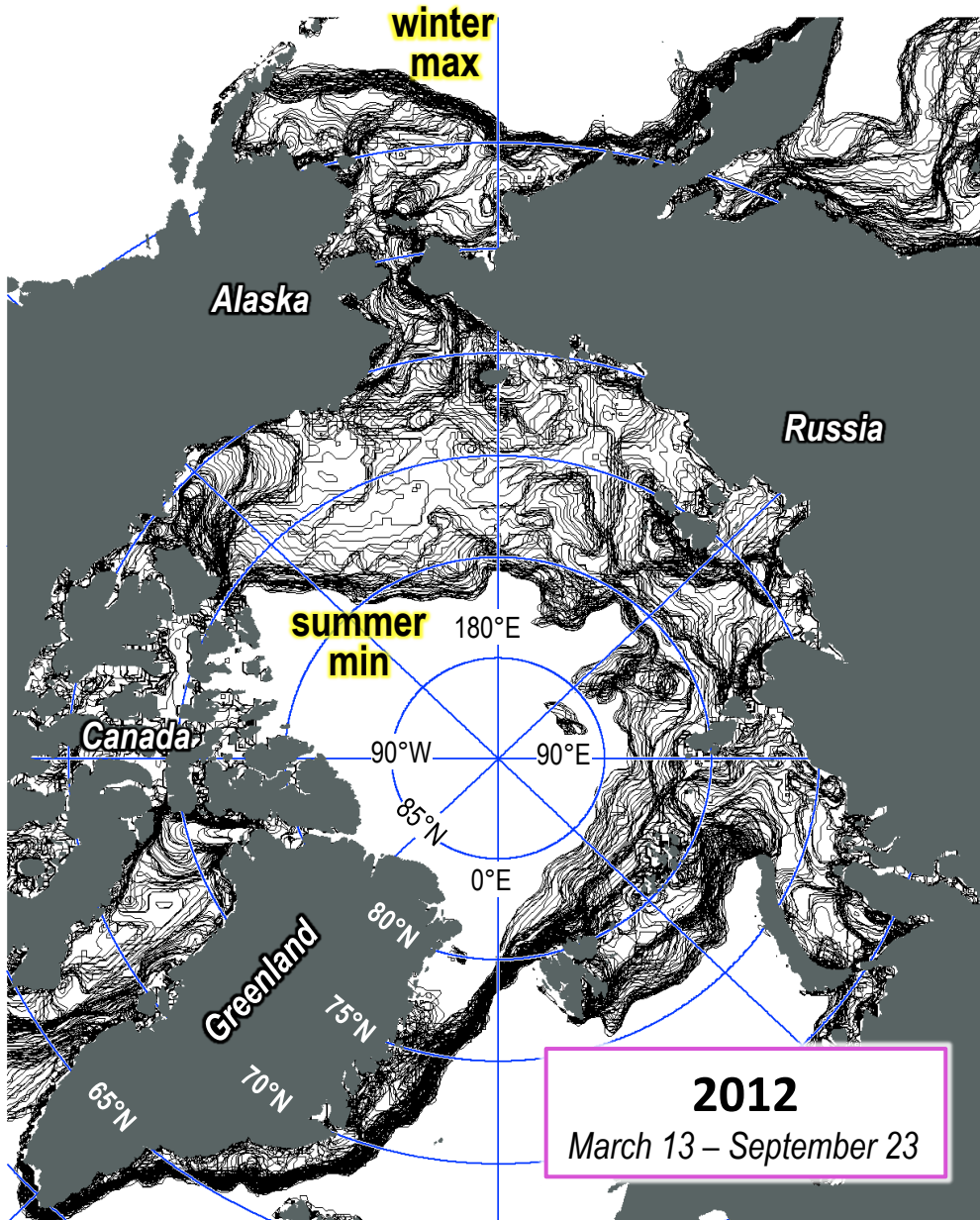
# A closer look



Daily 15% ice concentration contour  
= "ice edge"

SSM/I-SSMIS (NASA Team algorithm)

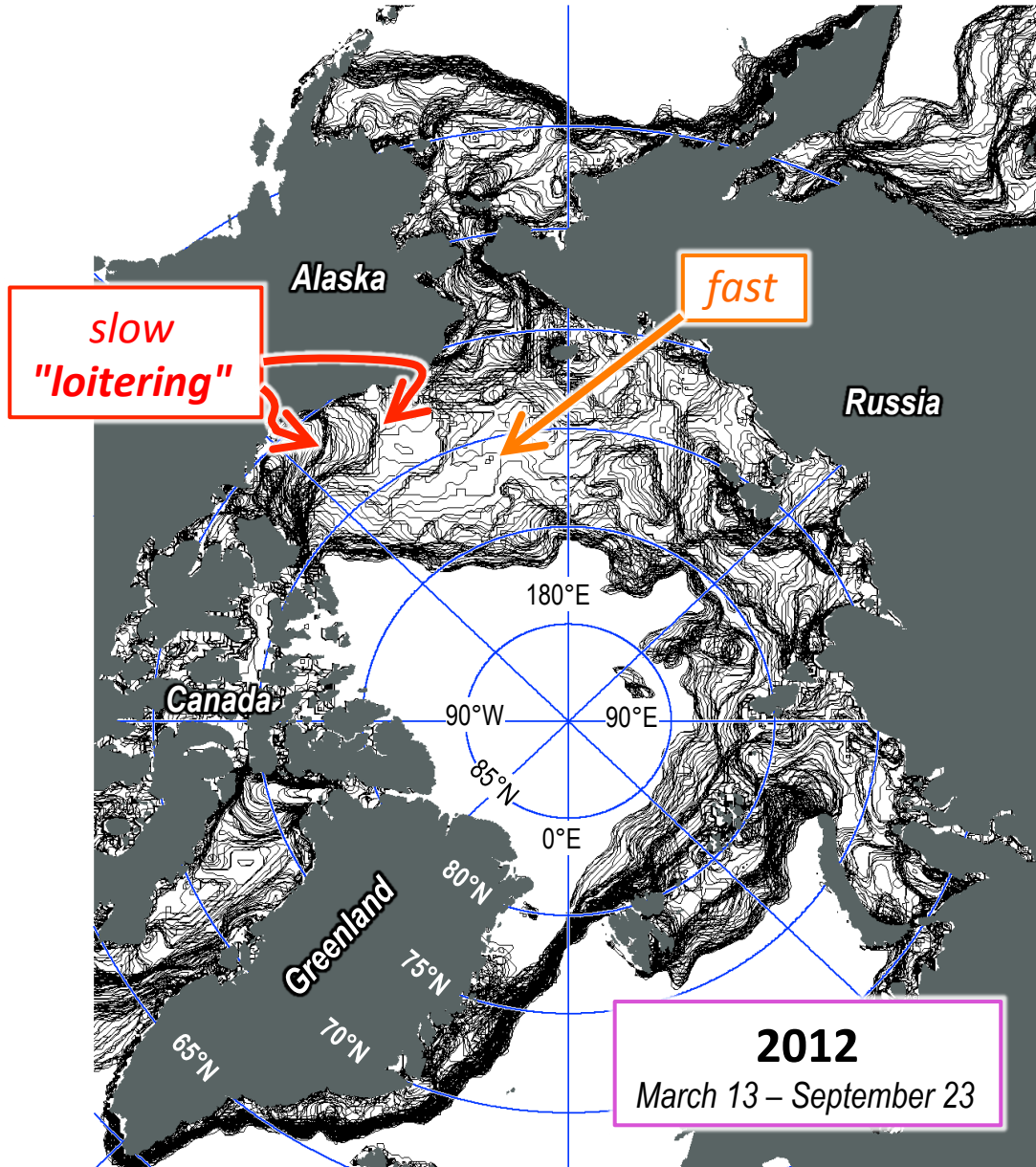
# A closer look



Daily 15% ice concentration contour  
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SSM/I-SSMIS (NASA Team algorithm)

The "SIZ"  
= Seasonal Ice Zone  
= **winter max** to **summer min**



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= "ice edge"

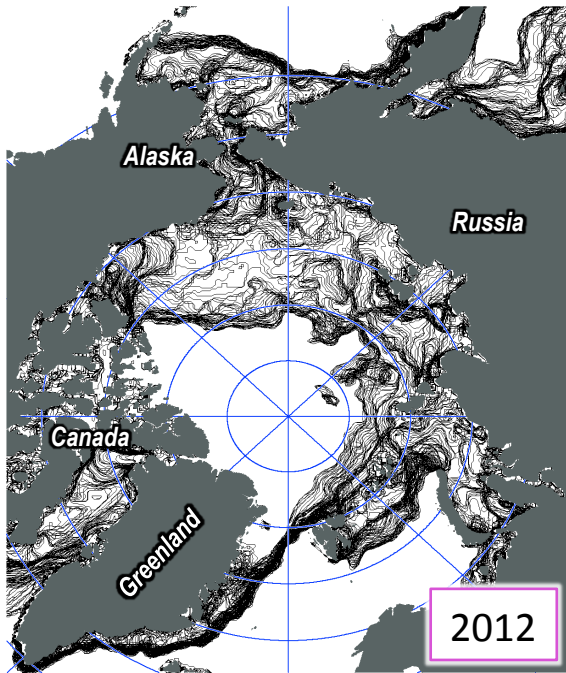
SSM/I-SSMIS (NASA Team algorithm)

## Other sea ice data sets:

- AMSR2 (3.25 km PMW)
- MASIE (NSIDC multi-sensor)

# Quantitative analysis

...on the 25 km grid



## Loitering ice edge:

$\leq 8$  km/day\*

$\geq 4$  days in a 25 km pixel

\*Ave ice speed 8-12 km/day

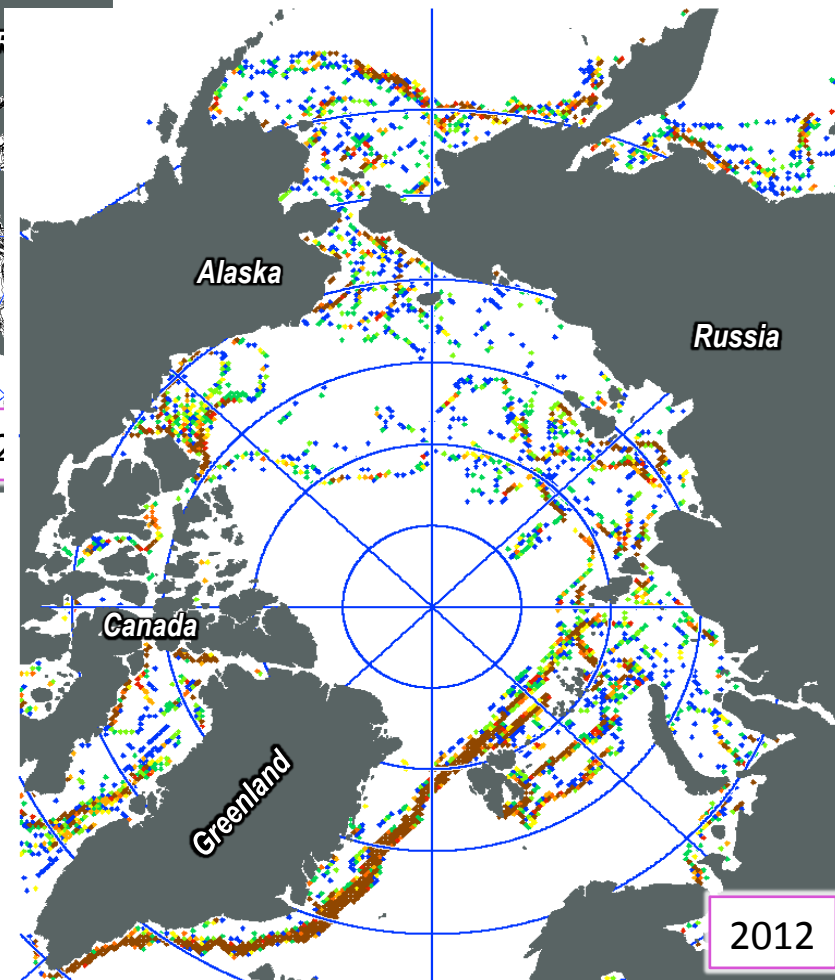
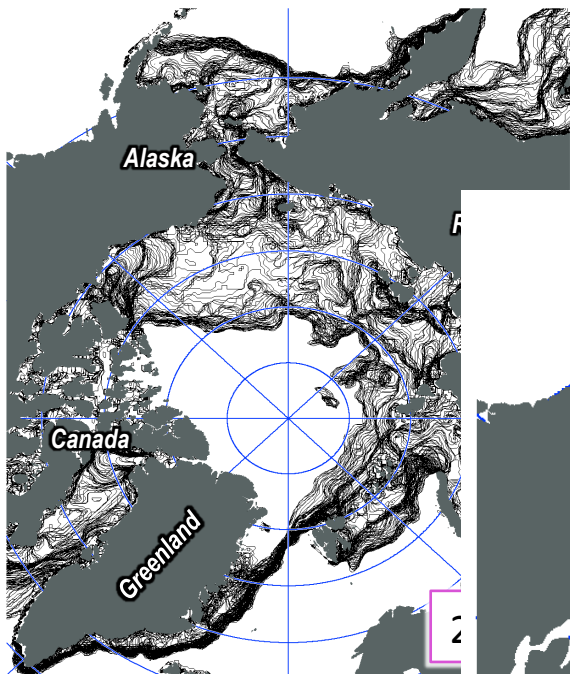
Spreen et al. (*GRL*, 2011)

Olason & Notz (*JGR*, 2014)



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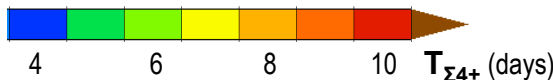
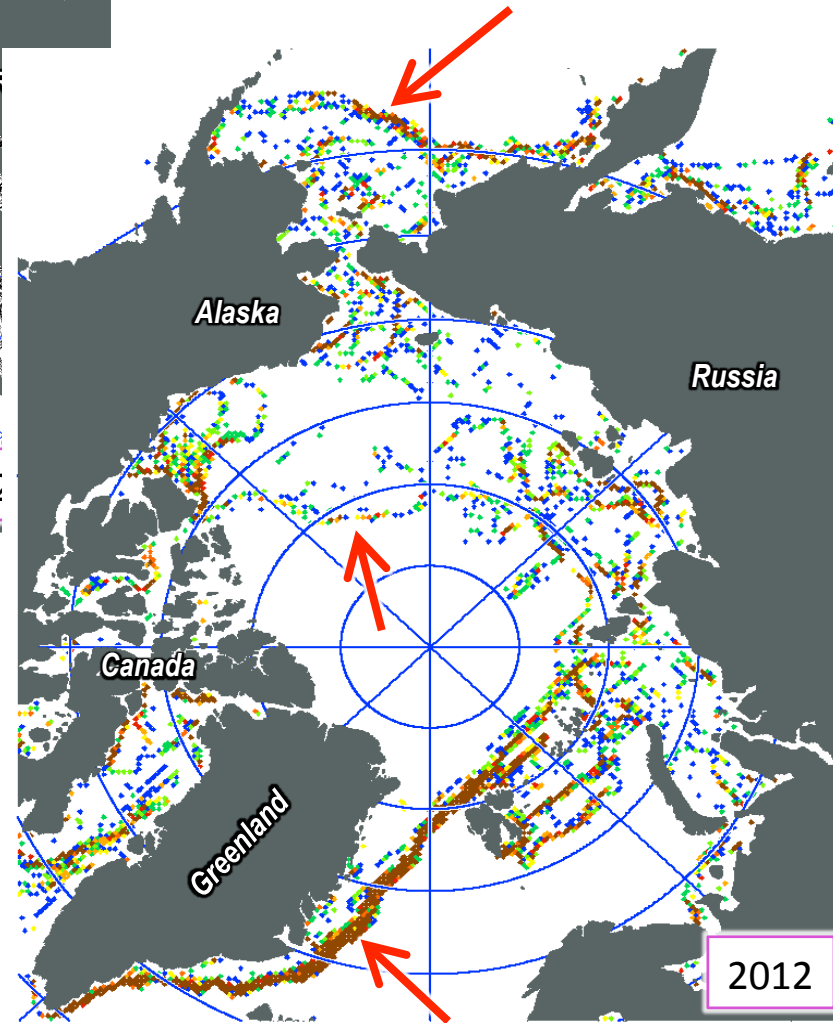
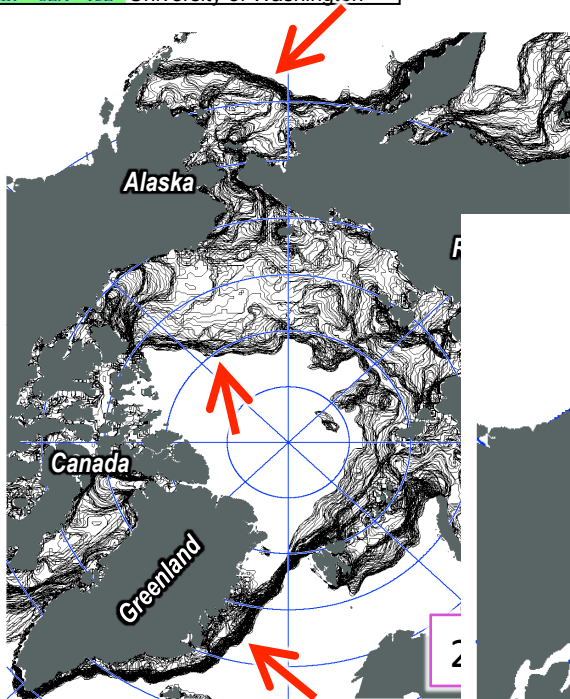
Olason & Notz (*JGR*, 2014)

# of days  
 the ice edge  
 loitered in a pixel



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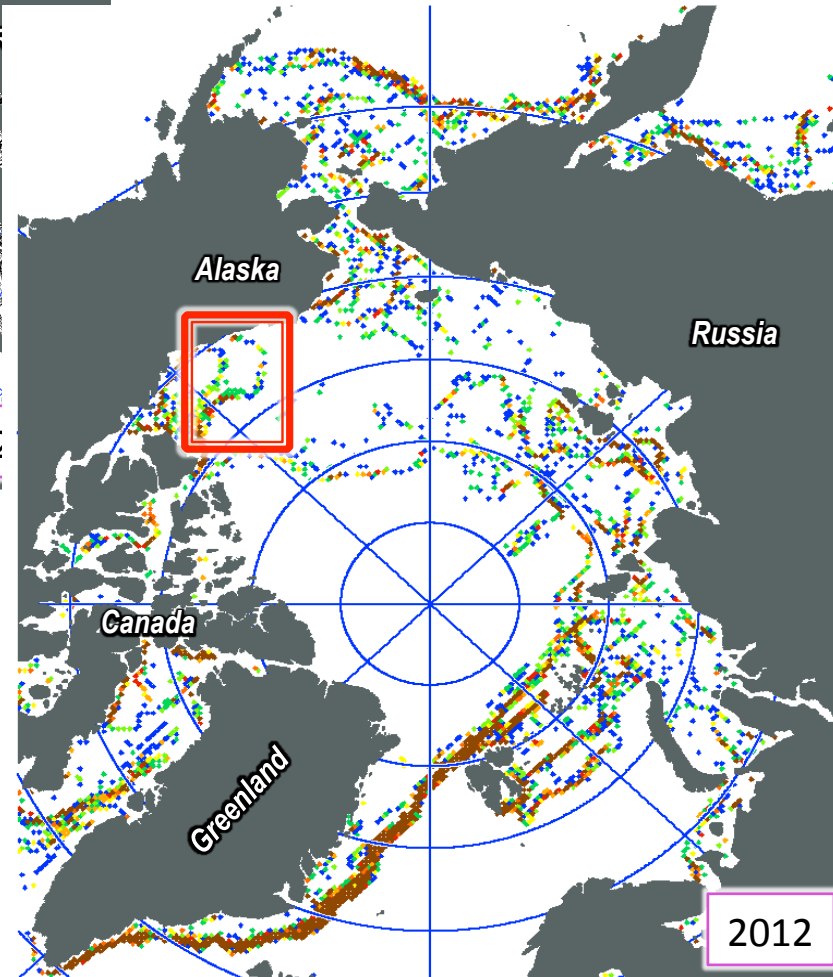
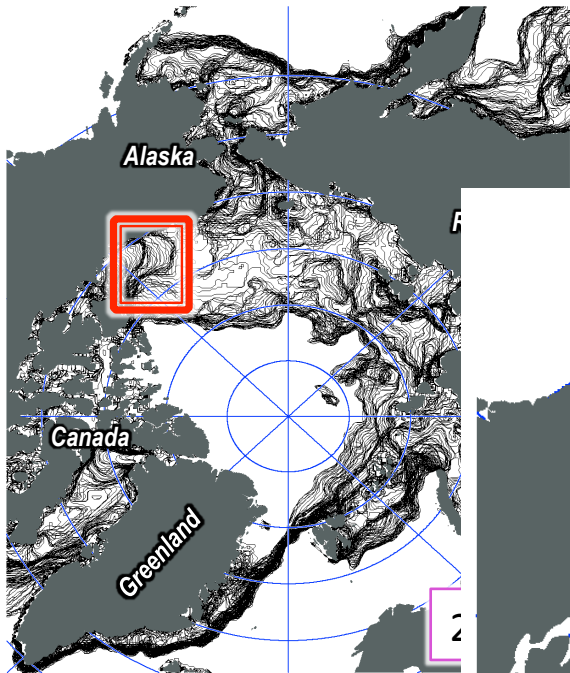
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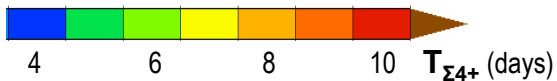
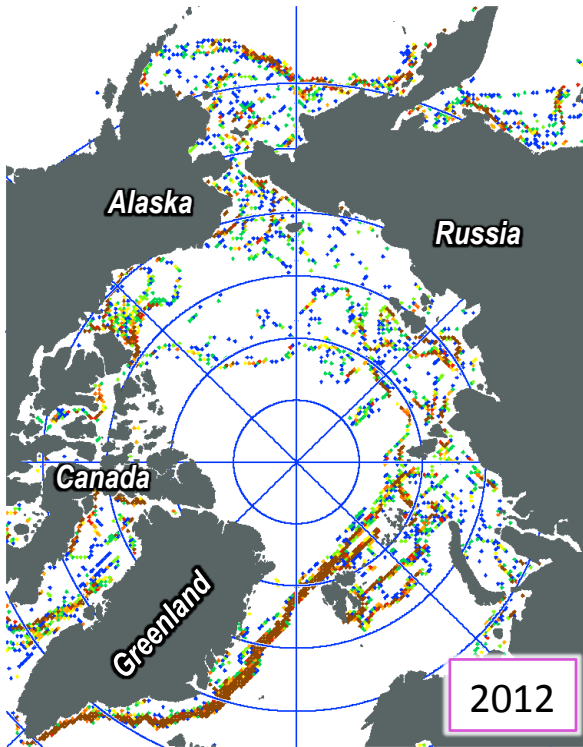
Olason & Notz (*JGR*, 2014)



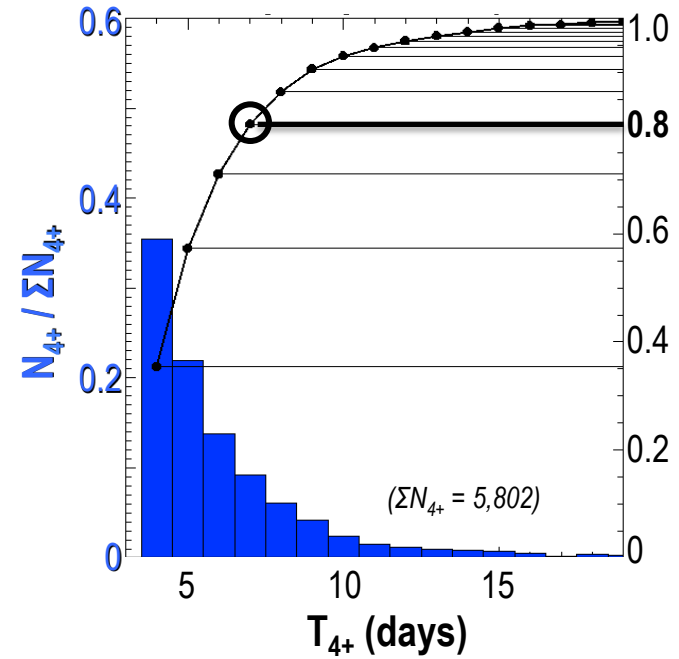
# of days  
the ice edge  
loitered in a pixel

# Space & Time Scales

1989-2013  
 SSMI/SSMIS



Loitering covers  
**20-25% of the SIZ**

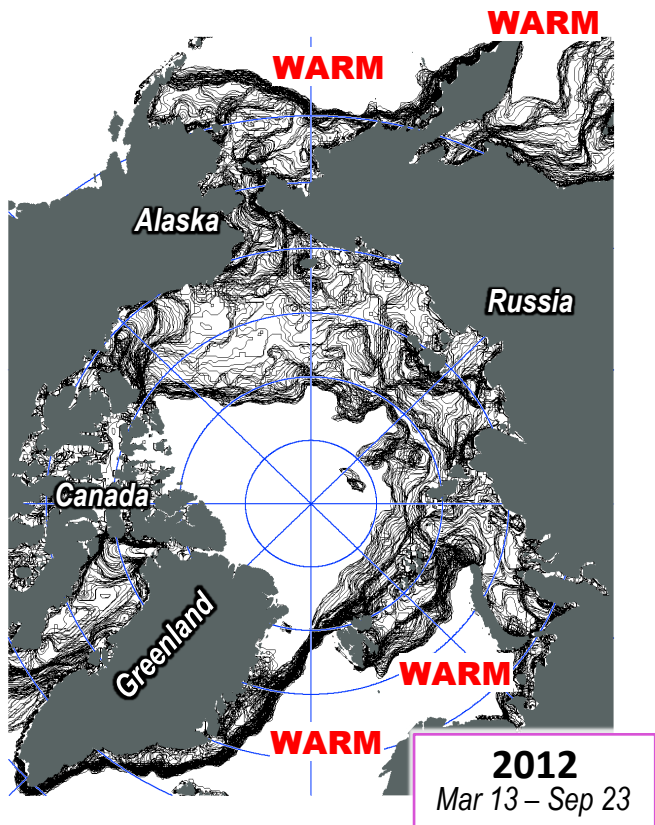


80% of loitering  
**events last 4-7 days**

*...synoptic storms...*

# Where does it loiter?

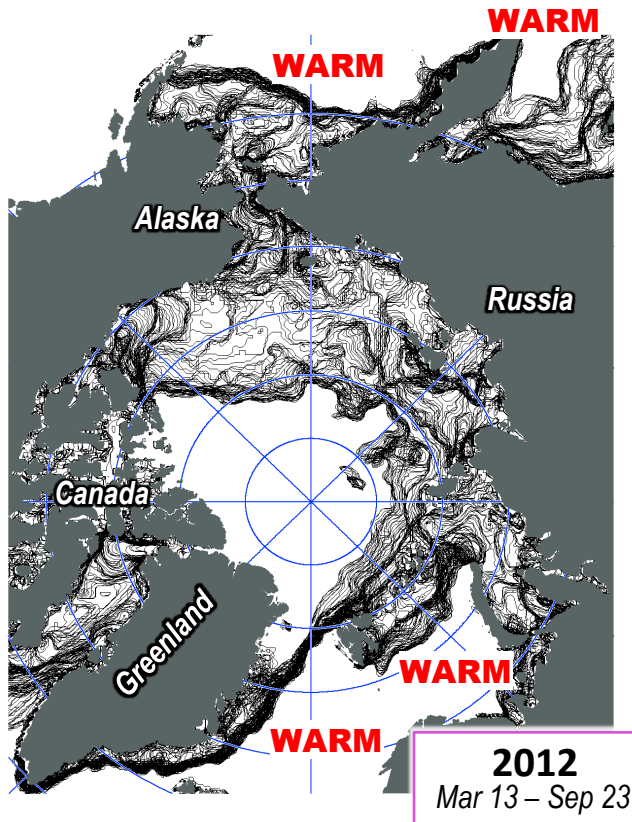
Winter ice max  
@ **warm** SST fronts



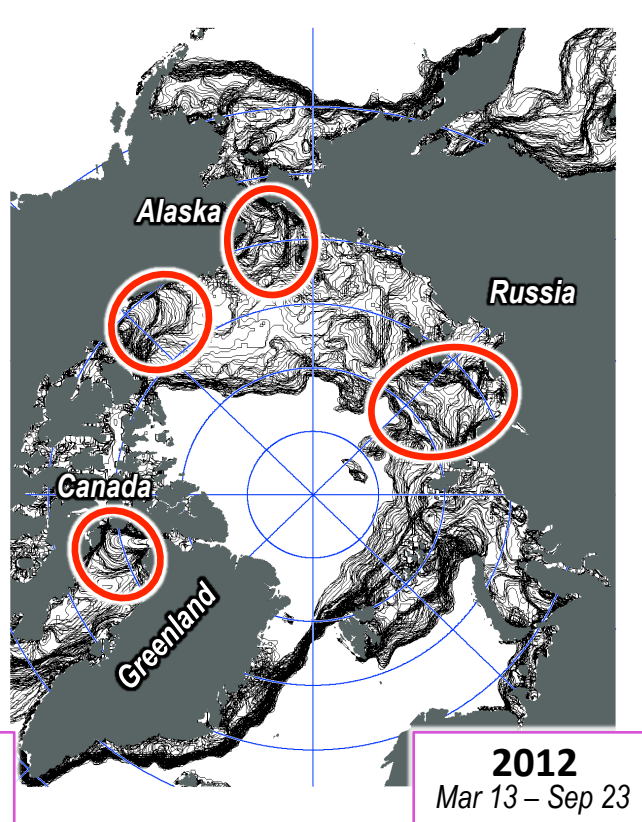


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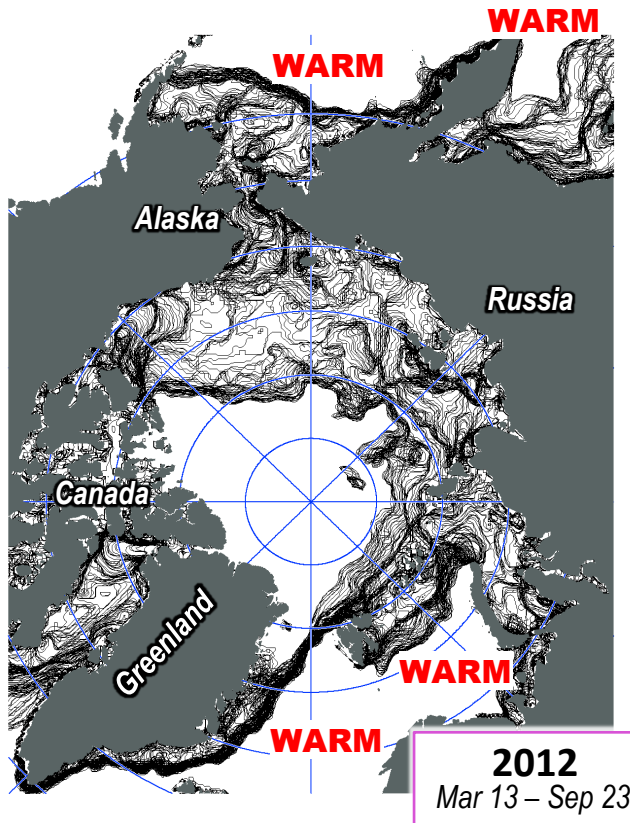
Within the SIZ  
in some places...*why?*



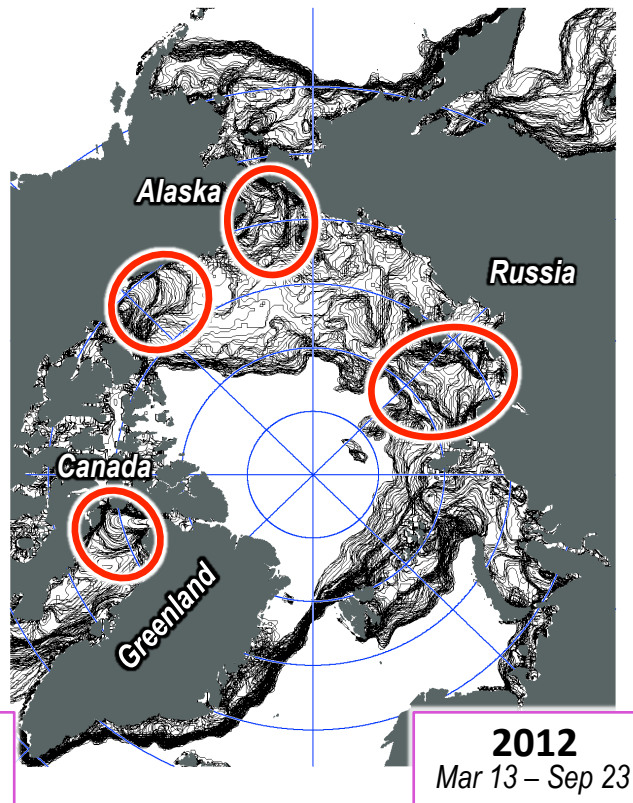
*N. Baffin, E. Beaufort,  
N. Chukchi, Laptev...*

# Why does it loiter?

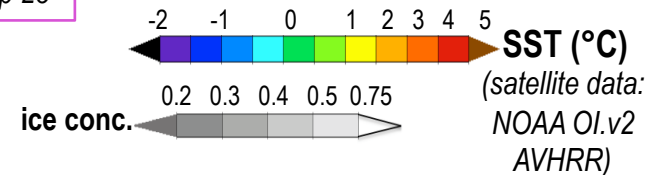
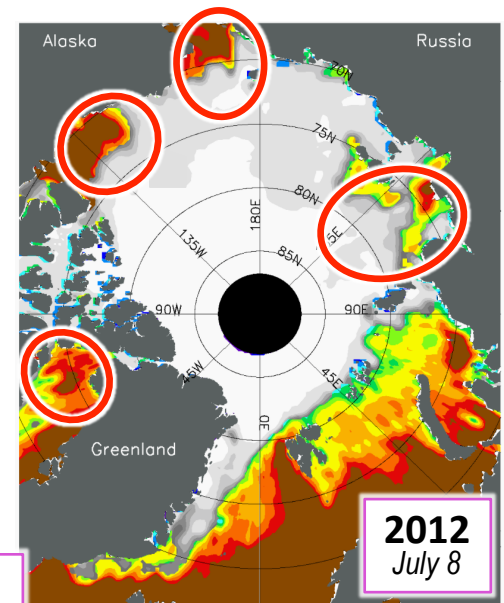
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Within the SIZ  
 in some places...*why?* →



Early ice retreat  
 ↓  
 early SST **warming**  
 ↓  
 loitering



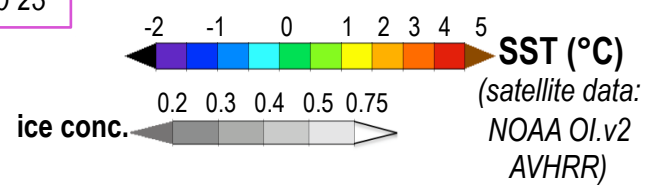
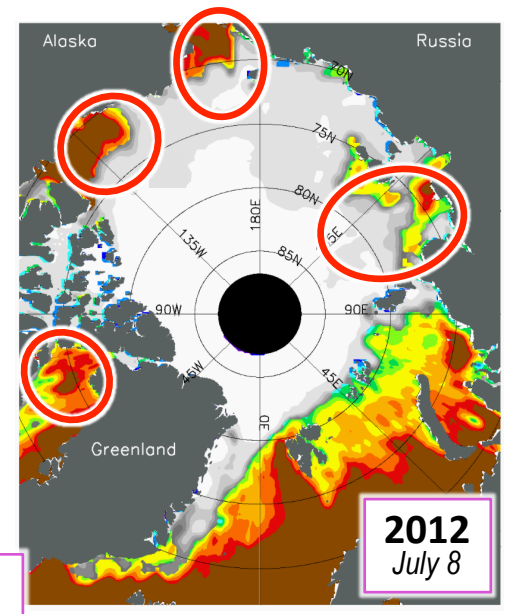
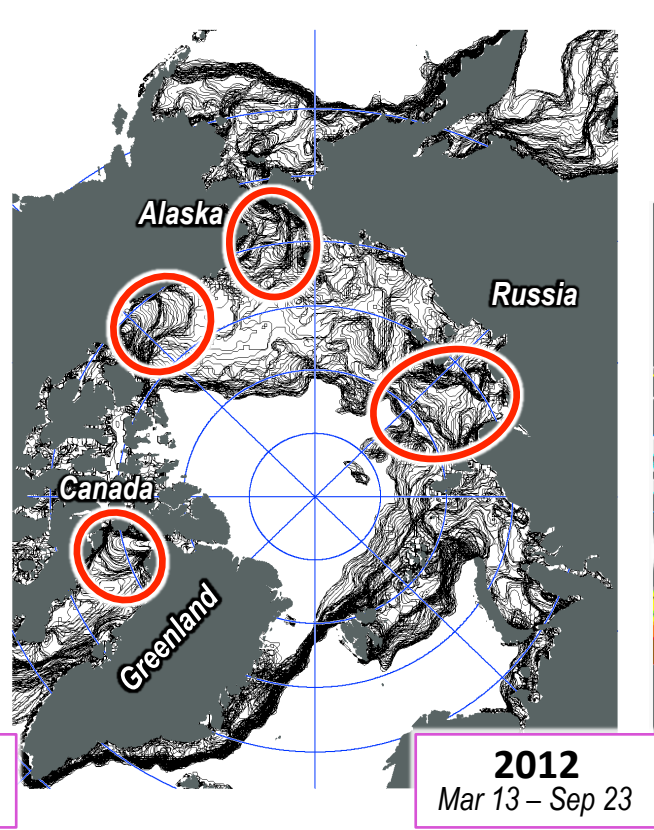
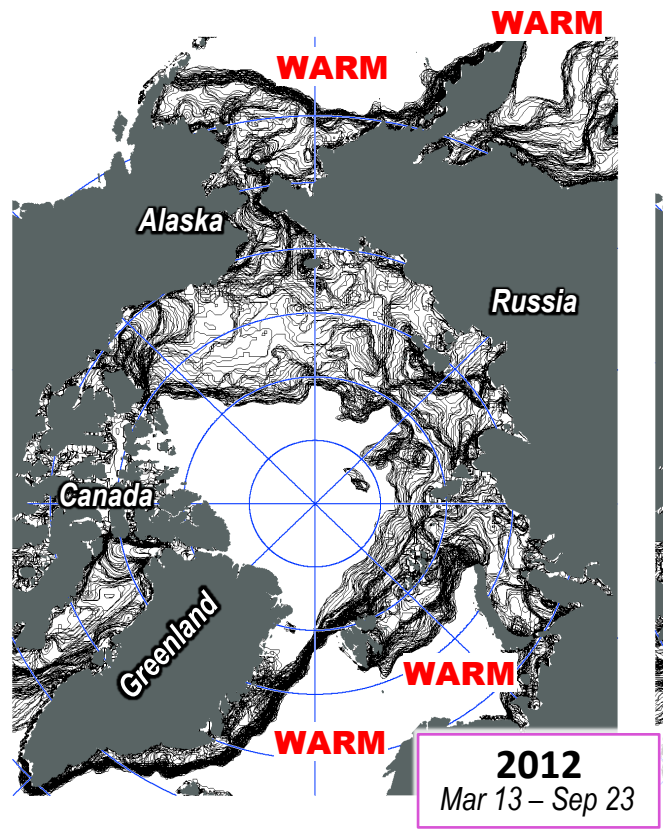
# Why does it loiter?

**Why early ice retreat here?**  
 Steele et al. (JGR, 2015)

Winter ice max  
 @ **warm** SST fronts

Within the SIZ  
 in some places...*why?* →

Early ice retreat  
 ↓  
 early SST **warming**  
 ↓  
 loitering

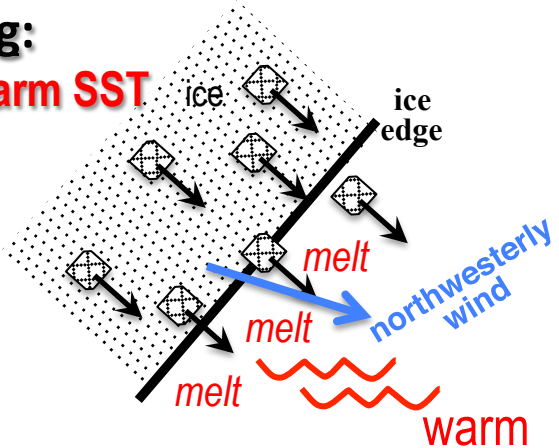




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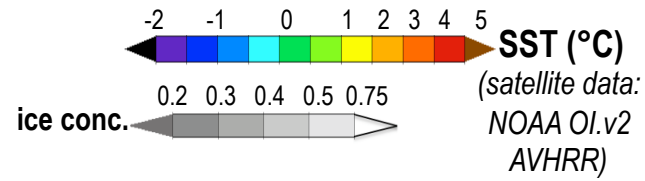
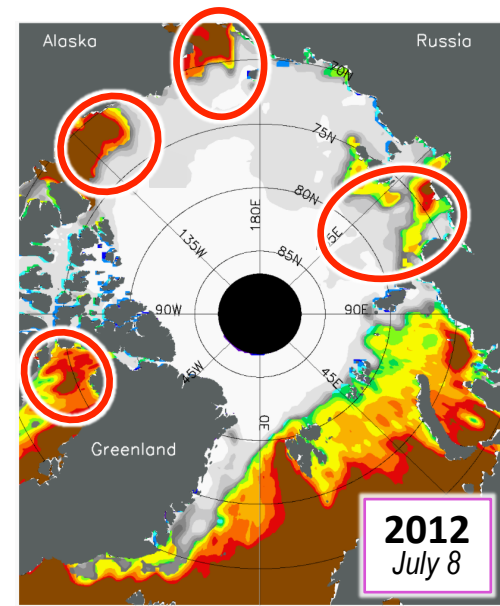
## Loitering:

wind + warm SST



Warm SST = 2.5°C above freezing  
 can melt ~ 35 cm/day

Early ice retreat  
 ↓  
 early SST warming  
 ↓  
 loitering

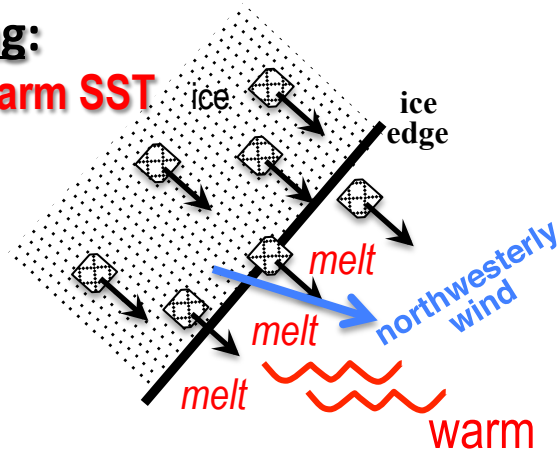




# Why does it loiter?

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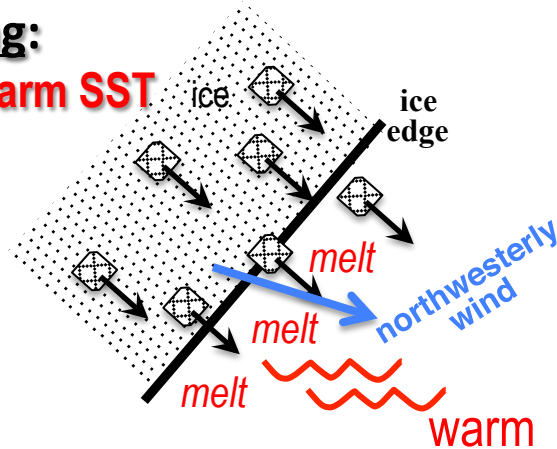
Warm SST = 2.5°C above freezing  
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...but how deep  
does that warm water extend?

# Ocean observing & loitering

## Loitering:

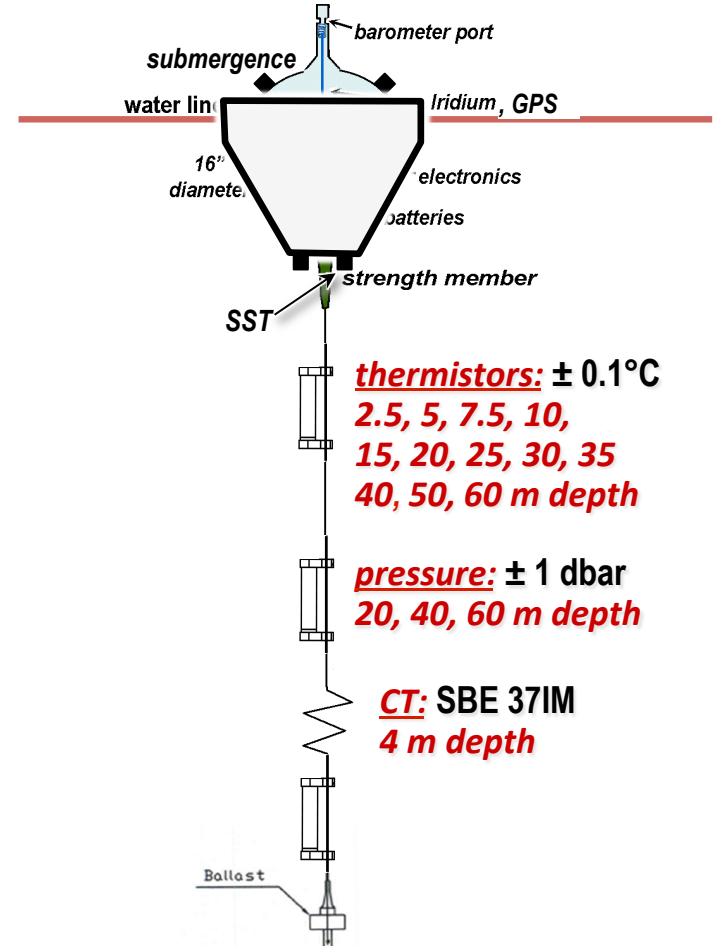
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## The UpTempO buoy program



# Ocean observing & loitering

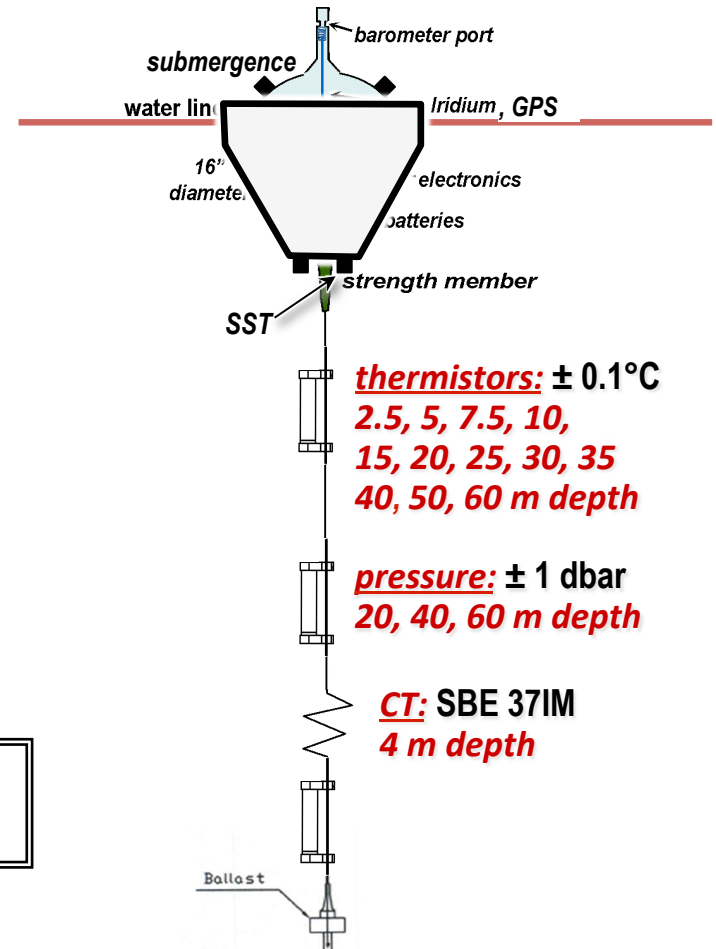
- Cost: → below \$15k
- Focus on the pan-Arctic SIZ
- **Surface** isothermal layer:
  - ~10-15 m early summer
  - ~15-20 m late summer
- **Subsurface** warm layer formation
  - also seen with related WARM buoy  
(V. Hill talk 9 am)

data & info:

<http://psc.apl.washington.edu/UpTempO/>

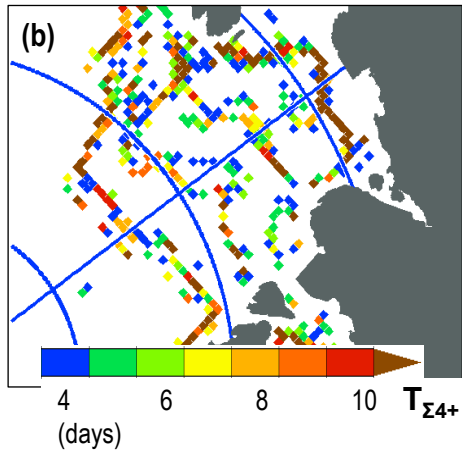
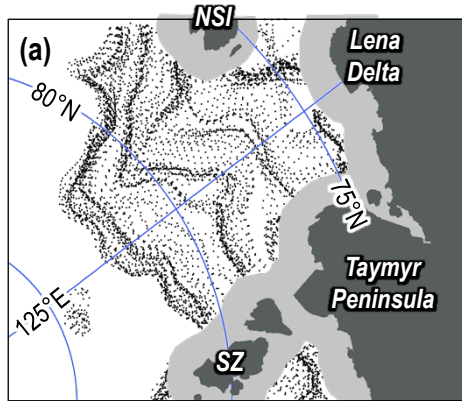


## The UpTempO buoy program



# Daily ice edge displacement $f(\text{Wind}, \text{SST})$

Laptev Sea  
(2011)



*Loiter,  
retreat,  
loiter,  
retreat,...*

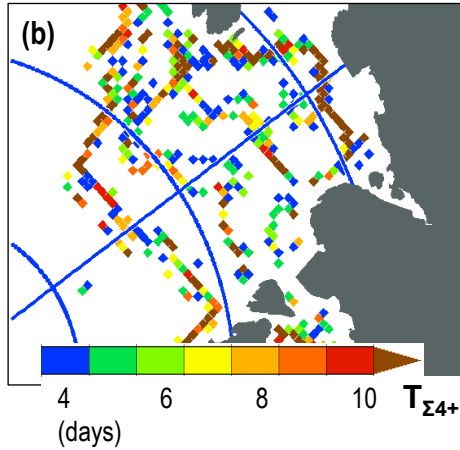
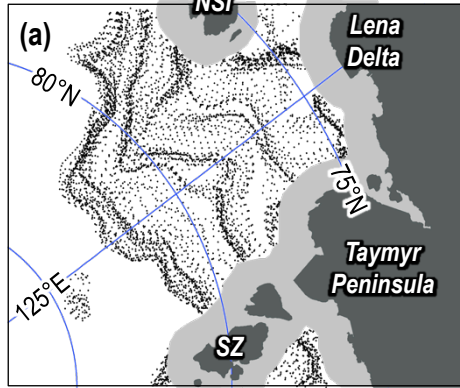


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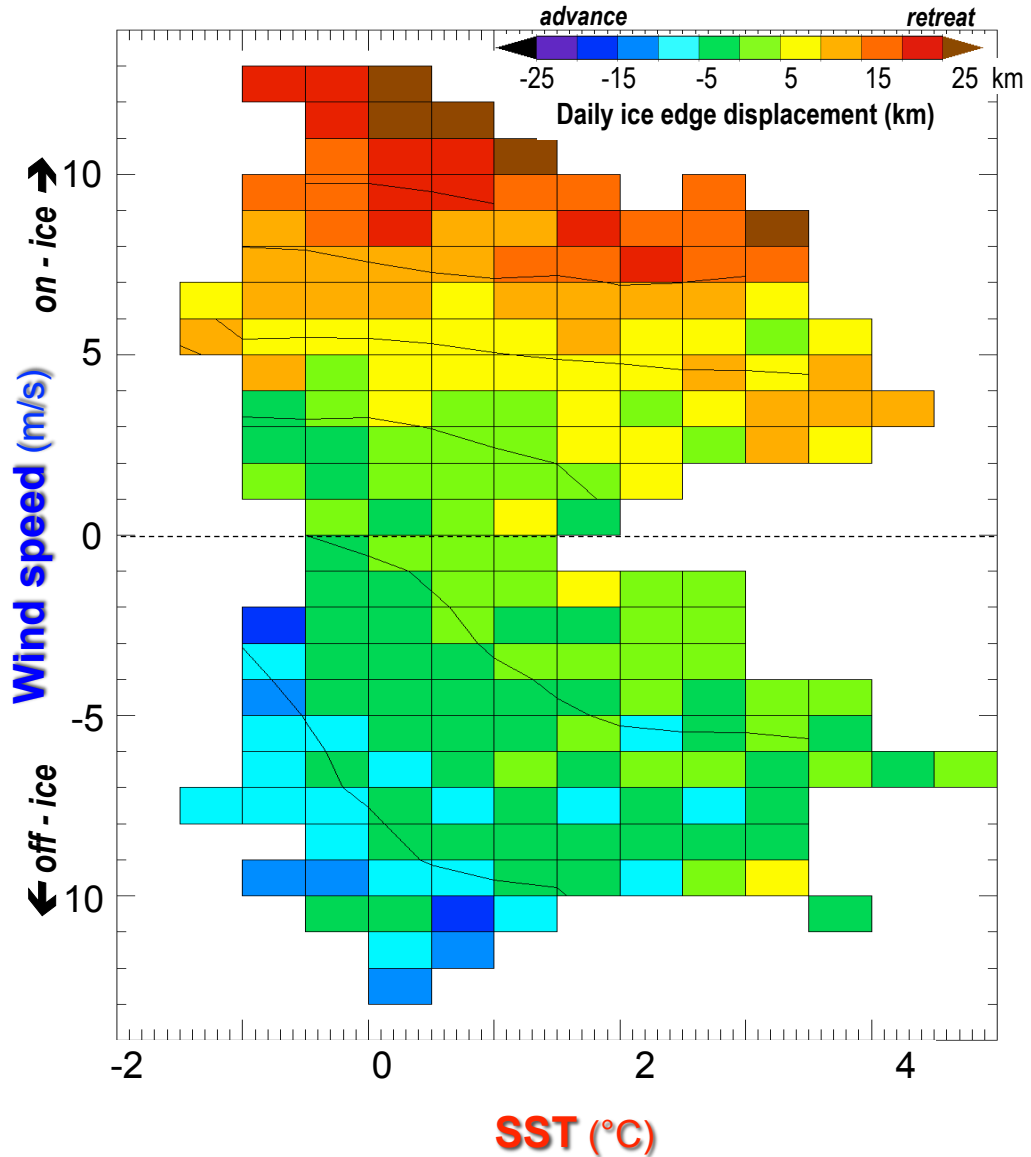
## f( Wind , SST )

Laptev Sea  
 (2007-2013)

Laptev Sea  
 (2011)

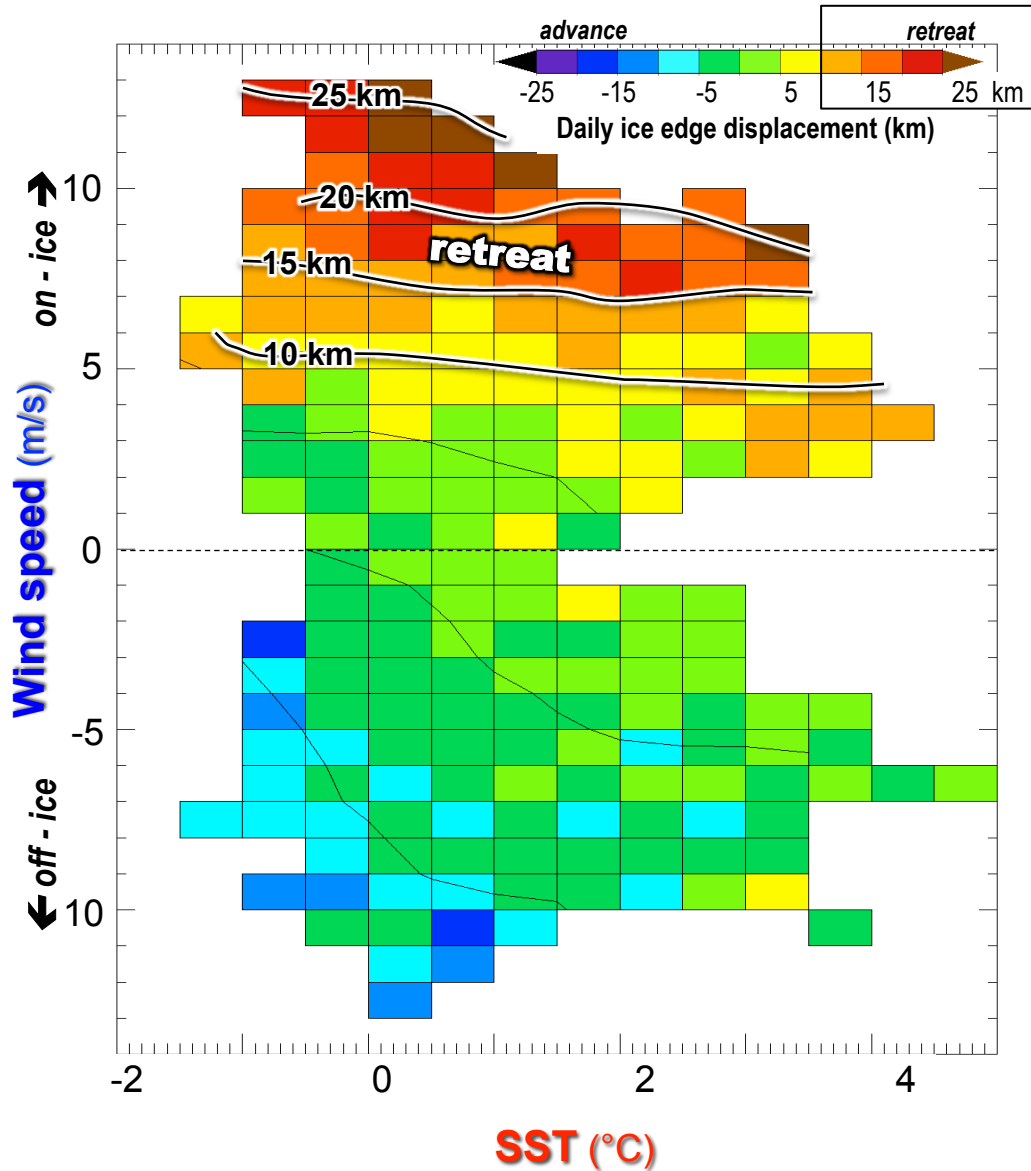


*Loiter,  
 retreat,  
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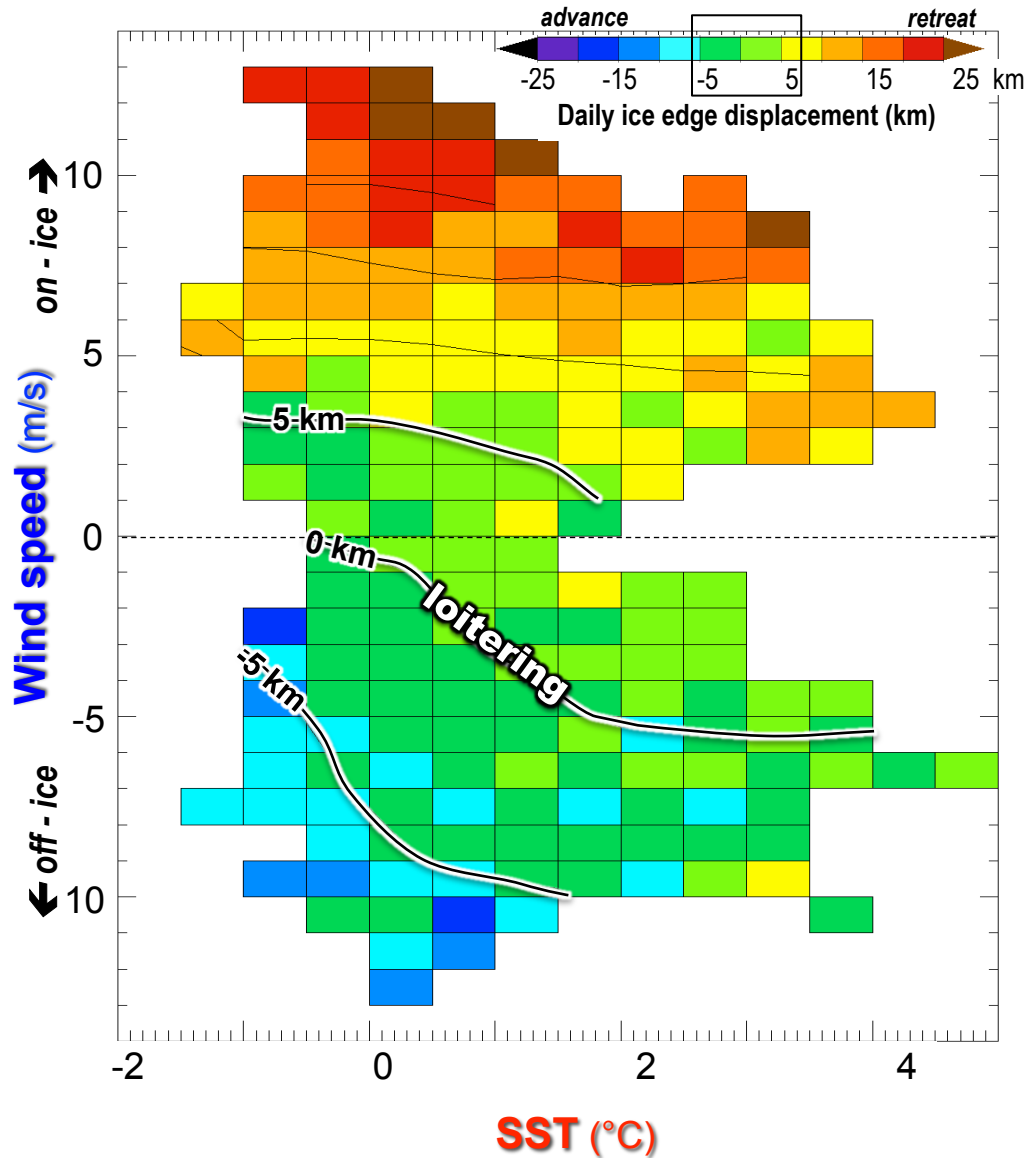


# Daily ice edge displacement $f(\text{Wind}, \text{SST})$

**Retreat:**  
on-ice wind,  
 $\neq f(\text{SST})$



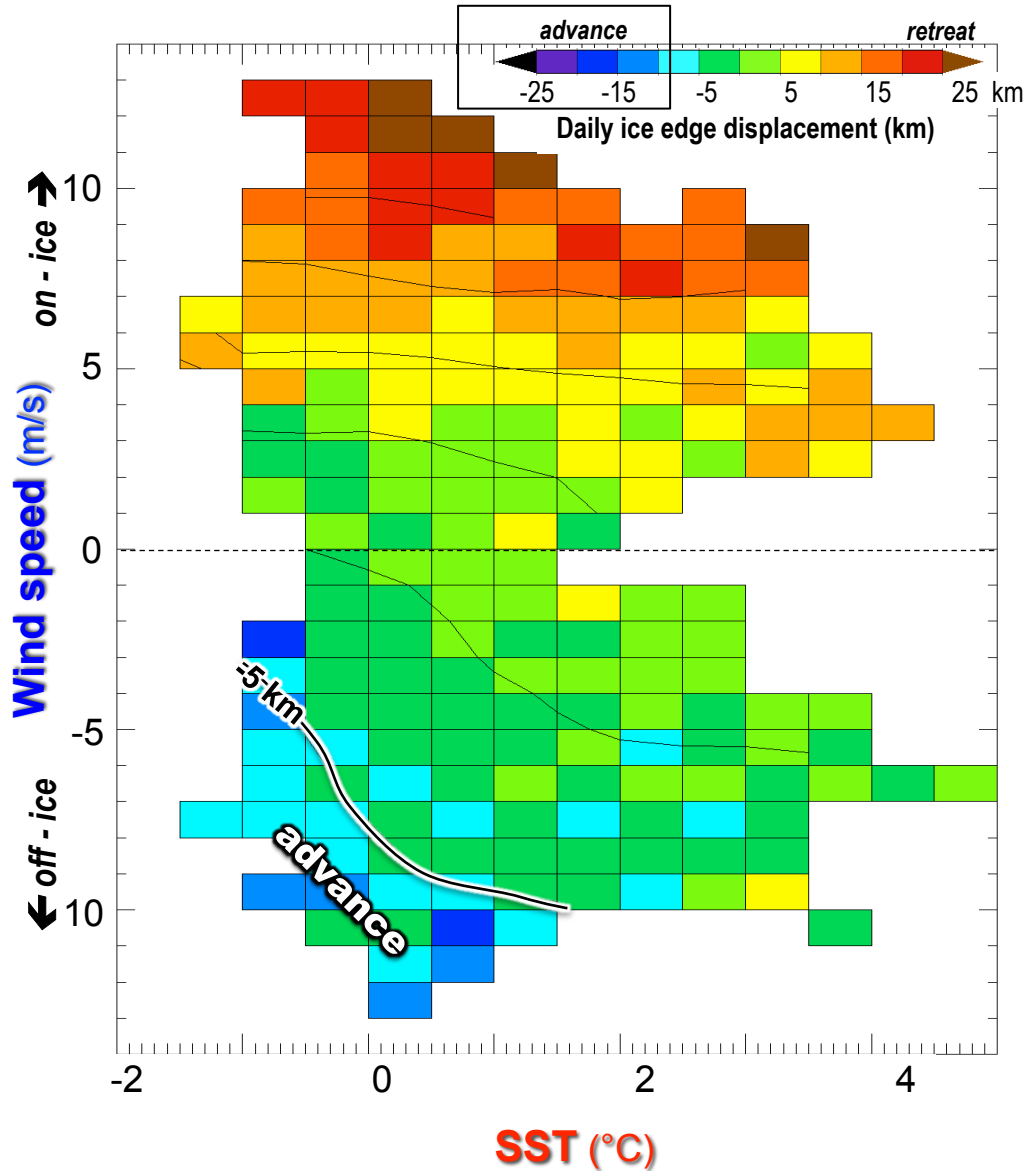
# Daily ice edge displacement $f(\text{Wind}, \text{SST})$



## Loitering:

- weak winds
- strong off-ice winds  
+ warm SST

# Daily ice edge displacement $f(\text{Wind}, \text{SST})$

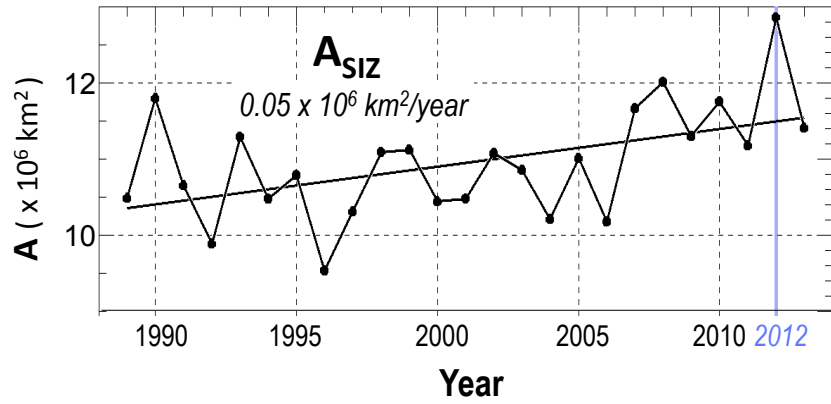


## Advance:

off-ice winds  
+ **COLD** SST

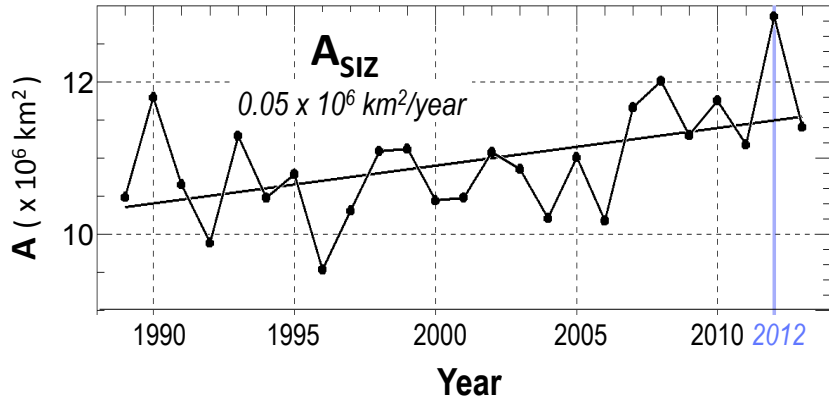


# Trends

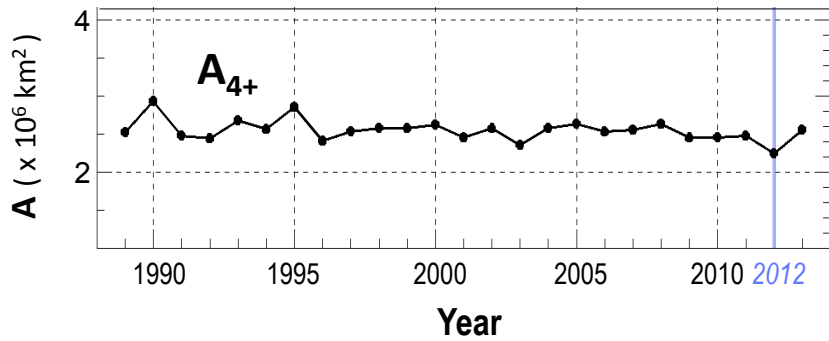


The area of the SIZ  $A_{SIZ}$  is increasing.

# Trends

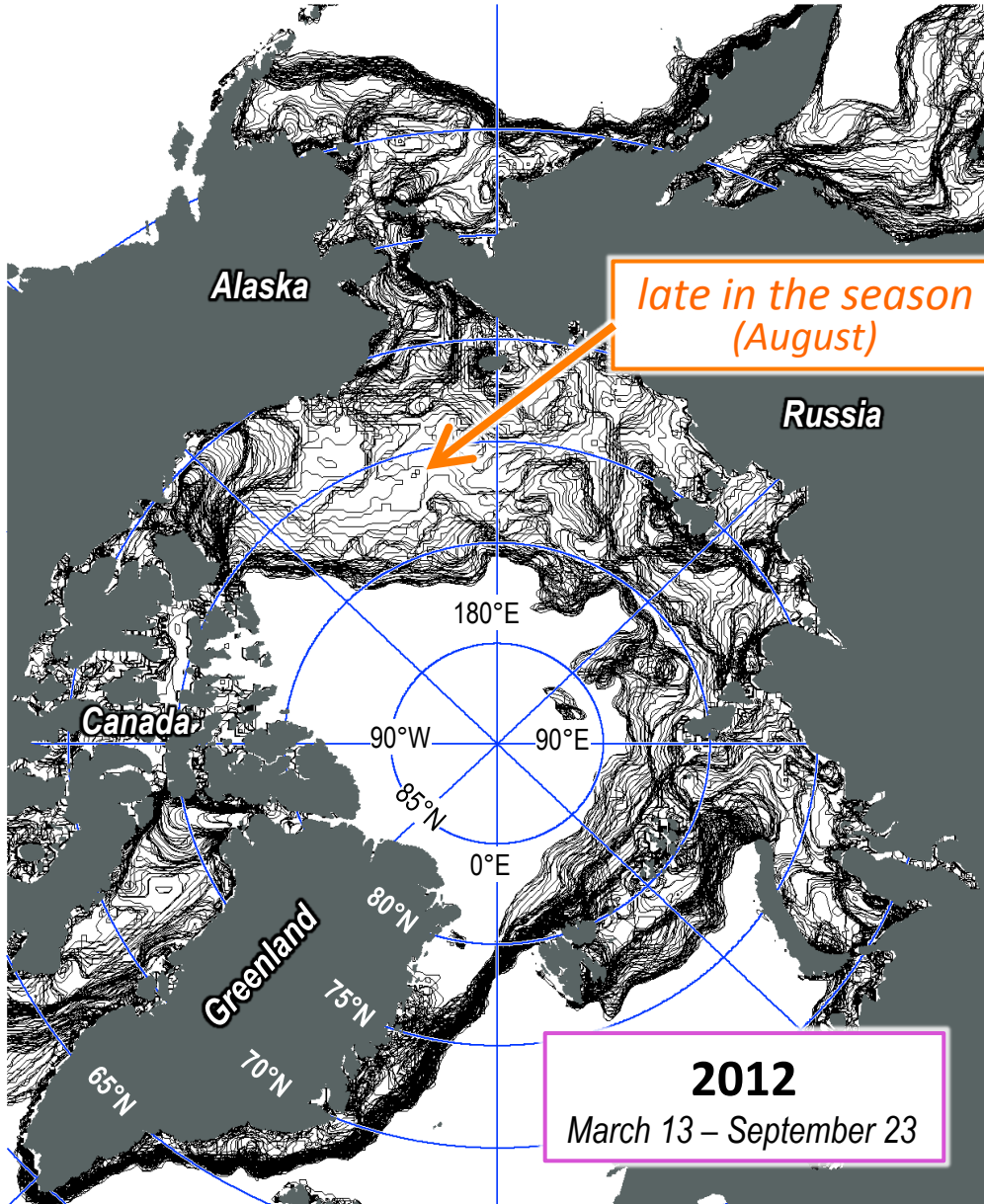


The area of the SIZ  $A_{SIZ}$  is increasing.



...but the area of loitering  $A_{4+}$  is not!

# Why isn't $A_{4+}$ increasing?



rapid retreat,  
cold SST,  
off-ice winds → *advance*,  
not *loitering*

# Final Thoughts

## The retreat season

- Retreat, "**Loitering**," Advance
- More loitering in the future, if retreat starts earlier (*warmer SST*)?



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## Who cares?

**Constant** retreat rate → **constant** conditions



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- increasing **stratification**
- suppressed **upwelling** of nutrients, heat, salt

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### Now it retreats!

- How does this "**left behind**" area evolve?
- What does the **rapidly retreating ice edge** look like?



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## Observing systems

- The **SIZ** is crucial!
- The SIZ is big...  
...**cheap ice/oc'n buoys**  
+ **remote sensing**



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*Thank  
you*