Loitering of the Retreating Sea Ice Edge in the Arctic Seas

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How fast does arctic sea ice retreat?

Pan-Arctic sea ice extent (Mkm²)

1981-2010 Average ± 2 standard deviations

2015

NSIDC: Nat'l Snow & Ice Data Ctr

1 Jan 1 Mar 1 May 1 Jul 1 Sep 1 Nov

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Arctic Obs Mtg: Seattle
Nov 18, 2015
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1981-2010 Average

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"retreat season"
A closer look

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

2012
March 13 – September 23
A closer look

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

2012
March 13 – September 23
A closer look

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

Other sea ice data sets:
- AMSR2 (3.25 km PMW)
- MASIE (NSIDC multi-sensor)

slow "loitering"

2012
March 13 – September 23
Quantitative analysis
...on the 25 km grid

Loitering ice edge:
≤ 8 km/day*
≥ 4 days in a 25 km pixel

*Avg ice speed 8-12 km/day
Spreen et al. (GRL, 2011)
Olason & Notz (JGR, 2014)
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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

Winter ice max

2012
Mar 13 – Sep 23
Where does it loiter?

Winter ice max
@ warm SST fronts

Within the SIZ
in some places... why?

N. Baffin, E. Beaufort,
N. Chukchi, Laptev...
Why does it loiter?

Winter ice max
@ warm SST fronts

Within the SIZ
in some places...why?

Early ice retreat
↓
early SST warming
↓
loitering

Winter ice max
2012
Mar 13 – Sep 23

Within the SIZ
2012
Mar 13 – Sep 23

SST (°C)
(satellite data:
NOAA OI.v2 AVHRR)

ice conc.

-2 -1 0 1 2 3 4 5
0.2 0.3 0.4 0.5 0.75

2012
July 8

WARM

Alaska
Russia
Canada
Greenland

WARM

WARM

WARM

WARM

WARM
**Why does it loiter?**

**Winter ice max**
- @ warm SST fronts

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

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

*Why early ice retreat here?*

Steele et al. (JGR, 2015)

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**Winter ice max**
- Alaska
- Russia
- Canada
- Greenland

**SST (°C)**
(satellite data: NOAA OI.v2 AVHRR)

**2012**
- Mar 13 – Sep 23

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**Early ice retreat**
- July 8

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**Why early ice retreat here?**

Steele et al. (JGR, 2015)
Why does it loiter?

Loitering:
wind + warm SST

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

Early ice retreat
early SST warming
loitering

(satellite data: NOAA OI.v2 AVHRR)
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...but how deep
does that warm water extend?
Ocean observing & loitering

Loitering: wind + warm SST

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

...but how deep does that warm water extend?

The UpTempO buoy program

- Submergence
- Barometer port
- Iridium, GPS
- 16" diameter
- Water line
- Electronics
- Batteries
- Strength member

Thermistors: ± 0.1°C
- 2.5, 5, 7.5, 10, 15, 20, 25, 30, 35, 40, 50, 60 m depth

Pressure: ± 1 dbar
- 20, 40, 60 m depth

CT: SBE 37IM
- 4 m depth
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/
Daily ice edge displacement 
\[ f(\text{Wind}, \text{SST}) \]

Laptev Sea
(2011)

Loiter, retreat, loiter, retreat,...
Daily ice edge displacement $f(\text{Wind},\text{SST})$

Laptev Sea (2011)

(a) Lena Delta, Taymyr Peninsula

(b) NSI, SZ, Loiter, retreat, loiter, retreat,...

Laptev Sea (2007-2013)

Daily ice edge displacement (km)

Wind speed (m/s)

SST (°C)

Advance, retreat

4 6 8 10 $T_{\Sigma 4+}$ (days)

4 -2 0 2 4

Loiter, retreat, loiter, retreat,...

-10 -5 0 5 10
Daily ice edge displacement
\( f(\text{Wind, SST}) \)

**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
Advance:

off-ice winds + COLD SST
The area of the SIZ $A_{SIZ}$ is increasing.
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...but the area of loitering $A_{4+}$ is not!
Why isn't $A_{4+}$ increasing?

late in the season (August)

rapid retreat,
cold SST,
off-ice winds $\Rightarrow$ advance,
not loitering

2012
March 13 – September 23
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 $\Rightarrow$ constant conditions
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Loitering ice edge:

• high melt
• 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