Measurements of floe size from ICESat-2 laser altimetry

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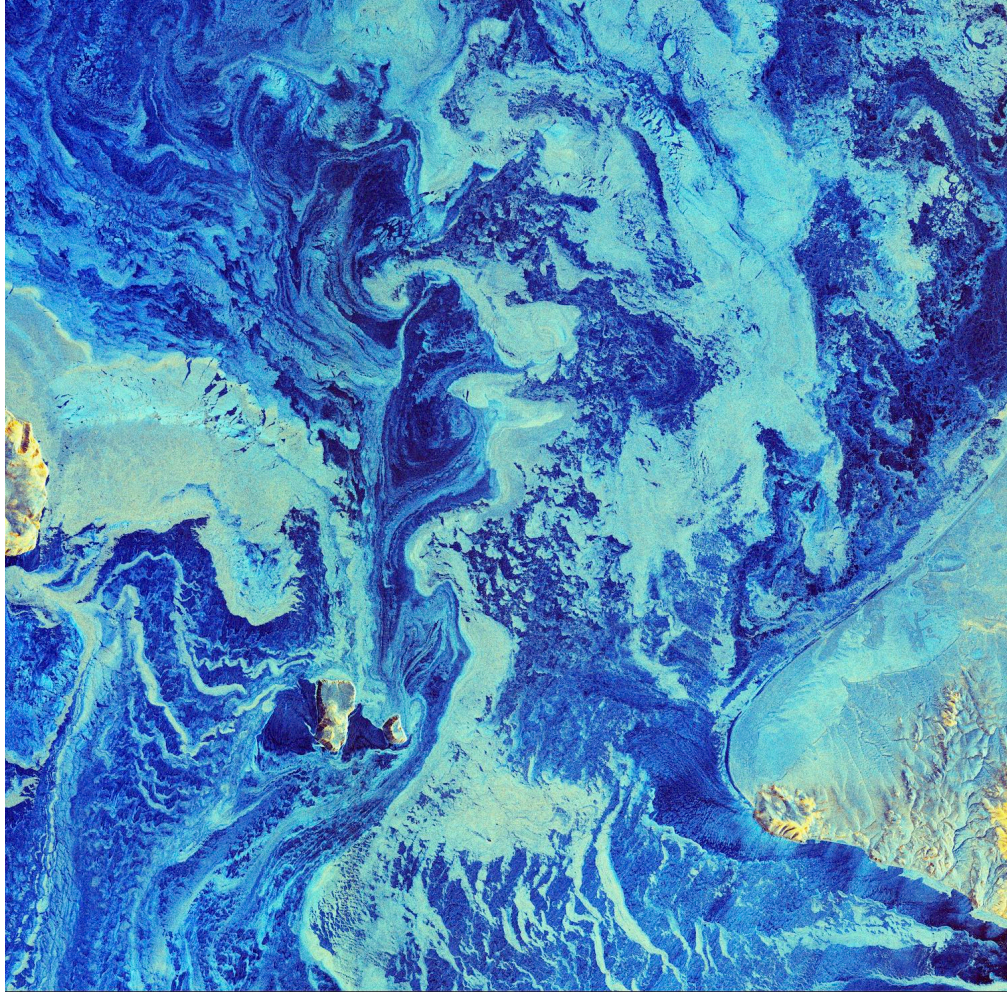
Background

Background: Floe size

- Sea ice modulates ocean-atmosphere fluxes in high-latitudes
- Sea ice is made up of many individual floes
- Often described by FSD
- Sea ice size scale impacts:
  - Ice melt rates
  - Oceanic mixed layer
  - Atmospheric boundary fluxes
  - Wave propagation



Background: Floe chord length

- Based on theoretical statistical discussion of Horvat et al. (2019), *The Cryosphere Discuss* [and refs within]
- D = chord length
- One dimensional measure of floe dimension
- Can be statistically related to floe size distribution for circular floes

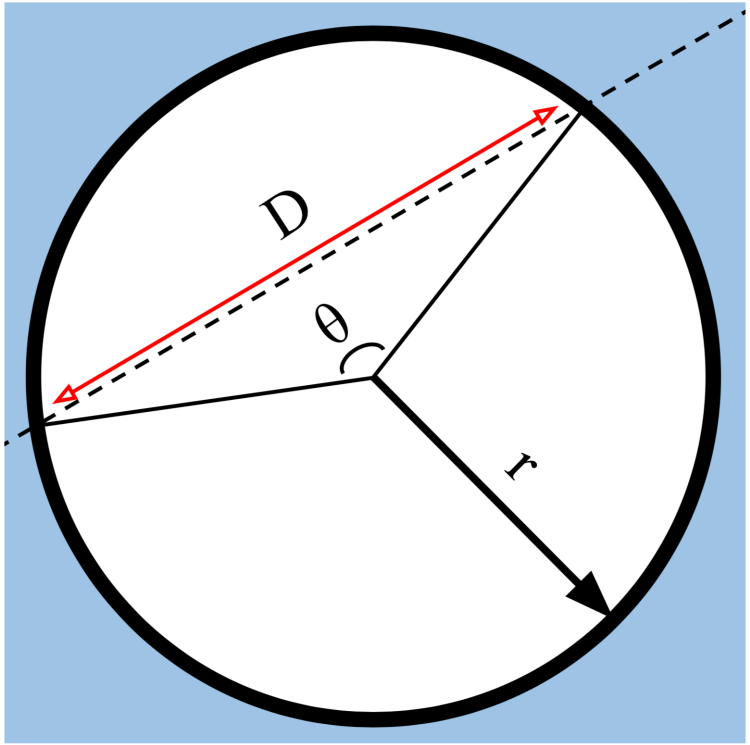


Figure: Horvat et al. (2019) *The Cryosphere Discuss*

Background: Floe chord length

- Based on theoretical statistical discussion of Horvat et al. (2019), *The Cryosphere Discuss* [and refs within]
- Also calculate
  - Representative radius:

$$\bar{r} = \frac{3\pi}{16}\frac{\langle D^3 \rangle}{\langle D^2 \rangle}$$

  - Floe fragmentation:

$$P = \frac{\pi}{2}\frac{\langle D^1 \rangle}{\langle D^2 \rangle}$$

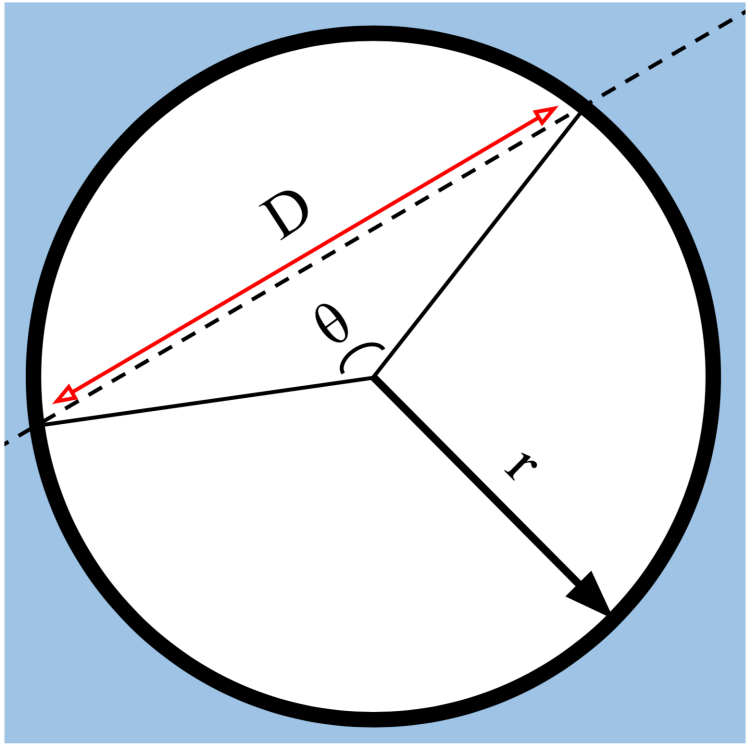
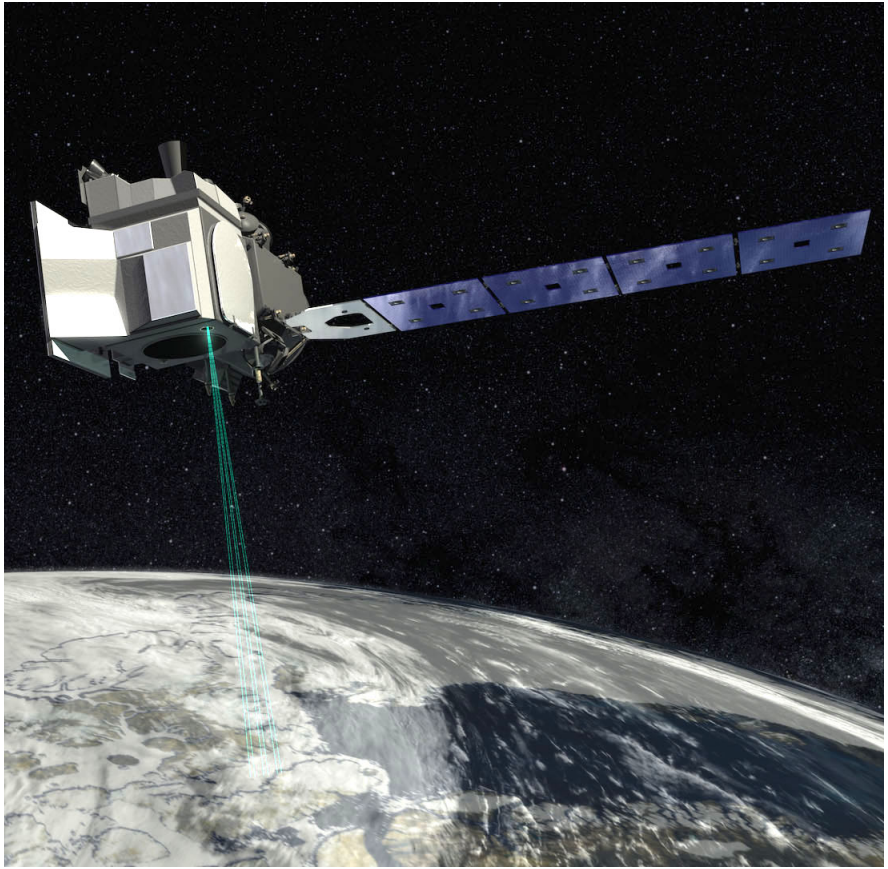


Figure: Horvat et al. (2019) *The Cryosphere Discuss*

ICESat-2

ICESat-2

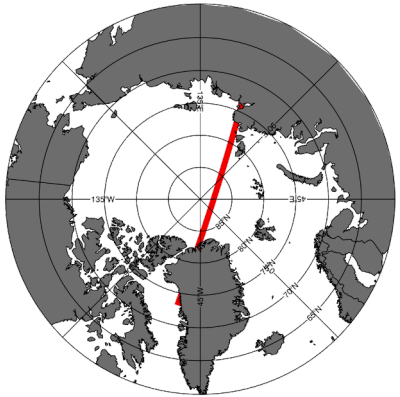
- Launched Sept 2018
- ATLAS: 6-beam laser altimeter
  - 3 strong; 3 weak; 3km across-track separation
  - Photon counting
  - ~17m footprint; 70cm along-track PRF
- Level-3 sea ice products:
  - Sea ice height (ATL07)
  - Sea ice freeboard (ATL10)

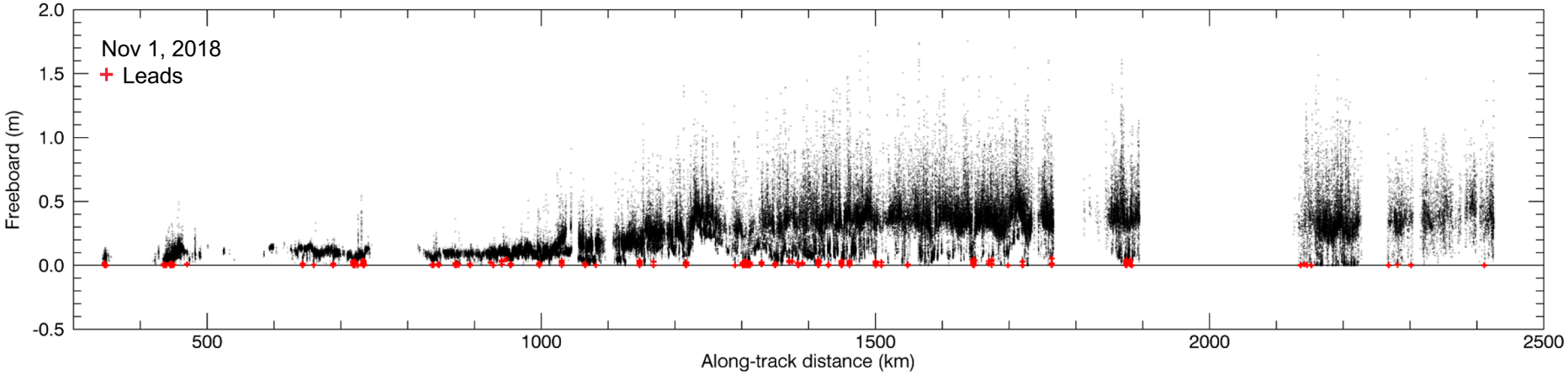


Deriving floe chord length

Sea ice freeboard: Floe chord length

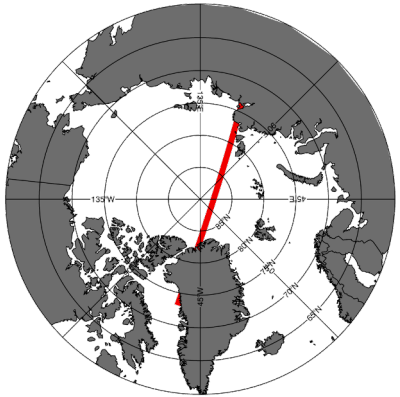
- Sea ice freeboard transect from Laptev Sea to Lincoln Sea; thinner ice to thicker ice

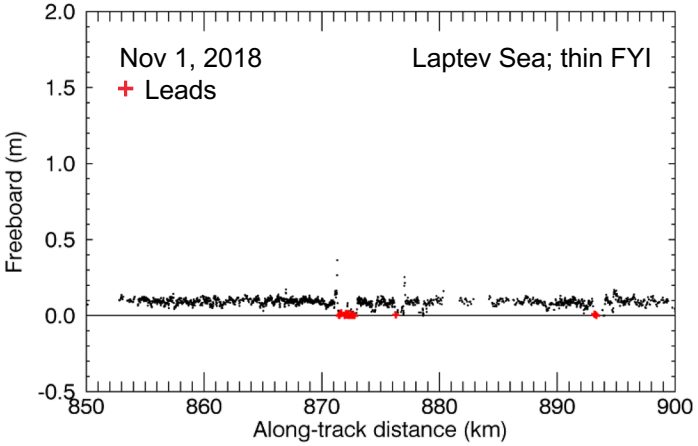


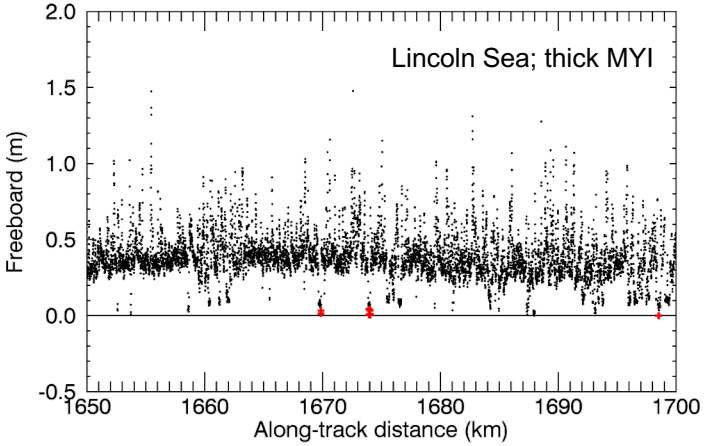


Sea ice freeboard: Floe chord length

- Sea ice freeboard transect from Laptev Sea to Lincoln Sea; thinner ice to thicker ice
- Can just use lead flags to determine floe chord length?

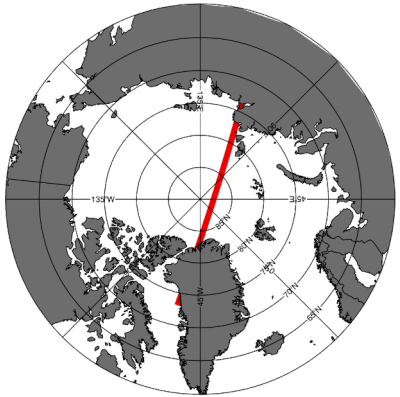


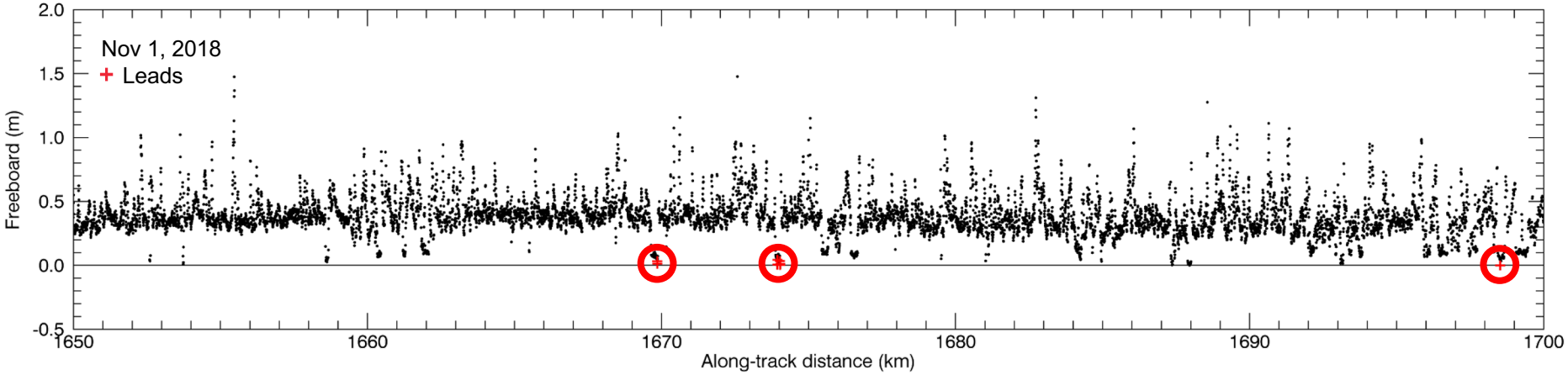




Sea ice freeboard: Floe chord length

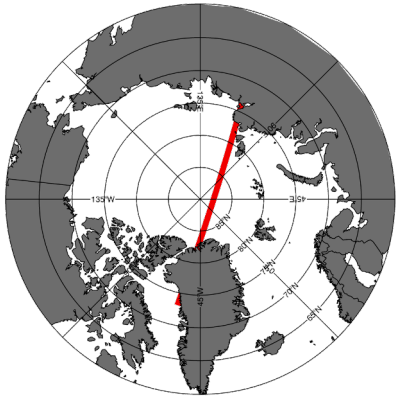
- Sea ice freeboard transect from Laptev Sea to Lincoln Sea; thinner ice to thicker ice
- Can just use lead flags to determine floe chord length? Not really

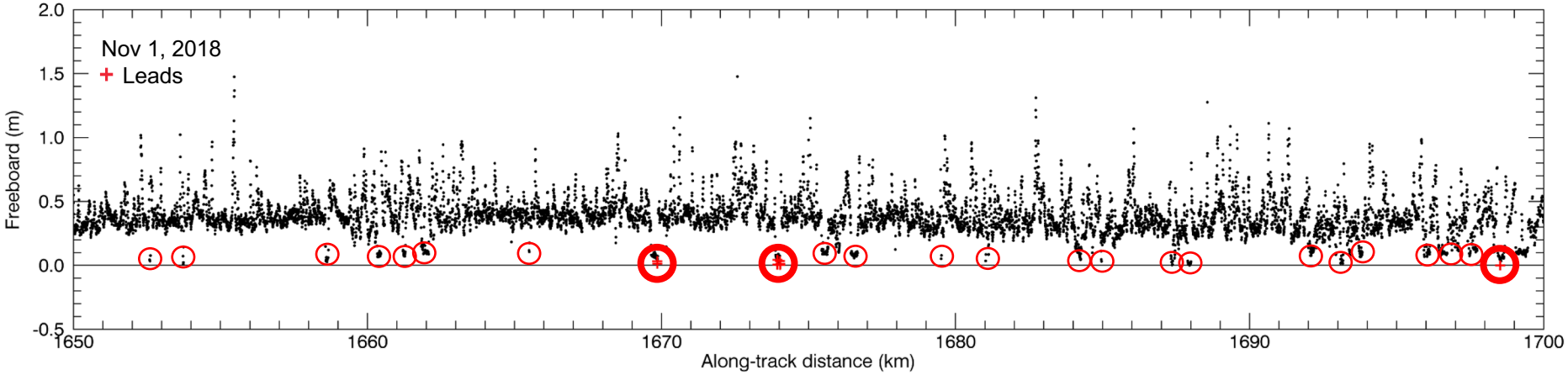




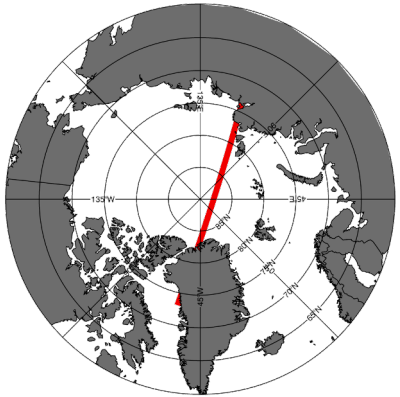
Sea ice freeboard: Floe chord length

- Sea ice freeboard transect from Laptev Sea to Lincoln Sea; thinner ice to thicker ice
- Can just use lead flags to determine floe chord length? Not really – many more ‘gaps’ than leads

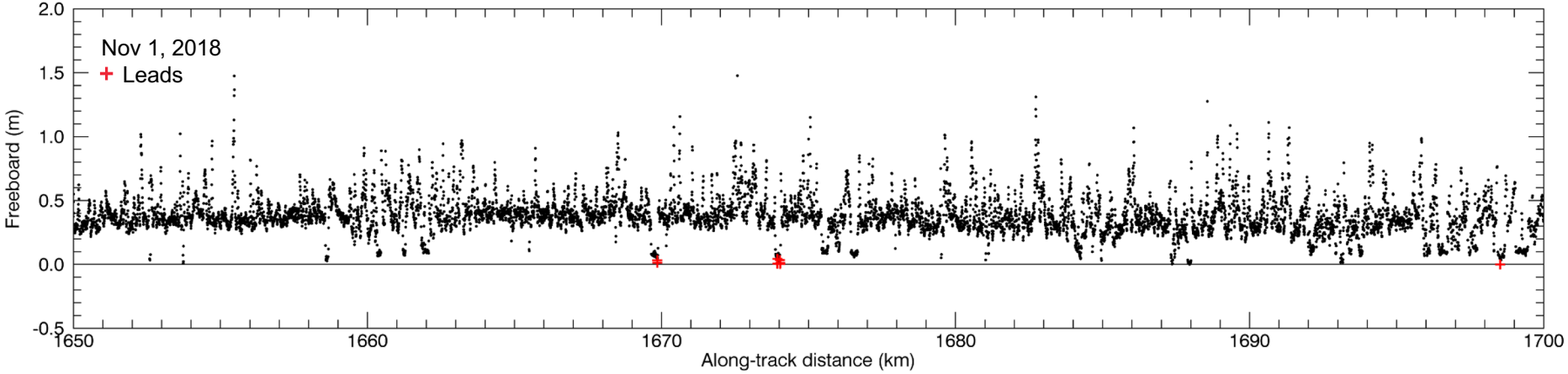




Sea ice freeboard: Floe chord length

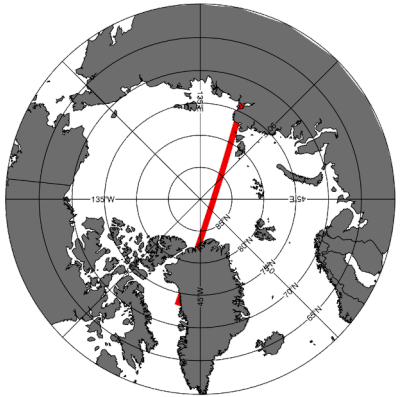


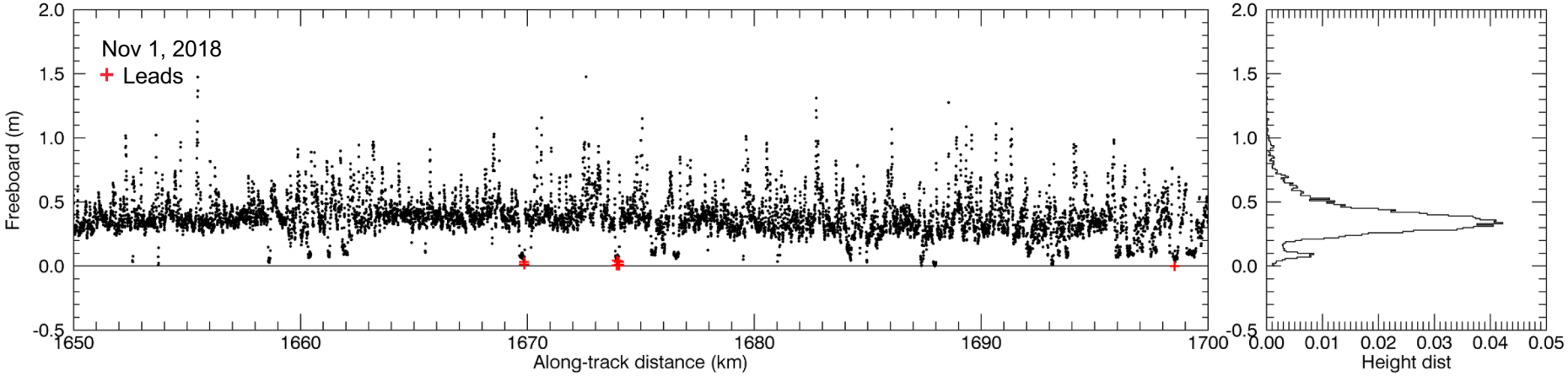
- Need to come up with method to find ‘gaps’ between floes
  - Has to work across different thickness and spatial scales



Sea ice freeboard: Floe chord length

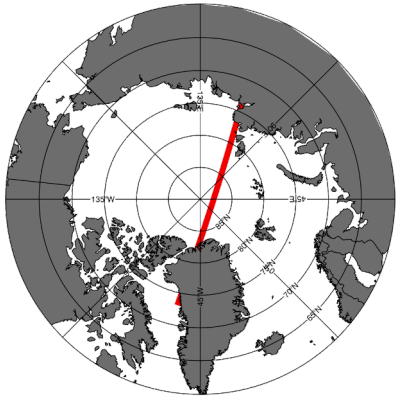
1. Look at height distribution in 50km segments

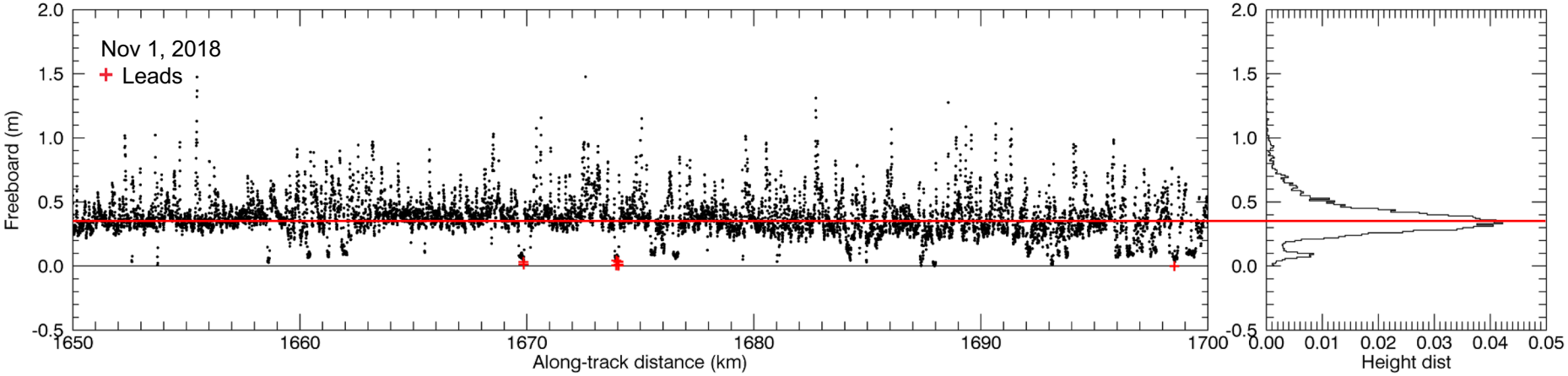




Sea ice freeboard: Floe chord length

1. Look at height distribution in 50km segments
2. Calculate 50th percentile of height





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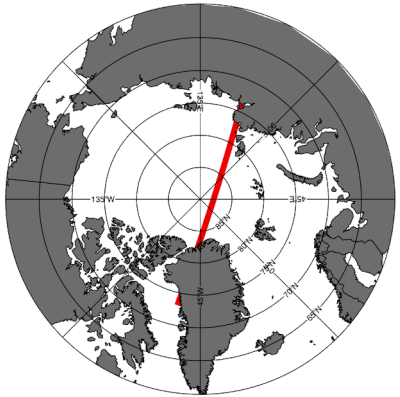
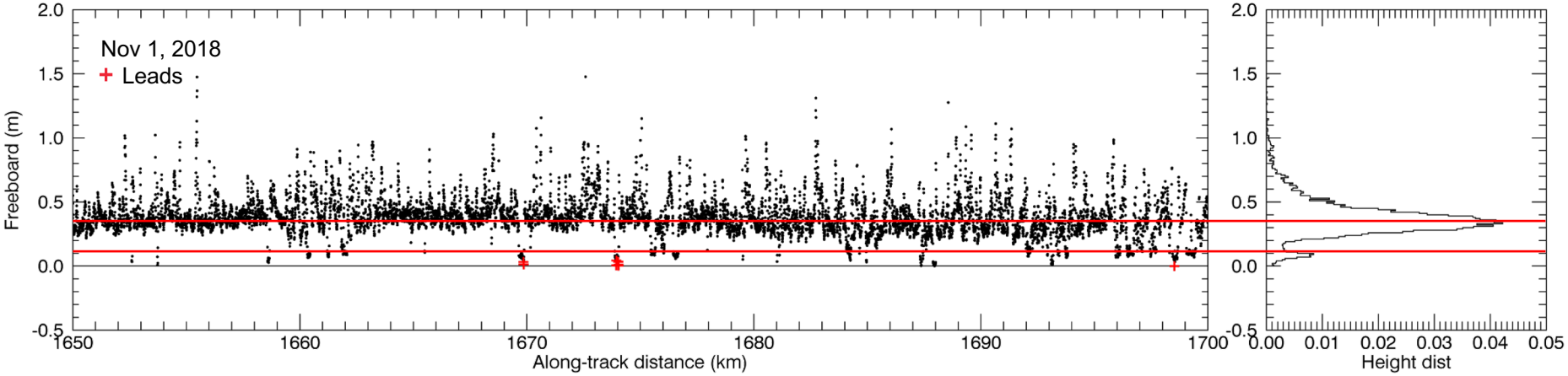


1. Look at height distribution in 50km segments
2. Calculate 50th percentile of height
3. Threshold height is 1/3rd of 50th percentile of height
4. Heights below threshold are flagged as potential ‘gaps’



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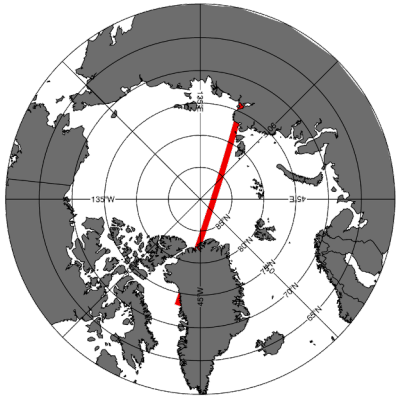

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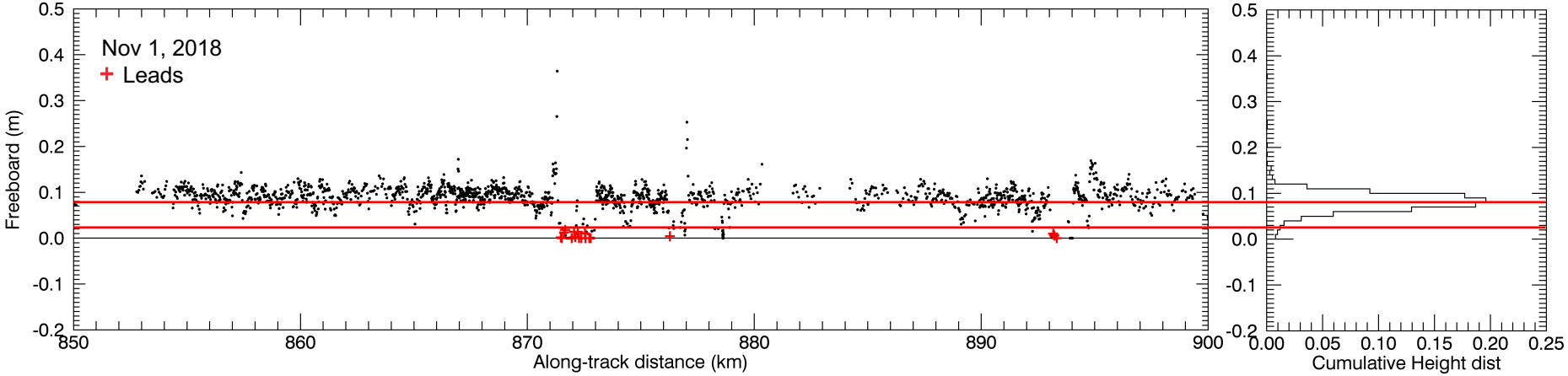

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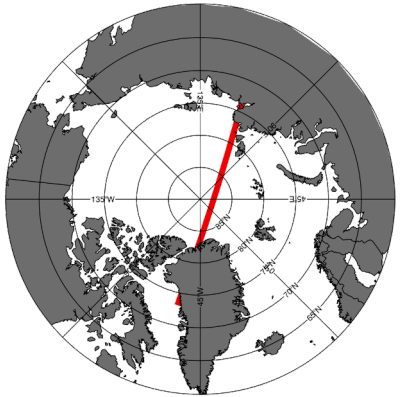
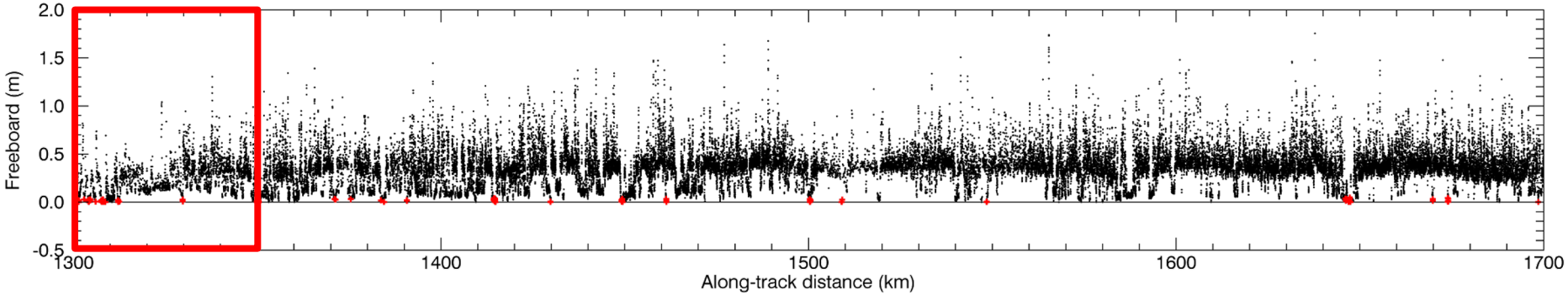
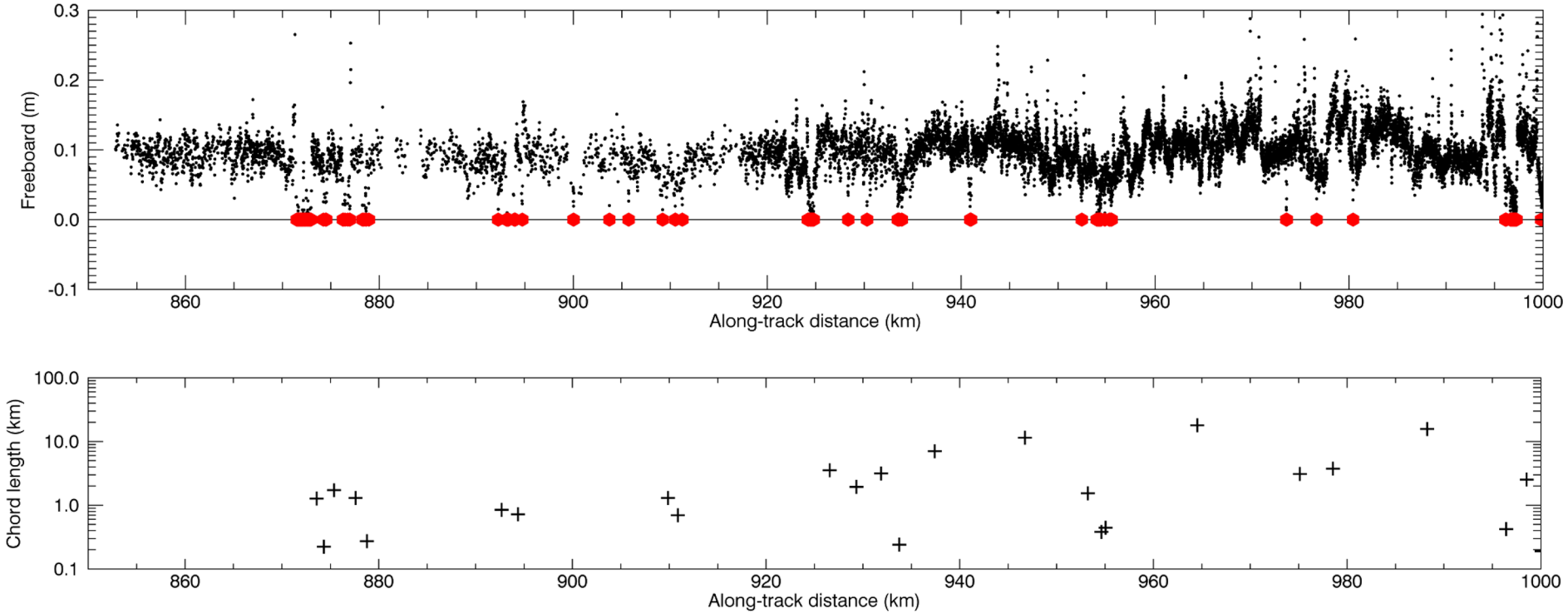


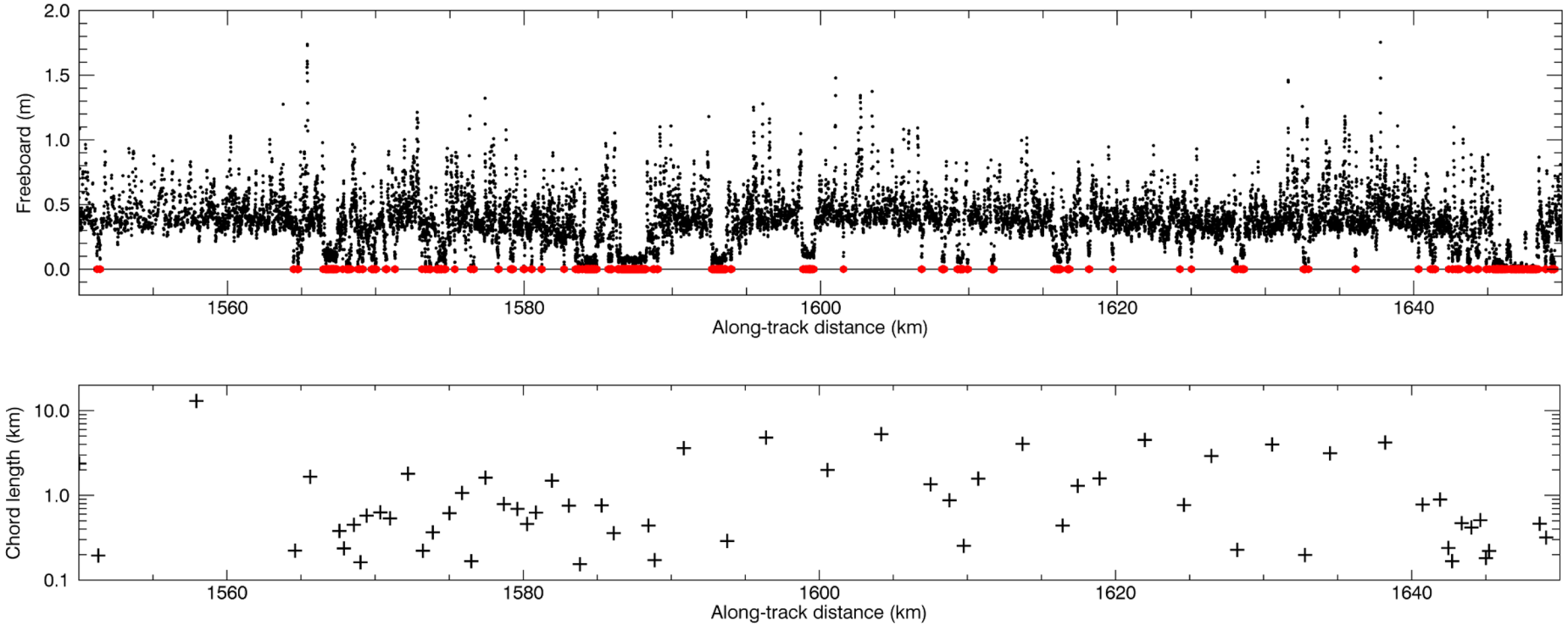
1. Look at height distribution in 50km segments
2. Calculate 50th percentile of height
3. Threshold height is 1/3rd of 50th percentile of height
4. Heights below threshold are flagged as potential ‘gaps’
5. Repeat procedure for 50km segments in 10km along-track increments



Sea ice freeboard: Floe chord length

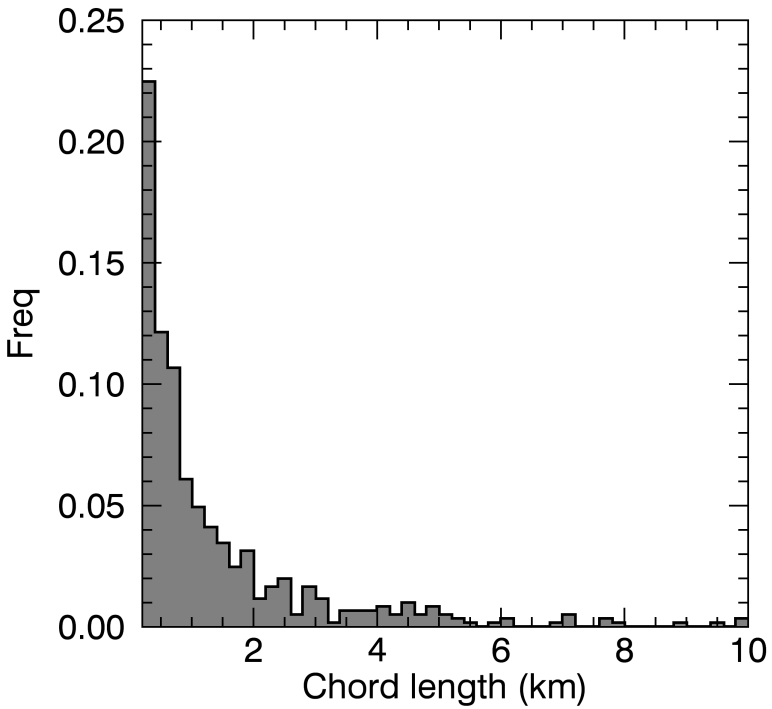


Sea ice freeboard: Floe chord length



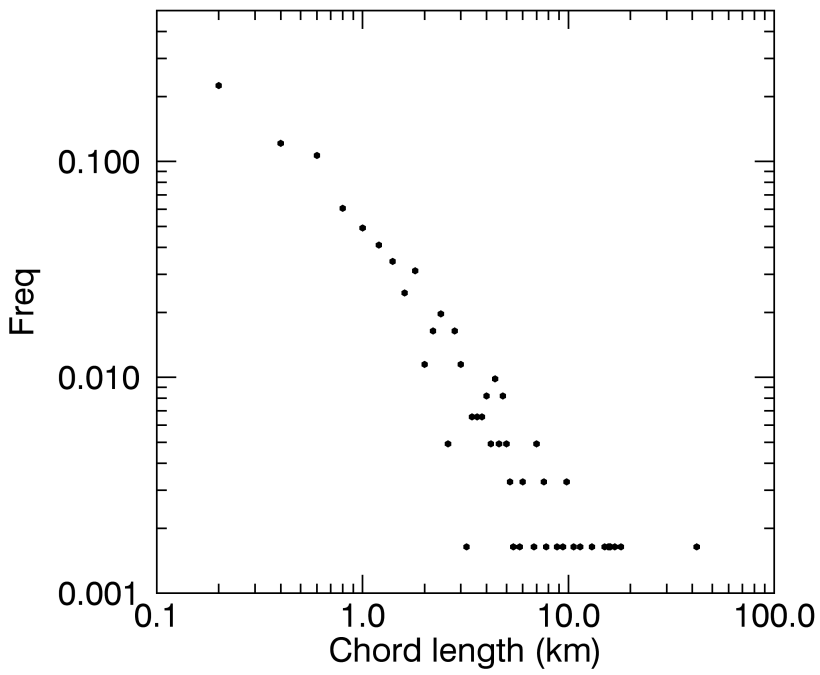
Chord length distribution

Chord length distribution: Single track



- Chord length distribution over single track
- Based on filtering minimum chord length ~150m
  - Based on requirement of two ‘ice’ measurements in between ‘gap’ measurements
- Discard chord lengths if missing height data over 100m or more

Chord length distribution: Single track



- Chord length distribution over single track
- Based on filtering minimum chord length ~150m
  - Based on requirement of two ‘ice’ measurements in between ‘gap’ measurements
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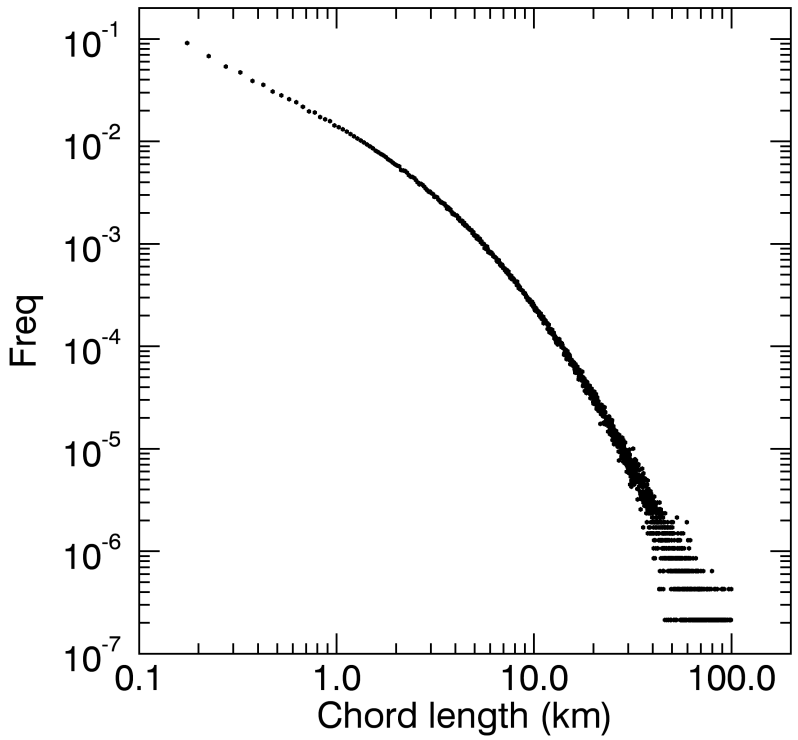
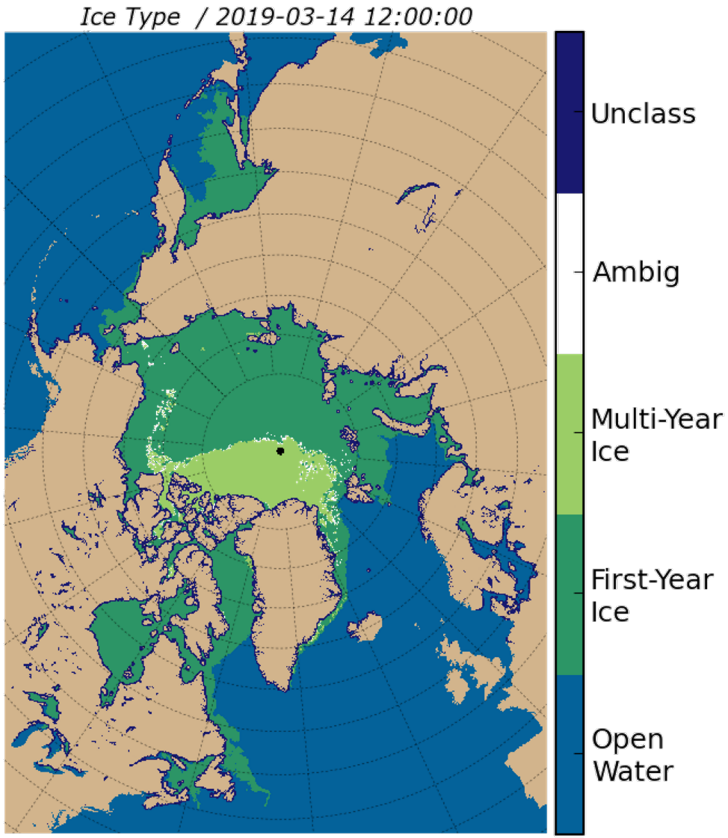
Chord length distribution: 2018-19 growth season



- Composite all chord length measurements between October–April
  - >4.5M individual measurements

Chord length distribution variability

- Can look at variability in the chord length distribution
  - Over the growth season
  - By ice type
  - Spatially
- Use OSISAF ice type mask



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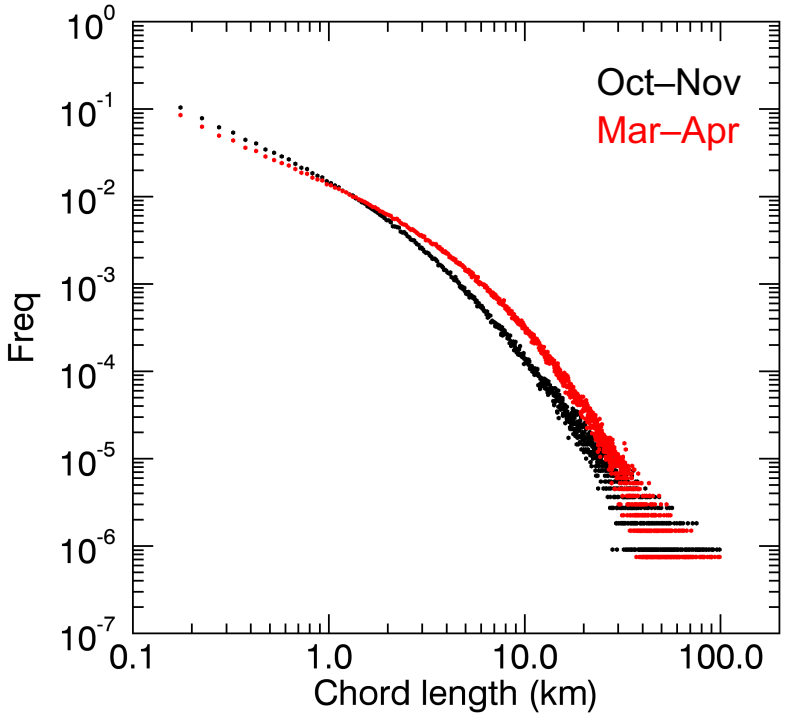
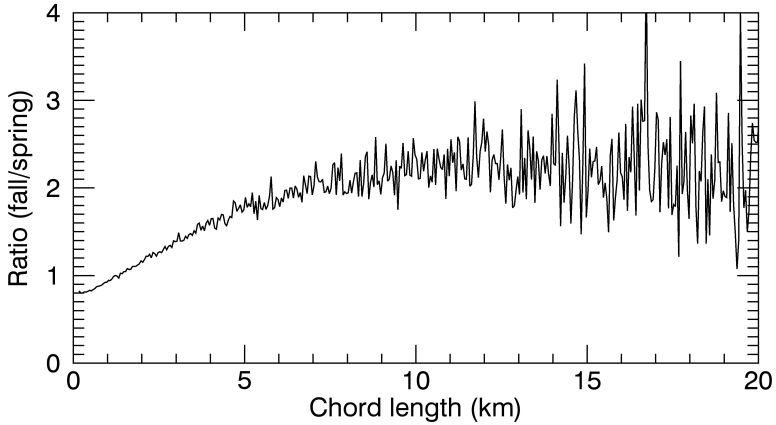
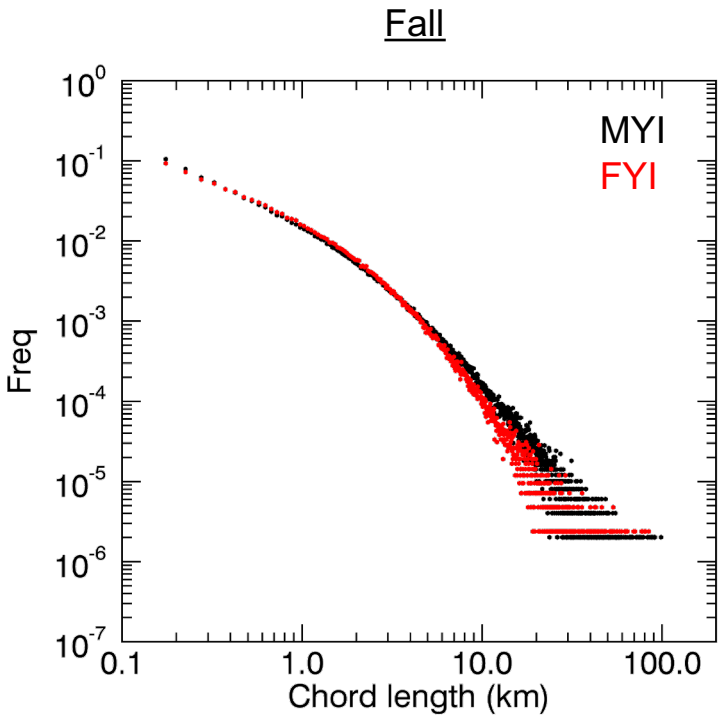
Chord length distribution: Seasonal

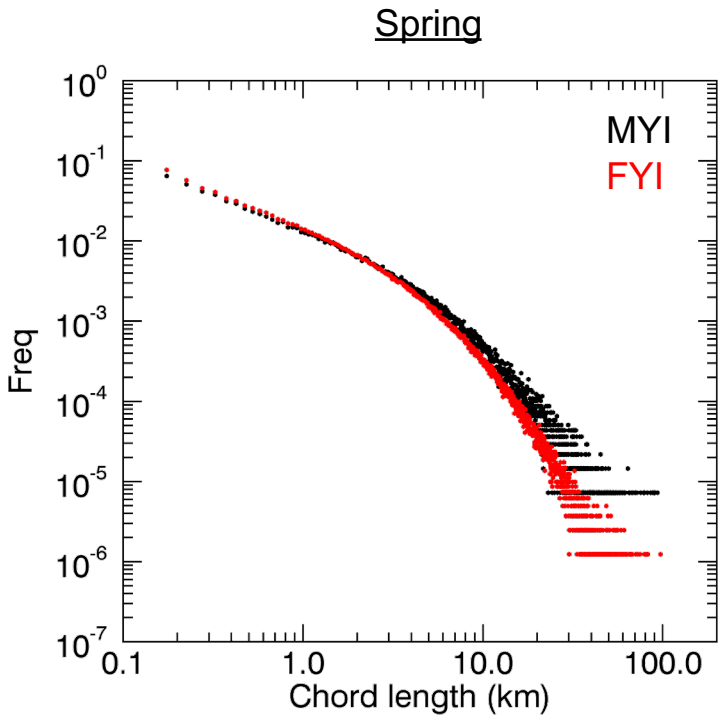


- Distribution between fall and spring



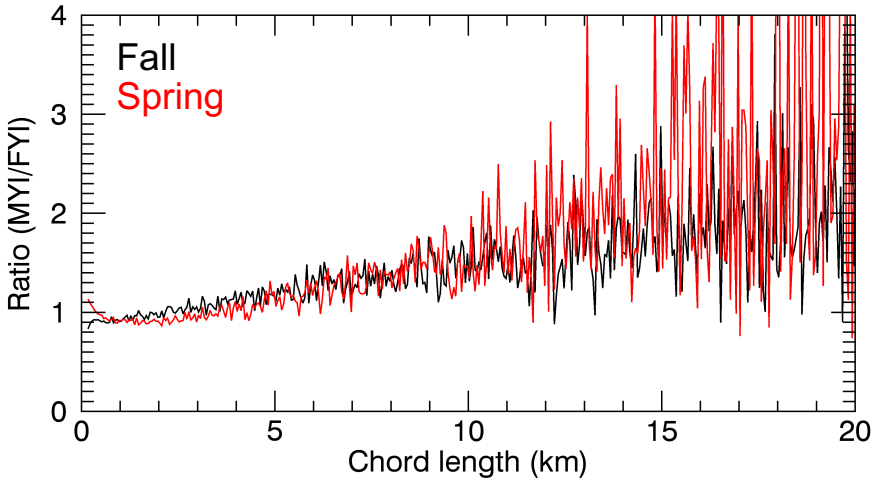
Chord length distribution: Seasonal & ice type





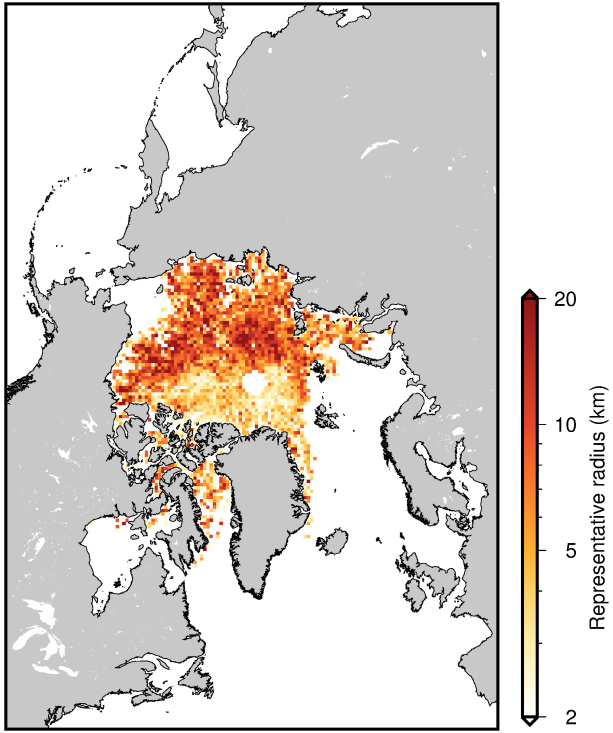
Chord length distribution: Seasonal & ice type

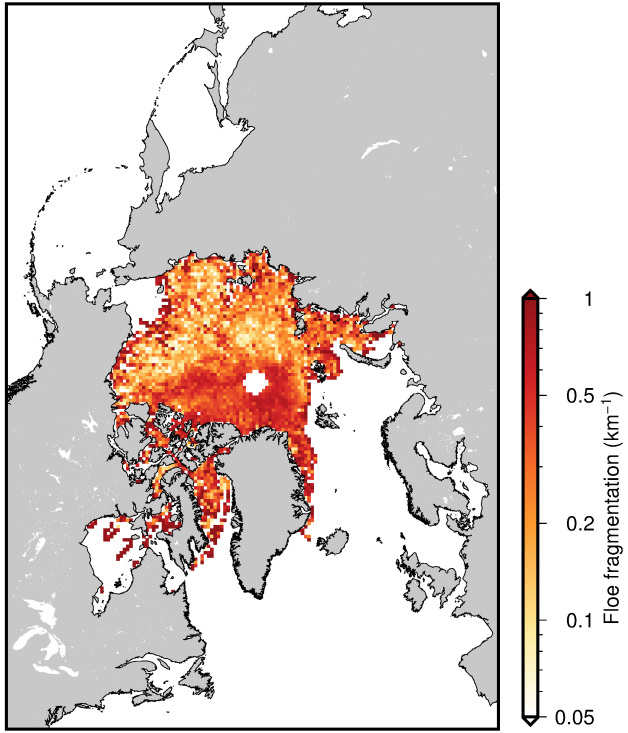
- Ratio of MYI to FYI chord length appears similar through the season
- ~50–100% more MYI chord length >10km
- ~10% less FYI chord length <2km

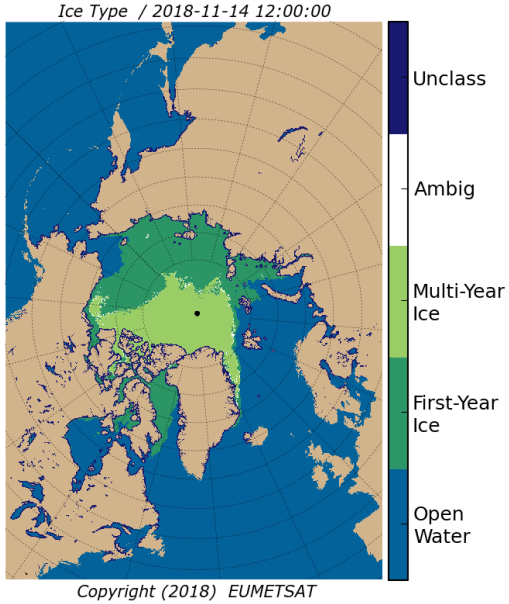


Chord length distribution: Spatial

November 2018

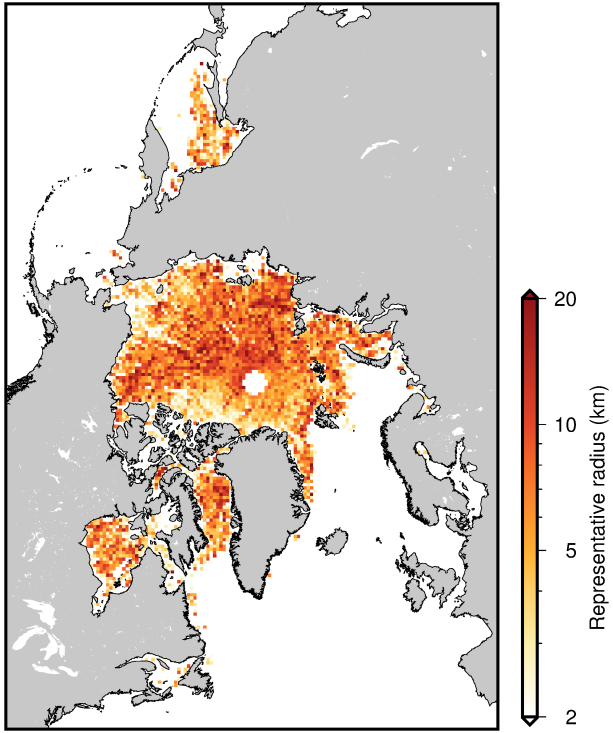


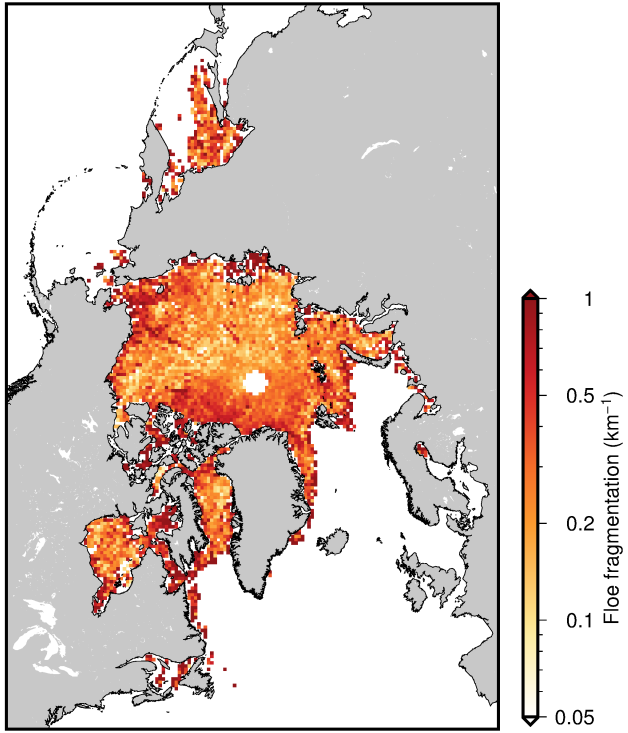


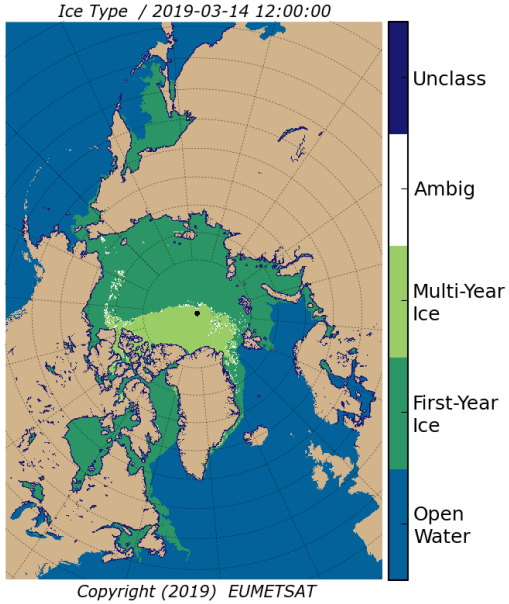


Chord length distribution: Spatial

March 2019







Chord length distribution: Spatial

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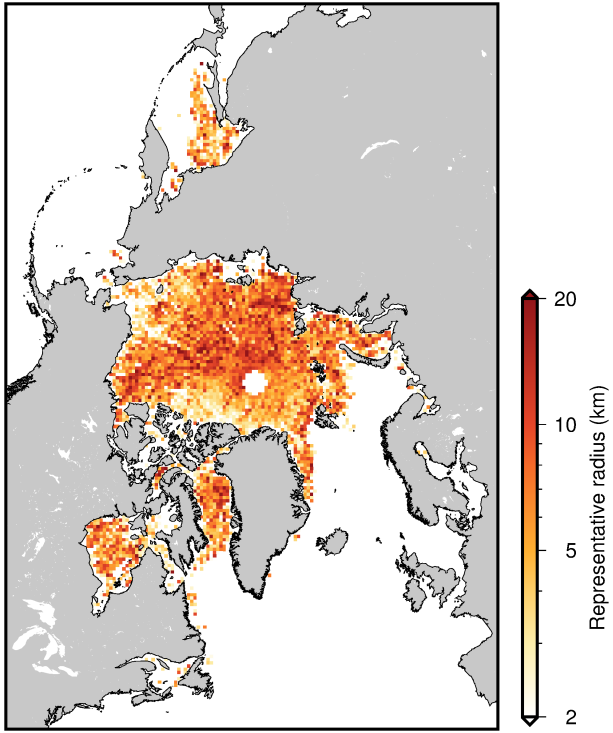
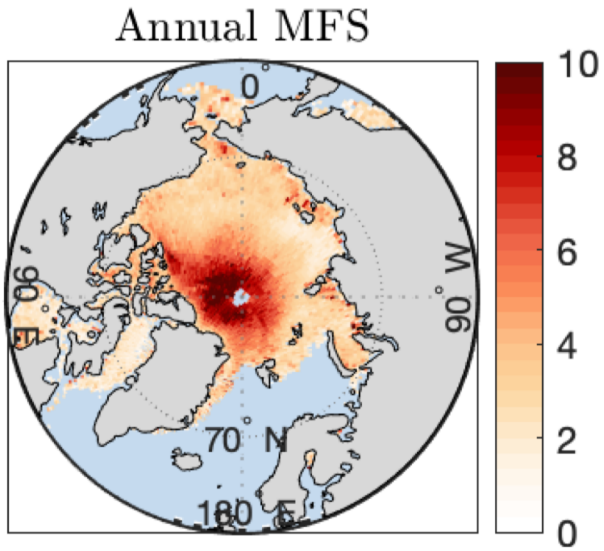
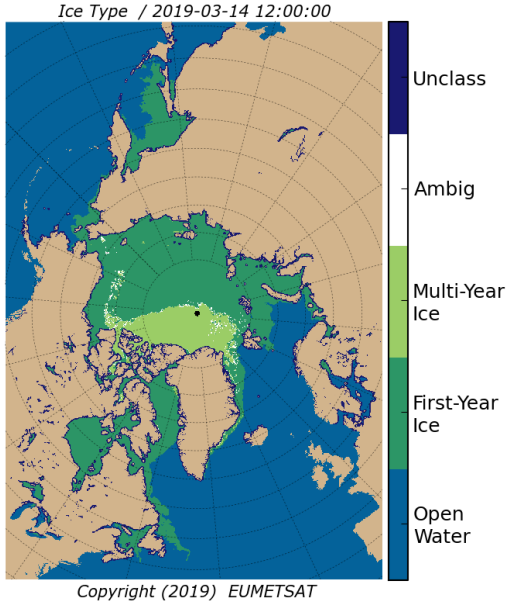




Climatological Arctic mean floe size (in km) from CRYOSAT-2 (Horvat et al.)



Conclusions & future considerations

Conclusions

- Floe size is important parameter for atmosphere-ocean coupling
- Can estimate floe chord lengths by identifying ‘gaps’ between floes in high-resolution laser altimetry from ICESat-2
  - Resolve floes with chord lengths from ~100m to ~50km
- See redistribution from smaller to larger floes during growth season
- Many more very large MYI floes than FYI floes
- ICESat-2 is <u>great</u>!

Future considerations

- Compare against coincident imagery
- Extend further into summer?
- Southern Ocean
- Joint floe size-freeboard distribution
  - Already see correlation with MYI/FYI
- Comparison with recent radar altimetry studies:
  - Horvat et al.
  - Tilling et al.

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