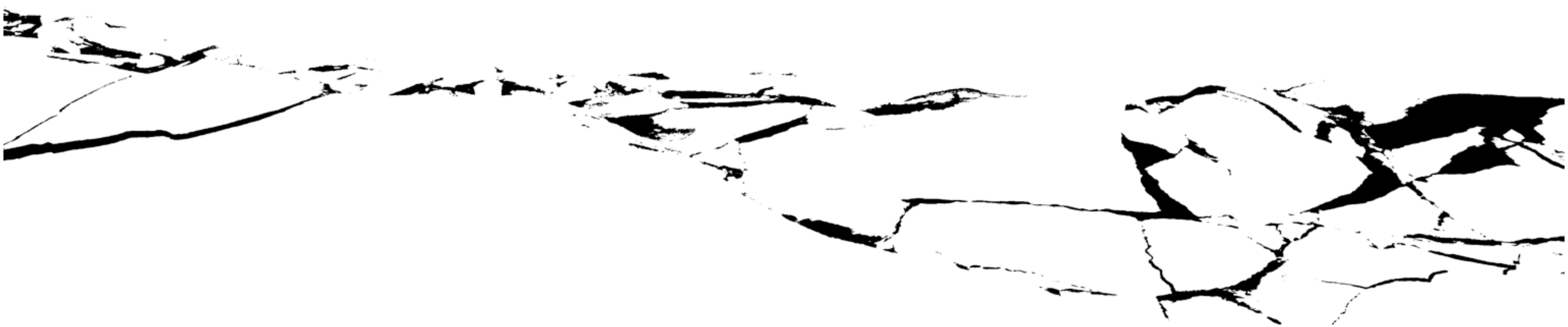
Characterizing Arctic sea ice topography using high-resolution IceBridge data

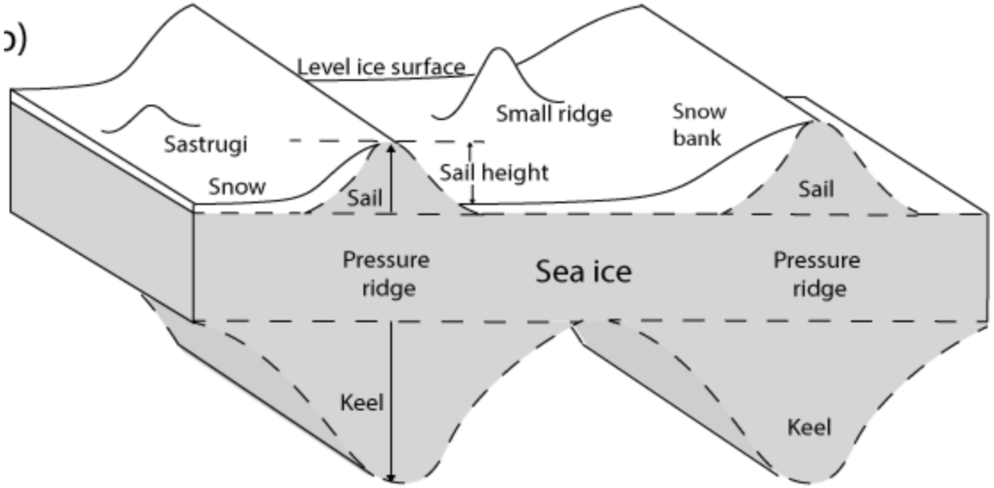
or

'What does the sea ice surface look like?'

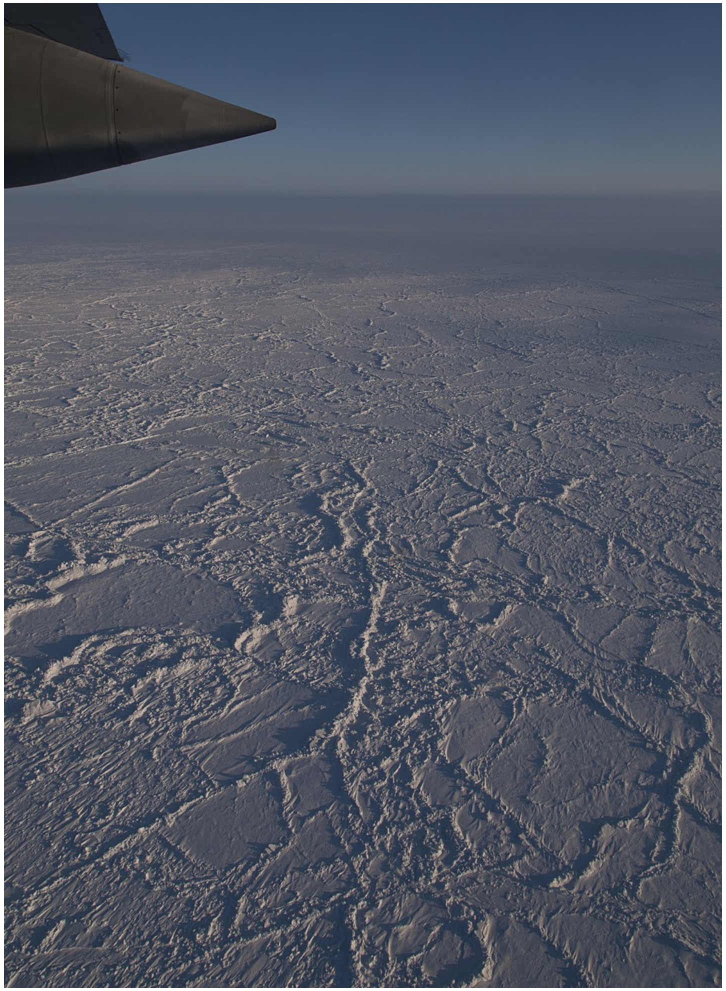


Alek Petty, Michel Tsamados, Nathan Kurtz, Sinead Farrell, Thomas Newman, Jeremy Harbeck, Jacqueline Richter-Menge and Daniel Feltham

Sea ice surface variability

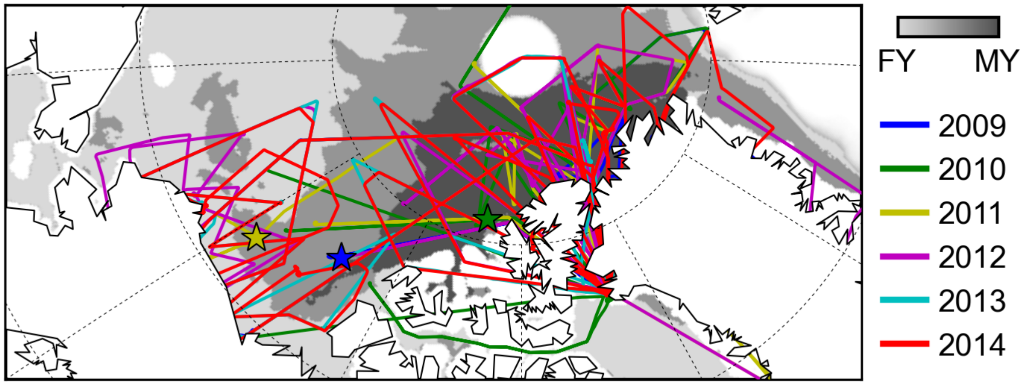


- Sea ice is a heterogeneous medium, which varies regionally and temporally.
- Pressure ridges (sails) often dominate the ice surface variability.
- Sastrugi, dunes, hummocks also likely to feature. A potential complication.



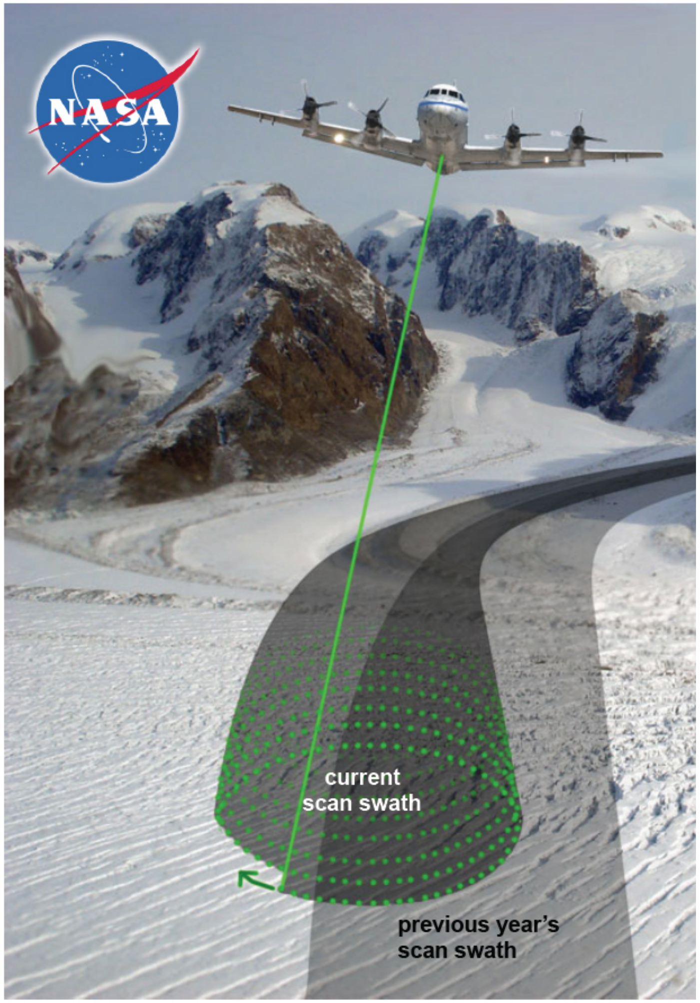
(Photo by Jeremy Harbeck, taken during an IceBridge sea ice flight)

The Airborne Topographic Mapper (ATM)

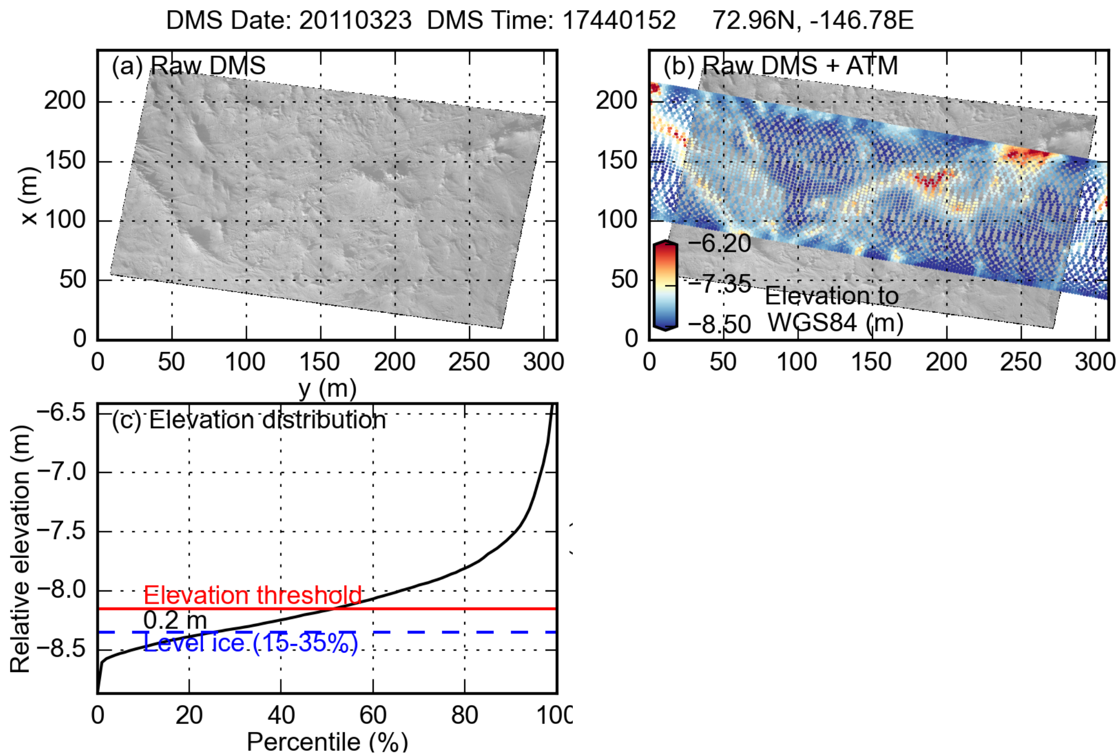


Year	2009	2010	2011	2012	2013	2014
Along-track coverage (km)	8,762	14,505	10,080	24,625	18,092	21,028
ATM swath area (km²)	2,216	5,043	2,432	6,284	4,614	5,232

- Doubling of the 'good' sea ice coverage since 2009.
- High data coverage in the Central Arctic
- Good coverage in the Beaufort Sea, a region of rapid sea ice decline.
- Can increasingly start to investigate interannual variability

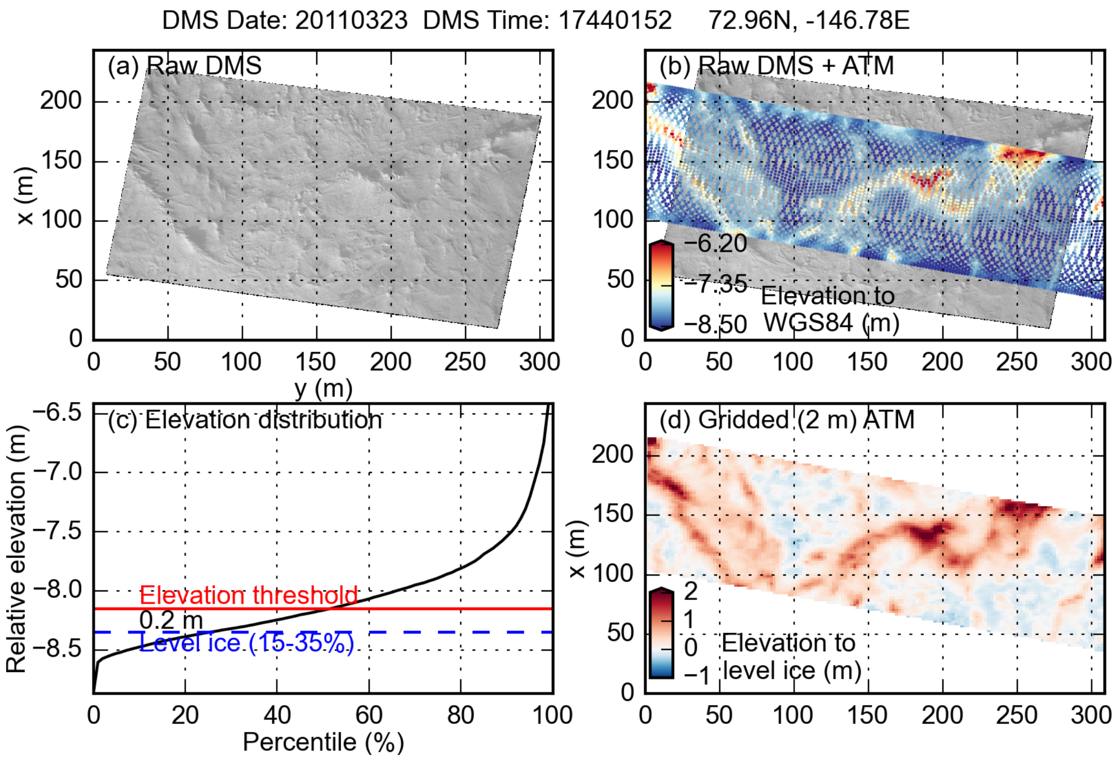


Sea ice surface profiling



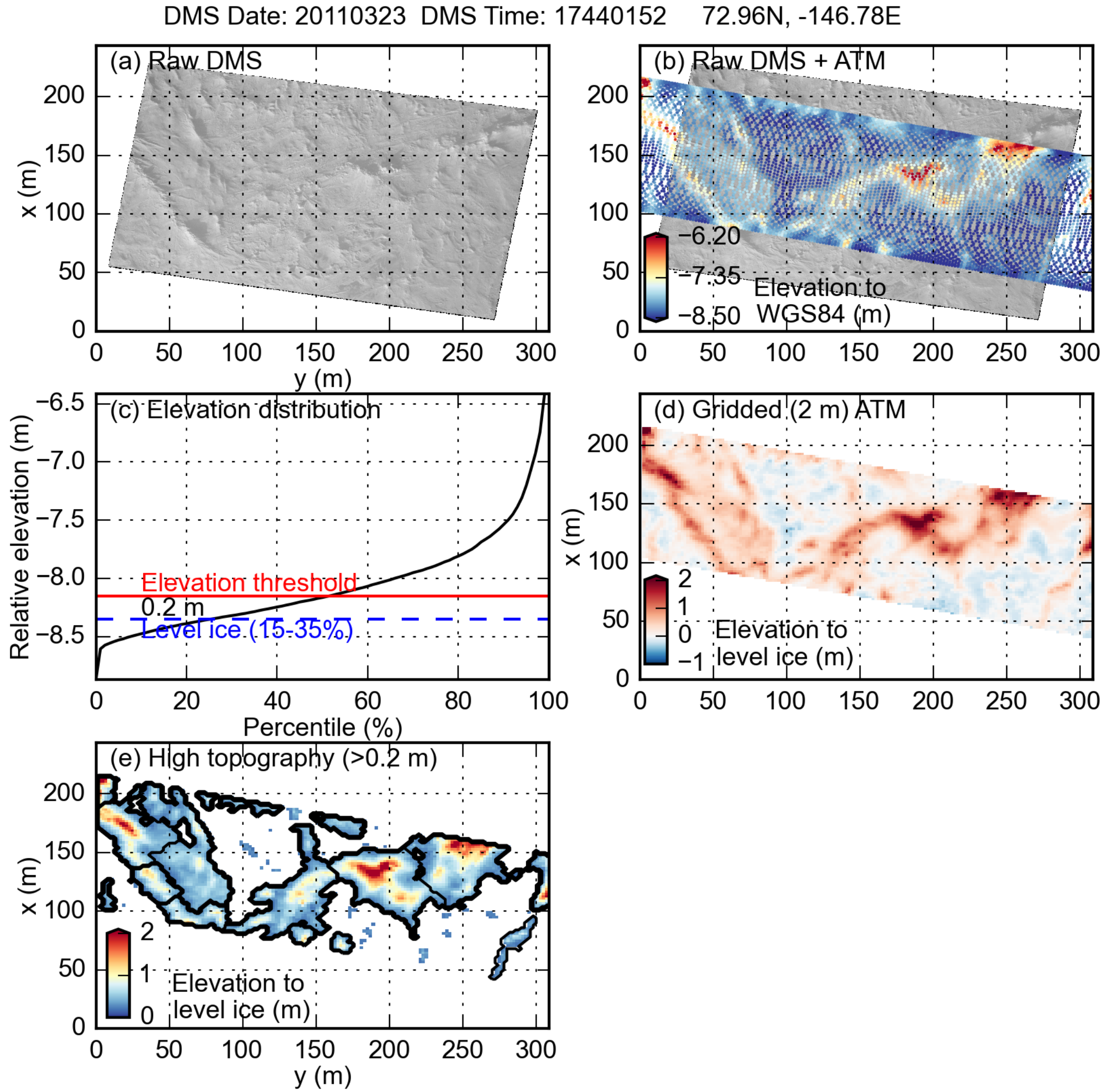
1. Find the lowest surface elevation gradient (modal elevation bin).

Sea ice surface profiling



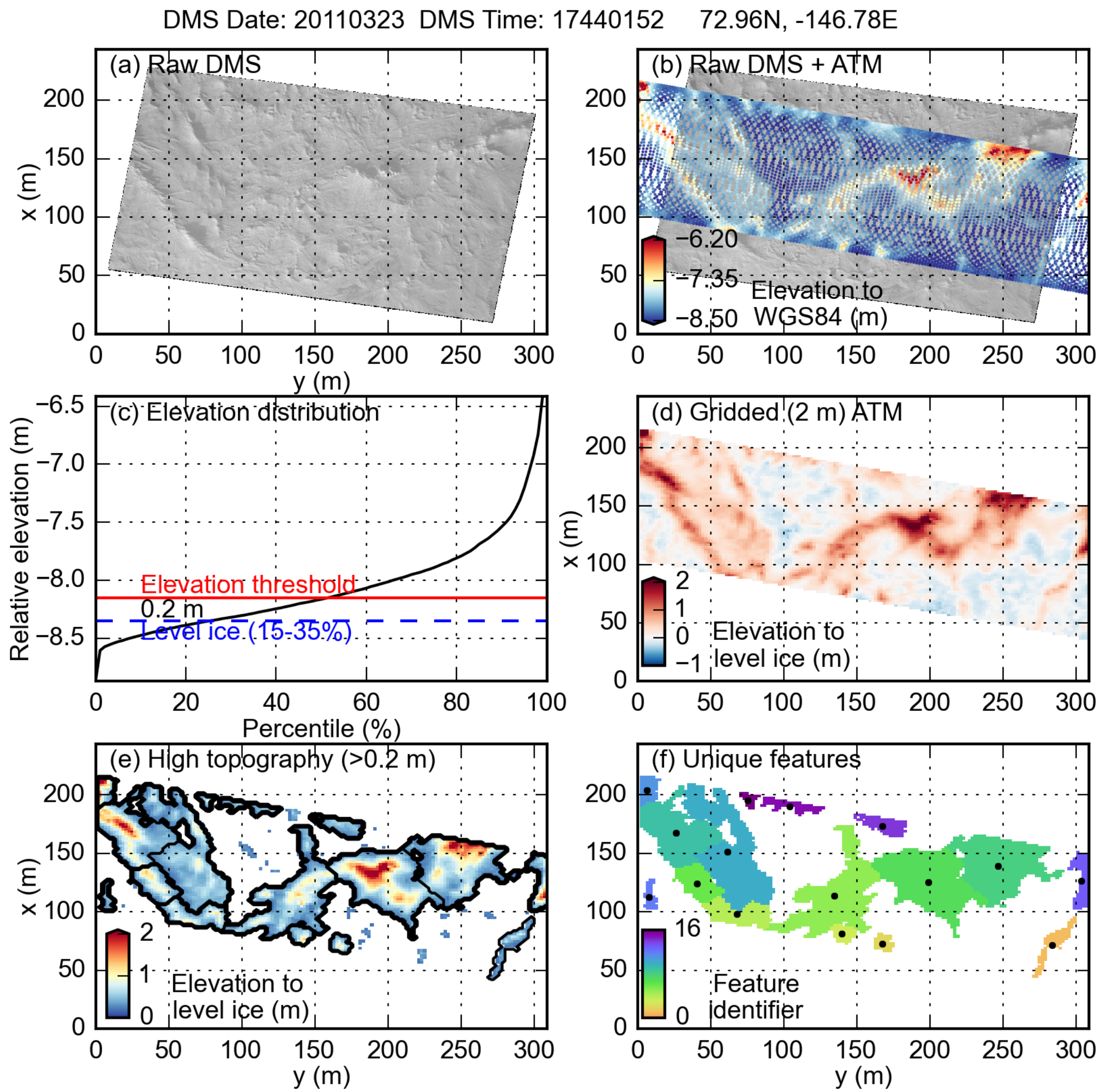
1. Find the lowest surface elevation gradient (modal elevation bin).
2. Grid the data using a simple linear interpolation scheme.

Sea ice surface profiling



1. Find the lowest surface elevation gradient (modal elevation bin).
2. Grid the data using a simple linear interpolation scheme.
3. Keep data above a given elevation threshold (e.g. 20 cm).
4. Find local maxima and apply watershed filter to separate `unique' features.

Sea ice surface profiling



1. Find the lowest surface elevation gradient (modal elevation bin).
2. Grid the data using a simple linear interpolation scheme.
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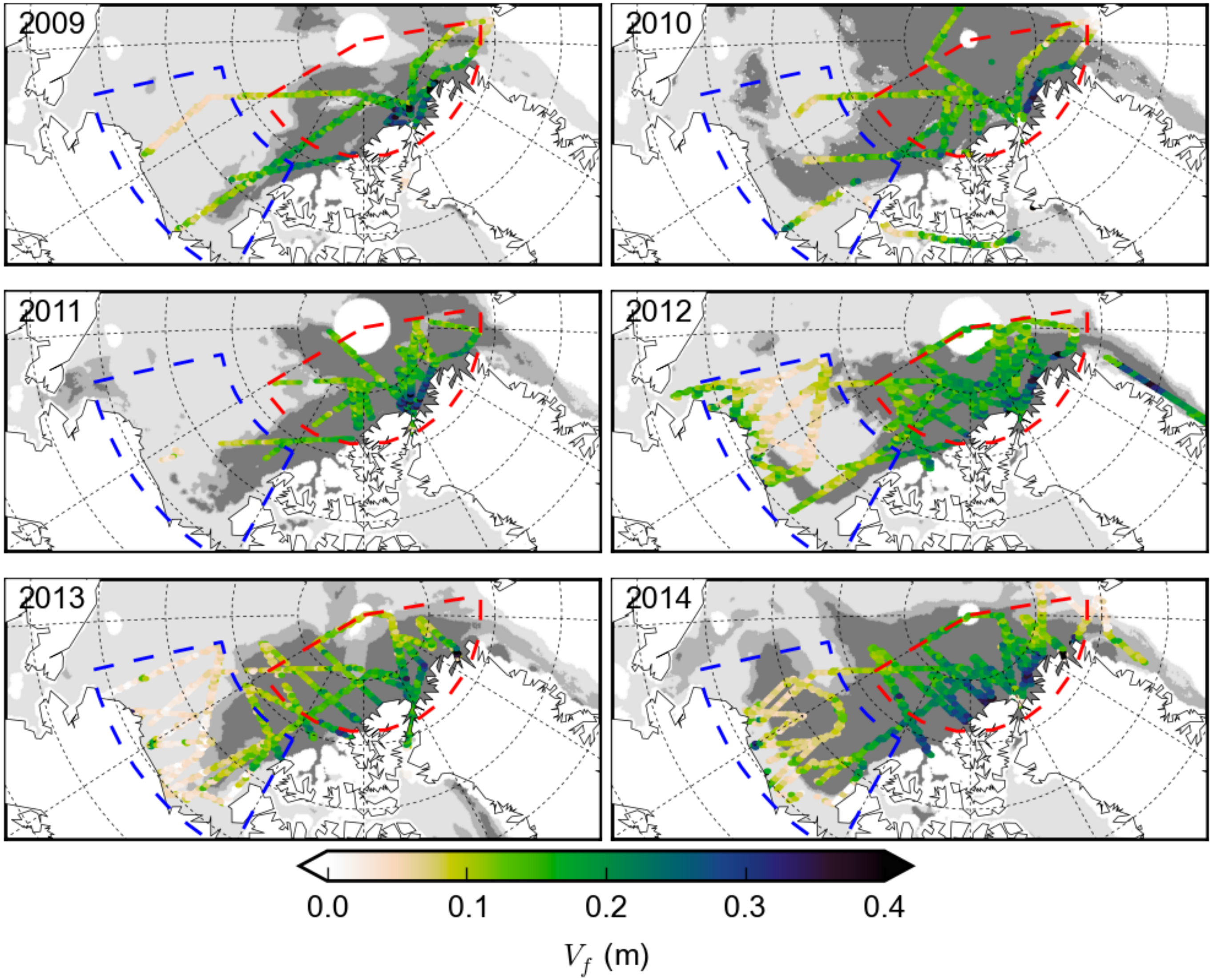
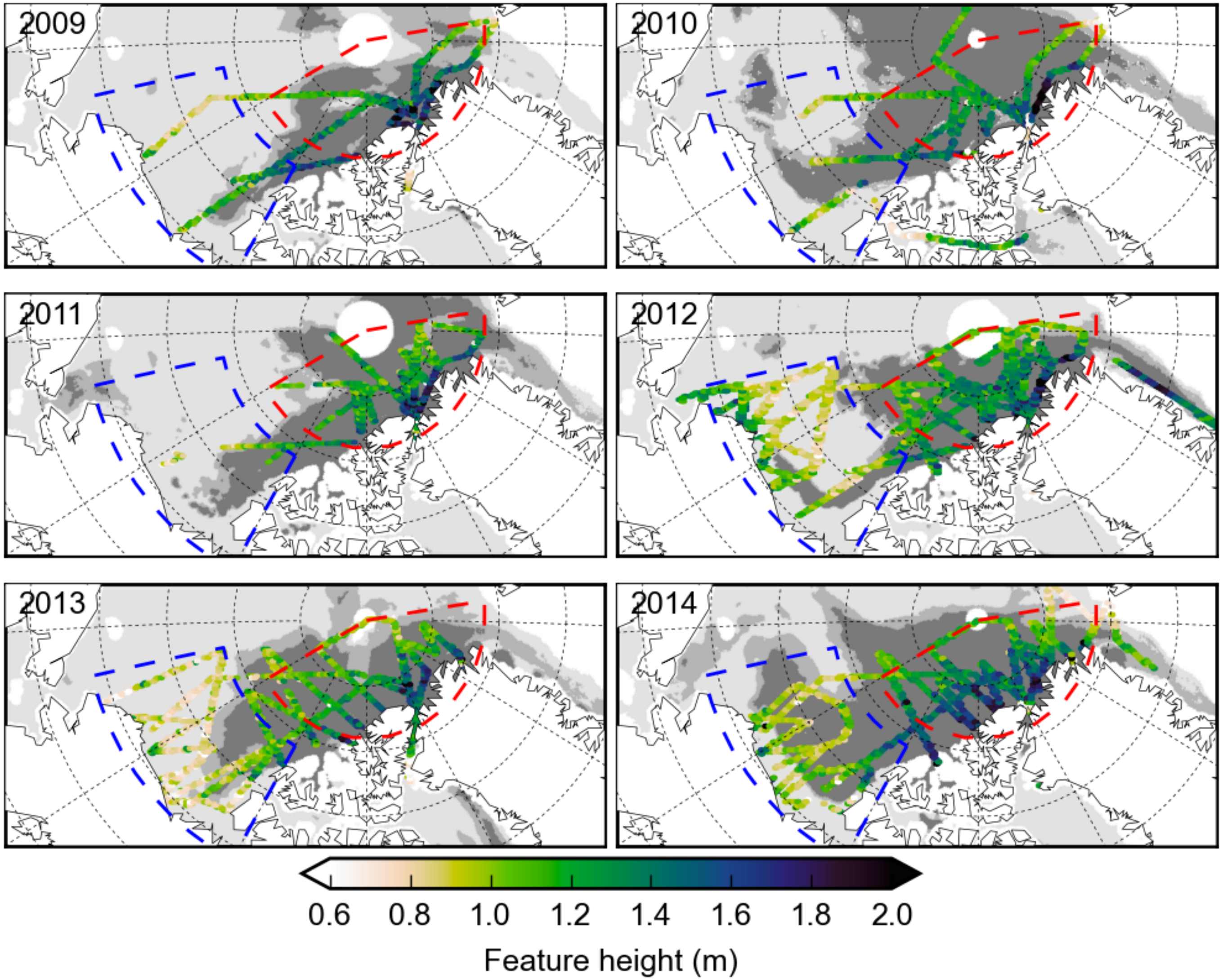
4. Find local maxima and apply watershed filter to separate `unique' features.
5. **Output individual statistics (e.g. height/ orientation) and bulk statistics (mean height/ volume).**

Results: Surface feature volume (per unit area)



Dark grey =MY, light grey=FY, from OSI-SAF ice type product

Results: Surface feature height



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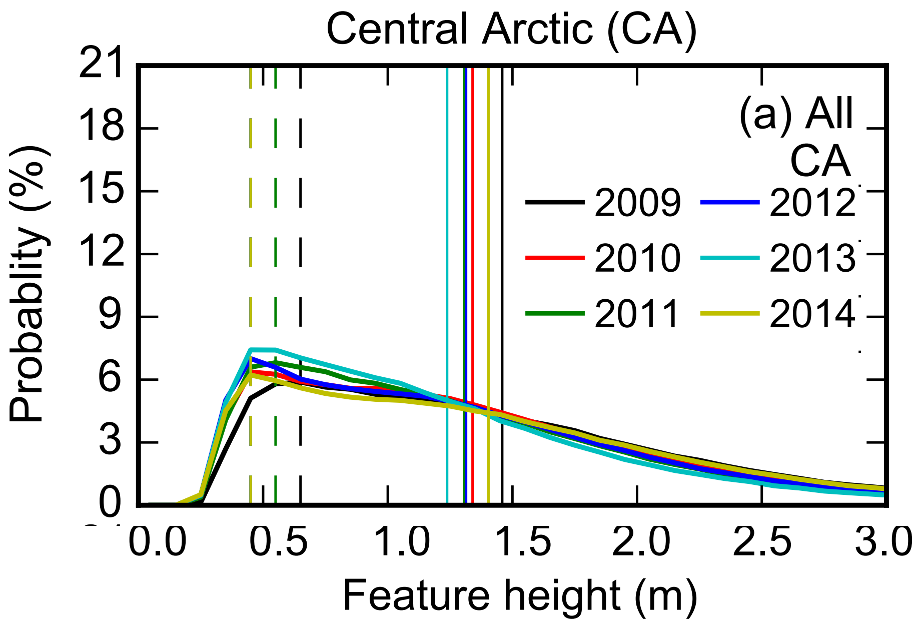
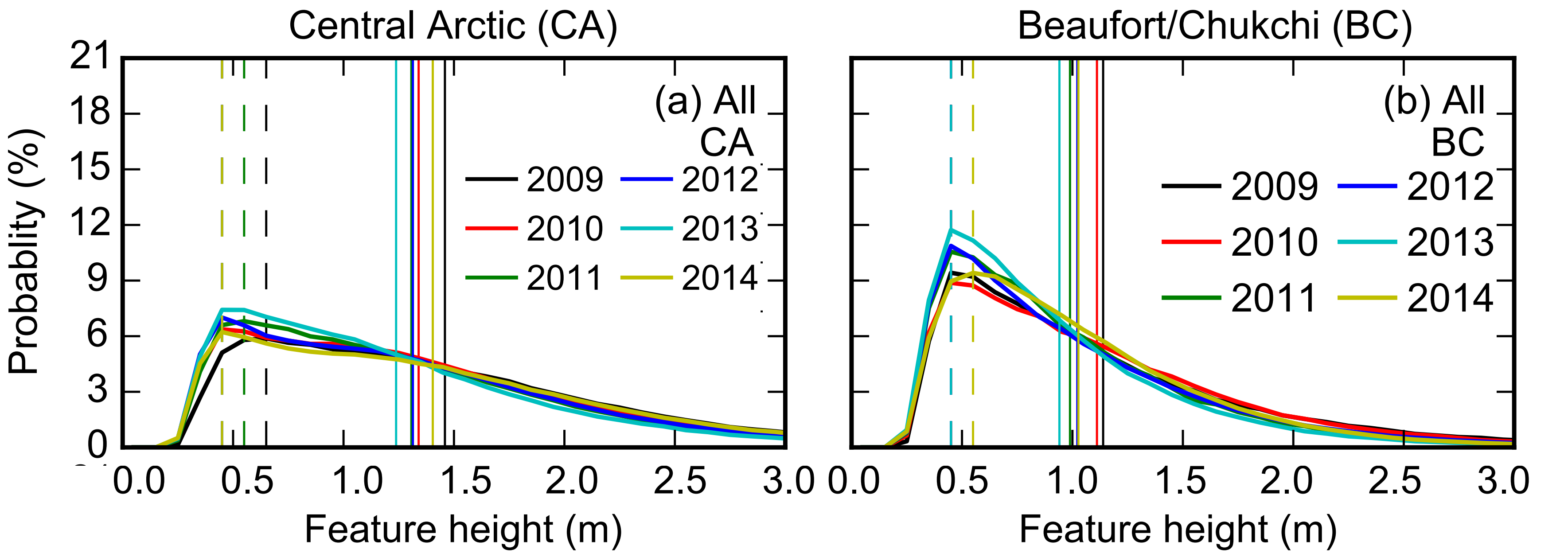
Feature height distributions



	Year	Mean (m)	Mode (m)
ALL	2009	1.46 (0.87)	0.65
	2010	1.34 (0.78)	0.45
	2011	1.31 (0.78)	0.55
	2012	1.31 (0.79)	0.45
	2013	1.24 (0.76)	0.45
	2014	1.40 (0.85)	0.45
	All	1.34 (0.81)	0.45

- Decrease in feature height from 2009 to 2013.
- Increase from 2013 to 2014.
- Results in-line with increased ice covergence through summer 2013, estimated in *Kwok, 2015, GRL.*

Feature height distributions



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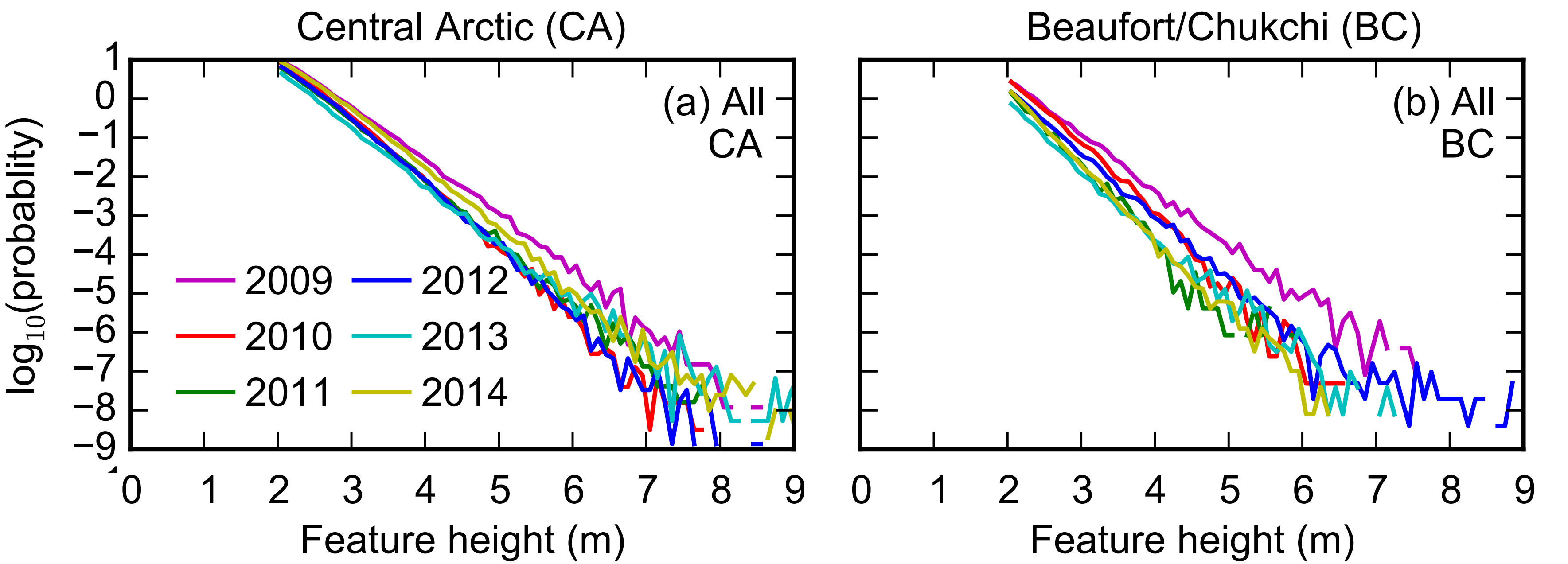
	Year	Mean (m)	Mode (m)
ALL	2009	1.14 (0.74)	0.45
	2010	1.11 (0.67)	0.45
	2011	0.99 (0.58)	0.45
	2012	1.02 (0.64)	0.45
	2013	0.94 (0.57)	0.45
	2014	1.03 (0.58)	0.55
	All	1.02 (0.63)	0.45

Feature height distributions (tails)

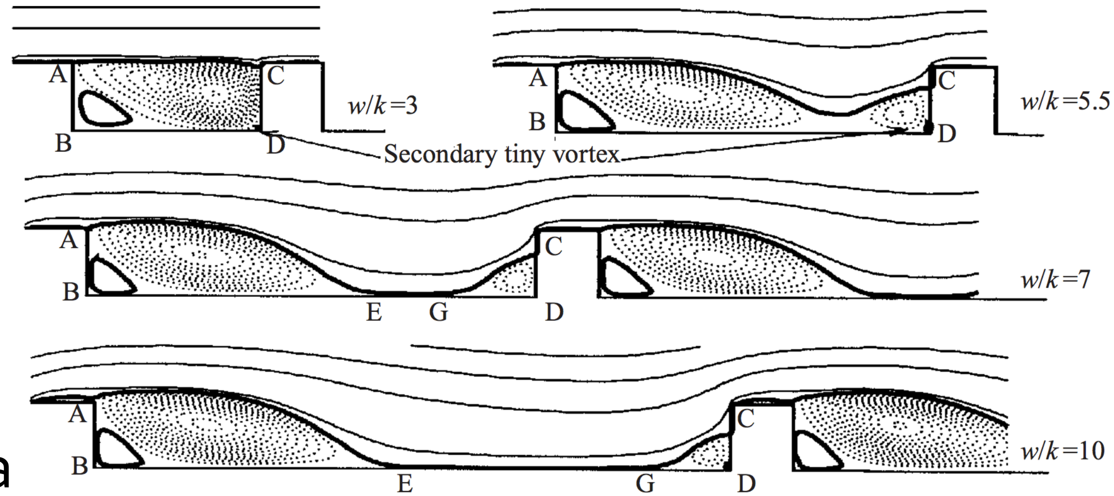


- Plot on a log-linear scale to highlight extremes of the probability distribution.
- Feature heights follow a simple exponential distribution.
- Clear interannual variability in feature height extremes (2009 has more significant tail), although beware sampling issues.

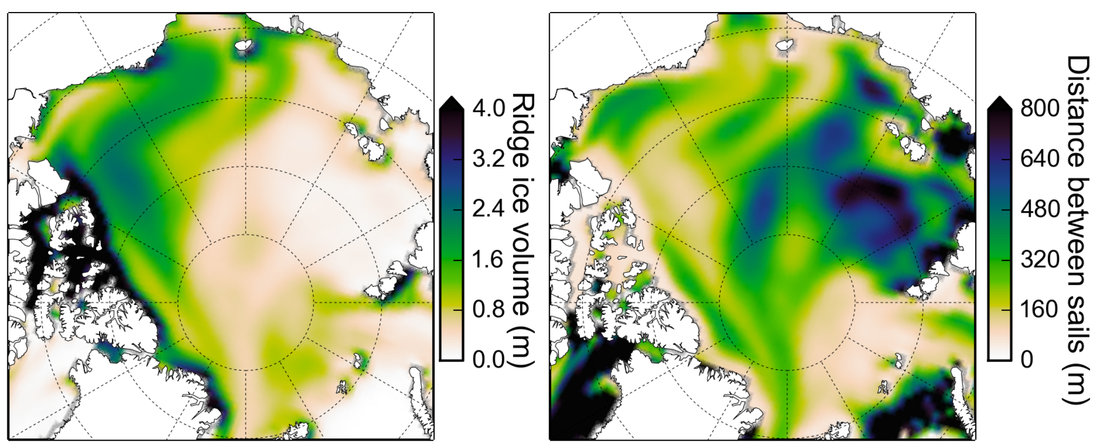
Exciting future work…

e.g. Atmospheric form drag over sea ice

- Form drag can be calculated explicitly using existing parameterizations.
- Drag recently incorporated into a sea ice climate model component (CICE).
- Model is still poorly constrained, due to a previous lack of observational data.



(Form drag parameterizations, taken from Leonardi et al., 2013)



(Example (March 2012) modeled ridging behavior in the new CICE drag parameterization)

Summary

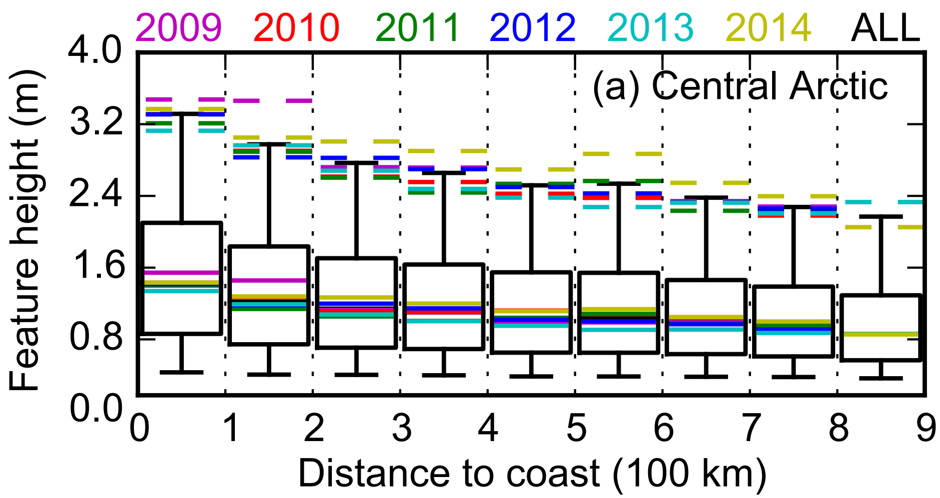
- A novel surface feature picking algorithm has been developed, suitable for 3D ATM data.
- Obtained detailed information regarding the regional and temporal variability in surface features.
- Exciting prospects for future applications, including form drag, fast ice and melt pond formation.

Questions?

Fast ice/melt ponds

Coastal sea ice deformation and fast ice regimes

- 100 km coastal proximity bins
- Individual flight line analysis needed for more detailed insight



Melt ponds and ice topography

- e.g. Flatter ice promotes shallow but extensive melt ponds to form.