Characterizing sea ice surface morphology using high-resolution IceBridge data

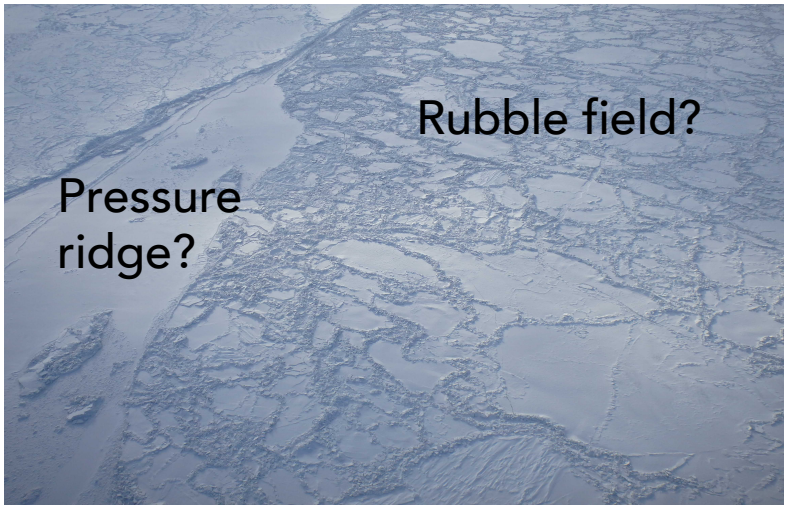
or

'What does the sea ice surface look like?'

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

The sea ice surface

(Sea ice in the Beaufort Sea)

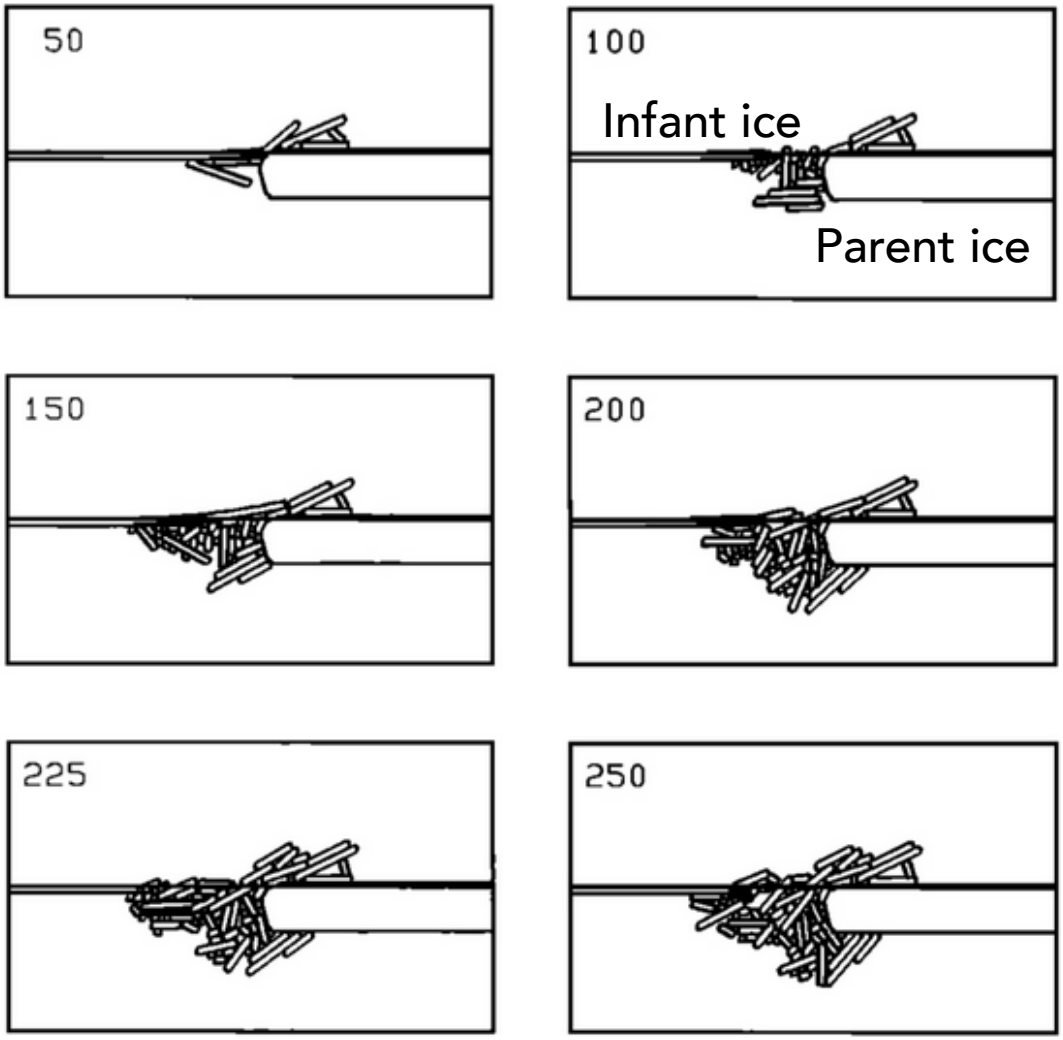


(Sea ice north of Alaska, from Tom Newman)

- *Various ice types all with unique surface profiles.*
- *Mainly interested in pressure ridge variability. But sastrugi, hummocks also likely to feature. A potential complication..*

(Barrow, AK ice shove event (www.gi.alaska.edu/snowice/sea-lake-ice/images/ice_events.html))

Sea ice pressure ridging



Sail (upper surface ridge extension)

Keel (lower surface ridge extension)

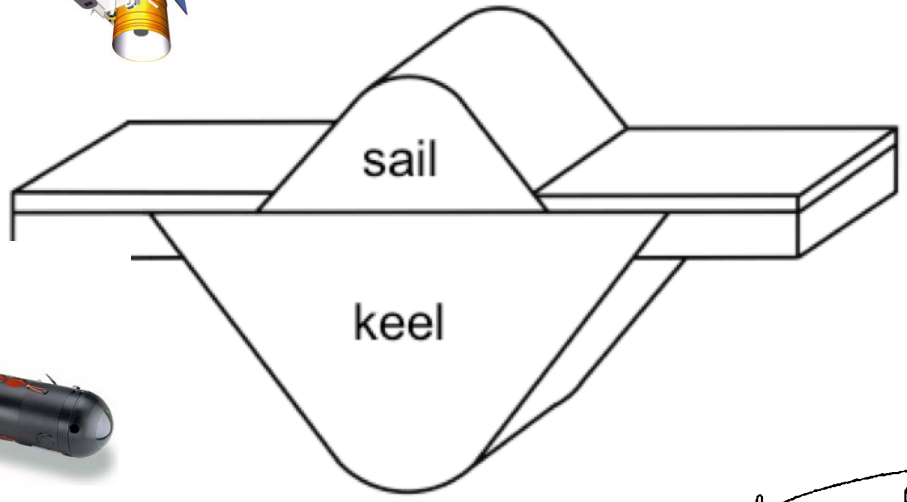
Eventually, these jagged features weather..

Numerical ridging simulation from Hopkins (1998)

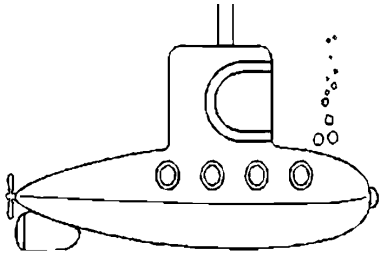
Previous ice morphology observations?

Satellites (radar backscatter)
e.g. ASCAT/ QuikSCAT/ CryoSat-2?

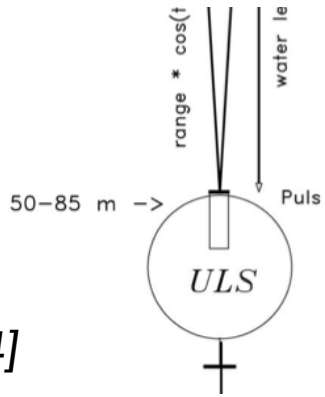
Helicopters
e.g. Haas et al., [2004]



AUVs
[e.g. Wadhams et al., 2004]



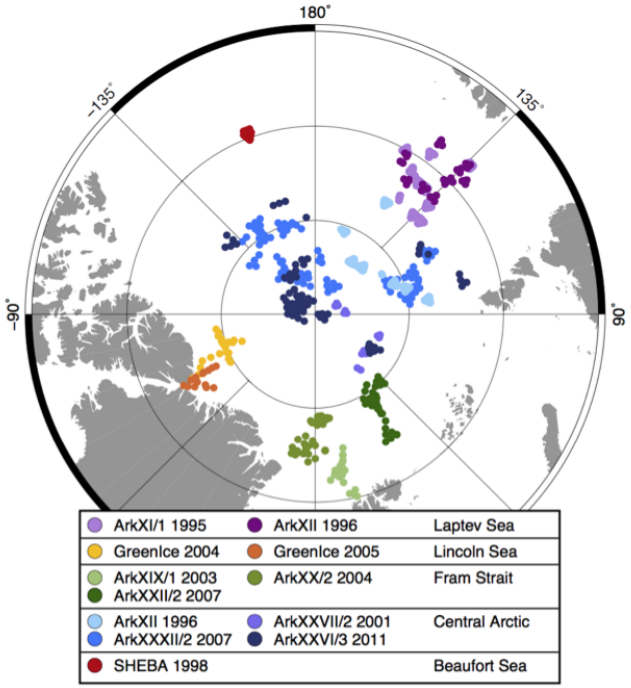
Submarines
[e.g. Wadhams & Davy, 1986]



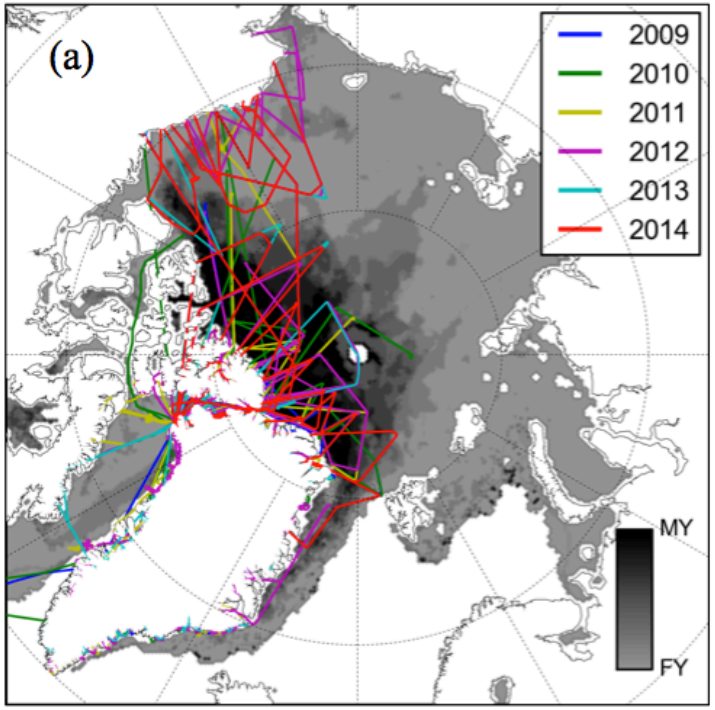
Upward looking sonar moorings
[e.g. Krishfield et al., 2014]

Previous airborne (helicopter) laser altimeter observations

From Castellani et al., (2014, JGR)



IceBridge sea ice coverage



IceBridge pros

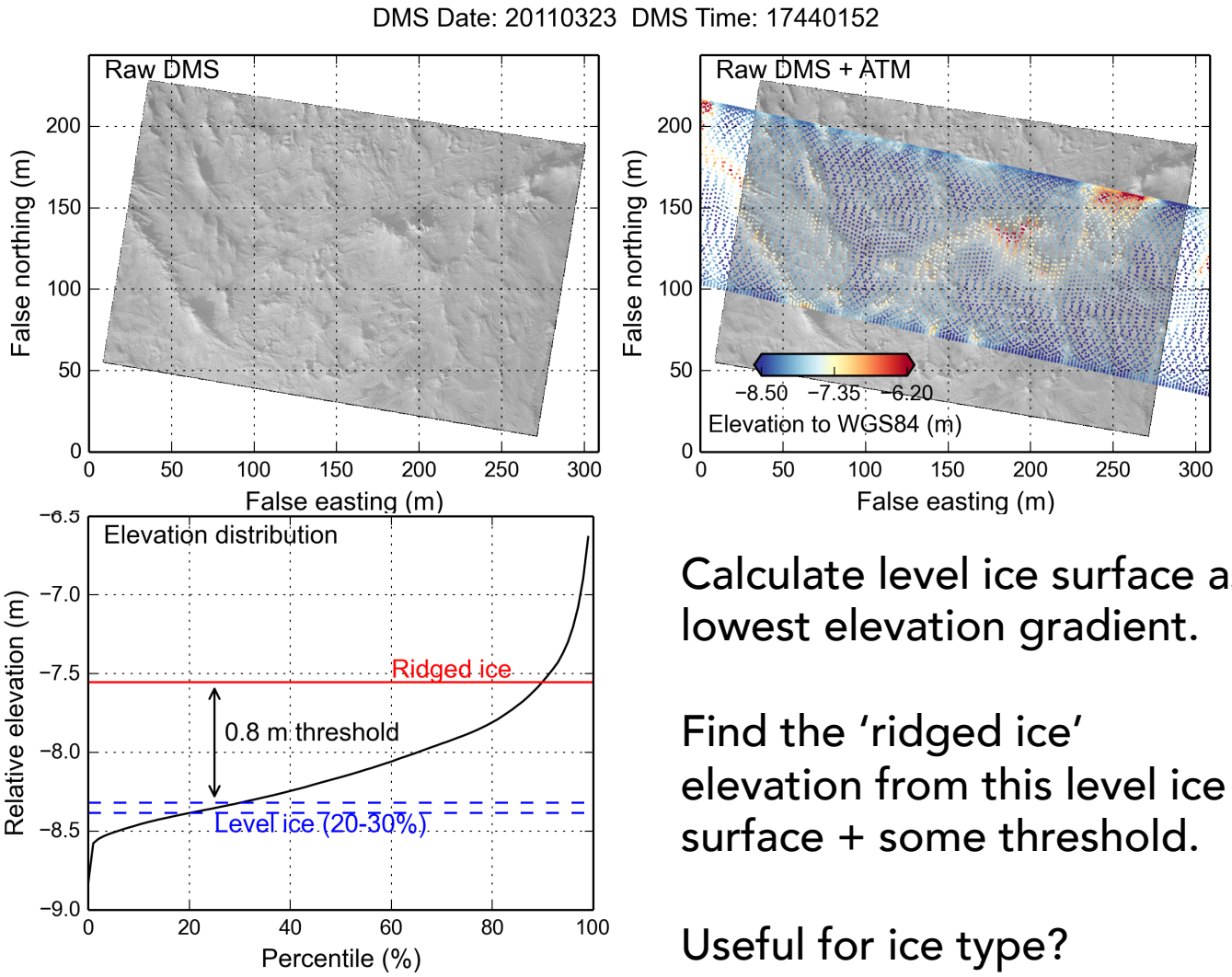
- *Profiling of various ice types over the SAME (monthly) time period.*
- *Lots of data in the Beaufort Sea, a region of rapid sea ice decline.*
- *Two-dimensional profiling!*

IceBridge cons

- *Nothing in the eastern Arctic. Can extrapolate from similar ice types though?*

Sea ice surface profiling with IceBridge data

- *A case studv*



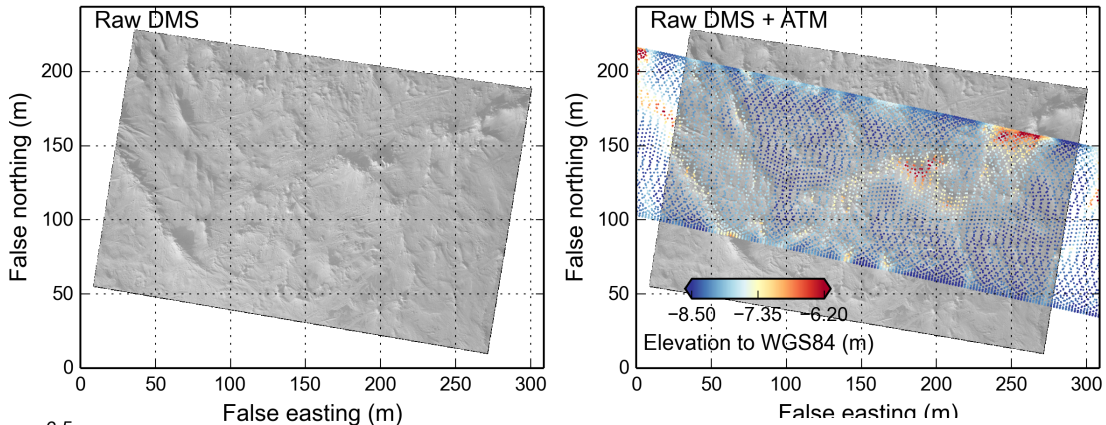
Calculate level ice surface as lowest elevation gradient.

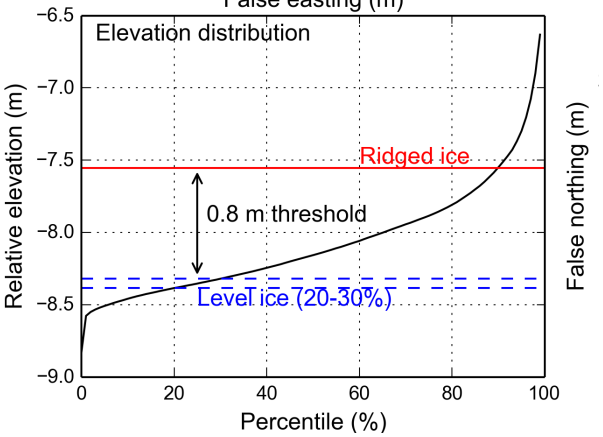
Find the 'ridged ice' elevation from this level ice surface + some threshold.

Useful for ice type?

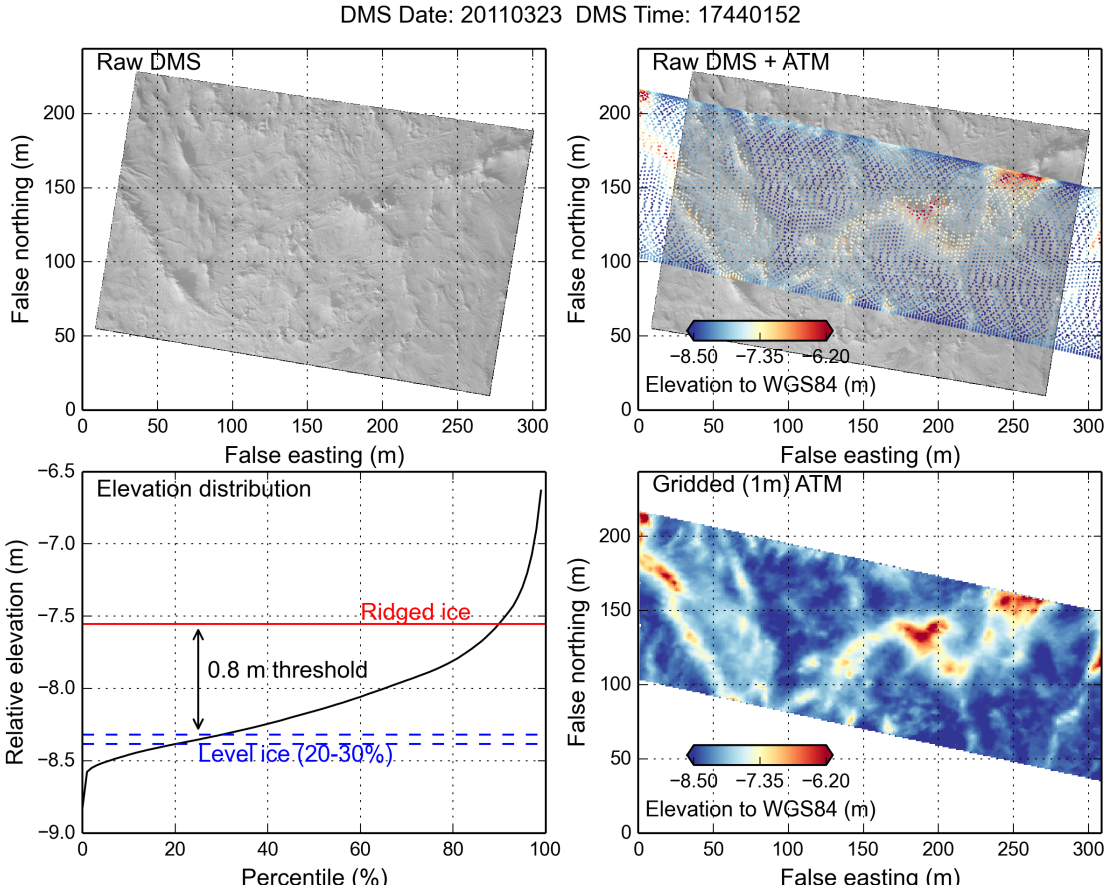
NB 0.8 m threshold used by Dierking [1995], Martin [2007] and Castellani [2014]

DMS Date: 20110323 DMS Time: 17440152





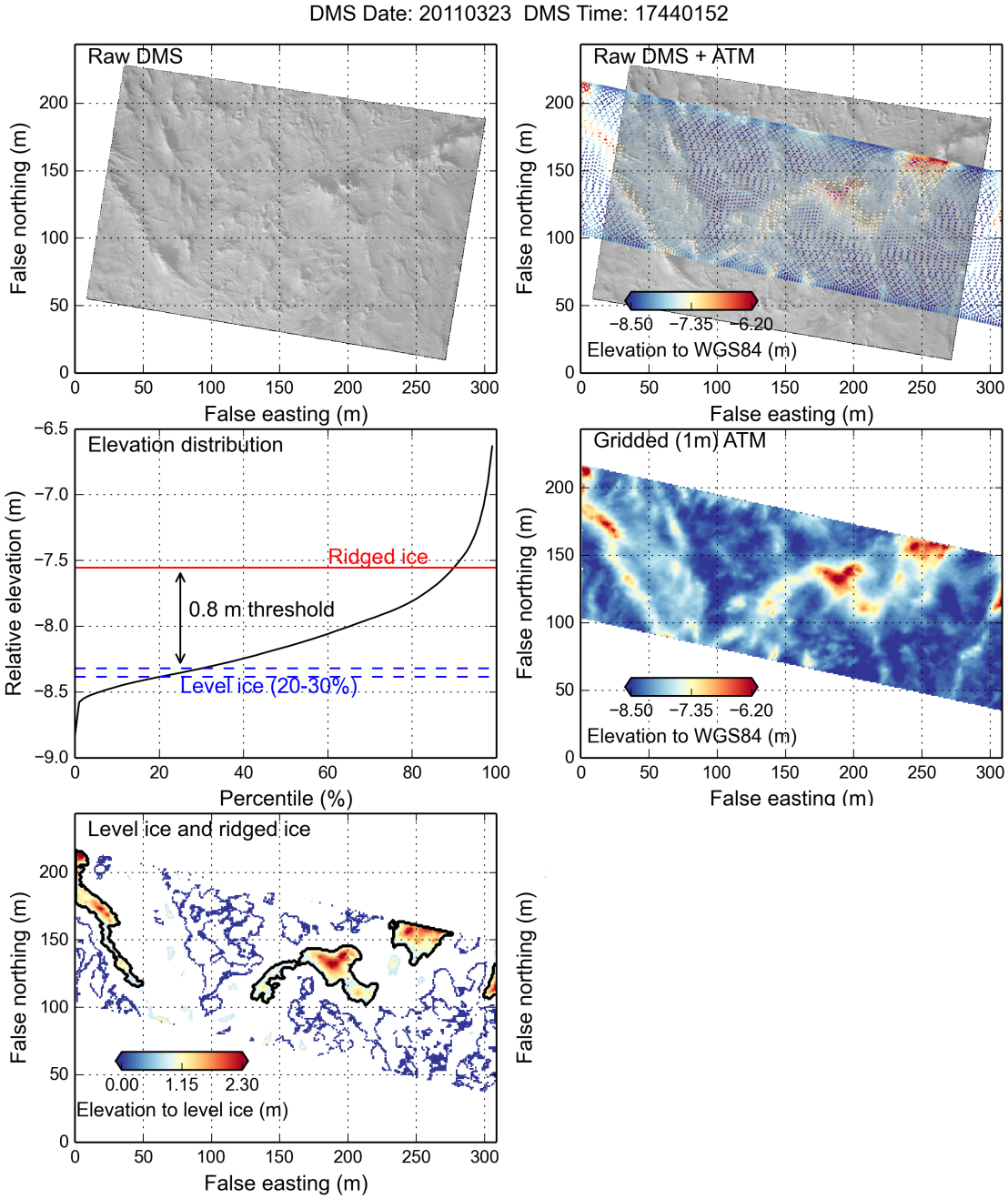
False northing (m)



1. Grid the data using a simple linear interpolation scheme.

b. Data is gridded onto the IceBridge polar stereo projection at 1 m resolution.

c. NB quite heavy interpolation n the middle of the swath!

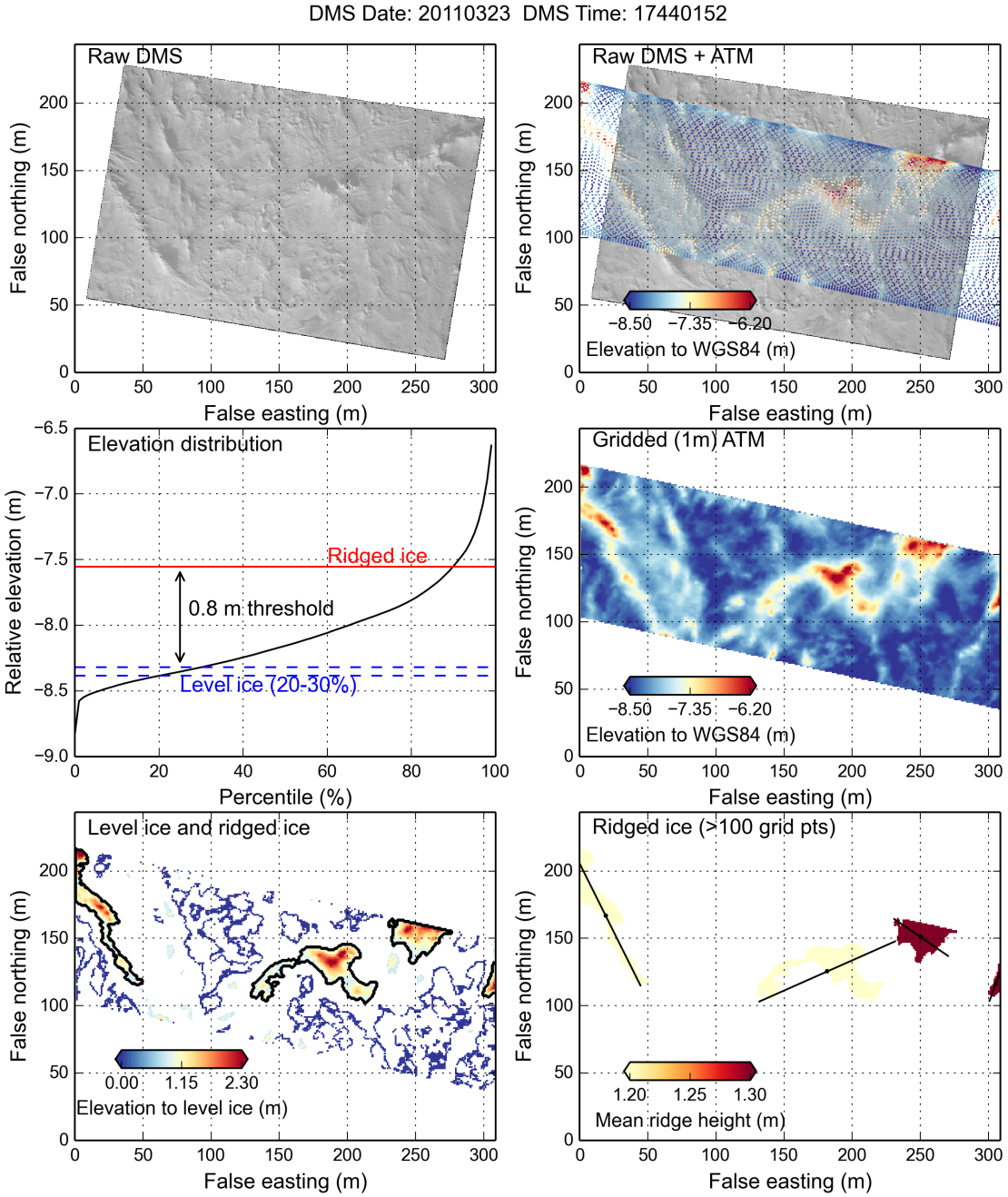


1. Grid the data using a simple linear interpolation scheme.

b. Data is projected onto the standard IceBridge projection at a 1 m resolution.

c. NB quite heavy interpolation n the middle of the swath!

2. Keep data above threshold and label unique ridges using a connected component algorithm.



1. Grid the data using a simple linear interpolation scheme.

b. Data is projected onto the standard IceBridge projection at a 1 m resolution.

c. NB quite heavy interpolation n the middle of the swath!

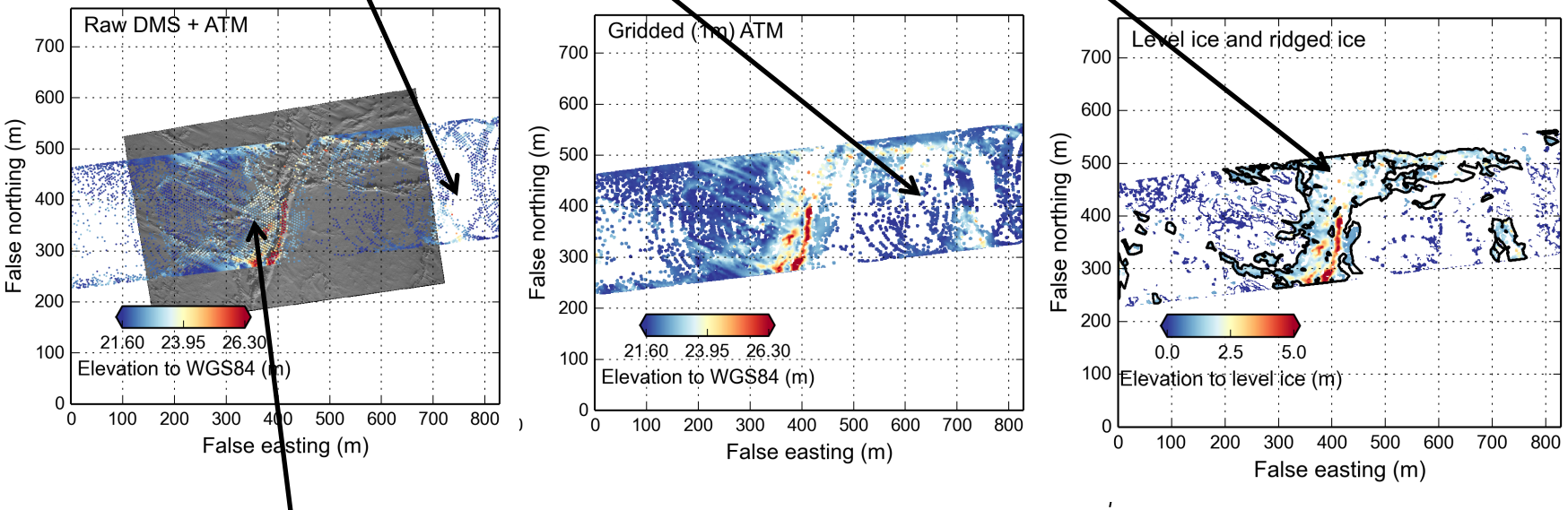
2. Keep data above threshold and label unique ridges using a connected component algorithm.

3. Get statistics (e.g. mean/ max height) of each ridge. Also calculate orientation (the vectors)

A couple of potential issues

ATM dropout.

- Limits the effective gridding and can over estimate ‘ridged ice’ area.



Snow build up next to ridges

- Snow piles up next to ridges increasing the area covered by this higher surface elevation

Processing all IceBridge ATM (sea ice) data

- Extract ATM data in 20,000 point sections (~*1 km* along track).
- Apply detection algorithm as detailed in the previous slides for each section.
- Output ridge statistics for each ATM file.

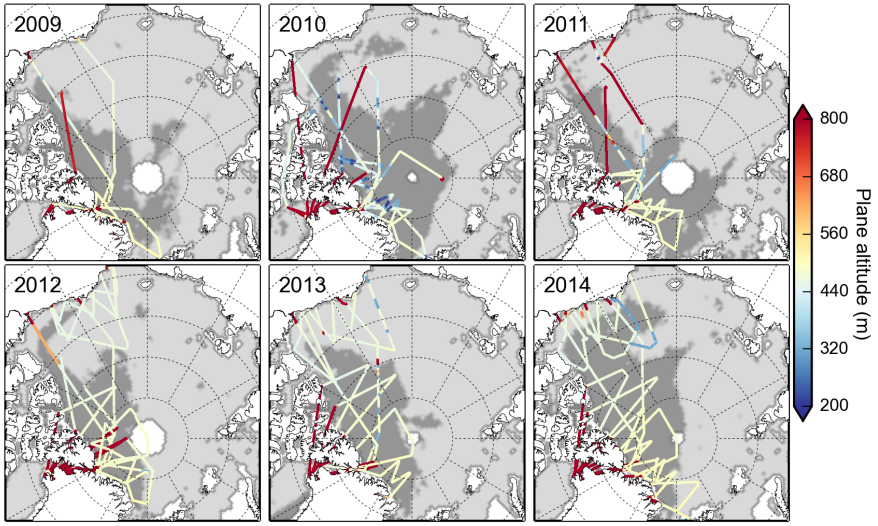
Quality control

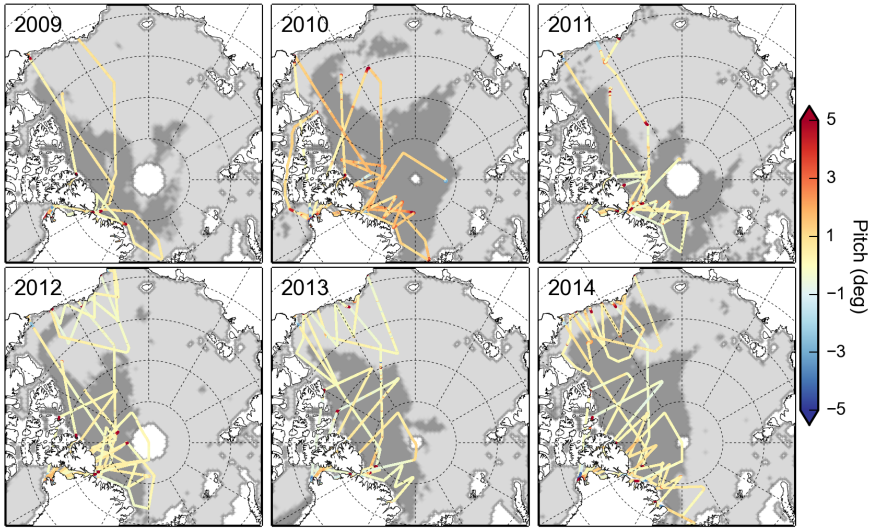
Mask the ATM data where:

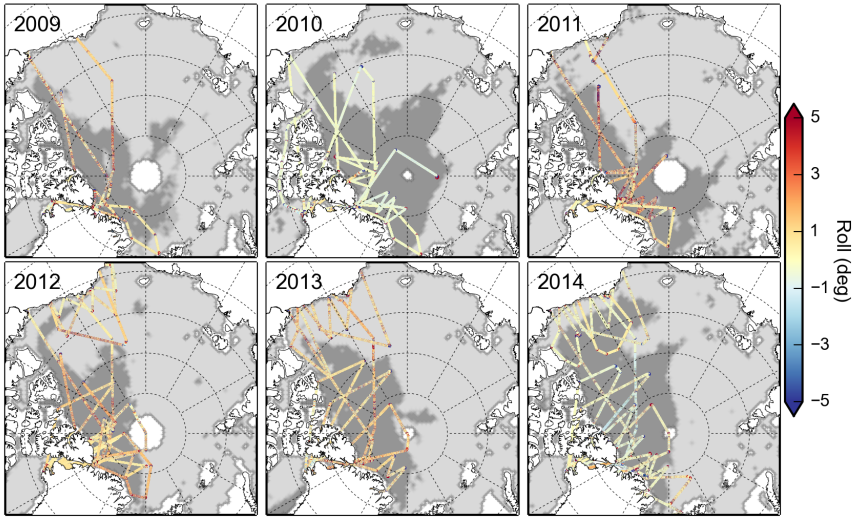
- The pitch/roll is less than 5 degrees (obtained from the ATM data).

Process data where:

- The mean concurrent ATM spot spacing (within the 1 km section) is less than 8 m (which is perhaps too high?).
- The altitude is between 300-700 m (from the PosAV data)


2009
2010
2011
2012
2013
2014
800
680
560
440
320
200
Plane altitude (m)


2009
2010
2011
2012
2013
2014
5
3
1
−1
−3
−5
Pitch (deg)

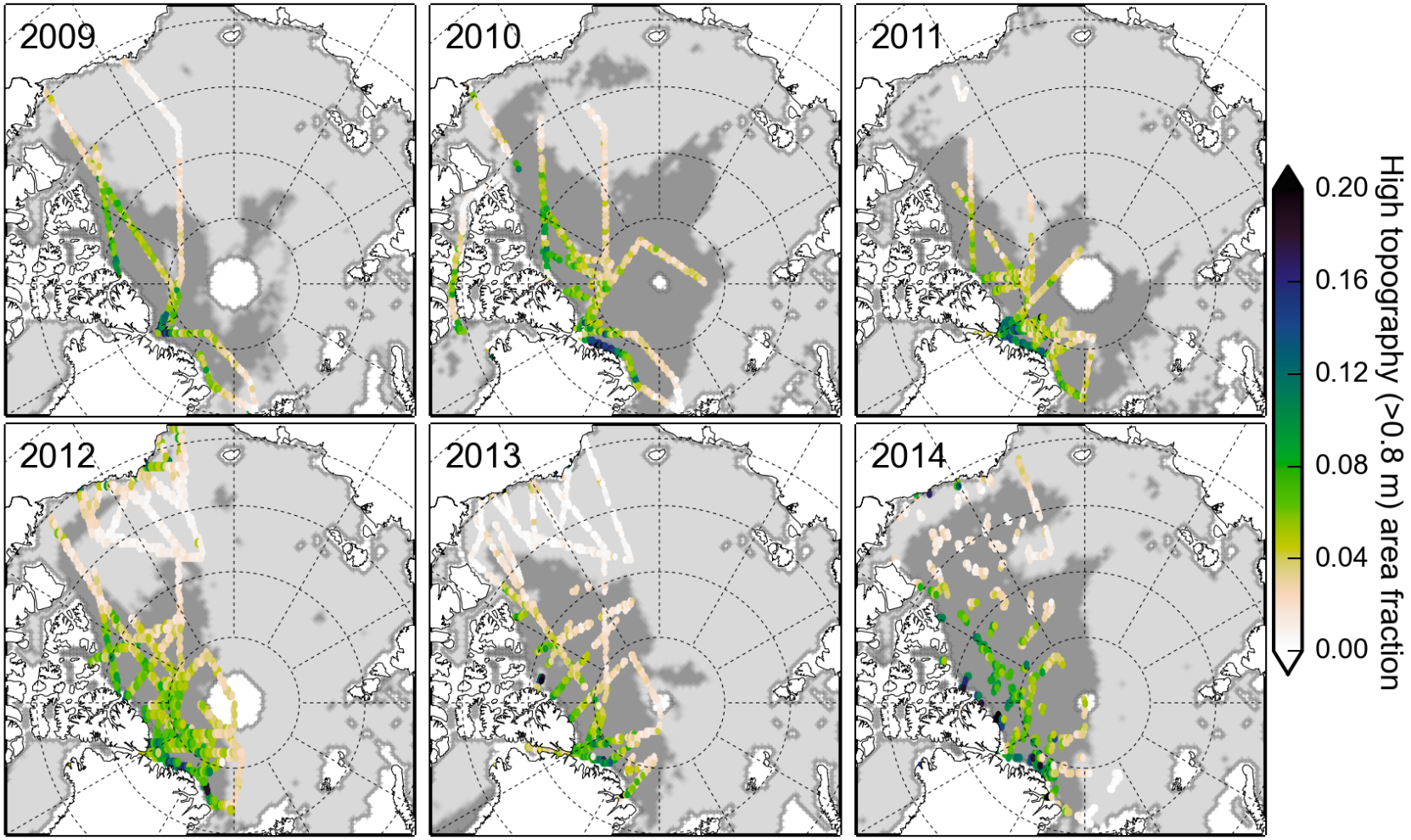

2009
2010
2011
2012
2013
2014
5
3
1
−1
−3
−5
Roll (deg)

Surface morphology statistics across all IceBridge sea ice flights

Extract bulk surface information

- *Sail (high topography) area, volume, mean height*

High surface topography fraction



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

Preliminary!

Surface morphology statistics

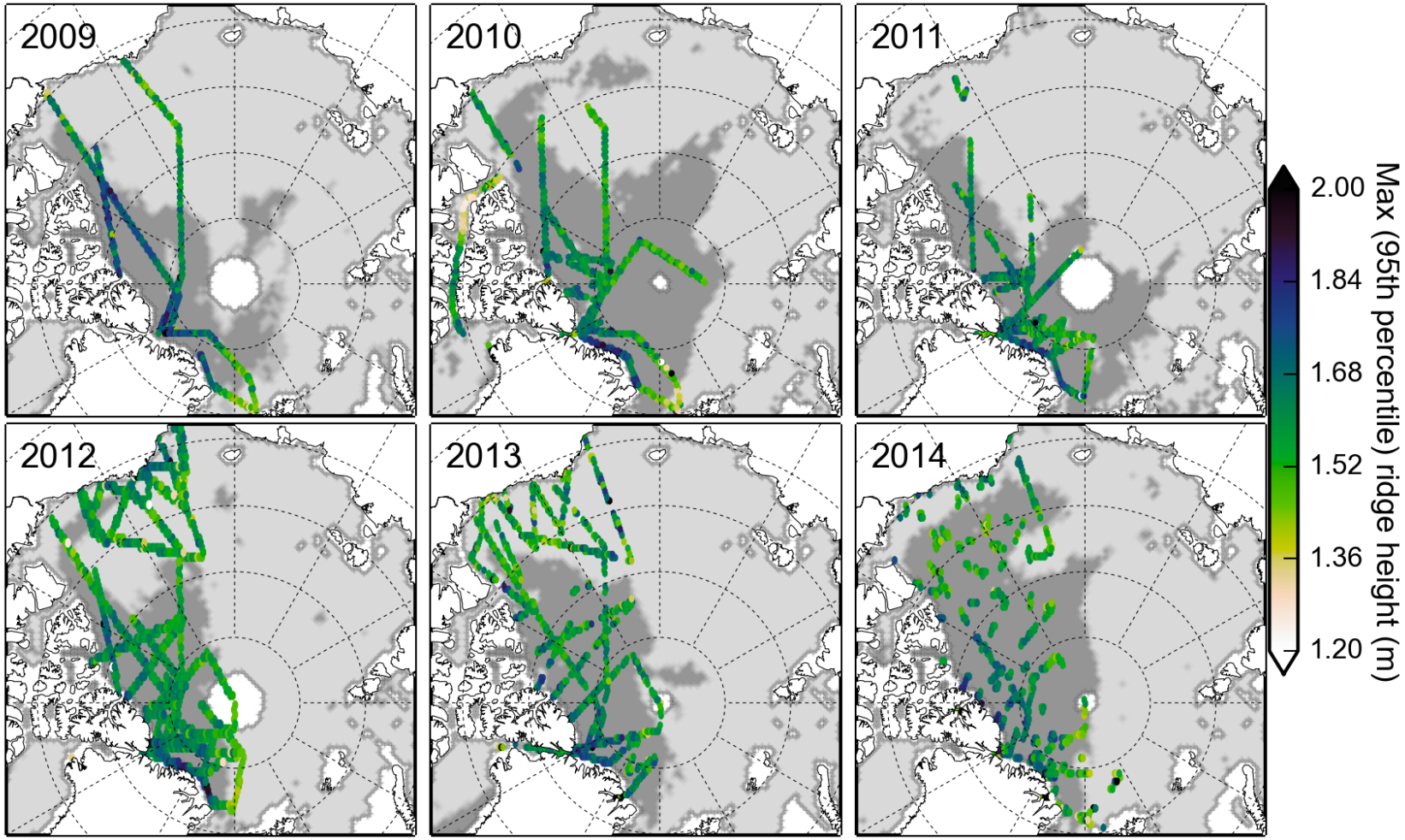
Bulk surface information

- *Sail (high topography) area, volume, height, area density*

Individual surface topography information

- *Mean sail (high topography) height, max sail height, sail orientation, spacing?*

Maximum sail (high topography) height



Preliminary!

Future work..

1. Algorithm testing!

2. Narrow swath data

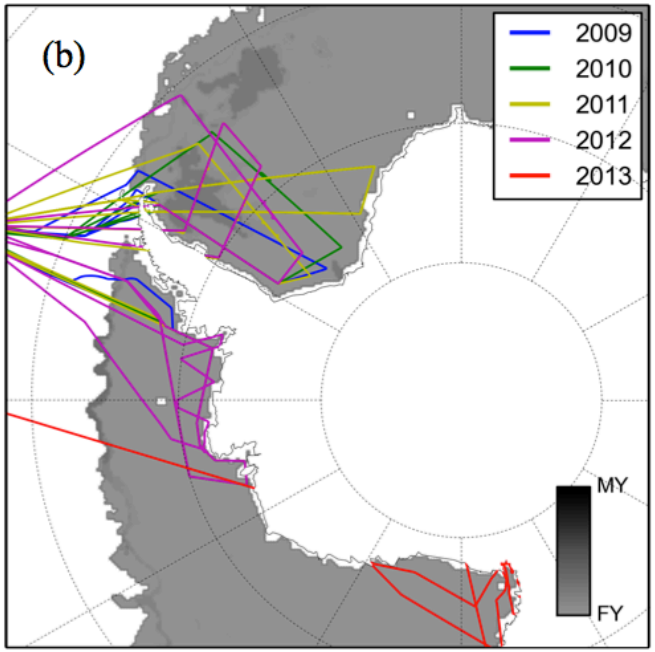
Potential Improvements:

- Improved spatial sampling, especially in the middle of the swath (1-2 m instead of up to 8 m).
- Will limit necessary interpolation between data points.

However:

- Reduces the spatial coverage
- Only have data from 2011 onwards

3. Antarctic sea ice too?! Why not...



Who might care about this?

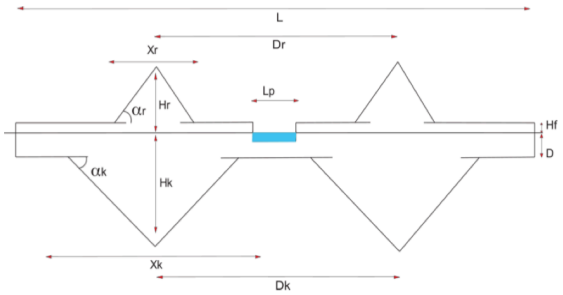
Sea ice observers

- *What is the surface being detected by the various remote sensing techniques?*

- *How much ice might be being missed?*

Sea ice modelers

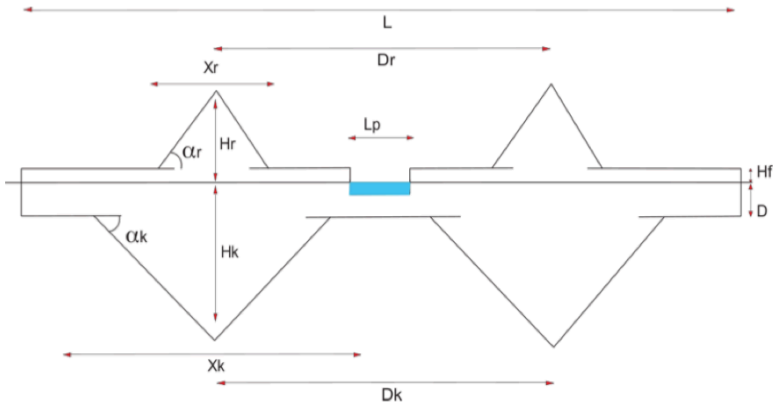
- *Observations can help constrain certain parameter choices included in new ridging/drag schemes.*
- *Michel to speak about this next!*

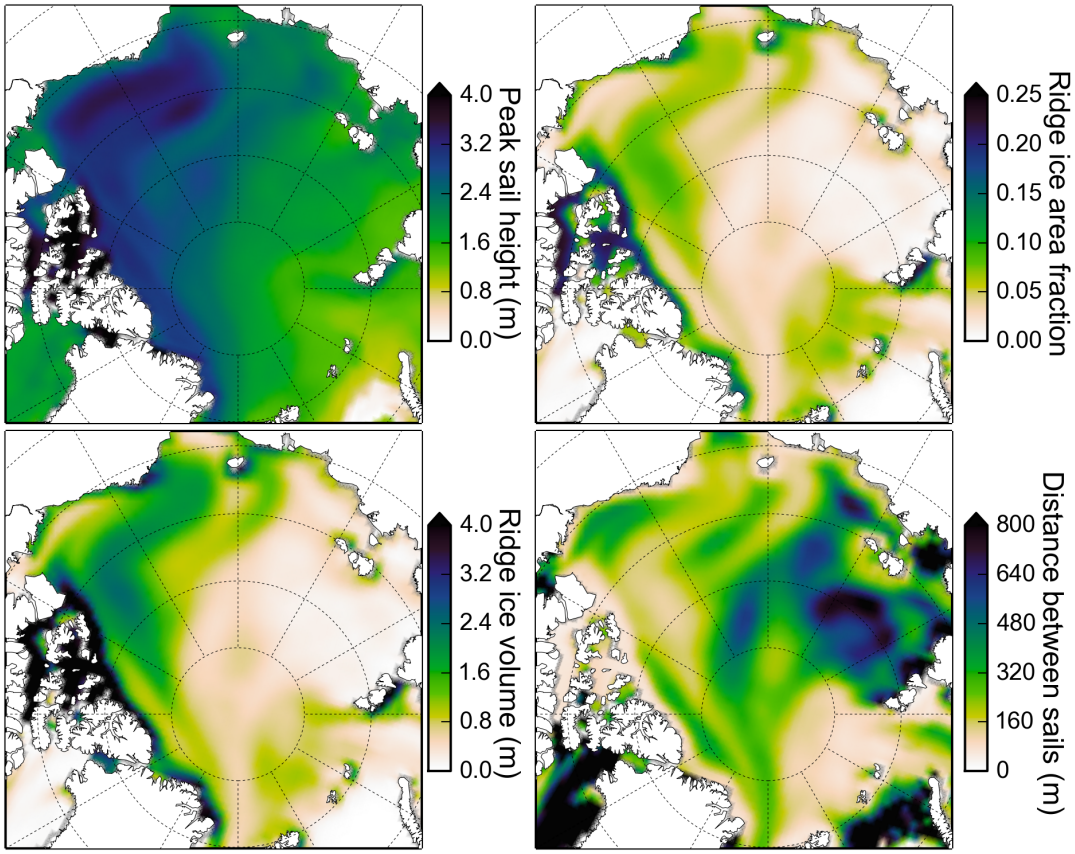


All polar scientists/ stakeholders…

- *Indicative of sea ice strength/ thickness*
- *Impacts the atmospheric and oceanic drag and thus the momentum, heat, freshwater, salt fluxes.*

Validating new drag parameterizations in the CICE sea ice model





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