EXPLOITING DIGITAL IMAGERY FOR SNOW SURFACE RETRIEVAL ON SEA ICE

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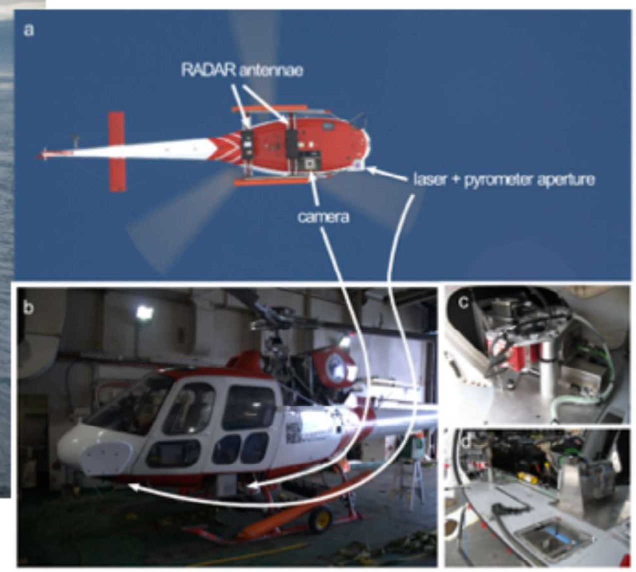
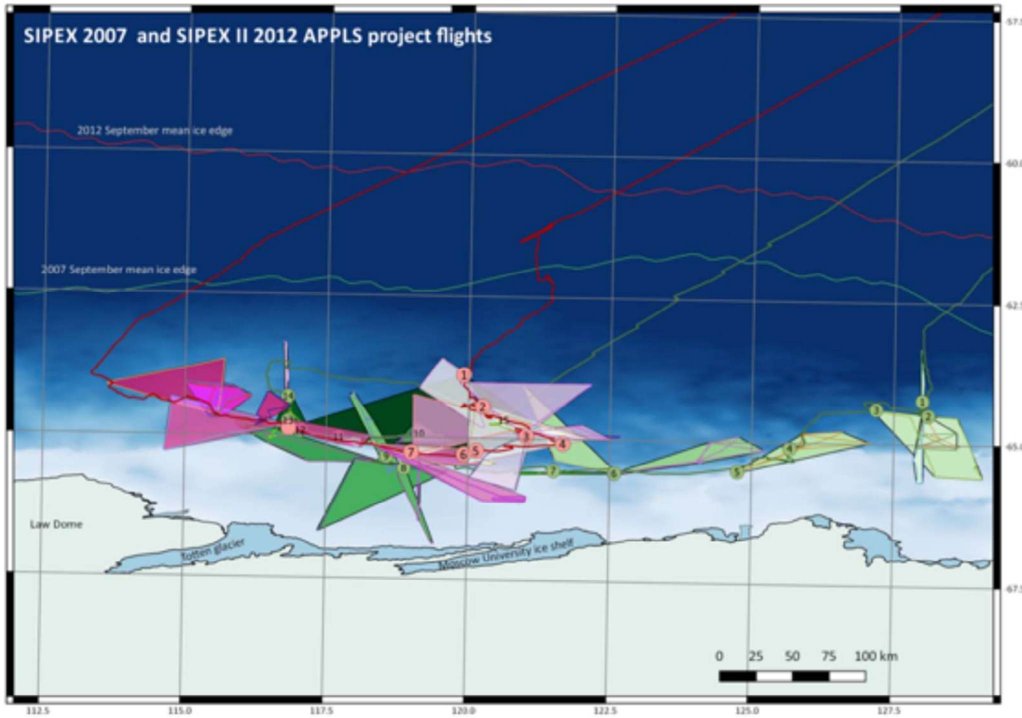
What, where, when



1

This talk goes all the way back to a project executed between 2007 and 2012, where the Australian Antarctic Division deployed an airbore LiDAR and camera in a modified helicopter (aka close range piloted drone). It was called the RAPPLS package – see: http://seaice.acecrc.org.au/crrs/rappls-technical-details/

What, where, when



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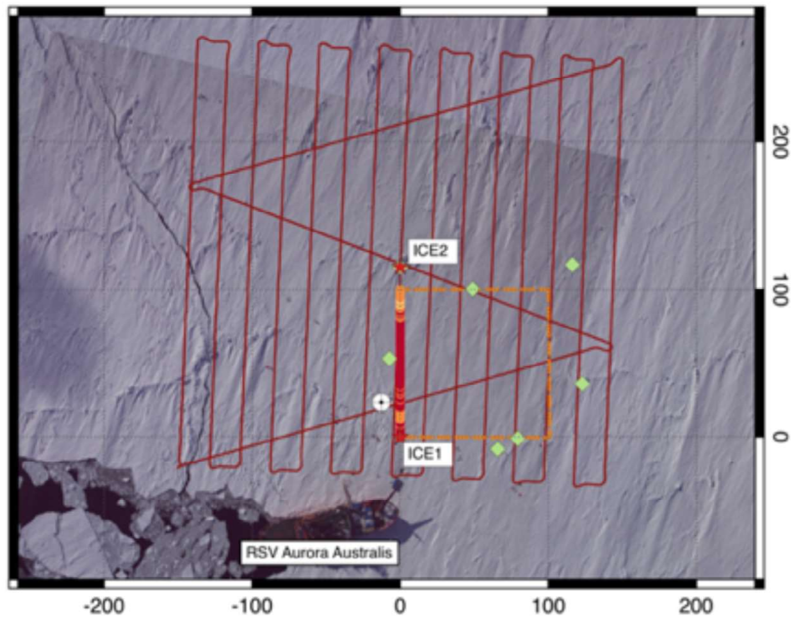
The RAPPLS instrument package surveyed a lot of sea ice. Green polygons show flights undertaken in 2007; pink polygons show 2012 flights. Three additional flying seasons (2008, 2009, 2010) took place in or near Prydz Bay.

Why aerial photos?



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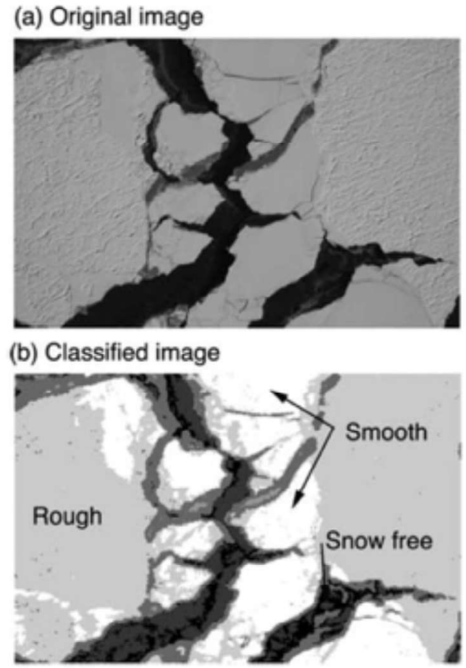
Digital aerial photos have many uses. Here, locally georeferenced imagery is used to show an interpretive map of an ‘ice station’ – a survey plot, a transect line, and the trajectory of an under-ice UAV.

Why aerial photos?



Worby, A. P., Markus, T., Steer, A. D., Lytle, V. I., & Massom, R. A. (2008). Evaluation of AMSR-E snow depth product over East Antarctic sea ice using in situ measurements and aerial photography. *Journal of Geophysical Research: Oceans*, *113*(5), 1–13. http://doi.org/10.1029/2007JC004181

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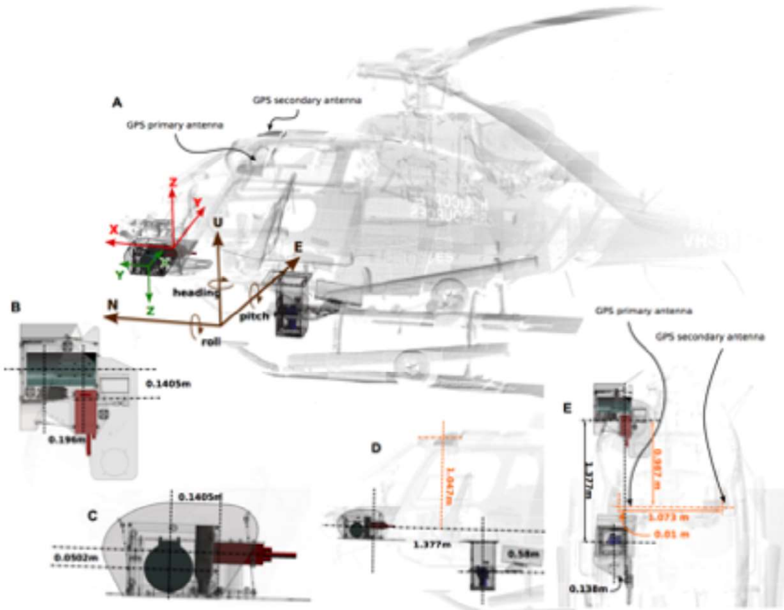
Images can also be used to learn about the ice being flown over. This shows an early attempt at object-based image analysis (OBIA) which segmented images using homogeneity ciriteria to split and merge groups of pixels (objects); and assigned classes based on the mean spectral and textural properties of those objects.

Why aerial photos?



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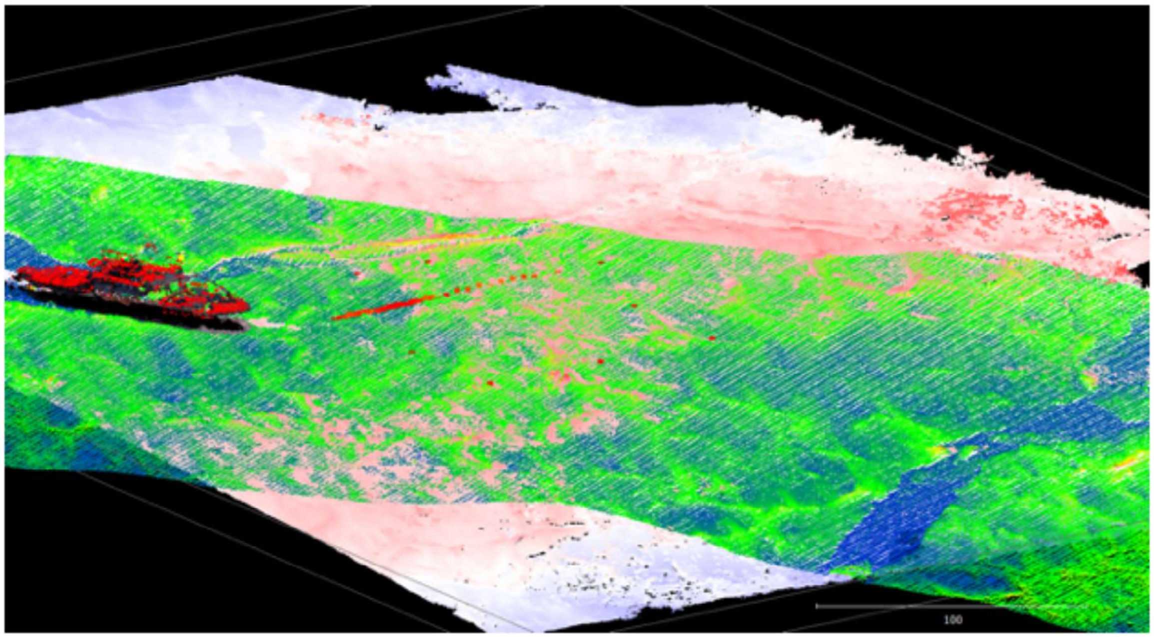
Aerial imagery also does not need a huge, capital intensive platform. The APPLS package was amazing, but you could buy a new ‘out of the box’ for every couple hours of flight time (with attendant increase in level of attention required for data quality)

Why aerial photos?



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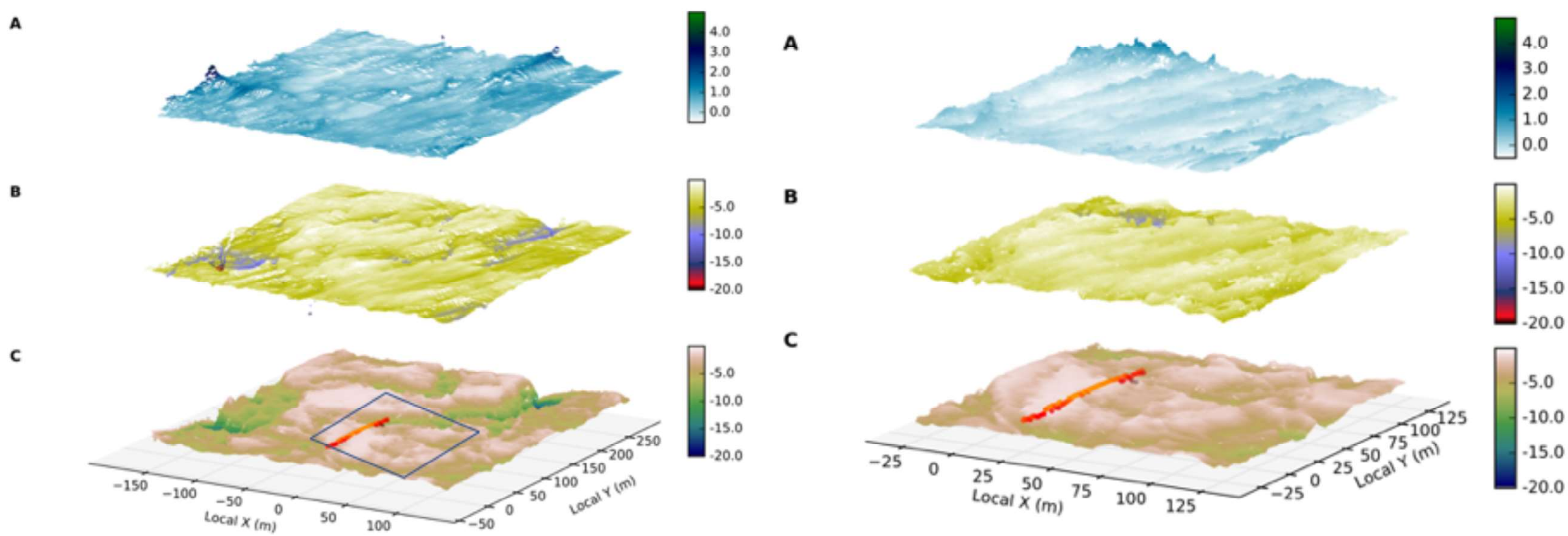
…and since 2006, we've been able to reconstruct sea ice in 3D from imagery! Here, we see LIDAR elevations in green/blue at about 1.5m point spacing and reconstructed-from-photographs elevation in blue-red at about 10cm point spacing. The line of orange dots is a drill hole transect.

Why aerial photos?



See: Skyllingstad, E. D., C. A. Paulson, W. S. Pegau, M. G. McPhee, and T. Stanton (2003), Effects of keels on ice bottom turbulence exchange, *J. Geophys. Res.*, 108, 3372, doi: 10.1029/2002JC001488, C12.

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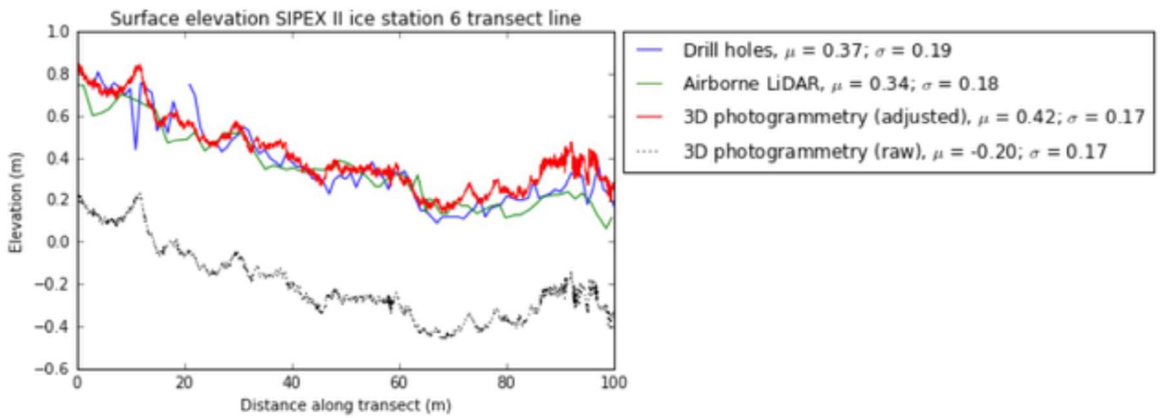
Why do we want 10cm point spacing? To see greater detail in surface topography. This slide shows we make a lot of mistakes in the shape of topography, especially trying to model ice draft from elevation. On the left is airborne LiDAR – with the top panel showing topography, the middle panel showing ice draft modelled from that topography, and the bottom panel showing the actual under ice topography from upward looking SONAR. The right side shows the same, using topography reconstructed from imagery.

The point here is that if we have high resolution data, we can try to make better guesses about relationships between classes of surface features (dunes, ridges, other things) and what happens underneath. If we get the shape underneath the ice wrong, we also get things like turbulent heat flux to the ice wrong (see the paper given in the slide).

Airborne LiDAR, drill holes and photo-topography



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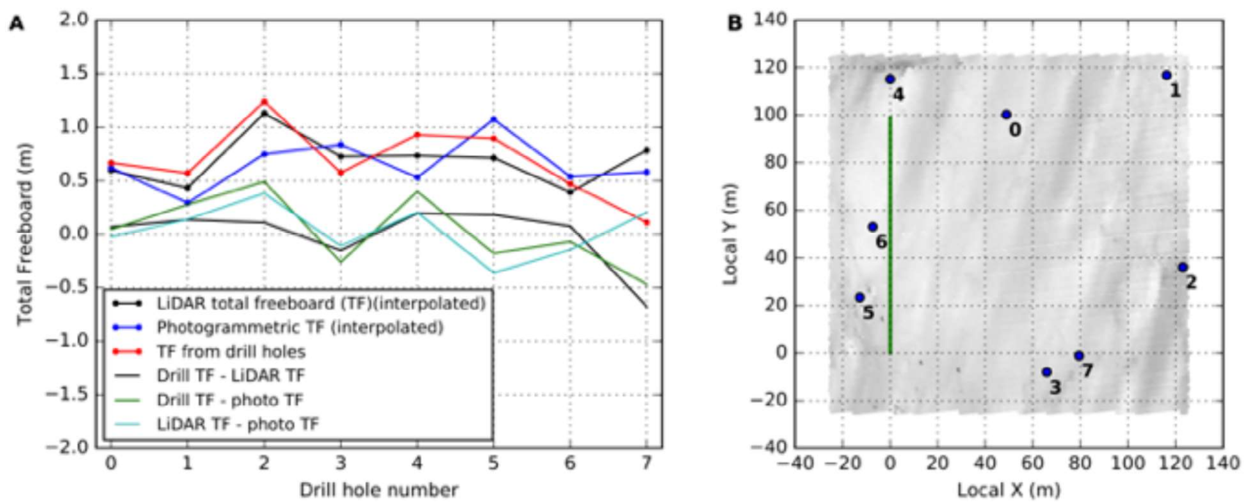
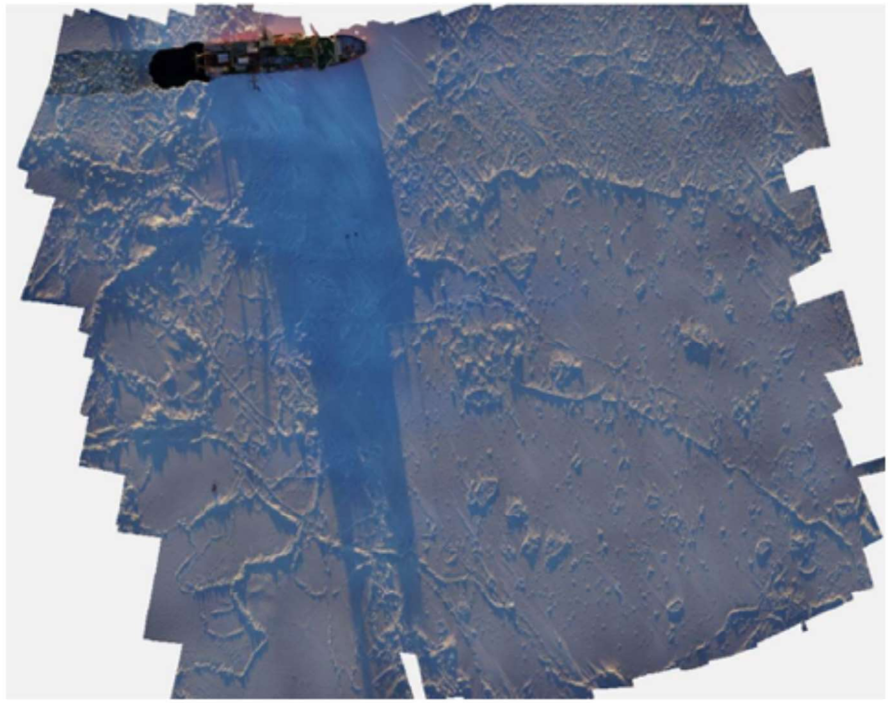
This slide shows that we can actually reproduce topography well – drill holes, LiDAR and imagery-derived terrain all match up. A constant offset was required for the photogrammetric elevation data because the height of reference points used was not measured well in the field.

Airborne LiDAR, drill holes and photo-topography



If we go beyond 2D, we are also OK. This slide also hints at a future for in situ drilling programs. If we are observing the top and the bottom of the ice floe using airborne and under-ice mapping sensors, we can adjust our drilling strategy to provide better 'control point' geometries, and focus on 'interesting features' rather than wear ourselves out drilling in a straight line. Slide 7 also shows a general phenomenon – we only drill the flattest part of a floe!

TLS vs photo-derived topography



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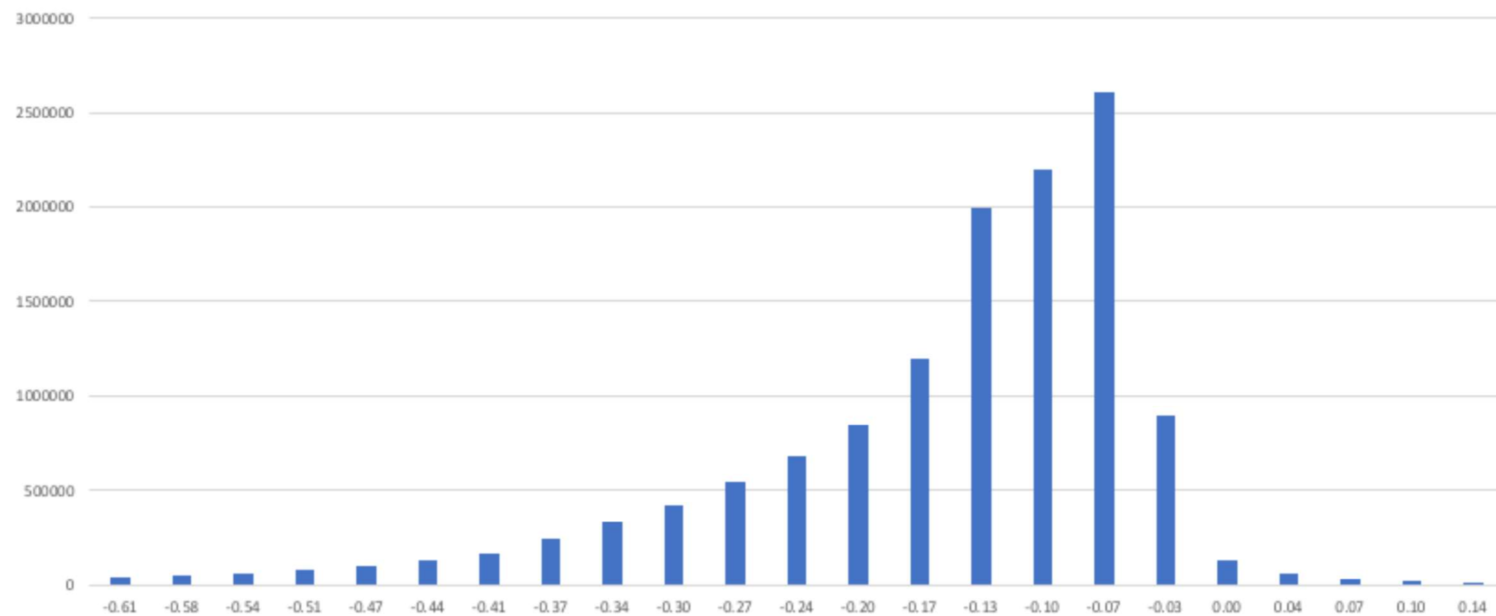
In the RAPPLS programme, we collected imagery for different purposes and found that we could use it to reconstruct ice and snow topography. More recent programs fly small UAVs specifically for the purpose of mapping snow and sea ice topography.

TLS vs photo-derived topography



Courtesy of Dr Guy Williams – unpublished result from the PIPERS Voyage

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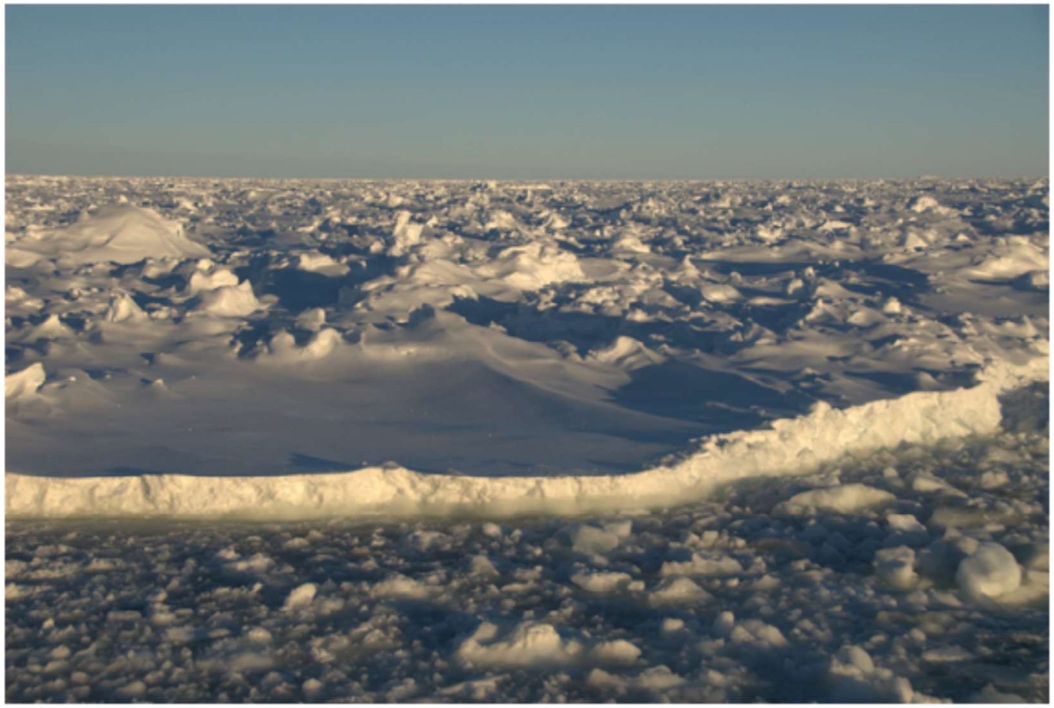
Here, we see that a dedicated imagery collection program for topographic reconstruction is comparable to terrestrial laser scanning – and with more complete coverage (no holes where the scanner beam is obstructed by ridges)

Why so much detail? Because snow is complex



Deformed sea ice encountered on SIPEXII

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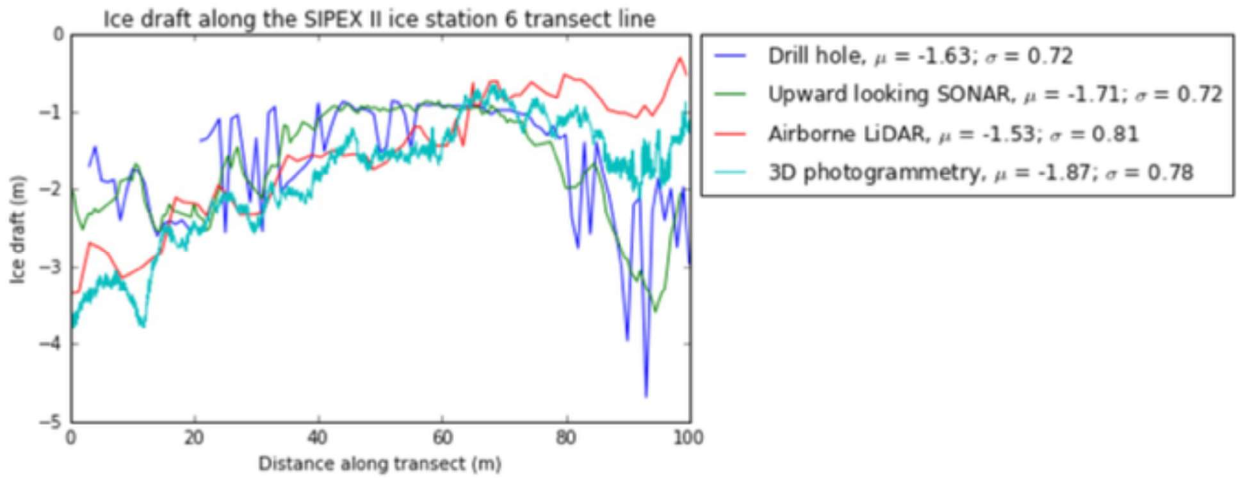
Focusing now on snow – reiterating the point made in slide 7 about the benefit of increased detail. Even 1.5m point spacing LIDAR misses important detail and variability in snow cover!

…and we want to estimate it's depth well!



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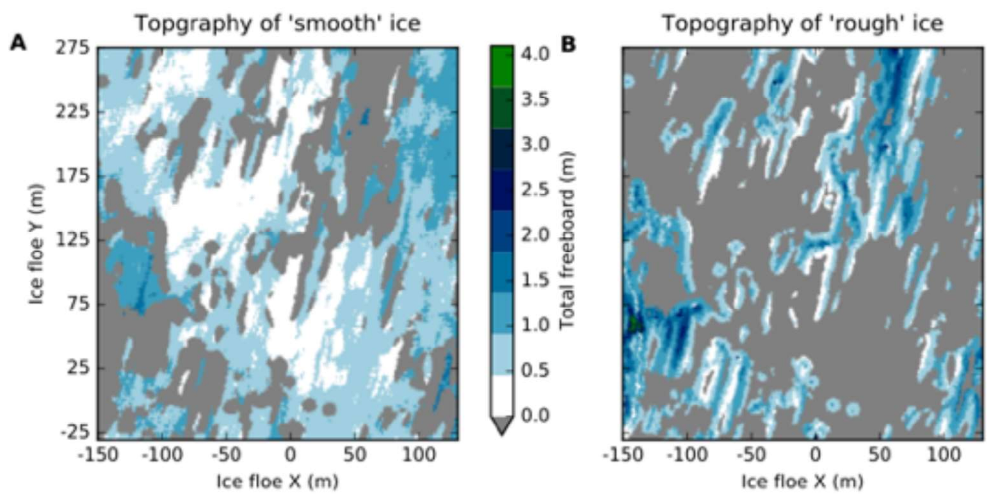
Adding detail in surface topography lets us estimate snow depth in more detail - here we got the best match with sonar-derived ice draft from highly detailed (10cm) photogrammetric topography

We also want to know about topography types



https://gist.github.com/adamsteer/67c7f6f42b4e7d14839b2599eea2cb87

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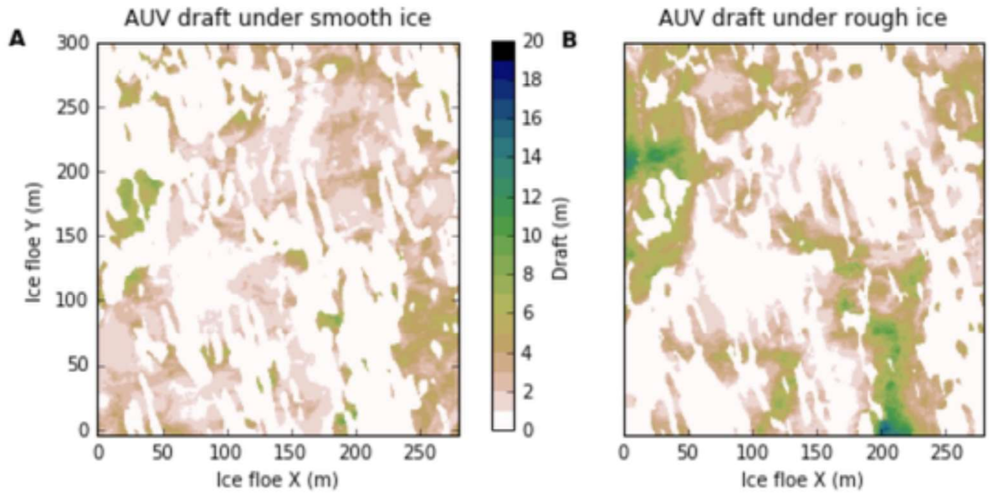
We also want to know about patterns of snow distribution. Here we can see an estimate of 'smooth' topography, which we might class as snow dunes – and 'rough' topography, which we might categorise as deformation ridges. Each has different snow depth distributions; and different elevation characteristics (for example, total freeboard of 'smooth' regions was lower than 'rough' regions).

…and see how they map to ice draft



https://gist.github.com/adamsteer/67c7f6f42b4e7d14839b2599eea2cb87

We also want to know how our different snow and topographic regimes map to what happens below the ice!

...and help us sample snow better

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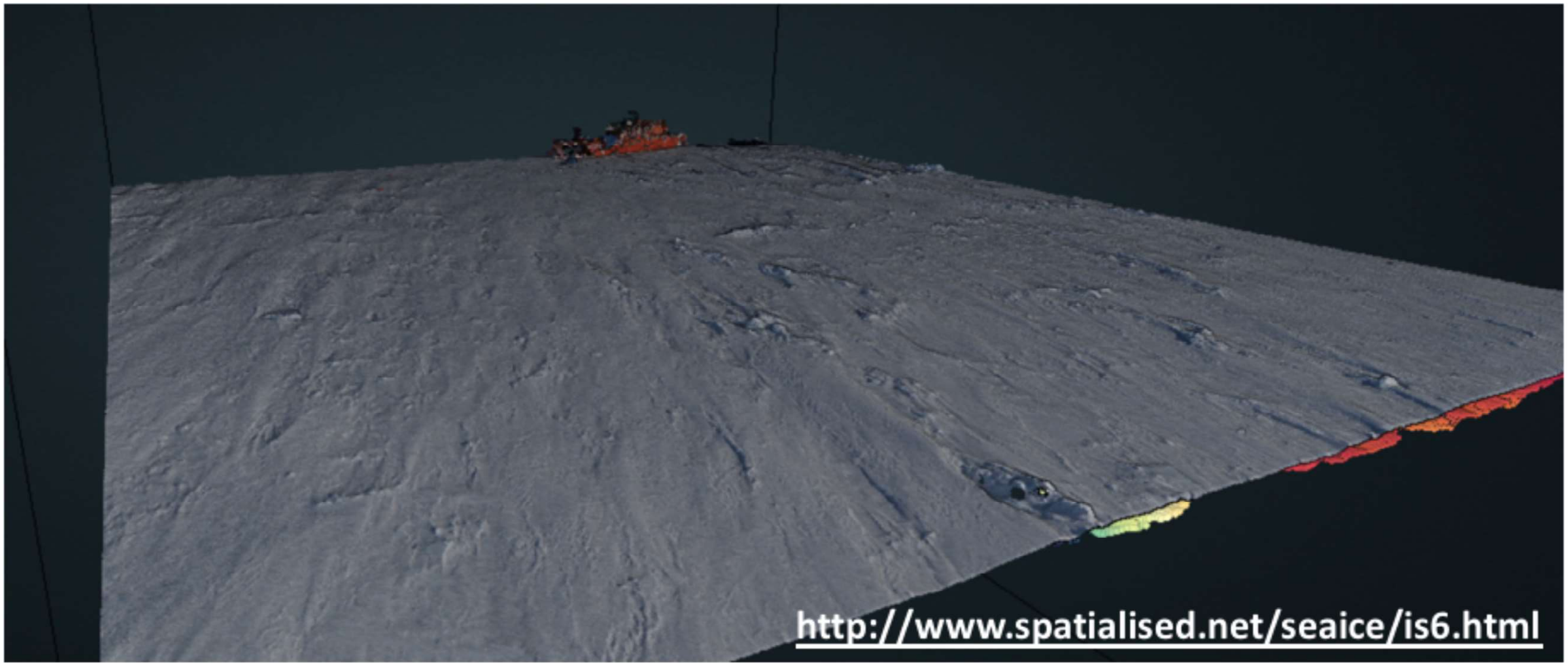
In turn, this detail will help us make better snow maps – and focus field effort on specific snow and surface topography types instead of trying to sample massive grids.

…and get:

- Better surface roughness characteristics at small scales, to inform larger scale observations
- Better ice thickness estimates at small scales
- **Direction toward more efficient use of limited in situ sampling time**

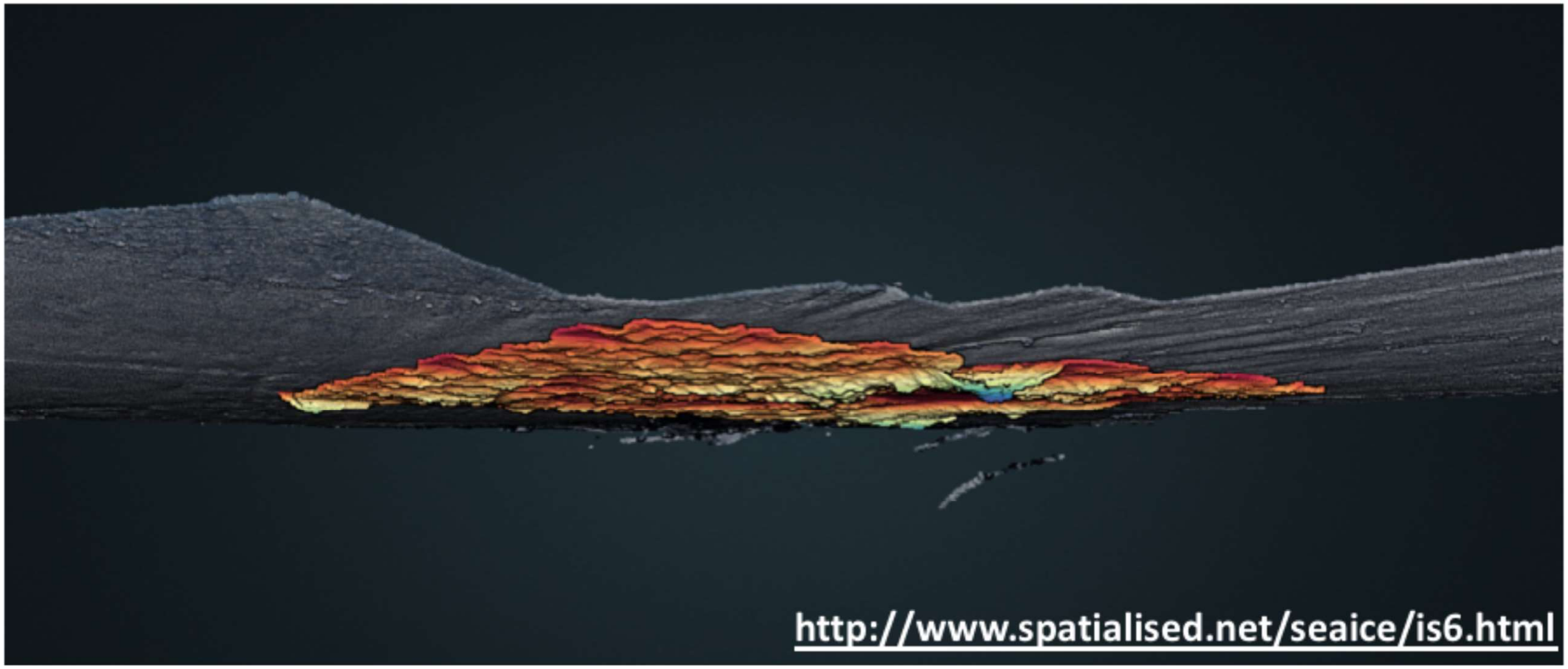
A text slide. Notes not required!

Finally, we can make awesome visualization tools!



…and this detail makes for awesome outreach tools. The URL is now live, please check it out!

…and get people excited about sea ice!



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As for slide 18, from under the ice.

The future part 1 – what should it look like?

- Coordinated and specific campaigns to collect imagery for analysis purposes (already underway)
- Use very visible ground control targets!
- Fly on sunny days – we **want** detail, shadows, contrast
- **Your subject matter is moving – adapt plans and practices accordingly**

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A few future notes.

The future – what should it look like?

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Very key slide! For targeted imagery collection campaigns, create very visible ground control points. There is a GPS antenna in here representing the origin of a floe-local coordinate system. But where is it? Next time, I'll paint a huge target on it (and characterise the effect of the paint on GPS signal prior to field deployment).

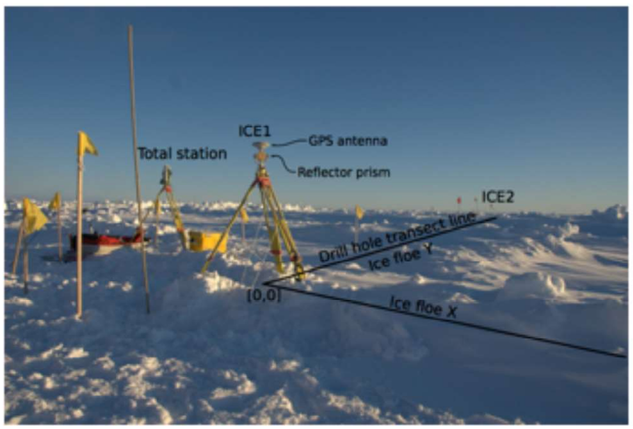
The future – what should it look like?

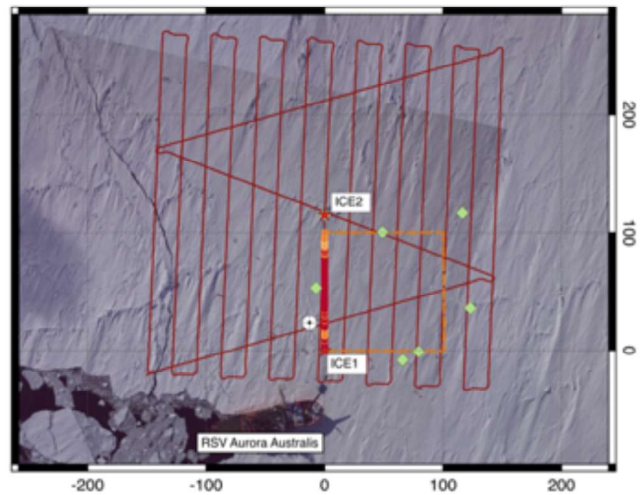
- Exploit sea ice radiometric properties (and use a good camera)
- Work on both machine learning approaches and rule-based classification approaches
- **Pixels are like humans, they work best when collaborating**

Use all the tools we can find – be diverse, not dogmatic. Use both machine learning and physics-based approaches!

The future – what should it look like?

- Using these tools, rethink in situ sampling
- **Move from collecting transect lines to well distributed 'ground control points'**





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Reiterating points made earlier – coordinate ground and airborne sampling for efficient use of resources

The future – what should it look like?

- There are a lot of data to play with - and computer vision/machine learning expertise is needed!

  See: https://data.aad.gov.au/metadata/records/aerial_photo_sea_ice

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Also mine existing data!

Most importantly… have fun!

…and this!

Thankyou!

This presentation also has an online version growing here:

https://adamsteer.github.io/talks/polar2018/#/

…which will have links to data sources, processing notes, code and a bibliography.

@adamdsteer

Thanks. The online talk is underway!