Integrated Technologies for Iceberg Surveying and Monitoring: A Comprehensive Data Collection Campaign in the Labrador Sea during the 2019 Iceberg Season

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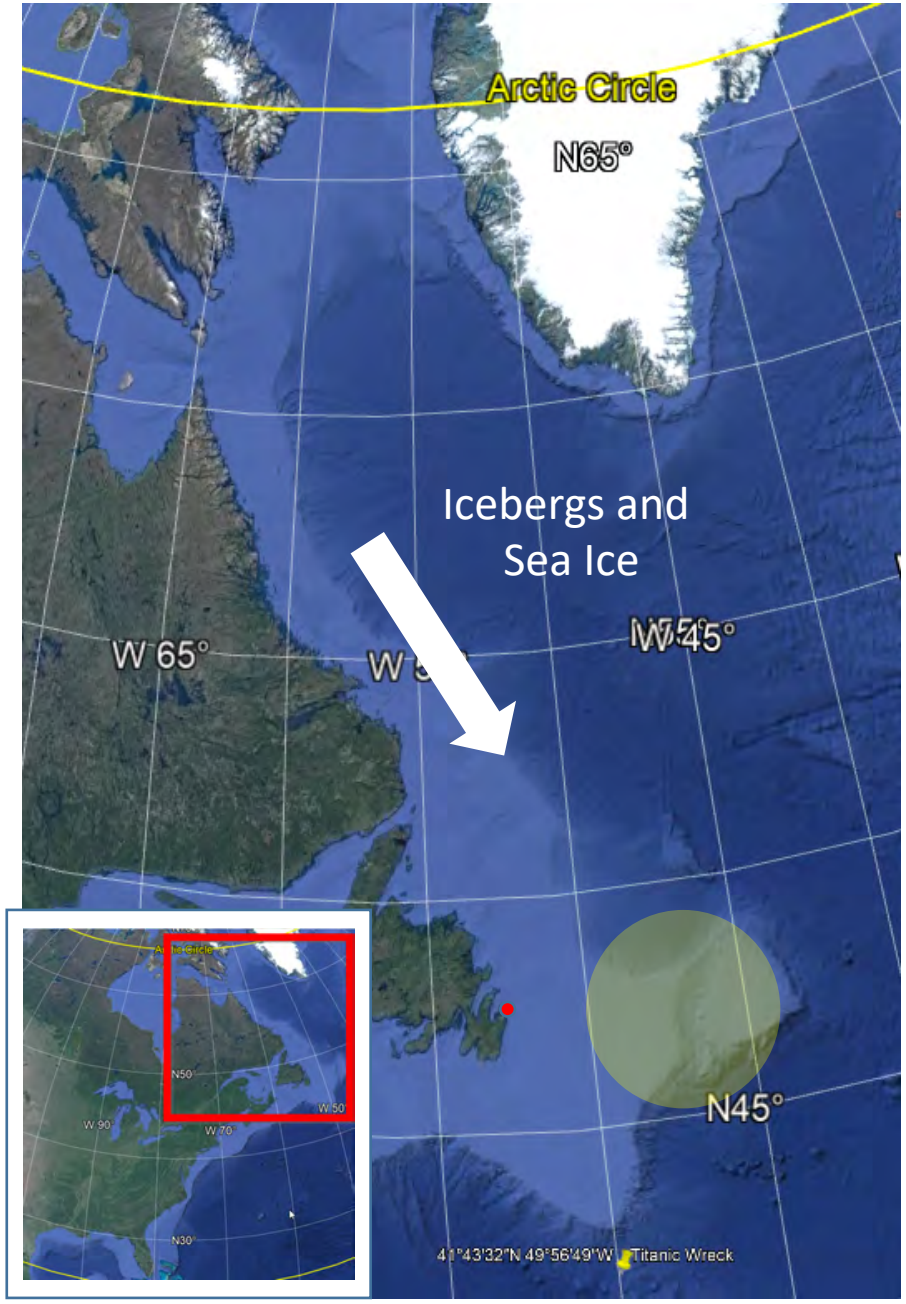
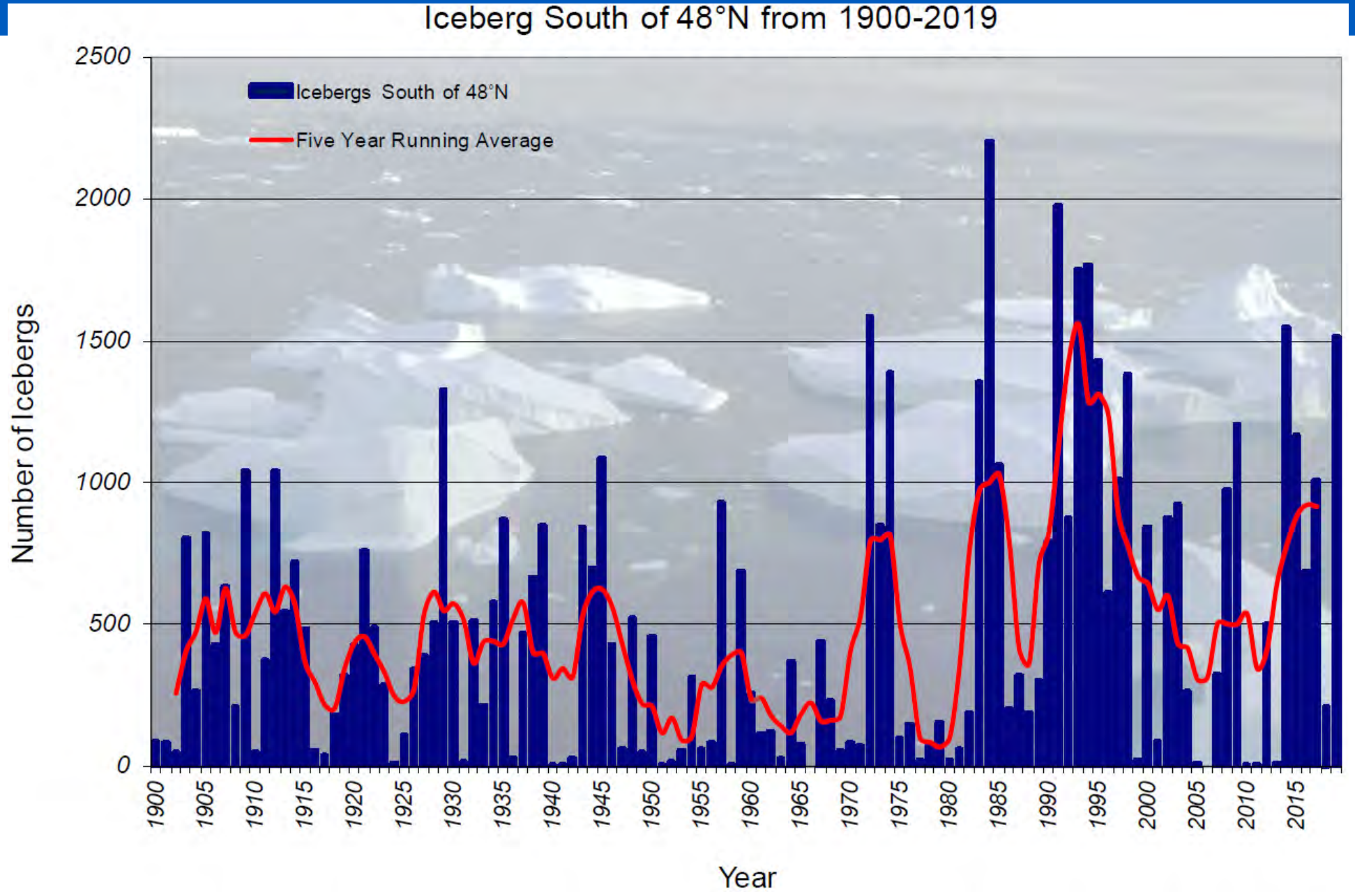
- Carl Thibaut (MakeTECH)
- Renat Yulmetov (C-CORE)

- Not-for-profit organisation (Specially Incorporated Entity of Memorial University of Newfoundland and Labrador)
- Applied research with expertise in:
  - Ice (and Harsh environment) engineering
  - Earth Observation and Remote Sensing Systems (recently adding ground stations and downlink services into the portfolio)
  - Geotechnical Engineering (including operation of a 5.5 m 200G centrifuge)

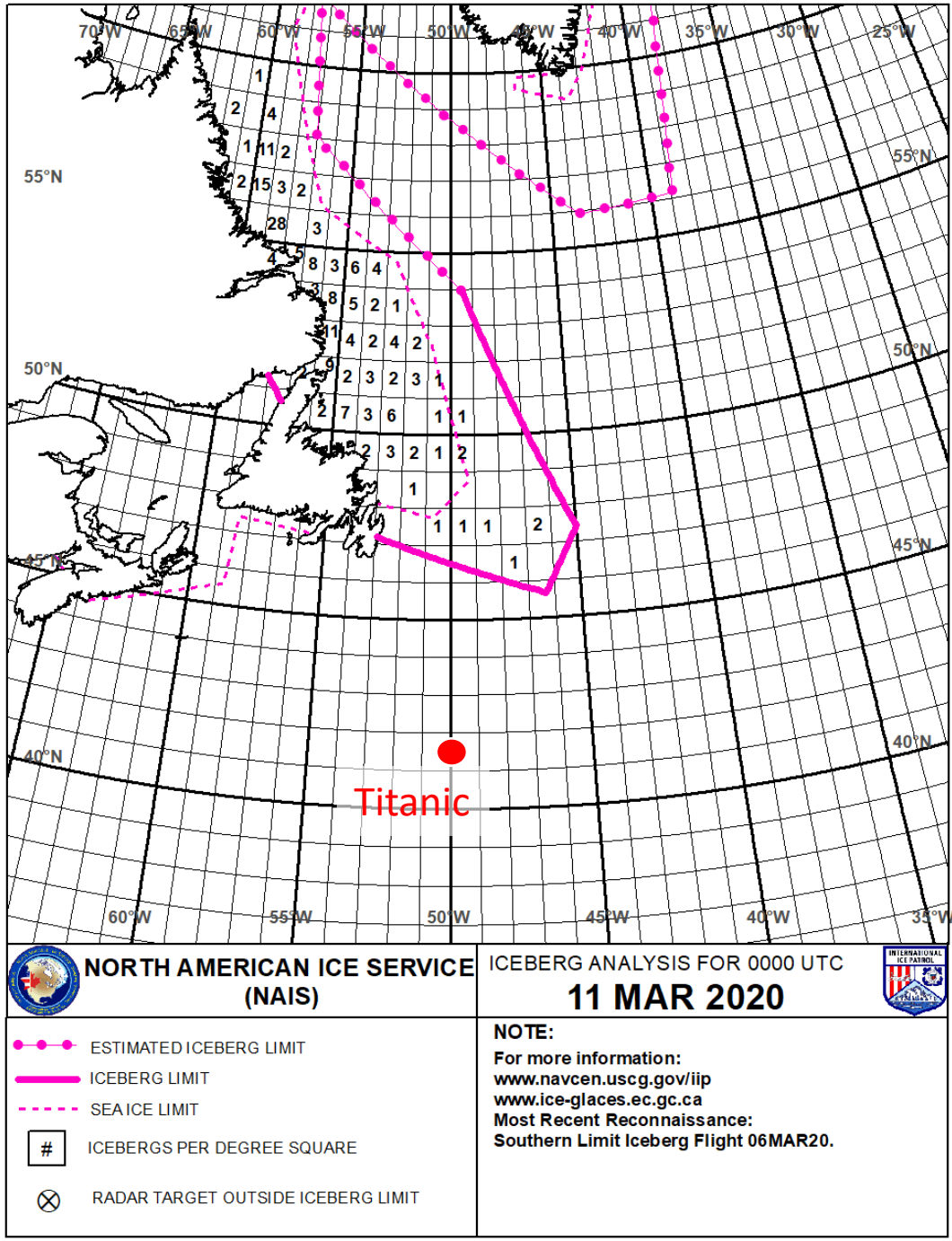




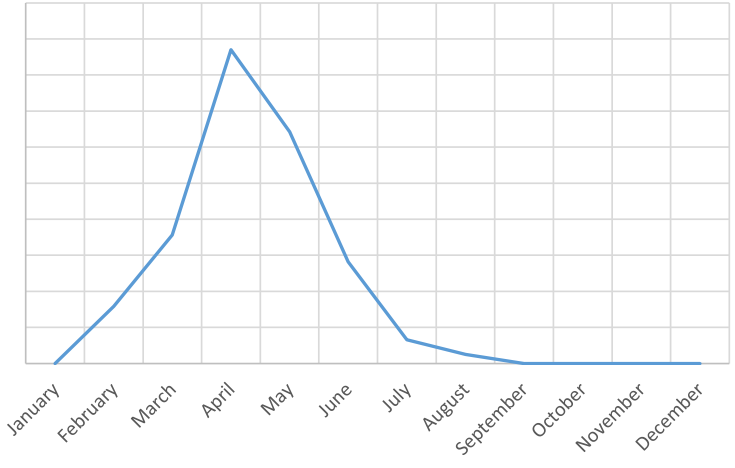
From International Ice Patrol 2019 annual report

Iceberg Areal Density

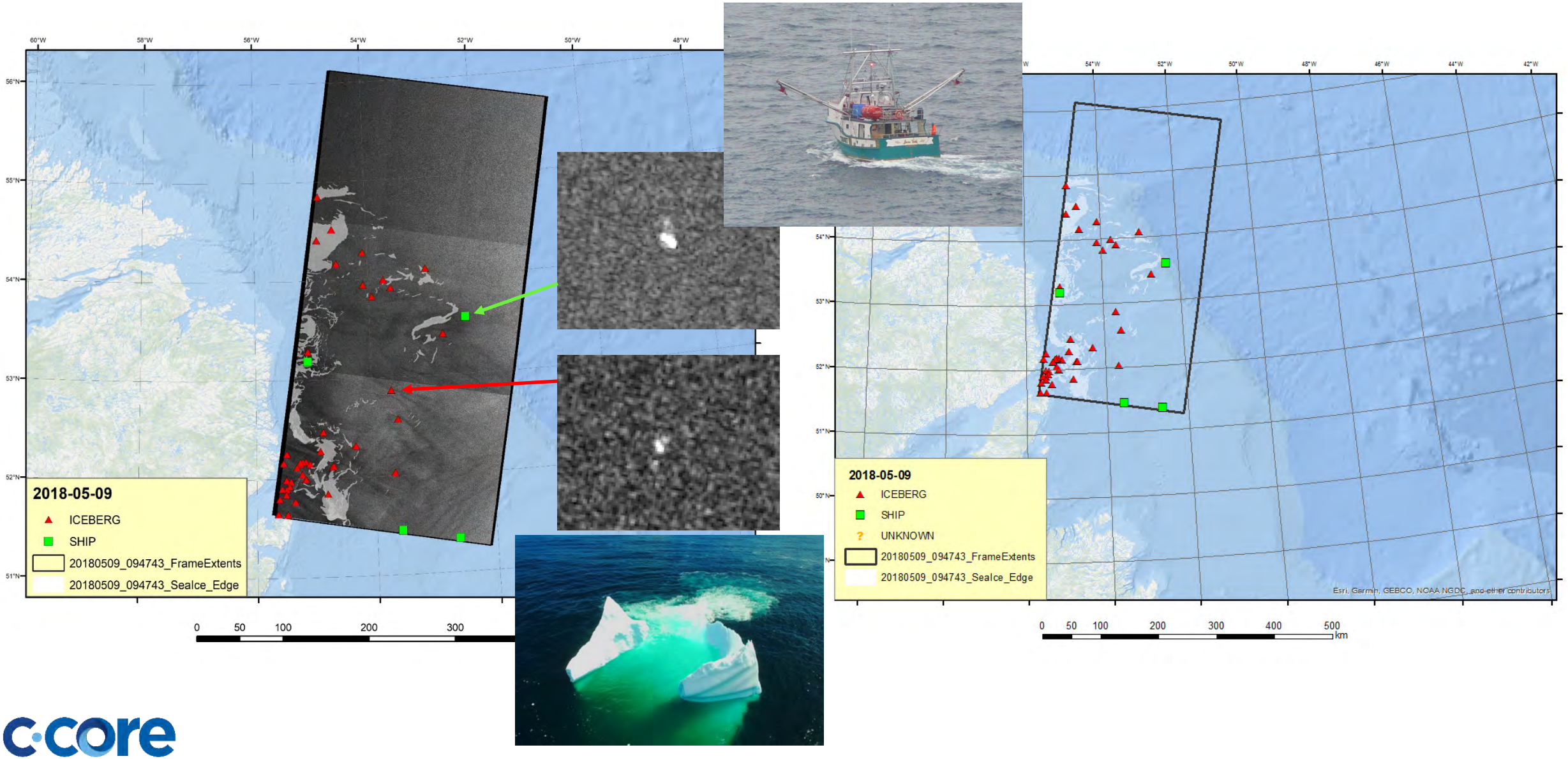
- Iceberg frequency, or *areal density*, is defined as the number of icebergs expected in a specified area at any given instant in time average over a year”
- Data sources:
  - International Ice Patrol
  - Aerial reconnaissance flights



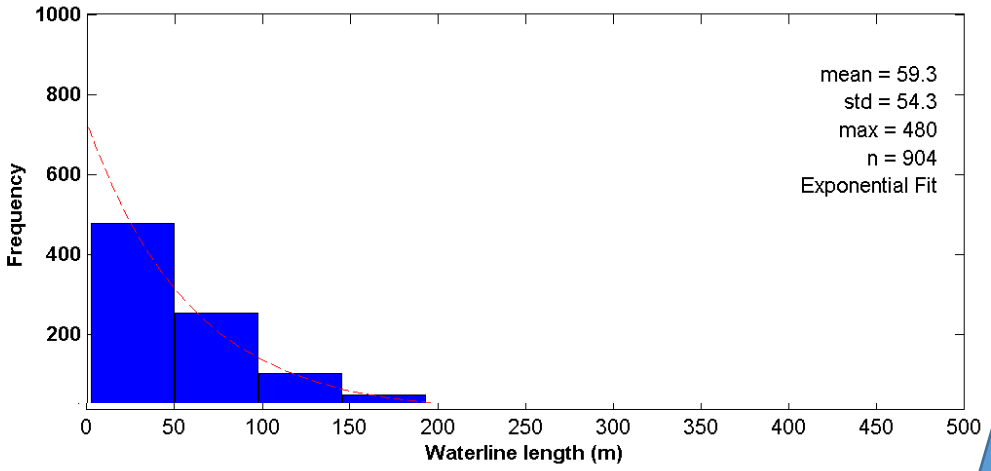
Monthly distribution of icebergs on Grand Banks



Satellite-Based Ship/Iceberg Monitoring with Sentinel-1

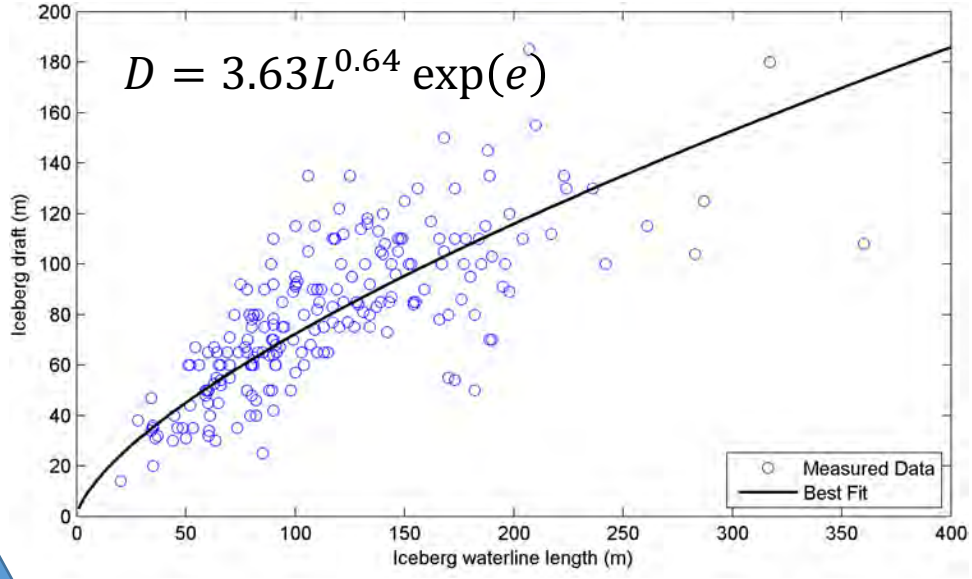


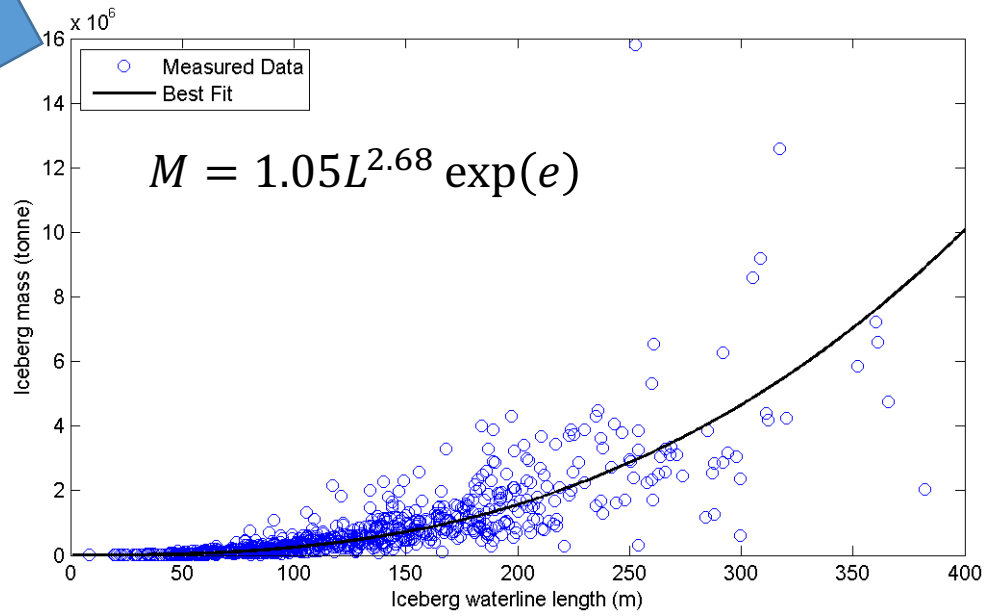
Iceberg Dimensions



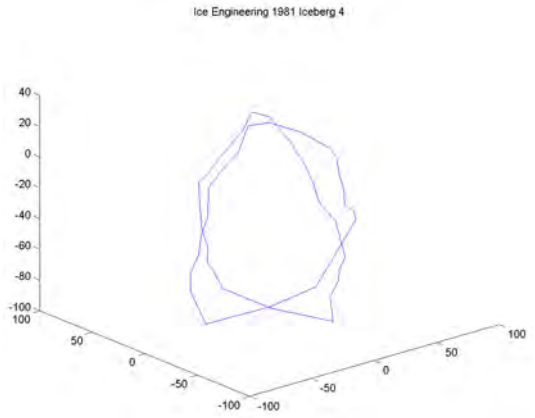
- Iceberg waterline length is defined as the largest projected width at the water surface.
- Relatively easy to measure; large database available for Grand Banks region.
- Other dimensions correlated to waterline length

Correlations

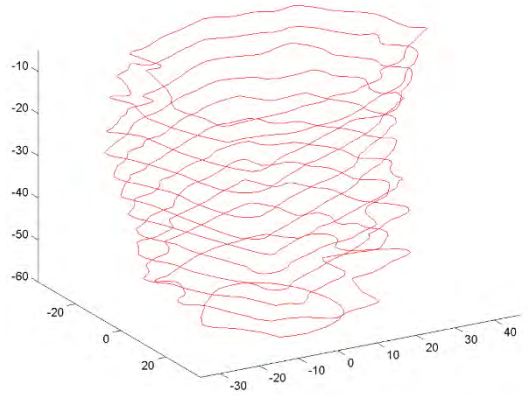




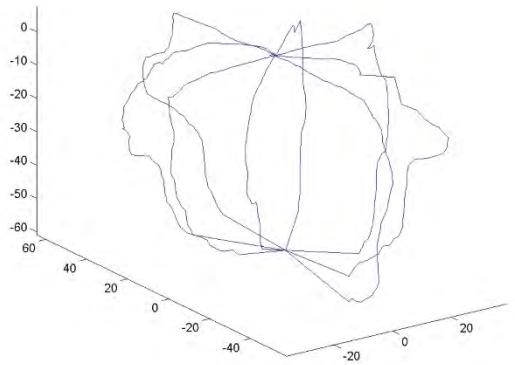
Iceberg Shape



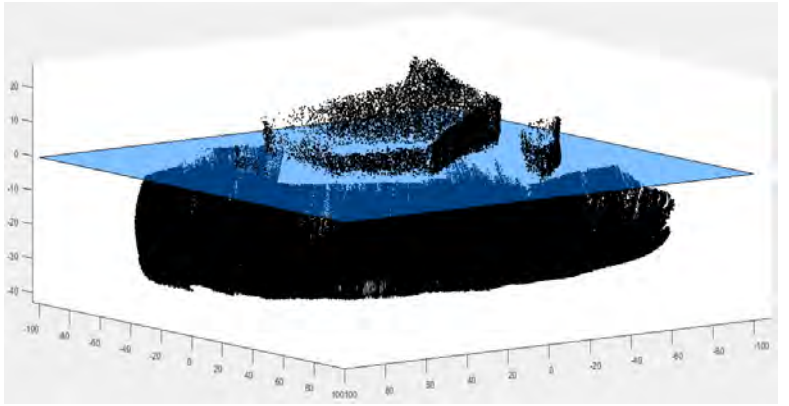
Early 1980's: two orthogonal profiles below and above water



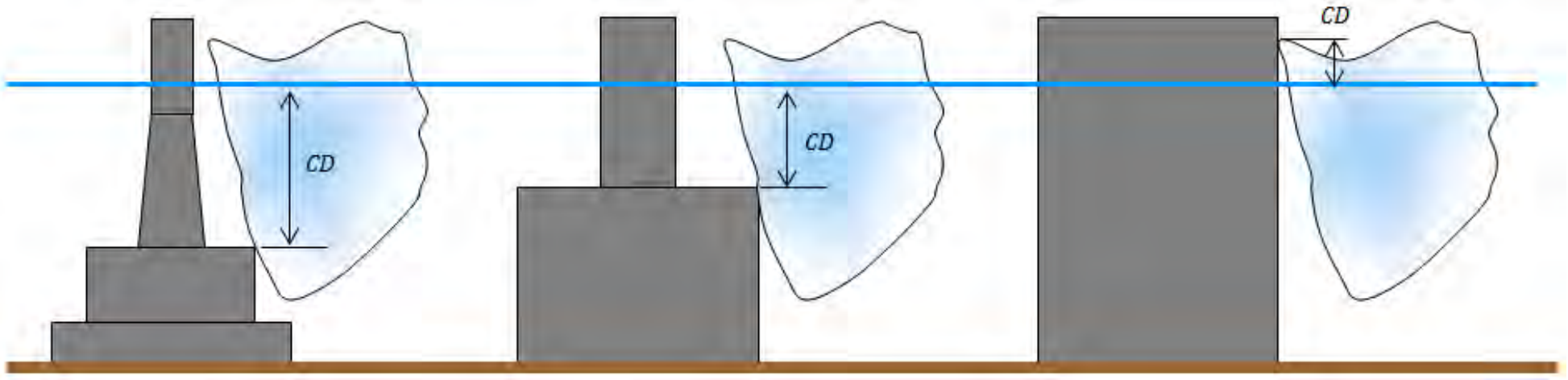
1984: complete underwater profiles; no above water good horizontal resolution



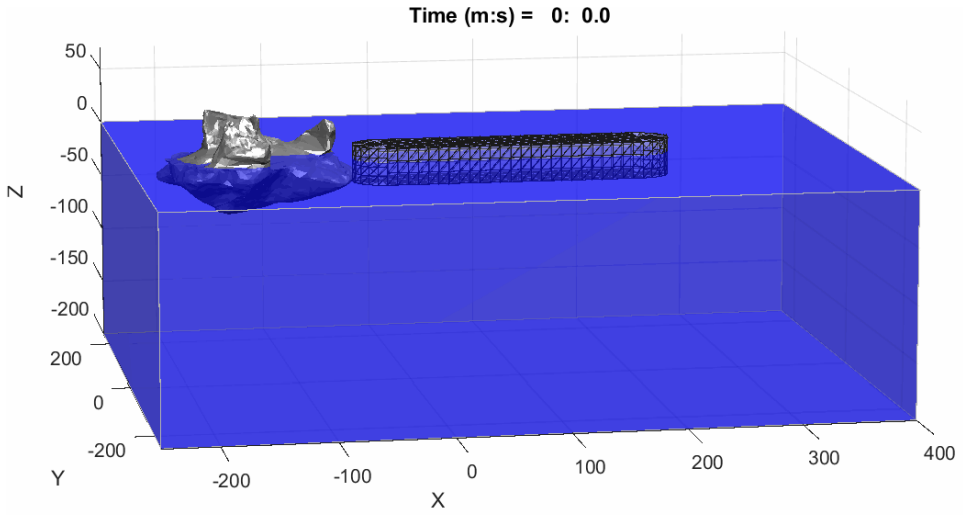
Early 2000's: complete 3D profiles based on 8 vertical profiles

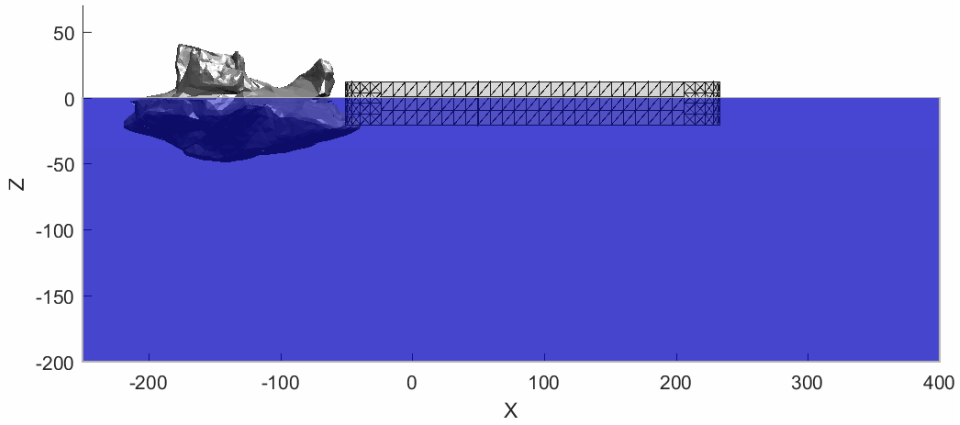


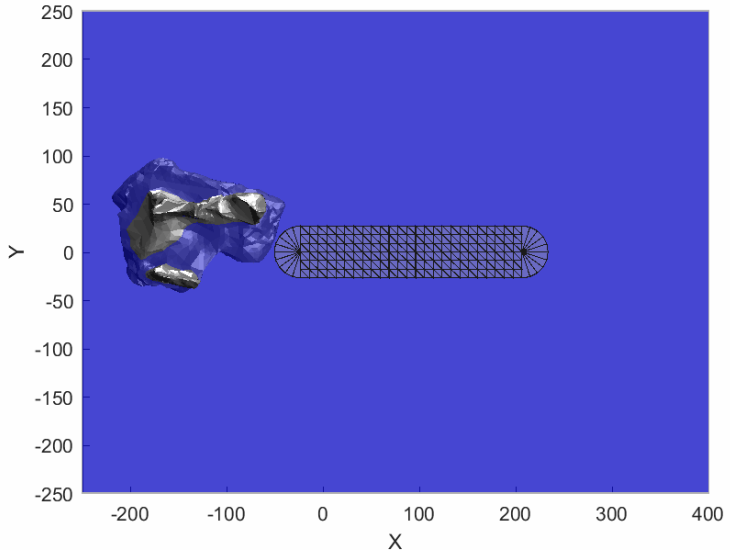
2012 (2015, 2017): complete 3D profiles; very high resolution

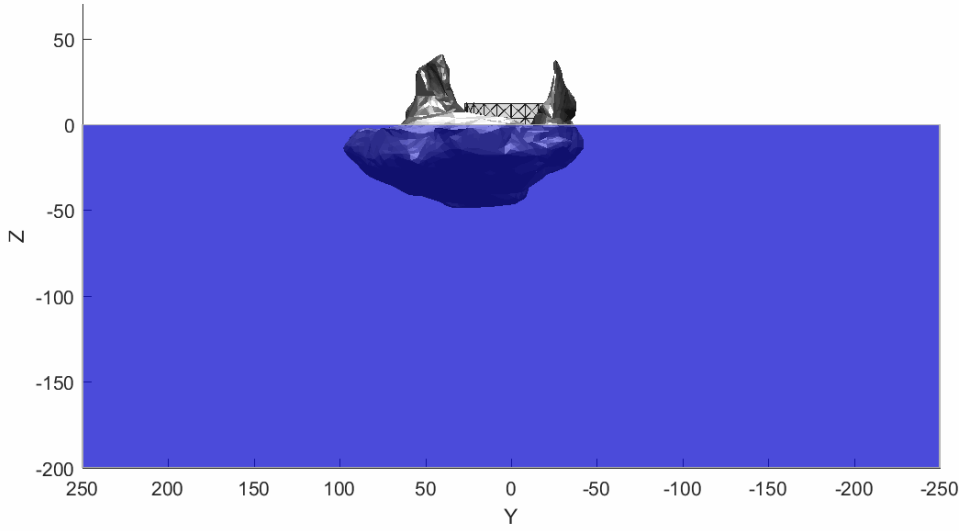


Modeling Iceberg Impact Loads - vessel

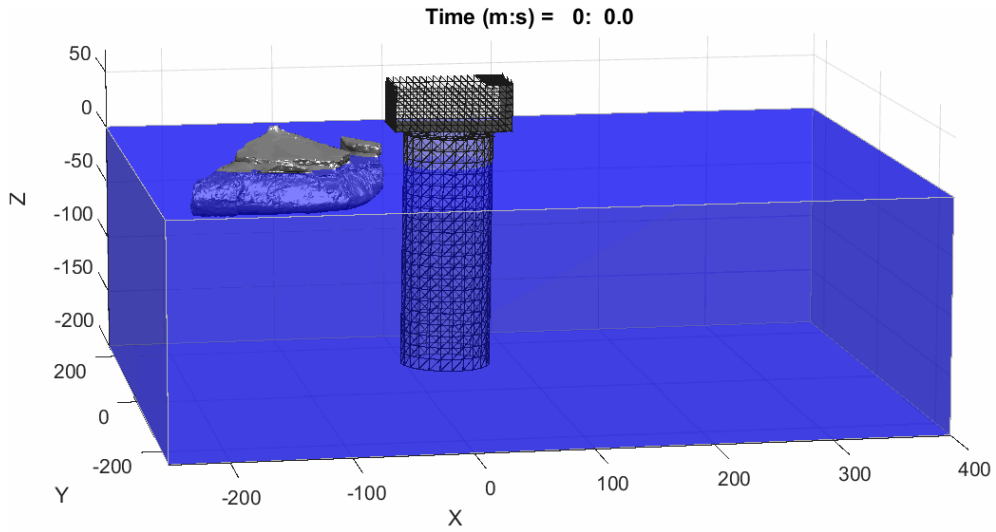


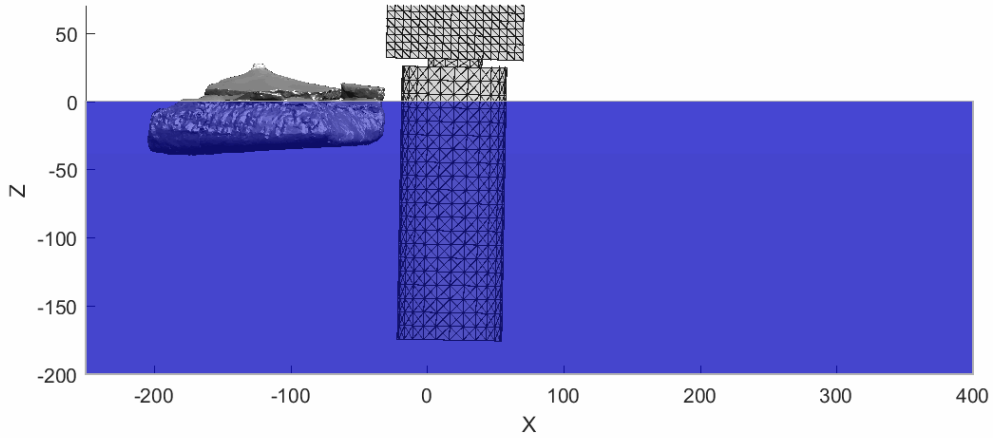


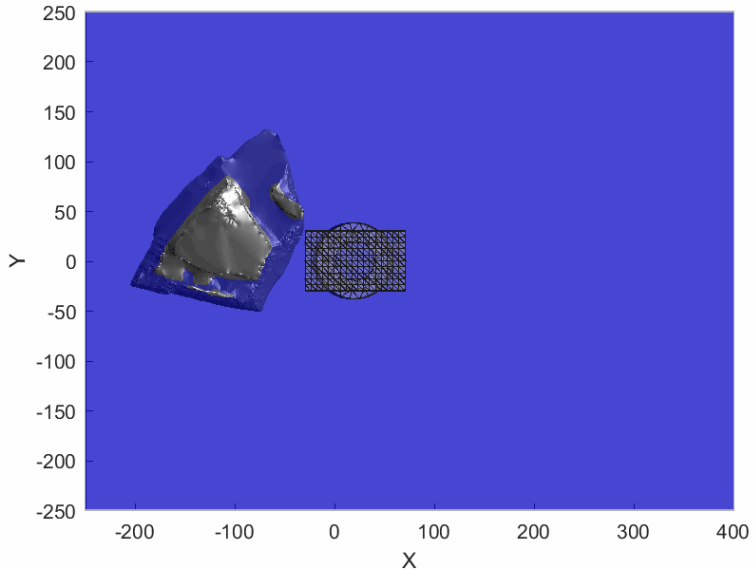


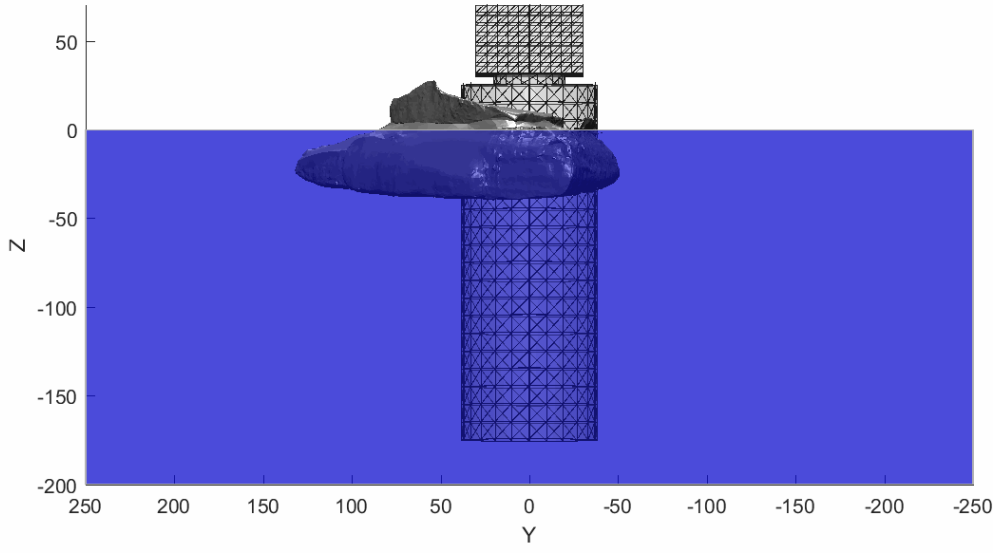


Modeling Iceberg Impact Loads - spar



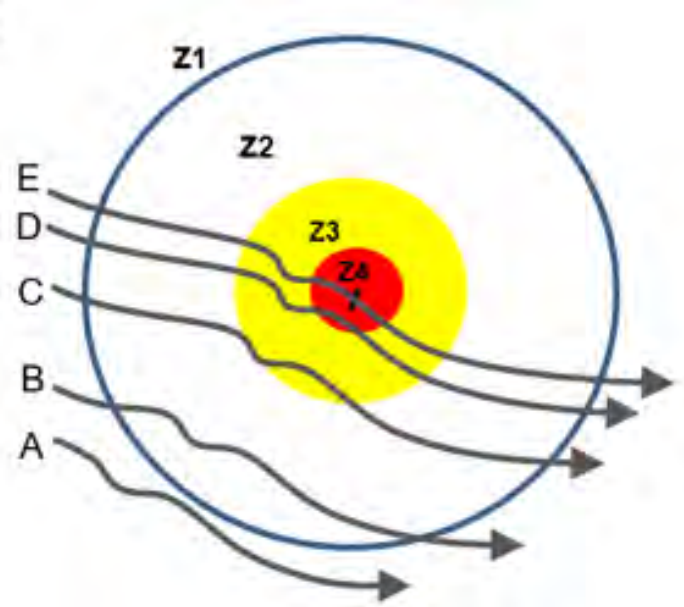






Iceberg Management Strategy

- Zones typically based on T-times and estimated iceberg CPA (closest point of approach)



Zone	Action
Z1	Detect and monitor
Z2	Physical management (towing / water canon)
Z3	Initiate shutdown once enters Z3
Z4	Disconnect once enters Z4

Evolution of Experience, Tools and Technology

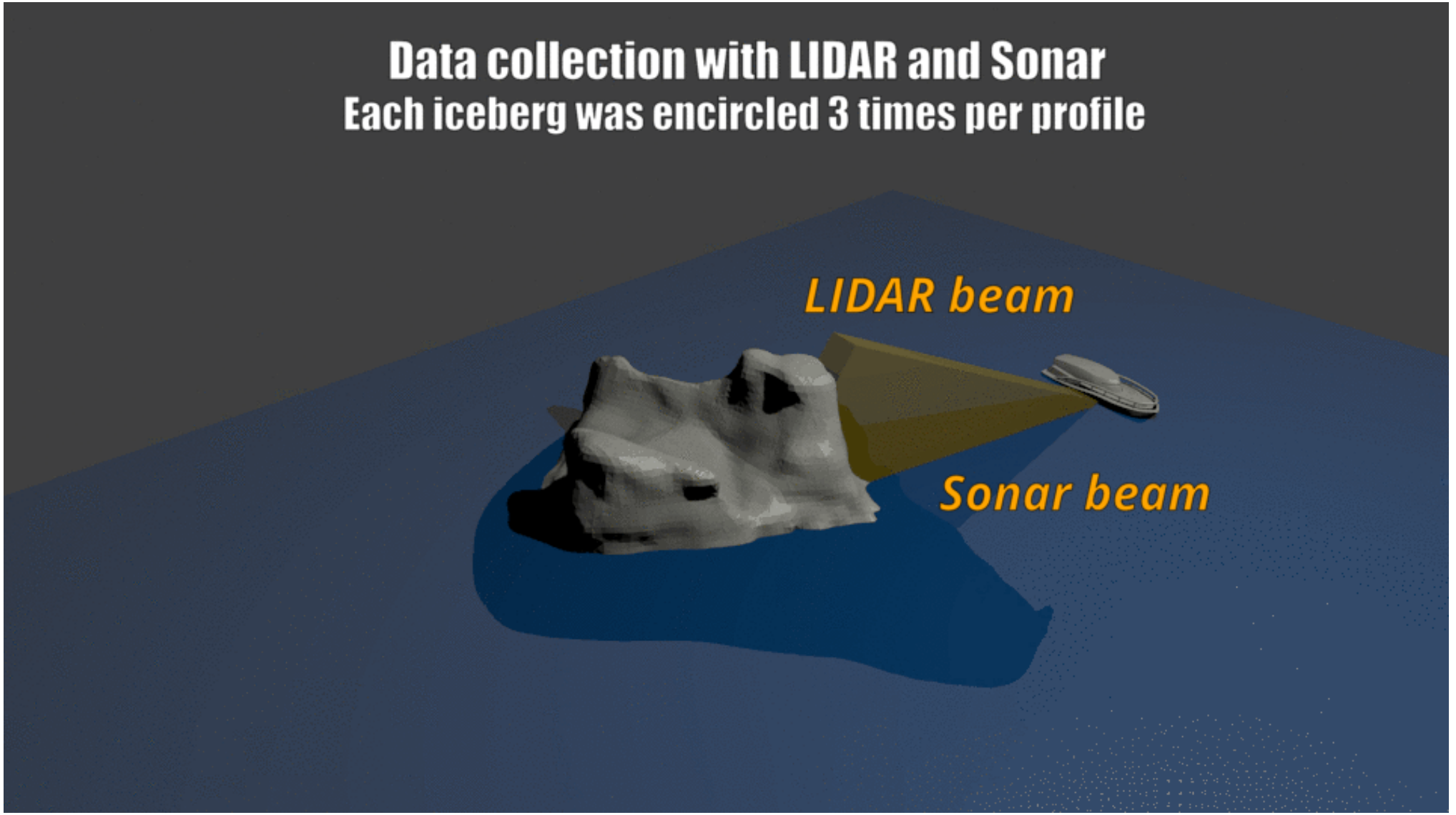



2017 – Nearshore



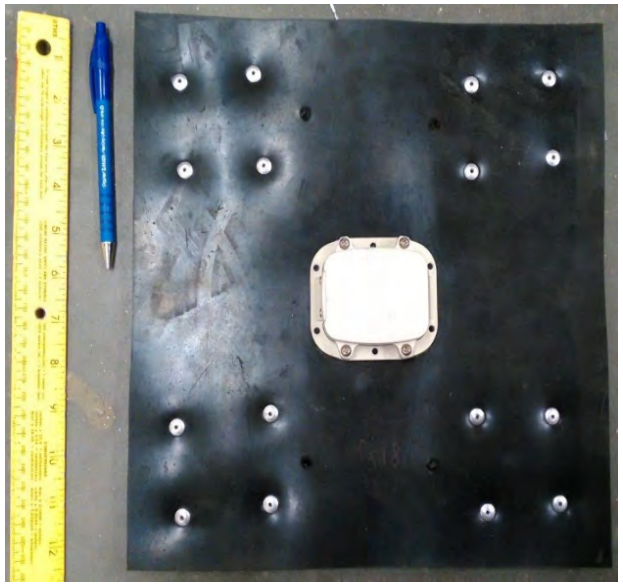
2018 – Offshore

SIMS data collection



GPS Tracker Unit

- 40 days longevity @ 30 min message frequency
- Low cost $200-300
- SmartONE GPS/Iridium unit; provided and supported by AtlasTrax

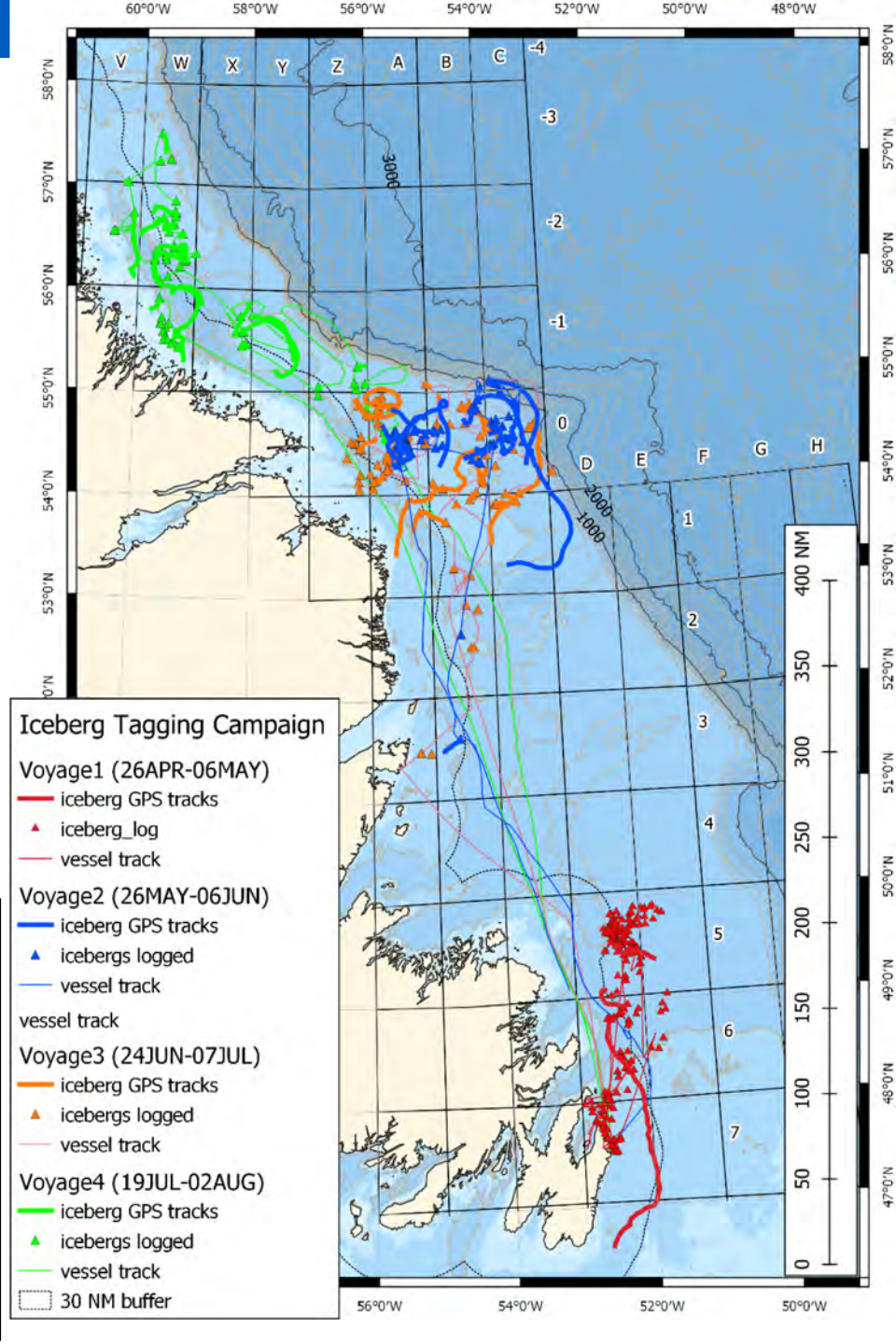


UAV fleet

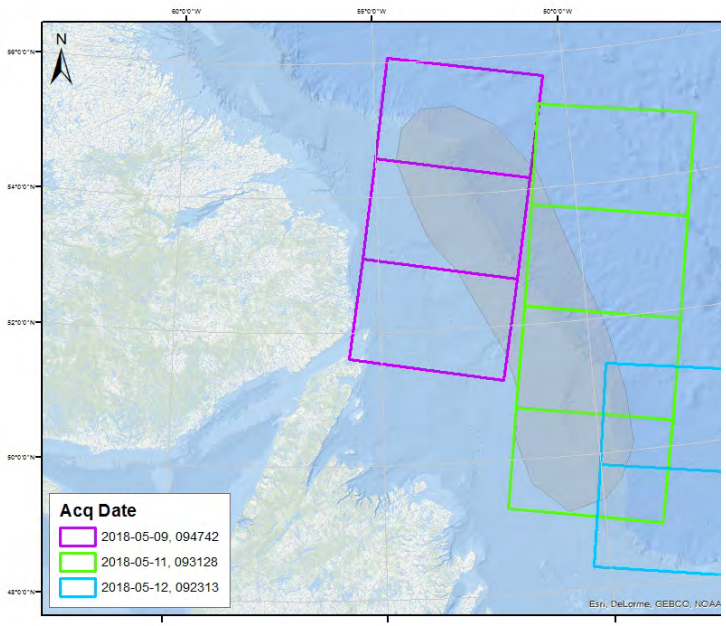
- Delivery UAV is a custom build by MakeTECH
- Photogrammetry UAV is a commercial off the shelf (currently using Autel EVO, used DJI, Yuneec)

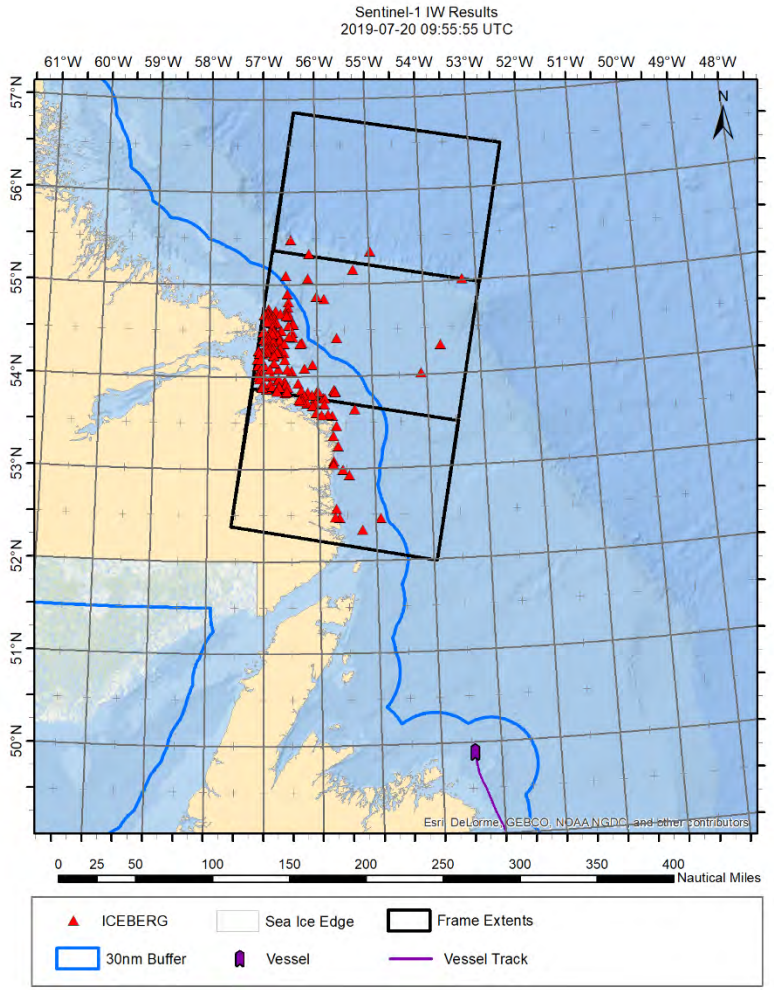
Campaign Overview

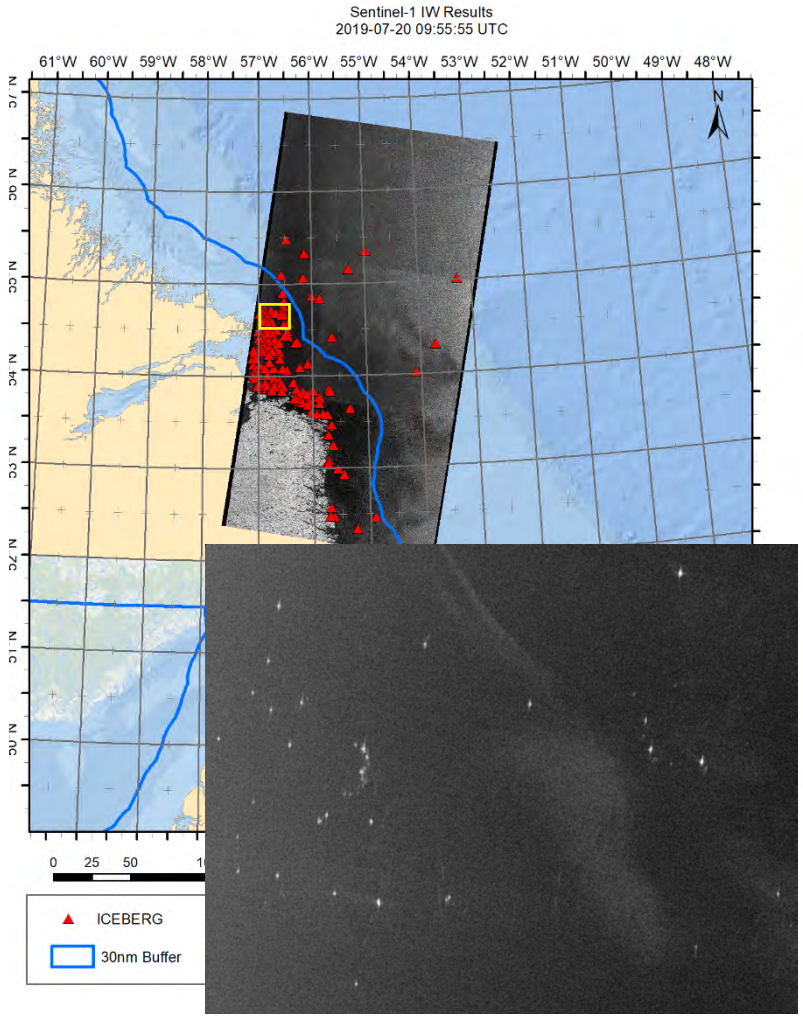
- Voyage 1 – APR/JUN – 11 days at sea
- #2 – MAY/JUN – 12 days
- #3 – JUN/JUL – 14 days
- #4 – JUL/AUG – 15 days
- Total of 52 days



Finding Icebergs using EO (usually Sentinel)







Tracker deploy.

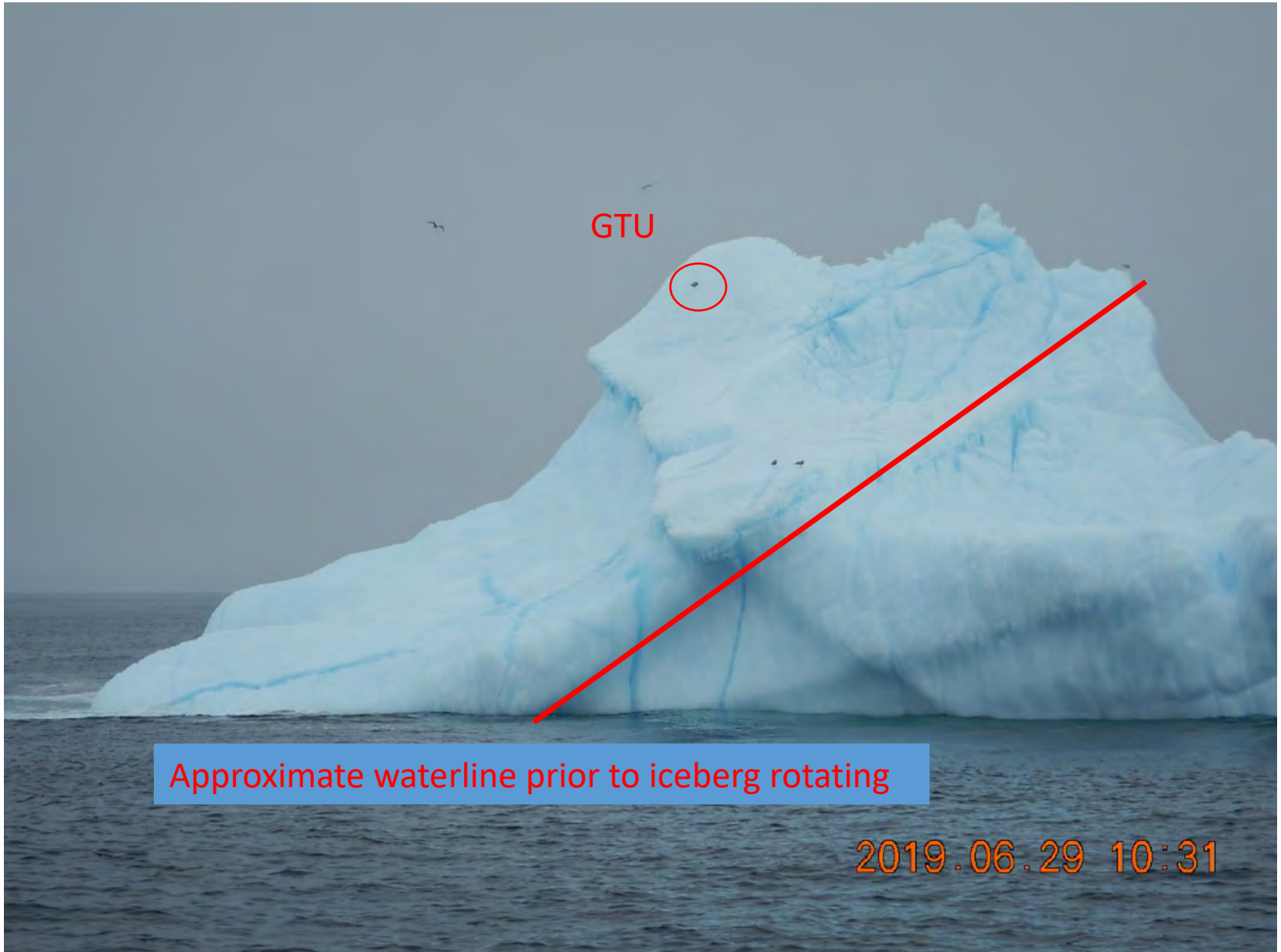
Tagging small icebergs
generally yields short duration tracks

- IB3029, a 24 m drydock/pinnacle
- 3 min track

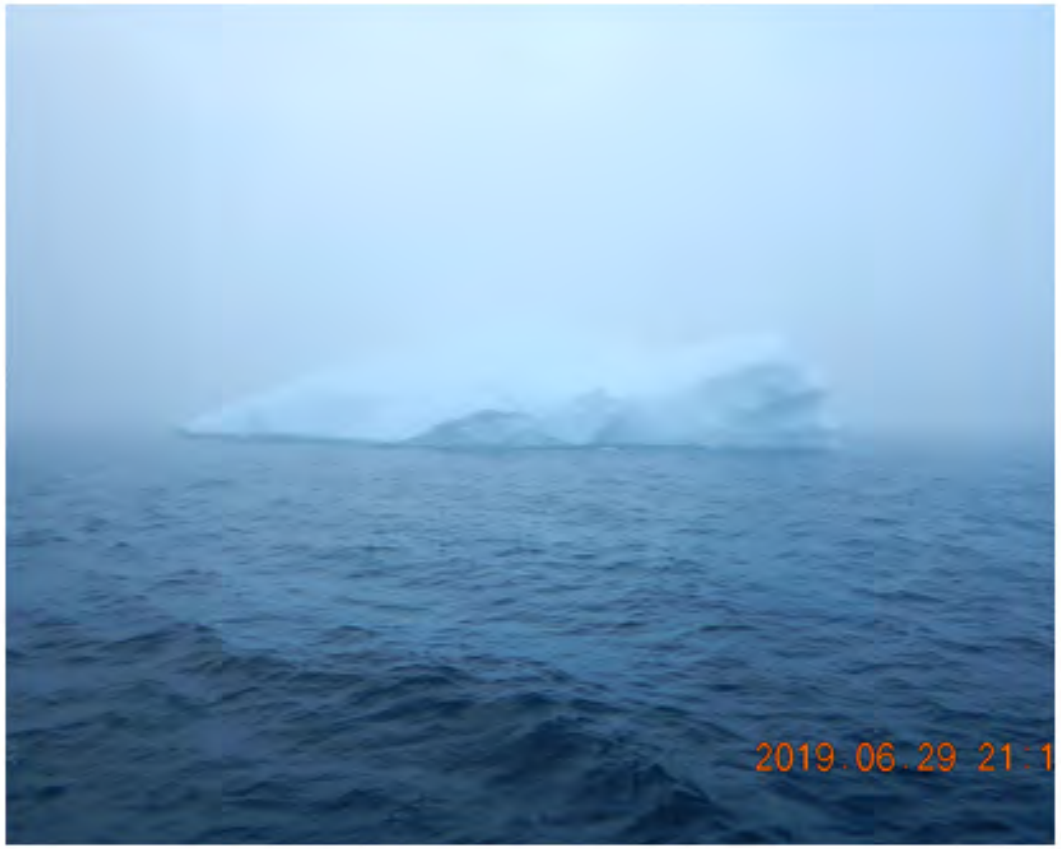
- IB3036 a 21 m iceberg
- 75 min track.

Icebergs shift position and or roll – a lot

- IB3038 - 57 m
- example of the GTU adhering to a steep slope
- 8 hr track
- Very slow rolling likely because iceberg is unstable



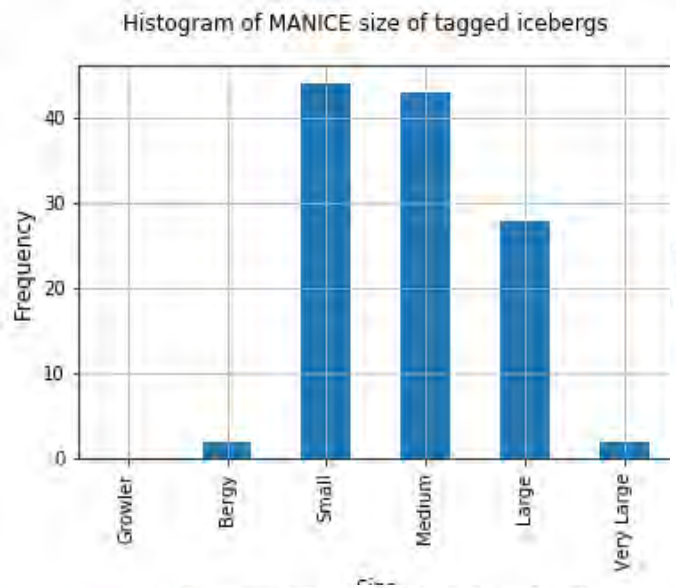
Visibility Issues

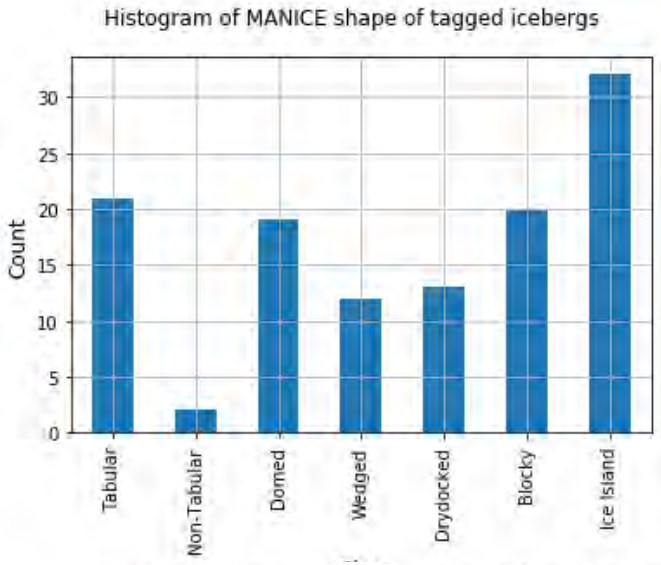


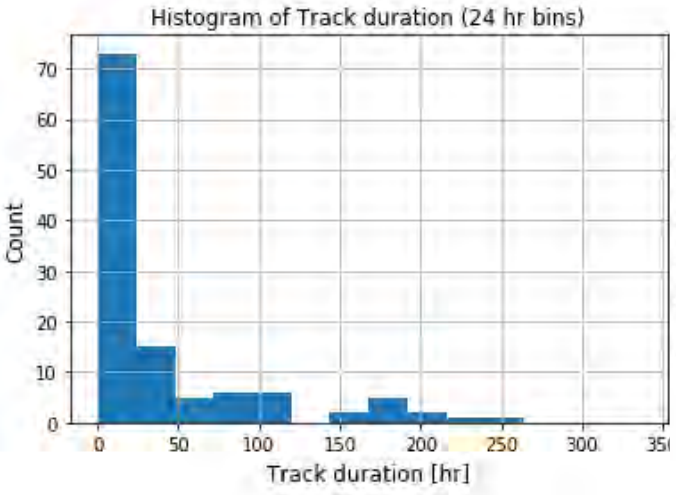
(i) (ii)

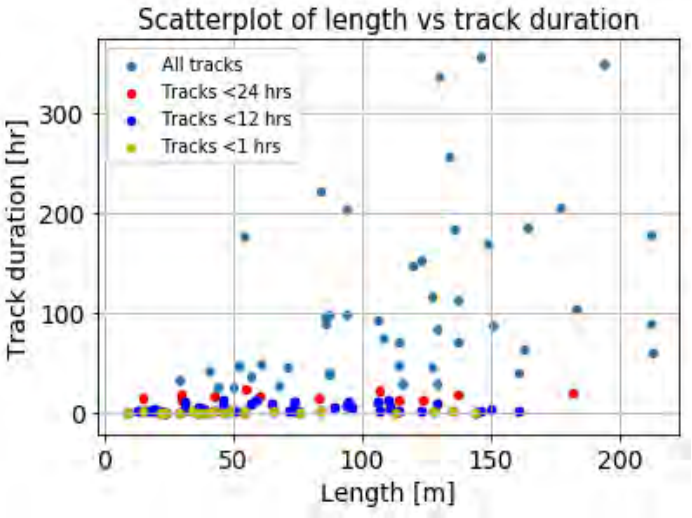
Figure 39. (i) IB3041 (38 m) and (ii) IB3044 (106 m) in low visibly conditions

Summary of the ‘tagged’ icebergs





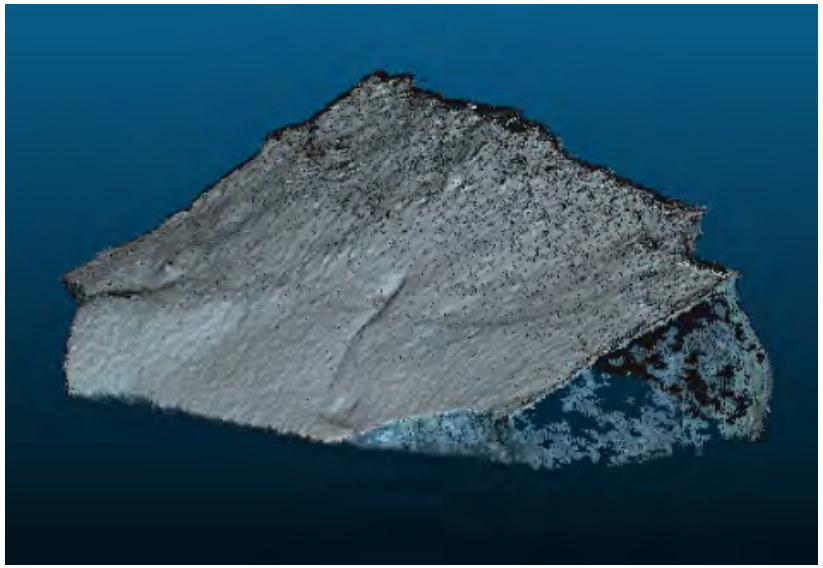




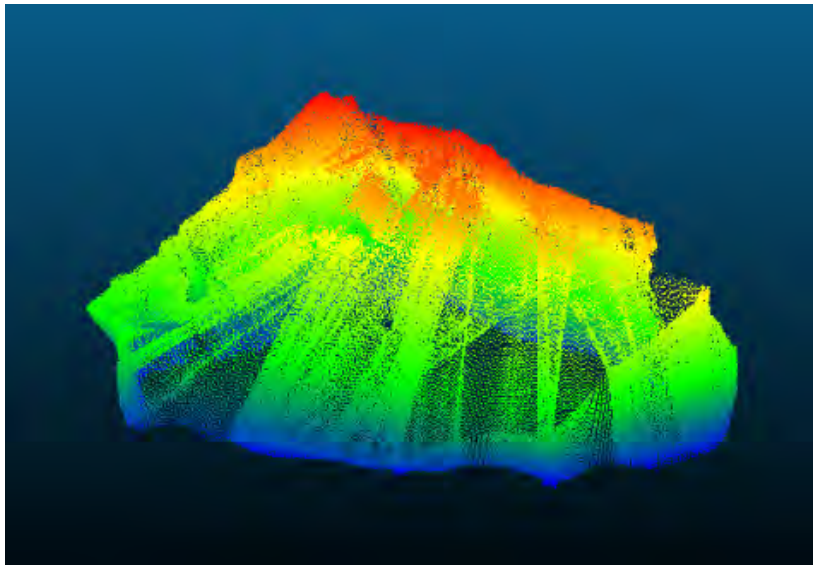
- All icebergs are unstable ‘eventually’
- Smaller icebergs generally yield shorter tracks:
  - Higher chance of waves washing GTU off
- Larger bergs can still have short tracks
  - Placement close to water line
  - Calving/breaking up

Photogrammetry

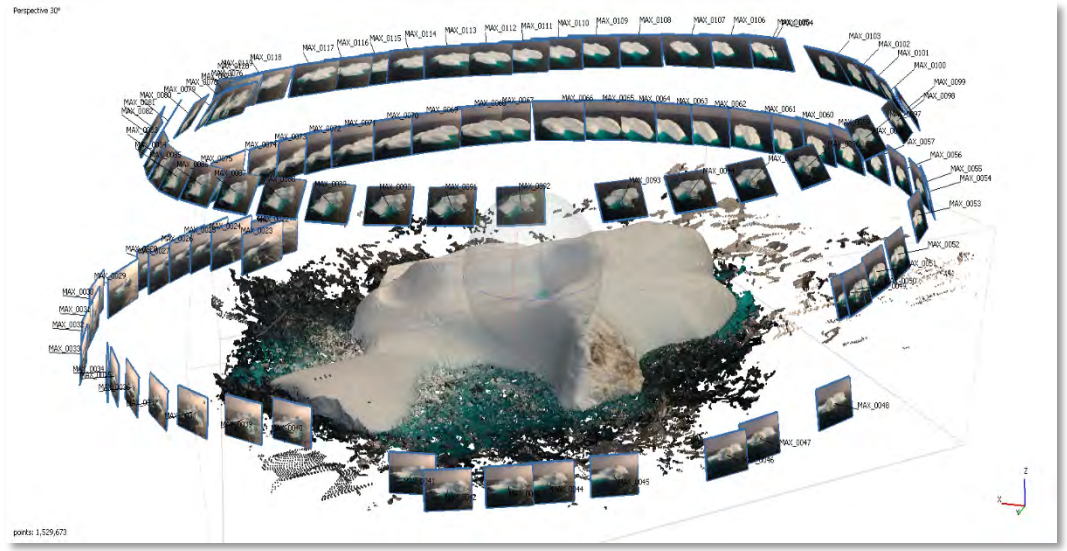
(i) UAV acquired photograph(s)



(ii) Photogrammetric reconstruction



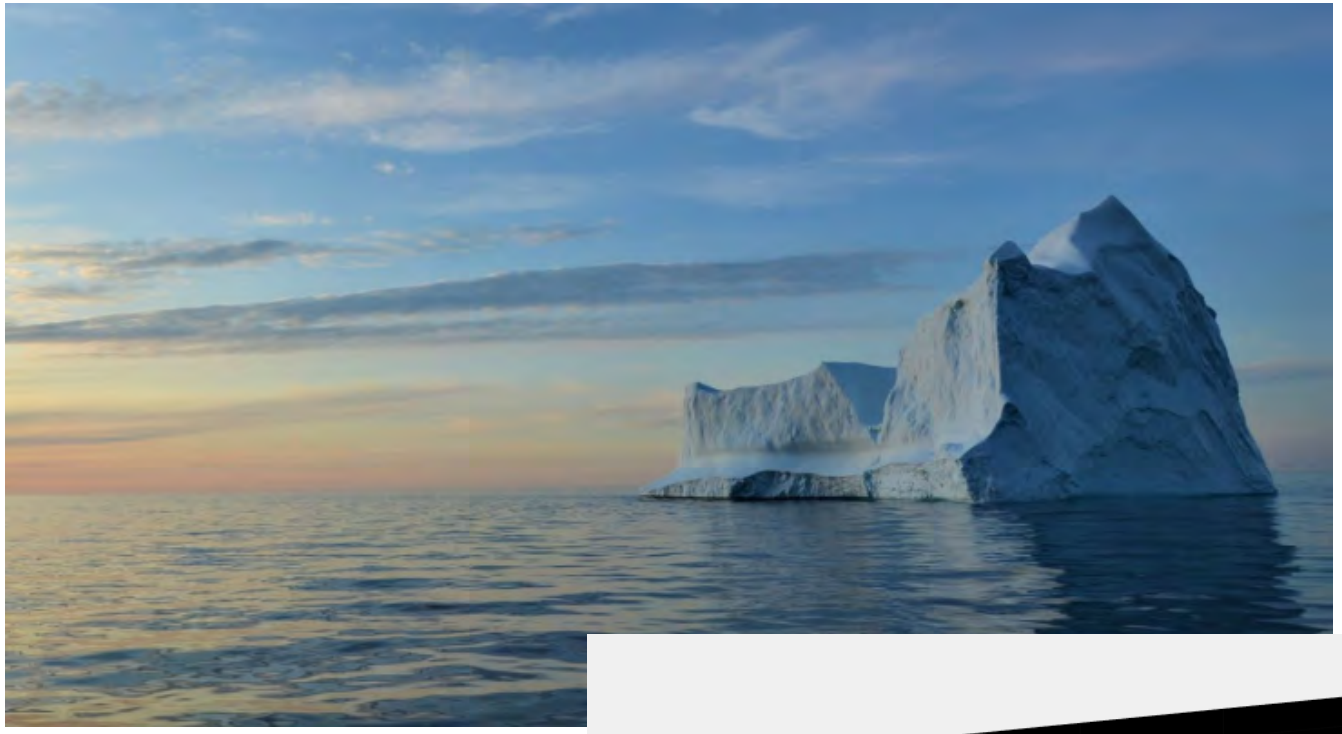
(iii) LiDAR data of the same iceberg



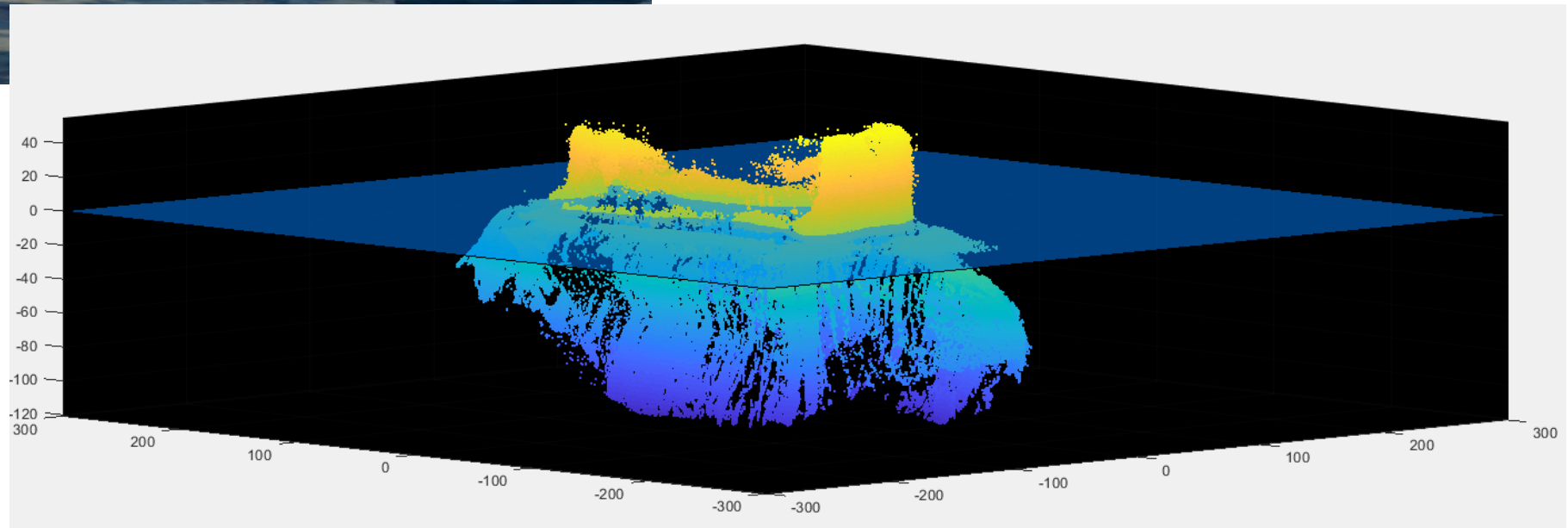
- Acquired using a ‘pro-sumer’ drone ($2000)
- Comparable results to LIDAR assuming reasonable visibility
- ~ 15 mins for a survey (from take-off to landing)

Parameter	Value
Waterline length (m)	73
Waterline width (m)	48
Sail Height (m)	21

2019 Sample Icebergs (Large Icebergs)

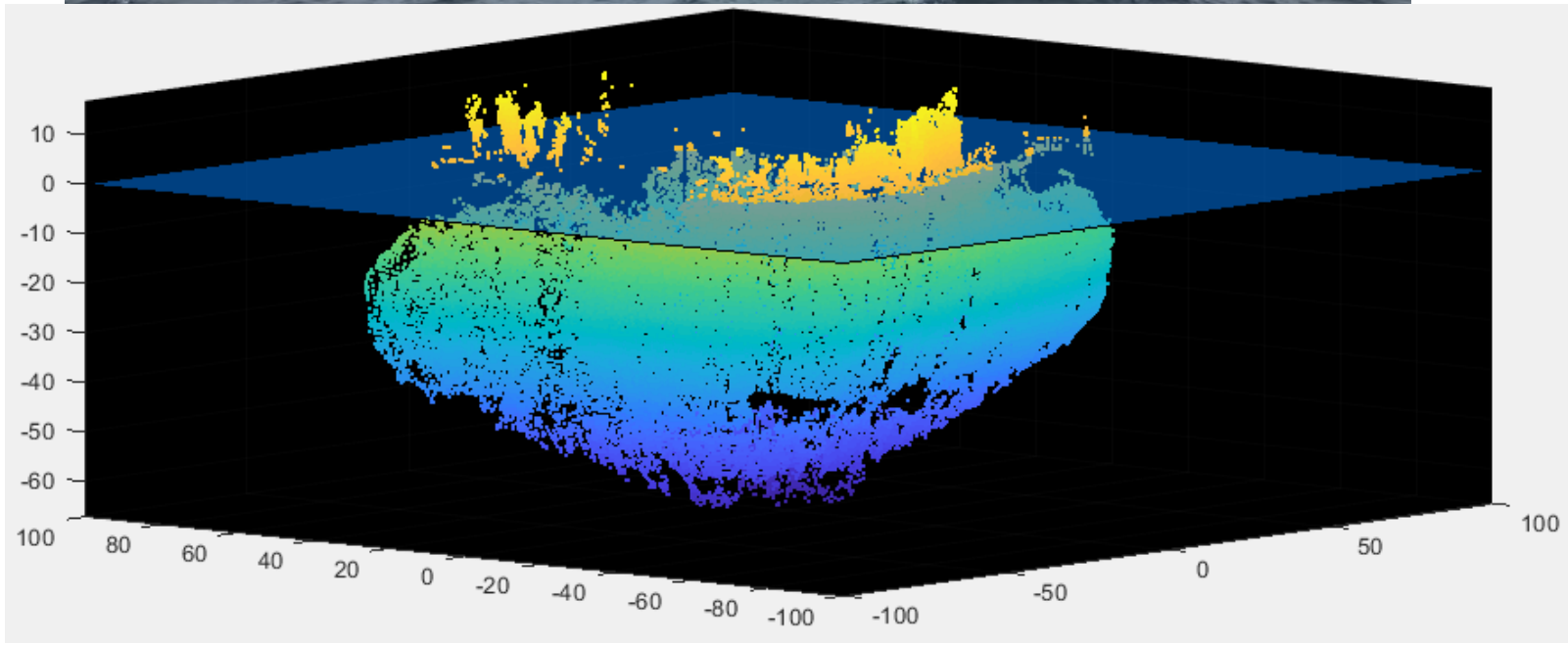


Wave Height	0.5 m
Wind Speed	5 kts
Visibility	Clear
Waterline Length	325 m
Draft	121 m
Height	55 m

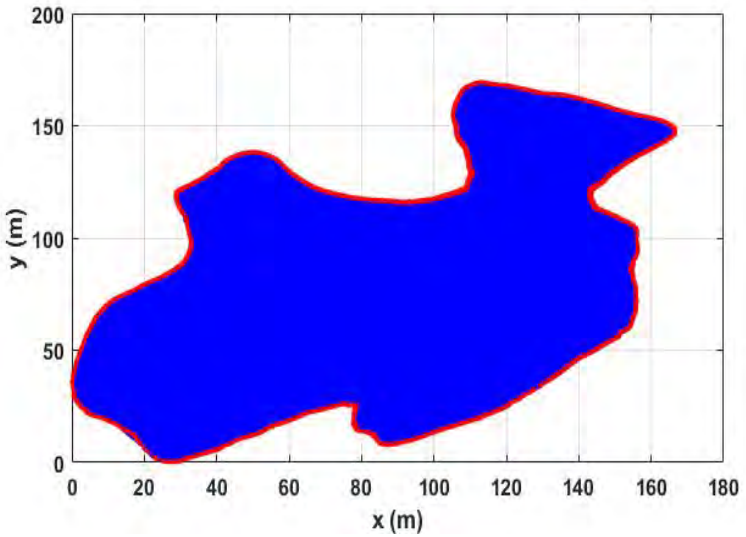


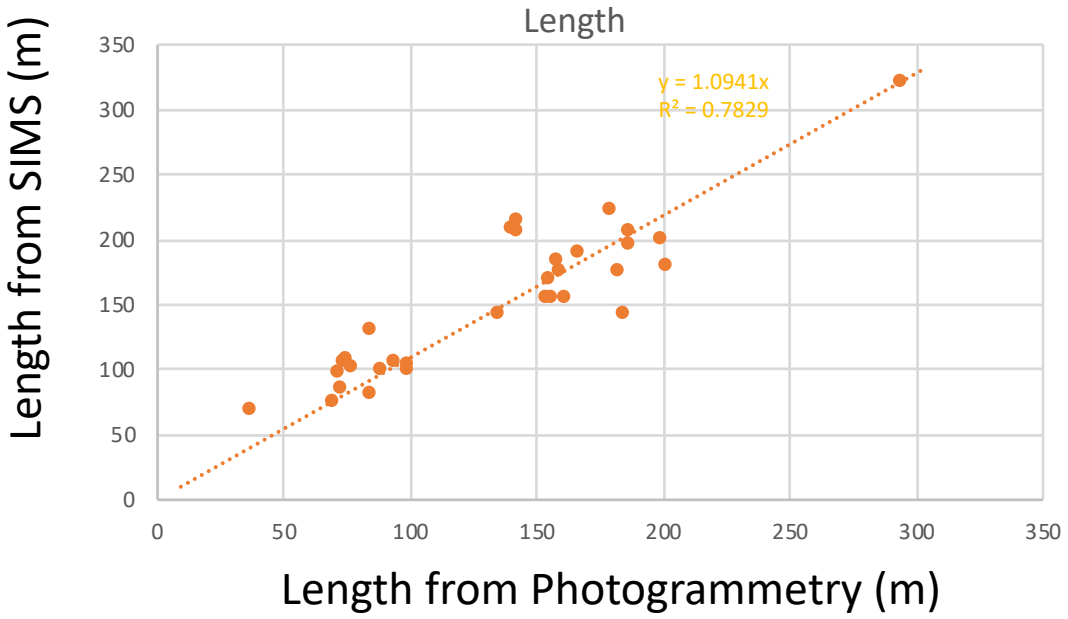
2019 Sample Iceberg (fog, drizzle & 3m seas)

Wave Height	3 m
Wind Speed	10 kts
Visibility	1/4 nautical mile
Waterline Length	143 m
Draft	67 m
Height	17 m

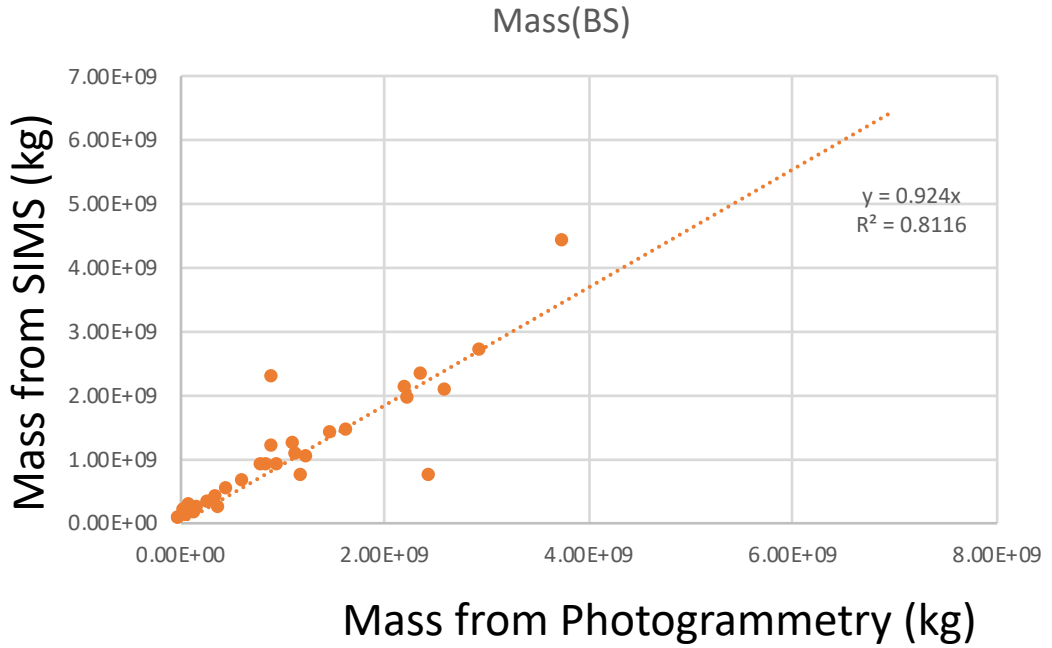


Lengths and mass comparisons

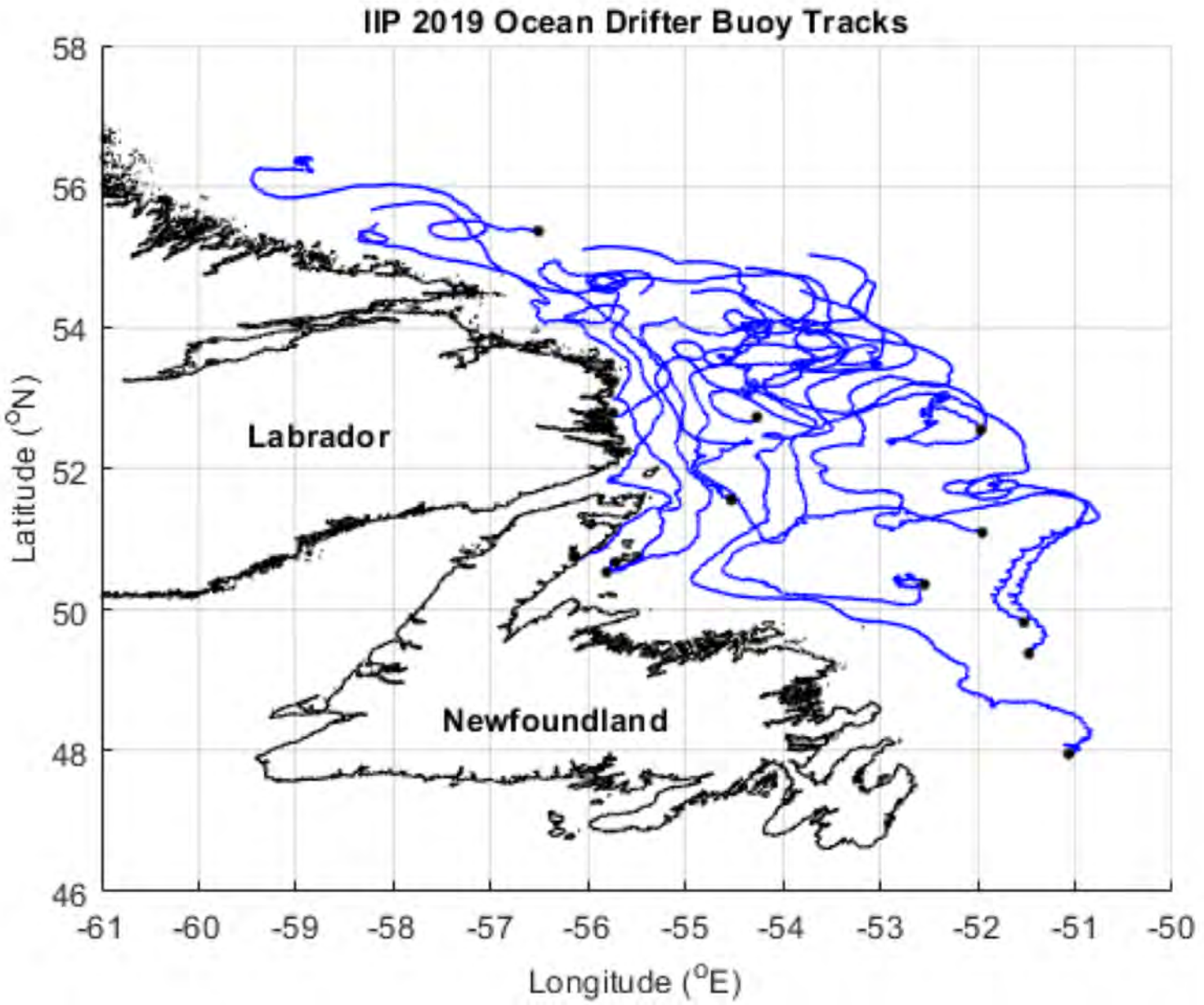




- Length and computed mass from two different measurement techniques allows us to compare results



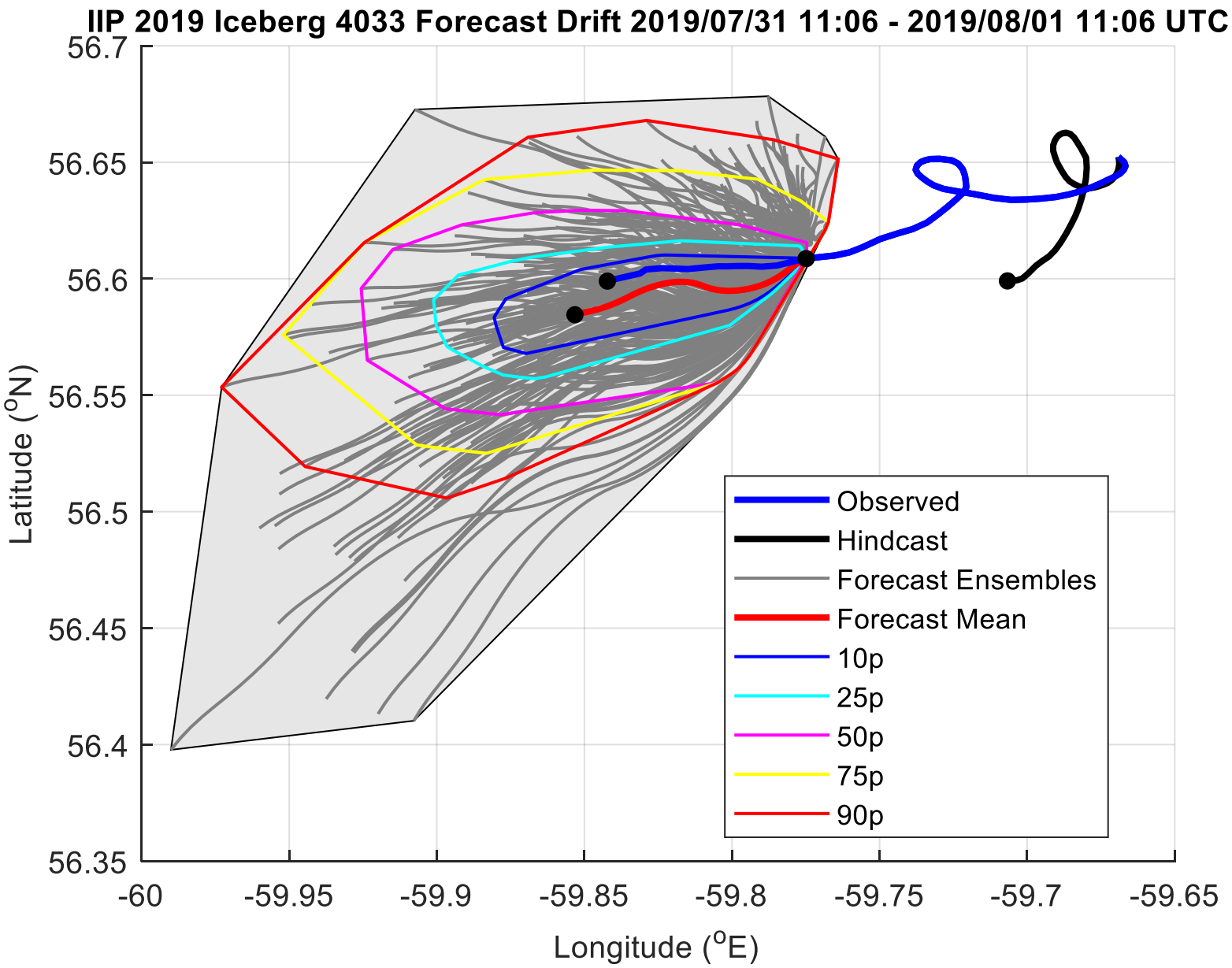
OCEAN DRIFTER BUOY TRACKS



- **13 ocean drifter buoys deployed over 3 voyages**
- **Tracks shown May 31 – August 30**
- **Measured currents at 15 m depth**
- **Used as ocean current input for drift forecasts for nearby icebergs**

Ensemble iceberg drift model

- **107 m blocky iceberg profiled**
- **183 hr track (blue track)**
- **Rred trajectory is ensemble mean.**



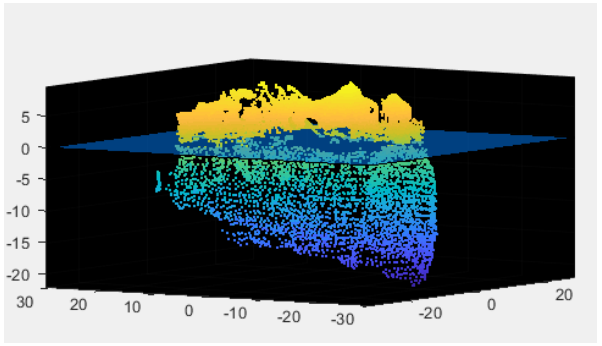
Lessons for UAVs around icebergs (harsh environments)

- Equipment will get damaged and lost, especially if you want to push the wind/swell/visibility, and target difficulty, environment
- Make cost-effective (cheap) nearly sacrificial UAVs

Summary

- Variety of technologies have been developed for surveying and monitoring icebergs
- Integrated LiDAR/Multibeam + associated processing chain is being used to rapidly (about 20 mins) generate 3D iceberg reconstructions
- Custom built UAVs has been used to deploy small, cost effective GPS/Iridium trackers:
- Commercial off-the-shelf UAVs have been used successfully for photogrammetric reconstructions
- Iceberg data, tracks and current data is being integrated into (amongst other things) ensemble drift predictions and probabilistic iceberg load tools
- UAVs need to be ‘sacrificial’ for harsh environments
- Working on refining the system to increase smaller iceberg GPS track dataset
- Planning another campaign, likely 2021, season to gather more icebergs and oceanographic data

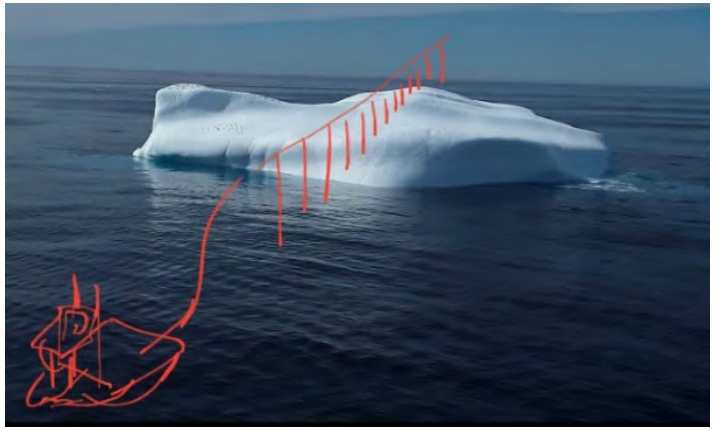
Thank you for your attention

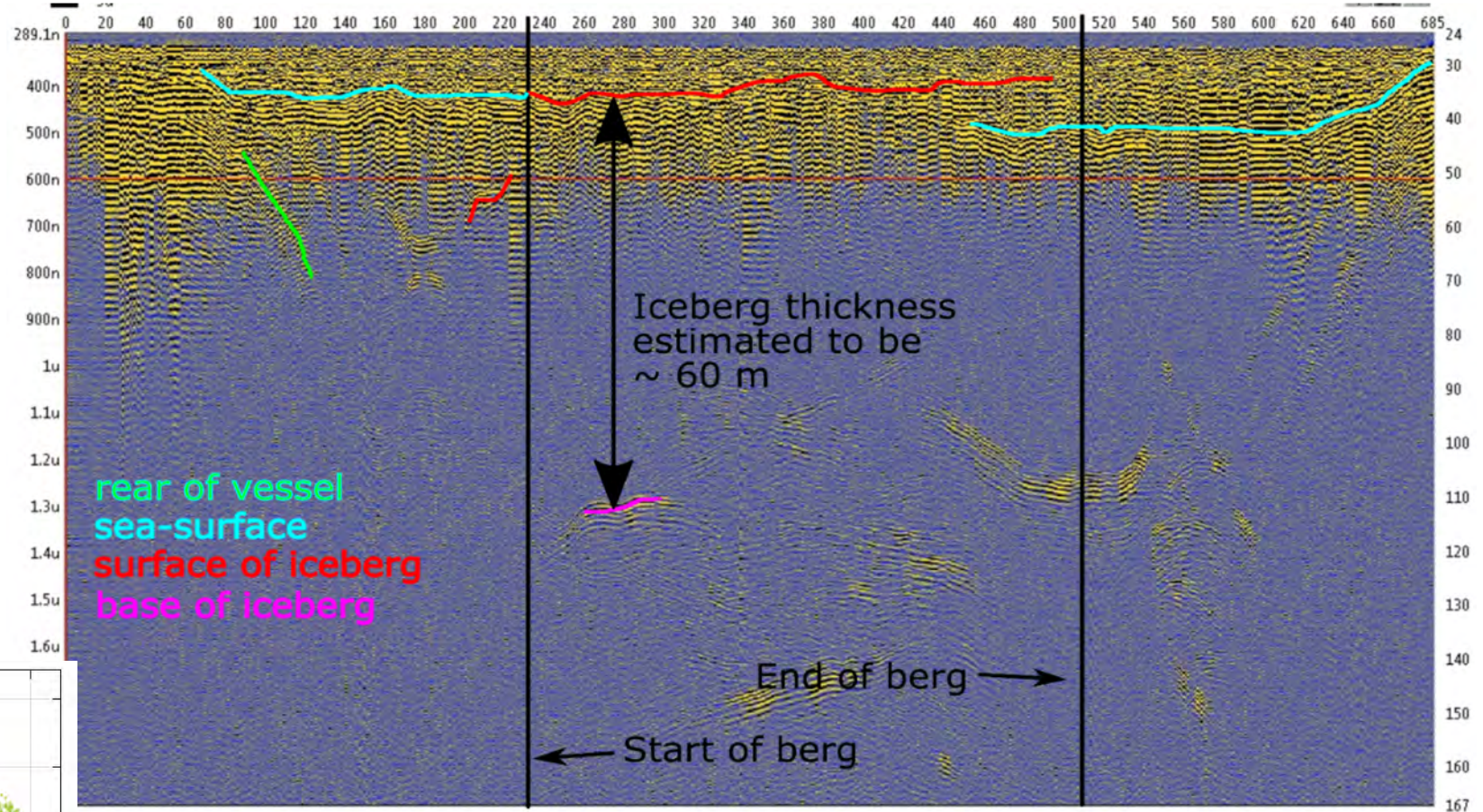


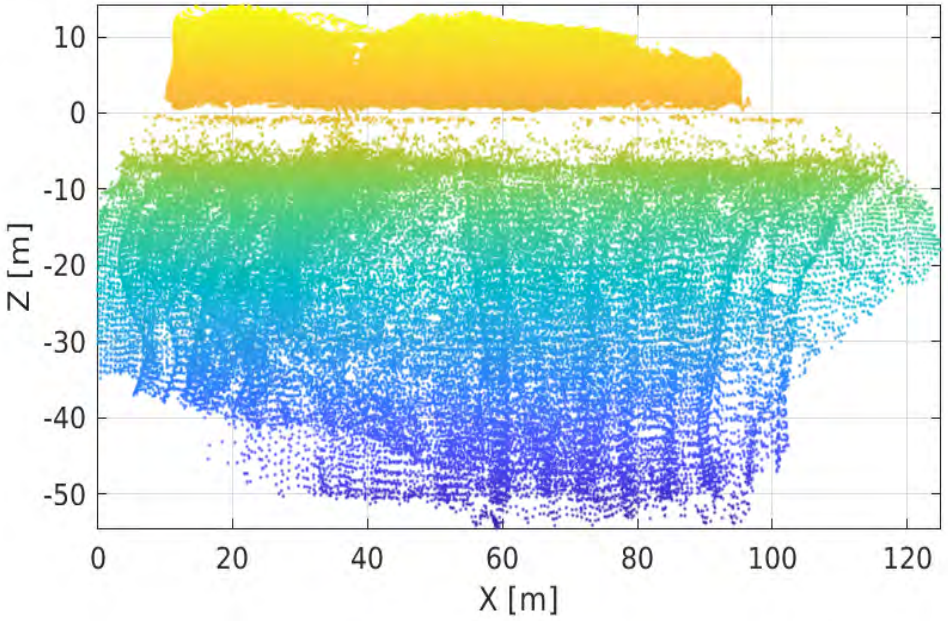
UAV mounted Ice Penetrating Radar

- IPR is a customized version of a radar used for Glacier surveying
- Antenna design is the limiting factor
  - Operates at 50 MHz
  - 50 m penetration depth
  - Each arm of antenna is 86 cm
  - Separation distance between Tx and Rx of about 60 cm
- Heavy Lift UAV developed around the antenna

IPR sample data







- LiDAR/multi-beam dataset of same berg