

Freeboard and HEM sea ice thickness measurements in 2005, 2006 and 2008

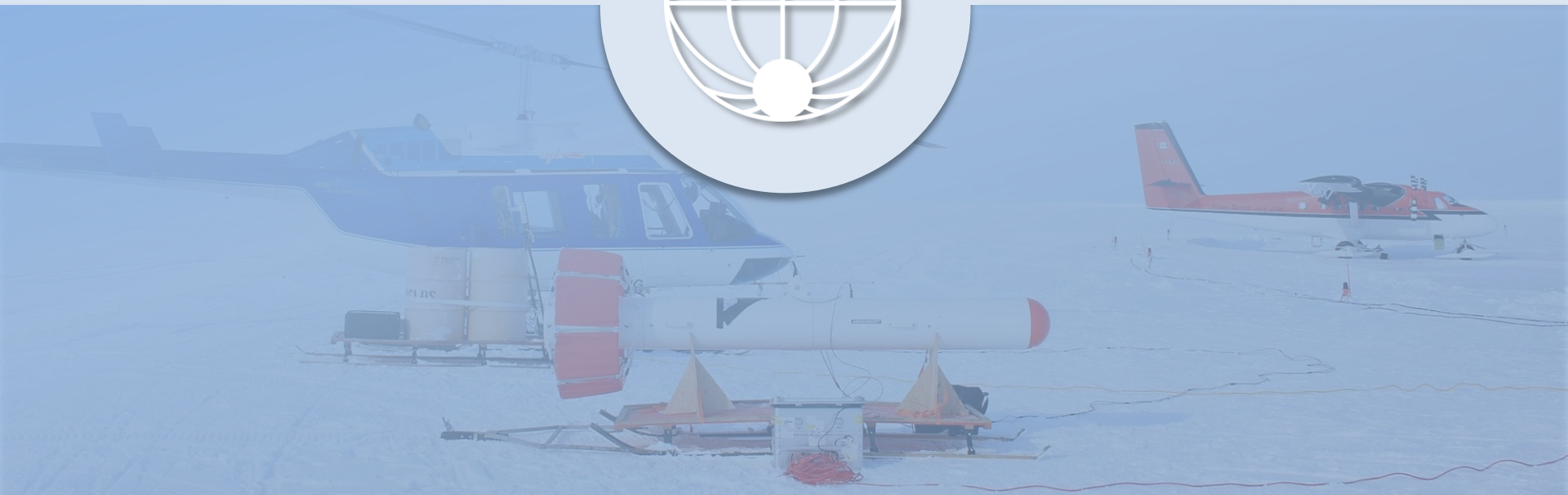
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³ DTU Space, Copenhagen

⁴ DMI, Copenhagen



Airborne Freeboard Measurements

Radar / Laser

- Radar Penetration on Arctic Sea Ice

Surface Properties

- Interpretation of Freeboard retrieval



Independent Sea Ice Thickness Estimates

Helicopter EM (HEM)



Comparison of Datasets

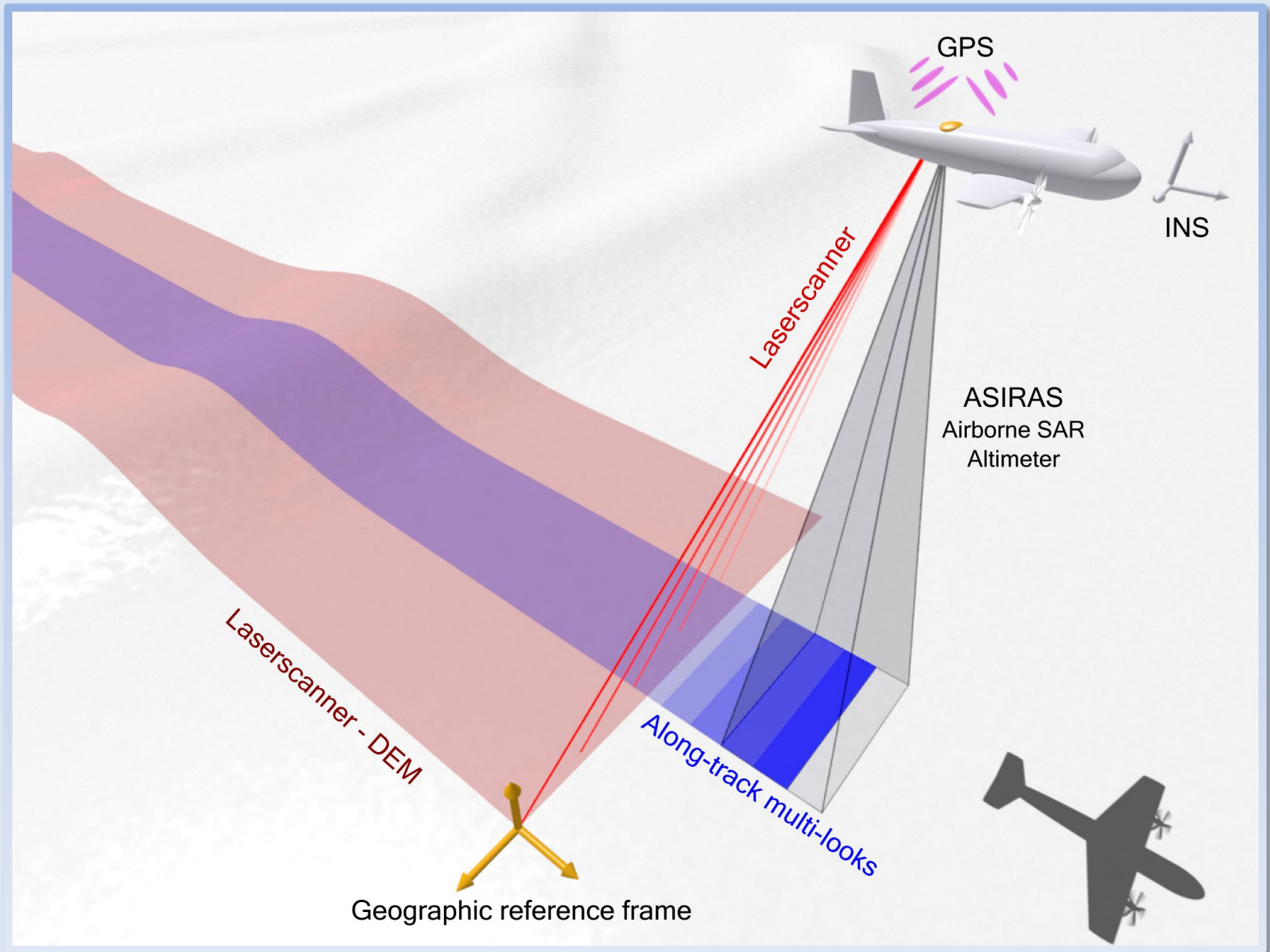
Statistical

- Sea Ice Thickness Distribution

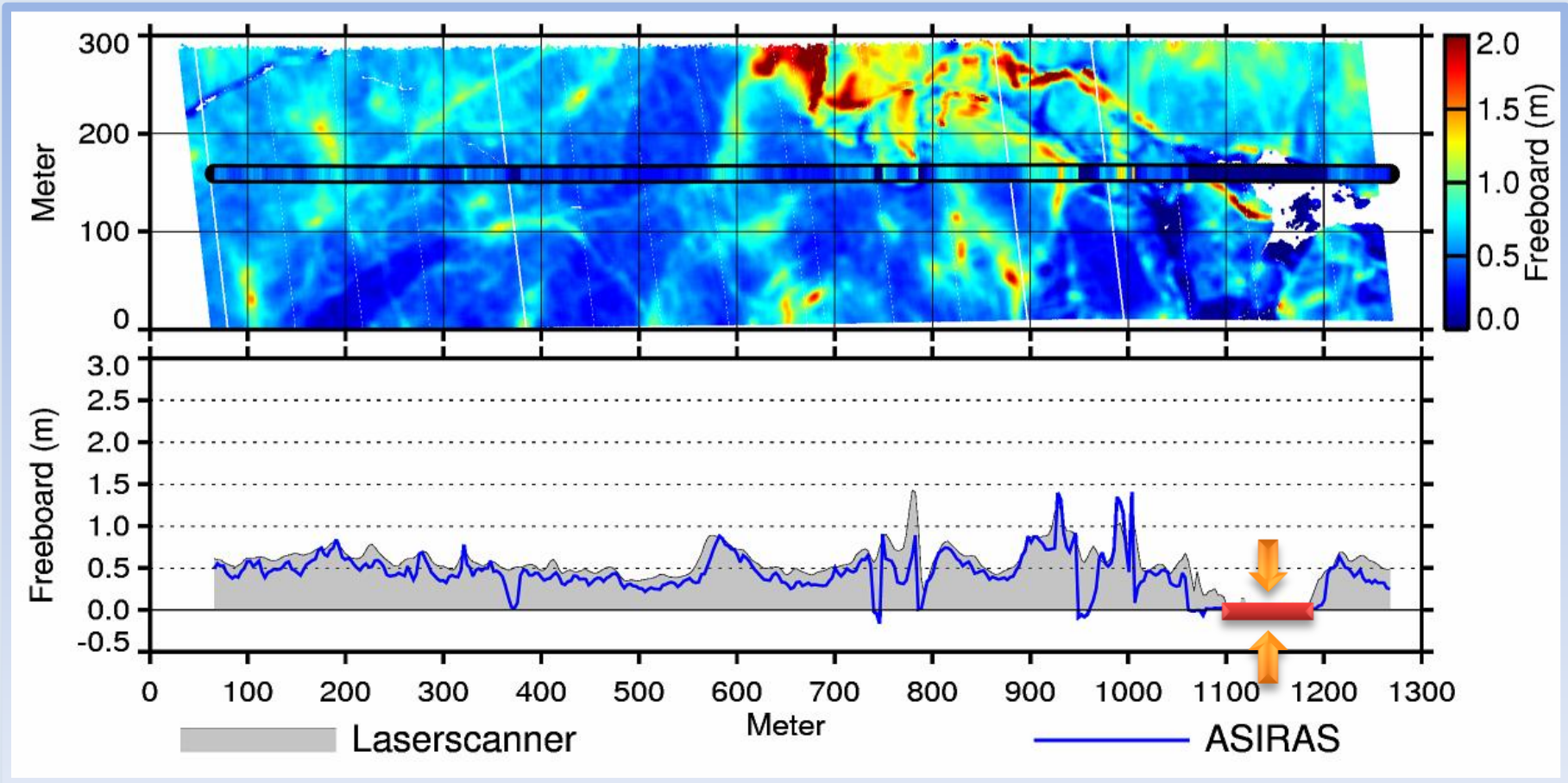
Direct

- Freeboard to Thickness Ratio

Freeboard: Aircraft Instrumentation

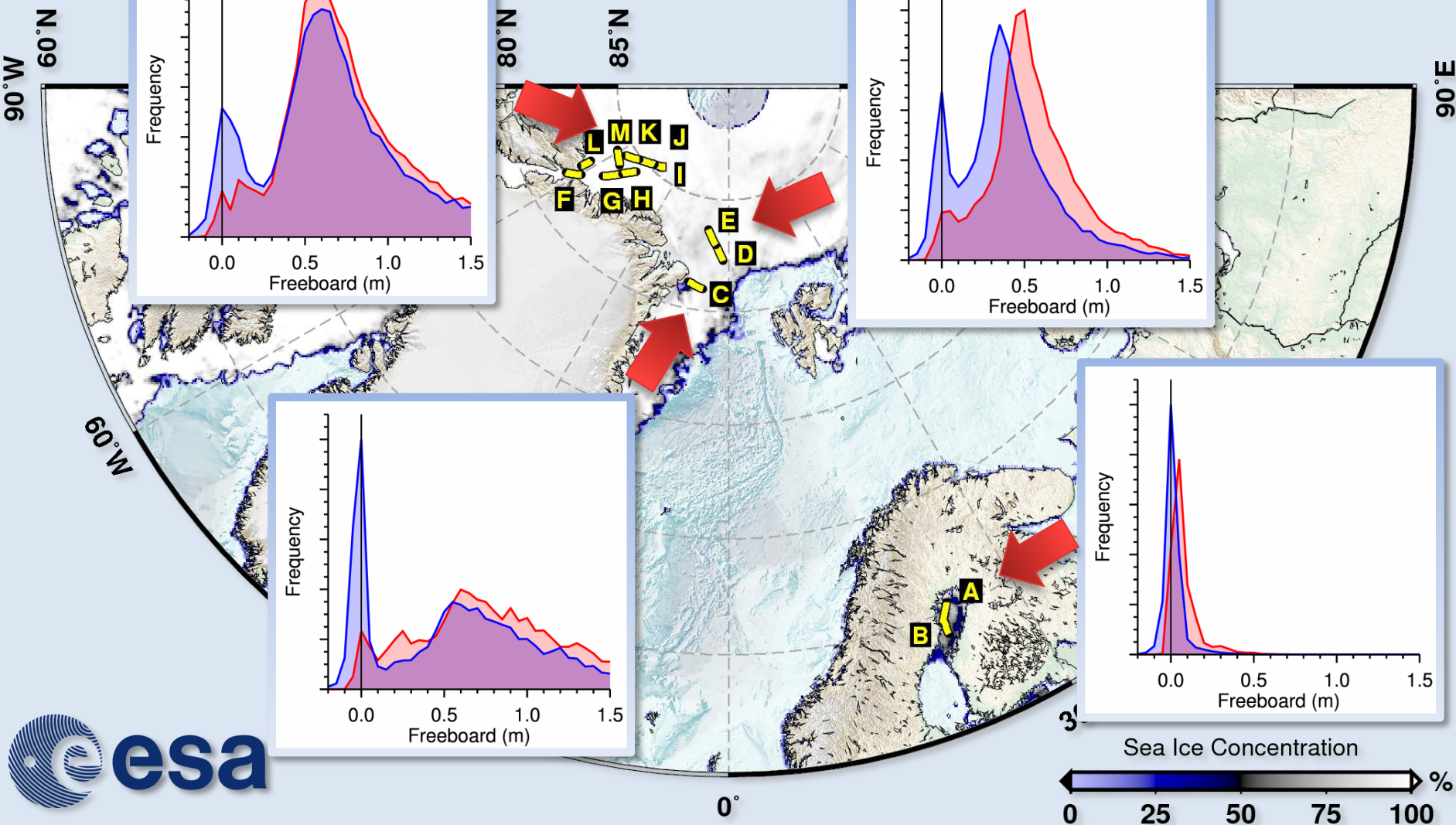


Freeboard retrieval



- TSRA Retracker
- Gridding of Laserscanner on ASIRAS footprint
- Manual detection of open water
 - Correction of Radar – Laser offset
 - Freeboard reference

Laser- and Radarfreeboard

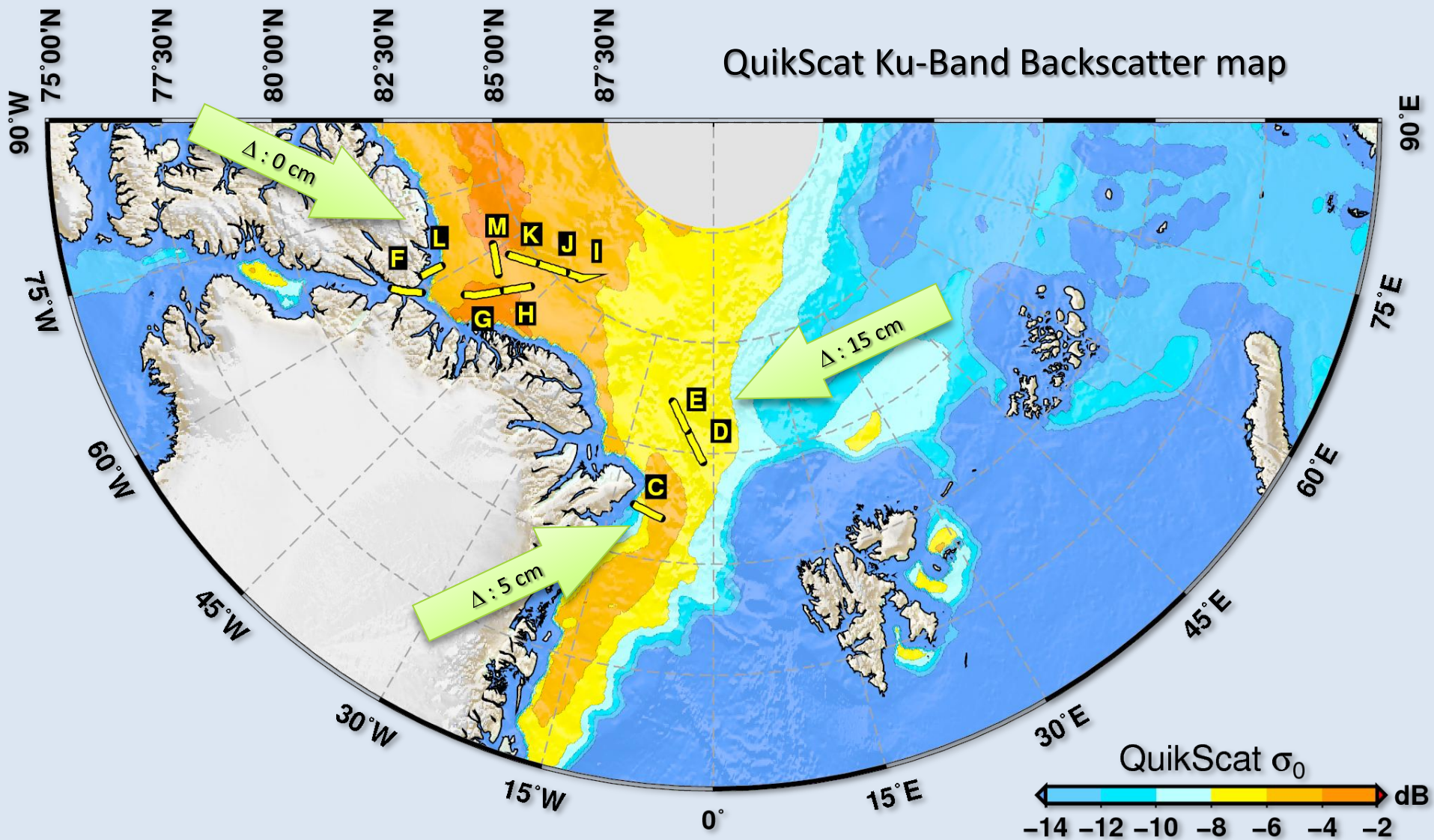


CryoVEx
2006 & 2008

CryoVEx
2005



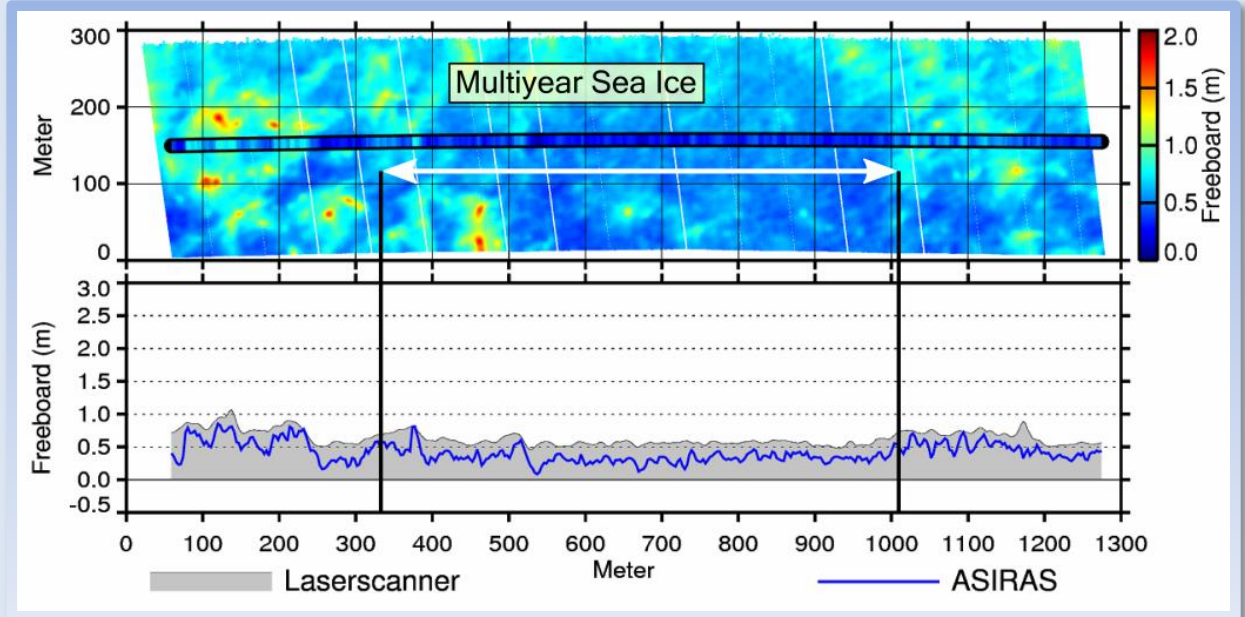
Regional Variations of Radar Snow Penetration (2006)



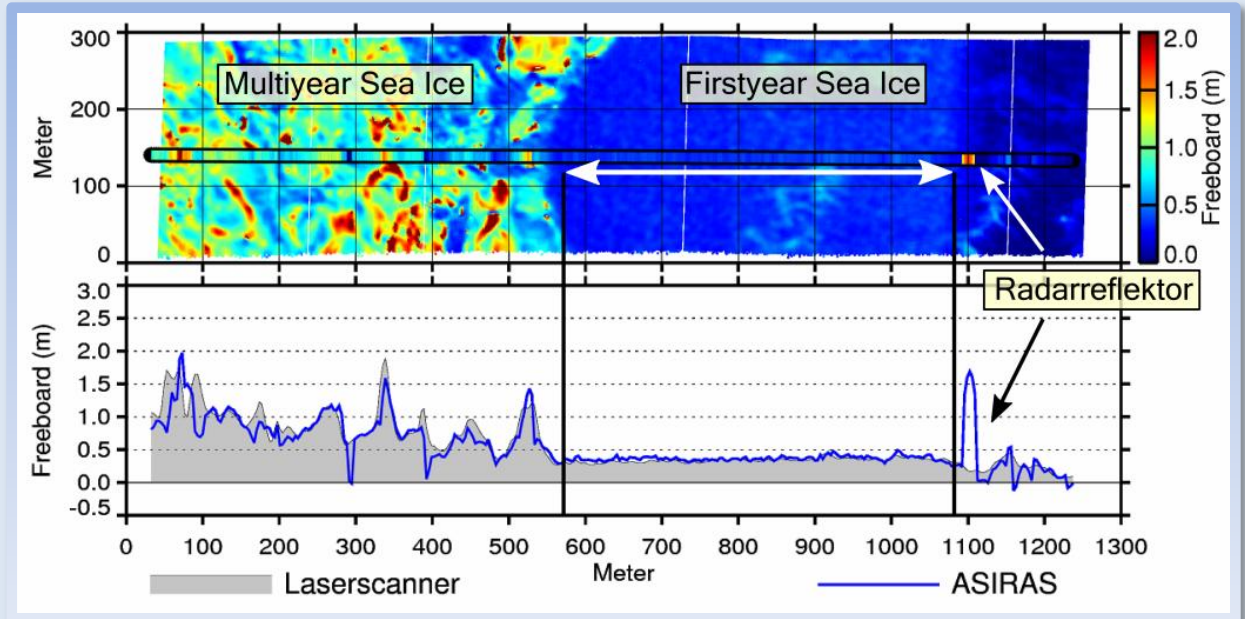
Δ = Mode Laser – Mode Freeboard

Radar Penetration over level ice

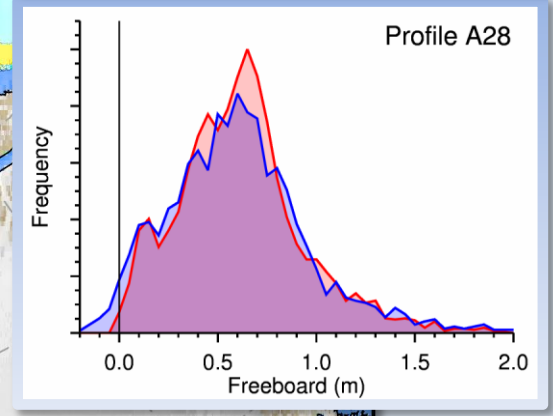
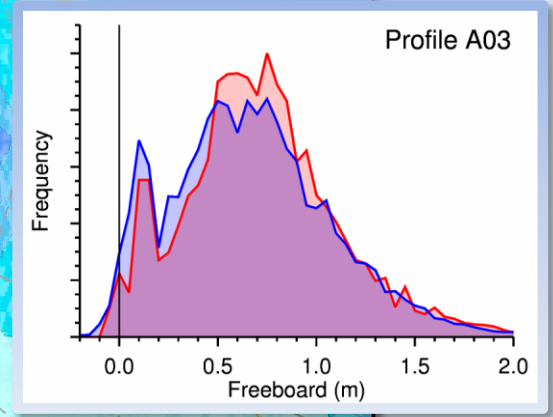
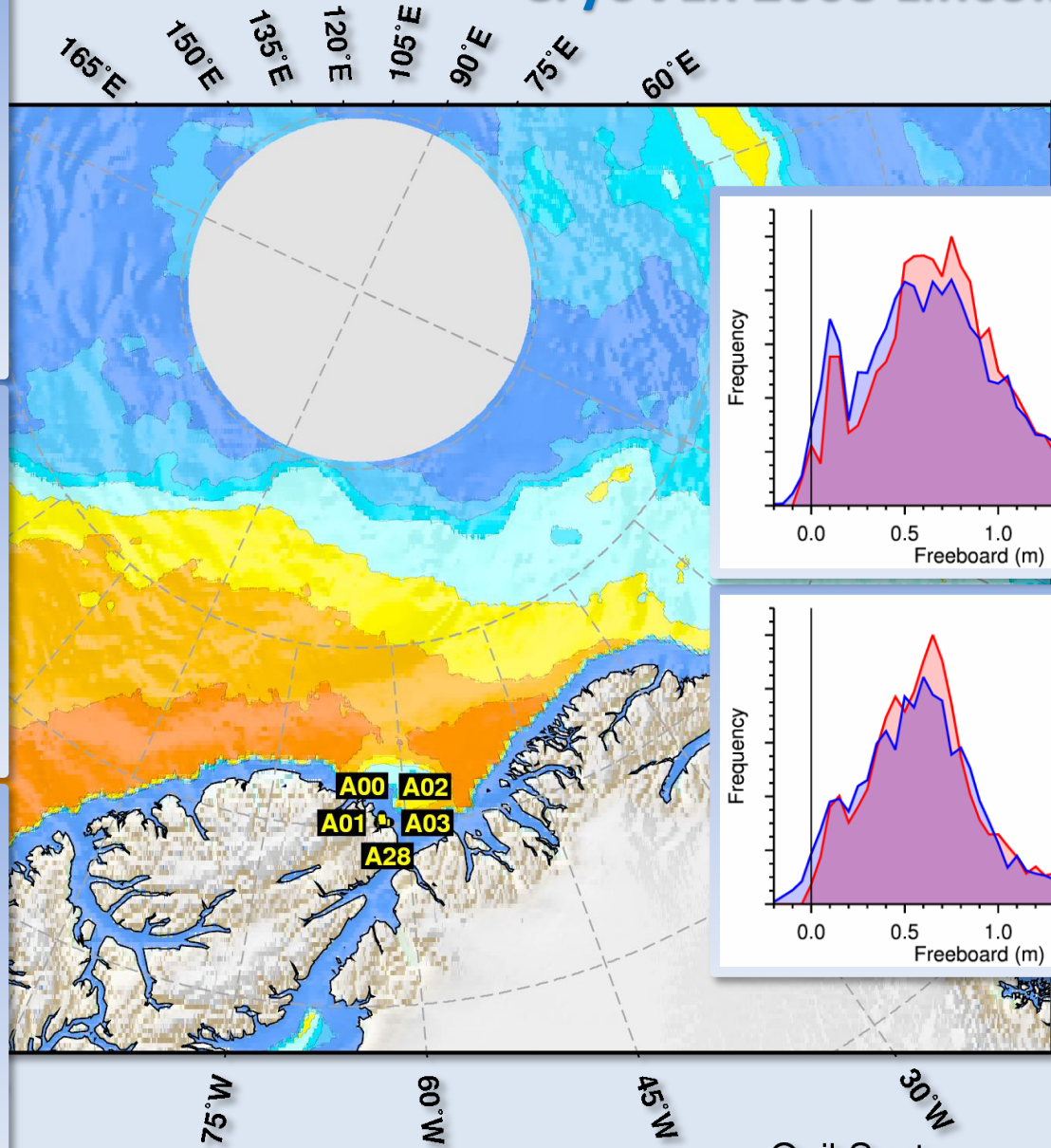
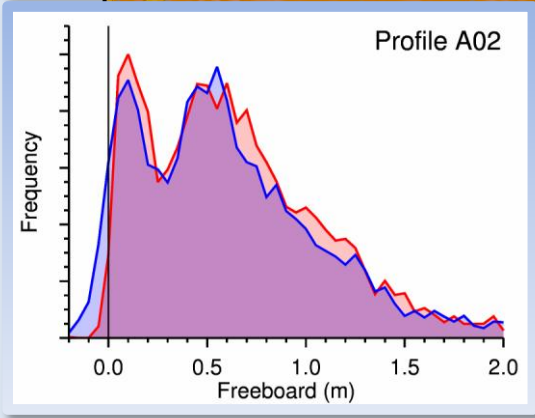
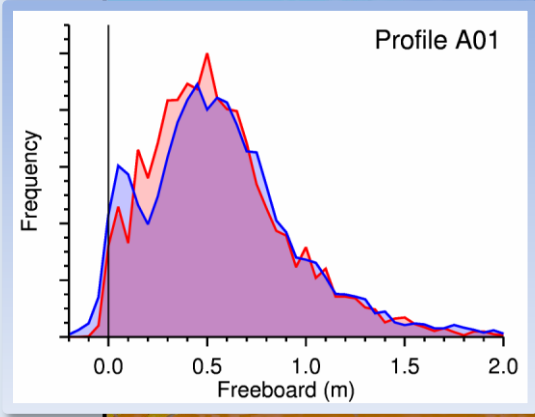
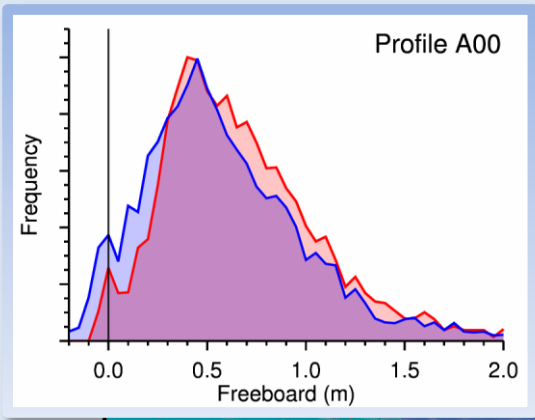
Greenland Sea



Lincoln Sea

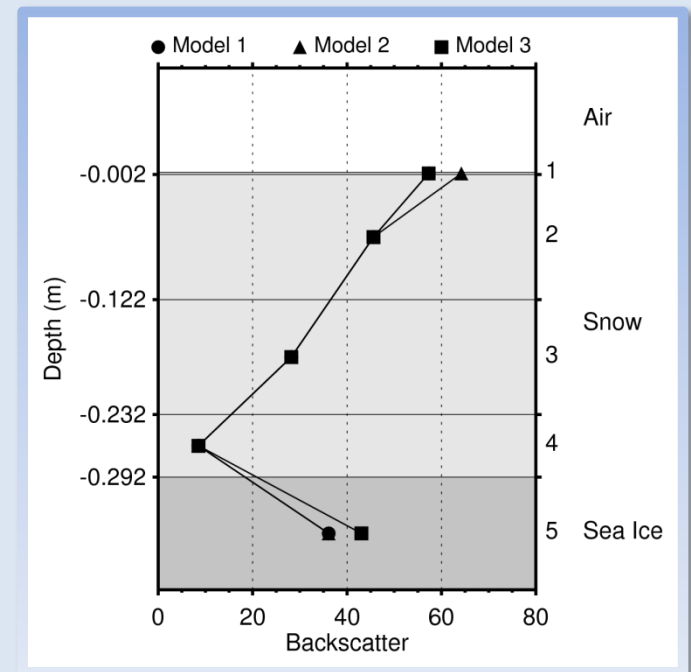


CryoVEx 2088 Lincoln Sea

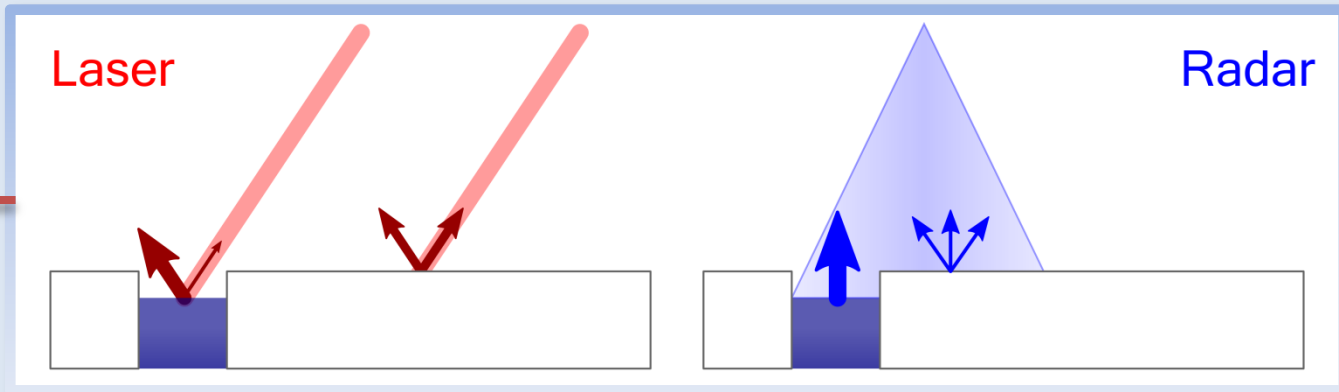
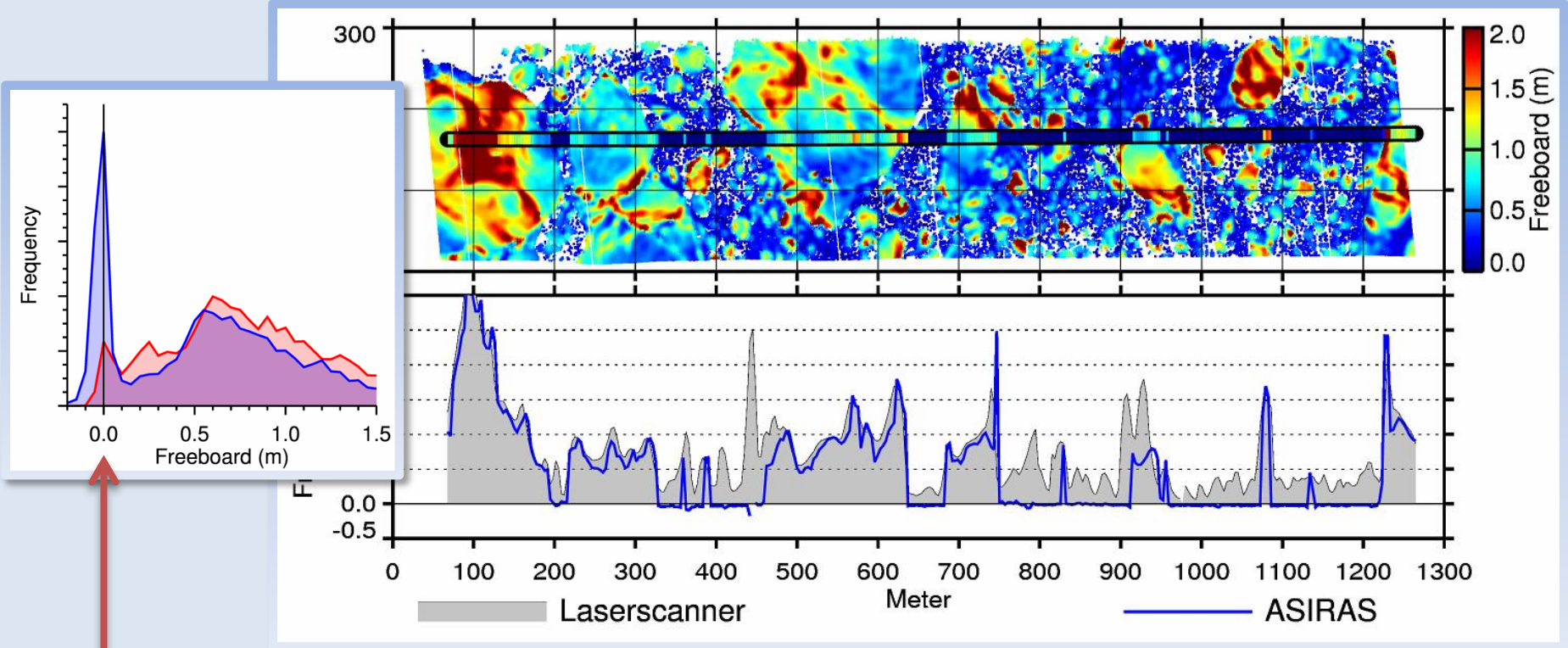


K_u Band Backscatter Model

- Radiative transfer model
 - Tonboe et al. 2006
- Model Initialisation:
 - Snow Pit, CryoVEx 2006
 - First year sea ice, Lincoln Sea
- Model 1 – 3:
Different roughness scenarios
- Backscatter dominated by radiation crust on snow surface



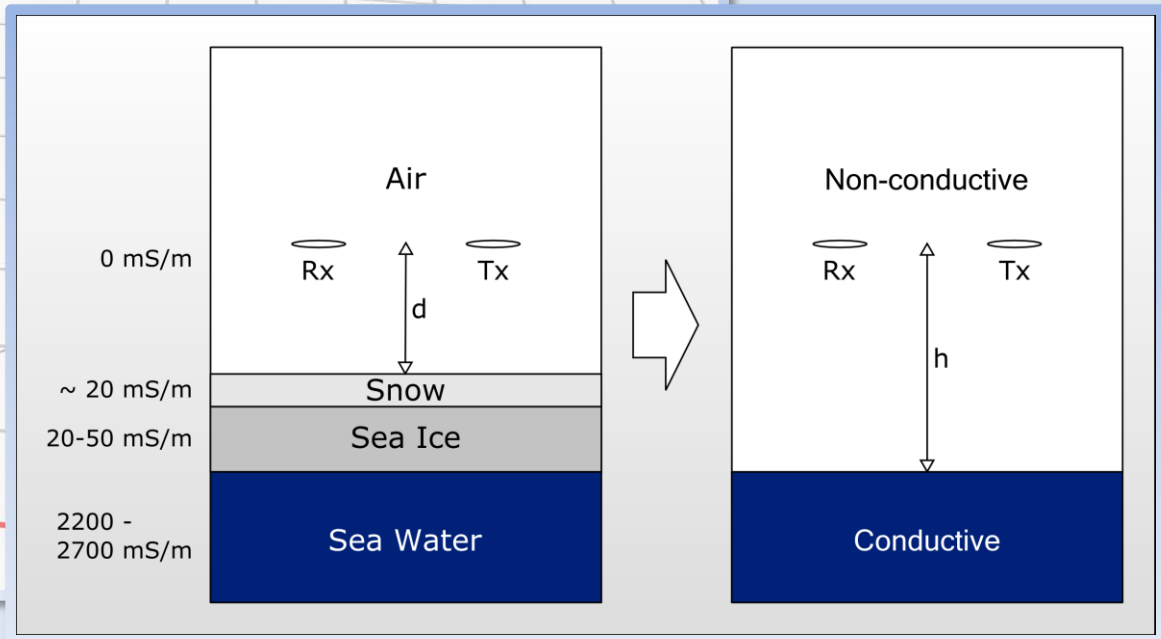
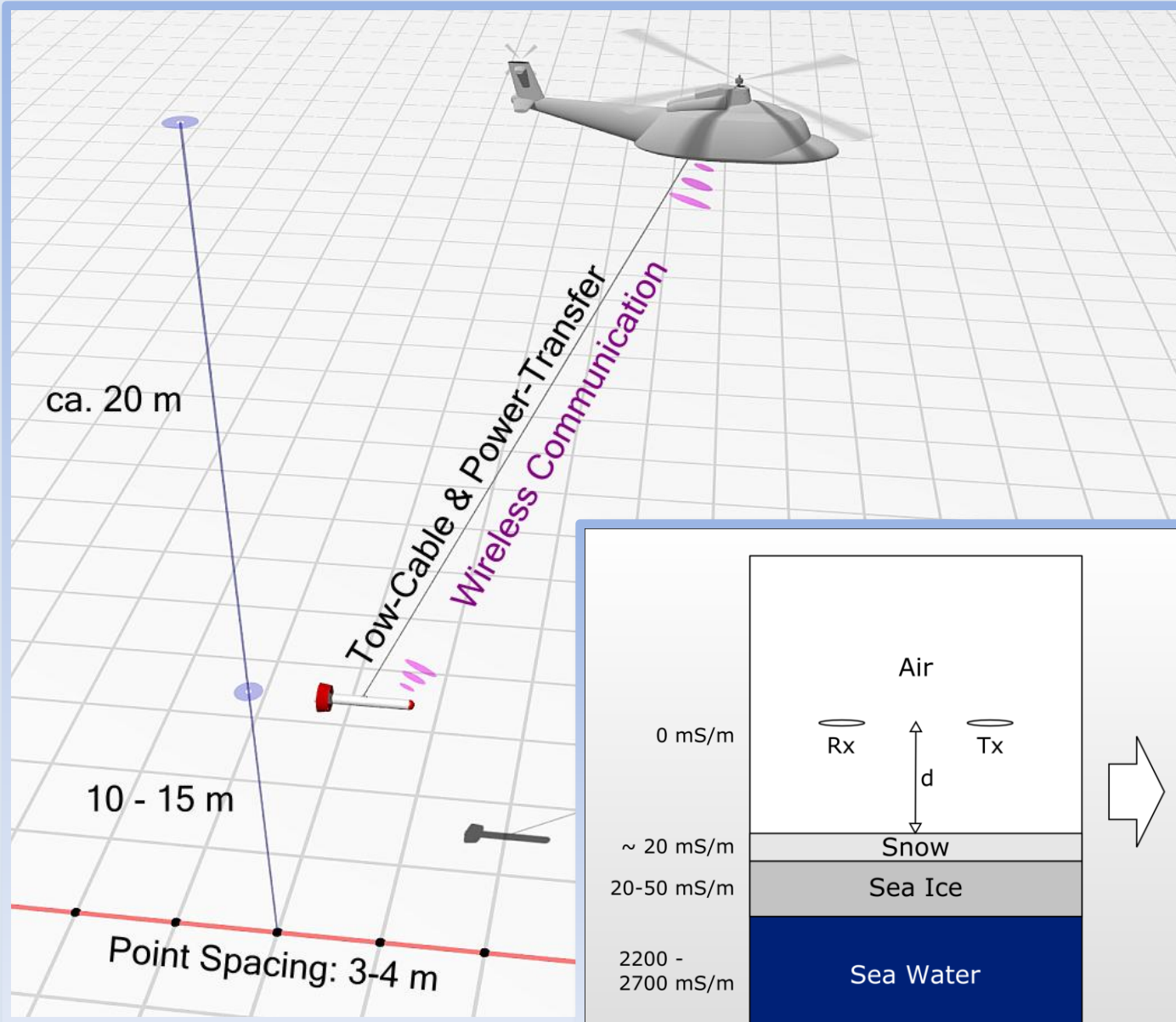
Effect of small floes on Radar freeboard



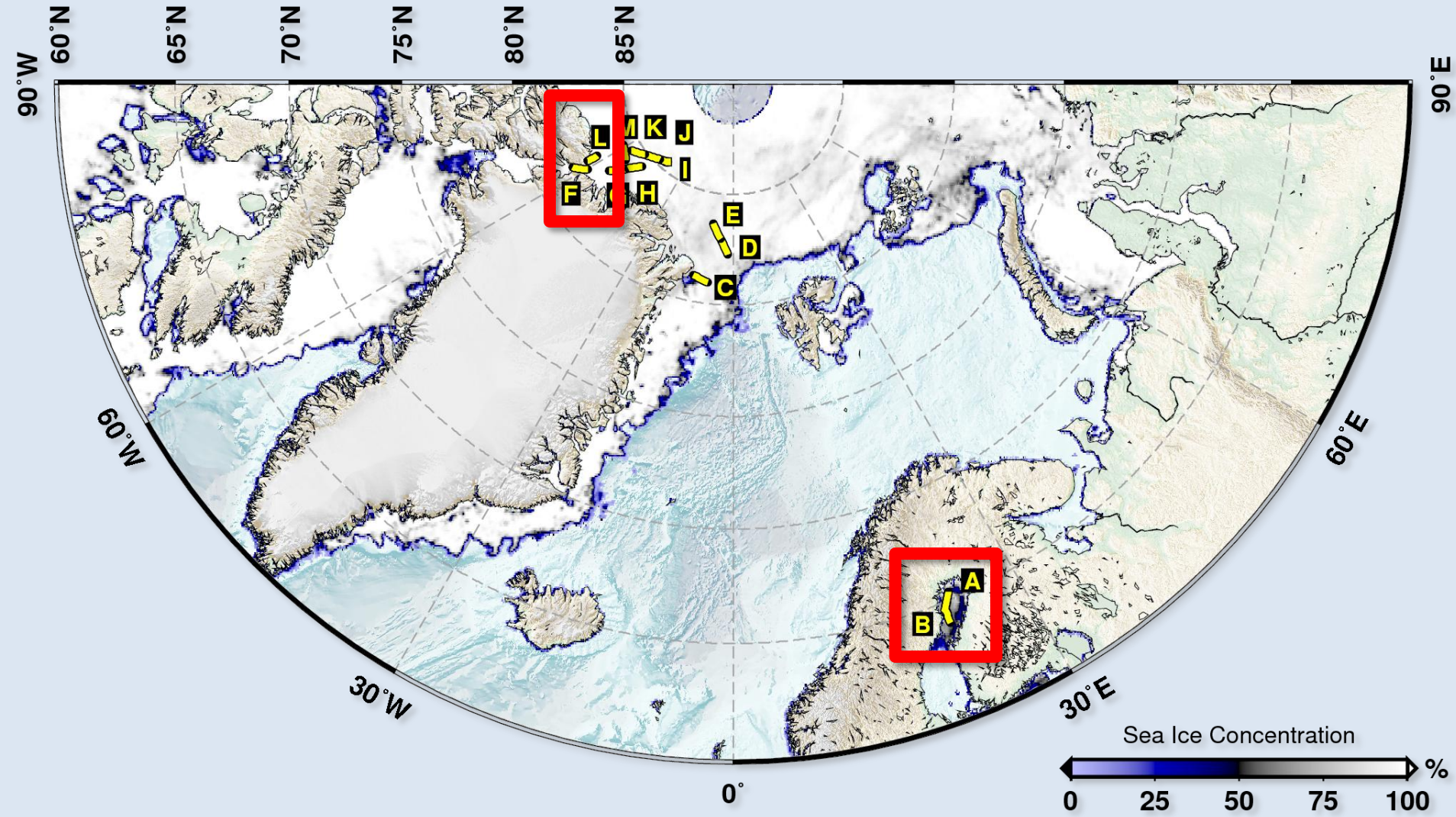
From Freeboard to Sea Ice Thickness



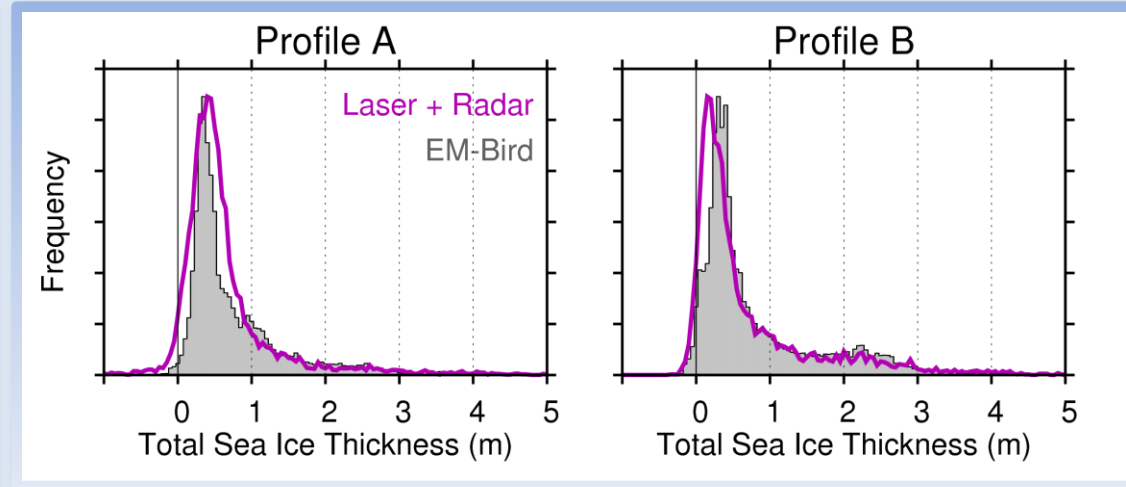
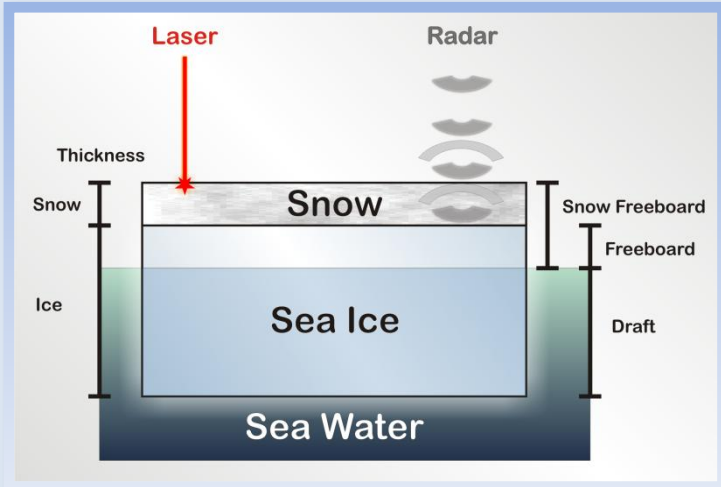
Helicopter EM (HEM)



Total Thickness: HEM vs. Altimetry



Baltic Sea (CryoVEx 2005)

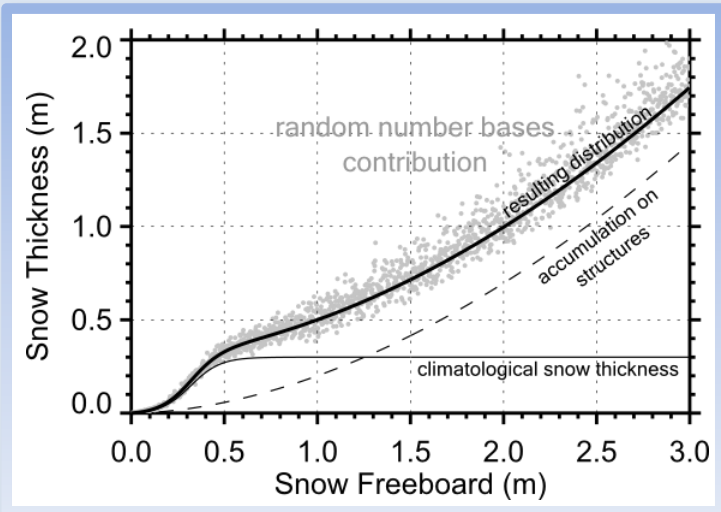
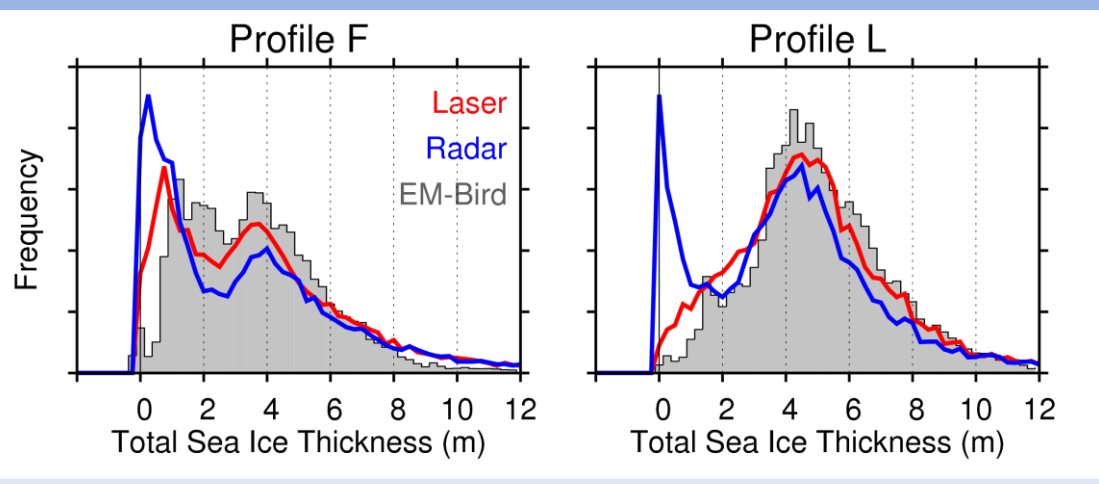
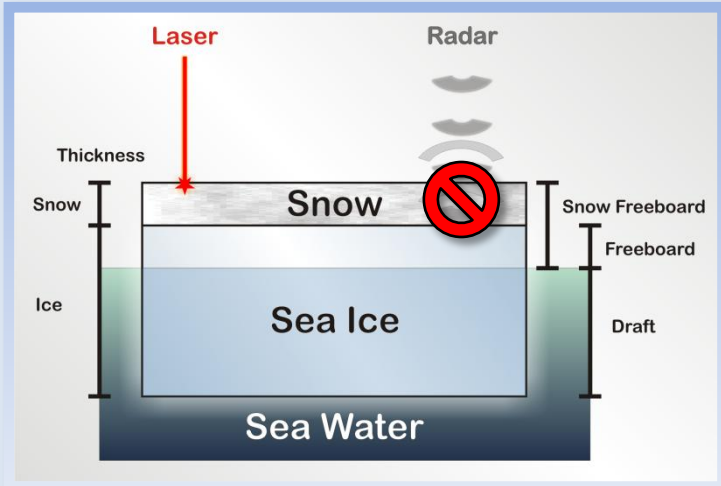


- Pointwise transformation
- Snow Thickness
 - Laser-Radar Difference
- Constant densities
 - Water 1003 kg/m^3
 - Sea ice 900 kg/m^3
 - Snow 280 kg/m^3

Mean Total Thickness (m)

	A	B
EM	0.78	0.83
Laser + Radar	0.78 (+0%)	0.67 (-19%)

Lincoln Sea (CryoVEx 2006)



Mean Total Thickness (m)		
	F	L
EM	3.7	5.3
Laser	3.8 (+2.7%)	5.0 (-5.6%)
Radar	3.5 (-5.6%)	4.4 (-17.0%)

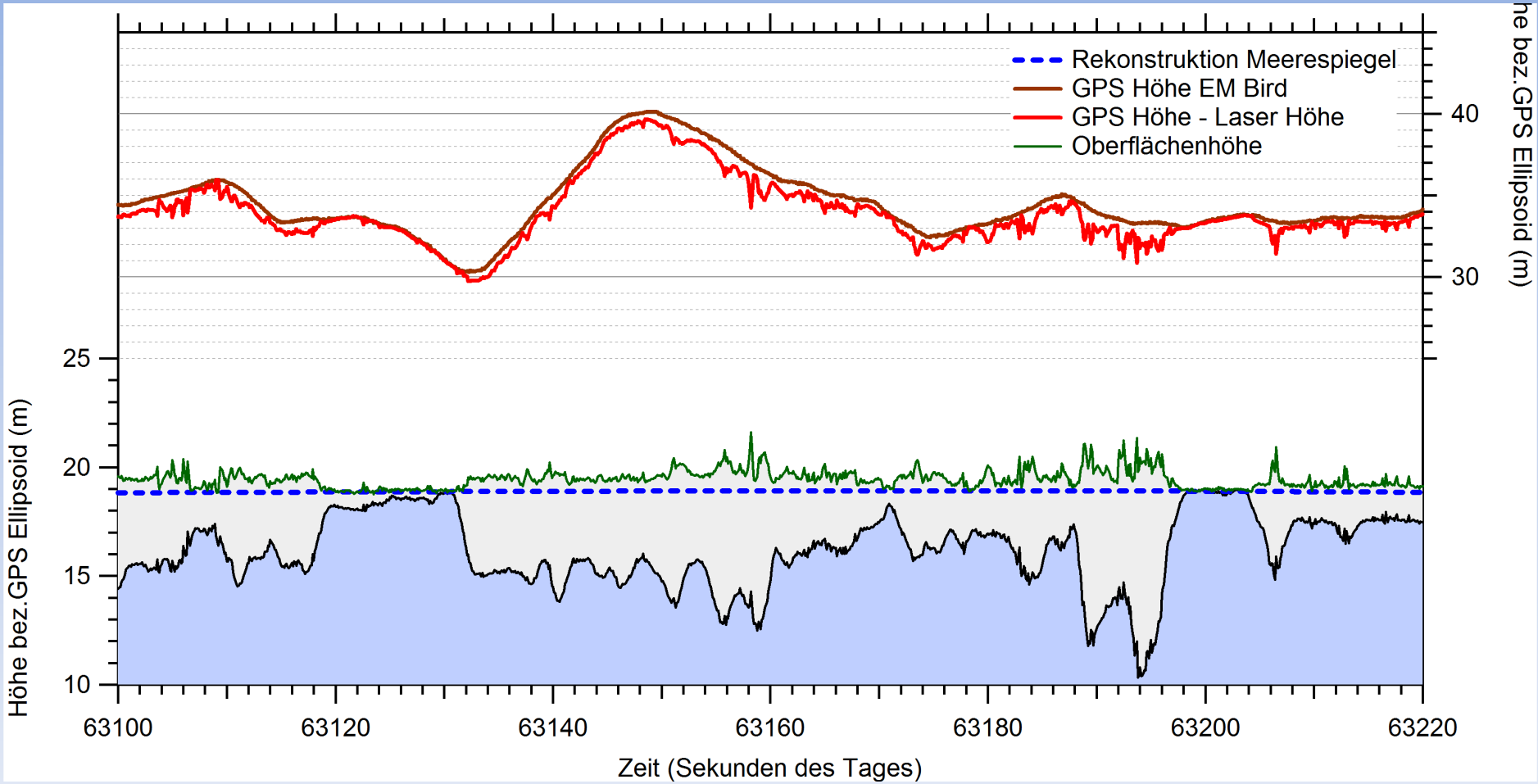
Density Water: 1024 kg/m³

Density Sea Ice: 925 kg/m³

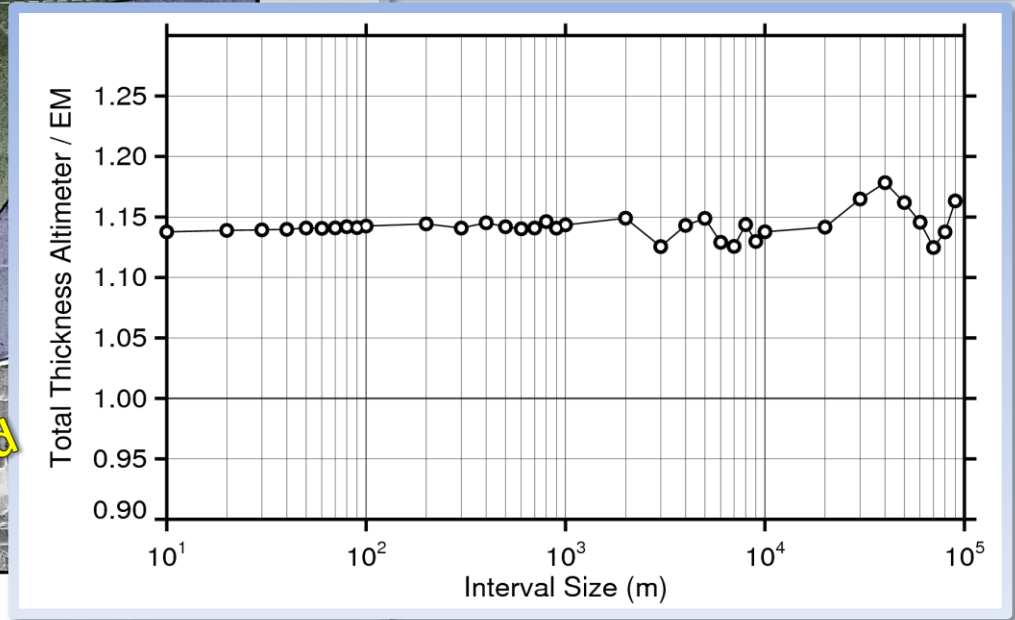
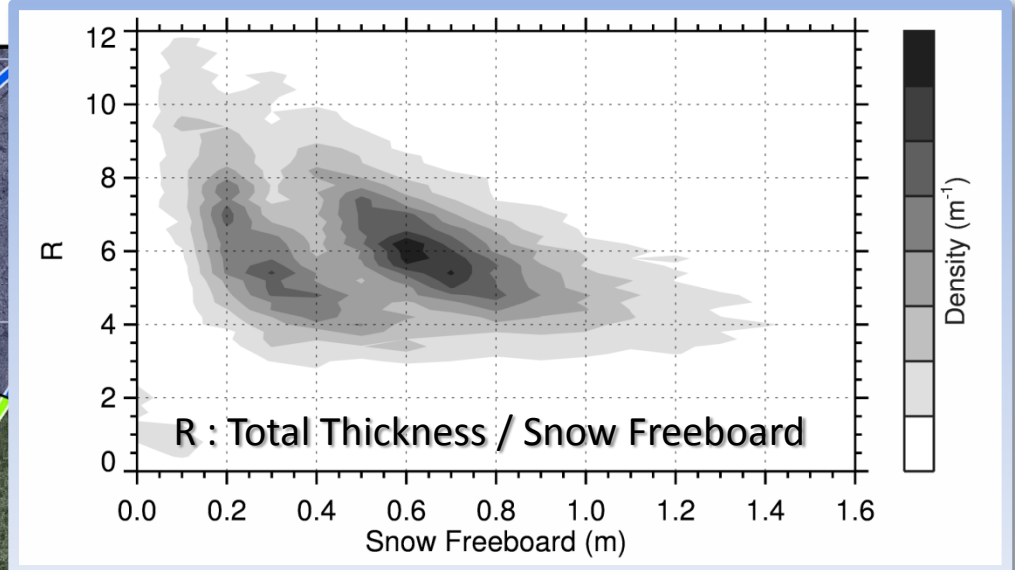
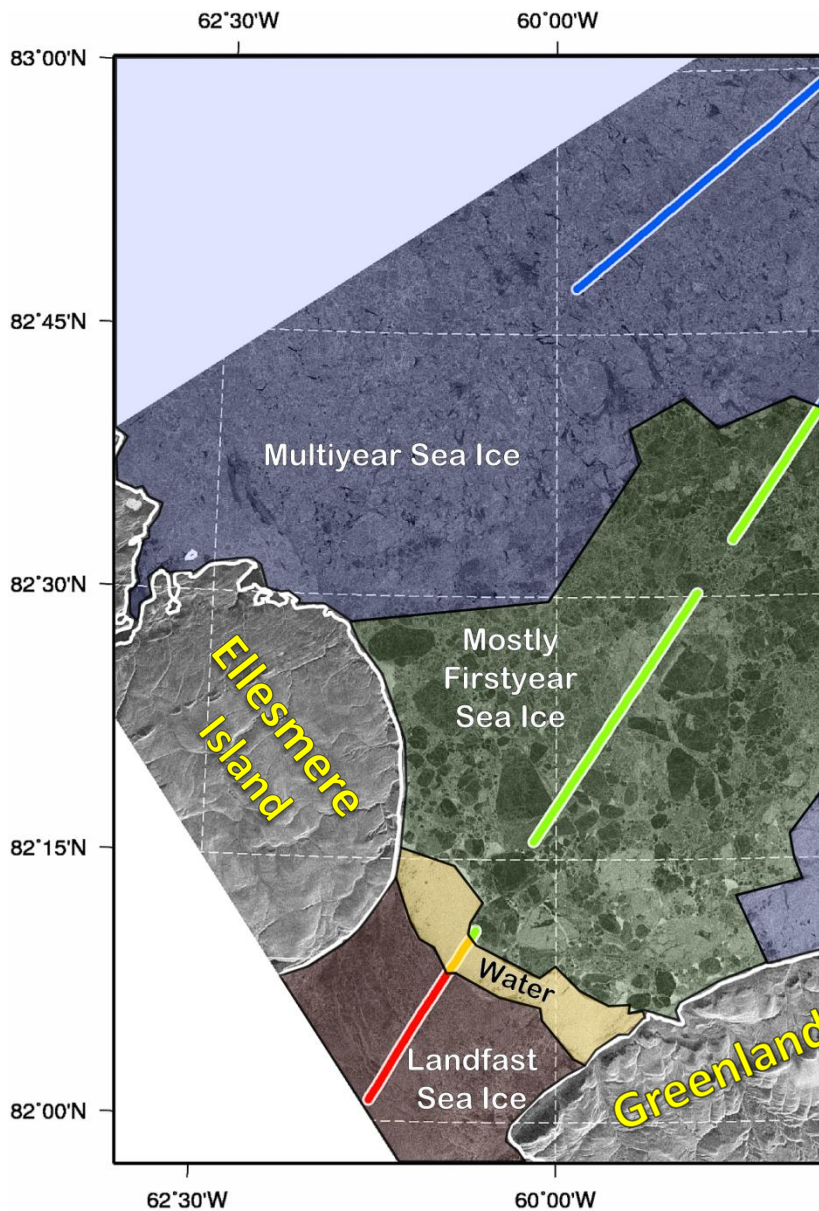
Density Snow: 280 kg/m³



EM-Bird Freeboard



Freeboard vs. HEM Ice Thickness - Direct Comparison



- Regional dependency of K_u -Band radar penetration over snow on Arctic sea ice
 - Backscatter of top snow surface important
 - QuikScat backscatter maps may be helpful
- Error of mean ice thickness by altimetry $< 20\%$ compared to HEM ice thickness
 - Systematic underestimation of radar freeboard based thickness due to preferential sampling of open water and thin ice
- Ratio of freeboard to ice thickness almost independent of scale

Recommendations for future Cal/Val activities

- Ku-Band radar penetration on Arctic sea ice
 - More In-Situ snow measurements
 - Different time of year
 - Other regions?
- Freeboard to Ice Thickness conversion
 - Sea ice density
 - Airborne method?
- CryoSat seaice future Cal/Val activities \Rightarrow *Daniel Steinhage*



THANK YOU