State-of-the-Art Mean Sea Surface and Geoid Model assessment in the Arctic and implications for Sea Ice Freeboard Retrieval

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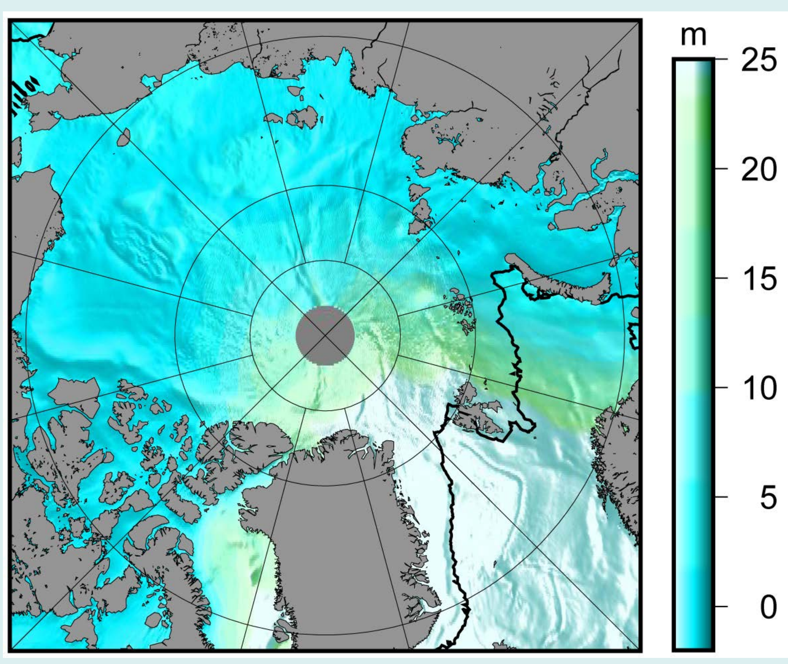
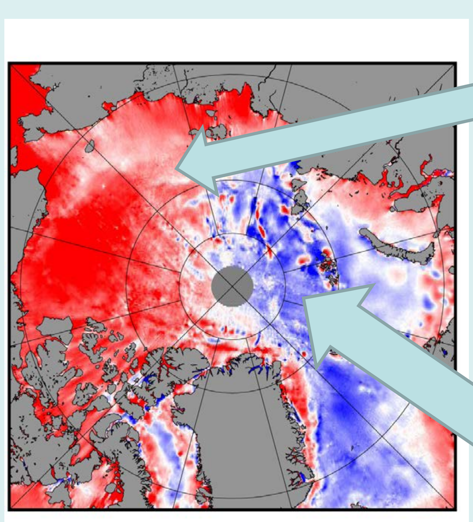
Introduction.

State-of-the-art Arctic Ocean mean sea surface (MSS) models and global geoid models (GGMs) are used to support sea ice freeboard estimation from satellite altimeters, as well as in oceanographic studies such as mapping sea level anomalies and mean dynamic ocean topography. However, errors in a given model in the high frequency domain, primarily due to unresolved gravity features, can result in errors in the estimated along-track freeboard. These errors are exacerbated in areas with a sparse lead distribution in consolidated ice pack conditions. Additionally model errors can impact ocean geostrophic currents, derived from satellite altimeter data, while remaining biases in these models may impact longer-term, multi-sensor oceanographic time-series of sea level change in the Arctic. This study focuses on an assessment of five state-of-the-art Arctic MSS models (UCL04/13, DTU15/13/10) and a commonly used GGM (EGM2008). We describe errors due to unresolved gravity features, inter- satellite biases, and remaining satellite orbit errors, and their impact on the derivation of sea ice freeboard. The latest MSS models, incorporating CryoSat-2 sea surface height measurements, show improved definition of gravity features, such as the Gakkel Ridge. The standard deviation between models ranges 0.03-0.25 m. The impact of remaining MSS/GGM errors on freeboard retrieval can reach several decimetres in parts of the Arctic.



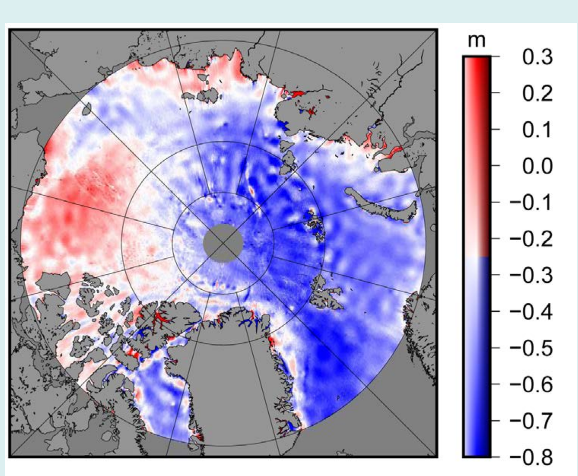
UCL13 MSS

MDT (MSS-Geoid) Differences

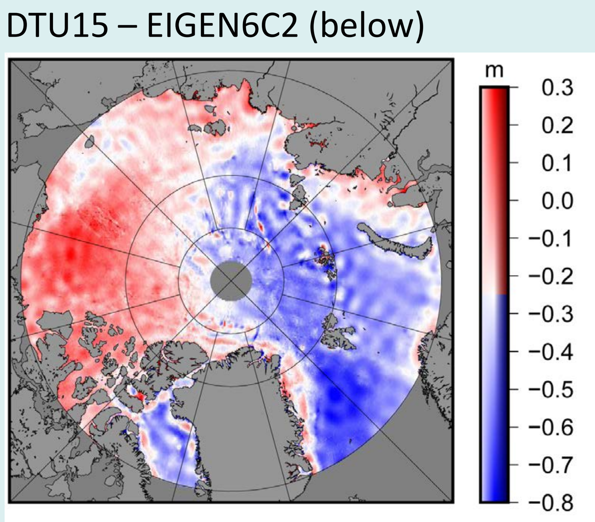


UCL13 – EGM2008:
Shows the high of the Beaufort Gyre, and the lower values in the Greenland and Norwegian Seas

But also shows large variability in the high frequency domain with sudden steep gradients illustrating the location of un-modelled gravity features, e.g. the Gakkel ridge



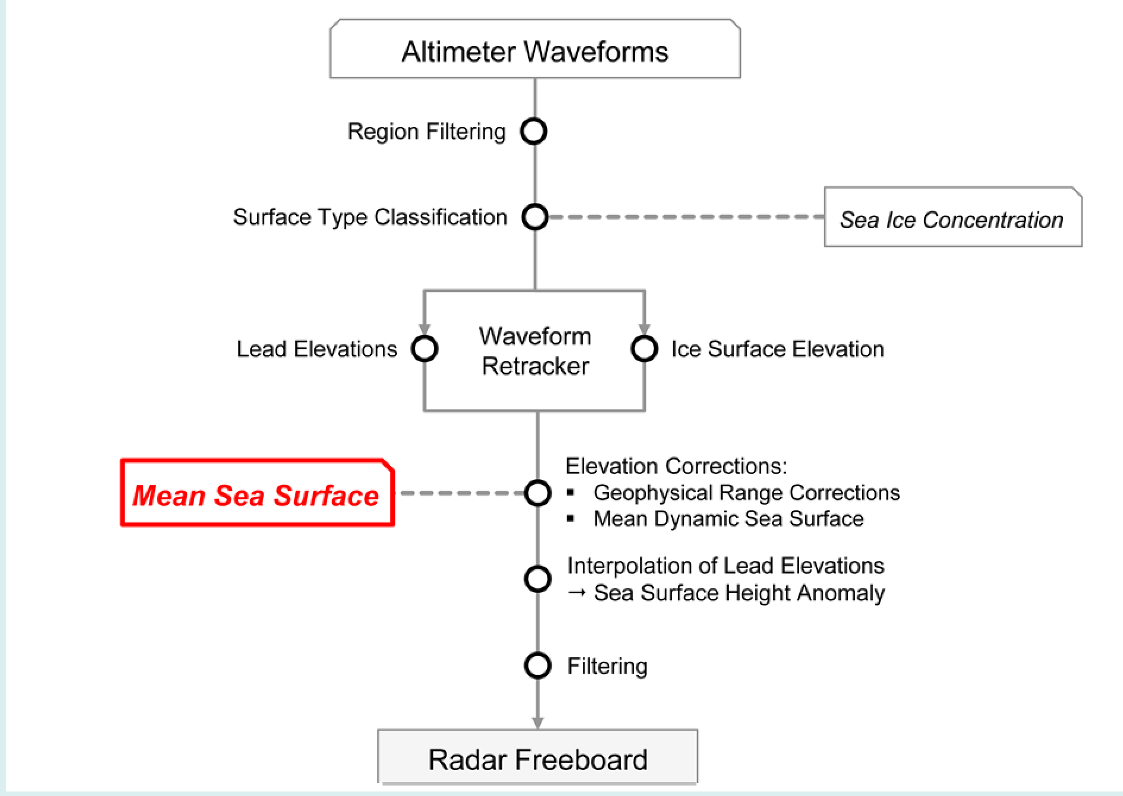
UCL13 – EIGEN6C2 (upper)
Both shows similar pattern to EGM08 differences
With suddent steep gradient and geoi d issues
DTU15 – EIGEN6C2 (below)



MSS vs Geoid for Freeboard Retrieval.

The Mean Sea Surface or geoid enters the Freeboard processing scheme:

Alfred Wegener Institute sea ice freeboard processing scheme



The MSS and geoid differ due the mean dynamic topography (MDT):

MDT = MSS – geoid

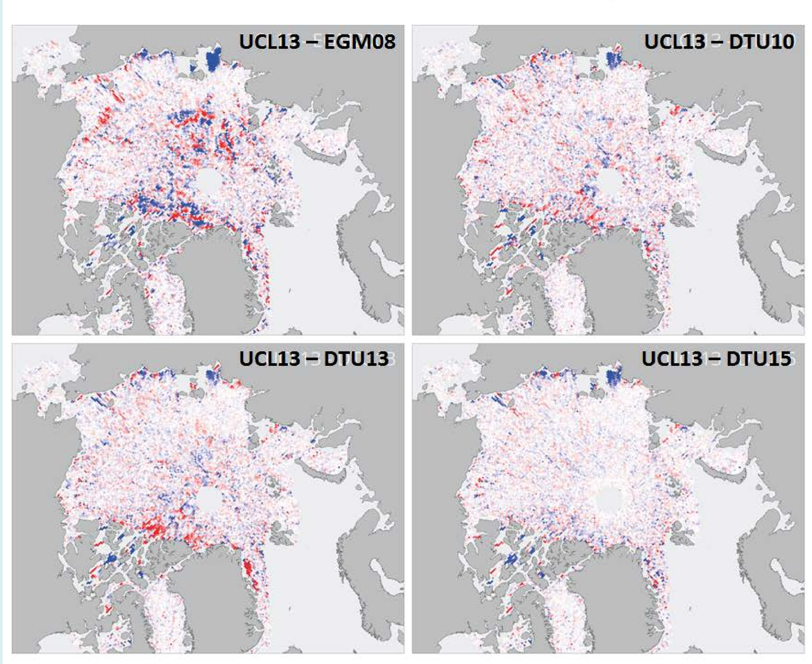
The MSS is based on altimetry data, and dependent on the presence of leads in the Arctic Ocean over the epoch of the mission whereas the geoid is primarily based on gravity observarions;

The following models have been assessed

- UCL13 MSS, provided in the CS-2 baseline C
- UCL04 MSS, provided in the CS-2 baseline B
- DTU15 MSS, provided freely, global field
- DTU13 MSS
- DTU10 MSS
- EGM08 geoid
- EIGEN6C2 geoid

Freeboard estimation

Differences in freeboard heights

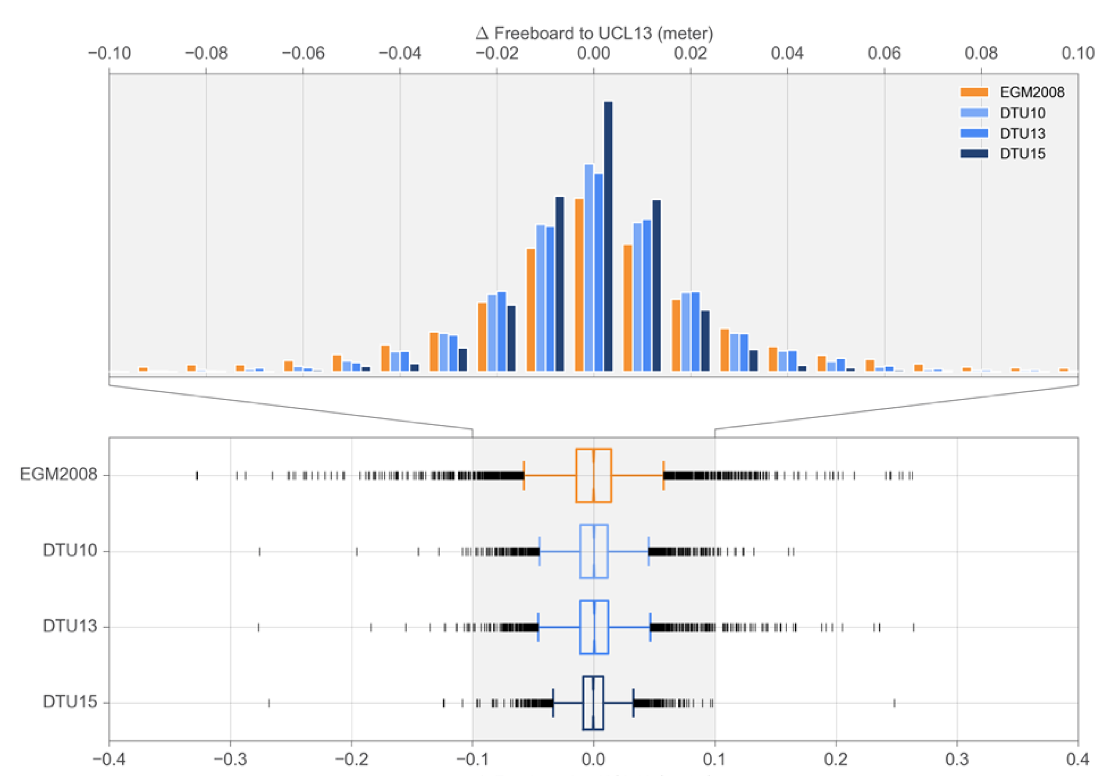


Statistics:
Freeboard
ΔSIF mean ~ 0 cm
ΔSIF std = 3-6 cm

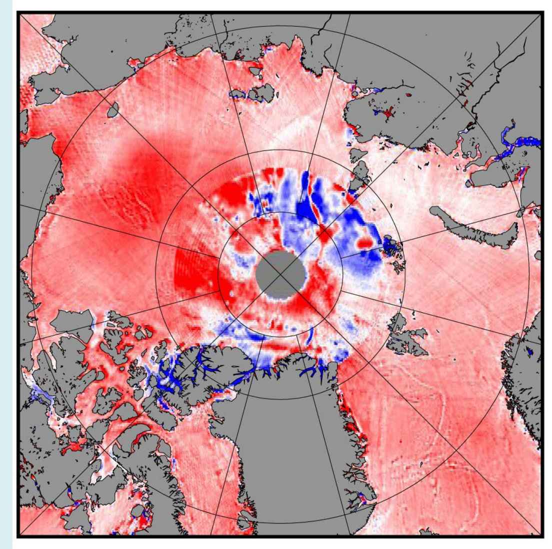
Thickness
ΔSIT mean ~ 0 cm
ΔSIT std = 24-54 cm

•Maximum sea ice freeboard difference in the central Arctic Ocean is 59 cm and is between UCL13-EGM08

Distribution of differences in freeboard heights

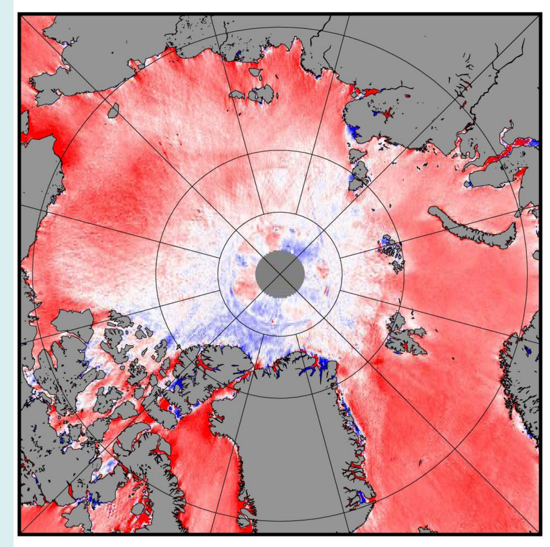


MSS Differences



UCL13MSS – UCL04 MSS

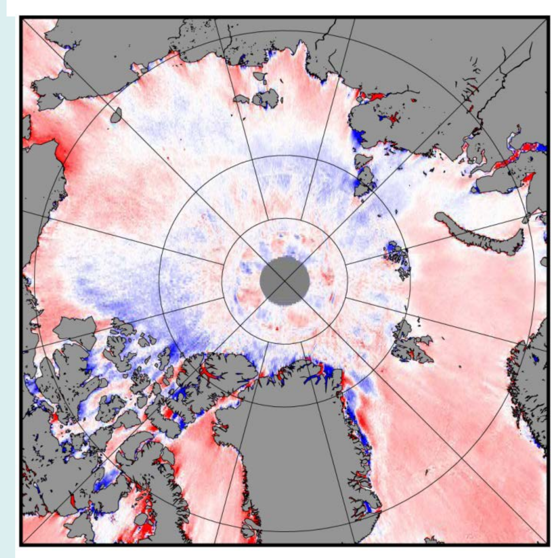
Large variability in the high frequency domain with sudden steep gradients north of 81.5˚N consistent with the remaining errors in EGM08



UCL13MSS-DTU10 MSS

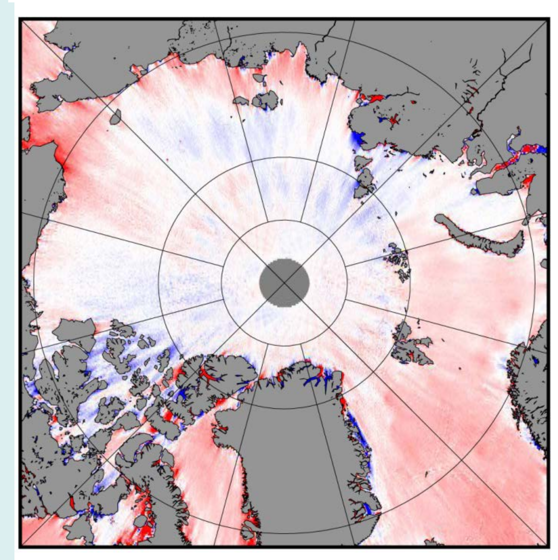
decimeter discontinuity around 86˚N parallel and a discontinuity smaller in magnitude at 81.5˚N

Also, large anomalies north of 86˚N



UCL13MSS-DTU13 MSS

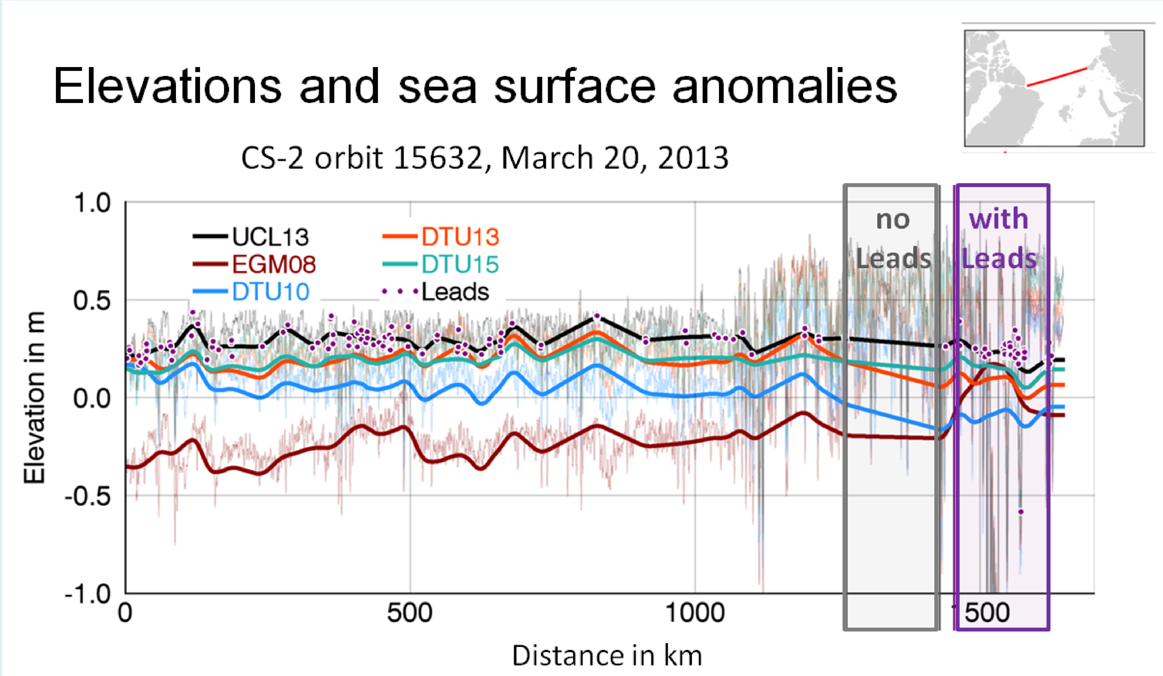
The (UCL13-DTU13) shows similar anomalies as with (UCL13-DTU10)

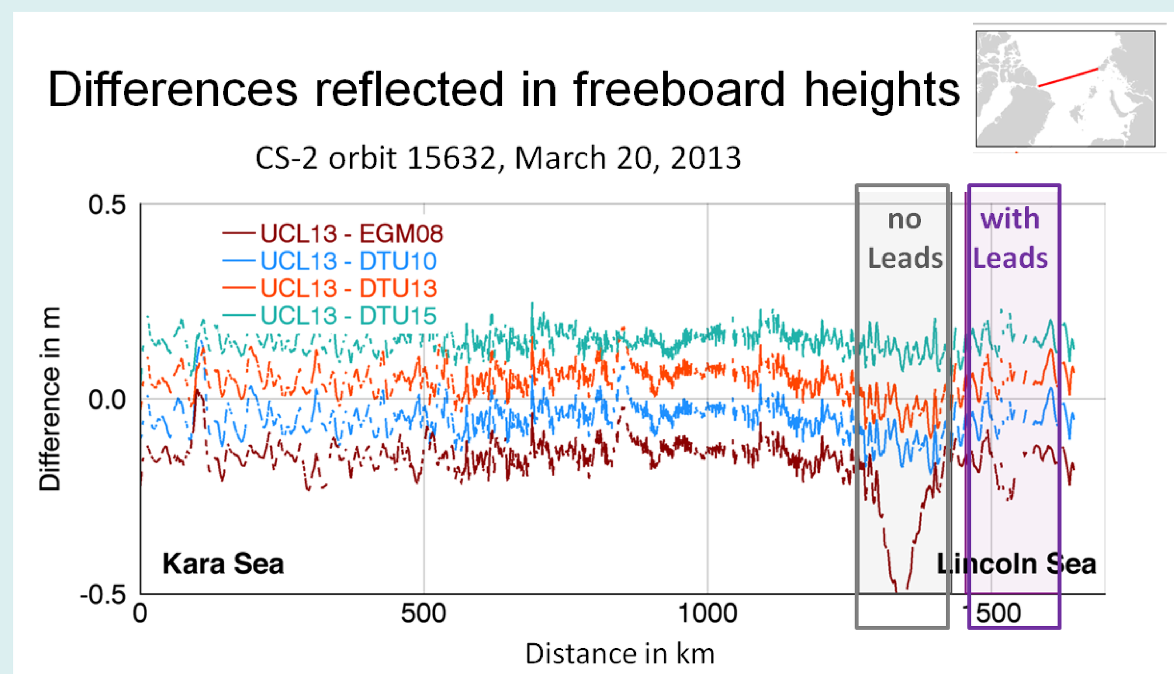


UCL13-DTU15

No discontinuities at 86˚N, nor the large anomalies north of 86˚N, however some persistent anomalies in overlap band at 81.5˚N
Convergence between models, with a standard deviation less than 10 cm, however ultra high-frequency noise is present in both data sets

Profile comparison





Summary and reference

The latest MSS models UCL13 and DTU15 have improved definition of unresolved gravity features, and there are no remaining discontinuities
Thus, we recommended the use of either DTU15 or UCL13 for sea ice freeboard retrieval.
Depending on choice of MSS model, regional freeboard results can vary locally by up to several cm, especially at the seasonal maximum of Arctic sea ice cover.

Skourup et al., (2017) An Assessment of State-of-the-Art Mean Sea Surface and Geoid models of the Arctic Ocean: Implications for Sea Ice Freeboard Retrieval, JGR Oceans, 2017 JCO, 13176, October 2017