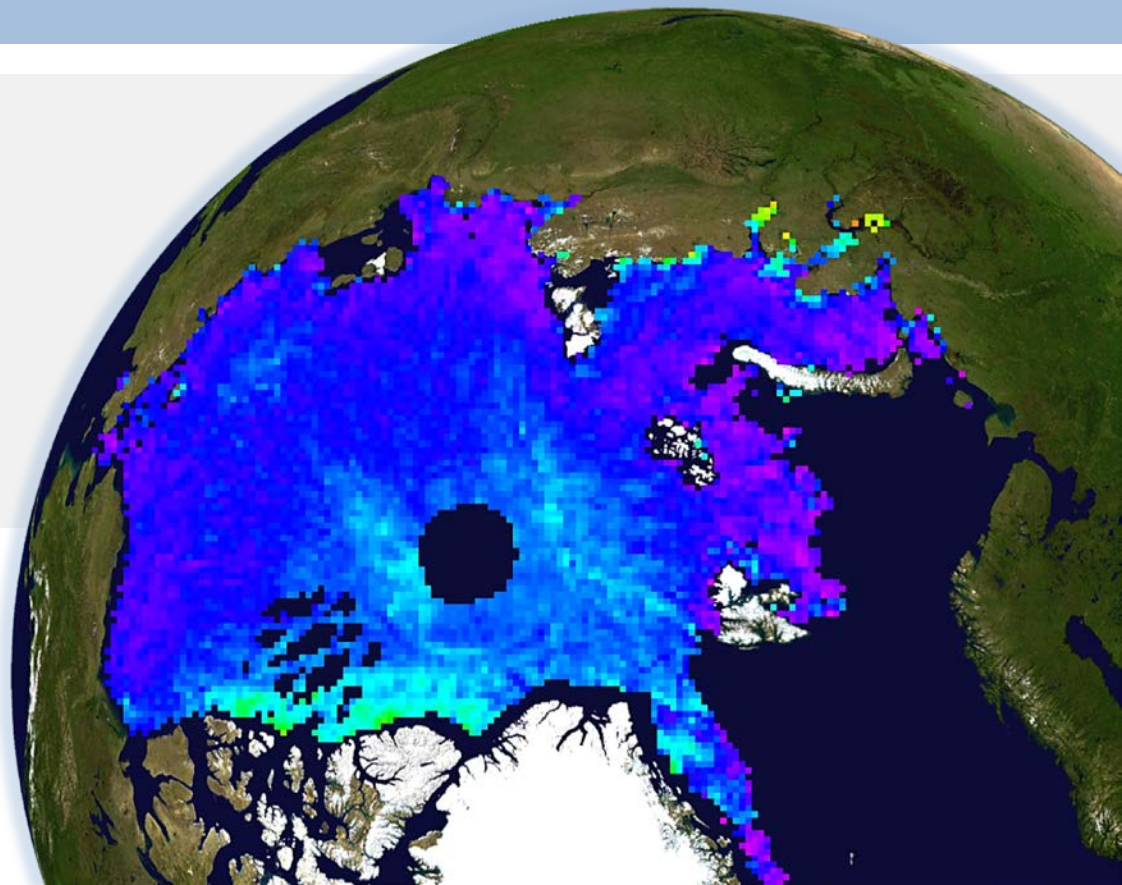
Mass balance of sea ice in both hemispheres

Airborne validation and the AWI CryoSat-2 sea ice data product

Stefan Hendricks
Robert Ricker
Veit Helm
Sandra Schwegmann
Christian Haas
Andreas Herber



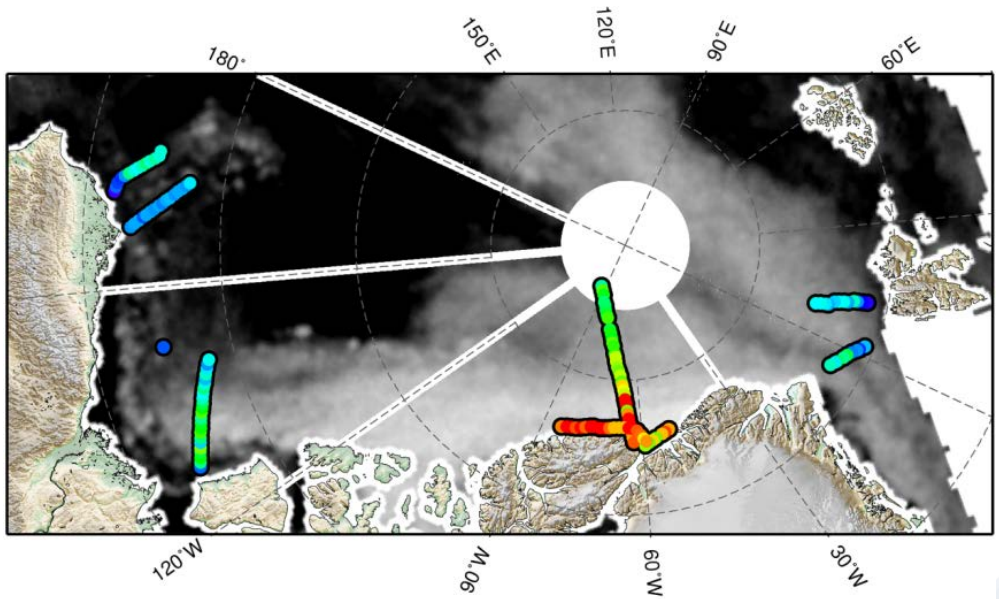
Outline

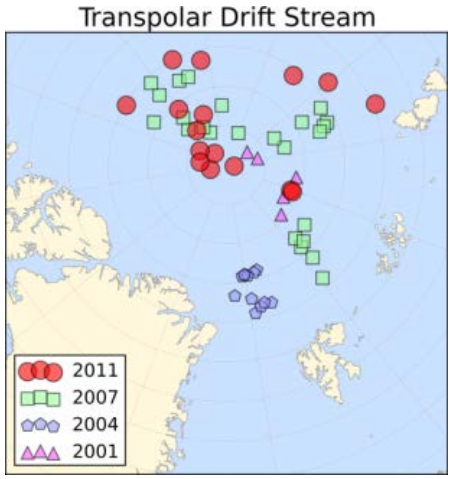
Airborne sea ice thickness (AEM)

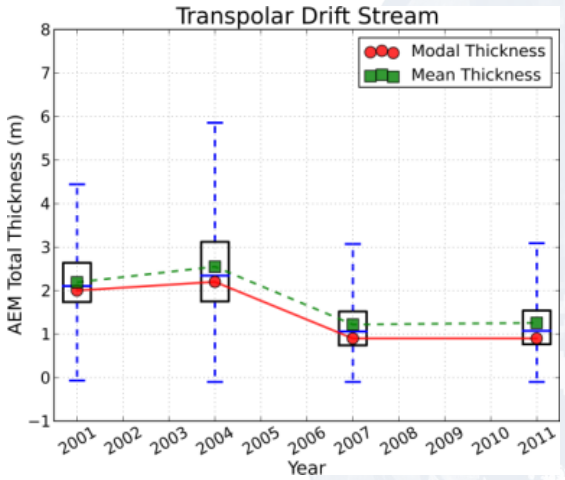
CryoSat-2 Calibration & Validation

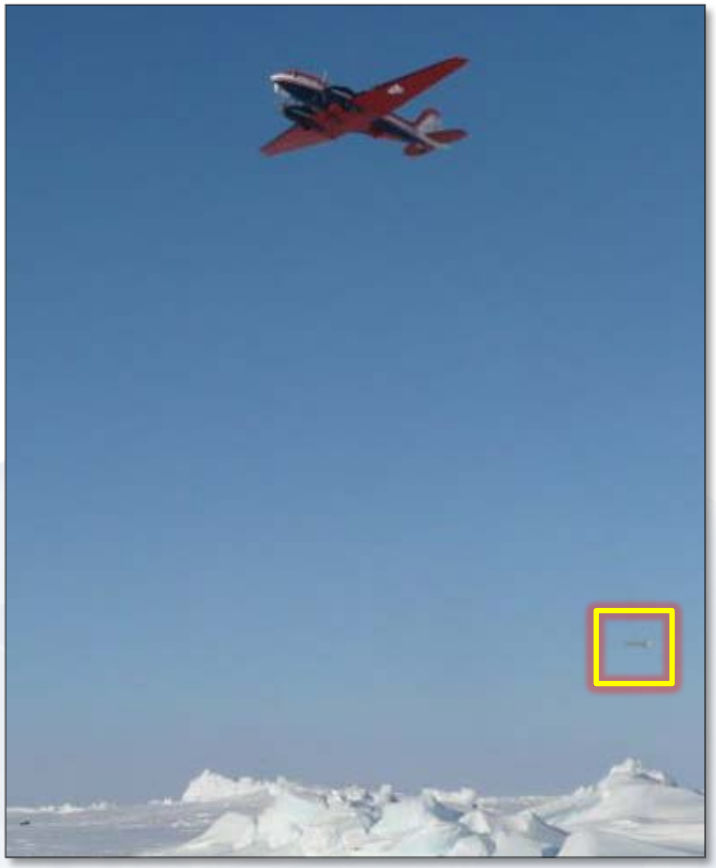
AWI Cryosat-2 sea ice data product

Airborne EM Sea Ice Thickness







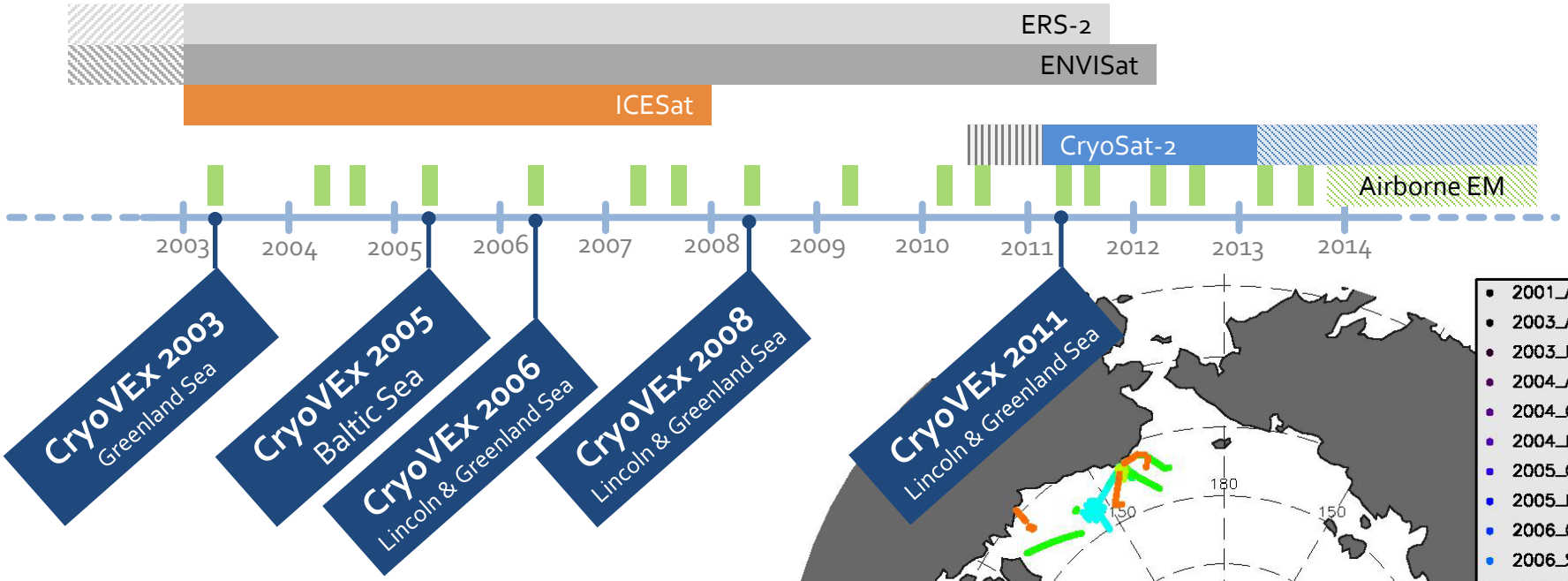


Airborne EM (AEM) Thickness

Sea-ice thickness data

Helicopter and fixed-wing aircrafts

Airborne EM and Satellite Mission

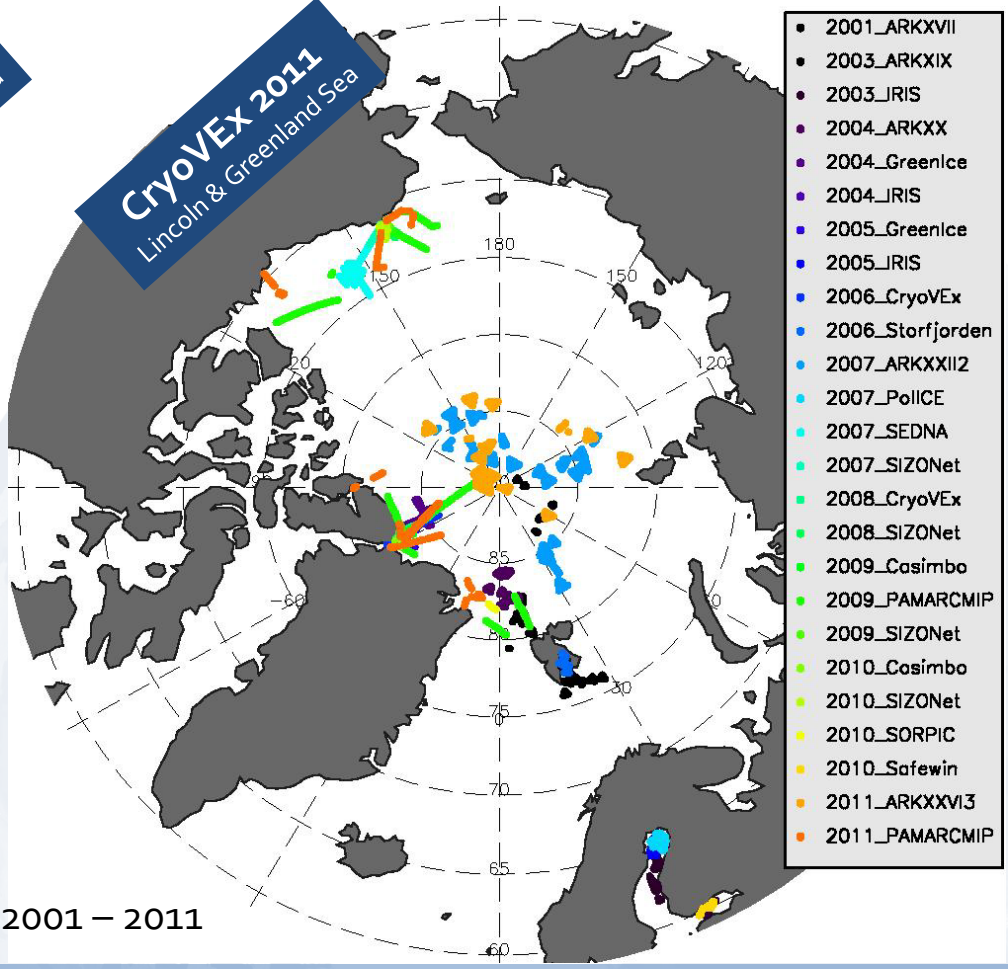


Airborne EM surveys

Alfred Wegener Institute

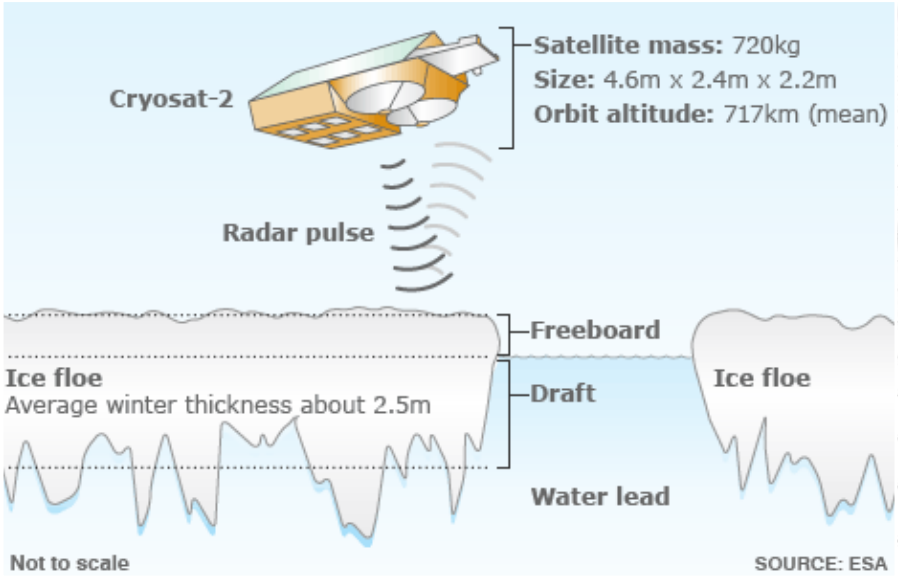
University of Edmonton/York

Norwegian Polar Institute



AWI: 2001 – 2011

CryoSat Cal/Val Concept



Sources of Uncertainty

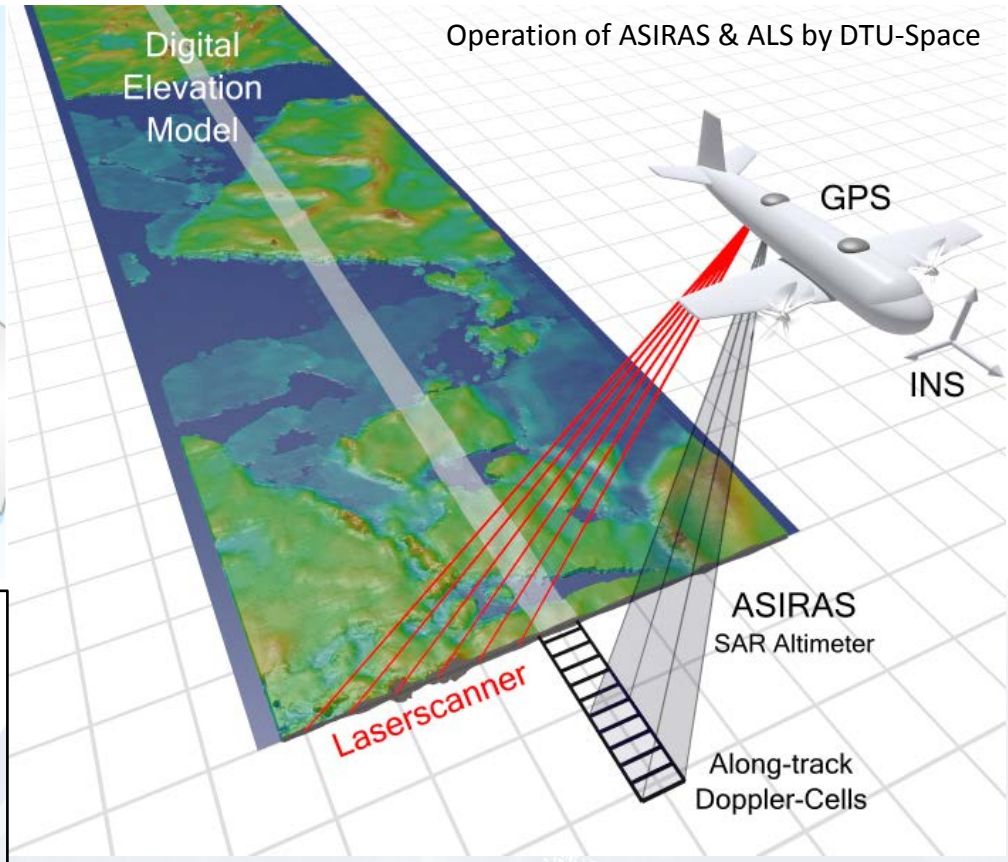
Sea surface height anomaly

Radar penetration into snow

Sub-footprint scale surface roughness

Variability of snow and ice density

Snow depth
(or snow-water-equivalent)



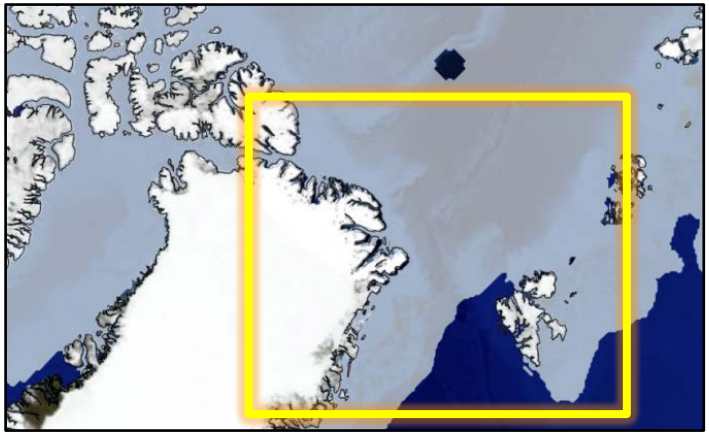
Laser – Radar Altimetry

Radar penetration into snow

High resolution validation data

Thickness retrieval validation

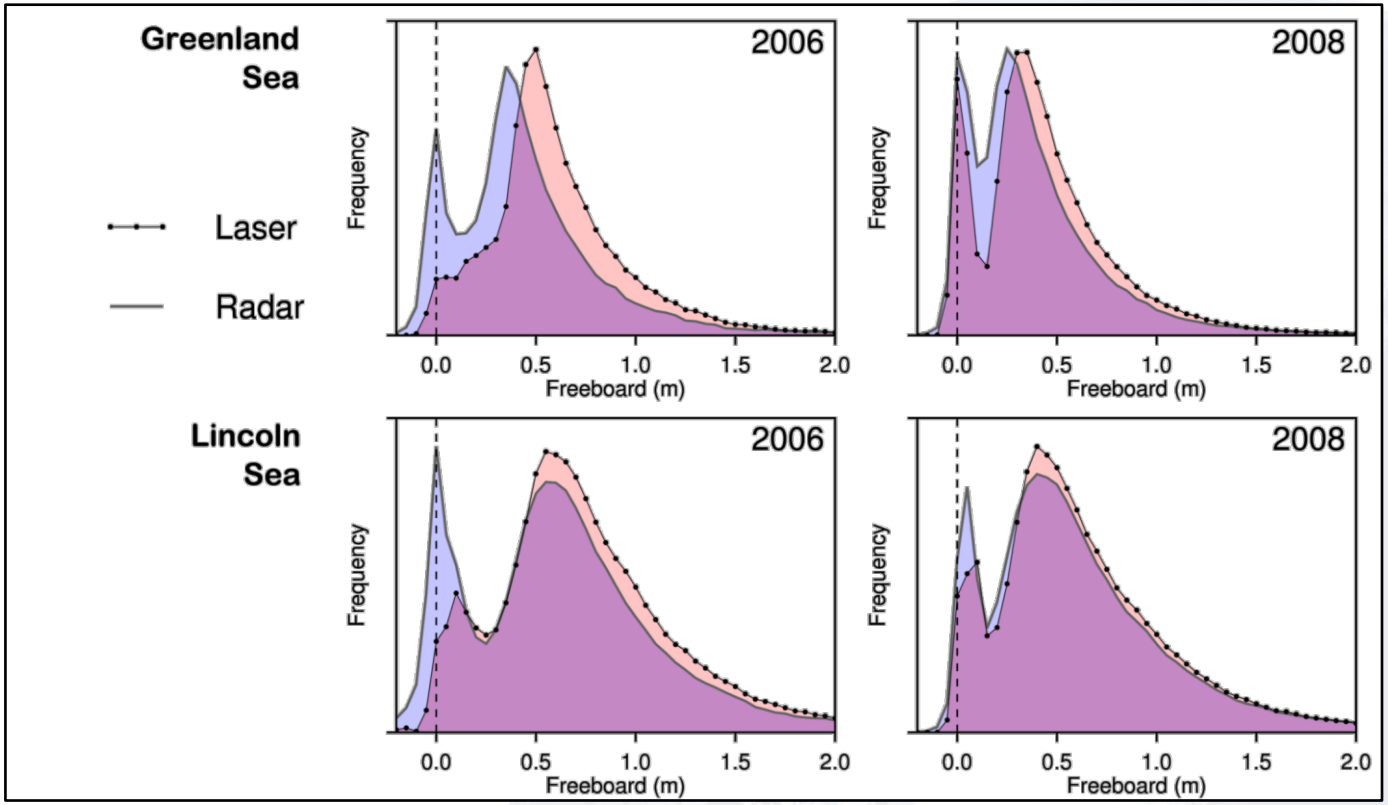
Radar Penetration into Snow



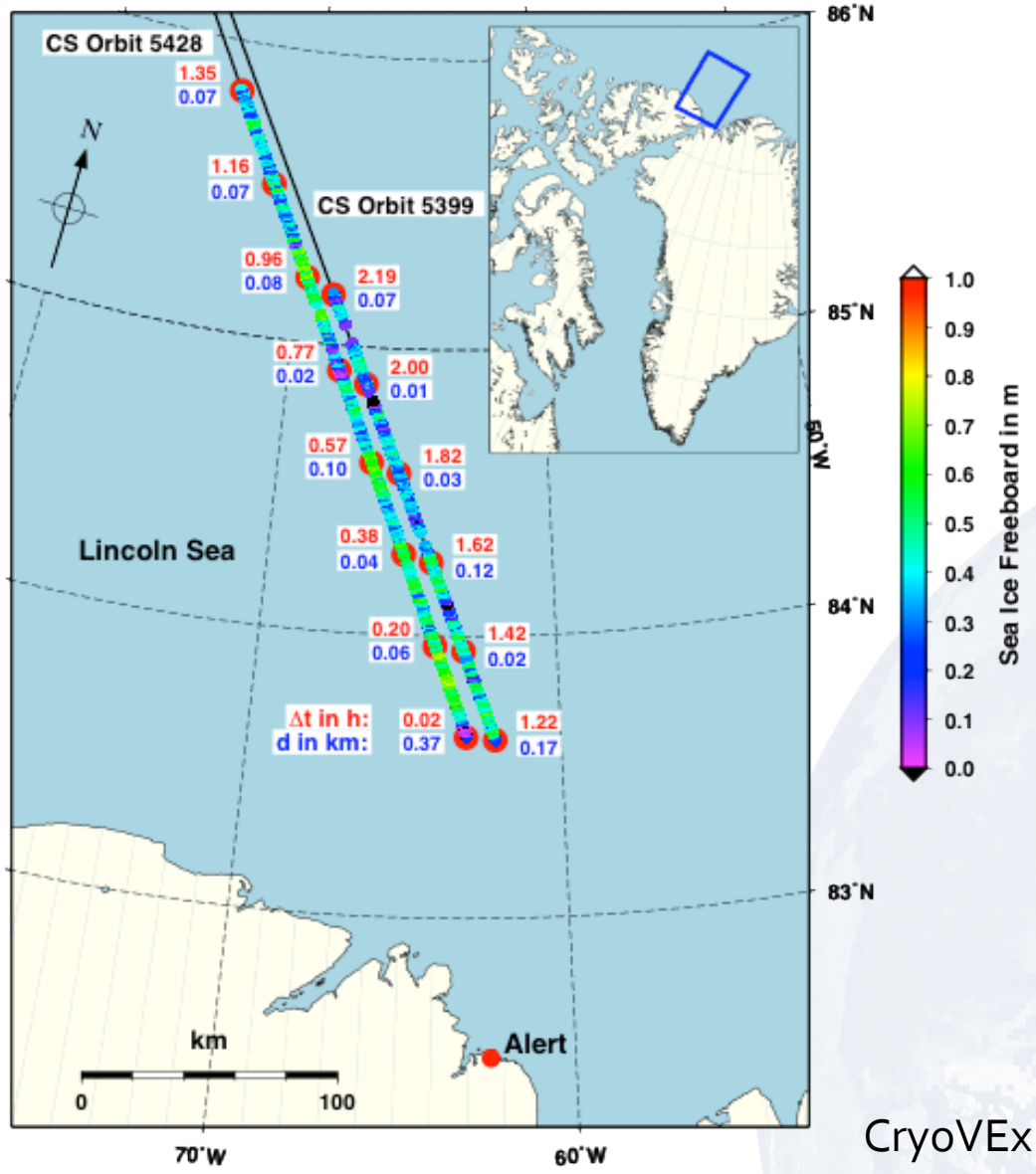
CryoVEx 2006/2008

Modal difference not large enough for typical snow depth

Might not have been „cold" snow anymore



Direct comparison to CryoSat-2



Twin Otter (DTU-Space)

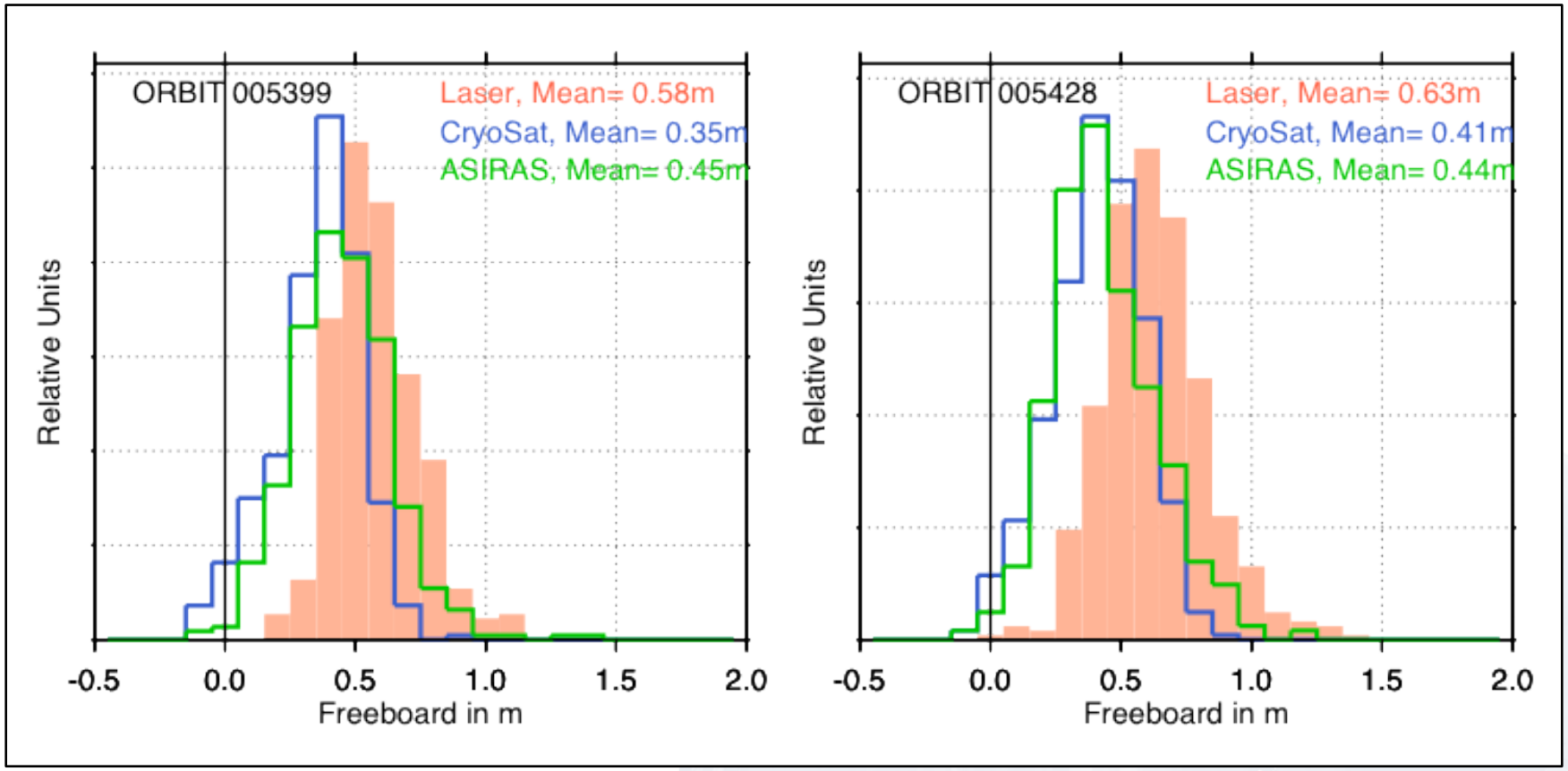
ASIRAS (Airborne CryoSat-2 simulator)
Airborne Laserscanner

Polar-5

EM-Bird (direct sea ice thickness)
Airborne Laserscanner

CryoVEx 2011, April 2011

Freeboard: Airborne vs. CryoSat-2

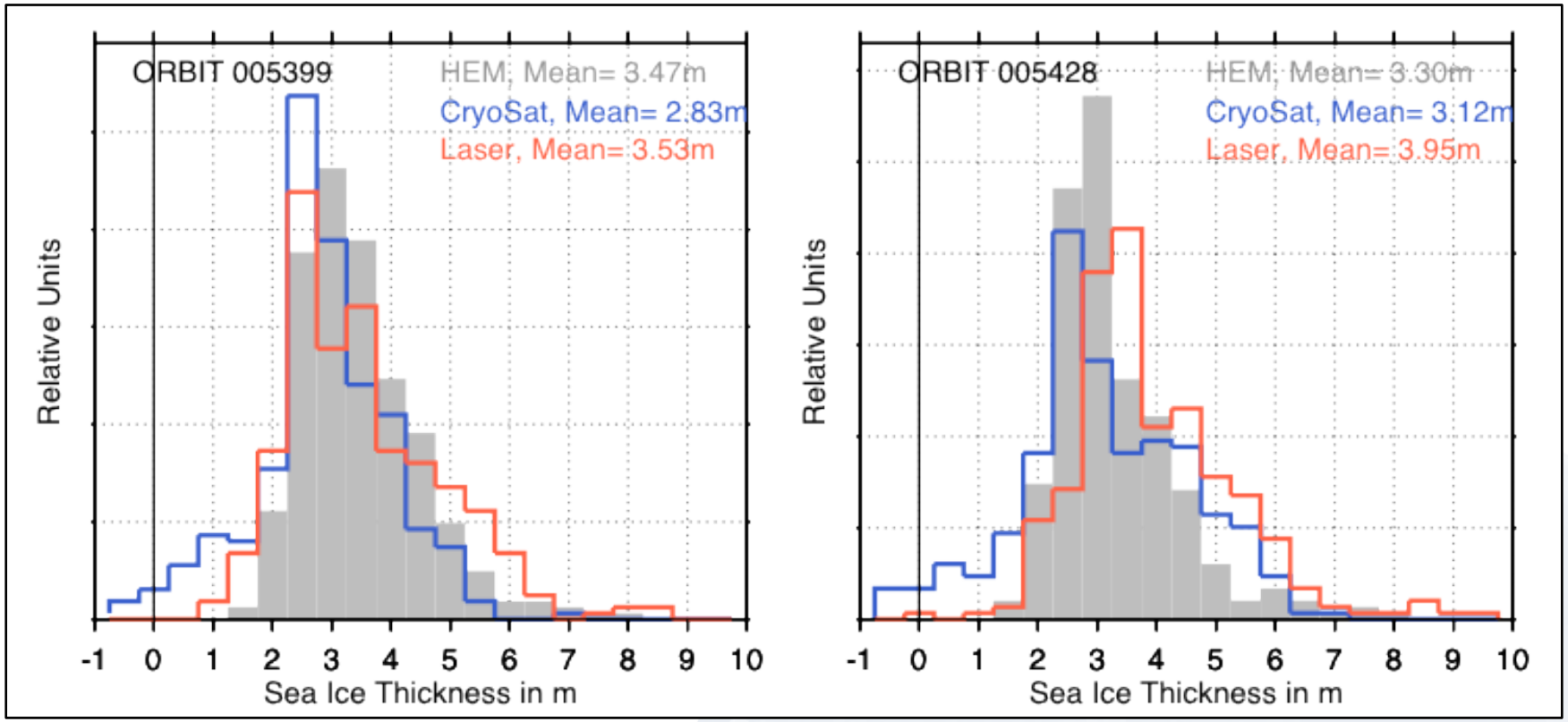


Airborne (laser & radar) and CryoSat-2 freeboard

Distribution of airborne radar and CryoSat-2 freeboard comparable

Difference to laser freeboard smaller than expected snow depth (even for dry & cold snow)

Thickness PDF: CryoSat-2 vs. EM-Bird



EM-Bird sea ice thickness and CryoSat-2 thickness

More scatter on ice thickness pdf of altimetry product than EM

Comparable mean values / EM-Bird data corrected for snow depth

Cal/Val – Summary

Airborne EM sea ice thickness

Data in the Arctic since 2001	Data overlap with all altimetry missions Continued data acquisition

Calibration & Validation Results

radar freeboard ≠ ice freeboard	unknown spatial pattern of radar penetration

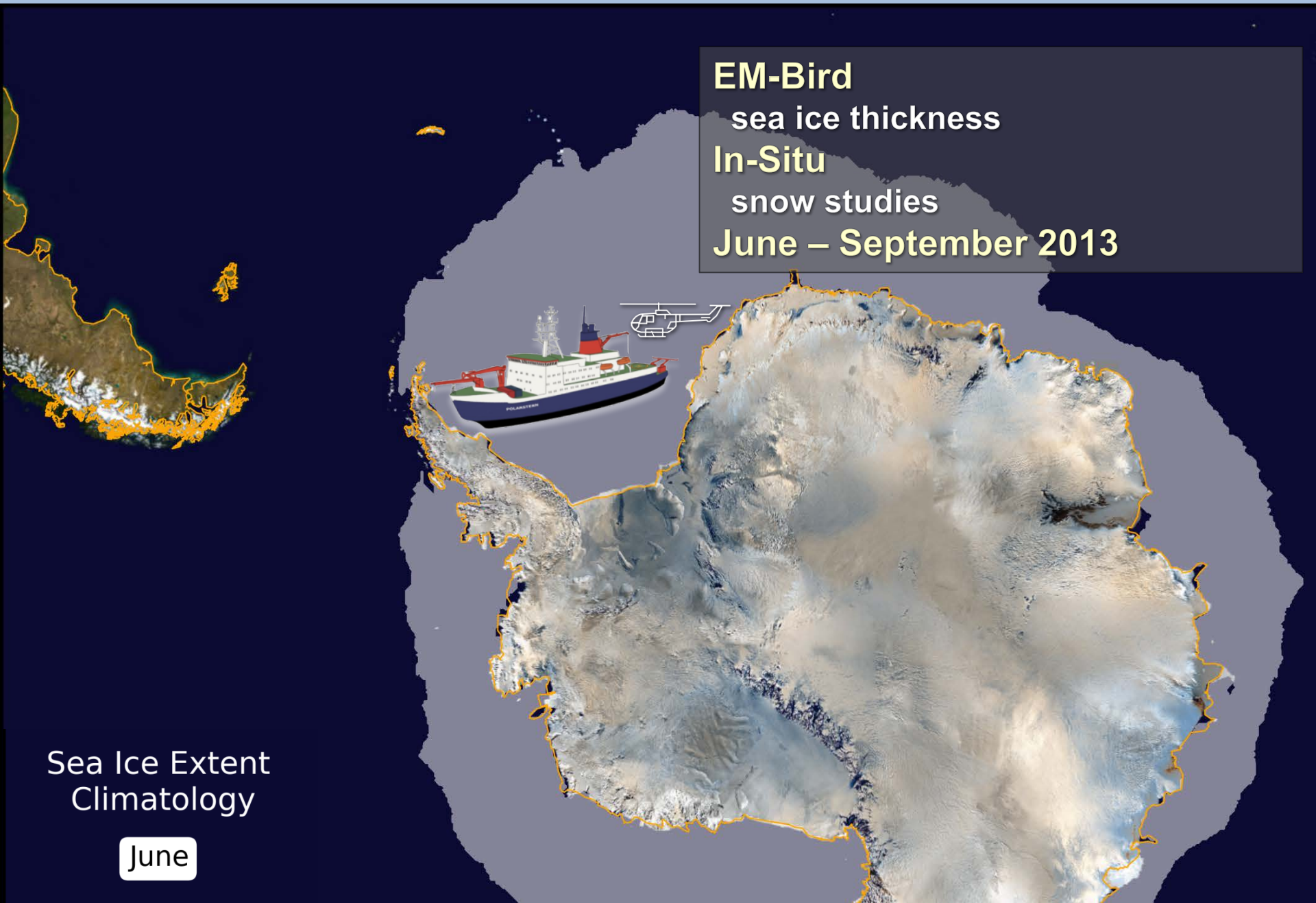
CryoVEx: good agreement of airborne and satellite freeboard & thickness

Remaining Issues

snow, snow, snow!	knowledge of spatial & temporal distribution limits thickness accuracy
surface roughness	planned forward model simulations

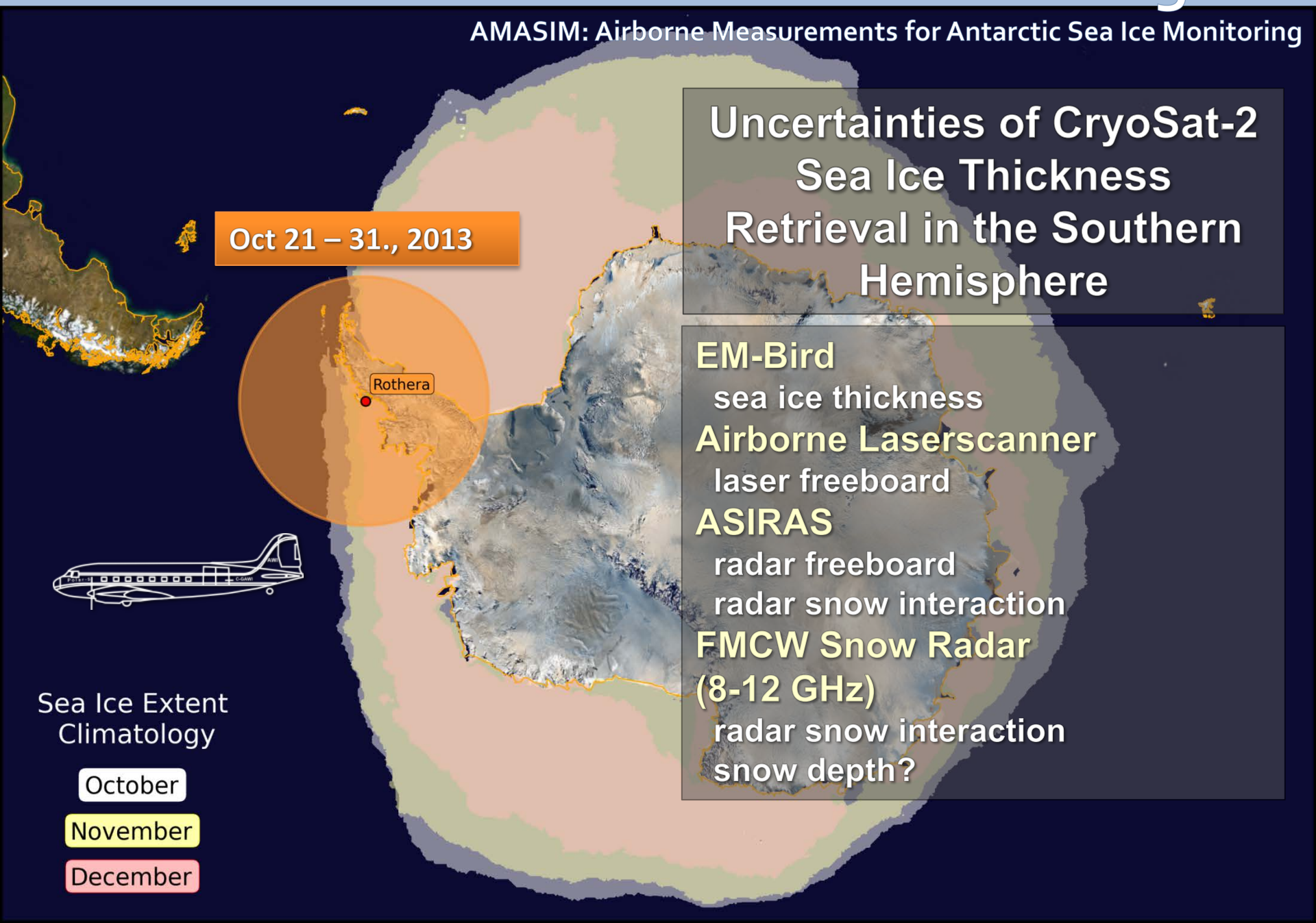
Parameterization for Antarctic sea ice

Polarstern Antarctic Winter Experiment



Antarctic Sea Ice Program

AMASIM: Airborne Measurements for Antarctic Sea Ice Monitoring



Uncertainties of CryoSat-2 Sea Ice Thickness Retrieval in the Southern Hemisphere

EM-Bird
- sea ice thickness

Airborne Laserscanner
- laser freeboard

ASIRAS
- radar freeboard
- radar snow interaction

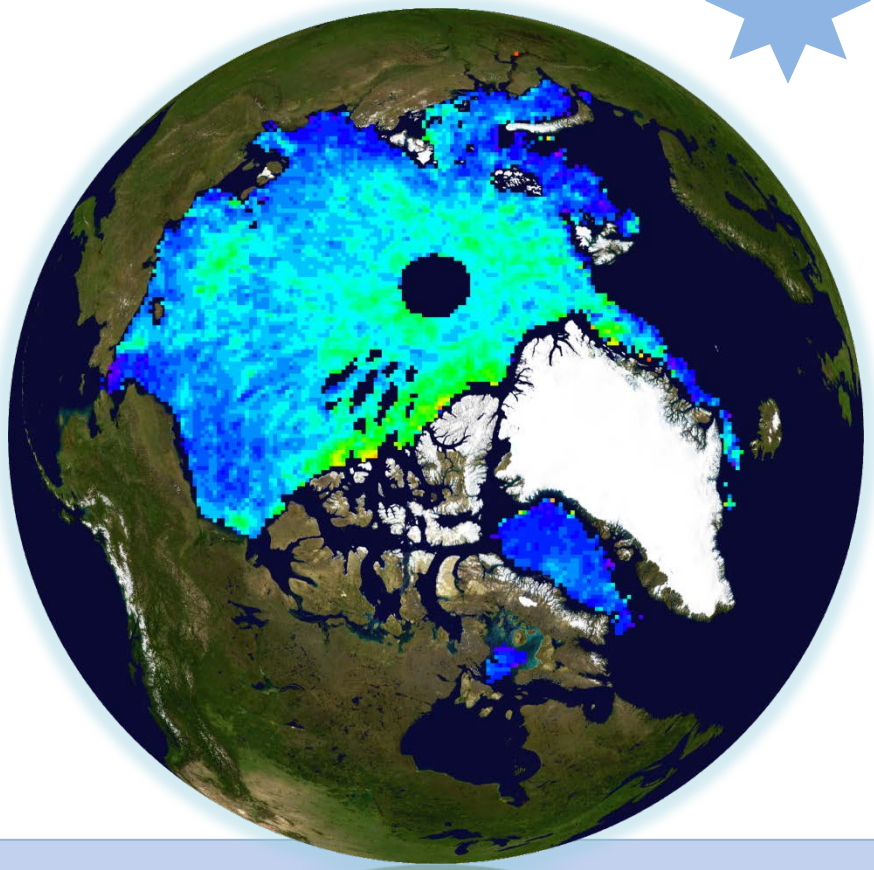
FMCW Snow Radar (8-12 GHz)
- radar snow interaction
- snow depth?

AWI CryoSat-2 sea ice product

First Results

Poster of Robert Ricker

AWI CryoSat-2 Sea-Ice Thickness Data Product and its Validation



CryoSat-2 processing scheme

✓ : Data Product

CryoSat-2 Level 1b

Range retracking (TSRA)

Lead detection

Mean SSH ✓

Mean SSH = *Geoid* + *Mean Dynamic Topography* (DTU10)

Radar Freeboard ✓

SSH-Anomaly ✓

Actual-SSH (WGS84) = *Mean SSH* + *SSH Anomaly*

Penetration correction

Isostatic Equilibrium

Snow Depth ✓

Modified Climatology

Ice Bridge Probabilistic

Snow and Ice Densities

Ice Type Mask ✓

Sea Ice Thickness ✓

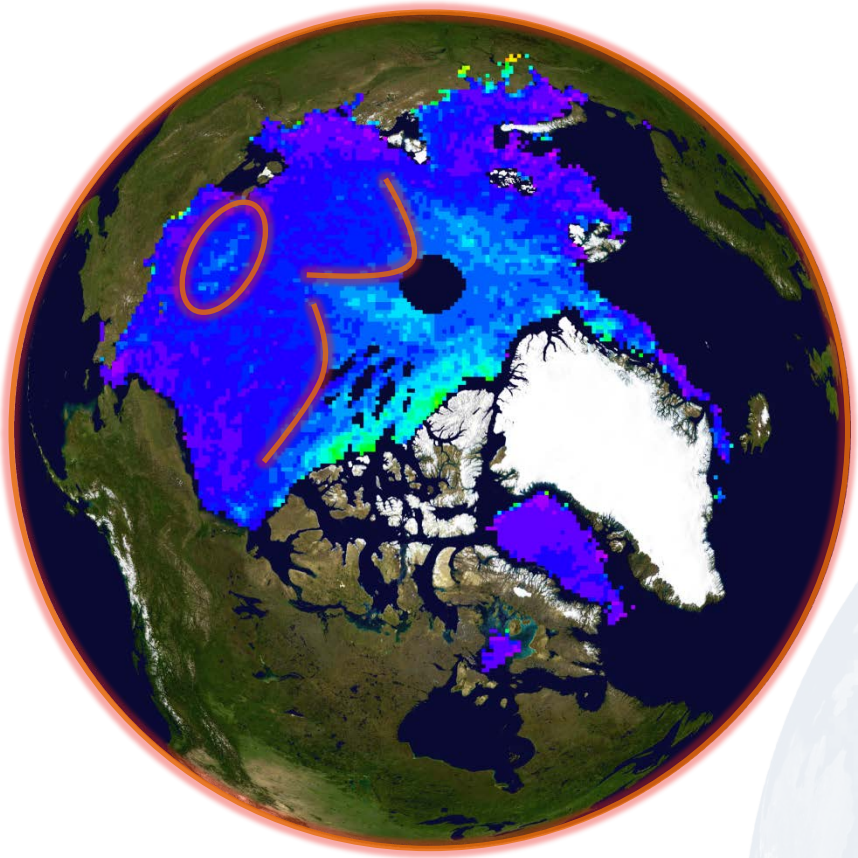
Uncertainty ✓

25 x 25 km grid

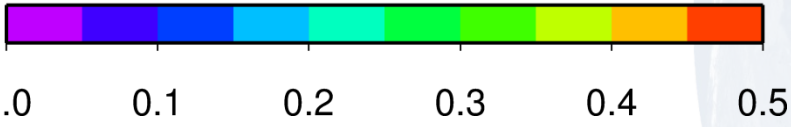
AWI

CryoSat-2: First results - Freeboard

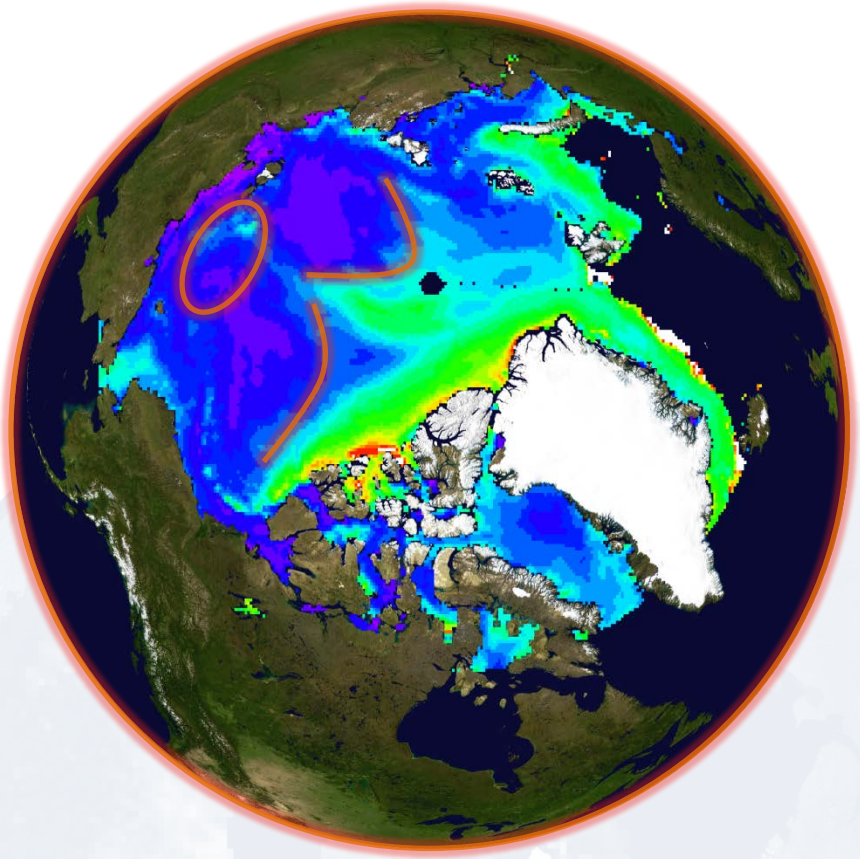
Radar Freeboard



Sea ice freeboard in m



ASCAT Backscatter



Backscatter

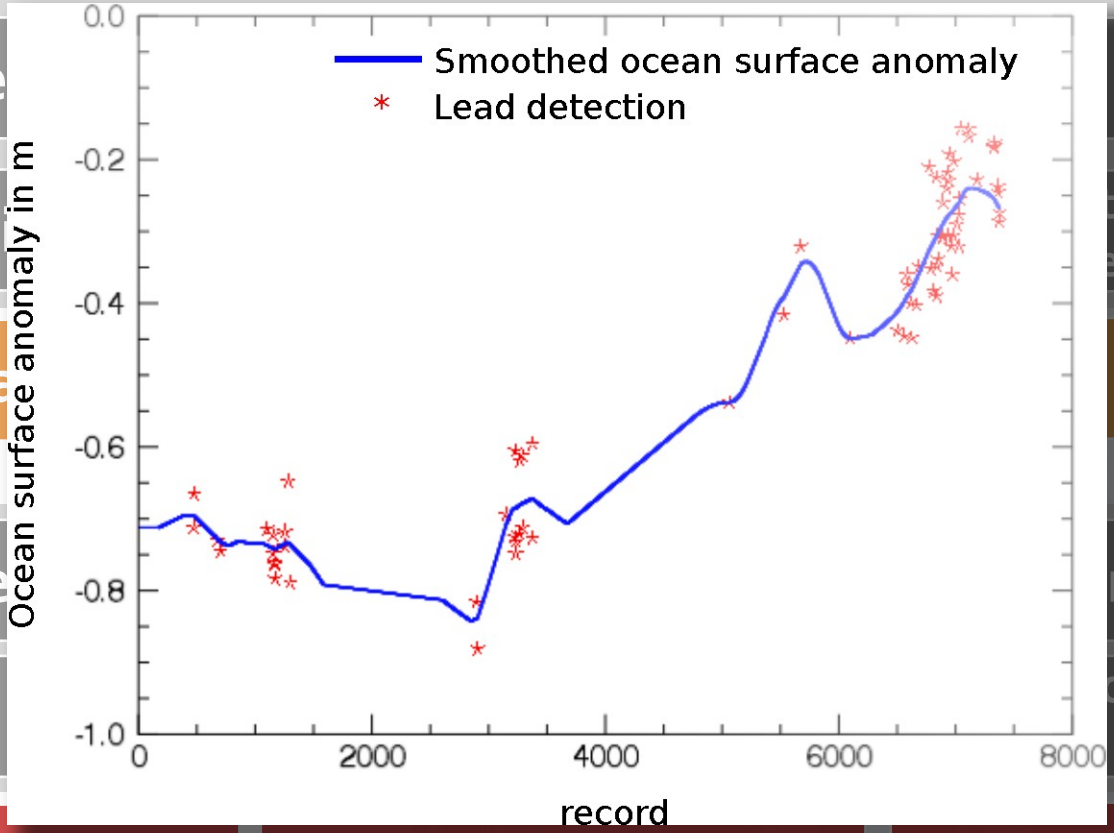
Low backscatter FYI

High backscatter MYI

Example: March 2011

Contribution to error budget

CryoSat-2 Level 1b	Speckle Noise	14 cm
Lead Dete		*
Retracki		ed
Freeboa		*
Snow De		m
Snow &		o
Thickness	Cumulative Error	2.5 m *



Decreasing with # detections

FYI / MYI

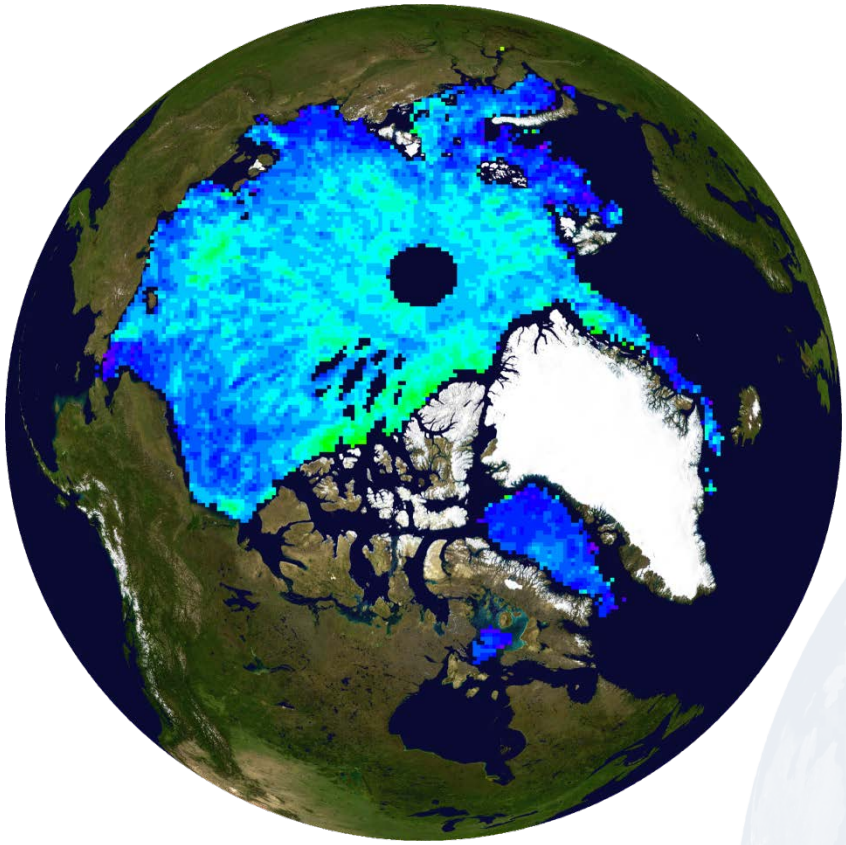
SNOW / ICE

* : Mean multi-look (point) error

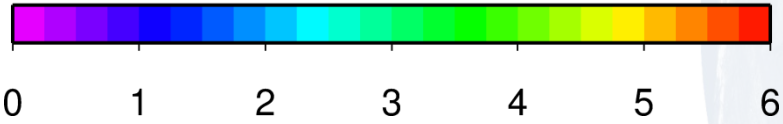
Error Propagation (Averaging 25 x 25 km)

CryoSat-2: First results

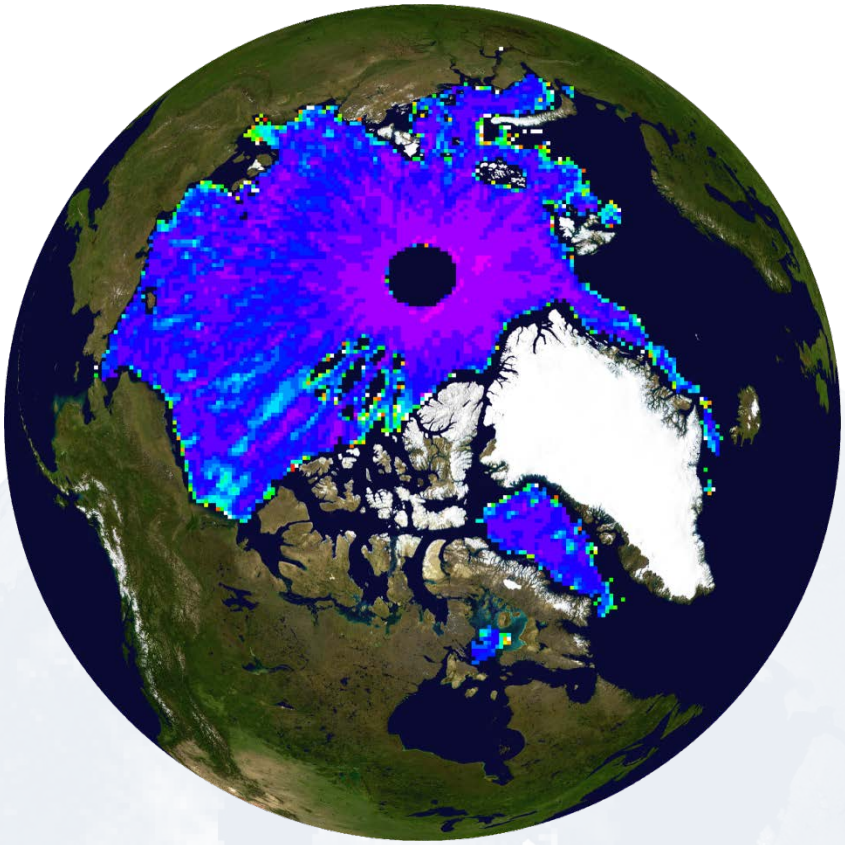
Sea Ice Thickness



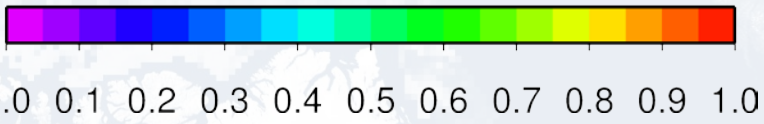
Sea ice thickness in m



Uncertainty



Sea ice thickness uncertainty in m



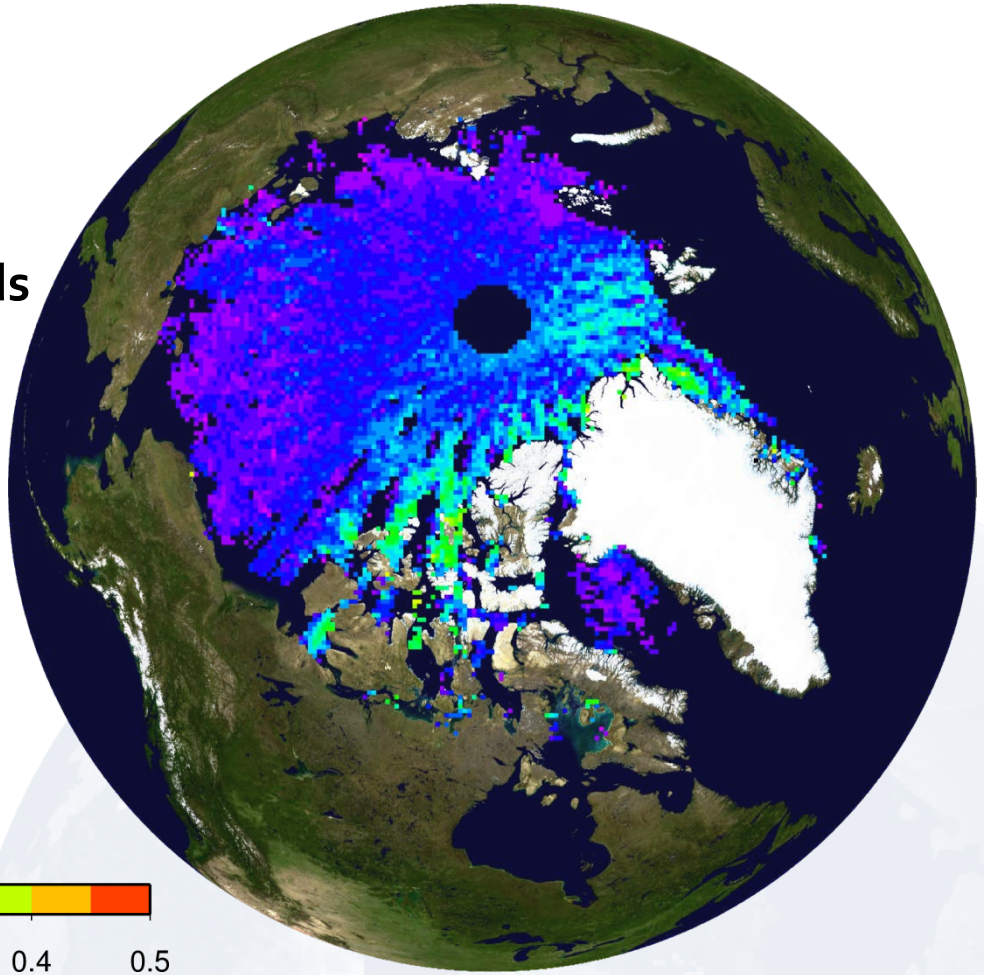
Example: March 2011

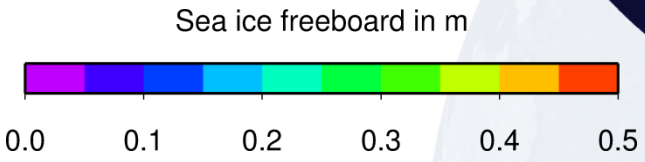
CryoSat-2Freeboard – Start of Surface Melt

Begin of Arctic-Wide melt season

CryoSat-2 data at end of month considerably affected by melt ponds

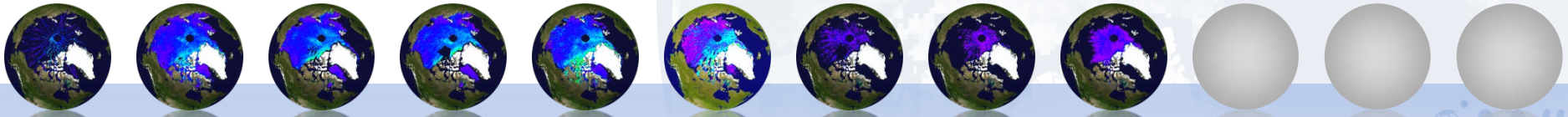
▶ Orbit pattern in radar freeboard





June

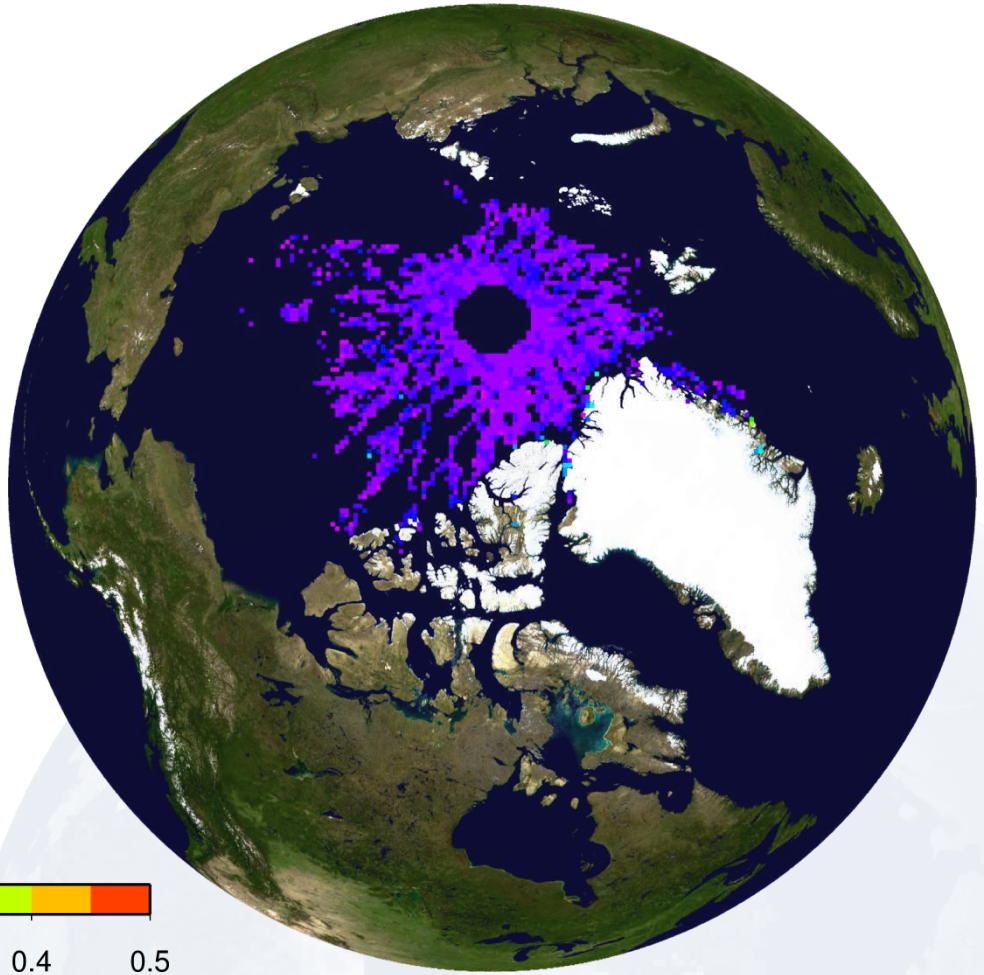
Processing pending

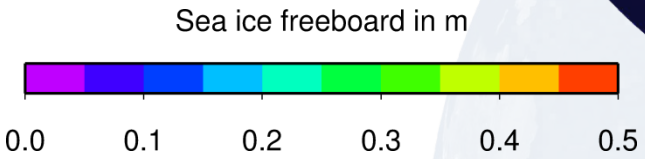


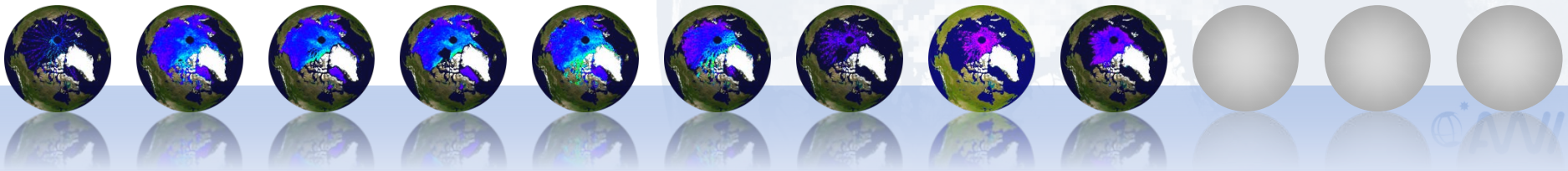
CryoSat-2 Freeboard – Developed Melt Ponds

Full melt season

CryoSat-2 data heavily affected by melt ponds





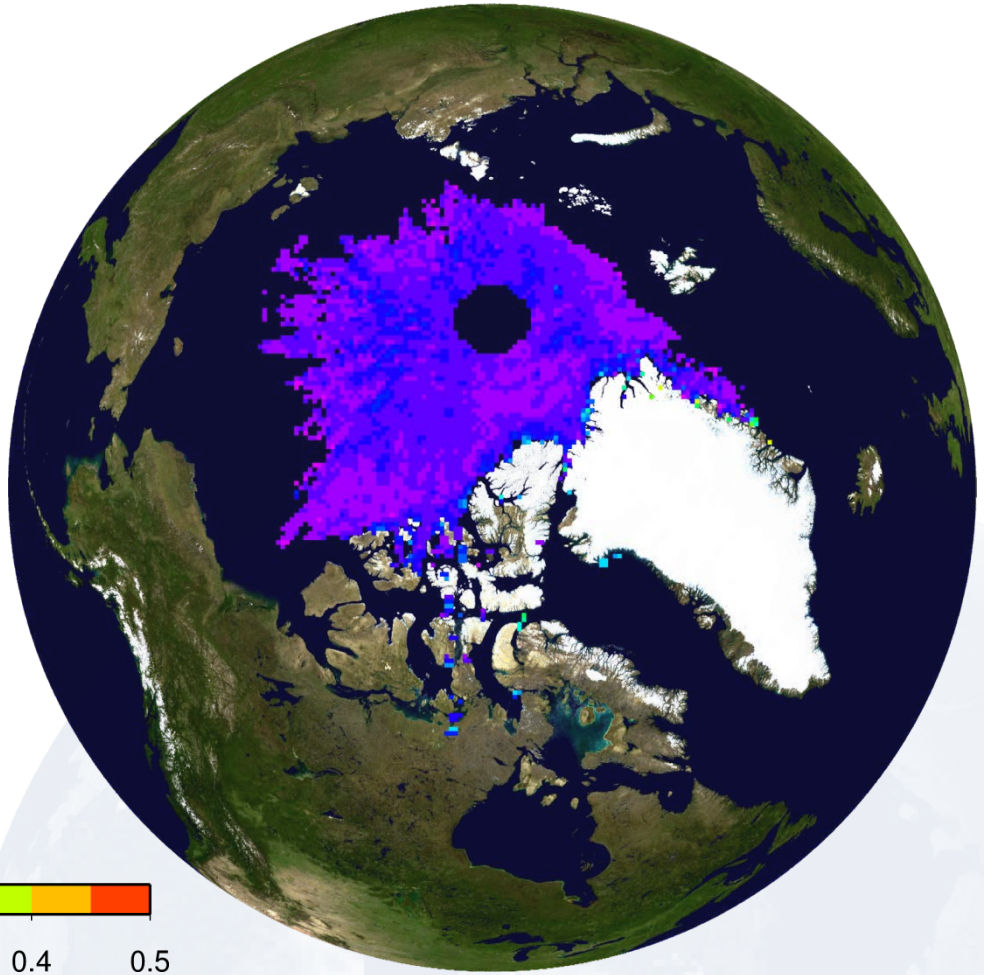


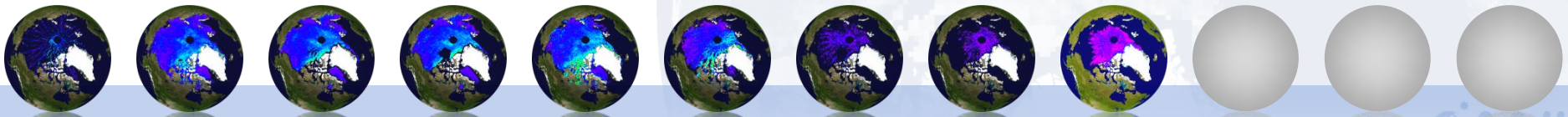
CryoSat-2 Freeboard – Refrozen Melt Ponds

Refreezing melt ponds

Considerably reduced gaps in CryoSat-2 data

Thickness Cal/Val data available from Polarstern cruises ArkXXVI/3 & ArkXXVII/3





Data Distribution

Public Access

Target Group:

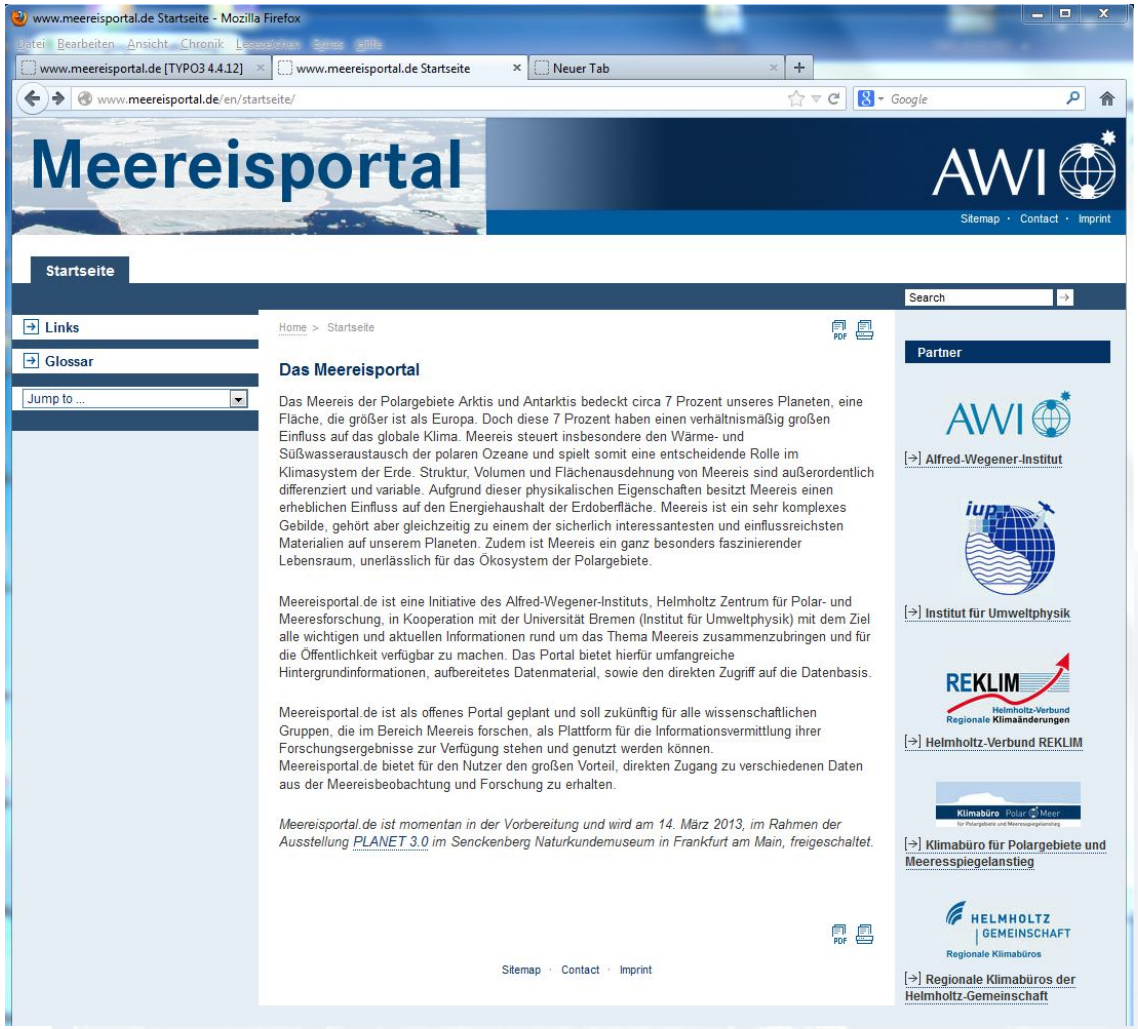
Scientists / (Interested) Public

Data format NetCDF

Mean SSH
SSH Anomaly
Freeboard
Snow depth
Ice Type
Thickness
Thickness Uncertainty

several revisions likely

Online Mapping Tool



http://www.meereisportal.de/

http://www.meereisportal.de/cryosat/

AWI CryoSat-2 sea ice product – Summary

AWI CryoSat-2 data

radar freeboard : in agreement with independent data sources

expected data availability : January – May (June) &
(September) October – December

updates and revisions on irregular basis

Goal: rapid-release data product in spring for sea ice prediction efforts (model initialization)

Remaining Issues

Product currently has "beta" status | Release in the next weeks

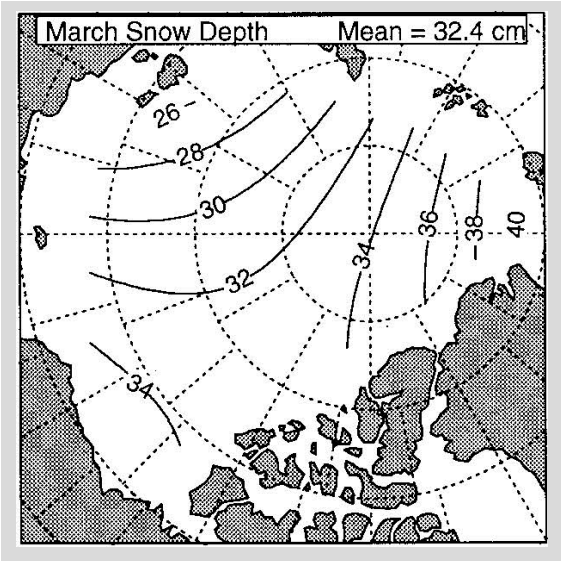
Better uncertainty estimation required

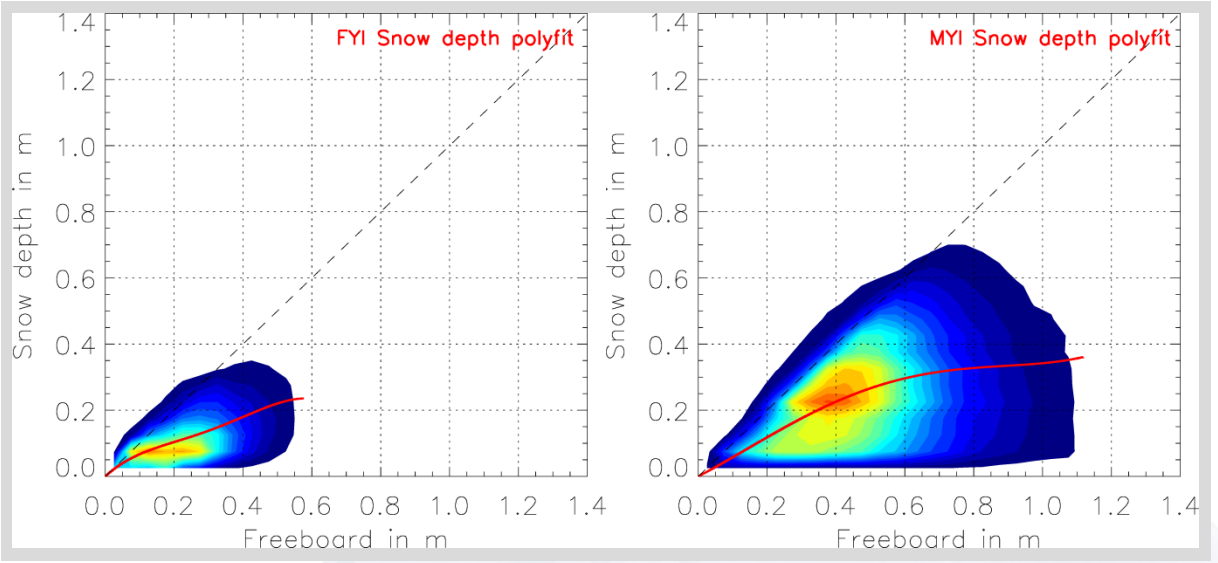
SARIn processing will be included

Better snow information needed

Thank You

Estimation of Snow Depth





Modified Climatology

Based on Warren et al. 1999

Factor 0.5 over FYI based on Operation IceBridge findings (Kurtz et al., 2009/2011)

IceBridge Probabilistic

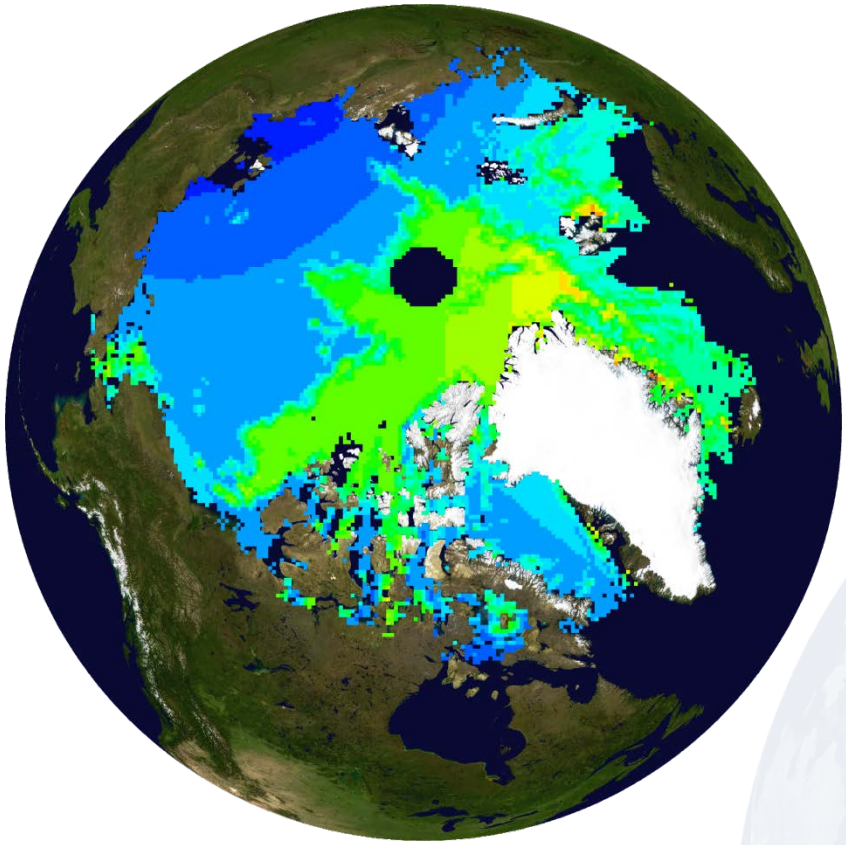
Based on fit laser freeboard and radar snow depth of Operation IceBridge data

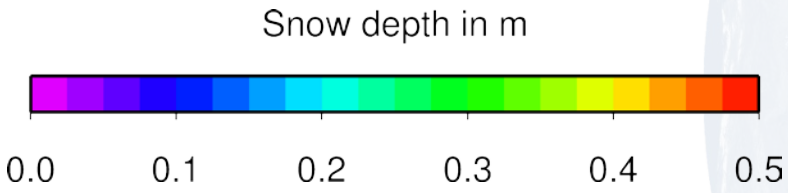
- Snow depth directly related to freeboard

Might be only valid in spring and western Arctic

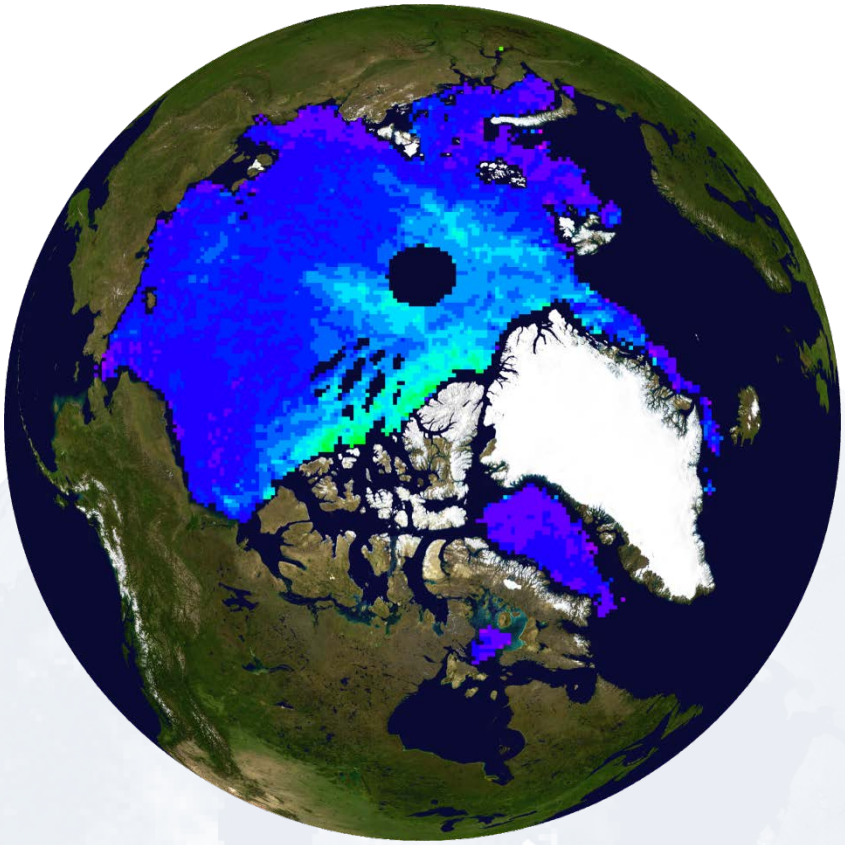
CryoSat-2: First results – Snow Depth

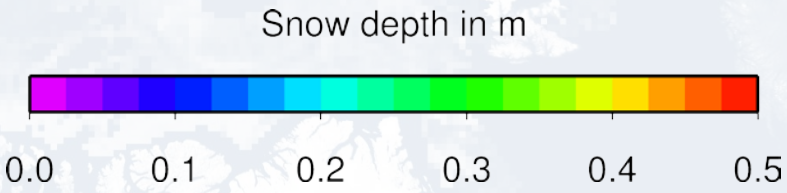
Modified Climatology





IceBridge Probabilistic





Example: March 2011