Development and First Results of a new Airplane Based Fixed Wing Electromagnetic Induction Sea Ice Thickness Sounder.

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Introduction

One of the big challenges in sea ice research is the determination of the polar sea ice thickness and its' spatial and temporal variability. Electromagnetic (EM) exploration is a suitable method. Ground based and Helicopter EM have a high accuracy of 0.1 m but a limited range. Therefore the AWI started to construct an airplanebased realization.

Motivation

Why do we measure sea ice thickness?

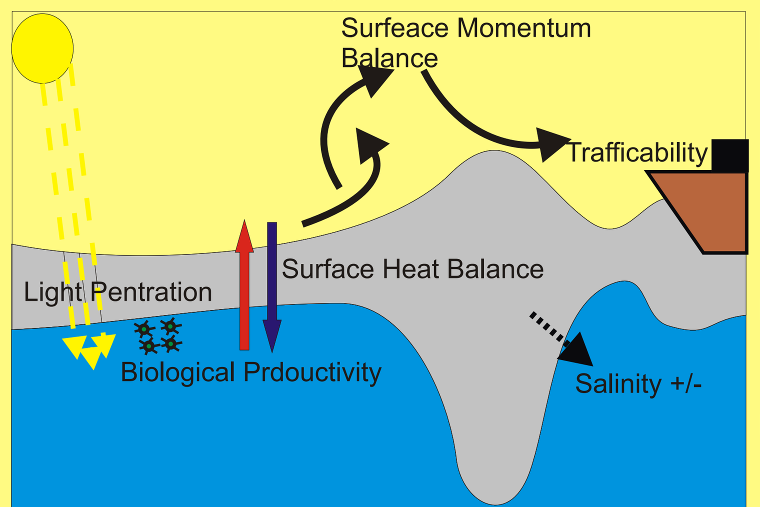

Figure 1: Processes influenced by sea ice thickness

- Ice thickness influences the processes shown in Figure 1.
- A good knowledge about sea ice thickness distributions is necessary for predictions of future climate change.
- A changing sea ice thickness distribution is an indicator for a changing climate.
- The ice thickness is necessary to determine the mass of ice in the ice cover.

Why is it difficult to measure sea ice thickness?

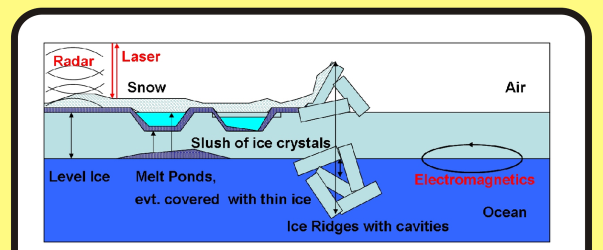
Figure 2: There is no unique definition of sea ice thickness

- The complex structure of sea ice does not allow for a unique definition of ice thickness. Different senors see different thickness.

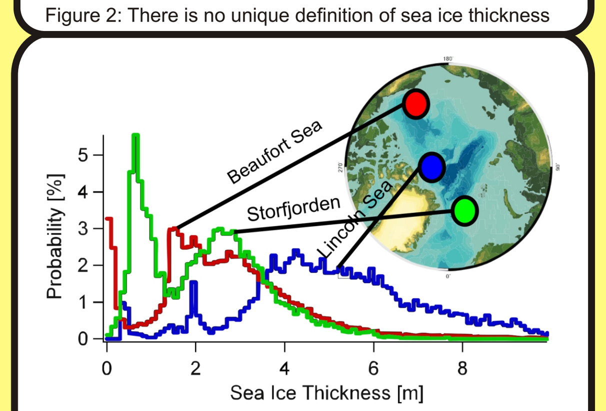

Figure 3: Three different sea ice thickness distributions

- Sea ice thickness varies in space and time.

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- To get a synoptic view of sea ice thickness, you have to measure on a daily basis and you have to cover the whole of the polar regions.

What kind of sea ice thickness sensors exist?

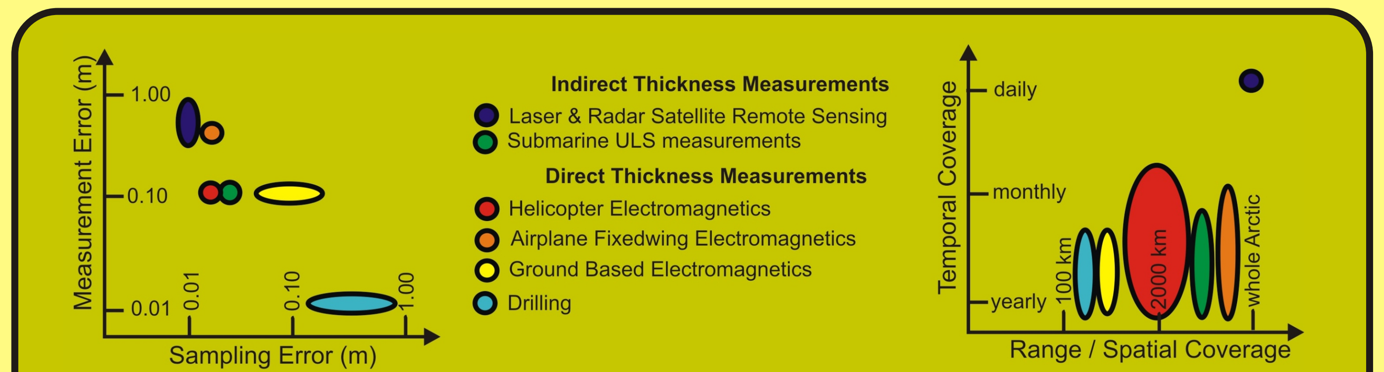


Figure 4: Common methods to measure sea ice thickness

- The parameters measurement- and sampling error and temporal- and spatial coverage are taken to qualify the different methods.

The History of EM sea ice thickness measurements at AWI

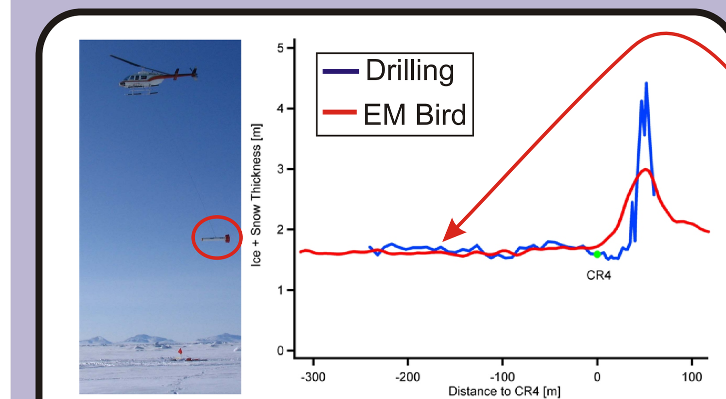


Figure 5: The AWI EM Bird and sample results

- Since 1991 usage of ground based EM31 instruments
- In 2001 construction of an helicopter EM Bird which is frequently used since then. Accuracy 0.1 m!
- In 2003 construction of another EM Bird to expand the activities.
- Several winter and summer campaigns took place in the Arctic and the Antarctic.
- In 2006 and 2007 development of an airplanebased EM system.

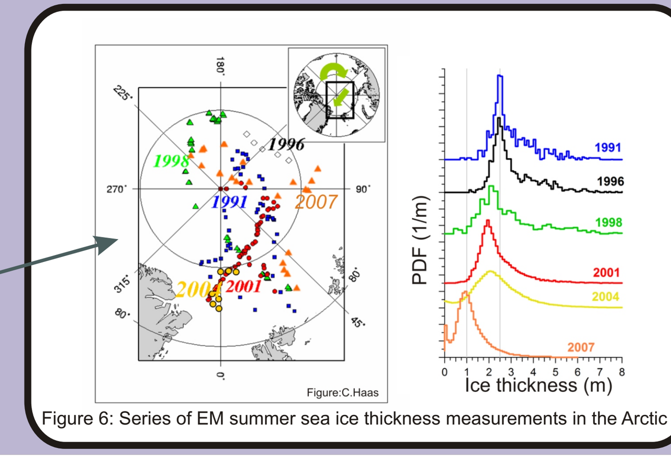


Figure 6: Series of EM summer sea ice thickness measurements in the Arctic

The new EM System

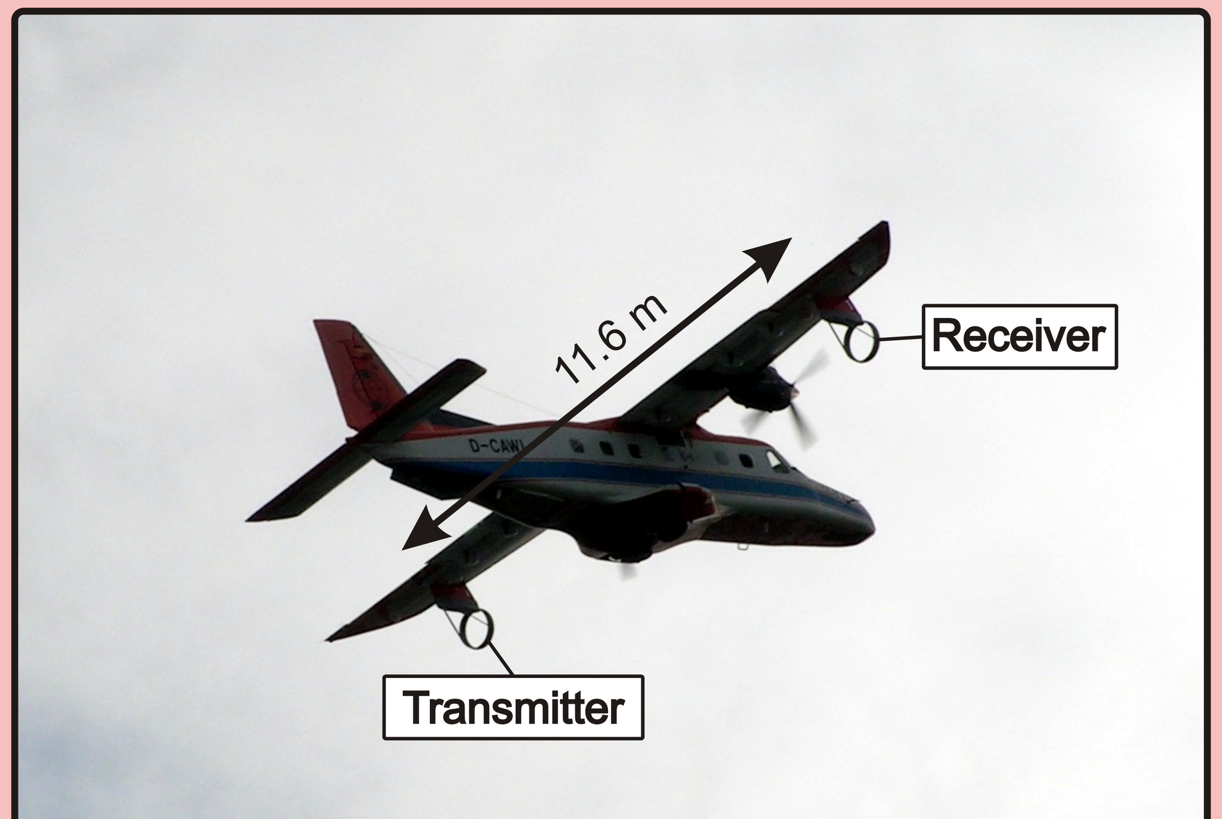
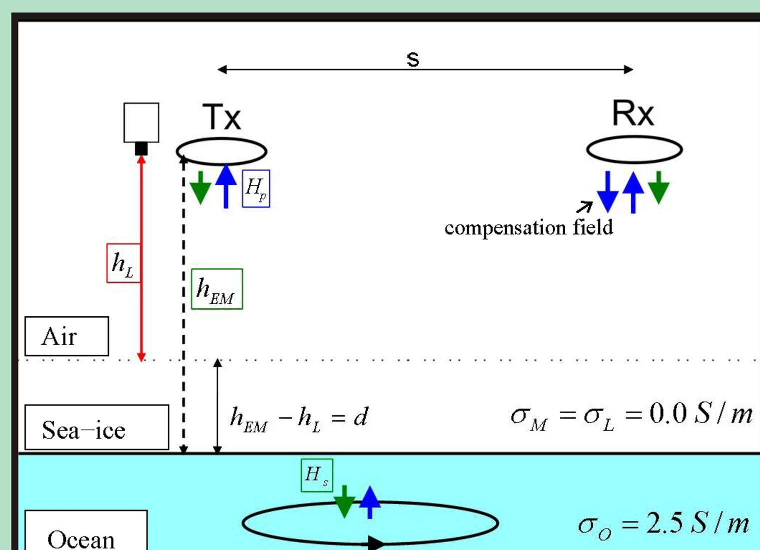


Figure 7: Dornier 228 with EM system

The instrument parameters:

Altimeter:	100 Hz Laser altimeter
Domain:	Frequency
Frequency range:	One frequency of 1960 Hz
Coil spacing:	11.6 m
Coil configuration:	Vertical coplanar
Magnetic Moment:	5 Am^2
Measuring Range:	200 ppm - 10^6 ppm
Vertical Resolution:	1 m to 2.5 m
Sampling rate:	10 Hz & 2 kHz
Range of Dornier 228:	540 - 1400 nautical miles
Operation flight height:	maximum of 100 ft
Operation speed:	80 to 100 knots

Theory of EM Sea Ice Thickness Measurements



Tx	Transmitter coil
Rx	Receiver coil
s	coil separation
σ_M	conductivity sea-ice
σ_L	conductivity air
σ_O	conductivity ocean
Hp	Primary magnetic field
Hs	Secondary magnetic field
h_L	Laser height
h_{EM}	EM height
d	Sea-ice thickness

Figure 8: Sketch of the EM sea ice thickness problem.

- Tx produces a primary magnetic field Hp.
- Induction processes in the ocean cause a secondary magnetic field Hs.
- Rx measures the ratio Hs/Hp.
- This ratio is a function of height over ocean
- EM height - Laser height = Ice thickness

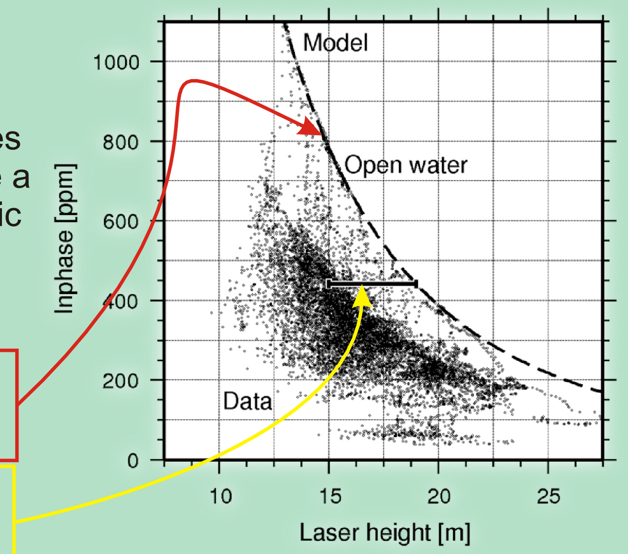


Figure 9: EM signal in ppm versus Laser height

Results & Challenges

A calibration flight over open water:

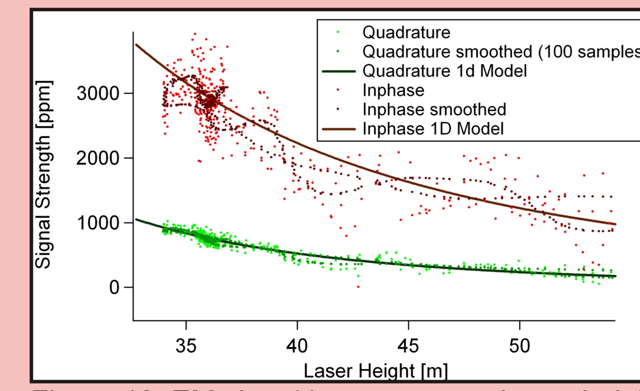


Figure 10: EM signal in ppm versus Laser height

Conversion ppm→thickness

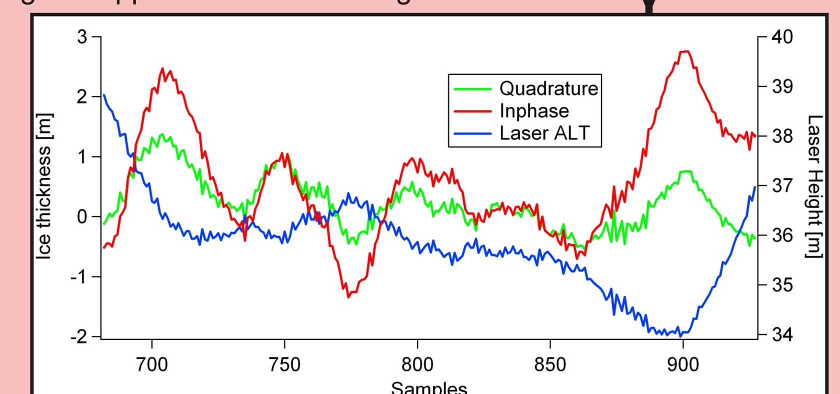


Figure 11: Sea ice thickness results over open water

The calibration factors are not constant in time

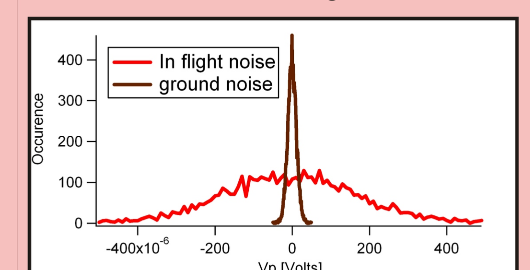


Figure 12: Noisehistogram

Heavy In Flight Noise

Challenges

Correction with Reference signal. A possible solution?

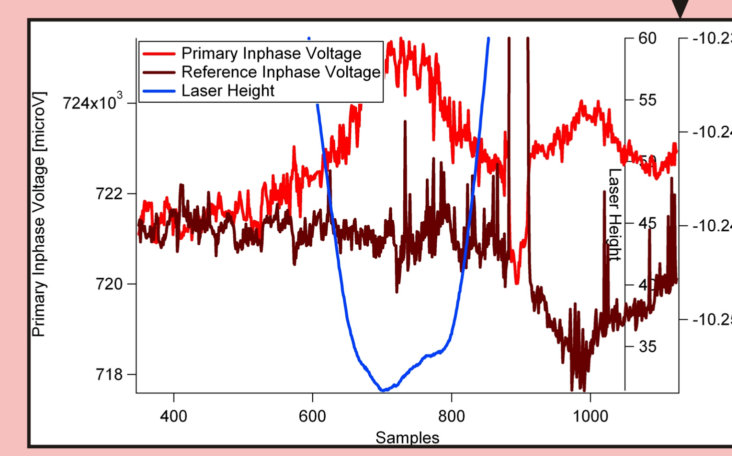


Figure 13: Recevier signal, reference signal and Altitude.

Conclusions and Outlook

The accuracy of the actual airplane system is not high enough for sea ice thickness measurements due to high noise and drifitng system paramters. The open question is whether this is related to inappropriate electronic components or to a principle problem of the fixed wing realization. The next project is a towed EM bird realization on the new polar airplane of the AWI, a Dc3.

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