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HELMHOLTZ-ZENTRUM FÜR POLAR-
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Campaign report

July 2010

TIFAX 2010 Summer Campaign

Sea ice thickness measurements with Polar 5 from Station Nord and Svalbard

HELMHOLTZ
ASSOCIATION

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1) Introduction

Transport of sea ice through Fram Strait affects the global climate through its influence on the thermohaline circulation. In recognition of its importance, the ice thickness distribution across Fram Strait and in the area north of Greenland was subject of the TIFAX 2010 field campaign. The ice thickness was investigated by means of an airborne electromagnetic (EM) system with a single-frequency of 4.08 kHz. The instrument was towed by a research aircraft (Polar 5) 15 meters above the ice surface. The method utilizes the contrast of electrical conductivity between sea water and sea ice to determine the distance to the ice-water interface. An additional laser altimeter yields the distance to the uppermost reflecting surface, hence ice thickness is obtained as the ice- plus snow thickness from the difference between the laser range and the EM derived distance. In this data report, all tracks/profiles taken during TIFAX 2010 are presented.

2) Flight operation

All EM Bird flights across Fram Strait and in the area north of Greenland were performed between July 19 and July 22, operated by Thomas Krumpen (AWI).
Tracks were taken towards a pre-defined point of return and back. Start and end node, the point of return and track length were chosen according to

1. the operating area of other ongoing campaigns,
2. available fuel capacity,
3. weather condition,
4. ice condition.

In total, 4 profiles were taken between July 19 and 22, 2010. The flight time amounts to roughly 24 hours.

3) Activities

a) EM tracks

The flight tracks contain 3 south-north transects and 1 east-west transects along 82° N. Flight tracks are divided into profiles with a length of 10 to 20 minutes to conduct in-flight instrument drift correction. The individual profiles are presented in section 6. Table 1 lists all tracks taken between July 19 and July 22, 2010.

Profile ID	*Comment*
20100719	
20100720	
20100721	
20100722	

Table 1 : EM BIRD: List of all tracks

4) Processing

a) Basic principle

The EM system consists of a transmitter/receiver system for harmonic electro-magnetic signals. The transmitter coil emits electromagnetic waves (primary field) at a certain frequency, which leads to induction of eddy currents in any conductive layers beneath the instrument. These eddy currents induce again an electromagnetic field (secondary field), which is measured together with the primary field by a receiver coil. Because of induction processes, the secondary field has a phase shift to the primary field. This phase shift together with the strength of the secondary field is a function of the thickness and the conductivity of layers underneath the instrument.
Due to the large conductivity contrast to the saline sea water, the air-, snow- and ice-layer can be assumed to be electrical insulators. With known sea water conductivity (see section b)) the EM signal can be modelled as a function of height above the sea level (Figure).

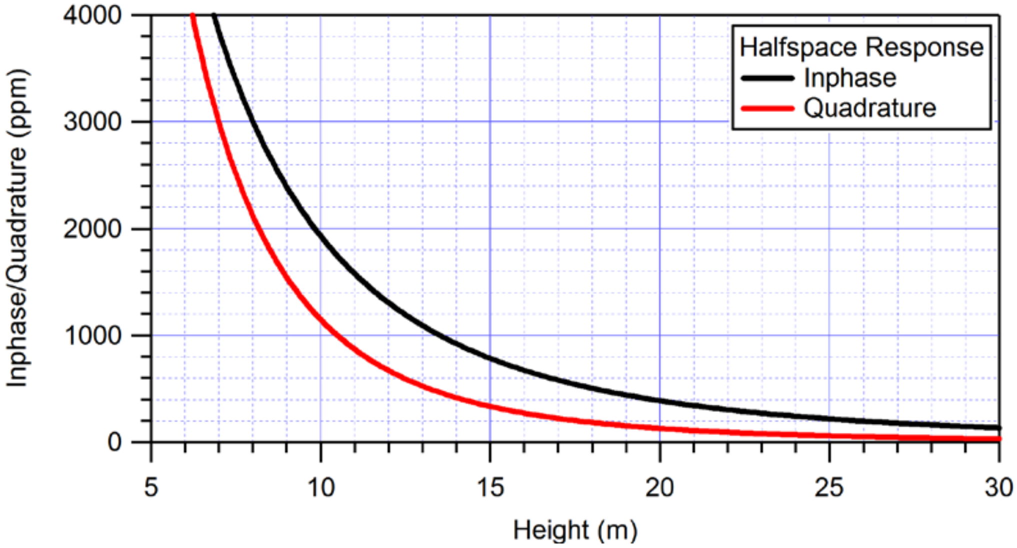


Figure 1 : Forward model results for inphase and quadrature channels (conductivity 2500 mS/m)

While the EM system gives the distances from the instrument to the sea surface (under the sea ice) a laser altimeter records the distances to the top of the sea ice or snow layer. The snow plus ice thickness is equal to the laser range minus the EM derived distance.

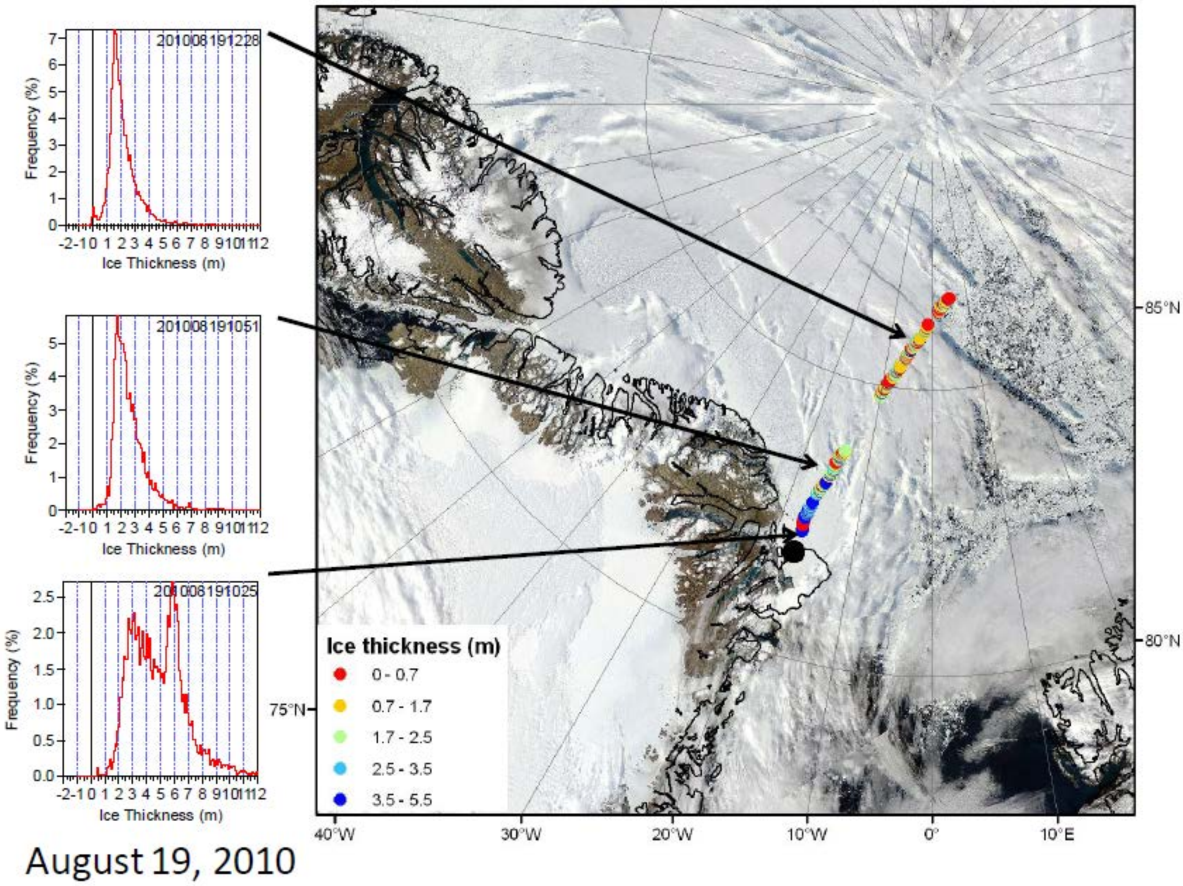
b) Sea water conductivity

A salt water conductivity of 2500 mS/m was used for data processing.

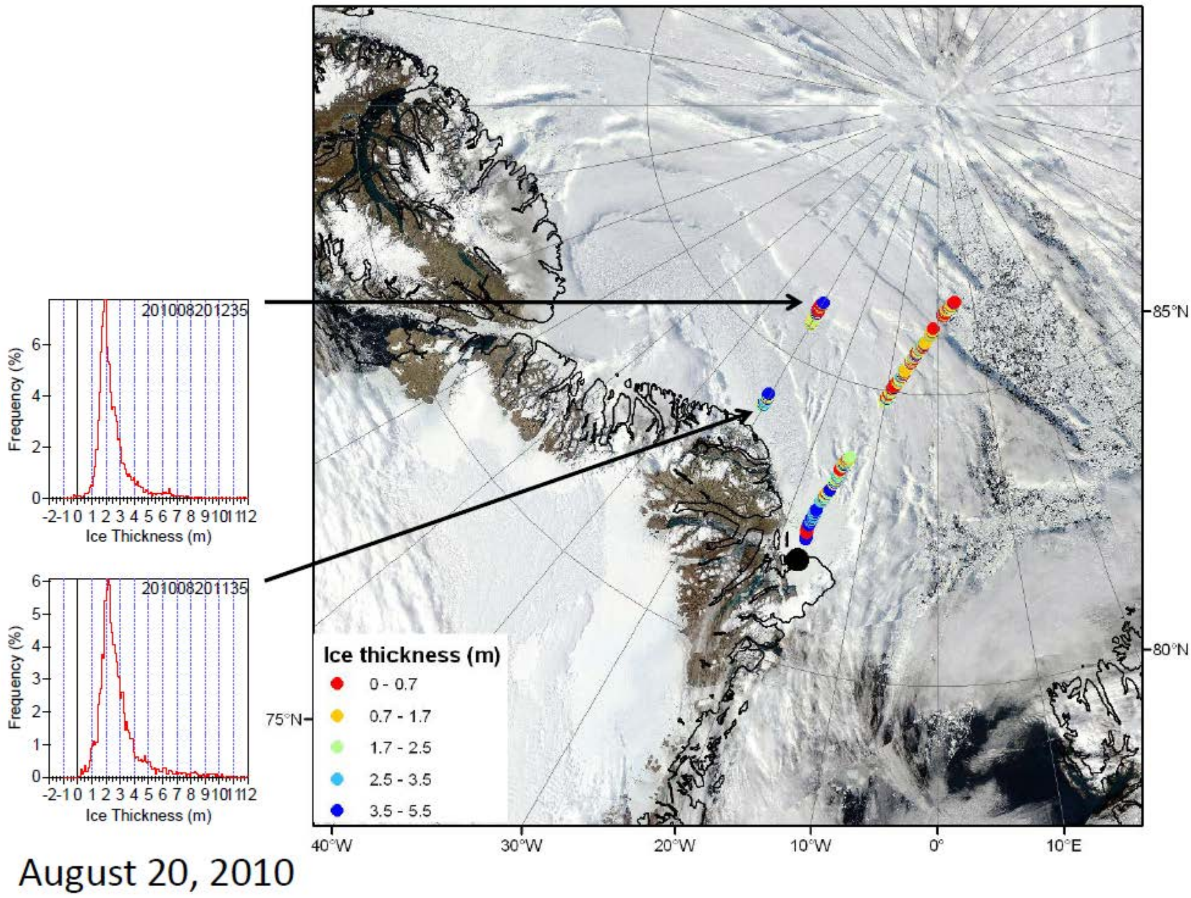
5) Individual Profiles

Below, the individual profiles for the specific dates are drown on top of a MODIS image. In addition, the ice thickness frequency distribution for individual sections (positions marked by black arrows) are shown.

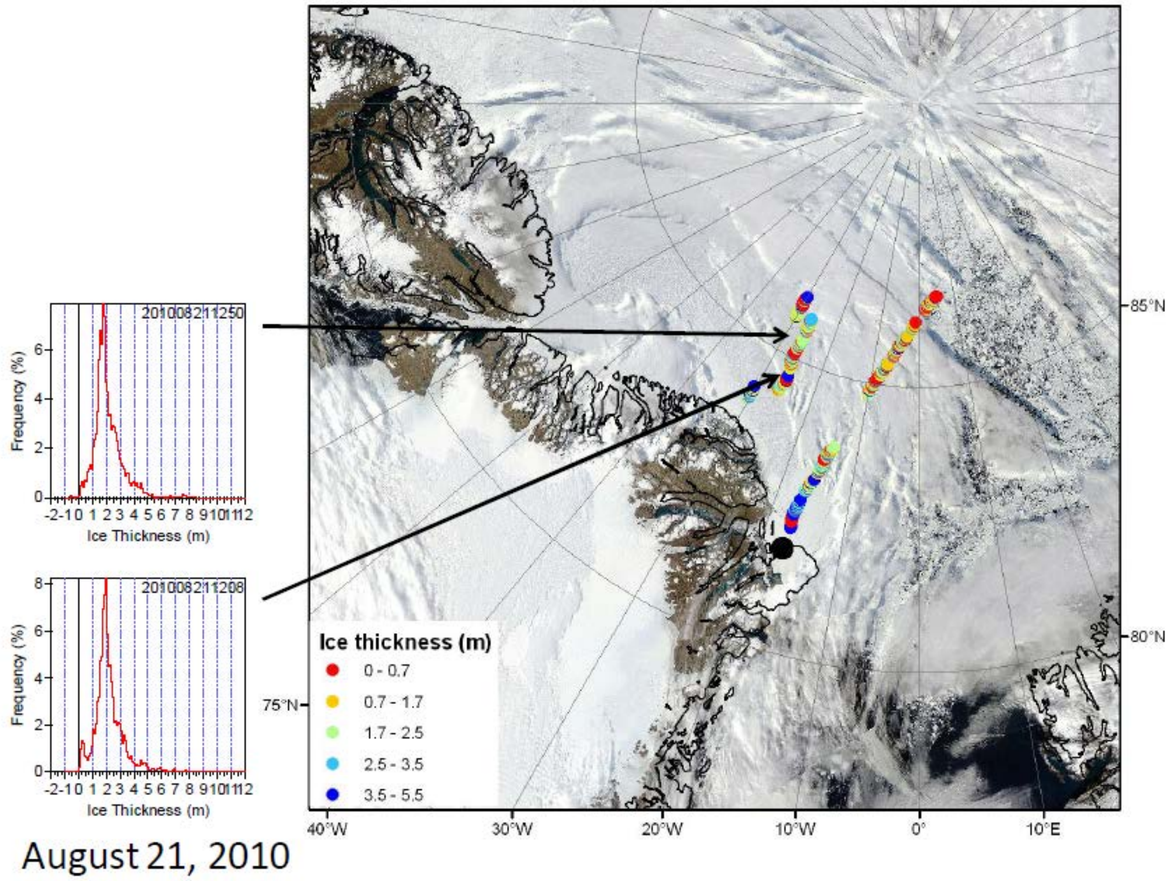
a) 20100719



b) 20100720

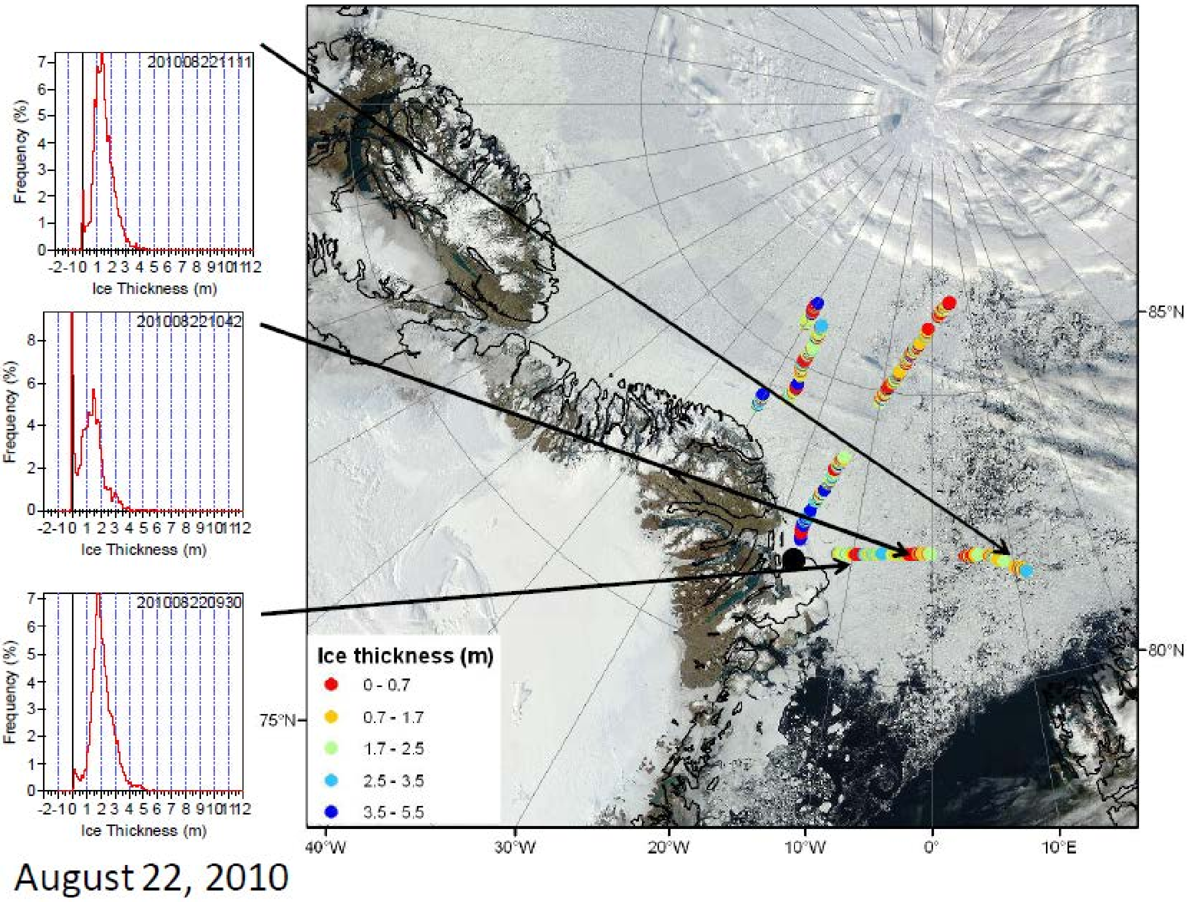

201008201235
Frequency (%)
Ice Thickness (m)
201008201135
Frequency (%)
Ice Thickness (m)
Ice thickness (m)
0 - 0.7
0.7 - 1.7
1.7 - 2.5
2.5 - 3.5
3.5 - 5.5
85°N
80°N
75°N
40°W
30°W
20°W
10°W
0°
10°E
August 20, 2010

c) 20100721



201008211250
Frequency (%)
Ice Thickness (m)
201008211208
Frequency (%)
Ice Thickness (m)
August 21, 2010
Ice thickness (m)
0 - 0.7
0.7 - 1.7
1.7 - 2.5
2.5 - 3.5
3.5 - 5.5
85°N
80°N
75°N
40°W
30°W
20°W
10°W
0°
10°E

d) 20100722



e) Data format

For each profile one data file is delivered. The file naming conventions is given by:

$profile_id_`allfinal.dat`.

The files are standard ASCII with MS Windows newline format. The first line can be skipped as a header.

Column	*Format*	*Unit*	*Description*
`af_lat`	`F12.7`	deg	Latitude
`af_lon`	`F12.7`	deg	Longitude
`af_gps_time`	`F12.7`	hour	Time
`af_dist`	`F12.3`	m	Distance since start of profile
`af_fid`	`I9`	-	Record number
`af_thick`	`F8.3`	m	Sea ice thickness [m]
`af_alt`	`F8.3`	m	Laser range [m]

Table 2 : Allfinal data format

6) Basic formulas

The primary and secondary magnetic field can be described as a harmonic signal with a frequency ω and a phase angle ϕ:

$$H_p = A_0 \cdot \sin(\omega t)$$
$$H_s = A_1 \cdot \cos(\omega t - \phi)$$

Equation 6-1

Where A_0 and A_1 are functions of the geometry of the transmitter – conductor – receiver system. The ratio of secondary to primary field can be separated into a real and imaginary part,

$$\frac{H_s}{H_p} = I + i \cdot Q$$

Equation 6-2

with *I* called Inphase and *Q* Quadrature. These values can be easily converted into amplitude *A* and Phase ϕ and vice versa via a transformation between cartesian and polar coordinate system:

$$A = \sqrt{I^2 + Q^2} \qquad \phi = \tan\left(\frac{Q}{I}\right)$$
$$I = A \cdot \cos\phi \qquad Q = A \cdot \sin\phi$$

Equation 6-3

Subsequently an amplitude phase correction of *I* and *Q* can be performed in polar coordinates:

$$I_{corr} = (A \cdot \Delta A) \cdot \cos(\phi + \Delta\phi)$$
$$Q_{corr} = (A \cdot \Delta A) \cdot \sin(\phi + \Delta\phi)$$

Equation 6-4

The model curves, which calculated by a solving a Hankel transformation, are approximated by a double exponential function for each *I* and *Q* channel,

$$[I|Q](h) = c_0 + c_1 \cdot e^{-c_2 h} + c_3 e^{-c_4 h}$$

Equation 6-5

where *h* is the height of the instrument above the conductive water layer. For a given *I* or *Q* a simple inversion of Equation 6-5 results in the EM derived distance to the conductor h_{em}.

Finally the snow plus sea ice thickness can be obtained by subtracting the laser range d_{laser} from this distance:

$$z_{ice+snow} = h_{em} - d_{laser}$$

Equation 6-6