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4	University of Bremen, Institute of Environmental Physics	UB	DE
5	The Chancellor, Masters and Scholars of the University of Cambridge	UCAM	UK
6	Norwegian Meteorological Institute, Norwegian Ice Service	Met.no	NO
7	Scientific foundation Nansen International Environmental and Remote Sensing Centre	NIERSC	RU
8	B.I. Stepanov Institute of Physics of the National Academy of Sciences of Belarus	IPNASB	BR

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Table of Contents

1 OVERVIEW	3
2 DATA SOURCES.....	4
2.1 (AWI) AIRBORNE EM SEA ICE THICKNESS.....	4
2.2 (AWI) IN-SITU SEA ICE AND SNOW THICKNESS.....	5
2.3 (AWI) SEA ICE SURFACE ROUGHNESS	6
2.4 (NIERSC) IN-SITU DATA FROM AIRBORNE EXPEDITIONS AND DRIFTING ICE STATIONS.....	6
3 DATA AVAILABILITY	7
3.1 AWI.....	7
3.2 NIERSC.....	9
4 BIBLIOGRAPHY AND FURTHER LITERATURE.....	10

List of Figures

Figure 2.1: Airborne EM sea ice thickness measuring setup with helicopters and fixed-wing airplanes.	4
Figure 2.2: Principle of Airborne EM sea ice thickness retrieval.	5
Figure 2.3: Typical histogram and profile of Airborne EM sea ice thickness measurements (PAMARCMIP 2009 campaign, 16. April 2009).	5
Figure 3.1: Map of airborne EM surveys since 2001 color-coded by campaign	7

List of Tables

Table 3.1: List of field campaigns with sea ice related data available in the PANGAEA database	8
Table 3.2: Data file format for EM-bird data in PANGAEA.....	8

SUMMARY

This report provides an overview of compiled in situ data from previous field experiments in sea ice areas, especially data on ice thickness, ice ridges, and other sea ice variables needed to validate the satellite retrievals. Data from several airborne EM surveys, including ice thickness and surface roughness data, as well as ground measurements are compiled and will be made available on the PANGAEA database for integration and validation in WP8. The in situ data collection in the Arctic will be integrated into the GMES coordinating in situ project (GISC) led by EEA.

(Leader: AWI, contribution from UCAM, NERSC, NIERSC and IP NASB)

1 Overview

The aim of the work package 2.1 is the compilation of existing in situ and airborne sea ice data from previous field campaigns and the provision of these data for validation purposes. For that reason, existing sea ice thickness and roughness data were collected, partially reprocessed, quality-controlled and converted into a uniform file format. The data will be made freely available on the PANGAEA (<http://www.pangaea.de/>) database.

There are three types of data sets available for sea ice thickness retrievals:

1. Airborne electromagnetic (EM) total (sea ice + snow) thickness
2. Surface roughness by laser altimetry
3. Ground measurements of sea ice thickness

The data have been measured between 1991 and today, and in some occasions, measurements from two or all three methods were performed coincidentally. All datasets have been collected during field campaigns lead by scientists of the Alfred Wegener Institute (AWI). Additional submarine sonar data is available from the University of Cambridge (UCAM) and is omitted in this report, because it will be made available within WP 6 of SIDARUS. UCAM also participated in field activities measuring ice thickness and ice freeboard in autumn of 2011. This data will be available to SIDARUS in a later phase of the project.

2 Data sources

2.1 (AWI) Airborne EM sea ice thickness

Airborne EM sea ice thickness measurements have been performed by the Alfred Wegener Institute (AWI) during several campaigns between 2001 and today, listed in Table 2.1. The measurement device, the so-called EM-Bird, is usually towed underneath an aircraft (helicopter or airplane) in a height of 40 to 50 ft above the sea ice surface. This method allows individual sea ice thickness profiles with a length of 200 km (helicopter) and up to 500 km (airplane).

The EM-Bird consists of a pair of transmitter and receiver coils. The transmitter coils emit an electromagnetic (EM) field that induces eddy currents in the saline sea water. The eddy currents in turn induce a secondary EM field that is sensed by the second receiver coil. The distance between the sea ice-water-interface and the EM-bird is estimated by an empirical relation connecting the phase and strength of the transmitted and received EM fields. The accuracy above level ice amounts to 0.1 m, while thicknesses of deformed sea ice (pressure ridges) can be underestimated between 50% and 80%. The underestimation depends on the footprint of the measurements, the salinity of the sea water and water inclusions in pressure ridges (*Haas et al.*, 2009; *Haas and Jochmann*, 2003).

A laser altimeter measures the distance between the EM-bird and the sea ice or snow surface. The distance between both heights corresponds to the total (sea ice + snow) thickness of the ice cover. A detailed description of the EM-bird system and measurement principle is given in *Haas et al.* (2009).

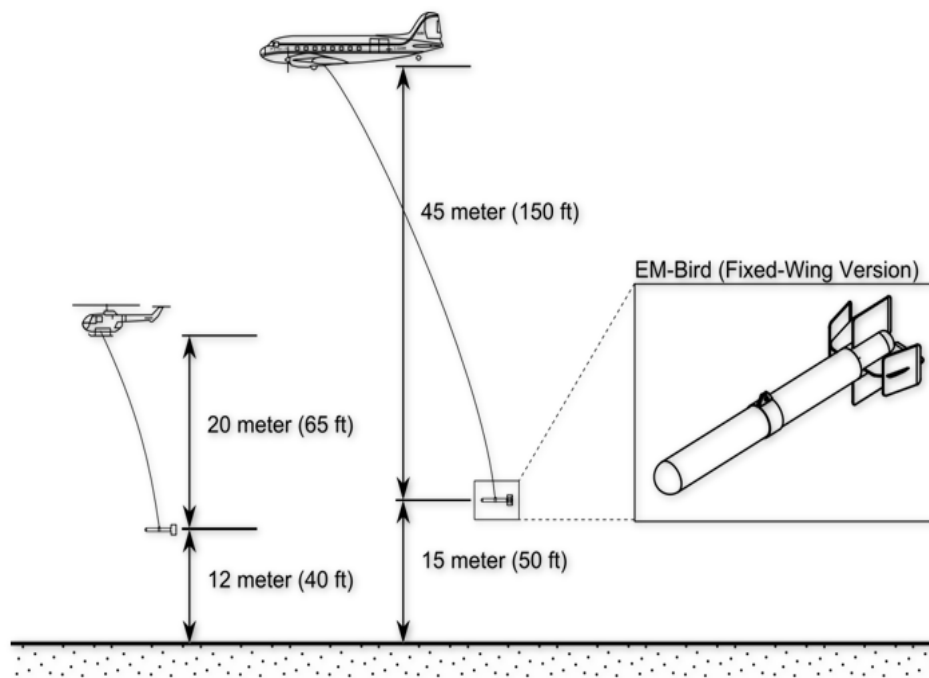


Figure 2.1: Airborne EM sea ice thickness measuring setup with helicopters and fixed-wing airplanes.

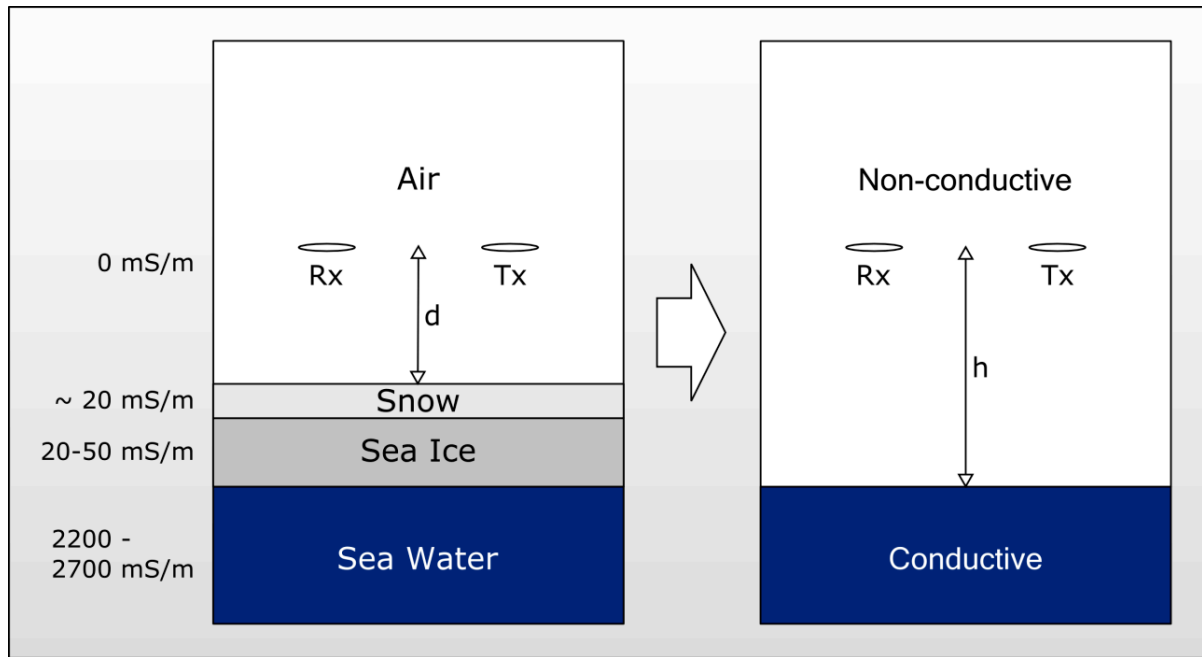


Figure 2.2: Principle of Airborne EM sea ice thickness retrieval. The EM response is used to estimate distance of the sensor platform to the ice-water interface, a laser altimeter for the distance to the top ice or snow surface. The electrical conductivity of the sea ice/snow layer is neglected.

An example for airborne EM ice thickness data is given in Figure 2.3 (Beaufort Sea during the PAMARCMIP campaign in 2009). The histogram displays the sea ice thickness distribution; the other figure images the profile of the survey. Such data can be used for validation of satellite-derived and modeled sea ice thicknesses. Additionally, in repeatedly sampled regions, an analysis of sea ice thickness changes by airborne sea ice thickness measurements is possible.

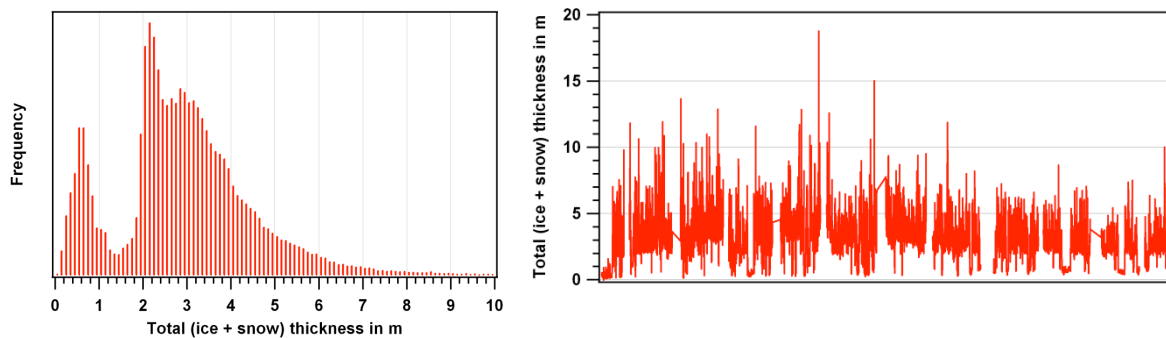


Figure 2.3: Typical histogram and profile of airborne EM sea ice thickness measurements (PAMARCMIP 2009 campaign, 16. April 2009).

2.2 (AWI) In-situ sea ice and snow thickness

There are two types of ground measurement data available at AWI: 1) data from drill-holes and 2) data from EM-ground surveys. Both comprise the possibility to additionally measure snow thicknesses with a ruler stick. The acquisition of ground EM ice thickness data (hand-

held EM device: EM31 MKII, Geonics Ltd. Canada) follows the principle of the airborne dataset. These data bring the possibility to validate and evaluate airborne sea ice thickness measurements, when both surveys have been performed concurrently. Especially the drill-hole data have a high accuracy, while EM-ground measurements suffer from basically the same inaccuracies as the airborne EM measurements, however at a higher spatial resolution.

2.3 (AWI) Sea ice surface roughness

The surface elevation or, more precisely, the surface roughness of sea ice is obtained from laser altimeters, which measure the distance to the sea ice with an accuracy of about ± 3 cm (Haas, 1998). To eliminate noise caused by aircraft height variations, a filtering method after *Hibler III* (1972) is applied to the data. The subtraction of the aircraft height alterations from the measured signal results in the surface roughness of the sea ice. Table 3.1 lists the field campaigns from which data are available.

2.4 (NIERSC) In-Situ data from airborne expeditions and drifting ice stations

In-situ measurements of Arctic sea ice from the airborne Sever expeditions: 1928, 1937, 1941, 1948-1952, and 1954-1989. The total data set includes measurements during 3771 landings and was obtained from the World Data Center for Glaciology/National Snow and Ice Data Center (NSIDC), Boulder, Colorado.

Parameters: ice thickness, ice freeboard, snow depth, snow density, floe size, size of ridges and hummocks, sastrugi size and area, and some others.

Simultaneous measurements of ice thickness, freeboard and snow depth on first-year ice during Sedov drift in winter 1937/1938: 41 measurements from October 26, 1937 until April 24, 1938.

Simultaneous measurements of ice thickness, freeboard and snow depth at the "North Pole -35" drifting station. Measurements were conducted at a polygon on multiyear ice floe in 45 points. The size of the polygon is 40 x 100 m, and the distance between points of measurements is 10 m along X-axis, and 20 m along Y-axis. 18 series of measurements were made during winter from September 21, 2007 until April 24, 2008.

Simultaneous measurements of ice thickness, freeboard and snow depth during Somov expedition in April-May 2006. Measurements were made in the north-eastern part of the Barents Sea at polygons on 7 ice stations.

3 Data availability

3.1 AWI

Campaigns for sea ice data retrievals have been performed over large parts of the Arctic as well as in the Baltic Sea (see Fig. 3.1) since 1991 (Airborne EM since 2001). Table 3.1 lists all available sea ice thickness and surface roughness data from the above mentioned methods available to SIDARUS. The data can be downloaded from the PANGAEA database (<http://www.pangaea.de/>) with full metadata and file format description. Data files contain information on the measurement date and time, the position and the ice thickness (Table 3.1).

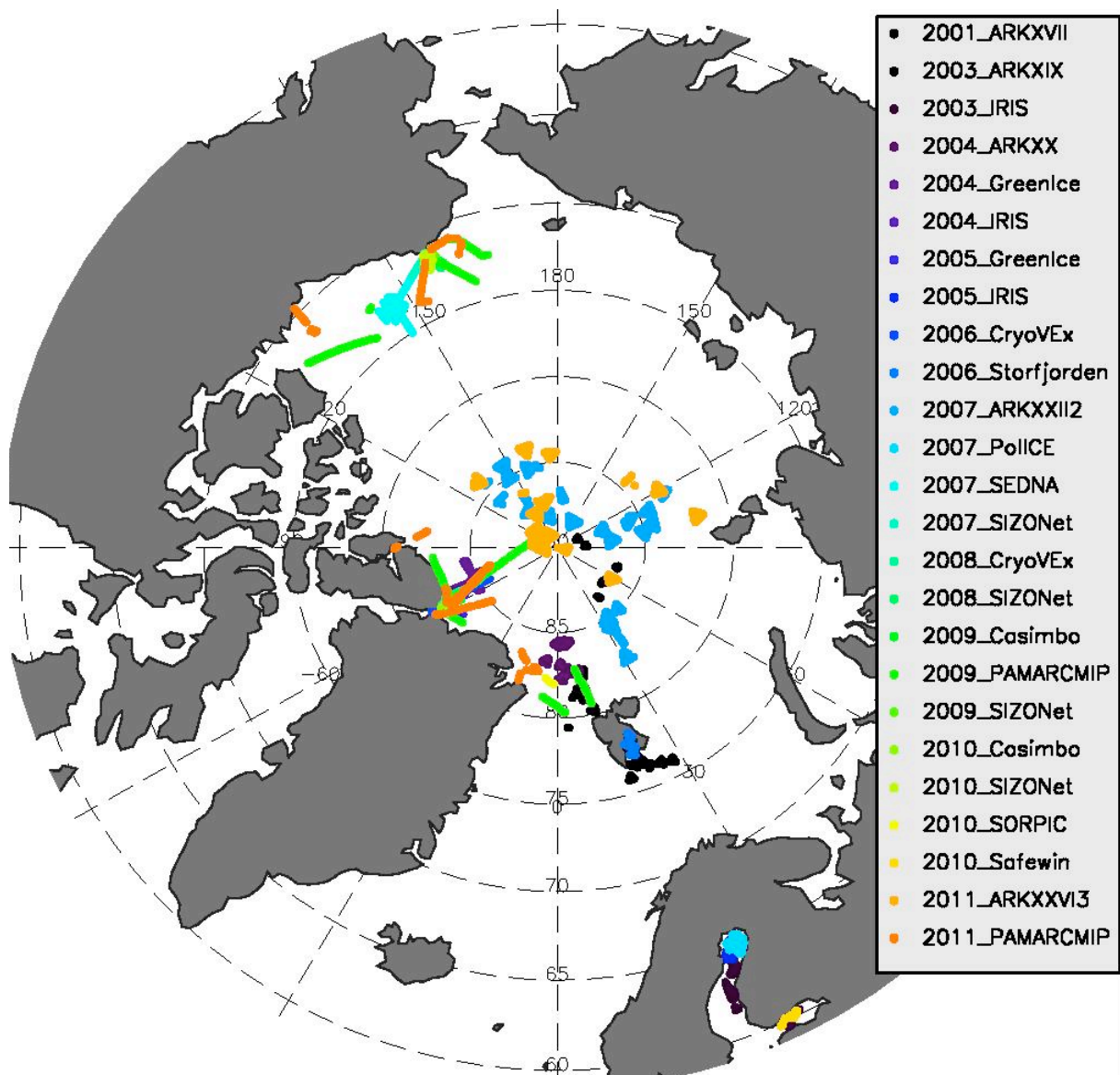


Figure 3.1: Map of airborne EM surveys since 2001 color-coded by campaign

Table 3.1: List of field campaigns with sea ice related data available in the PANGAEA database

Date	Campaign	Funding	Location	AEM	LIDAR	In-Situ
Aug/Sep 1991	ARKVIII	AWI	Arctic			x
Sep 1993	ARKIX	AWI	Laptev Sea			x
Jul/Aug 1995	ARKXI	AWI	Arctic		x	x
Aug/Sep 1996	ARKXII	AWI	Arctic		x	x
Aug/Sep 1998	SHEBA	AWI	Arctic		x	
Aug/Sep 2001	ARKXVII	AWI	Arctic	x	x	x
Feb 2003	IRIS	FIMR	Baltic Sea	x	x	
Mar/Apr 2003	ARKXIX	AWI	Longyearbyen	x	x	x
Feb/Mar 2004	IRIS	FIMR	Bay of Bothnia	x	x	
May 2004	GreenIce	EU	Lincoln Sea	x	x	
Jul/Aug 2004	ARKXX	AWI	Fram Strait	x	x	
Mar 2005	IRIS	FIMR	Bay of Bothnia	x	x	
May 2005	GreenIce	FIMR	Lincoln Sea	x	x	
May 2006	CryoVEx	ESA	Lincoln Sea	x		
May 2006	Storfjorden	NPI/EU	Longyearbyen	x		
Mar 2007	PolICE	FMI	Bay of Bothnia	x	x	
Apr 2007	SEDNA	NSF	Beaufort Sea	x		
Apr 2007	SIZONet	NSF	Beaufort Sea	x		
Apr 2007	PoleAirship	Total	Arctic		x	
Aug/Sep 2007	ARKXXII2	AWI	Arctic	x		x
Apr 2008	SIZONet	NSF	Beaufort Sea	x		
May 2008	CryoVEx	ESA	Lincoln Sea	x		
Apr 2009	PAMARCMIP	AWI	Lincoln Sea	x		
Apr 2009	SIZONet	NSF	Beaufort Sea	x		
May 2009	Casimbo	Canada	Lincoln Sea	x		
Mar 2010	Safewin	FMI	Baltic Sea	x		
Apr 2010	SIZONet	NSF	Beaufort Sea	x		
May 2010	Casimbo	Canada	Lincoln Sea	x		
May 2010	SORPIC	AWI	Fram Strait	x		
Mar/Apr 2011	PAMARCMIP	AWI	Arctic	x		
Aug/Sep 2011	ARKXXVII3	AWI	Arctic	x		x

Table 3.2: Data file format for EM-bird data in PANGAEA

Column	Description	unit
1	Date/Time	-
2	Latitude	degree
3	Longitude	degree
4	Ice thickness/ roughness	m

3.2 NIERSC

The Data is available directly from NIERSC. Contact person is Dr. Vitali Alexandrov.

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