Polar research in cool regions

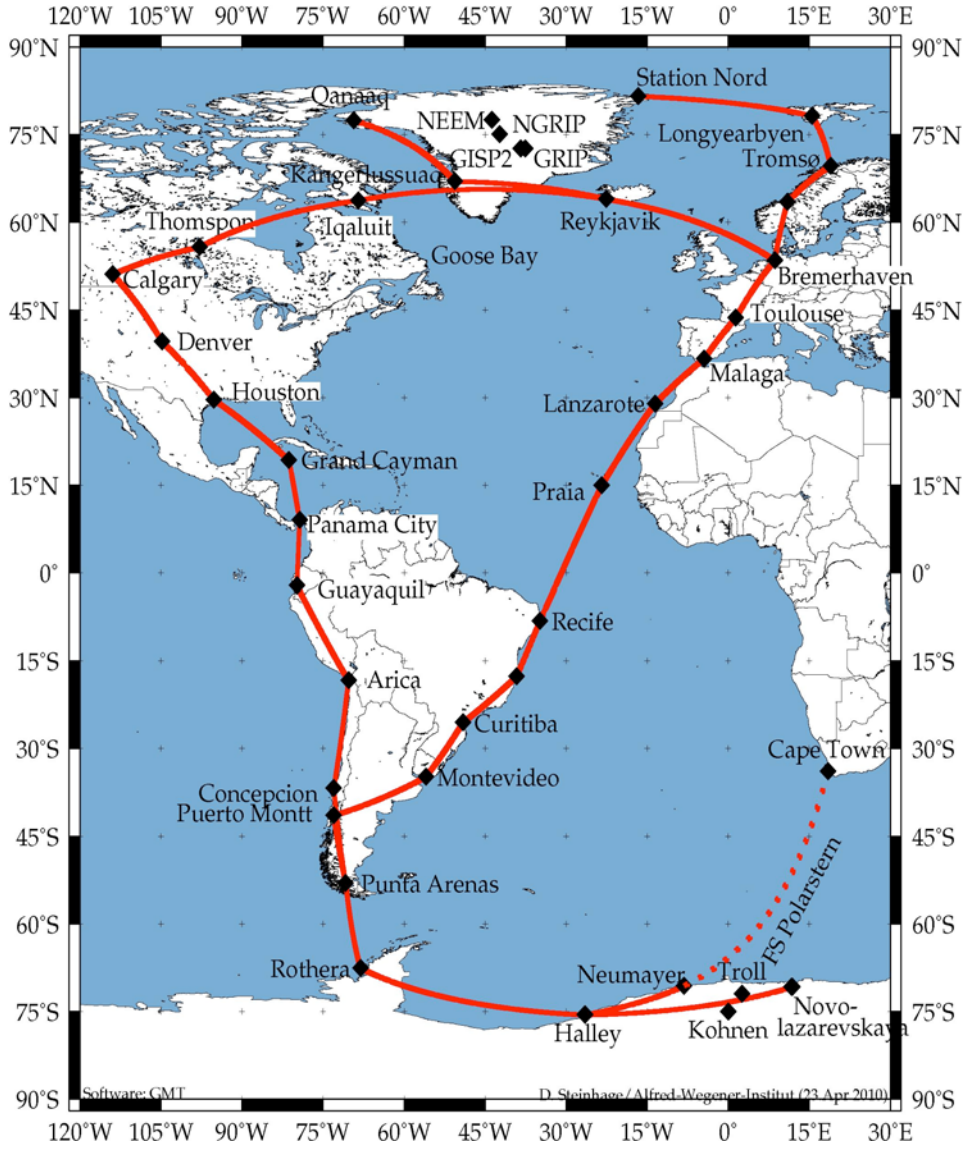
D. Steinhage
Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

- Introduction
- Aircraft used
- Basis in Antarctica

Foto: AWI

- Examples from surveys in the Arctic and Antarctica
  - * Atmospheric physics - PAMARCMIP
  - * Meteorology - MELTEX
  - * Glaciology - DoCo
- Outlook

Ferry routes from Bremerhaven to the polar regions



Distance from Bremerhaven to

Kangerlussuaq, Greenland: 3450 km

Longyearbyen, Svalbard: 2850 km

Neumayer, Antarctica: 18500 km

Calgary, Canada: 7400 km

Research aircraft at AWI

1983/84 POLAR 1 (Do 128) & POLAR 2 (Do 228)
1984/85 POLAR 2 & POLAR 3 (both Do 228)
25.02.1985 POLAR 3 shot down above Morocco
1985/86 POLAR 2 & POLAR 4 (Do 228)
25.01.2005 „hard" landing of POLAR 4
2007 POLAR 5 (Basler BT-67)

Foto: Stober, HFT Stuttgart

Foto: T. Boebel, AWI

Foto: AWI

Project POLAR 5

Foto: Basler

31.Oct 2006 - Placement of Order
27.Apr 2007 - Delivery (unpainted) Oshkosh (WI), USA
May-Aug 2007 - Certification work in Oshawa & Muskoka, Canada
Sep. 2007 - Integration of geophysical equipment in Bremerhaven, Germany
01.Oct 2007 - Commissioning of POLAR 5 in Bremerhaven
27.Nov 2007 - First scientific flight in Antarctica

Project POLAR 5


Foto: Basler


Foto: Gernandt, AWI

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Project POLAR 5


Foto: Basler


Foto: Gernandt, AWI

Foto: G. Schlaeger, 2007

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Technical parameters of POLAR 5

		POLAR 5 (Basler BT-67)	POLAR 2 (DO-228-101)
Technical parameter			
Length / height over-all	m	20.00 / 5.20	15.04 / 4.86
Wing span	m	29.00	16.97
Length / width of cabin	m	12.85 / 2.34	6.30 / 1.34
Height of cabin	m	2.00	1.35
Empty weight (wheel)	kg	8387	3720
Maximum take off weight	kg	13068	6400
Engine		Pratt & Whitney (PT6A-67R)	Garrett/AiRes. (TPE 331-5)
Engine power (per engine)	Ps	1281	700
Fuel consumption	l/h	570	350
Service ceiling	m	7600	7600
Mission parameter			
Max. payload (3 flight h)*	kg	2500	1000
Endurance without payload*	km	3000	3000
Maximum cruising speed	km/h	380	330
Number of passenger	pax	18	8
Maximum take off height	m	3800	3100
28V DC science power	A	550	350

* standard crew + survival equipment (weight in kg) + 45 min. reserve

Characteristics for science and logistics

- approx. 1700 km (6.5 h) range for geophysical/glaciological survey flights on skis
- space and electrical power for 5 racks
- 4 heavy payload & 2 light weight wing stations (150 kg/30 kg)
- nose and tail booms for various instruments
- winch for bird operations
- 2 belly doors with openings for up to 6 sensors
- up 12 openings in cabin roof for sensors
- 3 side panels for power and signal distribution
- external 220 V/AC in-take

- 2 t payload on flight legs of 750 km & empty on return
- capacity for up to 18 passengers (wheels only, on skis: 14)
- good take off performance at altitudes above 2500 m a.s.l.

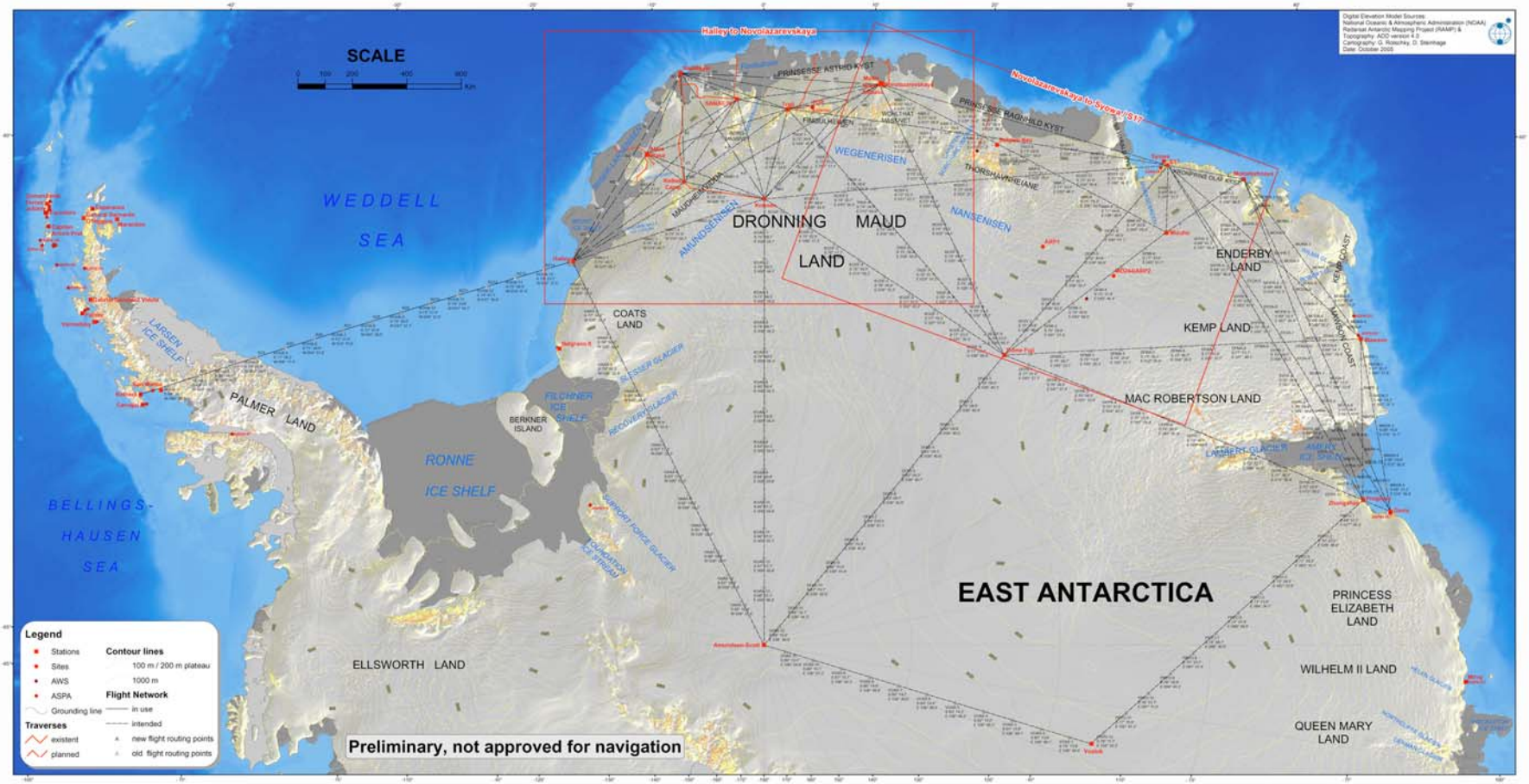
Aircraft missions

- **Science**
- **Search And Rescue (SAR)**
- **Logistics**

Foto: AWI

Foto: AWI

DRONNING MAUD LAND - SUGGESTED FLIGHT ROUTES



Scientific and logistic air operations in Antarctica

Novo airfield - 1 of 2 DROMLAN gateways into Antarctica

Foto: Steinhage, AWI

Neumayer II (1992-2009) & Neumayer III (28/02/2009-)

Foto: Steinhage, AWI

Foto: AWI

Kohnen - summer base for deep ice core drilling - EPICA

- DML: 75°00´S 0°07´E; 2890m asl; T -47°C
- 1996 - 2000: pre-site survey
- 2000 - 2002: construction of Kohnen Station and installation of the deep drilling system
- 2002 -2006: drilling to bedrock 2784 m; age ~ 300 000 a

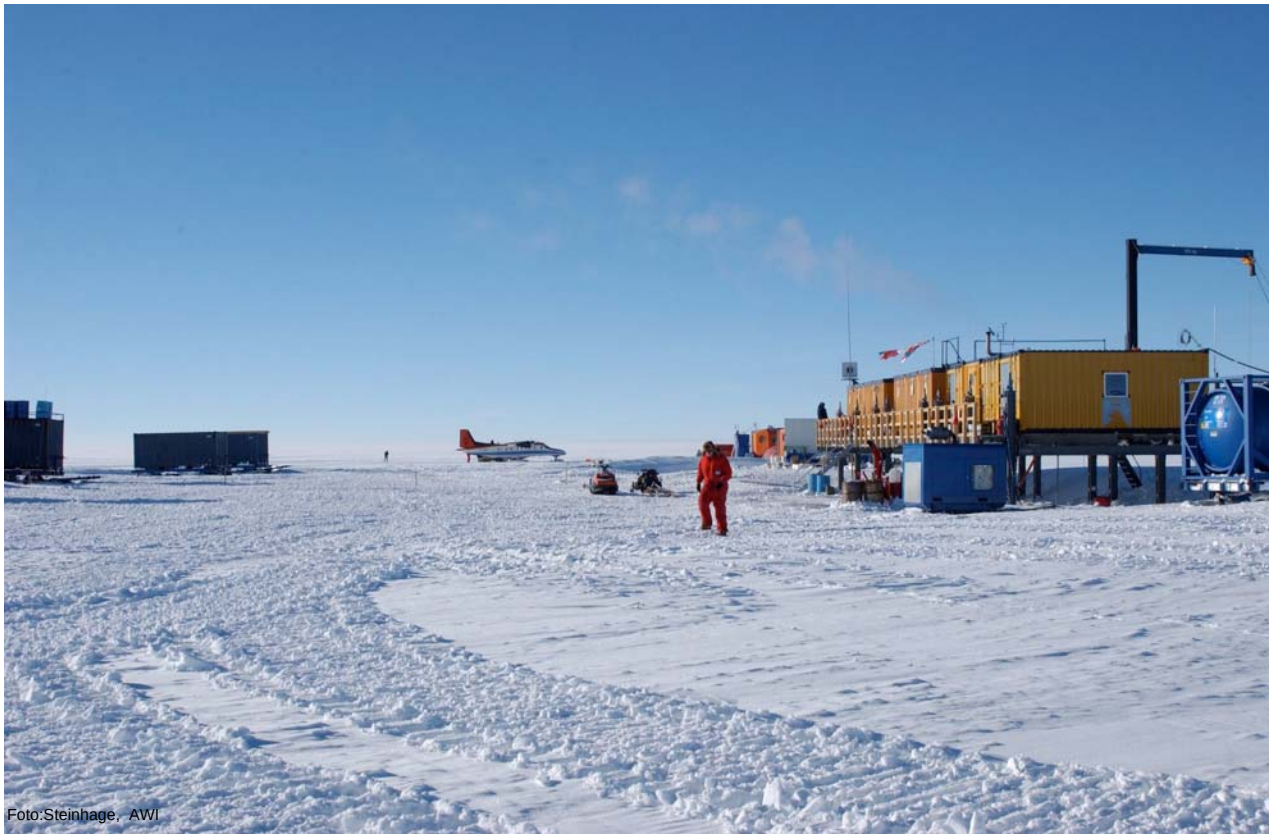


Foto:Steinhage, AWI

S17/Syowa - base of joint German-Japanese surveys

Foto: Steinhage, AWI

Foto: Steinhage, AWI

Foto: Steinhage, AWI

2007/08 - first season of POLAR 5 in Antarctica

Foto: Steinhage, AWI

Foto: Gernandt, AWI

Foto: AWI

Foto: Gernandt, AWI

Research topics of POLAR 5

Glaciology - Geophysics

- internal structure of ice and ice thickness
- anomalies of earth magnetic and gravity field
- laser and radar altimetry

Meteorology

- boundary layer studies above polar oceans and sea ice

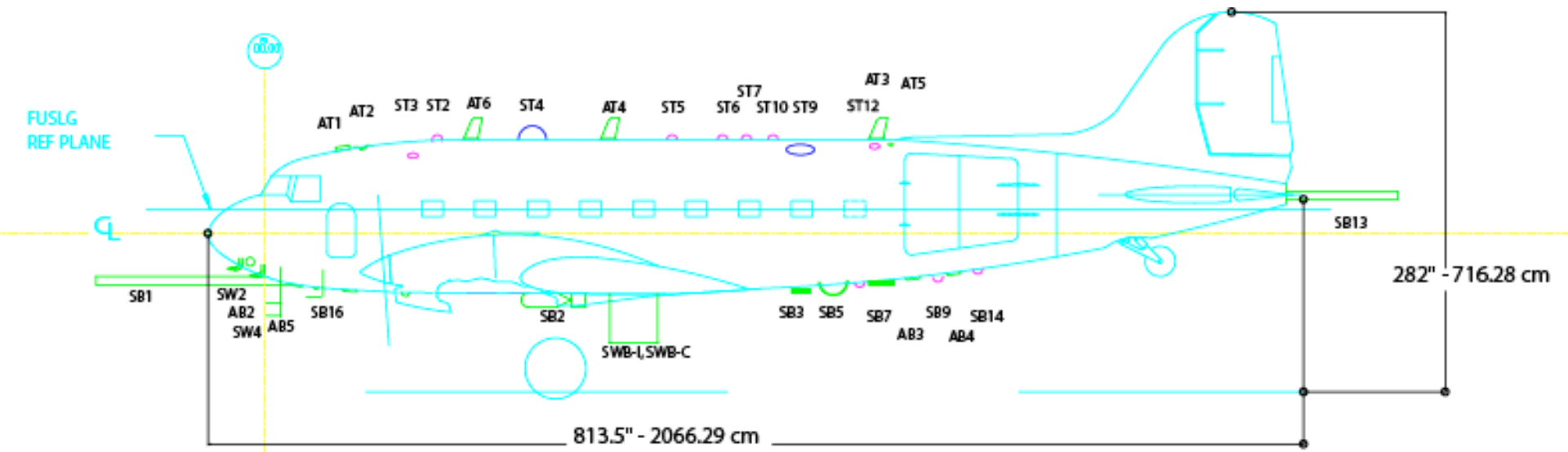
Atmospheric Chemistry/Physics

- in-situ measurements of aerosols and trace gases in the troposphere

Coastal Research

- biodiversity of literal communities, erosion processes in the Wadden Sea

Scientific modifications



Scientific Instruments Bottom

SB_1	- nose boom (protruding 115" before nose)	
SB_2 - belly close to/between gear	- fitting for bird	
SB_3 - 372.5-390.5/centered under cabin	- ASIRAS antenna (15.478" x 60.630" x 1.929" - 40 cm x 154 cm x 4.9 cm)	
SB_4 - 429.5/right hand wall	- drop sonde (launcher pipe insstalled through indicated hole just below floor level	
SB_5 - 401.0/23rd right stringer on floor	- albedometer with cover / IR scanner	(rectangular, round corners, max. length between rips x 19.685")
SB_6 - 401.0/23rd left stringer on floor	- LIDAR / laser scanner	(rectangular, round corners, max. length between rips x 19.685")
SB_7 - 420.5/23rd left stringer on floor	- downward looking video camera	(rectangular, round corners, max. length between rips x 19.685")
SB_8 - 420.5/23rd right stringer on floor	- laser altimeter (LD90/Optech/IBEO)	(rectangular, round corners, max. length between rips x 19.685")
SB_9 - 440.0/23rd left stringer on floor	- hyperspectral camera	(rectangular, round corners, max. length between rips x 19.685")
SB10 - 440.0/23rd right stringer on floor	- colour line scanner	(rectangular, round corners, max. length between rips x 19.685")
SB11 - 472.0/23rd left stringer on floor	- longwave radiation	
SB12 - 472.0/23rd right stringer on floor	- shortwave radiation	
SB13 - tail cone	- tail boom (extending min. 115" behind fuselage, 6" diameter)	
SB14 - 485.0/23rd left stringer on floor	- KT4	
SB15 - 485.0/23rd right stringer on floor	- KT15	
SB16 - belly before propellers	- CR2/humidity sensor	

23rd stringer = 3rd stringer from center line in drawing 02-2176P002 - Frame Station 363.5

Scientific Instruments Top

ST_1 - 106.0/ between stringer 2 and 3 right from center	- permanent GPS1
ST_2 - 125.0/center	- aerosol inlet
ST_3 - 106.0/between stringer 2 and 3 left from center	- permanent GPS2
ST_4 - 186.0/center	- grating spectrometer
ST_5 - 303.0/center	- permanent GPS 3
ST_6 - 345.0/center	- shortwave radiation
ST_7 - 364.0/center	- longwave radiation
ST_8 - 401.0/23rd right stringer on floor projected upwards	- LIDAR
ST_9 - 401.0/23rd left stringer on floor projected upwards	- albedometer
ST10 - 381.5/center	- upward looking Video camera
ST11 - 420.5/between stringer 2 and 3 right from center	- aerosol outlet
ST12 - 420.5/between stringer 2 and 3 left from center	- gas outlet

Scientific Systems Wall Installations

SW1 - nose/cockpit area - nezerov sonde (2" Rosemount)
SW2 - nose/cockpit area - CR2 humidity
SW3 - nose/cockpit area - temperature (2" Rosemount)
SW4 - nose/cockpit area - Vaisala humidity (2" Rosemount)

POLAR 5 - scientific systems

Glaciology - Geophysics

EMR, FMCW radar, gravimeter, magnetometer, ASIRAS (ESA), EM bird, laser scanner, long range laser altimeter

Physics of the Atmosphere

LIDAR, OPC, nephelometer, spectrometer, in-situ gas sampling, methane-sensor (GFZ) , short range laser altimeter, hyper-spectral camera, ...

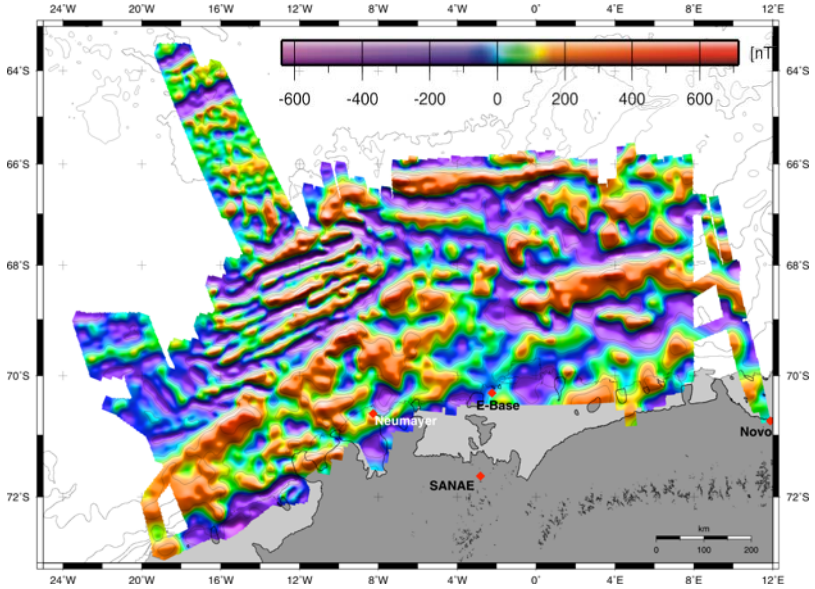
Meteorology

5-hole probe, radiation sensors, drop sounding system, radiation thermometer

General

Geodetic GPS, digital still camera, digital video camera

Geophysics/Glaciology



EMAGE

East Antarctic Margin Aeromagnetic and Gravity Experiment [*Jokat et al. (2003)]*

Profile length: 73900 km

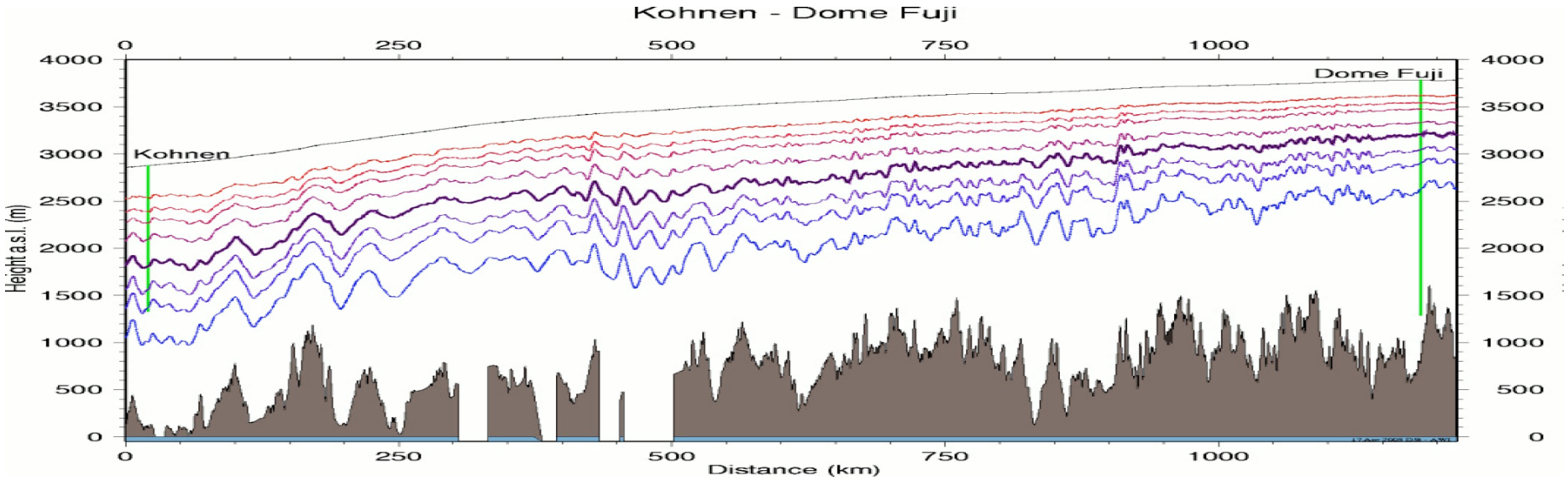
Area: 650000 km²

Line spacing: 5 – 15 km

Flight height: 100 - 1500m

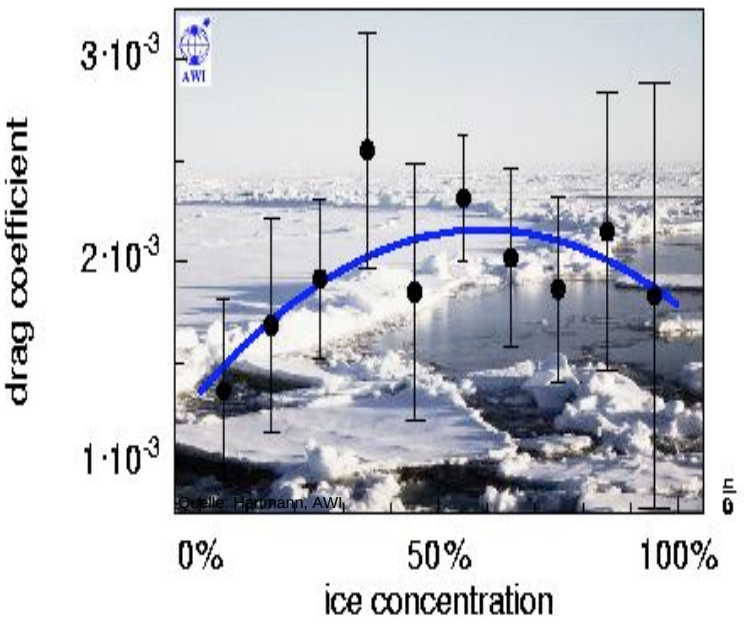
EPICA pre-site survey & FUJI

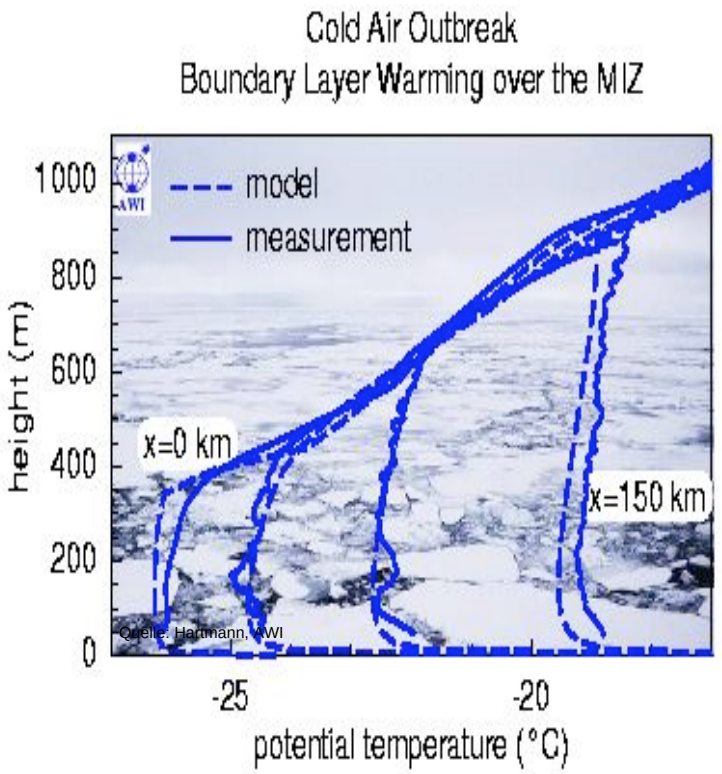
ice thickness mapped over an area > 10^6 km^2, 8 isochrones traced over 1217 km



Meteorology

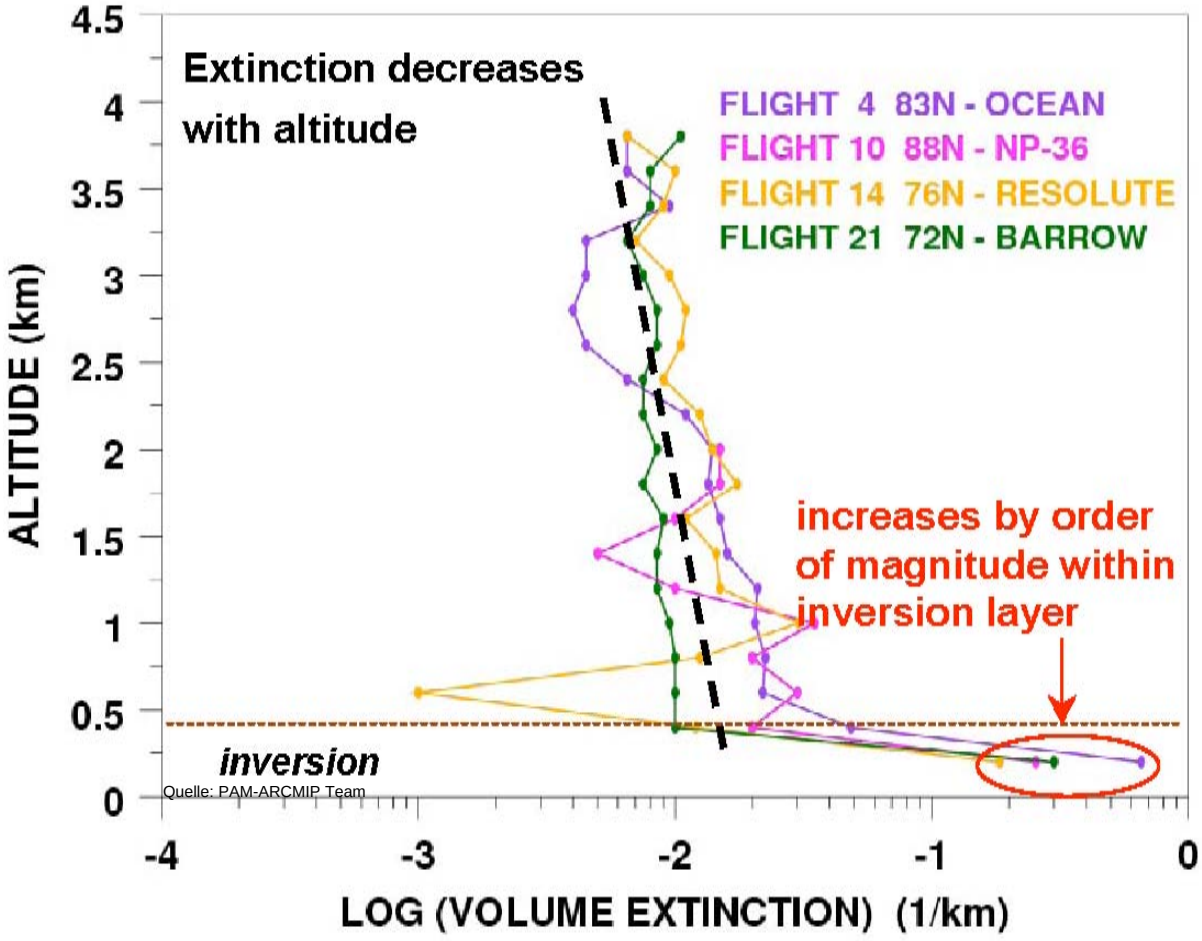
* Radiative and turbulent processes in the ABL and their interaction with surface inhomogeneity due to melt ponds, ridges and leads
* Turbulent processes in cold-air outbreaks with roll convection
* Transport of energy- and momentum above the marginal sea ice zone
* Radiative transport through Arctic stratus clouds





Atmospheric Physics

* Quantification of aerosol and water vapour variability
* Arctic methane emission dromswamps and other trace gases in polar regions emitted, e.g. by frostflowers

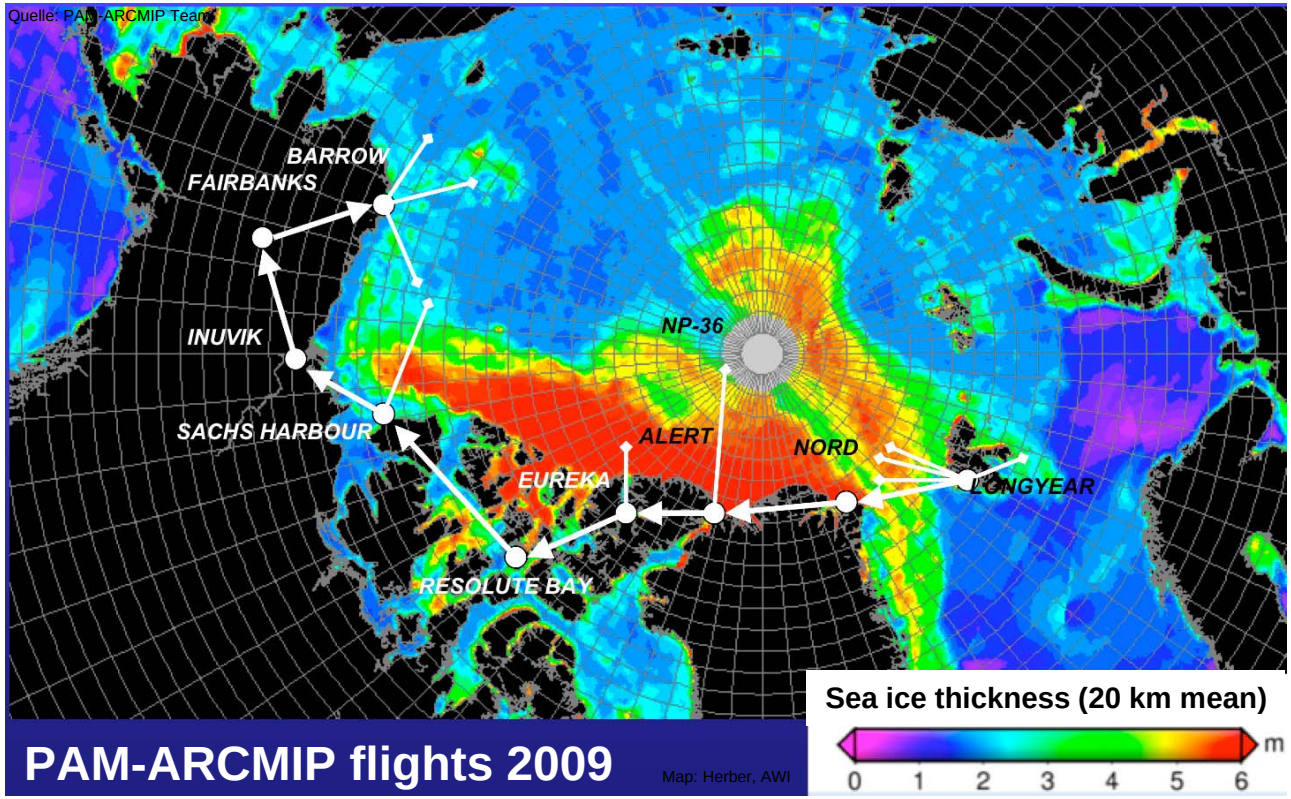


Quelle: PAM-ARCMIP Team

Quelle: PAM-ARCMIP Team

PAM-ARCMIP 2009 - rerun scheduled for 2011

Pan-Arctic Measurements and Arctic Climate Model Inter comparison Project
Measurements of sea ice thickness, trace gases, aerosols, and radiation with changing sensors and participants from AARI St. Petersburg (RUS), AWI Bremerhaven & Potsdam (D), CNR-ISAC Bologna (I), Environment Canada, ESA (NL), NOAA (USA), U Alberta (CDN), York U (CDN);
PI at AWI: K. Dethloff (AWI Potsdam) and A. Herber (AWI Bremerhaven)



EM-bird on POLAR 5

Foto: AWI

Foto: Watson, LCAS

Cabin on atmospheric research flight


Foto: Gehrmann, AWI


Foto: Gehrmann, AWI


Foto: Gehrmann, AWI

Cabin on atmospheric research flight

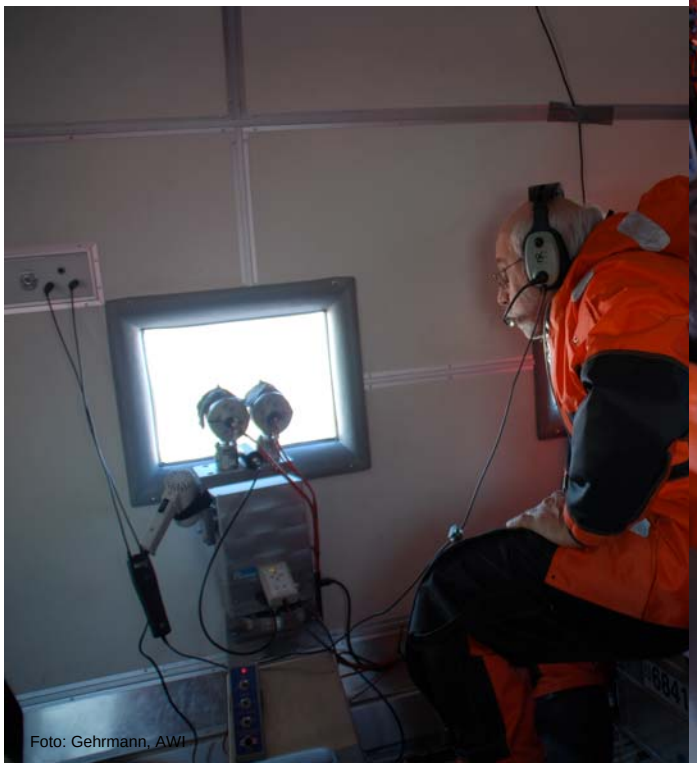
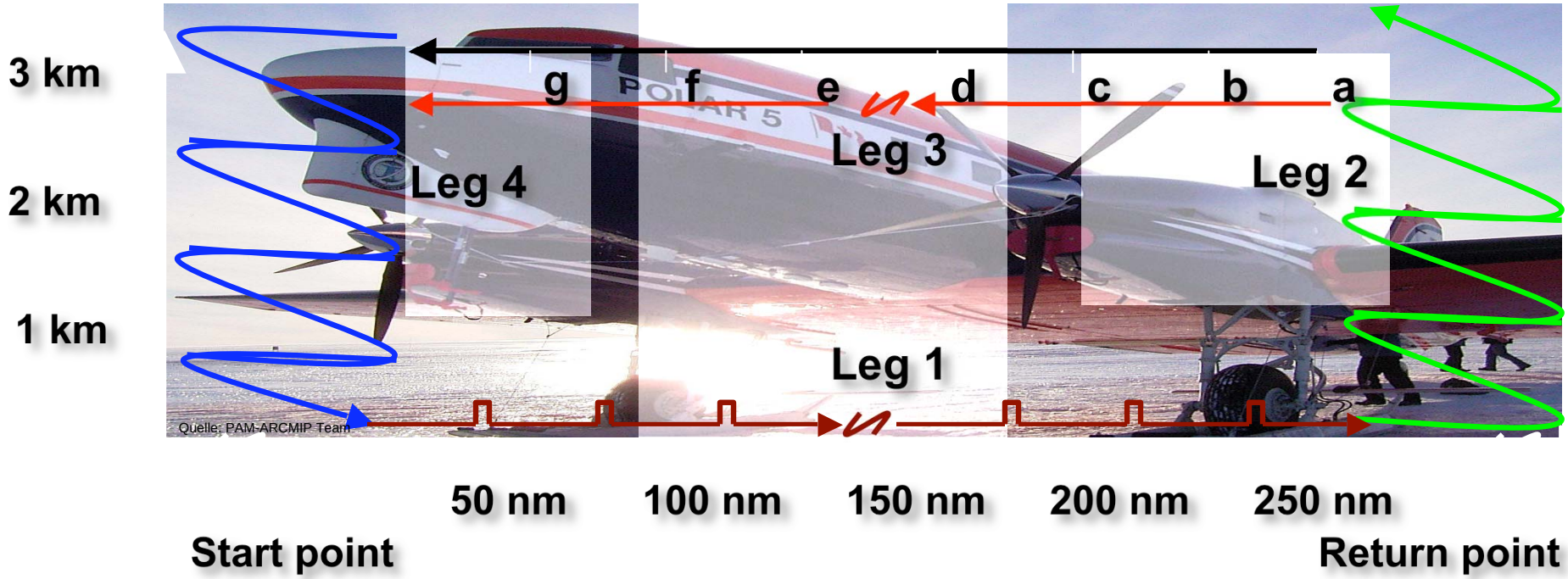


Foto: Gehrmann, AWI


Foto: Gehrmann, AWI


Foto: Gehrmann, AWI

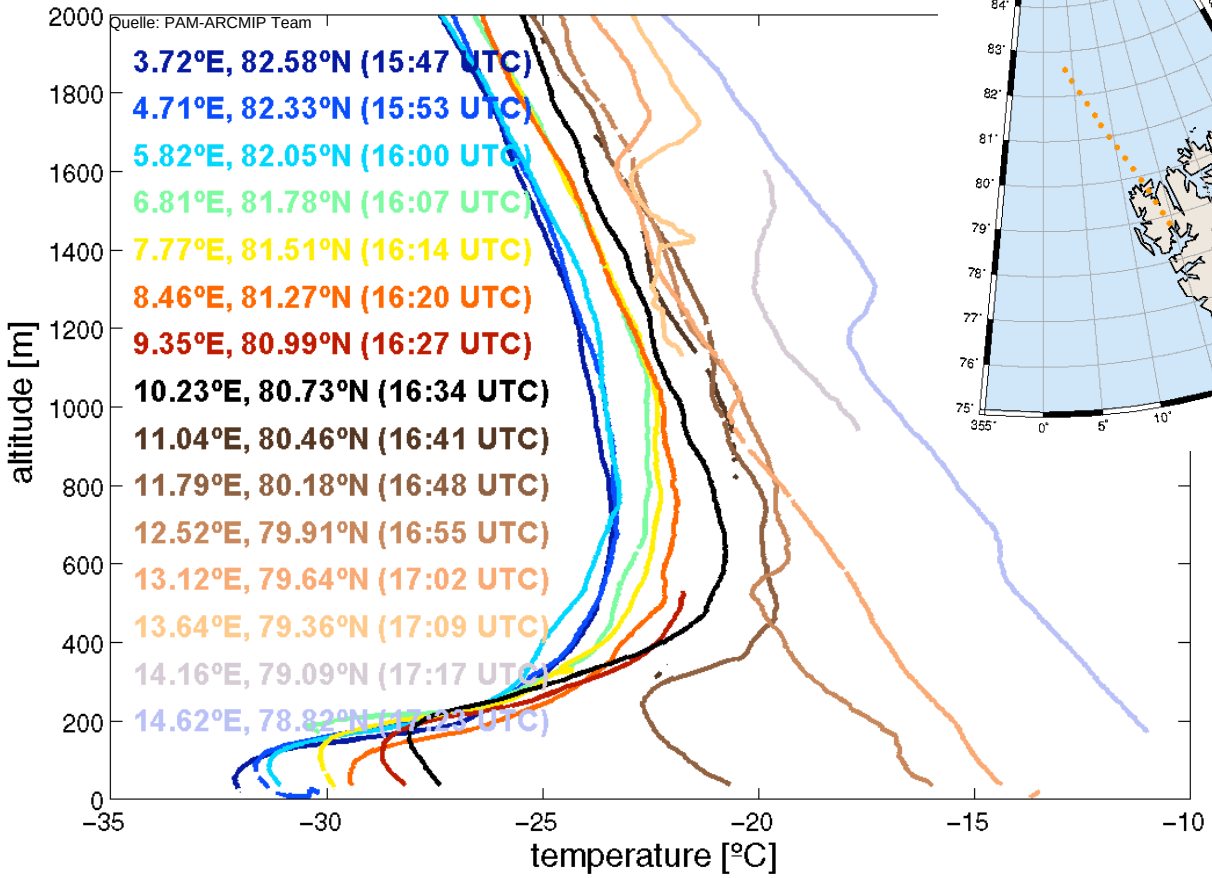
Flight track of a combined survey flight



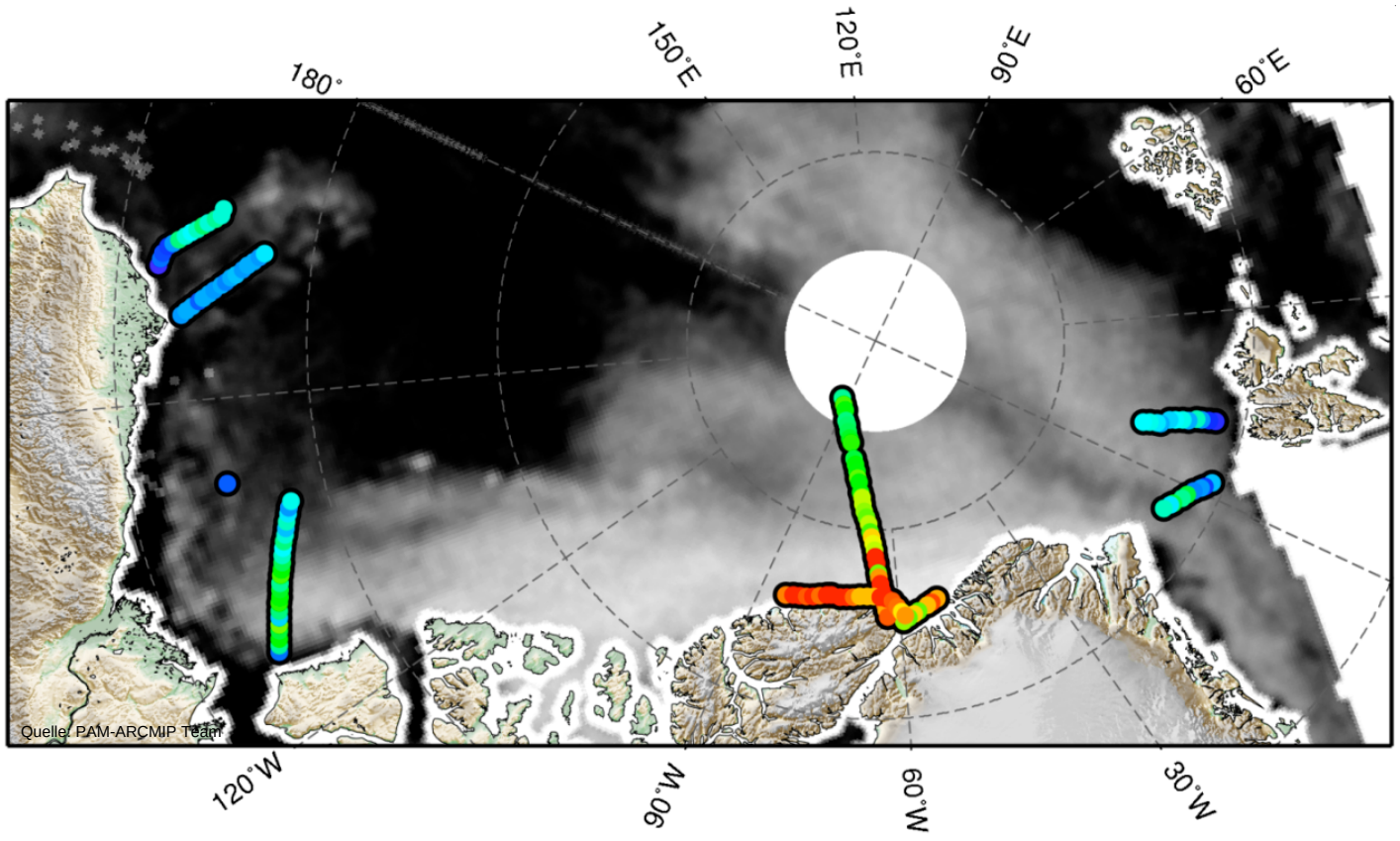
LEG 1: horizontal flight in 100 m for EM Bird, aerosol and trace gases
LEG 2: profile measurements for aerosol and trace gases in different levels
LEG 3: horizontal flight in 3000 m for drop sounding and trace gases
LEG 4: profile measurements for aerosol and trace gases in different levels

Dropsonde soundings

Inversion à no inversion [03-04-09]



Sea-ice thickness survey tracks



First results

* **Drop sondes** showed very interesting vertical structure in the planetary boundary layer during the long-range flights from different places throughout the North. A shallow PBL occurred every time.

* **During the** northbound flights first time large-scale sea-ice measurements with an EM-Bird were done. We crossed the complete multiyear ice zones, revealing prominent ice thickness gradients from the 2.5m.

* **Trace gases** measurements from EC show a very low levels of ozone and mercury over vast areas of the Arctic sea ice confirming earlier findings that these species were being depleted at lower levels over sea ice through reaction with BrO, over open water doesn't occurred.

* **The aerosol** appears to be haze in the boundary layer and in the mid-troposphere volcanic material from Redoubt volcano eruption.

The Aircraft Campaign MELTEX

Impact of melt ponds on energy and momentum fluxes between atmosphere and sea ice

Gerit Birnbaum[1], Christof Lüpkes[1], Jörg Hartmann[1], Wolfgang Dierking[1], André Ehrlich[2], Tom McElroy[3]

[1] Alfred Wegener Institute for Polar- and Marine Research, Bremerhaven
[2] University of Mainz
[3] Environment Canada

MAIN GOAL of MELTEX was to study radiation characteristics of sea ice and sea ice – atmosphere interaction in the first phase of the melt season in the Arctic.

MELTEX aimed

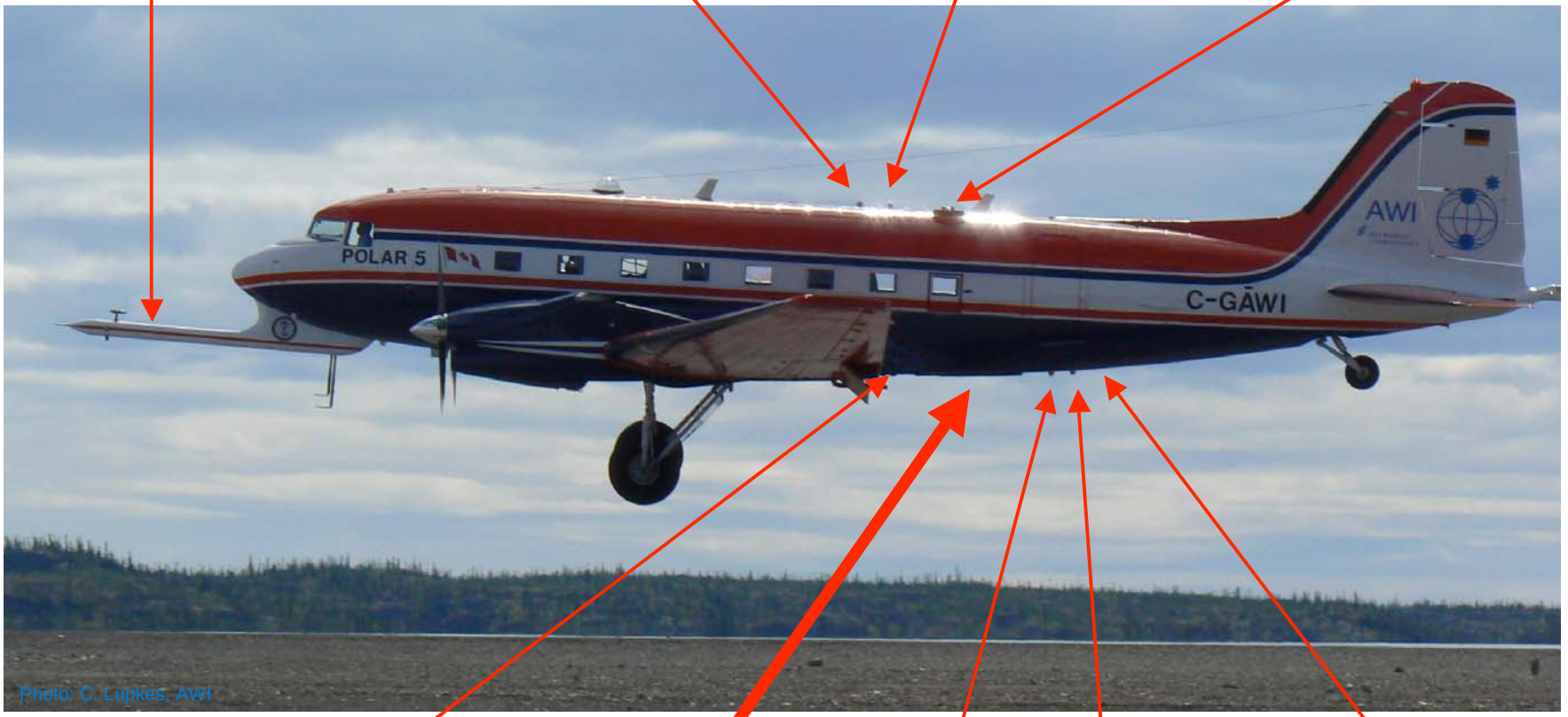
- **to determine pond fraction,**
- **to determine broadband and spectral surface albedo of melt-pond covered sea ice,**
- **to investigate heat transport in the atmospheric boundary layer over melting sea ice**
- **to collect data that can be used to improve algorithms for the retrieval of sea ice parameters such as melt pond fraction from satellite measurements.**

nose boom

pyranometer

pyrgeometer

spectral radiation sensors



spectral radiation sensors

altimeters,scanner, camera systems

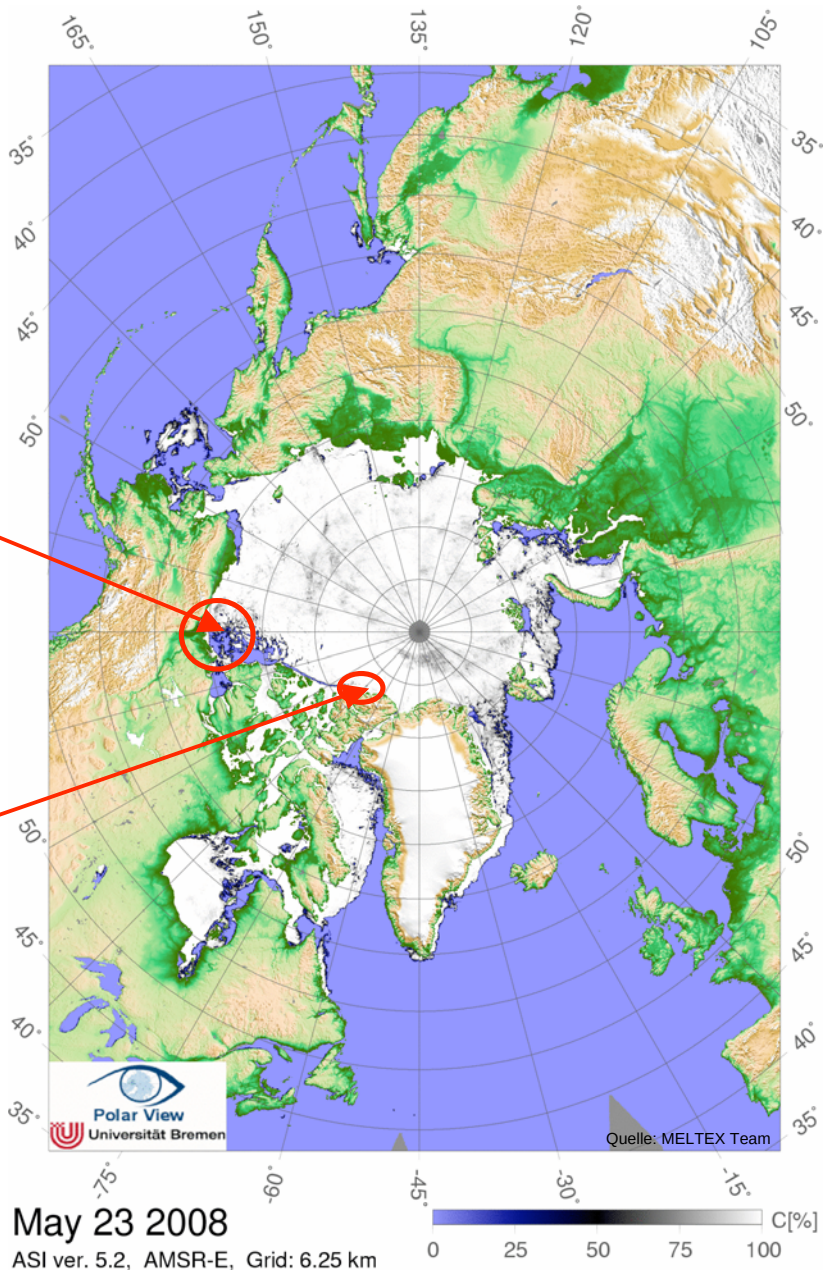
pyranometer

pyrgeometer

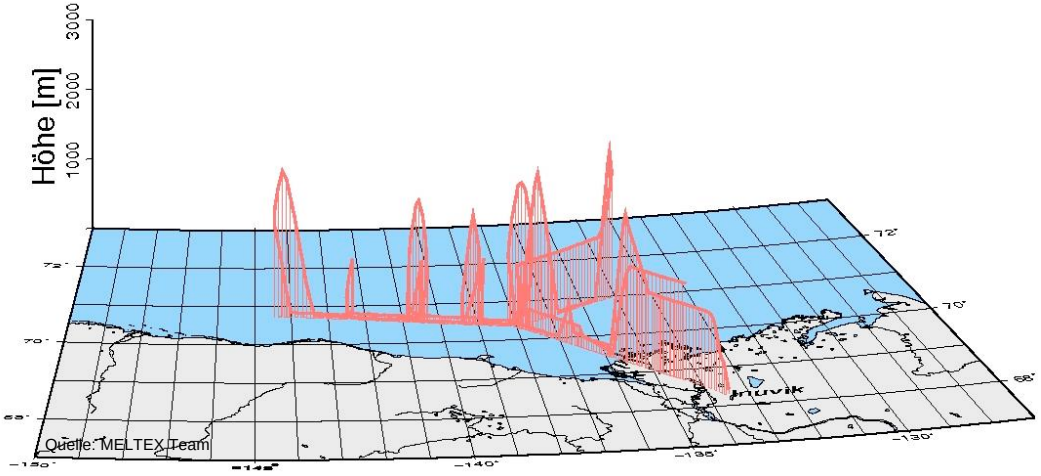
radiation thermometer

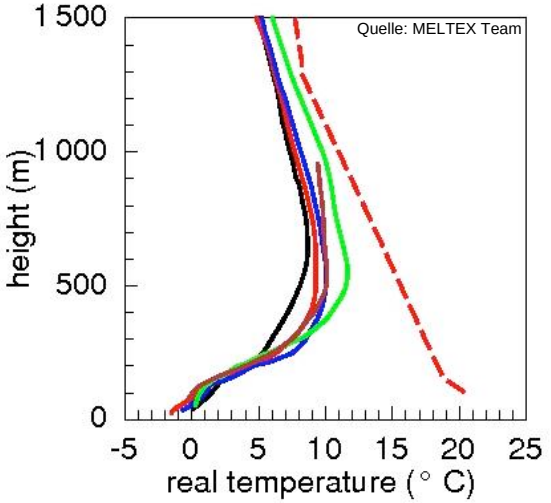
11 measurement flights
between 11 May and 7 June 2008
in the Southern Beaufort Sea
north of Inuvik

1 measurement flight
on 23 May 2008
north of Ellesmere Island

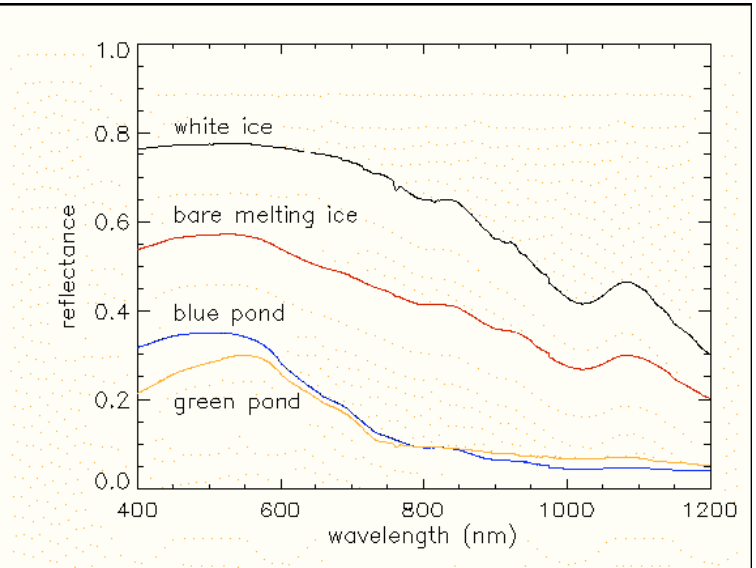


Flight on 04 June 2008





Vertical temperature profiles over land (-----) and over sea ice; heat flux towards the ice surface



Albedo of ponded sea ice

Spectral reflectance of ice and ponds measured during summer, 2001 near Barrow, Alaska [Tschudi et al., 2005]

Photo: AWI

Summary

- **MELTEX covered the initial evolution of melt ponds in the southern Beaufort Sea in late spring.**
- **Surficial melting mainly ocurred during periods of strong warm air advection interrupted by several days of cold northerly flow causing refreezing.**
- **The stage of melt pond development differed considerably between fast-ice and drifting sea ice.**

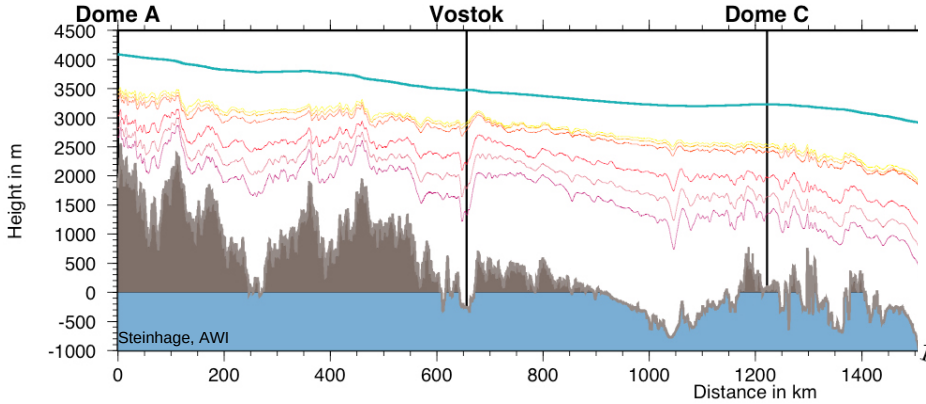
Photo: AWI

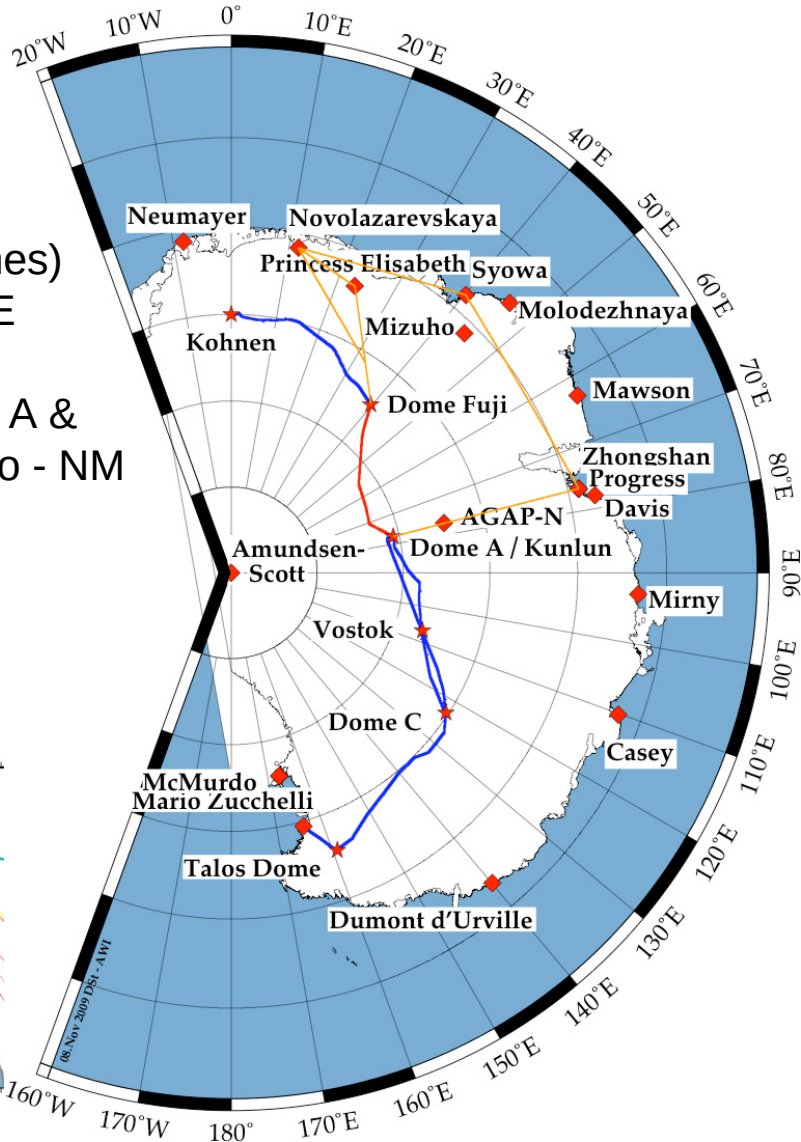
DOCO SURVEY 2007/08 - continuation 2010/11

DoCo 2007/08 (blue lines east) was supported by:
AARI/RAE, AAD, BGR, CHINARE, IPEV, JARE, PNRA

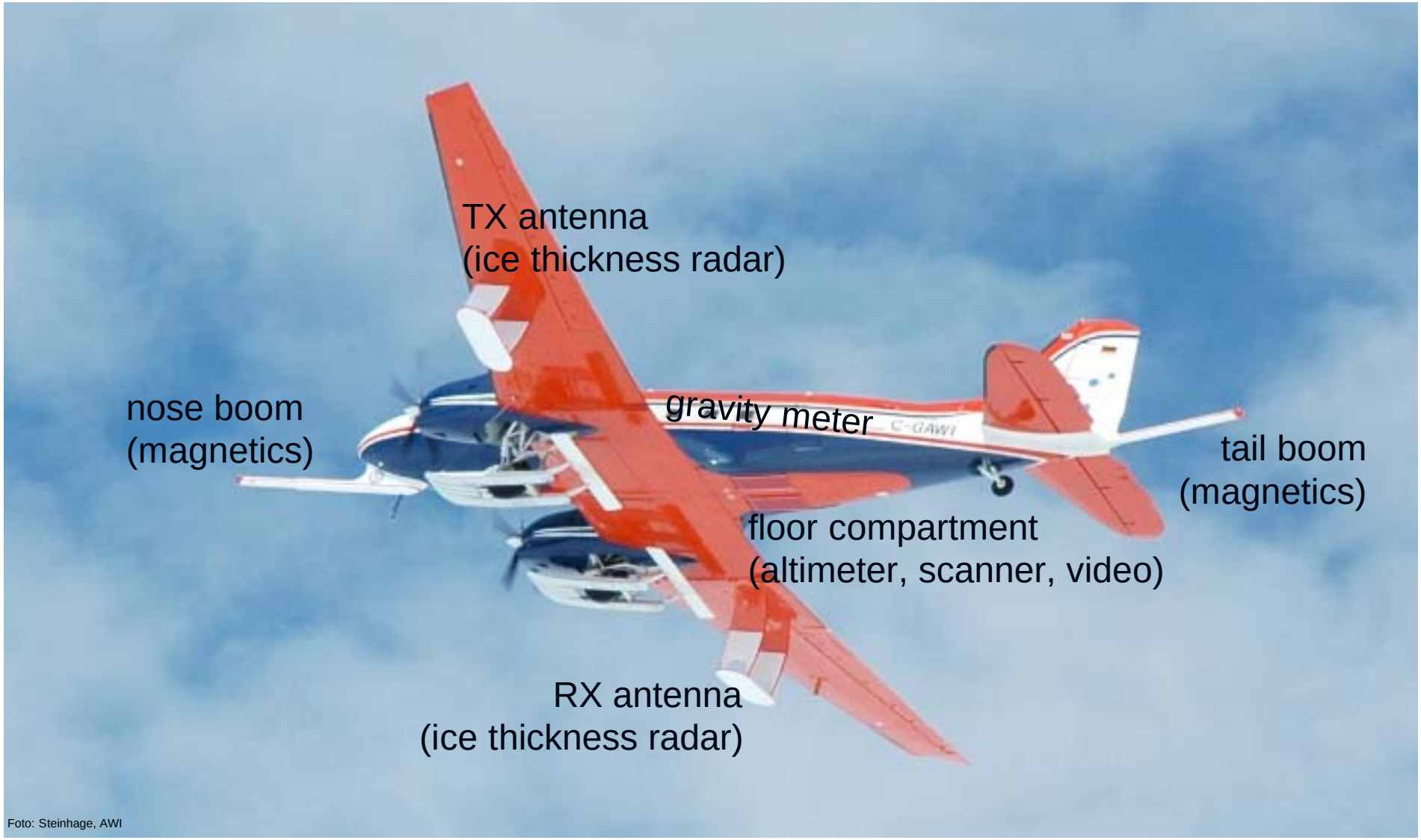
DoCo 2010/11 (red (survey) & yellow (logistics & ferry) lines)
Needs support by AARI, AAD, BELARE, CHINARE, JARE
Planned routing: Neumayer - Novo - S17 - Progress
Progress - AGAP-N - via Dome A &
Dome Fuji - depot DoCo - Novo - NM


Foto: Steinhage, AWI





Geoscientific instrumentation



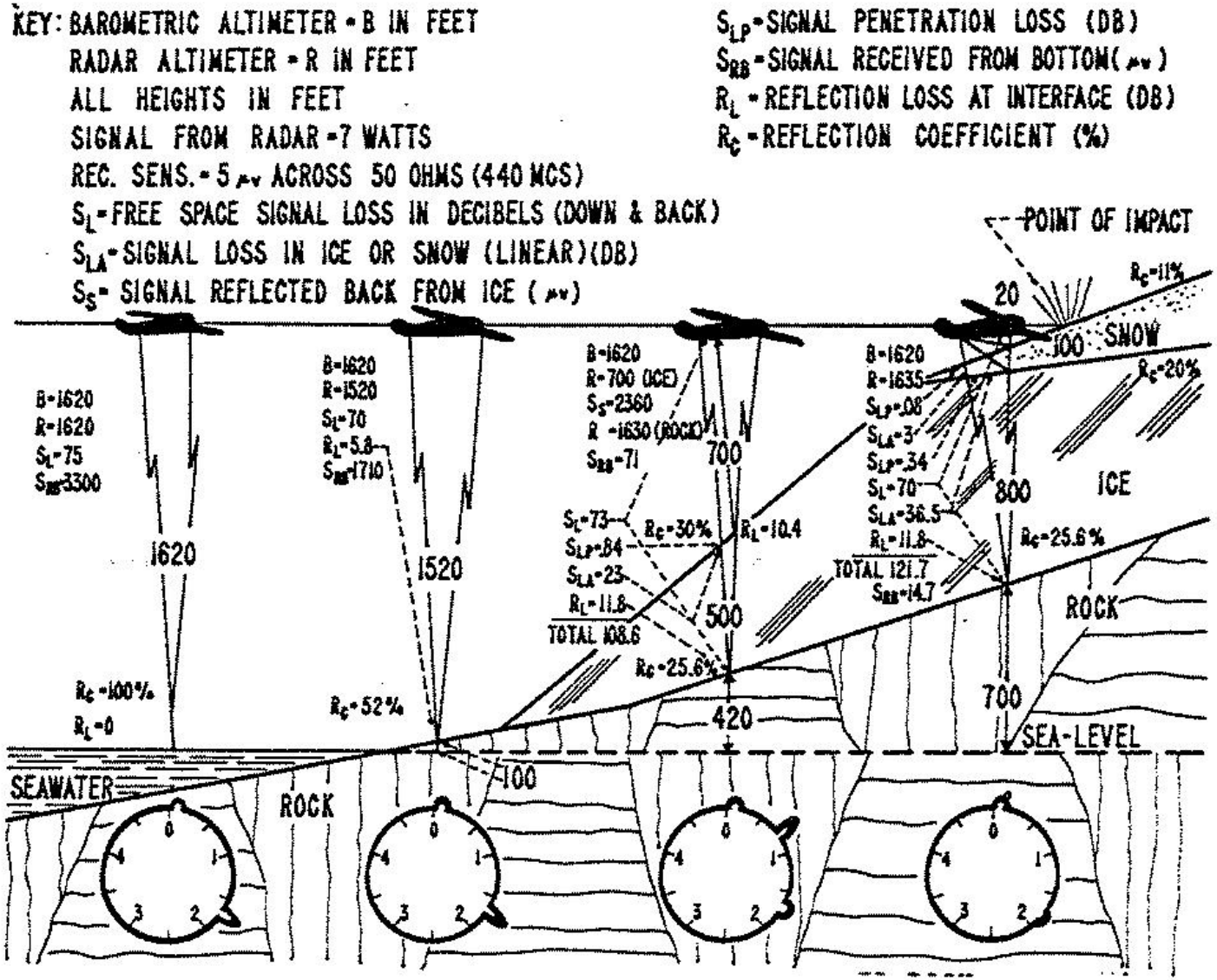
Preparations for survey flights in Antarctica

Foto: Steinhage, AWI

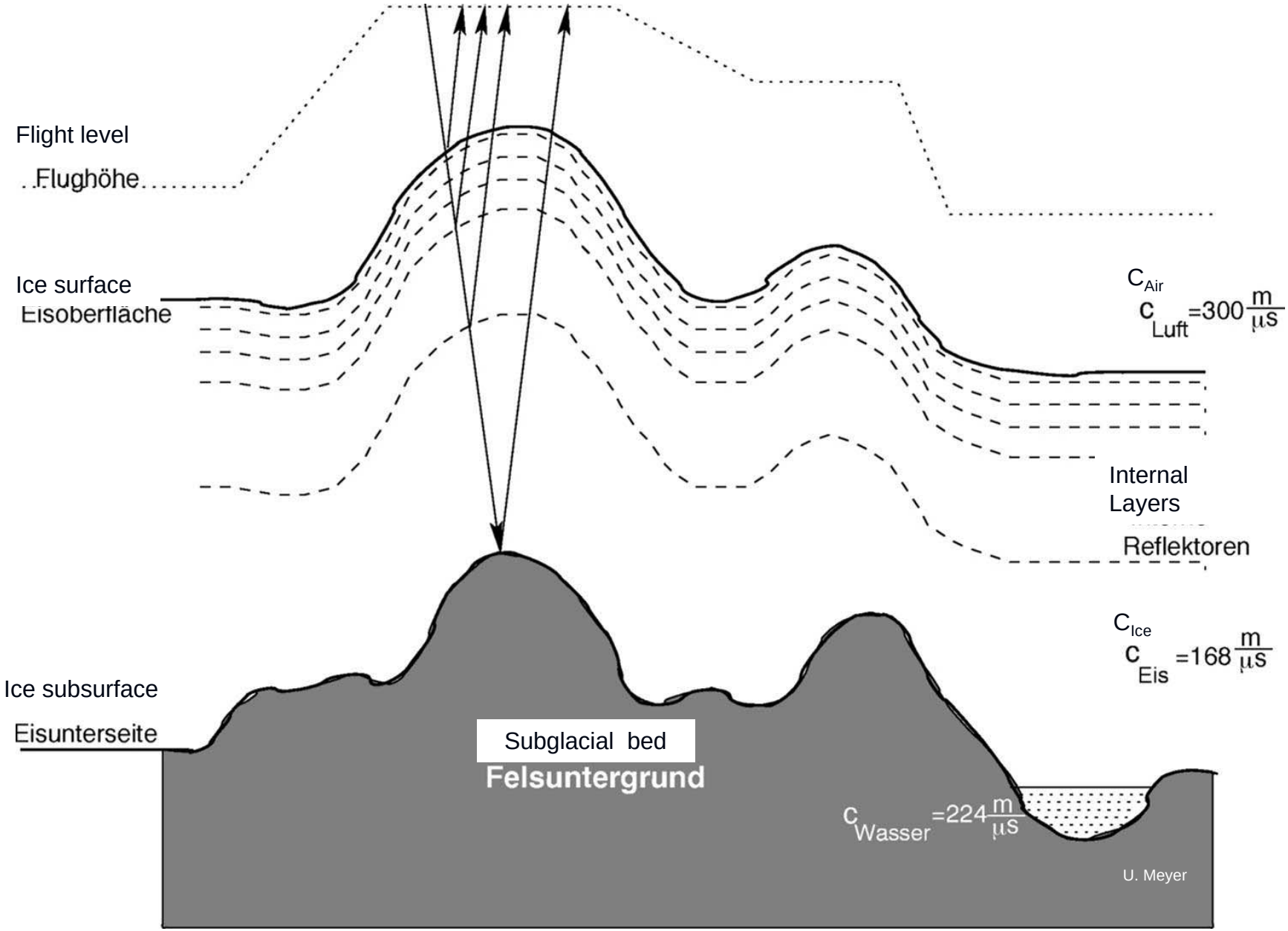

Foto: Steinhage, AWI

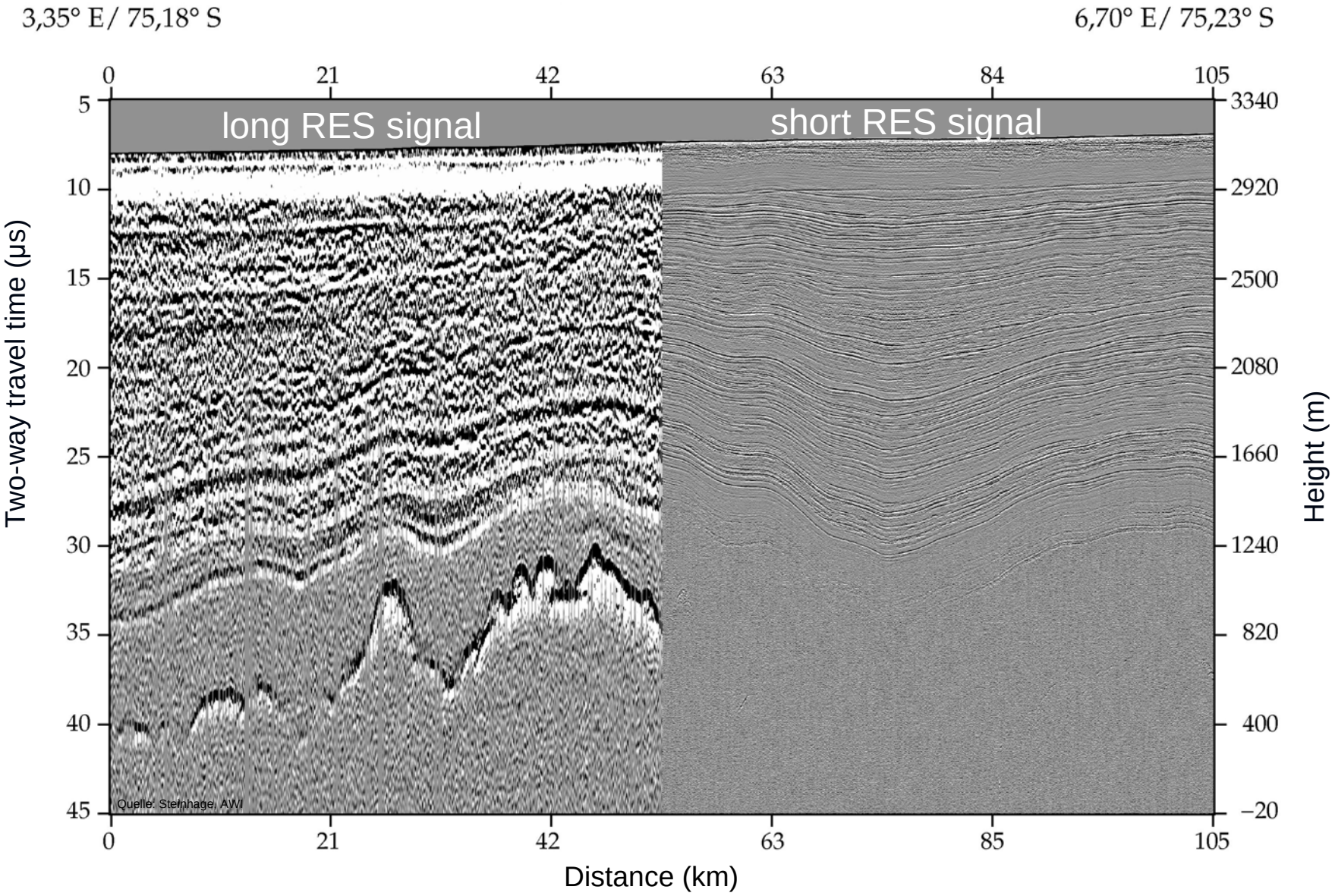

Foto: Steinhage, AWI

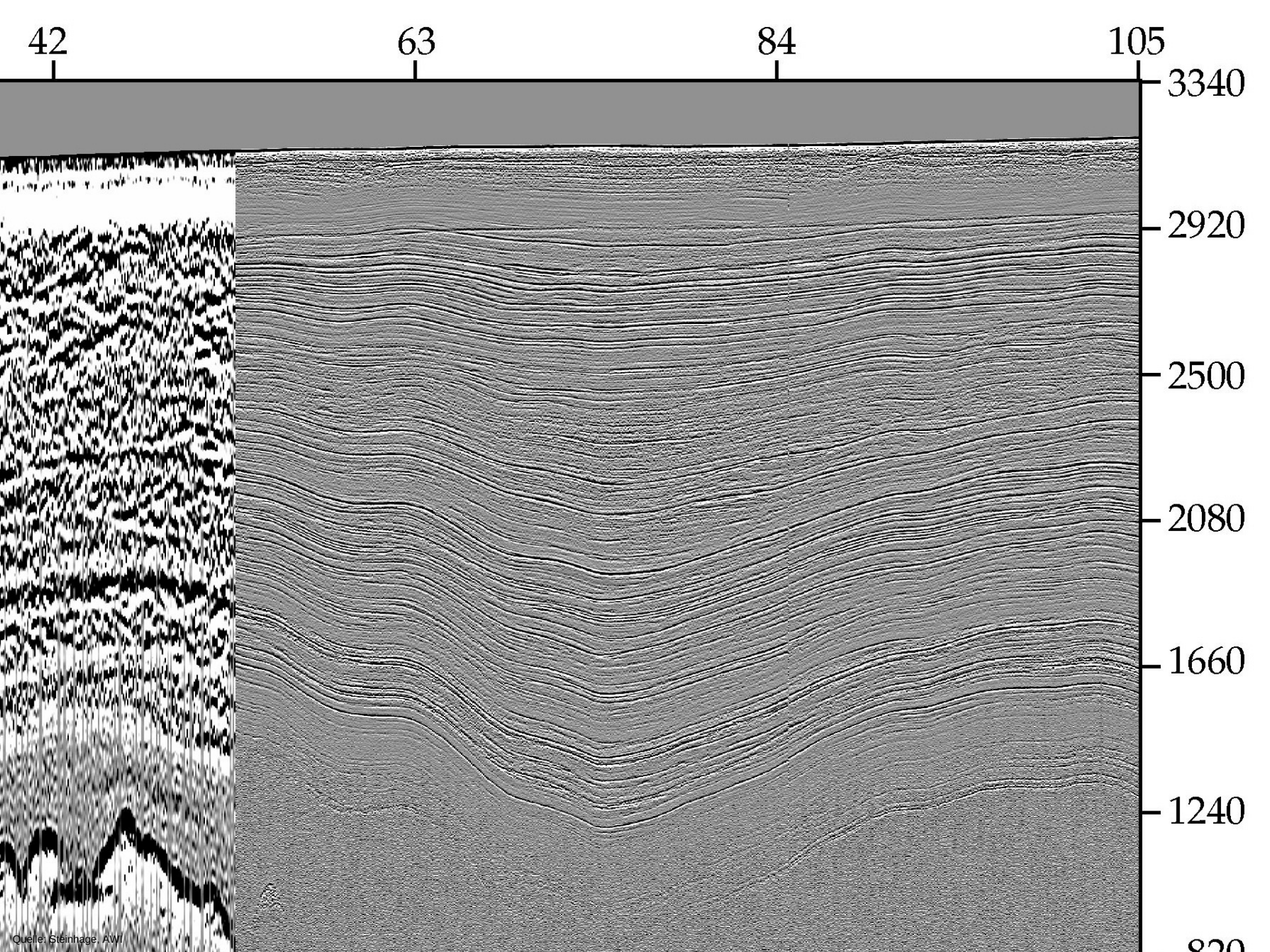
Foto: Steinhage, AWI



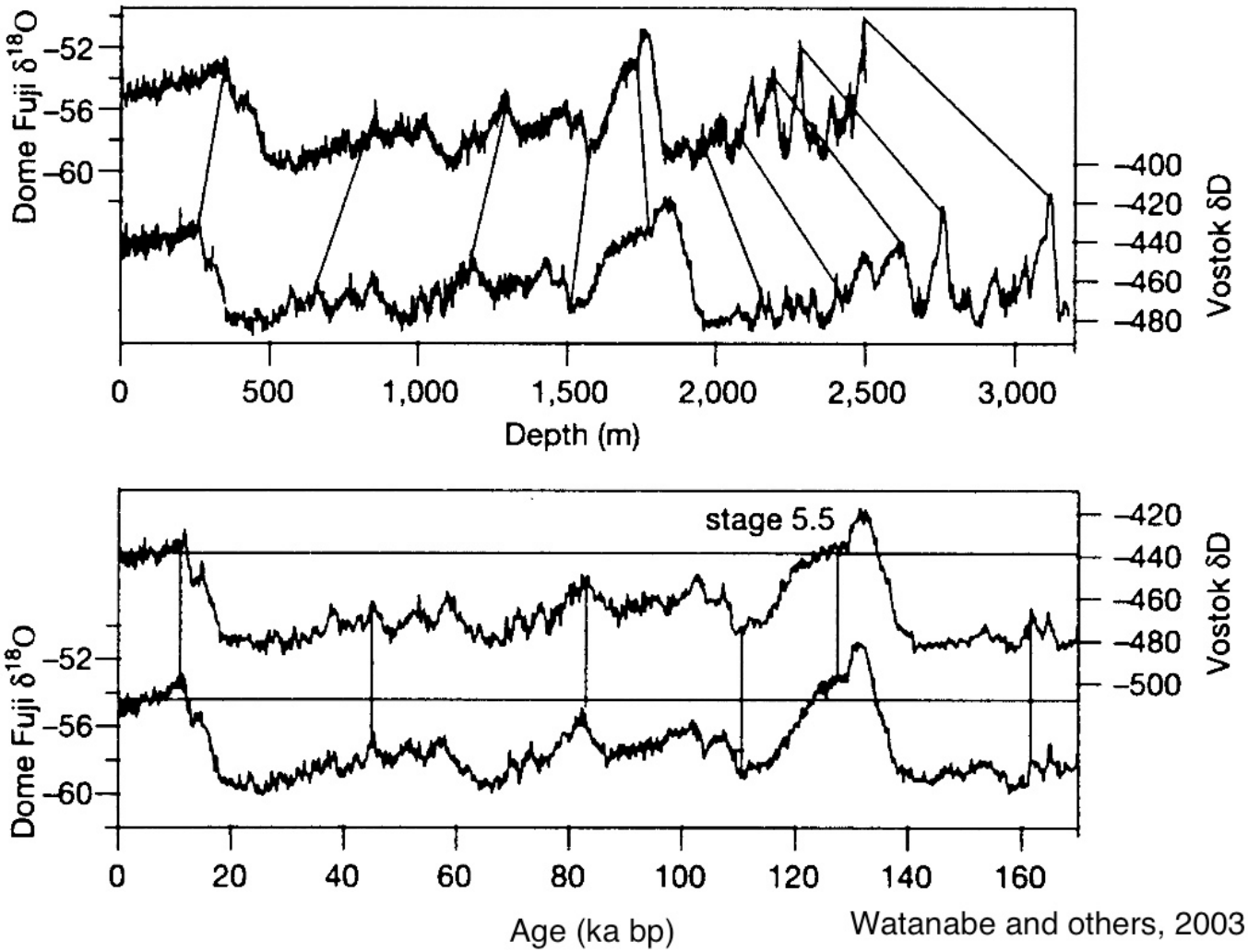
Waite & Schmidt, 1961


Flight level
Flughöhe
Ice surface
Eisoberfläche
c_{Air}
$c_{Luft} = 300 \frac{m}{\mu s}$
Internal
Layers
Reflektoren
c_{Ice}
$c_{Eis} = 168 \frac{m}{\mu s}$
Ice subsurface
Eisunterseite
Subglacial bed
Felsuntergrund
$c_{Wasser} = 224 \frac{m}{\mu s}$
U. Meyer

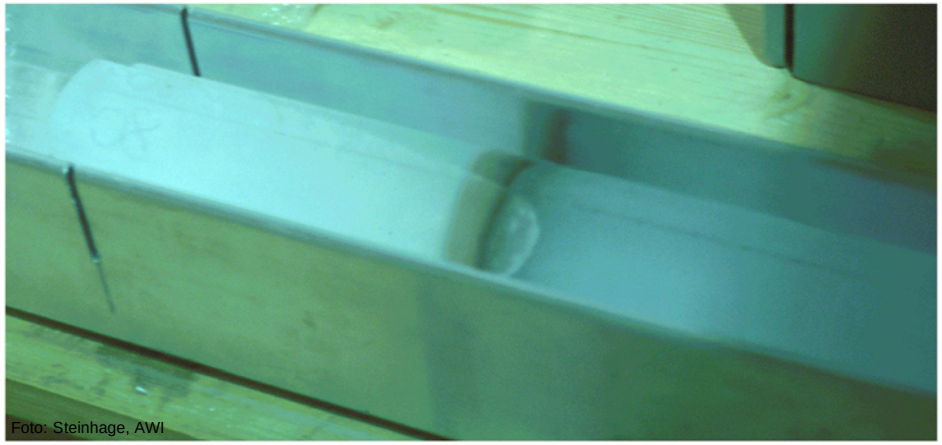

3,35° E/ 75,18° S
6,70° E/ 75,23° S
long RES signal
short RES signal
Two-way travel time (µs)
Height (m)
Distance (km)
0
21
42
63
84
105
85
5
10
15
20
25
30
35
40
45
3340
2920
2500
2080
1660
1240
820
400
−20
Quelle: Steinhage, AWI


42
63
84
105
3340
2920
2500
2080
1660
1240
820
Quelle: Steinhage, AWI

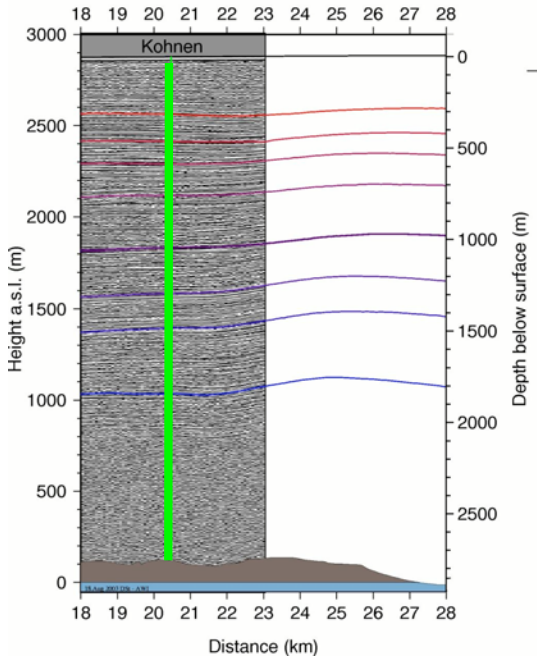
Comparing deep ice cores by means of dating



Watanabe and others, 2003



Ages of picked internal layers.



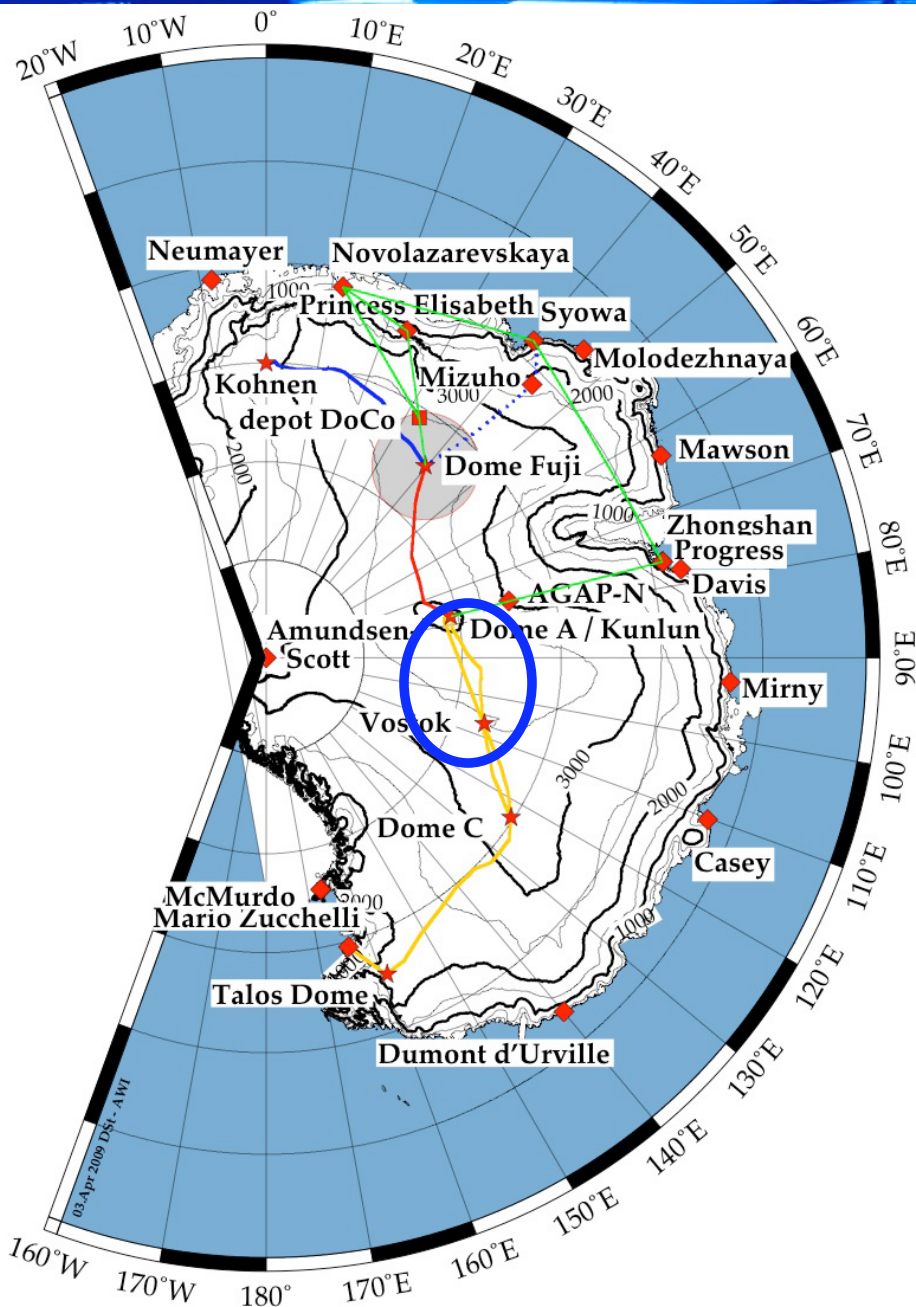
layer	Kohnen(EDML) depth below surface (m)	fr	age (a)	ML	Dome Fuji depth below surface (m)	age (ka) taken from Watanabe et al. 2003
			5131			
I-1	338		8052		166	4.9
I-2	486		10364		246	7.3
I-3	611		16256		310	9.5
I-4	784		25354		453	16.5
I-5	1068		37471		577	24.1
I-6	1316		47739		740	36.6
I-7	1506		71563		881	47.3
I-8	1866		n.d.		1160	70.1

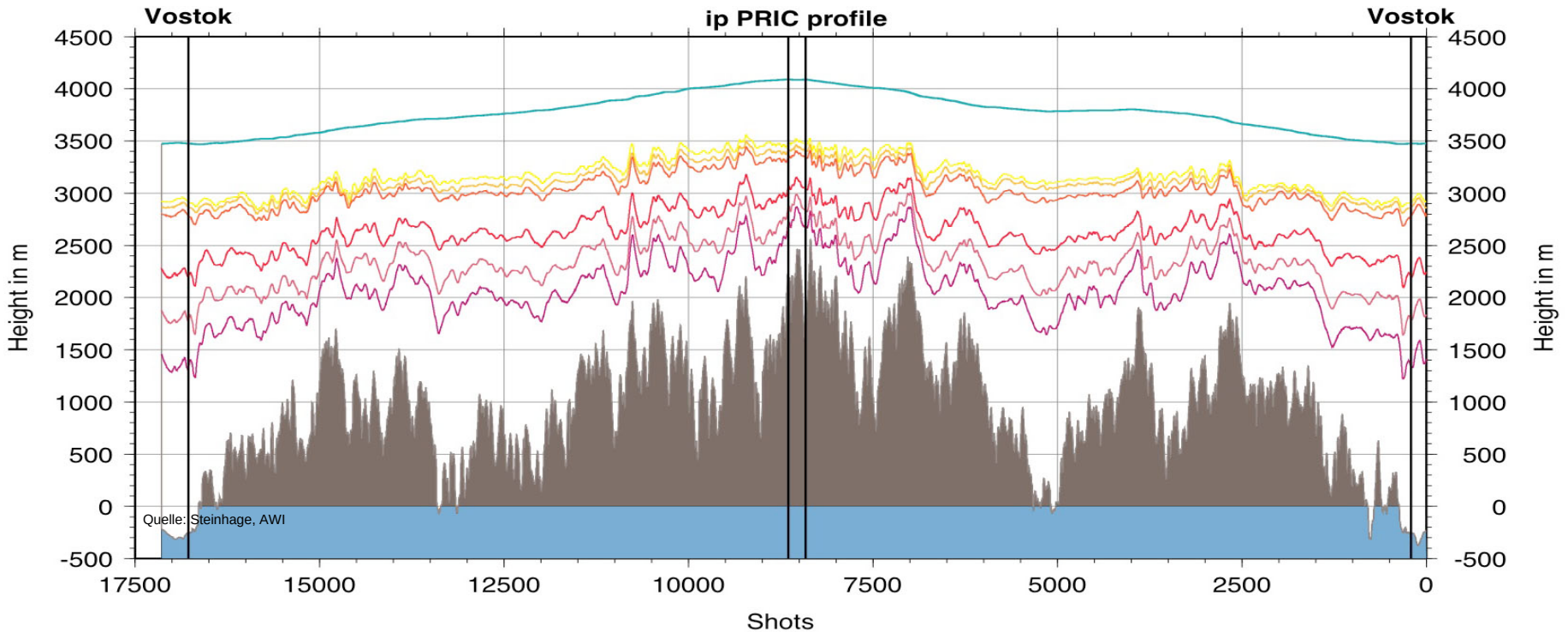
Pers. Mitt. F. Parenin, 2004

DoCo - Dome Connection
East Antarctica

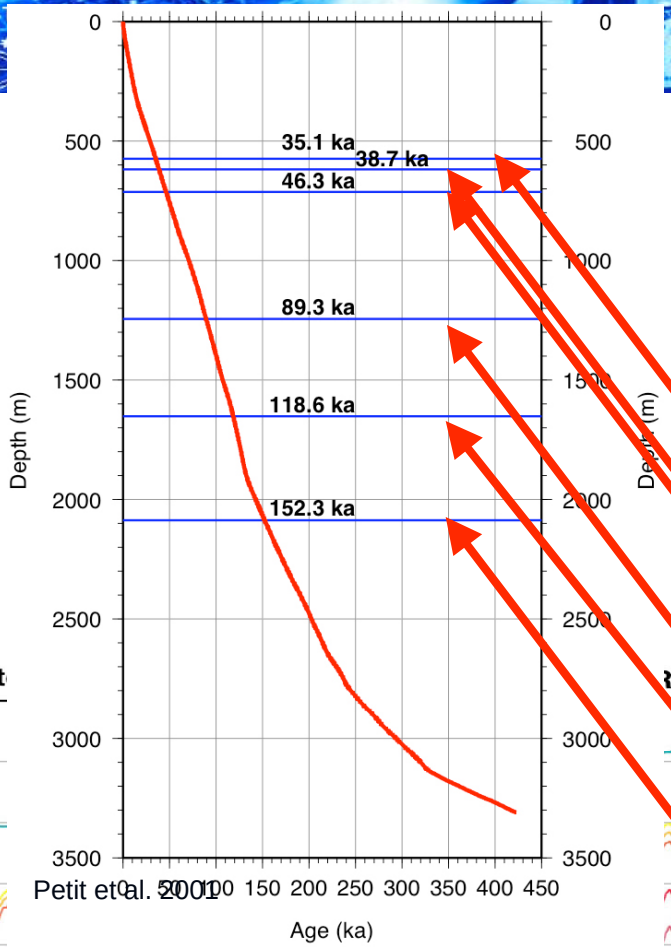
- ice thickness radar only
- flight level: 2000 ft agl
- altitude: up to 16000 ft

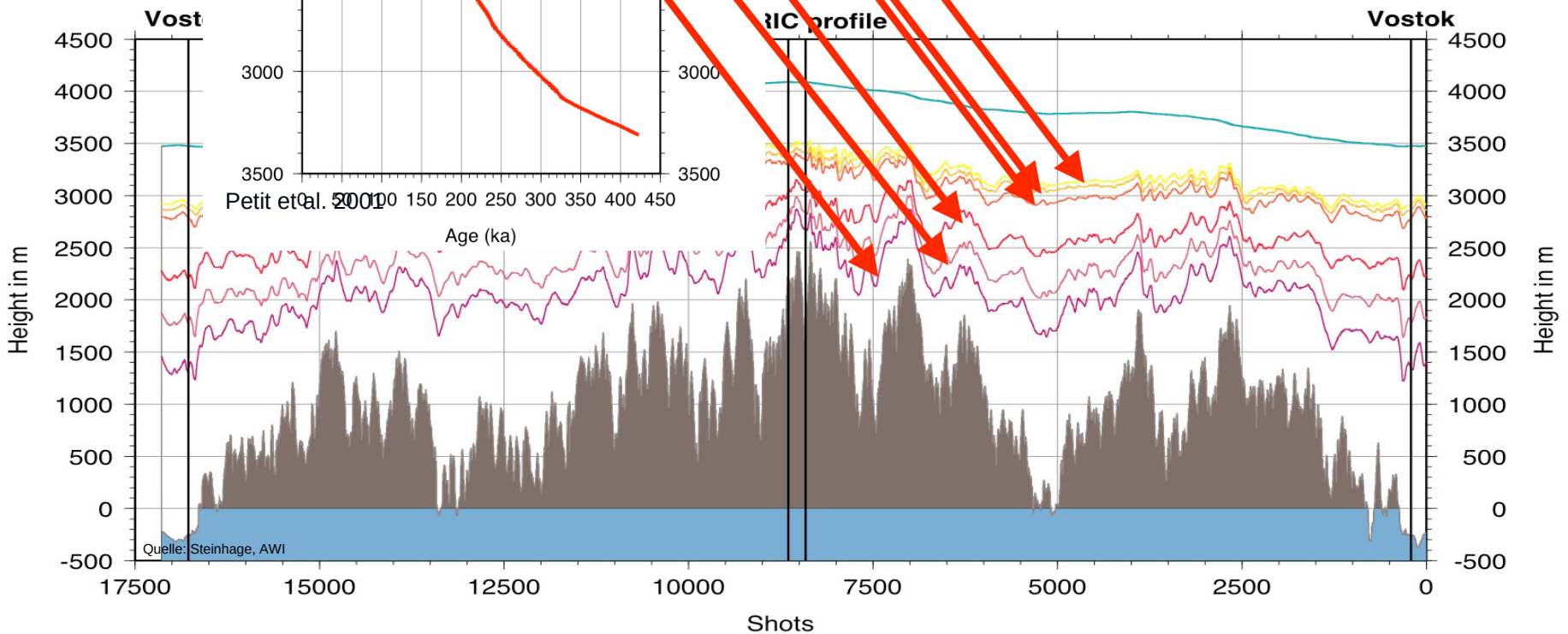
red - missing section
blue and yellow -
mapped sections
green - ferry




Vostok
ip PRIC profile
Vostok
Height in m
Height in m
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
17500
15000
12500
10000
7500
5000
2500
0
Shots
Quelle: Steinhage, AWI

Iso-chrone no.	Depth (m)	Age (ka) Vostok scale	Age (ka) EPICA DC scale
1	617.2	35.1	36.4
2	682.8	38.7	40.3
3	748.2	46.3	47.0
4	1050.6	89.3	91.5
5	1239.6	118.6	125.1
6	1413.5	152.3	173.8





Summary & outlook

- **Research aircraft are an indispensable tool for studying polar regions for many subjects.**
- **Airborne surveys are very well suited for improving international collaboration, by sharing aircraft, instruments, and data.**
- **Successful missions of POLAR 5 as e.g. PAM-ARCMIP and DoCo will be continued in near future.**

Thank you very much for Your attention.

Foto: Steinhage, AWI