DANISH NATIONAL
SPACE CENTER

Results of the CryoSat Validation Experiment – CryoVEx-2003

- Field work plan
- Observations
- Data anlysis and results
- Conclusions

Sine M. Hvidegaard[1], R. Forsberg[1], K. Keller[1], C. Haas[2], and A. Pfafling[2]
[1]Danish National Space Center
[2]Alfred Wegener Institute

Field Work Plan:

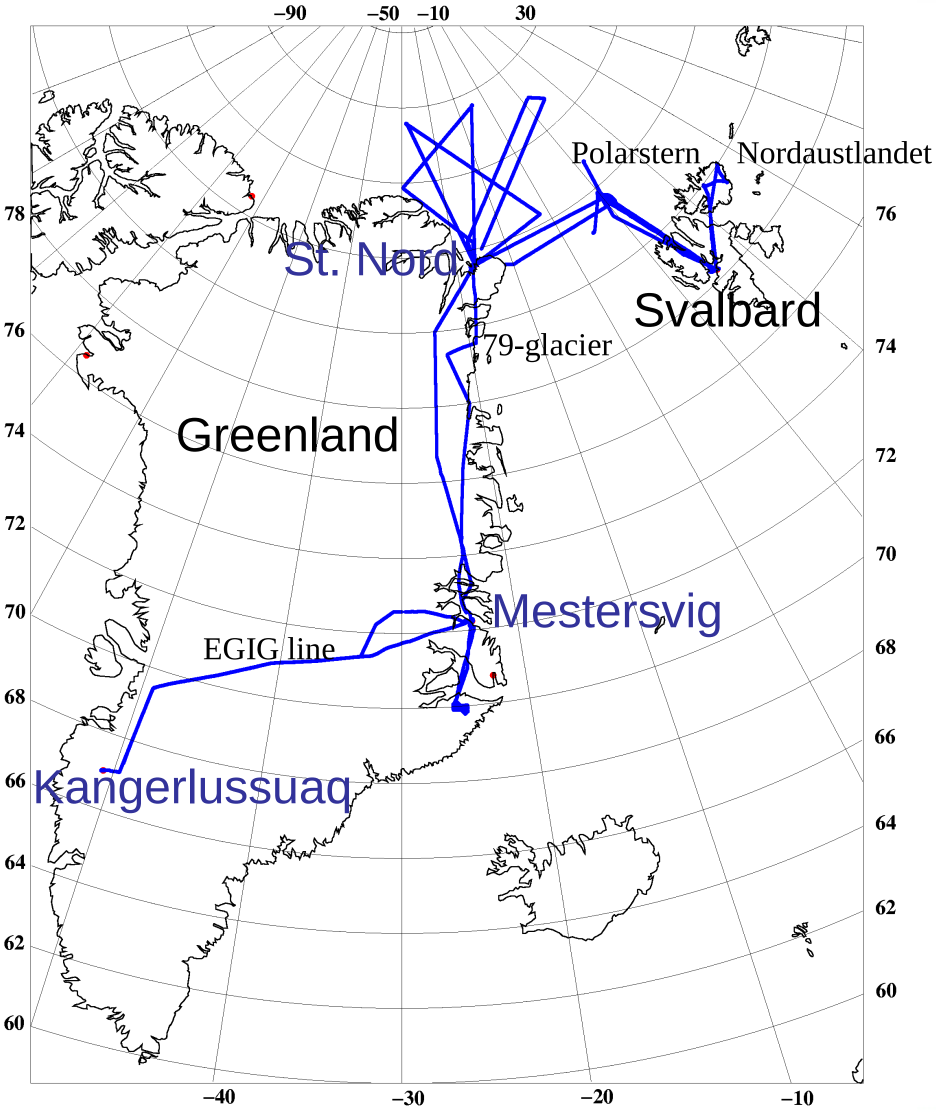
- Perform coincident laser scanner and D2P radar altimeter measurements over both sea ice and inland ice
- Coordinate observations from Twin Otter with Polarstern operations – especially with helicopter EM measurements
- Re-fly earlier laser scanner tracks

The 2003 Campaign

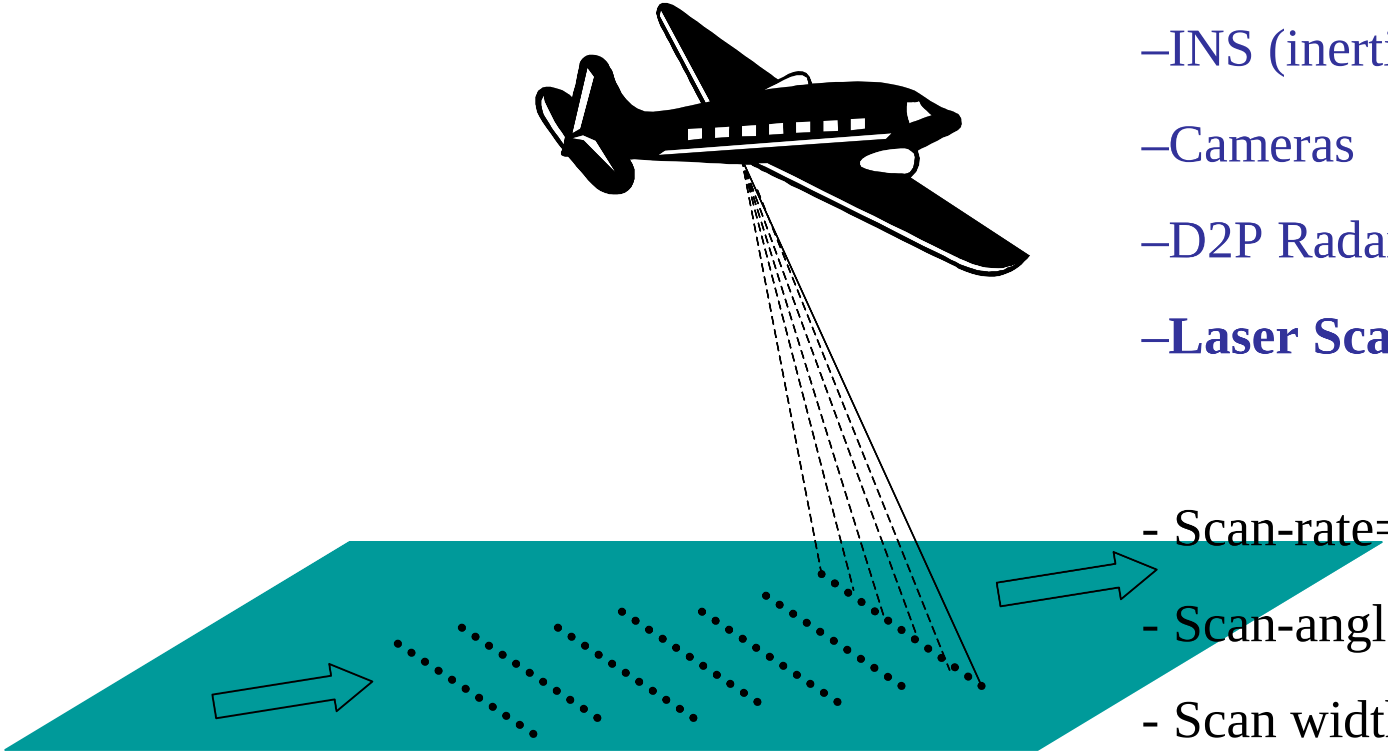
Objectives:
- Sea-ice profiles
- Coordinated flights around Polarstern
- Inland ice profiles

Survey activities:
April 5-9: Tests, SFJ to Nord
April 9-10: Flighs from Nord
April 11: Polarstern flight #1
April 15: Polarstern #2 + Nordaustlandet
April 17: ”Mow-the-lawn”
April 18-21: Nord flights + back
Total flight hours: 61

Chalenges:
Extreme cold conditions,
poor weather conditions,
hardware and communiction



Observation Method



- –GPS receivers
- –INS (inertiel navigation)
- –Cameras
- –D2P Radar system
- –**Laser Scanner** (LIDAR)

- Scan-rate=> 8 kHz data
- Scan-angle: +- 60 degrees
- Scan width ~ altitude
- Footprint: ~0.75 x 1.5 m

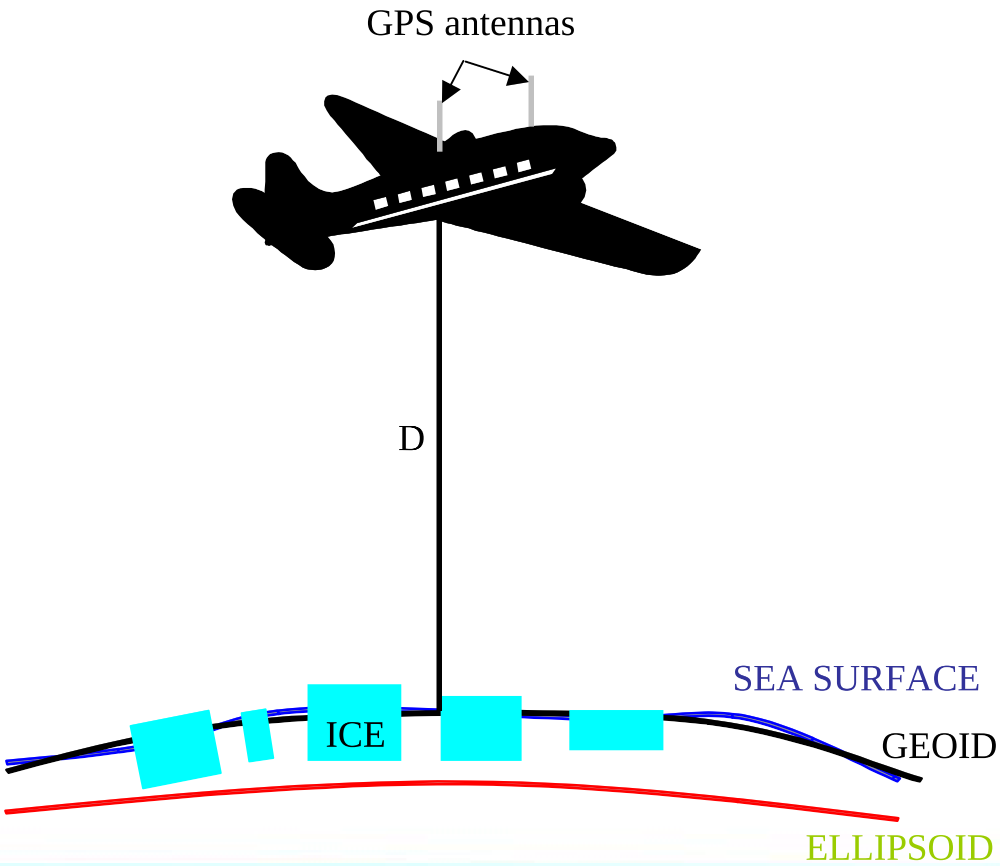
From laser heights to sea ice thickness

Basic principle: $F = h^{GPS} - D_{laser} - N - \Delta h$

F: Free-board height

N: Geoid height

Δh : Measurement errors, geoid errors and ocean dynamic topography (tides+mean)

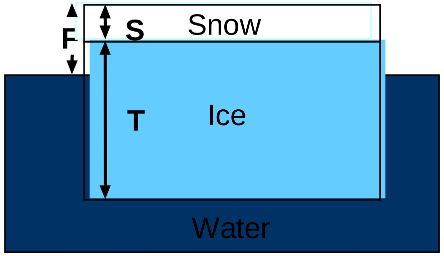


Freeboard to ice thickness:

- *Isostatic assumption*
- *Snow depth from climatology*

$$T = K * F$$

$$K = 1 + \frac{\rho_i h_i + \rho_s h_s}{h_i(\rho_w - \rho_i) + h_s(\rho_w - \rho_s)}$$



Freeboard to thickness ratio

- **K=5.0** from measurements on ice floe next to Polarstern, 850 kg/m3, 20 cm, 1024 kg/m3, 330 kg/m3

(825-890, 0-70 cm)

- K=6.0 from model (Wadhams 1992) 915kg/m3, 35 cm, 1024kg/m3, 330kg/m3 (mid April)

- In-situ samples of K:

Alert 2002 5.6 [5.3 – 6.6 (mid May)]

(snow: 340 kg/m3, 50 cm)

St. Nord 2002 3.0 – 3.5 (early May)

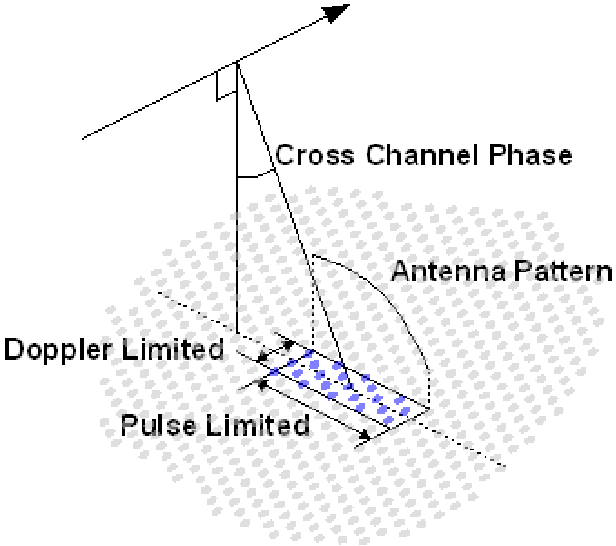
Polarstern 2003 5.0 [4.5-6.0 (mid April)]

(825-890 kg/m3, 20 cm)

Alert 2004 6.3 [5.9 – 6.8 (late May)]

(10-30 cm)

D2P radar



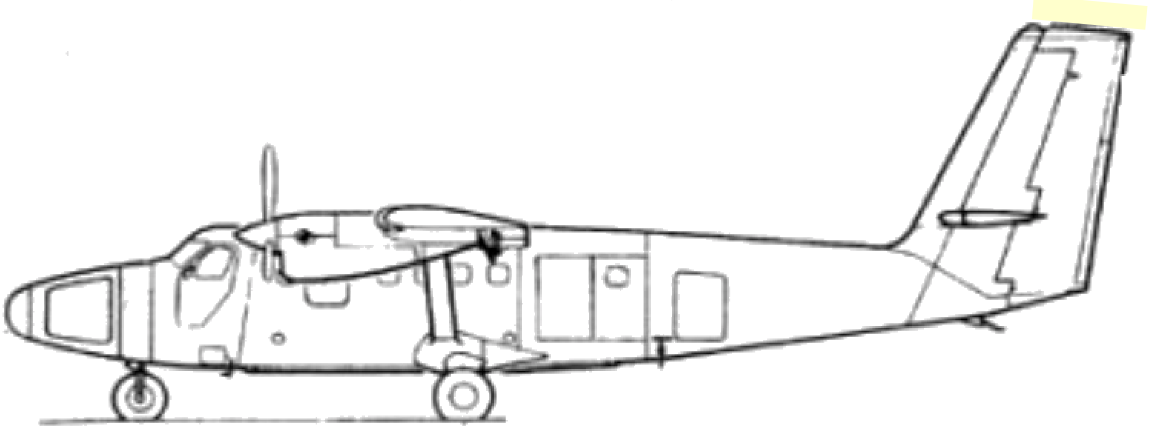
13.6 GHz CryoSat type

HEM system

TWIN-OTTER from Air Greenland

Twin-Otter OY-POF
at STATION NORD

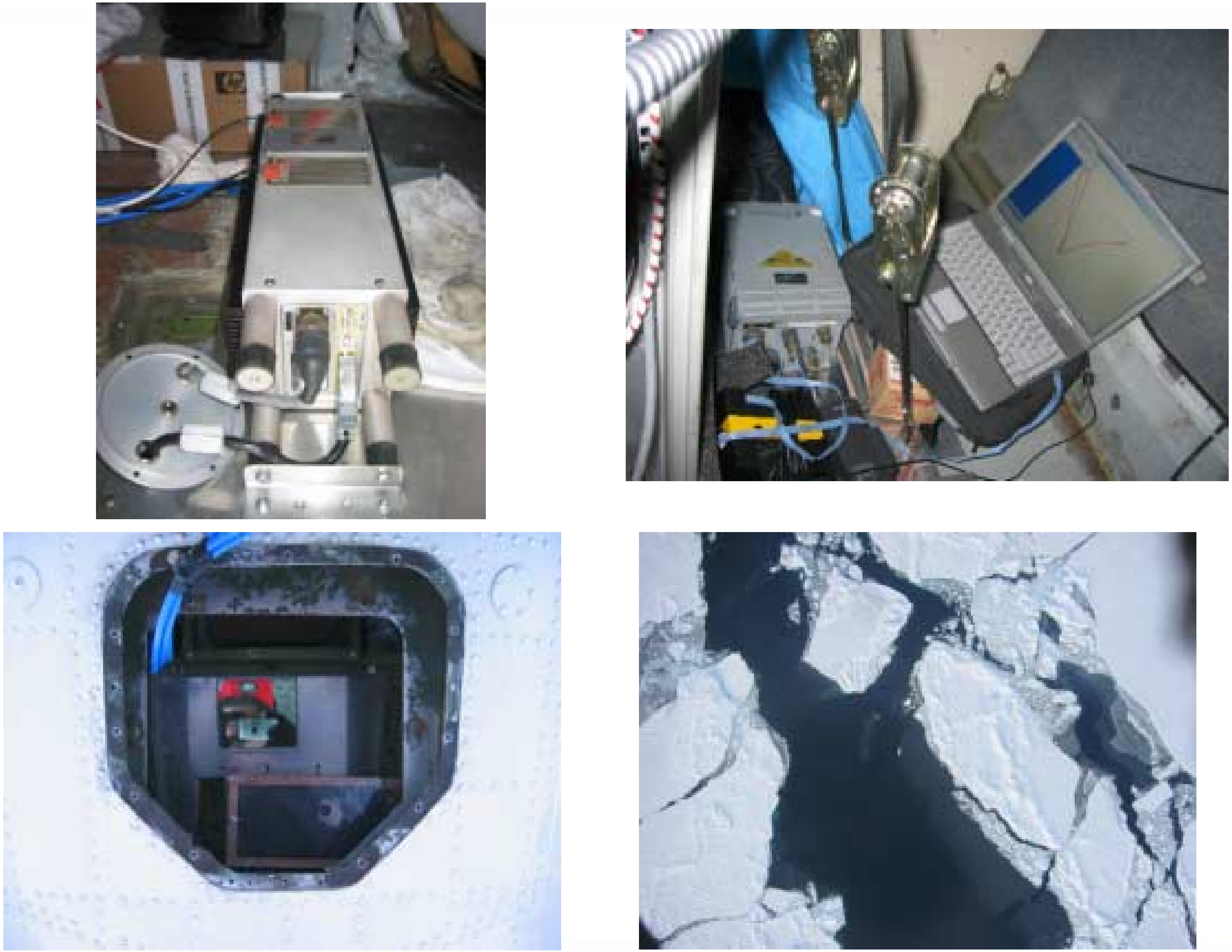
Installation



🟨 D2P Electronics Racks (Starboard Side)

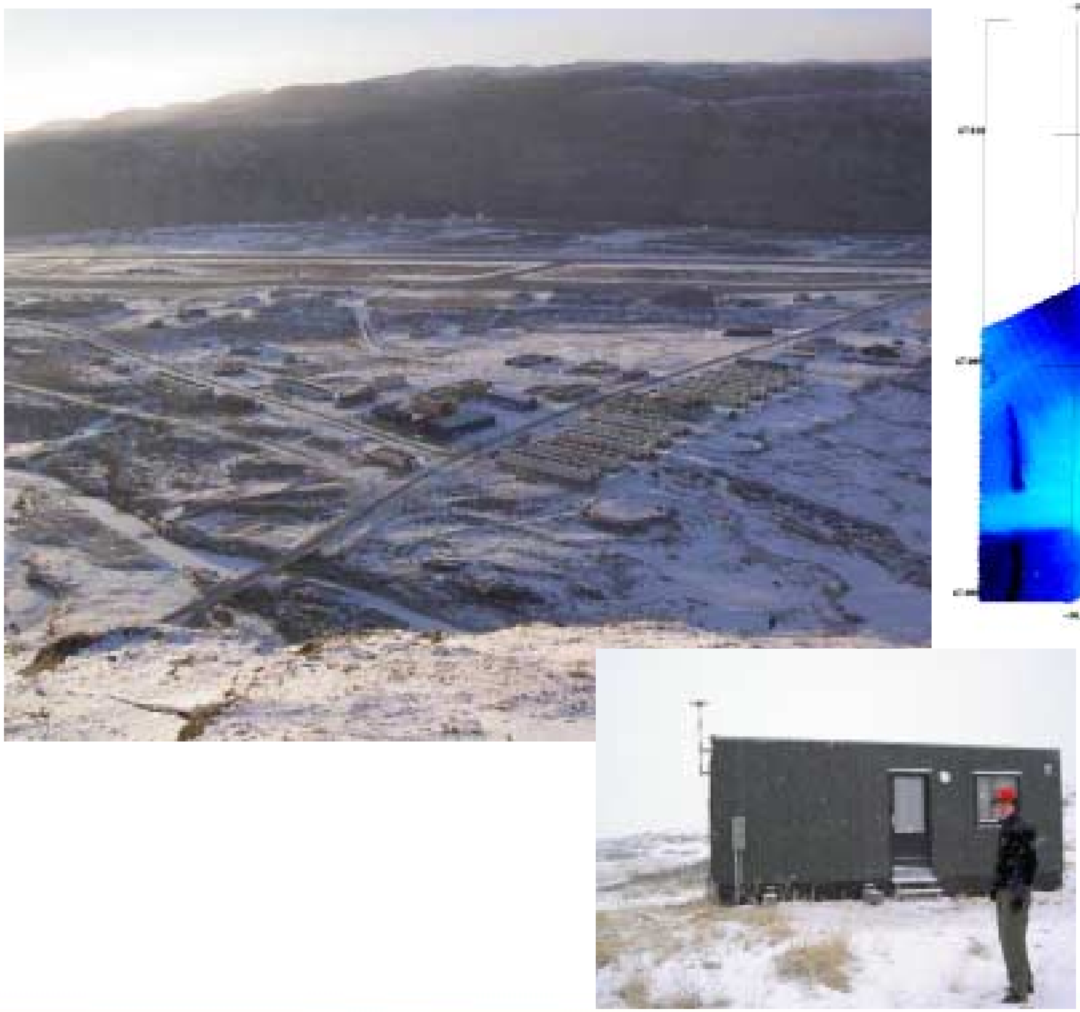
Calibration over building, open water and runways

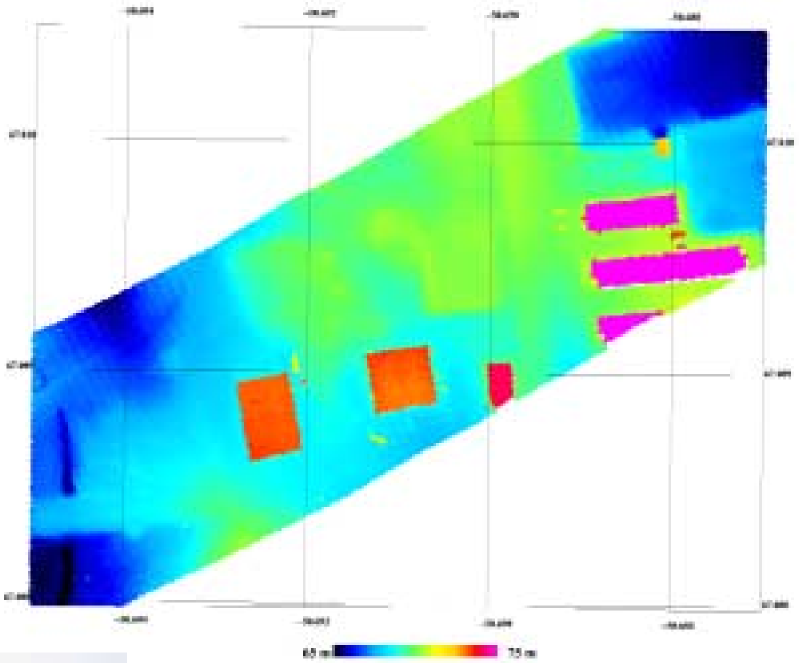
Installation – laser etc.

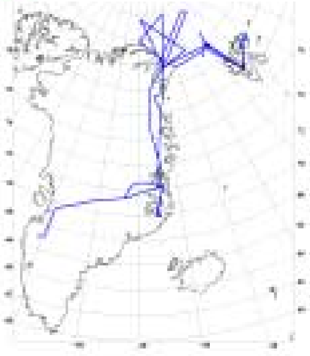


Installation (D2P radar)

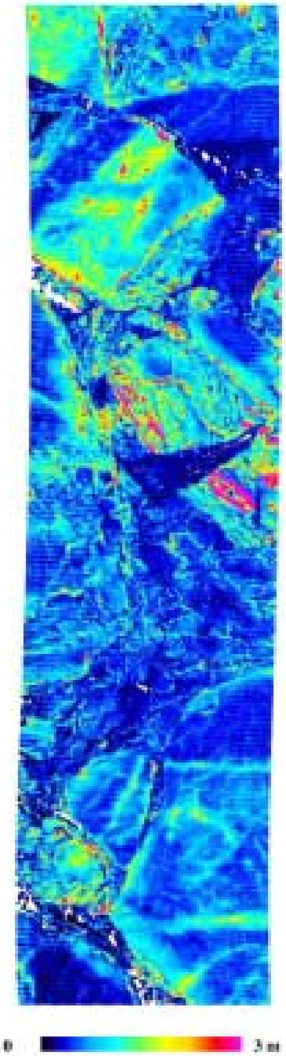
Søndre Strømfjord (Kangerlussuaq)



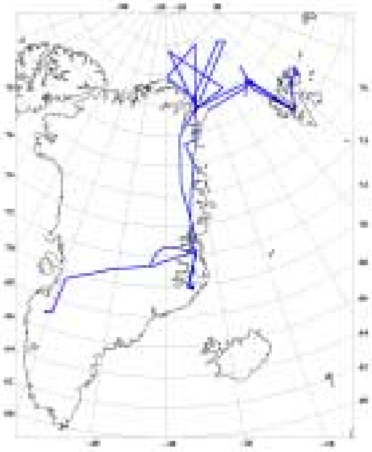




Sea Ice North of Svalbard

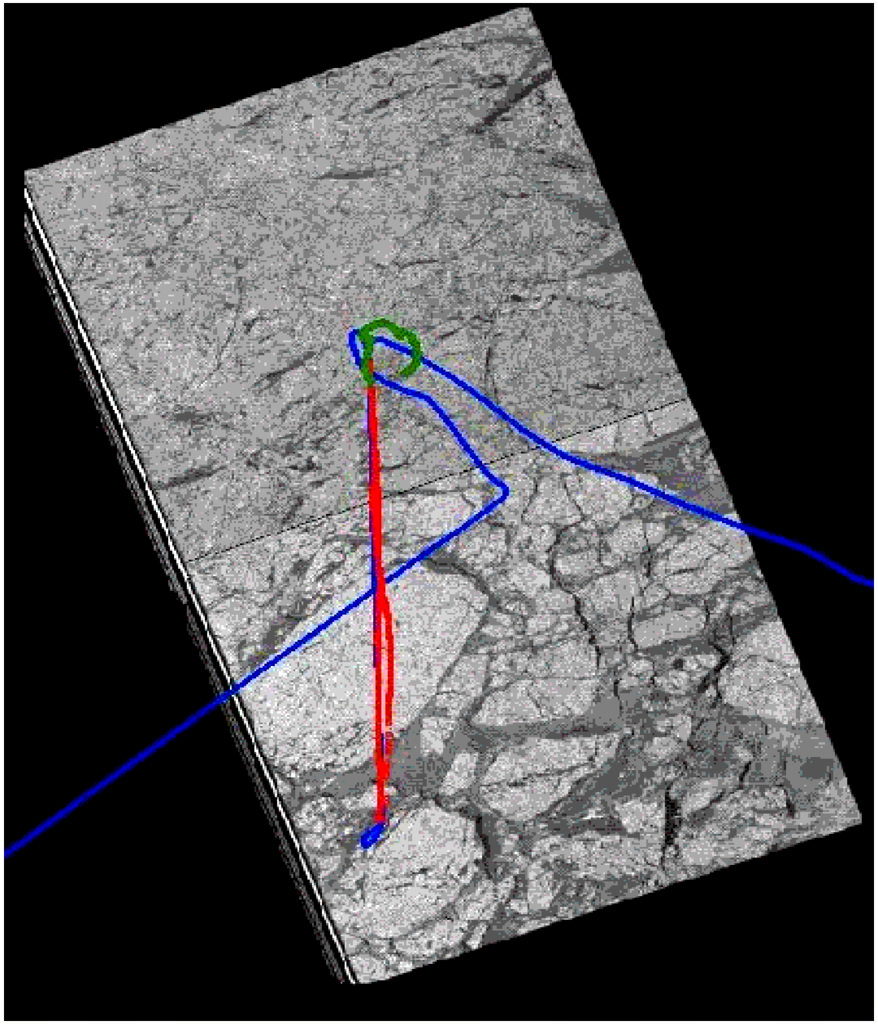


Polarstern from Twin Otter



Two contemporal and coincident flights, April 11th and April 15th

Laser scanner and HEM



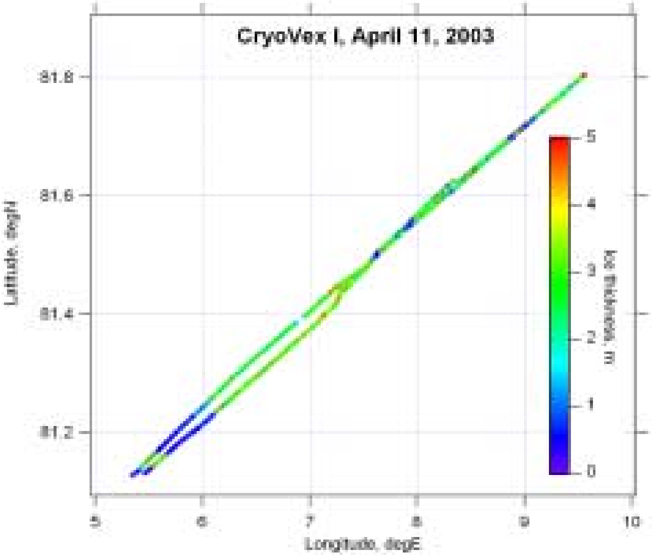
Helicopter (red)
Twin-otter (blue)
Polarstern drift Apr 11-17
(green)

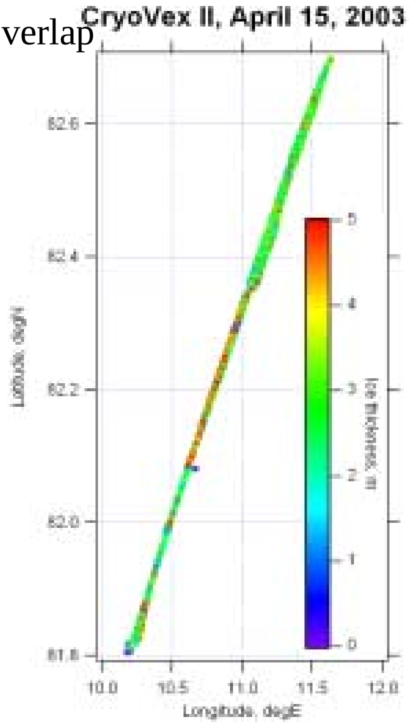
ASARbBackground (vertical
extension approx 200 km)

Joint flights, Twin-Otter and Helicopter

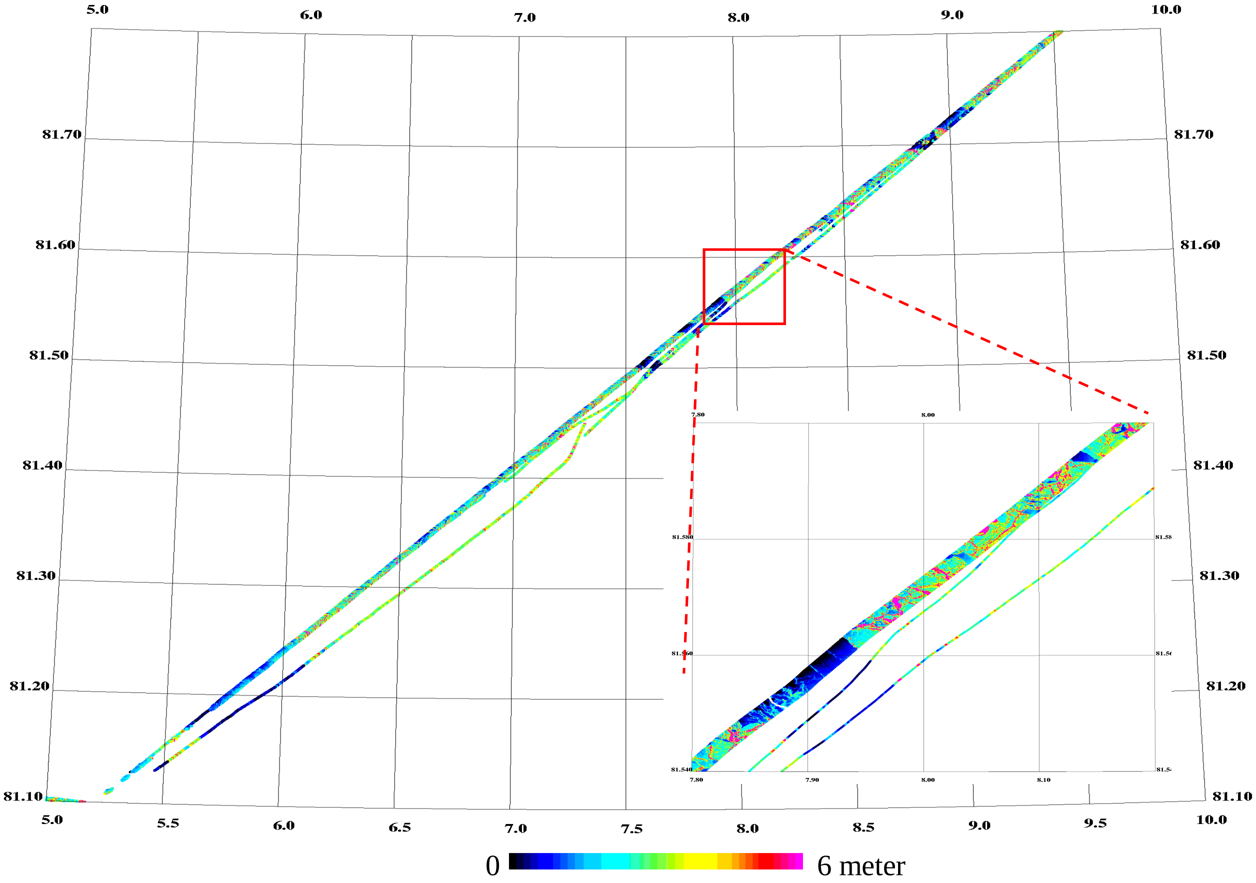
Principle:

- Predict positions of ship ahead of time
- Define helicopter and twin-otter waypoints, using icedrift information
- Communicate wpt's to Polarstern at T.O. departure time
- Two profiles (April 11 + April 15) – only April 15 with full overlap

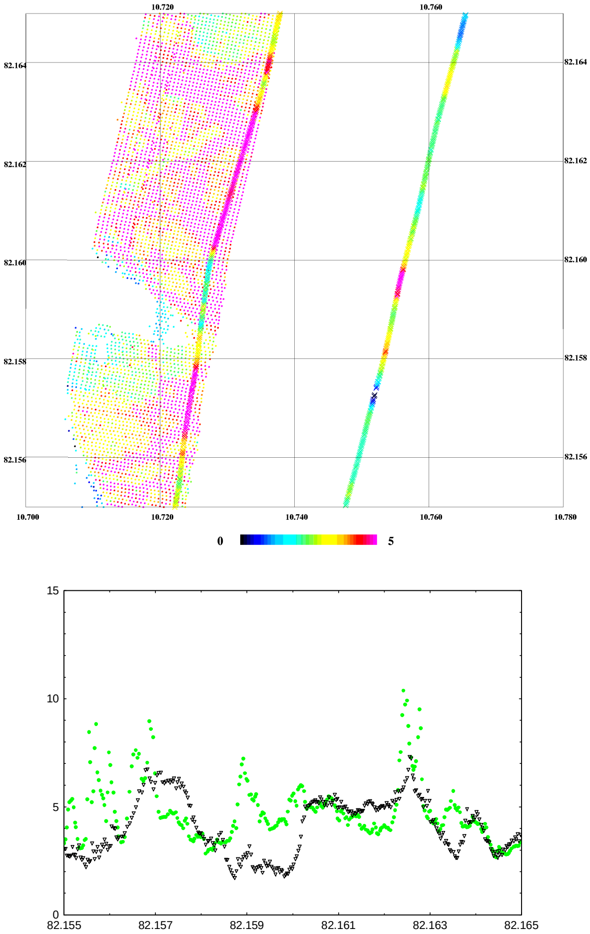




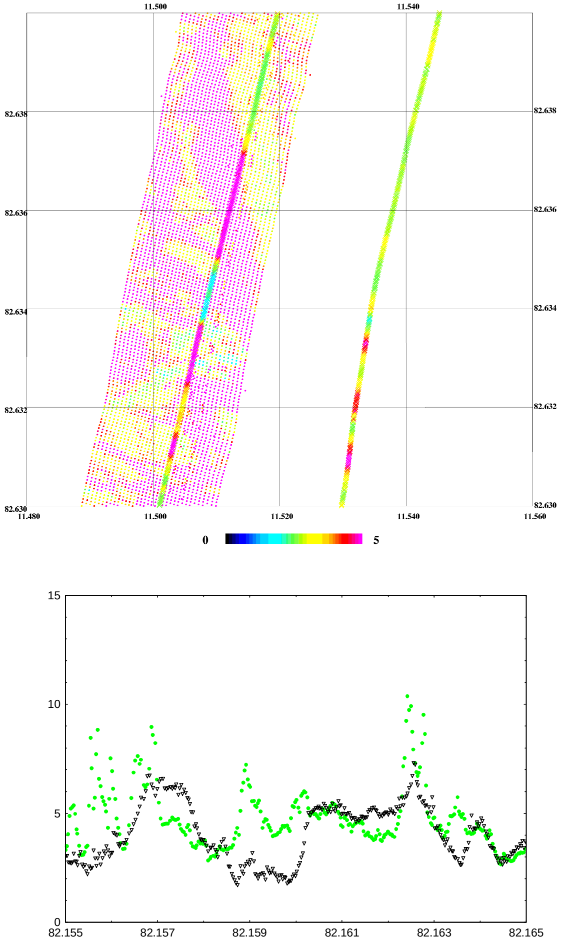
HEM vs. Laser thickness comparison – April 11



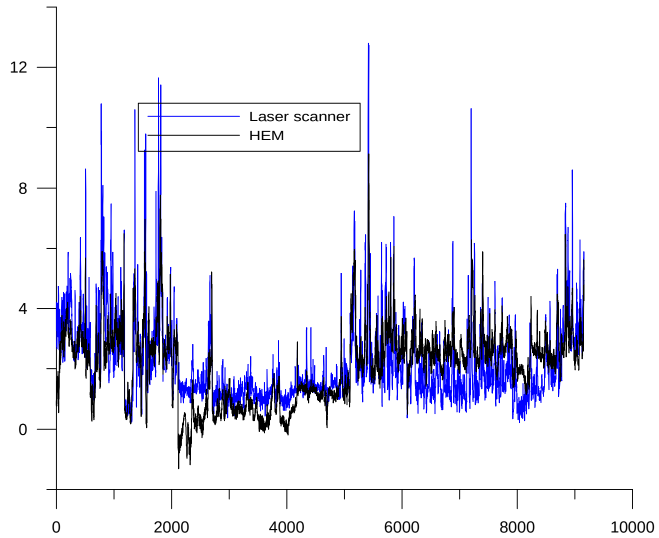
Ice drift correction – poorest fit far from ship

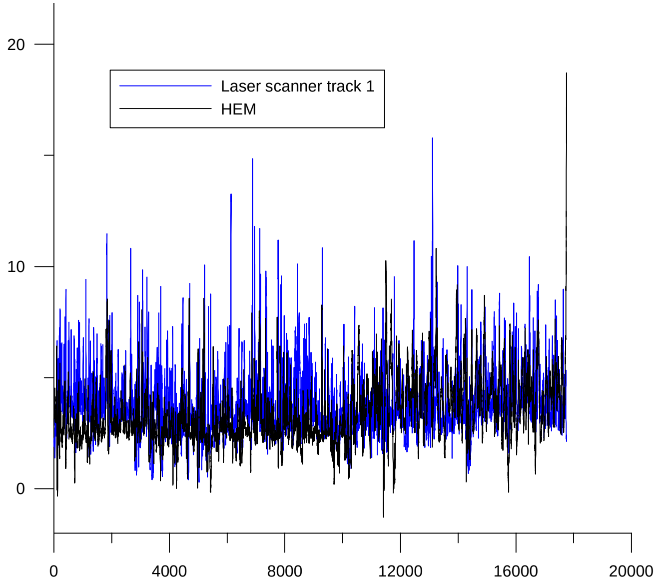


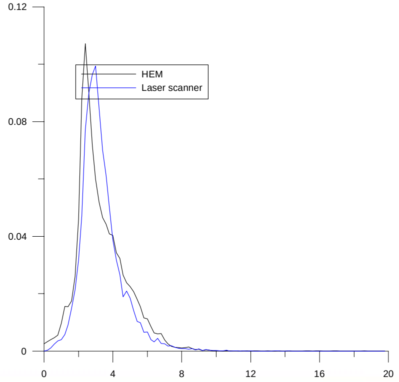
About 50 m off towards SE



Comparison of coincident points



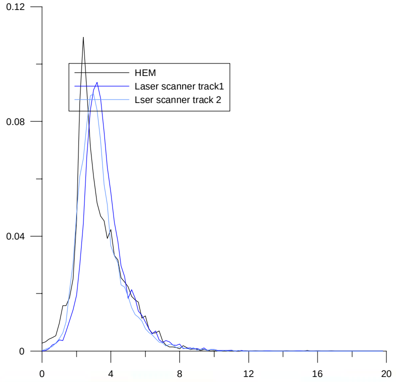




Mean:

2.1 m

2.1 m

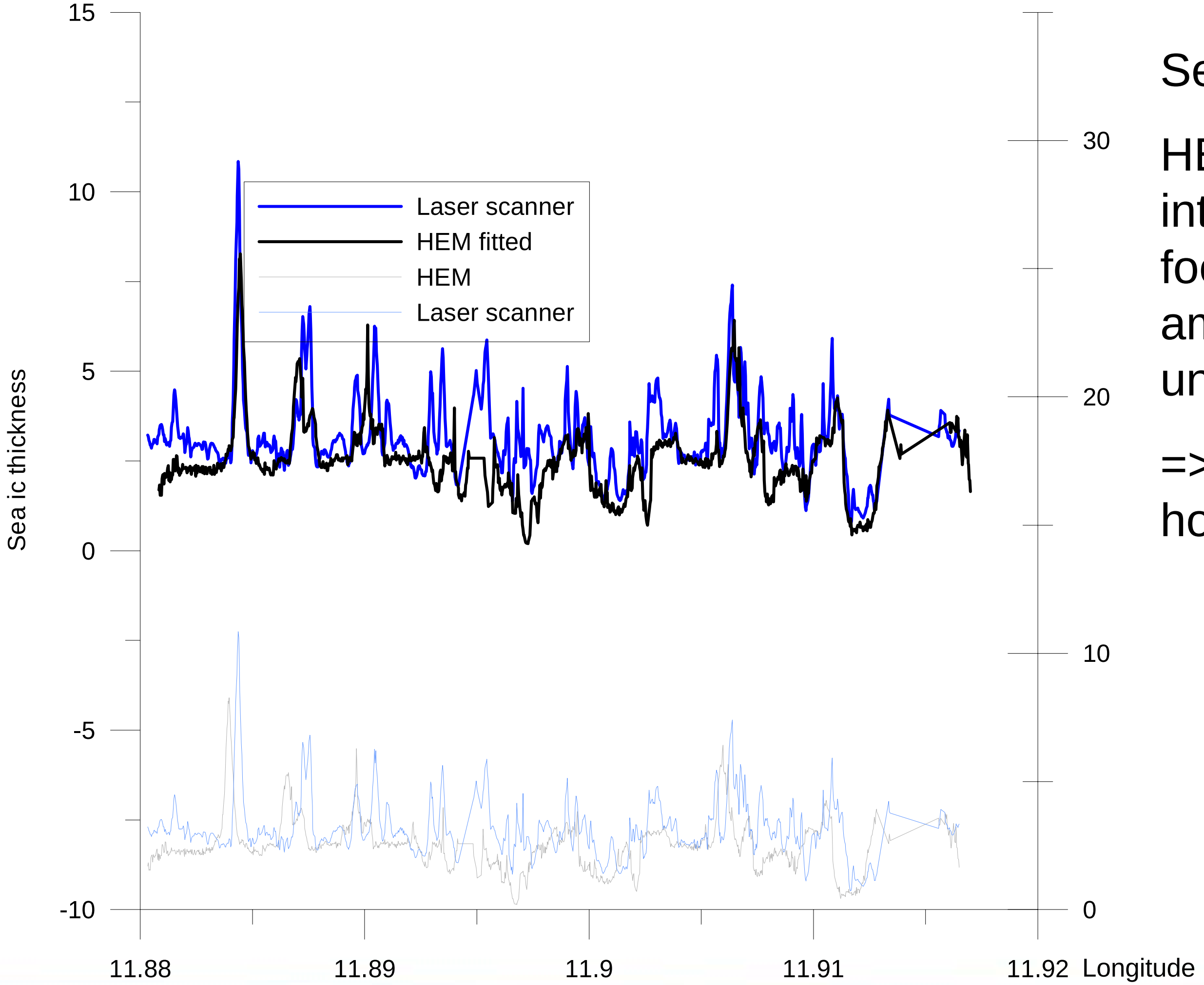


Mean:

3.8/3.7 m

3.4 m

Selection of April 15th



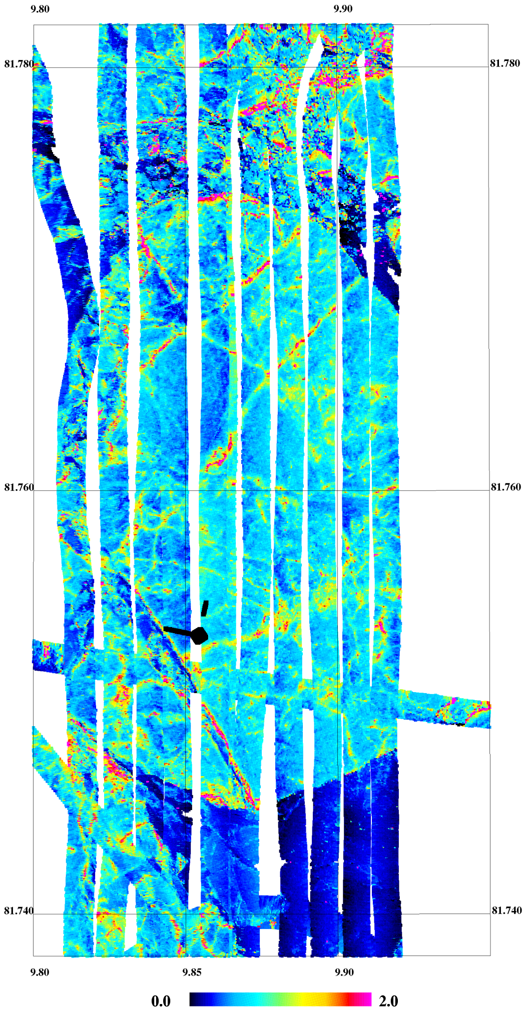
Section length: 4.5 km

HEM smoother, integrated over larger footprint and laser amplifying unsupported ridges.

=> Isostatic assumtion holds on this scale.

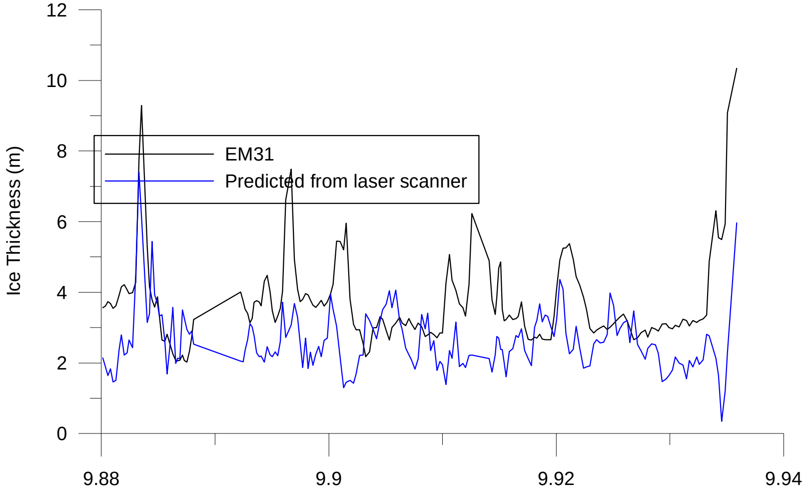
Mow-the-lawn survey

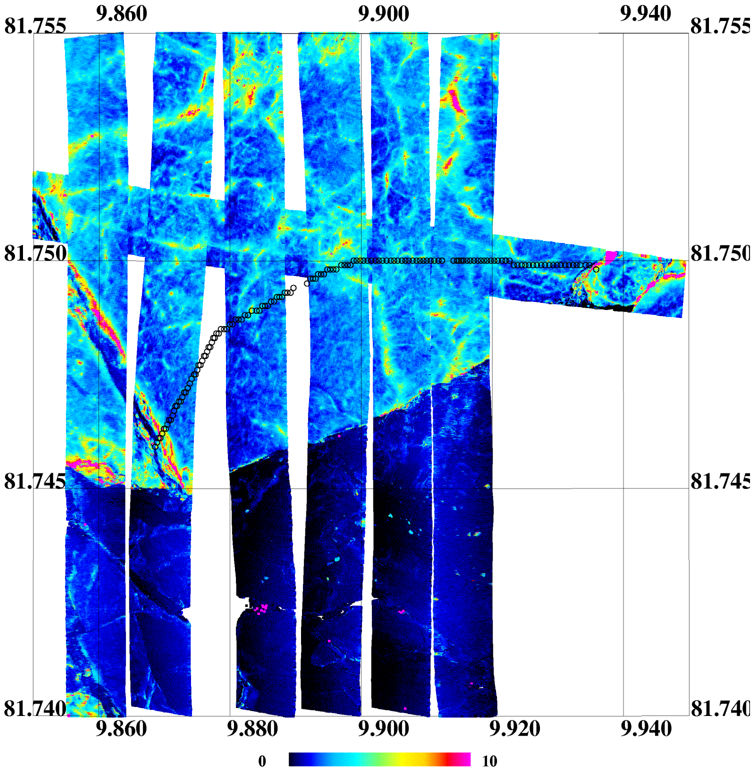
Laser scanner, circle 50 m	**3.1 m**
Drillings	**2.6 m**



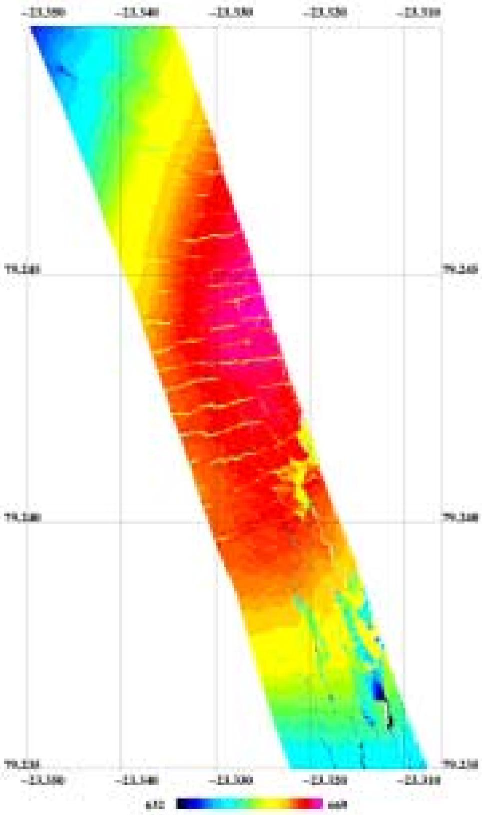
Floe and EM31

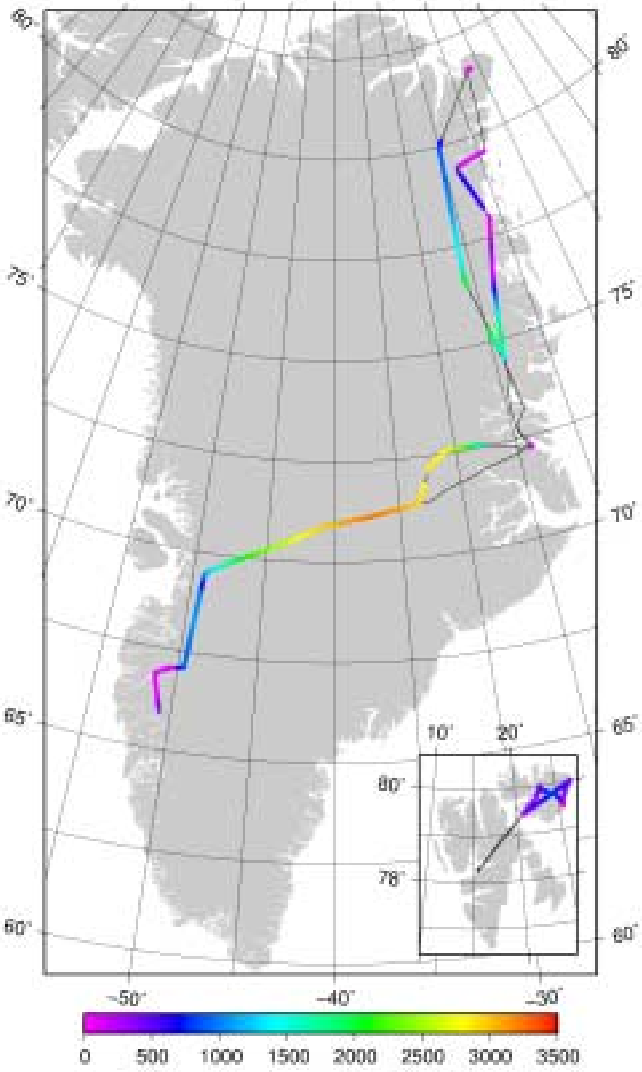
Laser sc. pred. to EM31	**3.2 m**
EM31	**3.6 m**



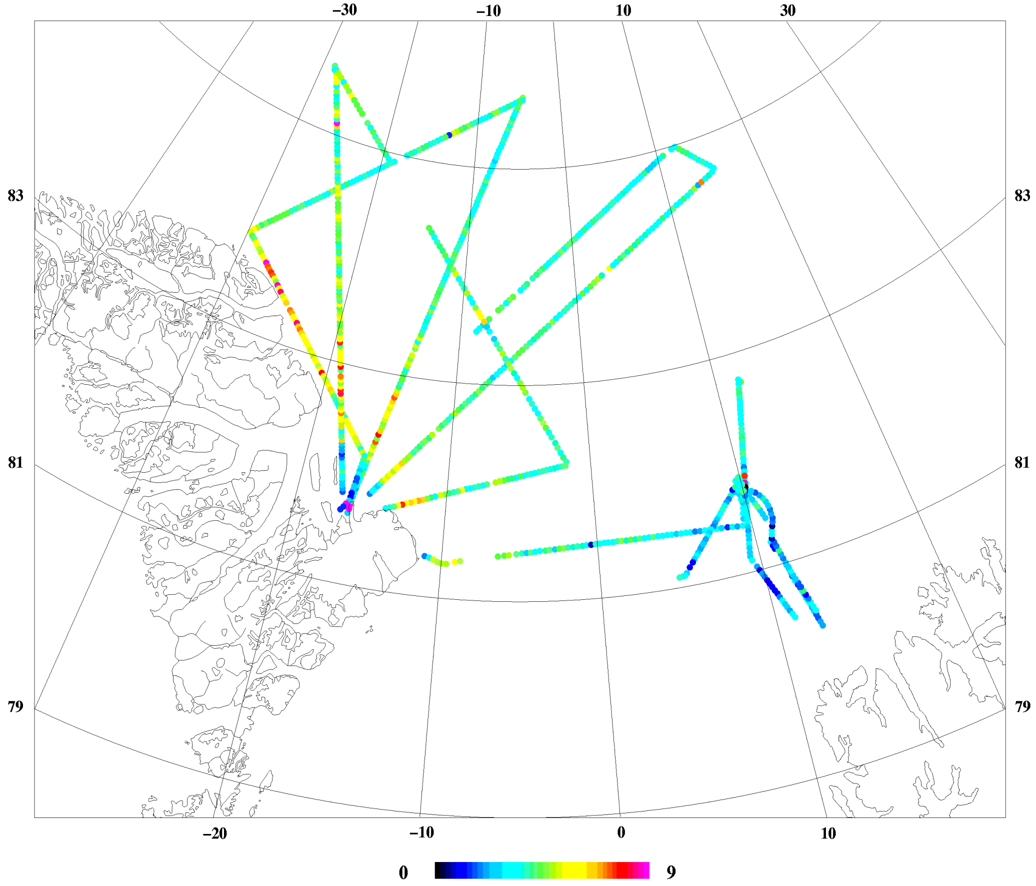


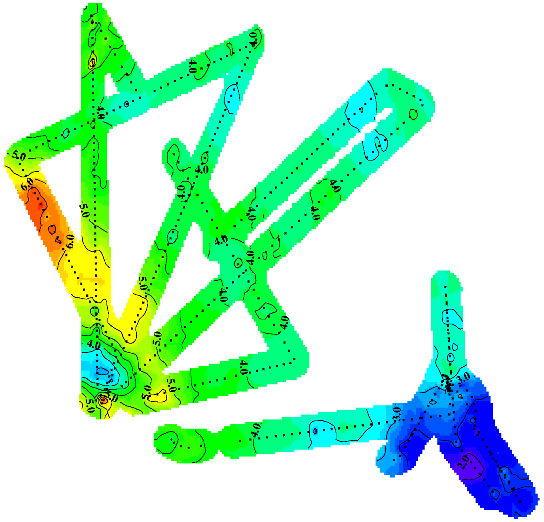
Laser scanner observations of inland ice



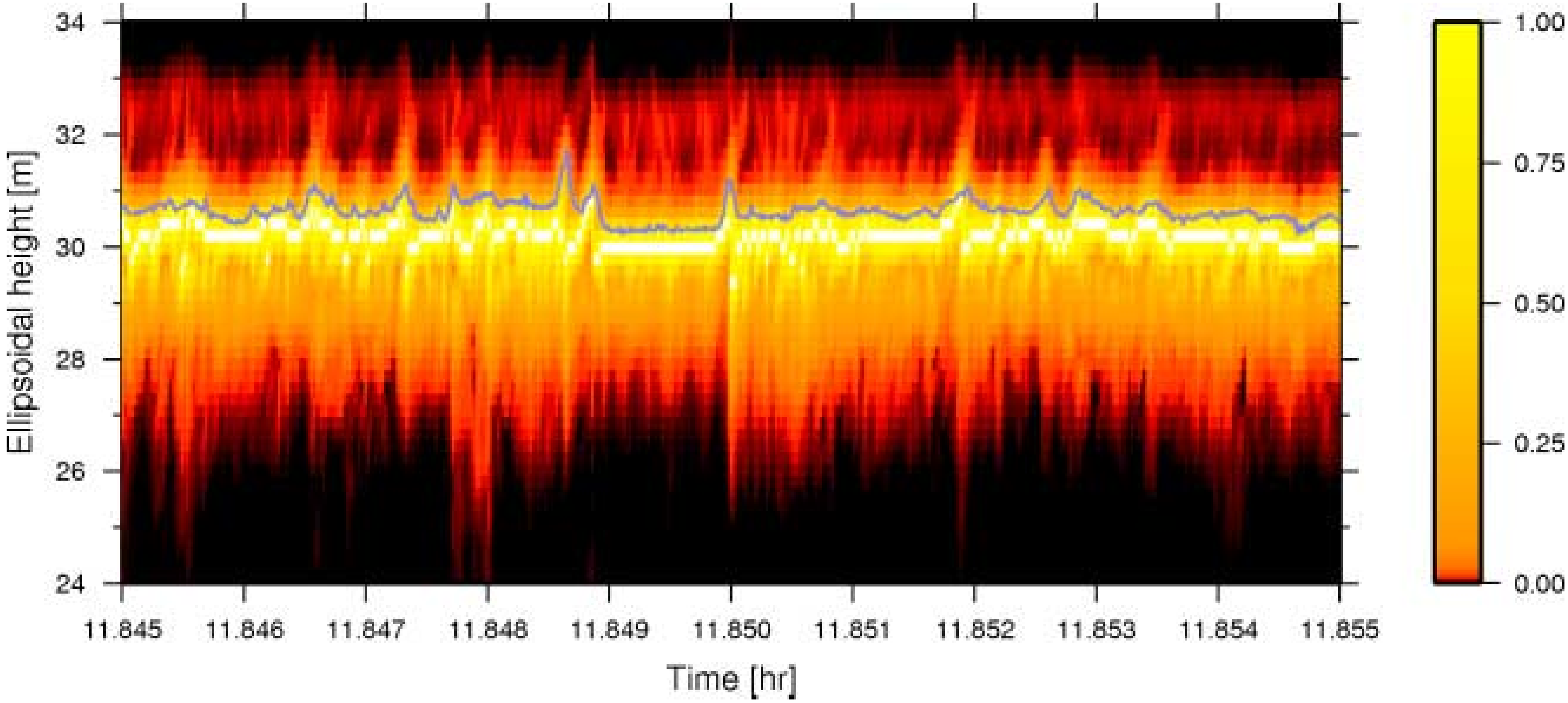


Sea ice thickness April 2003



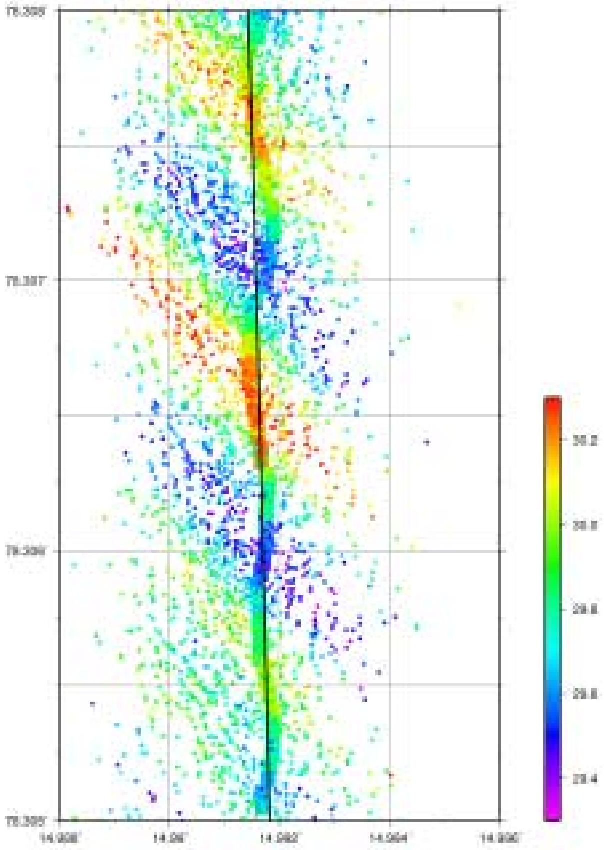


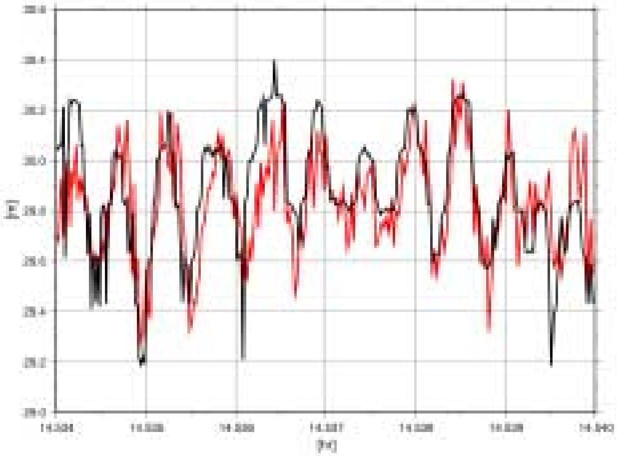
D2P and laser over sea ice north of Svalbard



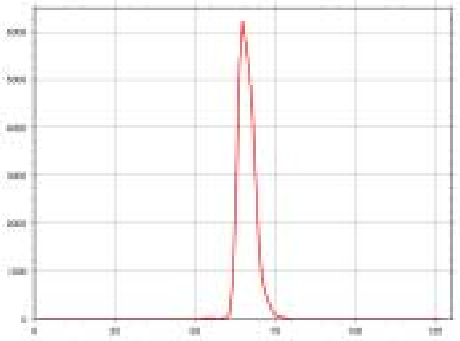
(D2P data courtesy C. Leuschen, APL)

Laser scanner vs. D2P radar – Fjord waves





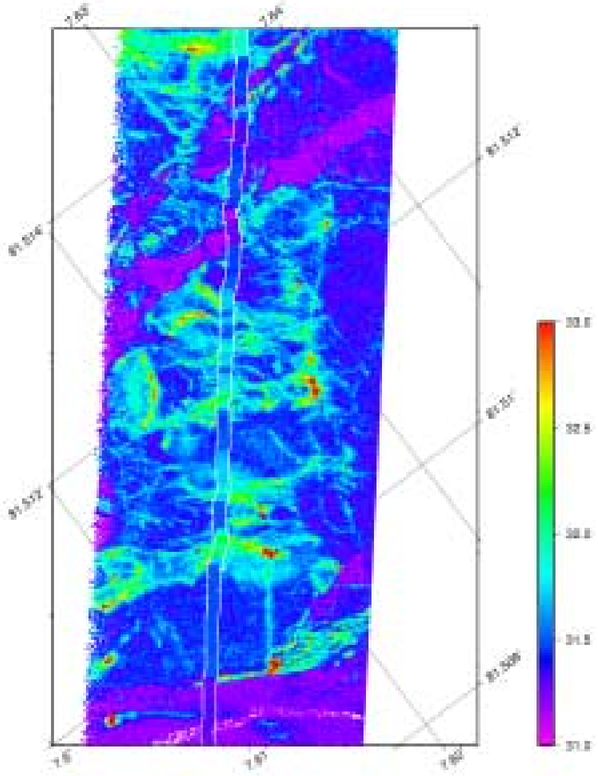
Red: laser
Black: D2P

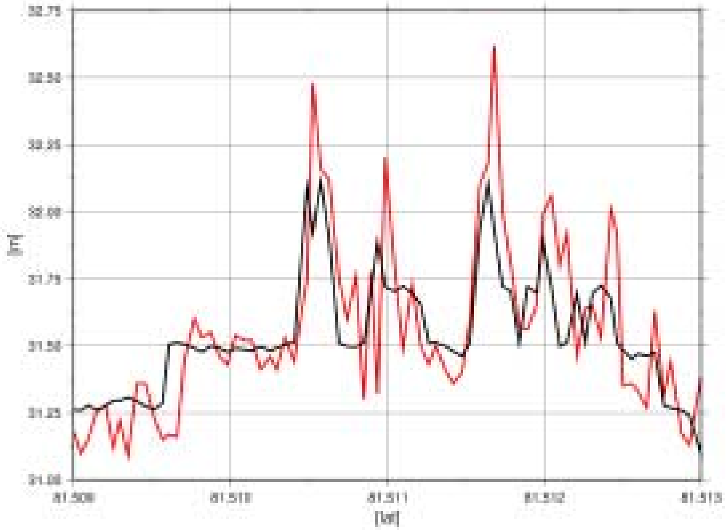


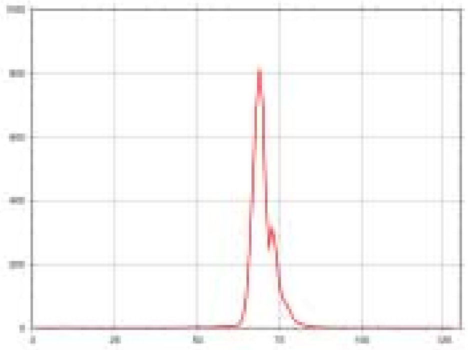
D2P return

Prepared by Lars Stenseng, DRC

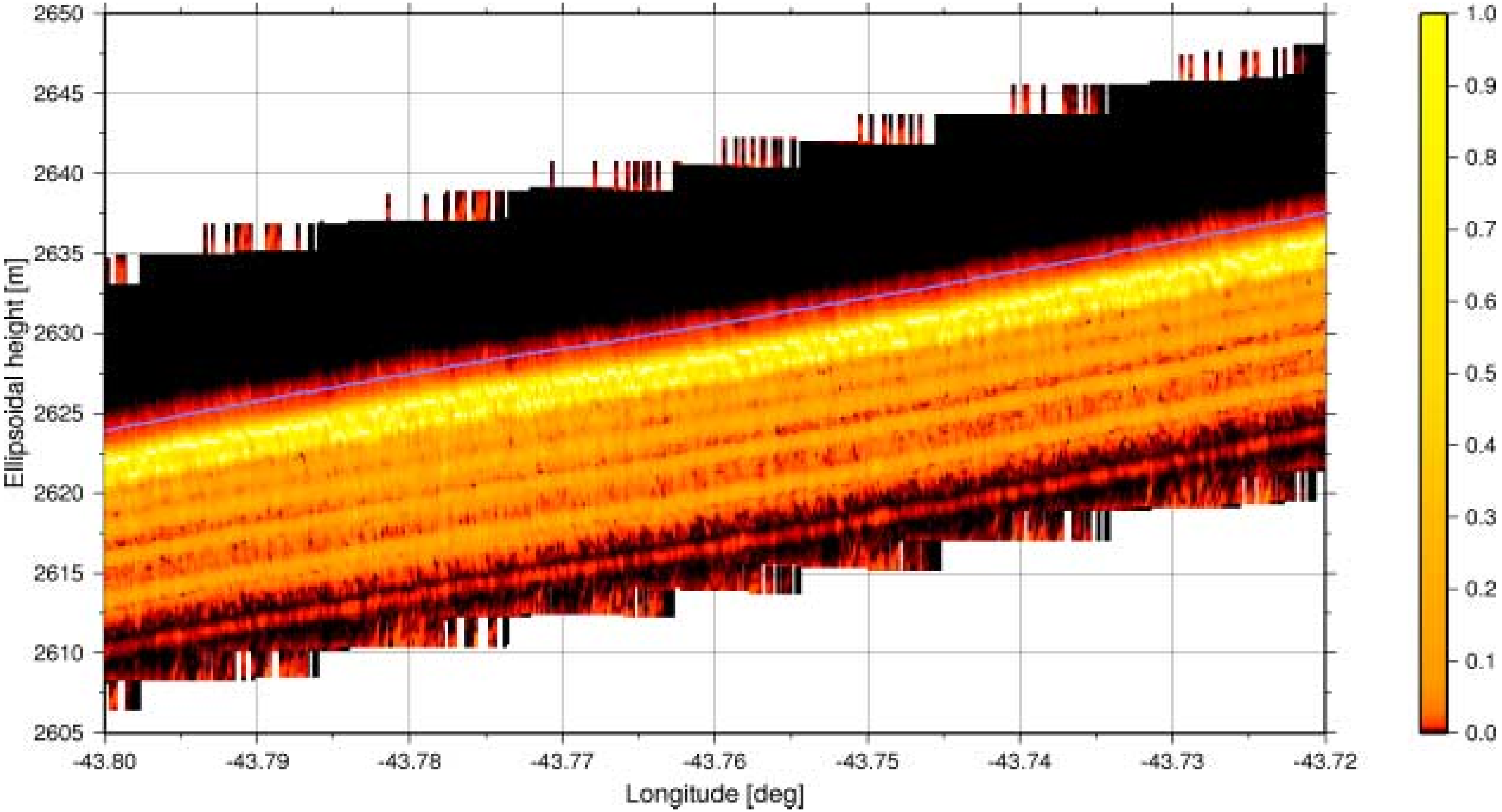
Laser scanner vs. D2P radar – sea ice



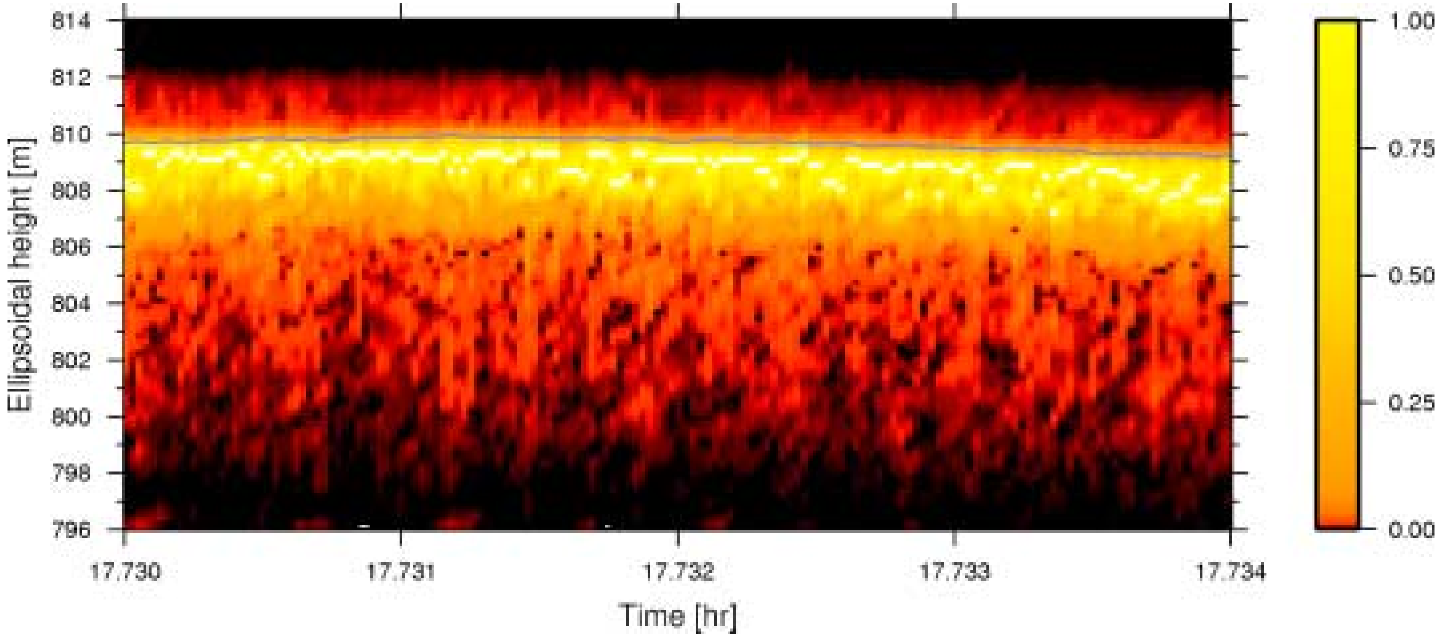




Laser scanner vs. D2P – EGIG line Greenland



Nordaustlandet, Svalbard



Conclusions

- Succesful observations from different ice covered areas: Greenland ice sheet, Austfonna Glacier, varying sea ice types (north of Greenland to Svalbard and Fram Strait near Polarstern)

- Succesful coincident work with HEM system. Lessons leart about joint operations and managing icedrift

- Lots of coincident laser scanner and D2P data – ongoing research about optimal analysis.

Sine M. Hvidegaard,smh@spacecenter.dk