Recent Airborne Gravity Surveys in Denmark and their impact on Geoid Computations

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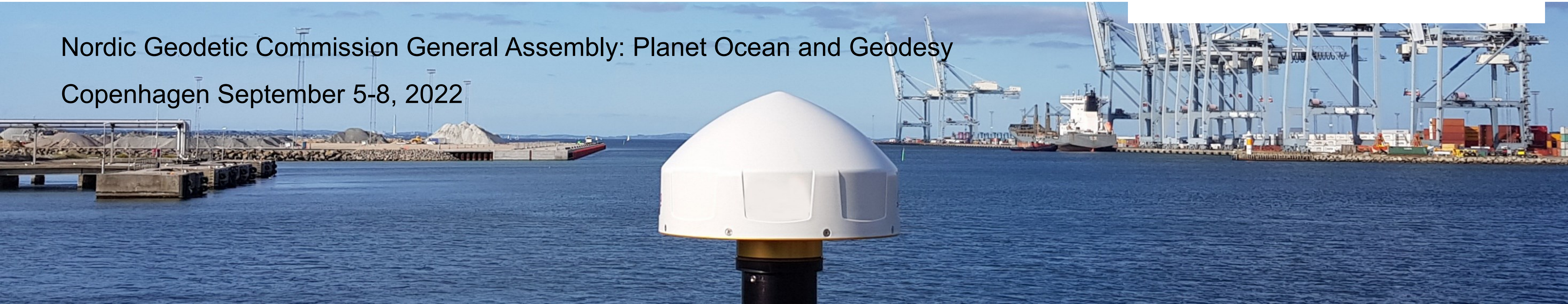


Nordic Geodetic Commission General Assembly: Planet Ocean and Geodesy

Copenhagen September 5-8, 2022

DTU Airborne Gravity Surveys in the Nordic / Baltic Area

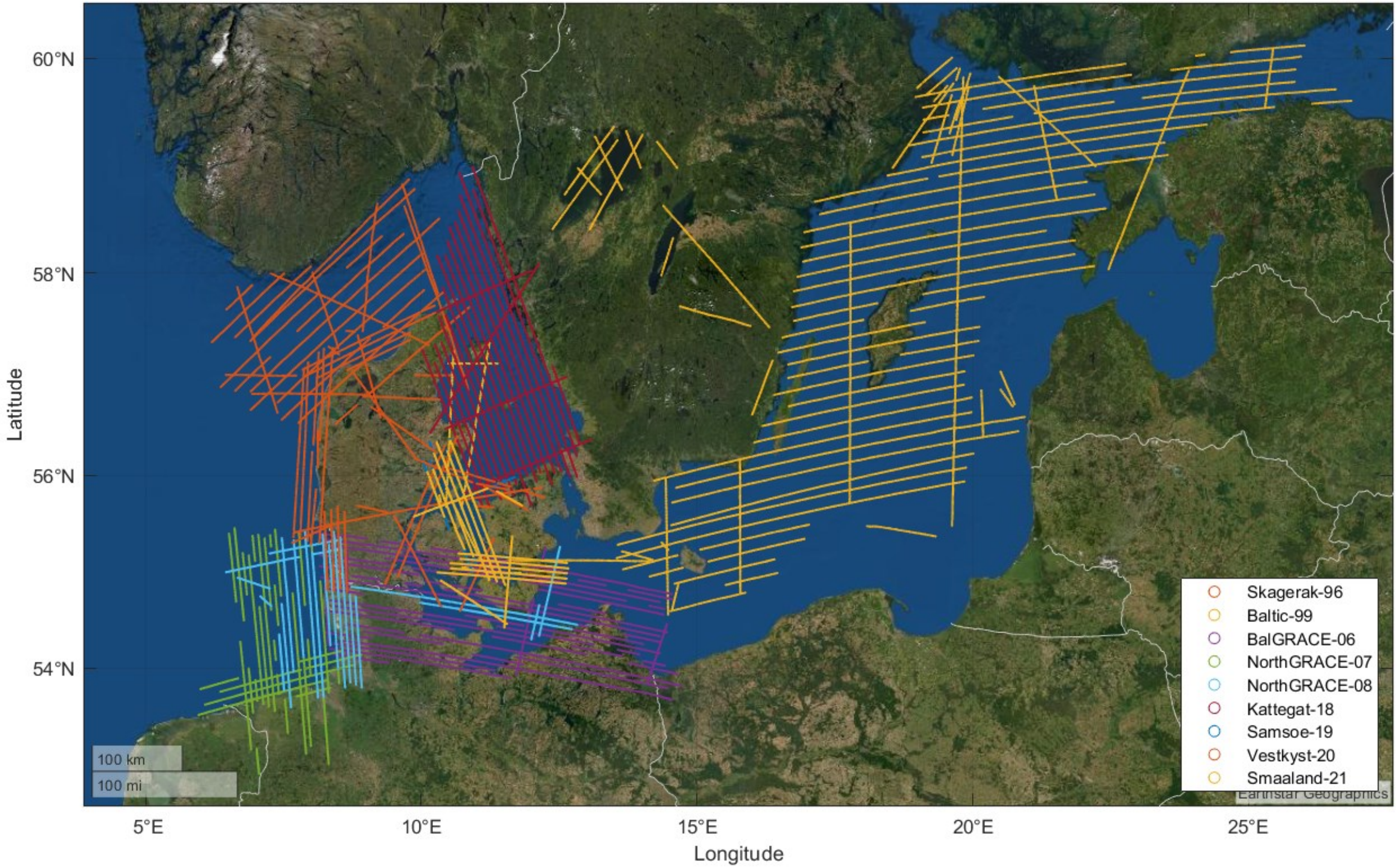
Airborne projects carried out by DTU Space in collaboration with other partners

Project
Skagerak-96
Baltic-99
BalGRACE-06
NorthGRACE-07
NorthGRACE-08
Kattegat-18
Samsoe-19
Vestkyst-20
Smaaland-21

"the old ones" (Skagerak-96 – NorthGRACE-08)

"strapdown era" (Kattegat-18 – Smaaland-21)

"small-aircraft era"



The “FAMOS Dataset” Excluding Airborne Observations

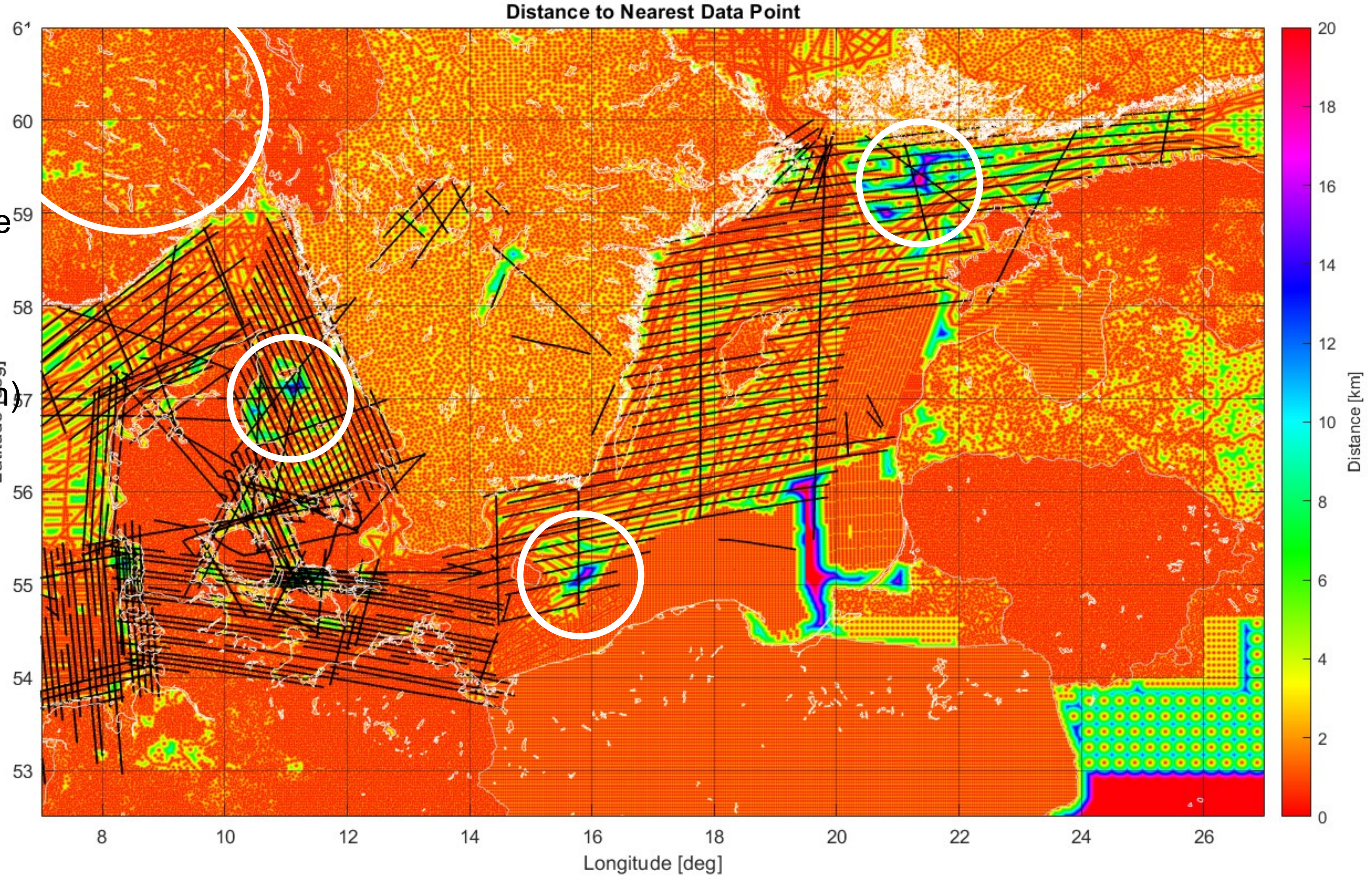
Dense data coverage in area

So why include airborne data?

- Main advantage: Data coverage
- Some ”data gaps” covered
- Coastal areas covered (seamless ocean-land transition)
- Potential coverage of mountain regions (which are often only measured in mountain valleys)

Main challenge

- Moving-base gravimetry introduces the topic of spatial resolution
- Possible introduction of ”long wavelength” errors

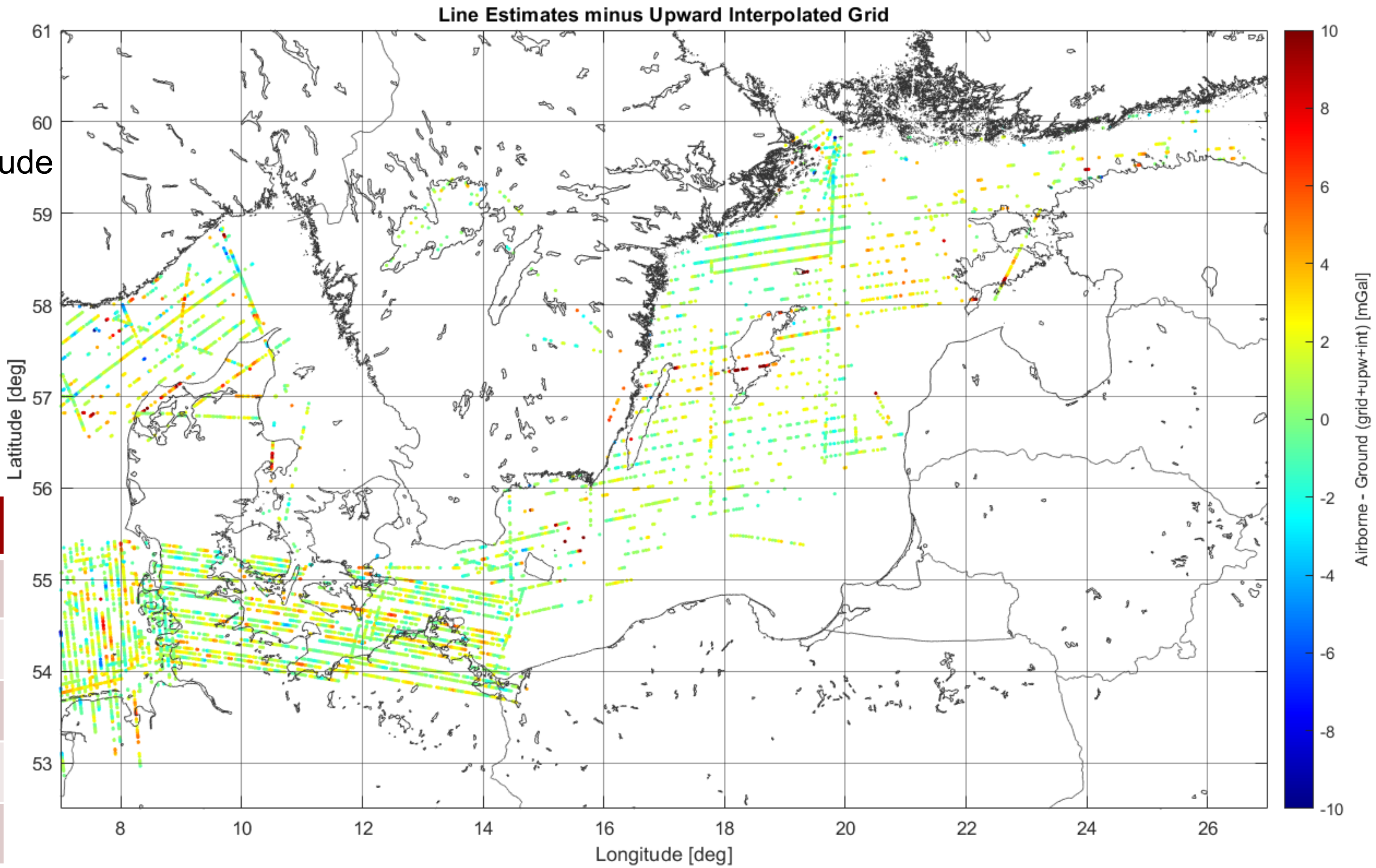


Comparison with ”Ground” Observations

Procedure:

1. Interpolate to regular grid
2. Upward continue to flight altitude (GRAVSOFT geofour)
3. Interpolate to flight lines
4. Form differences with airborne estimates
5. Sort away points more than 2 km from ground data

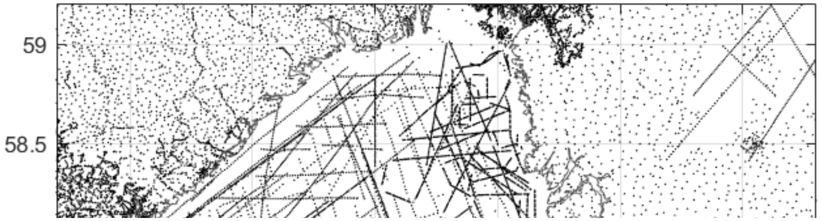
Project	Mean	Std
Skagerak-96	1.14	2.51
Baltic-99	0.99	2.18
BalGRACE-06	1.00	1.64
NorthGRACE-07	1.25	1.90
NorthGRACE-08	1.05	1.84

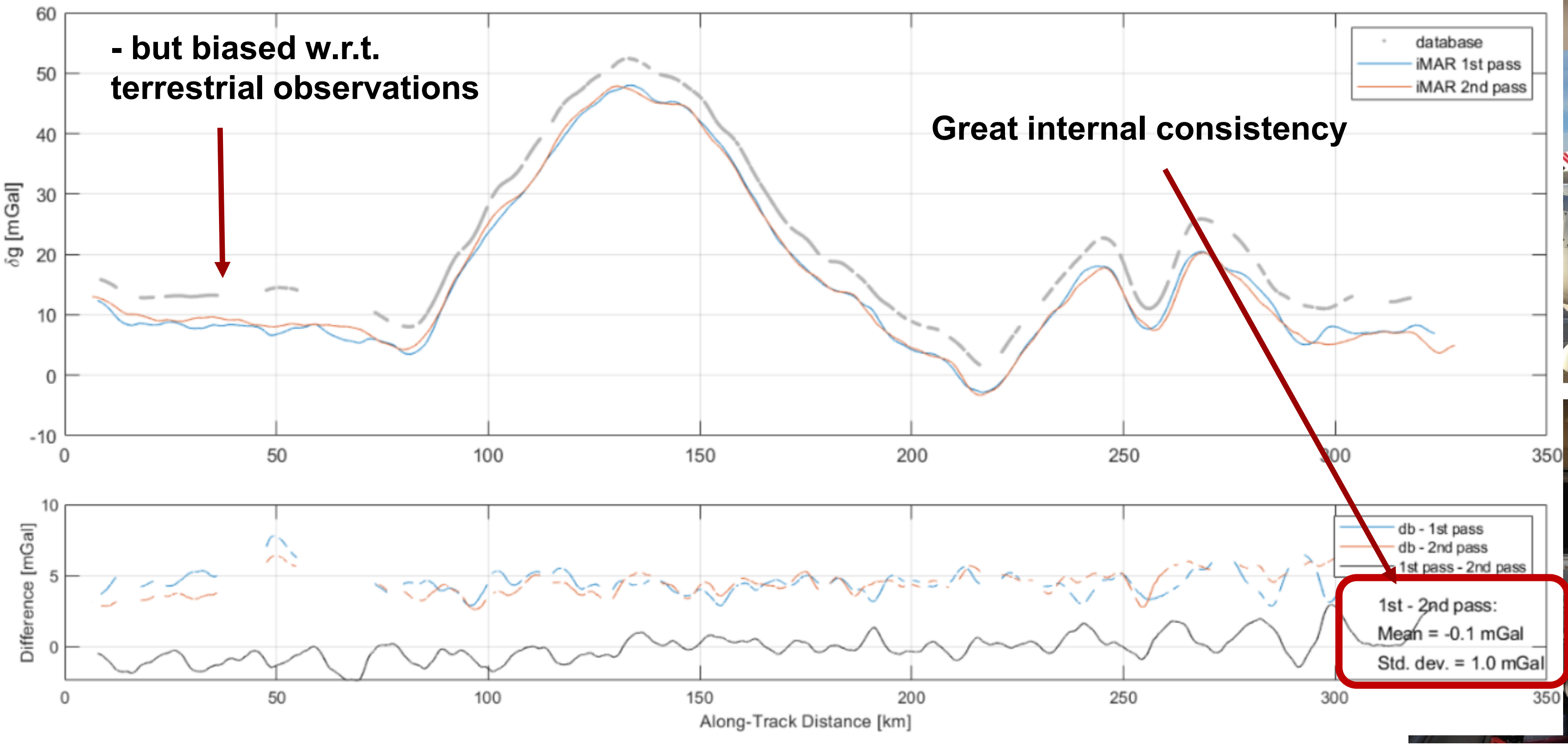


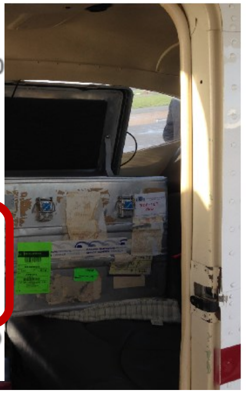
The "Strapdown Era"

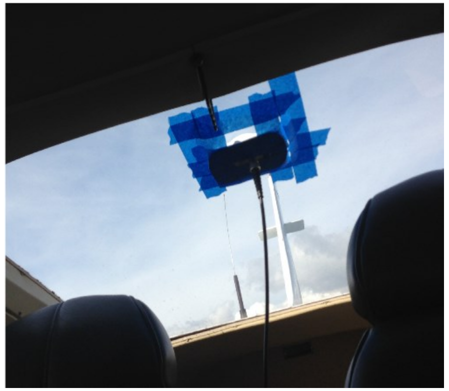
In 2016 DTU Space purchased an iMAR-iNAT-RQH Inertial Measurement System for strapdown gravimetry

First test flight immediatly afterwards
(~1h installation time)









The Strapdown Setup

Small and easy setup = practical advantages and operational flexibility!

iMAR iNAT-RQH (2016)
Inertial Measurement Unit
Size: ≈ 19 x 13 x 30 cm (shoebox size)
Weight: ≈ 8 kg

JAVAD DELTA GNSS Receiver
Size: ≈ 3 x 10 x 15 cm
Weight: ≈ 0.4 kg
NovAtel ANT-532-C Dual Frequency
GNSS Antenna
Size: ≈ 3 x 8 x 12 cm
Weight: ≈ 0.2 kg

Batteries
Size: ≈ 10 x 15 x 20 cm
Weight: ≈ 7.3 kg

Cables
Laptop

Total weight ≈20 kg

Main challenge: Long-term drift and bias issues!

Hypothesis: Sensors are sensitive to temperature variations.

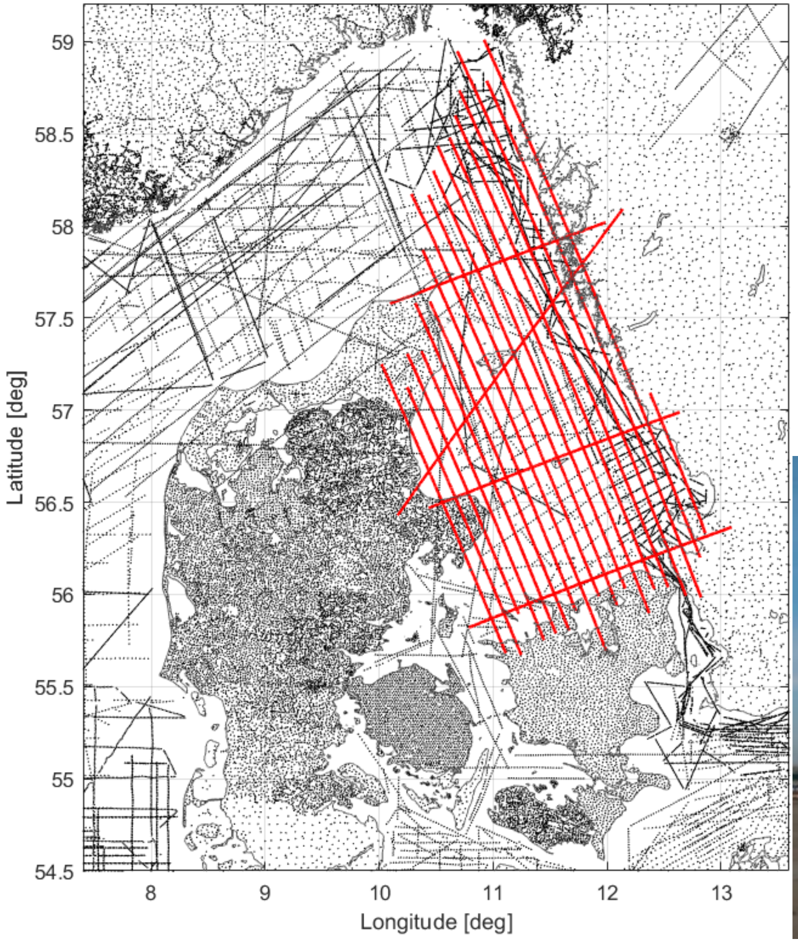
iTempStab (2018)
Temperature Stabilization Box

Size: ≈ 25 x 22 x 38 cm
Weight: +10 kg
Power consumption: max. 175 W (temp. dependent)

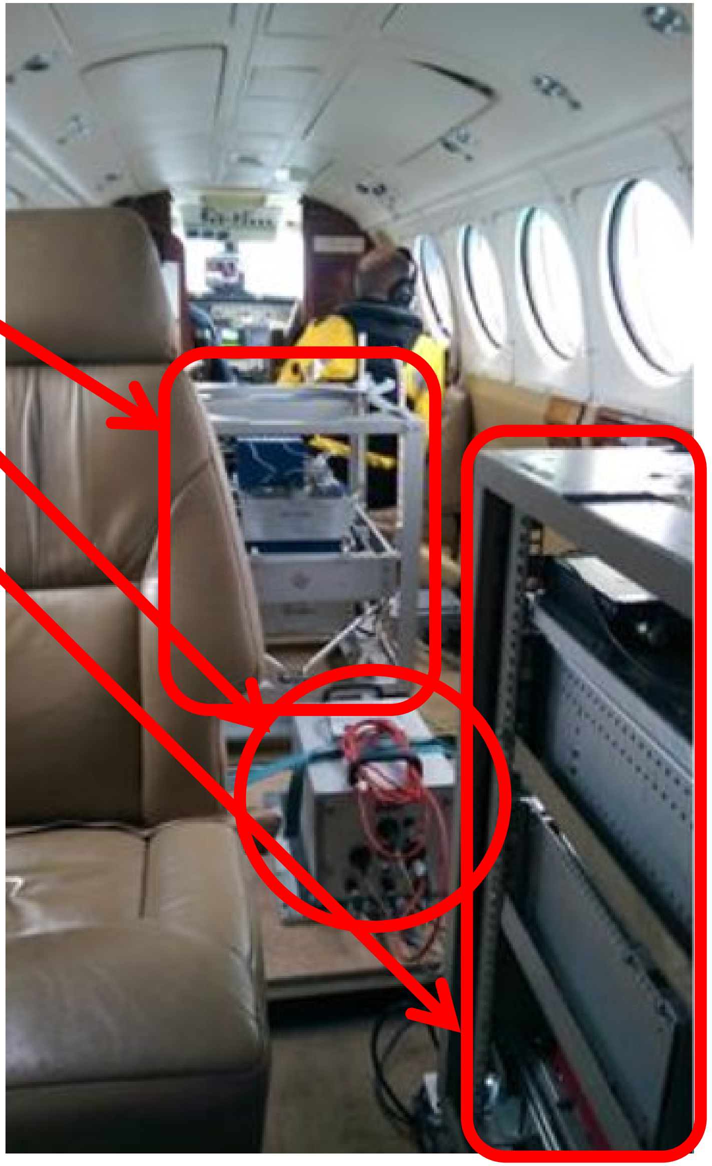
-> Can no longer run on batteries only

Testing the iTempStab Add-On

In 2018 DTU and Lantmäteriet carried out the ”Kattegat-18” survey, testing the iTempStab prototype

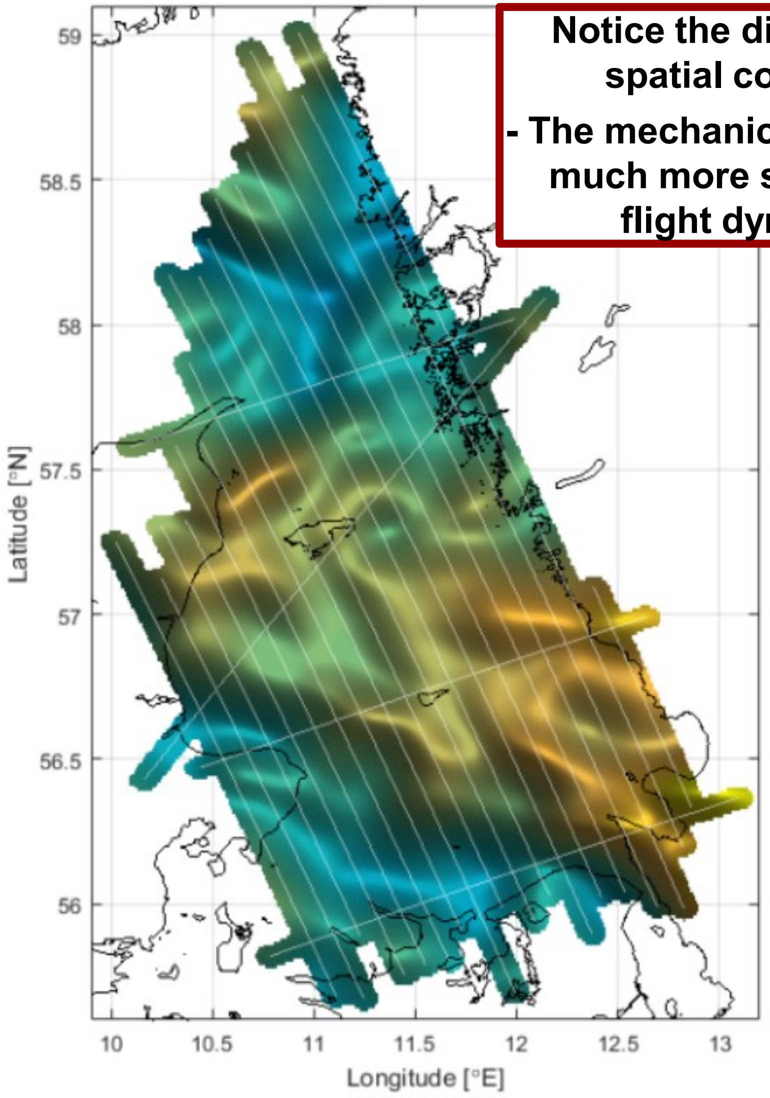


Beechcraft Super King Air 200

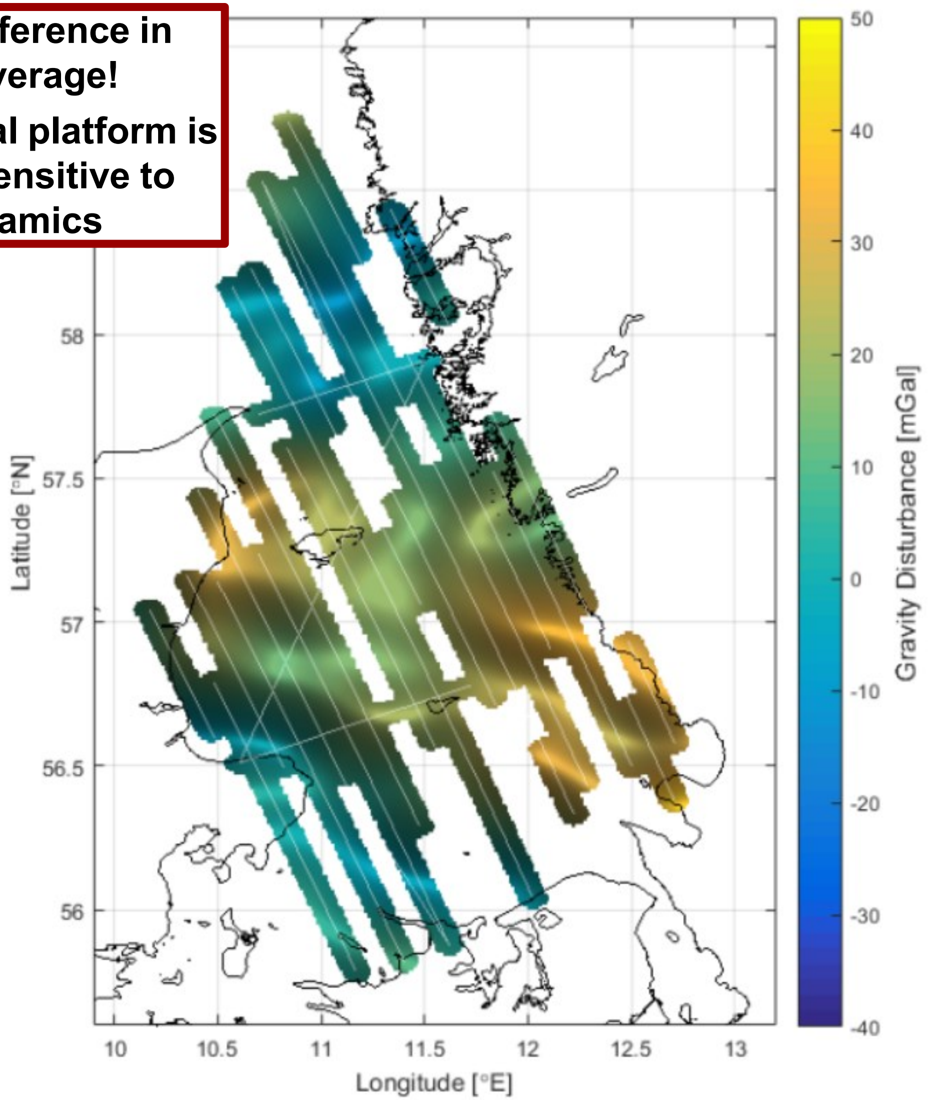


Data Coverage and Resolution: Strapdown vs. Platform

iMAR gravity disturbance estimates



ZLS gravity disturbance estimates



Notice the difference in spatial coverage!

- The mechanical platform is much more sensitive to flight dynamics

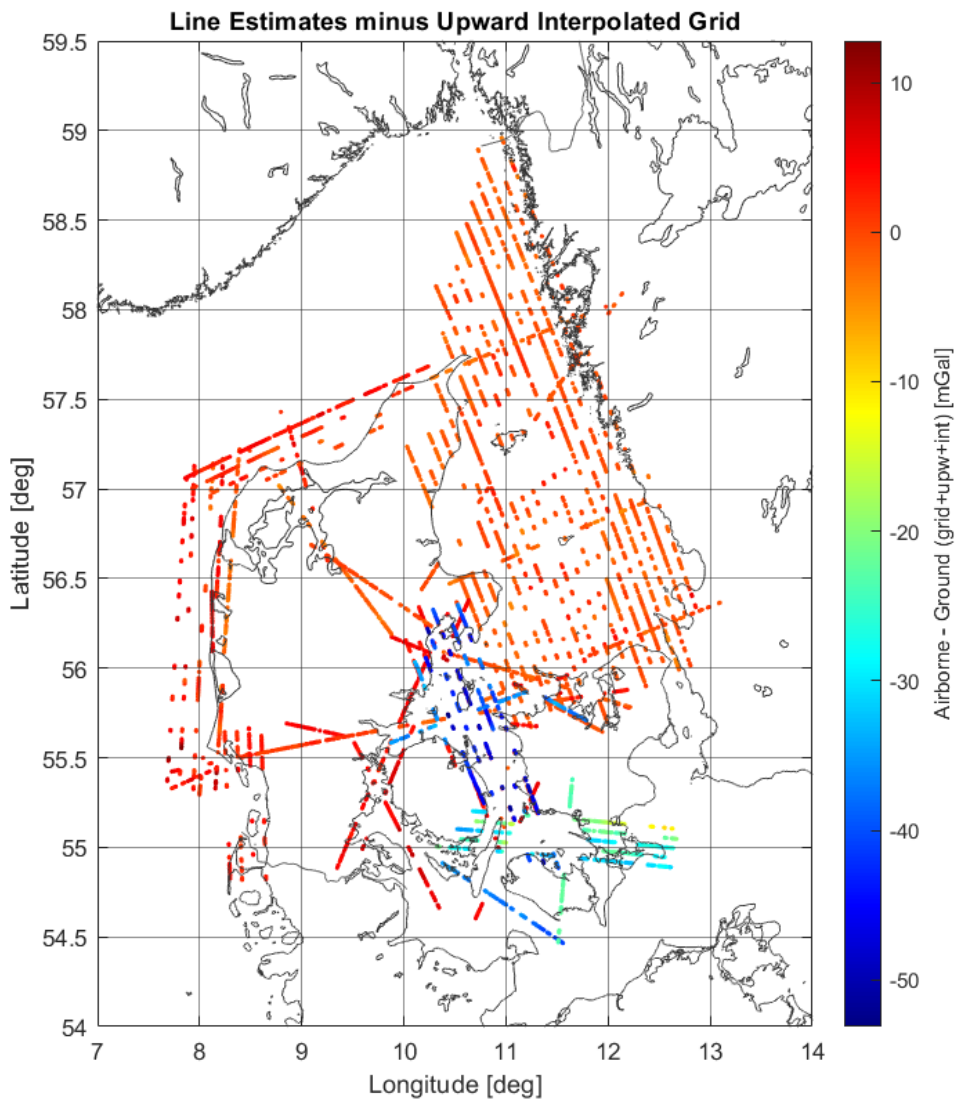
Cross-over statistics

	iMAR	ZLS	
Crossings	63	12	
Mean	0.0	0.3	mGal
Std. dev.	1.5	2.6	mGal
RMSE	1.0	1.8	mGal

iMAR - database statistics

Project	Mean	Std	
Kattegat-18	-0.70	1.29	mGal

The “Small-Aircraft Era”



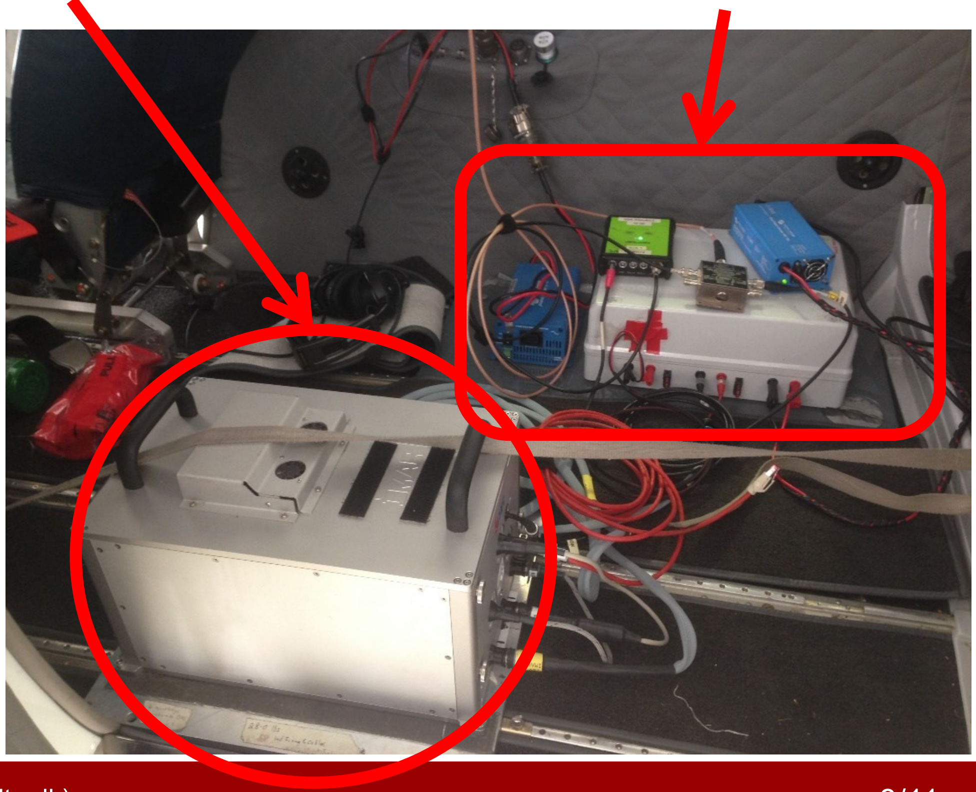
Vulcanair P68C (Partenavia)

iMAR – Database differences

Project	Mean	Std
Kattegat-18	-0.70	1.29
Samsoe-19	2.17	2.11
Vestkyst-20	2.24	2.74
Smaaland-21	-34.98	9.10

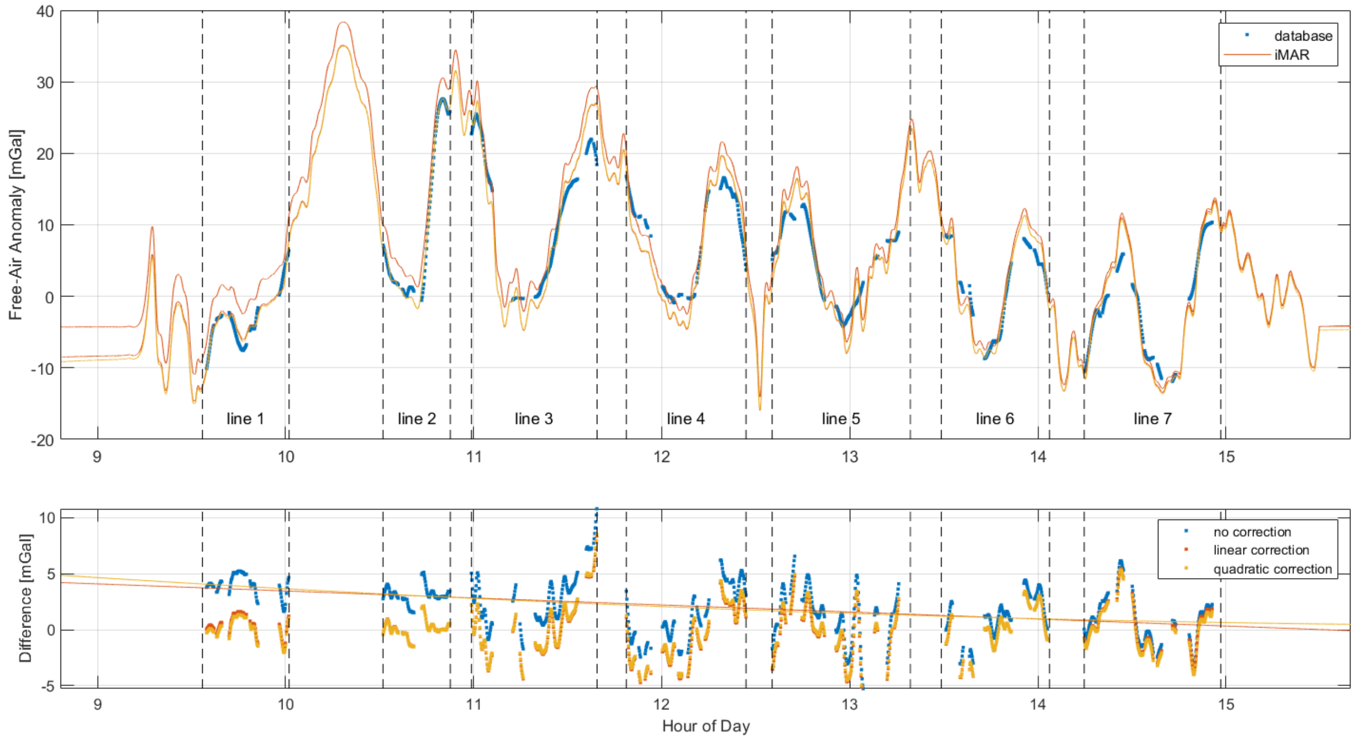
iMAR RQH IMU with iTempStab

24V Inverter, Battery Charger and Battery Package



Correcting Data for Bias and Drift

Gravity (disturbance) estimates along entire profile

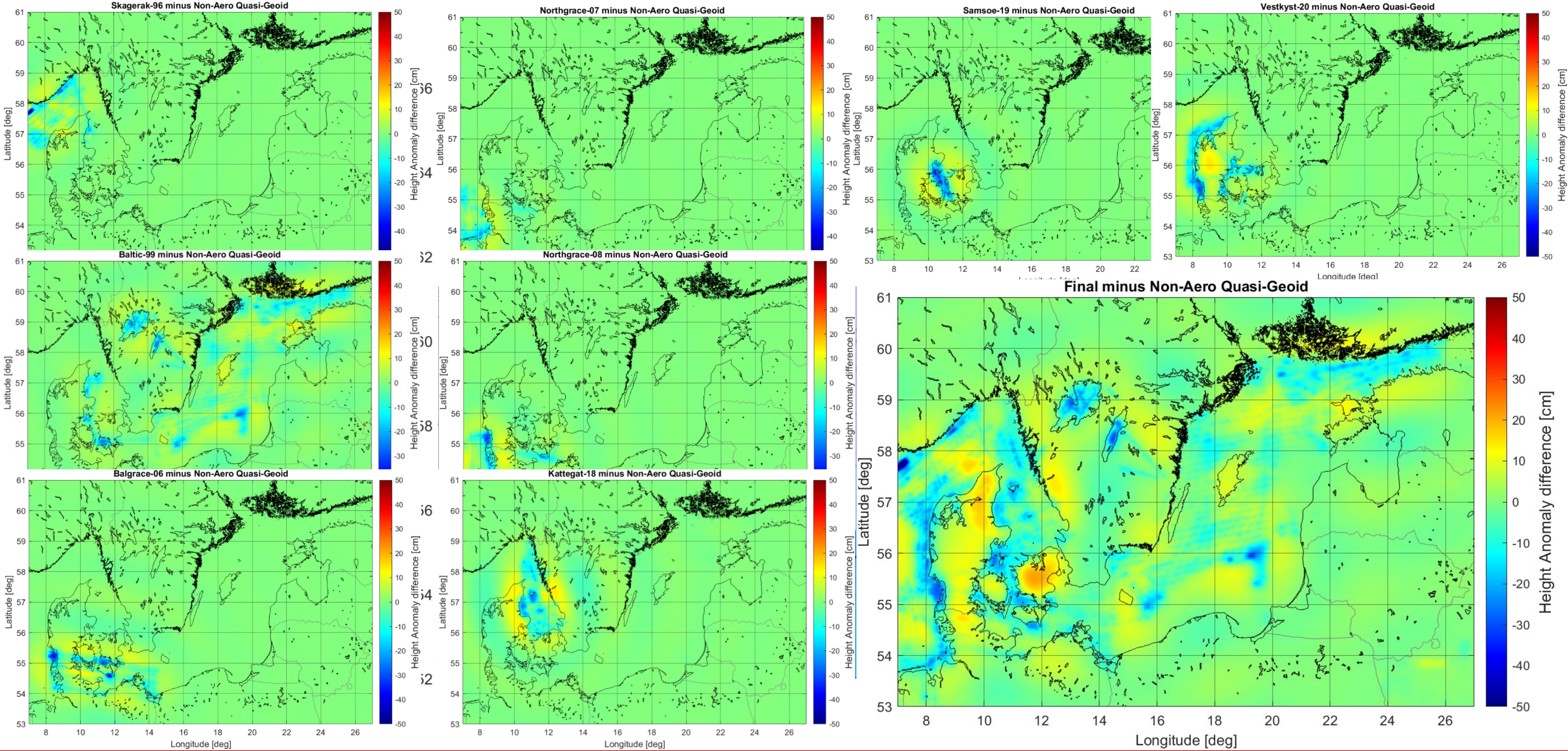


Internal cross-over statistics after correction

	Mean		
Project	**No correction**	**Linear correction**	**Quadratic correction**
Samsoe-19	2.6	1.0	0.7
Vestkyst-20	0.6	0.5	0.8
Smaaland-21	7.6	3.7	14.3
	Root-Mean-Square-Error (RMSE)		
Samsoe-19	2.5	1.5	1.4
Vestkyst-20	2.0	1.8	2.4
Smaaland-21	11.3	5.7	10.0

- Linear and quadratic models are fitted to the differences
- These models represent a long-term ”trend”
- They can be applied as a correction to the data

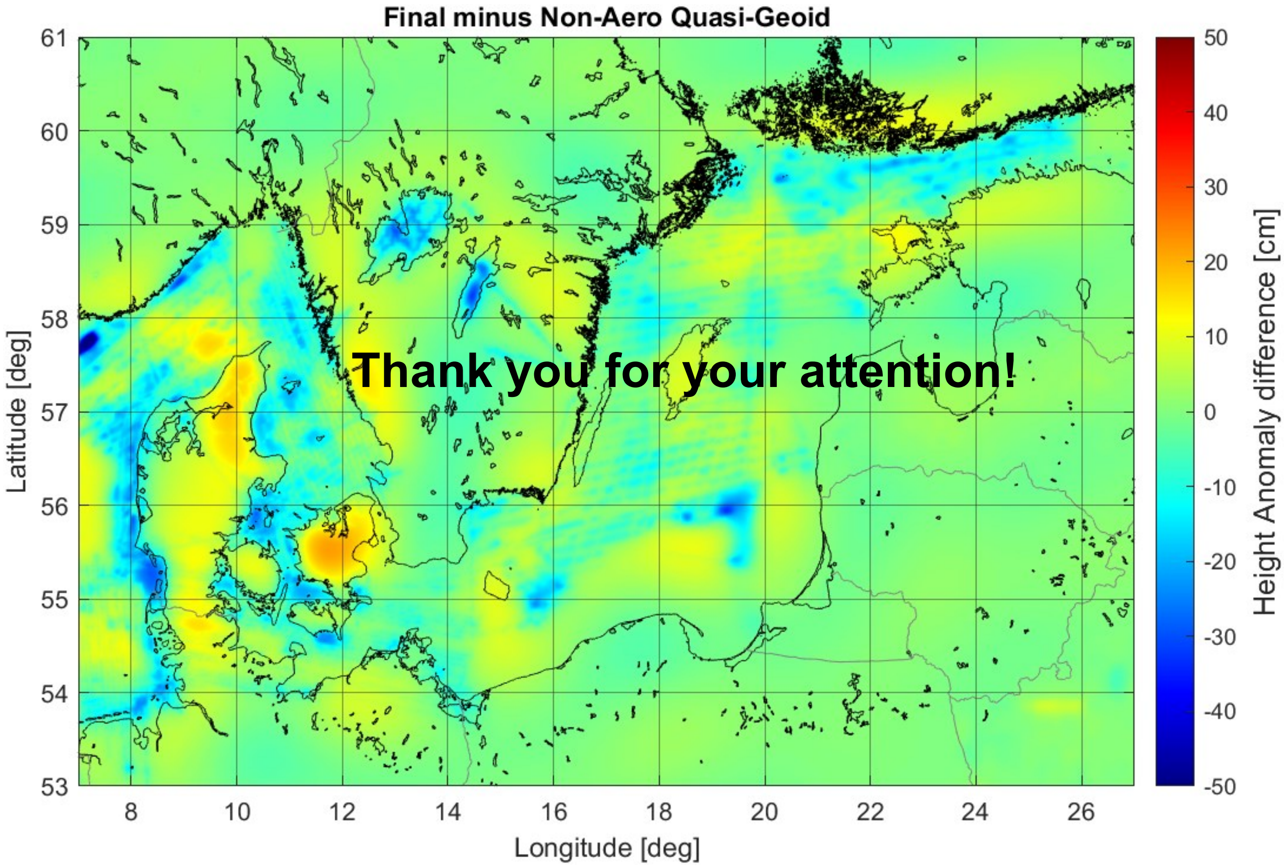
Influence on the (Quasi-) Geoid



Conclusions and Outlook

Conclusions

- Airborne measurements represent a significant contribution to the Baltic / FAMOS gravity data
  - Significant data coverage
  - Fills data voids
  - Potentially large influence on computed geoid (up to 50 cm!)
- Airborne measurements systems have undergone significant technological advances during the last 10 years
  - Improved resolution and spatial coverage
  - Small carriers
- Airborne data have potential bias and long-wavelength errors that could prograte into the Geoid if not properly taken care of



Outlook

- Methodology for comparing airborne and ground data, i.e. upward/downward continuation, should be further investigated (e.g. remove-compute-restore and collocation)
- Airborne (and shipborne) gravity data should be investigated for potential bias and long-wavelength errors
- Processing methods that directly account for bias and long-wavelength errors should be explored