Water levels in Danish lakes observed by CryoSat, SARAL/AltiKa, and Envisat

Karina Nielsen[1], Lars Stenseng[1], Heidi Villadsen[1], Ole B. Andersen[1], Per Knudsen[1], and Anders Nielsen[2]
karni@space.dtu.dk

[1]DTU Space National Space Institute Technical University of Denmark
[2]DTU Aqua, Technical University of Denmark

October 28, 2014

DTU Space
National Space Institute

Introduction

- Studying inland water is very important in relation to e.g. climate, water resource management, and hydrology application.
- Using radar altimetry to monitor water levels in rivers and lakes has been done for several years
- Until now this technique has mainly been used to study quite large inland water bodies
- With the recent missions such as CryoSat and SARAL/AltiKa it is possible to observe much smaller water bodies than previously due to the higher resolution

Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

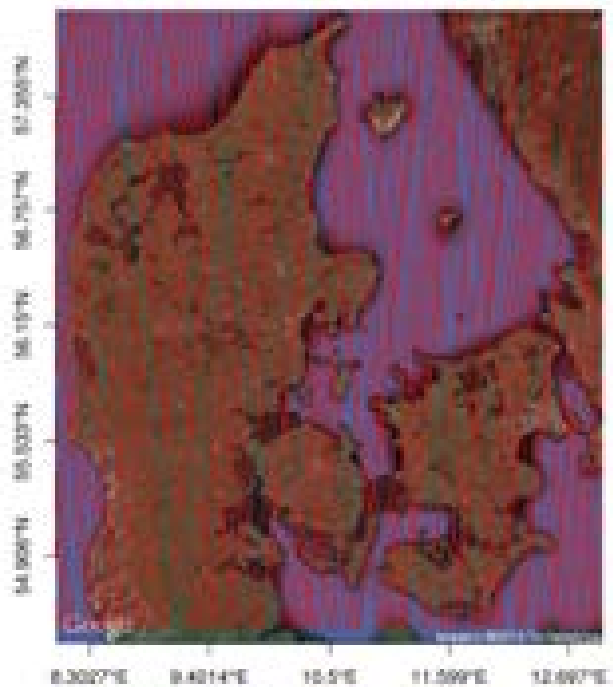
Study overview and area

- Our study area is 22 Danish lakes between 0.9 and 40 km^2
- We are comparing lake levels based on data from Envisat, CryoSat, and SARAL/AltiKa by considering:
  - along track data variability
  - mean lake level
- Is it possible to resolve the seasonal signal in some of these small lakes?

Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Data Cryosat

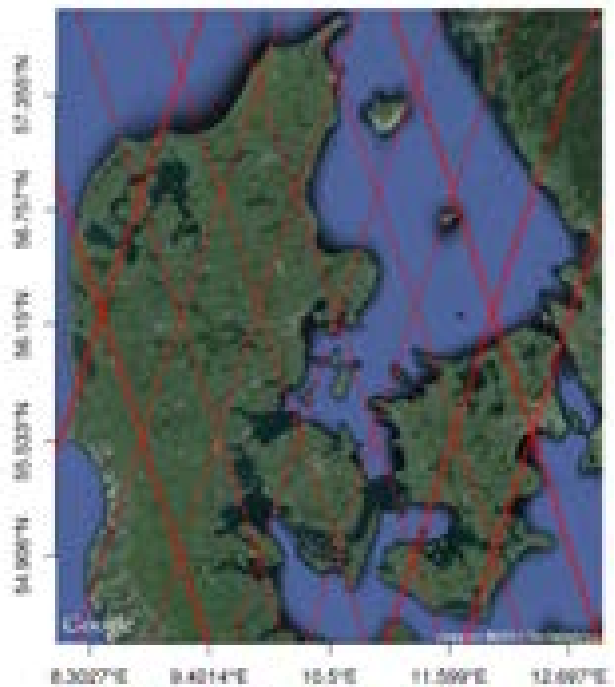
- Operates in LRM, SAR and SAR-In mode, here data in SAR mode is considered.
- Launched in 2010
- Repeat period of 369 days
- ESA L1b waveforms have been retracked at DTU using the LARS system, here 4 threshold retrackers + the ESA L2 heights are considered:



Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Data Envisat

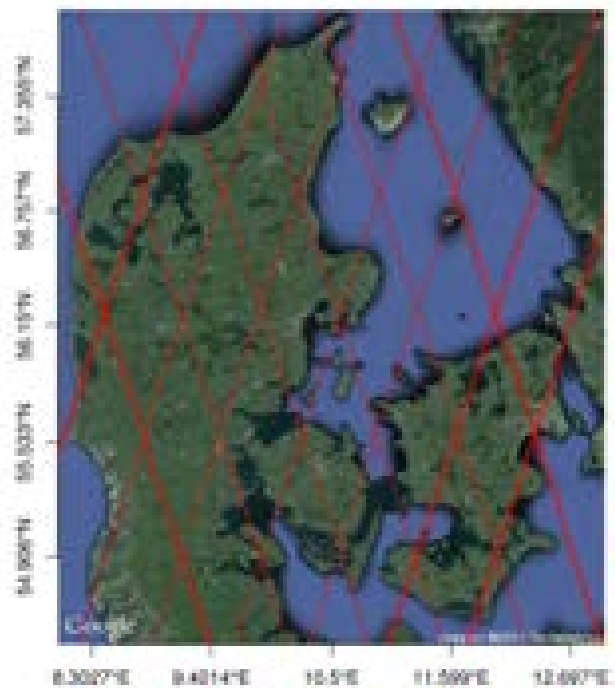
- Ku band radar altimeter
- Repeat period of 35 days
- Operated between 2003 and 2012
- We use 18Hz L2 heights based on the Ice1 and Ice2 retrackers



Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

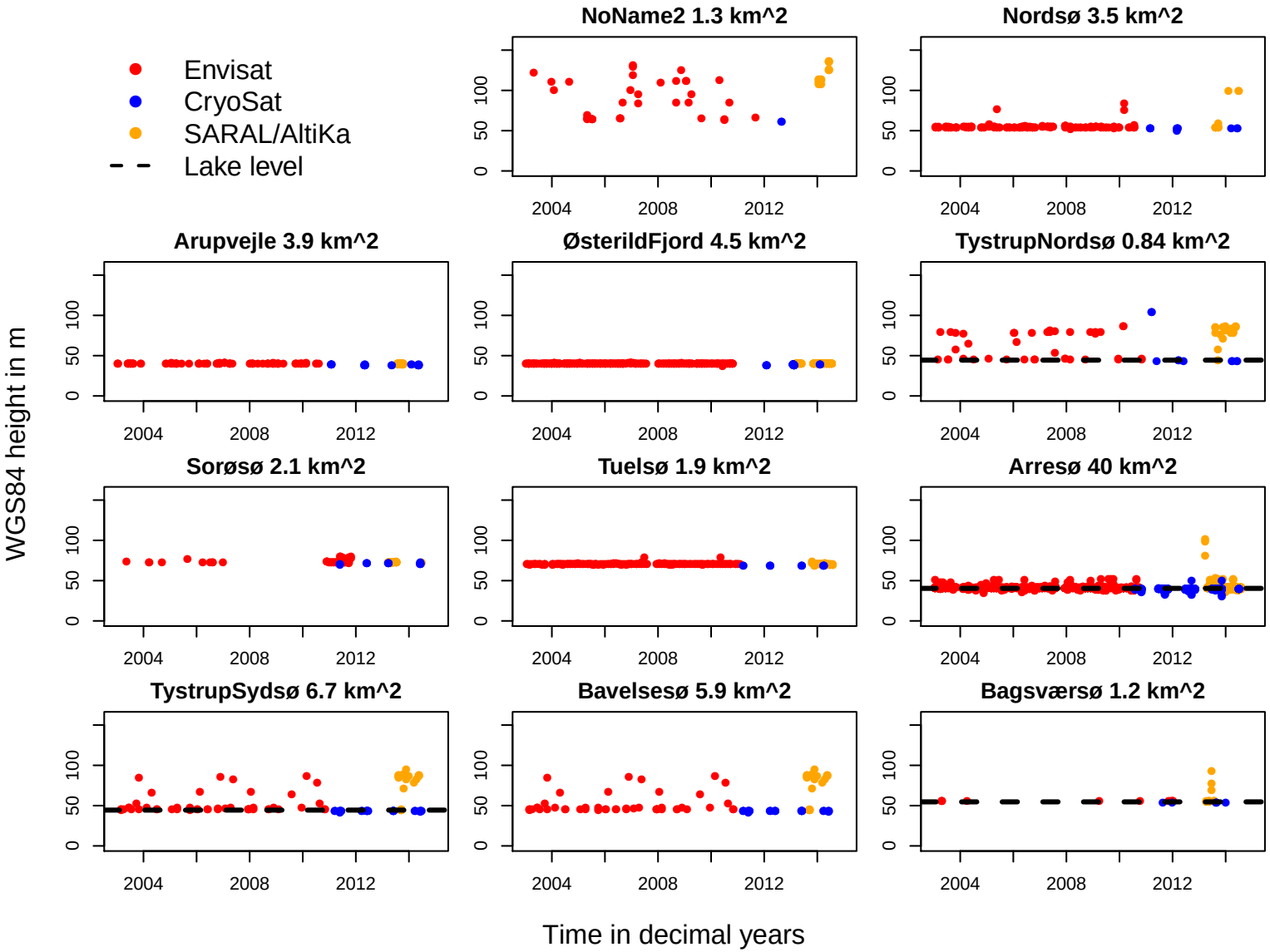
Data Saral/AltiKa

- Ka band altimeter
- Repeat period of 35 days
- Launched in February 2013
- We use 40Hz L2 heights based on the Ice1 and Ice2 retrackers (available from Aviso `http://www.aviso.altimetry.fr/`)



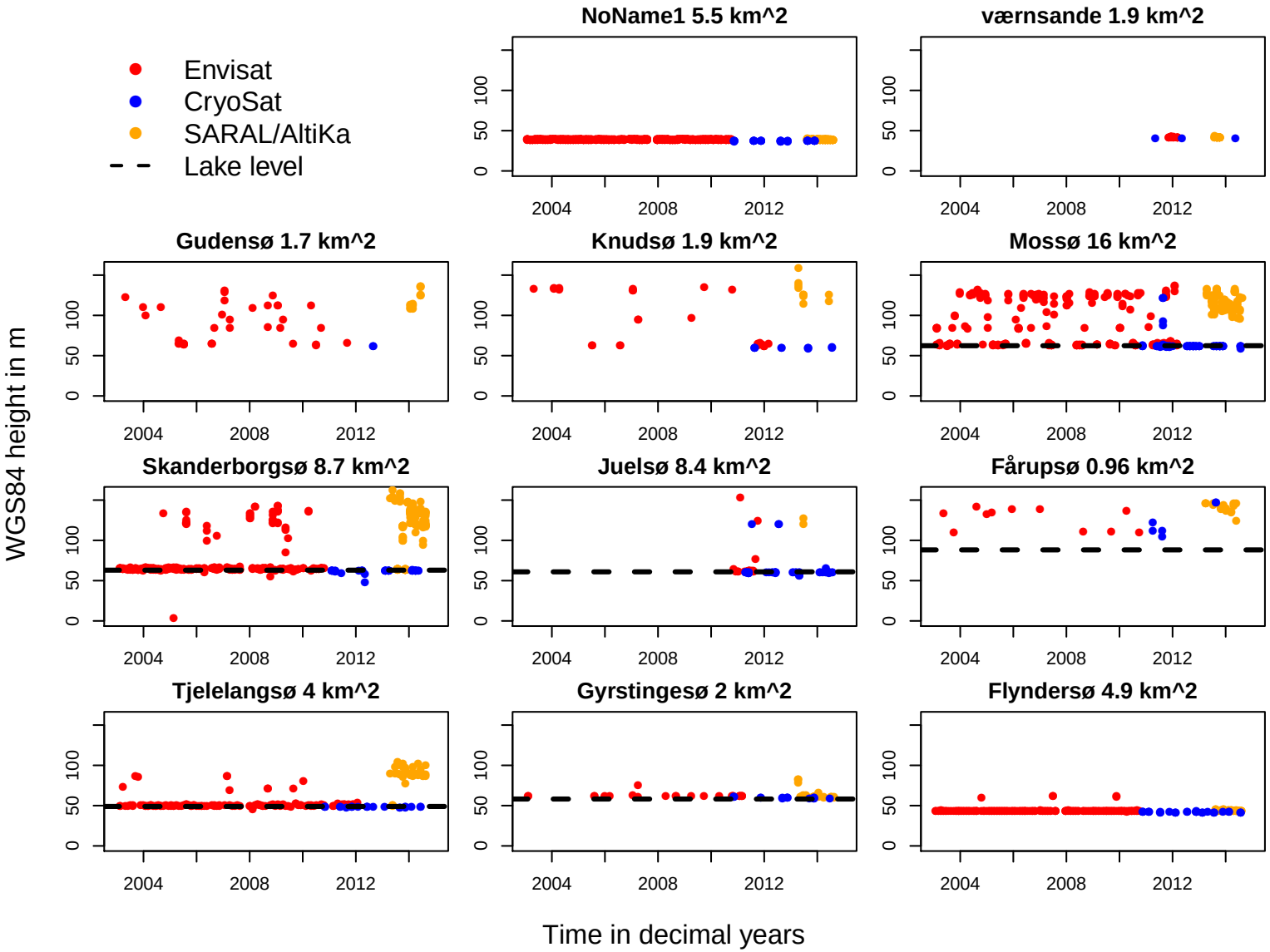
Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Data variability



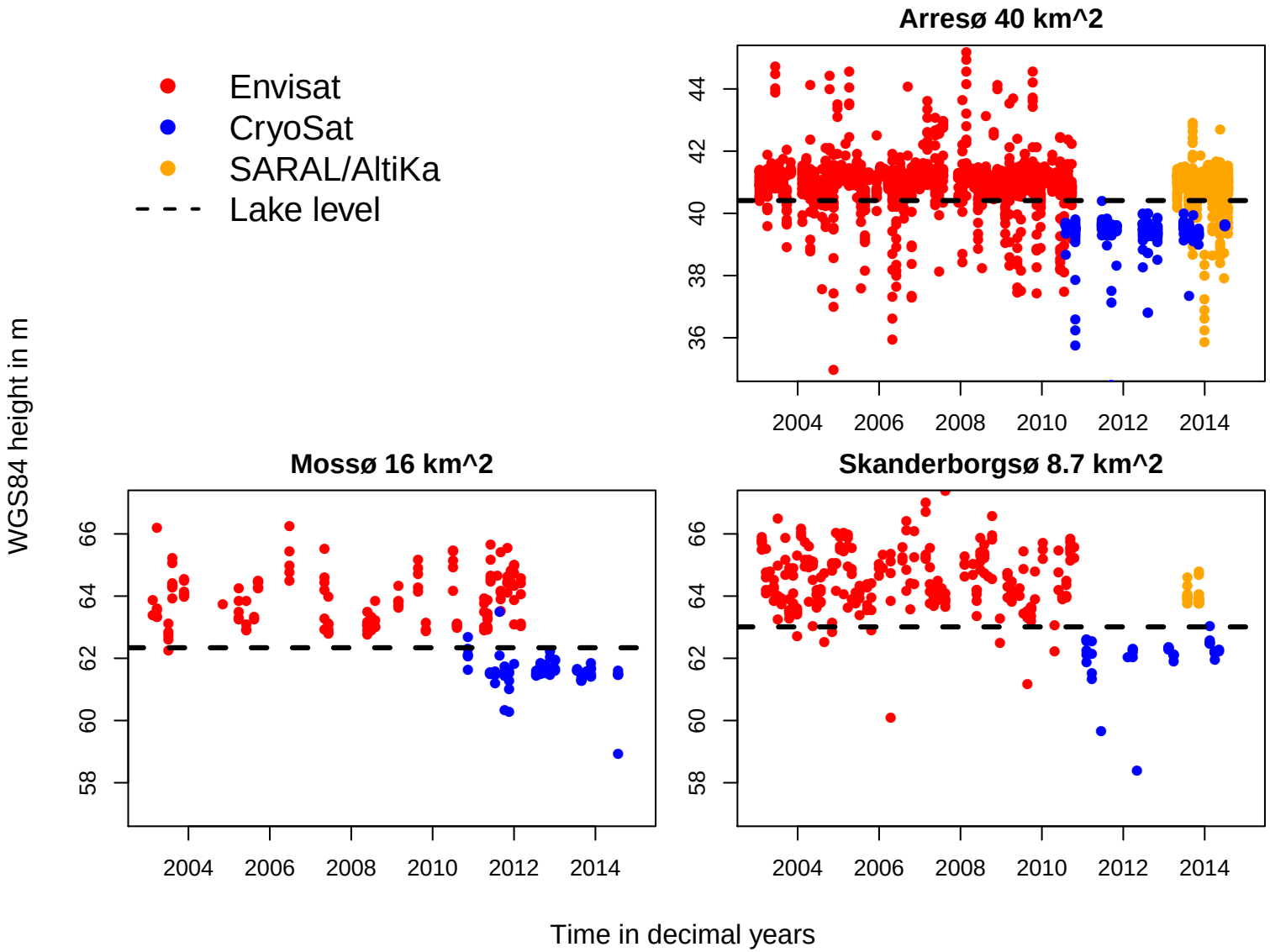
Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Data variability



Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Data variability



Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Deriving a robust mean lake level

Lake mask

Shape files provided by the Danish Geodata Agency are used to mask out Envisat, Cryosat, and SARAL/AltiKa heights over lakes

Deriving mean lake levels using a robust model

h_i is the i'th lake level measurement, which in the model is expressed as

$$h_i = \alpha(lake_i) + \beta(retracker_i) + \epsilon_i, \text{ where } \epsilon_i \text{ follows a t-distribution}$$

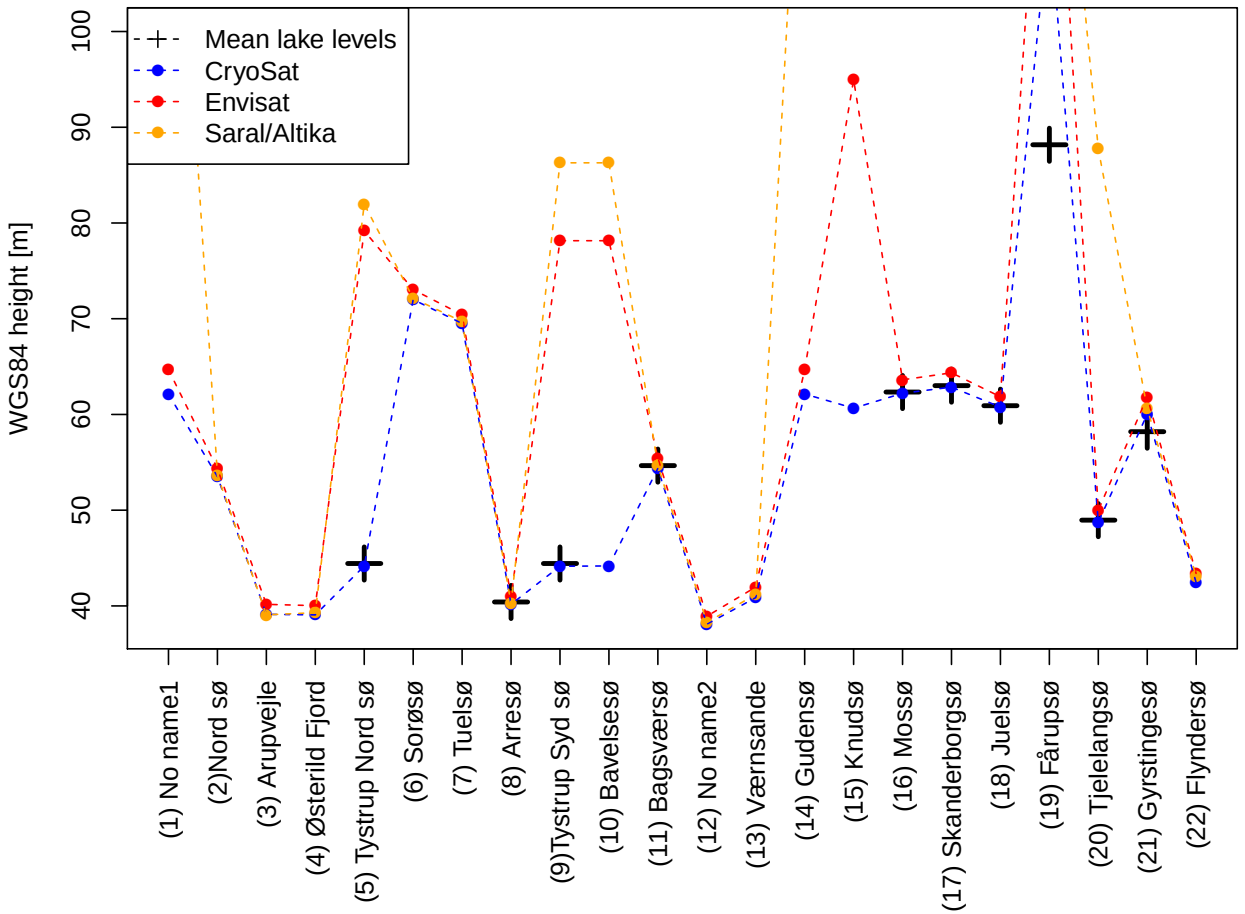
Here α is the lake level and β is a bias. We assume that $\sum \beta = 0$

Model statistics

	Envisat	CryoSat	SARAL/Altika
Retracker bias	6cm	3-10cm	5cm
Data std	0.8-1.0m	0.3-0.5m	0.8-1.2m

Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

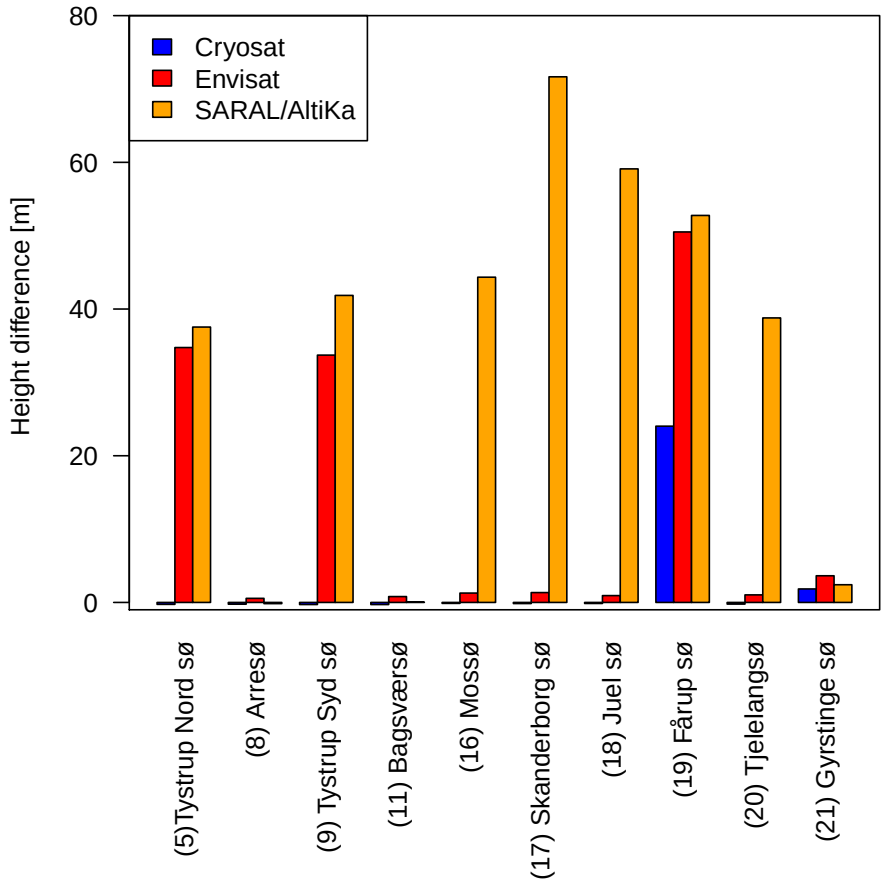
Validation of absolute mean lake levels



- Mean lake levels
  - Danish Geodata Agency, Wikipedia, Orbicon

Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Comparison of CryoSat, Envisat, and SARAL/AltiKa



	Cryo	Envi	Saral
(5)	-0.26	34.75	37.54
(8)	-0.24	0.56	-0.16
(9)	-0.29	33.72	41.86
(11)	-0.29	0.80	0.04
(16)	-0.13	1.28	44.34
(17)	-0.15	1.34	71.66
(18)	-0.14	0.93	59.10
(19)	24.03	50.51	52.76
(20)	-0.23	1.03	38.79
(21)	1.84	3.64	2.41

Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

The time varying (seasonal?) signal

Model including temporal variability

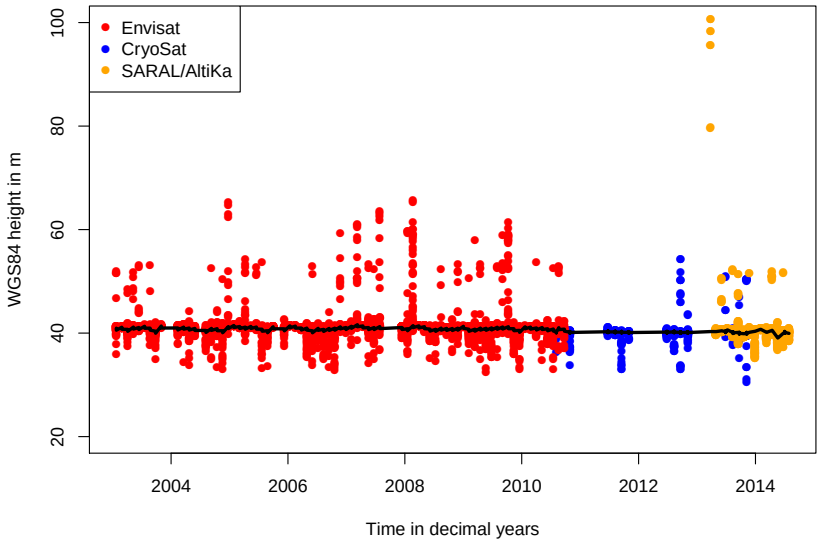
h_i is the i'th lake level measurement, which in the model is expressed as

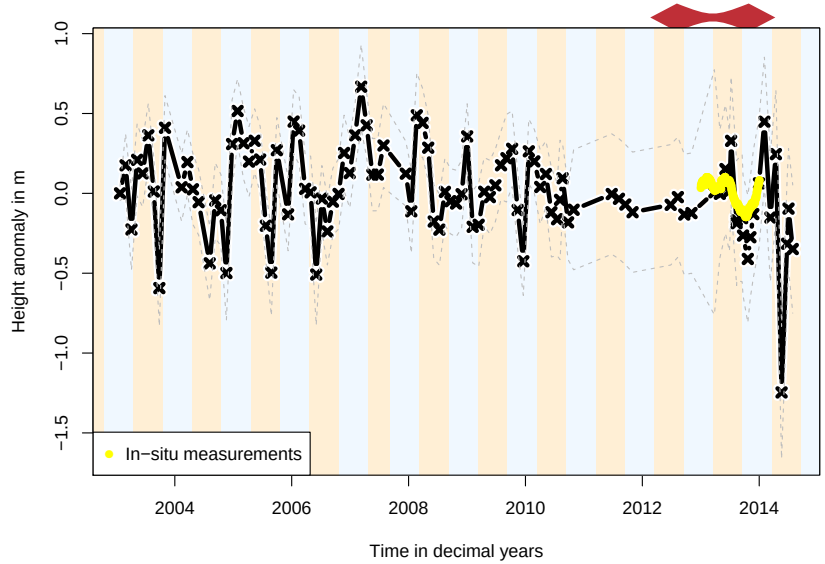
$$h_i = \alpha(lake_i) + \beta(retracker_i) + \lambda(time_i) + \epsilon_i$$

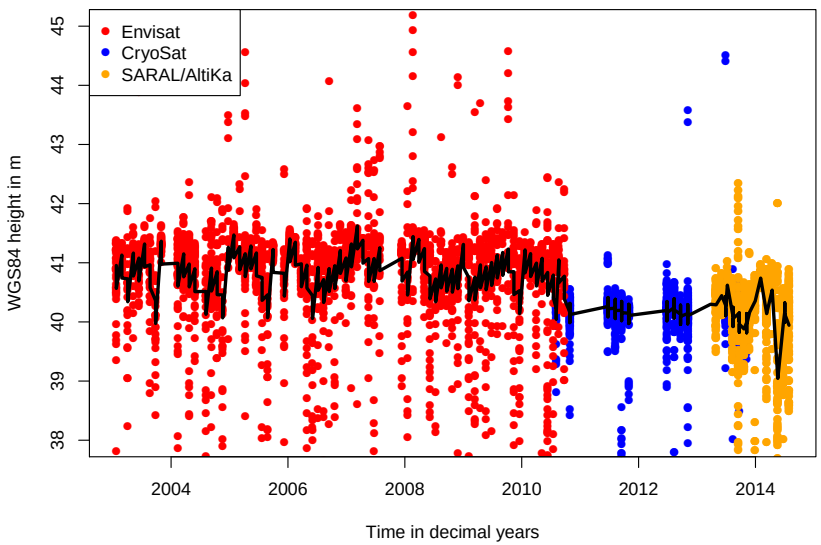
- Here mean α is the lake level and β is the retracker bias.
- ϵ_i is an error that follows a t-distribution
- $\lambda(time_i)$ is a random walk defined by $\lambda(time_i) = \lambda(time_{i\_i}) + \eta_i$

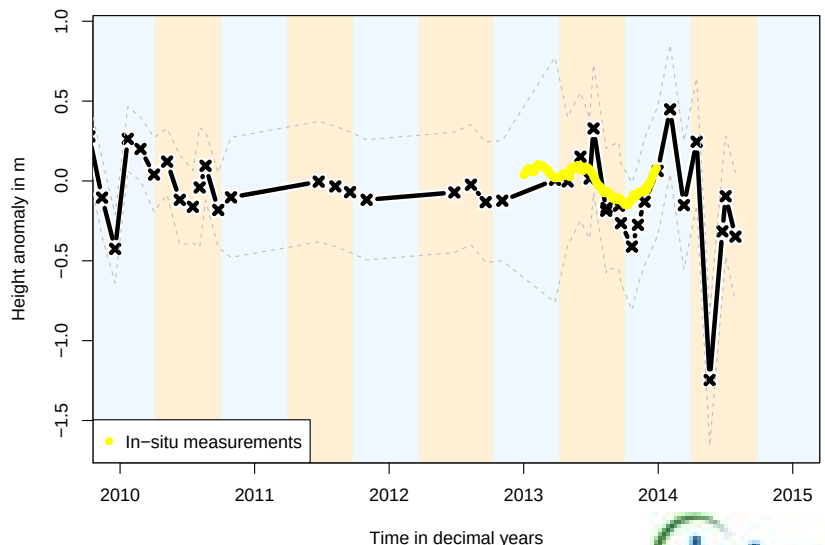
Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Time variable signal Arresø



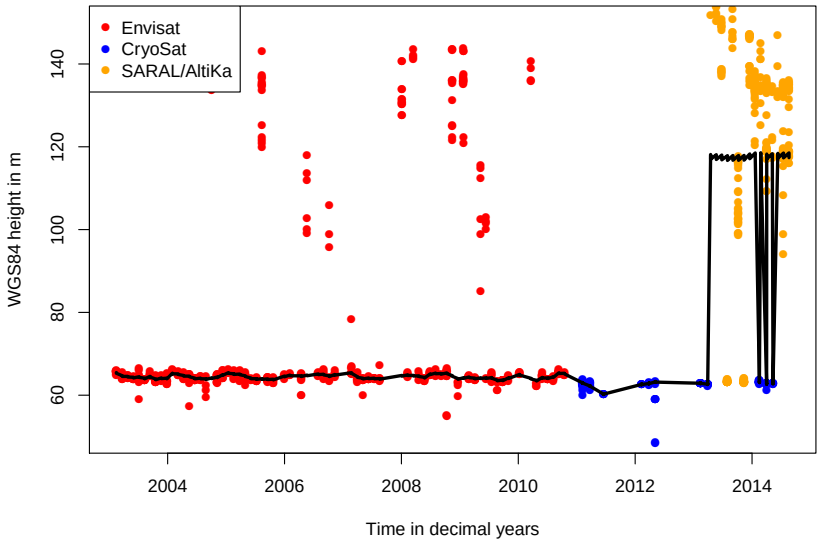


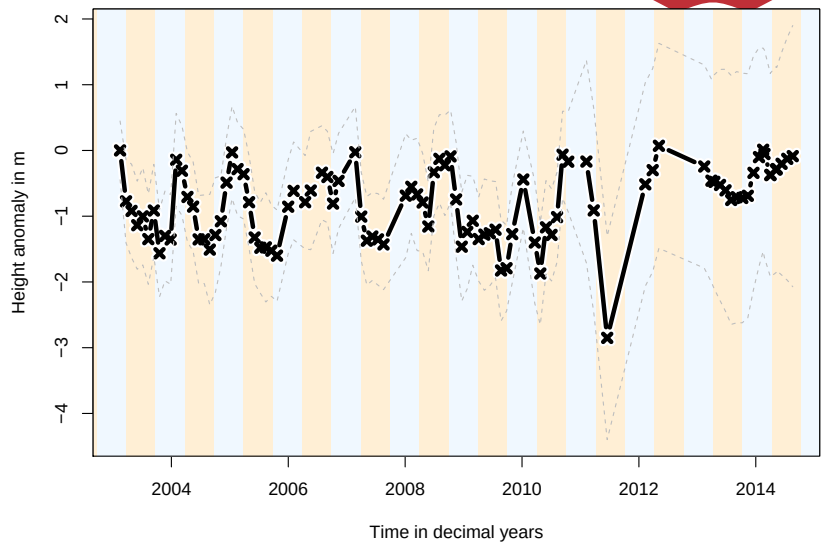


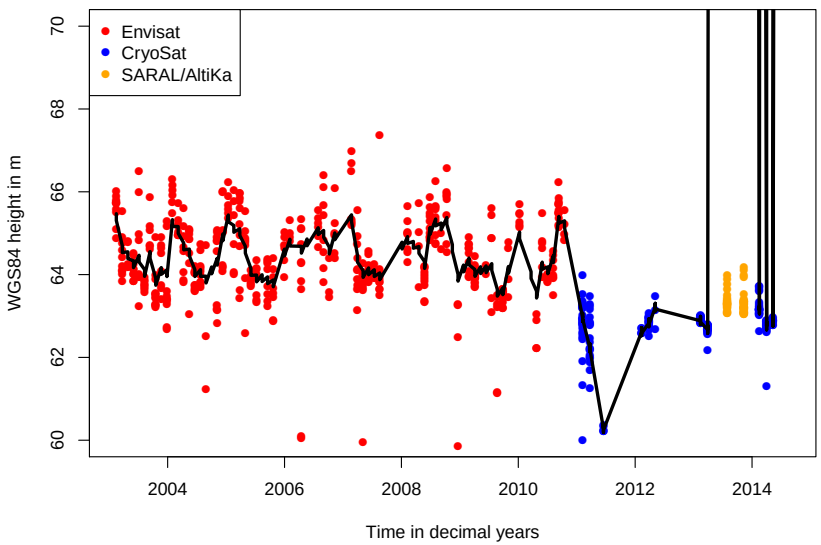


Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Time variable signal Skanderborg sø







Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Summary and conclusions

- We have compared lake levels based on data from Envisat, CryoSat and SARAL/AltiKa for 22 Danish lakes between 0.9 and 40 km^2
- CryoSat generally provides very stable heights
- Large biases in the lake levels are found for the SARAL/AltiKa data
- CryoSat mean lake levels compare well with independent heights based on laser data.
- The modeled time varying signal is at the moment to uncertain to accurately represent the seasonal signal.
- With Sentinel 3, which will also be carrying a SAR altimeter, we might be able to obtain accurate time series even for very small inland water bodies.

Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk

Thank you for your attention

Karina Nielsen, Lars Stenseng, Heidi Villadsen, Ole B. Andersen, Per Knudsen, and Anders Nielsen karni@space.dtu.dk