Using Ellipsoid as Vertical Reference for Seabed Mapping

Why?
How?

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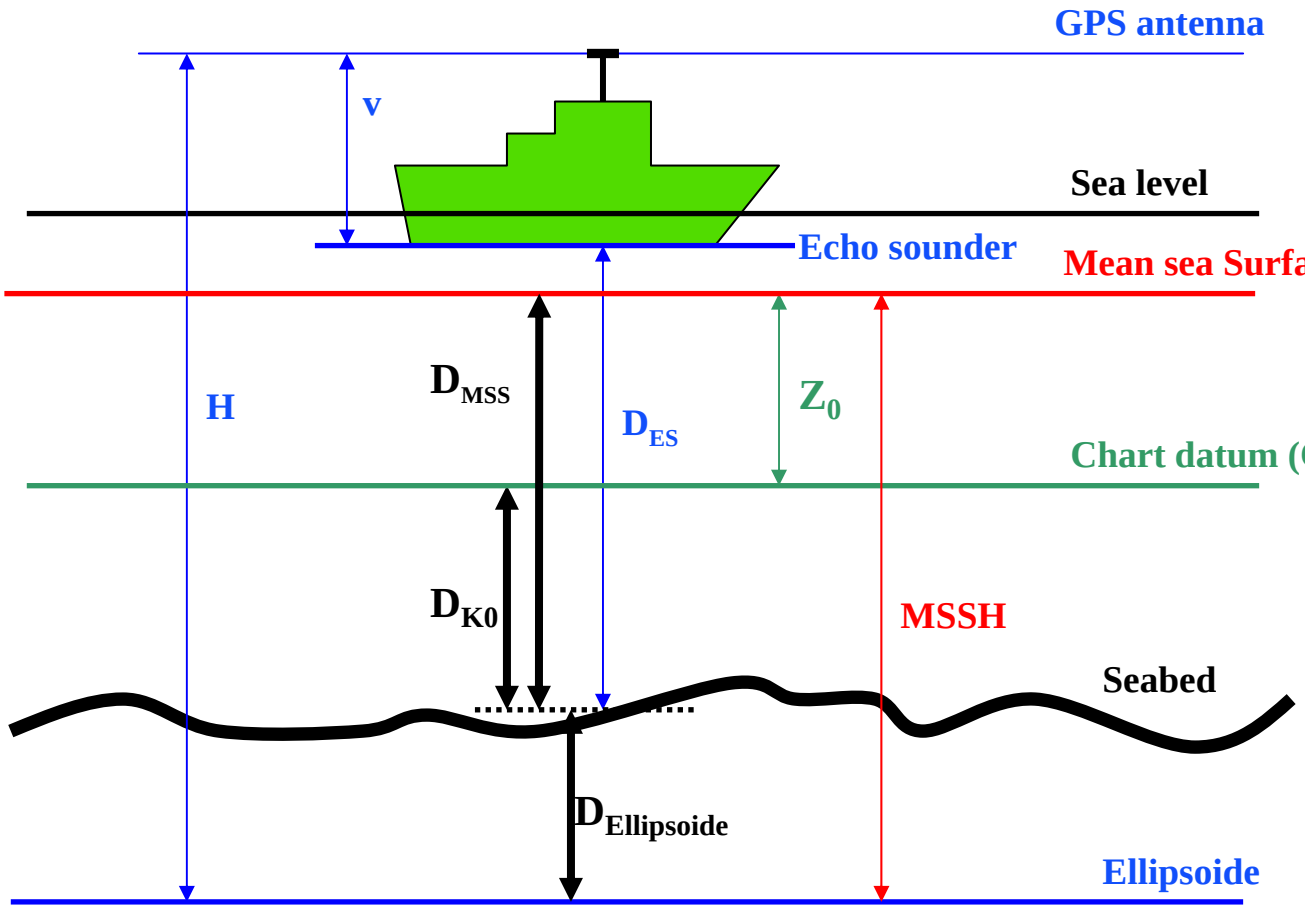
A definition

- **”A specialist is a person far away from home”**

Using Ellipsoid as Vertical Reference for Seabed Mapping



$D_{Ellipsoide}=H-D_{ES}-v$

$D_{MSS}=MSSH-D_{Ellip.}$

$D_{K0}= D_{MSS} - Z_0$

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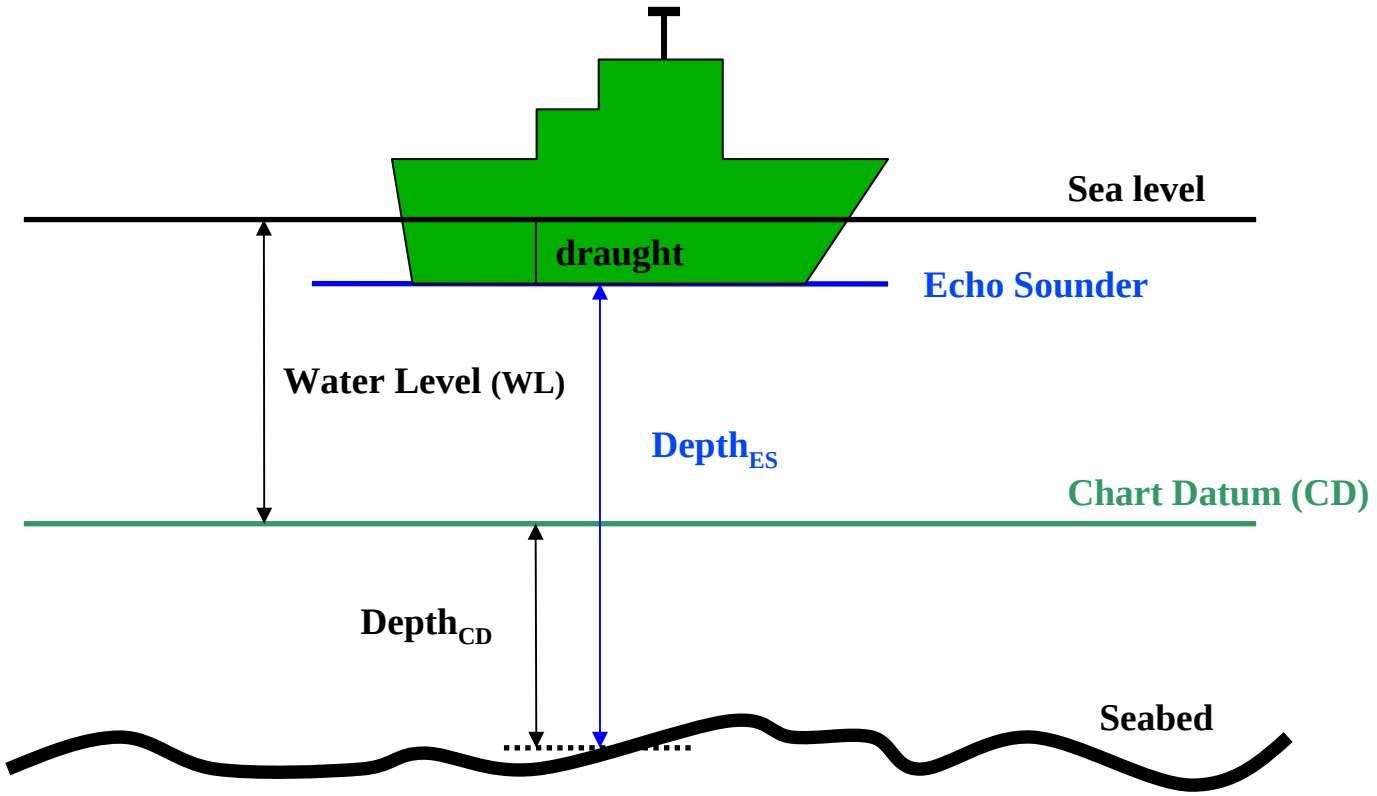
The other alternative:
Seabed mapping with water level data



$$Depth_{CD} = Depth_{ES} + draught - WL_{CD}$$

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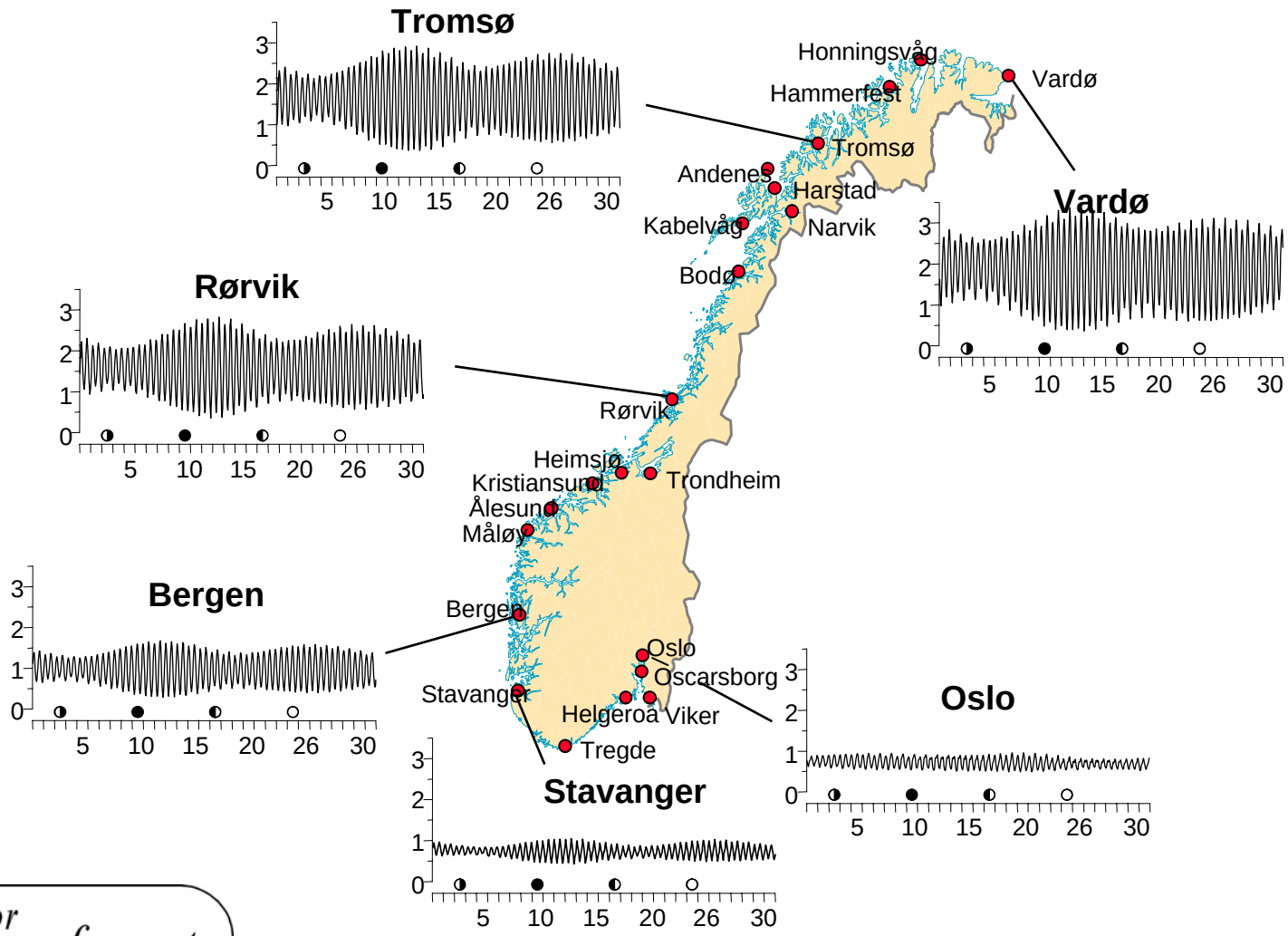
***Water level* at the time of seabed mapping must be removed from the depth data**

Methods to obtain water level data:

- **Permanent tide gauge possibly combined with tide zone**
- **Temporary tide gauge associated with a permanent tide gauge to get the relation to mean sea level**
- **Predicted tide (based on tide models)**
- **Use GPS to measure water level with ellipsoid as reference**

Permanent tide gauges operated by NHS

22 gauges along the coast of Norway og one gauge on Svalbard



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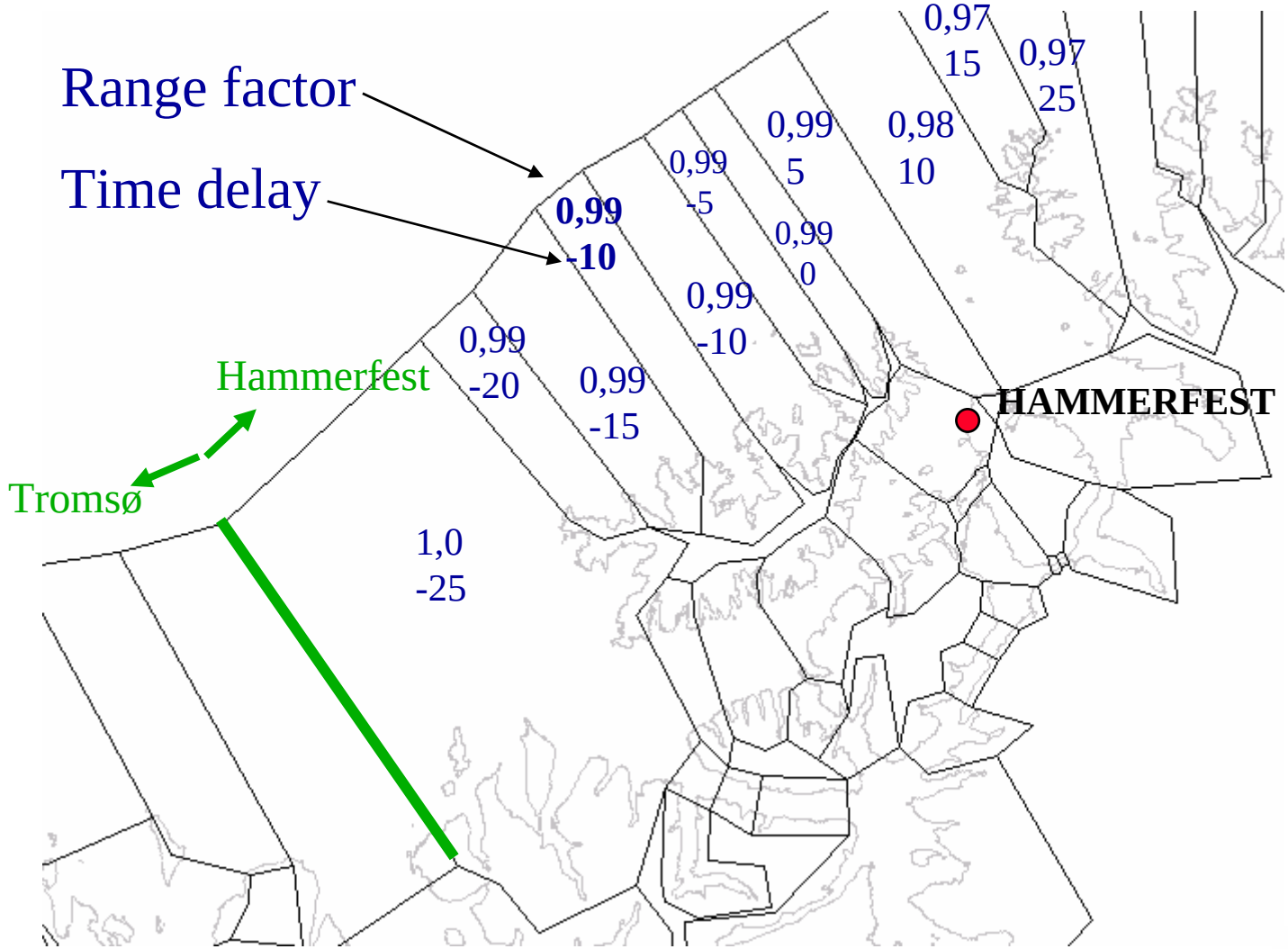
Tidal zones: Almost equal tide within a zone



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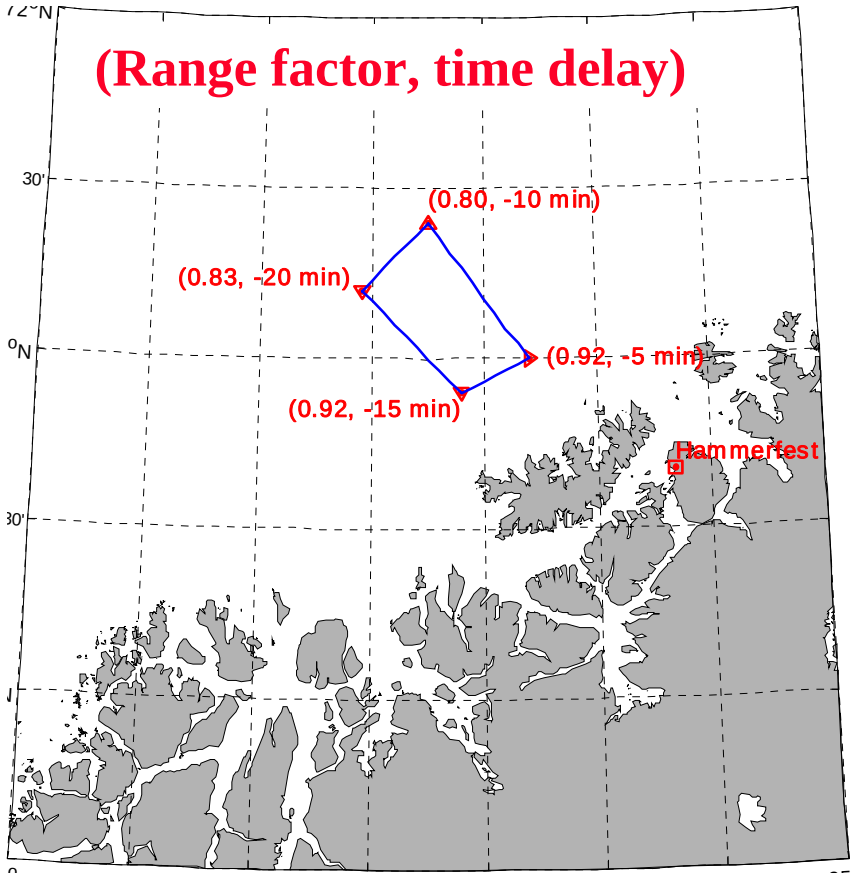
Range factor and time delay from Hammerfest



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What we need for using the ellipsoid as vertical reference for seabed mapping? (1 of 2)

Mandatory:

- **Vertical position of high quality**
  - **High quality GPS-receiver**
  - **Software for post processing of GPS-data (Terrapos)**
  - **Continuous logging of GPS-data**
- **The position of the GPS-receiver must be known in the coordinate system of the vessel**
- **The motion of the vessel must be known (attitude data: heave, roll, pitch and heading)**

What we need for using the ellipsoid as vertical reference for seabed mapping? (2 of 2)

Not mandatory:

- **If we want to convert to *mean sea level* we must know the difference between mean sea level and the ellipsoid. MSS (Mean Sea Surface) models can be used.**
- **If we want to convert to *Chart Datum* (CD) we must know the difference between Chart Datum and mean sea level . Along the Norwegian coast the Chart Datum is equal to LAT (lowest astronomical tide) with a few exceptions. Tide models can be used to estimate LAT at high sea.**

Accuracy achievable today (95%)

- **Vertical position**
  - **GNSS height:** δGNSS = 8 cm
- **Surface models**
  - **MSS:** δMSS = 10 cm (high sea) δMSS = ? cm (coast)
  - **LAT:** δLAT = 30 cm (high sea) δLAT = 10 cm (coast)
- **Accuracy is improving**
- **In a complete error budget all error sources must be included (echo sounder, sound velocity profile, attitude data, horizontal positioning,...)**

Advantages and disadvantages

- **Advantages:**
  - Water level measurements are not needed
  - Knowledge of the draught is not needed
  - Do not have to consider different tidal zones
  - Less possibility of mismatch in overlapping survey areas by using a consistent reference
  - GPS measured low frequency waves not measured by the heave sensor
  - (GPS measures heave better than the heave sensor?)
  - ...
- **Disadvantages**
  - High quality vertical position is needed
  - The position of the GPS-antenna relative to the echo sounder must be known
  - Confusing: The ellipsoidal depth will not represent the true ocean depth
  - MSS an LAT-models must be known to convert to mean sea level and and Chart Datum
  - MSS- and LAT-models are continuously improving (version control is necessary)
  - ...

Seabed mapping at high seas and close to the coast

- **At *high seas* it is favourable to use the ellipsoid as reference:**
  1. **Difficult to get good water level data at high seas**
  2. **There are good MSS-models covering these areas (except for high latitude and areas with sea ice)**
  3. **It does not matter that the LAT-surface is of less quality at high seas since the requirements for depth accuracy in navigational charts are weak at high seas.**
- **NHS can still not use the ellipsoid as reference *close to the coast*:**
  1. **MSS-models are still of poor quality**
  2. **The requirements for depth accuracy in navigational charts are stringent**

Still it is attractive in the future to use the ellipsoid close to the coast as well

Using ellipsoid as vertical reference How it has been done at NHS so far

- **Existing production line has been used**
- **Water level (based on permanent tide gauge in Hammerfest) has been delivered continuously to the vessel**
- **GPS has been logged continuously (1 Hz) and post processed with Terrapos → H_{GPS}**
- **GPS-height has been used to make a file with water level data.**
  - **$WL_{GPS} = H_{GPS}$ - heave - MSS (– Chart Datum)**
- **GPS-water level (WL_{GPS}) has replaced former delivered water level before depth processing and quality control**

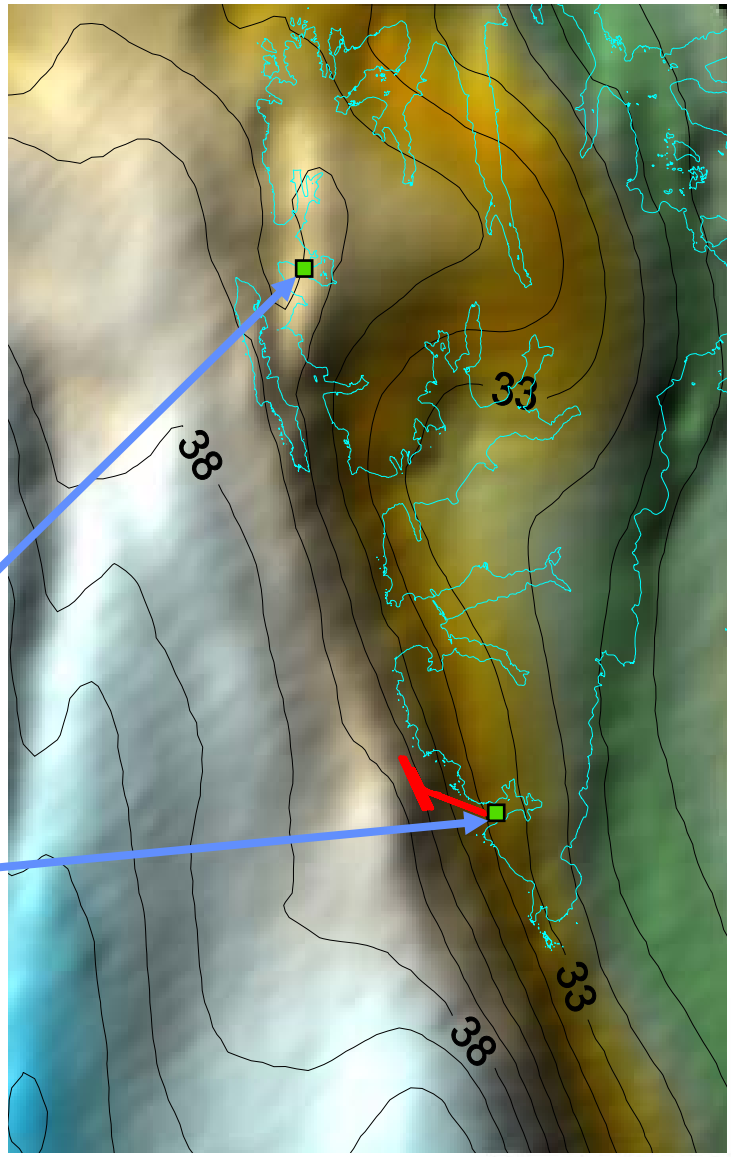
GPS-water level

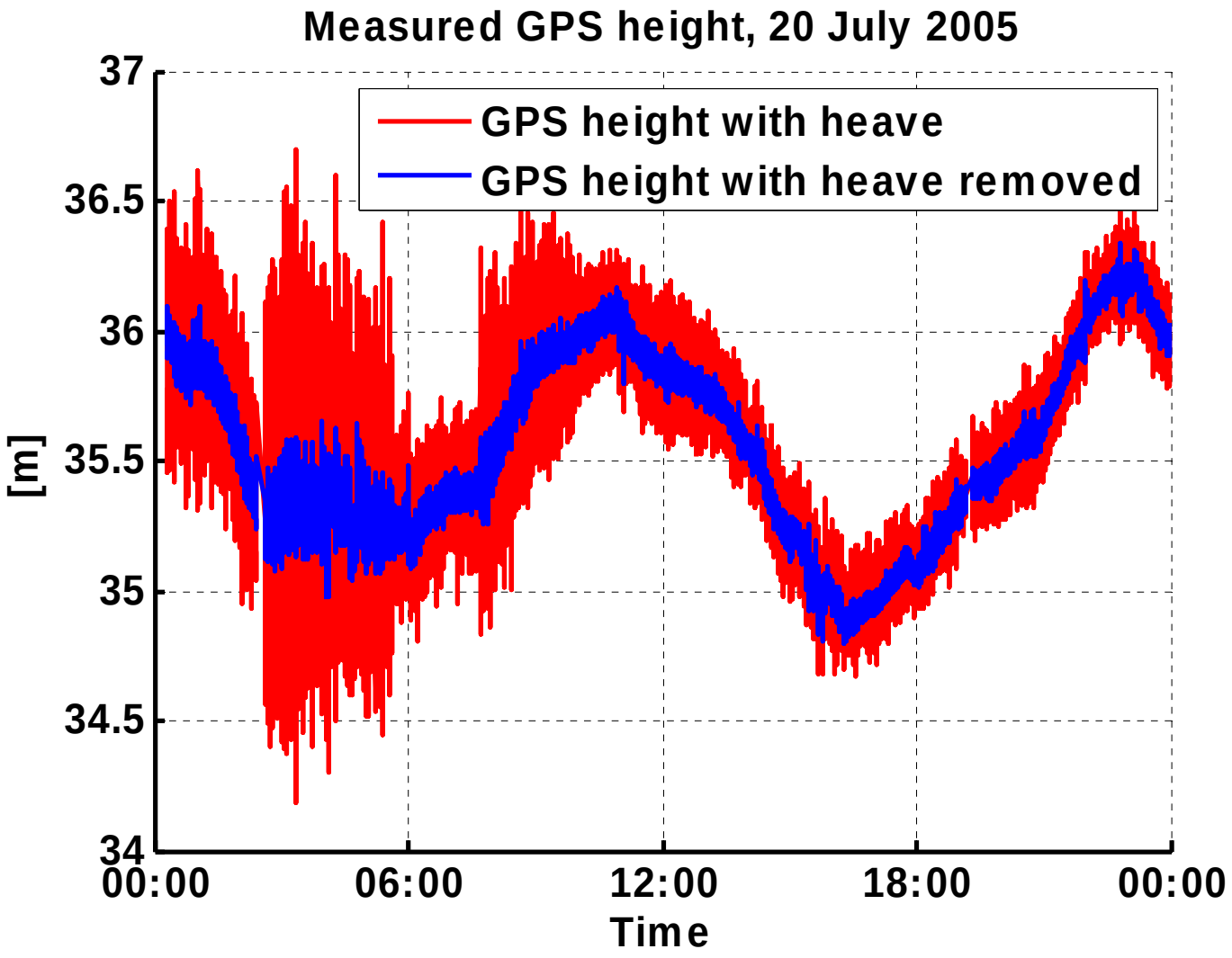
- **Calculating GPS-water level**
  - $WL_{GPS} = H_{GPS}$ - heave - MSS (– Chart Datum)

  The calculation is reversible. We store MSS and Chart Datum values
- **GPS-water level contain rests of heave probably because the heave-sensor is not perfect (we want to carry out a test)**
- **Test 1: GPS-water level has been compared with traditional water level (Svalbard and Mareano project)**
- **Test 2: Depth-data has been processed with both GPS-water level and water level from tide gauge and then compared**
- **Test 3: Accuracy of H_{GPS} has been tested**

Seabed mapping on Svalbard July 2005

- Comparing ”traditional method” with ”seabed mapping with ellipsoid as reference”
- Analysing: 20-21 July-05
- Ellipsoid as reference :
  - KMS04 from Danish National Space Centre
- Traditional method :
  - Permanent tide gauge in Ny-Ålesund
  - Temporary tide gauge in Hornsund





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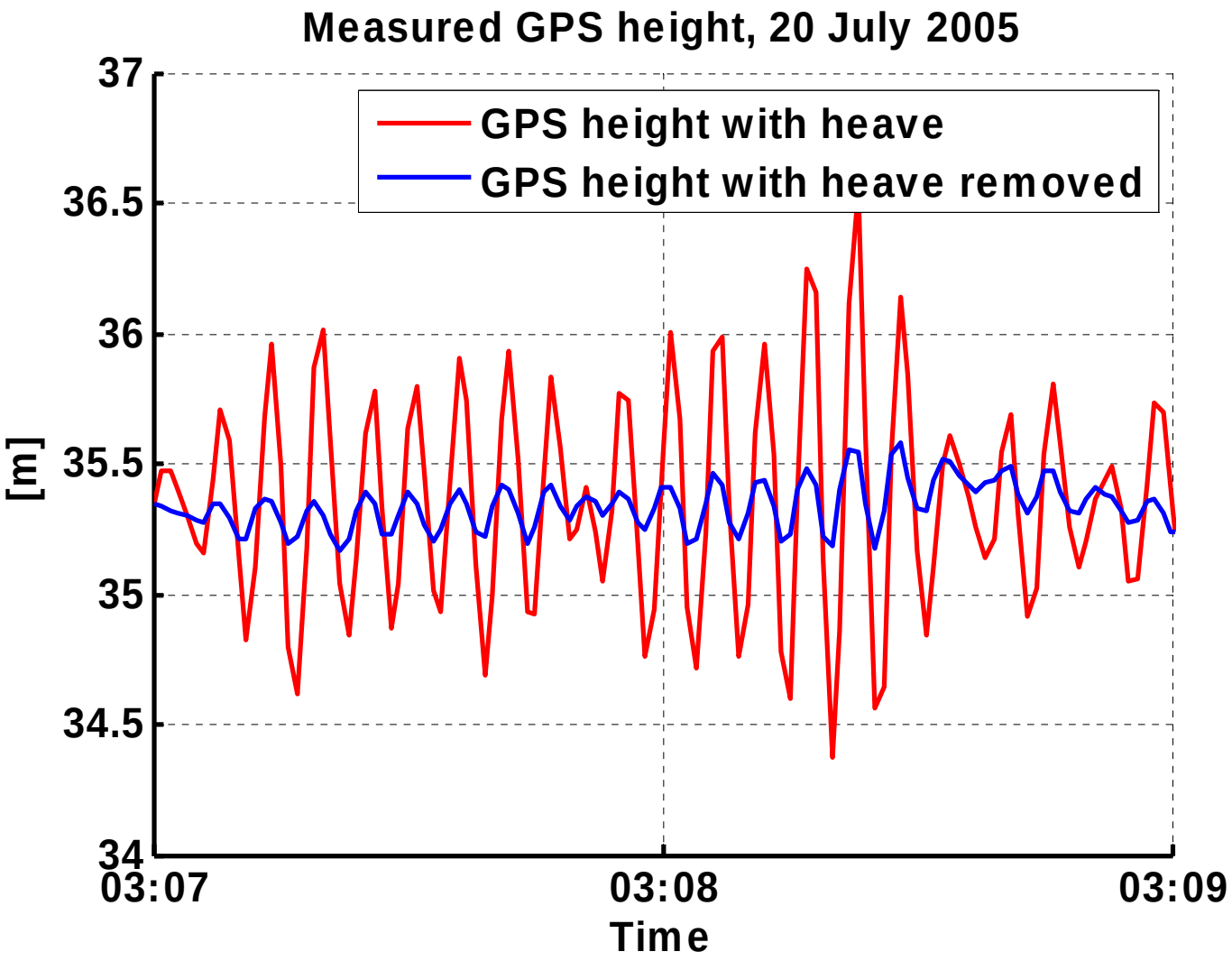

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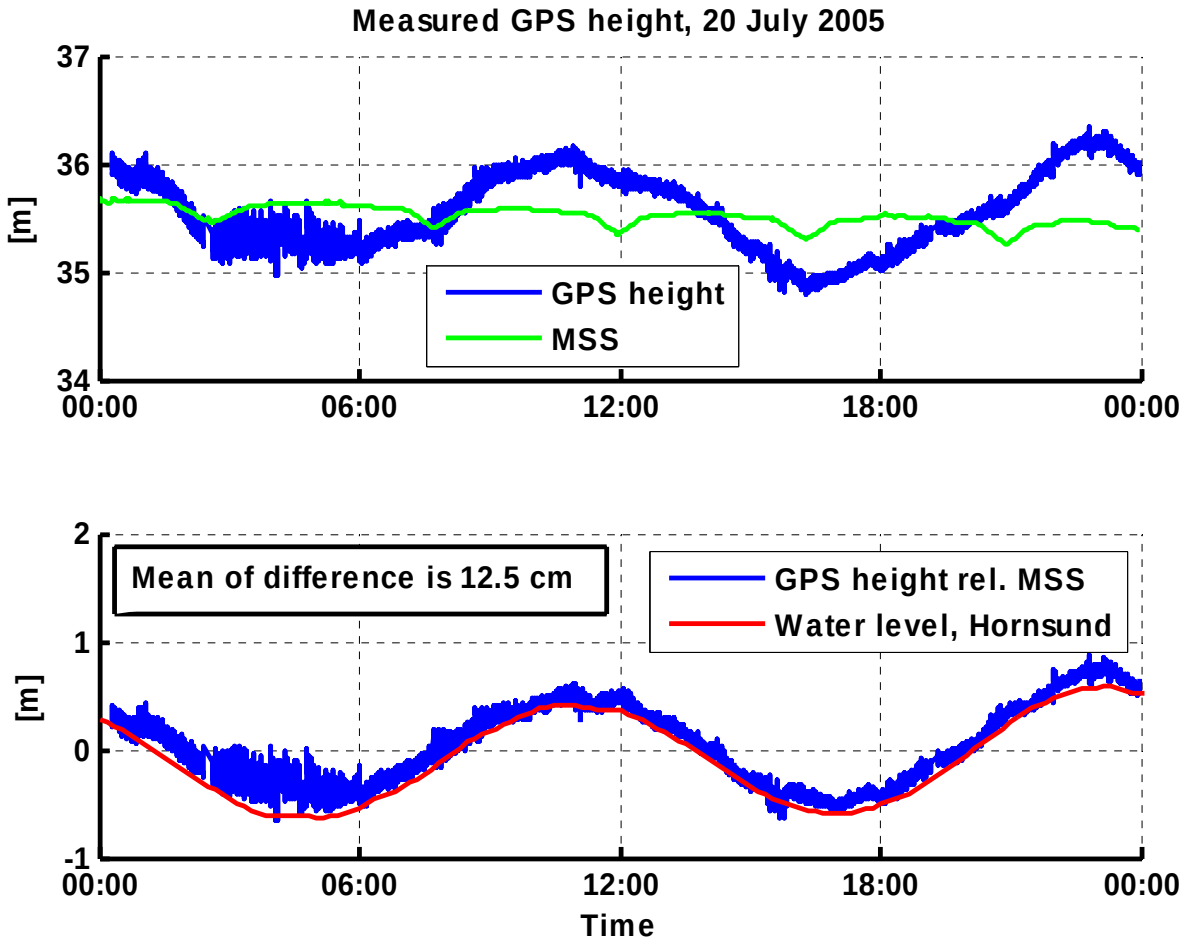
GPS-water level and water level from temporary tide gauge



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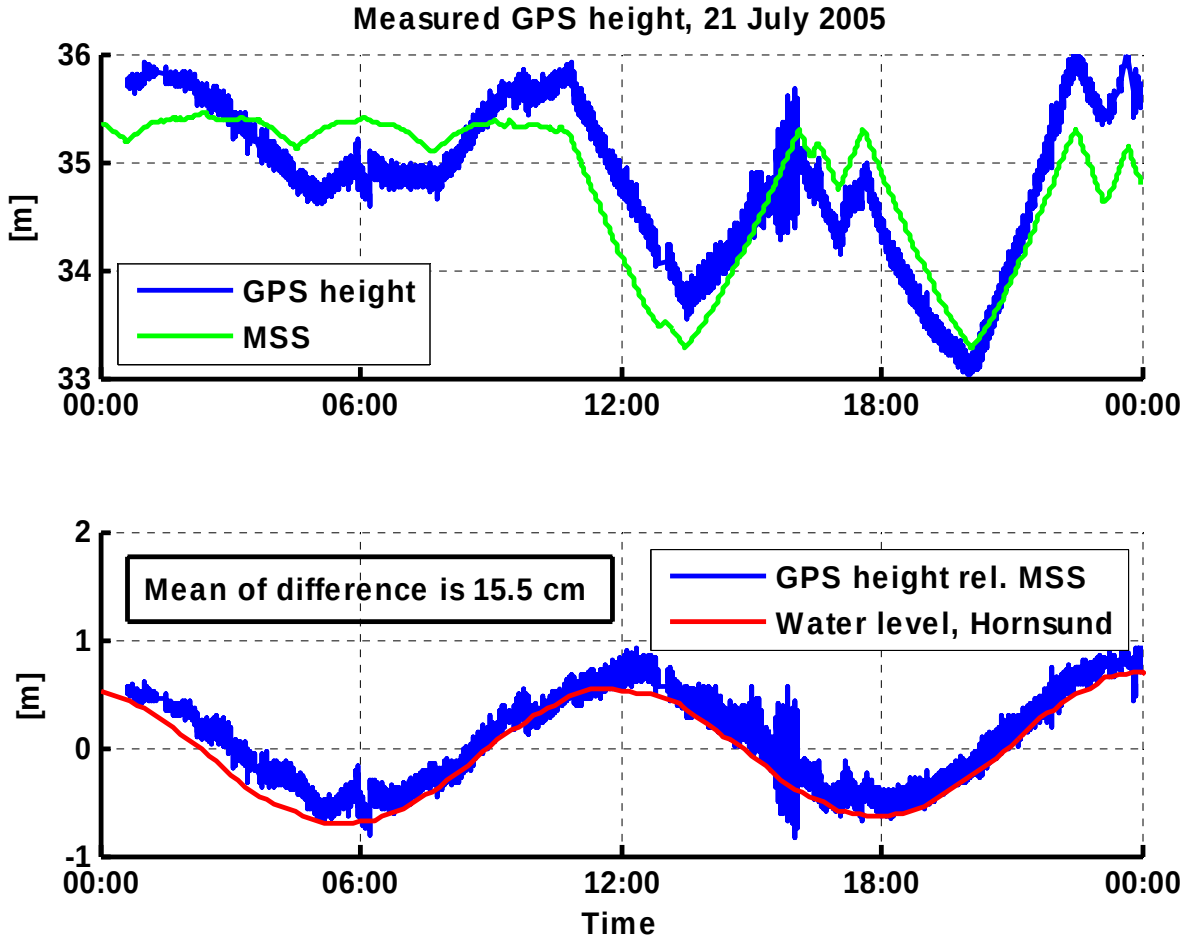

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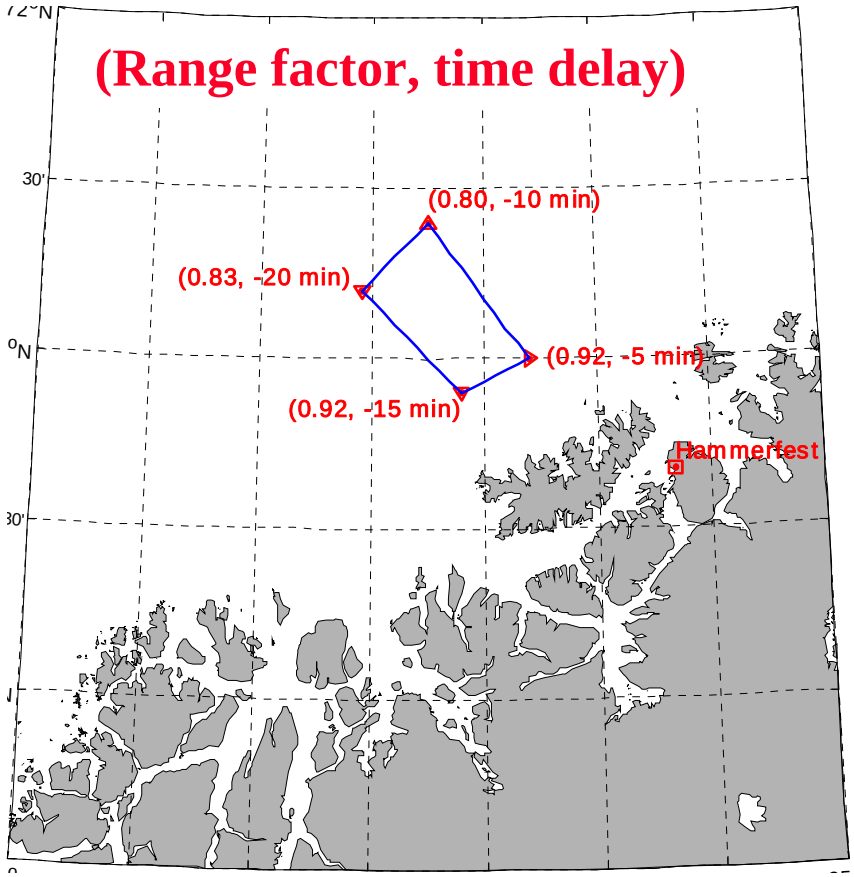

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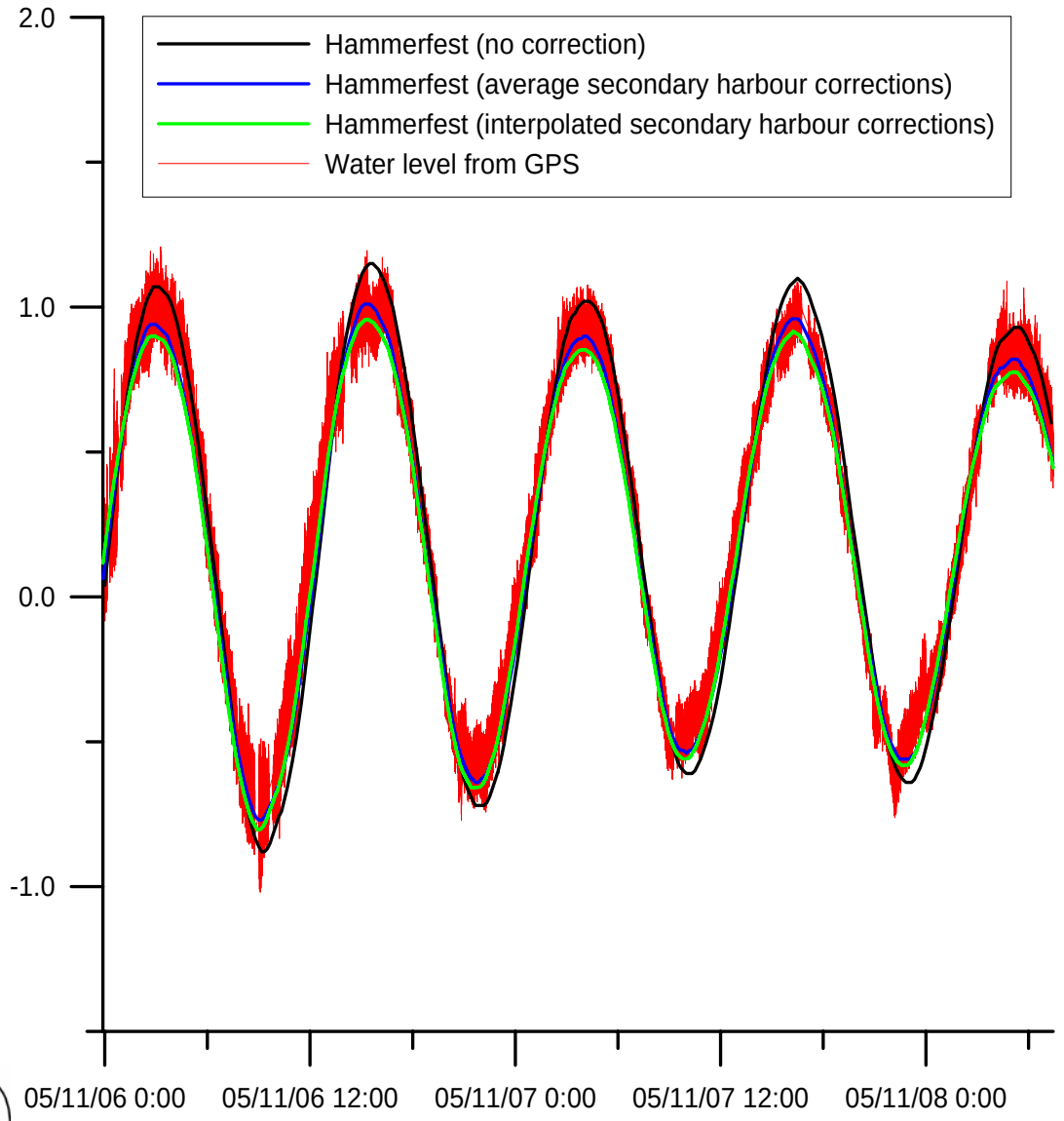
Water level relative mean sea level



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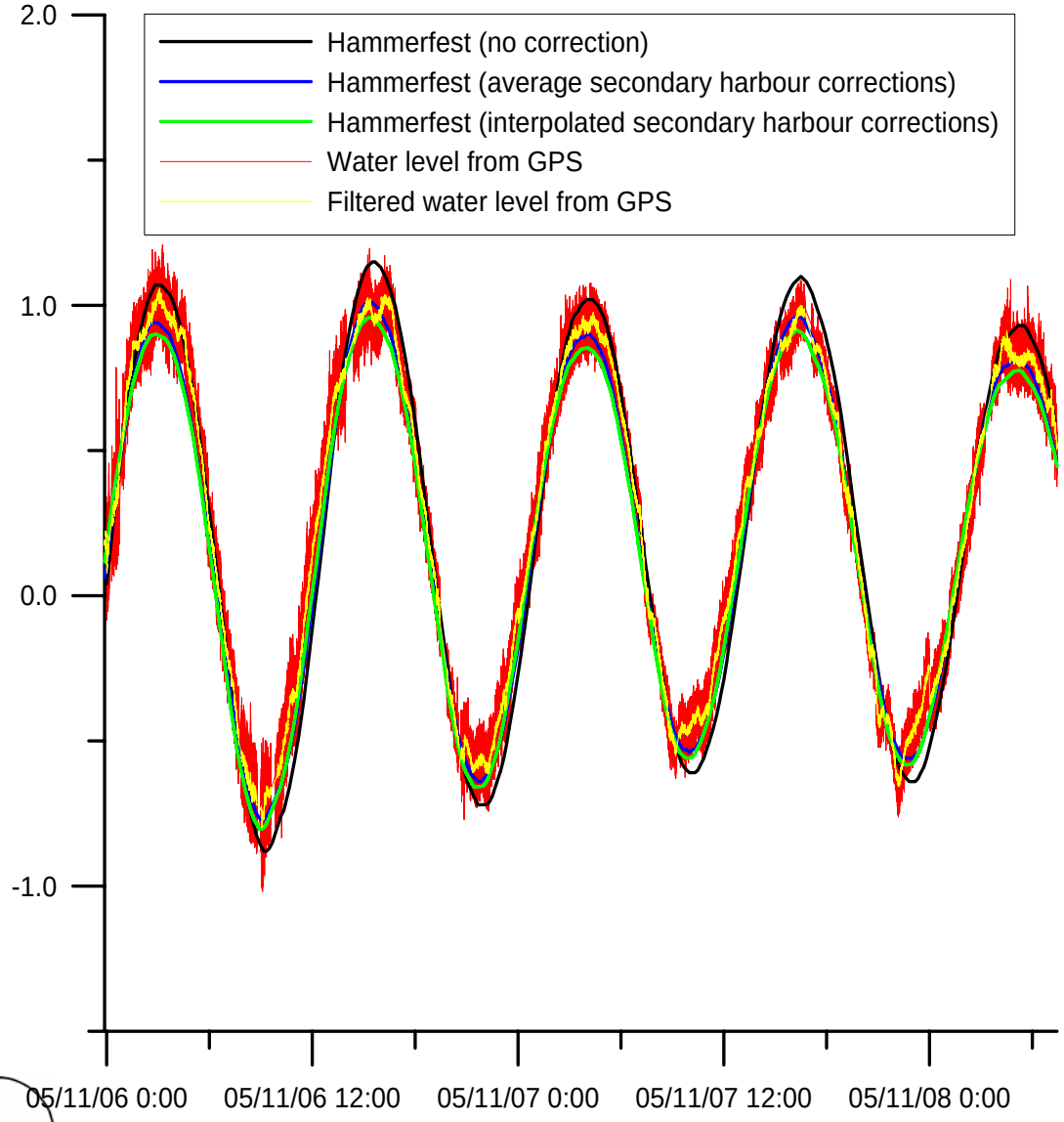

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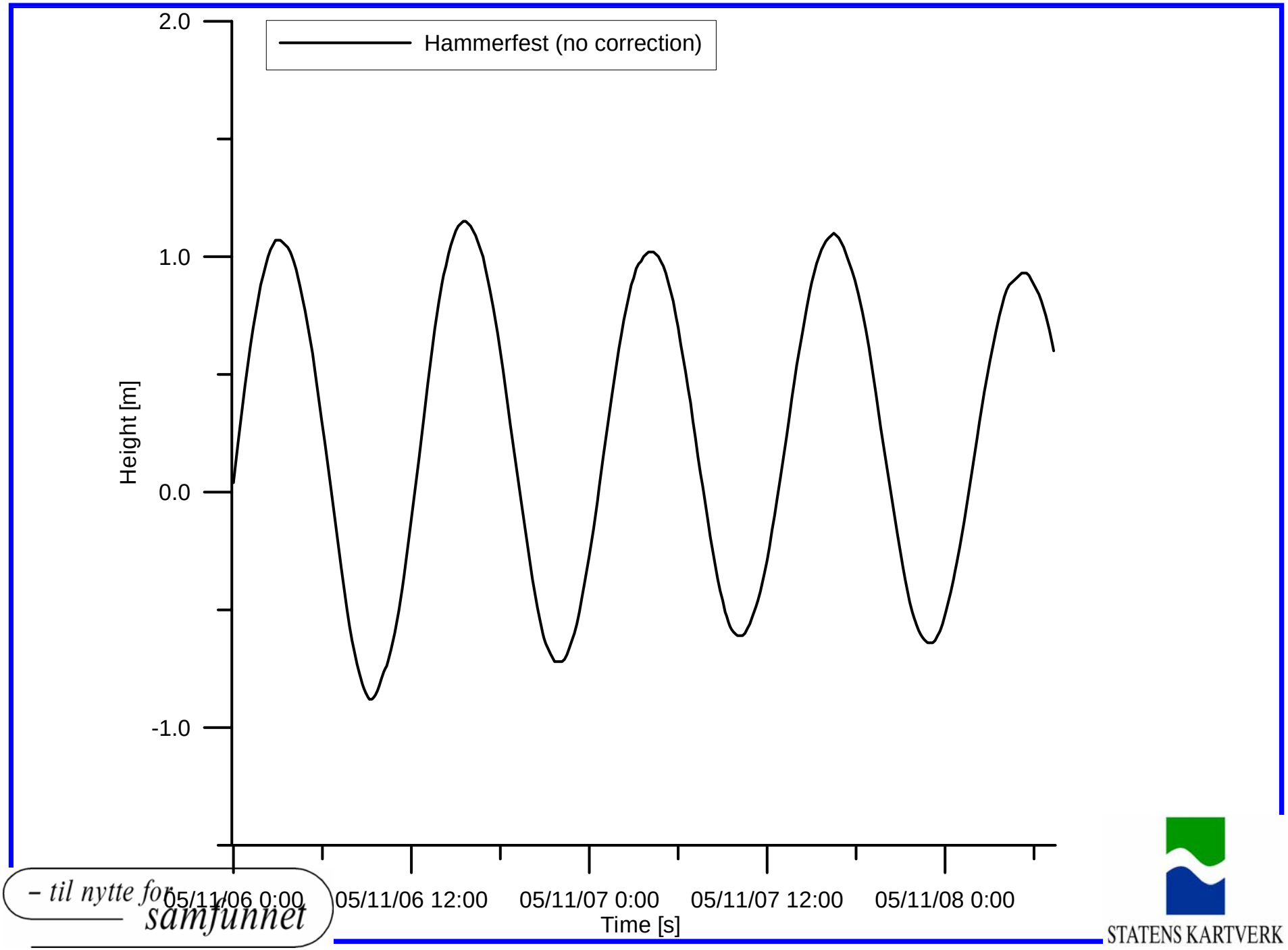

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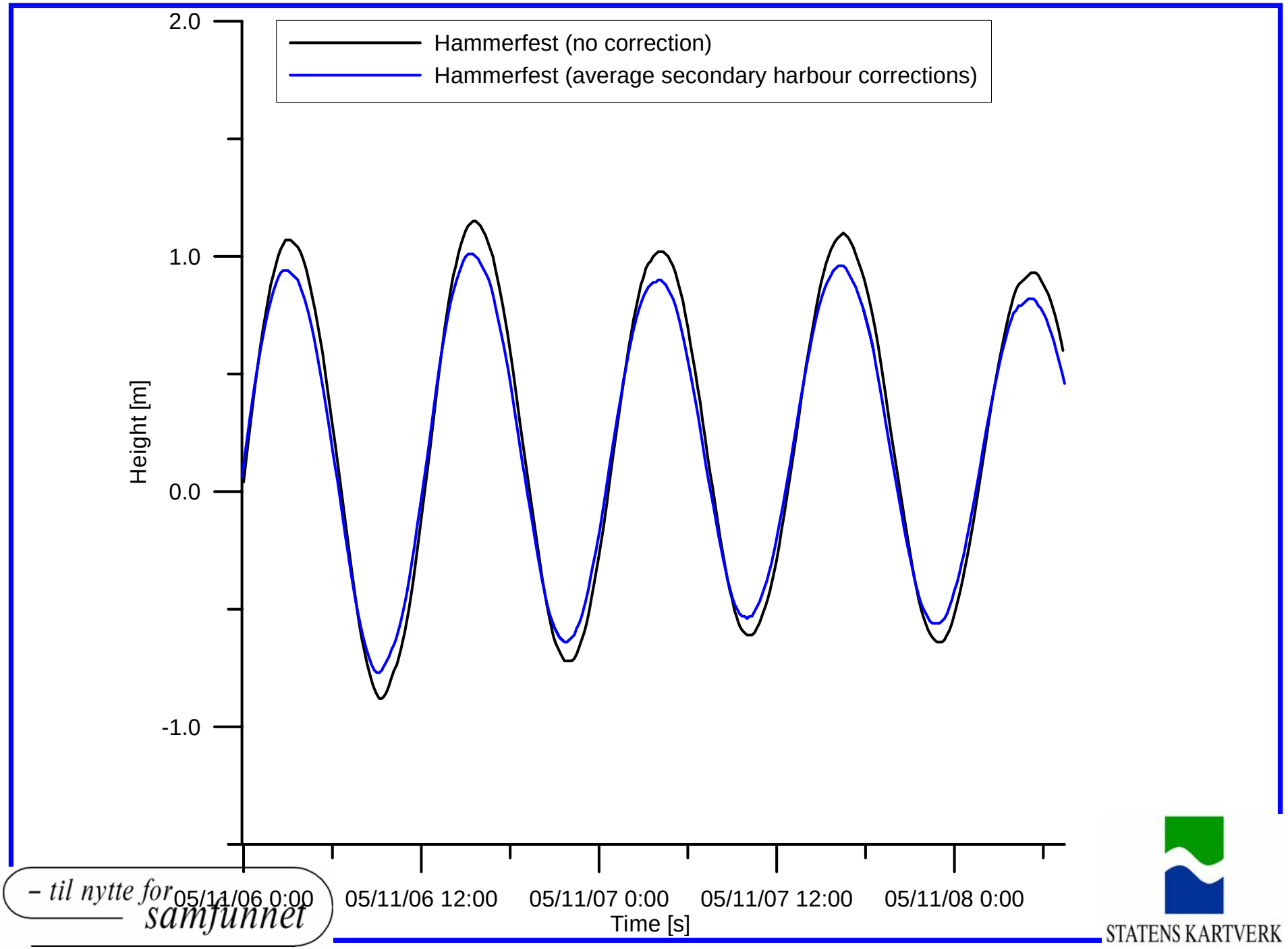

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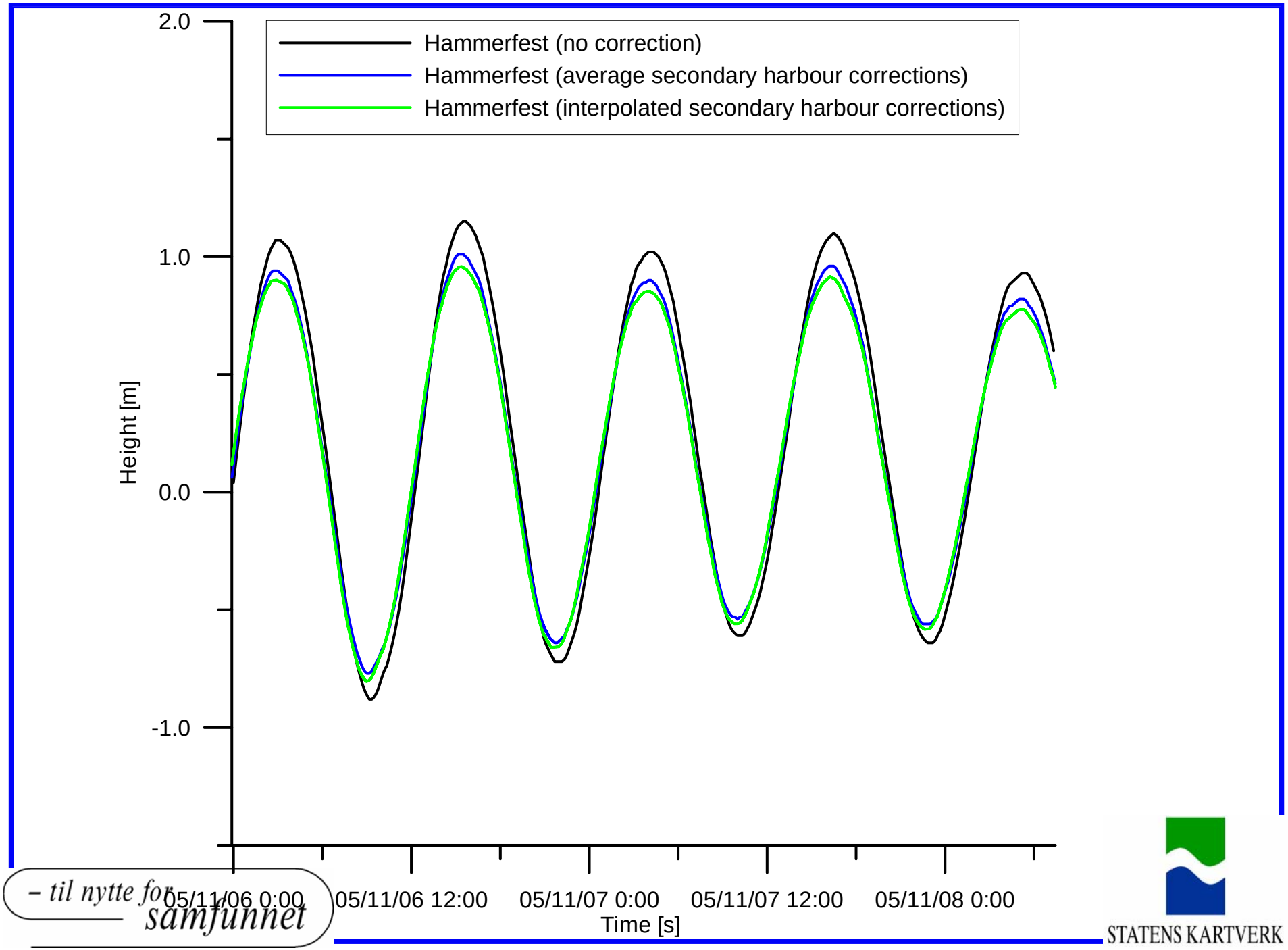

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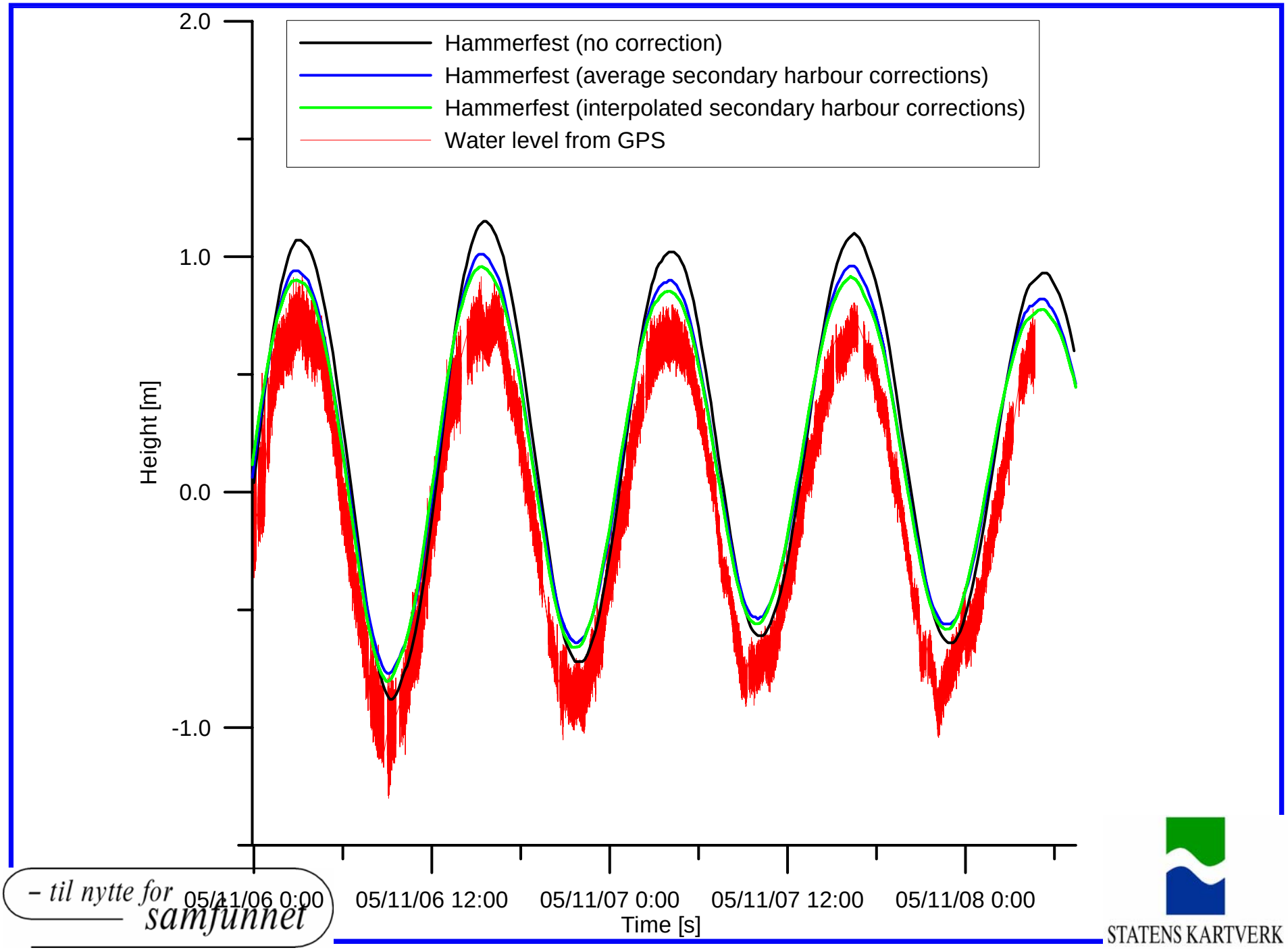

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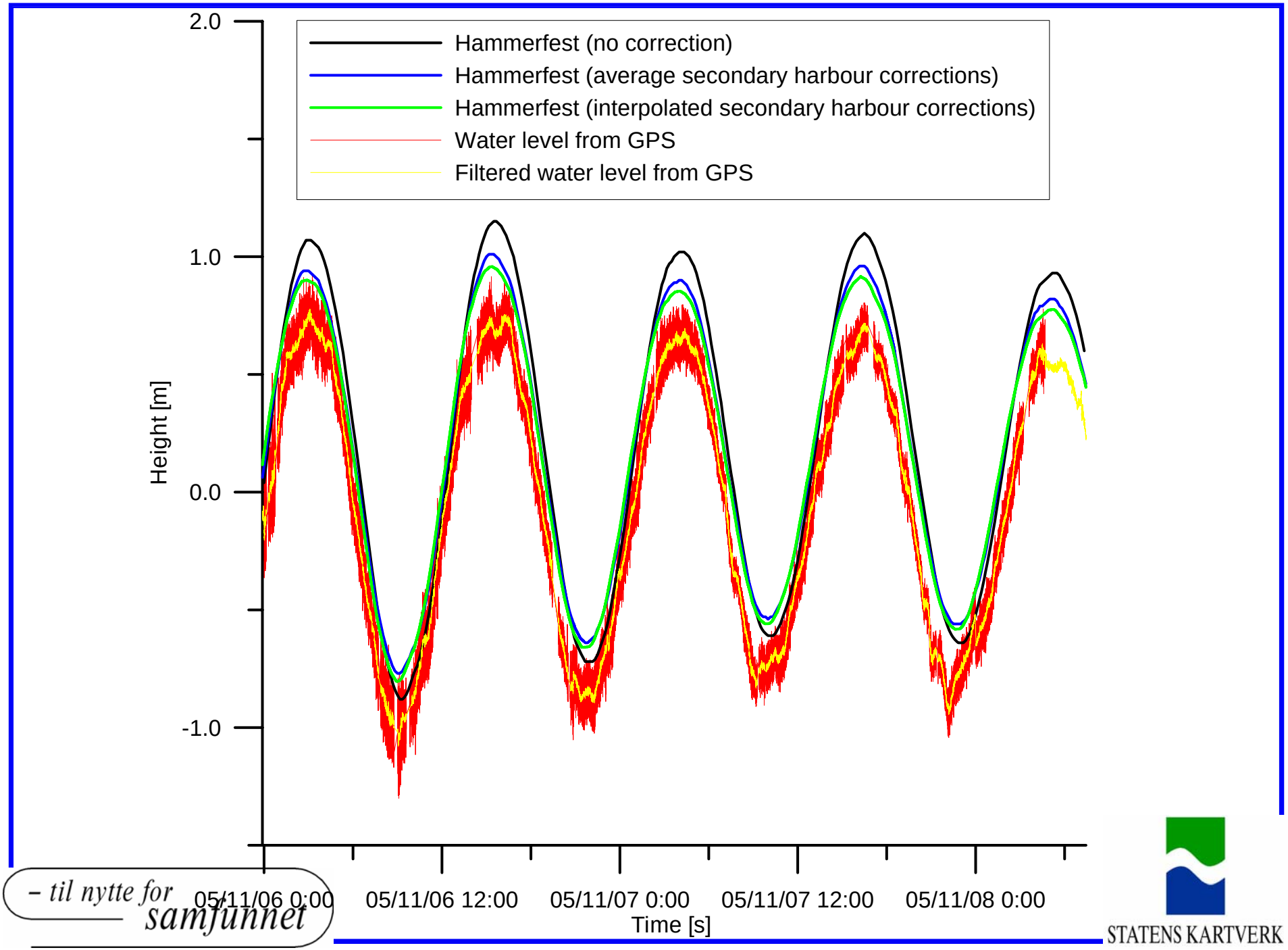

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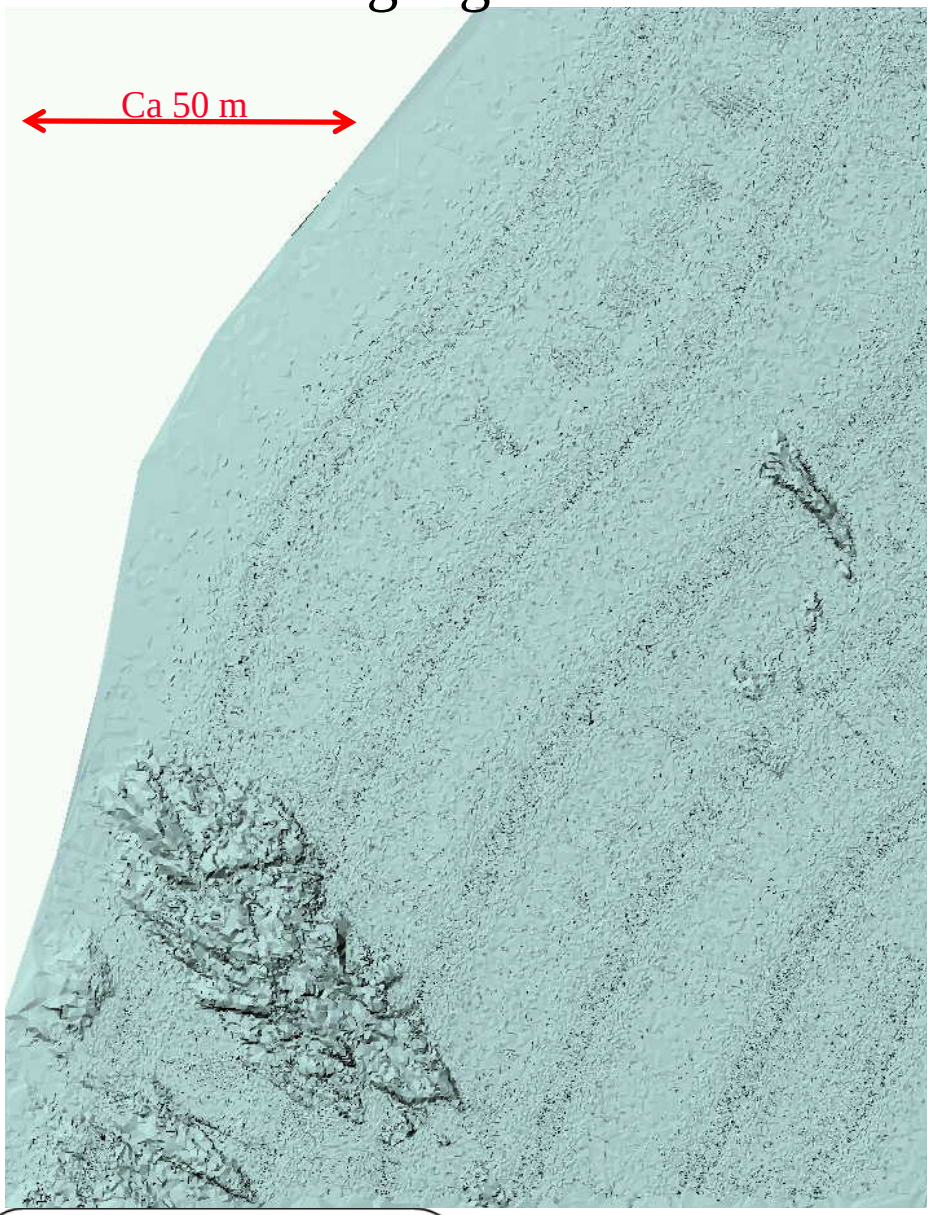
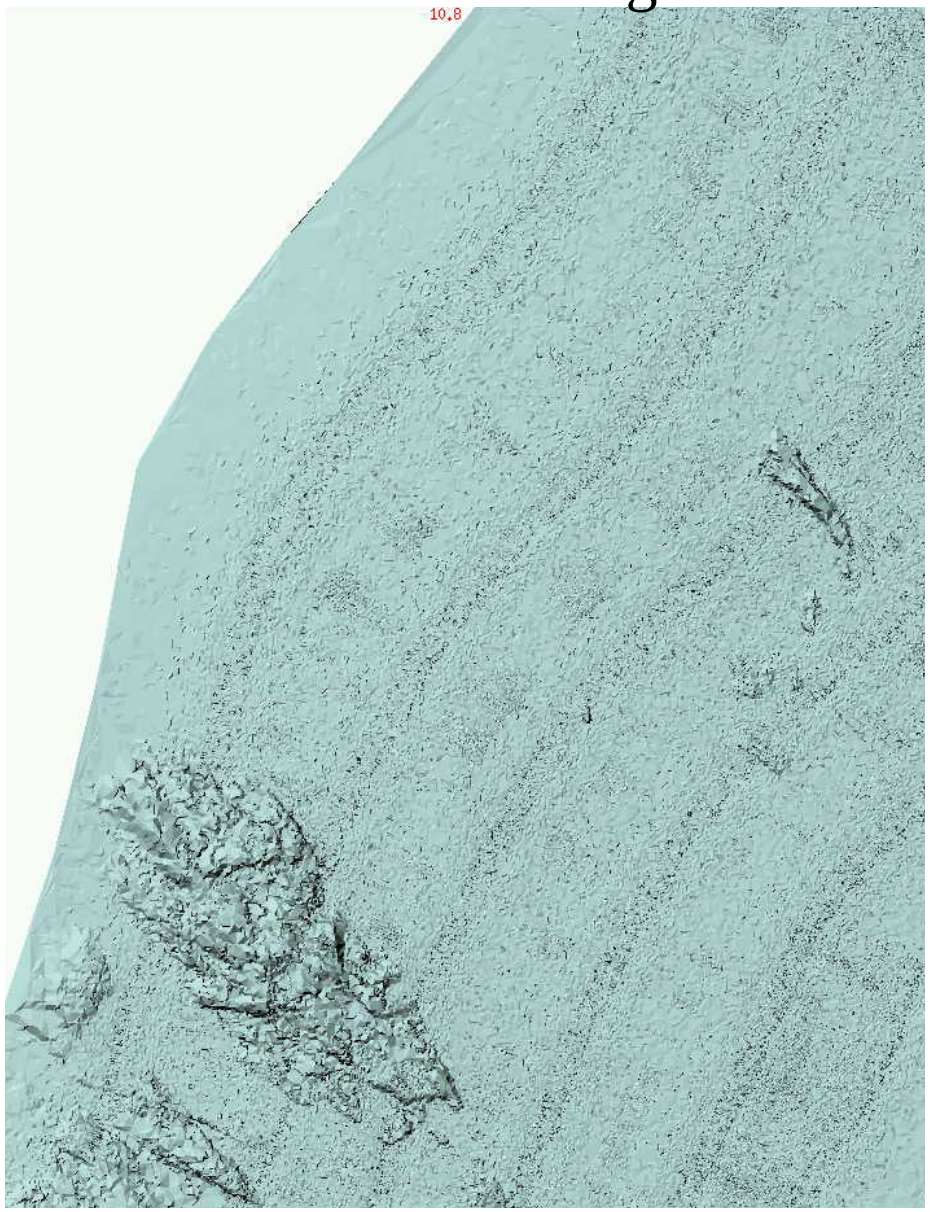
Tide gauge

GPS - heights





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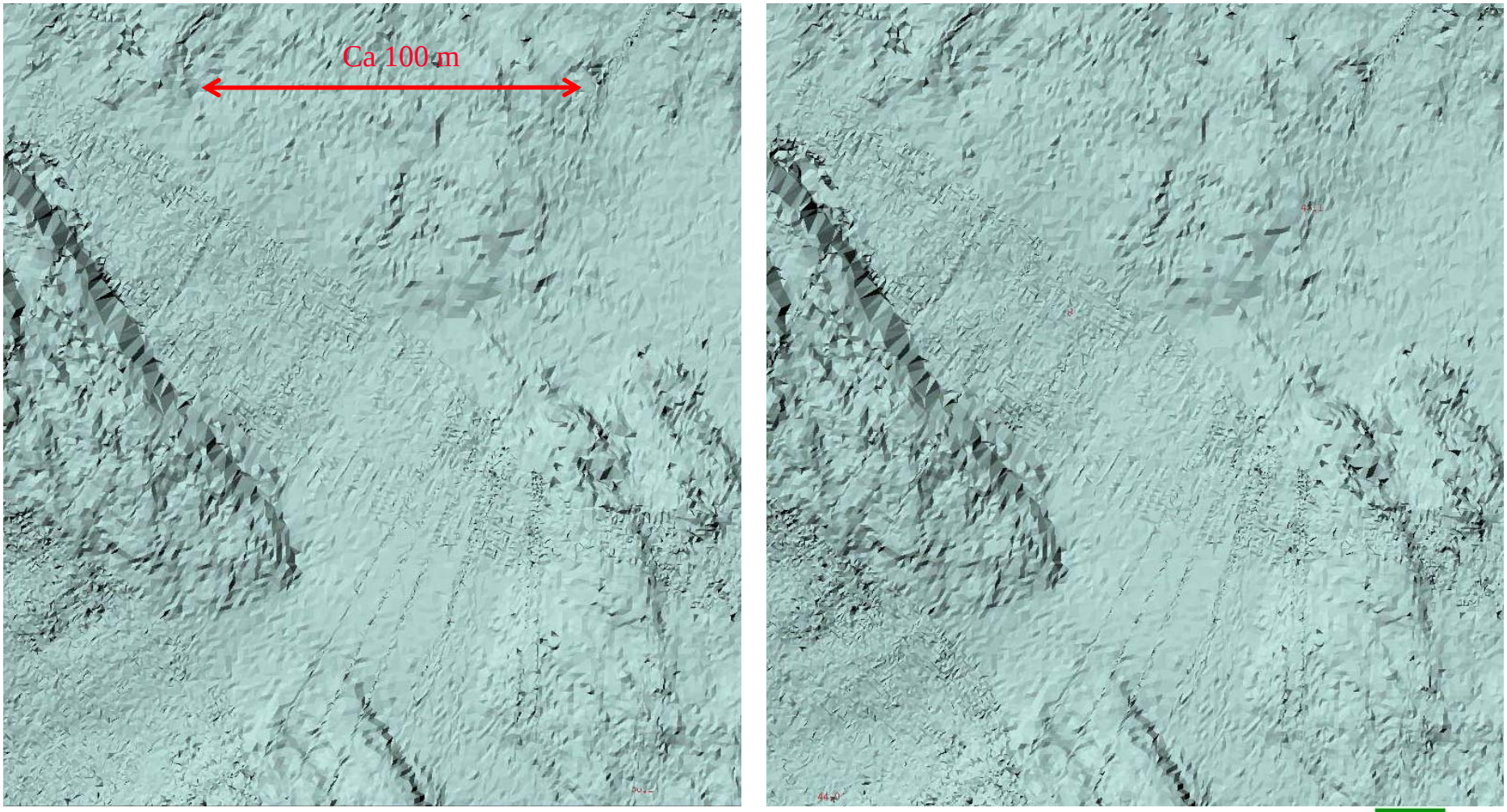
5-10 m depth, EM3000D

Tide gauge

GPS - heights



40 m depth, EM1002

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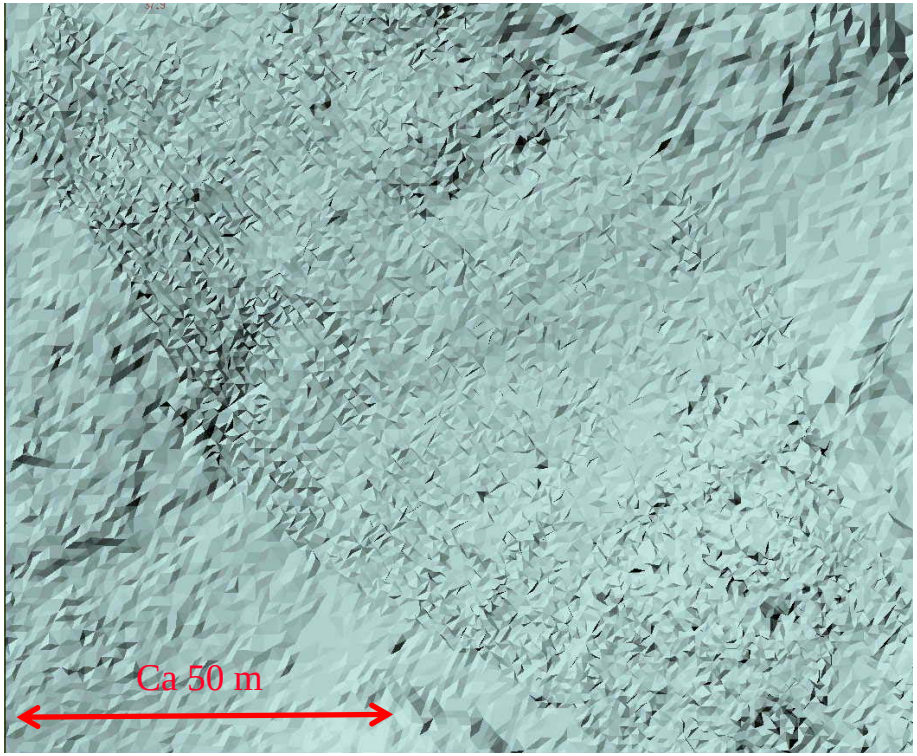
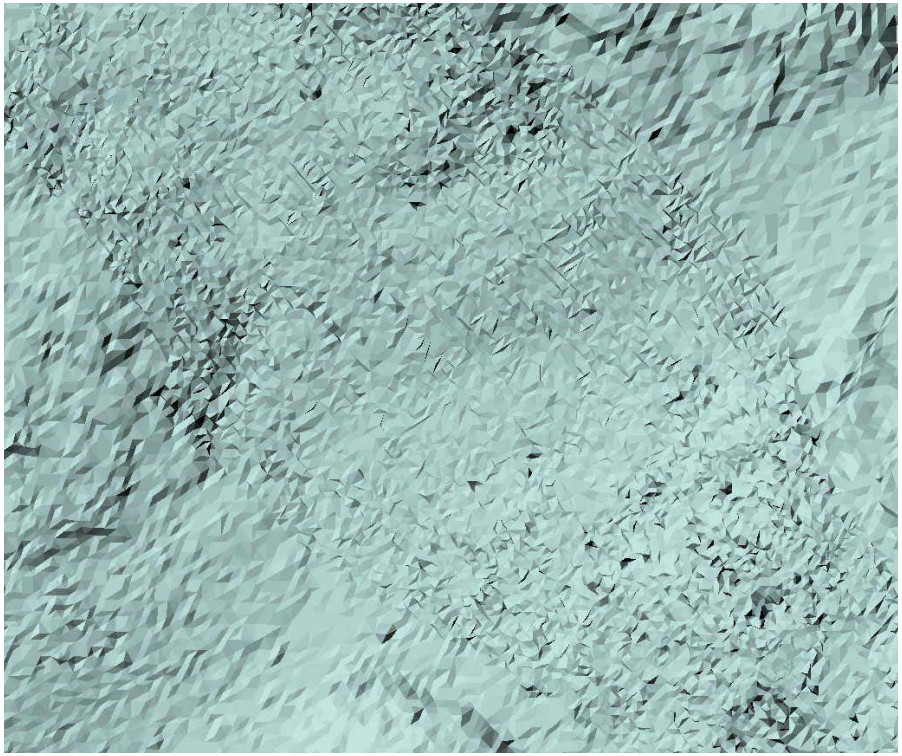
Tide gauge

GPS - heights





40 m depth, EM1002

Further work at NHS

- Document the accuracy of GPS-height
  - Test has been carried out
- Find out how to handle heave
  - Can we use GPS-height to measure heave? Test?
- Document error sources in connection with traditional water level measurements
- Compare GPS-water level and traditional water level
- Consider and possibly implement changes in the production line
  - Should depth data be stored relative to the ellipsoid, mean sea level or chart datum?
- Provide MSS and Chart Datum surfaces as well as a system for updating and version control

Conclusions

- To use the ellipsoid as vertical reference for seabed mapping is today a relevant method since the GPS-height has become more accurate.
- At high seas this method is especially favourable since it is difficult to provide reliable water level data
- There are MSS-models covering high seas. These can be used to convert from ellipsoid to mean sea level
- Tide models can be used to make Chart Datum surfaces. These can be used to convert from mean sea level to Chart Datum.
- GPS-height contain heave. When we subtract heave measured by the heave sensor we still observe rests of heave.