### The Swedish Height System RH 2000 as a National Realisation of EVRS

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## The third precise levelling of Sweden



- 1979 2003
- Approximately 50 000 km double run precise levelling
- Around 50 000 benchmarks
- Motorised levelling



# The Baltic Levelling Ring (BLR) —



- The latest precise levellings from all the Nordic and Baltic countries as well as Poland, Germany and the Netherlands.
- The processing has been made as a Nordic cooperation within the Working Group for Height Determination of the Nordic Geodetic Commission (NKG)
- The NKG work is described in a separate presentation by **Karsten Engsager**.
- Due to the severe Swedish time limitations for RH 2000, the work on system definition and postglacial land uplift model had to be finished by ourselves in January/ February 2005.

# **Definition of RH 2000**

- It was decided that RH 2000 should be defined as the Swedish realisation of EVRS.
- In agreement with the EVRS definition (which is rather general),
  - $\checkmark$  normal heights are utilised and
  - $\checkmark$  a zero system is applied for the permanent tide.
- To be as "European" as possible, the Normaal Amsterdams Peil (NAP) is used as zero level (as for EVRF 2000),
- The reference epoch is chosen to 2000.0 on the Nordic level (NKG).
- The postglacial land uplift model is constructed as a combination of
  - $\checkmark~$  The geophysical model of Lambeck, Smither and Ekman (1998).
  - ✓ The early 2005 version of the mathematical (empirical) model of Olav Vestøl.
     LANTMÄTERIET

## The geophysical land uplift model of Lambeck et al. (1998)



- $\checkmark$  the land uplift from the tide gauges of Ekman (1996),
- ✓ some lake level observations,
- $\checkmark$  ancient shore lines.
- The digitised version (NKG) is here assumed as Lambeck's model

### **Evaluation of Lambeck's model**



Residuals in the

- tide gauges
- permanent GPS stations, converted to apparent land uplift using the Eustatic sea level rise 1.32 mm/year and 6% geoid rise (Vestøl 2005).

Table 2.4: Statistics for the apparent uplift residuals for Lambeck's model mm/year.

| Observations       | #  | Min   | Max  | Mean  | StdDev | RMS  |
|--------------------|----|-------|------|-------|--------|------|
| All tide gauges    | 58 | -1.50 | 1.03 | -0.01 | 0.46   | 0.46 |
| Edited tide gauges | 56 | -1.50 | 1.03 | -0.02 | 0.46   | 0.46 |
| All GPS            | 55 | -1.64 | 1.46 | -0.25 | 0.71   | 0.75 |
| SWEPOS GPS         | 21 | -1.57 | 0.37 | -0.49 | 0.54   | 0.73 |

• Large errors in the central parts of Sweden!

## Vestøl's mathematical land uplift model

- **Olav Vestøl** gives more details about his work in another presentation.
- Only the model available in January 2005 is considered here (available at the RH 2000 deadline).
- Observations:
  - ✓ Tide gauges (Ekman 1996)
  - ✓ Permanent GPS (Lidberg 2004)
  - ✓ (Repeated) Levelling from Finland, Norway and Sweden (Saaranen, Vestøl and Svensson).
- Least squares collocation with unknown parameters to estimate the uplift in the observation points.

### Vestøl's model (January 2005)





### **Discussion of Vestøl's model**

- The model agrees well with the observations.
- It is <u>not</u> defined for the whole Baltic Levelling Ring (BLR)
- The cylinders in the outskirts of the area are disturbing.
  - ✓ They depend on a separate gridding algorithm. (Mean of four observations, one in each search quadrant if closer than 120 km.)
- The model looks rough (zigzag contour lines). Some smoothing might be motivated.
- A good way to extend Vestøl's model is to make use of Lambeck's model.



## The final model (RH 2000 LU)



- A combination of the models of Vestøl and Lambeck.
- A smoothed version of Vestøl's model in the central parts of the area
- A smooth transition to Lambeck's model in the outskirts.



### Evaluation of RH 2000 LU

50°



Table 4.1: Statistics for the residuals of RH 2000 LU (smoothed inverse distance model with minimum -2.00 mm/year). The maximum for "All tide gauges" is given for both the outlier stations Furuögrund/Oslo. Unit: mm/year.

|   | Observations       | #  | Min   | Max       | Mean | StdDev | RMS  |
|---|--------------------|----|-------|-----------|------|--------|------|
| 0 | All tide gauges    | 58 | -0.36 | 0.93/1.24 | 0.18 | 0.26   | 0.31 |
|   | Edited tide gauges | 56 | -0.36 | 0.55      | 0.14 | 0.19   | 0.23 |
|   | All GPS            | 55 | -1.15 | 1.46      | 0.13 | 0.52   | 0.53 |
|   | SWEPOS GPS         | 21 | -0.59 | 0.49      | 0.03 | 0.32   | 0.32 |



#### **Evaluation of Lambeck's model**



Table 2.4: Statistics for the apparent uplift residuals for Lambeck's model. Unit: mm/year.

| Observations       | #  | Min   | Max  | Mean  | StdDev | RMS  |
|--------------------|----|-------|------|-------|--------|------|
| All tide gauges    | 58 | -1.50 | 1.03 | -0.01 | 0.46   | 0.46 |
| Edited tide gauges | 56 | -1.50 | 1.03 | -0.02 | 0.46   | 0.46 |
| All GPS            | 55 | -1.64 | 1.46 | -0.25 | 0.71   | 0.75 |
| SWEPOS GPS         | 21 | -1.57 | 0.37 | -0.49 | 0.54   | 0.73 |



#### Adjusted height differences between using Lambeck and RH 2000 LU



#### Mean Sea Level (MSL) in RH 2000 –

Epoch: 2000



**Epoch: 2026 (extrapolation)** 



### Difference between RH 2000 and EVRF 2000



 Large differences because of the different land uplift epochs (1960/2000)



# Summary

- RH 2000 is defined as the Swedish realisation of EVRS.
- The RH 2000 adjustment was made using data from the whole Baltic Levelling Ring (BLR) with the Normaal Amsterdams Peil (NAP) as zero level.
- All levelling observations are reduced for the postglacial rebound to the reference epoch 2000.0 using the newly developed land uplift model RH 2000 LU.
- The model RH 2000 LU was adopted as the Nordic model **NKG2005LU** at the WGH meeting in Gävle, the 18<sup>th</sup>-19th of April, 2006.
- The adjusted heights agree reasonably well with MSL along the Swedish coasts.
- The difference between RH 2000 and EVRF 2000 is large due to the different land uplift epochs for the Nordic block.