Model-based hydrodynamic leveling; a power full tool to enhance the quality of the geodetic networks

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1. Background

- Criteria for assessing the quality of the geodetic network: precision and reliability

- Traditionally, spirit leveling is the method to realize the height datum of geodetic networks. However, it is not able to make a direct connection between areas separated by large water body

- Model-based hydrodynamic leveling (Fig.1) allows to do so;

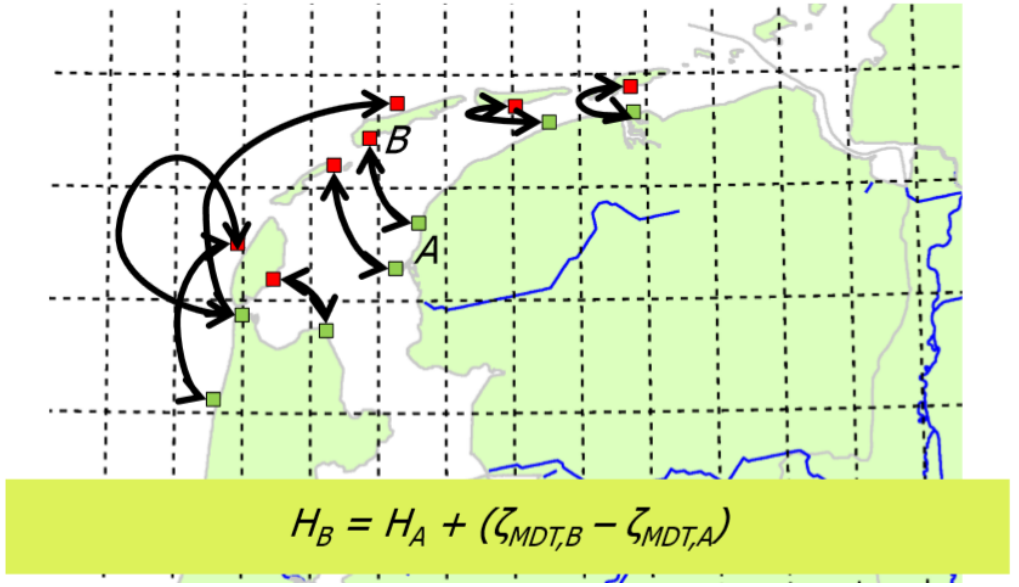

Fig 1: The theoretical concept of model-based hydrodynamic leveling (Credit: D.C. Slobbe)

Research Question

- To what extend adding model-based hydrodynamic leveling connections can improve the quality of the geodetic networks in terms of precision?

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2. Network Adjustment

- Case study: Realization of the European Vertical Reference Frame (EVRF) 2019 (Fig.2)
- Data: Location of height markers and variances of leveling observations used to realize the EVRF 2019 are provided by BKG, UK was removed from this realization but in this analysis, we added it.

Leveling observations for Russia, Belarus, and Ukraine were not available. Based on height marker locations, this part of network was artificially produced

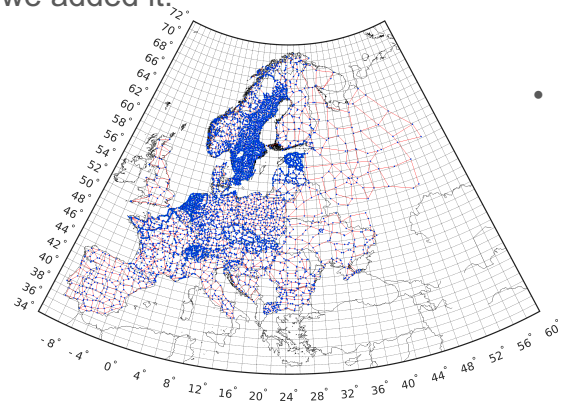

Fig 2: Height marker location (blue points) and leveling connection (red line)

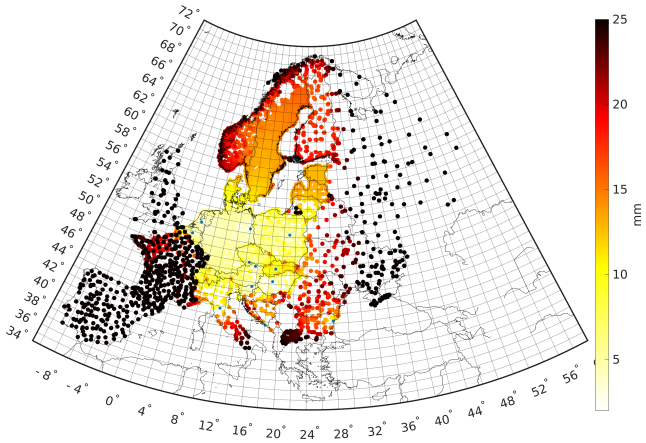

Fig 3: STD of estimated heights from network adjustment, location of datum points (blue dots)

- Constrained network adjustment: Using weighted least-quares with 12 datum points, we obtained the standard deviation of the estimated heights as shown in (Fig.3)

3. Hydrodynamic leveling connections

- We focus on North Sea area
- Tens of tide gauges available in the North Sea. Each tide gauge is a candidate. To reduce the computational efforts, we selected one per country. Except for the UK for which 2 were selected.(Fig.4)
- Between N tide gauge, N-1 independent connection could be established

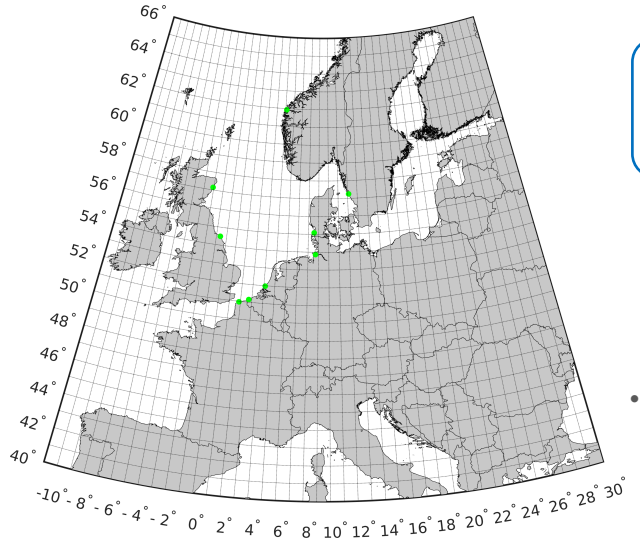

Fig 4: Location of candidate tide gauges (green dots)

(Slobbe et al., 2018) shows the promising results to obtain the 1cm accurate connections

- Uncertainty of connections is assumed to be 1cm; This is expected based on result of available hydrodynamic model in the area (3D DCSM-FM)

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3. Impact of adding hydrodynamic leveling to the network

- To assess the impact, hydrodynamic and spirit leveling data were combined, and the network was re-adjusted
- To select the best connections, all possible combinations among candidate tide gauges were assessed
- The best set of connections, provides the lowest average standard deviation for the height markers per country

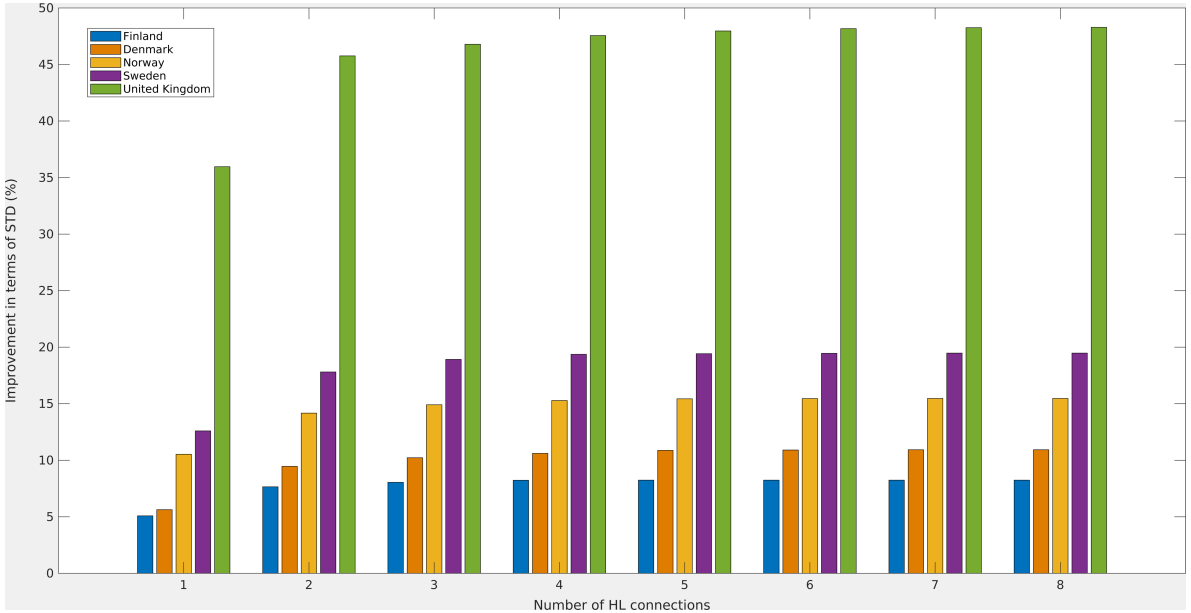

Fig 5: Improvement of precision per country in terms of STD

Results and conclusion

- Largest impact visible in North Sea countries that are poorly connected to the spirit leveling network
- Results show a significant improvement in terms of standard deviation (Fig. 5) compared to spirit leveling only solution
- Model-based hydrodynamic leveling allows to improve connection of the UK to the Unified European Leveling Network (UELN)