Title
Real-time validation of CoVadem derived water depths at locations with a fixated riverbed

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Introduction
CoVadem creates an up-to-date depth chart of inland waterways. The underlying data are obtained from measurements of vessels participating in the CoVadem initiative, each sharing their sensor data in the CoVadem Cloud-Based Processing Environment. To make sure that the underlying data is both accurate and reliable, we need a method that automatically filters out erroneous measurements. This paper presents a method in which measurements are compared in real-time at locations with a fixated riverbed i.e. not eroding or aggrading over time.

CoVadem measurement and post processing method

Description CoVadem initiative.
A growing fleet of about fifty vessels participating in the CoVadem initiative continuously measure, log and broadcast data with sensors that were already on board before they started participating in the project. The underkeel clearance is measured with a single beam echo sounder, vessel position with a GPS meter and vessel draught with a ship cargo meter (a calibrated system of pressure sensors). A video that explains the initiative in more detail can be found here.

All data from all vessels processed and combined, yields a chart of the up-to-date water depth of inland waterways in a very cost-effective way. Using hydrodynamic and hydrological models, we enrich the data with a forecast of the water depth. As such, it becomes possible to optimize cargo volumes and sail more efficiently (e.g. Bons et al., 2016).

CoVadem does not aim to determine the water depth with a precision equal to that of a multibeam echo sounder, as the single beam transducers used are typically less precise. However, the strength of CoVadem is that measurements are performed continuously, so that the information about the riverbed is always up-to-date, also at locations which are very dynamic or locations that are not surveyed with multibeam equipment. Even more information about the riverbed can be obtained, when looking at the trends of the CoVadem measurements since the latest available multibeam measurement.

Current post processing of measurements
Millions of measurements a day are translated into water depth using a ship squat calculation. Squat is the increased draught due to the flow of water past the ship hull (Figure 1). The forward speed of the ship pushes the water in front ahead. This water must return at the sides and below the ship. This results in an increased speed of the water, which, due to the Bernouilli effect induces a decreased pressure underneath the ship. This results in a water level depression in which the ship sinks (sinkage). The effect is not equal over the ship length due to the local changes in the ship hull over its length. This can cause the ship to trim. Ship squat is the combination of sinkage and (dynamic) trim.

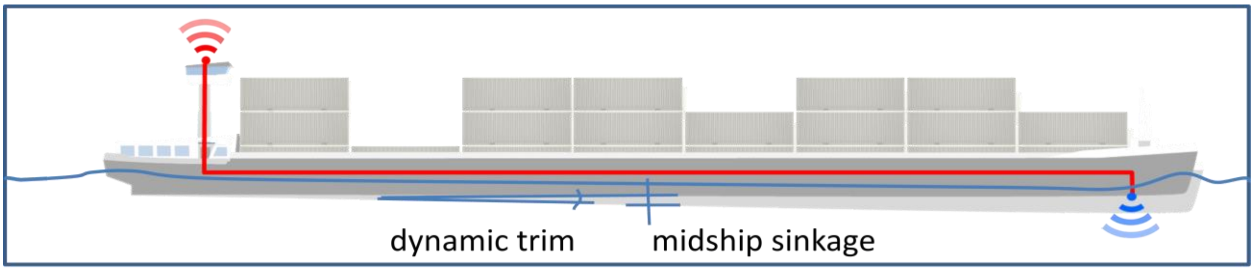

Figure 1: Squat is the combined effect of sinkage and dynamic trim

Within the CoVadem initiative, the underkeel clearance is measured at the echo sounder location of which the position is known on all participating vessels. Figure 2 shows that the fairway depth (water depth) at this location can be calculated by the summation of measured underkeel clearance, ship squat and initial zero speed draught.

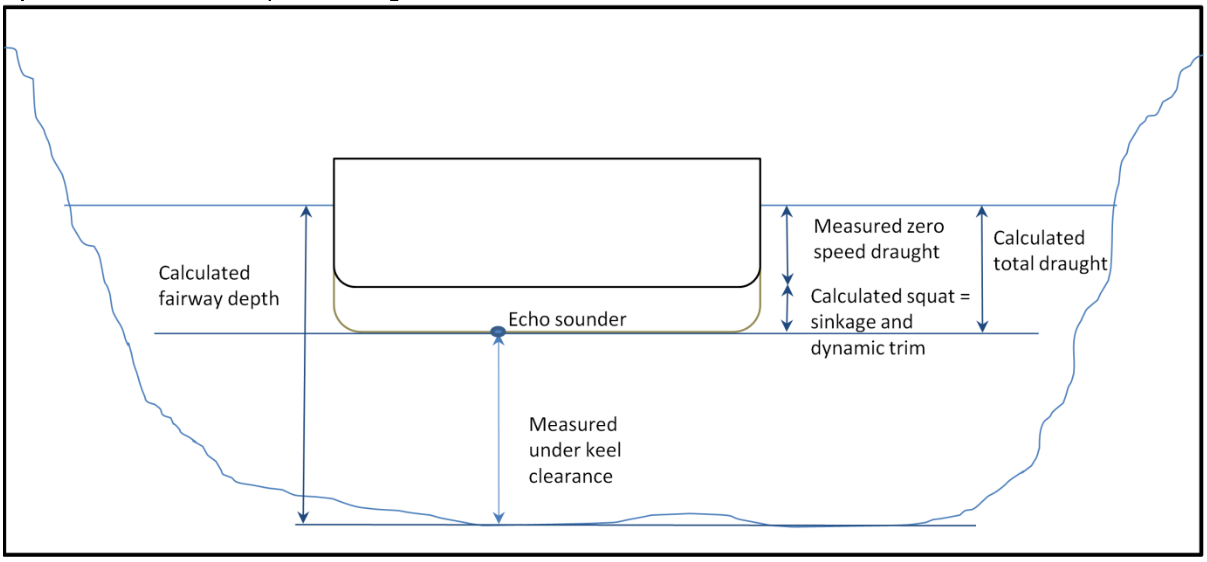

Figure 2: Effect of sinkage and dynamic trim on the total ship draught

Validation results

CoVadem water depth data is validated with multi beam data. First, the determined water depth should be translated to a riverbed level (Ref. Figure 3).

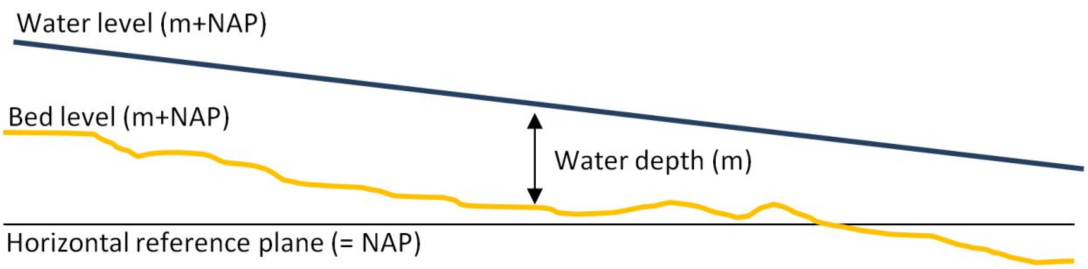

Figure 3: Definition sketch: note that both bed level and water level (and thus water depth) in rivers vary in time and space.

This is done by subtracting the measured water depth with the water level from a nearby water level gauge. By comparing the riverbed level from CoVadem to multibeam data, we have shown earlier that the average absolute error is in the order of 20 cm (Van der Mark et al., 2015). This validation was performed at locations for which recent multibeam measurements were available (Dutch Rhine branches Bovenrijn and Waal).

Outstanding challenges

Sometimes, the measurements of the vessels are incorrect due to problems with the equipment. A structural vertical offset is also seen, for instance due to equipment settings. To make sure that the depth chart is created based on accurate data only, we need a method that (a) automatically filters out erroneous data, and that (b) corrects the data such that the vertical offset minimizes. Such filtering and correction algorithms should be applied continuously, as a vessel that measures correctly today might measure incorrectly tomorrow because errors in the sensors can occur at any moment.

Proposed real-time validation

Validation on fixated locations

In the Netherlands, the river Waal is one of the main inland transport corridors. The river has an alluvial character, with erosion-sedimentation processes and dunes that migrate quickly over the riverbed. However, the bed level is more or less constant in time at the bends near Nijmegen and St. Andries. The riverbed has been fixated in these two bends to guarantee sufficient water depth over the entire navigation channel by creating an immobile layer of large stones. The result is that at these locations the riverbed is not eroding or aggrading over time. In the Netherlands, these locations are often referred to as “fixed layers”.

This paper presents a method in which the CoVadem data are compared in real-time at riverbed locations with a fixed layer. Officially acknowledged multibeam measurements are only performed a limited number of times a year, so only at locations with a fixed riverbed these measurements can be used for validation purposes for a longer time span.

The river bend near Nijmegen is selected as the starting location for the real-time water depth validation. Rijkswaterstaat (the maritime authority responsible for, amongst others, management and maintenance of the fairway) performs multibeam measurements of the Waal bi-annually.

Description of method

The proposed method can be used at locations that fulfill the following requirements:

1. There is a fixed layer in the riverbed.
2. The water level is available from a nearby water lever gauge
3. The majority of the CoVadem fleet passes the location on a regular basis

Automatically, every passage of a vessel over the fixed layer is categorized and selected. The water level at the moment of the passage is looked up and after a correction for the slope of the river, the riverbed level is calculated. This calculated riverbed level is compared with the riverbed level of a multibeam measurement at the same location.

Results obtained by this method

After comparison of the riverbed level at the fixed layer in the bend near Nijmegen, we are able to distinguish between vessels that produce erroneous or non-erroneous data for the current passage of the fixed layer. CoVadem aims at water depth measurements with an accuracy within 20 cm. Figure 4 and Figure 5 show that most measurements are within the intended accuracy.

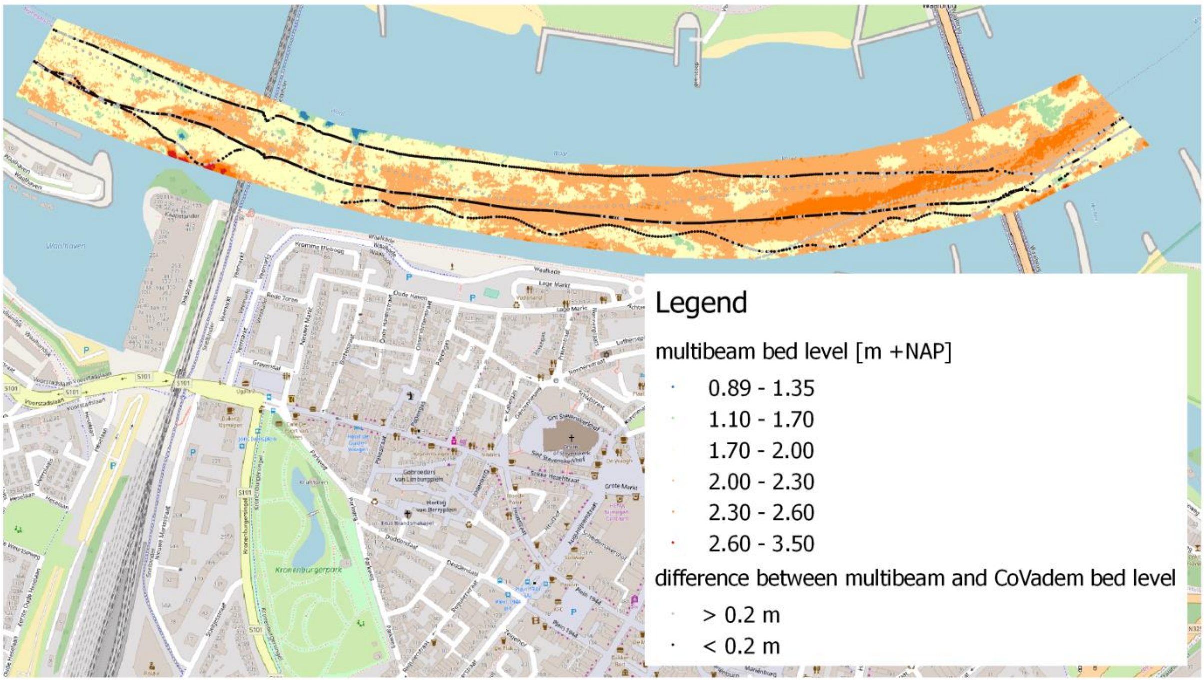

Figure 4 Comparison of CoVadem data with multibeam data for all measurements of the five vessels passing the fixed layer in the river Waal near Nijmegen on October 29 2016

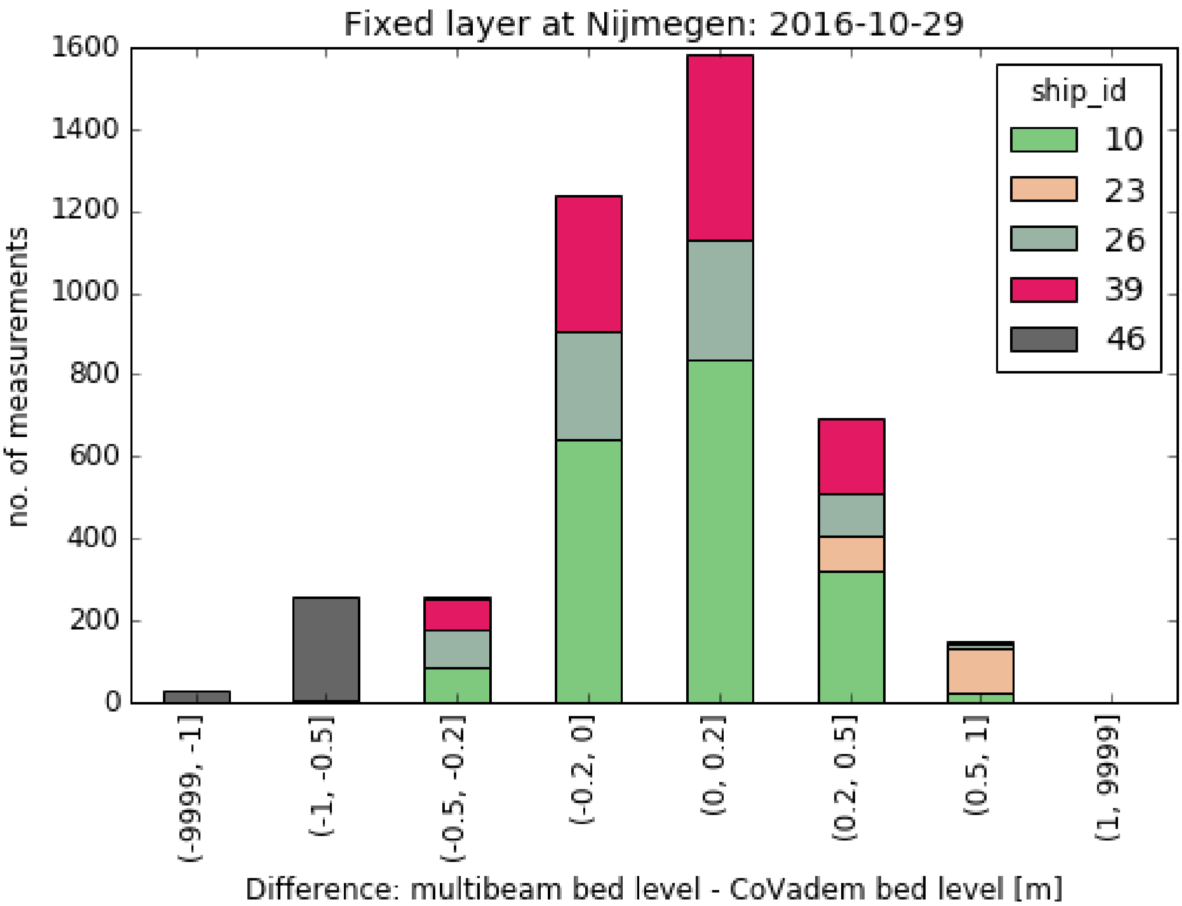

Figure 5 Comparison of CoVadem data with multibeam data for all measurements of the five vessels passing the fixed layer near Nijmegen on October 29 2016

Potential improvements due to this method

The presented validation method is first and foremost established to filter out erroneous measurements. Application allows the system to ensure that only accurate data are used in the following analyses.

It also enables us to further improve the ship squat calculation and the hydrodynamic model for the riverbed forecast. It becomes possible to compare the difference in riverbed levels from CoVadem and multibeam measurements of the current squat algorithm with those of a new algorithm over a longer time span. In this way it is possible to check whether the new algorithm indeed outperforms the old one before it is rolled out in the production environment.

Future possibilities of real time post processing

This real-time validation method can be extended to other locations with a fixed bed level. One possible location is the rocky riverbed in the Upper Rhine in Germany. Also artificially created structures, such as locks, offer the possibility of automated validation.

In the future, when the nature of the most critical erroneous measurements is understood, we will continue development towards implementation of real-time calibration of water depth measurements to correct for a structural vertical offset. This allows for the creation of more accurate depth charts without having to perform expensive calibrations on board of the individual participating vessels.

References

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Van der Mark C.F., Vijverberg T., Ottevanger W. (2015). Validation of Actual Depth Measurements by Inland Vessels, Smart Rivers 2015, Buenos Aires, Argentina.

https://www.covadem.org/

Biography

Ir. A. (Anke) Cotteleer studied marine technology at Delft University of Technology. She started her carrier in the offshore industry as marine engineer at Heerema and later at Aker Solutions where she was responsible for calculations regarding the design and installation of offshore platforms. Since 2010 she works at MARIN and performs research on marine traffic flows. Currently, she is involved in the CoVadem initiative as a data scientist.

Dr. Ir. C.F. (Rolien) van der Mark studied Civil Engineering at Delft University of Technology. She did her PhD research at Twente University on river bed forms. Since 2009 she is an expert in the field of inland shipping and river dynamics at Deltares. Within Deltares she is responsible for the portfolio and R&D programme “Inland waterways”. She has been involved in and in charge of consultancy and research projects dealing with navigability of inland waterways, river hydraulics and morphology and numerical modelling. Van der Mark is involved in the Dutch CoVadem initiative in which a fleet of inland ships continuously measures underkeel clearance, and these data are aggregated in a smart way and given back to the skippers for the purpose of more efficient sailing. Examples of other projects are the effects of measures on maintenance dredging, impact of drought on navigation in the Dutch rivers, impact of larger ships and propeller jets on bed and banks of the Gouwe. Furthermore she is involved in the development of a Deltares Toolbox for River and Inland Shipping.