Satellite altimetry Cal/Val for inland waters: How to couple FDRs and TDPs to FRMs?

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A fully metrological approach

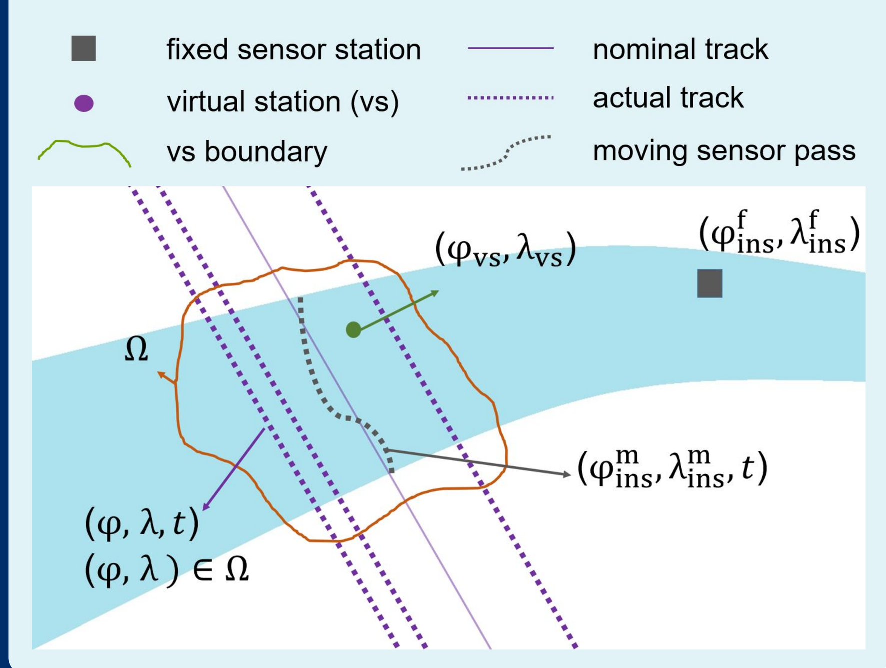
to validating satellite altimetry products is quite cumbersome. Our study establishes a general framework to validating Thematic Data Products (TDPs) against Fiducial Reference Measurements (FRMs) while drawing attention to the inherent connection between FRM and TDP procedures.

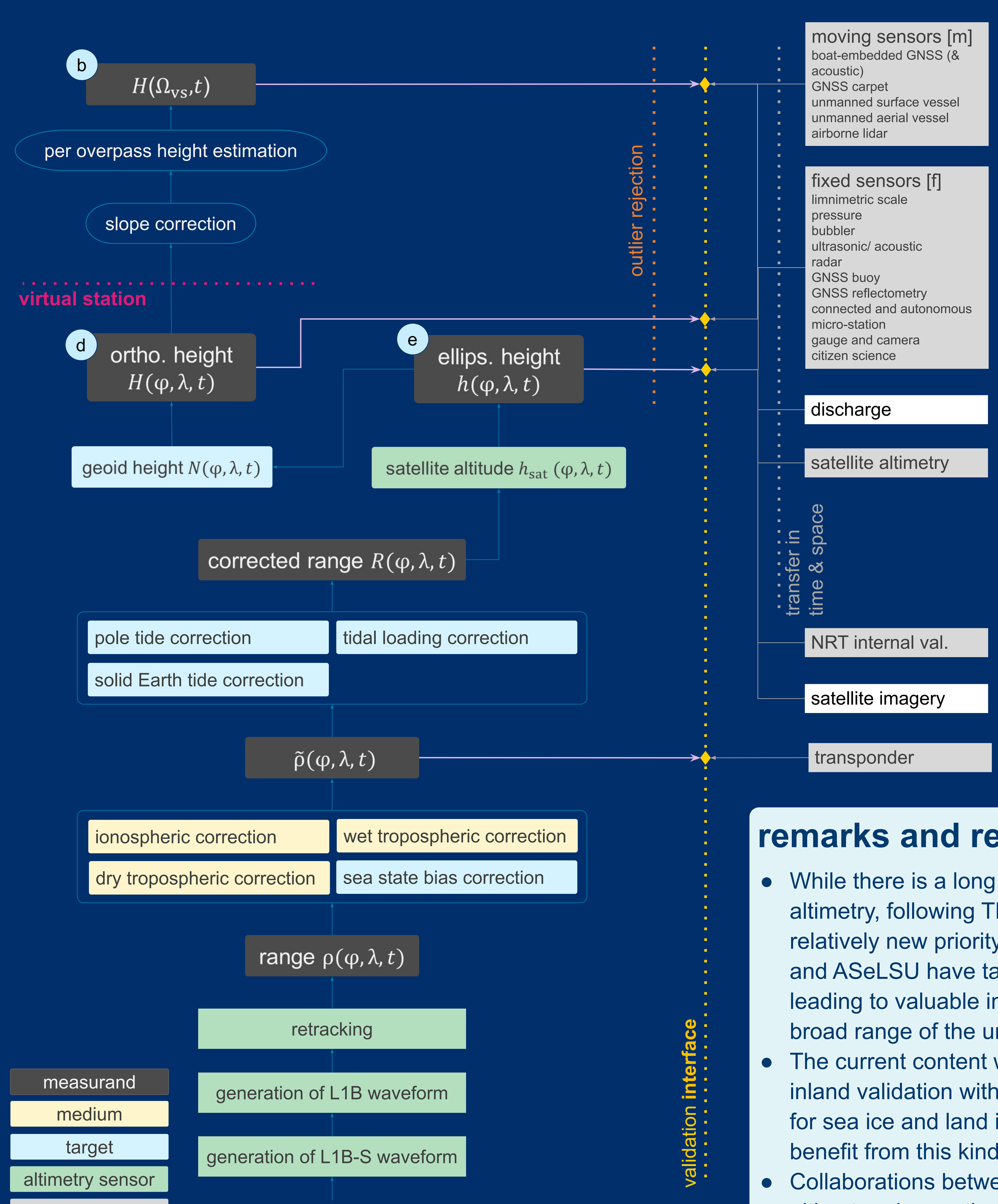
In the second half of this presentation, we focus on practical challenges in following the metrological concepts and encourage alternative solutions.

FDR and TDP

The central flowchart shows the TDP procedures by identifying the possible measurands for inland altimetry and their connection to FDRs. Validation can happen at different processing levels, with each satellite measurand validated against a different type of in situ data. To nominate the best measurand and validation scenario, however, depends on the circumstances.

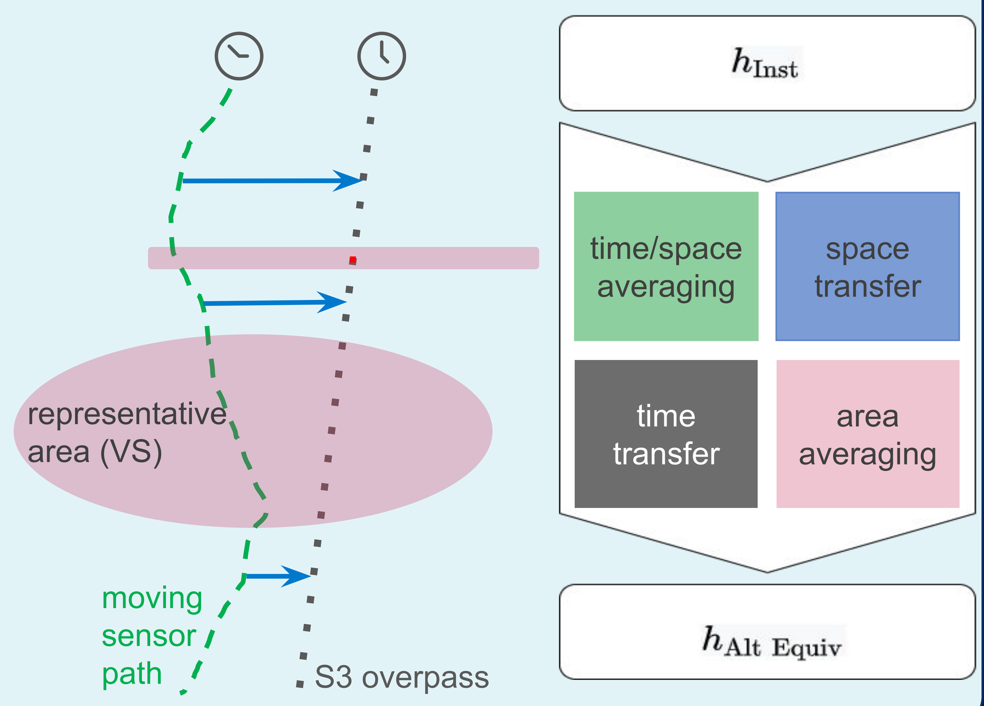
The flowchart is relevant for a generic validation set-up as depicted below.





FRM flow

It is clear that collecting in situ measurements, (here referred to as the instantaneous height) requires traceability to SI units. What is less emphasized however is the procedures required to ensure comparability between TDPs and FRMs. Depending on the validation scenario, these procedures may involve data averaging, time and space transfer, and area averaging. In practice, and due to lack of understanding, we may overlook a number of these procedures, e.g., time transfer.



remarks and recommendations

- While there is a long history to calibration/validation activities for satellite altimetry, following TDP and FRM standards in a fully metrological manner is a relatively new priority. The ongoing ESA-funded projects St3TART, FDR4ALT, and ASeLSU have targeted various aspects of such a metrological approach, leading to valuable initial outcomes. It is however important to acknowledge the broad range of the uninvestigated and further support similar activities.
- The current content was mainly developed to facilitate FRM procedures for inland validation within the St3TART project. That project will also be looking for sea ice and land ice applications. All surface types measured by altimetry benefit from this kind of analysis.
- Collaborations between metrology institutes and experts on both surface and altimeter observations are valuable.

challenges and solutions

Given that the water level time series of a virtual station is the selected measurand, on the right is the main body of an uncertainty tree diagram for the validation procedure.

The major challenge in quantifying uncertainty at level (a) is to come up with functional relationships to apply slope correction (b), time (f) and space (g) transfer.

Another source of complexity is to fully assess every single component in deriving altimetric water level in order to derive the associated uncertainties.

a $[\Delta_1, \dots, \Delta_n] = H(\phi_{vs}, \lambda_{vs}, t) - H_{Alt\ Equiv}(\phi_{vs}, \lambda_{vs}, t) + \delta$ — representation differences

b $H(\phi_{vs}, \lambda_{vs}, t) = median_{(\phi,\lambda)\in\Omega_{vs}, t_{20Hz}\in overpass} H_{sc}(\phi_{vs}, \lambda_{vs}, t_{20Hz})$

c $H_{sc}(\phi_{vs}, \lambda_{vs}, t_{20Hz}) = H(\phi, \lambda, t)_{20Hz} + dH_{slope}(\phi, \lambda, t)_{20Hz}$

d $H(\phi, \lambda, t)_{20Hz} = h(\phi, \lambda, t)_{20Hz} + N(\phi, \lambda, t)_{20Hz}$

e $h(\phi, \lambda, t)_{20Hz} = O_{sat} - R - C_{Earth\ tide} - C_{pole\ tide} - C_{tidal\ loading} - C_{SSB} - C_{wet\ trp} - C_{dry\ trp}$

f $H_{Alt\ Equiv}(\phi_{vs}, \lambda_{vs}, t) = H(\phi_{vs}, \lambda_{vs}, t') + dH_{time\ transfer}(\phi_{vs}, \lambda_{vs}, t')$

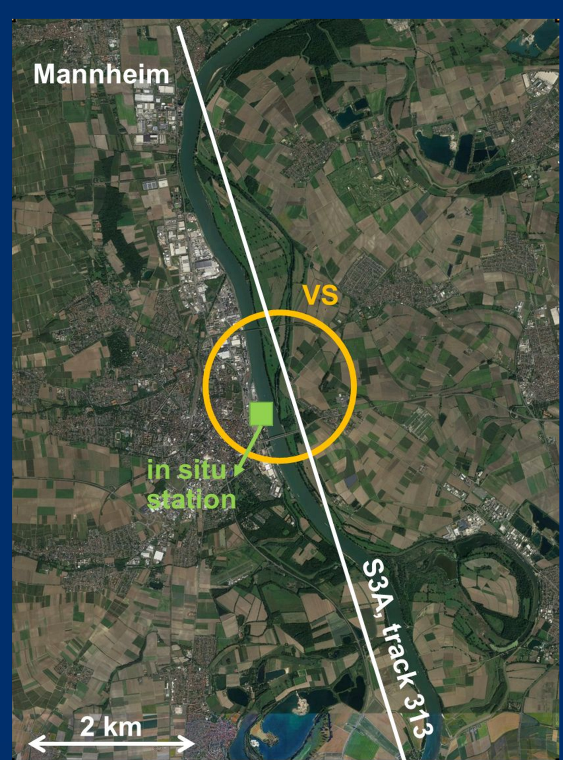
g $H(\phi_{vs}, \lambda_{vs}, t') = H_{Inst}(\phi_{ins}, \lambda_{ins}, t') + dH_{space\ transfer}(\phi_{ins}, \lambda_{ins}, t')$

h $dH_{slope}(\phi, \lambda, t)_{20Hz} = f(\phi, \lambda, t)$

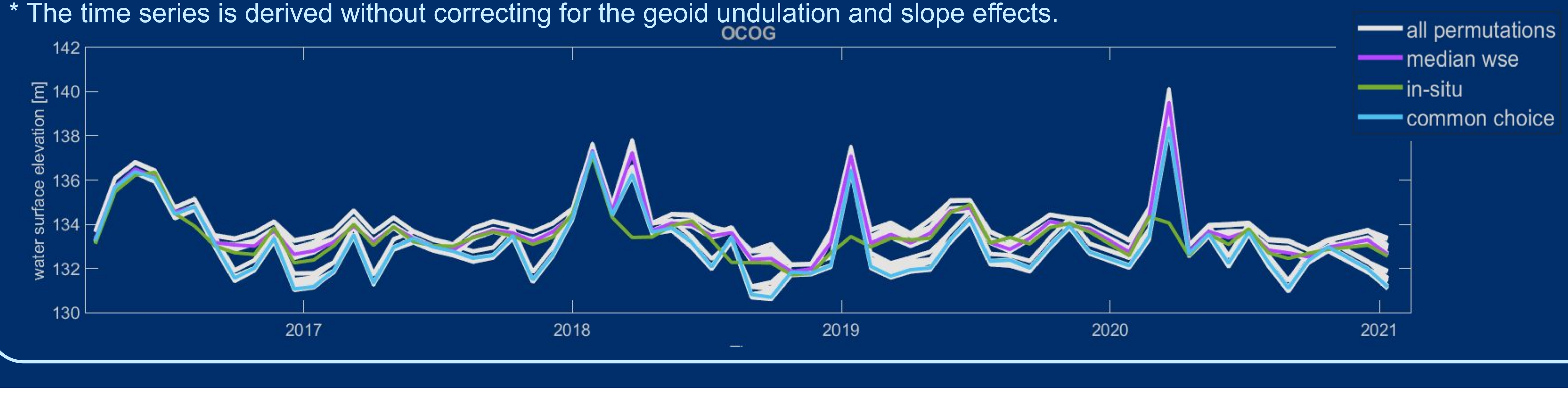
The uncertainty involved in deriving the water level time series of a virtual station (b) requires an in depth assessment of uncertainties at every processing step and associated with every single component. Depending on the situation however, we may opt for a sufficiently reliable realization of the uncertainty without the full break down of uncertainties for each component.

The figure below shows the water level time series of a virtual station over the Rhine near Mannheim in Germany. Every possible permutation of the officially distributed corrections has been used to estimate the water level. The extent to which these estimations vary is an alternative realization of a combined uncertainty.

Interestingly, the median of all permutations of corrections is a better estimator for the in situ water level than the more common choice of corrections (model wet/dry tropospheric correction at measurement altitude, 20Hz ionospheric correction, etc.). Same is true when using retrackers other than OCOG.



* The time series is derived without correcting for the geoid undulation and slope effects.



The geoid height is one of the main contributors to the uncertainty of altimetric water levels. As there is no way of 'truly' validating geoid models, our understanding of their uncertainty is limited to measures of differences between viable geoid models.

The figure below shows the differences between geoid models EIGEN6C3, EGM2008, and XGM2019 for Três Marias river and lakes Issyk-kul and Tana. As depicted, the differences at some points exceed 20 cm.