BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Supporting a Standardized Use/Definition of Uncertainty

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Introduction

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Reasoning:

- S-44 is the reference on Uncertainty for all other IHO publications.
- C-13 should better address the concept of Uncertainty.

HSPT previous work:

- Limitation #3: Limited number of definitions
- Limitation #6: Confusion between a-priori TPU and a-posteriori Qualification

Limitation #3: Limited number of definitions

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#3 – <u>Limited number of definitions</u>

- Why is it a problem?

→ It creates confusion. Ex: “detection capability” vs “feature detection”. “feature” not clearly defined. Uncertainty definition needs to be clarified

- Possible solution:

Check the International Vocabulary of Metrology

Handshake with DQWG

Excerpts from S-44 Edition 6

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From the S-44 Introduction:

S-44 vocabulary has been revised in order to more closely align with references typically used in metrology (e.g. Guide to the expression of uncertainty in measurement)

- Are we really satisfied?
- Have we really achieved this?

Excerpts from S-44 Edition 6

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From the S-44 glossary:

Total propagated uncertainty (TPU): Three dimensional uncertainty with all contributing measurement uncertainties included.

From the JCGM:

Combined Standard Measurement Uncertainty (CSMU): Standard measurement uncertainty that is obtained using the individual standard measurement uncertainties associated with the input quantities in a ***measurement model****.*

Excerpts from S-44 edition 6

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From Chapter 2.6:

A statistical method, combining all uncertainty sources for determining both the horizontal and the vertical positioning uncertainty, should be adopted to obtain THU and TVU respectively.

- *Does a statistical method suffice or should one consider a measurement model?*
- *Should the statistical method be different for the horizontal and vertical components?*

Measurement Models and Uncertainty Calculations

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Swath depth calculation model from Hare et al. (1995)

$$d = r \cos P \cos(\theta + R)$$

Special law of propagation of variances for independent random variables (algebraic form)

$$\sigma^2 = \sum_{i=1}^{N} \left(\frac{\partial d}{\partial x_i}\right)^2 \sigma_i^2$$

Measurement Models and Uncertainty Calculations

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Georeferencing Model from Seube (2020)

$$X_n = P_n + C_{bI}^{n}(C_{bS}^{bI} r_{bS} + a_{bI})$$

Law of propagation of variances for non-linear functions of random variables (matrix form)

$$\Sigma_{yy} = \mathbb{J}\Sigma_{xx}\mathbb{J}^{\top}$$

Main Questions

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1. Should the definition of TPU be aligned with that of the CSMU?
2. Should HSWG endorse a specific measurement model?
3. Should HSWG endorse a specific method to calculate TPU?

Limitation #6: Confusion b/w a-priori and a-posteriori

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#6 – Confusion between a-priori TPU and a-posteriori Qualification

- Why is it a problem:

→ A priori TPU is just an indicator and not reflects the real data quality and uncertainty after survey

- Possible solution:

In situ qualifications should be requested in order to check the a-posteriori compliancy of the survey (it doesn't has to be expressed only on Annexe A)

Excerpts from S-44 Edition 6

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From Chapter 2.6:

This estimation [THU and TVU calculations] should be updated during the survey to reflect changes from environmental conditions such as wind, waves, etc. in order to make appropriate changes to survey parameters.

- *Doesn't this sentence feel more like a guideline?*
- *How are survey parameters related to the TPU calculations?*
- *Wind and waves are not variables of the TPU calculations.*
- *Is the updated estimation an a posteriori estimation?*

Excerpts from S-44 Edition 6

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From Chapter 2.6:

Final uncertainty values for the survey may consist of an a priori and a posteriori calculation, explicitly empirical values (e.g. based on standard deviation of vertical depths alone), or some combination of the aforementioned values.

- *A posteriori hasn't been well defined in the standard*
- *Sounds like a free for all: "just pick the lowest value"*
- *Wouldn't it make sense to evaluate the calculation against the empirical value?*

Excerpts from S-44 Edition 6

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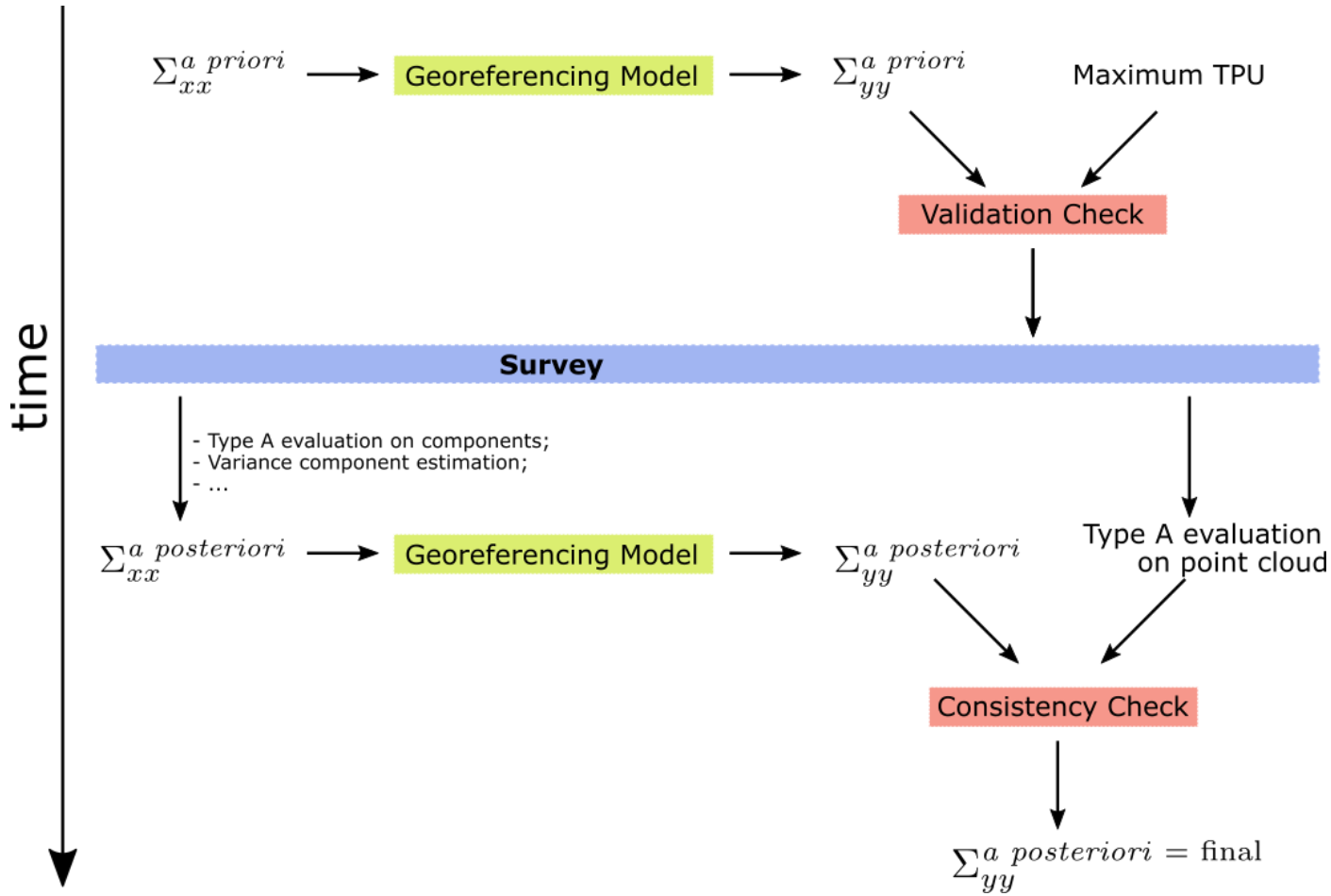
From Annex C.2:

Outside of a reference area it is not possible to determine the a posteriori uncertainty from the data set. The data set is the end result and contains all errors involved in the total process but it is not possible to calculate the a posteriori uncertainty from the data set. There are many techniques and procedures to check the hydrographic data set and they can provide proof that the data set is to be trusted, however no tool will calculate the a posteriori uncertainty of an area that is not well-known.

- *Again, a posteriori is not well defined.*
- *In adjustment theory, the a posteriori is just the result of the same functional model using optimal input variance (an possibly covariance) estimates.*

Interpretation of Survey Qualification



Main Questions

1. Which definition of a priori and a posterori should be adopted?
2. What quality metrics can be derived from the measured point cloud?
3. Which uncertainty should be considered the **final** uncertainty?

References

Hare, R., Mayer, L., & Godin, A. (1995). *Accuracy estimation of Canadian Swath and Sweep sounding systems*. Technical report, Canadian Hydrographic Service.

Seube, N. (2020). Validation of lidar survey data by comparison of several uncertainty models. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLIII-B3-2020*, 1385-1390. doi:10.5194/isprs-archives-XLIII-B3-2020-1385-2020