Application of metrological principles to EO

IDEAS-QA4EO Cal/Val Workshop#5
11th - 13th June 2024
Thessaloniki, Greece

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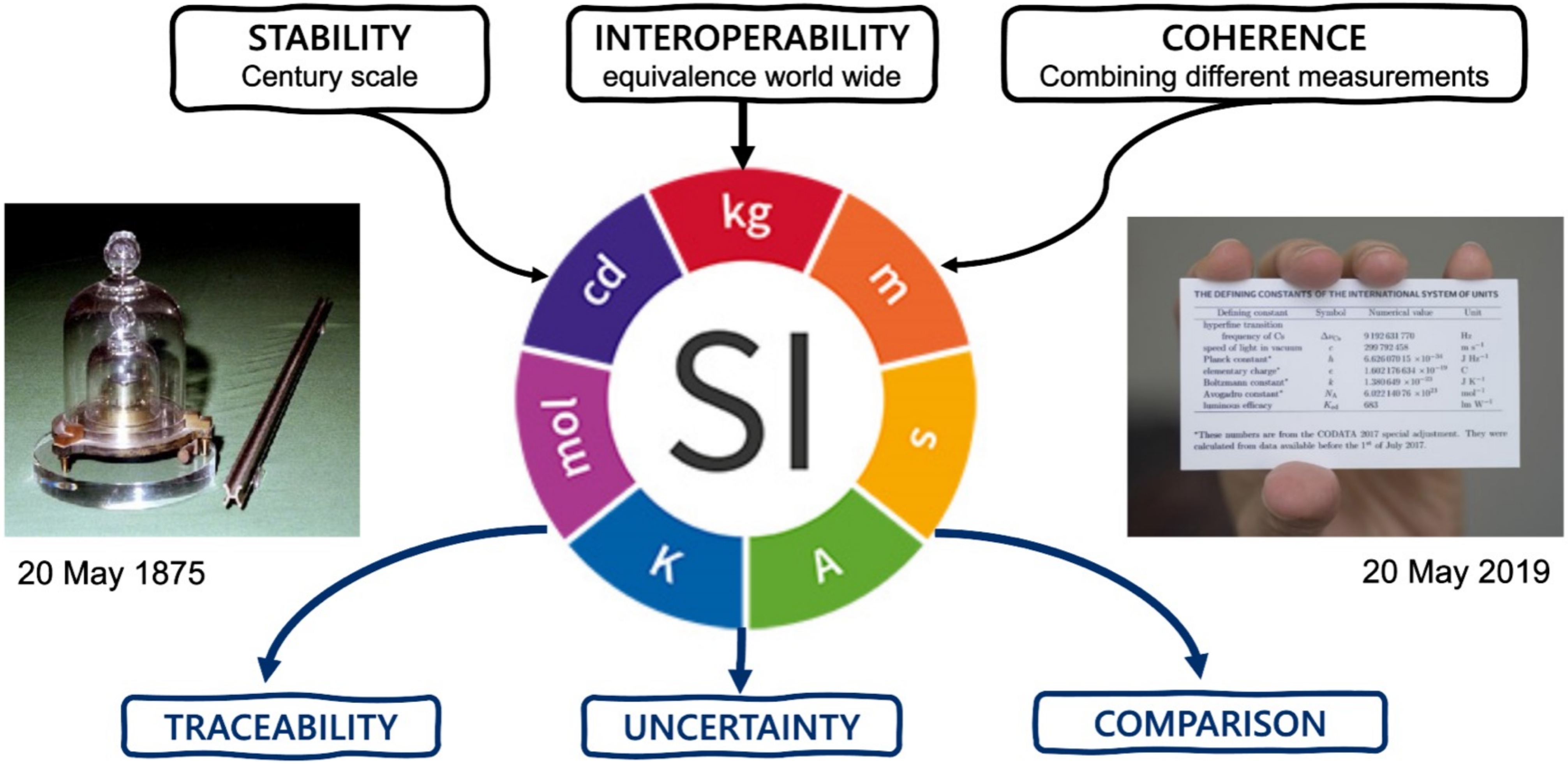
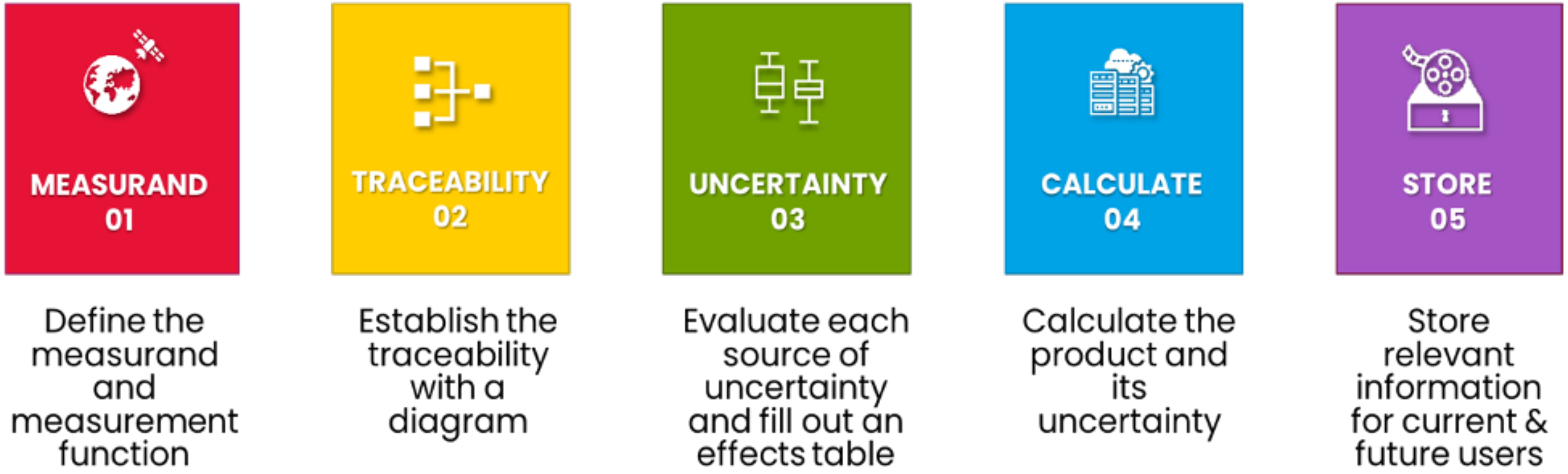
core principles of metrology



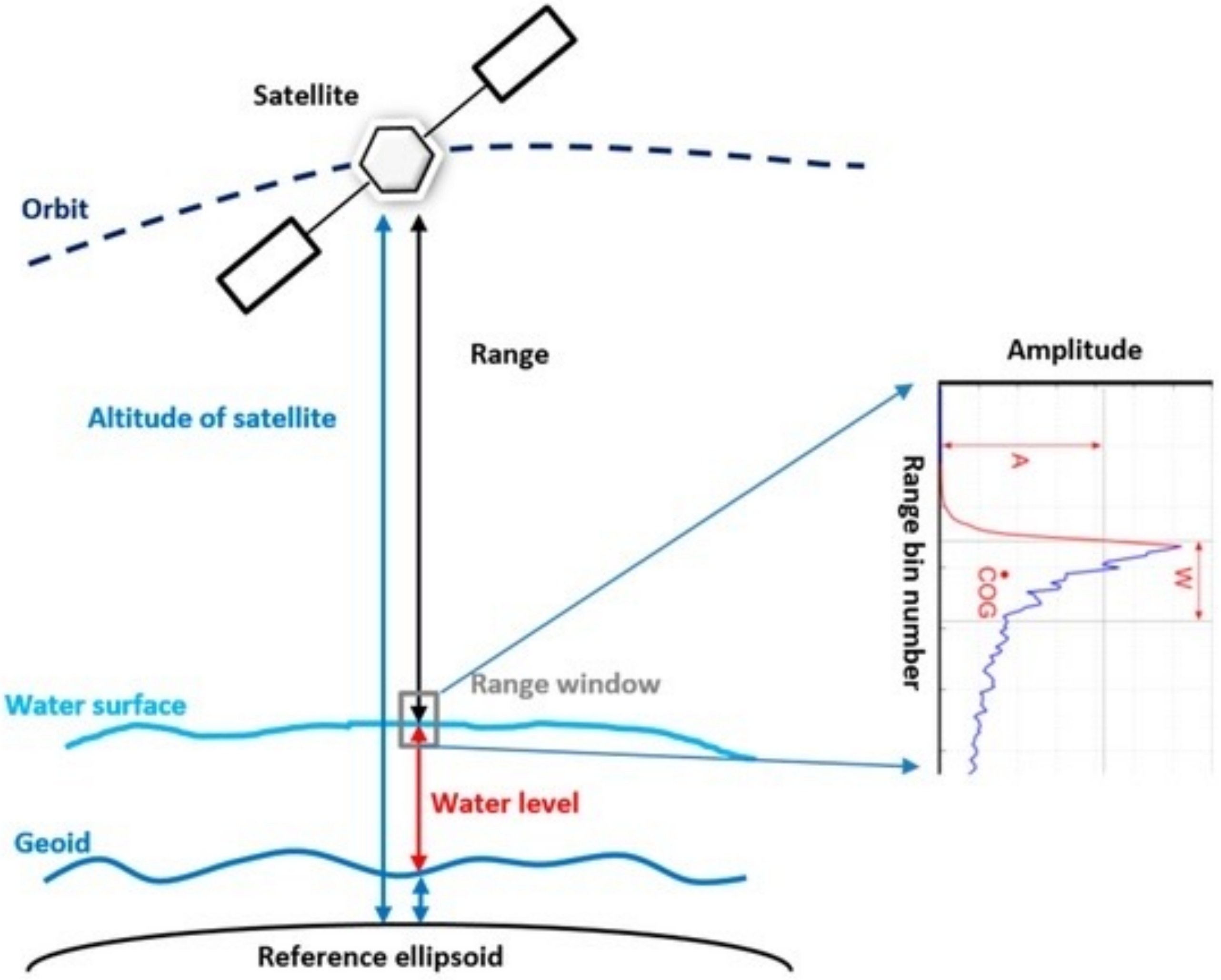
applying metrological principles to EO data

QA4EO defines high level frameworks to guarantee Quality Assurance for Earth Observation. Following the guidelines set by the FIDUCEO project, the steps to FDR/TDP or FRM uncertainty budget is currently defined as:



Guidance documentation and training material is available at www.qa4eo.org.

satellite radar altimetry & its applications

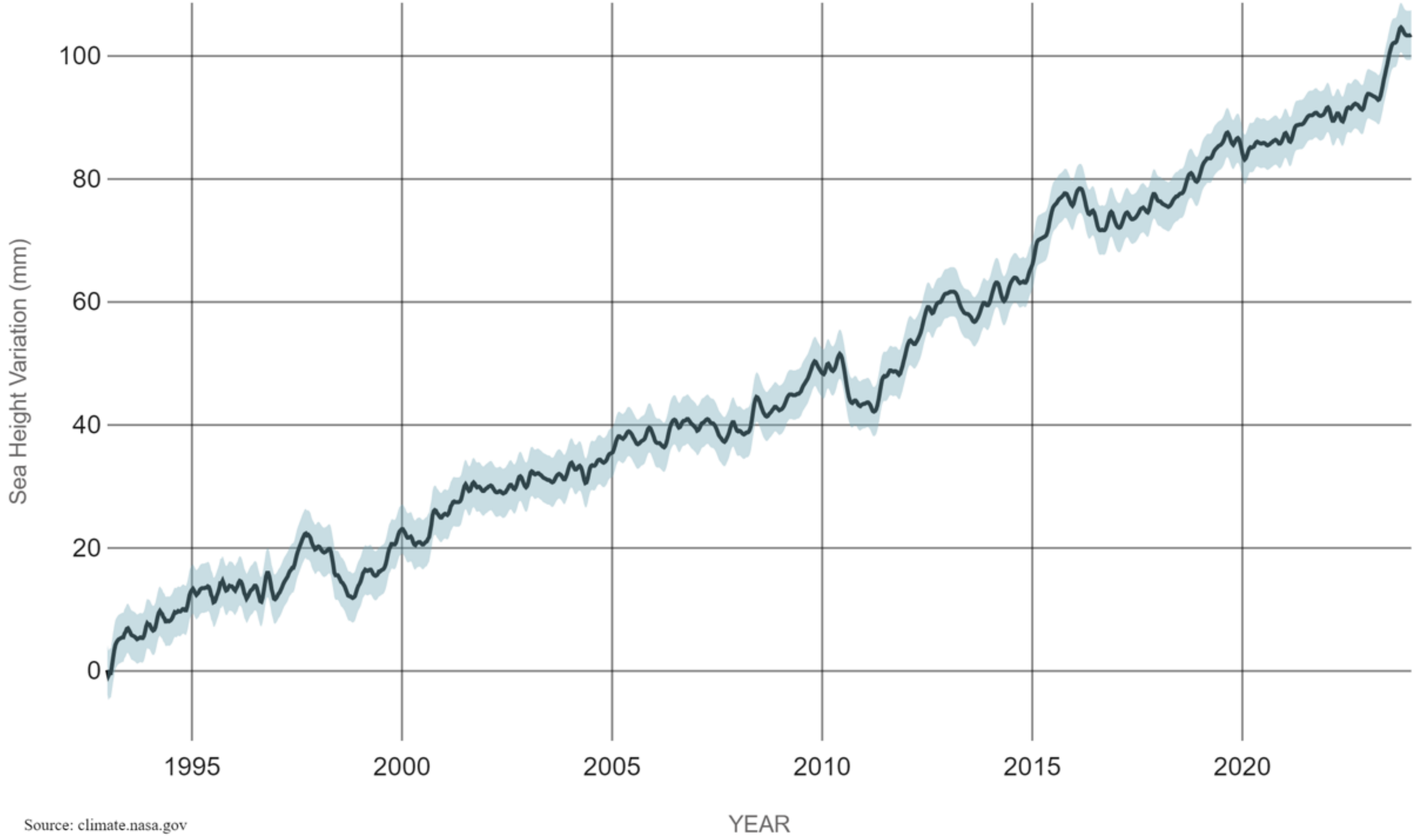


Jiang et al., (2017). CryoSat-2 altimetry applications over rivers and lakes. Water, 9(3), 211.

satellite radar altimetry & metrology

- ASeLSU & ASeLSU-FO

  ESA-funded project Assessment Sea Level rise Stability Uncertainty

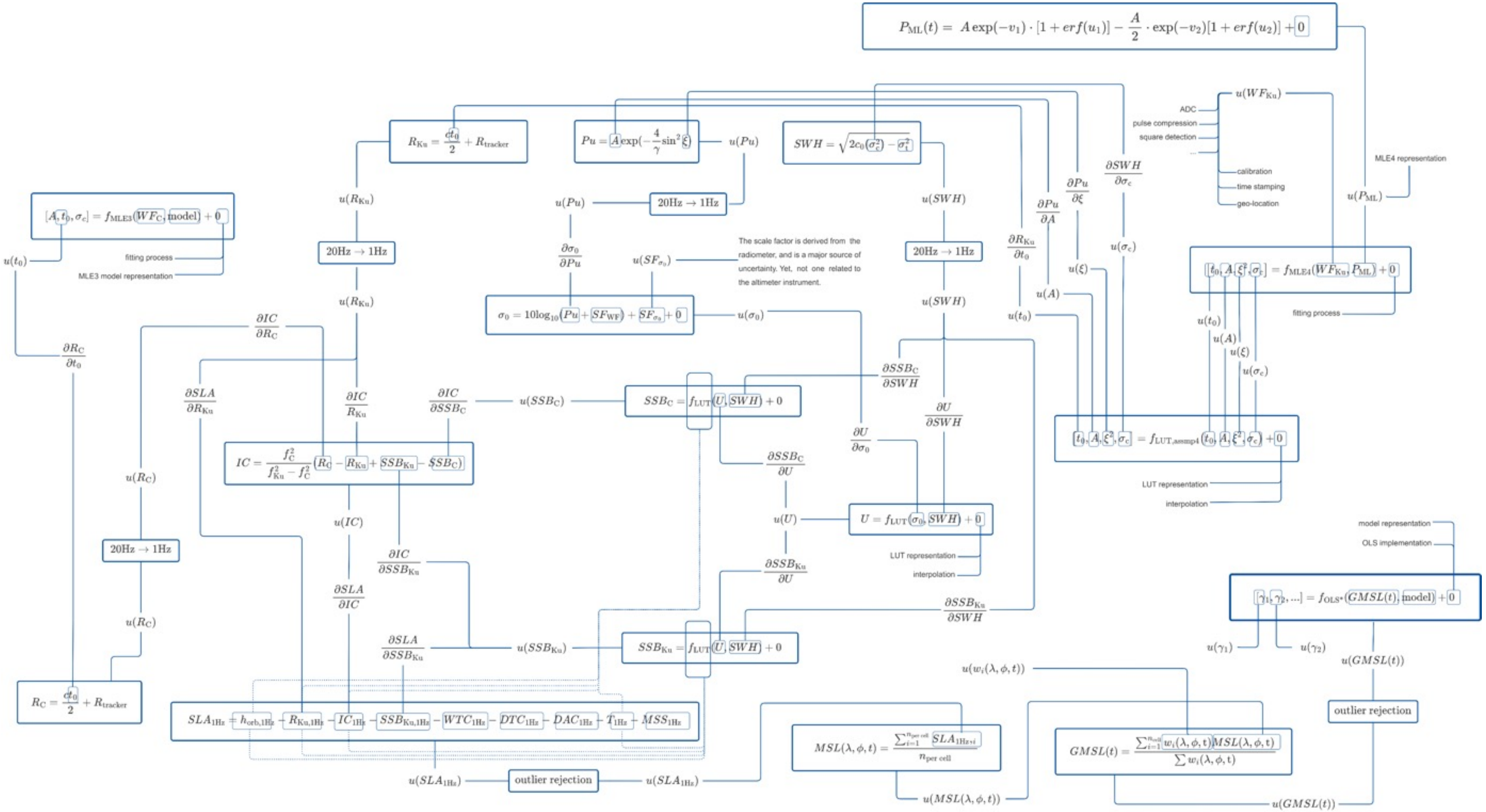


Source: climate.nasa.gov

satellite radar altimetry & metrology

- ASeLSU & ASeLSU-FO

ESA-funded project Assessment Sea Level rise Stability Uncertainty



satellite radar altimetry & metrology

- S3NGT-MPUA (ESA)

  Sentinel-3 Next Generation Topography mission

  preliminary Mission Performance and Uncertainty Assessment

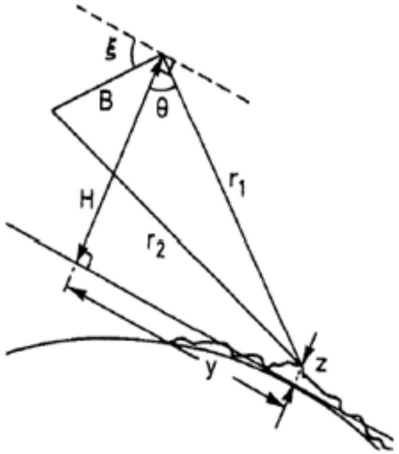
$$z = H - r\cos(\theta) + 0$$

$$\cos(\theta) = \cos(\xi)\sqrt{1-\sin^2(\theta-\xi)} - \sin(\xi)\sin(\theta-\xi)$$

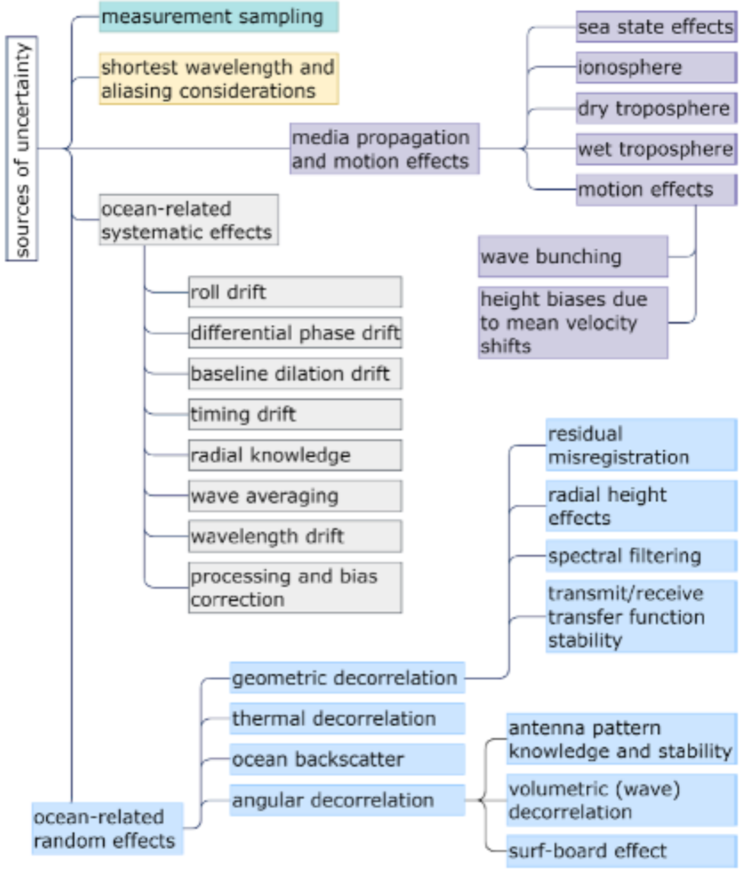
$$\sin(\theta-\xi) = \frac{(r+\Delta)^2 - r^2 - B^2}{2Br}$$

$$\Delta = -\frac{\Phi}{k}$$

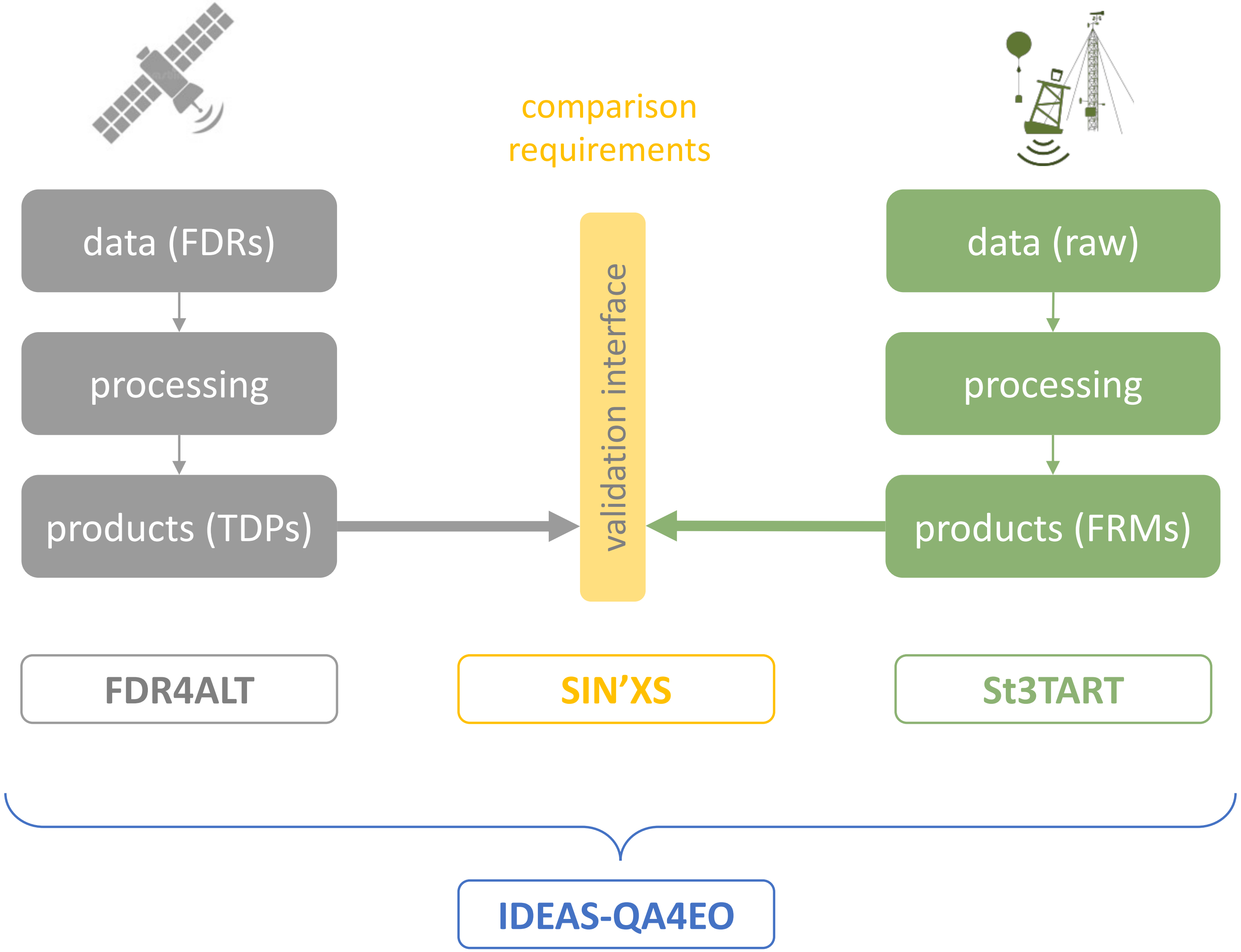
$$\Phi = \arctan\left[\frac{\mathrm{Im}(\Sigma_{n=1}^{N_L}\nu_1^n\nu_2^{*n})}{\mathrm{Re}(\Sigma_{n=1}^{N_L}\nu_1^n\nu_2^{*n})}\right] + 0$$

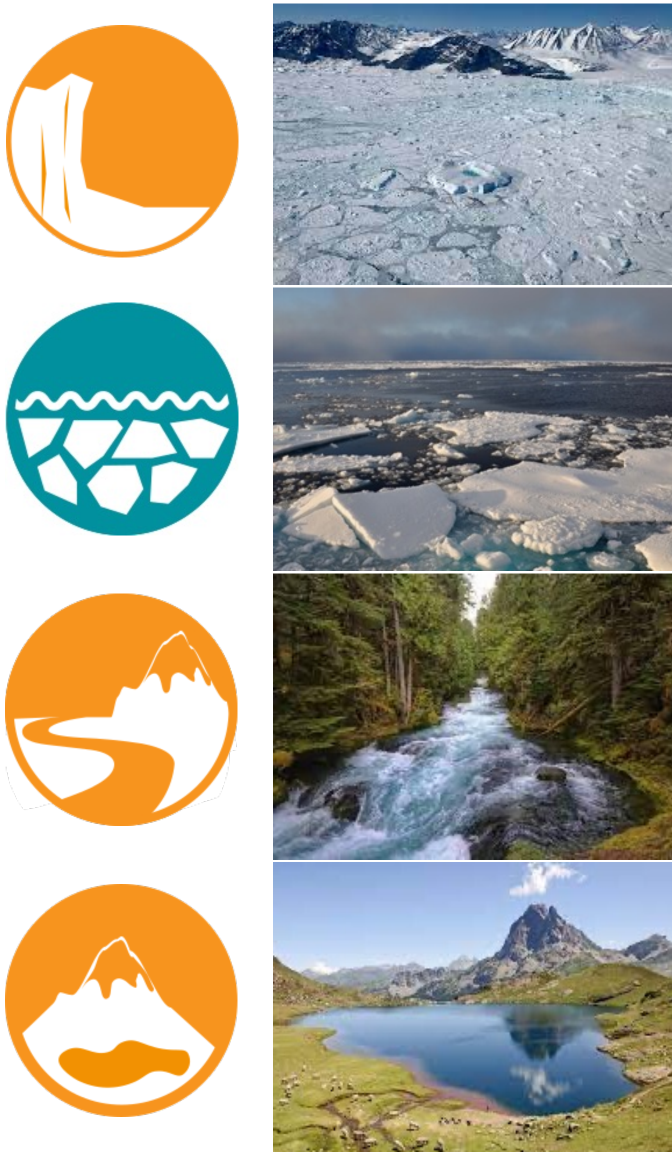


ξ : baseline tilt angle
θ : radar look angle
B : baseline length
z : height above local tangent plane
H : orbit height
r : range
Φ : differential phase
k : wave number
ν : received interferometer signal
N_L : number of look looks



satellite radar altimetry & metrology





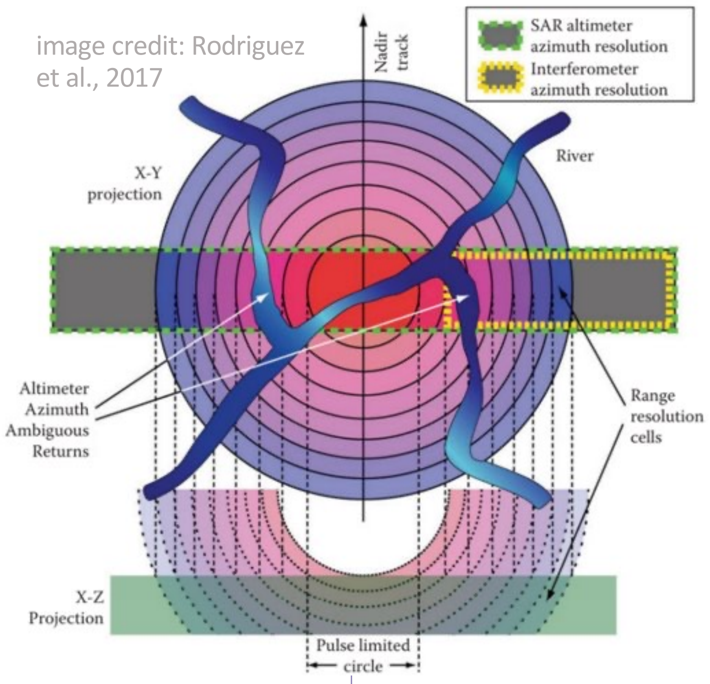
IDEAS-QA4EO case study: altimetry for hydrology

- GCOS identifies river discharge and lakes as ECVs and sets requirements on their products.
- Satellite radar altimetry is arguably one of the strongest means available to the hydrology community for monitoring inland water bodies because of its benefits of continuity, global coverage, open access, and insensitivity to light and cloud conditions.
- Both WMO and altimetry communities have raised concerns about lack of methodological attribution of uncertainty to data, proper archiving of processes and procedures and effective communication of uncertainty information to end-users.
- Through this case study, we are aiming at reviewing the literature to provide an overview of the available strategies towards quantifying uncertainties of hydrologic variables as derived from satellite altimetry data; while also identifying scientific gaps, challenges put forward by new mission concepts, and mismatch between reported uncertainties and requirements.

image credit: modified from gcos.wmo.int

IDEAS-QA4EO case study: motivation

image credit: Rodriguez et al., 2017



- levels of measurands
- data dissemination entities
- leve-2 and level-2+ data providers
- consistency of methods and interpretations

- maturity of FRMs
- cal-val approaches
- comparisons of comparisons

- GCOS requirements
- application-specific requirements
- interpretation of GCOS requirements

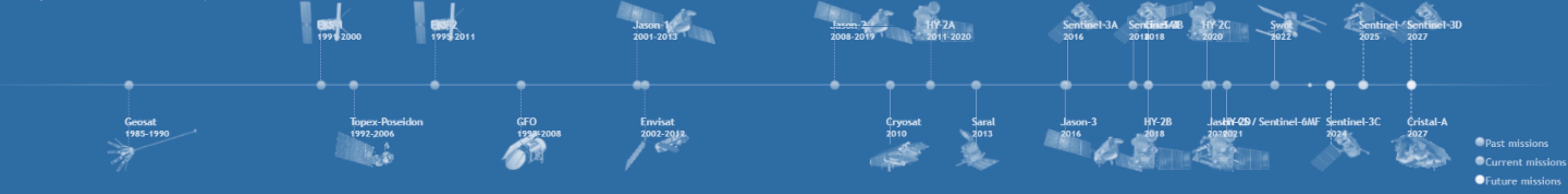
uncertainties?

- spatio-temporal coverage
- spatio-temporal resolution

- requirements on different processing techniques
- framework for inter-mission comparisons
- traceability to processing techniques
- uncertainty of input FDRs and low-level models

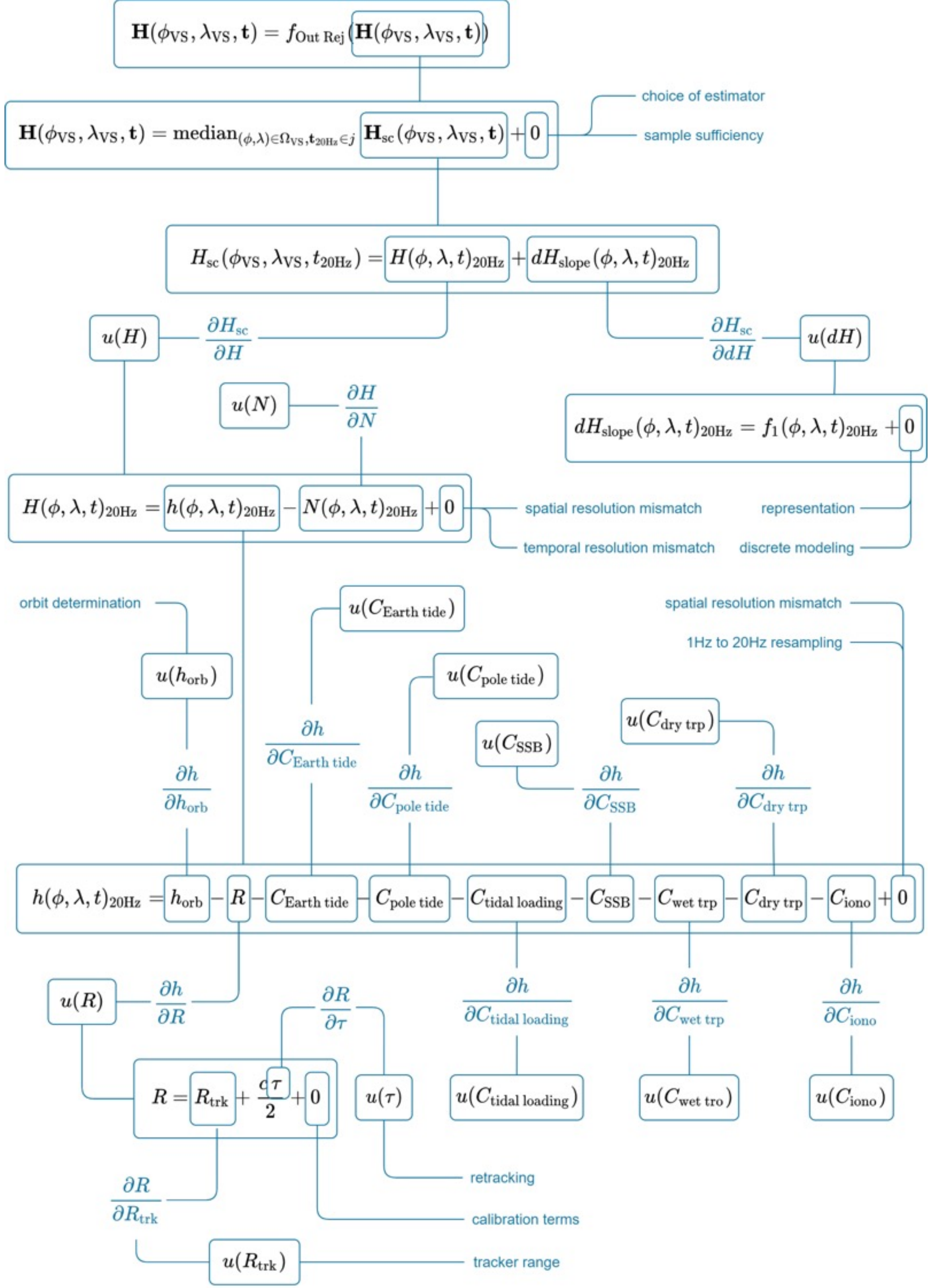
- requirements on multi-mission products for inland applications
- major challenges in meeting multi-mission requirements
- compatibility of mission-level and application-level requirements

image credit: aviso.altimetry.fr



traceability

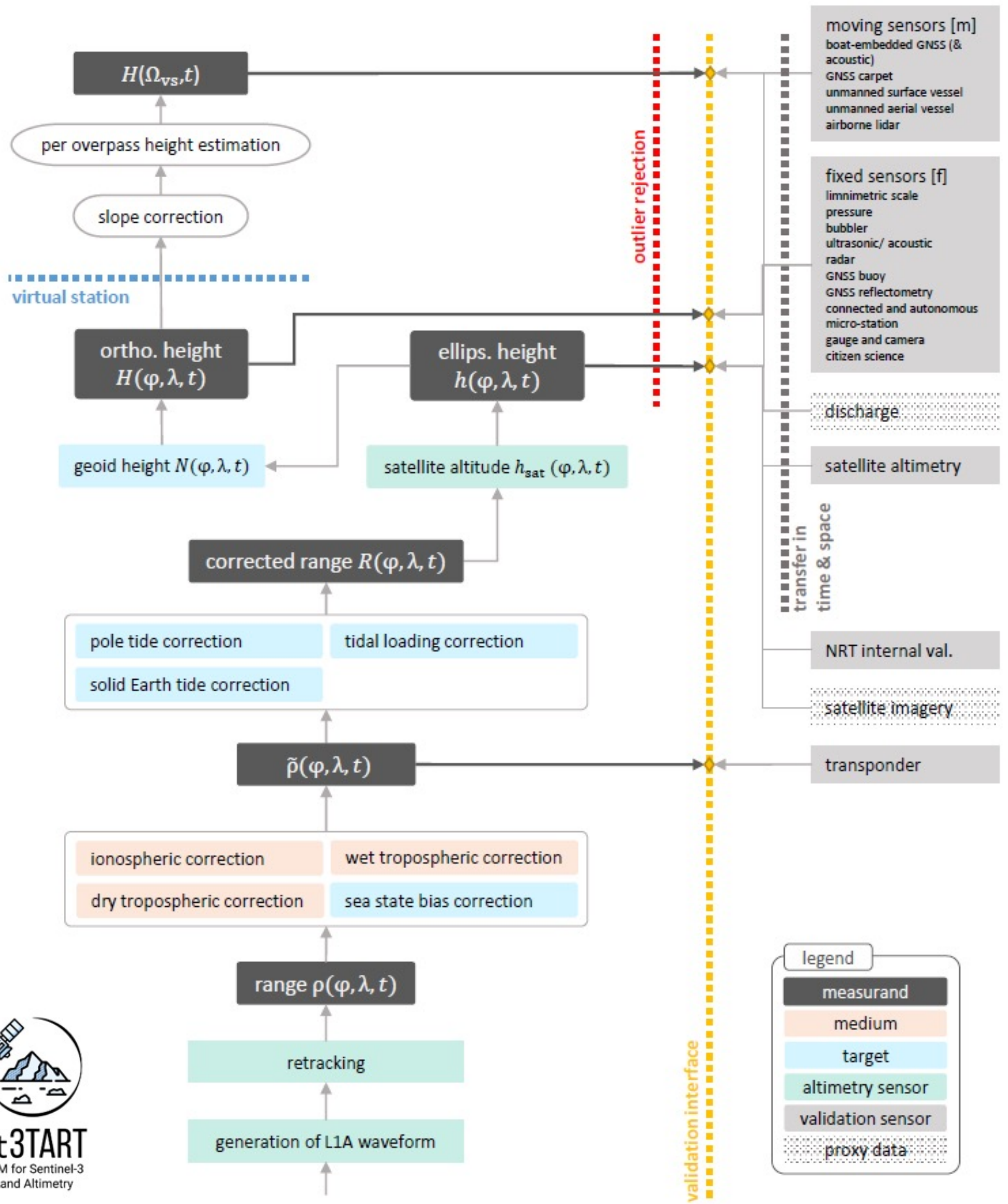
- good examples of flow diagrams, especially from level-2 data providers
- lack of mathematical formalism of measurement functions
- un-traceability of visual inspection processes, e.g., outlier detection
- lack of traceability in documenting inter-track and inter-mission bias corrections



St3TART
FRM for Sentinel-3
Land Altimetry

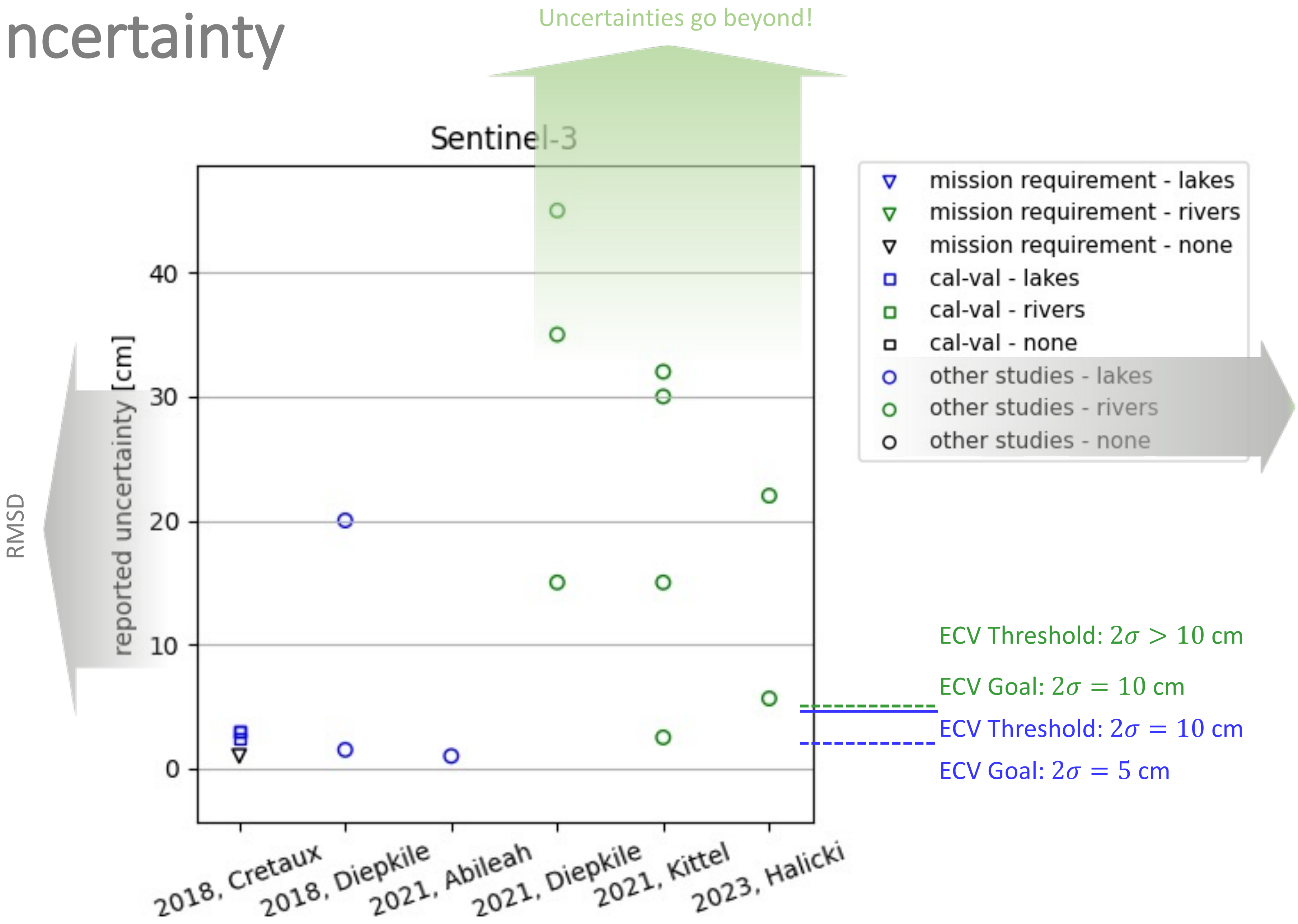
comparison

- comparisons as means of deriving uncertainties
  - Ideally, we want to estimate the uncertainty of both the satellite measurand and the equivalent in situ measurand, e.g., and FRM, and compare those uncertainties. In practice, a comparison is often carried out to provide a realization of uncertainty, only.
- comparison as means of validation
  - single-measurand comparison
  - multi-measurand comparison
- transfer methods
  - unrealistic realizations of uncertainty
  - implementation challenges



St3TART
FRM for Sentinel-3 Land Altimetry

uncertainty



- external realization of uncertainty
- under-characterized uncertainty of validation data
- no (or simplistic) account of data transfer uncertainties

identified needs

- terminology
  - ‘bias’ and ‘accuracy’ as a set of uncertainty indicators (Cretaux et al., 2018)
  - ‘We refer to error in ranging as precision and error in surface levels as accuracy.’ (Abileah and Vignudelli)
- defining standard uncertainty characterization framework
  - How to interpret the effect of subjective choices in data processing – e.g., spatial boundary selection criteria?
  - What is the minimum time frame (or sample count) for deriving uncertainties?
  - How shall we associate uncertainties to manual processes – e.g., outlier detection?
- transfer uncertainties – major challenge ignorance of which leads to over-estimation of uncertainties
- satellite track deviation – significant effect on river uncertainty estimates
- focus on comparisons!

outlook: links to other ESA projects

- developing first draft of quality assessment guidelines for satellite altimetry products over
  - inland waters
  - sea ice
  - land ice

Grade	Criteria
Not Assessed	Assessment outside of the scope of study.
Not Assessable	Relevant information not made available.
Basic	Traceability chain diagram and/or uncertainty tree diagram included, but missing some important steps.
Good	Traceability chain and/or uncertainty tree diagram documented identifying the most important steps and sources of uncertainty.
Excellent	Rigorous uncertainty tree diagram, with a traceability chain documented, identifying all reasonable steps and accompanying sources of uncertainty.
Ideal	Rigorous uncertainty tree diagram and traceability chain documented, identifying all reasonable steps and accompanying sources of uncertainty. Establishes and evidences full traceability to SI.

Self-Assessment					Independent Assessor
Nature of FRM	FRM Instrumentation	Operations/ Sampling	Data	Metrology	Verification
Descriptor	Instrument documentation	Automation level	Data completeness	Uncertainty characterisation	Guidelines adherence
Location/ availability of FRM	Evidence of traceable calibration	Measurand sampling/representativeness	Availability and Usability	Traceability documentation	Utilisation/Feedback
Range of instruments	Maintenance plan	ATBDs on processing/software	Data format	Comparison/calibration of FRM	Metrology verification
Complementary observations	Operator expertise	Guidelines on transformation to satellite Pixel	Ancillary data	Adequacy for intended class of instrument/measurand	Independent verification
				FRM CLASSIFICATION	**A B C D** (to be selected)