FRM4ALT



Fiducial Reference Measurements for Altimetry





Accurate monitoring of sea-level changes:

- Crucial for long-term climate change;
- Valuable in understanding oceans;
- Essential on explaining weather patterns.



ERS-1

Sea Level Trend 1993-01/2012-12 (mm/Yei

TOPEX/Poseidon

Satellite altimetry:

1985

1985

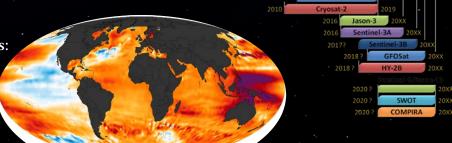
- Monitor changes in sea level;
- Continuously, unequivocally,
- Regional to global scales;
- With [mm/yr] accuracy;
- With respect to the center of mass of the Earth.



FRM to establish:

Monitoring of ocean and its changes:

- Objectively,
- Continuously,
- Homogeneously,
- Reliably.
- Free of errors and biases;
- Uninterrupted;
- Tied from one mission to the next.



2003

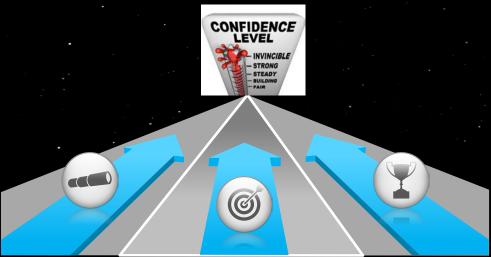
2009

2026

FRM Concept



"Independent ground measurements that provide the maximum <u>Return On Investment</u> for a satellite mission by delivering to users the required **confidence** in data products, in the form of **independent validation** results and satellite measurement **uncertainty estimation**, over the entire end-to-end duration of a <u>satellite mission</u>." Sentinel-3 Validation Team



Vision:

Independent, external calibration & validation of ALL altimetry missions.

Mission:

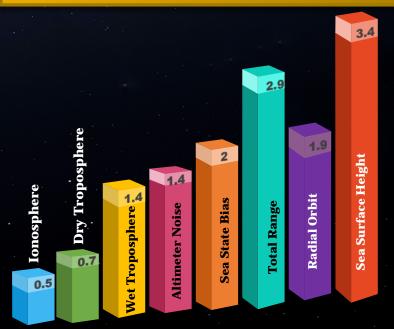
Documented SI-traceability of Cal/Val procedures, protocols, results with uncertainty budgets.

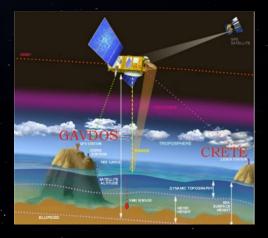
Goal:

Open & transparent FRM measurements, protocols and best practices.

➡ Uncertainties in Satellite Altimetry Sea-Surface Height

- Diverse satellite altimeters [S-3, Jason, CryoSat-2, HY-2, SARAL]
- Variant measuring techniques [LRM, SAR, SARIn, SWOT,...]
- Various operating frequencies (Ku, Ka, X-band, etc.)





Need to maintain an absolute Cal/Val site to:

- Regularly define,
- Control and
- Evaluate responses of any altimetric system.

SSH error budget [cm] for S-3 STM (Donlon et al., 2012).

Satellite Altimetry Cal/Val

"Calibration: Process of quantitatively defining the system responses to known, controlled signal inputs. Validation: Process of assessing, by independent means, the quality of the data products derived from the system outputs." Committee on Earth Observation Satellites

Microwave transponders are to calibrate

- altimetric range;
- Sigma0;
- Time-tagging errors;
- Baseline orientation in space.

Permanent Cal/Val facilities equipped with GNSS, tide gauges, buoys, meteorological sensors, etc., established near, but not exactly under the valid satellite measurements.

Relative Absolute
Prirect
Relative
Relative

Multi-mission cross-over calibration between different altimetry missions.

Tide gauge network to determine regional & global long-term (seasonal) trends in sea-level variation.



→ The FRM4ALT approach



Estimate the TRUE (accuracy) range between the satellite and the sea-surface using external means and the corresponding uncertainties (precision).

Accuracy

Problem of mean



Low Accuracy **High Precision** Precision

Problem of Variation



High Accuracy Low Precision

Step 1: Review of Components

Step 2: Procedures, **Protocols & Best Practices for FRM**

Step 3: Procedures to maintain uncertainty budget

Cal/Val Absolute

Coordinates

Time reference

Cal/Val Site location

Exhaustive Statistical analysis of any cause of uncertainty on:

Water Level

Atmospheric delays Control ties & Ground

monitoring

Geophysical effects Geoid & MDT models

Multi-Constellation Positioning (GNSS + DORIS + SLR)

Well-defined MWR, HF radar, Gliders, etc processing strategies & Software

Tide gauges: Diverse types & makes (acoustic, pressure, radar,...)

Measurement stability, linearity, accuracy, spectral characteristics, operating conditions, ...

Standardized procedures for FRM traceability

Quality control of observations & results

Regular in-situ instrument characterization & processing evaluation

High Accuracy High Precision

FOR EACH INDEPENDENT CAL/VAL METHODOLOGY (sea-surface. transponder, cross-calibration,..)

Permanent Facility for Altimetry Calibration Sea Surface Cal/Val OCC GAVDOS

Fiducial Reference Measurements for Altimetry (FRM4ALT) www.frm4alt.eu







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