

***FRM4ALT***

**Fiducial Reference Measurements for Altimetry**



## → Aim

Accurate monitoring of sea-level changes:

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

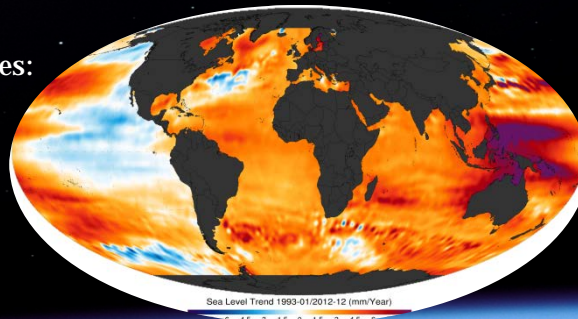


### Satellite altimetry:

- 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:

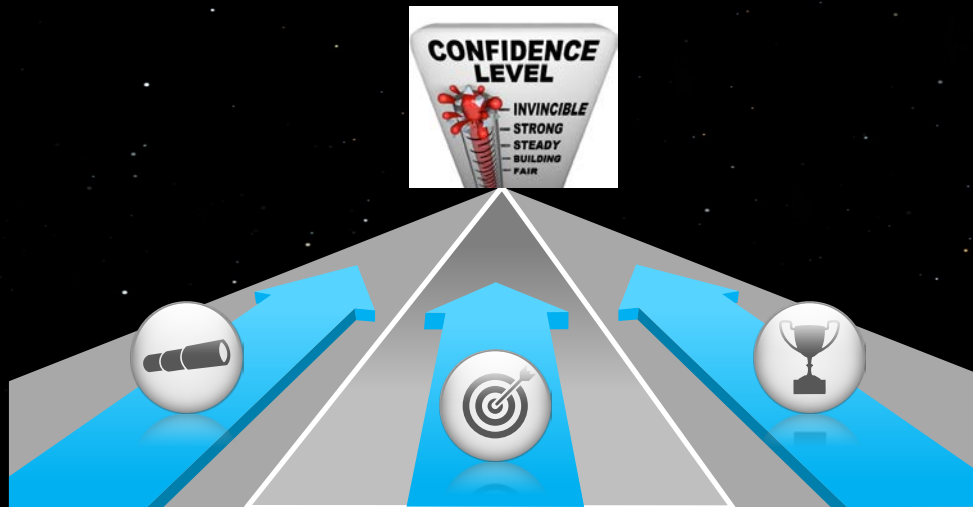
- Monitoring of ocean and its changes:
  - Objectively,
  - Continuously,
  - Homogeneously,
  - Reliably.
- Free of errors and biases;
- Uninterrupted;
- Tied from one mission to the next.





# FRM Concept ←

*“Independent ground measurements that provide the maximum Return On Investment 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 satellite mission.”* Sentinel-3 Validation Team



## **Vision:**

Independent, external calibration & validation of ALL altimetry missions.

## **Mission:**

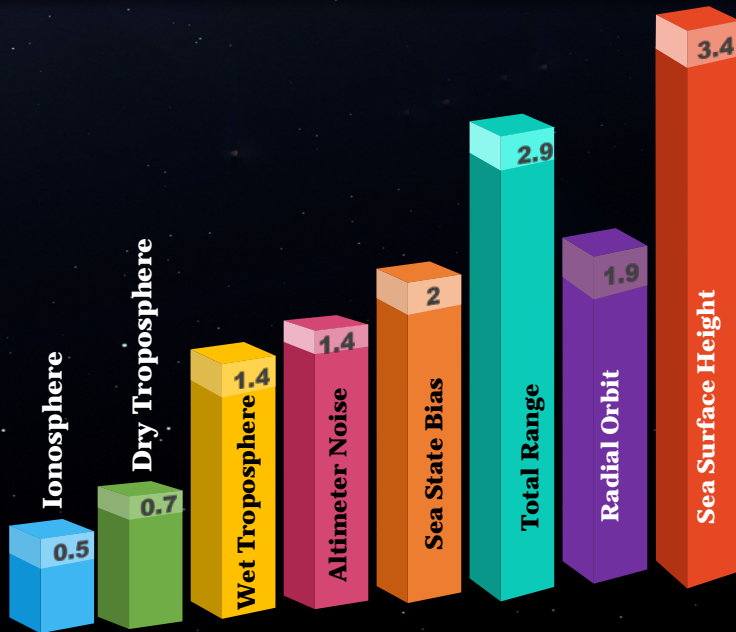
Documented SI-traceability of Cal/Val procedures, protocols, results with uncertainty budgets.

## **Goal:**

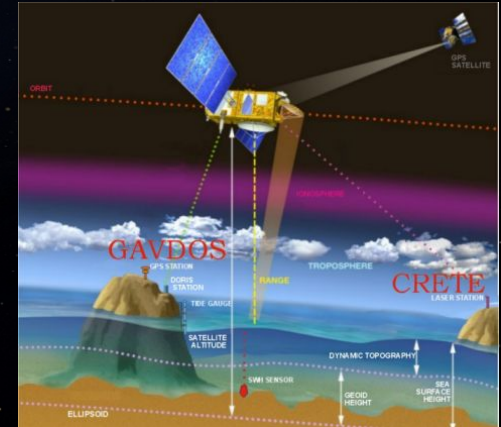
Open & transparent FRM measurements, protocols and best practices.

# ➔ 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.)



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



Need to maintain an absolute Cal/Val site to:

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

# Satellite Altimetry Cal/Val ←

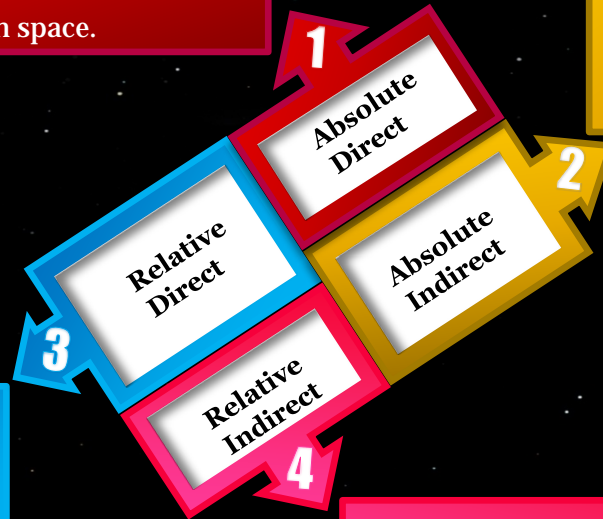
**“Calibration:** Process of quantitatively defining the system responses to known, controlled signal inputs.

**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.



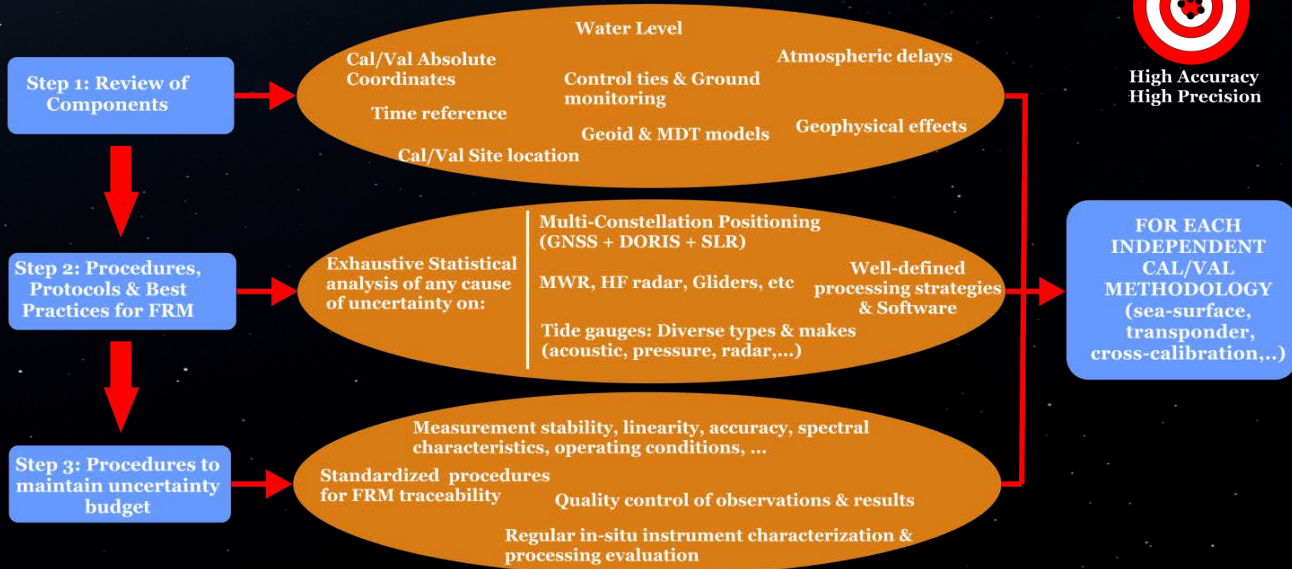
Multi-mission cross-over calibration between different altimetry missions.

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

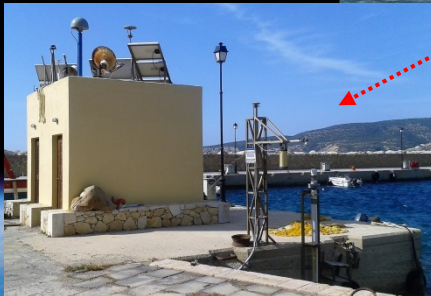
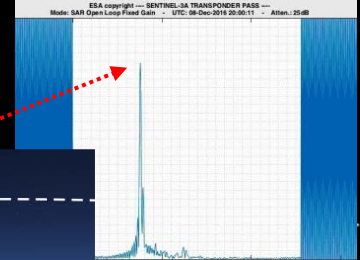
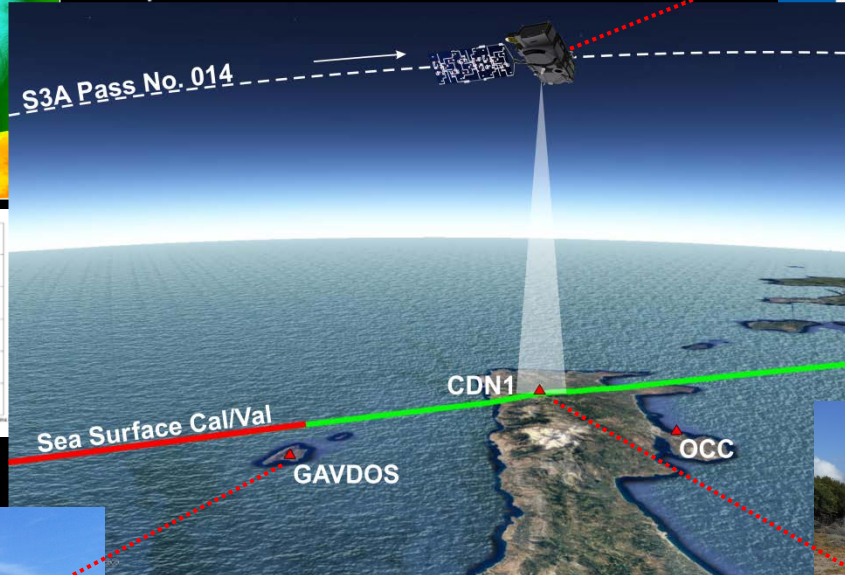
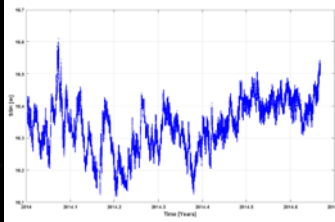
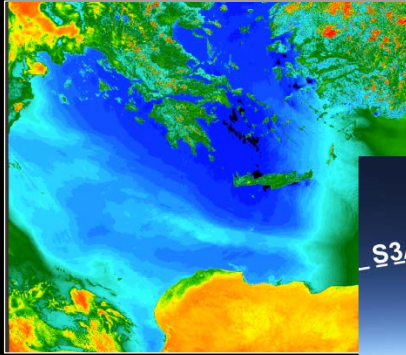


**Precision**  
Problem of Variation





# Permanent Facility for Altimetry Calibration



# Fiducial Reference Measurements for Altimetry (FRM4ALT)

[www.frm4alt.eu](http://www.frm4alt.eu)



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