Fiducial Reference Measurements for Satellite Altimetry Calibration in Crete, Greece

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Abstract

To establish a continuous, homogeneous and reliable monitoring of the ocean and its changes, altimetry observation have to be free of errors and biases, uninterrupted, but also tied from one mission to the next in an objective and absolute sense. Altimetry system's responses have to be, thus, continuously monitored and controlled for their quality, biases, errors, drifts, although relations among different missions have to be established on a common and reliable earth-centered reference system, maintained over a long period of time.

The objective of this presentation is to set the ground for Fiducial Reference Measurements for Satellite Altimetry in Gavdos and West Crete, Greece to "*establish and demonstrate SI-traceability of altimetry measurements and their use for satellite-derived altimeter calibration and validation*".

The concept of Fiducial Reference Measurements has been defined by the European Space Agency as: "*The suite of independent ground measurements that provide the maximum return-of-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*".

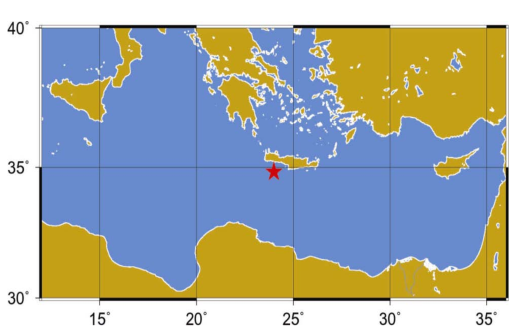
Results from this fiducial reference site will be based on historic Cal/Val site records, and would be the yardstick for building up capacity for monitoring the climate change records. This ground facility will be capable of defining and assessing any satellite altimeter measurements to known, controlled and absolute reference heights and signals with different techniques, processes and instrumentation.

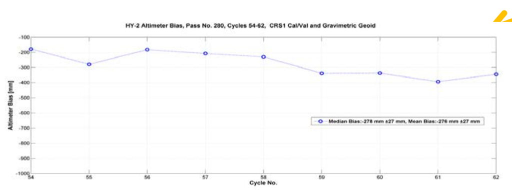
1. Fiducial Reference Measurements

- **SI-Calibration Traceability:** Evaluate uncertainty for the Système international d'unités (SI)-traceable measurements in altimeter calibration:
  - **Step 1:** Evaluate instrument error budget: (1) previous measurements, (2) experience with behavior & properties, (3) manufacturer's specifications, (4) previous calibration or other certificates, and (5) uncertainties assigned to reference data.
  - **Step 2:** Component error characterization and modeling (1) determination of each component and sub-systems, (2) evaluation of responses to various operating & environmental conditions, and (3) modeling of all influencing parameters on sensors.
  - **Step 3**: Validation of characterization for field sensors,
  - **Step 4:** Establish best practices for altimetry calibration.
- **Uncertainty budget Estimation:**
  - Define overall uncertainty budget for instruments, models, methodologies;
  - Establish propagation of uncertainties into the final altimeter calibration products;
  - Determine uncertainty budget for both sea-surface and transponder calibration.

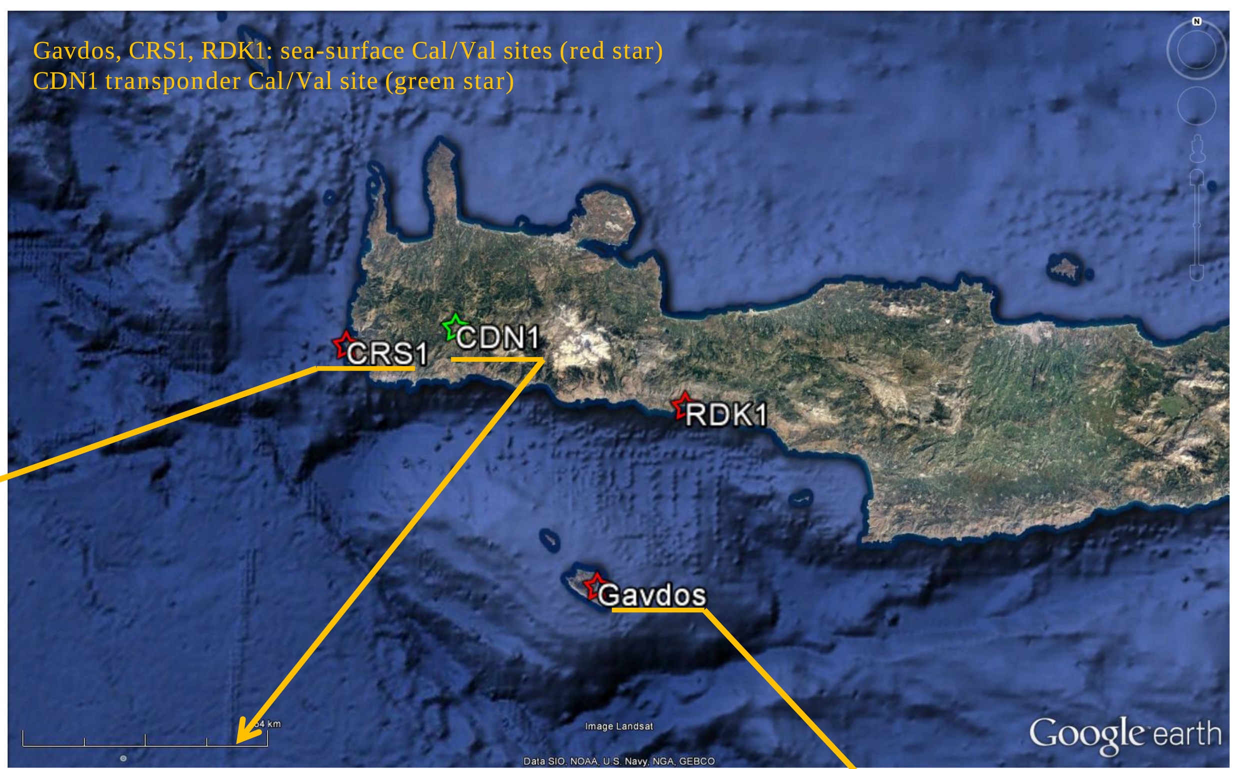
2. The Permanent Altimeter Calibration Facility

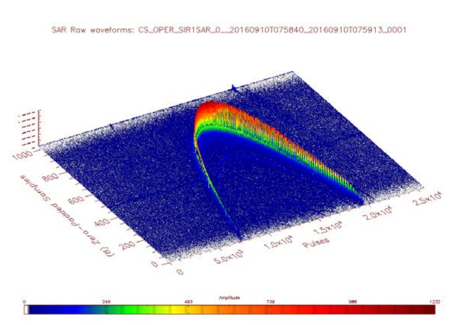
- Established in Gavdos/Crete as of 2001 and continuously providing calibration values for all altimeter satellites;
- two independent calibration techniques:
  - on land with a microwave transponder at CDN1 site, West Crete and,
  - at sea relying upon various Cal/Val locations on Gavdos and Crete.
- Multi-mission absolute and relative calibration at the PACF.



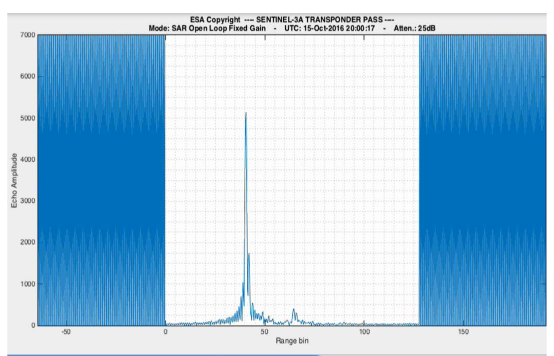


Chinese HY-2A Cal/Val @ CRS1, Pass No. 280, S-GDR

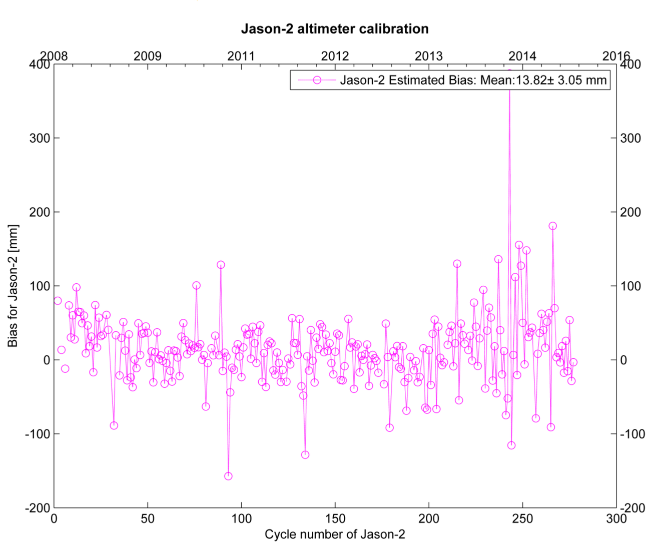




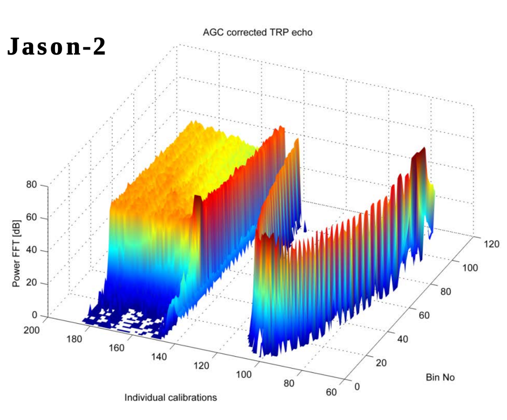
Cryosat-2 @ CDN1, 10-Sept-2016



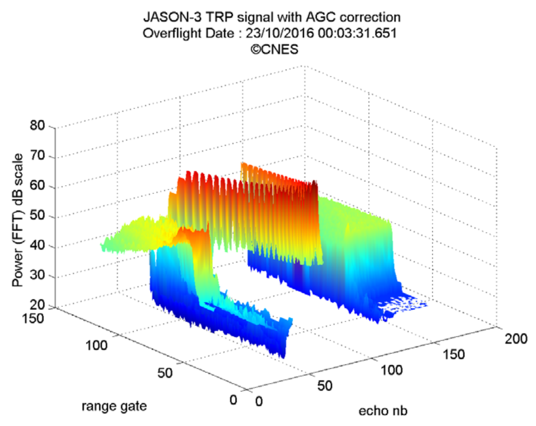
Sentinel-3A@CDN1, 15-Oct-2016



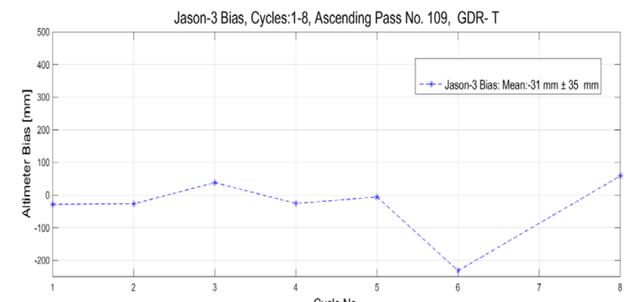
Jason-2



Jason-2 @ CDN1, Pass No.18 , 4-Aug-2016



Jason-3 @ CDN1, Pass No.18 , 23-Oct-2016

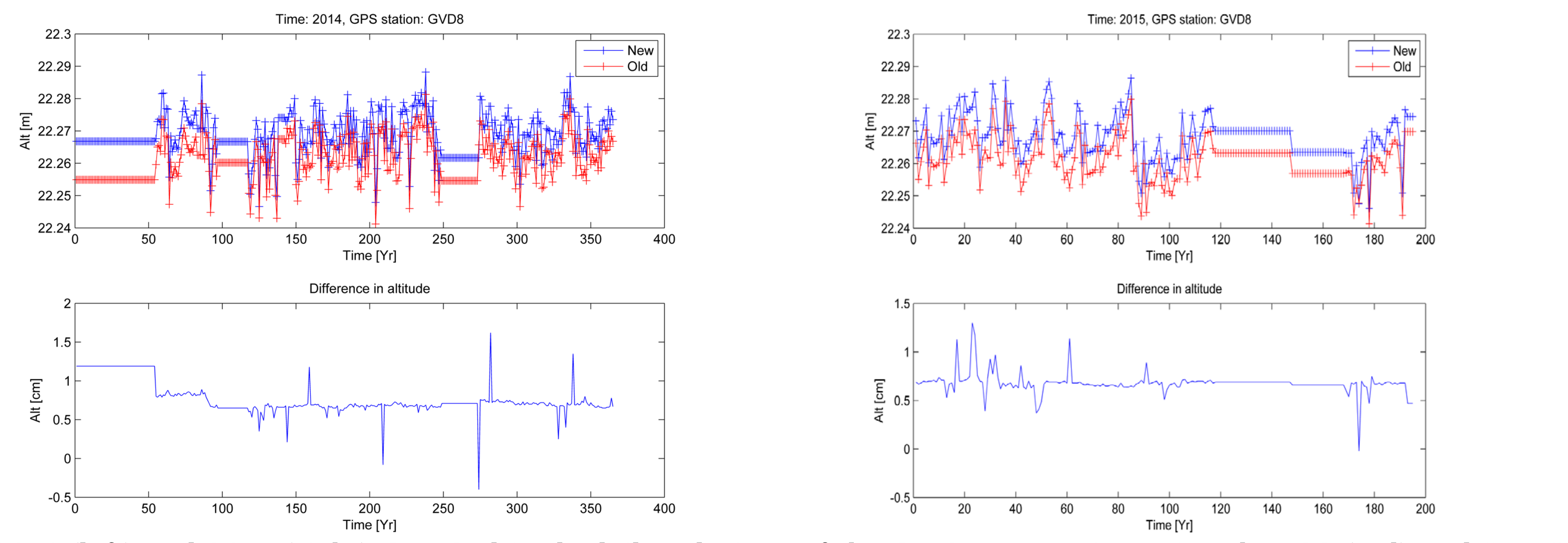


3. Towards FRM quality of Cal/Val results

- **Different tide gauge makes and measuring principles:**
  To determine the instrument's reference surface at sea with respect to center of mass of the earth;
  To assign accurate time for measurements;
  To establish uncertainty errors for the sea surface height and thus Cal/Val as connected with different tide gauges (i.e., radar, acoustic, pressure, etc.), various measuring principles and scales, sampling, drifts, geophysical conditions, GNSS heights, etc.

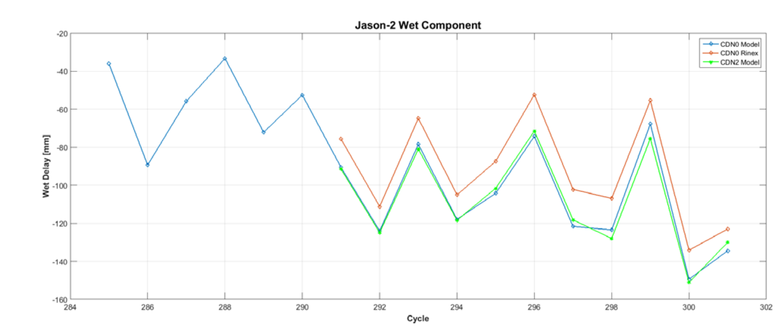
Error Source	Procedure
Time	Given by manufacturer, time standards, units, ...
Scale	"Van de Casteele" plot, establishment of reference, ...
Time shifts	Synchronization (GNSS, Laser, standards,...), Network Timing, ...
Zero point vs Reference Surface	Manufacturer, Empirical estimation, ...
Datum changes & drifts	Horizontal misalignment, Mounting structure, thermal expansion,...
Environmental Conditions	Reflectivity index, Air Temperature, Effective density for tide gauge measurements.

- **Absolute height characterization:**
  Investigate GNSS antenna: Using the IGS-derived antenna exchange file (ANTEX) and the ANTEX file after antennas' absolute characterization at certified Lab an offset of ~7mm was revealed.

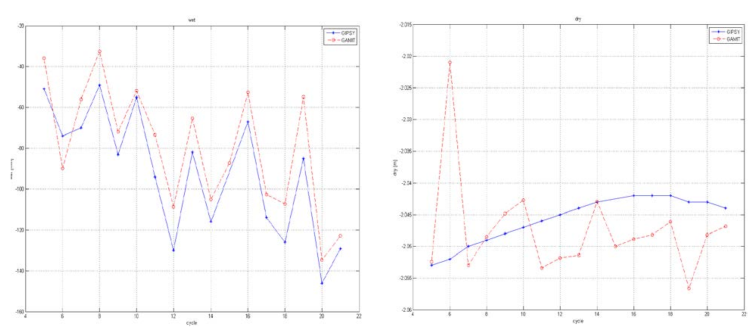


The 2014 (left) and 2015 (right) GVD8 altitude daily solutions of the GIPSY processing using the IGS (red) and "new" (after absolute calibration-blue) derived ANTEX files along with their residuals.

- **GNSS Processing Methodology & Propagation Error Estimation:**

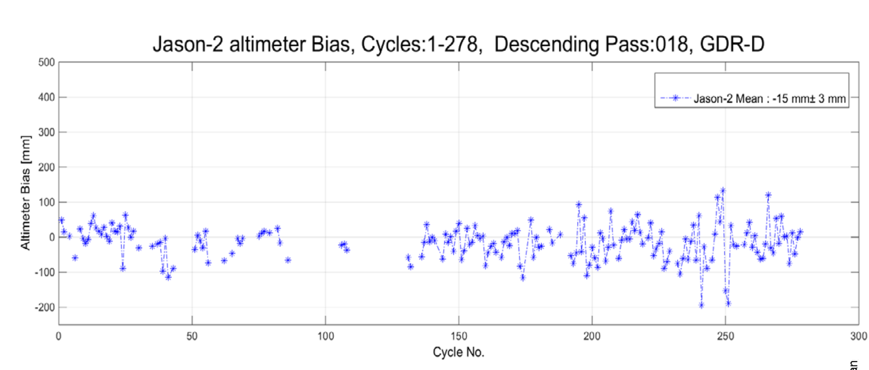


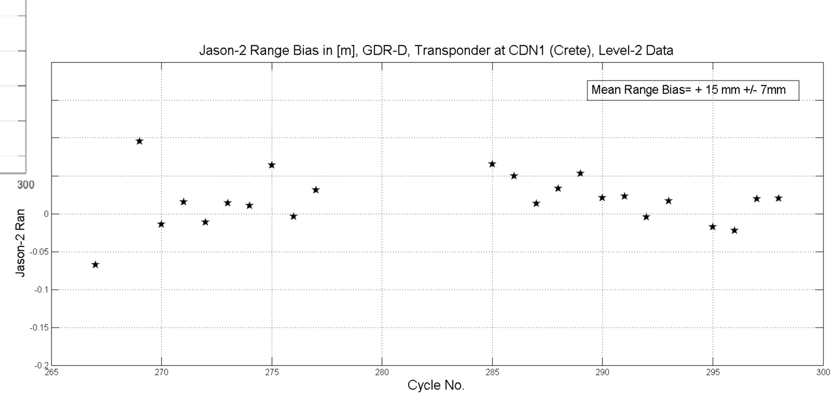
Wet troposphere delays using the GAMIT software using (a) models, and (b) local meteorological observations for two collocated GNSS receivers @ CDN1 Cal/Val site.



Wet and dry troposphere delays using the GAMIT and GIPSY scientific software packages

- **Transponder vs Sea-Surface Calibration methodologies**





Conclusions

- The Gavdos/Crete Cal/Val facilities to be used as reference standard for satellite altimetry calibration;
- Fiducial Reference Measurements will have documented SI-traceability;
- Uncertainty budget for all FRM instruments and measurements will be available and maintained;
- Protocols and community-wide management practices are defined, published openly and adhered to by FRM instrument deployments;
- Results will be robust, clear, unequivocal and easy to compare with those carried out at various geographical regions;
- Calibration will involve independent absolute (sea-surface & transponder) and relative (inter-calibration among missions) bias estimates;
- Directional Cal/Val errors will be revealed with descending and ascending orbits.

GeoMatLab DTU Space National Space Institute Space Geomatica Ltd.

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