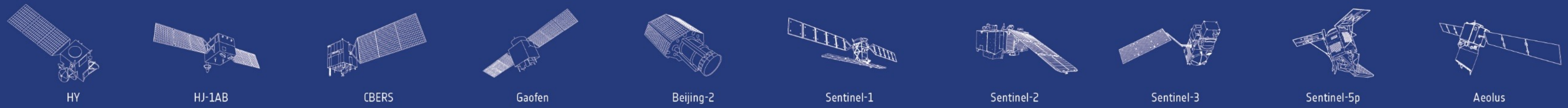

2023 DRAGON 5 SYMPOSIUM

3rd YEAR RESULTS REPORTING

11-15 SEPTEMBER 2023

[PROJECT ID. 59198]

ABSOLUTE CALIBRATION OF EUROPEAN & CHINESE SATELLITE ALTIMETERS ATTAINING FIDUCIAL REFERENCE MEASUREMENTS STANDARDS

Dragon 5 3rd Year Results Project

NSOAS
National Satellite Ocean Application Service

WEDNESDAY, 13/SEPT/2023: 9:00AM - 10:30AM

ID. 261

PROJECT TITLE: ABSOLUTE CALIBRATION OF EUROPEAN & CHINESE SATELLITE ALTIMETERS ATTAINING FIDUCIAL REFERENCE MEASUREMENTS STANDARDS

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PRESENTED BY: [DR. MU BO(NSOAS)]

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Project's Objectives

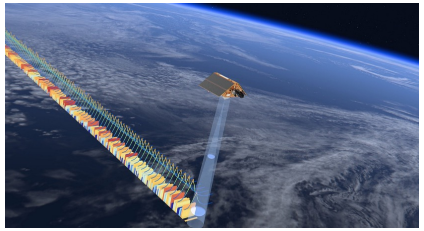
- Calibrate Satellite altimeters of Europe (S3/S6/CS2) & China (HY-2):
- - ESA Permanent Facility for Altimetry Calibration in Crete, Greece;
- - Chinese Altimeter Calibration Cooperation Plan.

- Results of Calibration to FRM Standards:
- - To absolute reference signals,
- - Traceable to SI-standards,
- - Different & redundant techniques (sea & land),
- - Various processes, diverse instrumentation, settings etc.

- Report FRM Uncertainty for Satellite Cal/Val Results

- Analyse Performance Against Other Missions.

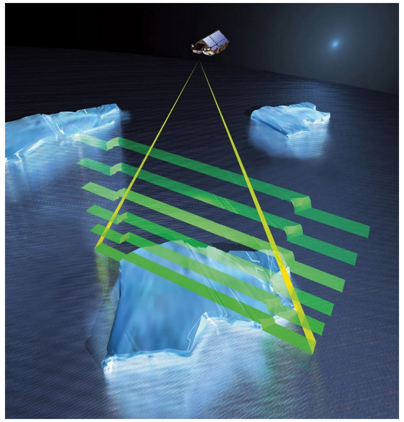
Dragon Altimeter Data Used:



European Satellite Altimeters:


Sentinel-3A (2016)

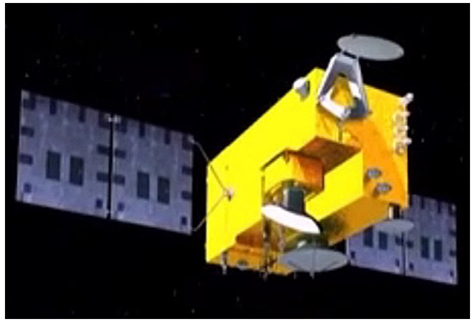

Sentinel-3B (2018)

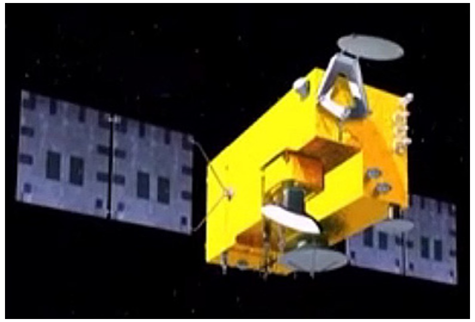

CryoSat-2 (2010)


Sentinel-6A (2021)

Chinese Satellite Altimeters:

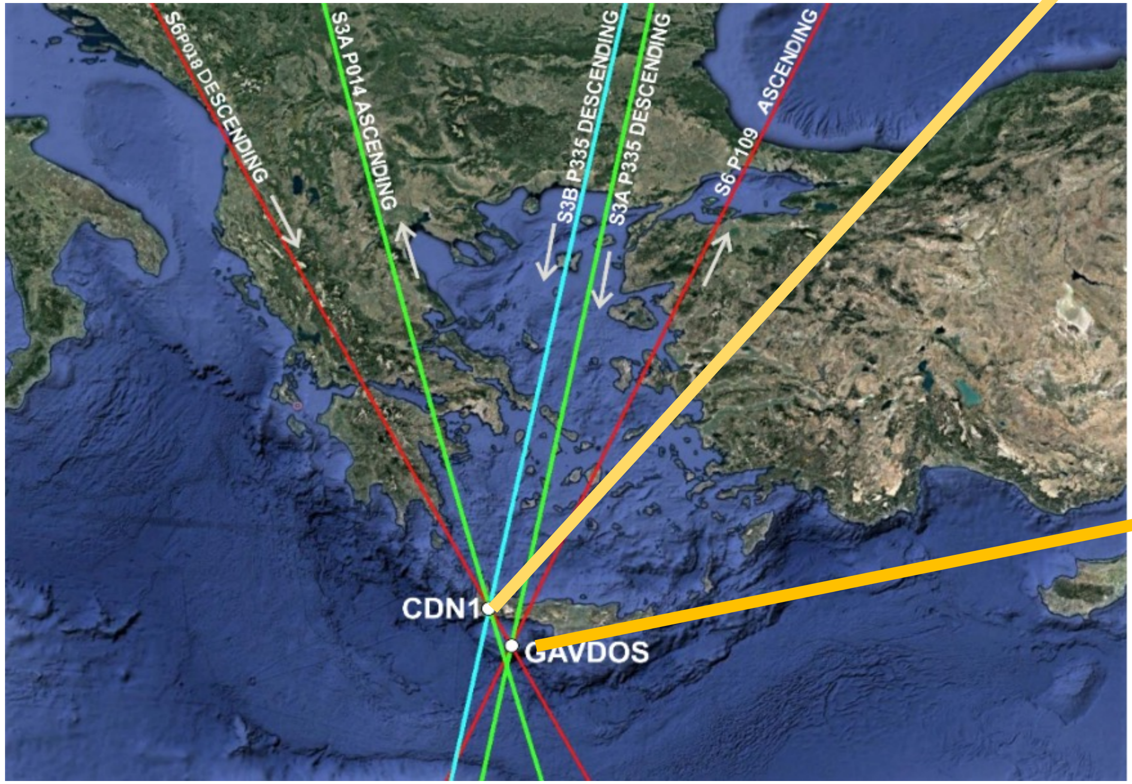

HY-2B (2018)


HY-2C (2020)


HY-2D (2021)

Gavdos/Crete Permanent Cal/Val Facilities

Transponders at ESA PFAC, Crete



Crete (CDN1 Transponder)

- Multiple Cross-over (S3A, S3B, Jason-3, S6, AltiKa, SWOT),
- Low clutter,
- Cross-calibration,
- Crystal clear signal of S3 Signals.

Gavdos (GVD1 Transponder)

S3A, Sentinel-6 (Ascending & Descending), sea-surface Cal/Val

Gavdos/Crete Permanent Cal/Val Facilities

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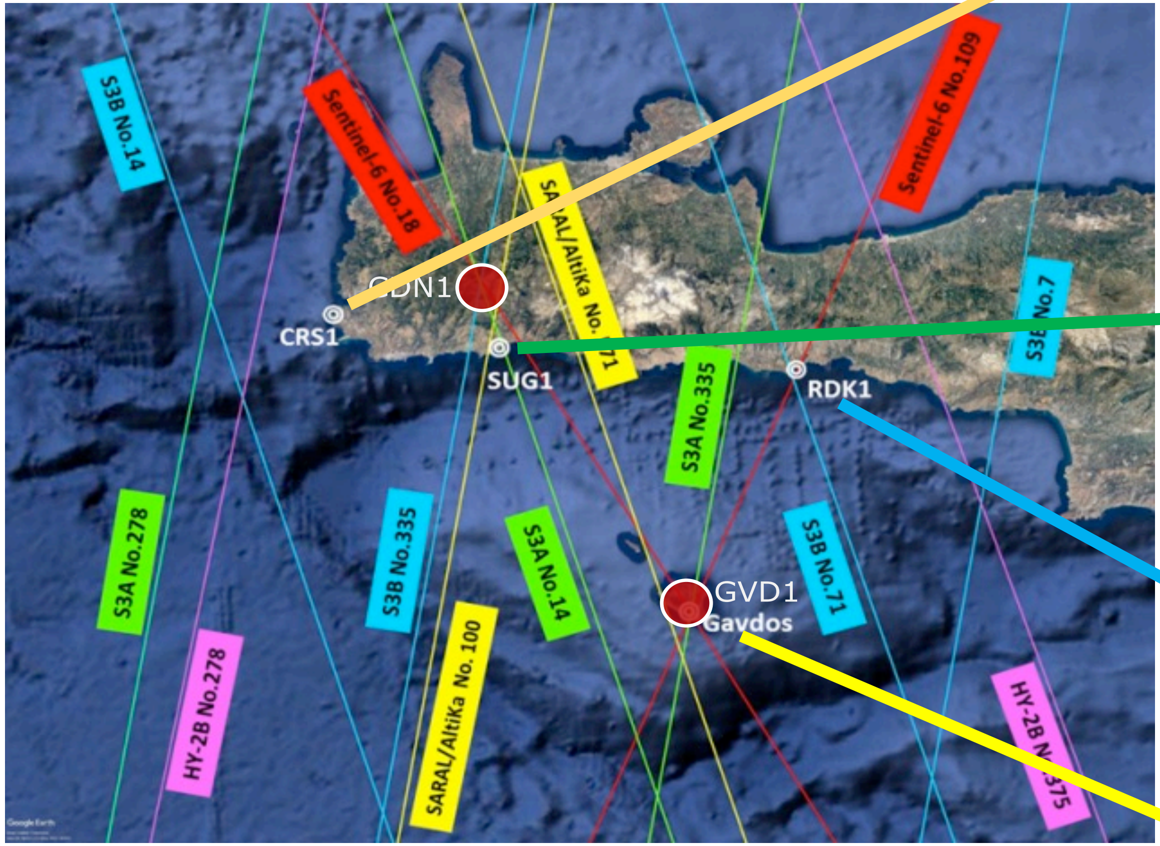
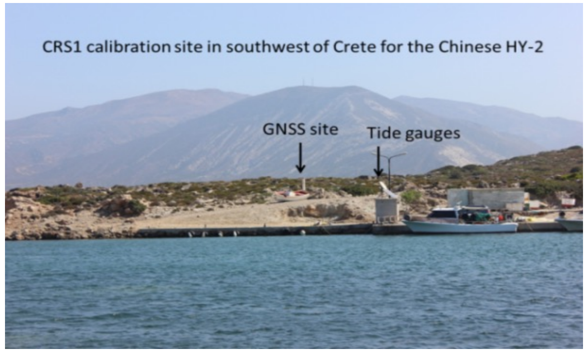
Sea-surface infrastructure, Crete



CRS1 Cal/Val site (South-West Crete)



SUG1 Cal/Val site (South Crete)

Gavdos Cal/Val site

RDK1 Cal/Val site (South Crete)

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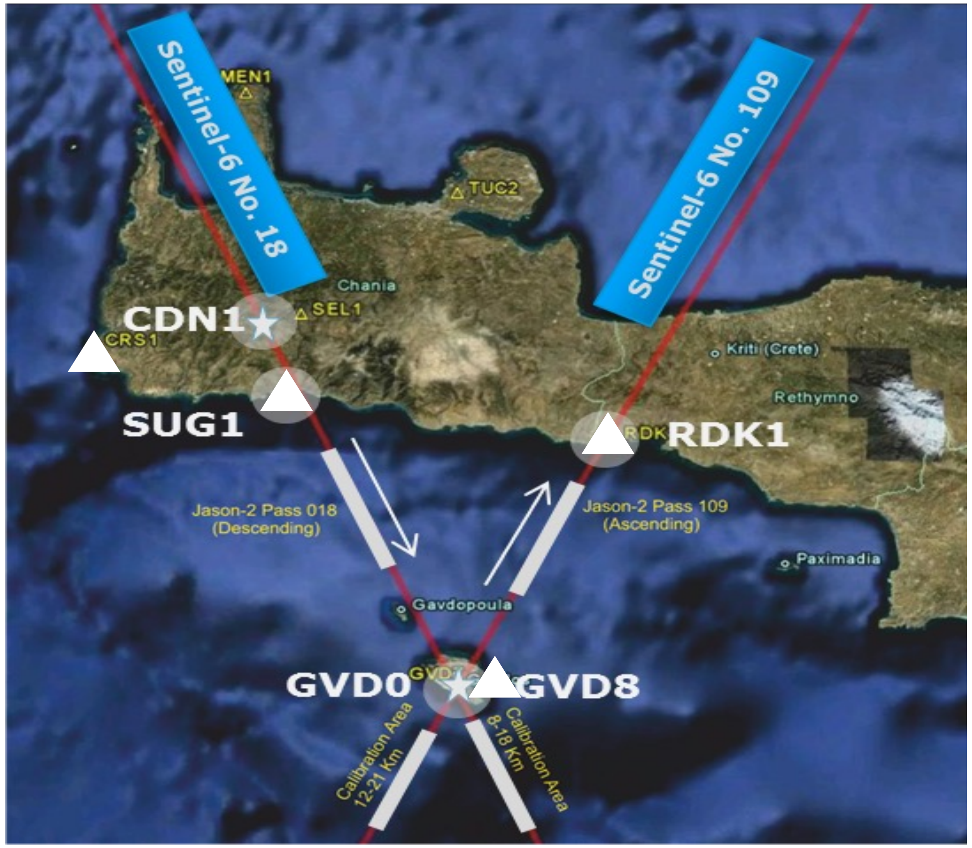
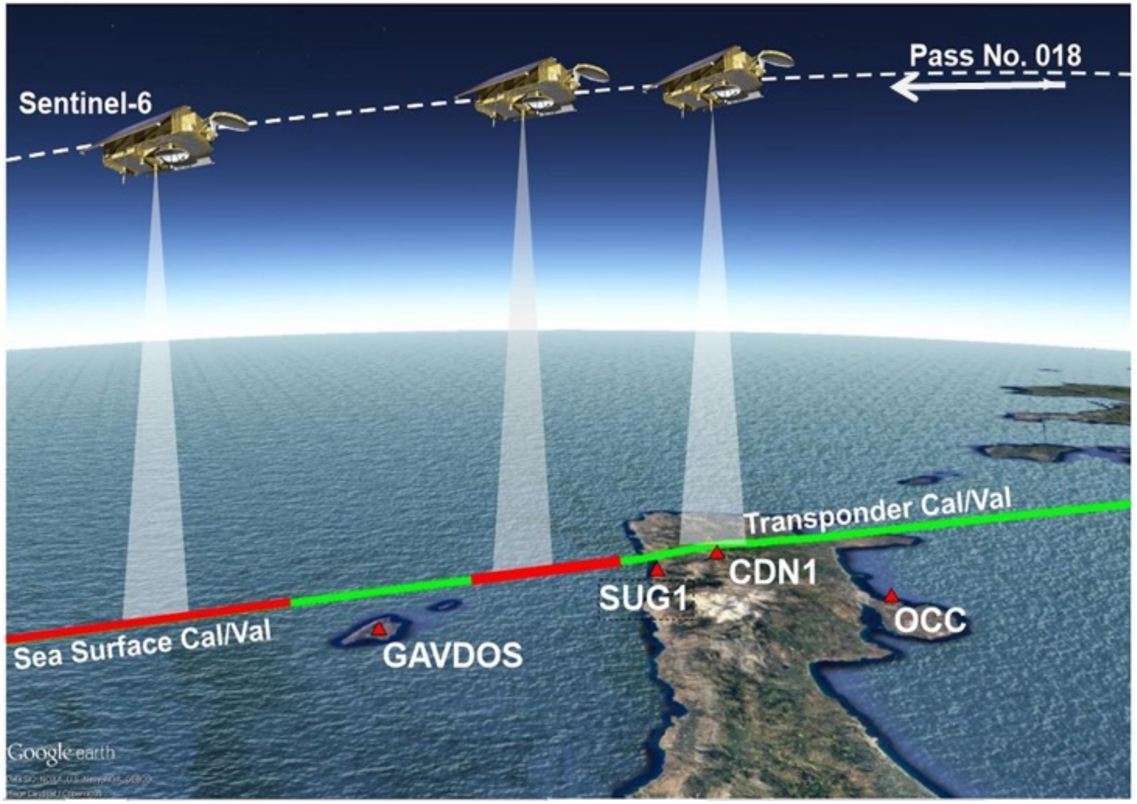
Gavdos/Crete Permanent Cal/Val Facilities

Transponders and sea surface Cal/Val sites at ESA PFAC, Crete





- ✓ **4 sea-surface & 2 transponder Cal/Val sites,**
- ✓ **Crossovers with S3A, S3B, JA3, S6, CryoSat-2, AltiKa, SWOT,**
- ✓ **Frequent (5 days), Redundant, Confident results, Directional errors**
- ✓ **Corner Reflectors.**

Simultaneous Transponder & Sea-Surface Cal/Val

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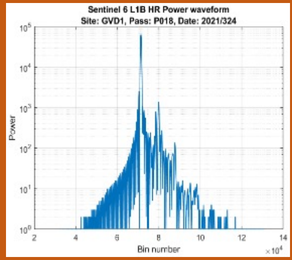
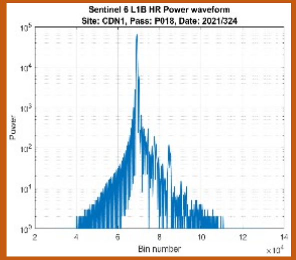
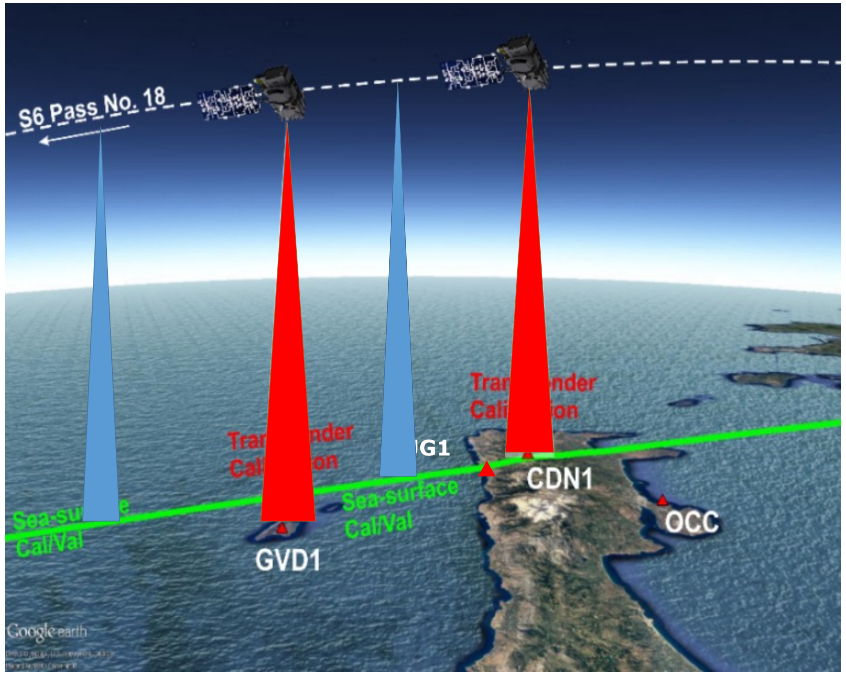
GVD1 Transponder

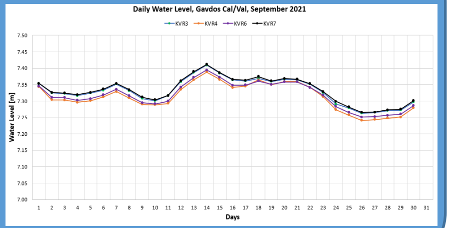


CDN1 Transponder

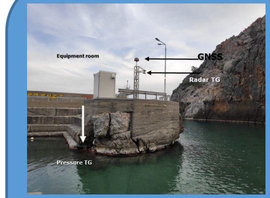


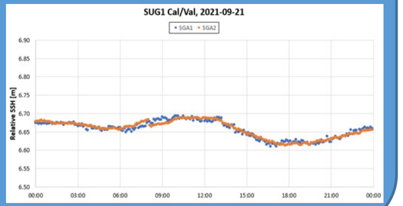


Gavdos sea-surface



SUG1 sea-surface





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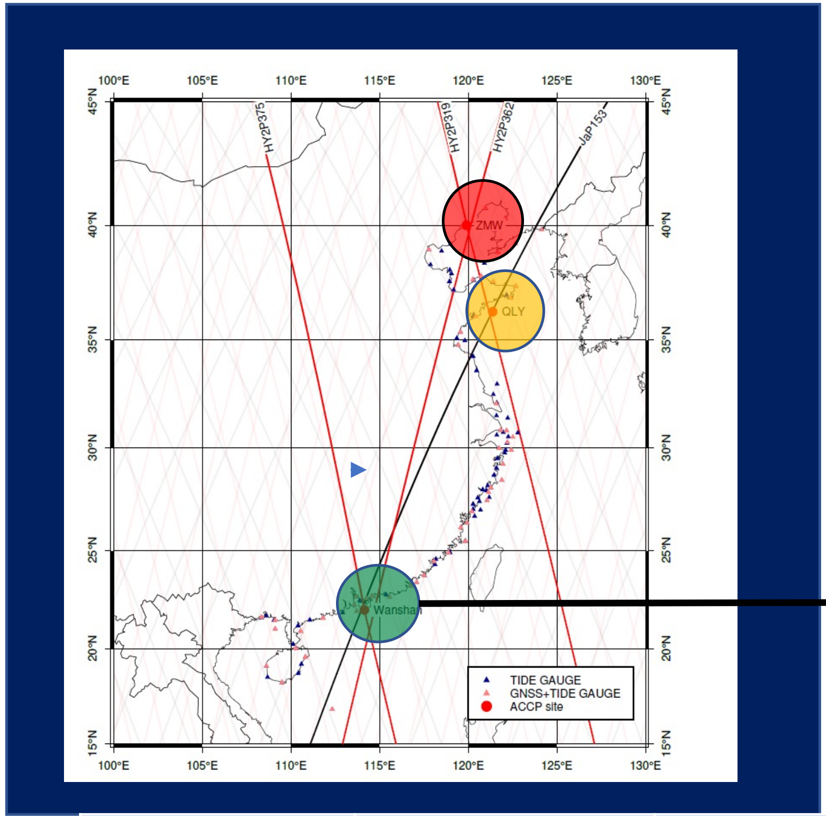
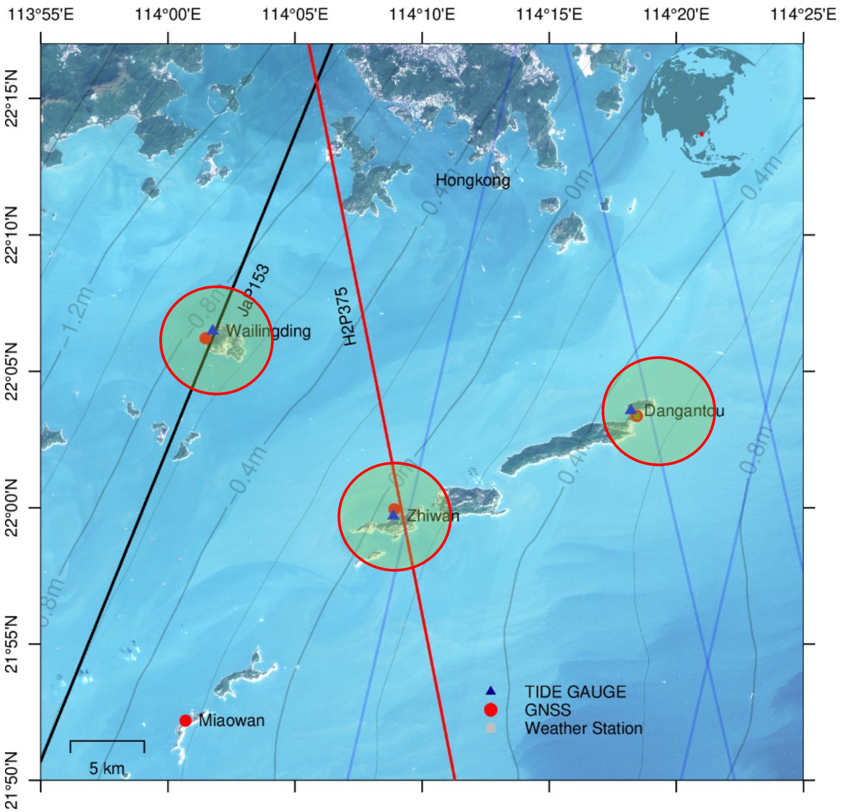
China Altimetry Calibration Cooperation Plan





ID	Cal/Val Site	Latitude	Longitude
QLY	Qianliyan (Qingdao)	121.385E	36.267N
ZMW	Zhimaowan (Bohai Sea)	119.920E	40.009N
Wanshan	Dangantou	114.303E	22.059N
Wanshan	Zhiwan	114.147 E	21.994
Wanshan	Wai Lingding	114.029E	22.108N

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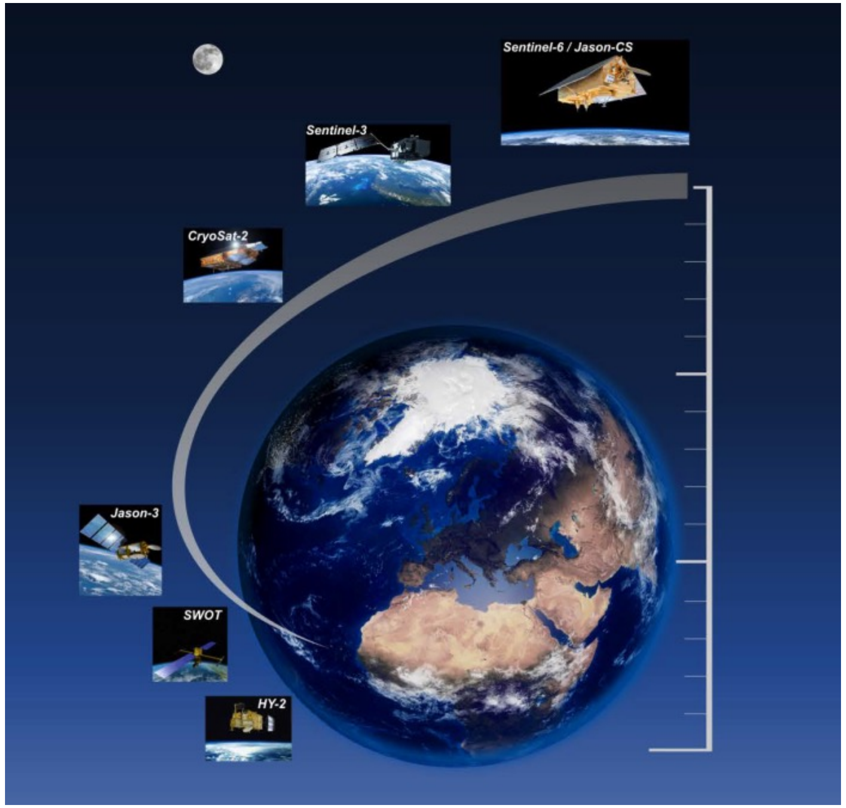
ESA Effort to:

- Earth observation reliable in the long term,
- Comparable world-wide,
- Impervious to instrument, setting, location, conditions, ….
- Build up objective and reliable record for Climate Change,
- Achieve Uniform, Absolute Standardization of Earth observation,



Why Need to Do that?:

- Place Trust on Earth data we produce;
- Communicate Correct information to Public (e.g., warnings);
- Right decisions for Policies in climate change & sea level change.

How to Achieve FRM for Altimetry Calibration?

- Connect Cal/Val to undisputed ground references,
- Evaluate each constituent contributing to Cal/Val uncertainty,
- Uncertainty on documented calibrations at reference sites,
- Uncertainty on metrology standards (speed of light, atomic time).

HY-2B and CRS1 & RDK1 Cal/Val sites, Crete

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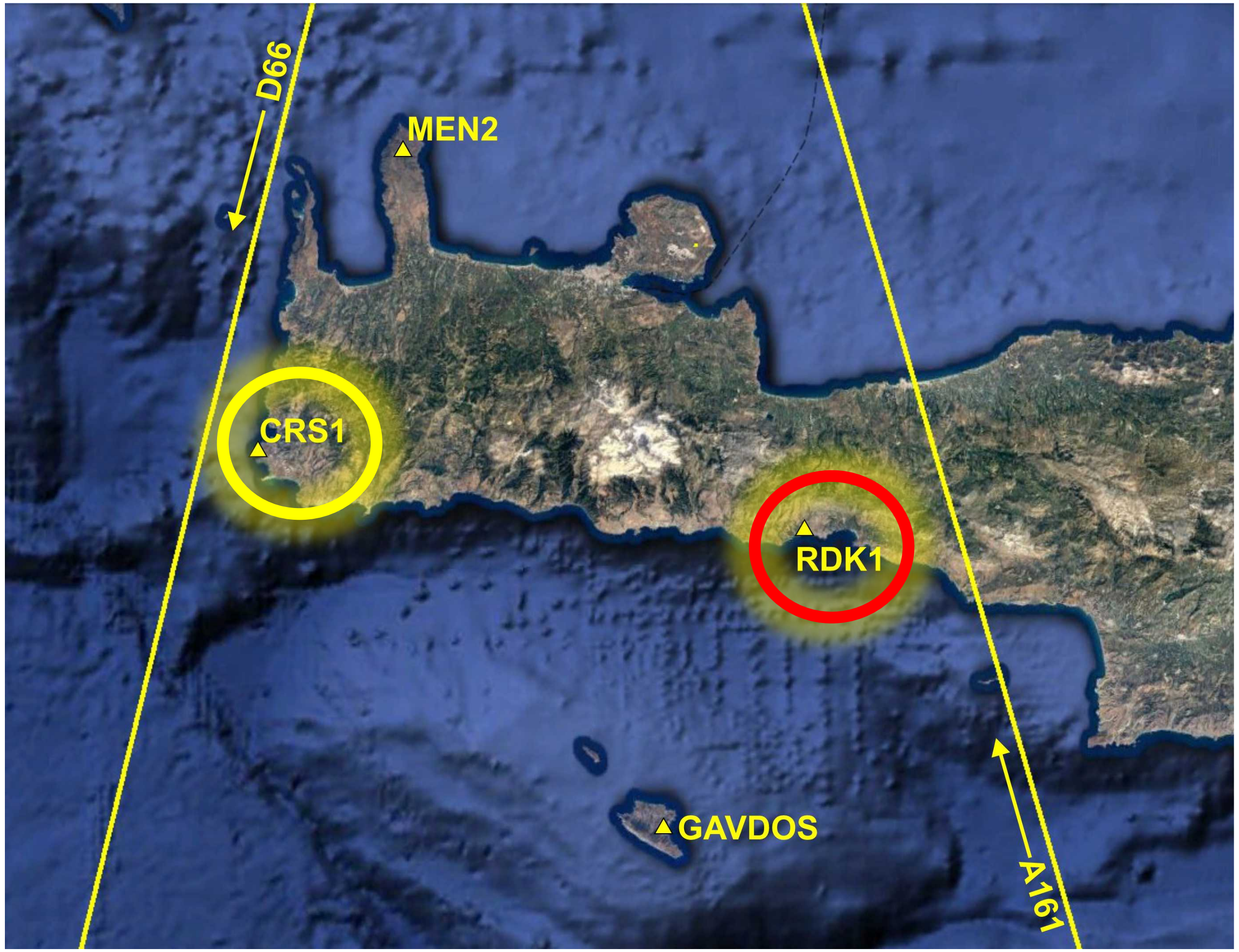

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HY-2B, Gavdos & RDK1 Together (A106)

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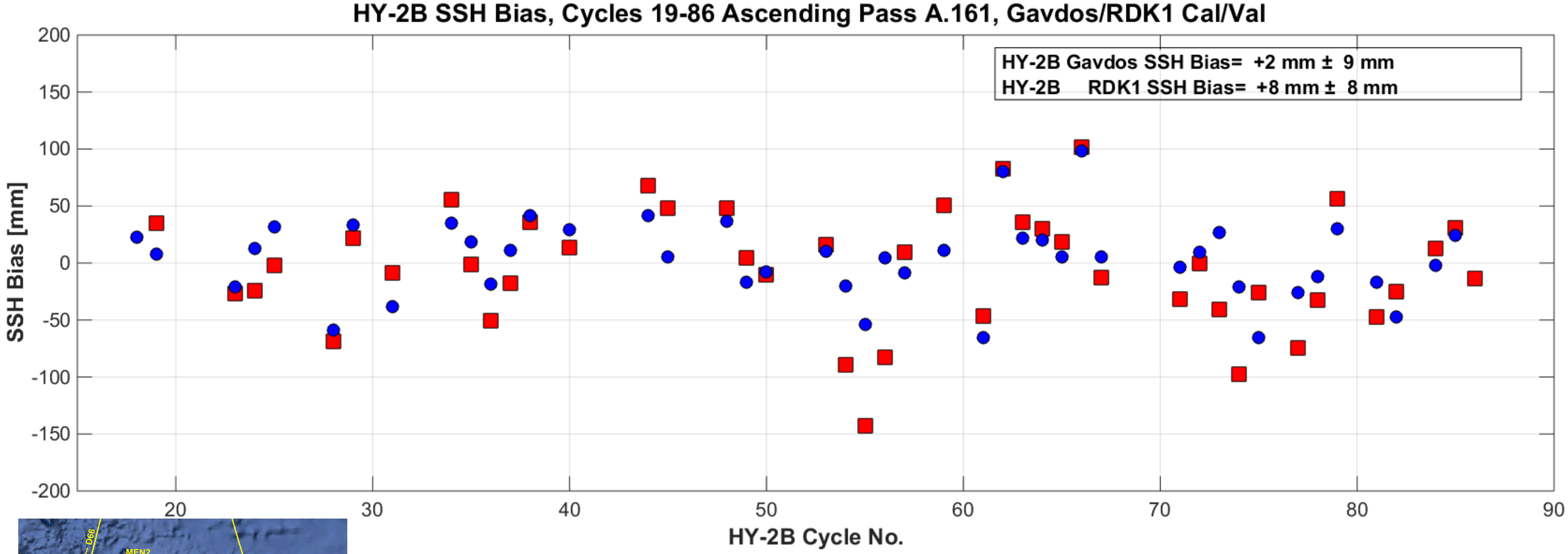

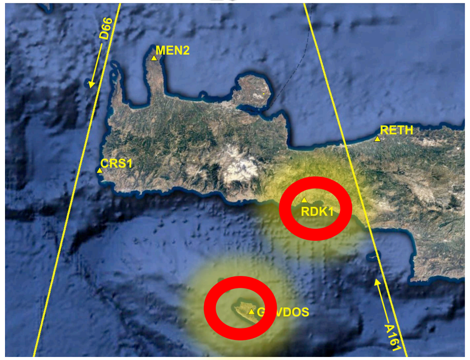

- HY-2B: Mean SSH Bias (GVD1): +2 mm ± 9 mm,
- HY-2B: Mean SSH Bias (RDK1): +8 mm ± 8 mm,
- FRM Uncertainty : ± 50 mm

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HY-2B, Crete CRS1 Cal/Val Results (D66)

Conclusions (1/2)

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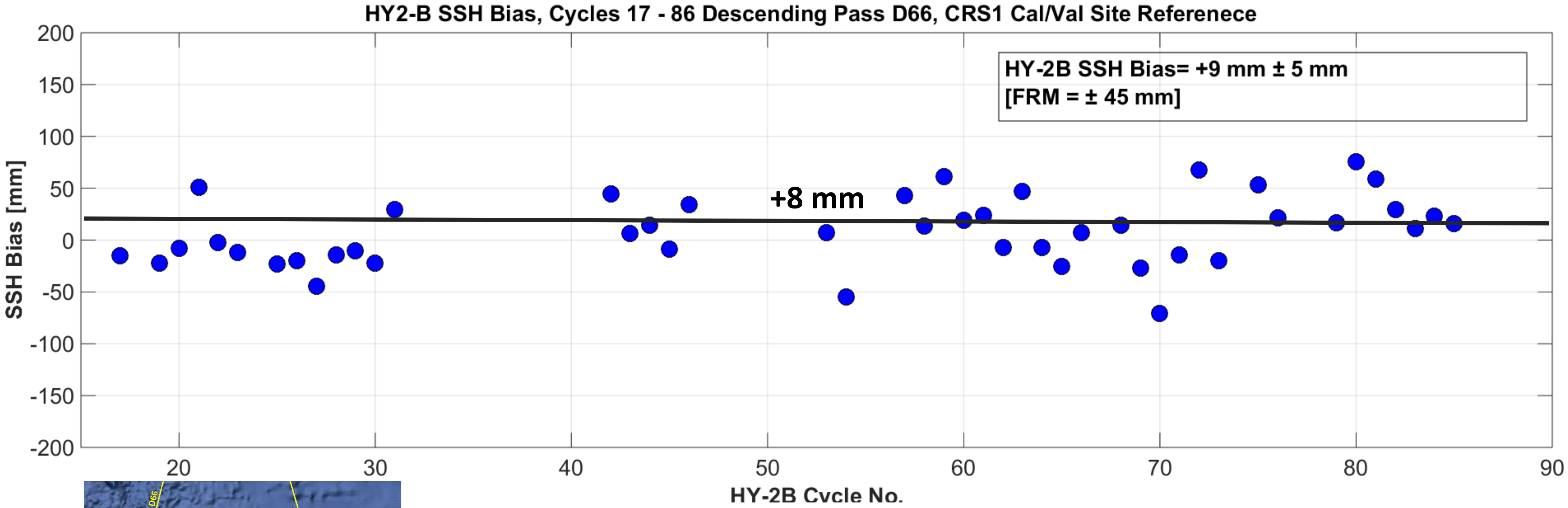

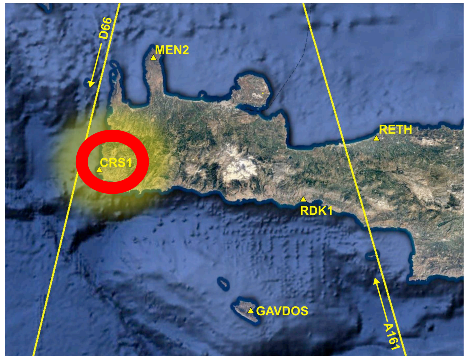

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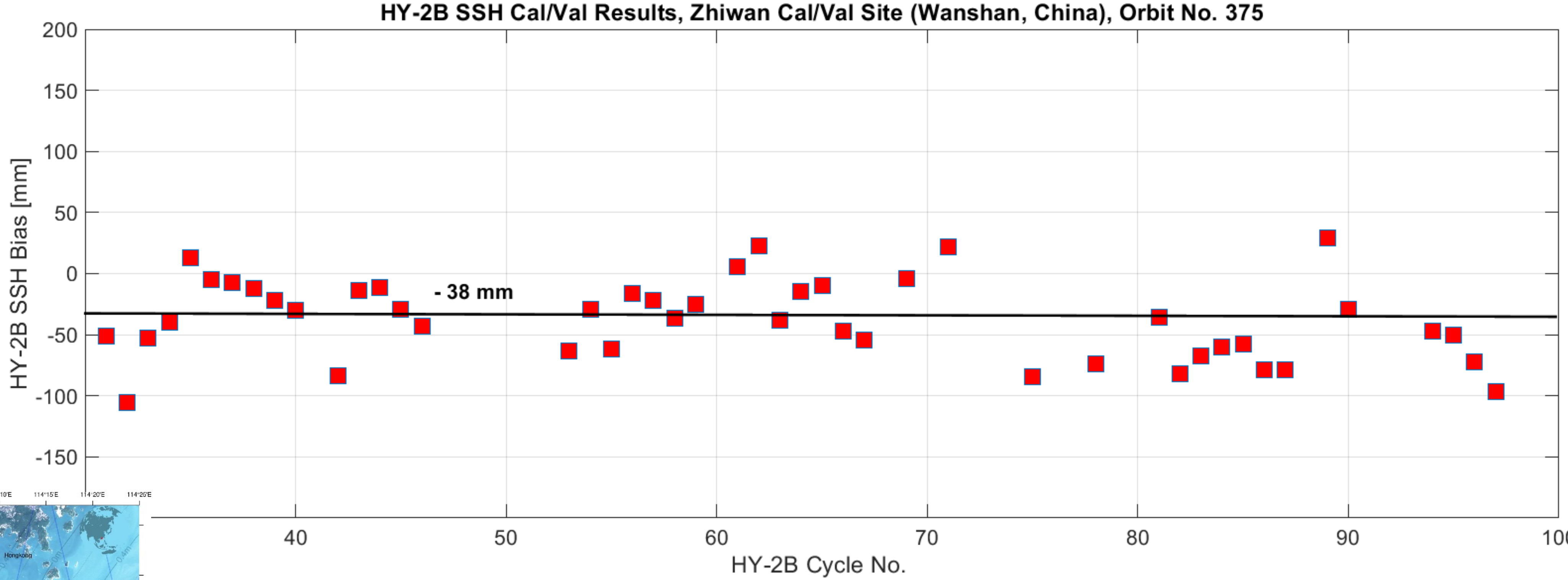
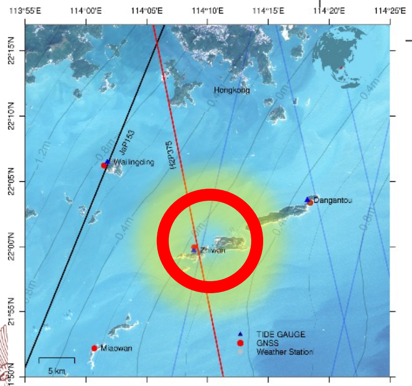
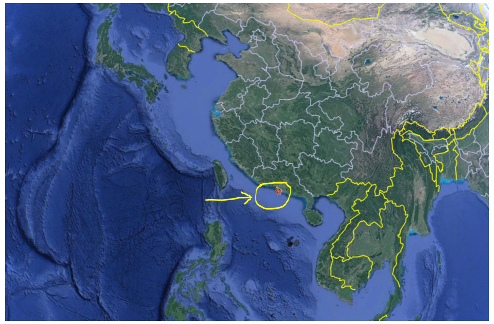
HY-2B, Wanshan-Zhiwan, China, Cal/Val Results





- HY-2B: Mean Bias: - 38 mm ± 3 mm,
- FRM Uncertainty : ± 50 mm



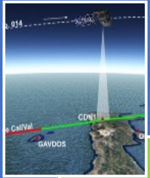
Conclusions (1/2)

- The HY-2B altimeter have been calibrated:
  - With uniform, standardized procedures, and best practices;
  - Upon trusted & indisputable ground reference standards;
  - At both Cal/Val infrastructures in Europe & China.

Cal/Val Site	Bias
Zhiwan island, China	–38 mm ± 3 mm
Qianliyan, China	+4 mm ± 4 mm
Wanshan, China	+12 mm ± 6 mm
CRS1, Crete, Europe	+9 mm ± 5 mm
RDK1, Crete, Europe	+8 mm ± 8 mm
GVD1, Crete, Europe	+2 mm ± 9 mm

Constituents of Uncertainty in Cal/Val Results

Site Selection



- Repeat Cycle
- Across-track distance
- Land contamination
- Water Depth
- Directional errors
- Multi-mission
- Reference surfaces
- Accessibility
- Security
- Ground stability
- Geodetic ties
- GNSS visibility
- Power supply & Communications

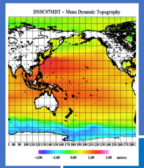
Absolute positioning

- Diverse GNSS satellites
- Diverse receivers & antennas
- Absolute GNSS antenna calibration
- 30s sampling rate
- 20 Hz high-rate ring buffer
- Reference frames
- Relative & absolute positioning
- Height diffs <2mm
- Diverse positioning systems (i.e., GNSS, DORIS, SLR, etc.)
- UTC time for time tagging
- At least 2-3 years of continuous operation.

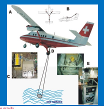
Atmospheric Delays

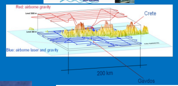
- GNSS-Derived ionospheric & zenith tropospheric delays at the time of satellite overpass
- Operation of meteo sensors
- Validation w.r.t. global/regional modeling
- Radiosondes, photometers, radiometers measurements
- OLCI observations.

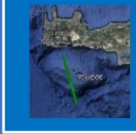
Geophysical effects

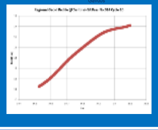


- Models for earth tides (solid earth, ocean tidal loading, pole tide) shall follow IERS conventions
- Establish reference geoid, MSS, MDT surfaces
- Validate reference surface with local/regional marine/aerial/terrestrial surveys









Water level determination

- Multiple (at least three) tide gauges of diverse measuring principle (radar, acoustic, pressure, floating).
- Geodetic ties between GNSS and tide gauge sensors via spirit leveling surveys with ± 1mm
- Calibration certificates from manufacturers for repeatability, reproducibility, hysteresis, drift, non-linearity, etc.
- Validation of instrument's performance, by the Cal/Val site operator, prior its permanent installation
- Field validation experiments to be conducted at least every 6 moths using a reference instrument
- Relative field calibration between operating tide gauges
- At least 1 hour of water level reading centered to the satellite overpass time of closest approach.

FRM Uncertainty Budget Analysis

Description	CRS1	RDK1	Wanshan
Tide-gauge sensor	±4 mm	± mm	±1 mm
Repeatability	±2.53 mm	±2.53 mm	±2.53 mm
Zero-point reference	±2.50 mm	±2.50 mm	±2.50 mm
GNSS receiver	±3.46 mm	±3.46 mm	±3.50 mm
GNSS repeatability	±0.08 mm	±0.09 mm	±0.10 mm
GNSS ARP	±4.04 mm	±4.04 mm	±5.00 mm
GNSS solution	±0.08 mm	±0.13 mm	±0.10 mm
GNSS velocity	±1.96 mm	±4.55 mm	±2.50 mm
GNSS integration	±3.75 mm	±3.75 mm	±3.75 mm
Control ties	±0.09 mm	±0.10 mm	±0.28 mm
Reference surfaces	±42.00 mm	±47.00 mm	±50.00 mm
Final Water level	±7.50 mm	±7.50 mm	±7.50 mm
Geoid slope	±5.77 mm	±5.77 mm	±3.50 mm
Processing	±0.29 mm	±0.29 mm	±0.29 mm
Unaccounted effects	±11.55 mm	±11.55 mm	±11.55 mm
Uncertainty budget	±45.41 mm	±50.44 mm	±52.66 mm

Conclusions (2/2)

- For HY-2B, the results of European and Chinese sites are close;
- The FRM uncertainty of CRS1, RDK1 and Wanshan is reported;
- Continue Calibration of European and Chinese altimeters;
- Analyze FRM Uncertainty at Chinese Cal/Val;
- Extend Cal/Val to HY-2C, HY-2D, S6, ... Cal/Val;
- Joint Journal Publication published@ **Remote Sensing (2023)**.