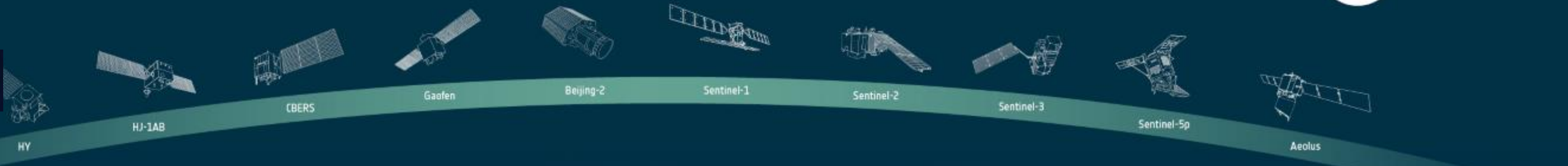


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# 2022 DRAGON 5 SYMPOSIUM

## MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

**[PROJECT ID. 59198]**

# ABSOLUTE CALIBRATION OF EUROPEAN & CHINESE SATELLITE ALTIMETERS ATTAINING FIDUCIAL REFERENCE MEASUREMENTS STANDARDS OVER THE 2ND YEAR OF DRAGON5

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# Dragon 5 Mid-term Results Project

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**THURSDAY (8:30AM - 9:00AM) & 20/OCT/2022,**
**1.3.1: CAL/VAL**

**ID. 129/1.3.1:1**

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

**PRINCIPAL INVESTIGATORS: STELIOS P. MERTIKAS; MINGSEN LIN**

**CO-AUTHORS: CHAOFEI MA; YUFEI ZHANG; DIMITRIOS PIRETZIDIS; YONGJUN JIA; BO MU; XENOFON FRANTZIS; COSTAS KOKOLAKIS; YANG LEI; ILIAS TZIAVOS**

**PRESENTED BY: STELIOS P. MERTIKAS**

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# Project 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.

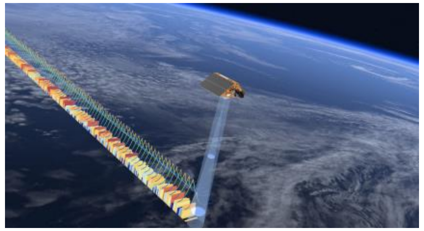
**Results of Calibration to FRM Standards:**

- 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.**

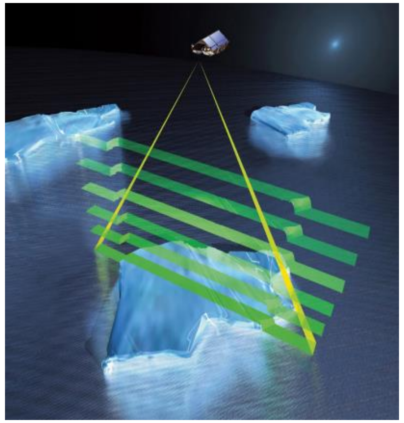
# Dragon Altimeter Data:



## 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

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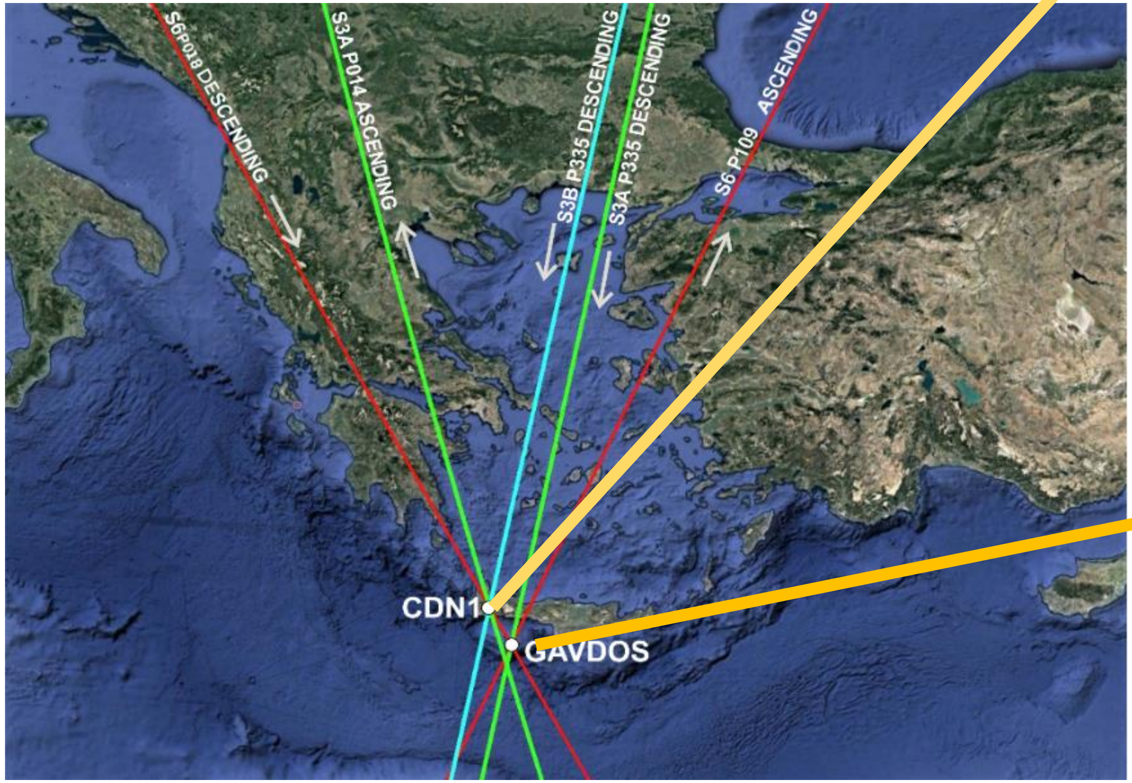
## Transponders at ESA PFAC, Crete




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

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# Gavdos/Crete Permanent Cal/Val Facilities

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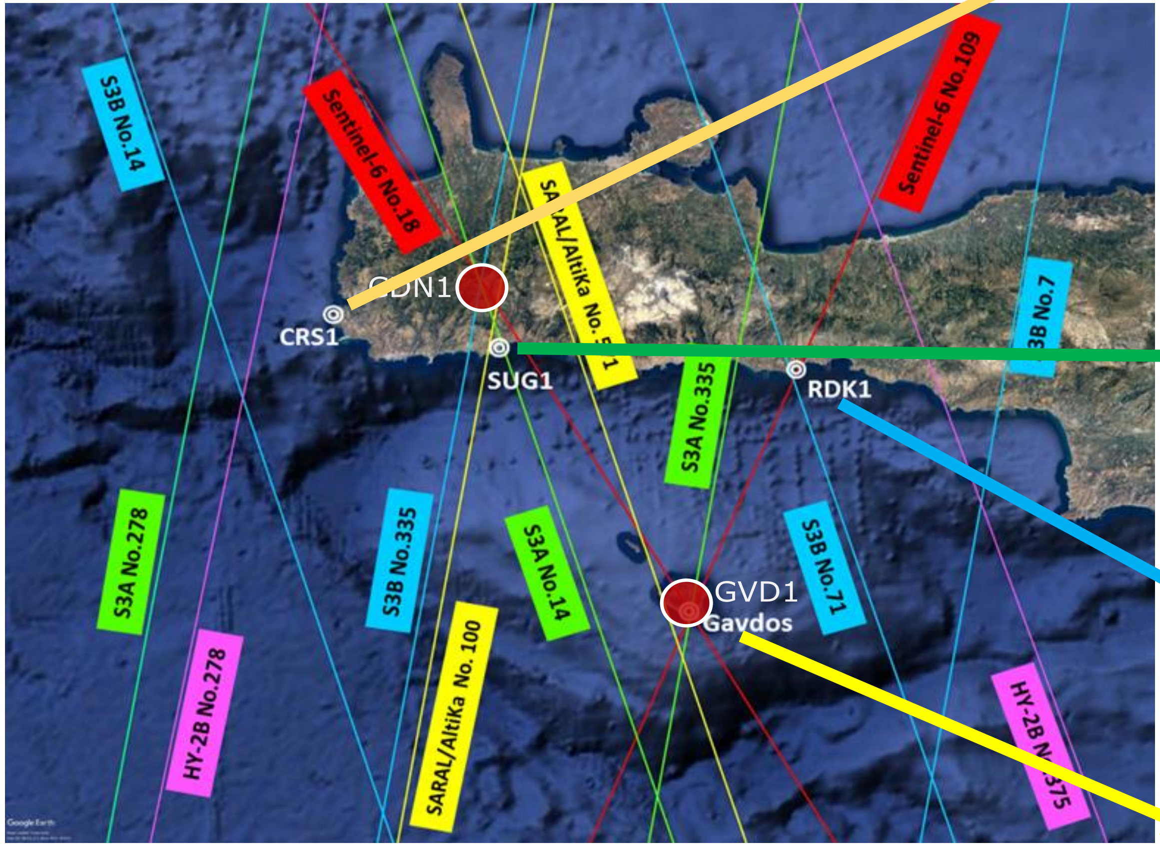
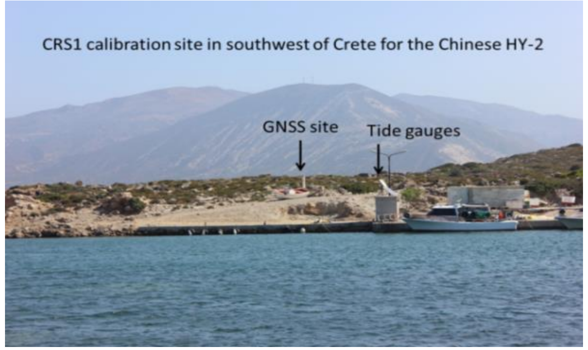
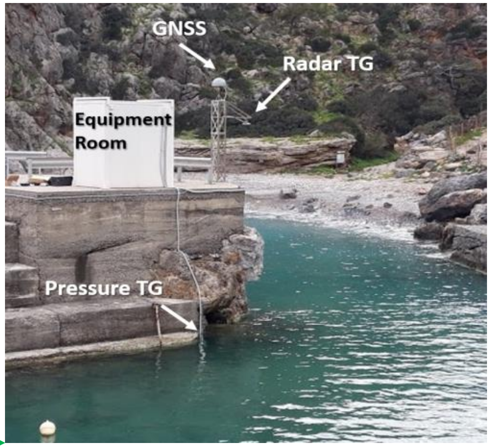
## Sea-surface infrastructure, Crete




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

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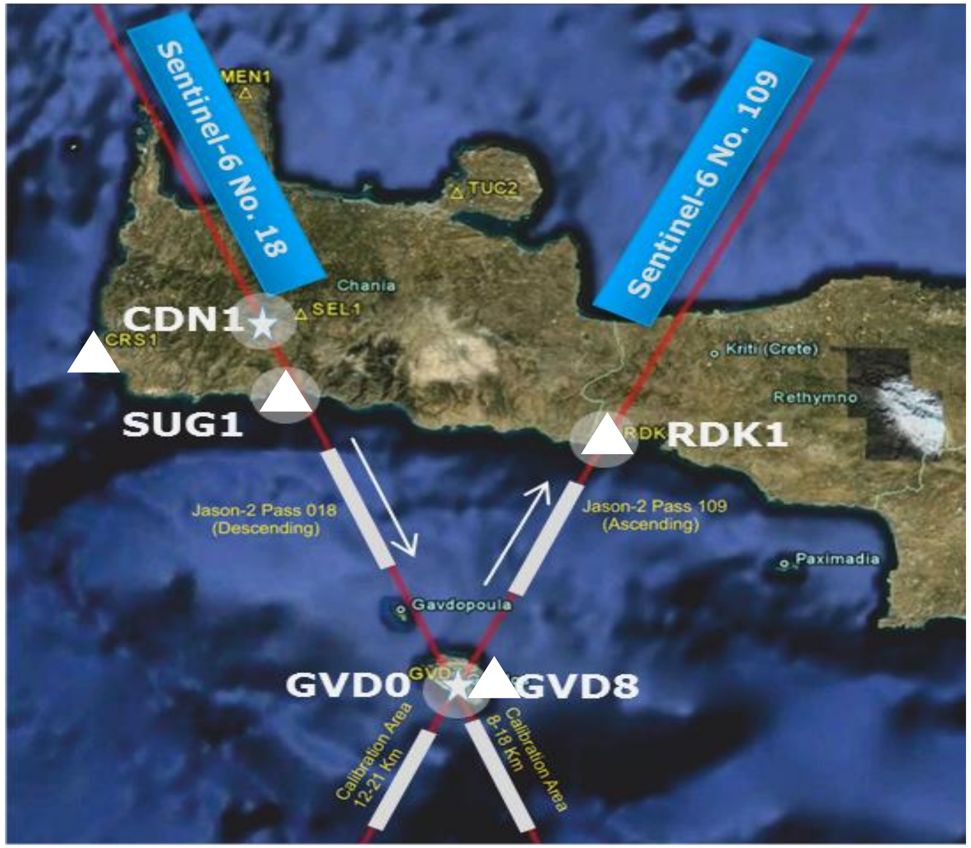
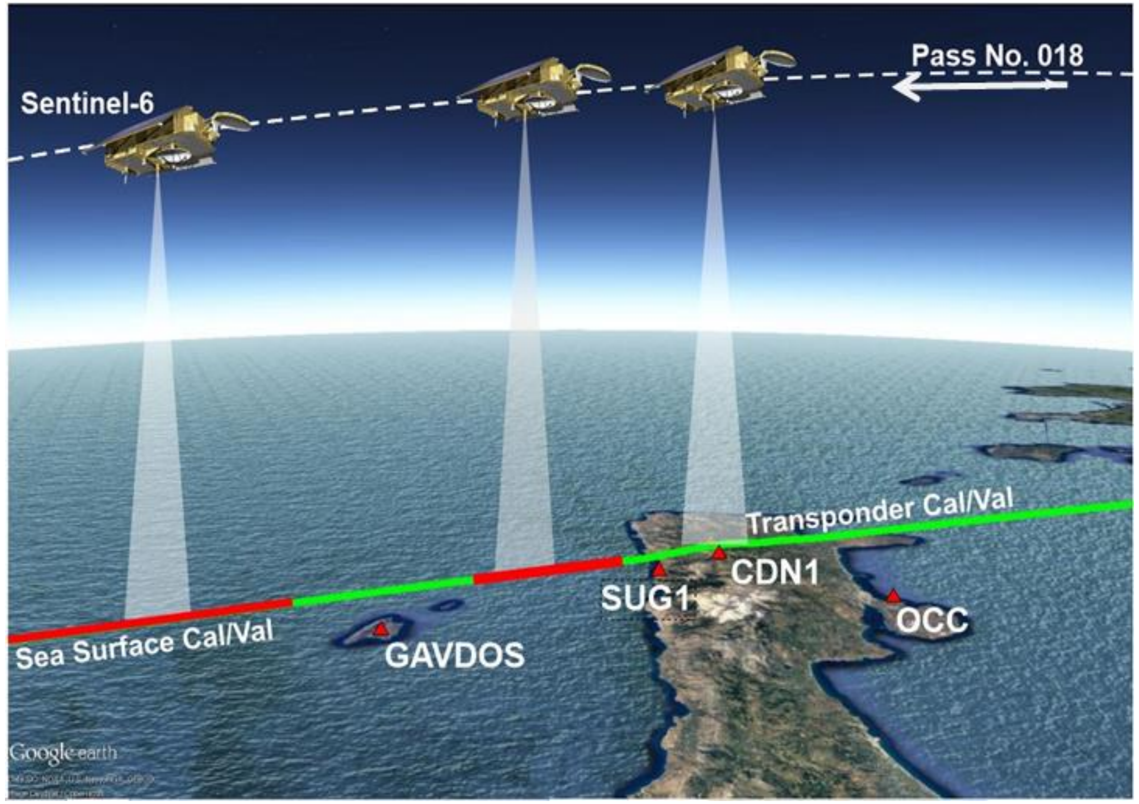
## Transponders and sea surface Cal/Val sites at ESA PFAC, Crete




- ✓ **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.**

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# Simultaneous Transponder & Sea-Surface Cal/Val

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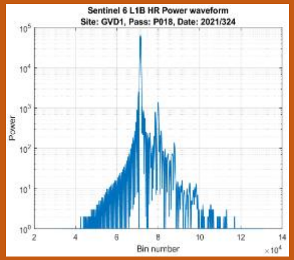
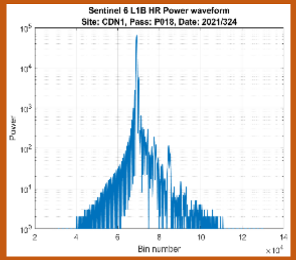
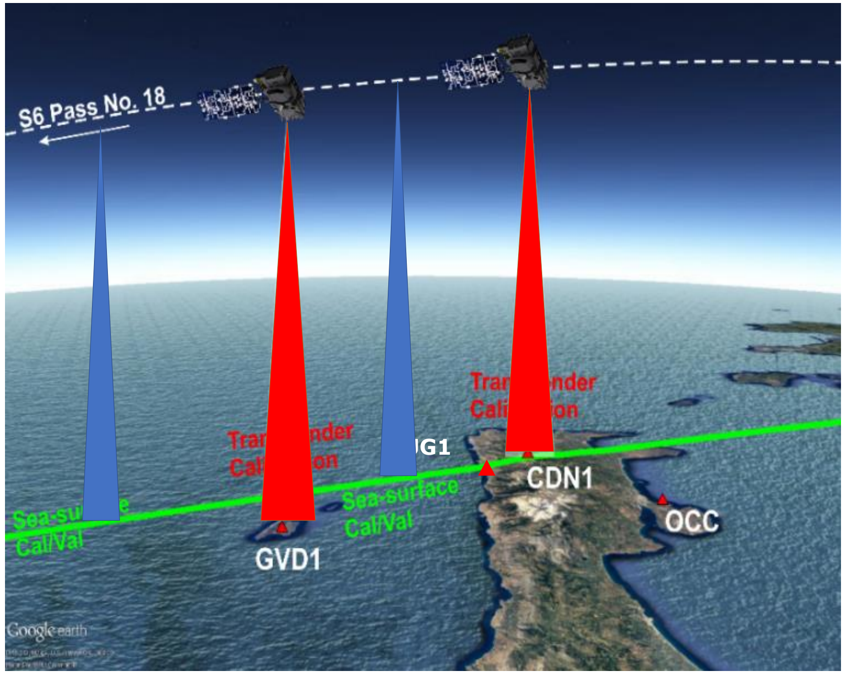
**GVD1 Transponder**



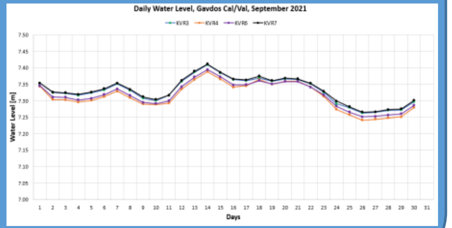

**CDN1 Transponder**



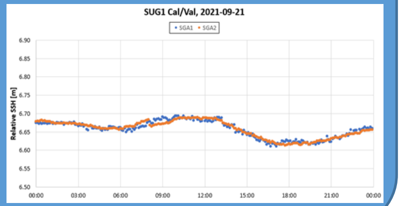





**Gavdos sea-surface**


**SUG1 sea-surface**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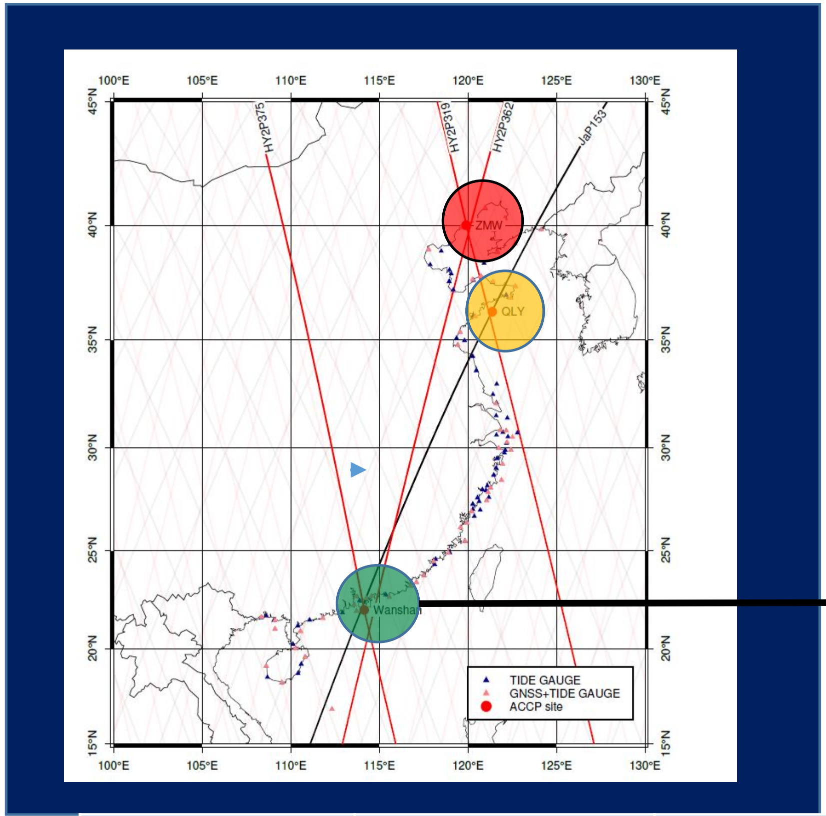
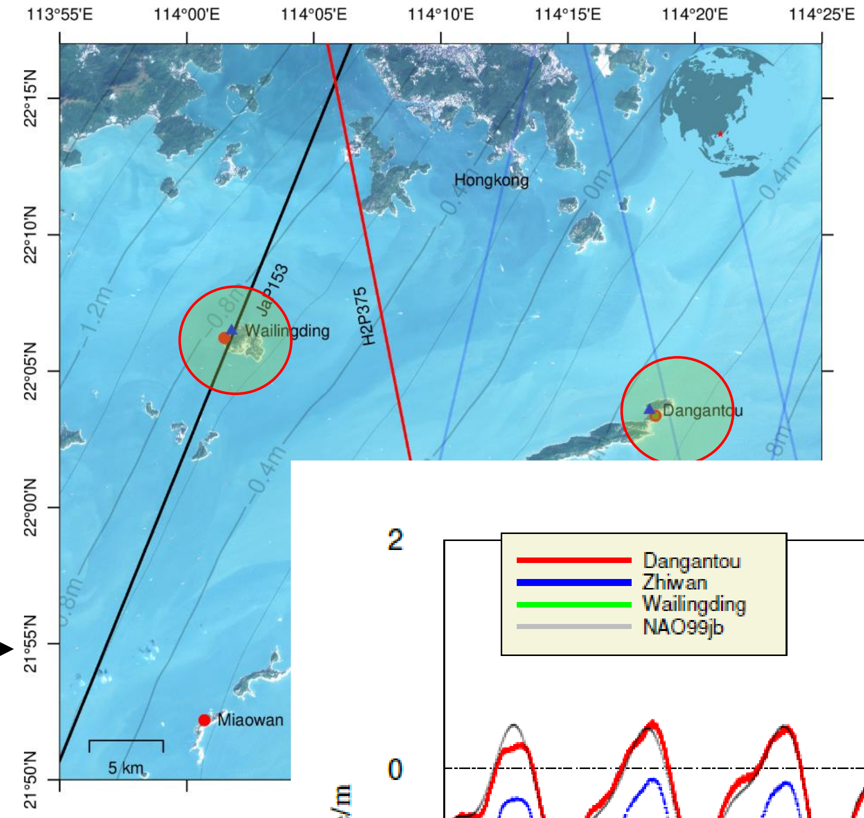
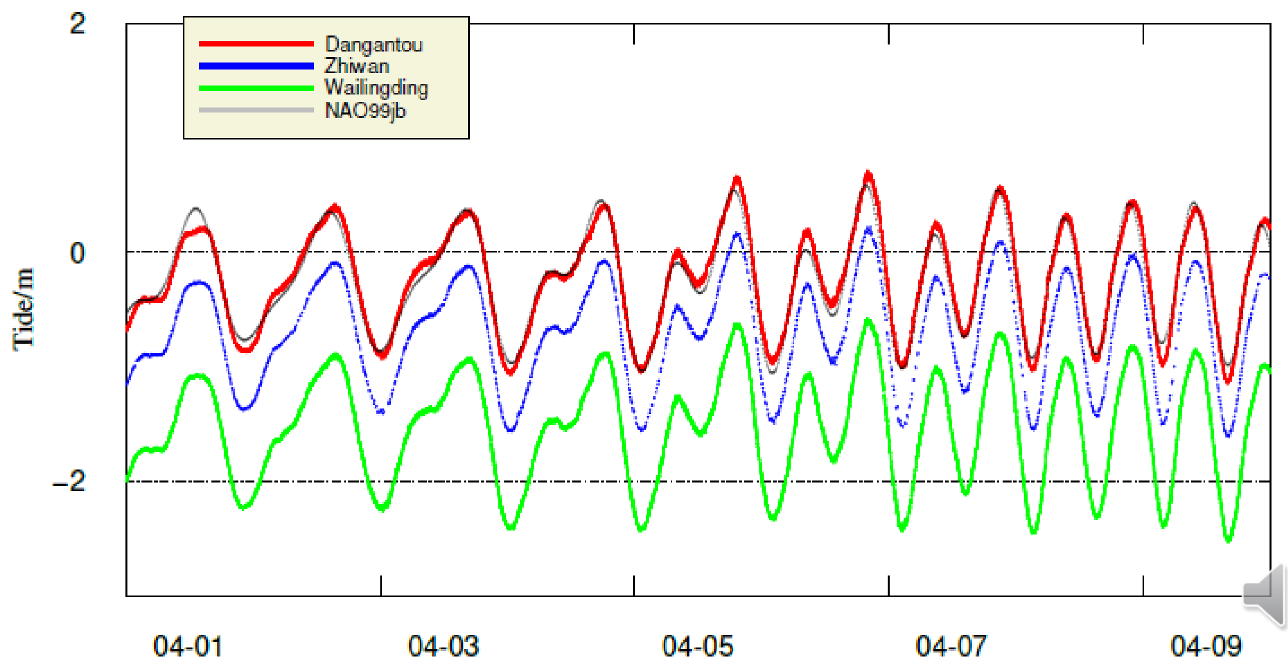
# China Altimetry Calibration Cooperation Plan



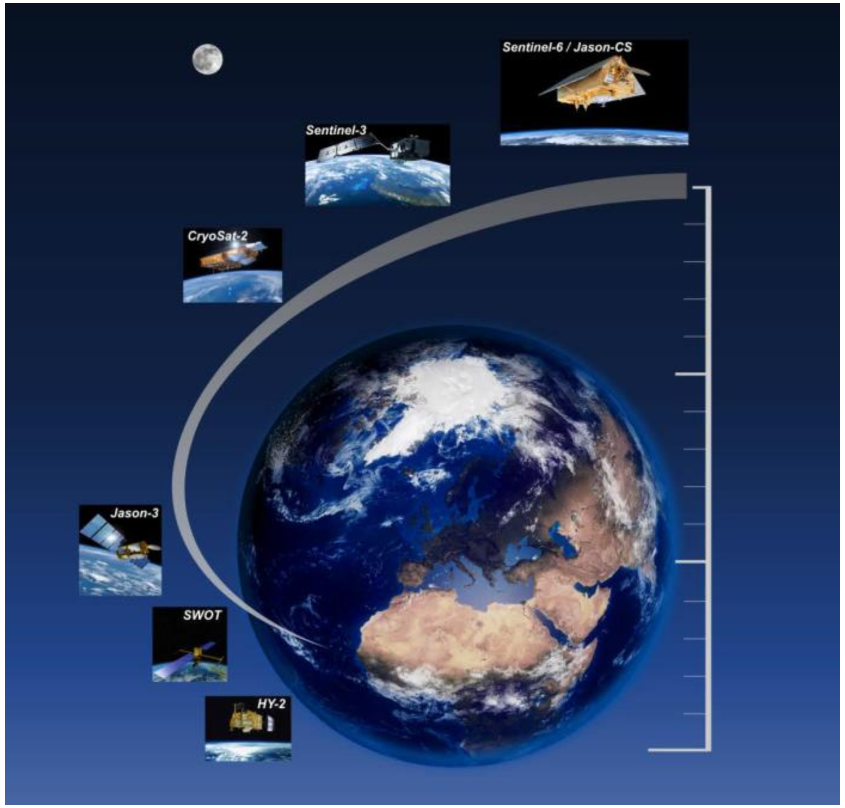

| ID | Cal/Val Site | Latitude | Longitude |
|---|---|---|---|
| QLY | Qianliyan (Qingdao) | 121.385E | 36.267N |
| ZMW | Zhimaowan (Bohai Sea) | 119.920E | 40.009N |
| Wanshan | Dangantou | 114.303E | 22.059N |
| Wanshan | Zhiwan | 114.147 E | 21.994 |
| Wanshan | Wai Lingding | 114.029E | 22.108N |



# Fiducial Reference Measurements for Altimetry

## ESA Effort to (FRM4ALT):

- 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).

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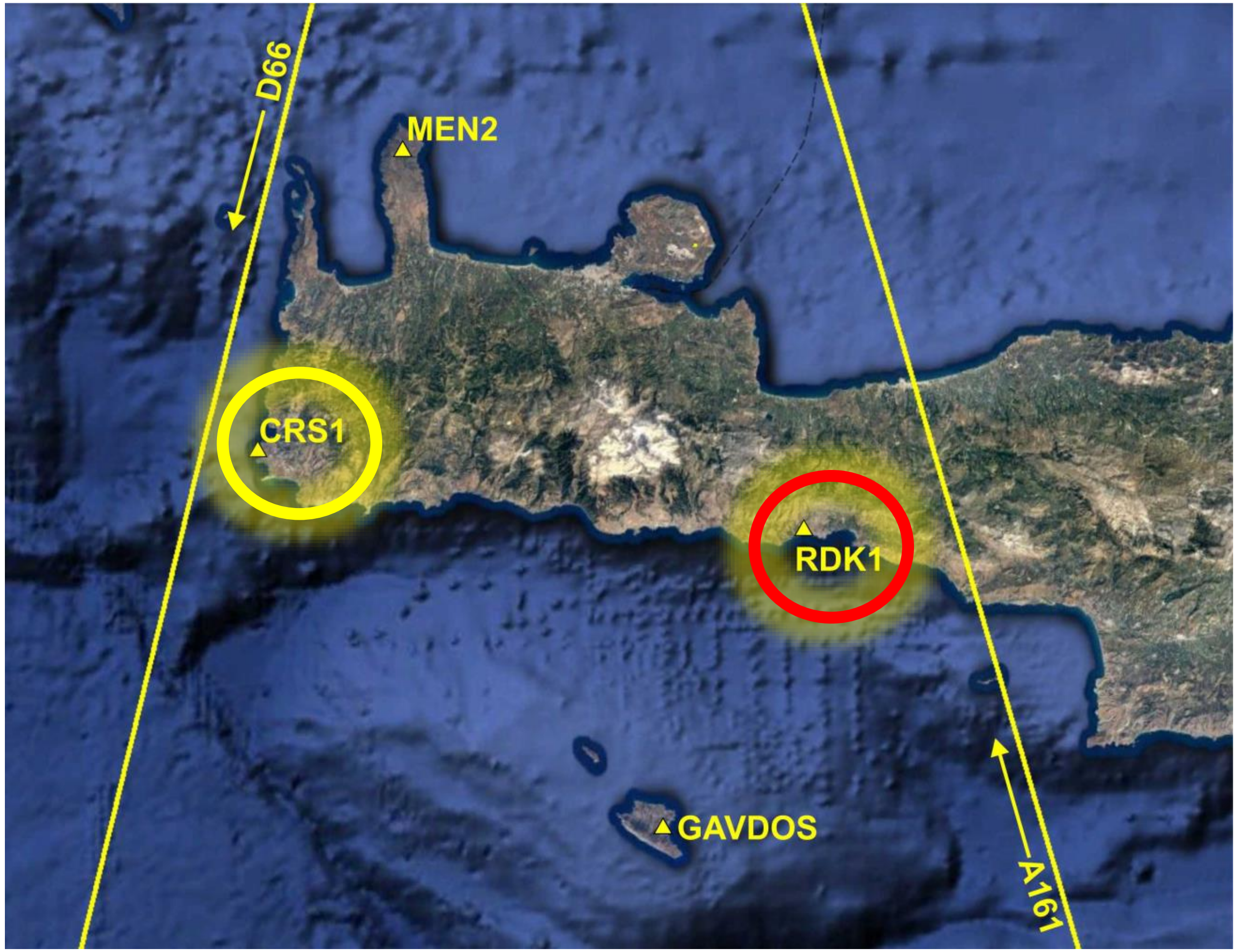
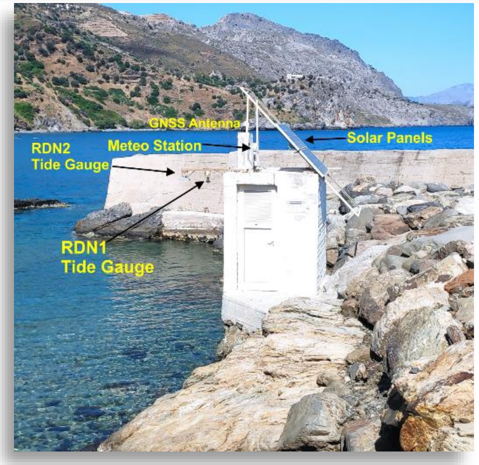
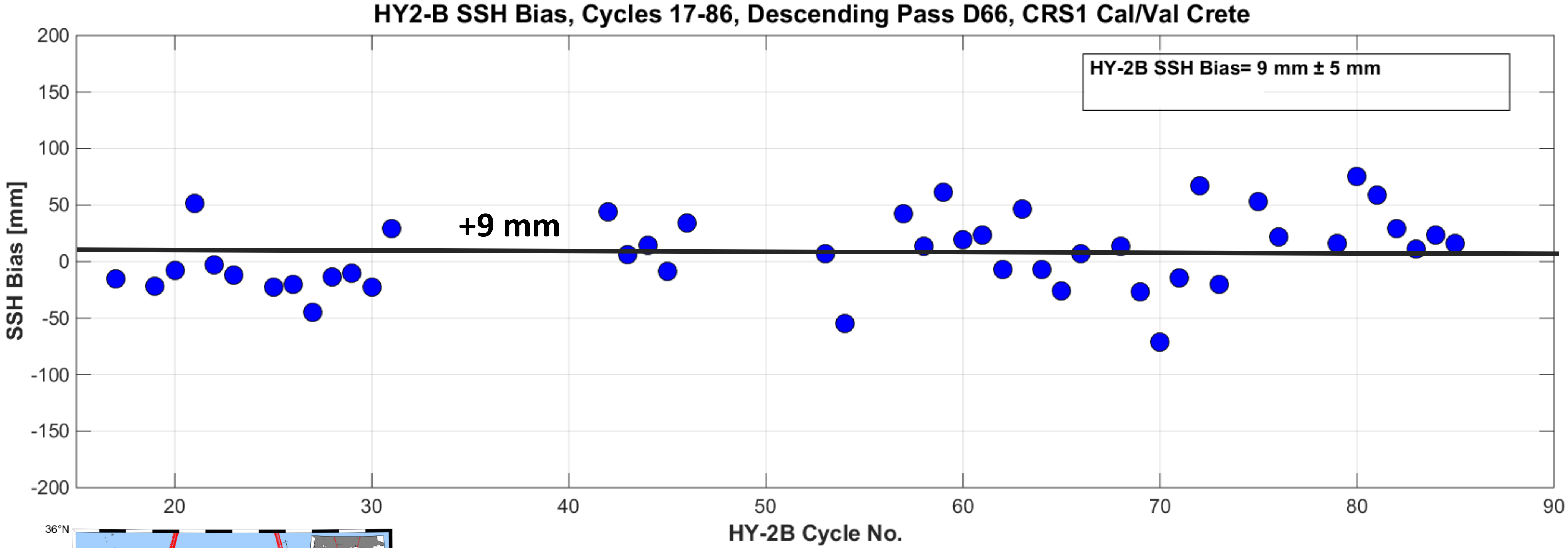
# HY-2B and CRS1 & RDK1 Cal/Val sites, Crete

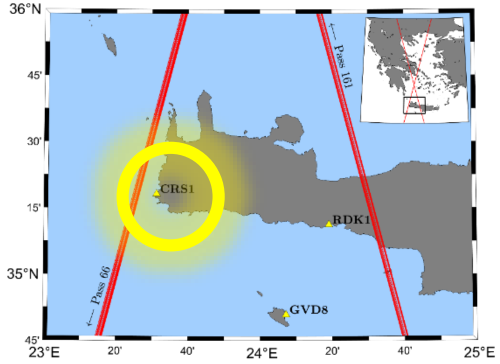






# HY-2B, Crete, CRS1 Cal/Val Results




- HY-2B: Mean Bias: +9 mm ± 5 mm,
- FRM Uncertainty : ± 45 mm

# HY-2B, Crete, RDK1 Cal/Val Results

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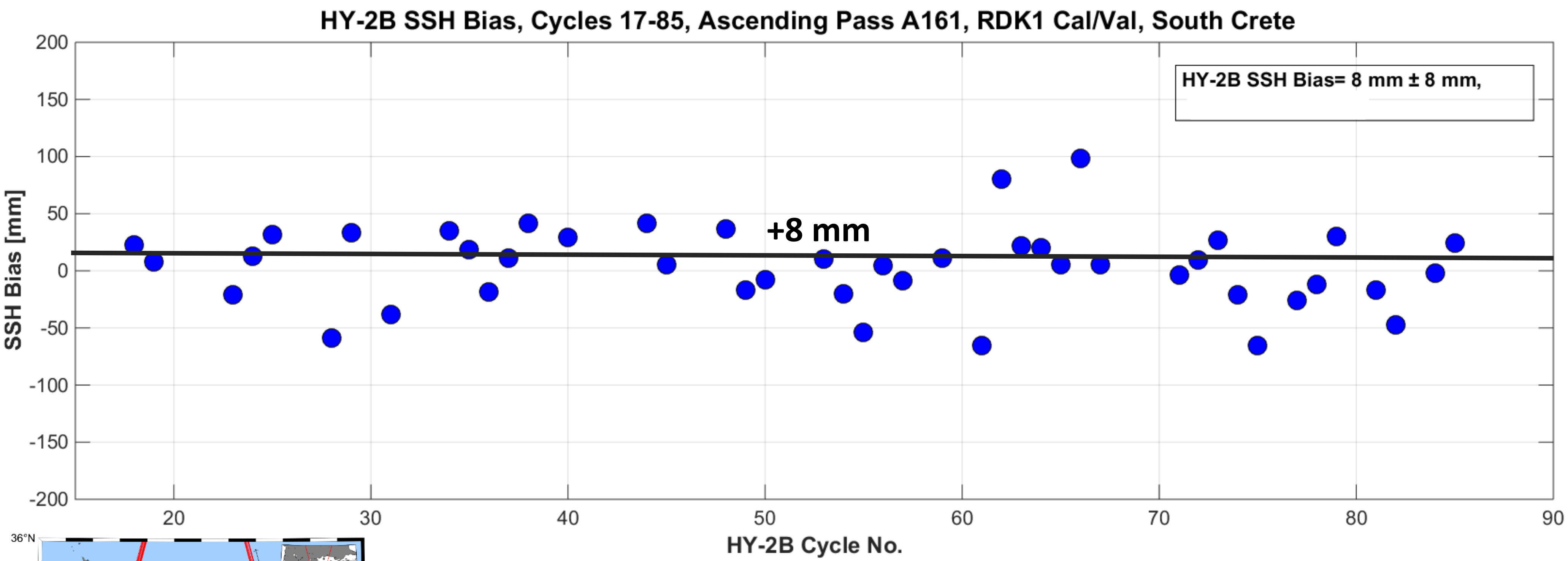


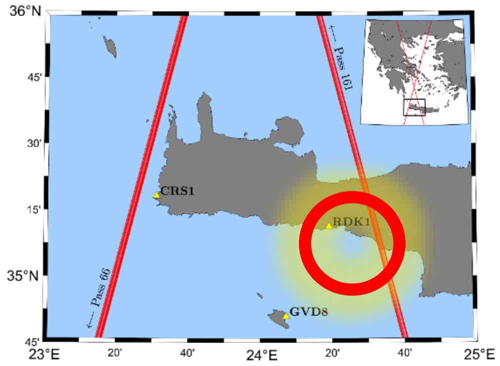


- HY-2B: Mean Bias: +8 mm ± 8 mm,
- FRM Uncertainty : ± 50 mm

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# HY-2B, Gavdos, GVD8 Cal/Val Results

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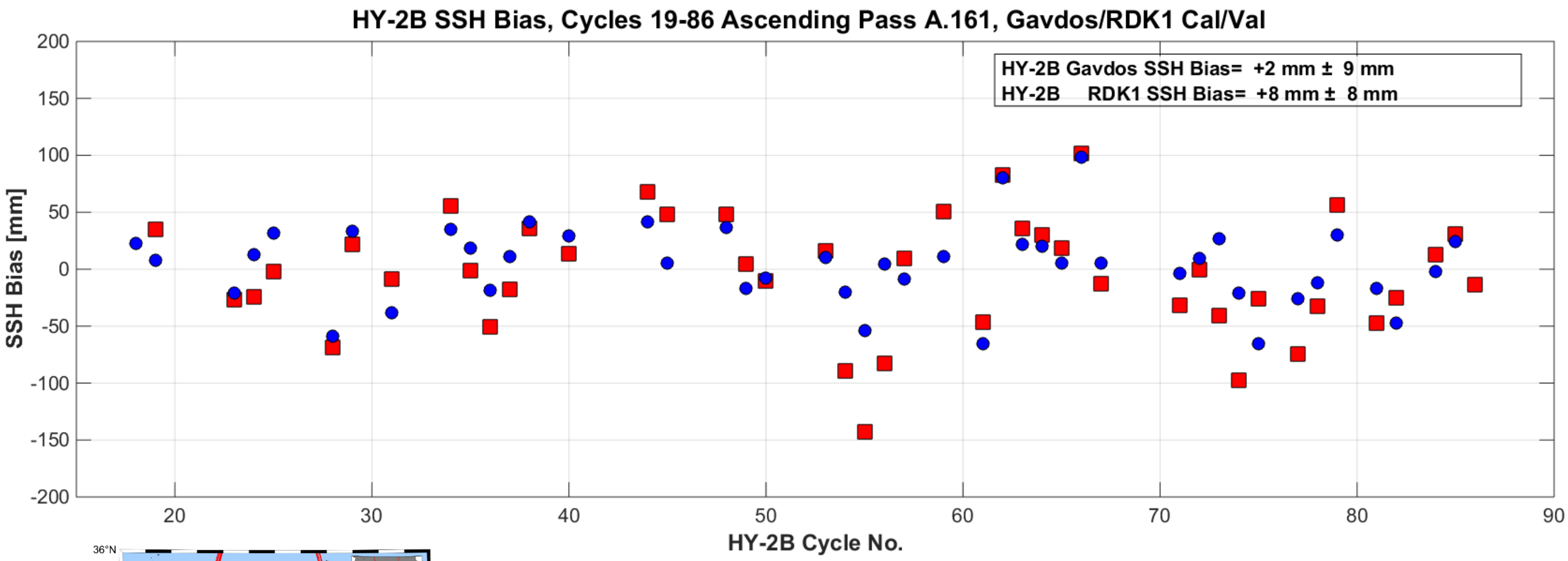


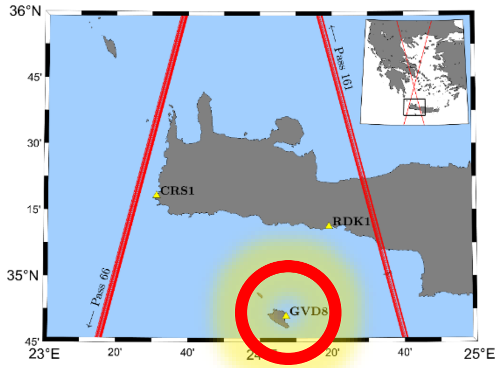


- HY-2B: Mean Bias: +2 mm ± 9 mm,
- FRM Uncertainty : ± 50 mm

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

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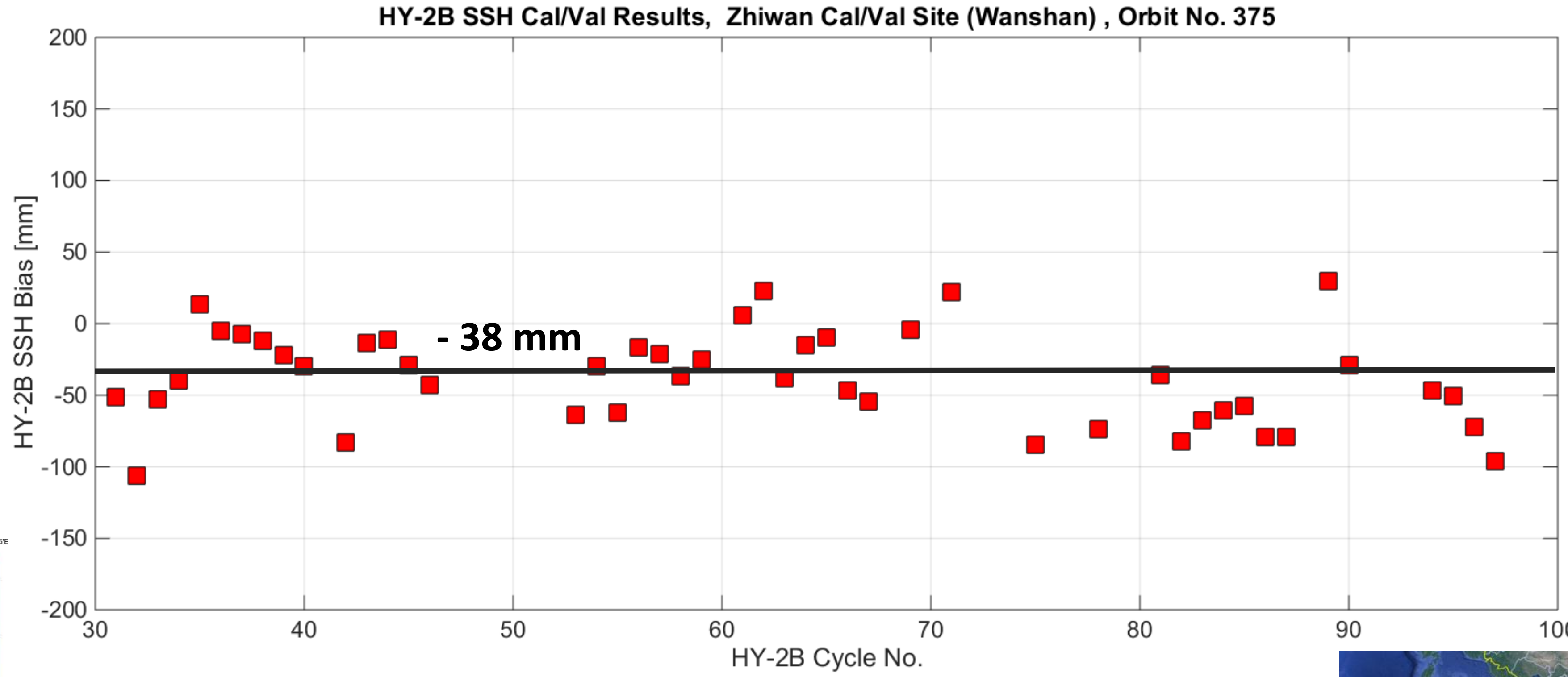


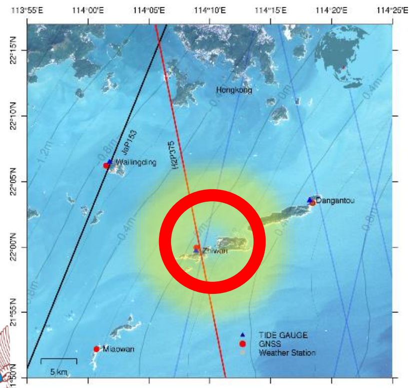


- HY-2B: Mean Bias: - 38 mm ± 3 mm,
- FRM Uncertainty : ± 50 mm

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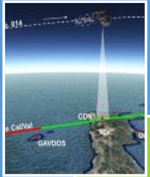
# Constituents of Uncertainty in Cal/Val Results

## 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

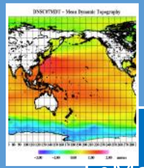
## Absolute positioning

- 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.

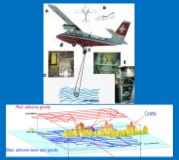
## Atmospheric Delays

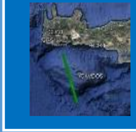
- GNSS-Derived ionospheric & zenith tropospheric delays at the time of satellite overpass
- Operation of meteo sensors
- Validation w.r.t. global/regional modeling
- Radiosondes, photometers, radiometers measurements
- OLCI observations.

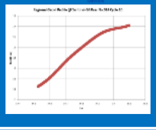
## Geophysical effects



- 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.

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# Uncertainty Budget for the SSH Cal/Val

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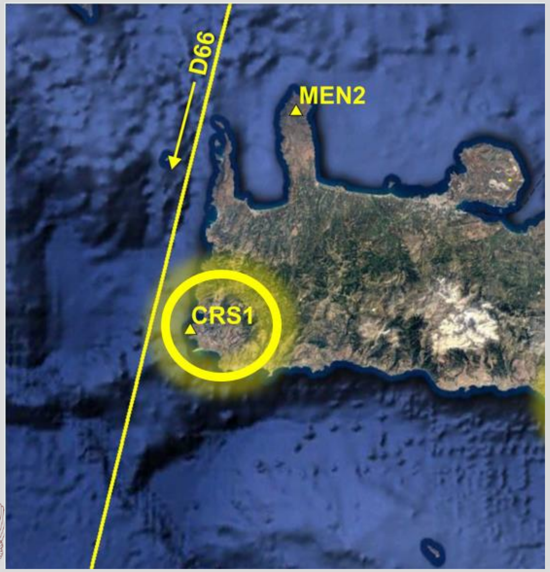
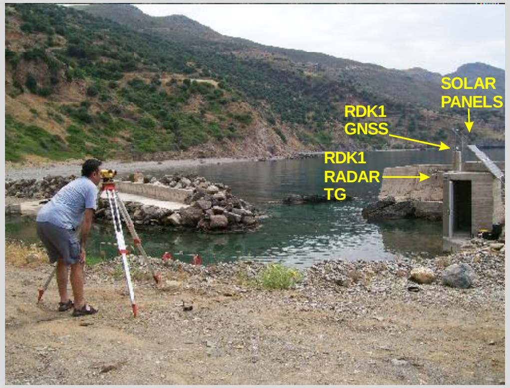
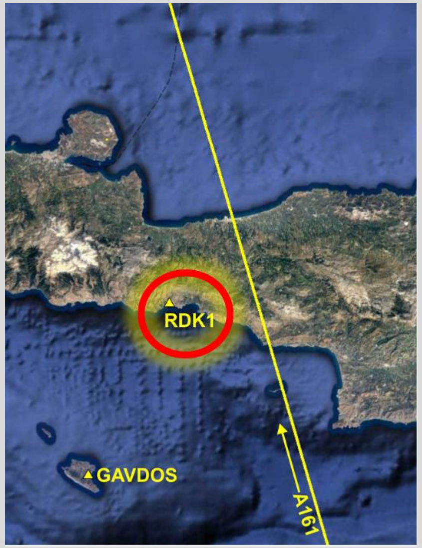



| Description | CRS1 | RDK1 |
|---|---|---|
| Tide gauge Sensor | ± 4 mm | ± 6 mm |
| Repeatability | ± 2.53 mm | ± 2.53 mm |
| Zero-point reference | ± 2.50 mm | ± 2.50 mm |
| GNSS Receiver | ± 3.46 mm | ± 3.46 mm |
| GNSS Repeatability | ± 0.08 mm | ± 0.09 mm |
| GNSS ARP | ± 4.04 mm | ± 4.04 mm |
| GNSS Solution | ± 0.08 mm | ± 0.13 mm |
| GNSS Velocity | ± 1.96 mm | ± 4.55 mm |
| GNSS Integration | ± 3.75 mm | ± 3.75 mm |
| Control Ties | ± 3.75 mm | ± 3.75 mm |
| Reference Surfaces | ± 42.00 mm | ± 47.00 mm |
| Final Water Level | ± 7.50 mm | ± 7.50 mm |
| Geoid Slope | ± 5.77 mm | ± 5.77 mm |
| Processing | ± 0.29 mm | ± 0.29 mm |
| Unaccounted Effects | ± 11.55 mm | ± 11.55 mm |
| Uncertainty Budget | ± 45.41 mm | ± 50.44 mm |

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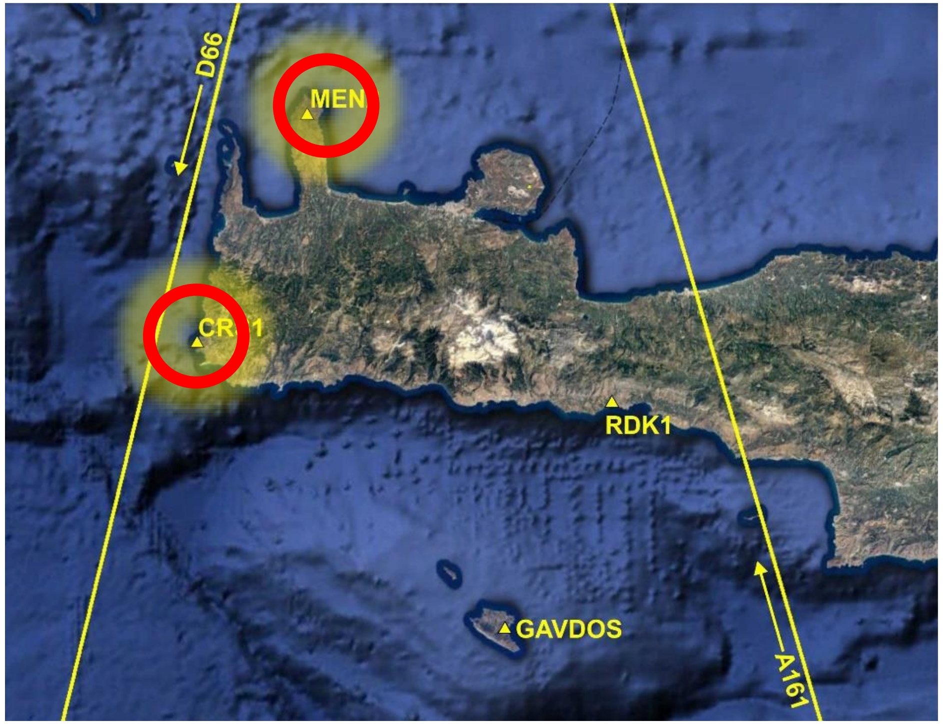
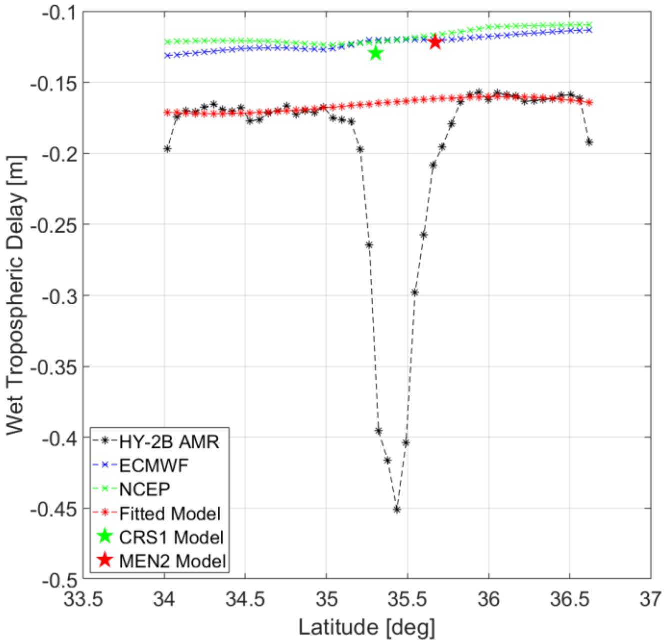
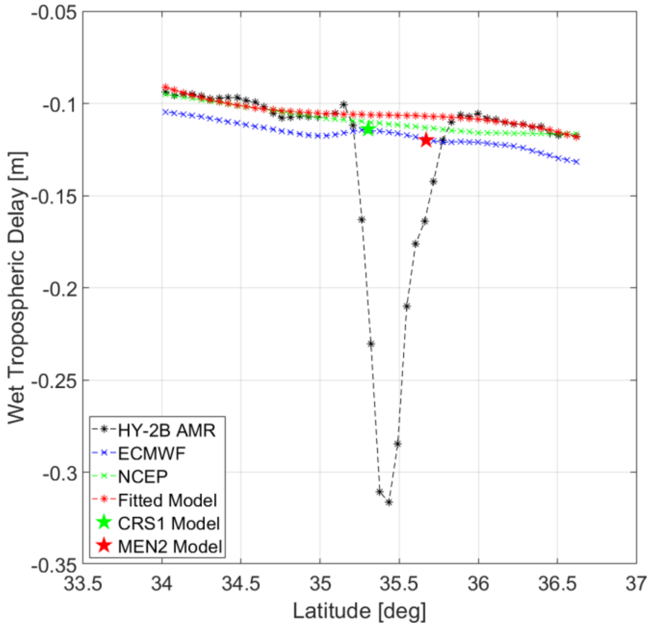
# HY-2B, Radiometer Calibration




| Difference | Average | $\sigma$ |
|---|---|---|
| HY-2B AMR – CRS1(GNSS) | -7 mm | ±27 mm |
| HY-2B AMR – MEN2 (GNSS) | +7 mm | ±30 mm |
| HY-2B AMR – ECMWF | + 3 mm | ±24 mm |
| HY-2B AMR – NCEP | -13 mm | ±25 mm |

# European Young Researchers

- European Young Researchers:
- **Costas Kokolakis**, PhD candidate;
- **Dr. Dimitrios Piretzidis**, Post-Doc researcher.
- Upgrade the SSH Altimeter Calibration Techniques;
- Design, Manufacture, Establish at a proper ground site a Corner Reflector for sigma-0 Altimeter Calibration;
- Determine Uncertainty on FRM Strategy.

| Name | Institution | Poster title | Contribution |
|---|---|---|---|
| Constantine Kokolakis | Technical University of Crete, Greece | Absolute Calibration of σ0 for European and Chinese Satellite Altimeters using Passive Corner Reflectors | First steps and tests for design, implementation and validation of corner reflectors for absolute sigma-naught calibration of satellite altimeters. |

# Conclusions

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- 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;
- Cross-calibrate diverse missions;
- Calibration of HY-2 microwave radiometer;
- Joint Journal Publication is ready to be submitted.

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