Precise Jason-2 absolute altimeter calibration by means of a microwave transponder

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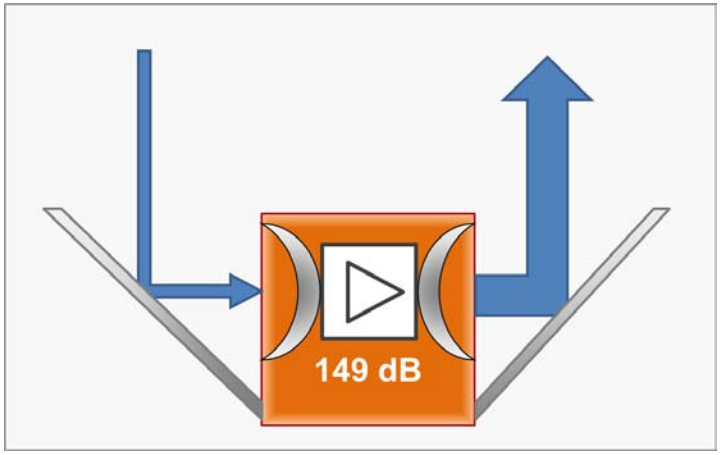
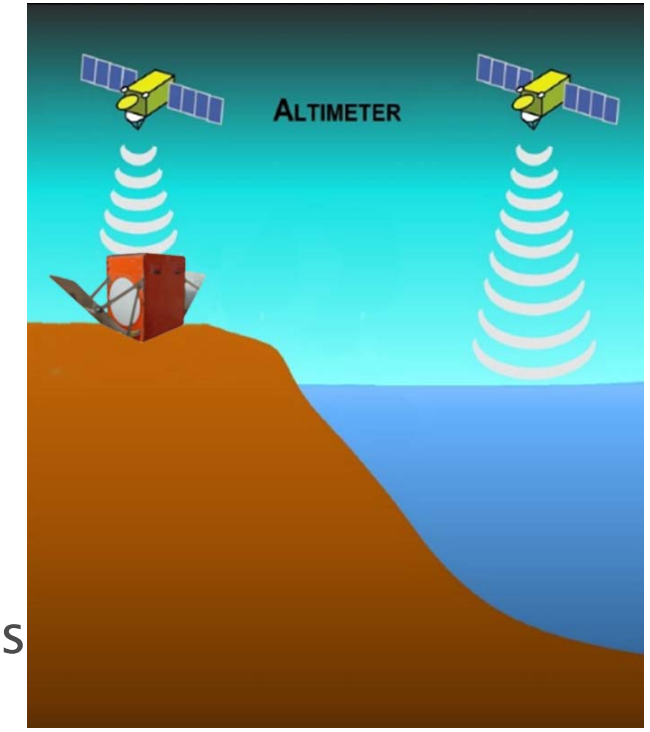
Microwave Transponder

- Ku-band signal repeater
  - Frequency: 13.75 GHz±300 MHz
  - Antenna diameter: 42 cm
  - Total system gain: 149 dB





- Major advantages
  - Stable point of reflection
  - Coastal and inland altimeter measurements
  - No influences from ocean dynamics

Principle of Transponder Calibration

Conventional Method

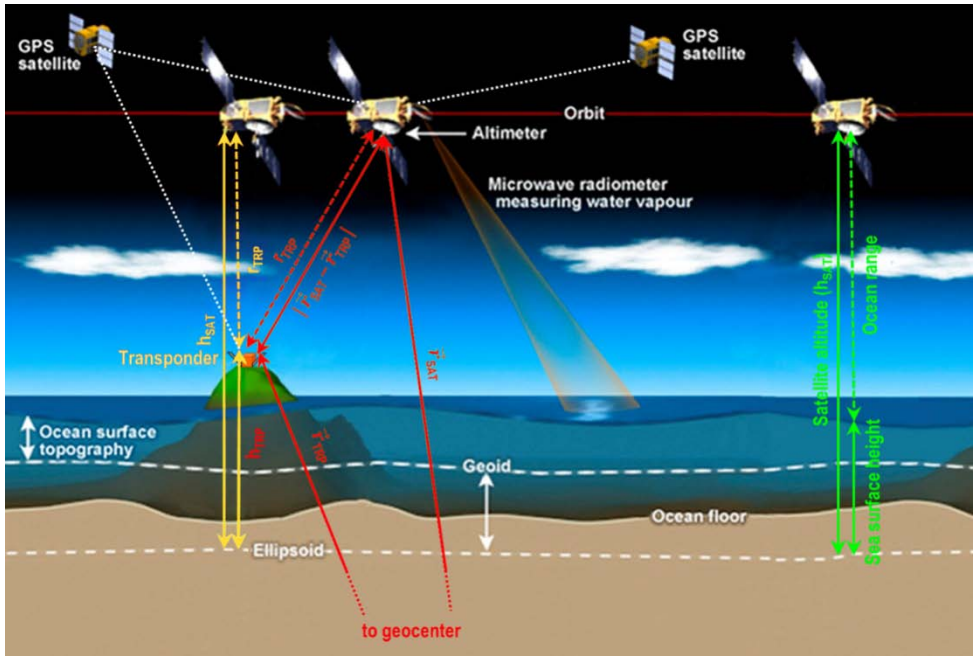
- Measurement of the nadir range to the sea surface
- Complementary in-situ observations from GPS buoys, tide gauges, etc.

$$B = \left(h_{SAT} - h_{LSL}^{ALT}\right) - SSH_{tide\ gauge}$$

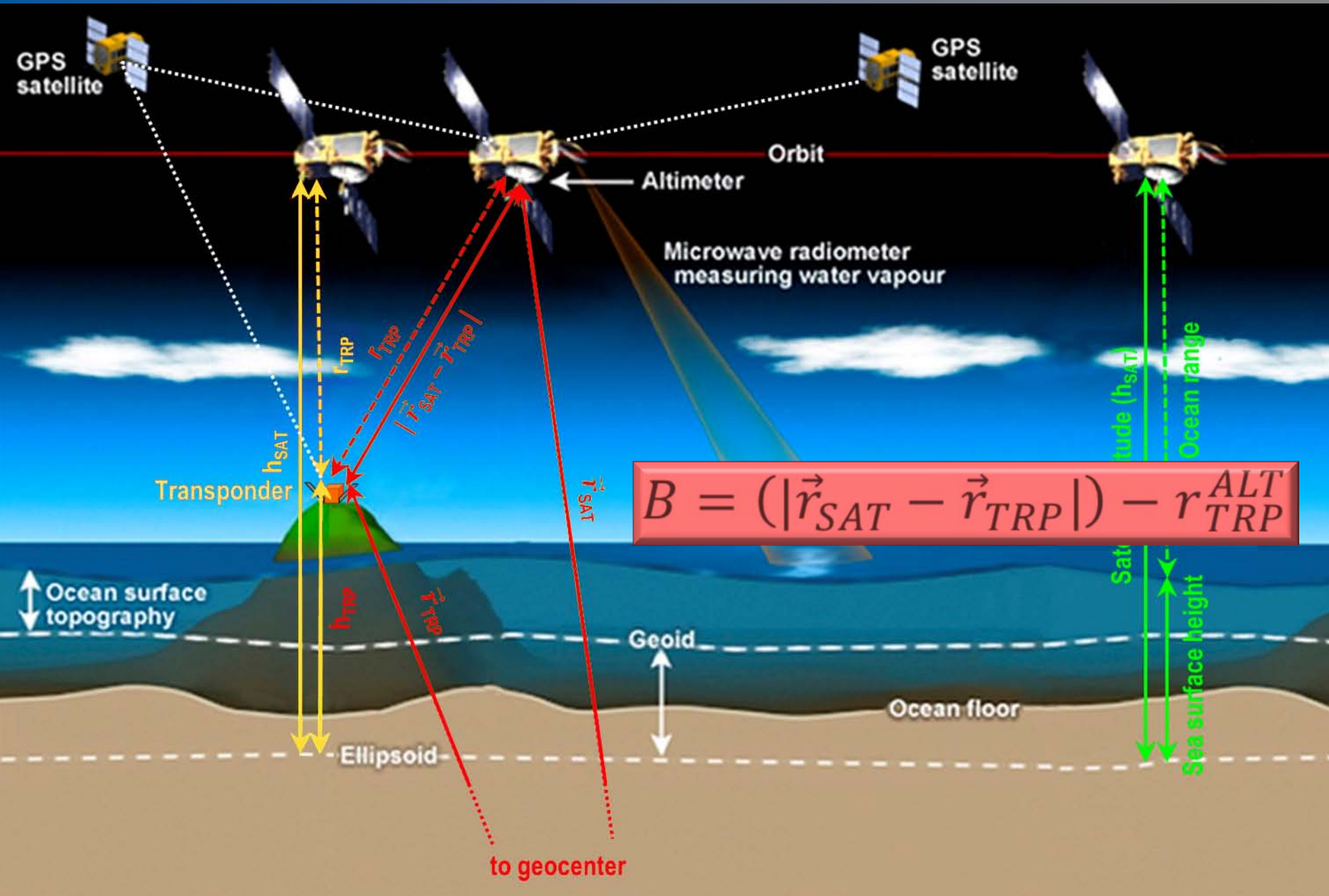
Transponder Method

- Measurement of the slant range to the transponder

$$B = \left(|\vec{r}_{SAT} - \vec{r}_{TRP}|\right) - r_{TRP}^{ALT}$$

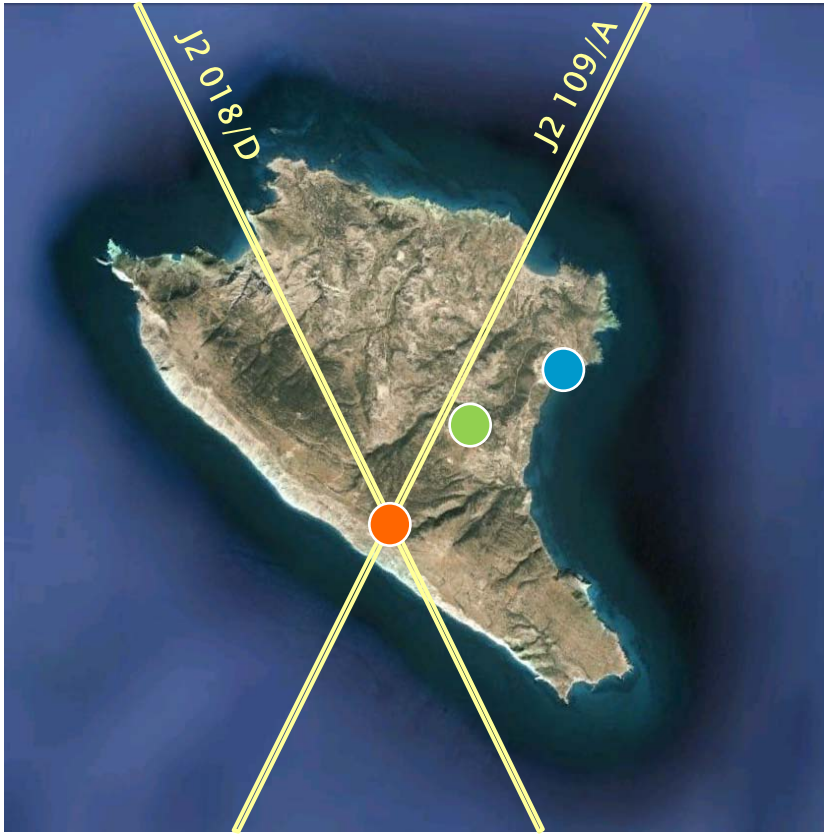


Principle of Transponder Calibration



Gavdos Cal/Val Station

- Gavdos cal/val station
  - Tide Gauge, DORIS, Transponder
  - Jason-2 cross-over: 018D/109A
- TRP site equipment
  - Concrete base
  - Fabric housing with acrylic glass roof
- Electric power supply
  - Photovoltaic unit
- Remote operation
  - GPRS-Modem



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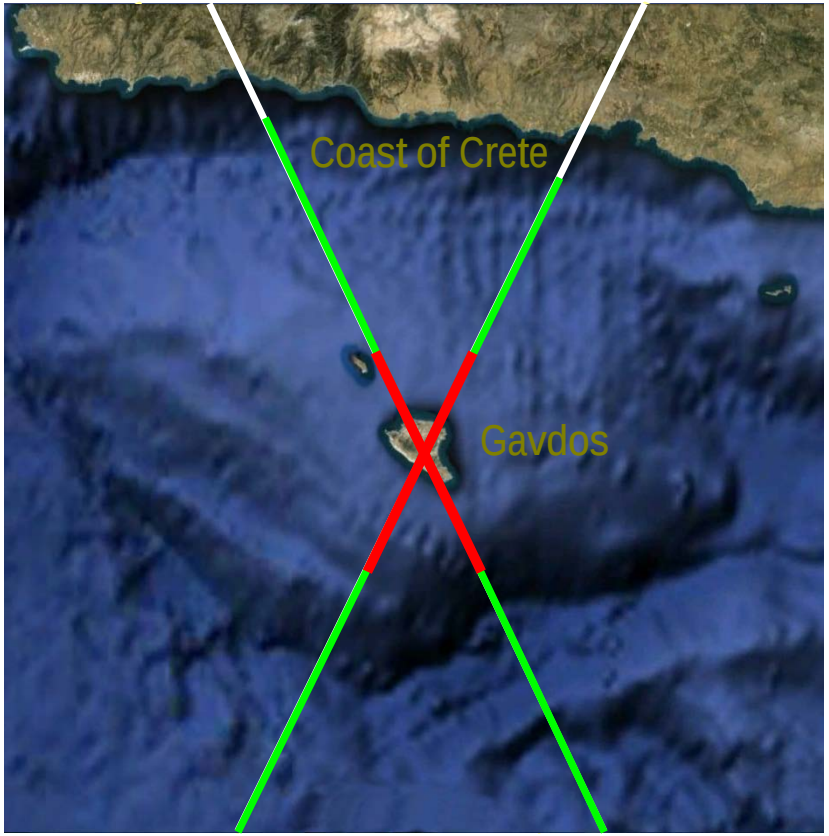
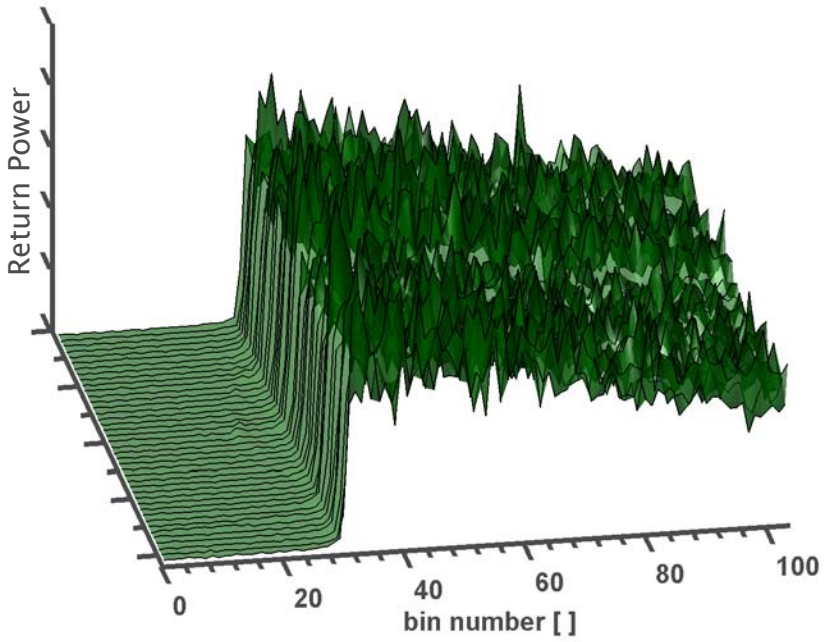
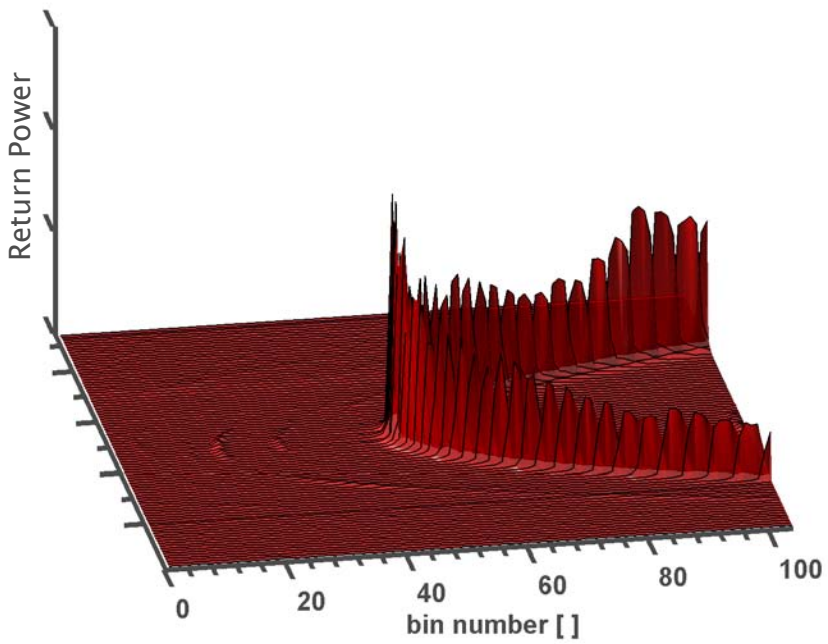


Ocean vs. Transponder Waveform

- **Ocean** – return pulse
  - Regionally generated response
  - Brown modelled signals

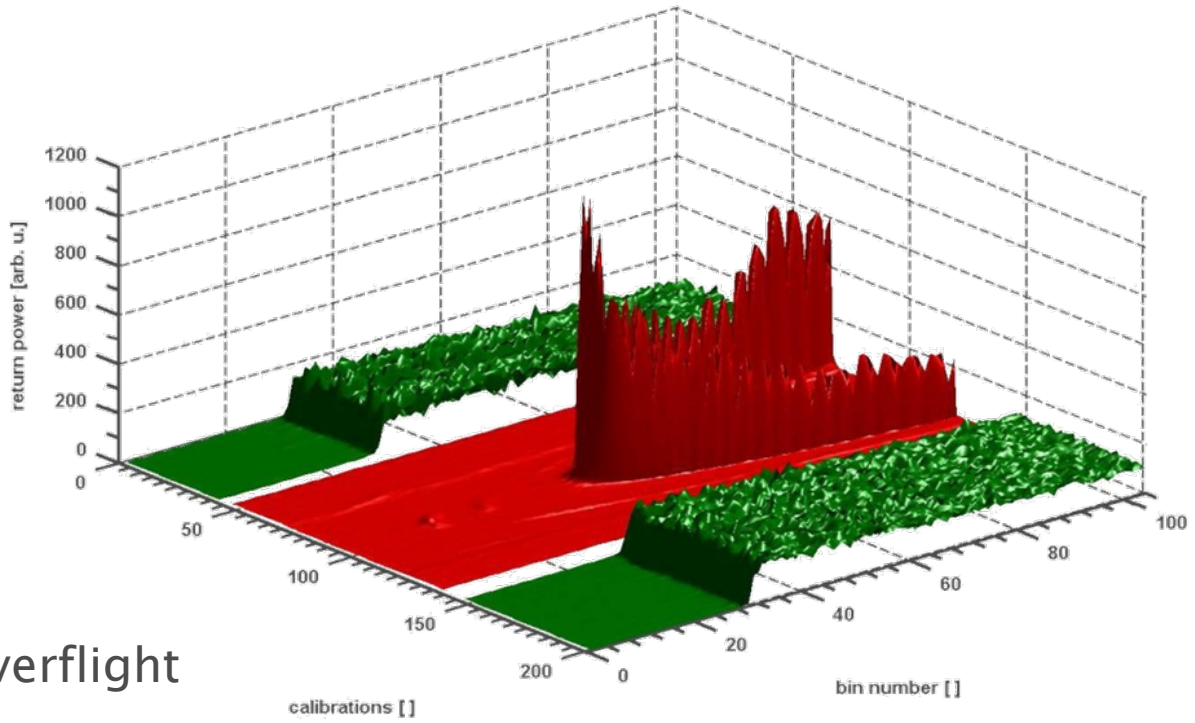


- **Transponder** – return pulse
  - Characteristics of point target response
  - Peak shaped signals



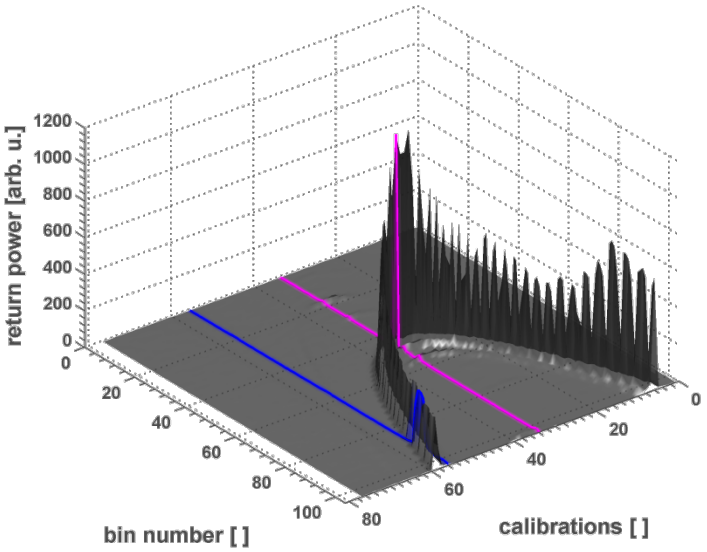
Jason-2 Altimeter Operation Modes

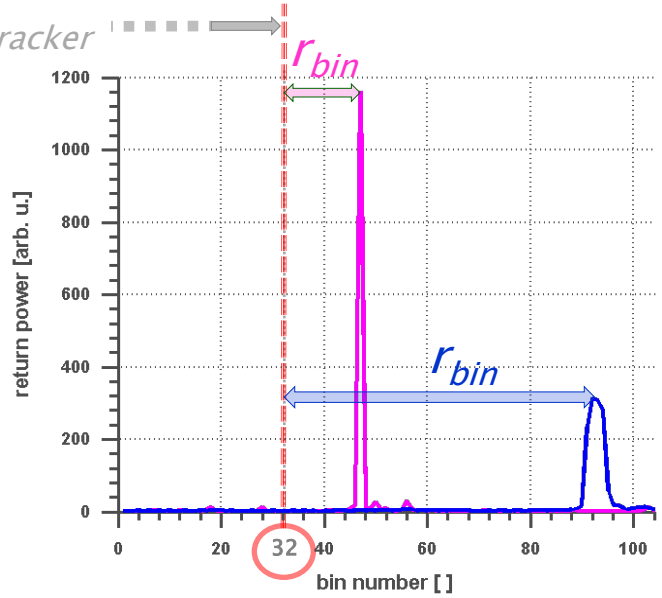
- Poseidon-3 modes of operation/calibration
  - **Tracking mode**
    - Loss of tracking mode due to sudden increase of land elevation
  - **CAL-2 mode**
    - Low resolution (150 ms sampling)
    - Complex handling
  - **DIODE / DEM**
    - 20 Hz waveforms
    - Simple handling
    - Locally activated for each transponder overflight
    - 104 bins @ 3.125 ns sampling



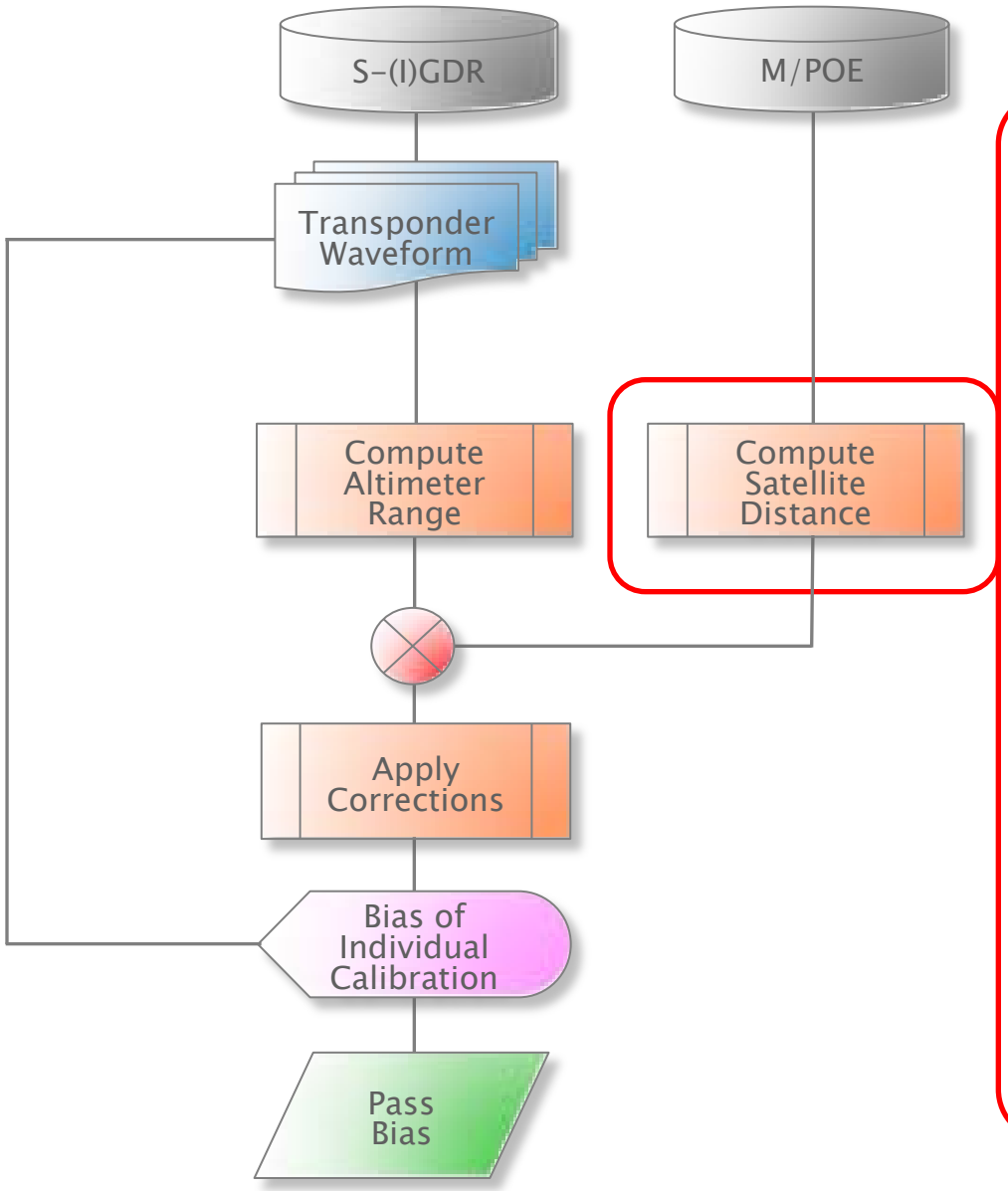
Altimeter Range from DIODE/DEM Mode

- DIODE/DEM generated transponder waveforms
  - Defined reference distance given with the products
    - Reference bin number 32 → Tracker range $r_{tracker}$
  - Bin range computed from exact epoch time of TRP reflection
    - Calibration close to point of overflight → Bin range r_{bin}
    - Calibration at outbound arc → Bin range r_{bin}
  - Altimeter range: $r_i = r_{tracker} + r_{bin} + \Delta r_{corr}$





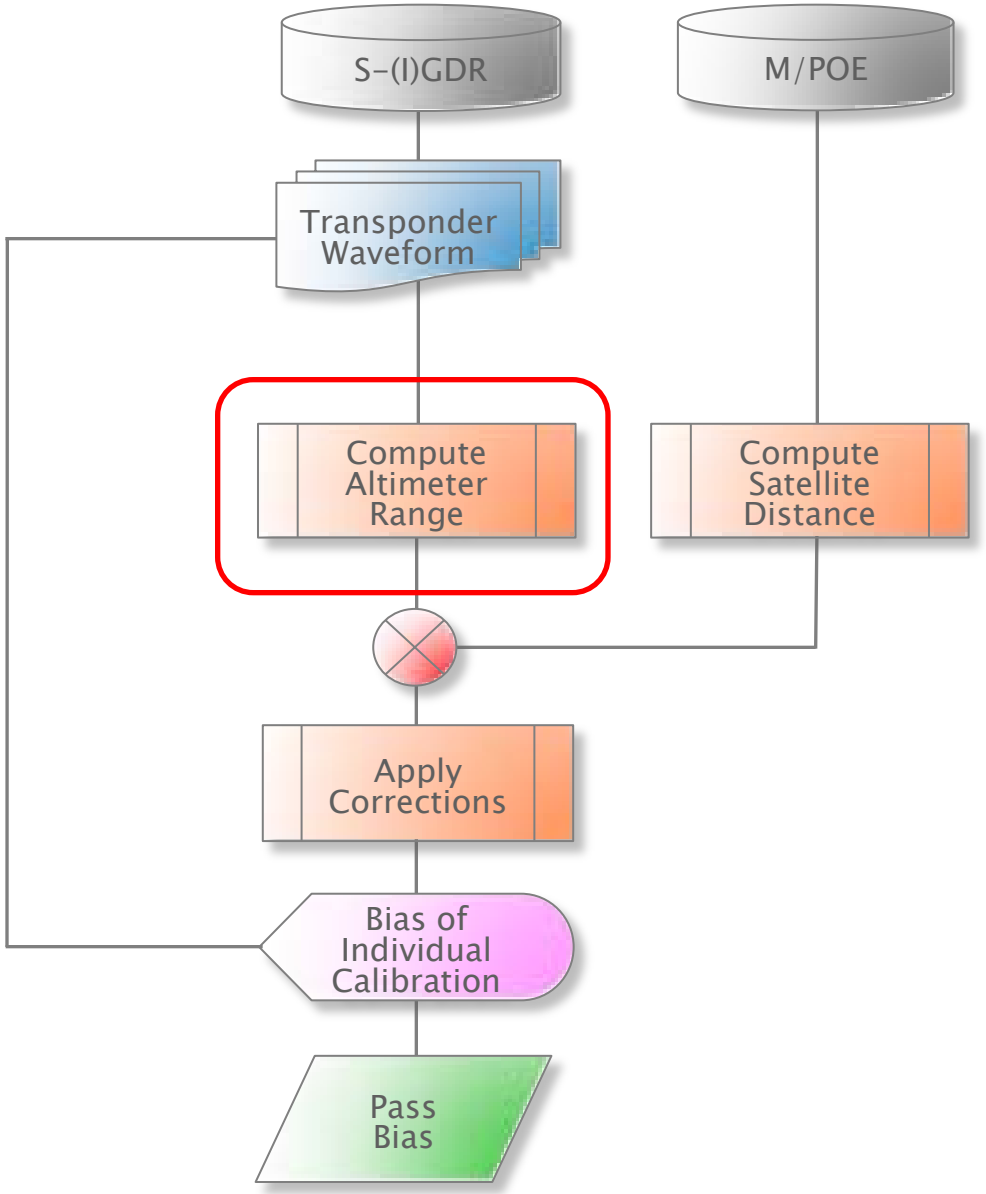
Transponder Calibration Flow Chart



- Distance between satellite and transponder
  - Satellite orbit position
    - MOE (S-IGDR)
    - POE (S-GDR)
  - Transponder position
    - GPS/leveling campaign
      - ITRF2005 coordinates
      - Epoch (DOY): 2010/305

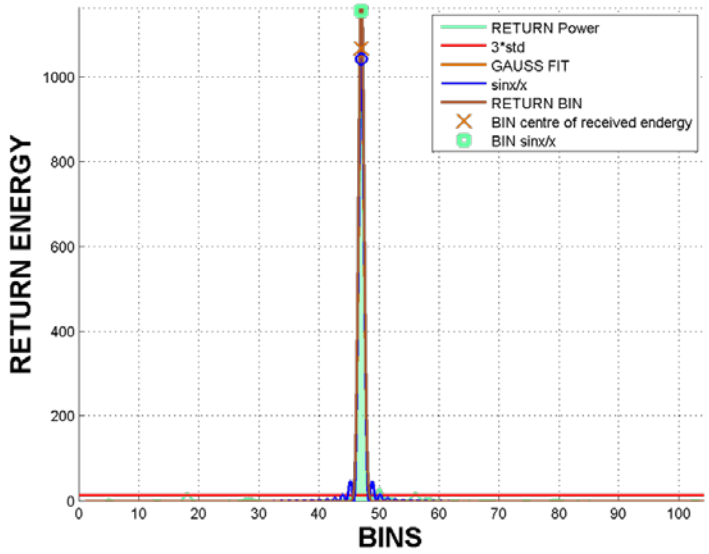
$\varphi = 34° 49' 17" N$
$\lambda = 24° 05' 27" E$
$h = 251.5\ m$

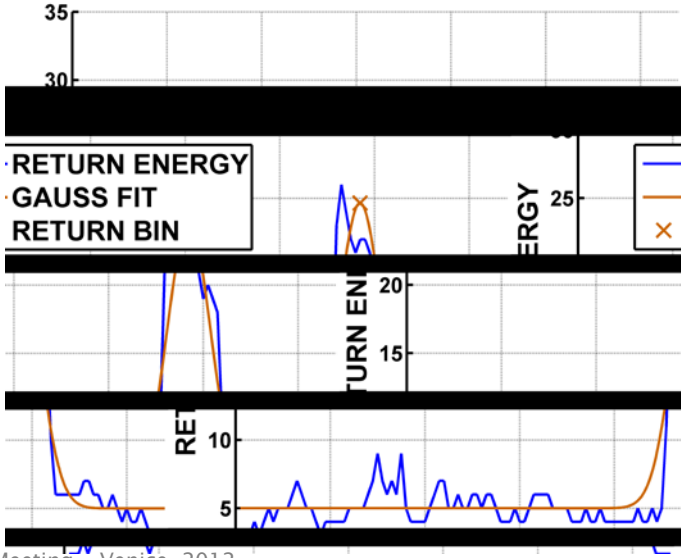
Transponder Calibration Flow Chart

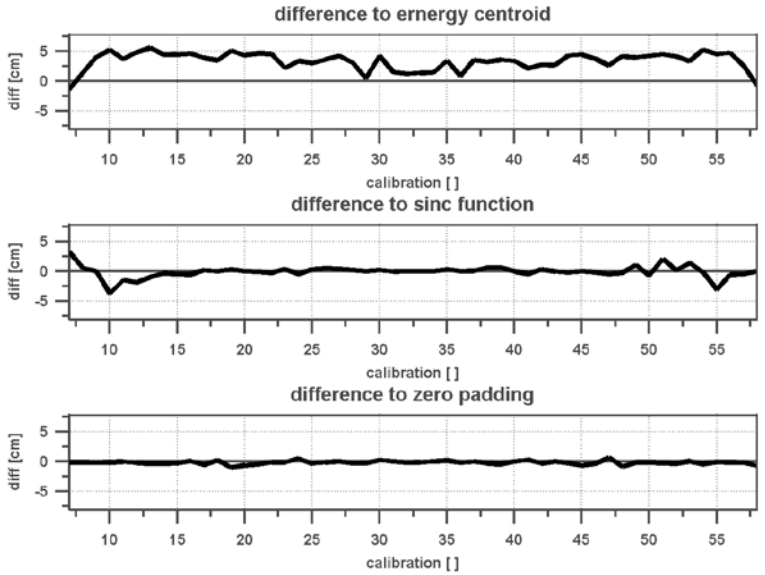


Transponder Waveform Retracking

- Fitting methods for TRP return bin computation
  - Gauss fit
  - Center of energy
  - Sinc-function
  - Zero-padding

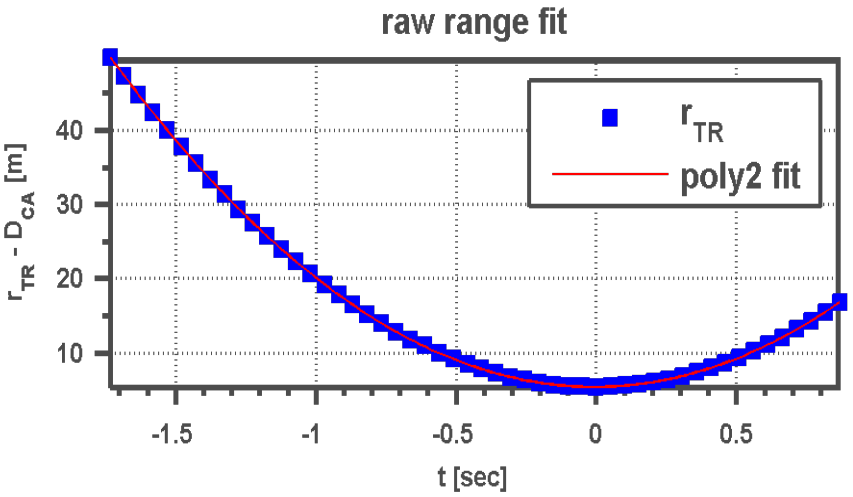


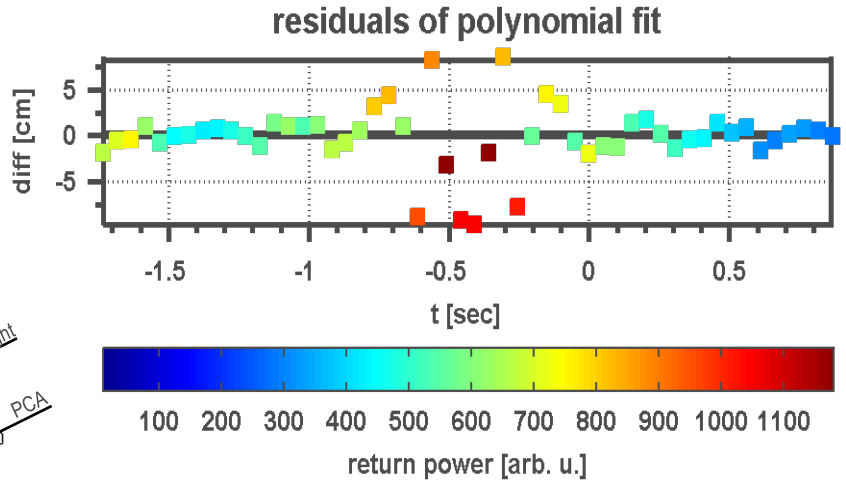


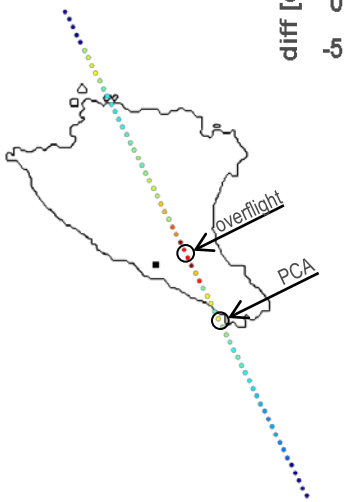


Altimeter Range Determination

- Approximation of individual calibrations (≈50 cals.)
  - Determination of TRP return bin
- Polynomial fit to all cals.
  - Bin fitting residuals
    - Large residuals at overflight
    - Correlation with max. return energy
  - Iterative fitting process with …
    - Inverse energy weighting
    - 3-σ outlier detection
  - Vertex defines PCA
    - Measure of timing bias

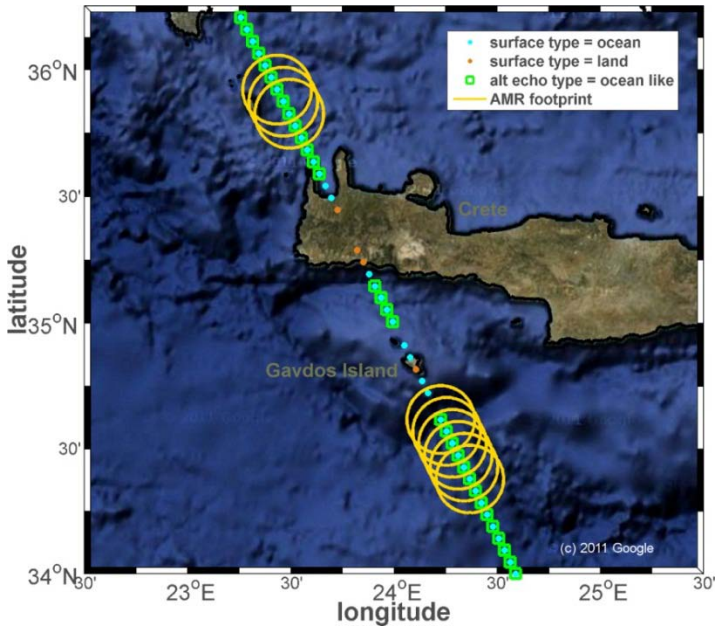


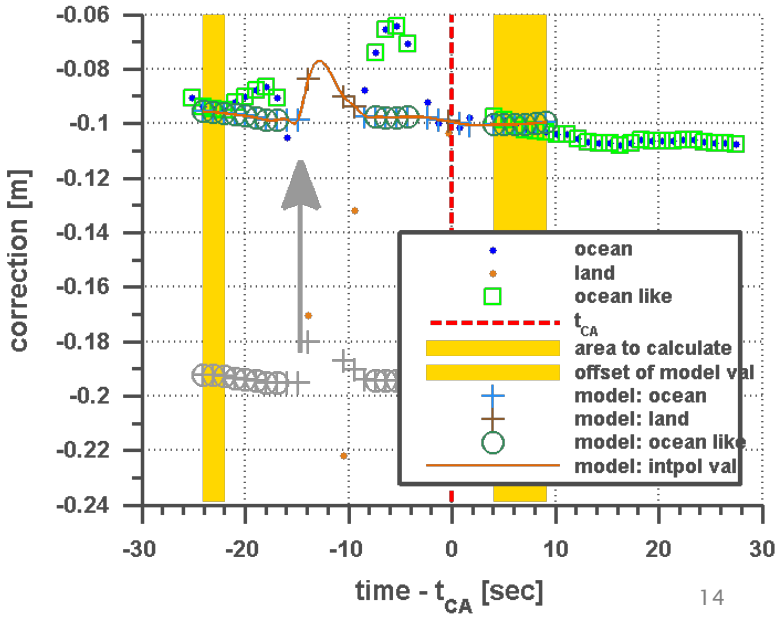




Altimeter Range Corrections

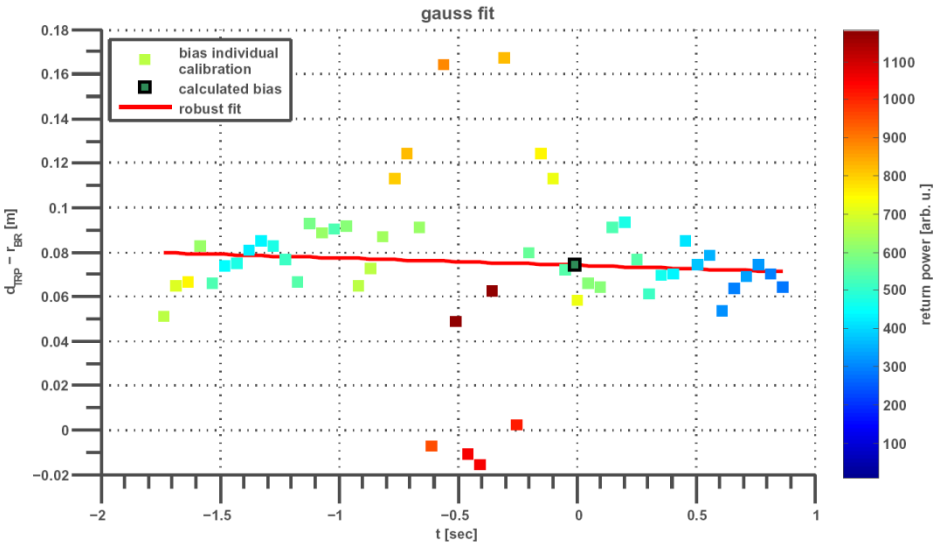
	Correction		Source
Altimeter	Altimeter Path Delay	Δr_{path}	GDR-T corr.
	Altimeter Phase Center	Δr_{cog}	GDR-T corr.
	DORIS USO Correction	Δr_{uso}	GDR
Transponder	TRP electronic delay	Δr_{elec}	HF Lab
	TRP geometric delay	Δr_{geom}	Manufacturer
	TRP signal delay roof	Δr_{pmma}	HF Lab
Propagation	Ionosphere	Δr_{iono}	GIM model
	Dry troposphere	Δr_{dry}	GDR
	Wet troposphere	Δr_{wet}	AMR + ECMWF
Geophysical	Solid Earth tides	Δr_{solid}	GDR
	Pole tides	Δr_{pole}	GDR
	Ocean loading	Δr_{load}	GDR
misc.	Pseudo-Doppler	Δr_{dopp}	computed
	Pseudo Time-Tag Bias	Δr_{dat}	CNES

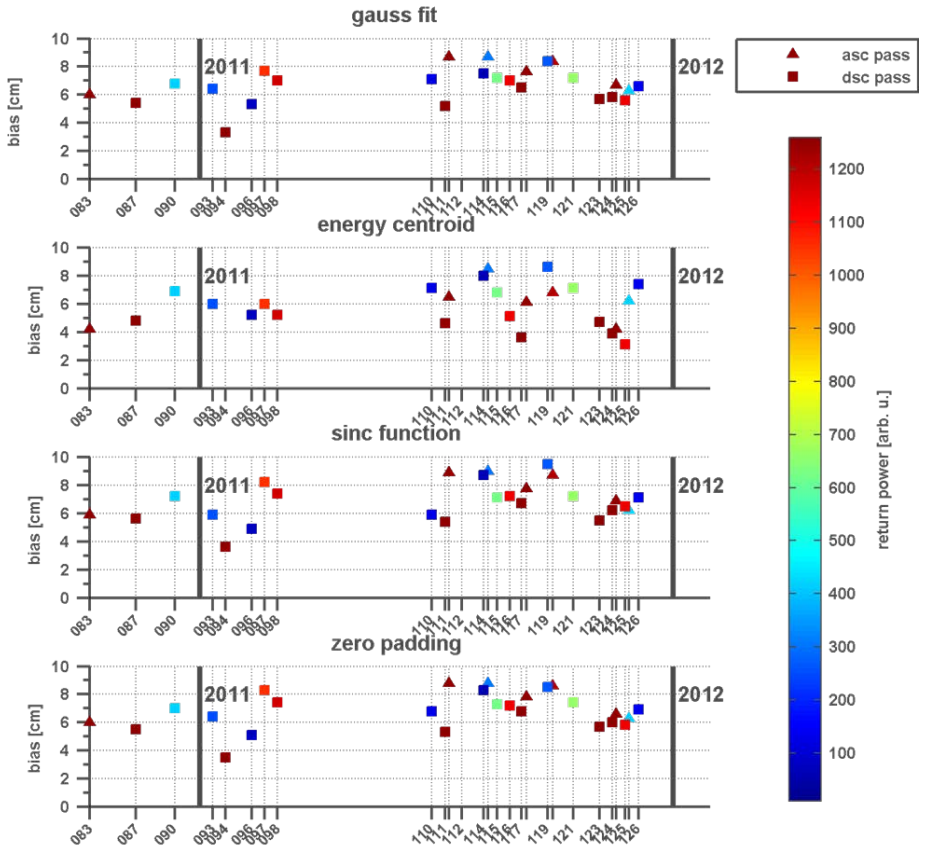




Altimeter Pass Bias Results

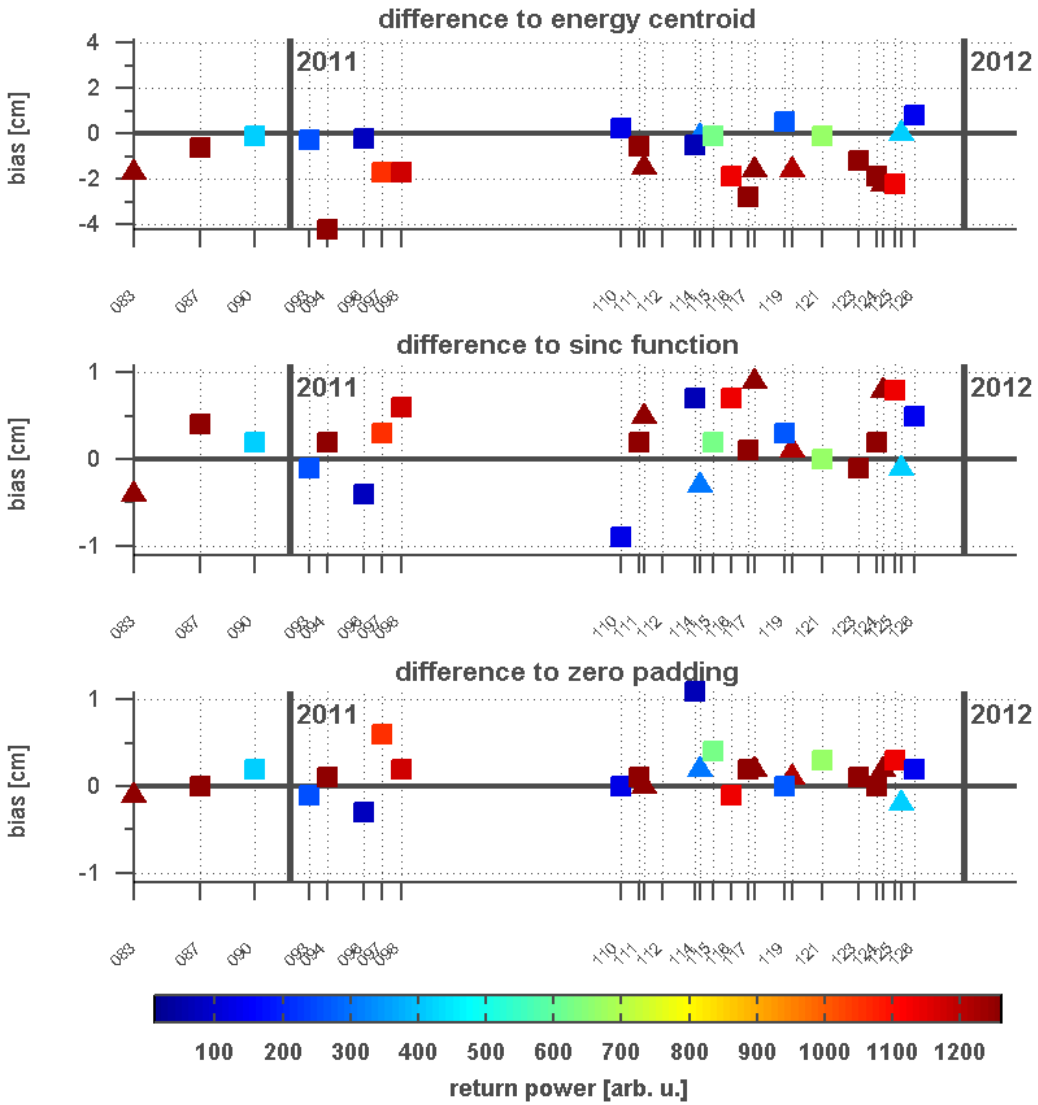
- Robust fit to final residuals
  - Inverse return power weighting
  - Pass bias taken at PCA
- Transponder Campaign
  - 27 Passes
  - 10/2010 – 01/2012





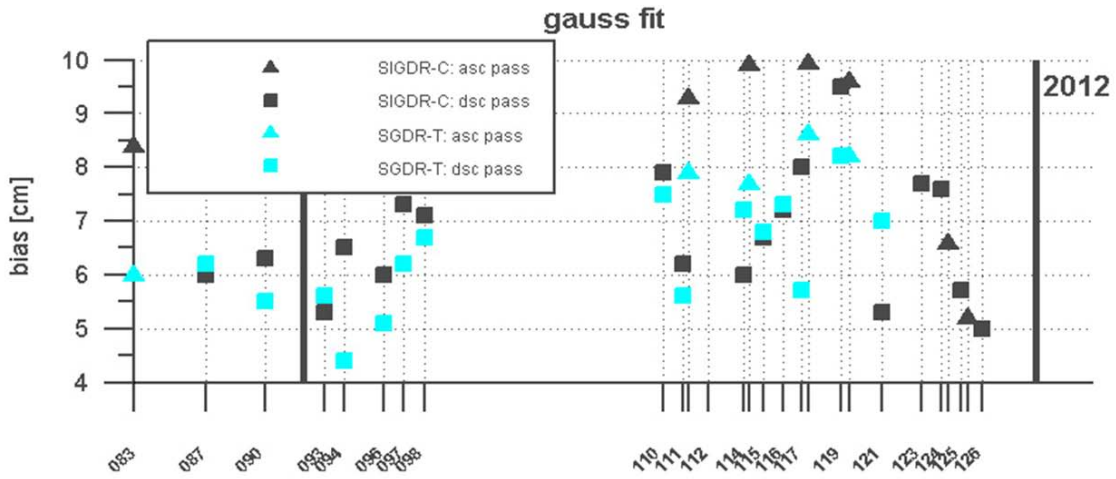
Discussion of Bias Results

- Differences wrt. Gauss fit
  - Sinc-function: <1cm
  - Zero-padding: <1cm
  - Energy centroid: < 2.5 cm
- No significant bias trend detectable



Discussion of Bias Results

- Data products
  - S-IGDR (MOE)
    - Latency: 2-3 days
  - S-GDR (POE)
    - Latency: 60 days



- Final Poseidon-3 altimeter bias
  - 6.8 ±0.3 cm

⇨ Still unknown systematic effect

Fitting Method		S-IGDR-T			
		Mean $\bar{x}$	Std. of mean $s_{\bar{x}}$	Std. s_i	Median $\tilde{x}$
Gauss fit	[cm]	6.8	0.3	1.6	6.8
Energy centroid	[cm]	5.7	0.4	2.1	6.0
Sinc function	[cm]	7.1	0.3	1.8	7.1
Zero padding	[cm]	7.0	0.3	1.7	6.9

A new method of precise Jason-2 altimeter calibration using a microwave transponder
Hausleitner et al., 2012, Marine Geodesy, Special Issue 3

Conclusion / Outlook

- Transponder method very suitable for precise altimeter calibration
  - Powerful applications for both inland and in coastal regions
  - High precision calibration may help to complement and validate conventional techniques
- Relevance for future missions
- Colocation of transponder and SLR facility