A Transponder for Calibrating Altimeters in Ku-band and C-band

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Summary

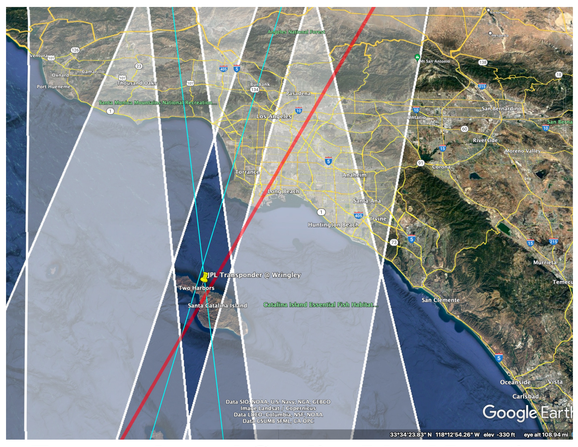
- JPL has developed a dual band transponder to calibrate radar altimeters in both Ku and C band.
- Transponder was installed on Catalina Island, California on October 29, 2021.
- Currently routinely operated for Sentinel-6 and Sentinel-3 missions.
- Will support the SWOT Nadir Altimeter calibration and has also operated with Jason-3 during the Sentinel-6 MF (S6) / Jason-3 (Ja3) tandem phase.
- Transponder has been designed to allow calibration of range, sigma0 and time tag bias.

Transponder Operations

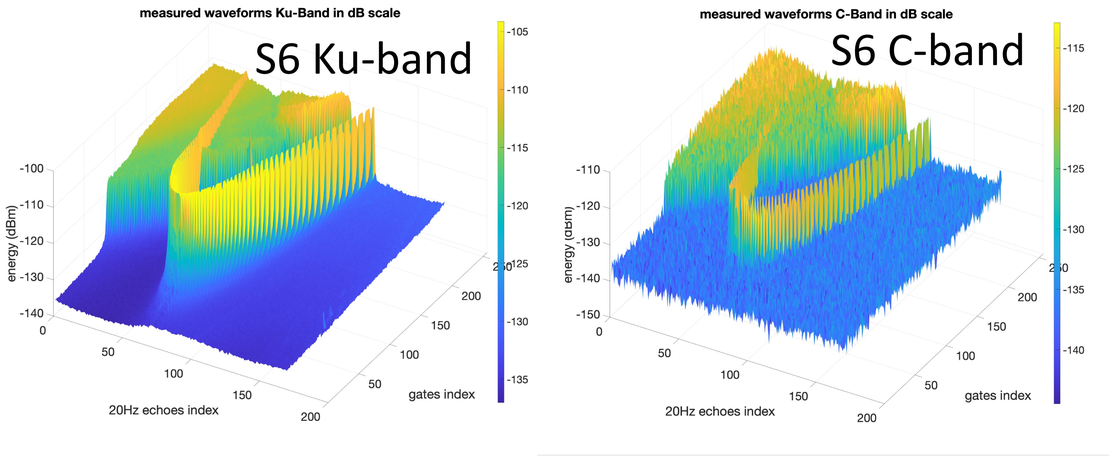
- For test and validation, the transponder has been operated at JPL with Sentinel-6 and Jason-3.
- Now installed on Catalina Island (around 30km off the coast, South-West of Los Angeles) and hosted by the Wrigley Institute (University of Southern California).
- Located 2.7km west of the Sentinel-6 reference ground track.
- Operates autonomously and activates its RF modules based on the predicted time of satellite flyovers.
- Since November, 14th 2021 routinely operated with Sentinel-6.
- Sentinel-6 using DEM mode starting cycle 50 (allowing for SAR products generation).
- Since April 14th, 2022 routinely operated with Sentinel-3.

Site	JPL	Catalina
S6 cycles	12 - 32	37 - current
Latitude	34.201676346°	33.446692629°
Longitude	-118.174087846°	- 118.479718873°
Height above Ellipsoid (WGS84)	365.6637m	35.4290m

Transponder installed on Catalina Island



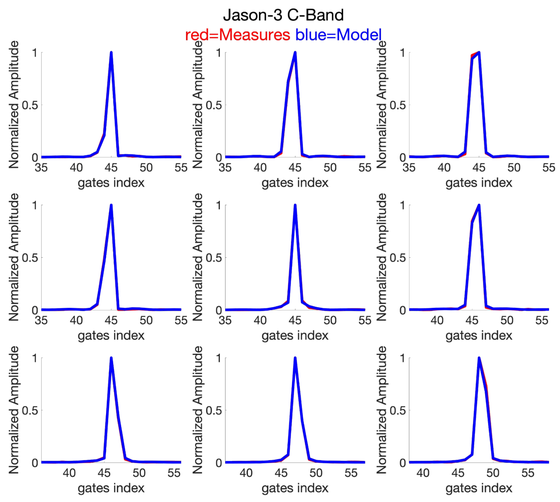
Transponder and Catalina Island Location
Sentinel-6 reference ground track in red
SWOT altimeter nadir ground tracks in blue



First Measurements on Catalina Island with Sentinel-6 operating in transponder mode November, 14th 2021

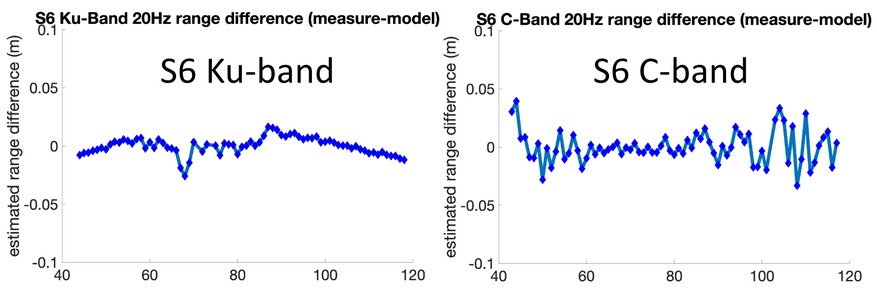
Processing and Results

- Processor has been initially developed for LRM mode echoes to support consistent intercalibration between Sentinel-6 MF and Jason-3 altimeters.
- Processing recently extended to SAR data (work still in progress). Sigma0 calibration functionality not been developed yet.

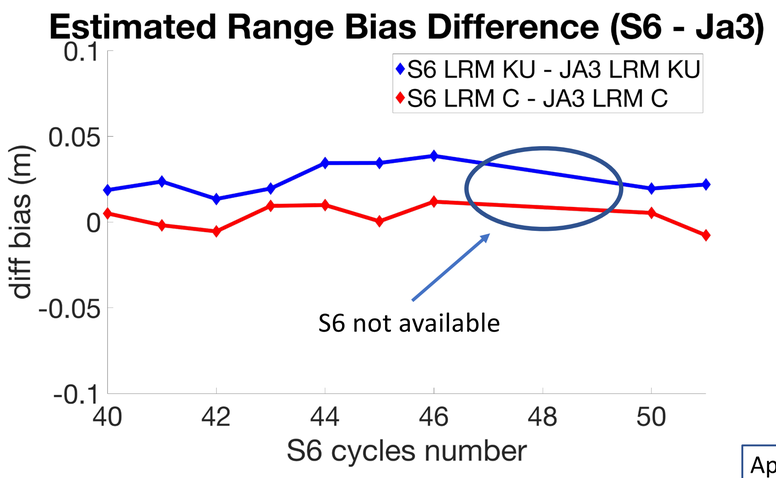


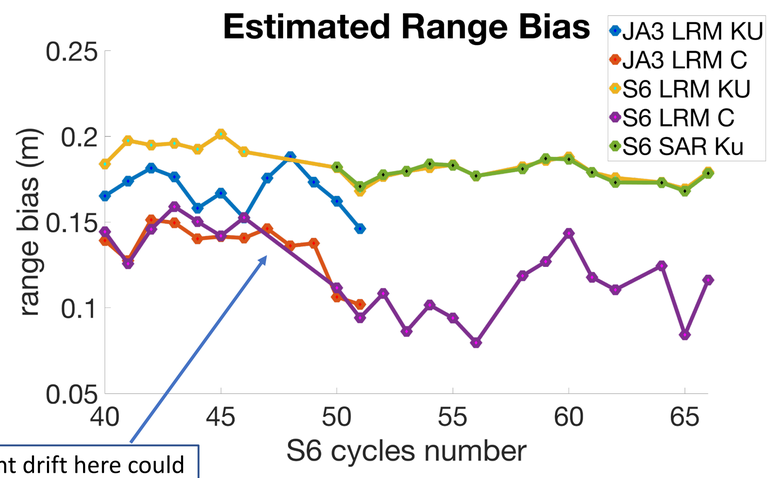
Modeled vs Measured 20Hz echoes

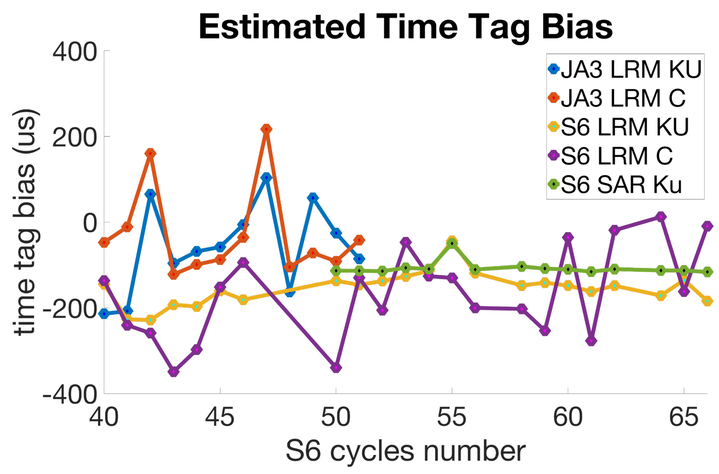
- Dataset : S6:NTC, PDAP F06/F07. Ja3 : GDR-F
- Processing based on iterative simulation of 20 Hz echoes and comparison with echoes measured by altimeter.
- 20Hz/9KHz (for LRM/SAR) range difference estimations between measurements and models allow determination of range and time tag bias.
- Propagation corrections:
  - dry troposphere is corrected for transponder altitude
  - wet troposphere is derived from continuous GPS
  - ionosphere is from JPL's Global Ionosphere Model (GIM)



Modeled vs Measured 20Hz echoes range differences
Note that the estimated range difference is noisier for C-band as the altimeter transmits fewer pulses in C-band compared to Ku-band.







Range Bias Difference (S6-Ja3)	mean (cm)	std (cm)
LRM Ku-band	-2.49	0.87
LRM C-band	-0.30	0.70
Time Tag Bias	**Mean (us)**	**Std (us)**
Ja3 LRM Ku-band	-58	104[2]
Ja3 LRM C-band	-28	107[2]
S6 LRM Ku-band	-154[1]	40
S6 LRM C-band	-166[1]	107
S6 SAR Ku-band	-111[1,3]	3.6[3]

Notes: 1) The relative position of the altimeter antenna vs satellite Centre Of Mass generates a bias of ~ -130us for S6. 2) Jason-3 satellite does yaw steering. 3) excluding cycle 55. 4) The absolute range bias is not yet consolidated and mean value should not be yet considered. For SAR an offset has been applied here to align with Ku LRM. 5) Time series starts at cycle 40 after S6 gain has been tuned for the transponder in Catalina.

Conclusions

- **First transponder for dual band altimeter calibration.**
- **Catalina site allows for intercalibrating S6 with other altimetry missions.**
- **Results demonstrate good performance in evaluating range bias both for the intermission comparison and for long term stability.**
- **Use of SAR appears promising and the excellent consistency with the LRM results confirms the simulation approach allows for good range bias estimation quality in LRM.**
- **For time tag, SAR offers much better performance but LRM appears suitable to detect anomalies.**

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