Absolute altimeter bias results from Bass Strait, Australia

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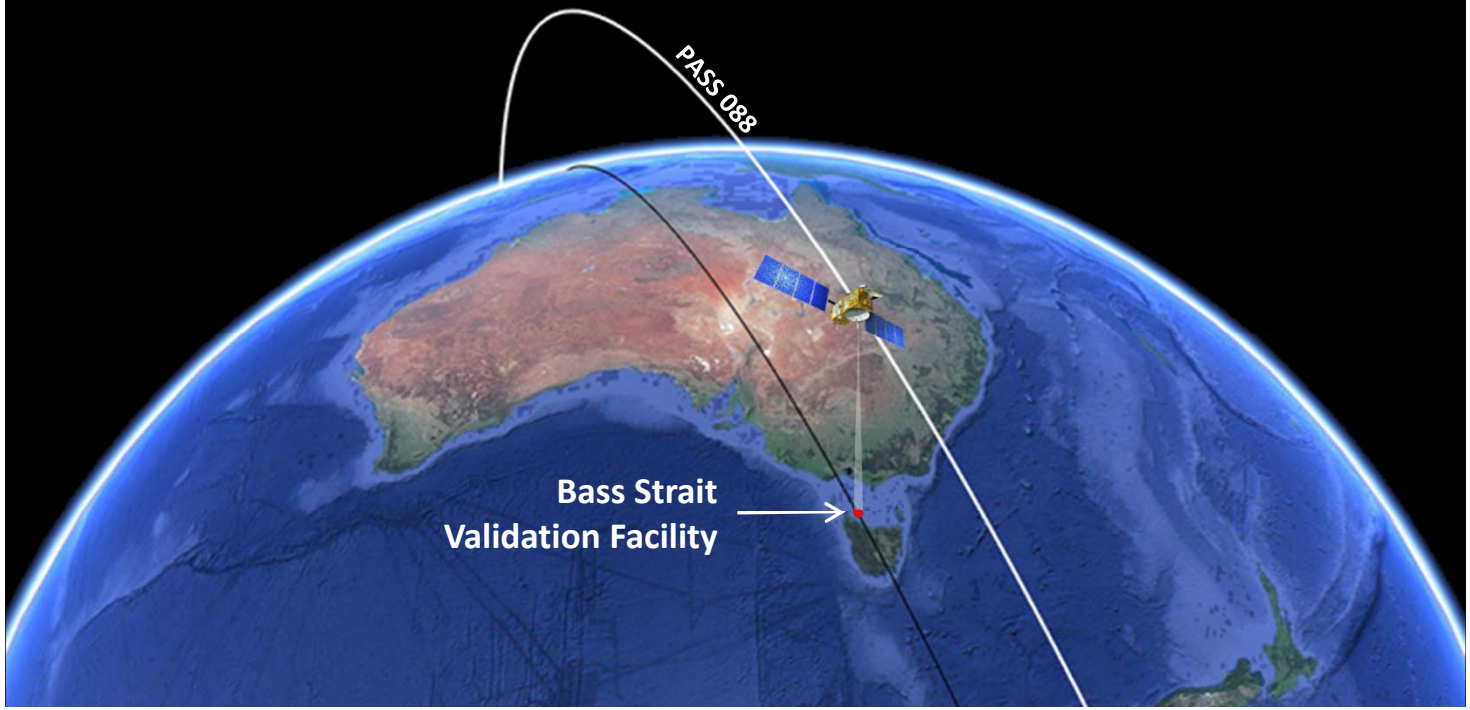


UNIVERSITY of TASMANIA
AUSTRALIA

CSIRO

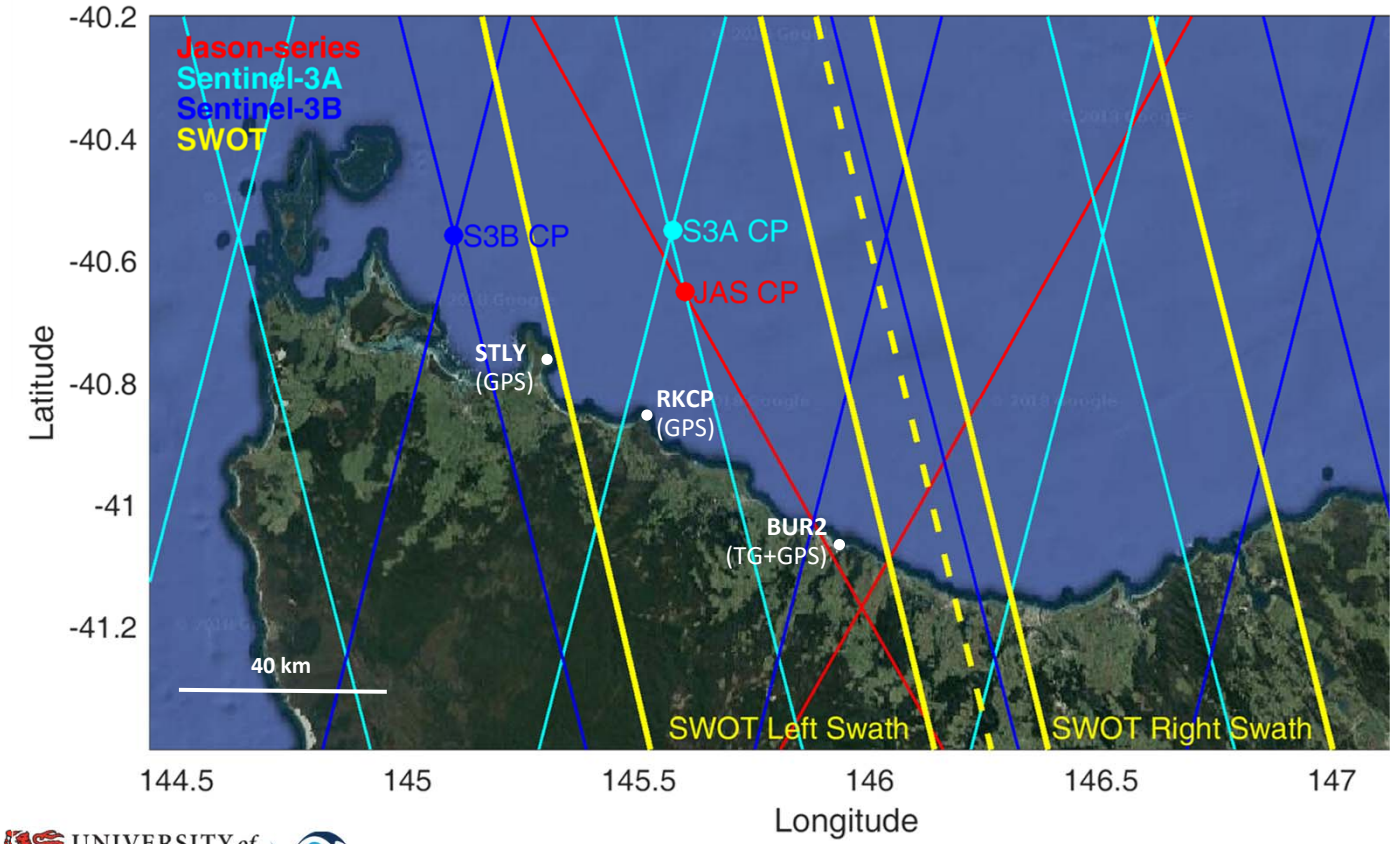
IMOS
Integrated Marine Observing System

Ocean Surface Topography Science Team Meeting

October 21-25, 2019

Chicago, USA

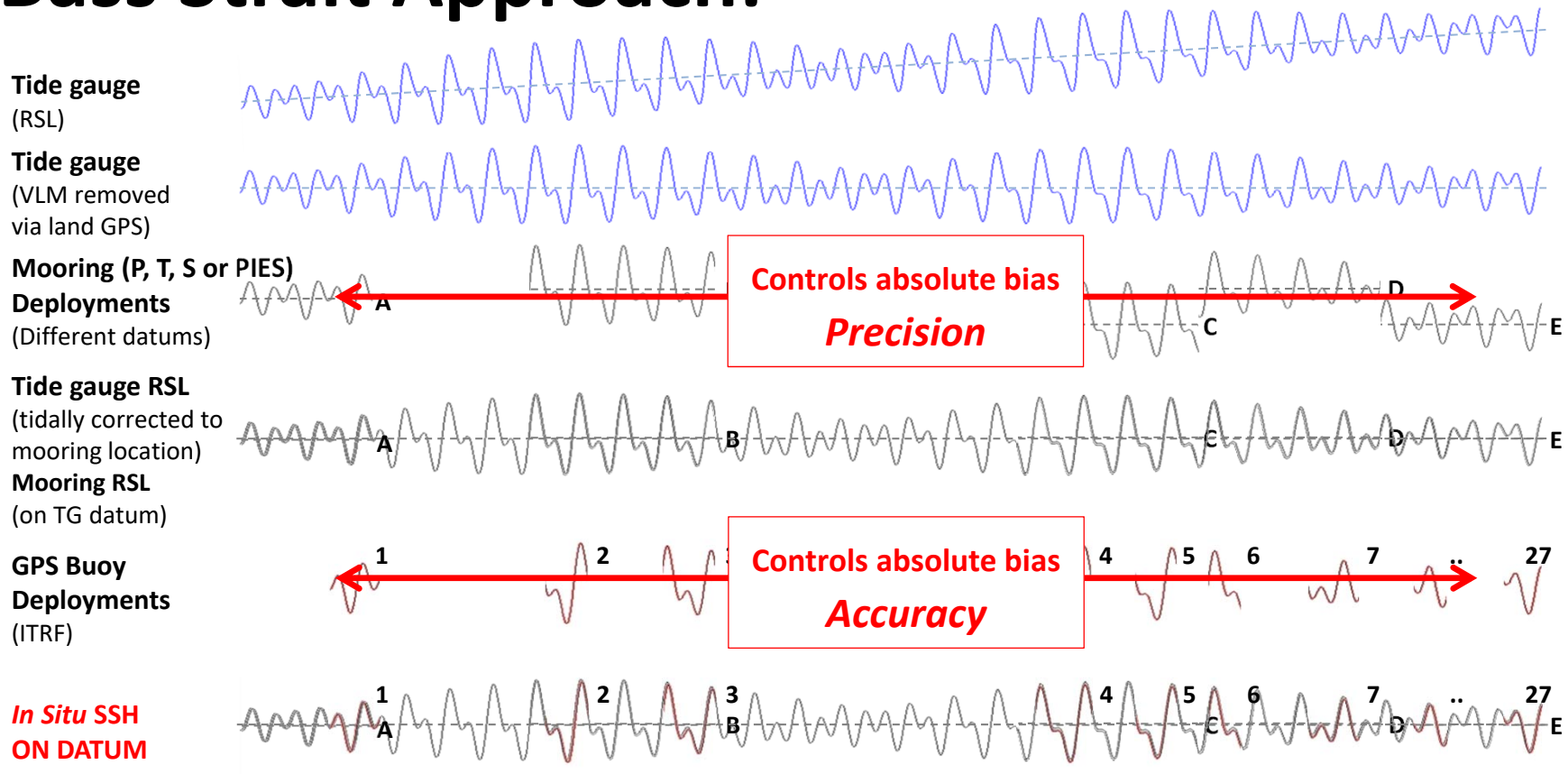
Bass Strait Validation Facility:



Key Activities:

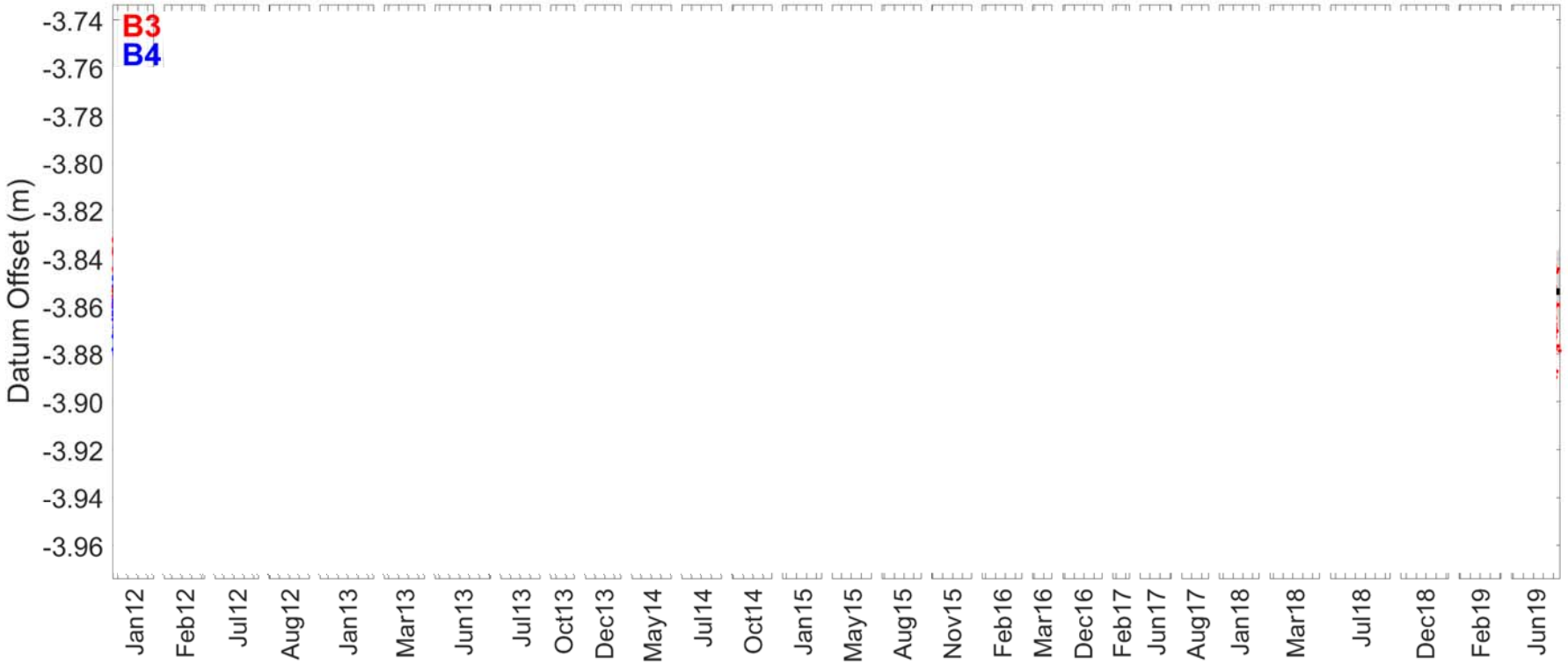
- Sustained monitoring at Jason-series (**JAS**), Sentinel-3A (**S3A**) and Sentinel-3B (**S3B**) CPs.
- Development of a current, waves, pressure inverted echo sounder (CWPIES) currently deployed at the S3B site.
- Development of new GNSS buoys and assessment of processing approaches in preparation for SWOT.

Bass Strait Approach:

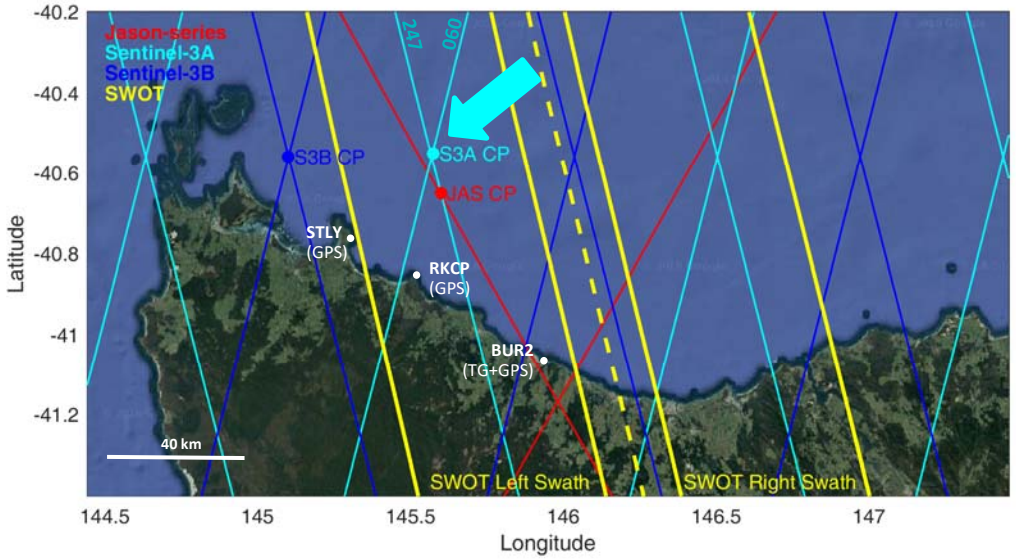


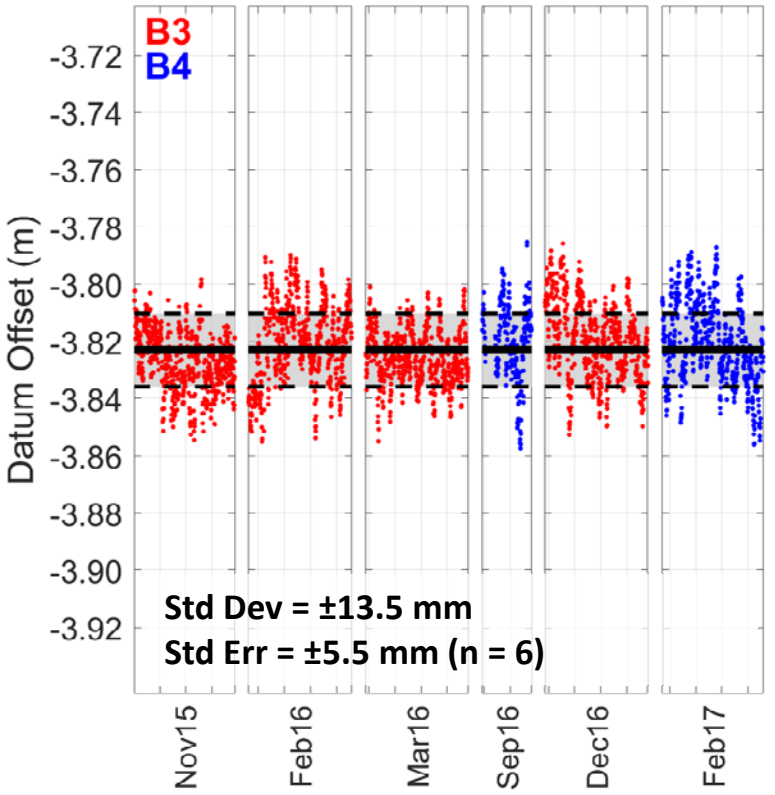
Datum Determination (Buoy - JAS Mooring):

- Filtered buoy – mooring yields the mooring datum offset with noise contributions from both sensors…

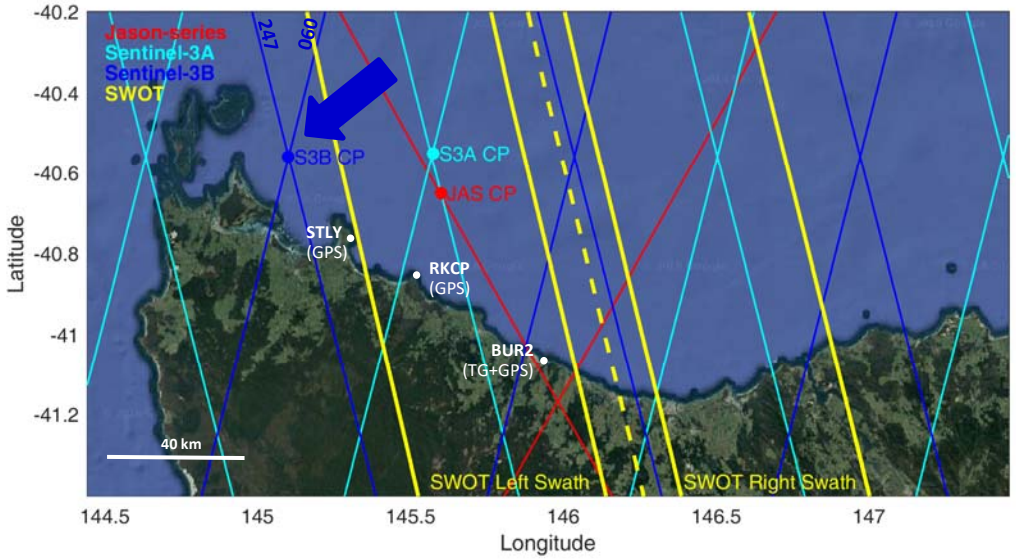


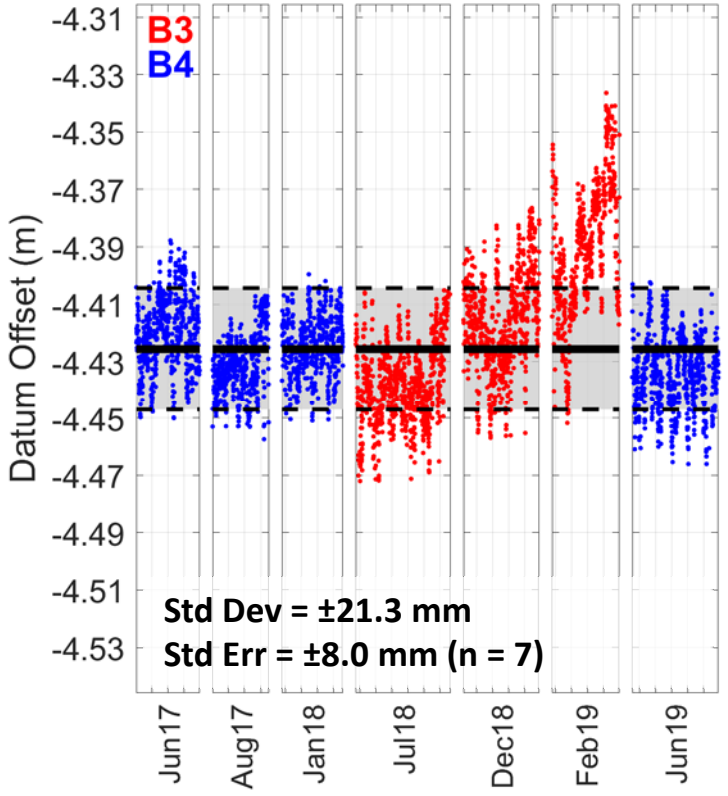
Datum Determination (Buoy - S3A Mooring):



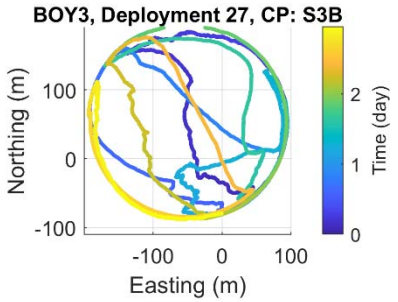


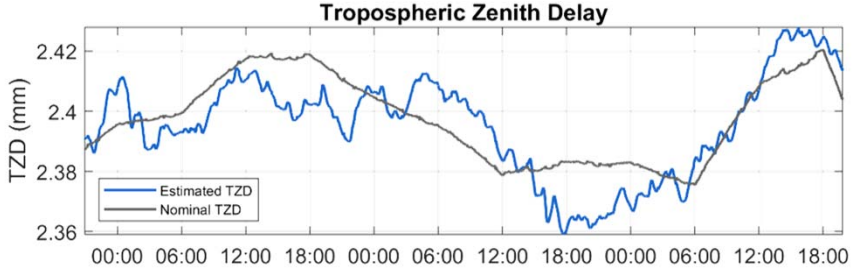
Datum Determination (Buoy - S3B Mooring):

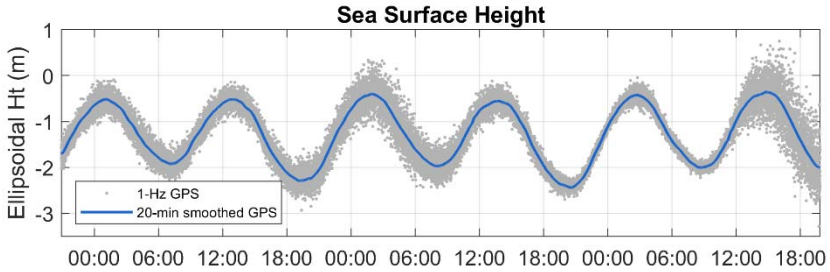


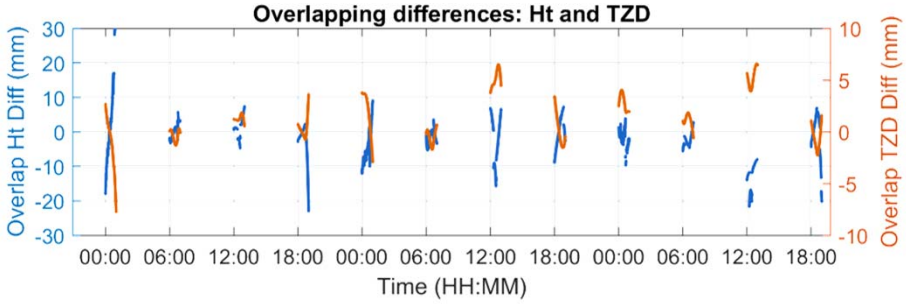


1-Hz GPS Buoy Solution – Typical Output

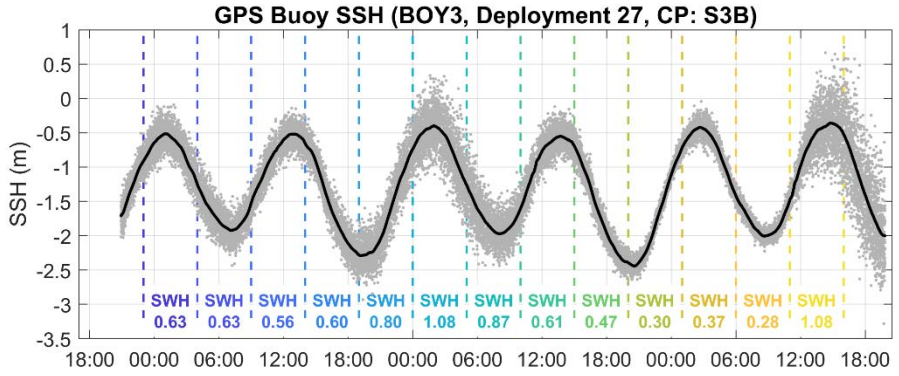


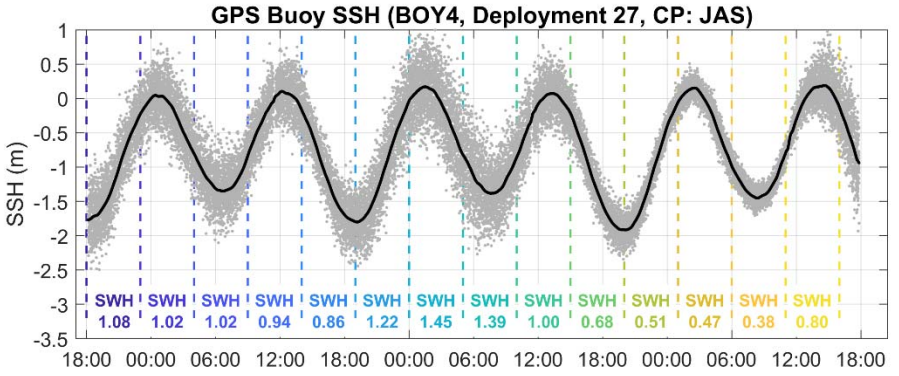


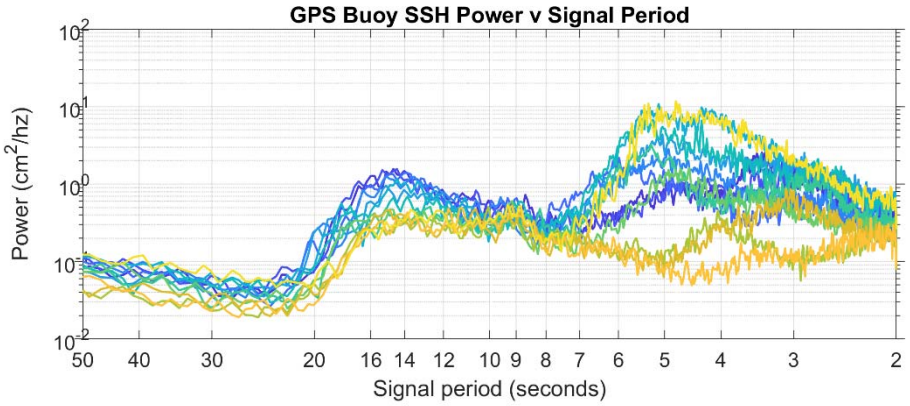


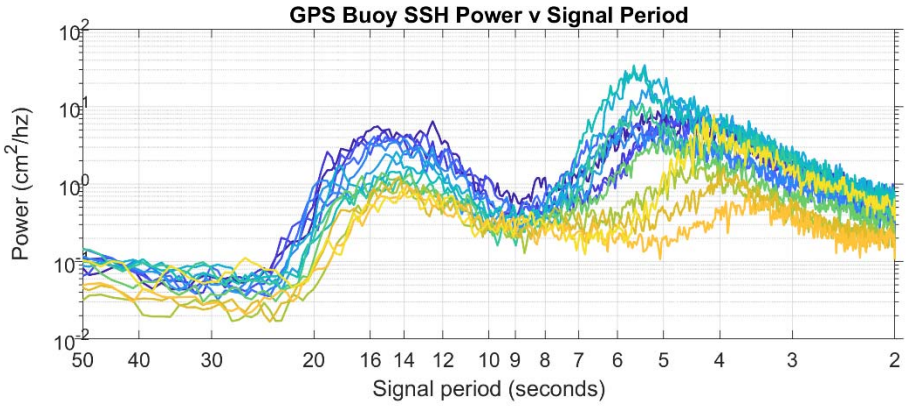


GPS Buoy SSH: JAS v S3B CPs (~44 km apart)

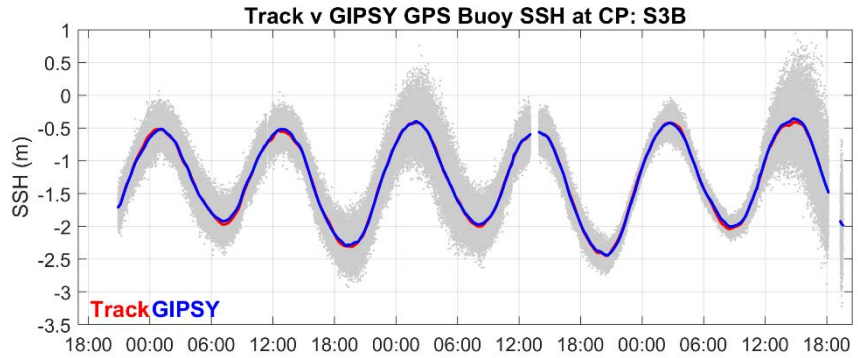


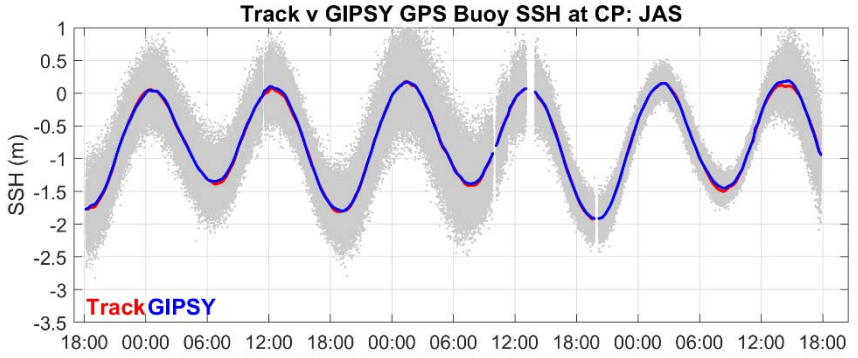


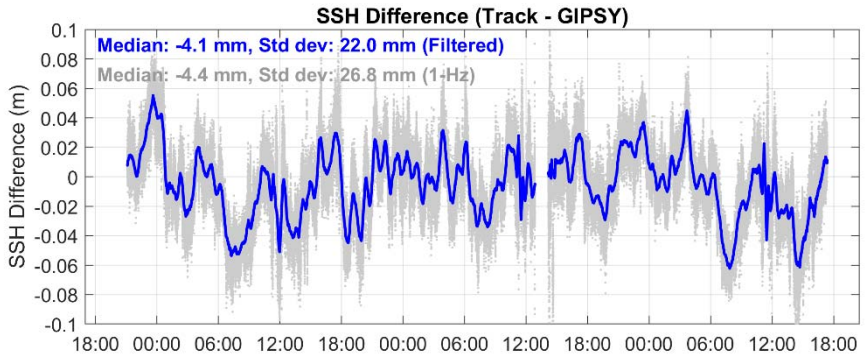


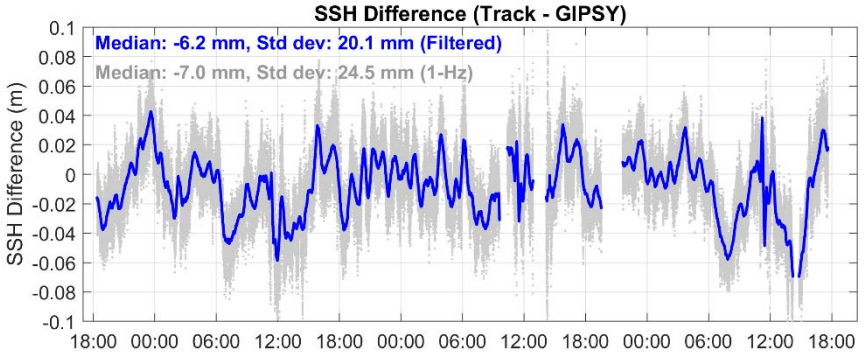


GPS Buoy SSH: Track v GIPSY Processing



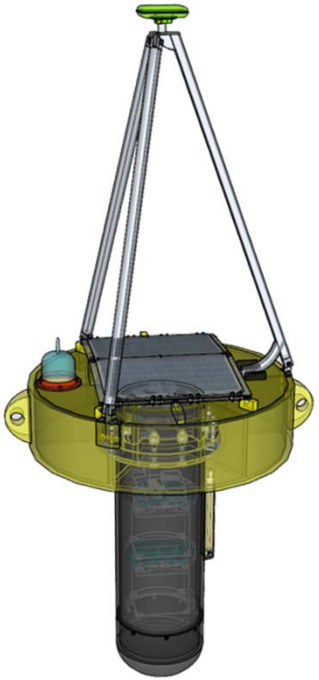


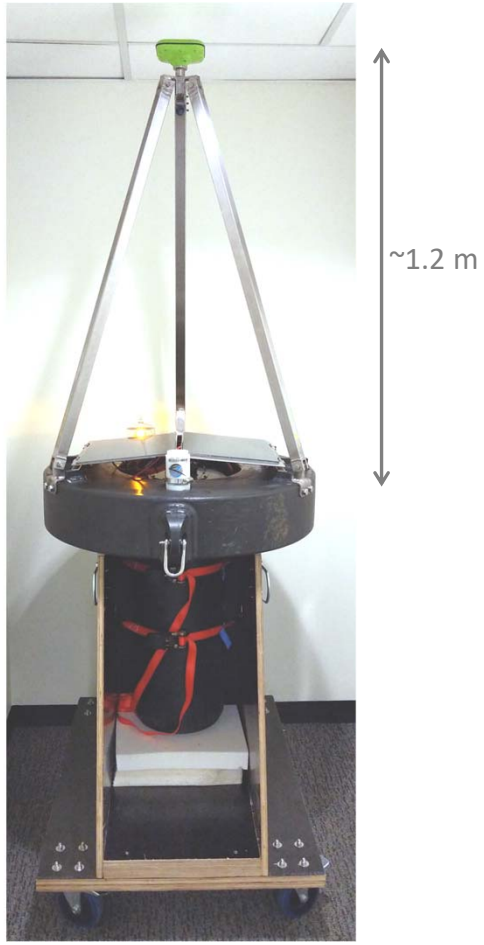




GNSS Buoy Development

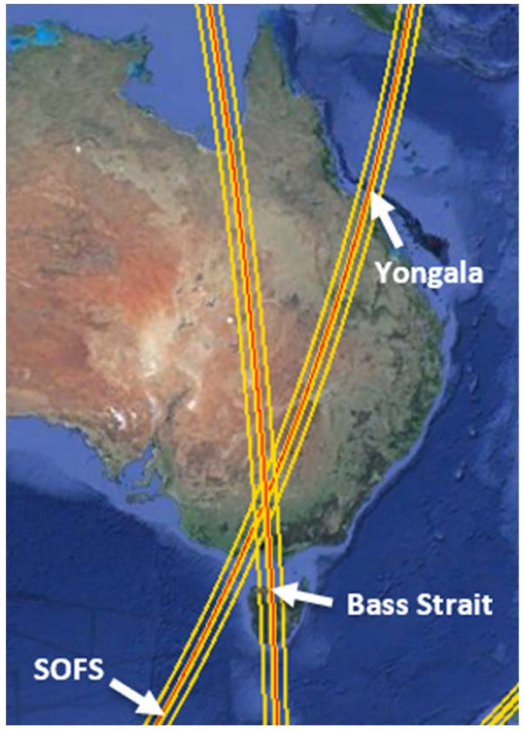
- IMOS/Utas ‘Mk V’ buoy now in testing.
- GNSS / INS / SST payload.
- 2 Hz positioning, 100 Hz orientation.
- Cellular telemetry, iridium tracking.
- Emphasis on investigating:
  - Systematic bias to buoyancy (ARP to water level) as a function of sea state and current velocity…
  - Systematic difference in SSH and ΔSSH as function of solution approach…

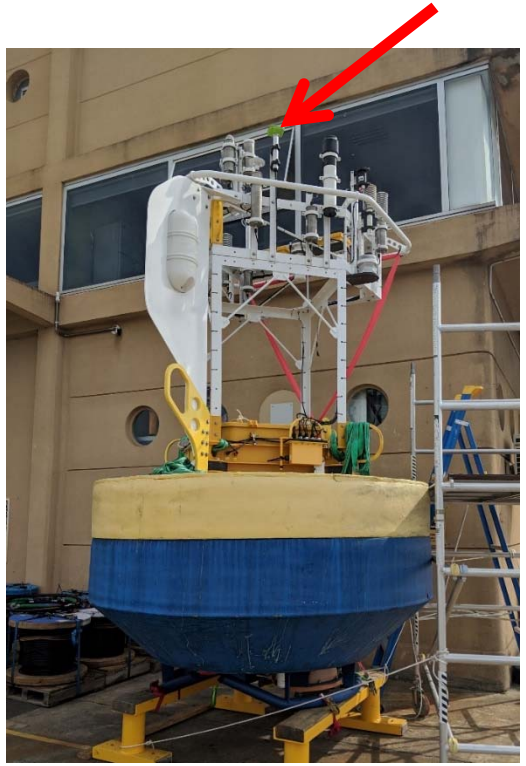




Southern Ocean (SOFS) Deployment

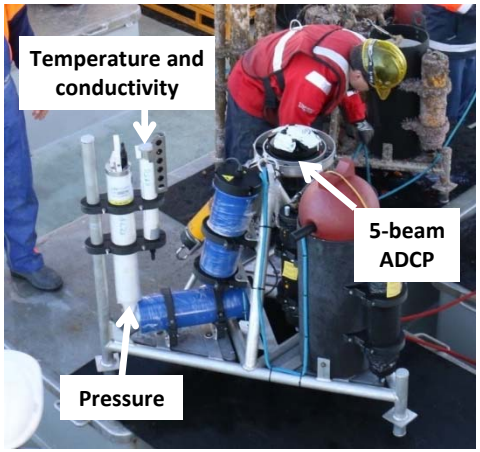
- Testing GNSS on the SOFS mooring (140°E, 47°S), deployed 17 March 2019.
- Currently have ~220 days of observations at 2 Hz.
- Mean SWH ~4.2 m.
- Numerous sensors through the column (most top 500 m).
- Successful heartbeat telemetry and remote configuration.
- Challenging platform dynamics.





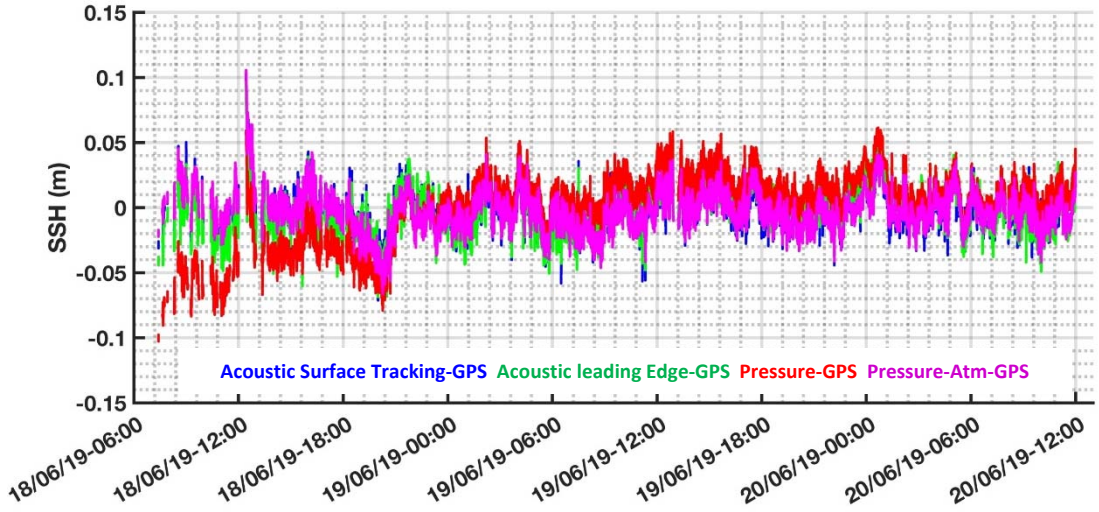
Current, waves, pressure inverted echo sounder (CWPIES) – S3B CP

- Now able to demonstrate the benefit of CWPIES for altimeter validation.
- The technique provides accurate SSH (at 2 Hz), wave field, currents, water column density and atmospheric pressure recovery without a surface expression.
- Key challenge to overcome was maintaining the vertically of the sensor in ~28 m water depth using a gimbal mount.
- Results comparable with GPS and traditional P / T / S mooring approach in terms of SSH, but delivers other observables of interest…

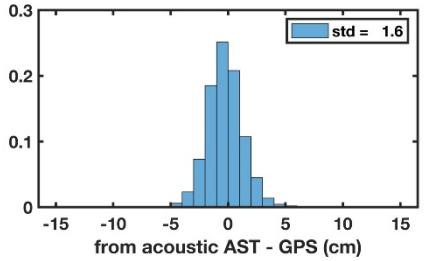


Development of CWPIES in Bass Strait

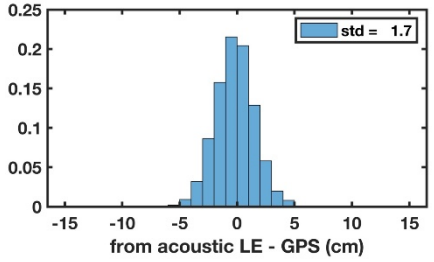
- Less sensitive to drift c.f. bottom pressure.
- Comparable wave field to GPS, comparable SSH to GPS and bottom pressure corrected for dynamic height and atmospheric pressure.



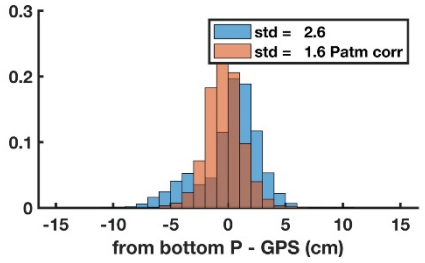
Acoustic surface tracking v GPS:
Std dev = 1.6 cm



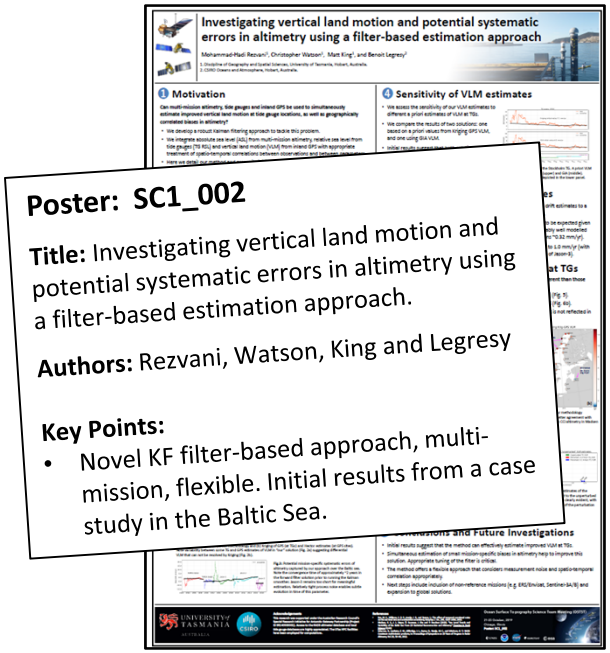
Acoustic leading edge v GPS:
Std dev = 1.7 cm



Bottom P / T / S + atm pressure v GPS:
Std dev = 1.6 cm



Other Recent Work



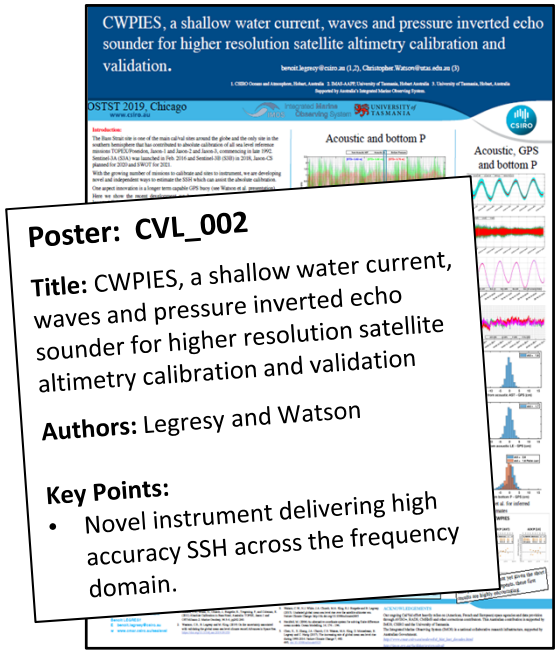
Poster: SC1_002

Title: Investigating vertical land motion and potential systematic errors in altimetry using a filter-based estimation approach.

Authors: Rezvani, Watson, King and Legresy

Key Points:

- Novel KF filter-based approach, multi-mission, flexible. Initial results from a case study in the Baltic Sea.



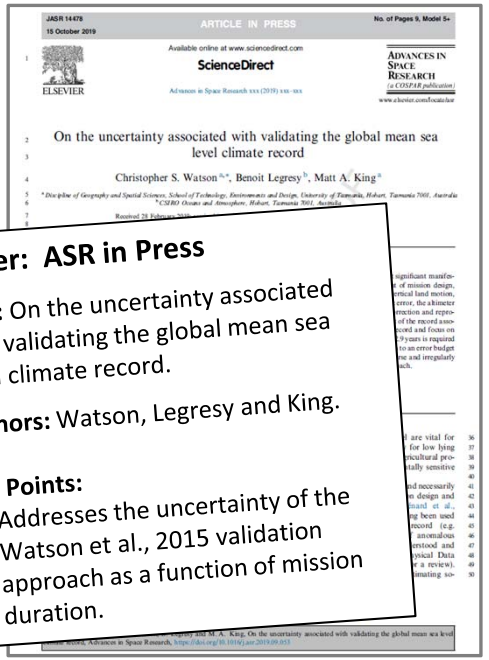
Poster: CVL_002

Title: CWPIES, a shallow water current, waves and pressure inverted echo sounder for higher resolution satellite altimetry calibration and validation

Authors: Legresy and Watson

Key Points:

- Novel instrument delivering high accuracy SSH across the frequency domain.



Paper: ASR in Press

Title: On the uncertainty associated with validating the global mean sea level climate record.

Authors: Watson, Legresy and King.

Key Points:

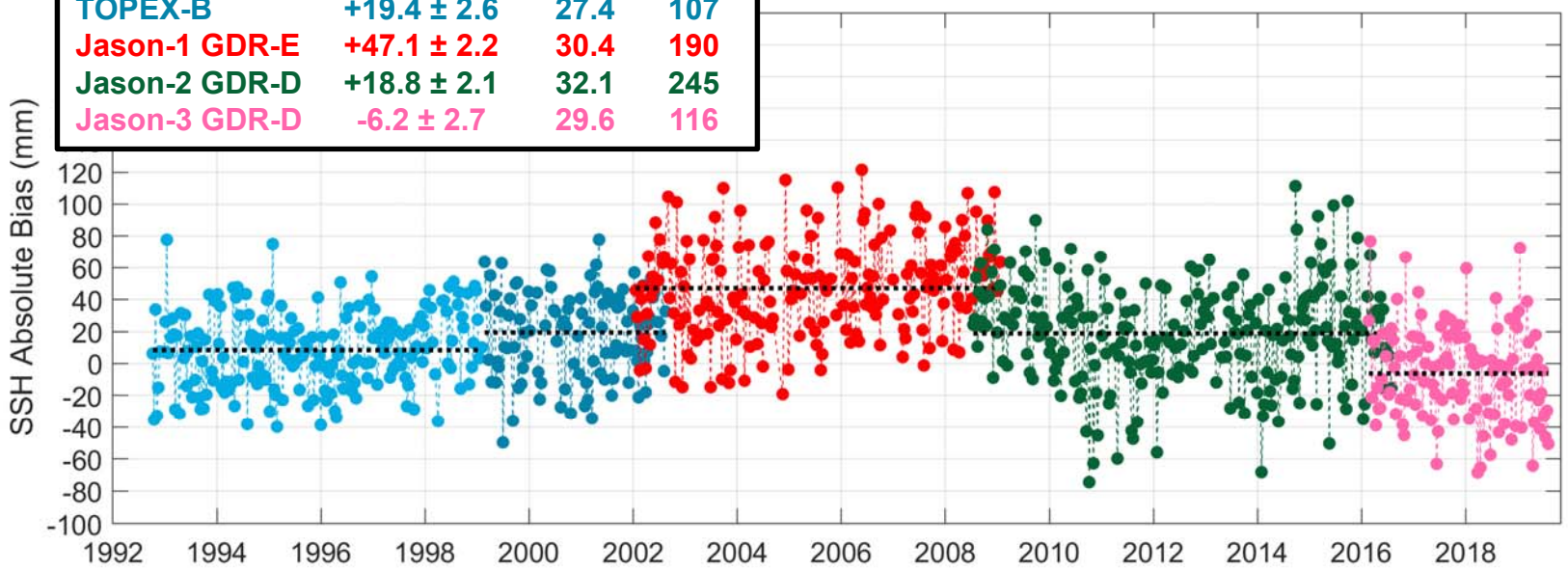
- Addresses the uncertainty of the Watson et al., 2015 validation approach as a function of mission duration.

Bass Strait
Absolute Bias Results

Absolute Bias at Bass Strait (vs TG)

(expect higher variability than against mooring).

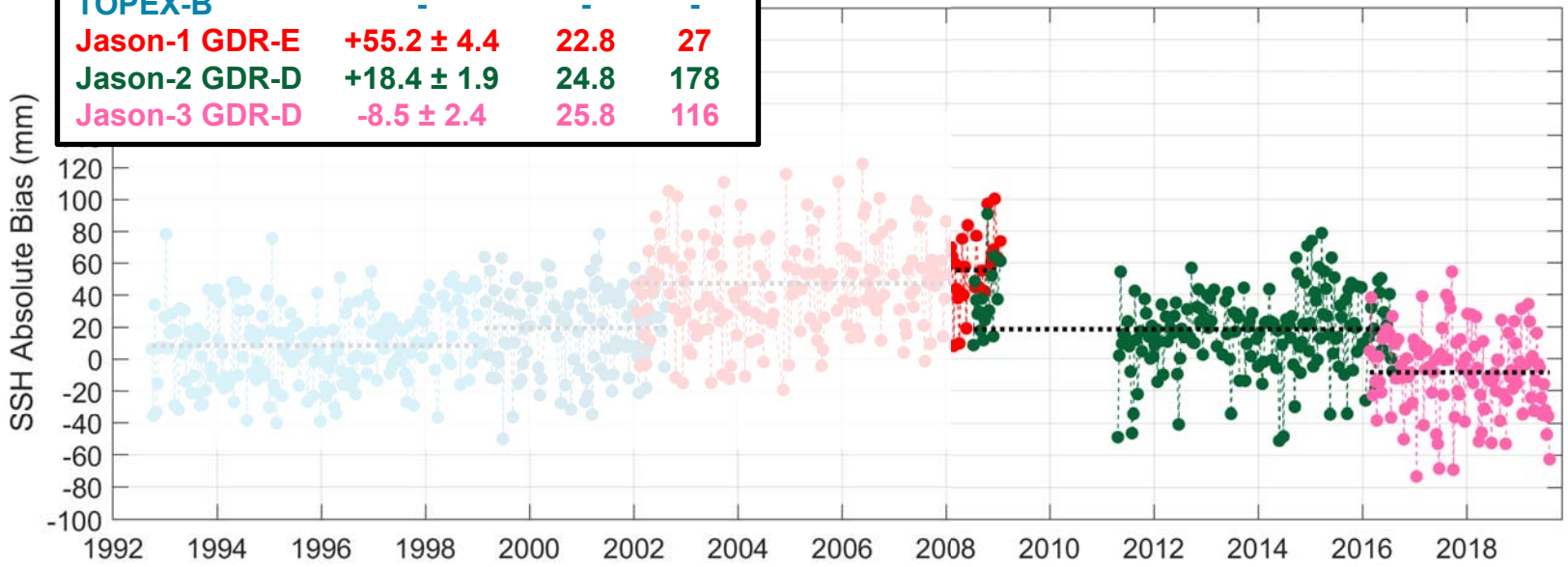
ALTIMETER	MEAN (mm)	σ	N
TOPEX-A	+8.4 ± 1.7	23.7	191
TOPEX-B	+19.4 ± 2.6	27.4	107
Jason-1 GDR-E	+47.1 ± 2.2	30.4	190
Jason-2 GDR-D	+18.8 ± 2.1	32.1	245
Jason-3 GDR-D	-6.2 ± 2.7	29.6	116



Absolute Bias at Bass Strait (vs Mooring)

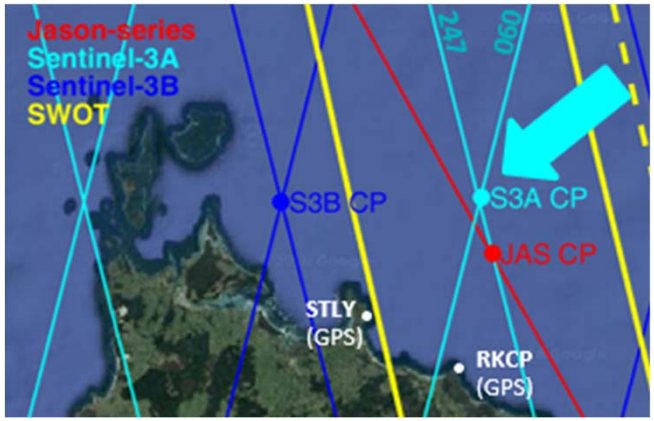
ALTIMETER	MEAN (mm)	σ	N
TOPEX-A	-	-	-
TOPEX-B	-	-	-
Jason-1 GDR-E	+55.2 ± 4.4	22.8	27
Jason-2 GDR-D	+18.4 ± 1.9	24.8	178
Jason-3 GDR-D	-8.5 ± 2.4	25.8	116

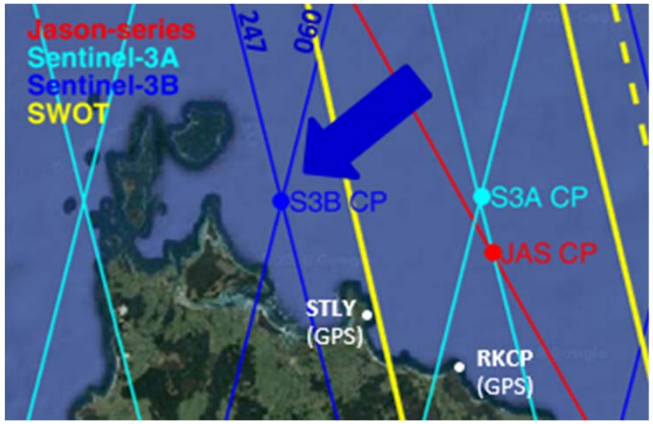
Formation Flight: J2-J1: ΔSSH = -24 mm (J1 SSH higher than J2)
Formation Flight: J3-J2: ΔSSH = -19 mm (J2 SSH higher than J3)



Sentinel-3A and Sentinel-3B

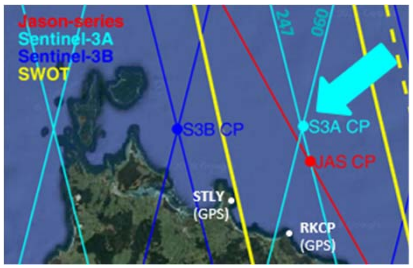
- Both S3A and S3B comparison points are located at cross over locations.
- S3A comparison point (**S3A**) is ~9 km north of our Jason-series comparison point (**JAS**).
- S3B comparison point (**S3B**) is ~44 km west (~28 m depth c.f. ~52 m depth, location of CWPIES deployment).

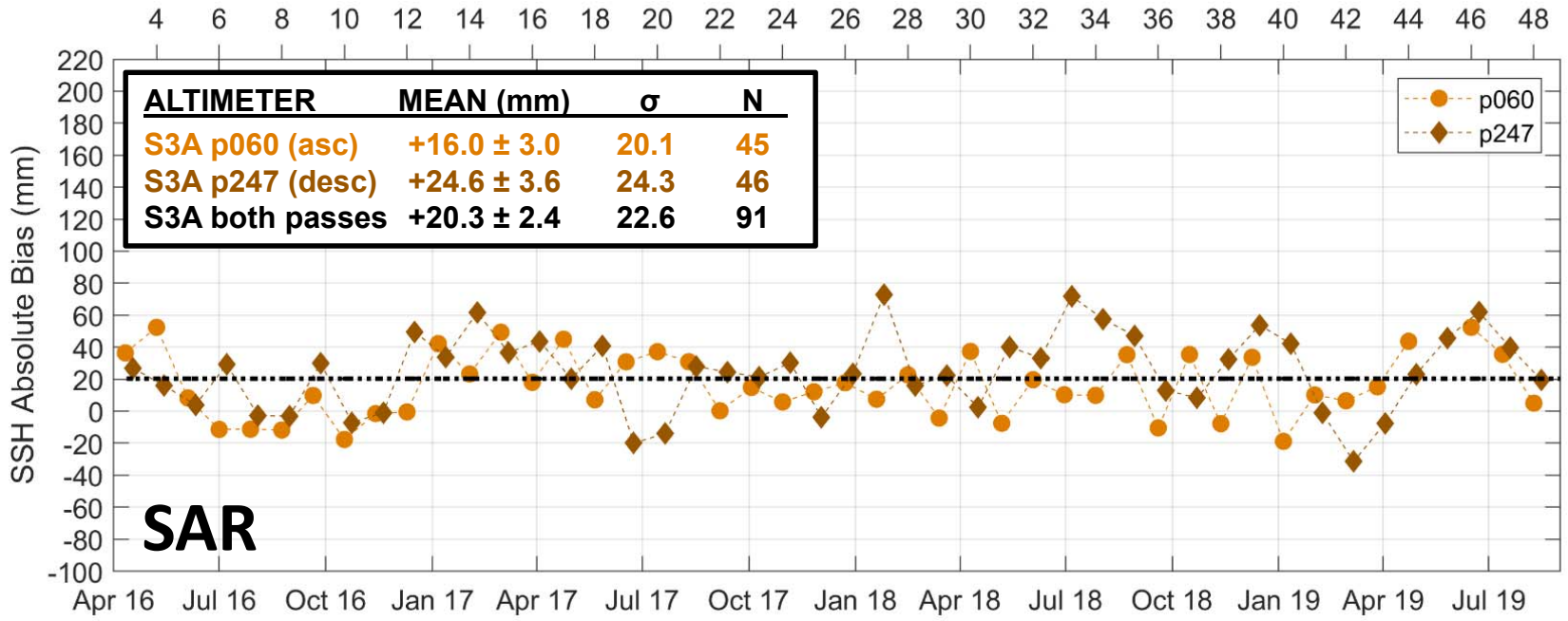




Sentinel-3A Absolute Bias (SAR)

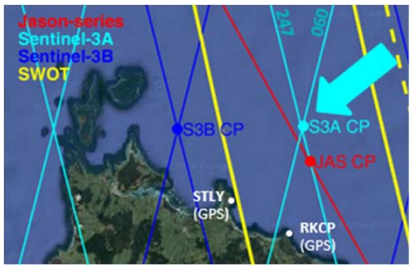
- **S3A, Non time critical data, Baseline 3 via RADS.**
- **Comparable bias estimates between asc/desc passes.**
- **Bias variability (stdev ~23 mm) is approaching the in situ noise.**

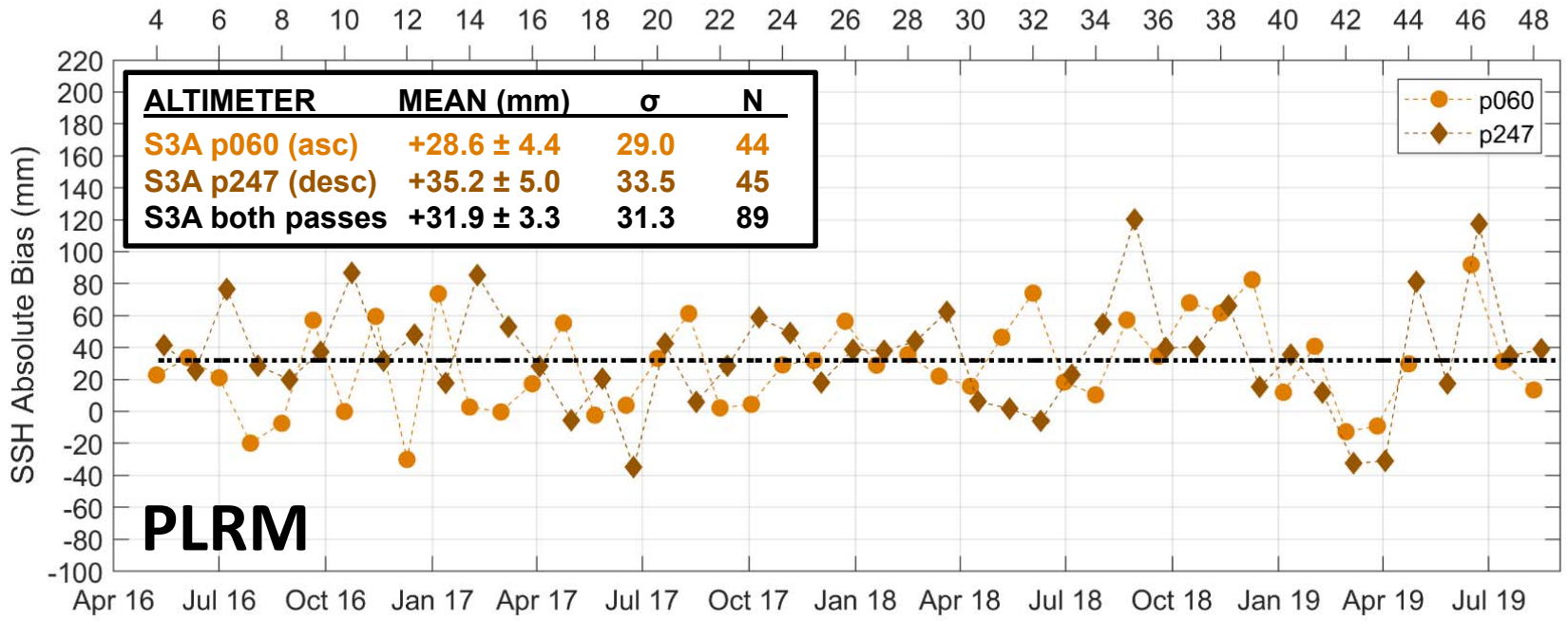




Sentinel-3A Absolute Bias (PLRM)

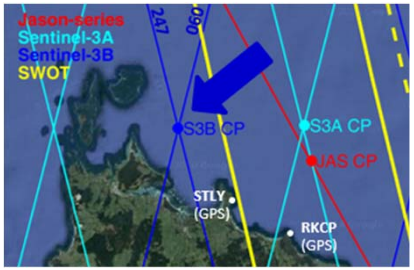
- S3A PLRM bias is ~12 mm higher than SAR (mean: 32 v 20 mm).
- S3A PLRM bias is more variable than SAR (stdev: 31 v 23 mm).

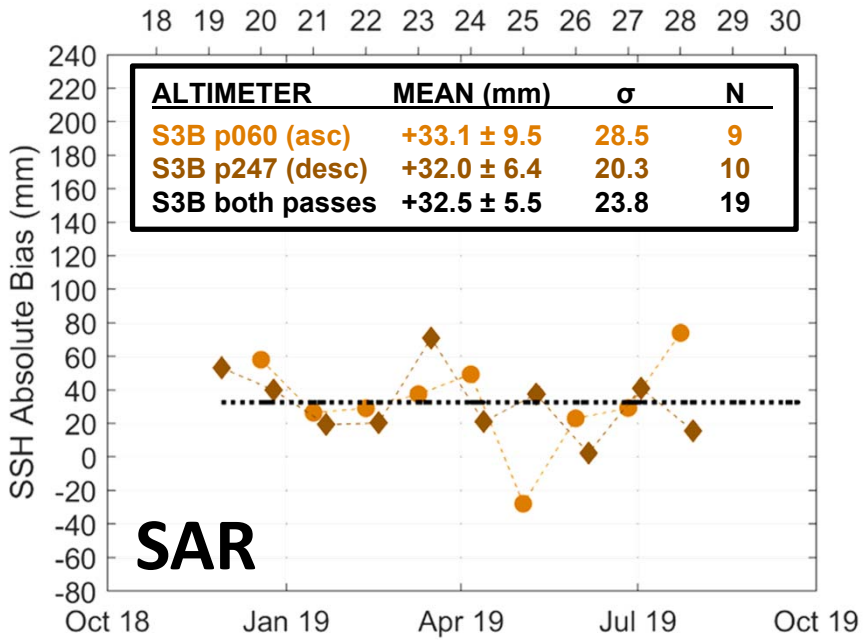


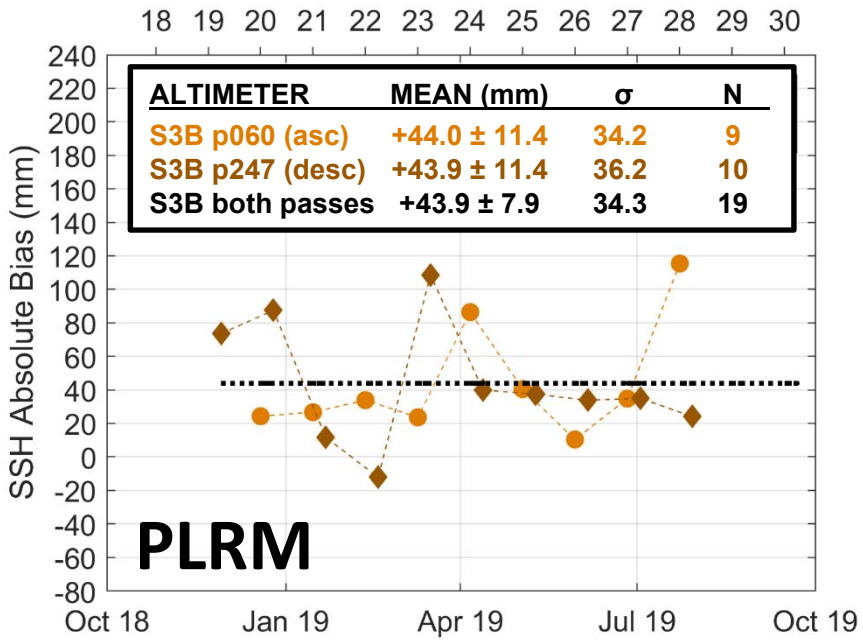


Sentinel-3B Absolute Bias

- **S3B SAR bias is ~12 mm higher than S3A. Within the noise of datum determination? (Note prior to orbit manoeuvrer, S3B at S3A CP yielded comparable bias estimates)**
- **Similarly to S3A, the S3B PLRM bias is ~11 mm higher than SAR (mean: 44 v 32 mm).**
- **Similarly to S3A, the S3B PLRM bias is more variable than SAR (stdev: 34 v 24 mm).**



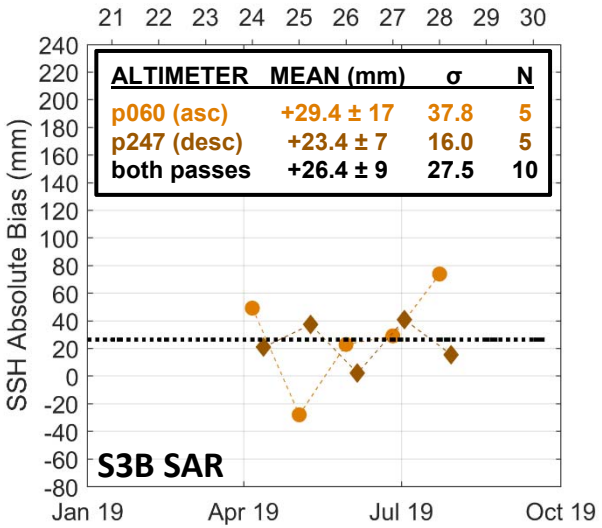




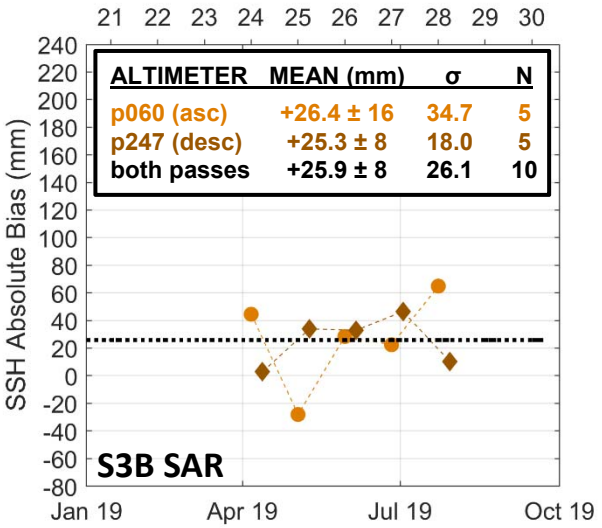
Evaluation of CWPIES against Sentinel-3B

- **Limited deployment duration presently only spans 5 cycles of S3B.**
- **CWPIES performance is <u>at least comparable</u> to standard SBE26 P/T/S solution.**

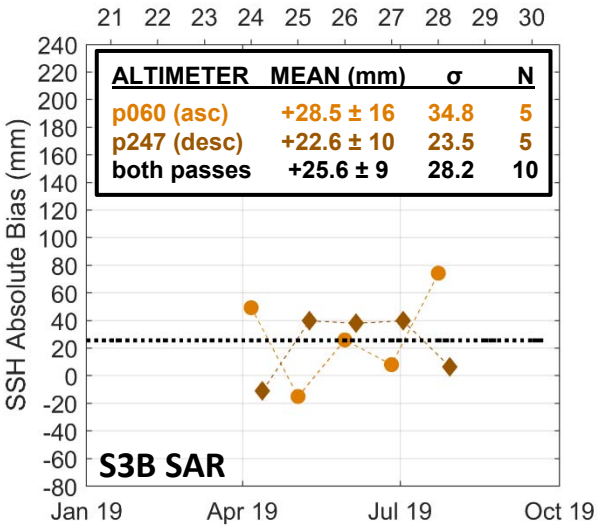
Pressure+T/S



CWPIES (Acoustic Surface Tracking - AST)



CWPIES (Leading Edge Tracking - LE)



Conclusions from Bass Strait

- Understanding differences in GPS buoy solutions at the 1-2 cm level is important in the context of future missions.
- Our development of a coastal 'PIES' has produced promising results – again important in the context of validating future missions.
- **Jason-1** (GDR-E) remains significantly different from zero which is not yet understood
- **Jason-3** (GDR-D) bias remains insignificantly different from zero (-8 mm).
- **S3A** SAR bias (Baseline 3) is +20 mm (stdev 23 mm). Bias and variability increases with PLRM.
- **S3B** SAR bias (Baseline 3) ~12 mm higher than **S3A**. Very similar increase to bias and variability when using PLRM.
- Non-averaging errors likely limit absolute bias uncertainty to ±10-15 mm.

Mission	Cycles	Absolute Bias	Std Dev
TOPEX-A	1 -> 235	+8 mm	24 mm (TG*)
TOPEX-B	236 -> 365	+19 mm	27 mm (TG*)
Jason-1 GDR-E	1 -> 259	+47 mm	30 mm (TG*)
Jason-2 GDR-D	1 -> 298	+19 mm **+18 mm**	32 mm (TG) **25 mm (Mooring)**
Jason-3 GDR-D	1 -> 128	-6.2 mm **-8.5 mm**	30 mm (TG) **26 mm (Mooring)**
S3A SAR S3A PLRM	3 -> 48 3 -> 48	**+20 mm** +32 mm	**23 mm (Mooring)** 31 mm (Mooring)
S3B SAR S3B PLRM	19 -> 29 19 -> 29	**+32 mm** +44 mm	**24 mm (Mooring)** 34 mm (Mooring)

* Solutions adopt VLM of -0.7 mm/yr at the tide gauge

Thankyou

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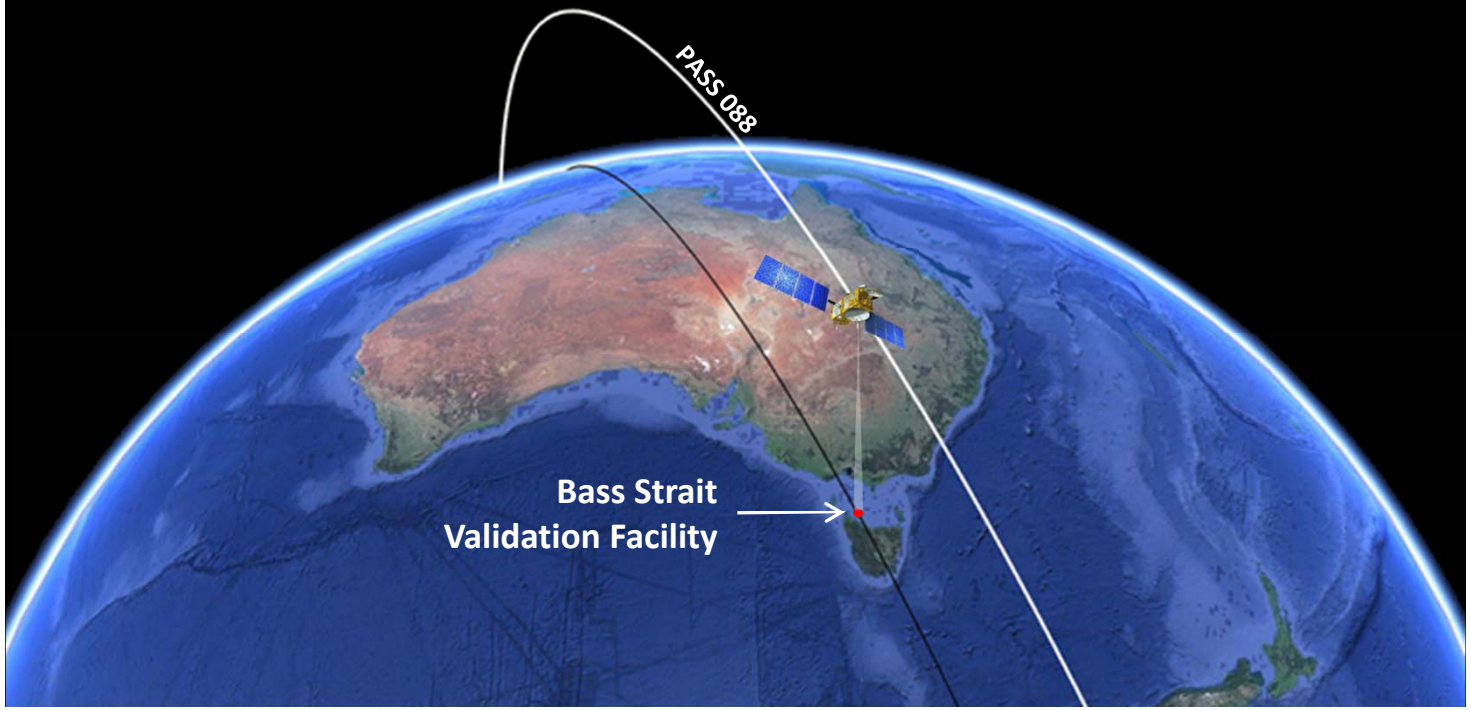

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Ocean Surface Topography Science Team Meeting

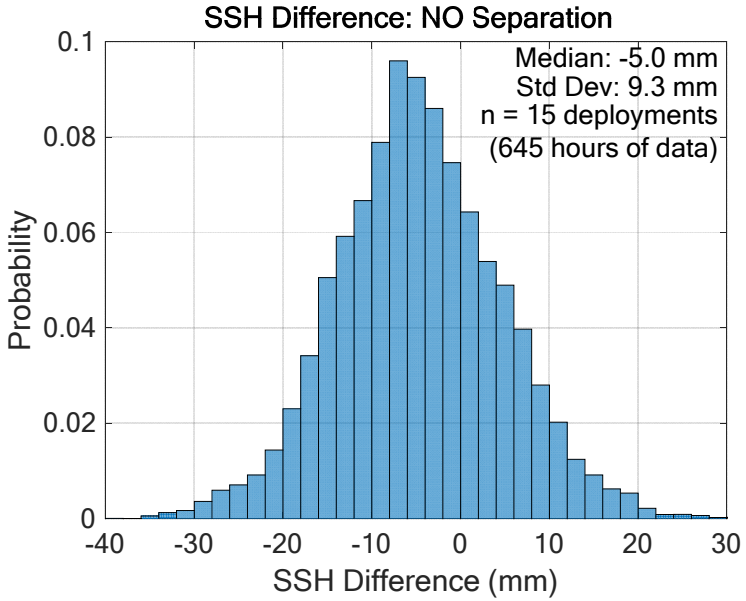
October 21-25, 2019

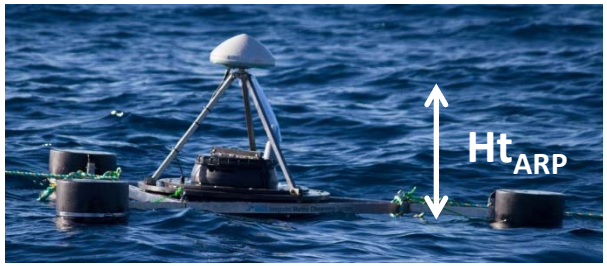
Chicago, USA

Spares

Buoy Processing Examples (ΔSSH)

- 15 deployments (645 hours, ~27 days) where we have 2 buoys within 20-40 m of each other.
- Each buoy is processed independently, but using the same reference stations.
- We compare low pass filtered data (20 min filter to attenuate swell, 5 min sampling), **i.e. expect ΔSSH = 0.**





- **Dominated by differences from 4 deployments, but provides important constraints when using buoys for ΔSSH…**

Datum Determination (Buoy - Tide Gauge):

- Slightly increased noise when comparing against coastal tide gauge (tidally corrected to CP location) ~50 km away.