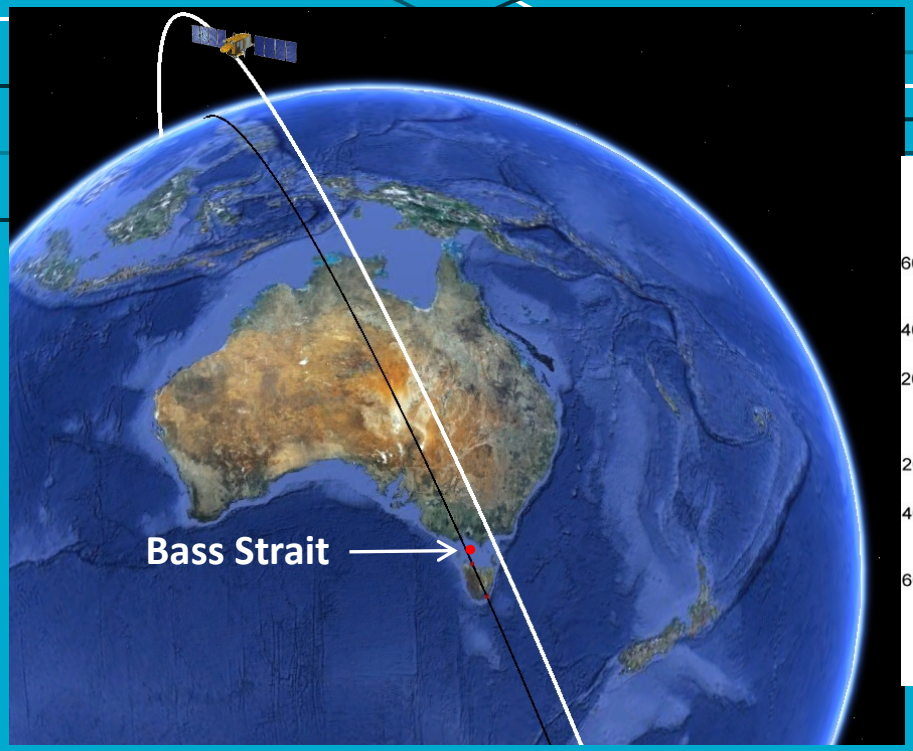
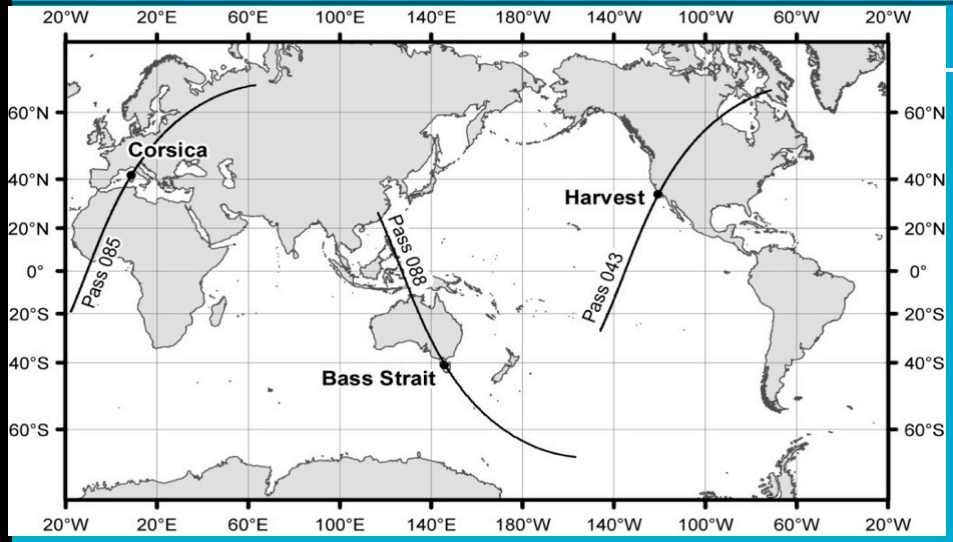
Satellite altimetry Australian activities

Benoit LEGRESY (CSIRO O&A Climate Science Centre)
Christopher WATSON (University of Tasmania), and many other colleagues





UNIVERSITY of TASMANIA AUSTRALIA

IMOS Integrated Marine Observing System

CSIRO

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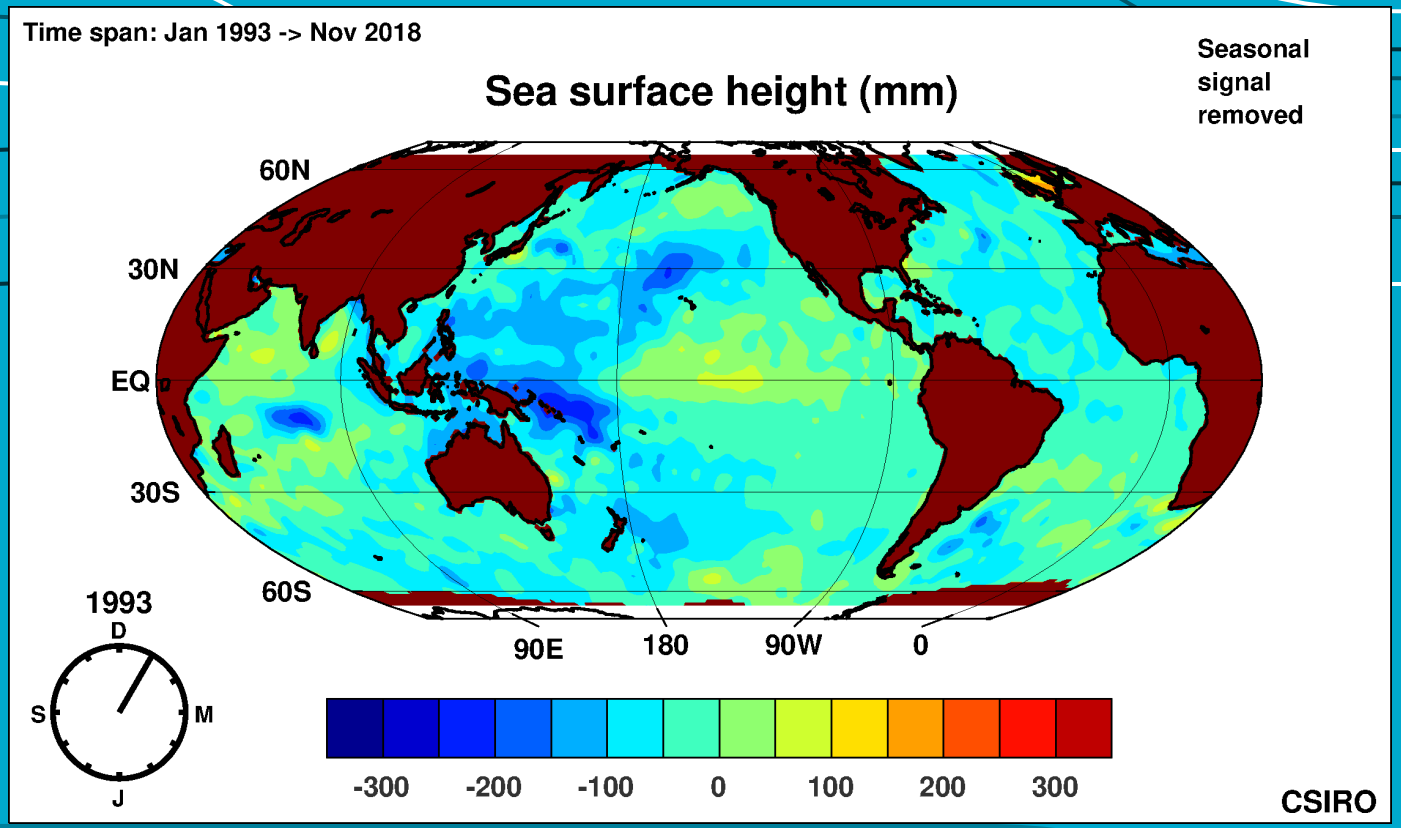
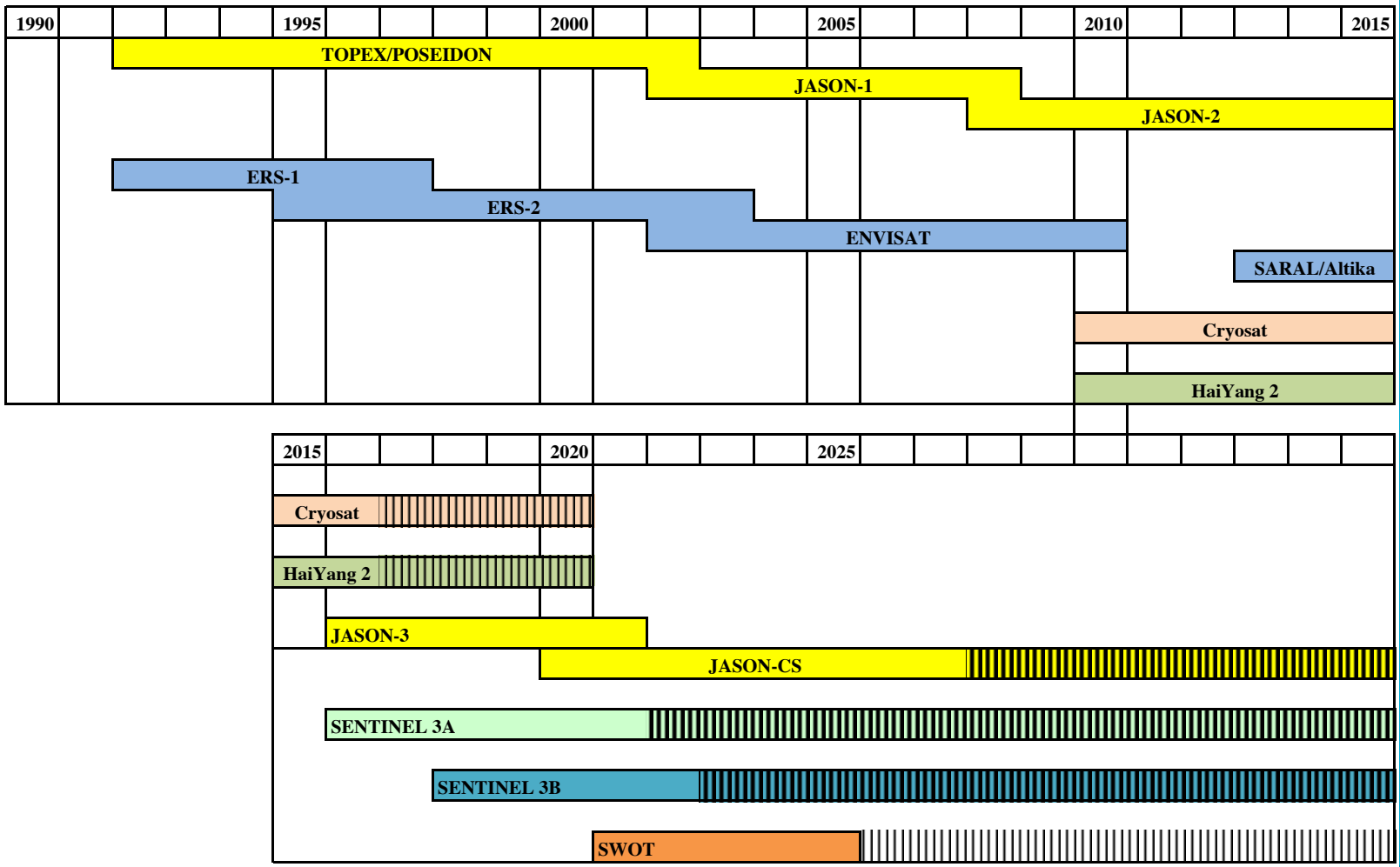
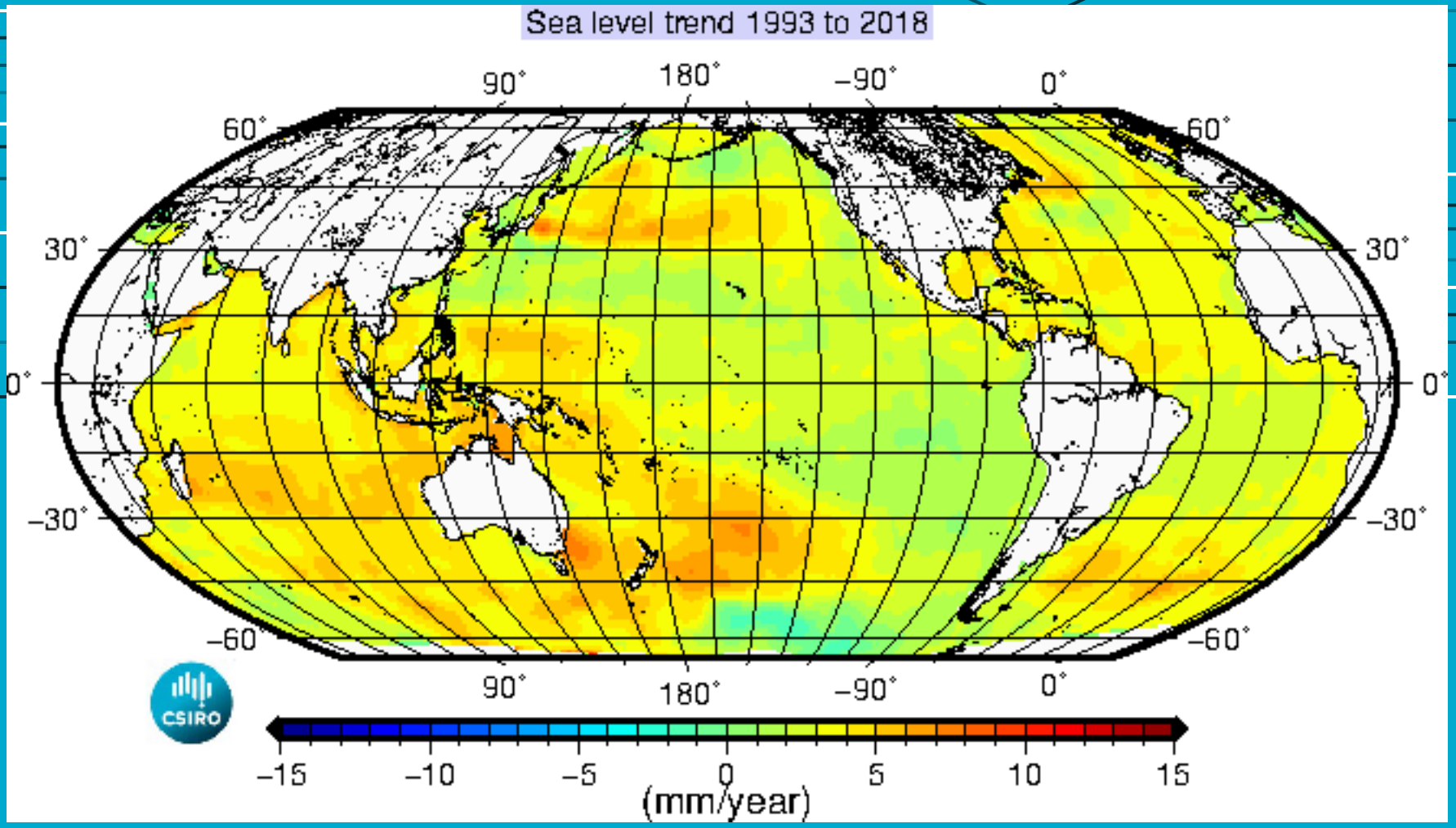


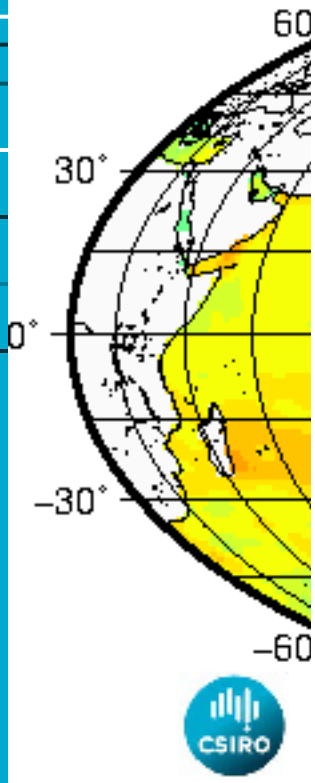
UNIVERSITY of TASMANIA AUSTRALIA

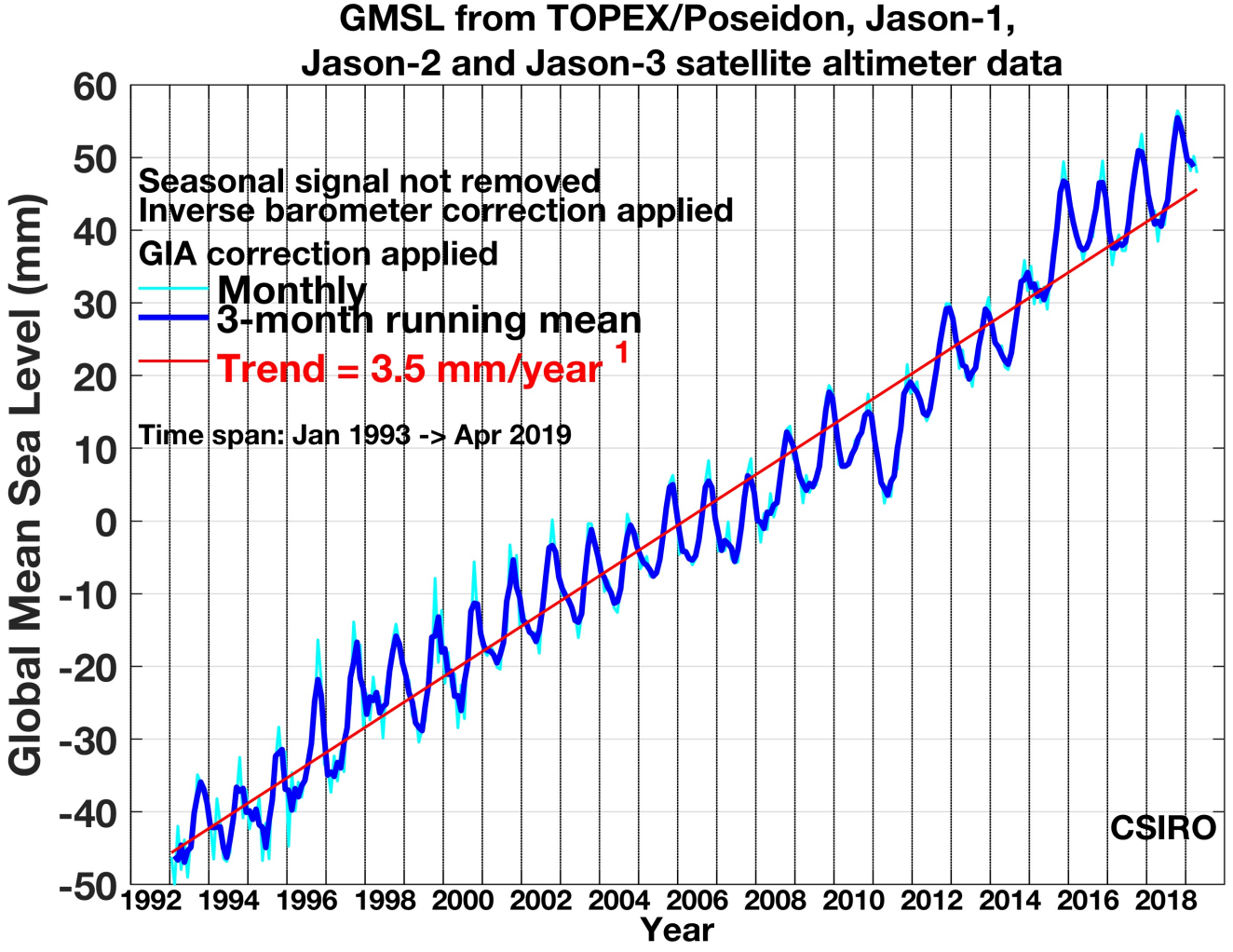
IMOS Integrated Marine Observing System

CSIRO

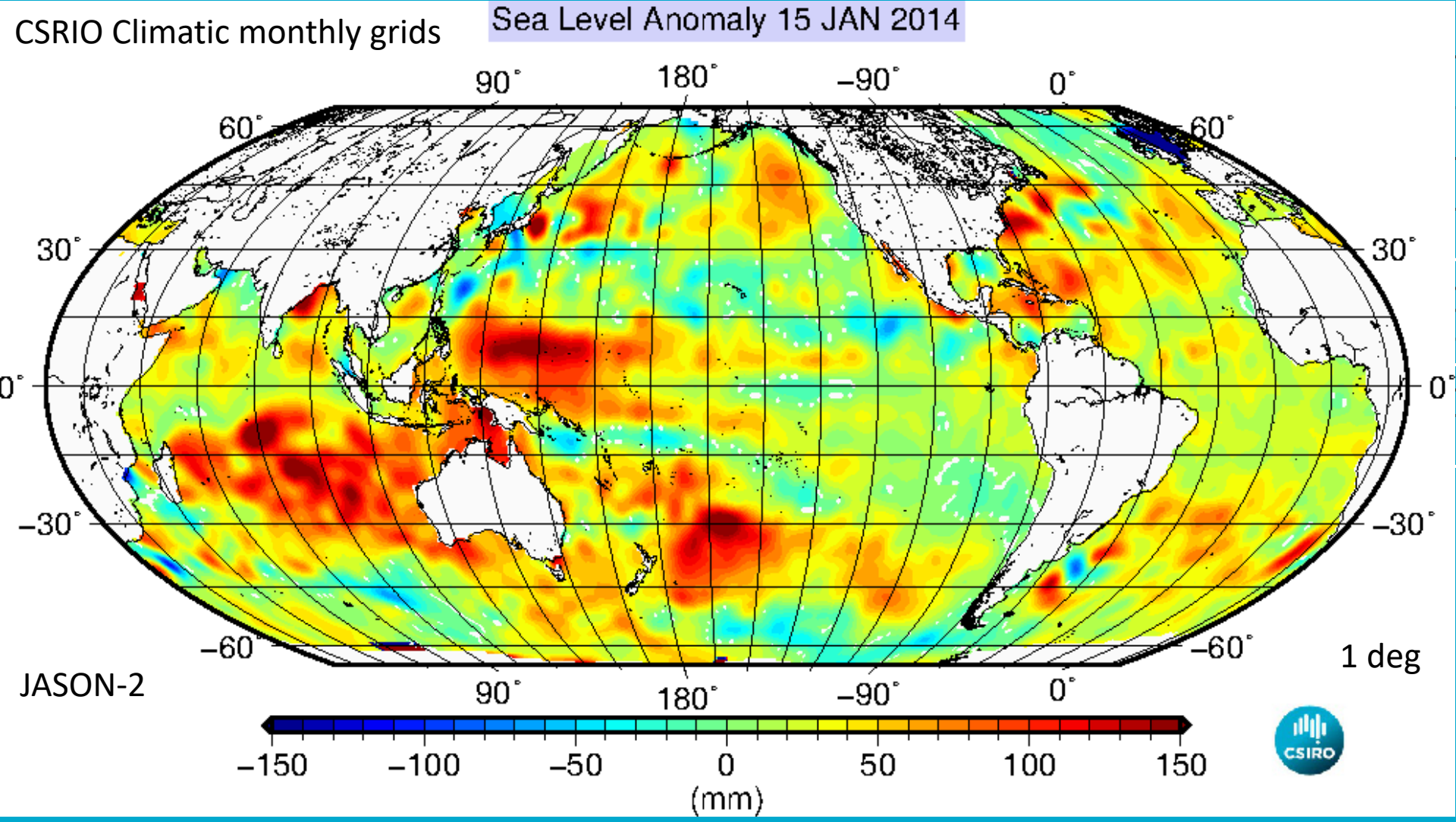

1990
1995
2000
2005
2010
2015
TOPEX/POSEIDON
JASON-1
JASON-2
ERS-1
ERS-2
ENVISAT
SARAL/Altika
Cryosat
HaiYang 2
2015
2020
2025
Cryosat
HaiYang 2
JASON-3
JASON-CS
SENTINEL 3A
SENTINEL 3B
SWOT


Sea level trend 1993 to 2018
90°
180°
−90°
0°
60°
30°
0°
−30°
−60°
−15
−10
−5
0
5
10
15
(mm/year)
CSIRO


60
30°
0°
-30°
-60


GMSL from TOPEX/Poseidon, Jason-1,
Jason-2 and Jason-3 satellite altimeter data
Seasonal signal not removed
Inverse barometer correction applied
GIA correction applied
Monthly
3-month running mean
Trend = 3.5 mm/year [1]
Time span: Jan 1993 -> Apr 2019
Global Mean Sea Level (mm)
Year
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
CSIRO

CSRIO Climatic monthly grids

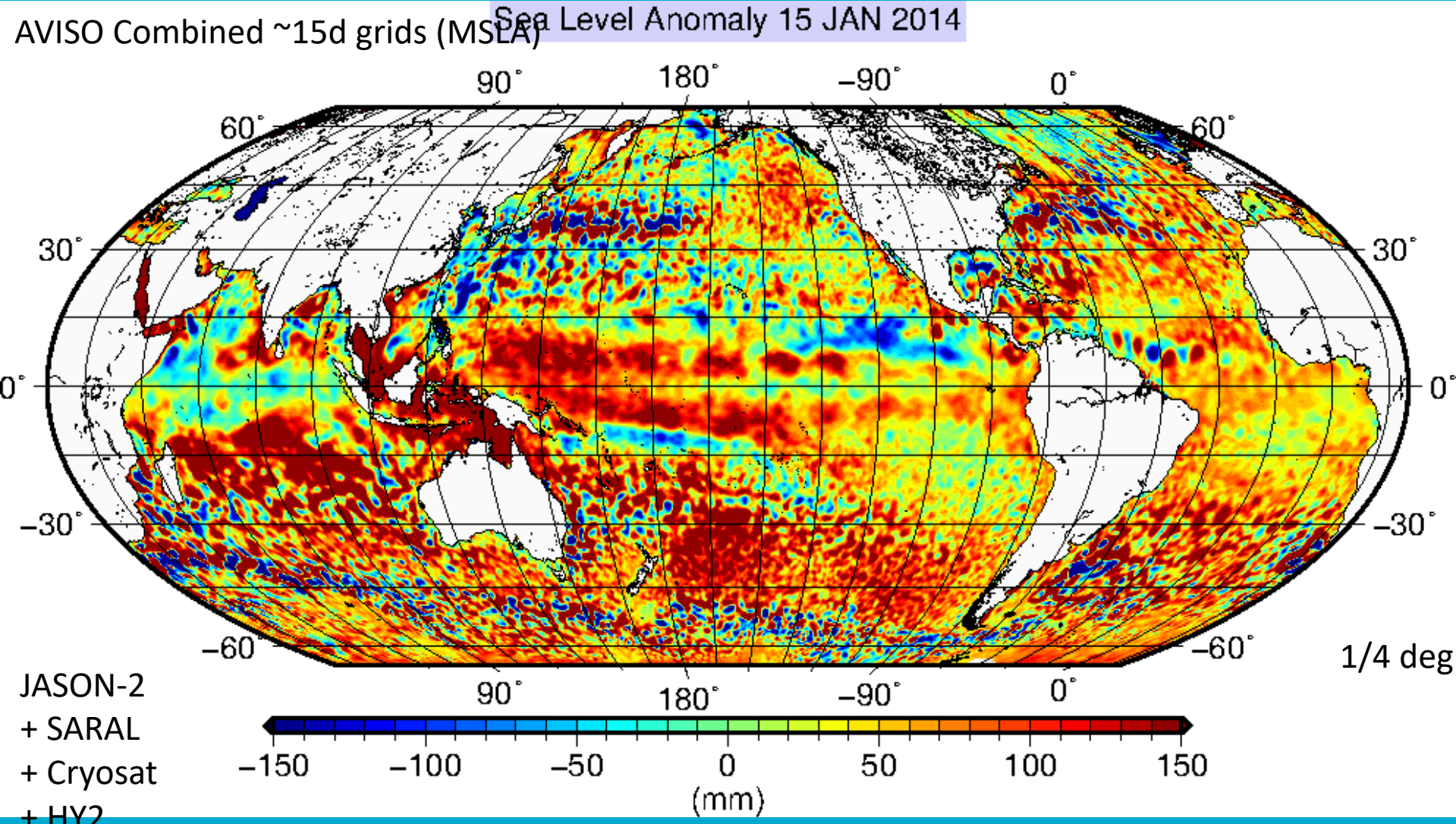


JASON-2

1 deg

http://www.cmar.csiro.au/sealevel/sl_data.html

AVISO Combined ~15d grids (MSLA)

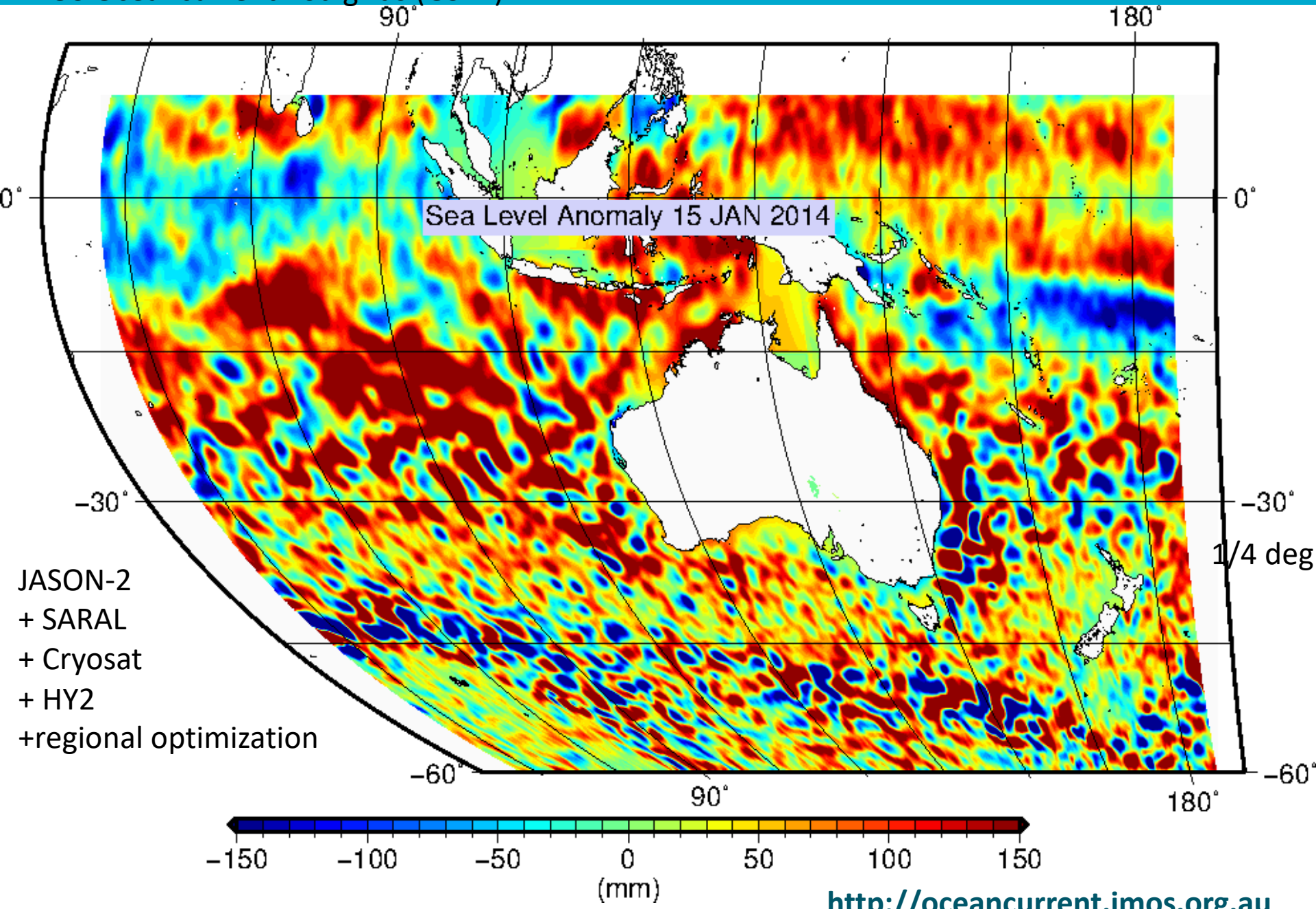


JASON-2
+ SARAL
+ Cryosat
+ HY2

1/4 deg

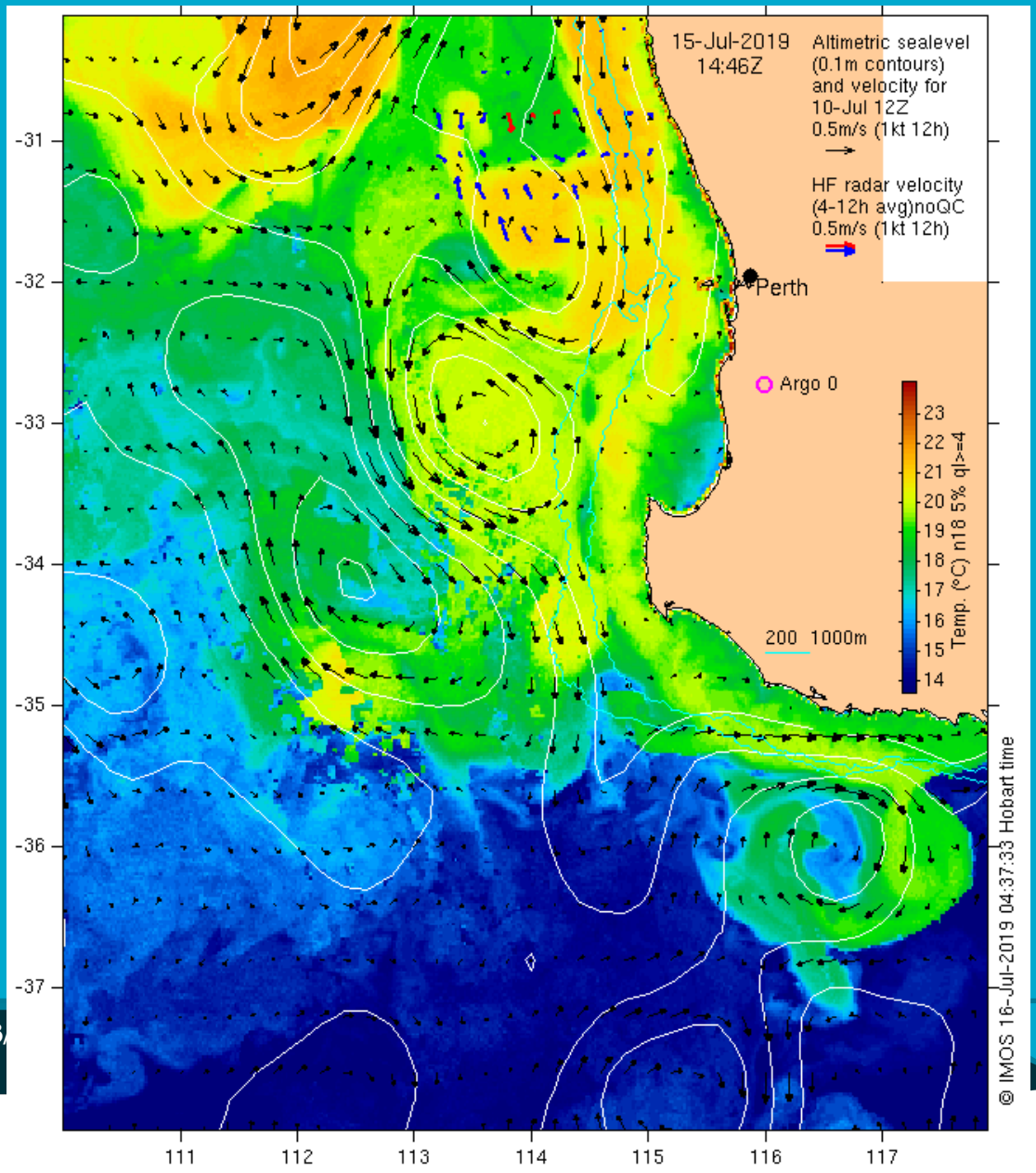
http://www.aviso.altimetry.fr

IMOS Oceancurrent 10d grids (GSLA)



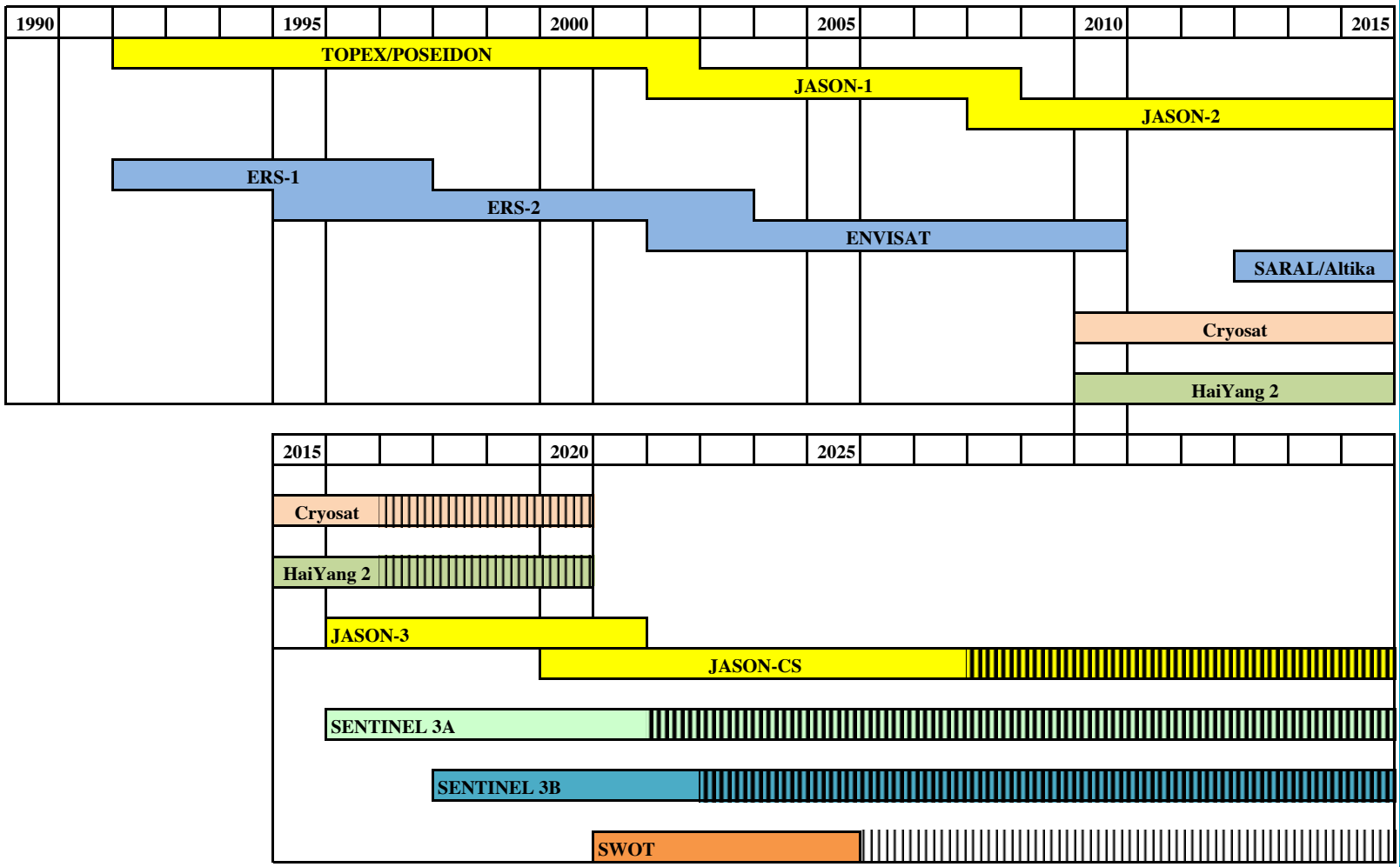
http://oceancurrent.imos.org.au

IMOS Oceancurrent 10d grids (GSLA)



1/4 deg

http://oceancurrent.imos.org.au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HaiYang 2
2015
2020
2025
Cryosat
HaiYang 2
JASON-3
JASON-CS
SENTINEL 3A
SENTINEL 3B
SWOT

The IMOS Satellite altimetry calibration facility

In situ instrumentation includes :

- moored oceanographic instruments at various comparison points,
- episodic GPS buoy deployments for absolute datum.
- Reference Tide gauge
- Land reference GPSs
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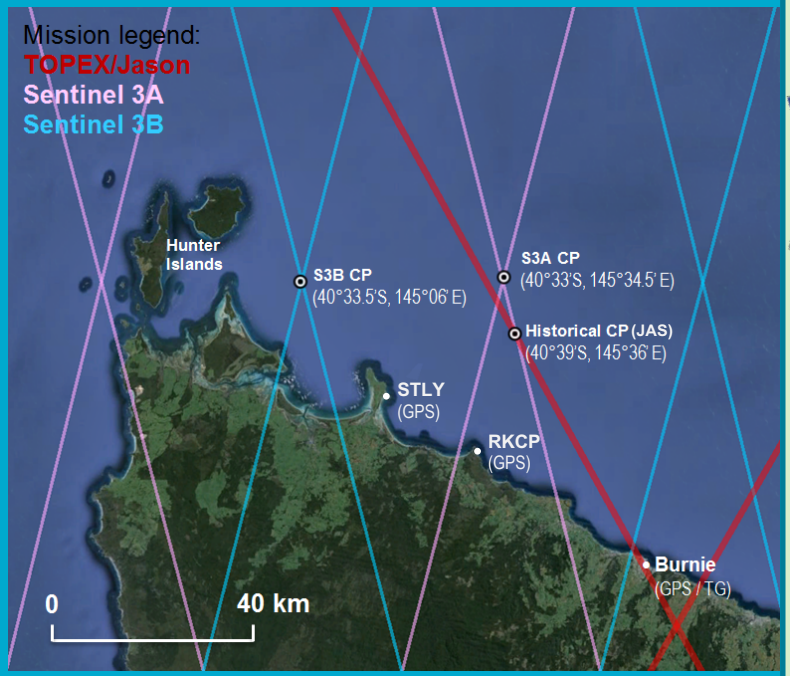
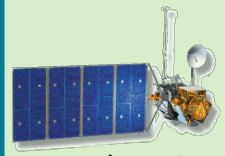


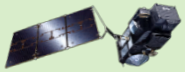


TOPEX / Poseidon
Aug 1992 -

Jason-1
Dec 2001 -

OSTM/Jason-2
June 2008 -

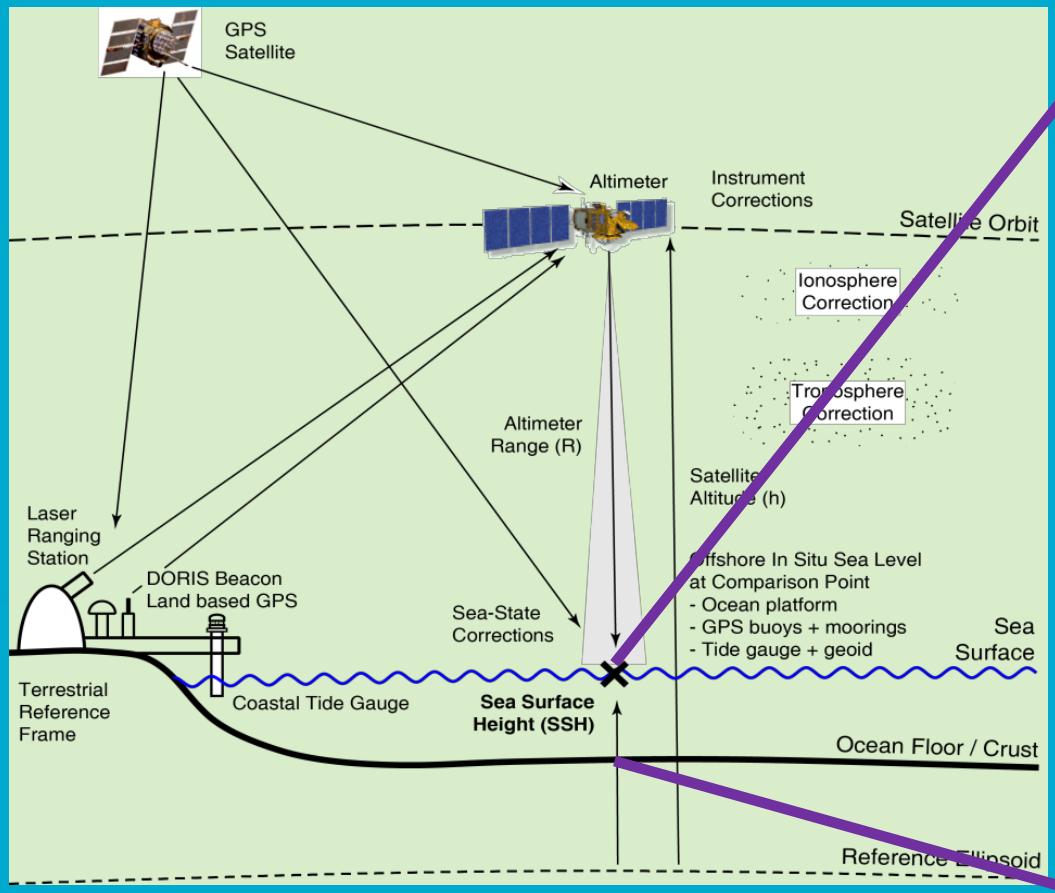
Jason-3
Jan 2016 -

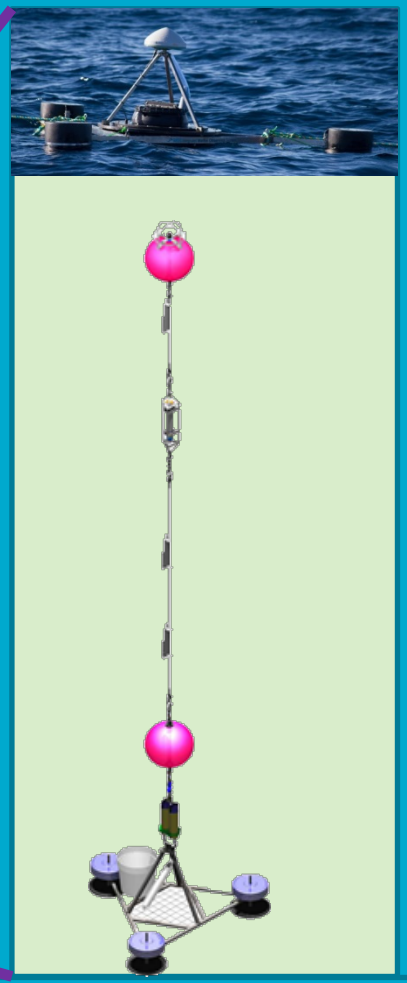


Sentinel-3A
Feb 2016 -

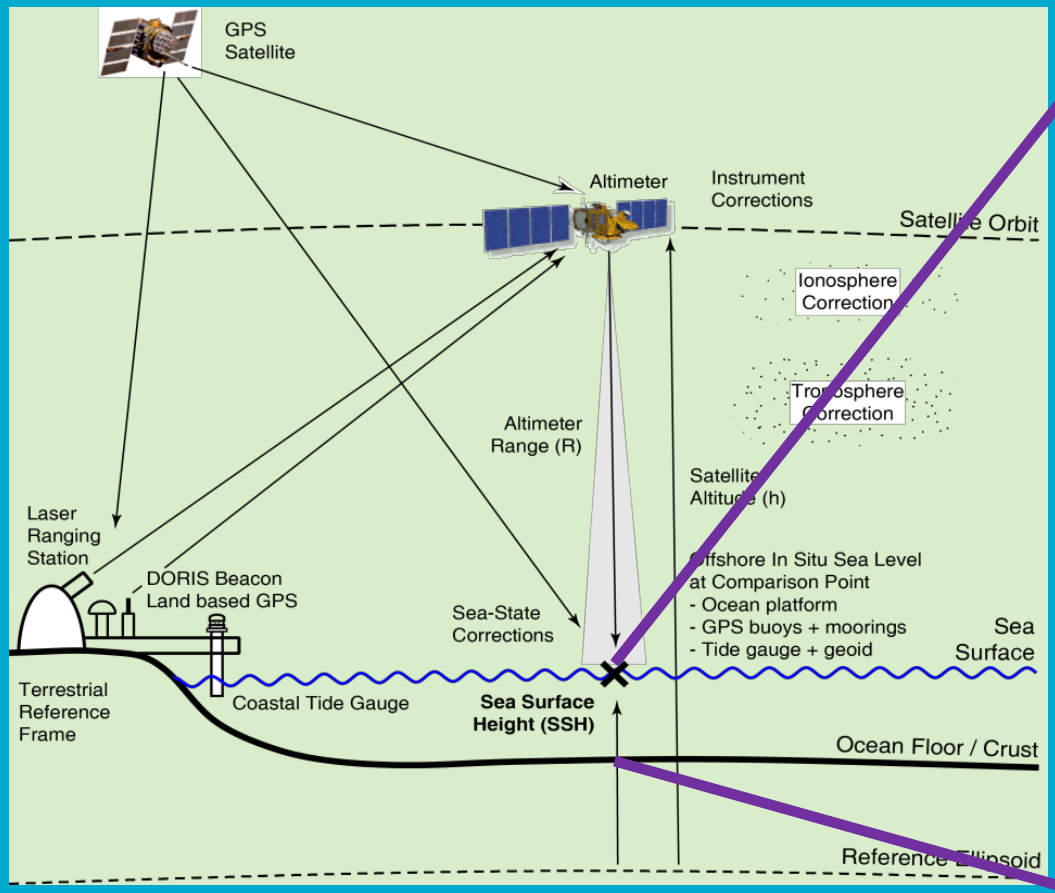
Sentinel-3B
Launching soon!

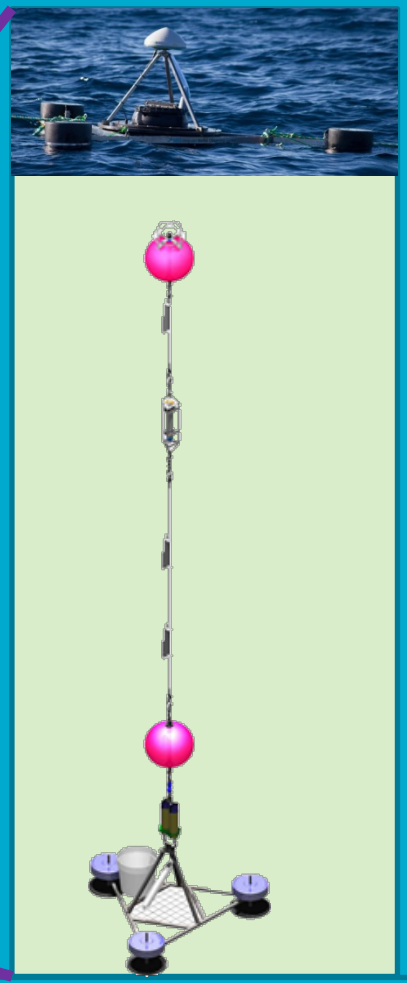
SSH @ Tide Gauge + datum (GPS)
SSH = Bot Pressure / [ρ(T,S) g] + datum (GPS) - IBE





Determination of the datum by GNSS
SSH = Bot Pressure / [ρ(T,S) g] + datum (GPS) - IBE





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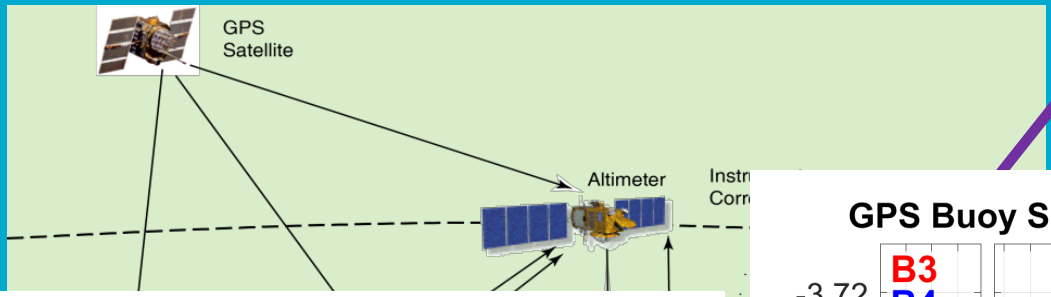
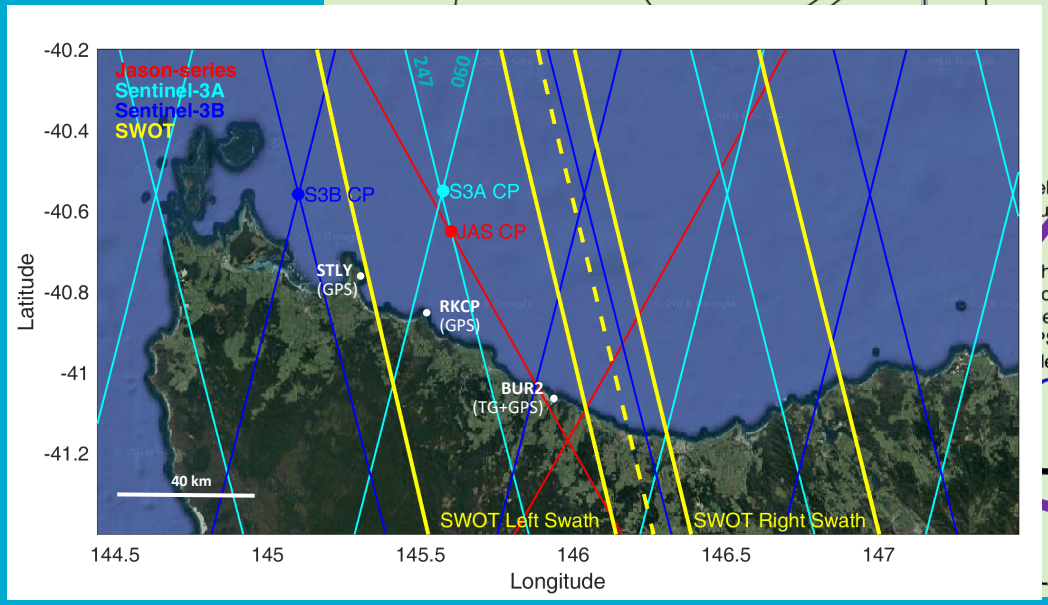
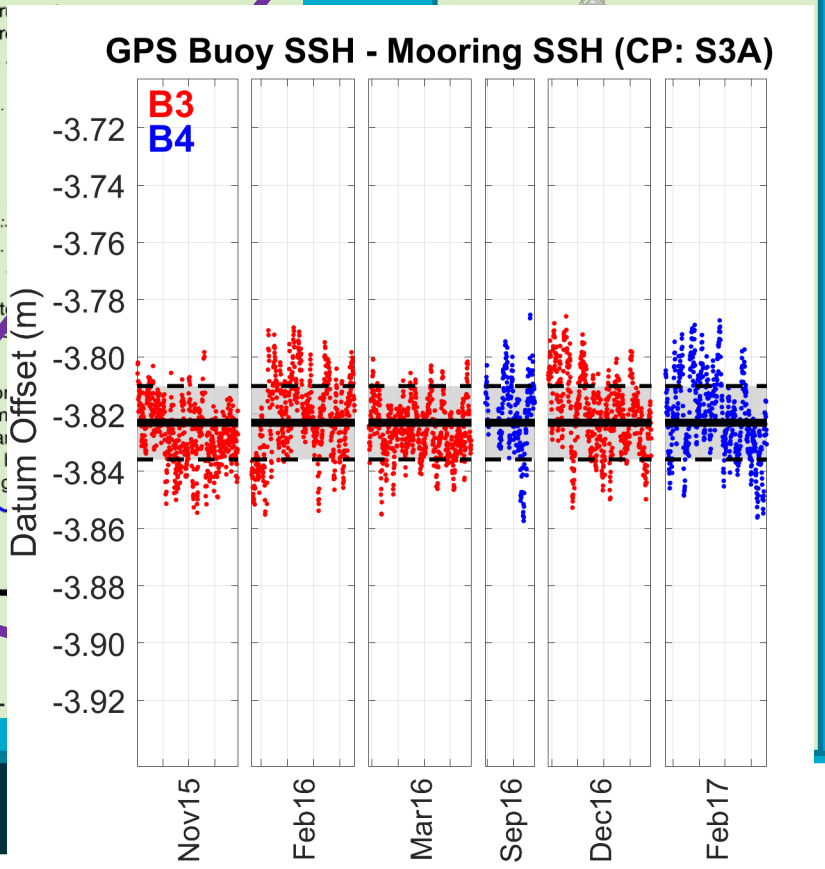
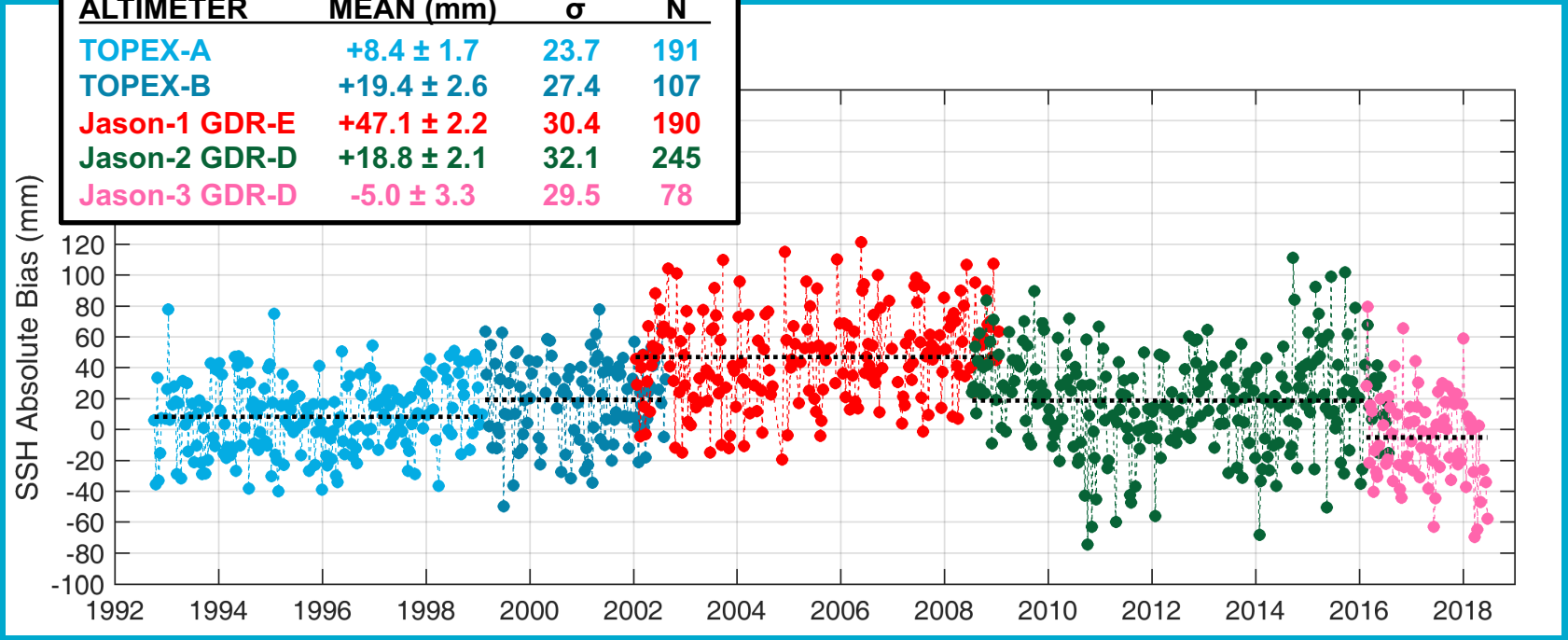






Absolute Bias at Bass Strait (vs Tide Gauge)

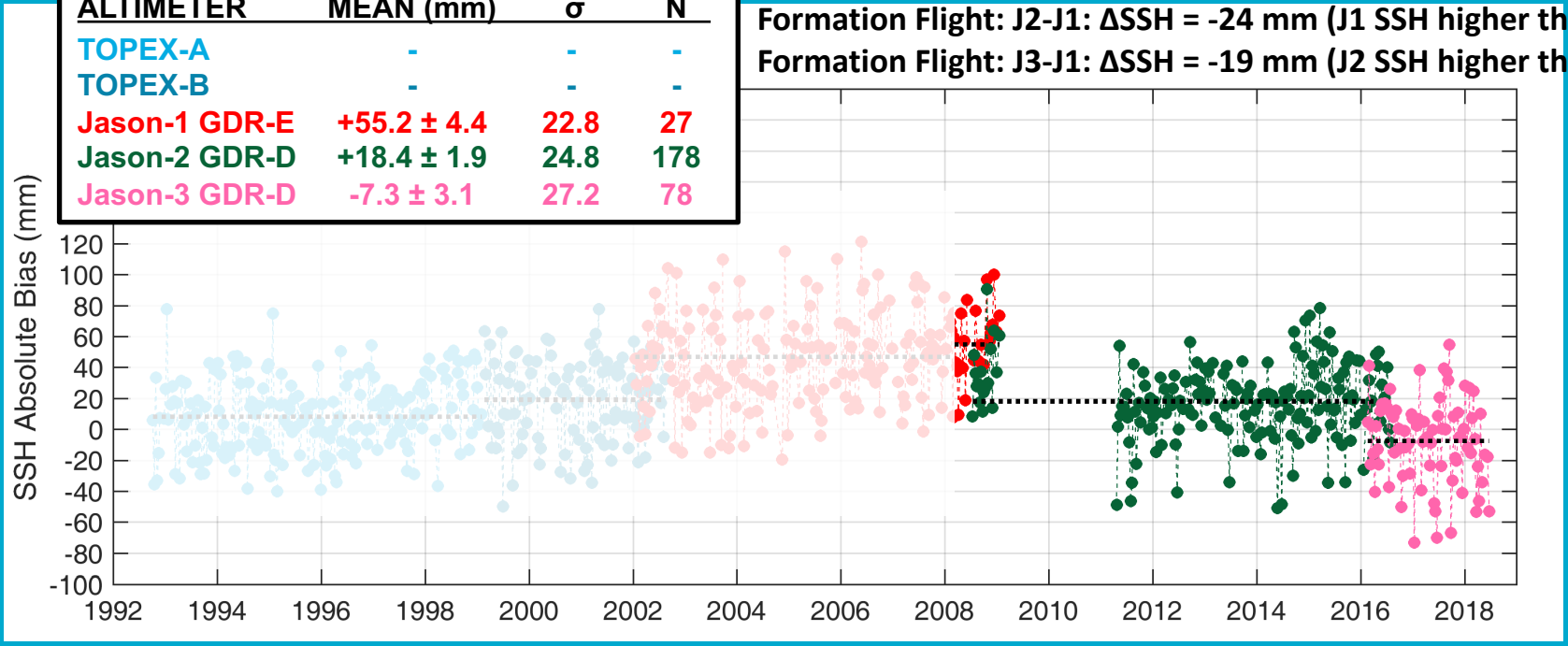
ALTIMETER	MEAN (mm)	σ	N
TOPEX-A	+8.4 ± 1.7	23.7	191
TOPEX-B	+19.4 ± 2.6	27.4	107
Jason-1 GDR-E	+47.1 ± 2.2	30.4	190
Jason-2 GDR-D	+18.8 ± 2.1	32.1	245
Jason-3 GDR-D	-5.0 ± 3.3	29.5	78



Absolute Bias at Bass Strait (vs Mooring)

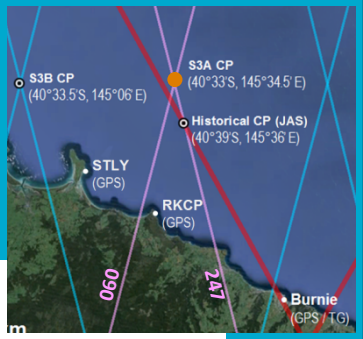
ALTIMETER	MEAN (mm)	σ	N
TOPEX-A	-	-	-
TOPEX-B	-	-	-
Jason-1 GDR-E	+55.2 ± 4.4	22.8	27
Jason-2 GDR-D	+18.4 ± 1.9	24.8	178
Jason-3 GDR-D	-7.3 ± 3.1	27.2	78

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

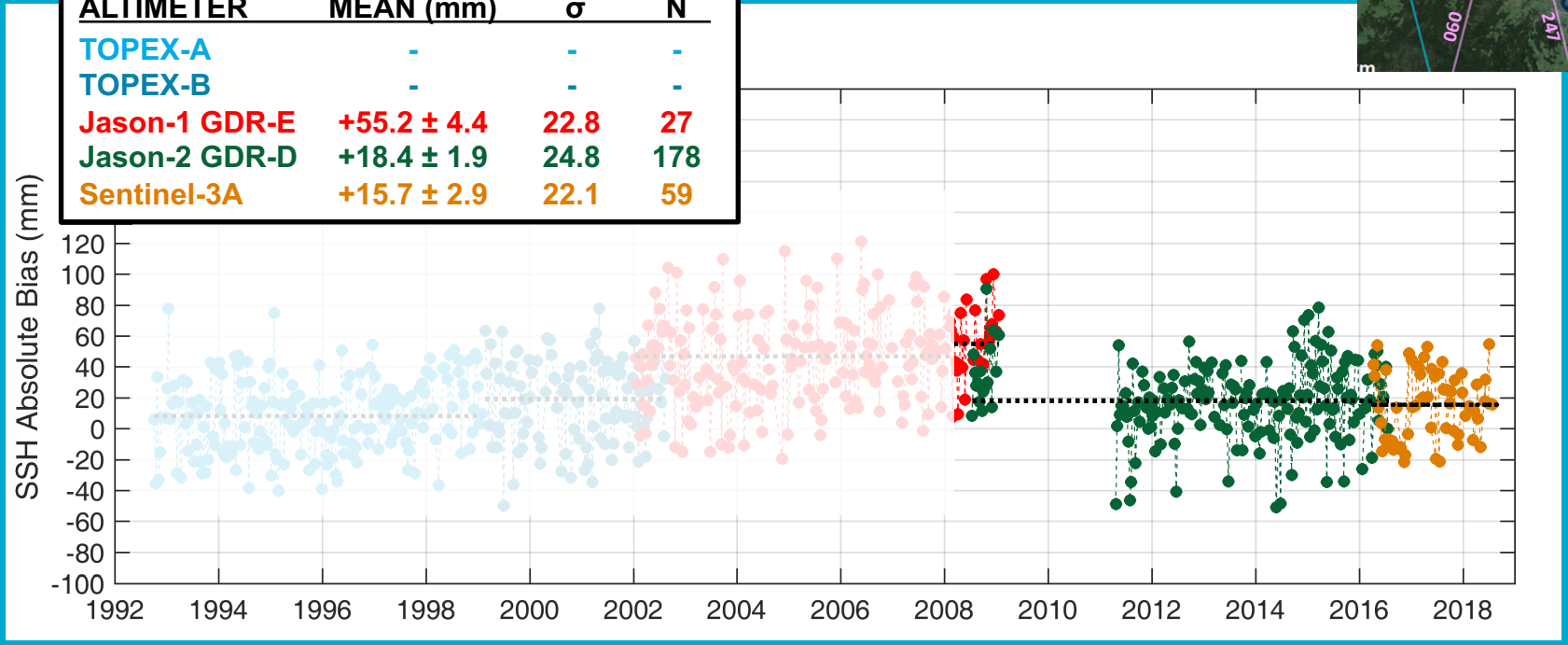


Absolute Bias at Bass Strait (vs Mooring)

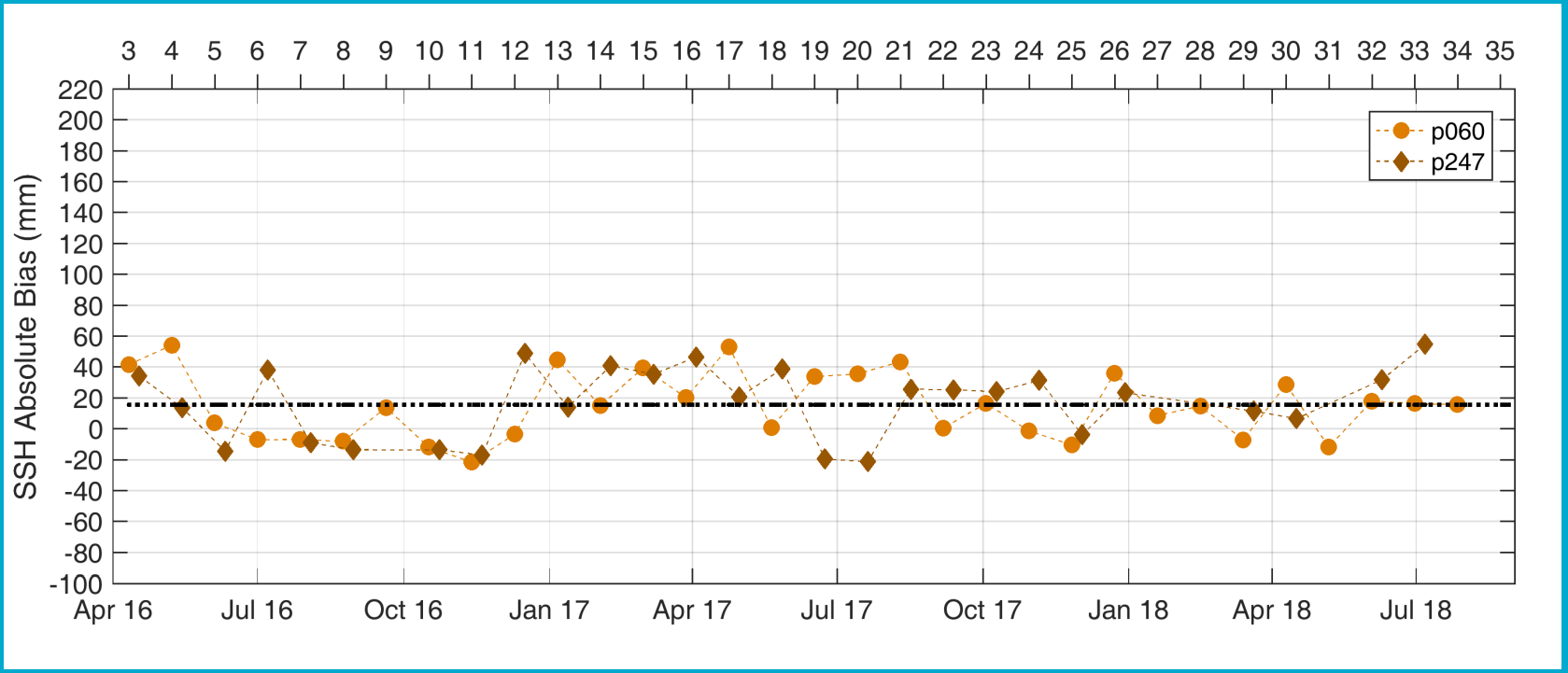
- **S3A Bassline 3 level 2 non time critical data. Cross-over between passes 060 & 247.**



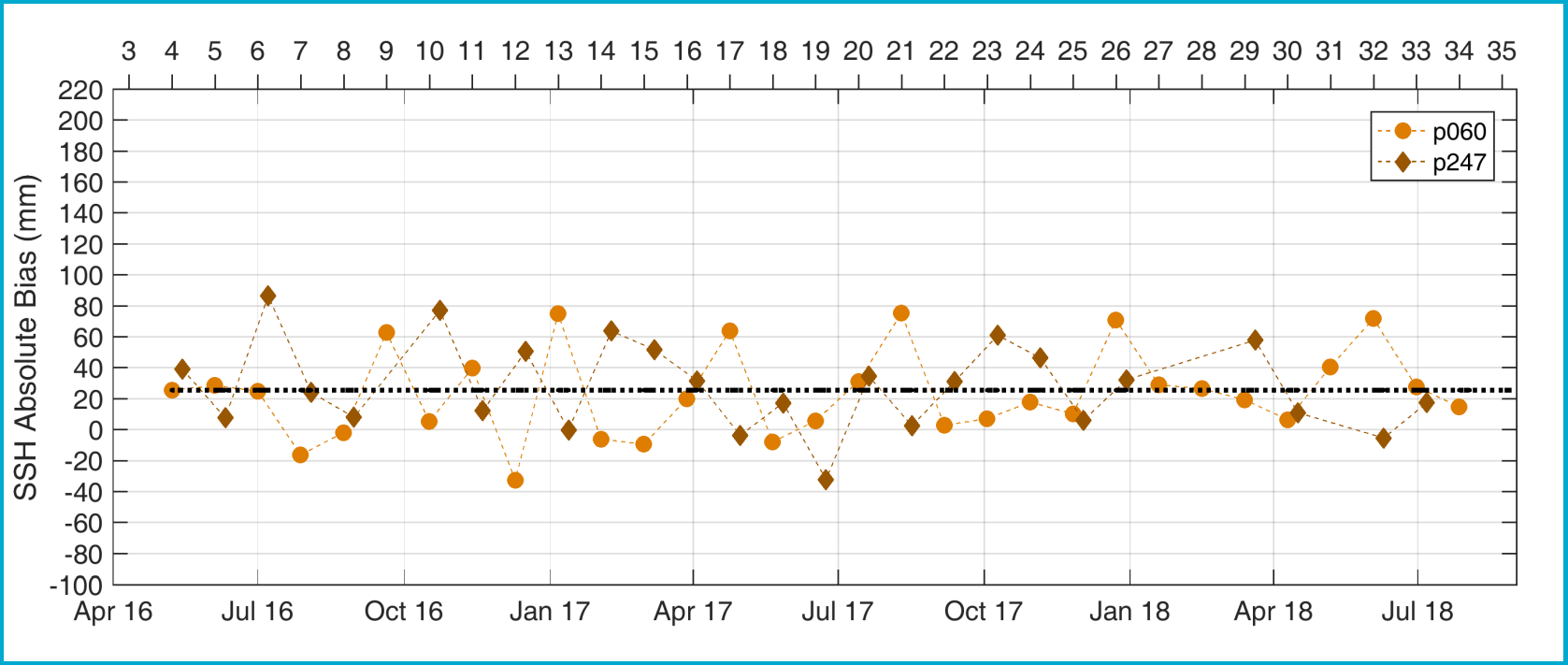
ALTIMETER	MEAN (mm)	σ	N
TOPEX-A	-	-	-
TOPEX-B	-	-	-
Jason-1 GDR-E	+55.2 ± 4.4	22.8	27
Jason-2 GDR-D	+18.4 ± 1.9	24.8	178
Sentinel-3A	+15.7 ± 2.9	22.1	59



S3A SAR Absolute Bias

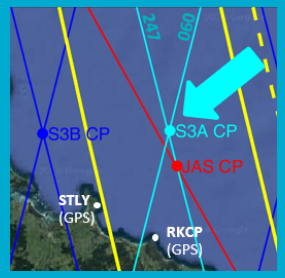


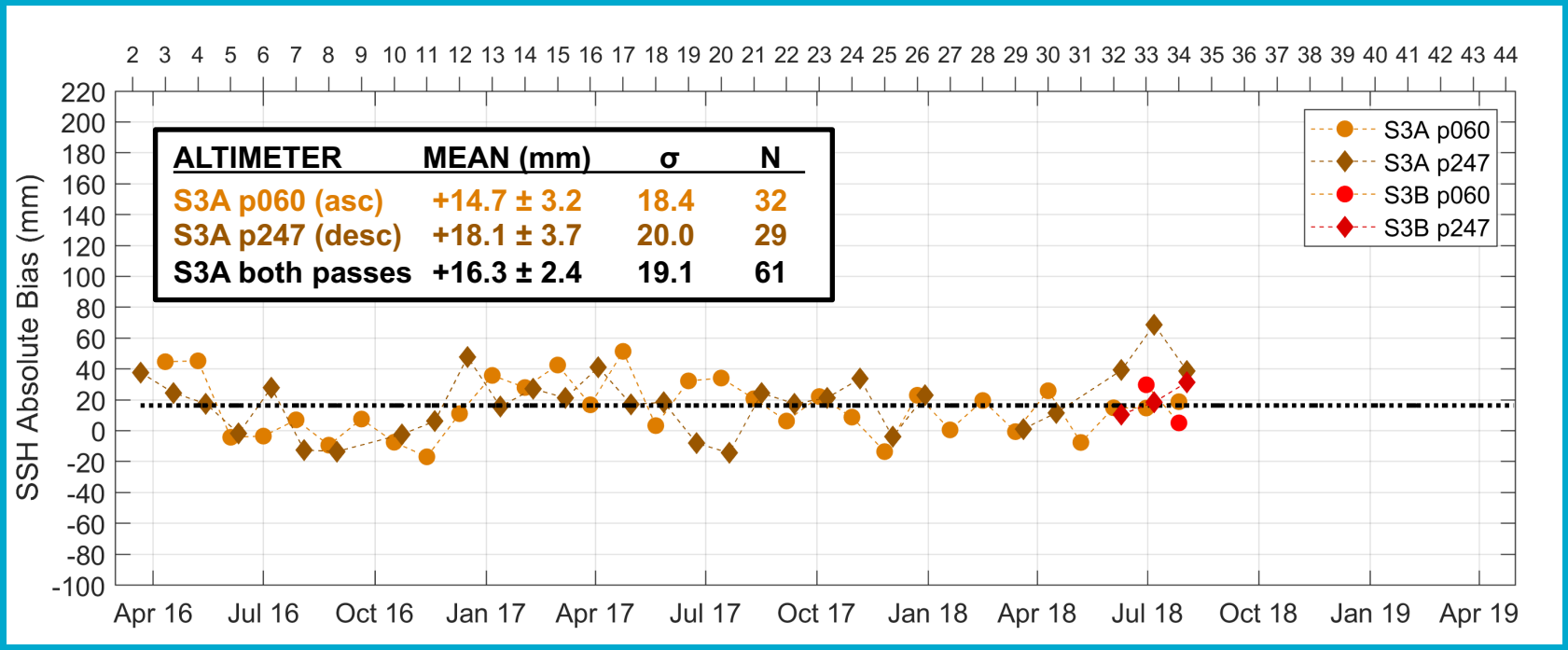
S3A PLRM Absolute Bias



Absolute Biases at S3A CP

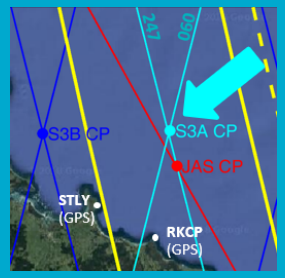
- **Comparison against mooring time series at S3A CP.**
- **Most recent reprocessing available.**
- **Bias from asc/desc passes are equivalent. Bias variability approaching in situ noise.**

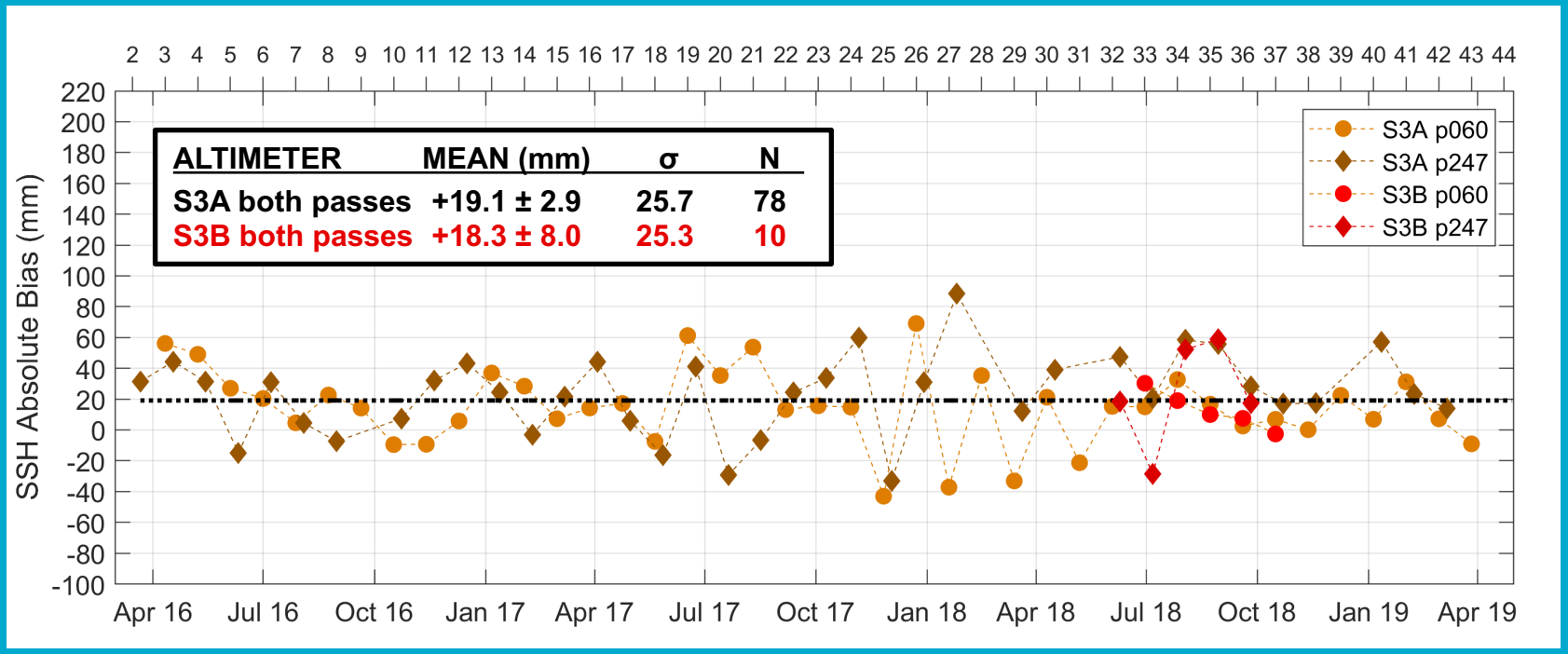




Absolute Biases at S3A CP

- **Comparison against tide gauge time series at S3A CP.**
- **Most recent reprocessing available.**
- **Bias from asc/desc passes are equivalent. Bias variability approaching in situ noise.**





The IMOS Satellite altimetry calibration facility

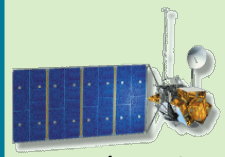
In situ instrumentation includes :

- moored oceanographic instruments at various comparison points,
- episodic GPS buoy deployments for absolute datum.
- Reference Tide gauge
- Land reference GPSs
- Meteorologic observations and regional models

Mission legend:
TOPEX/Jason
Sentinel 3A

OSTST 2017

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 -> 87	-5 mm **-7 mm**	29 mm (TG) **27 mm (Mooring)**
S-3A SAR S-3A PLRM	3 -> 34 3 -> 34	**+16 mm** +26 mm	**22 mm (Mooring)** 28 mm (Mooring)



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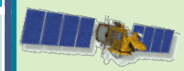
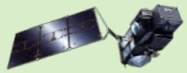
Dec 2001 -



OSTM/Jason-2
June 2008 -

Jason-3
Jan 2016 -



Sentinel-3A
Feb 2016 -

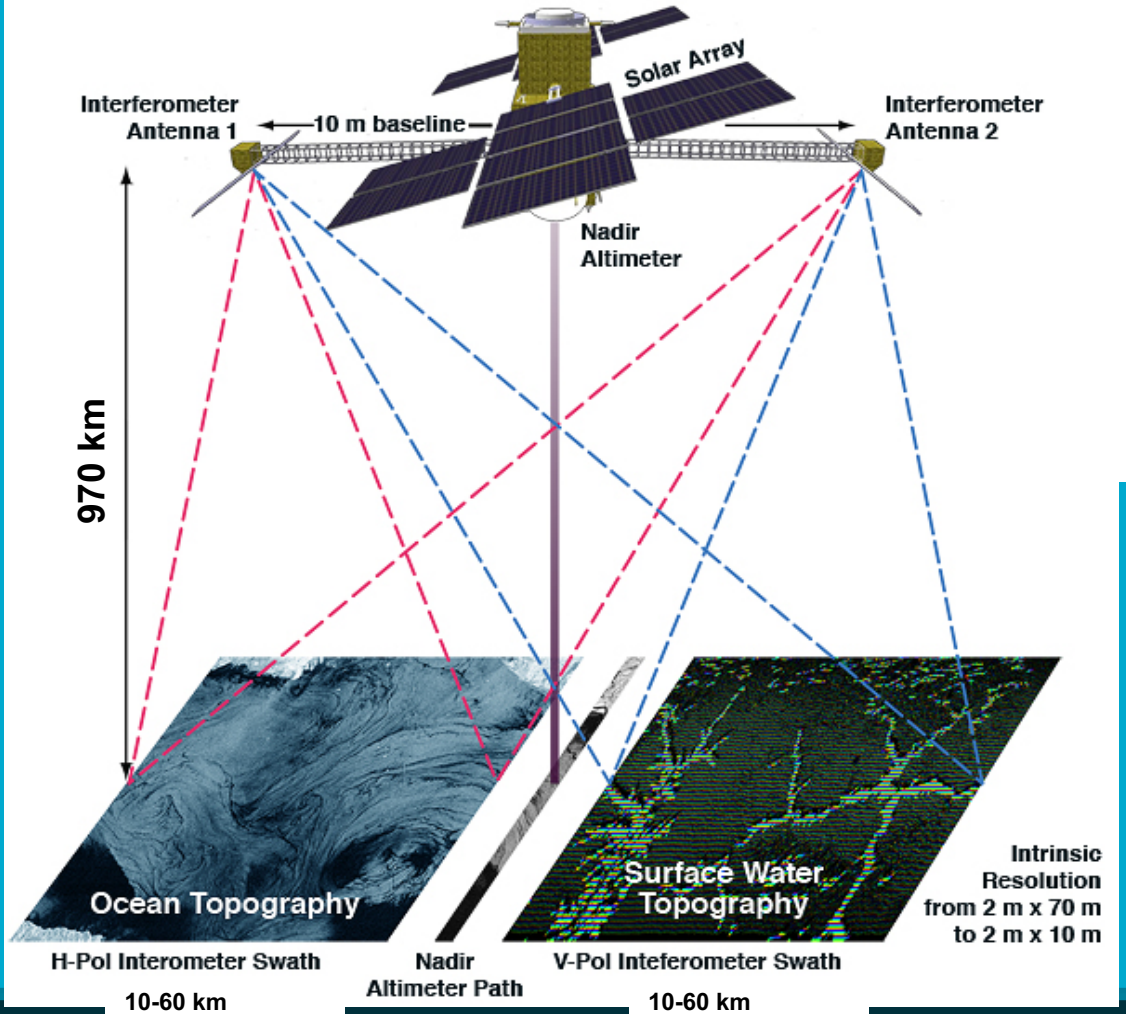
Sentinel-3B
Launching soon!

Given systematic contributions, formal error likely ~15 mm, marginally less for recent missions.

- S3A along track SAR altimeter demonstrated immediately the improvement in accuracy and resolution.
- S3B launched in 2018 and shows similar performance before reaching it's operational orbit
- S6 (Jason-CS) next year promise even better performance.
- SWOT is going to push this a lot further.

Not mentioned in this presentation :
- Sea Wave Height and Wind. IMOS new facility to integrate the collection of in situ wave with satellite products.

SWOT Surface Waters and Ocean Topography



- 2 swath topographic mapping of 50km either sides
- “classic” Jason type nadir altimeter
- improved res. radiometer

Over Ocean :
- 2km accurate gridding
- 250m pixel expert product

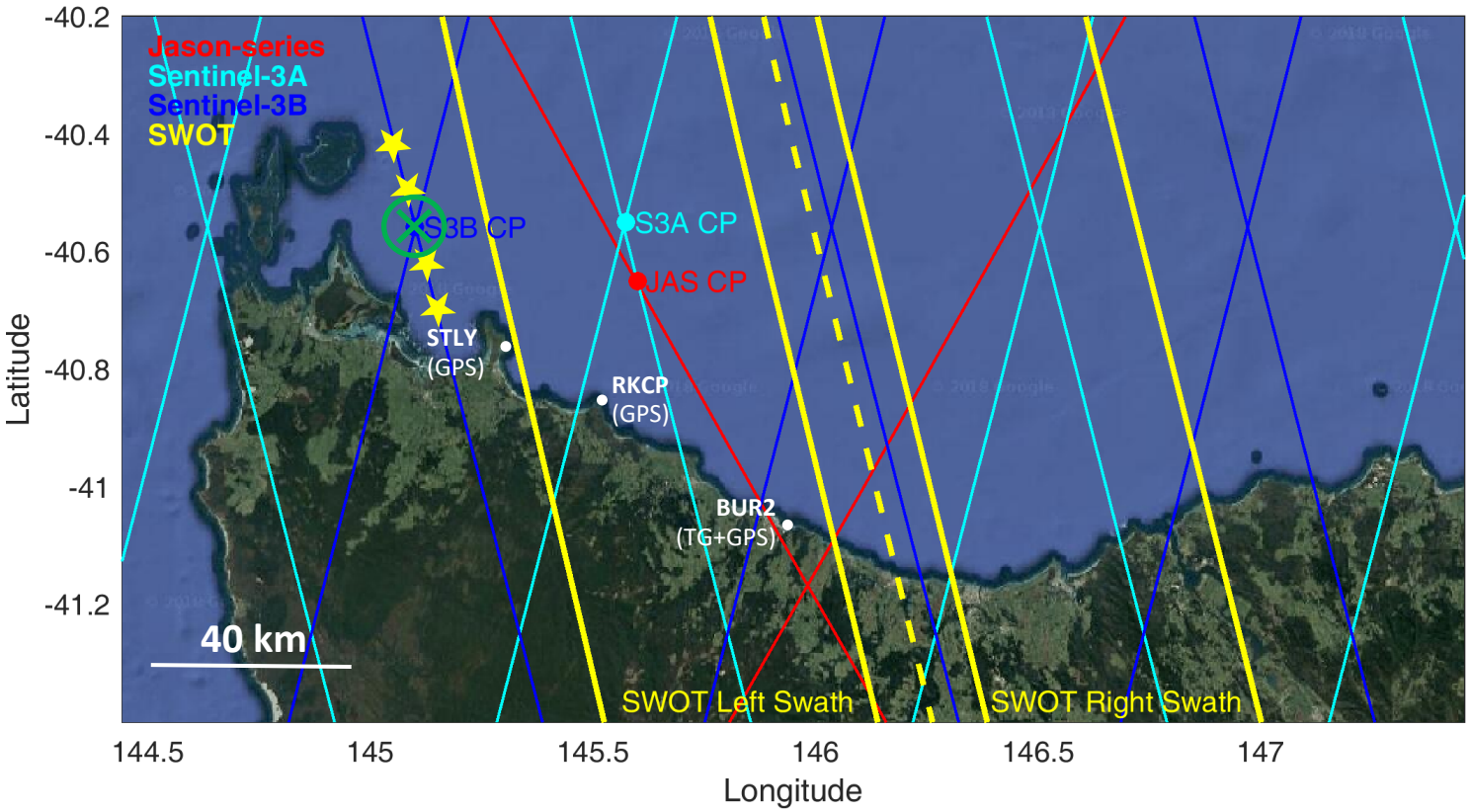
SWOT Surface Waters and Ocean Topography

GNSS buoy (SSH, wet trop, SST, waves)

CWPIES Mooring (SSH, U, V, waves, P, density)

P,T,S Mooring (SSH, P, T, S)

- 2019-20 : 5-6 points along Sentinel-3B line



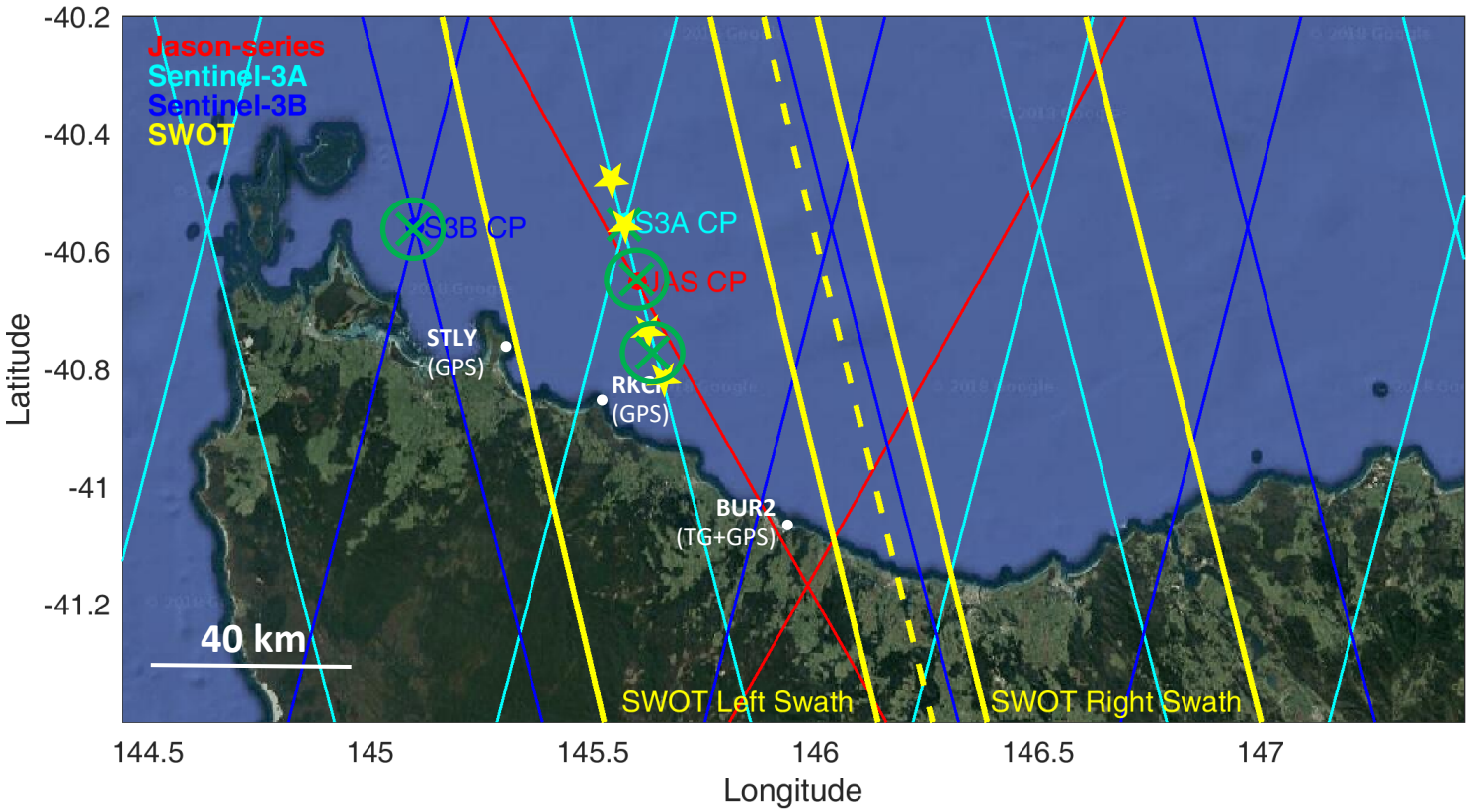
SWOT Surface Waters and Ocean Topography

GNSS buoy (SSH, wet trop, SST, waves)

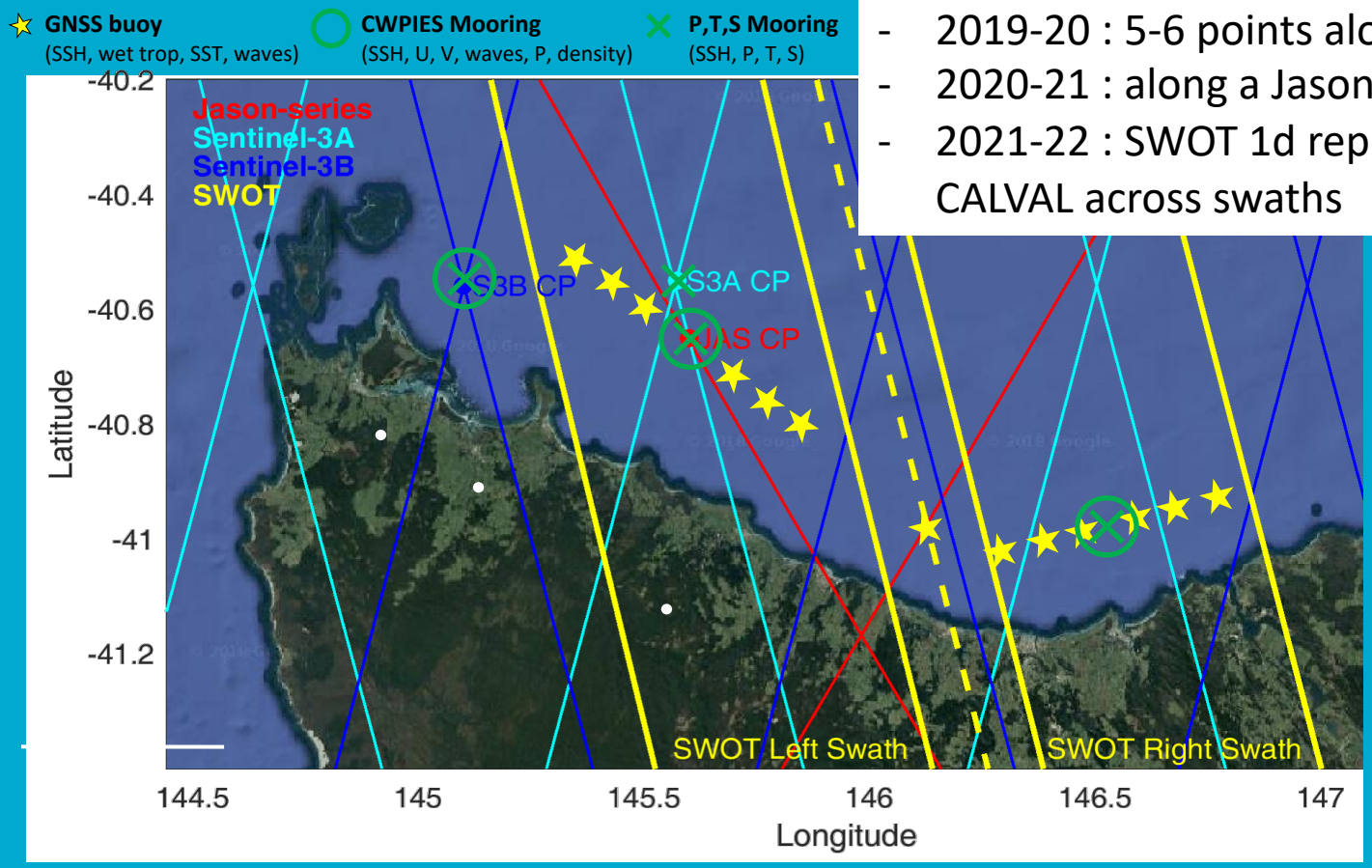
CWPIES Mooring (SSH, U, V, waves, P, density)

P,T,S Mooring (SSH, P, T, S)

- 2019-20 : 5-6 points along Sentinel-3B line
- 2020-21 : along a Jason-CS- Sentinel-6 line



SWOT Surface Waters and Ocean Topography



- 2019-20 : 5-6 points along Sentinel-3B line
- 2020-21 : along a Jason-CS- Sentinel-6 line
- 2021-22 : SWOT 1d repeat phase intense CALVAL across swaths

- S3A along track SAR altimeter demonstrated immediately the improvement in accuracy and resolution.

- S3B launched in 2018 and shows similar performance before reaching it's operational orbit

- S6 (Jason-CS) next year promise even better performance.

- SWOT is going to push this a lot further.

- The Integrated Marine Observing System is also able to respond to CALVAL needs of future missions like SWOT but also other candidates like SKIM (waves and currents)

Satellite altimetry calibration and validation in Bass Strait and around Australia

developments around new moorings and GNSS buoys

P.T.S

5 beams acoustic instrument,
Vertical beam ranges the surface.

Satellite altimetry calibration and validation in Bass Strait and around Australia

developments around new moorings and GNSS buoys

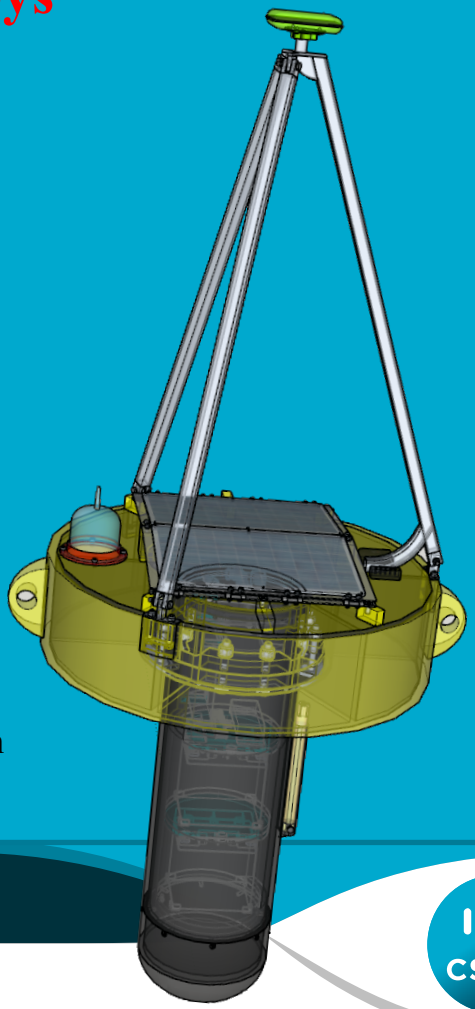
New GNSS buoys

New Mk-V GNSS buoy construction finally underway (x2):

- Custom design, fabricated largely from welded polypropylene.
- Payload includes GNSS+INS (Xeos Resolute GNSS, XSENS INS, waterproof Javad antenna) and SST (Seabird SBE56) sensors.
- Solar power system.
- Cellular telemetry, iridium tracking.
- ~60 kg deployment weight
- Low cost (US$15-20K ex GNSS)
- Aimed at deployment durations of ~1-2 months.
- First deployment ~June 2019.

XEOS Resolute GNSS receiver (Septentrio board)

XSENS INS to aid platform orientation and positioning



Pre launch platform and instruments calibrations

On-board system auto calibration

Processing chain

Global statistics from the data themselves and cross validation between satellites

In situ independent SSH