IMOS Integrated **Marine Observing** System





Satellite Altimetry

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Overview

Part I: Context and Background

- Altimetry review - reminder of what altimetry is (and isn't)
- Some example datasets

Part II: IMOS Sub-facility 11e: Satellite Altimetry Cal/Val

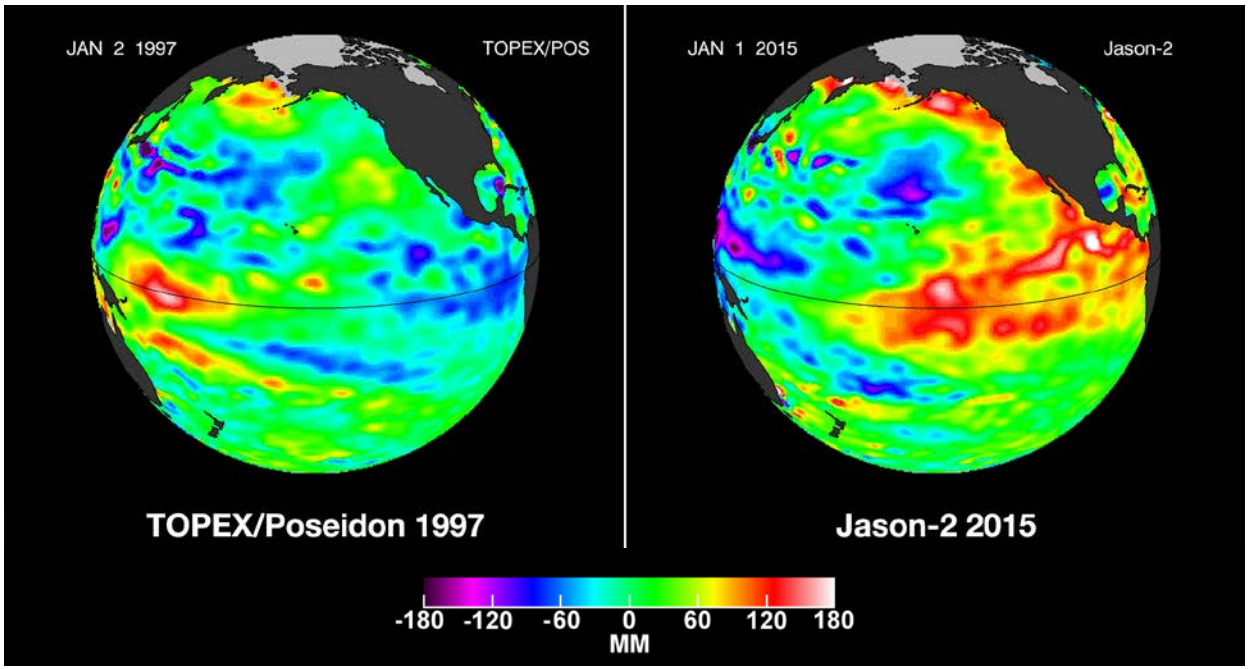
- Sea level as a climate data record
- IMOS altimetry cal/val: What? Why? And Where?

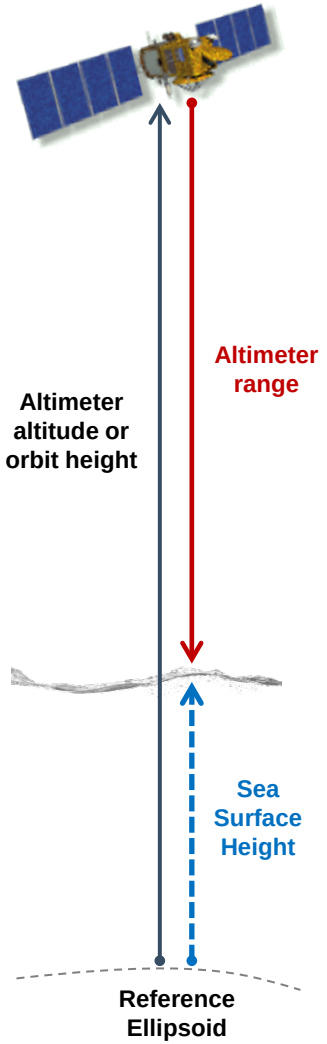
Part III: Satellite Altimetry 2015 and Beyond

- Update from the 9th Coastal Altimetry Workshop
- Overview of the breakout session on Wednesday

Altimetry Review

- Conceptually simple:
  - Height of the satellite…
  - minus range to the sea surface…
  - Gives the Sea Surface Height (SSH)
  - May be expressed relative to different surfaces (e.g. geoid, mean sea surface etc) to allow different inference.



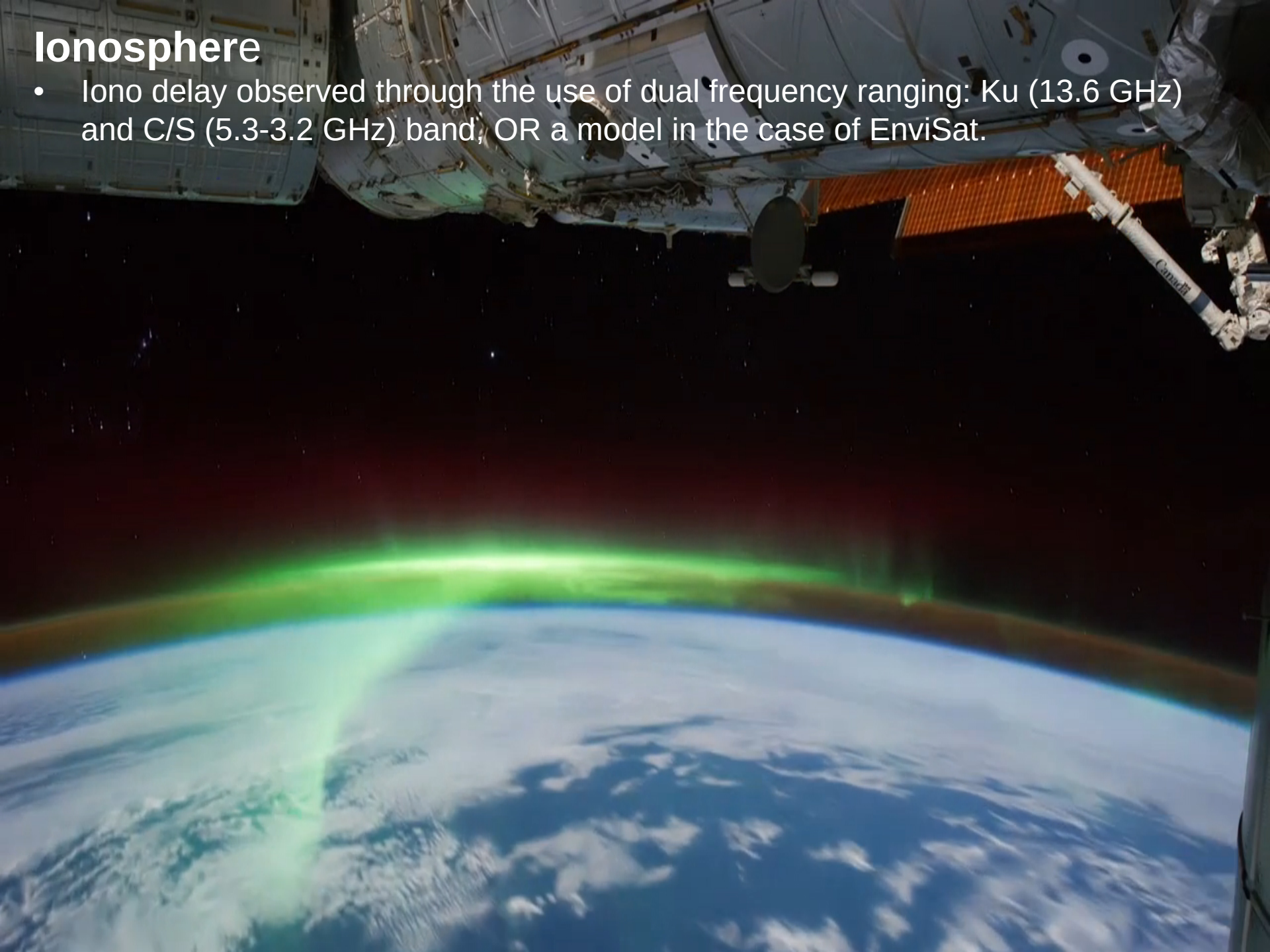


Orbit

- Multi-technique “Precision Orbit Determination”
- Time variable gravity fields (GRACE)
- Reference frame stability is critical

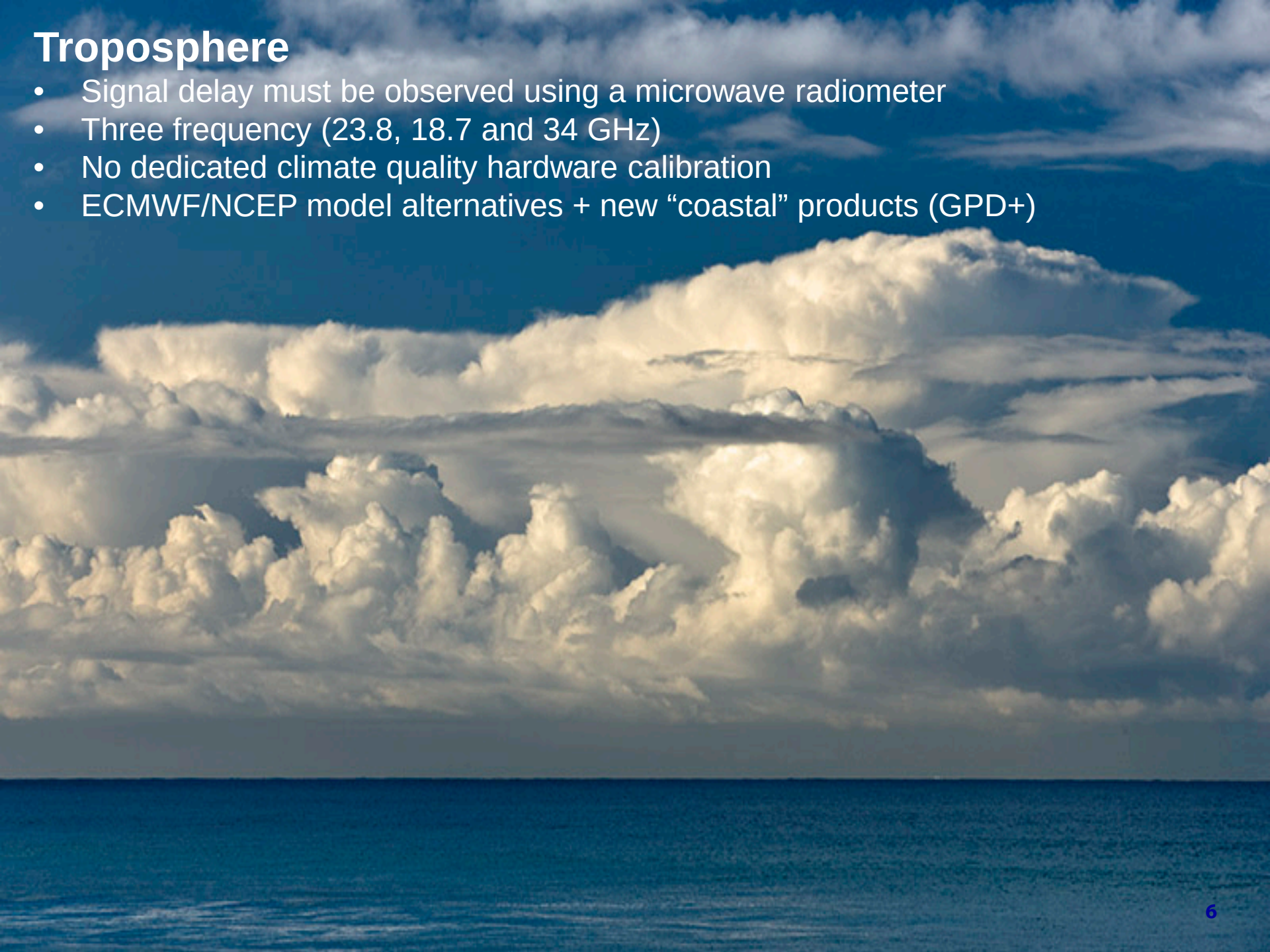
Ionosphere

- Iono delay observed through the use of dual frequency ranging: Ku (13.6 GHz) and C/S (5.3-3.2 GHz) band, OR a model in the case of EnviSat.



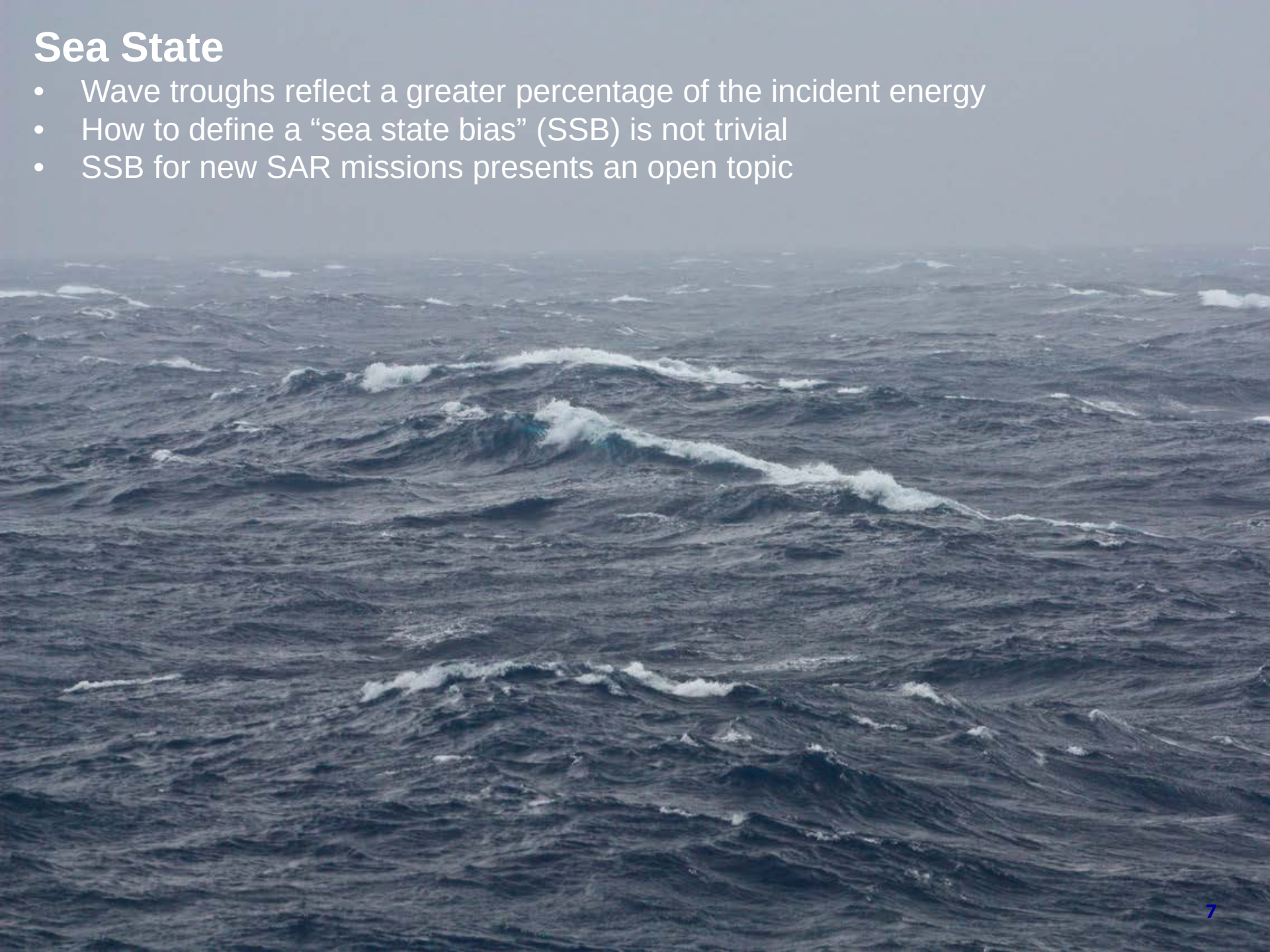
Troposphere

- Signal delay must be observed using a microwave radiometer
- Three frequency (23.8, 18.7 and 34 GHz)
- No dedicated climate quality hardware calibration
- ECMWF/NCEP model alternatives + new “coastal” products (GPD+)



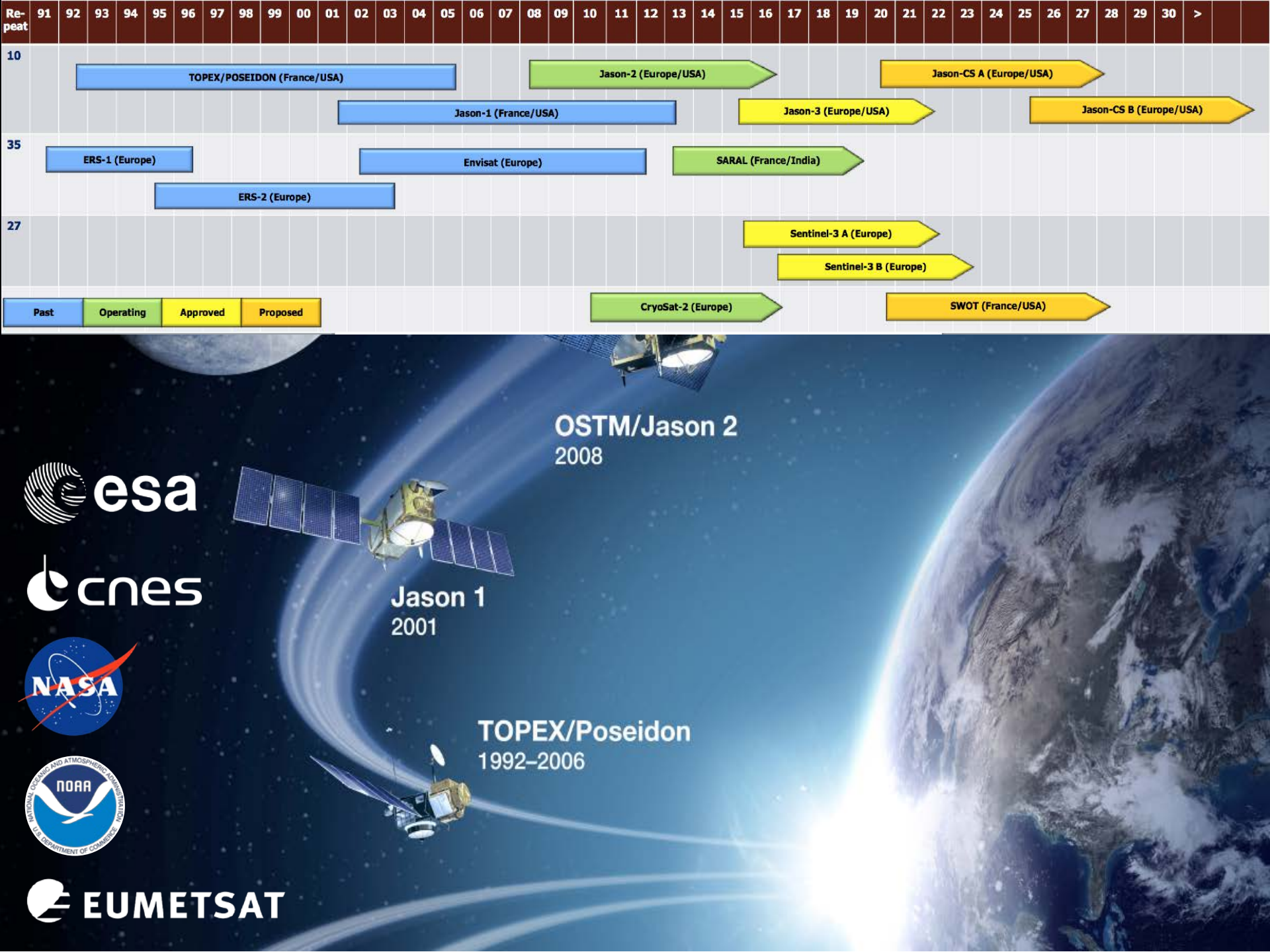
Sea State

- Wave troughs reflect a greater percentage of the incident energy
- How to define a “sea state bias” (SSB) is not trivial
- SSB for new SAR missions presents an open topic



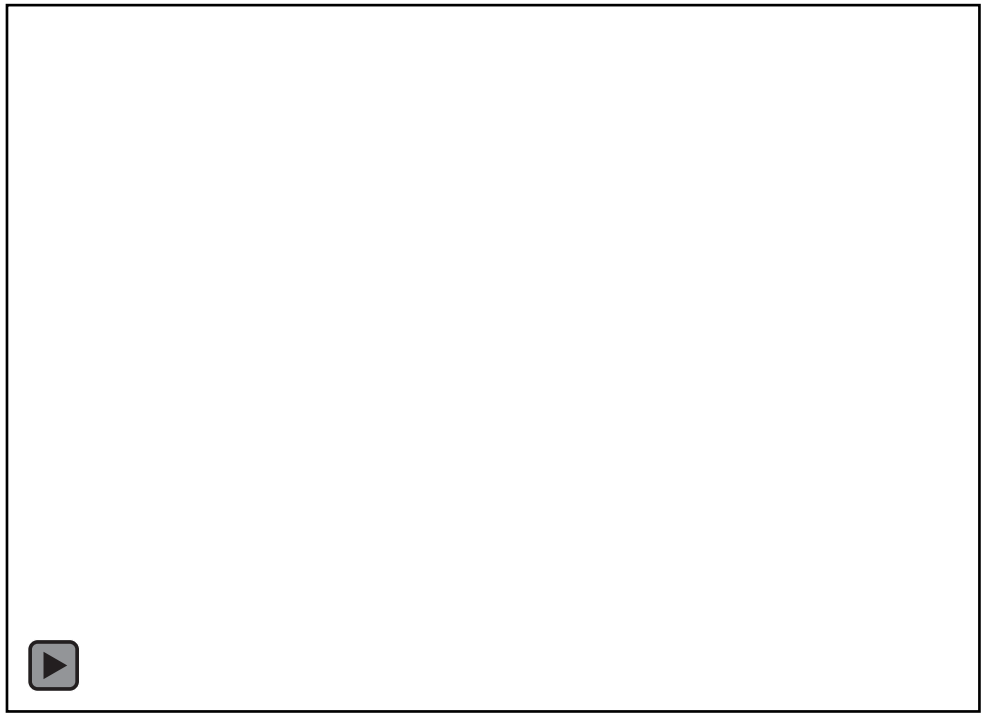
Coastal Issues

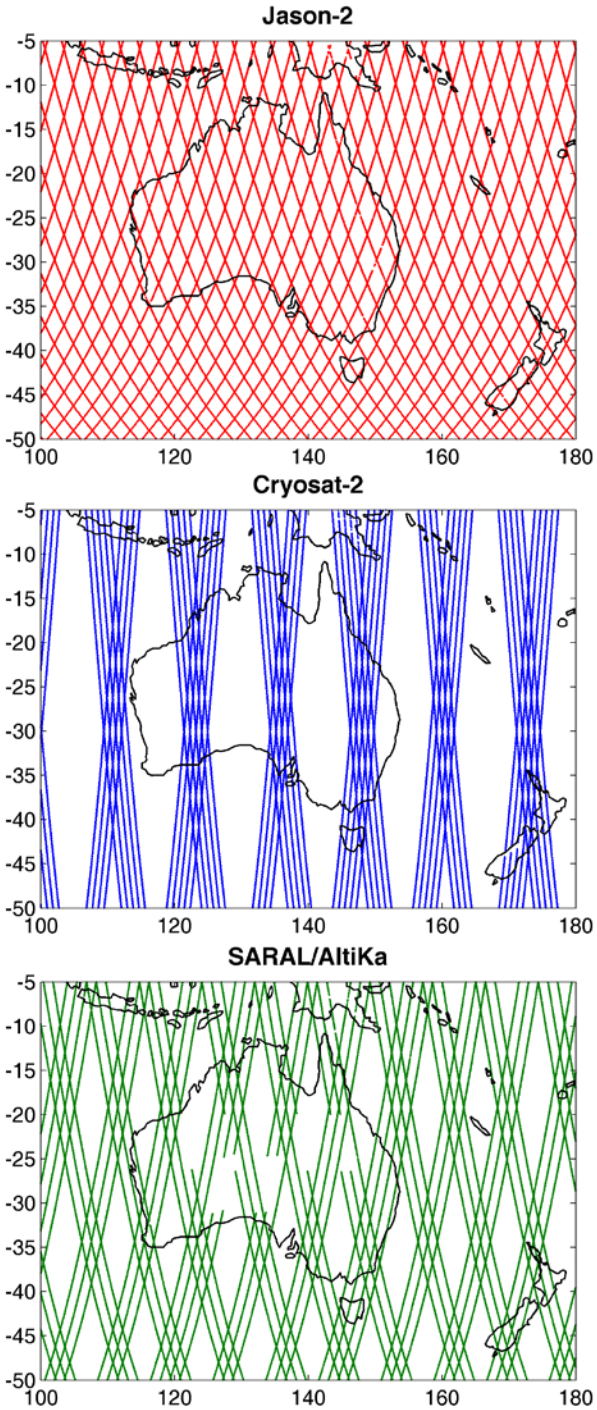
- Traditional altimetry is biased by land contamination close to the coast
- Path delay corrections (troposphere) also contaminated by land effects
- **Tidal models and mean sea surfaces often poor in coastal zone**


Re-peat
91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 >
10
TOPEX/POSEIDON (France/USA)
Jason-1 (France/USA)
Jason-2 (Europe/USA)
Jason-3 (Europe/USA)
Jason-CS A (Europe/USA)
Jason-CS B (Europe/USA)
35
ERS-1 (Europe)
ERS-2 (Europe)
Envisat (Europe)
SARAL (France/India)
27
Sentinel-3 A (Europe)
Sentinel-3 B (Europe)
Past
Operating
Approved
Proposed
CryoSat-2 (Europe)
SWOT (France/USA)
OSTM/Jason 2
2008
Jason 1
2001
TOPEX/Poseidon
1992–2006
esa
cnes
NASA
NOAA
EUMETSAT

Altimetry Sampling

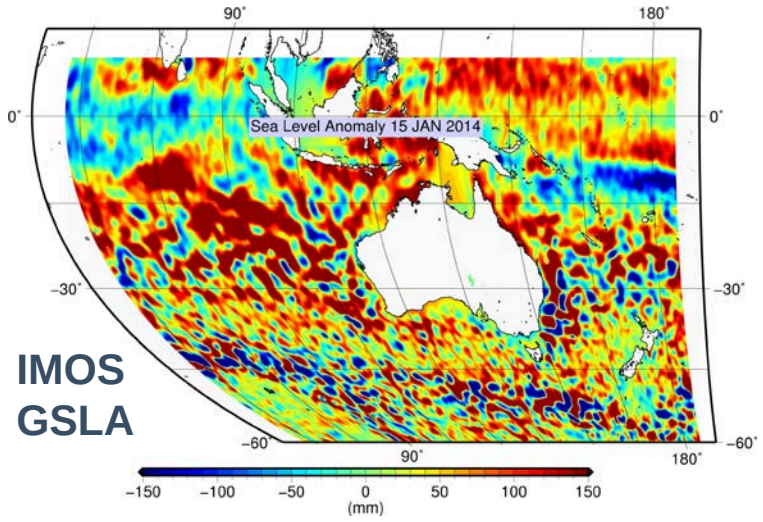
- All weather, nadir sampling along tracks (not swaths – yet)
- 10 day repeat for T/P / Jason-1 / Jason-2
- 35 day repeat for ERS / ENVISAT / SARAL
- 27 day repeat for Sentinel-3A/B (soon!)
- 369 day (30 day sub-cycle) Cryosat-2



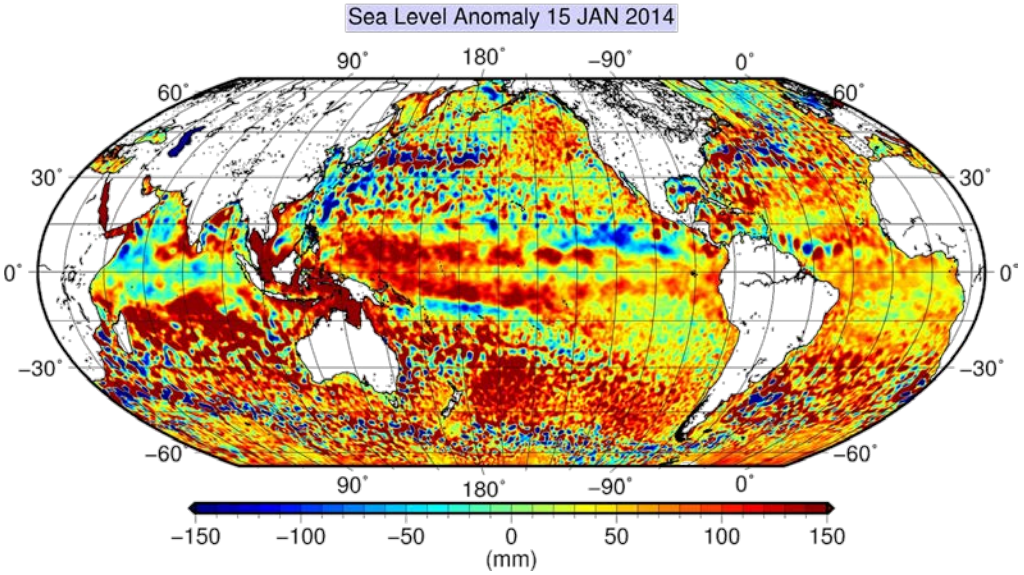


Products…

Spatial:	**Global to regional gridded (e.g. IMOS GSLA), or along track (e.g. RADS).**
Temporal:	**7 day (e.g. AVISO) to monthly mean (e.g. CSIRO). Near real time to delayed mode.**
Construction:	**Mono to multi-mission, everything done for you or DIY regarding corrections and reference models to best suit your application.**
Interested?	**Wednesday discussion session!**



IMOS GSLA



AVISO

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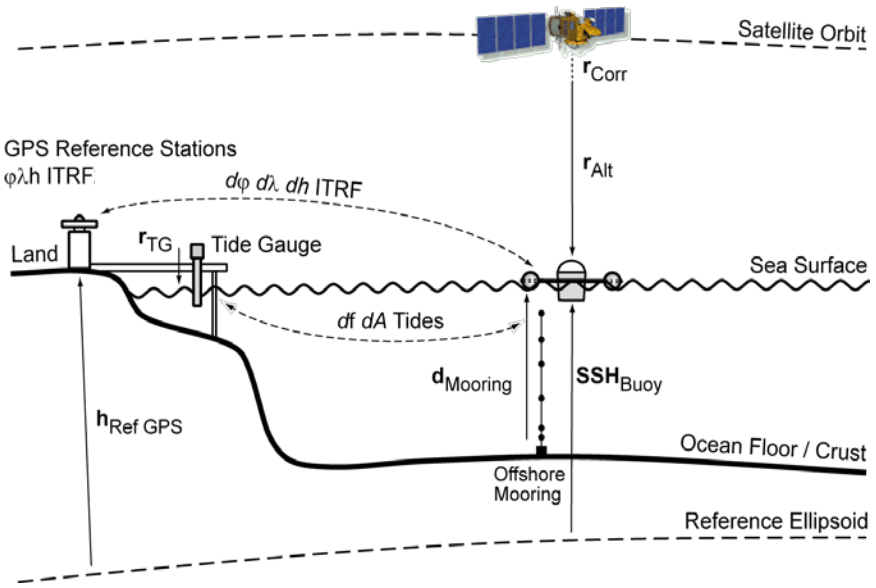
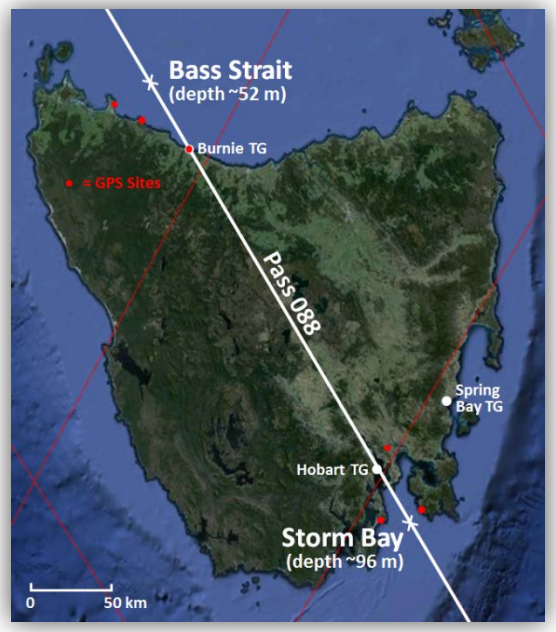
Part II: IMOS Altimetry Cal/Val

Sub-facility 11e: Satellite Altimetry Calibration and Validation contributes directly to the mission science team. Two main roles:

a) **Sustained in situ validation**
   ("absolute bias": sea level difference from truth)

b) **Validation of the climate record**
   ("bias drift": time variable error in sea level)





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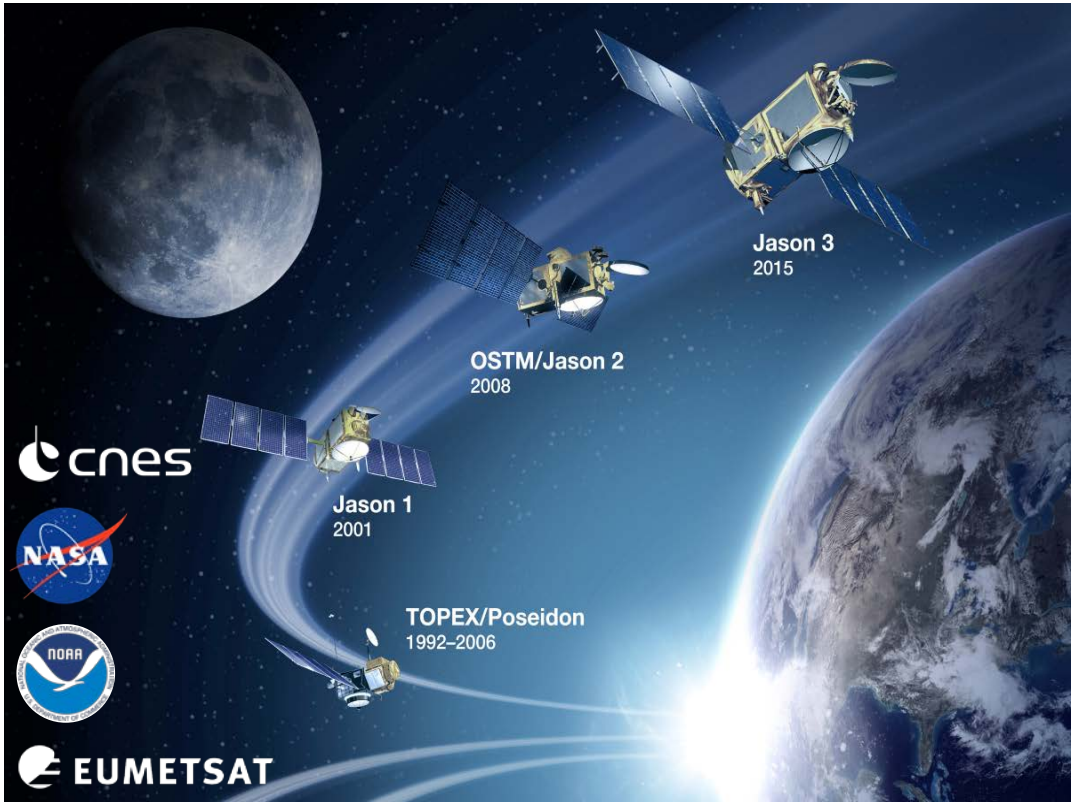
Mission Science Teams

- The Ocean Surface Topography Science Team (OSTST) oversees the Jason-class reference altimeter missions (NASA/CNES/NOAA/EUMETSAT).
- The IMOS cal/val effort is aimed directly to the OSTST cal/val group – important Australian contribution to satellite missions we are reliant on but do not contribute to directly as a nation.

- Rather than *calibrate* per se, the process is highly iterative *validation,* often leading to new releases of the Geophysical Data Record (GDR) which is the penultimate mission dataset.



JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 99, NO. C12, PAGES 24,505–24,516, DECEMBER 15, 1994

A southern hemisphere verification for the TOPEX/POSEIDON satellite altimeter mission

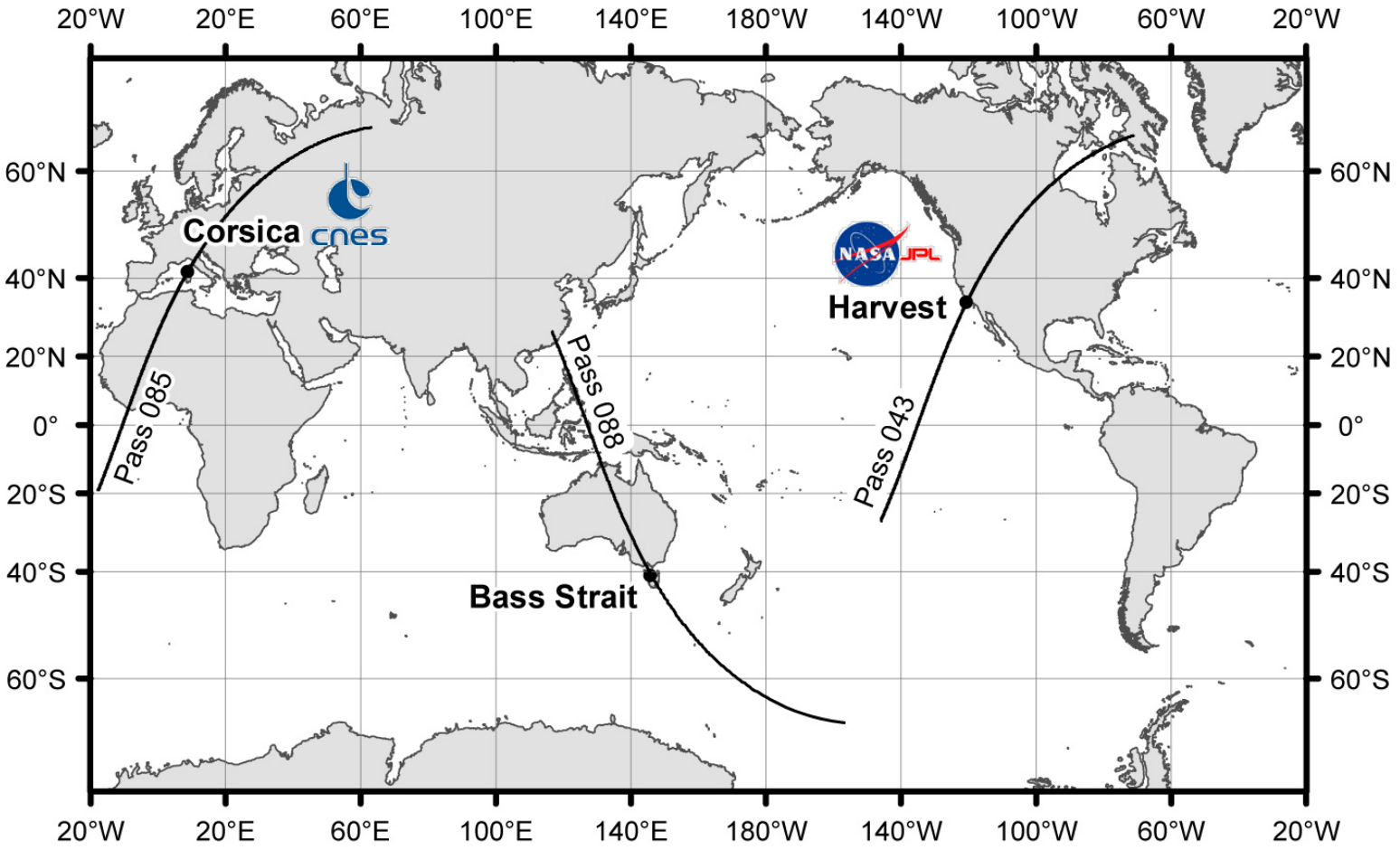
Neil J. White, [1,2] Richard Coleman, [1,2,3]

John A. Church, [1,2] P. J. Morgan, [4]

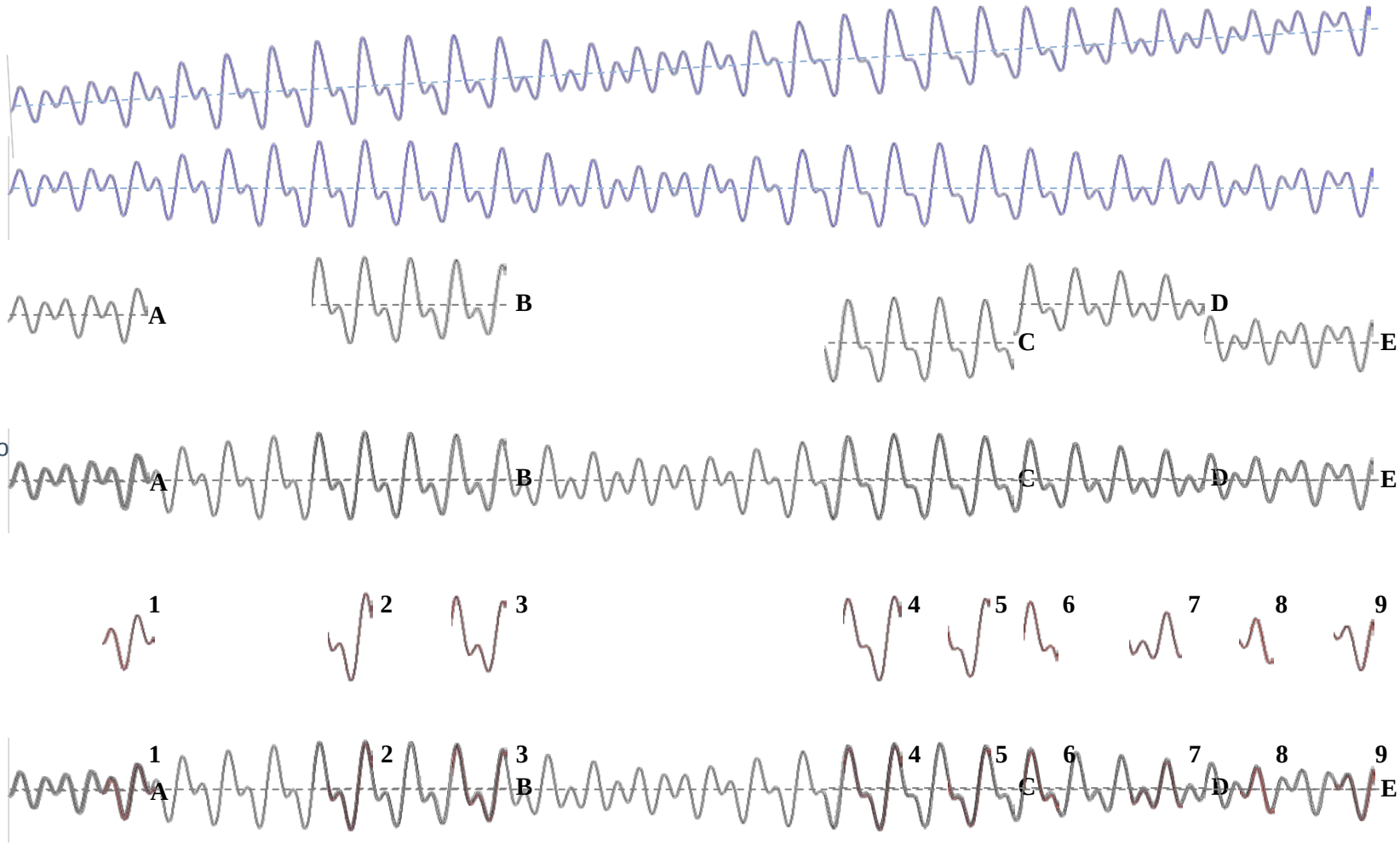
and S. J. Walker [2]

Abstract. As a check on the total system accuracy of the TOPEX/POSEIDON satellite, a southern hemisphere verification study was undertaken in Bass Strait (41°S) immediately adjacent to the Southern Ocean. An acoustic tide gauge and two pressure gauges were installed on the southern side of Bass Strait near where descending pass 88 crosses the Tasmanian coast. The tide gauge benchmark height

In situ validation (“Absolute Bias”)



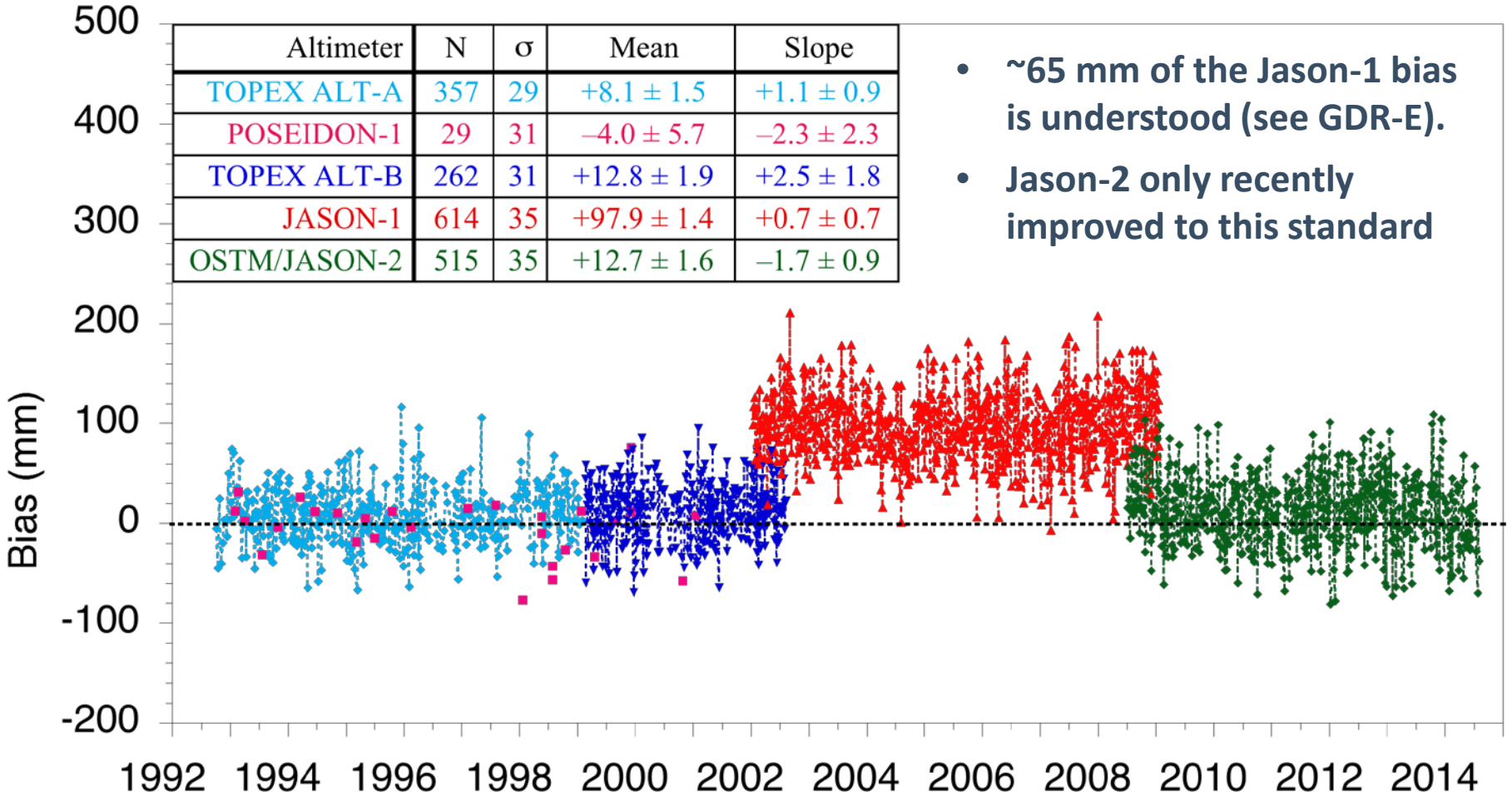
How we derive In Situ SSH



Combined Long-Term Calibration Record

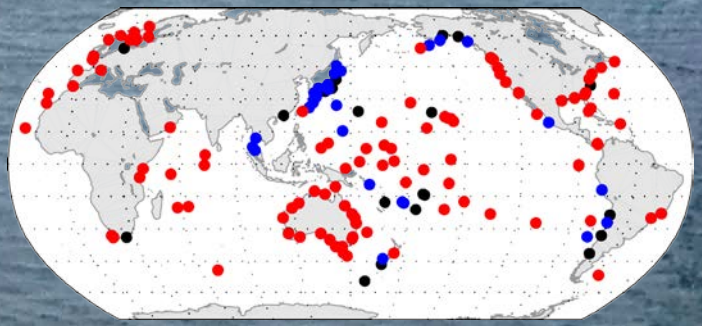
Nominal Time Series *(1777 total overflights)*

Altimeter	N	σ	Mean	Slope
TOPEX ALT-A	357	29	+8.1 ± 1.5	+1.1 ± 0.9
POSEIDON-1	29	31	–4.0 ± 5.7	–2.3 ± 2.3
TOPEX ALT-B	262	31	+12.8 ± 1.9	+2.5 ± 1.8
JASON-1	614	35	+97.9 ± 1.4	+0.7 ± 0.7
OSTM/JASON-2	515	35	+12.7 ± 1.6	–1.7 ± 0.9

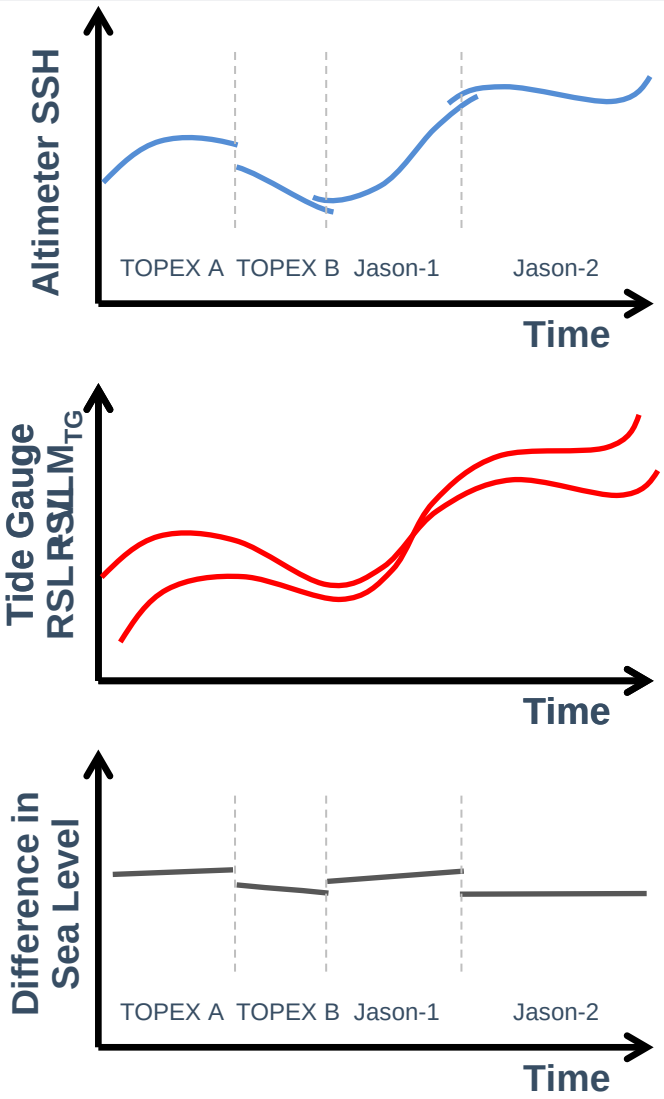


- **~65 mm of the Jason-1 bias is understood (see GDR-E).**
- **Jason-2 only recently improved to this standard**

Altimeter v Tide Gauge



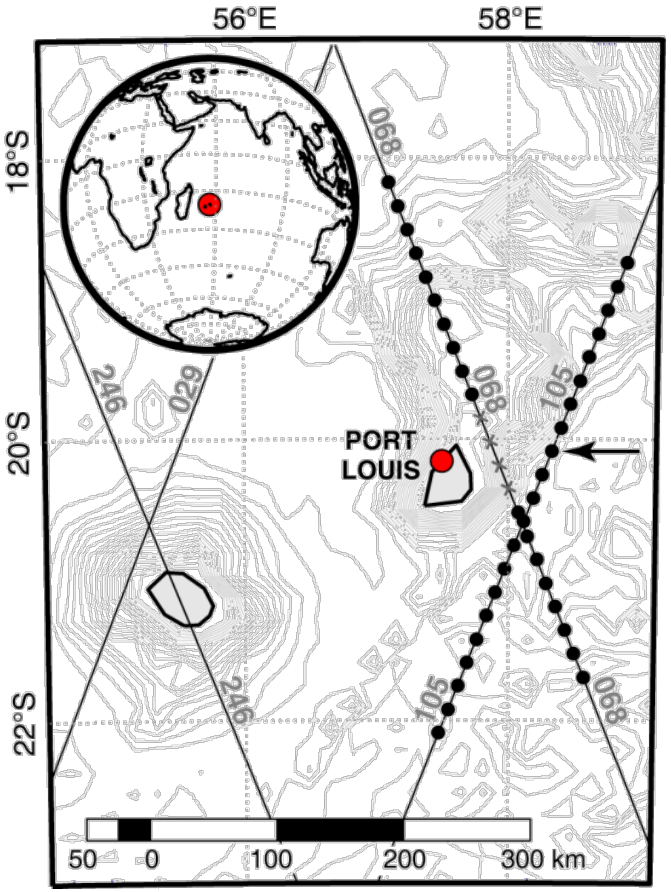
Altimeter v Tide Gauge

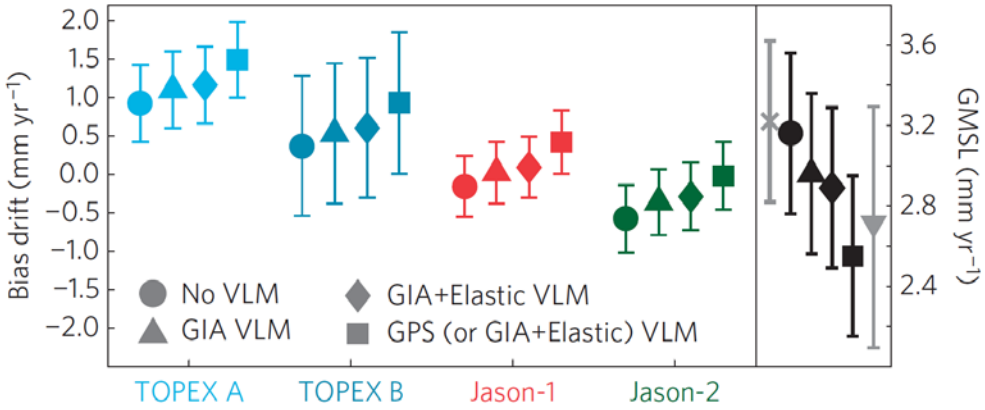


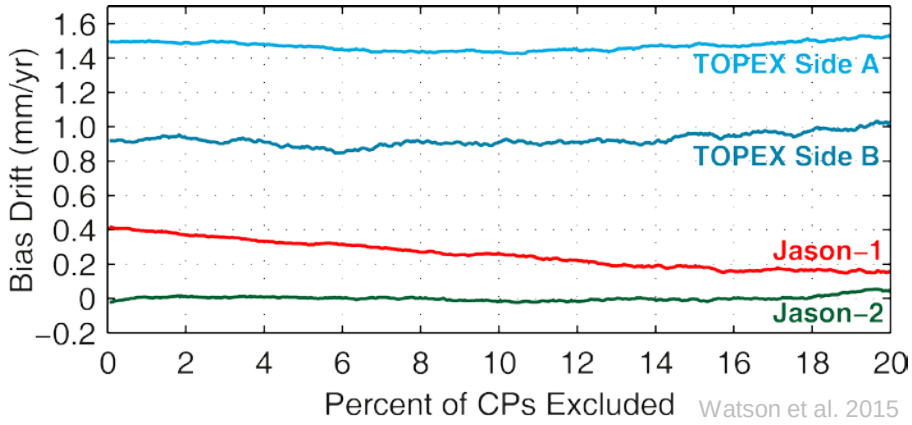
For any given comparison point, we form the difference in sea level (corrected for vertical land motion, VLM, using one of a few different strategies) and then parameterise:

- **Mission specific offsets**
- **Residual tide and across-track SSH slope**
- **Mission specific residual systematic error ("bias drift") modelled as a simple linear term.**

Altimeter v Tide Gauge







Watson et al. 2015

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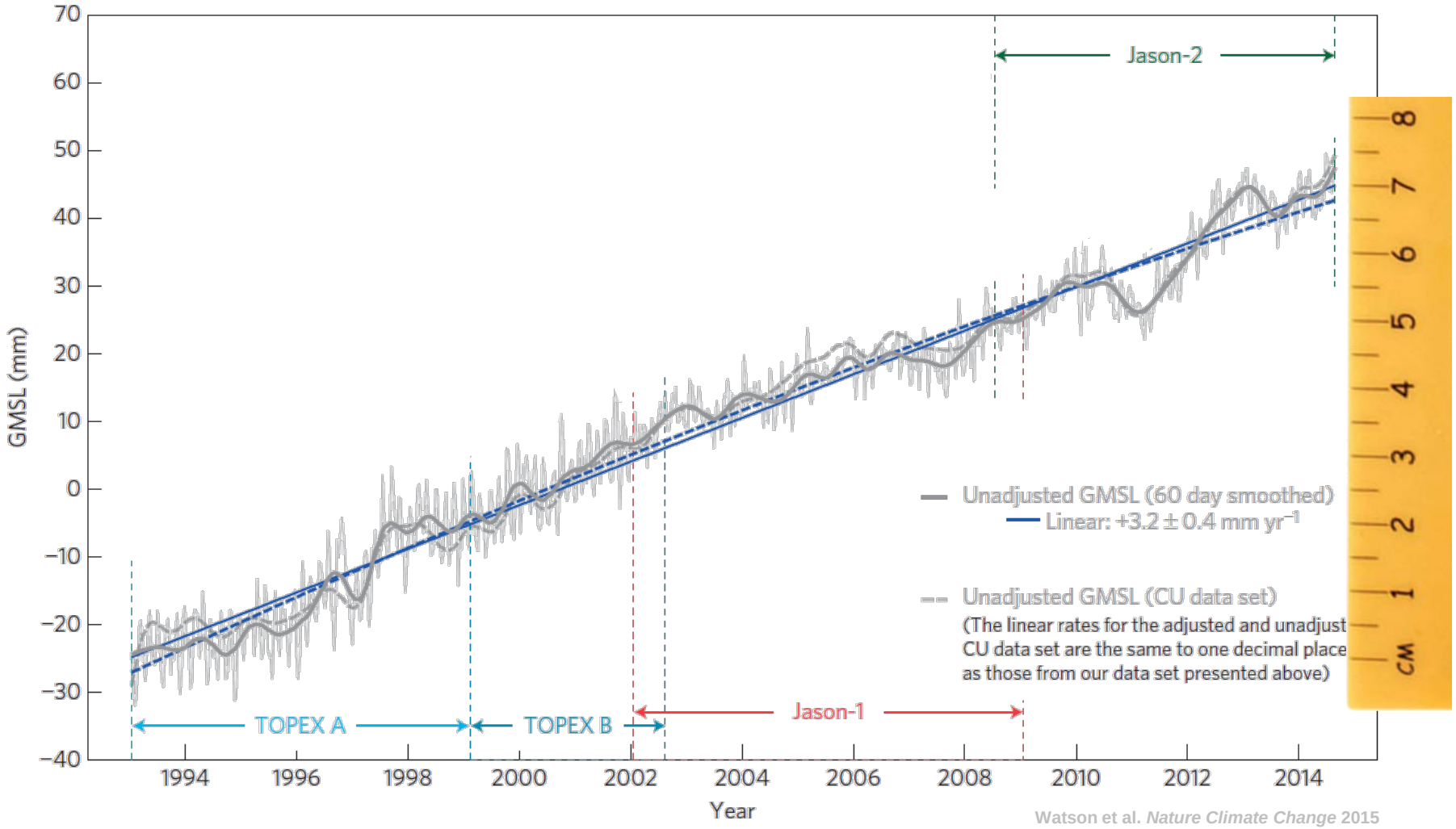
Global Mean Sea Level Trends



Watson et al. *Nature Climate Change* 2015

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Part III: 2015 and Beyond

- Significant progress in the coastal community:
  - Globally retracked products released (0-50 km using the ALES retracker, Jason-2 data available, Jason-1 end of 2015, will be in RADS).
  - New correction products available for the coastal zone (GPD+ wet delays from Uni Porto group).
  - Reminders of the need for appropriate MSS and tide models.
- Anticipation for new SAR missions (Sentinel-3, Jason-CS) offering ~250-300 m along track resolution, then wide swath altimetry with SWOT in 2020 -> game changing technology.

Wednesday Altimetry Discussion

- Format is flexible - let us know what is relevant to you.
- Possible discussion areas:
  - Altimeter basics
  - Coastal Issues
  - Product snapshots – AVISO, CSIRO, IMOS, RADS etc
  - Existing and future calibration/validation requirements
  - Australian opportunities for the SWOT mission
- See me or Elaine Miles if you have any requests!

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

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IMOS is a national collaborative research infrastructure, supported by Australian Government. It is led by University of Tasmania in partnership with the Australian marine & climate science community.

www.imos.org.au

The Operators of the IMOS infrastructure are:

sims sydney institute of marine science

CSIRO

Australian Government Bureau of Meteorology

Government of South Australia

SARDI Research and Development

Australian Government

Australian Institute of Marine Science

The University of Western Australia

Curtin University

Questions?

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