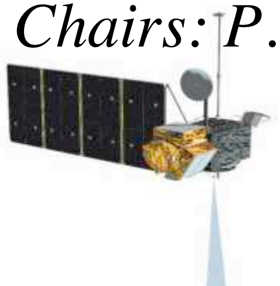
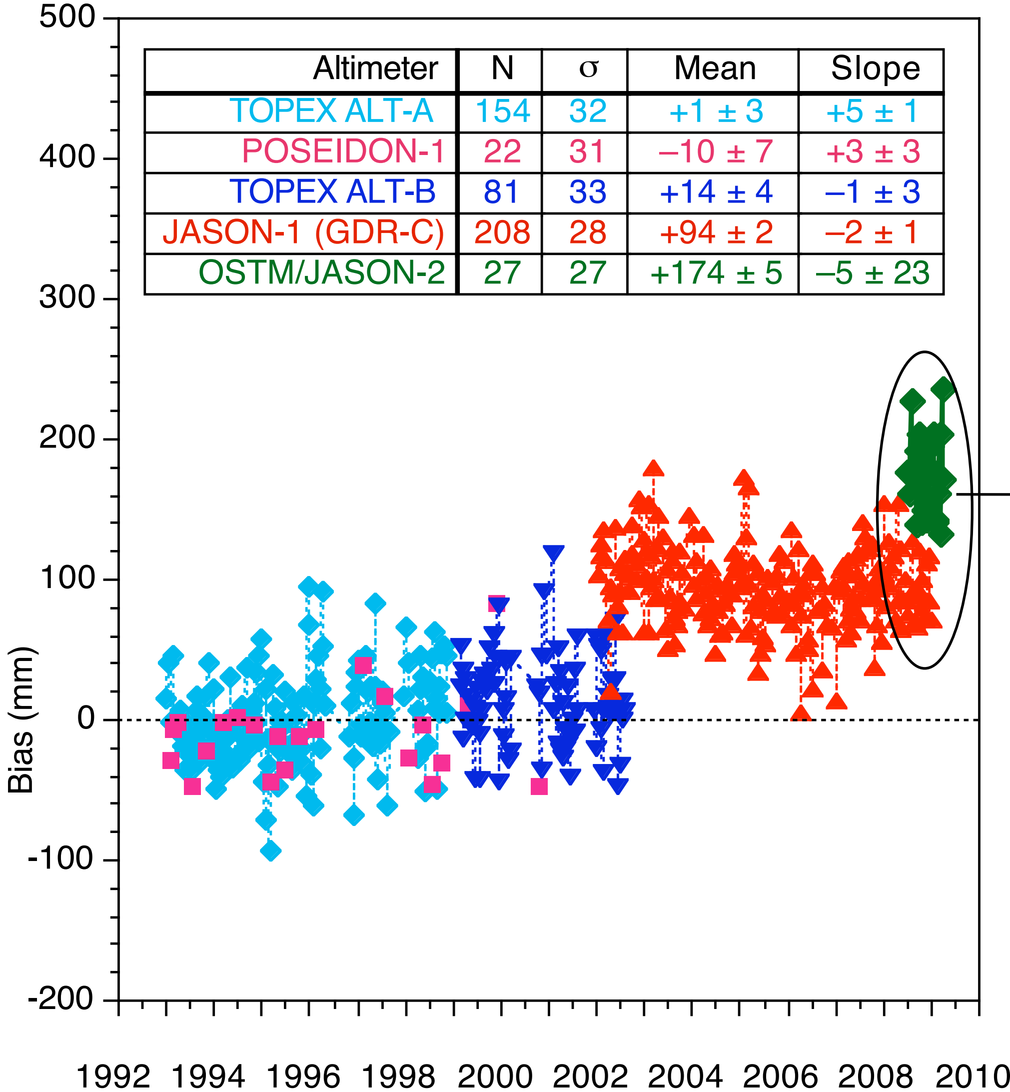
Local calibration/validation (*focusing on bias*): Monday, June 22

Chairs: P. Bonnefond, B. Haines, S. Nerem

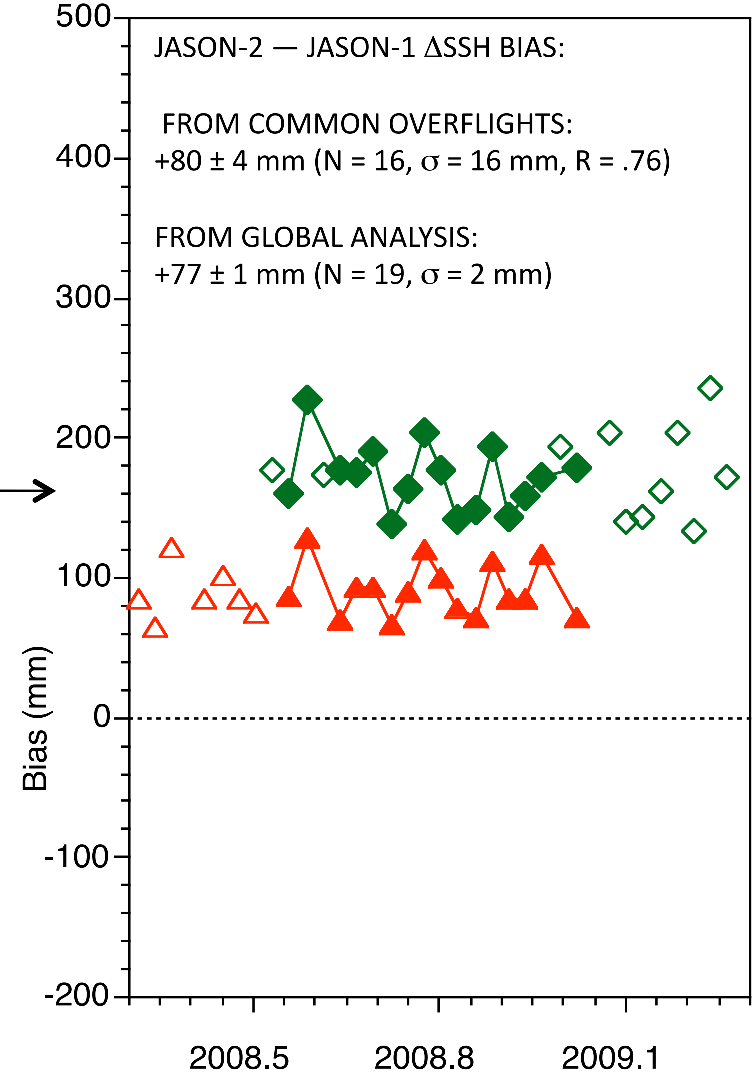


1400	HAINES Bruce	The Harvest Experiment: Calibration of the Climate Data Record from TOPEX/POSEIDON, Jason-1 and OSTM
1415	BONNEFOND Pascal	Absolute Calibration Of Topex/Poseidon, Jason-1 And Jason-2 Altimeters In Corsica
1430	WATSON Christopher	In-Situ Calibration at the Bass Strait Site, Australia
1445	MERTIKAS Stelios	Absolute altimeter calibration for Jason satellites using the GAVDOS permanent facility
1500	JAN Gwenaele	OSTM/Jason-2 sea surface height bias estimated by a regional in situ CalVal technique
1515	HAN Weiqing	Comparisons of altimeter data, reconstructed sea level and tide gauge data in the Indian Ocean
1530	ABLAIN Michaël	Quality assessment of tide gauge and altimeter measurements through SSH comparisons
1545	LEULIETTE Eric	Tide gauge and intersatellite calibrations of Jason-1 and Jason-2 geophysical data records
1600	BECKLEY Brian	Assessment of Jason-1 and OSTM global verification phase sea surface height collinear residuals
1610		Adjourn

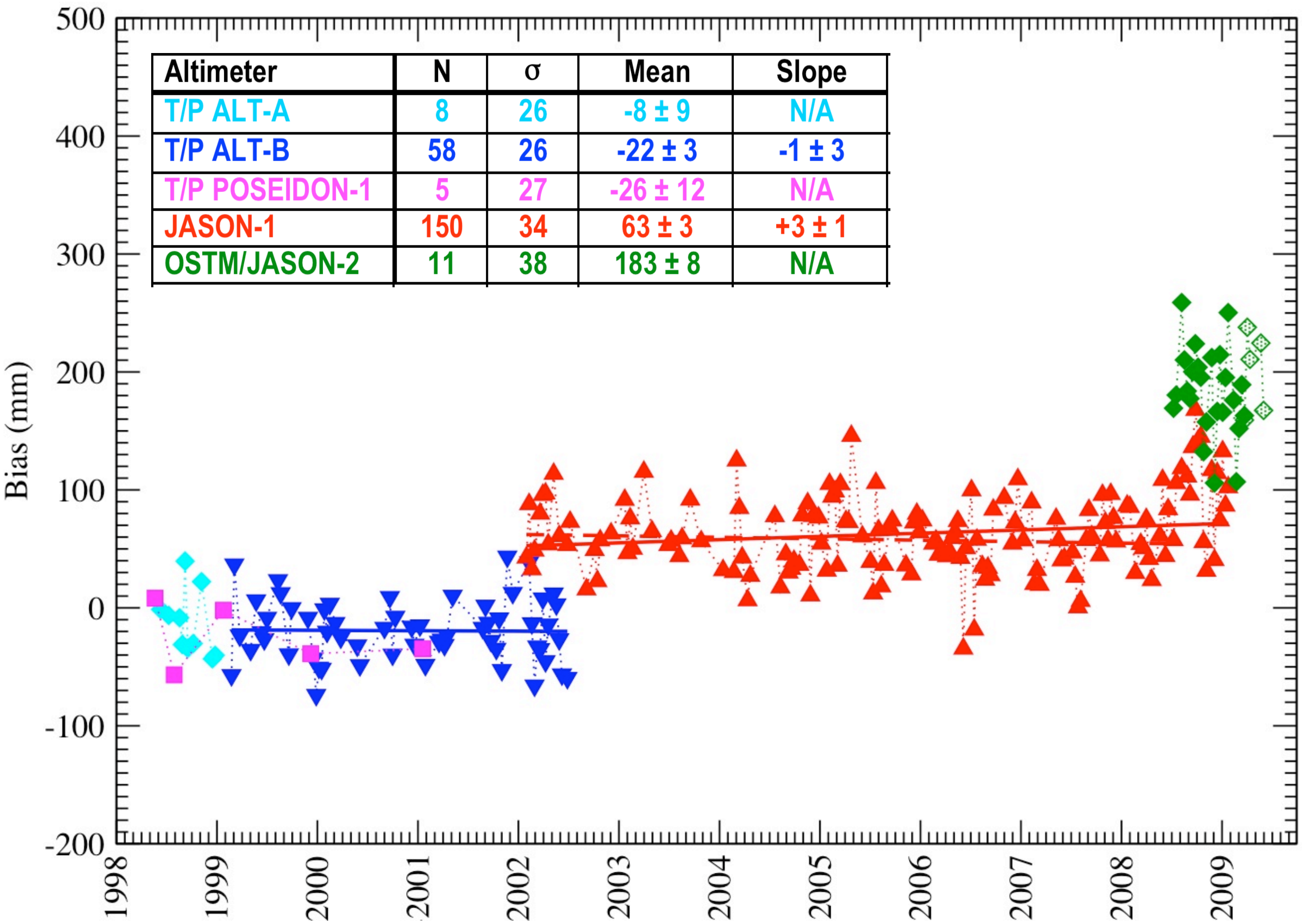
Harvest SSH Calibration Time Series



Altimeter	N	σ	Mean	Slope
TOPEX ALT-A	154	32	+1 ± 3	+5 ± 1
POSEIDON-1	22	31	−10 ± 7	+3 ± 3
TOPEX ALT-B	81	33	+14 ± 4	−1 ± 3
JASON-1 (GDR-C)	208	28	+94 ± 2	−2 ± 1
OSTM/JASON-2	27	27	+174 ± 5	−5 ± 23



Harvest site, Haines et al.



Altimeter	N	σ	Mean	Slope
T/P ALT-A	8	26	-8 ± 9	N/A
T/P ALT-B	58	26	-22 ± 3	-1 ± 3
T/P POSEIDON-1	5	27	-26 ± 12	N/A
JASON-1	150	34	63 ± 3	+3 ± 1
OSTM/JASON-2	11	38	183 ± 8	N/A

Products used:

T/P: MGDR + TMR replacement products + TVG ITRF05-rescaled orbits

Jason-1: GDR-C (cycle 1 to 259)

Jason-2: GDR-C (cycle 0 to 26)

The relatively high slope of Jason-1 (+3 mm/yr) is due to the most recent data (i.e., since Jason-2 launch): when this period is excluded the slope is not statistically significant (+1 ±1 mm/yr).

Corsica site, Bonnefond et al.

Conclusions

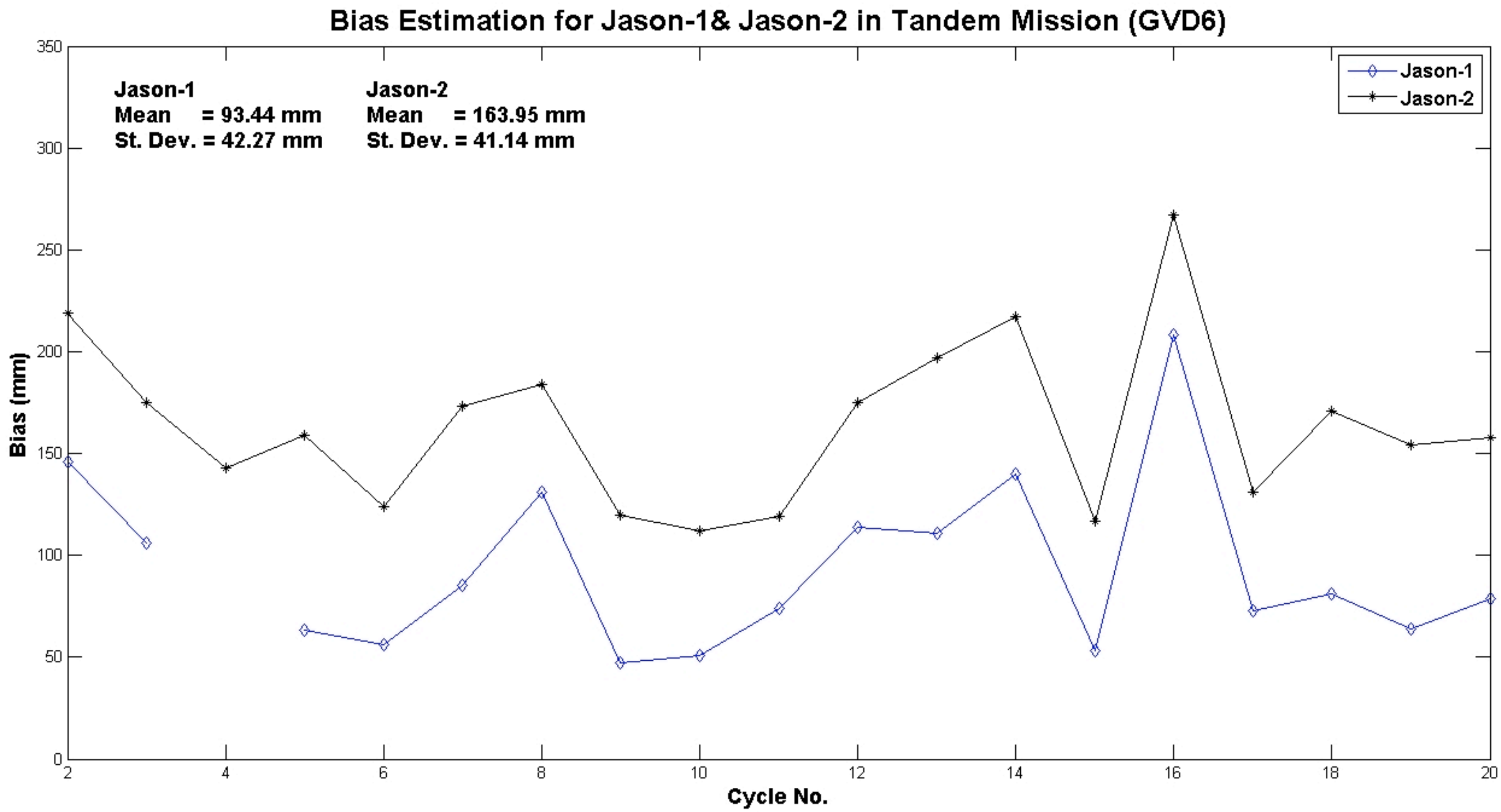
Data	Cycles	N	Mean Bias ± Std Error
Jason-1 GDR-C	001-259	212	+98.9 ± 2.8 mm
Jason-1 GDR-C	239-259	20	+107.4 ± 5.0 mm
Jason-2 GDR-C	000-020	15	+159.5 ± 8.5 mm
J-2 GDR-C – J-1 GDR-C	*as above*	*14*	*+45.5 ± 8.5 mm*
Jason-1 GDR-C (std JMR)	228-259	30	+104.6 ± 4.8 mm
Jason-1 GDR-C (updated JMR)	228-259	30	+102.8 ± 4.8 mm
Jason-2 GDR-C (std AMR)	000-026	16	+158.0 ± 8.1 mm
Jason-2 GDR-C (updated AMR)	000-026	15	+164.5 ± 9.1 mm

↓ +10mm

1. Investigate other ways to improvement our ability to transform the tide gauge SSH to the comparison point (i.e meteorological forcing etc).
2. Further investigate altimeter bias with and without Burnie FTLRS data used to determine orbits. Do we see geographically correlated effects?
3. SSB effects – results from Storm Bay.

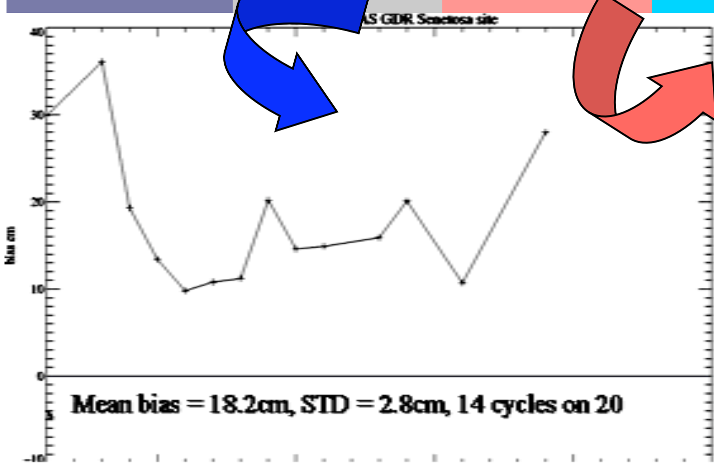
Bass Strait site, Watson et al.

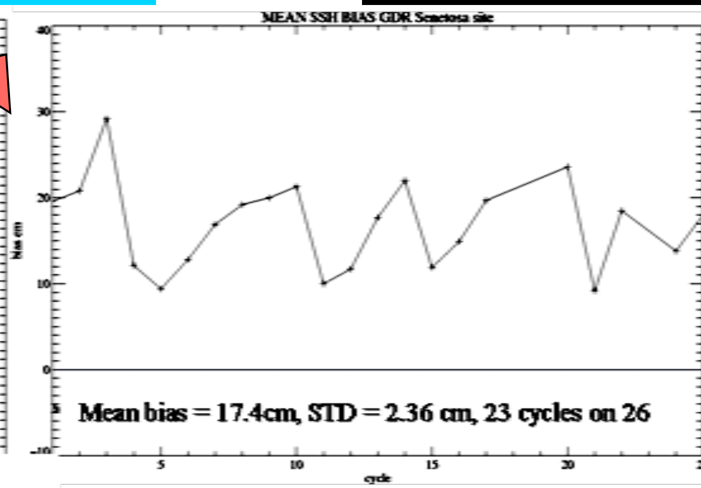
Jason-2 Bias Vs Jason-1 Bias Tandem

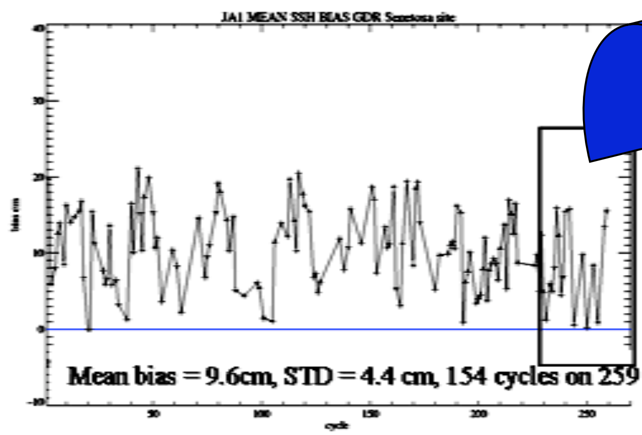


Gavdos site, Mertikas et al.

unit=cm	OSTM/JA-2				JA-1 GDR-c	
Pass n°	**85**	**222**	**9**	**MERGE**	**85**	**85**
ssh bias	18,2	17,4	16,5	17,4	10,3	9,6
std	2,8	2,4	2,6	2,3	4,3	4,4
cycles	14	23	19	23	15	154
% cy used	**70.0%**	88.5%	73.1%	**88.5%**	78.9%	59.4%
					cycles 239-259	cycle 1 to 259

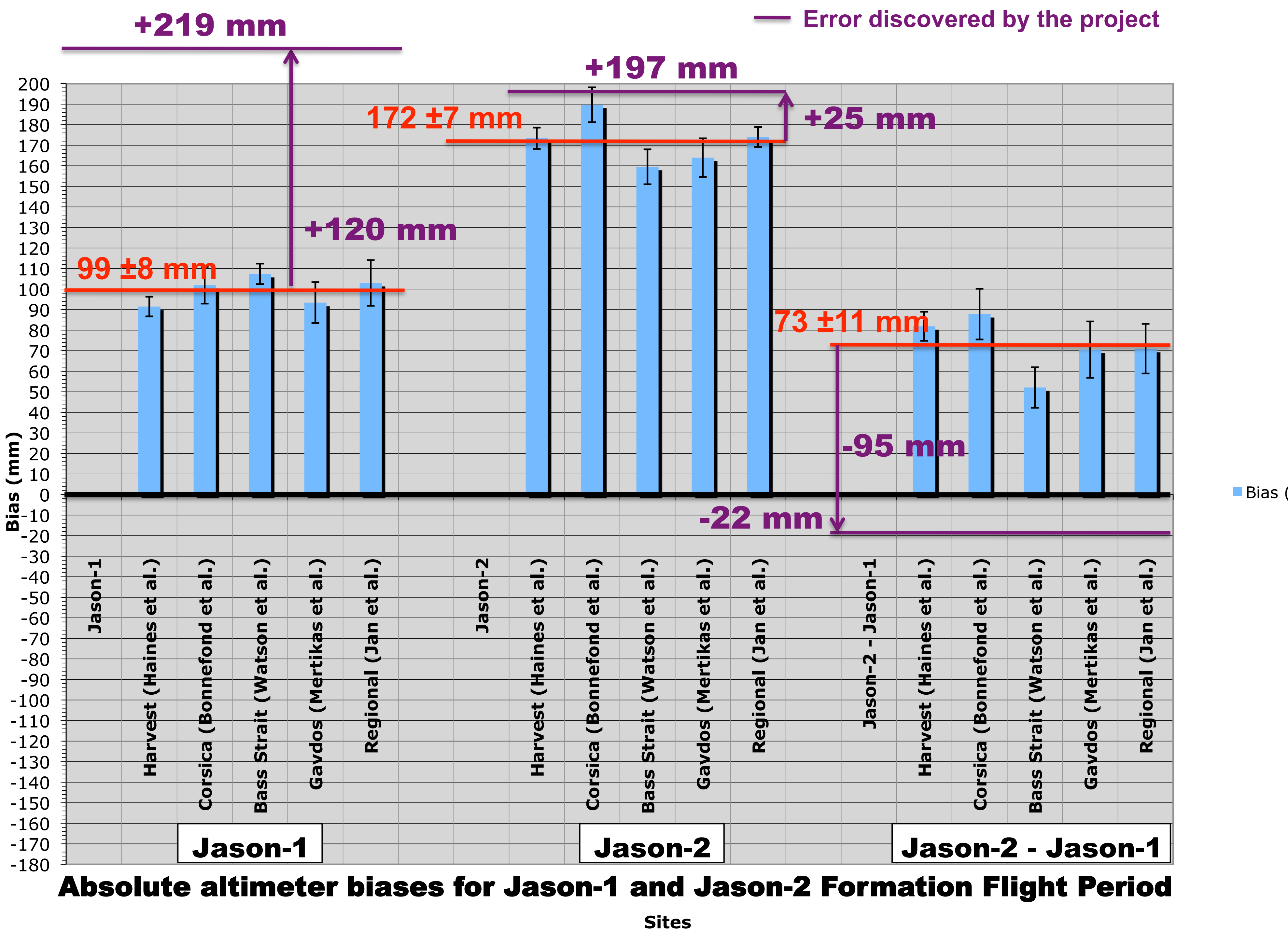






JA-1 bias= 10.3cm, std=4.3cm, 15 cycles on 20 (Ja1, ostm/Ja2 common period)

Regional approach, Jan et al.



Error discovered by the project
+219 mm
+197 mm
172 ±7 mm
+25 mm
+120 mm
99 ±8 mm
73 ±11 mm
-95 mm
-22 mm
Bias (mm)
Bias
Jason-1
Harvest (Haines et al.)
Corsica (Bonnefond et al.)
Bass Strait (Watson et al.)
Gavdos (Mertikas et al.)
Regional (Jan et al.)
Jason-2
Jason-2 - Jason-1
Absolute altimeter biases for Jason-1 and Jason-2 Formation Flight Period
Sites

Some in situ analysis key points:

- **Coherence of Jason-1&2 SSH bias** time series for all calibration sites reveals **similar behavior of the twin satellites' measurement systems.**
- **New coastal AMR product clearly improves agreement with GPS-derived path delay for coastal approaches;** waiting for this improvement for JMR
=> from in situ studies **this new correction increases the Jason-2 bias by 10mm**
- **Differences between absolute biases up to 15 and 30 mm respectively for Jason-1 and Jason-2: GCE? But which? Probably not the orbit but wet tropo and SSB (see D. Vandemark) surely contribute. In situ effects also contribute.**
- **~10 mm average for differenced ionospheric correction (J2–J1)** due to different bias for Ku and C bands for Jason-2 => **need to calibrate both bands**
- **No clear drift of the measurement systems** (T/P and Jason-1) revealed by the longest time series (Harvest, Corsica and Bass Strait)

	Jason-1 Ku-Band	Jason-1 C-Band	Jason-2 Ku-Band	Jason-2 C-Band
SSH Bias	+81 ± 6 mm	+90 ± 11 mm	+164 ± 13 mm	**+213 ± 18 mm**
Local SSB	3.4 ± 0.2 %	4.6 ± 0.4 %	3.4 ± 0.5 %	4.6 ± 0.7 %
Number of Overflights	217	216	28	25
Postfit σ	35 mm	63 mm	26 mm	37 mm

From Harvest, Haines et al.

Summary

- T/P, J1 and J2 (GDR) data have comparable agreements with the tide gauge observations in the Indian Ocean, with correlation coefficients generally exceeding 0.84, except in the northern BOB and Persian Gulf, where correlation coefficients are low (~0.6) or even negative and RMSE is large (121cm at station 138a);
- The temporal variations and linear trends of basin-averaged SLA from AVISO and TPJ1 gridded data (1992-2008) agree very well; the RMSE of (AVISO-TPJ1), however, shows regular spatial patterns with large errors (~8cm) south (north) of 20S (10N) and near the western boundary;
- The reconstructed sea level reproduces the mean seasonal cycle well; its linear trend of basin-mean sea level, however, is much larger than that of the satellite data; its temporal variability and amplitude do not seem to agree well with the tide gauge data.

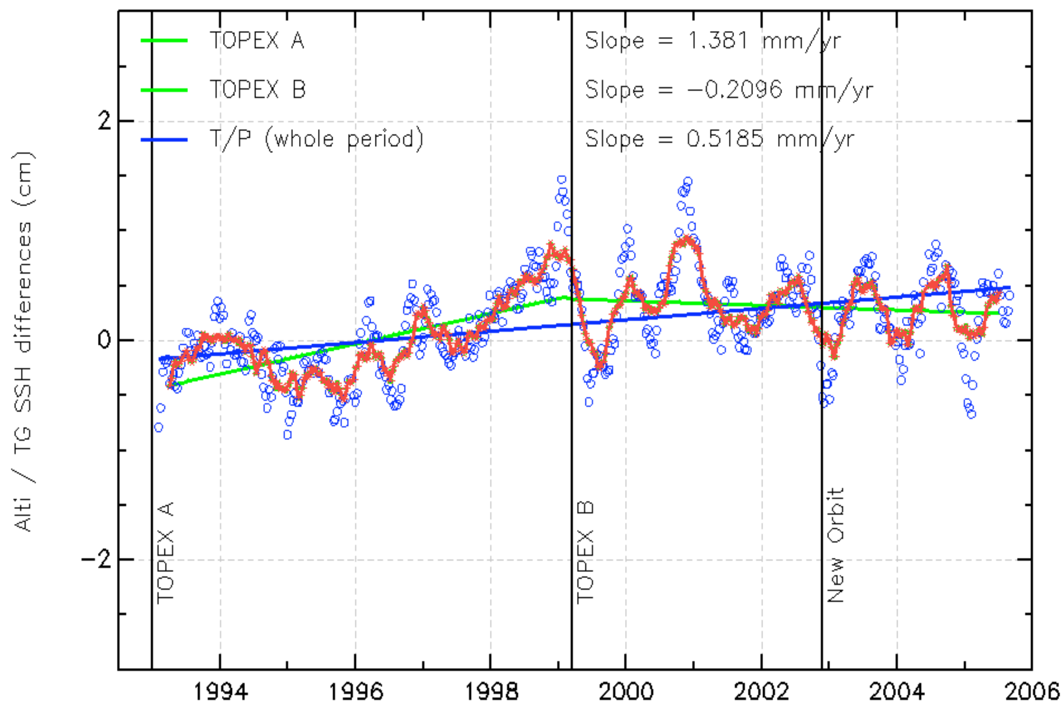
5 – Estimation of the MSL drift : TOPEX/Poseidon

- For TOPEX/Poseidon:

⇒ SSH have been calculated from updated M-GDR products : GSFC orbit (2008), new tidal and DAC corrections, corrected TMR, …

⇒ A weak drift with TG is observed close to **+0.5 mm/yr** over all the altimeter period

- The drift is very weak (**-0.2 mm/yr**) over the 7-year TOPEX B period whereas it is stronger over the 6-year TOPEX A period (**+1.3 mm/yr**)

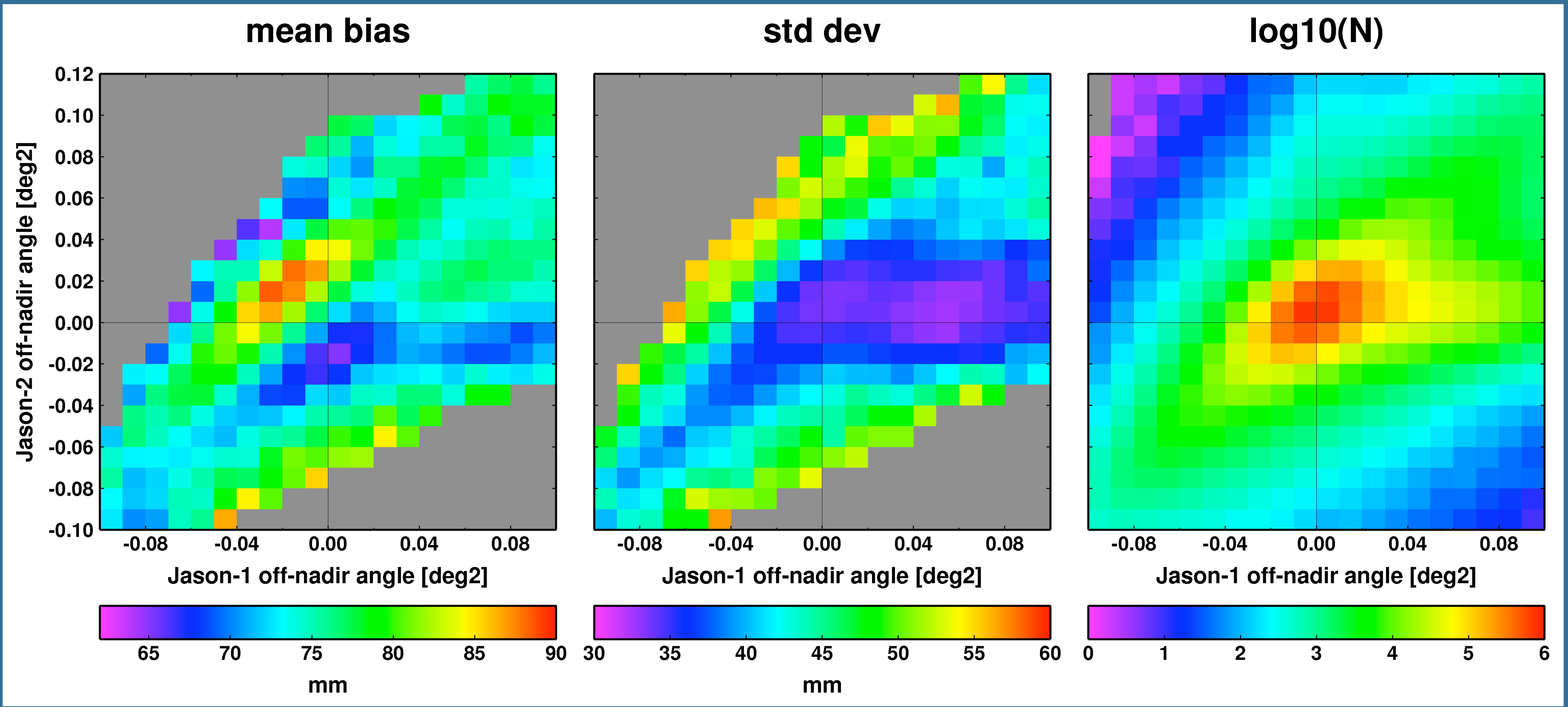


- The TOPEX-A SSH drift detected seems well correlated with the SWH and Sigma0 drifts aslo observed on the same period due to TOPEX-A anomalies.

⇒ No significant drift for **Jason-1** with TG is observed : **-0.1 mm/yr**

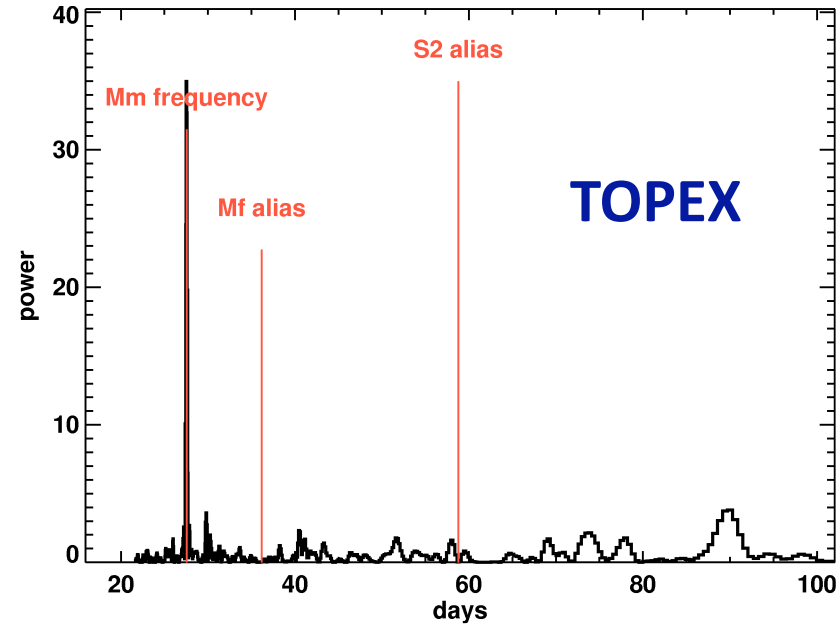
⇒ Significant drift for **Envisat** with TG is observed close to **-2.2 mm/yr** over all the period. Mainly due do inhomogeous products

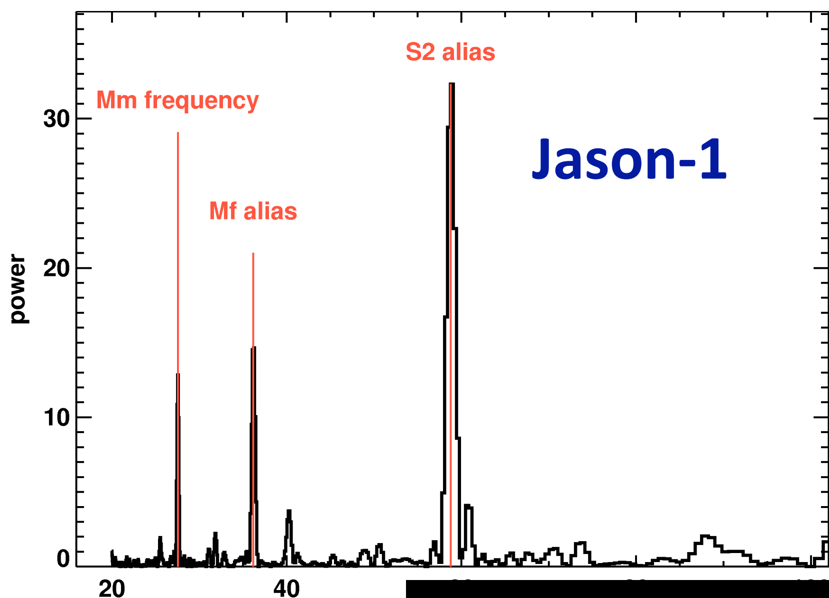
Jason-1/Jason-2 bias
tracker bias
dependence on nadir angle

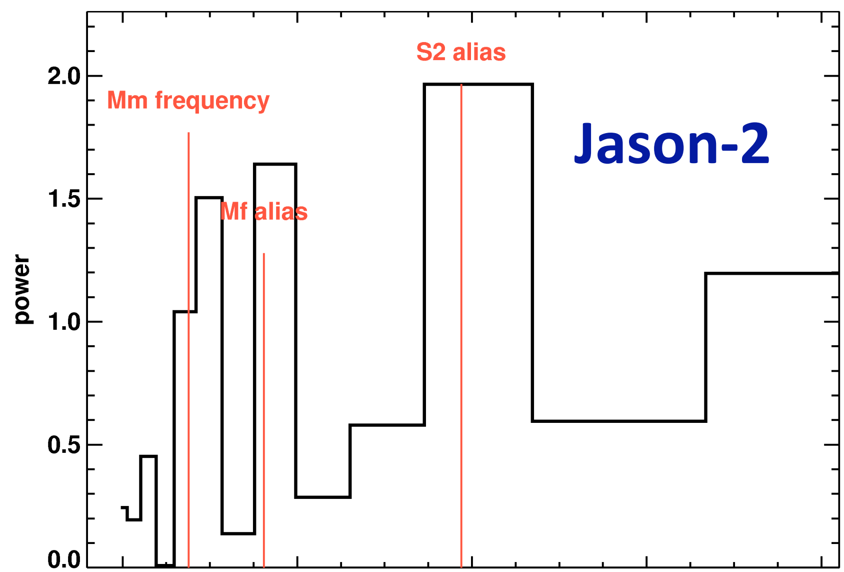


Tide gauge and intersatellite calibrations of Jason-1 and Jason-2 geophysical data records, Leuliette et al.

Power spectrum of altimeter – tide gauge time series



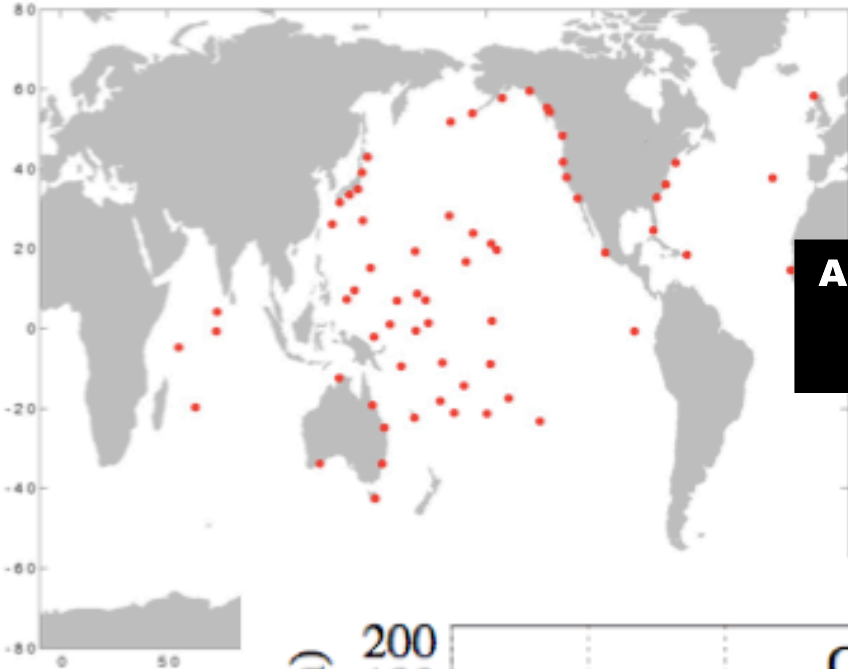




Tide gauge and intersatellite calibrations of Jason-1 and Jason-2 geophysical data records, Leuliette et al.

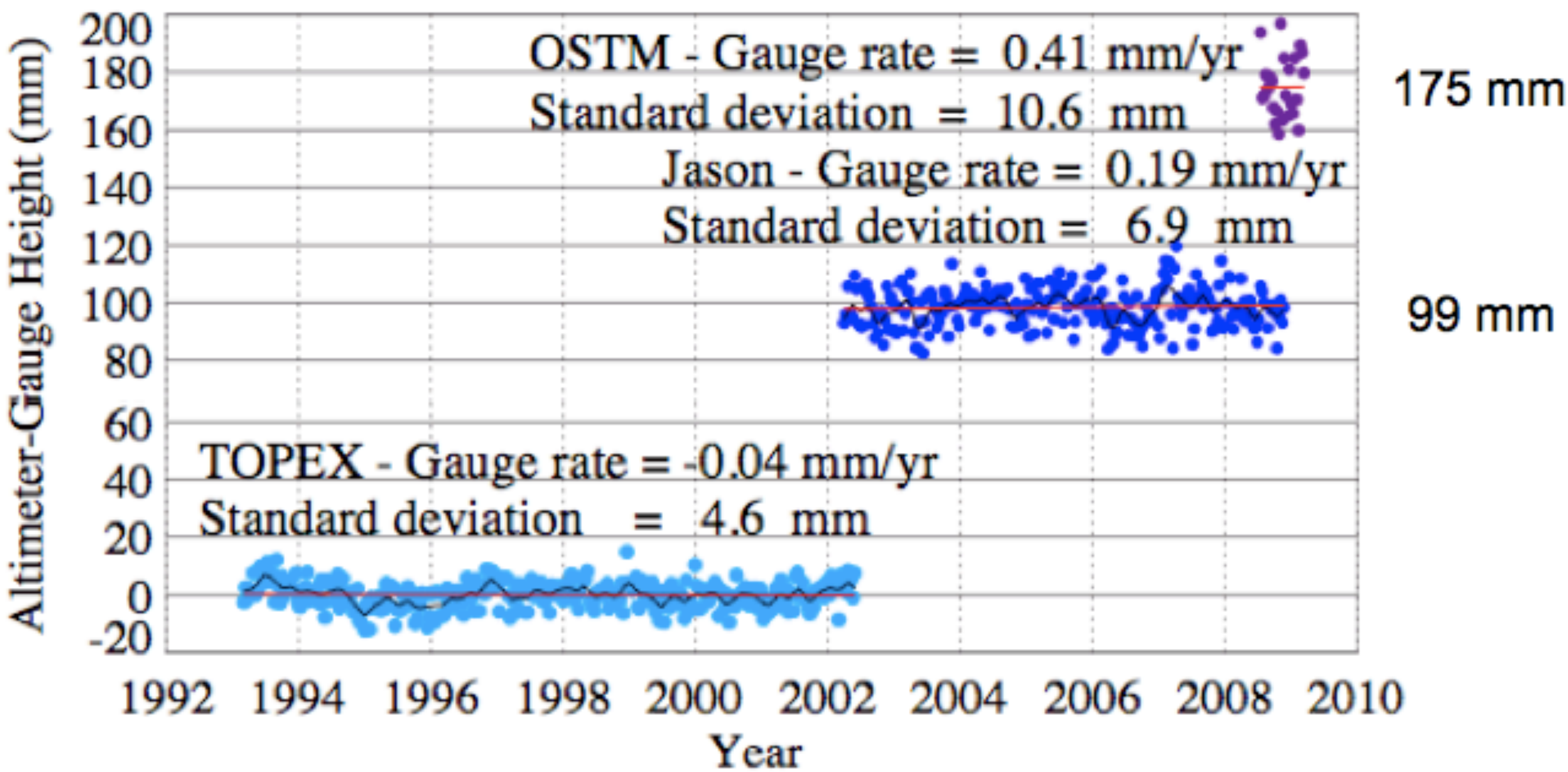
Tide Gauge Verification

Gary Mitchum – U. South Florida



Assessment of Jason-1 and OSTM Global Verification Phase Sea Surface Height Collinear Residuals, Beckley et al.

TOPEX MGDR_B (11 – 364), GSFC Std0809
Jason-1 GDR_C (1 – 259) , GSFC Std0905
OSTM GDR (1 – 26), GSFC Std0905



Some tide gauges versus altimetry global analysis key points:

- **No clear drift of the Jason-1 measurement system (with new JMR replacement product,** *Ablain et al., Beckley et al. and Leuliette et al.***)**
- **No clear drift of the T/P measurement system over the whole mission (differences between ALT-B and ALT-A should exist,** *from Ablain et al.***)**
- **Relative range** between Jason-2, Jason-1 and T/P (reference) is in very **good agreement with the absolute mean** derived from in situ analysis: **175 mm** *(172 mm from in situ)* for **Jason-2** and **99 mm** *(99 mm from in situ)* **for Jason-1** *(Beckley et al.)*
- The **Jason-2/Jason-1 relative SSH bias depends on off-nadir angles** *(Leuliette et al.)*
- **Ionospheric correction bias on Jason-2** confirmed to come from **different biases on Ku and C band** *(Beckley et al.)*
- **Jason-1 mean sea level has a significant 58-day signal**. Comparison with the TOPEX interleaved mission shows that the sea level residuals are correlated with solar intensity *(Leuliette et al.)*.
- **No clear impact of new set of orbits**, standard GDR-C ones from CNES are already very good *(Beckley et al.)*.

Global calibration/validation (*focusing on corrections quality assessment and error budget assessment*): Tuesday, June 23

Chairs: S. Desai, N. Picot

1100	PHILIPPS Sabine	Global Statistical Jason-2 Assessment and Cross-calibration with Jason-1: Parameter Analysis and System performances
1120	DETTMERING Denise	Global cross calibration of Jason-1/2 GDR-C data
1135	DECARVALHO Robert	Global cross calibration and validation of Jason-1 and Jason-2/OSTM products
1150	OLLIVIER Annabelle	Jason-1 / Jason-2 / Envisat Cross-Calibration
1205	LABROUE Sylvie	Calval analysis of latest release of TOPEX retracked data
1220	All	Discussion
1230		Adjourn

Conclusion

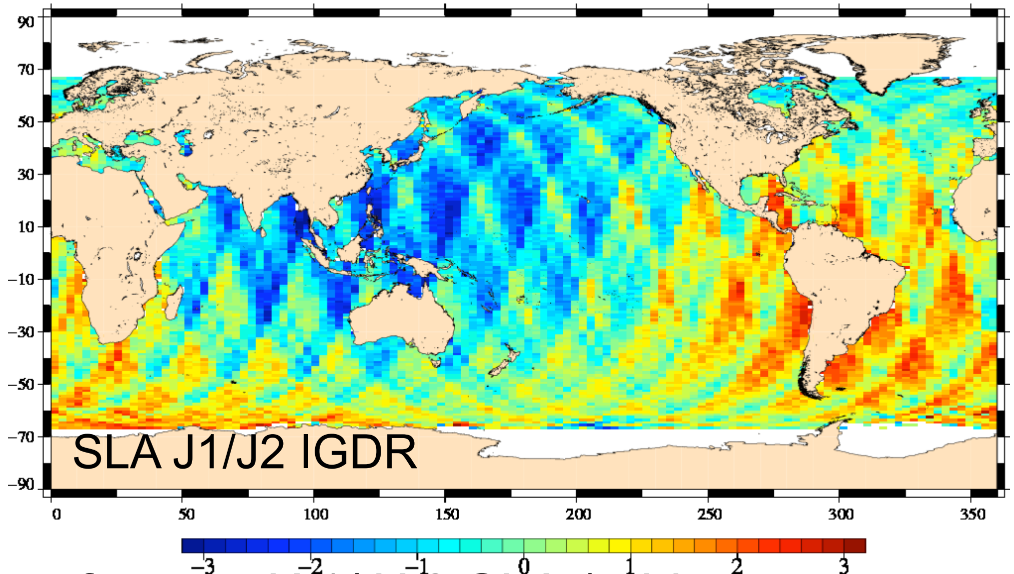
Parameter Analysis

System Performances

- Use of 20 Jason-2 cycles in formation flight configuration with Jason-1
- Very good consistency between altimetric parameters of Jason-2 and Jason-1
- JA2 radiometer (AMR) is near coast more stable than JMR
- AMR drift observed in IGDR are removed for GDR (ARCS), JA2 radiometer wet troposphere is therefore much more stable than JA1's. But could there not be a risk that real geophysical signal is also removed (which would have an impact on MSL) ?
- Model and JA1, JA2 altimeter wind speed histograms have different shapes (due to differences in backscatter coefficients)
- Parameter analysis reveal no particular behavior linked to use of different tracking modes (Median, Diode/DEM)

Global Statistical Jason-2 assessment and cross-calibration with Jason-1
Parameter Analysis and System Performances, Philipps et al.

SLA Performances and Consistency

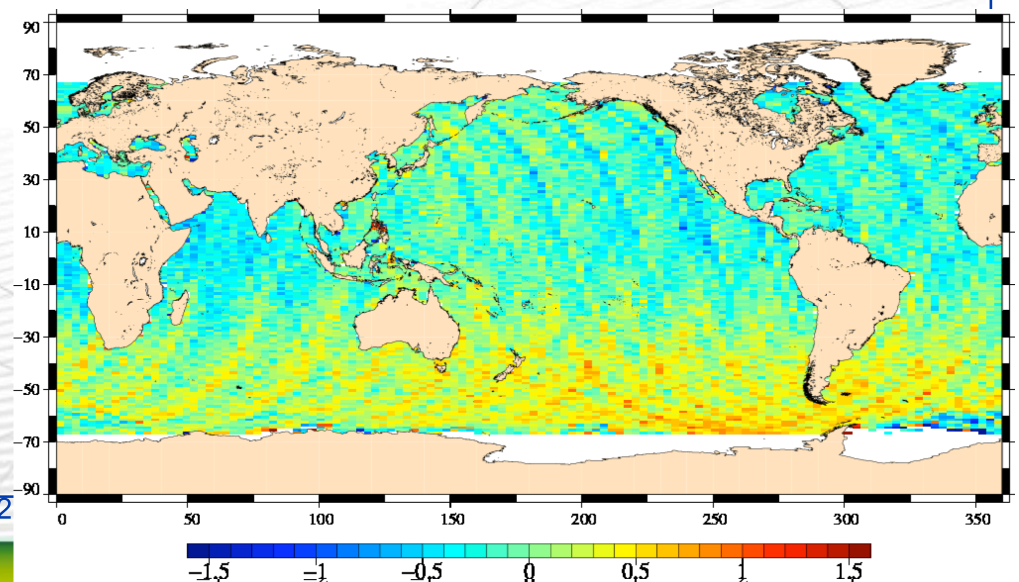


- For IGDR: Geographically correlated patterns (+/- 3cm amplitude)

Philipps et al.

Map of mean JA1/JA2 SLA (orbit – range - mss) differences over cycles 1 to 20

- For GDR: very good consistency, though a very small hemispheric bias (+/- 1 cm) is visible -> likely due to slight orbit calculation differences (only few GPS data for Jason-1)



Summary

Comparison of Jason-1 GDR-B and GDR-C

⇒ more valid crossovers with GDR-C

⇒ slightly better consistency of crossovers

⇒ mean bias between GDR-B and GDR-C of 3.9 cm

⇒ significant differences in dz realization (≈ 5 mm)

⇒ same magnitude for geographically correlated errors (up to 2 cm)

Comparison of Jason-1 GDR-C before and after orbit change

⇒ Last 4 cycles show a slightly different behavior than before orbit change

⇒ Maybe just uncertainties because of the interruption?

⇒ More data needed for significant result!

Relative calibration of Jason-2

⇒ **Relative Range Bias of 7.4 cm w.r.t. Jason-1**

⇒ No significant differences in center-of-origin realization for x and z

⇒ Small, but significant dy of 5 mm

⇒ **Geographically correlated errors up to 2 cm**

Summary and Conclusions

- J2-J1 ionosphere correction is biased by 8.5 mm due to different relative biases in Ku and C band ranges.
  - Ku-Band: 84 mm
  - C-Band: 131 mm
- Jason-2 has a ~ 4.5 cm bias between Ku and C band ranges
- Apparent scale error in J2-J1 ionosphere differences is statistical artifact current low ionosphere conditions (solar minimum).
- AMR wind speed appears to be drifting at 1.2 m/s/yr
  - Still under investigation
  - Negligible impact on wet path delay / sea level anomaly
- J2-J1 sigma0 bias observed to be -0.15dB
  - Likely contributing to J2-J1 altimeter wind speed bias/scale peculiarities.
  - Likely contributing to observed J2-J1 differences in the sea state bias.

Conclusion

- **Geographic / temporal coverage difference**
  - ➔ The performances of the 3 missions can be compared after averaging by boxes
  - ➔ Can also be completed by crossing results from 10 days cyclic observation (based on J2 cycles) to 35 days observations (based on EN cycles). Further results using this formalism are developed in Y.Faugere et al. Poster.

- **Envisat /Jason-2/Jason-1 are very precise missions**
  - ➔ Standard deviation of monomission cross-over differences around 4 cm (GDR), which enables a precise cross calibration

- **Jason-1 and -2 comparisons with Envisat GDR are very consistent**
  - ➔ The geographical biases observed on IGDR products disappears in the GDR thanks to the POE improvement compared to MOE.

- **In GDR, Jason-2 / Envisat has the same level of consistency as Jason-2/ Jason-1**

➔ This consistency is even more relevant considering that its orbit configuration is different from the Jason-1 and 2

➔ making Envisat a very precious input to quantify Jason-2 altimetric performances

Further results showing orbit orientated results are developed in A.Ollivier et al. Poster and presentation.

Conclusions

- Non regression results

  Comparisons with MGDR and Jason-1 data show that 2009 RGDR products are different from 2006 and 2007 releases

  - 2009 retracking do not change Range/SWH correlation. The 2009 SSB is the same than the SSB correction derived from MGDR data. The 2009 SSB is no more in agreement with Jason-1 SSB.
  - This change in SSB behavior clearly evidences that the Topex retracking changes the Topex tracker bias

- Analysis of the side A time series
  - The PTR drift appears to be well corrected for SWH but not for the range measurement.
  - The MSL trend obtained with 2009 RGDR is false with a negative trend of -0.8 mm/year.

- Analysis of the side B time series
  - SWH OK
  - Strange trend on the range on the year 2002
  - The MSL trend obtained with 2009 RGDR is of 3 mm/year, which makes a difference of 0.6 mm/year compared to MSL obtained with MGDR data. This discrepancy is significant since side B altimeter is known to be very stable (calibration with tide gauges, comparison with Jason-1)

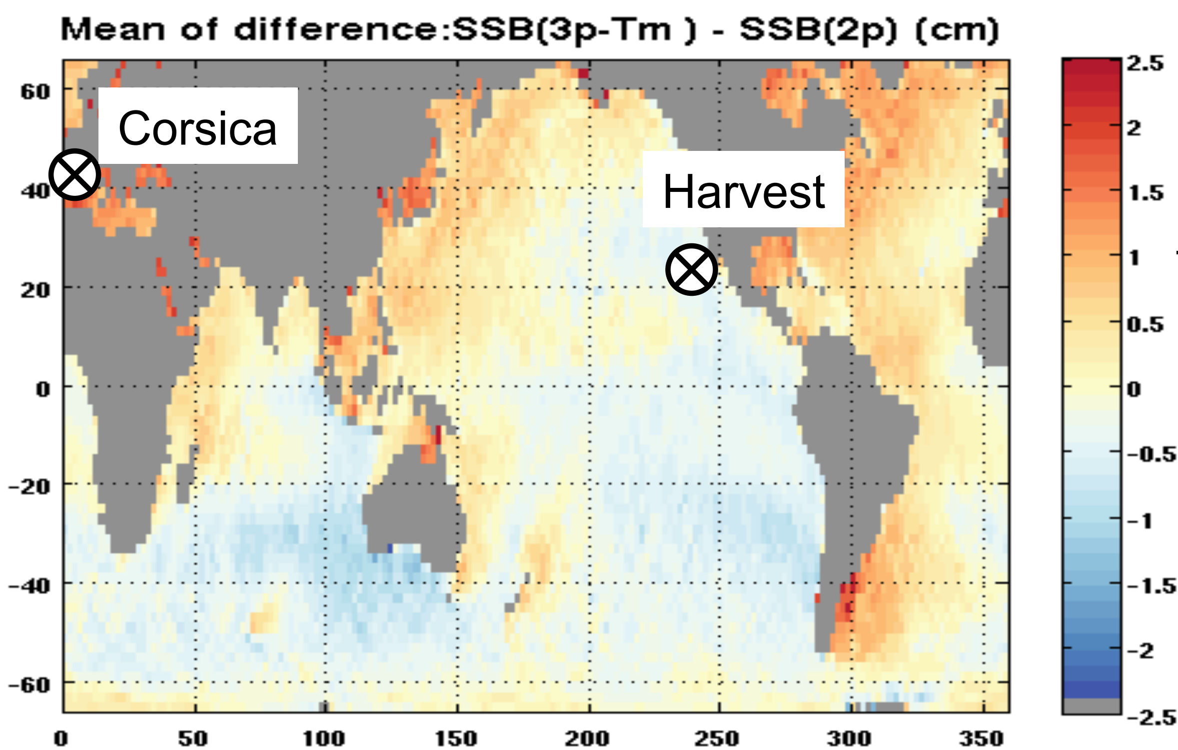
Some global analysis key points:

- **AMR** meet the requirements and is **better than JMR** when approaching the coast. Also **more stable than JMR**
- **Jason-2 has a ~4.5 cm bias between Ku and C band ranges**: causes a ~8.5 mm bias in the ionosphere correction
- **POE (GDR-C) improves standard deviation of SSH biases** compared to GDR-C (**from 40 to 35 mm**)
- **Good agreement of all parameters between Jason-1&2 (excepting relative range biases).**
- **Jason-1&2 show a very stable relative bias of 75 mm in terms of SSH and 83 mm in terms of range (without corrections); this is also compatible with mean value from in situ studies (73 mm for SSH)**
- **Jason-1 and -2 comparisons with Envisat GDR are very consistent**
- **Use of the T/P retracked products is not recommended at the moment, notably for MSL studies**; future work is needed especially on side A.

- **Most of the Jason-1/Jason-2 relative range bias (95mm) seems to come from an error in some parameterization files on Jason-1 and Jason-2. Needs to be further investigated but, if confirmed, both satellites are measuring sea surface too high by about 20cm.**

The Error Budget and SSB

Spatial error due to differing wave climates - CalVal Site example : Mediterranean Sea vs. US West Coast Pacific



SSH bias from cal/val sites
Jason1 - *in situ* (cm)

Site	2DSSB	3D
Harvest	9.9	8.7
Corsica	5.4	7.3
Difference	4.4	1.5

… thanks to Haines and Bonnefond teams…

- one independent estimate example using Jason-1 cycles 1-145