Regional in situ CALVAL of satellite altimeter range at non-dedicated calibration sites

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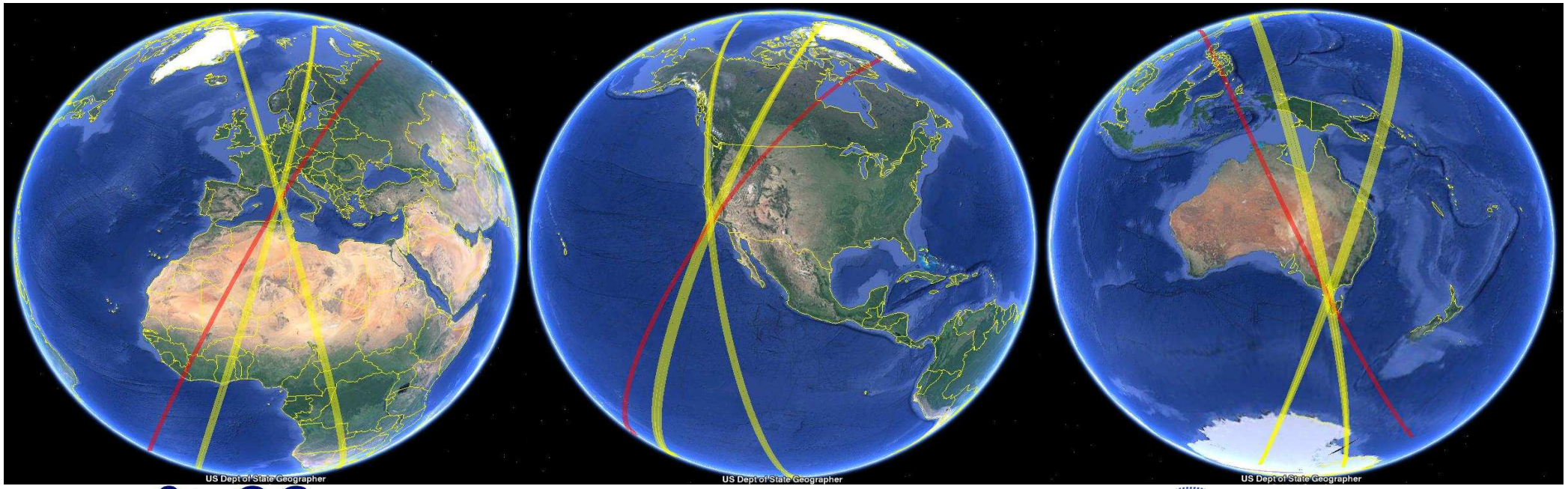


Altimeter SSH CALVAL

Main objectives:

✓ Altimeter performances: SSH stability (drifts), SSH bias between the altimetry missions

✓ Products improvement: Evaluation of new corrections and parameters (orbit, etc…)

Global CALVAL

✓ Intra/intermission comparisons:

→ at crossover points and along the tracks (boxes)

→ large patterns, geographically correlated errors, open ocean performances

✓ Comparisons to tide gauge global networks:

→ altimeter drifts, global coastal performances

Complementarity between all the methods

Local CALVAL

✓ Comparisons to georeferenced tide gauges at a few calibration sites:

→ altimeter absolute bias, drifts, geographically correlated errors, local coastal performances

→ limitation: only for the altimeters that fly over the calibration sites (mainly Jason suite)

Regional CALVAL method

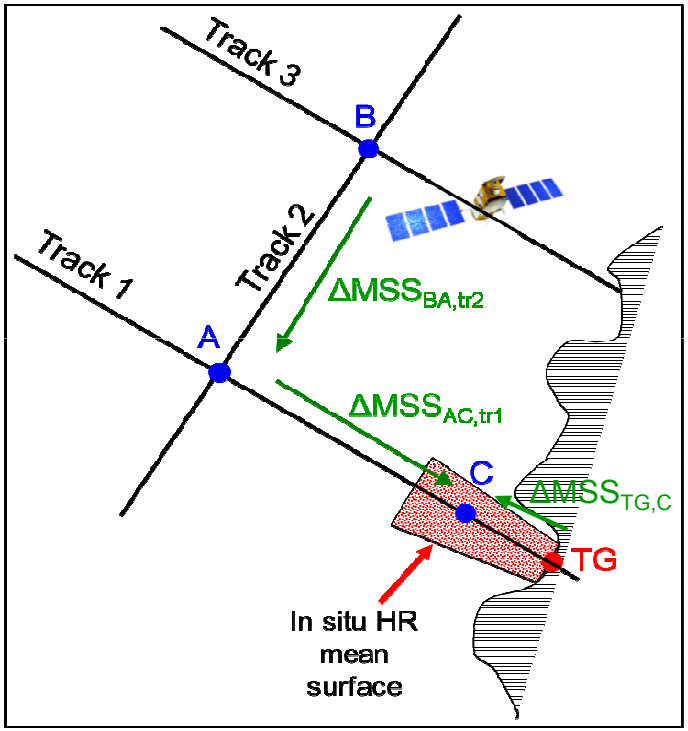
Combination of:

Absolute CALVAL: Direct comparison between altimeter and tide gauge SSH (point C).

- ✓ Only for satellite flying over the calibration sites.
- ✓ Directly comparable to the absolute bias estimates computed by the local in situ calval groups (Corsica, Harvest, Bass Strait, Gavdos…)

Offshore CALVAL: Computation of the bias on offshore passes (points A & B)

- ✓ Following a succession of accurate mean sea surface profiles, combining several missions
- ✓ Using a high resolution mean sea surface to link the *in situ* and altimetry SSH, when available (MSS otherwise)



Regional CALVAL method

Generic method:

➔ **Calibration of missions on new orbits**

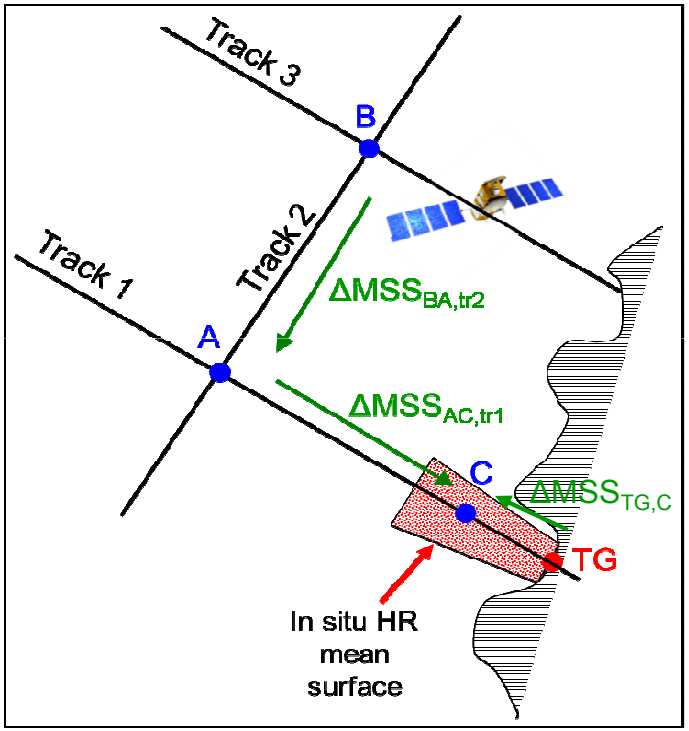
✓ After an orbit change (ex: interleaved TP/Jason-1/Jason-2)

✓ For satellites on orbits without dedicated calibration sites

➔ **Calibration of non-repetitive orbits**

✓ Missions on non-repetitive or drifting orbits (ex: CryoSat-2, SARAL/AltiKa)

Applicable to any calibration site: Corsica, Harvest Platform, Bass Strait, Gavdos…



Regional CALVAL method

Implemented:

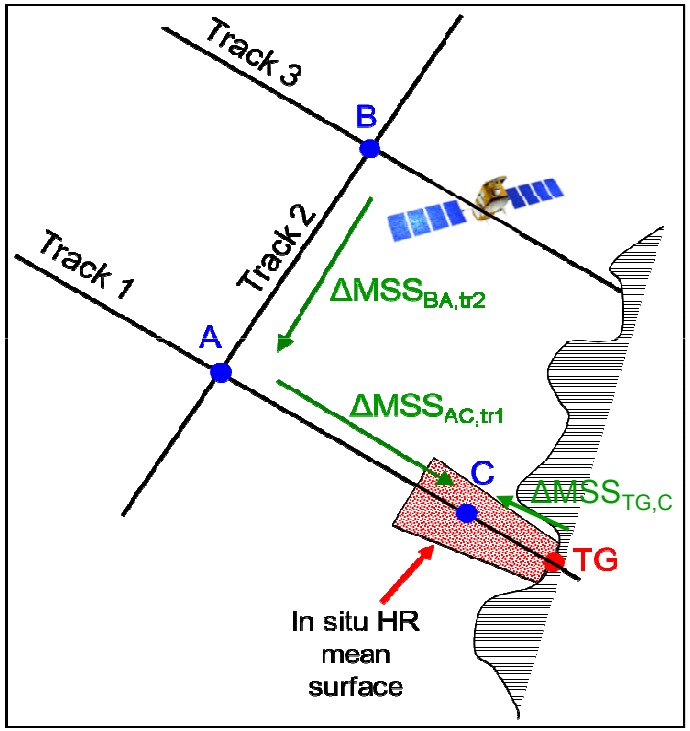
in Corsica (Senetosa & Ajaccio) for Topex, Jason-1, GFO, Jason-2, Envisat, SARAL/AltiKa

- ✓ Jan et al, 2003
- ✓ Cancet et al, 2012

at Harvest for Jason-2, Envisat, SARAL/AltiKa

at Bass Strait for Jason-2, Envisat, SARAL/AltiKa

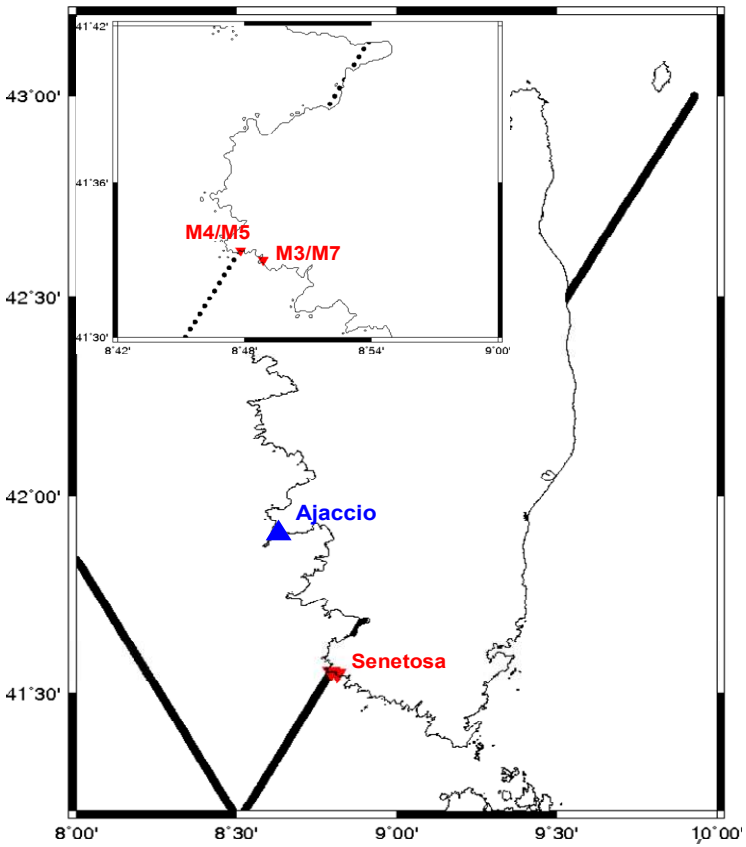
+ Sentinel-3A at the 3 sites (MPC-S3)
+ CryoSat-2 (SAR mode) in Harvest (SCOOP)



Jason-2 and Sentinel-3A CALVAL results

Calibration site of Corsica

- Senetosa (OCA/CNES)
  - 4 tide gauges (2 couples of twin instruments) since 1998
  - Under a TP/Jason-1/2/3 ground-track (085)
- Ajaccio (SHOM)
  - 1 tide gauge since 2002
  - Under an Envisat ground-track (130)



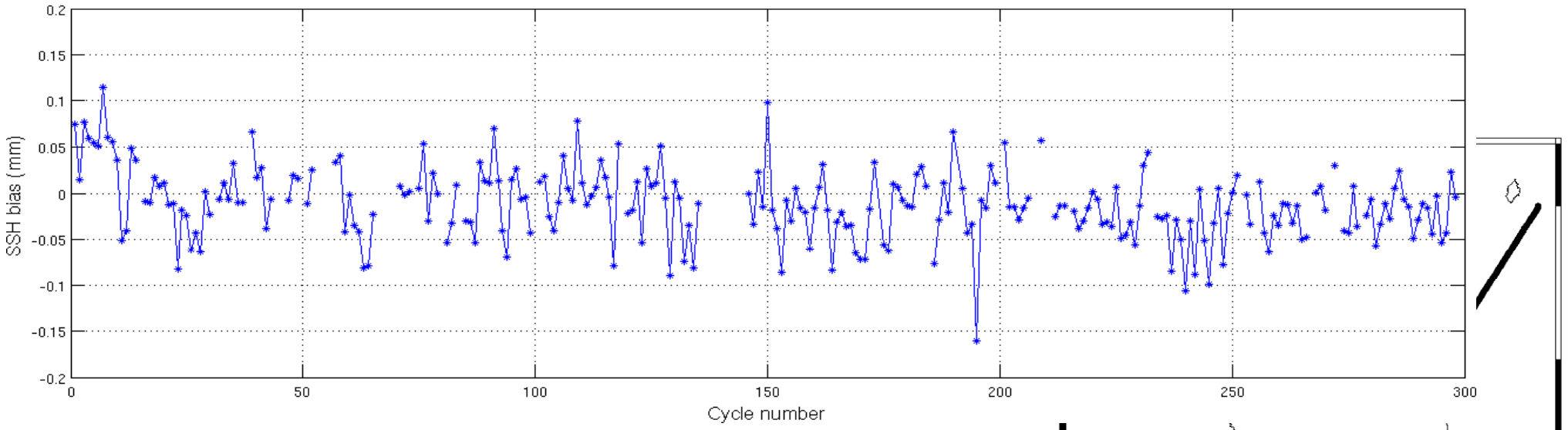
Altimetry data

	Jason-2	Sentinel-3A
Product version	GDR-D	MPC-S3 / EUMETSAT PDGS
Period	Cycles 1-298 07/2008 – 08/2016	Cycles 5-9 04/2016 – 09/2016
Frequency	20Hz	20Hz
Altimeter mode	LRM	SAR
Ionosphere	GIM	GIM
Wet troposphere	ECMWF model (land contamination)	ECMWF model (land contamination)
Sea State Bias	SSB ku	3.5 % of SWH
Tides	COMAPI regional model (CNES)	
DAC	High resolution global simulation (LEGOS)	

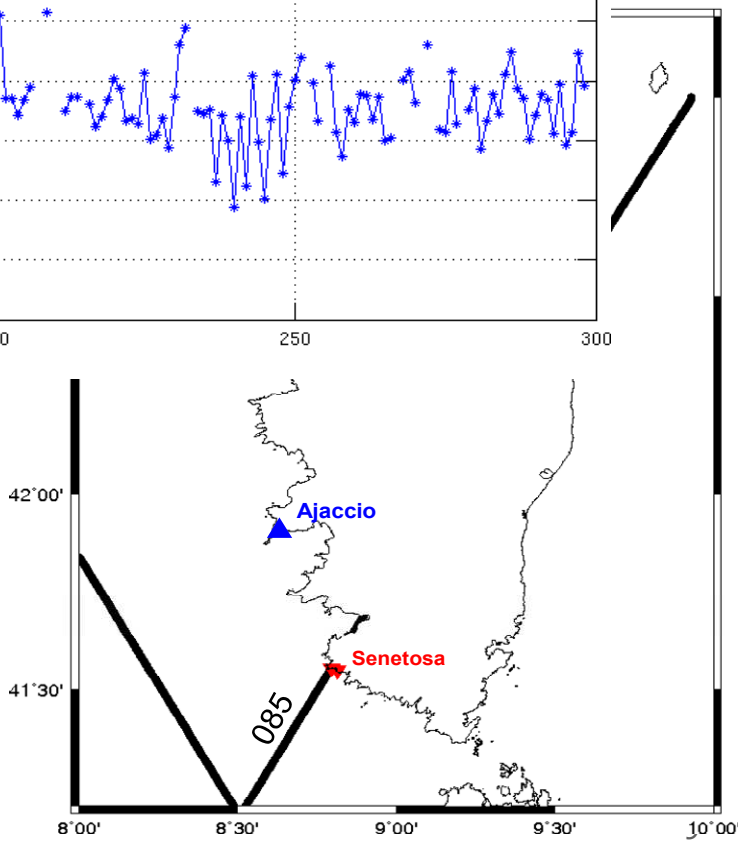
S3: Sometimes, 21 “20 Hz” Ku-band measurements.

Jason-2 absolute bias in Senetosa

Jason-2 GDR-D SSH bias estimates (m) at Senetosa – Track 085

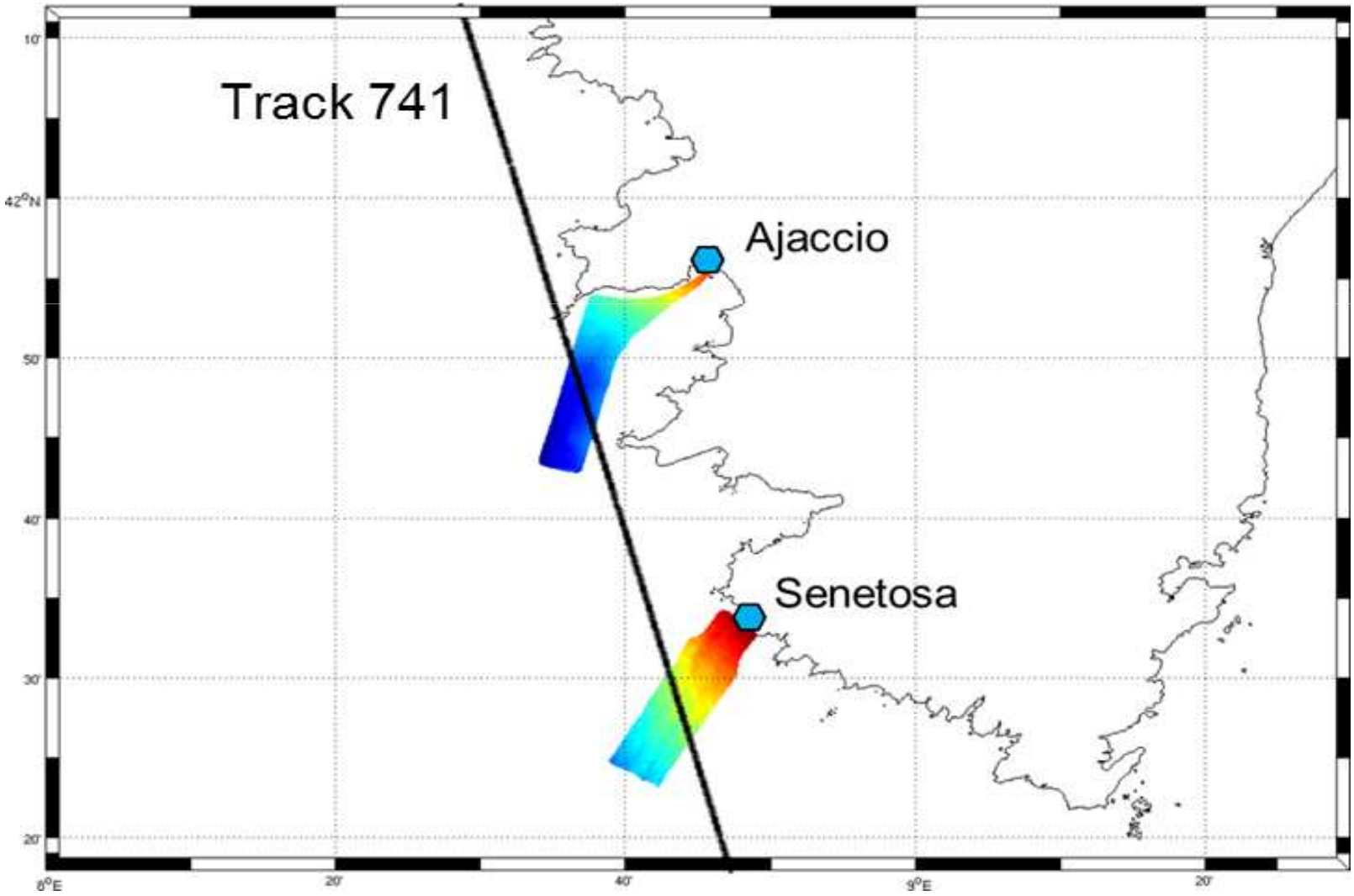


Jason-2 bias (mm) Cycles 1 to 298 (GDR-D)	Mean	Std	Nb of cycles
Track 085 (absolute bias)	-6.7 ± 2.1	35.7	277

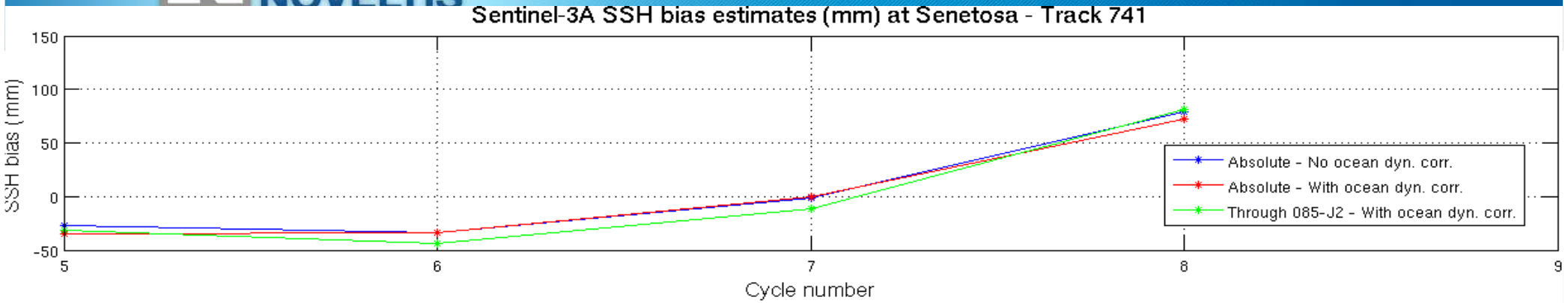


- Very stable results in Senetosa

Sentinel-3A absolute bias in Senetosa and in Ajaccio

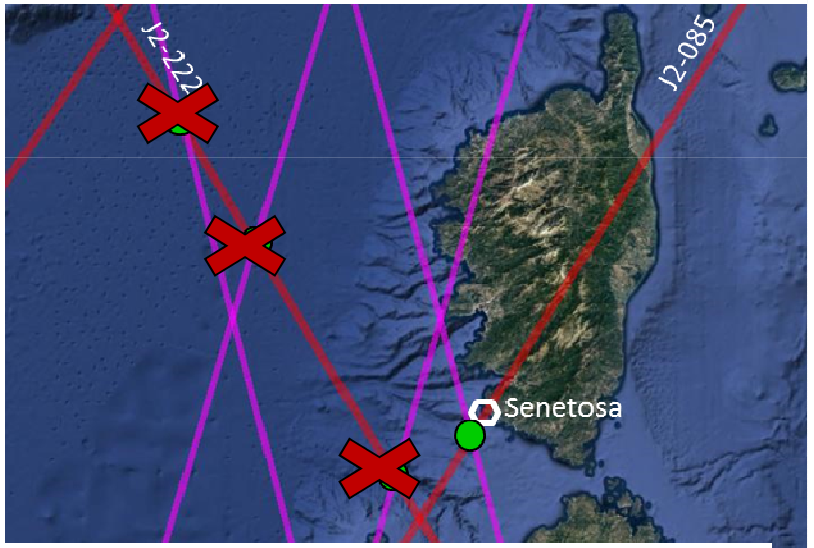


Sentinel-3A CALVAL in Senetosa



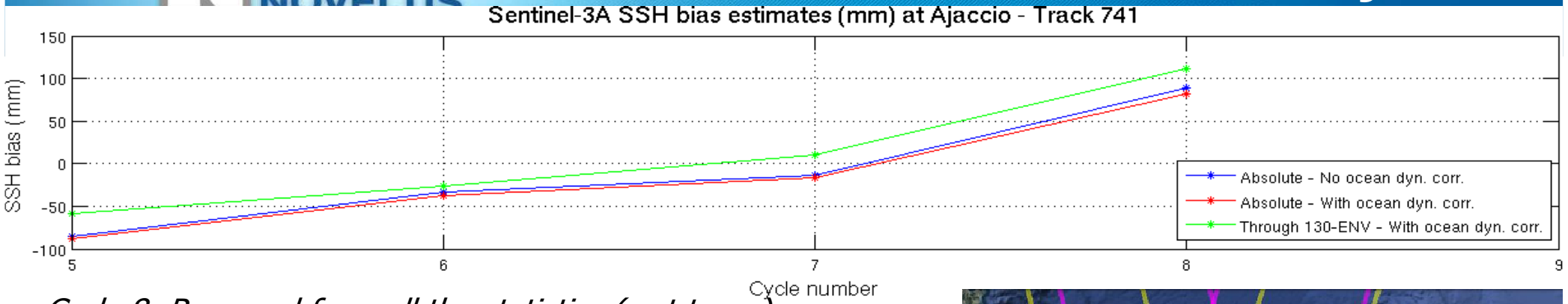
Cycle 8: Removed from all the statistics (wet tropo)

- ✓ Consistent results close to the tide gauge (3 cycles)
- ✓ Mean regional bias is close to absolute bias by chance, much variability in the offshore estimates
  ➔ need for more cycles to compute accurate offshore bias estimates.



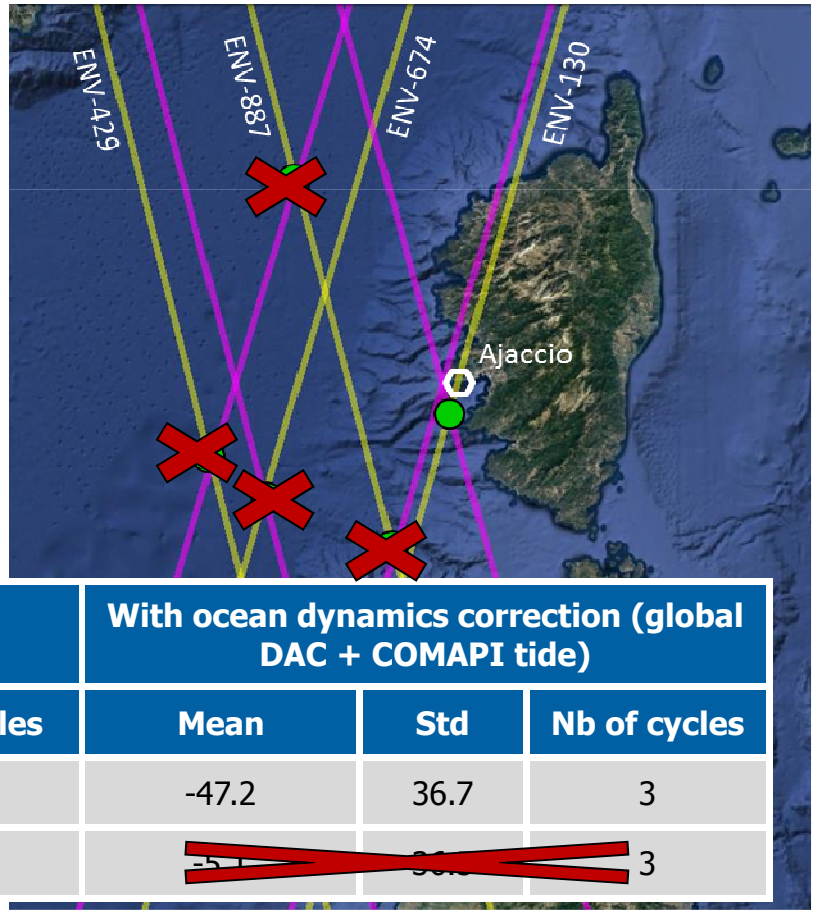
Sentinel-3A bias (mm) Cycles 5 to 9 (MPC-S3)	No ocean dynamics correction			With ocean dynamics correction (global DAC + COMAPI tide)		
	Mean	Std	Nb of cycles	Mean	Std	Nb of cycles
Track 741 (absolute method)	-20.8	17.5	3	-23.1	19.8	3
Mean regional bias in Senetosa	-19.4					3

Sentinel-3A CALVAL in Ajaccio



Cycle 8: Removed from all the statistics (wet tropo)

- ✓ Absolute bias estimates about 25mm lower in Ajaccio than in Senetosa (consistent with P. Bonnefond observations)
- ✓ Much variability in the offshore estimates (only 3 cycles) ➔ need for more cycles to compute accurate offshore bias estimates.



Sentinel-3A bias (mm) Cycles 5 to 9 (MPC-S3)	No ocean dynamics correction			With ocean dynamics correction (global DAC + COMAPI tide)		
	Mean	Std	Nb of cycles	Mean	Std	Nb of cycles
Track 741 (absolute method)	-44.3	36.9	3	-47.2	36.7	3
Mean regional bias in Ajaccio	-18.9	[illegible]	3	[illegible]	[illegible]	3

Conclusions on Jason-2 and Sentinel-3A CALVAL

- ✓ First calibrations of Sentinel-3A in Corsica (Senetosa and Ajaccio)
- ✓ Same work at Harvest and Bass Strait is underway

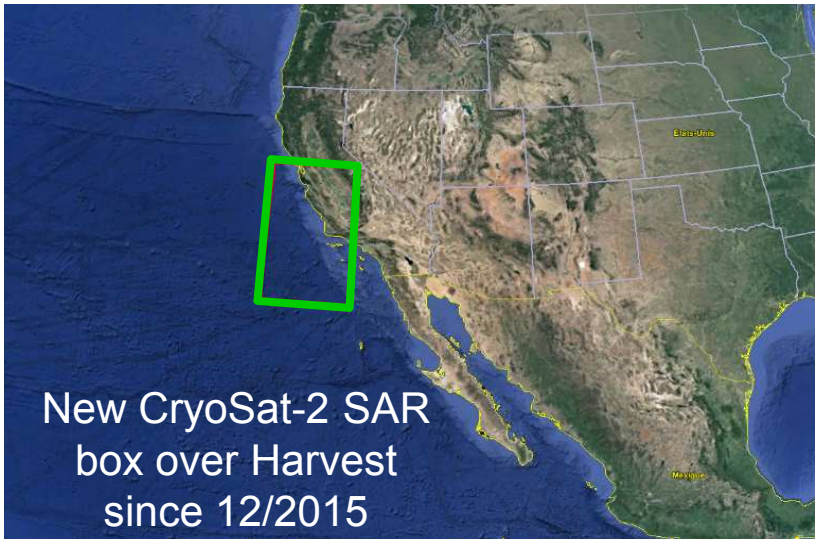
→ Jason-2 on interleaved orbit, SARAL on drifting orbit and Jason-3 could be monitored as well…

Some new perspectives for regional CALVAL

→ Analysis of the impact of the sea state on the altimeter SSH

An illustration with Jason-2

(SCOOP ESA project)



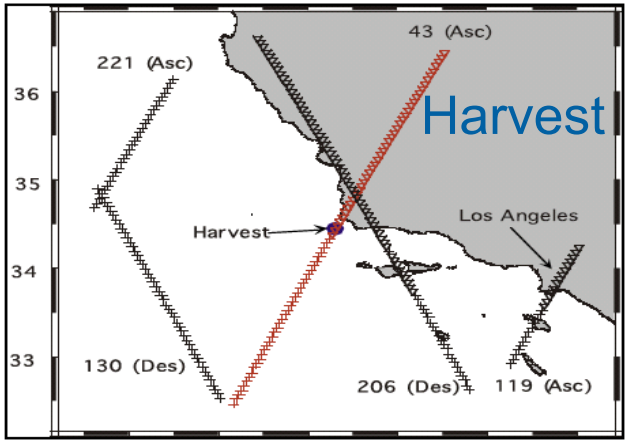
Sea state impact on the SSH

- Analysis of the altimeter SSH bias sensitivity to the major sea state components
  - Inputs:
    - Altimeter SSH bias → regional CALVAL method
    - Sea state parameters: HS *(SWH)*, HS0, HS1, HS2, HS3, wave direction, skewness, period… → IOWAGA model/buoy
  - Statistical analysis:
    - Correlations
    - Principal Components Analyses (PCA)

Sea state impact on the SSH

- An illustration with Jason-2...

→ Computation of the absolute SSH bias for the overflying Jason-2 tracks (2008-2015)



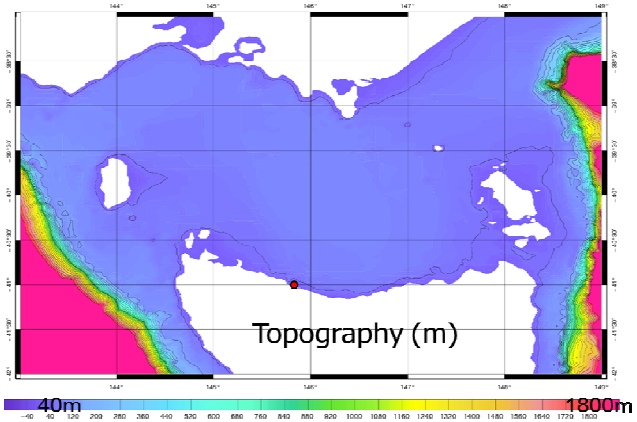
(Haines et al, 2012)

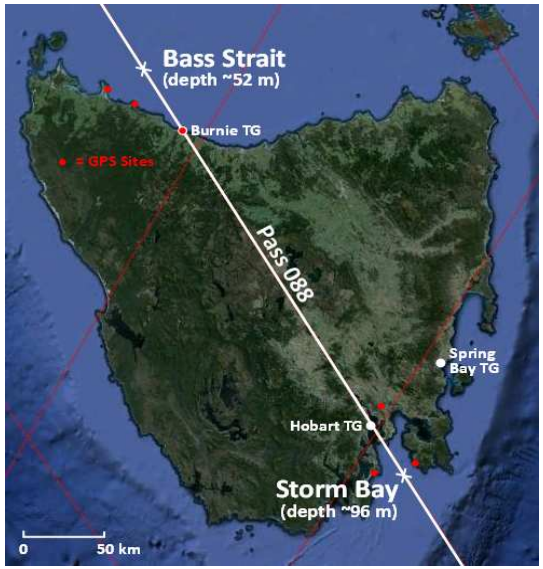
Harvest site

- ✓ Mainly governed by swell (open ocean)
- ✓ Tide gauge SSH time series entirely reprocessed and checked between 2002 and 2015 (JPL) + sea state correction

Bass Strait site

- ✓ Mainly governed by wind (enclosed basin)
- ✓ Quality controlled tide gauge SSH time series between 1992 and 2015 (UTAS)



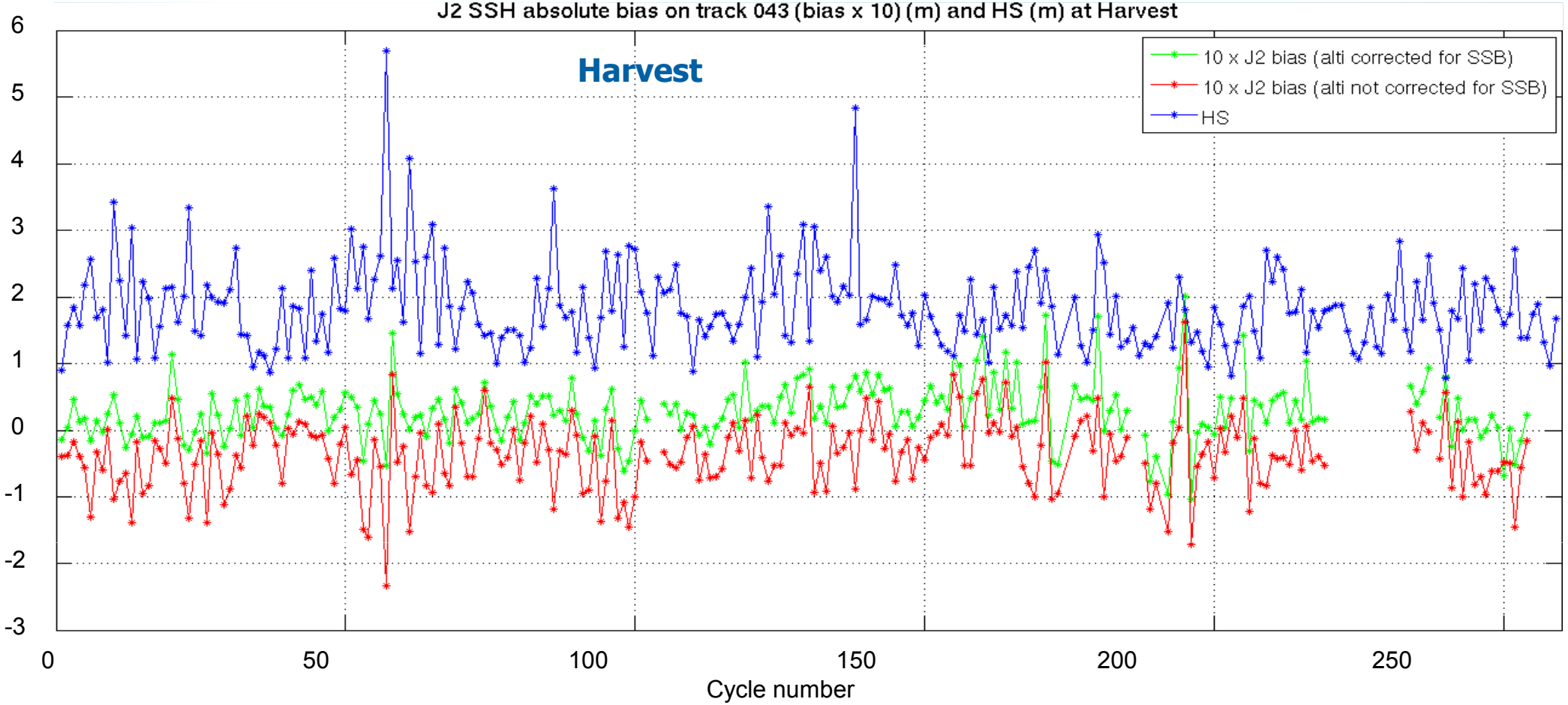


(Watson et al, 2013)

Sea state impact on the SSH

- An illustration with Jason-2...
  - IOWAGA model hindcast database (IFREMER)
    - Harvest : regional grid, 0.16° x 0.16° , 3 hours
    - Bass Strait : global grid, 0.5° , 3 hours
  - Parameters available in the IOWAGA hindcast database:
    - Total HS *(SWH)*
    - HS0: wind waves
    - HS1, HS2, HS3: main swell components

→ Evaluation of the sensitivity of the altimeter SSH bias to these parameters



Harvest: Comparison to 8 years of HS

In situ data (tide gauge) corrected for sea state from local buoy

Jason-2 SSH bias	Correlation with HS
No SSB correction	-0.48
With SSB correction	0.01

→ Anti-correlation between HS and J2 SSH bias when no SSB applied

→ Correlation disappears when SSB correction is used

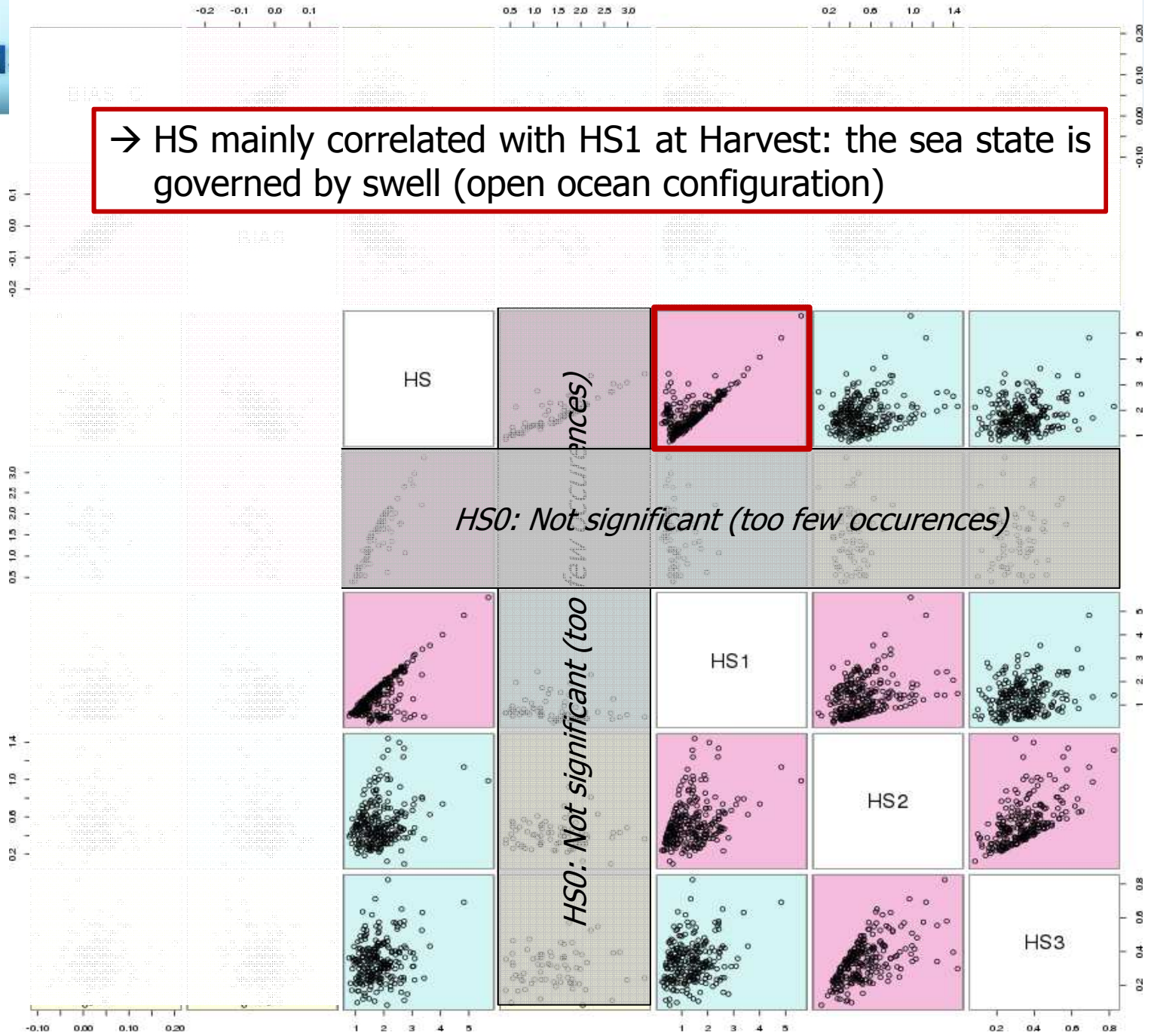
Harvest: Correlations between all the parameters

0.4 < |Corr| ≤ 1

0.2 < |Corr| ≤ 0.4

0 < |Corr| ≤ 0.2

→ HS mainly correlated with HS1 at Harvest: the sea state is governed by swell (open ocean configuration)



Harvest: Correlations between all the parameters

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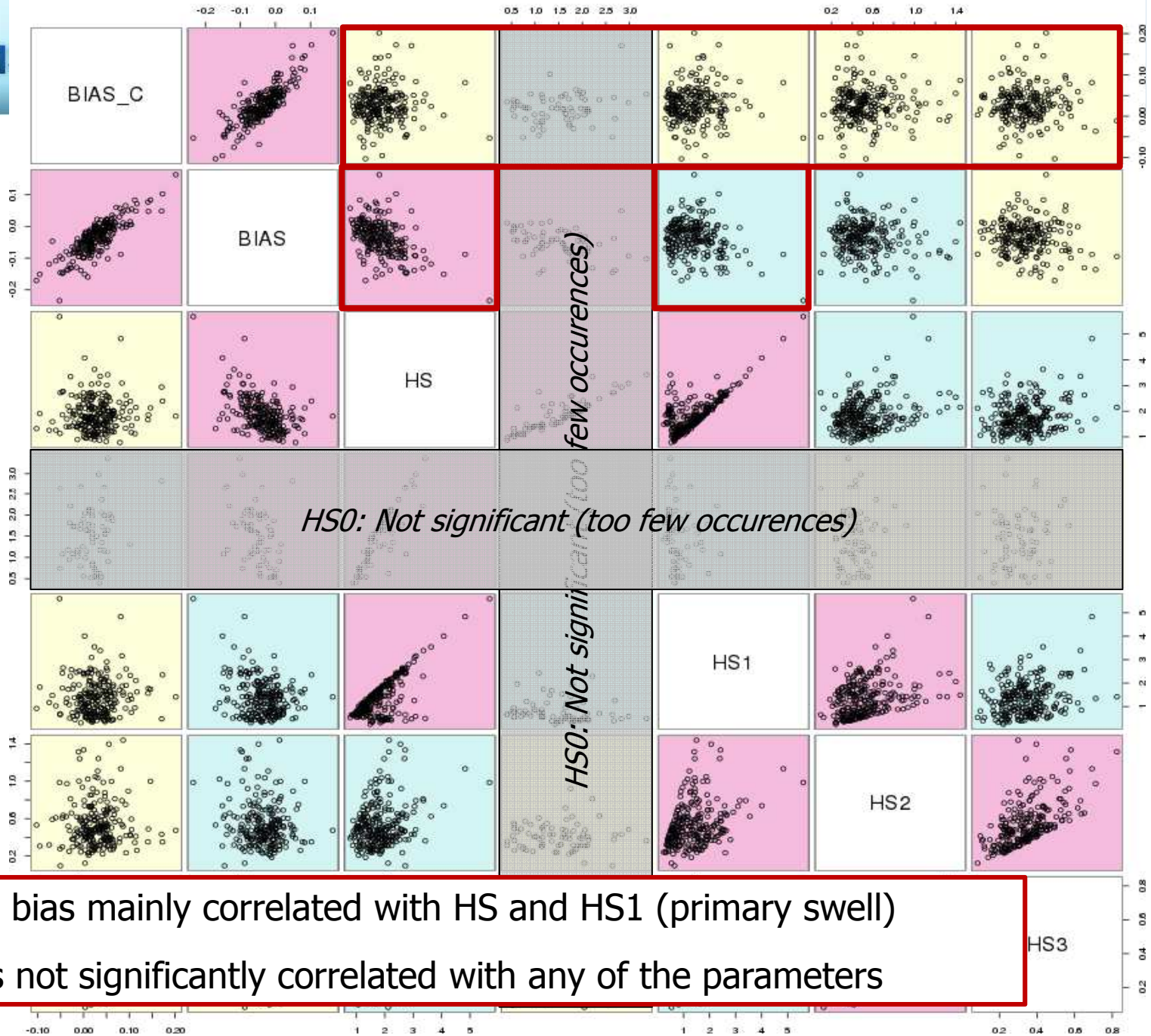
BIAS = J2 SSH bias not corrected for SSB

BIAS_C = J2 SSH bias corrected for SSB



→ SSB non-corrected alti bias mainly correlated with HS and HS1 (primary swell)

→ SSB-corrected alti bias not significantly correlated with any of the parameters

Sea state impact on the SSH

Another way to look at it: Principal Component Analysis (PCA)

BIAS = J2 SSH bias without SSB corr.

BIAS_C = J2 SSH bias with SSB corr.

5 variables: HS, HS0, HS1, HS2, HS3

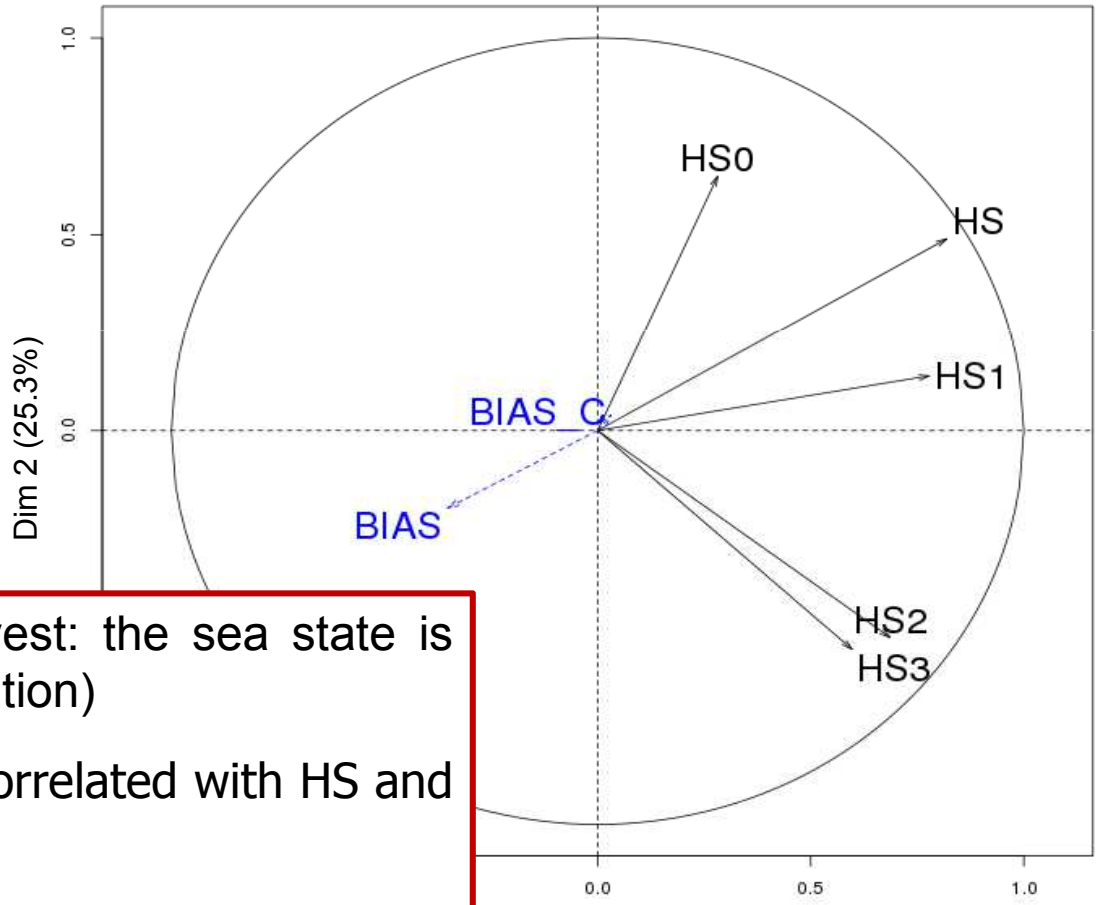
The first 2 dimensions explain 69% of the variance of the variables.

HS0 not significant (too few occurences)

Dim 1: related with HS2 and HS3

Dim 2: related with HS and HS1

Harvest: Variables factor map (PCA)



→ HS mainly correlated with HS1 at Harvest: the sea state is governed by swell (open ocean configuration)

→ SSB non-corrected alti bias mainly anti-correlated with HS and HS1 (primary swell)

→ SSB-corrected alti bias not significantly correlated with any of the parameters

Sea state impact on the SSH

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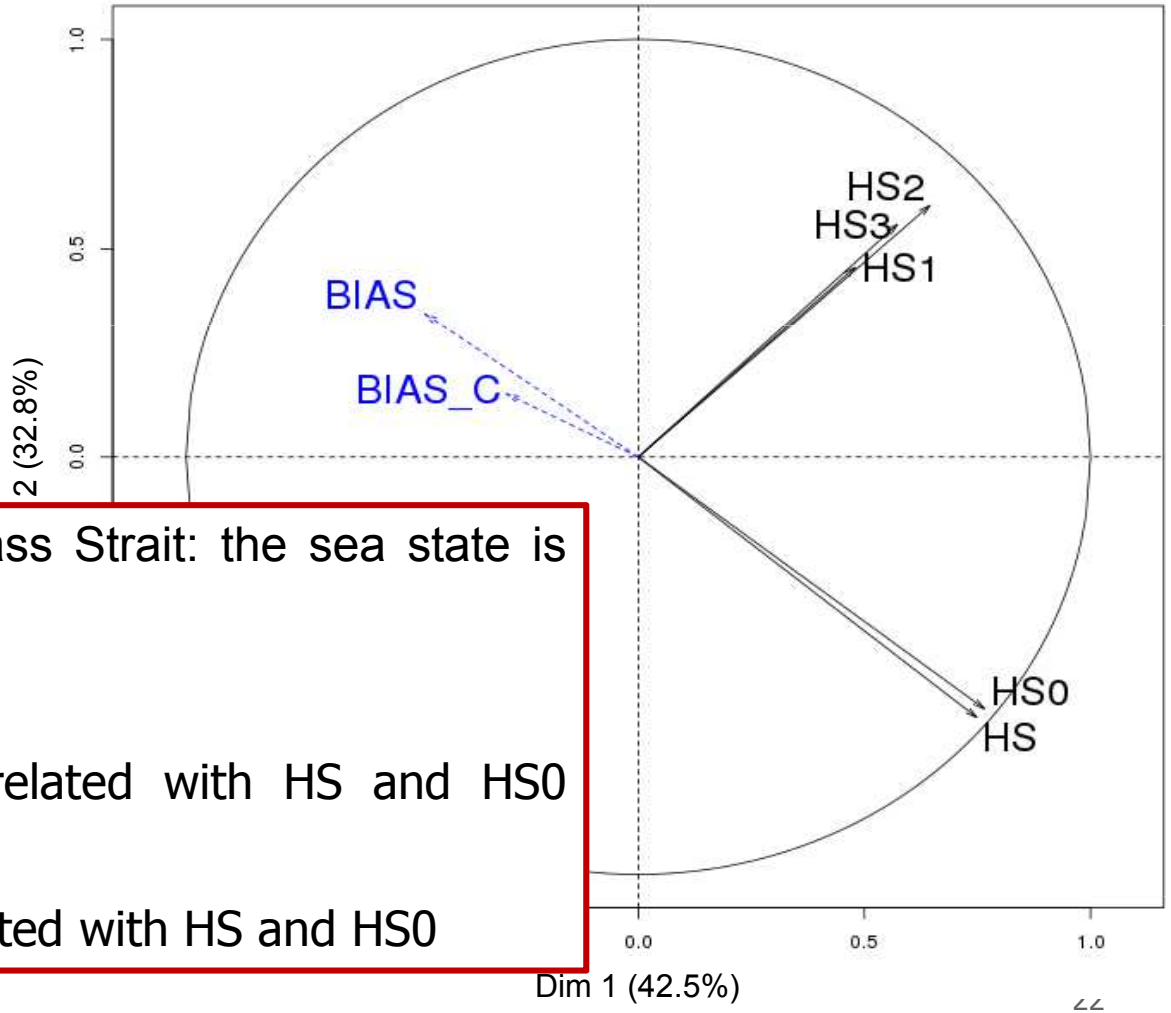
Bass Strait: Variables factor map (PCA)



Bass Strait:
In situ data (tide gauge) not corrected for sea state

→ HS mainly correlated with HS0 at Bass Strait: the sea state is governed by wind waves

→ HS1, HS2, HS3 very close

→ SSB non-corrected alti bias anti-correlated with HS and HS0 (wind waves)

→ SSB-corrected alti bias still anti-correlated with HS and HS0

Sea state impact on the SSH

- An illustration with Jason-2...
  - Very experimental analyses, but clearly show:
    - The dependency of the altimeter SSH bias to the sea state parameters when no SSB correction is applied to the altimeter SSH data (expected result).
    - No more dependencies with HS at Harvest when the altimeter SSH are corrected from SSB → « ideal case »
    - Still some dependencies with HS/HS0 at Bass Strait when the altimeter SSH are corrected from SSB but further analyses would be necessary (mooring data).
  - Next step: application to CryoSat-2 SAR data in Harvest

    ➔Dependency of the SAR mode SSH data to the SWH ?

    ➔Assessment of the SSB correction

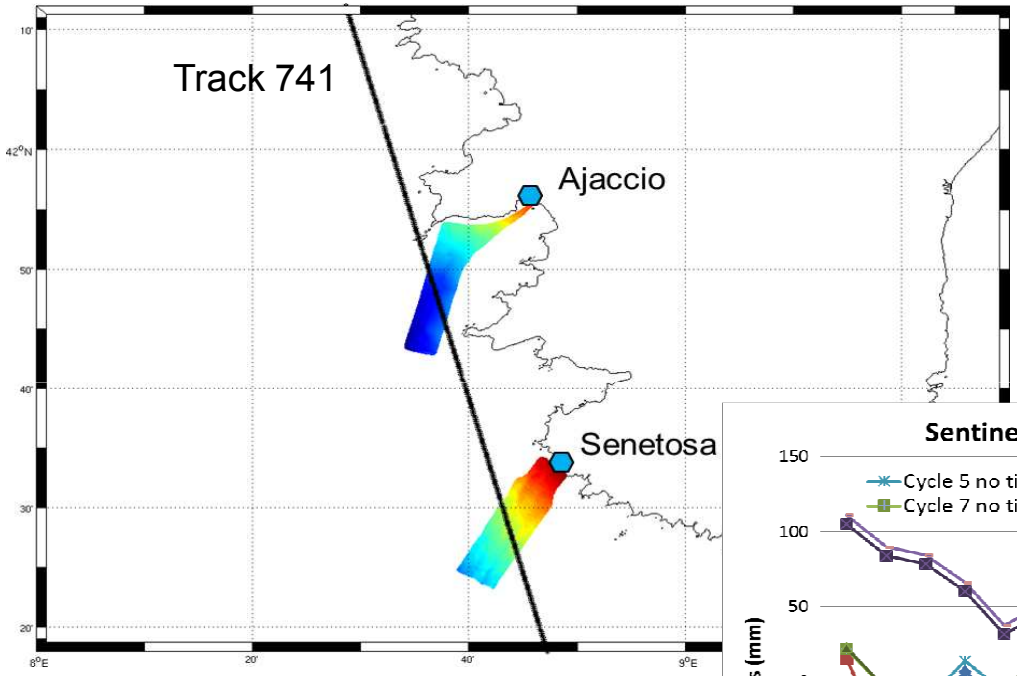
Conclusions and perspectives

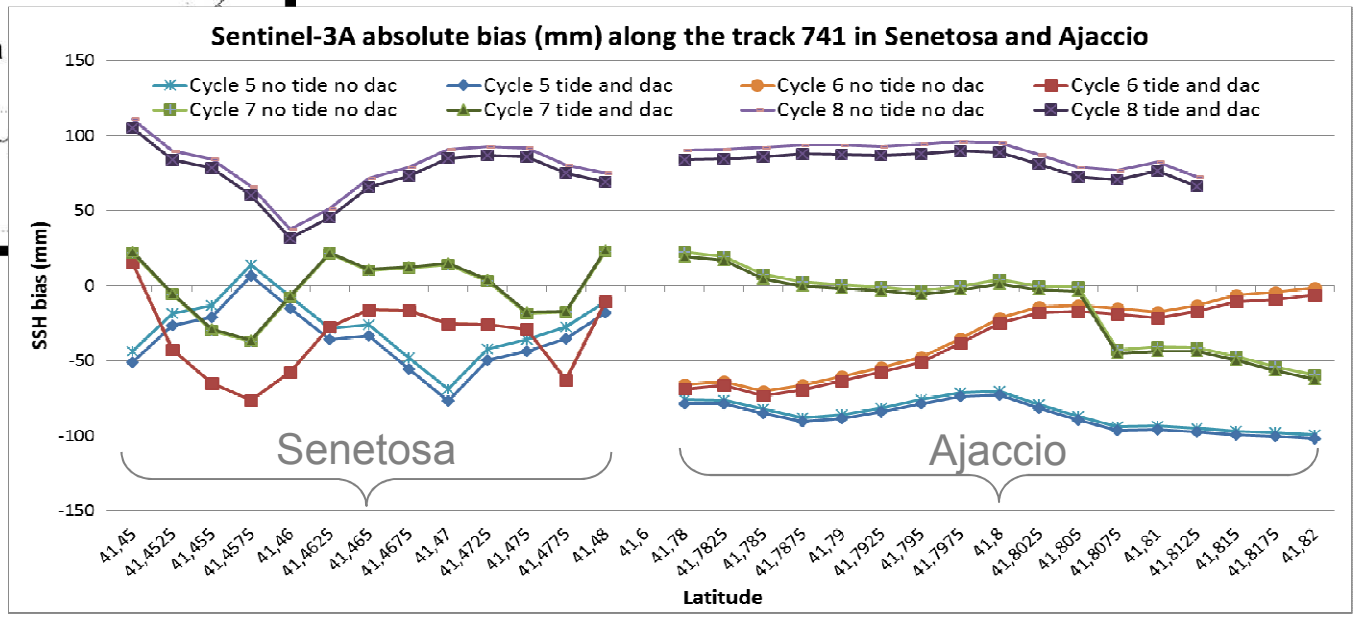
- ✓ Regional CALVAL = Link between the local and global CALVAL methods
- ✓ Some promising results for analyzing the SWH impact on altimeter SSH

→ Jason-2 on interleaved orbit, SARAL on drifting orbit and Jason-3 could be monitored as well…

Thank you !

Sentinel-3A absolute bias in Senetosa and in Ajaccio



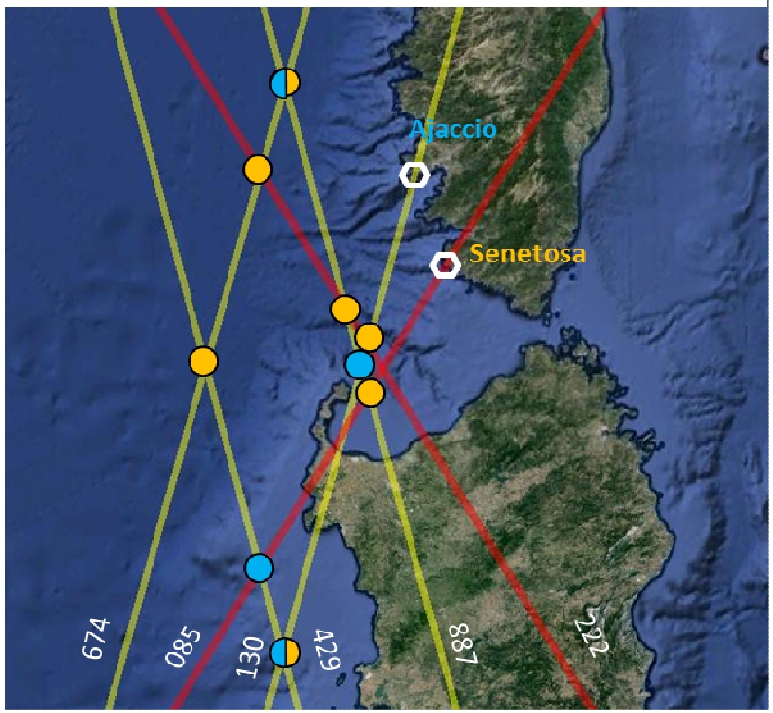


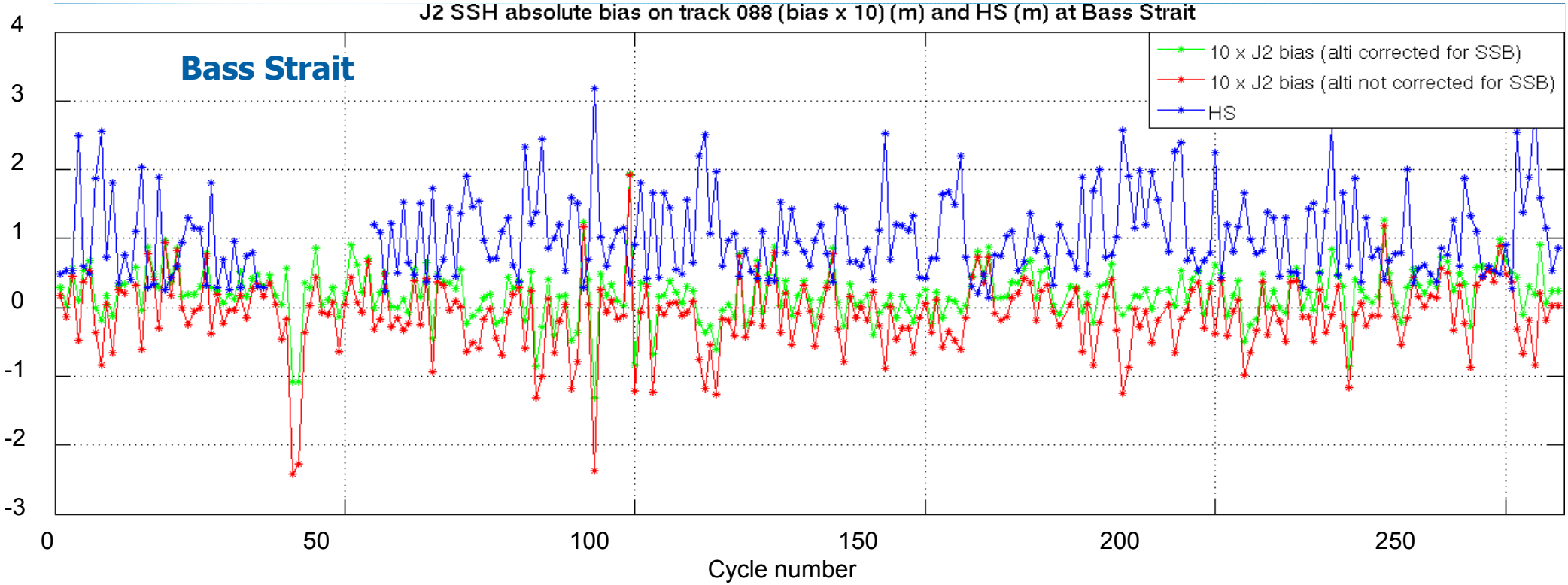
Cycle 8: Problem with wet tropospheric correction

Jason-2 regional bias in Senetosa and Ajaccio

Jason-2 bias (mm) Cycles 1 to 298 (GDR-D)	No ocean dynamics correction			With ocean dynamics correction (global DAC + COMAPI tide)		
	Mean	Std	Nb of cycles	Mean	Std	Nb of cycles
Track 085 (absolute method)	-6.7 ± 2.1	35.7	277	-9.1 ± 2.2	37.4	277
Mean regional bias in Senetosa	-10.9	39.0	284	-11.2	41.9	284
Mean regional bias in Ajaccio	-2.1	39.6	267	17.6	41.4	267

- Very stable results in Senetosa, both in absolute and regional configurations
- Still unexplained 2-cm difference in Ajaccio, but some tests showed it is linked to the tide correction → *under investigation*





Bass Strait: Comparison to 8 years of HS

In situ data (tide gauge) not corrected for sea state

Jason-2 SSH bias	Correlation with HS
Without SSB corr.	-0.69
With SSB correction	-0.41

→ Anti-correlation between HS and J2 SSH bias when no SSB applied

→ Bass Strait J2 SSH bias seems to be still sensitive to HS when SSB correction applied

BUT

It would be interesting to reproduce the exercise → using the mooring data (closer to altimetry ground-track)

→ With a higher resolution wave model

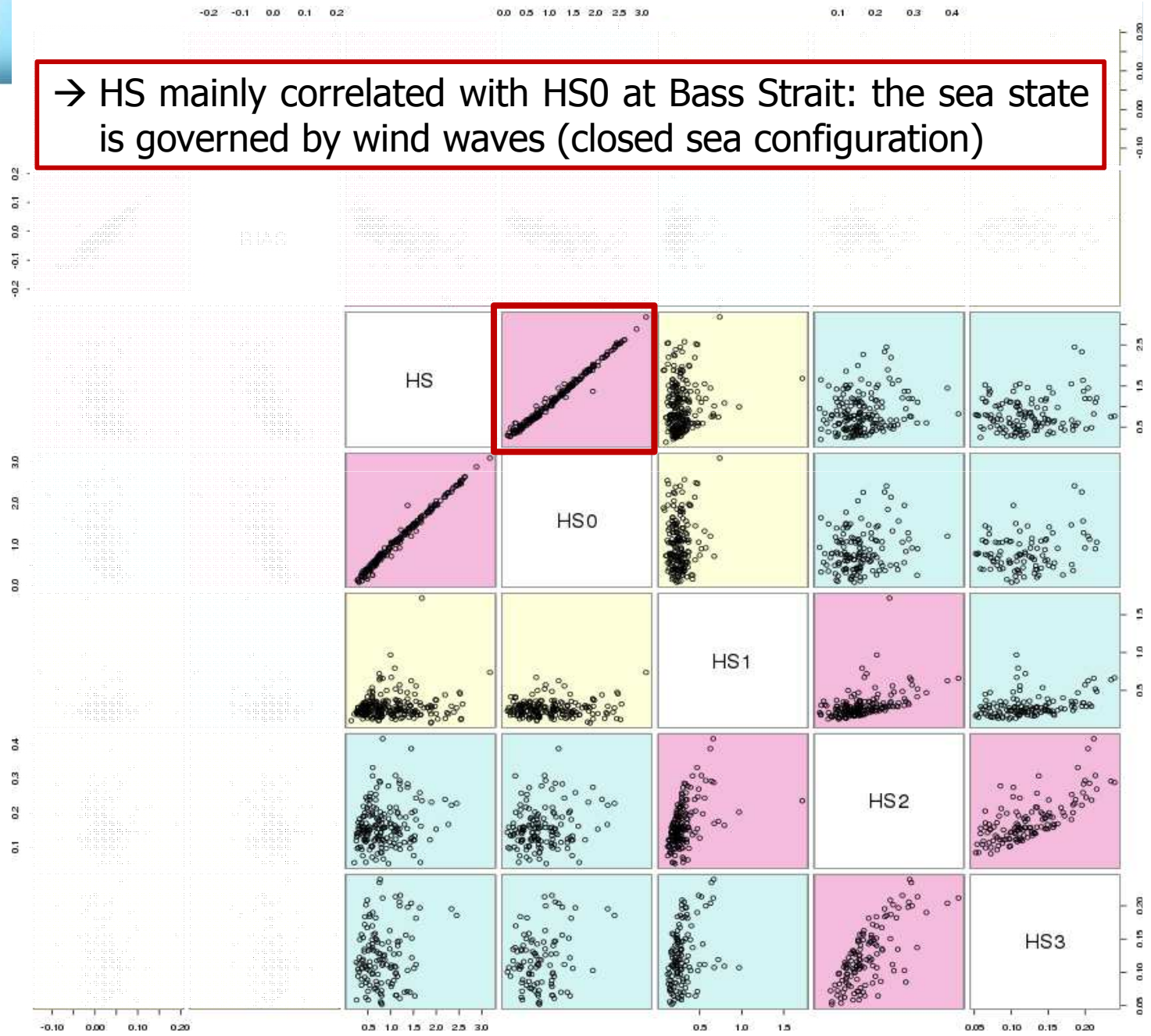
Bass Strait: Correlations between all the parameters

0.4 < |Corr| ≤ 1

0.2 < |Corr| ≤ 0.4

0 < |Corr| ≤ 0.2

→ HS mainly correlated with HS0 at Bass Strait: the sea state is governed by wind waves (closed sea configuration)



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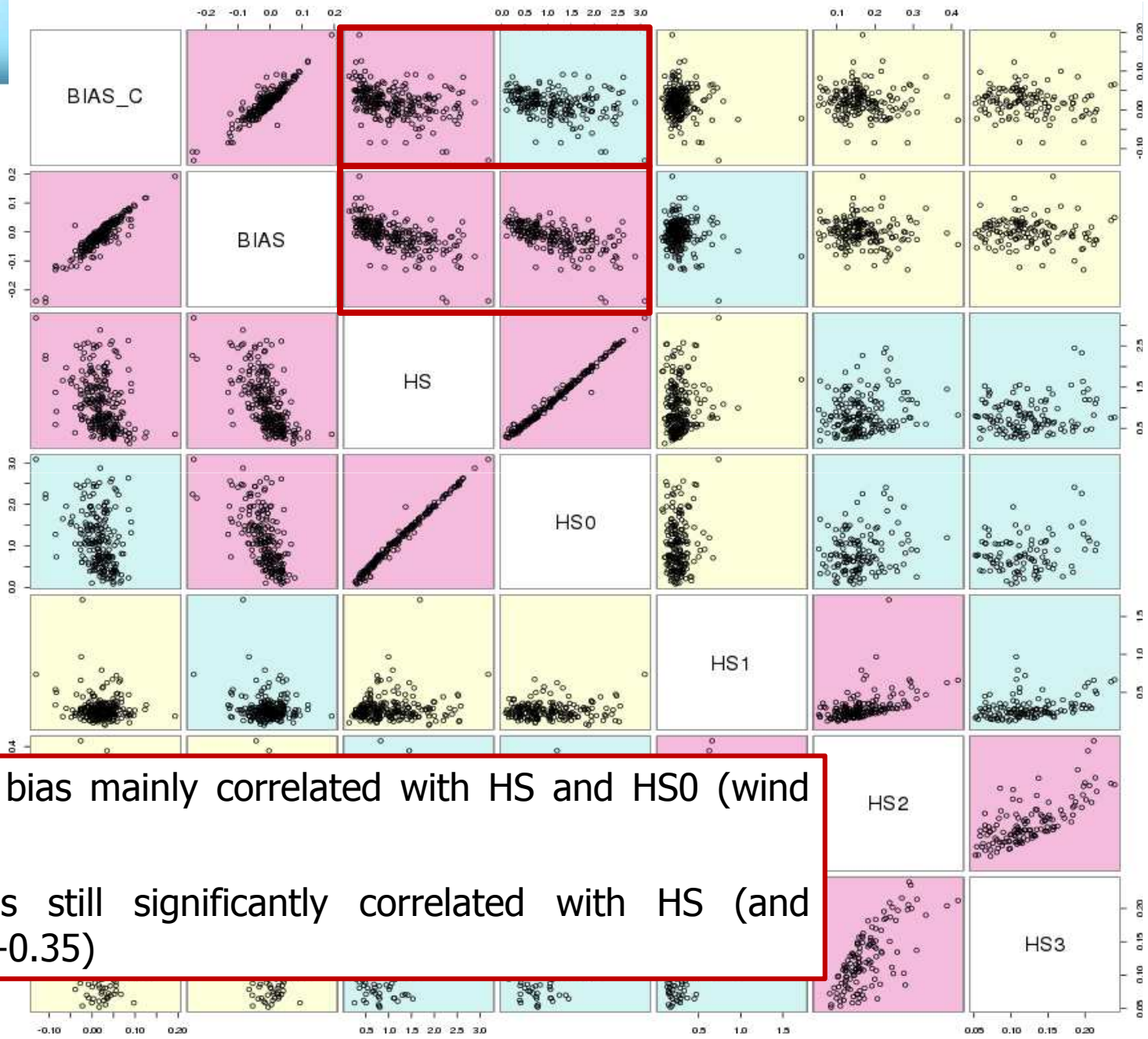

→ SSB non-corrected alti bias mainly correlated with HS and HS0 (wind waves)

→ SSB-corrected alti bias still significantly correlated with HS (and correlation with HS0 = -0.35)