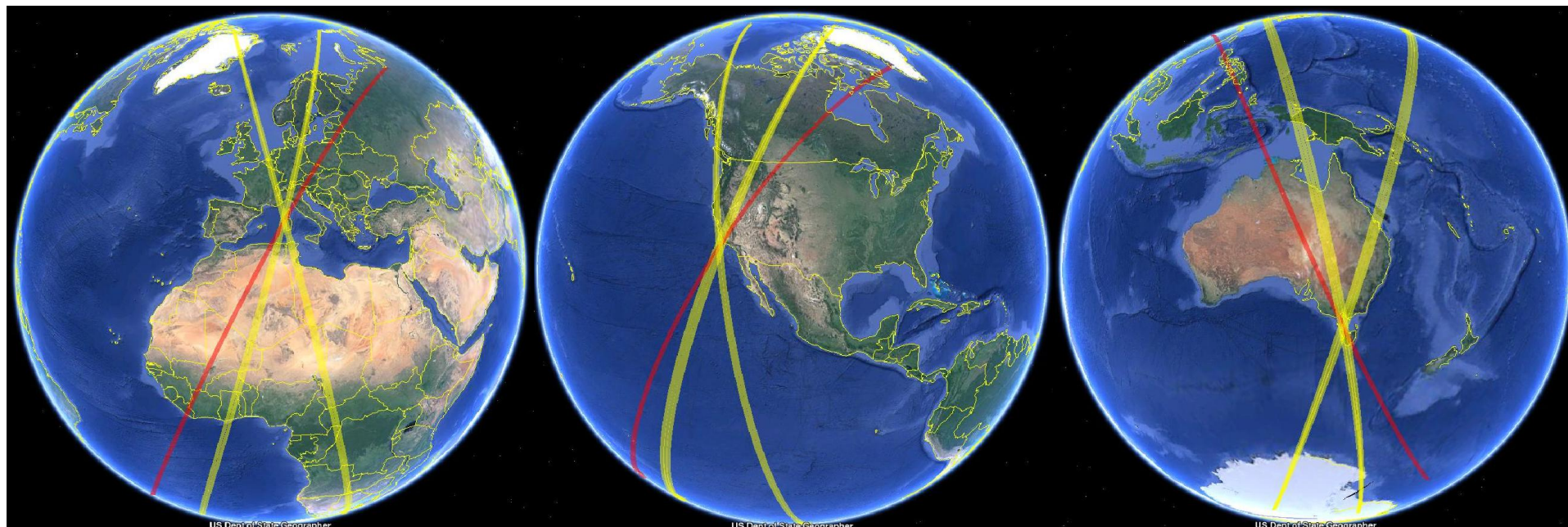


# Regional CALVAL of Jason-2 and Envisat at three calibration sites: Corsica, Harvest and Bass Strait

M. Cancet, C. Watson, B. Haines, P. Bonnefond,  
E. Jeansou, F. Lyard, P. Féménias



## Regional CALVAL method

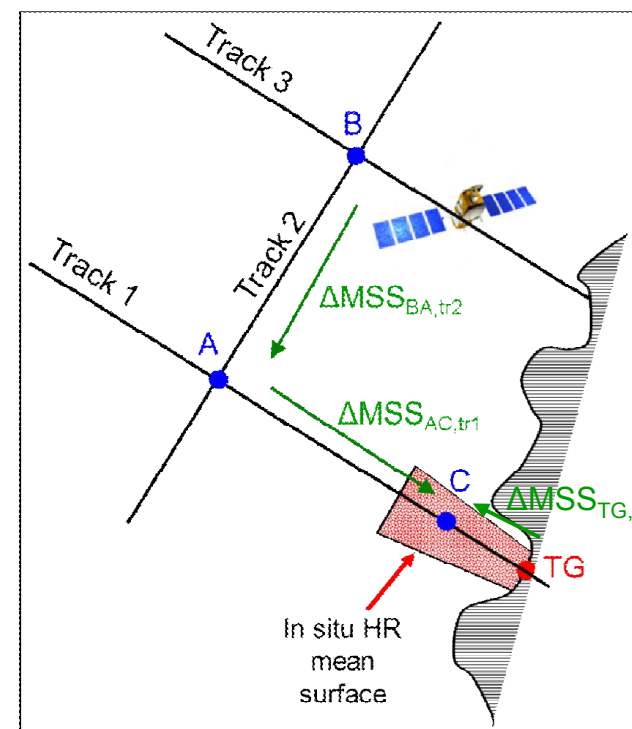
Combination of:

**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:

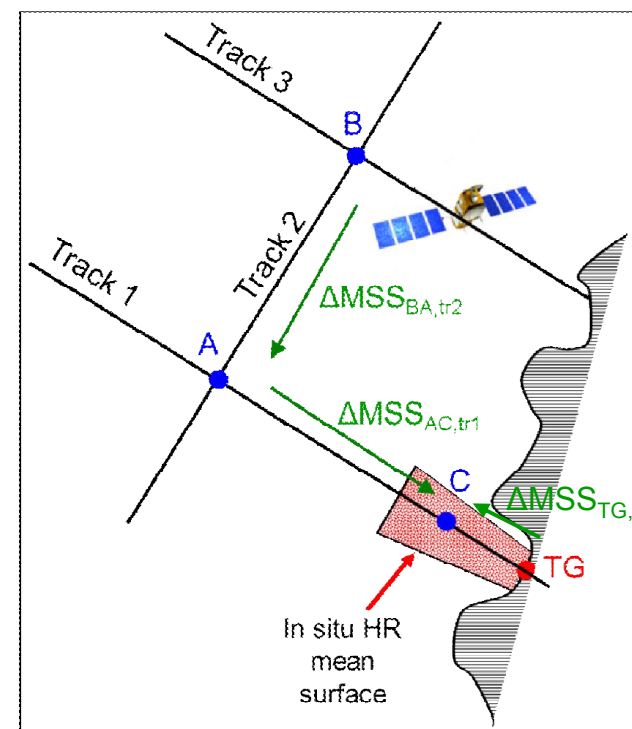
#### → Calibration of missions on new orbits

- ✓ After an orbit change (ex: interleaved TP & Jason-1, Envisat after October 2010, Jason-1 end-of-life)
- ✓ For orbits without dedicated calibration sites (ex: Sentinel-3).

#### → Calibration of non-repetitive orbits

- ✓ Missions on non-repetitive or drifting orbits (ex: CryoSat-2).

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





## Regional CALVAL method

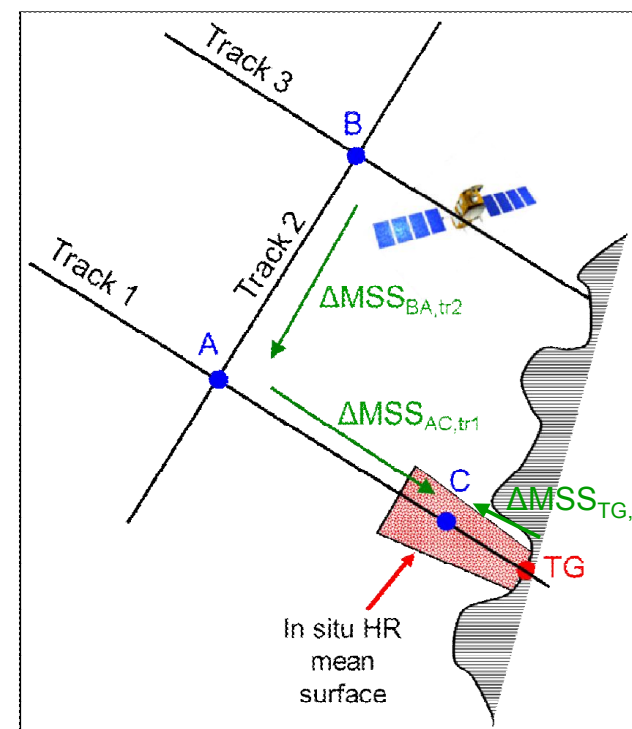
### Highly depends on:

- ✓ Good-quality SSH data (altimetry & tide gauge)
- ✓ Accurate mean sea surface profiles
- ✓ High resolution local mean sea surface (GPS survey) or accurate global MSS
- ✓ Ocean dynamics corrections: ocean tide and atmospheric effects between the offshore tracks and the coast

**Previously implemented in Corsica** (Senetosa & Ajaccio) for Topex, Jason-1, GFO, Jason-2 and Envisat

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

**and at Harvest** for Jason-2 and Envisat (→ OSTST 2013)



$$\begin{aligned}
 bias_{alti,tr3}(t) = & (SSH_{B,tr3}^{alti}(t) - dyn_{B,tr3}) - (SSH_{TG,tr1}^{gauge}(t) - dyn_{TG,tr1}) \\
 & + (\overline{SSH}_{TG,tr1}^{insitu} - \overline{SSH}_{C,tr1}^{insitu}) + (\overline{SSH}_{C,tr1}^{alti} - \overline{SSH}_{A,tr1}^{alti}) + (\overline{SSH}_{A,tr2}^{alti} - \overline{SSH}_{B,tr2}^{alti})
 \end{aligned}$$

## Verification of the altimeter SSH stability

- ▶ Jason-2 (GDR-D)
- ▶ Envisat nominal orbit (GDR-C v2.1) + GDR-D orbit *New !*
- ▶ Envisat drifting orbit (2010+, GDR-C v2.1)

## at the calibration sites of

- ▶ Corsica
  - Senetosa
  - Ajaccio
- ▶ Harvest
- ▶ Bass Strait *New !*

*Dedicated to*

*TP/Jason-1/2*

*Envisat (nominal orbit)*

*TP/Jason-1/2*

*TP/Jason-1/2*

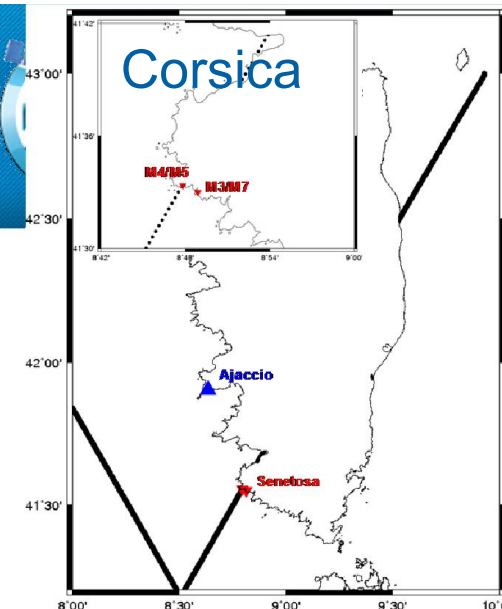
## Corsica site

### Ajaccio (SHOM):

- ✓ 1 tide gauge since 2002

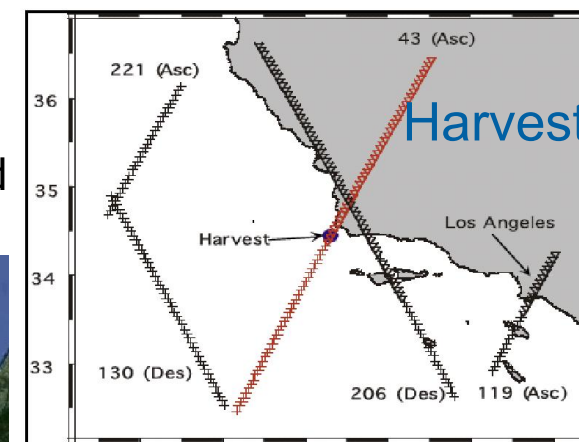
### Senetosa (OCA/CNES):

- ✓ 4 tide gauges (2 couples of twin instruments) since 1998



## Harvest site

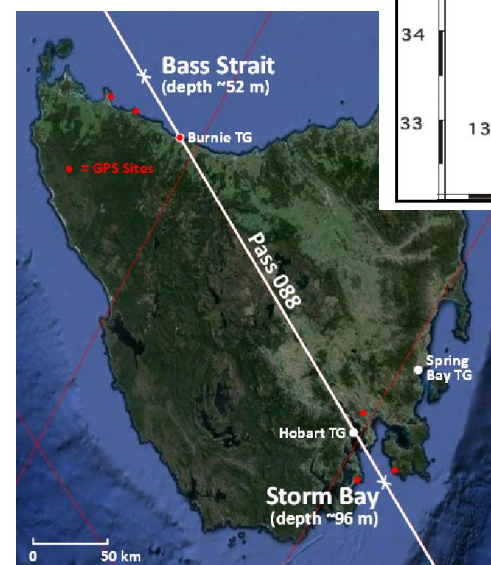
- ✓ Tide gauge SSH time series entirely reprocessed and checked between 2002 and 2012 (JPL)



(Haines et al, 2012)

## Bass Strait site

- ✓ Quality controlled tide gauge SSH time series between 1992 and 2014 (UTAS)



(Watson et al, 2013)

|                 | Jason-2  | Envisat  | Envisat 2010+                      |
|-----------------|--|--|------------------------------------|
| Product version | GDR-D  | GDR-C v2.1   | GDR-C v2.1                         |
| Period          | Cycles 1-223<br>07/2008 – 07/2014  | Cycles 7-93<br>06/2002 – 10/2010   | Cycles 93-113<br>10/2010 – 04/2012 |
| Ionosphere      | GIM  | GIM: only correction available for the whole mission (S-band loss)   |                                    |
| Wet troposphere | <ul style="list-style-type: none"><li>• <b>Corsica:</b> ECMWF model (land contamination)</li><li>• <b>Harvest:</b> Radiometer (S. Brown)</li><li>• <b>Bass Strait:</b> Radiometer (S. Brown)</li></ul> | ECMWF model, following recommendation not to use the radiometer correction provided in the GRC-v2.1 products |                                    |
| Tides           | <ul style="list-style-type: none"><li>• <b>Corsica:</b> COMAPI regional model (CNES)</li><li>• <b>Harvest:</b> FES2004</li><li>• <b>Bass Strait:</b> FES2004</li></ul>                                 |  |                                    |
| DAC             | High resolution global simulation (LEGOS)  |  |                                    |

The comparison with the other groups' results were systematically performed in the same conditions of corrections, except for the ionospheric correction at Bass Strait (dual-frequency for UTAS).



# Jason-2 regional CALVAL results

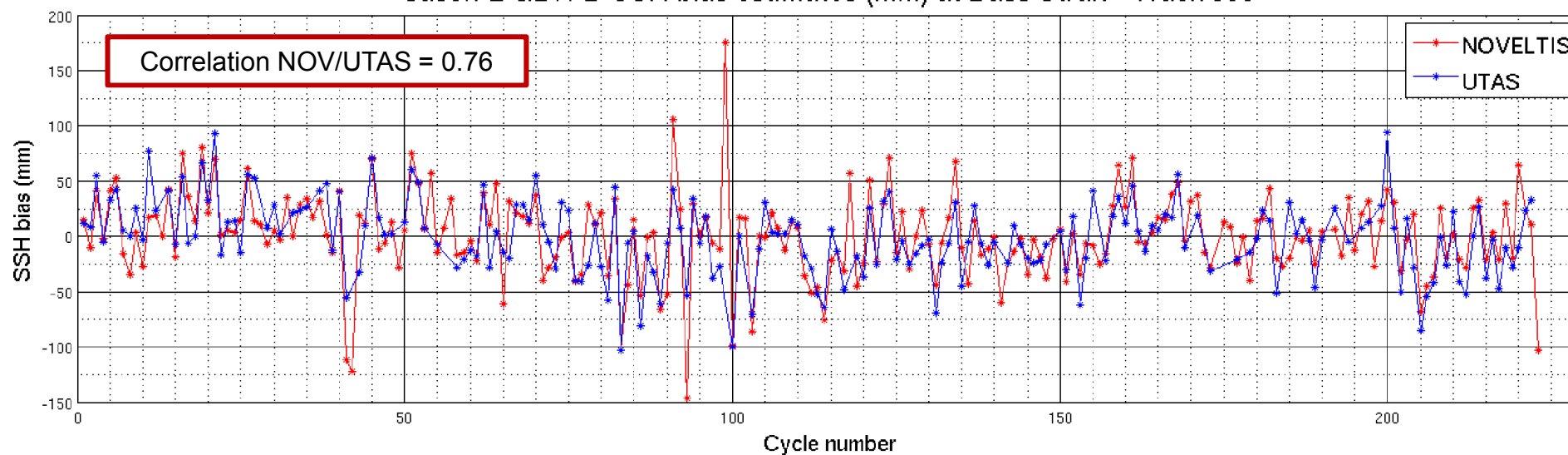


## Jason-2 CALVAL at Bass Strait

| Jason-2 bias (mm)<br>Cycles 1 to 223 (GDR-D)                               | Mean           | Std  | Nb of cycles |
|--|----------------|------|--------------|
| Track 088 (NOVELTIS)   | $1.02 \pm 2.6$ | 38.7 | 221          |
| Track 088 (NOVELTIS) common<br>cycles with UTAS ( <i>cycles 1 to 222</i> ) | $1.03 \pm 2.6$ | 36.2 | 196          |
| Track 088 (UTAS) ( <i>cycles 1 to 222</i> )                                | $-0.8 \pm 2.4$ | 34.0 | 196          |

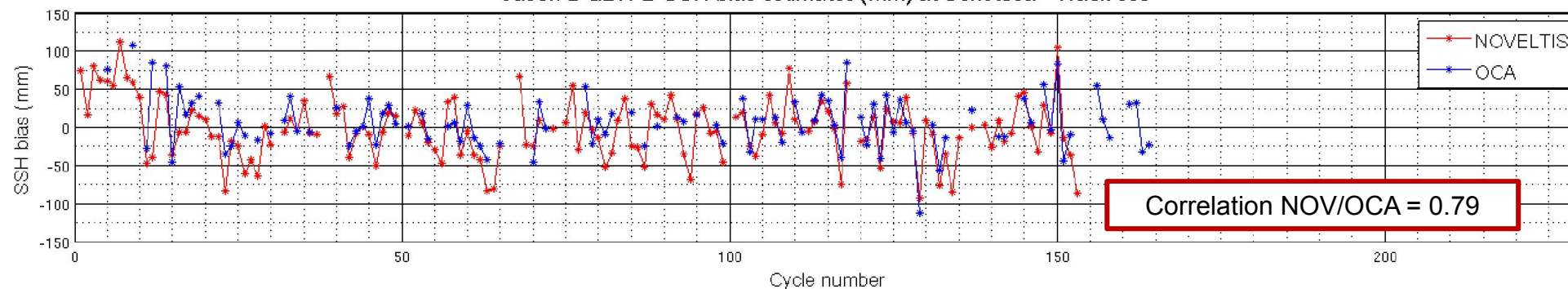


Jason-2 GDR-D SSH bias estimates (mm) at Bass Strait - Track 088

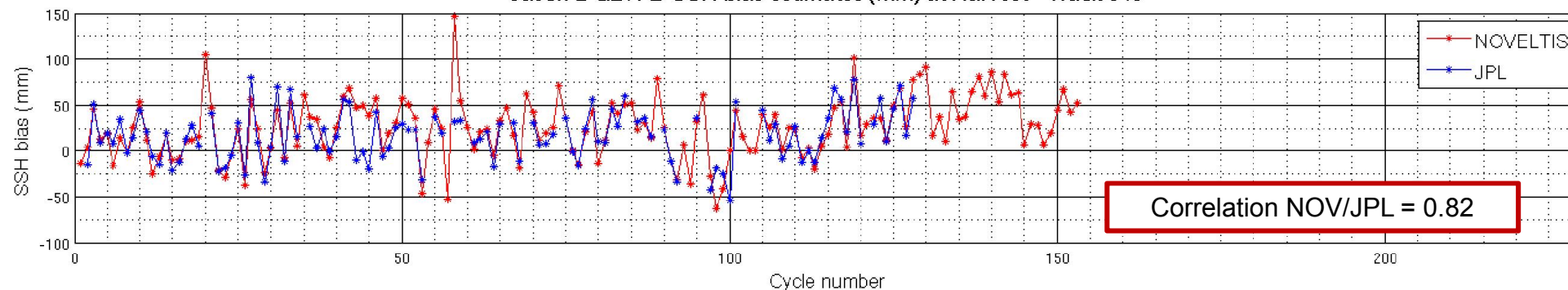




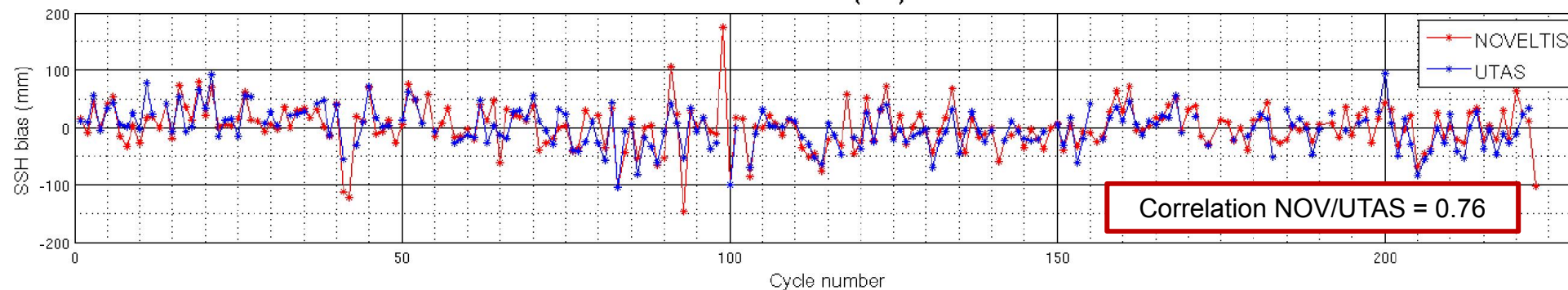
Jason-2 GDR-D SSH bias estimates (mm) at Senetosa - Track 085



Jason-2 GDR-D SSH bias estimates (mm) at Harvest - Track 043



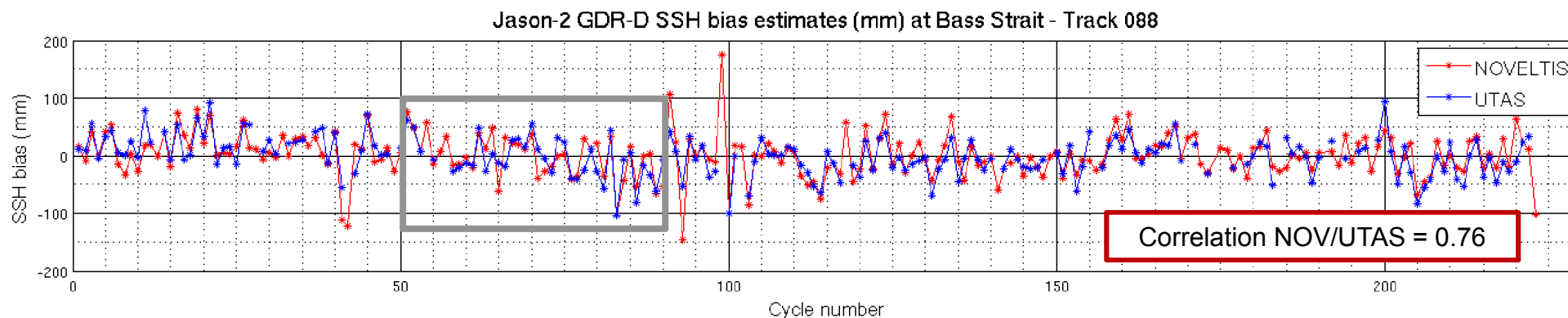
Jason-2 GDR-D SSH bias estimates (mm) at Bass Strait - Track 088





## Jason-2 CALVAL in Corsica, at Harvest and at Bass Strait

- ✓ Jason-2 GDR-D regional bias estimates close to 0 as expected
- ✓ Very good agreement between the local methods and Noveltis method, at the 3 sites
- ✓ Very coherent results from one site to the other
- ✓ At Bass Strait (most recent results):
  - no identified drift in the bias on the recent period
  - between ~cycles 50 and 80 (2009-2010), both techniques reveal an unexpected negative drift in the bias (unexplained at the moment)



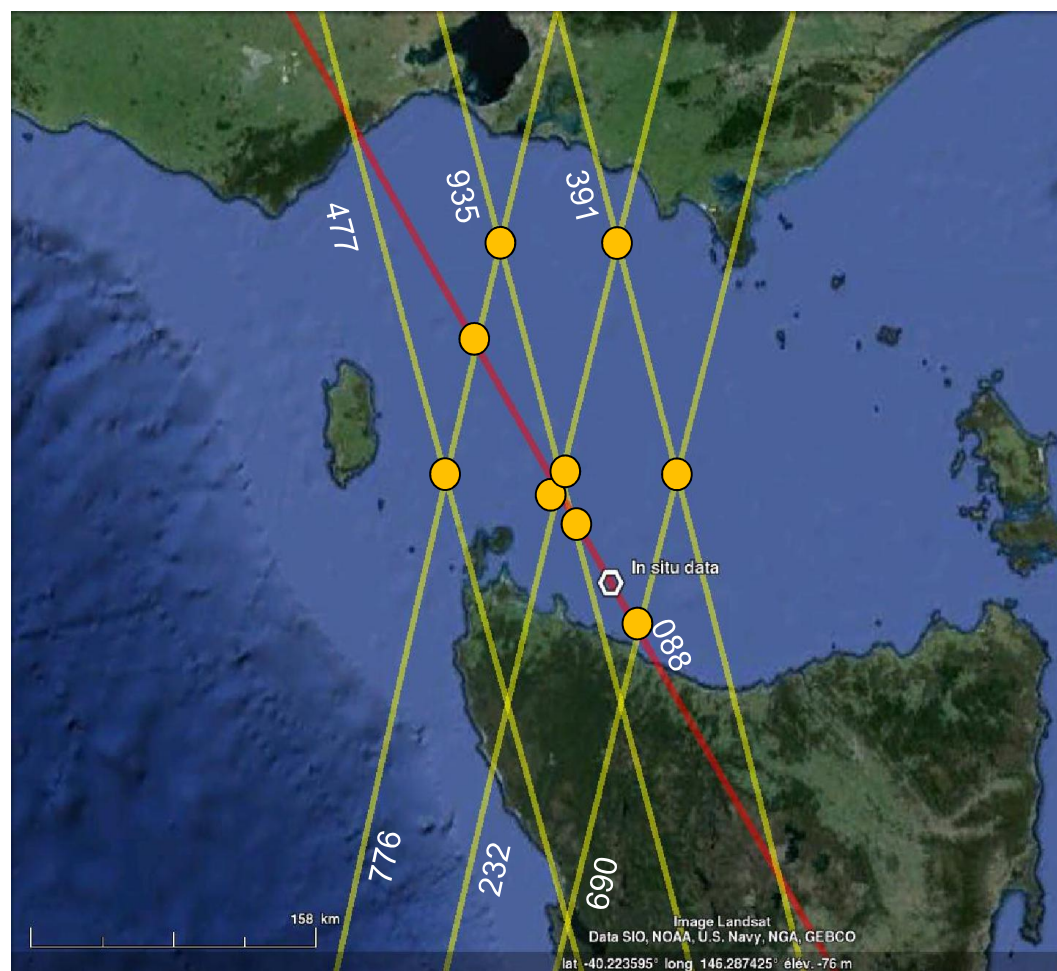




## Envisat regional CALVAL results

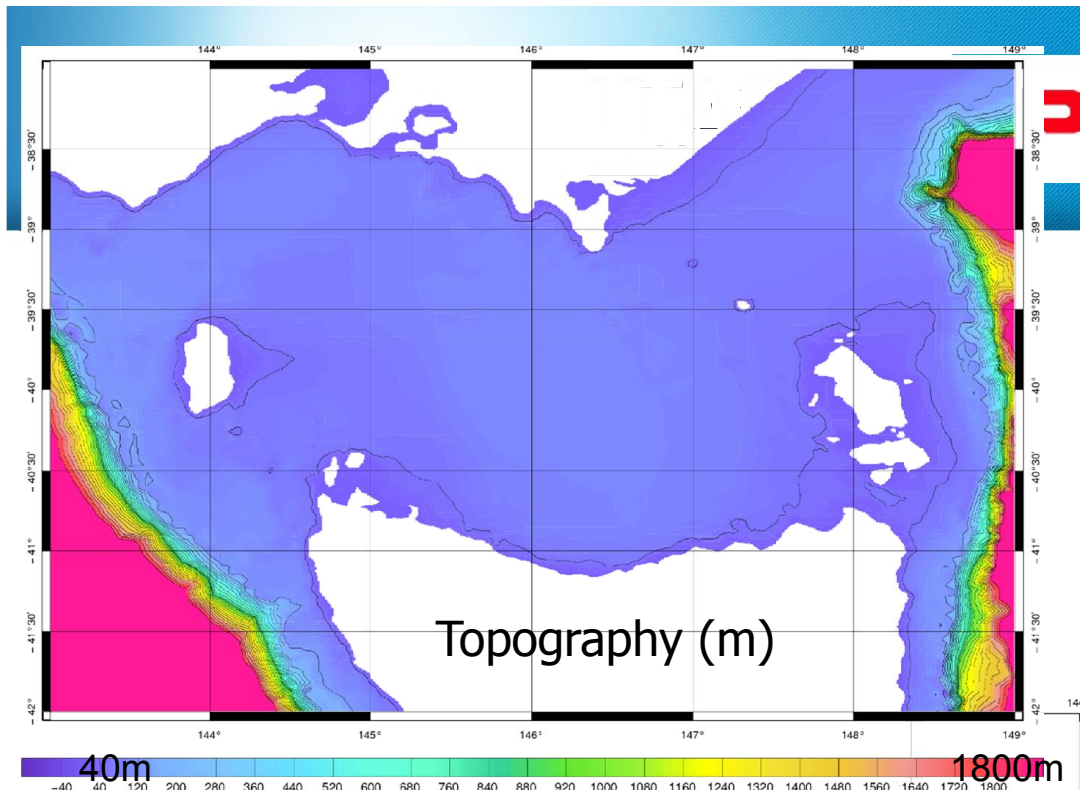


## Envisat CALVAL at Bass Strait (nominal orbit)



● Initial selection of crossover points

Much variability in the bias estimates at the farthest offshore points, even with the tide/DAC corrections.

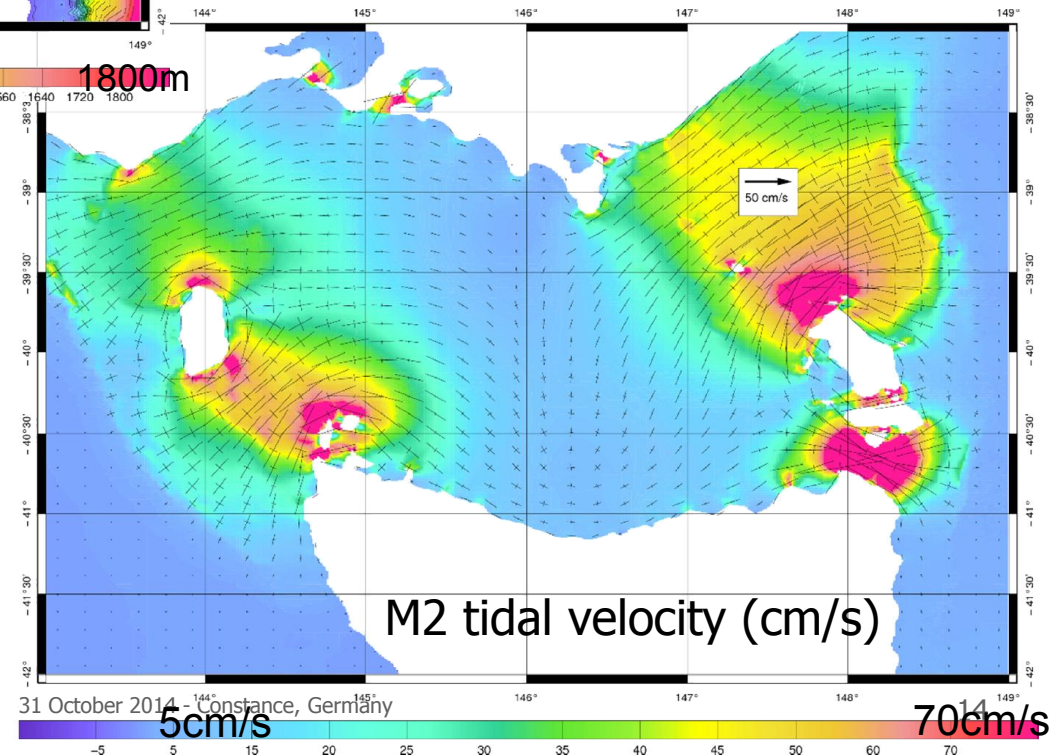


(From "Coastal and Marine Ecology of Temperate Australia" edited by A.J. Underwood & M.G. Chapman. UNSW Press)

Bass Strait = Shallow region (~40m)

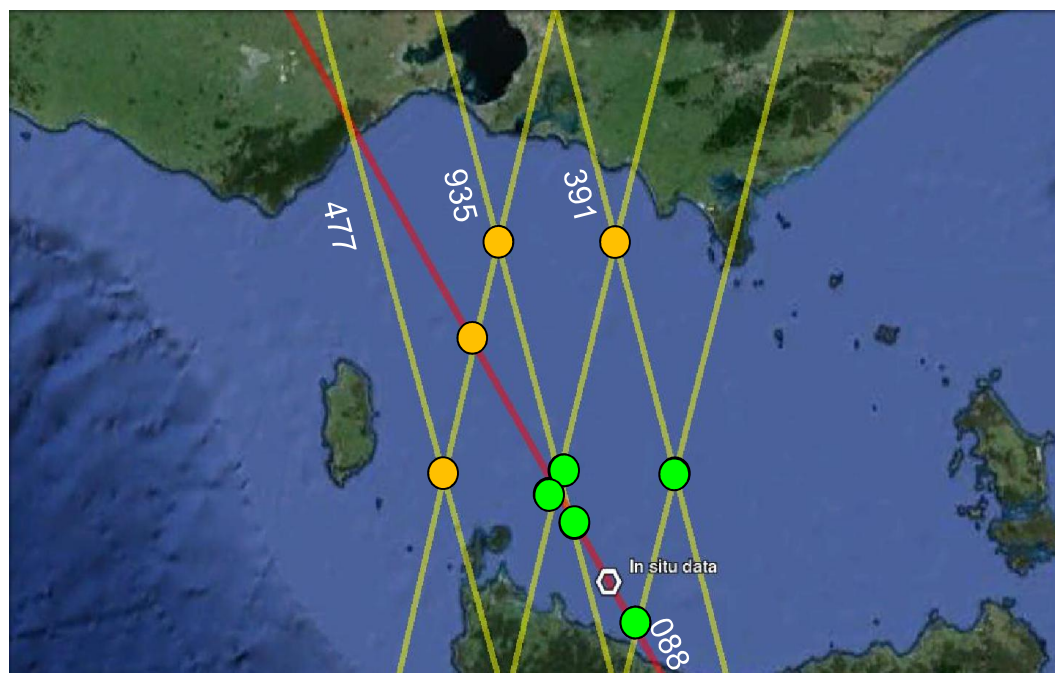
- + strong tidal currents
- + strong winds
- + strong currents' effects (EAC, Leeuwin Current)

- ➔ Much complex ocean circulation
- ➔ Impact on the offshore SSH bias





## Envisat CALVAL at Bass Strait (nominal orbit)



- Initial selection of crossover points
- Final selection

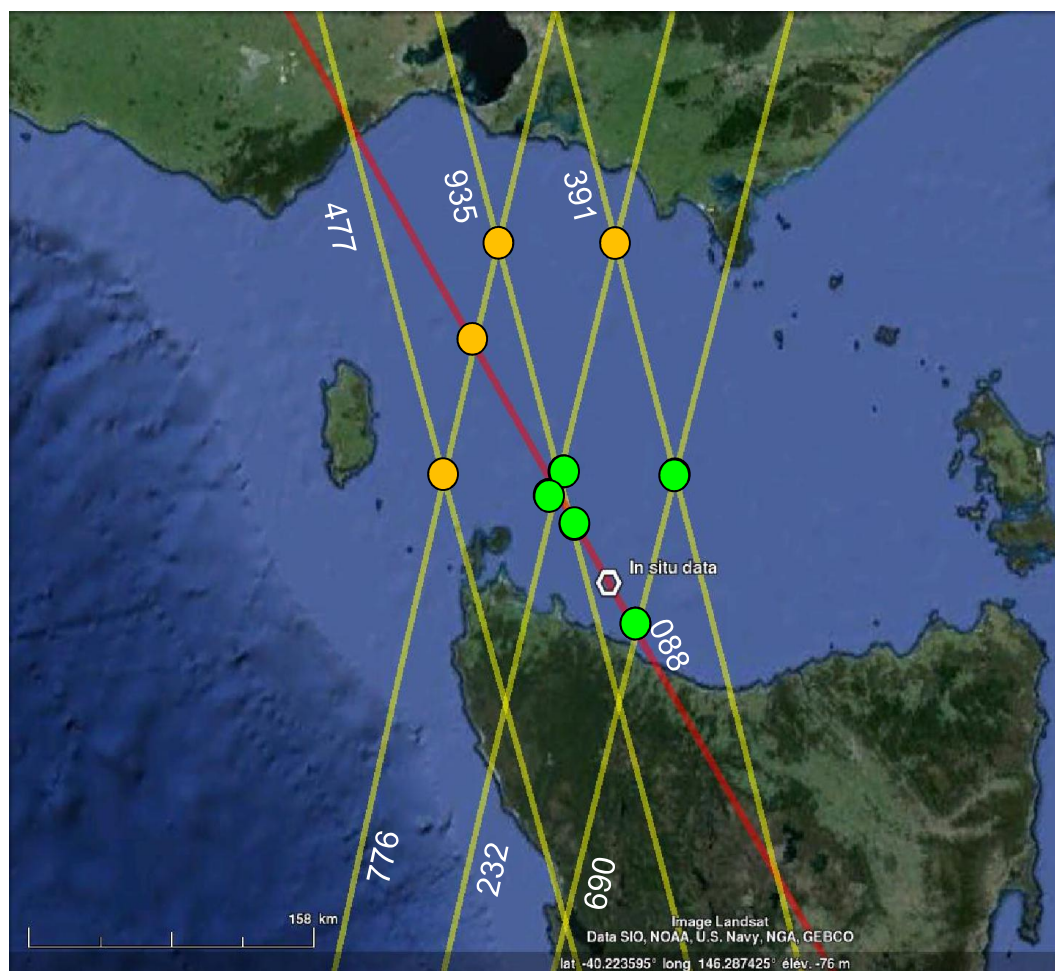
Much variability in the bias estimates at the farthest offshore points, even with the tide/DAC corrections.



| Envisat bias (mm)<br><b>BASS STRAIT</b> | No ocean dynamics correction |              |              | With ocean dynamics correction |             |              |
|---|------------------------------|--------------|--------------|--------------------------------|-------------|--------------|
|   | Mean                         | Std          | Nb of cycles | Mean                           | Std         | Nb of cycles |
| <b>Regional bias (mean)</b>             | <b>481.2</b>                 | <b>157.4</b> | <b>84</b>    | <b>494.1</b>                   | <b>59.2</b> | <b>84</b>    |



Very significant effect of the tide and DAC corrections

## Envisat CALVAL at Bass Strait (nominal orbit)



-  Initial selection of crossover points
-  Final selection

Much variability in the bias estimates at the farthest offshore points, even with the tide/DAC corrections.

- ➔ High resolution tide and DAC corrections (regional model) ?
- ➔ Additional ocean circulation delta-correction ?  
Ex : BRAN (IMOS)

➔ *To be tested...*



## Envisat CALVAL at Bass Strait (nominal orbit) **GDR-C v2.1**

| Envisat bias (mm)<br><b>BASS STRAIT</b> | With ocean dynamics correction |      |              |
|---|--------------------------------|------|--------------|
|   | Mean                           | Std  | Nb of cycles |
| Regional bias (mean)                    | 494.1                          | 59.2 | 84           |

| Envisat bias (mm)<br><b>HARVEST (OSTST 2013)</b> | With ocean dynamics correction |     |              |
|--|--------------------------------|-----|--------------|
|  | Mean                           | Std | Nb of cycles |
| Regional bias at Harvest (mean)                  | 480                            | 73  | 80           |

| Envisat bias (mm)<br><b>CORSICA (OSTST 2013)</b> | With ocean dynamics correction |     |              |
|--|--------------------------------|-----|--------------|
|  | Mean                           | Std | Nb of cycles |
| Regional bias at Ajaccio (mean)                  | 467                            | 50  | 56           |
| Regional bias at Senetosa (mean)                 | 437                            | 42  | 81           |

← Still unexplained

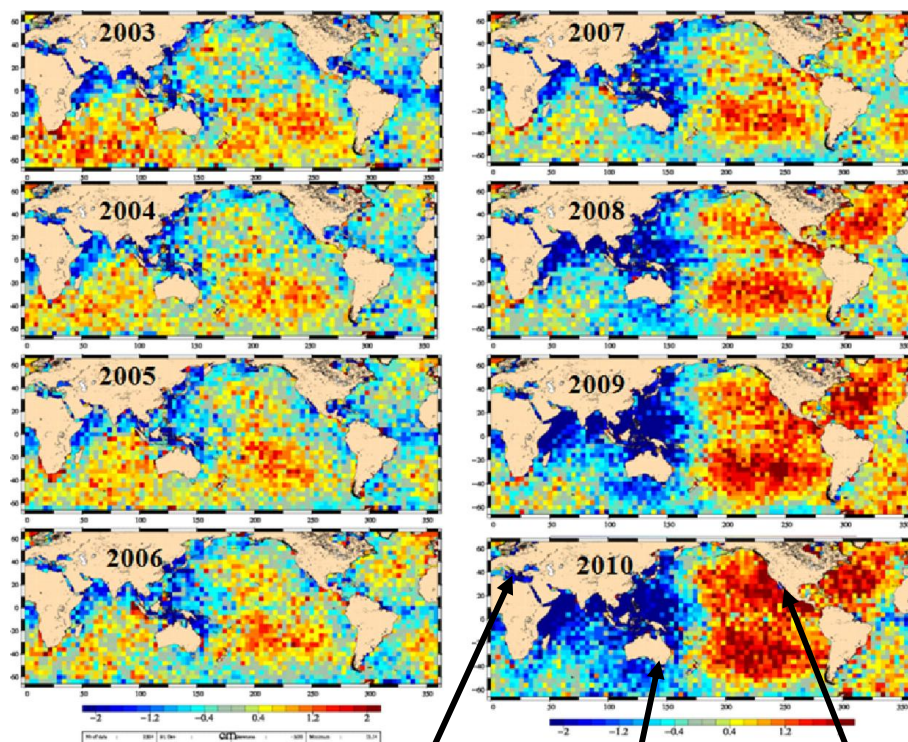
Differences in the bias estimates from one site to the other:

→ Linked to GDR-C orbit patterns ?

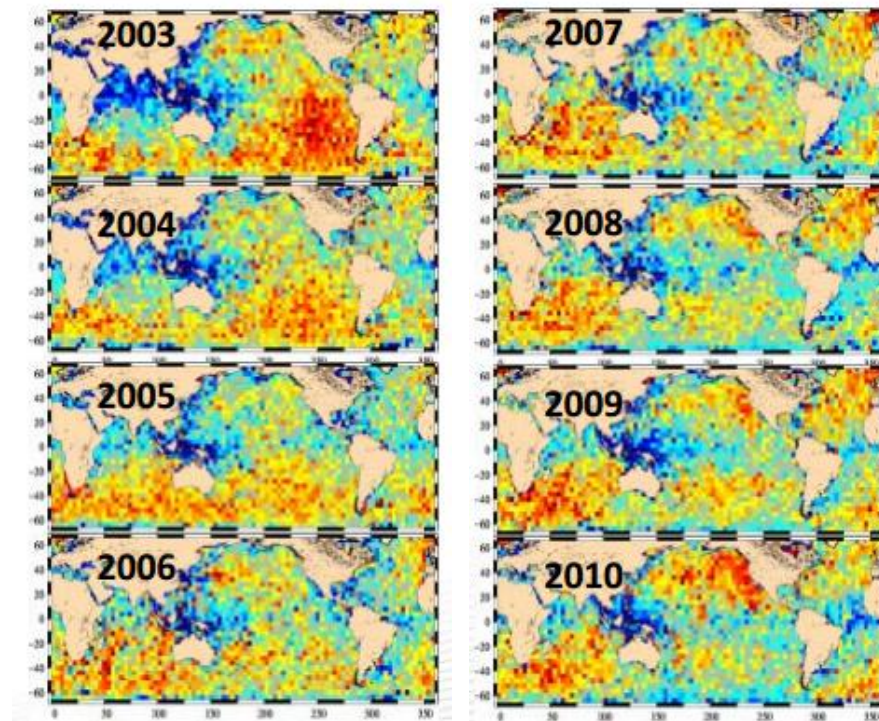
## Envisat CALVAL (nominal orbit)

Comparison Envisat GDR-C v2.1 products vs Jason-1 with GDR-D orbit  
(from A. Ollivier, OSTST 2012)

Envisat – GDR-C orbit



Envisat – GDR-D orbit





## Envisat CALVAL at Bass Strait (nominal orbit) GDR-D orbit

- ✓ Envisat GDR-D orbits downloaded via ESA ftp site

→ Remark: would be more convenient if available directly at the 1Hz/18Hz dates of measurement

- ✓ Recomputation of the bias estimates at each calibration site with the new orbit values:

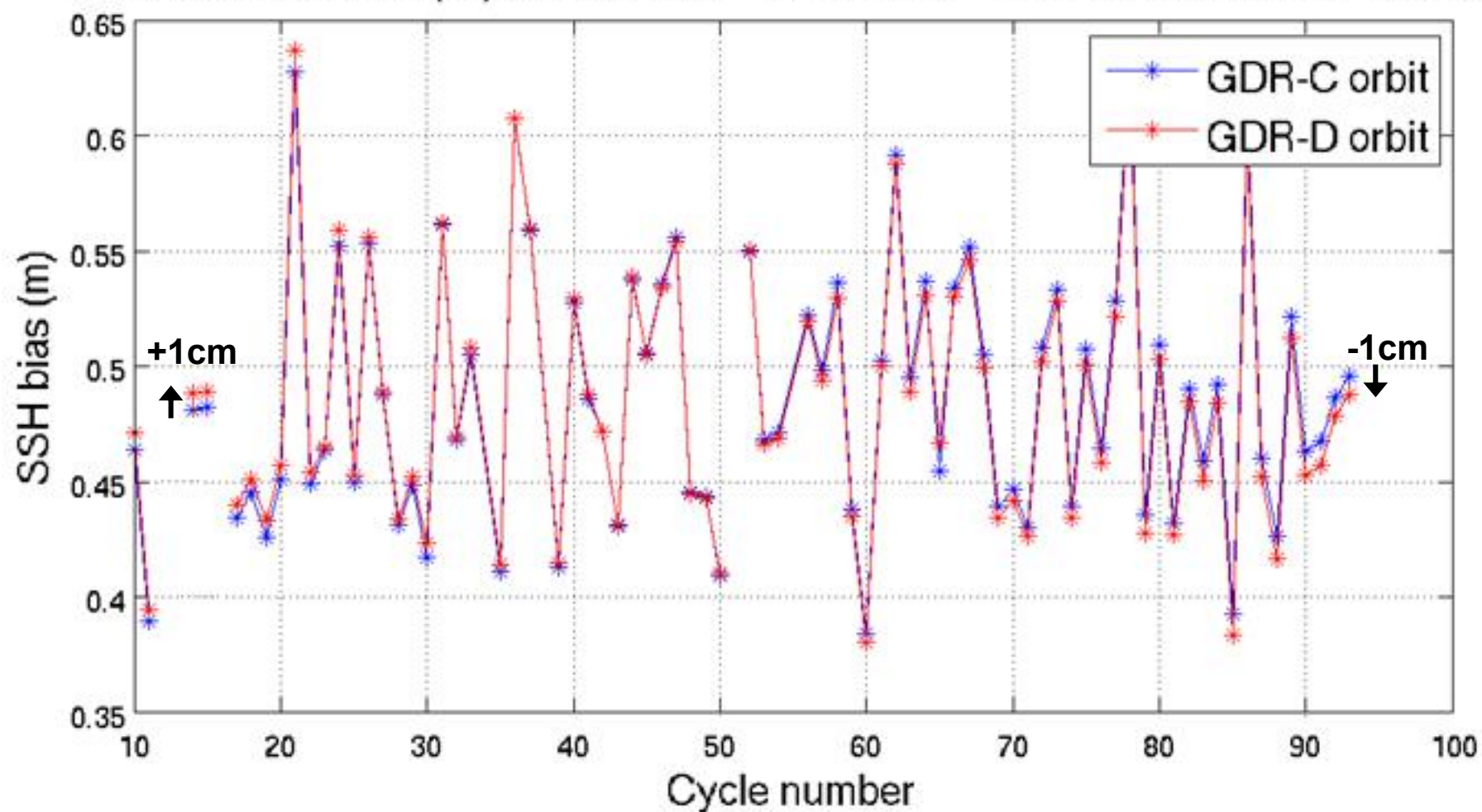
*Example at Bass Strait:*

| Envisat bias (mm)<br><b>BASS STRAIT</b> | GDR-C orbit |      |              | GDR-D orbit |      |              |
|---|-------------|------|--------------|-------------|------|--------------|
|   | Mean        | Std  | Nb of cycles | Mean        | Std  | Nb of cycles |
| Regional bias (mean)                    | 494.1       | 59.2 | 84           | 495.0       | 58.3 | 84           |

- ➔ No major impact on the mean regional bias
- ➔ Same conclusion for the other sites (Corsica and Harvest)

## Envisat CALVAL (nominal orbit) GDR-D orbit

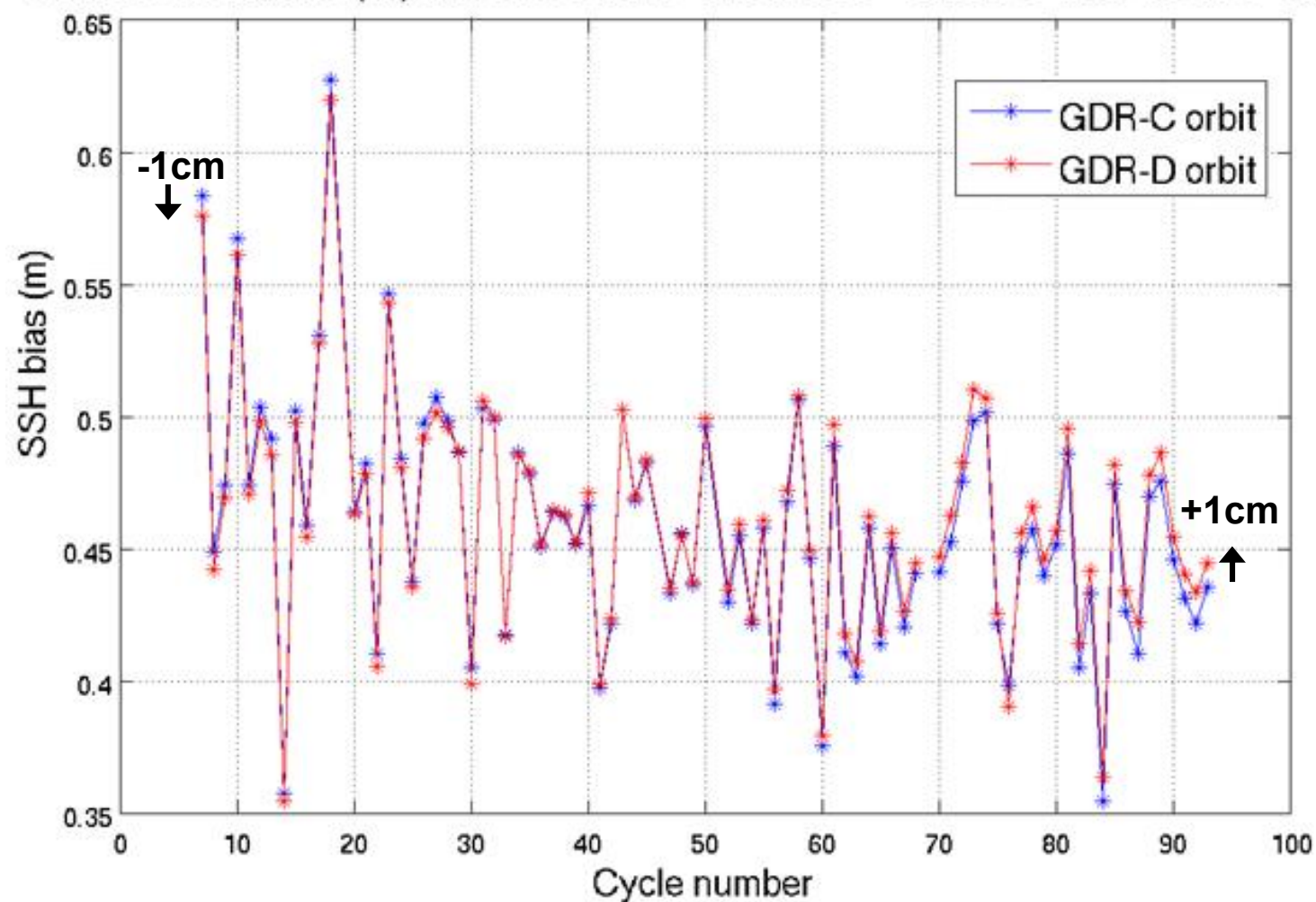
Envisat SSH bias (m) at Harvest - track 239 - GDR-C and GDR-D orbits





## Envisat CALVAL (nominal orbit) GDR-D orbit

Envisat SSH bias (m) at Bass Strait - track 690 - GDR-C and GDR-D orbits

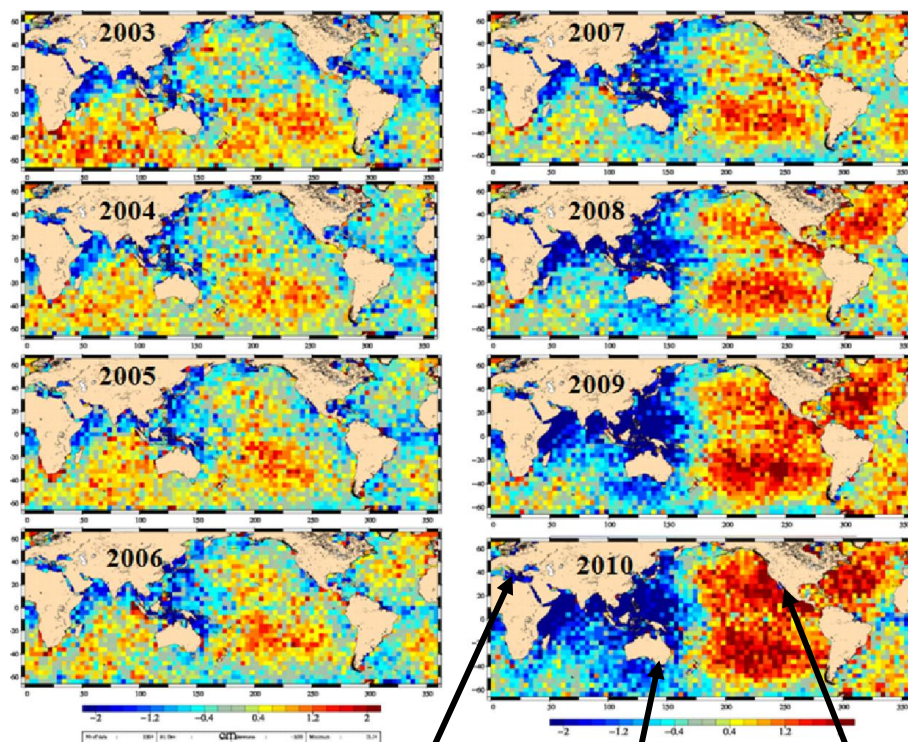




## Envisat CALVAL at Bass Strait (nominal orbit) **GDR-C orbit**

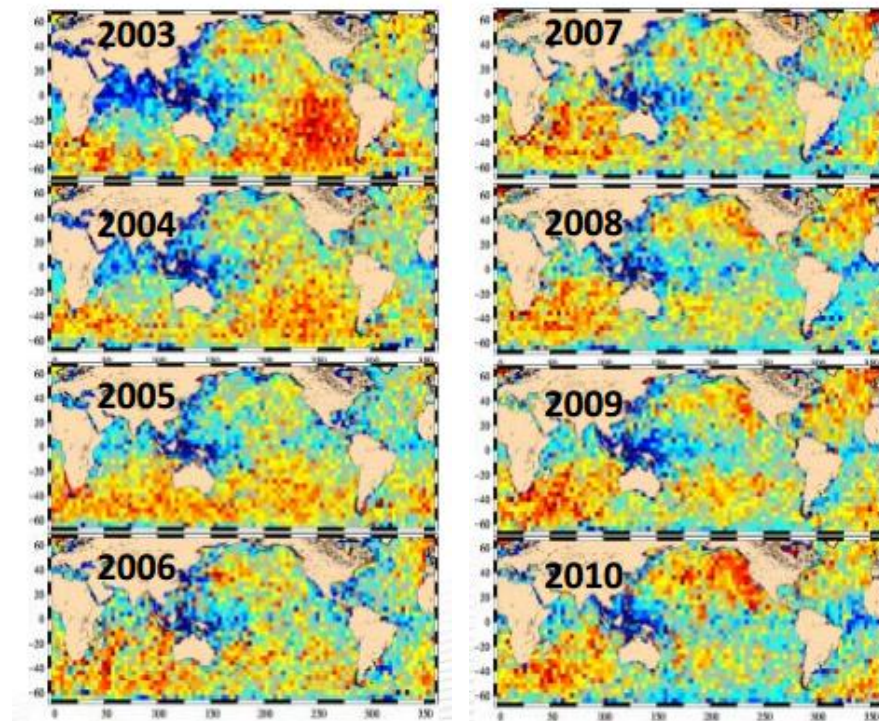
Comparison Envisat GDR-C v2.1 products vs Jason-1 with GDR-D orbit  
(from A. Ollivier, OSTST 2012)

Envisat – GDR-C orbit



Corsica Bass Strait Harvest

Envisat – GDR-D orbit





## Conclusions

- ✓ Regional CALVAL = Link between the local and global cal/val methods
  - Consistency with the other groups
    - At the local scale: UTAS, OCA and JPL results
    - At the global scale: CLS results
- ✓ First calibration of Envisat at Bass Strait !
  - Challenging site (complex ocean circulation), demanding high resolution modeling (tide, DAC, ocean circulation ?)
- ✓ Differences in the Envisat mean bias estimates at the various sites
  - Not due to the GDR-C orbits
  - Geographically correlated biases / errors in the corrections ?
  - Effect of residual ocean dynamics at some sites ?
- ✓ Clear impact of the GDR-D orbits on the Envisat bias estimate time series



## Perspectives

### *Short term*

- ✓ Investigation of the differences in Envisat bias depending on the site
- ✓ Paper in preparation with UTAS, OCA and JPL

### *Medium term*

- ✓ Implementation of the method for Sentinel-3
- ✓ Jason-2 and SARAL/AltiKa at the three sites ?
- ✓ Implementation of the method at Gavdos ?
- ✓ Any other current or future mission → generic method !