Coastal Sea Level Rise at Senetosa (Corsica) during the Jason altimetry missions *(CCI+ Sea Level Project)*

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ESA CLIMATE CHANGE INITIATIVE EXTENSION (CCI+)
The Coastal Sea Level Project (2019-2022)

4 Partners ➡️ CLS | LEGOS | TUM TECHNISCHE UNIVERSITÄT MÜNCHEN | National Oceanography Centre NATURAL ENVIRONMENT RESEARCH COUNCIL

➡️ JF. Legeais (CLS), Project manager
A. Cazenave (Legos), scientific coordinator
M. Passaro (TUM), team leader
F. Calafat (NOC), team leader

Objectives:

➢ Produce, validate and deliver consistent sea level time series in several coastal regions worldwide

➢ Compute sea level trends as close as possible to the coast in order to answer the question :" **Is sea level at the coast rising at the same rate as in the open ocean?**"

Approach:

➢ Use of **ALES (Adaptive Leading Edge Subwaveform)** retracking developed by Passaro et al. 2014 (TUM) + associated Sea State Bias (SSB) (Passaro et al., 2018)

➢ Use of **X-TRACK processing system** developed at LEGOS (CTOH; Birol et al., 2017)

6 regions considered:

Western Europe, Mediterranean Sea, Western Africa, Southeast Asia, Australia, India
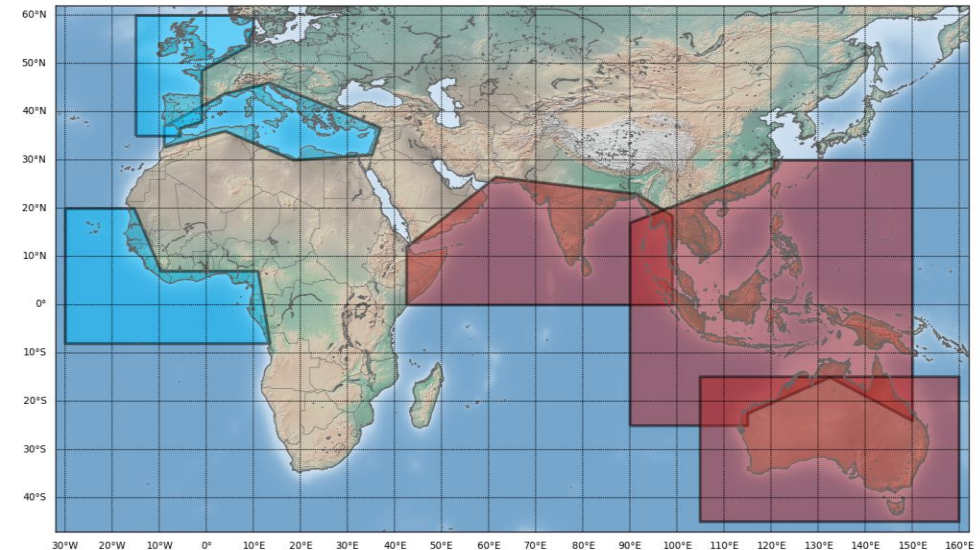
2.Focus on the Senetosa site

- **Located western Mediterranean sea, south of Corsisa**

- **Calibration site for the Topex/Poseidon and Jason missions instrumented with tide gauges and GNSS antenna**
  - ➢ **3 Tide gauges available over the study period**

Sea level trend (July 2002 - June 2016) - C3S product
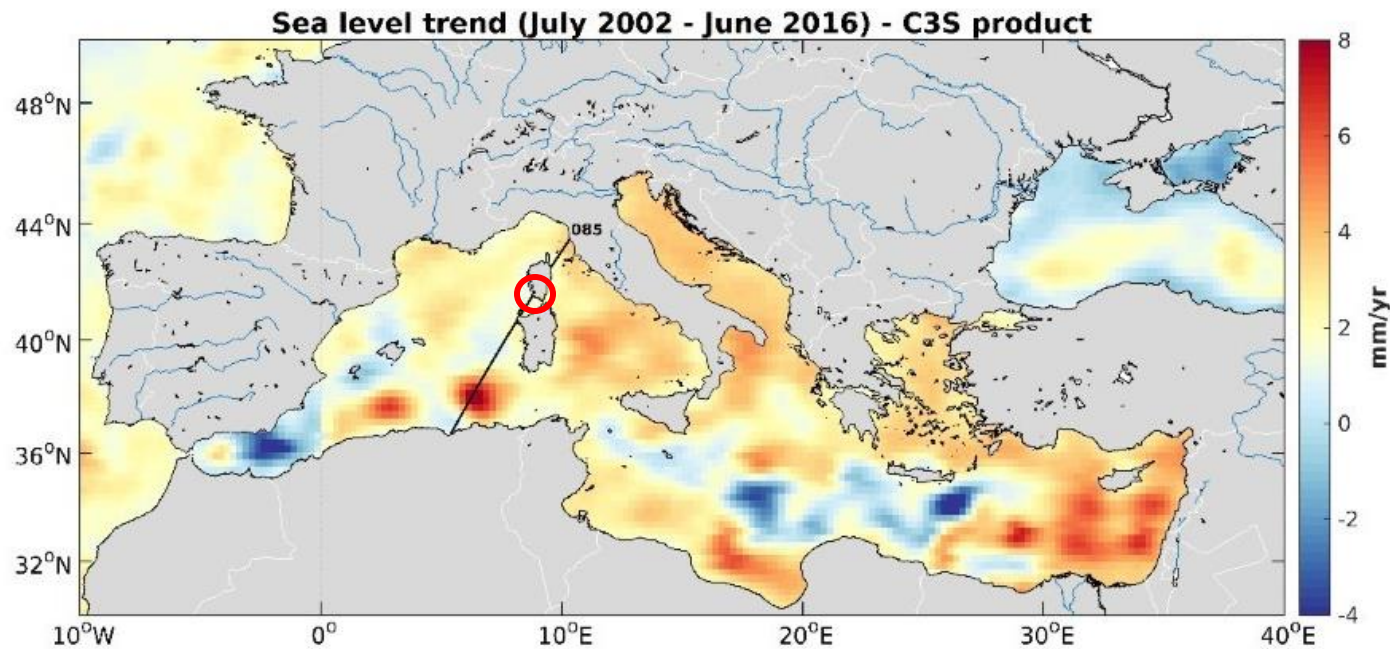
Google map of the Senetosa area

Tide gauge

Jason track

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3. CURRENT ANALYSIS

➤ **Missions considered so far:** Jason 1, Jason 2, Jason 3

➤ **Data: High resolution (20 Hz) sea level data from X-TRACK/ALES**

➤ **Period: July 2002 to June 2016 :** 14 years **& June 2002 to May 2018:** 16 years

➤ **Monthly averaging of sea level anomalies**

➤ **Annual and semi-annual signals removed**

➤ **Sea level trends computed at individual 20 Hz point along the satellite tracks, with focus on the last 15 km to the coast**

➤ **Each 20 Hz point is characterized by its distance to the nearest coast**
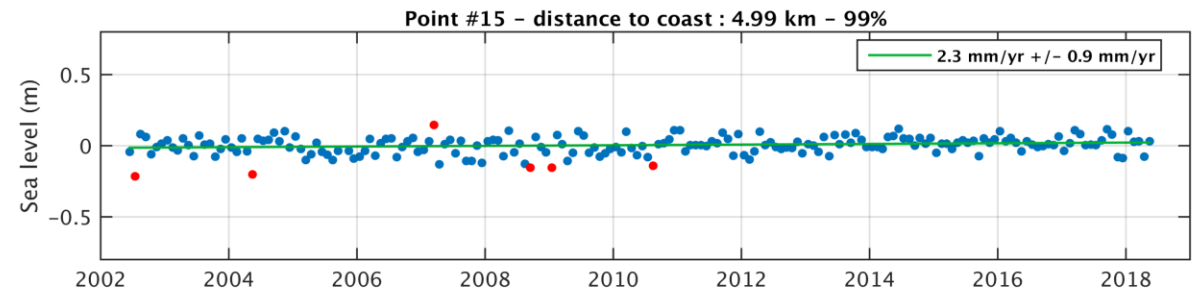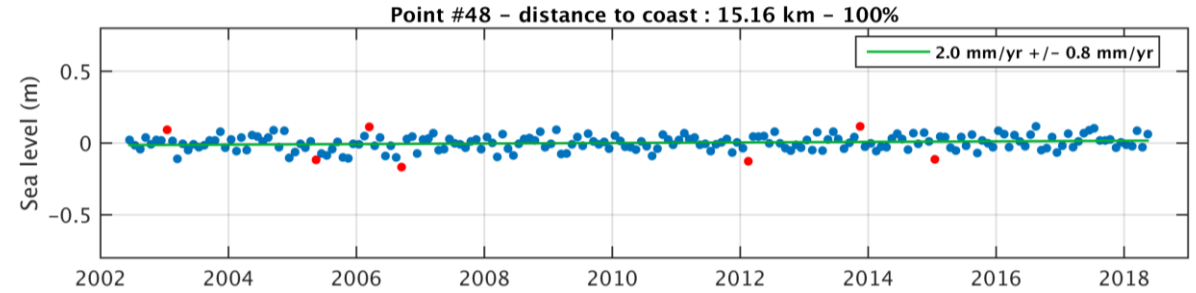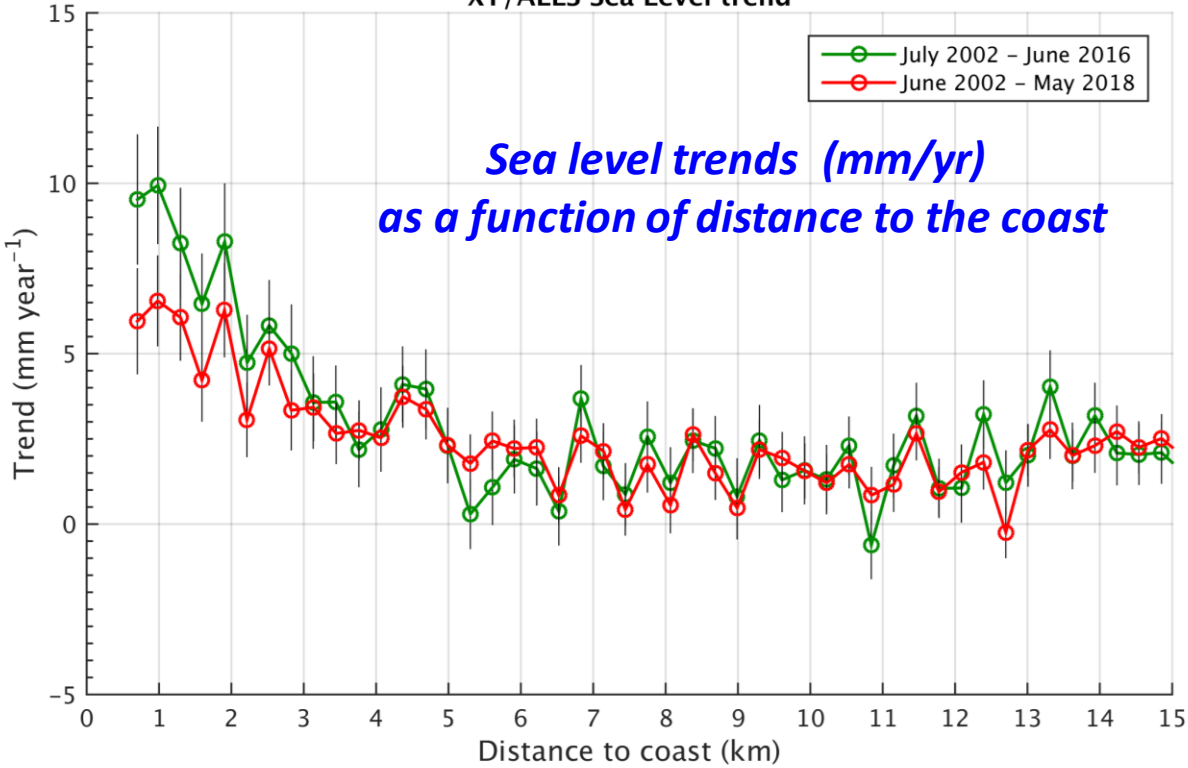
(GSHHS database; Smith & Wessel)

Preliminary results for Western Africa published in Marti et al., ASR, 2019
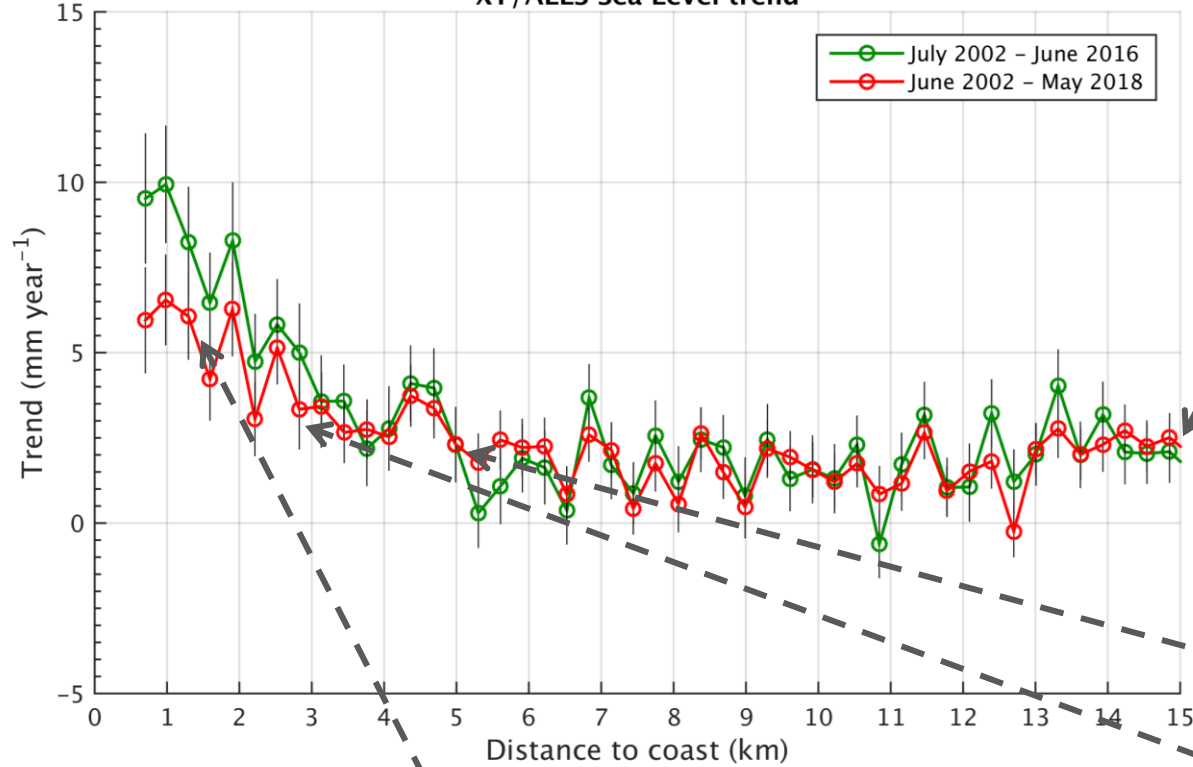
4. Coastal Sea Level Trends at Senetosa

Period 1: 2002-2016 (J1+J2)   Period 2: 2002-2018 (J1+J2+J3)
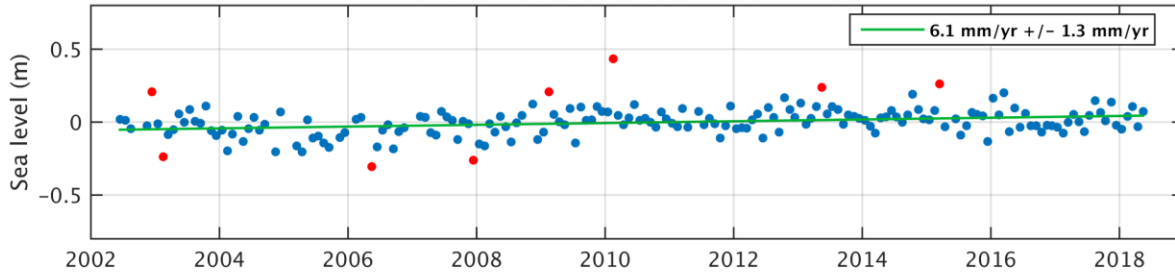

XT/ALES Sea Level trend
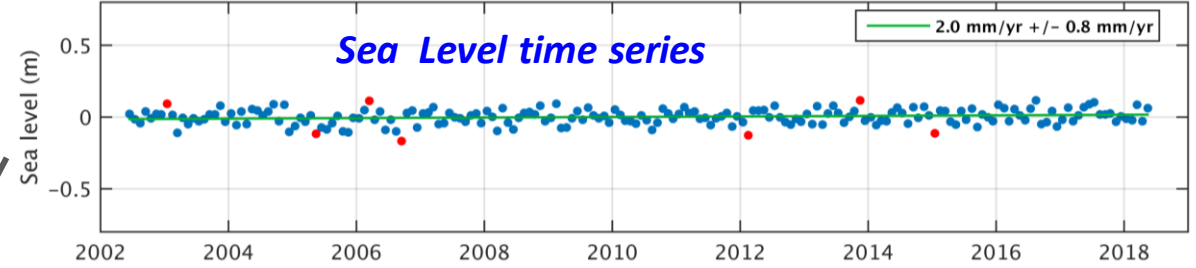
Sea level trends (mm/yr) as a function of distance to the coast

4. Coastal Sea Level Trends at Senetosa

Period 1: 2002-2016 (J1+J2)   Period 2: 2002-2018 (J1+J2+J3)

Questions:

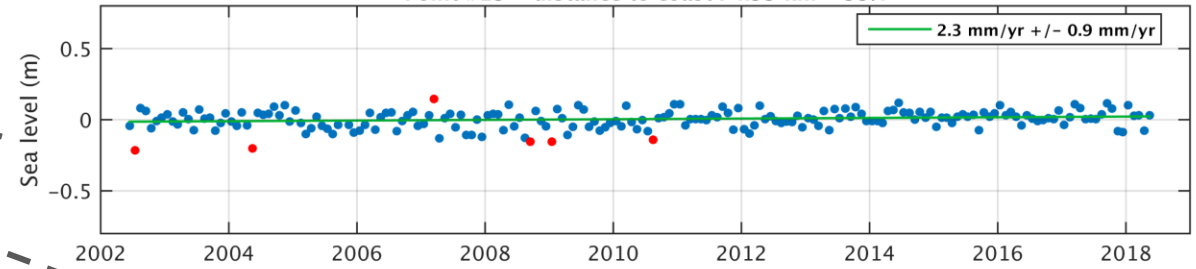**(1) Is the trend increase in the last 4-5 km to the coast due to artefacts in the data processing?**

Or
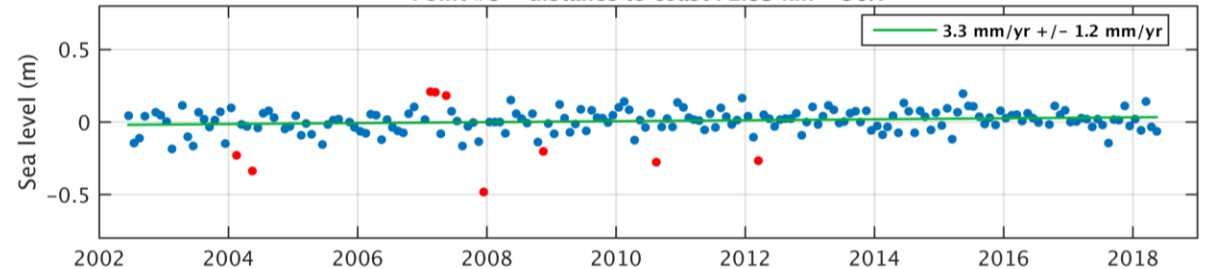
(2) Is it due to real physical processes?

Questions:

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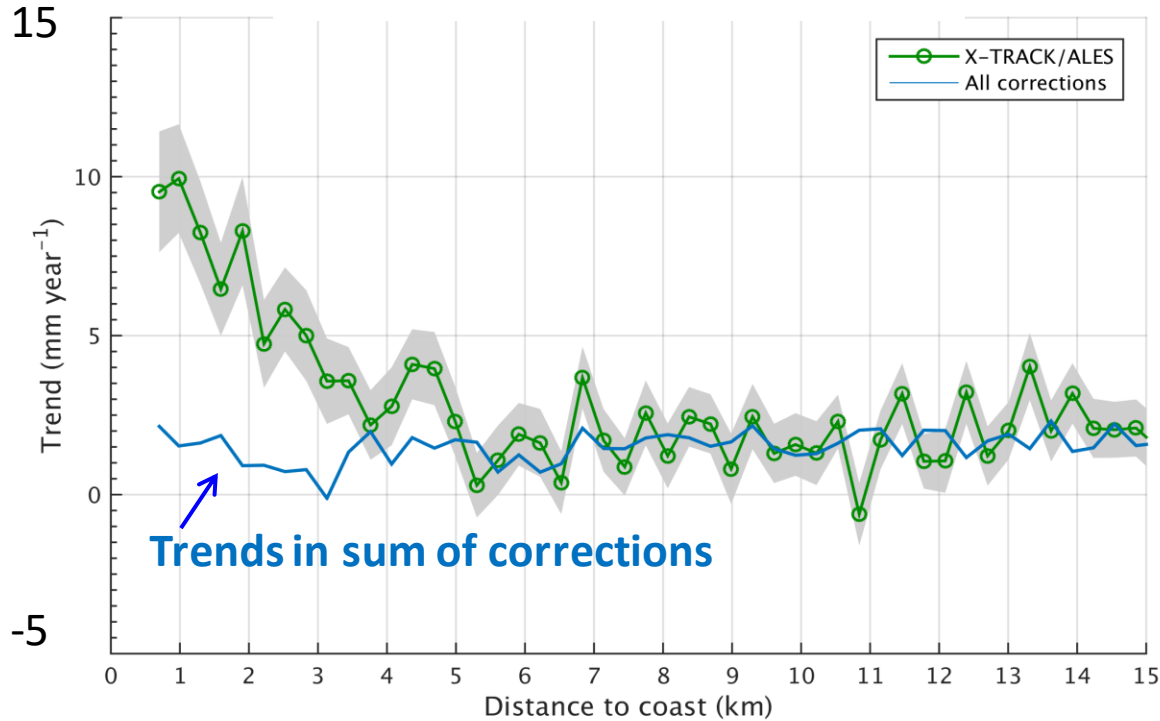
Or

(2) Is it due to real physical processes?

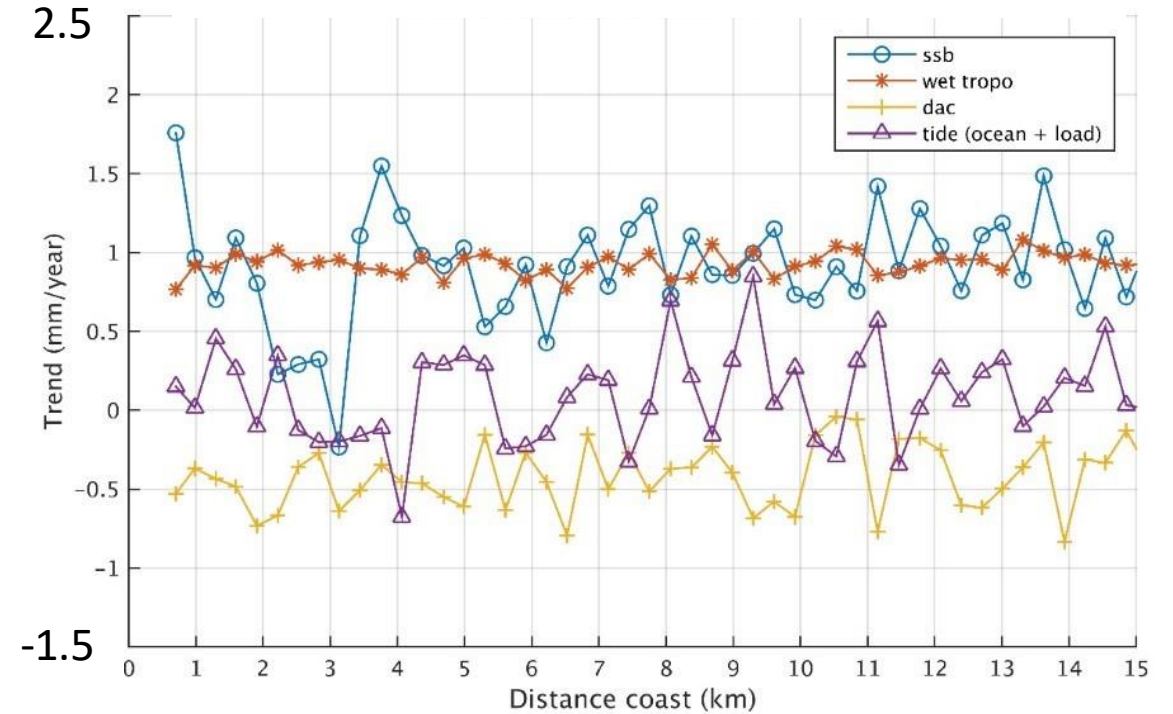*A series of tests have been performed to investigate question 1...*

Note: Tests have been performed over period 1 (2002-2016) but might be valid for the period 2 (2002-2018)

5.1 Trends in the geophysical corrections

Sea level trends

Trends in geophysical corrections as a function of distance to the coast

Trends in sum of corrections

- Geophysical corrections relatively stable, especially Wet Tropospheric correction

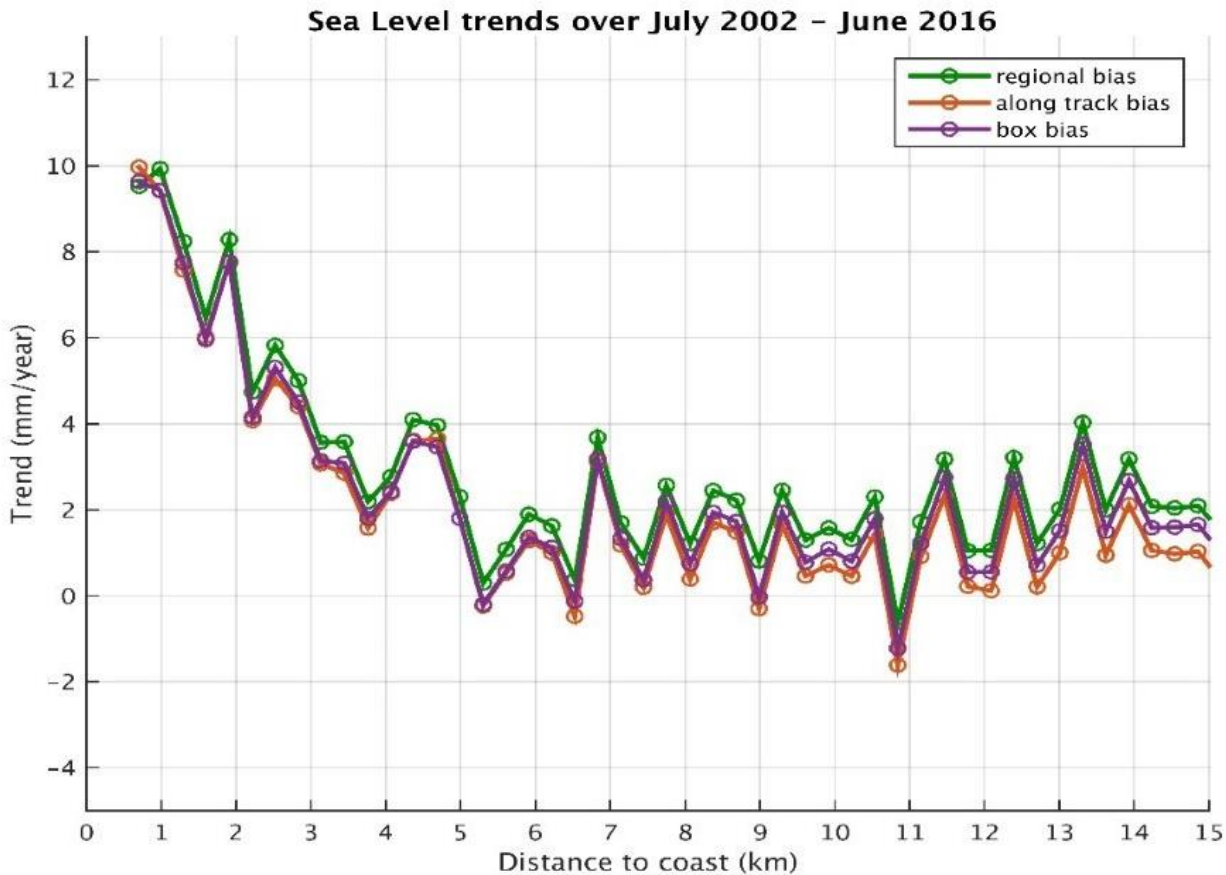- SSB trends begin to fluctuate from 4 km

➡ **Trends in sum of corrections cannot explain observed SLA trends**

5.2 Effect of intermission bias

3 intermission bias were computed:
- Regional bias: estimated over the Mediterranean Sea
- Along track bias
- Box bias: 1°x1° box

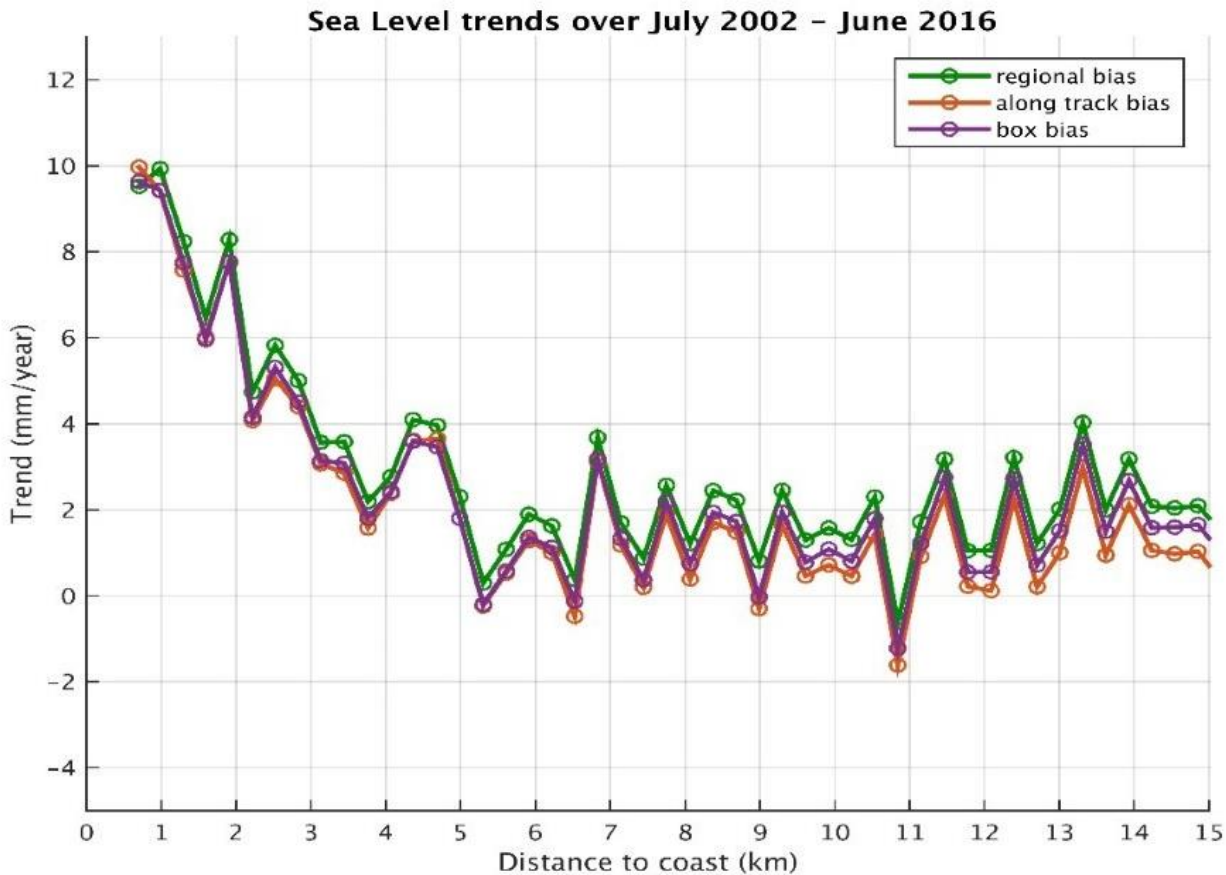Sea Level trends over July 2002 – June 2016

- Whatever the method used to compute the intermission bias, **trends are not affected**

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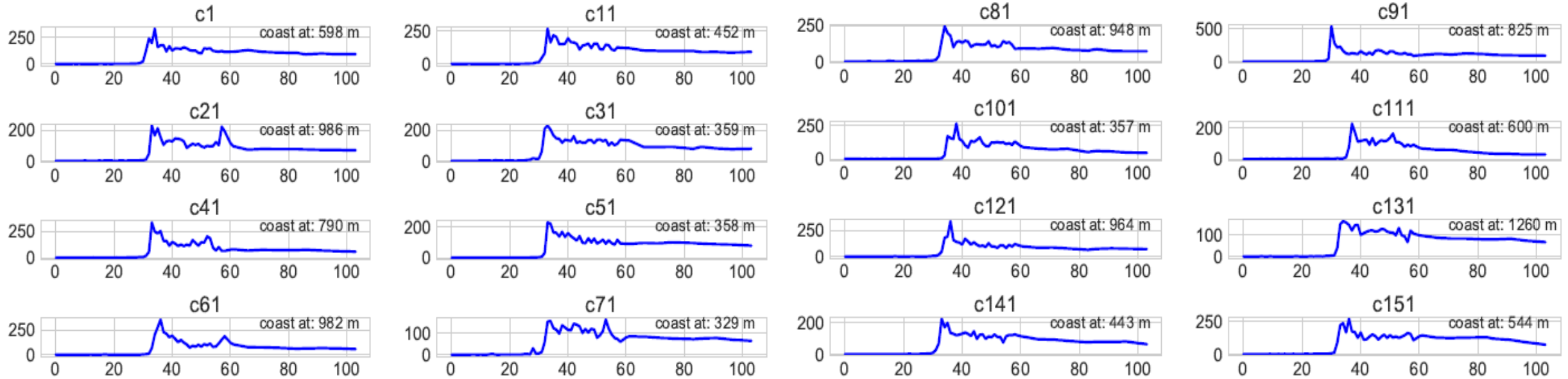

Sea Level trends over July 2002 – June 2016

- Whatever the method used to compute the intermission bias, **trends are not affected**

Instead of using a 'mean sea surface height' as reference, we also used a local geoid ⟶ same result
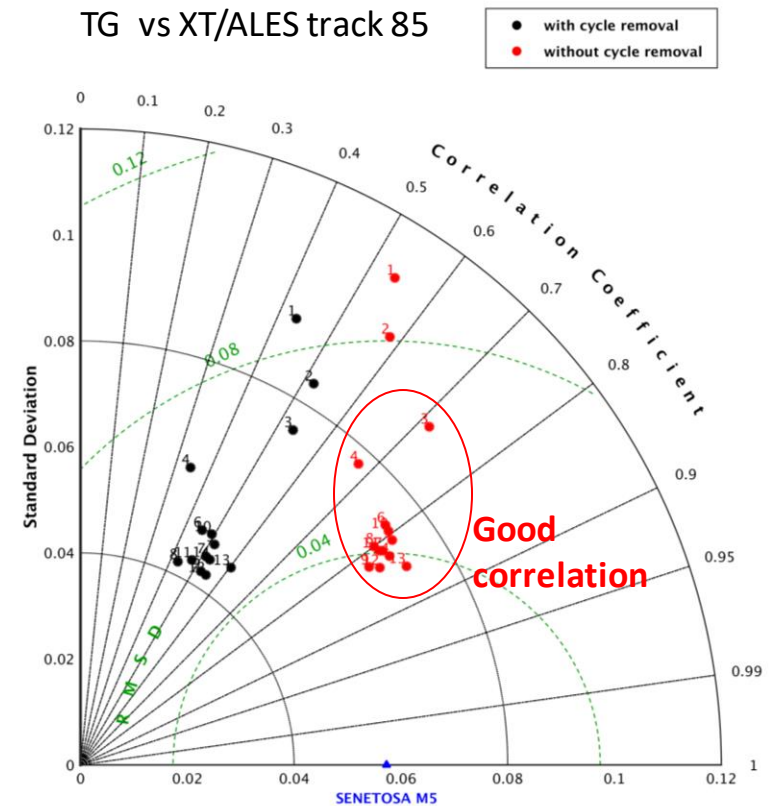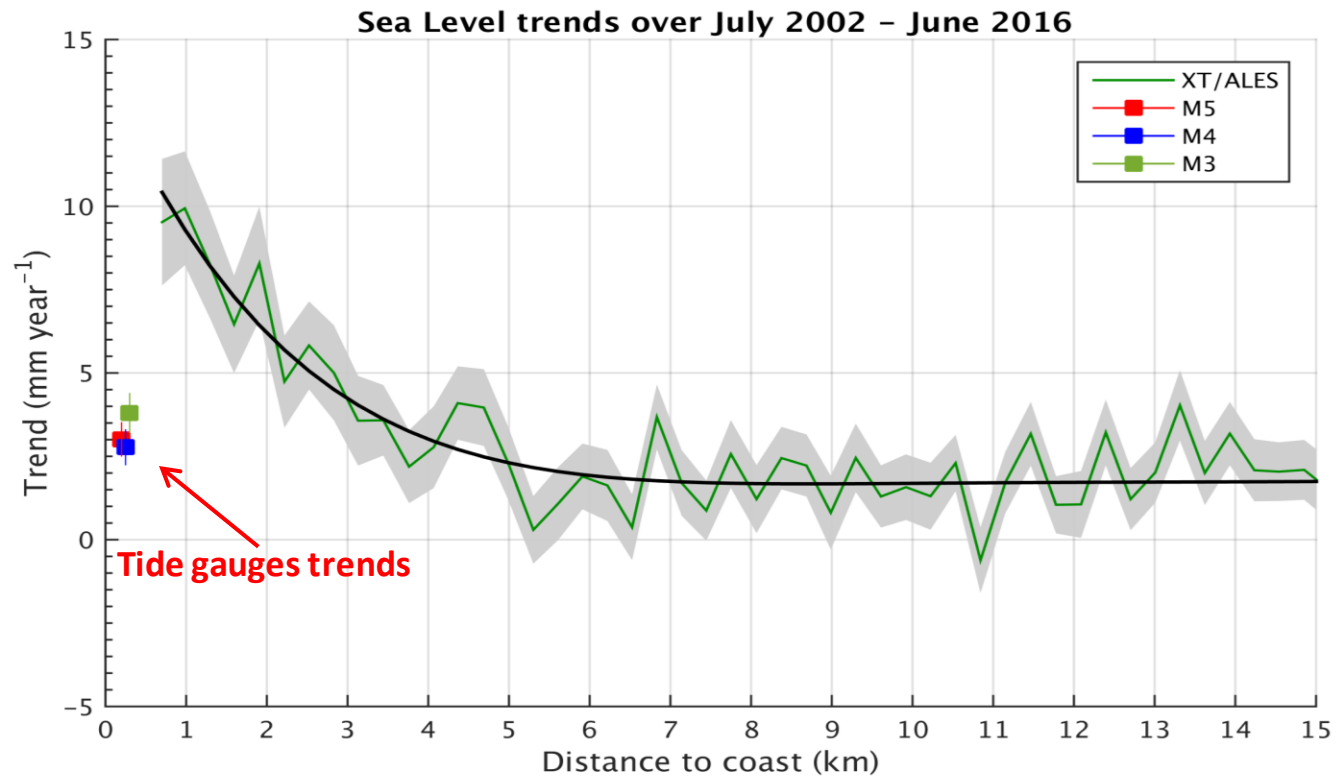
5.3 Waveforms

- Waveforms for Jason missions around 1km from the coast for 16 cycles

> **Waveforms have a leading edge sufficiently well-defined for a robust range determination**

5.4 Comparison with the tide gauges

Sea Level trends over July 2002 – June 2016

XT/ALES
M5
M4
M3

Trend (mm year^{-1})
Distance to coast (km)
Tide gauges trends

TG vs XT/ALES track 85

with cycle removal
without cycle removal

Correlation Coefficient
Standard Deviation
Good correlation
SENETOSA M5

SLA and TG trends agree for distances 2km-5km from coast
Low correlation (<0.6) for distance < 2 km
Note that the correlation begins to decrease from 4 km to coast

- <u>Question</u>: Why are SLA trends for distances < 2km from coast different from tide gauge trends?
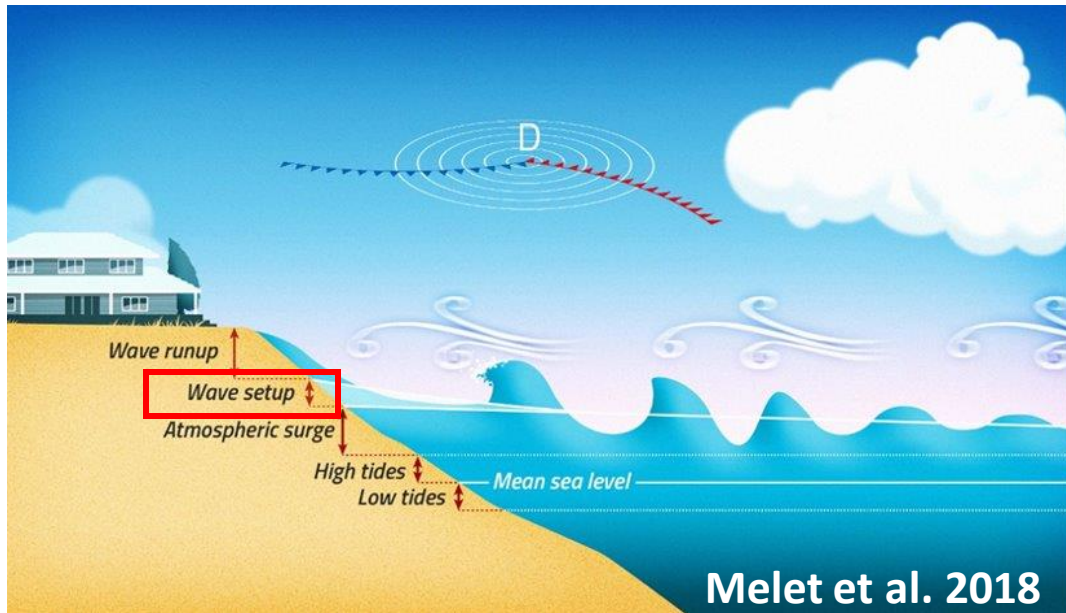
Questions:

(1) Is the trend increase in the last 4-5 km to the coast due to artefacts in the data processing?
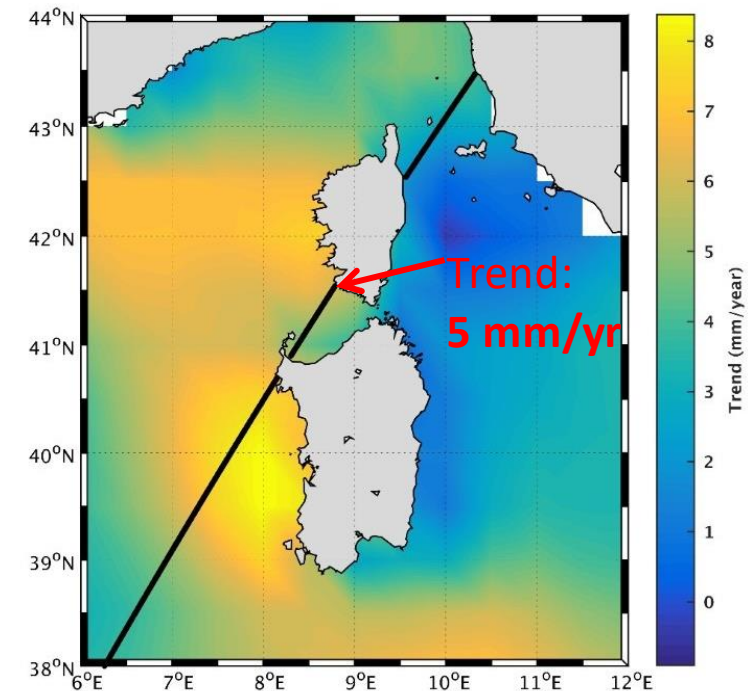
Or

(2) Is it due to real physical processes (waves? coastal current?...)

6.1 Effect of waves on SLA

- **Wave set up** : Time mean sea level elevation at wave breaking location (coast-1km)
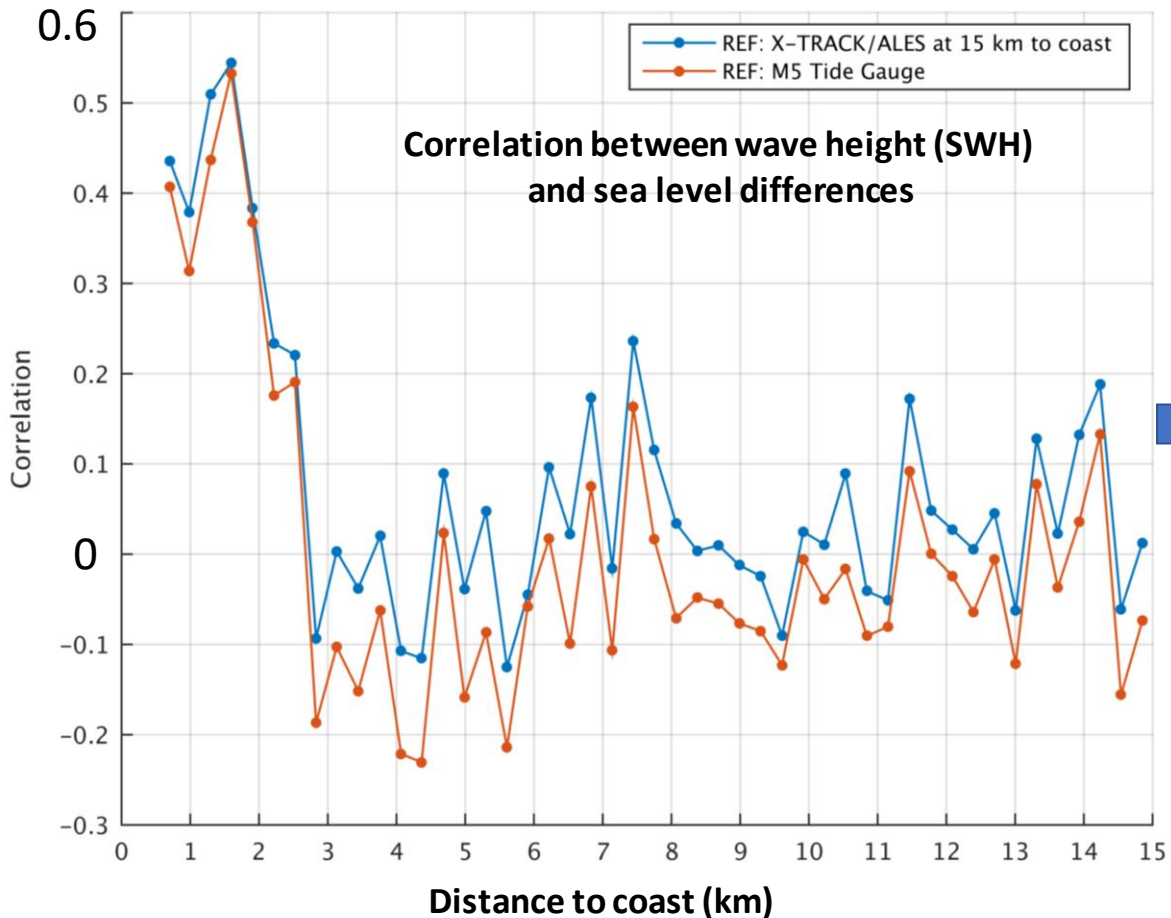 Proportional to offshore Significant Wave Height (SWH)
  ~ 20% of SWH

Melet et al. 2018

SWH **(ERA5 Reanalysis, 0.5° resolution)**

Trend: 5 mm/yr

Wave set up too small (< 1 mm/yr) and too localized close to the coast (X. Bertin, personal communication) → does not explain the observed SLA trend increase

6.2 Effect of waves on SSB (Sea State Bias)

- Correlation computed between SWH and the difference in sea level between each 20 Hz altimetry and a reference:

REF1 : X-TRACK/ALES at 15 km to coast

REF2 : M5 Tide Gauge

Correlation between wave height (SWH) and sea level differences

- Same correlation when considering the 2 references (M5 or the point at 15 km)

  - **Significant correlation between SWH and SLA differences between 1-3km**

  - **No correlation offshore**

Why are the "1km to 3 km" SLAs correlated with SWH ?

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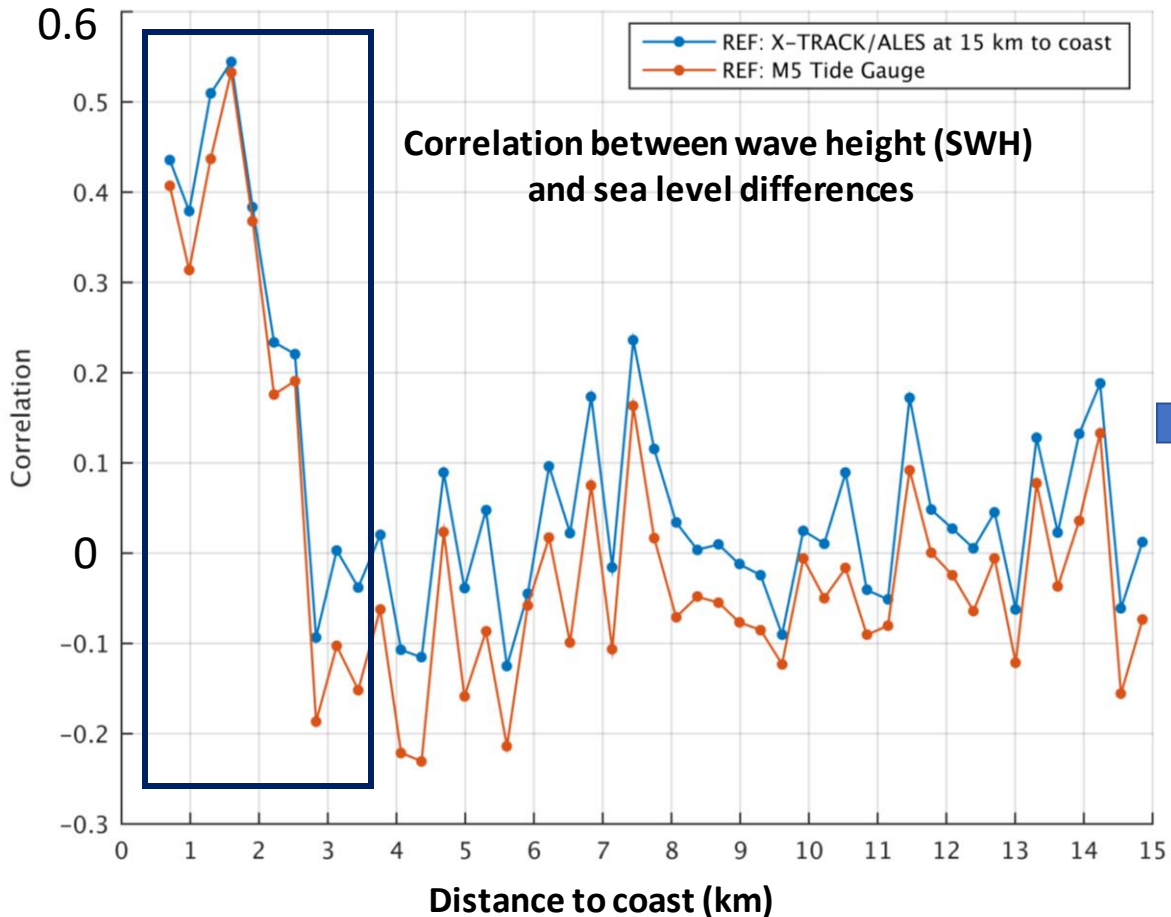 REF1 : X-TRACK/ALES at 15 km to coast

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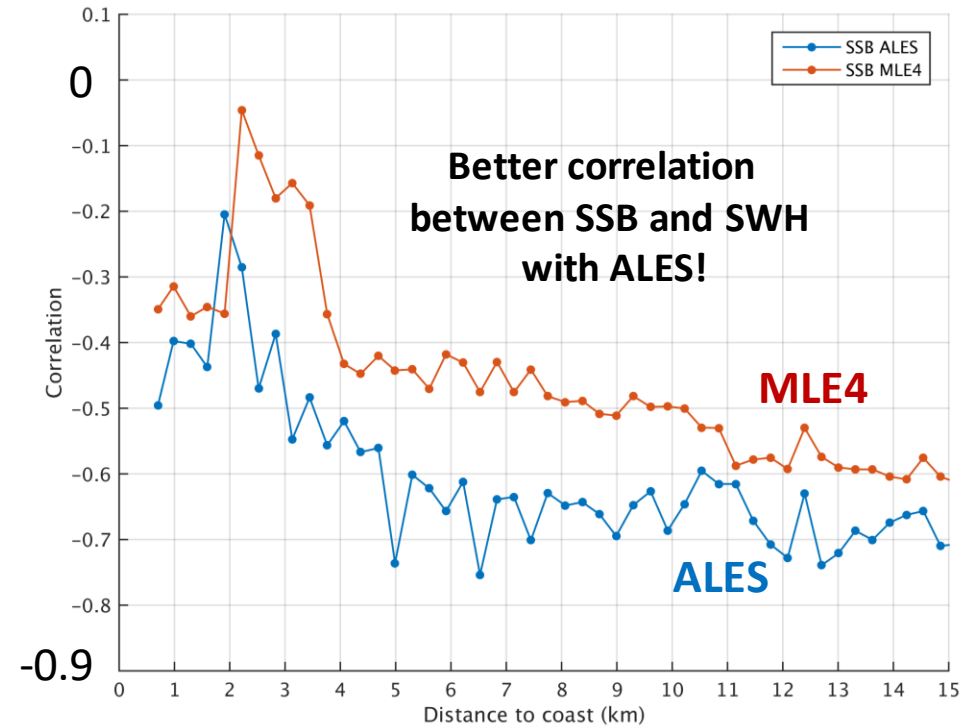
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6.2 Effect of waves on SSB

Correlation between SWH and Sea level differences
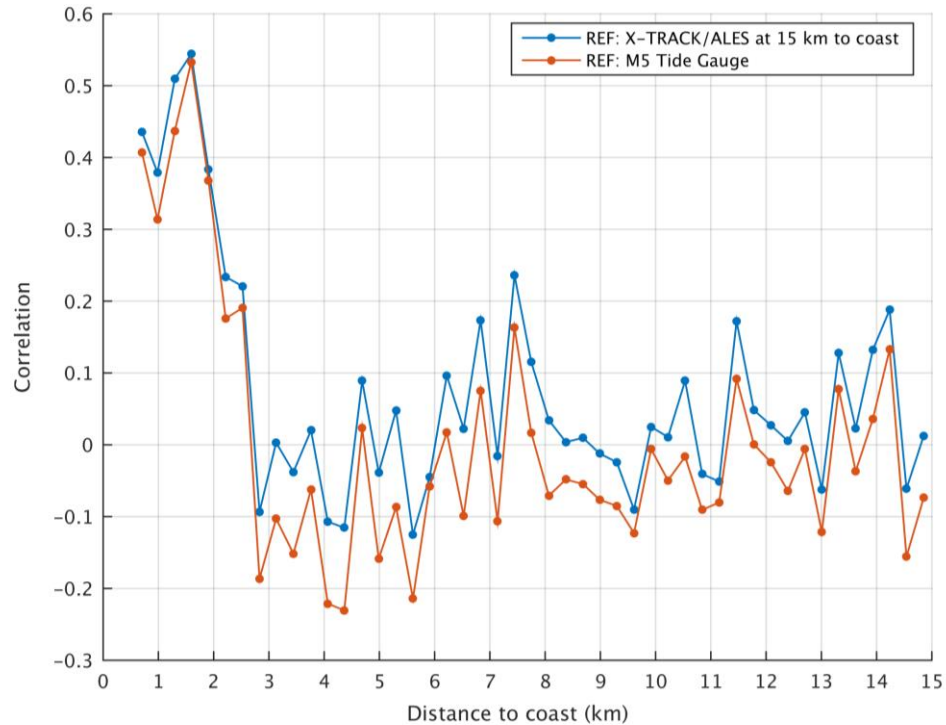
Correlation between SWH and SSB

- SSB is no longer significantly correlated with SWH in the last few kms to the coast

 ⮕ **Possible explanation : SSB relationship to SWH may not fully adequate between 1-3 km to the coast**

    → **Could explain the correlation between SLA (via SSB) and SWH**

However, it looks unlikely that even if SSB is wrong close to the coast, it can produce such large coastal SLA trends
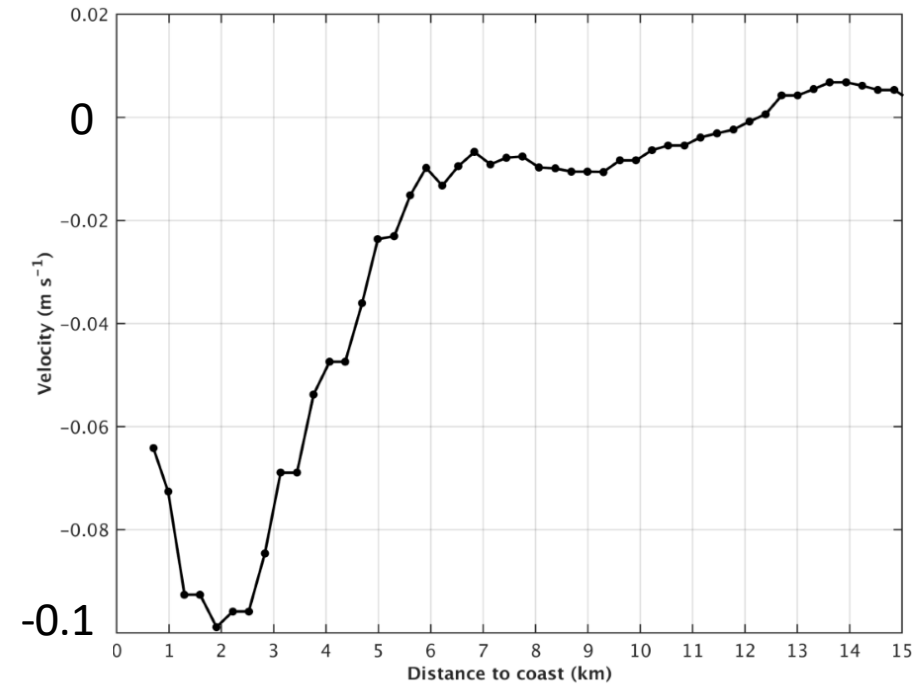
6.3 Further investigations: Effect of coastal currents

High-resolution (400 m) model (MARS3D) from IFREMER

Zonal Barotropic current -
MARS 3D – January 2014
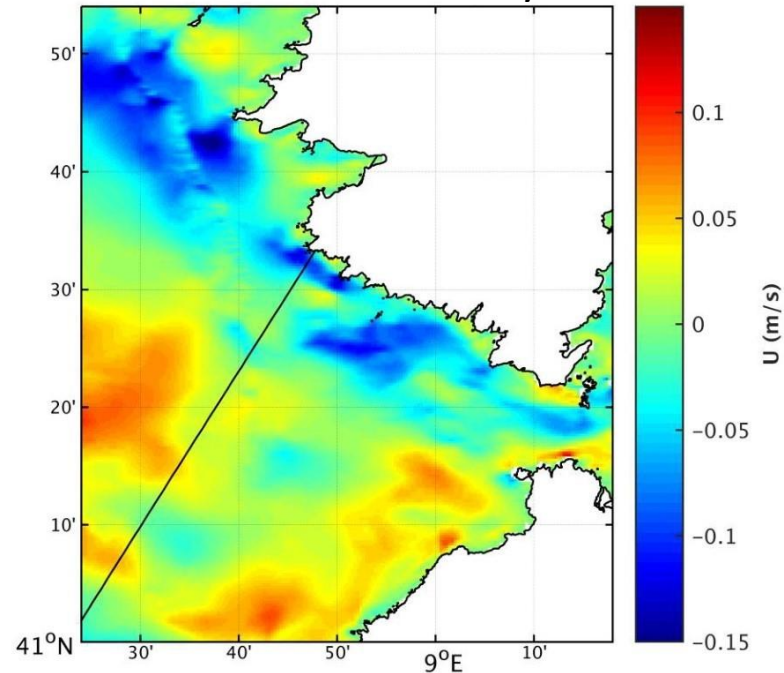
**Along-track zonal current velocity (Jan. 2014)**

- **A coastal current is present in winter at Senetosa, with a maximum amplitude at ~2 km from the coast**
- **Effects of coastal currents on sea level trends currently under investigation**

Conclusions

- **We observe a significant increase in sea level trend approaching the coast, from 2 mm/yr offshore to ~6 mm/yr at 1 km from coast (over 2002-2018)**

- **This behaviour can hardly be explain by artefacts in the data processing, e.g., wrong retracking, land contamination of the waveform, errors in the   geophysical corrections, sampling …**

- **Although SLA trends do not agree with tide gauge-based trends at the coast, we cannot exclude that they result from real physical processes**

- **The coastal current existing at Senetosa may eventually be responsible for the increasing trends. This need more investigations (currently ongoing)**

- **The correlation of SLA with wave height is likely due to the SSB correction (the SSB model may not be fully valid very close to the coast because of changes in wave properties)**

Exemple of constant trends along the track

From Poster 21 : Track 88 crossing Chinese coast
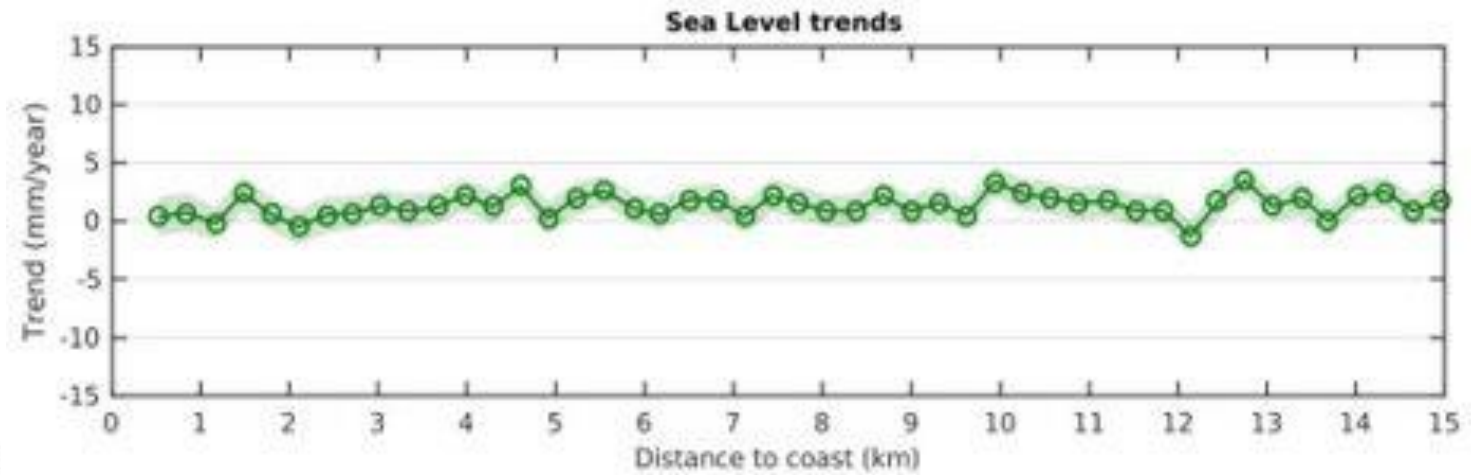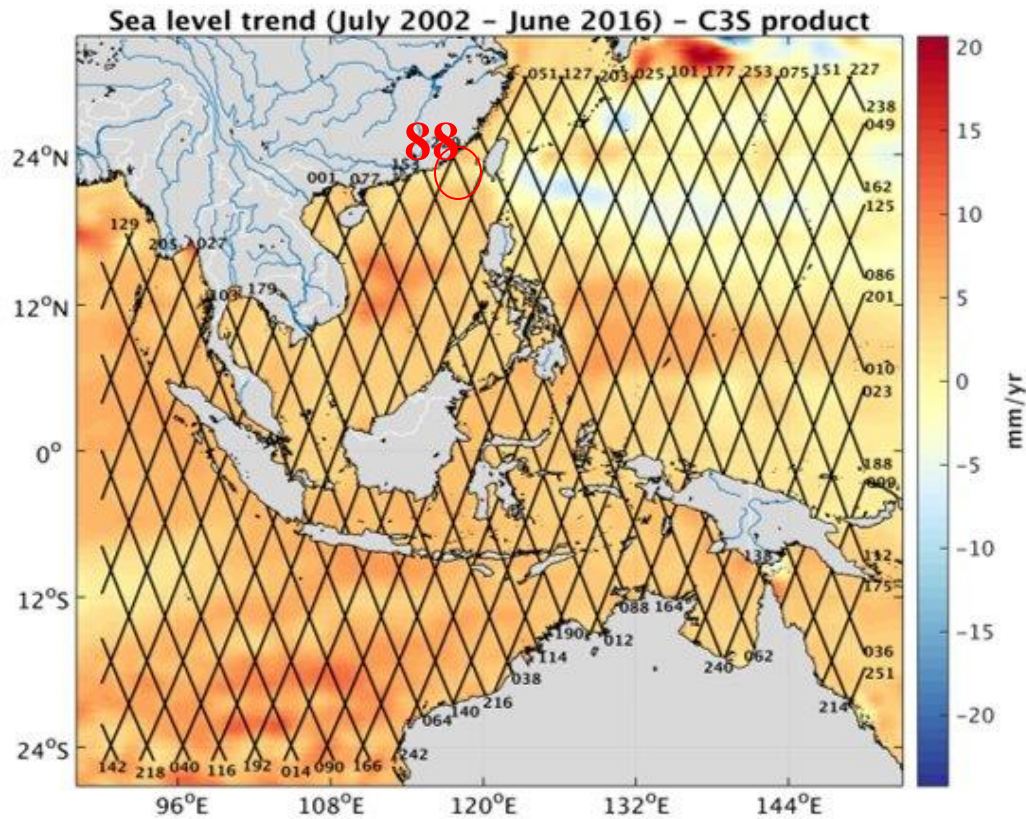
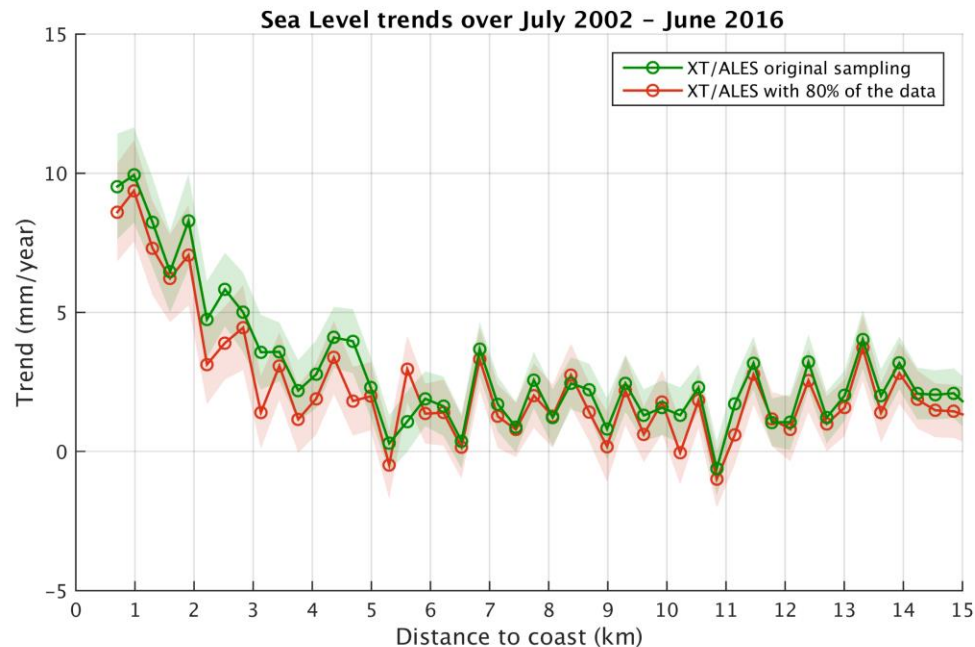Closest point to coast: 500 m
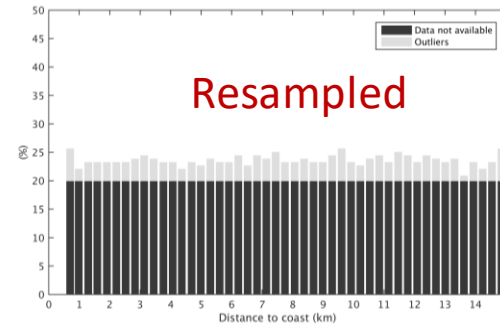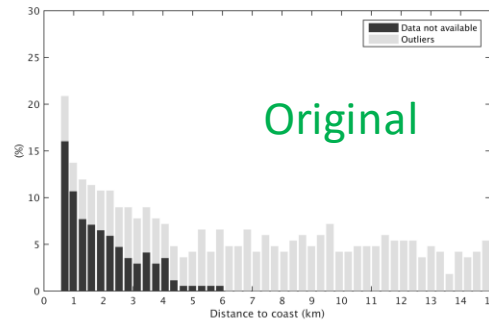
Thanks for your attention

Appendix 1: Effect of the number of missing data

Trends were computed with 2 datasets:
- the original XT/ALES track 85
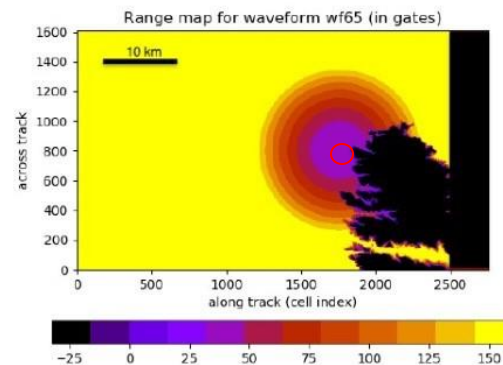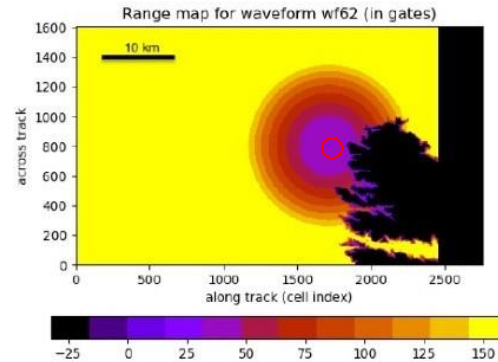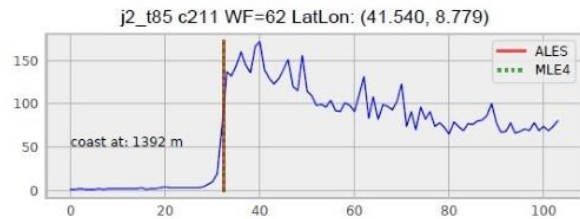- the XT/ALES track 85 only with the common data available

Missing data :

Original

Resampled

- Similar trends between data resampled (red) and original data (green)

The missing data do not affect the trends calculation

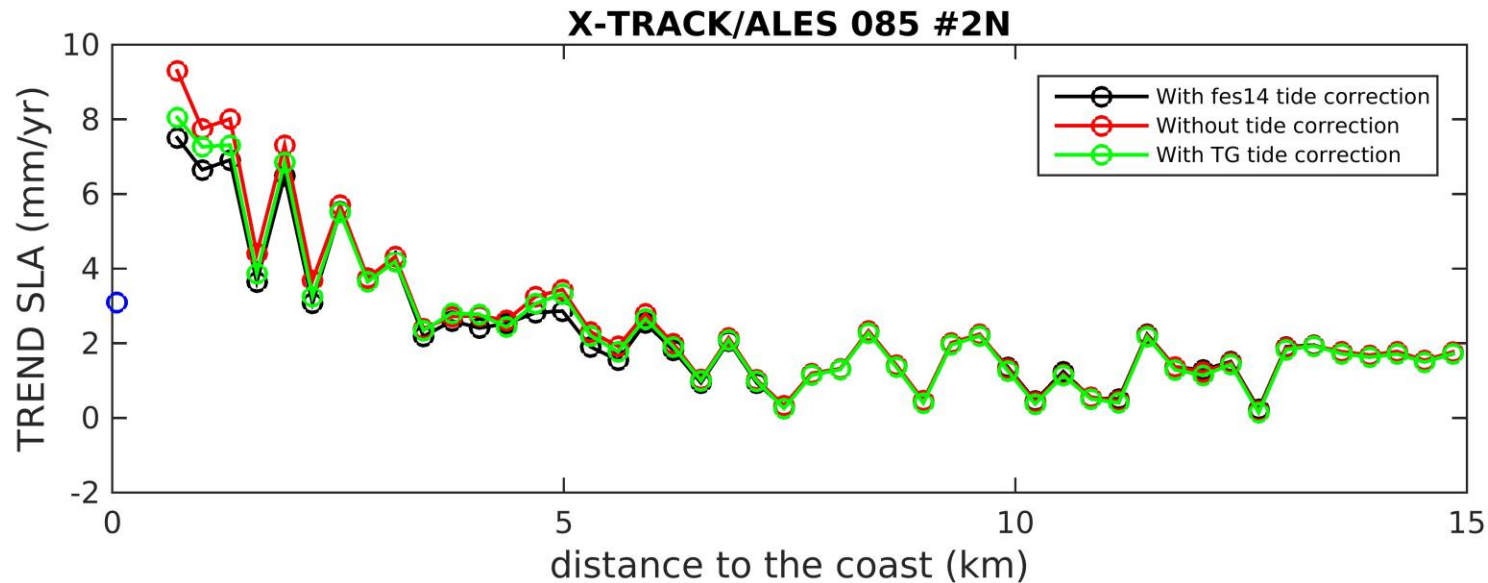# Appendix 2: Simulation of radar ground footprint

j2_t85 c211 WF=62 LatLon: (41.540, 8.779)

coast at: 1392 m

Range map for waveform wf62 (in gates)

- Simulation of the radar footprint corresponding to the detection of the leading edge (assuming flat land)

j2_t85 c211 WF=65 LatLon: (41.546, 8.784)

coast at: 534 m

Range map for waveform wf65 (in gates)

- ➢ Shows that in an ideal case, the detection of the leading edge corresponds to a reflection of the radar in the water.

Appendix 3: Validity of tide correction

XTRACK/ALES-20Hz 085 #2N-o-s Senetosa : 1.90 km to coast

Legend:
- With fes14 tide correction : 6.48 mm/yr
- Without tide correction : 7.31 mm/yr
- With TG tide correction : 6.85 mm/yr
- M5 TG :

X-TRACK/ALES 085 #2N

Legend:
- With fes14 tide correction
- Without tide correction
- With TG tide correction
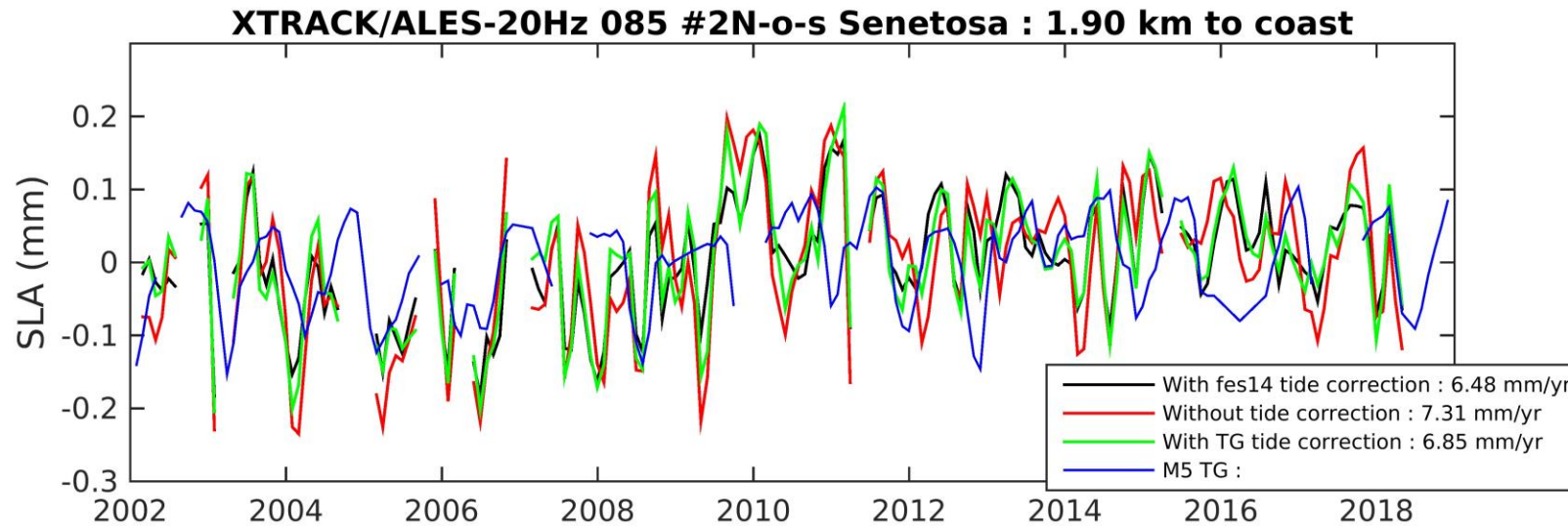
➢ Tide correction with fes 2014 do not affect the sea level trends behaviour near the coast

Appendix 4: XT/ALES vs XT/MLE4

Sea Level trends over July 2002 – June 2016
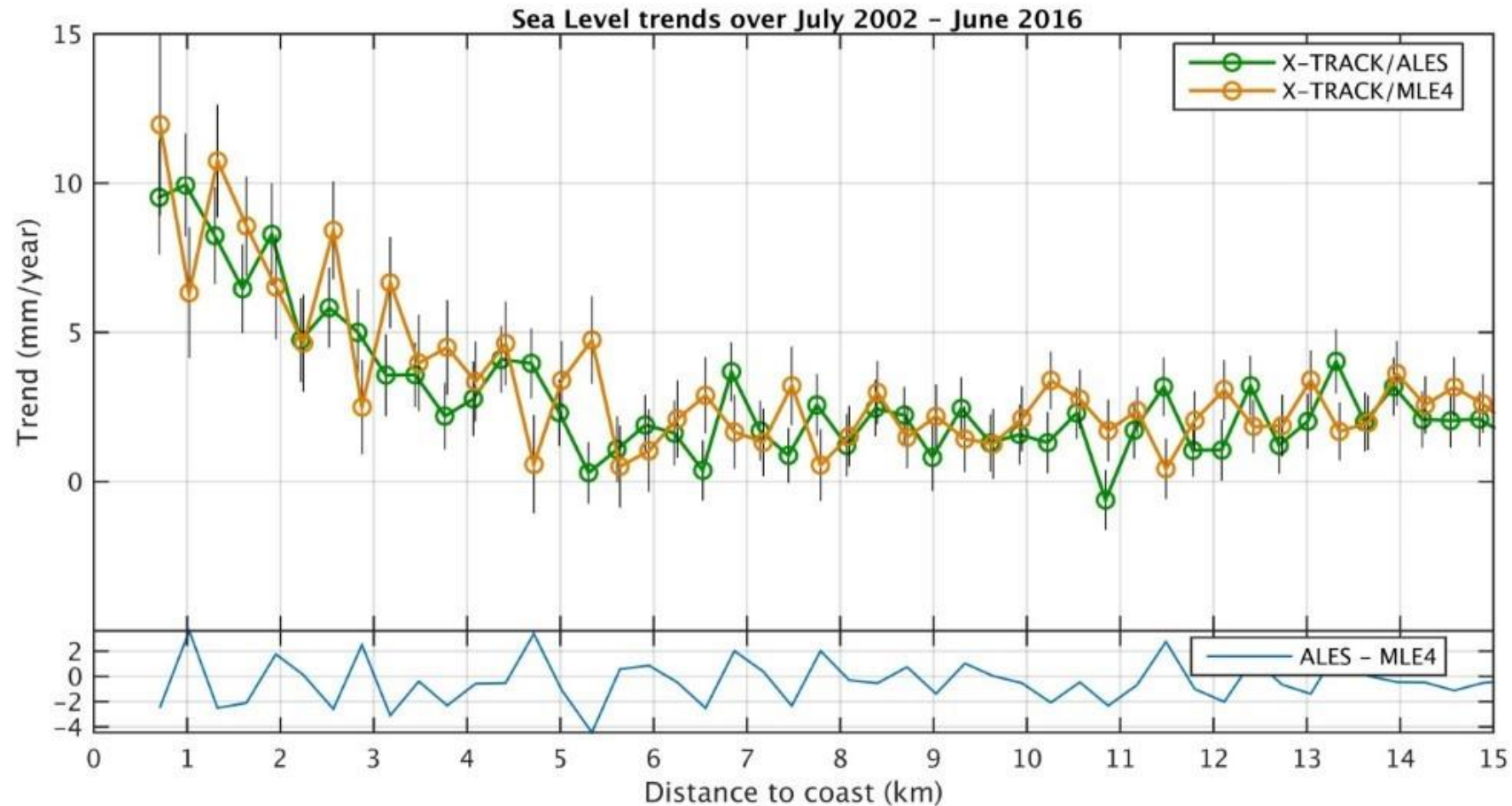
- Trends from 5km with MLE4 are less continuous than for ALES trends
- Errors in trend computation are also higher for MLE4

➢ However, whatever the retracker the same pattern is observed