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Climate-quality estimates of sea level in the coastal zone from the ESA Climate Change Initiative Sea Level Project

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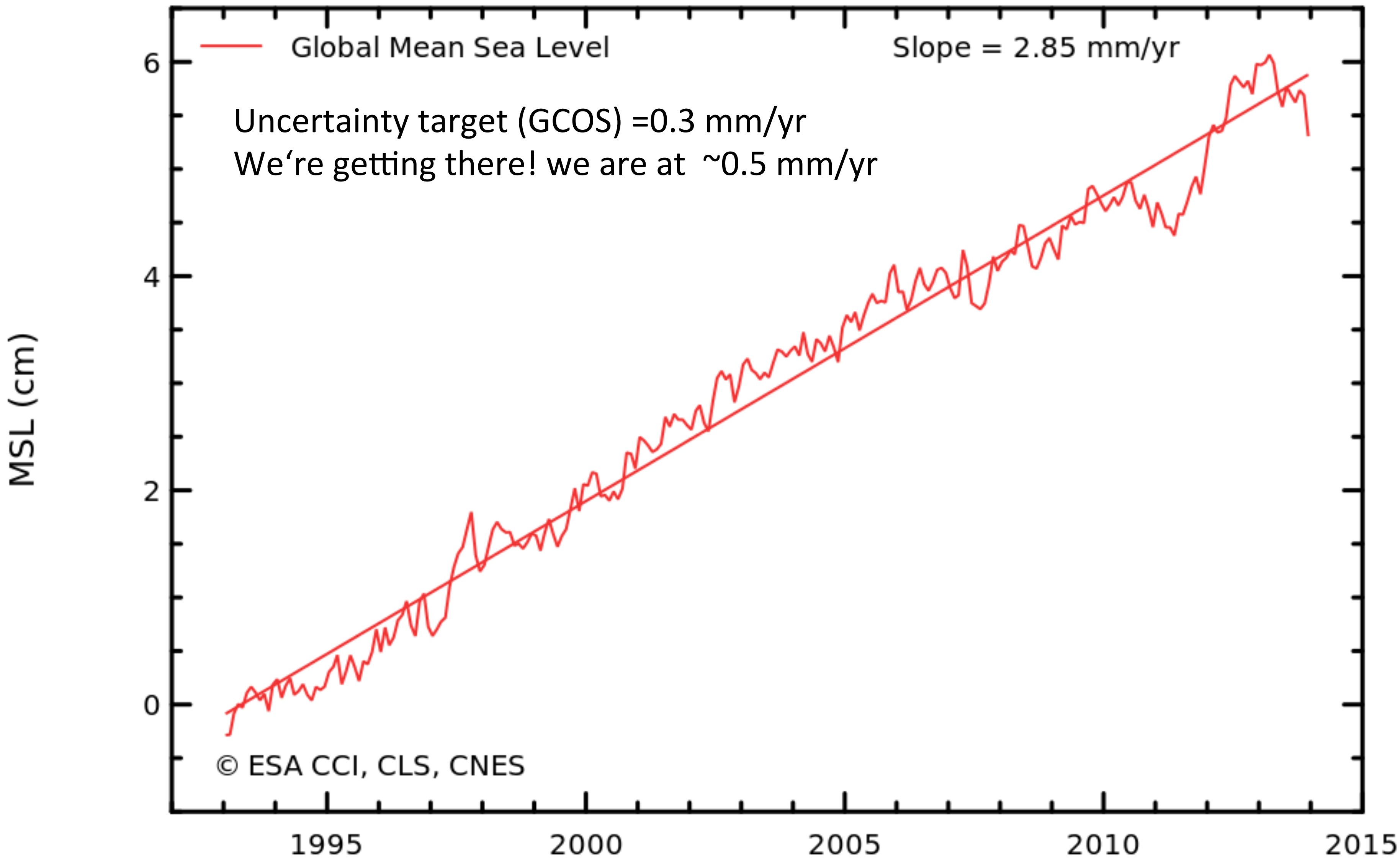
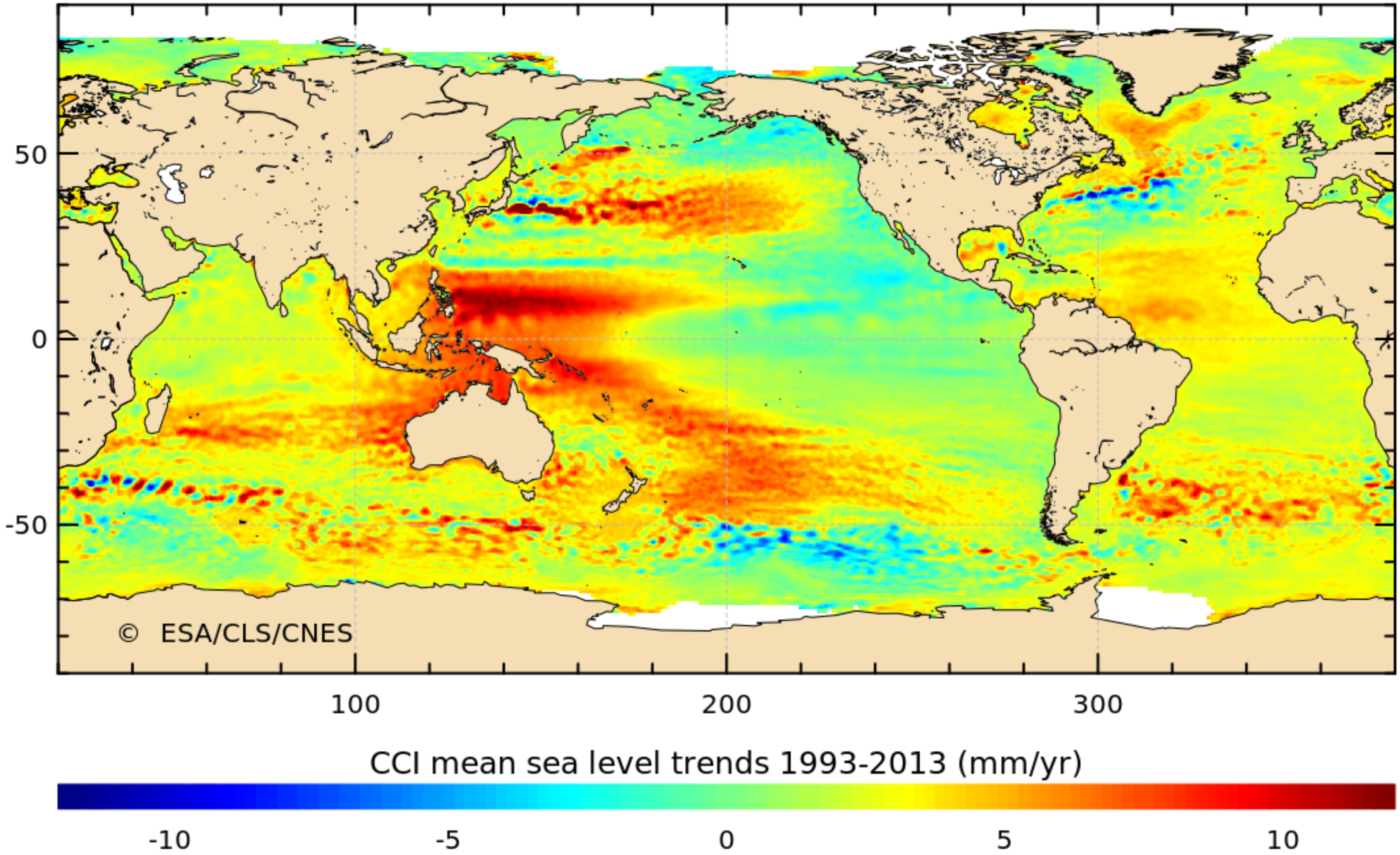
The ESA Sea Level CCI project

- aims at providing long-term monitoring of the sea level Essential Climate Variable (ECV) with regular updates, as required for climate studies
- SL CCI Phase 1 completed in Phase 2013

Data/documentation available at:
http://www.esa-sealevel-cci.org/


Global Mean Sea Level
Slope = 2.85 mm/yr
Uncertainty target (GCOS) =0.3 mm/yr
We‘re getting there! we are at ~0.5 mm/yr
© ESA CCI, CLS, CNES
MSL (cm)
6
4
2
0
1995
2000
2005
2010
2015



50
0
-50
100
200
300
© ESA/CLS/CNES
CCI mean sea level trends 1993-2013 (mm/yr)
-10
-5
0
5
10

Phase 2 (2014-17): more focus on the coast

- Wet tropospheric correction
- Better screening
- Retrackers' assessment
- Batch (2-d) retracking of waveforms
- Regional validation

- ...but first......

User requirements

- a necessary preamble to this work is a **quantification of the requirements for accuracy and long-term stability for climate-quality observations of sea level in the coastal zone**
- This was done by a survey in May 2014
  - we asked altimeter specialists, i.e. experts of the processing and/or analysis of altimetric data, drawn from the International Coastal Altimetry Community and from 14 different countries

Survey – the questionnaire

Coastal Sea Level Questionnaire
v1.0 Apr 2014

A short questionnaire on

Requirements for climate-quality monitoring of coastal sea level from satellite altimetry

Prepared by Paolo Cipollini, National Oceanography Centre, UK, cipo@noc.ac.uk
for the ESA Sea Level CCI Project, Phase 2 – WP1

Why this questionnaire?

Within Phase 2 of the ESA Sea Level CCI Project there is a specific task to update the User Requirements for climate-quality monitoring of sea level from satellite altimetry. Phase 1 of the project had summarized the requirements from different sources (including GCOS, WMO/WCRP, GOOS, OSTST, the Coastal Altimetry Community and the CCI's Climate Modelling User Group) in the following table[1]:

Synthesis of target sea level requirements from Sea Level CCI phase 1.

Observable	Horizontal resolution	Temporal resolution	Accuracy	Long-term Stability
Global mean sea level	Global mean	one orbital cycle[2]	**2-4 mm**	Decadal scale: < **0.3 mm/y** Annual scale: < **0.5 mm/y**
Regional sea level	50-100km	weekly	**1 cm**	**< 1 mm/y**
Mesoscale	15 km	daily	**0.5 cm**	(No strong requirements)

One issue that requires a dedicated focus in Phase 2 is **the coastal zone.** The purpose of this questionnaire – targeted to altimetry specialist and expert users of altimetry data – is to help us to define **specific requirements for altimetry in the coastal zone, in terms of:**
- Accuracy: congruence of the single value ('single' = 'averaged over one space and time grid cell') to the true value
- Long-term stability: consistency over time of the instrument calibration and corrections

Note that the requirements in question are those **for climate applications** – i.e. where one uses repeated observations to derive some statistical properties of the phenomena. A simple example to illustrate this concept: a one-off observation of some 'extreme' event does not belong to the 'climate' category;

[1] The full User Requirement Document that this table is taken from is available at http://www.esa-sealevel-cci.org/webfm_send/90
[2] Individual global mean sea level values are obtained by geographically averaging sea surface heights measured over the ocean during an orbital cycle (10 days for Topex and Jason satellites; 35 days for ERS and Envisat). To reach a 2-4 mm accuracy, individual (1Hz) sea surface height measurements must be accurate to 1-2 cm.

Coastal Sea Level Questionnaire
v1.0 Apr 2014

… and then just a few questions: please answer them based on your own experience.

Note that for each question you are asked to specify TWO values:
- *a THRESHOLD value (= the MINIMUM value that makes that parameter usable for at least one climate application)*
- *a TARGET value (= a "nice-to-have" value that will enable a fuller range of applications – TARGET values should be STRINGENT but REALISTIC at the same time!)*

Let us first focus on a LOCAL product, i.e. sea level on a single grid cell in the coastal zone (say a 15 km x 15 km stretch along the coast) and with a time resolution (i.e. time average) of ONE MONTH.

Q1) What level of ACCURACY of LOCAL altimetric measurements of sea level would be required?

THRESHOLD cm TARGET cm

Q2) What level of LONG-TERM STABILITY of LOCAL altimetric measurements of sea level would be required?

On an ANNUAL SCALE: THRESHOLD mm/y TARGET mm/y

On a DECADAL SCALE: THRESHOLD mm/y TARGET mm/y

Then let us think of a GLOBAL COASTAL product, i.e. one generated by quality-controlling and averaging all the measurements in the global coastal strip (0-15 km from coast) and with a time resolution of ONE MONTH.

Q3) What level of ACCURACY of GLOBAL COASTAL altimetric measurements of sea level would be required?

THRESHOLD cm TARGET cm

Q4) What level of LONG-TERM STABILITY of GLOBAL COASTAL altimetric measurements of sea level would be required?

On an ANNUAL SCALE: THRESHOLD mm/y TARGET mm/y

On a DECADAL SCALE: THRESHOLD mm/y TARGET mm/y

Space available for specific comments:

Done, thanks!
The results will be made available in the updated User Requirement Document (via http://www.esa-sealevel-cci.org) and discussed at ESA symposia, OSTST Meetings and Coastal Altimetry Workshops.

Requirements expressed as...

- ACCURACY (cm)
- STABILITY over 1-y period (mm/y)
- STABILITY over 10-y period (mm/y)

- for a LOCAL product
  - (single cell 15km x 15km x 1mth in the coastal zone)
- for a GLOBAL COASTAL product
  - global QC-screened 1-mth average in 15-km coastal strip

We asked for a THRESHOLD value (minimum to enable at least one application) and a TARGET value.

40 surveys handed out, 15 (38%) returned – we can start making some basic statistics.

results 1

ACCURACY (cm)		
Median and *[range]*		
LOCAL	THRESHOLD **3.0** *[1.0 , 15.0]*	TARGET **1.0** *[0.1 , 5.0]*
GLOBAL COASTAL	THRESHOLD **1.8** *[0.5 , 5.0]*	TARGET **1.0** *[0.1 , 3.0]*

ACCURACY (cm)		
First–Third quartile		
LOCAL	THRESHOLD **2.0–4.5**	TARGET **0.8–1.8**
GLOBAL COASTAL	THRESHOLD **0.6–2.0**	TARGET **0.4–1.0**

results 2

STABILITY over 1 year (mm/y)						
Median and *[range]*						
LOCAL	THRESHOLD	**3.0**	*[0.5 , 10.0]*	TARGET	**1.0**	*[0.2 , 6.0]*
GLOBAL COASTAL	THRESHOLD	**1.0**	*[0.3 , 5.0]*	TARGET	**0.5**	*[0.1 , 2.0]*

STABILITY over 1 year (mm/y)				
First–Third quartile				
LOCAL	THRESHOLD	**1.0–7.5**	TARGET	**0.5–2.5**
GLOBAL COASTAL	THRESHOLD	**0.6–2.0**	TARGET	**0.3–1.0**

results 3

STABILITY over 10 years (mm/y)						
Median and *[range]*						
LOCAL	THRESHOLD	**1.5**	*[0.3 , 5.0]*	TARGET	**1.0**	*[0.2 , 3.0]*
GLOBAL COASTAL	THRESHOLD	**0.9**	*[0.1 , 2.0]*	TARGET	**0.4**	*[0.1 , 1.0]*

STABILITY over 10 years (mm/y)				
First–Third quartile				
LOCAL	THRESHOLD	**1.0–3.0**	TARGET	**0.5–1.0**
GLOBAL COASTAL	THRESHOLD	**0.5–1.0**	TARGET	**0.2–0.5**

Improvement of radiometer-based WTC (UPorto)

- In CCI phase1 GPD wet tropospheric corrections were computed for the six main missions: ERS-1, ERS-2, Envisat, T/P, Jason-1 and Jason-2.
- These computations have been recently revisited and extended.
- Main results **in the coastal regions**:
- Very significant improvements for all ESA missions and T/P (particularly in the second half of this mission)
- Moderate improvement for Jason-1 (already includes a coastal improved WTC)
- Small or not significant improvement for Jason-2 (AMR GDR-D WTC is already a coastal improved WTC with good performance near the coast)

J. Fernandes

Improvement of radiometer-based WTC (UPorto)

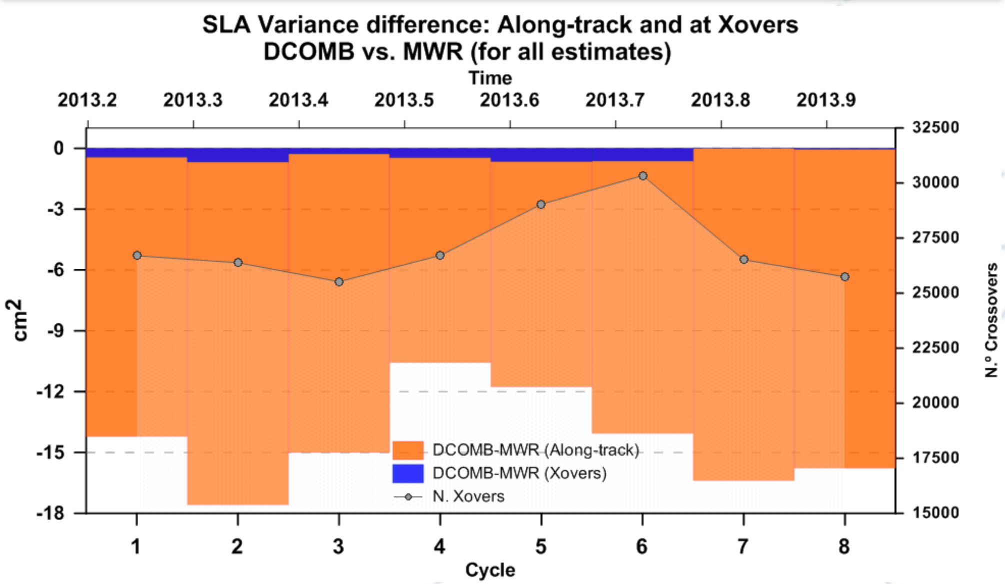
- In CCI phase2 computations will be extended to the six previous missions plus CryoSat-2 and SARAL/AltiKa.
- The new WTC will be based on the data combination of:
  - Valid MWR values (whenever available)
  - Wet path delays from scanning imaging MWR (SI-MWR) on board various remote sensing missions
  - GNSS-derived path delays
  - Global atmospheric models
- Emphasis will be put on the **long-term stability** of the WTC
- Next slide shows initial results for SARAL/AltiKa

J. Fernandes

WTC Computations for SARAL/AltiKa

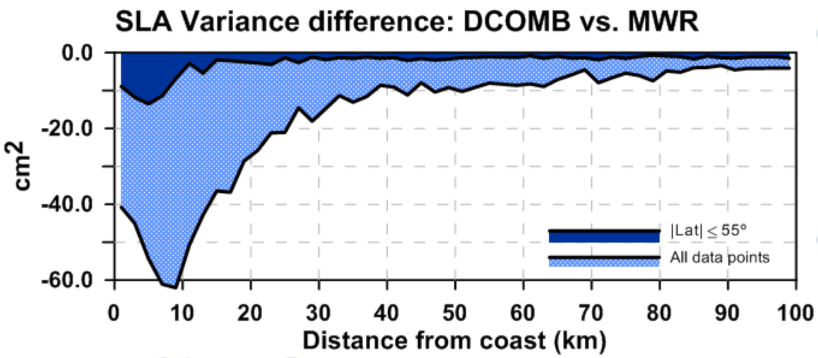
Contributions to the improvement of the wet tropospheric correction for SARAL/AltiKa, Lazaro et al, Poster 11 at SARAL/AltiKa workshop

- **Methodology:**
  - Two algorithms, developed by UPorto, based on data combination by Objective Analysis of different WTC data sets were tested on SA (Cycles 1 to 8, 2013): DComb (Data Combination) and GPD (GNSS-derived Path Delay).
  - DComb is independent from the on-board MWR while GPD is based on it and attempts to improve it using additional information.



- DComb, GPD, MWR-based and ECMWF WTC corrections have been inter-compared using various statistical analyses.

- **Main results:** DComb significantly decreases SLA variance globally, particularly in coastal regions up to 100 km from the coast and polar regions. Being independent from the on-board MWR WTC, it enables an independent evaluation of the latter. GPD is globally worse than DComb, too influenced by the on-board MWR.



Figures: DComb vs. MWR statistical diagnoses: (Top) difference in SLA variance, function of distance from coast; (Left): SLA variance difference (along-track and at crossovers).

J. Fernandes

Data Screening & Retracker assessment

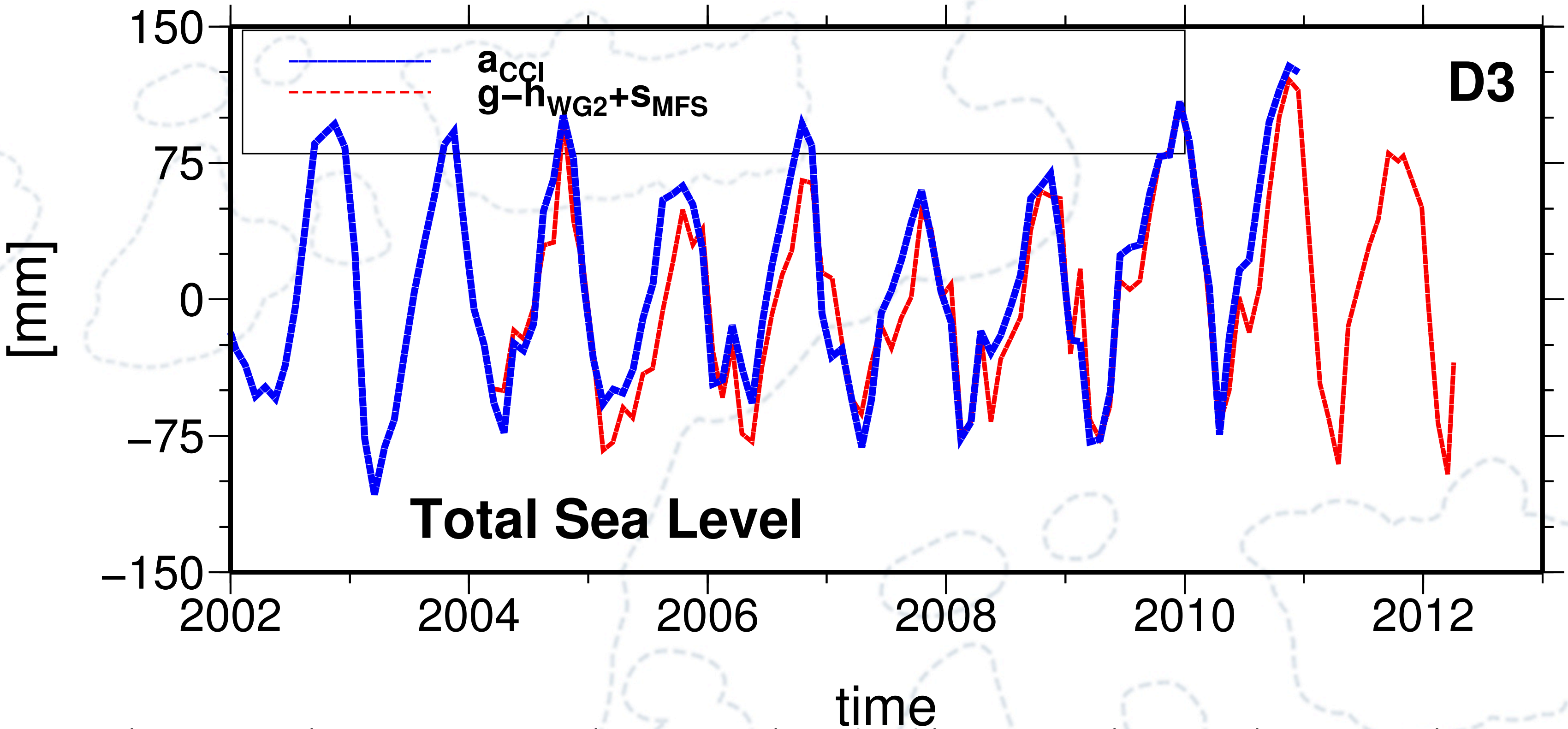
- Dedicated screening and filtering of existing data/ corrections at high-rate (20 Hz).
- objective is to find the optimum trade-off between not rejecting too many data while retaining only the information that is of climate-quality;
  - the criteria used over the open ocean may not be appropriate so they will be reassessed.
  - Improved criteria will be tested by comparing the derived sea level against tide gauges, looking in particular at the correct recovery of sea level trends.
- Performance assessment of the two main families of retrackers
  - retrackers fitting 'peaks' on top a Brown-like waveform
  - sub-waveform retrackers (such as ALES)

Batch retracking (PML)

- Conventional retracking algorithms fit each waveform independently
- we will investigate a retracker that **fits a model to multiple waveforms at once**: “2-D retracker”
- The premise of this so-called "2-D retracker" is that the fitted geophysical parameters τ, H_s and σ_0 will all be slowly varying functions of along-track distance, x. Imagine for instance a polynomial of order N
- Now, when retracking, say, 21 waveforms at once, the number of parameters to be fitted is reduced from 21x3 (if all tracked independently) to Nx3 (where N is the order of the polynomial).
- The reduction in the number of free parameters should enable more robust fitting, especially resilience to spurious peaks in the data.
- However, this is experimental R&D, so the practicality and efficacy of this idea is yet to be evaluated ...

G. Quartly, PML

Water Mass Budget - Validation of CCI ECV in Med



Mass (D1, WP1110), steric component (D2, WP1120), sea level (D3, WP1130), metrics (D4, WP1140)

From **basin averages**:

1. D3 in good agreement with D1+D2
2. D4 validation metrics (corr 0.93, std 2 cm in period 2004-2010)

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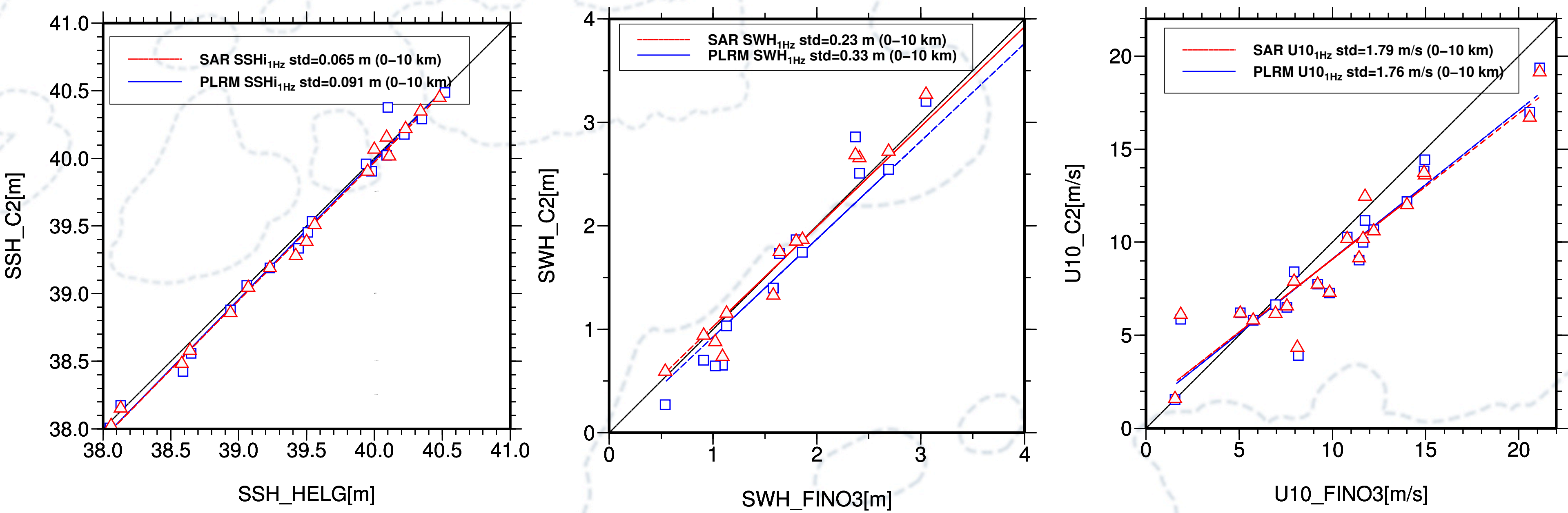
In-situ geodetic validation of CCI FCDR & other products

here : SAR ESRIN and PLRM (Reg B) for 4 years



Validation in **2010-2013** in **coastal zone (0-10 km) in the German Bight**:
SAR altimetry is more accurate than PLRM in the coastal zone:
SWH benefits the most from the SAR technique with the accuracy increasing by a factor 2, this factor is lower for SSH and U10.

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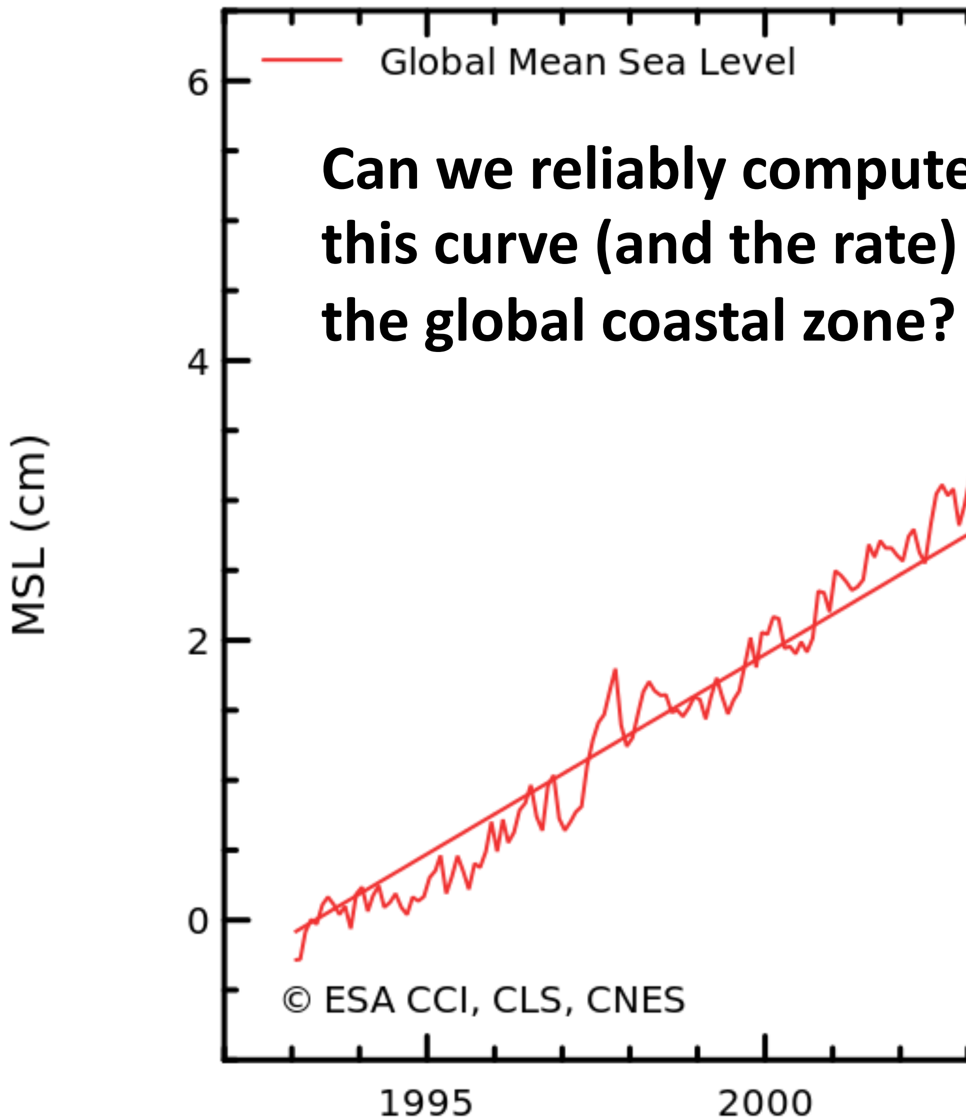
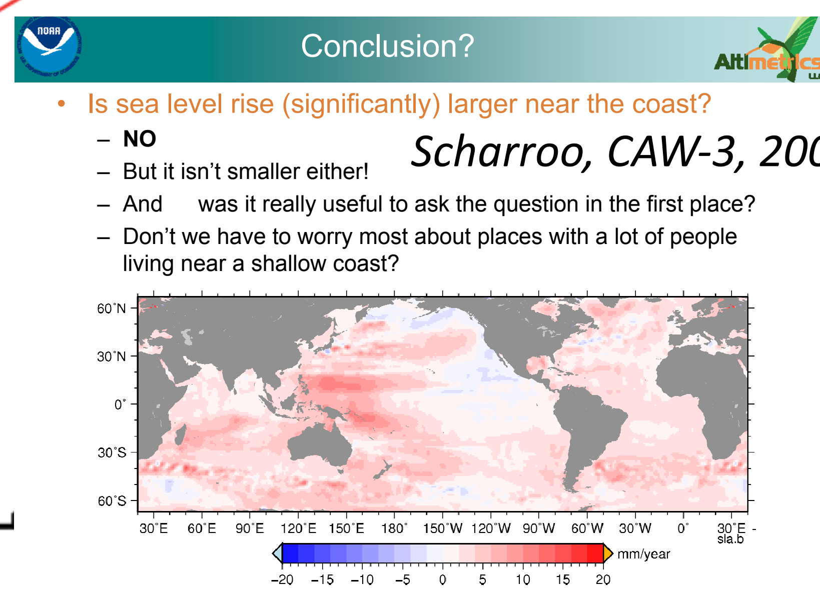
The final question

Can we reliably compute this curve (and the rate) for the global coastal zone?





Scharroo, CAW-3, 2009

Questions/suggestions welcome!