Sea Level CCI

Main Achievements of the 6 Years of the SL_cci Project

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Sea Level CCI Phase II – AR#3 and Final meeting – February 27-28th 2017

Context

GCOS
GLOBAL CLIMATE OBSERVING SYSTEM
http://gcos.wmo.int

esa
European Space Agency

CCI PROGRAM

- aerosol cci
- ozone cci
- ocean colour cci
- cloud cci
- sea ice cci
- land couer cci
- fire cci
- cmug cci
- sea level cci
- sst cci
- ghg cci
- glaciers cci
- soil moisture cci
- ice sheets greenland cci
- antarctic ice sheet cci

Objective: To realize the full potential of the long-term global Earth Observation archives from satellites to provide the best long term ECVs records as required by UNFCCC and GCOS

Overview

SL_cci phases I and II: from 2011 to 2016

1. **SL_cci improvements**
   - Generation of Sea Level products
   - Improvements of altimeter observations at climate scales
   - Sea Level estimation in the Arctic and coastal areas
2. **Quality Assessment**
   - Internal validation and closure budget approach
   - Comparisons with models
3. **Error Characterization**
   - Error budget and users requirements
   - Mean Sea Level error estimation
4. **Communication**
5. **Perspectives and future expectations**

The SL_cci Improvements

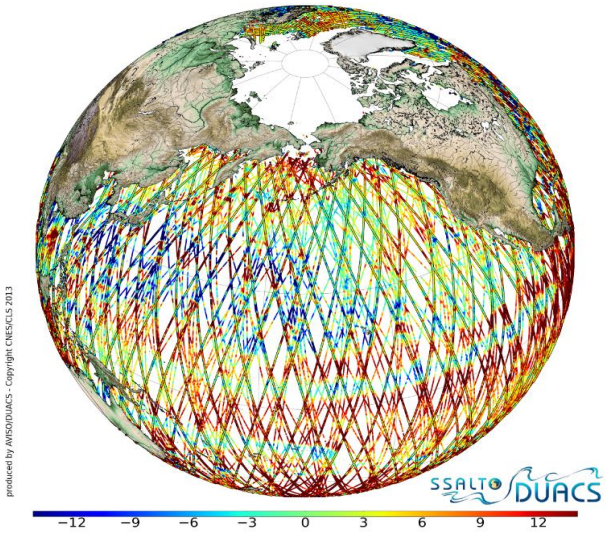
SL_cci Improvements

The reprocessed **v2.0 SL_cci** dataset:

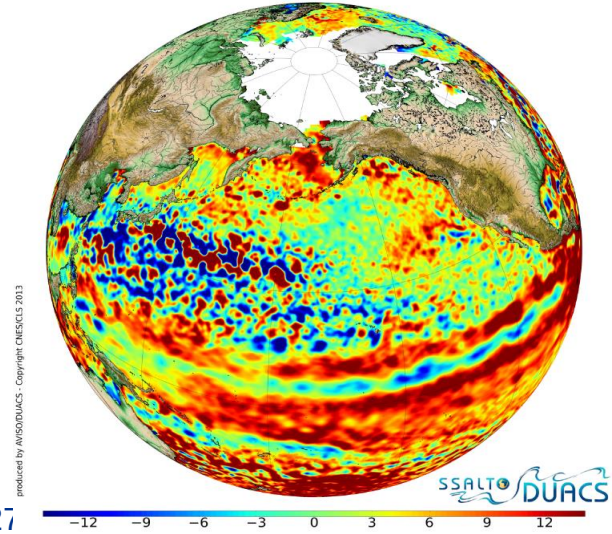
- 9 altimeter missions: TOPEX/Poseidon, Jason-1/2, ERS-1/2; Envisat, Geosat-FO, CryoSat-2 and SARAL/AltiKa
- 70 cumulated years
- Period: 1993-2015

The CNES/CLS DUACS system is used to:

Process along-track data



Produce merged gridded products

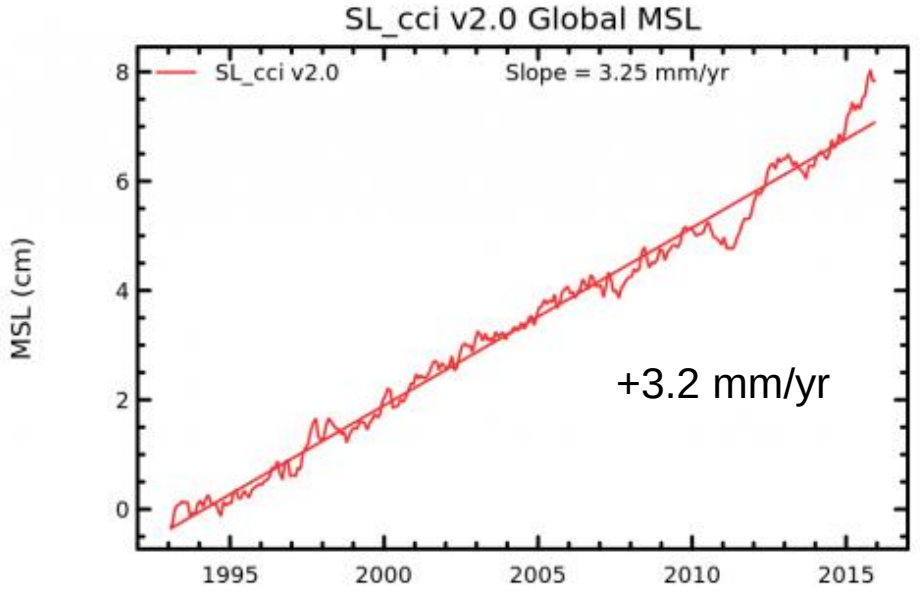


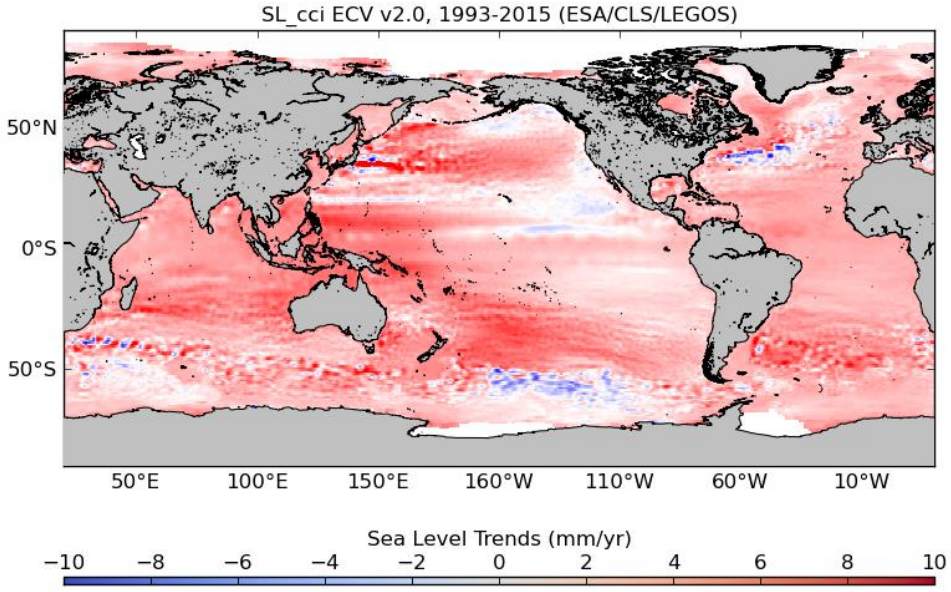
SL_cci Improvements

This has led to an accurate, stable, long-term, satellite-based sea level record at global and regional scales, designed to answer the users needs, for climate applications

The SL_cci ECV release v2.0 consists in **monthly sea level maps** and associated **ocean indicators**

Available via www.esa-sealevel-cci.org
Request at info-sealevel@esa-sealevel-cci.org

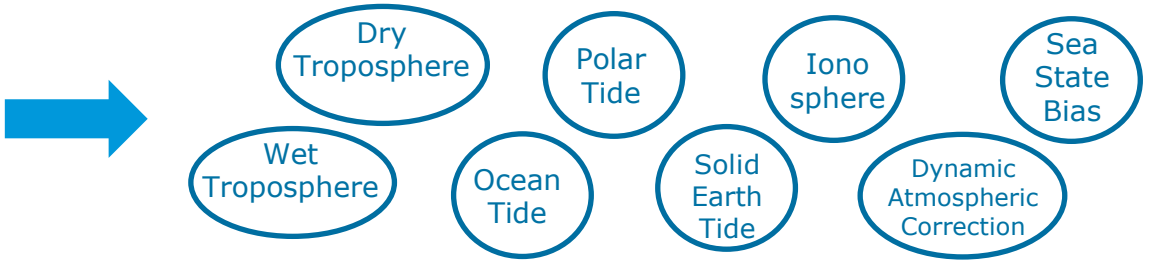




SL_cci Improvements

The altimeter sea level estimation relies on **various different subsystems**

Altimeter Sea Level
=
Orbit
- Altimeter Range
- ∑ Geophysical Corrections



⇒ A **huge amount of different algorithms** (Level 2) is required.

⇒ Main outcome of CCI: to set up **a formal protocol to develop, validate and select** the best algorithms that contribute to increase the **ECV homogeneity, stability**

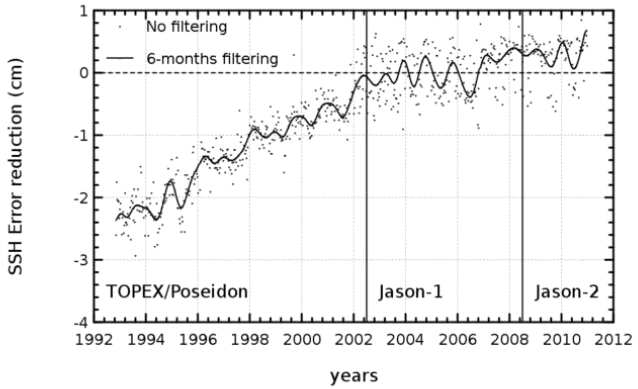
SL_cci Improvements

- The **major impacts** of the L2 altimeter corrections compared with the previous release (2012, Phase I) have been estimated distinguishing different **spatial and temporal climate scales:**

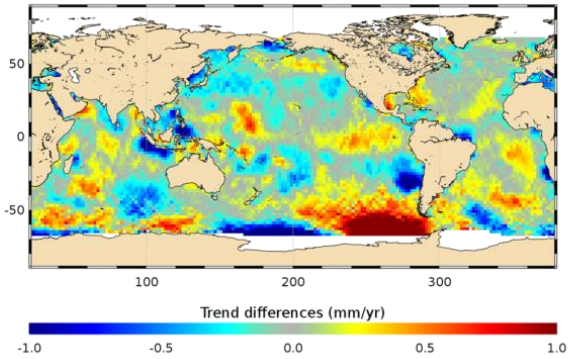
Climate Applications	Temporal Scales	v2.0 vs v1.1
Global Mean Sea Level	Long-term evolution (trend)	++
	Inter annual signals (> 1 year)	+
	Periodic Signals	+
Regional Mean Sea Level	Long-term evolution (trend)	+++
	Periodic Signals	++
Mesoscale	Signals < 2 months	++

Major impacts of the new altimeter L2 corrections:

• New **atmospheric correction** (Carrère et al., 2016) leads to a reduced SL error



Impact of using new atmospherical corrections



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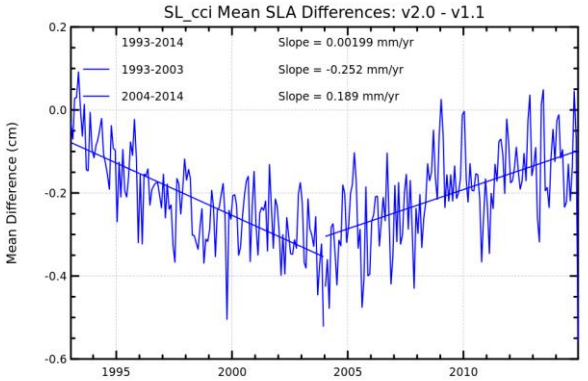

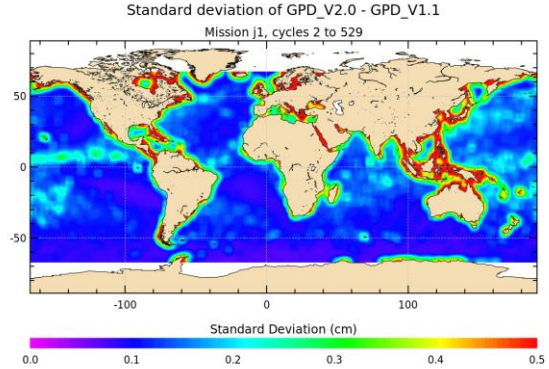

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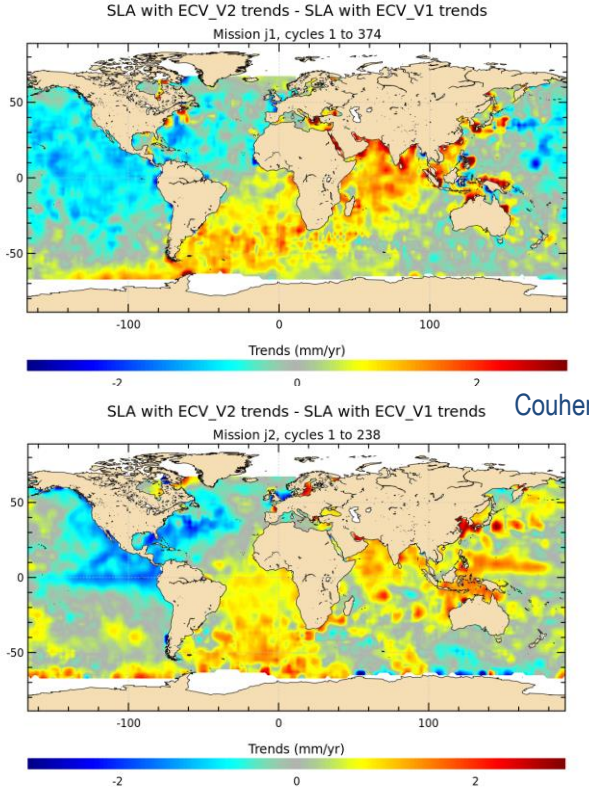

Couhert et al., 2015

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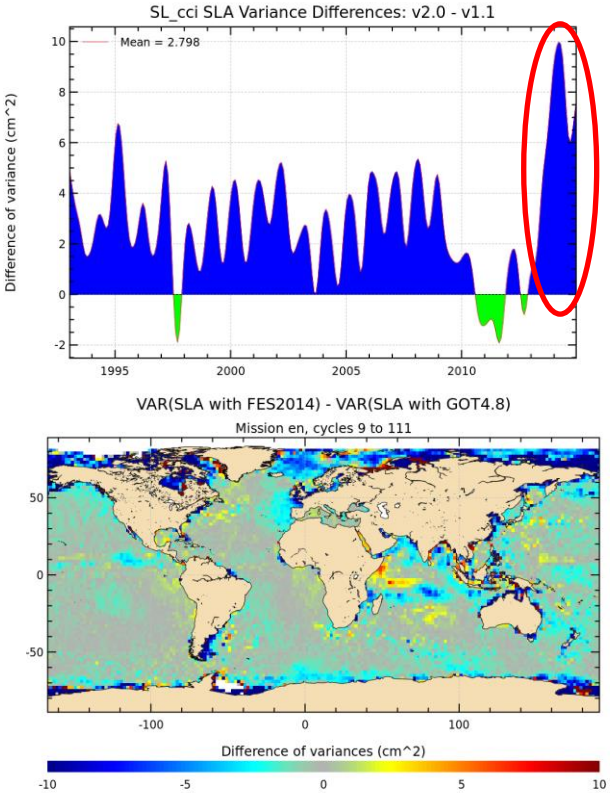
• Improved **mesoscale** estimation after 2012 due to the **inclusion of new missions** (CryoSat-2 and SARAL) and
• **Reduced sea level variance** in many **coastal areas** and at **high latitudes** due to the **new FES2014 ocean tide model**



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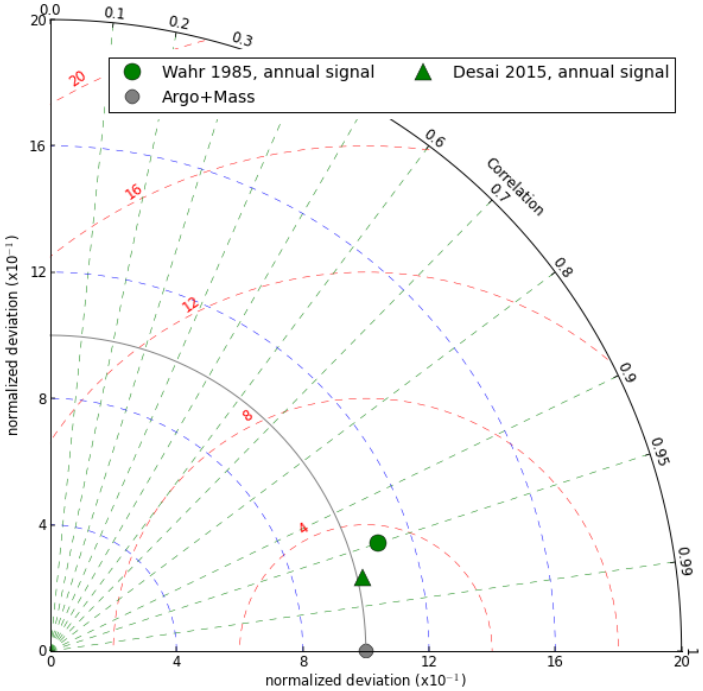
- The new **Polar Tide correction** (Desai, 2015) leads to an improved estimation of the **annual signal**.

- New **instrumental correction,** new **Mean Sea Surface** (MSS).



Analyses of the **altimetry constellation** on the MSL calculation have been performed:

- Impact of the loss of the Envisat mission (35-day orbit) was not statistically significant.

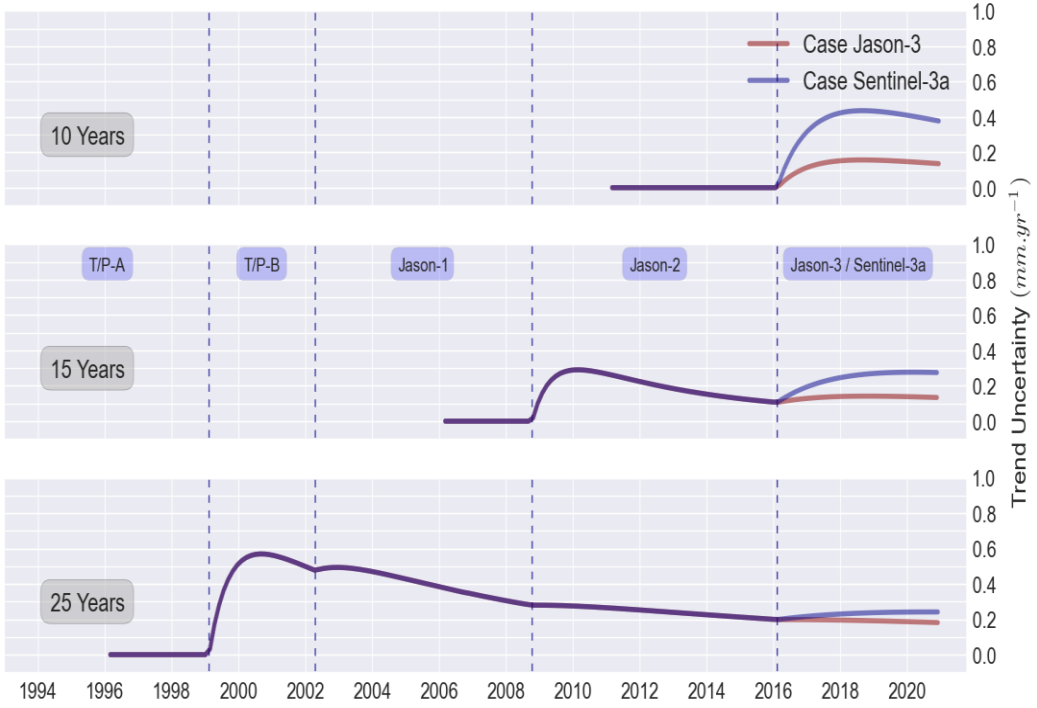
	ESA SL_cci @ ± 66°	Daily AVISO @ ± 66°		
		10day orbit	10day+35day orbit	10day+35day orbit **with 28-month gap**
Trend (mm/yr)	2.88±0.05	2.87±0.04	2.90±0.04	2.89±0.05

A.Shaw, P. Cipollini, F. Calafat, 2016

Analyses of the **altimetry constellation** on the MSL calculation have been performed:

- Impact of the loss of the Envisat mission (35-day orbit) was not statistically significant.

- Linking Sentinel-3 MSL time series to Jason-2 increases the trend uncertainty, due to the absence of a calibration phase, so it is recommended to use Jason-3.



Zawadzki et al., 2016

Improved sea level estimation in the **Arctic Ocean:**

• Poorly observed by altimetry due to sea-ice coverage

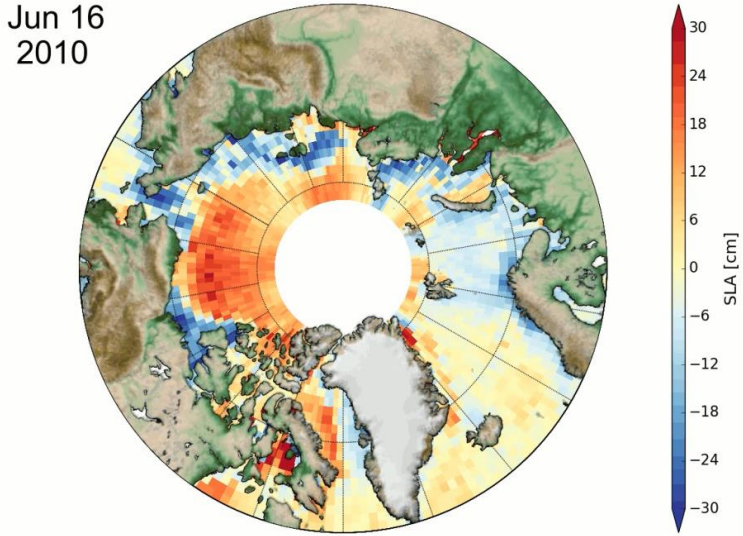
→ **New arctic Sea-Level products available** : new waveform classification and retracking algorithm for Envisat and SARAL missions (CLS/PML: Poisson et al., in prep)

Available via www.esa-sealevel-cci.org
Request at info-sealevel@esa-sealevel-cci.org

→ Improved data coverage

→ Better sea level quality (Carret et al, 2016)

Monthly sea level maps from Envisat data



• Additional effort focuses on the **adaptation of an existing retracking method** to this specific ice-covered region.

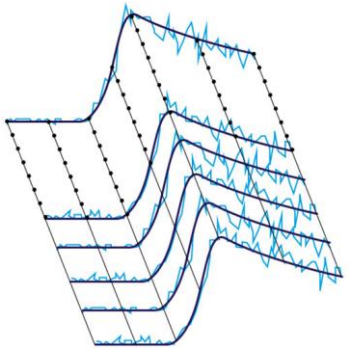
Improved sea level estimation in coastal areas:

- **Coastal improvements:**

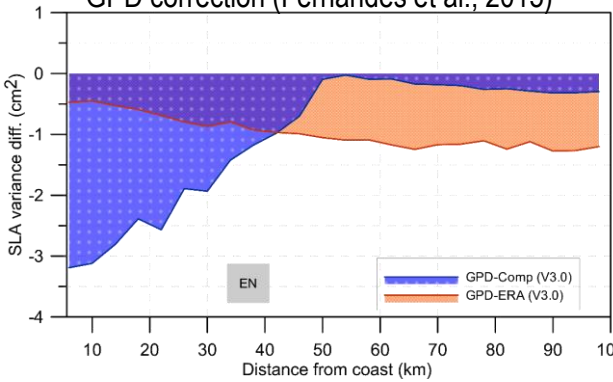
→Improved retracking of the altimeter radar echo in coastal areas (**2D waveform retracker**)

→ New **wet troposphere correction** based on radiometer and **GNSS** measurements (GPD)

→ New **ocean tide models** (FES14)



SLA variance reduction for Envisat using new GPD correction (Fernandes et al., 2015)



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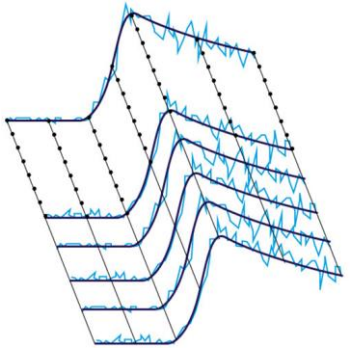

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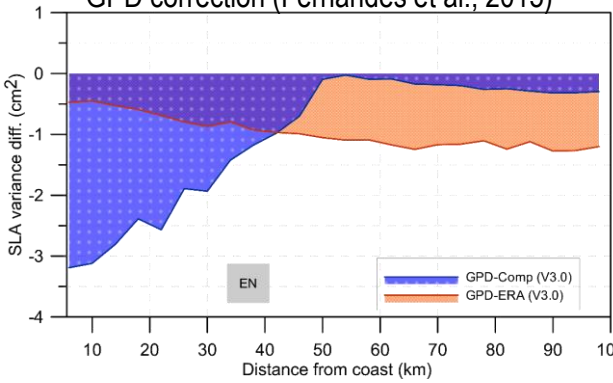
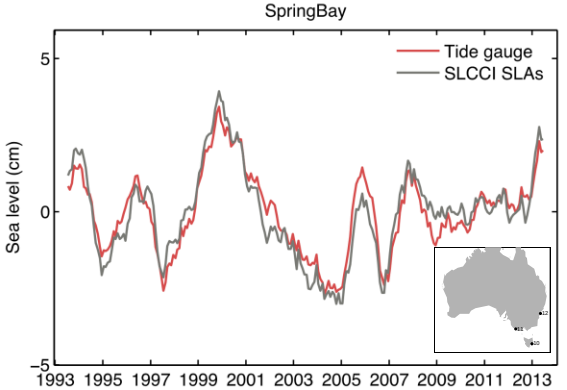


- **Coastal areas MSL validation:**

→ Regional **in-situ validation** against **geodetic data** (tide gauges + GPS)

→Validation with **tide gauges** and estimation of the **total relative sea level** at the coast



Quality Assessment

Quality Assessment

1- Validation
2- Comparison with models

The **quality of the Sea Level ECV** is assessed through:

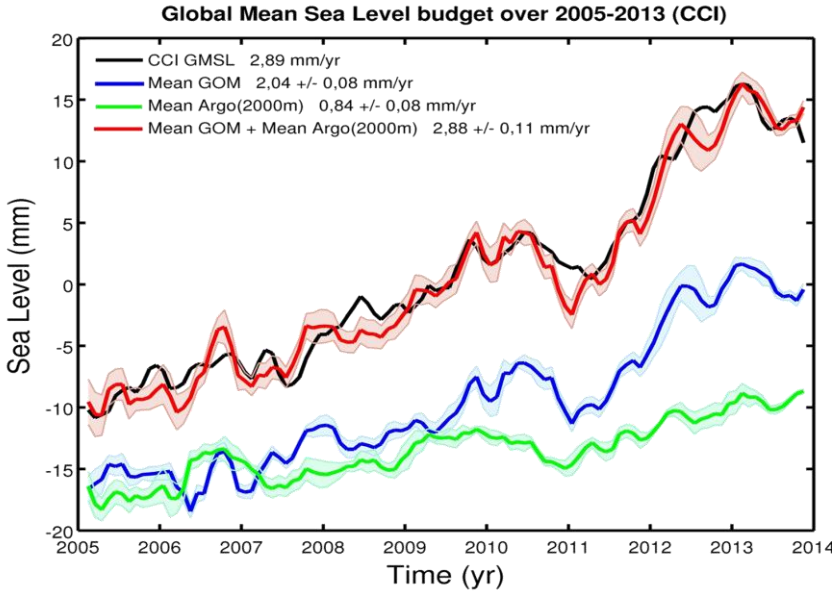
1. Internal validation:

Multi missions **inter comparisons** and **consistency analyses.**

2. Closure budget approach:

Global Mean Sea Level
= steric sea level changes + **ocean mass** variations

⇒When analyzing other GMSL products from international groups, the **best agreement is found with the SL_cci product**



- This approach will be fully exploited in the new **integrated cross-ECVs ESA Sea Level budget closure project**.

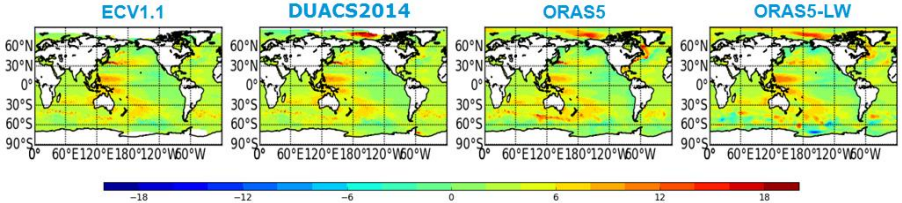
Quality Assessment

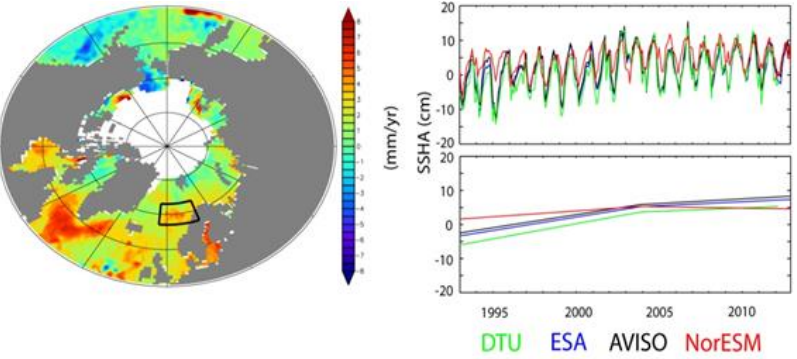
1- Validation
2- Comparison with models

The **quality of the Sea Level ECV** is assessed through:

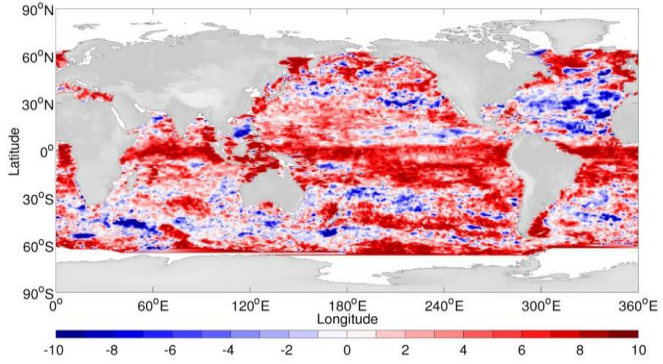
3. Comparison with ocean and coupled models outputs:

- Analyses of **MSL trends** and **subtropics signals**





- Comparison of the **SL_cci ECV** with **model outputs** at **high latitudes**



- Impact of the **assimilation of the Sea Level ECV** on the **performances of ocean models**

Error Characterization

Error Characterization

1- Error budget
2- MSL Uncertainties

- Altimetry measurements errors have been specified at different climate scales (Ablain et al., 2015)

Spatial Scales	Temporal Scales	User Requirements	Altimetry errors CCI products
Global Mean Sea Level (10-day averaging)	Long-term evolution (> 10 years)	0.3 mm/yr	**< 0.5 mm/yr**
	Inter annual signals (< 5 years)	0.5 mm over 1 year	**< 2 mm over 1 year**
	Periodic signals (Annual, 60-days,…)	Not defined	**Annual < 1 mm 60-day < 5 mm**
Regional Mean Sea Level (2x2 deg boxes and 10-day averaging)	Long-term evolution (trend)	1 mm/yr	**< 3 mm/yr**
	Inter annual signals (> 1 year)	Not Defined	**Not evaluated**
	Periodic signals (Annual, 60-days,…)	Not Defined	**Annual < 1mm 60-day < 5 mm**

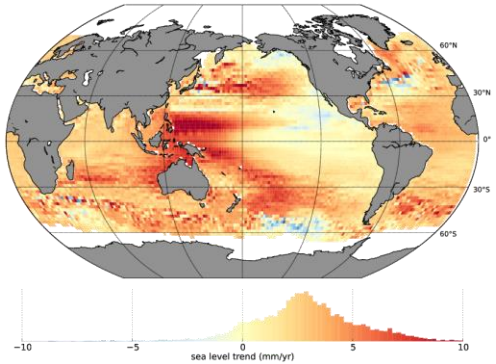
Ablain et al., 2015

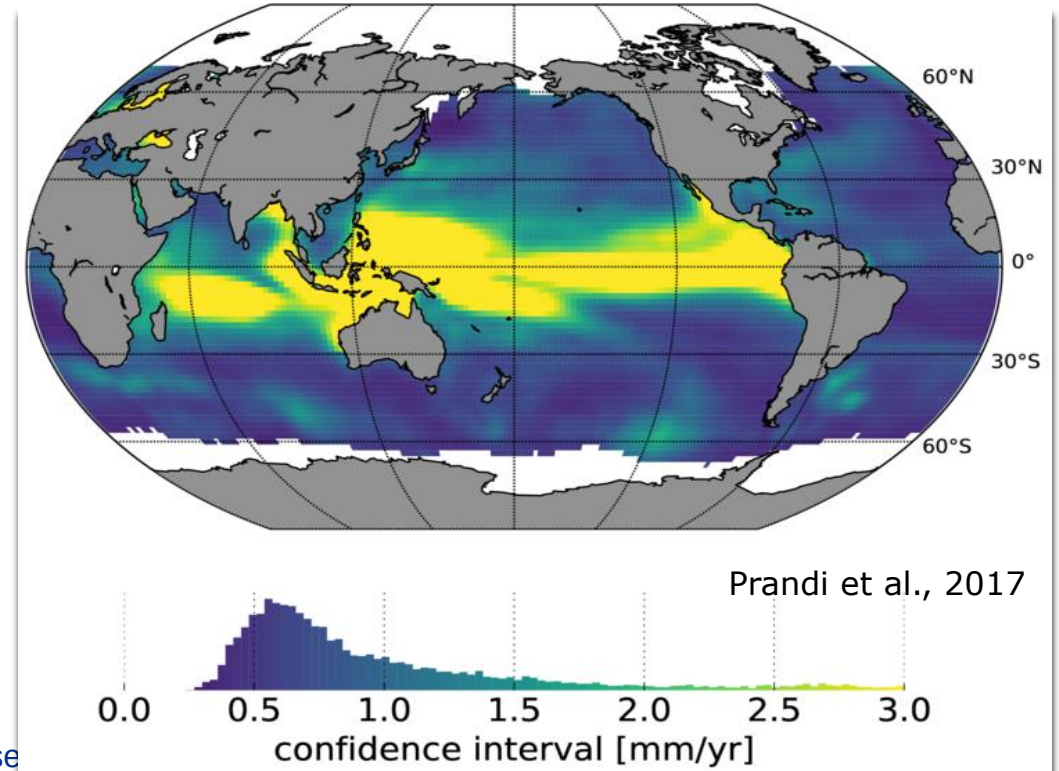
Error Characterization

1- Error budget
2- MSL Uncertainties

- Altimetry measurements errors have been specified at different climate scales (Ablain et al., 2015),
- And the regional MSL trends uncertainties have been haracterized (Prandi et al., 2017)

Regional MSL trends 1993-2015





Prandi et al., 2017

Communication

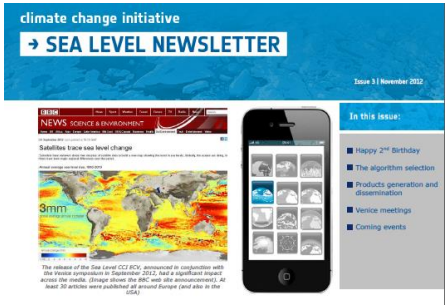
Communication

The **Sea Level ECV**: a wide range of **applications and users**:

- Analyses of the **global and regional sea level changes** (circulation, dynamics, variability and trends);
- Comparison with **ocean models** (validation) and impact of **data assimilation**;
- Comparison with other ECVs (Ocean colour, SST) and independent data (tide gauges);

⇒ More than **8 000 views and downloads of the publication** describing the v1.1 dataset

⇒ Regularly updated project **website** :
http://www.esa-sealevel-cci.org/



⇒ **Newsletters** regularly published (available on the website):

⇒ During the 6-year project, the SL_cci consortium has been involved in:

- ~ **110 peer-reviewed publications**
- ~ **25 international conferences, workshops**

⇒ Positive synergy within **cross project activities**:

- Contribution to a European network of expertise and collaboration with climate modellers (CMUG).

Perspectives and Expectations

Perspectives and Expectations

- End of SL_cci project phase II in early 2017

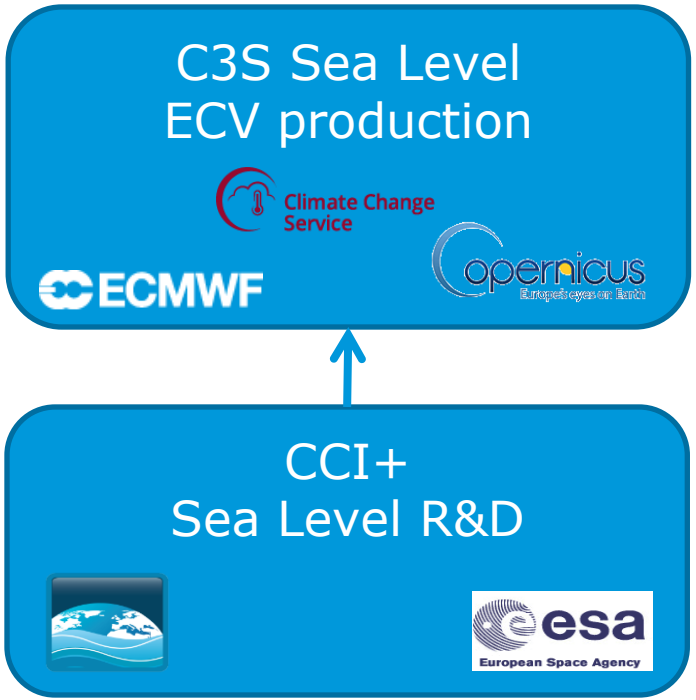
- **Copernicus Climate Change Service** (C3S, ECWMF) will set up a routine and sustained Service for the operational production of the Sea Level ECV (from 2017).

- **Strong needs to continue R&D for the Sea-Level project in the following CCI+ project** (from 2018):

→To reach **GCOS requirements** (see next slides)

→To allow the **C3S service evolution**

(strong interactions required between Copernicus and spatial agencies).



Perspectives and Expectations

- ***Improvements of observations***

  - To integrate **new altimeter missions**:
    → Jason-3, Sentinel-3a,/3b, Sentinel-6…

  - To integrate, evaluate **new Level-2 products**: => Do not forget historical missions
    → TOPEX/Poseidon repossessing (JPL/CNES)
    → ERS-1/ERS-2 (ESA), …

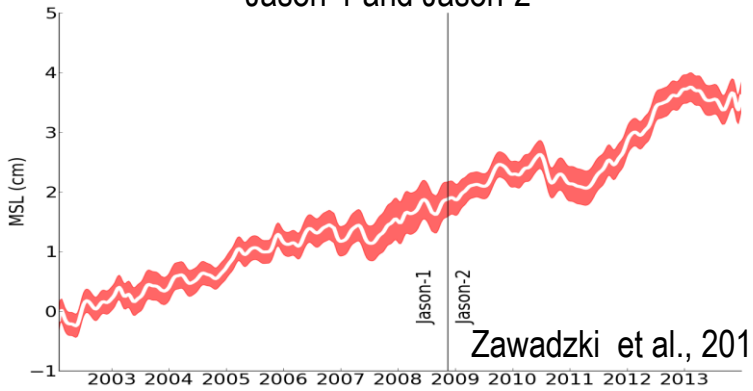
  - To **develop, integrate, evaluate new altimeter standards:**
    → new orbit solutions (new gravity fields,..)
    → new atmospheric corrections (ECMWF reanalysis)
    → more stable wet troposphere correction
    → new ocean tide models

Perspectives and Expectations

- ***Improvements of MSL estimation***

  - To better characterize MSL uncertainties:
    → At global, regional & inter-annual scales
  - To better characterize physical processes at climate scale (filtering, mapping processing).
  - To perform MSL closure budget studies :
    → To validate the MSL content and better know sea-level rise components

GMSL confidence envelop during Jason-1 and Jason-2



Zawadzki et al., 2015

New CCI Sea Level Budget Closure project (SLBC_cci)

- **2-year project** (KO meeting 6-7 March 2017, ESA/ESRIN)
- **Team**: **Project PI: Martin Horwatt,** TU Dresden; LEGOS; U. Bremen; U. Zürich; U Leeds; U. Frankfurt; DTU; NERSC; U. Reading; (Mercator-Ocean).

Perspectives and Expectations

- ***Improvements at high latitudes***

  - To improve **MSL estimations in ice-covered regions**:

    → To **extend times series** from 1993 onwards (ERS1 and ERS-2, Cryosat, Saral/Altika, Sentinel-3,…)

    → To **improve algorithms** (classification, retracking, editing, merging…)

    → To **validate MSL changes** (MSL closure budget, in-situ comparaisons,…)

Perspectives and Expectations

- ***Improvements of MSL estimation in coastal areas***

⇒Crucial importance regarding the **societal impact of climate change in coastal areas**.

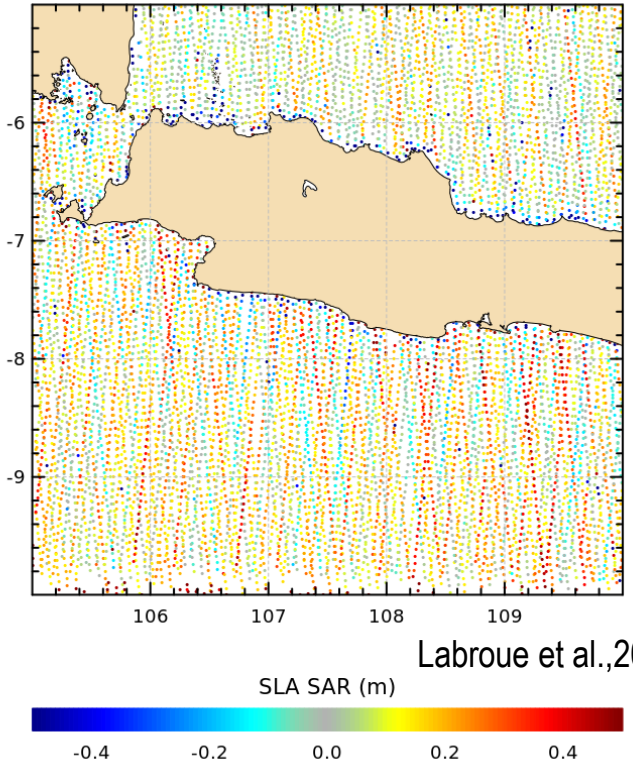
→ To **extend the climate record to the coasts**

→ To **fill the gap between open ocean and tide gauges**

→ To assess impact of various **corrections and vertical land motion**

→To benefit from **new altimetry missions in SAR mode** (Sentinel-3a,…) with better performances expected in coastal areas

- Objective: to provide **reliable information for policy makers** (cf the "*Regional sea Level Changes and Coastal Impacts*" WCRP/IOC conference, July 10-14, 2017, New York)



Labroue et al.,2016

Thanks for your attention!