Accurate Estimation of Regional Sea Level Changes with the ESA CCI Sea Level Essential Climate Variable

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The Sea Level Climate Change Initiative -Sea Level 2017 - July 10-14th 2017

Context

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

esa
European Space Agency

ESA CCI PROGRAM

- aerosol cci
- ozone cci
- ocean colour cci
- cloud cci
- sea ice cci
- land cover 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

1. The SL_cci Products
2. New Altimeter Standards and Impacts at Climate Scales
3. Error Characterization and Uncertainties
4. Perspectives and Expectations

The Sea Level CCI products

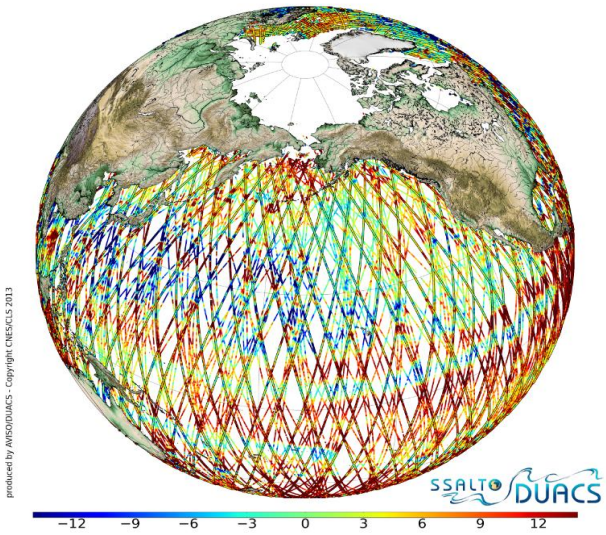
The SL_cci Products

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

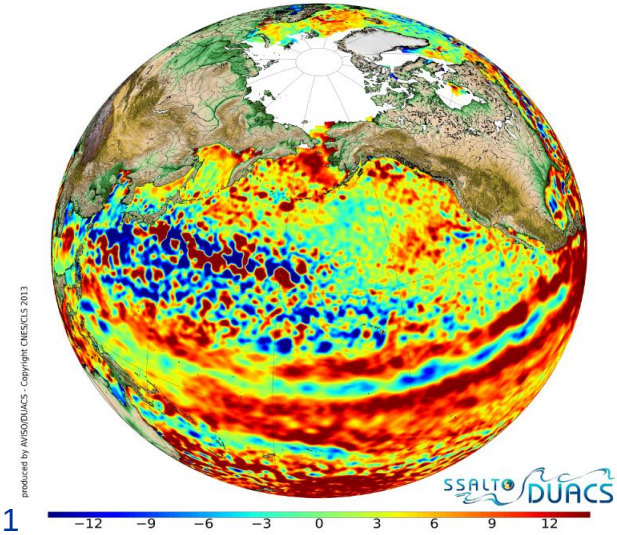
- **9 altimeter missions**: TOPEX/Poseidon, Jason-1/2, ERS-1/2; Envisat, Geosat-FO, CryoSat-2 and SARAL/AltiKa
- **70 cumulated years**
- **Period**: 1993-2015

The CNES/CLS DUACS system is used to:

Process along-track data



Produce merged gridded products

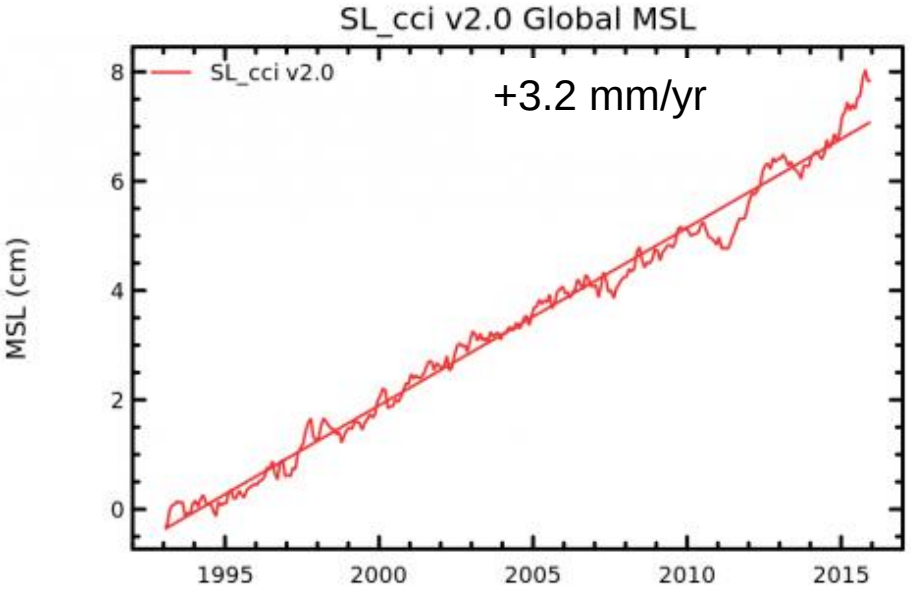


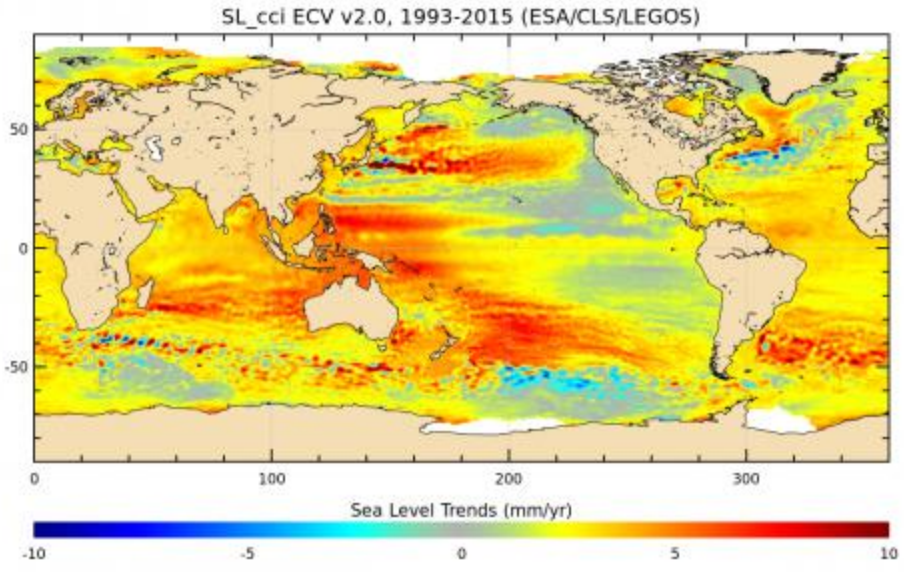
The SL_cci Products

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

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

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



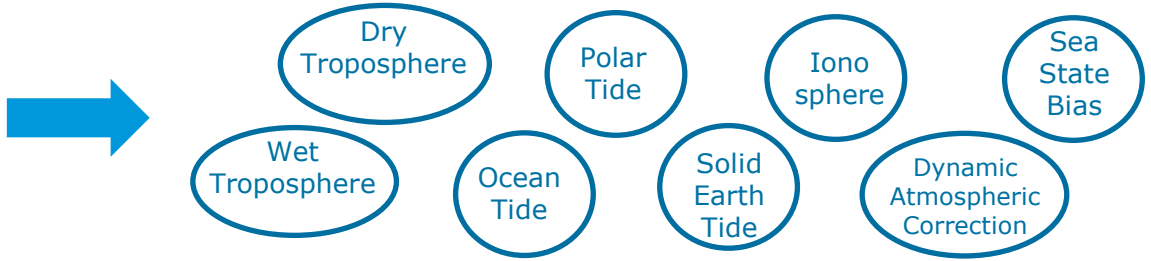


New Altimeter Standards and Impacts at Climate Scales

Impacts at Climate Scales

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 (different versions are available for each algorithm).

⇒ 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**

- Description of the selected **altimeter standards** in Quartly et al. (2017)
- ECV validation results in Legeais et al. (in prep.): see the following slides.

Impacts at Climate Scales

Global Mean Sea Level

- Long-term evolution
- Interannual Signals
- Periodic Signals

Regional Mean Sea Level

- Long-term evolution

Mesoscale

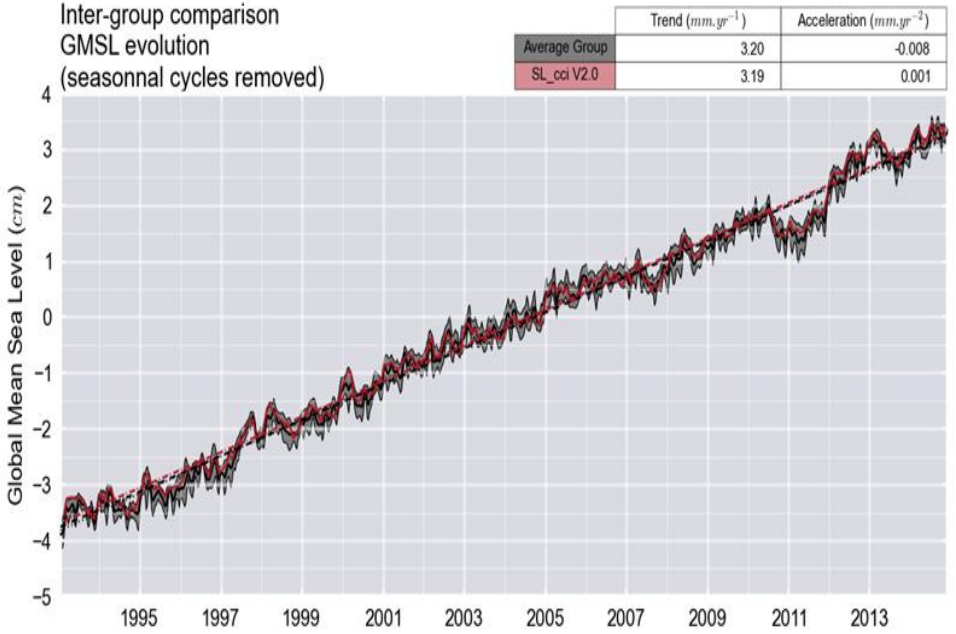
- Signals < 2 months and coastal areas

⇒ 3.2 mm/yr during 1993-2014 (homegenous trend with the ensemble mean of other GMSLs)

⇒ The **MSL stability** is confirmed by comparison with **tide gauges** measurements.

⇒ The quality of the ECV is also confirmed with a **budget closure** approach (Dieng et al., 2017):
Altimeter MSL = steric sea level changes
+ ocean mass variations

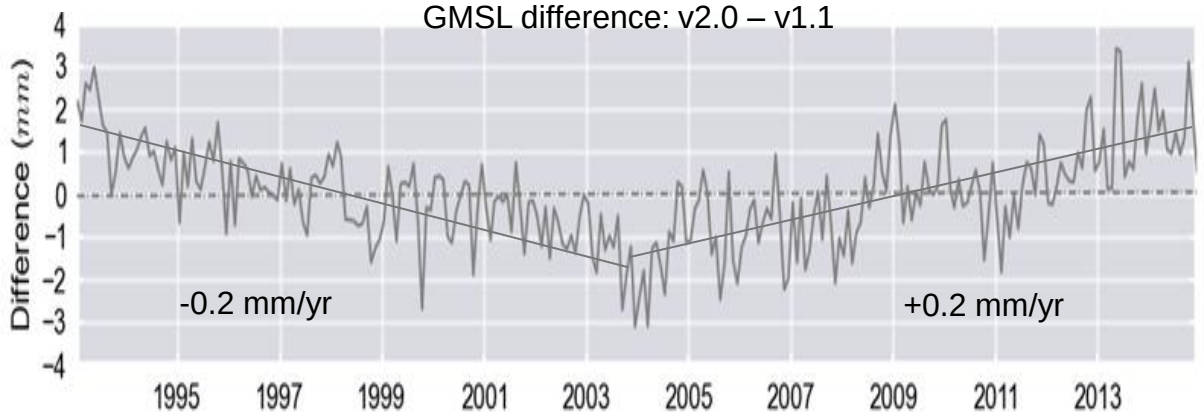
This approach is fully exploited in the recently launched **ESA Sea Level Budget Closure** project.



Impacts at Climate Scales

Global Mean Sea Level			Regional Mean Sea Level	Mesoscale
Long-term evolution	Interannual Signals	Periodic Signals	Long-term evolution	Signals < 2 months and coastal areas

- Significant impact at **decadal time scale** (+/- 0.2 mm/yr) compared to v1.1:



⇒ This evolution is attributed to the use of the **GPD+ wet troposphere correction** (based on radiometer and GNSS measurements, Fernandes et al., 2015).

⇒ The **different rate of the MSL rise** during the two altimetry decades is discussed in Dieng, Cazenave et al. (2017).

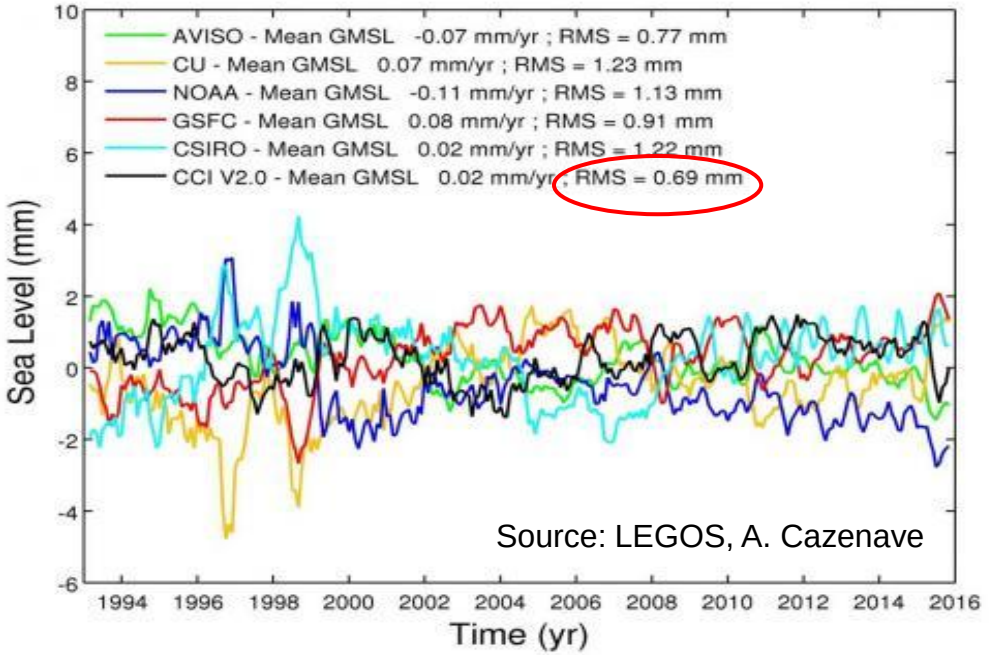
Impacts at Climate Scales

Global Mean Sea Level | Regional Mean Sea Level | Mesoscale

Long-term evolution | Interannual Signals | Periodic Signals | Long-term evolution | Signals < 2 months and coastal areas

- The **detrended GMSLs** from different groups have been **compared** to the **ensemble mean** of other GMSL
- The **smallest RMS of the differences** has been obtained with the **SL_cci v2.0**

⇒ This contributes to highlight the performance of this new sea level record.



Impacts at Climate Scales

Global Mean Sea Level

- Long-term evolution
- Interannual Signals
- **Periodic Signals**

Regional Mean Sea Level

- Long-term evolution

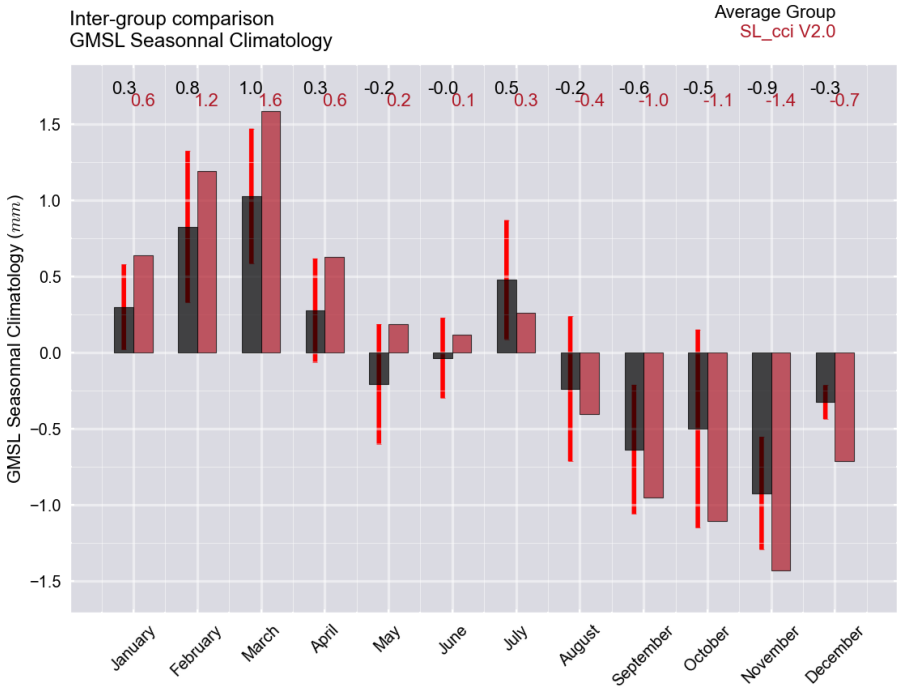
Mesoscale

- Signals < 2 months and coastal areas

- The **SL_cci v2.0 ECV** shows a smoother **sinusoidal annual cycle** than the one derived from the average group.

⇒ Comparisons with:
- Tide gauges (amplitude of the annual signal of the differences) and,
- Dynamic heights from the Argo network (correlation) suggest that the **annual cycle** is better estimated in the v2.0.

The **contributing standards** are:
- the orbit solutions (Couhert et al., 2015),
- the WTC (Fernandes et al., 2015),
- the pole tide correction (Desai, 2015).



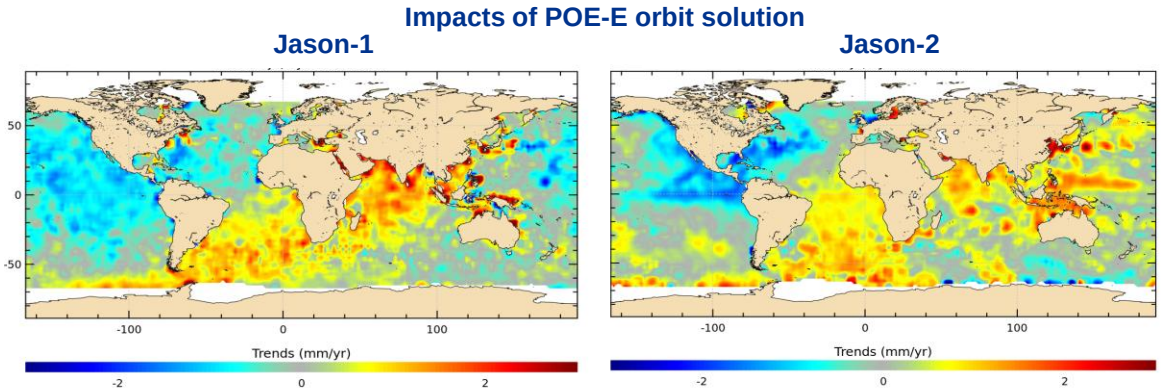
Impacts at Climate Scales

Global Mean Sea Level | Regional Mean Sea Level | Mesoscale

Long-term evolution | Interannual Signals | Periodic Signals | **Long-term evolution** | Signals < 2 months and coastal areas

- The **MSL trend differences** observed compared to the previous SL_cci version (1993-2014) are mainly due to:

⇒ The new **orbit solutions**:
POE-E (Couhert et al., 2015) and GFZ
(up to **2 mm/yr** MSL trend differences at basin scale)

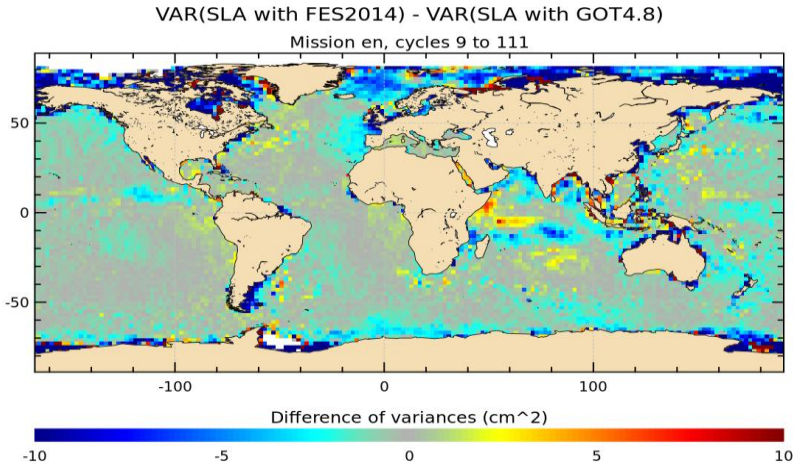


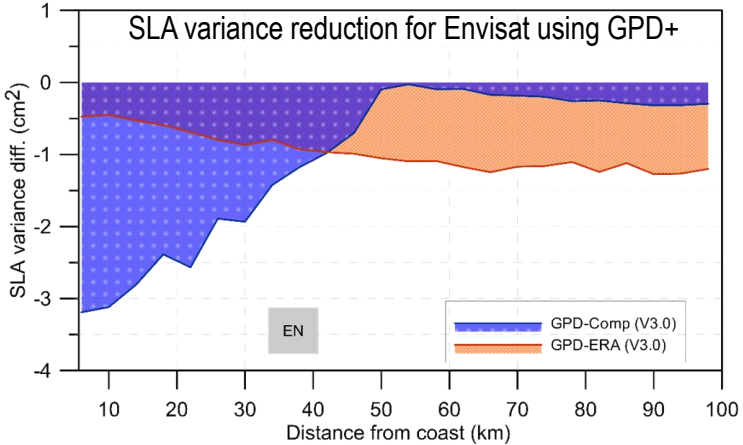
Impacts at Climate Scales

Global Mean Sea Level			Regional Mean Sea Level	Mesoscale
Long-term evolution	Interannual Signals	Periodic Signals	Long-term evolution	Signals < 2 months and coastal areas

- **Reduced sea level variance** in many **coastal areas** and at **high latitudes** due to the **new FES2014 ocean tide model**

- **Improved variance** estimation in **coastal areas** with the **GPD+ WTC** (Fernandes et al., 2015)





Error Characterization and Uncertainties

Error Characterization

1- Error budget
2- MSL Uncertainties

Altimetry measurements errors have been specified at different climate scales (Ablain et al., 2017)

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
	Annual cycle	Not defined	Annual < 1 mm
Regional Mean Sea Level (2x2 deg boxes and 10-day averaging)	Long-term evolution (trend)	< 1 mm/yr	< 3 mm/yr (except for western boundary currents)
	Inter annual signals (> 1 year)	Not Defined	Not evaluated
	Annual cycle	Not Defined	Annual < 1cm

Error Characterization

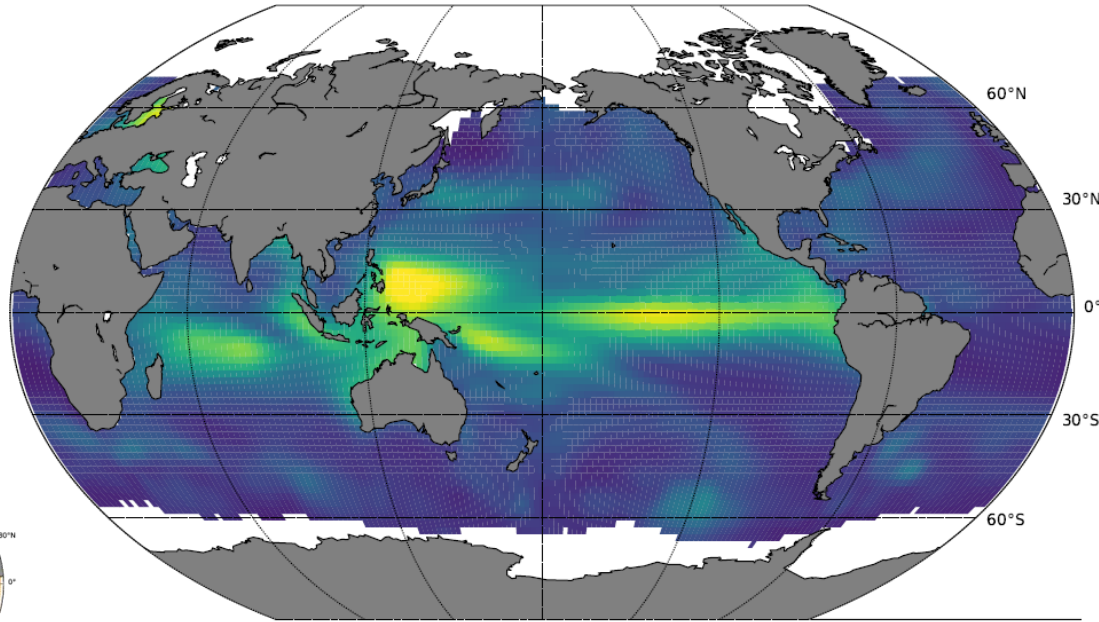
1- Error budget
2- MSL Uncertainties

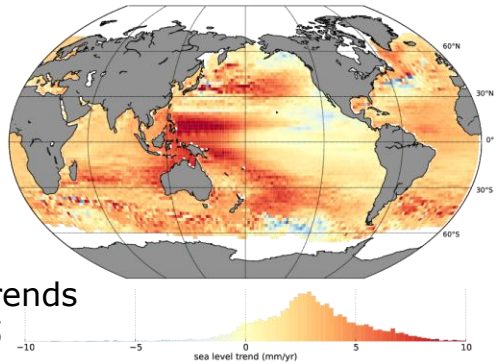
• The **confidence interval of the regional MSL trends** has been estimated**:**

- Part associated to the altimeter **instrumental errors** only,
- The uncertainty associated to the **GIA errors** and the **internal variability** of the ocean remain to be added.

⇒ Prandi et al. (in prep).

• In some areas, the uncertainty is greater than the signal





Regional MSL trends
1993-2015

Perspectives and Expectations

Perspectives and Expectations

- The **operational production** of the Sea Level ECV has been transferred to the European **Copernicus Climate Change Service** (C3S) (Dec. 2017).

⇒ Strong **interaction** is required between **Copernicus and spatial agencies** to reach the following **objectives**: - To allow the evolution of the **C3S sea level**,
- To reach **GCOS requirements** (see below)
- To provide **reliable information for policy makers**

Perspectives

Observations:

- Integrate new **altimeter missions** and evaluate new **standards** and **reprocessed** level 2 products.

Mean Sea Level:

- Better **characterize uncertainties** and **sea level rise components**; Improve the product validation.

Coastal Sea Level:

- The **challenge** is to determine if the coastal sea level is rising at the same rate as the **observed sea level in the open ocean**?
- Need to measure the **total relative sea level**

= GMSL + regional variability + local processes + Vertical Land Motion

Thank you for your attention!