Two Decades of Global and Regional Sea Level Observations from the ESA Climate Change Initiative Sea Level Project

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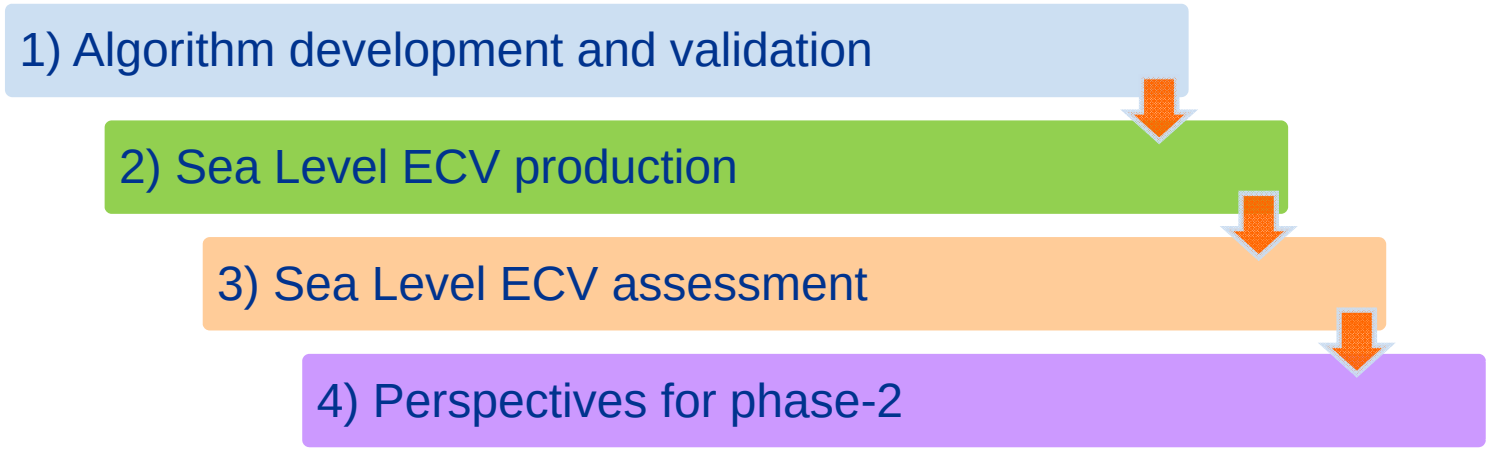
Outlines

- First phase of the SL-CCI project very soon achieved [2010,2013]

- It consists in generating space-based climate records of Seal Level observations from all the altimeter data with an integrated and consistent approach with the objective to:
  - ⇒ Reduce errors on the global mean sea level trend to <0.3 mm/yr
  - ⇒ Reduce errors on the interannual variability to <1 mm
  - ⇒ Reduce errors on regional sea level trends to <1 mm/yr

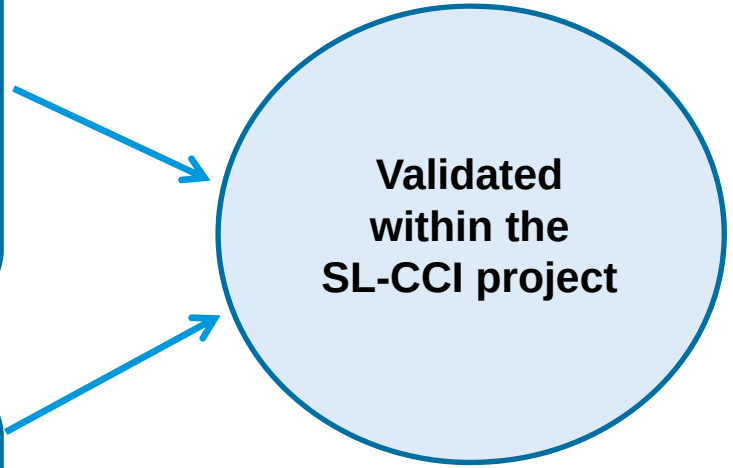


1) Algorithm development and validation

• News algorithms and altimeter corrections have been developed and tested:
- they are dedicated for Climate applications
- they come from Sea Level CCI partners but also from external projects or studies

SL-CCI new algo/corrections:
-New Orbit solutions (GFZ)
-New instrumental corrections (CLS/isardSAT)
-New wet Tropo corrections (University of Porto)
-New atmosphercical correction with ERA-interim (CLS)
-New ionospheric corrections (CLS)
-New algorithms to merge altimeter mission together (CLS)

External project and studies:
- Jason-2 reprocessing (SALP project / CNES)
- Envisat reprocessing (FPAC/ESA/CNES) :
- New orbit solutions (POD group)
- New tidal models (R.Ray, CNES/LEGOS/CLS)
- Mean Sea Surface (DTU, CNES/CLS)
- ERS-1/ERS-2 reprocessing (REAPER project / ESA)



1) Algorithm development and validation

Impact of new SL-CCI correction in SSH calculation in comparison with the reference one (AVISO standards,…)		
Climate Applications	**Temporal Scales**	**For 1 mission (Envisat, ERS, Jason, T/P,…)**
Global Mean Sea Level	**Long-term evolution (trend)**	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	**Long-term evolution (trend)**	
	Annual and semi-annual Signals	
Mesoscale	**Signals < 2 months**	

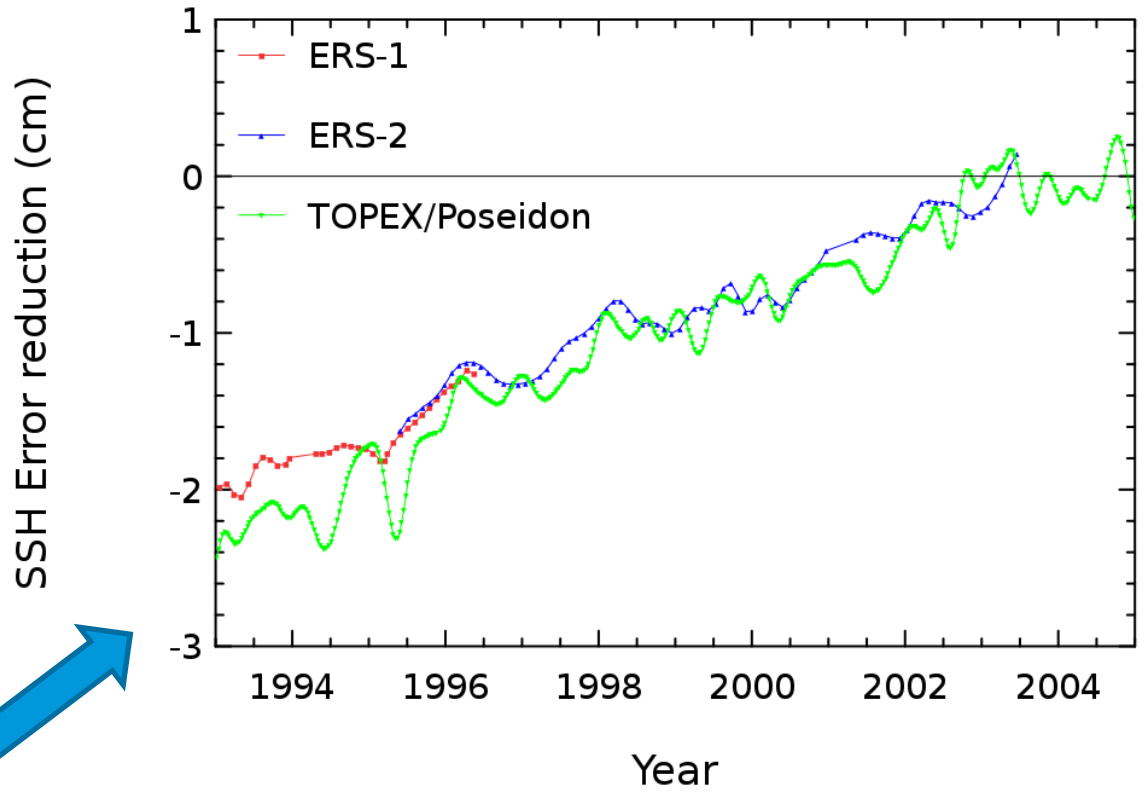
1) Algorithm development and validation

Impact of new SL-CCI in SSH calculation in comparison with AVISO standards			Definition of the indicator value		
Climate Applications	**Temporal Scales**	**For 1 mission (Envisat, ERS, Jason, T/P,...)**	**Significant impact**	**Low impact**	**No impact detected**
Global Mean Sea Level	**Long-term evolution (trend)**	NO IMPACT	**Trend >0.15 mm/yr**	**Trend> 0.05 mm/yr**	**Trend< 0.05 mm/yr**
	Inter annual signals (> 1 year)	+ LOW IMPACT	**Amplitude> 0.5 mm**	**Amplitude> 0.2 mm**	**Amplitude< 0.2 mm**
	Annual and semi-annual Signals	- **STRONG IMPACT**	**Amplitude> 1 mm**	**Amplitude> 0.2 mm**	**Amplitude< 0.2 mm**
Regional Mean Sea Level	**Long-term evolution (trend)**		**Trend > 0.5 mm/yr**	**Trend> 0.1 mm/yr**	**Trend< 0.1 mm/yr**
	Annual and semi-annual Signals		**Amplitude> 5 mm**	**Amplitude> 0.5 mm**	**Amplitude< 0.5 mm**
Mesoscale	**Signals < 2 months**		**Crossovers Variance differences > 1 cm²**	**Crossovers Variance differences > 0.2 cm²**	**Crossovers Variance differences < 0.2 cm²**

1) Algorithm development and validation

Atmospheric corrections derived from ECMWF reanalysis (ERA-Interim):
⇒very strong improvement on early altimetry years (1993-2000) : T/P, ERS1-ERS-2

Climate Applications	Temporal Scales	For TOPEX, ER1 and ERS-2
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+



Evolution of the SSH error reduction thanks to the new DAC corrections

1) Algorithm development and validation

Atmospheric corrections derived from ECMWF reanalysis :

⇒very strong improvement on early altimetry years (1993-2000) : T/P, ER1-ERS-2

Climate Applications	Temporal Scales	For TOPEX, ER1 and ERS-2
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
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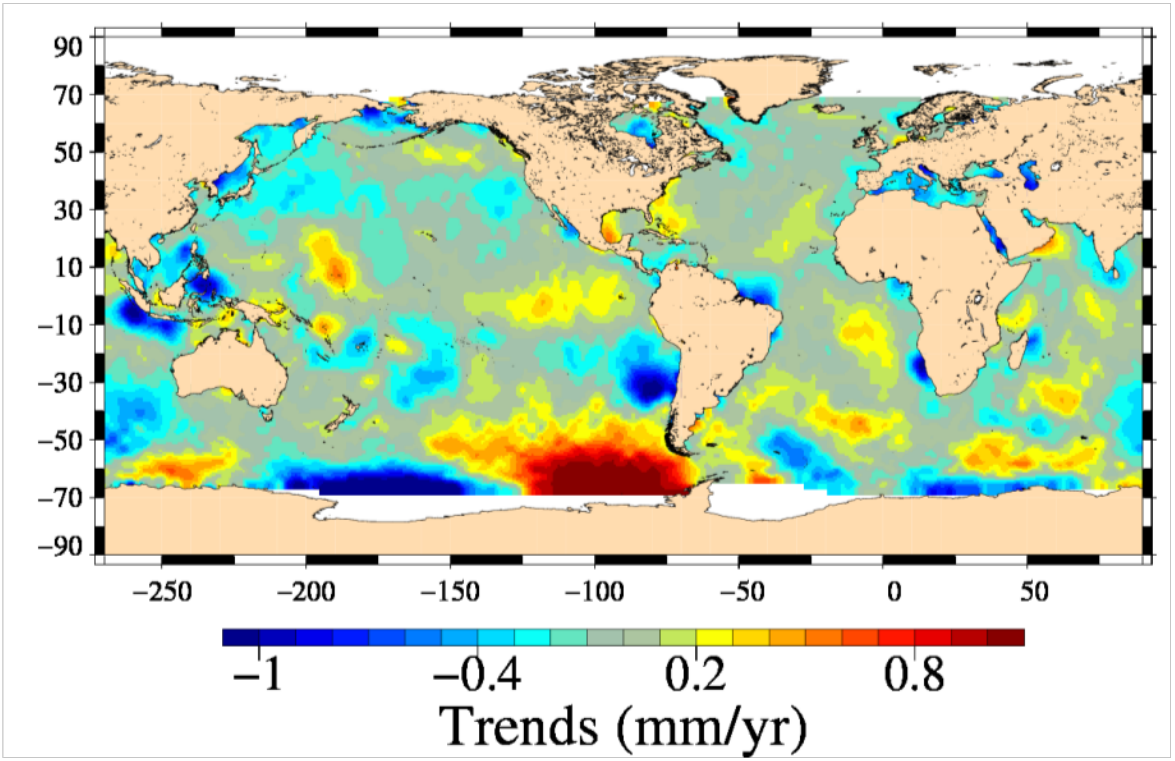
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+



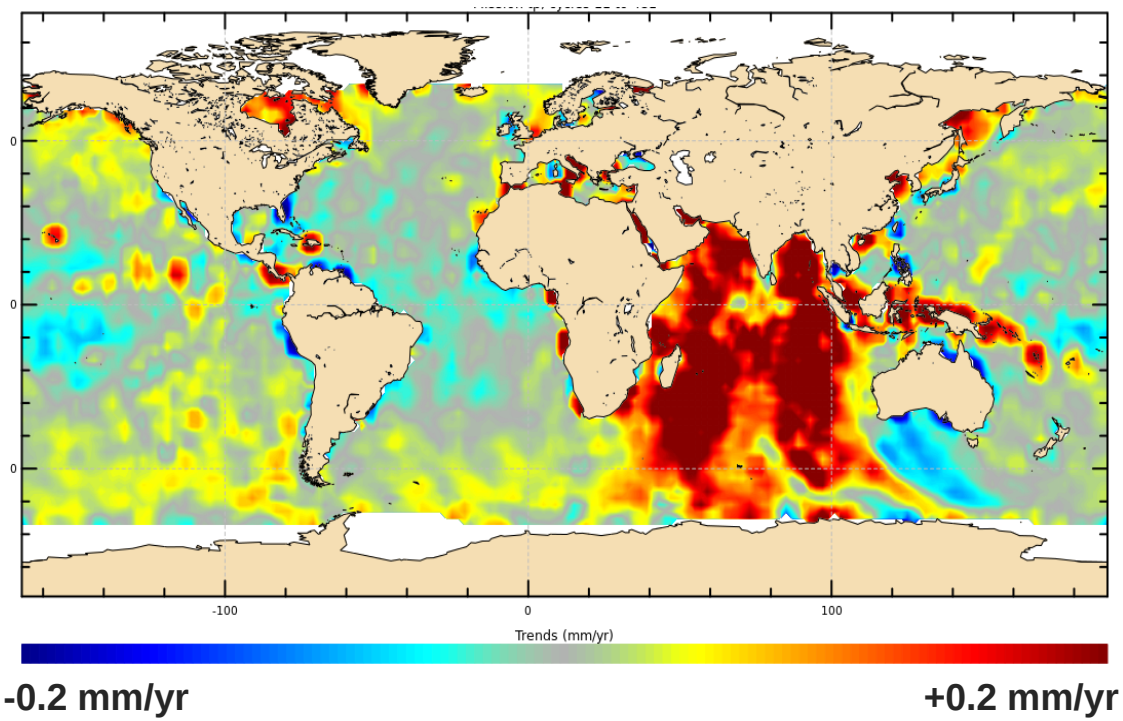
Impact of the new DAC correction on the regional MSL trends between 1993 and 2005

1) Algorithm development and validation

New Wet Tropospheric corrections (UoP) have been developed for all the missions :

⇒ Better than the reference ones on coastal areas and sometimes in open ocean

Climate Applications	Temporal Scales	For all the missions
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+



Impact of the new GPD correction on the regional MSL trends for T/P between 1993 and 2005

1) Algorithm development and validation

New algo/corr applied in SL CCI

No change with respect to reference (AVISO products)

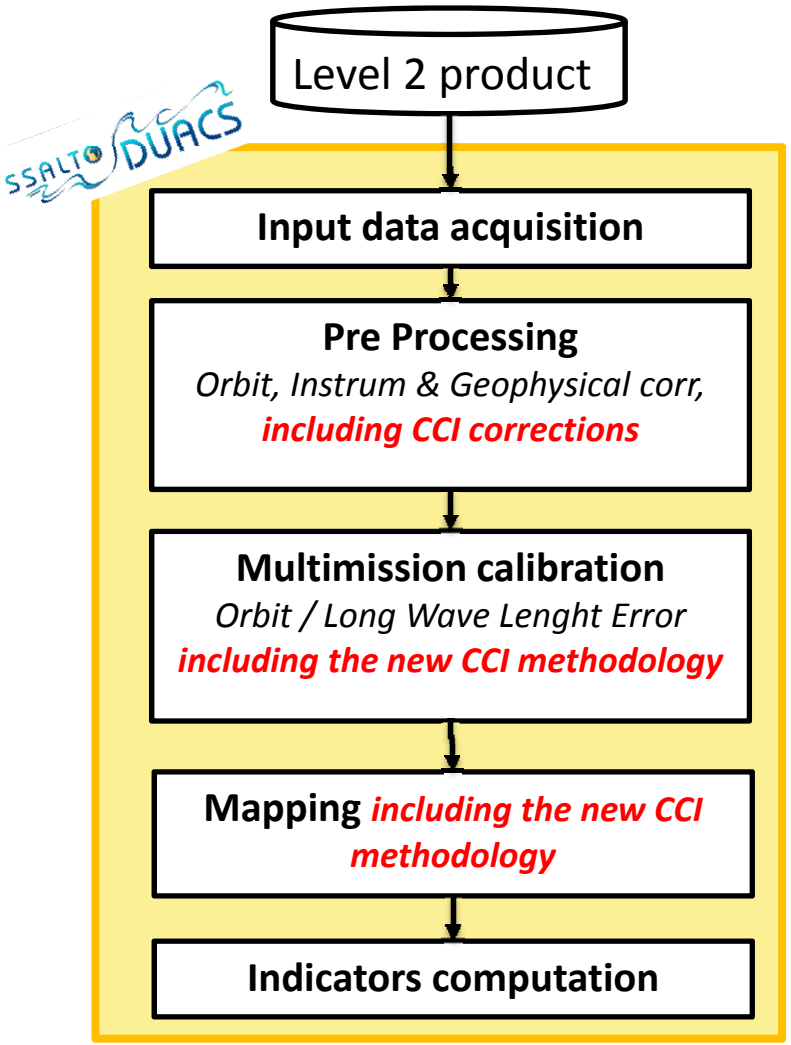
Corrections recently developed and to be apply in next ECV release

Selection meeting outputs

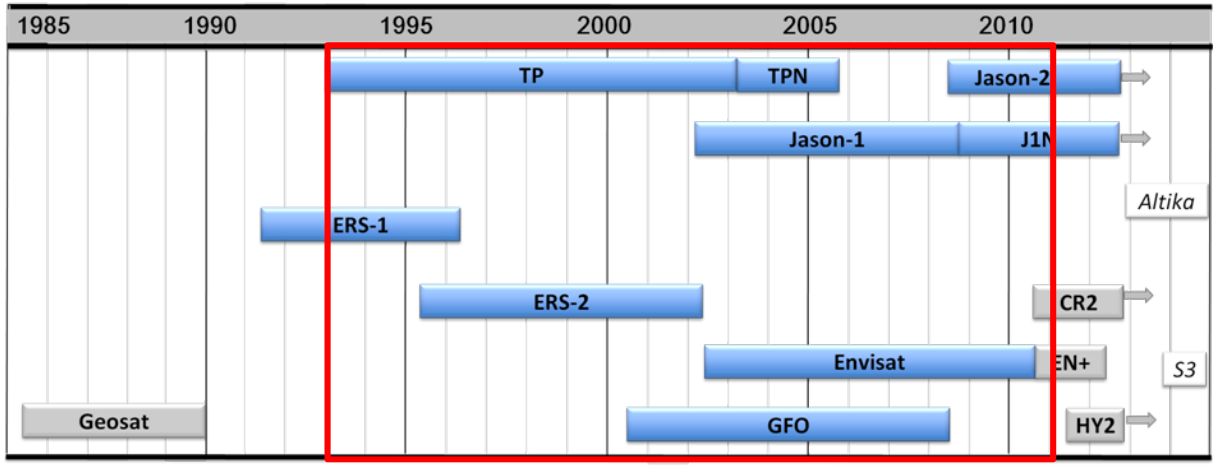
Discussions & recommendations available on the SL CCI web site

	ERS-1	ERS-2	EN	T/P	J1	J2	GFO
Orbit	Reaper	Reaper	GDRD		GDRD	GDRD	
Major Instrumental correction			PTR				
Sea State Bias			2007				
Ionosphere	Reaper		Rep.				
Wet troposphere	GPS-based	GPS-based	GPS-based	GPS-based	GPS-based	GPS-based	
Dry troposphere	Era Interim based						
Combined atmospheric correction	Era Interim based						
Ocean tide	GOT 4.8						
Solid Earth tide							
Pole tide							
MSS	DTU10						
Merging algorithms	New regional biases and monthly OI						

2) Sea Level ECV production



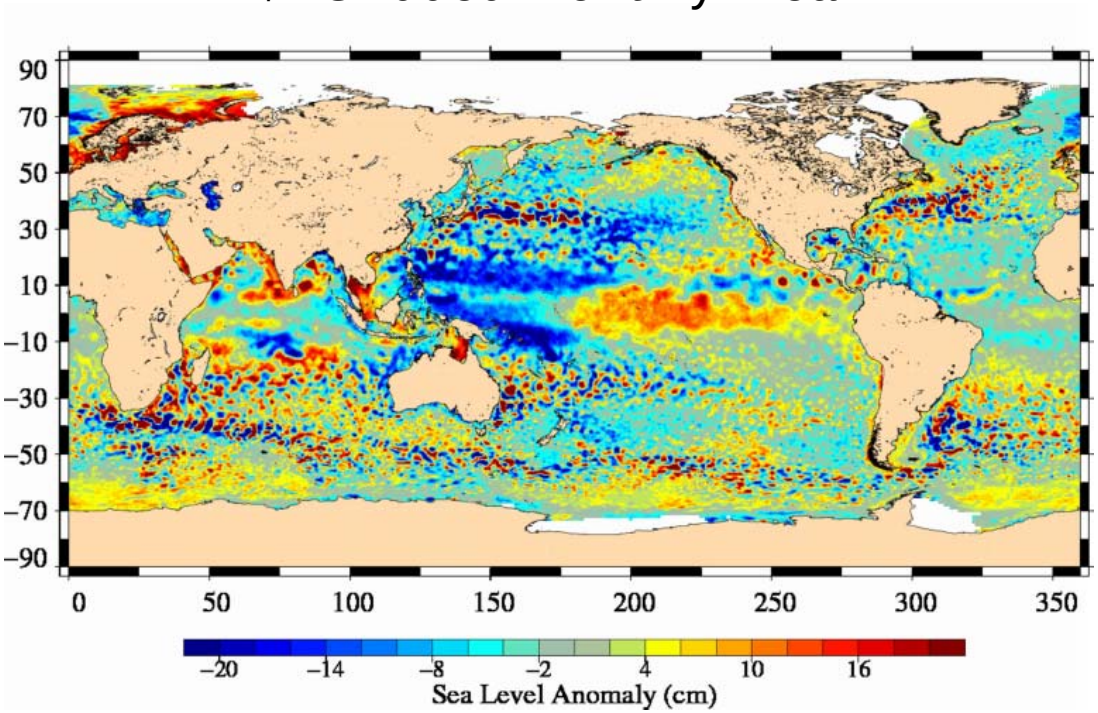
- 7 missions (re)processed:
  (T/P, Jason1/2, ERS-1/2, ENVISAT & GFO)
- Period: [1993-2010]
- 50 years of data (re)processed
- Based on SSALTO/DUACS infrastucture



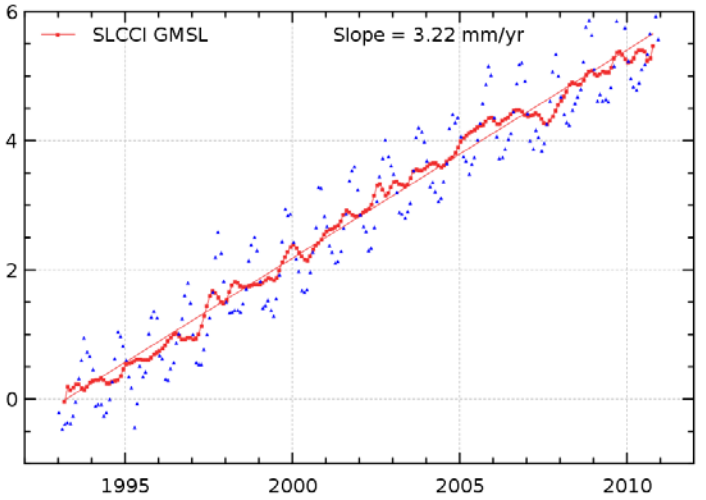
2) Sea Level ECV production

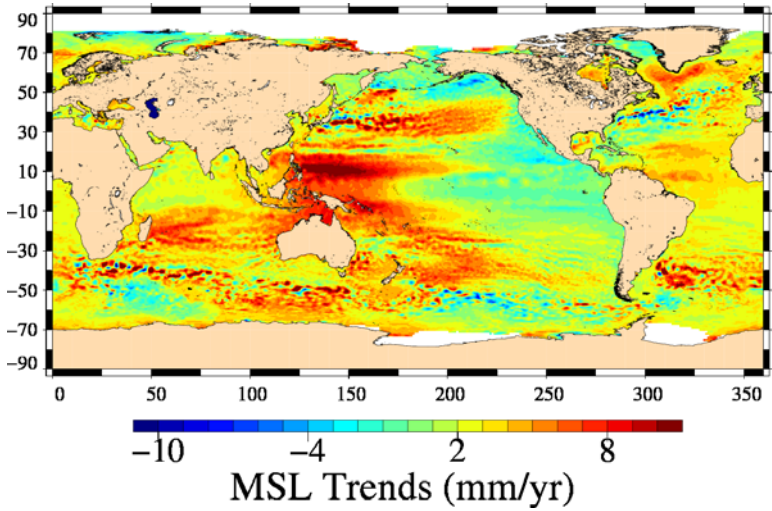
SLCCI ECV release : V1.0
available via: http://www.esa-sealevel-cci.org/
Please contact us: info-sealevel@esa-sealevel-cci.org

¼° Gridded Monthly mean



Global MSL evolution





2) Sea Level ECV production

• A new Sea-Level ECV release (V1.1) will be delivered by the end of the year :

⇒ It covers the same period [1993-2010] with the same altimeter missions

⇒ New altimeters standards have been taken into account :
- Jason-2 reprocessing (GDR-D release)
- Envisat GDR reprocessing (GDR V2.1 release)
- New GPS-based wet troposheric correction for all the missions

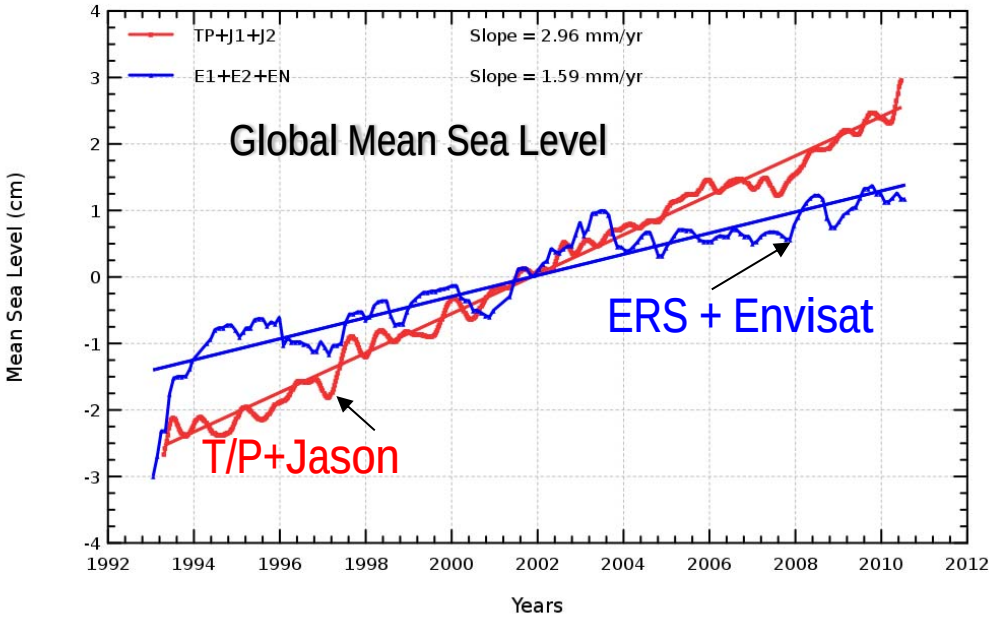
SLCCI ECV release : V1.1
Will be available via: http://www.esa-sealevel-cci.org/ before December 2013
Please contact us: info-sealevel@esa-sealevel-cci.org

3) Sea Level ECV assessment

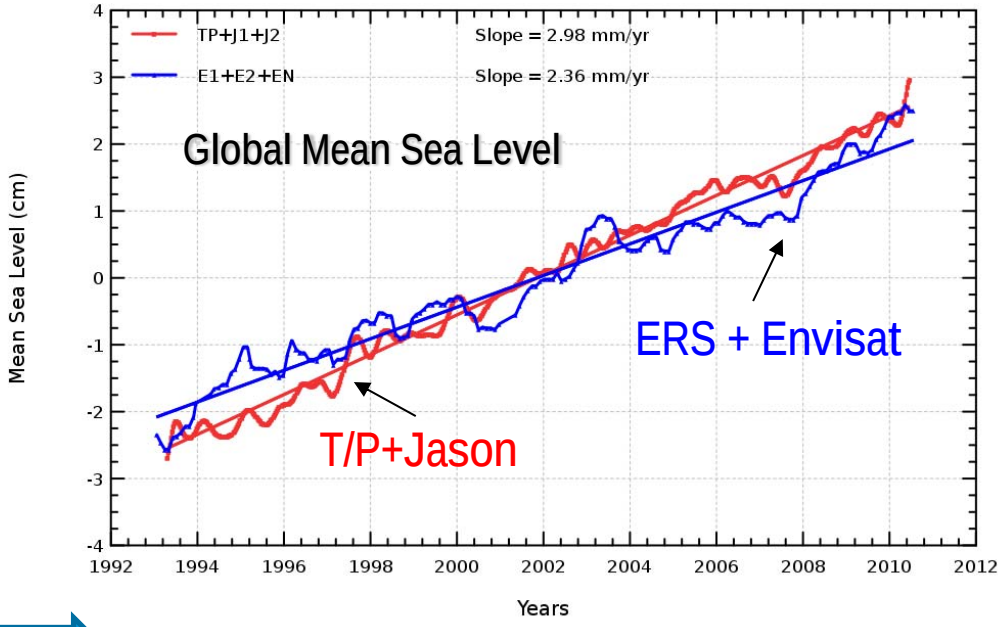
• The Global Mean Sea Level (GMSL) derived from ESA missions (ERS-1&2, Envisat) has been significantly improved:

⇒The long-term trend is now close to TOPEX/Jason-1/Jason-2 GMSL trend

⇒The inter-annual signal is more consistent with other missions



Before the SLCCI project



Now !

3) Sea Level ECV assessment

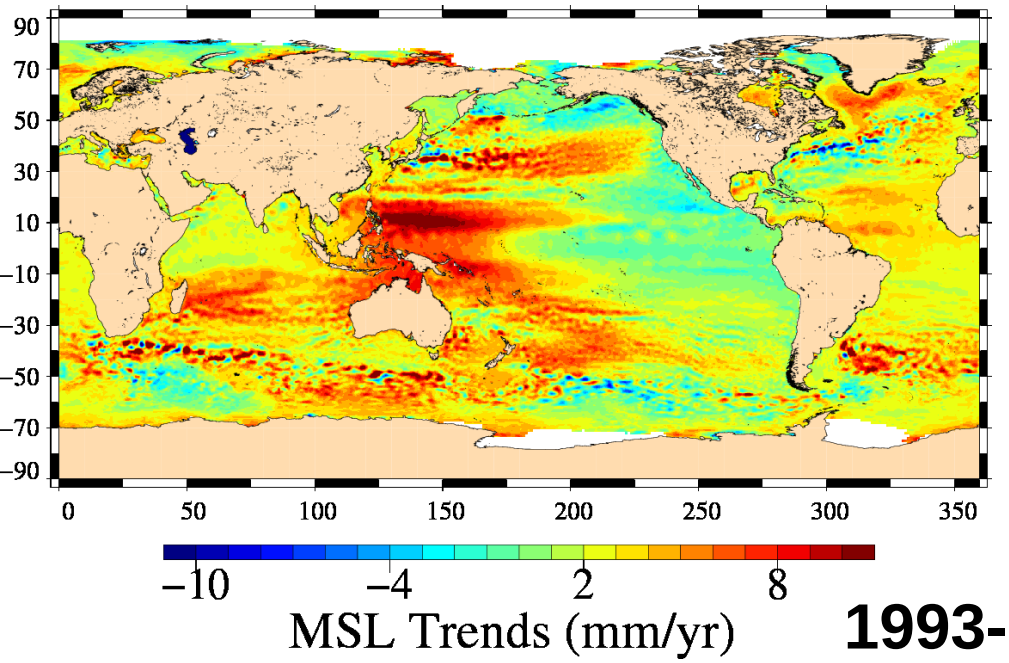
- The regional Mean Sea Level trends have been significantly improved :

⇒ differences in the range +/- 2 mm/yr at local scales

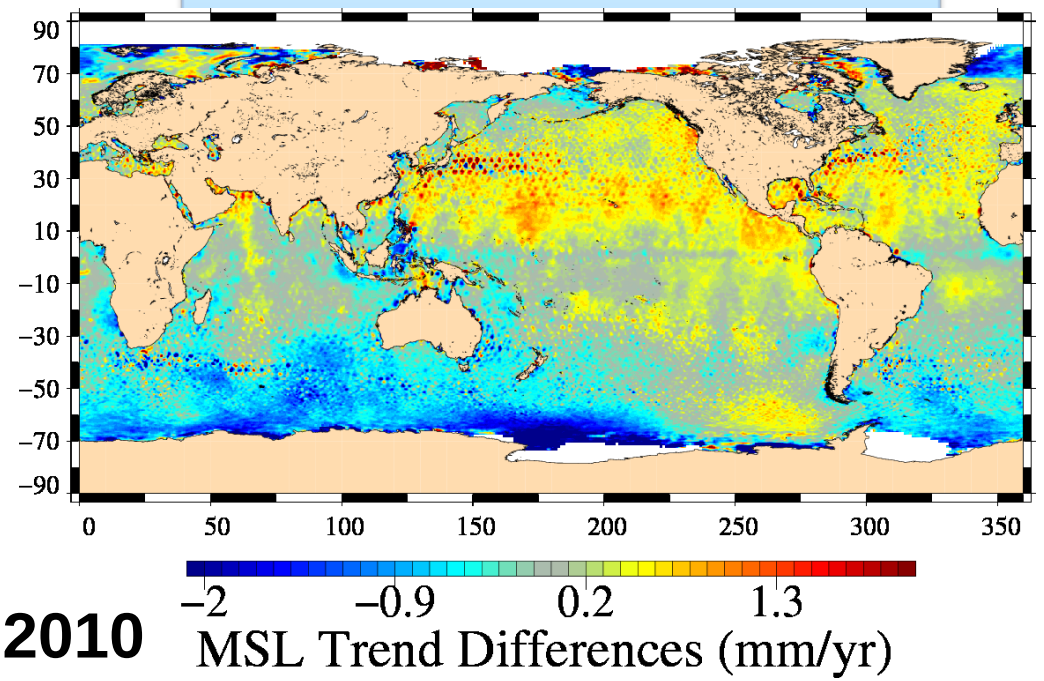
⇒ these differences are significant since regional Mean Sea Level trends are ranging between +/- 10 mm/yr from 1993 onwards

Regional MSL trends from SLCCI project

Improvements of SLCCI project on regional MSL trends



1993-2010



3) Sea Level ECV assessment

- Error characterisation of altimetry measurements at climate scales (Ablain et al, 2012)

Spatial Scales	Temporal Scales	User Requirements	Altimetry errors
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

3) Sea Level ECV assessment

- Error characterisation of altimetry measurements at climate scales (Ablain et al, 2012)

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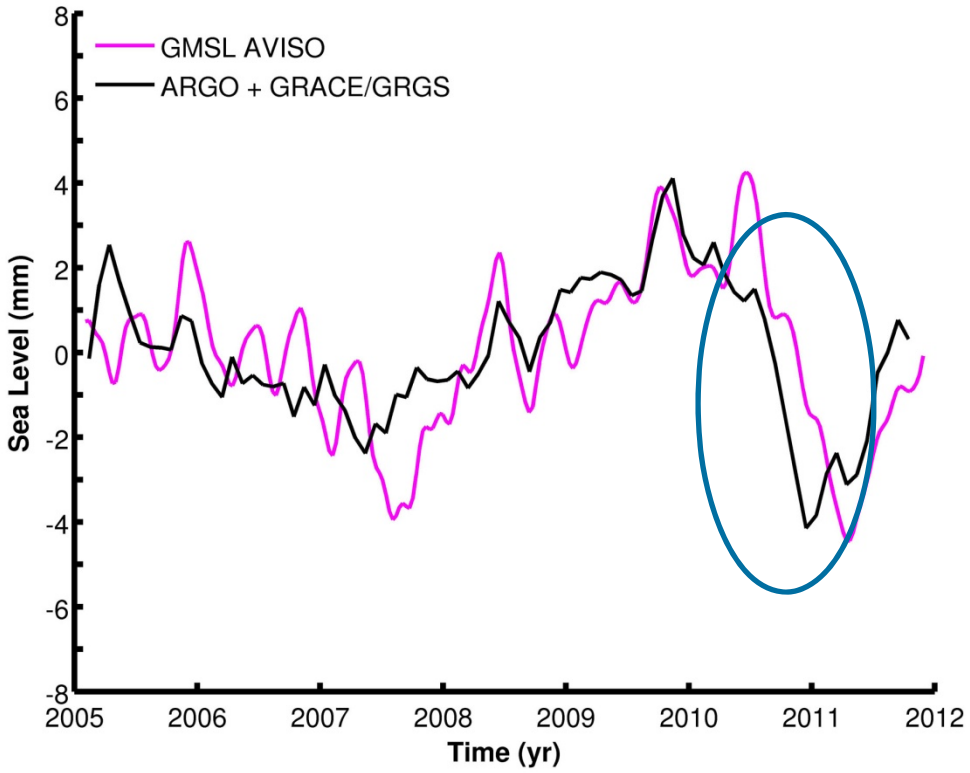
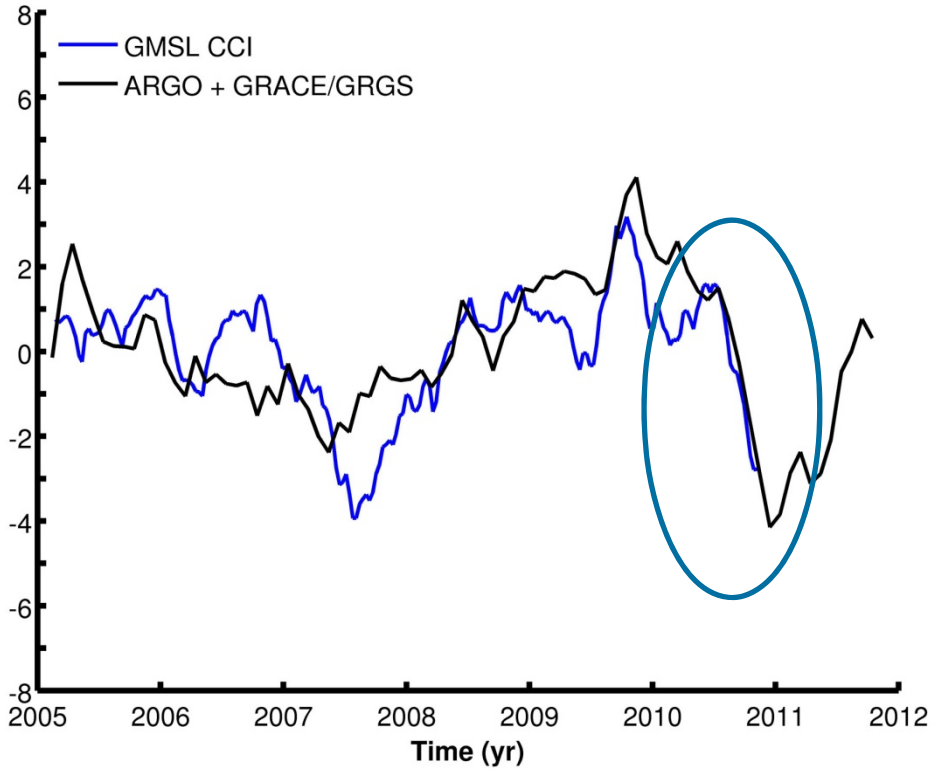
3) Sea Level ECV assessment

- ECV assessment by climate users:
- Validation of SL-CCI ECV products with models (on progress)
- Validation of SL-CCI ECV products via sea level budget studies (performed by LEGOS)





4) Conclusions and perspectives for phase-2

- During the first phase of SL-CCI project [2010-2013] , we have:

⇒ improved user requirements for Sea Level at climate scales
⇒ homogenized altimetry database for all the altimeter missions
⇒ reduced altimetry errors at climate scales
⇒ developed a formal validation protocol to select the best altimeter
⇒ generated Sea-Level ECV products over a 18-year period [1993-2013]
⇒ better characterized altimetry errors at climate scales
⇒ assessed Sea-Level ECV products
⇒ published several peer-review papers

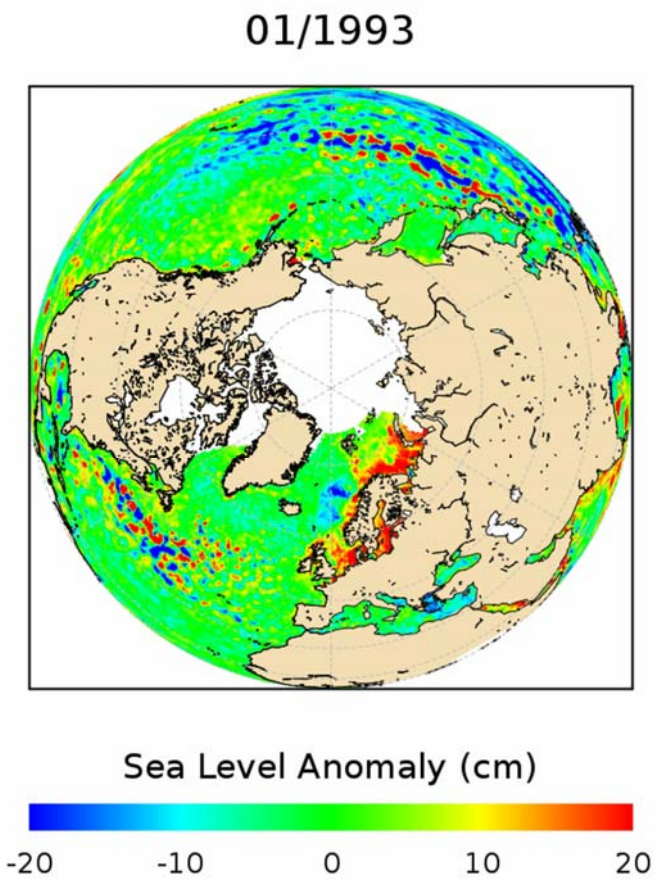
• "Despite we reached a good level of maturity and introduced major improvements, the User Requirements are not yet reached:a lot of improvement still remain. It is an ongoing effort…"

4) Perspectives for phase-2

- For phase 2 [2014-2016], we have proposed to :

⇒ continue improving user requirements

⇒ develop/validate new altimeter corrections or algorithms with a focus on dedicated areas (Arctic ocean, coastal areas)



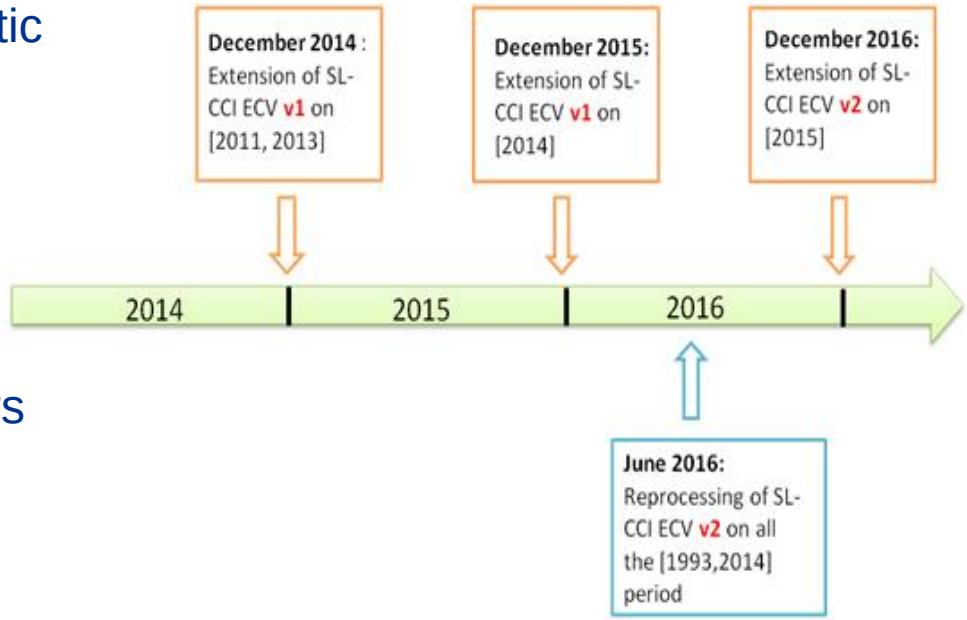
4) Perspectives for phase-2 [2014-2016]

• For phase 2 [2014-2016], we have proposed to :

⇒ continue improving user requirements

⇒ develop/validate new altimeter corrections or algorithms with a focus on dedicated areas (Arctic ocean, coastal areas)

⇒ produce new ECV release with time-series extension at the end of each year



⇒ perform the ECV assessment by climate users over the 3 next years :
- Validation with models
- Closure budget studies
- International comparison exercise
- Error characterisation