

# **Investigating and reducing the differences between the satellite altimetry-based Global Mean Sea Level time series provided by the different processing groups**

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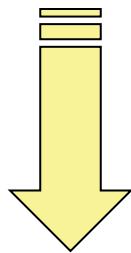
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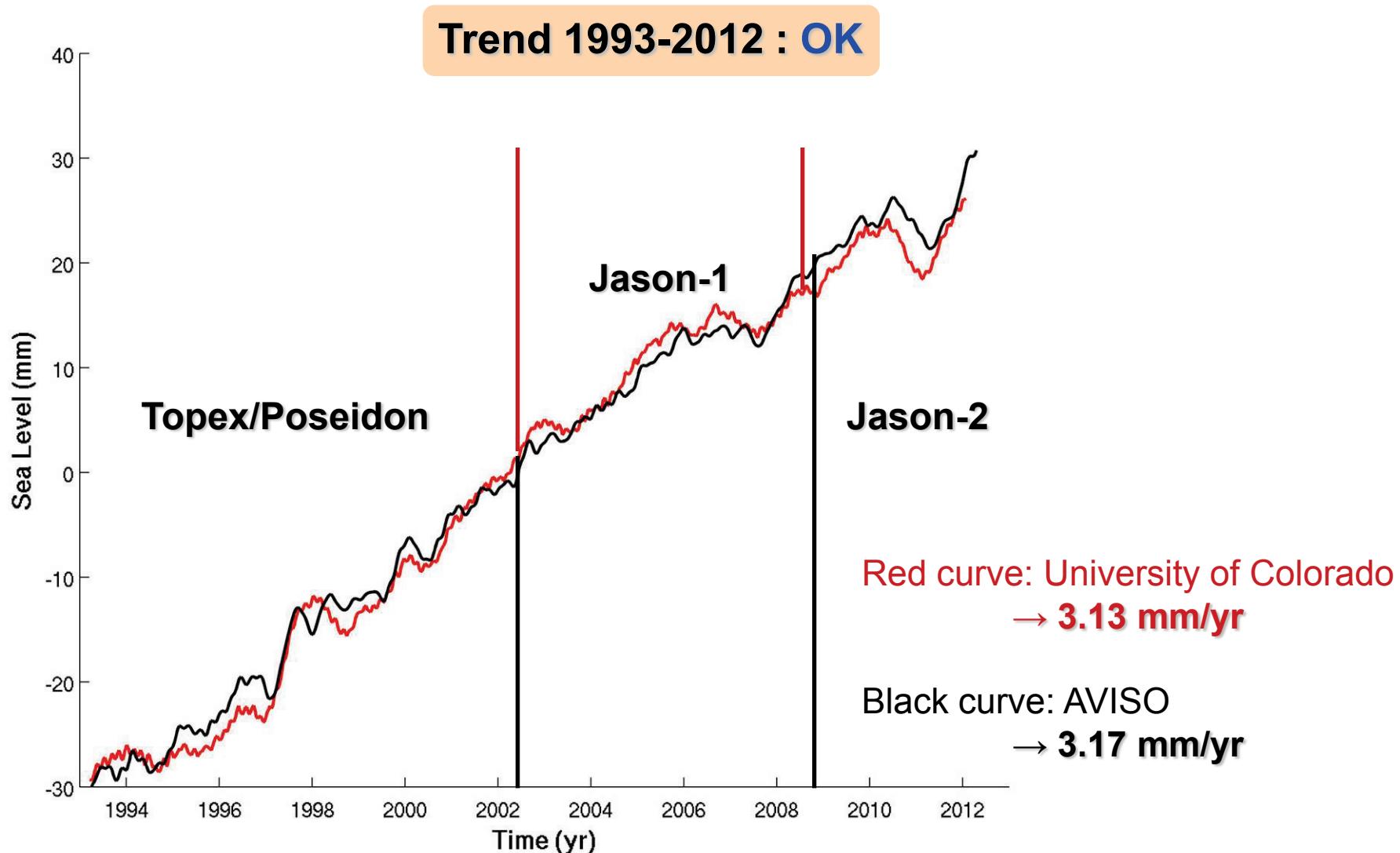
## Main satellite altimetry processing groups

- University of Colorado (CU)
- NASA/GSFC
- NOAA
- CSIRO
- CLS/AVISO



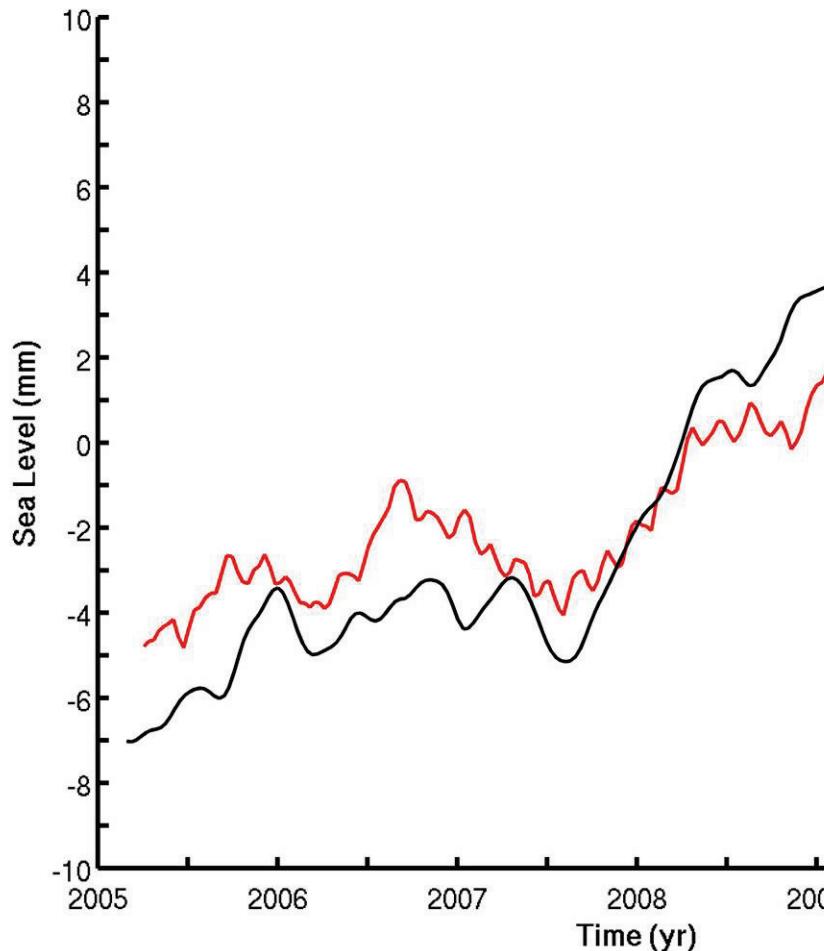
**Differences in trend and interannual variability** reported in the altimetry-based sea level time series processed by these groups

# Altimetry-based Global Mean Sea Level (GMSL)



# Altimetry-based GMSL 2005-2010

Trend 2005-2010 : PROBLEM !!



Red curve: University of Colorado  
Black curve: AVISO

Trends :

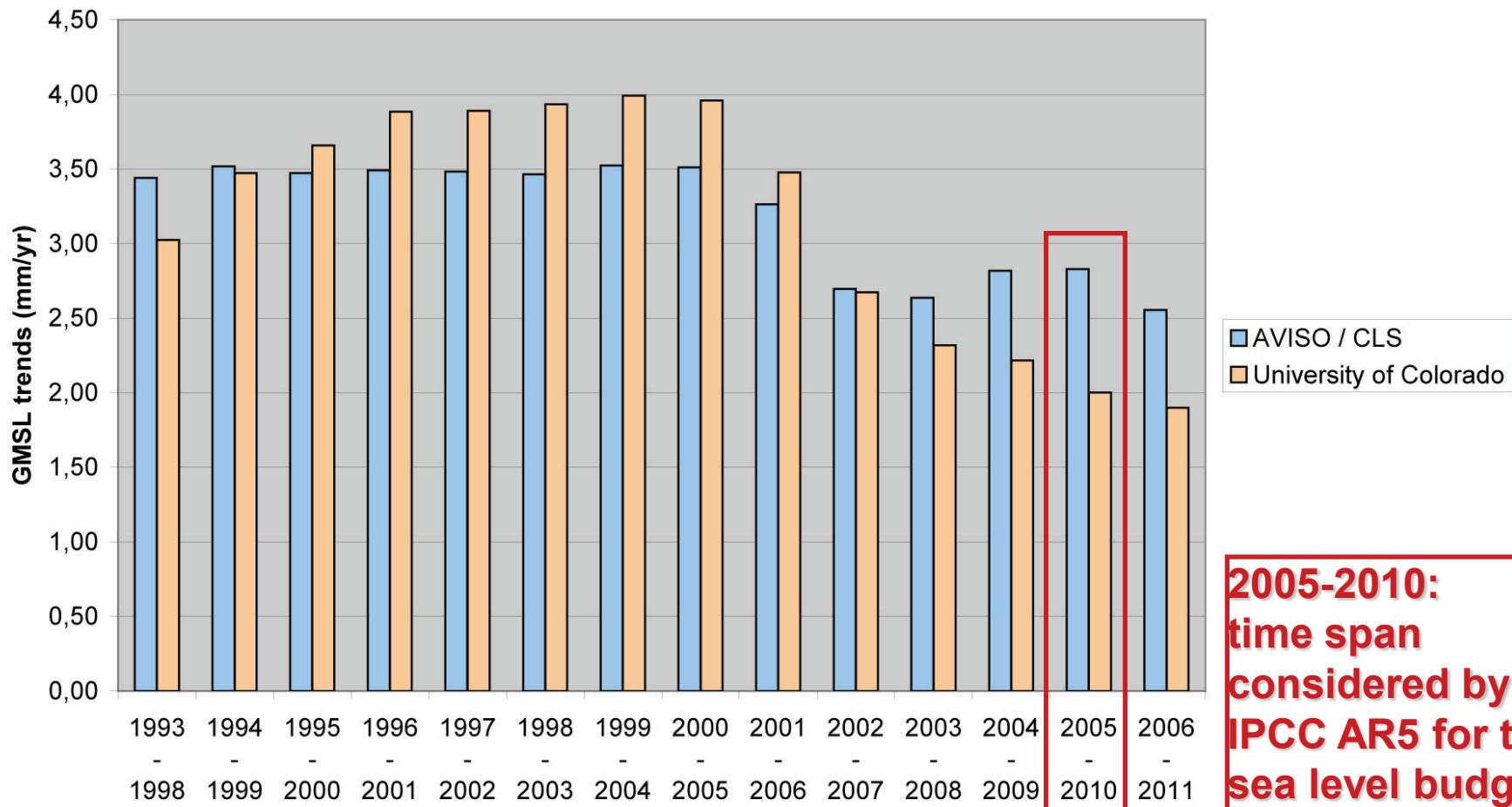
- CU: 2 mm/yr
- AVISO: 2.8 mm/yr

# 6 yr GMSL trends from AVISO and University of Colorado

1993 – 2010 → observed sea levels trends : OK

**Where do those differences come from ???**

2005 – 2010 → observed sea levels trends : PROBLEM !!



**2005-2010:  
time span  
considered by  
IPCC AR5 for the  
sea level budget**

## Masters et al' (2012) study

### Main conclusions about the GMSL time series differences

- largest differences caused by using gridded versus non-gridded sea surface height anomalies to compute the mean:

→ CU and GSFC: non-gridded averaging  
→ AVISO, NOAA and CSIRO: gridded averaging  
→ **differences are reduced when CU processing is recomputed using gridded anomalies**

- some differences induced by the minimum depth criterion:

→ CU: 120m  
→ AVISO and NOAA: 0m  
→ **removing the depth criterion from CU processing brings better agreement with NOAA and AVISO**

- small differences induced by the latitude weighting:

→ CU: inclination weighting  
→ AVISO and NOAA: cosine weighting  
→ **applying cosine weighting rather than inclination weighting reduces differences**

# **Objectives of the present study**

## **1. Investigate the effects of processing methodology to compute the GMSL:**

- *non gridded versus gridded SSH anomalies*
- *minimum ocean depth*
- *altimetry data validity flag*

## **2. Generate synthetic altimetry data during the Jason-1 operating period using MERCATOR OGCM**

## **3. Perform a series of test calculations of the GMSL time series**

## **4. Investigate other causes of difference (e.g., “JMR replacement” correction on Jason-1)**

# MERCATOR OGCM

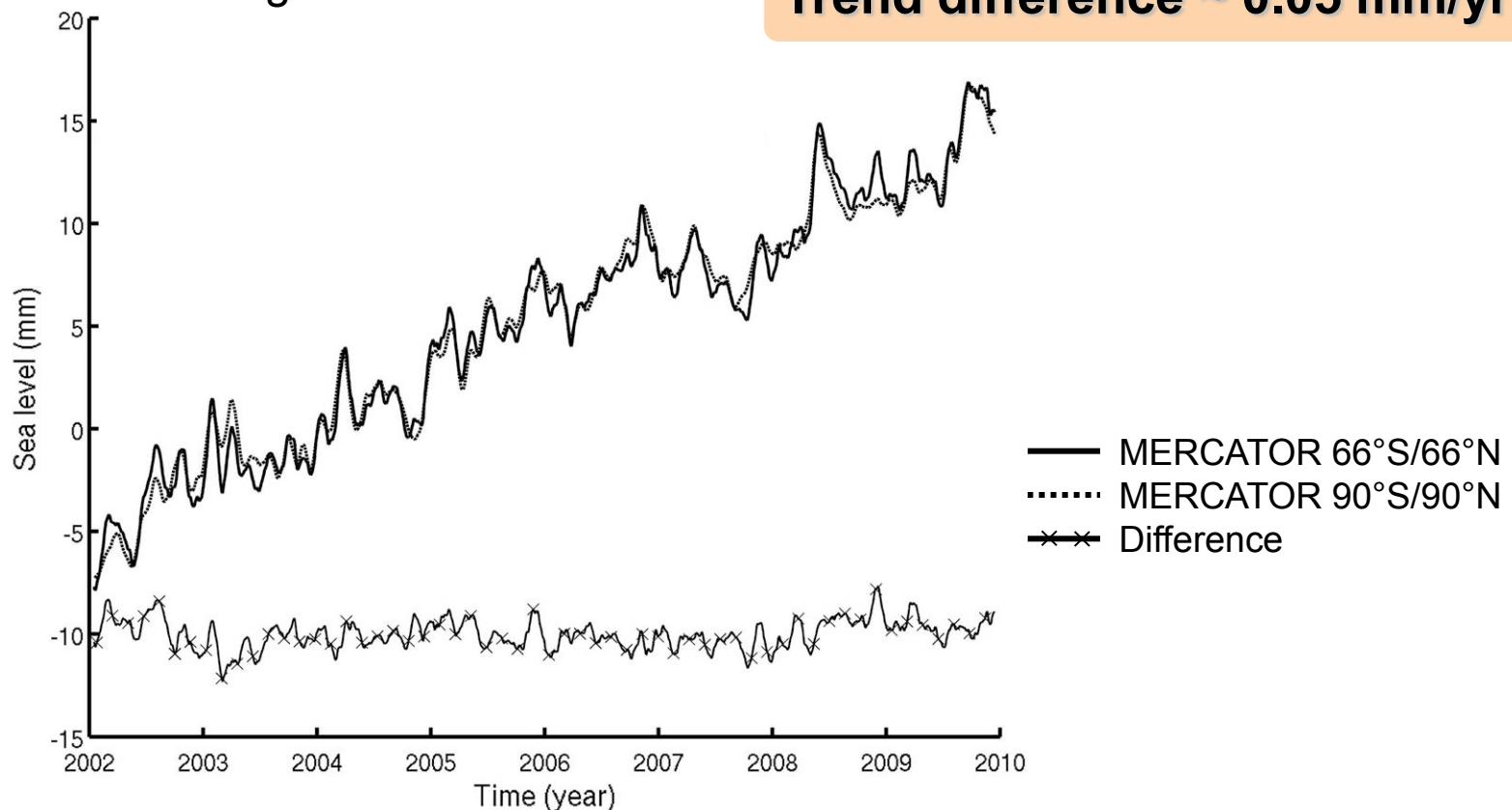
- Version GLORYS2V1 with data assimilation (temperature, salinity, satellite-based sea level anomalies, ...).
- The horizontal grid is the standard ORCA025 tri-polar grid (1440x1021 grid points). The three poles are located over Antarctic, Siberia and North Canada.
- Resolution:  $\frac{1}{4}$  degree at the equator. Resolution increases pole ward (the grid size is scaled by the cosine of the latitude, except in the Arctic).

# Effect of the 66°N/S coverage

(Synthetic altimetry data, January 2002 to December 2009)

- 1 Hz synthetic SSH (based on MERCATOR data) along the real Jason-1 satellite tracks → exactly same spatio-temporal coverage as real Jason-1 data
- Latitude coverage → 66°S-66°N

Trend difference ~ 0.05 mm/yr



**Series of tests** performed using different **averaging methods** and accounting or not for **shallow ocean depth**

**(1) Averaging methods:**

- along track averaging (as CU)
- simple gridding:  $1^\circ \times 1^\circ$ ,  $2^\circ \times 2^\circ$ (as AVISO),  $3^\circ \times 3^\circ$
- gridding with inverse distance weighting

**(2) Minimum ocean depth:**

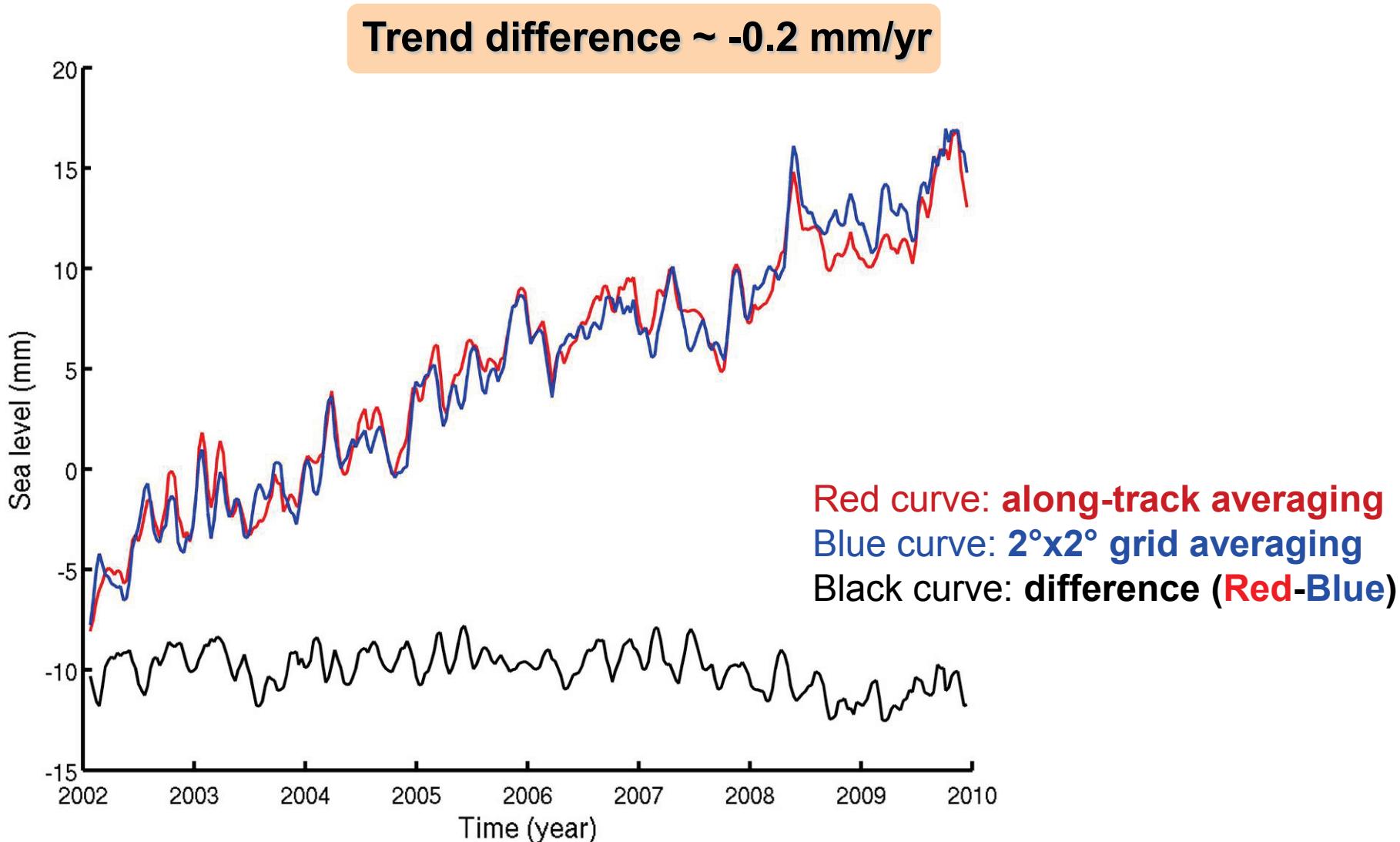
- 0m (as AVISO), 120m (as CU), 500m

**(3) Altimetric flag**

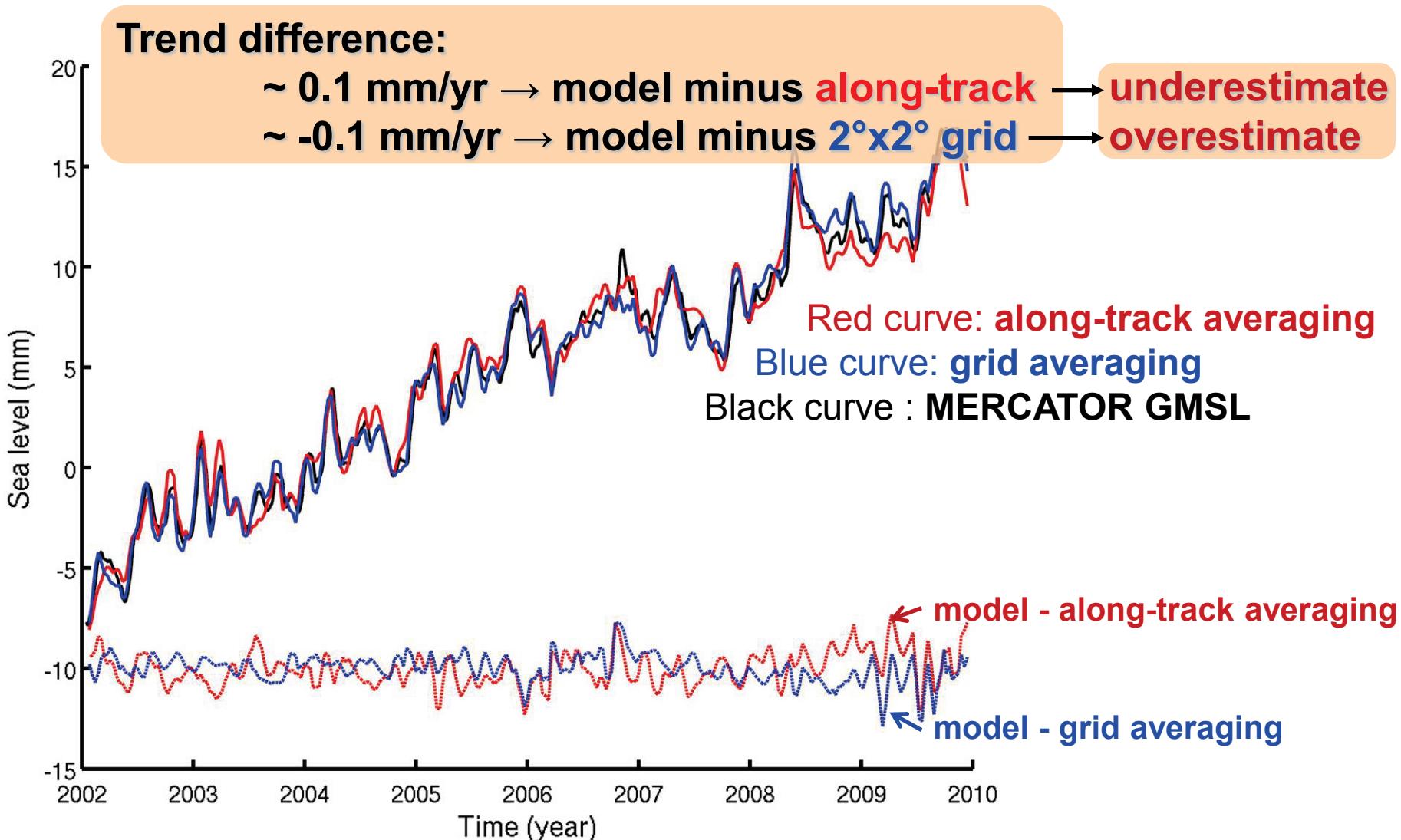
- based on AVISO validity flag

# Effect of the averaging method

## along-track versus $2^\circ \times 2^\circ$ grid

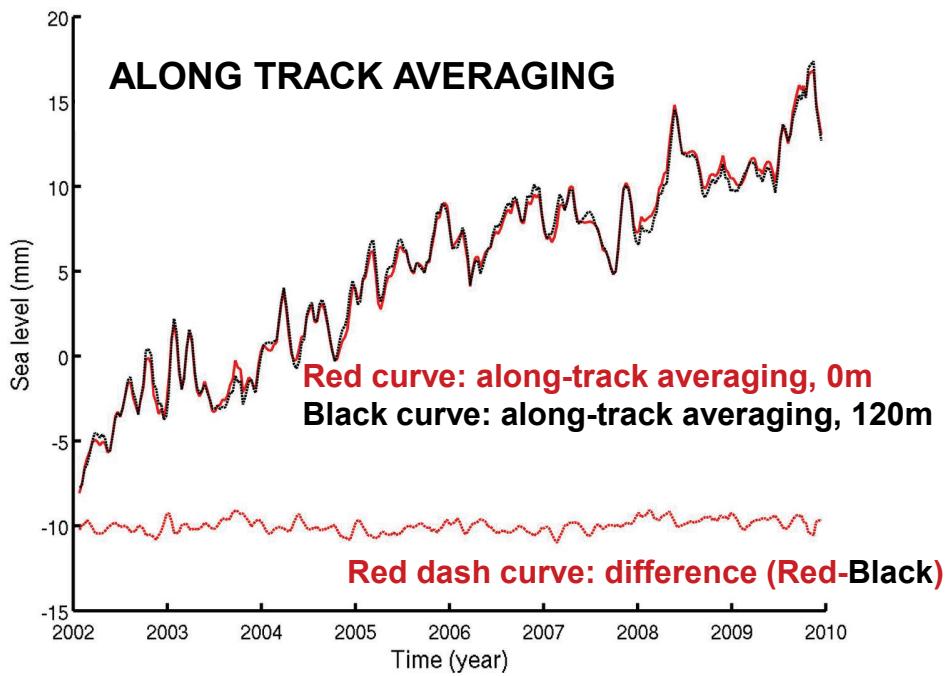


# GMSL: along-track & $2^\circ \times 2^\circ$ grid versus model (*«ground truth»*)

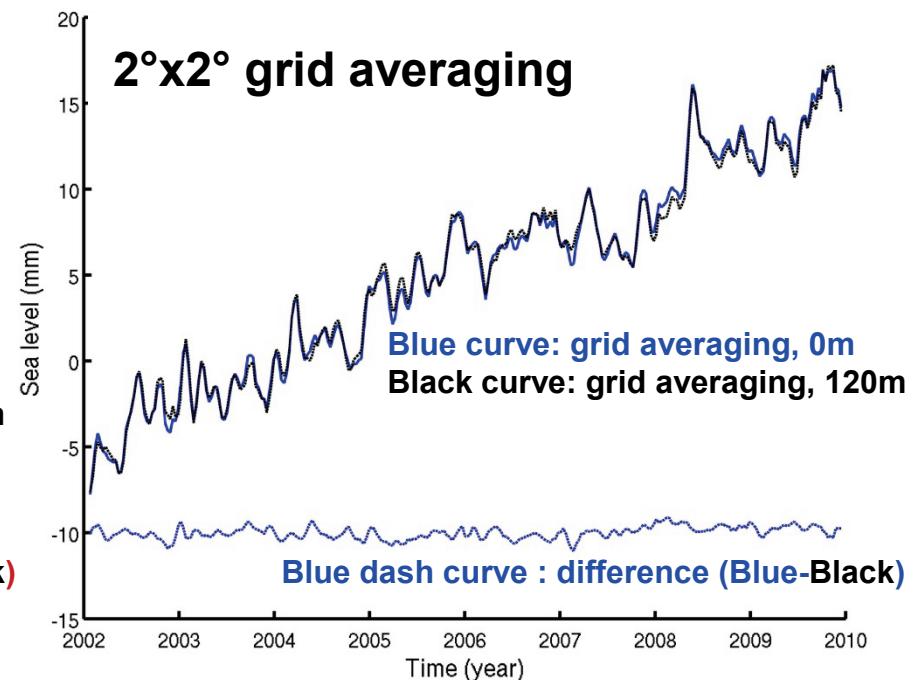


# Effect of minimum ocean depth (along track and grid averaging)

Trend difference (0m minus 120m)  
~ 0.05 mm/yr



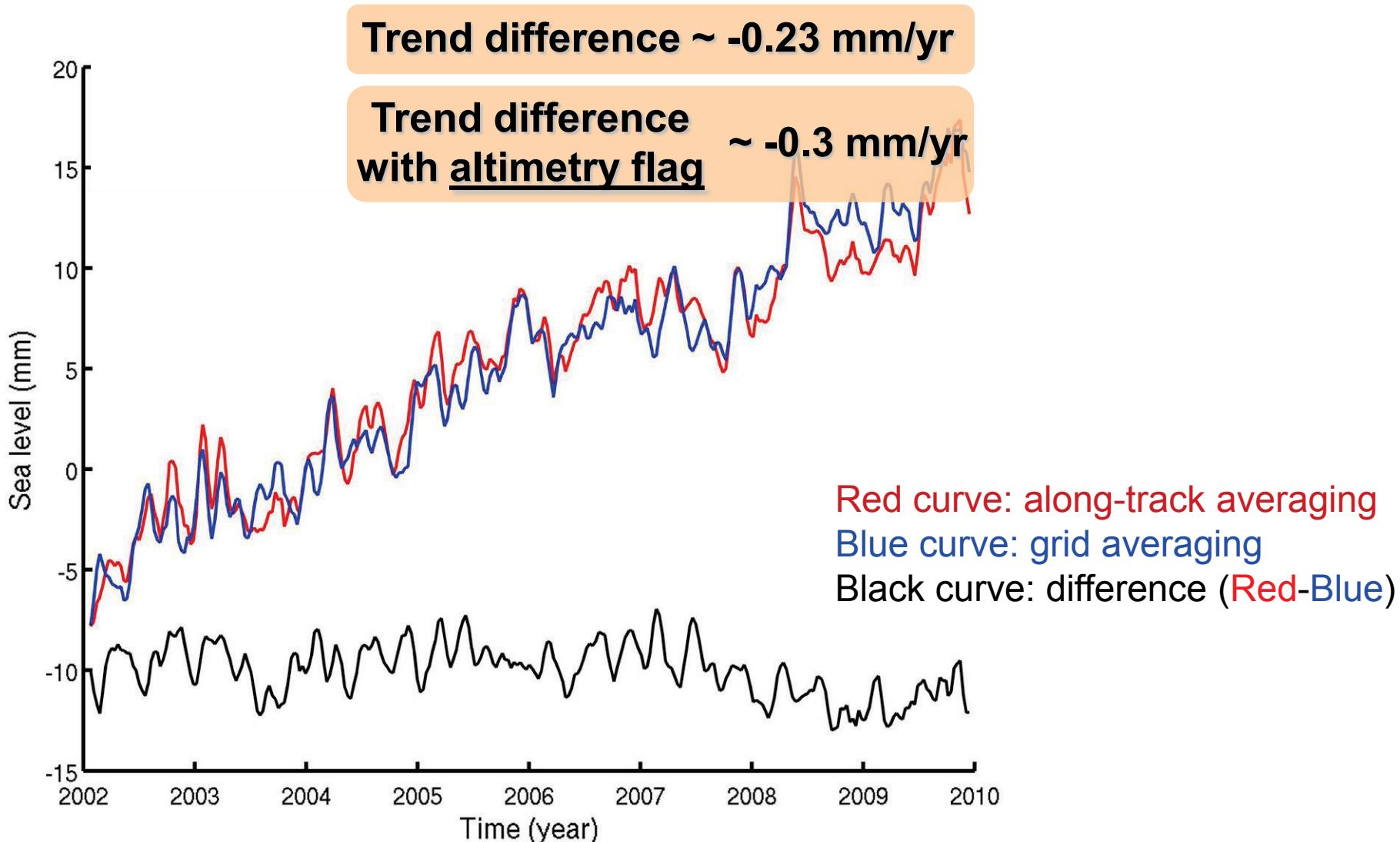
Trend difference (0m minus 120m)  
~ 0.05 mm/yr



Minimum Ocean Depth criterion tends to decrease GMSL trend

# Total effect (averaging + ocean depth)

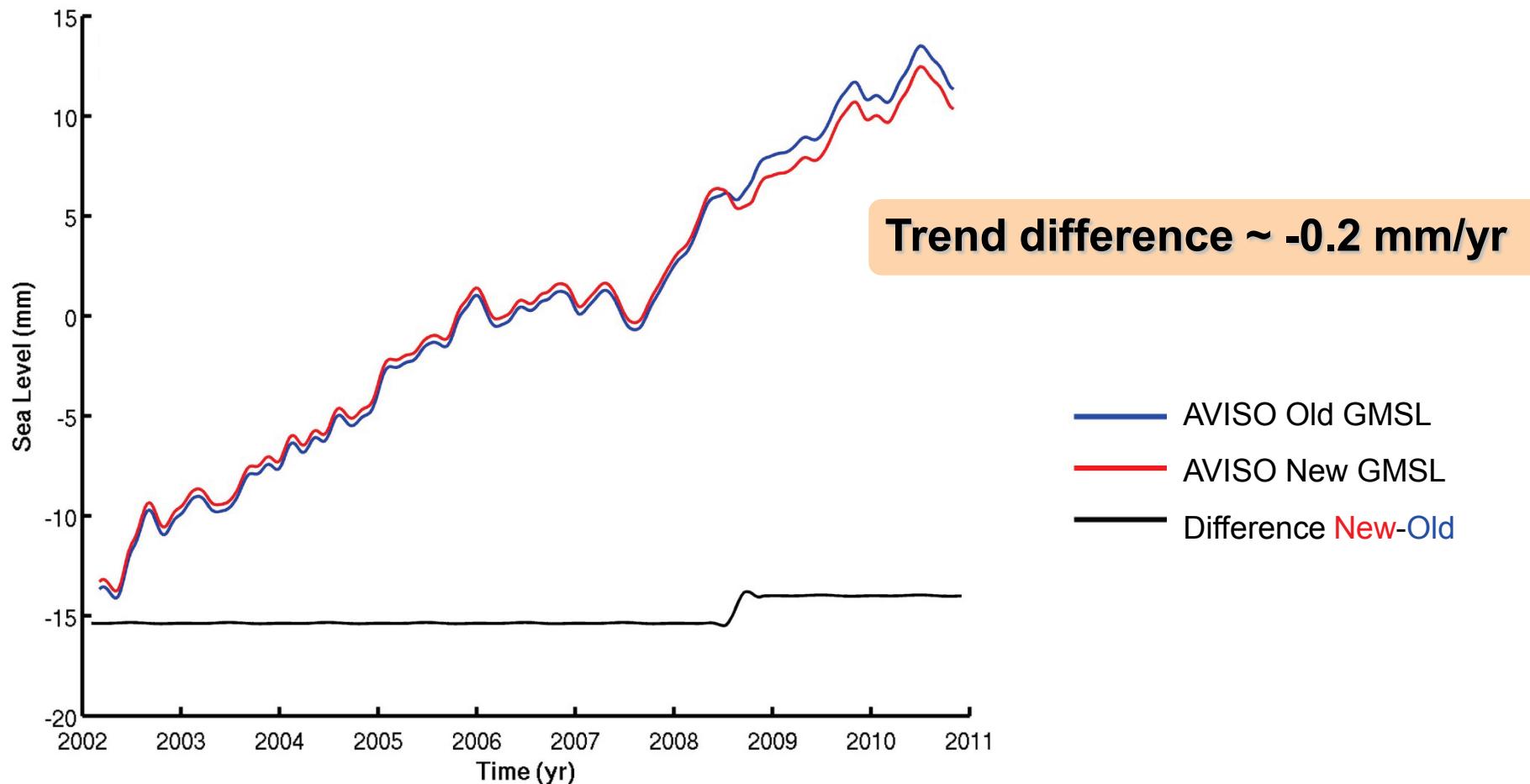
AVISO (2°x2° grid, 0m) versus CU (along-track, 120m)



# Conclusion part 1:

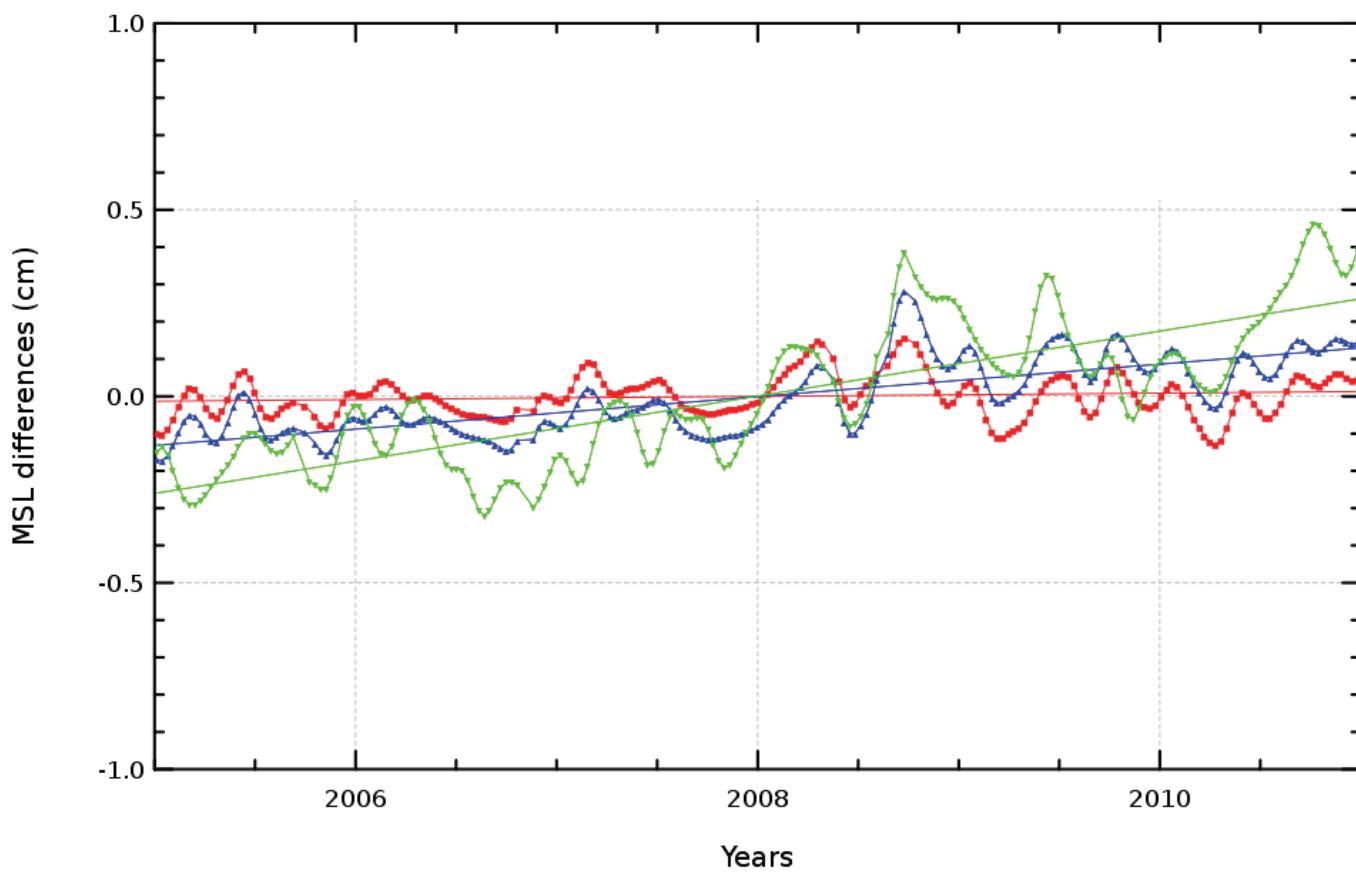
- Along track averaging versus model underestimates the GMSL trend (by ~ 0.1 mm/yr)
- $2^\circ \times 2^\circ$  gridding versus model overestimates the GMSL trend (by ~ 0.1 mm/yr)
- Along track averaging gives lower GMSL trends compared to gridding (difference of ~ 0.2 mm/yr)
- Minimum ocean depth effect: difference of ~ 0.05 mm/yr
- Total effect of processing methodology (**CU/alongtrack/120m/flag** versus **AVISO/ $2^\circ \times 2^\circ$ /0m/flag**) :  
 $\sim 0.3 \text{ mm/yr}$

## Part 2: effect of the JMR replacement correction on Jason-1 AVISO GMSL



## Part 2: effect of the JMR replacement correction on Jason-1 AVISO GMSL

— AVISO (AVISO method) - CU → Trend difference ~ 0.85 mm/yr  
— AVISO (CU method) – CU → Trend difference ~ 0.4 mm/yr  
— AVISO (CU method + JMR correction) - CU → Trend difference ~ 0.04 mm/yr



# Final conclusion

Accounting for:

- the total effect of processing methodology  
**(2002-2009: 0.3 mm/yr ; 2005-2010: 0.5 mm/yr)**

+

- incorrect JMR correction in the AVISO processing  
**(2005-2010: 0.3mm/yr)**

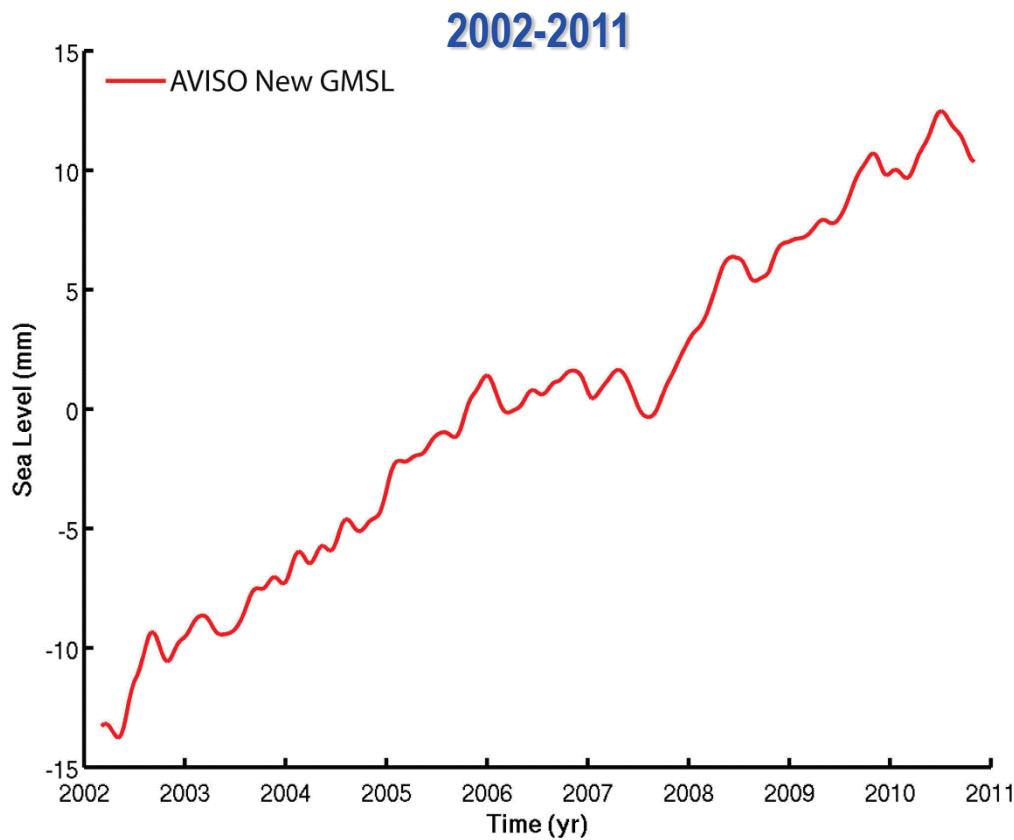
**totally explains the trend difference for 2005-2010**

**AVISO overestimated the GMSL trend**  
**CU underestimated the GMSL trend**

**The corrected trend for 2005-2010 is ~ 2.5 mm/yr**

# Thanks for your attention

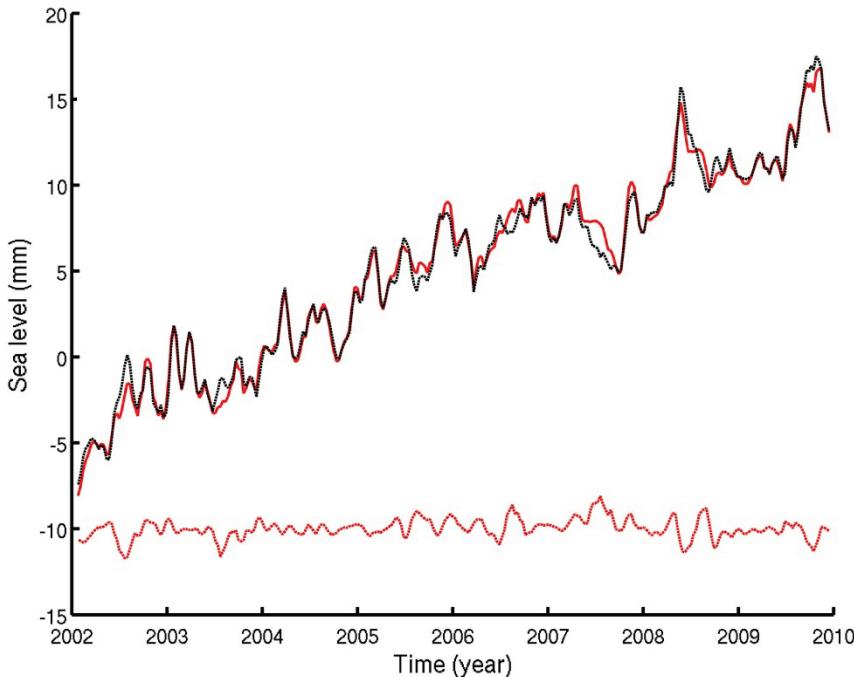
Latest improvements of the altimetry-based Global Mean Sea Level Record  
(improved processing methodology & geophysical corrections)





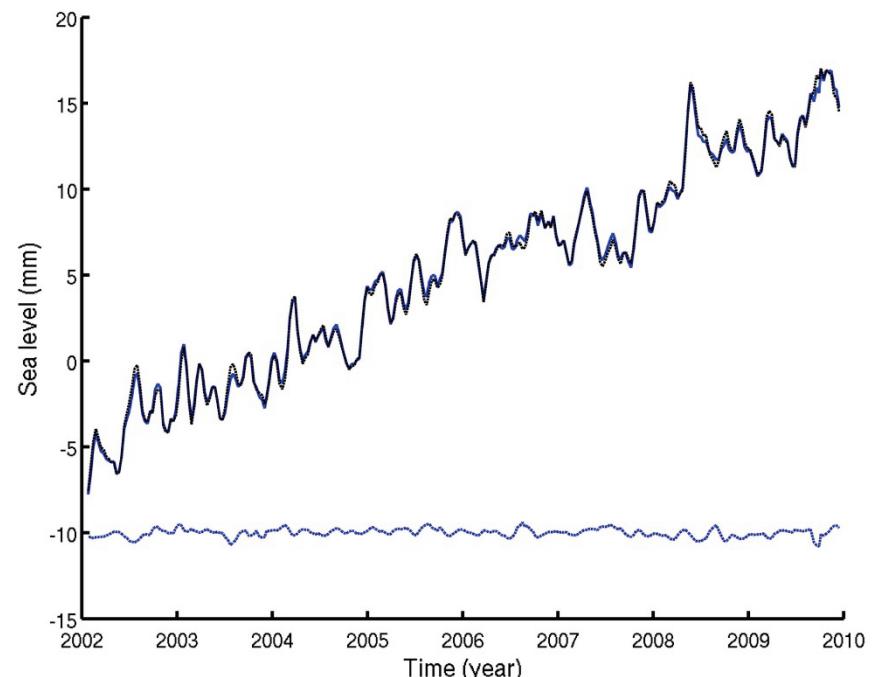
# Altimetry validity flag (along-track and grid averaging)

Trend difference  $\sim 0.05$  mm/yr



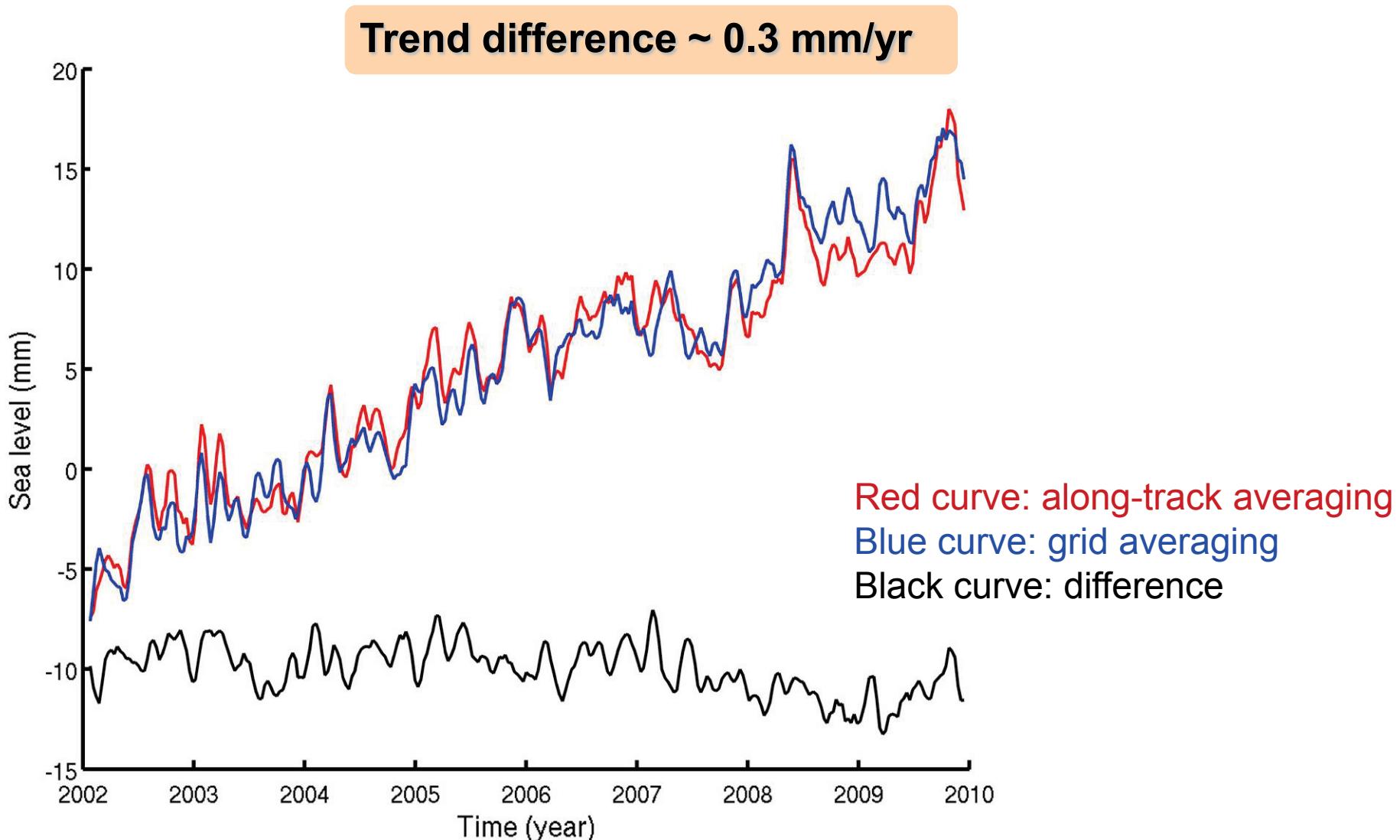
Red curve: along-track averaging without validity flag  
Black curve: along-track averaging with validity flag  
Red dash curve: difference

Trend difference  $\sim 0$  mm/yr

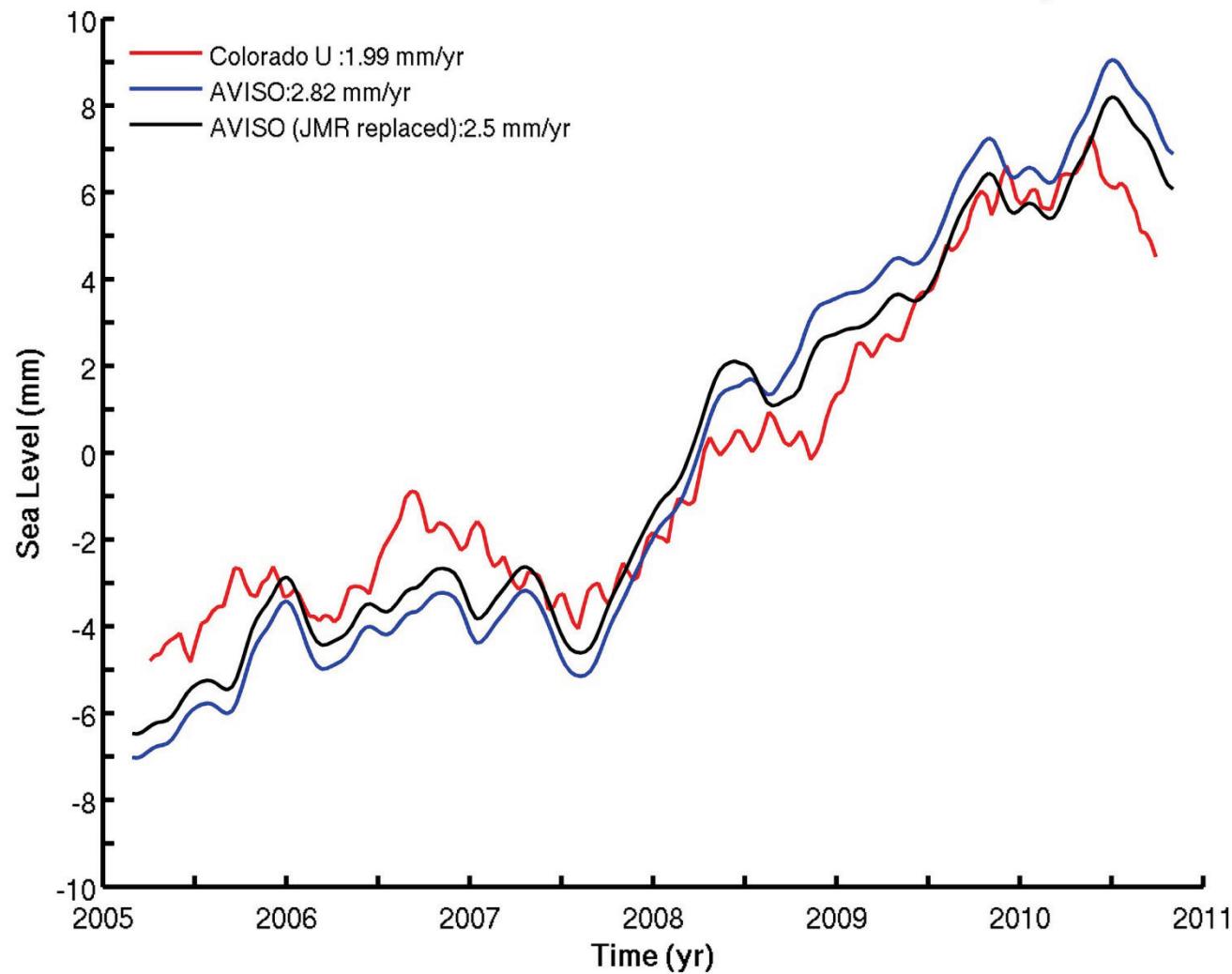


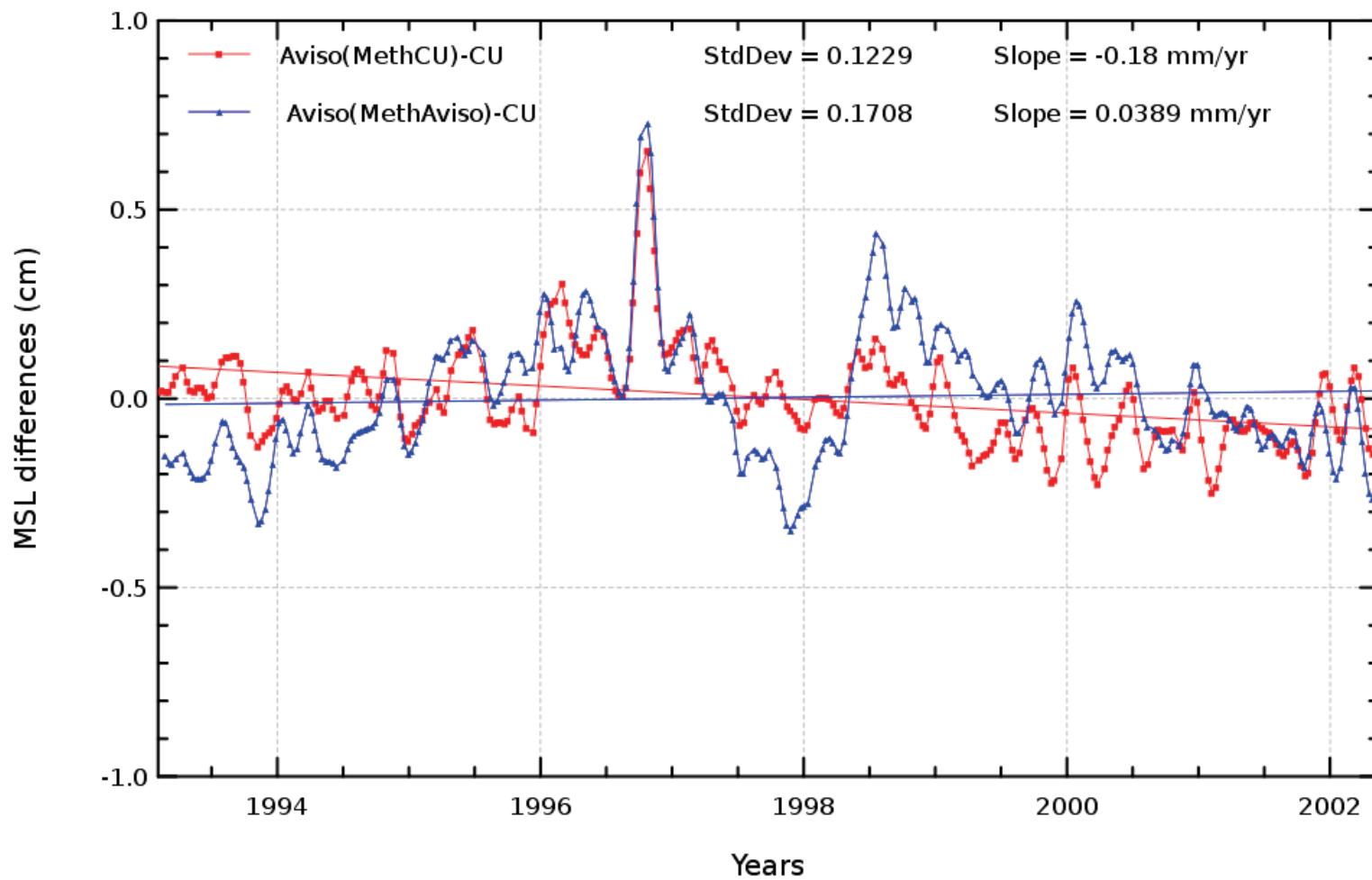
Blue curve: grid averaging without validity flag  
Black curve: grid averaging with validity flag  
Blue dash curve : difference

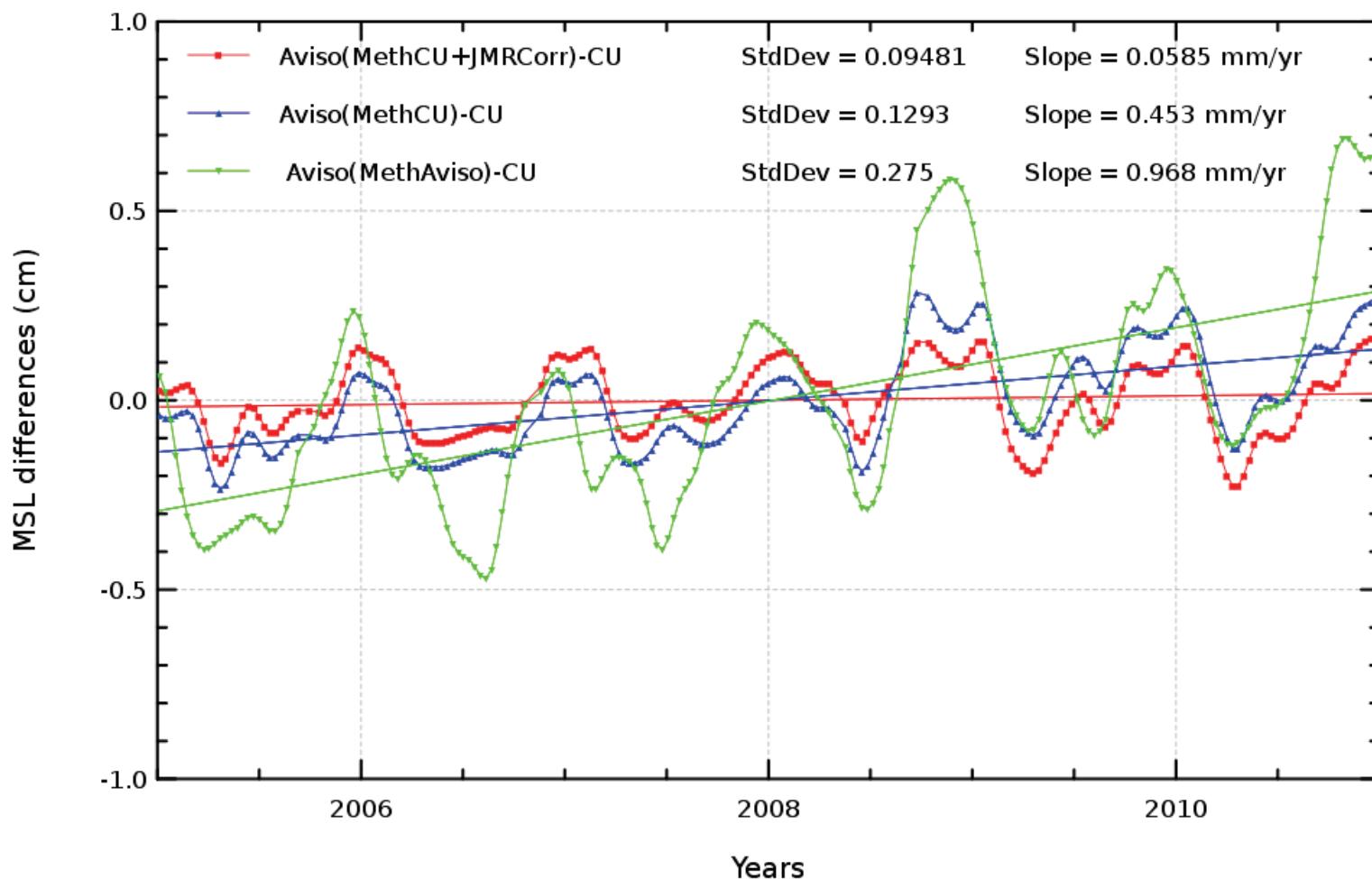
# Total effect (averaging method + ocean depth + flag) AVISO (grid, 0m, flag) versus CU (along-track, 120m, flag)

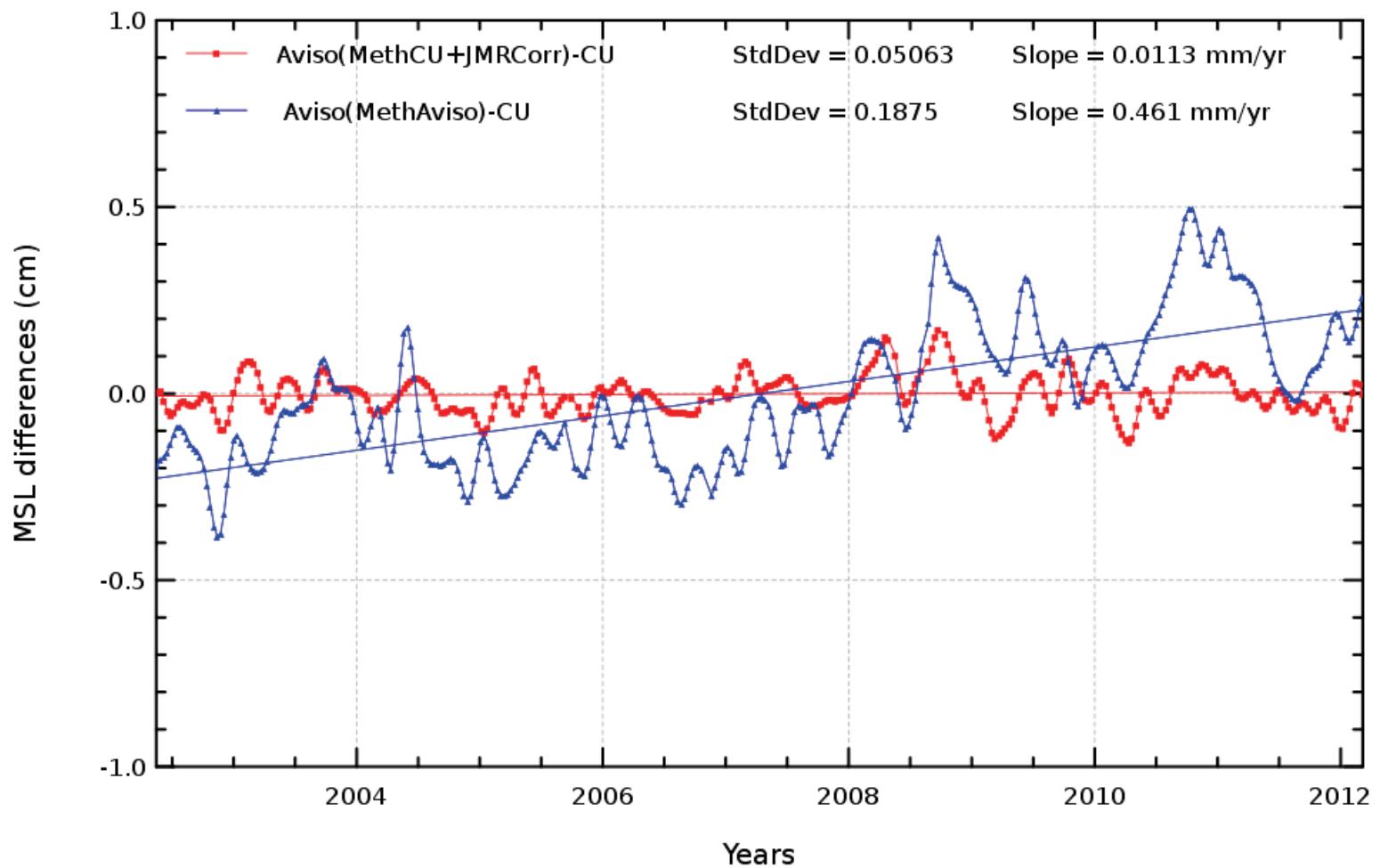


### Mean Sea Level from CLS/AVISO and Colorado University

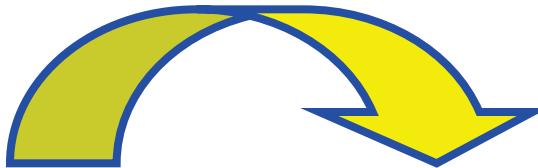




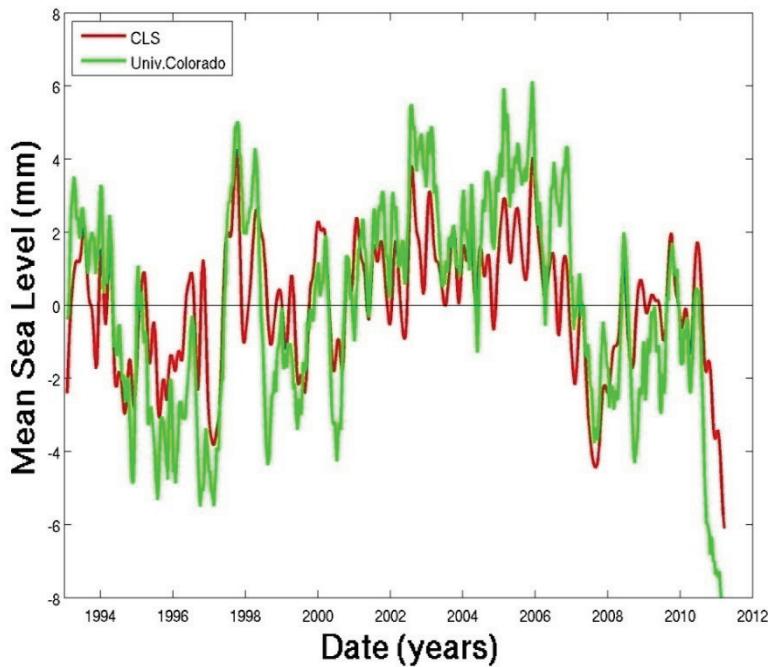




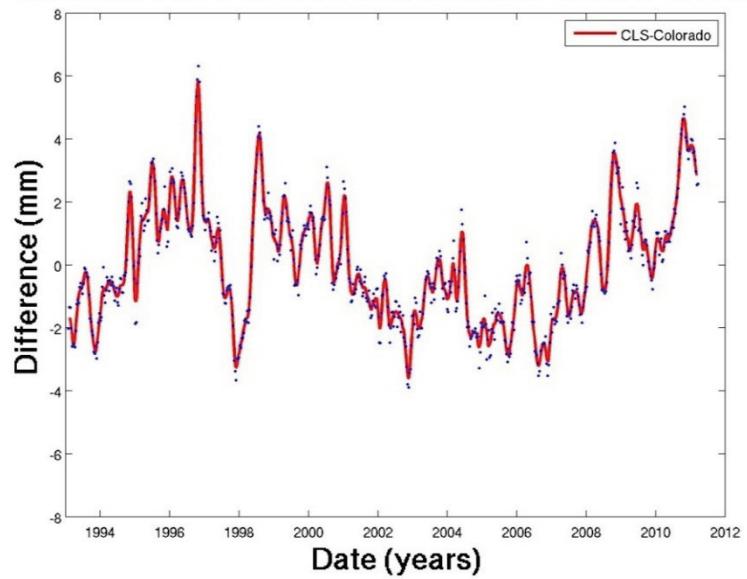
# Interannual variability



GMSL-CLS and Univ.of Colorado



Difference between CLS and Colorado Mean Sea Level



Detrended global mean sea level

Data from AVISO/CLS and University of Colorado

Difference between the two

## Effect of grid size on GMSL trend:

Along track versus grid averaging, trend differences:

- $1^\circ \times 1^\circ \rightarrow 0.1 \text{ mm/yr}$
- $2^\circ \times 2^\circ \rightarrow 0.2 \text{ mm/yr}$
- $3^\circ \times 3^\circ \rightarrow 0.25 \text{ mm/yr}$

## Effect of grid size on GMSL trend:

MERCATOR ( $1/4^\circ$ ) versus grid averaging, trend differences:

- $1^\circ \times 1^\circ \rightarrow 0 \text{ mm/yr}$
- $2^\circ \times 2^\circ \rightarrow 0.1 \text{ mm/yr}$
- $3^\circ \times 3^\circ \rightarrow 0.15 \text{ mm/yr}$

## Mercator:

- whole ocean domain versus synthetic data  $2^\circ \times 2^\circ / 66S-66N$   
→ Trend difference: **0.05 mm/yr**