Progress in reconstructing long term global sea level changes

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With contributions from Sönke Dangendorf, Guy Wöppelmann, Álvaro Santamaría-Gómez

CSIC

Consejo Superior de Investigaciones Científicas

Universitat de les Illes Balears

IMEDEA

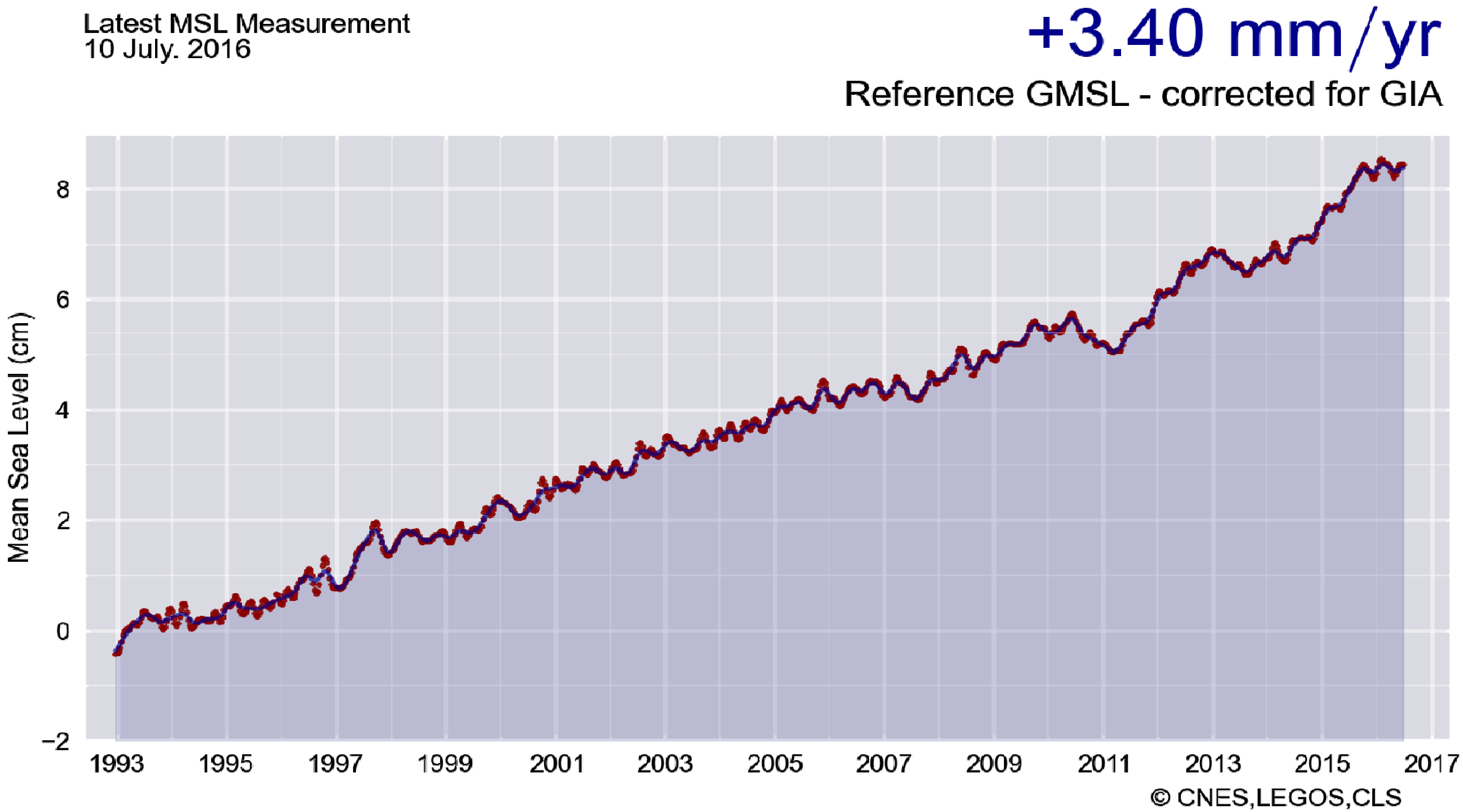
2016 Ocean Surface Topography Science Team (OSTST) meeting, 1-4 November 2016, La Rochelle

OUTLINE

- ❑ Overview of (some) past global sea level reconstructions
- ❑ New additional corrections and method
- ❑ New global sea level reconstruction

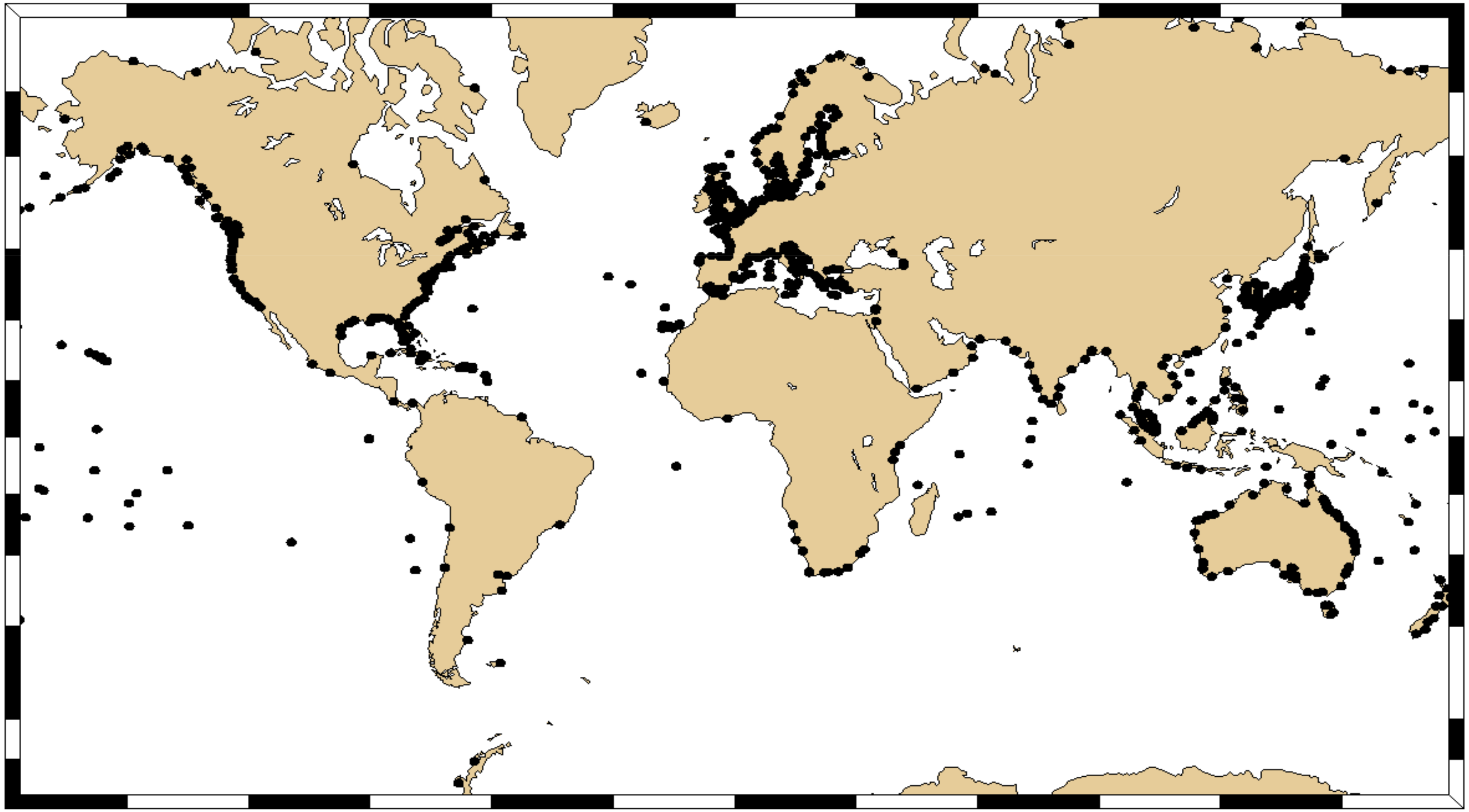
Satellite altimetry observations since 1992

Global mean sea level during the altimetry period



Before the altimetry era…

2010



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Global Sea Level Rise

BRUCE C. DOUGLAS

National Ocean Service, NOAA, Rockville, Maryland

Published values for the long-term, global mean sea level rise determined from tide gauge records exhibit considerable scatter, from about 1 mm to 3 mm/yr. This disparity is not attributable to instrument error; long-term trends computed at adjacent sites often agree to within a few tenths of a millimeter per year. Instead, the differing estimates of global sea level rise appear to be in large part due to authors' using data from gauges located at convergent tectonic plate boundaries, where changes of land elevation give fictitious sea level trends. In addition, virtually all gauges undergo subsidence or uplift due to postglacial rebound (PGR) from the last deglaciation at a rate comparable to or greater than the secular rise of sea level. Modeling PGR by the ICE-3G model of Tushingham and Peltier (1991) and avoiding tide gauge records in areas of converging tectonic plates produces a highly consistent set of long sea level records. The value for mean sea level rise obtained from a global set of 21 such stations in nine oceanic regions with an average record length of 76 years during the period 1880–1980 is 1.8 mm/yr ± 0.1. This result provides confidence that carefully selected long tide gauge records measure the same underlying trend of sea level and that many old tide gauge records are of very high quality.

Published values for global sea level rise for the last 50–100 years vary from about 1 to 3 mm/yr, with formal uncertainties ranging from 0.15 to 0.90 mm/yr. While there is not much doubt that sea level is rising, the scatter of results makes impossible a meaningful interpretation of the global balance of water in its various forms and locations.

stations are selected or rejected according to length and completeness of record, general agreement with other nearby stations over a common time interval, and freedom from obvious tectonic effects. Grouping of stations is done according to oceanic region. The station groups surviving this selection process form an extremely consistent set, particularly after correction for the effects of postglacial rebound (PGR) by the ICE-3G model of *Tushingham and Peltier* [1991]. In fact, the rms agreement of sea level rise for widely separated oceanic regions from long records exceeding 60–70 years, after correction for PGR, is so good (0.4 mm/yr) that one can simply aggregate them without regard to exact record length. This avoids the need for statistical methods such as empirical orthogonal function (EOF) analysis.

2. Low-Frequency Variations of Sea Level

Many hundreds of coastal and island tide gauges around the Earth regularly produce sea level data. However, this is

Paper number 91JC00064.

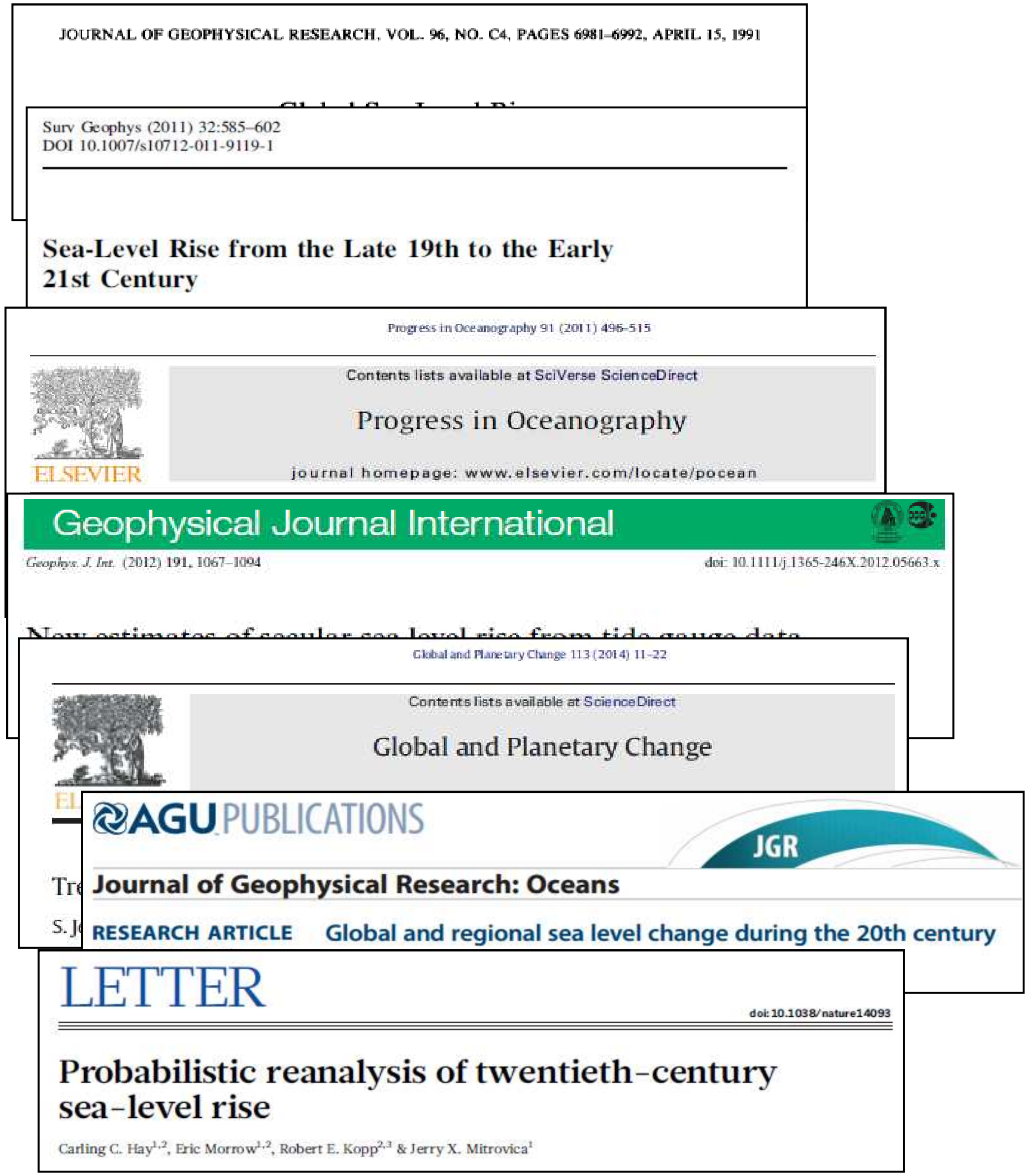
understand the interdecadal sea level fluctuations at a site.

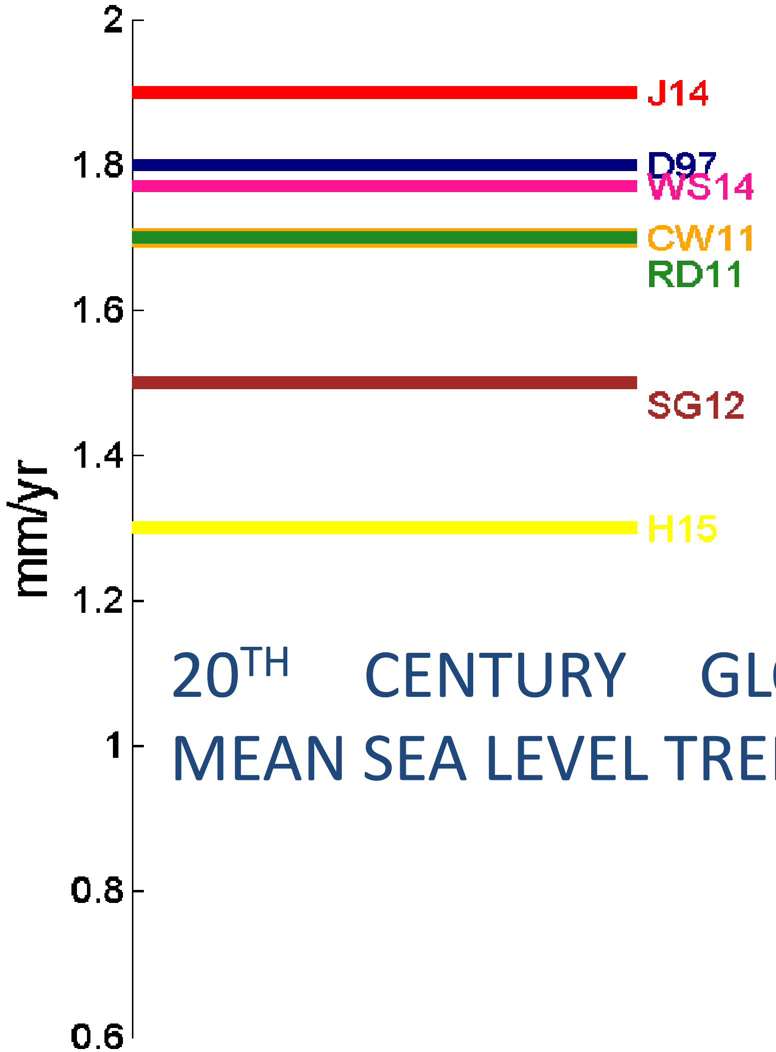
It is difficult to visualize the low-frequency variations of sea level in a plot of monthly or annual means. Seasonal and annual signals are so large and variable that the smaller, longer-period signals are obscured. Appropriate filtering is needed for visualization of these signals. In this paper a multiyear sliding median filter on monthly means of sea level is used for plots of monthly mean sea level. This filter simultaneously edits and smoothes the record.

Figure 1 shows the sea level record for San Francisco from 1854 to 1986 after removal by least squares of semiannual and annual terms, median filtering, and detrending. For Figure 1 a median filter width of 5 years was used, reducing the amplitude of 10-year cycles about 20% and that of 20 year period about 3%.

The signal remaining for San Francisco after detrending is rich with long-wavelength components, which will obviously have a significant effect on the trend computed for any subportion of the total record. To show the effect on trends of the low-frequency variations of sea level at San Francisco, Figure 2 presents the trend of sea level computed from successive 30-year spans from the original unfiltered monthly mean data. The average value of the trend is 1.2

SEA LEVEL RECONSTRUCTIONS

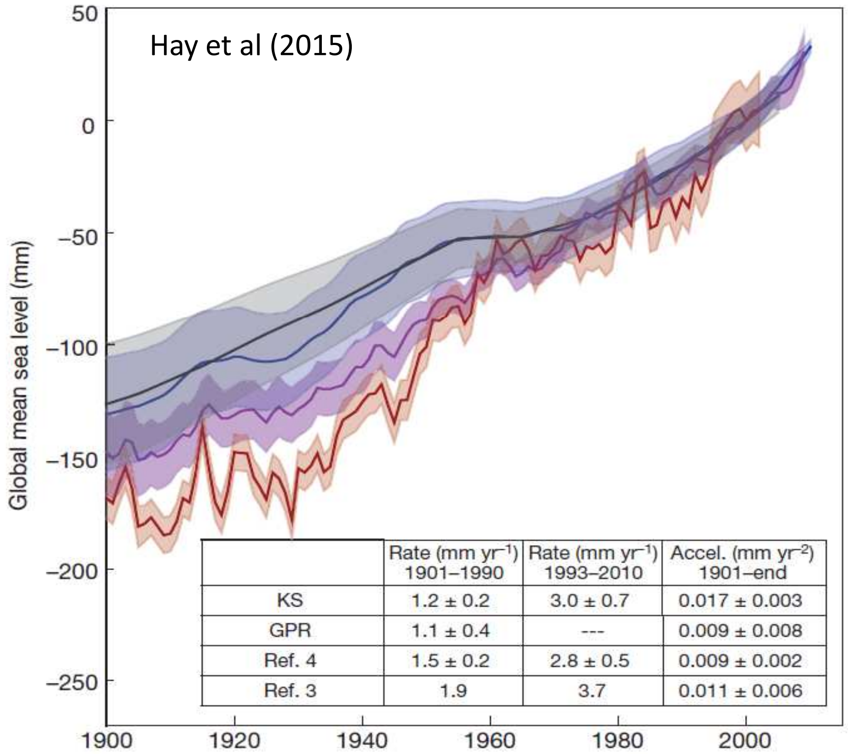




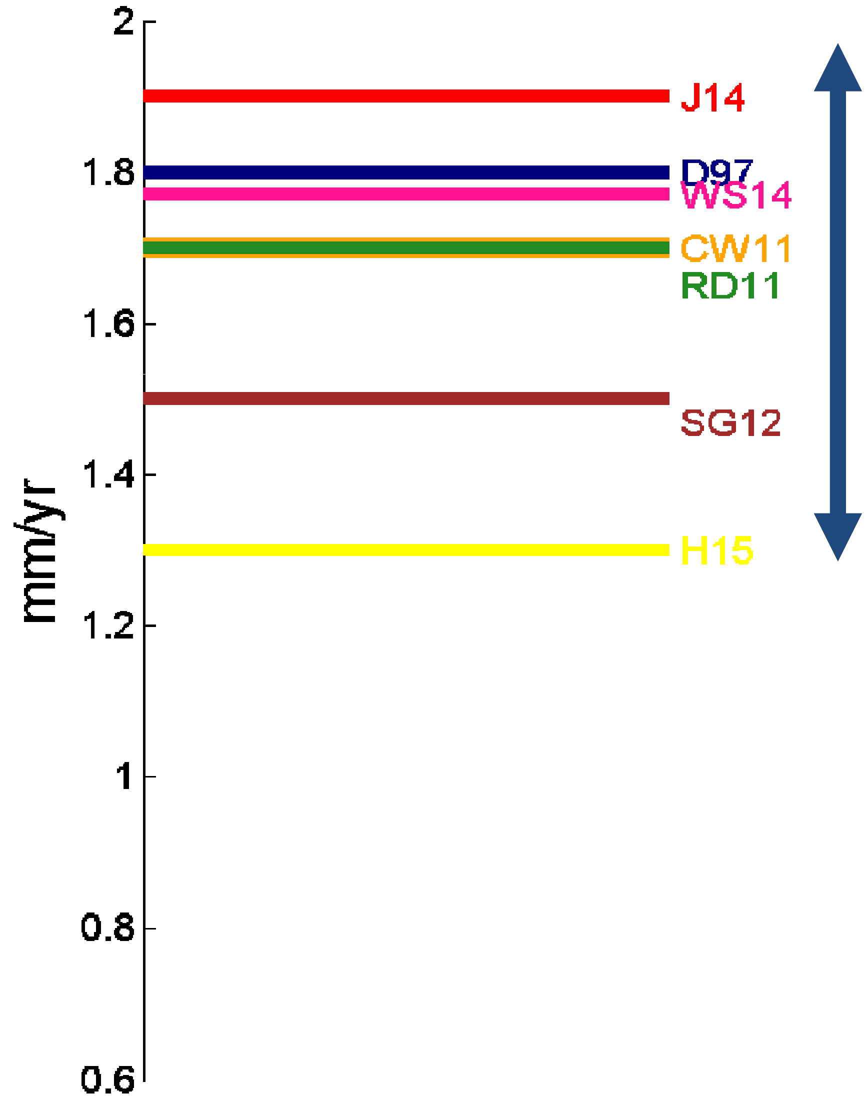
20^{TH} CENTURY GLOBAL MEAN SEA LEVEL TREND

SEA LEVEL RECONSTRUCTIONS

1- Relatively **large spread** in pre-Altimetry GMSL estimates, especially before 1960s



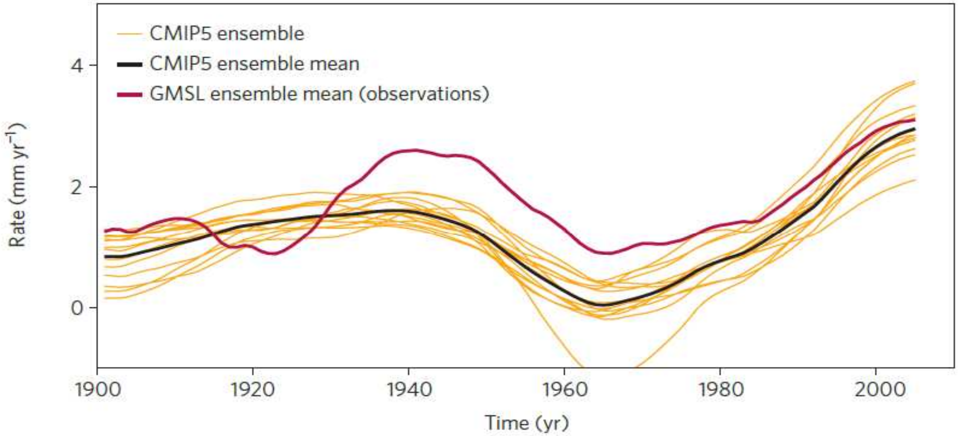
	Rate (mm yr^{-1}) 1901–1990	Rate (mm yr^{-1}) 1993–2010	Accel. (mm yr^{-2}) 1901–end
KS	1.2 ± 0.2	3.0 ± 0.7	0.017 ± 0.003
GPR	1.1 ± 0.4	---	0.009 ± 0.008
Ref. 4	1.5 ± 0.2	2.8 ± 0.5	0.009 ± 0.002
Ref. 3	1.9	3.7	0.011 ± 0.006



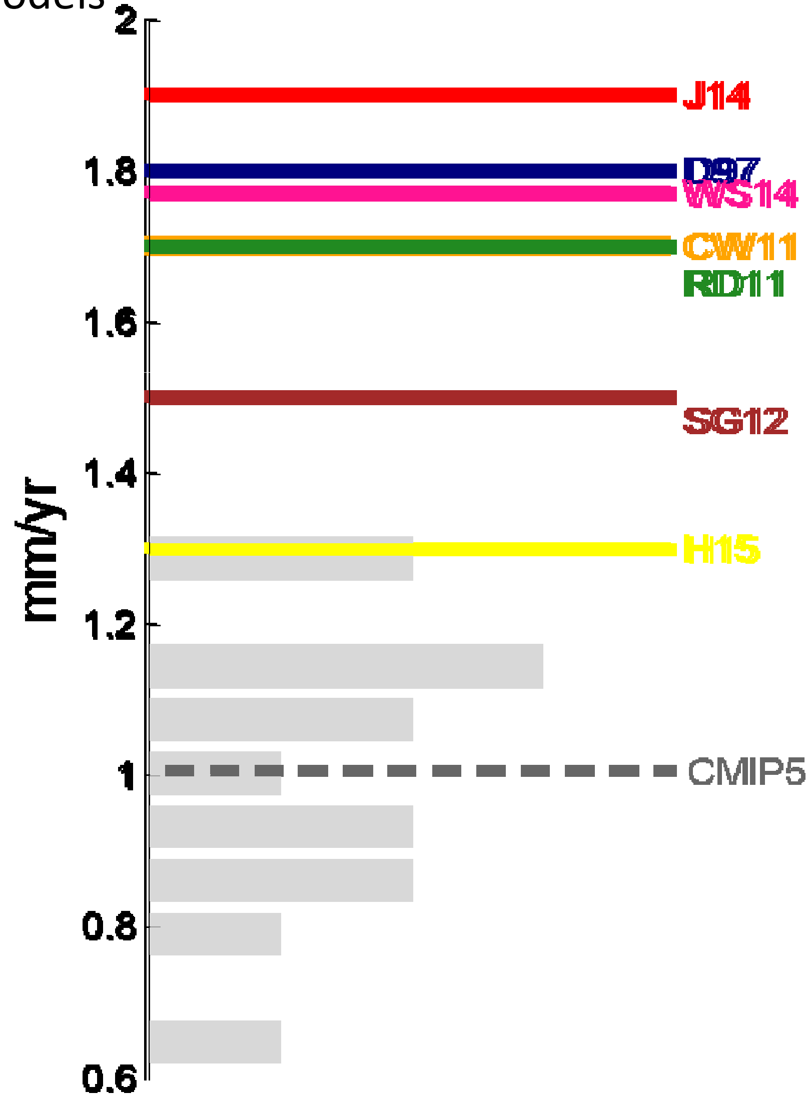
SEA LEVEL RECONSTRUCTIONS

1- Relatively **large spread** in pre-Altimetry GMSL estimates, especially before 1960s

2- Partly **inconsistent** with recent historical CMIP5 models



Dangendorf (2016)

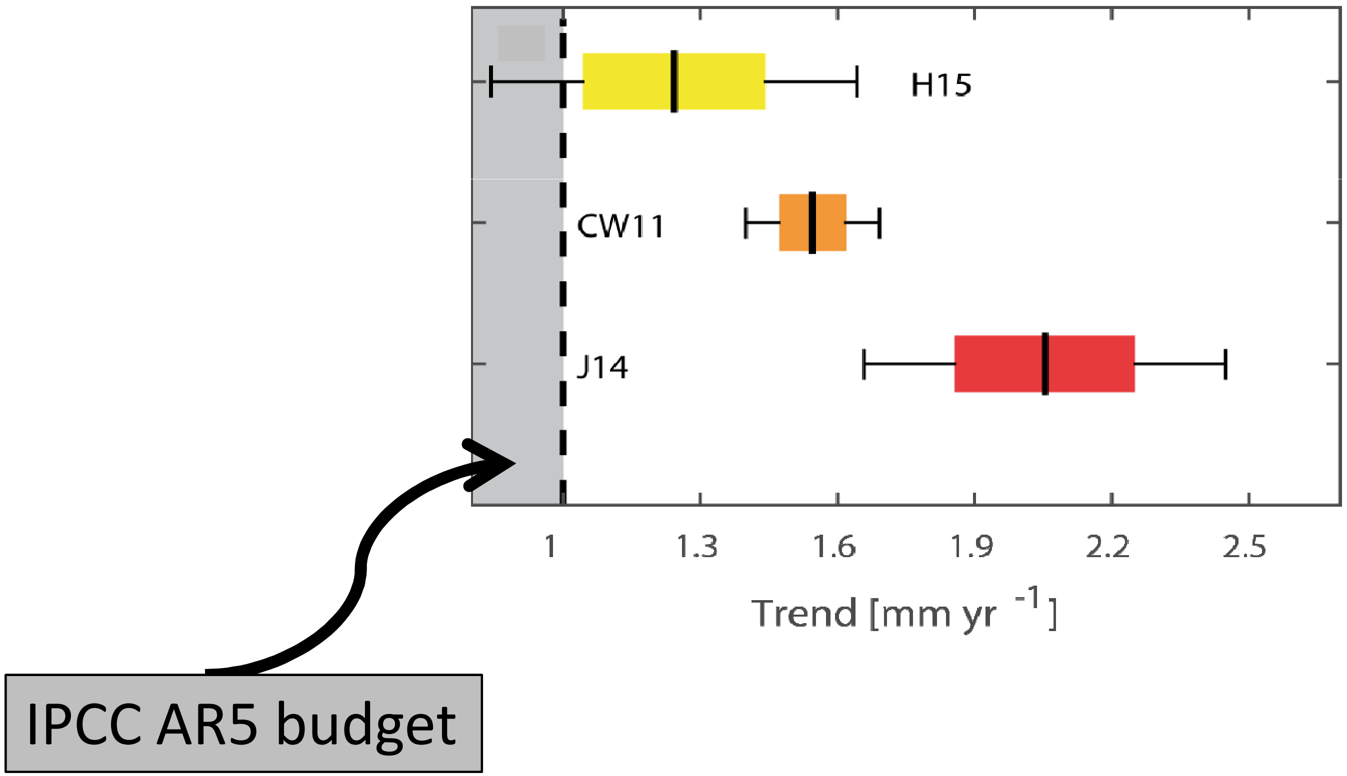


SEA LEVEL RECONSTRUCTIONS

1- Relatively **large spread** in pre-Altimetry GMSL estimates, especially before 1960s

2- Partly **inconsistent** with recent historical CMIP5 models

3- **Larger values** than the sum of individual independent contributors



NEW IMPROVEMENTS IN RECONSTRUCTIONS

Vertical land motion at tide gauges

Geoid variations at tide gauges

Tide gauges regional averaging

NEW CORRECTIONS   IN RECONSTRUCTIONS

Vertical land motion at tide gauges

Geoid variations at tide gauges

Tide gauges regional averaging

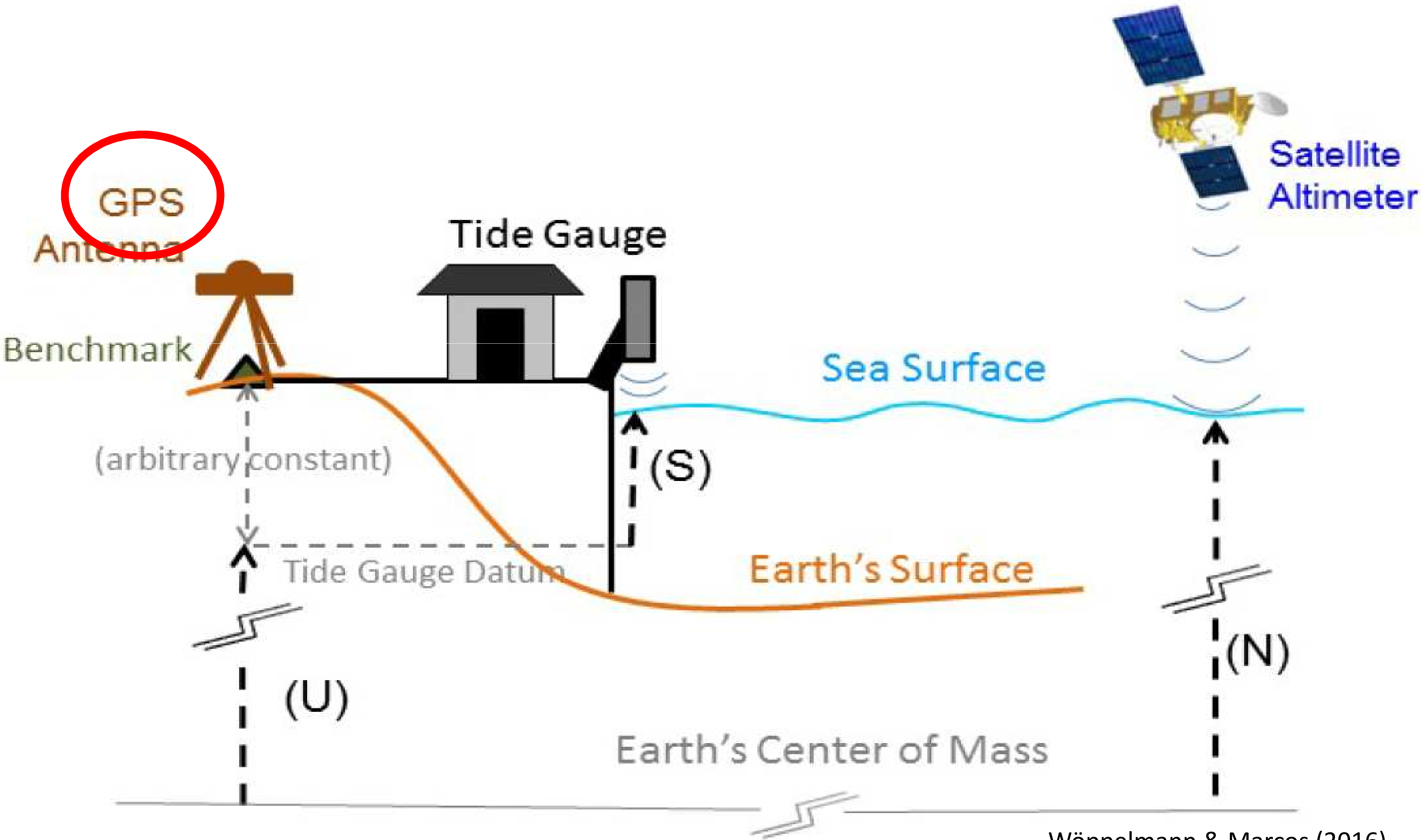
NEW APPROACH IN RECONSTRUCTIONS

Vertical land motion at tide gauges

Geoid variations at tide gauges

Tide gauges regional averaging

Vertical land motion at tide gauges

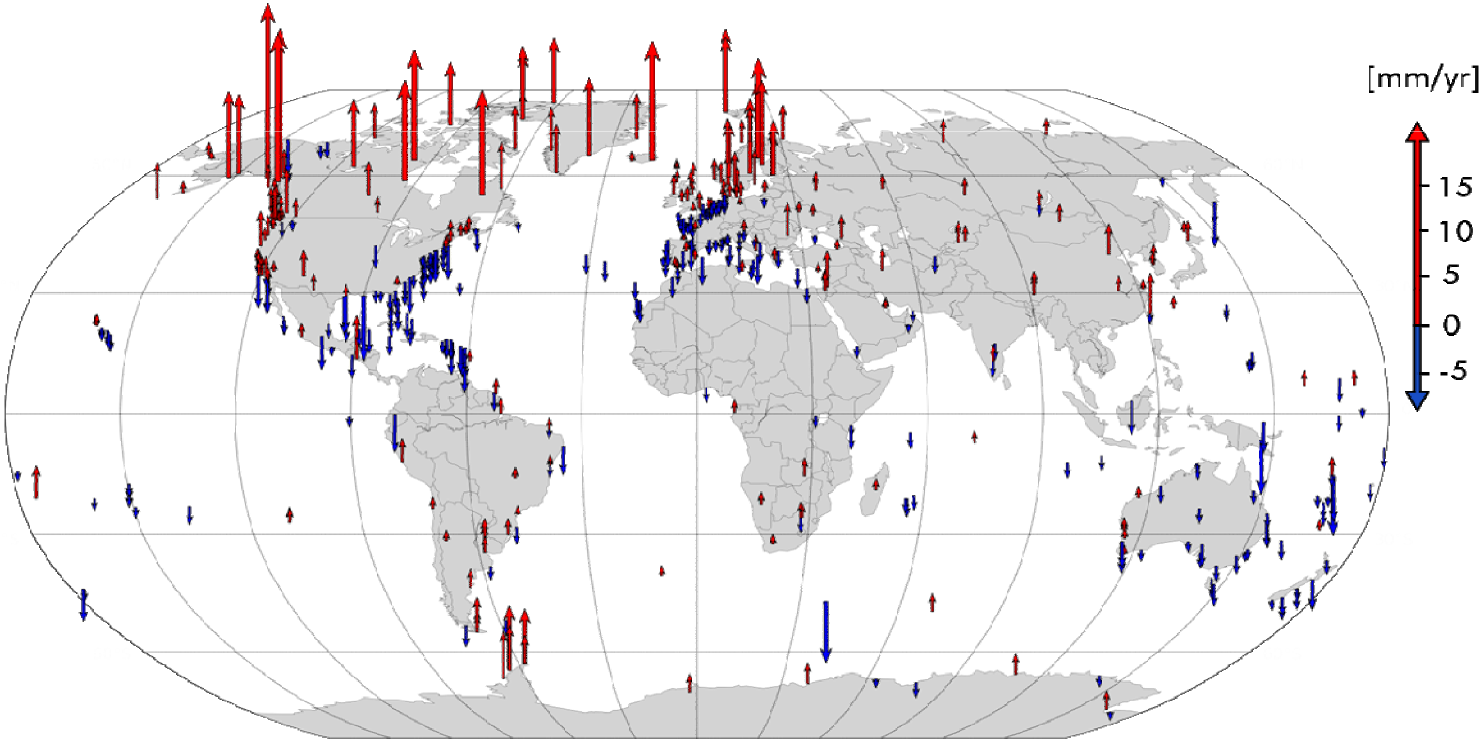


Wöppelmann & Marcos (2016)

Availability of GPS at tide gauge stations

ULR6 **(University of La Rochelle data centre)**
For sea level applications → 391 stations
Distance < 15 km from a tide gauge → 322 stations

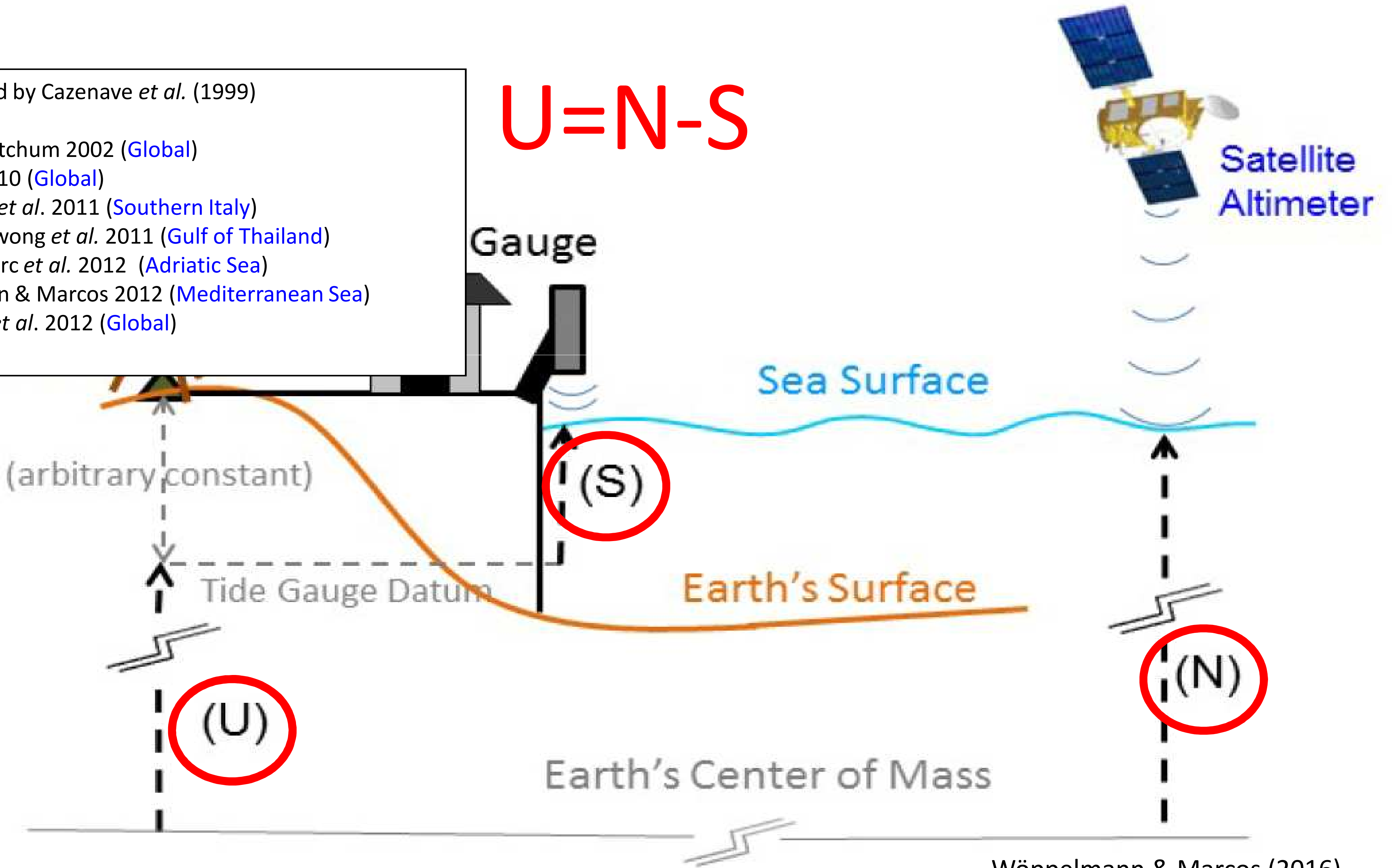
www.sonel.org



Vertical land motion at tide gauges

First published by Cazenave *et al.* (1999)
Many more:
- Nerem & Mitchum 2002 (Global)
- Ray *et al.* 2010 (Global)
- Braitenberg *et al*. 2011 (Southern Italy)
- Trisirisatayawong *et al.* 2011 (Gulf of Thailand)
- Fenoglio-Marc *et al.* 2012 (Adriatic Sea)
- Wöppelmann & Marcos 2012 (Mediterranean Sea)
- Ostanciaux *et al*. 2012 (Global)
-...

U=N-S



Wöppelmann & Marcos (2016)

Vertical land motion at tide gauges

485 VLM-corrected tide gauge stations

AGU PUBLICATIONS

Reviews of Geophysics

REVIEW ARTICLE
10.1002/2015RG000502

Key Points:
- Vertical land motion: a key element to understanding sea level change along the coasts

Vertical land motion as a key to understanding sea level change and variability

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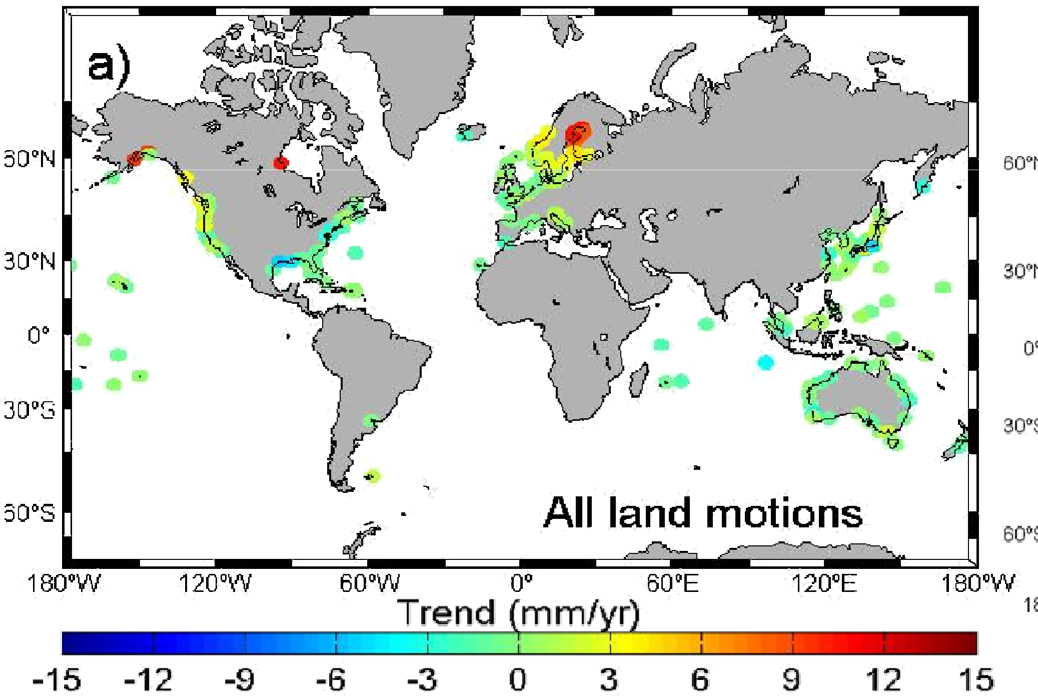
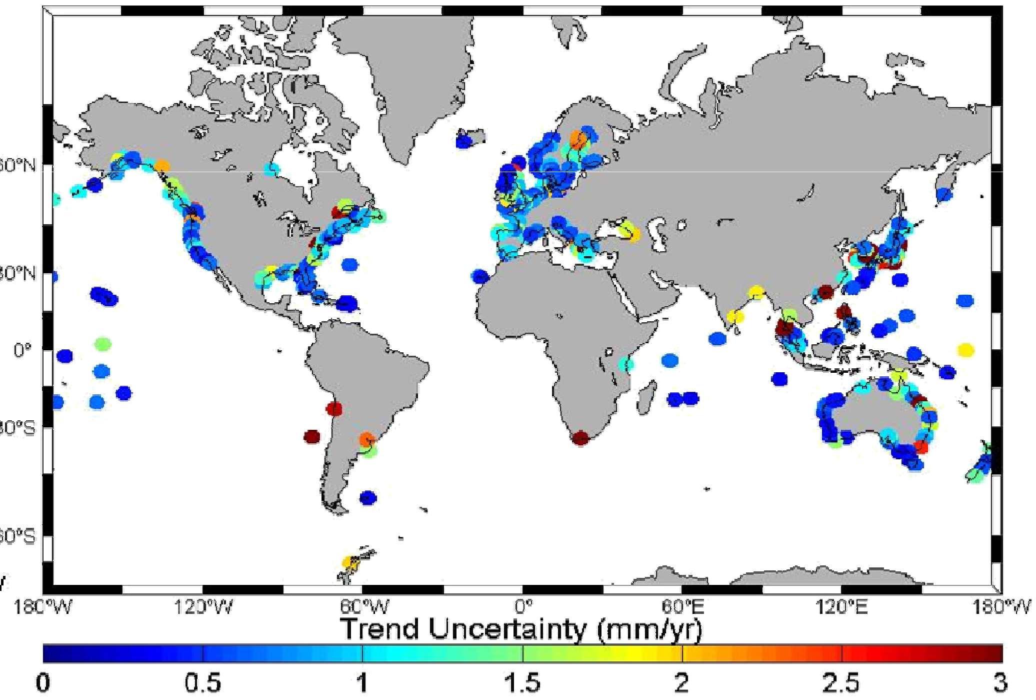
Trends



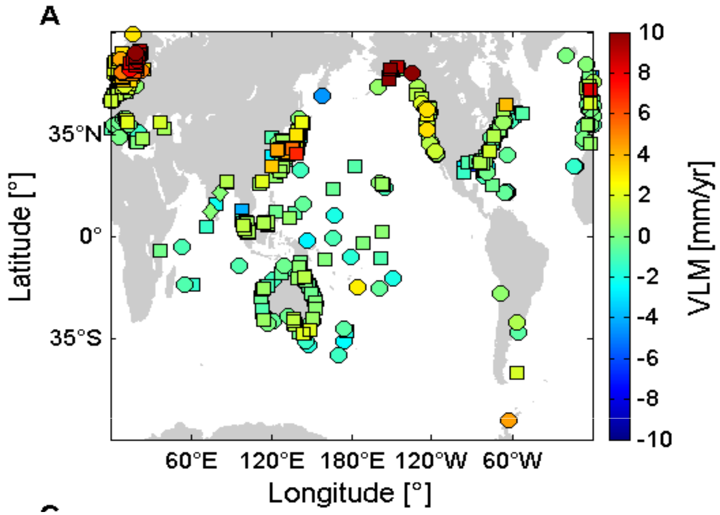
Trends uncertainties



Wöppelmann & Marcos (2016)

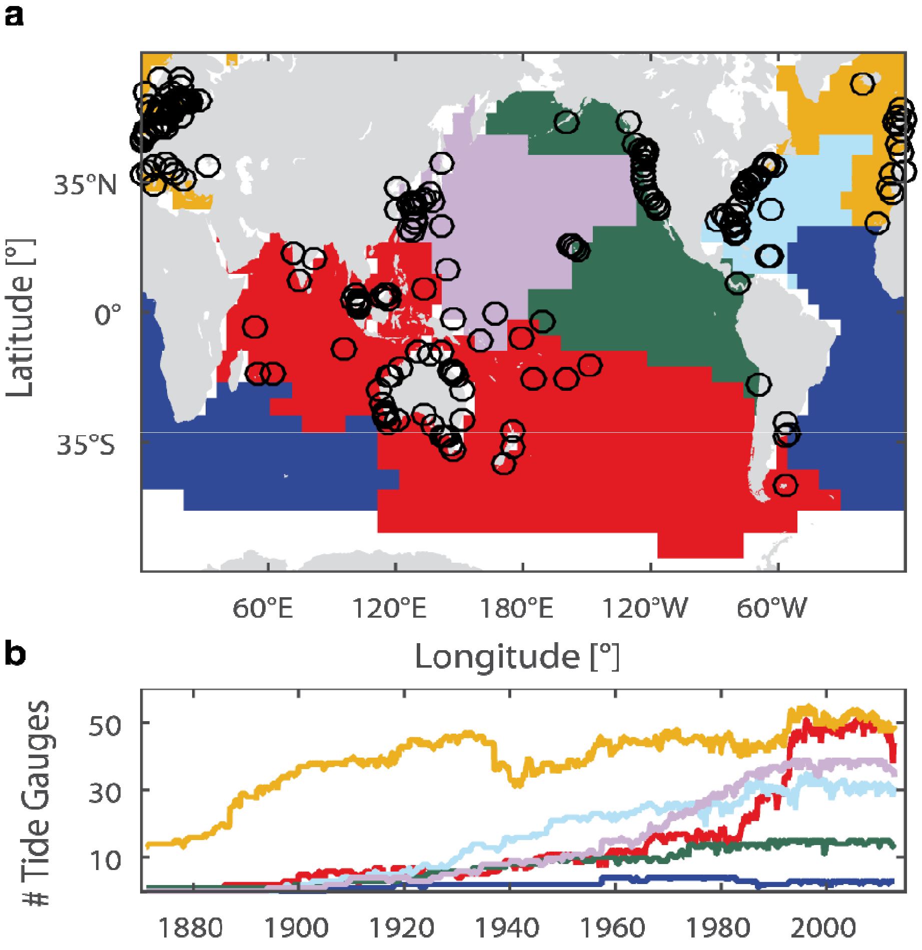
Vertical land motion and geoid changes at tide gauges

- **316** tide gauges corrected for VLM (**error <0.7 mm/yr**)
- Also for **geoid changes** due to terrestrial water storage (TWS) (including groundwater depletion (GWD) and water behind dams (WBD)) and glacier melting



Dangendorf et al (under review)

Tide gauges regional averaging

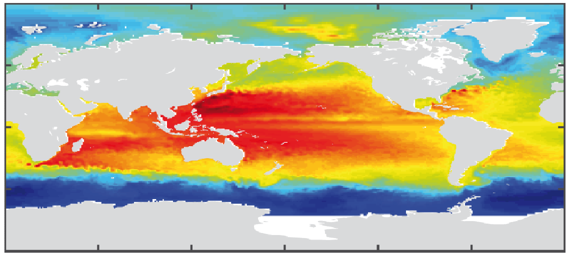


After Thompson and Merrifield (2014)

- ❑ Use of **coherent ocean regions** (Thompson and Merrifield, 2014)
- ❑ Tide gauge averaging approach based on Jevrejeva et al (2006) – "*virtual station*" technique (distance-weighted tide gauge averages within a region) **modified**

Tide gauges regional averaging

SODA/AOGCM SSH

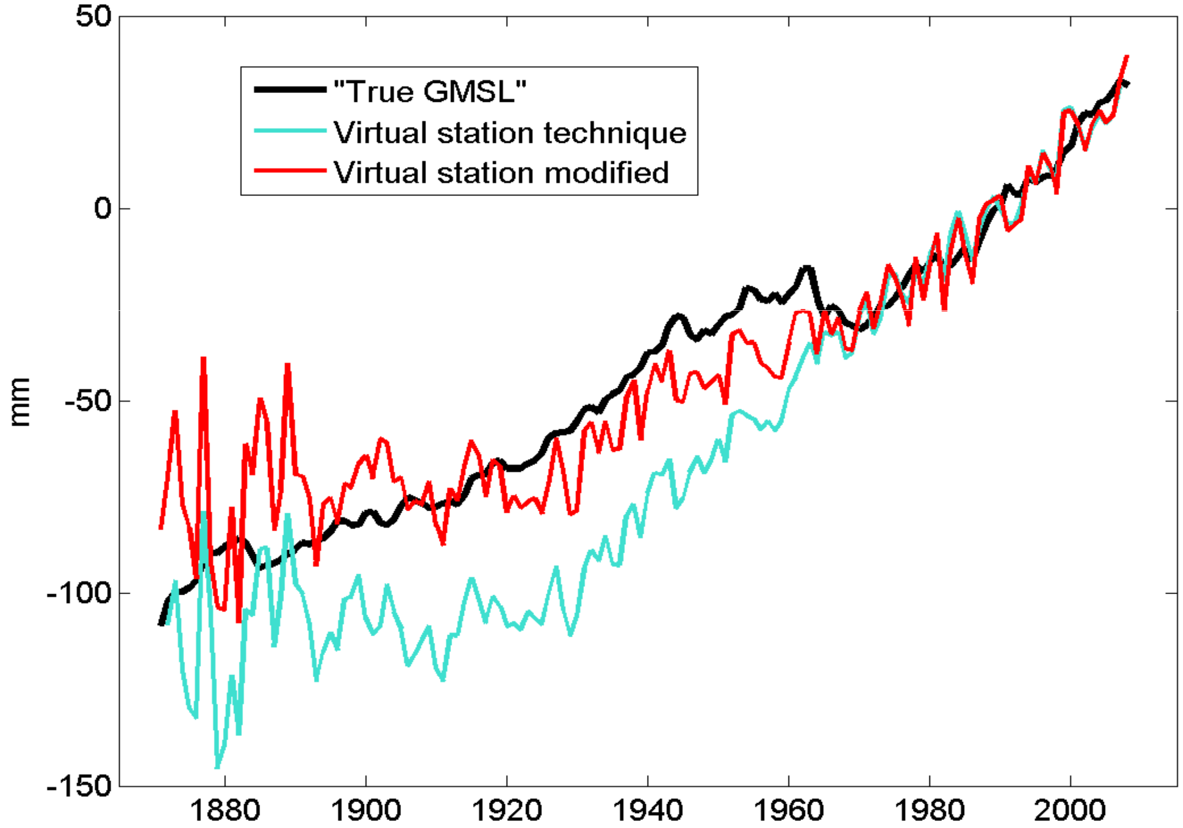


Carton & Giese (2008)

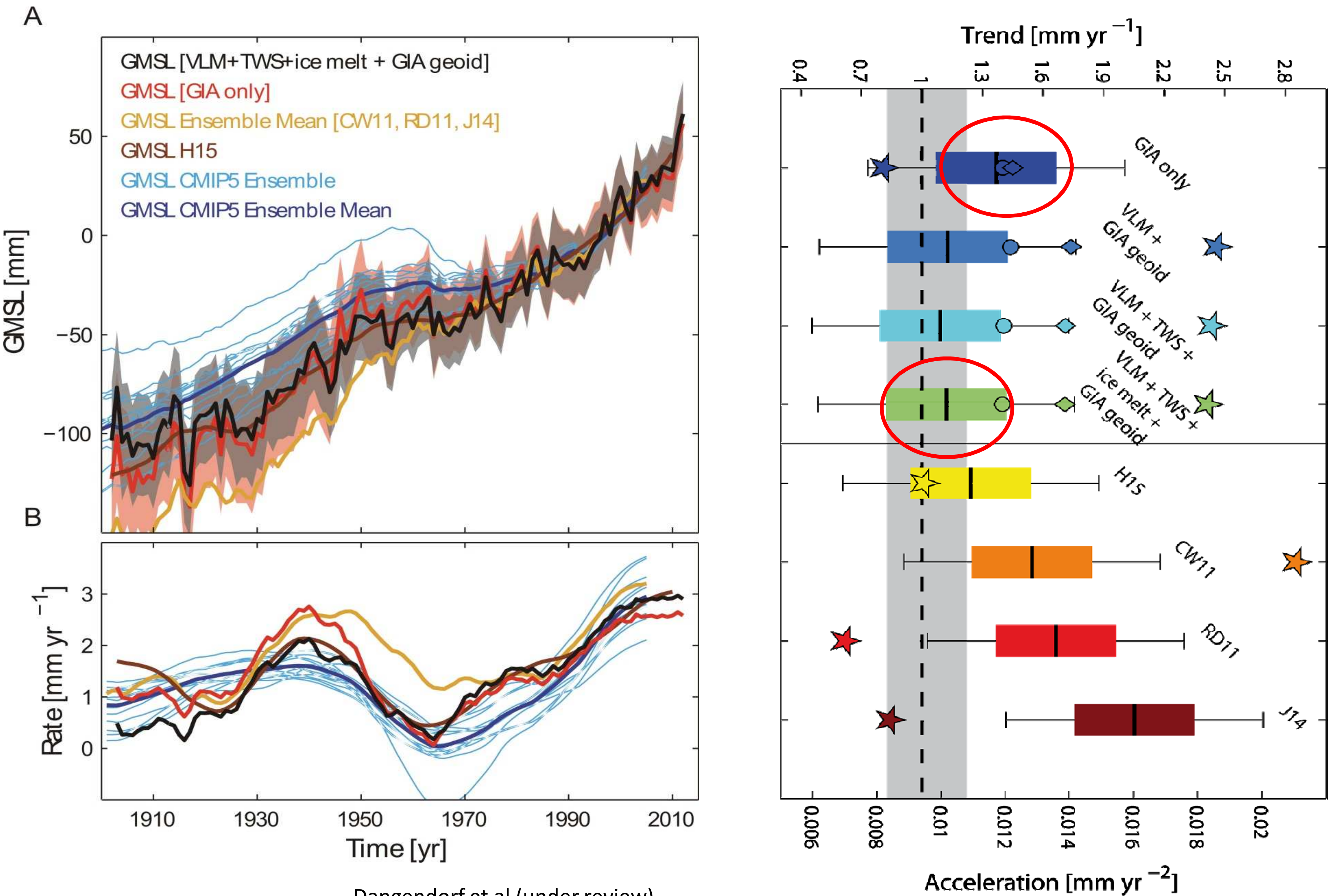
Averaging differenced tide gauge records

VS.

using a common datum



Global Mean Sea Level Reconstruction



Dangendorf et al (under review)

Global Mean Sea Level Reconstruction

The impact of VLM correction

~ -0,2 mm/yr

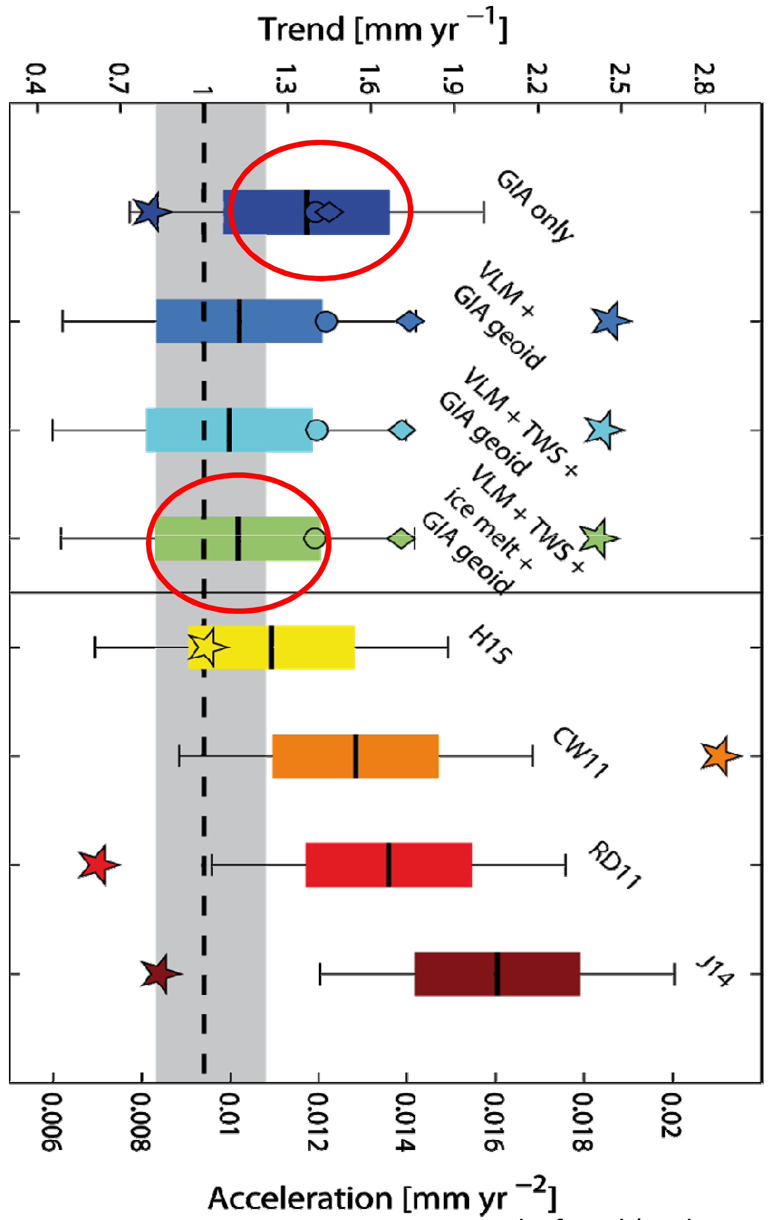
By contrast *Hamlington et al (2016)* -> **+0,2 mm/yr**

? Use of differenced tide gauge records

? GPS formal uncertainties

- ❑ Impact of VLM uncertainties **< 0,1 mm/yr** (if errors spatially uncorrelated)
- ❑ Impact of TG-GPS distance -> **negligible** at average separation distances of less than 15 km

Santamaría-Gómez et al (in preparation)



Dangendorf et al (under review)

CONCLUSIONS

- New approach to reconstruct 20th century GMSL – **easy** to implement and computationally efficient
- The new GMSL curve shows significantly **smaller trends** before 1990 (~1.1 mm/yr), which is more consistent with the value proposed by *Hay et al.* (2015)
- The new GMSL curve is now **more consistent** with the historical CMIP5 modelling attempts especially between the 1930s and 1970s
- Acceleration in GMSL is **stronger** than in any other reconstruction. Recent rates of GMSL are higher than earlier recorded periods.