1. Selection and quality control of tide gauge and GPS records

Monthly mean sea level records from the PSMSL tide gauge data repository [*Holgate et al.*, 2013] with datum control spanning at least 50 years from 1900, with more than 70% of valid data, and with a reliable GPS velocity [*Santamaría-Gómez et al.*, 2012], were first selected. This resulted in an initial set of 333 tide gauge-GPS pairs of time series. Sea level records that did not correlate with nearby (<500 km) stations were removed. The separation distance between the GPS antenna and the tide gauge was subsequently examined in relation to the geological setting. The aim was to ensure that both instruments were subject to the same vertical land motion. For instance, in areas affected by tectonics (e.g., Japan), the GPS was required to be co-located with the tide gauge, whereas in areas affected by a GIA gradient (e.g., Baltic) tide gauge-GPS pairs with a predicted GIA vertical land motion difference larger than 0.4 mm/yr were rejected. Overall, tide gauge-GPS pairs were required to be located on the same land (e.g., islands). It should be remembered that two working hypotheses are necessary when using GPS data to correct vertical land movements in sea level records. The first hypothesis requires that the linear vertical land movement estimated from the GPS data is consistent over the multi-decadal to century timescale of the tide gauge record. The second requires that the land motion detected by the GPS antenna is consistent with that affecting the tide gauge at the level of a few tenths of a millimeter per year, or that their local differential motion is monitored to that level of accuracy. Both are necessary working hypotheses, which have been discussed extensively in the literature [e.g., *Bevis et al.*, 2002; *Santamaría-Gómez et al.*, 2012]. Finally, both the tide gauge and the GPS time series underwent a thorough individual visual inspection for non-reported offsets and varying rates of change. The selection process resulted in a final set of 76 stations (Table S1) with a median length in the sea level records of 93 years (minimum length of 50 years) and a median separation distance between tide gauge-GPS pairs of 7.5 km (maximum separation distance of 90 km). The inverted barometer was applied to each selected tide gauge record using mean sea level pressure from [*Compo et al.*, 2011]. The time series were next corrected for vertical land motion using the GPS velocities from *Santamaría-Gómez et al.* [2012] and for the geoid contribution to sea level using the GIA model predictions from [*Peltier*, 2004].

2. Virtual station technique

Based on the linear correlations observed between de-seasoned and de-trended time series, coherent spatial patterns were delineated for the stations, resulting in seventeen regions (Table 1). Four regions out of the seventeen are, however, constituted by a single station. Table S1 (last column) displays the corrected sea level trends of the 76 stations and overall confirms our regional grouping. For each multi-station region, a ‘virtual station’ was built following *Jeverejeva et al.* [2006], based on the corrected sea level time series (Figure S1). This ‘virtual station’ technique avoids the problem of the uneven distribution of stations and creates a regional average time series weighting the stations according to their relative location. The thirteen regional time series were eventually averaged into hemisphere and global mean sea level curves, still using the method described in *Jeverejeva et al.* [2006] to derive the standard errors. However, at this stage the resulting curves and rates of global sea level change are arguable. At the few tens of a millimeter per year level, different choices in the averaging method may lead different values due to the hemispheric patterns, sampled areas and area-weighting. In this context, the range of published estimates between 1 and 2 mm/year reported by *Spada and Galassi* [2012] can easily be explained from the analysis choices.

3. Procedure for testing the significance in hemispheric differences

The standard errors for a group (regional or global) were processed using the bootstrap method like in *Jevrejeva et al.* [2006] with 50,000 random draws. This ensures that the standard deviations are representative even though the individual velocity data are too few and their distribution is not Gaussian. The Student test was applied to test the significance of the difference between the two hemispheres (rates of sea level change). In the last stage, comparing these multi-region groups with the global mean showed that the northern hemisphere group was not statistically different from the global mean, whereas the southern hemisphere group was significantly different.

4. Reference frame errors

GPS estimates of vertical land movement (VLM) at the tide gauges may be globally biased by errors in the definition of the origin and scale rates of the terrestrial frame realized by the GPS velocities [*Collilieux and Wöppelmann*, 2011]. A bias in the definition of the Earth's mass center displacement in the direction of the polar axis (Z) would display a latitudinal VLM error following $eZ \cdot \sin(lat)$ where eZ is the terrestrial frame error in the rate of the geocenter motion along the Z axis and *lat* represents the latitude [*Collilieux and Wöppelmann*, 2011]. If a positive (towards the North Pole) eZ error existed, VLM estimates in the northern hemisphere would be artificially increased whereas in the southern hemisphere they would be artificially reduced. Here we assess the reference frame error in the rate of the origin displacement along the Z axis of the ITRF twofold. First, we estimated its internal formal precision by computing the rate uncertainty of the weekly Satellite Laser Ranging translation time series used in the geocenter definition of the ITRF2008 [*Altamimi et al.*, 2011]. To do so, the uncertainty was estimated rigorously by taking into account the time correlation of the data through up to eleven different stochastic noise models. The noise model with the best maximum likelihood (composed of white noise plus flicker noise) provided a formal eZ precision of 0.23 mm/yr. Second, we evaluated its external accuracy by comparing GPS and GIA vertical velocities. GPS velocities given in the ITRF are expressed in a mean center of mass (CM) frame, while GIA velocities are expressed in a center of solid Earth (CE) frame. Since both frames are expected to translate negligibly (CM motion with respect to CE due to present-day ice loss is less than 0.1 mm/yr [*Métivier et al.*, 2010]), the comparison of GPS and GIA vertical velocities could be used to assess the eZ error in the GPS velocities. Taking a high-quality and well-distributed global GPS network as the International GNSS Service core reference network [*Rebishung et al.*, 2011], we estimated the scale factor and the Z translation rates between the GPS vertical velocities and the predicted GIA crustal velocities [*Peltier*, 2004]. GPS stations showing velocity residuals larger than 5 mm/yr were rejected assuming they are affected by local VLM effects not accounted for in the GIA model. For the retained 79 stations, the estimated parameters were 0.97 ± 0.11 for the scale factor rate and 0.29 ± 0.21 mm/yr for the Z translation rate. Both estimated parameters were not significant at 2 sigma level (null scale factor being 1). Although the internal assessment did not take into account possible bias of the geocenter definition resulting for instance from the poor distribution of the SLR observations, both the internal and external assessment were consistent. Therefore, we consider that the reference frame error along the Z axis would not be larger than 0.4 mm/yr (95% confidence interval).

5. Representativeness of tide gauge geographical coverage

Sea surface height at the closest grid point of each of the final set of 76 stations was selected from [*Carton and Giese*, 2013]. As the ocean model used is a volume conserving model, the time average volume change provided by the global steric sea level was added at each time step [*Griffies and Greatbatch*, 2012]. Note that the output of this realization has not been corrected for any model drift and therefore it is not expected to match the observed sea level trends. The individual time series were then grouped into regions and averaged using the 'virtual station' technique [*Jevrejeva et al.*, 2006], thus following the very same approach as for the tide gauge observations. They were then grouped into global and hemispheric mean sea level curves. On the other hand, area weighted global and hemispheric averages were also computed from the model output. Linear trends were computed for both sets of curves and for different period lengths ranging from 10 to 120 years and overlapping every 10 years. For example: 20-year periods correspond to 1871-1891, 1881-1901,…,1981-2001; 100 year periods correspond to 1871-1971, 1881-1981,…, 1901-2001. Figure S3 represents the trend values for each period length and for global and hemispheric averages. Results demonstrate that at secular time scales (100-year period) the difference between the 'virtual station' technique applied to our set of tide gauges and the actual area weighted averages is at most 0.15 mm/yr. This value is well below the observed differential rate between hemispheres. Figure S3 also evidences that for 20-year periods, such as the altimetry era, mean sea level trends at tide gauges may not be representative of the global or hemispheric mean, given the large scatter at these short periods. Furthermore, the scatter in the area weighted averages from the model output indicate that the hemispheric differences cannot be examined and differences in excess of 1 mm/year are likely in one or the other direction. Only periods longer than 40-50 years can be used with confidence.

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