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The Cryosphere
Discussions

TCD

Interactive comment

Interactive comment on "Brief Communication: The global signature of post-1900 land ice wastage on vertical land motion" *by* Riccardo E. M. Riva et al.

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General comments:

This paper addresses the elastic deformation of the Earth's crust in the vertical component due to ice mass changes during the last century. This topic is of great relevance for the sea-level community, where vertical land motion (VLM) corrections of the tide gauge (TG) records are needed in order to observe climate-driven sea-level change. In particular, this paper emphasizes the non-linear vertical deformation in far-field areas where most of the TGs used for sea-level change are installed. VLM corrections at the TGs are typically obtained from GIA crustal uplift predictions and, more recently, also from space geodetic observations (GPS). Despite the different advocacy for GIA or

GPS corrections found in the literature, both share a common limitation: they assume VLM at the TGs is linear throughout the sea-level record. This assumption is understandable due to the lack of independent observations to better constraint the VLM at the TGs. This paper provides new insights on the level of non-linear VLM expected from recent ice mass changes and completes the assessment of the non-linear VLM bounds from atm, ocean and hydrology loading. Therefore I recommend this paper for publication after considering some minor comments below.

Specific comments:

L21: “the century-long trend” in ice-mass loss . . . Also, a reference to the Fig. 1 (right) would be appropriate.

L26: “what is often not realized” by who? I believe is quite common to deal with solid Earth deformation due to loading at global scale.

L56: while the secular or mean VLM trends are probably indistinguishable in a CM or CE/CF frame, the interdecadal vertical deformation may be different depending on the chosen frame, which, in turn, may have an impact on the short-term trends shown in figs. 2 and 3. This is what happens with other loadings (atm, ocean and hydro) at the interannual variations leaving the long-term trend unchanged. Maybe it does not happen with the spatial pattern of the ice-mass unloading, so I suggest adding a sentence explaining why the CM frame was chosen and whether it has any impact on the results.

Fig. 2: if the format of the communication allows it, I would suggest to add two more maps showing the rate differences between the maps a) and c) and a) and d). This would support the discussion of the results and also fig. 3.

L66: accuracy of both, the melt distribution and the regional mass loss values.

L71: “most of Australia has been subsiding at rates larger than 0.4 mm/yr” this has been observed by GPS estimates since long ago without any plausible explanation thus far (see for instance Altamimi et al 2016). I suggest emphasizing this point.

L71: This is a very interesting spatial pattern in which northern TGs are uplifted faster in the last decade (captured by the GPS VLM corrections) compared to the last century, while southern TGs have subsided faster. This could partially explain the hemispheric difference in sea-level rise found by Wöppelamn et al. 2014. At the time that paper was published, this ice-mass loss fingerprint was unknown and it seems to me from your Fig. 2 that the average difference between the northern and southern TGs used by Wöppelman et al. 2014 could accommodate part of the hemispheric difference that was not explained by the uncertainties.

L71: In relation to my comments above. Similar to the GIA effect on the deepening of the ocean basins and the resulting global mean sea-level change (of about 0.3 mm/yr), is there any ocean basin effect due to recent ice-mass loss to be accounted for in the sea-level trend?

L89: The estimated changes in VLM rates appear to induce a periodic-like oscillation close to 60 years, especially in northern TGs close to the areas of ice-mass loss. Many of these TGs have very long records and were used to assess a global 60-year oscillation in sea-level by Chambers et al. 2012. I wonder how much of the observed 60-year oscillation is due to the ice-mass loss fingerprints shown here. A detailed analysis would be worth pursuing. A priori, the oscillation phase shown by Chambers et al. 2012 (Fig. 1) is consistent with your results.

L99-101: Note that we didn't correct or encouraged correcting for continental water mass loading due to the significant differences amongst the model outputs in terms of secular, as you mention in the next sentence, but also interannual deformation.

L113: "those approaches are limited by the fact that space geodetic observations are only available since the 1990's". Note that there exist alternative approaches in combining satellite altimetry and tide gauge observations that benefit from the longer TG series, thus reducing this limitation (see for instance Kuo et al., 2004 and Santamaría-

Gómez et al. 2014).

L115-117: This is probably the biggest limitation of using GPS for correcting long TG records (together with the lack of nearby GPS observations), especially when very short GPS series are used. However, it is not a limitation exclusive of the GPS VLM corrections, but also when using GIA corrections which neglect any non-linear VLM in addition to any other linear VLM that is not GIA.

L117: In relation to my comment above. The average VLM for the last 10 years for the 6 TGs shown in Fig. 3, does not seem to lie far from the average VLM over the last century. It would be interesting to have some statistics of the VLM deviation during the GPS era or the additional maps I suggested above.

L140: This is an interesting perspective, but one also needs to consider the uncertainties in the ice-mass loss fingerprints, which were not discussed in this brief communication. In addition, even after correcting for this effect, the VLM corrections (from GPS or GIA) will still be considered linear as a working hypothesis even if we have clues that they may not be (due to pole motion deformation, hydrologic loading, long-memory noise, etc.).

Technical corrections:

L28: “position of every other point on the Earth’s surface” with respect to the Earth’s center of mass.

L48: “cumulative mass loss” should be “equivalent sea-level change” or “barystatic sea-level change”.

L121: “induce” I would suggest “reveal” here.

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