Review of 'Trends and Uncertainties of Regional Barystatic Sea-level Change in the Satellite Altimetry Era'

In this manuscript, the authors have collected a large dataset of the sources of barystatic sea-level changes, computed the associated GRD fingerprints, and discuss the sources of uncertainty in the resulting GRD pattern. I think this dataset will be very useful for many applications in sea-level and climate research, and I'm convinced this work is a worthy contribution to the literature on this topic.

Nevertheless, I have a few technical and philosophical remarks and questions. I start with some general remarks, followed by line-by-line comments.

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General remarks

GR1 Intrinsic uncertainties:
The reported uncertainties from the individual data sets are assumed to be uncorrelated. Therefore, the trends are subsequently estimated using ordinary least squares with the uncertainties on the diagonal of the co-variance matrix. I don't think that this is the right approach to estimate the trend uncertainties due to intrinsic errors. For many estimates the uncertainties will be serially correlated, for example due to uncertainties that affect the trend. Like if the uncertainty in a GRACE time series is fully due to GIA uncertainties that only affect the trend, the aforementioned assumption doesn't hold, and the resulting errors are an underestimation. For estimates where the rates and their uncertainties are available, an approximation that often works well is to assume that the rate errors are uncorrelated, which is equal to assuming random walk. Then you can generate an ensemble of time series by perturbing the rate with random normal noise, and then integrate the rates to obtain the time series. Something like:

```
rate[t] # rate of a process, say in GT/yr
rate_unc[t] # uncertainty of the rate
for ens in 1:1000 # Let's make 1000 ensembles
  rate_ens = rate + rand_normal[length(t)]*rate_unc
  tseries_ens = cumsum(rate_ens) # This gives the time series in GT
end
```

can do the trick. A good way to verify the results is to compare the barystatic trend uncertainties in Gt/yr or mm/yr with those reported in the papers where the data sets came from.

GR2 Trend uncertainties:
I think the paper could use some more discussion on the meaning of the trend uncertainties, because their meaning is not trivial and explaining the meaning of these trend uncertainties is important for data users to correctly apply them. This is a bit of a philosophical point, but the auto-correlated residuals after estimating the trend are not per se due to measurement errors, but they could represent a real signal. An example is the drop in GMSL during the 2010/2011 La Nina event, and the acceleration in ice-sheet mass loss. Let's assume now that someone downloads the regional data as well as some altimetry data of regional sea level. Then the uncertainty in the unexplained residual (Local altimetry – local ocean mass) should not contain the trend

uncertainty given here. Altimetry will also see the acceleration and La Nina-like bumps and throughs and the difference probably shows much less interannual variations and thus has a lower trend uncertainty. However, when this user just uses the provided trend uncertainty and adds it in quadrature to some other errors, he or she will overestimate the uncertainties of the just computed difference. Some guidance could help here.

GR3 Barystatic sea level:
How do the global-mean time series and uncertainties look like? A simple plot with the global-mean time series from each component and the total might be a nice addition. That could also help verifying the 1993-2016 time series from models: do they show similar trends and variability as GRACE? For TWS, Scanlon et al. (2018) show some discrepancies between models and GRACE for TWS. Might be interesting to see whether estimates from WaterGAP and PCR-GLOBWB now perform better.

GR4 The term 'regional barystatic':
After Gregory et al. (2019), barystatic sea level should only refer to global-mean sea-level changes, and not to regional patterns. I'd remove the term 'regional barystatic' and replace it with 'Barystatic sea level and associated GRD patterns' or something like that

GR5 Glaciers and ice sheets:
A nasty problem when working with GRACE data for glaciers is that the GRACE resolution is pretty coarse compared to the size of some glaciers. Therefore, it's hard to separate the mass loss from peripheral glaciers in Greenland and Antarctica from the nearby ice sheets. The same goes for small glaciers in for example Asia, where mass changes from nearby TWS changes leak into the glacier mass change estimates. Did the authors take this into account? A possible way out is the method described in the supporting information of Reager et al. (2016): for the RGI regions where glacier mass loss dominates the GRACE mass change estimates, use GRACE, for the ice sheets, treat the glaciers as part of the ice sheets, and for the other regions, use another dataset (for example Malles & Marzeion, 2021 or Hugonnet et al. 2021) to separate glaciers from TWS. We have used such an approach in a recent paper on ocean heat content (Hakuba et al. 2021), and the scripts to do such a separation can be found on Github: look at the function `separate_mass_ctb` in https://github.com/thomasfrederikse/EEI_GRACE/blob/main/Code/mod/mod_budget_grace_mass_rsl_ens.py.

GR6 Used datasets.
The authors have collected a large and diverse set of sources for their barystatic estimates. I've listed below a few other data sets that could be added as well. Since new data sets appear all the time, this list isn't exhaustive and should be seen more as an idea rather than a demand to incorporate them in this manuscript.

Glaciers:
- Model estimates from Malles & Marzeion (2021). This data set also contains some estimates of the intrinsic errors due to model choices and input dataset.
- Satellite altimetry observations from Hugonnet et al. (2021).

Greenland:
- The model estimates from Mankoff et al. (2021)

Antarctica, Greenland and Glaciers:

- Bamber et al. (2018) provides an IMBIE-like assessment of mass loss from glaciers and ice sheets.

Terrestrial Water Storage

- Humphrey and Gudmundsson (2019) have TWS estimates based on a simple bucket approach trained with GRACE data. It comes with an ensemble from which uncertainties can be deducted.

Line-by-line comments

L10: the trend ranges, do they refer to the 95th percentile of the gridded field? I'd think the minimum trend will be lower very close to the ice sheet edges

L63-L64: "The structural uncertainty is related to the use of different datasets of the same process". The structural and intrinsic uncertainties, are they independent? I can imagine that for example in GRACE, there's an uncertainty in some atmospheric correction, and product A uses estimate A and product B uses estimate B for that process. Then parts of the intrinsic uncertainties also end up in the structural uncertainties.

L131: More of an idea than a comment: there's a lot of people looking for fingerprints to analyze altimetry data, so there might be quite some interest in complementary geocentric sea-level fingerprints.

L166 Average – typo

L179 The JPL mascon uncertainties do not represent the uncertainties due to the GIA correction. This uncertainty is actually pretty large, but a bit cumbersome to propagate into the final GRD patterns. It can be done by using uncertainty estimates from for example Caron et al. (2018) and Simon & Riva (2020, I'm sure some of the authors are aware of this study). Propagating the full GIA uncertainties into the fingerprints might be a bit too far-fetched for the current manuscript, but it's a good idea to mention that there's additional uncertainty related to GIA in these GRACE estimates.

Figure 2 It looks like the glacier mass balance from the CSR and JPL mascons has been estimated by splitting up some of the mascons. This is a bit tricky: for some regions, the mass changes of the whole mascon are dominated by small glaciers, and taking a part of the mascon induces an error. The opposite also happens. I'd recommend to not split mascons into smaller pieces. See also GR5 for a possible way out.

L255: Just out of curiosity: does the UCI dataset show any mass gains in East Antarctica?

L264: as a rule of thumb, the individual mascons from the JPL solution are all independent and agree more-or-less with the spatial resolution of the GRACE measurements. For other mascons, like GSFC and CSR ones that have a much higher resolution, the individual mascons are not fully independent of eachother.

Figure 4: This is a very interesting figure! I discovered a lot of intriguing phenomena when looking at it.

Figure 5: also related to GR1. If you check the uncertainties listed in Table 1 from the IMBIE Antarctic paper, the reported uncertainties, which are about 50 Gt yr-1 for 5-year periods, seem to be much higher than reported here. This is probably related to the assumption of uncorrelated uncertainties. Using the rates+uncertainties procedure from GR1 might solve this difference.

L375: Check the paper from Humphrey and Gudmundsson (2019), who provide some centennial estimates of TWS changes.

L381: Antarctica Ice Sheet typo

L429 Individuals typo

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