Dear Editor,

Thank you for providing us with the reviews. We appreciate the suggestions and questions of the reviewers, and we don't have any major objection. Please find our responses below (in blue).

Regards,

Athina Peidou

################################ Reviewer 1 #####################################

This paper presents some procedures that help in making vertical land displacements useful as complementary data to GRACE for inverting hydrological loads, including noise analysis, using discrepancies between GPS and GRACE to detect missed GPS offsets, and an improvement of the CMC Imaging method of Kreemer and Blewitt (2021). The data produced is ultimately very useful for researchers interested in hydrologic loading. Where will the VLD time-series be available?

Thank you for your comment. We provide the data repository in the Data Availability Section: "Data Availability: The data product described in the manuscript is available in zenodo (https://doi.org/10.5281/zenodo.8184285)."

Possible issue with Correlation presentation:

The calculation of correlation between GPS and GRACE (per watershed) is not clear to me, given that you have X GPS time-series and Y GRACE mascon time-series. I suspect there is a missing step, that doesn't seem to be explained: how GRACE data is translated to VLD at the station level. Please explain that.

Thank you for your comment.

0. We derive GRACE(-FO) VLD fields (lon, lat, Up displacement) using Eq. 1 (described in Davis et al., 2004) for each month that GRACE(-FO) was available starting in 2006 (because our GPS timeseries begin in 2006).

1. Subtract the reference period (09/2012) from each monthly up field.

2. GRACE(-FO) fields are estimated at a 0.5-degree spatial resolution (Eq.1). Thus, we extract GRACE(-FO) estimates at the station level by linearly interpolating the vertical displacement from the nearest 0.5-degree grid point neighbors to the station's location.

We added the following sentences in the main text.
"JPL releases gridded mascon fields, to derive spherical harmonics (C and S in Eq. 1). We transform fields of equivalent water height to normalized harmonic coefficients using the inverse of Eq. 9 in Wahr et al. (1998). Like GPS, we subtract GRACE(-FO) VLD field of September 2012 from each monthly field, for a common reference basis. Finally, we extract GRACE(-FO)

VLD prediction at the station level by linearly interpolating the VLD fields to the station's location."

We have revised the description of deriving GRACE-(FO) vertical displacements.

Furthermore, I don't see how a poor correlation can be attributed to a single station (as the case for St. Lawrence) ; this is assuming that the authors didn't mean to say that there was a missed GPS offset in all of the time-series, which seems unlikely.

You are right. The issue with the missed offset affected almost 25% of the stations located in the St. Lawrence watershed. We revised the manuscript and provide the exact number of stations affected (62) relative to the total number of sites in the watershed (243) (See Line 272).

Minor points:

Line 85. Kreemer and Blewitt did not introduce the term CMN, but rather used the term CMC (common mode components), which was first introduced by Tian and Shen (2016)

True. Thank you. We changed the reference to Tian and Shen, 2016.

Line 118. Originally is not used properly in this contextLine 118. "layout" should read "lay out"

Thank you. Done!

line 126-127: "We overcome CMC's limitation of include spatially correlated hydrology signals...". This sentence is grammatically not correct, nor is the context clear: which limitation? That includes both noise and unmodeled signal?

We strive to isolate noise from signal, thus we were interested in deriving the common-mode component reflecting surface hydrology signals and removing it from the respective GPS timeseries. We revised the sentence accordingly: We build on the existing CMC algorithm to remove hydrology signals from the error estimate by deriving surface loading signals from a hydrology model and removing them from the GPS up displacements (see Section *3 for more details).*

Line 192: I think P_lm is missing in front of "are the associated Legendre polynomials"

Thank you. The typo is now fixed.

Line 220: "*A* and *B* being the amplitude and phase". That is not how formula 2 is written, which is erroneous, should be A*cos(2*pi*t+B)

Thank you. The typo is now fixed.

Line 302-303: "We identified the need for antenna offset corrections (in the case of Great Lakes)". Before the St. Lawrence watershed was named in this context, now Great Lakes. Later (line 458) Lake Michigan is mentioned. Which is it?

Thank you. The sites are located in the Great Lakes region of the State of Michigan, which belongs to the southern west end of the St. Lawrence watershed. To avoid confusion, we refer consistently to the sites, as "sites located in the Great Lakes region" and we provide some more detail on the number of the stations affected by the offset issue.

################################ Reviewer 2 #####################################

The article is a valuable compilation of methods and approaches used in the geodetic literature to analyze time series. However, it contains several shortcomings that limit its understanding or use of the dataset. The main limitation is that the authors do not make the created dataset and its uncertainties available (as they promised in the abstract and introduction), which greatly prevents me from assessing its potential. Some of the results are presented laconically (as the uncertainties; I presume these are the uncertainties of trend, or…?), and others lack adequate explanations (where is the RW in the data coming from? Perhaps it is the result of inadequate series length? or other effects?). The authors are keen to streamline the procedure for qualifying the data for further analysis, but sometimes speeding up preprocessing or classification can lead to erroneous conclusions.

Thank you for your comments and recommendations. Please find our response below:

Major shortcomings include:

1. I believe that a key requirement for publishing an article in ESSD is that the proposed dataset be available. Unfortunately, I found nothing about this either in the article or in the supplementary materials. Do the authors plan to make available GPS VLDs that can be taken directly for comparison? Their uncertainties were also described, but are not available. Will these be the uncertainties of individual observations or the uncertainties of trends?

   Thank you for your comment. Please refer to the Data Availability section where the doi of the GPS VLD timeseries and their uncertainties are made publicly available:

   "Data Availability: The data product described in the manuscript is available in zenodo (doi:10.5281/zenodo.8184285)." https://doi.org/10.5281/zenodo.8184285.

   The uncertainties reported in this study reflect the noise of the GPS VLD timeseries, not the trends. We clarified this in the manuscript.

2. It would also be useful to make available a list of stations that the authors considered being those responding elastically to the applied load, their coordinates, and a list of stations excluded from comparisons as those responding poroelastically.

Thank you for the suggestion. When a station is marked as "not responding elastically", it does not necessarily mean it includes a porous response. Other reasons such as tectonic motions may explain the non-elastic behavior of the station. The root issue underlying a stations non-elastic behavior is not studied in this manuscript. The purpose of this study is to provide GPS timeseries characterized by an elastic solid Earth motion. Therefore, to avoid confusion we'd rather include only the product with the GPS stations that respond elastically.

3. The authors do not explain all the abbreviations used in the article.

   Thank you for your comment. We revised the manuscript and explained the remaining abbreviations.

4. Please show some of the GRACE and GLDAS time series against the GPS time series so that readers can get a general idea of how the time series agree with each other. Not all users of the dataset need to be geodesists.

   Thank you for your comment! We added a plot with GPS, GLDAS and GRACE(-FO) up estimates) in the supplements (S2) and we now explain in detail how we derived GLDAS up displacements in the manuscript (Section 3.1 lines 430-446).

5. It is not clear how the authors converted the TWS available for JPL mascons to displacements. Equation 1 does not describe the entire procedure.

   Thank you for your comment. We revised the description of our GRACE-FO processing to be more specific. We also added the following sentence that cites the reference we used to derive *C* and *S*:

   "JPL releases gridded mascon fields, to derive spherical harmonics (C and S in Eq. 1). We transform fields of equivalent water height to normalized harmonic coefficients using the inverse of Eq. 9 in Wahr et al. (1998)."

   Wahr, J., Molenaar, M. and Bryan, F., 1998. Time variability of the Earth's gravity field: Hydrological and oceanic effects and their possible detection using GRACE. *Journal of Geophysical Research: Solid Earth*, *103*(B12), pp.30205-30229.

6. It is also unclear how the authors interpolated the gap between GRACE and GRACE-FO. This is because they present trend estimates for the period 2018-2021.5, which includes a gap of more than a year in GRACE observations.

   Thank you for the comment! You are correct about the missing data due to GRACE/GRACE-FO gap. As described in the introduction our main interest is to process GPS VLD estimates for use in GRACE/GRACE-FO combined solution. Thus, we do not interpolate for the missing GRACE(-FO) months.

   The last time-window contains GRACE-FO data starting in June 2018 that extend until June 2021 (3-years). Therefore, trends reported for the final time-window are derived using GPS VLD estimates only during the epochs that GRACE-FO data are available. We revised the manuscript accordingly.

We did not interpolate the series during the GRACE(-FO) gap, thus the last time-window reflects trends estimated using only GRACE-FO solutions (past June 2018) and GPS timeseries between June 2018 and 2021.

Equation 2 lacks time dependency y(t).

Thank you. Fixed.

7. It is not clear what “ccs” means in the CMN algorithm.

   ccs is the slope of the r_{MAD} coefficient with respect to the distance of the station to the reference site (Fig.5 shows the r_{MAD} coefficient wrt the distance). Please see the referenced work of Kreemer and Blewitt (2021) about the CMC processing steps. To avoid confusion, we added in the main text:

   ccs is the median trend of the r_{MAD} coefficients of a station against their distance with the reference station.

8. It is not clear with which noise model the authors perform the analysis for CMC and CMCHF.

   CMC and consequently CMCHF provide a robust way to quantify spatial correlation of the noise. Please refer to the Paragraph *Common Mode Noise* in Section 3, that describes the way spatially correlated noise is estimated using CMC technique.

9. Table 1: What μ means here? Why the authors do not compare the amplitudes of noise or the percentage contribution of different noises to the analyzed combinations? This might be interpretable.

   Thank you for your comment. μ signifies the mean. We added the description in Section 3.2. Mean (μ), median and standard deviation (std) values are shown in Table 1.

   We also found your recommendation on quantifying how much each noise model contributes to the combined power law noise very constructive. Instead of actual numbers we report the percentage contribution of each of the noise models in the total noise.

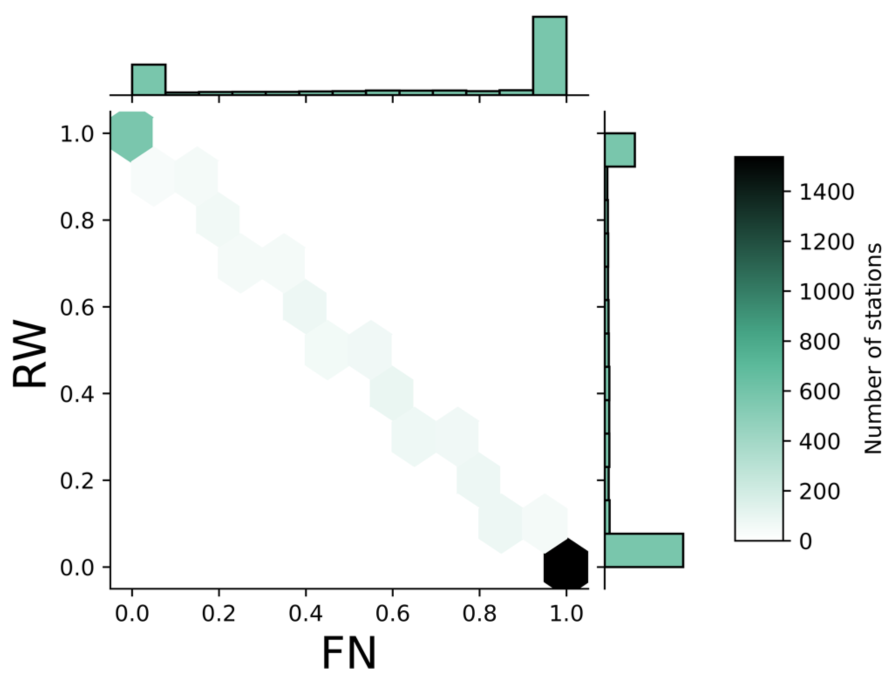
   There are two cases where noise models are combined as described in the manuscript, the case with white noise being combined with flicker noise (WN+FN) and the case with white, flicker and random walk (WN+FN+RW) noise being all combined together. In the first case, flicker noise dominates the spectrum in the vast majority of stations. In particular, white noise is almost zero for 2943 stations (describes >80% of the total noise for only 87 stations in our whole datasample).

We also analyzed the amplitude of the noise of each noise model with respect to the length of the series. No clear picture is drawn between this amplitude, (σ_{PL} as described in the manuscript and on Bos et al., 2008;2013) and the length of the series. We added the following statement to the main manuscript:

"We additionally analyzed the amplitude of the noise of each noise model (σ_{PL}) with respect to the length of the input series. Results did not identify any clear relationship between σ_{PL} and the length of each station's timeseries."

In the second case (WN+FN+RW) white noise is again almost entirely absent, and noise is driven by a combination of flicker and random walk. Therefore, we will only analyze the percentage contribution of FN and RW.

We plot a hexbi diagram to describe the relative contribution of each noise model to the total noise. The percentage contribution of each noise model is resembled by hexagonal bins, and the color of the bins represents the number of stations that exhibit this particular percentage. Histograms that reflect the number of stations having a certain percentage [0 1] are overlayed on the two axes. The relative contribution of each of the noise models is shown in the figure below. Half of the stations (~1550) exhibit exclusively flicker noise (dark green hexagon centered at 1 on FN axis), 600 stations exhibit exclusively random walk noise (hexagon centered at 1 in the RW axis), and the rest of the data sample (880) stations is partially described by both noise models.



We added a short discussion in the main manuscript and the supplement. Thanks again for the recommendation!

10. Figure 6: Is this the uncertainty of trend, or…

This is the uncertainty of the VLD timeseries and not the trend's uncertainty. To avoid confusion, we added the following description under Fig.6 label: *Uncertainty of GPS timeseries estimated using various techniques.*

The authors mentioned a case of unlogged offset. It is presented in the supplementary materials, but only for one case. I think the authors should approach the topic more descriptively and present other cases in which unlogged offsets were also corrected manually.

Thank you. The unlogged offset contaminated almost 25% of the stations located at the St. Lawrence watershed. Please see the revised version of the manuscript.

11. Lines 229-230: The authors mention describing interesting cases in Supplements, but they are missing there.

Please let us copy Line 263. "We discuss an interesting case in Supplements, where stations located in the St. Lawrence basin demonstrate a negative trend $\boldsymbol{a} = -1.26$."

We provide more analysis in the case of St Lawrence in the Supplementary material. As mentioned above, a quarter of the stations of this watershed experienced this offset.

Several sentences in the text are missing a noun or verb, the authors should carefully review the entire text.

Thank you! We have reviewed the sentences.