Dear Peter Jan van Leeuwen,

we are thankful for the constructive criticism and the suggestions made about the manuscript. In the following you find detailed answers to the points that were raised.

Reviewer's comments and author's answers:

The manuscript discusses the estimation of mantel viscocities using sea-level observation in a particle filter. The manuscript is well written, and the results are interesting even though the set-up is highly simplified. I suggest publication after the following minor comments are taken into account.

Line 78: Strange sentence, not sure what the authors want to convey.

A: The aim of the sentence was to explain the name of particle filter. It was removed.

Line 79: Note that the output of the filter is the weighted posterior ensemble, from which a weighted mean can be calculated. This mean can be a poor estimate of the posterior pdf if that pdf is strongly non-Gaussian. Please add a small discussion of these facts.

A: The description of the filter output has been changed in the manuscript. A short discussion about the posterior pdf estimate and the situation in this study was added.

Line 102: Resampling hardly changes the ensemble variance of the weighted ensemble, which is the relevant ensemble in this case. The weighting itself reduces the variance in the ensemble.

A: The sentence was changed and now states that weighting reduces the ensemble variance.

Line 105: It would be good to mention that of the three methods the second is the correct methods, and the 1st and 3rd are approximations.

A: The fact was added to the text.

Line 111: I assume the authors mean N(0,a \sigma^U,L). Note that it is common to have the (co)variance of the distribution as the second argument of N(..,..) and not the standard deviation.

A: It was changed to standard notation here and in subsequent occurrences in the text.

Line 114: Setting a=0.5 \sigma is a large value to perturb each viscosity with. However, it is perhaps good to mention that the standard deviation of the ensemble as a whole only increases by a factor 1.12 (= sqrt(1 + 0.25)) through this procedure.

A: The mentioned piece of information was added in terms of variance (increase of variance by 25%) for consistency.

Line 115: Probabilistic resampling means that one has to draw N random numbers, where

N is the ensemble size. A more accurate resampling method is Stochastic Universal Resampling, in which only one random number is drawn, and it is also faster! This could be mentioned. Since after resampling relatively large random perturbations are added to the particles the difference will be minor in this case.

A: Stochastic Universal Resampling as another possibility was mentioned in the text and a discussing sentence has been added..

Line 165: mu
A: The typo was corrected.

Line 174-175: Please remove this sentence, it is just a repetition of what was said before.

A: Agreed. The sentence was deleted.

Since the variance in the initial ensemble is chosen as large as the mean many initial particles will have negative viscosities. What is done when a negative viscosity is drawn? A similar question for later in the run, what is done if the 'jittering' after resampling produces negative viscosities?

A: In those cases mentioned, the absolute value was used in case of a resulting negative viscosity.

Related to this, the figures show different mean viscocities than the table 2. Please correct the one that is incorrect.

A: The table caption was not accurate. Shown in Table 2 are mean and standard deviations of the initial perturbations that were added on top of the target viscosities. The table caption was corrected.

It would be good to show the effective ensemble size, defined as N_eff = 1/sum_i (w_i^2) in which the w_i are the normalized weights, such that sum_i w_i = 1. This allows the readers to judge the quality of the ensemble. My suspicion is that N_eff is rather low, as low as 2-5 members at time, which is close to degeneracy.

A: A figure showing the effective ensemble size was added. The effective ensemble size is mostly quite high. In the presented case (cases A, B, and C in setup 1), it only drops right after a big melt water pulse when also the residuals of the predictions w.r.t. observations are very high. In the newly added case E in setup 1, it drops significantly when the observation uncertainties are reduced since in that case suddenly a large number of ensemble members have bad performance values (low likelihood). Nevertheless, the effective ensemble size increases in the next assimilation step.

Fig 10: caption, change left and right to top and bottom.

A: Done. Thank you!

Line 309: I don't understand this sentence, please clarify.

A: “Common approach” in viscosity determination from GIA means that an ensemble of, say, 50 members with pre-defined viscosity structures is used in a run of forward models. Paleo-sea level observations are then used to determine the best fitting model via RMS

errors of sea level predictions. This way, only the best model of the initial ensemble can be determined. With our approach we can obtain a model that was not in the initial ensemble and fits the observations best. The sentence was rephrased a bit to make it clearer.

Section 2: I'm not an expert in this field and would suggest providing the set of equations being solved to gain an idea of the complexity of the problem at hand.

A: The complete set of equations that are solved can be found in the references given in the respective parts of the manuscript. However, we have added the most basic equations in the appendix.

Section 7: It would be good to also include a discussion of the accuracy of the underlying ice model and its expected influence on the results.

A: Naturally, the forcing due to the ice load plays a key role in GIA. Therefore, uncertainties of the ice model have a large impact on the resulting viscosity values. However, uncertainties for ice models are usually not provided. We added some discussion about the possible influence of ice load errors and the resulting magnitude of viscosity uncertainty but a comprehensive analysis was not part of this study. Ice model uncertainty is also a problem in conventional viscosity determination and does not distinguish our approach from the conventional one. Therefore, we focused on the methodology of our approach and refrain from a detailed analysis of this matter.