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Interactive comment on "Present-day surface deformationof the Alpine Region inferred from geodetic techniques" *by* Laura Sánchez et al.

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We highly appreciate the careful and constructive reviews provided by Jeff Freymueller and Roberto Devoti. Their comments have greatly improved the quality of this manuscript. Please find in the following (1) comments from Referees, (2) authors' response, (3) changes in manuscript. A PDF version of these comments is also provided.

Kindest regards, L. Sánchez, Ch. Völksen, A. Sokolov, H. Arenz, F. Seitz

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Answers to J. Freymueller (Referee)

Comment: This paper documents a data set, deformation model and strain field for the Alpine region, based on a homogeneously processed GPS/GNSS data set. The organization is good and clear, and most of the paper is fine as it is. There are a number of minor English errors, which I have marked in the annotated manuscript, and I will only note the more important points here.

Answer: All suggestions included by the reviewer in the annotated manuscript were addressed in the reviewed version of the paper.

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Comment: The analysis methods are sound and are well described, except for a few details about the LSC approach that need to be added. The first missing point in the LSC description relates to the "common trend" (mentioned in the intro paragraph for section 5, but not otherwise defined). I suspect that in this case they are referring to the motion of the Eurasian plate, but this is not clear because so far the presentation of the results has already been presented relative to the Eurasian plate. If the LSC was performed on motions relative to Eurasia, then this should be stated explicitly instead of bringing in a new and different term that is undefined. If they have removed some additional trend from the velocities relative to Eurasia before the LSC, then they need to describe that at some point in section 5.

Answer: In the introductory part of section 5, we present a general description of the steps we follow for the computation of the deformation model. We did not mention "the Eurasian plate motion" as "the common trend motion" explicitly, because it is valid for the horizontal component of the deformation model only. For the vertical component, we have to consider also a "common trend motion", which is not represented by the "Eurasian plate motion". We thank the reviewer for pointing out this source of misunderstanding. To make our description clear, we add the following sentence in the introductory part of section 5 (page 12, lines 12-15):

"The common trend motion in the horizontal component is usually well-represented by the motion of the tectonic plate underlying the area of study, in this case the Eurasian plate (see section 5.1). The common trend motion in the vertical component may be assumed to be the average vertical movement of the area of study. In this work, we infer this mean vertical movement from the station velocities directly (see section 5.2 and appendix B)."

In the same section, we changed the sentences (page 12, lines 15-19):

"The pointwise residual velocities are correlated with the existing tectonic structures (Fig. 1) and then, they are interpolated to a regular grid. The interpolation of the residual velocities provides us with the deformation model (sections 5.2 and 5.3), which is the basis for the computation of the strain field (section 6). The common trend motion removed from the initial station velocities is restored to the deformation model to get a continuous velocity field (section 5.4)."

to:

"Once the trend motion is removed from the horizontal and vertical station velocities, the pointwise residual velocities are correlated with the existing tectonic structures (Fig. 1) and then, they are interpolated to a regular grid. The interpolation of the residual velocities provides us with the deformation model (sections 5.2 and 5.3), which is the basis for the computation of the strain field (section 6). The common trend motion (i.e., the Eurasian plate motion and the average vertical motion) removed from the initial station velocities is restored to the deformation model to get a continuous velocity field (section 5.4)."

In section 5.1, we clearly write that we are removing the Eurasian plate motion from the station velocities before the interpolation (page 13, line 30):

"The Eurasian plate motion is removed from the station horizontal velocities (v_phi, v_lambda)."

In the last paragraph of section 5.1 we also added the following (page 14, lines 1-2):

"After removing the Eurasian plate motion from the station horizontal velocities, the LSC interpolation is applied following the formulation described in appendix B. "

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Comment: The second missing point is that the covariance function is not described well. This could be added as a supplement, but I found the description in terms of the correlation distance d to be very brief. How do we know this distance is optimal?

Answer: To address this suggestion, we added the Appendix B (pages 24 and 25) with all the equations we used for the LSC approach. We also provide there some details about the selection of the correlation distance d. Please see Appendix B at the end of the attached PDF file.

The following sentences are now included in the first paragraph of section 5.1 (page 13, lines 13-21):

"According to the station distribution in our network (Fig. 2), the initial maximum distance was set to 100 km for selecting the points of a collocation domain. If not enough points were found, the distance was enlarged until the necessary number of at least four points was available. The grid size for the interpolation was set to 25 km x 25 km. This grid size is chosen as appropriate since it corresponds to the mean station spacing in the most densely covered region within the network (i.e., the French and Swiss Alps). A larger grid size would average out the results and this filtering should be avoided. Appendix B provides a detailed description of the LSC formulation applied in this study."

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Comment: My only other concern relates to the continuous model and how accurate it may be across the Po plain where there are no data. There is actually quite a strong difference in the horizontal deformation between the western Alps and the vicinity of Bologna, and in the absence of data the model puts essentially a linear gradient across the data gap. Obviously the authors can't do better than this without having a good geophysical model to more accurately fill in this gap, but I think they should add explicit caveats to the model strain rates across this area. The uncertainties they present do actually assume that the covariance function accurately describes the spatial correlation of the data equally across the whole region, and that might not be true. Therefore, the uncertainties across data gaps in areas of stronger deformation might be higher than reported if the geophysical signal here does not actually look like the covariance function.

Answer: This recommendation is addressed including the following sentence at the end of section 5.2 (page 15, line 24; page 16, lines 1-3):

"In the southern front of the Alps, the orientation of the deformation vectors presents a slightly progressive westward rotation from the area of Venice toward the Po Basin. These findings are quantitatively equivalent to the results presented by Möller et al. (2011) and Devoti et al. (2011, 2017). However, it should be kept in mind that due to the low number of GNSS stations we processed in the Po Basin, our results are highly influenced by the linear gradient imposed by the LSC approach to the deformation model. To increase the reliability of our model in this particular zone, a major number of GNSS stations covering the Italian Alpine forelands should be considered."

Please also note the supplement to this comment:
https://www.earth-syst-sci-data-discuss.net/essd-2018-19/essd-2018-19-AC1-supplement.pdf

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Discussion paper