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.

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

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:

(1) All suggestions included by the reviewer in the annotated manuscript were addressed in the reviewed version of the paper.

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.

(2) 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 ($v\varphi$, $v\lambda$).

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.

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?

(3) 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 these answers.

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.

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.

(4) 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.

Answers to R. Devoti (Referee)

The authors present a kinematic representation of the Alpine region obtained from a large, but not complete, network of GNSS stations. They process and analyze GPS and GLONASS data and estimate the constant (secular drift) velocity field of more than 300 points across the Alps. The data processing sounds fine and aligned to the highest geodetic standards. The results are well exposed and displayed. The time series cover the time span from 2004 to 2016, would expect that they were up to date. I understand that such analysis are time-consuming but it's a pity that new geodetic solutions turn up to be already "aged". Another point that I would rise is the completeness of the GNSS network, there are plenty of public stations on the Italian side of the Alps that are missing in this study: the SPIN, Piemonte-Lombardia network (28stations, www.spingnss.it); the Veneto network (30stations, retegnssveneto.cisas.unipd.it); the TPOS, Trento network (11stations, www.tpos.provincia.tn.it); the STPOS, Bolzano network (9 stations, www.stpos.it) and the RING, INGV (ring.gm.ingv.it) network. As a matter of fact, there are many dozens of more stations available in the Alpine region, this will certainly downgrade the value of the results.

(1) One of the main motivation of this work was to evaluate the quality and stability of the GNSS stations available in the Alpine region, especially those stations installed in 2005 in the frame of the EU project INTERREG IIIB "ALPS-GPSQUAKENET". When we started this evaluation in May 2015, we realized that no metadata existed for many stations. In other words, we were not able to identify if, for instance, a discontinuity in the station position time series was caused by an antenna change, or a renovation of the station monument, or a landslide, or an earthquake, etc. In contrast, the Italian GNSS arrays mentioned by the reviewer are ideally implemented and maintained: the station characteristics are adequately described in site log files, the observational data is available in appropriate formats and with correct headers, and the stations operate continuously and with high reliability. From this perspective, we decided to concentrate our initial efforts to evaluate if the other stations could offer comparable performance to be combined or included in a larger GNSS network (as suggested by the reviewer). "Recovering" the metadata of some stations (especially antenna changes) was a very time consuming task, because we had to analyse the time series station by station and to compute multi-year solutions iteratively until we were sure about the stations providing reliable results. When we were ready with this task and we had a good inventory of the GNSS stations, we considered to integrate stations of the before mentioned (Italian) networks. But then the IGS (International GNSS Service) announced the introduction of the ITRF2014 (IGS14) as reference frame for the generation of its products (GNSS satellite orbits, Earth orientation parameters and corrections to the phase centre variations of receiving and transmitting GNSS antennae). The switch from an ITRF realization to a new one causes "artificial discontinuities" in the position time series, which mislead the estimation of the station velocities. Changing from ITRF2008 (IGS08) to ITRF2014 (IGS14), the artificial discontinuities reach more than 10 mm in some cases. To face this inconvenience, we discussed two possibilities: (a) To compute the larger GNSS network (including the Italian and other additional well-documented stations) using the "old" ITRF2008 (IGS08). In this case, we could process the GNSS data only from 2004 to January 2017 (when the ITRF2014/IGS14 was adopted) and our results would refer to the "old" reference frame. (b) The other possibility is to wait until the IGS generates historical products referring to the new ITRF2014 (IGS14) and then to reprocess all available stations since 2004. In this case, we can extend the time series beyond January 2017 and our results would refer to the "new" reference frame. Processing the GNSS data using

ITRF2008 or ITRF2014 demands a very large amount of work and time and we do not want to do this work twice; therefore, we decided to follow the second possibility and to process the larger GNSS network (including the Italian stations) using the ITRF2014. At this moment, we are waiting for the ITRF2014-based IGS products to start the data processing. As the results, which we obtained during 2016 and 2017, are highly precise and consistent, different colleagues motivated us to make them available (e.g. the EPN (EUREF Permanent Network) Dense Velocity Working Group chaired by Elmar Brockmann) and, consequently, we published the complete data set of our results in PANGAEA and submitted this manuscript to ESSDD.

We agree with the reviewer about the age of the geodetic GNSS solutions. However, they are consistent (Reference Frame IGb08) and we are confident that once the ITRF2014-based IGS products are available for the previous years (2004 to 2016), we could reprocess the available GNSS data in the Alpine region and maintain our solution up-to-date, at least up to a new version of the ITRF is released. Of course, we will include the Italian stations in the new processing.

The manuscript is fluently written and the findings and scientific issues are clearly stated. I strongly suggest to add all available data to their analysis, at least for future releases.

(2) We highly appreciate this suggestion and we will follow it. To address this suggestion in the paper, we included the following sentence in section 5.2 (page 16, lines 2-3):

To increase the reliability of our model in this particular zone* [Po Basin], *a major number of GNSS stations covering the Italian Alpine forelands should be considered.

Abstract: adequate, all findings are well detailed, a little lengthy.

Introduction: relevant, good references and complete.

Geologic and tectonic framework: excellent scheme focused on the Alpine and surrounding regions.

Distribution of the CO-GNSS stations: The authors collect a huge number of GNSS stations in the region but I do not find any RING station of the INGV permanent network in Italy (http://ring.gm.ingv.it). Their GPS data are publicly available since 2015, the network covers the Italian peninsula and extends in the Po plain and alpine region, where about 20 stations are located in the region of interest. Nor other existing public GNSS data are considered (see complete list above). I'm wondering why those data are neglected in the current work, they should be included in such a review analysis.

(3) Please see answer (1)

Analysis of GNSS data and determination...: Figure 4 (caption): BOLG time series, it is stated that the blue vertical lines represent seismic events, please indicate location and magnitude of those events. Which events did occur in 2005 and 2009 near Bologna? Are these really seismic events occurring nearby?

(4) We thank the reviewer for addressing this issue. We have looked into the details of the position time series of BOLG again and tried to describe the true problem in a more precise way. The monumentation of the site BOLG caused the discontinuities in 2005 and 2009 due to freezing of water in winter. The monumentation consists of an outer tube that incorporates an inner tube carrying the antenna. During precipitation events, rain fills the outer tube. The freezing water inside the outer tube raises the inner tube and leads to sudden changes in height. It was therefore not seismic event but the poor construction of

the monumentation. Sara Bruni addresses the problem in her paper (Bruni et al., 2014, see the updated references for this added paper). To clarify this statement, we modified the figure capture as follows (see Figure 4, page 9):

Figure 4: Position time-series of the station BOLG located in Bologna, Italy. Discontinuities in 2005 and 2009 (indicated by blue vertical lines) are caused by the poor monument construction of the site. Freezing water in the outer tube incorporating an inner tube carrying the antenna raised the inner tube like a piston. In 2009 the inner tube was put to its original place (Bruni et al., 2014). The blue line in 2012 represents the discontinuity caused by seismic events occurred on May 20 (Mw 6.0) and May 29 (Mw 5.8), 2012 in northern Italy (11.230°E, 44.890°N and 11.086°E, 44.851°N, respectively). Piecewise sinusoidal lines in light green represent a functional model approximating the seasonal motions detected at the station.

4.3 Velocity solution: (line 9 page 10) to me the stated shortening (0.5-1 mm/a) is underestimated, probably 1-2 mm/a is more appropriate looking at the velocity map, could the author strengthening their estimates with plots showing velocity projections along the given directions? After reading line 20 on page 14, I'm persuaded that the numbers should be somehow supported by supplementary velocity profiles.

(5) Page 10, line 9: We erroneously wrote "0.5 – 1 mm/a"; the correct text is "0.5 – 2 mm/a" (see page 10, line 12). The reviewed version of the paper includes this correction.

Following the recommendation of the reviewer, we include a new figure with two profiles: one with a cross-section along longitude 6.5°E and the second one along longitude 13°E. This figure and the corresponding description is added at the end of section 5.2. In this way, we can show both vertical and horizontal (N) deformations. Added text reads (pages 18 and 19):

Figure 13 shows two velocity profiles crossing the Alps along longitudes 6.5°E and 13°E, respectively. In both cases, the vertical component (Vu) of the surface deformation presents a high correlation with the local topography. The profile in the Western Alps clearly shows the light subsidence (-0.6 mm/a) close the Liguro-Provençal Basin (near latitude 43°N). The large uplift rates (more than 1.5 mm/a) in the border area between France and Switzerland (around latitude 45.5°N), and a decreasing uplift rate towards the North up to the Rhine Basin (latitude 48°N), where subsidence is observed. In the Eastern Alps, the gradient of the vertical velocity is stronger in the southern part than in northern area. South of latitude 46°N, the subsidence (up to -1 mm/a) detected in the Venetian-Friuli Basin can be well observed. North of latitude 46°N, we find uplift rates up to 1.2 mm/a in the border area between Italy and Austria (latitude 45°N). These rates diminish up to 0.3 mm/a in the border area between Austria and Germany (latitude 48°N). The North component (Vn) of the deformation model along longitude 6.5° suggest a very small (no significant) surface deformation in the Western Alps, while along longitude 13°E, it captures the plate boundary region where the Adria plate collides with the European plate. The quite strong velocity gradient of nearly 2 mm/a over about 80 km (between latitudes 46°N and 47°N) makes evident the NS compression occurring in the southern front of the Southern Alps.

The new figure is:

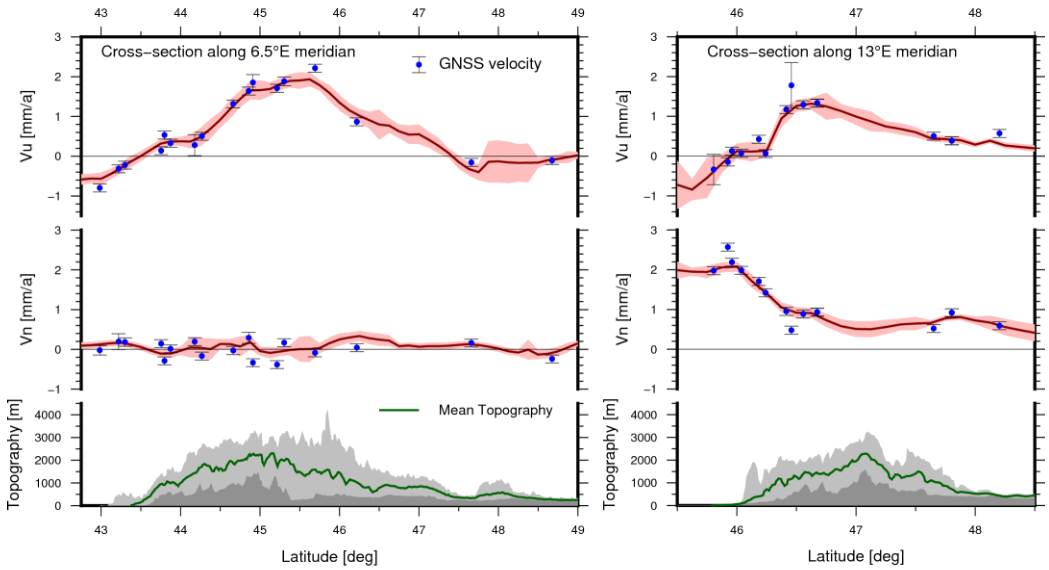

Figure 13: Velocity profiles in the Western Alps (cross-section along longitude 6.5 E, left) and in the Eastern Alps (cross-section along longitude 13°E, right). Blue dots with error bars represent the observed station velocities (with 68% confidence). Red lines represent the North (Vn) and the vertical (Vu) components of the deformation model with their uncertainty (light red stripe). Green line shows the average topography in the profile swath, with light and dark grey shadows showing the maximum and minimum elevations, respectively.

(line 11 page 11): it is stated that the orogenic gravitational movement is slower than GIA, but in the following lines the authors concluded that the GIA effects are negligible. So what is then uplifting the Alps? I would suggest to re-state the sentence (line 11) in order to not contradict the final conclusion.

(6) We thank the reviewer for pointing out this source of confusion. To avoid misunderstanding, we deleted the sentence *"According to this, and recognizing that the GIA effects are smaller than the estimated accuracy of the vertical velocities, we assume GIA effects so far negligible."* (See page 11, line 20).

5.1 Least-squares collocation (LSC) approach: (line27, page 13) I would suggest to compare the eurasian euler pole with the original ITRF2008 pole, given in: Altamimi, Z., L. Métivier, and X. Collilieux (2012), ITRF2008 plate motion model, J. Geophys. Res., 117, B07402, doi:10.1029/2011JB008930.

(7) As suggested by the reviewer, we included the comparison with the Euler pole published by Altamimi et al. 2012. However, we should mention that Altamimi et al. performed this computation in a 3D coordinate system; i.e., they use geocentric Cartesian coordinates XYZ for the estimation of the plate Euler poles. It is well known that the vertical coordinate estimates with GNSS are 2 - 3 times worse than the horizontal one. Consequently, the uncertainties of the vertical coordinate are totally propagated into the Euler pole estimation. To avoid this, we perform the Euler pole estimation with horizontal coordinates (latitude and longitude) only (motion on the sphere). This formulation is more appropriate in this study, because the LSC interpolation is computed separately for the horizontal and vertical components (see new Appendix B in the manuscript). The difference between both approaches is well mirrored in the precision estimates of both computations. The suggestion of the reviewer is addressed with the following sentences (page 13, lines 32-39):

The Eurasian plate motion is removed from the horizontal velocities (v_φ, v_λ) of the stations. The corresponding rotation vector Ω (260.74° ± 0.53°E, 55.14° ± 0.27°N, 0.2598 ± 0.0011 °/Ma) is inferred from our CO-GNSS stations located on the stable part of the plate following

the approach presented by Drewes (1982; 2009). Our values are very similar to the rotation vector derived from the ITRF2008 Ω (261.15° ± 0.85°E, 55.23° ± 0.35°N, 0.2570 ± 0.0025 °/Ma), see Altamimi et al. (2012). The small differences are a consequence of the different station distribution (stations used for the estimation of Ω in this study and in the ITRF2008 are not the same) and the different time-span considered for the station velocity estimation (our study includes observations up to May 2016, while the ITRF2008 includes observations up to May 2009, Altamimi et al. 2011).

5.2 Horizontal deformation model: The authors should compare their results also vs. Devoti et al., 2017 that publish a recent velocity solution for the entire Mediterranean region, the reference is: Devoti et al. (2017), A Combined Velocity Field of the Mediterranean Region. Annals of Geophysics, 60 (2), doi:10.4401/ag-7059.

(8) We realized the existence of this paper (Devoti et al. 2017) after our paper submission to ESSDD. However, we have already compared both results and we were waiting for the revision of our paper to include the comparison. The corresponding changes/additions are:

Section 4.3 (Velocity solution; page 10, lines 12-15):

Based on our few CO-GNSS sites in the Apennines, we see apparently an extension of 2 - 4 mm/a across these mountains and a 0.5 - 2 mm/a shortening across the southern front of the Eastern Alps. These findings are in agreement with the conclusions presented by Devoti et al. (2017) in a recent study. They infer a crustal extension rate of about 3 mm/a across the Apennine Belt and a compression of about 2 mm/a towards the Adriatic foreland (see Devoti et al. 2017, Fig. 9, profiles A-B and C-D).

Section 5.2 (Horizontal deformation model; page 15, line 13):

These vectors also make evident a shortening of about 2 mm/a across the southern front of the Eastern Alps, in the northern area of the Venetian-Friuli Basin. This is in agreement with the results published by Devoti et al. (2017), Métois et al. (2015) and Cheloni et al. (2014).

Section 5.3 (Vertical deformation model; page 17, lines 4-7):

We do not detect a significant subsidence in the western part of the Po Basin; this may be a consequence of the poor distribution of our CO-GNSS stations in that region. Actually, Devoti et al. (2017) inferred a mean subsidence rate of about -0.8 mm/a in the Po Basin. The maximum (-3 mm/a) and minimum (-0.5 mm/a) magnitudes occur near Venice and in the eastern margin of the West Alps, respectively (see Devoti et al., 2017, Fig. 6).

(line 3 page 14): please label the Periadriatic line in the map (at least in figure 1).

(9) Done (see Figure 1 and its caption, page 5)

(line 17and19, page 14) the 6-16 longitude span seems too wide (entire region), probably the authors would like to indicate a narrower zone, please check the longitude limits.

(10) We rewrite these sentences in a clearer form (see 15, lines 6-11):

Unlike the Western Alps, where the deformation vectors indicate a very small (insignificant) internal surface deformation, the Central Alps present an increasing north-oriented deformation from 0.2 mm/a at the longitude 6°E to 0.6 mm/a close longitude 11°E. This

deformation pattern continues over the Southern Alps up to longitude 13°W, where the deformation vectors describe a progressive eastward rotation toward the Pannonian segment, reaching magnitudes up to 1.3 mm/a and an orientation of about N20°E near longitude 16°E. These vectors also make evident a shortening of about 2 mm/a across the southern front of the Eastern Alps, in the northern area of the Venetian-Friuli Basin.

Figure 12: I appreciate a lot the uncertainty map in this figure, it well supplement the associated estimates.

Typos line 8, page 8: plus/minus character is lacking on the horizontal and vertical thresholds.

(11) Corrected.

Additional changes in the manuscript:

Thanks to the comments sent by Michele Carafa, we add the following sentence in section 6 (page 21, lines 20-22):

This compression presents maximum strain-rate values of about 20 x 10-9 a^{-1} in the Venetian-Friuli and Po Basins. These findings are in agreement with previous works published by Serpelloni et al. (2005, 2006), Caporali et al. (2009), Bennett et al. (2012) and Cheloni et al. (2014); <u>especially, the continuous compression regime we inferred along the Adriatic coastline fits very well with the strain model presented by Carafa and Bird (2016).</u>

Added references:

Altamimi, Z., Métivier L., and Collilieux X.: ITRF2008 plate motion model, J. Geophys. Res., 117, B07402, doi:10.1029/2011JB008930, 2012.

Bruni, S., Zerbini, S., Raicich, F., Errico, M., and Santi, E. Detecting discontinuities in GNSS coordinate time series with STARS: case study, the Bologna and Medicina GPS sites. Journal of Geodesy, 88(12),doi: 10.1007/s00190-014-0754-4 , 2014.

Carafa M.M.C., and Bird P.: Improving deformation models by discounting transient signals in geodetic data: 2. Geodetic data, stress directions, and long-term strain rates in Italy, J. Geophys. Res. Solid Earth, 121, 5557–5575, doi:10.1002/2016JB013038, 2016.

Devoti R., D'Agostino N., Serpelloni E., Pietrantonio G., Riguzzi F., Avallone A., Cavaliere A., Cheloni D., Cecere G., D'Ambrosio C., Falco L., Selvaggi G., Métois M., Esposito A., Sepe V., Galvani A., Anzidei M.: A combined velocity field of the Mediterranean Region, Annals of Geophysics, 60(2): S0215, doi:10.4401/ag-7059, 2017.

Appendix B: Least-square collocation equations

The basic least-square collocation formula is given by (e.g. Moritz, 1973; Drewes, 1978):

$$\mathbf{v}_{pred} = \mathbf{C}_{new}^{T}\left(\mathbf{C}_{obs} + \mathbf{C}_{nn}\right)^{-1}\mathbf{v}_{obs} \qquad \text{(B1)}$$

$\mathbf{v}_{obs}$ contains the velocities observed at the geodetic stations (Fig. 7 and Fig. 8). $\mathbf{v}_{pred}$ contains the velocities to be predicted at the continuous grid of 25 km x 25 km (Fig. 9 and Fig. 11). $\mathbf{C}_{obs}$ is the correlation matrix between observed velocities. $\mathbf{C}_{new}$ is the correlation matrix between predicted and observed velocities. $\mathbf{C}_{nn}$ is the noise covariance matrix; i.e., it contains the uncertainty of the station velocities obtained within the multi-year solution (error ellipses and error bars in Fig. 7 and Fig. 8).

The empiric correlation between the observed velocities may be written as

$$C_{obs}(d_{ik}) = E\{v_i \cdot v_k\}, \tag{B2}$$

E is the expectation; i,k represent the geodetic stations and $(d_{i,k})$ is the distance between the stations i and k. The C_{obs} values are classified in Δ_j class intervals with j = 1 … 10. The cross-covariance $C_{obs}(\Delta_j)$ and auto-covariance $C_{obs}(d{=}0) = C_0$ are determined for each interval Δ_j:

$$C_{obs}(\Delta_j) = \frac{1}{n_j}\sum_{i<k}^{j} v_i \cdot v_k \quad ; \quad C_{obs}(d=0) = C_0 = \frac{1}{n}\sum_{i=1}^{n} v_i^2 \ , \tag{B3}$$

n stands for the number of stations available at the domain defined by d, while n_j represents the number of stations available at each class interval Δ_j. After estimating the discrete empirical covariances with Eq. (B3) they are approximated by a continuous function $C(d_{ik})$; in this case, the exponential function:

$$C(d_{ik}) = a\, e^{-b \cdot d_{ik}} \tag{B4}$$

The function parameters a and b are estimated by a least-squares adjustment. $\mathbf{C}_{obs}$ is symmetrical and its main diagonal $(i{=}k)$ contains the values C_0. The elements of $\mathbf{C}_{new}$ are computed using the same Eq. (B4) as a function of the distance between the grid node to be interpolated and the geodetic stations. The precision σ^2_{new} of the predicted values is assessed with (Moritz 1973):

$$\sigma^2_{new} = C_0 - \mathbf{C}^T_{new}(\mathbf{C}_{obs} + \mathbf{C}_{nn})^{-1}\mathbf{C}_{new} \tag{B5}$$

To fulfil the statistical condition of stationarity, the correlation function Eq. (B4) has to be identical for all points located in the d-region; i.e., the exponential function must be homogeneous over the entire domain of known and predicted points. A consequence of the isotropy and stationarity conditions is that any trend (e.g. plate tectonics) in the given set of point parameters has to be removed before starting the collocation procedure. As horizontal and vertical station motions are dominated by different mechanisms (see section 4.3), it is necessary to apply the LSC procedure separately. For the horizontal model, the northeast movement of the Eurasian plate defines the trend motion to be removed from the station velocities. For the vertical model, the trend motion is given by the mean value of the vertical station velocities available at each d-region.

As mentioned in section 5, the deformation model is computed at a regular grid of 25 km spacing interval. This grid size is chosen as appropriate since it corresponds to the mean station spacing (about 20 to 30 km) in the most densely covered region within the network (the French and Swiss Alps, see Fig. 2). For the horizontal component of the deformation model, the minimum correlation distance d is defined to be 100 km. This radius provides an overlap between adjacent grid points and allows a certain degree of smoothing. For areas with poor station coverage, the correlation distance is extended until at least four stations are included in the LSC. For the vertical component, a larger correlation distance (up to 300 km) is needed as the number of rejected outliers is higher for the vertical station velocities than for the horizontal ones.