<u>RESPONSE FOR ANONYMOUS REFEREE #1:</u>

COMMENT #1 (PAGE 2):

"…Because of a very low temporal resolution, survey GPS observations cannot catch that. Even if by chance the measurements are made during a transient event, longer measurements ahead would be necessary, in order to have a precise estimation of the trend before any burst, just to be able to detect it. In order to monitor transient aseismic processes, it is necessary to integrate and combine permanent continuous observations…"

Response:

Tectonic movements, like aseismic creep, can be monitored even using long-term campaign observations. Slip deficit is the key factor to determine if creep exists or not. In that case, it's not an essential issue to establish permanent stations. Results would lead us for this kind of permanent continuous observations if necessary. Also, earlier studies which uses space geodesy didn't require or mention permanent GPS stations for this phenomena, and final outcomes of these studies given at Table 1&2 and Figure 6.

COMMENT #2 (PAGE 2):

"…They are correct writing that it is "always related to the geological characteristics and fault geometry", however, I have major concerns about the ability of deciphering between models of slip with measurements so sparse and actually so far away from the fault trace that this network geometry provides."

Response:

Figure 9 includes *Yavasoglu et al. 2015* graphics that shows the optimum perpendicular distances from a creeping fault, 3 and 10 km on both sides. Project mainly maintained on this basis to configure profiles and yearly observations. We try to understand block movements around the region, and results of the TDEFNODE modeling indicates that the distribution of the stations were sufficient to represent blocks along the creeping parts of the NAF.

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COMMENT #3 (PAGE 2):

"The authors show on fig. 9 the creep rate profiles. There's a first issue, the axis is labelled "slip rate" with "mm" units: : : is it mm/yr or is it "slip" that is showed?..."

Response:

Figure fixed as "mm/year" for the axis.

COMMENT #4 (PAGE 2):

"…(The location of stations at 3 km and 10km on this graph could be highlighted in order to emphasize their point)…"

Response:

Figure 9 revised as follows:

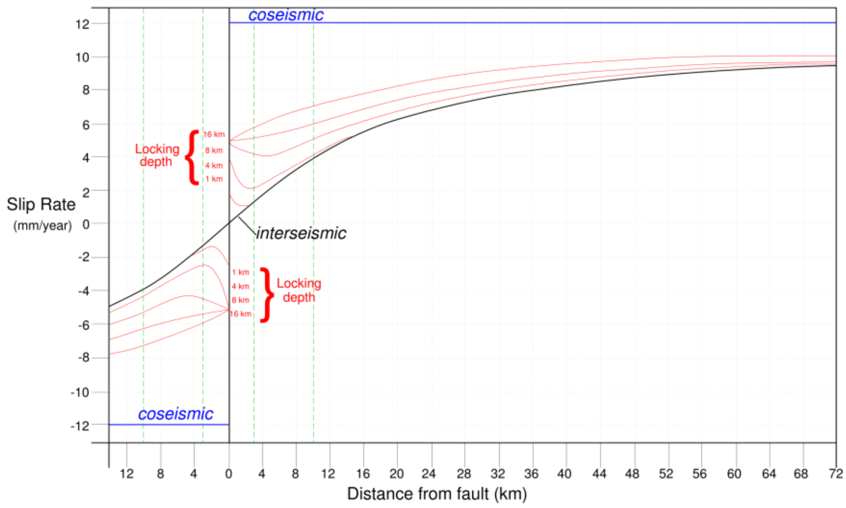


Figure 9. Slip rate along a fault plane during interseismic and coseismic events. Blue lines represents the coseismic, and black line represents the interseismic behaviour, where red lines demonstrates the aseismic creep ratios at two sides of the fault for different locking depths. Vertical green lines indicates 3 and 10 km on the both sides of the fault where the interseismic behaviour disintegrates from aseismic creep (after Yavasoglu et al. 2015).

COMMENT #5 (PAGE 3):

"…- The interseismic deformation is non-unique, it also depends on the locking depth and can show a strong gradient a short distance from the fault.This has to be accounted for in this graph and discussed in the text…"

Response:

By this project, we established GPS networks around the both regions, Ismetpasa and Destek. This gives us the opportunity to monitor a large area. For this reason, several campaign stations established around the NAF to represent the block movements, which based on the theoretical studies.

COMMENT #6 (PAGE 3):

"…Fig.6 shows the offset at the fault, which cannot reproduced by such a simple interpolation. More data at very small scale around the fault appear necessary, for example InSAR or directly surface measurements (offset sidewalk or walls as mentioned in the text l.64)…"

Response:

This project based on GPS observations. InSAR or direct measurements on the field and involving these data with our results is another research issue for the future. Interpolation along the profiles from the GAMIT/GLOBK results gives us a quick overview for the creep behavior, they are not used for final outcomes.

Also, we didn't get any result about the creep rate at the 3rd profile, because it was impossible to estimate the movement using interpolation due to local deformation at the south of the profile, and station velocities removed from the input data used to model the fault and blocks with TDEFNODE. This procedure explained in the text.

COMMENT #7 (PAGE 3):

"…- Fig 11c : there are no data on the first 12 km, meaning on side of the fault according to the model, on what is based this model ?

- Fig 11d : it is in fact possible to draw a single straight line crossing all the points, same question, on what is based the model ?

- Fig 13 : same question, the model is not at all crossing the points on the south side of the fault…"

Response:

Our model based on Figure 9 elementarily but there are some limitations when applied on the field. Also, those fault perpendicular distances are not the exact locations to seize creep; they should be around those locations.

Another issue is that the site selection is heavily relevant with the ground truth. It was not always possible to find out a suitable location for campaign points at the given distances/locations, or they cannot maintain a straight profile on practical applications (inconvenient soil structure, impractical locations for GPS observations due to surrounding obstacles, etc.). For these reasons, we select the closest locations for the stations based on our model.

COMMENT #8 (PAGE 4):

"…Furthermore, the paper does need a lot of work with regards to English language usage to make it readable and understandable by the international scientific community, with recurrent grammar and conjugation mistakes (see details below)."

All of these make the paper very hard to understand. Being a non-native English speaker myself, I do realize how difficult this exercise is, but it should not be the reviewer's burden and I strongly suggest that the authors have a native English speaker help with the manuscript writing before re-submitting…"

Response:

Based on this comment, a total check including proofreading has done.

COMMENT #9 (PAGE 5):

"…Figure 1: it is useful to have a first context figure but it does not seem useful to show it at such a large scale, it could be centered on the NAF between 23 and 40◦E, 35 and 42◦N. I guess everything that is not mentioned in the text, therefore that does not have an influence on the creeping segments, should not need to be on the figure. On the contrary, it misses quite a lot of important information for the understandings of the paper: the very first one being where are the locations of Ismetpasa and Destek ?

Please, more generally, show on the map ALL the location of cities mentioned in the text (Baymoren & Gerede for ex.)?..."

Response:

Following figure prepared for the manuscript. Both segments have their labels according to the nearest villages, thus İsmetpaşa and Destek settlements shown on the figure.

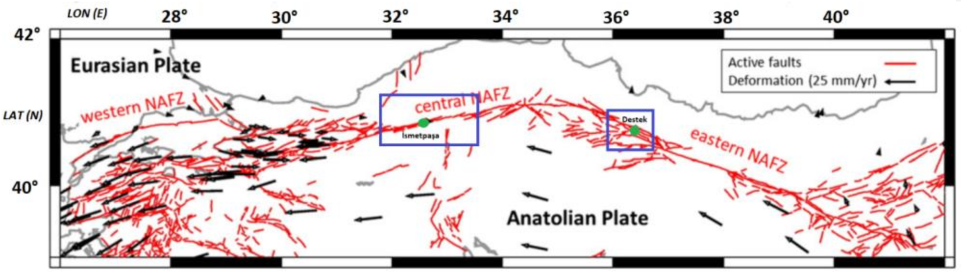


Figure 8. Active fault segments on the North Anatolian Fault (NAF). Blue rectangles defines İsmetpaşa and Destek segments from west to east, respectively (after Bohnhoff et al. 2016).

COMMENT #10 (PAGE 5):

"…The authors also mentioned the historical seismicity along the 2 segments (l.61-68), where did these earthquakes occur exactly respective to the 2 creeping segments? The GPS network at this scale would also be interesting to actually have a sense of its footprint…"

Response:

Following figure added in the manuscript.

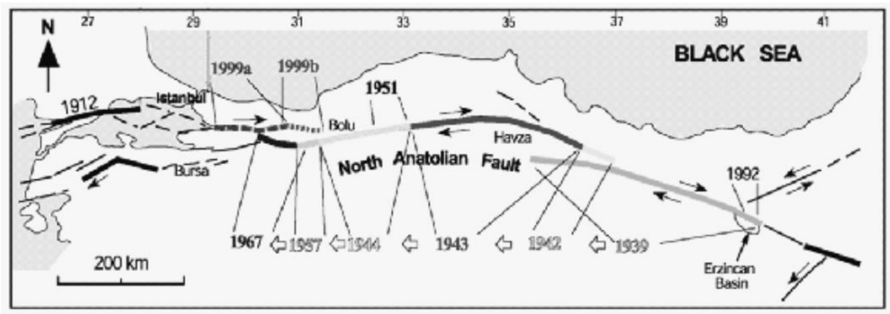


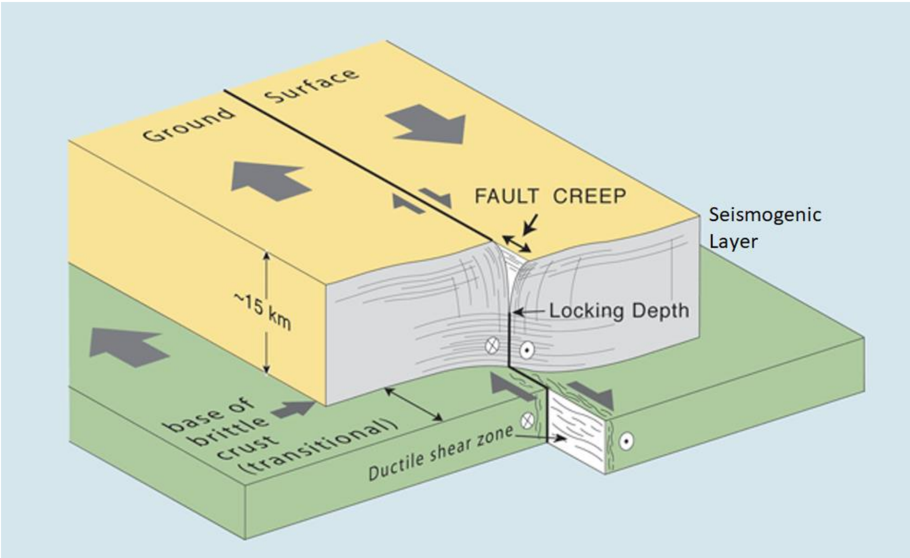
Figure 4. Earthquakes on the North Anatolian Fault between 1939-1999. Both 1943 and 1944 earthquakes suspected to have influence on the creeping phenomena (from Kutoglu et al. 2010).

COMMENT #11 (PAGE 5):

"…Figure 2: the label of seismogenic zone is missing…"

Response:

Figure edited and label added.



COMMENT #12 (PAGE 5):

"…Figure 3: I don't really see the point of this figure, the scale is too small to be able to locate the region on the NAF, and it is too large to see any hints of aseismic creep? Is there any pictures showing the creep ? If so, they could be added as a composite figure showing this pictures and their location ? As it is, this figure is useless…"

Response:

Close up photos for the creeping segments from *Karabacak et al. 2011* added after Figure 3.

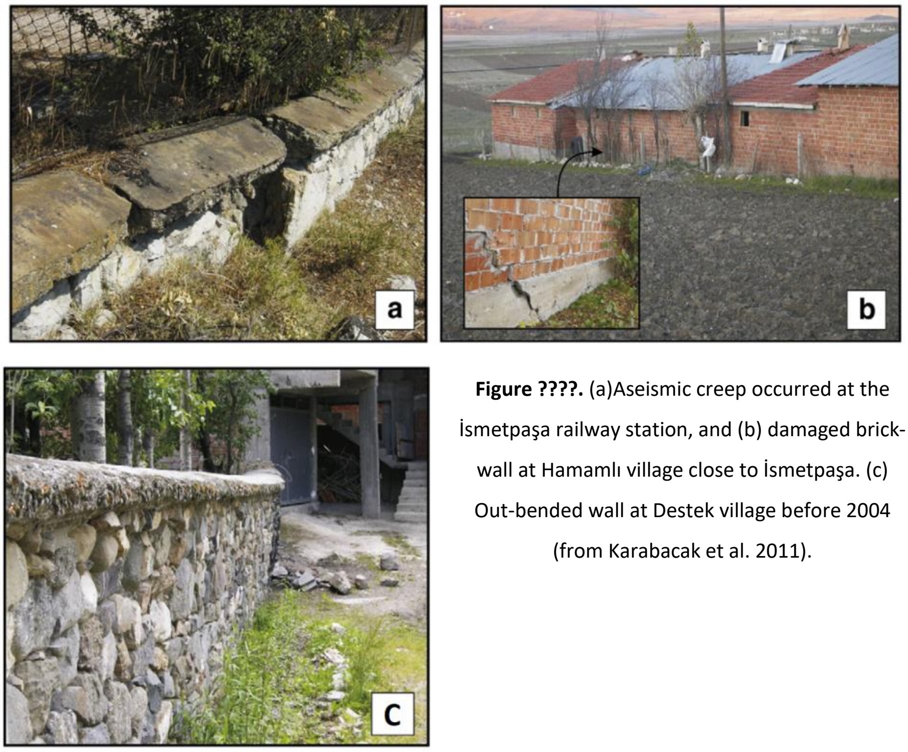


Figure ????. (a)Aseismic creep occurred at the İsmetpaşa railway station, and (b) damaged brick-wall at Hamamlı village close to İsmetpaşa. (c) Out-bended wall at Destek village before 2004 (from Karabacak et al. 2011).

COMMENT #13 (PAGE 6):

"…Figure 4: On sub-figure (b), there are 3 fault trace, the GPS profile only encompasses 2 of them… where is supposed to occur the creep ? Why ignoring the 3rd fault? Discuss that…"

Response:

Profile established according to the observed creep at Destek Village, other fault traces on the south are secondary faults and no creep has not reported around those locations.

COMMENT #14 (PAGE 6):

"…Figure 5: the dataset is quite dense which make this figure difficult to read. Typically, it is hardly possible to read the station codes - which are in fact not needed. There again, rescale the map : there are no data from 26 to 28◦E and from 38.1 to 40◦E. The uncertainty is missing from the arrow legend. The fault trace, even simplified, should appear. Caption: "relative to fixed Eurasia" instead of "when Eurasian plate selected as fixed". Later on: "the westward motion of the Anatolian plate" instead of "the Anatolian plate's motion to the west…"

Response:

Figure 5 represents the all continuous stations(CORS-TR) and contributes a view for the size of project area. Both segments and station velocities detailed at figures 10 and 12.

The uncertainty can be scaled using the current arrow legend.

Figure explanation corrected and fault trace for North Anatolian Fault added as follows:

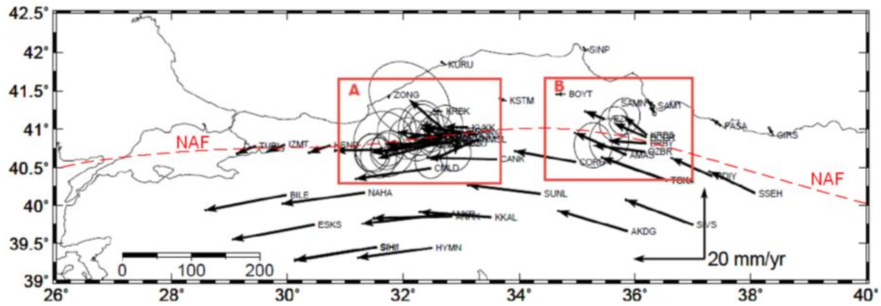


Figure 5. *GLOBK results for station velocities relative to fixed Eurasian. (A) includes the Ismetpasa segment, and Destek segment is inside (B). Dashed lines represents the fault trace of North Anatolian Fault (NAF). Velocities at the north of the NAF are very small as expected, where south velocities indicates the westward motion of the Anatolian plate (after Aladoğan 2017).*

COMMENT #15 (PAGE 6):

"…Figure 6: this figure is very complicated and I am not sure it is really useful. The geological structure is hardly mentioned in the text, and the creep values estimated in previous studies are already recapitulated in table 1. Table 7 and table 1 could be gathered, ordering table 1 as function of profiles and then adding the creep values from this study to compare them ?..."

Response:

This figure is a brief summary of our study after GAMIT/GLOBK evaluation. Approximate profile locations, station velocities, creep interpolation and geological structure of the segments represented in detail. In addition, observations in the history with respect to their method also mentioned in the figure.

Geological structure is responsible for aseismic creep and it's a fact, and this study focused on GPS observations and try to estimate fault parameters caused by this structure in any case.

Figure 6 is an intermediate step to predict creep ratios, but final results gathered from TDEFNODE. Also, it was impossible to predict creep at 3rd profile and this figure shows where we had drawback through the process.

COMMENT #16 (PAGE 6):

"…Figure 7: this is one is directly taken from a PhD unmodified, maybe it can go in supplement?..."

Response:

This figure represent the locking on a fault and outcome of slip deficit between two tectonic blocks. It may remain in the text.

COMMENT #17 (PAGE 6):

"…Figure 10 - 12: why all the white on these 2 figures instead of zooming in on the data ? Add red arrow and the legend "model" / "observed" along with the scale. What are all the squares lying on the fault ?..."

Response:

Dashed lines in Figures 10 and 12 represents the block model boundaries within TDEFNODE. A large scale was necessary to demonstrate the width and length of the creeping segments.

In the explanation of the figures, we explain what those red and black arrows implies. Square on the fault represents the fault and make it easy to observed fault trace and profiles' situations . An explanation added in the explanation under the figures as follows:

"Figure 10. *Model area for Ismetpasa segment with Eurasian plate (AVRA) on the north and Anatolian plate (ANAD) on the south (dashed lines), divided by the creeping segment of the NAF. Black and red arrows represent the observed and modeled velocities respectively, obtained from GAMIT/GLOBK and TDEFNODE. Five profiles are numbered from west to east with 001 to 004, where 005 represents the intermediate profile established during the 1st campaign. Two stations (SLYE and CGCS) on the south-end of the profile 003 removed from the model due to unexpected velocities.* ***Rectangles implies the fault trace****."*

"Figure 12. *Model area for Destek segment with Eurasian plate(AVRA) on the north and Anatolian plate(ANAD) on the south(dashed lines), divided by the creeping segment of the NAF. Black and red arrows represent the observed and modeled velocities respectively, obtained from GAMIT/GLOBK and TDEFNODE. 004 represents the profile in the area* ***and rectangles implies the fault trace****."*

COMMENT #18 (PAGE 6):

"…Figure 11 - 13 : there's obviously no data further than 25 km from the fault, re-scale the profiles. Same remark for the y-axis, the smallest velocity is -2 or -3 mm/yr, re-scale the velocity axis. What are the dashed red lines ? What is the "transverse"?..."

Response:

Profiles rescaled for both x- and y- axis. Dashed red lines represents the block boundaries, explanations are in the statement and "transverse" removed from the figures.

COMMENT #19 (PAGE 7):

"…coordinates of the Euler pole estimated to rotate the velocities in fixed Eurasia…"

Response:

Euler pole coordinates added in the manuscript as follows:

"During TDEFNODE process, one of the tectonic blocks should be chosen as fixed to estimate the fault parameters. Therefore, Euler pole defined as (0, 0, 0) for Eurasian plate and (30.7, 32.6, 1.2) for Anatolian plate. Values represent latitude, longitude and angular velocity, respectively (McClusky et al. 2000)."

COMMENT #20 (PAGE 7):

"…coordinates of all sites (Table 6). In which frame are given the velocities ? ITRF08 or fixed Eurasia ? Indicate it but velocities both in ITRF08 and fixed Eurasia should be given…"

Response:

Those velocities calculated with GAMIT/GLOBK for fixed Eurasia. Explanation for the table fixed as follows:

"Table 6. All cGPS and campaign point with their velocities and location errors (uncertainties) when Eurasian plate selected as fixed."

COMMENT #21 (PAGE 7):

"…Table 5 could be gathered with table 4 with a symbol with stations used for stabilitation…"

Response:

Stations used for GLOBK stabilization are marked and situation added in the explanation for the table:

"Table 5. IGS stations defined in the site.defaults file of GAMIT to constitute reference frame (indicates stations selected for GLOBK stabilization)".*

COMMENT #22 (PAGE 7):

"…l.159-160: "GPS data for cGPS and IGS stations downloaded to cover every six month between August 2009-2016 to increase the stabilisation at the GLOBK step." I don't understand what means "to cover every 6 months" ? The stabilization is important over the campaign dates, then if the stabilisation stations are IGS stations, their positions and velocities are very well known in the ITRF08 : : : Another robust stabilization approach, maybe more efficient than processing data over a longer period than the campaign, is to combine IGS h-files at the dates of campaign in the GLOBK process (to download either from SOPAC or MIT – code sh_get_hfiles in gg)…"

Response:

Observations over the campaign points completed approximately in July – August term at 2014 – 2016. "to cover every 6 months" is an explanation for downloaded and processed cGPS stations' data at campaign observation dates and also every January at those years. So, text has been revised as follows:

"GPS data for IGS and cGPS stations' data processed at campaign observation dates. In addition, observations for those stations during January(for 7 days) included at the GAMIT/GLOBK step to increase the stabilization of the designed networks."

COMMENT #23 (PAGE 7):

"…l.165-167: "Results show that the velocity of the stations inside the Anatolian plate are gathering up to 15- 20 mm/year (Fig 5), which is similar with the previous studies (McClusky et al. 2000, Reilinger et al. 2006, Yava¸soglu et al. 2011)." In what frame ? ITRF08 or fixed Eurasia ? What does mean Âninside the Anatolian plateÂ ´ z ? Located ˙ on the Anatolian plate ? "ranging from 15 to 20 mm/yr" instead of "gathering up to…"

Response:

Addition to the explanation of Figure 5 describes that those velocities calculated when Eurasia selected as fixed. Also, this text changed as follows after the comment:

"Results show that the velocity of the stations located on the Anatolian plate are ranging from 15 to 20 mm/year (Fig 5), which is similar with the previous studies (McClusky et al. 2000, Reilinger et al. 2006, Yavaşoglu et al. 2011)."

COMMENT #24 (PAGE 8):

"…Tables 6 : The uncertainties given in table 6 (of less than 0.1mm/yr in some cases) are totally unrealistic, they must be formal errors from the globk process, in which case it is necessary to precise at how many sigmas. Going further I think the authors are mixing "errors", "uncertainties" and "repeatabilities" (l.179 : "repeatability of the ORMN and KDZU stations indicate abnormal deformation"). They are different things, please clarify what is used, and indicate all the necessary information…"

Response:

At table 6, uncertanties around 0.1 mm/year refer cGPS stations (CORS-TR) at designed network. Also, it can be seen that the uncertainties for campaign stations are much more bigger than those values because data from them are discontinuous and do not cover a complete year.

On the other hand, considering 3 campaign observations for ORMN and KDZU stations, we found evidence for deformations around those locations considering the repeatability graphics after GAMIT step. To clarify the situation, text revised as follows:

"GAMIT process indicates abnormal deformation for ORMN and KDZU campaign stations, so their data removed from block modelling step."

<u>RESPONSE FOR ANONYMOUS REFEREE #2:</u>

COMMENT #1 (PAGE 2):

"…The abstract can be extended with the results of block geometry…"

Response:

According to this comment, following statement added to the abstract:

"Also, aseismic creep behavior is limited to some depths and decays linearly to the bottom of seismogenic layer at both segments."

COMMENT #2 (PAGE 2):

"…There are many fault names mentioned in the paper. The fault name should be provided in Figure 4…"

Response:

Profile at Destek segment established on the creeping fault trace. Faults on the south are secondary faults and no aseismic creep reported at those locations. To clarify the situation, following statement added to the explanation of Figure 4:

*"*Fault traces on the south of profile 006 are secondary faults."

COMMENT #3 (PAGE 2):

"…The previous results of the studies conducted to determine creep rate in the Ismetpasa segment between1970 and 2016 can be given as figure…"

Response:

Table 1 and Figure 6 includes those information. A figure would be more complex to demonstrate all the studies because they would interlace each other.

COMMENT #4 (PAGE 2):

"…Some of content is repeated. For example ´Page 7 last paragraph (line 143-147) same as 'GPS Data Evaluation' section line 158-160. Suggest revising or deleting…"

Response:

That repeated text deleted.

COMMENT #5 (PAGE 2):

"…There are Turkish sentences or word in ´Figure 7 and in the manuscript. These sentences should be deleted in the paper…"

Response:

Figure 7 and Turkish sentences fixed according to the comment.

COMMENT #6 (PAGE 2):

"…The citation publications and references should be checked, eg; Poyraz vd. 2011 ´ instead of Poyraz et al. 2011…"

Response:

Citations fixed in the text.

COMMENT #7 (PAGE 2):

"…Some figures are not enough resolution. So, these figures should be rearranged. For example, Figure 5,6 and 11…"

Response:

Figure 5 replaced with the high resolution copy.

Figure 6 has the highest resolution and prepared with another software. It is the best output of the that.

Figure 11 includes 5 different profiles. They are rearranged according to the comment.

COMMENT #8 (PAGE 2):

"…The parameter values used in block modeling (such as locking depth, Euler poles) should be explained in a few sentences in the paper…"

Response:

That information added in the text as follows:

"During TDEFNODE process, one of the tectonic blocks should be chosen as fixed to estimate the fault parameters. Therefore, Euler pole defined as (0, 0, 0) for Eurasian plate and (30.7, 32.6, 1.2) for Anatolian plate. Values represent latitude, longitude and angular velocity, respectively (McClusky et al. 2000)."

COMMENT #9 (PAGE 2):

"…The chi-square value can be given in ´text (between lines 254-263 in the page 16)…"

Response:

Chi-square results are (1.00) and (1.01) for Ismetpasa and Destek segments, respectively. These results added in the text before the figures of modeled area.

Monitoring aseismic creep trend in Ismetpasa and Destek segments throughout the NAF with a large scale GPS network

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[3] ITU, Graduate School of Science Engineering and Technology, Maslak, Istanbul, Turkey

Abstract

North Anatolian Fault Zone (NAFZ) is an intersection area between Anatolian and Eurasian plates. Arabian plate, ~~Also another plate is responsible for this formation, Arabian plate,~~ which squeezes the Anatolian plate from the south between Eurasian plate and itself is also responsible for this formation. This tectonic motion causes Anatolian plate to move westwards with almost a 20 mm/year velocity which has caused~~s~~ destructive earthquakes in the history. Block boundaries that~~,~~ form~~ing~~ the faults~~,~~ are generally locked to the bottom of seismogenic layer because of the friction between blocks, and responsible for these discharges. However, there are also some unique events observed around the world, which may cause partially or fully free slipping faults. This phenomenon is called "aseismic creep", and may occur through the entire seismogenic zone or at least to some depths. Additionally ~~and~~, it is a rare event in the world located~~,~~ ~~with~~in two reported segments along the North Anatolian Fault (NAF)~~:~~ which are Ismetpasa and Destek.

In this study, we established GPS networks covering thoese segments and made three campaigns between 2014-2016. Considering the long term geodetic movements of the blocks (Anatolian and Eurasian plates), ~~previous studies for each segment, calculated~~ surface velocities and fault parameters are calculated.~~;~~ The results of the model indicate that aseismic creep still continues to some rates~~,~~ of 13.2±3.3 mm/year at Ismetpasa and 9.6±3.1 mm/year at Destek. Additionally, aseismic creep behavior is limited to some depths and decays linearly to the bottom of the seismogenic layer at both segments. This study suggests ~~Results indicates~~ that this aseismic creep behavior will not prevent a medium-large scale earthquake in the long term.

Açıklamalı [O1]: Text added after comment #1 from Anonymous Referee #2

Key words: NAFZ, aseismic creep, GPS, block modelling

Introduction

Fault zones all around the world are formed by the tectonic plate motions and is a natural boundary between blocks. They are generally locked to the bottom of seismogenic layer and cannot slip freely compared to the velocities within the blocks because of the friction between rocks.

Therefore, movement in these regions generally minimal and causes earthquakes when the motion of the blocks overrides the friction force. After discharge (earthquake), faults begin to accumulate strain and this cycle continues until the next earthquake (Reid 1910, Yavaşoğlu 2011).

NAF(North Anatolian Fault) is a tectonic plate boundary between Anatolian and Eurasian plates. It slowly moves ~20 mm/year to the west by the overthrusting Arabian plate from the south and compresses the plate motion with the help of a massive Eurasian plate in the north. Tho~~e~~se tectonic forces constitute North Anatolian Fault, which lies between Karliova triple junction from the east to the Aegean Sea to the west for almost 1200 km long. The width of the fault trace ranges between ~~It extends from~~ 100 m to 10 km. ~~along the zone and south part,~~ Anatolian plate~~,~~ moves 20-25 mm/year to the west relative to the Eurasian plate. There are velocity variations ~~changes~~ along the fault that is, west region moves faster than the eastern part~~,~~ and is a right-lateral strike slip fault (Fig. 1) (Ketin 1969-1976, McClusky et al. 2000, Cakir et al. 2005, Şengör et al. 2005, Reilinger et al. 2006, Yavaşoğlu et al. 2011, Bohnhoff et al. 2016).

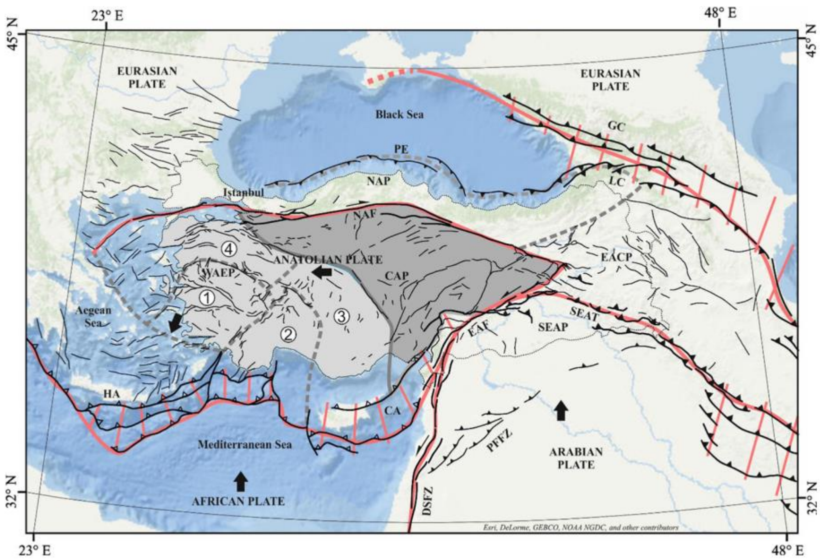
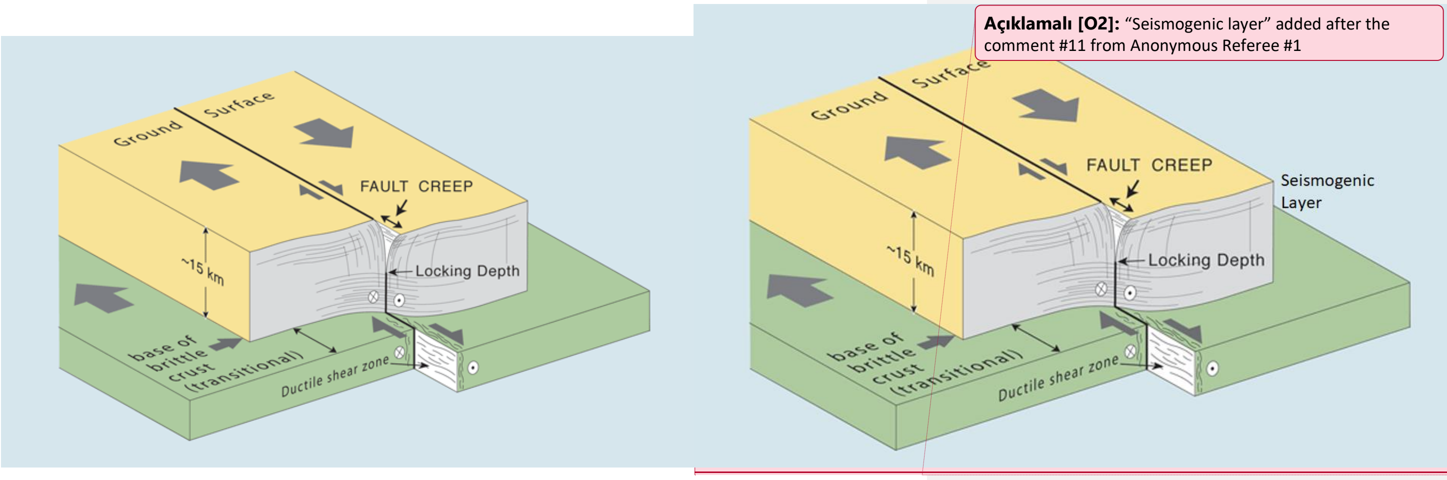


Figure 1. Formation of the North Anatolian Fault and interacting tectonic plates (from Emre et al. 2018). Anatolian plate moves westwards due to African and Arabian plates overthrusting. (1)West Anatolian graben systems, (2) Outer Isparta Angle, (3) Inner Isparta Angle, and (4) Northwest Anatolia transition zone. The original version of the figure is available in Emre et al. 2018.

Earthquake mechanisms might have different characteristics in some regions. Faults may move freely without an earthquake and this motion reported at some unique places like Hayward fault (Schmidt et al. 2005), the Superstition Hills fault(Wei et al. 2011) and Ismetpasa segments (Cakir et al.

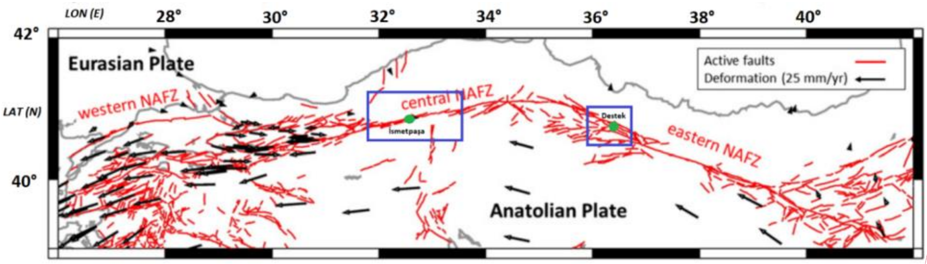
2012) which ~~, and~~ can be observed from the surface(Ambraseys 1970, Yavasoglu et al. 2015). This phenomenon is called “aseismic creep” and may occur in two different ways~~:~~. If the creep takes place to the bottom of seismogenic layer and the surface velocities are equal or close to the long-term tectonic velocities, there will not be enough strain accumulation for a large scale earthquake (Şaroğlu ve Barka 1995, Cakir et al. 2005). On the other hand, if that~~is~~ free motion is not observed to the bottom of the seismogenic layer or observed surface velocities are smaller than the tectonic velocities, strain will accumulate to a final earthquake (Fig. 2) (Karabacak et al. 2011, Ozener et al. 2013, Yavasoglu et al. 2015). Also, aseismic creep in a region may occur continuously or fade out after some period (Kutoglu et al. 2010).



Açıklamalı [O2]: “Seismogenic layer” added after the comment #11 from Anonymous Referee #1

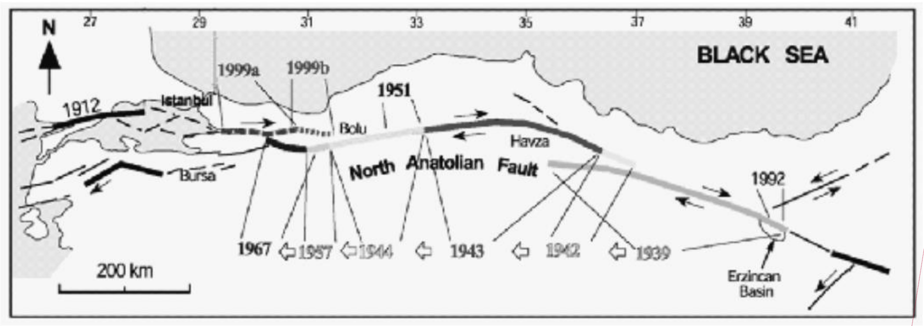
Figure 2. Aseismic creep structure in a fault zone. Fault may slip freely to some depths and locked after to the bottom (URL-1).

NAF reported to have segments which show~~s~~ aseismic creep ~~until~~ since 1970 ~~:~~at Ismetpasa and with a more recent discovery, Destek~~, where the second site is a more recent discovery~~ (Ambraseys 1970, Karabacak et al. 2011). Aseismic creep at the Ismetpasa is reported to occur along ~70-80 km, from Bayramoren ~~at the~~ (east) to the Gerede ~~at the~~ (west) (Fig. 3). It was discovered at the wall of the Ismetpasa train station at 1970 and several minor and large scale studies monitored the area ~~until~~ since then (Table 1). ~~This~~ That segment hosted~~s~~ three destructive earthquakes (1943 Tosya M_w=7.2, 1944 Gerede M_w=7.2, 1951 Kursunlu M_w=6.9) that may have triggered or affected the creep (Şaroğlu ve Barka 1995, Cakir et al. 2005, Karabacak et al. 2011, Kaneko et al. 2013) (Fig. 4).



Açıklamalı [O3]: Added after the comment #9 from Anonymous Referee #1

Figure 3. Active fault segments on the North Anatolian Fault (NAF). Blue rectangles define Ismetpasa and Destek segments from west to east, respectively (after Bohnhoff et al. 2016).



Açıklamalı [O4]: Added after the comment #10 from Anonymous Referee #1

Figure 4. Earthquakes on the North Anatolian Fault between 1939-1999. Both 1943 and 1944 earthquakes suspected to have influence on the creeping phenomena (from Kutoglu et al. 2010).

All the studies around theose segments indicates the continuity of creep but the results are inconsistent and cannot clearly refer whether this that event has an increasing trend or not. Most of the researches (Ambraseys 1970, Aytun 1982, Eren 1984, Altay& and Sav 1991, Deniz et al. 1993, Kutoglu et al. 2008&2009&2013, Karabacak et al. 2011, Ozener et al. 2013, Bilham et al. 2016) generally are on a micro-scale and focused on the Ismetpasa or a network near this village with geodetic methods, while others on a macro-scale with InSAR (Deguchi 2011, Fialko et al. 2011, Köksal 2011, Kaneko et al. 2013, Cetin et al. 2014, Kutoglu et al. 2013) which needs a ground truth (Fig 5&63).

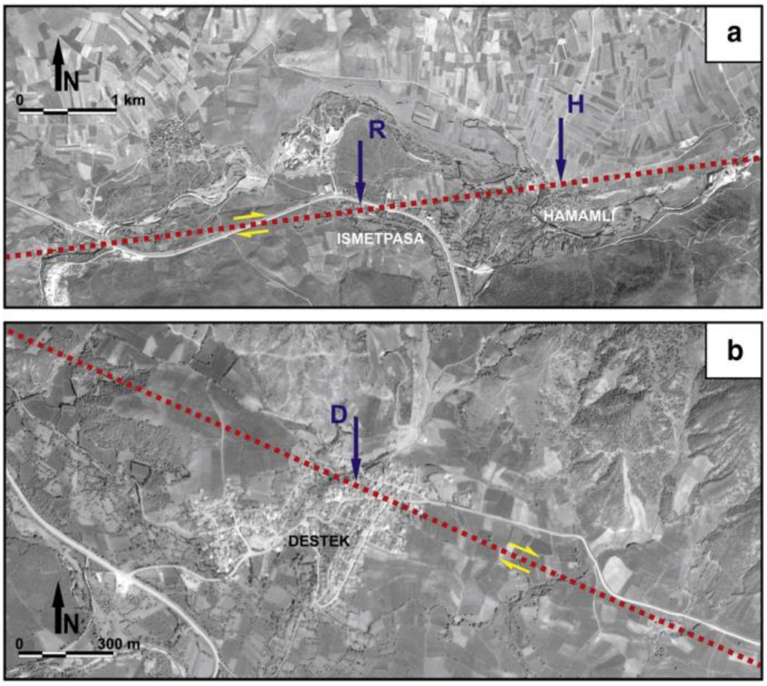


Figure 53. Reported aseismic creep zones at Ismetpasa (a) and Destek (b) segments from a recent study. (a) “R” shows creep observed at the wall at the Ismetpasa train station, and “H” shows the creep at Hamamli village. (b) “D” represents the reported creep at Destek town (from Karabacak et al. 2011).

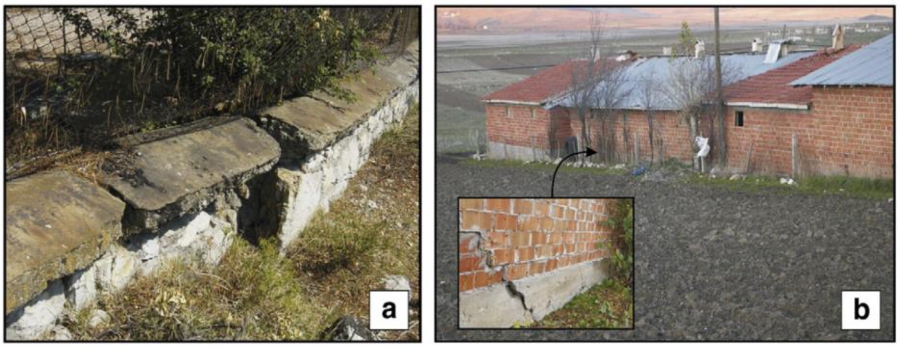


Figure 6. Aseismic creep sites (a)at Ismetpasa railway station, and (b) damaged brick-wall at Hamamlı village close to Ismetpasa. (c) Out-bended wall at Destek village (from Karabacak et al. 2011).

Açıklamalı [O5]: Added after the comment #12 from Anonymous Referee #1

Thoese results cannot reveal the creep trend clearly. In addition, a ground network is required to exhibit the fault characteristics clearly along these segments. For this reason, we established a ground network forming profiles around thoese segments and made three observations annually from 2014 to 2016.

Table 1. Studies and their results to observe aseismic creep at the Ismetpasa segment between 1970-2016.

Study	Creep rate(cm/year)	Years covered	Method
Ambraseys(1970)	2.0 ± 0.6	1957-1969	Wall offset measurements
Aytun(1982)	1.10 ± 0.11	1969-1978	Doppler
Eren(1984)	1.00 ± 0.40	1972-1982	Trilateration
Deniz et al.(1993)	0.93 ± 0.07	1982-1992	Trilateration
Cakir et al.(2005)	0.80 ± 0.30	1992-2000	InSAR
Kutoglu&Akcin(2006)	0.78 ± 0.05	1992-2002	GPS
Kutoglu et al.(2008)	1.20 ± 0.11	2002-2007	GPS
Kutoglu et al.(2010)	1.51 ± 0.41	2007-2008	GPS
Karabacak et al.(2011) [1.region]	0.84 ± 0.40	2007-2009	LIDAR
Karabacak et al.(2011) [2. region]	0.96 ± 0.40	2007-2009	LIDAR
Deguchi(2011)	1.4	2007-2011	PALSAR
Fialko et al.(2011)	1.0	2007-2010	PALSAR
Ozener et al.(2013)	0.76 ± 0.10	2005-2011	GPS
Köksal(2011)	1.57 ± 0.20	2007-2010	DInSAR
Görmüş(2011)	1.30 ± 0.39	2008-2010	GPS
Kaneko et al.(2013)	0.9 ± 0.2	2007-2011	InSAR
Cetin et al.(2014)	0.8 ± 0.2	2003-2010	InSAR(PSI)
Altay and &Sav(1991)	0.76 ± 0.1	1982-1991	Kripmetre
Kutoglu et al.(2013)	1.3 ± 0.2	2008-2010	GPS
Kutoglu et al.(2013)	1.25 ± 0.2	2007-2010	InSAR
Ambraseys(1970) - Bilham et al.(2016) revision	1.04 ± 0.04	1957-1969	Revaluation of photographs
Aytun(1982)	1.50	1957-1969	Revaluation of photographs
Aytun(1982) – Bilham et al.(2016) revision	1.045 ± 0.035	1957-1969	Revaluation of photographs
Bilham et al.(2016)	0.61 ± 0.02	2014-2016	Creepmeter

Table 2. Studies and their results to observe aseismic creep at the Destek segment.

Study	Creep rate (cm/year)	Years covered	Method
Karabacak et al.(2011)	0.66 ± 0.40	2007-2009	LIDAR
Fraser et al.(2009)	0.6	2009	Trench study

Network Design Around the Creeping Segments

Designing a monitoring network around tectonic structures is always related to the geological characteristics and fault geometry, which includes the locking depth and earthquake related motions (coseismic movements) through the fault. Previous studies indicate that the velocities for the stations distant from the fault plane can be used to derive long-term plate velocities, while nearby station velocities are suitable to detect the locking depth of a fault (Taskin et al. 2003, Halıcıoğlu et alvd. 2009). In addition, velocities of the observation stations gradually decrease when their locations approach to the fault plane. Another factor is the number of the stations and this is related to the fault length and widenesswidth, but the station locations perpendicular to the fault plane must not exceed the (±1/√3) of the locking depth. Also, ~~some~~ several research~~es~~ specify this limit to the double of the depth (Taskin et al. 2003, Kutoglu and ~~&~~Akcin 2006, Kutoğlu et al~~vd~~. 2009, Halıcıoğlu ~~vd~~et al. 2009, Poyraz et al~~vd~~. 2011, Bohnhoff et al. 2016). For this purpose, the following equation is used in general to obtain to proper distances of the observation stations from the fault plane:

$$V(x) = \frac{V_T}{\pi} \arctan(\frac{x}{D}) \tag{1}$$

where:

- V : Fault parallel velocity
- V_T : Long term tectonic plate velocity
- x : Distance to fault plane
- D : Locking depth of the fault (Halıcıoğlu et al.~~vd~~ 2009).

Location of the stations may vary according to the geological surface elements, but they are generally established on the both sides of the fault to form a profile on each block to obtain surface velocities (Yavasoglu et al. 2015).

Geologic structure at the tectonic block boundaries and fault plane geometry also affects the tectonic behaviour. To better understand this mechanism, established network around the fault zone is observed with different techniques periodically or continuously. The variation of the observations are clues to detect ~~these~~ those amplitudes, and GPS is the most common technique for ~~this~~ that kind of studies. This technique is very effective and efficient to collect data from ground stations established around the faults (Poyraz et al~~vd~~. 2011, Aladoğan et al~~vd~~. 2017).

Profiles intersect with fault plane vertically are used to estimate the locking depth. However, in such regions like Ismetpasa and Destek, there is an additional locking depth deduced from the previous studies, which indicates that the creeping layer of the seismogenic zone does not reach to the bottom, but around 5-7 km depth in ~~these~~ those areas (Kaneko et al. 2013, Ozener et al. 2013, Cetin et al. 2014, Bilham et al. 2016, Rousset et al. 2016). For this reason, aseismic layer's attenuation depth is another crucial element to understand the creeping mechanism (Fig ~~1~~2). Also considering the 5-7 km depth value with the *Eq.1*, station locations are chosen as 3 and 10 km on the both sides of the fault forming profiles, while NAF general locking depth is around 15 km (McClusky et al. 2000, Poyraz et al~~vd~~. 2011, Bohnhoff et al. 2016).

Before the 3 epochs of observations, a network was planned forming 4 profiles at the Ismetpasa, and 1 profile at the Destek segments and including surrounding continuous GPS stations(Real Time Kinematic Continuously Operating Reference Stations-RTK CORS) (Fig ~~4~~7). Aim of this study was to monitor this network periodically to calculate the velocity field with combining the results with CORS station velocities and estimate the creep ratio within the Ismetpasa and Destek segments (Yavasoglu et al. 2015).

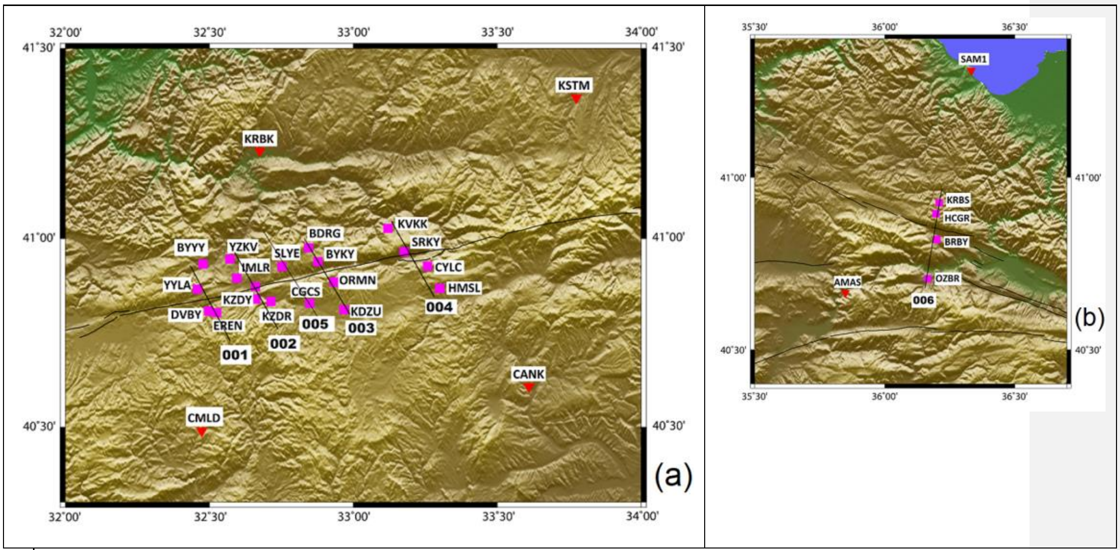


Figure 47. Planned profiles and campaign GPS stations(pink) at Ismetpasa(a) on the left and Destek(b) on the right. Profiles 001-004 planned and established on the Ismetpasa segment, and profile 005 added to the network using two suitable stations. Profile 006 is on Destek segment. Fault traces on the south of profile 006 are secondary faults. Other continuous GPS sites (RTK CORS) shown in red(after Yavasoglu et al. 2015).

Açıklamalı [O6]: Added after comment #2 from Anonymous Referee #2

While establishing the network, first consideration for 3 and 10 km on the both sides of the fault generally occurred, but some minor changes took place according to the geological structure of the area. In addition, another profile between the 2nd and 3rd profiles formed with the suitable location of two unplanned stations. Finally, there are 5 profiles within ~70 km along the Ismetpasa and 1 profile along the Destek.

Observations are completed ~~on the stations completed~~ around the July and August for 3 years using relative geolocation based on carrier phase observations with GPS technique (Table 3). Force centering equipment and GPS masts were used when necessary. First campaign was on the 235-238 and 241 GPS days in 2014, second was on 215-221 GPS days in 2015, and the last one was between 210-220 GPS days in 2016.

Table 3. Campaign stations, their locations and facility types.

Profile number	Station ID	Site	Latitude (°)	Longitude (°)	Type of facility
001	BYYY	Büyükyayalar	40.49	32.48	Bronze
	YYLA	Yayla Village	41.45	31.78	Bronze
	DVBY	Davutbeyli Village	39.43	32.50	Bronze
	EREN	Elören Village	40.81	32.50	Bronze
002	YZKV	Yazıkavak Village	40.80	32.53	Bronze
	IMLR	İmanlar Village	40.95	32.57	Bronze
	HMMP	Hamamlı Village	40.90	32.60	Pillar
	KZDR	Kuzdere Village	41.23	32.68	Pillar
005 (intermediate)	SLYE	Kapaklı Village	41.85	32.72	Pillar
	CGCS	D100 wayside	39.86	32.85	Pillar
003	BDRG	Boduroğlu Village	39.89	32.76	Bronze
	BYKY	Beyköy Village	40.83	32.85	Pillar
	ORMN	Forest	40.94	32.86	Bronze
	KDZU	Kadıözü Village	40.88	32.93	Pillar
004	KVKK	Kavak Village	40.81	32.97	Bronze
	SRKY	Sarıkaya Village	41.03	33.12	Bronze
	CYLC	Çaylıca Village	40.97	33.18	Bronze
	HMSL	Hacımusla Village	40.93	33.26	Pillar
006	KRBS	Korubaşı Village	40.82	36.20	Bronze
	HCGR	Hacıgeriç Village	40.71	36.17	Bronze
	BRBY	Borabay	40.90	36.20	Pillar
	OZBR	Özbaraklı Village	39.66	35.87	Pillar

After the first campaign, KZDY station was damaged and removed from rest of the project. Raw data collected for a minimum of 8 hours at each station for the rest of the project and evaluated with GAMIT/GLOBK software (Herring et al. 2015a, 2015b) at first, then the results used as input to block modelling software TDEFNODE (McCaffrey 2002, 2009). A total of 63 stations (22 campaign, 30 surrounding RTK CORS, 11 IGS) are used in this network to monitor Ismetpasa and Destek segments and the remaining region between them (Table 4).

Table 4. Continuous GPS(RTK CORS) stations and their locations.

Station ID	Province	Station ID	Province	Station ID	Province
AKDG	Yozgat	**FASA**	Ordu	**RDIY**	Tokat
AMAS	Amasya	**GIRS**	Giresun	**SAM1**	Samsun
ANRK	Ankara	**HEND**	Sakarya	**SIH1**	Eskişehir
BILE	Bilecik	**HYMN**	Ankara	**SINP**	Sinop
BOLU	Bolu	**IZMT**	İzmit	**SIVS**	Sivas
BOYT	Sinop	**KKAL**	Kırıkkale	**SSEH**	Sivas
CANK	Çankırı	**KRBK**	Karabük	**SUNL**	Çorum
CMLD	Ankara	**KSTM**	Kastamonu	**TOK1**	Tokat
CORU	Çorum	**KURU**	Bartın	**VEZI**	Samsun
ESKS	Eskişehir	**NAHA**	Ankara	**ZONG**	Zonguldak

GPS Data Evaluation

~~In this study, all campaign station observed between 2014-2016 for 3 campaigns and data were evaluated with GAMIT/GLOBK software. Also,~~ GPS data for cGPS and IGS stations' data processed at campaign observation dates. In addition, observations for those stations during January (for 7 days) included at the GAMIT/GLOBK step to increase the stabilization of the designed networks. ~~downloaded to cover every six month between August 2009-2016 to increase the stabilization at the GLOBK step.~~

Açıklamalı [O7]: Text revised for the comment #22 from Anonymous Referee #1

The networks linked to the ITRF 2008 global coordinate system by using surrounding IGS sites (Table 5) (Yavaşoglu et al. 2011, Herring et al. 2015a, 2015b). After the transformation with GLOBK, the root mean square (rms) of the stations was only 0.7 mm/year.

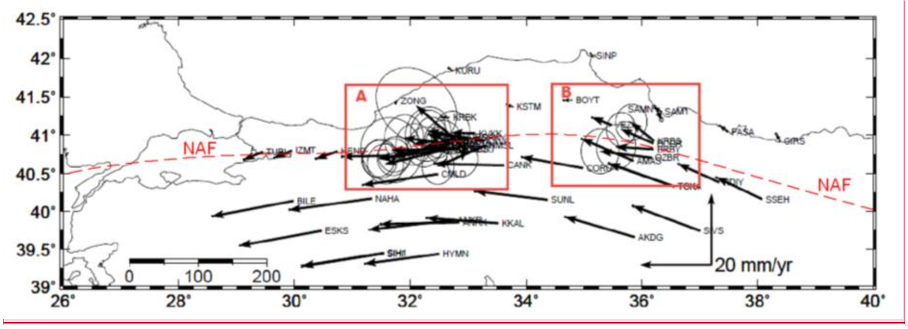
Table 5. IGS stations defined in the site.defaults file of GAMIT to constitute reference frame (* indicates stations selected for GLOBK stabilization)~~.~~

Açıklamalı [O8]: Table and explanation revised for the comment #21 from Anonymous Referee #1

Station ID	City/Country
ANKR	Ankara/Turkey
BUCU*	Bucharest/Romania
CRAO*	Simeiz/Ukraine
MATE*	Metara/Italy
ONSA*	Onsala/Switzerland
SOFI*	Sofia/Bulgaria
TEHN*	Tehran/Iran
TELA	Tel Aviv/Israel
TUBI	Kocaeli/Turkey
WZTR*	Koetzting/Germany
ZECK*	Zelenchukskaya/Russia

Results show that the velocity of the stations ~~inside~~ located on the Anatolian plate are ~~gathering~~ ranging from ~~up to~~ 15 - to 20 mm/year (Fig ~~5~~8), which is similar with the previous studies (McClusky et al. 2000, Reilinger et al. 2006, Yavaşoglu et al. 2011).

Açıklamalı [O9]: Text revised for the comment #23 from Anonymous Referee #1



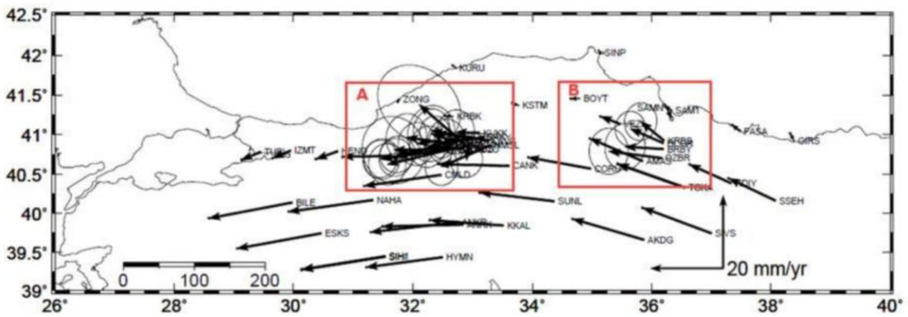


Figure ~~5~~8. GLOBK results for station velocities relative to fixed ~~when~~ Eurasian plate~~ selected as fixed~~. (A) includes the Ismetpasa segment, and Destek segment is inside (B). Dashed lines represent the fault trace of North Anatolian Fault (NAF). Velocities at the north of the NAF are very small as expected, where south velocities indicate~~s~~ the westward motion of the Anatolian plate~~'s motion to the west~~ (~~from~~after Aladoğan 2017).

The GLOBK results for all of the station velocities are used as input for block modelling to predict the aseismic creep ratio within fault plane in the predefined segments (Table 6, Fig.9~~6~~).

Table 6. All cGPS and campaign point velocities and location errors (uncertainties) when Eurasian plate selected as fixed.~~.~~

Station ID	Velocity(mm/yr)		Error		Station ID	Velocity(mm/yr)		Error	
	V_{EAST}	V_{NORTH}	V_{EAST}	V_{NORTH}		V_{EAST}	V_{NORTH}	V_{EAST}	V_{NORTH}
AKDG	-19.5	5.7	0.1	0.1	**KDZU**	-14.1	12.3	4.6	4.4
AMAS	-14.5	6.2	0.1	0.1	**KKAL**	-20.1	1.5	0.1	0.1
ANRK	-22.1	-0.5	0.1	0.1	**KRBK**	-2.3	0.1	0.1	0.1
BDRG	-7.8	1.1	1.7	1.9	**KRBS**	-6.4	5.2	1.8	2.1
BILE	-22.8	-4.3	0.1	0.1	**KSTM**	-1.9	0.6	0.1	0.1
BOLU	-12.8	-0.2	0.1	0.1	**KURU**	-0.9	0.5	0.1	0.1
BOYT	-2.5	-0.1	0.1	0.1	**KVKK**	-6.6	0.2	2.1	2.5
BRBY	-10.6	0.6	2.3	2.6	**KZDR**	-18.7	-4.5	2.1	2.3
BYKY	-6.1	-0.7	1.5	1.8	**NAHA**	-23.1	-3.2	0.1	0.1
BYYY	-6.8	-1.0	2.1	2.4	**ORMN**	-0.6	-4.4	1.8	2.0
CANK	-19.4	0.5	0.1	0.1	**OZBR**	-14.4	1.8	2.2	2.6
CGCS	-19.2	-0.4	3.5	3.7	**RDIY**	-11.4	5.1	0.1	0.1

Açıklamalı [O10]: Revised for the comment #14 from Anonymous Referee #1

A high resolution copy of the figüre added for comment #7 from Anonymous Referee #2

Açıklamalı [O11]: Explanation of the table revised for the comment #20 from Anonymous Referee #1

CMLD	-21.1	-3.0	0.1	0.1	**SAM1**	-1.9	1.3	0.2	0.2
CORU	-17.2	3.1	0.1	0.1	**SAMN**	1.3	-3.0	0.2	0.2
CYLC	-15.5	2.8	2.0	2.4	**SIH1**	-22.8	-3.6	0.1	0.2
DVBY	-16.6	-2.5	2.0	2.3	**SIHI**	-22.8	-3.6	0.1	0.2
EREN	-17.6	-2.3	1.9	2.1	**SINP**	-0.7	0.5	0.1	0.1
ESKS	-23.1	-4.2	0.1	0.1	**SIVS**	-18.8	7.0	0.1	0.1
FASA	-2.2	1.8	0.1	0.1	**SLYE**	-8.2	-1.7	2.0	2.3
GIRS	-1.0	2.1	0.1	0.1	**SRKY**	-10.1	-1.1	2.1	2.5
HCGR	-9.1	3.9	1.7	1.9	**SSEH**	-12.8	6.1	0.1	0.1
HEND	-6.0	-2.2	0.1	0.1	**SUNL**	-20.4	2.4	0.1	0.1
HMMP	-14.9	-2.5	2.0	2.0	**TOK1**	-18.4	6.4	0.1	0.1
HMSL	-13.4	-5.8	1.8	2.1	**VEZI**	-5.3	2.1	0.1	0.1
HYMN	-20.9	-2.7	0.1	0.1	**YYLA**	-12.2	-3.3	1.9	2.1
IMLR	-11.5	1.6	2.3	2.6	**YZKV**	-4.4	1.5	2.6	3.1
IZMT	-5.0	-2.1	0.1	0.1	**ZONG**	-0.5	-0.7	0.1	0.1

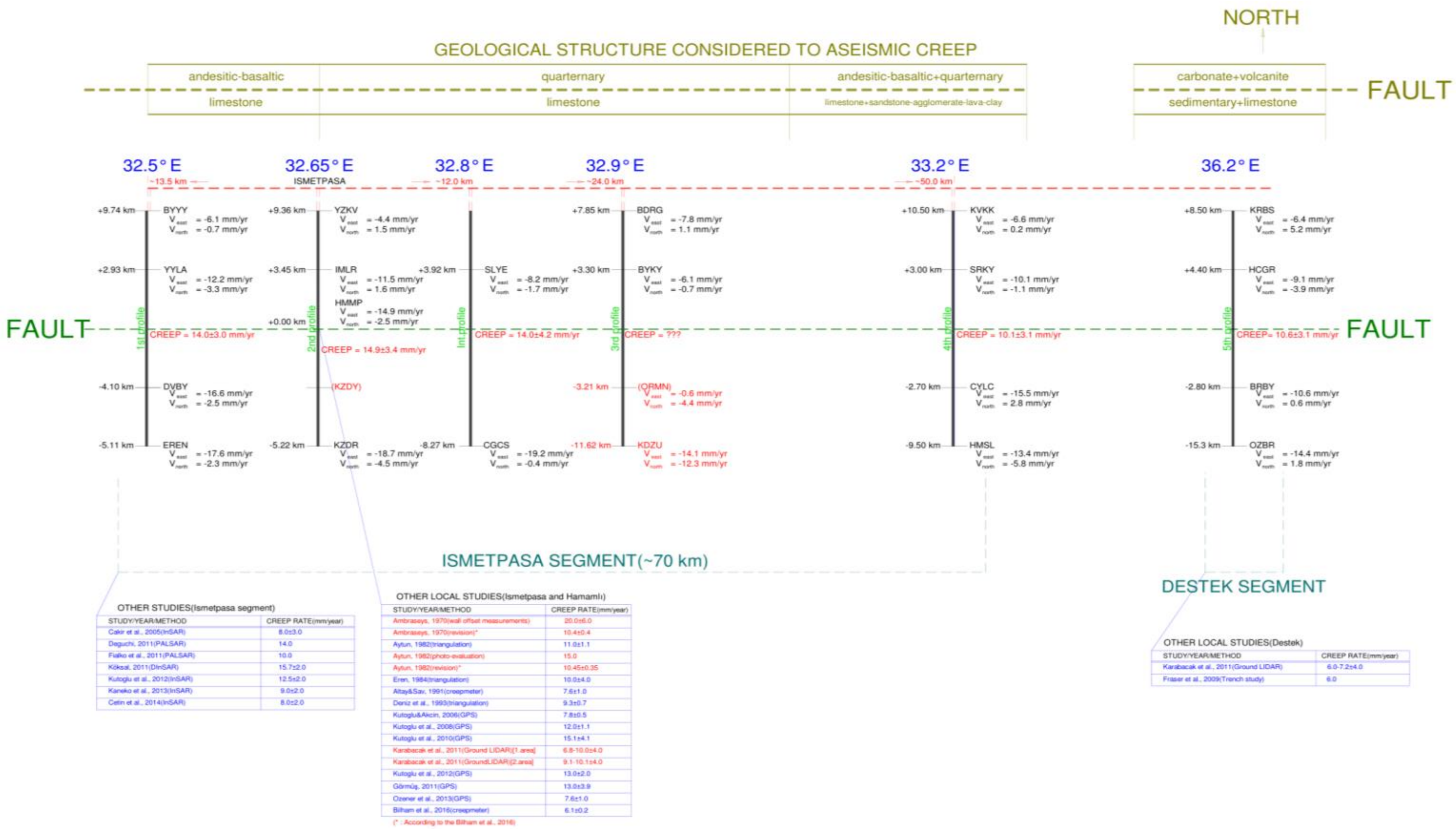


Figure ~~6~~9. Geological structure related to the aseismic creep, station velocities, estimated creep ratio, and earlier studies around the Ismetpasa and Destek regions (Akbaş et al. 2002. , Cetin et al. 2014)

Aseismic creep ratio estimated by interpolation through the profiles using surface velocities except the 3rd profile at first (Table 7).

GAMIT process ~~At the Ismetpasa segment, repeatability of the ORMN and KDZU stations~~ indicates abnormal deformation for ORMN and KDZU campaign stations, so their data removed~~.~~ ~~Therefore,~~ from the block modelling step. Additionally, the creep estimation for that profile unfeasible. Actually, this is not a drawback for block modelling, because the remaining station velocities are all used to model the region uneventfully.

Açıklamalı [O12]: Text revised for the comment #24 from Anonymous Referee #1

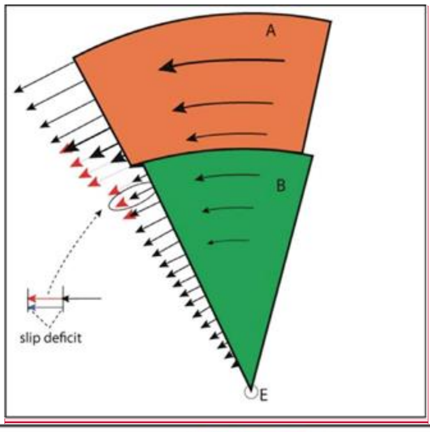
Table 7. Aseismic creep rate at the Ismetpasa segment.

Profile	Aseismic creep rate(mm/year)
001	14.0±3.0
002	14.9±3.6
005(intermediate)	14.0±4.0
004	10.1±3.0

With the calculated surface velocities, Destek segment also have a creep trend through the campaign period. Estimated creep rate in this study according to GLOBK results is 10.6±3.1 mm/year in this region, and indicates aseismic creep similar with the recent studies (Fraser et al. 2009, Karabacak et al. 2011).

Block Modelling

Station velocities are suitable to predict surface and block motions around them locally. On the other hand, observations inside the blocks provide adequate long-term block velocities and rotations with high precision. Blocks generally demonstrate a regular movement, but their motion differ at their boundaries from this overall velocity. They cannot move freely around the faults because of the friction of rocks, generally infer underspeed, may down to none (Fig 10~~7~~). Th~~is~~at difference in the velocity is called “slip deficit”~~,~~ and causes earthquakes after the friction threshold is surpassed ~~s~~ (Kutoglu and ~~&~~Akcin 2006, McCaffrey 2014, Yavasoglu et al. 2015).



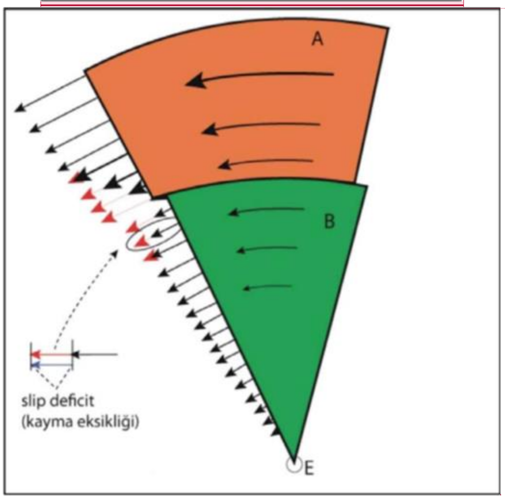


Figure 10~~7~~. Motions of tectonic blocks around the same Euler pole and slip deficit at their boundaries. Long-term block velocities evolve at the fault zones and gap between them is responsible for strain accumulation and earthquakes (from Cakmak 2010).

Slip deficit represents that ~~blocks'~~ expected velocities of the blocks pass through some deformations regarding the geological structure when approaching the fault zone and frequently decreases. This is based ~~up~~on the geometry of the fault plane, which can only be predicted and based on the surface velocities. In ~~this~~ that context, TDEFNODE software used in this study to predict the fault plane locking interaction regarding the depths, which calculates variations of the block motions, strain accumulation within the blocks~~,~~ and rotations through interseismic or coseismic period (Okada 1985, McCaffrey 2009, Yavaşoğlu 2011).

Basic input for the software includes GPS velocities, blocks with Euler poles, ~~user's~~ fault geometry ~~prediction~~ and locking depth~~, generally acquired after seismic researches~~. Interacting blocks

Açıklamalı [O13]: Figured revised after comment #5 from Anonymous Referee #2 are represented as elastic blocks and assumed to have elastic deformation because of their rotation around Euler poles. All of the defined system is assumed to float inside a half-space where one of the blocks is fixed and have zero strain or movement. Fault geometry is defined by the user with nodes, and their locking ratios (phi) can be defined manually or as a function of depth (Fig. 11~~8~~). Then, the software predicts the underground velocities based on the routines of *Okada* (1985)~~,~~ and estimates the surface velocities according the defined values. Fault geometry estimation is the key feature to minimize the difference between observed and predicted surface velocities with the help of χ^2 test result, which represents the accuracy of the entire model (McCaffrey 2002, Aktuğ ~~ve~~ and Çelik 2008, Yavasoglu et al. 2011).

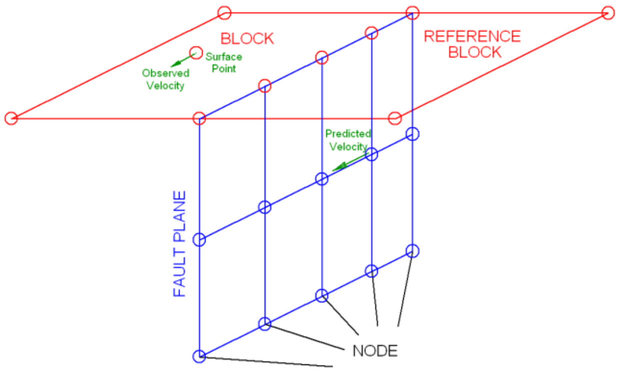


Figure 11~~8~~. Fault plane geometry defined to the control file of TDEFNODE. Nodes divides the fault plane into sub-regions to defined depths and their locking ratio may differ from each other.

TDEFNODE is not only~~can be~~ used for interacting blocks for interseismic strain accumulation, but also for faults which are partially or fully free slipping~~,~~ like aseismic creep. Software's model is suitable to define the locking ratios of all nodes independently from (0-1). (0) represents that the fault at that node is freely slipping, and (1) for a fully locked node. ~~This~~ That allows user to define the fault plane with layers by using depth contours~~,~~ and to predict the fault plane if ~~these~~ those layers are partially or fully locked (Url-2).

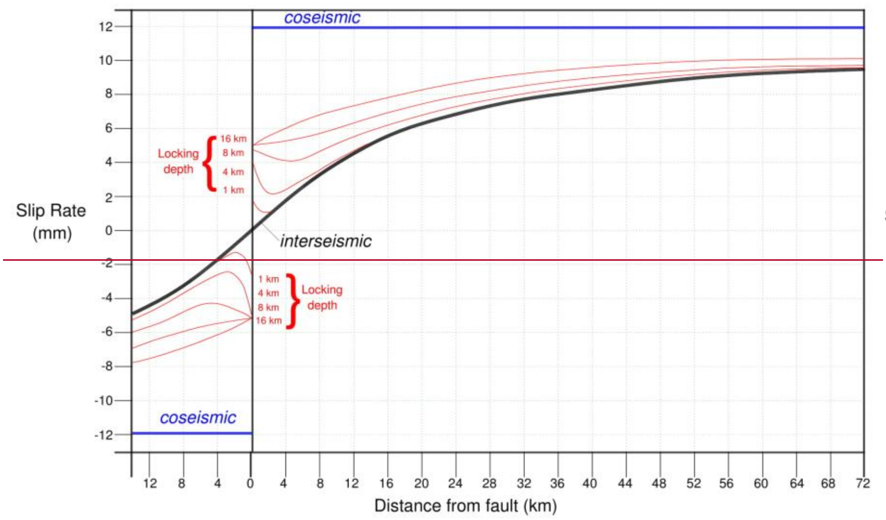
Aseismic creep is an earthquake-free motion along the earth surface, but in some cases it's hard to detect whether this motion is a free slipping event or ~~and~~ an interseismic movement. Thus, the observation network around the fault plane should be planned carefully regarding the ±3-10 km station locations mentioned before (Fig 12~~9~~).

During TDEFNODE process, one of the tectonic blocks should be chosen as fixed to estimate the fault parameters. Therefore, Euler pole is defined as (0, 0, 0) for the Eurasian plate and (30.7, 32.6, 1.2) for the Anatolian plate. Values represent latitude, longitude and angular velocity, respectively (McClusky et al. 2000).

Açıklamalı [O14]: Text added for the comment #19 from Anonymous Referee #1

Text added for the comment #8 from Anonymous Referee #2

Açıklamalı [O15]: Figure revised for the comment #4 from Anonymous Referee #1



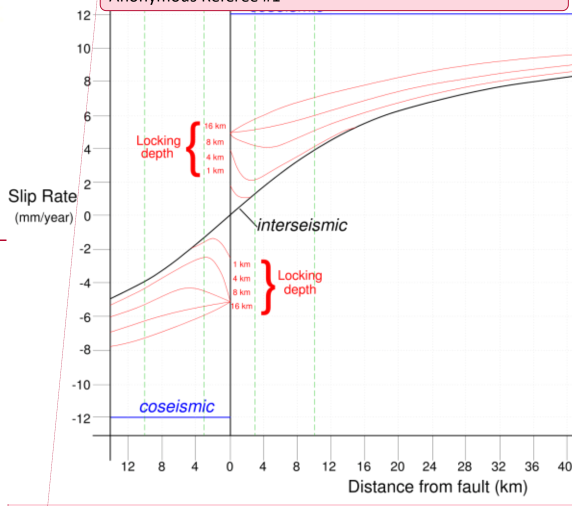


Figure 129. Slip rate along a fault plane during interseismic and coseismic events. Blue lines represents the coseismic, and black line represents the interseismic behaviour, where red lines demonstrates the aseismic creep ratios at two sides of the fault for different locking depths. Green lines indicates 3 and 10 km on the both side of the fault where the interseismic behavior disintegrates from aseismic creep (after Yavasoglu et al. 2015).

Figure 129 demonstrates the suitable distances to detect aseismic creep. If an aseismic creep is suspected on a fault plane, then the optimum locations for the observation stations should be around 3 and 10 km on both sides of the fault, and can be resolved from the interseismic movements. Therefore, observation stations, which are mentioned before, are established around the fault as profiles to detect this discrepancies, and to detect the main locking depth of the fault and attenuation depths for the creep event. Their locations are suitable to evaluate both creeping ratios and locking depths of the faults.

Discussion

Station velocities all around the region indicates the relative motion of the Anatolian plate regarding the Eurasian plate. Movements ranges between 15-24 mm/year inside the southern plate where the northern motion reaches down to ~1 mm/year. This That result is consistent with the previous studies (~24±2 mm/year)(McClusky et al. 2000, Reilinger et al. 2006, Yavasoglu et al. 2011). In addition, model locking depths and results are similar with a more recent study with InSAR, which indicates that the locking depth of the fault at Ismetpasa segment around 13-17 km and long-term tectonic movement is about 24-30 mm/year (Hussain et al. 2018).

Special features of the ~~I~~inspected segments~~' special features~~ are revealed by the network established near the fault plane. Regarding the surface velocities of the observation points, profiles on both Ismetpasa and Destek segments indicate~~s~~ movements. ~~This~~ That ranges between 10.1-14.9 mm/year and 10.6 mm/year for Ismetpasa and Destek segments, respectively.

~~On the other side,~~ Additionally, modeled fault plane evaluation for observed and calculated station movements demonstrates similar results with the locking depths of ~~the~~ both creeping and seismogenic layers (Fig. 13~~0~~). Station velocities on the south of the NAF are faster than the north-end as expected (Fig. 14~~1~~). Regarding the long-term geodetic block motions, modeled weighted locking ratios indicate~~s~~ a 13.0±3.3 mm/year of aseismic creep all over the Ismetpasa segment. ~~This~~ That movement does not include the whole fault plane, thus the creeping layer seems to slip freely to 4.5 km depths from the surface and decays between 4.5-6.75 km. The seismic data and previous studies (Cakir et al. 2005, Yavaşoğlu et al. 2011, Hussain et al. 2019) indicate~~s~~ that the locking depth all over the fault as ~15 km. This result demonstrates the fully locked portion of the fault plane is between 6.75-15 km, which supported by the χ^2 test result (1.00).

Açıklamalı [O16]: Text added for the comment #9 from Anonymous Referee #2

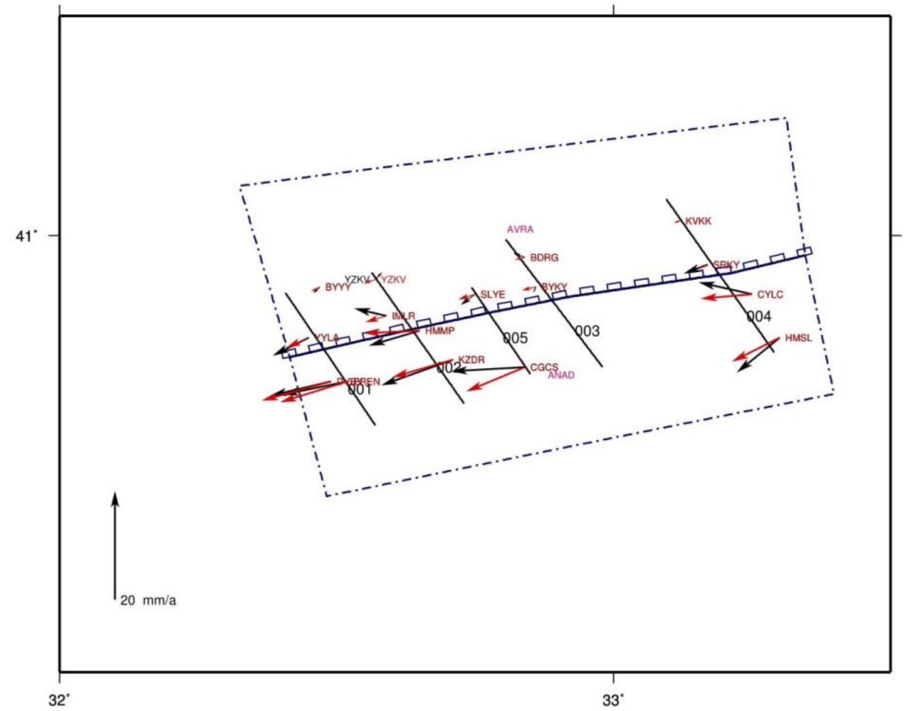
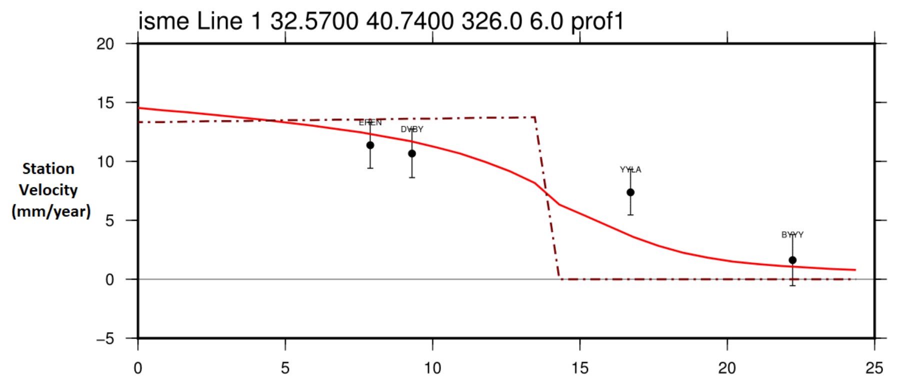


Figure 13~~0~~. Model area for Ismetpasa segment with Eurasian plate (AVRA) on the north and Anatolian plate (ANAD) on the south (dashed lines), divided by the creeping segment of the NAF. Black and red arrows represent the observed and modeled velocities respectively, obtained from GAMIT/GLOBK and TDEFNODE. Five profiles are numbered from west to east with 001 to 004, where 005 represents the intermediate profile established during the 1st campaign. Two stations (SLYE and CGCS) on the south-end of the profile 003 removed from the model due to unexpected velocities. Rectangles imply the fault trace.

Açıklamalı [O17]: Added after the comment #17 from Anonymous Referee #1

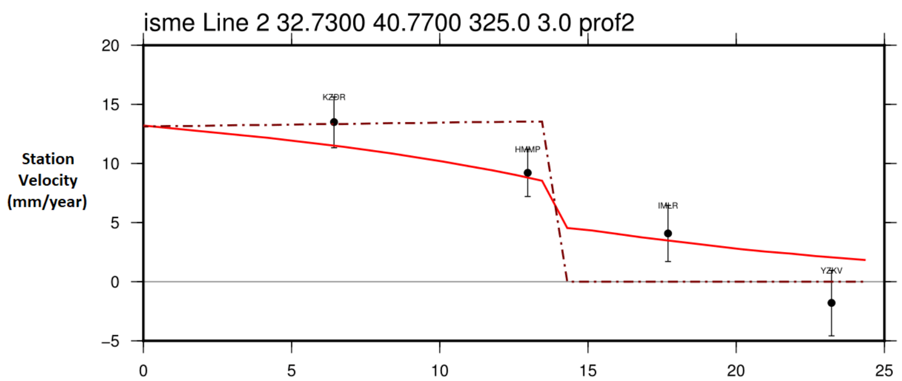
(a)



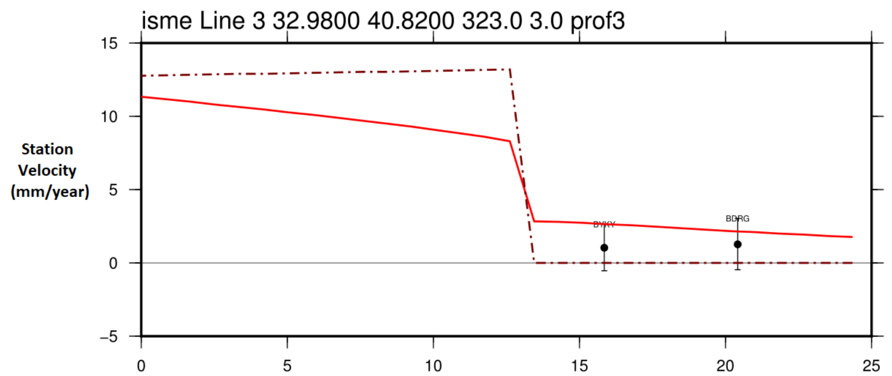
Açıklamalı [O18]: Figures revised for “(mm/year)” for the comment #3&18 from Anonymous Referee #1

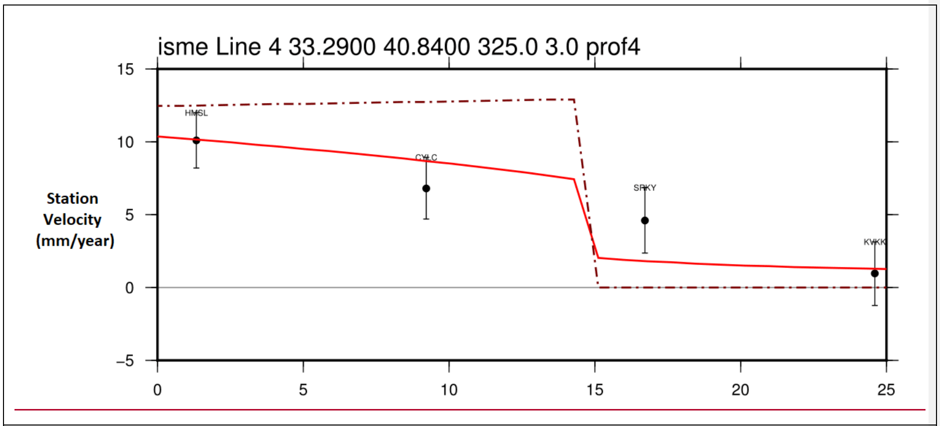
Figures rearranged after comment #7 from Anonymous Referee #2

(b)

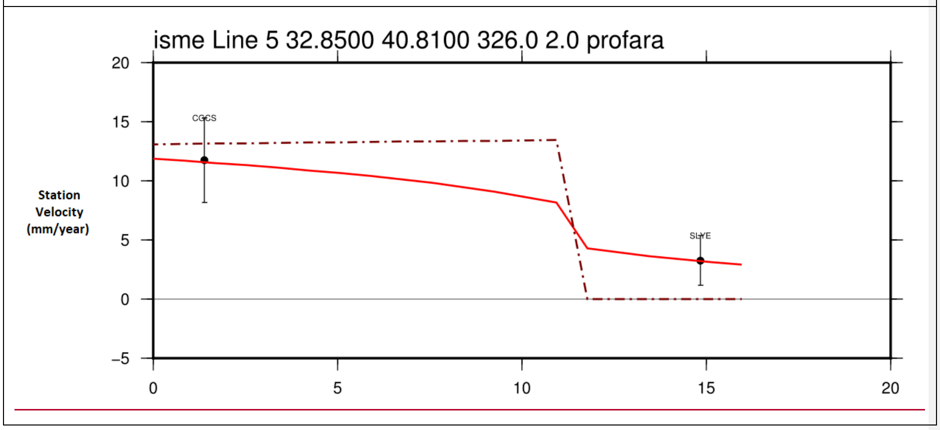


(c)



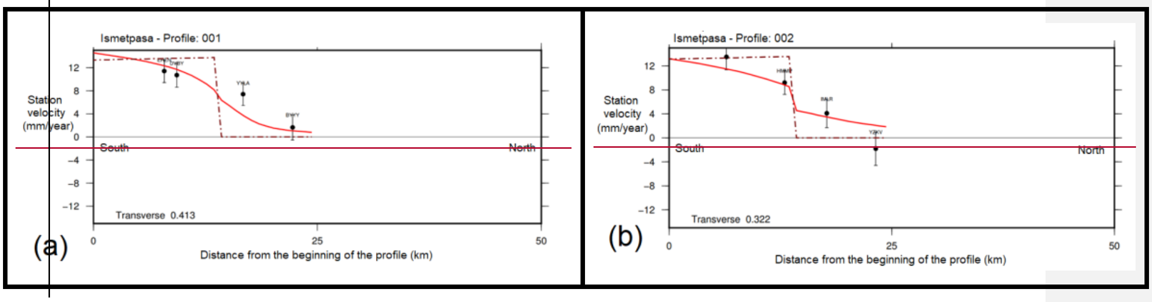


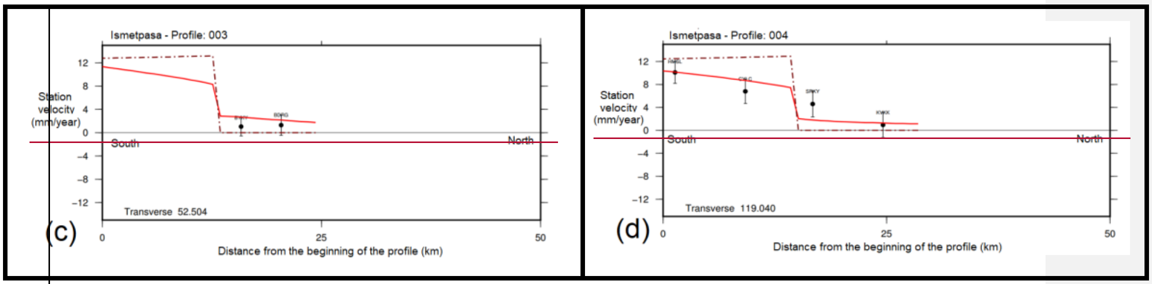
(d)



(e)

Figure 14. Station velocities distant 25 km for each side(east-west)through the profiles 001-005. Each station represented by a block dot, its code, and error ratio with vertical lines. Dashed lines are the block boundaries and red lines for the trend of velocity variations. Profiles 001-004 shown with a, b, c, and d, respectively. Intermediate profile(005) shown as (e). All the profiles are dispread from south to north.





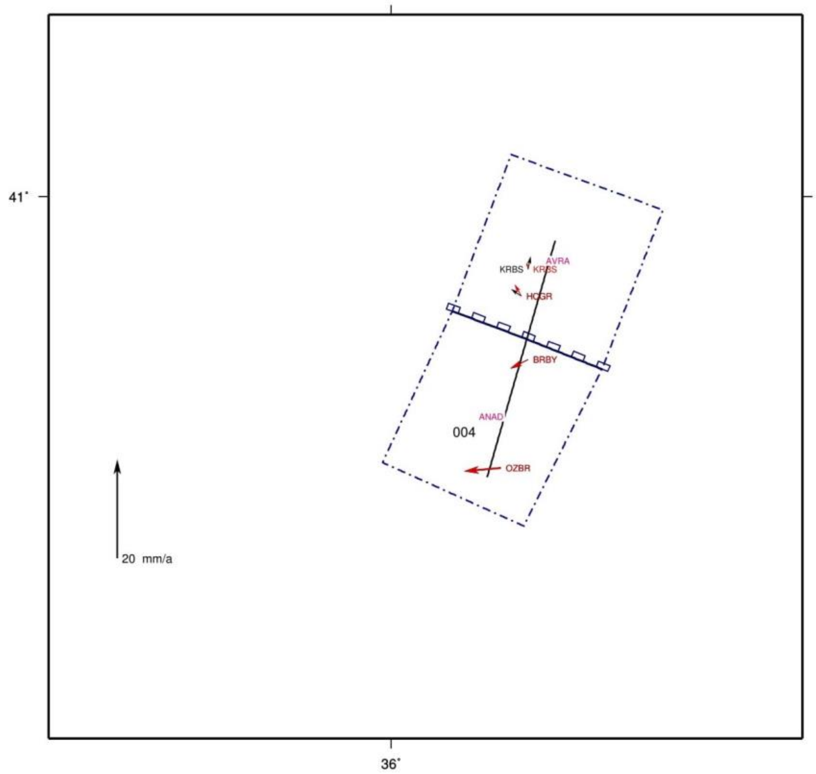
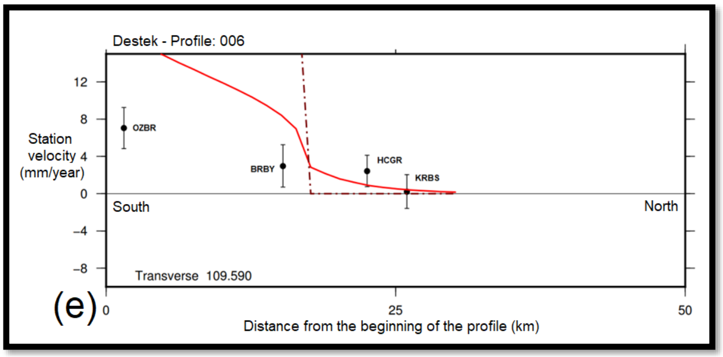
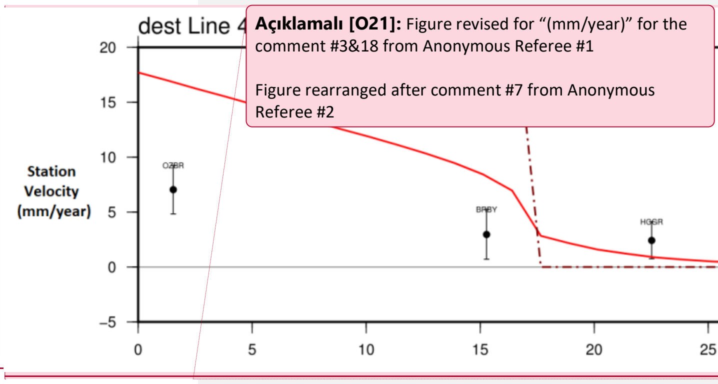


Figure 15~~2~~. Model area for Destek segment with Eurasian plate(AVRA) on the north and Anatolian plate(ANAD) on the south(dashed lines), divided by the creeping segment of the NAF. Black and red arrows represent the observed and modeled velocities respectively, obtained from GAMIT/GLOBK and TDEFNODE. 004 represents the profile in the area and rectangles imply the fault trace.

Açıklamalı [O20]: Added after the comment #17 from Anonymous Referee #1





Açıklamalı [O21]: Figure revised for "(mm/year)" for the comment #3&18 from Anonymous Referee #1

Figure rearranged after comment #7 from Anonymous Referee #2

Figure 1~~3~~6. Station velocities and profile (006) for the Destek profile. Each station represented by a block dot, its code, and error ratio with vertical lines. Dashed lines are the block boundaries, and red lines for the trend of velocity variations. Profile dispread from south to the north.

~~On the other hand, ~~Moreover, ~~P~~paleomagnetic data indicates a predominantly clockwise rotation of the blocks bordered by the faults between Ismetpa~~s~~şa and Destek segments. Examining the results with this study promotes ~~this~~ that behavio~~u~~r with the GPS field of the region, especially on the Anatolian side of the NAF (Figure 1~~0~~3&15~~2~~) (İşseven and~~&~~ Tüysüz, 2006).

We find no clear evidence for attenuation at both segments.~~, o~~On the contrary, there is a slight increase at Ismetpasa and almost 50% of an increase at Destek regarding the previous studies. The frequency of this phenomenon at both ~~sites~~ segment is unclear, but results at *Hussain et al. (2018)* assists that~~is~~ argument~~,~~ that the creep event will continue until the next large-scale earthquake.

Conclusion

NAF reported to have a creeping phenomena at Ismetpasa since 1970 and observed with different techniques for a long time period with a recent discovery at Destek. All the previous studies concentrate on~~ the~~ whole segments or at least some regions along ~~these~~ those segments. With this study, a GPS network covering the whole Anatolian region along the NAF is established for the first time and results for the velocity area used as input for block modeling. Also, the first GPS network covering Destek segment established during this study.

Network design and location of the observation points distinguished according to the main locking depth of the NAF and attenuation depth for the aseismic creep event. Model results show similar outcomes for both Ismetpasa and Destek segments, where locking depth for ~~these~~ those segments are ~15 km, and attenuation for the creeping layer depths varies between ~4-6 km.

Through all the models, results for this study indicate~~s~~ that the creeping behaviour still continues at both Ismetpasa and Destek segments, with a ratio of 13.0±3.3 mm/year and 10.6±3.1 mm/year, respectively. Block modeling and seismic data indicate~~s~~ that the creeping segment does not reach to the bottom of the seismogenic layer (~15 km) and is limited to some depths, which may not prevent a medium-large scale earthquake in the long term. In addition, we found no evidence for the attenuation of aseismic creep. Also, the frequency of this movement at Ismetpasa is unclear and it is not possible to predict the aseismic creep ratio precisely for long-term, but results might indicate a small increase in the trend regarding the previous studies in the region.

~~On the other hand,~~ Additionally, the creeping ratio seems to increase almost 50% at the Destek segment considering the previous studies, which might indicate a relief at that segment. However, according to the model, aseismic creep is limited to some depths (~6.0 km) and creep ratio is smaller than the long term block movements. The increasing trend is not sufficient to release all the strain in ~~this~~ that segment. This might indicate strain accumulation on the both ends of the segment.

The established network by this study should be monitored periodically for the assessment of the frequency of aseismic creep precisely, which may include possible clues for a clear fault plane definition and earthquakes. In addition, results indicate~~s~~ that this creep event will be monitored to the next earthquake, which might reveal valuable information for fault zone layout model.

Acknowledgements

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