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Interactive comment on "Fault distance-based approach in thermal anomaly detection before strong Earthquakes" *by* Arash Karimi Zarchi and Mohammad Reza Saradjian Maralan

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We appreciate the time and effort that you have dedicated to providing your valuable feedback and your insightful comments on our manuscript. We have been able to incorporate changes to reflect most of the suggestions you have provided and will be accessible in our next uploading manuscript.

Before we get to the comments, we believe it is better to explain how this method can be used in predicting the earthquake:

Consider 5 of the earthquakes have already occurred and the 6th earthquake has not

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Discussion paper

happened yet. Using the information regarding these 5 earthquakes we could find the corresponding fault since the locations of the epicentres are known for these 5 earthquakes. Since we know the exact days and intensities for these 5 earthquakes we can compute the optimal value of K for anomaly detection methods and generate our network for ANN (since many studies have investigated these earthquakes using similar anomaly detection methods we could also use their results regarding the optimal value for K). Now that the K value and our network are generated we can move to the next step, the 6th earthquake. It is true that we do not have the coordinates of the epicentre for this earthquake; we do know the locations of all the faults in the country (on greater scale the world). We can use data regarding every fault to test them in anomaly detection method and ANN to see if any anomalies can be detected in them and if they do what intensity these anomalies can cause. Since the fault correspond to the 6th earthquake is one of the faults in the country we ultimately see anomalies regarding the data from this fault which indicates the possibility in occurrence of an earthquake near the area with the intensity computed from ANN.

General comments

1-Fault identification: often, a "fault systems" rather than a single fault, is activated during strong EQs. How the method can handle this? Not clear. In addition, the identification and selection of the fault is, even in this work, carried out aftermath, when the epicentre position is well known: how can manage this in terms of EQ forecast?

In cases that multiple faults are engaged and a "fault systems" is activated, buffers can still be made around the multiple faults but it is highly recommended to consider only active faults to reduce the number of faults and test each fault individually to see which one has the similar pattern to the rest of the earthquakes.

2-LST anomaly identification: to remove natural/observational noise, authors consider "…a previous year with no strong seismic activities…" and subtract this "linear function" from the data. In my opinion, 1 year is not enough to be considered as repre-

sentative of the actual "normal" conditions of the area. A single year, in fact, can be affected by other (e.g. meteorological) forcing factors, limiting its representativeness for a "normal" year and significantly impacting in thermal anomaly identification.

It is true that using only a linear function and data regarding the previous year cannot entirely removes natural/observational noises it does remove the seasonal changes, which contains majority of these noises. Moreover, since LST's changes depend on various factors it is almost impossible to remove these noises completely.

3-coefficients k: to detect a thermal anomaly, authors apply two different methods, both requiring a threshold test based on a "k" coefficient that seems determined in a totally arbitrary way. K values determination, as well as their possible variability and dependence on different environmental/observational/geographical conditions should be better justified and assessed. Additionally, it is not completely clear how the average and sigma are computed.

As mentioned, we can compute the optimal value of K using data regarding the other 5 earthquakes. As for the average and sigma, we will insert their equations in the future manuscript accordingly.

4-Buffer radius: authors consider LST mean computed in buffer radius from 1 to 20 km. Why limiting R < 20km? It is well known that the "preparation zone" of a strong EQ could be as large as the Dobrovolsky theory (Dobrovolsky et al. 1979), i.e R = 100,43M (with M= magnitude). In particular, for M=6 a radius of about 400 km can be expected for the EQ preparation zone. Moreover, if thermal anomalies are related to fault degassing, gases (e.g. CO_2) might be spread in large areas, also depending on meteorological conditions (e.g. wind intensity and direction) and/or local topography. Therefore, the limitation at 20 km should be better explained and scientifically justified.

It is true that the earthquake's preparation zone is much farther than 20km but in distant zones, each earthquake follows a different pattern and using them in ANN and anomaly detection method will result in very weak network and lower the outcome accuracy.

5-How ANN works to estimate EQ intensity? Have the authors trained the network using the same dataset they used for results or an independent one?

I hope my explanation in the beginning of this letter provides the necessary information regarding this issue.

Specific comments

Figure 3: what do the black dots mean?

The black dots in figure 3 represent the LST mean value in each day and buffer zone. curve fitting was used to show a smoother curve in diagram.(the smooth fitted curve is just for better showing the diagram and the exact LST mean was used in any algorithm mentioned in this study)

-It is not clear how the fault distance map is used in the process. Please clarify.

-Not clear how the LST mean is computed in buffer radius. In particular, please better explain the following sentence: "It should be noted that width of each buffer is only 1 km and R is the buffer radius (distance) from the related fault."

These two comments are connected. The LST mean is computed in each buffer radius using the fault distance map. Since pixels in same buffer zones have the same value in the fault distance map, we could use it to average the LSTs in each buffer zone. "It should be noted that width of each buffer is only 1 km and R is the buffer radius (distance) from the related fault" this phrase means each buffer is subtracted from its next buffer. For example, the buffer with 4 km radius consists of only pixels in the range of 3-4 km.

-Lines 204-207: authors assert that anomaly far from the epicentre are not used for ANN. Thus, authors are using epicentre information for filtering data, but epicentre position is only available after EQ occurred, so this study appears as a retrospective analysis as well, and cannot be used for forecasting

I hope my explanation in the beginning of this letter provides the necessary information regarding this issue.

-Lines 230-231: "Although these anomalies are not as strong as the anomalies detected near the time of the earthquake, they seem to be related to some seismic activities rather than being a false alarm": how authors can assert this? What is the scientific basis for asserting this?

Some earthquakes (aftershocks) was reported around the same days these anomalies were detected but their intensities were not even close to the main earthquakes (MS≤4). That's why we could not be certain about these anomalies on what have caused them but perhaps using the word "false alarm" is a strong word so we will change it in the future manuscript.

-Lines 233-234: ..." Many anomalies detected by this method are related to the earthquake...". Again, how authors can affirm this?

What we meant was that these anomalies are most likely be related to the earthquake and can be used in anomaly detections and ANN since they appeared around the day of the earthquakes and have similar pattern in most of the earthquakes.

-Lines 244-245: "ANN results also show high correlations between thermal anomaly data and 245 the earthquakes intensity." What exactly does this sentence mean?

This sentence means that the stronger the earthquake the greater the difference LST between the detected anomaly and its surroundings both in day and distance. In other word, a strong earthquake not only has a greater anomaly on the day of the earthquake during the investigation days but also has a greater anomaly in the nearest buffer to the fault on the day of the earthquake.

Cited reference Dobrovolsky I P, Zubkov S I and Myachkin V I, 1979 Estimation of the size of the earthquake preparation zones Pure Appl. Geophys. 117 1025–44.

Please also note the supplement to this comment:
https://nhess.copernicus.org/preprints/nhess-2020-391/nhess-2020-391-AC1-supplement.pdf

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