

**Third Referee Report on MS angeo-2019-97 “Historical Aurora
Borealis Observations in Anatolia during medieval period:
Implications for the past solar activity” by N. Maden**

General Comments

Apparently, the author has slightly improved this manuscript but the revision seems only stopgap and cannot resolve the problems at its roof. Therefore, I have addressed my concerns as positively as possible and tried to show how to revise this manuscript more explicitly. The novelty issue should be resolved pushing scientific implications for the medieval grand maximum and the extreme solar particle storm in 774/775, as the author does not have any novelty in the source records. The usage of “Anatolia” is highly problematic, as Constantinople, providing more than half of involved reports, is situated in the European side. The author needs to be more explicit about the obtained implication for the solar activity around the extreme solar particle storm in 774/775. The climatological discussions must be removed as the current evidence does not satisfy scientific threshold and will reduce the value of this manuscript. Overall, these comments are minimal requirements for publication in the *Annales Geophysicae*, which “publishes original articles and short communications (letters) on research of the Sun–Earth system...”. The author is dully requested to address these comments appropriately and improve his scientific discussions and English grammar.

Specific Comments

1. Novelty of the Records

Unfortunately, compiling local auroral reports from existing catalogs does not guarantee novelty. This is especially the case, as the author explicitly admitted that he has not consulted the original historical documents and declined to provide example images of the original historical documents. The readers *would* have found its novelty, if the author *extracted* auroral records not from existing catalogs but from original historical documents.

Even more seriously, more than half of the auroral reports in this catalog (9 out of 14) are derived not from Anatolia but from Constantinople. As Constantinople is situated in the European side (“Macedonia” in the Byzantine Epoch or “Rumelia” in the Ottoman

Epoch), they are not classified as “historical Anatolian Aurora”. This is explicitly shown in Figure 1. Therefore, this catalog must drop these 9 records, in order to let this manuscript be a “historical Anatolian Aurora catalog”.

Therefore, the author needs to show its novelty in his scientific discussions, as these data are not new and more than half of them are not from Anatolia.

2. “Strength of the Aurora” and their Validity

This has been much improved, removing misleading usage of likeliness evaluations. However, the narrative in L61-70 is then too long. Given the author’s existing discussions, this lengthy phrase (“Neuhäuser and Neuhäuser (2015) are implemented ... cannot be classified as extreme events associated with extreme magnetic storms.”) should be revised and connected more to their scientific discussions as follows:

“Recently, such candidate records of mid-latitude aurorae have been intensively investigated (*e.g.*, Usoskin *et al.*, 2013; Stephenson, 2015), due to the discovery of footprints of an extreme solar particle storm in the cosmogenic isotopes around 774/775 (Miyake *et al.*, 2012; Usoskin *et al.*, 2013; Mekhaldi *et al.*, 2015). While Neuhäuser and Neuhäuser (2015) suggested five likeliness “criteria” and rejected most of the candidate aurorae around this event. However, these criteria actually contradicted auroral behaviour during the extreme space weather events (Kimball, 1960; Kataoka and Iwahashi, 2017; Kataoka *et al.*, 2019; Kataoka and Kazama, 2019). Indeed, Stephenson *et al.* (2019) rejected these criteria and their analyses on the basis of multiple counter-examples during the extreme space weather events and confirmed an enhanced solar activity around this epoch. Their conclusion is consistent with the isotope evidence for the extreme solar particle storm such as the detected ratio of Be10 and Cl36 (Mekhaldi *et al.*, 2015), latitudinal concentration of C14 concentration (Uusitalo *et al.*, 2018), and coincidental spikes of the multiple cosmogenic isotopes in both hemispheres (Büntgen *et al.*, 2018).”

3. Solar Activity around 774/775

In order to push their scientific novelty, the author needs to expand this section, rather than dropping it. Extending what the author has written, I would suggest writing as

follows, on the basis of what the author has claimed.

“The low-latitude aurorae of 772-773 are interesting, as being very close to the extreme solar event of 774/775 (Miyake et al., 2012; Usoskin et al., 2013; Mekhaldi et al., 2015). These low-latitude aurorae are quite close from the extreme solar particle storm in 774/775 and support not the solar minimum (Neuhäuser and Neuhäuser, 2015) but high solar activity back then (Usoskin *et al.*, 2013; Mekhaldi *et al.*, 2015; Stephenson *et al.*, 2019).”

4. Chronological Coverage

To say “1453 is considered the end of the medieval period by historians”, the authors must provide evidence. This is the end of Byzantine Empire, not the medieval epoch. I do not think the Ottoman conquest of the Constantinople is a benchmark of the medieval epoch. After all, it is not “medieval Anatolia” but “Byzantine Anatolia” that the author surveyed.

5. Definition of the Medieval Anatolia

The revision of Figure 1 can be mistaken as concealment, as Constantinople is anyways situated not in the Anatolian side but in the European side. The existing title with “Anatolia” is anyways highly misleading. If the author wishes to keep this title, the author must drop 9 records from Constantinople. The territory of Anatolia and modern Republic of Turkey is not the same.

6. Relationship with Past Solar Activity and Climate Change

As I commented before, the author must not mix up the solar activity and the terrestrial climate changes (see Vaquero and Trigo, 2012; Lockwood et al., 2017). As the author does not have a clear tie between the medieval solar maximum and medieval warm period, the author needs to discard almost everything between P12L269 and P14L309: “*This study could also be significant constraints for exploration of solar activity on Earth’s atmosphere and climate during the historical periods previously proved by Bard and Frank (2006). ... An important increase in agricultural production and population seems to have occurred in Anatolia after the year of 1100*”. If the author wishes to claim this relationship, he needs more supporting evidence and write another

article.

Then, the author needs to rewrite his discussion on the medieval grand maximum focusing not on the periodicity but on the amplitude of solar cycles. I would suggest writing as follows.

“Vaquero and Trigo (2012) stated the period from 1095 to 1204 as an average solar cycle length, whereas this needs to be carefully compared with the reconstructed solar cycles on the basis of cosmogenic isotopes (Miyahara *et al.*, 2008; Kataoka *et al.*, 2017). Nevertheless, this period is characterised with numerous records of sunspots and aurorae shown in Vaquero and Vazquez (2009) and supported by Anatolian reports compiled in this article. This is highly consistent with an appearance of a gigantic sunspot in 1128 that caused a serious geomagnetic storm (Willis and Stephenson, 2001) and contrasts well with the Oort Minimum (Usoskin *et al.*, 2007, 2017; see also Inceoglu *et al.*, 2015). Indeed, Bekli *et al.* (2017) demonstrated that the naked-eye sun spot observations from 974 to 1278 and aurora records from 965 to 1273 show multiple unusual peaks related to the high solar activity at latitudes below 45° by using Chinese and Korean historical sources.”

9. Conclusion

I appreciate that the author compiled auroral reports in Anatolia and Balkan Peninsula (Constantinople) from existing catalogs and compared them with other scientific results. However, unfortunately, what the author did in the climatological context does not satisfy scientific threshold and needs much more scientific supports. This can be done only writing another article for that issue. Therefore, the fifth and sixth conclusions must be removed, as well as the discussions on the climate change. Instead, the author should add their finding on the high solar activity around the extreme solar particle storm in 774/775 in the conclusion.

Minor Comments

P1L14-17: “High Aurora activity during the years around 1100 in Anatolia and Middle East is quite consistent with the past solar variability and planetary climatic changes drastically impacting on the economy and human events.” => “High auroral activity

around the extreme solar particle storm in 774/775 and the medieval grand maximum in 1100s in Anatolia and Middle East is quite consistent with the past solar variability reported in other scientific literature”

P7L145: Neuhäuser and Neuhäuser (2015) did not do anything more than HARRAK (1999) for Zuqnin Chronicle. Just cite HARRAK (1999). These Zuqnin records have been intensively analysed in Hayakawa et al. (2017). Cite it here and Table 2 #11.

P8L187: Cite references for definition of the Armenian years.

P14L313: “Medieval grand maximum” should not be mixed up with “Medieval Climate Anomaly”.