Angeo-2022-4 Response to referee

We thank the editor and referee for taking the time to read our revised manuscript. After carefully reading and considering the referee comments, we have made the following revisions (**in bold**) to the manuscript.

- Figure 2: What about this one (or similar), where d**Δ H**/d*t* is also depicted?
  - **We find this graph useful and have included a similar figure in our manuscript as Fig 2, as suggested.**
- "… Please, use **ΔH** to avoid confusion. … Note that the two occurrences of "d" in d**Δ H**/d*t* should not be italicized"
  - **After considering this point, we decided to change all occurrences, where H refers to the baseline subtracted magnetic field vector, to "ΔH". We also corrected the formatting of d's in the derivative notations.**
- "Regarding the reliability of the external/internal separation of the geomagnetic field perturbations, I understand that the arguments given by the authors in the new version of the manuscript and in their response to my comments point to a reasonable separation. However, given the importance of this point in the manuscript, the authors should give further arguments beyond more or less reasonable speculation. I also understand that they do not have an alternative code at hand to compare separation methods independent from each other (based, e.g., on SCHA, or on an EM forward solver capable of providing the separation given the ground conductivity structure shown in Juusola et al., 2020). So, in an attempt of flexibility on my side, I propose to the authors an alternative check based on SECS: … "
  - **This is a valid suggestion, and actually a similar reliability analysis has been performed previously in Juusola et al., 2020 (Section 4.3):** "*… By removing the three nearest stations of ABK, KIL, and MUO, we can significantly decrease the density of the network around KIR. We run the magnetic field separation with this reduced network and then compute k, similar to the analysis presented in Sect. 3.2 and 3.3. The resulting internal contributions are 26 % (22 %) for Bx, 39 % (30 %) for By, 58 % (47 %) for dBx/dt, and 66 % (51 %) for dBy/dt. The numbers in parentheses give the corresponding contribution for the intact network (Table 1). There is some increase in the internal contribution with the reduced network, indicating that structures smaller than what the network can resolve at 90 km altitude may be mapped underground instead. However, the relative behavior of the different parameters remains unchanged. This indicates that although our numbers are somewhat sensitive to the station configuration, the conclusions drawn from them should still be valid.*"
  - **We also note that since our analysis covers over 20 years, the number of available stations changes over that time. We have included the number of stations used in SECS separation each year in Figure 10 (also attached here). The amount of stations has doubled between 1996 and 2018. Still, there is no obvious trend, for example, in Fig. 9, which shows the mean direction and standard deviation of magnetic field directions at three stations. This suggests that the number of stations used in SECS separation does not significantly affect our results. Mention of this was also added to Section 4.1 L 211-214.**

- **Finally, a thorough analysis on the reliability of the SECS method should be done in the future. However, it is not a straightforward task. Comparing to a different method would only tell about differences between the chosen methods. So far, there is no "ground truth" to which to compare the method. Also, running the SECS code for different station configurations takes time. Repeating the analysis, for example, for one year of data, on ten different station configurations would take over a month of computing time. This reliability check is still an important and interesting topic for future manuscripts.**

- **"**After rereading the manuscript, I realize that the significance of Figure 9 is rather limited, and I think it could be improved. …"
  - **Figure 9 was modified to include standard deviations for each year. Also relevant text was added L155-159.**

Minor points:

- L39: "the" is repeated.
  - **Fixed**
- L48: "more complex than that of"
  - **OK**
- L75: Please, cite the studies the authors refer to.
  - **Citations to Viljanen, 2001 and Viljanen, et al. 2011 were added L 75**
- L78: "… where Δ**H** is the baseline-subtracted total …"
  - **OK, L 79**
- Figure 3, panel 5): the authors have selected a high range of values for the vertical axis (-100º to 100º) to highlight the small amplitude of the variations of $\Delta\theta(\Delta\mathbf{H})$ compared to those of $\Delta\theta(\mathrm{d}\Delta\mathbf{H}/\mathrm{d}t)$. However, the range of this axis does not coincide with the range of panel 6. Either impose the same range, o rather use a more adjusted range, commensurate with the depicted variation, e.g., +-20º.
  - **Changed the y-range in Fig. 3 panel 5 to the suggested +/- 20º.**
- L166: Add something like: "… 90 degrees, which is the mean of an even
- distribution in $\Delta\boldsymbol{\theta}$".
  - **OK**
- L192: This citation is inappropriate. The referred article performs the separation based on Spherical Harmonic Analysis (SHA), which is suitable for the entire globe. In any case, perhaps Spherical Cap Harmonic Analysis (SCHA) could be one of the suggested regional methods, but it should be noted that difficulties could arise if the size of the sources is larger than that of the region under study. In fact, many of the workers that attempted to model external field variations by SCHA encountered difficulties in the proper separation of external and internal fields for the above-mentioned reason, as discussed in Torta (2020)*. In the case of high latitudes, the main source of geomagneticdisturbances is closely related to the auroral electrojet, which is especially limited in latitude, so SCHA could probably perform comparably to SECS.
  *Torta, J.M., 2020, Modelling by Spherical Cap Harmonic Analysis: A Literature Review, Surv Geophys 41, 201–247. https://doi.org/10.1007/s10712-019-09576-2
  - **Previous citation removed and replaced with *Torta, 2020* . L202**
- L193: "… will be a small portion of the true external field present in the modelled internal field …"
  - **OK, L202-203**
- L252: "The mean of the relative …"
  - **OK, L264**
- L261 and 162: Replace "Appendix …" with "Figures … in Appendices A and B".
  - **OK, L273-274**
- L275: Viljanen et al. (2001, p. 1110)

- **OK, L288**

- Figure A2: Use the format yyyy/mm instead of yyyym or yyyymm in the headers of each subplot.
  - **Ok, date format changed as suggested in Fig. A2**

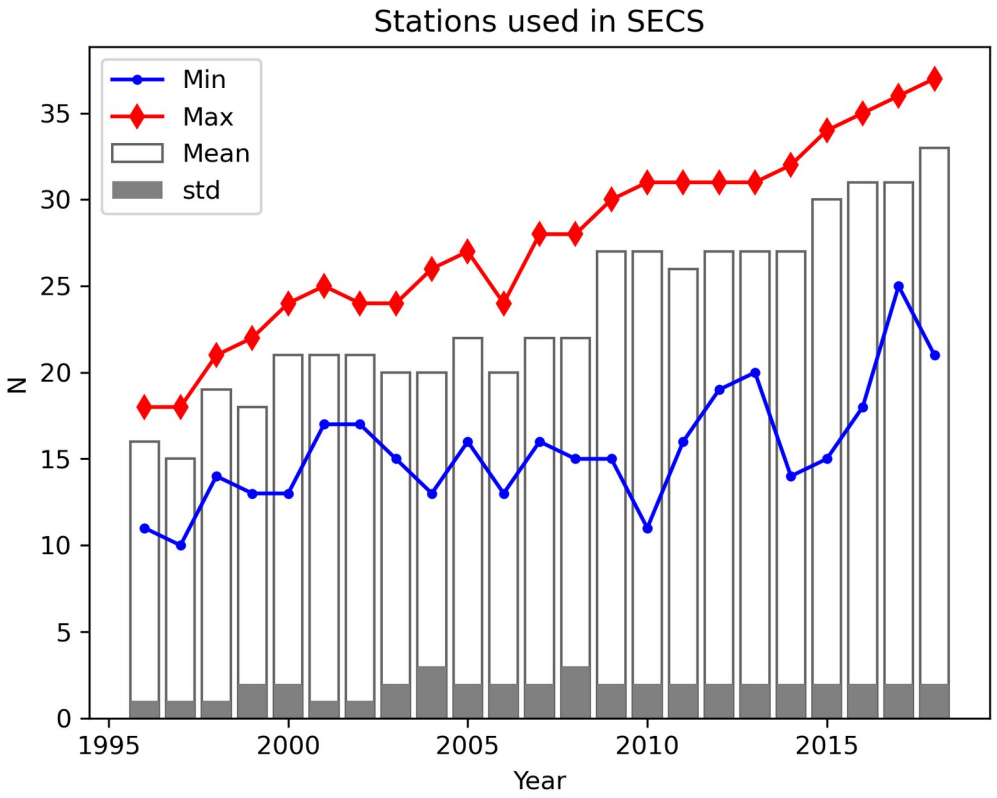

Figure 1: New Figure 10 in manuscript. Number of stations used in SECS analysis each year. Numbers are calculated from daily values.