RC2: 'Comment on egusphere-2025-2563', Jan Wittke, 02 Sep 2025

We would like to thank the reviewer for the helpful comments.

The paper by Matsushita et al, “The azimuth observation by GNSS: A case study at Kakioka” describes how to perform GNSS measurements for geomagnetic observatory work.

Please see my comments below:

The paper is well written and the methods as well as the procedures are presented in a concise way. After reading the whole paper, I was wondering about the scientific significance of the approach. Even this might be a relative new way for some geomagnetic observatories, GNSS observations is a common practice in surveying and a well established method. To improve the paper I would suggest following:

- The introduction should cover more the pro and cons of different GNSS survey modes with respect geomagnetic observatory work.

Response:

We have included the pros/cons from the perspective of observation time and the number of instruments used – which is equal to the cost.

- The allover critical value is β_{GSNN}. There should be a serious discussion how this angle is derived out of the GPS measurements. How does the distance between the points influence the accuracy? How does the calculation is affected with errors?

Response:

We have included more detail of the process of derivation of θ_{GNSS}.

GNSS is basically a technique that determines ground-based positions using radio waves from satellites. However, the relative positioning method in GNSS determines the positional relationship between two points (referred to as the baseline vector). The RTKLIB software utilized for the analysis in this study enables the selection of this baseline vector as an output. Subsequently, the azimuth is calculated from the north-south and east-west components of this vector.

The azimuth deviation relative to position is expressed as the arctangent of the ratio of the position deviation perpendicular to the line of the points to its distance. Here, letting these be δθ, δy, and d, respectively, the equation can be expressed as follows: $\delta\theta = \arctan(\delta y/d)$. As can be seen from this equation, the effect on azimuth becomes smaller as the distance between points increases.

- As the angles β_1 and β_2 are measured with a theodolite are they also affected by DoV? When yes, how does this influence affect the overall angle θ_2 ?

Response:

There is almost no effect of DoV.

The effect of DoV on azimuth is most significant when the target is at the zenith and becomes zero on the same horizontal plane. In this theodolite measurement, targets and theodolite can be considered to be on nearly the same horizontal plane, so the effect is negligible.

- In the comparison between Polaris observations and GNSS observations, there should be a summary on the Polaris observation method and how uncertainties are compared to the GNSS

method. As the authors identify a potential derivation between both methods it remains unclear which one is more absolute accurate. Is it possible to correct the more inaccurate value with the other method?

Response:

In reality, the azimuth values derived from Polaris observations are defined based on observational results. The inaccuracy referred to here is simply the difference between the defined values and the GNSS results.

Roughly speaking, Polaris's azimuth definition is as follows: if the average of the observational results does not deviate significantly from the previous year's average, the previously defined value is retained. If there is a significant deviation, a new value is redefined after the investigation of its cause. In the past, an earthquake caused the azimuth mark's pillar to shift.

With respect to potential derivation, it is difficult to determine which method is incorrect, as this depends entirely on the assumed shape of the Earth. Is it geoid shape like bumpy or rotating ellipsoidal. However, the modeling of the geomagnetic field typically assumes a sphere or ellipsoid, we would like to say that the GNSS method is more absolute accurate. But, it should be noted that continuity with past data and consistency with other observatories must also be considered, making it quite complicated.

Yes, it is possible to correct one to another. The simplest way is to add the difference obtained from both methods. Determining the DoV by measuring the local geoid is also possible.

We have included these points in the text.