M_{split} estimation as an alternative approach for GNSS baseline adjustment in networks affected by outliers

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INTRODUCTION

Global Navigation Satellite Systems (GNSS) have become a conventional technique used in geodesy and surveying applications, including establishing geodetic networks built for deformation monitoring. To obtain the most accurate site coordinates, typically, a post-processing of GNSS data collected at a network of sites is applied. Such a solution may be conducted in a single step using a so-called multi-station mode, or in a two-step procedure with a single-baseline solution followed by a network adjustment. As former studies show, in the case of the precise local networks, both approaches may deliver comparable solutions in terms of accuracy and reliability. This study investigates the latter approach and contributes to handling of outliers during GNSS baseline adjustment. Conventional estimation methods mostly fail to handle outliers in such cases, and even robust methods are sensitive to outliers of a large share. Moreover, the data-cleaning methods are also insufficient as they typically cannot identify multiple outliers. In response, one presents an alternative approach based on M_{split} estimation.

OBJECTIVE

One focuses on a precise GNSS network established for ground deformation monitoring, specifically the one built at the open-pit mine. In this case, there might be several sources of outlying observations, including gross errors or sudden, unpredictable ground movements. The study shows how the proposed estimation method addresses the problem of outliers of different origins present in GNSS networks.

METHODS

The study compares the adjustment results of two basic M_{split} estimation variants, i.e., the squared and the absolute ones, with least-squares estimation (LS) and the Huber method (an example of robust M-estimation). In the case of the squared M_{split} estimation (SMS) and the absolute M_{split} estimation (AMS), one obtains two solutions that are equally important (SMS1 and SMS2, AMS1 and AMS2, respectively).

The data simulate different variants:

- Variant I: height measurement of point KK01 is affected by outlier – one vector is affected by gross error,
- Variant II: height measurements of point KK01 are affected by outliers – three vectors are affected by gross errors,
- Variant III: height measurements of points KK02, and KK26 are affected by outliers – two vectors are affected by gross errors,
- Variant IV: height measurements of points KK01, KK02, KK04, KK06, KK15, KK17, KK21, KK24, and KK26 are affected by outliers – ten vectors are affected by gross errors,
- Variant V: points KK10, KK21, KK24, and KK26 are subsiding during measurements – fifteen vectors are measured after the subsidence.

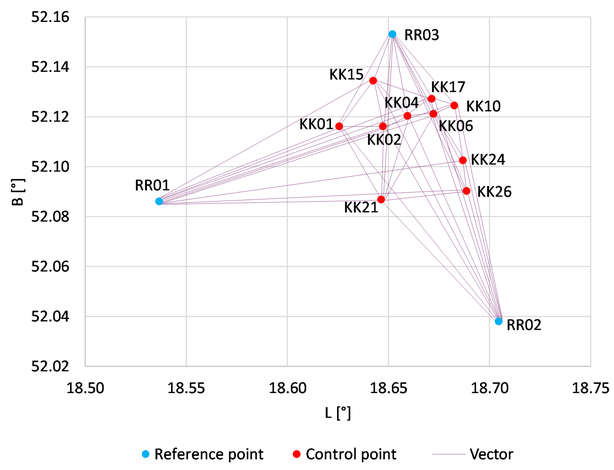

Fig. 1. GNSS network

RESULTS

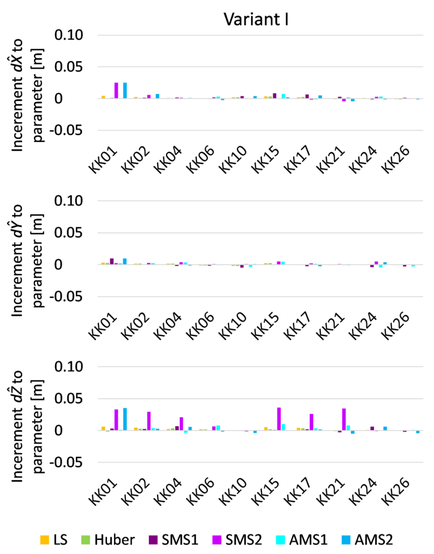

Fig. 2. Estimated increments $d\hat{X}, d\hat{Y}, d\hat{Z}$ obtained for different methods in variant I

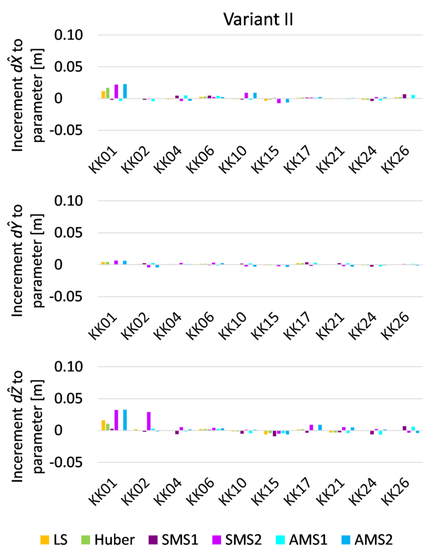

Fig. 3. Estimated increments $d\hat{X}, d\hat{Y}, d\hat{Z}$ obtained for different methods in variant II

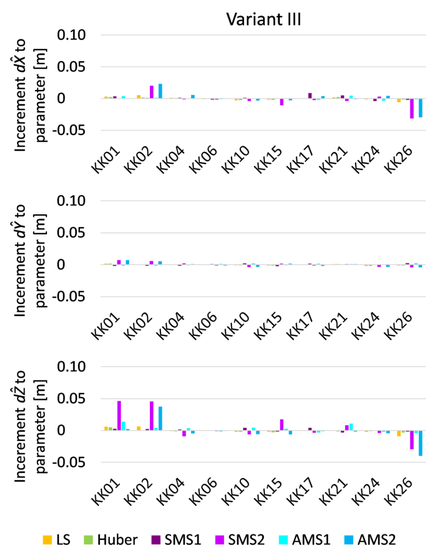

Fig. 4. Estimated increments $d\hat{X}, d\hat{Y}, d\hat{Z}$ obtained for different methods in variant III

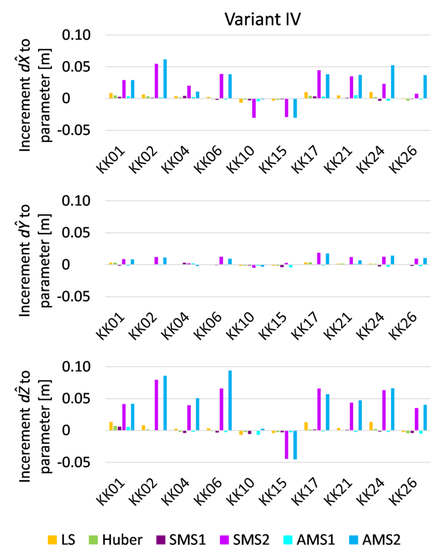

Fig. 5. Estimated increments $d\hat{X}, d\hat{Y}, d\hat{Z}$ obtained for different methods in variant IV

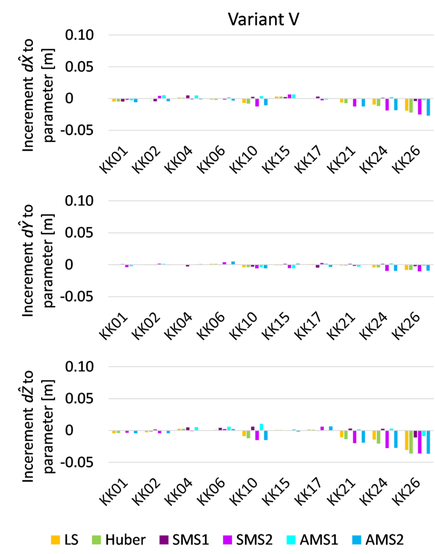

Fig. 6. Estimated increments $d\hat{X}, d\hat{Y}, d\hat{Z}$ obtained for different methods in variant V

UN-GGCE COMMUNICATION CONTRIBUTION

M_{split} estimation provides two equally valid solutions:

- Solution 1 – point positions at the beginning of the measurements,
- Solution 2 – point positions after subsidence (or movement, or when some measurements are affected by outliers).

In such a context, the second solution is not erroneous but provides valuable information on the point shift at the epoch at hand. That might be important in the prediction of landslides or other mining damages.

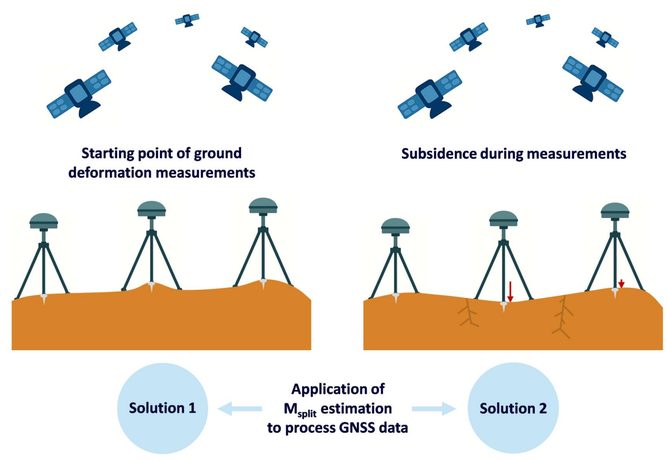

Fig. 7. Graphical summary of how M_{split} estimation might be useful in geohazards

CONCLUSIONS

One demonstrates that the approach based on M_{split} estimation outperforms the conventional estimation methods. M_{split} estimation proves its ability to manage the outliers of different types and magnitudes. The first solutions of M_{split} estimation (SMS1 and AMS1) are almost always approximately 0 m, while the second solutions (SMS2 and AMS2) can provide valuable information about gross errors during measurements or point subsidence.

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