Status of the new German DIN standards project "InSAR–Radarinterferometry for the detection of ground movements"

Volker Spreckels

Chairman of DIN NA 005-03-02 AA – Photogrammetry and Remote Sensing, Germany, (volker.spreckels@rag.de)

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ABSTRACT

The German DIN institute for standards works on the new standards project DIN 18740-9 "InSAR – radar interferometry for the detection of ground movements". Due to the increasing availability of radar satellite data and applications the need for clear and comparable terms and definitions, validated methods and processing as well as ground reference data has been committed to DIN. First meetings with representatives and experts from universities, research and development, public authorities, associations and industries have taken place and it had been commonly agreed to set up this new standard project. A close alignment with international developments of CEN and ISO is intended. The current work of the standards committee DIN NA 005 "DIN-Normenausschuss Bauwesen (NABau)" - NA 005-03 FB "Fachbereich Geodäsie, Geoinformation" - NA 005-03-02 AA "Photogrammetrie und Fernerkundung" will be presented.

I. INTRODUCTION

Due to the increasing number of radar satellites and data archives modern advanced interferometric SAR techniques (InSAR) found their way into day-to-day practice. The detection and monitoring of ground movements is of great interest for the corporate and public sector.

Nation-wide analysis had been made by private companies for several countries like the UK, The Netherlands and Germany (TerraMotion, 2022), but the georeferencing and ground movement validation is not definitely clear.

From the official side some nation-wide InSAR surveys are present like for Italy (Costantini *et al.,* 2017), The Netherlands (Netherlands Geodetic Commission, 2018), Norway (NGU, 2018) and Germany (BGR, 2019). This Germany-wide available "*BodenBewegungsdienst Deutschland* (BBD)" set up by the *Federal Institute for Geosciences and Natural Resources (BGR)* and the *German Aerospace Center (DLR)* meanwhile coexist with official German ground motion services (Figure 1). An already operating service is the "*Saarländisches Bodenbewegungskataster (SaarBoBeKa)*" (SaarBoBeKa, 2022) a German federal state service of the "*Landesamt für Vermessung, Geoinformation und Landentwicklung* (LVGL)". LVGL realized SaarBoBeKa in 2022 in cooperation with Saarlands mining authorities "*Oberbergamt des Saarlands* (OBA)" and the former German hard coal mining company "*RAG Aktiengesellschaft* (RAG)" (Spreckels and Engel, 2022) (Figure 2).

Even in 2022 the "*Bodenbewegungskataster NRW*" from the survey authorities "*Geobasis NRW*" is awaited for the German federal state of North Rhine-Westphalia (Riecken *et al.,* 2019).

For Europe the "*European Ground Motion Service* (EU-GMS)" (Frei, 2017) is under development as an element of the "*Copernicus Land Monitoring Service, CLMS*" (CLMS, 2016).

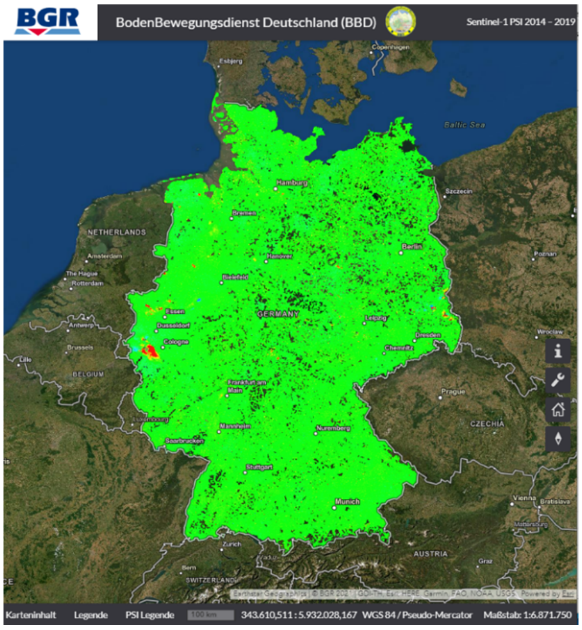

Figure 1. The Germany-wide available, free accessible "*BodenBewegungsdienst Deutschland (BBD)*", based on Sentinel-1A/B Persistent Scatterer Interferometry (PSI) for ascending and descending orbits. Image courtesy BGR.

II. INSAR - METHODS

On FRINGE 2003 the "*European Space Agency* (ESA)" approved to support the validation of the following different InSAR methods: *Permanent Scatterer™ Interferometry* - PSI (Ferretti *et al*., 1999; 2000; 2001), *Small Baseline Subset Algorithm* - SBAS (Berardino *et al.,* 2002), *Interferometric Point Target Analysis* - IPTA (Werner *et al.,* 2003) as well as other developments from *e.g*. (Hanssen *et al.,* 2005; Adam *et al.,* 2003; Kampes and Adam, 2005).

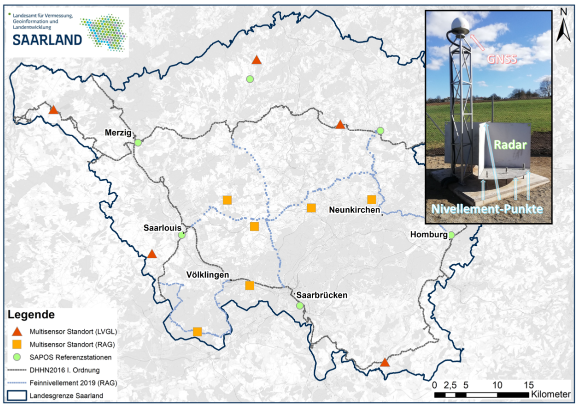

Figure 2. LVGL's ground motion service "SaarBoBeKa", based on combined levelling / GNSS- / double corner reflector stations (MSST) and Sentinel-1A/B Persistent Scatterer Interferometry (PSI) for ascending and descending orbits. LVGL-MSST: red triangles; RAG-MSST: orange squares; SAPOS GNSS Reference stations: green circles. Levelling lines: light grey (LVGL) and light blue (RAG). Image courtesy LVGL.

Another SBAS based development is the "Intermittent Small Baseline Subset" - ISBAS (Lanari *et al.*, 2007).

At this point we see that it is necessary to evaluate this bandwidth of manifold InSAR surveys *e.g*. provided by corporate services as well as services from federal states, from countries or from Europe-wide analyses. The basics, the potentials and the limitations of these diverse, sometimes open to the public results have definitely to be determined to avoid misinterpretation.

Some initiatives have already worked on the evaluation and validation of InSAR-results.

III. International / European Initiatives

The *Terrafirma* project as part of the *"Global Monitoring for Environment and Security Program"* (GMES) had been set up by ESA with the aim to provide a Europe-wide ground motion hazard information service (Terrafirma, 2005-2015) (Figure 3). A *"Product Validation"* and a *"Process Validation"* were established to examine and demonstrate the reliability and accuracy of PSI-methods for ground motion surveys in comparison to ground truth reference data (Hanssen *et al.,* 2008; Crosetto *et al.,* 2009) and for a quality management (Adam and Parizzi, 2008; Adam *et al.,* 2009) (Figure 4).

The standards of the *"International Organization for Standardization"* (ISO) is working on InSAR standards. Here, the Technical Committee ISO/TC 211 *"Geographic Information/Geomatics"*, ISO/TS 19159-3:2018 *"Calibration and validation of SAR/InSAR sensors"* has, up to now, primarily set the focus on the sensors, for their calibration and validation. The contact to ISO/TC 211 will be sought for a close coordination between DIN and ISO.

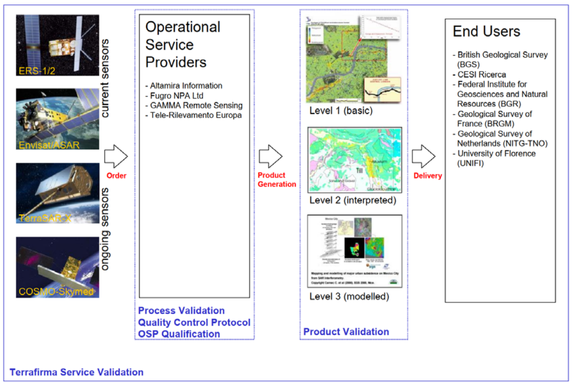

Figure 3. Validation components of the Terrafirma Services: "*Process Validation*" and "*Product Validation*" (Figure 1 in Adam *et al.,* 2010).

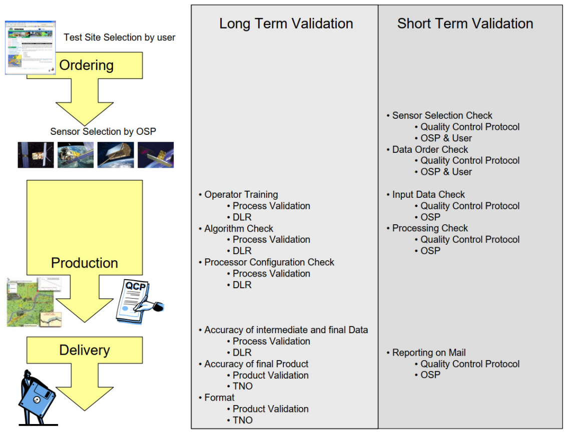

Figure 4. Service elements (yellow) for Level 1 basic products and Long Term / Short Term Validation. (Figure 3 in Adam *et al*., 2010).

IV. National Initiatives

National initiatives dealing with the application of InSAR analyses in day-to-day business are only known to the author for Germany. If other national initiatives are planned, in progress or have been finished, the author will be pleased for a small note or a feedback to the according drafts.

One German initiative was published in 2013, set up by the *"German Mine Surveyor Association"* (DMV)[1]. DMV published guidelines for the *"Deployment of satellite-based radar-interferometric methods for the detection of mining induced ground movements"* (DMV, 2013). The aim was to handle InSAR techniques within the ordinances of the federal mining authorities related to the daily work of the companies within the frame of the ground movement monitoring. These guidelines are currently under revision and will be updated to the latest state of the art in 2022.

Furthermore the *"Working group of the German Survey Authorities"* (AdV)[2] is busy working on a guide

[1] DMV: Deutscher Markscheider Verein e.V., Arbeitskreis „Interferometrie"

[2] AdV: Arbeitsgemeinschaft der Vermessungverwaltungen Deutschlands – Arbeitskreis 6, Raumbezug.

for the "*Use of radar-interferometry in the geodetic spatial reference*" to handle InSAR within the tasks of federal surveying authorities (Riecken and Krickel, 2019).

It is clear to be seen that national and even international standards are necessary to lay the framework for associations, agencies, organizations, data- / service provider and customer as an appropriate means to issue rules and guidelines for producer- and consumer-protection. Here, special attention is paid to the georeferencing of ascending and descending orbit - InSAR-analyses and the validation of movements detected in Line-of-Sight (LOS), as well as the calculated movement components in height and east-west direction against GNSS- and terrestrial ground truth measurements.

V. Standardization

Already since 2015 a standard for InSAR has been discussed at the DIN working committee NA 005-03-03 "*Photogrammetrie und Fernerkundung*" for the standards series 18740 (Baltrusch and Reulke, 2017).

The main topics are

- Terminology.
- InSAR techniques.
- Sensors, processors, algorithms.
- Corrections (atmosphere, topography, …)
- Data availability (free, commercial).
- Requirements on processors and data.
- Application scopes.
- Precise geolocalisation and georeferencing.
- Accuracy requirements for georeferencing.
- *e.g*. with corner reflectors and other sensors.
- Data formats, data provision.
- Cartographic presentation.

In 2017 DIN organized a workshop with presentations held by universities, providers and customers. The need for regulations had been expressed so that the working committee began to look for possible and interested members to be consulted for an active participation. In 2019 a working group had been established but due to the Covid-19 pandemic the activities lost a bit of their momentum. In 2022 the partly reorganized working group will focus on the listed topics in sub-workgroups and plans to publish a draft to the end of the year 2023.

Over the years lots of new techniques and developments have been observed for their potential or market maturity and for their possible importance for the standardization works. New developments for InSAR processing came to market like multi-orbit high resolution SAR interferometry, the decomposition to height- and east-west-movement components from ascending and descending orbit data. An important topic is the correct and accurate georeferencing of InSAR-results. The experience with corner reflectors (CR), double corner reflectors (D-CR) and additional measurement equipment like GNSS and levelling measures will definitely be considered closer.

At the moment different types of double corner reflector stations are realized in Germany:

The German "*Federal Agency for Cartography and Geodesy*" (BKG) installs platforms at the "*Integriertes Geodätisches Referenznetz Deutschland (GREF)*" stations on a deep founded 2 m concrete ring. Two separate trihedal, perforated sheet - CR and a multi-use pillar in the middle are installed on one carrier frame (Friedländer and Liebsch 2019). Levelling points build the connection to the German Height Reference System "*Deutsches Haupthöhennetz 2016 (DHHN2016)*". BKG has already installed 3 D-CR at in total 23 stations as to be seen in Figure 5. An accompanying installation of *Compact Active Transponder* (CAT) is planned.

Figure 5. BKG's station Bremgarten. Image courtesy Bundesamt für Geodäsie und Kartographie (BKG).

The survey authority of the German Saarland (LVGL) use solid stainles steel D-CR founded in down to the solid ground set reinforced concrete blocks. These blocks contain the D-CR and a permanent GNSS station on a lattice mast. Levelling points are set in the D-CR and the concrete block to build the connection to the German Height Reference System "*Deutsches Haupthöhennetz 2016 (DHHN2016)*", see Figure 6. Five of these "*Multisensor-Reference Stations* (MSST)" have been installed in 2021 and operate since March 2022 (Spreckels and Engel, 2022).

The former German hard coal mining company RAG uses nearly the same LVGL configuration. RAG put the D-CR and the GNSS station on a 2 m x 2 m x 2 m reinforced concrete block and uses a self-sufficient solar- / wind power supply, see Figure 7 (Schulz and Schäfer, 2022; Spreckels and Engel, 2022; Spreckels, 2022).

In the Netherlands a network of patented, combined GNSS and D-CR stations, the so called "Integrated Geodetic Reference Stations" (IGRS), see Figure 8, has been installed in parts of The Netherlands (Hanssen et al., 2018).

Figure 6. LVGL's MSST Felsberg. Image courtesy LVGL.

Figure 7. RAG's MSST Primsschacht (left) and solar & wind power supply on RAG's MSST Lauterbachschacht (right). Image courtesy ALLSAT & RAG.

Figure 8. The Netherlands: Integrated Geodetic Reference Station (IGRS). Patented D-CR and GNSS-platform (Hanssen *et al.,* 2018, page 3).

The practical experience of BKG, LVGL and RAG will be considered and accordingly implemented into the work of the DIN committee. It is furthermore intended to establish contact to foreign expertise and to keep a close contact to ISO/TC 211 so that the national and international activities will pull together and not oppose each other.

And, thought before, even future developments will be taken into account like MDA's planned particular CHORUS mission presented end of 2021 (MDA, 2021). Here a collaborative multi-sensor constellation of X- and C-band satellites is foreseen. The satellites move on inclined orbits that allow data recording up to maximum latitudes at 62,5° by ruling out the polar regions (Bamford, 2022).

VI. Conclusion and Outlook

The DIN standards committee DIN NA 005-03-02 AA "*Photogrammetrie und Fernerkundung*" is working on the standards series DIN 18740-9 "*InSAR – radar interferometry for the detection of ground movements*". The working group consists of experts from federal agencies, survey authorities and companies. Additional expertise will be obtained by workshops held together with the members of the remote sensing community in a close exchange of experience.

In 2022 the working group will focus on the topics listed in Section V in different sub-workgroups with the aim to publish a draft of the standard to the end of the year 2023.

Even a close contact to ISO/TC 211 is wanted as well as to foreign experts and groups that we friendly invite to get in contact with us.

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