GETTING READY FOR THE GENERATION OF A NATIONWIDE GROUND MOTION PRODUCT FOR GREAT BRITAIN USING SAR DATA STACKS: FEASIBILITY, DATA VOLUMES AND PERSPECTIVES

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ABSTRACT

This paper discusses the feasibility of monitoring ground stability and motion across the entire British landmass using satellite InSAR techniques. The ERS-1/2 and ENVISAT archive data availability, topographic visibility and land cover constraints for multi-temporal InSAR techniques to succeed across Britain are analysed. Data volumes, hardware and software requirements for the generation of a nationwide InSAR product are discussed, with a view to both novel processing methods to extend InSAR across unfavourable land covers, and parallel and cloud computing systems to decrease InSAR processing time demands. The P-SBAS method implemented into ESA's G-POD platform is tested for London and Newcastle using ERS-1/2 1992-2000 and ENVISAT 2002-2008 image stacks, revealing a decrease of the processing time demand from several days to only ~8 hours per image frame.

Index Terms— InSAR, SBAS, ground motion, Great Britain, big data science

1. INTRODUCTION

The interest in generating satellite Interferometric Synthetic Aperture Radar (InSAR) ground motion products has grown in recent years. This reflects the increased level of awareness and confidence of the scientific community and end-users in InSAR techniques, the enhanced understanding of the precision and accuracy that their derived products can achieve, and the large SAR archives that have been built progressively since the 1990s by several space agencies and made available for a variety of land applications.

A wealth of InSAR studies of geological processes arising from natural and/or anthropogenic causes has been carried out for urban and semi-urban areas in and outside Europe. These studies have used image stacks acquired from a range of SAR sensors with medium to very high spatial resolution, local to wide area coverage, monthly to weekly or even daily revisiting cycles, and weeks up to several years-long monitoring time series.

Some recent projects have also aimed to map land deformation over entire regions, districts, counties and even whole countries. In particular, impressive full national Persistent Scatterers (PS) databases have been generated for Italy (~300,000 km^2) via the Extraordinary Plan for Environmental Remote Sensing (EPRS-E) [1], the Netherlands and part of Germany and Belgium (~70,000 km^2) [2], and via the ESA Terrafirma Wide Area Product (WAP) for half of Greece, northern Germany, the Scheldt estuary in The Netherlands, and western Turkey [3-4] for a total of ~220,000 km^2. These demonstrated the scientific and operational impact of these processing techniques and their derived ground motion products.

With the aim of getting ready for the acquisition and processing of SAR data over the whole of Great Britain and the generation of a nationwide ground motion product, on behalf of the British Geological Survey I have led an assessment of the feasibility of monitoring the landmass with ERS-1/2 SAR and ENVISAT IS2 Advanced SAR (ASAR) imagery, and analysed archive data availability, geometric distortions and land cover control on the success of InSAR analyses [5]. This assessment both addressed the scientific and operational question about whether a nationwide monitoring of ground motion with space-borne InSAR would succeed in Great Britain, and helped to identify and understand controlling factors, limitations and possible solutions to undertake such a monitoring.

This paper summarises the findings of the feasibility assessment [5], identifies the data volumes, hardware and software requirements necessary to generate the nationwide ground motion product, and presents preliminary results from the implementation of the new Parallel-SBAS (P-SBAS) algorithm for London and Newcastle.

2. STATE-OF-THE-ART: CONSTRAINTS AND REQUIREMENTS

The feasibility study in Great Britain revealed the potential for multi-temporal InSAR for the entirety of the landmass using ERS-1/2 SAR data acquired along descending orbits, with over 7,000 images archived between 1991 and 2001 in total, distributed across 109 standard frames (~65 scenes per frame). Over 2,000 scenes are also available in ascending mode for the same period, distributed across 103 standard frames (~20 scenes per frame, on average) (Fig.1).

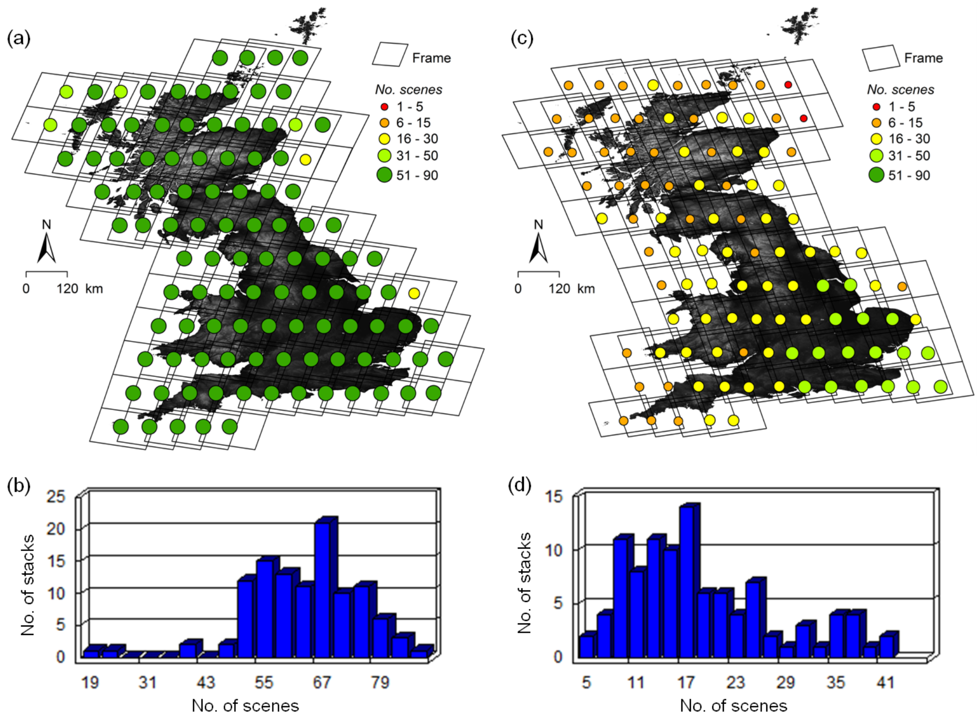

Figure 1: ERS-1/2 SAR image availability over Great Britain in (a-b) descending and (c-d) ascending mode for the full set of standard image frames in each mode. Maps in (a) and (c) are overlapped onto shaded relief of NEXTMap® DTM at 50m resolution. Datum: WGS84. NEXTMap® Britain © 2003, Intermap Technologies Inc., All rights reserved. Modified from [5].

Simulation of SAR layover, foreshortening and shadow to the ERS-1/2 and ENVISAT line-of-sight based on the NEXTMap® DTM showed limited control of local topography on the terrain visibility to the radar sensors. In particular, the results showed that only ~1.4% of the ~230,000 km^2 landmass could be affected by shadow and layover in each mode, with just ~0.04% overlapping between ascending and descending mode distortions. This indicates that only a negligible proportion of Great Britain cannot be monitored using either imaging mode [5].

Subsequent calibration of the CORINE Land Cover 2006 dataset allowed the quantification of land cover control on the distribution and density of PS. The analysis revealed that over 2.5 million monitoring targets for each acquisition mode could be retrieved using a set of image frames covering the entire landmass and exploiting PS processing approaches. The potential impact of such techniques for natural and anthropogenic geohazard mapping and monitoring is showcased for London in [6].

2.1. InSAR across unfavourable land covers

The predominance of non-urban regions across the landmass exerts significant control on the potential for PSI methods to identify scatterers in Great Britain, with main challenges in rural and grassland regions where only a few radar targets per square kilometre can be extracted and monitored via multi-interferogram processing of C-band data.

Newly developed multi-temporal InSAR techniques such as SqueeSAR™ [7] and the Intermittent Small Baseline Subset (ISBAS) [8] approach have looked to increase the coverage of results by working on distributed scatterers (e.g., debris, non-cultivated land, or low vegetation cover) or intermittently coherent surfaces, respectively.

ISBAS, in particular, a multi-looked, low-resolution approach recently developed at the University of Nottingham, has proved its capability at providing remarkable improvements in the number and density of identified monitoring solutions across rural, natural and even woodland terrain in Derbyshire and Leicestershire in England [8], the South Wales Coalfield and areas of blanket peat in north Wales [9-10].

By filling the coverage gaps of InSAR results across land cover types that generally are unfavourable for conventional C-band InSAR and providing up to 40 times more monitoring targets than a conventional SBAS implementation [11], this technique may solve the problem of very low or no potential to identify monitoring targets across averagely low coherence non-urban areas of Great Britain, thus making possible a better understanding of ground stability and terrain motions affecting the landmass.

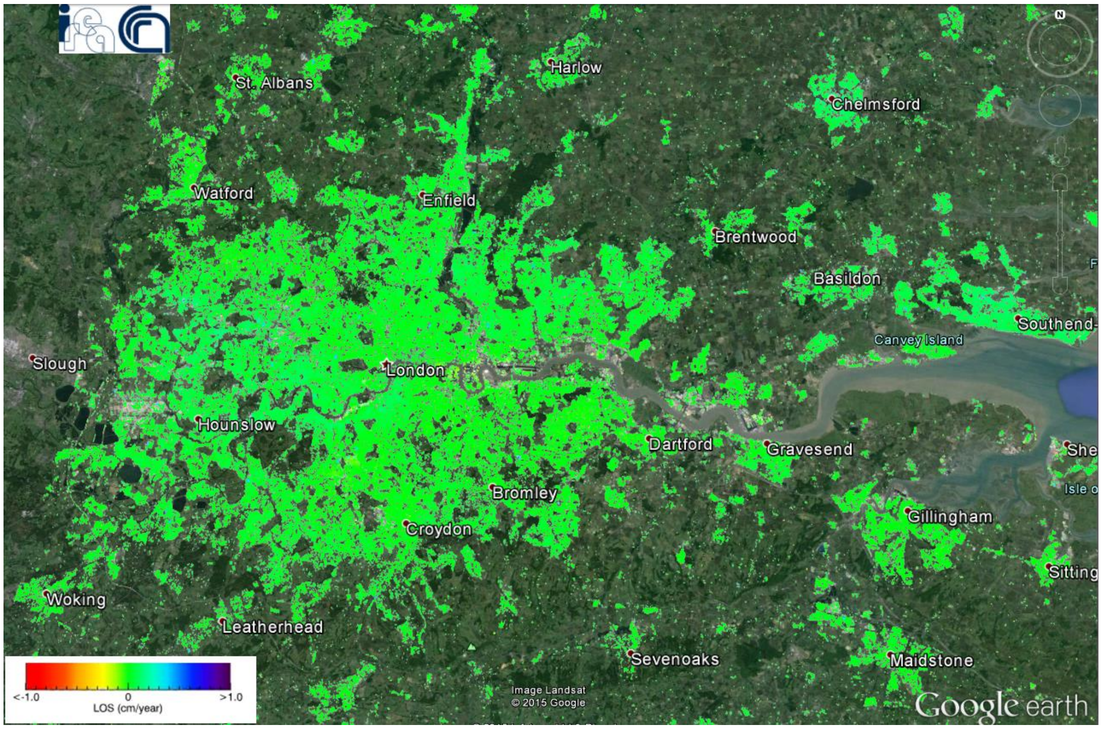

Figure 2: P-SBAS results obtained by processing a stack of 34 ERS-1/2 SAR scenes acquired between 1992 and 2000 over London, UK, using the G-POD platform. Results are overlapped onto Google Earth imagery © Infoterra Ltd & Bluesky.

2.2. Hardware and software requirements

The volumes of data involved in the process of generating such a nationwide ground motion product, from the input image data from the archives, to the generated derived products, require considerable hardware and software resources.

Accounting for the overlapping area between the available standard frames of archived ERS-1/2 SAR scenes for Great Britain, it is estimated that only ~50% of these frames would be necessary to achieve complete nationwide coverage in each acquisition mode (i.e. using either odd or even standard frames in Fig.1). The hardware resources to store, backup and archive the input data only (~5,000) – as delivered by ESA in single look complex format – would amount to over 2.5TB. The disk space required to process the data increases notably, with for instance a 200GB space needed to process a typical ERS-1/2 SAR descending mode stack with ~65 scenes with the SBAS approach.

Besides the hardware requirements that, nowadays, can be easily fulfilled at relatively low cost, the needs in terms of processing software are largely more demanding. During over 15 years of experience with multi-temporal InSAR processing, the radar community has experienced that processing routines can require several days or weeks for a final processing result to be generated when using desktop personal computers with average performances. This can be acceptable in some circumstances, but is obviously not in emergency response applications (when timings to generate results are crucial), and for wide area applications such as the generation of the nationwide product for Great Britain.

Experiments with cloud computing platforms and parallelised algorithms, for instance, the new computational model of Parallel-SBAS (P-SBAS) by IREA-CNR, Terradue Srl and ESA, revealed that processing times can decrease by a factor of 7 with parallel processors consisting of an architecture with 8 nodes, each equipped with 2 quad-core CPUs and 32GB of RAM [12-13].

Two examples of ERS-1/2 and ENVISAT processing results from preliminary tests I carried out with the P-SBAS algorithm on ESA's G-POD platform are shown in Fig.2 and Fig.3. In these two cases, processing times in G-POD were of only ~8 hours each for a stack of 34 ERS-1/2 over London covering the period 1992-2000, and a stack of 18 ENVISAT scenes covering Newcastle in 2002-2008.

Another aspect to account for in this context is data management, for instance the handling and visualisation of large volumes of InSAR results, including GIS-ready shapefile databases, with thousands of monitoring targets per processed frame, and their full deformation time series. The EPRS-E product for the Italian territory, made available via the National Geoportal of the Ministry of the Environment, Territory and Sea [1], illustrates a tangible example of how such data volumes can be visualised on web platforms.

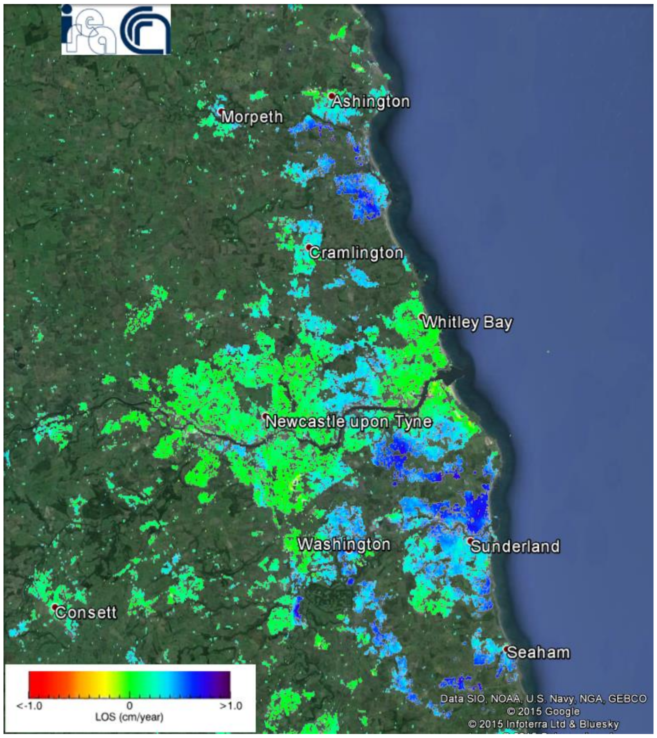

Figure 3: P-SBAS results obtained by processing a stack of 18 ENVISAT SAR scenes acquired between 2002 and 2008 over Newcastle, UK, using the G-POD platform. Results are overlapped onto Google Earth imagery © Infoterra Ltd & Bluesky.

3. CONCLUSIONS

This study summarised the findings of the feasibility assessment of satellite InSAR methods to generate nationwide ground stability and motion products for the landmass of Great Britain.

The necessary data volumes, hardware and software requirements are identified, and some preliminary results from the implementation of the P-SBAS algorithm onto the G-POD platform for London and Newcastle with ERS-1/2 and ENVISAT data are presented. A remarkable improvement in the InSAR processing time demand is achieved by using the platform, with only ~8 hours per image stack required to complete the image analysis, from raw satellite data to final SBAS products.

Despite the challenges associated with storing, processing and analysing big SAR data volumes, the way is open for routine nationwide analysis, and this preliminary assessment paves the way for its implementation across the entire landmass of Britain.

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