# Optimising the ERS InSAR data supply chain for commercial applications in ground displacement detection

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## ABSTRACT

An objective of the European Space Agency is to develop and support the commercial exploitation of ERS SAR interferometry for the detection of ground displacements. However, seen from the point of view of the value adding industry, there are a number of obstacles to this goal, particularly in terms of the data supply chain, and specifically, data acquisition and access. Some of the obstacles are inherent to the mission design and are not addressable, but others involve systems and processes which appear, at least from the outside, as though they could be modified to enhance the potential for commercial applications. The data supply chain components that are considered with suggestions for improvement fall within four areas: acquisition planning, metadata availability, data delivery and pricing policies.

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## Introduction

ERS SAR interferometry (InSAR) for ground displacement detection has proved a truly remarkable remote sensing success, providing a completely new Earth-management capability unimagined by most of us only a decade ago. With this success, must go credit to the European Space Agency for adapting systems that were never intended to provide data in accordance with the tight constraints imposed by InSAR, and also to the inspirational scientists who had the foresight and imagination to develop the technique for ERS SAR data in the first place. With an undoubted (though still not necessarily accepted) economic utility, commercial EO value-adders are enthusiastic to apply the technique if and when they can, and the Space Agency is keen to support and promote InSAR activity.

To some extent, ERS InSAR has become a victim of its own success: InSAR was never in the mind of the ERS mission designers, and attempts at commercial application *strain* the supply chain from start to finish – from orbit periodicity to atmospheric artefacts. Even with the first class support of ESRIN staff, attempts at fulfilling the wants of customers for ground displacement products has shown the InSAR supply chain to be fragile, particularly in terms of SAR data acquisition and access. Though much of the difficulty is presented by mission design, it would appear, at least from the outside, as though some systems and processes could be modified to greatly enhance the potential for commercialism.

This paper attempts to highlight components of the SAR data supply chain which might be modified to ease commercialism. No cost/benefit analysis has been undertaken, and the following points are made somewhat qualitatively, as seen through the eyes of an EO value-adder. The supply chain components that are considered fall within four areas: acquisition planning, metadata availability, data delivery and pricing policies.

## Acquisition planning

Commercial InSAR for subsidence and earthquakes usually means that a customer wants a contemporary measurement of displacement (often having first been convinced of the technique by historic results generated using archive data). A customer will often be quite specific in quantifying the period over which a measurement should be made, such as, 2 years back from the date of order. Commercial InSAR tends to mean a new SAR acquisition, which then has to be geometrically paired in terms of perpendicular baseline ($B_{perp}$), against a scene from archive whilst conforming to the customer's temporal requirements. In practice, this is proving difficult.

There is often insufficient data in the archive against which a new acquisition can be paired to suit the temporal requirements. This might be because archive scenes have simply not been acquired over the area in sufficient quantity, or that archive scenes have been acquired but do not geometrically comply with the new acquisition. Recently, ESA has made some efforts to ensure that a new acquisition is $B_{perp}$ compliant with particular archive scenes by manoeuvring the satellite, though not always with success. Such action does not appear operationally practical.

There seems to be little practical substitute for an archive that is well populated with a good selection of acquisitions over, say, the last two years. This is chicken & egg situation where to develop markets, a good archive is required, but ESRIN do not wish to acquire on a 'speculative' basis. ERS-1 is beyond its designed life-expectancy, and all current SAR acquisitions, including those fulfilling commercial orders, are usually made by ERS-2 - currently around 12,000 SAR frames per month, acquired by 39 ground stations (S. Jutz, October 1999). The satellite is only tasked to acquire when a specific production request is made (usually either commercial, Announcement of Opportunity or Pilot Project). Mission control have generally abandoned any background or 'speculative' acquisition campaigns, excepting those involving ground stations that might only be available for reception for a few months a year. Because of finite satellite resources, ESRIN positively discourage speculative acquisitions that might end up in archive with no user (G. Kohlhammer, October 1999).

However, speculative acquisition campaigns would seem necessary if the InSAR market is to be encouraged. Such a campaign need not be random as sites of interest with potential can be identified. A first pass might be to exclude all regions with dense vegetation (a threshold on the Tandem Mission Quick Look archive or on NDVI AVHRR?), and then include all regions with high seismic activity (e.g. GSHAP database[1]), and then arid environments with dense population centres, and then the more arid oil fields, etc, etc. This kind of pro-active acquisition over zones of high seismicity is, in fact, one of the major recommendations of the Earthquake Disaster Management Support Project of the Committee on Earth Observation Satellites (CEOS, 1999).

This argument begs the question of ERS-2 SAR acquisition capacity; how much of it, if any, is left unfulfilled per unit-period, and what are the other mission and policy objectives that have effect?

Suggestions:

- Investigate further the practicalities of specific satellite manoeuvres to ensure $B_{perp}$ compliancy.
- Investigate the feasibility of speculative acquisitions to build archives over regions of commercial InSAR potential.

## Metadata availability

***Orbit state vectors***

To compute perpendicular baselines and reliably perform InSAR processing, one needs to know the precise location of the satellite, in terms of orbit state vectors, at or near the time of image acquisition. Poor access to this information is proving a major obstacle to commercialism.

The state vector data is restituted after image acquisition and then made available by D-PAF at three different frequencies and at three corresponding levels of accuracy – *Rapid* (available within 1-2 days), *Preliminary* (available within 1-2 weeks) and *Precise* (available after 2 months). Because of its improved temporal resolution, it is the *Precise* information that is usually required to perform reliable InSAR processing. Processing without precise knowledge of satellite location usually results in 'phase trend' artefacts in interferograms. These often appear as additional interferometric fringes which could be mistaken for ground displacement, and so need to be at least identified and if possible removed.

[1] Global Seismic Hazard Assessment Project, Swiss Federal Institute of Technology, Zurich (http://www.seismo.ethz.ch/)

In some cases and with certain software, results can be cleaned of the artefacts by an experimental and interative 'de-trending' process, or a re-estimation of satellite position and re-processing, though these techniques are not altogether reliable and can leave ambiguity. As long as the SAR data is more than 2 months old, the *Precise* state vector data is available on CD-ROM from Eurimage at a cost of €100 and so all is well.

However, problems persist with new acquisitions. Commercial InSAR often means customers wanting a latest measurement, and so a programming of ERS-2 might ensue. An estimation of the $B_{perp}$ (or of the orbit state vectors) of this 'planned' acquisition against any one scene in archive cannot be predicted at the level of accuracy required for reliable processing, and so the specification by the customer for temporal separation becomes more of a guide, dependent upon the variety of the archive population. Though a significant obstacle to commercialism, one can understand the technical constraints operating. But another obstacle, more frustrating, lies in the poor access to the state vector data <u>after</u> the scene acquisition.

A typical scenario might first involve programming a new SAR acquisition – with the requisite 15 days' notice - to produce an up-to-date or contemporary InSAR result. A further 2 weeks would then be necessary after acquisition for the new scene to appear on DESCW, together with its $B_{perp}$ values against archive data. In the event that this would create an InSAR pair, both with suitable $B_{perp}$ and temporal separation – which is not guaranteed, it would then take a further 10 days or so for delivery of the data before any InSAR processing could begin.

Attempts have been made by NPA to speed up this process in practice: for example, we might have taken delivery of a SAR scene, say 10 days after acquisition; *Preliminary* state vector data for the new and the archive scenes (available 1 week after scene acquisition) are then used to choose a scene from archive to make the InSAR pair. These data arrive in another 10 days or so. Now we can interferometrically process the pair, but still have to wait another <u>5 weeks</u> for the *Precise* state vector data needed to produce an unambiguous result. Besides the CD-ROM orbit state vector products mentioned above, online lists are published by D-PAF, but we understand these are only freely available to AO PIs.

Suggestions:

- Make state vector data free of charge.
- Make online lists openly accessible.
- Ideally, provide *Precise* state vector data with SAR data, and/or
- Speed up availability of *Precise* state vector data, particularly for <u>individual</u> acquisitions.

***Perpendicular baseline***

The perpendicular baseline, or $B_{perp}$, between two SAR scenes of an InSAR pair is critical to the successful generation of an interferogram. For ground displacement detection, the $B_{perp}$ should be as small as possible to provide a large altitude of ambiguity and thus negate any confusion with general topography. The criticality of the $B_{perp}$ is dependent upon the resolution of the digital elevation model used in the differential process – the coarser the DEM, the smaller the $B_{perp}$ needs to be.

When using older archive data, there is no problem as appropriate metadata is made available in the FRINGE database. However, problems begin when trying to identify $B_{perp}$ compliant archive data against a new acquisition, as baselines between the two do not appear in the database until at least a week after the new image acquisition (there are methods to estimate the $B_{perp}$ by analysis of the *Precise Orbit* data for the archive scene (available after 2 months) against the *Rapid Orbit* (available after 2 days) data for the new acquisition, though this is very time-consuming, taking around 20 minutes per combination analysed). This all delays the identification of SAR data for ordering.

An ideal scenario that would allow rapid identification and ordering of InSAR pairs would be for the FRINGE database to be updated on a daily basis, so that if an image was acquired yesterday we would know today whether it was worth purchasing together with a corresponding scene from archive. This is of particular relevance to enabling a faster response to disasters. Such daily FRINGE updates would, of course, become obsolete as the monthly update is compiled.

Suggestion:
- Provide daily updates to FRINGE database.

## Data delivery

In the experience of NPA, SAR data takes, upon average, around 10 days to arrive from Eurimage after ordering, and for many applications, this lead time is acceptable. InSAR applications, however, introduce new requirements. First, the issues raised above concerning acquisitions and metadata access delay the placement of firm orders, and second, in the event of an earthquake, the disaster management community want ground deformation products as soon as is possible; the value of the product decaying rapidly as days pass.

Consequently, the delay in SAR data delivery compounds an already lengthy process. It is appreciated that there may be justifiable logistical difficulties involved, but these might, to some extent, be alleviated by a form of *priority ordering* facility in combination with an appropriate *premium* on the data price (*cf* Radarsat International *Near Real Time*, *Rush* and *Regular* services). In conclusion, NPA would ideally like to see an optional express service promising SAR data delivery within 48 hours.

Suggestion:
- Improve SAR data delivery times, perhaps supported by a corresponding surcharge.

## Pricing policy

The commercial market for InSAR products is still immature. Potential customers new to InSAR require a good deal of convincing of the technique's reliability before they will commit to an order. In NPA's experience with subsidence mapping, this is provided by promoting either historic results over their area of interest or results of a different area, but depicting the detection of similar displacement phenomena.

Earthquakes pose a more difficult problem: significant events tend to be sudden and catastrophic with no warning. Relief agencies and risk managers want information on deformation and damage extent as quickly as possible, and so the value of potential InSAR products decays rapidly as the information they might provide is gathered by more conventional means or not at all. By the time a prospective customer might be convinced, the data ordered and processed (notwithstanding the issues made above), the event is usually history.

To improve commercialism, we need to immediately procure the SAR data as soon as a significant event has occurred, process them and then advertise the product for sale by email to as wide a relevant audience as possible. This is a business risk, but one that can be shared: the SAR data provider invests in acquisition, transcription and dissemination, the value-adder in speculative processing and marketing. To stimulate commercial sales of earthquake products, NPA would like to see some form of routine sale-or-return mechanism with the data provider. A similar system is desirable in cases of poor $B_{perp}$ compliancy of a newly acquired scene against archive.

Commercialism can also be threatened by the enthusiastic efforts of the data providers to provide free datasets for research, which can lead to the free posting of results on websites. These results might not be pixel-georeferenced or in the best format, but sufficient information might be contained to forestall a commercial sale to a customer aware of the URL where the information is shown. There is a conflict of interests here, as the free provision of data certainly instigates a wider understanding of InSAR to the good of us all, but meanwhile can undermine commercial effort. A suggestion might be to delay the academic publication of such results until after a fixed period during which the value-adding industry has a chance to make sales, or else we accept to sacrifice high profile events like Izmit in the broader interest.

Suggestions:

- Delay the publication of results derived from free datasets.
- Make earthquake-relevant datasets available to EO value-adders on sale-or-return basis.

## Conclusion

It is hoped that this paper does not appear too critical of the European Space Agency - it is warmly acknowledged that considerable effort has been made to optimise the InSAR data supply chain, and support from ESRIN is always enthusiastic and helpful. Indeed, the author is sure that those involved are only too well aware of the issues discussed here. They must concede, however, that we have systems and processes *adapted* from the original ERS mission, where InSAR for ground displacement detection and its commercialism requires completely new approaches in areas such as orbit control, data archiving, data and metadata access, and policy. To apply all the approaches needed for an ideal ERS InSAR service is probably not possible, but small steps can be made that would greatly benefit commercial effort.

In our busy day to day world, advances in remote sensing capability progress frustratingly slowly, and sometimes we are obscured from the huge shift taking place from research to commercialism. All people involved in the InSAR product supply chain have had to ascend steep learning curves, and have had to deal with many new types of challenge. But a good deal has been done, and excellent lessons have been learned for both Envisat and the preparation of at least concept systems that would routinely serve the exciting new market for ground displacement products - we know where to go. In 10(?) years time, when we have constellations of dedicated SAR instruments, giving us an online, near real time capability to routinely map the shifting Earth, we'll look back and remember where the apprenticeship was undertaken!

### References


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