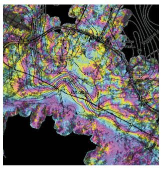

FRINGE '99

Advancing ERS SAR Interferometry from Applications towards Operations

Liège, Belgium, 10 – 12 November 1999

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FRINGE '99
Advancing ERS SAR Interferometry from Applications towards Operations

Outcome of the
2nd ESA International Workshop on ERS SAR
Interferometry

1. SCOPE

This information note summarises the outcome of the 2nd ESA International Workshop on ERS SAR Interferometry : 'FRINGE99 - Advancing ERS SAR Interferometry from Applications towards Operations', held in Liege, Belgium 10–12 November 99. This event was organised by ESA/ESRIN and hosted by Centre Spatial de Liege. It brought together about 160 participants who presented 80 presentations and 20 posters arranged in 7 thematic sessions.

2. ORGANISATION & FEEDBACK

The main objective was to review & assess the maturity & operational readiness of ERS SAR Interferometry Applications following the rapid advances made since the 1st ESA International Workshop held in Zurich 3 years ago.

The Workshop opened with a special 'hot news' session on the important results associated with recent earthquake in Izmit, Turkey for which ESA had established a special action to coordinate with international groups exploiting ERS SAR data.

The workshop concluded with a Plenary session during which important feedback was provided by participants on how ESA could further improve the future interferometric exploitation of ERS & Envisat missions data. For information, ESA gave a brief summary of the new ERS/ENVISAT Data Policy and the future acquisitions strategy of ERS-1.

The following main comments were raised during the Plenary :-

Regarding ERS:

- continue ERS-2 operations beyond ENVISAT commissioning,
- monitor, every month, 80 defined high-risk volcanos with ERS-2,
- provide an AO mechanism that allows access to ERS data in the case of exceptional natural events (as per Izmit), as & when they occur,
- continue to improve the reliability of ERS services from Foreign Stations (some missed acquisitions have occured),
- discount bulk purchases of ERS SAR RAW or SLC data (a method of overcoming atmospheric artifacts),
- provide a baseline forecast service for future acquisitions,
- following the outstanding achievement of radiometric calibration, provide the technical information necessary to allow even more precise geometrical calibration of the ERS system required for interferometry (automatic use of ground control points),

Regarding ENVISAT:

- concern was expressed that the large number of ASAR modes of operation could lead to reduced opportunities to perform interferometry;
- recommend the use of ASAR Image Mode; one subswath, one polarisation (Swath 6, HH) for systematic volcano monitoring,
- investigate the optimum bandwidth to be used with ASAR Wide Swath Mode for SAR Interferometry (full bandwidth results in reduced Signal to Noise ratio),
- synchronise along track Wide Swath Mode burst timing to enable SAR interferometry between separate WSM acquisitions (note : known not to be technically feasible),
- provide ENVISAT orbit data in a consistent and stable format from the beginning of the mission,
- provide S/W tools to handle ASAR Level 0 data from the beginning of the mission.

A summary of the key results is given below for each of the 7 thematic sessions.

3. SESSION SUMMARIES

DIGITAL ELEVATION MODELS (large-scale aspects, detailed quality assessments)

DEM's from ERS InSAR are today being routinely produced by non-expert users from commercially available S/W and actively utilised within projects such as Telecoms planning, Ortho-correction of optical satellite landmaps, Hydrological modeling & Cartography in developing countries.

The DTED-2 DEM accuracy specification has been proved to be achievable with ERS Tandem data. The initial choice of data is very important with respect to the final DEM quality, the main factors being coherence (vegetation), weather (especially thunderstorms), topography (steep slopes) and freeze/melt conditions.

Quality control procedures for some of these effects have been developed and are being used in the commercial sector (eg. atmospheric artifacts can be removed by cross-checking with external low-resolution DEM's). Access to information that characterises the ERS Tandem data quality greatly aids both commercial & scientific exploitation (eg. the recent ESA study reported at this workshop, using interferometric Quick-Looks to evaluate the potential of DEM generation for the N. American continent; approx 25 M km^2).

The production of DEM's is no longer limited to small areas. A number of projects for entire countries using ERS were described including the United Kingdom for higher-education purposes & Slovenia for Telecoms planning purposes.

A few Value-Adding companies are offering commercial services based on space radar-derived DEM's. Atlantis Scientific (Canada), one of the leading companies in this area, reports that commercial revenues from DEM's are growing and that ERS Tandem is the largest used source of data for provision of their DEM services; approximately 400 images (3 times the amount of J-ERS and 20 times the amount of Radarsat used by them for DEM's). The main sales are made in the Oil/Gas/Mining, Telecoms & Defense markets.

LAND MOTION (subsidence, slides)

A growing number of projects with ERS are being conducted in collaboration with local authorities responsible for risk management, urban planning and environmental management. These projects are addressing ground subsidence induced by human activities such as mining, subway construction and water pumping as well as natural effects. In addition, several landslides are being studied in Italy and China, and previously unknown slides have been detected in the Austrian Alps.

A wide range of subsidence rates have been analysed, from more than 10cm/year (Mexico city) to less than 1 mm/year (Padova, Italy). For landslides, the slip rates are generally higher; in the order of m/year.

The loss of coherence for vegetated and snow covered regions is the main limitation associated with this technique. This is not a problem for urban areas where good results are obtained for timescales of several years. Atmospheric artifacts can be minimised or eliminated when multiple acquisitions are available and a novel approach to this problem via the complex correlation of interferograms shows promise.

The long term stability of the ERS instrument and orbit, together with availability of historical, global archived data, make the ERS mission the primary source of data for this application. The 2-D spatial maps of ground motion complement well the existing sources of in-situ point measurements from GPS or Leveling surveys, which would be costly to extend in geographic coverage.

A few Value-Adding companies are offering commercial services based on ERS and targeted towards Oil&Gas, Mining companies and Water resource departments.

ICE MOTION (glaciers, polar streams)

First results were given of large scale projects to produce a DEM and ice flow for all of Greenland and parts of Antarctica (the VECTRA project, within the ERS AO3). In addition, a number of non-polar glaciers have been studied.

The retrieval of 2-D ice flow requires both ascending and descending ERS Tandem coverage. There remain a number of technical challenges to be addressed; eg. loss of coherence (temporal & volume scattering), atmospheric artifacts & tidal motion effects near the grounding zone. Nevertheless, the results show very good agreement with in-situ & model data, where available, and the grounding line can be located with much improved accuracy over conventional methods (ie. 10's m as opposed to 10's km). An operational processing chain is being set up by Danish Technical University for ice flow production of Greenland on the large scale.

A new technical development of 'speckle tracking' was reported. While this leads to 2-D ice motion with reduced accuracy, it has the advantage of requiring only 1 interferometric pair and can be applied to 35-day repeat data, thereby allowing full continuity into the ENVISAT mission. Only limited areas have been studied to date with ERS via this technique and there is considerable scope to investigate wider regions of the polar ice caps.

The ERS Tandem data represents a valuable and unique source for high-resolution and accurate of polar & glacial fast ice flow. For the polar ice masses, the studies with ERS will take a few years to complete, however, this information, when available, will be a key scientific input to addressing issues of global change (ie. monitoring ice mass balance, verifying ice dynamical models and estimating sea level rise & oceanic circulation).

THEMATIC MAPPING (land cover & change, forests, snow)

The additional information provided by ERS Tandem coherence is being used together with the conventional image amplitude for an expanding number of applications. Many encouraging results were presented in the following areas :-

- forest mapping, detection of logging & fire damage, retrieval of boreal forest biomass & classification of tree species,
- mapping of snow properties (dry/wet),
- mapping of flood extent & river networks,
- agricultural crop classification & height measurement,
- land surface classification via fuzzy logic techniques,
- mapping of land surface erosion.

Multi-temporal Tandem data sets serve to reduce errors and open up the possibility of tracking changes in time. The next step is to validate these first results on a wider geographic scale in order to consolidate these applications.

DLR (Germany) reported that an operational processing chain is currently being put in place to provide an updated & high-resolution forest map for the large region of Siberia; an area undergoing rapid human intervention, the impact of which is unknown.

A new thematic product, based entirely on ERS Tandem, is being offered as a commercial service by SpotImage. This is the first SpotImage image product based on data not provided by the SPOT satellites, and results from a jointly-funded co-operative activity with ESA on ERS market development.

TECTONICS (quakes, faults)

ERS SAR Interferometry is being used widely to monitor the pre/co/post-seismic displacement fields of a growing number of earthquake and fault zones around the world, eg. Dinar (Turkey), Manyi (Tibet), Umbria (Italy), Hector Mine (USA), San Francisco (USA), Izmit (Turkey) and some areas of the Dead Sea and Iceland.

The new dimension that this technique brings is that of complete spatial maps of ground movement, which would be difficult and costly to obtain by conventional geodetic methods. This information is substantially improving and giving new insight into the geological models of these phenomena.

Some of the national agencies responsible for monitoring earthquake events have been fully involved in these projects with ERS, and Civil Protection authorities are showing increased interest in utilising the results.

Volcanos

The surface deformation associated with a large number of volcanos has been studied and it is now understood which type of volcanos are best suited for the monitoring of activity by ERS SAR Interferometry (eg. Shield volcanos and large calderas).

There is an increasing move to integrate information derived from ERS into the monitoring and decision processes of national authorities. INDRA (Spain) reported that an operational processing system is being set up to be tested on the Canary islands with a view to full deployment later in Ecuador.

The demand for continued and systematic 35-day repeat coverage of high risk areas by ERS is clearly voiced by the geological scientific community. This is required not only to build up a reliable historical archive thereby increasing the possibility to study eruption events when they occur, but also to support pre-cursor monitoring activity and track evolution of the current volcanic status.

TECHNIQUES (algorithms, methods)

The underpinning R&D continues to advance in addressing some of the more complex and subtler issues associated with SAR Interferometry. Progress was reported in the following areas :-

- Atmospheric phase effects and their impact on DEM’s,
- Automated methods for large-scale DEM production,
- Direct geocoding,
- Further refining Phase Unwrap methods to cope with problematic conditions,
- Improved methods for estimating baseline/orbit parameters.

A significant recent development reported by Politecnico di Milano, as a result of the AO-3, is that of the Permanent Point Scatterers (PPS); ie. exploiting naturally occurring phase-stable targets. Although this technique requires a significant time series of ERS 35-day repeat data (ie. > 20 images), it fully characterises a network of reference points on the ground that allow accurate motion measurements, free from atmospheric artifacts, to be retrieved from future acquisitions of ERS.

POLIMI report that it may be possible for these motion measurements to be made in areas where coherence is lost in the conventional 35-day repeat approach. This would extend the range of subsidence / quake / fault / volcano monitoring applications. Furthermore, the ground network of PPS characterised by ERS may be compatible with ENVISAT ASAR data. This exciting possibility would preserve the technical heritage built up by the ERS missions in a way that could be passed on and further directly exploited by the ENVISAT mission.

4. CONCLUSIONS

It is evident that ERS has, and continues to be, the biggest single driver in the development of SAR Interferometric applications. It represents the largest worldwide archive of spaceborne SAR data to date. In addition, the ERS Tandem global archive is both a world-first and unique to ESA.

DEM's from ERS Tandem data are being used in a growing number of applications by a wider community. Large-scale projects are starting up, and a few Value-Adding companies are offering commercial services. Accuracy's are being achieved from ERS Tandem data that are comparable with those quoted for the up-coming SRTM mission (although it is recognised that this mission will provide a complete global DEM within ± 60 deg latitude). Data quality was identified as a key issue impacting exploitation.

Thematic mapping/change detection via SAR Interferometry are leading to new exploitation possibilities of the ERS Tandem global archive. The related applications are rapidly consolidating and first commercial services are on the market.

Fast Ice motion applications are unique to the ERS Tandem mission. They are providing key missing scientific input to addressing issues of global climatic change.

The complete range of Land motion applications are possible only due to the long-term historical archive of 35-day repeat data and the stability of the ERS system (instrument & orbit). According to Prof. D. Sandwell of UCSD California, the 8-year time series of ERS is changing the way that current-day geodesy is being performed. Results from ERS are being increasingly integrated into national risk monitoring activities. However, it should be noted that, for natural disaster events, these results cannot always be supplied on a timescale compatible for support of immediate disaster management activities due to the coverage & re-visit capabilities of a single satellite.

In order to fully realise the complete range of exploitation capabilities offered by ERS SAR Interferometry and enhance the robustness of new commercial services, there is a demand for support information and activities that go beyond the basic data services offered by ESA today. Specific requests made at this workshop include the assessment of ERS data quality for identified interferometry applications, together with optimisation and forecasting of satellite baselines for specific events.

5. FUTURE CONSIDERATIONS

There was consensus that there is great potential for further exploitation of the existing global ERS Tandem archive. In addition, the related applications are fuelling further demand for new Tandem acquisitions. Although this demand cannot be met today by ERS, given the current operational constraints & capabilities of the ERS-1 satellite, this information provides useful guidance for future EO SAR missions.

It was fully recognised that the operational ERS 35-day repeat capability, coupled with the 9-year historical archive, is a unique and invaluable asset that is creating innovative and useful SAR-based risk monitoring applications. This asset can be maintained and extended with the ENVISAT ASAR, giving the perspective and opportunity of a 15 – 20 years exploitable resource for the future.

Furthermore, specifically for identified high-risk zones, there was a strong recommendation from participants of this workshop that the 35-day archive should be systematically augmented in the future with ERS, and continued in the ENVISAT mission.

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