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DOCUMENT

INSARAP 2014 Session Summaries, Seed Questions Discussions and Recommendations

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1 INTRODUCTION

This document gathers the session summaries with seed questions discussion and recommendations of the INSARAP2014 workshop (http://seom.esa.int/insarap), organised by the European Space Agency at ESRIN, Frascati, Italy, from 10 to 11 December 2014, in the context of the Scientific Exploitation of Operational Missions (SEOM) element.

1.1 Workshop objectives and themes

The main objectives of the INSARAP2014 workshop are:

- Present Sentinel-1 interferometric results in TOPS mode.
- Adapt InSAR and PSI processing techniques to TOPS SAR data.
- Discuss the first InSAR and PSI results over selected pilot sites.
- Assess the synergy between Sentinel-1 and previous C-band SAR missions.

The workshop is focused on technical issues related to the processing and exploitation of Sentinel-1 TOPS data as well as the demonstration of early interferometric results obtained by various scientific groups. Part of the workshop is dedicated to the discussion on the findings of ESA's INSAR performance studies with TOPS data (two consortia) that were kicked off in March 2014.

1.2 Scientific and organising committees

Scientific Committee

Dr. Andrew Hooper, *University of Leeds*
Prof. Fabio Rocca, *Politecnico di Milano*
Prof. Jordi J. Mallorqui, *Universitat Politècnica de Catalunya*
Dr. Pau Prats, *DLR (HR)*
Dr. Riccardo Lanari, *IREA-CNR*
Dr. Urs Wegmüller, *Gamma Remote Sensing*
Dr. Yngvar Larsen, *NORUT*

Organising Committee

Yves-Louis Desnos, *ESA-ESRIN*
Francesco Palazzo, Serco S.p.A support ESA-ESRIN
Michael Foumelis, RSAC c/o ESA-ESRIN

1.3 Workshop participation

The workshop was open to scientists and Sentinel-1 experts in TOPS InSAR. Scientists specialists in TOPS presented their preliminary contributions/results after a reviewing process by the Scientific Committee.

1.4 The workshop in numbers

The workshop programme consisted of 3 (no parallel) sessions. A total number of 18 oral presentations (3 keynote addresses, 14 technical talks and one summary discussion) were presented.

Date	Session
Wednesday 10 December 2014	Opening
	INSARAP Consortium results by DLR-HR, e-GEOS, INGV & GFZ
	INSARAP Consortium results by Norut, PPO.labs, Univ. of Leeds, PGI & NGU
Thursday 11 December 2014	Sentinel-1 TOPS InSAR results
	Round Table Discussion
	Closing

Figure 1 Workshop sessions

The workshop's presentations are on line published at:

http://seom.esa.int/insarap/page_participation.php

The workshop has been attended by a total of 52 participants originating from 13 countries (see figure 1 for national distribution of the participants).

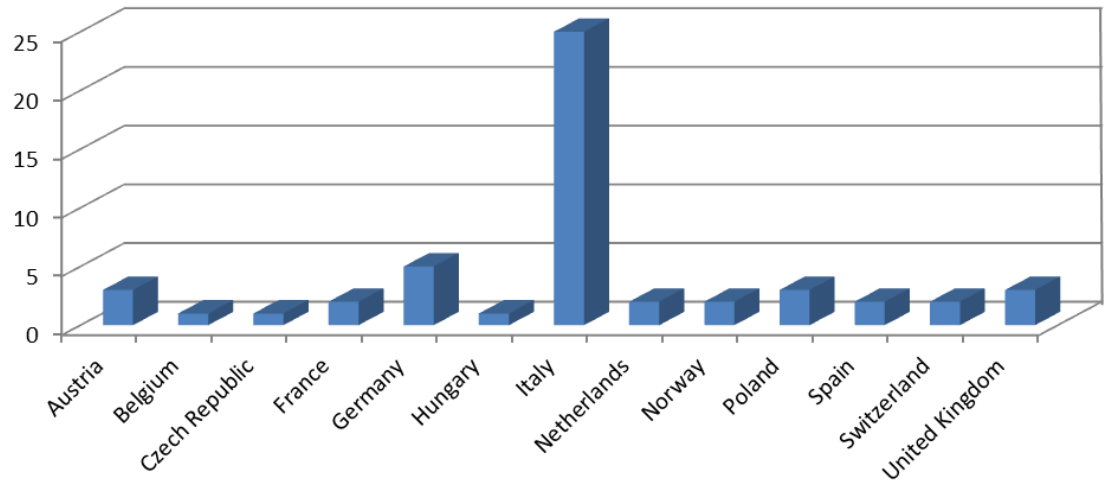

Figure 2 National distribution of the participants

1.5 Workshop programme

The workshop programme is provided below.

Opening Session (10 December 2014)

09:00 Welcome and introduction, Y-L Desnos, ESA

09:15 Sentinel-1 mission status, P. Potin, ESA

09:30 Sentinel-1 On-line Data Access , J. Martin, ESA

Session: **INSARAP Consortium results by DLR-HR, e-GEOS, INGV and GFZ**

09:45 Presentation of consortium and brief description of pilot sites

10:15 Interferometric TOPS chain description

10:45 Special considerations in the TOPS case

11:15 Coffee Break

11:45 Investigations with Sentinel-1 IW data

12:15 Options for PSI time series processing

12:45 Preliminary scientific results with Sentinel-1
(Mexico City, Vesuvius - Campi Flegrei & Istanbul)

13:15 Lunch Break

Session: **INSARAP Consortium results by Norut, PPO.labs, Univ. of Leeds, PGI and NGU** (Chair: D. Geudtner, ESA)

14:30 Overview - "InSARap at a glance"

15:00 Sentinel-1 TOPS - technical challenges (and opportunities)

16:00 Coffee Break

16:30 Sentinel-1 for InSAR based scientific applications
(Quality Control, Landslides, Tectonics and Volcanoes, Non-Stationary, Summary)

17:30 Welcome Cocktail

18:30 End of First Day

Session: **Sentinel-1 TOPS InSAR results** (11 December 2014)

09:00 Sentinel-1 InSAR Capabilities: Results from the Sentinel-1A Commissioning Phase, D. Geudtner, ESA

09:15 Adaptation of DIAPASON processing software to Sentinel-1 TOPS interferometry, J. Duro, Altamira

09:45 Sentinel-1 InSAR progress and experience at GAMMA, U. Wegmüller, Gamma Remote Sensing AG

10:15 Enabling the processing of Sentinel-1 TOPS data with the open-source DORIS software, F. van Leijen, Delft University of Technology

10:45 Coffee Break

11:00 SBAS-DInSAR processing chain for Interferometric Wide Swath Sentinel-1 data, M. Manunta, IREA-CNR

11:30 Sentinel-1a Interferometry using the Integrated Wide Area Processor – First Experiences, R. Brcic, DLR

12:00 Lunch Break

14:00-17:00 Round Table Discussion (Chairs: Y-L. Desnos & F.Rocca)

17:00 End of workshop

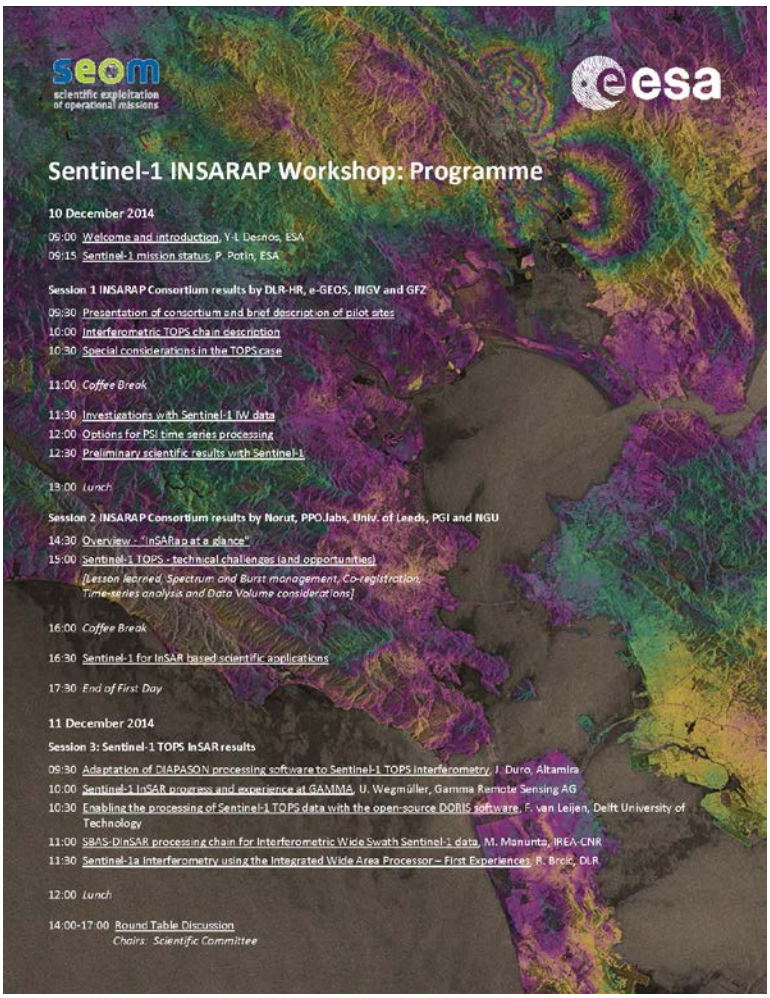

Figure 3 INSARAP workshop flyer

2 OPENING SESSION

2.1 Presentations Summary

The first day initiated with the presentations of the SEOM Program Element by Y-L. Desnos, followed by the Sentinel-1 Mission Status Overview by P. Potin, and the Sentinel-1 On-line Data Access by J. Martin.

3 INSARAP CONSORTIUM RESULTS BY DLR-HR, E-GEOS, INGV AND GFZ

3.1 Presentations Summary

The findings of the ESA INSARAP study Consortium A were presented.

The first Consortium was presented by Pau Prats, DLR. The goal of the study is to assess the interferometric performance of the TOPS mode onboard the Sentinel-1 satellite. Among the sources of the data used, Prats referred to Radarsat 2,Terrasar X, and Sentinel-1. He described the methodology used to focus and azimuth co-register TOPS data. He noticed that not only the overlap zones between bursts in the same swath, but also those between the swaths can be used and the final results were shown to be fully compliant with the specifications. The final interferograms are indeed very satisfying, even in areas with high relief: large elevation changes, as in the case of the Etna, do not create significant jumps.

Indeed, there can be phase discontinuities at the swath and burst boundaries, but these will be due to geophysical causes, only. He discussed many of these effects in the following presentation, and he showed that these differences might be used for investigation of the correspondent phenomena. As a first example, differences in observation timings and Line Of Sight can identify changes in the water vapor in the atmosphere, or changes in the ionosphere crossed. So, ionosphere investigation could be carried out looking at the phase jumps at the burst or swaths edges. The direction of motion of the targets, if any, if seen from different Lines Of Sight will be identifiable in two dimensions. This could be useful both for glaciers motions studies as well as for tectonical ground motion studies.

The effects of the orbital tube was also considered, in that any across track baseline long B, with respect to the virtual satellite position, induces a 2B long variation of the azimuth position, along the orbit. In case of very long takes, even synchronizing at best, the variation of the azimuth component could impact on the azimuth spectral decorrelation. However, this effect can be limited first by the limited length of the takes, that is a small part of the orbit anyhow, and then also controlling the orbit eccentricity and limiting the maximal baselines.

In his third presentation, Prats appreciated the quality of the burst synchronization (2ms std) and observed minor issues like the fine details of the azimuth spectrum shape or the correction to be carried out to take into account the finite time of emission of the range chirp, both correctible in software.

Minati (E-geos) discussed the Persistent Scatterers studies, presenting results on the simulated Terrasar X data. He appreciated the advantage of the rapid revisit times, increasing the coherence levels, and discussed the possibility of mosaics and burst data processing, finally expressing questions on the availability of long term data stacks, and the processing on demand of raw data. Very interesting and important experimental results on Mexico City were presented by Nannini (DLR), who showed very nice persistent scatterers distributions using just 5 images, the last taken only three days earlier. The increased coherence allowed favorable comparisons with the much longer time series taken with Radarsat 2.

Preliminary scientific results on the study of the locked Izmit fault were shown by Walter (GFZ). Borgstrom (INGV) showed preliminary results on the Campi Flegrei area, and interferometric images of volcanic ground motion in Tenerife taken with Sentinel-1. He advocated the use both of ascending and descending orbits to get two motion components.

4 INSARAP CONSORTIUM RESULTS BY NORUT, PPO.LABS, UNIV. OF LEEDS, PGI & NGU

4.1 Presentations Summary

The findings of the ESA INSARAP study Consortium B were presented.

The second consortium was presented by Larsen (Norut) who, after the general presentation of the present and future activities, introduced their specific themes of interest, namely subsidence in Polish mines, and ground motion along the fjords in Norway, apart from the already mentioned subsidence in Mexico City and Izmit fault studies. He showed that the co-registration problem had been conceptually understood, but many challenges still existed, also due to the limited availability of TOPS data at the time of the Workshop. Larsen also presented the preliminary activities in Norway in the Nordnes fjord test site and the need there of ascending and descending orbits, also for the orientation of the fjords. Perski showed the activities for a pilot study to monitor potential terrain surface deformation associated with hydraulic fracturing in Poland. He showed the numerous (60) corner reflectors that have been installed, with a 1.5m deep concrete base, and GPS positioned to 2mm. He showed the traces of the CR's on Sentinel 1 images, ready for the time evolution studies. UAV's will be used for the surveillance of the site. Gonzalez (Leeds U.) affirmed that the Sentinel-1 constellation will be transformative for Tectonic and Volcanic Geodesy, and the early results are very encouraging. He showed the strip map

interferograms of the 2014 South Napa earthquake and underlined the continental implications of the Sentinel 1 mission and its capability of measuring in 5 years tectonic strain of 10 nanoradians/year.

5 SENTINEL-1 TOPS INSAR RESULTS

5.1 Presentations Summary

First Geudtner recalled the results from the Sentinel-1A Commissioning Phase. Then, in four successive talks, Duro (Altamira), Wegmueller (Gamma), F. van Leijen, (DUT), and Manunta (IREA) all presented the enabling of the processing of Sentinel-1 TOPS Data respectively with Diapason, the experience within Gamma Remote Sensing, the processing with the Open-Source DORIS Software, and finally the processing within IREA for applications to Small Baselines Subset analyses. None found severe difficulties in the processing, and all achieved useful and compliant results.
In particular, Wegmueller observed that the S1 IWS coherence is useful for land use characterization and parameter retrieval. Over forests, the 12 day repeat interval results in mostly very low coherence values which is useful for forest non-forest discrimination but which has only a very limited potential for forest parameters retrieval. The wide area coverage is very attractive.
Manunta (IREA) recalled also the possibility of use of G-POD (ESA---Grid Processing on Demand) facilities, federating more than 350 CPU (recently IREA too) in about 70 locations and with a total of 330TB of storage, also in cloud environment.
Finally Brcic (DLR) gave an ample demonstration of the possibilities of DLR for processing vast areas with a software well capable of processing and mosaicking. He showed that the wide area processing software IWAP was successfully adapted to process burst-mode acquisitions in TOPS and Scansar.

Scientific research activities presented in the session:

1. **Sentinel-1 InSAR Capabilities: Results from the Sentinel-1A Commissioning Phase**, *D. Geudtner, ESA*
2. **Adaptation of DIAPASON processing software to Sentinel-1 TOPS interferometry**, *J. Duro, Altamira*
3. **Sentinel-1 InSAR progress and experience at GAMMA**, *U. Wegmüller, Gamma Remote Sensing AG*
4. **Enabling the processing of Sentinel-1 TOPS data with the open-source DORIS software**, *F. van Leijen, Delft University of Technology*
5. **SBAS-DInSAR processing chain for Interferometric Wide Swath Sentinel-1 data**, *M. Manunta, IREA-CNR*

6. **Sentinel-1a Interferometry using the Integrated Wide Area Processor – First Experiences**, *R. Brcic, DLR*

5.2 Proposed Seed Questions

1) *What is the InSAR acquisition strategy for Sentinel-1? ESA / Copernicus product distribution strategy? Are SLCs systematically available or not?*
2) *Will there be consistent large archives available everywhere (e.g. for PSI)?*
3) *Would it be useful for the scientists that ESA delivers coregistered SLCs? Only orbit information and external DEM (optionally ellipsoid) would be used for that purpose. The images would be coregistered to the reference orbit, i.e., no need to have a "real" reference image. Which kind of product would the scientists prefer to have, e.g., "L1B", "coregistered and mosaicked", "only coregistered", etc.?*
4) *Is it really necessary to consider the small line-of-sight variation in TOPS (about 1.4°) for L2/L3 products and for modelling?*
5) *Is the TOPS coregistration problem completely characterized yet, or are we still seeing effects that we cannot explain?*
6) *Is it possible to find a consensus on atmospheric models towards the "standardization" of atmospheric-corrected Sentinel-1 differential InSAR products? Does the community have the right algorithms to cope with the new atmospheric features we observe in TOPS InSAR-data due to the spatial coverage and increased coherence?*

5.3 Seed question 1 discussion and recommendation

What is the InSAR acquisition strategy for Sentinel-1?
ESA/Copernicus product distribution strategy?
Are SLCs systematically available or not?

Discussion

- The acquisition strategy for Sentinel -1 was summarized by Potin. The main areas of studies will be the tectonic areas around the world (alternating with ascending and descending passes every repeat cycle, therefore with the possibility to perform InSAR every 24 days), whereas Europe will be covered with ascending and descending passes at each repeat cycle. The high repeat coverage of the entire world (land) is a long term challenging issue, and talks are starting with the relevant Copernicus services on that.

- There are currently some constraints to ensure the systematic acquisition over U.K. areas due to the presence of calibration sites requiring specific planning, in particular for the L2 ocean validation. Miranda observed that the present constraint will be relaxed in the next months as soon as acquired data will be processed to level 2 and preliminary validated, and many conflicts appearing now will be solved.

Recommendation

- The request was made of using strip map mode for small islands of volcanic interest. Potin mentioned that although the default mode over land is IW, the use of SM could be performed provided it does not create conflicts with other applications, e.g. maritime surveillance.

- Ensure consistency of acquisitions over UK (Cal/Val test sites) or provide clear information about planned data-takes (in kml format, so as to allow zooming in), as scientists need to get detailed information to plan their field campaigns.

- Extend systematic SLC generation to all tectonic areas; ensure that also geohazard supersites and INSARAP test sites are enclosed.

- Make precise orbit data available to scientists

- Facilitate searches for SLC data in the data hub, eg by listing where the data have been acquired (action closed since the update of the science hub)

- Make interferometric searches easier (or provide clear instructions how to run them)

5.4 Seed question 2 discussion and recommendation

Will there be consistent large archives available everywhere (e.g. for PSI)?

Discussion

- As for the production of SLC, they will be available on line for all the supersites and for the scientifically relevant areas, namely Greece, Turkey, Japan, Antarctica, Mexico.

- Duro asked about the possibility for asking for acquisitions and for SLC's. Rosich replied that requests for specific individual acquisitions by the scientific community are not foreseen. Inputs for the systematic observation plan are collected by ESA at

the various S1 workshops and considered to the maximum extend in the definition of the systematic observation plan definition.

- The S1 operations scenario foresees that up to 25% of the acquired IW data will be systematically processed to SLC in Routine Operations to cover world key areas for insar applications. Thus the amount of available SLC products will slightly increase in the next months to reach this target by spring 2015. SLC data is systematically generated over a set of defined areas, which will be gradually enlarged in line with the increase of processing SLC volume in spring 2015. Individual requests for SLC processing by the scientific community are not supported but as for the observation scenario, inputs to the systematic SLC production areas are collected by ESA at the various S1 workshops and considered to the maximum extend in the definition of the SLC production scenario.

- ESA takes note that the scientific community would welcome an increase of the amount of data systematically processed to SLC, potentially up to 100%. This would require a change in the S1 operations baseline to be agreed with the EU and major sizing evolutions in the ground segment. ESA cannot, at this stage, take any commitment on this further increase of SLC processing and schedule but will assess with the EC the possibility of further increasing the overall SLC volume after the target of 25% for the S1A routine operations has been achieved by Spring 2015.

- The Collaborative Ground Segments will operate independently.

Recommendation

- Prepare time series of SLCs over defined areas (agiculture, ice, towns...) in asc/desc every 12 days and make them easily retrievable from the data hub

5.5 Seed question 3 discussion and recommendation

Would it be useful for the scientists that ESA delivers coregistered SLCs?

- ***Only orbit information and external DEM (optionally ellipsoid) would be used for that purpose. The images would be coregistered to the reference orbit, i.e., no need to have a "real" reference image.***
- ***Which kind of product would the scientists prefer to have, e.g., "L1B", "coregistered and mosaicked", "only coregistered", etc.?***

Discussion

- The possibility of an open focusing software, yielding coregistered images was discussed and many asked if they had to develop a IWS focusing system. Bally observed that the development of the processor started in 2012. A white paper on that is available: the polygons where the SLC's will be available have been defined by the scientific community. After a question of Van Leejen, it was observed that the situation for the Netherlands will be cleared in a short time.

- Potin observed also that the operational processor (executable) developed by MDA under ESA contract can be provided free of charge to the European and Canadian direct receiving stations as part of the Copernicus Sentinel Collaborative Ground Segment, but there are no plan to make available this processor executable openly, in particular to the scientific community. Miranda observed also that MDA is not the unique source for a focusing system.

- Engdahl said that ESA's Sentinel-1 open source toolbox will be available in March 2015 and will support TOPSAR functionalities.

- On the issue of accessing the Sentinel-1 archive, Potin mentioned that the mirror sites that are being set up in national collaborative ground segment will certainly play an important role. In addition, discussions have started between the EC and ESA on the possibility to provided long term access of archived data by all users from the ESA-managed core ground segment. In the current baseline this functionality is limited to the Copernicus services, the opening of the archive to all users with be the object of technical assessment, it is anticipated that the impact on the ground segment of such functionality will be very high.

Recommendation

- Extend rolling archives retention time.

5.6 Seed question 4 discussion and recommendation

Is it really necessary to consider the small line-of-sight variation in TOPS (about 1.4°) for L2/L3 products and for modelling?

Discussion

- The effects of the LOS changes is clear and physically understood and there was consensus that it would not hinder the use of the image, but rather offer new possibilities.

5.7 Seed question 5 discussion and recommendation

Is the TOPS coregistration problem completely characterized yet, or are we still seeing effects that we cannot explain?

Discussion

- It was remarked that the co registration is operating faithfully and the residuals, if the restituted orbits are used, are very small and geometrically consistent. Indeed, Prats repeated that all discrepancies have a geophysical origin and that they can be well explained and maybe used for better understanding of the physical phenomena.

5.8 Seed question 6 discussion and recommendation

Is it possible to find a consensus on atmospheric models towards the "standardization" of atmospheric-corrected Sentinel-1 differential InSAR products?

Does the community have the right algorithms to cope with the new atmospheric features we observe in TOPS InSAR-data due to the spatial coverage and increased coherence?

Discussion

- The Numerical Weather Predictions available at ECMWF, even after 3 months, will be useful for the correction of the data. The consensus was that the new features will be interesting to study and that new information will be gathered. It is important to guarantee a good cooperation with the meteorological researchers so that this information will be synergized and its use optimized.

ANNEX 1 – LIST OF PARTICIPANTS

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