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Deliverable C2.1: Canary Islands deformation activity map V1

A deliverable of

Task C: Sentinel-1 software development and data processing

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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
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TN	Technical Note	X

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EXECUTIVE SUMMARY

This document describes the technical aspects of the delivered deformation activity map (V1) over the Canary island site: the Deformation Activity Map, including the Time Series information for each measured Persistent Scatterer, and the Hotspots Activity Map.

REFERENCE DOCUMENTS

N°	Title
RD1	DoW Part C
D.E3.2	Periodically upgraded geohazard activity maps over the two test sites of the project (V0)
D.C2.1 (V0)	Deliverable C2.1: Canary Islands area deformation activity map V0

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REVIEW: CORE TEAM

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1 INTRODUCTION

In this document are discussed the technical aspects of the two delivered deformation activity maps (version 1) of the Canary Islands test site: the Deformation Activity Map, including the Time Series (TS) information for each PS (Persistent Scatterer), and the derived Hotspots Activity Map.

It is worth to underline that at this step the deformation activity map includes all the typologies of surface deformation. This includes the anthropic ones, like for example those caused by construction or mining, which are usually not included in a Geohazard Activity Map.

The data processing to obtain the Deformation Activity Map has been performed by using the software tools developed and owned by the CTTC. The used procedure includes two main steps. The first one consists in the calculation of the stack of interferograms and coherences, while the second one consists in the generation of the deformations maps. The Canary Island site has a very high coherence for temporal baselines up to 150 days, in most of the covered area. This allowed to use the PS approach described in Devanthéry et al. 2014[(1)]. Compared to the first delivery, there is an improvement in the robustness of the results thanks to the increase of the period covered by the dataset.

In this iteration, we deliver two different levels of deformation activity map: (i) a Deformation Activity Map containing all the measured points; and (ii) the HotSpots Activity Map derived by analyzing the velocity data in a Geographic Information System (GIS) environment, as described in D.3.2[(2)]. The HotSpots Activity Map will be the main input, in terms of radar information, for the generation of the Geohazard Activity Maps.

The document consists of 6 sections: after the introduction, Section 2 describes the Sentinel-1 dataset at hand; Section 3 explains the processing and the technical aspects of the Deformation Activity Map; section 4 explains the processing to obtain the HotSpots Activity Map; section 5 describes the delivered maps and Section 6 underlines particular aspects of the results.

2 DATASET DESCRIPTION

The processed dataset consists of 51 Sentinel-1 Wide Swath images acquired during the period spanning from 5th November 2014 to 19th September 2016 (see Table 2-1). Table 2-1 shows the acquisition dates of the images: it can be observed that the maximum time interval of consecutive images is 48 days. The super master image is marked in red in Table 2-1, while the images used in the delivery v0 are marked in green. The main characteristics of the used images are summarized in Table 2-2. Figure 2-1 shows the footprint of the processed datasets consisting in 18 bursts divided in 3 swaths.

To process the interferometric products, we have used the SRTM Digital Elevation Model provided by NASA, and the precise orbits.

To derive the deformation map we have generated a network of 414 interferograms with a maximum temporal baseline of 156 days. The maximum temporal baseline has slightly increased with respect the v0 (108 days). The criteria used to derive it has been the same, i.e. a statistical analysis of the decrease of the coherence with respect the temporal baseline.

The selected resolution has been the multi-look 2 by 10 that corresponds to a footprint of approximately 28 by 40 m. This resolution is a compromise between the density of measureable points, due to coherence, and a resolution high enough to detect small deformation phenomena.

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[1] Devanthéry, M. Crosetto, O. Monserrat, M. Cuevas-González, B. Crippa. An approach to persistent scatterer interferometry. Remote Sens., 6 (7) (2014), pp. 6662–6679.

[2] Deliverable DE3.2: Periodically upgraded geohazard activity maps over the two test sites of the project (V0).

Nº image	Date	Nº image	Date	Nº image	Date
1	05/11/2014	18	27/07/2015	35	16/02/2016
2	17/11/2014	19	08/08/2015	36	28/02/2016
3	29/11/2014	20	20/08/2015	37	11/03/2016
4	11/12/2014	21	01/09/2015	38	23/03/2016
5	23/12/2014	22	13/09/2015	39	04/04/2016
6	04/01/2015	23	25/09/2015	40	16/04/2016
7	16/01/2015	24	07/10/2015	41	28/04/2016
8	28/01/2015	25	19/10/2015	42	10/05/2016
9	09/02/2015	26	31/10/2015	43	22/05/2016
10	21/02/2015	27	12/11/2015	44	03/06/2016
11	05/03/2015	28	24/11/2015	45	15/06/2016
12	17/03/2015	29	06/12/2015	46	09/07/2016
13	29/03/2015	30	18/12/2015	47	21/07/2016
14	22/04/2015	31	30/12/2015	48	02/08/2016
15	09/06/2015	32	11/01/2016	49	14/08/2016
16	03/07/2015	33	23/01/2016	50	07/09/2016
17	15/07/2015	34	04/02/2016	51	19/09/2016

Table 2-1 Dates of the 51 processed Sentinel-1 images. In red is highlighted the date of the super-master image, while in green are indicated the images used in v0.

Satellite	Sentinel-1
Acquisition mode	Wide Swath
Period	Nov 2014 - September 2016
Minimum revisit period [days]	12
Wavelength (λ) [cm]	5.55
Polarization	VV
Full resolution (azimuth/range) [m]	14/4
Multi-look 1x5 resolution (azimuth/range) [m]	14/20
Multi-look 2x10 resolution (azimuth/range) [m]	28/40
Orbit	Descending
Incidence angle of the area of interest	36.47º - 41.85º

Table 2-2 Main characteristics of the processed data.

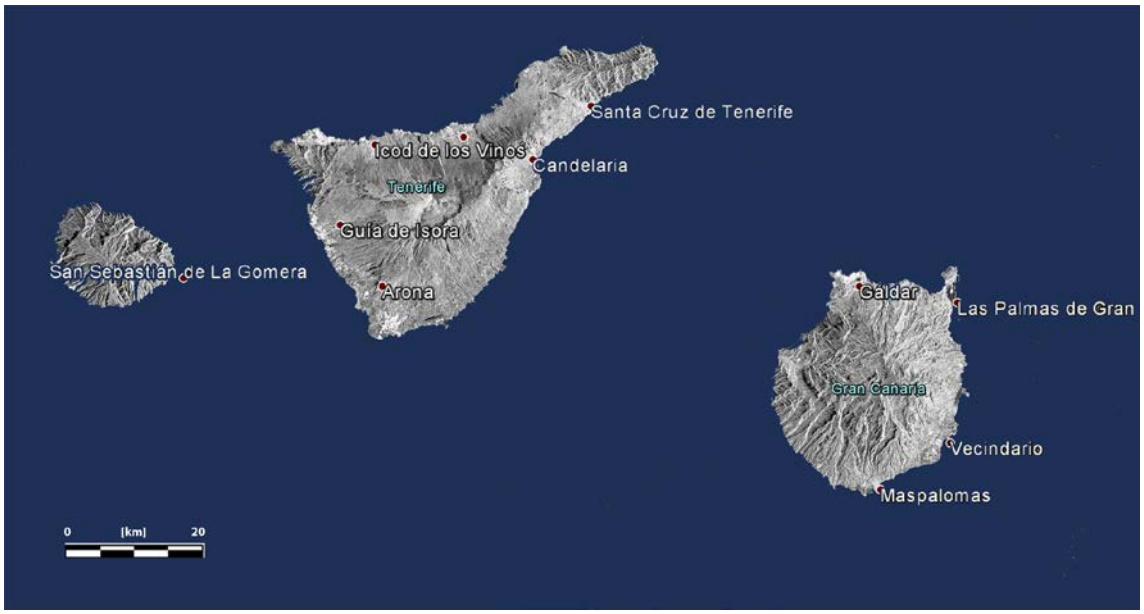

Figure 2-1 Mean amplitude image, geocoded and superimposed to a Google Earth image.

3 DEFORMATION ACTIVITY MAP

In the Canary Islands test site we have not changed the approach to generate the activity maps. It is a robust approach using multi-baseline interferograms, which is described in Devanthery et al. 2014[3]. For this second iteration (v1), we have used all the available images (including the dataset used for v0), in order to collect a long enough stack of images. For the following iteration, we will remove the six first months of measurements and we will add the next six ones.

The final point selection has been based in two different criteria: (i) the standard deviation (σ) of the residues between the estimated deformation velocity and the original interferometric phases, and (ii) a spatial criterion based on the variability of a point with respect its neighbors. The first one has been useful to remove the noisy points in terms of temporal behavior, while the second one has filtered the isolated points. The used threshold for the σ has been ±10 mm. We have selected this relatively high threshold in order to keep also non-strictly linear deformations. However, as a general statistic, the noise level (σ) of the estimated velocities has been evaluated to be ± 2 mm/yr.

Compared to the delivery v0, we have increased the number of points from 1082727 up to 1256701, from which 731250 are in Tenerife, 76389 are in La Gomera and 449063 in Gran Canaria. Moreover, it has been possible to improve the atmospheric phase removal of the North area of Tenerife.

The identification of the active phenomena is done in base of the deformation velocity. The threshold to discriminate between stable or moving point is ±4 mm/y (2σ). The total number of points identified as non-stable are 8283, less than 1% of the total number of measured points. Figure 3-1 shows an identified active area in Tenerife Island. It is located in the South-East of the island and is a subsidence phenomenon related to the activities of a landfill industry. This area was also active during the period of the first delivery. In particular, for this area, the mean velocity of the subsidence is -33.5 mm/yr (red area), while in the first delivery the mean velocity was -41.4 mm/yr. In this sense, it is observed a smooth decrease on the deformation velocities.

[3] Devanthéry, M. Crosetto, O. Monserrat, M. Cuevas-González, B. Crippa. An approach to persistent scatterer interferometry. Remote Sens., 6 (7) (2014), pp. 6662–6679.

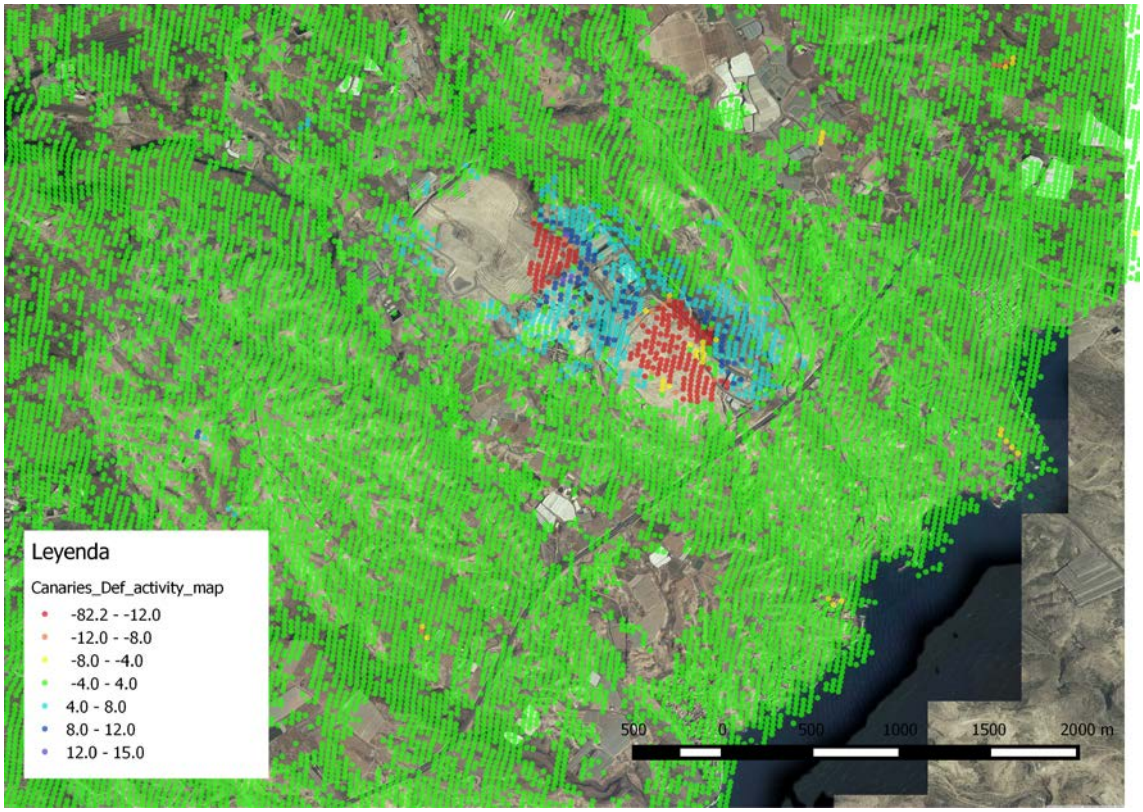

Figure 3-1 Active deformation area located in the South-East of Tenerife.

4 HOTSPOTS ACTIVITY MAP

The aim of the HotSpots Map generation is to perform a rapid identification (and monitoring, after the first validation) of the more probable "true deformation zones" (the hotspots) over the spatial noise of the velocity data. The final map has to be a clear input to be validated and integrated with other data (e.g. geohazard inventories, ground truth information, etc.) in order to determine the nature of the deformation and thus to generate a Geohazard Activity Map.

The HotSpots Map has been generated by following a partial implementation of the procedure described in the deliverable D.E3.2[4]. Figure 4.1 shows the flow chart of the used implementation. The main input is the deformation velocity map derived from radar data. The PS with absolute velocity (|v|) higher than a stability threshold (2σ) are selected. This threshold is a value representing the general noise of the data. Finally, from this subset of points (PS_m), only those areas with at least 5 PS_m within a fixed distance between themselves are considered HotSpots.

According to the statistical characteristics of the results, the error (σ) of the velocity measurements is around ±2.0 mm/yr (note that in the first iteration the error was ±5 mm). Hence, the threshold value of 4 mm/yr is set to distinguish active from stable PS (stability threshold) for the Canary Islands test site.

[4] Deliverable DE3.2: Periodically upgraded geohazard activity maps over the two test sites of the project (V0).

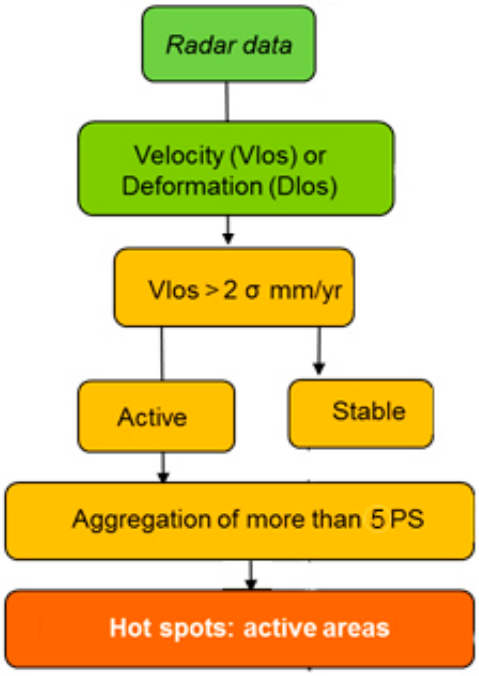

Figure 4-1: Flow chart of the methodology to identify the HotSpots. The green indicates the input data, the light orange indicates the procedure steps, while the dark orange the output of the methodology.

Once selected the PSs with a deformation velocity greater than 4 mm/yr (absolute value), groups of at least 5 neighbour PSs, sharing their influence area, have been aggregated. In order to define the influence area of every PS, we consider the multilook used in the processing to select the approximated footprint of a PS. The original resolution of the PS is 14 by 4 m. The applied multilook is 2 by 10 and yields an approximate PS area of 28 by 40 m. We calculate the radius of the circle inscribing a 40 by 40 m area where the PS is located and we multiply it by a factor of 1.3 to ensure that neighbouring pixels are selected. If the grouped PS are less than 5, they are considered to be a not significant deformation for a regional scale analysis. Finally, the HotSpots are classified using the maximum velocity (V_m) as follow:

- *Class 1*: $| V_m | > 1$ cm/yr.
- *Class 2*: $2\sigma < | V_m | \leq 1$ cm/yr

388 hotspots have been identified (114 Class 1): 218 in Tenerife, 150 in Gran Canaria and 20 in La Gomera. Compared with the v0, and considering only the Class 1 HotSpots, the number of coincident HotSpots between v0 and v1 is 55 of the 89 detected in v0. In this sense, it must to be underlined that the thresholds used to derive the v0 and v1 are quite different, and hence the comparison of the results is qualitative. We expect to provide a consistent v0, v1 and v2 HotSpots maps in terms of thresholding at the delivery of v3.

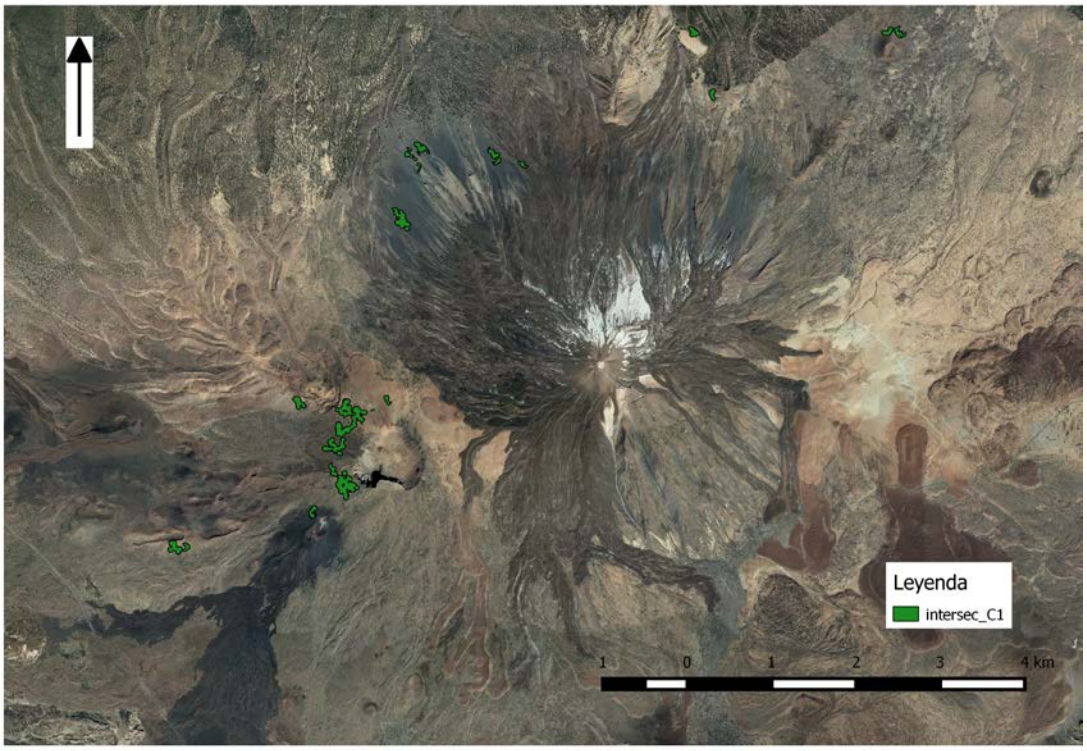

Figure 4-2: HotSpots detected in v0 and v1 in the Teide caldera area.

5 MAP DESCRIPTION

The delivered Deformation Activity Map consists in a shapefile of points with the following attribute fields:

Field	Description	Units
ID	Name of the point	-
Row	Radar image line	-
Col	Radar image column	-
Fi	WGS84 Geographic Latitude	[º]
Lambda	WGS84 Geographic Longitude	[º]
E	WGS84 UTM zone 32N - East	[m]
N	WGS84 UTM zone 32N - North	[m]
H	SRTM Height	[m]
Velocity	Point displacement velocity	[mm/yr]
S0	Sigma zero of the residuals of the velocity estimation	[mm]
Daaaa/mm/dd	Deformation value at the date aaaa/mm/dd	[mm]

Table 5-1 Description of the fields of the final deformation activity map shape file.

The delivered HotSpots Activity Maps consist in two shapefiles of polygons:

- D.C2.1_Canary_Island_HS_Canaries_GT_4mm_yr_v1: it contains the HotSpots with a velocity greater than 4 mm/yr
- D.C2.1_Canary_Island_HS_Canaries_LT_-4mm_yr_v1: it contains the HotSpots with a velocity lower than -4 mm/yr

The attribute fields of the shapefiles are:

Field	Description	Units
ID	Identification Number of the hotspot	-
Join_Count	Number of unstable points (velocity higher than 3 mm/yr) grouped in the hotspot	-
Row	Radar image line	-
Col	Radar image column	-
Fi	WGS84 Geographic Latitude	[º]
Lambda	WGS84 Geographic Longitude	[º]
E	WGS84 UTM zone 32N - East	[m]
N	WGS84 UTM zone 32N - North	[m]
H	SRTM Height	[m]
Velocity_mean	Mean velocity of the hotspot (average of displacement velocities of the grouped PSs)	[mm/yr]
Sigma0_mean	Mean sigma zero of the residuals of velocity estimation of the hotspot (average of the Sigma0s of the grouped PSs)	[mm]
Daaaa/mm/dd	Mean cumulated deformation of the hotspot at the last date of the dataset (aaaa/mm/dd)	[mm]
Velo_max	Maximum velocity of the PSs grouped in the hotspot (in terms of absolute value)	[mm/yr]
Velo_min	Minimum velocity of the PSs grouped in the hotspot (in terms of absolute value)	[mm/yr]
Class	Classification of the hotspots based on the Velo_max: Class = 1 if Velo_max ≥10 mm/yr. Class = 2 if Velo_max < 10 mm/yr.	-

Table 5-2: Description of the fields of the final HotSpot Activity map shape file.

6 OBSERVATIONS

- The total number of points is 1256701: 731250 in Tenerife, 449063 in Gran Canaria and 76389 in La Gomera.
- The deformations are in **Line of Sight**, i.e. they represent the projection of the real 3D displacement in the direction “satellite-point”.
- The negative values represent points that are moving far from the satellite (i.e. subsidence in case of vertical displacements). The negative ones represent those that are moving towards the satellite.
- Compared with the first delivery we have an improvement on the deformation measurements. However, the comparison between the v0 and v1 is not significant. For the last delivery of the project, we will provide consistent maps.