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First assessment of the interferometric capabilities of SAOCOM-1A: new results over the Domuyo Volcano, Neuquén Argentina

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Abstract

Differential Interferometric Synthetic Aperture Radar (DInSAR) has been used for measuring ground deformations with high both spatial and temporal resolutions. The effectiveness of this technique has been extensively proved using mainly C and X band because of the availability of SAR platforms operating in these frequencies. In vegetated areas, L-band SAR is more adequate because of their less sensitivity to temporal decorrelation. This work presents a review of the characteristics of the L-band Argentinian satellite SAOCOM-1A and its potential in deformation monitoring. In order to show it, we processed a dataset acquired over the Domuyo Volcano (Neuquén, Argentina). Time series and mean deformation maps are validated against those computed using a Sentinel-1 dataset spanning the same time period. Results show an inflation pattern of 6 cm between August 2019 and May 2020. As expected and despising the scarce availability of SAOCOM scenes, its mean velocity map is admittedly more coherent in comparison with the Sentinel-1. Thus, we demonstrate, for the first time, the computation of deformation time series using SAOCOM data.

Keywords: DinSAR, L-band, SAOCOM, Volcano deformation

I. INTRODUCTION

DInSAR is a technique that has been successfully used for generating large-scale surface deformation maps affecting an area of interest with sub-centimetric resolution. The deformation could be associated to several phenomena such as volcanic activity, oil and water extraction, seismic events, landslide, ice flow mapping, among others (Astort *et al.*, 2019; Cigna *et al.*, 2012; Goldstein & Werner, 1998; Lanari *et al.*, 2010; Velez *et al.*, 2011).

DInSAR makes use of the phase information available in the SAR signal for measuring the travel path difference between two acquisitions made at different times and orbital positions. Interferometric signal quality is commonly measured using a unitless quantity known as coherence, being it any process affecting the signal. In order to reduce the temporal and geometric decorrelation, SAR data must be acquired from relatively close tracks (spatial baseline) and times (temporal baseline). Displacement maps are obtained after a proper compensation of unwanted phase contributions, such as those originated by topography, residual orbital ramps, atmospheric and ionospheric patterns, among others (Hanssen, 2001; Hooper *et al.*, 2007; Rosen *et al.*, 2010).

An effective way for studying the dynamics of deformation phenomena and its temporal behavior is the generation of deformation time series and mean deformation velocity maps. This is possible by combining information obtained from multiple SAR images over a period of time. A well-known approach is the Small Baseline Subsets method (Berardino *et al.*, 2002). It relies on the combination of SAR scenes constraining the spatial and temporal baselines in order to preserve a higher number of pixels in the final solution. The set of computed interferograms are then inverted using least-squares criteria in order to retrieve the displacement that occurred at each epoch with respect to a reference time.

Decorrelation behavior is strongly linked to the wavelength of the SAR signal. SAR systems operate at different frequencies. Lower frequencies radars (e.g. L-band) lead to increased critical perpendicular baselines in comparison to higher frequencies radars (e.g. C or X-band), resulting in an increment of useful interferometric pairs for DInSAR applications (Sandwell *et al.*, 2008).

However, temporal baselines play the most important role in the quality of interferometric products which its optimal value depends on the application (Gupta, 2017; Massom & Lubin, 2006). Large values of temporal baseline lead to a loss of coherence by temporal decorrelation, which also increases rapidly with higher frequency, and indeed it represents one of the main limitations of InSAR technology (Bamler & Hartl, 1998a; Pepe & Calò, 2017). This type of decorrelation can be caused by physical changes in the terrain due to surface deformation, changes in vegetation, anthropic activities, freezing, thawing, movement of leaves due to wind, among others (Bamler & Hartl, 1998b), leading the dispersion characteristics to differ as a function of time (Hanssen, 2001; Pepe & Calò, 2017).

In the last years, worldwide Space Agencies are showing an increasing interest in the development of SAR systems operating at L-band. This fact is verified considering the successfully L-band systems already operating such as ALOS-2/PALSAR-2 (Japan Aerospace Exploration Agency, JAXA) (JAXA, 2019) and the forthcoming ones TANDEM-L (German Aerospace Center, DLR) (DLR, 2019), NISAR Mission (NASA and ISRO) (NASA, 2019) and ALOS-4 /PALSAR-3 (JAXA, 2019).

The National Commission of Space Activities of Argentina (CONAE) has developed two satellites carrying an L-band polarimetric SAR instrument, the SAOCOM 1-A (CONAE, 2019), which is already operational, and SAOCOM 1-B (CONAE, 2019), which was launched in August 30, 2020.

The aim of this work is to present the SAOCOM mission and its main characteristics. In order to evaluate its interferometric capabilities, we present the first results processing a dataset acquired over Domuyo volcano (Neuquén, Argentina). We compare our results with deformation maps computed using Sentinel-1 data.

In Section II we summarize the SAOCOM mission and its principal technical aspects for interferometry processes. Section III describes geologic aspects and unrest evidence of Domuyo volcano. Data sets and results are presented in Section IV and V, respectively.

II. SAOCOM MISSION

SAOCOM (Satélite Argentino de Observación con Microondas) is a constellation of two high-resolution, full-polarimetric SAR satellites. Together with the COSMO-SkyMed constellation of the Italian Space Agency (ASI), they constitute a system for the synergic use of X-band (COSMO-SkyMed) and L-band (SAOCOM) SAR data (Battagliere *et al.*, 2019; Virelli *et al.*, 2014) known as Italian-Argentine Satellite System for Emergency Management (SIASGE). The aim of this mission is to contribute to an emergency system through monitoring events such as floods, earthquakes, landslides, volcanic activity, among others and to generate operative soil moisture maps to support agriculture as well. However, the main purpose of the mission is to retrieve and generate operative soil moisture maps to support the agriculture. Thus, it has defined a series of sites where acquisitions are made systematically (background mission). It corresponds to the Pampean region of Argentina, which represents the main area in the country dedicated to agriculture and cattle production.

Revisit-time for single-pass acquisitions with SAOCOM-1A is 16-day while with both satellites, it will be reduced to 8-day (Euillades *et al.*, 2015). In Table 1 the main characteristics of SAOCOM mission are summarized.

The SAR instrument operates at a frequency of 1.275 GHz and supports three imaging modes (Stripmap Mode (SM), Topsar Narrow (TN) (A and B) and Topsar Wide (TW), providing different spatial resolutions and coverage. All observation modes can take advantage the left and right (default) looking capabilities provided by the satellite platform (Giraldez, 2003). Additionally, each imaging mode can be acquired with different polarizations: two single polarization modes (i.e. HH or VV), two dual polarization modes (i.e. HH and HV or VV and VH), one quad polarization mode (i.e. HH, HV, VH and VV) and two compact polarization (CP) modes (circular right and left). The general characteristics of each acquisition mode are detailed in Table 2. A graphical representation of the different acquisition modes is shown in Figure 1 (CONAE, 2020b).

SAOCOM products, with different levels of processing, are available in an open-access catalog. There are four different processing levels: L1A, L1B, L1C and L1D for which a general description can be found in Table 3. However, to download data or schedule a new data acquisition, it is necessary to have the respective permissions (see in the Appendix, section “Registration for Users of SAOCOM Products” of CONAE (2020a) for more details).

SAOCOM Level 1 products are generated for several acquisition modes and polarizations. Each acquisition mode has different beam positions, allowing the satellite to target different terrain locations to obtain a wide range of incidence angles, as we have previously shown in Figure 1.

The geolocation accuracy of the data depends mainly on the precision of the orbit determination. CONAE provides two types of orbit ephemeris, the faster one corresponds to the data processed with onboard GPS giving as a result an absolute geo-referencing accuracy better than 90 m on the ground. In the second and more precise one, the data is processed after two days resulting in an absolute geo-referencing accuracy better than 70 m on the ground (CONAE, 2020a). However, our results show that the orbital ephemeris is better than that stipulated as a requirement.

In the Appendix, a brief review of the SAOCOM Level 1 product description is done.

III. STUDY AREA

The Domuyo Volcanic Complex (DVC), known as the “Patagonian roof”, is located in the northwestern sector of Neuquén Province (36°38’S, 70°25’W) over the northernmost region of the Cordillera del Viento, in Argentina. It is the largest one of a series of young volcanoes arranged in the NW-SE direction, with a maximum elevation of 4709 m a.s.l. (Chiodini *et al.*, 2014; Tassi *et al.*, 2016). At a larger scale (Figure 2), Domuyo volcano belongs to a zone that has evolved as a consequence of convergence between the Nazca and the South America plates for the last 20 Ma years, known as Southern Volcanic Zone (SVZ) (Chiodini *et al.*, 2014).

The formation of the DVC has a complex geological history, where the composition of the main edifice does not respond to a typical central conduit stratovolcano formation (Páez *et al.*, 2014). Igneous and sedimentary rocks compose the main edifice associated with the infilling of the Neuquén Basin (Precuyan cycle, Cuyo, and Mendoza group), alongside an igneous basement (Choiyoi group and Varvarco Granodiorite). Later inverted and deformed within two stages (upper-Cretaceous and Miocene-Pliocene), which were afterward intruded by a Pliocene granitic stock (Folguera *et al.*, 2007; Llambías *et al.*, 1978; Miranda *et al.*, 2006).

The oldest Cenozoic volcanism begins with intermediate to basic Miocene rocks (Fm. Charilehue) that were affected by the last tectonic deformation event (Miranda *et al.*, 2006). The volcanic rocks surrounding the Domuyo volcano are represented by two compositional and temporally differentiable volcanic cycles (Brousse & Pesce, 1982; Chiodini *et al.*, 2014). A Lower Volcanic Cycle (Upper Pliocene to early Pleistocene) with calcoalkaline characteristics and mostly andesitic compositions that generated explosive eruptions, and a Superior Volcanic Cycle (Middle to Upper Pleistocene), associated to a high potassium calcium-alkali nature, dominated mostly by dacitic to rhyolitic rocks. This way, the last

Pleistocene volcanism (0,72±0,1 Ma to 0,11±0,02 Ma) from DVC was developed through monogenetic emission centers, distributed southwest of the main edifice (monogenetic dome forming structures) for a period of 610,000 years (Brousse & Pesce, 1982; Miranda *et al.*, 2006; Páez *et al.*, 2014).

Alongside this flank volcanism, a huge geothermal field considered a fault-controlled system (Pesce, 2010) has been developed with the second-highest advective heat flux measured in a hydrothermal system in the world after Yellowstone (Chiodini *et al.*, 2014). Based on geochemical analyses of gas and water samples, Tassi *et al.* (2016) proposed two possible reservoir levels: a relatively shallow hydrothermal reservoir characterized by medium-enthalpy conditions; and a deeper, high-enthalpy reservoir, which has been hypothesized by the Japan International Cooperation Agency (JICA) as well (JICA, 1983, 1984).

IV. EVIDENCE OF UNREST

For many years, there were a lot of controversies as to consider DVC as an active volcano. Only some evidence of phreatic activity in 2003, where two hydrothermal explosions occurred at El Humazo (Mas *et al.*, 2009). Alongside some hypotheses elaborated by Chiodini *et al.* (2014) and Tassi *et al.* (2016), based on the geochemical data, which indicated that the very large heat flux emitted was difficult to explain in terms of either the cooling of the old magmatic intrusions or the most recent volcanic activity. A possible younger volcanic activity was yet to be found and documented.

Until 2018, when a pattern deformation from InSAR was detected by Lundgren *et al.* (2018), that revealed a gentle to null subsidence from 2008 to 2014, which abruptly started inflating in 2014 until the present, with a surprising rate of 11 cm/year. In contrast, to a relatively steady thermal output from 2008 to 2013, that abruptly started to decline trough 2017, based on a thermal analysis using an algorithm that captures the diffuse emissions of heat through the volcanic edifice (Lundgren *et al.*, 2020, 2018).

This afterward led to the work presented by Astort *et al.* (2019), where evidence of unrest was found through the combination of seismic monitoring data, gravimetric and magnetic campaign data, as well as InSAR deformation maps, accompanied by a model of the source of the unrest.

With this new evidence discovered, the Argentine Geological and Minning Survey (SEGEMAR) re-evaluated his Relative Risk Ranking for Argentina (Elissondo & Farıas, 2016; Elissondo & Villegas, 2011), adding the DVC to the list of active volcanoes in the country, classifying number 16 of the ranking. This also led to the development of a plan from the Argentine Observatory of Volcanic Surveillance (OAVV) from SEGEMAR, to develop a monitoring network over the DVC to monitor its activity and try to understand better the origins of this unrest episode.

In this context, the possibility to use new radar information from the SAOCOM constellation might bring up new information regarding the unrest process of the DVC.

V. SYNTHETIC APERTURE RADAR DATA

The SAR dataset considered in this work consist of 7 ascending (Path:44, Row:387) scenes acquired by the SAOCOM-1A Mission (CONAE, L-Band) between August 2019 and May 2020 with a side-looking angle (ϑ) of about 40.7^{o} It is important to note that the low number of images used in this work is a consequence of the recent start of the SAOCOM-1A operative phase. The polarization acquired is single-pol (SP) HH and the operation mode is S7 (Stripmap Mode, beam position 7), covering a 1272 km^2 area surrounding the Domuyo edifice (Figure 3).

For the SAOCOM dataset, we compute 18 differential interferograms, summarized in Table 4, with a maximum spatial and temporal baseline of 1475 m and 288 days, respectively. We applied a multi looking factor of 10, in the azimuth and range directions, obtaining a roughly pixel size of 35x50 m. For comparison purposes, 23 ascending (Path: 18, Frame:1055) scene acquired by Sentinel-1A Mission

(European Space Agency, C-Band), covering the same period and the same area was processed with a side-looking angle (ϑ) of about 33.3^{o}. Sentinel dataset was acquired in Interferometric Wide (IW) mode. Only three bursts of the sub-swath 1, including the area of interest, were considered.

In the Sentinel case, we compute 71 interferograms with a maximum spatial and temporal baselines of 120 m and 252 days, respectively. The multi looking factor applied was of 2 and 20, in the azimuth and range directions, giving a roughly pixel size of 31x47 m. Figure 4 (a and b) shows the interferometric SAR distribution selected for both cases in the temporal versus perpendicular baselines plane. Topography was compensated using the 30 m SRTM Digital Elevation Model (Farr *et al.*, 2007). Both datasets were processed using the SBAS approach (Berardino *et al.*, 2002). No common band filtering was applied in this work.

SAOCOM-1A dataset used in this study has the most accurate orbit ephemeris currently available (70 m of absolute geo-referencing accuracy as a requirement). Nevertheless, even when the accuracy appears to be better than the stipulated as a requirement, it is a large error when considering the precision of Sentinel-1 dataset (about 10 cm). This low precision in the orbital information can generate errors in parallel and perpendicular baseline estimation, which induces artifacts known as orbital ramps in azimuth and range directions, and whose superposition can result in a ramp with any orientation. This kind of phase artifact has been extensively studied in the past, proposing several approaches for removing them from the interferograms (Buckley *et al.*, 2000; Knedlik *et al.*, 1999; Rosen *et al.*, 2004). During the processing of SAOCOM-1A data, range ramps became evident, as shown in Figure 5.

In this work, we apply the approach proposed by Pepe *et al.* (2011), where the estimation of the orbital errors is performed on the set of the available interferograms. These estimations are afterward used for adjusting the orbital data for each individual scene. The resulting differential interferograms after orbital error compensation are shown in Figure 6.

In Table 5 we show the perpendicular and parallel baseline values calculated before and after the orbital error compensation. From this table, we observe that the main contribution to the residual ramps came from the misestimation of the perpendicular baseline. It is congruent with the results shown in Figure 5, where the direction of the ramps are mainly in the range direction.

Once orbital residual phase was removed, patterns of not-well compensated phase are still present. This effect, which could be associated with stratified atmosphere, can mask out the deformation signal. This should be compensated or reduced, avoiding introducing undesired seasonal behavior in the time series (Samsonov *et al.*, 2014). Moreover, the influence of the atmosphere also depends on the radar frequency and the sensor look-angle (Rongier *et al.*, 2019). Greater look angles generate an excess on the traveled path, increasing the atmospheric phase contribution in the interferograms. In order to compensate for this effect, we corrected each differential interferogram using Zenith Total Delay (ZTD) corrections provided by the Generic Atmospheric Correction Online Service (GACOS) before phase unwrapping and time-series computation (Yu *et al.*, 2018a,b, 2017).

The European Center for Geodynamics and Seismology (ECGS, Luxembourg) and the Research Institute of Paleobiology and Geology (IIPG, National University of Río Negro, Argentina) have developed a monitoring system working in near real-time over the Domuyo volcano. Because they have the availability of ascending and descending datasets acquired by Sentinel-1 A/B radars, they decompose the Line of Sight (LOS) deformation in horizontal (east-west) and vertical (up-down) components. This decomposition reveals that the horizontal component of the LOS displacement observed over the volcanic complex can be considered negligible, being the deformation pattern mainly vertical (Figure 7). The time series are calculated using Sentinel-1 data and are available at InSAR automated Mass processing Toolbox for Multidimensional time series (MasTer) (Samsonov *et al.*, 2020).

To perform a comparison between Sentinel and SAOCOM we should remove the look-angle (ϑ) dependence. This is possible projecting the LOS displacement in the vertical component due to the fact that the horizontal component could be considered negligible, as we previously stated. Therefore, we projected our results on the vertical component using Equation 1.

$$d_v = \frac{d_{LOS}}{\cos(\vartheta)} \quad (1)$$

where the Line-of-Sight displacement (d_{LOS}) is related to the interferometric phase through equation 2 (Euillades *et al.*, 2015) in absence of other phase components.

$$d_{LOS} = \frac{\lambda}{4\pi} \Delta\phi^{DinSAR} \quad (2)$$

VI. RESULTS

SBAS processing results are shown in Figure 8. LOS deformation maps derived from SAOCOM-1A (a) and Sentinel-1 (b) data were computed considering a coherence threshold of 0.7.

We identified the presence of an inflation process with a rate of roughly 6 cm/year centered at the edifice of the Domuyo volcano. The observed deformation pattern is more noticeable in the mean deformation map of Sentinel than of SAOCOM map. This effect has two explanations. On one side, longer wavelength systems are less sensitive for measuring deformation using interferometric techniques (Sandwell *et al.*, 2008). On the other side, a higher side looking angle, depending on the mode used for acquiring the dataset, render less sensitive the system to vertical deformation. In this work, both conditions are present when comparing the SAOCOM results against those of the Sentinel-1.

Accordingly, Figure 9 shows the vertical projection of the LOS mean displacement velocity maps. From this Figure we can see the similarity between both results. However, the number of coherent points on the SAOCOM case overcome the one observed in the Sentinel one as we expected for using L-band data.

With the aim to exemplify this effect, we computed coherence histograms (Figure 10) considering two interferometric pairs covering the same spatial area and time span between February and May, 2020 (96 days). As can be observed, higher coherence values are more frequent in the SAOCOM case, despite the coherence loss due to the perpendicular baseline is practically negligible in the Sentinel interferogram ($B_\perp$ = 2 m) versus the SAOCOM one ($B_\perp$ = 1089 m).

Finally, in order to evaluate the temporal behavior of the displacement respect to a reference point (indicated in Figure 9 as Rf), we extracted time series of selected points around the Domuyo volcano from both data sets. This is depicted in Figure 11 (labeled as 1 to 6 in the velocity maps), where it is possible to observe a correspondence between displacements of both sensors with deformation of 6 cm being congruent with those observed by ECGS & IIPG.

VII. CONCLUSION

In this work we present the main characteristics of SAOCOM-1A mission and the first results of its use for computing deformation time series. For comparison purpose, we also processed a dataset of Sentinel-1 acquired over the same area spanning the same time. Our results show the good quality of SAOCOM data. Even when the orbital accuracy was lower than for Sentinel-1, applying an orbital algorithm correction allows us to recompute the orbital ephemeris improving the resulting interferograms. It is remarked that the residual orbital phase in the original interferograms indicates a better accuracy than the informed as a requirement (70 m) even when the number of available data is not enough to estimate a confident statistical analysis. Additionally, due to the high relief present in our area of interest, a correction to reduce the atmospheric phase contribution was applied.

Despite the fact of SAOCOM limited available data due to its short operating time, we could detect deformation of at least 6 cm spanning August 2019 to May 2020 over the Domuyo volcano, related to inflation of the volcanic edifice. Domuyo Volcano has been added to the list of active volcanoes in the country, ranking 16 in the Relative Risk Ranking for Argentina. For this reason, having new data from a sensor as SAOCOM represents a powerful tool for its monitoring.

Analyzing the mean LOS displacement maps, calculated using the SBAS algorithm, we found a lower sensitivity to the vertical component for SAOCOM compared with Sentinel-1. Supported by free time series available for Domuyo volcano and provided by ECGS & IIPG we found that the horizontal component was negligible, allowing us to reproject our results on the vertical component. Computed time series are consistent between both processing. Additionally, the use of L-band data shows a higher number of coherent points than Sentinel-1 (C-band), even with the low number of SAOCOM images available for this study.

SAOCOM-1A results show better coherence than Sentinel, in particular in those portions with the presence of vegetation, despite the fact that temporal resolution is 16 days against 6 of Sentinel-1. It is a key feature of L-band radar, being it important for studying vegetated areas like i.e., volcanic ones in Central America.

APPENDIX

SAOCOM LEVEL-1A PRODUCT DESCRIPTION

The SAOCOM L1 standard product is composed of a structure in which the content depends on the level data type. There are 4 different standard products distinguishable as Level 1A, 1B, 1C, and 1D. The general structure of the product is described as a DATA file (a zip file containing the products itself) and a description metadata XML file in XEMT format. On the metadata file, a description of the overall content of the product, and other details regarding download and processing performed on data during the data processing can be found. On the other hand, the zip file contains all the scientific and ancillary data. The number of measurement data and XML files contained in the data zip depends on acquisition mode and polarization.

The SAR image is contained in a binary geoTIFF. Since the geoTIFF file sizes commonly are bigger than 4 GB a big tiff file encoded is required. The SAR data is written in single precision floating point and from the 8 bytes for each sample of SLC products 4 corresponds to the real part and 4 to the imaginary part.

The XML file contains all the metadata associated to the SAR image. Information about the geoTIFF data are related to the main properties and parameters of the raster binary data as the number of samples, number of lines, header offset size, etc. High-level information regarding the data set e.g acquisition mode, sensor, image type, radar carrier frequency, among others, are also included. In addition, information such as the sampling frequencies and bandwidths corresponding to the data acquisition is available at this level. Information related to the position and velocity of the sensor along the orbit is provided too. Note that orbit products are not currently provided as independent products.

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Caption Figures:

Figure 1. Graphical representation of the different acquisition modes of SAOCOM-1 (CONAE, 2020b). Stripmap Mode (SM), Topsar Narrow (TN) (A and B), Topsar Wide (TW).

Figure 2. Geographical location of the Andean volcanic belt (yellow triangles), where the red triangle represents the Domuyo Volcanic Complex, which belongs to the Southern Volcanic Zone.

Figure 3. Covered area by SAOCOM-1A (red) and Sentinel-1A (blue) over the area of interest. Black contour is the Domuyo Volcanic Complex.

Figure 4. Interferometric SAR distribution for SAOCOM (a) and Sentinel-1 (b) in the temporal-perpendicular baselines plane. Lines linking different acquisition dates correspond to the computed interferograms.

Figure 5. Interferometric phases computed using SAOCOM-1A data. Residual ramps are introduced by the uncertainties of the satellite's ephemeris.

Figure 6. Interferometric phases after removing the residual orbital ramps.

Figure 7. Time series plot of the horizontal (blue) and vertical (green) projection LOS displacement calculated by ECGS & IIPG using Sentinel-1 data over Domuyo Volcano. The orange box shows the time period encompassed by the SAOCOM dataset and the blue ones the displacement considered between the analyzed time period.

Figure 8. LOS mean displacement velocity maps generated by processing SAOCOM-1A data (a) and Sentinel-1 data (b) spanning August 2019 to May 2020.

Figure 9. Vertical LOS mean displacement velocity maps generated by processing SAOCOM-1A data (a) and Sentinel data (b) spanning August 2019 to May 2020.

Figure 10. Coherence histogram for SAOCOM (a) and Sentinel-1 (b) interferometric pairs with a time span of 96 days between February and May, 2020.

Figure 11. Displacement time-series for 6 SAR points surrounding Domuyo volcano respect a reference point (Rf). Magenta crosses represent Sentinel-1, green dots represent SAOCOM-1A and the blue dotted line represents the point considered as the reference.

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Frequency (MHz)	1275
Max. Bandwidth (MHz)	50
Transmit Power (Kw)	4.1
PRF (Hz)	up to 2500 per channel
Mission lifetime	5 years
Orbit	Heliosynchronous
Altitude (km)	620
Operation time	15 minutes average per orbit
Antenna looking angle	rightside (default)
Spatial resolution (m)	10 – 100
Total incidence angle range (deg)	20 – 50
Swath width (km)	20 – 350
Polarimetric capabilities	single, dual, quad & compact pol

Table 1: SAOCOM mission general features (CONAE, 2020a).

Mode	Beam Position	Polarization	Minimum Incidence Angle Range		Nominal Spatial Resolution		Minimum Swath Width (ground range) [km]
					L1A Products	L1B. L1C. and L1D Products	
			Near range [deg]	Far range [deg]	Ground Range x Azimuth [m x m]	Ground Range x Azimuth [m x m]	
Stripmap	S1	SP & DP	20.7-48.8	25.0-50.2	10x5	10x10	49.7
	S2						52.3
	S3						61.4
	S4						65.7
	S5						49.1
	S6						55.6
	S7						48.0
	S8						31.9
	S9						31.1
Stripmap	S1	QP	17.6-34.6	19.6-35.5	10x6	10x10	21.9
	S2						22.0
	S3						21.0
	S4						25.4
	S5						23.4
	S6						29.4
	S7						20.9
	S8						25.1
	S9						22.1
	S10						14.2
TOPSAR Narrow	TNA	SP & DP	24.4	38.3	10x30	30x30	176.3
	TNB		38.2	47.1			150.2
TOPSAR Narrow	TNA	QP	17.6	27.3	10x50	50x50	109.9
	TNB		27.2	35.5			108.8
TOPSAR Wide	TW	SP & DP	24.9	48.7	10x50	50x50	353.7
TOPSAR Wide	TW	QP	17.6	35.5	10x100	100x100	218.1

Table 2: Resolution and coverage for each acquisition mode and different polarization combination (Single-Pol (SP), Dual-Pol (DP), Quad-Pol (QP).

Level	Name	Description
L1A	Single Look Complex (SLC)	Complex data, radiometrically calibrated, data is in slant range, no geometric corrections are made.
L1B	Detected Image (DI)	Contains georeferenced data in ground range, data is radiometrically calibrated.
L1C	Ground Ellipsoid Corrected (GEC)	Data is radiometrically calibrated and geocoded based on ellipsoid.
L1D	Ground Terrain corrected (GTC)	Data is radiometrically calibrated and geocoded based on Digital Elevation Model.

Table 3: SAOCOM data processing levels (CONAE, 2020a).

N	Date 1	Date 2	$B_\perp$[m]	B_t[days]
0	Aug 2, 2019	Sept 3, 2019	37	32
1	Aug 2, 2019	Oct, 05 2019	894	64
2	Aug 2, 2019	Feb 26, 2020	486	207
3	Sept 3, 2019	Oct 05, 2019	856	32
4	Sept 3, 2019	Feb 10, 2020	221	159
5	Sept 3, 2019	Feb 26, 2020	523	175
6	Oct 05, 2019	Feb 10, 2020	634	127
7	Oct 05, 2019	Apr 30, 2020	580	208
8	Oct 05, 2019	May 16, 2020	440	224
9	Feb 10, 2020	Feb 26, 2020	744	15
10	Feb 10, 2020	May 16, 2020	1076	96
11	Apr 30, 2020	May 16, 2020	139	15
12	Aug 2, 2019	Apr 30, 2020	1475	272
13	Aug 2, 2019	May 16, 2020	1335	288
14	Sept 3, 2019	Apr 30, 2020	1437	240
15	Sept 3, 2019	May 16, 2020	1297	256
16	Oct 05, 2019	Feb 26, 2020	1379	143
17	Feb 10, 2020	Apr 30, 2020	1216	80

Table 4: Set of interferograms computed from the SAOCOM-1A dataset (Stripmap (S7) single-pol). Perpendicular and temporal baseline are refer as $B_\perp$ and B_t, respectively.

N	Date	$B_\perp$[m]	$B_\perp$corrected[m]	$B_\parallel$[m]	$B_\parallel$corrected[m]
0	Feb 10, 2020	0	0	0	0
1	Aug 02, 2019	260.050	255.482	233.881	233.555
2	Sept 03, 2019	221.877	214.809	111.348	110.995
3	Oct 05, 2019	-638.302	-638.928	-569.678	-569.151
4	Feb 26, 2020	748.091	744.570	626.973	626.175
5	Apr 30, 2020	-1222.44	-1237.25	-1114.80	-1113.70
6	May 16, 2020	-1081.91	-1096.25	-1006.63	-1005.65

Table 5: Perpendicular and parallel baseline before and after orbital correction. Perpendicular and parallel baseline are refer as $B_\perp$ and $B_\parallel$, respectively.

- Satélite Argentino de Observación con Microondas (SAOCOM).
- Differential Interferometric Synthetic Aperture Radar (DInSAR).
- Domuyo volcanic complex (DVC).
- Potential of the polarimetric L-band Argentinian satellite SAOCOM-1A for deformation monitoring.
- Review of the characteristics of the L-band Argentinian satellite SAOCOM-1A.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: