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USUARIO DE PRODUCTOS

SAOCOM PROJECT

SAOCOM 1
Mission Acquisition Plans

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APPLICABLE DOCUMENTS		
N°	CODE	TITLE
DA1	PNE	Plan Espacial Nacional Argentina en el Espacio

REFERENCE DOCUMENTS		
N°	CODE	TITLE
RE1	SAO-MIS-PL-00012-A	Integrated Mission Acquisition Strategy
RE2	SAO-MIS-HB-00001-C	SAOCOM Mission Products Definition
RE3		Catálogo SAOCOM – Manual de Usuario

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1. About the document

1.1. Objective

The objective of this document is to describe the systematic image acquisition plan for the SAOCOM 1 Mission. This plan has global coverage, with an emphasis on Argentina, and includes the planning for both satellites of the constellation, SAOCOM-1A and SAOCOM-1B, for each 16-day orbital cycle.

1.2. Scope

This document is intended for all stakeholders interested in SAOCOM products.

1.3. List of acronyms and abbreviations

ASI	*Agenzia Spaziale Italiana* (Italian Space Agency)
CEOS	Committee on Earth Observation Satellites
CONAE	*Comisión Nacional de Actividades Espaciales* (National Commission on Space Activities of Argentina)
GIS	Geographic Information System
IMAS	Integrated Mission Acquisition Strategy
ROI	Region of Interest
SAOCOM	*Satélite Argentino de Observación Con Microondas* (Argentine Microwave Observation Satellite)
SAR	Synthetic Aperture Radar
SIASGE	*Sistema Ítalo-Argentino de Satélites para la Gestión de Emergencias* (Italian-Argentine Satellite System for Emergency Management)

2. Introduction

The SAOCOM 1 Mission, within the framework of the National Space Program [DA1], has designed a strategy for the image acquisition plan, both over Argentina and globally, including both satellites of the constellation (SAOCOM-1A and SAOCOM-1B). This is known as the Integrated Mission Acquisition Strategy, or IMAS.

The strategy aims to provide global coverage while optimizing revisit times over Argentine territory. Specifically, the IMAS Plan was designed to:

- meet the primary mission objective, i.e., the generation of soil moisture products and strategic application products in the Argentine Pampas region,
- provide frequent, adequate, and timely coverage of the Argentine Sea,
- provide frequent and optimized coverage of continental Argentina, besides the Pampas region, to meet the general mission objectives,
- provide optimized coverage of the Antarctic region, particularly the Argentine Antarctic Sector,
- support Argentine summer Antarctic campaigns,
- provide optimized coverage of the surrounding areas of neighboring countries,
- provide global coverage by organizing acquisitions in suitable schemes to make the most of the available resources.

This planning is based on the needs identified by CONAE from its experience with users and other national and third-party missions. This plan covers around 3,000 acquisitions per 16-day orbital cycle, representing a complex optimization process aimed at largely satisfying users' interests while keeping the mission goals in view.

The plan considers the time of year and frequency for acquisitions, as well as the mode of observation for each region of interest. A general Acquisition Plan is generated for each orbital cycle based on these considerations. In the Ground Station, users' requests are dynamically integrated into this plan. The SAOCOM acquisition plan viewer only includes the acquisitions outlined in the IMAS plan and does not include users' requests.

Conflicts between the planned IMAS acquisitions and users' requests are managed according to priorities. Therefore, it is likely that some planned acquisitions may not be carried out due to overlapping with higher-priority requests. This plan is thus nominal, representing what is planned. The SAOCOM catalog can be consulted for acquired images (https://catalog.saocom.conae.gov.ar/catalog/#/).

It is worth mentioning that according to mission objectives, the acquisitions planned for the Argentine Pampas region have high priority and they will generally not be cancelled due to other requests, except in exceptional cases. Similar conditions apply to acquisitions over the Argentine Sea and calibration acquisitions.

From this planning, interested parties can subscribe to the acquisitions they find of interest through the corresponding tool of the SAOCOM catalog (RE3[1]).

[1] https://catalogos.conae.gov.ar/catalogo/docs/SAOCOM/Manual_Usuario_SAOCOM_Feb-2023.pdf

Finally, while the systematic plan is intended to remain stable over time, it is scheduled to be periodically reviewed to update it if new needs are detected.

3. Description of the Acquisition Plan

The IMAS Plan originates with the SAOCOM mission [RE1] and has evolved over time up to its current version. The initial design included several scenarios with different scopes. For acquisitions over Argentina, approximately 20 application areas were defined, each with its region of interest and specific acquisition mode, to be captured throughout the year in different specific periods. Globally, the focus was on obtaining image series over forested areas, consistent with CEOS recommendations.

Due to the intrinsic behavior of SAR instruments and the internal calibration requirements, a certain amount of time, known as the *guard time*, must elapse between one acquisition and the next one. This creates acquisition *gaps* that can vary between approximately 120 and 200 km in length along the pass (see 3.1.1.3 Overlap dynamics), depending on the acquisition modes used (see Appendix 1: SAOCOM Acquisition Modes).

Thus, even though acquisitions from both satellites were complementary to improve coverage, the diversity of modes used, and the large number of application areas made it difficult to achieve optimized coverage, creating areas that were impossible to cover when considering the guard time between acquisitions.

For this reason, the various application areas over Argentina were grouped, choosing the most appropriate acquisition modes, adjusting their geographic extent, and extending the acquisition period to the entire year for all cases. In 2024, the plan was redesigned, dividing the country into a few regions. This new plan is simpler, more understandable, systematic, and resolves the limitations of the previous plan, without compromising the usefulness of the acquisitions for various applications. As a result, coverage is optimized, and revisit over Argentina is increased. It also allows greater predictability of future acquisitions encouraging SAOCOM image users to manage their requests more efficiently (see 3.1 Acquisition plan for Argentina and surrounding areas).

On a global scale, i.e., outside of Argentina and its neighboring areas, acquisitions were extended to cover all regions, not just forested areas, and the acquisition period was extended to the entire year. To maximize onboard memory and data download to ground stations, the plan for these regions is structured using 45 latitude bands[2] of 470 km width, with 25 km overlap on both sides of the band. The acquisitions in the different modes corresponding to these bands alternate cycle by cycle to achieve global coverage with the best possible revisit times according to this scheme (see 3.2 Global acquisition plan).

[2] Space comprised between two latitudes.

3.1. Acquisition plan for Argentina and surrounding areas

3.1.1. Continental Argentina

3.1.1.1.Ascending orbits

As mentioned before, the design of the new acquisition scheme for the IMAS plan grouped the various application areas to consider only a few regions over the continental Argentine territory for optimization purposes.

Finally, a division was made into three regions for both ascending[3] and descending[4] orbits, aiming, as far as possible, to maintain the same acquisition modes used previously to have historical time series.

Figure 1 shows the three regions proposed for acquisitions in ascending orbit.

Figure 1. Regions defined for ascending orbit acquisitions over Argentina and surrounding areas.

[3] Ascending orbit refers to the trajectory from south to north.
[4] Descending orbit refers to the trajectory from north to south.

Region 1A includes the northwestern mountain range and part of Patagonia. It is covered by both satellites using three StripMap Dual Pol modes, necessary for full coverage. The acquisition scheme also aims to provide interferometric pairs.

Region 2A covers the southern mountain range and Patagonian sectors. This region, being further south, only requires two StripMap Dual Pol modes for full coverage. One mode is used for each satellite to improve revisit times, also allowing interferometric pairs.

Region 3A includes the Pampas region and the northeastern part of the country. This region is covered by six StripMap Quad Pol modes, particularly for soil moisture map generation in the Pampas region, the mission's main objective. Three modes are used for each satellite, complementing one another.

Note that the division of these regions, particularly the boundary between Region 1A and Region 2A, follows the geometry of ascending orbits to minimize acquisition conflicts.

Table 1 shows the acquisition modes used in ascending orbits for each of the three regions.

TABLE 1. Ascending orbit acquisition modes for Argentina and surrounding areas.

	ASCENDING ACQUISITION MODES	
SCENARIOS	SAOCOM-1A	SAOCOM-1B
Region 1A	S3DP, S4DP, S5DP	S3DP, S4DP, S5DP
Region 2A	S3DP	S4DP
Region 3A	S5QP, S7QP, S9QP	S4QP, S6QP, S8QP

3.1.1.2. Descending orbits

The division of regions for descending orbits followed a similar criterion to that of ascending orbits. Figure 2 shows the three regions proposed for acquisitions in descending orbit.

Region 1D includes the northern part of the country and much of the mountain range. It is covered by both satellites using three StripMap Dual Pol modes. These modes are necessary for full coverage, particularly in the northern part. The acquisition scheme also aims to provide interferometric pairs.

Region 2D covers much of Patagonia and the southern mountain range. This region, being further south, only requires two StripMap Dual Pol modes for full coverage. As with the ascending orbit case, one mode is used for each satellite to improve revisit times, also providing interferometric pairs.

Region 3D includes the Pampas region and Argentine Mesopotamia. This region is covered by the TOPSAR Narrow Quad Pol A and B modes, particularly for soil moisture map generation in the Pampas region, the mission's main objective. One mode is used for each satellite, complementing one another.

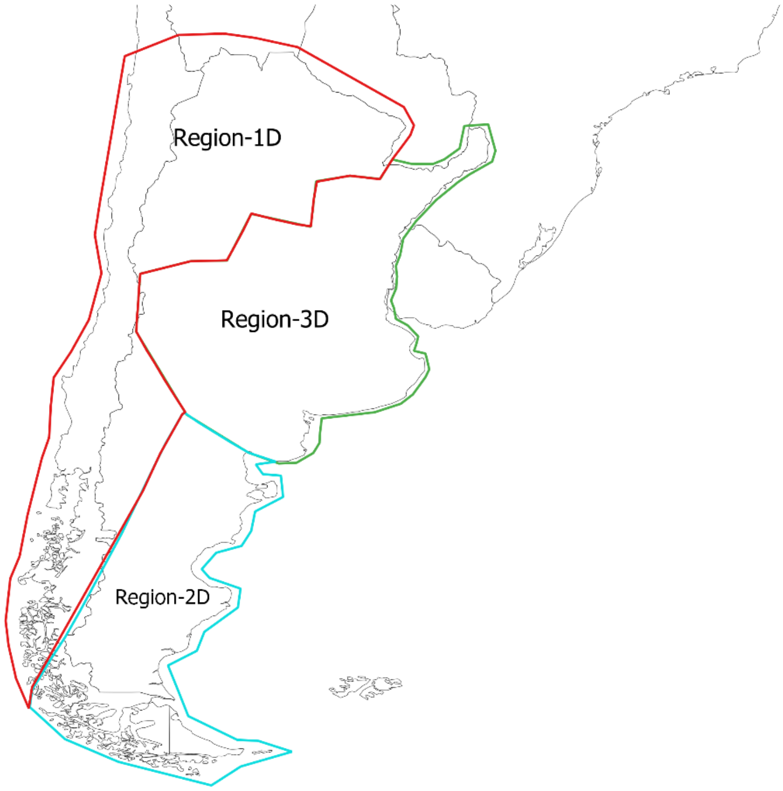


Figure 2. Regions defined for descending orbit acquisitions for Argentina and surrounding areas.

Note that the division of these regions, particularly the boundary between Region 1D and Region 2D, follows the geometry of descending orbits to minimize acquisition conflicts.

Table 2 shows the acquisition modes used in descending orbits for each of the three regions.

TABLE 2. Descending orbit acquisition modes for Argentina and surrounding areas.

	DESCENDING ACQUISITION MODES	
SCENARIOS	SAOCOM-1A	SAOCOM-1B

Region 1D	S3DP, S4DP, S5DP	S3DP, S4DP, S5DP
Region 2D	S3DP	S4DP
Region 3D	TNBQP	TNAQP

3.1.1.3. Overlap dynamics

As mentioned earlier, due to the guard time, there is a gap between successive acquisitions, which can vary between 120 and 200 km in length, depending on the acquisition modes involved.

To cover these gaps, an overlap dynamic was proposed at the borders between regions, where the transition between acquisition modes occurs.

This dynamic involves varying the length of the acquisitions at the region boundaries, with alternating forward and backward movements, to cover the gaps that appear in the acquisition mode change zones. This scheme repeats every few cycles, depending on the number and type of acquisition modes involved in each region.

Figure 3 shows an example of this scheme for the transition between Region 1 and Region 3 for ascending orbits. In this case, the number of cycles involved is three, as there are three different acquisition modes used in each region.

In Figure 3 a), in the Northwestern region of Argentina, it can be seen that in Cycle 17, S9QP acquisitions of Region 3 advances into Region 1, causing corresponding S3DP acquisitions of Region 1 to move back. It can also be observed that other S9QP acquisitions in Region 3 move back while the corresponding S3DP acquisitions in Region 1 advance. Three cycles later, in Cycle 20, the opposite occurs. In Figure 3 b), it can be seen that the acquisitions that moved forward in Cycle 17 move back in Cycle 20 and vice versa. Figure 3 c) shows the acquisitions from Cycles 17 and 20 overlapped, demonstrating how the gaps are covered.

This figure also shows that the acquisitions in Cycle 20 extend to the north, which is due to the coverage scheme for the surrounding areas of Argentina. The choice of which acquisitions advance and which move back in each cycle is based on Plan design considerations that are beyond the scope of this document. The goal here is to illustrate the overlap scheme applied to region boundaries, so the gaps due to guard times are covered. Note that these transition zones are covered less frequently, but otherwise, they would remain uncovered.

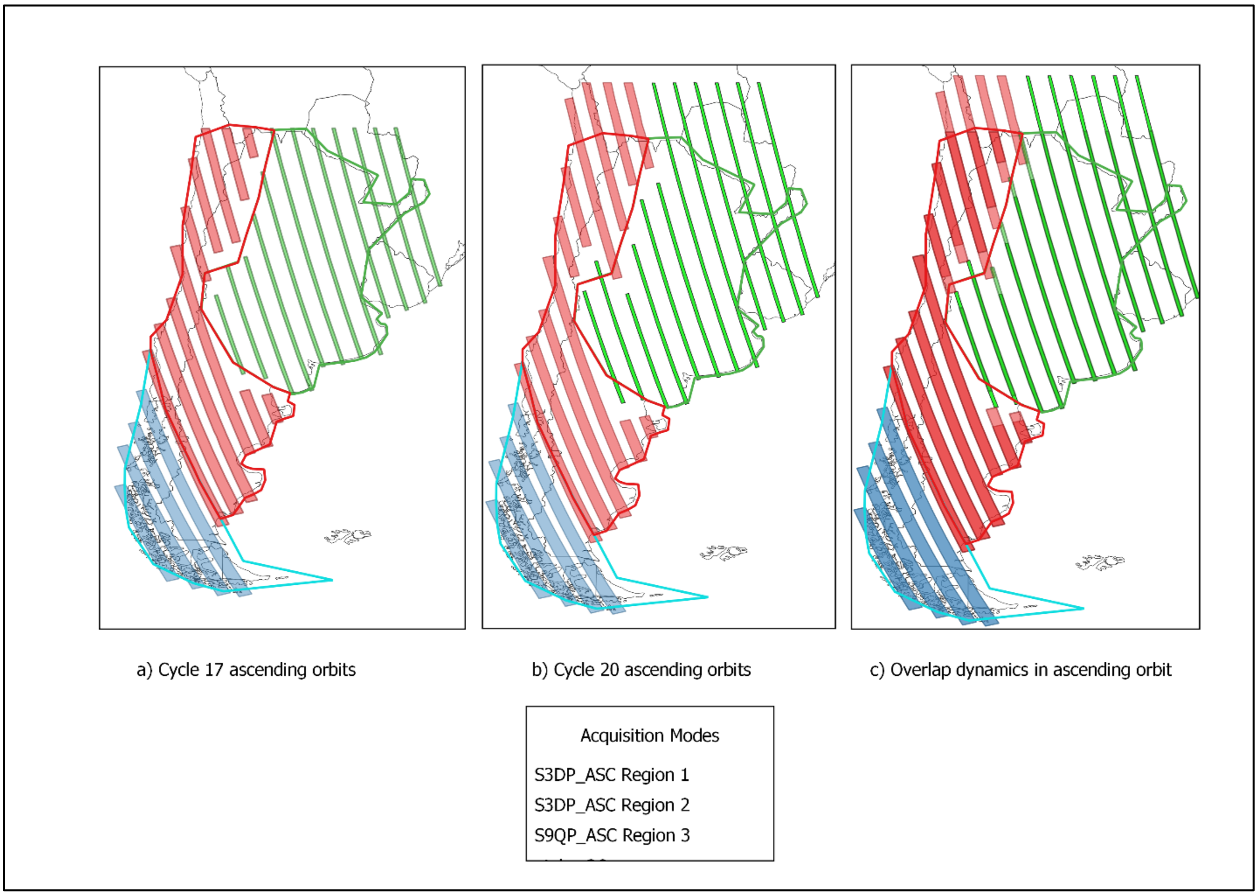


Figure 3. Overlap dynamics for gap coverage in acquisition modes transition zones: a) Cycle 17, ascending orbits, showing the gaps between S3DP modes of Region 1 and S9QP modes of Region 3, b) Cycle 20, ascending orbits, to fill the gaps in Cycle 17, acquisition lengths are changed in this transition zone between regions, c) overlapping of both cycles showing gap coverage. More details in the text.

3.1.2. Argentine maritime spaces and Antarctica

For the maritime spaces, the area encompassing the exclusive economic zone and much of the Argentine continental shelf is covered using TOPSAR Narrow A Dual Pol mode passes, in both ascending and descending orbits, in all cycles. This scenario is designed to provide images for maritime monitoring in this region. Figure 4 shows the area of interest.

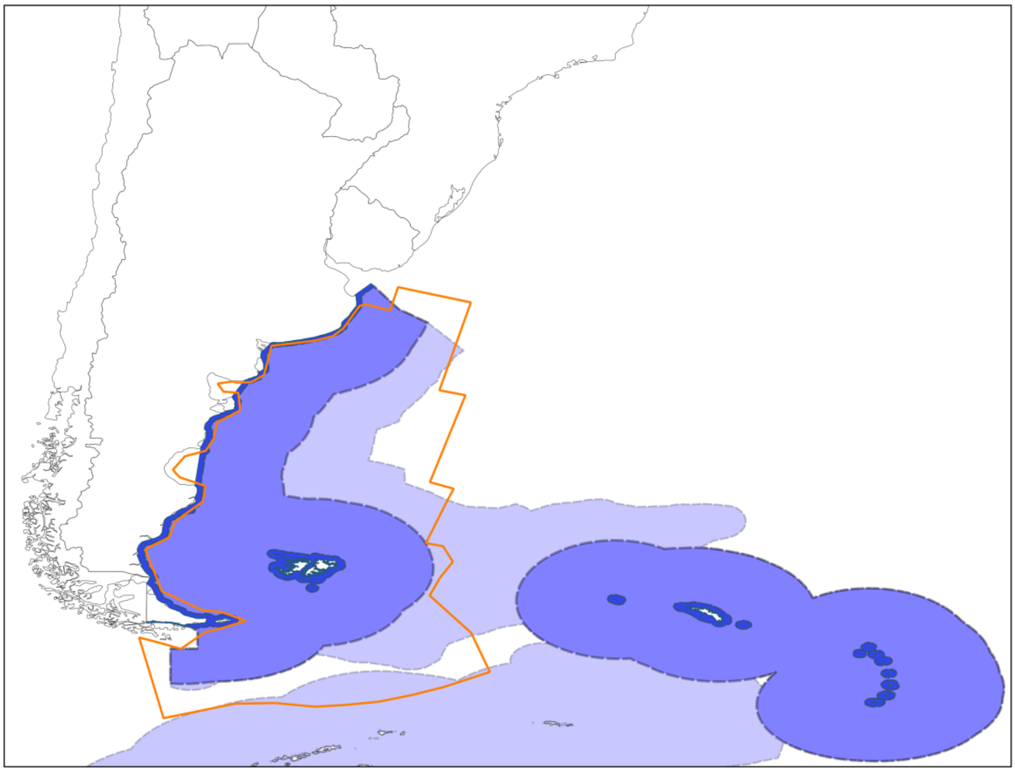


Figure 4. The orange border polygon shows the defined region for ascending and descending orbit acquisitions to capture part of the Argentine maritime spaces. The territorial sea, exclusive economic zone, and continental shelf are shown in different shades of blue, from darker to lighter.

For the Antarctic zone, the region of interest was designed based on the Argentine Antarctic Sector, including much of it and surrounding areas of interest for maritime navigation and monitoring the evolution of Antarctic ice.

As this region is located in high southern latitudes, there is significant overlap between adjacent passes. This overlap was utilized in the acquisition strategy to select passes stratified by latitude using the TOPSAR Narrow A Dual Pol mode in all cycles in descending orbit. Figure 5 shows the area of interest with a continuous blue line.

It is worth mentioning that specific acquisitions for supporting the Summer Antarctic Campaign have priority and are conducted using the TOPSAR Wide Dual Pol mode in both ascending and descending orbits. Figure 5 shows this area of interest with a dotted green line.

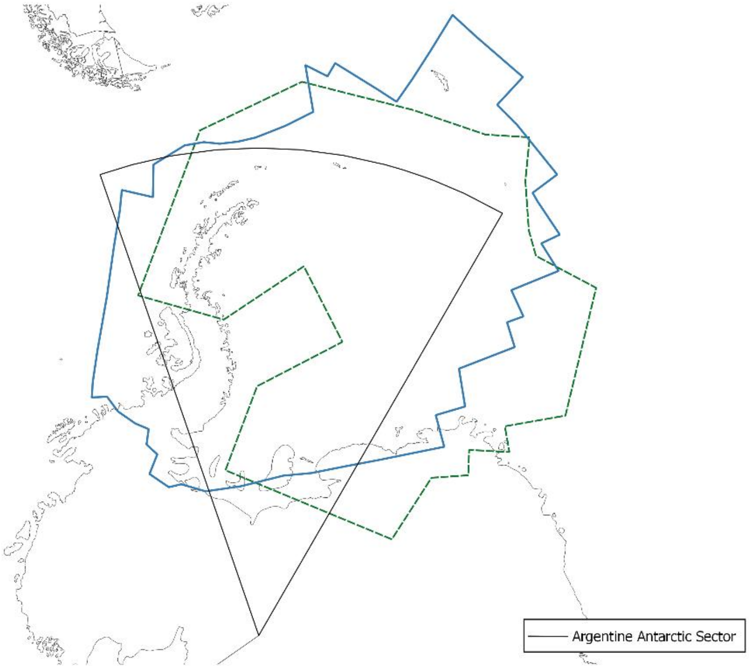


Figure 5. The blue border polygon shows the region defined based on the Argentine Antarctic Sector, using descending passes. The dotted green border polygon refers to the area where acquisitions are made to support the Summer Antarctic Campaign in ascending and descending orbits.

3.2. Global acquisition plan

As mentioned earlier, for the rest of the world, i.e., outside Argentina and its neighboring areas, a global coverage plan was designed. For optimization of onboard memory use and ground station data download, it is structured in latitudinal bands of approximately four degrees in latitude.

This plan uses a combination of StripMap Dual Pol and TOPSAR Narrow Quad Pol acquisition modes in both ascending and descending orbits, depending on each specific region. Each latitudinal band for a given cycle is selected based on acquisitions from previous cycles to achieve global coverage.

It should be noted that, through an agreement with the Italian Space Agency (ASI) within the framework of the Italian-Argentine Satellite System for Emergency Management (SIASGE), an ASI exclusivity area was defined, mainly covering the European continent, which is planned by that agency. For this reason, the IMAS acquisition plans from cycle 15 of 2022 onwards do not include these acquisitions.

Figure 6 shows an example of the scheme used for the Global Plan.

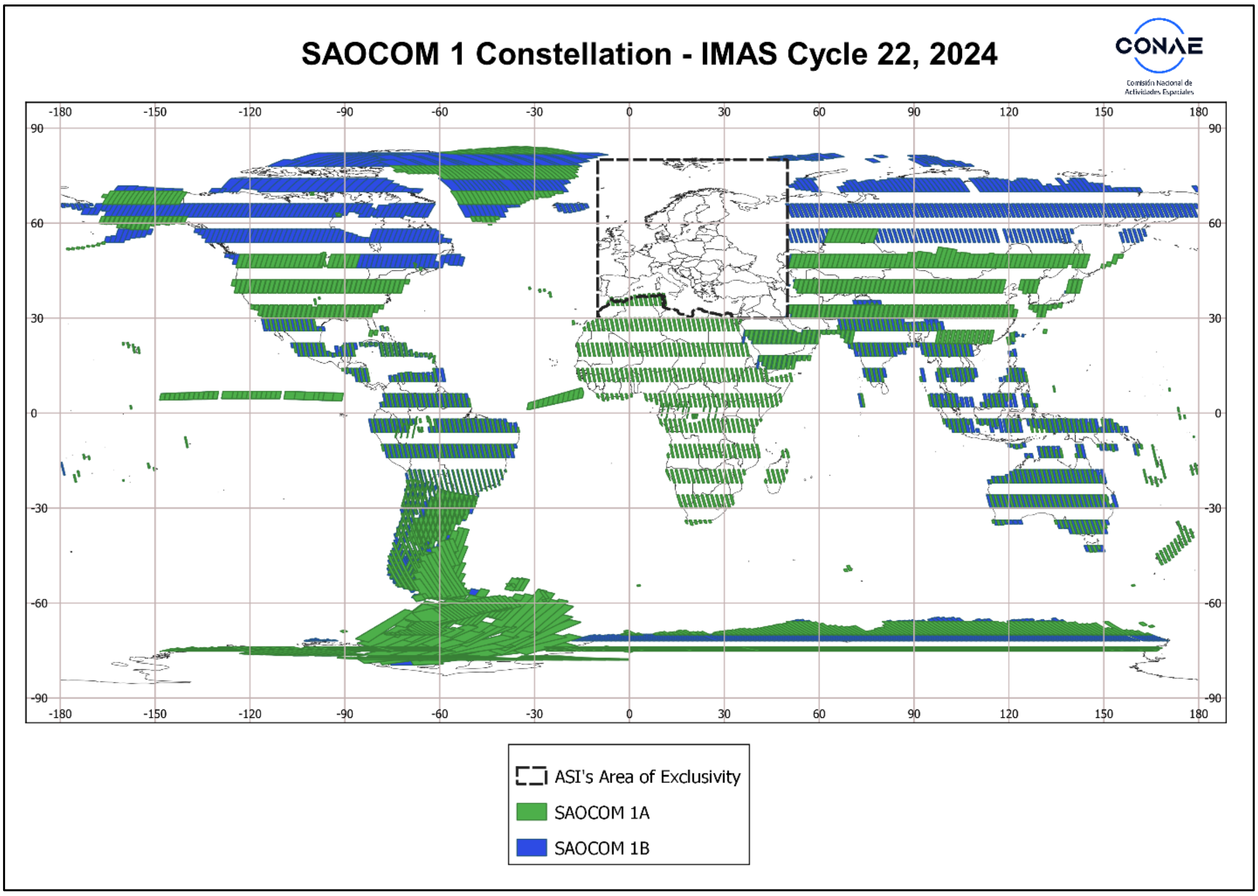


Figure 6. IMAS global acquisition plan for cycle 22 of 2024. Acquisitions over the continental and maritime territory of Argentina, including Antarctica, are also shown for completeness. The dotted black border polygon corresponds to the ASI exclusivity area.

3.3. Considerations on the scope of the plans

The passes graphed for each individual acquisition are based on nominal beams coverage and orbits.

In this sense, due to the maneuvers for orbit maintenance, the actual pass over the terrain can shift up to ± 3 km in a perpendicular direction to the pass (across-track) from its nominal position. Generally, efforts are made to keep this within a more confined value, between ± 2 km from the nominal position.

By convention, the individual nominal passes shown in the planning are calculated and represented on the WGS 84 terrestrial ellipsoid. However, because of the SAR instrument's functioning mode, the actual pass position generally shifts from the nominal pass. This shift depends on the monitored terrain height, i.e., its topography, and the incidence angle of the acquisition mode used, occurring in the across-track direction, moving away from the suborbital track. For a nominal right-looking direction, ascending passes will shift approximately Eastward and descending passes westward. This shift is larger for higher elevations and smaller incidence angles. For example, with an incidence angle of 25° and an elevation of 2000 meters, the shift will be around 4 km, whereas with an incidence angle of 40° and an elevation of 500 meters, it will be around 600 meters.

Additionally, the start and end times for each acquisition are estimated using nominal orbits, so the actual times can have a difference of around 10 seconds.

Therefore, regions located at the edges of a pass may be partially included in the image corresponding to that pass and partially in the image corresponding to the adjacent pass.

Finally, it must be considered that the final planning also includes users' requests, and conflicts are resolved according to priorities and system capabilities. As a result, actual acquisitions may differ from the IMAS plan. The following point provides more details on this matter. Acquired images can be consulted in the SAOCOM catalog (https://catalog.saocom.conae.gov.ar/catalog/#/).

4. Product evaluation

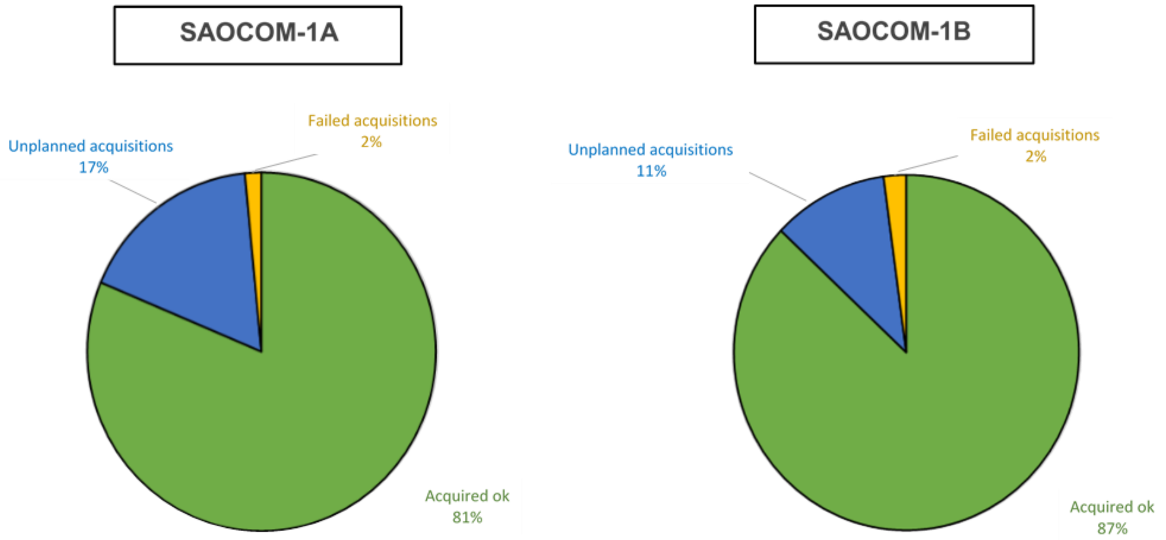
As mentioned earlier, the IMAS plan corresponds to the systematic planning for each cycle. Then, at the Ground Station, users' requests are added, conflicts between acquisitions are resolved based on priorities, and other system issues such as memory capacity and data download capabilities are considered. Therefore, the passes present in this product correspond to a nominal plan, and actual acquisitions will generally differ to some extent from the IMAS plan.

To evaluate the success rate of systematic acquisitions of this plan, a monitoring method was designed. Considering the duration of an orbital cycle, it explores the acquisitions database at the Ground Station and contrasts it with the requested acquisitions to find:

- Successful acquisitions from the IMAS plan, which are present in the SAOCOM catalog.
- Unplanned acquisitions, for example, due to conflicts with higher-priority acquisitions or cancellations due to satellite platform maintenance or orbital maneuvers.
- Failed acquisitions, for example, due to issues during data downloading to a ground station or during processing.

This information was used to generate statistics on these quantities with the purpose of evaluating the success rate relative to IMAS requests.

Figure 7 shows, as an example, data on requested acquisitions, successfully acquired acquisitions, unplanned acquisitions, and failed acquisitions, both in tabular and graphical form using pie charts. Although these data correspond to a specific orbital cycle, this example was chosen for its representative values of the IMAS Plan monitoring.



Requested acquisitions	1519
Acquired ok	1235
Unplanned acquisitions	261
Failed acquisitions	23

Requested acquisitions	1704
Acquired ok	1483
Unplanned acquisitions	185
Failed acquisitions	36

Figure 7. Statistics on requested acquisitions, successfully acquired acquisitions, unplanned acquisitions, and failed acquisitions. Although the values in this figure correspond to a specific orbital cycle, they are representative of the success rate of acquisitions of the IMAS Plan.

5. Description of the Attribute Table

The attribute table refers to the set of information related to each acquisition, treated as geographic entities. Files such as KML or shapefiles can contain attributes for each element. These attributes can be represented in table form within a GIS environment.

The following is the list of available attributes for each acquisition and their meanings.

name:	Name of the region of interest (ROI), to which the acquisition mode with its polarization and the direction of the orbit are added. For example: Region-1A — Name of the region of interest S3DP — Acquisition mode and polarization ASC — Direction of the orbit ASC: Ascending DES: Descending
platform:	Satellite used for the acquisition, SAO1A or SAO1B (SAOCOM 1A or SAOCOM 1B)
orb_start:	Nominal UTC date/time of start of the orbit (by convention, the orbit point closest to the North Pole is taken).
tadq_start:	Nominal UTC date/time of start of the acquisition.
orbit_end:	Nominal UTC date/time of end of the orbit (by convention, the orbit point closest to the North Pole is taken, which coincides with the start of the next orbit).
tadq_end:	Nominal UTC date/time of end of the acquisition.
ini_row:	Initial row, according to the nominal Path/Row scheme
final_row:	Final row, according to the nominal Path/Row scheme
pol_mode:	Acquisition polarization.
sub_mode:	Acquisition sub-mode.
mode:	Acquisition mode.
look_dir:	Sensor pointing or orientation (nominally right-looking).
orbit:	Orbit direction (Ascending or Descending).
path:	Path, according to the nominal Path/Row scheme.

6. Appendix 1: SAOCOM Acquisition Modes

The following figure shows the tree of SAOCOM products [RE2].

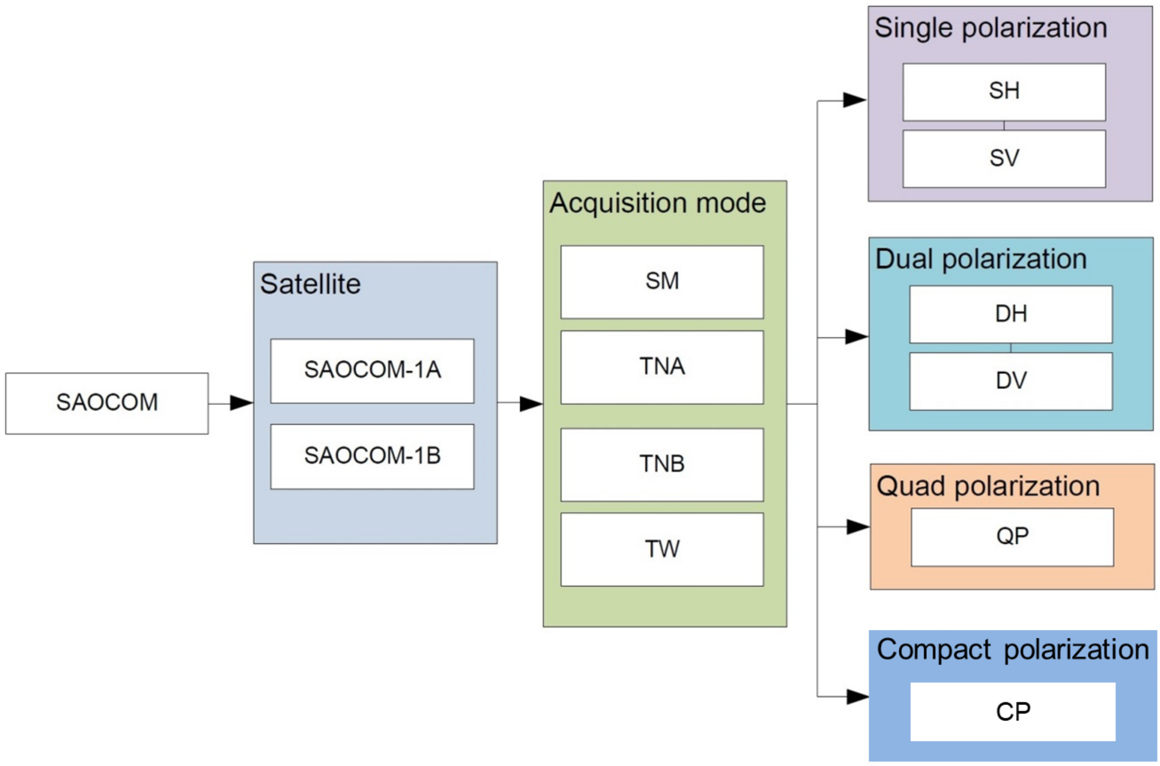


Figure 8. Tree of SAOCOM products.

The available polarizations are:

- Single (SP): The system emits and receives in the same linear polarization (horizontal-H or vertical-V), i.e., HH or VV.
- Dual (DP): The system emits in one linear polarization and receives both linear polarizations simultaneously, i.e., HH and HV, or VV and VH.
- Quad (QP): The system alternately emits both linear polarizations and receives them simultaneously, i.e., HH, HV, VH, and VV.
- Compact Polarization (Circular Linear, CL-POL): The system transmits a circular polarization (right or left) and receives two linear polarizations simultaneously, i.e., right-H and right-V or left-H and left-V.

The available acquisition modes are:

- StripMap: With Single, Dual, or Quad (Complete) Polarization. In this mode, the radar points in a fixed direction while capturing a continuous strip, providing narrower swaths with higher spatial resolution.
- TOPSAR Narrow: With Single, Dual, or Quad (Complete) Polarization. In this mode, the radar changes its pointing direction along the track to capture multiple strips, covering a wider swath width with lower spatial resolution compared to StripMap.
- TOPSAR Wide: With Single, Dual, Quad (Complete), or Compact Polarization (technological mode). In this case, the radar changes its pointing direction along the track to capture more strips, covering a wider swath width with lower spatial resolution compared to TOPSAR Narrow.

SAOCOM products are generated using a standard size scheme. This approach aims to standardize cataloging and distribution.

The resulting shapes meet the following criteria:

- Any product of a given mode and sub-mode, at any part of the orbit or at any time, has nominally fixed azimuth and range sizes[5] (measured on the ground). This can be slightly altered due to orbit velocity, altitude, or attitude variations, as acquisition is defined in reference to orbit time. Other factors such as different incidence angles, Earth's non-sphericity, etc., can also alter the product length.
- All products within the same acquisition mode (StripMap, TOPSAR Narrow, or TOPSAR Wide), regardless of the polarization mode (single, dual, compact, or quad-pol), have the same nominal azimuth length. Hence, the aspect ratio is not maintained across different modes and sub-modes.
- The relationship between the azimuth lengths of different acquisition modes (StripMap, TOPSAR Narrow, and TOPSAR Wide) is an integer. The TOPSAR Wide is 2 times longer than the TOPSAR Narrow, and the TOPSAR Narrow is 3 times longer than the StripMap (see Figure 9).

[5] Azimuth refers to the direction of motion of the satellite, and range refers to the perpendicular direction.

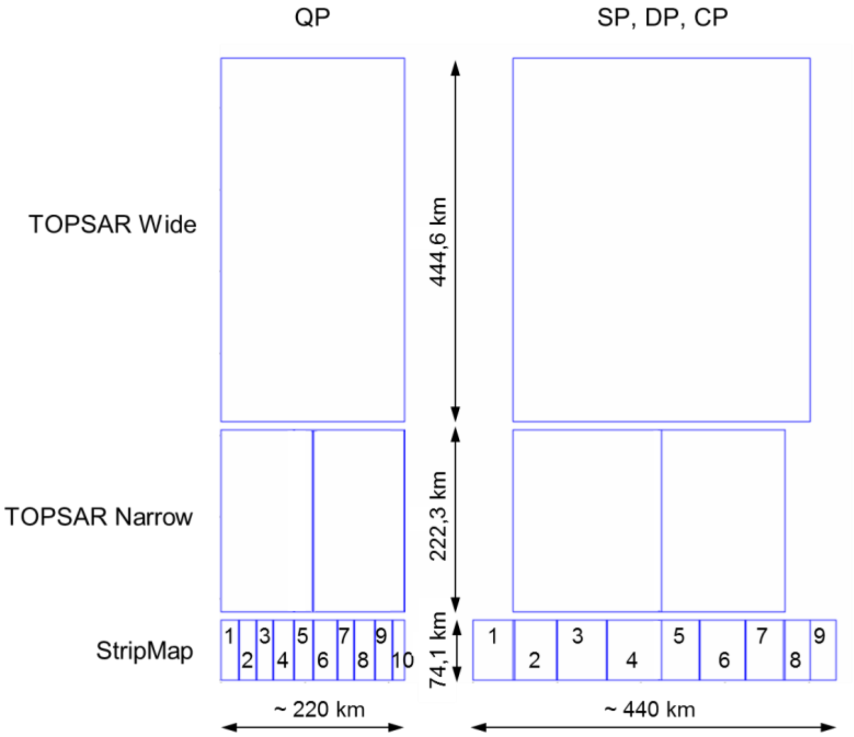


Figure 9. Approximate (nominal) dimensions in azimuth and total field of view for the different acquisition modes. On the left: quad-pol modes. On the right: single, dual, and compact pol modes. From top to bottom: TOPSAR Wide (the two large frames at the top), TOPSAR Narrow (the four medium-sized frames), and StripMap (the nineteen small frames).

7. Appendix 2: Global Distribution Grid: Path and Row

Standard Level 1 products are generated and distributed in standard-sized scenes (frames). These frames are designed to be geolocated according to a fixed global grid, consisting of elements called Path and Row [RE2]. This facilitates cataloging, image requests by users, and product search for multi-temporal analysis.

The grid design is based on the following criteria:

- A Path is defined as the strip observed by the satellite along its trajectory during an orbit.
- The Path number is constant within a given orbit, and the Row number varies along the Path (with latitude).
- Each grid element is defined by its Path and Row numbers.
- The Path numbering starts at 1 for a Path that mostly crosses water (Atlantic and Pacific Oceans) both in the ascending and descending parts of the corresponding orbit and increases sequentially westward until reaching the maximum value of 237. This prevents changes between Paths 237 and 1 over land areas.
- Path numbers are consecutive for geographically adjacent Paths, making cataloging and requests more convenient. Note that the Path number does not coincide with the orbit number within a 16-day orbital cycle.
- Any acquisition in a given orbit, regardless of acquisition mode, polarization, or sub-mode, has the same Path number.
- The Row number starts at 1 at the maximum latitude of the orbit (near the North Pole) and increases sequentially up to 600 when the satellite completes an orbit, i.e., when it returns to the maximum latitude of the orbit (near the North Pole). For descending passes, the Row number increases from 1 to 300 (near the South Pole), while for ascending passes, the numbering continues from 301 to 600.
- The Row number is only consecutive for StripMap frames, while for TOPSAR Narrow and TOPSAR Wide frames, it has steps of 3 and 6 respectively, due to the scale factor mentioned between different acquisition modes.
- The Row number refers to the start of the acquisition. Hence, two images sharing the same initial line on the grid have the same Row number, regardless of the mode (and consequently of its azimuth size).

- Two adjacent Rows of the same acquisition mode and sub-mode have a 5% spatial overlap in azimuth with each predecessor and successor Row. This represents an effective 10% common area between consecutive images.

Figure 10 presents an example of the Path and Row numbering scheme, showing products from different QP acquisition modes on the common grid. The scenes in this example correspond to an ascending pass and share the same Path and Row numbers (Path=M, Row=N) as they share the same initial line.

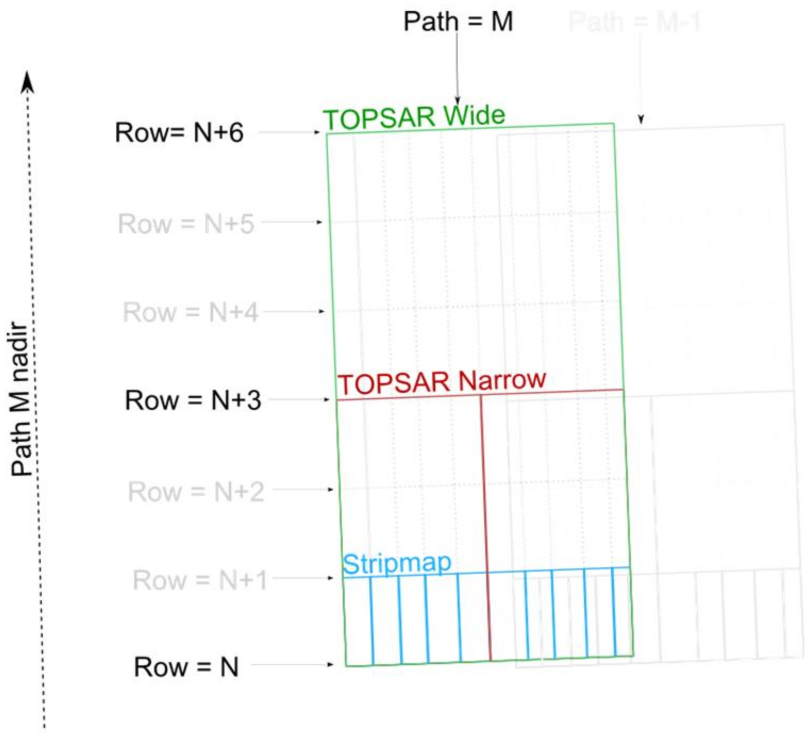


Figure 10. Different QP products of different modes placed on the common grid. StripMap frames are shown in light blue, TOPSAR Narrow frames in red, and the TOPSAR Wide frame in green. All scenes in this example have the same Path and Row numbers (Path=M, Row=N) as they share the same initial line (ascending pass).