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INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

SERVICE
DE GEODESIE
ET DE METROLOGIE

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ITRF local tie survey at Calern, Caussols – France

DIFFUSION OUVERTE

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Abstract

The ITRF2020 realization (most recent frame of the International Terrestrial Reference System) computed by the ITRS product Centre (IGN Geodesy research team from IPGP) is the result of the reference frames combination from four space geodesy techniques (i.e., GNSS, DORIS, SLR and VLBI). One way to achieve one common frame consists in adding to the combination results from co-located sites local tie surveys. The Observatoire de la Côte d'Azur (OCA) on the Calern plateau near Grasse in south-east of France hosts three space geodetic techniques (GNSS, SLR and Doris) and a VLBI campaign reference point. This report describes the local tie survey carried out in February 2023 and presents the associated results.

Acknowledgements

We would like to express our thanks to OCA team in Calern, with a special thanks to all the team working on the Laser. Their very nice welcome, their cooperative work on technical and administrative aspects contributed for a great part to the success of this work.

1 Introduction

1.1 Context

The International Terrestrial Reference Frame (ITRF) is the result of a combination of different terrestrial reference frames provided by the four space geodetic techniques (i.e. GNSS, DORIS, SLR and VLBI). To perform this combination between independent reference frames, local tie surveys between co-located space geodetic instruments, precisely measured and expressed in three dimensions are necessary.
One way to improve the ITRS realization consists in adding to the combination tie vectors from new co-located sites or to improve the local tie accuracy on former sites.
This document presents the local tie survey performed in Calern, which took place on February 2023. The goals were the following:

- Assign coordinates to the reference points of the InSar reflectors tested on site;
- Provide tie vectors between instrument reference points (i.e. SLR, DORIS, GNSS and InSar reflectors);
- Determine distance between SLR telescope and a test reflector on mast 2.6 km away
- Produce a survey result file in SINEX format only for ITRF points.

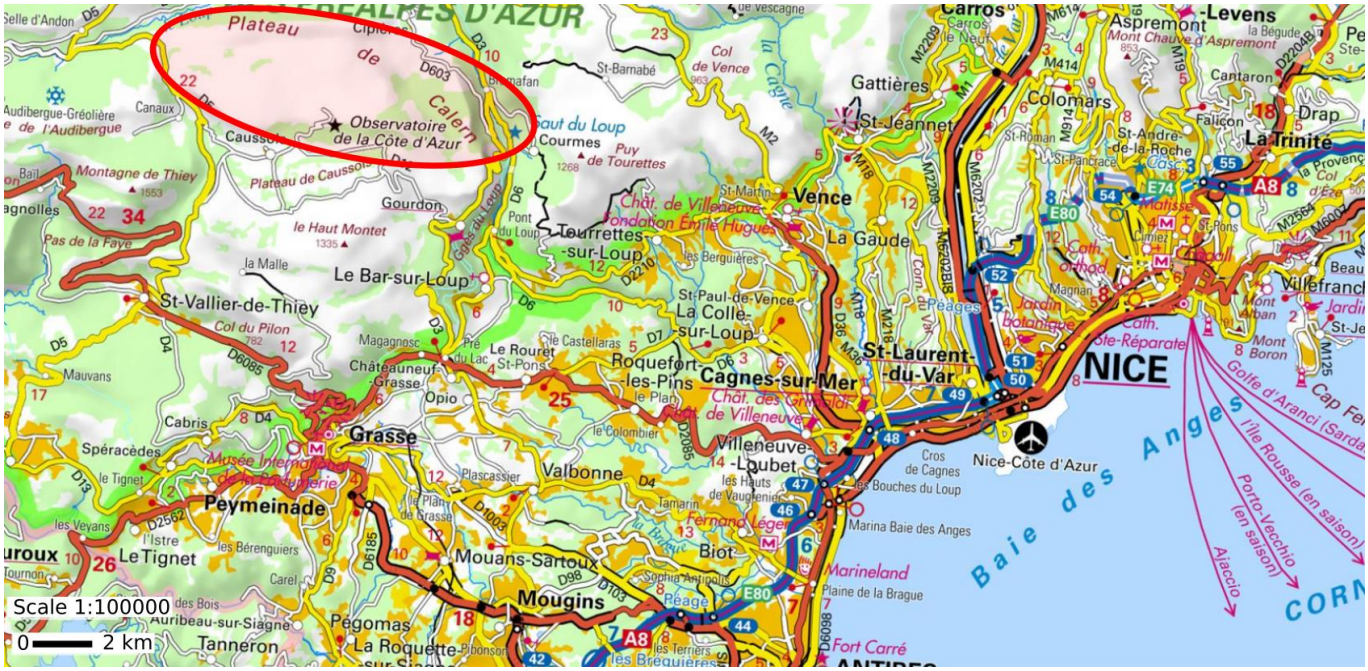
1.2 Glossary

ARP: Antenna Reference Point
CNES: Centre National d'Études Spatiales (France)
DOMES: Directory Of MErit Sites, ITRF product center site numbering
DORIS: Doppler Orbitography and Radiopositioning Integrated by Satellite
GGOS: Global Geodetic Observing System
GNSS: Global Navigation Satellite System
IDS: International DORIS Service
IERS: International Earth Rotation and Reference Systems Service
IGN: Institut National de l'Information Géographique et Forestière (France)
IGS: International GNSS Service
InSAR : Interferometric Synthetic Aperture Radar
ITRF: International Terrestrial Reference Frame
LLR: Lunar Laser Ranging
OCA: Observatoire de la Côte d'Azure
SAR : Synthetic Aperture Radar
SINEX: Solution INdependent Exchange
SLR: Satellite Laser Ranging
VLBI: Very Long Baseline Interferometry

2 Co-localisation site description

2.1 Site information

Although this co-location site is located at Caussols municipality on the Calern plateau, it is also often called Grasse.
This site hosted by Observatoire de la Côte d'Azur (OCA) is about 10 km north of Grasse and 30 km west of Nice.



Location map (www.geoportail.gouv.fr)

The geodetic site is located around Meo building (the LLR and SLR telescope). It's on the North part of the Observatory.

2.2 Co-located geodetic points

On a geodetic point of view, this observatory site is of a great interest; indeed, there are:

- The telescope SLR and LLR, usually named Meo (CDP number 7845 and acronym GRSM)
- 2 GNSS stations, GRAS and GRAC
- A DORIS beacon, GR4B
- An SAR corner reflector (It is planned to include CC SAR in the ITRF local tie survey of the main collocated sites)
- A former SLR telescope, GRSF (CDP number 7846) dismantled but a witness marker still exists,
- A former transportable laser range station, named FTLRS (CDP number 7829), dismantled without any marker,
- A former DORIS station, only the mast is still existing without any marker.
- A VLBI campaign station marker (CDP number 7605).

The following table sums up the active geodetic techniques co-located on site.

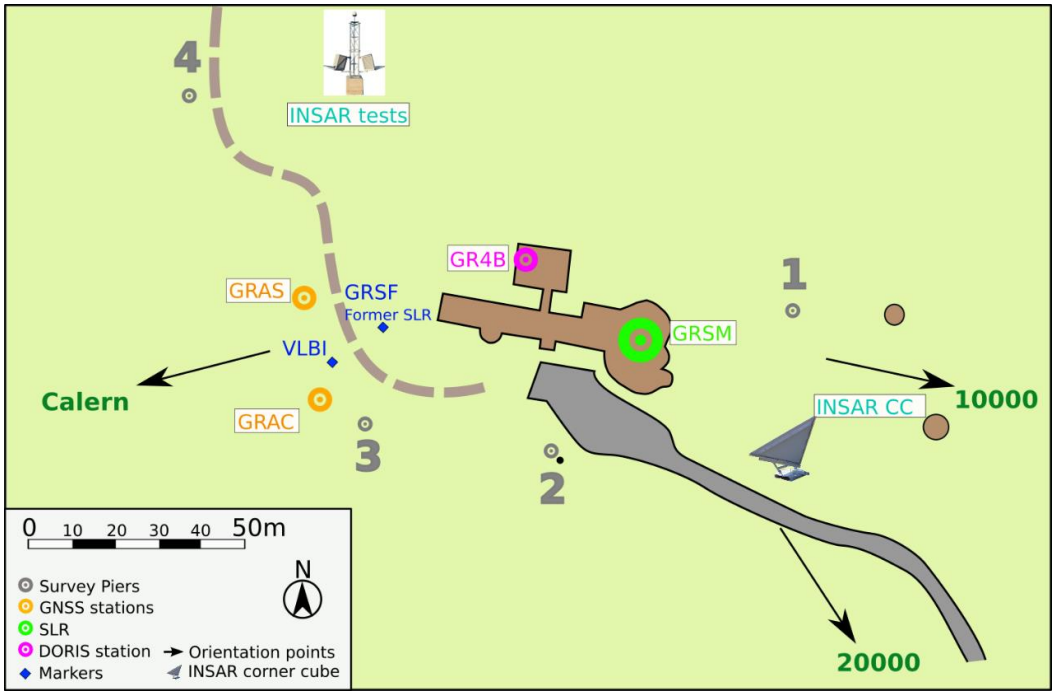
Technique Name	DOMES n°	Description	Acronym / CDP N°
GNSS	10002M006	Antenna mount reference point / Pillar	GRAS
GNSS	10002M010	Antenna mount reference point / Pillar	GRAC
SLR	10002S002	Telescope, intersection of the rotation axes	GRSM/7845
DORIS	10002S019	DORIS antenna reference point	GR4B
InSAR	-	Corner reflector reference point	GRCC temporary acronym

The following table sums up the geodetic markers attached to a former geodetic campaign or a former instrument co-located on site.

Technique Name	DOMES n°	Description	Acronym / CDP N°
VLBI	10002M003	Concrete Slab /Mobile VLBI mark 1989	7605
SLR	10002M004	Concrete Slab/ 25 mm brass mark	GRSF/7846

In addition of these geodetic points, other points are included in the local tie survey:

- 4 concrete survey pillars
- The reference points of 2 corner reflectors and a GNSS antenna being tested in the north of the site,
- 2 orientations points located 700m and 300m from the site,
- 1 SLR test reflector also used for orientation located about 2.5km from Meo.



Points location

3 Local tie survey description

3.1 Organization

The local tie was performed from January 30th to February 9th 2023 by 4 surveyors from IGN-Fr:

- Clemence Belon,
- Tanguy Garmond,
- Thomas Donal
- Damien Pesce

3.2 Equipment

The following section provides the characteristics of the surveying equipment that was used. The surveying instruments belong to IGN. The equipment is regularly checked and calibrated at IGN.

Equipment	Trademark, Serial ref. n°	Specifications, accuracy
Total stations	• Leica TM60 s/n: 890908 • Leica TM50 s/n: 371604 • Leica TDA5005 s/n: 438772	Distance measurement: std. dev. 0.6 mm + 1 ppm Angular measurement: std. dev. 0.15 mgon (0.5")
Prism set Reflector & tribrach	• Leica GPF121 • Leica GDF 24	Distance correction 0.0 mm
Spherical prism 1.5”	Leica	Distance correction +35.0 mm
Reflector mini pole	Leica GLS14	H = 0.200 m
Mini-reflector	Leica GMP101	Distance correction 17.5 mm
Pocket weather tracker (meteorological station)	Kestrel 4500NV s/n 2020534	Temp. std. dev. 0.5°C Pressure std. dev. 1 hPa
GNSS unit	• Leica GX1230GG s/n: 472268 + Leica AX1202GG s/n: 08350011 • Leica GX 1230+ GNSS s/n 481999 + Leica AS10 s/n: 10071020	Theoretical static post-processing accuracies: Horiz. 5 mm + 0.5 ppm Vert. 6 mm + 0.5 ppm
Electronic level	Leica DNA03 + Leica invar bar code staffs	Measurement std.dev: 0.1mm

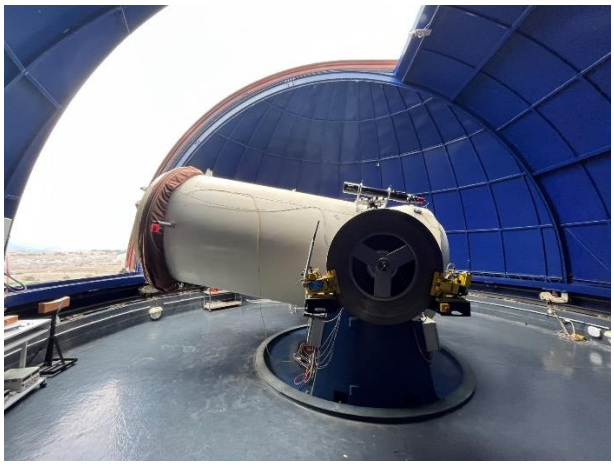
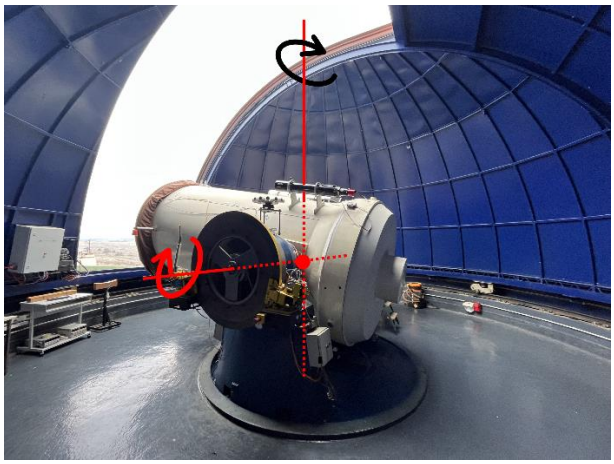
NB.: All these survey instruments allow the observations to be recorded electronically on memory cards or storage devices and then downloaded to a laptop computer for on-site checking.

3.3 ITRF co-located points

3.3.1 SLR Stations

3.3.1.1 Meo station

The Meo station was installed in 1980 and is part of the ILRS network. The telescope is a Cassegrain Coude type with an aperture of 1.54m. The station has also been developed for lunar laser ranging measurement.

CDP n°: 7845 Acronym: GRSM	DOMES number: 10002S002
 Overview	 Reference point
Description: Orthogonal projection of the Elevation rotation axis on the Azimuth rotation axis.	

The SLR measurement refer to an unmaterialized point in the telescope that is the orthogonal projection of the horizontal telescope axis on the vertical telescope axis.

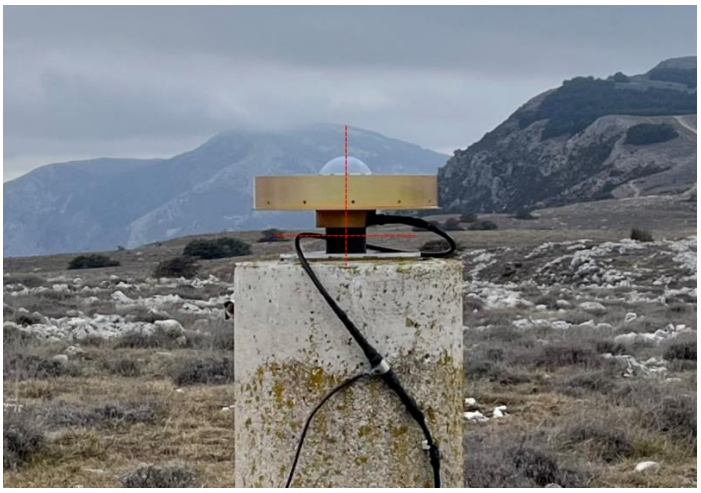
3.3.1.2 Former laser station reference point

CDP n°: 7846 Acronym: GRSF	DOMES number: 10002M004
 Overview	 Detail view
Description: 25 mm brass marker fixed on concrete slab	

3.3.2 Permanent GNSS stations

3.3.2.1 GRAS

The GNSS permanent station GRAS operated by CNES since 1996 is part of IGS and RGP networks.

Acronym: GRAS	DOMES number: 10002M006
 Overview	 Detail view
Description: the reference point is 0.0350 m under the Antenna Reference Point (ARP)	

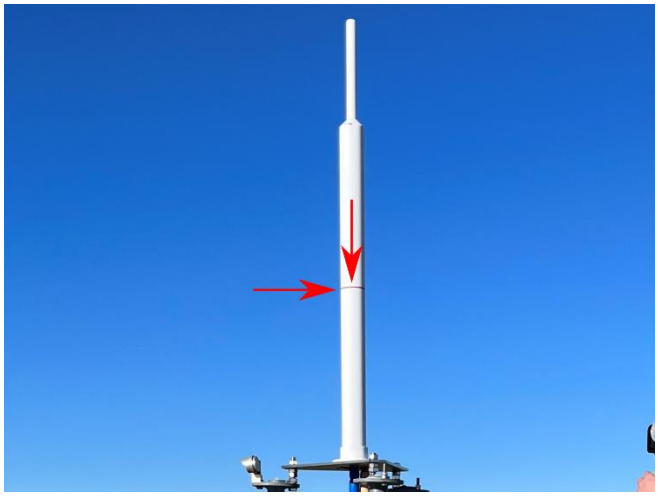
3.3.2.2 GRAC

The GNSS permanent station GRAC operated by IGN-FR and is part of RGP network since 2001 and IGS network since 2013.

Acronym: GRAC	DOMES number: 10002M010
 Overview	 Detail view
Description: the reference point is 0.0500 m under the Antenna Reference Point (ARP)	

3.3.3 DORIS station

The DORIS station GR4B was installed in 2013 replacing the station GR3B.

Acronym: GR4B	DOMES number: 10002S19
 Overview	 Detail view
Description: the reference point is located 0.390 m above the antenna base-mounting surface on the antenna vertical axis	

3.3.4 Former mobile VLBI campaign reference point

CDP n°: 7605	DOMES number: 10002M003
 Overview	 Detail view
Description: 1989 mobile VLBI campaign main reference mark.	

Mobile VLBI campaign at Calern in 1989

3.3.5 INSAR reflector

The reflector was installed in December 2018. Its azimuth is 263°

Acronym: GRCC	DOMES number: 10002SXXX
 Overview	 Detail view
Description: the reference point is the intersection point of the 3 planes.	

3.4 Other survey points

All surveying operations have been carried out in such a way to provide the highest accuracy for the 3D vectors determination between reference points.

3.4.1 Total station points

3.4.1.1 Piers

There are four pillars around the site to make the survey easier. Centring plates were embedded on the top of each pier and four levelling benchmarks were placed on each concrete base.

Pillar n°4 with a reflector; benchmarks are in the red circle

Pillar with a reflector

Levelling on benchmark, pillar n°3

Total station on pillar n°3

3.4.1.2 Former DORIS mast

A total station was installed on the former DORIS mast (GR3B) on the rooftop of the main building.

Prism on the DORIS mast

3.4.1.3 Automatic total station

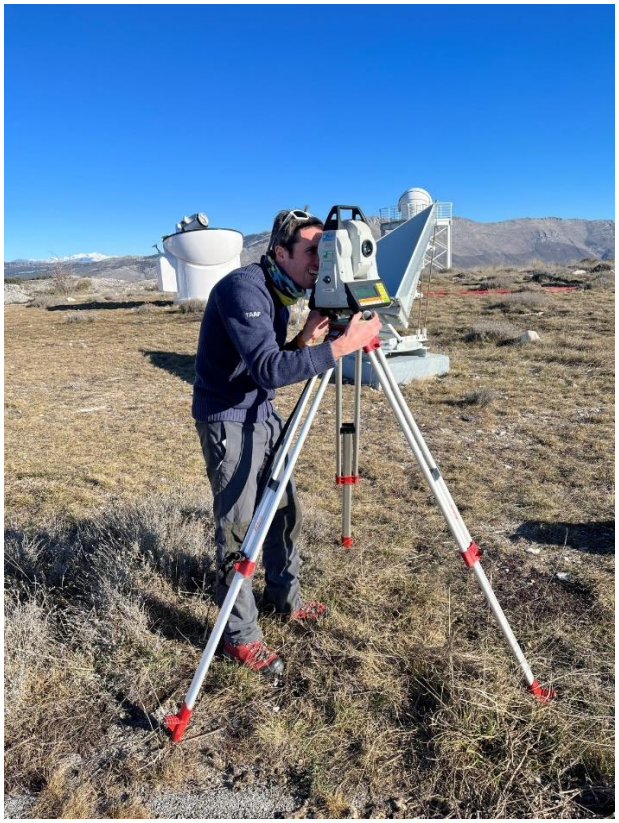
A total station is permanently fixed to the rooftop, on the table where FLRS was previously installed. This total station was tested to automatically determine the telescope reference point. Automatic and manual measurements from this station were included in the survey.

Automatic total station

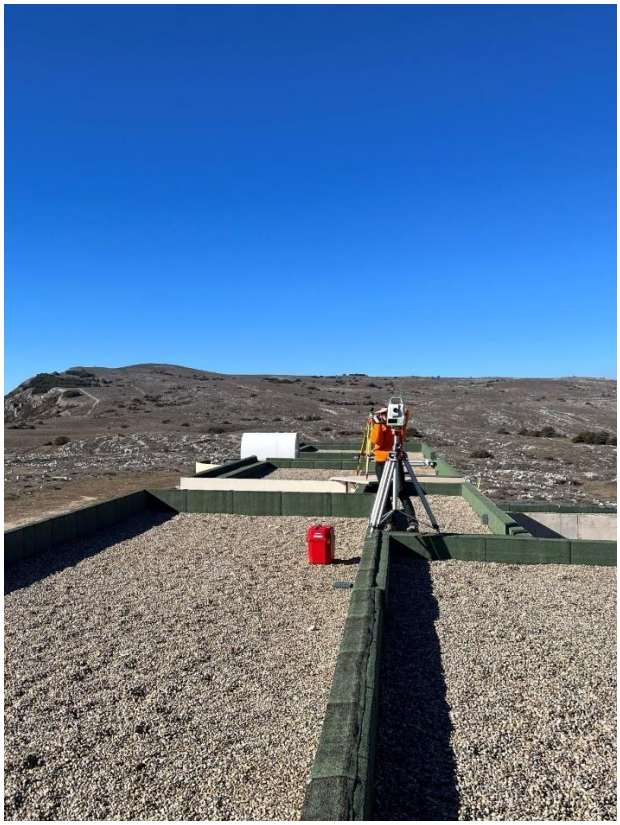
3.4.1.4 Temporary points on tripods

In order to improve the survey figure, 7 total stations on tripods were temporary set up.

- 1 on the rooftop (point n°6000);
- 3 around the main INSAR reflector (1000, 2000 and 3000);
- 2 around the tested INSAR reflectors (7000 and 8000);
- 1 near GRAS GNSS station (4000);



Station n°2000



Station n°6000

During the previous surveys, a tripod was set up on a concrete slab with a marker on the roof. But this was not stable enough to obtain good measurement, so it was abandoned.

3.4.2 Orientation points

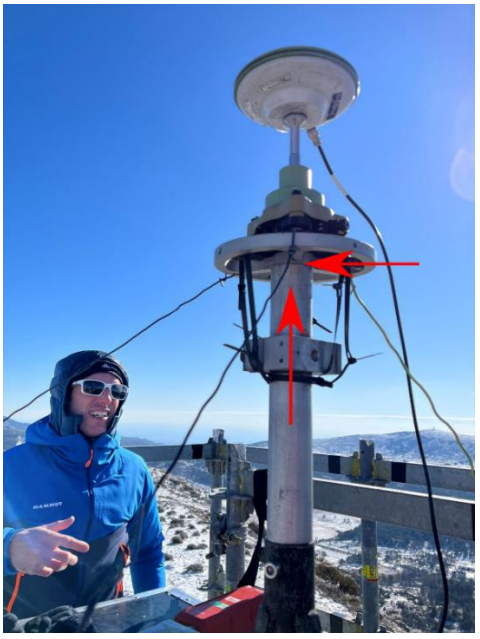
To get the orientation to the ITRF, two points were setup far away. One is centred on air vent axis of the Calern's water reservoir (about 672 m from MeO). For the survey, it is named 10000.

Process n° 10000	
 Overview (photo 2013)	 Detail view
Description: top of air vent (point engraved).	

The second one is a centering marker fixed on an old concrete pier near Tarot buildings (about 294 m from Meo). For the survey, it is named 20000.

Process n° 20000	
 Overview (photo 2013)	 Detail view (photo 2013)
Description: Top of pillar self-centering marker.	

In order to obtain a distance from Meo reference point, a calibration mast (with reflector), located on the summit of Calern mountain (2.5km) was observed by GNSS. As this point was observed by almost all the total stations, it could be used as an orientation point. For the survey, it is named 30000.

Process n° 30000	
 Overview	 Detail view
Description: 1.5” spherical prism (not visible on the pictures).	

3.4.3 INSAR reflectors points

3.4.3.1 Reflector South-East

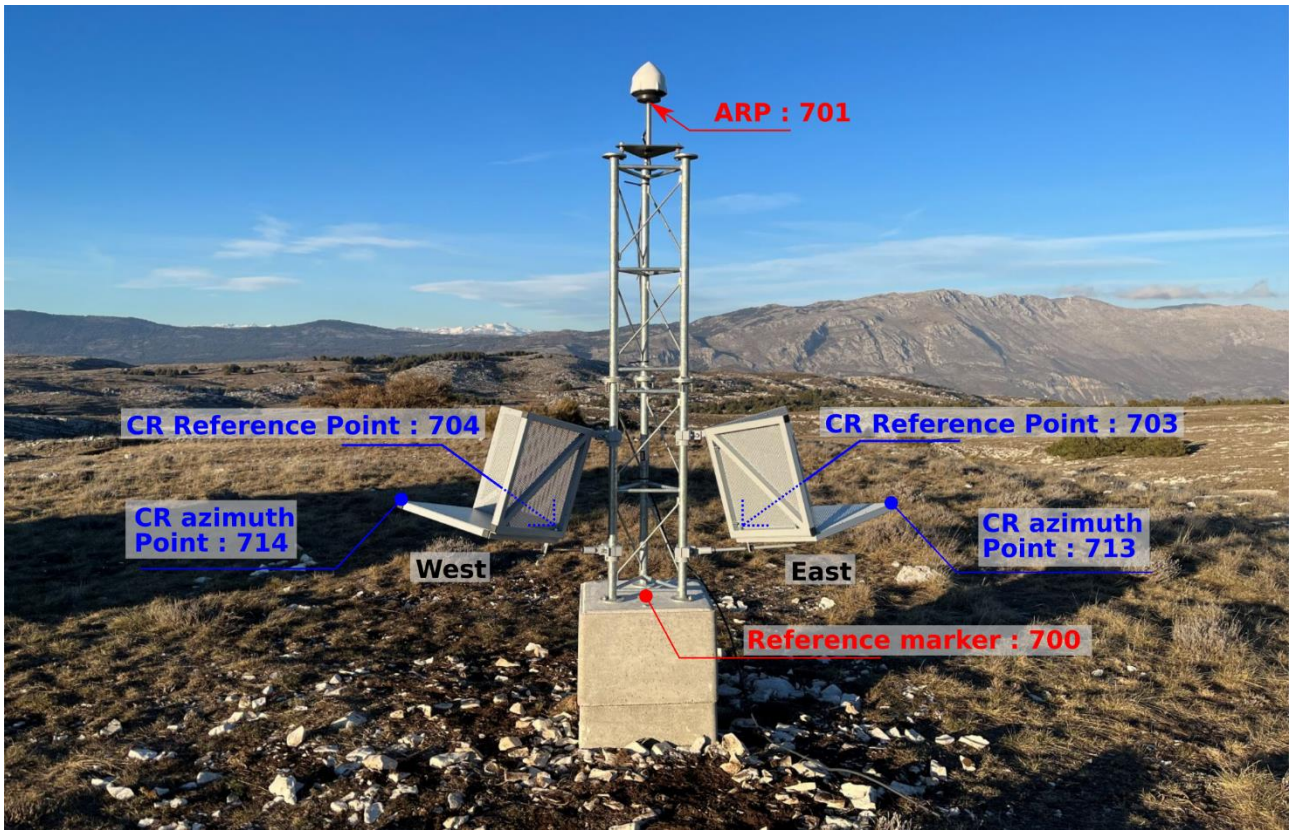
In addition to its reference point, the reflector has three 3D monitoring spherical targets on each end (n°401 to 403) and 4 benchmarks on its concrete base (n°441 to 444).

Spherical target

Levelling benchmarks

3.4.3.2 Tested reflectors North-West

A double SAR corner reflector with a GNSS antenna was installed during the survey on a 2m height mast for testing purposes.

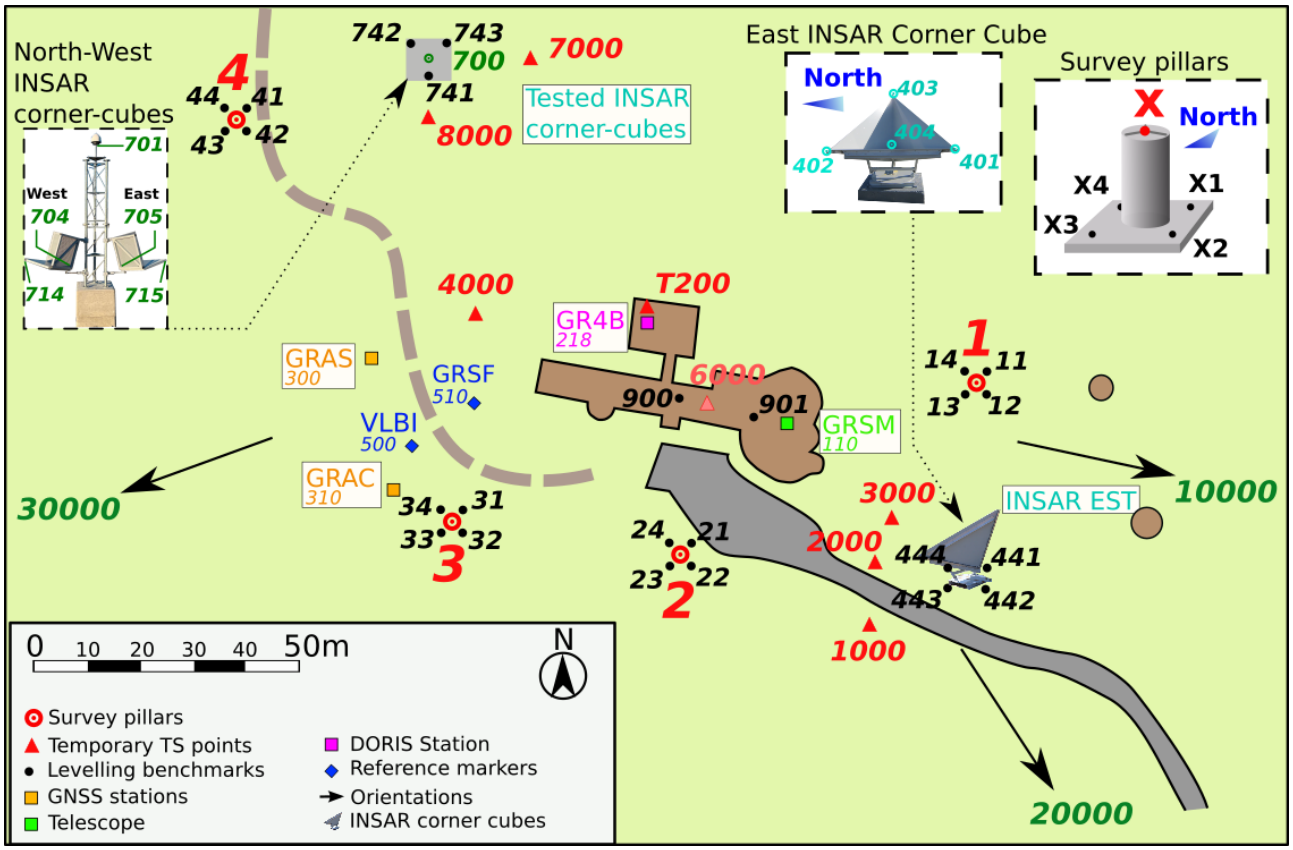


Corner reflectors and the GNSS antenna with the reference points and their process names

The concrete bloc where the mast is fixed have also 3 levelling benchmarks (points n°741 to 743).

Levelling benchmark n°741

3.5 Site map



3.6 Survey method

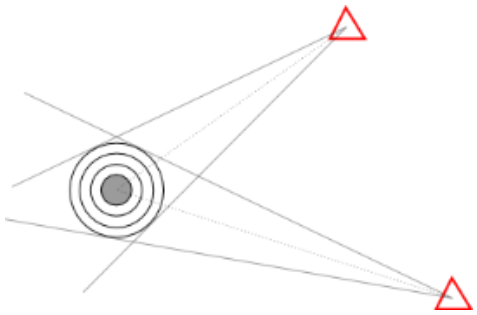
All the visible lines of sight were observed with total station. Horizontal directions and zenith angles were observed in data sets, each set consisting in one reading in both direct and reverse theodolite positions. Distance measurements were observed at least once over each line. Meteorological data (atmospheric pressure and temperature) were recorded at each station and used to correct distance measurements.

As far as direct levelling is concerned, forward and backward runs were observed between each benchmark. At the beginning of the spirit levelling, the instrument collimation was checked. The electronic level instrument was set to perform two readings on an invar bar code staff, and measurements were repeated if the difference between the two readings was inconsistent.

For a small figure like this one, conventional terrestrial observations are more accurate than GNSS measurements. The GNSS observations are only used to get the polygon orientation.

3.6.1 GNSS antenna reference points

The reference point has been determined indirectly for the antennas. From each surveying station aiming at the antenna, right and left tangents on the bottom (ARP points n° 301 and 311) were observed. In the adjustment, horizontal and vertical angle observations were averaged. Both antennas were also observed by direct levelling. For GRAS, the top of the antenna plate (0.0376 m up to the ARP, height supplied by the manufacturer) was observed. For GRAC, it is not possible to install a staff on a characteristic point of the antenna. A level was placed at the same height as the ARP using a tripod with adjusted height (rack and pinion) and a reading was taken on a staff on a benchmark. Then, on the observation file, a reading on ARP was added with the value 0.0000 m.



Top view

3.6.2 DORIS antenna reference point

An indirect approach was used to determine the reference point for the DORIS antenna. From each surveying station aiming at the DORIS antenna, right and left tangents to the antenna close to the ARP (red circle n°218), close to 2 GHz phase centre (points 219) and close to antenna base (n°214) were observed. In the adjustment, only horizontal angle observations were averaged because vertical positions of those points are not precisely defined.

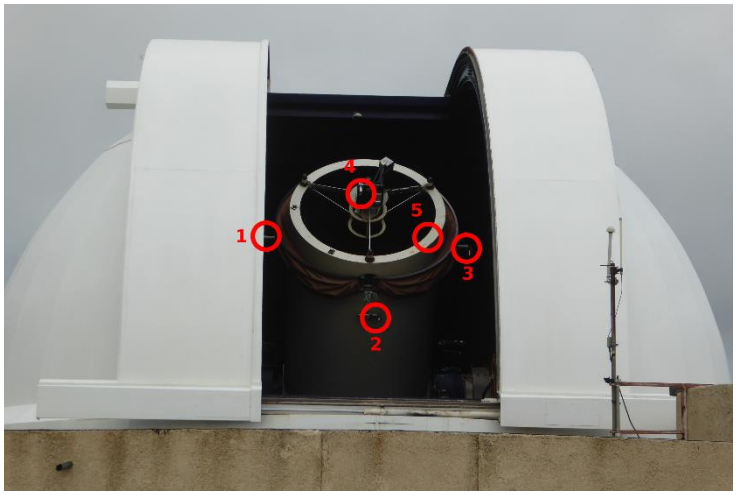
The height of antenna mount plate (bottom of the antenna) was also determined by direct levelling.

In the final process, the ARP was determined as the point on the same vertical as the centre of the bottom of the antenna (points 214) but 0.390 m up of the bottom with the accuracy of 5mm. It was also checked that the bottom of the antenna point and the two phase center points are on the same vertical.

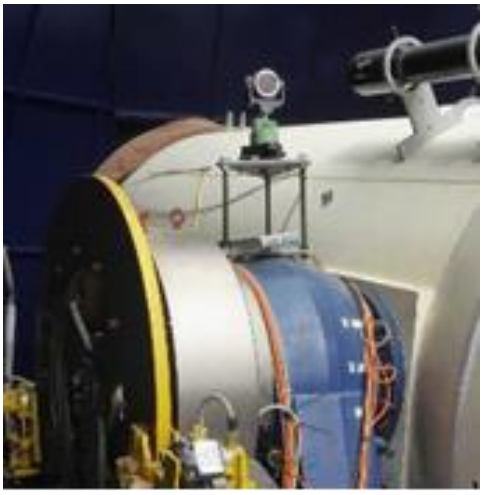
3.6.3 Meo telescope reference point

The reference point is not physically determined. To obtain its position, we need to know the parameters of the telescope's axes of rotation. These parameters can be determined using circles formed by the positions of targets on the telescope in various azimuths (vertical axis) and elevation (horizontal axis) of the telescope.

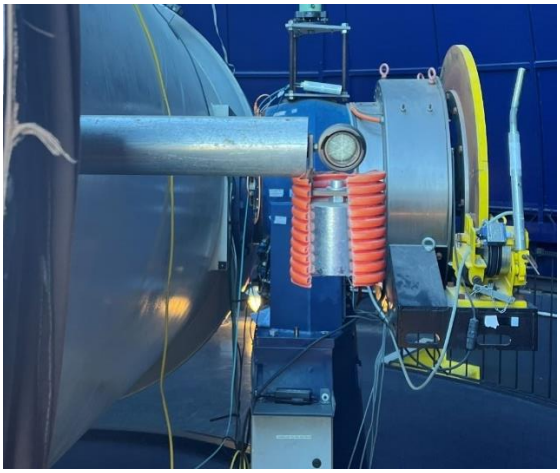
During the survey, some reflectors were fixed to the telescope and observed in several telescope positions from three total stations (6000, T1 and T2) and also from the motorized total station. There are 2 sessions per station, one for the vertical axis (azimuth movements only) and one for the horizontal axis (elevation movements only).



Prism numbers on Meo



Prism number 6 on Meo



Prism n°3, same model as n°1 and 2

Prism n°5, same model as n°4

In the adjustment analysis, targets 1 to 3 are rejected because they have slightly higher residuals than the other targets, probably due to the quality of the prisms.

3.6.4 Corner reflector INSAR

East Corner reflector:

The reference point, that is the intersection point of the 3 plane surfaces of the CR, is determined thanks to a prism on standard pole. It is also observed in direct leveling. The 3 spherical targets were observed with total stations (at least 3 stations without distances) and with direct leveling. The distances (accuracy 0.2mm) between the targets and the reference point were provided by the manufacturer of the corner reflector, those were integrated to the adjustment for a better determination of the points.

Tested Corner reflector:

The characteristic points of the corner reflector were observed with a prism on a standard pole.

3.6.5 Geodetic marker

The VLBI marker and the former SLR marker were observed using prisms on mini-pole (height 0.200m).

3.6.6 Orientations

GNSS observations were carried out in order to align the terrestrial survey network to IGS20 reference frame. The point 10000 and 20000 were observed during 5 hours. The point 30000 was observed during 27 hours. GPS and Glonass constellations were recorded with a sampling rate of 30s

4 Computation and data analysis

4.1 On site validation

Total station and levelling observations were checked on site and converted into the adjustment format. GNSS data were validated after a quick baseline calculation.

4.2 IGS alignment

4.2.1 GRAS IGS Coordinates

GRAS coordinates proceed from the IGS0OPSSNX_20230290000_07D_07D_CRD.SNX file (i.e., IGS20 weekly combined solution for the days 029 to 035 of the year 2023 – IGS20 epoch 2023.09).

4.2.2 Orientation points

The GNSS baselines were processed with Leica Infinity software version 3.3.1. The IGS precise ephemerides were used as well as the IGS antenna phase offset files.
We obtained 3 baselines from GRAS to the points 10000, 20000 and 30000.
Those baselines and their covariance matrices will be used for the final adjustment.

4.3 Final adjustment

The data was processed using 3D least-square adjustment with IGN Comp3D version 5.22 software. A first adjustment was processed with the three orientations observations. The input file comes from:

- Total station observations: horizontal and zenith angles, distances;
- Levelling observations: height differences.
- Centering equations: relative position between points;
- GNSS baselines;
- Dimensions of the East CR INSAR (distances from the targets to the refrence point, see 3.6.4);
- GRAS reference point coordinates, constrained at 0.1 mm to its IGS20 epoch 2023.09 values.

The computation was done in a local Lambert projection that makes it easy to compare changes in coordinates since 2009.
The terrestrial adjustment was processed with ellipsoidal height and taking into account for each point the vertical deflection from the geoid model EGM08.
The a priori standard deviations used for most of the observations with total station are:

- 0.7 mgon + *0.2 mm* (Relative std. dev. applied only to close sights) for horizontal angles;

- 0.8 mgon + 0.2 mm (SD relative applied only to close sights) for vertical angles;
- 0.2 mm for distances to prism;
- 0.07 mm for a direct levelling observation (a read on back staff and a read on front staff).

For the close sights, the final angular precision of an observation takes into account the absolute precision and the one relative to the inverse of the computed distance between the two points coordinates at current iteration. For angular measurements, the final precision of an observation is computed according to the following forumla:

$$\sigma_{abs} + \frac{\sigma_{rel}}{distance}$$

The results show that the residuals on the three orientations are consistent with a priori standard deviation values. This first adjustment provides an azimuth and its standard deviation from GRAS to point 30000.
A second adjustment with minimal constraints was processed with the same parameters and almost the same observations. The GRAS azimuth to 30000 was added but the GNSS baselines were removed.
This adjustment provides coordinates and a covariance matrix of our survey work.

5 Results

5.1 Adjusted coordinates and confidence intervals

The results of the adjustment are the coordinates of all points and their confidence ellipsoids in the IGS20 reference frame at epoch of the observations (i.e., epoch 2023.09).

5.1.1 ITRF points

The table below provides the 3D coordinates of the ITRF points.

Cartesian Coordinates IGS20 epoch 2023.09			
Point – *process nb*	X (m)	Y (m)	Z (m)
7845 – *110* 10002S002	4581691.8252	556196.5280	4389355.3825
GRAS – *300* 10002M006	4581690.6564	556115.1797	4389361.0049
GRAC – *310* 10002M010	4581708.1040	556132.9824	4389341.4837
GR4B – *220* 10002S019	4581680.9303	556167.0697	4389371.0676
7605 – *520* 10002M003	4581697.2946	556126.2611	4389351.7685
7846 – *510* 10002M004	4581693.1056	556135.0460	4389355.0352

The table below provides confidence ellipsoid (3D) at 2.5σ (that means the results have a probability of 90% to be inside the ellipsoid).

3D confidence regions 2.5 σ (90 percent)			
Point – *process nb*	½ axis (mm)	Azimuth (gr)	Tilt (gr)
7845 – *110* 10002S002	1.04	40.4	0.1
	0.82	140.4	0.0
	0.66	51.1	99.9
GRAS – *300* 10002M006	0.25	-	-
	0.25	-	-
	0.25	-	-
GRAC – *310* 10002M010	1.24	35.1	0.0
	0.83	135.1	199.9
	0.56	138.5	99.9

3D confidence regions 2.5 σ (90 percent)			
Point – *process nb*	½ axis (mm)	Azimuth (gr)	Tilt (gr)
GR4B – *220* 10002S019	12.06	25.2	100.0
	5.35	156.3	0.0
	4.92	56.3	200.0
7605 – *520* 10002M003	1.07	62.7	0.0
	0.83	162.7	0.0
	0.54	91.0	100.0
7846 – *510* 10002M004	0.97	59.2	0.0
	0.80	159.2	0.1
	0.48	155.1	99.9

The whole covariance matrix was computed. Covariance submatrix for the main points of interest was extracted from it for the next ITRF solution computation. Finally, this covariance submatrix was converted into SINEX format. The resulting SINEX file (10002_IGN_2023-032_v10.SNX) is provided in appendix 6.1.1. and a SINEX file with the INSAR CR reference point is provided in appendix 6.1.2 (10002_IGN_2023-032_v20.SNX).

5.1.2 INSAR Corner reflectors points

The table below provides the 3D coordinates of the INSAR CR points.

Cartesian Coordinates IGS20 epoch 2023.09			
Point – *process nb*	X (m)	Y (m)	Z (m)
GRCC – *404* 10002SXXX	4581703.8293	556222.9999	4389335.2937
401	4581704.9513	556222.3148	4389334.6474
402	4581703.5484	556221.8631	4389336.1755
403	4581704.7063	556223.6257	4389336.2851
700	4581697.2946	556126.2611	4389351.7685
701	4581693.1056	556135.0460	4389355.0352
704	4581650.3848	556100.6402	4389402.0285
714	4581651.9926	556100.8338	4389403.5791
705	4581650.7133	556100.2569	4389402.1629
715	4581650.9760	556099.6150	4389402.2363

The table below provides confidence ellipsoid (3D) at 2.5σ (that means the results have a probability of 90% to be inside the ellipsoid).

3D confidence regions 2.5 σ (90 percent)			
Point – *process nb*	½ axis (mm)	Azimuth (gr)	Tilt (gr)
GRCC – *404* 10002SXXX	1.52	37.6	199.9
	1.22	137.6	199.9
	0.56	170.5	99.9
401	1.26	42.4	0.2
	0.91	142.4	0.4
	0.58	112.7	99.5
402	1.26	41.1	0.1
	0.87	141.1	0.6
	0.57	128.0	99.4
403	1.27	40.0	0.2
	0.88	140.0	0.5
	0.57	114.0	99.5
700	1.36	87.9	0.1
	0.94	187.9	0.1
	0.56	124.9	99.9
701	1.31	80.8	199.8
	0.80	180.8	197.4
	0.74	186.3	97.4
704	3.48	67.3	89.6
	3.41	45.9	9.8
	2.54	146.4	3.4
714	5.45	87.9	199.9
	5.19	8.7	99.6
	5.04	187.9	0.3
705	3.48	68.2	110.2
	3.40	46.3	9.6
	2.54	146.8	3.4
715	5.44	102.9	0.1
	5.18	110.7	100.1
	5.05	2.9	0.0

5.2 Vectors

The following table shows vectors in Cartesian coordinate system (IGS20 ep.2023.09):

	ΔX (m)	ΔY (m)	ΔZ (m)
GRAS → 7845	1.1688	81.3482	-5.6224
GRAS → GRAC	17.4476	17.8028	-19.5212
GRAS → GR4B	-9.7261	51.8900	10.0627

6 Annexes

6.1.1 SINEX file: 10002_IGN_2023-032_v10.SNX

```
%=SNX 2.10 IGN 24:067:38440     23:032:43200 23:032:43200 C 00018
*-------------------------------------------------------------------------------
+FILE/COMMENT
* File created by COMP3D v5.22dev-win
* Original computation file: Calern_23_IGN.comp
* Matrix Scalling Factor used:          0.9281
-FILE/COMMENT
*-------------------------------------------------------------------------------
+SITE/ID
*CODE PT __DOMES__ T _STATION DESCRIPTION__ APPROX_LON_ APPROX_LAT_ _APP_H_
 GR4B  A 10002S019 D                        6 55 16.4  43 45 17.4  1323.8
 GRAS  A 10002M006 P                        6 55 14.1  43 45 17.1  1319.3
 GRAC  A 10002M010 P                        6 55 14.8  43 45 16.2  1319.9
 7846  A 10002M004 L GRSF                   6 55 14.9  43 45 16.8  1318.7
 7605  A 10002M003 R Mobile VLBI mark 1989  6 55 14.5  43 45 16.7  1318.6
 7845  A 10002S002 L GRSM - Meo             6 55 17.7  43 45 16.7  1323.3
-SITE/ID
*-------------------------------------------------------------------------------
+SOLUTION/EPOCHS
*Code PT SOLN T Data_start__ Data_end____ Mean_epoch__
-SOLUTION/EPOCHS
*-------------------------------------------------------------------------------
+SOLUTION/ESTIMATE
*INDEX TYPE__ CODE PT SOLN _REF_EPOCH__ UNIT S __ESTIMATED VALUE____ _STD_DEV___
     1 STAX   GR4B  A    1 23:032:43200 m    2 0.458168093030926E+07 0.37399E-02
     2 STAY   GR4B  A    1 23:032:43200 m    2 0.556167069727832E+06 0.20876E-02
     3 STAZ   GR4B  A    1 23:032:43200 m    2 0.438937106758600E+07 0.36559E-02
     4 STAX   GRAS  A    1 23:032:43200 m    2 0.458169065637979E+07 0.96338E-04
     5 STAY   GRAS  A    1 23:032:43200 m    2 0.556115179712356E+06 0.96338E-04
     6 STAZ   GRAS  A    1 23:032:43200 m    2 0.438936100490255E+07 0.96338E-04
     7 STAX   GRAC  A    1 23:032:43200 m    2 0.458170810401055E+07 0.36940E-03
     8 STAY   GRAC  A    1 23:032:43200 m    2 0.556132982487349E+06 0.36887E-03
     9 STAZ   GRAC  A    1 23:032:43200 m    2 0.438934148372264E+07 0.36437E-03
    10 STAX   7846  A    1 23:032:43200 m    2 0.458169310556803E+07 0.28366E-03
    11 STAY   7846  A    1 23:032:43200 m    2 0.556135046031438E+06 0.35747E-03
    12 STAZ   7846  A    1 23:032:43200 m    2 0.438935503522033E+07 0.28157E-03
    13 STAX   7605  A    1 23:032:43200 m    2 0.458169729463491E+07 0.30721E-03
    14 STAY   7605  A    1 23:032:43200 m    2 0.556126261119498E+06 0.39383E-03
    15 STAZ   7605  A    1 23:032:43200 m    2 0.438935176846691E+07 0.30232E-03
    16 STAX   7845  A    1 23:032:43200 m    2 0.458169182518098E+07 0.33665E-03
    17 STAY   7845  A    1 23:032:43200 m    2 0.556196527960126E+06 0.35265E-03
    18 STAZ   7845  A    1 23:032:43200 m    2 0.438935538251776E+07 0.33331E-03
-SOLUTION/ESTIMATE
*-------------------------------------------------------------------------------
+SOLUTION/MATRIX_ESTIMATE L COVA
*PARA1 PARA2 ____PARA2+0__________ ____PARA2+1__________ ____PARA2+2__________
     1     1 0.139868199110354E-04
     2     1 0.143499900550553E-05 0.435794215406449E-05
     3     1 0.943529303220030E-05 0.891352472308131E-06 0.133658658295642E-04
     4     1 0.928106569241861E-08 -.537254099848982E-13 -.724743800723269E-14
     4     4 0.928105218625178E-08
     5     1 0.162899655053092E-14 0.928104568556325E-08 -.867100336817320E-15
     5     4 -.562648356056146E-18 0.928105219013583E-08
     6     1 0.130386713793777E-13 -.518068571545729E-13 0.928104519507275E-08
```

```
     6     4 -.236256017834946E-18 0.369037738098948E-18 0.928105218752079E-08
     7     1 0.655013913314783E-07 -.200863850089973E-07 -.249978322816011E-07
     7     4 0.928103439091410E-08 -.216873023727855E-14 -.171594996966917E-13
     7     7 0.136454317610284E-06
     8     1 -.285865413327844E-07 0.102089479502136E-06 0.217635935547228E-07
     8     4 -.185162207189938E-13 0.928104996092568E-08 -.178487569064646E-13
     8     7 -.432373684002426E-07 0.136068440232004E-06
     9     1 -.240000533885317E-07 0.129256562969703E-07 0.618789770494297E-07
     9     4 0.207727250494205E-13 0.252776930492239E-14 0.928107221607135E-08
     9     7 -.831054991718366E-07 0.342537038904063E-07 0.132768910230087E-06
    10     1 0.634385745526870E-07 -.196280063200479E-07 -.262158100433959E-07
    10     4 0.928104913703262E-08 -.379042522762953E-15 -.293783817284352E-14
    10     7 0.619228662478422E-07 -.241866612288947E-07 -.237331396880300E-07
    10    10 0.804620574786492E-07
    11     1 -.243299550205080E-07 0.103631985762917E-06 0.169312916307129E-07
    11     4 -.207812648087113E-13 0.928104968512231E-08 -.200314185247897E-13
    11     7 -.214487482297043E-07 0.103948050870156E-06 0.138348275943050E-07
    11    10 -.223760180669724E-07 0.127781593620882E-06
    12     1 -.257137797874336E-07 0.118767089242173E-07 0.605822929643737E-07
    12     4 0.576915979528278E-14 0.706945461320725E-15 0.928105774588737E-08
    12     7 -.241338848147097E-07 0.166270595032727E-07 0.587589551595765E-07
    12    10 -.427755538614123E-07 0.117678580118877E-07 0.792811042879049E-07
    13     1 0.628706522740933E-07 -.191201960611457E-07 -.240315555875977E-07
    13     4 0.928104475296926E-08 -.910879742998645E-15 -.716661144664923E-14
    13     7 0.615183393028589E-07 -.219144431173386E-07 -.218697969345758E-07
    13    10 0.609674075423976E-07 -.231143970091509E-07 -.228053047121151E-07
    13    13 0.943803485234206E-07
    14     1 -.250707841126689E-07 0.103866850441629E-06 0.178136157014886E-07
    14     4 -.116186266939253E-13 0.928105079781540E-08 -.111944968519152E-13
    14     7 -.201407069086757E-07 0.105394963576635E-06 0.124833661892293E-07
    14    10 -.228986576266422E-07 0.107129140389514E-06 0.148881345135937E-07
    14    13 -.319403734655545E-07 0.155098341118558E-06
    15     1 -.232739596304379E-07 0.115539283617588E-07 0.599020258712987E-07
    15     4 0.916121050382600E-14 0.111830223270520E-14 0.928106101793589E-08
    15     7 -.220876834655494E-07 0.143076794724923E-07 0.587201086223049E-07
    15    10 -.227750801973804E-07 0.151312568359015E-07 0.577459419159076E-07
    15    13 -.458863849553985E-07 0.194536383911685E-07 0.913989489591497E-07
    16     1 0.824767858103370E-07 -.165681592459653E-07 -.380928703676571E-07
    16     4 0.928105503173736E-08 0.333408058282257E-15 0.275165235949746E-14
    16     7 0.686969909893147E-07 -.348556114380894E-07 -.268879634139854E-07
    16    10 0.665512193152440E-07 -.256041929174373E-07 -.289594663949582E-07
    16    13 0.645738657379356E-07 -.276348256701848E-07 -.249170207157404E-07
    16    16 0.113335683347584E-06
    17     1 -.234984895306905E-07 0.106389141349011E-06 0.164265020270252E-07
    17     4 -.843607776606675E-13 0.928104196830587E-08 -.813507751470022E-13
    17     7 -.183830699711372E-07 0.104912519551351E-06 0.107618896808258E-07
    17    10 -.216729762206764E-07 0.105677265708694E-06 0.137165212568125E-07
    17    13 -.210535543003268E-07 0.106816171001592E-06 0.131597991708139E-07
    17    16 -.239653609234033E-07 0.124365161380782E-06
    18     1 -.372214884006400E-07 0.908291463411587E-08 0.809348422259079E-07
    18     4 0.981880246364817E-14 0.120163324254922E-14 0.928106164712292E-08
    18     7 -.288459923882620E-07 0.278707006478299E-07 0.647552398373167E-07
    18    10 -.293585327317852E-07 0.180542700852919E-07 0.635311547714892E-07
    18    13 -.257651639507791E-07 0.201356804720272E-07 0.612270255959393E-07
    18    16 -.425893596425426E-07 0.178260437027903E-07 0.111092673881339E-06
-SOLUTION/MATRIX_ESTIMATE L COVA
%ENDSNX
```

6.1.2 Temporary SINEX file with InSar CR: 10002_IGN_2023-032_v20.SNX

```
%=SNX 2.10 IGN 24:123:47318     23:032:43200 23:032:43200 C 00021
*-------------------------------------------------------------------------------
+FILE/COMMENT
* File created by COMP3D v5.22-win
* Original computation file: Calern_23_IGN.comp
* Matrix Scalling Factor used:          0.9281
-FILE/COMMENT
*-------------------------------------------------------------------------------
+SITE/ID
*CODE PT __DOMES__ T _STATION DESCRIPTION__ APPROX_LON_ APPROX_LAT_ _APP_H_
 GRCR  A 10002Sxxx   InSar corner reflector   6 55 18.8  43 45 15.9  1320.4
 GR4B  A 10002S019 D                          6 55 16.4  43 45 17.4  1323.8
 GRAS  A 10002M006 P                          6 55 14.1  43 45 17.1  1319.3
 GRAC  A 10002M010 P                          6 55 14.8  43 45 16.2  1319.9
 7846  A 10002M004 L GRSF                     6 55 14.9  43 45 16.8  1318.7
 7605  A 10002M003 R Mobile VLBI mark 1989    6 55 14.5  43 45 16.7  1318.6
 7845  A 10002S002 L GRSM - Meo               6 55 17.7  43 45 16.7  1323.3
-SITE/ID
*-------------------------------------------------------------------------------
+SOLUTION/EPOCHS
*Code PT SOLN T Data_start__ Data_end____ Mean_epoch__
-SOLUTION/EPOCHS
*-------------------------------------------------------------------------------
+SOLUTION/ESTIMATE
*INDEX TYPE__ CODE PT SOLN _REF_EPOCH__ UNIT S __ESTIMATED VALUE____ _STD_DEV___
     1 STAX   GRCC  A    1 23:032:43200 m    2 0.458170382928076E+07 0.44295E-03
     2 STAY   GRCC  A    1 23:032:43200 m    2 0.556222999878674E+06 0.51833E-03
     3 STAZ   GRCC  A    1 23:032:43200 m    2 0.438933529365150E+07 0.44270E-03
     4 STAX   GR4B  A    1 23:032:43200 m    2 0.458168093030926E+07 0.37399E-02
     5 STAY   GR4B  A    1 23:032:43200 m    2 0.556167069727832E+06 0.20876E-02
     6 STAZ   GR4B  A    1 23:032:43200 m    2 0.438937106758600E+07 0.36559E-02
     7 STAX   GRAS  A    1 23:032:43200 m    2 0.458169065637979E+07 0.96338E-04
     8 STAY   GRAS  A    1 23:032:43200 m    2 0.556115179712356E+06 0.96338E-04
     9 STAZ   GRAS  A    1 23:032:43200 m    2 0.438936100490255E+07 0.96338E-04
    10 STAX   GRAC  A    1 23:032:43200 m    2 0.458170810401055E+07 0.36940E-03
    11 STAY   GRAC  A    1 23:032:43200 m    2 0.556132982487349E+06 0.36887E-03
    12 STAZ   GRAC  A    1 23:032:43200 m    2 0.438934148372264E+07 0.36437E-03
    13 STAX   7846  A    1 23:032:43200 m    2 0.458169310556803E+07 0.28366E-03
    14 STAY   7846  A    1 23:032:43200 m    2 0.556135046031438E+06 0.35747E-03
    15 STAZ   7846  A    1 23:032:43200 m    2 0.438935503522033E+07 0.28157E-03
    16 STAX   7605  A    1 23:032:43200 m    2 0.458169729463491E+07 0.30721E-03
    17 STAY   7605  A    1 23:032:43200 m    2 0.556126261119498E+06 0.39383E-03
    18 STAZ   7605  A    1 23:032:43200 m    2 0.438935176846691E+07 0.30232E-03
    19 STAX   7845  A    1 23:032:43200 m    2 0.458169182518098E+07 0.33665E-03
    20 STAY   7845  A    1 23:032:43200 m    2 0.556196527960126E+06 0.35265E-03
    21 STAZ   7845  A    1 23:032:43200 m    2 0.438935538251776E+07 0.33331E-03
-SOLUTION/ESTIMATE
*-------------------------------------------------------------------------------
+SOLUTION/MATRIX_ESTIMATE L COVA
*PARA1 PARA2 ____PARA2+0__________ ____PARA2+1__________ ____PARA2+2__________
     1     1 0.196204187738456E-06
     2     1 -.526827017832525E-07 0.268664805763560E-06
     3     1 -.144471003475783E-06 0.272933613857873E-07 0.195980339070399E-06
     4     1 0.899943283220153E-07 -.295686461962825E-07 -.443324354582026E-07
     4     4 0.139868199110354E-04
     5     1 -.129157568989799E-07 0.104449709735044E-06 0.568021261963547E-08
```

```
 5     4 0.143499900550553E-05 0.435794215406449E-05
 6     1 -.464682117844234E-07 0.229395622631934E-07 0.886887279941788E-07
 6     4 0.943529303220030E-05 0.891352472308131E-06 0.133658658295642E-04
 7     1 0.928103921353156E-08 -.112378370034985E-12 0.275783004706011E-13
 7     4 0.928106569241861E-08 -.537254099848982E-13 -.724743800723269E-14
 7     7 0.928105218625178E-08
 8     1 -.158921757487357E-14 0.928103856855196E-08 0.336404870506977E-14
 8     4 0.162899650053092E-14 0.928104568556325E-08 -.867100336817320E-15
 8     7 -.562648356056146E-18 0.928105219013583E-08
 9     1 -.124959159907889E-13 -.108379520561292E-12 0.928107878002872E-08
 9     4 0.130386713793777E-13 -.518068571545729E-13 0.928104519507275E-08
 9     7 -.236256017834946E-18 0.369037738098948E-18 0.928105218752079E-08
10     1 0.703059918614480E-07 -.204883924900949E-07 -.299807681463584E-07
10     4 0.655013913314783E-07 -.200863850089973E-07 -.249978322816011E-07
10     7 0.928103439091410E-08 -.216873023727855E-14 -.171594996966917E-13
10    10 0.136454317610284E-06
11     1 -.399914424745126E-07 0.110209196554451E-06 0.325715839681870E-07
11     4 -.285865413327844E-07 0.102089479502136E-06 0.217635935547228E-07
11     7 -.185162207189938E-13 0.928104996092568E-08 -.178487569064646E-13
11    10 -.432373684002426E-07 0.136068440232004E-06
12     1 -.276055745272132E-07 0.123098045854734E-07 0.656486152991385E-07
12     4 -.240000533885317E-07 0.129256562969703E-07 0.618789770494297E-07
12     7 0.207727250494205E-13 0.252776930492239E-14 0.928107221607135E-08
12    10 -.831054991718366E-07 0.342537038904063E-07 0.132768910230087E-06
13     1 0.695255869883181E-07 -.243354215739962E-07 -.319713858286062E-07
13     4 0.634385745526870E-07 -.196280063200479E-07 -.262158100433959E-07
13     7 0.928104913703262E-08 -.379042522762953E-15 -.293783817284352E-14
13    10 0.619228662478422E-07 -.241866612288947E-07 -.237331396880300E-07
13    13 0.804620574786492E-07
14     1 -.277582781709313E-07 0.106502002079806E-06 0.201175661417733E-07
14     4 -.243299550205080E-07 0.103631985762917E-06 0.169312916307129E-07
14     7 -.207812648087113E-13 0.928104968512231E-08 -.200314185247897E-13
14    10 -.214487482297043E-07 0.103948050870156E-06 0.138348275943050E-07
14    13 -.223760180669724E-07 0.127781593620882E-06
15     1 -.316418490140158E-07 0.163812234336421E-07 0.661199482510709E-07
15     4 -.257137797874336E-07 0.118767089242173E-07 0.605822929643737E-07
15     7 0.576915979528278E-14 0.706945461320725E-15 0.928105774588737E-08
15    10 -.241338848147097E-07 0.166270595032727E-07 0.587589551595765E-07
15    13 -.427755538614123E-07 0.117678580118877E-07 0.792811042879049E-07
16     1 0.667097486262122E-07 -.226561782911917E-07 -.276055340896029E-07
16     4 0.628706522740933E-07 -.191201960611457E-07 -.240315555875977E-07
16     7 0.928104475296926E-08 -.910879742998645E-15 -.716661144664923E-14
16    10 0.615183393028589E-07 -.219144431173386E-07 -.218697969345758E-07
16    13 0.609674075423976E-07 -.231143970091509E-07 -.228053047121151E-07
16    16 0.943803485234206E-07
17     1 -.308307750515345E-07 0.108930262712432E-06 0.231524796576696E-07
17     4 -.250707841126689E-07 0.103866850441629E-06 0.178136157014886E-07
17     7 -.116186266939253E-13 0.928105079781540E-08 -.111944968519152E-13
17    10 -.201407069086757E-07 0.105394963576635E-06 0.124833661892293E-07
17    13 -.228986576266422E-07 0.107129140389514E-06 0.148881345135937E-07
17    16 -.319403734655545E-07 0.155098341118558E-06
18     1 -.265824954658446E-07 0.145634989070406E-07 0.629104972431379E-07
18     4 -.232739596304379E-07 0.115539283617588E-07 0.599020258712987E-07
18     7 0.916121050382600E-14 0.111830223270520E-14 0.928106101793589E-08
18    10 -.220876834655494E-07 0.143076794724923E-07 0.587201086223049E-07
18    13 -.227750801973804E-07 0.151312568359015E-07 0.577459419159076E-07
18    16 -.458863849553985E-07 0.194536383911685E-07 0.913989489591497E-07
19     1 0.104179882620268E-06 -.356924100424982E-07 -.590023904546421E-07
19     4 0.824767858103370E-07 -.165681592459653E-07 -.380928703676571E-07
```

```
    19     7 0.928105503173736E-08 0.333408058282257E-15 0.275165235949746E-14
    19    10 0.686969909893147E-07 -.348556114380894E-07 -.268879634139854E-07
    19    13 0.665512193152440E-07 -.256041929174373E-07 -.289594663949582E-07
    19    16 0.645738657379356E-07 -.276348256701848E-07 -.249170207157404E-07
    19    19 0.113335683347584E-06
    20     1 -.274662277267300E-07 0.109332228164936E-06 0.200678715006919E-07
    20     4 -.234984895306905E-07 0.106389141349011E-06 0.164265020270252E-07
    20     7 -.843607776606675E-13 0.928104196830587E-08 -.813507751470022E-13
    20    10 -.183830699711372E-07 0.104912519551351E-06 0.107618896808258E-07
    20    13 -.216729762206764E-07 0.105677265708694E-06 0.137165212568125E-07
    20    16 -.210535543003268E-07 0.106816171001592E-06 0.131597991708139E-07
    20    19 -.239653609234033E-07 0.124365161380782E-06
    21     1 -.601336246388549E-07 0.287304452371006E-07 0.101469538375180E-06
    21     4 -.372214884006400E-07 0.908291463411587E-08 0.809348422259079E-07
    21     7 0.981880246364817E-14 0.120163324254922E-14 0.928106164712292E-08
    21    10 -.288459923882620E-07 0.278707006478299E-07 0.647552398373167E-07
    21    13 -.293585327317852E-07 0.180542700852919E-07 0.635311547714892E-07
    21    16 -.257651639507791E-07 0.201356804720272E-07 0.612270255959393E-07
    21    19 -.425893596425426E-07 0.178260437027903E-07 0.111092673881339E-06
-SOLUTION/MATRIX_ESTIMATE L COVA
%ENDSNX
```

Diffusion interne		
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Diffusion externe		
Organisme	**Fonction ou Prénom Nom**	**Adresse électronique**
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Mots-clé

GNSS ; SLR ; DORIS ;InSar ; local tie survey

Résumé

La réalisation ITRF2020 (dernière en date de l'International Terrestrial Reference System) calculée par l'équipe géodésie IGN de l'IPGP est le résultat de la combinaison des référentiels terrestres issus des quatre techniques de géodésie spatiale (à savoir GNSS, DORIS, SLR et VLBI). Pour réaliser un repère unique, un moyen consiste à ajouter dans la combinaison les résultats de rattachements sur des sites co-localisés. Sur le plateau de Calern (06) l'UMR Géoazur de l'Observatoire de la Côte d'Azur héberge une station SLR, une station DORIS, deux stations GNSS et des réflecteurs InSar. Le présent rapport décrit le rattachement de précision réalisé en février 2023 sur ce site et présente les résultats obtenus.

Matériel

Système d'exploitation	**Logiciel**
Windows 10 Professionnel	Microsoft Office

Validation

	Fonction	**Nom**	**Visa**
Commanditaire	Chef de département	Sébastien Saur	24//06/2024
Relecteur		Thomas Donal	04/07/2024
Approbateur	Chef adjoint de service	Olivier Jamaet	11/12/2024