SERVICE
DE GEODESIE
ET NIVELLEMENT

HARTEBEESTHOEK

LOCAL TIE SURVEY

reported by

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Résumé

Ce document est réalisé suite au rattachement géodésique effectué courant février 2014 à Hartebeesthoek (Afrique du Sud). Il est élaboré dans le cadre de la contribution de l'IGN à l'ITRF2014.

This document is realized after the geodetic survey carried out on February 2014 at Hartebeesthoek (South Africa). It is performed within the framework of IGN contribution to ITRF2014.

Matériel

Système d'exploitation	**Logiciel**
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Validation

	Fonction	**Nom**	**Visa**
Commanditaire	Chef d'unité RSI	Bruno Garayt	24/11/2015 signé
Rédacteur principal	Responsable de production	Jean-Claude Poyard	27/02/2015 signé
Rédacteur	Chef adjoint d'unité PMS	Jean-Michael Muller	27/02/2015 signé
Lecteur	Chef d'unité PMS	Xavier Collilieux	05/10/2015 signé
Approbateur	Chef de service	Thierry Person	25/11/2015 signé
Vérificateur	Responsable qualité	Bruno Garayt	30/12/2015 signé

Diffusion

Organisme / Service	Fonction / Nom	Numérique	Papier
IGN / DPR	Directeur / Philippe Gerbe	oui	-
IGN / DPR	Directeur adjoint / Didier Moisset	oui	-
IGN / DPC / SP / CKP	Chargé MO géodésie / François Becirspahic	oui	-
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IGN / DPR / SGN	Resp. qualité / Bruno Garayt	oui	-
IGN / DPR / SGN / PMC	Resp. documentation / Xavier della Chiesa	non	3
IGN / DPR / SGN / PMT	Resp. produits / François L'Ecu	oui	-
IGN / DPR / SGN	Chefs de départements	oui	-
IGN / DPR / SGN / PMM	Thomas Donal	oui	-
IGN / DPR / SGN / PMS	Jean-Michael Muller	oui	1
IGN / DPR / SGN / PMM	Jean-Claude Poyard	oui	1
IGN / DPR / SGN / PMM	Jérôme Saunier	oui	1
IGN / DPR / SGN / PMM	Charles Velut	oui	-
IGN / DRE / SRIG / LAREG	Zuheir Altamimi	oui	-
HARTEBEESTHOEK	Directeur adjoint / Ludwig Combrinck	oui	1

Contents

Executive Summary

The International Terrestrial Reference Frame (ITRF) is the result of a combination of different terrestrial reference frames provided by four space geodetic techniques (i.e. GNSS, SLR, DORIS and VLBI). To perform this combination of independent reference frames, it is necessary to have some precisely measured relative coordinates between space geodetic observing systems at co-located sites.
One way to improve the ITRS realization consists in adding in the combination more three dimensional tie vectors at some of these sites or to provide more accurate ties. For this purpose, missing or old ties have to be surveyed.

THE 2014 HARTEBEESTHOEK LOCAL TIE SURVEY

On a geodetic perspective Hartebeesthoek is fundamental site since the four space geodetic techniques GNSS, SLR, DORIS and VLBI are operating. Moreover some space geodetic observing systems like GNSS and VLBI already operate two instruments and SLR will have a second instrument in the upcoming years with the advent of a Lunar Laser Ranging station.

In summer 2003, a local tie survey was carried out by IGN (France) in collaboration with NASA. Coordinates and vectors between five space geodetic observing instruments and ten concrete piers were computed and published in a survey report on June 2005.

On December 2013, Professor Ludwig Combrinck Associate Director of HartRAO pointed out to some survey organizations the necessity to do another site survey at Hartebeesthoek. Indeed since last survey a lot of changes have happened:

- addition of a 15 m geodetic VLBI antenna into the IVS network ;
- suspicion of instability in one of the formerly used calibration piers (not connected to bedrock) ;
- addition of new calibration piers anchored into bedrock ;
- need of re-survey the SLR (MOBLAS-6) after ten years ;
- deployment of the Lunar Laser Ranging station.

This call to contributions was successful since some organizations gave their approval.

During February 2014, the local tie survey was carried out at Hartebeesthoek under the supervision of IGN and NASA. Our experience feedback leads to split the site in two sub-sites (i.e. in a co-located site the geodetic instruments are distant from less than some hundred meters).

This joint effort lead to an exciting exchange of knowledge and a great opportunity to share our views and make transfers of skills.
Besides, IGN is in charge of some precise survey specifications elaboration. The draft document was updated with additional comments after this survey and should be available soon.

ACKNOWLEDGEMENTS

We would like to express our special thanks to Professor L. Combrinck who is at the origin of this survey work, and to Roelf Botha.
We also want to acknowledge all his colleagues from Hartebeesthoek for their very cooperative work in a technical and administrative point of view (especially the workshop, crane driver and space geodetic instruments operators who made this work a success).
We don't forget here all other people (especially from the kitchen) for the “extras” which made us really enjoy our stay in South Africa.
Finally, we thank all the surveyors and students who took part in this local tie survey.

GLOSSARY

DOMES: Directory of Merit Sites (station reference point number given by ITRF product centre)

DORIS: Doppler Orbitography and Radiopositioning Integrated by Satellite

GPS : Global Positioning System

GNSS: Global Navigation Satellite System

HartRAO: Hartebeesthoek Radio Astronomy Observatory

IDS : International DORIS Service

IGN: Institut national de l'information géographique et forestière (France)

IGS : International GNSS Service

ILRS: International Laser Ranging Service

IVP: Invariant Point

IVS: International VLBI Service for Geodesy & Astrometry

SAC: Satellite Application Centre

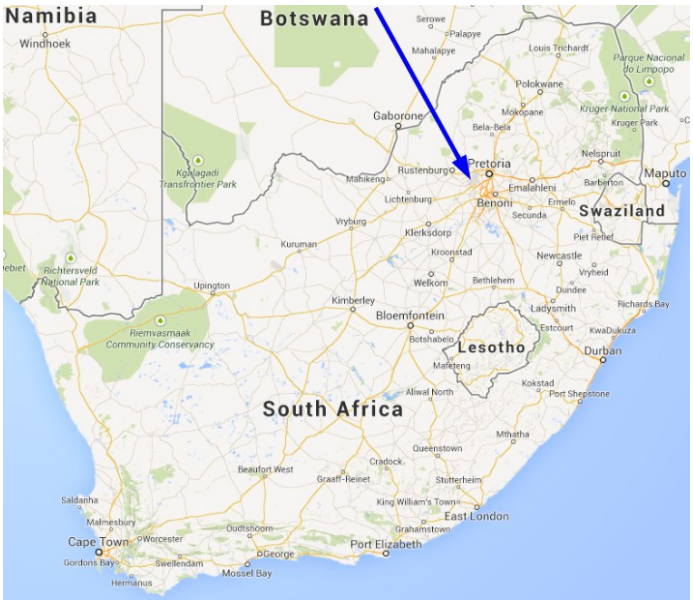
SLR: Satellite Laser Ranging

VLBI: Very Long Baseline Interferometry

1 Co-located site informations

1.1 Site description

The Hartebeesthoek site is located in a valley in the Magaliesberg hills, 50 km north-west of Johannesburg, in the province of Gauteng, South Africa.



This co-located site can be split into two sub-sites distant by about 2 km.

- The Hartebeesthoek Radio Astronomy Observatory (HartRAO) operating as a National Research Facility under the auspices of the National Research Foundation (NRF). This sub-site has three space geodetic techniques. On this site, one can find a 26-meter VLBI radio telescope, a 15-meter VLBI radio telescope, a 30-inch diameter SLR telescope (MOBLAS-6), one LLR on deployment and the IGS GNSS station (HRAO). The site is organized so that 7 reinforced concrete piers surround the space geodetic instruments. These piers are 1.2 m to 3 m high and their diameter is 0.5 m. They are all equipped with self-centring devices and are mostly used for supporting SLR calibration targets.

- The Satellite Application Centre (SAC) depending on Council for Scientific and Industrial Research is part of South Africa National Space Agency (SANSA). This sub-site has two space geodetic techniques (DORIS and GNSS). A DORIS antenna is installed, very close to another IGS GNSS permanent station (HARB). Three pillars equipped with self-centring devices have been set up around this site.

For each sub-site, a local control network of piers and tripods was surveyed, from which the instruments were observed and tied together with GNSS observations.
According to our experience feedback we did not connect these two sub-sites together using the two IGS GNSS permanent stations.

1.2 Co-located Points

1.2.1 Table of points

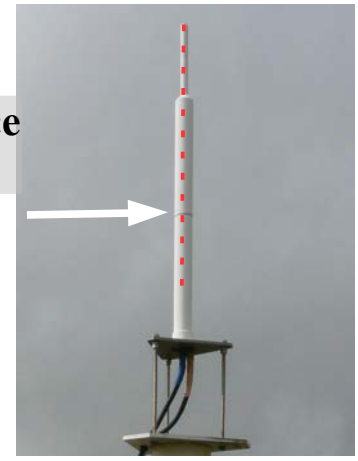
The following table sums up the main points of interest per sub-site.

Technique Name	DOMES number	Description	Code
Satellite Application Centre			
GNSS SAC	30302M009	Brass mark on a concrete pad	HARB
DORIS	30302S008	DORIS antenna reference point (starec type)	HBMB
Hartebeesthoek Radio Astronomy Observatory			
VLBI 15m	30302S009	Intersection of rotation axis of a 15m VLBI antenna	7378
VLBI 26m	30302S001	26m VLBI antenna ref. pt.	7232
SLR Moblas-6	30302M003	SLR mark 1993	7501
LLR	-	Lunar Laser Ranging station under deployment	-
GNSS HartRAO	30302M004	Krugersdorp/SS6TRI monument	HRAO

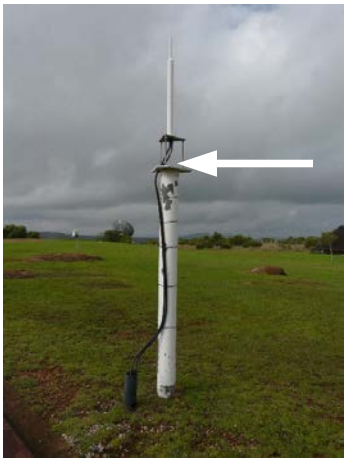
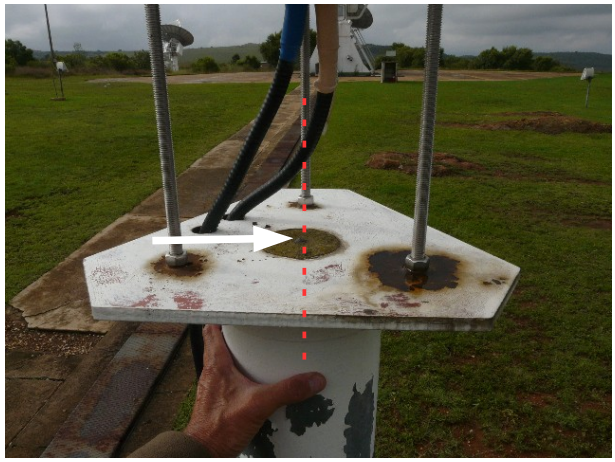
Table 1 – IERS Network site information can be found at http://itrf.ign.fr

1.2.2 DORIS station

On the SAC sub-site there is a DORIS station since March 1988. It has been upgraded many times. One of the last change made raised by about 0.2 m the antenna stainless steel supporting plate. The DORIS antenna reference point (HBMB) is the centre of the antenna red ring, 0.390 m above the upper triangular plate. The station log is presented in appendix 6.1.

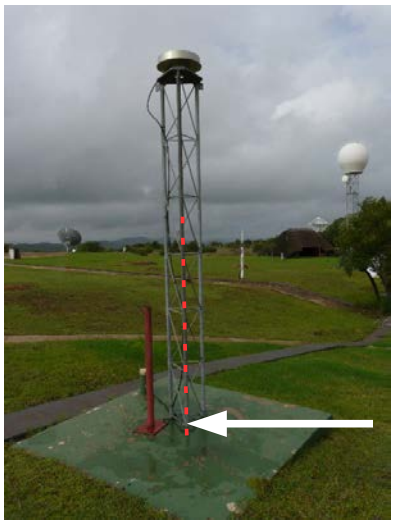
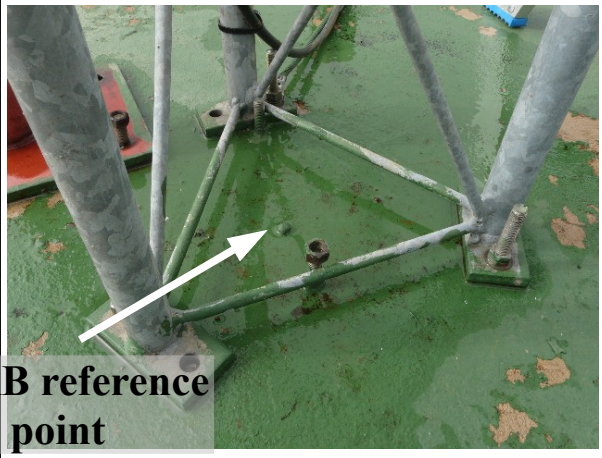
Acronym: HBMB	DOMES number: 30302S008
	
General view	Close-up view (reference point)
Description: DORIS antenna reference point (Starec type)	

The DORIS antenna reference point is tied with his fiducial mark set up on top of the DORIS metallic mast filled with concrete.

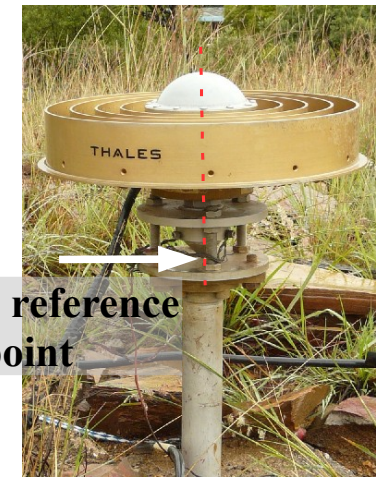
Acronym: DORIS_mark_3	DOMES number: 30302M008
	
General view	Close-up view (reference point)
Description: Brass mark on top of a steel pole.	

1.2.3 GNSS stations

There is a GNSS station managed by CNES on SAC, HARB. This station is part of IGS network (cf station log appendix 6.2).

Acronym: HARB	DOMES number: 30302M009
 General view	 Close-up view (reference point)
Description: Brass mark on a concrete pad - Antenna height is **3.052 m**.	

In HartRAO there is also a GNSS station part of IGS network, HRAO. (cf station log in appendix 6.3)

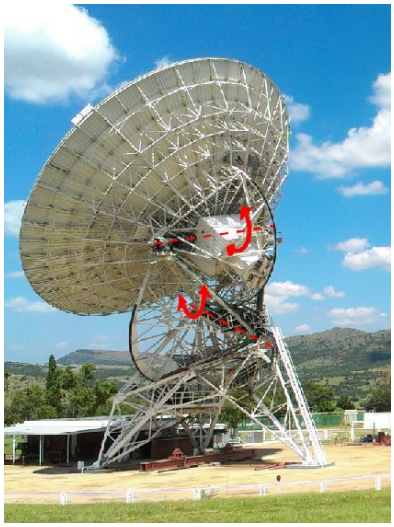
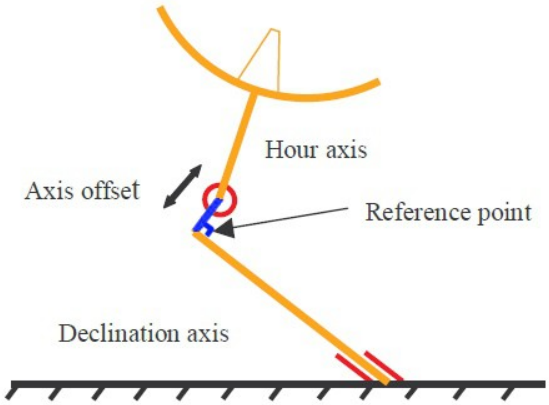
Acronym: HRAO	DOMES number: 30302M004
 General view	 Close-up view (reference point)
Description: HRAO reference point is on top of a steel mast (under the self-centring device). The antenna height is **0.0814 m**.	

1.2.4 VLBI stations

For the VLBI antenna, the measurement data is received at the phase centre of the receiver feed horn. The VLBI reference point (or invariant point, IVP) is generally described as the point where the two rotation axes intersect. But for some antennas, the rotation axes do not intersect, and in this case the IVP (VLBI reference point) is described as the secondary axis projection over the primary axis (i.e. intersection of the fixed axis (Hour Axis) with the perpendicular plane containing the moving one (Declination Axis)).

Two VLBI are operating at HartRAO.

- A 26 m radio telescope is part of the International VLBI Service for Geodesy and Astrometry. This telescope was used to establish the absolute reference point for the country's national survey system (Hartebeesthoek94 Datum). The station log is given in appendix 6.4.

Acronym - CDP number: 7232	DOMES number: 30302S001
 General view	 Close-up view (reference point)
Description: 26m VLBI antenna reference point.	

Benchmark :

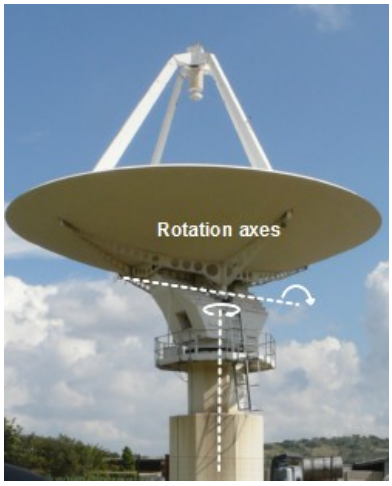
One of the 3 concrete blocks of the VLBI antenna legs is equipped with a benchmark for stability check.

Picture from 2003 report →

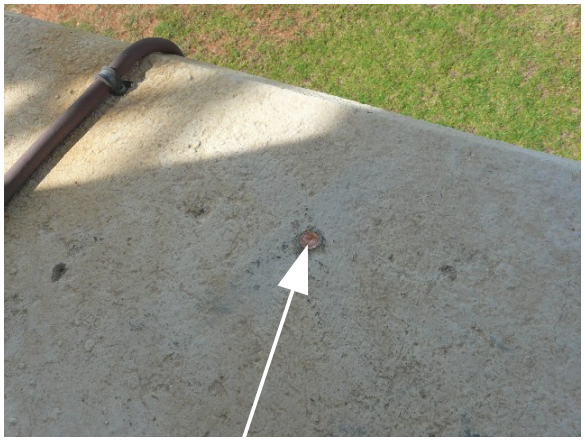
Reference benchmark V100.

Reference benchmark V100

- The 15m radio telescope built in 2007 is also part of the International VLBI Service for Geodesy and Astrometry.

Acronym - CDP number: 7378	DOMES number: 30302S009
	
General view	Close-up view (reference point)
Description: Intersection of rotation axes of a 15m VLBI antenna	

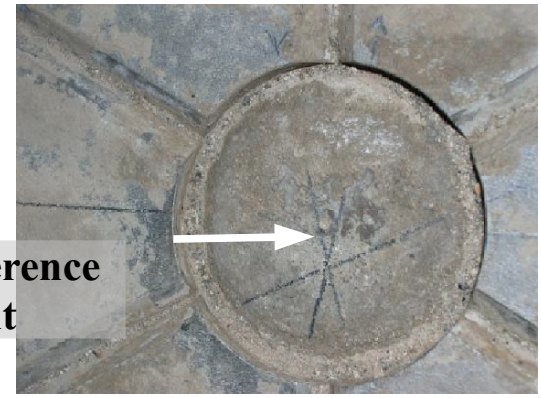
A mark has been added (on the concrete pedestal; see below).

Name for the survey: - V1999	DOMES number: -
	
General view	Close-up view (reference point)
Description: Mark (embedded coin).	

1.2.5 Laser Ranging stations

- A Satellite Laser Ranger (Moblas-6) is based at and operated by HartRAO in a joint project with NASA. The SLR measurements refer to a point in the telescope where the two rotation axes intersect. This reference point can not be materialized. The offset from the top of the SLR telescope to the horizontal axis is **0.489 m** (manufacturer value cf. Garayt et al. (2005) Hartebeeshtoek co-location survey available for downloading on ITRF website in section IERS Network / Local surveys).

The SLR System Reference Point (SRP) is a ground mark as described in the site log (cf appendix 6.5).

Acronym: HARL CDP: 7501	DOMES number: 30302M003
 General view	 Close-up view (reference point)
Description: SLR ground mark 1993 : brass mark with a stainless steel plate around.	

- Moreover a Lunar Laser Ranger is under deployment.

Name during survey: LLR_ref and LLM	DOMES number: -
 General view	  Close-up view (fiducial mark) Centring plate carved M17
Descriptions: LLR_ref : rotation axis intersection LLM : ground self-centring plate (carved M17) under the LLR station.	

1.2.6 Piers

On each sub-site, a network of reinforced concrete piers is set-up.

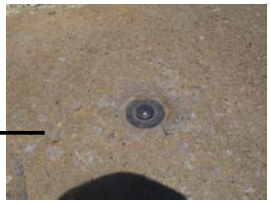
➢ SAC sub-site: 3 pillars equipped with self-centring devices have been set up around this site, on a 500m-side triangle.

Location

See location of piers on Google earth view below.

Equipment

Two piers are equipped with levelling benchmarks (see hereafter archive pictures).

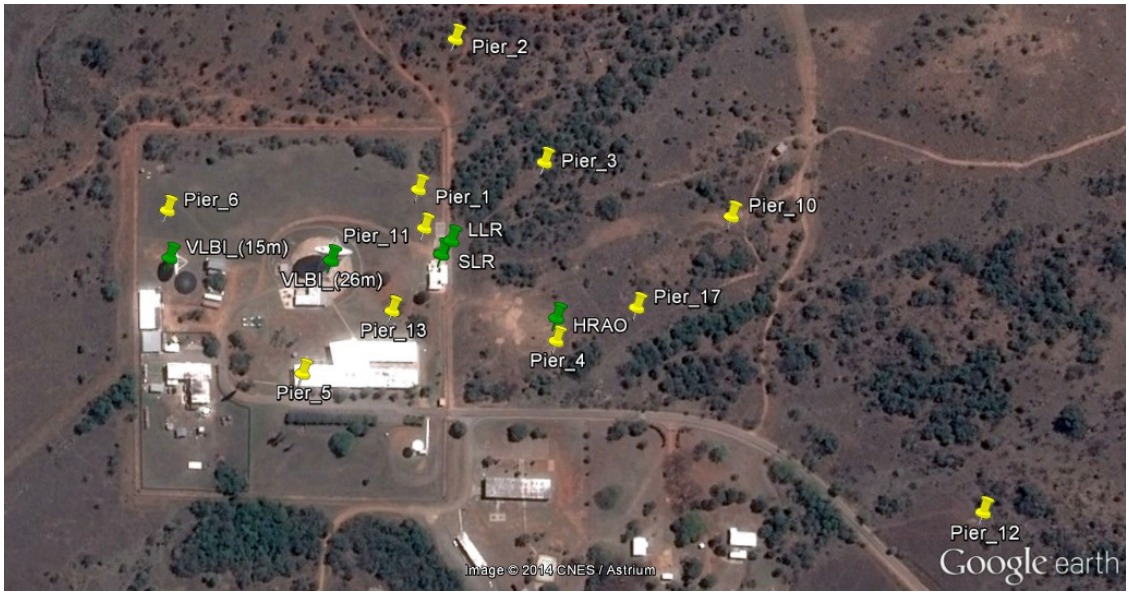
Pier P412	
 General view	 Close-up view (top of pillar)
	 Associated benchmark (not used in this survey).
Description: Axis and top of self centring device on top of pillar.	

Pier P418	
 General view	 Close-up view (top of pillar)
	Associated benchmark
Description: Axis and top of self centring device on top of pillar.	

Pier P403
no picture available.
Description: Axis and top of self centring device on top of pillar.

➢ HartRAO sub-site: 11 piers (7 that existed in 2003 and 4 new ones) surrounding the space geodetic instruments have been set-up, on a 500m-wide area.

Location



Equipment

These piers are 1.2 m to 3 m high. Some of them are used for SLR calibration prisms. They are all equipped with self-centring devices and with a levelling benchmark embedded at their base. The old piers are named 1, 2, 3, 4, 5, 6 and 17.

Pier 1
1_P (old name : 7) : self-centering plate 1111 : benchmark

Pier 2
2_P (old name : Cal Pier A) : self-centering plate 20 : benchmark

(extract from archive / 2003 report)

Pier 3
3_P (old name : Cal Pier B) : self-centering plate 30 : benchmark

(extract from archive / 2003 report)

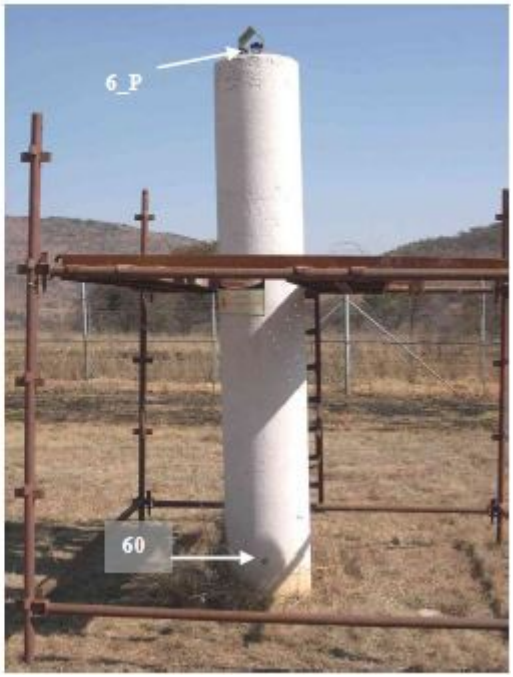
Pier 4 was partially destroyed. A new self centring plate (carved M-18) has been embedded on top of the pillar at the beginning of the survey. The new coordinates are slightly different.

Pier 4 (new centring plate)	
 General view	 Self-centring plate on top of the pillar (Close-up view) 40 (benchmark)
Description: Axis and top of self centring plate on top of pillar.	

Pier 5 is located on the roof of the main building and pier 6 is unstable.

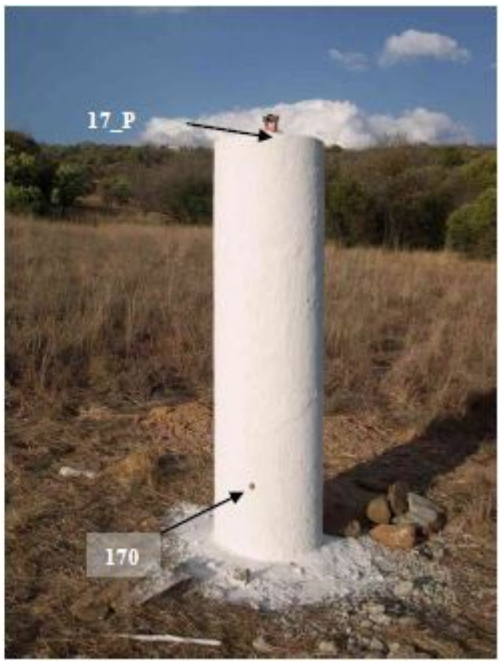
Pier 5
5_P (old name : Cal Pier D) : self-centering plate 50 : benchmark

Pier 6
6_P (old name : Cal Pier E) : self-centering plate 60 : benchmark



(extract from archive / 2003 report)

Pier 17
17_P (new pier) : self-centering plate 170 : benchmark



(extract from archive / 2003 report)

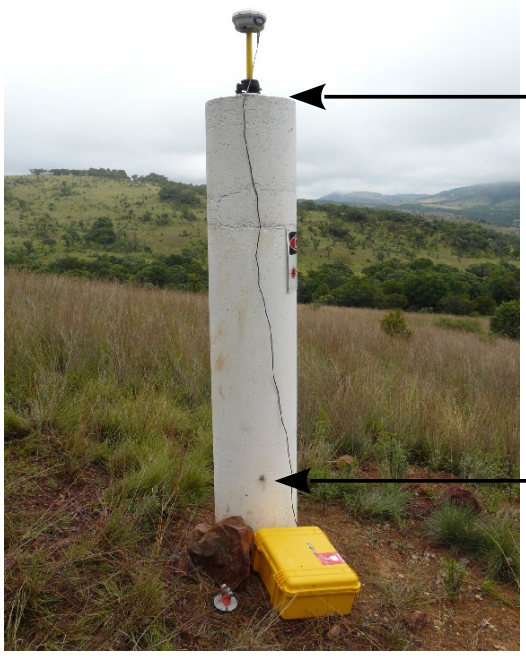
Pier 10	
 General view	10_P (self-centring plate) 100 (benchmark)
Description: Axis and top of self centring device on top of pillar.	

Pier 11

General view

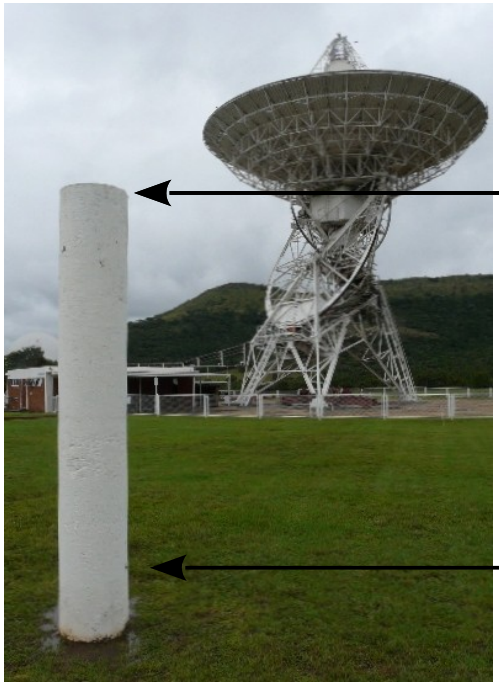
Description: Axis and top of self centring device on top of pillar.

Pier 12



General view

Description: Axis and top of self centring device on top of pillar.

Pier 13	
 General view	13_P (self-centring plate) 130 (benchmark)
Description: Axis and top of self centring device on top of pillar.	

All the new piers are equipped with a stainless steel benchmark manufactured by HartRAO workshop on the basis of the IGN 2003 brass model.

2 Human and material resources

2.1 Contributors

As budgets became restricted, when Pr. L. Combrinck pointed out the necessity to do another site survey at Hartebeesthoek, it has been decided to associate in this task a large number of organizations involved in surveying. This call for collaboration has been favourably received : South African government surveying departments, University as well as topographic instrument manufacturers took part in this work. This survey at one of the fundamental ITRF sites was carried out with South African resources under the leadership of IGN-F and NASA. Some surveyors were more familiar within centimetre accuracy surveys and had to improve their methodology to reach metrology accuracy.

Hereafter is the list of the (main) members of the survey team gathered by Pr. L. Combrinck:

Mulemwa Akombelwa : University of KwaZulu-Natal (Durban)

Troy Carpenter : Sub-contractor for NASA from Strategic-services, Inc (USA)

Ahmad Desai : Rural Dev. & Land Reform / Nat. Geo-spatial Information (Cape Town)

Sabelo Humphrey Mguli: Rural Development & Land Reform / Surveyor General (Pretoria)

Ndinae Netshivhangoni : Rural Development & Land Reform / Nat. Geo-spatial Inf. (Cape Town)

D. Anton Reynecke : Rural Development & Land Reform / Surveyor General (Pretoria)

Cilence Munghemezulu : HartRAO

Jean-Michael Muller : IGN (France)

Jean-Claude Poyard : IGN (France)

(from left to right: S. H. Mguli, J-C. Poyard, N. Netshuvhangoni, A. Reynecke, J-M. Muller, C. Munghemezulu, T. Carpenter, M. Akombelwa (A. Desai away))

2.2 Instrumentation

Instruments belonging to various entities were gathered for the survey. The following table provides the specification and identification of the equipment used.

Equipment	Trademark, Serial ref. n°	Specifications, accuracy
Total station (IGN)	Leica TDA5005 S/N 438772	EDM st. dev. 1mm + 1 ppm Angular st. dev. 0.15 mgon (0,5") Annually checked by IGN
Total station	Leica TM30 S/N 364716	EDM st. dev. 1mm + 1 ppm Angular st. dev. 0.15 mgon (0,5") Checked by Leica
Total station	Trimble Vx DR Plus S/N 95010327	EDM st. dev. 1mm + 2 ppm Angular st. dev. 0.30 mgon (1") Optron Calibrated on Oct. 30 2013
Polygonation set (2) Prism & tribrach (IGN)	Leica GPH1P (S/N 28452, 28453)	Dist. Corr. 0.0 mm
Prism & tribrach (3)	HartRAO equipment	Dist. Corr. 4.0 mm (+/- 0,5 mm)
Device: Prism mini rod	Leica GLS14 n°40914	-
Mini prism (2)	Leica	Dist. Corr. 17.5 mm (+/- 0,5 mm)
Mini-prism, target (magnetic)	-	Dist. Corr. 17.5 mm
Pocket weather tracker (meteorological station)	Kestrel 4500NV serial n°672710	Temp. st. dev. 0.5°C Pressure st. dev. 1 hPa
Translation stage (NASA)	TLRS-2 & n°77/95	-
GNSS unit (4)	Receiver&Antenna: Trimble TRMR8 (model 3) (n°5243499294, 5242495552)	Static post-processing accuracies Horiz. 3 mm + 0.1 ppm Vert. 3,5 mm + 0.4 ppm
GNSS unit (3)	Receiver: Topcon GB1000 Antenna: Topcon CR-G3 + TPSH radome	Static post-processing accuracies Horiz. 3 mm + 0.5 ppm Vert. 5 mm + 0.5 ppm
Electronic level	Trimble Dini n°771416	1.3 mm per km (with folding staff) Optron Calibrated on Dec. 07 2012
Staff + heavy foot plate (2)	Trimble TD25 telescopic bar code rod (2,4 m)	Accuracy 1 mm
Tripods (5)	Leica n°667301 & Trimble n° B3921, B3922, B3970, B3973	Made of wood

All these instruments allowed the observations to be recorded electronically on memory cards or storage devices and to be downloaded on a computer.

We want to thank the following persons who took part in the survey as topographic instrument providers:

Barend J. Bornman from Aciel Geomatics for the Leica TM30 total station and accessories.

Jochem Erasmus from OPTRON for the Trimble VX total station

Aslam Parker from Rural Development & Land Reform for the Trimble GNSS units + Dini level.

A part of the survey equipment

3 Survey description

3.1 General points

The 2 sub-sites were considered as 2 individual surveys. For both sub-sites, a control network of piers was surveyed. Then targets and prisms wisely set on each space geodetic instruments were observed from these control networks. All the surveys were conducted in order to provide the highest accuracy in the point position. Lastly the sets of points were used to compute the reference point of the instruments and 3D vectors between the observing instruments.

The survey has combined GNSS (mainly for orientation), levelling and topometric observations. In order to include the surveys into a common ITRF, the coordinates of the two IGS GNSS permanent stations were constrained to their ITRF2008 epoch 2014:058 values in the adjustment.

Before starting the survey, adjusted coordinates accuracy has been evaluated using simulation with the 3D least squares adjustment software Comp3D, developed at IGN. This led us to add a few temporary stations on tripods to reach the requirements.

3.2 Planning

The survey took place from February 13th to March 5th 2014. The meteorological conditions have been appropriate for such a fieldwork during the two first weeks but at the end we had to deal with rain and storms. It is worth mentioning that the roofs of the SLR and LLR dome can be only open when there is no risk of rain.

	DATE																			
	February																March			
ACTION	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2	3	4	5
Arrival, reconnaissance				Sunday																	
Equipment check & calibration																					
Preparations, training, bush clearing,																					
Control network survey																					
VLBI (15m) survey																					
GNSS observations																					
VLBI (26m) survey																					
SLR survey																					
SAC survey																					
LLR																					
Levelling																					
Computation, Data cleaning, Adjustment											Sunday							Sunday			
Departure																					

Schedule of the various survey tasks.

3.3 Network survey

All the visible lines of sights have been observed with the Leica total stations.

Horizontal directions and zenith distances were observed in sets, in both direct and reverse telescope positions. The station data were rejected if the difference between the values on the opening target was greater than 1 mgon. Distance measurements were observed over each line once in both direct and reverse positions. Meteorological data (atmospheric pressure and temperature) were recorded at the beginning of each station in order to apply distance corrections.

All the piers are concrete piers with self-centring devices embedded in the top. During the observations, trivet plates manufactured by HartRAO workshop were used, which ensured targets and total stations to be always on the same planimetric position. For each total station and prism, the height above the reference point was measured after each set-up with a tape measurement.

At HartRAO sub-site, we embedded a benchmark on each new pier before carrying out the levelling. The electronic level instrument was set to perform readings on bar code rod. Before each workday, the instrument collimation was checked. As far as direct levelling is concerned, a forward run and a backward run were observed between each benchmark. If the difference between the two runs was greater than 1 mm, a third run was completed.

For piers 1, 2, 3, 5, 6 and 17, we considered that the height between the benchmark and the top of the centring plate is the same as in 2003.

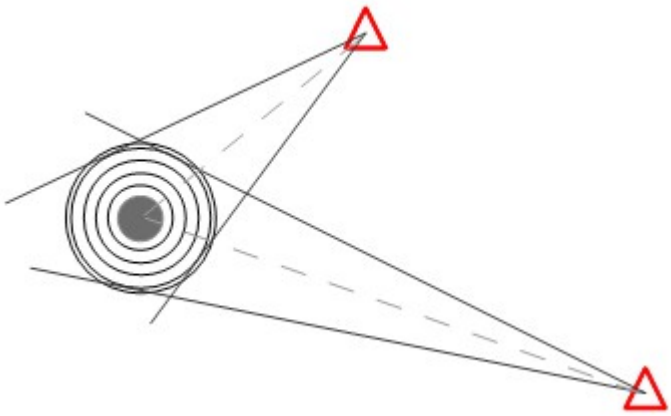
For the small piers or when the slope was large enough we set directly the rod on the benchmark and on the top of the self-centring plate. For the taller piers, we checked the self-centring plate horizontality and set the rod in reverse mode close to the pier (see opposite).

3.4 Indirect Observations

Some of the points were not directly accessible by topometric observations. Here are described the methods we used to handle this issue.

3.4.1 GNSS antenna

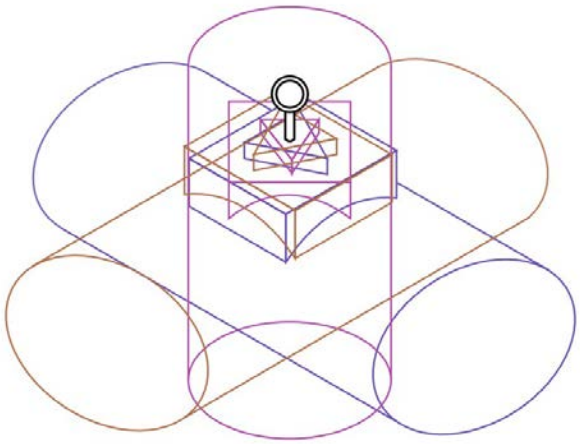
In order to compute the planimetric position of an antenna when the axis is not directly recordable we use the principle of the left and right hand sides tangential observations reduced by averaging and then intersected in the geodetic adjustment in the conventional manner (i.e. simply with an average of horizontal angles of both sides we can simulate a direct observation of the vertical axis of the antenna).



For the altimetric measurements see p. 32 and 35.

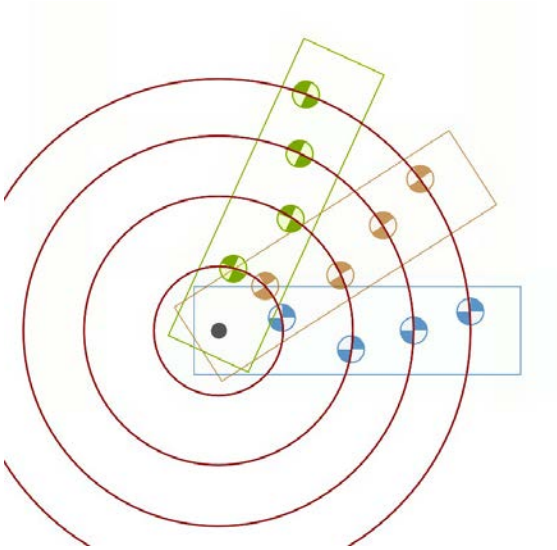
3.4.2 Telescopes

When the primary axis of an instrument is precisely vertical and the top of the instrument is accessible, we put a corner cube on the axis to materialize it. With two theodolites we intersect the corner cube, then change the telescope horizontal orientation and correct the corner cube position until it does not move when the instrument moves. Then it is set precisely on the axis, which is perfectly known with one point since it is considered perfectly vertical.



The corner cube remains immobile when the horizontal orientation of the instrument changes

For the secondary axis we have to measure targets on several positions of the telescope. By fitting parallel circles using least squares, we are able to determine the axis.



Every target move on a circle centred on the rotation axis

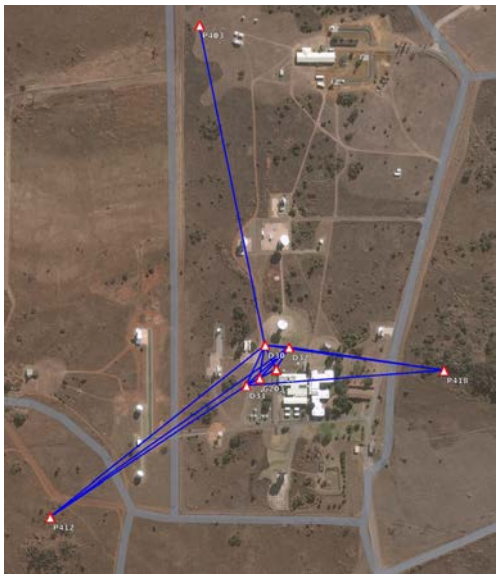
3.4.3 VLBI antennas

On VLBIs we need to use targets to determine both axes. When the two axes do not intersect we have to project the secondary axis on the primary one.

3.5 Observations polygons

3.5.1 SAC observation polygon

This control network polygon includes three concrete piers, the DORIS mast and the IGS GNSS antenna « HARB » on a steel tower. Three tripods close to the points of interest were resected and added in the polygon network as temporary stations. The blue lines are the distance and angle observations.



SAC observation polygon

HARB GNSS antenna intersections

For the planimetric position, the tangential directions of the choke ring antenna were observed from three stations close to the two points of interest. The antenna has not been measured by direct levelling. The observed position is reduced to the ARP using the manufacturer and station log values (see below some elements on HRAO GNSS antenna observations).

HARB antenna intersections
References for vertical determination (side view)

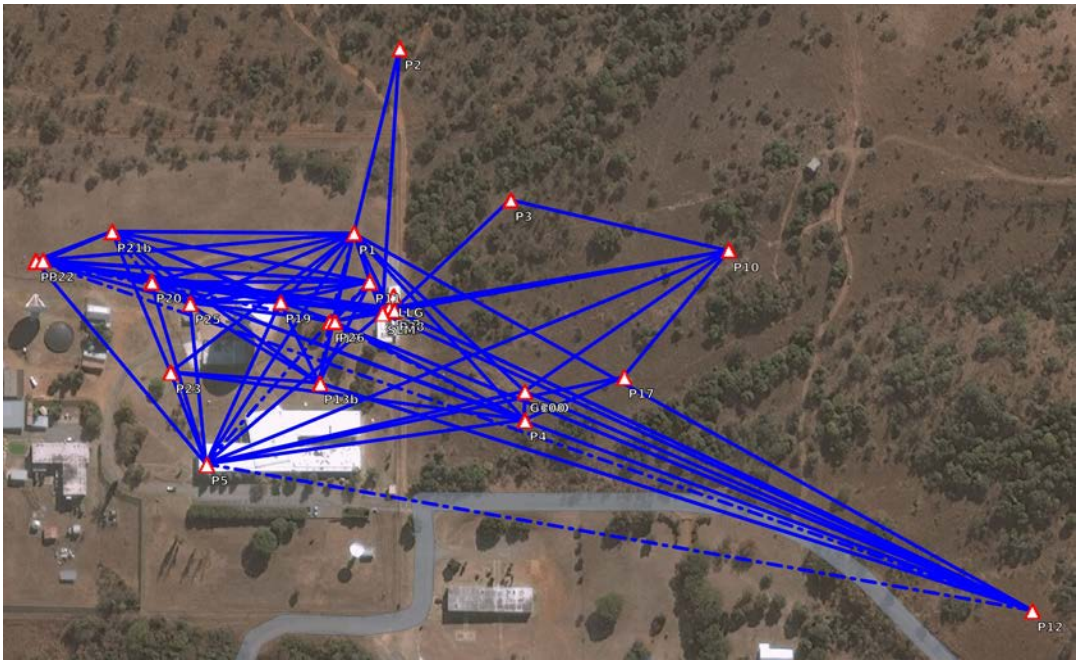
Then the eight points were surveyed by indirect levelling (see opposite: a prism put on a mark).

HBMB DORIS antenna intersections

Same principle: the DORIS antenna position was determined indirectly by observation to the sides of the antenna at the physical red marker line. The reduced average observations were then included in the geodetic least square adjustment.

3.5.2 HartRAO observation polygon

This control network polygon includes 11 concrete piers: the 7 pillars which already exist in 2003 and 4 new piers. Tripods were sometimes resected and added to this network of piers to survey the space geodetic instruments.



HartRAO observation polygon

We started to survey the IGS GNSS antenna (which has been intersected), continued with targets and prisms on the two VLBI antennas (15 m radio-telescope first and then 26 m antenna) and finished with satellite laser ranger telescope (SLR) and lastly we surveyed the LLR yoke.

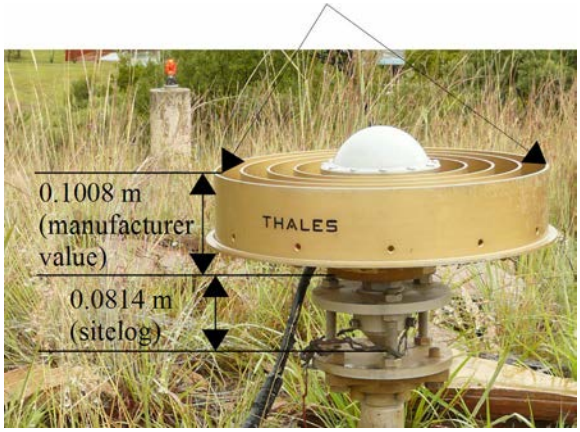
HRAO GNSS antenna intersections

In order to find the planimetric position of the antenna, the directions tangent to the left and the right hand sides of the choke ring antenna were observed from all the stations of the polygonation from which the antenna was visible (i.e. 4 stations). In the adjustment, the mean value of the directions tangential to the antenna (from a same station), was used to process the planimetric position.

The antenna has not been measured by direct levelling. The observed position is reduced to the ARP using the manufacturer and station log values.

See below some elements on HRAO GNSS antenna observations.

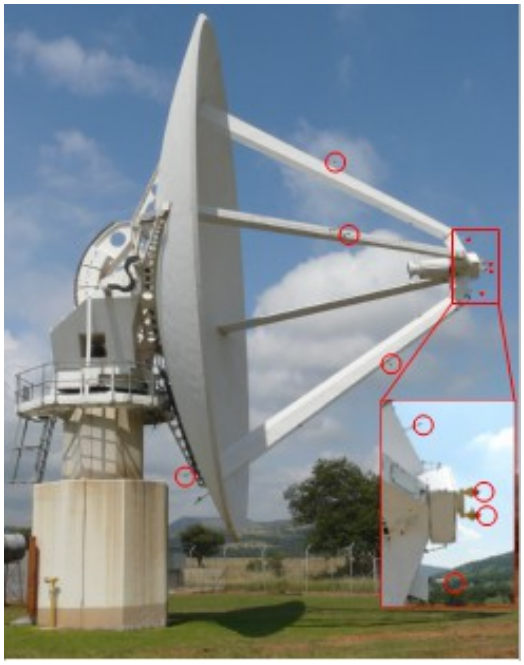
HRAO antenna intersections
References for vertical determination



VLBI 15 m rotation axis determination

In order to find the rotation axes of the 15 m radio-telescope, a set of targets (4 prisms and 2 candle targets on magnetic supports) were installed on the antenna. These targets plus the pins of two existing security lights have been aimed with the total stations from three positions and so on after the antenna rotation. Nine positions of the antenna were surveyed. By computation, the set of coordinates allows to determine circles centred on the vertical and horizontal rotation axes.

VLBI (15m)
Targets on 15 m VLBI dish



These targets were numbered V1PPn with V1 for the 15m VLBI, PP for the dish position (01 to 09) and n (1 to 8) for the name of the (coloured) target. No antenna model (antenna deformation depending from elevation angle or dilatation with temperature) has been applied. The temperature during all the survey

has been recorded and fluctuate between 22 and 27.5 °C and the pressure was around 866.6 hPa (cf appendix 6.6).

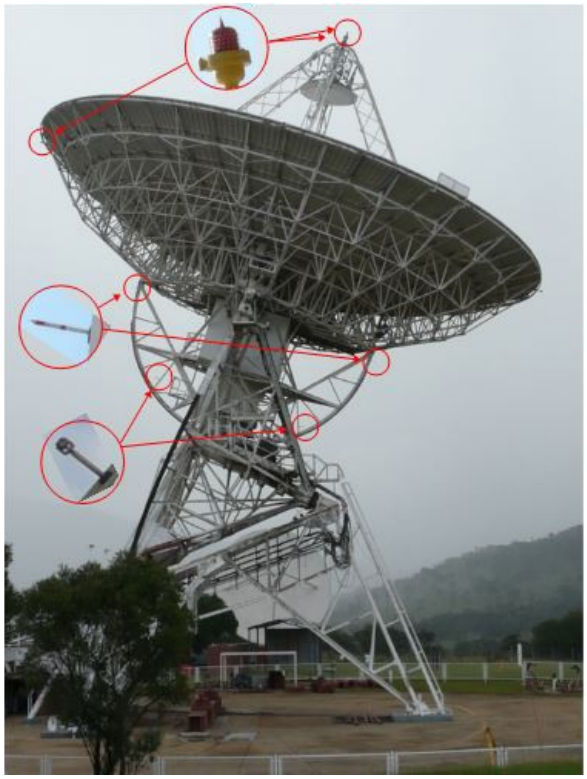
VLBI 26 m rotation axis determination

We used the same principle as for the 15 m VLBI. We found on the structure some existing targets and added some others on magnetic supports. The visible targets were then shot from three stations (Pier_5, Pier_13 and P_23) in five positions of the dish for the primary axis.

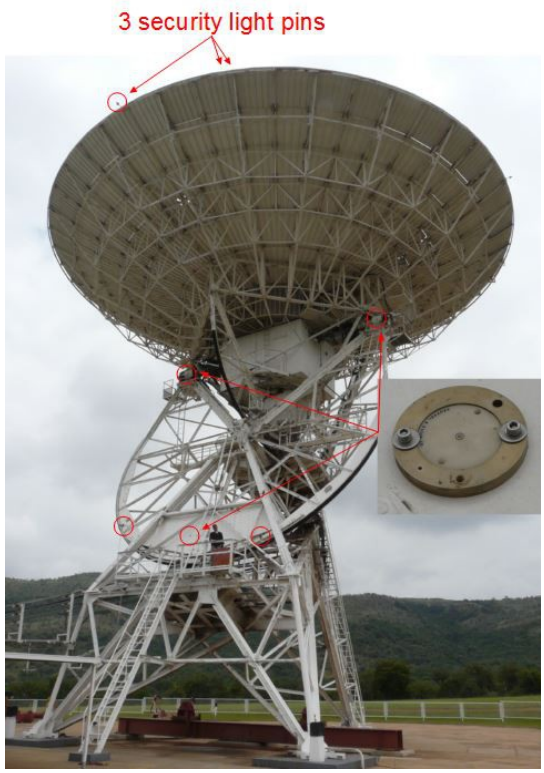
For the secondary axis the targets were shot from three stations (Pier_11, Pier_13, P_23).

The hour / declination mount of this antenna made the observation of the antenna difficult since the dish of the antenna hides much of the structure from view when rotating around one of the axes. We had to have different targets and stations for each axis.

VLBI (26m)
Targets on 26 m VLBI antenna



Targets for secondary axis determination



Targets for primary axis determination

These targets were numbered V2Pnn with V2 for the 26m VLBI, P for the dish position (1 to 9) and n (1 to 13) for the name of the target.

No antenna model (antenna deformation depending from elevation angle or dilatation with temperature) has been applied. The temperature during all the survey has been recorded and fluctuate between 17.5 and 25.5 °C and the pressure was around 862 hPa (cf appendix 6.6).

SLR rotation axis determination

The SLR System Reference Point (SRP) is a ground mark as described in the station log (see appendix 6.5). It was difficult to observe because of the laser support vehicle tires.

The Satellite Laser Ranger invariant reference point (IVP), defined as the intersection of the azimuth axis with the perpendicular elevation axis, has been also determinated.

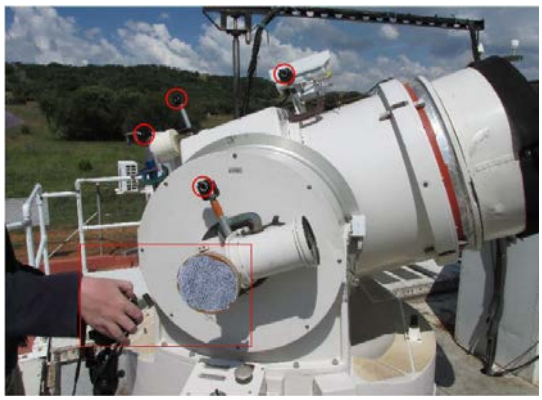
For the vertical axis (or planimetric position) we determined its position, from one total station set up on the nearest pier. The telescope was rotated up-side-down to receive the translation stage on its centring plate. Then a prism set on the translation stage was sighted and the distance recorded. The SLR has been rotated by 180° around the vertical axis, and the same prism sighted again. Lastly the translation stage was adjusted of half the difference between the two distances. The same procedure was followed with the SLR telescope oriented at 90° from the original position. At the end we checked that the target didn't move (with its bubble still levelled), when sighted with the total station, regardless the direction the SLR is pointing.

For the elevation axis, an indirect approach was again used: we measured prisms on the SLR telescope during (elevation) SLR rotational sequences and thus derived the elevation axis through a process of three-dimensional circle fitting to the three dimensional coordinates of the observed targets.

As a check, we also determined by photogrammetry a point on the elevation axis and surveyed it by intersection from three stations.

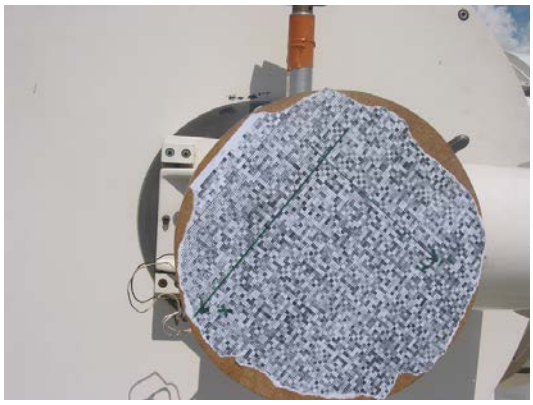
SLR Moblas

Prism or target for vertical axis determination

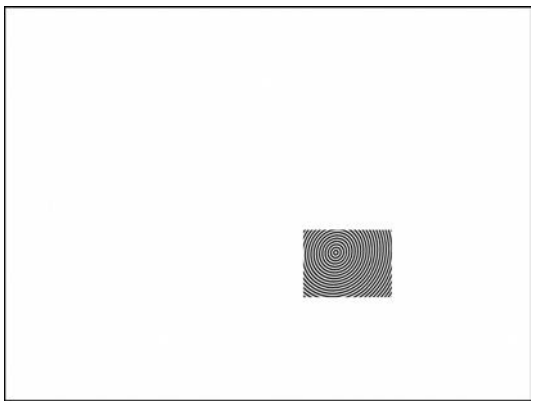


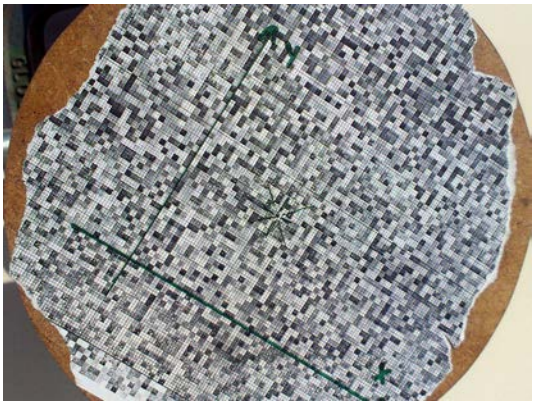
Prisms and photogrammetry device for horizontal axis determination

Photogrammetric method



Pictures from the same point of view before and after rotation





The fix point is found by correlation and reported as a target on the paper

LLR rotation axis determination

We used the same method for the LLR rotation axis determination (without photogrammetry).

LLR

Prism for vertical axis determination

Prisms for horizontal axis determination

3.6 Polygons bearings by GNSS Observations

In order to provide an ITRF orientation for the local control networks, some piers were surveyed by GNSS on each sub-site. Data from the two IGS permanent stations HRAO and HARB were collected too.
The GNSS observations for the piers were carried out with the following specifications:

- Cutoff angle 0°
- Sampling 30 sec.

All the antenna heights are related to GNSS antenna reference point. They were measured with an accuracy of 0.001 m.

The following tables present the different sessions and equipment used:

HartRAO site:

Point	Date (length)	Ant. Height (m)	Ant. Model
Pier_1	Feb. 24 (16h)	0.027	TPSCR.G3 (with radome)
Pier_5	Feb. 24 (17h)	0.028	TPSCR.G3 (with radome)
Pier_6	Feb. 24 (16h20)	0.102	TPSCR.G3 (with radome)
Pier_10	March, 3 (7h40)	0.345	TRMR8_GNSS
Pier_12	March, 3 (7h10)	0.349	TRMR8_GNSS
HRAO	Feb. 24 & March, 3 (24h)	0.0814	ASH701945E_M

SAC site:

Point	Date (length)	Ant. Height (m)	Ant. Model
Pier_412	Feb. 27 (4h45)	0.337	TRMR8_GNSS
Pier_418	Feb. 27 (4h50)	0.345	TRMR8_GNSS
HARB	Feb. 27 (24h)	3.052	TRM59800.00

4 Computations

4.1 On site validation

The computation validations on the site were a good opportunity to discuss least squares usage and the basic usage of Comp3D and the free and open source computation software GnuGama.

4.1.1 Ground control networks

Each local control network has been pre-processed on site in order to point out any weakness in the observations. The observations have been checked in a local coordinate system by a 3D least squares adjustment with the Comp3D software.

The following a priori standard deviation values for the different observations from total stations have been used :

- 0.8 mgon for horizontal angles,
- 1.2 mgon for vertical angles,
- 1 mm for distances.

The levelling observations at HartRAO have also been validated on site by adjustments between two successive benchmarks. The precision is around 1 mm for HartRAO levelling network.

4.1.2 GNSS baselines process

GNSS data were converted to RINEX format. The GNSS baselines have been processed on site with Leica Geo Office v8.1 software.

4.2 Final process (Office validation)

4.2.1 GNSS network

Data from the piers were processed with Leica Geo Office Version 8.1 software ; the two IGS stations were used but lastly we archived only the baselines computed with the nearest one.

The main features of the adopted processing parameters are presented hereafter:

- Original set of "absolute" GNSS antenna calibrations (igs08.atx).
- Precise orbits
- Saastamoinen troposphere model
- Cut off angle 15°

For this solution, the reference points (HRAO & HARB) have been constrained (0.1 mm) to their ITRF2008 coordinates at the observation epoch.

4.2.2 HartRAO and SAC general survey networks

Both sites have been computed with Microsearch GeoLab 2001 software, 2001.9.20.0 version and Comp3D v4 to ensure there is no mistake. But the final analysis of the network observations has been carried out with GeoLab for SAC sub-site and Comp3D v4 for HartRAO sub-site. In order to get the best relative accuracy between point coordinates, the input files did include all the topometric observations (i.e. we mixed direct levelling with total station observations like distances, horizontal and zenithal angles). GNSS results have been used to derive reference frames. Indeed, the set of coordinates allows to orientate the two polygons with the following bearings :

<u>SAC sub site</u>

- Origin: HARB coordinates heavily constrained
- Orientation: azimuth between HARB IGS station and piers 412 and 418

```
AZIM  from  HARB to P412:  262.8143 grades   0.003 (standard deviation)
AZIM  from  HARB to P418:   97.1227 grades   0.002 (standard deviation)
```

HartRAO sub-site

- Origin: HRAO coordinates heavily constrained
- Orientation: azimuth between piers P1, P6 and HRAO to P12

```
AZIM  from  P1    to P12:  132.2673 grades   0.003 (standard deviation)
AZIM  from  HRAO  to P12:  125.9394 grades   0.004 (standard deviation)
AZIM  from  P6    to P12:  121.4644 grades   0.002 (standard deviation)
```

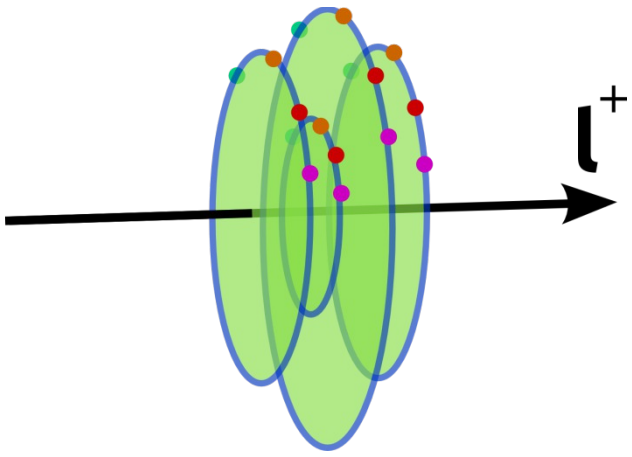
These two "topometric" adjustments give us coordinates and a covariance matrix for all the points of surveys. Some of them are only prisms or targets surveyed during instrument rotational sequences and theoretically describing arcs of circles centred on the rotational axes.

4.2.3 Reference point by rotation axis intersection

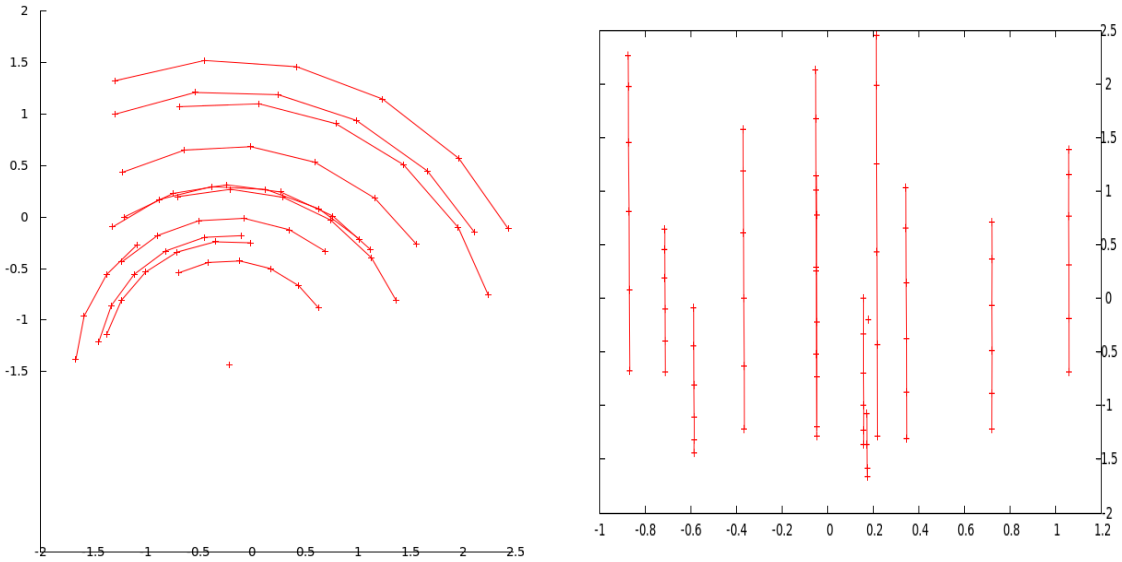
We used a Gauss-Helmert model least squares adjustment to estimate the axis position and orientation in a Comp3D local frame.

Horizontal axis

For each position of the instrument we determined several target coordinates. With several positions, we could have an estimation of the displacement of each target when the instrument was moving. The displacement of each target is on a circle, orthogonal to the axis.



The centre of the circles are on the axis, the circles are orthogonal to the axis.



Displacement of the targets, side and top view

The observations are the 3D coordinates of points, with their precisions.

The relations between observations and parameters are:

- the distance between a point and the centre of the circle is the radius;
- the vector between the centre and the point is orthogonal to the axis.

Axis parametrization, general model

In the local frame, the axis parametric equations are:

	$x = a \cdot l + x0$
	$y = b \cdot l + y0$
	$z = c \cdot l + z0$

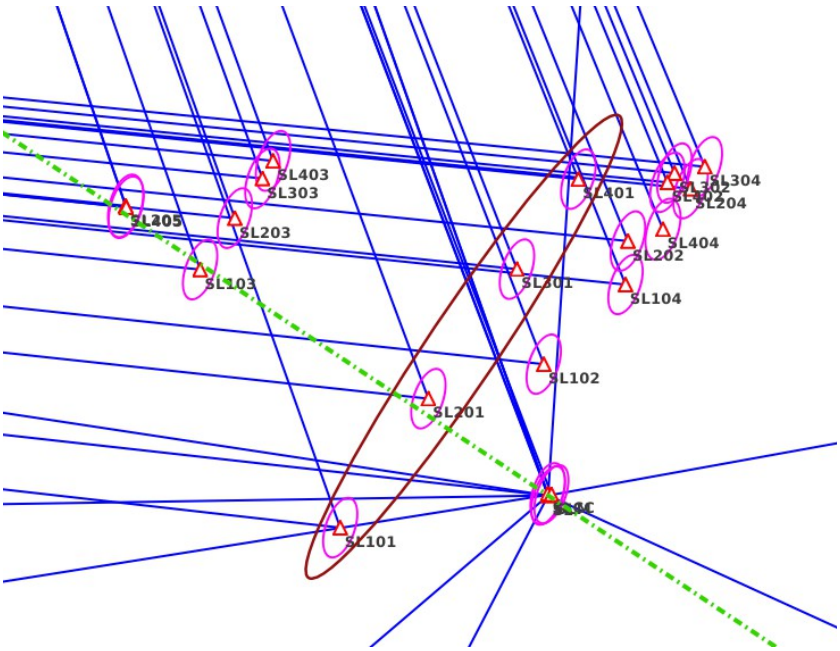
for every l in $]-\infty;+\infty[$.

The axis has 4 degrees of freedom. Firstly, depending on the main orientation of the axis (along x, y or z), either a, b or c is fixed to 1. Secondly, the corresponding constant to that direction (x0, y0 or z0) is chosen to have l positive and small at the instrument centre. This choice is arbitrary since the value of l has no physical meaning.

Axis parametrization, example of SLR

To illustrate this method we take the example of the MOBLAS 6 horizontal angle determination and explain how a priori values for the parameter to determine were obtained and arbitrarily fixed parameters were chosen:

On the compensated topometric map we can see the displacement of target 1 (SL101, SL201, SL301, SL401) on a vertical circle.



Map close-up on the MOBLAS 6 targets

We can imagine the horizontal axis (in green), orthogonal to the circle.

We can see that the main direction of the axis is x, so we fix a = 1.

In this case, the initial direction vector of the axis is close to (1,-0.7,0).

The axis is described as:

$x = l+x0$

$y = b \cdot l+y0$

$z = c \cdot l+z0$

We have to fix x0, y0 or z0 to have an origin point on the axis. We choose to fix x0, x being the main direction.

We want x0 such as l is positive and small for every target; as the first target coordinates is around (- 50, 182, 1410), we choose x0 = -51m.

The axis is now:

$x = l-51$

$y = b \cdot l+y0$

$z = c \cdot l+z0$

and the initial parameters are:

b = -0.7; c = 0; y0 = 182m; z = 1410m

Then we add the four circles corresponding to the four targets, each is represented by 2 parameters: the circle centre abscissa on the axis and its radius. It is respectively initialized to 0.5 and 0.7 (same value for every circle).

Observation equations :

The observations are, for every position of every target:

1) The target moves on a circle whose centre is on the axis:

$$(li \cdot 1+1-xij)^2 + (li \cdot b+y0-yij)^2 + (li \cdot c+z0-zij)^2 - ri^2 = 0$$

where i is the target index and j the position index,

li the abscissa of circle i, ri the radius of the circle,

xij,yij,zij the coordinates of target i on position j.

2) the vector between the target and the centre of the circle is orthogonal to the axis:

$$(li \cdot 1) \cdot (li \cdot 1+1-xij) + (li \cdot b) \cdot (li \cdot b+y0-yij) + (li \cdot c) \cdot (li \cdot c+z0-zij) = 0$$

Results for SLR :

A Gauss-Helmert model is used, with weights for every coordinate taken from Comp3D results.

The system is stabilized after 9 iterations, the square root of the variance unit factor is sigma0=0.98125.

The results are :

b= -6.84073209992242e-01

c= -1.73756280829573e-03

y0= 1.83020228704209e+02m

z0= 1.41000456335266e+03m

l1= 5.16245286416901e-01m

r1= -6.65767398719270e-01m

l2= 6.50581552833372e-01m

r2= -7.38127029312956e-01m

l3= 5.33797117606916e-02m

r3= -2.58008081706597e-01m

l4= 6.90000442213227e-01m

r4= 7.77054311393264e-01m

We can check that the vector orientation and origin is correct, and the circles abscissas and radius are reasonable (they are sometimes negative because they only appear as r^2 in the equations).

We can get the precisions on the parameters, and we use sigma_y0 and sigma_z0 as a tip for the axis determination precision.
Here we have sigmay0 = 7.3e-04m and sigmaz0 = 5.6e-04m.

Here are the results of the axis determinations :

	sigma0	sigmaX0 (m)	sigmaY0 (m)	sigmaZ0 (m)	Distance between axes (m)
LLR_hz	2,52	-	0,0008	0,0006	0,0023
SLR_hz	0,98	-	0,0007	0,0006	0,0014
VLBI 15m_hz	0,68	-	0,0005	0,0004	1,4909
VLBI 15m_vert	0,75	0,0004	0,0004	-	-
VLBI 26m_hz	1,23	-	0,0012	0,0009	6,6940
VLBI 26m_vert	0,75	0,0003	0,0009	-	-

Results for all instrument :
We searched for the closest point to the horizontal and vertical axis, taking the centre of the segment perpendicular to both axes. The length of this segment is a clue about the point precision (or the instrument defaults).

If the two axes are not supposed to intersect, we compute P and Q, respectively on the primary and the secondary axis where (PQ) is orthogonal to both axes. P is the published point.

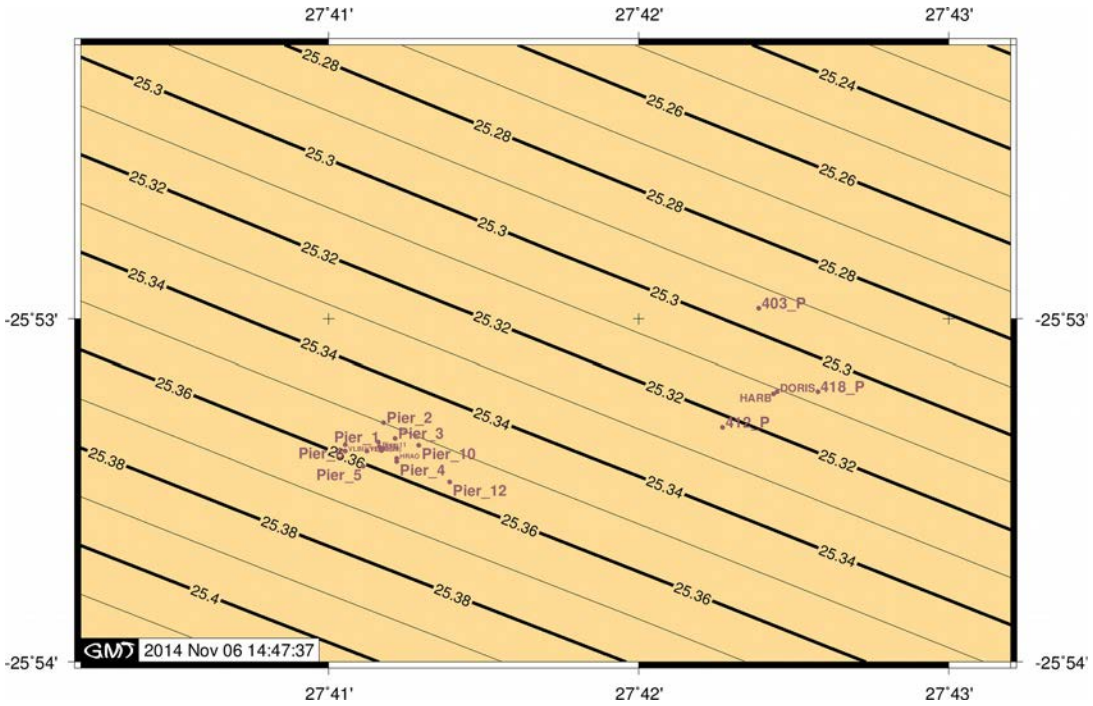
4.2.4 Importing SLR and VLBI reference points into topometric computation

To add the reference points into the topometric computation, we imported in the adjustment software reference point coordinates with their full variance matrix including their links between all the points. The precision of the telescope centre is given by sigmay0 and sigmaz0.

4.2.5 Orientation of the tie vectors

To express the topographic survey results into a global frame, we checked the vertical deflection (i.e. geoid slope).
In this area the vertical deflection reach 4 mm per 100 m in the worse case. For SAC sub-site, since surveyed points are very close, we didn't consider the vertical deflection (for less than 20 m, the error is estimated of

few tenth of mm). But at HRAO sub-site where points can be 250 m apart, we took into account the geoid slope with a 6-parameters transformation estimation between local and geocentric coordinates.



EGM08 at Hartebeesthoek (geoid height in metre)

4.2.6 Georeferencing

The topometric compensation has been done in a Cartesian local frame, aligned with the geoid.
The local coordinates of HRAO have a 100 times stronger constraint than the other points.

All the coordinates have been expressed into geocentric using the best fitting 6-parameters rigid transformation (T and R) from local coordinates of the 4 GNSS points to their geocentric coordinates.

	Mesure				Poids	Résidus terrain				Résidus locaux			
Pt_Vise	mes.X	mes.Y	mes.Z	hV	σ	res.X mm	res.Y mm	res.Z mm	norme res.	res. radial	res.X norm	res.Y norm	res.Z norm
HRAO	5085352.44000	2668396.02000	-2768731.38000	0	1000.00	-2.44	0.51	0.48	2.54	0.48	0.00	0.00	0.00
P1	5085428.40000	2668326.67000	-2768649.24000	0	1000.00	-0.08	-0.67	-0.64	0.93	-0.64	0.00	0.00	0.00
P5	5085415.46000	2668225.40000	-2768765.75000	0	1000.00	1.23	0.17	-0.41	1.30	-0.41	0.00	0.00	0.00
P6	5085499.77000	2668160.61000	-2768659.62000	0	1000.00	1.29	-0.01	0.58	1.41	0.58	0.00	0.00	0.00

$$georef = R \cdot (local - T) \qquad (\text{i.e. } Coordinates_{georef} = R \cdot (Coordinates_{local} - T))$$

Where R is the rotation and T the translation between local and georeferenced coordinates.

The variance-covariance matrix of the 5 exported points (i.e. HRAO, SLM, LLR_ref, V15_ref, V26_ref) was converted to geocentric using the formula:

$$sigma\_georef = R\_ \cdot sigma\_local \cdot R\_'$$

Where R_ is a 15x15 matrix composed by 5 times R on the diagonal.

4.2.7 Point names in HRAO sub-site computation

LLR ref	Axis intersection of LL
SLR ref	Axis intersection of SLR
V15 ref	Secondary axis projection on primary axis of 15m-VLBI
V26 ref	Secondary axis projection on primary axis of 26m-VLBI
LLR centre	Temporary point: centre of LLR frame
SLR centre	Temporary point: centre of SLR frame
V15 centre	Temporary point: centre of 15m VLBI frame
V26 centre	Temporary point: centre of 26m VLBI frame
HRAO	HRAO IGS station (constrained station)
P1	Pier
P5	Pier
P6	Pier
P2	Pier
P3	Pier
P4	Pier
P10	Pier
P11	Pier
P12	Pier
P13	Pier
P13b	Pier (bad centring) just for TM30 obs on 25/02
P17	Pier
P18	Tripod
P19	Tripod
P20	Tripod
P21	Tripod
P21b	Tripod
P22	Tripod
P23	Tripod
P25	Reference mark of 26m VLBI
P26	Tripod
P27	Tripod
P28	Tripod
VB1	1D point: Reference benchmark of 26m VLBI
TMOB6	1D point: Moblas side benchmark
BT12	1D point: Temporary benchmark
B0	1D point: Pier
B1	1D point: Pier P1

B2	1D point: Pier P2
B3	1D point: Pier P3
B4	1D point: Pier P4
B5	1D point: Roof pier P5
B6	1D point: Pier P6
B10	1D point: Pier P10
B11	1D point: Pier P11
B12	1D point: Pier P12
B13	1D point: Pier P13
B17	1D point: Pier P17
G100	measured point 0.182m above HRAO
GN	1D point: Levelling north side of HRAO IGS station
GS	1D point: Levelling north side of HRAO IGS station
GE	1D point: Leveling north side of HRAO IGS station
GW	1D point: Levelling north side of HRAO IGS station
CP1	1D point: Confort point close to Moblas
SL	Moblas top centring plate
SLCC	Moblas top centring plate: NASA corner cube
OT1	1D point: Moblas top of 35.5mm ocular when centring plate is on top
OB1	1D point: Moblas top of 35.5mm ocular when centring plate is on bottom
SLM	Moblas ground centring plate centre (height or the top of the plate the plate is centred on the original punchmark
LL	Prism on LLR vertical axis
LLM	LLR ground centring plate centre (height or the top of the plate the plate is centred)
LLG	LLR vertical axis projected on ground centring plate (height or the top of the plate)
V1999	15m VLBI benchmark
V1011 to V1088	15m VLBI targets positions V1ppn : 15m VLBI with position pp and target n (pp : 01 to 08, n : 1 to 8)
V2101 to V2913	26m VLBI targets positions V2pnn : 26m VLBI with position p and target nn (p : 1 to 9, n : 01 to 13)
SL101 to SL404	SLR targets positions SLpnn : SLR position p and target nn (p : 1 to 4, nn : 01 to 04)
SL205	SLR target (photogrammetry point in position 2)
SL405	SLR target (photogrammetry point in position 4)
L11 to L54	LLR targets positions Lpn : LLR position p and target n (p : 1 to 5, n : 1 to 4)

5 Results

5.1 SAC sub-site

5.1.1 Adjusted coordinates and vectors

The results of the adjustment are the coordinates of all points as well as their confidence ellipsoids in ITRF2008 at the mean epoch of the observations (i.e. epoch 2014 : 058).

Here is a table with the 3D coordinates and confidence region at 95% of the main points of interest.

```
================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0            GRS 80      UNITS: m,GRAD Page 0004
================================================================================
Adjusted XYZ Coordinates:
                           X-COORDINATE       Y-COORDINATE       Z-COORDINATE
 CODE FFF STATION                STD DEV            STD DEV            STD DEV
 ---- --- ------------ ------------------ ------------------ ------------------
 XYZ      DORIS_rep          5084652.8859       2670347.2967      -2768470.4415 m       0
                                   0.0028             0.0029             0.0025
 XYZ      HARB               5084657.6130       2670325.2920      -2768480.9920 m       0
                                   0.0009             0.0009             0.0009
 XYZ      HBMB               5084653.4254       2670347.5830      -2768470.7403 m       0
                                   0.0020             0.0022             0.0017
 XYZ      P403               5084867.8025       2670347.3395      -2768064.7761 m       0
                                   0.0068             0.0068             0.0040
 XYZ      P412               5084728.1507       2670054.2543      -2768650.5584 m       0
                                   0.0034             0.0026             0.0022
 XYZ      P418               5084555.5250       2670542.8787      -2768474.1564 m       0
                                   0.0027             0.0024             0.0016

================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0            GRS 80      UNITS: m,GRAD Page 0011
================================================================================
2-D and 1-D Station Confidence Regions (95.000 and 95.000 percent):
STATION           MAJOR SEMI-AXIS  AZ     MINOR SEMI-AXIS             VERTICAL
----------- -------------------- --- ------------------ --------------------
DORIS_rep                  0.0071  75             0.0059               0.0056
HARB                       0.0023  90             0.0023               0.0018
HBMB                       0.0054  74             0.0037               0.0042
P403                       0.0161  77             0.0042               0.0154
P412                       0.0053  57             0.0023               0.0081
P418                       0.0054  87             0.0023               0.0062

================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0            GRS 80      UNITS: m,GRAD Page 0012
================================================================================
3D Station Confidence Regions (95.000 percent):
STATION        MAJ-SEMI (AZ,VANG)    MED-SEMI (AZ,VANG)    MIN-SEMI (AZ,VANG)
----------- -------------------- -------------------- --------------------
DORIS_rep        0.0081 ( 75,  0)      0.0080 (173, 90)      0.0067 (345,  0)
HARB             0.0026 ( 82,  0)      0.0026 (259, 90)      0.0026 (352,  0)
HBMB             0.0061 (254,  0)      0.0061 (153, 90)      0.0042 (344,  0)
P403             0.0219 (129, 90)      0.0184 (257,  0)      0.0048 (347,  0)
P412             0.0115 (162, 90)      0.0061 ( 57,  0)      0.0026 (327,  0)
P418             0.0089 (166, 90)      0.0062 (267,  0)      0.0026 (357,  0)
```

Main vectors :

2014 Campaign			
Vectors	dX	dY	dZ
HARB → DORIS rep	-4.7271	22.0047	10.5505
HARB → HBMB	-4.1876	22.2910	10.2517

(values are in metre, the tenth of millimetre is indicative)

From the whole covariance matrix, a covariance submatrix has been extracted with the main points of interest (i.e. HARB and HBMB). Finally, this covariance submatrix has been converted into the SINEX format using the « geotosnx » tool provided by Z. Altamimi. The resulting SINEX file (30302_IGN_2014-058_v10.SNX) is presented in annex 6.10.

5.1.2 Comparison with 2003 survey

As DORIS antenna has been raised up on November 2006 by 174 mm (in order to remove the N-type bent cable connectors); we are only able to compare the vectors between DORIS_repère and HARB.

We get the coordinates of the following points of interest from the 2014 Microsearch GeoLab adjustment.

- HARB reference point (marker) 30302M009
- DORIS_repère (marker) 30302M008
- HBKB DORIS ref. pt. before nov. 21st, 2006 30302S006
- HBMB DORIS ref. pt. after nov. 21st, 2006 30302S008

This allows us to compare some vectors elements between 2003 and 2014 campaigns.

(quote : on IDS website, the values from HBMB to HBKB are dX = -0.138, dY = -0.075 and dZ = 0.075).

Vectors		2003 Campaign	2014 Campaign
HARB → DORIS_rep.	dX	-4,7280	-4,7271
	dY	22,0058	22,0047
	dZ	10,5515	10,5505
		HBKB (DORIS ref. pt)	HARB → HBMB + HBMB → HBKB
HARB → HBKB DORIS_ref. Point	dX	-4,3261	-4,1876 +(-0,138) = -4,3256
	dY	22,2155	22,2910 + (-0,0750) = 22,2160
	dZ	10,3294	10,2517 + 0,075 = 10,3267

Comparisons (2003 to 2014)		Vectors Differences (X,Y,Z)	Local Differences (E,N,U)
HARB → DORIS_rep		0,0009	-0,0014
		-0,0011	-0,0008
		-0,0010	0,0007
HARB → HBKB DORIS_ref. Pt		0,0005	0,0002
		0,0005	-0,0021
		-0,0027	0,0018

(values are in metre, the tenth of millimetre is indicative)

These very small differences between the two campaigns led us to validate our results and within 1 mm accuracy level.

5.2 HARTRAO sub-site

5.2.1 Adjusted 3D coordinates and vectors

The results of the adjustment are the coordinates of all points with their residuals. The table hereafter sums up the main points of interest in a 3D Cartesian **local** coordinate system (i.e. in a Cartesian coordinate system centred at the origin point / Z axis according to the vertical line at the origin point).

3D adjusted coordinates in a local orthogonal coordinate system

Point	X	Y	Z	relation number	mean normalized residual	designation
LLR_ref	-44.0234	192.3826	1410.3523	3	----	
SLR_ref	-50.2228	182.5206	1410.0003	3	----	
V15_ref	-241.4551	179.3322	1409.3798	3	----	
V26_ref	-128.5515	177.8037	1415.6794	3	----	
HRAO	30.4595	138.5219	1414.1438	5	0.00	HRAO IGS station (fixed version)
P1	-66.2332	227.7237	1409.7996	116	1.06	Pier
P5	-149.9002	97.3604	1408.0325	161	0.97	Pier
P6	-246.4417	212.2920	1401.7744	104	0.93	Pier
P2	-40.3704	332.3990	1411.1110	6	1.80	Pier
P3	22.2124	246.6940	1413.6276	7	1.05	Pier
P4	30.3435	122.3443	1413.1678	74	0.82	Pier
P10	145.7259	217.9487	1425.2830	52	1.27	Pier
P11	-57.0270	200.3175	1408.8298	175	1.19	Pier
P12	317.7504	14.5206	1439.9245	43	1.04	Pier
P13	-85.9855	143.2707	1405.8008	46	1.19	Pier
P17	86.3932	146.5355	1415.8283	10	1.81	Pier
SL	-50.2232	182.5200	1410.4859	29	1.57	Moblas top of black centring plate
SLCC	-50.2240	182.5237	1410.4856	5	0.46	On Moblas top centring plate : NASA corner cube
SLM	-50.2160	182.5224	1406.7758	6	3.03	Moblas ground centring plate centre (height or top of the plate centred on the original punchmark)

Point	X	Y	Z	relation number	mean normalized residual	designation
LL	-44.0233	192.3838	1409.4360	6	0.73	Prism on LLR vertical axis
LLM	-44.0280	192.3713	1407.4482	6	0.40	LLR ground centring plate centre (height or top of the plate, the plate is centred)
LLG	-44.0247	192.3823	1407.4497	4	0.10	LLR vertical axis projected on ground centring plate (height or top of the plate)

(values are in metre, the tenth of millimetre is indicative)

The mean normalized residuals are good and close to 1 when there's a large number of relations.

3D adjusted coordinates in Cartesian geocentric

Name	X	Y	Z
LLR ref	5085404.8558	2668339.4016	-2768681.2726
SLR ref	5085403.6428	2668331.7642	-2768689.9912
V15 ref	5085490.7707	2668161.5223	-2768692.5919
V26 ref	5085442.7381	2668263.8213	-2768696.7157
HRAO	5085352.4427	2668396.0141	-2768731.3817
P1	5085428.4000	2668326.6735	-2768649.2375
P5	5085415.4622	2668225.4010	-2768765.7467
P6	5085499.7731	2668160.6140	-2768659.6194
P2	5085457.9008	2668371.3586	-2768555.6403
P3	5085397.6886	2668410.4405	-2768633.8411
P4	5085345.4639	2668392.2215	-2768745.5096
P10	5085338.4692	2668518.8519	-2768664.7886
P11	5085412.7531	2668328.8602	-2768673.4696
P12	5085191.5464	2668636.0300	-2768854.1897
P13	5085401.7381	2668290.3782	-2768723.4687
P17	5085330.8938	2668447.8731	-2768724.9070
SL	5085404.0296	2668331.9667	-2768690.2037
SLCC	5085404.0311	2668331.9666	-2768690.2003
SLM	5085401.0716	2668330.4226	-2768688.5816
LL	5085404.1263	2668339.0189	-2768680.8714
LLM	5085402.5402	2668338.1812	-2768680.0147
LLG	5085402.5441	2668338.1870	-2768680.0054

(values are in metre, the tenth of millimetre is indicative)

Main vectors :

2014 Campaign			
Vectors	dX	dY	dZ
SLR_ref → HRAO	-51.2001	64.2500	-41.3906
SLR_ref → V26_ref	39.0953	-67.9428	-6.7246
SLR_ref → V15_ref	87.1279	-170.2419	-2.6007
SLR_ref → P6	96.1303	-171.1501	30.3718
SLR_ref → P10	-65.1736	187.0878	25.2026
SLR_ref → P12	-212.0964	304.2659	-164.1985

(values are in metre, the tenth of millimetre is indicative)

5.2.2 Comparison between 2003 and 2014 survey results

Vectors		2003	2014	Distances 2003	Dist. 2014	Diff.
SLR_ref → HRAO	dX	-51,1998	-51,2001	91,9915	91,9929	-0,0014
	dY	64,2482	64,2500			
	dZ	-41,3906	-41,3906			
SLR_ref → V26_ref	dX	39,1001	39,0953	78,6767	78,6758	0,0008
	dY	-67,9398	-67,9428			
	dZ	-6,7367	-6,7246			
SLR_ref → P6	dX	96,1305	96,1303	198,6364	198,6350	0,0014
	dY	-171,1525	-171,1501			
	dZ	30,3669	30,3718			

Comp. (2003 to 2014)		Vectors Diff. (X,Y,Z)	Local Diff. (E,N,U)
SLR_ref → HRAO		-0,0003	0,0018
		0,0018	0,0003
		0,0000	0,0006
SLR_ref → V26_ref		-0,0048	-0,0003
		-0,0030	0,0084
		0,0121	-0,0104
SLR_ref → P6		-0,0002	0,0023
		0,0024	0,0048
		0,0049	-0,0014

These two local tie survey carried out with more than ten years of interval match at a few millimetres level. The comparison of results coming from different software and orientation methods shows differences at 1 mm level.

6 Appendices

6.1 HBMB (DORIS) station log

Note: only the most relevant information is retained in the following extract.

The complete version of this site log is available at: http://ids-doris.org/network/sitelogs.html

```
    HARTEBEESTHOEK DORIS site description form

0. Form

    Prepared by  : SIMB (DORIS installation and maintenance department)
    Date prepared: 29/01/2013
    Report type  : UPDATE


1. Site location information

    Site name             : HARTEBEESTHOEK
    Site DOMES number     : 30302
    Host agency           : SANSA Space Operations
    City                  : Hartebeesthoek
    State or province     : Pretoria
    Country               : SOUTH AFRICA
    Tectonic plate        : AFRC
    Geological information:

    Geographical coordinates (ITRF):
        North Latitude      :   -25 deg 53' 13''
        East Longitude      :    27 deg 42' 27''
        Ellipsoid height    :  1559 m
        Approximate altitude:  1534 m


2. DORIS antenna and reference point information
(...)

2.5
    Four character ID       : HBMB
    Antenna model           : Starec 52291 type
    Antenna serial number   : 134
    IERS DOMES number       : 30302S008
    CNES/IGN number         : 303024
    DORIS SSALTO number     : 1387
    Date installed (dd/mm/yy): 22/11/2006
    Date removed (dd/mm/yy) :
    Antenna support type    : 2 meter tubular mast 0.15 m diameter
    Installed on            : Mast extends 4 meters deep (3 m in soil + 1 m in
                              rock). Mast filled with concrete
    Height above ground mark: 0.678 m
    Ground mark type        : Mark on top of the mast.
    Ground mark DOMES number: 30302M008
    Notes                   : Antenna raised by 174 mm in order to remove the
                              N-type bent cable connectors


3. DORIS beacons information
(...)

4. ITRF coordinates and velocities of the current DORIS ref. point (HBMB)

    Solution        :
    Epoch           : 2005.0

    X = 5084653.440 m    Y = 2670347.412 m    Z = -2768470.902 m
    Sig X = 0.003 m    Sig Y = 0.003 m    Sig Z = 0.002 m

    VX = -0.0015 m/y    VY = 0.0197 m/y    VZ = 0.0166 m/y
    Sig VX = 0.0001 m/y    Sig VY = 0.0001 m/y    Sig VZ = 0.0001 m/y


5. IERS colocation information
(...)
```

```
6. Tide Gauge colocation information
(...)

7. Local site ties

7.1
    Point description     : DORIS Alcatel antenna reference point (HBKA)
    DOMES number          : 30302S202
    Differential components from the current DORIS ref. point (HBMB)
    to the above point (in the ITRS):
    dX (m)                : -11.928
    dY (m)                : 2.468
    dZ (m)                : -26.120
    Accuracy (m)          : 0.02
    Date measured         : 01/08/2000
    Additional information: Survey by IGN-F

7.2
    Point description     : DORIS Alcatel antenna reference point (HBLA)
    DOMES number          : 30302S005
    Differential components from the current DORIS ref. point (HBMB)
    to the above point (in the ITRS):
    dX (m)                : -11.971
    dY (m)                : 2.687
    dZ (m)                : -26.814
    Accuracy (m)          : 0.002
    Date measured         : 01/08/2000
    Additional information: Survey by IGN-F

7.3
    Point description     :  IGS station" HRAO"
    DOMES number          : 30302M004
    Differential components from the current DORIS ref. point (HBMB)
    to the above point (in the ITRS):
    dX (m)                : 699.034
    dY (m)                : -1951.575
    dZ (m)                : -260.640
    Accuracy (m)          : 0.001
    Date measured         : 01/08/2003
    Additional information: Survey by IGN-F

7.4
    Point description     : IGS station "HARB"
    DOMES number          : 30302M009
    Differential components from the current DORIS ref. point (HBMB)
    to the above point (in the ITRS):
    dX (m)                : 4.188
    dY (m)                : -22.290
    dZ (m)                : -10.254
    Accuracy (m)          : 0.001
    Date measured         : 01/08/2003
    Additional information: Survey by IGN-F

7.5
    Point description     : SLR mark (CDP 7501)
    DOMES number          : 30302M003
    Differential components from the current DORIS ref. point (HBMB)
    to the above point (in the ITRS):
    dX (m)                : 747.659
    dY (m)                : -2017.167
    dZ (m)                : -217.841
    Accuracy (m)          : 0.001
    Date measured         : 01/08/2003
    Additional information: Survey by IGN-F

7.6
    Point description     : DORIS Starec antenna reference point (HBKB & HBLB)
    DOMES number          : 30302S006
    Differential components from the current DORIS ref. point (HBMB)
    to the above point (in the ITRS):
    dX (m)                : -0.138
    dY (m)                : -0.075
    dZ (m)                : 0.075
    Accuracy (m)          : 0.001
    Date measured         : 01/11/2006
    Additional information: Survey by IGN-F
                             HBKB & HBLB are the same point (upgrade to Master Beacon of the station)


8. Meteorological Instrumentation
(...)

9. DORIS network contacts

cf http://ids-doris.org/network/sitelogs.html
```

6.2 HARB (GNSS) station log

Note: only the most relevant information is retained in the following extract.

The complete version of this site log is available at: ftp://igs.org/pub/station/log/harb_20140612.log

```
     HARB Site Information Form (site log)
     International GNSS Service
     See Instructions at:
       ftp://igscb.jpl.nasa.gov/pub/station/general/sitelog_instr.txt

0.   Form

     Prepared by (full name) : Jean-Paul CARDALIAGUET
     Date Prepared           : 2014-06-12
     Report Type             : UPDATE
     If Update:
      Previous Site Log      : harb_20131028.log
      Modified/Added Sections: 3.6,3.7


1.   Site Identification of the GNSS Monument

     Site Name               : Hartebeesthoek
     Four Character ID       : HARB
     Monument Inscription    : NONE
     IERS DOMES Number       : 30302M009
     CDP Number              : None
     Monument Description    : STEEL MAST
       Height of the Monument: 3 m
       Monument Foundation   : CONCRETE BLOCK
       Foundation Depth      :
     Marker Description      : BRASS NAIL
     Date Installed          : 2000-08-09
     Geologic Characteristic :
       Bedrock Type          :
       Bedrock Condition     :
       Fracture Spacing      :
       Fault zones nearby    :
         Distance/activity   :
     Additional Information  : Station located at the site
                             : of the 2-GHz CNES Tracking Station.
                             : Monument is a 12mm domed brass mark in a 2m
                             : sided,
                             : 0.35 m thick concrete slab.


2.   Site Location Information

     City or Town            : Pretoria
     State or Province       :
     Country                 : Republic of South Africa
     Tectonic Plate          : AFRICAN
     Approximate Position (ITRF)
       X coordinate (m)      : 5084658
       Y coordinate (m)      : 2670325
       Z coordinate (m)      : -2768481
       Latitude (N is +)     : -255312.84
       Longitude (E is +)    : +0274227.00
       Elevation (m,ellips.) : 1555.0
     Additional Information  :


3.   GNSS Receiver Information

(…)

3.7  Receiver Type           : TRIMBLE NETR9
     Satellite System        : GPS+GLO+GAL+BDS+SBAS
     Serial Number           : 5046k71645
     Firmware Version        : 4.85
     Elevation Cutoff Setting: 3 deg
     Date Installed          : 2014-06-12T14:30Z
     Date Removed            : CCYY-MM-DDThh:mmZ
     Temperature Stabiliz.   : 18 Â± 25
     Additional Information  : satellite system is also GALILEO + SBAS
```

```
4.   GNSS Antenna Information


(…)

4.5  Antenna Type            : TRM59800.00     NONE
     Serial Number           : 5037353965
     Antenna Reference Point : BPA
     Marker->ARP Up Ecc. (m) : 3.0520
     Marker->ARP North Ecc(m): 0.0000
     Marker->ARP East Ecc(m) : 0.0000
     Alignment from True N   : 0 deg
     Antenna Radome Type     : NONE
     Radome Serial Number    :
     Antenna Cable Type      : NEOTEK &  cable coaxial with amplifier
     Antenna Cable Length    : 60 m
     Date Installed          : 2011-11-30T14:00Z
     Date Removed            : CCYY-MM-DDThh:mmZ
     Additional Information  : Antenna support is a 3m triangular metal
                             : support



5.   Surveyed Local Ties

5.1  Tied Marker Name        : IGS monument HRAO
     Tied Marker Usage       :
     Tied Marker CDP Number  :
     Tied Marker DOMES Number: 30302M004
     Differential Components from GNSS Marker to the tied monument (ITRS)
       dx (m)                : 694.842
       dy (m)                : -1929.285
       dz (m)                : -250.384
     Accuracy (mm)           : 2 mm
     Survey method           : GPS CAMPAIGN
     Date Measured           : 2000-08-09
     Additional Information  : Survey by IGN-France

5.2  Tied Marker Name        : DORIS antenna HBKB
     Tied Marker Usage       :
     Tied Marker CDP Number  :
     Tied Marker DOMES Number: 30302S006
     Differential Components from GNSS Marker to the tied monument (ITRS)
       dx (m)                : -4.327
       dy (m)                : 22.214
       dz (m)                : 10.332
     Accuracy (mm)           : 1 mm
     Survey method           : GPS CAMPAIGN
     Date Measured           : 2000-08-09
     Additional Information  : Survey by IGN-France

5.3  Tied Marker Name        : IGS monument HARK (former location of the GPS
     Tied Marker Usage       :
     Tied Marker CDP Number  :
     Tied Marker DOMES Number: 30302M007
     Differential Components from GNSS Marker to the tied monument (ITRS)
       dx (m)                : -32.350
       dy (m)                : 41.266
       dz (m)                : -13.245
     Accuracy (mm)           : 1 mm
     Survey method           : GPS CAMPAIGN
     Date Measured           : 2000-08-09
     Additional Information  : Survey by IGN-France



6.   Frequency Standard



7.   Collocation Information

7.1  Instrumentation Type    : DORIS
       Status                : PERMANENT
       Effective Dates       : 2000-08-10/CCYY-MM-DD
       Notes                 : DORIS antenna HBKB

7.2  Instrumentation Type    : VLBI
       Status                : PERMANENT
       Effective Dates       : (CCYY-MM-DD/CCYY-MM-DD)
       Notes                 :
```

```
8.   Meteorological Instrumentation

(...)

9.   Local Ongoing Conditions Possibly Affecting Computed Position

(...)


10.  Local Episodic Effects Possibly Affecting Data Quality

(...)

11.  On-Site, Point of Contact Agency Information

     Agency                   : SANSA
     Preferred Abbreviation   : SANSA
     Mailing Address          :
     Primary Contact
       Contact Name           : Tiaan Strydom - Satellite Applications Center
       Telephone (primary)    : 00 27 12 334 5017
       Telephone (secondary)  : 00 27 12 334 5000
       Fax                    :
       E-mail                 : tstrydom@sansa.org.za
     Secondary Contact
       Contact Name           : Carlos de Oliveira
       Telephone (primary)    : 00 27 12 334 5017
       Telephone (secondary)  : 00 27 12 334 5000
       Fax                    :
       E-mail                 : CdOliveira@sansa.org.za
     Additional Information   :


12.  Responsible Agency (if different from 11.)

     Agency                   : Centre National d'Etudes Spatiales
     Preferred Abbreviation   : CNES
     Mailing Address          : CNES DCT/ME/NC - 18, avenue Edouard Belin
                              : 31401 - Toulouse  cedex 09 - France
     Primary Contact
       Contact Name           : Jean-Paul Cardaliaguet
       Telephone (primary)    : (33) 5.61.27.31.98
       Telephone (secondary)  :
       Fax                    : (33) 5 61 28 15 36
       E-mail                 : regina.operation@cnes.fr
     Secondary Contact
       Contact Name           : Alain Brissaud
       Telephone (primary)    : (33) 5.61.28.23.66
       Telephone (secondary)  :
       Fax                    : (33) 5.61.28.14.17
       E-mail                 :
     Additional Information   :

13.  More Information

     Primary Data Center      : IGN
     Secondary Data Center    : CDDIS
     URL for More Information:
     Hardcopy on File
       Site Map               :
       Site Diagram           : X
       Horizon Mask           : (Y)
       Monument Description   : X
       Site Pictures          :
     Additional Information   :
     Antenna Graphics with Dimensions

TRM59800.00

                        -----
                      /
                     |             |
   +-------------------------------------------------+     <--  0.1020  TCR
   |                                                 |
   |                                                 |
   |                                                 |
   |                                                 |
+--+-------------------------------------------------+--+   <--  0.0381
+-------------------+-------------+-------------------+   <--  0.0350  BCR
                     |             |
                    =|             |
                     +------x------+                     <--  0.0000  BPA=ARP

<--                       0.3810                     -->
```

6.3 HRAO (GNSS) station log

Note: only the most relevant information is retained in the following extract.

The complete version of this site log is available at: ftp://igs.org/pub/station/log/hrao_20130221.log

```
     HRAO Site Information Form (site log)
     International GNSS Service
     See Instructions at:
       ftp://igscb.jpl.nasa.gov/pub/station/general/sitelog_instr.txt

0.   Form

     Prepared by (full name) : Nic Flores
     Date Prepared           : 2013-02-21
     Report Type             : UPDATE
     If Update:
      Previous Site Log      : hrao_20120416.log
      Modified/Added Sections: 0,4.11,4.12,4.13,10.2


1.   Site Identification of the GNSS Monument

     Site Name               : Hartebeesthoek RAO
     Four Character ID       : HRAO
     Monument Inscription    : (none)
     IERS DOMES Number       : 30302M004
     CDP Number              :
     Monument Description    : CEMENT FILLED STEEL PIPE/PILLAR
       Height of the Monument: 0.5
       Monument Foundation   : CONCRETE BLOCK
       Foundation Depth      : 36
     Marker Description      :
     Date Installed          : 1996-09-05T00:00Z
     Geologic Characteristic : BEDROCK
       Bedrock Type          : IGNEOUS
       Bedrock Condition     : JOINTED
       Fracture Spacing      : 1-10 cm
       Fault zones nearby    :
         Distance/activity   :
     Additional Information  : HRAO is located on the Pretoria Series of the
                             : Transvaal System. Territory occupied or else
                             : underlain by the System embraces the greater
                             : part of the Central Transvaal. The Transvaal
                             : System is of Precambrian age. The antenna and
                             : buildings are situated on Ongeluk Lava
                             : (Andesite).
                             : Geological info from "NASA Space Geodesy
                             : Program:Catalogue of Site Information",
                             : Technical Memorandum 4482, March 1993, p196.
                             : Interlocking steel rod 36 m deep grouted on
                             : the bottom 10 m and isolated in PVC for the
                             : next 15 meters. The antenna mount is a self-
                             : centering adjustable mount on top of the steel
                             : pipe (monument).


2.   Site Location Information

     City or Town            : Krugersdorp
     State or Province       :
     Country                 : South Africa
     Tectonic Plate          : AFRICAN
     Approximate Position (ITRF)
       X coordinate (m)      : 5085352.5970
       Y coordinate (m)      : 2668395.9920
       Z coordinate (m)      : -2768731.5510
       Latitude (N is +)     : -255324.38
       Longitude (E is +)    : +0274113.13
       Elevation (m,ellips.) : 1414.3
     Additional Information  : Latitude, Longitude and Elevation derived from
                             : ITRF96 coordinates at epoch 1997.0, from Z.
                             : Altamimi/IGN.
                             : HartRAO is situated 60 km NW of Johannesburg.
                             : HartRao is a National Research Facility which
                             : operates within the foundation for Research
                             : Development.
```

```
                           : Site information from "NASA Space Geodesy
                           : Program:Catalogue of Site Information",
                           : Technical Memorandum 4482, March 1993, p196.


3.   GNSS Receiver Information
(...)

3.8  Receiver Type           : ASHTECH Z-XII3
     Satellite System        : GPS
     Serial Number           : LP00801
     Firmware Version        : CD00
     Elevation Cutoff Setting: 4
     Date Installed          : 2012-04-12T00:00Z
     Date Removed            : CCYY-MM-DDThh:mmZ
     Temperature Stabiliz.   : none
     Additional Information  :


4.   GNSS Antenna Information
(...)

4.13 Antenna Type            : ASH701945E_M    NONE
     Serial Number           : CR6200610005
     Antenna Reference Point : BPA
     Marker->ARP Up Ecc. (m) : 0.0814
     Marker->ARP North Ecc(m): 0.0000
     Marker->ARP East Ecc(m) : 0.0000
     Alignment from True N   : 0
     Antenna Radome Type     : NONE
     Radome Serial Number    :
     Antenna Cable Type      :
     Antenna Cable Length    :
     Date Installed          : 2013-02-21T10:00Z
     Date Removed            : CCYY-MM-DDThh:mmZ
     Additional Information  : New inline amplifier installed
                             : Manufacturer Raven Industries
                             : Model Number LA-21-L1L2-N


5.   Surveyed Local Ties

5.1  Tied Marker Name        : 26 m VLBI antenna
     Tied Marker Usage       :
     Tied Marker CDP Number  :
     Tied Marker DOMES Number: 30302S001
     Differential Components from GNSS Marker to the tied monument (ITRS)
       dx (m)                : 90.280
       dy (m)                : -132.198
       dz (m)                : 34.658
     Accuracy (mm)           : 10
     Survey method           :
     Date Measured           : CCYY-MM-DDThh:mmZ
     Additional Information  : ITRF96 coordinates epoch 1997
                             : for HRAO and VLBI points differential
                             : components
                             : The SLR/VLBI/HRAO/HART/DORIS differential
                             : components will be determined in a high
                             : precision GPS survey later this year



6.   Frequency Standard
(...)

7.   Collocation Information

7.1  Instrumentation Type    : VLBI
       Status                : PERMANENT
       Effective Dates       : (CCYY-MM-DD/CCYY-MM-DD)
       Notes                 : The VLBI telescope routinely participates in
                             : IRIS, CORE-A and Syowa experiments



8.   Meteorological Instrumentation
(...)


9.   Local Ongoing Conditions Possibly Affecting Computed Position
(...)


10.  Local Episodic Effects Possibly Affecting Data Quality
(...)
```

```
11.  On-Site, Point of Contact Agency Information

     Agency                  : Jet Propulsion Laboratory
     Preferred Abbreviation  : JPL
     Mailing Address         : 4800 Oak Grove Drive
                             : Pasadena, CA
                             : USA    91109
     Primary Contact
       Contact Name          : David A. Stowers
       Telephone (primary)   : 818-354-7055
       Telephone (secondary) :
       Fax                   : 818-393-4965
       E-mail                : dstowers@jpl.nasa.gov
     Secondary Contact
       Contact Name          : UNAVCO Network Engineer
       Telephone (primary)   : 303-381-7500
       Telephone (secondary) :
       Fax                   : 303-381-7451
       E-mail                : ggn-ops@ls.unavco.org
     Additional Information  :


12.  Responsible Agency (if different from 11.)

     Agency                  : HartRAO
     Preferred Abbreviation  : HRAO
     Mailing Address         : PO BOX 443
                             : Krugersdorp
                             : 1740
                             : South Africa
     Primary Contact
       Contact Name          : Ludwig Combrinck
       Telephone (primary)   : 27-12-3260742
       Telephone (secondary) :
       Fax                   : 27-12-3260756
       E-mail                : ludwig@hartrao.ac.za
     Secondary Contact
       Contact Name          : Marisa Nickola
       Telephone (primary)   : 27-12-3260742
       Telephone (secondary) :
       Fax                   :
       E-mail                : marisa@hartrao.ac.za
     Additional Information  :

13.  More Information

     Primary Data Center     : JPL (ODC-Operational Data Center)
     Secondary Data Center   : CDDIS (GDC-Global Data Center)
     URL for More Information:
     Hardcopy on File
       Site Map              :
       Site Diagram          : (Y)
       Horizon Mask          : (Y)
       Monument Description  : (Y)
       Site Pictures         : (Y)
     Additional Information  :
     Antenna Graphics with Dimensions

ASH701945E_M

                        +-------+
                       /     +     \
                      |      +      |
    +-----------------+-------------+------------------+    <--  0.1006 TCR
    |                                                   |
    |                                                   |
    |                                                   |
    |                                                   |
  +-+---------------------------------------------------+-+  <--  0.0376
  +-------------------+-------------+-------------------+  <--  0.0346 BCR
                      |             |
                      |             |
                      +------x------+                      <--  0.0000 BPA=ARP

  <--                      0.3794                      -->

   ARP: Antenna Reference Point
   L1: L1 Phase Center                  L2: L2 Phase Center
   TCR: Top of Chokering                 BCR: Bottom of Chokering
   TGP: Top of Ground Plane              BGP: Bottom of Ground Plane
   TPA: Top of Preamplifier              BPA: Bottom of Preamplifier
   TOP: Top of Pole                      BAM: Bottom of antenna mount

All dimensions are in meters.
```

6.4 VLBI 26 m station log

Note: only the most relevant information is retained in the following extract.

The complete version of this station log is available at: ftp://ivscc.gsfc.nasa.gov/pub/config/ns/hartrao.config.txt

```
Network Station Configuration File
International VLBI Service

Refer to the instructions in the file
ftp://ivscc.gsfc.nasa.gov/config/instructions.txt
for how to fill out and submit this form.
990624 nrv Form version 0.5
990702 nrv Form version 0.6
990713 nrv Form version 0.7
991020 nrv Form version 0.8

0. Form

   Prepared by (full name): Ludwig Combrinck
   Date prepared          : 2000-MAY-15
   Report type            : new

1. Site identification

   Site name              : Hartebeesthoek Radio Astronomy Observatory
   Site 8-letter code     : HARTRAO
   Site 2-letter code(s)  : Hh
   IERS DOMES number      : 30302S001
   CDP occupation code    :
   CDP monument number    : 7232
   Surveyed into national network?: yes
   IGS station code       : HRAO
   ILRS station name      :
   Additional information : MOBLAS6 will be collocated during 2000

2. Site information

2.1 Site location information

   City or Town           : Krugersdorp
   State or Province      : Gauteng
   Country                : South Africa
   Tectonic plate         : African
   Approximate position
     X coordinate (m)     : 5085442.780
     Y coordinate (m)     : 2668263.483
     Z coordinate (m)     : -2768697.034
     Latitude (deg)       : -25.88975199 S
     Longitude (deg)      : 27.68539261 E
     Elevation (m)        : 1415
     Source of position   : ITRF
   Additional information : Elevation is above WGS84 ellipsoid


2.2 Site local survey network information

   Number of reference markers : 12
   Type of marker         :  pillar
   Frequency of surveying :  annual
   Surveying method       :  GPS
   Survey instruments used:  GPS
   Accuracy               :  +/- 3 mm
   Survey performed by    :  Ludwig Combrinck
   Survey documentation   :  report
   Most recent survey date:  2000-mar-10
   Results provided to IERS:  yes
   Results provided to CDDIS: no
   Person responsible     :  Ludwig Combrinck
   Additional information :

2.3 Site descriptive information
(...)
```

```
3. Antenna information

   Diameter (m)           : 26
   Axis type              : HADC
   Axis offset (m)        : 6.6956 +- 2.3 mm
   Slew rate first axis   : 0.5 deg/sec
   Slew rate second axis  : 0.5 deg/sec
   Limit stops first axis : -88,+88
   Limit stops second axis: -88,+45
   Horizon mask data      : (Pairs of values separated with /.
                              Either line segment end points:
                              Az1 El1/Az2 El2/..../Azlast Ellast
                              or step function:
                              Az1 El1/Az2 El2/..../Azlast )
   Occupation dates       : (yyyy-mmm-dd to yyyy-mmm-dd)
   Additional information : (multiple lines allowed)

4. Receiver information
(…)

5. Cables between receiver and back end
(…)
6. Data acquisition system information
(…)

7 Meteorological instrumentation
(…)

8. Time and frequency standards
(…)

9. Auxilliary equipment information
(…)

10. Co-location information
(…)

11. Field System computer information
(…)

12. Known RFI sources
(…)

13. On-site contact information

   Agency                 : Hartebeesthoek Radio Astronomy Observatory
   Shipping address       : CSIR Clearing Officer
                            Johannesburg International Airport
                            To: HartRAO
                            Attention: Frans Nortje/Annette Joubert
                            Tel: 012-841 3545
   Postal address         : (if different, multiple lines)
   URL of site web page   :http://www.hartrao.ac.za
   On-site Friend of VLBI
     Name                 :Jonathan Quick
     Telephone (primary)  :+27 12 326 0742
     Telephone (alternate):
     Fax                  :+27 12 326 0756
     E-mail               :jon@hartrao.ac.za
   On-site VLBI operations room
     Telephone (primary)  : +27 12 326 0742
     Telephone (alternate):
     Fax                  : +27 12 326 0756
     E-mail               :
   Other on-site contact
     Name                 : Ludwig Combrinck
     Telephone (primary)  : +27 12 326 0742
     Telephone (alternate):
     Fax                  : +27 12 326 0756
     E-mail               : ludwig@hartrao.ac.za
   Additional information : (multiple lines allowed)

14. Responsible agency (if different from on-site information)
(...)

15. More information
```

6.5 HARL (SLR) station log

Note: only the most relevant information is retained in the following extract.

The complete version of this site log is available at: http://ilrs.gsfc.nasa.gov/network/stations/active/HARL_sitelog.html

```
     ILRS Site and System Information Form
     International Laser Ranging Service

0.   Form

     Prepared by (Full Name)   : Nikki Desch
     Preparer E-mail           : nikki.desch@exelisinc.com
     Date Prepared             : 2012-10-01
     Report Type               : UPDATED
     Format Version            : 1.0


1.   Identification of the Ranging System Reference Point (SRP)

     Site Name                 : Hartebeeshoek Radio Astronomy Observatory
     IERS DOMES Number         : 30302M003
     CDP Pad ID                : 7501
     Subnetwork                : NASA
     Description               : MONUMENT
     Monument Description      : PILLAR
     Monument Inscription      : None
     Mark Description          : Bullseye
     Date Installed            : 1993-07-12
     Date Removed              : (yyyy-mm-dd)
     Geologic Characteristic   : Andesite
     Additional Information    : monument is a brass marker with a stainless
                               : steel plate around the marker


2.   Site Location Information

     City or Town              : Johannesburg
     State or Province         : Gauteng
     Country                   : South  Africa
     Tectonic Plate            : African
     Approximate Position
       X coordinate          [m]: 5085401.135
       Y coordinate          [m]: 2668330.108
       Z coordinate          [m]: -2768688.865
       Latitude            [deg]: 25.8897 S
       Longitude           [deg]: 27.6861 E
       Elevation             [m]: 1406.822
     Additional Information    : (multiple lines)


3.   General System Information

3.01 System Name               : Moblas-6
     4-Character Code          : HARL
     CDP System Number         : 06
     CDP Occupation Number     : 02
     Eccentricity to SRP (if Not Identical With SRP)
       North                 [m]: -0.003 +- 0.001
       East                  [m]: -0.006 +- 0.001
       Up                    [m]: 3.228  +- 0.001
       Date Measured           : 2000-08-07
     Date Installed            : 2000-06-09
     Date Removed              : (yyyy-mm-dd)
     Additional Information    : Previously occupied by MTLRS


4.   Telescope Information

4.01 Receiving Telescope Type  : Cassegrain
       Aperture              [m]: 0.762
       Mount                   : AZ-EL
     Xmitting Telescope Type   : Refractor
```

```
        Aperture              [m]: 0.163
      Tracking Camera Type      : NONE
        Model                   :
        Manufacturer            :
        Field of View       [deg]:
        Minimum Magnitude   [mag]:
      Transmit/Receive Path     : SEPARATE
      Transmit/Receive Switch   : NONE
      Max Slew Rate Az    [deg/s]: 20
      Max Slew Rate El    [deg/s]: 5
      Max Used Tracking Rate Az : 5
      Max Used Tracking Rate El : 3
      Telescope Shelter         : ROLL-BACK ROOF
      Daylight Filter Type      : Omega optical 532NB1 9114
      Dayl. Filt. Bandwidth  [nm]: 100
      Adjustable Attenuation    : RECEIVE
      Transmit Efficiency       : 0.94
      Receive Efficiency        : 0.76
      Date Installed            : 2000-06-09
      Date Removed              : (yyyy-mm-dd)
      Additional Information    : (multiple lines)

  5.  Laser System Information
(…)

  6.  Receiver System
(…)

  7.  Tracking Capabilities
(...)

  8.  Calibration
(...)

  9.  Time and Frequency Standards
(...)

 10.  Preprocessing Information
(...)

 11.  Aircraft Detection
(...)

 12.  Meteorological Instrumentation

(...)

 13.  Local Ties, Eccentricities, and Collocation Information

 13.01 Collocated Permanent Geodetic Systems

      GPS                       : IGS
        Date Installed          : 1996-09-05
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      GLONASS                   : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      DORIS                     : IDS
        Date Installed          : 2000-08-09
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : HBKB
      PRARE                     : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      VLBI                      : YES
        Date Installed          : 1961-01-01
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      Gravimeter                : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)

 13.01.02 Collocated Permanent Geodetic Systems

      GPS                       : IGS
        Date Installed          : 1996-09-05
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      GLONASS                   : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
```

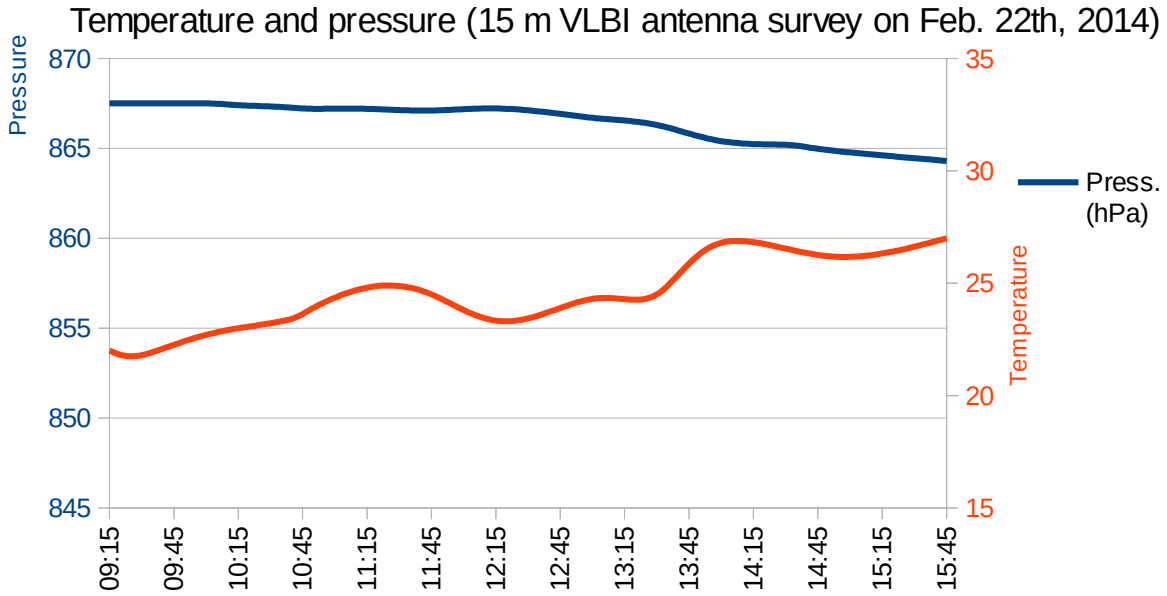
```
      DORIS                     : IDS
        Date Installed          : 1997-05-30
        Date Removed            : 2000-08-08
        Additional Information  : HBLA
      PRARE                     : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      VLBI                      : YES
        Date Installed          : 1961-01-01
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      Gravimeter                : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)

13.01.03 Collocated Permanent Geodetic Systems

      GPS                       : IGS
        Date Installed          : 1996-09-05
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      GLONASS                   : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      DORIS                     : IDS
        Date Installed          : 1988-03-10
        Date Removed            : 1997-05-23
        Additional Information  : HBKA
      PRARE                     : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      VLBI                      : YES
        Date Installed          : 1961-01-01
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)
      Gravimeter                : NO
        Date Installed          : (yyyy-mm-dd)
        Date Removed            : (yyyy-mm-dd)
        Additional Information  : (multiple lines)

13.02.01 Local Ties from the SRP to Other Monuments or Systems on Site

         Monument Name          : HRAO
         Instrumentation Type   : GPS
         Instrumentation Status : PERMANENT
         DOMES Number           : 30302M004
         CDP Number             : (XXXX)
         Differential Components (ITRS)
           dx                 [m]: 48.6258 +- 0.0030
           dy                 [m]: -65.5916 +- 0.0014
           dz                 [m]: 42.7988 +- 0.0024
           Date Measured        : 2003-08-01
           Determined by        : IGN
         Date Installed         : 1996-09-05
         Date Removed           : (yyyy-mm-dd)
         Additional Information : (multiple lines)

13.03.01 Eccentricities Between Other Monuments on Site

         From: Monument Name    : HRAO
               DOMES Number     : 30302M004
               CDP Number       : (XXXX)
         To:   Monument Name    : 7232
               DOMES Number     : 30302S001
               CDP Number       : 7232
         Differential Components (ITRS)
           dx                 [m]: 90.3001 +- 0.0039
           dy                 [m]: -132.1879 +- 0.0023
           dz                 [m]:  34.6539 +- 0.0044
          Date Measured         : 2003-08-01
           Determined by        : IGN
         Additional Information :

13.03.02 Eccentricities Between Other Monuments on Site

         From: Monument Name    : HARL
               DOMES Number     : 30302M003
               CDP Number       : 7501
         To:   Monument Name    : VLBI
               DOMES Number     : 30302S001
               CDP Number       : 7232
         Differential Components (ITRS)
```

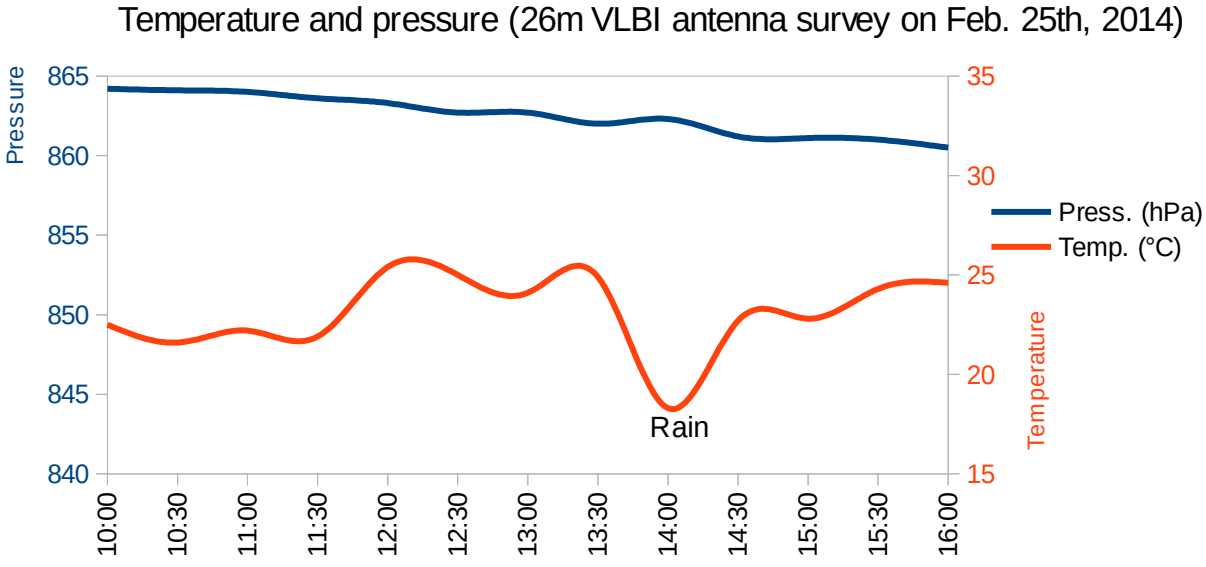
```
           dx                [m]:  41.680  +- 0.0158
           dy                [m]: -66.564  +- 0.075
           dz                [m]:  8.131  +- 0.039
           Date Measured       : 1996-06-01
           Determined by       : Ludwig Combrinck
         Additional Information : (multiple lines)


 14.   Local Events Possibly Affecting Computed Position

(...)

 15.   On-Site, Point of Contact Agency Information

       Agency                    : Hartebeesthoek Radio Astronomy Observatory
       Mailing Address           : P.O. Box 443
                                 : Krugersdorp 1740
                                 : South Africa

       Primary Contact
         Contact Name            : Ludwig Combrinck
         Telephone (primary)     : +2712 301 3100
         Telephone (secondary)   : +2712 301 3224
         Fax                     : +2712 301 3300
         E-mail                  : ludwig@hartrao.ac.za
       Secondary Contact
         Contact Name            : Willy Moralo
         Telephone (primary)     : +2712 301 3100
         Telephone (secondary)   : +2712 301 3224
         Fax                     : +2712 301 3300
         E-mail                  : willy@hartrao.ac.za
       Additional Information    : (multiple lines)


 16.   Responsible Agency (if different from 15.)

       Agency                    : NASA, Code 453
       Mailing Address           : Code 453
                                 : NASA GSFC
                                 : Greenbelt, MD 20771 USA
       Primary Contact
         Contact Name            : David McCormick
         Telephone (primary)     : 301-286-2354
         Telephone (secondary)   : 301-377-2711
         Fax                     : 301-286-0328
         E-mail                  : David.R.McCormick@nasa.gov
       Secondary Contact
         Contact Name            : Curtis Emerson
         Telephone (primary)     : 301-286-7670
         Telephone (secondary)   : 301-286-3065
         Fax                     : 301-286-0328
         E-mail                  : Curtis.M.Emerson@nasa.gov
       Additional Information    : (multiple lines)


 17.   More Information

       URL for More Information  : www.hartrao.ac.za
       Hardcopy on File
         Site Map                : NO
         Site Diagram            : NO
         Horizon Mask            : NO
         Monument Description    : NO
         Site Pictures           : Yes
       Additional Information    :
```

6.6 VLBI antenna positions and meteorological data

Temp (°C)	Pressure (hPa)	Position	Elevation (°)	Antenna azimuth (°)
23,9	867,2	1	1,009	-82,678
24,8	867,2	2	23,822	-82,679
24,5	867,1	3	49,885	-82,678
23,3	867,2	4	74,025	-82,678
24,5	866,3	5	90,044	-82,678
26,8	865,4	6	90,034	-174,198
27,4	865,2	7	90,037	4,124
26,2	864,9	8	90,045	99,78

15 m VLBI antenna positions





6.7 LGO report (GNSS baselines)

Hartebeesthoek_GNSS

1.1 Projet information

Nom du Projet:	HartRAO_GNSS (2)
Date de création:	04/11/2014 20:12:19
Fuseau Horaire:	2h 00'
Nom Syst. Coordonnées:	WGS 1984
Logiciel d'application:	LEICA Geo Office 8.1
Date et heure de début:	02/24/2014 09:30:44
Date et heure de fin:	03/03/2014 16:58:14
Points occupés manuellement:	7
Noyau de Post-Traitement:	PSI-Pro 3.0
Traité:	05/27/2014 16:20:38

1.2 Processing parameters

Paramètres	Sélectionnés
Angle de Coupure:	15°
Type d'Ephémérides:	Précises
Type de solution:	Automatique
Type GNSS:	Automatique
Fréquence:	Automatique
Fixer les ambiguïtés jusqu'à:	80 km
Durée mini pour solution flottante (statique):	5' 00"
Taux d'échantillonnage:	Tout Utiliser
Modèle Troposphérique:	Saastamoinen
Modèle Ionosphérique:	Automatique
Utiliser modélisation statistique:	Oui
Distance mini.:	8 km
Activité ionosphérique:	Automatique

1.3 Baseline results

HARB - 412	Référence: HARB	Mobile: 412
Type de capteur / N° S:	TRIMBLE / 71645	R8Model3 / 5242498562
Type d'antenne / N° S:	TRM59800.00 NONE / -	TRMR8_GNSS NONE / -
Hauteur d'antenne:	3.0520 m	0.3370 m
Coordonnées:		
X:	5084657.6130 m	5084728.1744 m
Y:	2670325.2920 m	2670054.2675 m
Z:	-2768480.9920 m	-2768650.5733 m

Type de solution:	Phase: toutes fixes		
Type GNSS:	GPS		
Fréquence:	L1/E1 et L2		
Ambiguïté:	Oui		
Plage horaire:	02/27/2014 12:46:14 - 02/27/2014 17:30:14		
Durée:	4h 44' 00"		
Qualité:	ET X: 0.0003 m	ET Y: 0.0002 m	ET Z: 0.0002 m
	Qlté Pos: 0.0002 m	Qlté Alt: 0.0003 m	ET Pente: 0.0001 m
Vecteur Ligne Base:	dX: 70.5614 m	dY: -271.0245 m	dZ: -169.5813 m
	Pente: 327.4004 m	dAlt: 16.8797 m	
DOP (min-max):	GDOP: 1.6 - 6.3		
	PDOP: 1.5 - 5.2	HDOP: 0.8 - 1.8	VDOP: 1.2 - 4.9
Nombre de satellites utilisés:	GPS: 17		
	GLONASS: -		

HARB - 418	Référence: HARB	Mobile: 418
Type de capteur / N° S:	TRIMBLE / 71645	R8Model3 / 5243499294
Type d'antenne / N° S:	TRM59800.00 NONE / -	TRMR8_GNSS NONE / -
Hauteur d'antenne:	3.0520 m	0.3450 m
Coordonnées:		
X:	5084657.6130 m	5084555.5519 m
Y:	2670325.2920 m	2670542.8962 m
Z:	-2768480.9920 m	-2768474.1710 m

Type de solution:	Phase: toutes fixes		
Type GNSS:	GPS		
Fréquence:	L1/E1 et L2		
Ambiguïté:	Oui		
Plage horaire:	02/27/2014 12:22:14 - 02/27/2014 17:14:14		
Durée:	4h 52' 00"		
Qualité:	ET X: 0.0002 m	ET Y: 0.0001 m	ET Z: 0.0001 m
	Qlté Pos: 0.0001 m	Qlté Alt: 0.0003 m	ET Pente: 0.0001 m
Vecteur Ligne Base:	dX: -102.0611 m	dY: 217.6042 m	dZ: 6.8210 m
	Pente: 240.4467 m	dAlt: 6.7588 m	
DOP (min-max):	GDOP: 1.6 - 6.3		
	PDOP: 1.5 - 5.2	HDOP: 0.8 - 1.9	VDOP: 1.2 - 4.9
Nombre de satellites utilisés:	GPS: 18		
	GLONASS: -		

HRAO - P1	Référence: HRAO	Mobile: P1
Type de capteur / N° S:	ASHTECH / 801	TOPCON / 8
Type d'antenne / N° S:	ASH701945E_M NONE / -	TPSCR.G3 NONE / -

Hauteur d'antenne:	0.0814 m	0.0270 m
Coordonnées:		
X:	5085352.4410 m	5085428.4007 m
Y:	2668396.0160 m	2668326.6739 m
Z:	-2768731.3820 m	-2768649.2372 m
Type de solution:	Phase: toutes fixes	
Type GNSS:	GPS	
Fréquence:	L1/E1 et L2	
Ambiguïté:	Oui	
Plage horaire:	02/24/2014 10:01:44 - 02/25/2014 01:59:14	
Durée:	15h 57' 30"	

Qualité:	ET X: 0.0001 m	ET Y: 0.0001 m	ET Z: 0.0001 m
	Qlté Pos: 0.0001 m	Qlté Alt: 0.0001 m	ET Pente: 0.0000 m
Vecteur Ligne Base:	dX: 75.9597 m	dY: -69.3421 m	dZ: 82.1448 m
	Pente: 131.6281 m	dAlt: -4.3409 m	
DOP (min-max):	GDOP: 1.6 - 17.1		
	PDOP: 1.5 - 13.0	HDOP: 0.8 - 4.4	VDOP: 1.2 - 12.2
Nombre de satellites utilisés:	GPS: 26		
	GLONASS: -		

HRAO - P5	Référence: HRAO	Mobile: P5
Type de capteur / N° S:	ASHTECH / 801	TOPCON / 8
Type d'antenne / N° S:	ASH701945E_M NONE / -	TPSCR.G3 NONE / -
Hauteur d'antenne:	0.0814 m	0.0280 m
Coordonnées:		
X:	5085352.4410 m	5085415.4630 m
Y:	2668396.0160 m	2668225.4001 m
Z:	-2768731.3820 m	-2768765.7470 m
Type de solution:	Phase: toutes fixes	
Type GNSS:	GPS	
Fréquence:	L1/E1 et L2	
Ambiguïté:	Oui	
Plage horaire:	02/24/2014 09:30:44 - 02/25/2014 01:59:14	
Durée:	16h 28' 30"	

Qualité:	ET X: 0.0001 m	ET Y: 0.0001 m	ET Z: 0.0001 m
	Qlté Pos: 0.0001 m	Qlté Alt: 0.0001 m	ET Pente: 0.0000 m
Vecteur Ligne Base:	dX: 63.0220 m	dY: -170.6159 m	dZ: -34.3650 m
	Pente: 185.1014 m	dAlt: -6.1056 m	
DOP (min-max):	GDOP: 1.6 - 6.3		
	PDOP: 1.5 - 5.2	HDOP: 0.8 - 2.0	VDOP: 1.2 - 4.9

Nombre de satellites GPS: 26
utilisés: GLONASS: -

HRAO - P6	Référence: HRAO	Mobile: P6
Type de capteur / N° S:	ASHTECH / 801	TOPCON / 8
Type d'antenne / N° S:	ASH701945E_M NONE / -	TPSCR.G3 NONE / -
Hauteur d'antenne:	0.0814 m	0.1020 m
Coordonnées:		
X:	5085352.4410 m	5085499.7733 m
Y:	2668396.0160 m	2668160.6126 m
Z:	-2768731.3820 m	-2768659.6191 m
Type de solution:	Phase: toutes fixes	
Type GNSS:	GPS	
Fréquence:	L1/E1 et L2	
Ambiguïté:	Oui	
Plage horaire:	02/24/2014 10:28:44 - 02/25/2014 01:59:14	
Durée:	15h 30' 30"	

Qualité:	ET X: 0.0001 m	ET Y: 0.0001 m	ET Z: 0.0001 m
	Qlté Pos: 0.0001 m	Qlté Alt: 0.0001 m	ET Pente: 0.0000 m
Vecteur Ligne Base:	dX: 147.3323 m	dY: -235.4034 m	dZ: 71.7629 m
	Pente: 286.8300 m	dAlt: -12.3602 m	
DOP (min-max):	GDOP: 1.6 - 6.3		
	PDOP: 1.5 - 5.2	HDOP: 0.8 - 2.0	VDOP: 1.2 - 4.9

Nombre de satellites GPS: 26
utilisés: GLONASS: -

HRAO - p10	Référence: HRAO	Mobile: p10
Type de capteur / N° S:	ASHTECH / 801	R8Model3 / 5242498562
Type d'antenne / N° S:	ASH701945E_M NONE / -	TRMR8_GNSS NONE / -
Hauteur d'antenne:	0.0814 m	0.3450 m
Coordonnées:		
X:	5085352.4410 m	5085338.4787 m
Y:	2668396.0160 m	2668518.8562 m
Z:	-2768731.3820 m	-2768664.7946 m
Type de solution:	Phase: toutes fixes	
Type GNSS:	GPS	
Fréquence:	L1/E1 et L2	
Ambiguïté:	Oui	
Plage horaire:	03/03/2014 09:15:14 - 03/03/2014 16:58:14	
Durée:	7h 43' 00"	

Qualité:	ET X: 0.0002 m	ET Y: 0.0001 m	ET Z: 0.0001 m
	Qlté Pos: 0.0001 m	Qlté Alt: 0.0002 m	ET Pente: 0.0001 m

Vecteur Ligne Base:	dX: -13.9624 m	dY: 122.8402 m	dZ: 66.5874 m
	Pente: 140.4227 m	dAlt: 11.1516 m	
DOP (min-max):	GDOP: 1.6 - 6.3		
	PDOP: 1.4 - 5.2	HDOP: 0.8 - 2.0	VDOP: 1.2 - 4.9
Nombre de satellites utilisés:	GPS: 20		
	GLONASS: -		

HRAO - p12	Référence: HRAO	Mobile: p12
Type de capteur / N° S:	ASHTECH / 801	R8Model3 / 5243499294
Type d'antenne / N° S:	ASH701945E_M NONE / -	TRMR8_GNSS NONE / -
Hauteur d'antenne:	0.0814 m	0.3490 m
Coordonnées:		
X:	5085352.4410 m	5085191.5664 m
Y:	2668396.0160 m	2668636.0379 m
Z:	-2768731.3820 m	-2768854.1994 m
Type de solution:	Phase: toutes fixes	
Type GNSS:	GPS	
Fréquence:	L1/E1 et L2	
Ambiguïté:	Oui	
Plage horaire:	03/03/2014 09:36:44 - 03/03/2014 16:48:44	
Durée:	7h 12' 00"	

Qualité:	ET X: 0.0002 m	ET Y: 0.0002 m	ET Z: 0.0001 m
	Qlté Pos: 0.0001 m	Qlté Alt: 0.0003 m	ET Pente: 0.0001 m
Vecteur Ligne Base:	dX: -160.8746 m	dY: 240.0219 m	dZ: -122.8174 m
	Pente: 313.9670 m	dAlt: 25.8094 m	
DOP (min-max):	GDOP: 1.6 - 6.3		
	PDOP: 1.4 - 5.2	HDOP: 0.8 - 2.0	VDOP: 1.2 - 4.9
Nombre de satellites utilisés:	GPS: 20		
	GLONASS: -		

6.8 SAC Input File (Microsearch GeoLab 2001)

```
 TITL SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
 SURVEY CARRIED OUT BY SOUTH-AFRICAN&NASA&IGN SURVEYORS ON FEBRUARY 2014

 COMP ADJ
 ELIP GRS 80                 6378137  6356752.3141   0.0000   0.0000   0.0000 m
 MAXI         15
 CONF YES YES YES YES NO
 PSOL NO  YES
 PMIS NO  NO
 PRES YES NO
 PADJ NO  NO  YES YES YES NO
 VARF YES YES NO
 RTST TAU MAX
 LUNT m    1.000000000000
 CONV    0.00010
 CLEV     95.000
 ANGT GRD
 LDEC 4

*************************************************************************************************
*  LIST OF POINTS for the SURVEY ADJUSTMENT   (ITRF ACRONYMS, n° DOMES  and  POINTS DESCRIPTION) *
*************************************************************************************************

*POINTS OF INTEREST
*------------------

*GNSS
*HARB     : 30302M009 = IGS GNSS station ref. pt. is the marker => Sitelog Antenna Height = 3.052 m

*DORIS
*HBMB     : DOMES 30302S008 = DORIS antenna ref. pt. (Starec type) = DORIS HBMB 400MHz Phase Centre
*HBMB/2GHz: (no DOMES ) = DORIS HBMB 2GHz Phase Centre


*G2 is HARB_TCR
*G202 is the prism -0,118 m below HARB_ARP
*G203 is the prism 0,100 m above HARB (marker)
*D1 is DORIS 2GHz phase centre
*D2 is DORIS 400MHz phase centre (~ DORIS antenna reference point)
*D3 is DORIS antenna base
*D07 is the prism 0,100m above DORIS_marker
*DORIS plate is 0,230 m above marker (Troy measurment)
*DORIS base to DORIS is +0.390 m +/- 1mm (manufacturer value)


****APPROXIMATES COORDINATES*****
 PLH  000 D07          S 25 53  12.66689 E 27 42  26.86502    1559.0428 m       0
 PLH  000 HBMB_2GHz    S 25 53  12.66698 E 27 42  26.86510    1560.1118 m       0
 PLH  000 HBMB         s 25 53 12.666960 e 27 42 26.865120    1559.6228 m       0
 PLH  000 HBMB_base    S 25 53  12.66699 E 27 42  26.86508    1559.2592 m       0
 PLH  000 D30          S 25 53  11.64606 E 27 42  26.34666    1558.9436 m       0
 PLH  000 D31          S 25 53  13.35814 E 27 42  25.46887    1560.8519 m       0
 PLH  000 D32          S 25 53  11.73245 E 27 42  27.47095    1558.6395 m       0
 PLH  000 G2           S 25 53  13.06106 E 27 42  26.08641    1561.1657 m       0
 PLH  000 G202         S 25 53  13.06104 E 27 42  26.08641    1561.1652 m       0
 PLH  000 G203         S 25 53  13.06106 E 27 42  26.08644    1558.1095 m       0
 PLH  000 HARB         S 25 53  13.06098 E 27 42  26.08641    1558.0788 m       0
 PLH  000 P403         S 25 52  58.11135 E 27 42  23.27760    1553.0462 m       0
 PLH  000 P412         S 25 53  18.91854 E 27 42  16.29040    1574.9585 m       0
 PLH  000 P418         S 25 53  12.70813 E 27 42  34.70962    1564.8333 m       0


*with a geoide model
 GFIL D:\temp\GEOIDE\GEOIDGLB.gsp


*********************AZIMUT DEDUCTED FROM THE GPS DETERMINATION*********************************

*difference between AZIM and GAZI ? la comparaison des résultats donne la meme chose.

 AZIM     HARB         P412                      262 81    43.0      0.003
 AZIM     HARB         P418                       97 12    27.0      0.002
*GAZI     HARB         P412                      262 81    43.0      0.004
*GAZI     HARB         P418                       97 12    27.0      0.003
```

```
*HARB IGS08 EPOCH 2014:058 (2014/02/27) COORDINATES CONSTRAINED AT 1 MM
 3DC
 XYZ  000 HARB               5084657.6130       2670325.2920      -2768480.9920 m
 COV  CT DIAG
 ELEM                0.000001               0.000001               0.000001


***********************************CENTRING EQUATIONS*****************************************

* CENTRING EQUATIONS: PRISM ABOVE MARKER
 3DD
 PLH  000 G203         S 25 53  13.06000 E 27 42  26.09000    1558.1000 m       0
 PLH  000 HARB         S 25 53  13.06000 E 27 42  26.09000    1558.0000 m       0
 COV  LG DIAG
 ELEM                0.000004               0.000004               0.000004

* CENTRING EQUATIONS: PRISM BELOW ANTENNA TCR
 3DD
 PLH  000 G2           S 25 53  13.06000 E 27 42  26.09000    1561.4200 m       0
 PLH  000 G202         S 25 53  13.06000 E 27 42  26.09000    1561.2000 m       0
 COV  LG DIAG
 ELEM                0.000004               0.000004               0.000004


* CENTRING EQUATIONS: PRISM (D07 H=0,100 m) ABOVE DORIS_rep
 3DD
 PLH  000 D07          S 25 53  12.70000 E 27 42  26.90000    1559.1000 m       0
 PLH  000 DORIS_rep    S 25 53  12.70000 E 27 42  26.90000    1559.0000 m       0
 COV  LG DIAG
 ELEM                0.000004               0.000004               0.000004



* A virer
* CENTRING EQUATIONS: PRISM ABOVE MARKER
*2DD
*PL   00  G203         s 25 53 13.060000 e 27 42 26.090000
*PL   00  HARB         s 25 53 13.060000 e 27 42 26.090000
*COV  LG DIAG
*ELEM                  0.0001                 0.0001

* CENTRING EQUATIONS: PRISM BELOW ANTENNA TCR
*2DD
*PL   00  G2           S 25 53  13.06000 E 27 42  26.09000
*PL   00  G202         S 25 53  13.06000 E 27 42  26.09000
*COV  LG DIAG
*ELEM                  0.0001                 0.0001



 HIST NEW

*tape measurement
 OHDF     G2           G203                             -3.0580      0.002
*HARB_ARP to marker -3.056 m (d'où ça sort ? valeur calculée ?)

***************************TOTAL STATION OBSERVATIONS*****************************************

*HT       G2               0.102
*HT       G202            -0.118
*HT       G203             0.100
 SIGM HT       0.001
 HT       P403             0.273
 HT       P412             0.263
 HT       P418             0.253



*Données reduites
* D:\Hartebeesthoek\Data\corrected\20140228\Sansa-SAC_0228.obs
* fichier créé le 28/02/2014 à 14:12:55
*Tours d'horizon
* Station n°1 D30
* Temperature: 22.0 °C - Pression: 636.0 mmHg - Correction meteo: 54.0 ppm
* Date/heure debut:
* Date/heure fin  :
* Numero de cycle: 0

 SIGM

 DSET
 DIR      D30          P403                    +  0  0     0.0         8
 DIR      D30          P412                    +269 94    32.0         8
 DIR      D30          D31                     +240 52    52.0         8
```

```
*5 D30            G200              223.1175     0.0008 0.0000   0.0000   0.0000
*5 D30            G201              223.6321     0.0008 0.0000   0.0000   0.0000
 DIR      D30          G2                      +223 37    48.0         8
 DIR      D30          G202                    +223 37    43.0         8
 DIR      D30          G203                    +223 37    31.0         8

*5 D30            D01               185.4456     0.0008 0.0000   0.0000   0.0000
*5 D30            D02               185.4875     0.0008 0.0000   0.0000   0.0000
 DIR      D30          HBMB_2GHz               +185 46    66.0         8

*5 D30            D03               185.4154     0.0008 0.0000   0.0000   0.0000
*5 D30            D04               185.5151     0.0008 0.0000   0.0000   0.0000
 DIR      D30          HBMB                    +185 46    53.0         8

*5 D30            D05               185.4108     0.0008 0.0000   0.0000   0.0000
*5 D30            D06               185.5248     0.0008 0.0000   0.0000   0.0000
 DIR      D30          HBMB_base               +185 46    78.0         8
 DIR      D30          D07                     +185 46    82.0         8
 DIR      D30          P418                    +121 76    16.0         8
 DIR      D30          D32                     +118 27    59.0         8

 ZANG     D30          P403                    +100 84    40.0         12
 ZANG     D30          P412                    + 97 11    46.0         12
 ZANG     D30          D31                     + 97 91     2.0         12

*6 D30            G200               96.6517     0.0012 0.0000   0.0000   0.0000
*6 D30            G201               96.6523     0.0012 0.0000   0.0000   0.0000

 ZANG     D30          G2                      + 96 65    20.0         12
 ZANG     D30          G202                    + 96 96    93.0         12
 ZANG     D30          G203                    +101  5    18.0         20

*6 D30             D01               97.8502     0.0012 0.0000   0.0000   0.0000
*6 D30             D02               97.8509     0.0012 0.0000   0.0000   0.0000

 ZANG     D30          HBMB_2GHz               + 97 85     6.0         12

*6 D30             D03               98.7495     0.0012 0.0000   0.0000   0.0000
*6 D30             D04               98.7501     0.0012 0.0000   0.0000   0.0000

 ZANG     D30          HBMB                    + 98 74    98.0         12

*6 D30             D05               99.4194     0.0012 0.0000   0.0000   0.0000
*6 D30             D06               99.4194     0.0012 0.0000   0.0000   0.0000

 ZANG     D30          HBMB_base               + 99 41    94.0         12
 ZANG     D30          D07                     + 99 81    75.0         12
 ZANG     D30          P418                    + 98 33    80.0         12
 ZANG     D30          D32                     +100 61    69.0         12

 DIST     D30          P403                          425.3298     0.0010 m
 DIST     D30          P412                          358.8588     0.0010 m
 DIST     D30          D31                            58.1234     0.0010 m
 DIST     D30          G202                           44.2036     0.0010 m
 DIST     D30          G203                           44.1609     0.0010 m
 DIST     D30          D07                            34.5783     0.0010 m
 DIST     D30          P418                          235.2210     0.0010 m
 DIST     D30          D32                            31.4187     0.0010 m

* Station n°2 D31
* Temperature: 23.2 °C - Pression: 635.9 mmHg - Correction meteo: 55.0 ppm
* Date/heure debut:
* Date/heure fin  :
* Numero de cycle: 0

 DSET
 DIR      D31          P418                    +  0  0     0.0         8

*5 D31             G200              373.2401     0.0008 0.0000   0.0000   0.0000
*5 D31             G201              374.4093     0.0008 0.0000   0.0000   0.0000
 DIR      D31          G2                      +373 82    47.0         8
 DIR      D31          G202                    +373 82    28.0         8
 DIR      D31          G203                    +373 82    55.0         8

*5 D31             D01               373.0487     0.0008 0.0000   0.0000   0.0000
*5 D31             D02               373.0801     0.0008 0.0000   0.0000   0.0000
 DIR      D31          HBMB_2GHz               +373  6    44.0         8

*5 D31             D03               373.0251     0.0008 0.0000   0.0000   0.0000
*5 D31             D04               373.1025     0.0008 0.0000   0.0000   0.0000
 DIR      D31          HBMB                    +373  6    38.0         8

*5 D31             D05               373.0194     0.0008 0.0000   0.0000   0.0000
*5 D31             D06               373.1087     0.0008 0.0000   0.0000   0.0000
 DIR      D31          HBMB_base               +373  6    41.0         8
```

```
 DIR      D31          D07                     +373  5    90.0         8
 DIR      D31          D32                     +358 37     0.0         8
 DIR      D31          D30                     +332 58    85.0         8
 DIR      D31          P412                    +167 37    27.0         8

 ZANG     D31          P418                    + 98 95    78.0         12

*6 D31             G200              98.6418     0.0012 0.0000   0.0000   0.0000
*6 D31             G201              98.6419     0.0012 0.0000   0.0000   0.0000

 ZANG     D31          G2                      + 98 64    18.0         12
 ZANG     D31          G202                    + 99 36    18.0         12
 ZANG     D31          G203                    +108 58    53.0         12

*6 D31             D01              101.0635     0.0012 0.0000   0.0000   0.0000
*6 D31             D02              101.0634     0.0012 0.0000   0.0000   0.0000

 ZANG     D31          HBMB_2GHz               +101  6    34.0         12

*6 D31             D03              101.7659     0.0012 0.0000   0.0000   0.0000
*6 D31             D04              101.7656     0.0012 0.0000   0.0000   0.0000

 ZANG     D31          HBMB                    +101 76    58.0         12

*6 D31            D05               102.2873     0.0012 0.0000   0.0000   0.0000
*6 D31            D06               102.2871     0.0012 0.0000   0.0000   0.0000

 ZANG     D31          HBMB_base               +102 28    72.0         12
 ZANG     D31          D07                     +102 59    71.0         12
 ZANG     D31          D32                     +101 88     1.0         12
 ZANG     D31          D30                     +102  8    98.0         12
 ZANG     D31          P412                    + 97  2    84.0         12

 DIST     D31          P418                          258.1098     0.0010 m
 DIST     D31          G202                           19.4745     0.0010 m
 DIST     D31          G203                           19.6527     0.0010 m
 DIST     D31          D07                            44.3528     0.0010 m
 DIST     D31          D32                            74.9439     0.0010 m
 DIST     D31          D30                            58.1235     0.0010 m
 DIST     D31          P412                          307.9176     0.0010 m

* Station n°3 D32
* Temperature: 24.5 °C - Pression: 635.9 mmHg - Correction meteo: 56.0 ppm
* Date/heure debut:
* Date/heure fin  :
* Numero de cycle: 0

 DSET
 DIR      D32          P418                    +  0  0     0.0         8

*5 D32             D01              124.3263     0.0008 0.0000   0.0000   0.0000
*5 D32             D02              124.3707     0.0008 0.0000   0.0000   0.0000
 DIR      D32          HBMB_2GHz               +124 34    85.0         8

*5 D32             D03              124.2951     0.0008 0.0000   0.0000   0.0000
*5 D32             D04              124.4010     0.0008 0.0000   0.0000   0.0000
 DIR      D32          HBMB                    +124 34    81.0         8

*5 D32             D05              124.2884     0.0008 0.0000   0.0000   0.0000
*5 D32             D06              124.4085     0.0008 0.0000   0.0000   0.0000
 DIR      D32          HBMB_base               +124 34    85.0         8
 DIR      D32          D07                     +124 35    39.0         8

*5 D32             G200             138.5021     0.0008 0.0000   0.0000   0.0000
*5 D32             G201             138.9073     0.0008 0.0000   0.0000   0.0000
 DIR      D32          G2                      +138 70    47.0         8
 DIR      D32          G202                    +138 70    48.0         8
 DIR      D32          G203                    +138 70    28.0         8
 DIR      D32          D31                     +144  1    37.0         8
 DIR      D32          P412                    +151 25    41.0         8
 DIR      D32          D30                     +195 97    73.0         8

 ZANG     D32          P418                    + 97 98    73.0         12

*6 D32             D01               97.1904     0.0012 0.0000   0.0000   0.0000
*6 D32             D02               97.1914     0.0012 0.0000   0.0000   0.0000

 ZANG     D32          HBMB_2GHz               + 97 19     9.0         12

*6 D32             D03               98.1236     0.0012 0.0000   0.0000   0.0000
*6 D32             D04               98.1233     0.0012 0.0000   0.0000   0.0000

 ZANG     D32          HBMB                    + 98 12    34.0         12

*6 D32             D05               98.8178     0.0012 0.0000   0.0000   0.0000
*6 D32             D06               98.8162     0.0012 0.0000   0.0000   0.0000
```

```
 ZANG     D32          HBMB_base                + 98 81    70.0         12
 ZANG     D32          D07                      + 99 23     4.0         12

*6 D32             G200               97.0256     0.0012 0.0000   0.0000  0.00000
*6 D32             G201               97.0257     0.0012 0.0000   0.0000  0.00000

 ZANG     D32          G2                       + 97  2    57.0         12
 ZANG     D32          G202                     + 97 27    54.0         12
 ZANG     D32          G203                     +100 48    81.0         12
 ZANG     D32          D31                      + 98 12    13.0         12
 ZANG     D32          P412                     + 97 23    92.0         12
 ZANG     D32          D30                      + 99 38    35.0         12

 DIST     D32          P418                           203.8801     0.0010 m
 DIST     D32          D07                             33.3486     0.0010 m
 DIST     D32          G202                            56.2538     0.0010 m
 DIST     D32          G203                            56.2041     0.0010 m
 DIST     D32          D31                             74.9441     0.0010 m
 DIST     D32          P412                           382.2524     0.0010 m
 DIST     D32          D30                             31.4189     0.0010 m


 HIST ALL
 END
```

6.9 SAC Output File (Microsearch GeoLab 2001 Adjustment Listing)

```
================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0            GRS 80      UNITS: m,GRAD Page 0001
================================================================================
Fri Jul 11 15:37:15 2014

Input file:  D:\JCPOYARD\En_cours_Poy\Hartebeesthoek\Geolab\SANSA-SACv4\Sansa-SACv4.iob
Output file: D:\JCPOYARD\En_cours_Poy\Hartebeesthoek\Geolab\SANSA-SACv4\Sansa-SACv4.lst
Options file: C:\Program Files (x86)\Microsearch\GeoLab\default.gpj

Geoid File:  D:\temp\GEOIDE\GEOIDGLB.gsp
 ------------------------------------------------------------------------------
|             PARAMETERS               |             OBSERVATIONS             |
|--------------------------------------------------------------------------------|
|   Description    |      Number       |   Description     |      Number      |
|--------------------------------------------------------------------------------|
| No. of Stations  |          15       | Directions        |          34      |
| Coord Parameters |          45       | Distances         |          22      |
| Free Latitudes   |          15       | Azimuths          |           2      |
| Free Longitudes  |          15       | Vertical Angles   |           0      |
| Free Heights     |          15       | Zenithal Angles   |          34      |
| Fixed Coordinates|           0       | Angles            |           0      |
| Astro. Latitudes |           0       | Heights           |           0      |
| Astro. Longitudes|           0       | Height Differences|           1      |
| Geoid Records    |           0       | Auxiliary Params. |           0      |
| All Aux. Pars.   |           3       | 2-D Coords.       |           0      |
| Direction Pars.  |           3       | 2-D Coord. Diffs. |           0      |
| Scale Parameters |           0       | 3-D Coords.       |           3      |
| Constant Pars.   |           0       | 3-D Coord. Diffs. |           9      |
| Rotation Pars.   |           0       |                   |                  |
| Translation Pars.|           0       |                   |                  |
|                  |                   |                   |                  |
|                  |    --------       |                   |    --------      |
| Total Parameters |          48       | Total Observations|         105      |
|--------------------------------------------------------------------------------|
|                      Degrees of Freedom =        57                          |
 --------------------------------------------------------------------------------

--------------------------------------------------------------------------------
                        SUMMARY OF SELECTED OPTIONS
--------------------------------------------------------------------------------
    OPTION                                |   SELECTION
--------------------------------------------------------------------------------
    Computation Mode                      |   Adjustment
    Maximum Iterations                    |   15
    Convergence Criterion                 |   0.00010
    Residual Rejection Criterion          |   Tau Max
    Confidence Region Types               |   1D 2D 3D Station
    Variance Factor (VF) Known            |   Yes
    Scale Covariance Matrix With VF       |   Yes
    Scale Residual Variances With VF      |   No
    Force Convergence in Max Iters        |   No
    Distances Contribute To Heights       |   No
    Compute Full Inverse                  |   Yes
    Optimize Band Width                   |   Yes
    Generate Initial Coordinates          |   Yes
    Re-Transform Obs After 1st Pass       |   No
    Geoid Interpolation Method            |   Bi-Quadratic
--------------------------------------------------------------------------------
```

```
================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0            GRS 80      UNITS: m,GRAD Page 0002
================================================================================
Adjusted PLH Coordinates:
                                LATITUDE         LONGITUDE  ELIP-HEIGHT
 CODE FFF STATION                STD DEV           STD DEV      STD DEV
 ---- --- ------------ ----------------- ----------------- ------------
 PLH  000 D07          S 25 53  12.66686 E 27 42  26.86501    1559.0120 m       0
                                 0.0015            0.0021       0.0022
 PLH  000 D30          S 25 53  11.64603 E 27 42  26.34665    1558.9127 m       0
                                 0.0015            0.0022       0.0021
 PLH  000 D31          S 25 53  13.35811 E 27 42  25.46885    1560.8211 m       0
                                 0.0015            0.0021       0.0021
 PLH  000 D32          S 25 53  11.73243 E 27 42  27.47095    1558.6086 m       0
                                 0.0015            0.0022       0.0021
 PLH  000 DORIS_rep    S 25 53  12.66686 E 27 42  26.86501    1558.9120 m       0
                                 0.0024            0.0029       0.0029
 PLH  000 G2           S 25 53  13.06103 E 27 42  26.08640    1561.2367 m       0
                                 0.0016            0.0022       0.0021
 PLH  000 G202         S 25 53  13.06101 E 27 42  26.08639    1561.0163 m       0
                                 0.0015            0.0021       0.0021
 PLH  000 G203         S 25 53  13.06104 E 27 42  26.08642    1558.1788 m       0
                                 0.0015            0.0021       0.0021
 PLH  000 HARB         S 25 53  13.06098 E 27 42  26.08641    1558.0788 m       0
                                 0.0009            0.0009       0.0009
 PLH  000 HBMB         S 25 53  12.66693 E 27 42  26.86511    1559.5919 m       0
                                 0.0016            0.0021       0.0022
 PLH  000 HBMB_2GHz    S 25 53  12.66695 E 27 42  26.86509    1560.0810 m       0
                                 0.0016            0.0021       0.0022
 PLH  000 HBMB_base    S 25 53  12.66697 E 27 42  26.86507    1559.2283 m       0
                                 0.0016            0.0021       0.0022
 PLH  000 P403         S 25 52  58.11131 E 27 42  23.27766    1553.0153 m       0
                                 0.0022            0.0064       0.0078
 PLH  000 P412         S 25 53  18.91849 E 27 42  16.29038    1574.9276 m       0
                                 0.0014            0.0019       0.0041
 PLH  000 P418         S 25 53  12.70814 E 27 42  34.70961    1564.8024 m       0
                                 0.0009            0.0022       0.0032


================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0            GRS 80      UNITS: m,GRAD Page 0003
================================================================================
Adjusted PLO Coordinates:
                                LATITUDE         LONGITUDE     O-HEIGHT
 CODE FFF STATION                STD DEV           STD DEV      STD DEV
 ---- --- ------------ ----------------- ----------------- ------------
 PLO  000 D07          S 25 53  12.66686 E 27 42  26.86501    1533.7774 m       0
                                 0.0015            0.0021       0.0022
 PLO  000 D30          S 25 53  11.64603 E 27 42  26.34665    1533.6793 m       0
                                 0.0015            0.0022       0.0021
 PLO  000 D31          S 25 53  13.35811 E 27 42  25.46885    1535.5851 m       0
                                 0.0015            0.0021       0.0021
 PLO  000 D32          S 25 53  11.73243 E 27 42  27.47095    1533.3753 m       0
                                 0.0015            0.0022       0.0021
 PLO  000 DORIS_rep    S 25 53  12.66686 E 27 42  26.86501    1533.6774 m       0
                                 0.0024            0.0029       0.0029
 PLO  000 G2           S 25 53  13.06103 E 27 42  26.08640    1536.0009 m       0
                                 0.0016            0.0022       0.0021
 PLO  000 G202         S 25 53  13.06101 E 27 42  26.08639    1535.7805 m       0
                                 0.0015            0.0021       0.0021
 PLO  000 G203         S 25 53  13.06104 E 27 42  26.08642    1532.9430 m       0
                                 0.0015            0.0021       0.0021
 PLO  000 HARB         S 25 53  13.06098 E 27 42  26.08641    1532.8430 m       0
                                 0.0009            0.0009       0.0009
 PLO  000 HBMB         S 25 53  12.66693 E 27 42  26.86511    1534.3573 m       0
                                 0.0016            0.0021       0.0022
 PLO  000 HBMB_2GHz    S 25 53  12.66695 E 27 42  26.86509    1534.8464 m       0
                                 0.0016            0.0021       0.0022
 PLO  000 HBMB_base    S 25 53  12.66697 E 27 42  26.86507    1533.9937 m       0
                                 0.0016            0.0021       0.0022
 PLO  000 P403         S 25 52  58.11131 E 27 42  23.27766    1527.7965 m       0
                                 0.0022            0.0064       0.0078
 PLO  000 P412         S 25 53  18.91849 E 27 42  16.29038    1549.6836 m       0
                                 0.0014            0.0019       0.0041
 PLO  000 P418         S 25 53  12.70814 E 27 42  34.70961    1539.5692 m       0
                                 0.0009            0.0022       0.0032


================================================================================
```

SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0 GRS 80 UNITS: m,GRAD Page 0004

Adjusted XYZ Coordinates:

CODE	FFF	STATION	X-COORDINATE STD DEV	Y-COORDINATE STD DEV	Z-COORDINATE STD DEV		
XYZ		D07	5084652.9656 0.0020	2670347.3385 0.0022	-2768470.4852 0.0017	m	0
XYZ		D30	5084671.7431 0.0020	2670340.8976 0.0022	-2768442.1721 0.0017	m	0
XYZ		D31	5084664.2569 0.0020	2670309.3591 0.0021	-2768490.4174 0.0017	m	0
XYZ		D32	5084655.9176 0.0020	2670367.9456 0.0022	-2768444.4319 0.0016	m	0
XYZ		DORIS_rep	5084652.8859 0.0028	2670347.2967 0.0029	-2768470.4415 0.0025	m	0
XYZ		G2	5084660.1278 0.0020	2670326.6125 0.0022	-2768482.3720 0.0017	m	0
XYZ		G202	5084659.9525 0.0020	2670326.5202 0.0022	-2768482.2754 0.0017	m	0
XYZ		G203	5084657.6918 0.0020	2670325.3339 0.0021	-2768481.0371 0.0016	m	0
XYZ		HARB	5084657.6130 0.0009	2670325.2920 0.0009	-2768480.9920 0.0009	m	0
XYZ		HBMB	5084653.4254 0.0020	2670347.5830 0.0022	-2768470.7403 0.0017	m	0
XYZ		HBMB_2GHz	5084653.8150 0.0020	2670347.7869 0.0022	-2768470.9544 0.0017	m	0
XYZ		HBMB_base	5084653.1359 0.0020	2670347.4298 0.0022	-2768470.5825 0.0017	m	0
XYZ		P403	5084867.8025 0.0068	2670347.3395 0.0068	-2768064.7761 0.0040	m	0
XYZ		P412	5084728.1507 0.0034	2670054.2543 0.0026	-2768650.5584 0.0022	m	0
XYZ		P418	5084555.5250 0.0027	2670542.8787 0.0024	-2768474.1564 0.0016	m	0

SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0 GRS 80 UNITS: m,GRAD Page 0005

Residuals (critical value = 3.508):
NOTE: Observation values shown are reduced to mark-to-mark.

TYPE	AT	FROM	TO	OBSERVATION STD DEV	RESIDUAL STD DEV	STD RES PPM
AZIM		HARB	P412	262 81 43.0 0.0	0.0 0.0	0.0 *
AZIM		HARB	P418	97 12 27.0 0.0	-0.0 0.0	-0.0 *
XCT	HARB			5084657.61300 0.0010	0.0000 0.0000	0.0000 *
YCT	HARB			2670325.29200 0.0010	-0.0000 0.0000	-0.0000 *
ZCT	HARB			-2768480.99200 0.0010	-0.0000 0.0000	-0.0000 *
ELAT		G203	HARB	0 00 0.00000 0.0020	0.0016 0.0013	1.2762 16419.76
ELON		G203	HARB	0 00 0.00000 0.0020	-0.0005 0.0004	-1.0718 4588.68
EHGT		G203	HARB	-0.10000 0.0020	-0.0000 0.0009	-0.0000 0.00
ELAT		G2	G202	0 00 0.00000 0.0020	0.0004 0.0019	0.2253 1972.70
ELON		G2	G202	0 00 0.00000 0.0020	-0.0002 0.0019	-0.0936 797.45
EHGT		G2	G202	-0.22000 0.0020	-0.0004 0.0020	-0.2046 1811.28
ELAT		D07	DORIS_rep	0 00 0.00000 0.0020	-0.0000 0.0000	-0.0000 0.00*
ELON		D07	DORIS_rep	0 00 0.00000 0.0020	0.0000 0.0000	0.0000 0.00*
EHGT		D07	DORIS_rep	-0.10000 0.0020	-0.0000 0.0000	-0.0000 0.00*
OHDF		G2	G203	-3.05800 0.0020	0.0001 0.0019	0.0627 39.93
DIR		D30	P403	0 0 -0.0 8.0	0.0 0.0	0.0 *
DIR		D30	P412	269 94 32.0 8.0	4.1 6.2	0.7
DIR		D30	D31	240 52 52.0	-2.3	-0.3

					8.0	6.7	
DIR	D30	G2	223	37	48.0	1.9	0.6
					8.0	3.3	
DIR	D30	G202	223	37	43.0	10.4	1.9
					8.0	5.5	
DIR	D30	G203	223	37	31.0	9.0	1.7
					8.0	5.3	
DIR	D30	HBMB_2GHz	185	46	66.0	1.4	0.5
					8.0	2.5	
DIR	D30	HBMB	185	46	53.0	0.6	0.2
					8.0	2.5	
DIR	D30	HBMB_base	185	46	78.0	-0.7	-0.3
					8.0	2.5	
DIR	D30	D07	185	46	82.0	-1.2	-0.3
					8.0	4.4	
DIR	D30	P418	121	76	16.0	-13.2	-2.1
					8.0	6.2	
DIR	D30	D32	118	27	59.0	-10.0	-1.9
					8.0	5.3	
ZANG	D30	P403	100	88	48.6	-0.0	-0.0
					12.0	0.0	
ZANG	D30	P412	97	16	12.1	15.2	1.5
					12.0	10.0	
ZANG	D30	D31	97	91	2.0	4.9	0.4
					12.0	11.5	
ZANG	D30	G2	96	65	20.0	-5.7	-0.5
					12.0	10.5	
ZANG	D30	G202	96	96	93.0	-2.2	-0.2
					12.0	10.5	
ZANG	D30	G203	101	5	18.0	-64.4	-3.4
					20.0	19.0	
ZANG	D30	HBMB_2GHz	97	85	6.0	2.2	0.2
					12.0	9.1	
ZANG	D30	HBMB	98	74	98.0	-2.0	-0.2

SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0 GRS 80 UNITS: m,GRAD Page 0006

Residuals (critical value = 3.508):
NOTE: Observation values shown are reduced to mark-to-mark.

TYPE	AT	FROM	TO	OBSERVATION STD DEV	RESIDUAL STD DEV	STD RES PPM
				12.0	9.1	
ZANG	D30	HBMB_base	99 41	94.0	2.5	0.3
				12.0	9.1	
ZANG	D30	D07	99 81	75.0	0.8	0.1
				12.0	9.1	
ZANG	D30	P418	98 40	64.5	-4.7	-0.5
				12.0	9.9	
ZANG	D30	D32	100 61	69.0	5.3	0.5
				12.0	10.6	
DIST	D30	P403		425.33349	0.0000	0.0000
				0.0010	0.0000	0.00*
DIST	D30	P412		358.84696	-0.0001	-0.1858
				0.0010	0.0008	0.41
DIST	D30	D31		58.12340	-0.0000	-0.0521
				0.0010	0.0009	0.83
DIST	D30	G202		44.20360	0.0004	0.4560
				0.0010	0.0009	9.20
DIST	D30	G203		44.16090	-0.0003	-0.3815
				0.0010	0.0009	7.70
DIST	D30	D07		34.57830	0.0008	0.8368
				0.0010	0.0009	21.75
DIST	D30	P418		235.21452	0.0004	0.4685
				0.0010	0.0008	1.55
DIST	D30	D32		31.41870	0.0002	0.2600
				0.0010	0.0009	7.64
DIR	D31	P418	0 0	0.0	13.0	2.0
				8.0	6.4	
DIR	D31	G2	373	82	47.0	-1.7	-0.8
					8.0	2.1	
DIR	D31	G202	373	82	28.0	1.8	0.6
					8.0	3.1	
DIR	D31	G203	373	82	55.0	4.5	1.5
					8.0	3.0	
DIR	D31	HBMB_2GHz	373	6	44.0	-2.8	-0.5
					8.0	5.1	
DIR	D31	HBMB	373	6	38.0	-1.2	-0.2
					8.0	5.1	
DIR	D31	HBMB_base	373	6	41.0	1.5	0.3
					8.0	5.1	
DIR	D31	D07	373	5	90.0	1.7	0.3
					8.0	5.8	
DIR	D31	D32	358	37	0.0	10.6	1.5
					8.0	7.1	

DIR	D31	D30	332	58	85.0	-20.4	-3.1
					8.0	6.6	
DIR	D31	P412	167	37	27.0	-6.9	-1.2
					8.0	5.7	
ZANG	D31	P418	99	2	1.9	9.5	0.9
					12.0	10.3	
ZANG	D31	G2	98	64	18.0	1.5	0.3
					12.0	5.9	
ZANG	D31	G202	99	36	18.0	-1.2	-0.2
					12.0	5.6	
ZANG	D31	G203	108	58	53.0	6.7	1.4
					12.0	5.0	
ZANG	D31	HBMB_2GHz	101	6	34.0	1.0	0.1
					12.0	10.0	
ZANG	D31	HBMB	101	76	58.0	3.6	0.4
					12.0	10.0	
ZANG	D31	HBMB_base	102	28	72.0	-0.4	-0.0
					12.0	10.0	
ZANG	D31	D07	102	59	71.0	-4.9	-0.5
					12.0	10.0	
ZANG	D31	D32	101	88	1.0	0.4	0.0
					12.0	11.7	
ZANG	D31	D30	102	8	98.0	-10.7	-0.9
					12.0	11.5	
ZANG	D31	P412	97	8	27.2	-11.5	-1.3
					12.0	9.1	

SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0 GRS 80 UNITS: m,GRAD Page 0007

Residuals (critical value = 3.508):
NOTE: Observation values shown are reduced to mark-to-mark.

TYPE	AT	FROM	TO	OBSERVATION STD DEV	RESIDUAL STD DEV	STD RES PPM
DIST		D31	P418	258.10577	-0.0003	-0.3419
				0.0010	0.0008	1.01
DIST		D31	G202	19.47450	0.0017	2.0823
				0.0010	0.0008	89.67
DIST		D31	G203	19.65270	0.0014	1.6529
				0.0010	0.0008	70.40
DIST		D31	D07	44.35280	0.0005	0.6230
				0.0010	0.0009	12.38
DIST		D31	D32	74.94390	-0.0001	-0.0613
				0.0010	0.0009	0.75
DIST		D31	D30	58.12350	-0.0001	-0.1602
				0.0010	0.0009	2.55
DIST		D31	P412	307.90543	0.0005	0.6113
				0.0010	0.0008	1.54
DIR		D32	P418	0 0	-0.0	5.4	0.9
					8.0	5.7	
DIR		D32	HBMB_2GHz	124 34	85.0	-2.6	-0.5
					8.0	4.7	
DIR		D32	HBMB	124 34	81.0	-1.1	-0.2
					8.0	4.7	
DIR		D32	HBMB_base	124 34	85.0	1.4	0.3
					8.0	4.7	
DIR		D32	D07	124 35	39.0	4.7	0.9
					8.0	5.0	
DIR		D32	G2	138 70	47.0	-6.1	-0.9
					8.0	7.0	
DIR		D32	G202	138 70	48.0	-2.2	-0.3
					8.0	7.1	
DIR		D32	G203	138 70	28.0	6.3	0.9
					8.0	7.0	
DIR		D32	D31	144 1	37.0	-9.6	-1.3
					8.0	7.3	
DIR		D32	P412	151 25	41.0	-3.8	-0.6
					8.0	6.4	
DIR		D32	D30	195 97	73.0	7.6	1.3
					8.0	5.9	
ZANG		D32	P418	98 6	62.6	-3.4	-0.4
					12.0	9.1	
ZANG		D32	HBMB_2GHz	97 19	9.0	-2.9	-0.3
					12.0	8.8	
ZANG		D32	HBMB	98 12	34.0	-0.8	-0.1
					12.0	8.8	
ZANG		D32	HBMB_base	98 81	70.0	-2.1	-0.2
					12.0	8.8	
ZANG		D32	D07	99 23	4.0	2.9	0.3
					12.0	8.8	
ZANG		D32	G2	97 2	57.0	1.9	0.2
					12.0	11.0	
ZANG		D32	G202	97 27	54.0	7.4	0.7
					12.0	11.0	
ZANG		D32	G203	100 48	81.0	10.1	0.9

```
                                                          12.0     10.9
ZANG              D32          D31             98 12      13.0      6.1      0.5
                                                          12.0     11.7
ZANG              D32          P412            97 28      29.6     -1.9     -0.2
                                                          12.0     10.2
ZANG              D32          D30             99 38      35.0     -4.4     -0.4
                                                          12.0     10.6
DIST              D32          P418                  203.87225  -0.0002  -0.2175
                                                        0.0010   0.0008     0.83
DIST              D32          D07                    33.34860   0.0001   0.1448
                                                        0.0010   0.0009     3.83
DIST              D32          G202                   56.25380  -0.0002  -0.2760
                                                        0.0010   0.0008     4.16
DIST              D32          G203                   56.20410  -0.0005  -0.6101
                                                        0.0010   0.0008     9.16
DIST              D32          D31                    74.94410  -0.0003  -0.2802
                                                        0.0010   0.0009     3.42
DIST              D32          P412                  382.24107  -0.0003  -0.4249
================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0           GRS 80      UNITS: m,GRAD Page 0008
================================================================================
Residuals (critical value = 3.508):
NOTE: Observation values shown are reduced to mark-to-mark.
                                                  OBSERVATION RESIDUAL  STD RES
TYPE AT           FROM         TO                     STD DEV  STD DEV      PPM
---- ------------ ------------ ------------ ----------------- -------- --------
                                                        0.0010   0.0008     0.88
DIST              D32          D30                    31.41890   0.0000   0.0434
                                                        0.0010   0.0009     1.28


================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0           GRS 80      UNITS: m,GRAD Page 0009
================================================================================

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   0.4 -                           |::***::|
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R                                  |:::|:::|
e                                 *|:::|:::|*
l                                  |:::|:::|
a                                  |:::|:::|
t  0.3 -                          * |:::|:::| *
i                                  |:::|:::|
v                                 *  |:::|:::|--*
e                                  |:::|:::|:::|
                                   |:::|:::|:::|
F                                *   |:::|:::|:::*
r                                  |:::|:::|:::|
e                               *    |:::|:::|:::|*
q  0.2 -                           |:::|:::|:::|
u                              *    |:::|:::|:::| *
e                                  |:::|:::|:::|
n                                  |:::|:::|:::|
c                              *    |:::|:::|:::|  *
y                                 ---|:::|:::|:::|
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   0.1 -                      *    |:::|:::|:::|:::|    *
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            |:::|  ***        |:::|:::|:::|:::|:::|:::|:::|::***
   +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
      -4      -3      -2      -1       0       1       2       3       4
              Histogram of Standardized Residuals (105 residuals)
```

```
================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
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================================================================================

 ------------------------------------------------------------------------------
|                                                                              |
|                  S T A T I S T I C S     S U M M A R Y                       |
|                                                                              |
 ------------------------------------------------------------------------------
|                                  |                                           |
|     Residual Critical Value Type |               Tau Max                     |
|     Residual Critical Value      |                3.5083                     |
|     Number of Flagged Residuals  |                   0                       |
|     Convergence Criterion        |                0.0001                     |
|     Final Iteration Counter Value|                     4                     |
|     Confidence Level Used        |               95.0000                     |
|     Estimated Variance Factor    |                0.8849                     |
|     Number of Degrees of Freedom |                    57                     |
|                                  |                                           |
 ------------------------------------------------------------------------------
|                                                                              |
|                  Chi-Square Test on the Variance Factor:                     |
|                                                                              |
|                   6.3244e-01  <  1.0000  <  1.3264e+00  ?                    |
|                                                                              |
|                             THE TEST PASSES                                  |
|                                                                              |
 ------------------------------------------------------------------------------

 ------------------------------------------------------------------------------
|                                                                              |
| NOTE:  All confidence regions were computed using the following factors:     |
|        ------------------------------------------------------------------    |
|        Variance factor used      =          0.8849                          |
|        1-D expansion factor      =          1.9600                          |
|        2-D expansion factor      =          2.4477                          |
|        3-D expansion factor      =          2.7955                          |
|                                                                              |
|        Note that, for relative confidence regions, precisions are            |
|        computed from the ratio of the major semi-axis and the spatial        |
|        distance between the two stations.                                    |
|                                                                              |
 ------------------------------------------------------------------------------
```

```
================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0             GRS 80      UNITS: m,GRAD Page 0011
================================================================================
2-D and 1-D Station Confidence Regions (95.000 and 95.000 percent):
STATION            MAJOR SEMI-AXIS  AZ     MINOR SEMI-AXIS             VERTICAL
------------ ---------------------- --- ------------------- --------------------
D07                         0.0053  75              0.0036               0.0042
D30                         0.0055  75              0.0036               0.0042
D31                         0.0053  73              0.0036               0.0042
D32                         0.0054  77              0.0035               0.0042
DORIS_rep                   0.0071  75              0.0059               0.0056
G2                          0.0055  71              0.0036               0.0042
G202                        0.0054  73              0.0036               0.0042
G203                        0.0051  74              0.0036               0.0041
HARB                        0.0023  90              0.0023               0.0018
HBMB                        0.0054  74              0.0037               0.0042
HBMB_2GHz                   0.0054  74              0.0037               0.0042
HBMB_base                   0.0054  74              0.0037               0.0042
P403                        0.0161  77              0.0042               0.0154
P412                        0.0053  57              0.0023               0.0081
P418                        0.0054  87              0.0023               0.0062
```

```
================================================================================
                SANSA-SAC SOUTH AFRICA DORIS GNSS LOCAL SURVEY
Microsearch GeoLab, V2001.9.20.0            GRS 80      UNITS: m,GRAD Page 0012
================================================================================
3D Station Confidence Regions (95.000 percent):
```

STATION	MAJ-SEMI (AZ,VANG)	MED-SEMI (AZ,VANG)	MIN-SEMI (AZ,VANG)
D07	0.0061 (75, 0)	0.0061 (173, 90)	0.0042 (345, 0)
D30	0.0062 (75, 0)	0.0060 (169, 90)	0.0041 (345, 0)
D31	0.0060 (253, 0)	0.0059 (119, 90)	0.0041 (343, 0)
D32	0.0062 (77, 0)	0.0060 (190, 90)	0.0040 (347, 0)
DORIS_rep	0.0081 (75, 0)	0.0080 (173, 90)	0.0067 (345, 0)
G2	0.0063 (251, 0)	0.0060 (158, 90)	0.0042 (341, 0)
G202	0.0061 (253, 0)	0.0060 (128, 90)	0.0041 (343, 0)
G203	0.0059 (74, 0)	0.0059 (254, 90)	0.0041 (344, 0)
HARB	0.0026 (82, 0)	0.0026 (259, 90)	0.0026 (352, 0)
HBMB	0.0061 (254, 0)	0.0061 (153, 90)	0.0042 (344, 0)
HBMB_2GHz	0.0061 (254, 0)	0.0061 (153, 90)	0.0042 (344, 0)
HBMB_base	0.0061 (254, 0)	0.0061 (153, 90)	0.0042 (344, 0)
P403	0.0219 (129, 90)	0.0184 (257, 0)	0.0048 (347, 0)
P412	0.0115 (162, 90)	0.0061 (57, 0)	0.0026 (327, 0)
P418	0.0089 (166, 90)	0.0062 (267, 0)	0.0026 (357, 0)

```
Fri Jul 11 15:37:16 2014
```

6.10 SAC SINEX File

```
%=SNX 1.00 IGN 14:192:00000 IGN 14:058:00000 14:058:00000 C 00006
*------------------------------------------------------------------------------
+FILE/COMMENT
* File created by geotosnx software (Z.Altamimi)
* Original input file: SAC_2014.COV
* Matrix Scalling Factor used:         1.0000000000
-FILE/COMMENT
*------------------------------------------------------------------------------
+SITE/ID
*CODE PT __DOMES__ T _STATION DESCRIPTION__ APPROX_LON_ APPROX_LAT_ _APP_H_
 HBMB  A 30302S008   30302S008               27 42 26.8 -25 53 12.6  1559.6
 HARB  A 30302M009   30302M009               27 42 26.0 -25 53 13.0  1558.1
-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   HBMB  A    1 14:058:00000 m    2 0.508465342540000E+07 0.21111E-02
     2 STAY   HBMB  A    1 14:058:00000 m    2 0.267034758300000E+07 0.18993E-02
     3 STAZ   HBMB  A    1 14:058:00000 m    2 -.276847074030000E+07 0.19214E-02
     4 STAX   HARB  A    1 14:058:00000 m    2 0.508465761300000E+07 0.94068E-03
     5 STAY   HARB  A    1 14:058:00000 m    2 0.267032529200000E+07 0.94068E-03
     6 STAZ   HARB  A    1 14:058:00000 m    2 -.276848099200000E+07 0.94068E-03
-SOLUTION/ESTIMATE
*------------------------------------------------------------------------------
+SOLUTION/MATRIX_ESTIMATE L COVA
*PARA1 PARA2 ____PARA2+0__________ ____PARA2+1__________ ____PARA2+2__________
     1     1 0.445695050781811E-05
     2     1 0.549205360012704E-06 0.360725872389326E-05
     3     1 -.485667024977915E-06 0.113170190793498E-05 0.369186687174249E-05
     4     1 0.884888407542618E-06 0.672933207987838E-12 -.648387621287886E-13
     4     4 0.884888254947972E-06
     5     1 -.619157318924518E-12 0.884888215613146E-06 -.127571879599724E-11
     5     4 0.105271986694307E-15 0.884888254869508E-06
     6     1 -.646086114432704E-13 0.138628545976066E-11 0.884888305728679E-06
     6     4 -.119334235378055E-15 0.216925168811457E-15 0.884888254759982E-06
-SOLUTION/MATRIX_ESTIMATE L COVA
%ENDSNX
```

6.11 HartRAO Output File (Extract of COMP3D Adjustment Listing)

HartRAO computation 11

Configuration du chantier

Nom du chantier :	HartRAO computation 11
Description du chantier :	with matlab georef
Nom du fichier COR :	coord.cor
Nom du fichier OBS :	obs.obs
Unité angulaire :	1
Origine du chantier :	0.0000 | 0.0000
Nombre de chiffres :	4
Itérations après convergence :	10
Coefficient de réfraction :	0.12
Latitude moyenne :	-25.88975081
Type de calcul :	1

Informations sur le calcul

σ0 initial :	9.6750
itération :	9.67498921 1.03359288410551E34
itération :	1.06570967 8.07844747
itération :	1.06254446 0.00297889
itération :	Converge!
Itération :	1.06251473 0.00002798

itération :	1.06291163 -0.00037340
itération :	1.06310692 -0.00018370
itération :	1.06294779 0.00014971
itération :	1.06261855 0.00030984
itération :	1.06289193 -0.00025721
itération :	1.06238758 0.00047473
itération :	1.06335882 -0.00091337
itération :	1.06247863 0.00082843
itération :	1.06324481 -0.00072061
itération :	1.06249864 0.00070228
σ0 final :	1.0625
Nombre d'itérations :	14

Initialisation de la projection stéréographique

Ellipsoïde	**Désignation :**	Ellipsoïde International
	demi axe :	6378388
	e2 :	0.00672267
Données du chantier	**Latitude moy. :**	-25.8898 °
	Rayon calculé :	6365070.1349
Point origine : calculé	**X0 :**	0.0000
	Y0 :	0.0000

Données en entrée

Nombre de Points	: 192
Nombre de Mesures	: 1531
Nombre de Tours	: 118
Nombre de visées verticales	: 0
Nombre de Clichés	: 0
Nombre de Repères	: 4

Structuration de la matrice normale

Groupe :	192
Nb_groupe :	192

Rangement de la matrice normale

N_depart :	20

Nombre d'inconnues : 706

Taille de la matrice : 48611

Type de calcul

Inversion : FAUX

Avant compensation : FAUX

Juste propagation : FAUX

Contraintes internes : FAUX

Tirages Monte-Carlo : 0

Unité : mm

Coordonnées compensées 3D

dans le repère cartésien centré au point origine / Axe Z selon la verticale au point origine

Point	X	Y	Z	nb_rel	résidus moyens	
LLR_ref	-44.0234	192.3826	1410.3523	3	----	
SLR_ref	-50.2228	182.5206	1410.0003	3	----	
V15_ref	-241.4551	179.3322	1409.3798	3	----	
V26_ref	-128.5515	177.8037	1415.6794	3	----	
LLR_center	-44.0106	192.3756	1410.3508	63	0.10	
SLR_center	-50.3163	183.0119	1410.2486	51	0.05	
V15_center	-243.4465	182.6410	1414.6211	129	0.25	
V26_center	-128.5538	176.6561	1422.9408	153	0.59	
HRAO	30.4595	138.5219	1414.1438	5	0.00	HRAO IGS station (fixed version)
P1	-66.2332	227.7237	1409.7996	116	1.06	HRAO IGS station
P5	-149.9002	97.3604	1408.0325	161	0.97	HRAO IGS station
P6	-246.4417	212.2920	1401.7744	104	0.93	HRAO IGS station
P2	-40.3704	332.3990	1411.1110	6	1.80	Pier
P3	22.2124	246.6940	1413.6276	7	1.05	Pier
P4	30.3435	122.3443	1413.1678	74	0.82	Pier
P10	145.7259	217.9487	1425.2830	52	1.27	Pier
P11	-57.0270	200.3175	1408.8298	175	1.19	Pier
P12	317.7504	14.5206	1439.9245	43	1.04	Pier

Point	X	Y	Z	nb_rel	résidus moyens	
P13	-85.9855	143.2707	1405.8008	46	1.19	Pier
P13b	-85.9901	143.2626	1405.8003	116	0.70	Pier (bad centering) just for TM30 obs on 25/02
P17	86.3932	146.5355	1415.8283	10	1.81	Pier
P18	-79.9331	177.7753	1405.2214	26	1.30	Tripod
P19	-107.8676	188.9486	1402.3673	106	1.50	Tripod
P20	-181.1362	200.3525	1402.8902	171	0.70	Tripod
P21	-203.1565	228.8782	1401.6335	22	0.77	Tripod
P21b	-203.1567	228.8780	1401.7658	186	0.70	Tripod
P22	-241.8535	212.5632	1400.2063	56	1.16	Tripod
P23	-169.9504	149.2858	1402.8617	123	0.82	Tripod
P25	-159.0294	188.5273	1401.9828	23	0.95	Reference mark of 26m VLBI
P26	-77.5266	178.1711	1405.3331	30	1.95	Tripod
P27	-45.9190	185.6838	1408.3633	104	1.15	Tripod
P28	-43.6428	184.3876	1408.4306	112	0.99	Tripod
VB1	-2.5006	10.0022	1402.5475	6	1.16	Reference benchmark of 26m VLBI
TMOB6	76.0168	6.0013	1406.8641	6	0.52	Moblas side benchmark
BT12	306.0684	-107.0239	1422.3543	6	0.37	Temporary benchmark
B0	90.0199	-105.0232	1404.3311	13	0.60	Pier
B1	62.3145	49.9274	1407.1514	9	0.97	Pier
B2	88.1761	154.6029	1409.5560	7	0.69	Pier
B3	150.7594	68.8999	1411.4336	9	0.53	Pier
B4	158.8938	-55.4501	1412.2606	10	0.24	Pier
B5	-21.3503	-80.4379	1401.1709	8	0.70	Roof pier
B6	-117.8943	34.4933	1398.9790	7	0.78	Pier
B10	274.2748	40.1575	1424.4531	8	1.47	Pier
B11	71.5216	22.5206	1407.1403	11	0.85	Pier
B12	446.3006	-163.2740	1437.9177	5	0.32	Pier
B13	42.5630	-34.5258	1403.2376	9	0.80	Pier
B17	214.9430	-31.2571	1414.3408	7	1.54	Pier
G100	30.4595	138.5219	1414.3258	11	1.14	measured point, 0.182m above HRAO
GN	159.0085	-39.2730	1414.3244	4	0.07	Leveling north side of HRAO IGS station

Point	X	Y	Z	nb_rel	résidus moyens	
GS	159.0085	-39.2730	1414.3176	4	0.07	Leveling north side of HRAO IGS station
GE	159.0085	-39.2730	1414.3185	4	0.07	Leveling north side of HRAO IGS station
GW	159.0085	-39.2730	1414.3237	4	0.07	Leveling north side of HRAO IGS station
CP1	7.4016	3.8008	1408.8353	6	1.19	Confort point close to Moblas
SL	-50.2232	182.5200	1410.4859	29	1.57	Moblas top centering plate
SLCC	-50.2240	182.5237	1410.4856	5	0.46	Moblas top centering plate : NASA corner cube
OT1	77.0171	2.0004	1410.0187	4	0.42	Moblas top of 35.5mm ocular when centering plate is on top
OB1	77.0171	2.0004	1410.0170	4	0.42	Moblas top of 35.5mm ocular when centering plate is on bottom
SLM	-50.2160	182.5224	1406.7758	6	3.03	Moblas ground centering plate center (height or the top of the plate, the plate is centered on the original punchmark)
LL	-44.0233	192.3838	1409.4360	6	0.73	Prism on LLR vertical axis
LLM	-44.0280	192.3713	1407.4482	6	0.40	LLR ground centering plate center (height or the top of the plate, the plate is centered)
LLG	-44.0247	192.3823	1407.4497	4	0.10	LLR vertical axis projected on ground centering plate (height or the top of the plate)
V1999	-239.9118	180.1306	1403.5095	11	1.43	15m VLBI benchmark
V1011	-248.3631	188.1236	1408.8378	9	0.68	15m VLBI position 1 target 1
V1012	-248.2142	187.9222	1410.5689	9	0.63	15m VLBI position 1 target 2
V1013	-242.9746	187.2299	1409.4396	9	0.26	15m VLBI position 1 target 3
V1014	-246.6059	185.9892	1406.6614	9	0.33	15m VLBI position 1 target 4
V1015	-245.7806	184.9214	1413.1959	9	0.26	15m VLBI position 1 target 5
V1016	-242.9002	181.2111	1403.6789	9	0.64	15m VLBI position 1 target 6
V1021	-248.0238	187.6954	1412.6342	9	0.43	15m VLBI position 2 target 1
V1022	-247.4741	186.9813	1414.1338	9	0.46	15m VLBI position 2 target 2
V1023	-242.6860	186.8639	1411.6295	9	0.43	15m VLBI position 2 target 3

Point	X	Y	Z	nb_rel	résidus moyens	
V1024	-246.9211	186.3943	1409.5572	9	0.43	15m VLBI position 2 target 4
V1025	-244.5996	183.4157	1415.0590	9	0.35	15m VLBI position 2 target 5
V1026	-244.2203	182.8972	1404.4644	9	0.40	15m VLBI position 2 target 6
V1031	-246.5723	185.8464	1416.3131	9	0.49	15m VLBI position 3 target 1
V1032	-245.6740	184.6853	1417.2665	9	0.64	15m VLBI position 3 target 2
V1033	-241.7516	185.6725	1413.6801	9	0.35	15m VLBI position 3 target 3
V1034	-246.4071	185.7411	1412.8003	9	0.35	15m VLBI position 3 target 4
V1035	-242.8360	181.1645	1416.0903	9	0.27	15m VLBI position 3 target 5
V1036	-245.3600	184.3533	1406.2856	9	0.35	15m VLBI position 3 target 6
V1041	-244.4671	183.1612	1418.4774	9	0.48	15m VLBI position 4 target 1
V1042	-243.4072	181.7955	1418.7511	7	0.29	15m VLBI position 4 target 2
V1043	-240.4712	184.0394	1414.8077	9	0.39	15m VLBI position 4 target 3
V1044	-245.1934	184.1928	1415.1943	9	0.59	15m VLBI position 4 target 4
V1045	-241.1075	178.9577	1415.8355	9	0.42	15m VLBI position 4 target 5
V1046	-245.8763	185.0140	1408.5372	9	0.27	15m VLBI position 4 target 6
V1051	-242.8455	181.0915	1419.0551	9	0.13	15m VLBI position 5 target 1
V1052	-241.7821	179.7189	1418.8444	7	0.19	15m VLBI position 5 target 2
V1053	-239.5117	182.8160	1415.0398	9	0.64	15m VLBI position 5 target 3
V1054	-244.0989	182.7975	1416.2440	9	0.39	15m VLBI position 5 target 4
V1055	-240.0623	177.6224	1415.0388	9	0.50	15m VLBI position 5 target 5
V1056	-245.8831	185.0229	1410.1355	9	0.27	15m VLBI position 5 target 6
V1057	-242.4291	180.5818	1419.4065	9	0.59	15m VLBI position 5 target 7
V1058	-242.2827	180.3736	1419.4113	9	0.91	15m VLBI position 5 target 8
V1062	-241.8335	178.9937	1418.8440	9	0.18	15m VLBI position 6 target 2
V1067	-242.6760	178.3240	1419.4070	9	0.32	15m VLBI position 6 target 7
V1068	-242.4723	178.4764	1419.4114	9	0.79	15m VLBI position 6 target 8
V1071	-239.7719	180.8166	1419.0534	8	0.24	15m VLBI position 7 target 1
V1077	-240.2607	180.3721	1419.4064	9	0.80	15m VLBI position 7 target 7
V1078	-240.4601	180.2143	1419.4129	9	0.61	15m VLBI position 7 target 8
V1081	-240.1368	177.5144	1419.0543	7	0.55	15m VLBI position 8 target 1
V1082	-241.1436	178.9289	1418.8448	8	0.61	15m VLBI position 8 target 2
V1087	-240.5333	178.0415	1419.4066	9	1.02	15m VLBI position 8 target 7
V1088	-240.6707	178.2556	1419.4112	9	0.96	15m VLBI position 8 target 8
V2101	-107.2150	179.1598	1423.6745	7	1.40	26m VLBI target
V2102	-107.1491	179.0567	1423.4571	7	1.12	26m VLBI target

Point	X	Y	Z	nb_rel	résidus moyens	
V2103	-118.5333	166.7895	1425.1246	9	0.97	26m VLBI target
V2104	-124.3445	180.8966	1422.8578	7	0.50	26m VLBI target
V2105	-120.3800	175.9986	1412.7452	7	0.28	26m VLBI target
V2106	-133.8049	179.7572	1419.9096	9	0.75	26m VLBI target
V2108	-134.3927	177.1259	1414.6548	9	0.69	26m VLBI target
V2201	-115.7320	183.9354	1433.5430	7	0.78	26m VLBI target
V2202	-115.5369	183.8678	1433.3993	7	0.79	26m VLBI target
V2203	-122.5605	169.0289	1429.7500	9	0.78	26m VLBI target
V2204	-129.6745	181.3288	1423.7498	7	0.35	26m VLBI target
V2205	-119.9111	178.3471	1417.5982	9	0.71	26m VLBI target
V2206	-135.5336	178.0476	1416.3757	9	0.73	26m VLBI target
V2208	-132.5935	175.7442	1411.8010	9	0.56	26m VLBI target
V2301	-141.8042	183.8032	1433.2667	7	0.69	26m VLBI target
V2302	-141.5886	183.8608	1433.3827	7	0.79	26m VLBI target
V2303	-134.8179	168.9456	1429.5768	9	0.64	26m VLBI target
V2304	-137.2070	178.3430	1417.5844	9	0.87	26m VLBI target
V2305	-127.4464	181.3238	1423.7448	7	0.69	26m VLBI target
V2307	-121.7172	178.4272	1417.1457	9	1.11	26m VLBI target
V2308	-125.8054	175.3483	1410.9832	7	0.36	26m VLBI target
V2401	-149.9889	179.0412	1423.4187	7	1.00	26m VLBI target
V2402	-149.8879	179.1407	1423.6237	7	0.99	26m VLBI target
V2403	-138.6505	166.6978	1424.9331	9	1.07	26m VLBI target
V2404	-136.7591	176.0243	1412.7987	9	1.54	26m VLBI target
V2406	-127.4463	174.7047	1409.4748	7	1.35	26m VLBI target
V2407	-123.8671	180.0097	1420.4157	9	1.00	26m VLBI target
V2408	-123.2637	176.4507	1413.2619	9	0.93	26m VLBI target
V2501	-128.8202	185.6609	1437.1067	7	0.53	26m VLBI target
V2502	-128.5701	185.6544	1437.0908	7	0.58	26m VLBI target
V2503	-128.7225	169.8295	1431.4036	9	0.42	26m VLBI target
V2504	-134.5229	180.3537	1421.7359	7	0.60	26m VLBI target
V2505	-122.6028	180.3534	1421.7421	7	0.81	26m VLBI target
V2506	-134.6901	176.2435	1412.6508	9	0.65	26m VLBI target
V2507	-122.0421	176.5934	1413.3575	9	0.88	26m VLBI target
V2508	-129.3425	175.0798	1410.4289	7	0.32	26m VLBI target
V2601	-128.8154	172.6172	1435.7030	7	1.02	26m VLBI target

Point	X	Y	Z	nb_rel	résidus moyens	
V2602	-128.5649	172.6250	1435.6874	9	0.89	26m VLBI target
V2603	-128.7123	166.2223	1420.1378	9	0.96	26m VLBI target
V2609	-128.5050	175.2073	1418.5043	9	0.38	26m VLBI target
V2701	-128.8103	166.7040	1429.7808	7	0.51	26m VLBI target
V2702	-128.5601	166.7190	1429.7709	9	0.65	26m VLBI target
V2703	-128.7084	168.9450	1413.1024	9	0.47	26m VLBI target
V2803	-128.7217	179.6222	1436.2438	7	0.60	26m VLBI target
V2811	-128.5174	175.3866	1423.1780	9	0.25	26m VLBI target
V2813	-128.5091	177.6921	1427.3156	9	0.59	26m VLBI target
V2903	-128.7195	172.2298	1433.5615	7	0.43	26m VLBI target
V2910	-128.6034	186.1178	1418.4225	9	0.89	26m VLBI target
V2911	-128.5164	175.3954	1420.1953	7	0.08	26m VLBI target
V2913	-128.5072	175.2201	1424.9296	9	0.26	26m VLBI target
SL101	-50.6693	182.4510	1410.5902	9	0.70	SLR target
SL102	-50.2325	182.8018	1410.7032	9	0.90	SLR target
SL103	-50.9701	183.0048	1410.2584	9	1.39	SLR target
SL104	-50.0571	182.9727	1410.6221	9	0.43	SLR target
SL201	-50.4802	182.7278	1410.6663	9	0.31	SLR target
SL202	-50.0519	183.0660	1410.4978	9	0.41	SLR target
SL203	-50.8956	183.1151	1410.2348	9	0.97	SLR target
SL204	-49.9175	183.1784	1410.3067	9	0.71	SLR target
SL205	-51.1300	183.1415	1410.0018	4	2.16	SLR target (photogrammetry)
SL301	-50.2900	183.0057	1410.5595	9	0.48	SLR target
SL302	-49.9518	183.2118	1410.1479	9	0.63	SLR target
SL303	-50.8362	183.2002	1410.1466	9	1.34	SLR target
SL304	-49.8869	183.2255	1409.8978	9	1.36	SLR target
SL401	-50.1582	183.1989	1410.2972	9	0.28	SLR target
SL402	-49.9672	183.1920	1409.7588	9	1.26	SLR target
SL403	-50.8135	183.2381	1410.0189	9	1.02	SLR target
SL404	-49.9767	183.0914	1409.5196	6	0.07	SLR target ** recalcule par rayonnement
SL405	-51.1288	183.1385	1410.0015	4	1.68	SLR target (photogrammetry)
L11	-44.2411	192.8599	1410.8859	9	0.25	LLR target
L12	-43.7468	191.8914	1409.7901	9	0.61	LLR target
L13	-43.6462	192.3615	1410.3532	9	0.39	LLR target

Point	X	Y	Z	nb_rel	résidus moyens	
L14	-44.4056	192.4189	1410.3385	9	0.48	LLR target
L21	-44.2228	193.0843	1410.5107	9	0.50	LLR target
L22	-43.7665	191.6471	1410.1766	9	0.71	LLR target
L23	-43.6463	192.3587	1410.3480	9	0.46	LLR target
L24	-44.4059	192.4109	1410.3382	9	0.57	LLR target
L31	-44.2308	192.9734	1409.9411	9	0.52	LLR target
L32	-43.7571	191.7562	1410.7736	9	0.70	LLR target
L33	-43.6469	192.3524	1410.3440	9	0.70	LLR target
L34	-44.4062	192.4005	1410.3447	9	0.44	LLR target
L41	-44.2487	192.7592	1409.7448	9	0.53	LLR target
L42	-43.7377	191.9773	1410.9792	9	0.90	LLR target
L43	-43.6476	192.3470	1410.3442	9	0.40	LLR target
L44	-44.4063	192.3975	1410.3506	9	0.43	LLR target
L51	-44.3122	191.9790	1409.7917	9	0.63	LLR target
L52	-43.6715	192.7815	1410.9417	6	0.06	LLR target
L53	-43.6477	192.3418	1410.3546	9	0.38	LLR target
L54	-44.4052	192.4064	1410.3639	9	0.55	LLR target

Adjusted 3D coordinates

(in a Cartesian geocentric coordinate system)

Name	X	Y	Z
LLR ref	5085404.8558	2668339.4016	-2768681.2726
SLR ref	5085403.6428	2668331.7642	-2768689.9912
V15 ref	5085490.7707	2668161.5223	-2768692.5919
V26 ref	5085442.7381	2668263.8213	-2768696.7157
LLR center	5085404.8460	2668339.4108	-2768681.2783
SLR center	5085404.0739	2668331.8848	-2768689.6577
V15 center	5085497.1507	2668162.6211	-2768691.9038
V26 center	5085448.0799	2668266.6219	-2768700.9189
HRAO	5085352.4427	2668396.0141	-2768731.3817
P1	5085428.4000	2668326.6735	-2768649.2375
P5	5085415.4622	2668225.4010	-2768765.7467
P6	5085499.7731	2668160.6140	-2768659.6194
P2	5085457.9008	2668371.3586	-2768555.6403
P3	5085397.6886	2668410.4405	-2768633.8411
P4	5085345.4639	2668392.2215	-2768745.5096
P10	5085338.4692	2668518.8519	-2768664.7886
P11	5085412.7531	2668328.8602	-2768673.4696
P12	5085191.5464	2668636.0300	-2768854.1897
P13	5085401.7381	2668290.3782	-2768723.4687
P13b	5085401.7367	2668290.3723	-2768723.4758
P17	5085330.8938	2668447.8731	-2768724.9070
P18	5085411.8057	2668302.4954	-2768692.1741
P19	5085426.8319	2668278.8331	-2768680.8765
P20	5085465.7017	2668216.4861	-2768670.8466
P21	5085485.9617	2668202.2489	-2768644.6357
P21b	5085486.0672	2668202.3040	-2768644.6935
P22	5085496.4969	2668164.0764	-2768658.6906
P23	5085440.7364	2668216.0193	-2768716.7754
P25	5085450.1348	2668233.2833	-2768681.0884
P26	5085410.9296	2668304.7534	-2768691.8667
P27	5085401.5620	2668335.5326	-2768686.4307
P28	5085400.0568	2668337.3133	-2768687.6260
VB1	5085308.8269	2668335.9078	-2768841.9396
TMOB6	5085274.2360	2668406.4275	-2768847.4224
BT12	5085135.9819	2668593.6833	-2768955.8635

Name	X	Y	Z
B0	5085222,7836	2668395,2448	-2768946,1977
B1	5085297,8158	2668403,3255	-2768808,0307
B2	5085328,1881	2668448,4666	-2768714,9105
B3	5085267,4674	2668487,2822	-2768792,8306
B4	5085216,2662	2668469,6040	-2768905,0612
B5	5085281,5197	2668300,2934	-2768922,7019
B6	5085369,0708	2668237,2038	-2768818,3504
B10	5085209,3349	2668596,2662	-2768824,3710
B11	5085282,9319	2668405,9137	-2768832,6818
B12	5085061,4726	2668712,9528	-2769013,2613
B13	5085271,2212	2668367,0665	-2768882,2991
B17	5085201,2347	2668525,0130	-2768884,2036
G100	5085352,5877	2668396,0902	-2768731,4612
GN	5085224,1119	2668473,8501	-2768891,4088
GS	5085224,1065	2668473,8473	-2768891,4059
GE	5085224,1072	2668473,8477	-2768891,4062
GW	5085224,1113	2668473,8498	-2768891,4085
CP1	5085306,8371	2668346,0465	-2768850,2640
SL	5085404,0296	2668331,9667	-2768690,2037
SLCC	5085404,0311	2668331,9666	-2768690,2003
OT1	5085274,7373	2668407,8202	-2768852,3992
OB1	5085274,7359	2668407,8195	-2768852,3985
SLM	5085401,0716	2668330,4226	-2768688,5816
LL	5085404,1263	2668339,0189	-2768680,8714
LLM	5085402,5402	2668338,1812	-2768680,0147
LLG	5085402,5441	2668338,1870	-2768680,0054
V1999	5085485,6858	2668160,5970	-2768689,3105
V1011	5085496,9479	2668156,9622	-2768684,4463
V1012	5085498,1799	2668157,7768	-2768685,3834
V1013	5085494,5780	2668161,8039	-2768685,5131
V1014	5085493,5724	2668157,1754	-2768685,4163
V1015	5085497,9816	2668160,4211	-2768689,2300
V1016	5085487,6272	2668158,2407	-2768688,4124
V1021	5085499,6490	2668158,7627	-2768686,4892
V1022	5085500,3120	2668159,7315	-2768687,7865
V1023	5085496,0469	2668162,9007	-2768686,7985
V1024	5085496,1824	2668158,1889	-2768686,3162
V1025	5085498,3348	2668161,9402	-2768691,3981
V1026	5085489,5182	2668157,7422	-2768687,2386
V1031	5085501,1903	2668161,2108	-2768689,7590

Name	X	Y	Z
V1032	5085501,0835	2668162,1692	-2768691,2199
V1033	5085496,7857	2668164,3436	-2768688,7657
V1034	5085498,2745	2668159,8673	-2768688,3199
V1035	5085497,4664	2668163,4763	-2768693,8736
V1036	5085492,0616	2668157,7897	-2768686,7238
V1041	5085500,8980	2668163,4349	-2768693,1198
V1042	5085500,0955	2668164,2108	-2768694,4678
V1043	5085496,4575	2668165,6174	-2768690,7273
V1044	5085499,0190	2668161,6286	-2768690,7581
V1045	5085495,6071	2668164,4527	-2768695,7477
V1046	5085494,3506	2668158,4077	-2768687,1126
V1051	5085499,8045	2668164,6924	-2768695,2339
V1052	5085498,6119	2668165,2675	-2768696,3767
V1053	5085495,7236	2668166,3159	-2768691,9291
V1054	5085498,8072	2668162,7535	-2768692,4717
V1055	5085493,9705	2668164,7743	-2768696,6011
V1056	5085495,6305	2668159,0716	-2768687,8024
V1057	5085499,6939	2668165,1046	-2768695,8458
V1058	5085499,5492	2668165,1941	-2768696,0352
V1062	5085498,3550	2668165,0747	-2768697,0289
V1067	5085498,9360	2668164,4282	-2768697,8773
V1068	5085498,9038	2668164,6413	-2768697,7421
V1071	5085498,2687	2668167,3576	-2768695,4805
V1077	5085498,6052	2668166,9821	-2768696,0345
V1078	5085498,6420	2668166,7763	-2768696,1793
V1081	5085497,1622	2668166,3649	-2768698,4516
V1082	5085498,0100	2668165,6728	-2768697,0876
V1087	5085497,8309	2668166,2680	-2768698,1313
V1088	5085497,9812	2668166,1917	-2768697,9406
V2101	5085439,7176	2668286,3320	-2768698,9864
V2102	5085439,4739	2668286,2785	-2768698,9843
V2103	5085441,3487	2668274,4062	-2768710,7485
V2104	5085447,6976	2668271,1748	-2768697,0677
V2105	5085435,9058	2668269,4644	-2768697,0583
V2106	5085449,3042	2668261,3341	-2768696,8055
V2108	5085444,3738	2668258,0832	-2768696,8783
V2201	5085453,3829	2668283,8842	-2768698,9993
V2202	5085453,1516	2668283,9832	-2768698,9974
V2203	5085447,7705	2668273,2279	-2768710,7536
V2204	5085451,0519	2668266,9156	-2768697,0683

Name	X	Y	Z
V2205	5085440,4620	2668272,3847	-2768697,0646
V2206	5085446,6312	2668257,9792	-2768696,8006
V2208	5085440,7302	2668258,2031	-2768696,8752
V2301	5085465,2260	2668260,6550	-2768698,9980
V2302	5085465,2404	2668260,9061	-2768698,9969
V2303	5085453,2956	2668262,2847	-2768710,7532
V2304	5085448,4858	2668257,0626	-2768697,0626
V2305	5085450,0107	2668268,8855	-2768697,0707
V2307	5085440,9717	2668270,6125	-2768696,7950
V2308	5085436,7716	2668263,7918	-2768696,8741
V2401	5085459,3426	2668248,3248	-2768698,9822
V2402	5085459,4974	2668248,5201	-2768698,9822
V2403	5085450,5080	2668256,4939	-2768710,7477
V2404	5085443,5688	2668254,9884	-2768697,0589
V2406	5085436,0836	2668261,5777	-2768696,7945
V2407	5085445,1875	2668270,3968	-2768696,7991
V2408	5085437,8321	2668267,2187	-2768696,8773
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V2502	5085462,8390	2668274,3479	-2768699,0021
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V2507	5085437,3959	2668268,3693	-2768696,7906
V2508	5085437,8697	2668260,3735	-2768696,8738
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V2602	5085456,6807	2668271,1226	-2768710,1110
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V2609	5085443,9629	2668264,5166	-2768700,2850
V2701	5085449,8000	2668267,2350	-2768712,8587
V2702	5085449,6816	2668267,4554	-2768712,8410
V2703	5085437,3328	2668260,8080	-2768703,5601
V2803	5085459,9022	2668272,6358	-2768704,0592
V2811	5085447,7611	2668266,4957	-2768702,1646
V2813	5085451,9448	2668268,7004	-2768701,8970
V2903	5085454,9062	2668270,0168	-2768709,5383
V2910	5085448,1621	2668266,6087	-2768690,4338
V2911	5085445,3880	2668265,2516	-2768700,8542
V2913	5085449,0874	2668267,2031	-2768703,0792
SL101	5085404,2932	2668331,6012	-2768690,3114

Name	X	Y	Z
SL102	5085404.3160	2668332.1064	-2768690.0451
SL103	5085404.3827	2668331.3085	-2768689.6682
SL104	5085404.2359	2668332.2625	-2768689.8560
SL201	5085404.3730	2668331.8566	-2768690.0957
SL202	5085404.1705	2668332.2341	-2768689.7178
SL203	5085404.3721	2668331.3870	-2768689.5587
SL204	5085403.9993	2668332.2960	-2768689.5332
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SL301	5085404.3070	2668332.0368	-2768689.7989
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SL303	5085404.3071	2668331.4200	-2768689.4437
SL304	5085403.6776	2668332.1617	-2768689.3123
SL401	5085404.1115	2668332.0831	-2768689.5107
SL402	5085403.5912	2668332.0257	-2768689.2818
SL403	5085404.2094	2668331.3944	-2768689.3539
SL404	5085403.3661	2668331.8970	-2768689.2677
SL405	5085404.3036	2668331.0877	-2768689.4358
L11	5085405.5666	2668339.5286	-2768681.0762
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L22	5085404.3121	2668339.4064	-2768681.8576
L23	5085404.6679	2668339.7288	-2768681.2923
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L31	5085404.8530	2668339.1659	-2768680.5616
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L42	5085405.0658	2668339.8344	-2768681.9109
L43	5085404.6610	2668339.7237	-2768681.3011
L44	5085405.0382	2668339.0648	-2768681.2584
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6.12 HartRAO SINEX File

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* File created by geotosnx software (Z.Altamimi)
* Original input file: hrao2014.cov
* Matrix Scalling Factor used:         1.0000000000
-FILE/COMMENT
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 7501  A 30302M003   30302M003              27 41 10.2 -25 53 22.9  1406.8
 7378  A 30302S009   30302S009              27 41 03.3 -25 53 23.0  1409.4
 7232  A 30302S001   30302S001              27 41 07.4 -25 53 23.0  1415.7
 HRAO  A 30302M004   30302M004              27 41 13.1 -25 53 24.3  1414.1
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     3 STAZ   LLRn  A    1 14:058:00000 m    2 -.276868127250000E+07 0.23768E-02
     4 STAX   7501  A    1 14:058:00000 m    2 0.508540107160000E+07 0.10008E-02
     5 STAY   7501  A    1 14:058:00000 m    2 0.266833042260000E+07 0.15251E-02
     6 STAZ   7501  A    1 14:058:00000 m    2 -.276868858160000E+07 0.22737E-02
     7 STAX   7378  A    1 14:058:00000 m    2 0.508549077060000E+07 0.23642E-02
     8 STAY   7378  A    1 14:058:00000 m    2 0.266816152220000E+07 0.24115E-02
     9 STAZ   7378  A    1 14:058:00000 m    2 -.276869259190000E+07 0.61735E-02
    10 STAX   7232  A    1 14:058:00000 m    2 0.508544273800000E+07 0.17312E-02
    11 STAY   7232  A    1 14:058:00000 m    2 0.266826382130000E+07 0.20530E-02
    12 STAZ   7232  A    1 14:058:00000 m    2 -.276869671570000E+07 0.39056E-02
    13 STAX   HRAO  A    1 14:058:00000 m    2 0.508535244270000E+07 0.10000E-04
    14 STAY   HRAO  A    1 14:058:00000 m    2 0.266839601410000E+07 0.10000E-04
    15 STAZ   HRAO  A    1 14:058:00000 m    2 -.276873138170000E+07 0.10000E-04
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*------------------------------------------------------------------------------
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     2     1 0.437458759716702E-06 0.379566069876247E-05
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     4     4 0.100151470263764E-05
     5     1 0.417369022922606E-06 0.247254438951616E-05 0.260000000000000E-05
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     6     1 0.839155987943013E-06 0.310317455973677E-05 0.481021366671357E-05
     6     4 0.116921684446655E-05 0.276594205487220E-05 0.516958731046222E-05
     7     1 0.983333738475558E-06 0.352276577366331E-05 0.414405352990454E-05
     7     4 0.134565862134943E-05 0.313437452994644E-05 0.443058521590075E-05
     7     7 0.558953830560078E-05
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     8     4 0.880642346604091E-06 0.338974603324620E-05 0.434983091718257E-05
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     9     4 0.227759778613423E-05 0.846780974837138E-05 0.125212084147554E-04
     9     7 0.132468496752113E-04 0.137724072879750E-04 0.381116712354613E-04
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-SOLUTION/MATRIX_ESTIMATE L COVA
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