Assessment of the impact of the latest generation of ground antennas and beacons on DORIS station positioning quality

Guilhem Moreaux (CLS), Frank Lemoine (NASA),
Hugues Capdeville (CLS) and Jérôme Saunier (IGN)

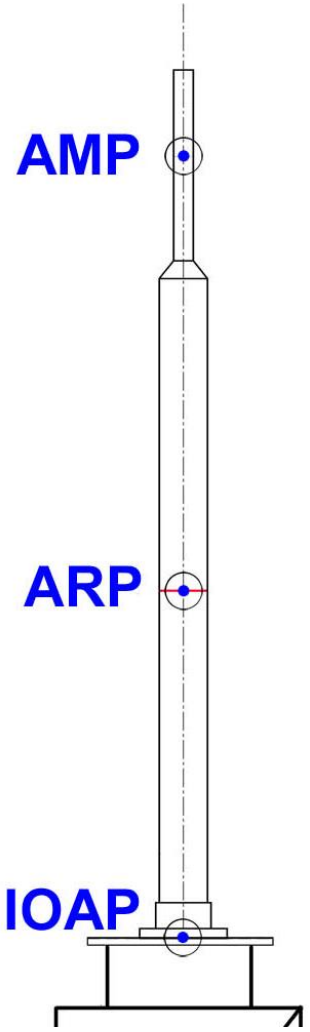
This work has been supported by CNES French Space Agency under contract 250097/24097

Antenna Position Error Budget

Three characteristic points used in measurements for a DORIS station:

- **ARP**: Antenna Reference Point = point to which the a priori coordinates of the station are assigned.
- **AMP**: Actual Measurement Point = electronic reference point from which Doppler measurements are taken.
- **IOAP**: Instrument Optical Measurement Point = point readily optically accessible for topometric measurements.

⇒ ***In data processing, the relative positions of theses points are known by definition.***



Error sources:

Manufacturing errors:

- AMP centering w.r.t. antenna radome.
- AMP position w.r.t. antenna base (IOAP).
- ARP-AMP alignment w.r.t. antenna axis.

Surveying errors:

- Antenna verticality adjustment.
- Local tie survey.

Strict manufacturing specifications => development of Starec-C antenna in 2014

- Saunier, J., Auriol, A., Tourain, C., 2016. Initiating an error budget of the DORIS ground antenna – genesis of the Starec antenna type C. Adv. Space Res. 58 (12), 2717–2724. https://doi.org/10.1016/j.asr.2016.02.013

The Starec-C DORIS ground antenna

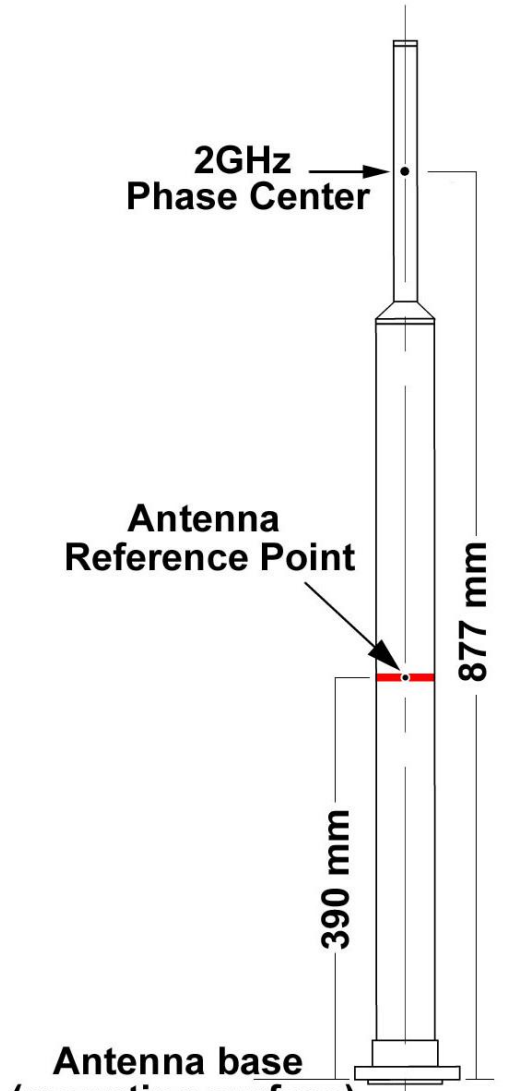
Work with the manufacturer to consolidate the antenna specifications

Main improvements:

- Alignment of the upper tube of the antenna radome w.r.t. the lower tube.
- Perpendicularity of the mounting base w.r.t. the antenna axis.
- Centering and perpendicularity of the cable connector to mount a surveying prism under the antenna.
- Positioning of the 2GHz radiating element with millimeter accuracy in the vertical direction w.r.t. ARP.
- Better control of the reproducibility of the antennas manufacturing.

Starec-C Error budget:

Error type	Error source	Direction	Error value (mm)
Manufacturing	AMP centering/radome	Horizontal	±1
Manufacturing	Alignment ARP-AMP/axis	Horizontal	±1
Manufacturing	AMP position/base	Vertical	±1
Characterization	2 GHz PC position and associated phase law	Vertical	±2
Surveying	Verticality adjustment	Horizontal	±1
Surveying	Local tie survey	H/V	±1



⇒ **uncertainties of the 2GHz PC position were significantly reduced:**
from 5 (Starec-B) to 2mm (Starec-C) in the vertical direction.

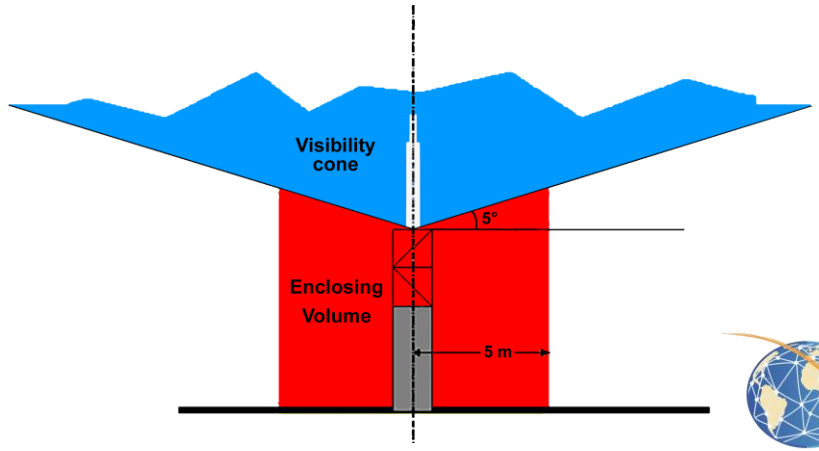
Other developments than can improve station performance

4th generation DORIS Beacon

- Manufactured with up-to-date electronics.
- Addition of a signal amplifier at the base of the antenna: nominal signal power.
- Larger distance (50 m cables instead of only 15 m) between beacon and antenna, providing better options for antenna placement.
- Higher autonomy.
- Deployment from 2019: 79% of the network stations already equipped (49 stations).

Antenna relocation

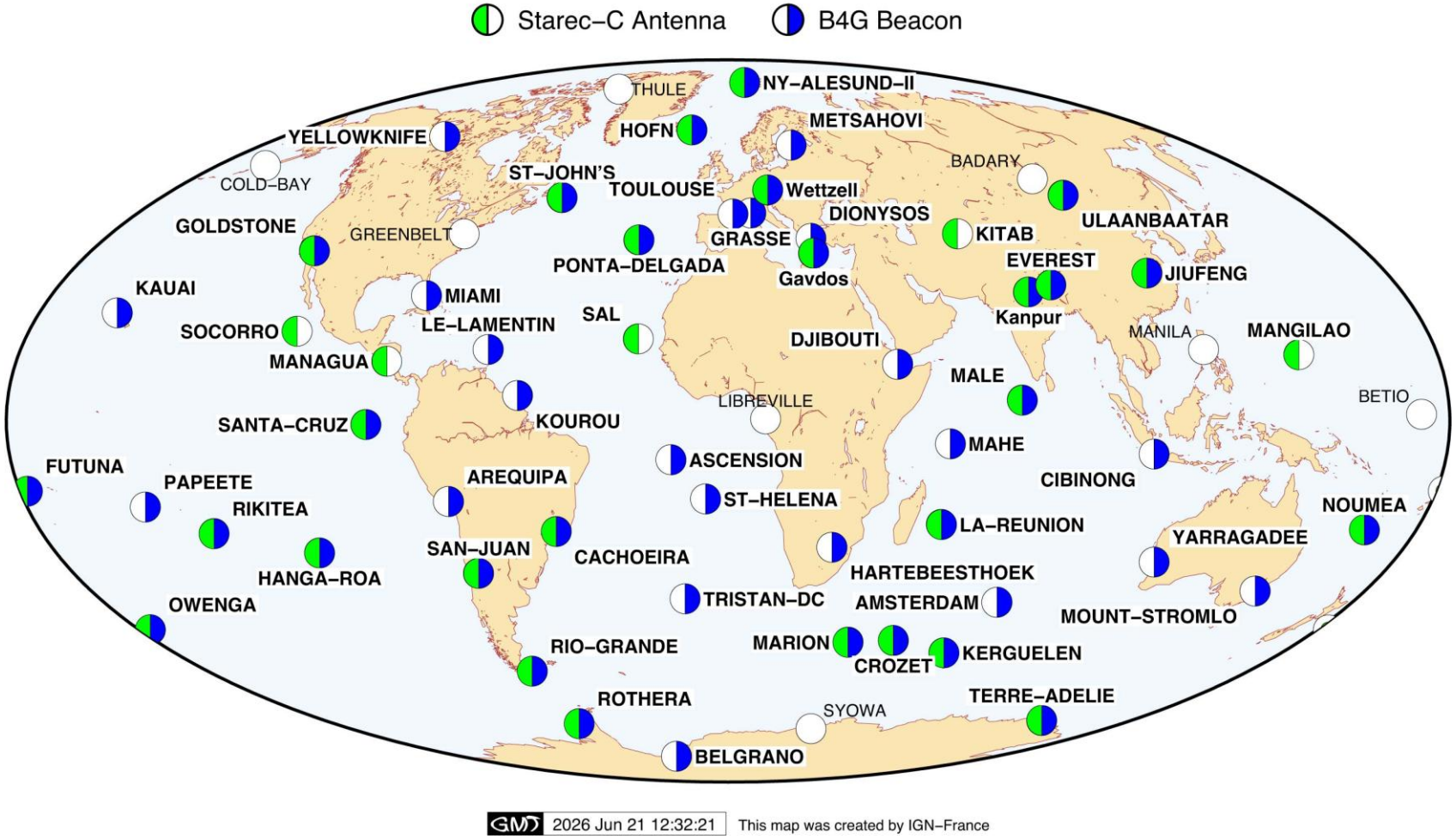
- Better visibility: reducing obtructions.
- Better RF environment: reducing multipath.
- Better stability: new antenna monument built to geodetic specifications.



Starec-C Antenna Deployment

The deployment and installation of Starec-C antennas began in 2014

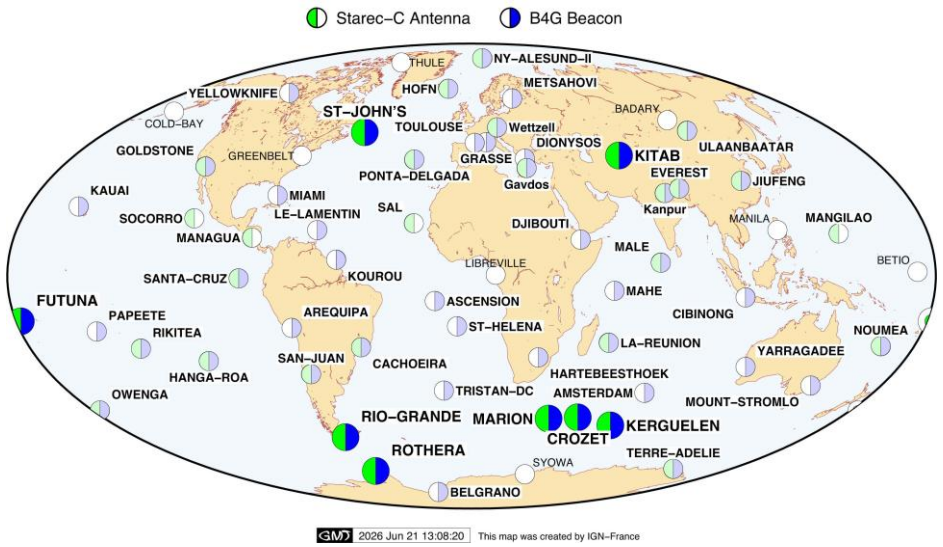
- Performed by IGN during the installation, renovation or maintenance of DORIS sites.
- Today, 33 out of 62 sites are equipped with Starec-C.



Starec-C Sites Selection

Selection criteria

- No antenna relocation.
- Enough data: time period > 2 years.
- No discontinuity according to DPOD2020 v6.0.

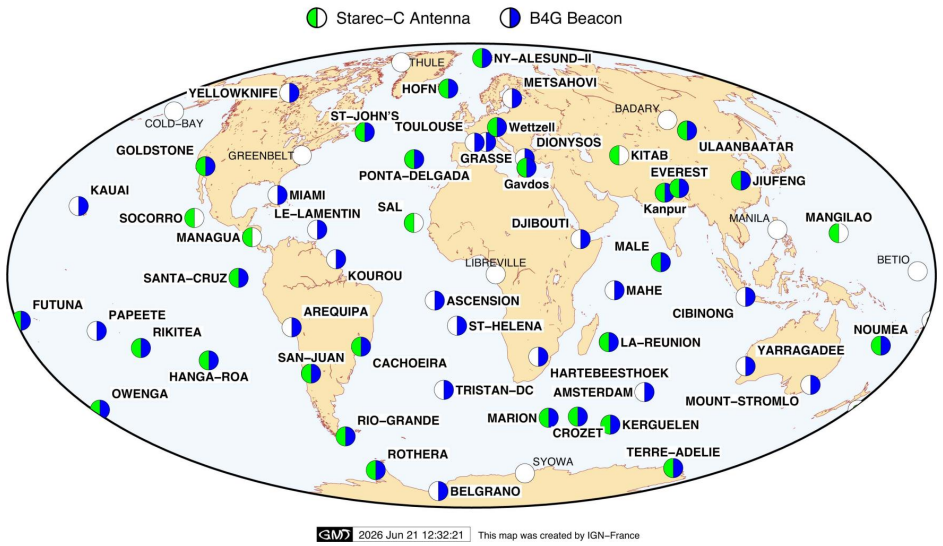


Site	Acronym	Beacon	DOMES ground mark	Antenna	Time period
Crozet	CRQB	2819014 (3.0)	91301M001	147 Starec-B	2009/03/27-2020/05/12
	CRQC	19054006I (4.0)	91301M001	192 Starec-C	2020/05/14-2024/02/02
Futuna	FUUB	2819056 (3.0)	92902M002	144 Starec-B	2012/05/17-2022/09/15
	FUUC	21204067I (4.0)	92902M002	201 Starec-C	2022/09/16-
Kerguelen	KETB	2819051 (3.0)	91201M006	146 Starec-B	2009/03/31-2014/03/24
	KEVC	1200093 (3.1)	91201M006	173 Starec-C	2016/05/15-2019/05/20
Marion	MAUB	3690069 (3.0)	30313M001	168 Starec-B	2014/04/16-2023/04/17
	MAVC	22154078I (4.0)	30313M001	210 Starec-C	2023/04/29-
Rio Grande	RIRB	2819037 (3.0)	41507M005	128 Starec-B	2012/03/29-2018/08/28
	RISC	3690072 (3.0)	41507M005	181 Starec-C	2018/08/28-
Rothera	ROVB	3690074 (3.0)	66007M002	136 Starec-B	2011/02/03-2015/01/10
	ROWC	3690074 (3.0)	66007M002	149 Starec-C	2015/01/10-2018/02/22
St-John's	STKB	2819047 (3.0)	40101M002	162 Starec-B	2016/07/26-2019/06/19
	STKC	19054004 (4.0)	40101M002	200 Starec-C	2019/06/25-

4G Beacon Sites Selection

Selection criteria

- No antenna relocation/change.
- Enough data: time period > 2 years.
- No discontinuity according to DPOD2020 v6.0.



Site	Acronym	Beacon	Antenna	Time period
Amsterdam	AMVB	2819021 (3.0)	145 Starec-B	2015/12/15-2020/12/08
		19474026I (4.0)		2020/12/09-
Dionysos	DIOB	3690081 (3.0)	129 Starec-B	2018/10/25-2021/03/05
		20094030I (4.0)		2021/03/06-
Mahé	MAIB	1200002 (3.2)	91 Starec-B	2018/11/22-2021/11/29
		19104020I (4.0)		2021/11/30-
Metsahovi	MEUB	2819018 (3.0)	143 Starec-B	2012/06/29-2021/08/10
		19104009I (4.0)		2021/08/11-
Miami	MIAB	2819057 (3.0)	112 Starec-B	2016/02/11-2020/03/13
		19104012I (4.0)		2020/03/14-
Yarragadee	YASB	2819034 (3.1)	57 Starec-B	2011/06/16-2020/12/17
		20094029I (4.0)		2020/12/18-

Data Selection

Selection citeria

- Single satellite solutions to avoid any impact of the time evolution of the DORIS constellation as in multi-satellite solutions.
- SAA free missions.
- Missions with data from 2013 to 2020 at least.

➔ Cryosat-2 and Saral

Cryosat-2 (707-727 km, 92°) since 2010/04/08 (DGXX)
Saral (706-772 km, 98.65°) since 2013/02/25 (DGXX)

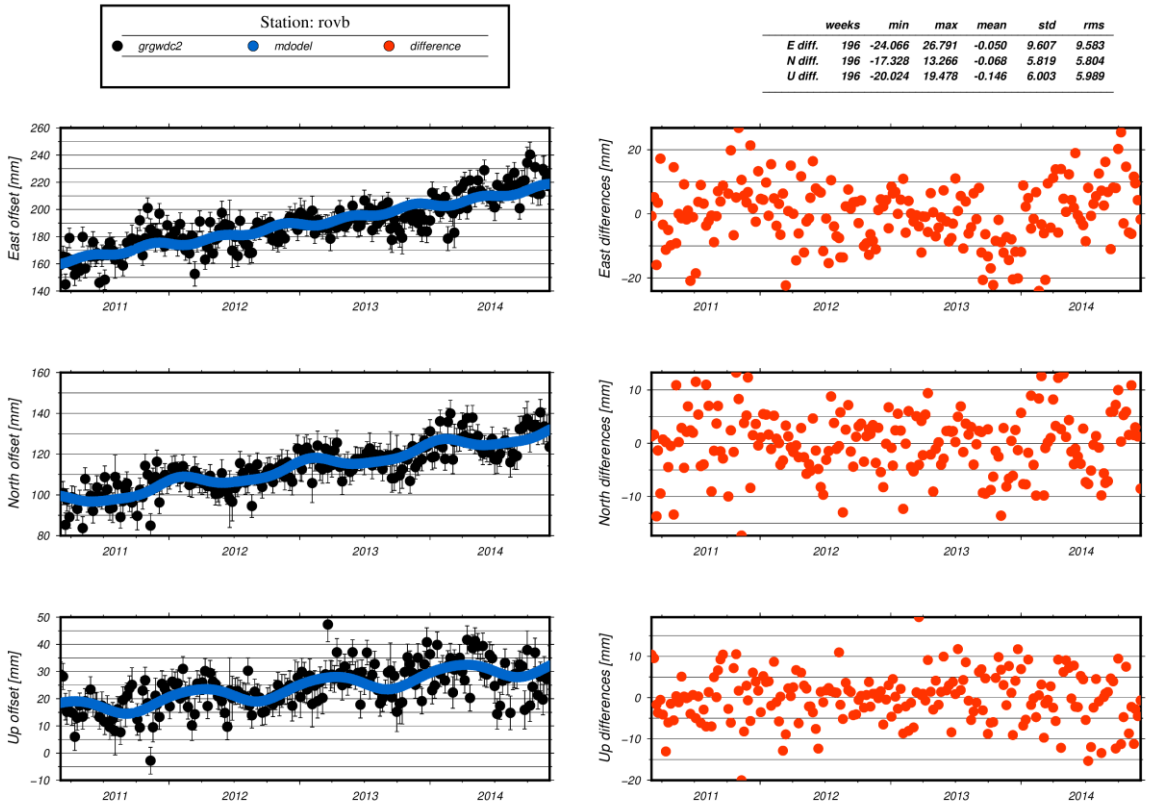
Data Processing/Analysis

- **Step 1: computation of DORIS station coordinate time series** (aligned onto ITRF2020-u2024) as done routinely done for the IDS AC and CC series.

- **Step 2: linear augmented modelization** (X=North, East, Up ; dt = decimal part of the time)

$$X(t) = a^X + b^X(t - t_0) + c_a^X \cos(2\pi dt) + s_a^X \sin(2\pi dt) + c_s^X \cos(4\pi dt) + s_s^X \sin(4\pi dt)$$

- **Step 3: computation of weekly station position residuals** (input – linear augmented model)



	weeks	min	max	mean	std	rms
E diff.	196	-24.066	26.791	-0.050	9.607	9.583
N diff.	196	-17.328	13.266	-0.068	5.819	5.804
U diff.	196	-20.024	19.478	-0.146	6.003	5.989

Preliminary Conclusions

- **Not easy to assess the impact of the Starec-C antennas as the upgrade of the ground antenna is very often coupled with a beacon change.**
- **Few sites (7) satisfy our selection citeria for the Starec-C study. Only 1 sites with antenna upgrade only.**
- **Six sites satisfy our selection citeria for the 4G beacon study.**
- **RMS of station position residuals from GRG Cryosat-2 and Saral single satellite solutions are at the order of the aposteriori errors.**

➔ **Multi-satellite combined solutions**

(GRG, GSC, GRG+GSC).

➔ **Cumulative solutions.**

➔ **Review analysis benchmarks.**