3rd Weather Radar Calibration and Monitoring Workshop
WXRCalMon2021
17 – 19 November 2021, Toulouse , France

THE ARGENTINIAN METEOROLOGICAL RADAR

SOLAR CALIBRATION AND MONITORING

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www.invap.com.ar/en/divisions/defense-security-and-environment/c-band-weather-radar/

SINARAME
Brief history of the RMA weather radar development

SINARAME
History of the RMA radar

Ministerio de Obras Públicas Argentina

Secretaría de Infraestructura y Política Hídrica

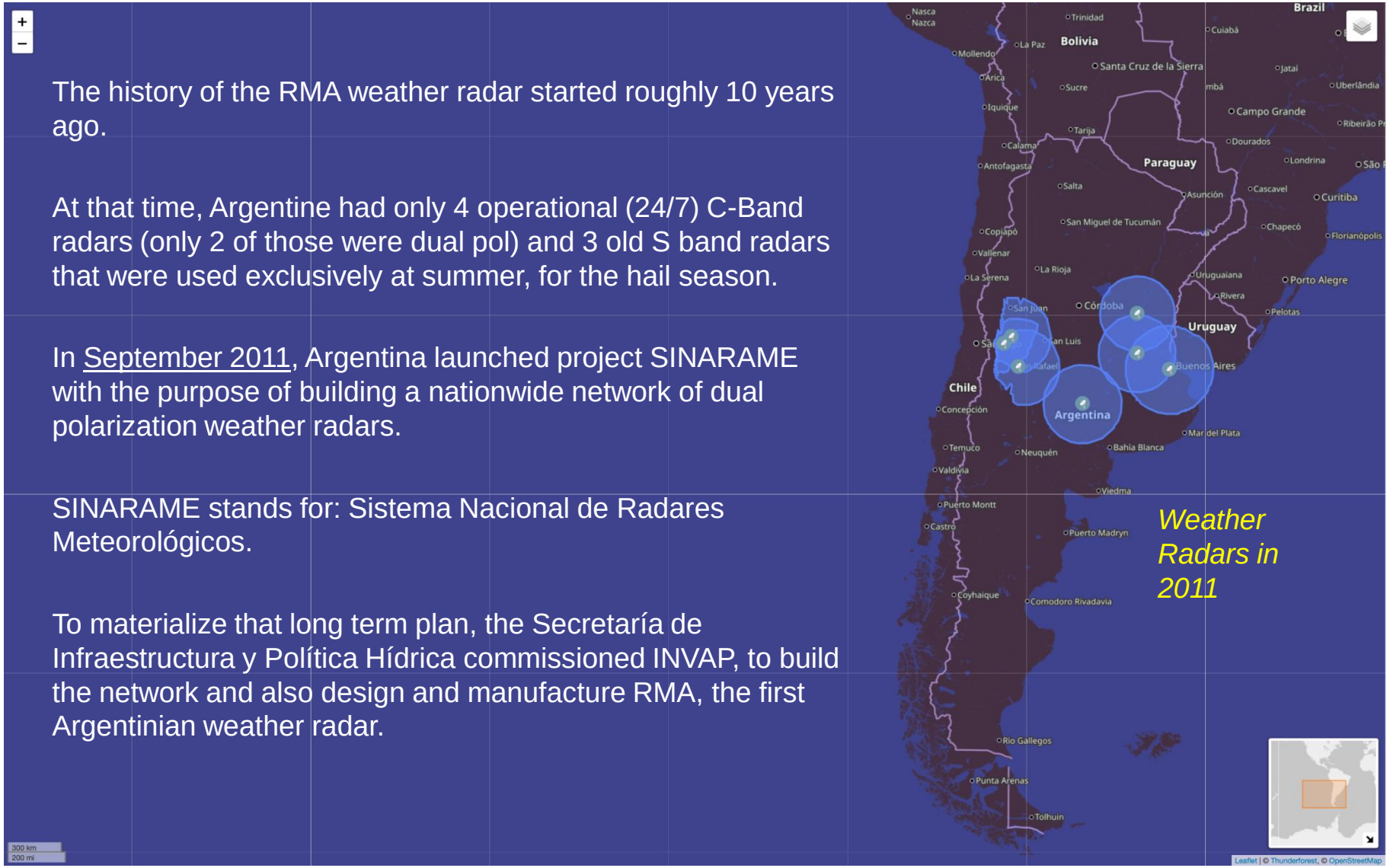
The history of the RMA weather radar started roughly 10 years ago.

At that time, Argentine had only 4 operational (24/7) C-Band radars (only 2 of those were dual pol) and 3 old S band radars that were used exclusively at summer, for the hail season.

In September 2011, Argentina launched project SINARAME with the purpose of building a nationwide network of dual polarization weather radars.

SINARAME stands for: Sistema Nacional de Radares Meteorológicos.

To materialize that long term plan, the Secretaría de Infraestructura y Política Hídrica commissioned INVAP, to build the network and also design and manufacture RMA, the first Argentinian weather radar.



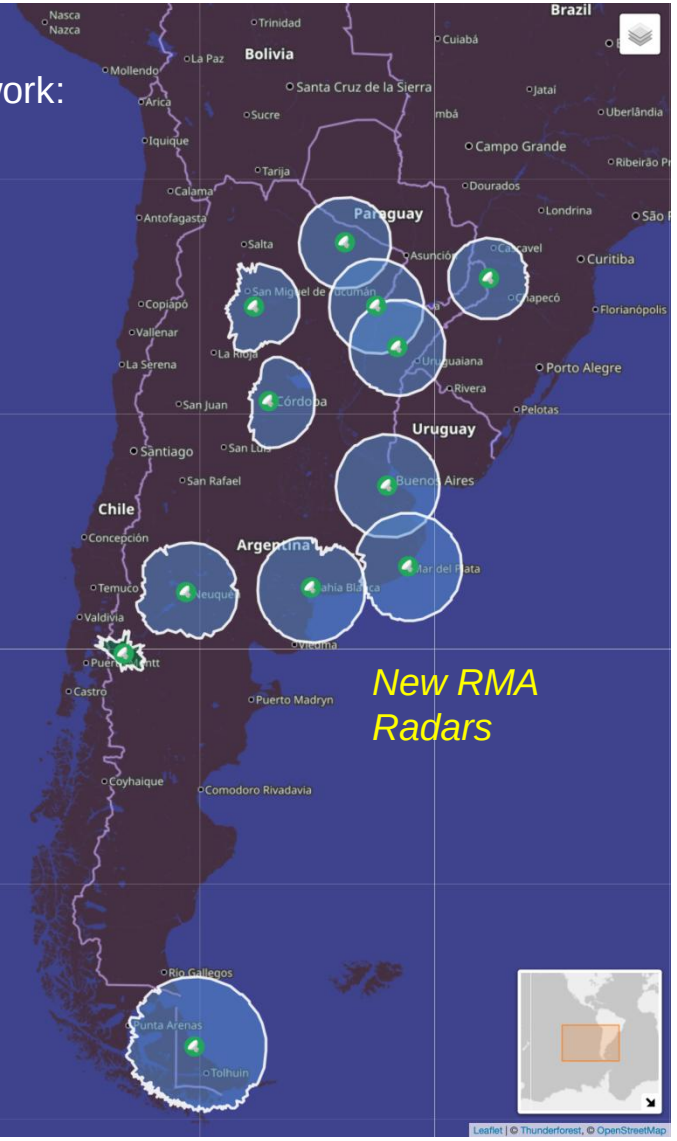
SINARAME
network of weather radars

Ministerio de Obras Públicas Argentina

Secretaría de Infraestructura y Política Hídrica

The complete list of RMA units connected to the SINARAME network:

- RMA 0 – BAR, Bariloche, Rio Negro
- RMA 1 – COR, Córdoba, Córdoba
- RMA 2 – EZE, Ezeiza, Buenos Aires
- RMA 3 – ITA, Las Lomitas, Formosa
- RMA 4 – SIS, Resistencia, Chaco
- RMA 5 – IRI, Bernardo de Irigoyen, Misiones
- RMA 6 – MDQ, Mar del Plata, Buenos Aires
- RMA 7 – NQN, Neuquén, Neuquén
- RMA 8 – MER, Mercedes, Corrientes
- RMA 9 – RGR, Rio Grande, Tierra del Fuego
- RMA10 – ESP, Bahía Blanca, Buenos Aires
- RMA11 – RHN, Termas de Río Hondo, Santiago del Estero



SINARAME
History ... (continuation)

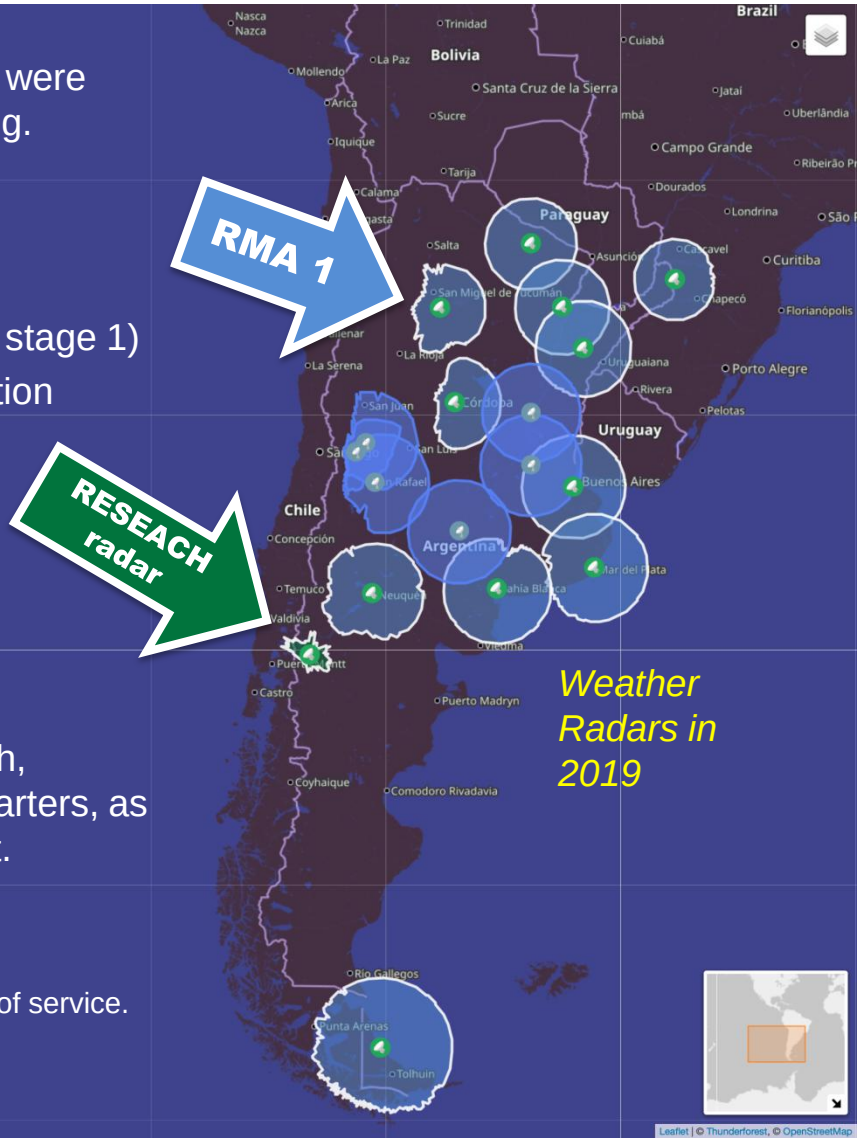
Ministerio de Obras Públicas Argentina

Secretaría de Infraestructura y Política Hídrica

By the first quarter of 2019, 12 new C band RMA units were connected to the network and running 24/7 all year long.

INVAP deliverables for SINARAME were:

- COP - the Center of OPerations (in Buenos Aires, stage 1)
- RMA1 - the first radar, model for the serial production (located in Córdoba, stage 1)
- 10 new RMA sites (stage 2)
- 53 new automatic weather stations (stage 2)

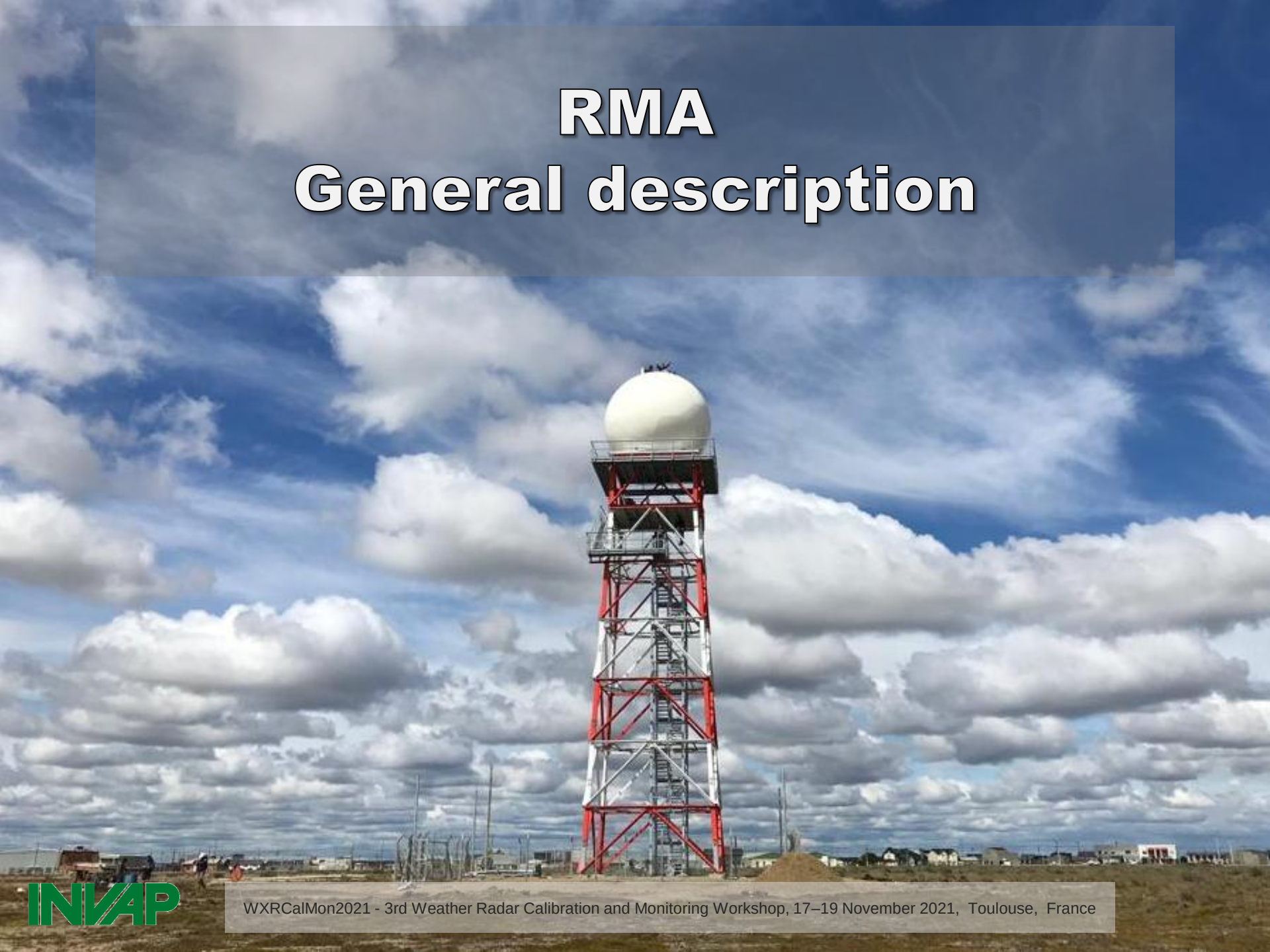


In Bariloche, INVAP maintains and operates a research, development & training radar, very close to its headquarters, as part of its process of continuous product improvement.

This site is known as RMA0

Note: one of the pre SINARAME C band dual pol radars was put out of service.

RMA
General description



RMA – General description

- RMA is a novel C-band, Doppler, dual polarization, simultaneous transmit and receive, magnetron based weather radar.

- Since its first conception it was meant to serve both as an operational radar and a research tool; for that reason it includes a development framework consisting of an embedded python interpreter with access to key internal radar state data, and a mechanism for the user to add new commands to the radar control unit in the form of python scripts.

- Above this framework, a solar calibration semi-automated procedure was implemented as a minimal set of python commands, with the goals of making the code readily available to extend and also being easily user auditable.

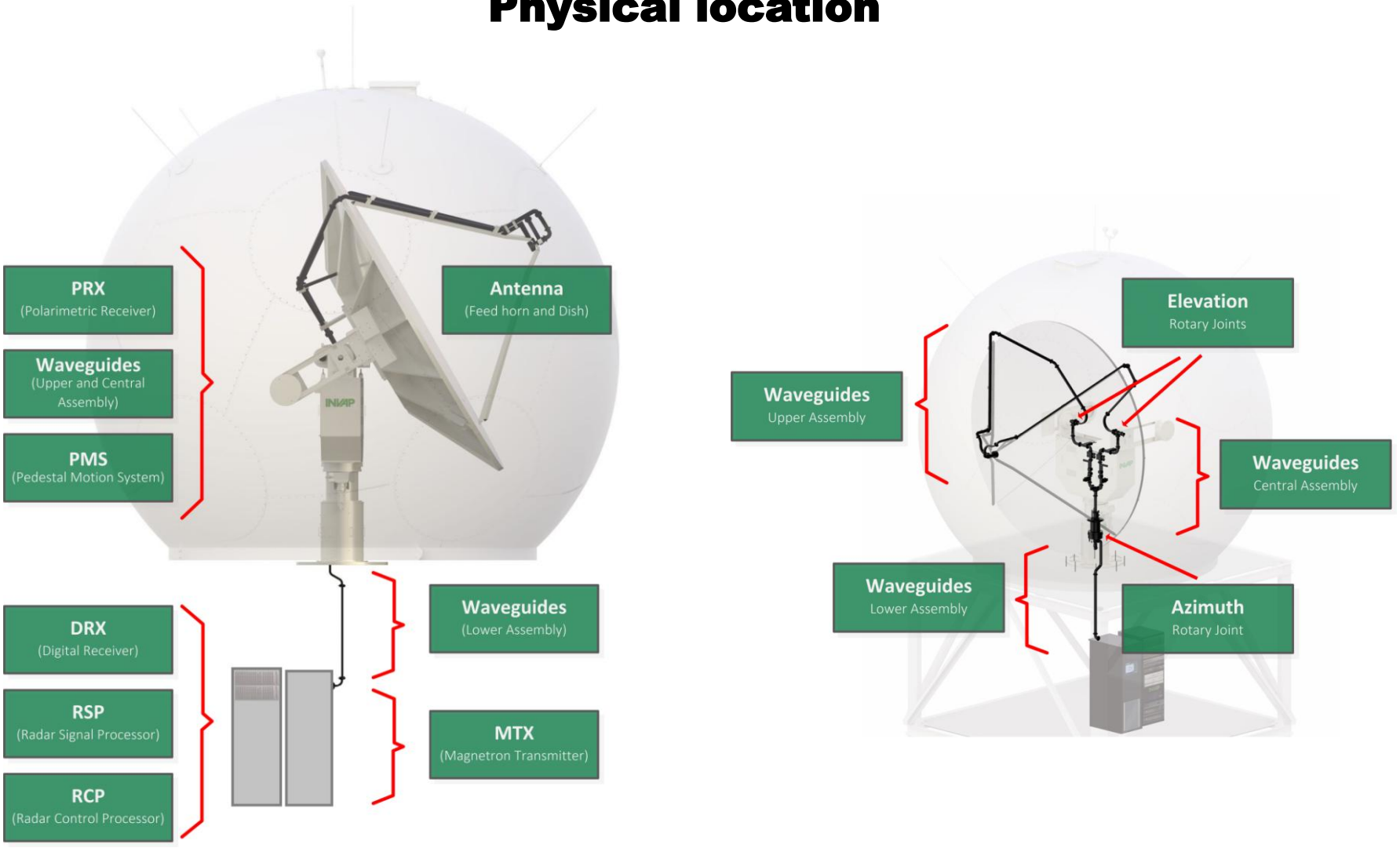
- As a result of this implementation, the radar delivers not only pointing calibration parameters: azimuth and elevation offsets but also a set of plots that aids in the assessment of the quality of the data used for calibration and some extra useful parameters for monitoring the health of the radar receiving chain.

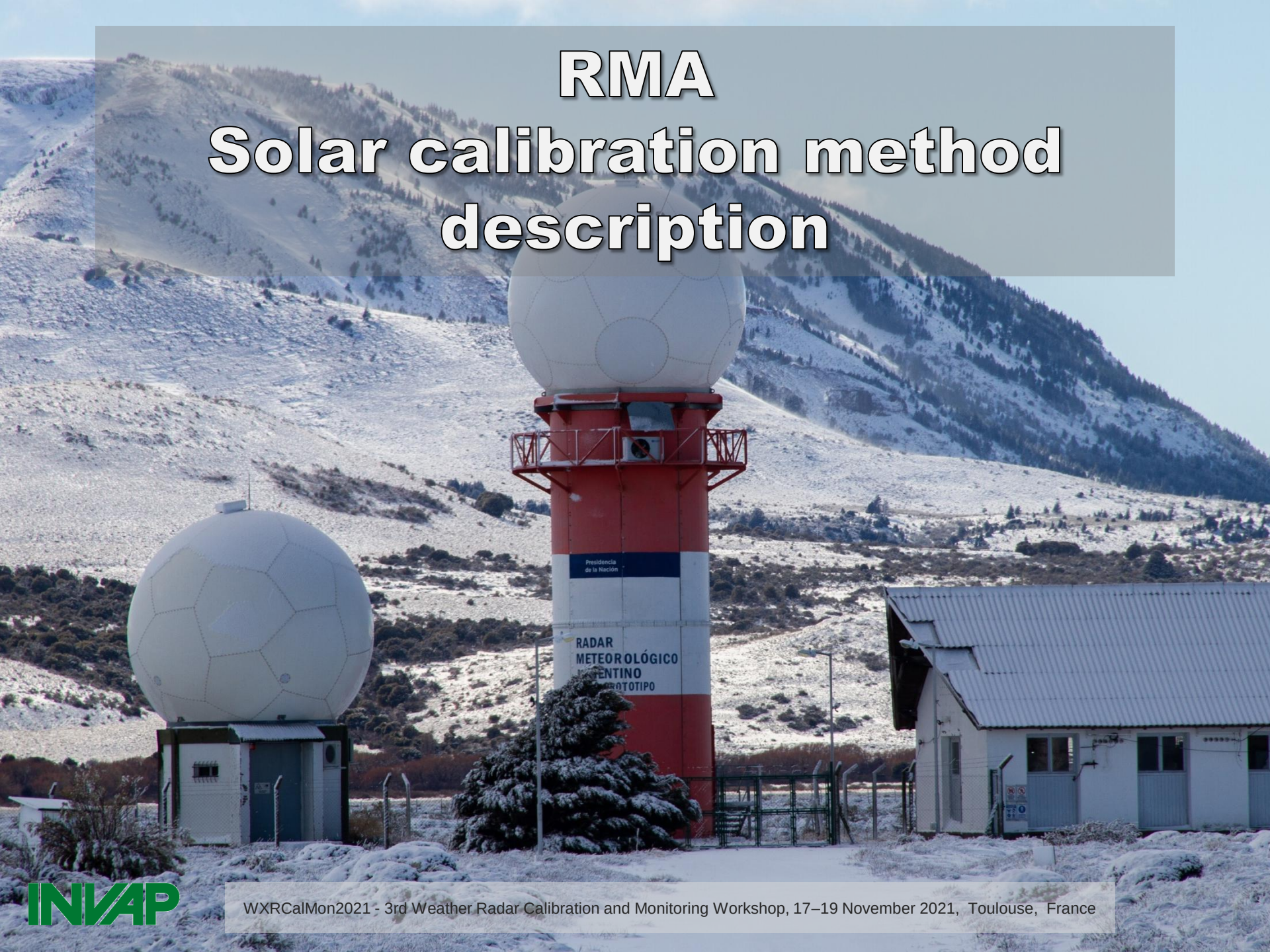
RMA – Technical specifications

Parameter	Value
Brand and Model	INVAP RMA-C320 (Doppler, dual polarization)
Operational frequency	C-Band, 5600 - 5650 MHz (1 MHz steps)
Dual Pol transmission mode	Simultaneous transmission and reception (H + V)
System Sensitivity (ISO/DIS 19926-1:2019)	Better than -7 dBZ at 50 km with 1us pulse and for SNR=0 dB including atmospheric attenuation and radome and waveguide losses
Radome losses	0.4 dB (dry, one way)
Transmitter	Coaxial Magnetron, solid state modulator
Peak power	250 to 320 kW (10kW steps)
Pulse duration	0.5 to 2.0 us (100 ns steps)
Max duty cycle	0.001 (0.1%)
Antenna	Parabolic, center feed, 4.48 meters
Gain	45.4 dBi +/- 0.5dB @5625 MHz
Beam width @ -3dB (typical)	0.90° @5625 MHz
side lobes	Better than -27 dB
cross-pol isolation	Better than -35 dB
Receiver	Antenna mounted, over azimuth, double conversion superheterodyne
Intermediate Frequency (IF):	First: 905 MHz, Second: 70 MHz
noise figure	Better than 3 dB

RMA – Main subsystems

Physical location





RMA
Solar calibration method description

Dedicated solar scans goals

Pointing calibration:

- Azimuth and elevation offsets
- Pedestal leveling check

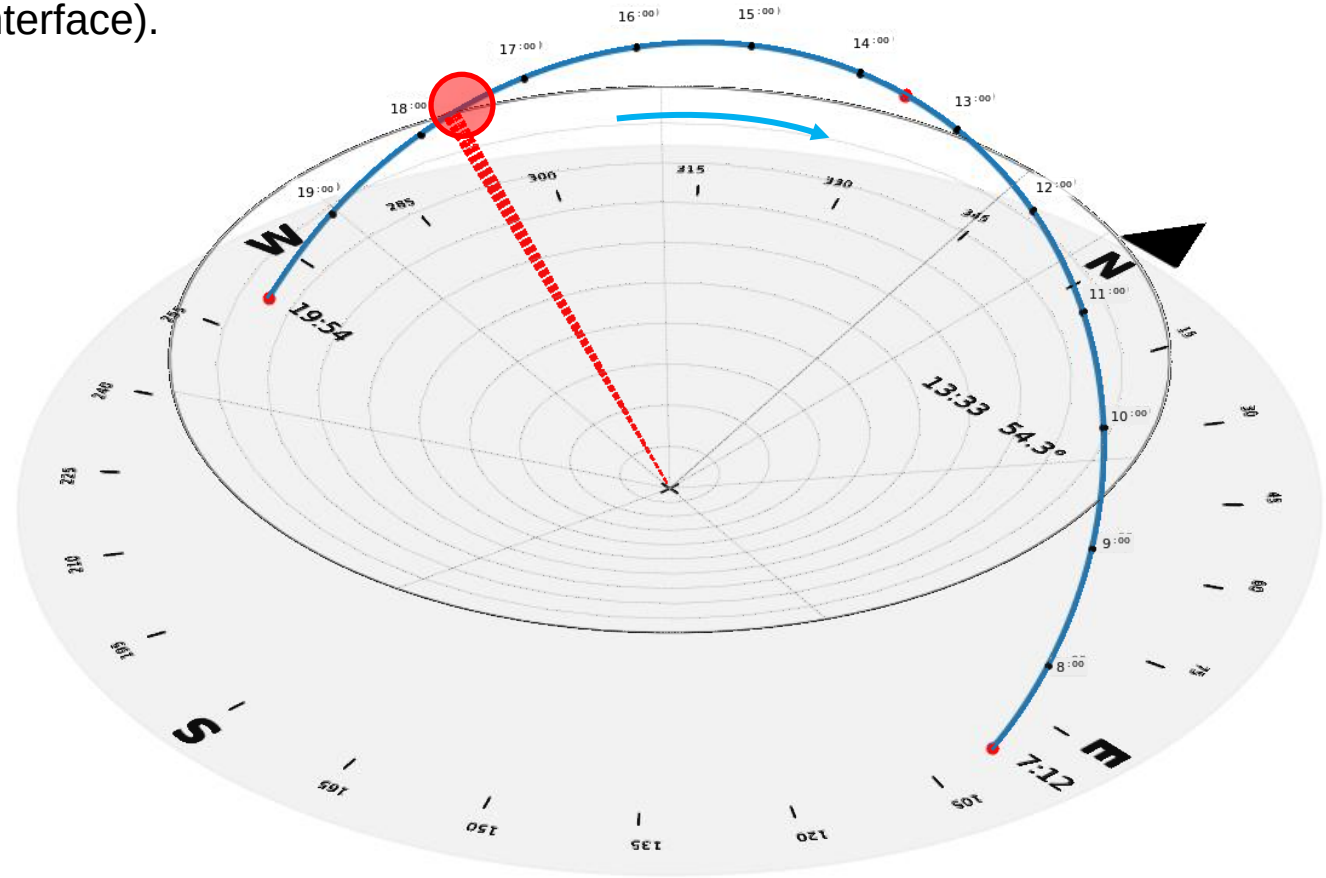
Monitoring of:

- Antenna main lobe beamwidth
- Absolute gain in RX (comparison against DRAO)
- Differential gain (between H and V) in RX

Solar calibration, scanning strategy

The scanning strategy is composed by a single “volume”, that repeats the same PPI scan.

The PPI scan parameters (speed, elevation, etc.) are automatically calculated by the radar, as a function of the elevation where the sun is expected to be seen in the following 5 minutes (from the time the radar operator run the python calibration script through the command interface).

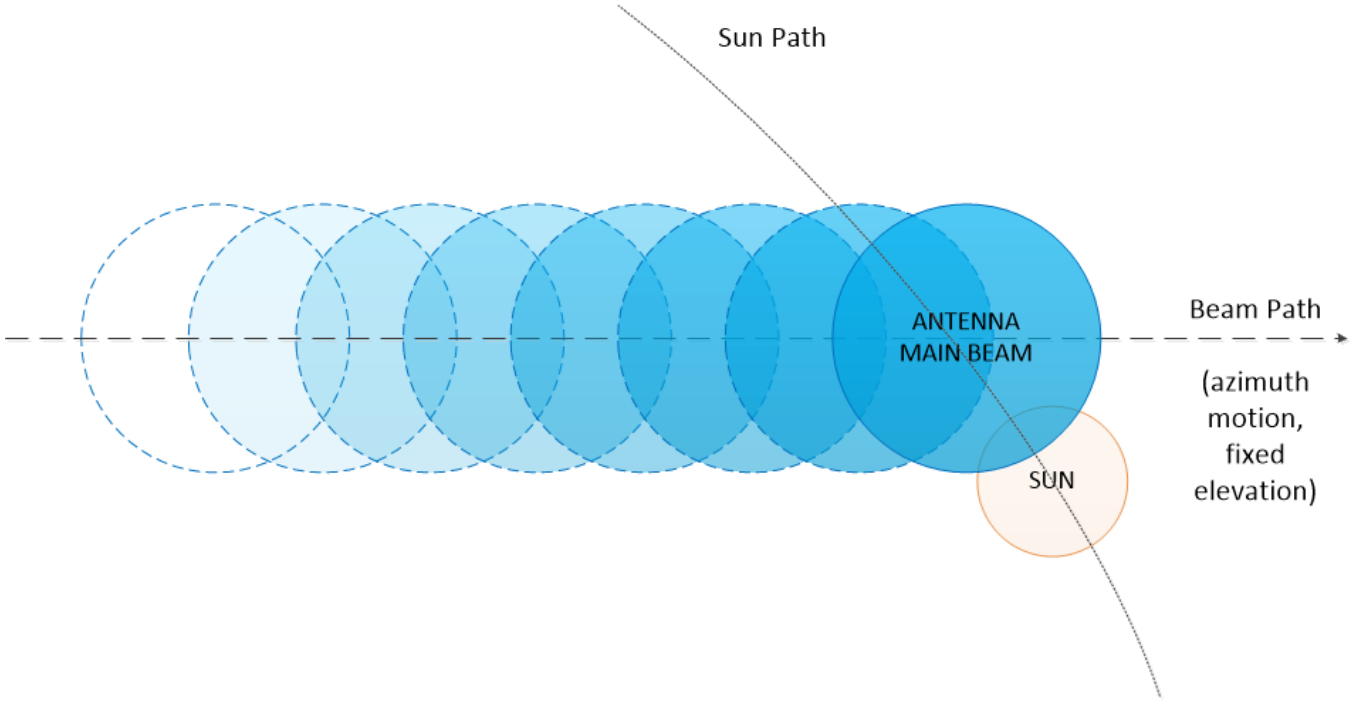


Solar calibration, scanning strategy (continuation)

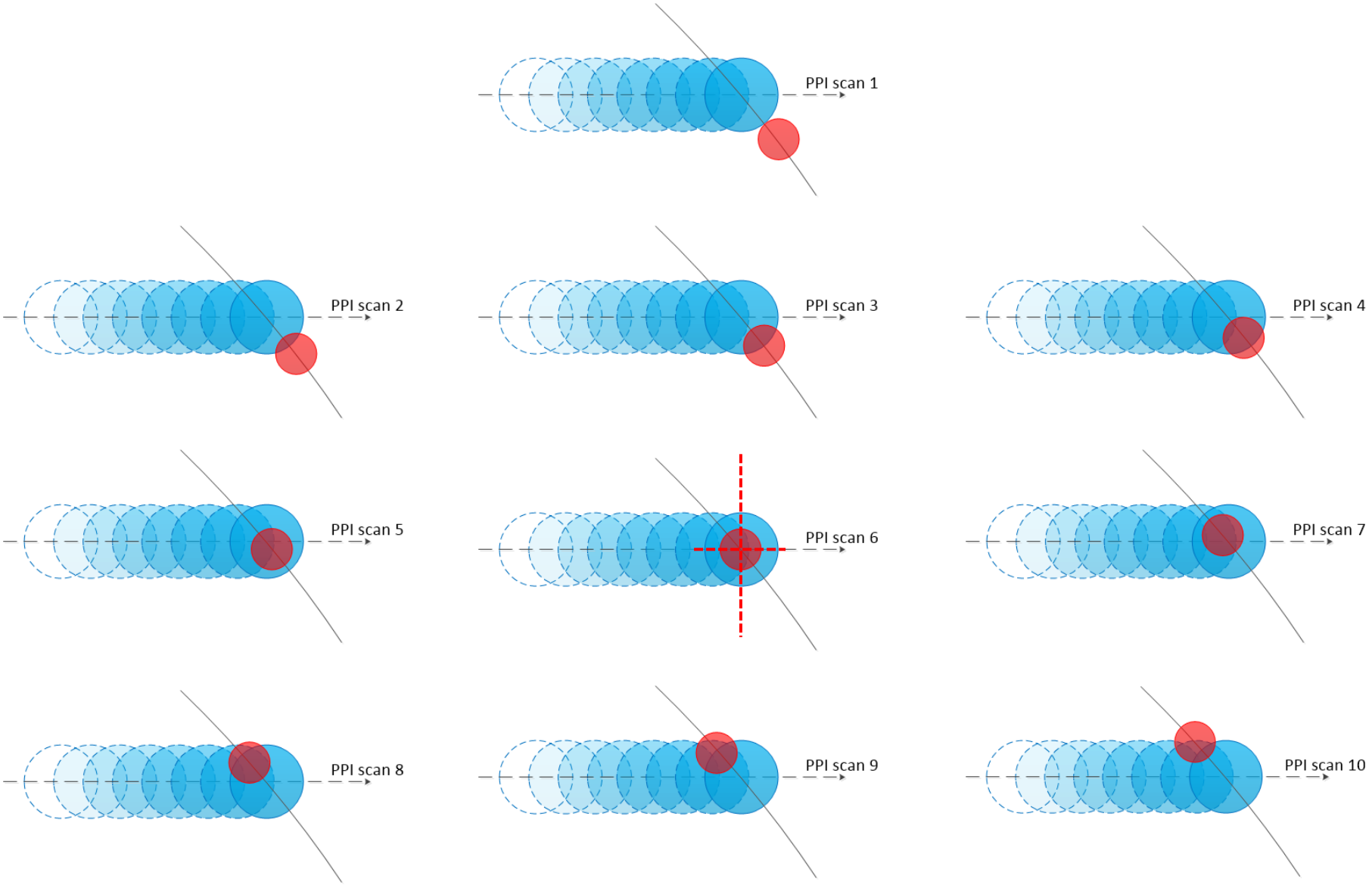
So… we basically wait for about 10 minutes for the sun to move and cross the elevation of the PPI scan.

During this time, the radar captures the radiation collected by the antenna and save it as I/Q time series.

While running the calibration scanning strategy, the radar is in RX mode only (no pulses are transmitted).



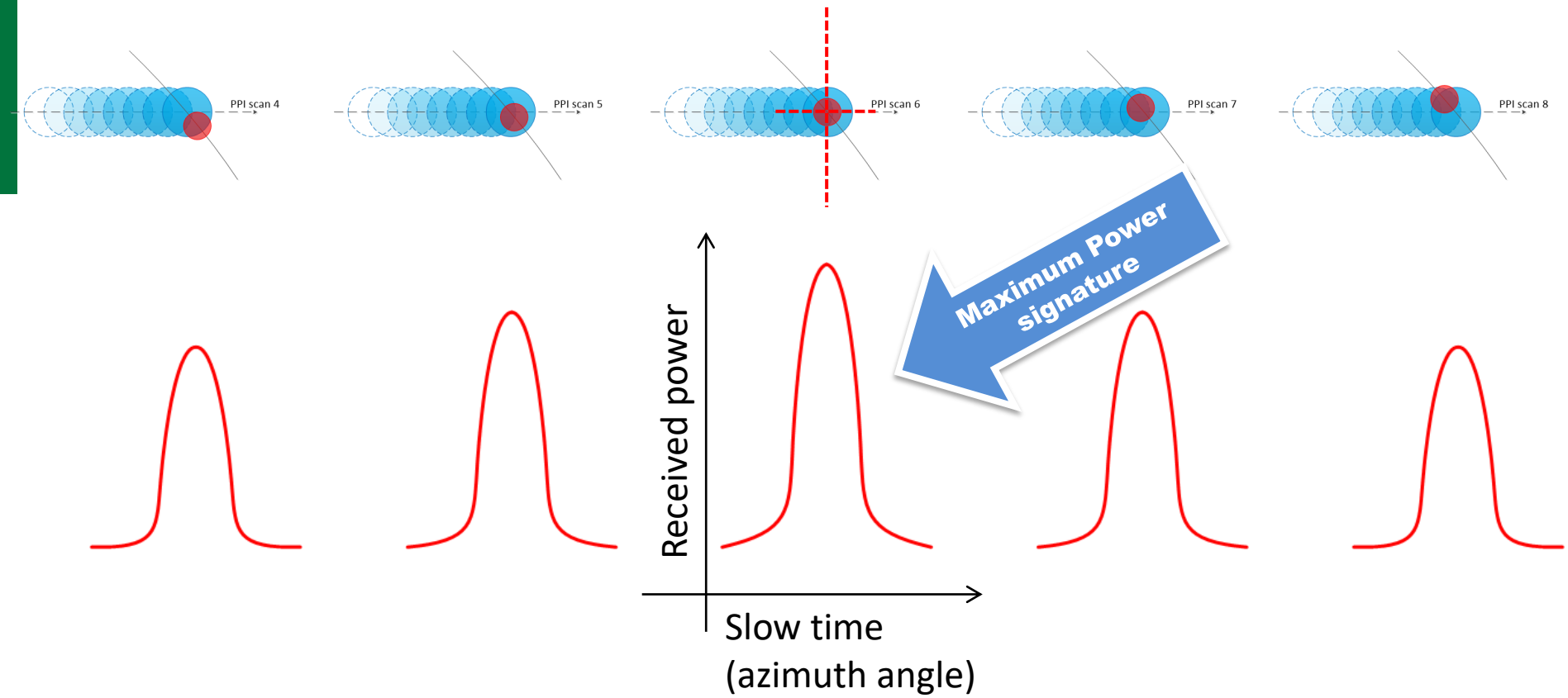
Solar calibration, scanning strategy (continuation)



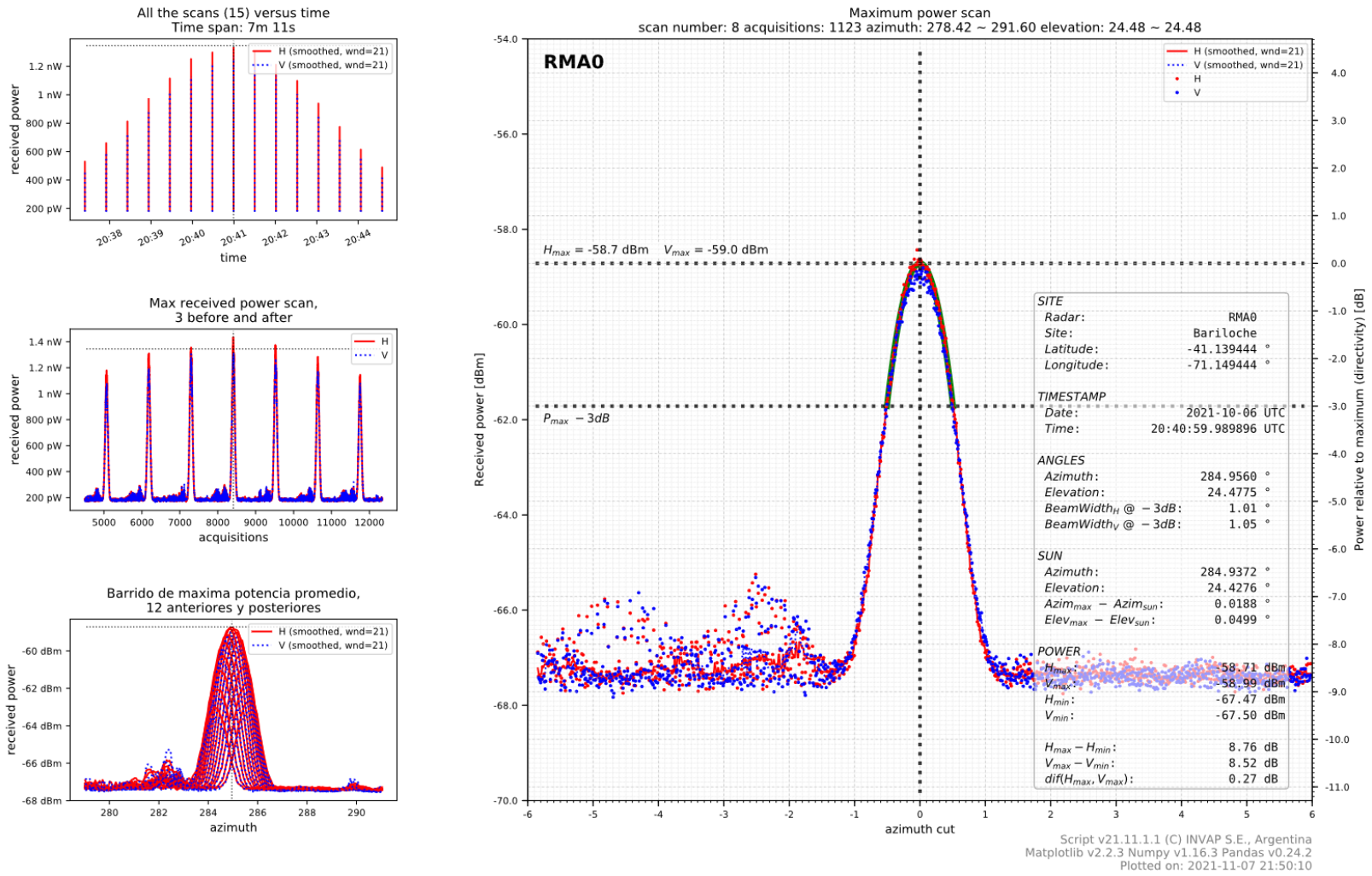
Example views from the southern hemisphere

Solar calibration, power signature

Received power, hits its maximum when the sun disc center is perfectly aligned with the antenna beam center



Solar calibration, test report (graph)

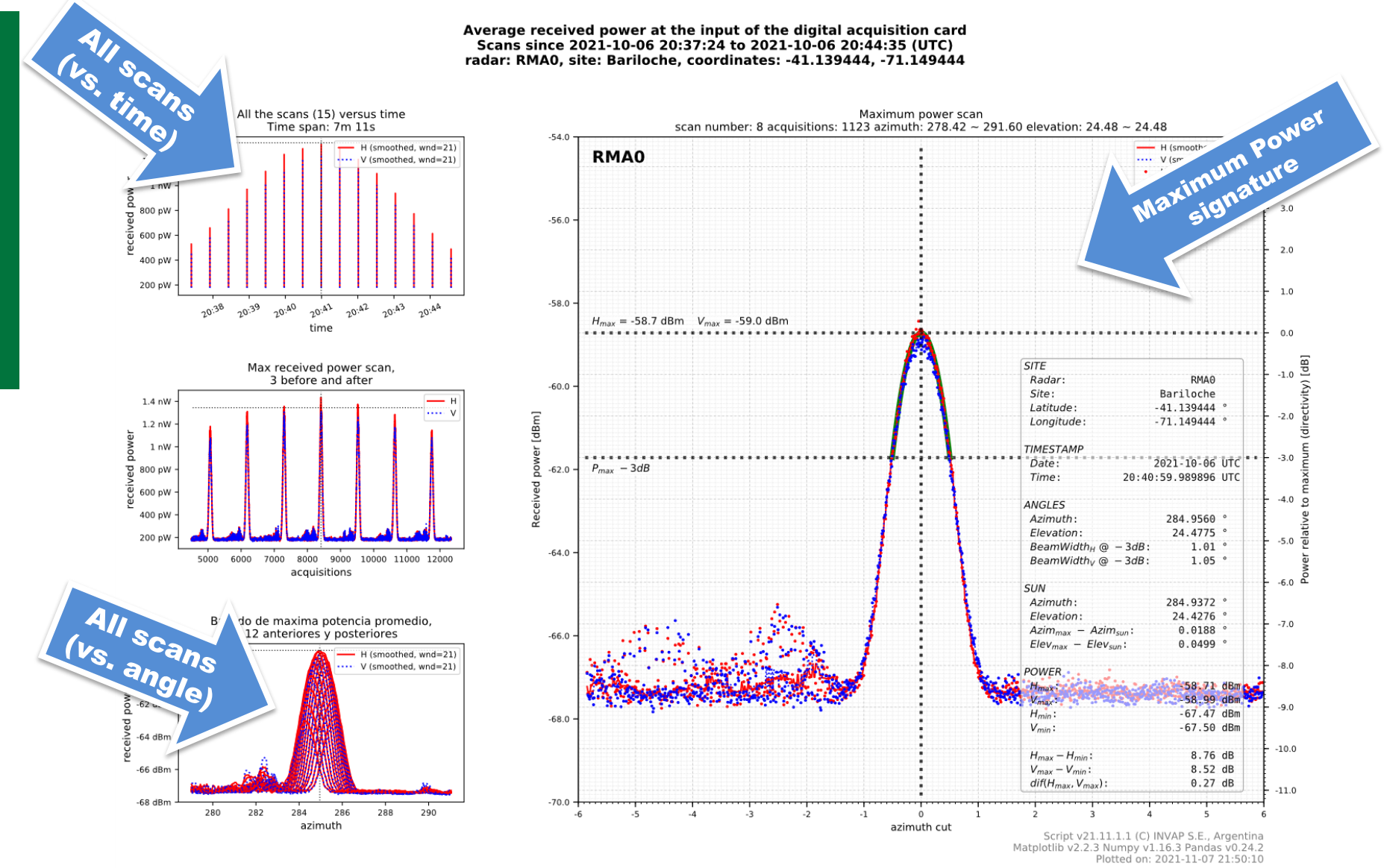


Solar calibration, test report (graph)

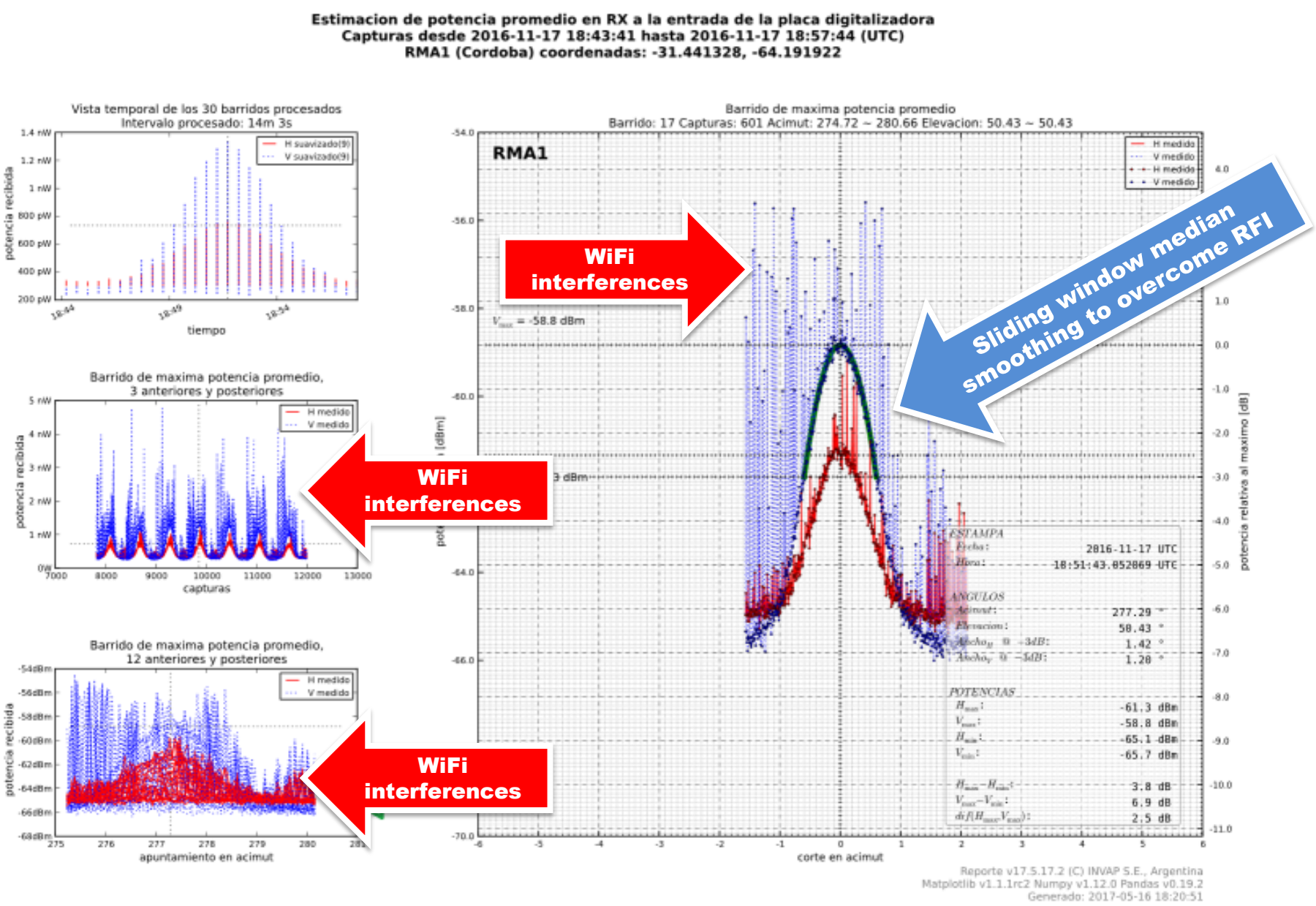
All scans (vs. time)

All scans (vs. angle)

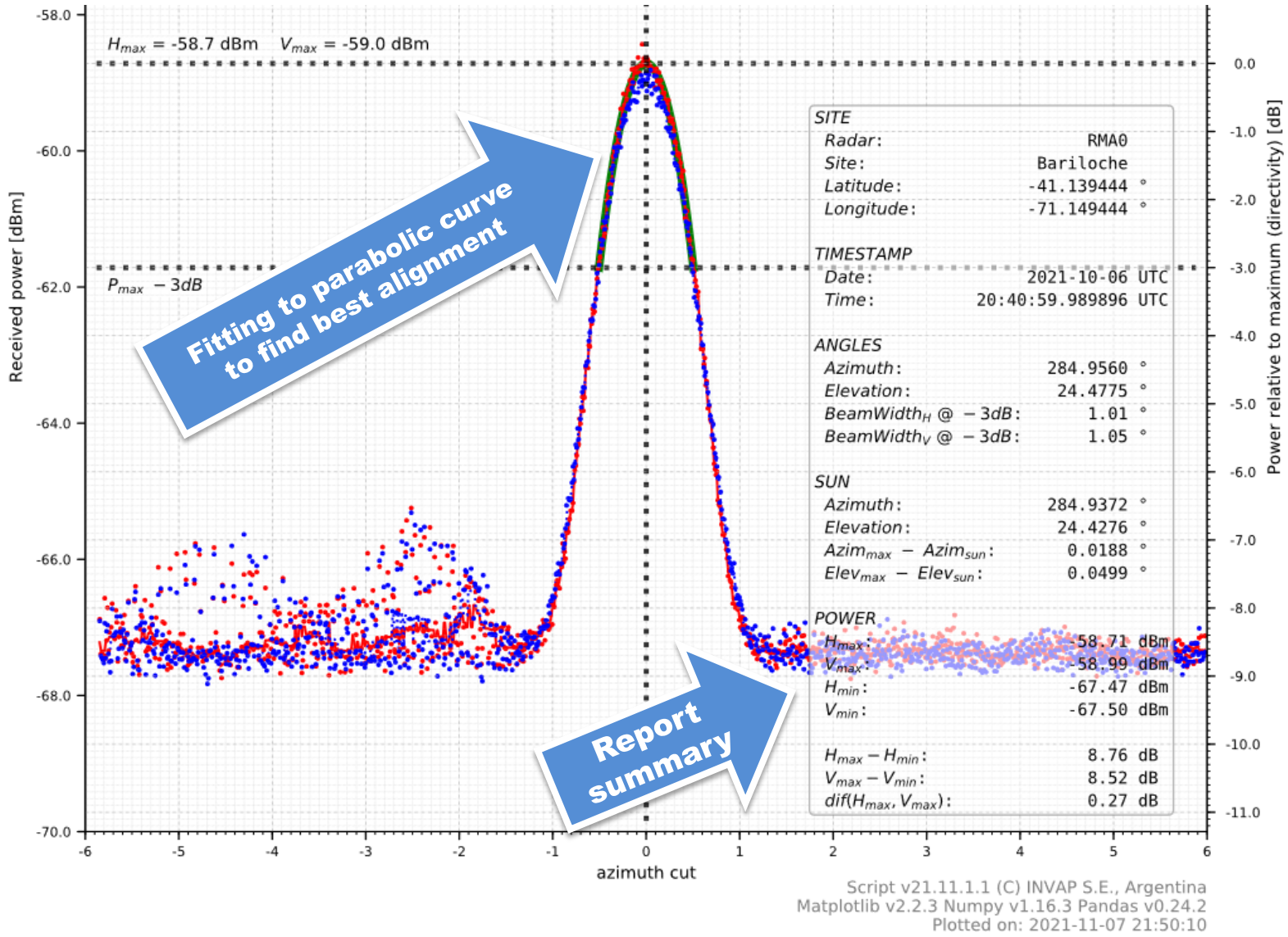
Maximum Power signature



Solar calibration, test report (graph)



Solar calibration, test report (graph)



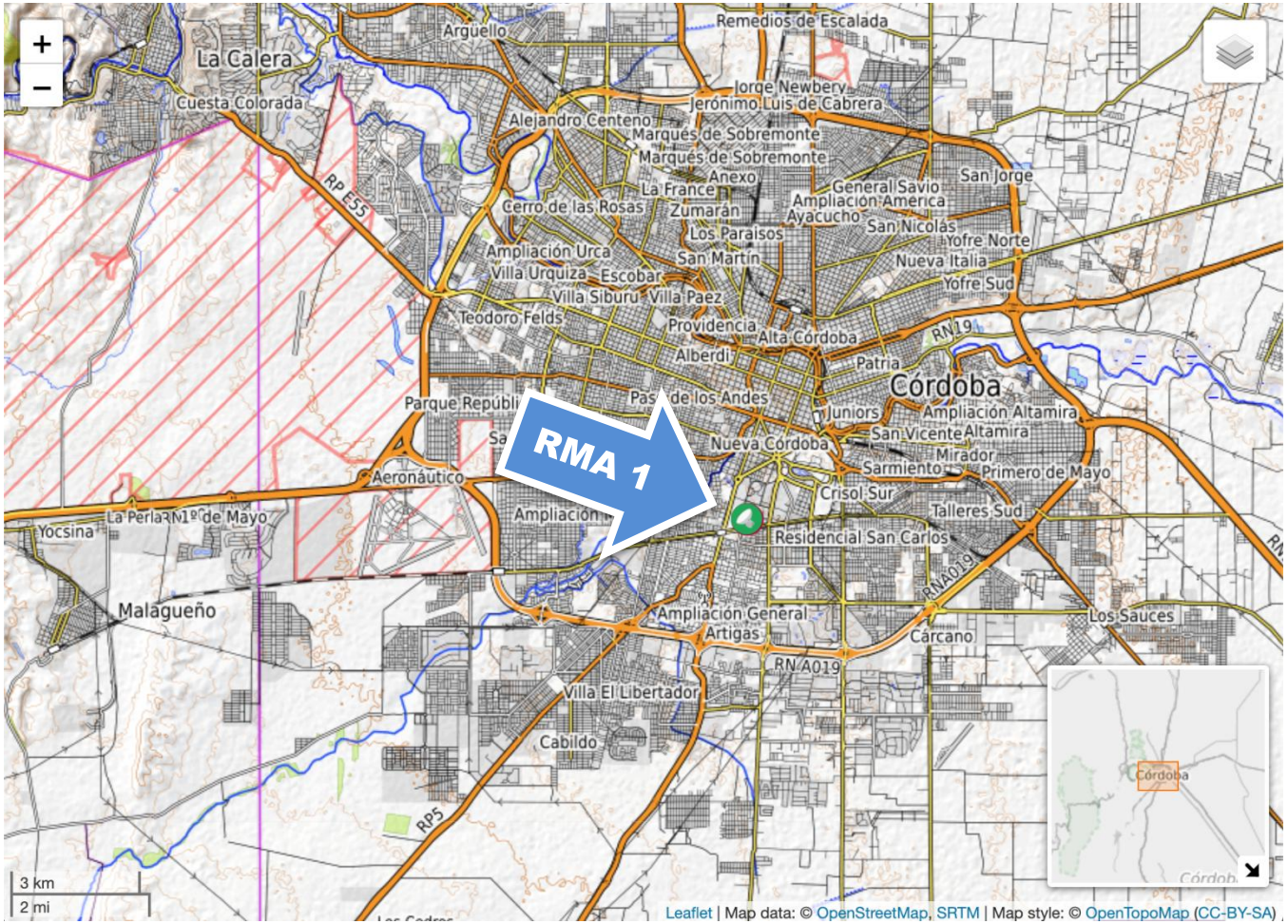
RMA1 – Sun calibration 2018 RELAMPAGO campaign

INVAP

RMA1 Sensor location

Cordoba Province, capital city

Lat: -31.441328°, Lon: -64.191922°, 484 m. a. m. s. l.



SINARAME – RMA1, Córdoba

Universidad Nacional de Córdoba

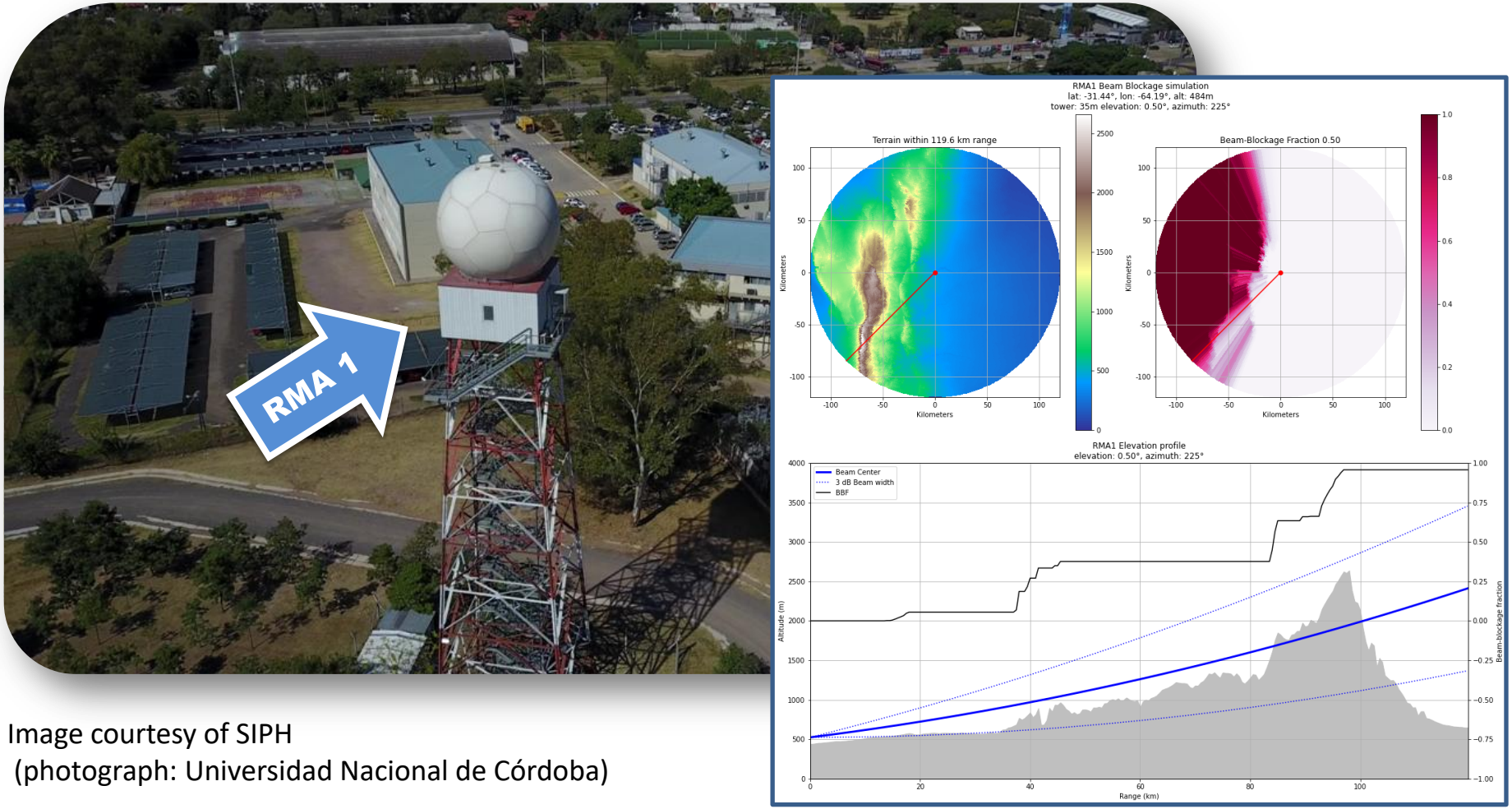
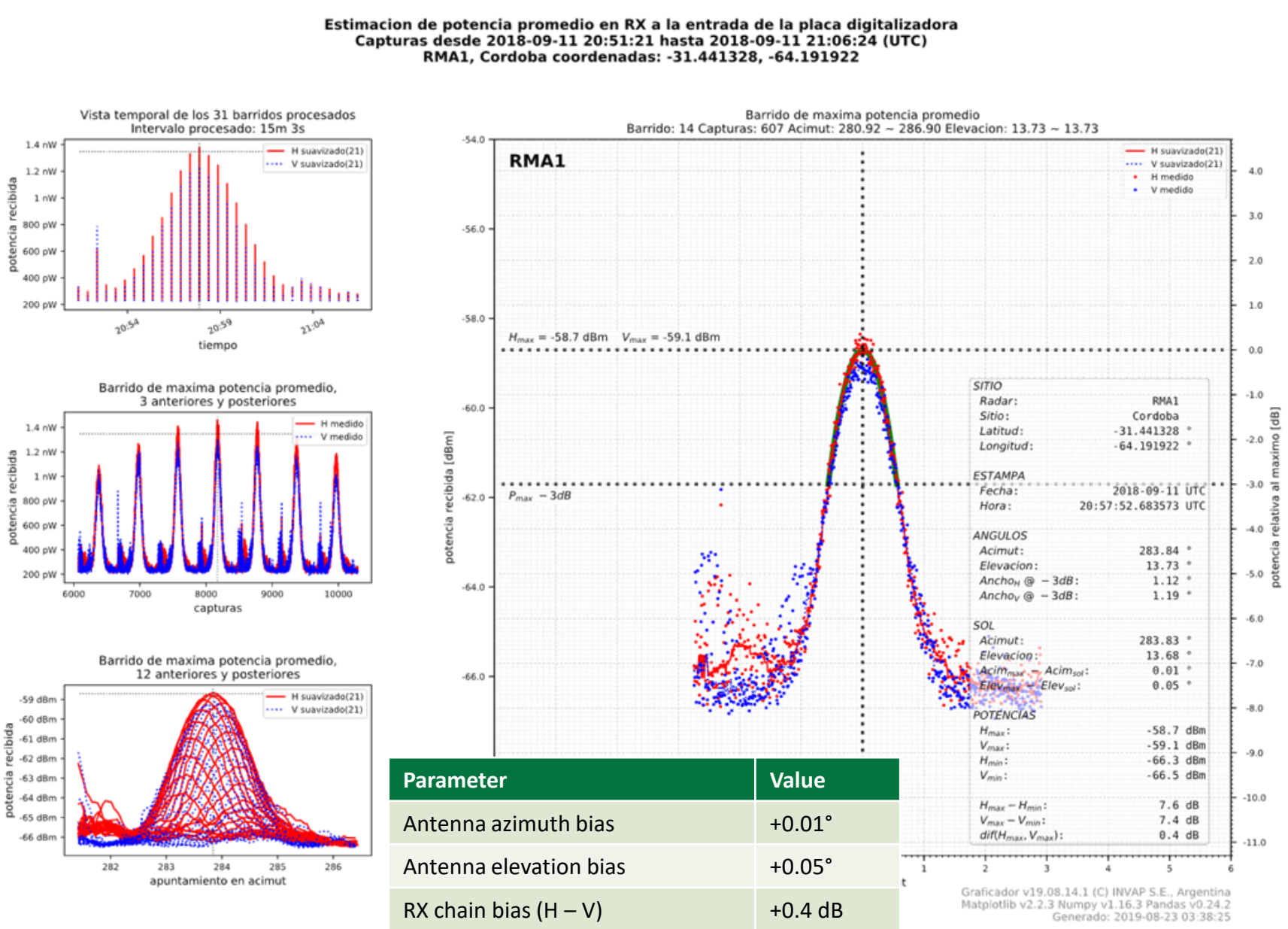


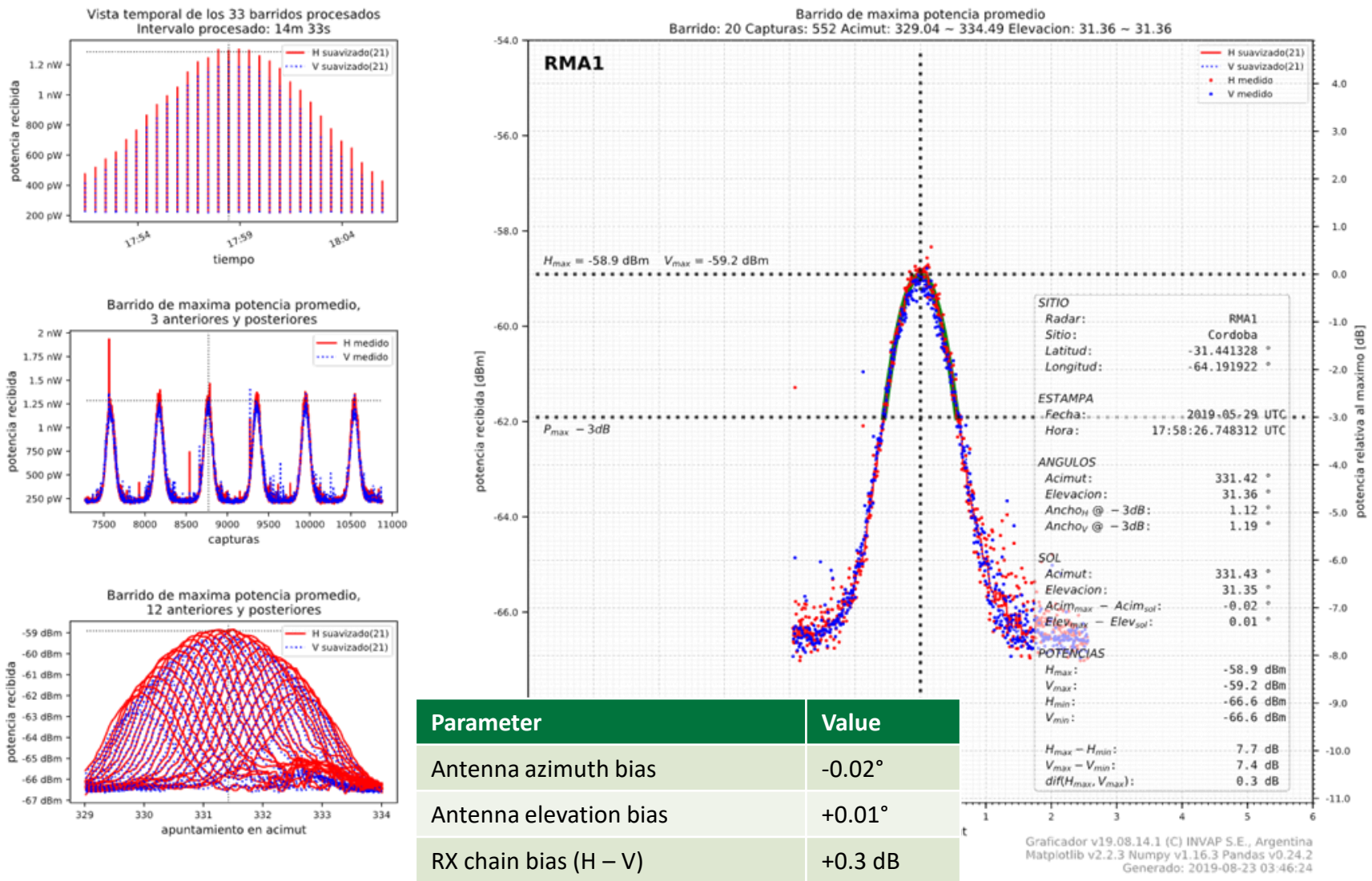
Image courtesy of SIPH
(photograph: Universidad Nacional de Córdoba)

Pointing calibration, solar scans (2018-09-11)



Parameter	Value
Antenna azimuth bias	+0.01°
Antenna elevation bias	+0.05°
RX chain bias (H – V)	+0.4 dB

Pointing calibration, solar scans (2019-05-29)



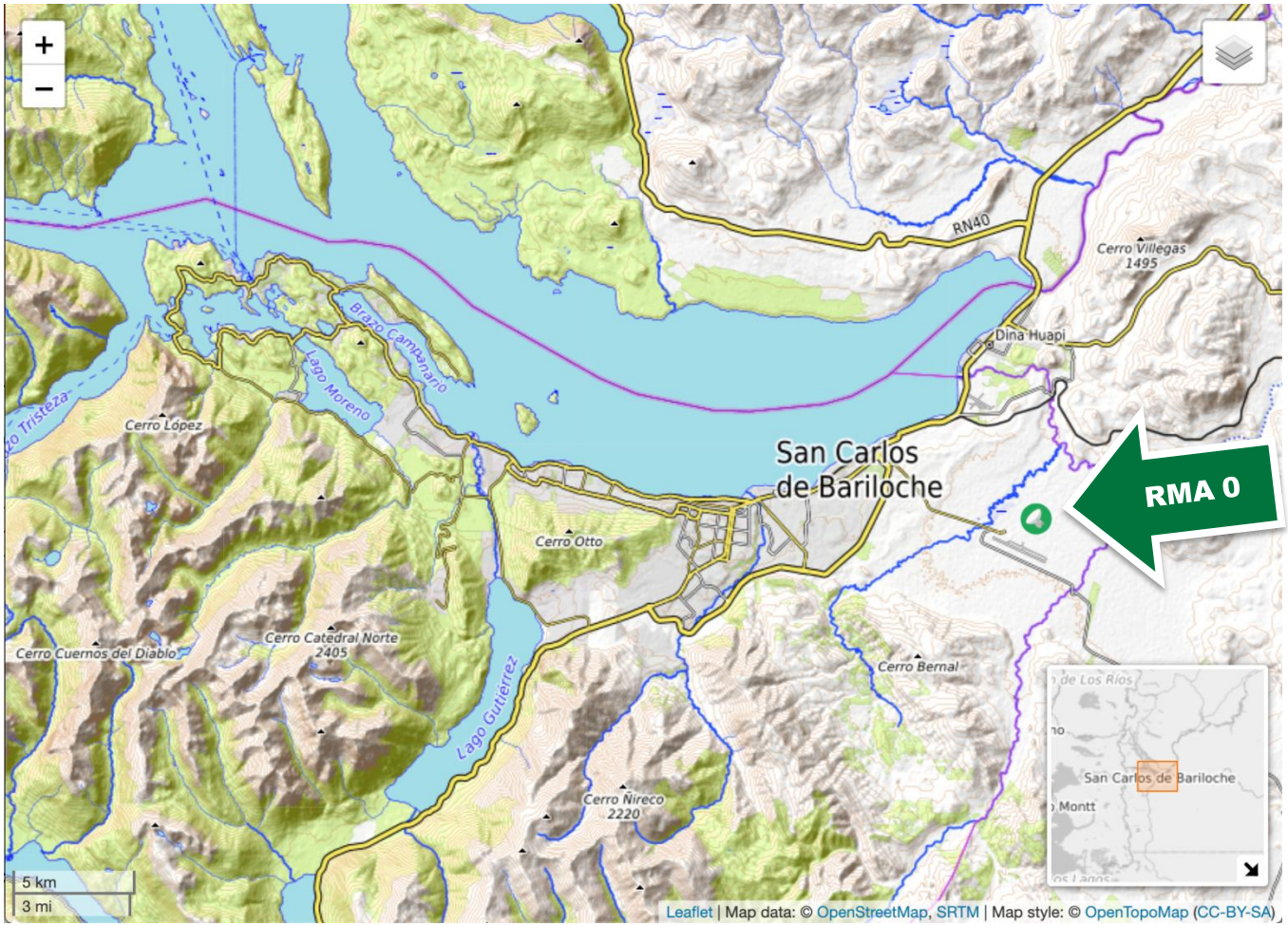
Parameter	Value
Antenna azimuth bias	-0.02°
Antenna elevation bias	+0.01°
RX chain bias (H – V)	+0.3 dB

RMA0 – Sun calibration 2021 WORKSHOP campaign

RMA0 Sensor location

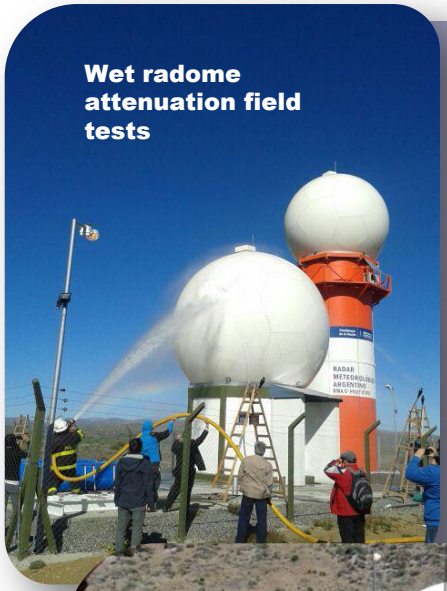
Bariloche, Rio Negro

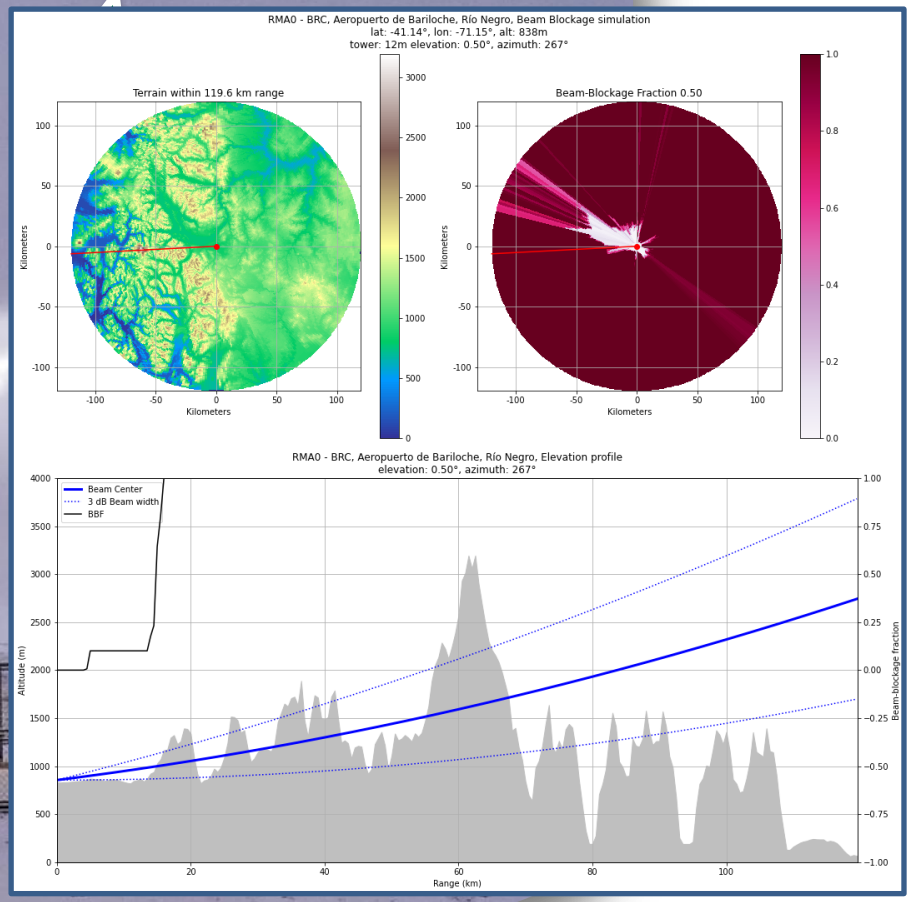
Lat: -41.139444°, Lon: -71.149444°, 838 m. a. m. s. l.



INVAP – RMA0, Bariloche

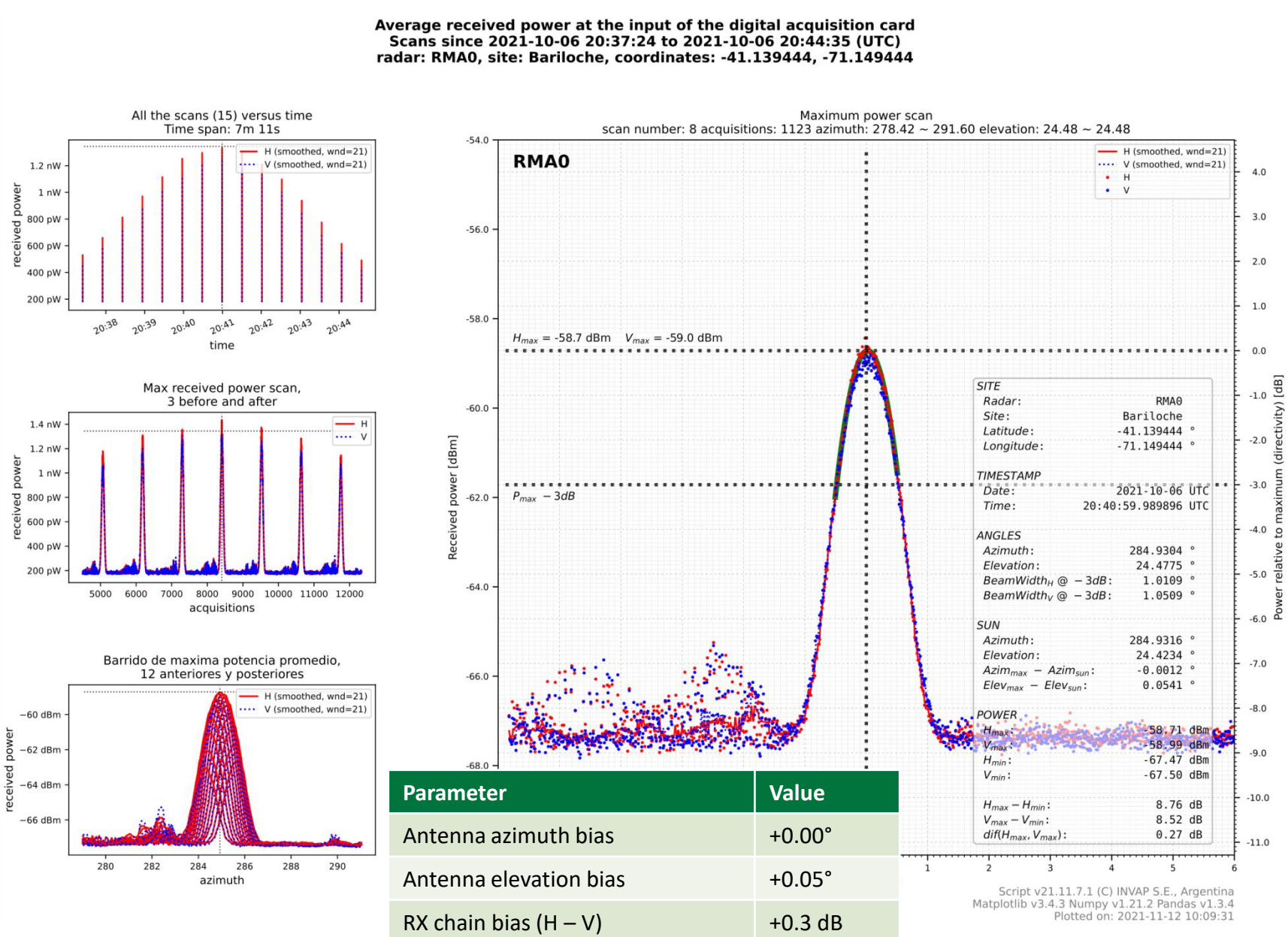
Bariloche airport, Rio Negro, Argentina





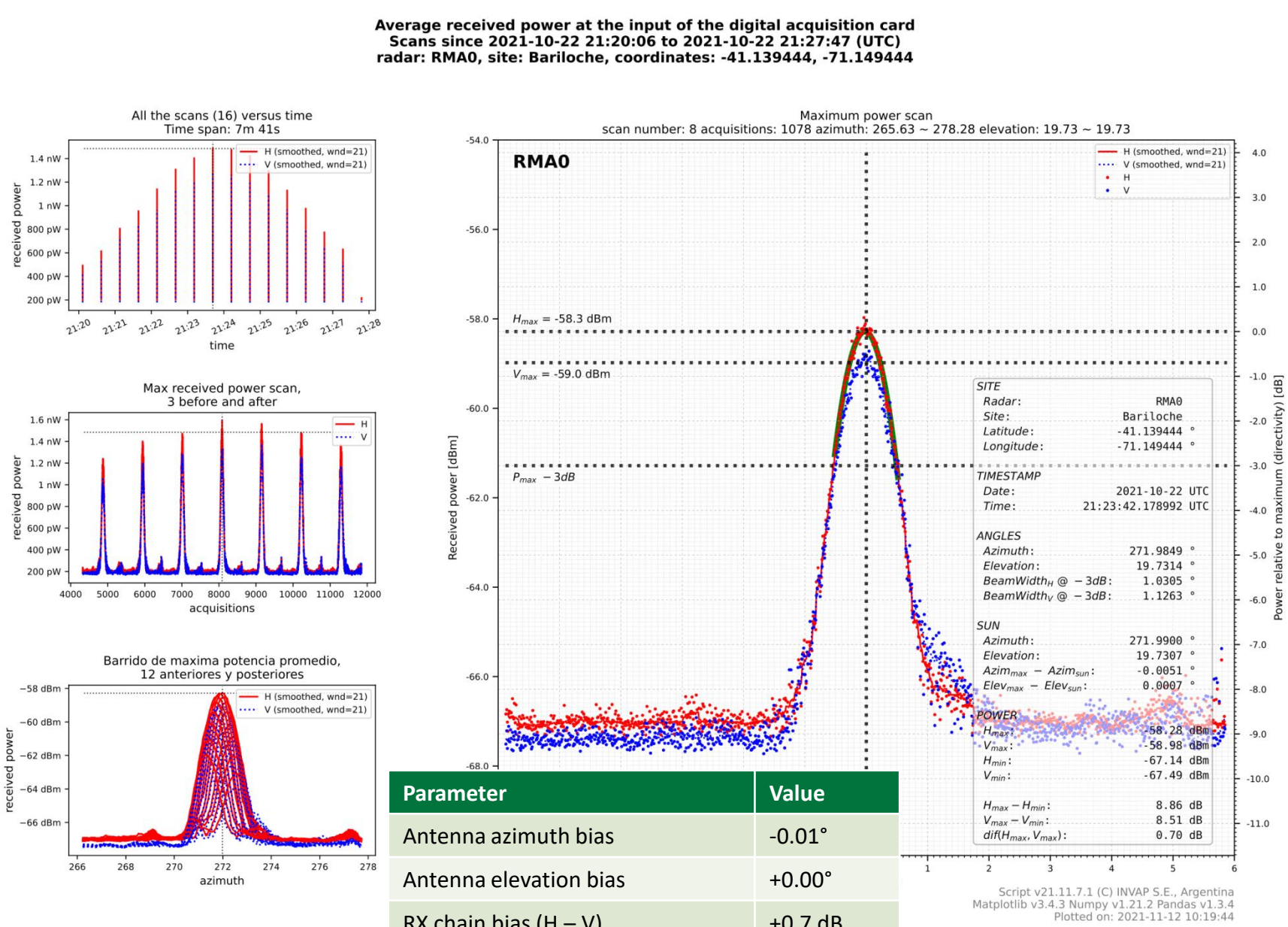
Images © INVAP

RMA0 – Pointing calib., solar scans (2021-10-06)



Parameter	Value
Antenna azimuth bias	+0.00°
Antenna elevation bias	+0.05°
RX chain bias (H – V)	+0.3 dB

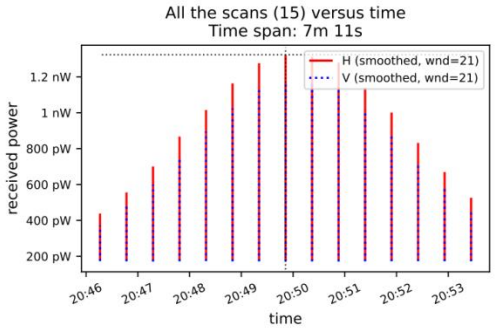
RMA0 – Pointing calib., solar scans (2021-10-22)

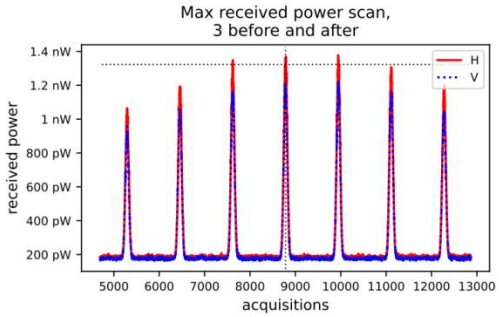


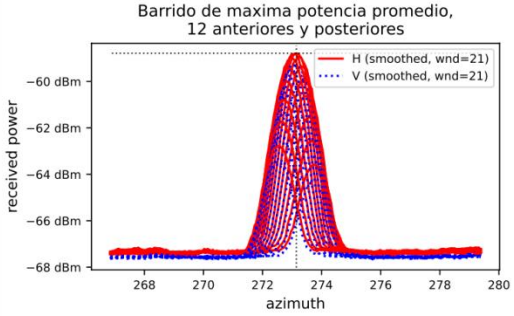
Parameter	Value
Antenna azimuth bias	-0.01°
Antenna elevation bias	+0.00°
RX chain bias (H – V)	+0.7 dB

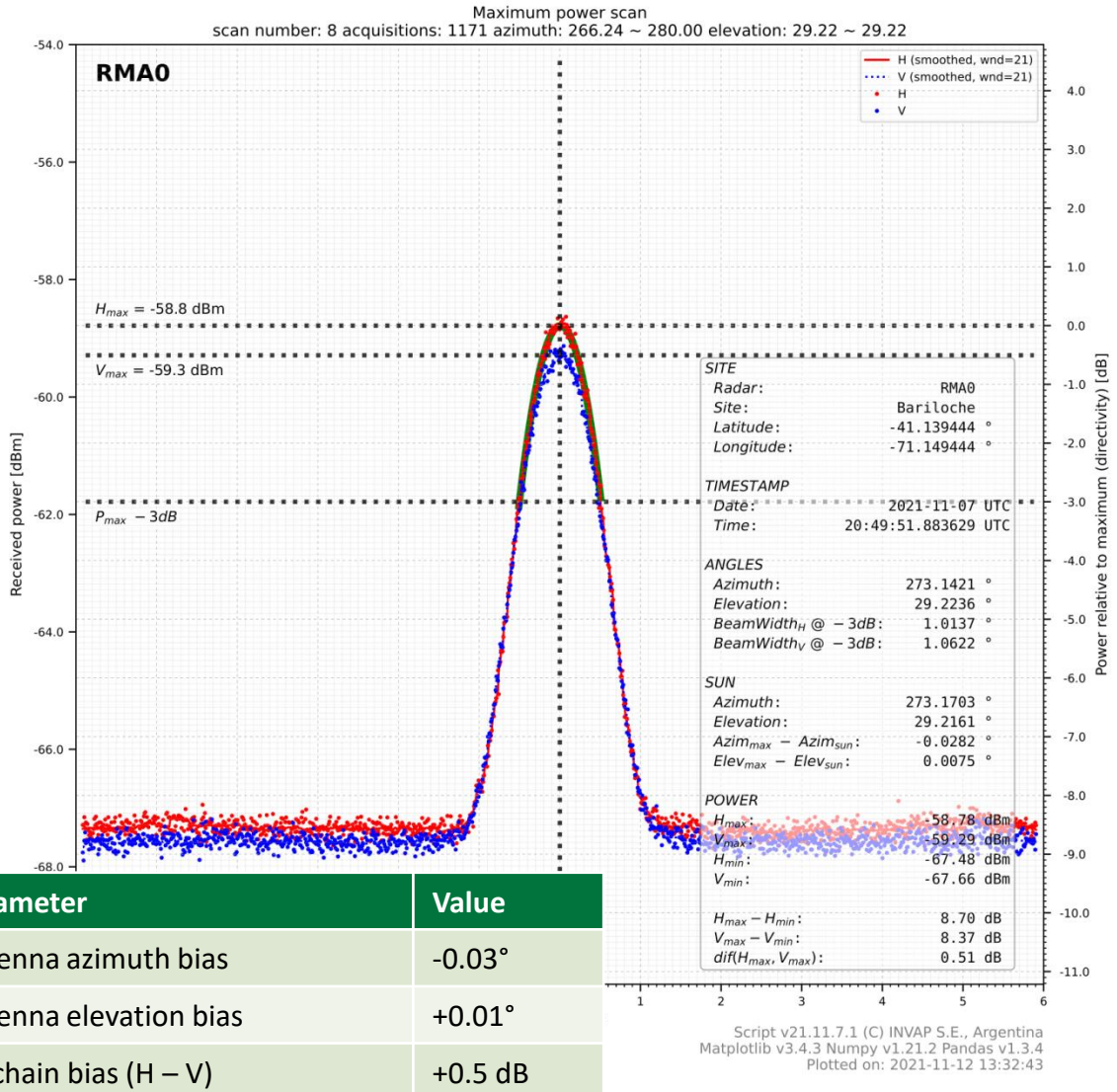
RMA0 – Pointing calib., solar scans (2021-11-07)

Average received power at the input of the digital acquisition card
Scans since 2021-11-07 20:46:16 to 2021-11-07 20:53:27 (UTC)
radar: RMA0, site: Bariloche, coordinates: -41.139444, -71.149444



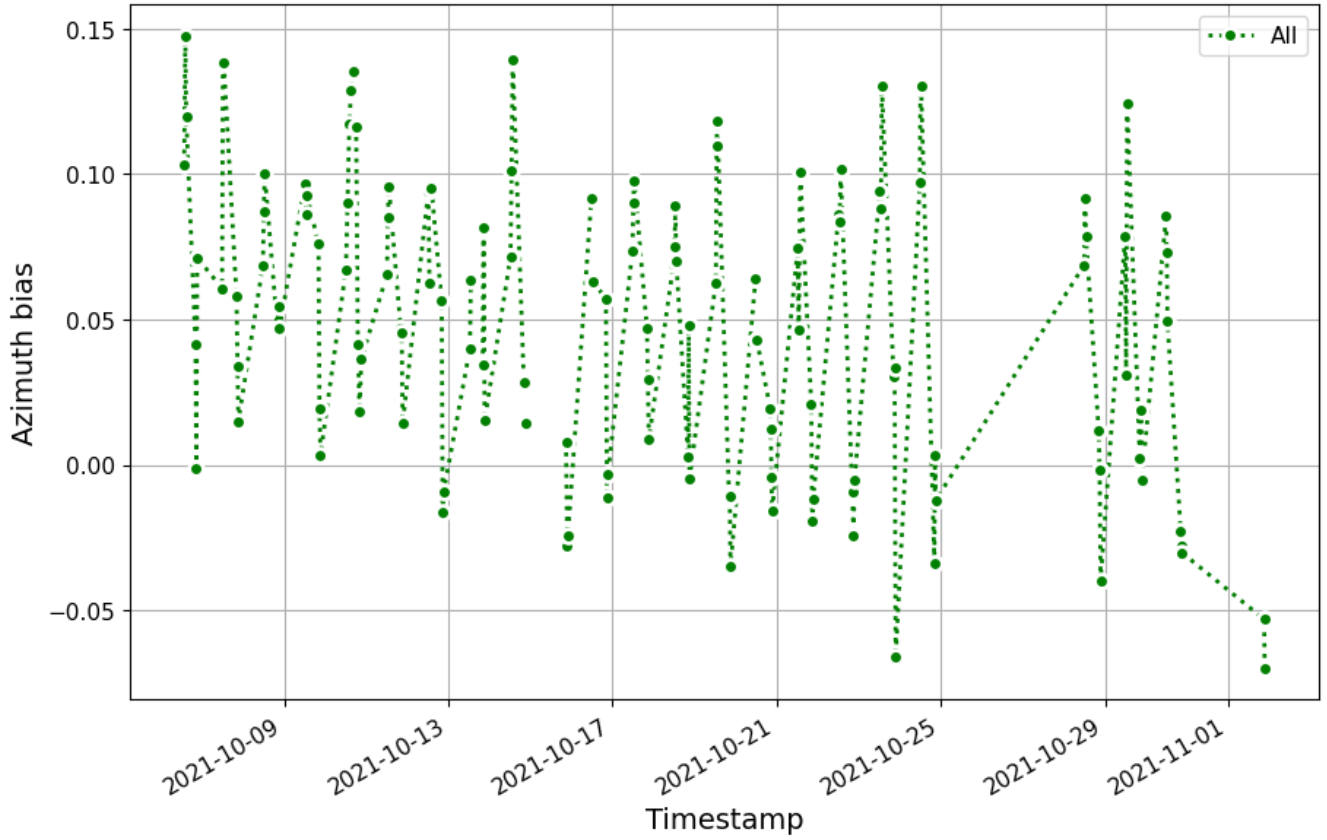






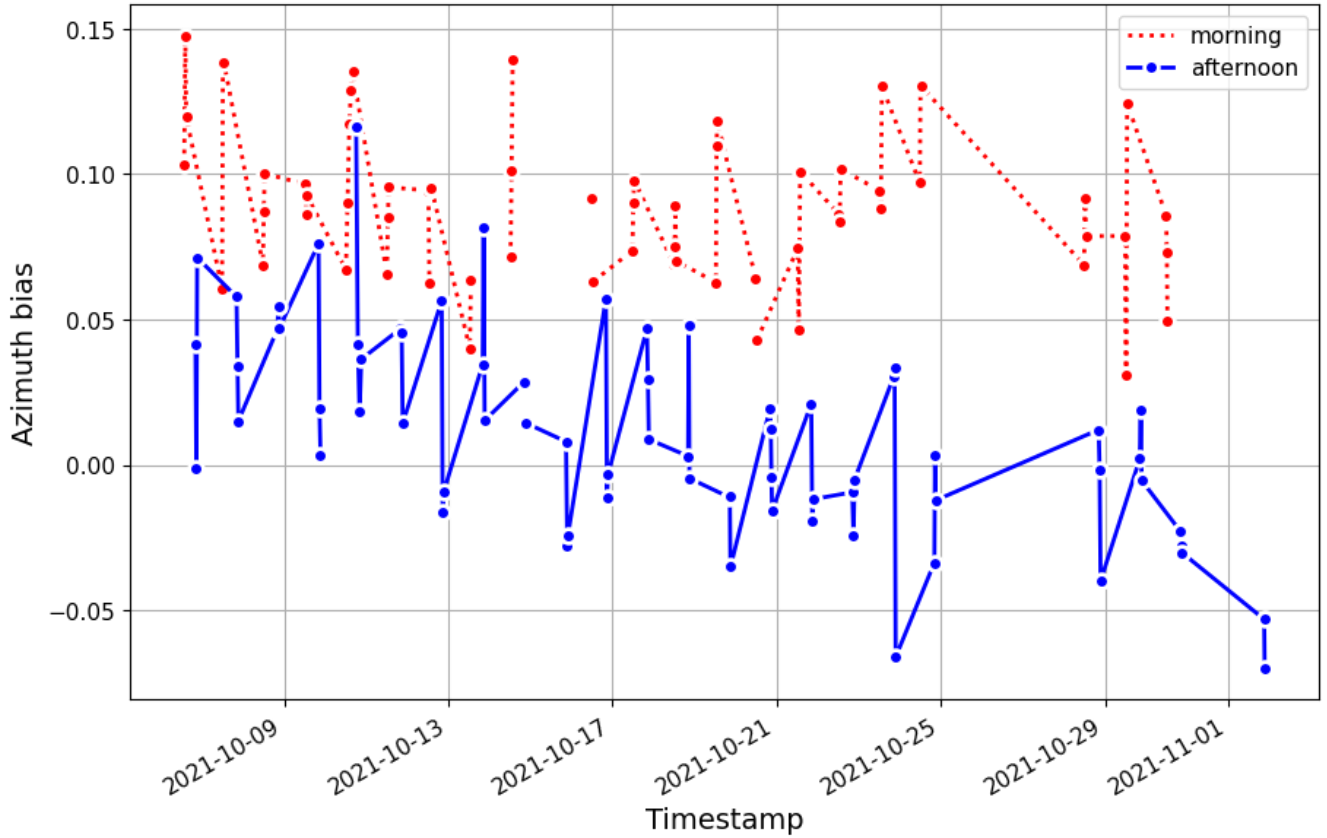
Parameter	Value
Antenna azimuth bias	-0.03°
Antenna elevation bias	+0.01°
RX chain bias (H – V)	+0.5 dB

RMA0 – Azimuth bias statistics



Azimuth bias	mean:	0.05 deg
	standard deviation:	0.05 deg

RMA0 – Azimuth bias statistics

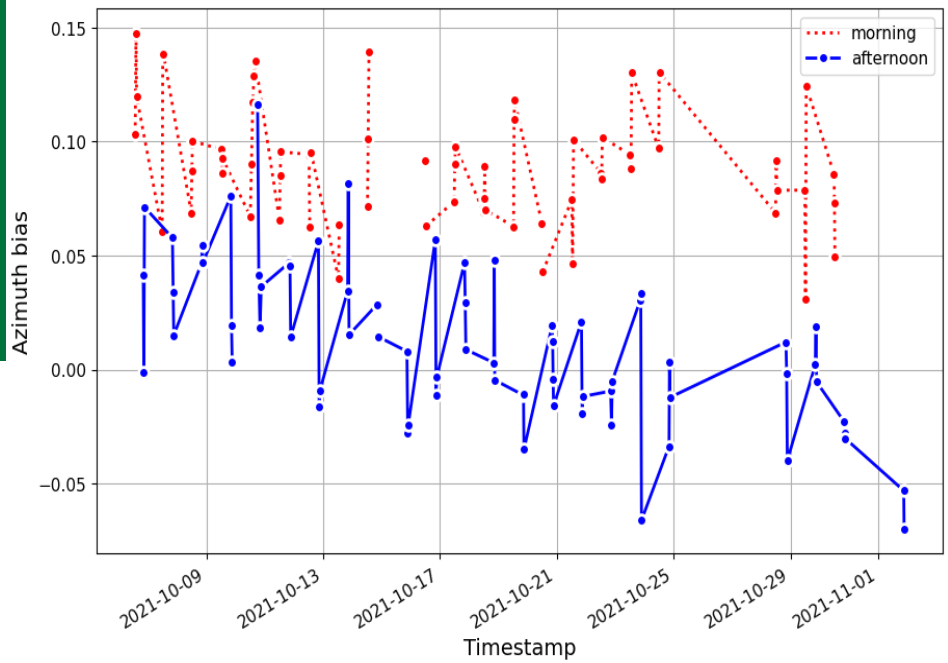


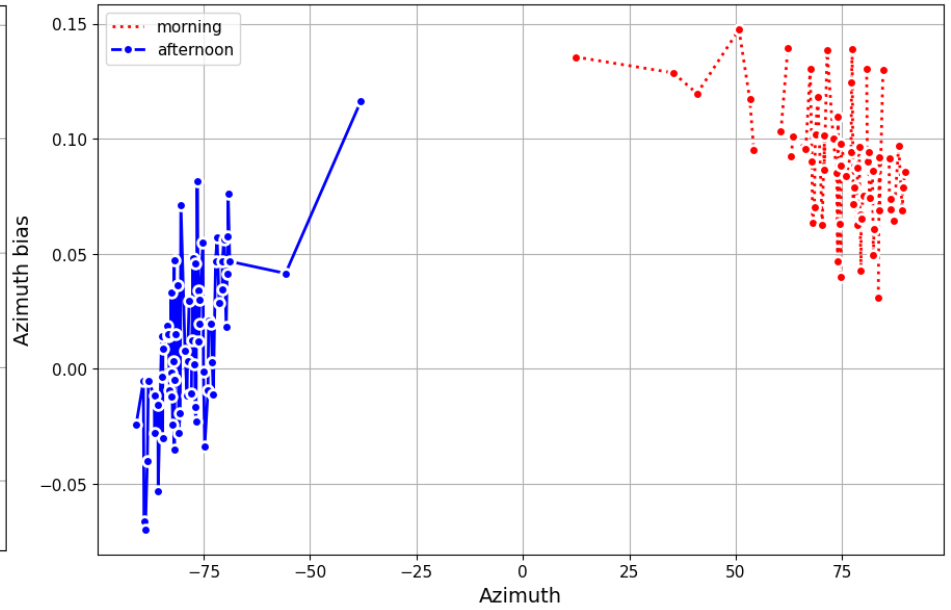
Azimuth bias

morning mean: m_M = 0.09 deg
morning standard deviation: s_M = 0.02 deg

afternoon mean : m_A = 0.01 deg
afternoon standard deviation s_A = 0.03 deg

RMA0 – Azimuth bias statistics



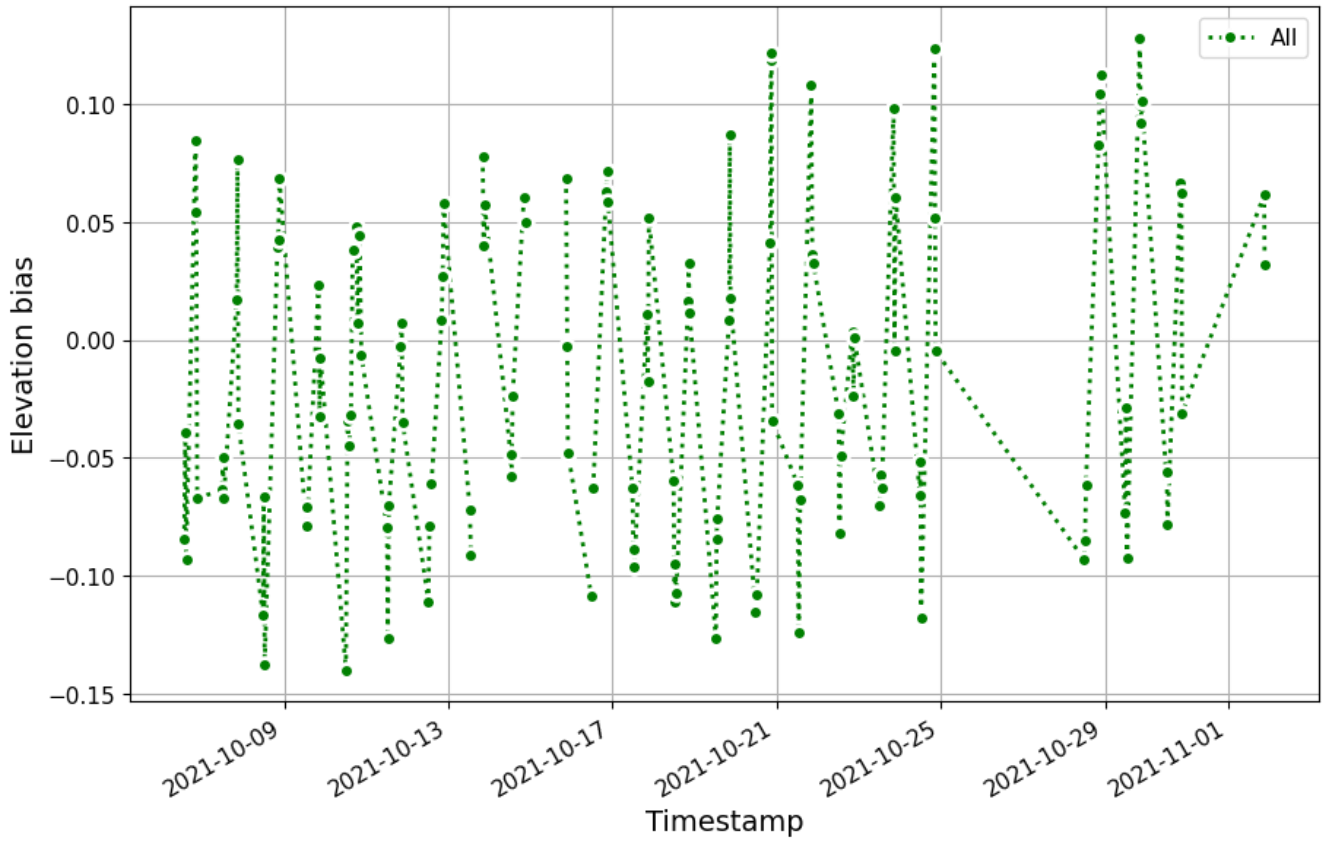


Azimuth bias

morning mean: m_M = 0.09 deg
morning standard deviation: s_M = 0.02 deg

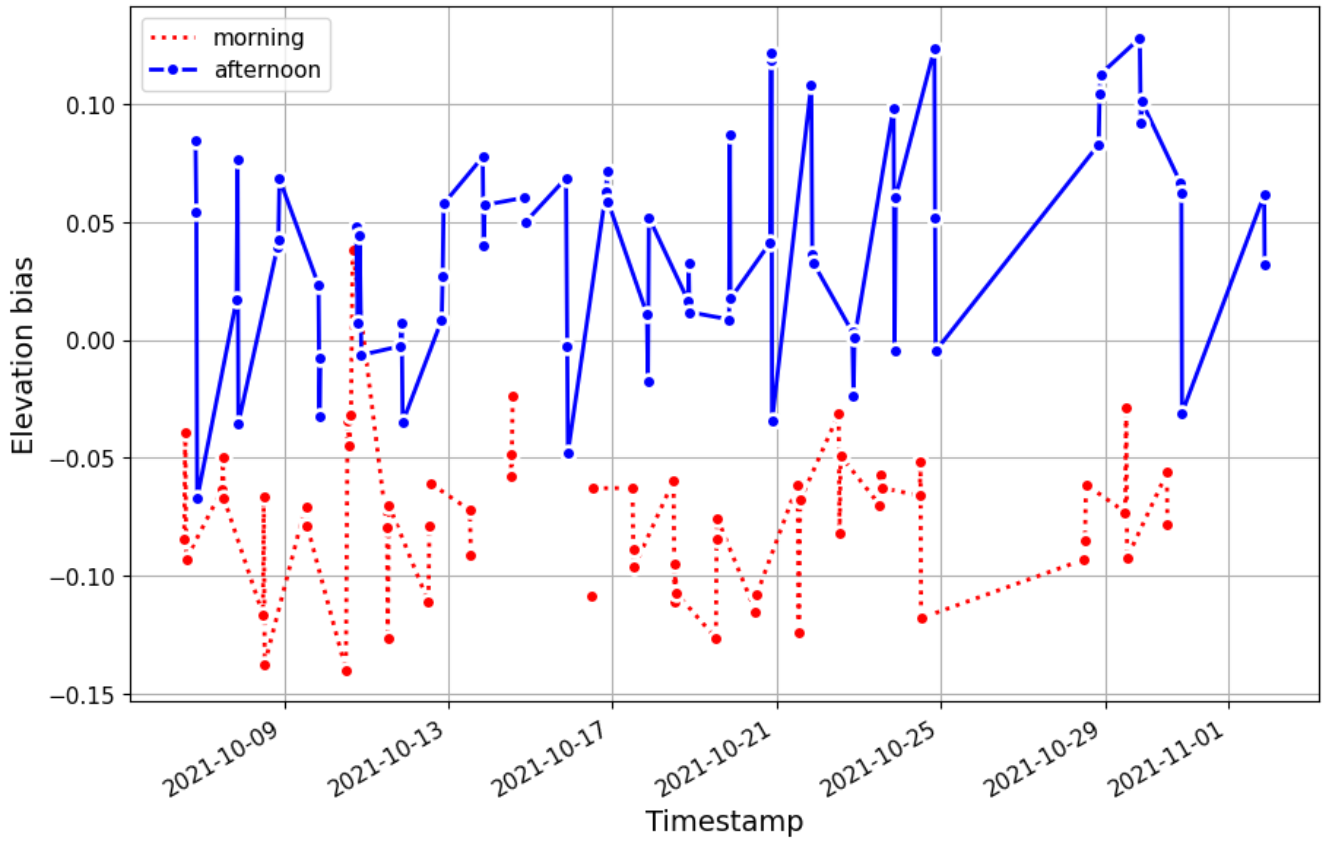
afternoon mean : m_A = 0.01 deg
afternoon standard deviation s_A = 0.03 deg

RMA0 – Elevation bias statistics



Elevation bias	mean:	-0.02 deg
	standard deviation:	0.07 deg

RMA0 – Elevation bias statistics



Elevation bias

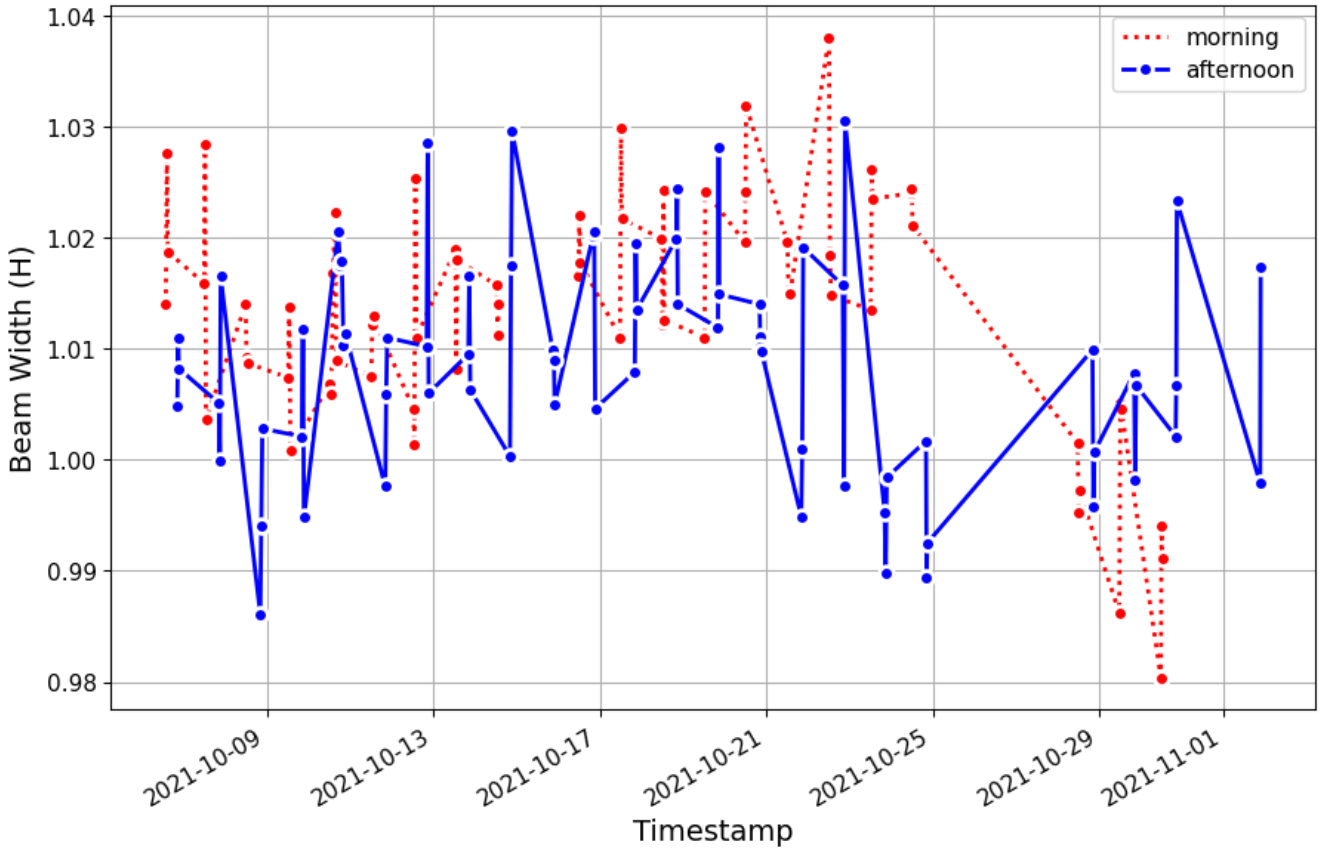
morning mean: $m_M = -0.07$ deg

morning standard deviation: $s_M = 0.03$ deg

afternoon mean : $m_A = 0.04$ deg

afternoon standard deviation $s_A = 0.04$ deg

RMA0 – Antenna beamwidth statistics



Antenna beamwidth

(including broadening by solar disk and compensated for elevation)

morning mean: m_M = 1.01 deg

morning standard deviation: s_M = 0.01 deg

afternoon mean : m_A = 1.00 deg

afternoon standard deviation s_A = 0.01 deg

Conclusions

Method remarks

- Results are representative of the operational performance of the radar, since the “sun scan” is just a simple PPI scan, similar to those used operationally.

- Easy for the user to:
  - Execute (simple commands, no parameters)
  - Understand (report summary with all the relevant results)
  - Validate (quality check through visual inspection of the graph)

- Better resolution than the encoders (fitting and interpolation at pulse to pulse level)

- Robust to interferences

Method limitations

- Requires taking the radar out of operations
- At best, restricted to elevations between 10° (refraction) and 70° (azimuth broadening), at high latitudes the range may be smaller
- Slightly less accurate in elevation than in azimuth (less elevation data)

Thanks for your attention