



Estimation of High-Rate Tropospheric Delays with Differential GNSS

David Gomez

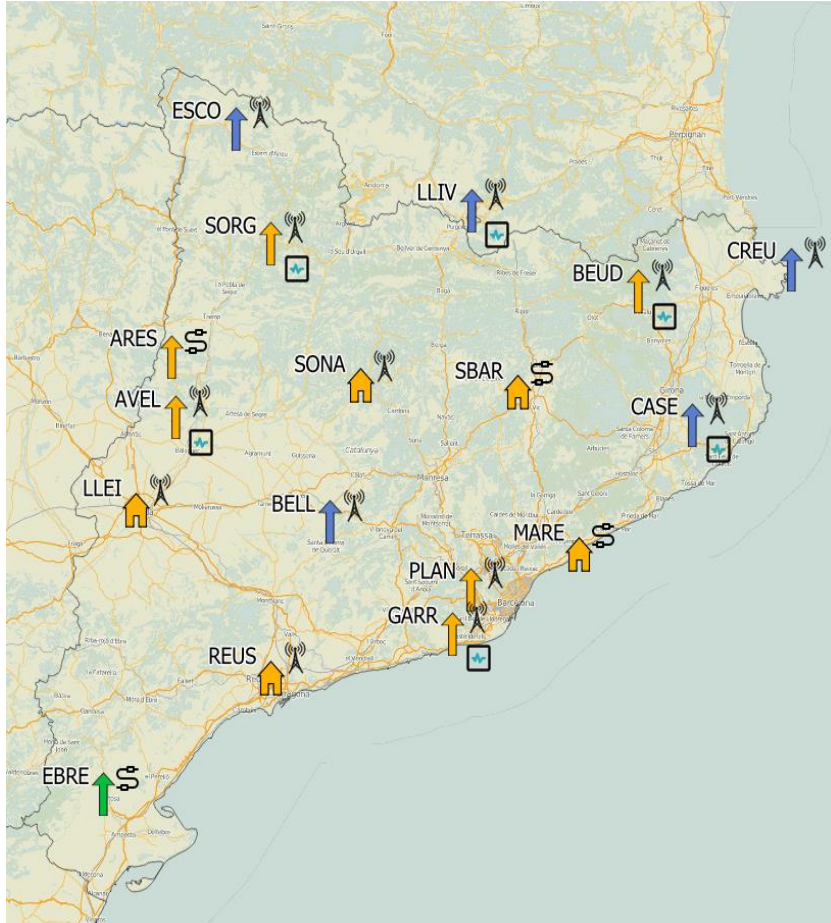
Geodesy and Administrative Boundaries Unit

Outline

ICGC's activities in the GNSS domain

isardSAT project's requirements

Tasks to meet Requirements



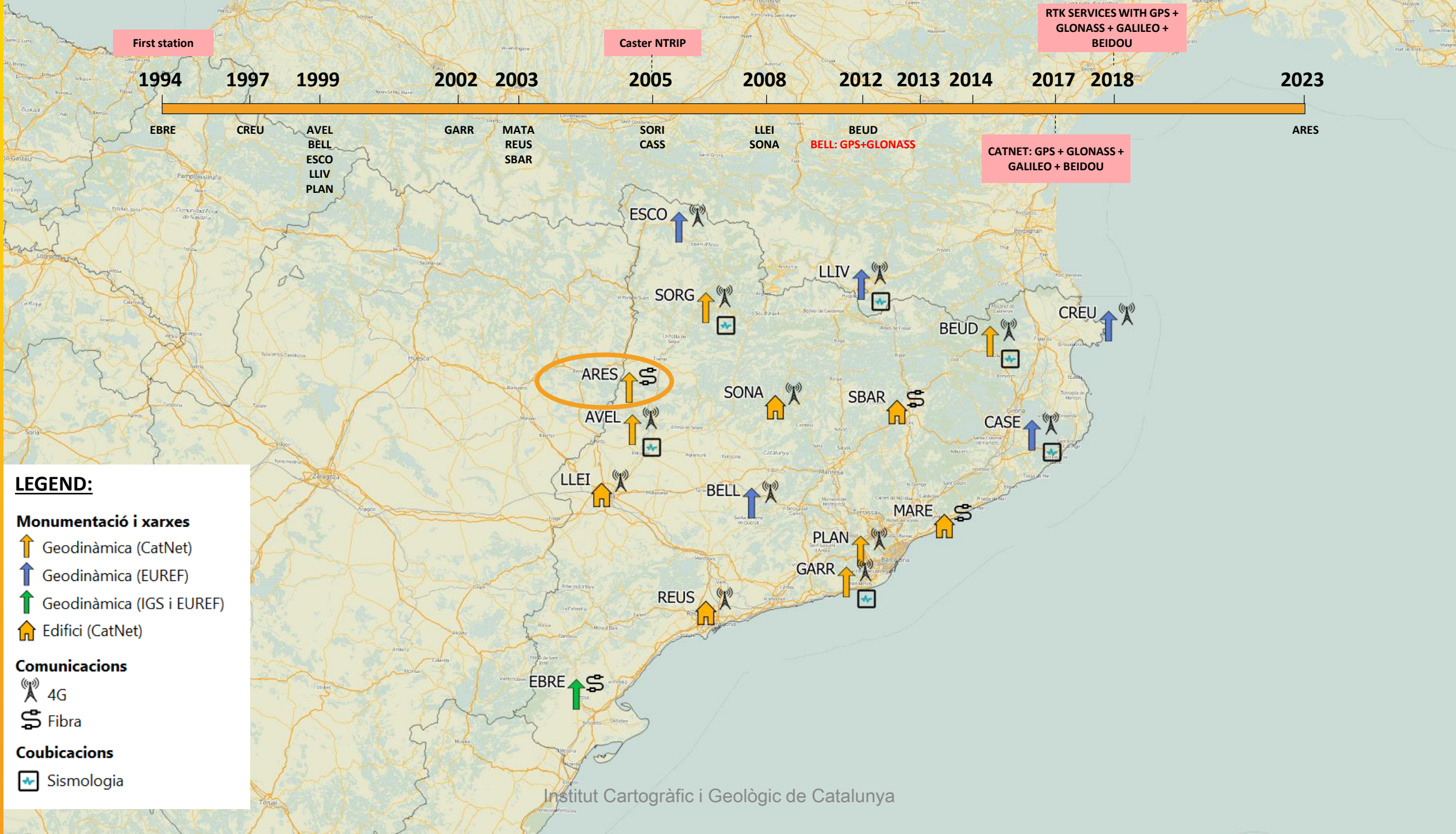
CatNet Network of Permanent Stations



Precise Positioning Services



GNSS Data Analysis Center: CADI



CatNet Network

17 permanent GNSS stations
(6 EUREF and 1 IGS)



LEGEND:

Monumentació i xarxes

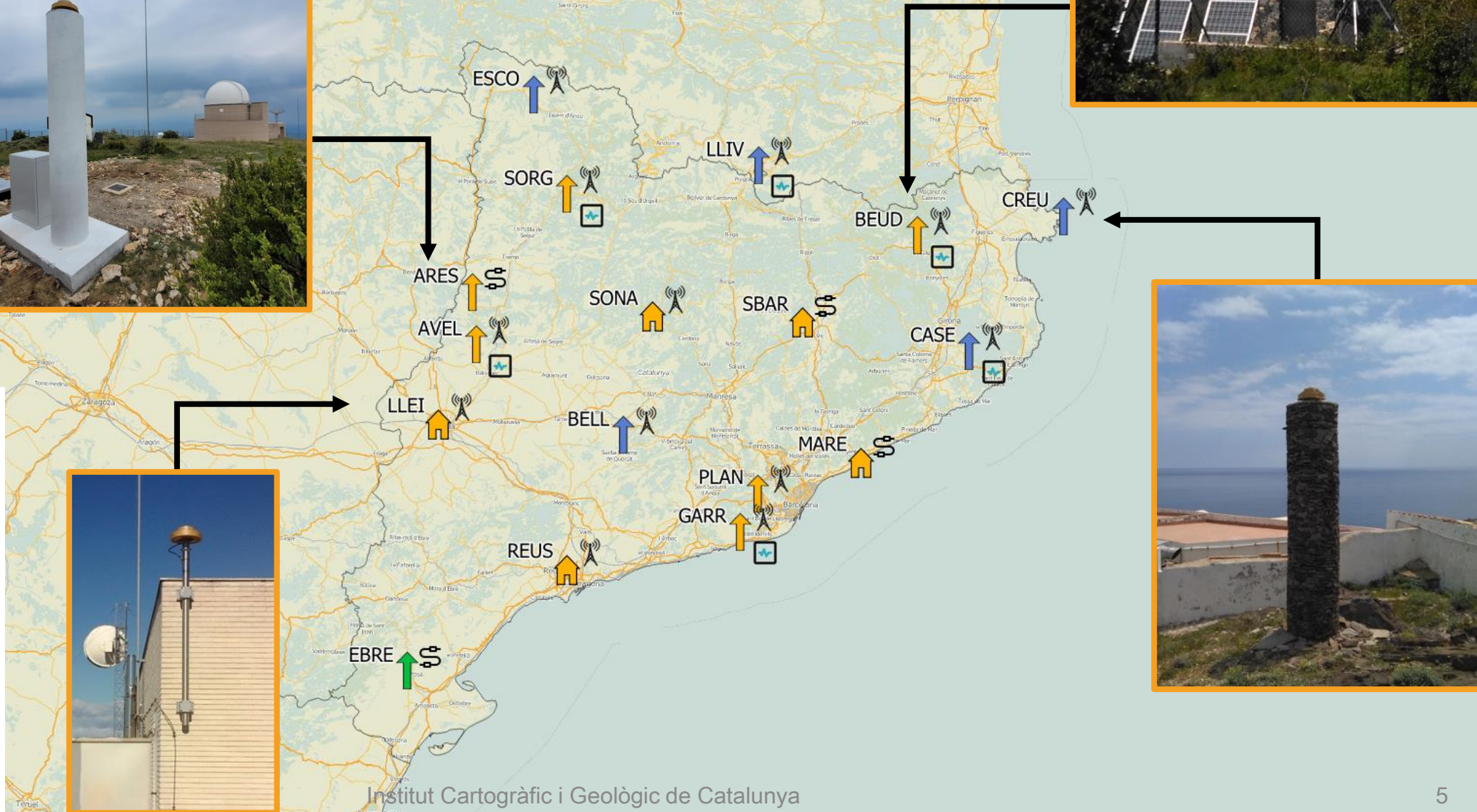
- ↑ Geodinàmica (CatNet)
- ↑ Geodinàmica (EUREF)
- ↑ Geodinàmica (IGS i EUREF)
- 🏠 Edifici (CatNet)

Comunicacions

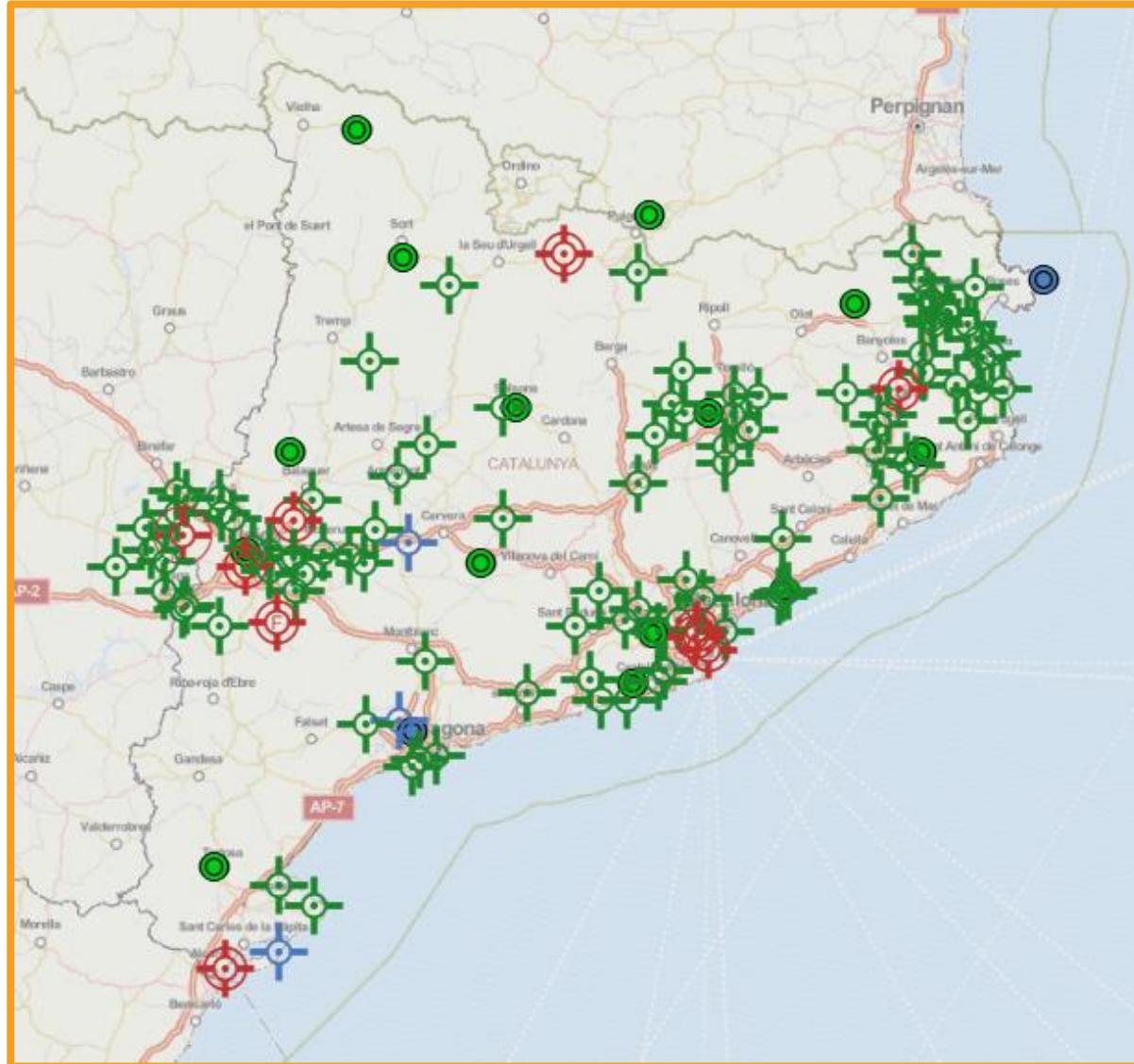
- 📶 4G
- 💰 Fibra

Coubicacions

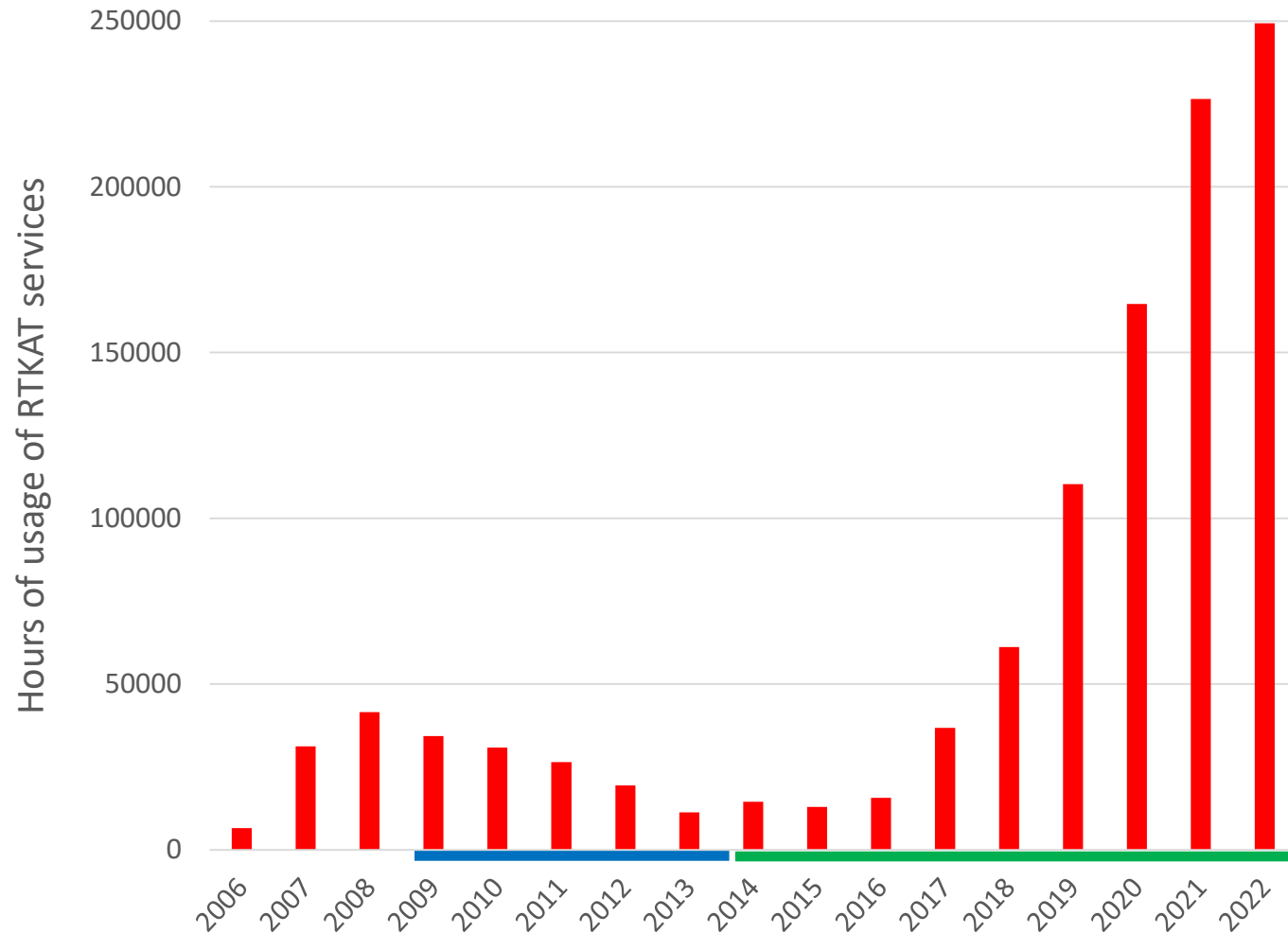
- 📶 Sismologia



Usage of real-time positioning services



Usage of RTK services in hours



15/3/2024

Institut Cartogràfic i Geològic de Catalunya

CONSTRUCTION CRISIS

Year	RTKAT	%RTKAT
2006	6559	
2007	31174	375.3
2008	41559	33.3
2009	34273	-21.3
2010	30886	-11.0
2011	26503	-16.5
2012	19411	-36.5
2013	11297	-71.8
2014	14519	28.5
2015	12978	-11.9
2016	15675	20.8
2017	36805	134.8
2018	61130	66.1
2019	110296	80.4
2020	164649	49.3
2021	226519	37.6
2022	249318	10.1

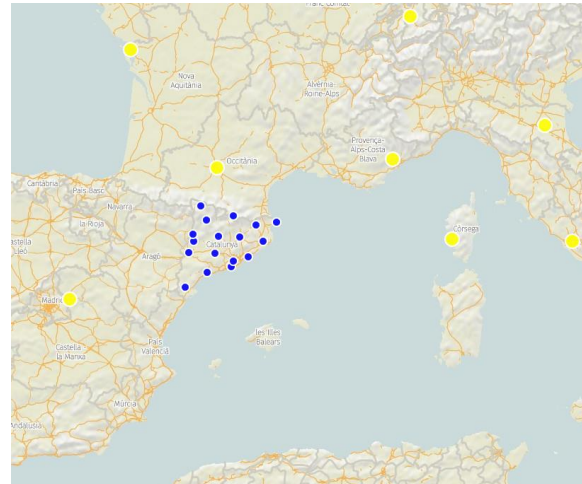
PRECISION AGRICULTURE

Process with **BerneseSW 5.4**

Main products:

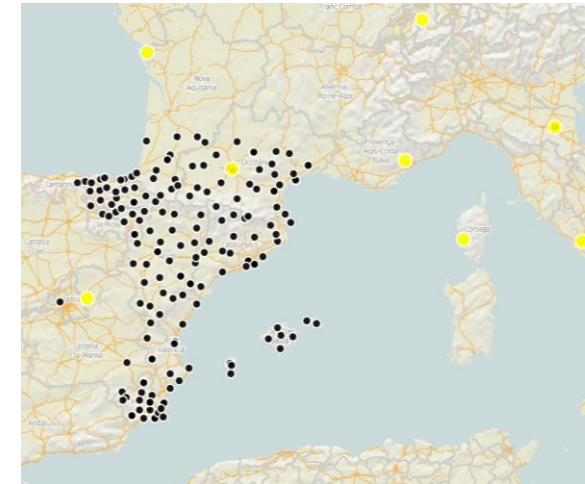
- **Coordinates**
- **Velocities**

Daily and **weekly** solutions



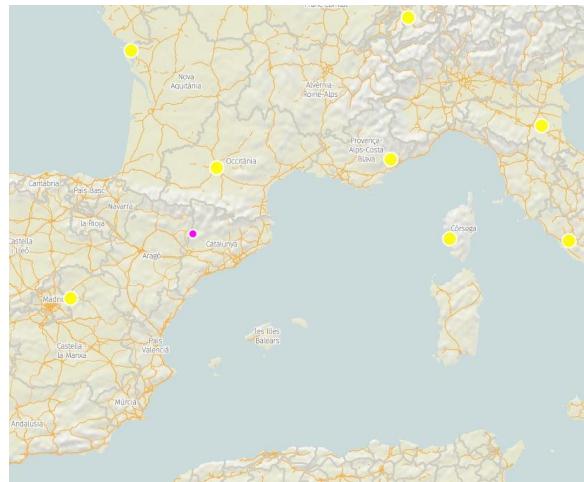
AJUST_CATNET

Official Reference Frame Catalonia



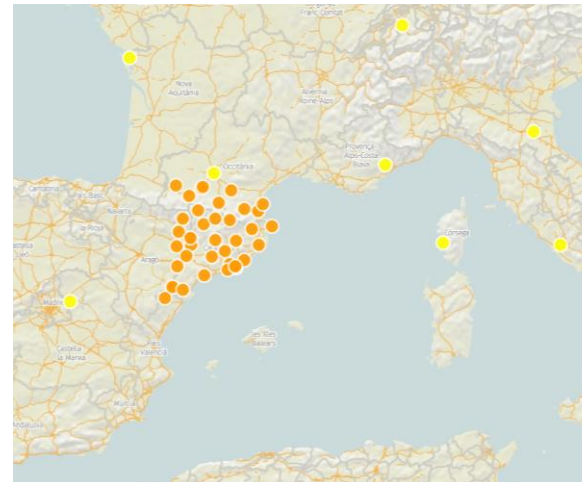
DAC_CAT

EPN Densification project



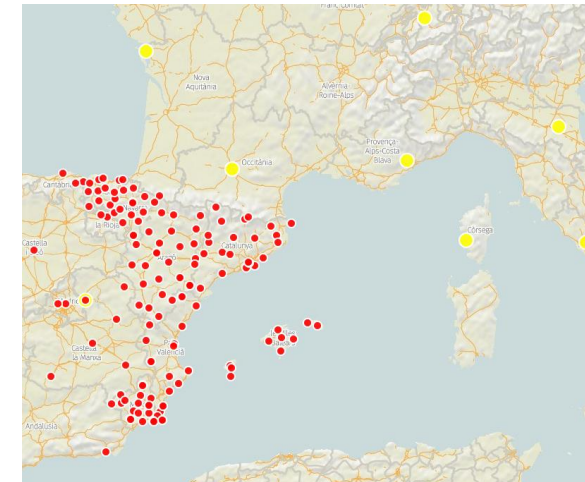
TROPO_ARES

ZTD Delay



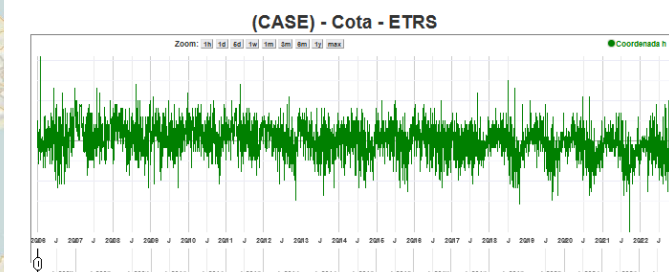
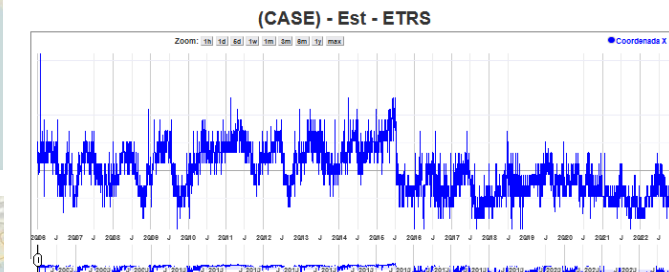
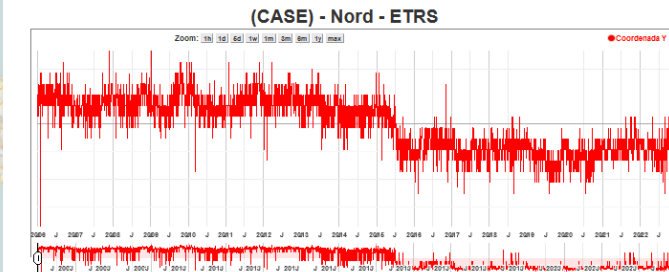
CATNET_SPIDER

Reference Frame RT Services

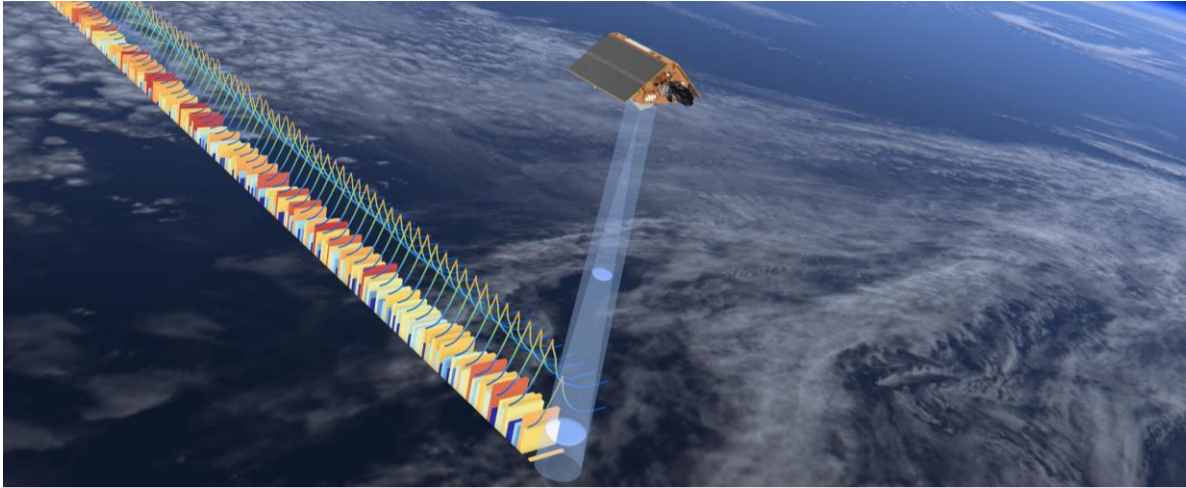


IBERIA

Official Reference Frame Spain



isardSAT project's requirements



Sentinel-6 Michael Friedrich (S6-MF)

PROJECT

Radar altimeter absolute range measurements with Corner Reflector

Objective

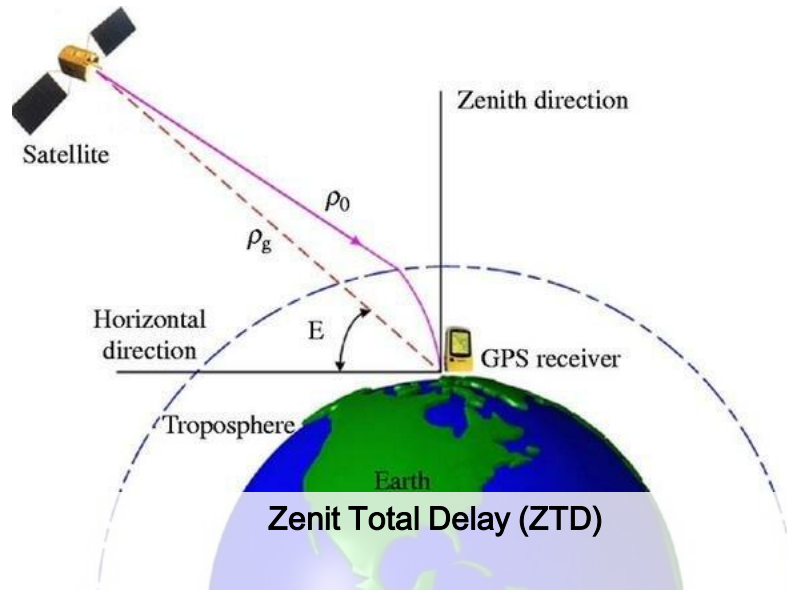
Validate a new methodology to *calibrate Radar Altimeter* with passive elements instead of active elements



Corner Reflector

Requirements and constrains

- Satellite illuminates Corner Reflector only 5'' (approx.)
- Orbital period of 10 days
- Distance of 1300km between satellite and Corner Reflector
- Achieving STD of 1cm of precision



- Achieving STD of 1cm
- High accuracy* in *ZTD* determination
- High accuracy* in height Corner Reflector coordinate
- Satellite illuminates Corner Reflector only 5'' (approx.)
- Minimal time difference* between *ZTD measurement* and *satellite's overhead pass: High-rate Tropospheric delays*
- Orbital period of 10 days
- Minimal Delay* between the *satellite pass* and the *delivery of ZTD values*



Tasks to meet Requirements



Build a new Reference Station
ARES



Leveling between the Corner Reflector
and ARP



Set up Bernese



Validate results



Reinforced concrete block



Reinforced concrete pillar



ARES monument

ARES 13431M001

Reinforced *Concrete Pilar* (3 m)

Receiver Leica ***GR50***

Antenna Leica ***LEIAR25.R4***

RINEX since 29th of June 2023:

- Hourly 1 second rate
- Daily 30 second rate



AGE2 temporary GNSS station

Temporary GNSS station before ARES was built

RINEX files since 20th of February 2023

Receiver Trimble *NetR9*

Antenna Trimble *Zephyr Geodetic II*

Leveling



Leveling between Corner Reflector Reference Point and Antenna Reference Point.

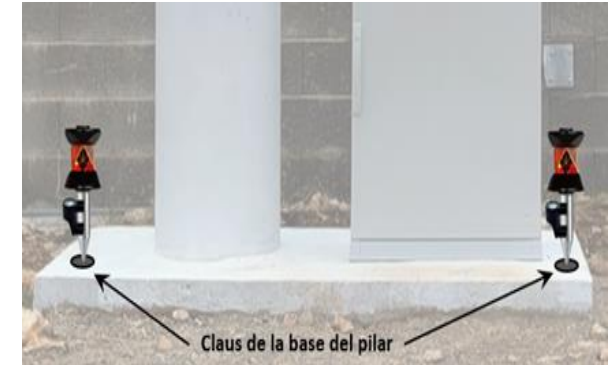
Split into two segments:

Corner Reflector Reference Point → Pillar benchmarks

Leveling precision: 1,8 mm



Corner Reflector Reference Point



Pillar benchmarks

Pillar benchmarks → Antenna Reference Point

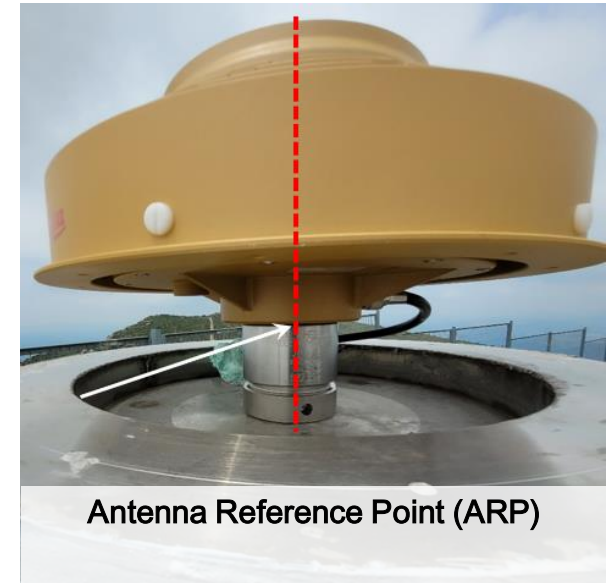
Leveling precision: 0,7 mm

Corner Reflector Reference Point → Antenna Reference Point

Leveling precision: **2 mm**



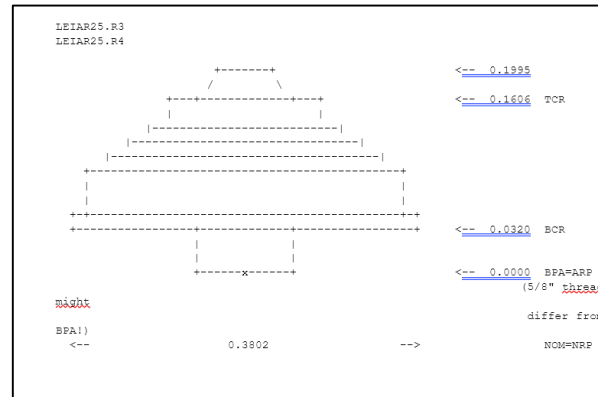
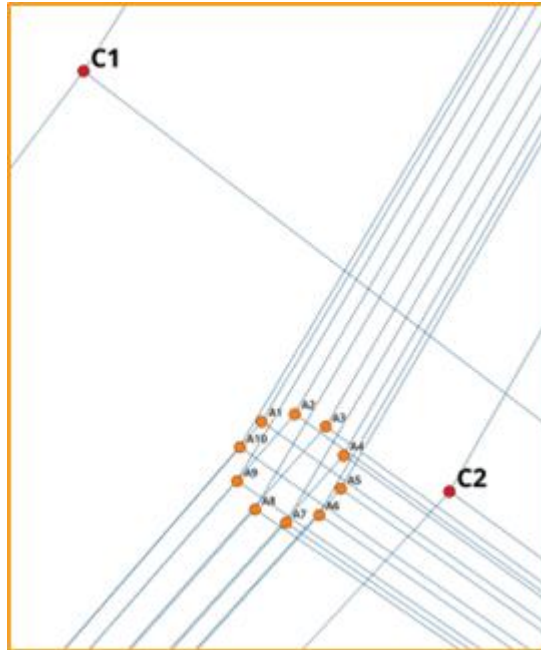
Pillar benchmarks



Antenna Reference Point (ARP)

Procedure Indirect measurement

- 3 instrument stations
- Measurements of the 10 equidistant antenna holes
- Average of the 10 measurements
- Lower the avg measurement to ARP



Antenna GNSS dimensions



Mini prism



Mini prism

<i>Mean pole model:</i>	IERS2010_v1.2.0
<i>Subdaily pole model:</i>	DESAI2016
<i>Antenna corrections:</i>	igs20.atx
<i>Orbit, Clock, bias products:</i>	COD00PSRAP
<i>Ocean tidal model:</i>	FES2014b
<i>Atmospheric tidal model:</i>	NONE
<i>Troposphere model:</i>	VMF3
<i>Absolute individual ant. calib.:</i>	NONE
<i>Consider antenna rotations:</i>	checked from STA file
<i>Antenna calib. method:</i>	NONE or ADOPTED from GPS

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

EDITPCF 3: BPE SERVER VARIABLES

PARAMETERS: may contain several of the following characterization separated by semicolon - DESCRIPTION=

Variable	Default	Parameters
		General and model files:

V_MEANPL	IERS2010_v1.2.0	DESCRIPTION=Mean pole model
V_SUBMOD	DESAI2016	DESCRIPTION=Subdaily pole model
V_NUTMOD	IAU2000R06	DESCRIPTION=Nutation model
V_PCV	I20	DESCRIPTION=Antenna phase center (PCV) model
V_PCVINF	ANTENNA	DESCRIPTION=PCV information file
V_SATINF	SATELLIT	DESCRIPTION=Satellite information file
V_SATCRX	SAT_\$Y+0	DESCRIPTION=Satellite problem file
V_ORBDIR	\${D}/COR	DESCRIPTION=Directory with orbit products
V_ORB	COD00PSRAP	DESCRIPTION=Orbit/ERP, CLK, bias information
		Reference frame and station related files:

V_REFDIR	\${D}/REF54	DESCRIPTION=Directory with basic Bernese files
V_REFINF	IGS20	DESCRIPTION=Master/reference CRD/VEL filename
V_REFPSD	IGS20	DESCRIPTION=PSD corrections (ITRF2014 or higher)

Bernese BPE set up



GPSEST 6.1.1: Site-Specific Troposphere Parameters 1

ZENITH PATH DELAY PARAMETERS

Mapping function (hh mm ss)

Parameter spacing (hh mm ss)

HORIZONTAL GRADIENT PARAMETERS

Gradient estimation model

Parameter spacing (hh mm ss)

A PRIORI SIGMAS

	Absolute	Relative
Zenith path delay	5.00 meters	5.00 meters
Horizontal gradients	5.00 meters	5.00 meters

EXTRACTION OF PARAMETERS FOR TROPOSPHERE SINEX FILE

Offset (hhh mm ss) Time resolution (hh mm ss)

GPSEST 6.1.1: Site-Specific Troposphere Parameters 1

ZENITH PATH DELAY PARAMETERS

Mapping function (hh mm ss)

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EXTRACTION OF PARAMETERS FOR TROPOSPHERE SINEX FILE

Offset (hhh mm ss) Time resolution (hh mm ss)

ADDNEQ2 9: Options for Atmospheric Parameters

ABSOLUTE CONSTRAINING

Troposphere zenith path delays		meters
Troposphere gradients		meters
Global ionosphere parameters		TECU

RELATIVE CONSTRAINING AND VALIDITY INTERVAL OF CONSTRAINT

Troposphere zenith path delays	5.0 meters	01 00 00 (hh mm ss)
Troposphere gradients	5.0 meters	24 00 00 (hh mm ss)
Global ionosphere parameters		(hh mm ss)

EXTRACTION OF PARAMETERS FOR TROPOSPHERE SINEX FILE

Offset (hhh mm ss) Time resolution (hh mm ss)

Trial and Error

Phase Residual Screening (R2S_EDT/GPSEST)

1h / 30' / 10' / 5' → *Works for 30'*

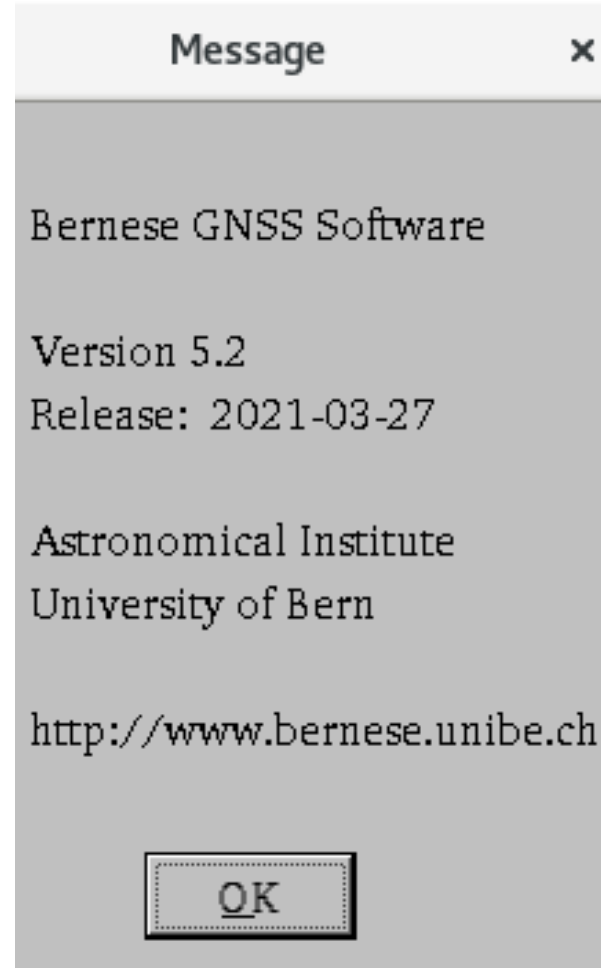
Final baseline processing (R2S_FIN/GPSEST)

1h / 30' / 10' / 5' / 22 → *Works for 5'*

Time resolution of parameters of Troposphere RINEX file



AGE2 temporary station



Bernese 5.2

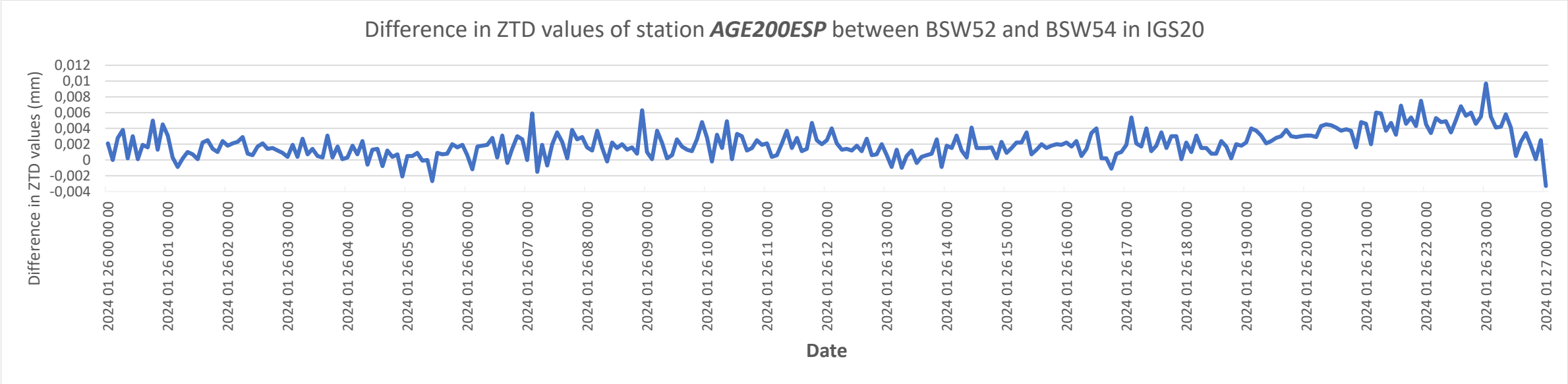
Updated Bernese 5.2 to compute in IGS20

Differences Bernese 5.2 vs Bernese 5.4

	BSW5.2	BWS5.4
<i>Mean-pole model</i>	None	IERS2010_V1.2.0
<i>Troposphere model</i>	VMF1	VMF3

Validate results





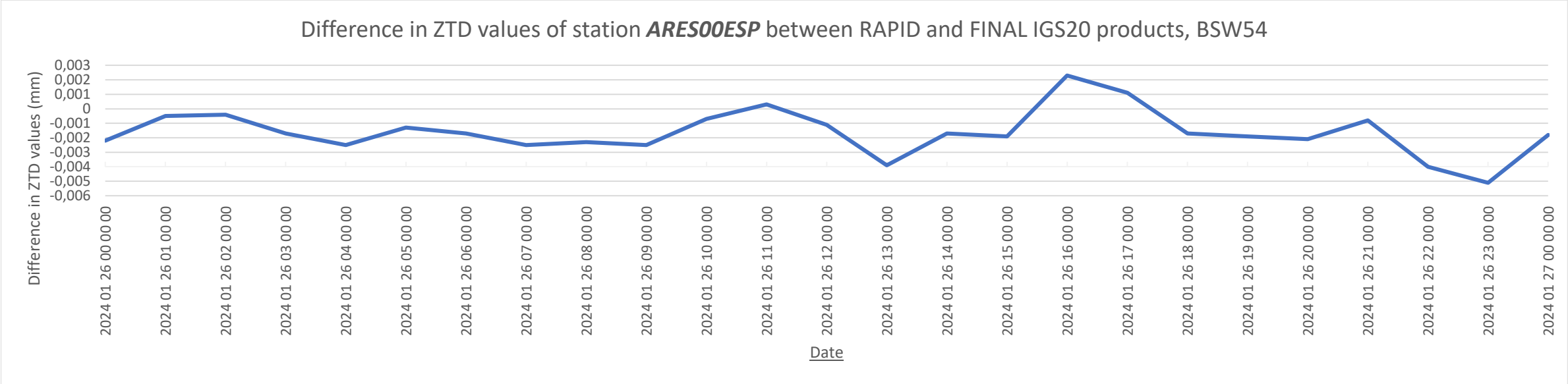
Difference between ZTD values computed in IGS20 with BSW 5.2 and 5.4

Descriptive Stat.	Value (mm)
Maximum	0,010
Minimum	-0,003
Standard deviation	0,002
Average	0,002

	BSW 5.2	BSW 5.4
Elevation cutoff angle:	3°	3°
Trop. Mapping function:	WET VMF	WET VMF3
Sampling Trop:	300	300



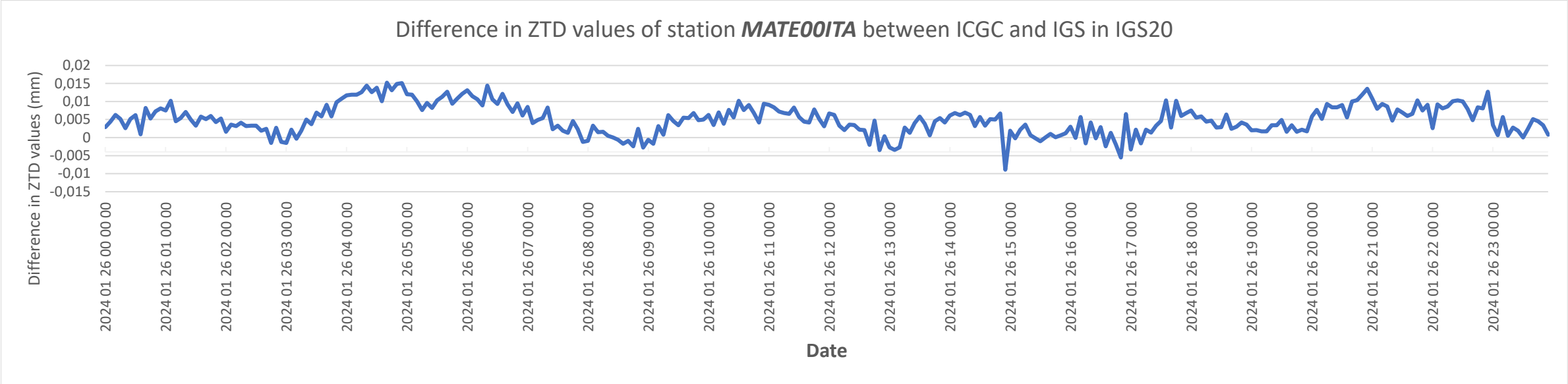
Validate Results



Descriptive Stat.	Value (mm)
Maximum	0,002
Minimum	-0,005
Standard deviation	0,001
Average	-0,001

Difference between ZTD values computed using RAPID and FINAL IGS20 products (BSW 5.4)

	RAPID	FINAL
Elevation cutoff angle:	3°	3°
Trop. Mapping function: VMF3	WET VMF3	WET
Sampling Trop:	300	3600



Descriptive Stat.	Value (mm)
Maximum	0,015
Minimum	-0,008
Standard deviation	0,004
Average	0,005

Difference between ZTD values computed by ICGC and IGS20 troposphere products (BSW 5.4)

	ICGC	IGS
Elevation cutoff angle:	3°	7°
Trop. Mapping function: GMF	WET VMF3	WET
Sampling Trop:	300	300

Found a systematism of 4-6 millimeters with all IGS stations

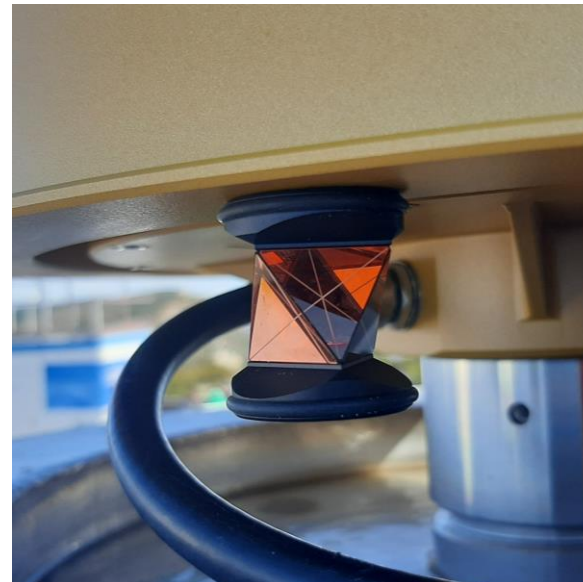
Summary

To fulfill the project's requirements, we had to:

- Set up a permanent station closed to Corner Reflector
- Compute accurate coordinates of the Corner Reflector
- Precise leveling between Corner Reflector RP and ARP
- Compute ZTD every 5' with Bernese 5.4 with RAPID products

Conclusion

The use of the ZTD values by isardSAT improve their results



Bernese GNSS Software

Version 5.4

Release: 2023-10-16

Astronomical Institute
University of Bern

<http://www.bernese.unibe.ch>

User ID: 116

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Moltes gràcies



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