The GeoMetre project: a comprehensive study to advance local tie metrology

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for the **GeoMetre Consortium**

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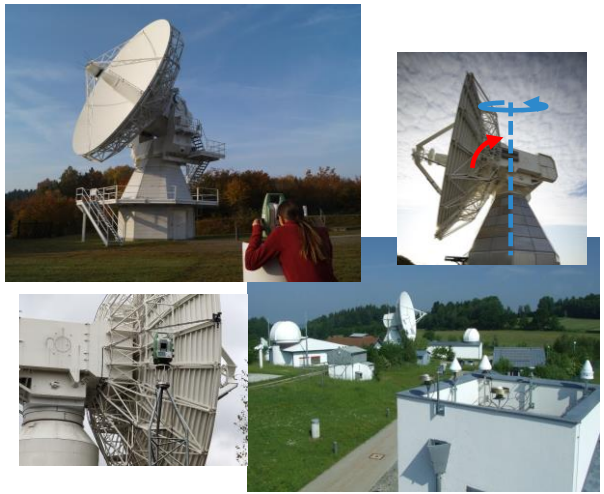
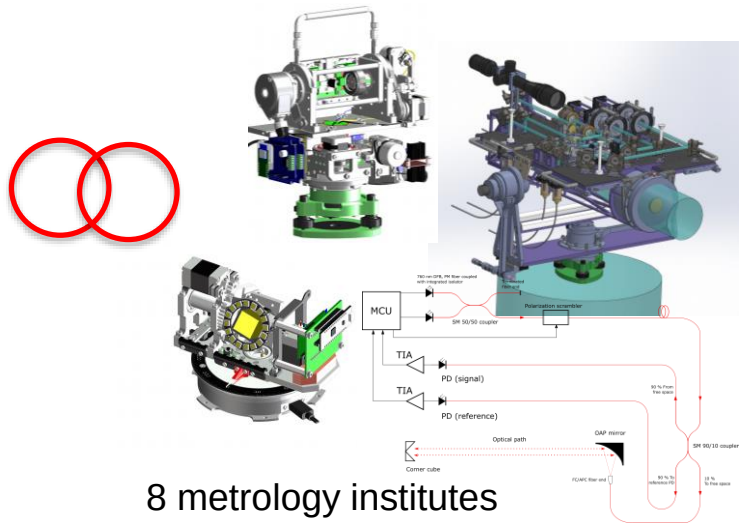
Motivation for the GeoMetre project



8 geodetic institutes



8 metrology institutes

The GeoMetre project unites geodesists and metrologists tackling:

- Can advance in instrumentation and measurement strategy improve local tie metrology?
- Can traceability to the SI definition of the metre for reference frames be tightened?

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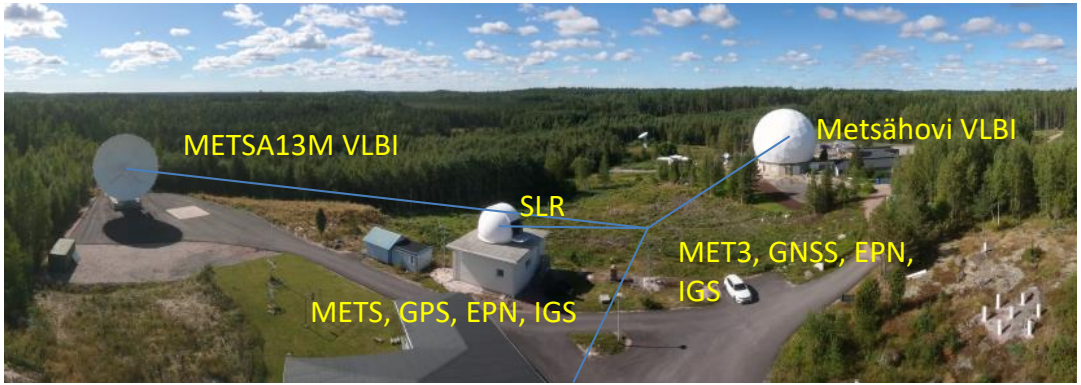
Modern local tie network: core-site Metsähovi

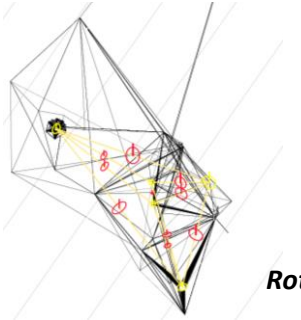
SI-traceable scale *from Nummela Standard Baseline*

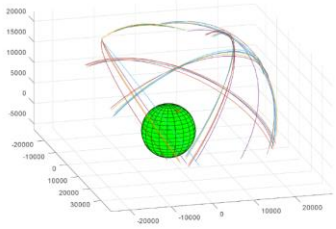


Translation*: Coordinates in ITRF for MET3, IGS and EPN GNSS point*

Local survey and monitoring *measurements in tachymeter system*

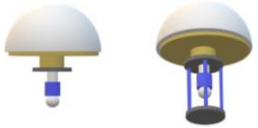
Instrument orientation in global frame: geoid model





Rotation

Global orientation of the network



Accurate ***micro-local-tie*** *between GNSS ARPs and prisms*

➔ 3D network adjustment directly in global frame
Observation equations in global geodetic system

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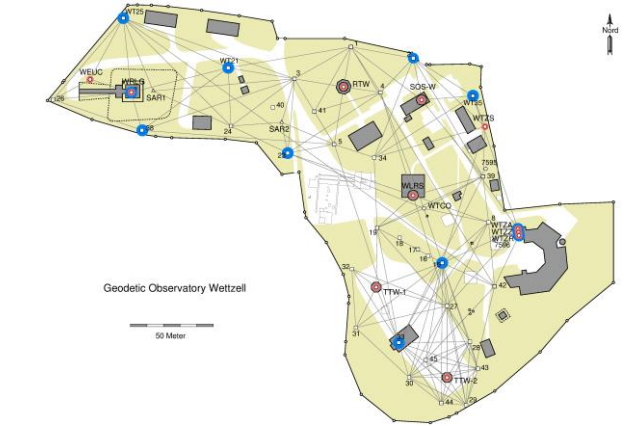
Transformation-free approach: core-site Wettzell

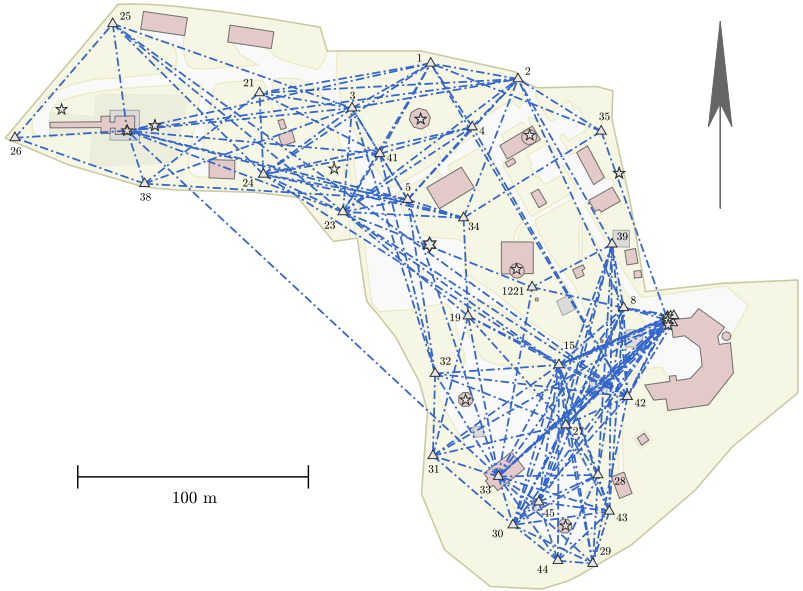
- Accuracy of measured deflection of vertical about 1 µrad (astronomical and gravimetric)
- GNSS accuracy:
  - Short baselines: substantial vertical orientation error (3 mm @ 100 m ≈ 30 µrad error)
  - Long baselines: (L1/L2 direct) problematic, L3 less accurate
- Terrestrial measurement:
  - First velocity correction (distance)
  - Beam bending (zenith angle)

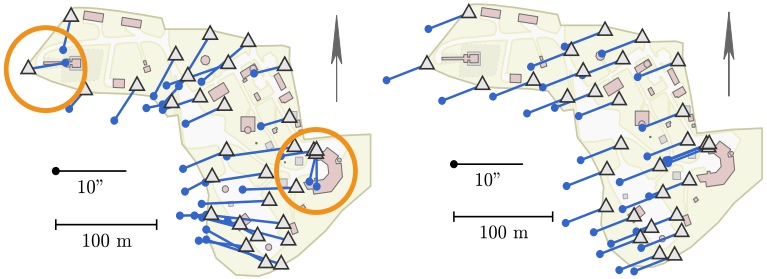
➔ Recommendation:
- Horizontal orientation by distant targets (GNSS/terrestrial)
- Vertical orientation by using ellipsoidal coordinates plus correction for deflection of vertical



Operator-Software Impact

- Joint measurement campaign with CNAM at Wettzell
- Study for consideration of vertical deflections in local tie networks treating deflections as
  - Deterministic parameters
  - Or parameters to be estimated
- Strong dependence on network datum
  - Network tilting
  - Network bending





➔ Vertical deviations of about $0.5 - 2.5$ mm caused by Operator-software impact

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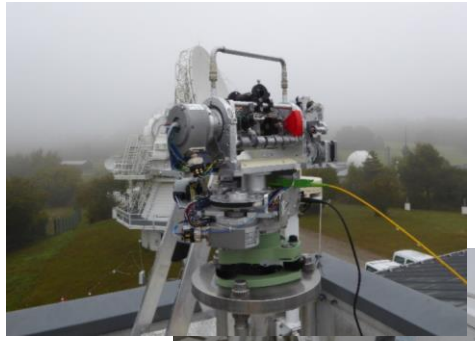
Multilateral VLBI reference point determination

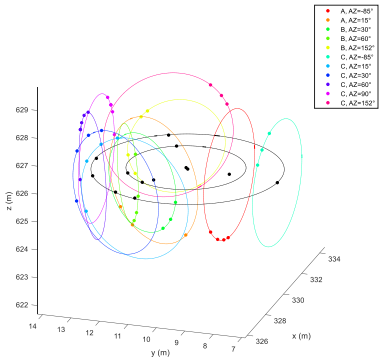
le cnam

DistriMetré:

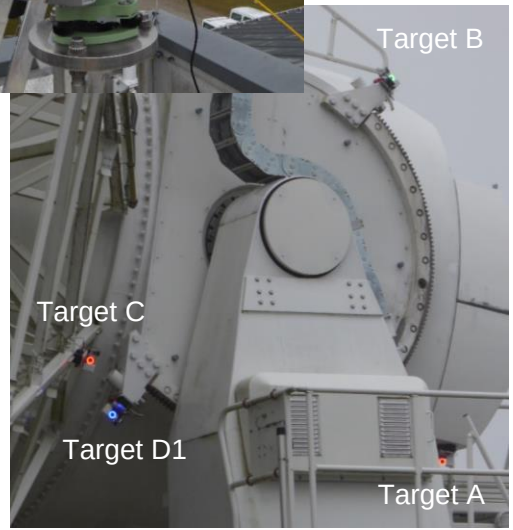
- Robust ranging technique (RF modulated optical signal)
- One optical telemetric source with four fiber-optic output ports and four compact optical heads
- Position uncertainties between $70\ \mu m$ and $304\ \mu m$ for the targets installed on the radio telescope
- VLBI reference point determination at VGOS antenna in Wettzell
- Analysis in combination with polar observations jointly measured with Frankfurt UAS

➔ Pre-analysis: Variance component estimation indicates multilateration distances being three times better





Multilateration



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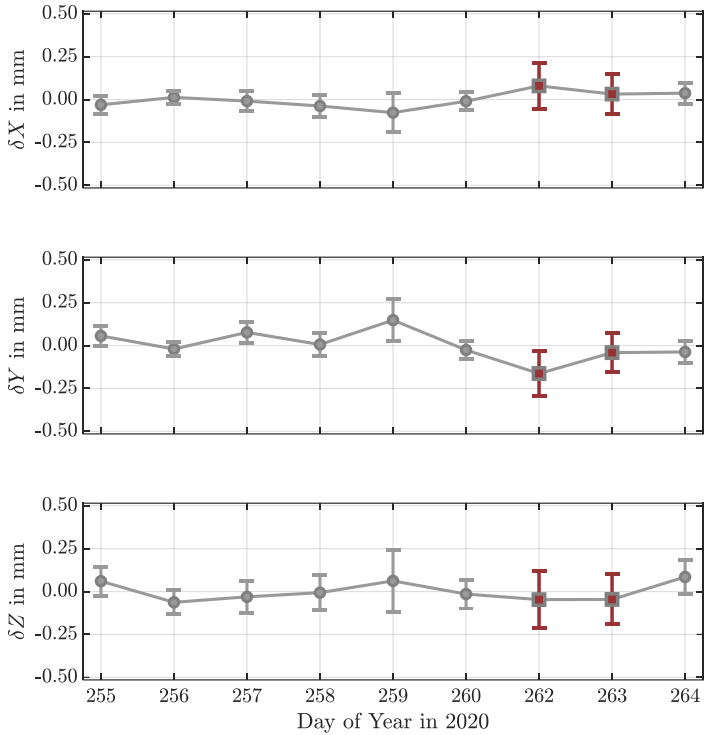
Advancing SLR/VLBI Reference Point Determination

- Improved model for in-process reference point determination
- Evaluation of close range photogrammetry at SLR telescope Wettzell using
  - Traditional multi-image analysis (grey dots)
  - Concatenated transformation (red squares)
- Development of bundle-adjustment software package for rigorous data analysis

➔ More details at Unified Analysis Workshop



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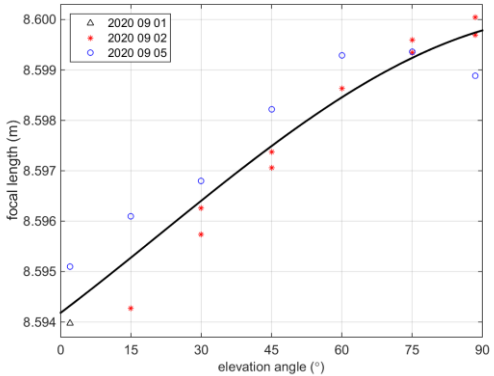
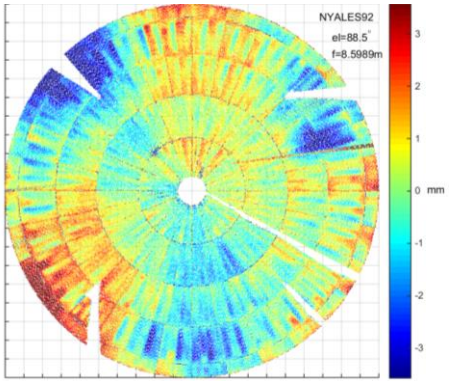
Deformation of VLBI receiving unit

- 3D scanning of 20 m dish of legacy VLBI antenna at Ny-Ålesund (receiver in primary focus)
  - 3D scanner mounted on one of the upper beams
  - Interferometer laser ranger mounted in telescope center for distance vertex-receiver as function of elevation and temperature
- Analysis by least square fitting to parabola
- Deformation curve derived





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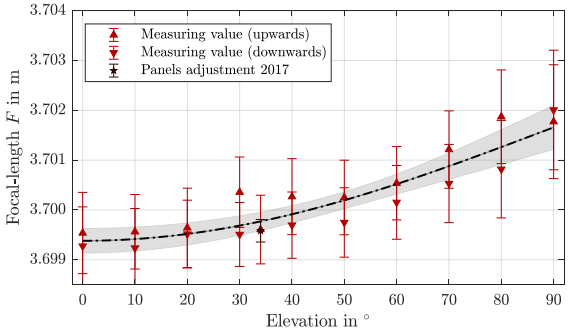
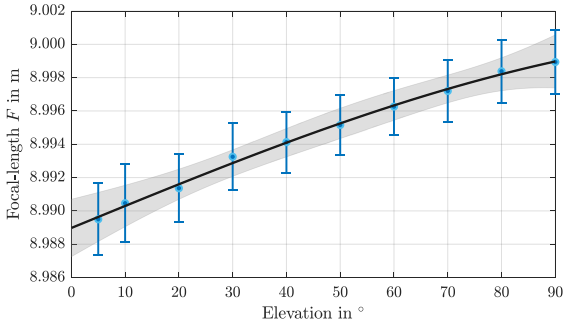
Deformation of VLBI receiving unit

- Joint measurement campaigns with Bochum UAS
- Unmanned Aerial Vehicle (UAV) based data acquisition
  - VGOS antennas at Onsala and Wettzell
  - Legacy VLBI antenna at Wettzell
- Derivation of elevation-dependent
  - Focal-length deformations
  - Sub-reflector variations
  - Vertex shifts

➔ Elevation dependent correction of signal path variations



VGOS antenna at Onsala published in 2019



Legacy VLBI antenna at Wettzell published in 2022

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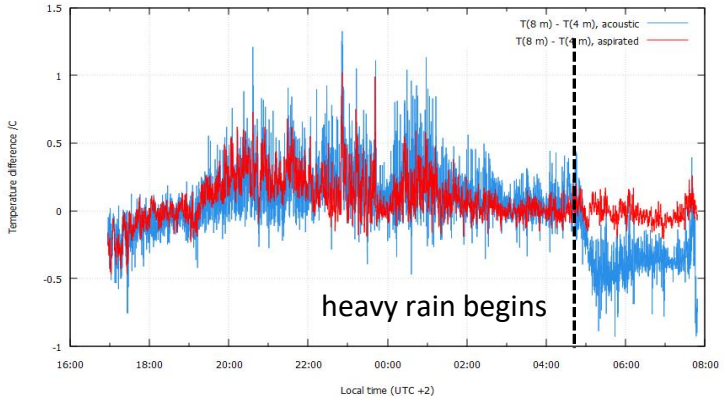
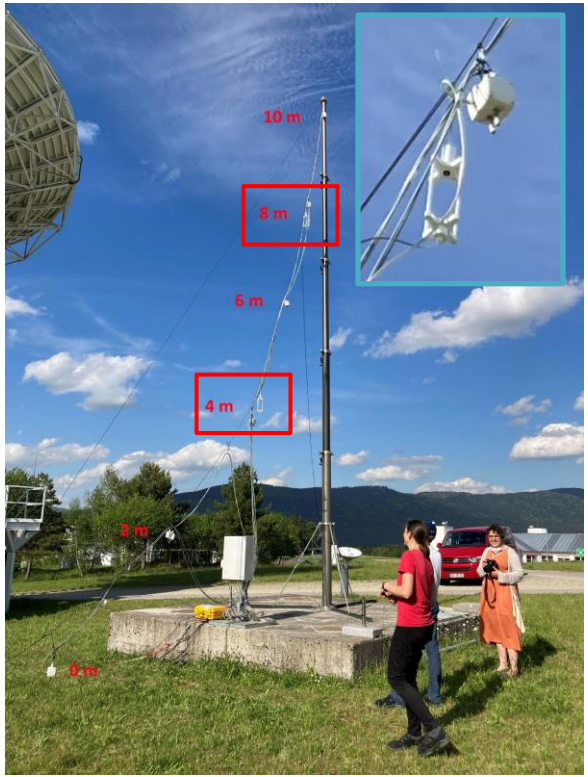
Refractive beam bending correction

- Measurement of vertical temperature gradients
- Comparison of passive and aspirated Pt1000 sensors and ultrasound-based thermometers mounted on 10 m mast close to VGOS antennas at Wettzell





➔ Gradients of ultrasound and aspirated sensors agree well:
Pt1000s: 0.091 °C/m ATGSM: 0.103 °C/m

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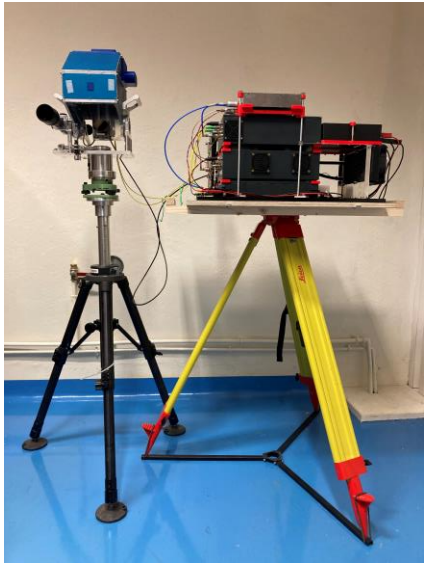
Scale definition: new long distance meters

le cnam

PTB Physikalisch-Technische Bundesanstalt Nationales Metrologieinstitut

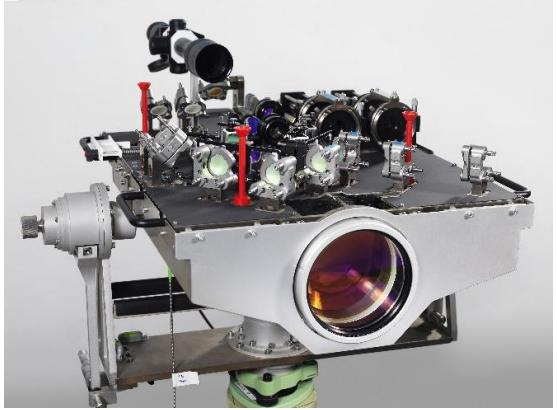
Target: reduction of uncertainty of scale and orientation of surveillance network

- Development of SI-traceable long distance range meters with low uncertainty
- Exploiting intrinsic refractivity compensation



Arpent system:

- RF modulation
- 780 nm and 1560 nm
- All-fibred design
- Flexible in use, well portable



TeleYAG-II system:

- Absolute interferometry
- 532 nm and 1064 nm
- Complex set-up

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Measurement campaigns

Targets:

- Network measurements
- System verification
- “Metrologist” calibration to measurement environment
- Sometimes systems were not mature enough

➔ The work will be continued!

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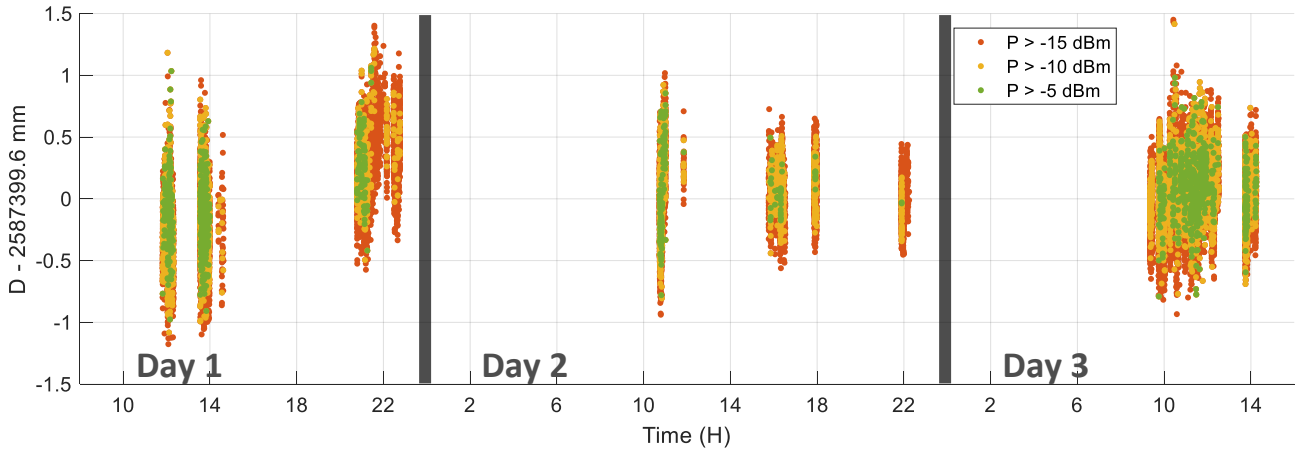
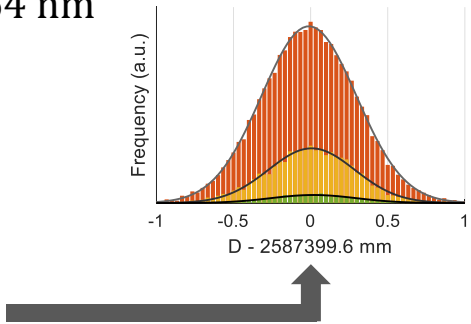
Verification of SLR versus Arpent/EDM

Comparison of the distance difference between two corner cubes separated by about 2.6 km

- Two-colour ADM Arpent from CNAM, at 780 nm and 1560 nm
- Two-colour SLR from Observatoire de la Côte d'Azur, at 532 nm and 1064 nm
- Data analysis of the measurements of the Two-colour SLR is still ongoing





normal distribution
with $\sigma \sim 300\ \mu m$

➔ Result of the 2-colour ADM from CNAM: average distance of $2587399.6\ mm \pm 0.3\ mm$

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Conclusions

- GeoMetre project has focused on local tie metrology

- Scope included
  - Identification of possible angles for improvement
  - Novel measurement and analysis strategies
  - Development of novel instrumentation designed for these approaches

- SINEX Contribution to ITRF2020 for Metsähovi and Wettzell

- Analysis of many experiments is still ongoing

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Thank you for your attention!

First progress meeting in Paris, 2020

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