GRUAN / ICM-16

Status GDP development M10/M20

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Outline

M10

1. M10 vs M10 Temperature comparisons
2. Dataflow for M10/M20 & L1/L2
3. Status of M10 Technical Document

M20

1. Temperature experiment, and uncertainties
2. Relative humidity experiment, repeatability, and reproducibility
3. Perspectives

M10 / M20, TRACIS* experiment at SIRTA Observatory

1. M10-GDP, RS41-GDP and M20 intercomparison

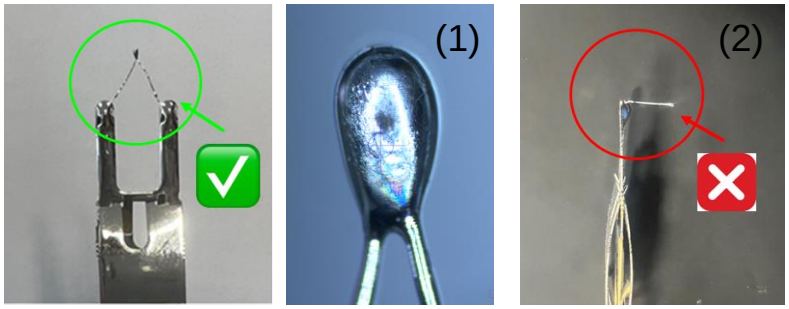
** Tropospheric Research campaign on Air humidity Content by Ipral lidar at SIRTA*

M10 vs M10 comparisons

Reproducibility issue has been identified :

(1) Coating problem

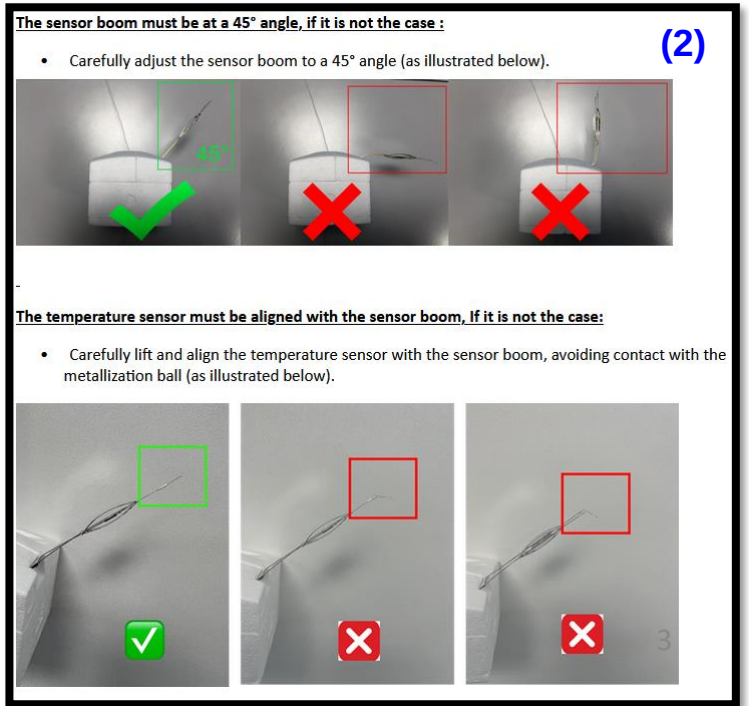
(2) Bending problem



AND solutions have been implemented (June 2023) :

(1) new packaging

(2) revised set-up before launch



Reproducibility of M10 temperature in soundings

1- Meteomdem (Ury, France)

Flight#	Launch	# of M10	Configuration	Day/Night
1	03/09/2022	2	🙂-🙂	Day
2	06/09/2022	2	🙂-🙂	Day
3	21/12/2022	3	🙂-😐-😐 / 0°-90°-90°	Day
4	26/01/2023	3	🙂-🙂-😐 / 0°-0°-45°	Day
5	27/01/2023	4	🙂-🙂-😐-😐 / 0°-0°-45°-90°	Day
6	26/07/2023	3	🙂-😐-😐 / 0°-45°-90°	Day
7	07/08/2023	3	🙂-😐-😐 / 0°-45°-90°	Day
8	01/03/2023	3	☹-🙂-🙂	Day
9	03/03/2023	3	🙂-☹-☹	Day
10	07/04/2023	3	🙂-☹-☹	Day
11	16/05/2023	3	🙂-😐-🙂	Day
12	30/05/2023	3	🙂-☹-🙂	Day
13	20/02/2024	3	🙂-😐-☹	Night
14	28/02/2024	3	🙂-🙂-☹	Night
15	12/04/2024	2	🙂-🙂	Day
16	23/04/2024	2	🙂-🙂	Day
17	30/05/2024	2	🙂-🙂	Day

🙂: No coating or inclination problems; 😐: Inclination problem; ☹: Coating problem

2- MeteoSwiss (Payerne, Switzerland)

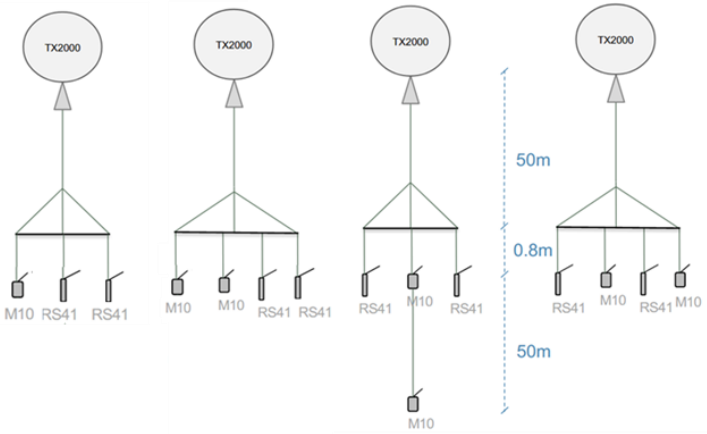
Flight#	Launch	# of M10	Configuration	Day/Night
1	17/06/2021	2	? - ?	Day
2	09/12/2021	2	? - ?	Day
3	15/12/2021 #1	2	? - ?	Day
4	15/12/2021 #2	2	? - ?	Day
5	16/12/2021 #1	2	? - ?	Day
6	16/12/2021 #2	2	? - ?	Day
7	19/01/2022	2	? - ?	Day
8	20/01/2022	2	? - ?	Day
9	12/04/2022	2	? - ?	Day
10	05/05/2022	2	? - ?	Day
11	23/05/2022	2	? - ?	Day
12	25/01/2023	2	🙂-☹	Day
13	09/02/2023	2	🙂-☹	Day
14	15/02/2023	2	☹-☹	Day
15	16/02/2023	2	🙂-🙂	Day
16	30/04/2024	2	🙂-🙂	Day
17	28/05/2024	2	🙂-🙂	Day
18	10/06/2024	2	🙂-🙂	Day
19	17/06/2024	2	🙂-🙂	Day
20	21/08/2024 #1	2	🙂-🙂	Day
21	21/08/2024 #2	2	🙂-🙂	Day
22	22/08/2024 #1	2	🙂-🙂	Day
23	22/08/2024 #2	2	🙂-🙂	Day

🙂: No coating or inclination problems; ☹: Inclination problem
?: No information about coating or bending

3- DWD (Lindenberg, Germany)

Flight#	Launch	# of M10	Configuration	Day/Night
1	27/04/2022	2	? - ?	Day
2	21/11/2023	2	? - ?	Day
3	28/11/2023	2	? - ?	Day
4	12/12/2023	2	🙂-☹	Day
5	10/01/2024	2	🙂-☹	Day
6	11/01/2024	2	🙂-🙂	Day
7	16/01/2024	2	🙂-☹	Night
8	18/01/2024	2	🙂-☹	Day
9	19/01/2024	2	🙂-🙂	Day
10	23/04/2024	2	🙂-🙂	Day
11	06/05/2024	2	🙂-🙂	Day
12	07/05/2024	2	🙂-🙂	Day
13	14/05/2024	2	🙂-🙂	Day
14	25/06/2024	2	🙂-🙂	Day
15	01/07/2024	2	🙂-🙂	Day
16	08/07/2024	2	🙂-🙂	Day
17	15/07/2024	2	🙂-🙂	Day
18	23/07/2024	2	🙂-🙂	Day
19	29/07/2024	2	🙂-🙂	Day
20	06/08/2024	2	🙂-🙂	Day

🙂: No coating or inclination problems; ☹: Inclination problem
?: No information about cc



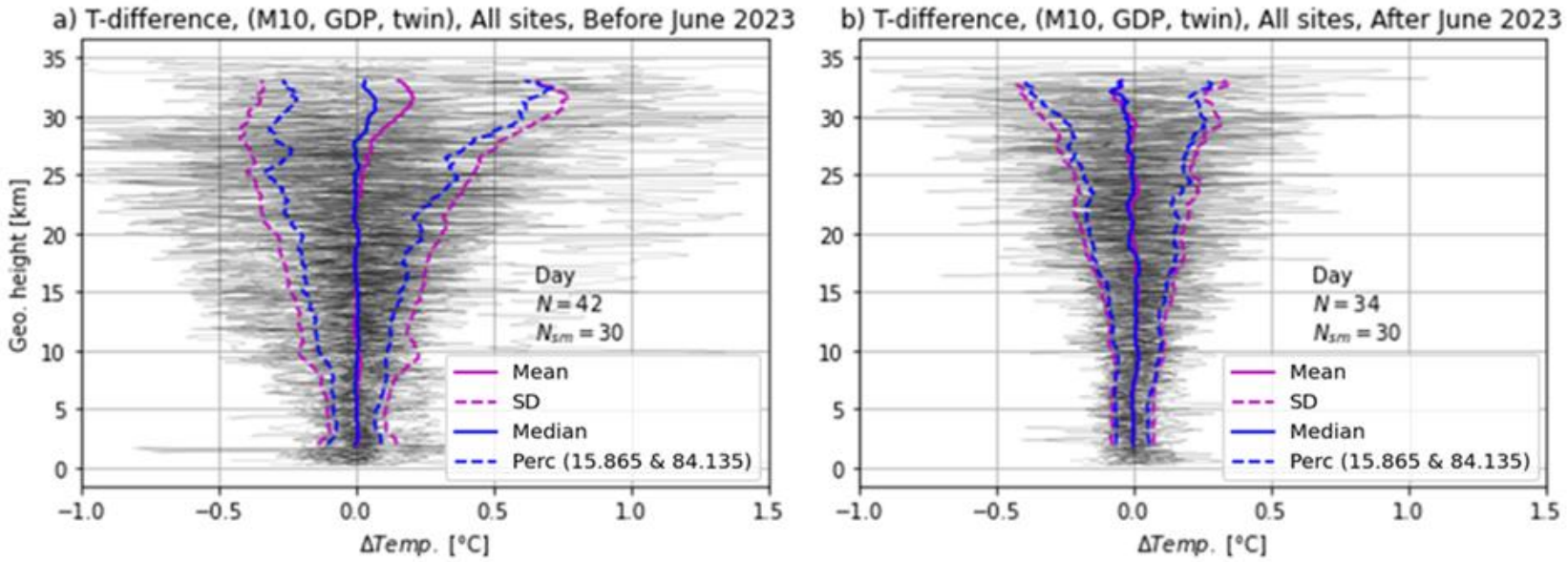
Goal

Perform daytime and nighttime radiosoundings with M10/RS41

- Assess data quality when multiple radiosondes are attached to the same rig
- Support the GRUAN certification process for reliable and traceable observations

Reproducibility of M10 temperature in soundings

All sites (Meteomodem, MeteoSwiss, DWD) – Daytime (n=76)



Before June 2023 (left panel):

- High variability in temperature differences
- Reflects earlier sensor performance issues

After June 2023 (right panel):

- Consistent improvement and reduced variability
- Confirms enhanced precision and measurement reproducibility

Conclusion

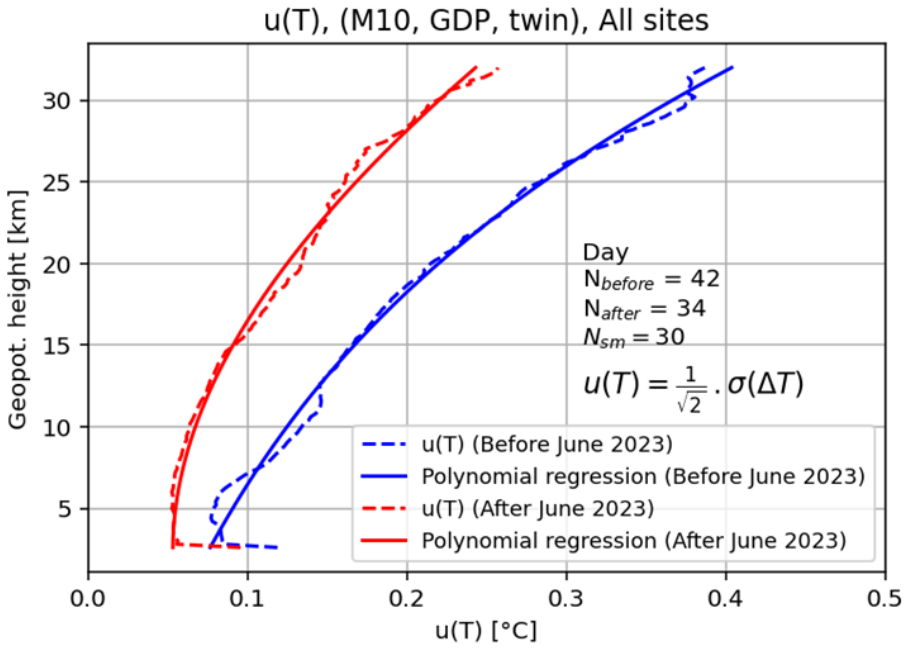
- Multi-site integration provides a robust estimate of reproducibility uncertainty
- Post-June 2023 adjustments → major improvement in M10 reliability and consistency

Reproducibility of M10 temperature in soundings

Associated measurement uncertainties

Methodology

- 76 M10 twin soundings from three sites (Ury, Payerne, Lindenberg)
  - Before June 2023: 42 | After June 2023: 34
- Assuming mean (ΔT) = 0
  - $u_{rep} = \frac{1}{\sqrt{2}} \cdot \sigma(\Delta T)$)



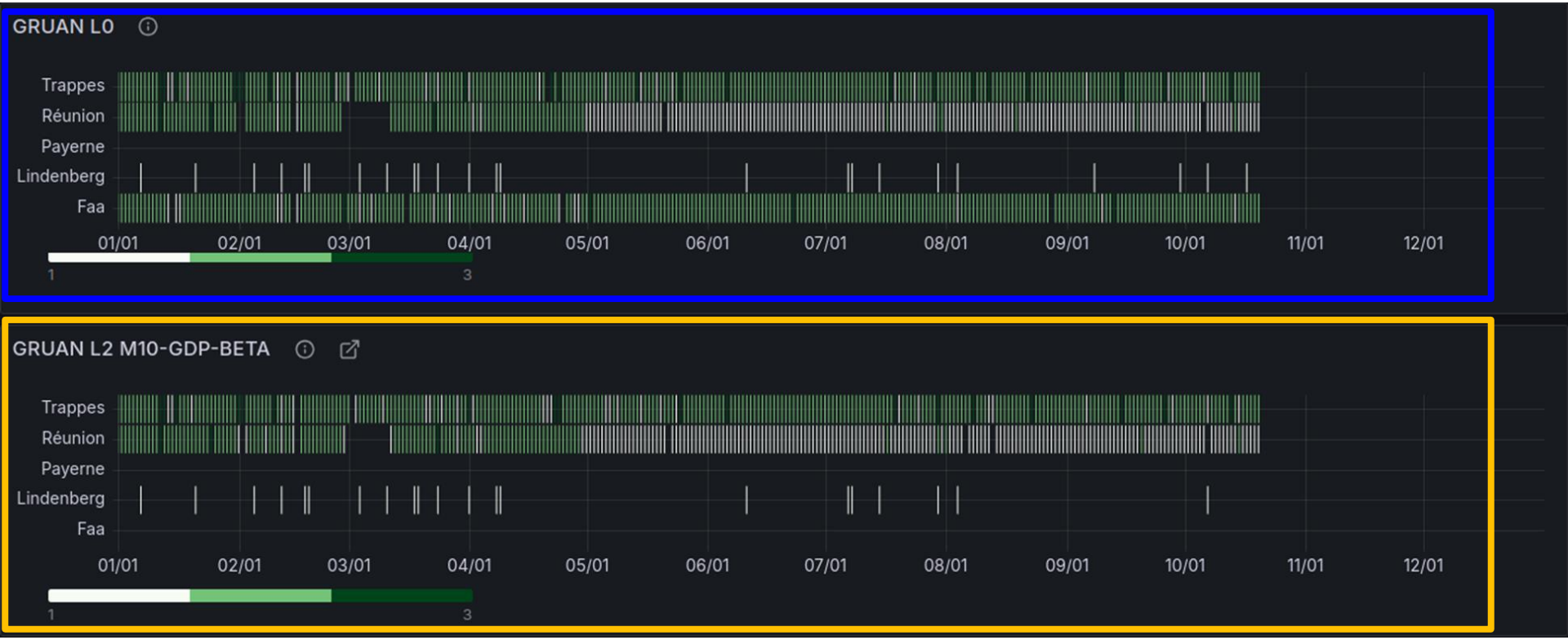
Conclusion

Lower uncertainty after June 2023 → improved sensor performance

M10-M20 dataflow L1 and L2-GDP, time series in 2025

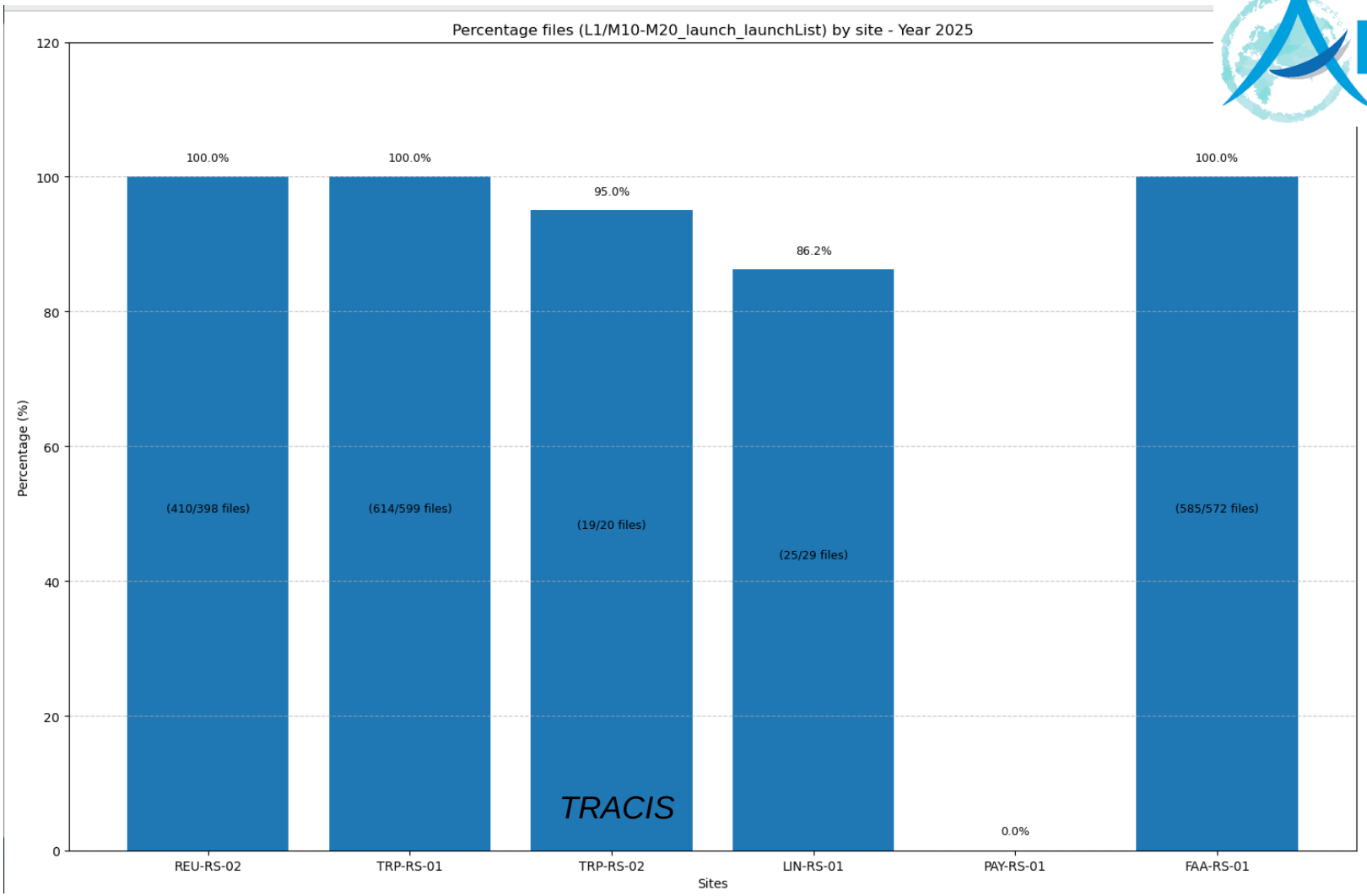
TRP / REU / LIN / FAA in 2025 for L1

TRP / REU / LIN in 2025 for L2-GDP



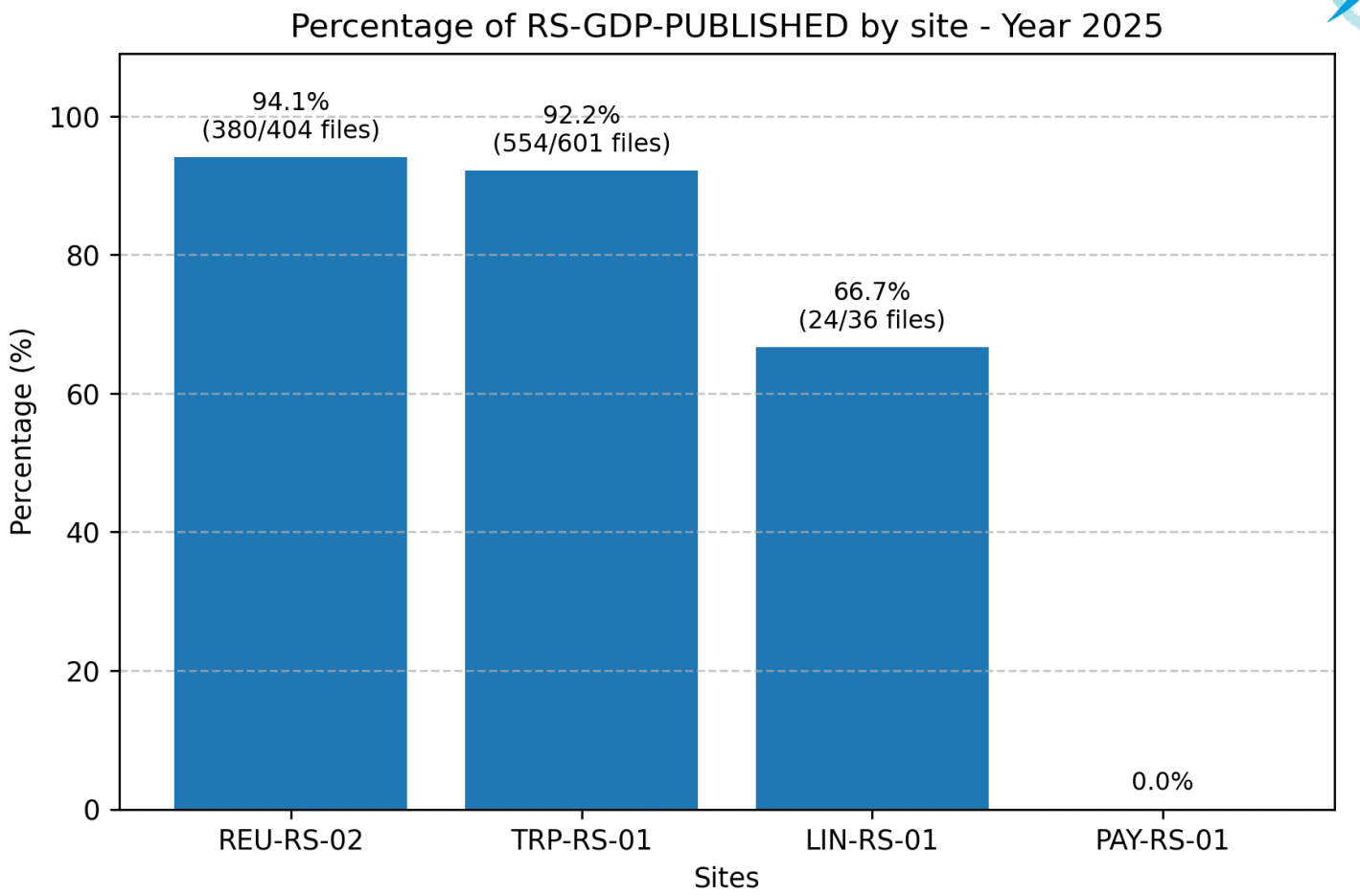
M10-M20 dataflow L1, statistics

TRP / REU / LIN / FAA in 2025



M10 dataflow L2 GDP, statistics

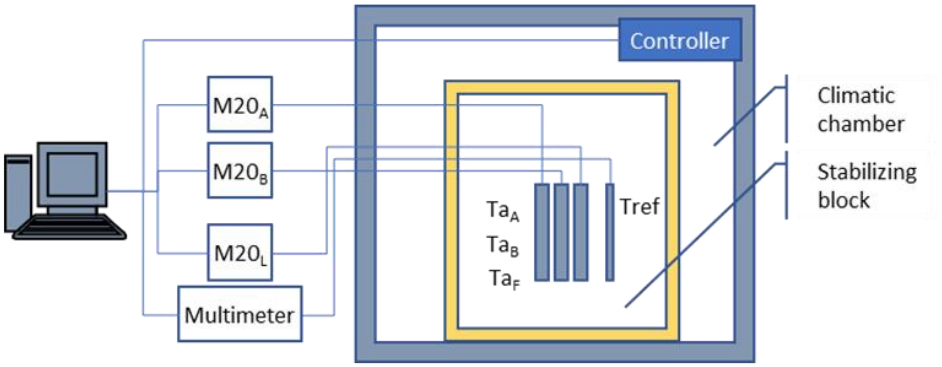
TRP / REU / LIN in 2025



M20 GDP progression

Temperature Calibration Experiment

Climate chamber @ LMD/Ecole Polytechnique

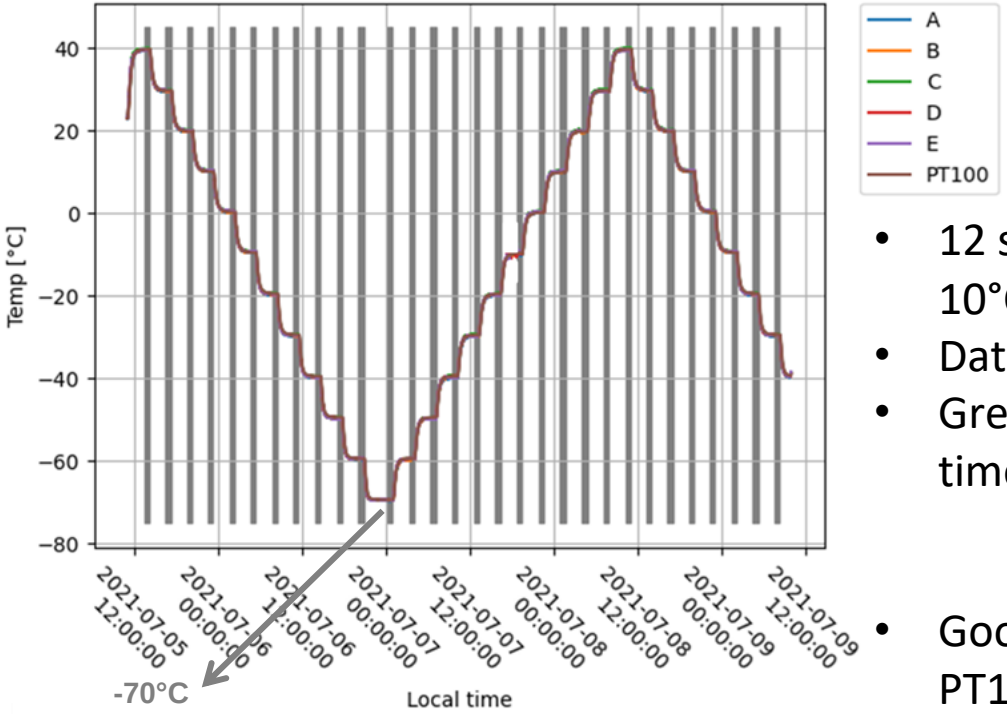


Schematization of climatic chamber, and stabilizing block

- Calibration tests made @LMD/Ecole Polytechnique (Same methodology as for M10).
- Five M20 are chosen as representative radiosondes.
- Reference PT100 [u_{ref}=0.03 K (k=1)].

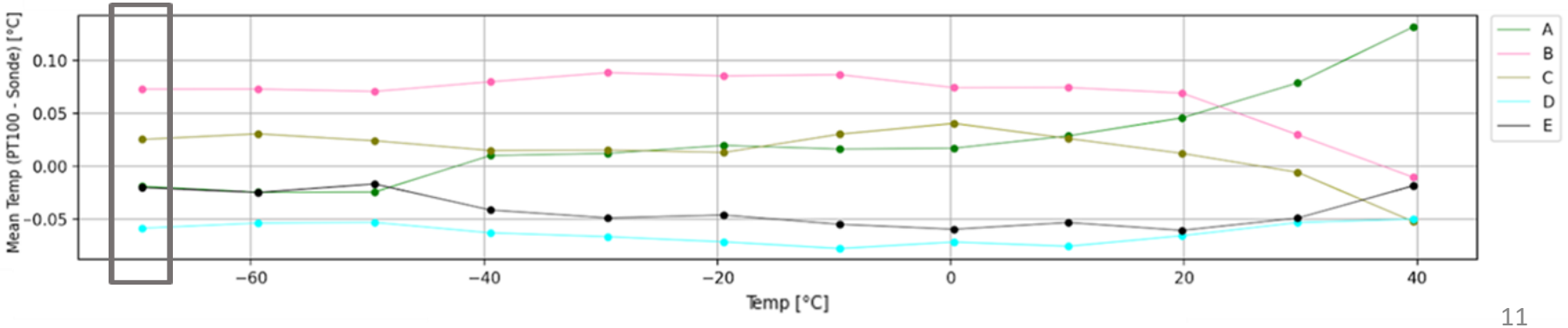
M20 GDP progression

Temperature Calibration Experiment



- 12 stabilized temperatures from 40 to -70°C per 10°C steps, stabilized for 3 hours.
- Data resolution: 10s.
- Grey shaded block: last 10% of the stabilized time

- Good correlation between Temp M20 and PT100, with a max difference of 0.15° C.



M20 GDP progression

Temperature Calibration uncertainties

- 4 uncertainties related to the M20: linearity, repeatability, reproducibility, and resolution.
- 3 uncertainties related to Ref PT100: calibration, repeatability and resolution.
- Results ≈ 0.11°C (K=1)

M10: 0.11 °C (k=1)

Duvernoy et al. 2015 WMO Report n°119 (Same methodology as for M10)

Parameter	Name	Description	Standard uncertainty [°C] k=1
$u(T_{a\text{-}lin})$	Uncertainty of temp_raw linearity	Maximum bias from reference	0.150/√(3)
$u(T_{a\text{-}repe})$	Uncertainty of temp_raw repeatability	Standard deviation of mean stabilized values	0.045
$u(T_{a\text{-}repro})$	Uncertainty of temp_raw reproducibility	Maximum standard deviation along all stabilized values	0.075/√(3)
$u(T_{a\text{-}reso})$	Uncertainty of temp_raw resolution	Minimum difference between two indications	0.020/√(12)
$u(T_{ref\text{-}cal})$	Uncertainty of Tref calibration	Calibration certificate including the PT100 and the acquisition system	0.045
$u(T_{ref\text{-}repe})$	Uncertainty of Tref repeatability	Standard deviation of mean stabilized values	0.016
$u(T_{ref\text{-}reso})$	Uncertainty of Tref resolution	Minimum difference between two indications	<0.003/√(12)
$u(T_{a\text{-}cal})$	Uncertainty of Ta_raw calibration	Composition of $u(T_{a\text{-}lin})$, $u(T_{a\text{-}repe})$, $u(T_{a\text{-}repro})$, $u(T_{a\text{-}reso})$, $u(T_{ref\text{-}cal})$, $u(T_{ref\text{-}repe})$, $u(T_{ref\text{-}reso})$	0.107

M20 GDP progression

RH Calibration Experiment

Standard humidity Chamber (SHC)

- **Humidity levels:** 0.2 – 11.3 – 33.1 – 75.5 – 97.6 – 100 %
- **Stabilization time:** max 10 min
- **Setup:** 2 radiosondes operated simultaneously
- **Reproducibility:** 10 radiosondes / type (for statistical validity)
- **Repeatability:** 5 iterations (back ↔ forth) per pair

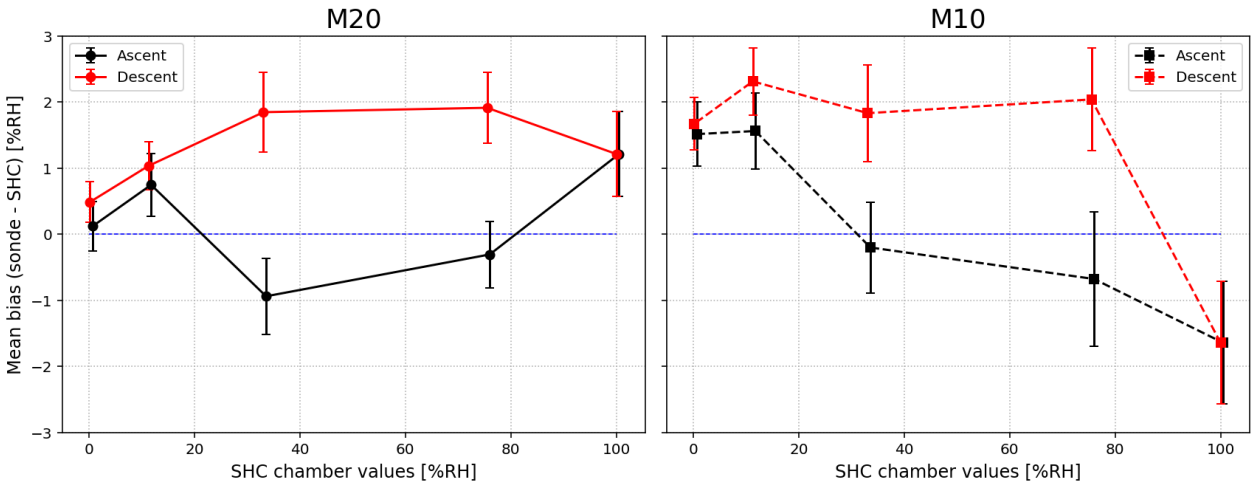
M20 GDP progression

RH_{raw} Calibration Experiment results

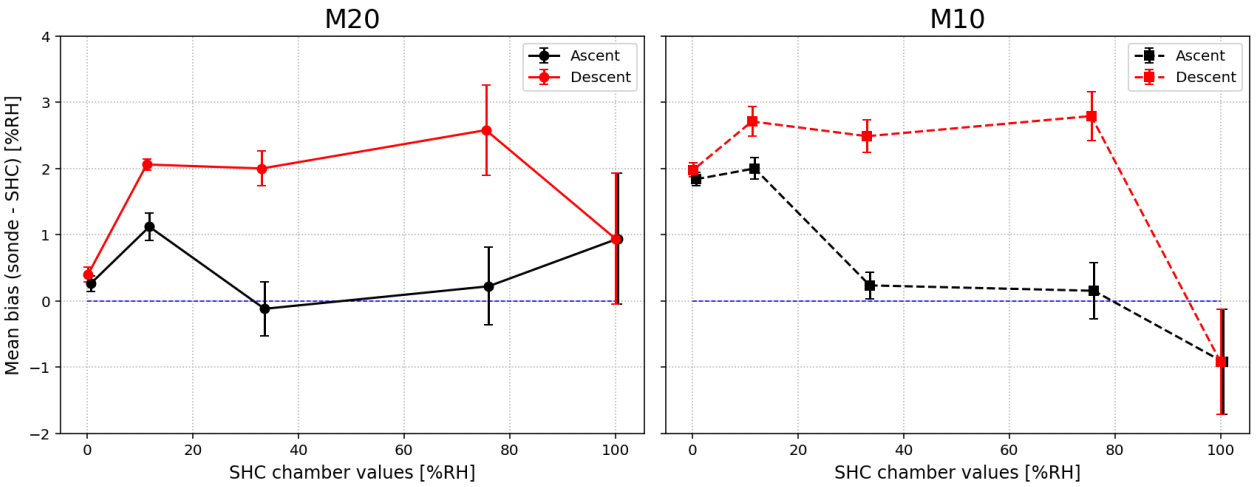
- Difference between black & red lines = slow-regime effect
- Sensor shows RH bias depending on previous humidity conditions
- Convergence toward true RH value occurs after ≈10 minutes (typical tropospheric timescale)

→ Demonstrates M20 sensor's reproducibility and response-time limitations due to the slow-regime effect.

Reproducibility (x10)



Repeatability (x5)



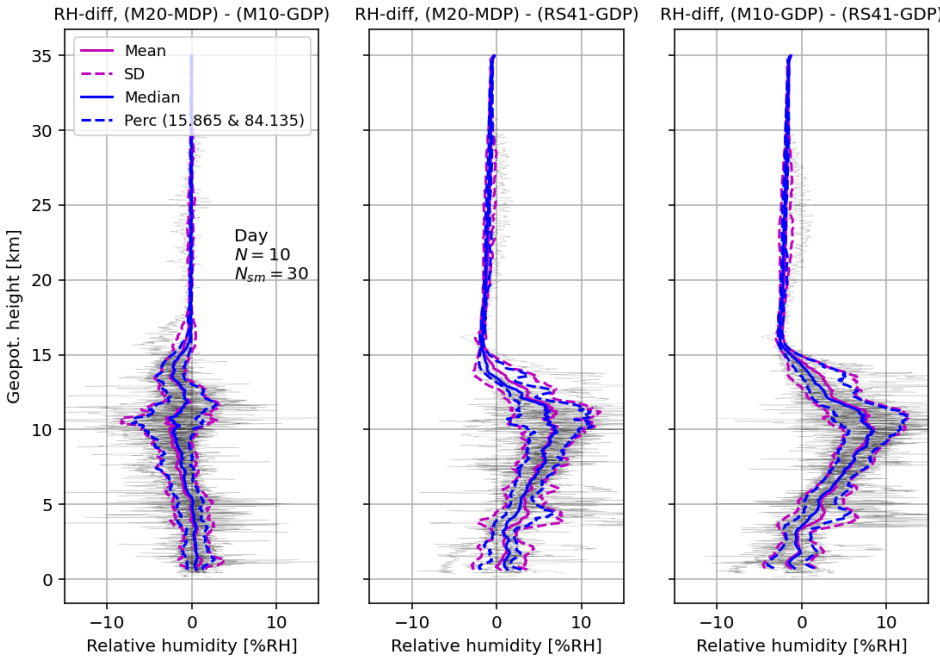
M10 / M20, TRACIS experiment at SIRTA Observatory

Intercomparison campaign (TRACIS*) – Preliminary Results

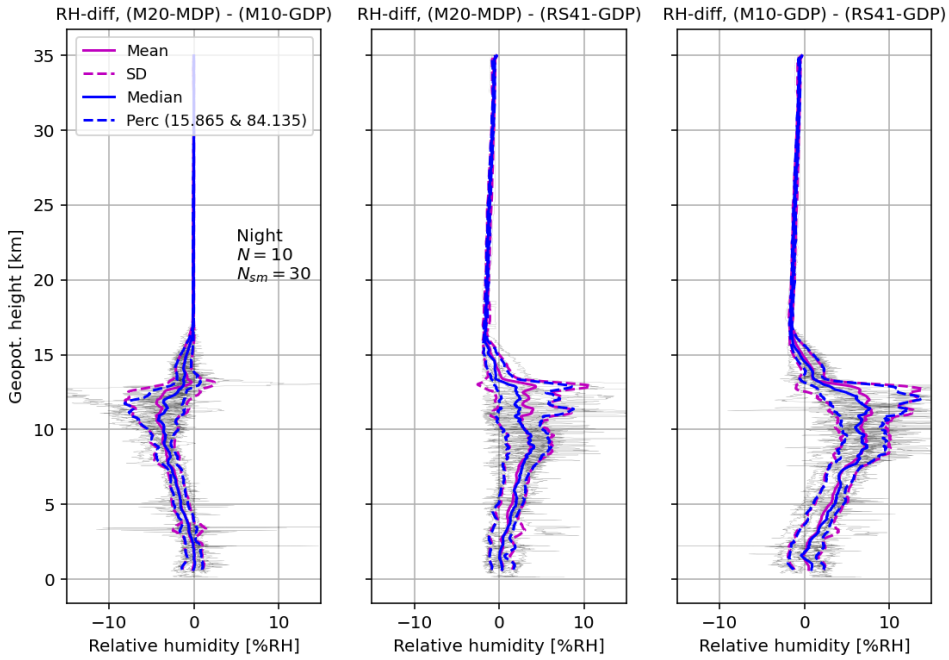
** Tropospheric Research campaign on Air humidity Content by Ipral lidar at SIRTA*

Relative Humidity

Daytime



Nighttime

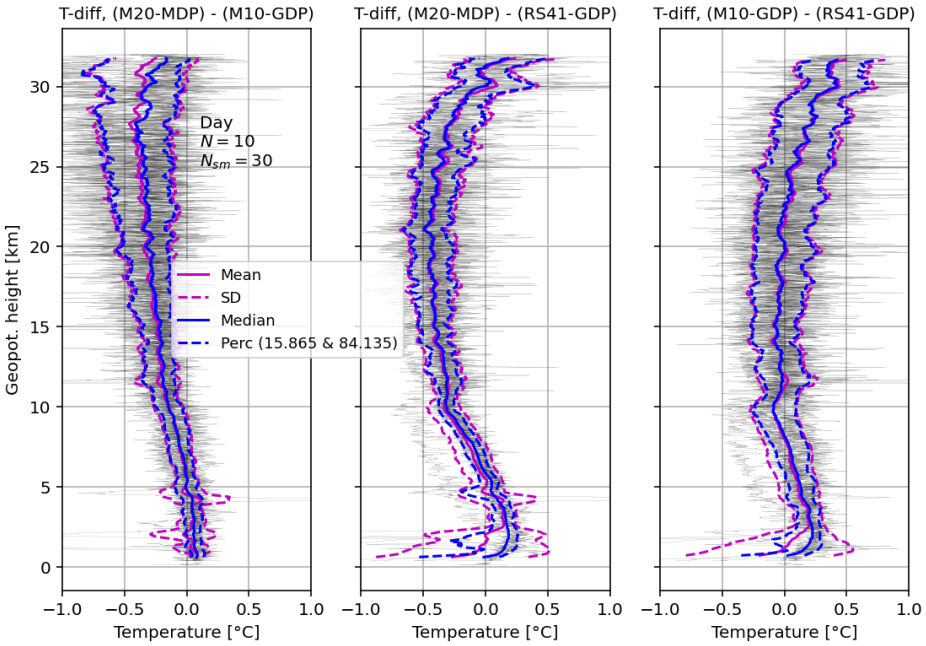


M10 / M20, TRACIS experiment at SIRTA Observatory

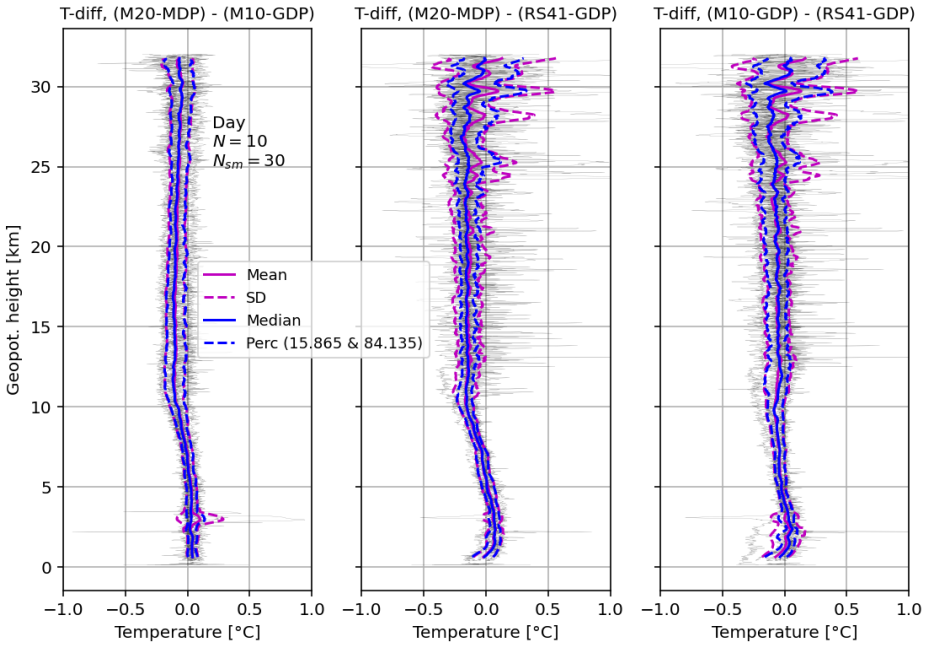
Intercomparison campaign (TRACIS) – Preliminary Results

Temperature

Daytime



Nighttime



Conclusions

M10

- Improvement in M10 temperature reproducibility
- **Certification expected very soon (in the coming weeks)** : Reviewer feedback received in May 2025 and full responses sent in August 2025.

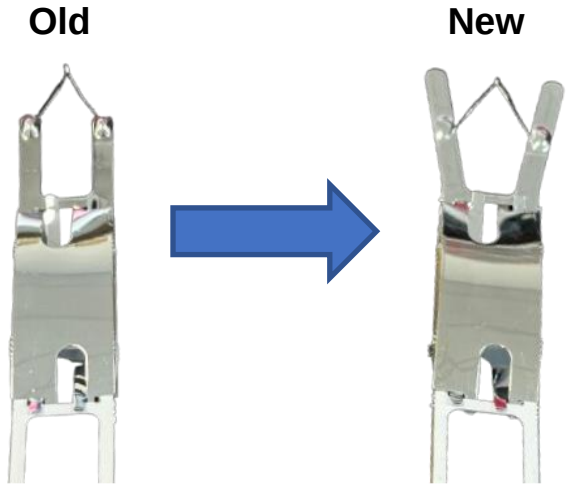
M20

- Consistency of Temperature calibration Uncertainties between M10 and M20
- Same approach for RH
- TRACIS: good agreement between M20, M10, and RS41 (T/RH)

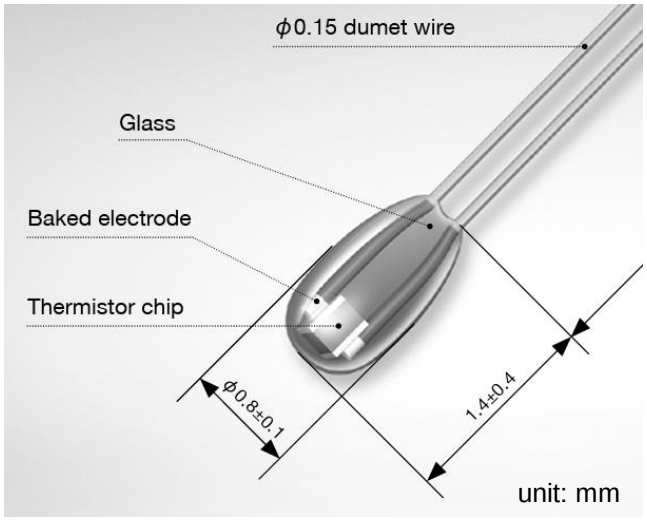
Perspectives

- Start the certification for Modem M20
- Development of a new sensor boom

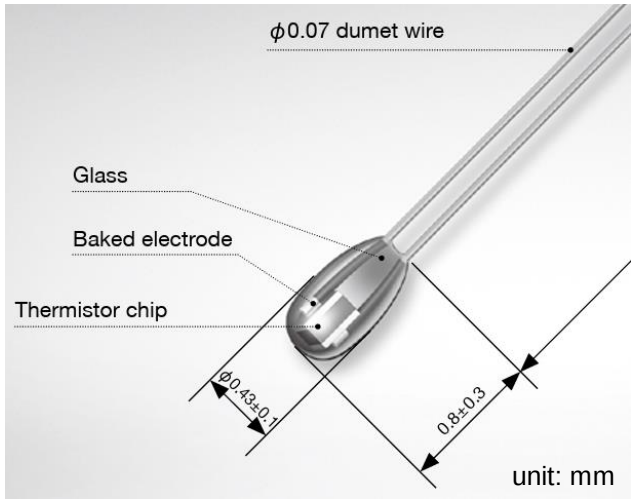
→ with a new thermistor



Old



New



Questions?

Thank you for your attention