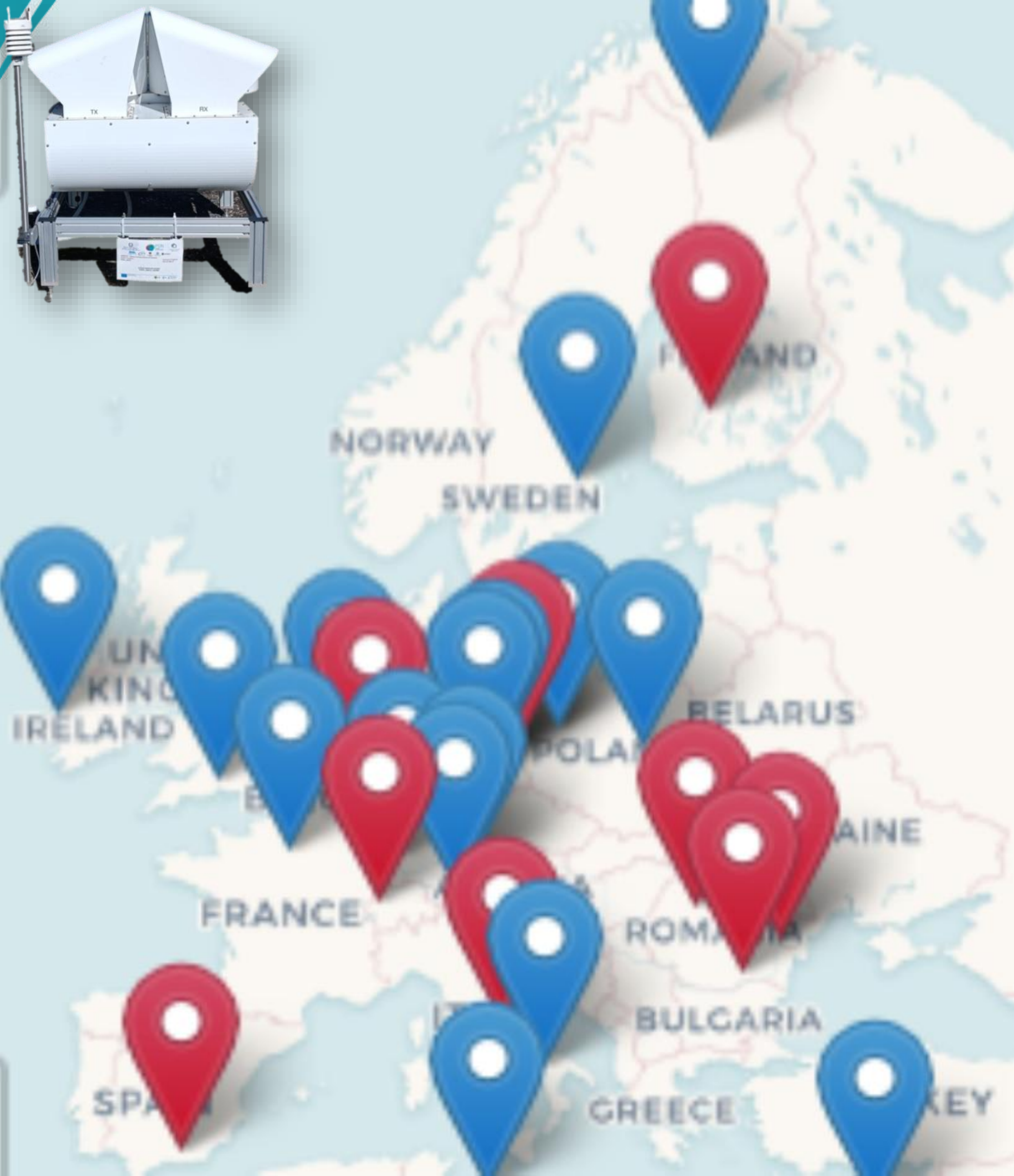


ACTRIS
CCRES

Vicarious calibration monitoring of the 89 GHz passive channel of RPG FMCW 94 cloud radars for the ACTRIS network

Opportunity for a routine product?

Davide Rossi, Mario Montopoli, Domenico Cimini
and support from AQ-NF team
(davide.rossi@graduate.univaq.it)

Outline

- **Motivation**
- **Spatial and temporal context**
- **Absolute calibration and vicarious calibration technique**
- **Vicarious calibration method in brief**
- **Examples of vicarious calibration monitoring over ACTRIS observatories**
- **Conclusions**
- **Future developments**

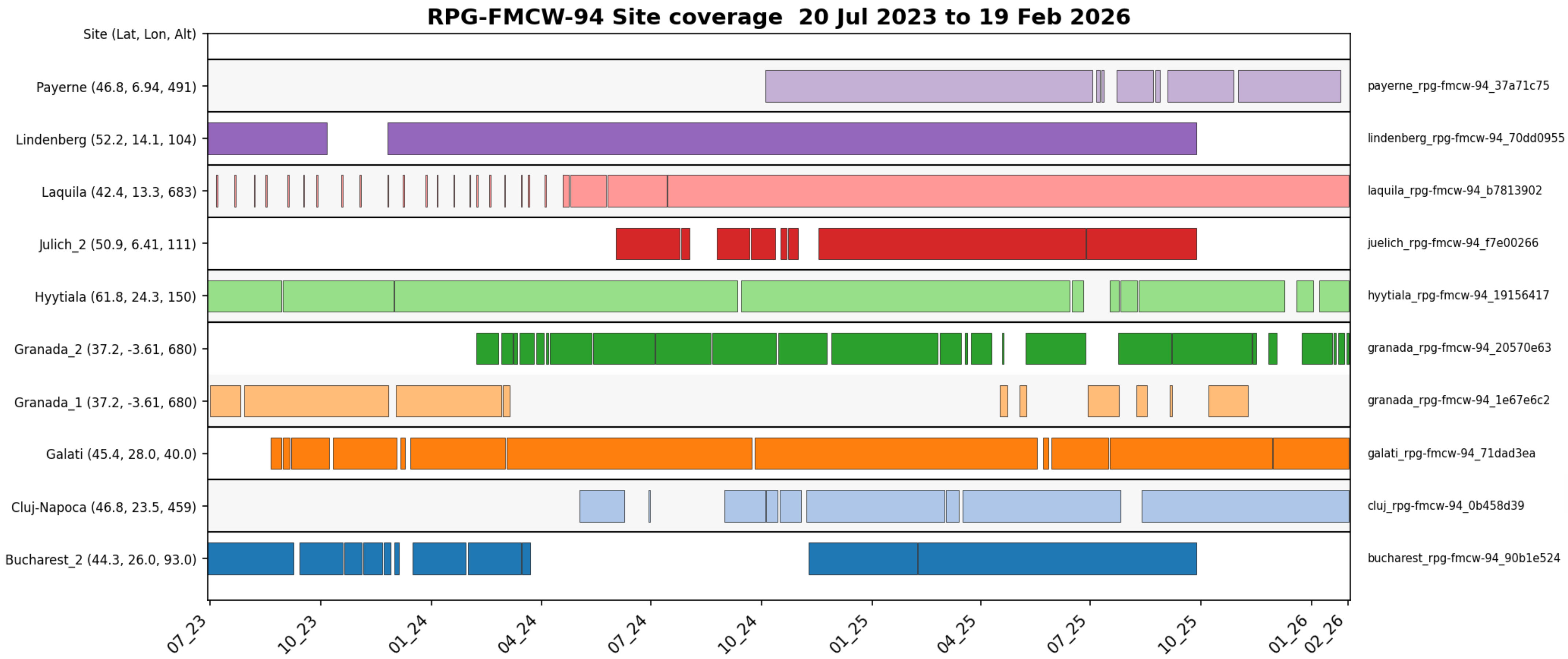
Motivation & goal

- **Motivation**: radiometric observations are prone to calibration drifts between maintenance cycles. Detecting and eventually correcting these shifts is essential for high-quality, continuous observational datasets and to improve Liquid Water Path (LWP) and Liquid Water Content (LWC) retrievals

- **Goal:** to monitor and maintain the calibration of 89 GHz channel in RPG-FMCW-94 cloud radars across the ACTRIS network, ensuring long-term data consistency through uncalibrated measurements correction.

Spatial and temporal context

- Ground based observations: 89 GHz passive channel of RPG FCMW 94
- 9 among ACTRIS observatories
- Time range: Jul 2023 – Feb 2026, updates ongoing…



ACTRIS CCRES

Absolute calibration and vicarious calibration

Absolute calibration

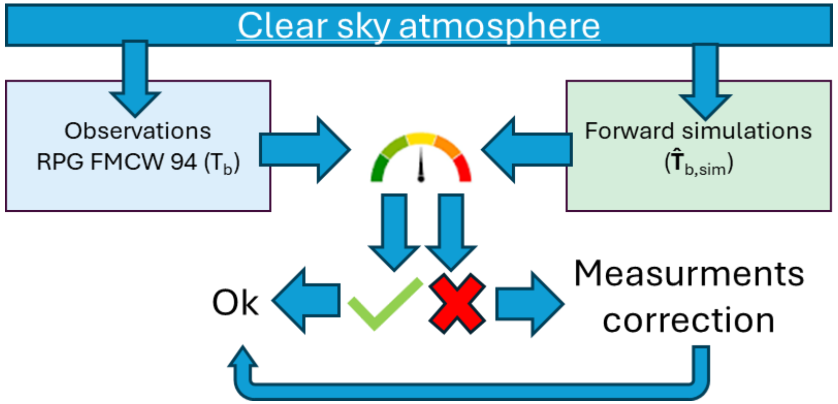
- Accurate measurements come from a well calibrated instrument
- To be performed every 6 months to ensure accurate measurements (hot/cold procedure)

Bulky tools, inconvenient procedure, but necessary!

- Detect Drifts: constant monitoring of instrument calibration

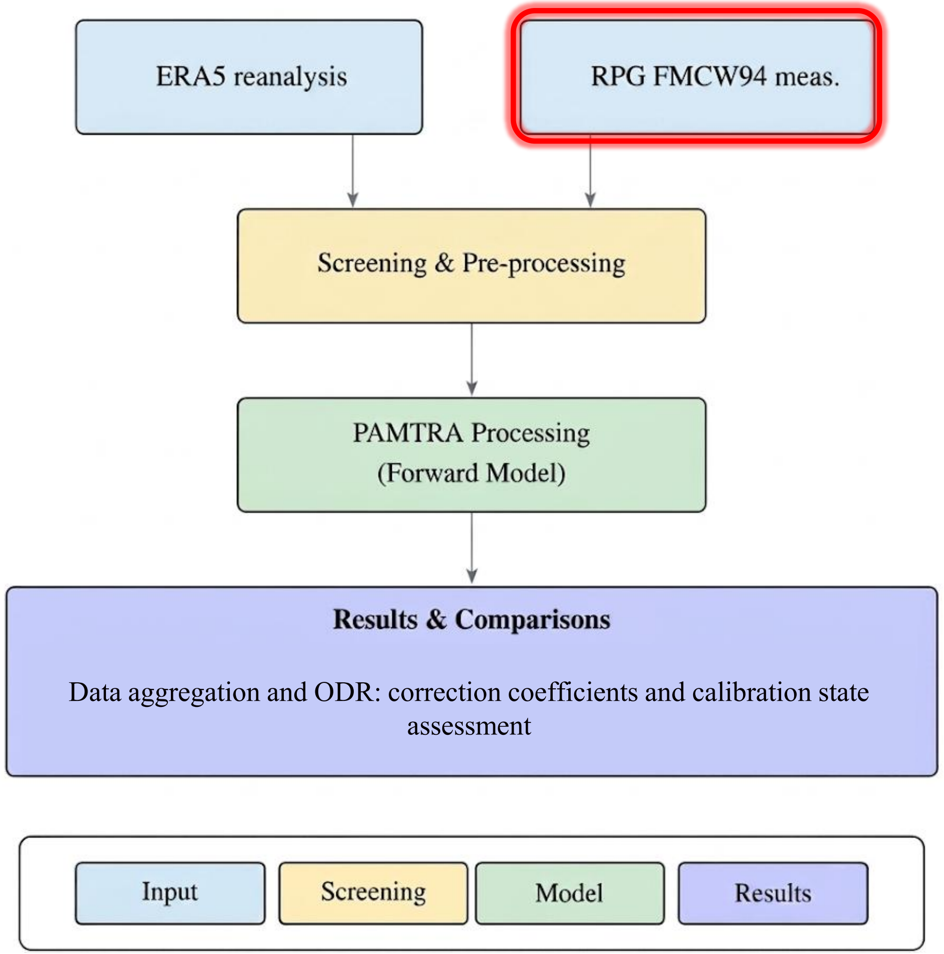
Vicarious calibration

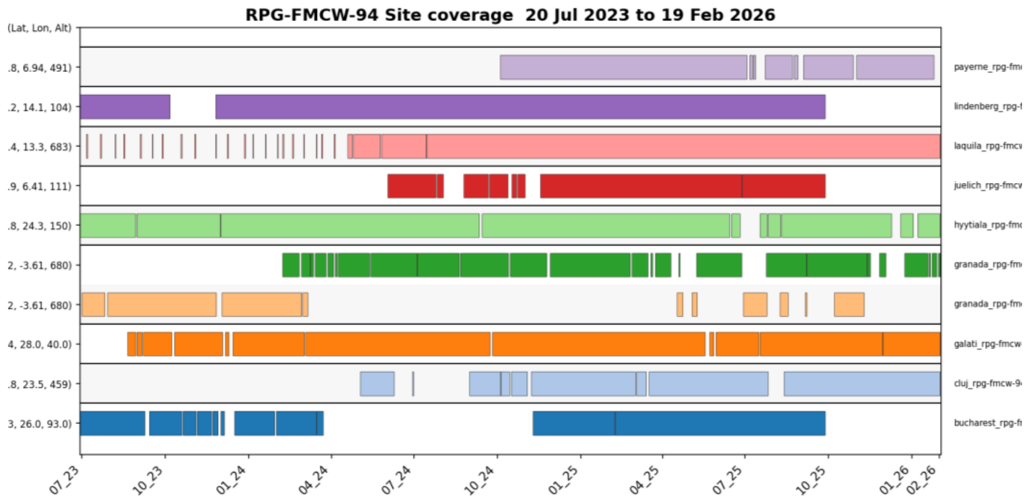
- Can supplement absolute calibration
- Comparison of measured signal against simulated one using **clear sky atmosphere as reference**
- Eventual measurement correction
- **Primary focus: 89 GHz passive channel**



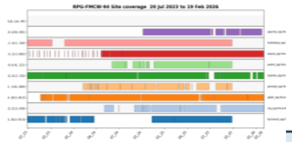
Vicarious calibration in brief

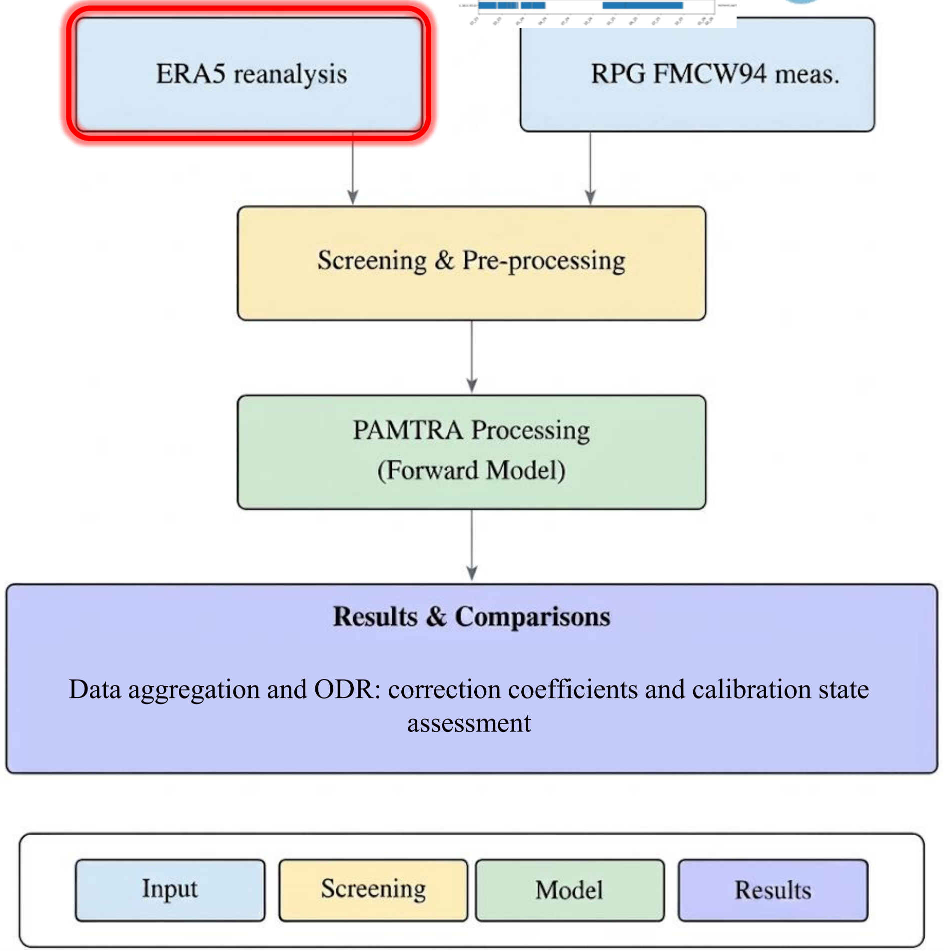
ACTRIS
CCRES



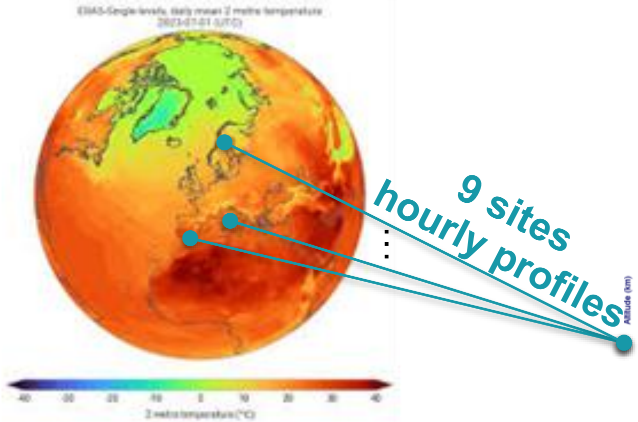


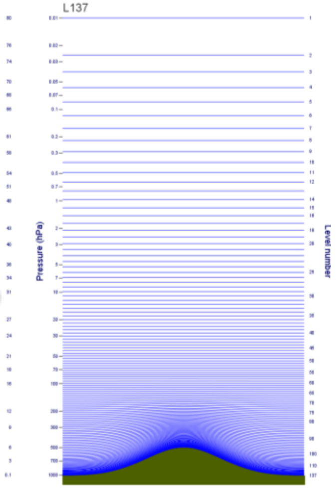
Vicarious calibration in brief





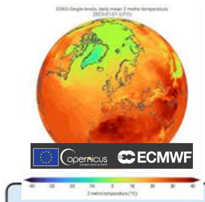
Reanalysis vertical profiles

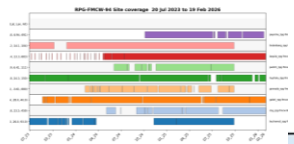


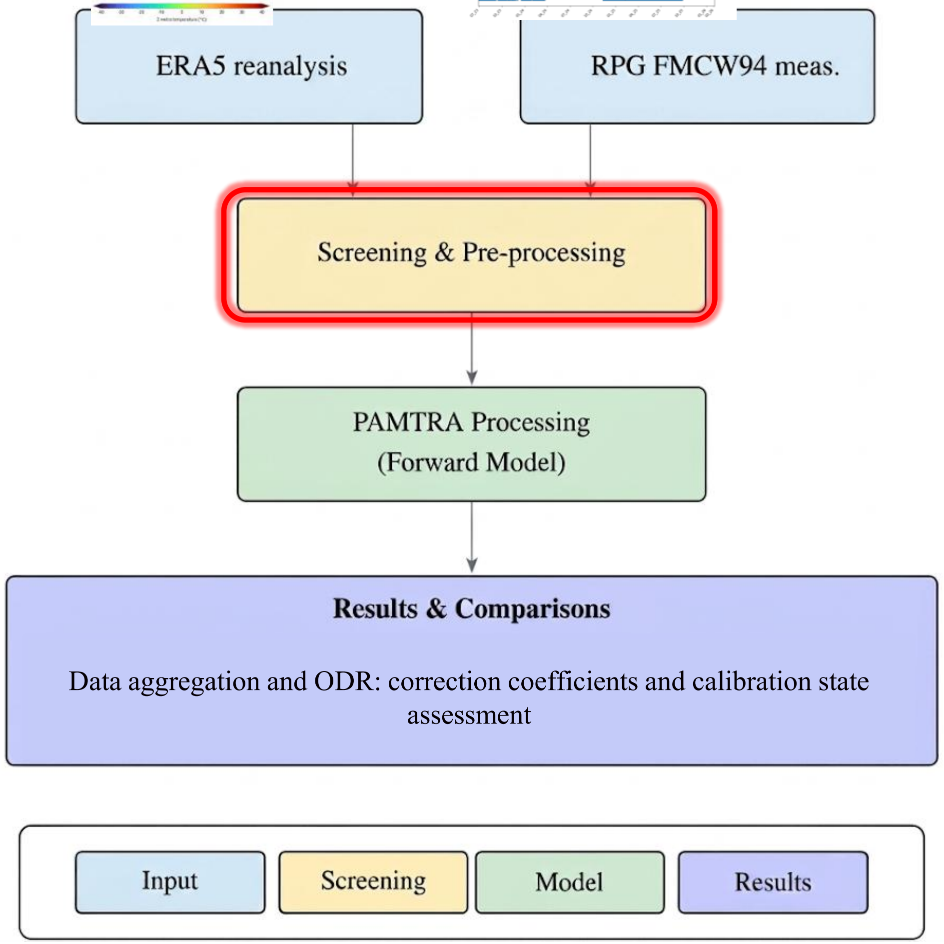


Data type	Gridded
Horizontal coverage	Global
Horizontal resolution	Reanalysis: 0.25° x 0.25°
Temporal coverage	1940 to present
Temporal resolution	Hourly

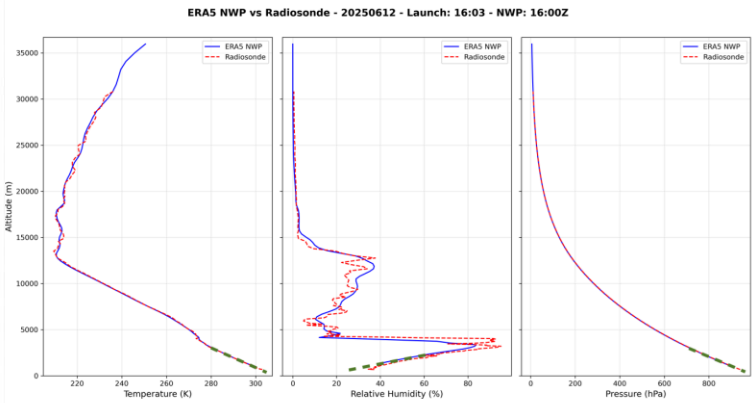
Vicarious calibration in brief



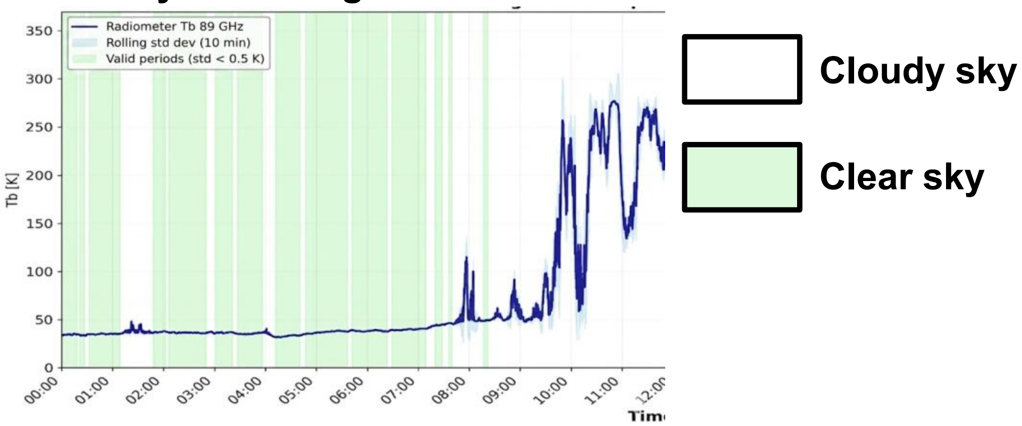




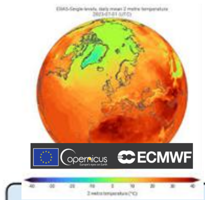
ERA5 vertical atmospheric profile extrapolation to surface

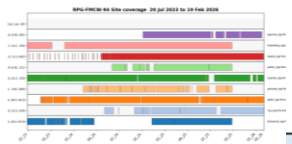


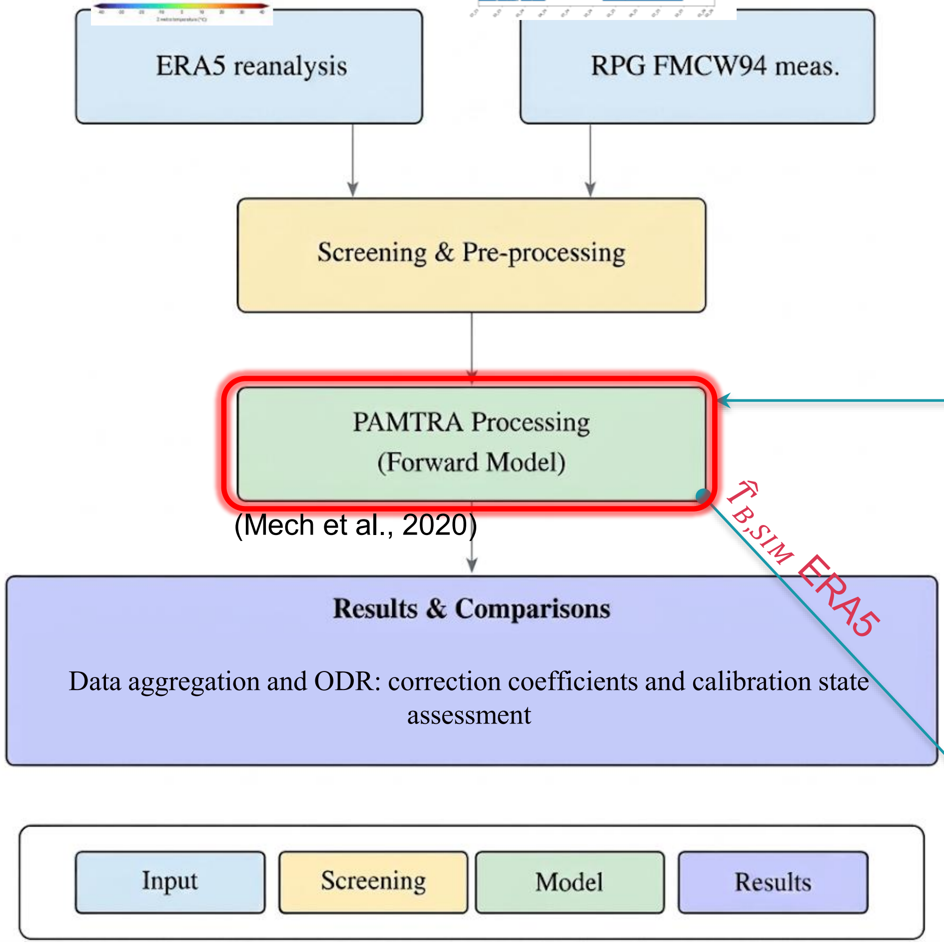
Clear sky screening

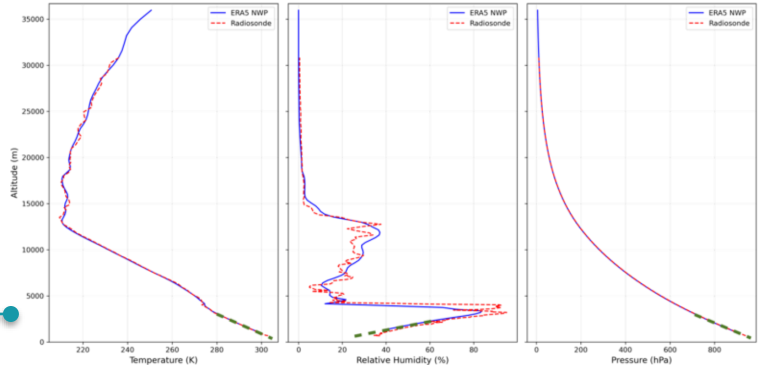


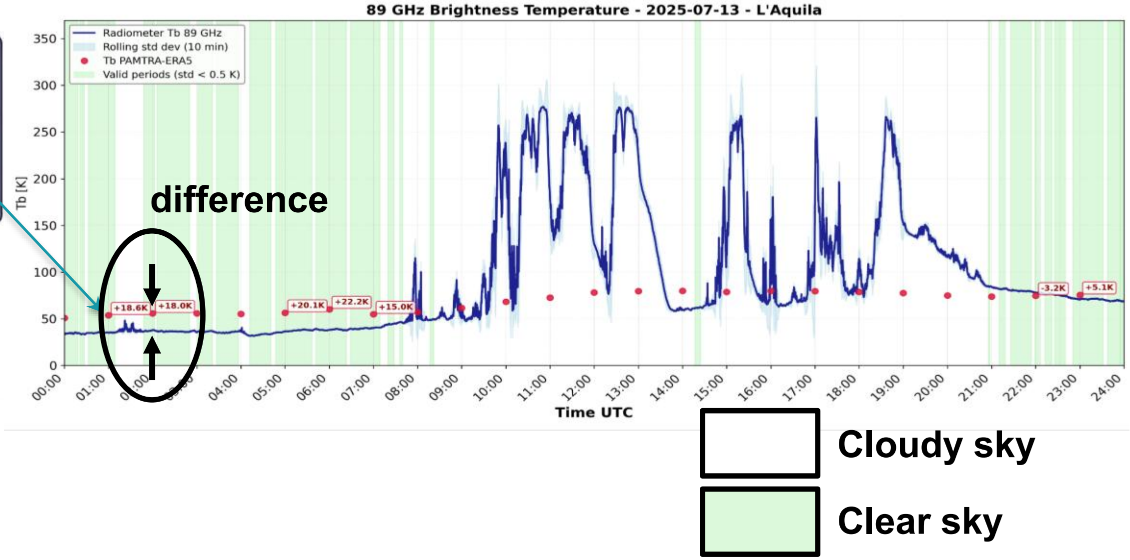
Vicarious calibration in brief



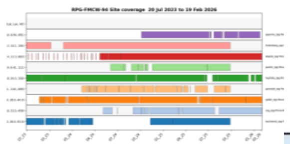


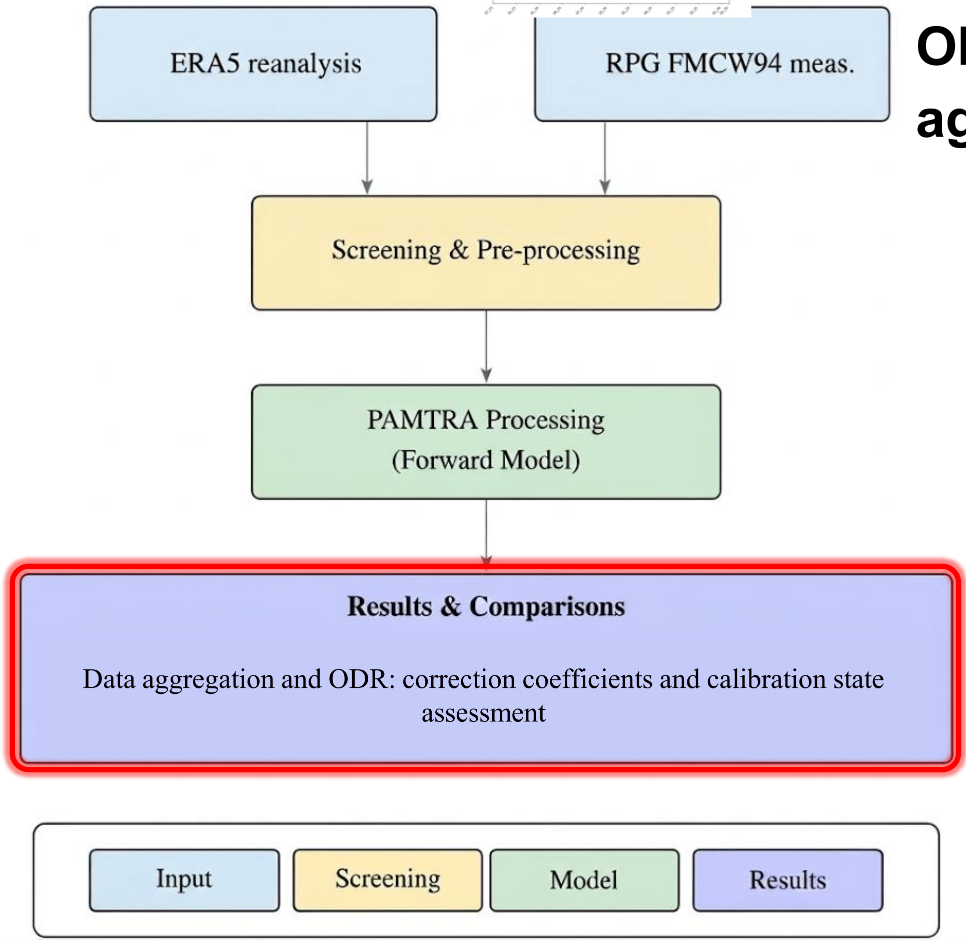




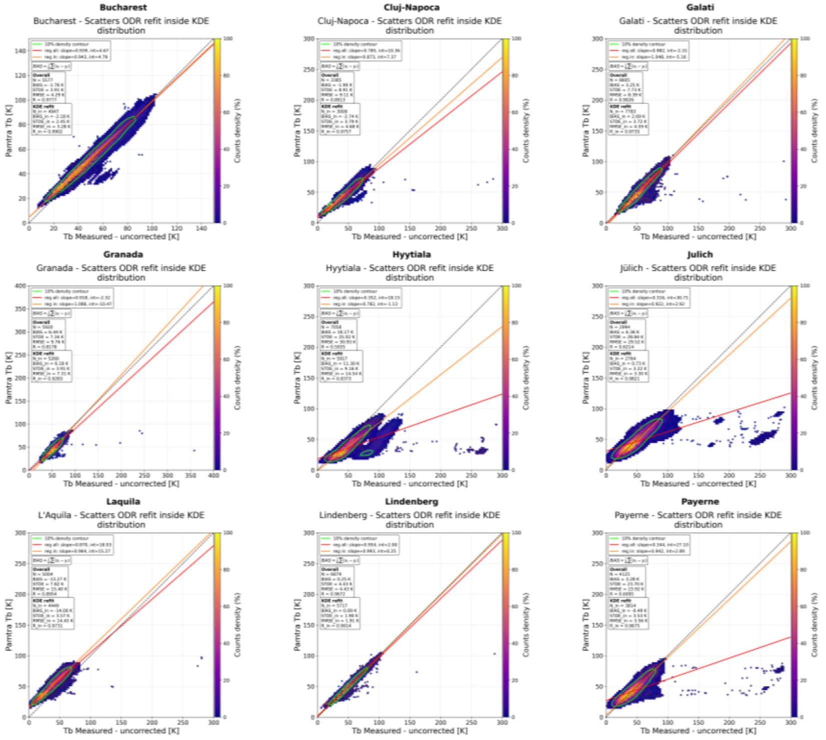


Vicarious calibration in brief





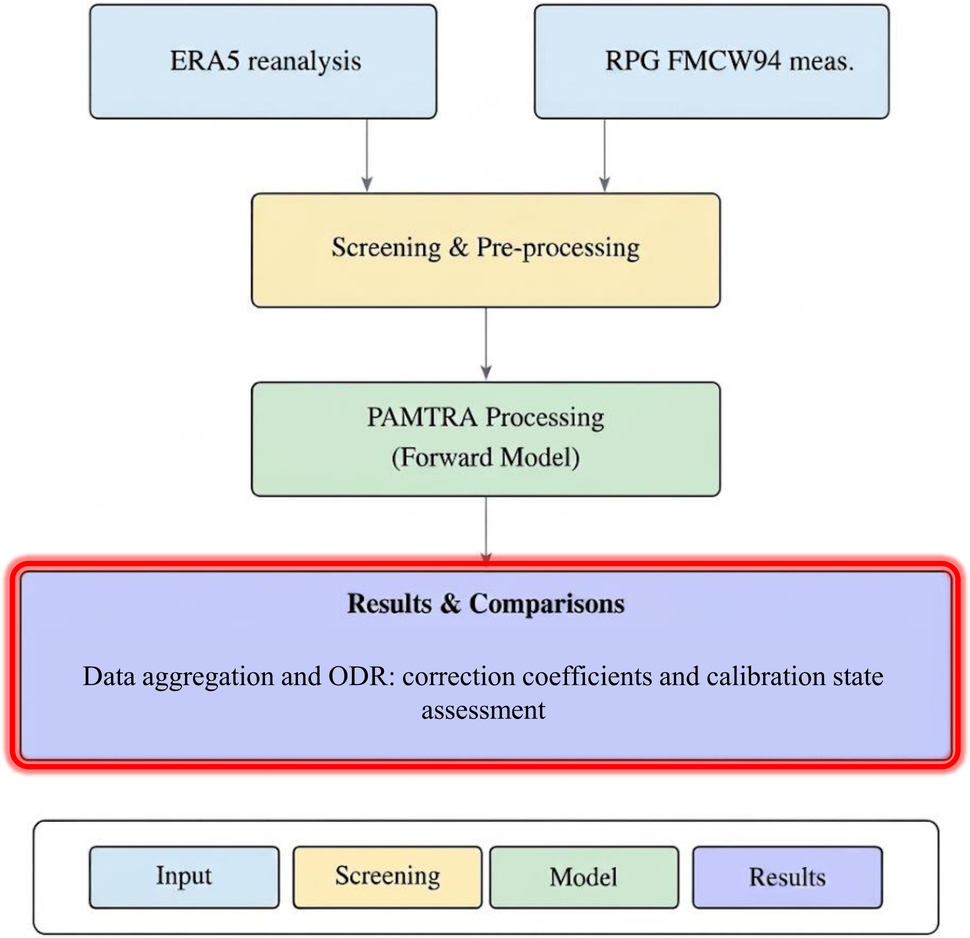
Observed (T_b) and simulated ($\hat{T}_{B,SIM}$) data aggregation – ERA5, whole dataset, per station



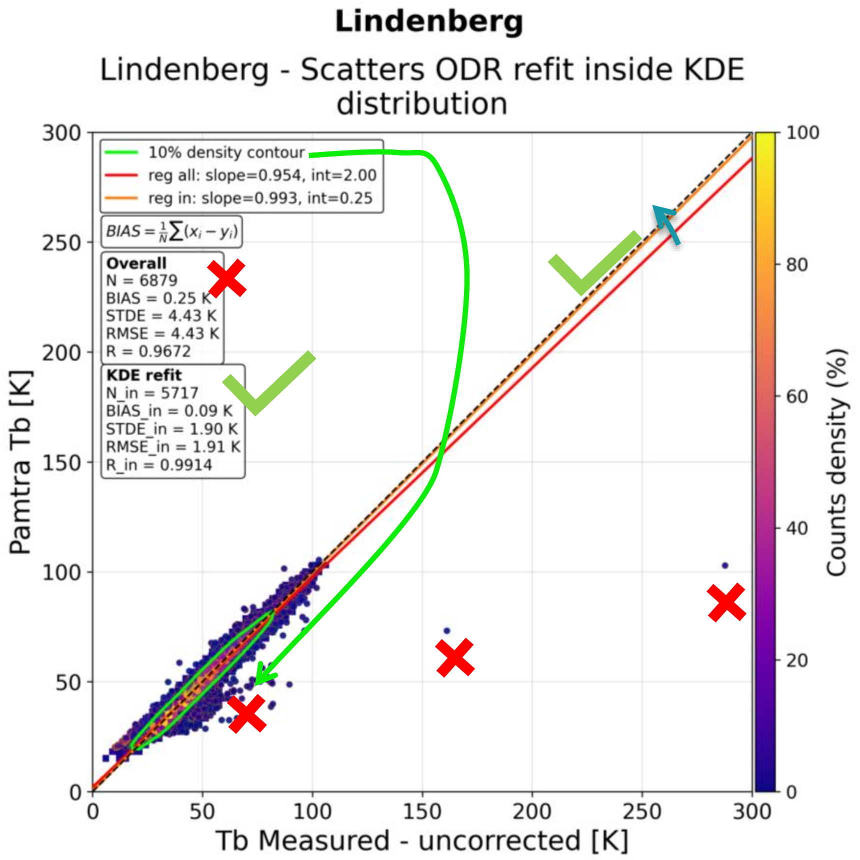
9 EU stations

- Bucharest
- Cluj-Napoca
- Galati
- Granada
- Hyytiala
- Julich
- L'Aquila
- Lindenberg
- Payerne

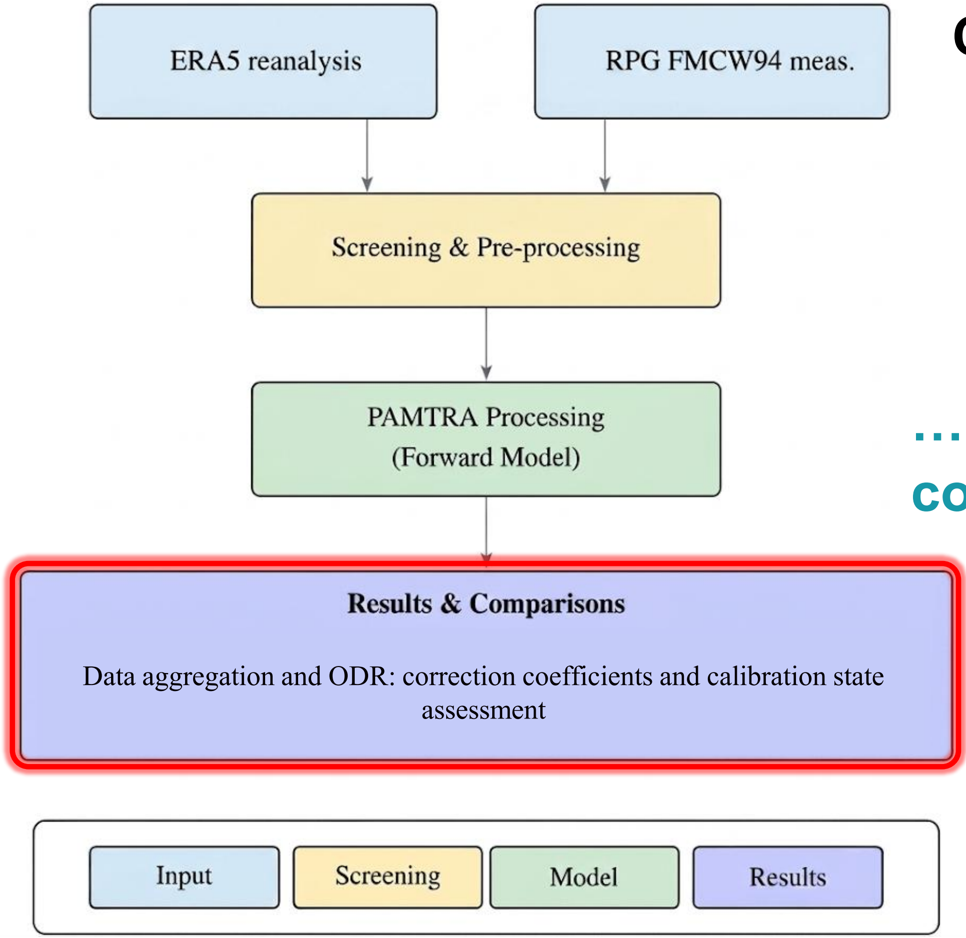
Vicarious calibration in brief



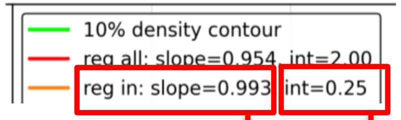
Outliers filtering



Vicarious calibration in brief



Calibration state assessment…



… and correction

$$T_{b,corr} = T_{b,obs} \cdot S \;\; \& \;\; I$$

Per station

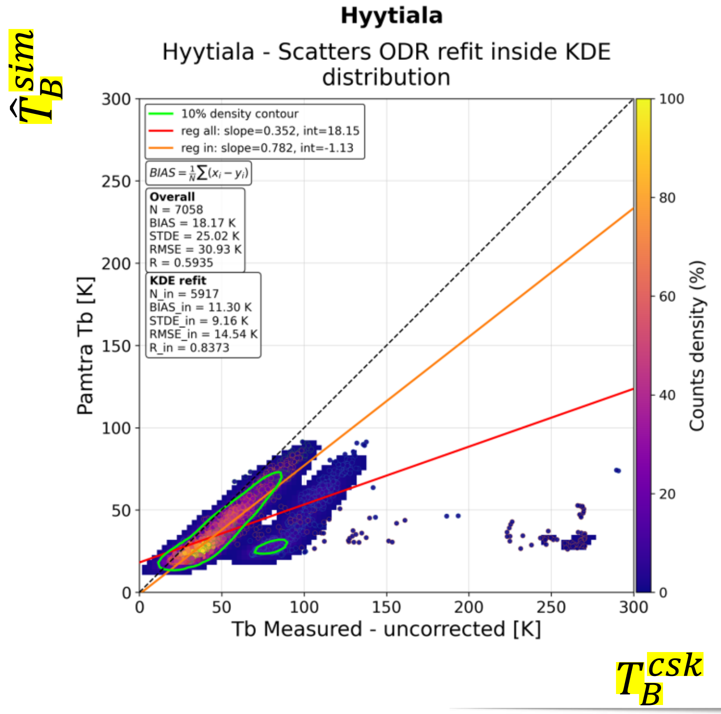
Per calendar month

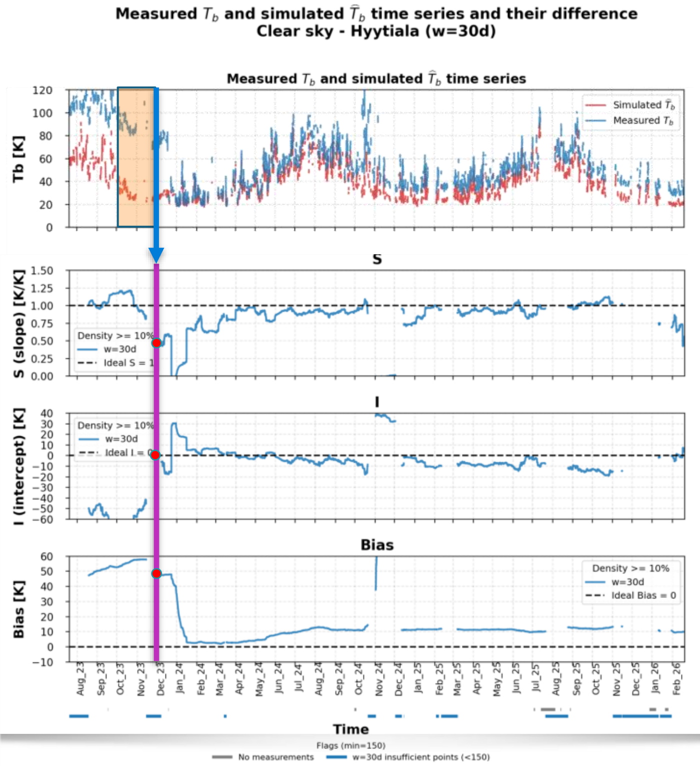
Moving window analysis

- Some stations (i.e: Hyttiala) exhibited a large temporal variation of the instrument calibration state
- Aggregating data over periods belonging to different calibration states would lead to the calculation of wrong correction coefficient S & I
- A continuous analysis is needed → 30days hourly updating moving windows

- Linear regression of $\hat{T}_B^{sim}$ vs. T_B^{csk} in a 30-day window (*W*) wrt the considered hour to estimate slope (*S*), intercept (I) and bias *B*=$< T_B^{csk} - \hat{T}_B^{sim} >_W$
- Only windows with at least 150 clear sky points are retained.
- The window *W* slides at hourly steps and *S*, *I*, *B* are updated consequently.

- Perfect calibration requires *S*=1 & *I*=0 & *B*=0
- Otherwise, within a tolerance, a miscalibration flag may be raised
- **Miscalibrated data may be recalibrated wrt simulations (assumed as reference)**



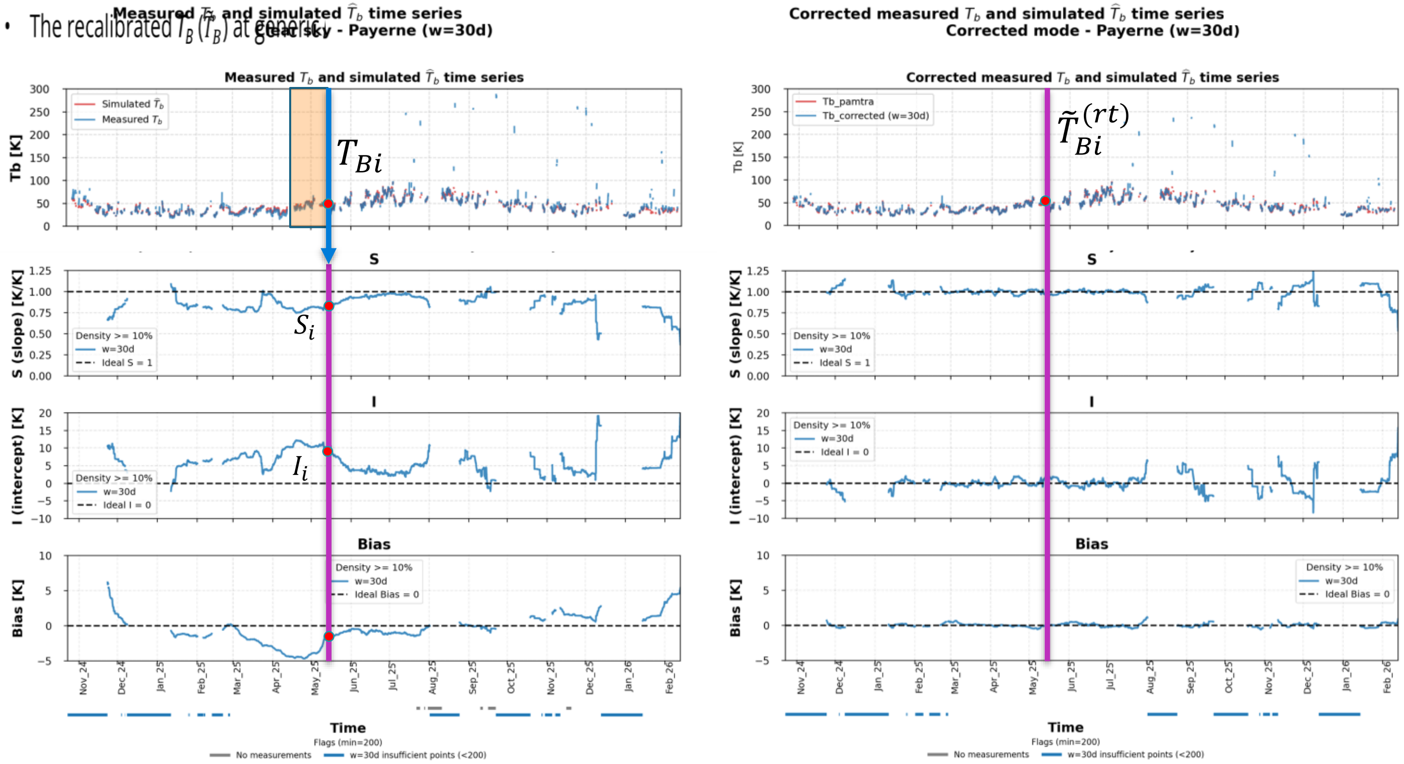


Run time calibration

- The recalibrated T_B ($\tilde{T}_B$) at generic ***i***-th hour "***t***$_i$" is obtained as:

$$\tilde{T}_{Bi}^{(rt)} = T_{Bi} \cdot S_i + I_i$$

S_i, I_i are calculated within a window *W that covers 30days before time index i*



S, I, B are computed on

$\tilde{T}_B^{(rt)}$ vs. $\hat{T}_B^{sim}$

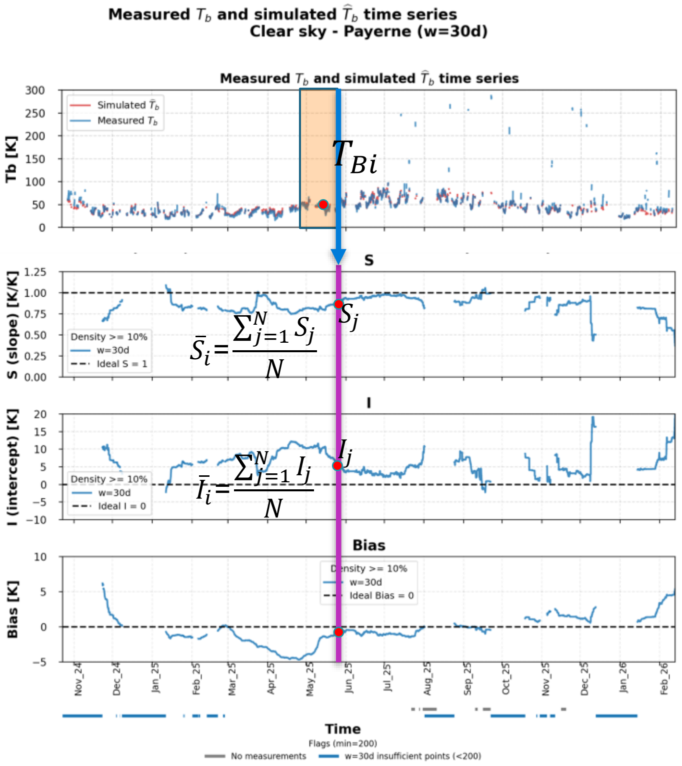
to assess the effect of recalibration

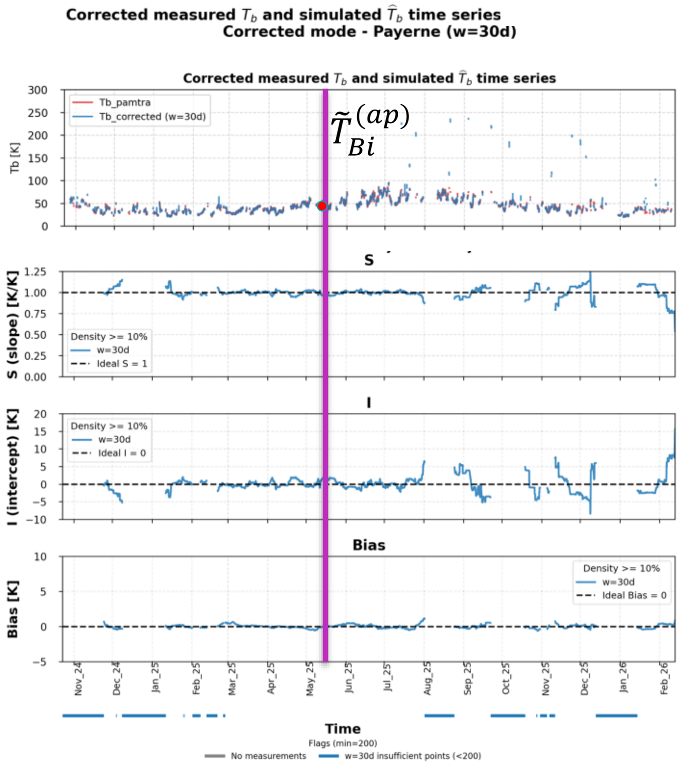
A posteriori time calibration

- The recalibrated T_B ($\tilde{T}_B$) at generic *i*-th hour "t_i" is obtained as:

$$\tilde{T}_{Bi}^{(ap)} = T_{Bi} \cdot \bar{S}_i + \bar{I}_i$$

$\bar{S}_i, \bar{I}_i$ are the average slope and intercept over *N* windows of length 30 days, *W,* which extremes always include the time index *i.*

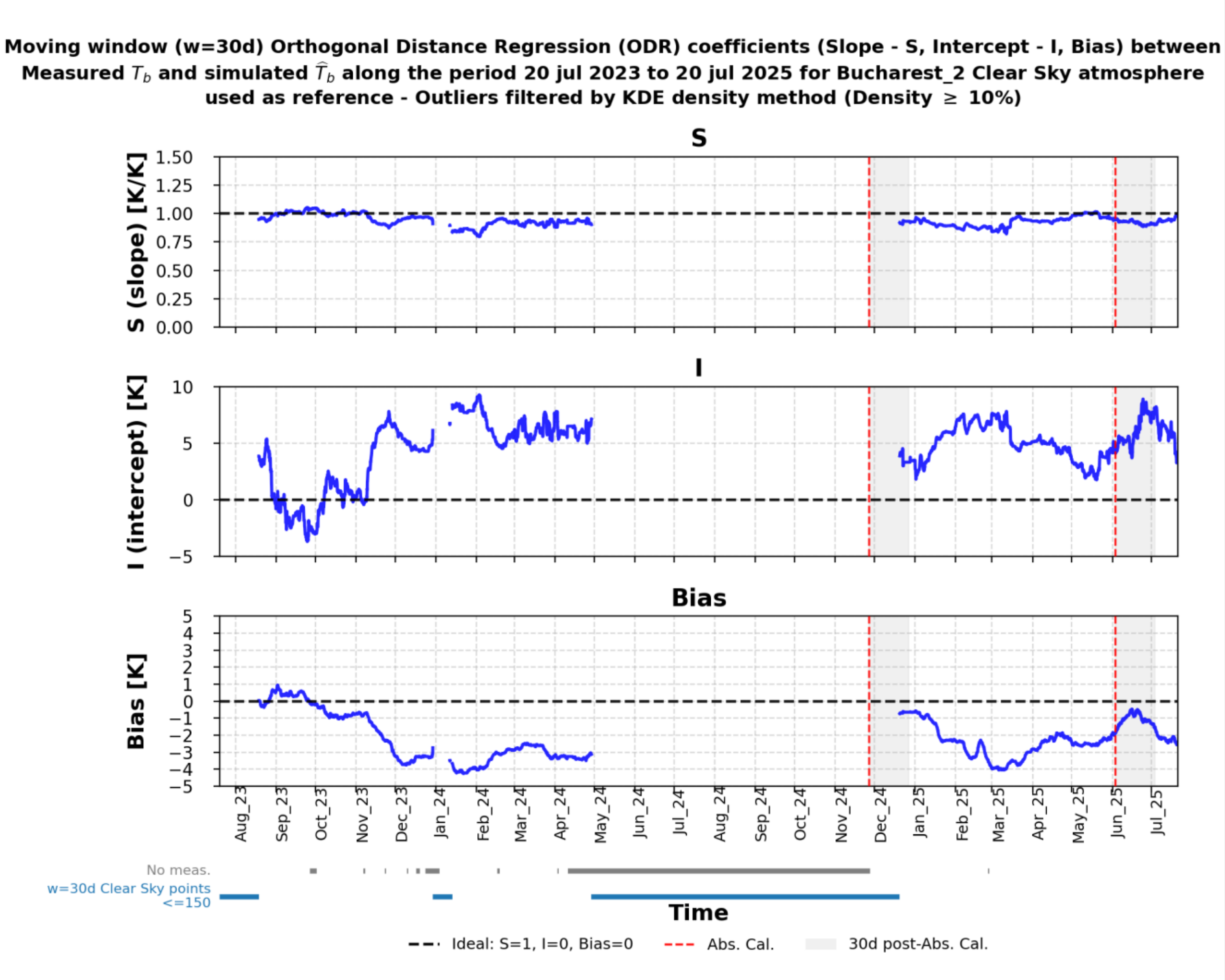




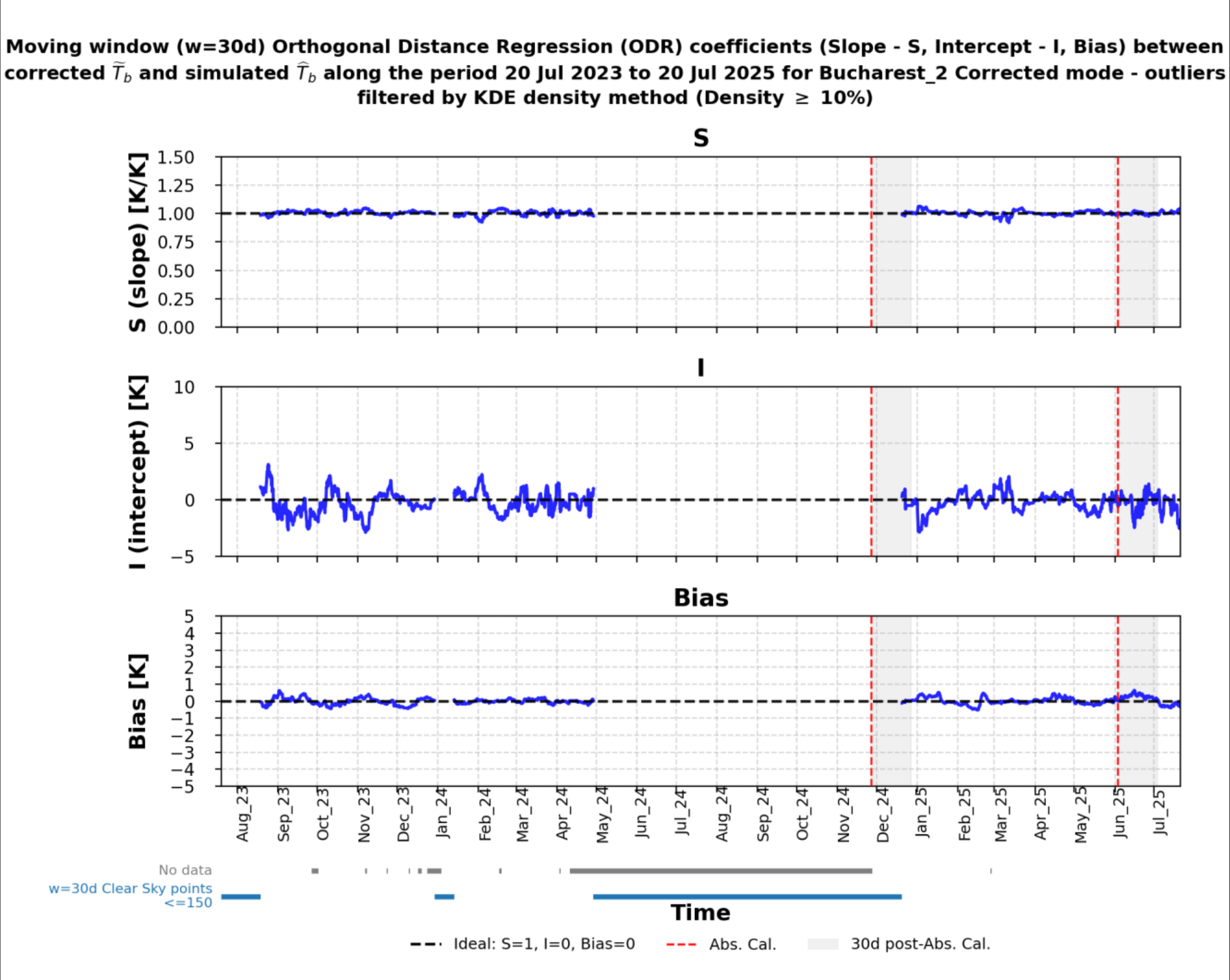
S, I, B are computed on $\tilde{T}_B^{(ap)}$ vs. $\hat{T}_B^{sim}$ to assess the effect of recalibration

Calibration assessment & a posteriori time calibration
Bucharest

Measured



Corrected (a-posteriori)



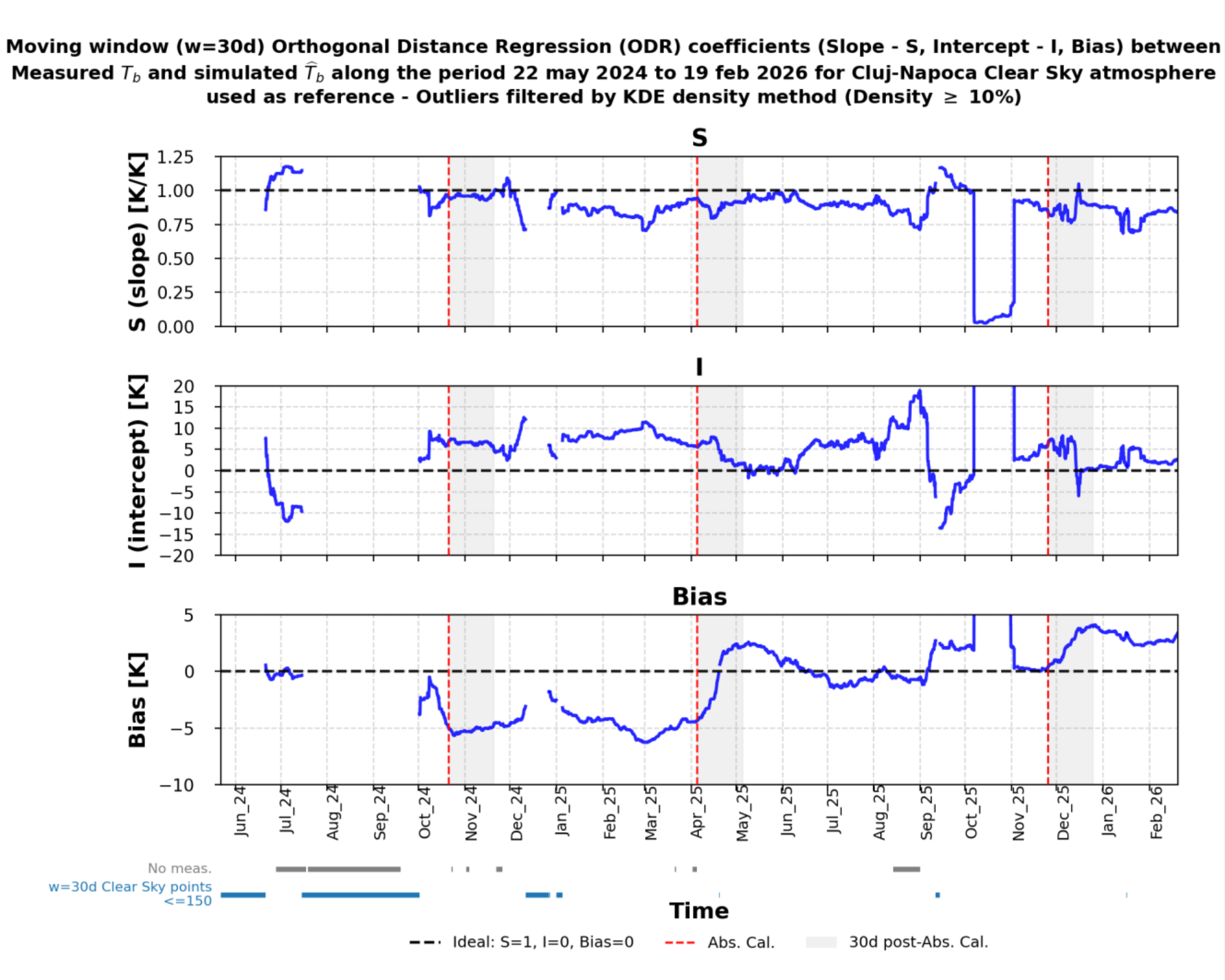
__Acknowledgements__ to Toanca Flori, Anca Nemuc and all INOE colleagues

Calibration assessment & a posteriori time calibration
Cluj-Napoca

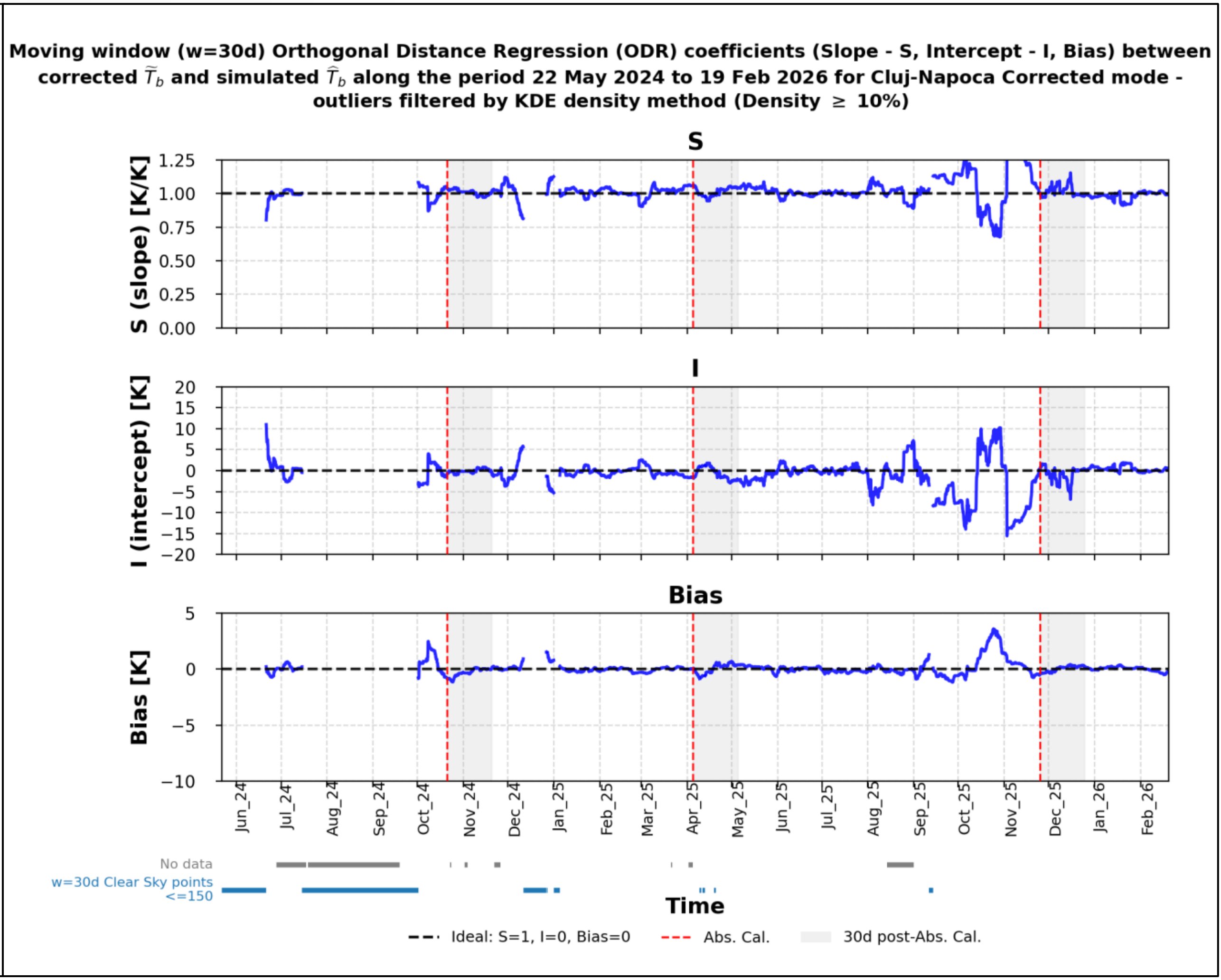
Locations

?2026-03-04 – now	Bucharest
2024-05-22 – 2026-03-03	Cluj-Napoca

Measured



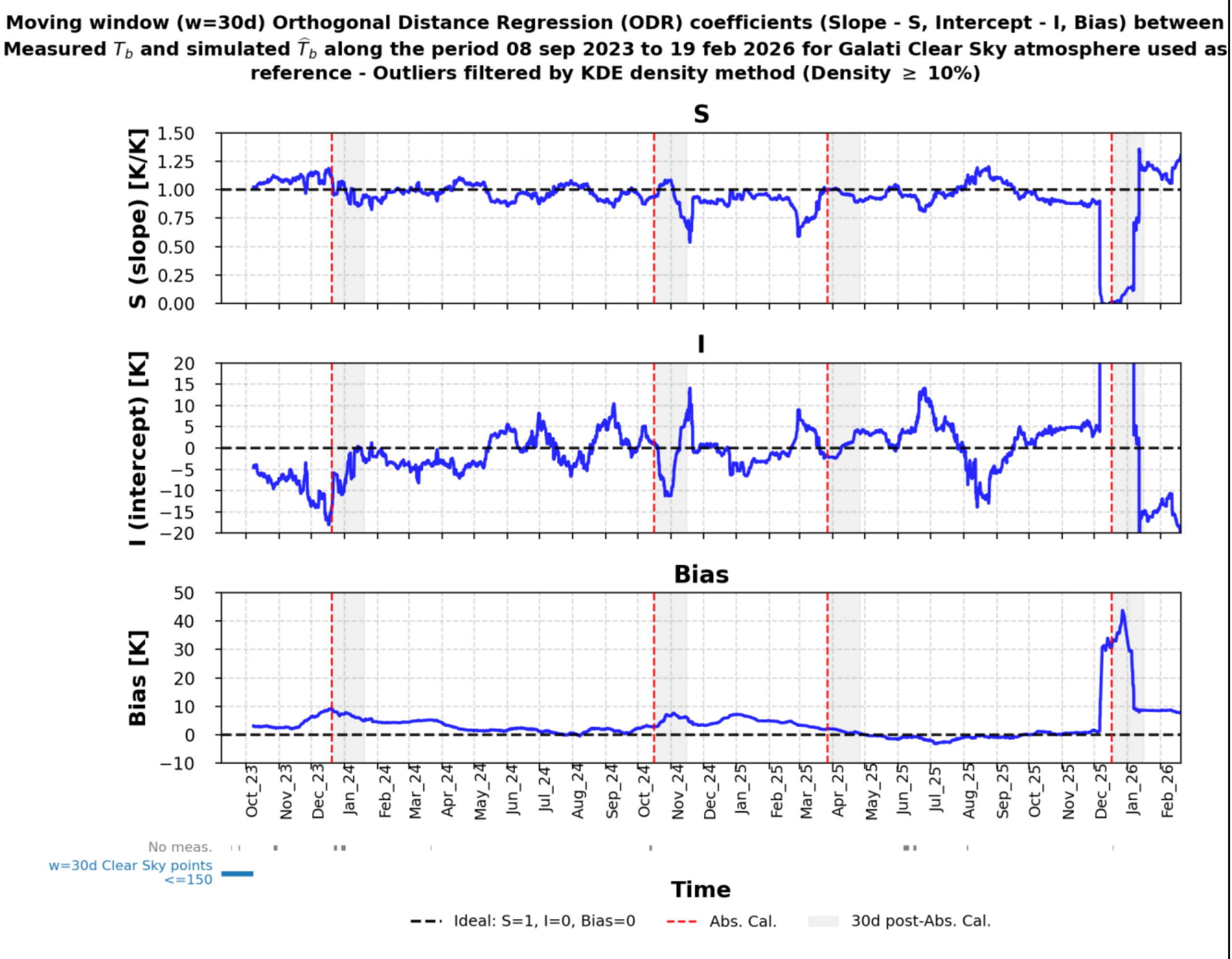
Corrected (a-posteriori)



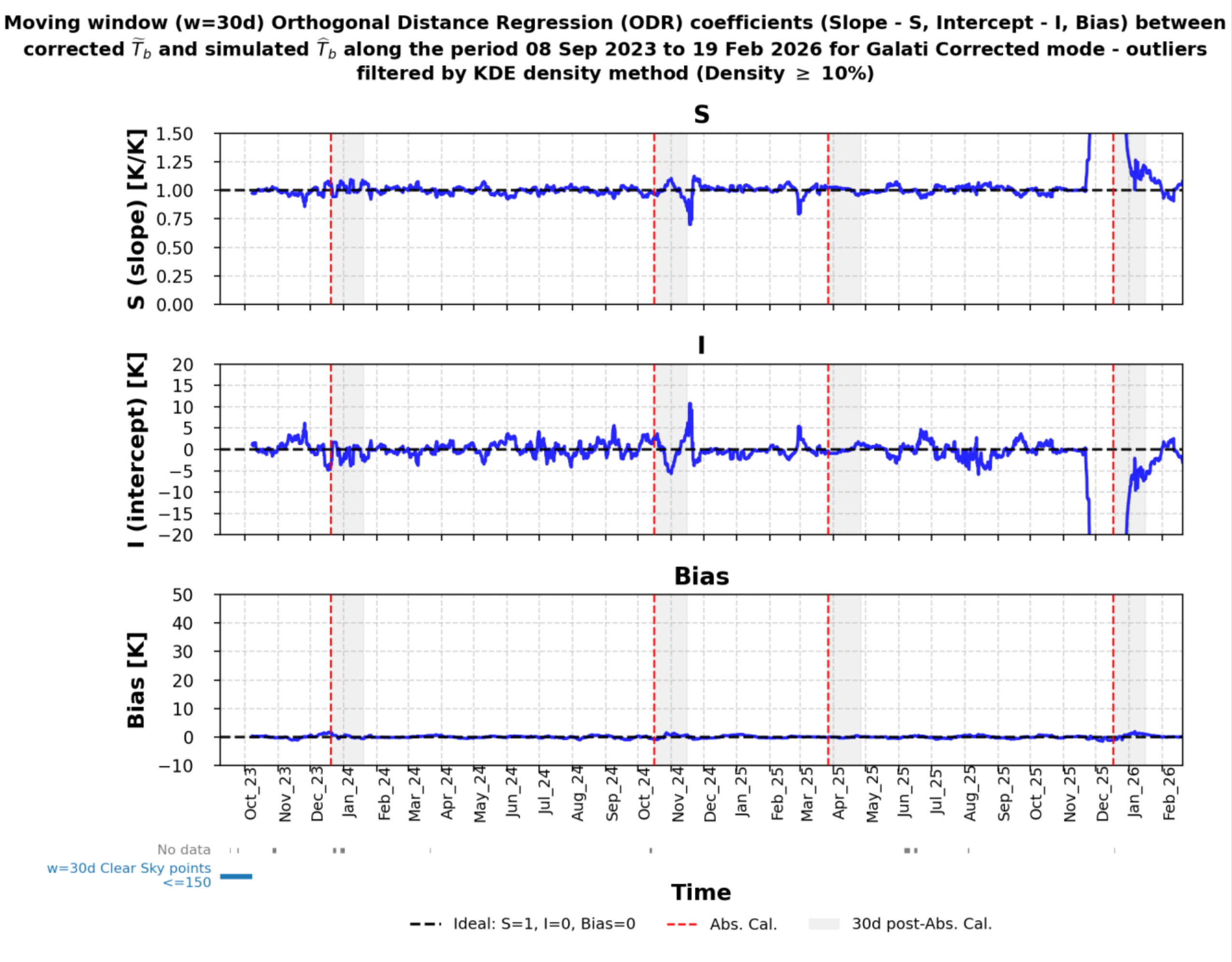
__Acknowledgements__ to Andrei - Titus Radovic and UBBCLUJ colleagues

Calibration assessment & a posteriori time calibration
Galati

Measured



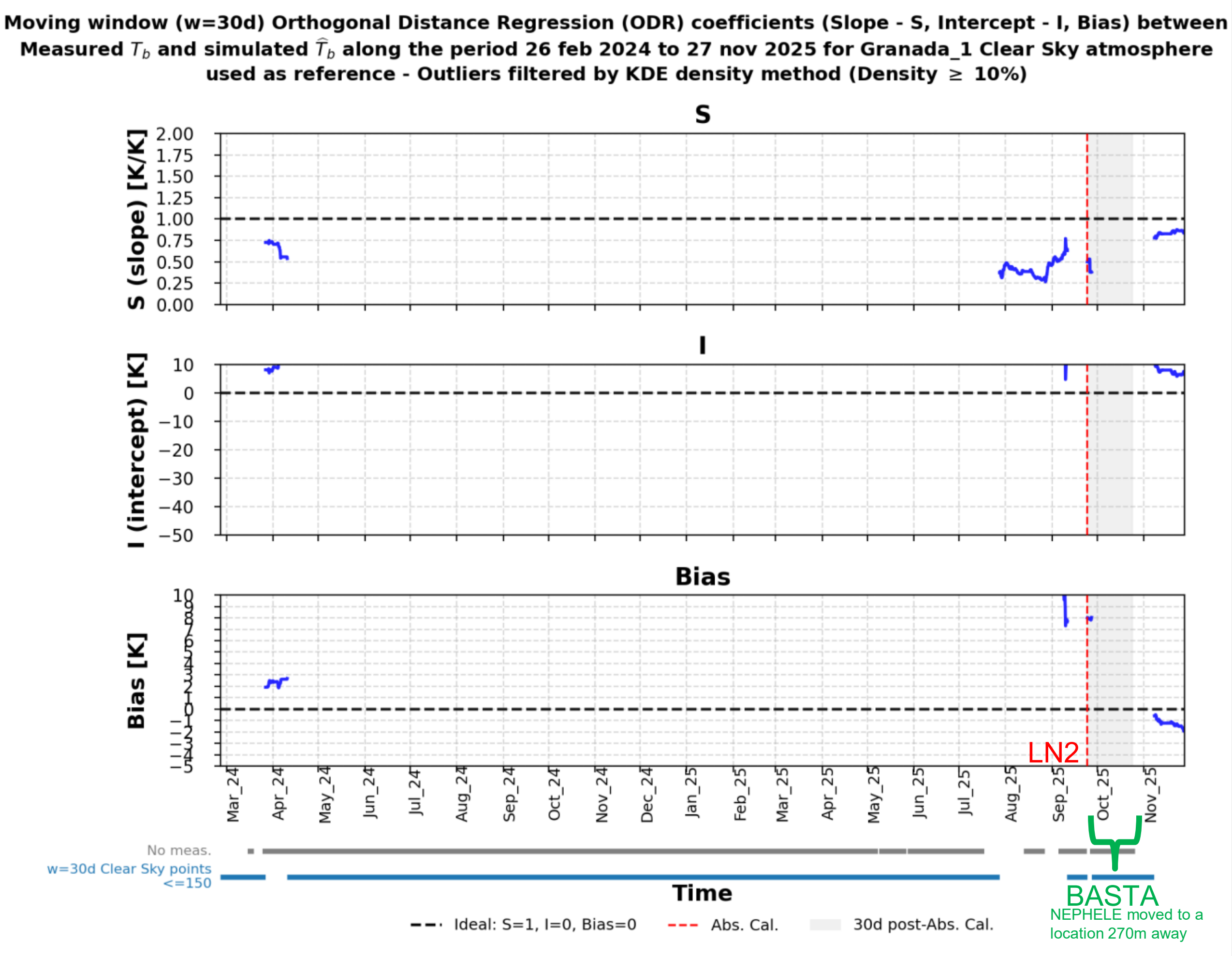
Corrected (a-posteriori)



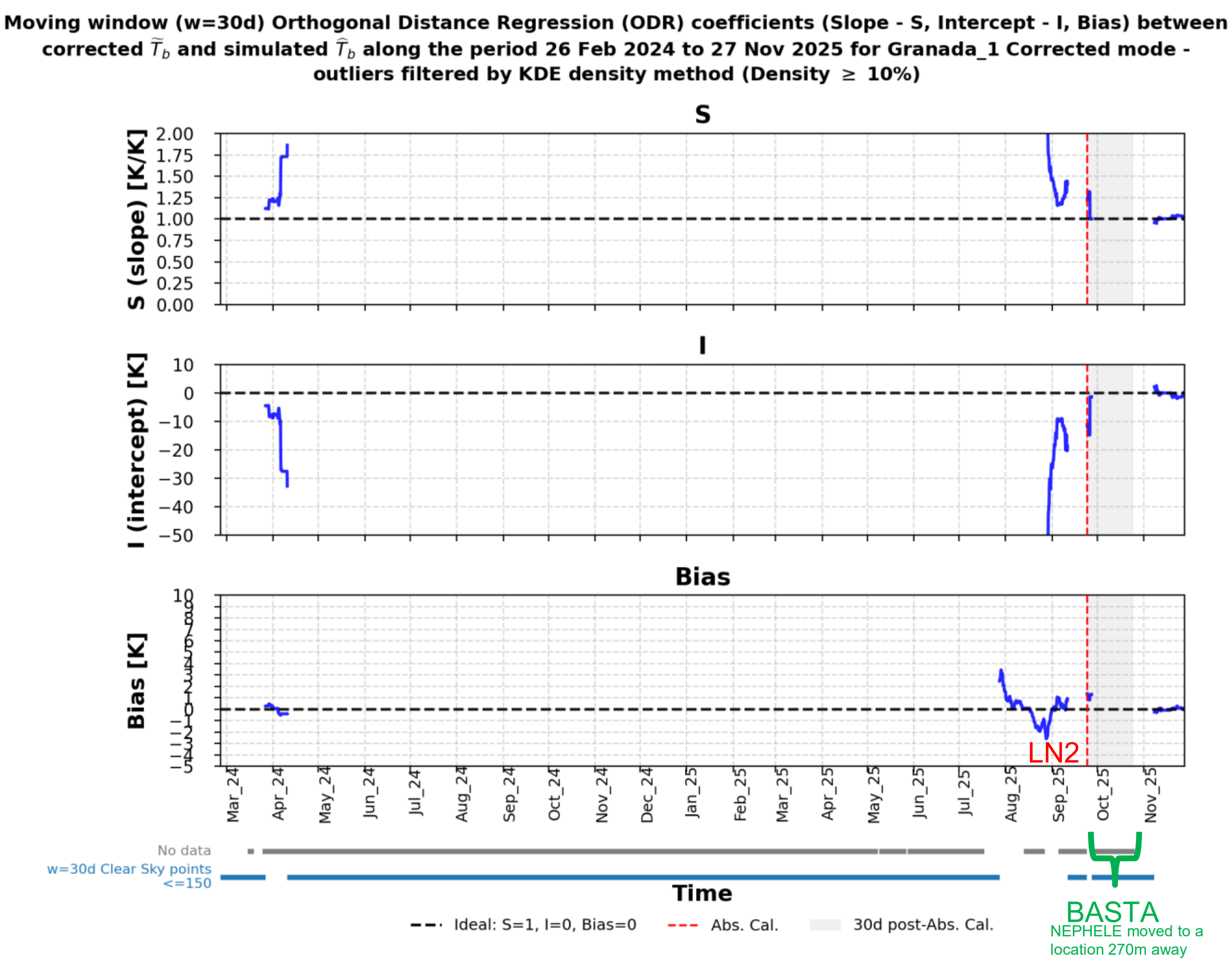
Acknowledgements *to Daniel Constantin, Mirela Voiculescu and UGAL colleagues*

Calibration assessment & a posteriori time calibration
Granada (Nephele)

Measured



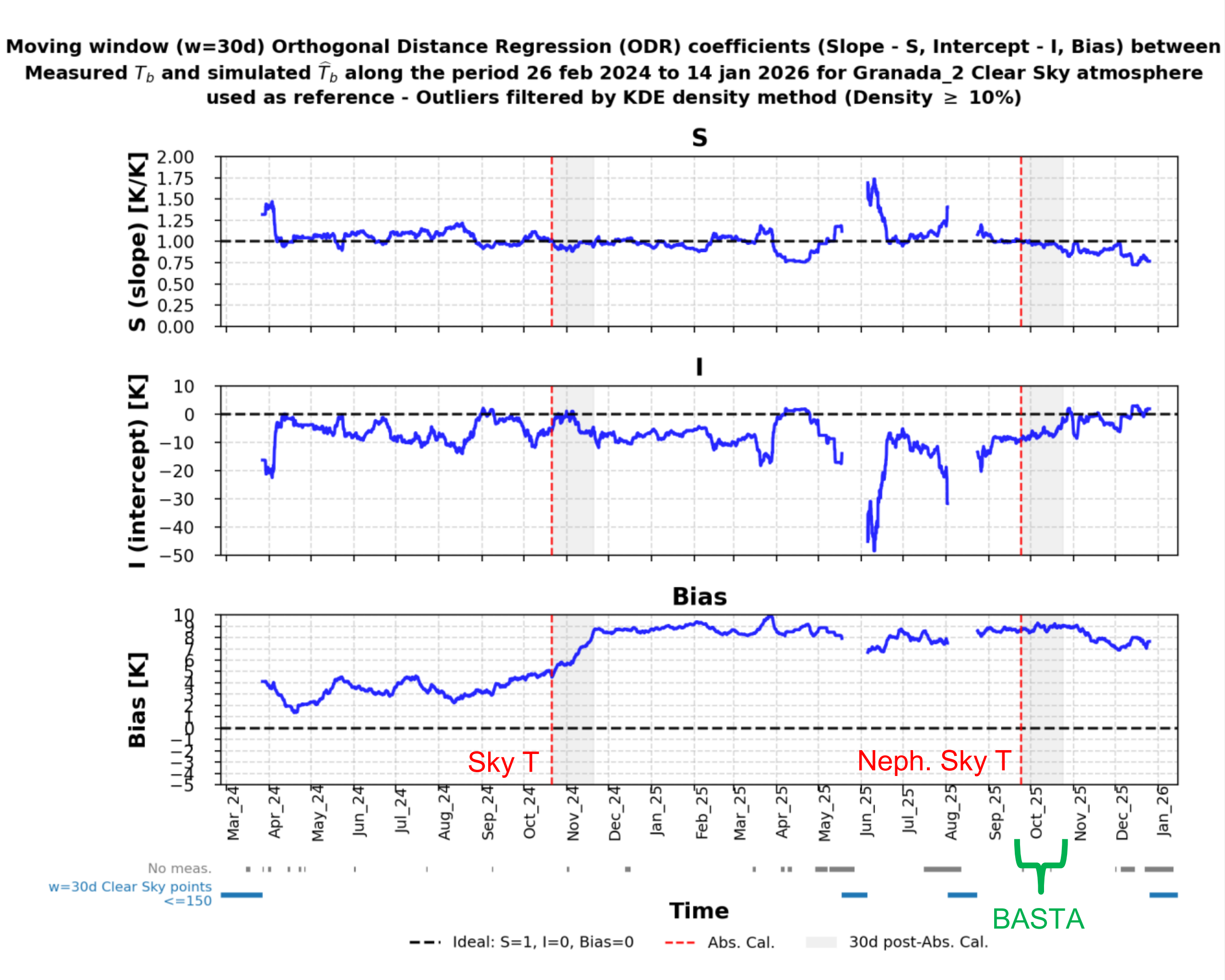
Corrected (a-posteriori)



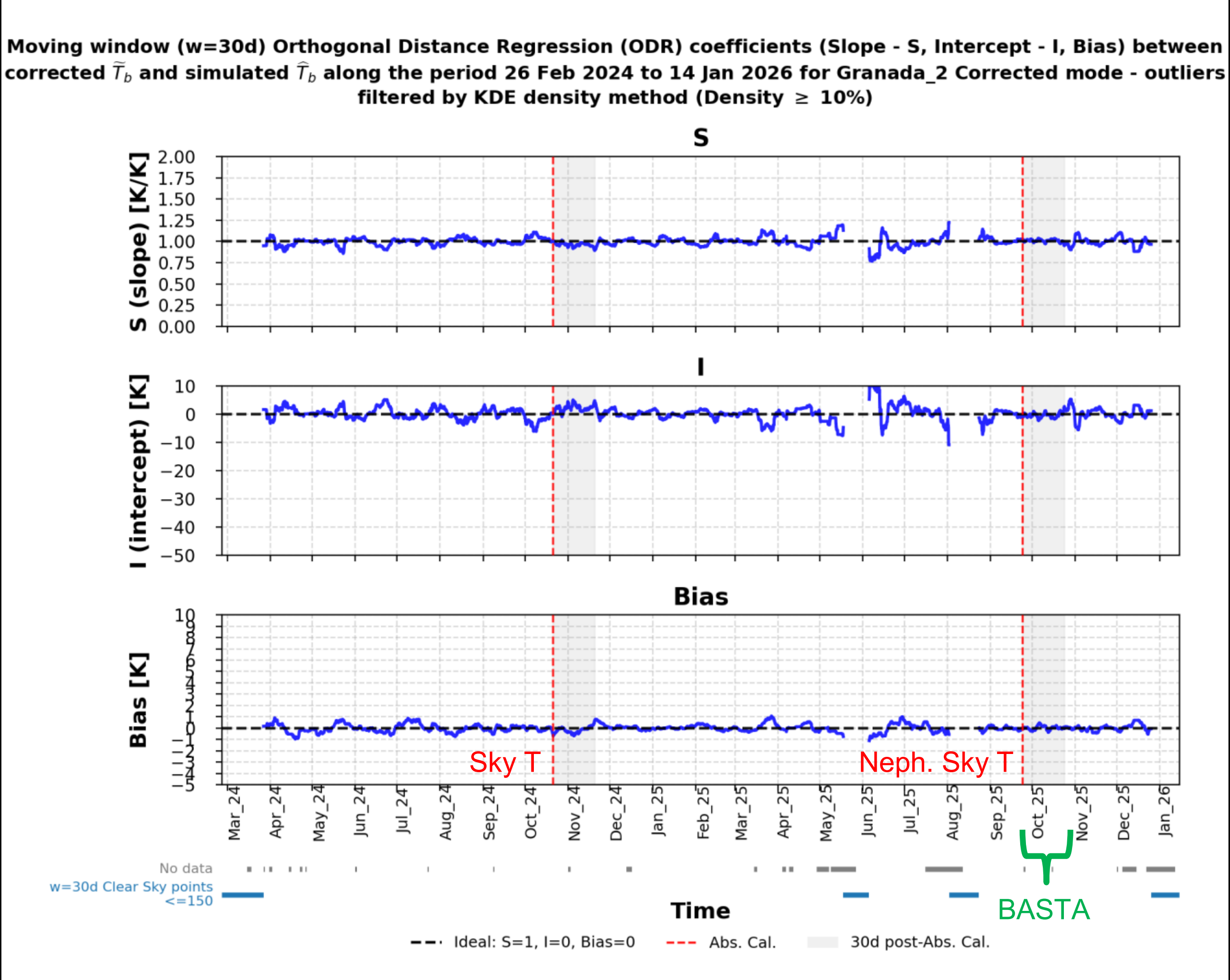
Acknowledgements *Maria J. Granados-Muñoz and UGR colleagues*

Calibration assessment & a posteriori time calibration
Granada (Nebula)

Measured



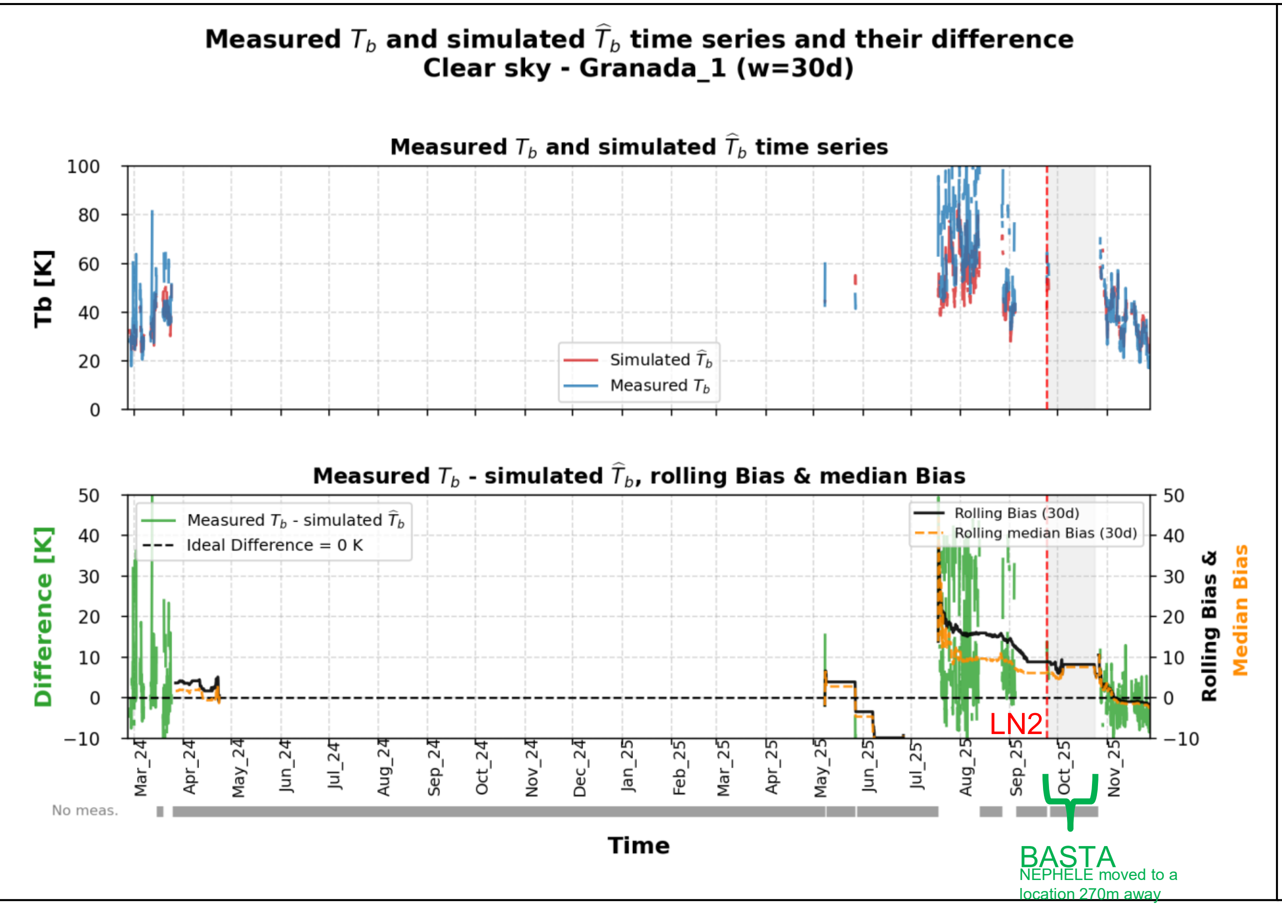
Corrected (a-posteriori)



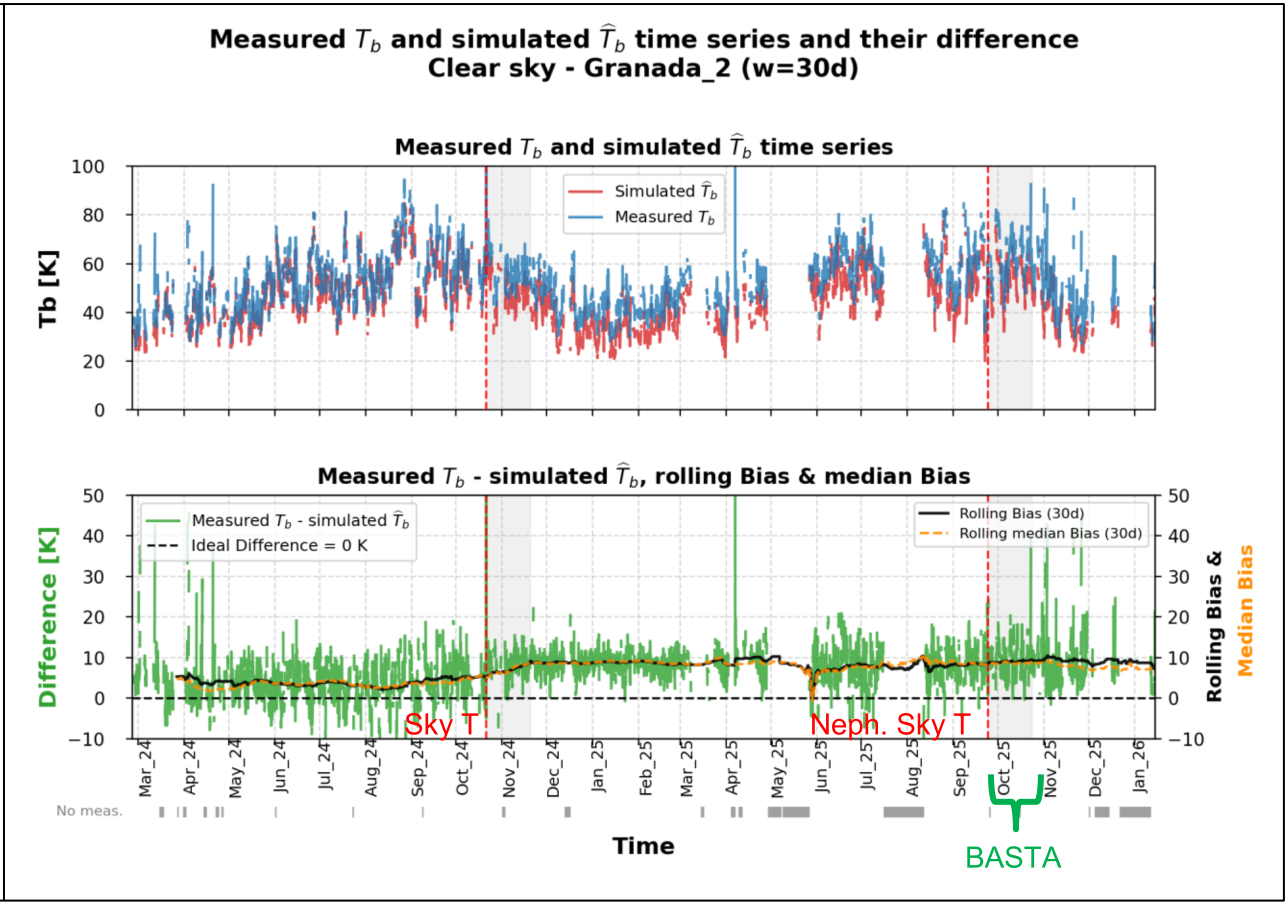
Acknowledgements *Maria J. Granados-Muñoz and UGR colleagues*

Calibration assessment - Granada insights
Nebula vs Nephele cal.

Nephele - measured



Nebula - measured

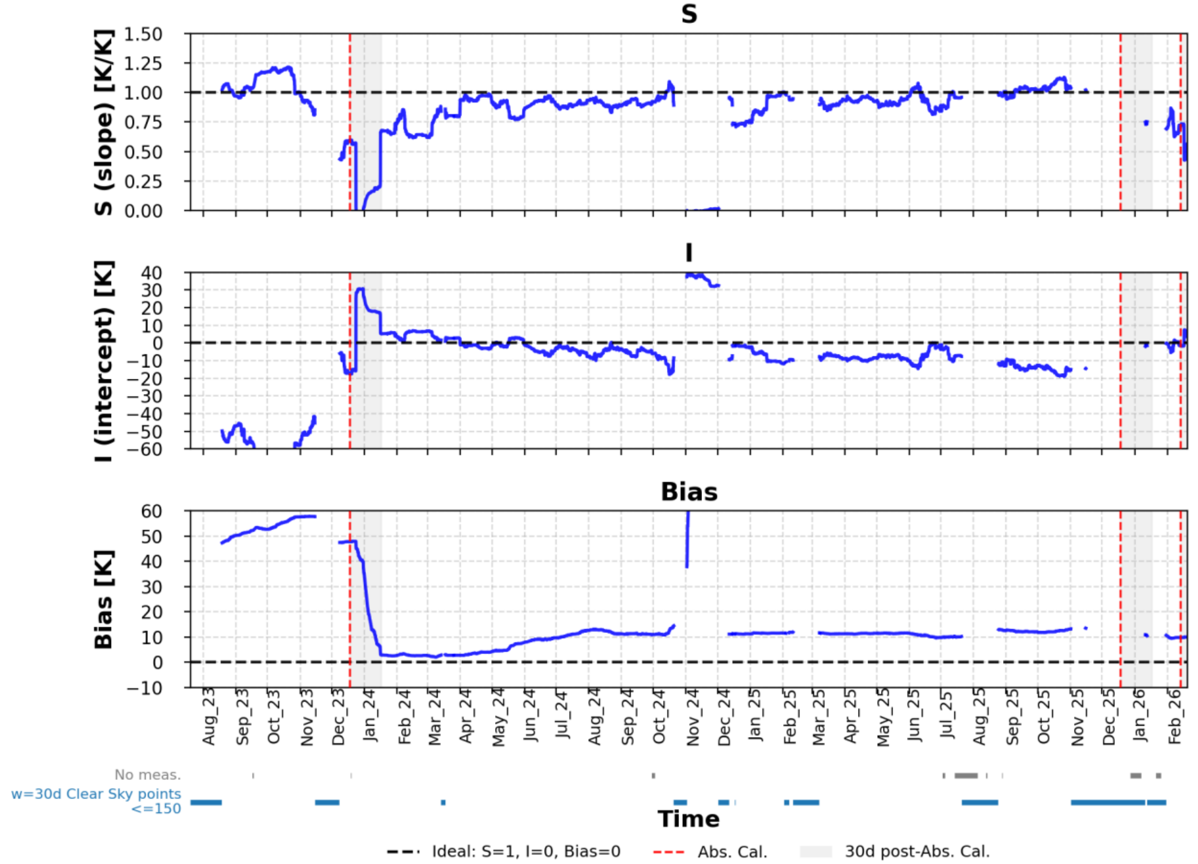


Acknowledgements *Maria J. Granados-Muñoz and UGR colleagues*

Calibration assessment & a posteriori time calibration
Hyyttiala

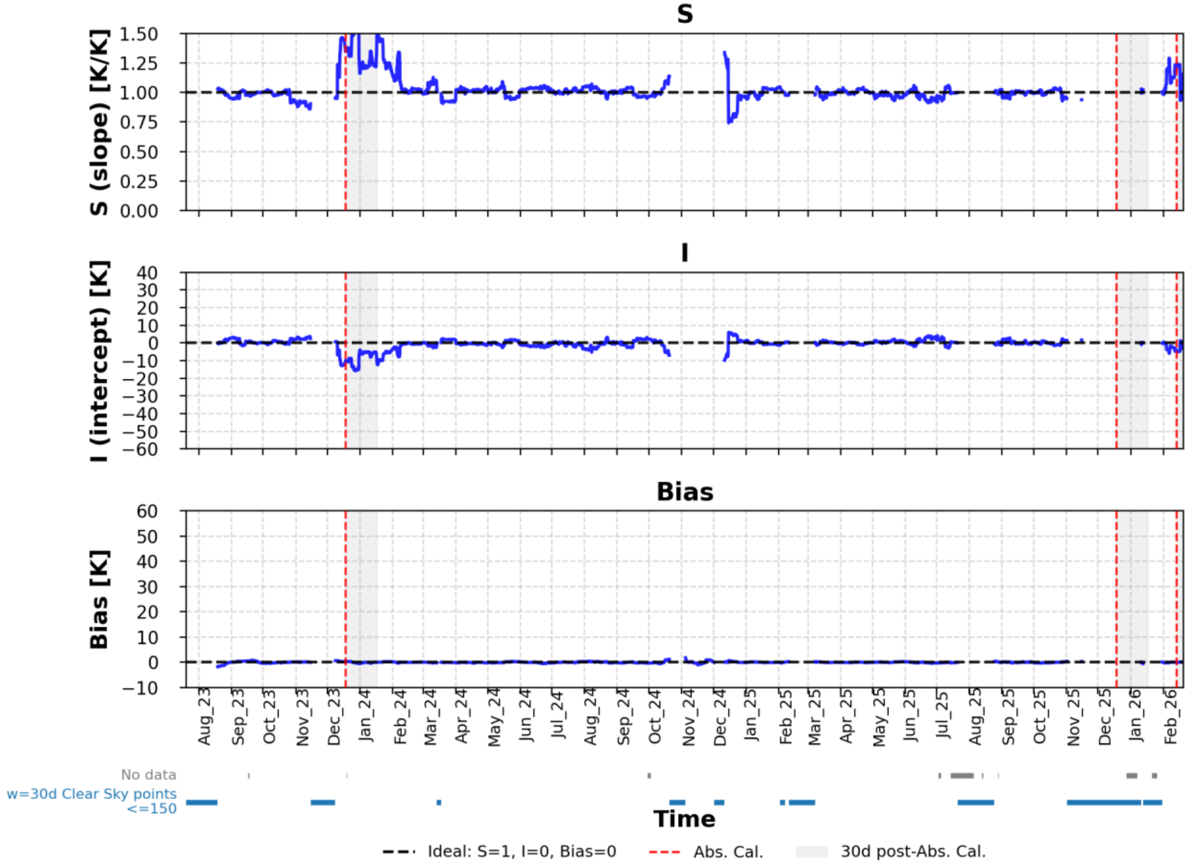
Measured

Moving window (w=30d) Orthogonal Distance Regression (ODR) coefficients (Slope - S, Intercept - I, Bias) between Measured T_b and simulated $\widehat{T}_b$ along the period 20 jul 2023 to 19 feb 2026 for Hyytiala Clear Sky atmosphere used as reference - Outliers filtered by KDE density method (Density ≥ 10%)



Corrected (a-posteriori)

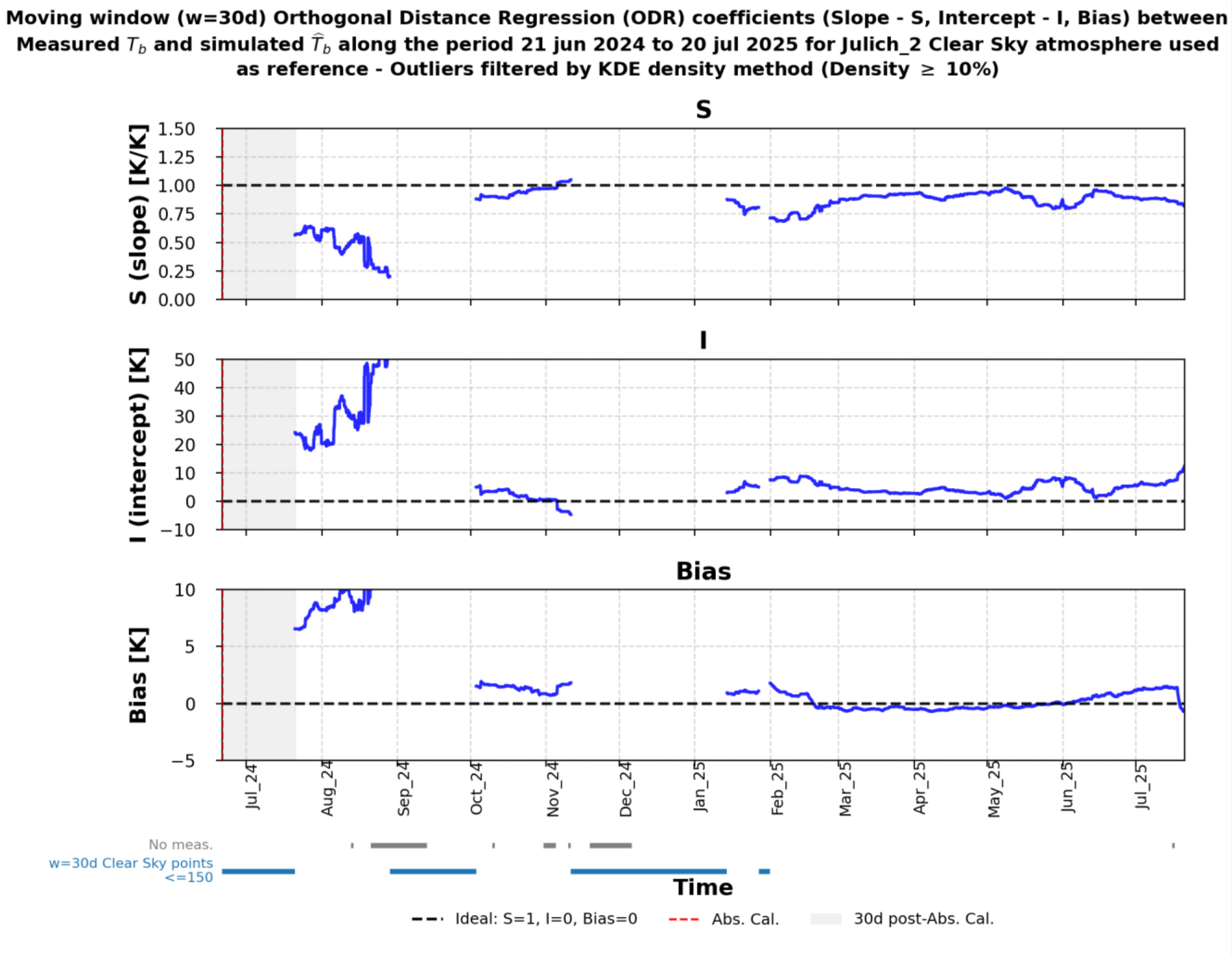
Moving window (w=30d) Orthogonal Distance Regression (ODR) coefficients (Slope - S, Intercept - I, Bias) between corrected $\widetilde{T}_b$ and simulated $\widehat{T}_b$ along the period 20 Jul 2023 to 19 Feb 2026 for Hyytiala Corrected mode - outliers filtered by KDE density method (Density ≥ 10%)



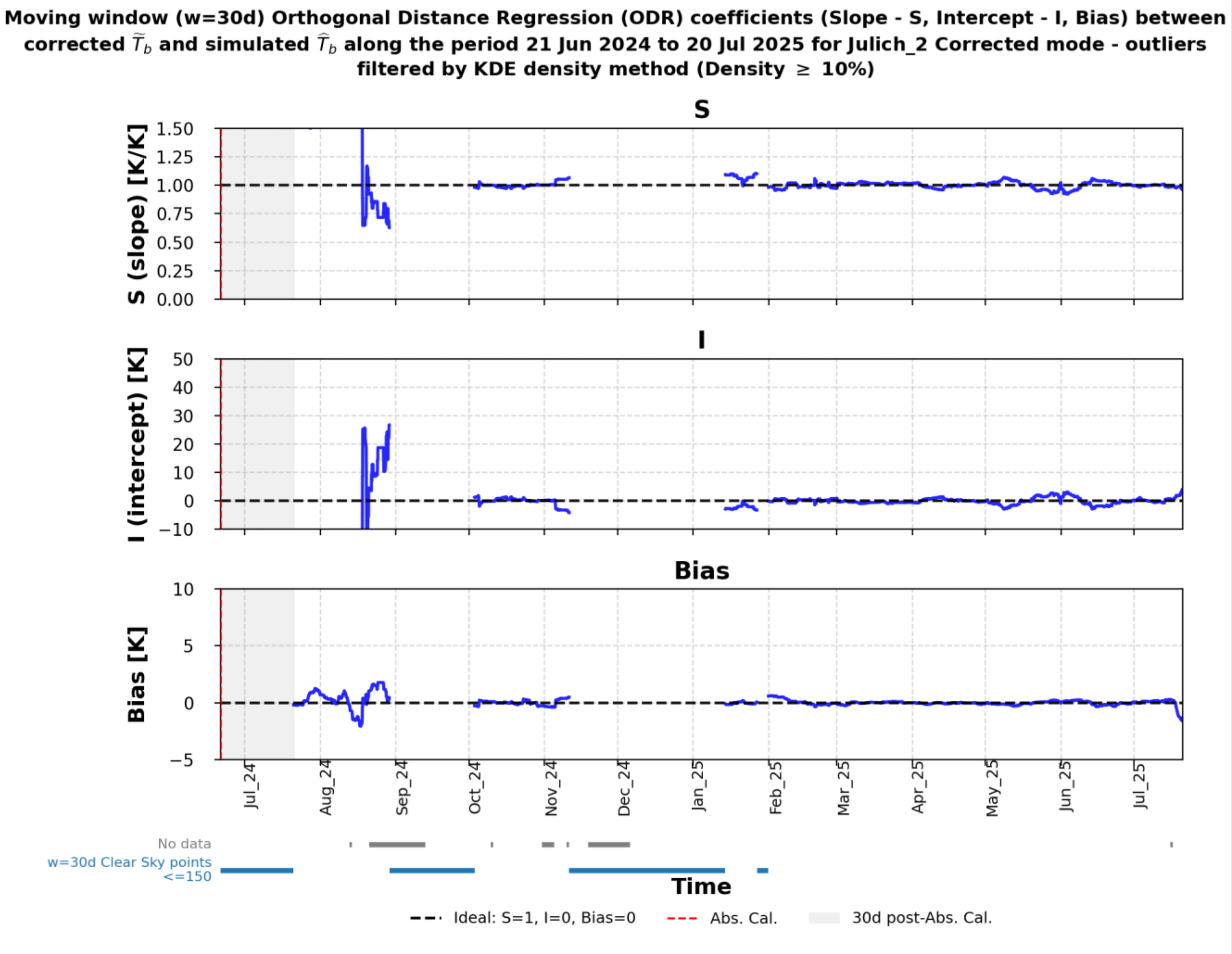
Acknowledgements Dmitri Moisseev, and Helsinki INAR colleagues

Calibration assessment & a posteriori time calibration
Julich

Measured



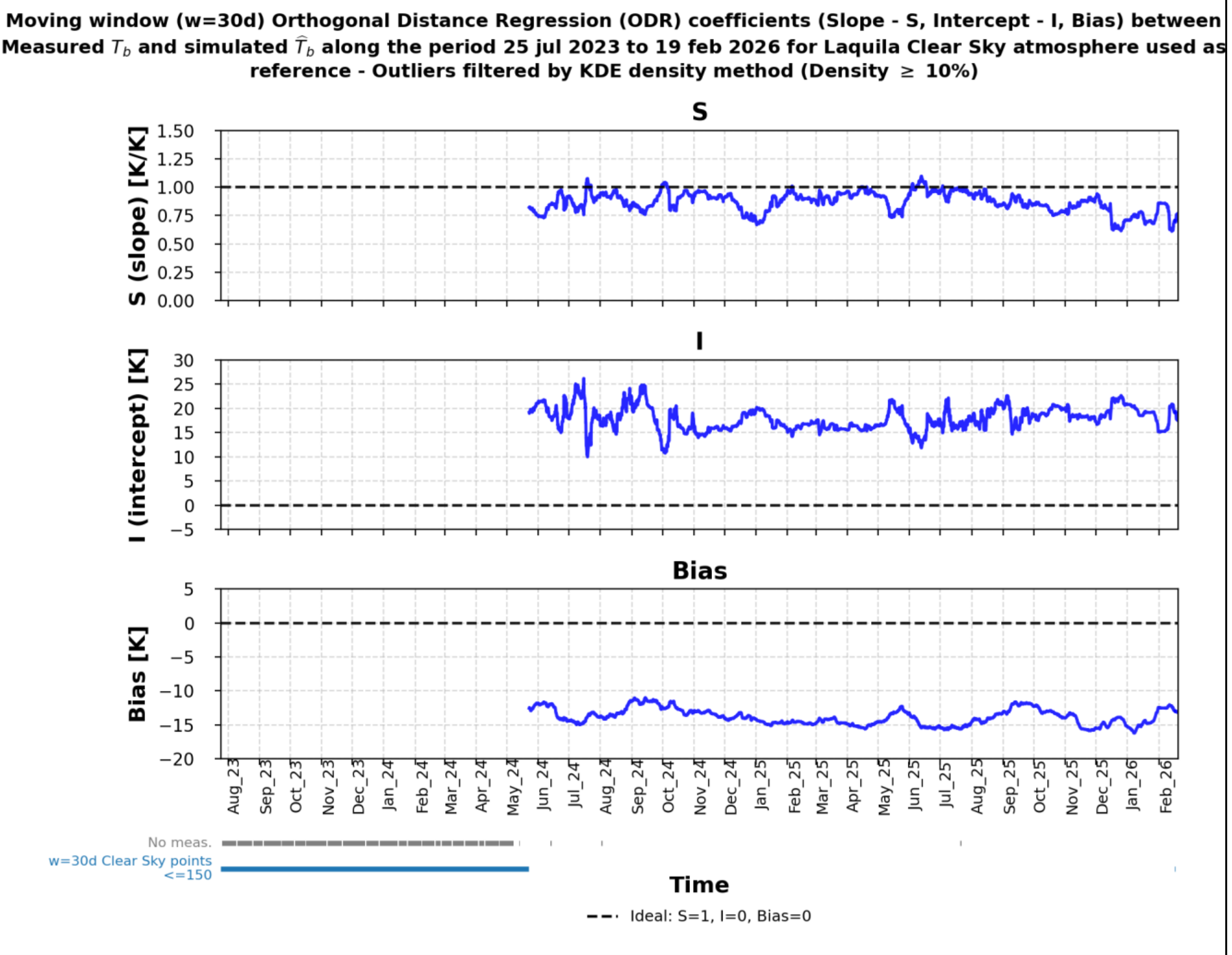
Corrected (a-posteriori)



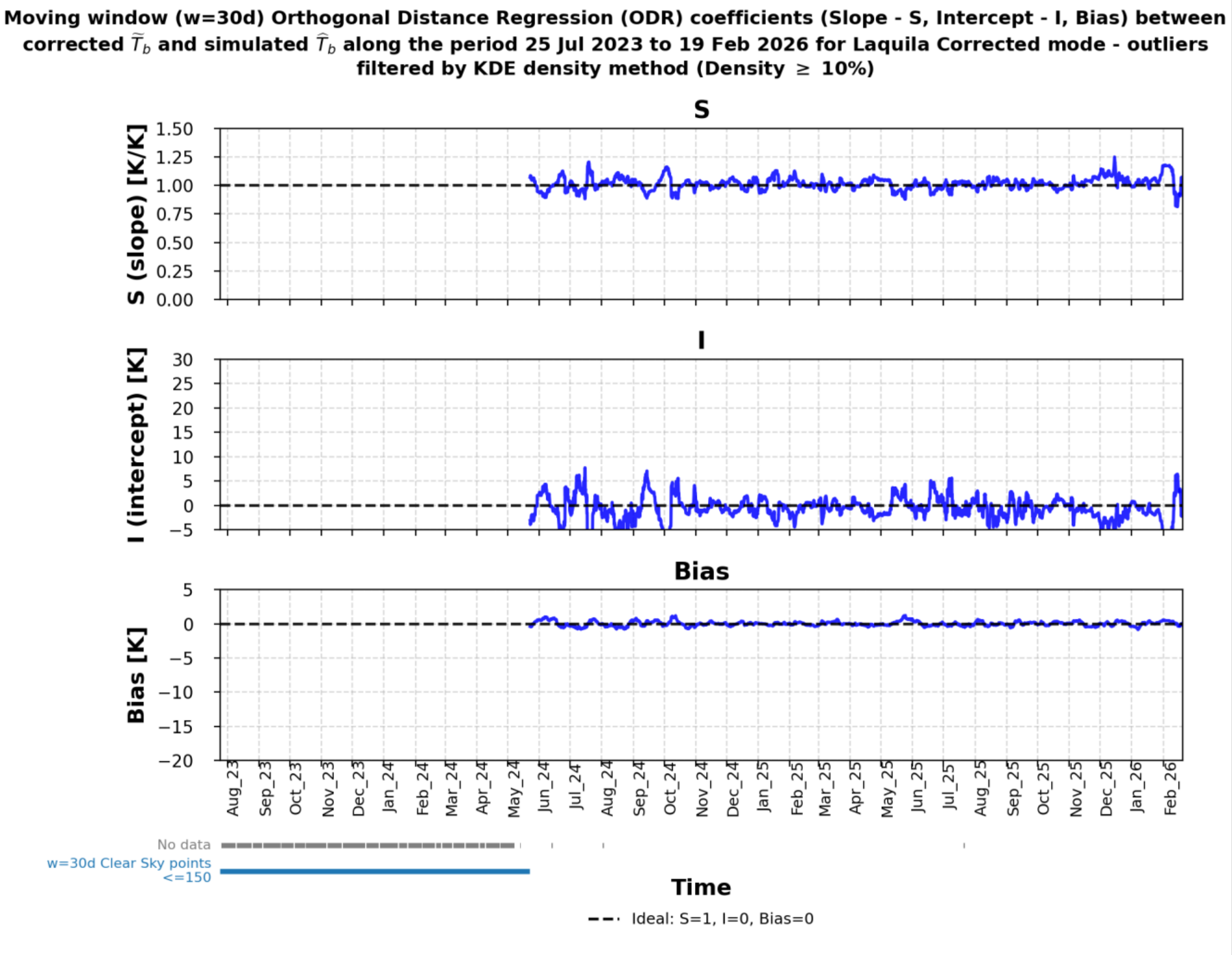
Acknowledgements *Bernhard Pospichal*, and uni-koeln colleagues

Calibration assessment & a posteriori time calibration
L'Aquila

Measured



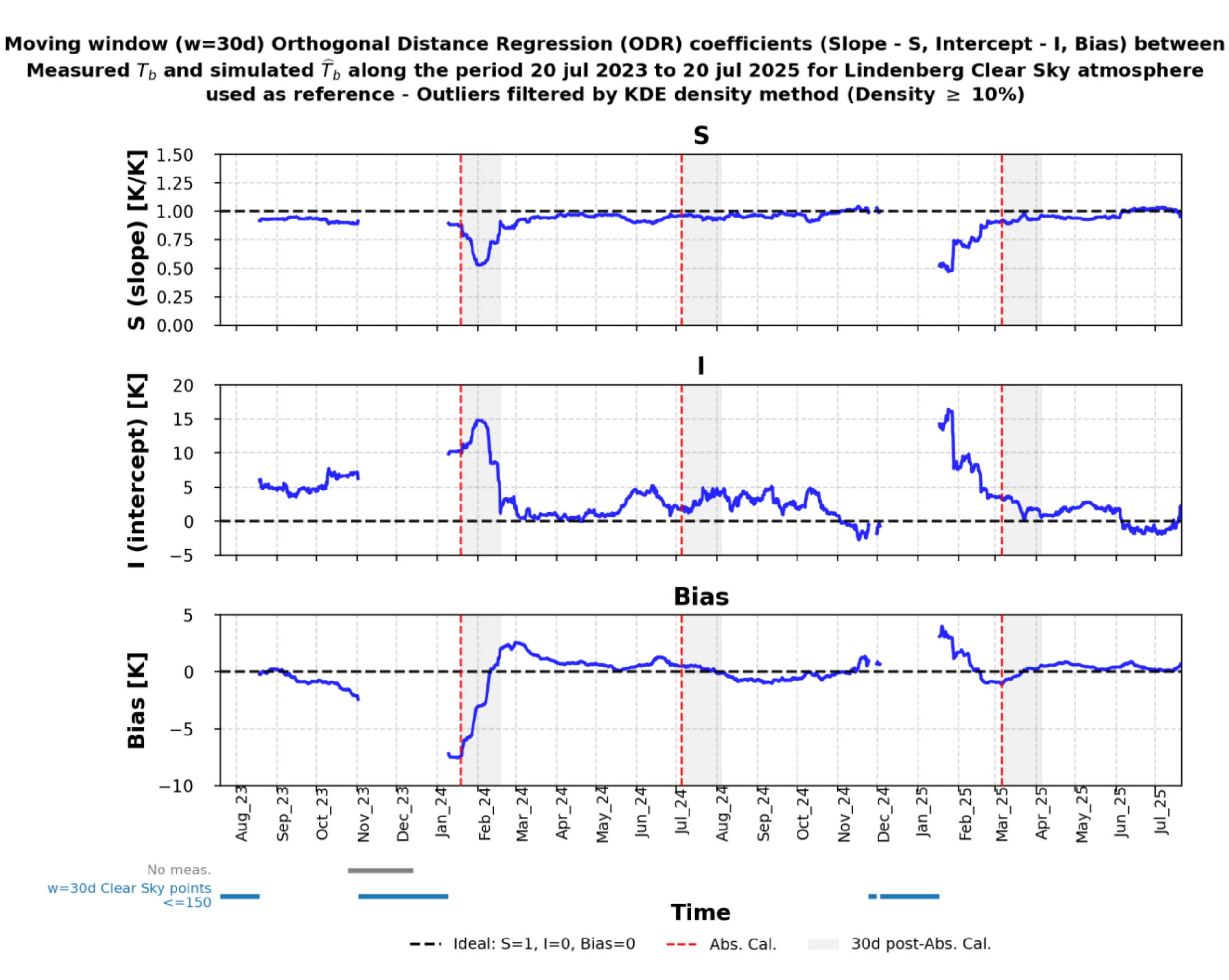
Corrected (a-posteriori)



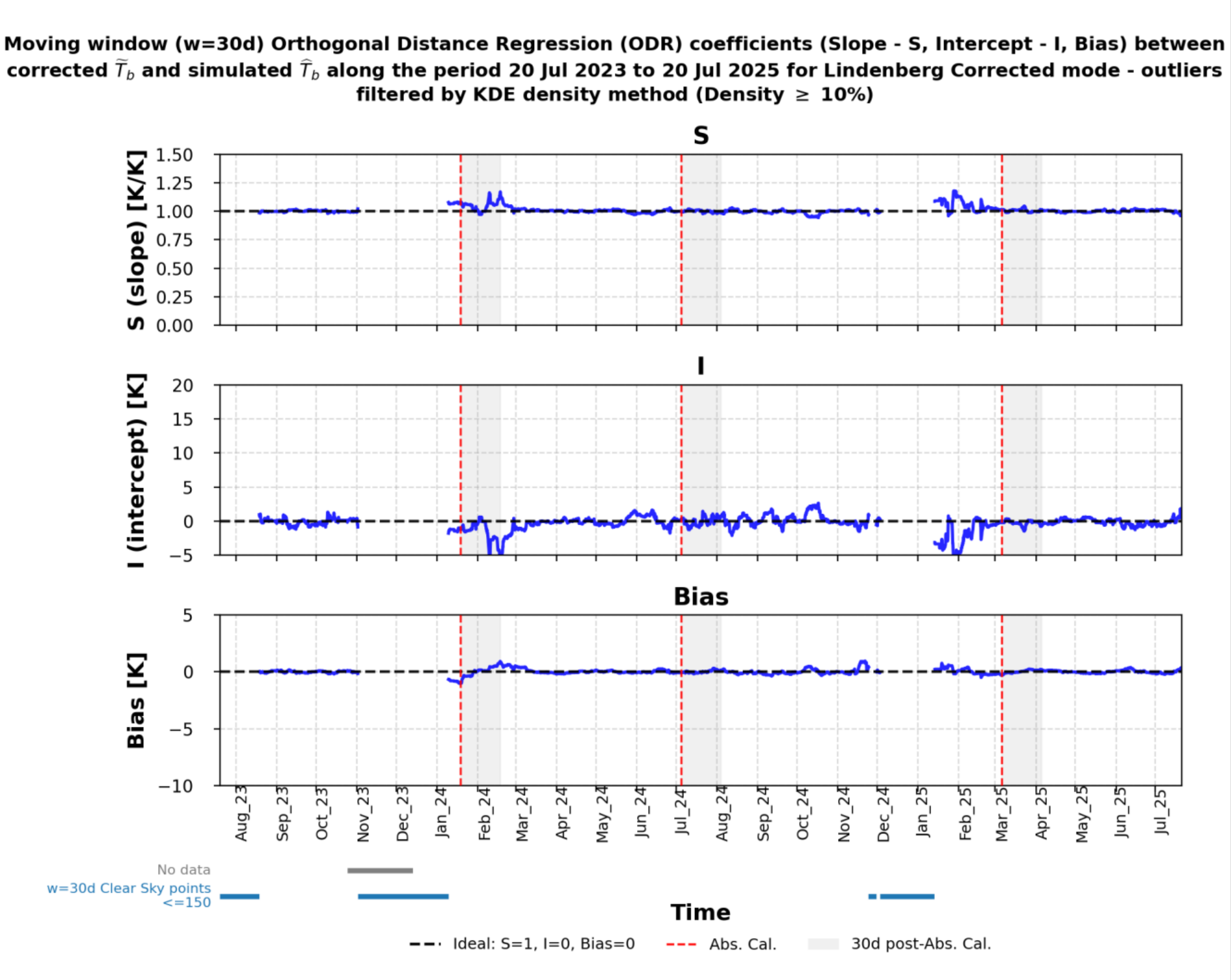
Acknowledgements *Marco Iarlori, Saverio di Fabio, Raffaele Lidori, and CETEMPS colleagues*

Calibration assessment & a posteriori time calibration
Lindenberg

Measured



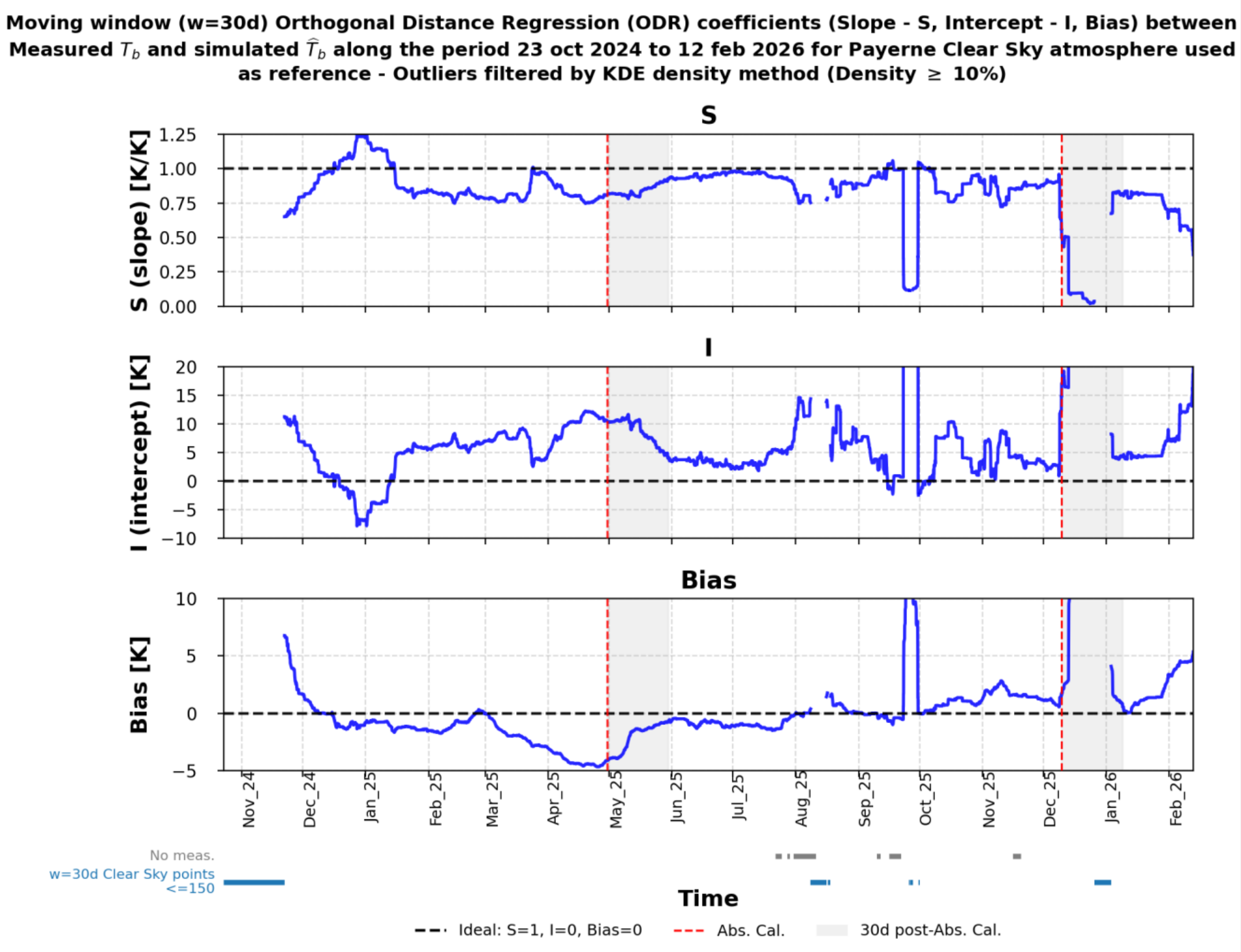
Corrected (a-posteriori)



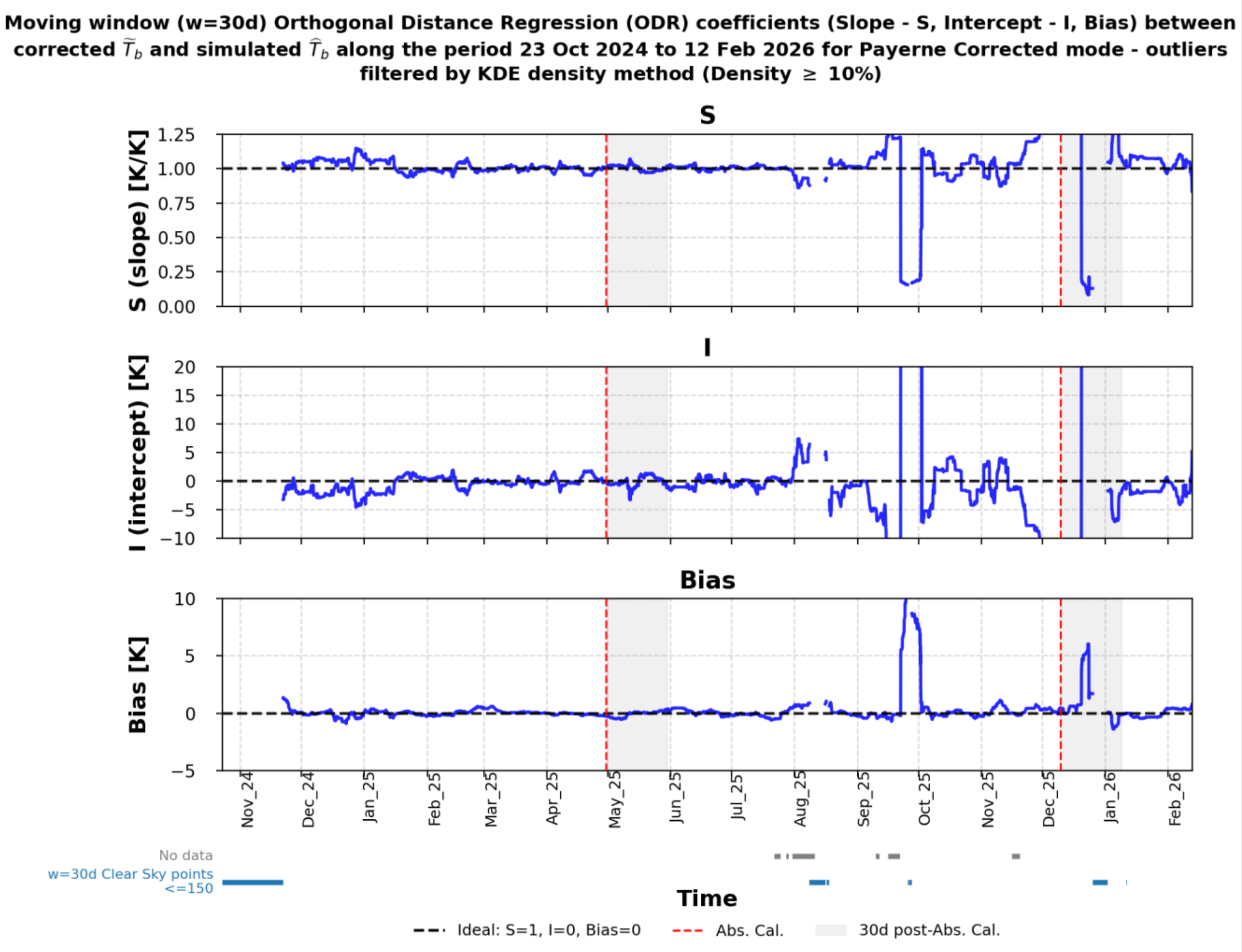
Acknowledgements *Christine Knist and DWD colleagues*

Calibration assessment & a posteriori time calibration
Payerne

Measured

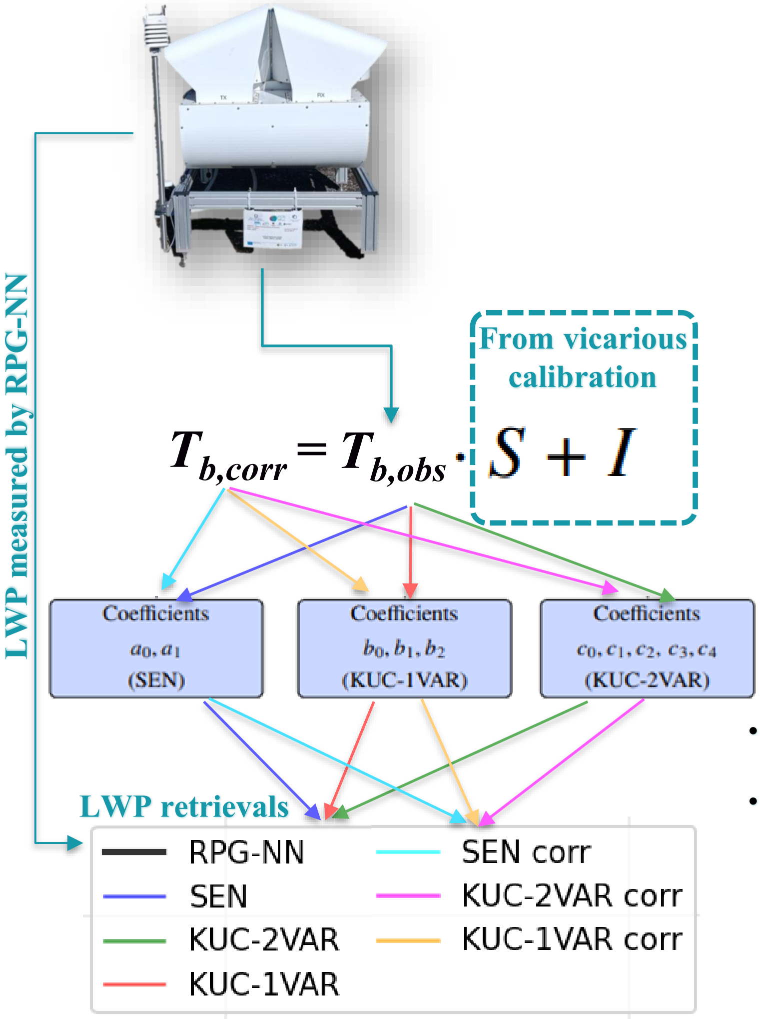


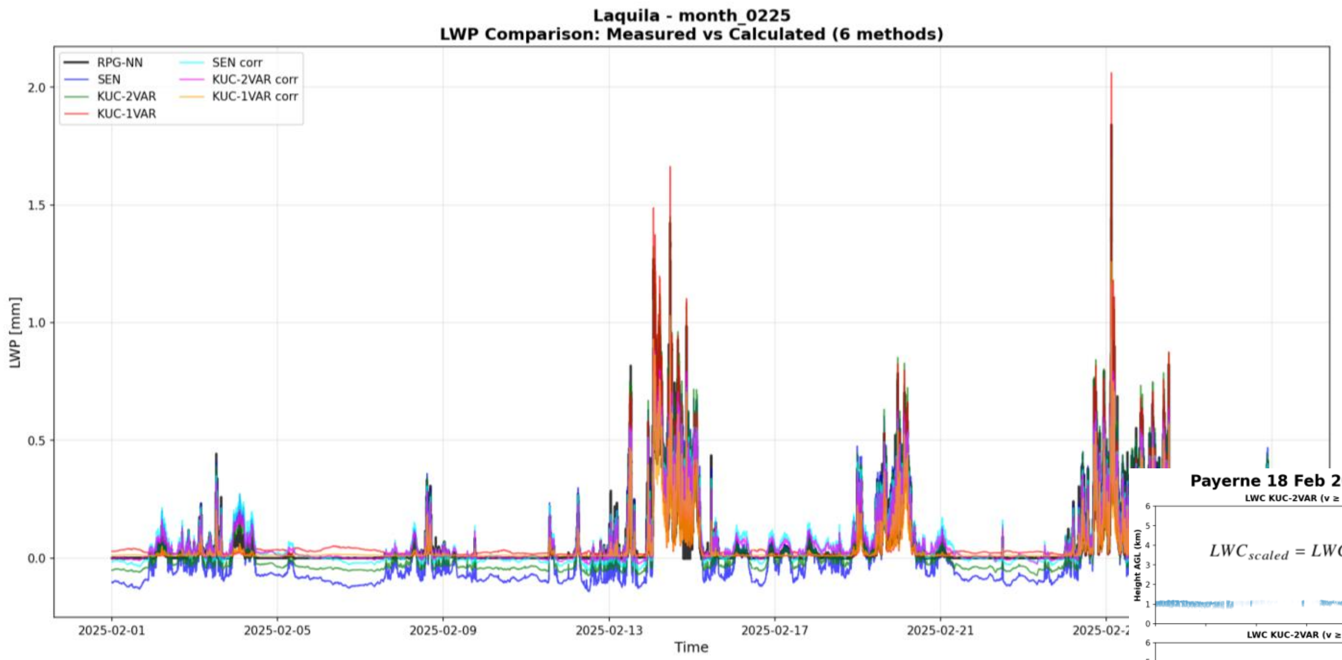
Corrected (a-posteriori)



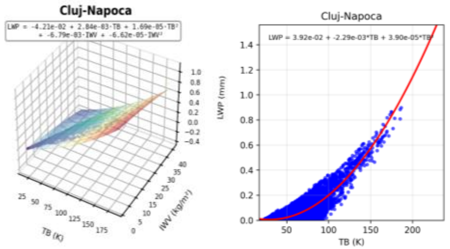
Acknowledgements *Rebecca Gugerli, Renaud Matthey and UNIBE colleagues*

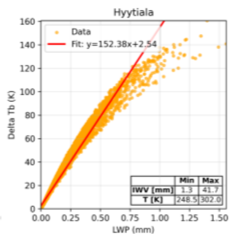
Impact of recalibration on LWP and LWC





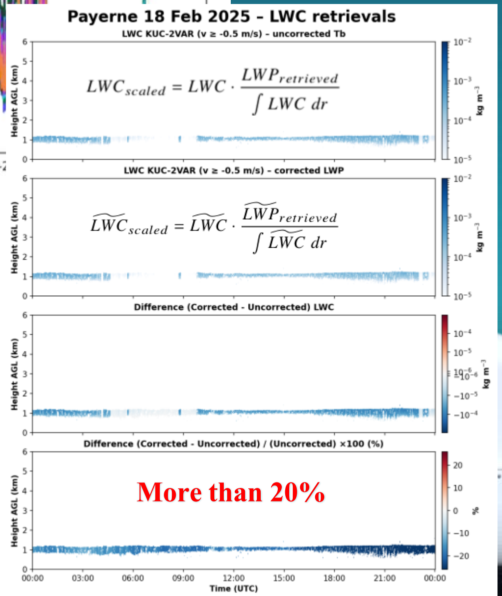
- *Computed from literature, ERA5 LWP vs simulations in a synthetic controlled environment – site specific –*
- *IWV from ERA5*





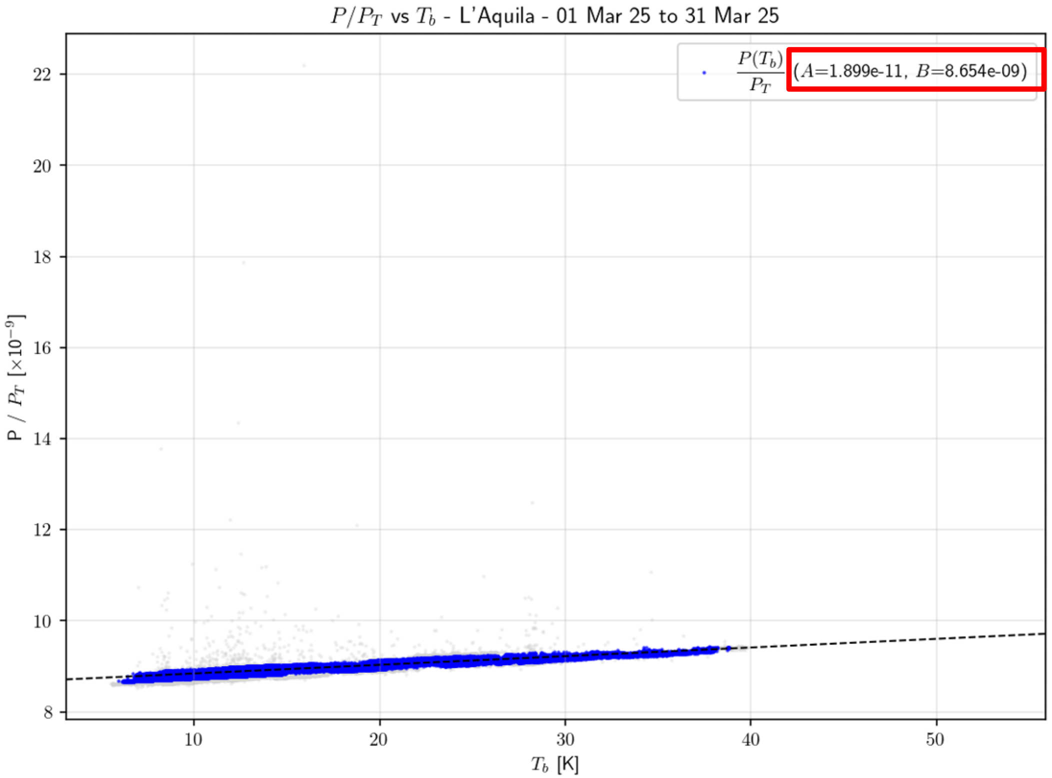
(Kuchler et al. 2017) (Cimini et al. 2007)

- Non precipitating (simplified) cloud screening → v > -0,5 m/s
- Z-LWC power law equation with «Atlas (1956)» coefficients



Active channel VC – in progress/preliminary

- RX antenna is shared between active and passive channel
- Vicarious calibration of passive channel can be transferred, with caution, to the active channel
- Received ADC total active channel power (P) is first normalized by transmitted power (P_T) and then mapped to T_b
- Clear sky screening → active channel sensitivity to atmospheric emission
- Linear regression gives the equivalent reflectivity correction coefficients A and B



Limitation: *the reflectivity correction is applied as a constant along the vertical. Range dependent analysis extension ongoing*

!! PRELIMINARY !!

Conclusions

- Abs calibration is sometimes evident by VC method (but not always)
- Some station ran with biased measurements
- Moving-window approach to VC allows for a supplementary online monitoring of the calibration state of each instrument over time
- Short (Hyttiala June to October 2024) and long (Galati 2023-2024) periodicity should be further investigated
- Brightness temperature correction allows for a bettter LWP and LWC estimation

Future developments

- **Short term:**
  - Technical discussion within ACTRIS community
  - Publication is in preparation
  - Active channel VC transfer
- **Mid/Long term:**
  - Developing ML or NN algorithms for synergistic LWC retrievals
  - Compensating Path Integrated Attenuation (PIA) in radar data , fully exploiting synergy between active and passive collocated observations
  - Method refinement and eventual implementation of routine monitoring tool?
  - Extension of the method to other instruments' passive channels?

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Thank you !

Questions?
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