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Selection of reference instruments and data analysis

G. Martucci, G. Romanens, C. Felix, A. Haefele, Y.-A. Roulet

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	TYPE	PROVIDER	8th UAII	STATUS	ATM LAYER	COMMENT
TEMP	MULTITHERMISTOR	LMS	YES	OPER	T/S	
	MTR	MEISEI	YES	OPER	T/S	
W V	CFH	DMT	YES	OPER	T/S	
	P-CFH	ETHZ	NO	DEV	T/S	
	SKYDEW	MEISEI	NO	DEV	T/S	
	FLASH-B	CAO	NO	OPER	(T)/S	DESCENT
	SNOW-WHITE	METEOLABOR	YES	OPER	T/(S)	

Working reference:

The payload limitation, costs and the high sensitivity (contaminations) of reference instruments, are limiting factors that prevent flying the reference instruments for all comparison fights during the future WMO/UAII2021 campaign.

A pragmatic, but nevertheless objective approach is required to identify suitable working references.

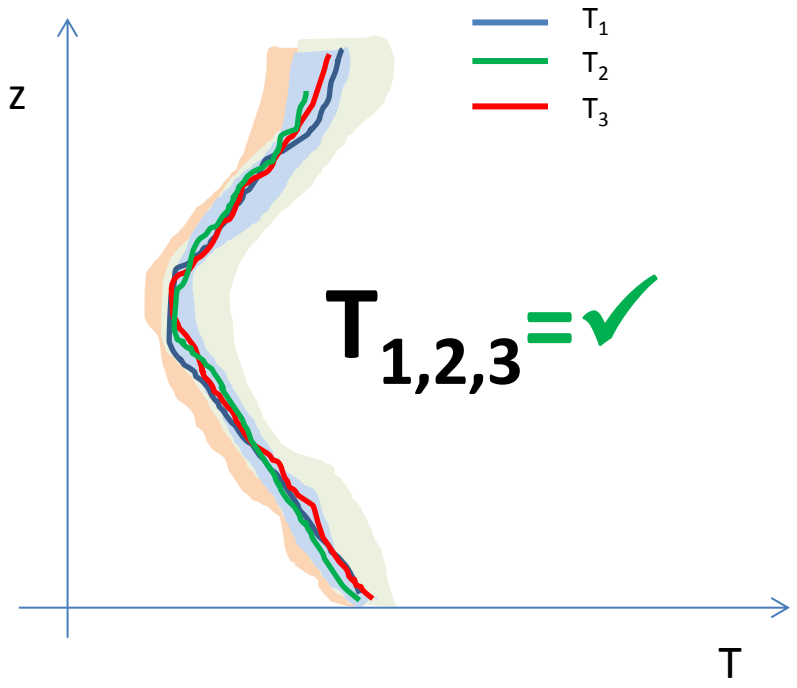
For years, the core of the GRUAN network has been to establish standard criteria and requirements to obtain high quality measurements. One objective of GRUAN is to characterize radiosounding systems from a scientific (development) and technical point of view with an highlight on defining the traceability and the uncertainty. By doing so, GRUAN becomes a natural and robust framework where to define which radiosondes are the most suitable in terms of reliability to be retained as working reference radiosonde.

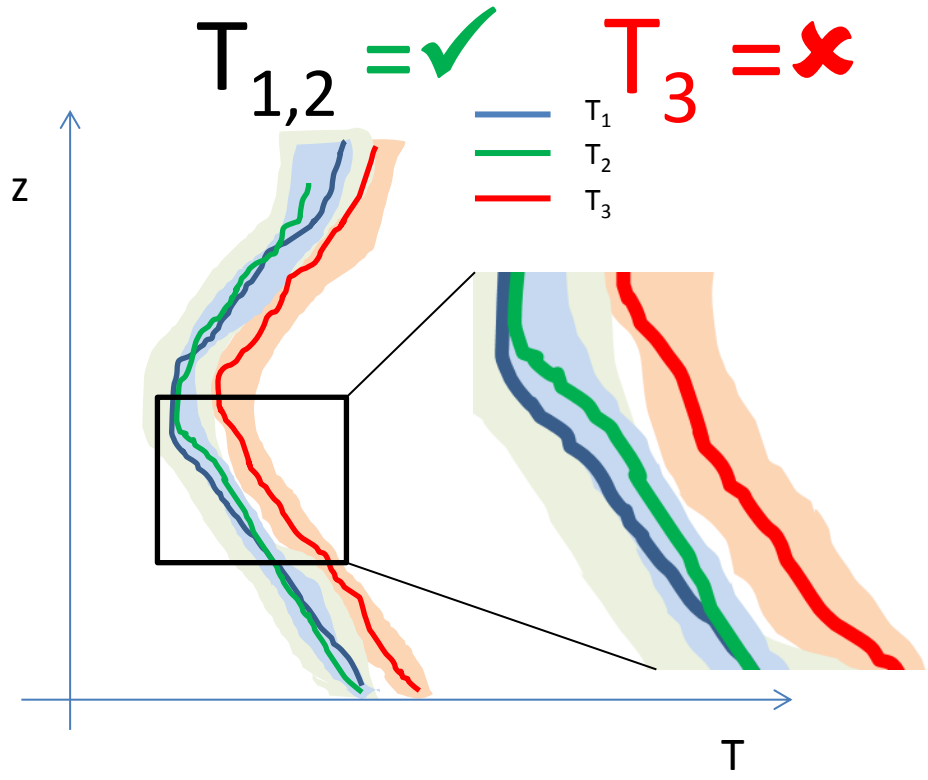
Consequently, the selection of transfer and reference sondes in the framework of the UAII2021 could (or should) be performed based on the existing statistical and technical information available from the GRUAN database. This would allow the IOC to make an unbiased choice about which sondes to select as “transfer sondes” without necessarily performing a pre-intercomparison session of test flights (sondes vs sondes) that would results in an enormous effort both financial and technical.

For what it is the choice of the “reference” sondes (q and T), these must be non-commercial scientific sondes with proven high quality performances and a mature status of development.

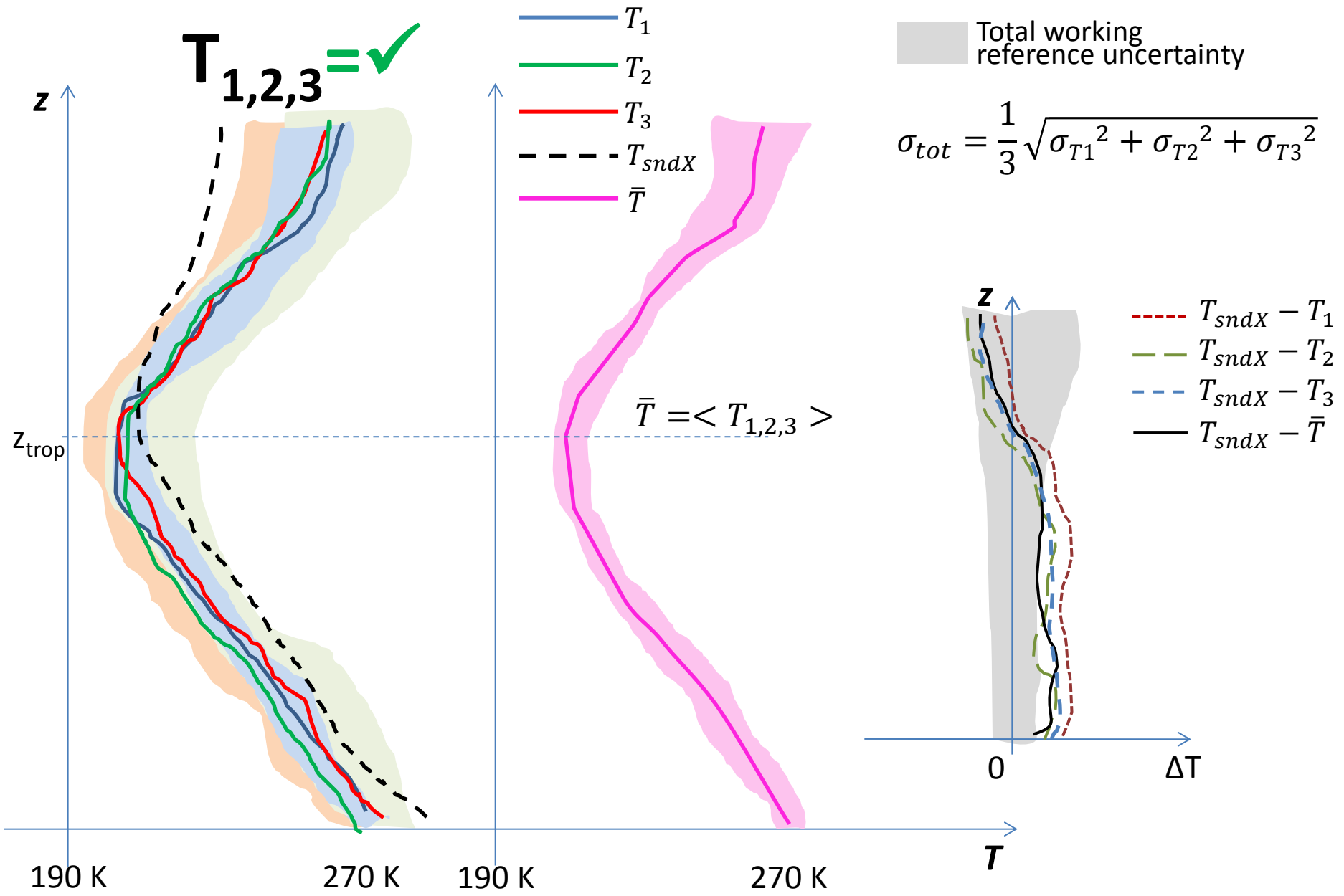
- Selection of reference radiosounding systems among the ones certified by GRUAN.
- The selected systems are fully characterized in terms of uncertainty at each level *z*. Three radiosondes can be selected to form a reference triplet (working references).
- The working references must be consistent amongst each other, namely:
  - For each flight the sondes are tested for consistency for each parameter (T, q, u, v) at each level *z*. For each measured parameter, e.g. T, the consistency can be expressed as:
    - $T_{2,3}(z)-\Delta T_{2,3}(z) \le T_1(z) \le T_{2,3}(z)-\Delta T_{2,3}(z)$
    - $T_{1,3}(z)-\Delta T_{1,3}(z) \le T_2(z) \le T_{1,3}(z)-\Delta T_{1,3}(z)$
    - $T_{1,2}(z)-\Delta T_{1,2}(z) \le T_3(z) \le T_{1,2}(z)-\Delta T_{1,2}(z)$

    } Consistency condition

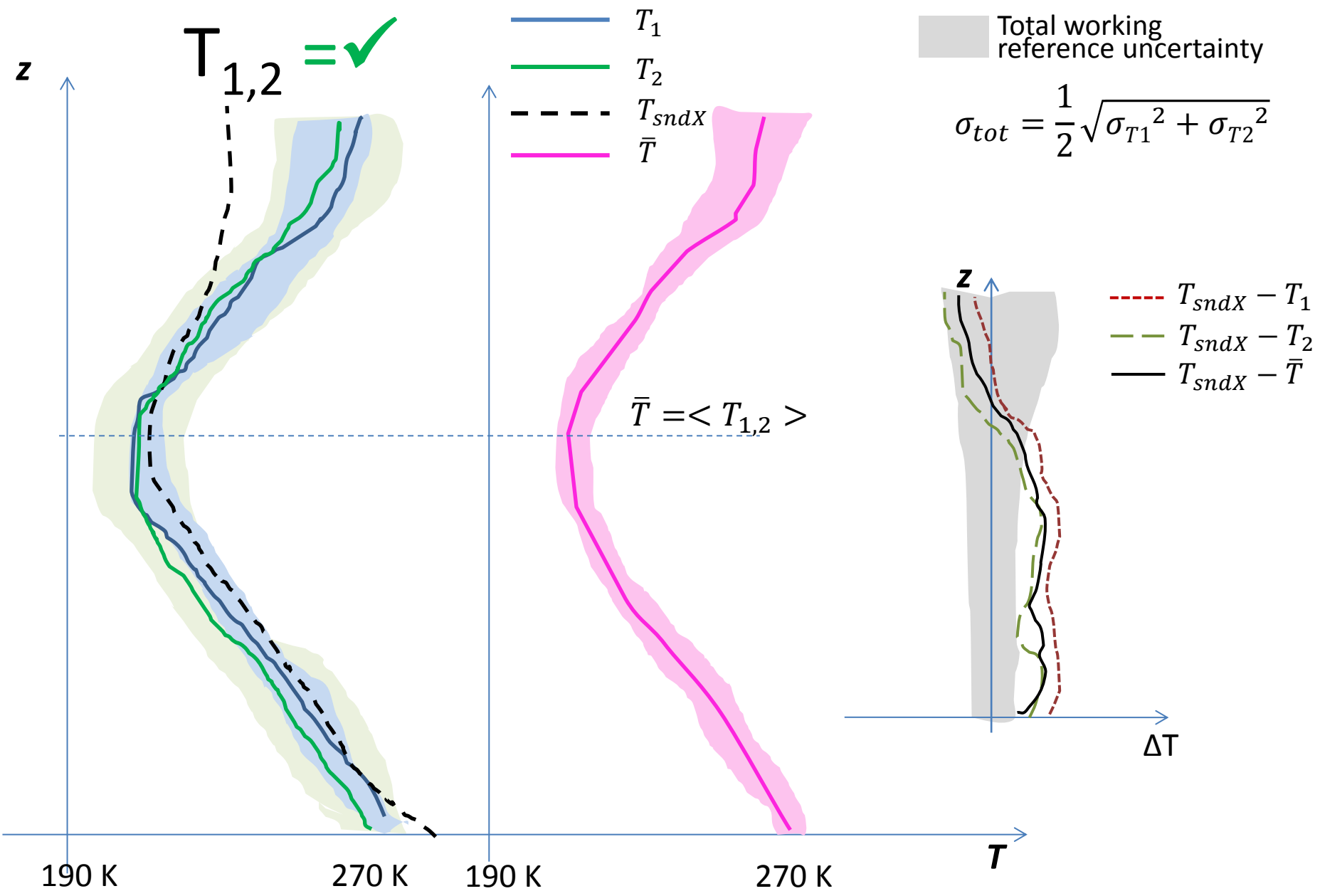




For a specific flight: all working references are accepted based on the consistency condition

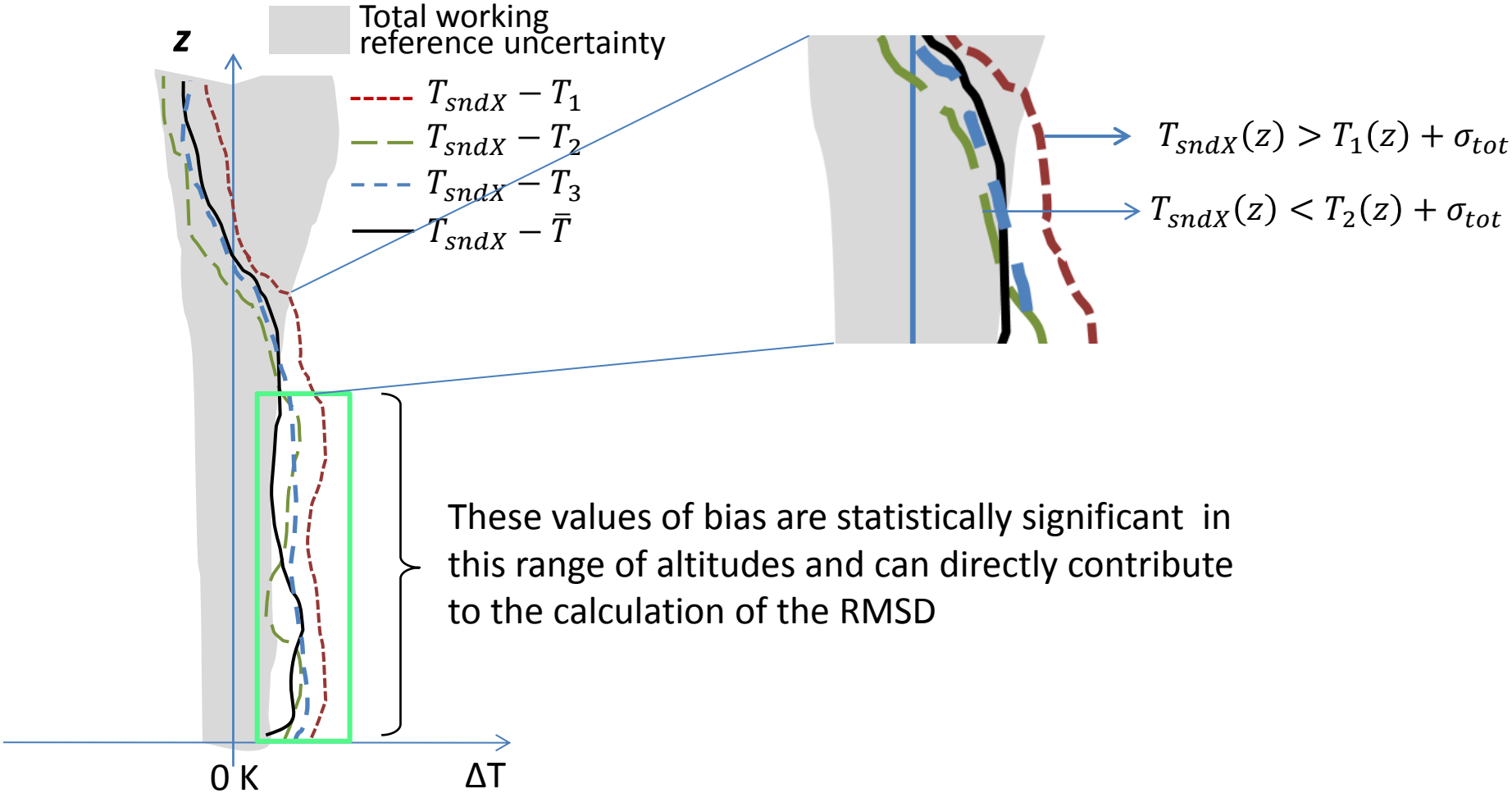


For a specific flight: working reference 3 is rejected based on the consistency condition



How the significant biases with respect to the working references are selected and used?

Only the biases that do not overlap with the total working reference uncertainty σ_{tot} can be regarded as statistically different from the working references. Then, only the points at ranges z for which $|\Delta T| > \sigma_{tot}$ are retained for the calculation of the final bias and RMSD

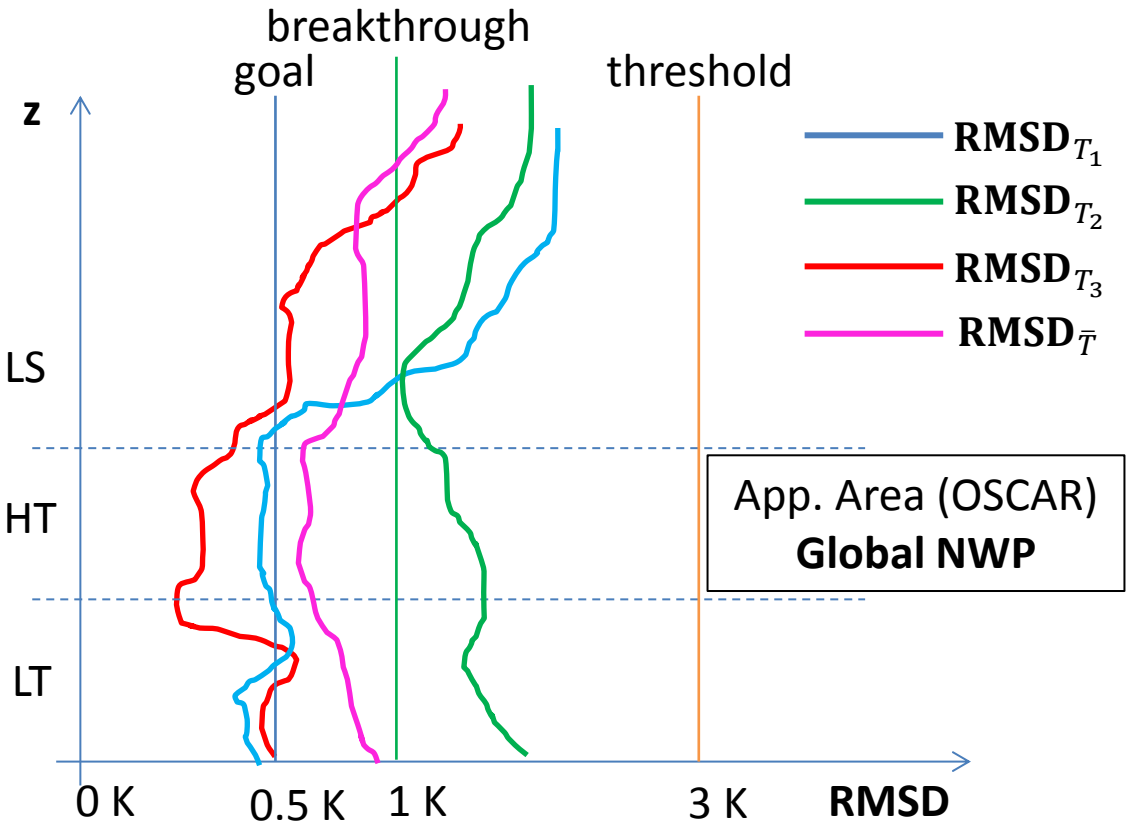


These values of bias are statistically significant in this range of altitudes and can directly contribute to the calculation of the RMSD

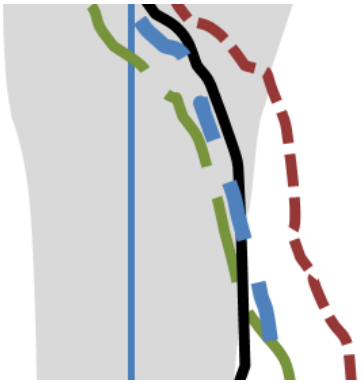
At the end of the intercomparison, after *N* flights, the total root mean square deviation (RMSD) of each sonde versus each working reference is calculated for those altitudes where $|\Delta T| > \sigma_{tot}$

$$\mathbf{RMSD}_k(z) = \sqrt{\frac{\sum_{i=1}^{N}\left(T_{i,sndX}(z) - T_{i,k}(z)\right)^2}{N}}$$

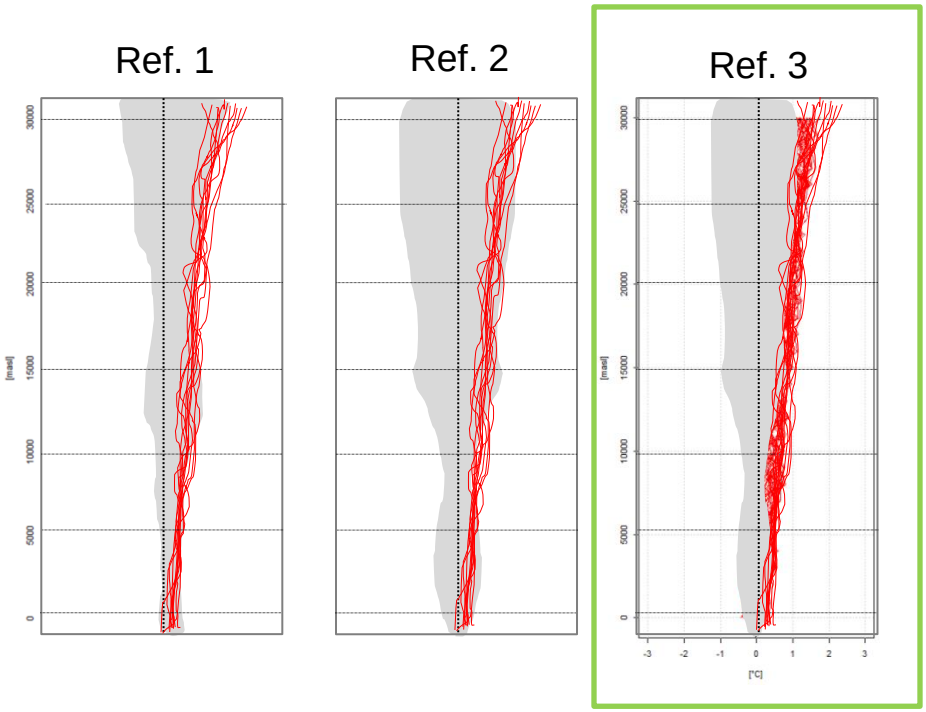
Where $T_{i,k}$ is the reference temperature profile measured by the *k*th working reference during the *i*th flight and $T_{i,sndX}$ is the temperature profile measured by the sonde *sndX* during the *i*th flight

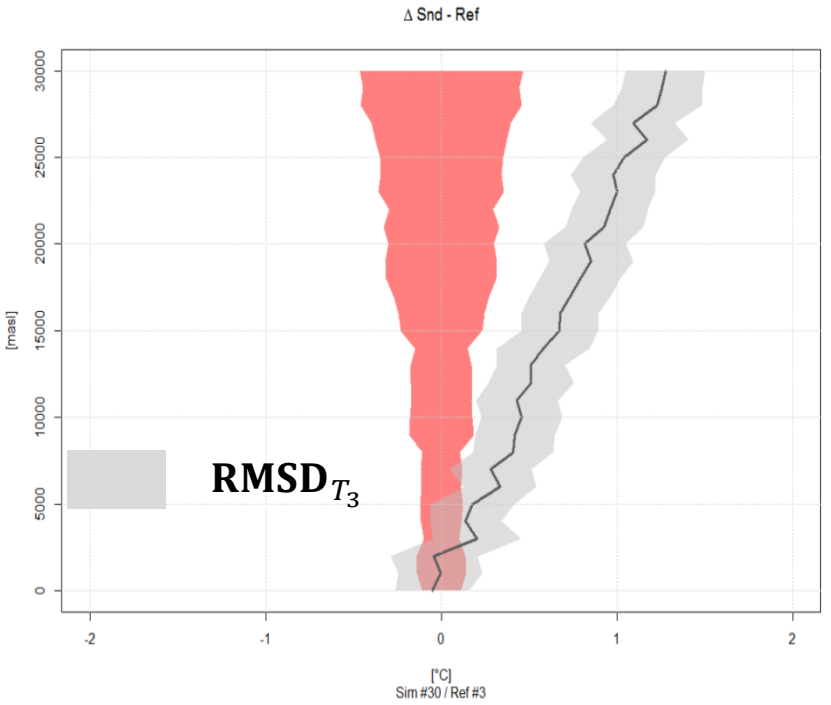


Each RMSD profile is calculated, potentially, from a different number of points for each level z. This is due to the fact that the sonde sndX at level z can have a statistically significant bias with respect to one working reference but not with the other.



The final assessment of the sonde sndX is obtained using the mean bias and the RMSD with regard to each working references.
The overall biases counting the highest number of statistically significant points $(T_{i,sndX}(z) - T_{i,k}(z))$ is retained as the statistically most representative.





This selection procedure is very strict as it chooses the “farthest” working reference (only largest biases). Based on this assessment method, the sonde sndX is more likely to fit “breakthrough” and “threshold” targets.

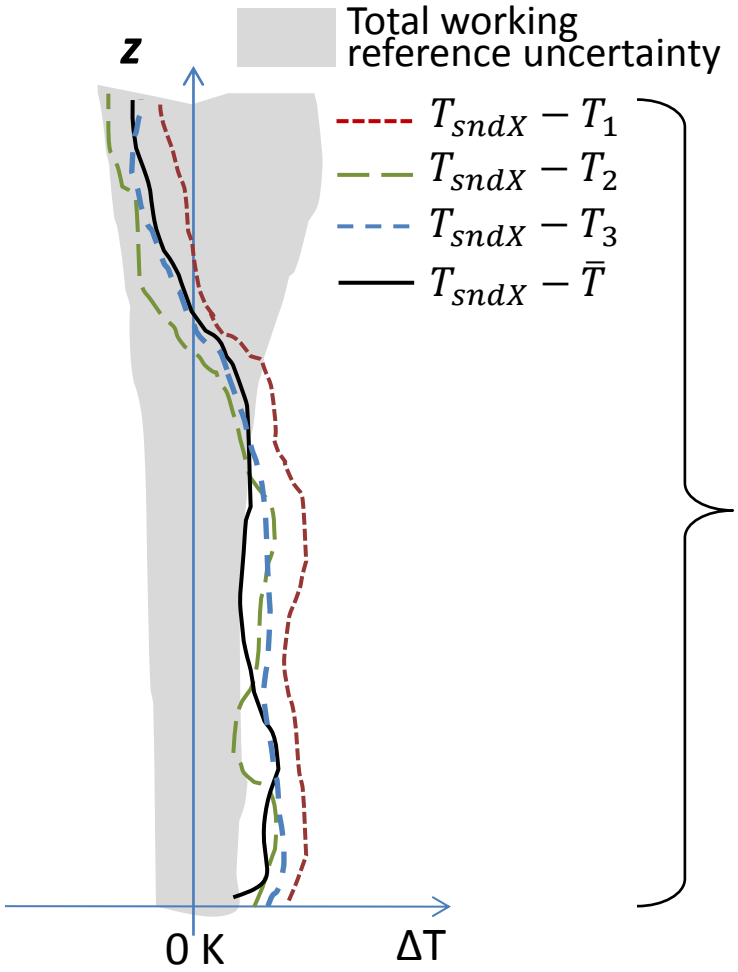
What about a scientific reference for humidity and temperature?

The scientific reference (e.g., CFH for humidity , LMS multi thermistor for the temperature) cannot be flown for all flights, for both financial and technical reasons. The scientific references must then remain a reference used exclusively to monitor and correct the functioning of the working references.

A scientific reference can then be flown for the following reasons:

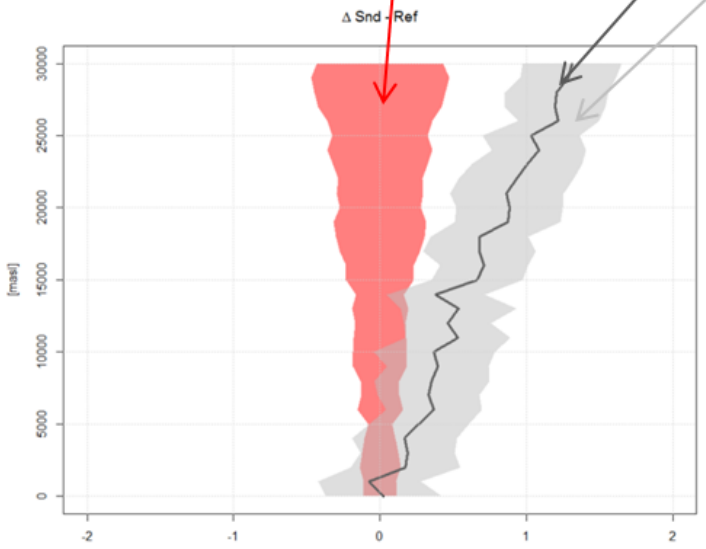
- One, or more, working references are systematically rejected and need to be re-characterized/checked against the scientific reference.
- A minimum number of flights of the scientific references can be decided beforehand in order to gather enough data to re-conduct the final biases and RMSD related to the working references to the scientific reference.
- …..

OPTION 2:



All data are retained despite the fact that the bias is statistically significant or not. Then, all ΔT(z) points from all flights contribute to the RMSD. The final mean bias corresponds then to an average of the ΔT(z) for all z-levels and all flights

Flights	Sonde X	REF [#]	U Ref [#]	Delta
#1	L#0 15.2 L#1 14.9 L#3 -10.1 … L#N	L#0 15.0 μ[1,2,3] L#1 15.2 μ[1,2] L#3 -9.6 μ[1,3] … L#N	**L#1 0.2 u[1,2,3]** **L#2 0.2 u[1,2]** **L#3 0.3 u[1,3]** **…** **L#N**	**L#1 0.2** **L#2 -0.3** **L#3 -0.5** **…** **L#N**
#2	L#0 15.0 L#1 14.5 L#3 -9.8 … L#N	L#0 15.3 μ[1,3] L#1 14.1 μ[1,2] L#3 -9.6 μ[1,2,3] … L#N	**L#1 0.3 u[1,3]** **L#2 0.3 u[1,2]** **L#3 0.2 u[1,2,3]** **…** **L#N**	**L#1 0.3** **L#2 -0.4** **L#3 -0.2** **…** **L#N**
#N	…	…	…	…
			L#1 0.2 **L#2 0.15** **L#3 0.2** **…** **L#N**	**L#1 μ 0.25 σ 0.07** **L#2 μ -0.35 σ 0.07** **L#3 μ -0.35 σ 0.21** **…** **L#N**



RMSD(z=L#1…L#N)

MeteoSwiss
Operation Center 1
CH-8058 Zurich-Airport
T +41 58 460 91 11
www.meteoswiss.ch

MeteoSvizzera
Via ai Monti 146
CH-6605 Locarno-Monti
T +41 58 460 92 22
www.meteosvizzera.ch

MétéoSuisse
7bis, av. de la Paix
CH-1211 Genève 2
T +41 58 460 98 88
www.meteosuisse.ch

MétéoSuisse
Chemin de l'Aérologie
CH-1530 Payerne
T +41 58 460 94 44
www.meteosuisse.ch