Intercomparison of RS92 and RS41 using climatic chambers and wind tunnel: update on the data analysis

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Objectives

✓Provide a further contribution to dual radiosoundings for the proper management of the transition from RS92 to RS41

✓ Assess and compare RS92 and RS41 performance (in terms of T stability and calibration error), as well as characterize the T bias between the two sonde types, at different controlled T, RH, p and wind speed conditions inside climatic chambers and using reference sensors traceable to SI standards

Methodology

1° step: simultaneous T, RH measurements from the two sonde types inside the climatic chamber Kambic KK-105 CHLT, which simultaneously and independently controls RH and T inside.

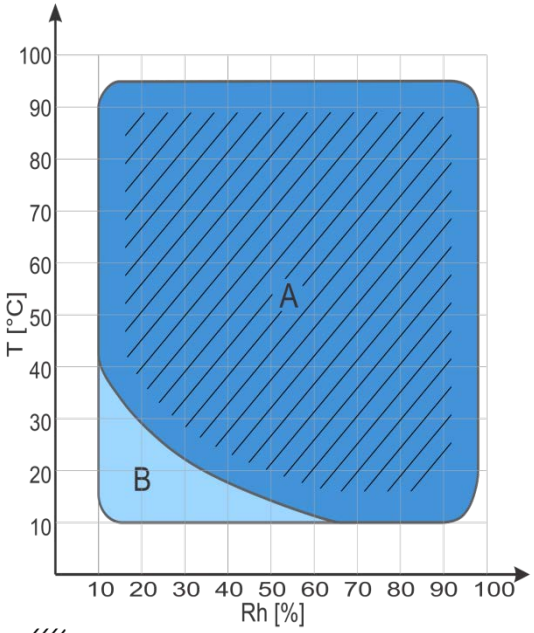
2° step: simultaneous T measurements from the two sonde types during steep temperature transitions, by quickly moving both the sondes between two climatic chambers set to different T, in order to study the effects of T transitons on sondes' performances and their T bias

3° step: simultaneous T measurements from the two sonde types inside the INRiM's climatic chamber with wind generation EDDIE **(E**arth **D**ynamics **D**irect **I**nvestigation **E**xperiment), which simultaneously and independently controls T, p and wind speed inside

1° step: Climatic chamber Kambic

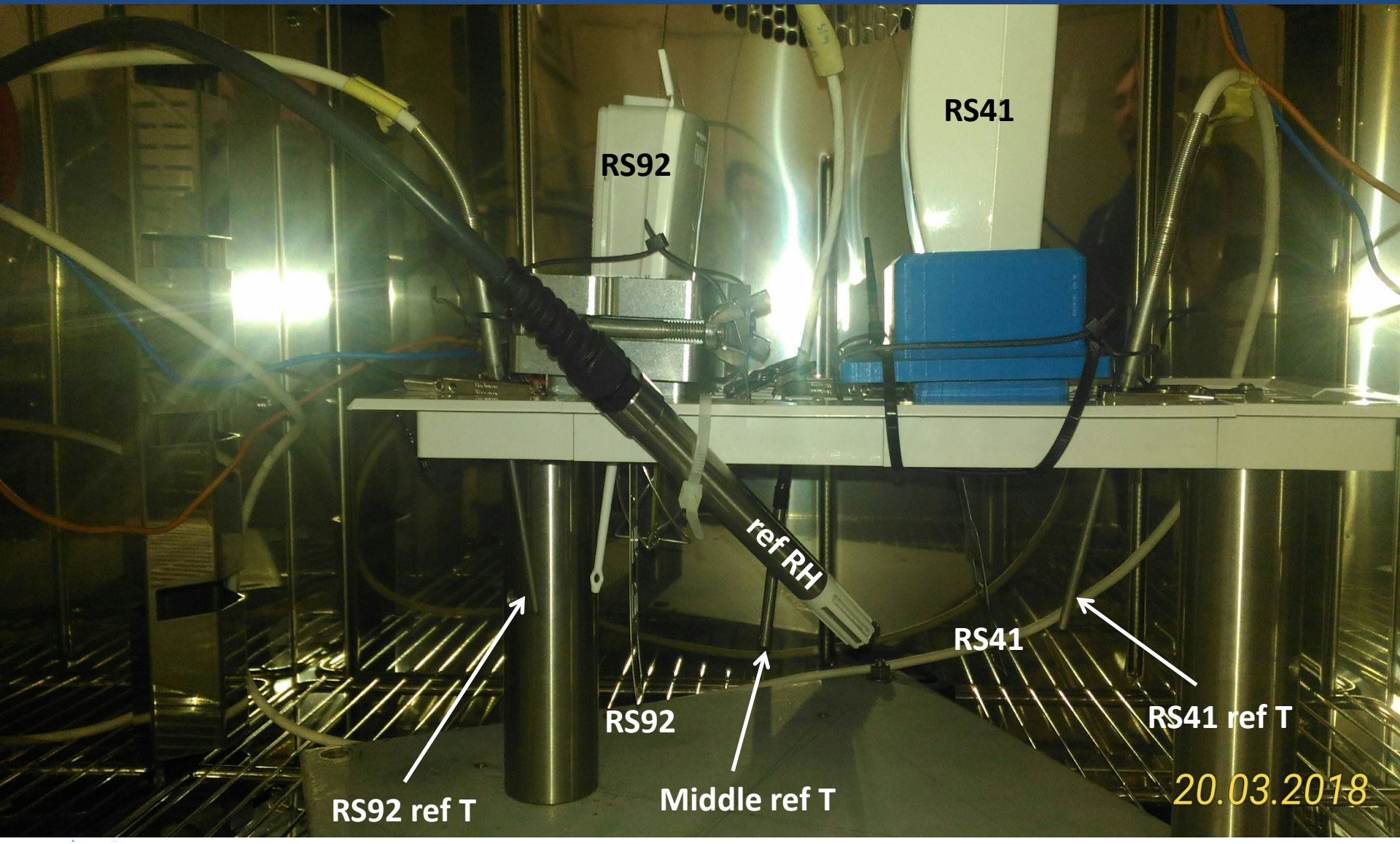
Kambic KK-105 CHLT

- T control in the range : -40°C…180°C
- T stability over time: ±0.1°C
- T uniformity: ±0.3°C
- RH control in the range: 10%…98% **only for T in the range: 10°C…95°C**
- RH stability over time: ±0.5 %



- Ideal range
A - Standard range
B - Extended humidity range

1° step: Measurement setup



1° step: Measurements

9 Kambic points :

- 6 (RH, T) points: with RH = 20%, 40%, 98% and T=20°C, 40°C
- 3 T points, with T= -40°C, -20°C, 0°C (no RH control)

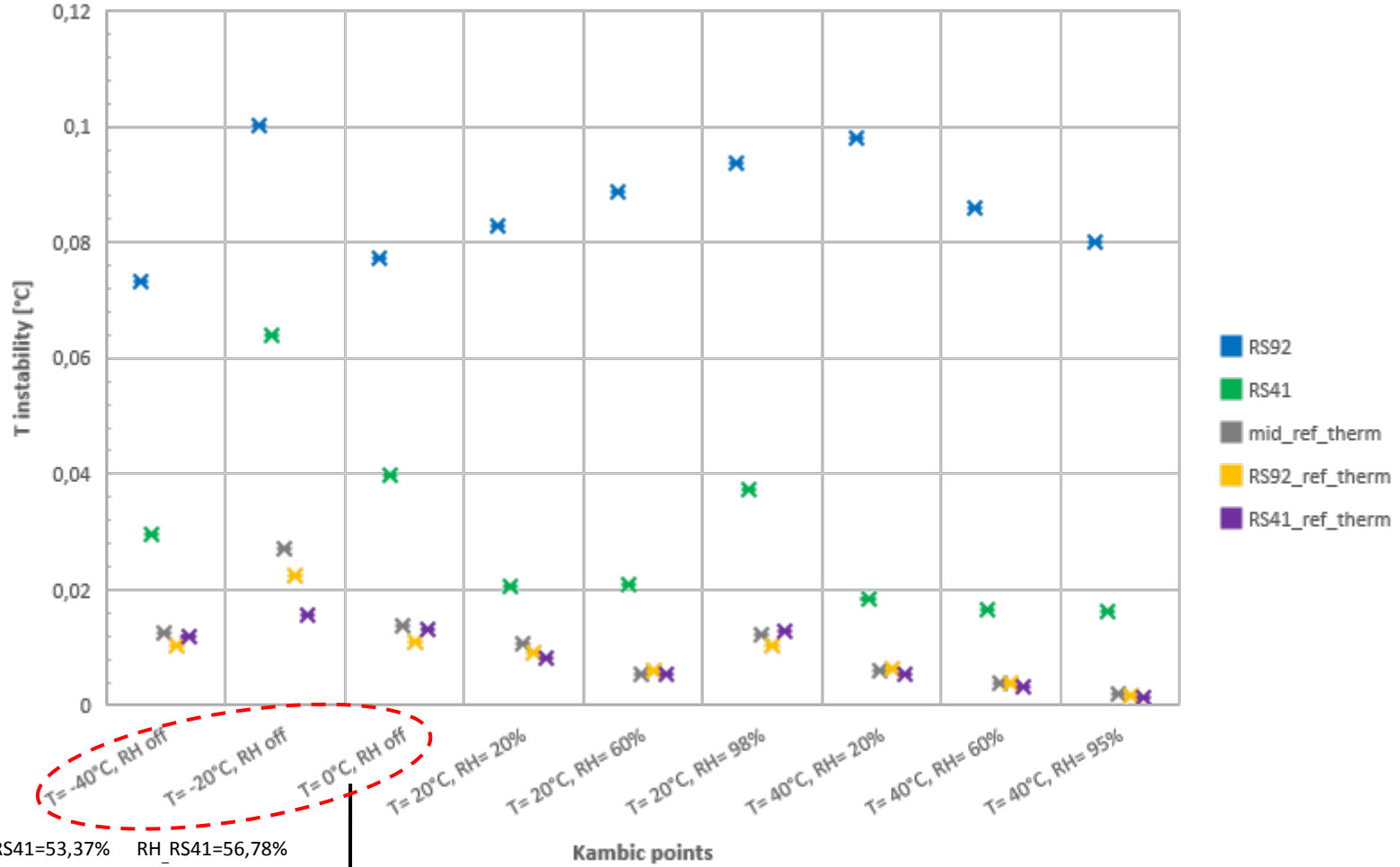
Acquisition:

Time: during the stability conditions of chamber (minimum variations in the chamber control sensors and reference sensors)

Duration: from 5 to 10 min

Time resolution: 1 s (time resolution of raw data of Vaisala system)
Time resolution references: 3 s (lower resolution of Super-DAQ acquisition system)

1° step: Temperature Instability



RH_RS41=53,37%
RH_RS92=51,2%
No ref_Hygro

RH_RS41=56,78%
RH_RS92=55,02%
No ref_Hygro

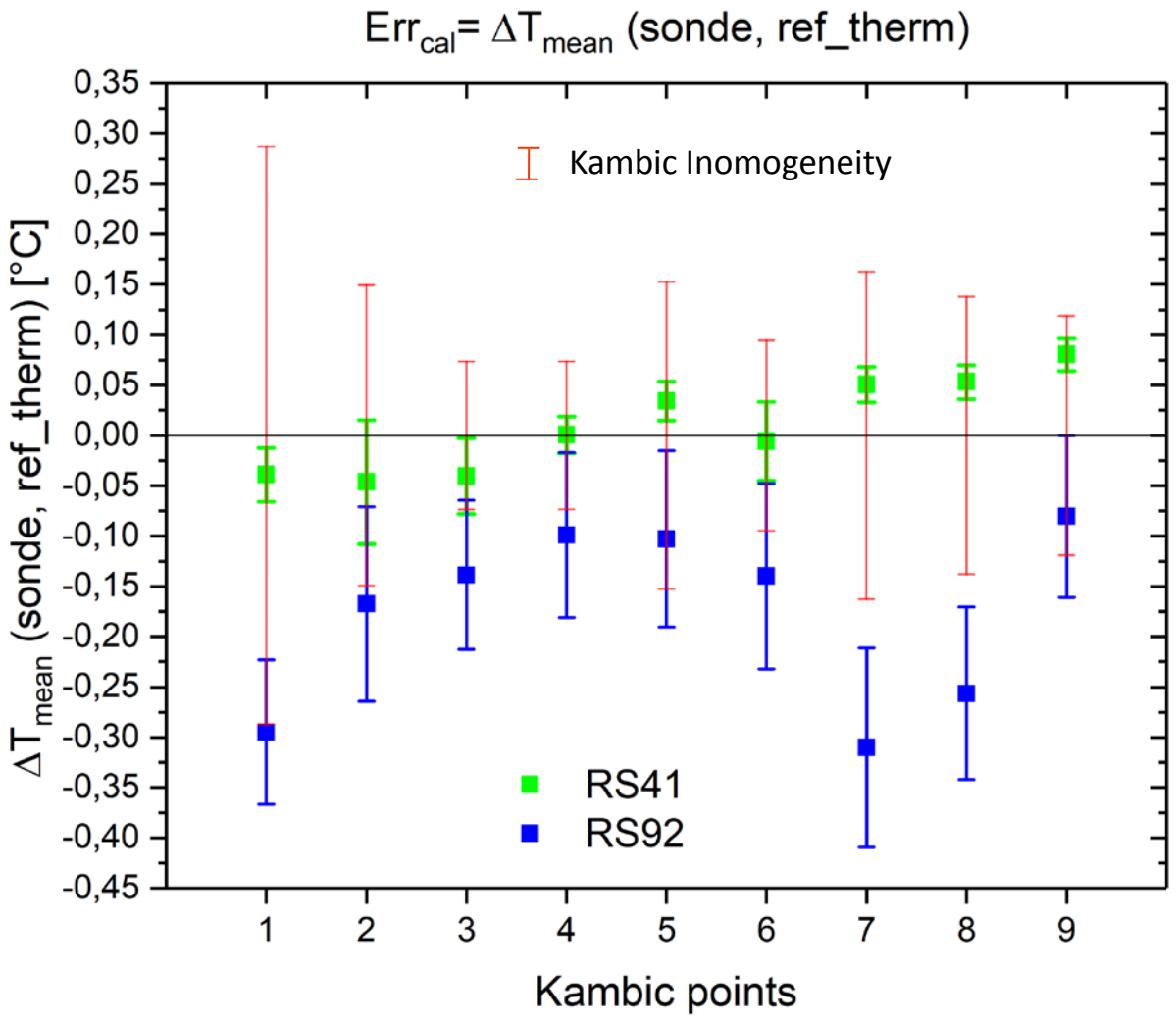
RH_RS41=71,59%
RH_RS92=70,19%
RH_ref_Hygro=70,19%

RS41 more stable than RS92
RS41_Instability : ±0.016°C (40°C, 95%) → ±0.064°C (-20°C)
RS92_Instability : ±0.073°C (-40°C) → ±0.1°C (-20°C)

T=-20°: sonde instabilities increase non-linearly, increasing the chamber instability

Instability_ratio (RS92,RS41): 1.6 (-20°C) → 5.3 (40°C, 95%) ➡ RS41 ≈ 2 ÷ 5 times more stable than RS92

1° step: T Calibration Error



-0.18°C -0.18°C -0.15°C -0.15°C -0.15°C -0.27°C -0.27°C -0.27°C

Vaisala Ground Check ΔT$_{RS92}$

Kambic_Inomogeneity:
±0.29°C (Pt 1: -40°C) → ±0.07°C (Pts 3,4: 0°C; 20°C, 20%)

if the chamber inhomogeneity in the regions between each sonde and the co-located therm is small enough (<0.05 °C) to consider the therm measurement is as an effective (true) reference for the sonde:

ΔT (sonde, ref_therm) = Err$_{cal}$ (sonde)

Err$_{cal}$ (RS41) < Err$_{cal}$ (RS92)

RS41 more accurate than RS92

$$Err_{cal}^{mean}(RS41) = \Delta T_{mean}(RS41, ref\_therm)$$

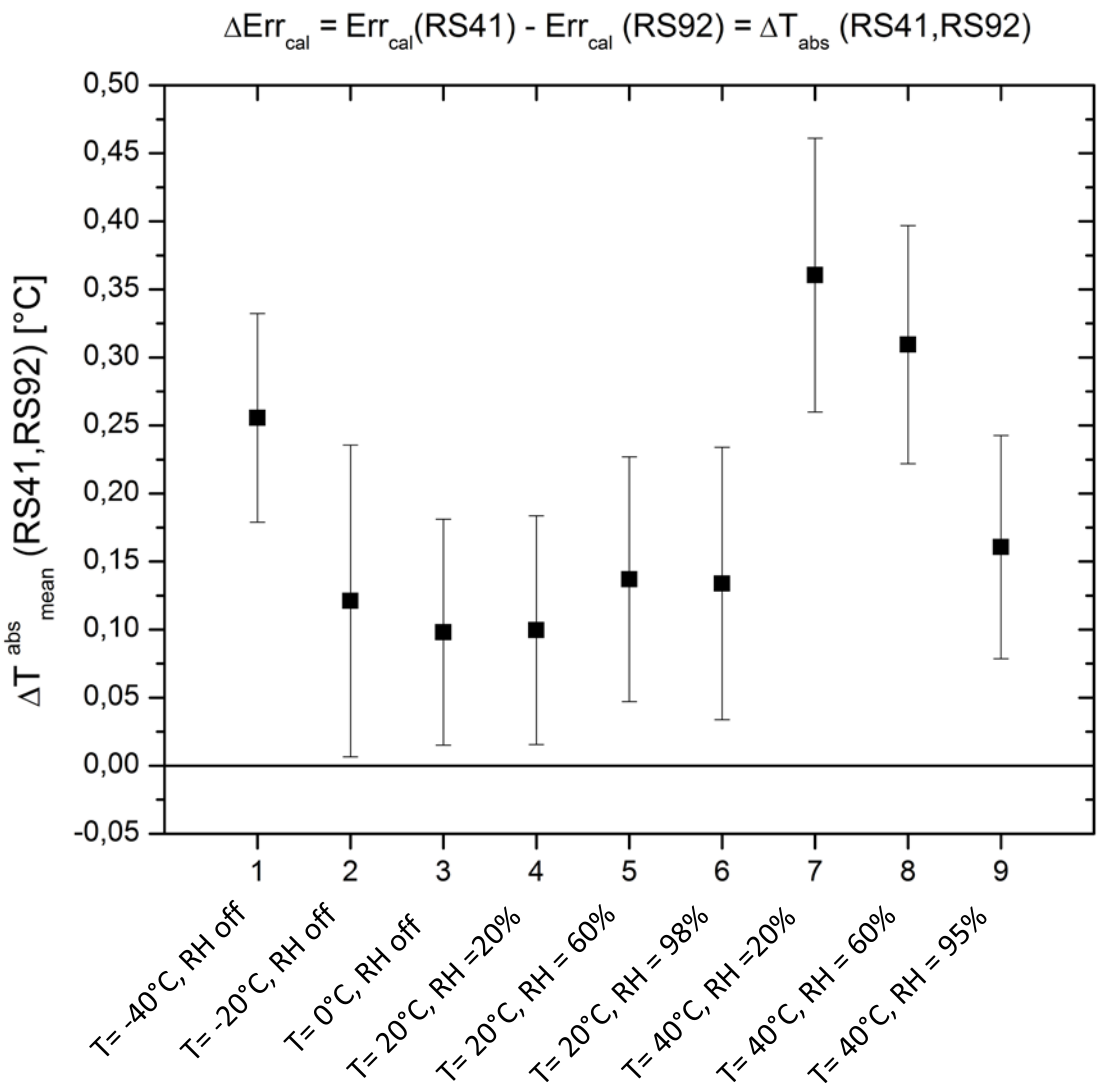
-0.05°C (Pt 2) → 0.08°C (Pt 9)

$$Err_{cal}^{mean}(RS92) = \Delta T_{mean}(RS92, ref\_therm)$$

-0.31°C (Pt 7) → -0.08°C (Pt 9)

It's better not to apply the GC correction!

1° step: T Bias between RS41 & RS92



$\Delta T_{abs} > 0$ ($T_{RS41} > T_{RS92}$)

$$\Delta T_{abs}^{mean}(RS41, RS92)$$

0.1°C (pts 3,4) → 0.36°C (pt 7)

Results possibly less reliable in Pts 1, 7 and 8, where the measured chamber inhomogeneity is higher.

2° step: Twin chambers

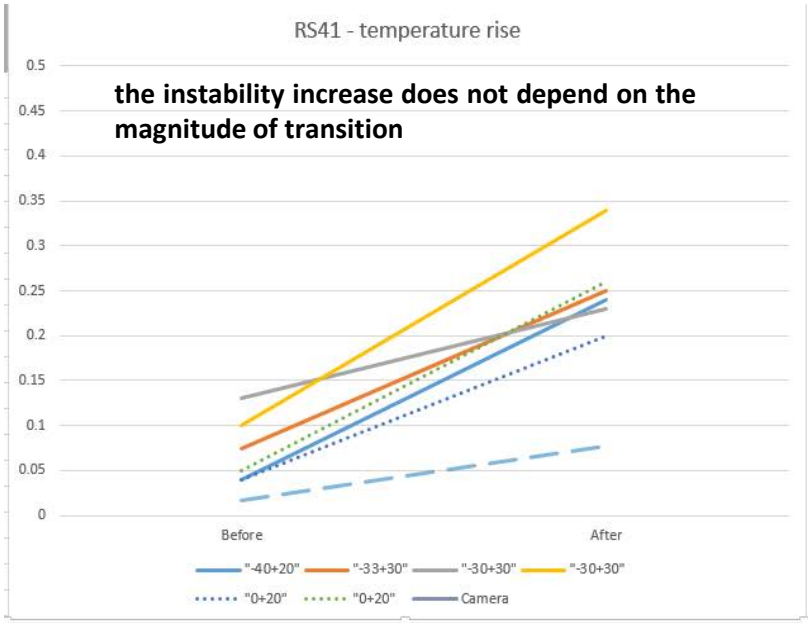
Measurements performed during a series of fast temperature transitions, by moving very quicly (≈ 10s) the same measurement setup used for the 1°step between two different climatic chambers, set at different temperatures

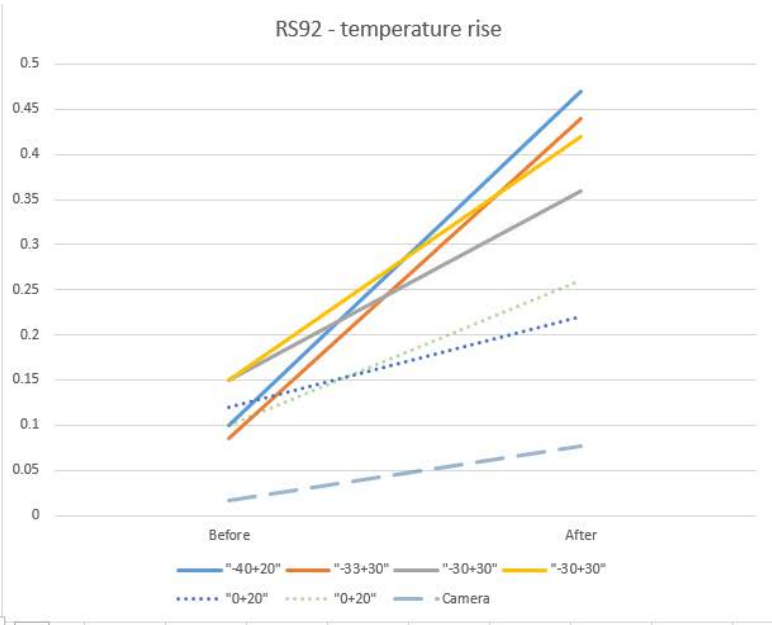
Transitions:

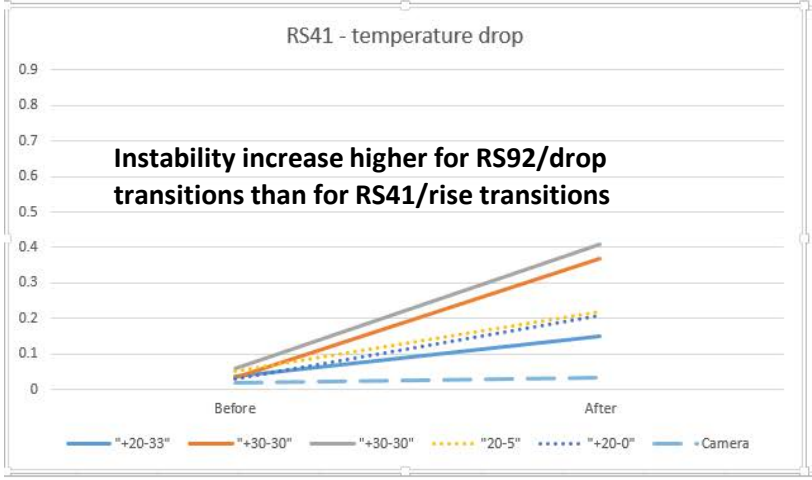
- -40 °C -> 20 °C -> -30 °C
- Repeated -30 °C -> 30 -> - 30 °C
- Repeated 0 °C -> 20 °C -> 0 °C

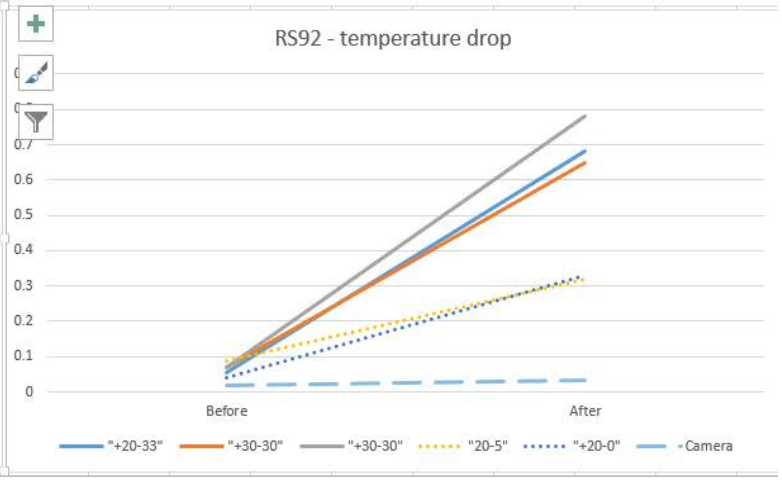
2° step: Temperature Instability

T Instability [°C]







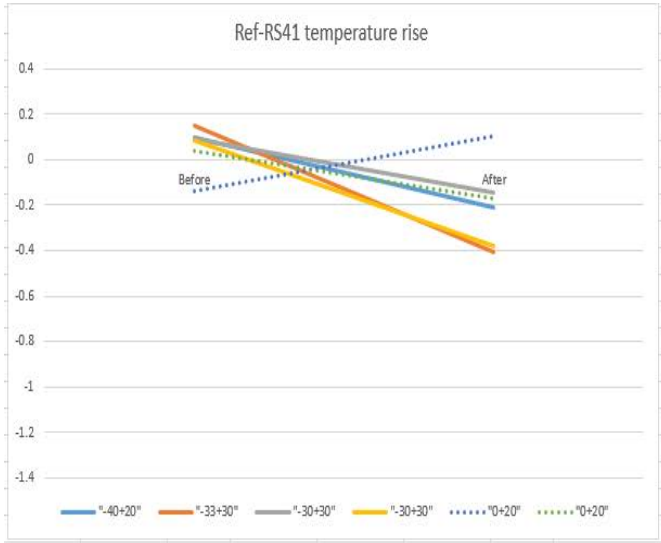


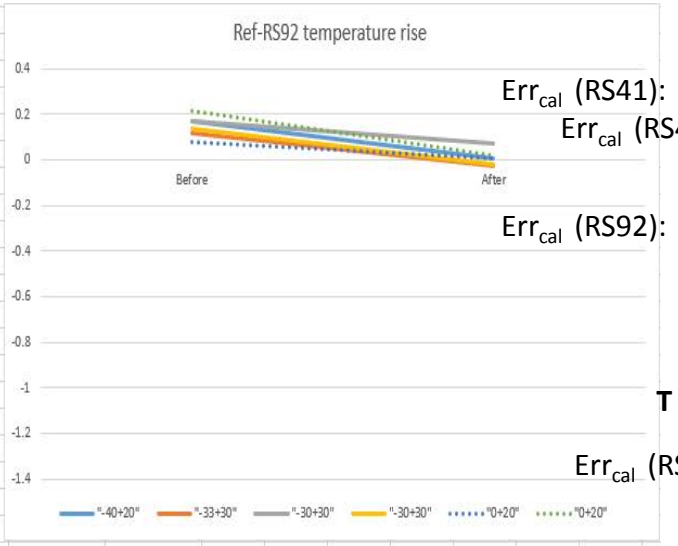
RS41 more stable than RS92 before and after all transitions

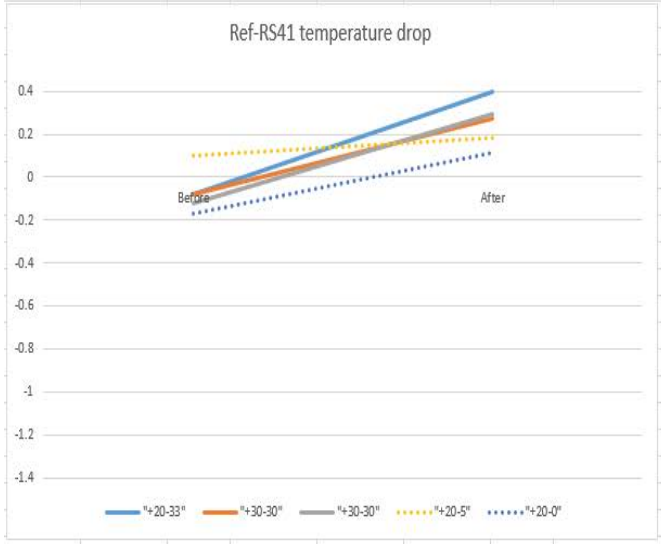
Instability before transitions: similar of 1°step: < 0.15°C for RS41, up to 0.15°C for RS92

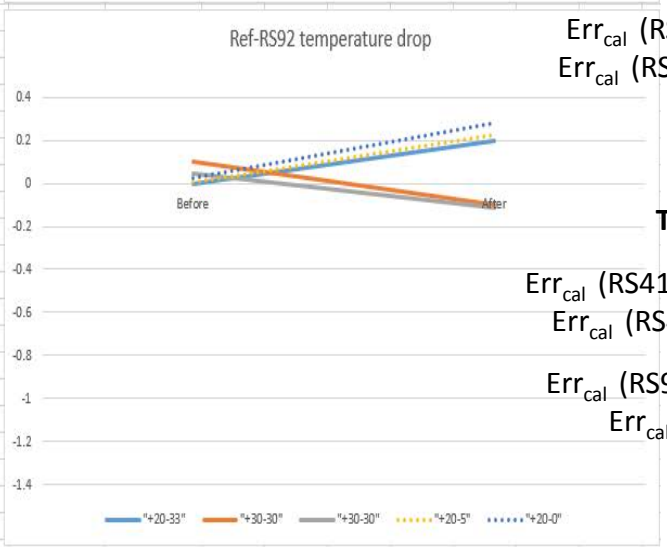
Instability after transitions: [0.15°C, 0.4°C] for RS41; [0.3°C, 0.8°C] for RS92

2° step: T Calibration Error









ΔT_{mean} (Ref – sonde) [°C]

T rise transitions

Err_{cal} (RS41): [-0.15°C, -0.05°C] → [0.15°C, 0.4°C]
Err_{cal} (RS41) increases (more for stronger transitions)

Err_{cal} (RS92): [-0.2°C, -0.08°C] → [-0.07°C, 0.02°C]
Err_{cal} (RS92) decrease

T drop stonger transitions

Err_{cal} (RS41): ≈ 0.1°C → [-0.4°C, -0.3°C]
Err_{cal} (RS41) increase

Err_{cal} (RS92): [-0.1°C, -0.05°C] → ≈ 0.1°C
Err_{cal} (RS92) does not change significantly

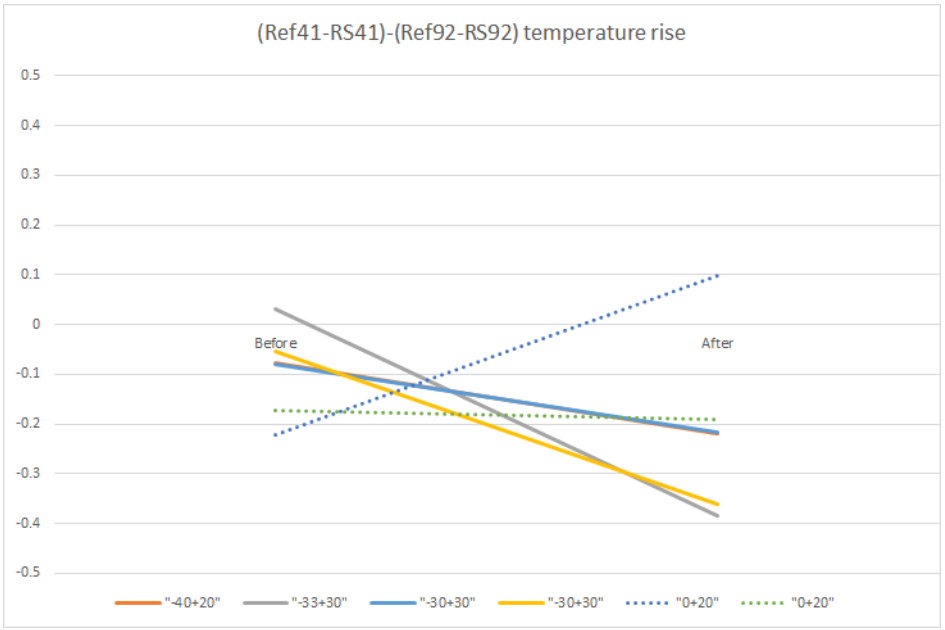
T drop smaller transitions

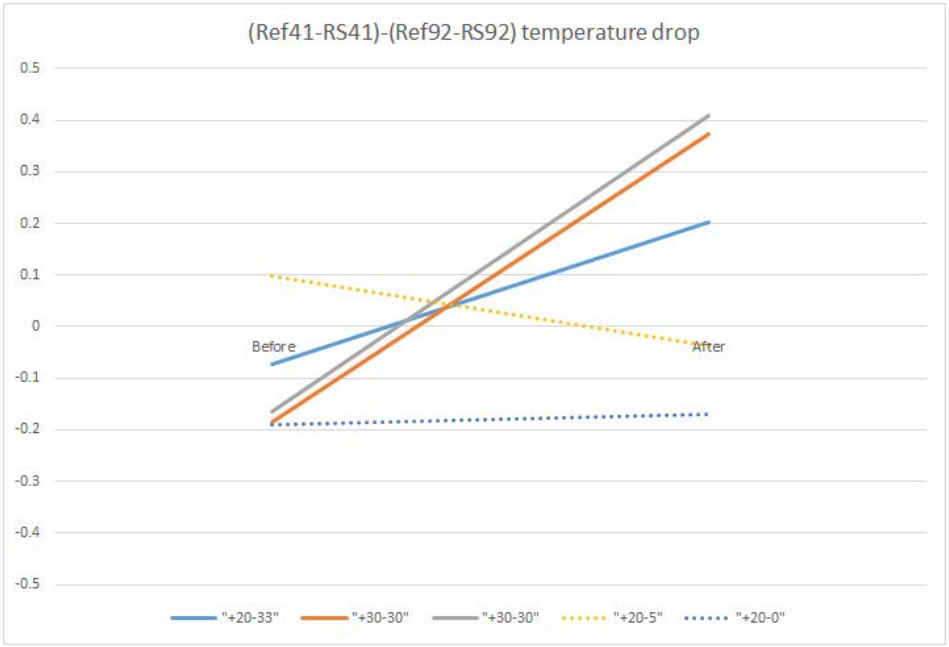
Err_{cal} (RS41): 0.2°C → -0.1°C or -0.1°C → 0.2°C
Err_{cal} (RS41): decrease or increase of 0.1°C

Err_{cal} (RS92): < -0.05°C → -0.3°C or -0.2°C]
Err_{cal} (RS92) increase of 0.2-0.3°C

For rise transitions and drop stronger transitions: Err_{cal} (RS41) increases up to ±0.4°C, Err_{cal} (RS92) decreases or does not change significantly
For drop smaller transitions: Err_{cal} (RS41) does not change significantly , Err_{cal} (RS92) increases up to -0.3°C

2° step: T Bias between RS92 & RS41





ΔT_{abs}^{mean} (RS92,RS41) [°C]

Before transitions:
$\Delta T_{abs}^{mean}(\mathbf{RS92}, \boldsymbol{RS41})$: **-0.2°C → 0.1°C**
RS41 generally warmer than RS92

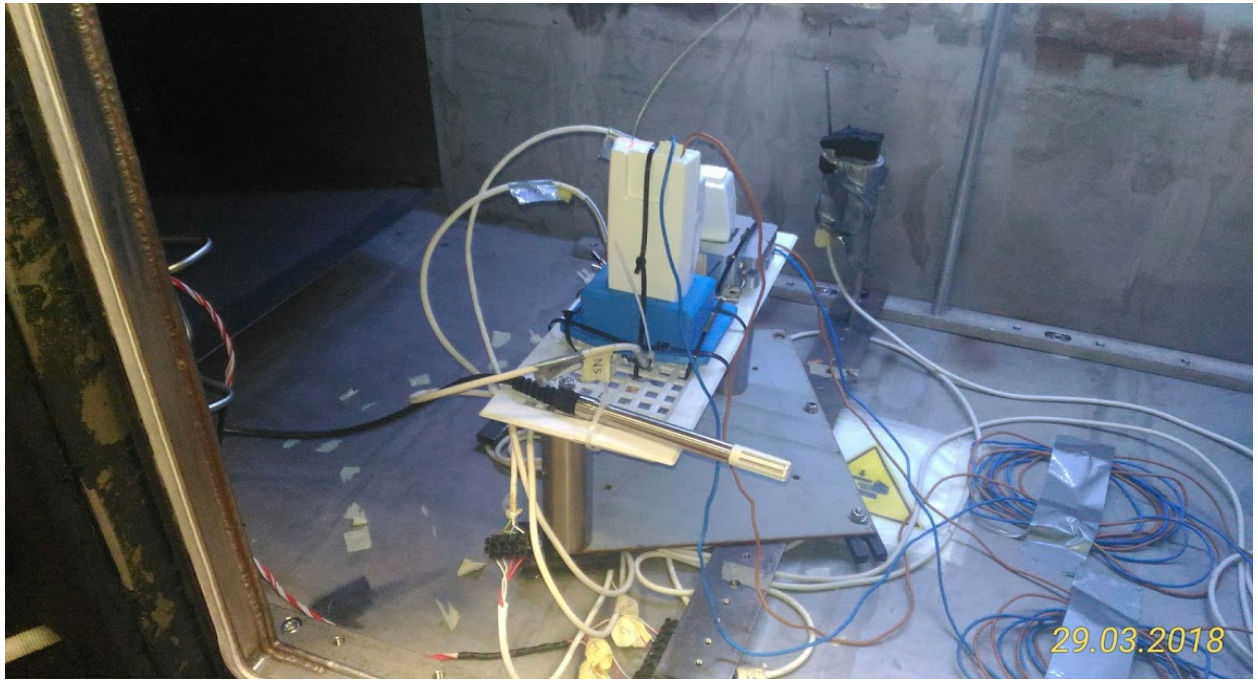
After transitions:
T bias between the sondes: **increases for larger (50-60 C°) transitions up to ±0.4°C; decreases or does not change significantly for smaller (15-20 C°) transitions** (dot lines)

3° step: Wind-pressure tunnel

Measuremnt points inside the climatic chamber/wind tunnel:

- 30 °C (2 m/s, 8 m/s, 15 m/s) lab. atmospheric pressure
- 15 °C (2 m/s, 8 m/s, 15 m/s) lab. atmospheric pressure
- 0 °C (2 m/s, 8 m/s, 15 m/s) lab. atmospheric pressure
- -10 °C (2 m/s, 8 m/s, 15 m/s) lab. atmospheric pressure
- -20 °C (5 m/s, 15 m/s)* @ (800 hPa, 500 hPa and **350 hPa)**

* (nominal value)



Measurement frame inside EDDIE **(E**arth **D**ynamics **D**irect **I**nvestigation **E**xperiment)

3° step: Temperature Instability

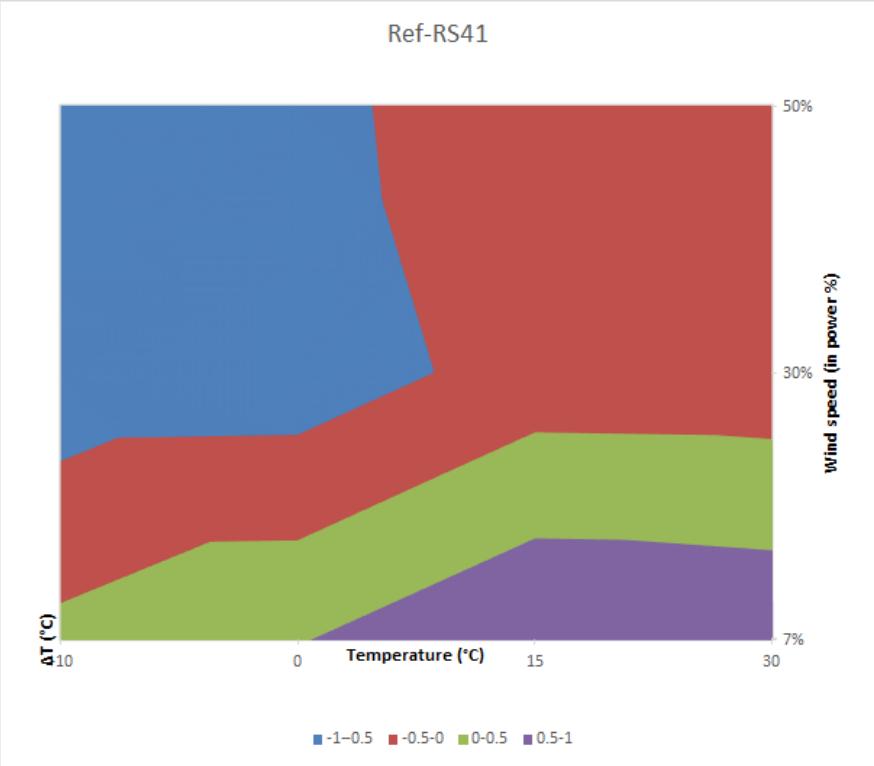
Lab.atmospheric pressure
Wind speed: 7% = 2m/s,
30% = 8m/s, 50% = 15m/s

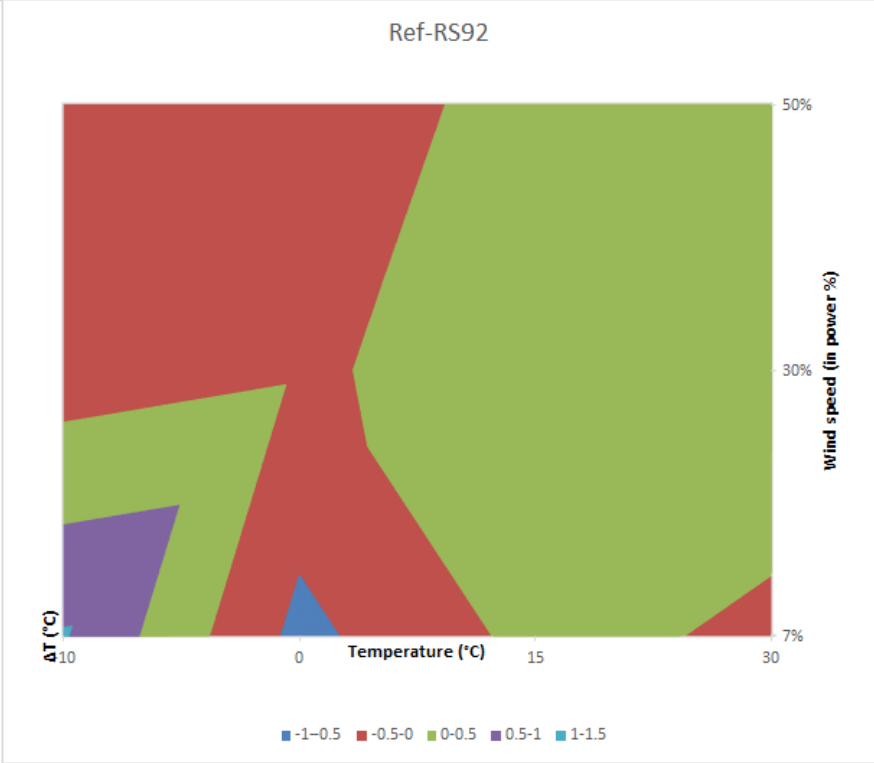
RS41 more stable than RS92

Instability increases with decreasing wind speed and increasing temperature inside the chamber

At low wind speed (2m/s) and high T (15°C, 30°C), max instability: [0.2°C, 0.3°C] for RS41; [0.4°C-0.5°C] for RS92

3° step: T Calibration Error





Err_{cal} (Sonde) = ΔT_{mean} (Sonde, Ref_therm)

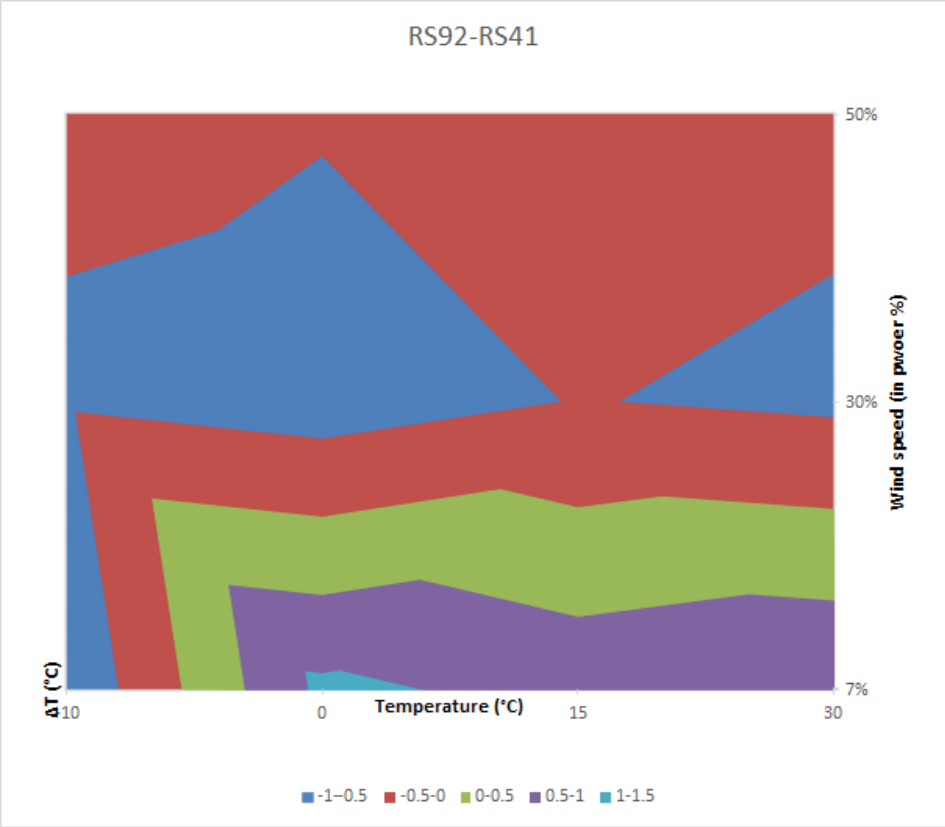
ΔT_{mean} (Ref_therm, Sonde) = Ref - Sonde= -Err_{cal} (Sonde)

RS41 more accurate than RS92 at low wind speed (7%, 2m/s) and low T (-10°C): Err_{cal} (RS41)= [-0.5°C, 0°C], Err_{cal} (RS92)= [-1.5°C, -1°C]

RS41 less accurate than RS92:

- **at high wind speed (30-50%, 2-8m/s) and low T (-10°C, 0°C): Err_{cal} (RS41) = [0.5°C, 1°C] , Err_{cal} (RS92) = [0°C, 0.5°C] ;**
- **at low wind speed (7%, 2m/s) and high T (15°C, 30°C): Err_{cal} (RS41)= [-1°C, -0.5°C] , Err_{cal} (RS92) = [-0.5°C, 0.5°C]**

3° step: T Bias between RS92 & RS41



ΔT_{abs}^{mean} (RS92,RS41) = RS92 - RS41= $[Err_{cal}$ (RS92) - Err_{cal} (RS41)$]_{mean}$

from negative values (RS92 colder than RS41) in the range [-1°C, -0.5°C]
(at wind speed 30% = 15m/s, T = -10°C, 0°C, 30°C)

to positive values (RS92 warmer than RS41) in the range [1°C, 1.5°C]
(at wind speed 7% = 2m/s, T =0°C)

Conclusions and Outlook

✓**T Instability:**
1° step: RS41 more stable than RS92, instabilty <0.06°C for RS41, < 0.1°C for RS92 ;
2° step: RS41 more stable than RS92, T transitions increase sonde instability, up to 0.4°C for RS41, up to 0.8°C for RS92;
3° step: RS41 more stable than RS92, instabilty <0.3°C for RS41, < 0.5°C for RS92 (significantly higher than 1° step)

✓**T Calibration error:**
1° step: RS41 more accurate than RS92, Err_{cal}(RS41)[-0.05°C, 0.08°C], Err_{cal} (RS92) [-0.31°C, -0.08°C];
2°step: T rise and drop stronger (50-60°C) transitions increase Err_{cal}(RS41) up to ±0.4°C and decrease or don't change Err_{cal}(RS92) up to ±0.1°C; T drop smaller (20°C) transitions do not change Err_{cal}(RS41) [-0.1°C, 0.2°C] and increase Err_{cal}(RS92) up to -0.3°C;
3° step: RS41 more or less accurate than RS92, Err_{cal}(RS41) up to > ±0.5°C, Err_{cal} (RS92) up to < -1°C (significantly higher than 1° step)

✓**T bias:**
1° step: ΔT(RS92,RS41) [-0.36°C, -0.1°C];
2°step: T stronger (50-60°C) transitions increase ΔT up to ±0.4°C, T smaller (20°C) transitions decrease or don't change ΔT [-0.2°C, 0.1°C];
3° step: ΔT(RS92,RS41) negative or positive up to < -0.5°C or > 1°C (significantly higher than 1° step)

➢ Continue data analysis for measurements inside the wind tunnel at atmospheric pressures lower than lab. atmospheric pressure (800,500,350hPa)

➢ Repeat the experiment with other pairs of sondes to obtain more general results representative of the two sonde types

Thanks for your attention!

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