Version 1.0 of 2025-03-21

Final Report on Key Comparison EURAMET.M.P-K4.2020 in the Range from 1 Pa to 15 kPa of Absolute and Gauge Pressure

Wladimir Sabuga [1], Sven Ehlers [1], Martin Vičar [2], Dominik Pražák [2], Janez Šetina [3], Yasin Durgut [4], David Szabo [5]

March 2025

ABSTRACT

This report presents the results of the EURAMET key comparison EURAMET.M.P-K4.2020 (EURAMET Project No. 1494), performed in the range of 1 Pa to 15 kPa of absolute and gauge pressure. Five National Metrology Institutes (NMIs), Physikalisch-Technische Bundesanstalt (PTB), Český Metrologický Institut (CMI), Institut za Kovinske Materiale in Tehnologije (IMT), Ulusal Metroloji Enstitüsü (UME), and RISE Research Institutes of Sweden AB (RISE), participated in the comparison. The comparison was realised as a direct comparison of the PTB, IMT, UME, and RISE standards with the CMI standard, transported to CMI and operated in the CMI premises. The measurements were performed in the period from September 2019 to April 2022. All participants' results obtained for absolute and gauge pressure are equivalent with the reference value of the present comparison and with each other. Being linked to the respective CCM key comparison, CCM.P-K4.2012, some results at some pressures show bigger deviations than their uncertainties, which presumably deals with the uncertainty of the link.

[1] Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany
[2] Český Metrologický Institut (CMI), Okružní 31, CZ-63800 Brno, Czech Republic
[3] Institut za Kovinske Materiale in Tehnologije (IMT), Lepi pot 11, SI-1000 Ljubljana, Slovenia
[4] Ulusal Metroloji Enstitüsü (UME), P.O. 54, TR-41470 Gebze/Kocaeli, Turkey
[5] RISE Research Institutes of Sweden AB (RISE), P.O. Box 857, SE-501 15 Borås, Sweden

CONTENT

1. INTRODUCTION

This report presents details and results of EURAMET key comparison (KC) EURAMET.M.P-K4.2020 carried out in the range of absolute and gauge pressure from 1 Pa to 15 kPa.

Since the last EURAMET KC in the same pressure range, EURAMET.M.P-K4.2010 [1], and the CCM KC in the range from 1 Pa to 10 kPa of absolute pressure, CCM.P-K4.2012 [2], new primary pressure standards for the range from 1 Pa to 15 kPa were established at European National Metrology Institutes (NMIs) PTB, IMT, UME and RISE, demanding their performance and equivalence to be demonstrated. At the EURAMET TC-M meeting held in Budapest on 9 April 2019, it was agreed to organise a new EURAMET KC to check the equivalence of the new standards. This KC was also registered as EURAMET Project No. 1494.

PTB was agreed for piloting this KC.

The comparison was conducted in accordance with the Technical Protocol prepared by the PTB and approved by the participants.

CMI, which had participated in and piloted EURAMET.M.P-K4.2010, as well as participated in CCM.P-K4.2012, offered to take part in the present EURAMET KC in order to provide a link to the former CCM KC. Moreover, CMI offered their national standard to act as a transfer standard (TS), which all other NMIs' standards, laboratory standards (LS), had to be compared directly with. However, it was agreed that the CMI standard will not travel, all other NMIs had to travel with their standards to CMI instead.

This report presents details and results of the present comparison.

The following sections provide a brief description of the laboratory standards, the organisation and chronology of the comparison, and the calibration procedure required by the Technical Protocol. Methods for reduction and analysis of the calibration data were used to provide, as much as possible, a uniform treatment of the results from individual laboratories, whether their standards were travelling (PTB, IMT, UME, RISE) or transfer (CMI) ones.

2. ORGANISATION AND CHRONOLOGY OF THE COMPARISON

As NMIs' standards were compared directly with the CMI standard, it required them to be transported to CMI and operated there by the NMIs' staff. Unfortunately, the comparison occurred at the time of the covid pandemic, with travelling being impossible for a long period, which considerably delayed carrying out the comparison. The times of NMIs' measurements at CMI are given in Table 1.

Table 1. Timetable of NMIs' measurements at CMI

Measurement time	NMI
19-24 September 2019	PTB
3-7 April 2020	IMT
7-13 October 2021	UME
5-8 April 2022	RISE

3. LABORATORY STANDARDS

Several principal measurement methods were tested by this comparison: force-balanced piston gauges (FPG), a static expansion system (SES), a deadweight pressure balance (PB), and other calibrated pressure transducers. CMI, PTB, UME and RISE used FPGs as laboratory standards, which were operated in both absolute and gauge pressure mode. All 4 FPGs had a traceability to the NMIs PBs, with the FPGs of PTB, RISE and CMI having been additionally characterised as primary pressure standards based on dimensional measurements. In addition, the FPG of CMI served, in this KC, as a transfer standard, which all participants compared their standards directly with at the CMI site. In all measurements with the FPGs, their operation, the data aquisition and calculation of the measured pressure were performed in accordance with the standard FPG8601 procedure and using the FPG-Tool software of the manufacturer.

IMT absolute pressure standards were an SES, being a primary pressure standard, and a PB. As the SES could not be transported to CMI, IMT provided a travelling standard package composed of a Quartz Bourdon Gauge and a set of capacitance diaphragm gauges (CDGs), calibrated at IMT against its SES and PB and brought to CMI for the comparison with the CMI FPG.

All standard used by the laboratories are described below.

3.1. CMI FPG – TRANSFER STANDARD

The FPG of CMI was a digital non-rotating piston gauge FPG8601 [3], manufactured by Fluke/DH-Instruments, USA and identified by serial number 107, in combination with a reference vacuum gauge 627B1TDD1B manufactured by MKS Instruments, USA, identified by serial number 000754687.

The effective area (A_0) of the piston-cylinder assembly (PCA) of the FPG was evaluated by the measurement of the piston-cylinder geometry and validated by cross-float measurements against a dead-weight pressure balance [4]. It is the same both for gauge and absolute modes and has a standard uncertainty of $9.5 \cdot 10^{-6}$. An intercomparison with the Slovak SMU was performed in 2002, with the Finnish MIKES in 2003, within EUROMET.M.P-S2 in 2006, COOMET.M.P-K14 in 2009, CCM.P-K4.2012 in 2012 [2], and also in the negative gauge pressure range within EURAMET.M.P-S12.

The standard uncertainty (u) of pressure (p) measured with the CMI FPG standard, in both absolute and gauge pressure modes, is

$$u_{\mathrm{CMI}} \equiv u(p) = 0.01\ \mathrm{Pa} + 1.4 \cdot 10^{-5} \times p\ . \qquad (1)$$

All uncertainties designated in this report by symbol "u" are standard uncertainties ($k = 1$).

This FPG of CMI was used as a transfer standard in the present KC, similarly to the former KC EURAMET.M.P-K4.2010, for which the experience of CMI is described in [5].

3.2. PTB FPG

PTB’s laboratory standard was an FPG8601, identified by serial number 183, in combination with a reference vacuum gauge 627B1TDD1B, manufactured by MKS Instruments, USA, identified by serial number 18074853.

It is a primary pressure standard traceable to PTB dimensional and mass standards, with the main input quantities: the effective area of the PCA, the load cell (internal balance) and, in case of the absolute pressure, the reference vacuum gauge, the latter being traceable to the PTB vacuum standards. The internal balance measuring the force acting on the piston was calibrated by loading reference masses. The FPG was studied within the EMPIR joint research project 14IND06 pres2vac [6], and its A_0 was determined using PCA's dimensional properties and applying the rarefied gas dynamics to the gas flow inside the piston-cylinder gap [7, 8]. It was validated below 300 Pa by comparison against the PTB static expansion system (SE2) and above 1 kPa against the primary mercury manometer (Schwien) and the Boltzmann constant pressure balance [9-11], being German national pressure standards, and showed full agreement within their uncertainties. Based on the dimensional data and the experiments, A_0 in absolute and gauge mode was found to be the same with a relative standard uncertainty of $4.4 \cdot 10^{-6}$.

The uncertainty of pressure measured with the PTB FPG standard is

$u(p) = 0.007\ \mathrm{Pa} + 5.5 \cdot 10^{-6} \times p$ in absolute mode and

$u(p) = 0.007\ \mathrm{Pa} + 5.3 \cdot 10^{-6} \times p$ in gauge mode.

3.3. UME FPG

UME’s laboratory standard was an FPG8601, serial number 124. It was calibrated against a primary piston-cylinder unit (serial No 329) by UME. A_0 in absolute and gauge mode is the same and has a relative standard uncertainty of $1.7 \cdot 10^{-5}$. The uncertainty of pressure measured with the UME FPG standard was estimated to be in absolute and gauge pressure mode the same:

$$u(p) = 0.01\ \mathrm{Pa} + 1.8 \cdot 10^{-5} \times p\ .$$

3.4. RISE FPG

The RISE national and traveling standard is a digital non-rotating piston gauge FPG8601 manufactured by Fluke Calibration, identified by serial number 113, in combination with a reference vacuum gauge 627B1TDD1B manufactured by MKS Instruments, identified by serial number 1008058. The RISE FPG has a long history as a secondary standard with regular calibrations of the effective area against the NMIs national standard. It was characterised as a primary pressure standard within the EMPIR joint research project 14IND06 pres2vac [6] in the same way as the FPG of PTB [8], but has been continuously calibrated to further evaluate the dimensionally measured value. So currently the FPG8601 is tracable to PTB pressure standards through regular calibrations of RISE national standards at PTB.

The uncertainty of pressure is

$u(p) = 0.015\ \text{Pa} + 2.0{\cdot}10^{-5} \times p$	in absolute mode and
$u(p) = 0.010\ \text{Pa} + 2.0{\cdot}10^{-5} \times p$	in gauge mode.

3.5. IMT STANDARDS

IMT absolute pressure standards to be validated by this comparison are their new primary static expansion system (SES) for the range from 1 Pa to 3 kPa combined with a pressure balance Ruska 2465A, identified by serial number 52651, and piston-cylinder assembly identified by serial number TL 1462, covering the range (of the comparison) from 3 kPa to 15 kPa.

The uncertainty of these standards is estimated as

$u(p) = \sqrt{(0.001\ \text{Pa})^2 + (6{\cdot}10^{-4} \times p)^2}$	at 1 Pa < p < 10 Pa	(SES)
$u(p) = 4{\cdot}10^{-4} \times p$	at 10 Pa ≤ p < 3 kPa	(SES)
$u(p) = \sqrt{(0.1\ \text{Pa})^2 + (1.6{\cdot}10^{-5} \times p)^2}$	at 3 kPa ≤ p < 15 kPa	(Ruska)

For gauge pressure, IMT standards are a differential capacitance diaphragm gauge (CDG-diff) MKS Baratron Model 226A, identified by serial number 02253303, for the range from 1 Pa to 250 Pa, a Quartz Bourdon Gauge Ruska 7000 (QBG), identified by serial number 52932, for the range above 250 Pa to 1.5 kPa, and a Ruska 2465A pressure balance, the same as used for absolute pressure but operated in gauge mode, for the range above 1.5 kPa to 15 kPa.

The uncertainty of these standards is estimated to be

$u(p) = \sqrt{(0.02\ \text{Pa})^2 + (2.5{\cdot}10^{-4} \times p)^2}$	at 1 Pa < p < 250 Pa	(CDG-diff)
$u(p) = \sqrt{(0.05\ \text{Pa})^2 + (3{\cdot}10^{-5} \times p)^2}$	at 250 Pa ≤ p < 1.5 kPa	(QBG)
$u(p) = \sqrt{(0.1\ \text{Pa})^2 + (1.6{\cdot}10^{-5} \times p)^2}$	at 1.5 kPa ≤ p < 15 kPa	(Ruska)

The IMT SES could not be transported to CMI. Therefore, for absolute pressure measurements, IMT provided a travelling standard package composed of the Quartz Bourdon Gauge Ruska 7000, the same which is used as IMT gauge pressure reference standard, but operated in absolute mode, and an absolute capacitance diaphragm gauge (CDG-abs) Pfeiffer Vacuum, Model CMR 274 (109 Pa FS range), identified by serial number 44310292.

The travelling standards were calibrated at IMT and then brought to CMI. Calibration was repeated after return from CMI in order to assess uncertainty contribution due to transport stability.

The QBG was used as a travelling standard at 300 Pa to 15 kPa., and CDG-abs in the range from 1 Pa to 100 Pa. With included contribution of transport stability, the uncertainty of the traveling standard package in absolute mode was estimated to:

$u(p) = \sqrt{(0.0015\ \text{Pa})^2 + (6{\cdot}10^{-4} \times p)^2}$	at 1 Pa < p ≤ 100 Pa	(CDG-abs)
$u(p) = \sqrt{(0.05\ \text{Pa})^2 + (2{\cdot}10^{-4} \times p)^2}$	at 100 Pa < p < 3 kPa	(QBG)
$u(p) = \sqrt{(0.1\ \text{Pa})^2 + (2{\cdot}10^{-5} \times p)^2}$	at 3 kPa ≤ p < 15 kPa	(QBG)

For gauge pressure the laboratory standards CDG-diff and QBG were used as travelling standards. The pressure balance Ruska was not transported to CMI, its range was also covered by the QBG. With included contribution of transport stability, the uncertainty of the traveling standard package in gauge mode was estimated to:

$u(p) = \sqrt{(0.02\ \text{Pa})^2 + (2.5{\cdot}10^{-4} \times p)^2}$ at 1 Pa < p ≤ 100 Pa (CDG-diff)

$u(p) = \sqrt{(0.05\ \text{Pa})^2 + (5{\cdot}10^{-5} \times p)^2}$ at 100 Pa < p < 3 kPa (QBG)

$u(p) = \sqrt{(0.1\ \text{Pa})^2 + (2{\cdot}10^{-5} \times p)^2}$ at 3 kPa ≤ p < 15 kPa (QBG)

4. CALIBRATION PROCEDURE AND MEASUREMENT CONDITIONS

The nominal pressure points were (1, 3, 10, 30, 100, 300, 1000, 3000, 10000 and 15000) Pa of both, absolute and gauge pressure. Measurements were made in 2 series for absolute pressure and in 2 series for gauge pressure. Each series was performed on a different day.

The pressure transmitting medium was nitrogen. In the case of FPGs, nitrogen entered the FPG controller as a dry gas and then adjusted to a relative humidity of about 50 % within the FPG.

The comparison measurements were performed in a CMI laboratory free of vibrations, with air conditioning able to ensure ambient temperature stable within 0.2 °C during one measurement point and with minimized disturbances due to instabilities of atmospheric pressure (doors etc.).

Preparation of LS for measurements and its operation at CMI site was done by the LS owner with assistance of the CMI staff. LS was located close to TS to keep the pressure line between the two instruments as short as possible.

The height difference between the reference levels of LS and TS was 141 mm in the case of IMT, and below 2 mm in all other cases. It was measured with a standard uncertainty of about 1 mm.

Both LS and TS were switched on at least 24 h before the start of the comparison.

For FPGs, linearity of their mass comparators was checked before the start of the comparison measurements, as well as stability of zero and internal calibration indication (using internal standard mass) of their load cells.

In all measurements of the CMI FPG against the PTB, UME and RISE FPGs, a CDG MKS Baratron of type 698A01TRA with a control unit of type 270, provided and calibrated by CMI, was set up between LS and TS, connected to them by bellows of the same diameters and volumes, to separate LS and TS and to measure the pressure difference between them. However, during the measurements, the pressures of TS and LS were adjusted to keep the pressure difference, indicated by the CDG, as near to zero as possible. In all measurements, the maximum pressure differences measured by the CDG were about 1.3 Pa in gauge mode and about 0.9 Pa in absolute mode, usually at 10 kPa and 15 kPa, and pressure differences typically below 0.1 Pa at lower pressures. The CDG was heated to 318.15 K during the absolute mode, and not heated during the gauge mode measurements. Before starting the comparison measurements, both LS and TS were zeroed and then calibrated internally. A check of the internal calibration was repeated every four hours. Then, both instruments were zeroed again, and the zero was checked and read. During these operations, the isolation valve between LS and TS was closed, and the CDG by-pass valve stayed open. At this combination of valves stings, the target nominal pressure was set by that FPG which was isolated from the CDG. Then, the target pressure was generated by another FPG and applied to both sides of the CDG connected by the by-pass valve being opened. After pressure stabilization, the zero of the CDG was read. Then, the by-pass valve was closed, and the isolating valve open.

In the measurements of the CMI FPG against the IMT travelling standards, CDGs and QBG, in which no effect due to a flow between TS and LS was expected, they were connected directly without the separating CDG.

After stabilization of the LS, TS and CDG (when used) readings, 5 values were recorded, each obtained by averaging outputs of the LS, TS and CDG over the time of about but not less than 1 min.

After measuring a pressure point, a check of the CDG zero drift was performed and a correction, if necessary, applied.

For the absolute mode measurements, the reference vacuum gauges of the FPGs were checked by means of an SRG mounted between the reference ports of LS and TS.

During the gauge mode measurements, the reference ports of LS and TS were open to atmosphere.

With **2 series** for each, absolute and gauge measurement, and **5 values** recorded at each nominal pressure, **10 results** were available for each LS compared with TS at each nominal pressure.

5. REPORTED DATA AND ITS REDUCTION

For each pressure point j ($j = 1, \dots, N$; $N = 10$) of the comparison of laboratory i ($i = 1, \dots, n$; $n = 4$) with CMI, the following data were reported by the laboratory and by CMI:

p_{ij}	LS pressure at the LS pressure level,
$p_{\mathrm{T}ij}$	TS pressure at the TS pressure level,
u_{ij}	uncertainty of p_{ij},
$u_{\mathrm{T}ij}$	uncertainty of $p_{\mathrm{T}ij}$,
t_{ij}	LS temperature,
$t_{\mathrm{T}ij}$	TS temperature,
$t_{\mathrm{amb}ij}$	ambient temperature (in gauge mode only),
$p_{\mathrm{amb}ij}$	ambient pressure (in gauge mode only),
$p^*_{\mathrm{CDG}ij}$	differential pressure reading of CDG, not zero corrected,
$s_{\mathrm{CDG}ij}$	standard deviation of the CDG differential pressure reading,
$p_{\mathrm{CDG01}ij}$	zero differential pressure reading of CDG before measuring $p^*_{\mathrm{CDG}ij}$,
$p_{\mathrm{CDG02}ij}$	zero differential pressure reading of CDG after measuring $p^*_{\mathrm{CDG}ij}$,
C_{CDG}	calibration factor of CDG,
T_{CDG}	absolute temperature of CDG,
h_i	height difference between the reference levels of LS and TS.
g	local gravity acceleration

Main data reported by the participants are presented in Annex 1.

As a KC reference level, the TS reference level was chosen.

The difference (d_{ij}) of the LS pressure p_{ij}, corrected to the TS reference level by δ_{ij}, and the TS pressure $p_{\mathrm{T}ij}$ is

$$d_{ij} = p_{ij} + \delta_{ij} - p_{\mathrm{T}ij},\ \text{with} \tag{2}$$

$$\delta_{ij} = pc_2 - p_{\mathrm{T}}c_1 + p_h(1 + c_2) + p_{\mathrm{CDG}}, \tag{3}$$

where the symbols mean

p_{CDG}	CDG differential pressure corrected for zero and calibration factor,
p_h	head correction,
c_1	thermal transpiration correction of TS pressure to CDG temperature,
c_2	thermal transpiration correction of LS pressure to CDG temperature,

and are calculated by

$$p_{\mathrm{CDG}} = [p^*_{\mathrm{CDG}} - (p_{\mathrm{CDG01}} + p_{\mathrm{CDG02}})/2] \cdot C_{\mathrm{CDG}}, \quad (4)$$

$$p_h = \left(\rho_{\mathrm{g}} - \rho_{\mathrm{amb}}\right) gh, \quad (5)$$

$$c_1 = f(p_{\mathrm{T}}, T_{\mathrm{T}}, T_{\mathrm{CDG}}) \cdot [(T_{\mathrm{CDG}}/T_{\mathrm{T}})^{0.5} - 1], \quad (6)$$

$$c_2 = f(p, T, T_{\mathrm{CDG}}) \cdot [(T_{\mathrm{CDG}}/T)^{0.5} - 1]. \quad (7)$$

The thermal transpiration correction was applied only for absolute pressure measurements at pressures below 100 Pa. For all other measurements, and all measurements of IMT, c_1 and c_2 were set to zero.

Here are

ρ_{g}	density of the pressure gas,
ρ_{amb}	density of the ambient gas, air density in gauge pressure and zero in absolute pressure measurements,
T_{T}	TS absolute temperature,
T	LS absolute temperature,
$f(\ldots)$	thermal transpiration correction factor (0…1), calculated according to [12].

On the right hand side of equations (3) and (10), and in equations (4) to (7) on left and right hand sides, indices ij are omitted for better readability.

The mean of N repeated measurements (d_i) was calculated as a weighted mean of d_{ij}, weighted by the Type B uncertainties of d_{ij} ($u_{d_{ij}}$), which were considered fully correlated,

$$d_i = \sum_{j=1}^{N} \left(d_{ij}/u^2_{d_{ij}}\right) \Big/ \sum_{j=1}^{N} \left(1/u^2_{d_{ij}}\right), \quad (8)$$

and calculated as

$$u_{d_{ij}} = \left(u^2_{ij} + u^2_{\mathrm{T}ij} + u^2_{\delta_{ij}}\right)^{0.5}, \quad (9)$$

$$u_{\delta_{ij}} = \left\{u_h^2 + u^2_{\mathrm{CDG,B}} + 2u_{\mathrm{CDG,B}}\, u_{\mathrm{T,B}} + \left[\frac{c_2}{c_1}(p + p_h) - p_{\mathrm{T}}\right]^2 u_c^2 + s^2_{\mathrm{CDG}}\right\}^{0.5}, \quad (10)$$

where are

u_h	uncertainty of head correction p_h,
$u_{\mathrm{CDG,B}}$	type B uncertainty of p_{CDG},

$u_{\mathrm{T,B}}$ type B uncertainty of p_{T} as given for the CMI FPG in 3.1,

u_c uncertainty of thermal transpiration corrections c_1 and c_2,

taken as

$$u_h = \left(\rho_{\mathrm{g}} - \rho_{\mathrm{amb}}\right) g u(h), \tag{11}$$

$$u_{\mathrm{CDG,B}} = 0.3\ \mathrm{mPa} + 0.01 p_{\mathrm{CDG}}, \tag{12}$$

$$u_c = 0.1 c_1\ . \tag{13}$$

Term $2u_{\mathrm{CDG,B}}\, u_{\mathrm{T,B}}$ in (9) takes into account correlation between $u_{\mathrm{CDG,B}}$ and $u_{\mathrm{T,B}}$, because the CDG was calibrated by the CMI FPG.

According to (2) and (8), the weighted mean LS pressure (p_i), TS pressure ($p_{\mathrm{T}i}$), pressure correction (δ_i) and their uncertainties (u_i), ($u_{\mathrm{T}i}$), and (u_{δ_i}) for N repeated measurements are given by:

$$p_i = \sum_{j=1}^{N} \left(\frac{p_{ij}}{u_{d_{ij}}^2}\right) \Big/ \sum_{j=1}^{N} \left(\frac{1}{u_{d_{ij}}^2}\right), \tag{14}$$

$$p_{\mathrm{T}i} = \sum_{j=1}^{N} \left(\frac{p_{\mathrm{T}ij}}{u_{d_{ij}}^2}\right) \Big/ \sum_{j=1}^{N} \left(\frac{1}{u_{d_{ij}}^2}\right), \tag{15}$$

$$\delta_i = \sum_{j=1}^{N} \left(\frac{\delta_{ij}}{u_{d_{ij}}^2}\right) \Big/ \sum_{j=1}^{N} \left(\frac{1}{u_{d_{ij}}^2}\right), \tag{16}$$

$$u_i = \sum_{j=1}^{N} \left(\frac{u_{ij}}{u_{d_{ij}}^2}\right) \Big/ \sum_{j=1}^{N} \left(\frac{1}{u_{d_{ij}}^2}\right), \tag{17}$$

$$u_{\mathrm{T}i} = \sum_{j=1}^{N} \left(\frac{u_{\mathrm{T}ij}}{u_{d_{ij}}^2}\right) \Big/ \sum_{j=1}^{N} \left(\frac{1}{u_{d_{ij}}^2}\right), \tag{18}$$

$$u_{\delta_i} = \sum_{j=1}^{N} \left(\frac{u_{\delta_{ij}}}{u_{d_{ij}}^2}\right) \Big/ \sum_{j=1}^{N} \left(\frac{1}{u_{d_{ij}}^2}\right). \tag{19}$$

With these definitions,

$$d_i = p_i + \delta_i - p_{\mathrm{T}i}\ . \tag{20}$$

The type B uncertainty of d_i ($u_{\mathrm{B}d_i}$), the type A uncertainty of d_i ($u_{\mathrm{A}d_i}$), and the combined uncertainty (u_{d_i}) were calculated by

$$u_{\mathrm{B}d_i} = \left[u_i^2 + u_{\mathrm{T}i}^2 + u_{\delta_i}^2\right]^{0.5}, \tag{21}$$

$$u_{\mathrm{A}d_i} = \left[\sum_{j=1}^{N} \frac{\left(d_{ij} - d_i\right)^2}{u_{ij}^2} \Big/ \sum_{j=1}^{N} \frac{1}{u_{ij}^2} \cdot \frac{1}{N-3}\right]^{0.5}, \tag{22}$$

$$u_{d_i} = \left[u_{\mathrm{B}d_i}^2 + u_{\mathrm{A}d_i}^2\right]^{0.5}. \tag{23}$$

The CMI mean pressure (p_T) and its uncertainty (u_T) for comparison with all n laboratories were calculated by

$$p_\mathrm{T} = \sum_{i=1}^{n} \left(\frac{p_{\mathrm{T}i}}{u_{\mathrm{T}i}^2}\right) \Big/ \sum_{i=1}^{n} \left(\frac{1}{u_{\mathrm{T}i}^2}\right), \quad (24)$$

$$u_\mathrm{T} = \sum_{i=1}^{n} \left(\frac{1}{u_{\mathrm{T}i}}\right) \Big/ \sum_{i=1}^{n} \left(\frac{1}{u_{\mathrm{T}i}^2}\right). \quad (25)$$

Results for d_i, their uncertainties and mean uncertainties of LS and TS pressures are presented in Annex 2.

6. STABILITY OF THE TRANSFER STANDARD

For the FPG8601 instrument used as the transfer standard, its manufacturer Fluke Calibration states a 1 year's stability with a standard uncertainty contribution of 1.7 mPa + 2.8·10^{-6} $\times p$ for absolute and 2.8·10^{-6} $\times p$ for gauge mode [13].

In the former EURAMET KC, EURAMET.M.P-K4.2010, LNE reported for their FPG stabilities of the load cell and the effective area contributing standard uncertainties of 1·10^{-6} $\times p$ and 5·10^{-6} $\times p$, respectively, in both absolute and gauge mode [1].

For the FPG used as a transfer standard in the present KC, in measurements performed in gauge mode against a dead weight piston gauge (PG) as a reference in 2019 and 2022, a relative change in the effective area of the FPG of 3·10^{-6} was observed, corresponding to a 1 year's change of 1·10^{-6}. Assuming the 1 year's stability of the reference PG to be of 0.1·10^{-6} and of the load cell as 0.53·10^{-6}, the maximum contribution to a pressure proportional component of the uncertainty due to the FPG instability over 1 year was estimated as 1.2·10^{-6}, in both absolute and gauge mode. The 1 year's instability of the residual gas pressure measurement, in absolute mode, was estimated to contribute maximum 0.002 Pa.

Based on all this information, and taking into account the resolution of the load cell of 1 mPa, the standard uncertainty's contributions due to TS instability over time (t), $u_\mathrm{Tstab}(t)$, of

$$u_\mathrm{Tstab}(t) = (2\ \mathrm{mPa} + 1.2\cdot 10^{-6} \times p) \cdot t/\mathrm{year}, \text{ in absolute mode and} \quad (26)$$

$$u_\mathrm{Tstab}(t) = 1\ \mathrm{mPa} + 1.2\cdot 10^{-6} \times p \cdot t/\mathrm{year}, \text{ in gauge mode,} \quad (27)$$

were taken as realistic estimates.

With the duration of the present KC of $t_\mathrm{E} = 2.54$ years, the respective contributions ($u_\mathrm{Tstab,E}$) are equal to

$$u_\mathrm{Tstab,E} = 5.1\ \mathrm{mPa} + 3.1\cdot 10^{-6} \times p, \text{ in absolute mode and} \quad (28)$$

$$u_\mathrm{Tstab,E} = 1\ \mathrm{mPa} + 3.1\cdot 10^{-6} \times p, \text{ in gauge mode.} \quad (29)$$

7. DEGREES OF EQUIVALENCE

The present comparison has the following specific features:

- The CMI standard acts as a transfer standard but also as a contributor to the reference value (KCRV) of the comparison (p_KCRV).
- There is no physical standard, whose pressure would have been measured against LS and TS. Instead, a virtual travelling standard is considered whose p_KCRV is to be defined in such a way that it fulfils differences between LS and TS, d_i, determined by the comparison.
- LS pressures to be used for p_KCRV calculation can be expressed in terms of differences from the mean of the TS pressure (p_T) as $p_\mathrm{T} + d_i$. The contribution of TS is given by p_T.

- For the evaluation of the degree of equivalence, the values of p_T and p_KCRV are meaningless, and only d_i, u_i, u_T, and u_{d_i} are of importance.

For each participant, the degree of equivalence in relation to the reference value of the comparison is expressed in terms of a deviation from p_KCRV, D_T for CMI and D_i for all other laboratories, and the expanded uncertainty of this deviation, U_{D_T} or U_{D_i}, taken with the coverage factor k = 2.

The results of all 5 participants were considered as independent and, consequently, p_KCRV was defined as a weighted mean of the participants results according to [14]:

$$p_\mathrm{KCRV} = \frac{1}{V}\left(\sum_{i=1}^{n}\frac{p_\mathrm{T}+d_i}{u_i^2}+\frac{p_\mathrm{T}}{u_\mathrm{T}^2}\right),\ \text{ with} \tag{30}$$

$$V = \sum_{i=1}^{n}\frac{1}{u_i^2}+\frac{1}{u_\mathrm{T}^2}\ . \tag{31}$$

The combined expanded (k = 2) uncertainty of p_KCRV ($U_\mathrm{KCRV,EURAMET}$) is calculated, taking into account (20), by

$$U_\mathrm{KCRV,EURAMET} = 2\left\{\frac{1}{V^2}\left[\left(Vu_\mathrm{T}-\sum_{i=1}^{n}\frac{u_{\mathrm{T}i}}{u_i^2}\right)^2+\left(\sum_{i=1}^{n}\frac{1}{u_i}\right)^2+\left(\sum_{i=1}^{n}\frac{u_{\delta_i}}{u_i^2}\right)^2\right]+u_\mathrm{Tstab,E}^2\right\}^{0.5}. \tag{32}$$

The deviations from p_KCRV are calculated as

$$D_i = p_\mathrm{T}+d_i-p_\mathrm{KCRV} = d_i-\frac{1}{V}\sum_{i=1}^{n}\frac{d_i}{u_i^2}, \tag{33}$$

$$D_\mathrm{T} = p_\mathrm{T}-p_\mathrm{KCRV} = -\frac{1}{V}\sum_{i=1}^{n}\frac{d_i}{u_i^2}. \tag{34}$$

The observed chi-squared values (χ^2_obs), calculated by

$$\chi^2_\mathrm{obs} = \sum_{i=1}^{n}\frac{D_i^2}{u_i^2}+\frac{D_\mathrm{T}^2}{u_\mathrm{T}^2} \tag{35}$$

for each pressure point of the KC, lie between 0.3 and 7.4 for the absolute pressure comparison and between 0.3 and 7.5 for the gauge pressure comparison. These values are smaller than 9.5, at which the chi-squared test at probability of 95 % passes, so that the chosen method of the reference value calculation can be accepted.

The standard uncertainties of deviations D_i and D_T, $u_{D_i}$and u_{D_T}, are calculated from uncertainties of d_i, the latter being composed of type A and type B uncertainties. From type A uncertainties $u_{\mathrm{A}d_i}$ defined by eq. (21), type A uncertainties of D_i and D_T, $u_{\mathrm{A}D_i}$ and $u_{\mathrm{A}D_\mathrm{T}}$, respectively, are given by

$$u_{\mathrm{A}D_i} = \left[u_{\mathrm{A}d_i}^2\left(1-\frac{2}{Vu_i^2}\right)+\frac{1}{V^2}\sum_{i=1}^{n}\frac{u_{\mathrm{A}d_i}^2}{u_i^4}\right]^{0.5} , \tag{36}$$

$$u_{\mathrm{A}D_\mathrm{T}} = \frac{1}{V}\left[\sum_{i=1}^{n}\frac{u_{\mathrm{A}d_i}^2}{u_i^4}\right]^{0.5} . \tag{37}$$

The uncertainties of type B of D_i and D_T, $u_{\mathrm{B}D_i}$ and $u_{\mathrm{B}D_\mathrm{T}}$, respectively, calculated from (33) and (34) using (20) and assuming that all $u_{\mathrm{T}i}$ as well as all u_{δ_i} are correlated, are given by:

$$u_{\mathrm{B}D_i} = \left[u_i^2-\frac{1}{V}-\frac{1}{V^2u_\mathrm{T}^2}+\left(u_{\mathrm{T}i}-\frac{1}{V}\sum_{i=1}^{n}\frac{u_{\mathrm{T}i}}{u_i^2}\right)^2+\left(u_{\delta_i}-\frac{1}{V}\sum_{i=1}^{n}\frac{u_{\delta_i}}{u_i^2}\right)^2\right]^{0.5} , \tag{38}$$

$$u_{\mathrm{B}D_\mathrm{T}} = \frac{1}{V}\left[\sum_{i=1}^{n}\frac{1}{u_i^2}+\left(\sum_{i=1}^{n}\frac{u_{\mathrm{T}i}}{u_i^2}\right)^2+\left(\sum_{i=1}^{n}\frac{u_{\delta_i}}{u_i^2}\right)^2\right]^{0.5} . \tag{39}$$

The combined expanded (k = 2) uncertainties of D_i and D_T, U_{D_i} and U_{D_T}, respectively, were calculated, taking into account the uncertainty due to TS instability (26), by

$$U_{D_i} = 2\left(u_{\mathrm{A}D_i}^2+u_{\mathrm{B}D_i}^2+u_{\mathrm{Tstab,E}}^2\right)^{0.5} , \tag{40}$$

$$U_{D_\mathrm{T}} = 2\left(u_{\mathrm{A}D_\mathrm{T}}^2+u_{\mathrm{B}D_\mathrm{T}}^2+u_{\mathrm{Tstab,E}}^2\right)^{0.5} . \tag{41}$$

The degrees of equivalence of the laboratories in pairs are expressed in terms of deviations of the laboratories results from each other, $D_{\mathrm{T}l}$ for CMI and laboratory l and D_{il} for laboratories i and l, and the expanded uncertainties of these deviations, $U_{D_{\mathrm{T}l}}$ or $U_{D_{il}}$, respectively, taken with the coverage factor k = 2.

The pairwise differences are given by:

$$D_{il} = d_i - d_l , \tag{42}$$

$$D_{\mathrm{T}l} = d_l . \tag{43}$$

According to (20), the expanded (k = 2) uncertainties of D_{il} and $D_{\mathrm{T}l}$, $U_{D_{il}}$and $U_{D_{\mathrm{T}l}}$, are calculated by

$$U_{D_{il}} = 2\left[u_i^2+u_l^2+(u_{\mathrm{T}i}-u_{\mathrm{T}l})^2+\left(u_{\delta_i}-u_{\delta_l}\right)^2+u_{\mathrm{A}d_i}^2+u_{\mathrm{A}d_l}^2+u_{\mathrm{Tstab,E}}^2\right]^{0.5} , \tag{44}$$

$$U_{D_{\mathrm{T}l}} = 2\left[u_l^2+u_{\mathrm{T}l}^2+u_{\delta_l}^2+u_{\mathrm{A}d_l}^2\right]^{0.5} . \tag{45}$$

The degrees of equivalence for absolute and gauge pressure comparisons are presented in Table 2 and Table 3, respectively. In these Tables, the symbols
D_i denote both D_i and D_T, calculated by equations (33) and (34), respectively.
U_i denote both U_{D_i} and U_{D_T}, calculated by equations (40) and (41), respectively.
D_{il} denote both D_{il} and $D_{\mathrm{T}l}$, calculated by equations (42) and (43), respectively.
U_{il} denote both $U_{D_{il}}$ and $U_{D_{\mathrm{T}l}}$, calculated by equations (44) and (45), respectively.

According to Table 2 and Table 3, at all nominal pressures in both absolute and gauge pressure comparisons, except in 1 of 100 results for gauge pressure measurements, $|D_i| \leq U_i$ and $|D_{il}| \leq U_{il}$, and thus the condition of equivalence at the k = 2 level of confidence is satisfied. In gauge mode at a pressure of 10 Pa, the red shaded cells in Table 3 the results of UME and IMT show a marginally bigger difference $|D_{il}| = 0.055$ Pa than its uncertainty $U_{il} = 0.054$ Pa.

The degrees of equivalence of NMIs results with respect to the key comparison reference values are presented graphically for the absolute pressure comparison from Figure 1 to Figure 10, and for the gauge pressure comparison from Figure 11 to Figure 20, as plots of deviations D_i. The uncertainty bars are the values of U_i at the k = 2 confidence level.

Table 2. Degrees of equivalence for the absolute pressure comparison at nominal pressures (p_{nom}): Deviations of NMIs' results from the reference value (D_i) with their expanded uncertainties (U_i) and differences between NMIs' pressures (D_{il}) with their expanded uncertainties (U_{il}), all given in Pa.

NMI	p_{nom} / Pa	EURAMET KCRV		CMI		PTB		RISE		UME		IMT	
		D_i	U_i	D_{il}	U_{il}	D_{il}	U_{il}	D_{il}	U_{il}	D_{il}	U_{il}	D_{il}	U_{il}
CMI	1	0.004	0.023			-0.013	0.026	-0.004	0.037	-0.003	0.029	0.005	0.021
	3	-0.003	0.022			-0.019	0.027	-0.004	0.039	-0.003	0.029	-0.001	0.021
	10	-0.007	0.022			-0.009	0.026	0.005	0.042	-0.006	0.030	-0.010	0.024
	30	-0.006	0.022			-0.010	0.027	-0.014	0.042	-0.003	0.031	-0.003	0.042
	100	0.002	0.028			0.011	0.037	-0.020	0.045	-0.002	0.036	-0.002	0.123
	300	0.000	0.038			0.002	0.048	-0.010	0.057	0.001	0.054	0.000	0.163
	1000	-0.009	0.055			-0.008	0.063	-0.037	0.097	-0.004	0.095	-0.008	0.422
	3000	-0.034	0.116			-0.042	0.124	-0.102	0.215	-0.008	0.218	0.082	0.262
	10000	-0.087	0.332			-0.115	0.356	-0.209	0.625	-0.059	0.602	0.209	0.571
	15000	-0.112	0.468			-0.144	0.511	-0.284	0.867	-0.088	0.796	0.221	0.800
PTB	1	0.017	0.019	0.013	0.026			0.009	0.035	0.010	0.027	0.018	0.019
	3	0.016	0.019	0.019	0.027			0.015	0.037	0.016	0.027	0.018	0.020
	10	0.002	0.017	0.009	0.026			0.014	0.039	0.004	0.027	-0.001	0.023
	30	0.004	0.015	0.010	0.027			-0.004	0.039	0.007	0.028	0.007	0.041
	100	-0.008	0.019	-0.011	0.037			-0.031	0.042	-0.013	0.034	-0.013	0.124
	300	-0.002	0.020	-0.002	0.048			-0.012	0.052	0.000	0.043	-0.002	0.163
	1000	-0.001	0.022	0.008	0.063			-0.028	0.081	0.004	0.075	0.000	0.421
	3000	0.008	0.037	0.042	0.124			-0.060	0.177	0.034	0.162	0.124	0.246
	10000	0.028	0.095	0.115	0.356			-0.094	0.493	0.056	0.479	0.324	0.493
	15000	0.033	0.139	0.144	0.511			-0.139	0.700	0.056	0.636	0.365	0.695
RISE	1	0.008	0.032	0.004	0.037	-0.009	0.035			0.001	0.038	0.010	0.033
	3	0.001	0.034	0.004	0.039	-0.015	0.037			0.001	0.039	0.003	0.035
	10	-0.012	0.035	-0.005	0.042	-0.014	0.039			-0.011	0.042	-0.016	0.039
	30	0.007	0.034	0.014	0.042	0.004	0.039			0.011	0.042	0.010	0.052
	100	0.022	0.035	0.020	0.045	0.031	0.042			0.018	0.044	0.018	0.127
	300	0.010	0.043	0.010	0.057	0.012	0.052			0.012	0.058	0.010	0.167
	1000	0.028	0.074	0.037	0.097	0.028	0.081			0.032	0.102	0.029	0.427
	3000	0.068	0.165	0.102	0.215	0.060	0.177			0.094	0.218	0.184	0.299
	10000	0.122	0.466	0.209	0.625	0.094	0.493			0.150	0.633	0.418	0.688
	15000	0.172	0.663	0.284	0.867	0.139	0.700			0.196	0.895	0.505	0.966
UME	1	0.007	0.023	0.003	0.029	-0.010	0.027	-0.001	0.038			0.009	0.026
	3	0.000	0.023	0.003	0.029	-0.016	0.027	-0.001	0.039			0.002	0.026
	10	-0.001	0.022	0.006	0.030	-0.004	0.027	0.011	0.042			-0.005	0.029
	30	-0.003	0.022	0.003	0.031	-0.007	0.028	-0.011	0.042			-0.001	0.045
	100	0.005	0.024	0.002	0.036	0.013	0.034	-0.018	0.044			0.000	0.124
	300	-0.001	0.035	-0.001	0.054	0.000	0.043	-0.012	0.058			-0.002	0.166
	1000	-0.005	0.068	0.004	0.095	-0.004	0.075	-0.032	0.102			-0.003	0.426
	3000	-0.026	0.151	0.008	0.218	-0.034	0.162	-0.094	0.218			0.090	0.294
	10000	-0.028	0.451	0.059	0.602	-0.056	0.479	-0.150	0.633			0.268	0.676
	15000	-0.024	0.593	0.088	0.796	-0.056	0.636	-0.196	0.895			0.309	0.910
IMT	1	-0.001	0.010	-0.005	0.021	-0.018	0.019	-0.010	0.033	-0.009	0.026		
	3	-0.002	0.010	0.001	0.021	-0.018	0.020	-0.003	0.035	-0.002	0.026		
	10	0.003	0.015	0.010	0.024	0.001	0.023	0.016	0.039	0.005	0.029		
	30	-0.003	0.037	0.003	0.042	-0.007	0.041	-0.010	0.052	0.001	0.045		
	100	0.004	0.121	0.002	0.123	0.013	0.124	-0.018	0.127	0.000	0.124		
	300	0.000	0.160	0.000	0.163	0.002	0.163	-0.010	0.167	0.002	0.166		
	1000	-0.001	0.419	0.008	0.422	0.000	0.421	-0.029	0.427	0.003	0.426		
	3000	-0.116	0.238	-0.082	0.262	-0.124	0.246	-0.184	0.299	-0.090	0.294		
	10000	-0.296	0.463	-0.209	0.571	-0.324	0.493	-0.418	0.688	-0.268	0.676		
	15000	-0.333	0.650	-0.221	0.800	-0.365	0.695	-0.505	0.966	-0.309	0.910		

Table 3. Degrees of equivalence for the gauge pressure comparison at nominal pressures (p_{nom}): Deviations of NMIs results from the reference value (D_i) with their expanded uncertainties (U_i) and differences between NMIs' pressures (D_{il}) with their expanded uncertainties (U_{il}), all given in Pa.

NMI	p_{nom} / Pa	EURAMET KCRV		CMI		PTB		RISE		UME		IMT	
		D_i	U_i	D_{il}	U_{il}	D_{il}	U_{il}	D_{il}	U_{il}	D_{il}	U_{il}	D_{il}	U_{il}
CMI	1	-0.004	0.028			-0.001	0.035	-0.009	0.045	0.004	0.036	-0.050	0.062
	3	-0.003	0.026			0.004	0.030	-0.014	0.040	0.004	0.039	-0.050	0.066
	10	-0.006	0.025			-0.002	0.029	-0.016	0.041	0.002	0.034	-0.053	0.060
	30	-0.002	0.036			0.003	0.036	-0.012	0.067	-0.001	0.050	-0.046	0.124
	100	-0.001	0.044			0.002	0.042	-0.006	0.088	0.000	0.059	-0.047	0.142
	300	0.005	0.063			0.007	0.054	-0.023	0.225	-0.003	0.225	-0.063	0.609
	1000	-0.007	0.096			-0.005	0.085	-0.040	0.282	-0.005	0.264	-0.053	0.734
	3000	-0.024	0.169			-0.026	0.146	-0.052	0.456	-0.008	0.604	0.040	1.111
	10000	-0.099	0.522			-0.112	0.456	-0.125	1.356	-0.131	2.229	0.194	3.026
	15000	-0.148	0.723			-0.171	0.667	-0.129	1.432	-0.220	1.792	0.107	2.360
PTB	1	-0.003	0.014	0.001	0.035			-0.008	0.035	0.005	0.030	-0.049	0.055
	3	-0.007	0.011	-0.004	0.030			-0.019	0.030	0.000	0.031	-0.055	0.055
	10	-0.004	0.011	0.002	0.029			-0.014	0.031	0.004	0.028	-0.051	0.051
	30	-0.005	0.011	-0.003	0.036			-0.015	0.047	-0.004	0.037	-0.049	0.106
	100	-0.003	0.010	-0.002	0.042			-0.008	0.058	-0.003	0.045	-0.049	0.116
	300	-0.003	0.012	-0.007	0.054			-0.031	0.182	-0.010	0.195	-0.071	0.565
	1000	-0.002	0.018	0.005	0.085			-0.035	0.213	0.000	0.209	-0.047	0.677
	3000	0.002	0.035	0.026	0.146			-0.027	0.352	0.018	0.527	0.066	0.992
	10000	0.013	0.100	0.112	0.456			-0.013	1.027	-0.019	1.971	0.306	2.659
	15000	0.023	0.128	0.171	0.667			0.042	1.072	-0.050	1.471	0.278	1.856
RISE	1	0.005	0.027	0.009	0.045	0.008	0.035			0.013	0.038	-0.041	0.053
	3	0.011	0.023	0.014	0.040	0.019	0.030			0.019	0.037	-0.036	0.055
	10	0.010	0.025	0.016	0.041	0.014	0.031			0.018	0.036	-0.037	0.052
	30	0.010	0.041	0.012	0.067	0.015	0.047			0.011	0.054	-0.033	0.093
	100	0.005	0.051	0.006	0.088	0.008	0.058			0.005	0.065	-0.041	0.108
	300	0.028	0.172	0.023	0.225	0.031	0.182			0.021	0.179	-0.040	0.472
	1000	0.033	0.200	0.040	0.282	0.035	0.213			0.035	0.208	-0.012	0.570
	3000	0.029	0.328	0.052	0.456	0.027	0.352			0.044	0.460	0.093	0.866
	10000	0.026	0.968	0.125	1.356	0.013	1.027			-0.006	1.710	0.319	2.369
	15000	-0.019	1.023	0.129	1.432	-0.042	1.072			-0.092	1.550	0.236	1.969
UME	1	-0.008	0.021	-0.004	0.036	-0.005	0.030	-0.013	0.038			-0.054	0.055
	3	-0.007	0.025	-0.004	0.039	0.000	0.031	-0.019	0.037			-0.055	0.059
	10	-0.008	0.021	-0.002	0.034	-0.004	0.028	-0.018	0.036			-0.055	0.054
	30	-0.001	0.032	0.001	0.050	0.004	0.037	-0.011	0.054			-0.045	0.108
	100	0.000	0.039	0.000	0.059	0.003	0.045	-0.005	0.065			-0.046	0.126
	300	0.007	0.188	0.003	0.225	0.010	0.195	-0.021	0.179			-0.061	0.539
	1000	-0.002	0.199	0.005	0.264	0.000	0.209	-0.035	0.208			-0.047	0.639
	3000	-0.016	0.510	0.008	0.604	-0.018	0.527	-0.044	0.460			0.048	1.012
	10000	0.032	1.936	0.131	2.229	0.019	1.971	0.006	1.710			0.325	2.976
	15000	0.073	1.437	0.220	1.792	0.050	1.471	0.092	1.550			0.328	2.312
IMT	1	0.046	0.048	0.050	0.062	0.049	0.055	0.041	0.053	0.054	0.055		
	3	0.048	0.051	0.050	0.066	0.055	0.055	0.036	0.055	0.055	0.059		
	10	0.047	0.047	0.053	0.060	0.051	0.051	0.037	0.052	0.055	0.054		
	30	0.044	0.100	0.046	0.124	0.049	0.106	0.033	0.093	0.045	0.108		
	100	0.046	0.113	0.047	0.142	0.049	0.116	0.041	0.108	0.046	0.126		
	300	0.068	0.556	0.063	0.609	0.071	0.565	0.040	0.472	0.061	0.539		
	1000	0.045	0.664	0.053	0.734	0.047	0.677	0.012	0.570	0.047	0.639		
	3000	-0.064	0.969	-0.040	1.111	-0.066	0.992	-0.093	0.866	-0.048	1.012		
	10000	-0.293	2.590	-0.194	3.026	-0.306	2.659	-0.319	2.369	-0.325	2.976		
	15000	-0.255	1.786	-0.107	2.360	-0.278	1.856	-0.236	1.969	-0.328	2.312		

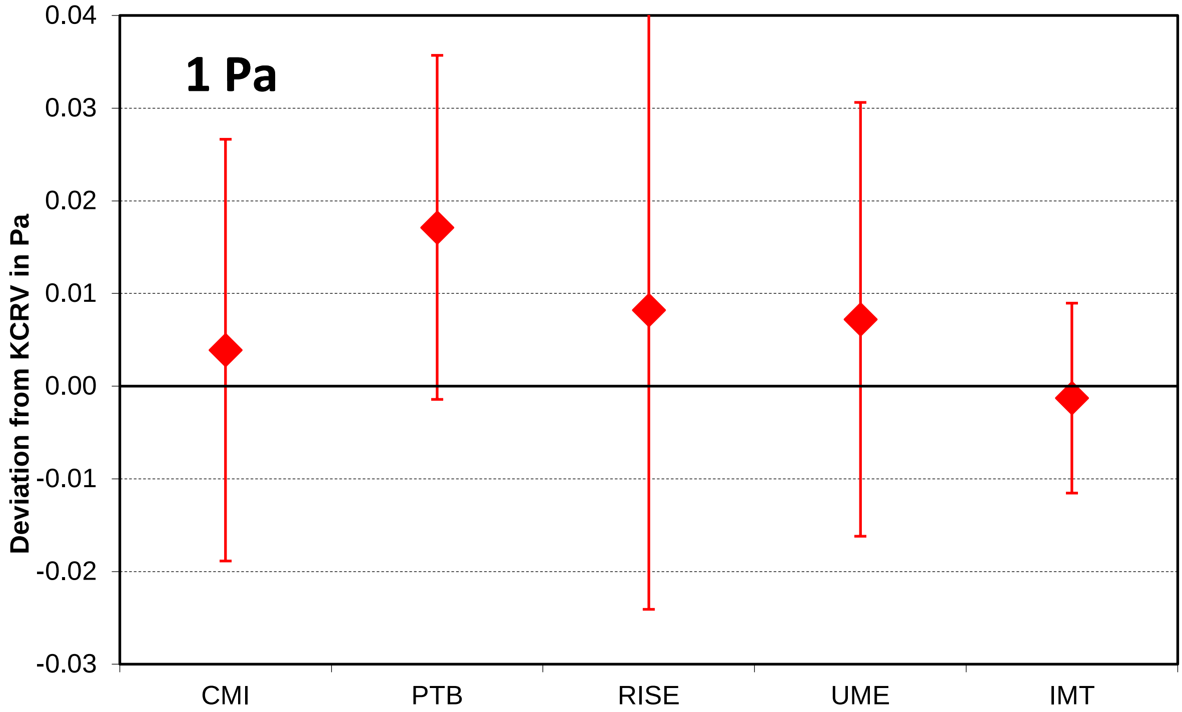

Figure 1. Deviations of NMIs results from KCRV at 1 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

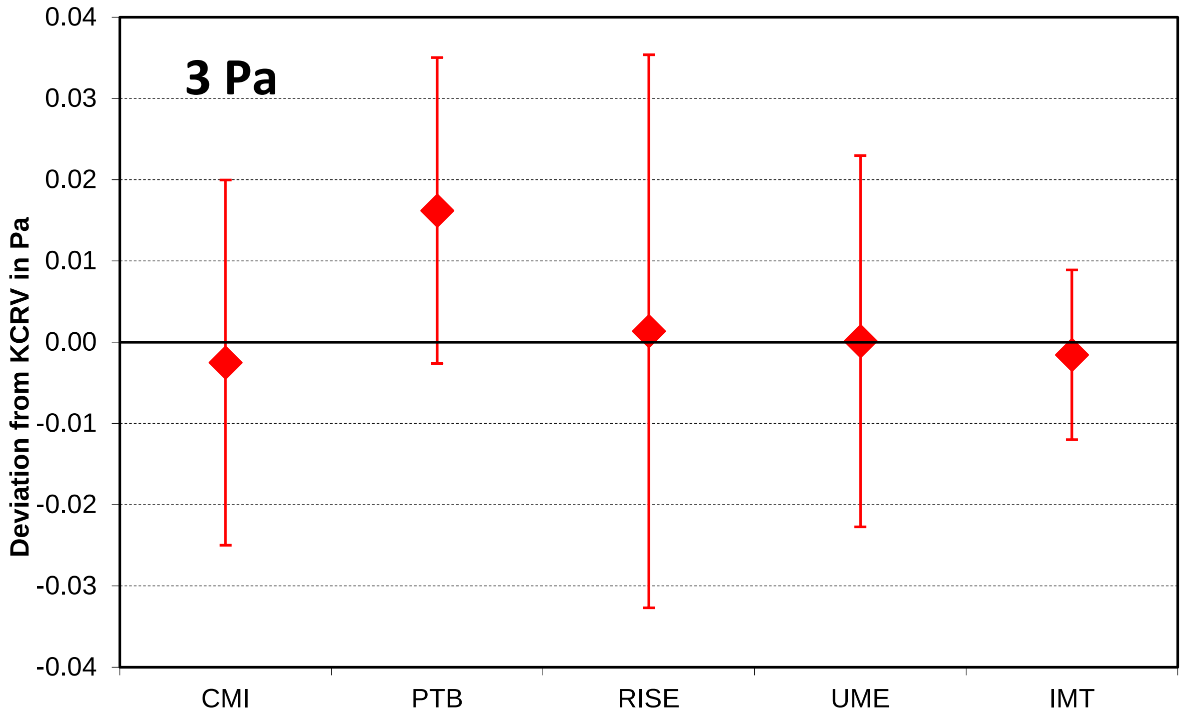

Figure 2. Deviations of NMIs results from KCRV at 3 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

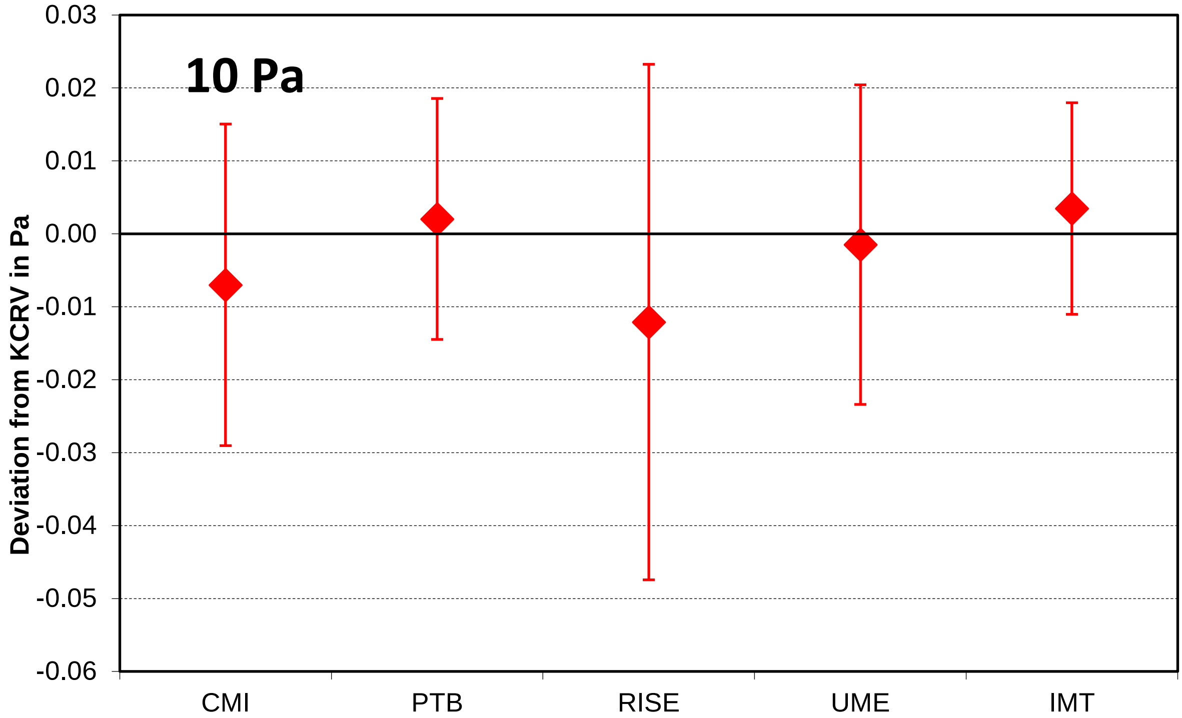

Figure 3. Deviations of NMIs results from KCRV at 10 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

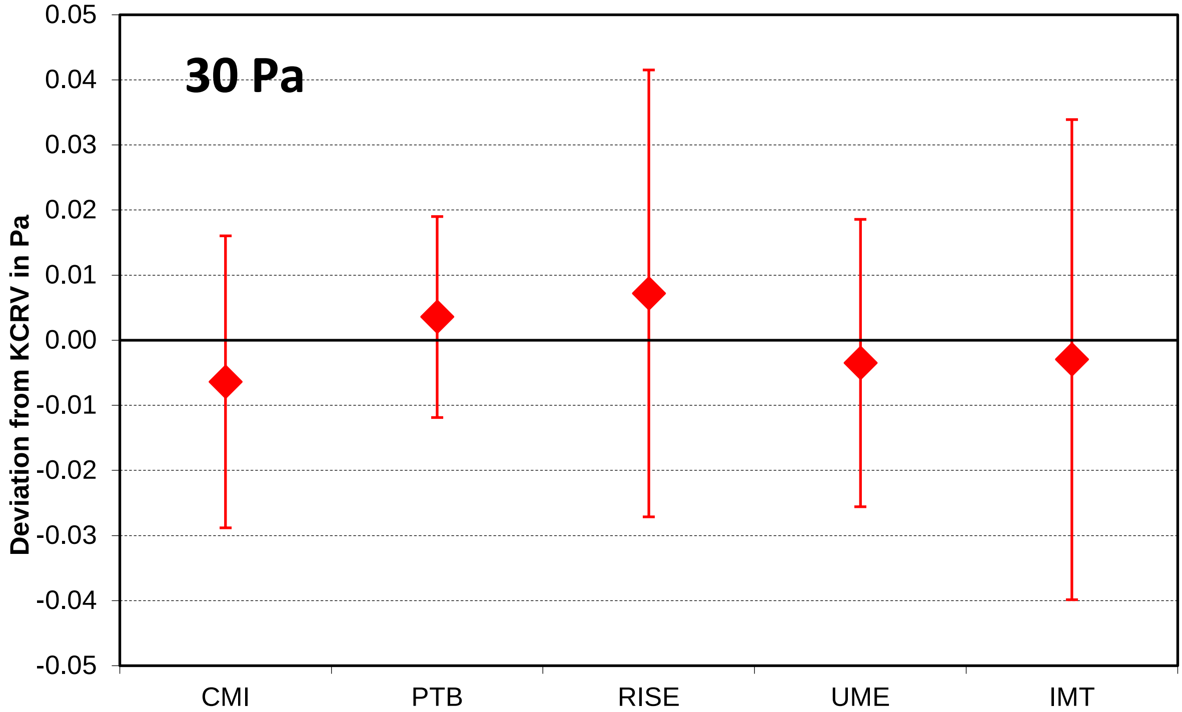

Figure 4. Deviations of NMIs results from KCRV at 30 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

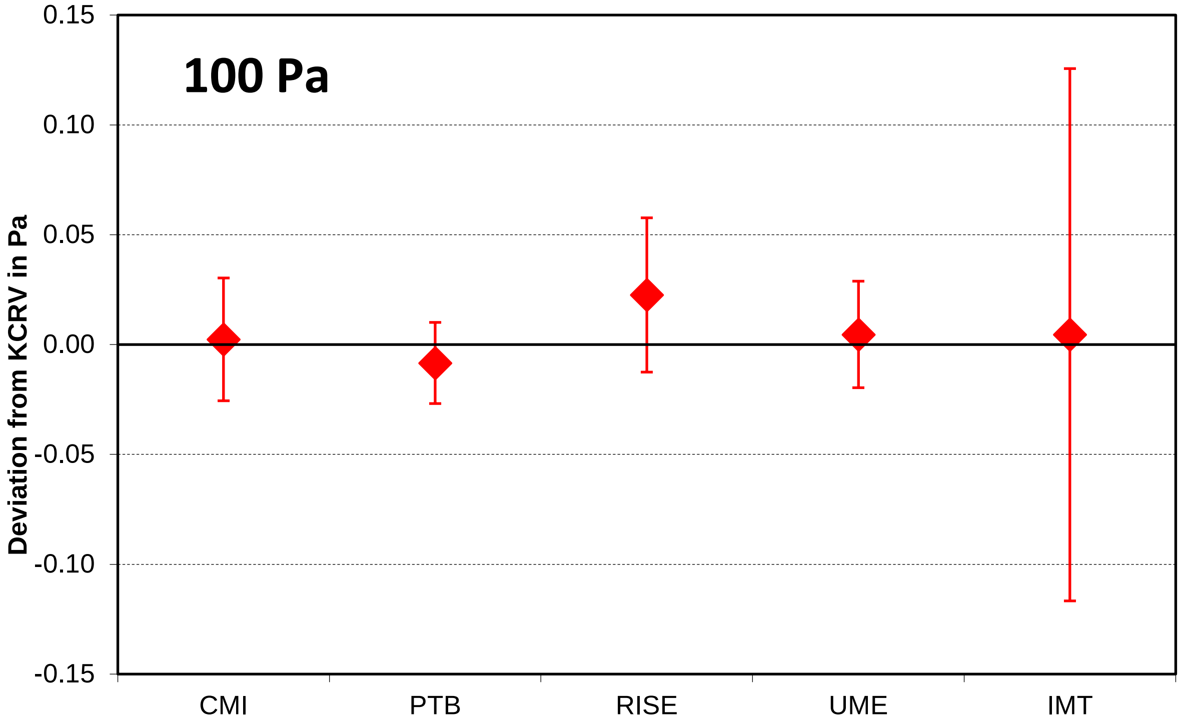

Figure 5. Deviations of NMIs results from KCRV at 100 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

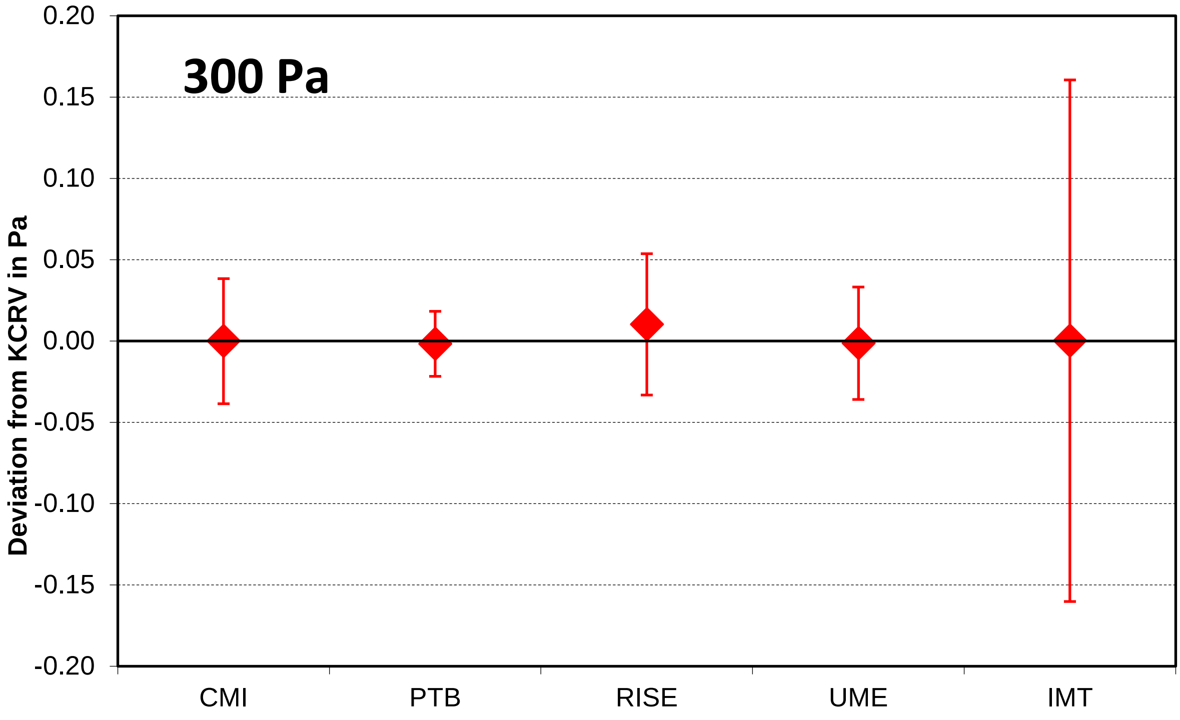

Figure 6. Deviations of NMIs results from KCRV at 300 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

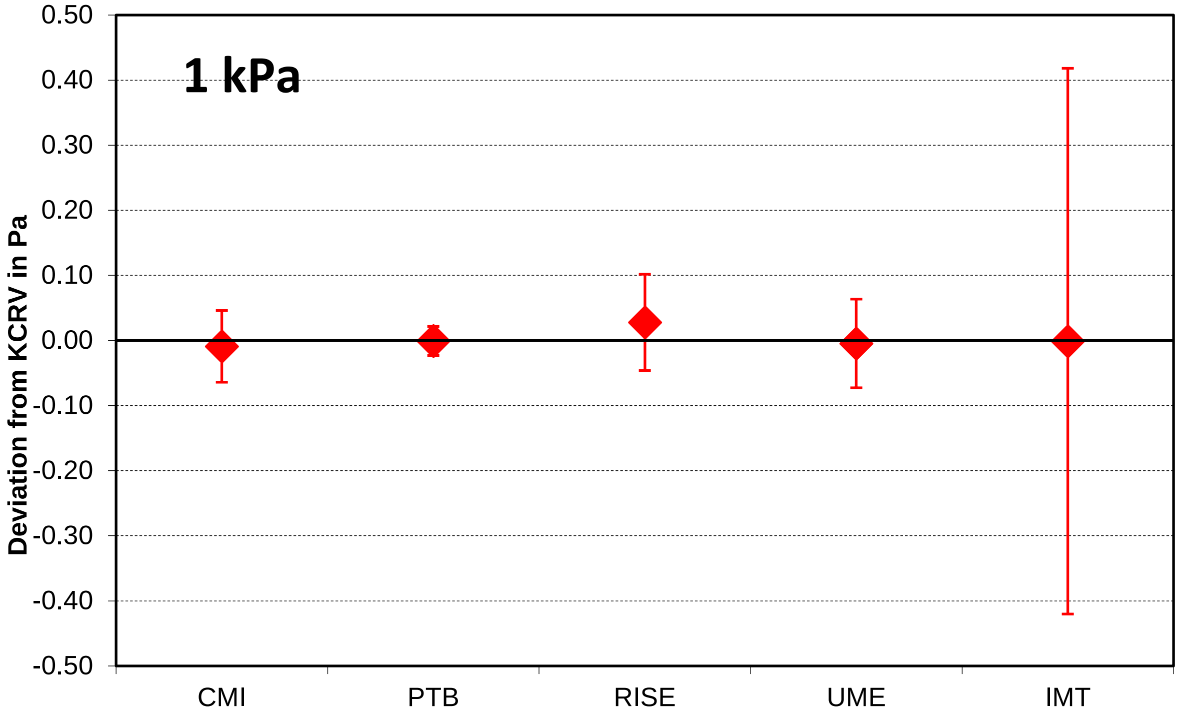

Figure 7. Deviations of NMIs results from KCRV at 1 kPa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

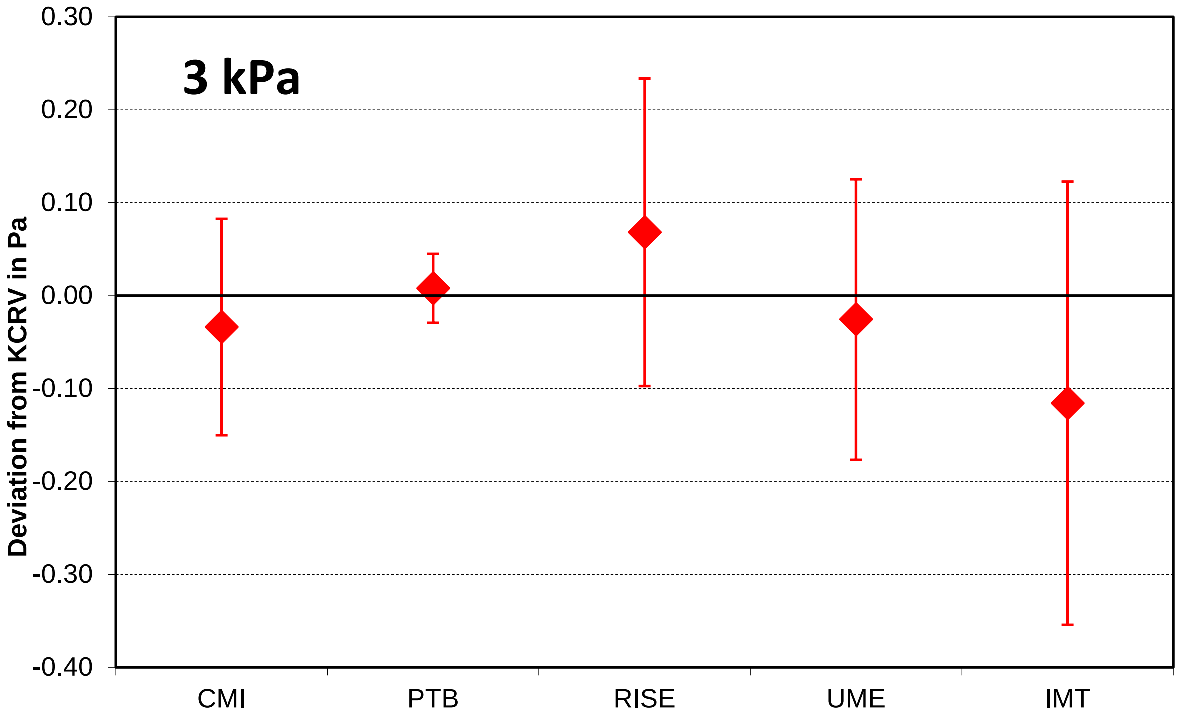

Figure 8. Deviations of NMIs results from KCRV at 3 kPa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

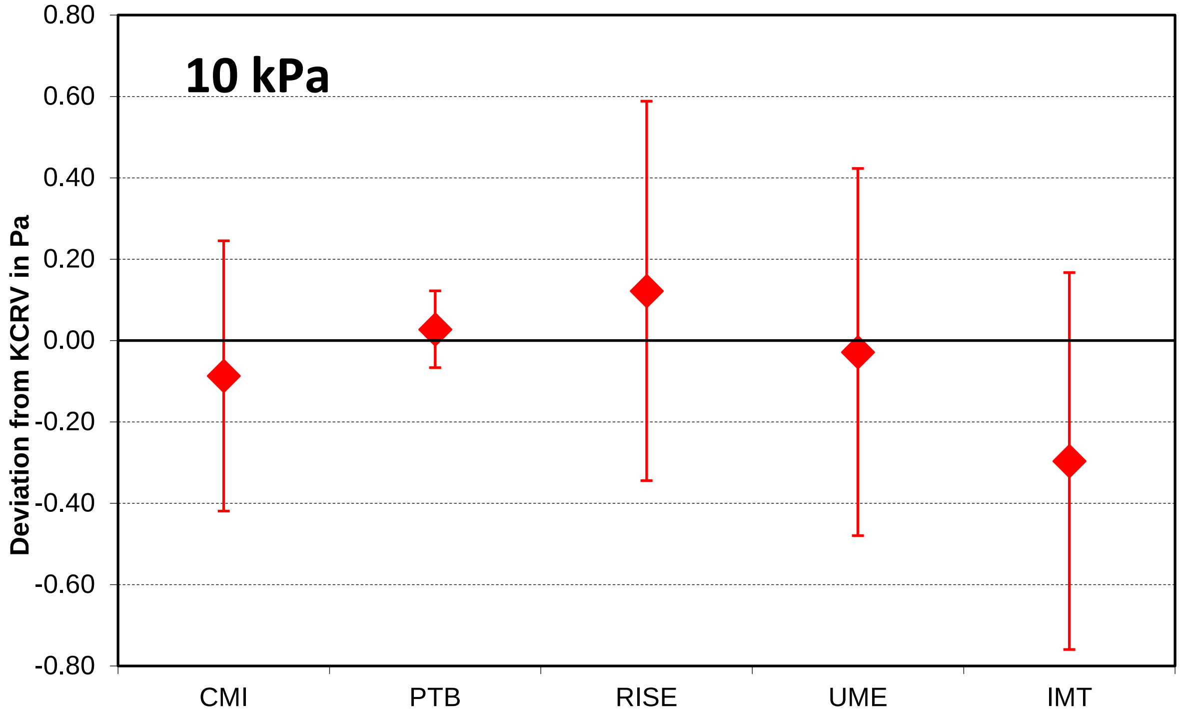

Figure 9. Deviations of NMIs results from KCRV at 10 kPa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

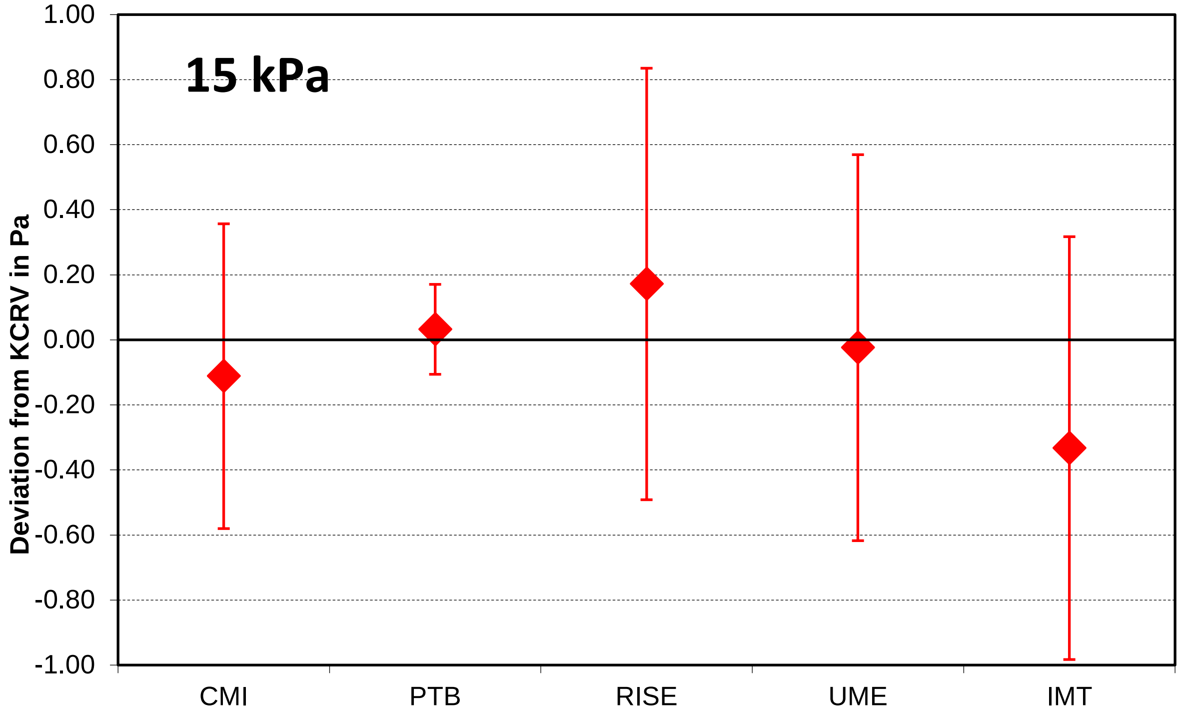

Figure 10. Deviations of NMIs results from KCRV at 15 kPa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

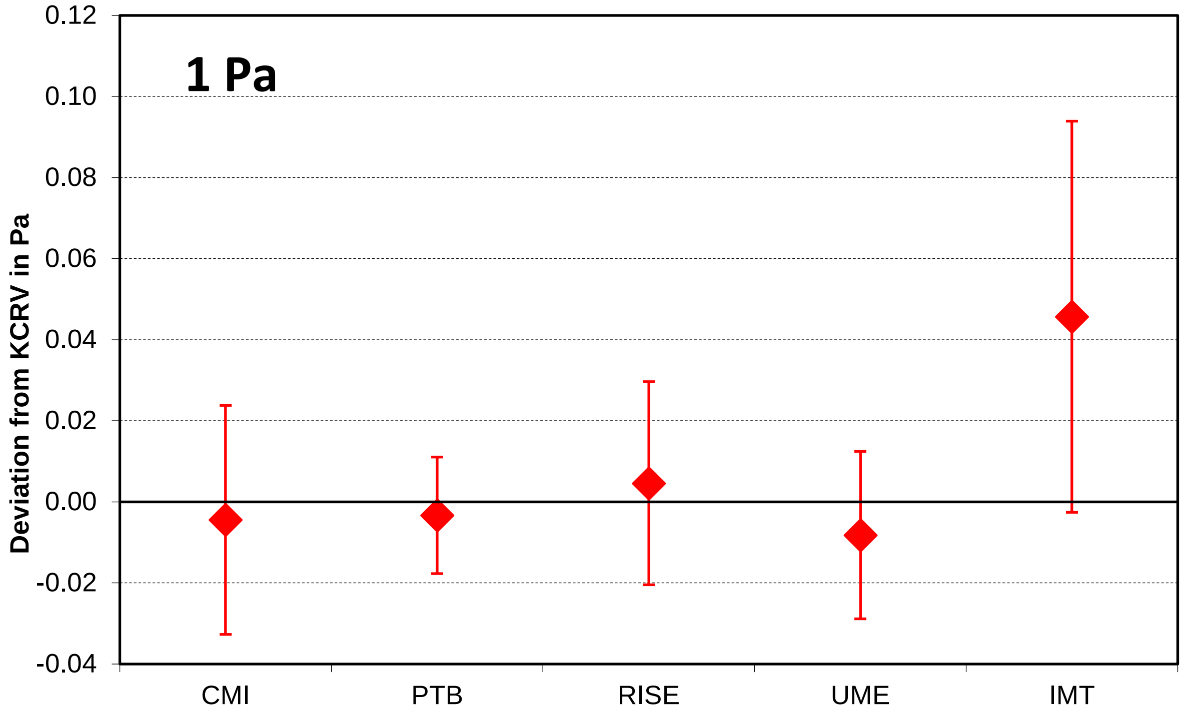

Figure 11. Deviations of NMIs results from KCRV at 1 Pa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

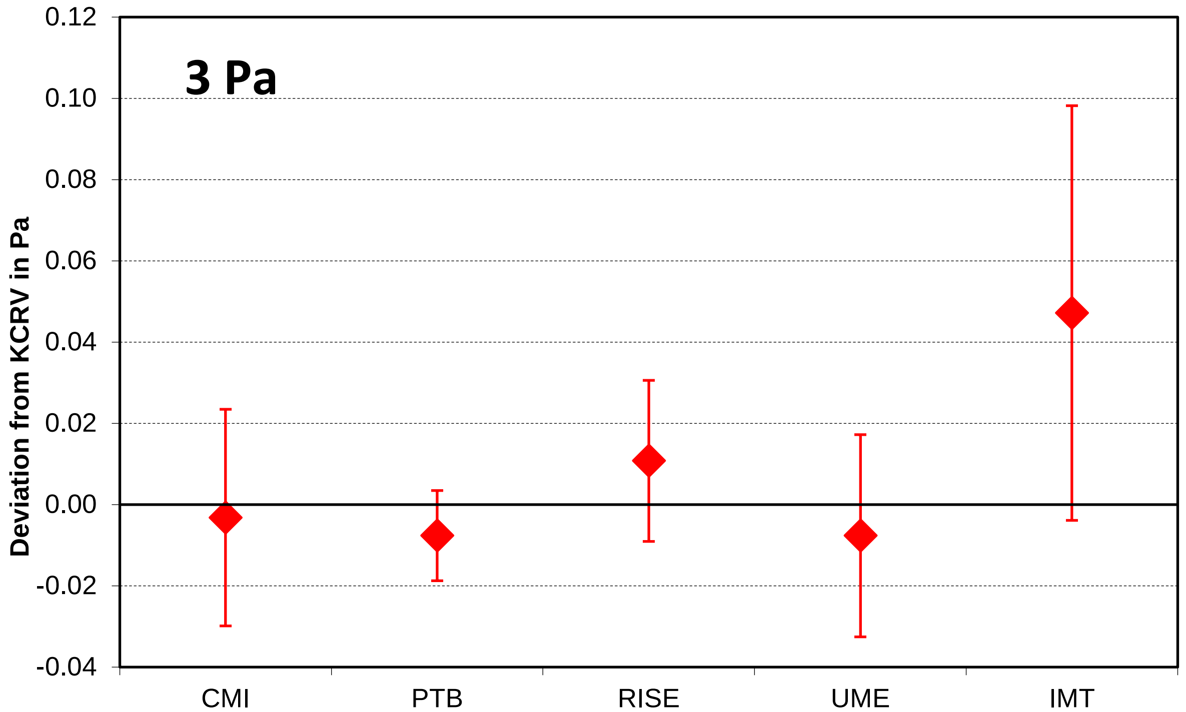

Figure 12. Deviations of NMIs results from KCRV at 3 Pa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

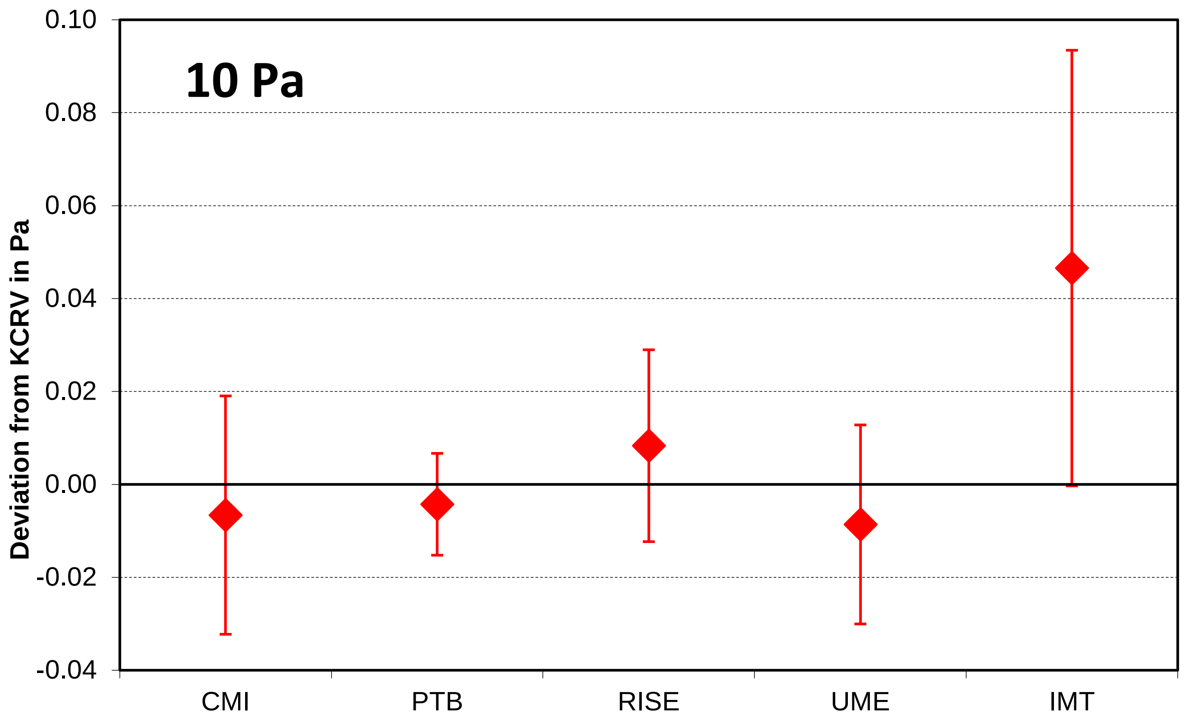

Figure 13. Deviations of NMIs results from KCRV at 10 Pa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

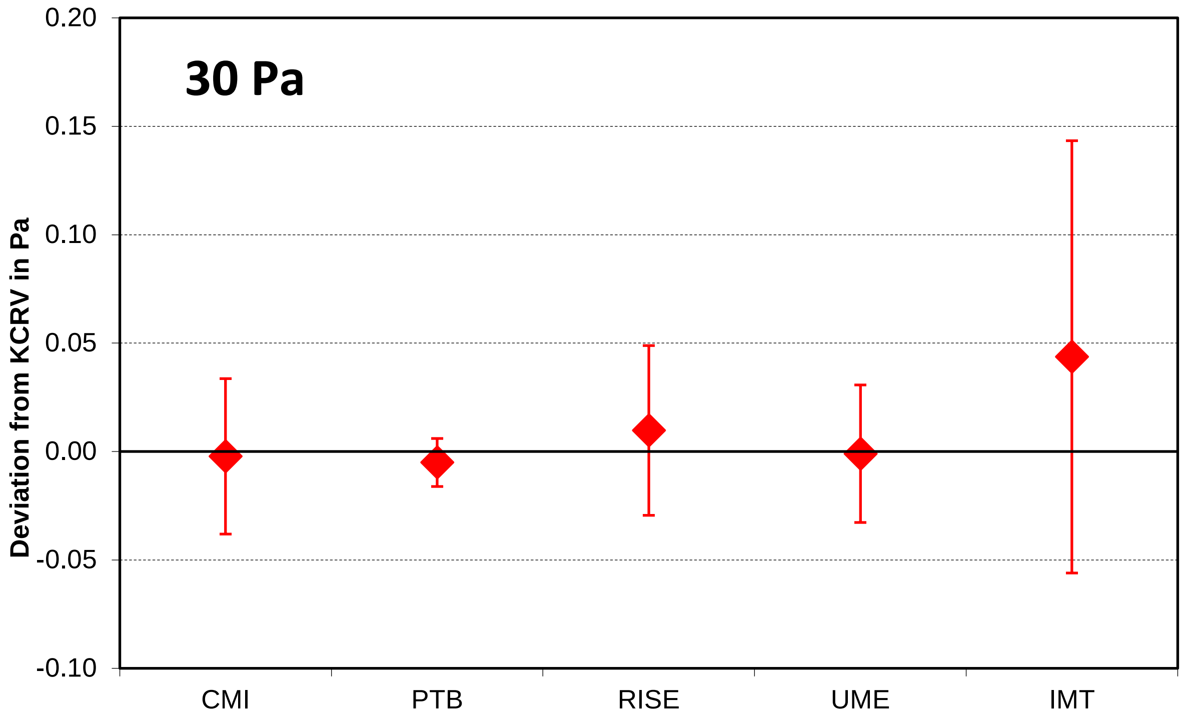

Figure 14. Deviations of NMIs results from KCRV at 30 Pa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

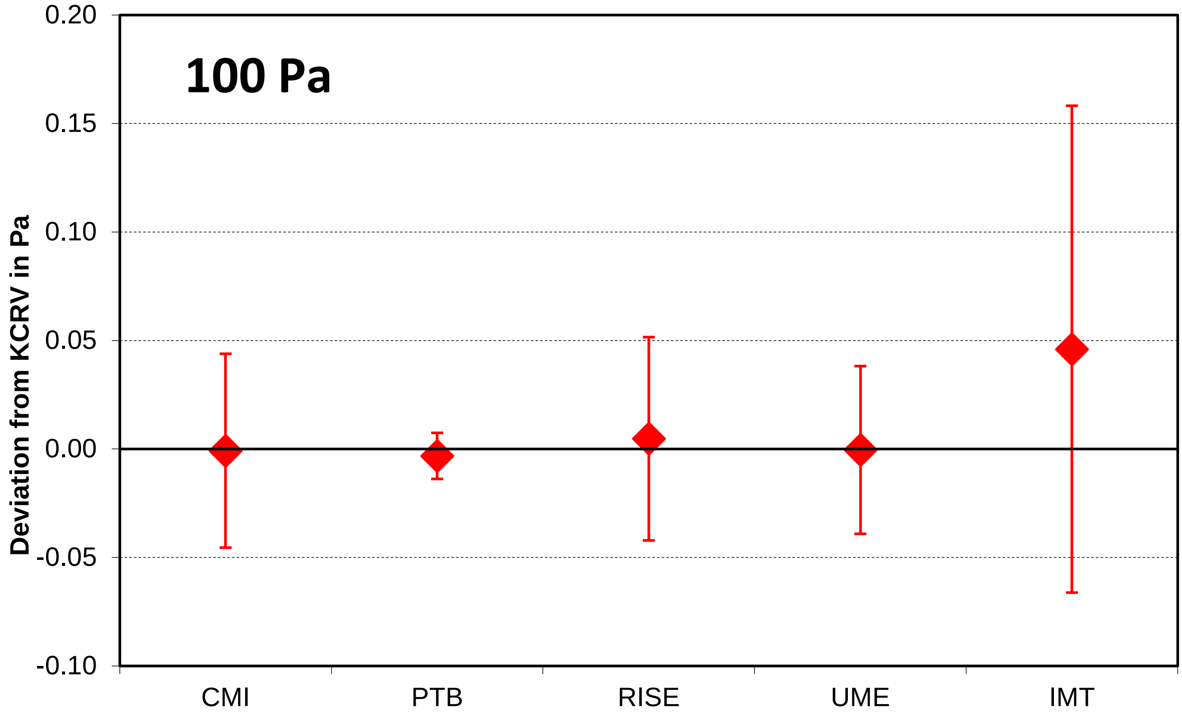

Figure 15. Deviations of NMIs results from KCRV at 100 Pa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

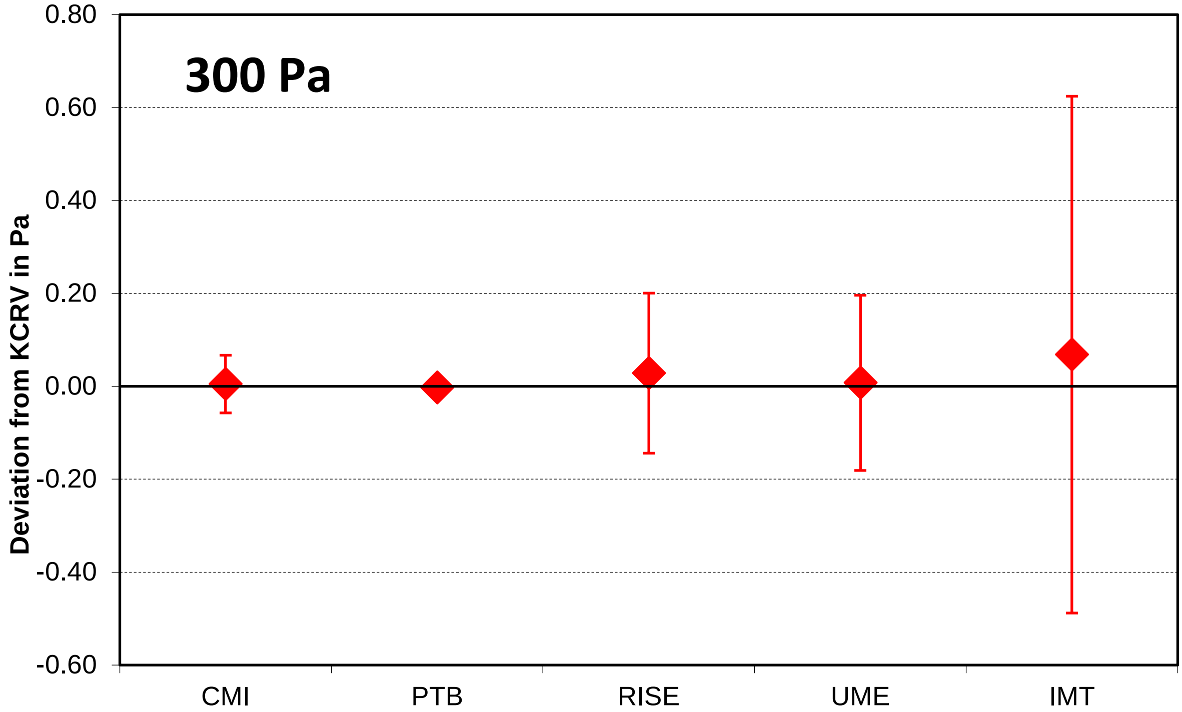

Figure 16. Deviations of NMIs results from KCRV at 300 Pa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

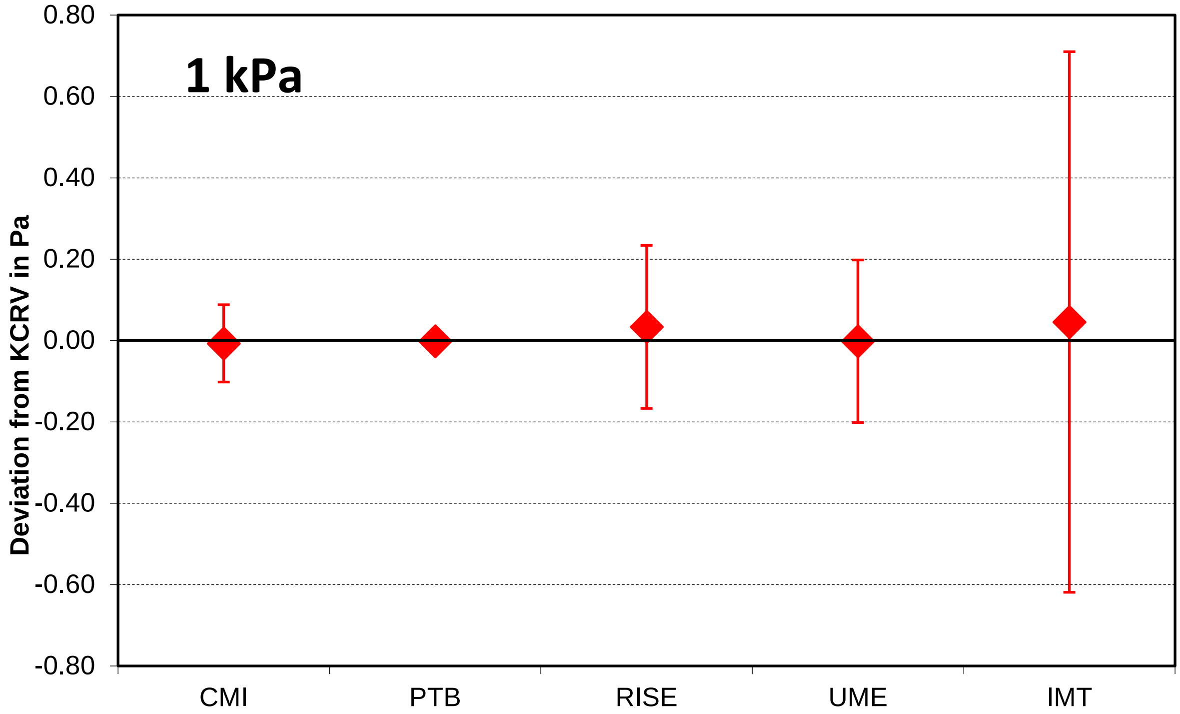

Figure 17. Deviations of NMIs results from KCRV at 1 kPa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

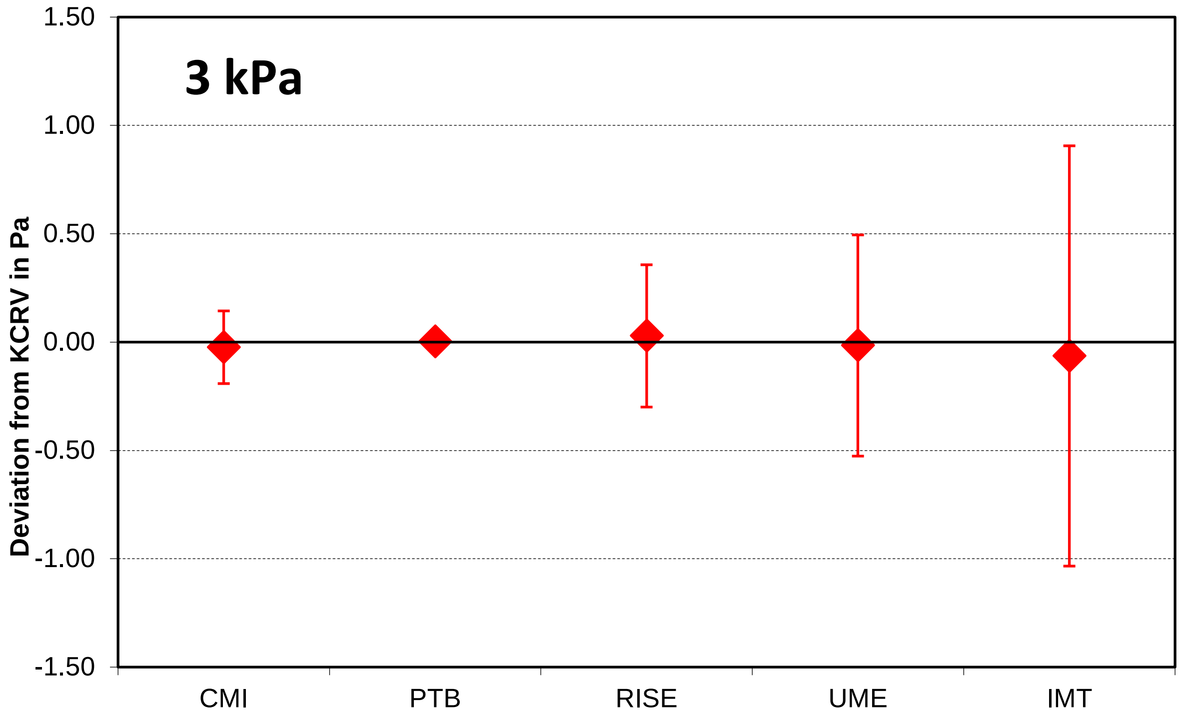

Figure 18. Deviations of NMIs results from KCRV at 3 kPa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

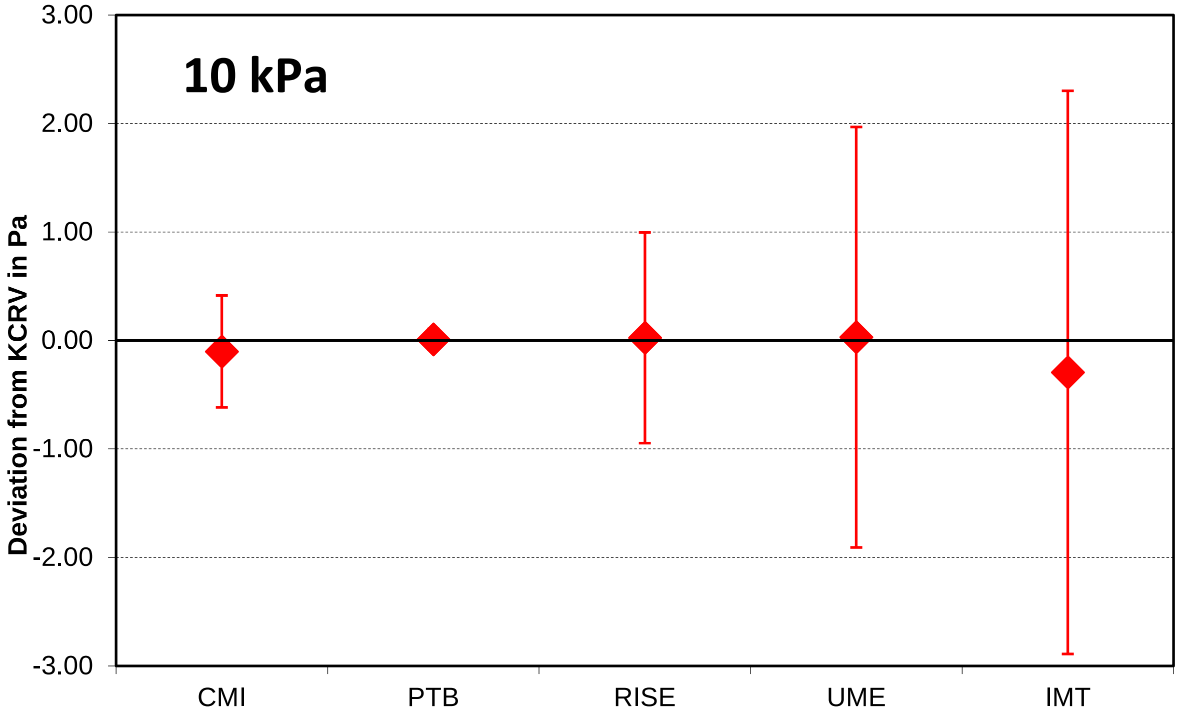

Figure 19. Deviations of NMIs results from KCRV at 10 kPa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

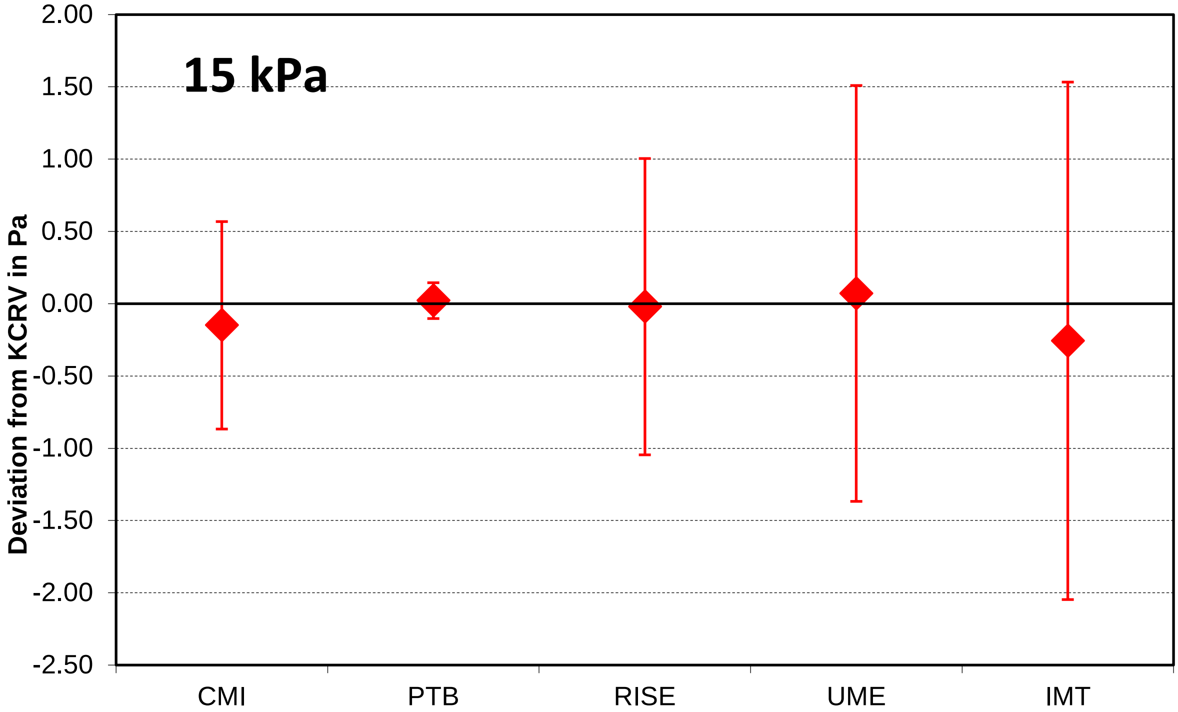

Figure 20. Deviations of NMIs results from KCRV at 15 kPa of gauge pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

8. LINKING TO REFERENCE VALUE OF CCM KEY COMPARISON CCM.P-K4.2012

The results of the present KC in absolute pressure mode can be linked to the KCRV of CCM.P-K4.2012, at the common nominal pressure points of both KCs, using the CMI results obtained in the present and the CCM comparison. The deviation of NMI i from the KCRV of the CCM KC ($D_{i,\mathrm{CCM}}$) is given by

$$D_{i,\mathrm{CCM}} = d_i + D_{\mathrm{CMI,CCM}} \,, \tag{46}$$

where $D_{\mathrm{CMI,CCM}}$ is the deviation of the CMI result from the KCRV of the CCM KC.

The deviation of the KCRV of the present EURAMET KC from the KCRV of the CCM KC, ($D_{\mathrm{EURAMET,CCM}}$) is given by

$$D_{\mathrm{EURAMET,CCM}} = -D_{\mathrm{T}} + D_{\mathrm{CMI,CCM}} \,. \tag{47}$$

The standard uncertainty of $D_{i,\mathrm{CCM}}$ ($u_{D_{i,\mathrm{CCM}}}$) is calculated from the uncertainty of d_i, u_{d_i}, and the uncertainty of $D_{\mathrm{CMI,CCM}}$ ($u_{D_{\mathrm{CMI,CCM}}}$) taking into account that each of these uncertainties contains the uncertainty of the CMI standard, u_{CMI}, which should be appropriately subtracted from them.

Deviations $D_{\mathrm{CMI,CCM}}$ and their expanded ($k = 2$) uncertainties ($U_{D_{\mathrm{CMI,CCM}}}$), $U_{D_{\mathrm{CMI,CCM}}} = 2u_{D_{\mathrm{CMI,CCM}}}$, are given in the final report of CCM.P-K4.2012 [2], Table 5, columns D_j and U_j. According to equation (22) in this report, the standard deviation of $D_{\mathrm{CMI,CCM}}$, at each pressure, was calculated by

$$u_{D_{\mathrm{CMI,CCM}}} = \left[\left(1 - \frac{2}{N_{\mathrm{CCM}}}\right) u^2_{\mathrm{CMI,CCM}} + \frac{1}{N^2_{\mathrm{CCM}}} \sum_{j}^{N_{\mathrm{CCM}}} u_j^2\right]^{0.5} , \tag{48}$$

where are

N_{CCM}	number of the participants in CCM.P-K4.2012, $N_{\mathrm{CCM}} = 6$,
$u_{\mathrm{CMI,CCM}}$	standard uncertainty of the CMI result in CCM.P-K4.2012, given in the final report of CCM.P-K4.2012 [2], Table 4, column $u_{\mathrm{c}}(p_j)$,
u_j	standard uncertainty of participant j, one of which is CMI.

Equation (48) can be rewritten as

$$u_{D_{\mathrm{CMI,CCM}}} = \left[\left(1 - \frac{2}{N_{\mathrm{CCM}}} + \frac{1}{N^2_{\mathrm{CCM}}}\right) u^2_{\mathrm{CMI,CCM}} + \frac{1}{N^2_{\mathrm{CCM}}} \sum_{j \neq j_{\mathrm{CMI}}}^{N_{\mathrm{CCM}}} u_j^2\right]^{0.5} . \tag{49}$$

Herewith

$$u_{D_{i,\mathrm{CCM}}} = \left[u^2_{d_i} - u^2_{\mathrm{CMI}} + \left(1 - \frac{2}{N_{\mathrm{CCM}}} + \frac{1}{N^2_{\mathrm{CCM}}}\right)\left(u^2_{\mathrm{CMI,CCM}} - u^2_{\mathrm{CMI}}\right) + \frac{1}{N^2_{\mathrm{CCM}}} \sum_{j \neq j_{\mathrm{CMI}}}^{N_{\mathrm{CCM}}} u_j^2 + u^2_{\mathrm{Tstab,C-E}}\right]^{0.5} , \tag{50}$$

where $u_{\mathrm{Tstab,C-E}}$ is stability of the CMI FPG over the time from the beginning of CCM.P-K4.2012 to the end of the present KC, equal to $t_{\mathrm{C-E}} = 7.05$ years, calculated by (26) and resulting in

$$u_{\text{Tstab,C-E}} = 14 \text{ mPa} + 8.5{\cdot}10^{-6} \times p \ . \tag{51}$$

Finally, the expanded (k = 2) uncertainty of $D_{i,\text{CCM}}$ ($U_{D_{i,\text{CCM}}}$) is calculated by

$$U_{D_{i,\text{CCM}}} = 2\left[u_{d_i}^2 + u_{D_{\text{CMI,CCM}}}^2 - \left(2 - \frac{2}{N_{\text{CCM}}} + \frac{1}{N_{\text{CCM}}^2}\right)\left(u_{\text{CMI,CCM}}^2 - u_{\text{CMI}}^2\right) + u_{\text{Tstab,C-E}}^2\right]^{0.5}. \tag{52}$$

The degrees of equivalence between participants in the present EURAMET KC, denoted by index i, and participants in CCM.P-K4.2012, denoted by index m, are given by the differences of their results (D_{im}) and the expanded ($k = 2$) uncertainties of these differences ($U_{D_{im}}$). They are determined using the differences between the CMI and laboratories' results within the CCM KC ($D_{\text{CMI},m}$) and their expanded (k = 2) uncertainties ($U_{D_{\text{CMi},m}}$), which are given in the final report of CCM.P-K4.2012 [2], Table 5, columns $D_{jj'}$ and $U_{jj'}$.

Herewith

$$D_{im} = d_i + D_{\text{CMI},m} \ , \tag{53}$$

$$U_{D_{im}} = 2\left[u_{d_i}^2 + \left(U_{D_{\text{CMi},m}}/2\right)^2 - 2u_{\text{CMI}}^2 + u_{\text{Tstab,C-E}}^2\right]^{0.5}. \tag{54}$$

The degrees of equivalence of the present EURAMET KC's results in relation to the KCRV and participants' results of CCM.P-K4.2012 are presented in Table 4.
Deviations of the EURAMET results from the CCM KCRV and the expanded (k = 2) uncertainties of these deviations, $D_{i,\text{CCM}}$ and $U_{D_{i,\text{CCM}}}$, were calculated by equations (46) and (52), respectively.

Deviations of the NMIs' EURAMET and CCM KC results and the expanded (k = 2) uncertainties of these differences, D_{im} and $U_{D_{im}}$ (in the table denoted by U_{im}), were calculated by equations (53) and (54), respectively.

The orange shaded cells in Table 4 indicate results for which the condition of equivalence at the k = 2 level of confidence is not satisfied, that is, where $\left|D_{i,\text{CCM}}\right| > U_{i,\text{CCM}}$ or $|D_{im}| > U_{im}$.

The degrees of equivalence of the NMIs results in the present comparison with respect to the key comparison reference values of CCM.P-K4.2012 are shown graphically from Figure 21 to Figure 29 as plots of deviations $D_{i,\text{CCM}}$ together with the deviations of the CCM.P-K4.2012 participants, taken from the final report of CCM.P-K4.2012 [2], Table 5. The uncertainty bars of the NMIs' deviations are the expanded uncertainties of these deviation the k = 2 confidence level.

In addition, by yellow filled symbols, Figure 21 to Figure 29 show deviations of the KCRV of the present EURAMET KC from the KCRV of the CCM KC, $D_{\text{EURAMET,CCM}}$, calculated by equation (47), and of the CCM KCRV itself, being per definition equal zero. The uncertainty bars of these deviations are the expanded (k = 2) uncertainties of the EURAMET KCRV, $U_{\text{KCRV,EURAMET}}$, and of the CCM KCRV, $U_{\text{KCRV,CCM}}$, (not uncertainties of the deviations!). Uncertainties $U_{\text{KCRV,EURAMET}}$ were calculated by equation (32). Uncertainties $U_{\text{KCRV,CCM}}$ were calculated by

$$U_{\text{KCRV,CCM}} = 2\frac{1}{N_{\text{CCM}}}\left[\sum_{j}^{N_{\text{CCM}}} u_j^2\right]^{0.5} , \tag{55}$$

taking into account the definition of the KCRV in the final report of CCM.P-K4.2012 [2], equation (20) and participants' standard uncertainties given in the last column of Table 4 in that report.

Table 4. Degrees of equivalence for absolute pressure of the results of the present EURAMET.M.P-K4.2020 and the CCM.P-K4.2012 comparison at nominal pressures (p_{nom}): Deviations of the EURAMET KC NMIs (i) results from the CCM KCRV ($D_{i,\mathrm{CCM}}$) with their expanded uncertainties ($U_{i,\mathrm{CCM}}$) and differences between the EURAMET KC NMIs (i) and the CCM KC NMIs (m) results (D_{im}) with their expanded uncertainties (U_{im}), all given in Pa.

NMI i	p_{nom} / Pa	CCM KCRV		NMI m: PTB, CCM [1]		NMI m: NMIJ		NMI m: NIST		NMI m: CENAM		NMI m: VNIIM	
		$D_{i,\mathrm{CCM}}$	$U_{i,\mathrm{CCM}}$	D_{im}	U_{im}	D_{im}	U_{im}	D_{im}	U_{im}	D_{im}	U_{im}	D_{im}	U_{im}
PTB	1	0.016	0.043	0.016	0.047	0.015	0.047	0.010	0.046	0.026	0.053	0.017	0.054
	3	0.032	0.043	0.032	0.047	0.030	0.048	0.026	0.046	0.047	0.054	0.037	0.054
	10	0.037	0.044	0.033	0.049	0.032	0.072	0.028	0.046	0.081	0.065	0.040	0.054
	30	0.062	0.054	0.044	0.065	0.048	0.167	0.037	0.046	0.180	0.117	0.051	0.055
	100	0.050	0.062	0.010	0.069	0.046	0.187	0.012	0.053	0.187	0.218	0.054	0.060
	300	0.061	0.124	0.019	0.078	0.044	0.171	0.022	0.061	0.183	0.634	0.100	0.071
	1000	0.133	0.365	0.027	0.100	0.056	0.195	0.059	0.076	0.361	2.137	0.285	0.133
	3000	0.032	0.199	0.022	0.190	0.112	0.340	0.152	0.120	0.072	0.170	-0.218	0.950
	10000	0.235	0.359	0.265	0.557	0.235	0.761	0.435	0.297	0.445	0.340	-0.065	1.043
RISE	1	0.007	0.050	0.007	0.054	0.006	0.054	0.001	0.053	0.017	0.059	0.008	0.060
	3	0.017	0.052	0.017	0.055	0.015	0.056	0.011	0.055	0.032	0.061	0.022	0.061
	10	0.023	0.055	0.019	0.059	0.018	0.079	0.014	0.056	0.067	0.073	0.026	0.063
	30	0.066	0.063	0.048	0.072	0.052	0.170	0.041	0.056	0.184	0.121	0.055	0.063
	100	0.081	0.067	0.041	0.073	0.077	0.189	0.043	0.059	0.218	0.219	0.085	0.065
	300	0.073	0.127	0.031	0.083	0.056	0.174	0.034	0.068	0.195	0.635	0.112	0.077
	1000	0.162	0.372	0.056	0.124	0.085	0.209	0.088	0.106	0.390	2.139	0.314	0.152
	3000	0.092	0.265	0.082	0.259	0.172	0.383	0.212	0.213	0.132	0.244	-0.158	0.966
	10000	0.329	0.626	0.359	0.758	0.329	0.918	0.529	0.593	0.539	0.615	0.029	1.163
UME	1	0.006	0.045	0.006	0.049	0.005	0.049	0.000	0.048	0.016	0.054	0.007	0.055
	3	0.016	0.045	0.016	0.049	0.014	0.049	0.010	0.048	0.031	0.055	0.021	0.055
	10	0.034	0.046	0.030	0.051	0.029	0.073	0.025	0.048	0.078	0.067	0.037	0.055
	30	0.055	0.056	0.037	0.066	0.041	0.168	0.030	0.049	0.173	0.118	0.044	0.057
	100	0.063	0.061	0.023	0.068	0.059	0.187	0.025	0.052	0.200	0.218	0.067	0.059
	300	0.062	0.126	0.020	0.081	0.045	0.173	0.023	0.065	0.184	0.635	0.101	0.075
	1000	0.129	0.372	0.023	0.123	0.052	0.208	0.055	0.104	0.357	2.138	0.281	0.151
	3000	-0.002	0.268	-0.012	0.262	0.078	0.385	0.118	0.216	0.038	0.247	-0.252	0.967
	10000	0.179	0.604	0.069	0.739	0.179	0.902	0.379	0.569	0.389	0.592	-0.121	1.151
IMT	1	-0.002	0.040	-0.002	0.044	-0.003	0.044	-0.008	0.043	0.008	0.050	-0.001	0.051
	3	0.014	0.040	0.014	0.044	0.012	0.045	0.008	0.043	0.029	0.051	0.019	0.051
	10	0.038	0.043	0.034	0.048	0.033	0.071	0.029	0.045	0.082	0.064	0.041	0.053
	30	0.055	0.063	0.037	0.072	0.041	0.170	0.030	0.056	0.173	0.121	0.044	0.063
	100	0.063	0.132	0.023	0.136	0.059	0.221	0.025	0.128	0.200	0.247	0.067	0.131
	300	0.063	0.198	0.021	0.174	0.046	0.231	0.024	0.167	0.185	0.653	0.102	0.171
	1000	0.133	0.554	0.027	0.429	0.056	0.461	0.059	0.424	0.361	2.178	0.285	0.438
	3000	-0.092	0.304	-0.102	0.299	-0.012	0.411	0.028	0.260	-0.052	0.286	-0.342	0.978
	10000	-0.089	0.573	-0.059	0.714	-0.089	0.882	0.111	0.536	0.121	0.561	-0.389	1.135

[1] PTB participated in the EURAMET.M.P-K4.2020 and the CCM.P-K4.2012 KCs with different standards.

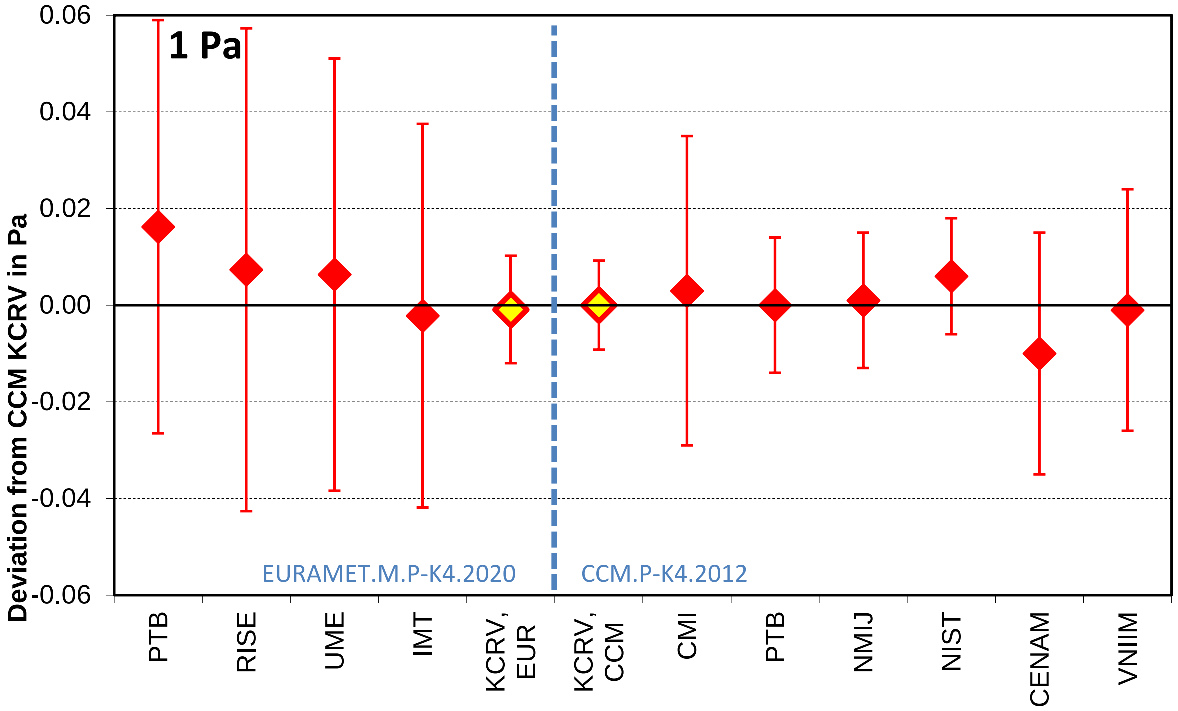

Figure 21. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 1 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

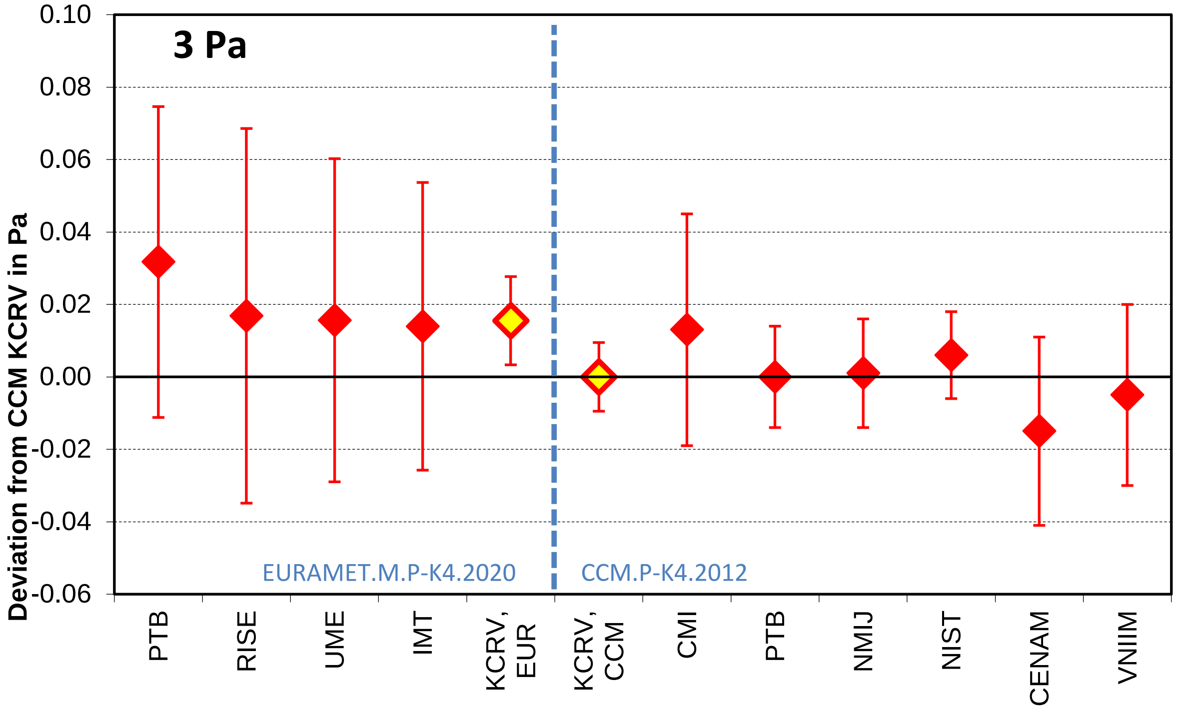

Figure 22. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 3 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

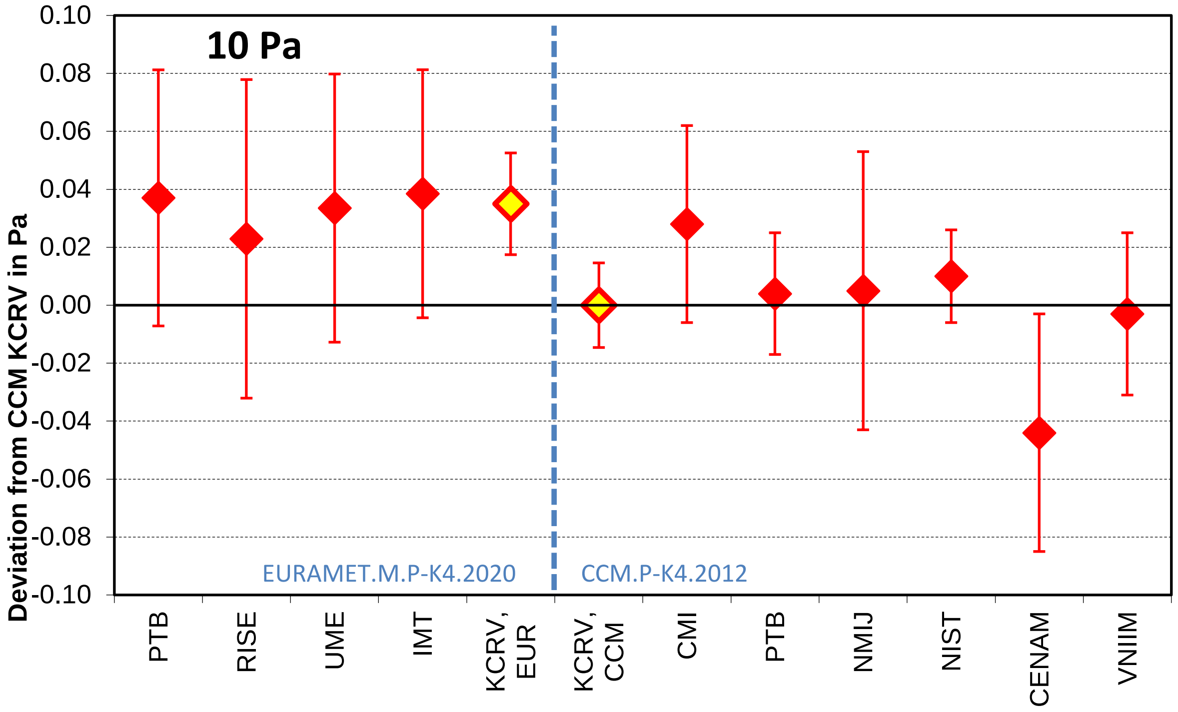

Figure 23. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 10 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

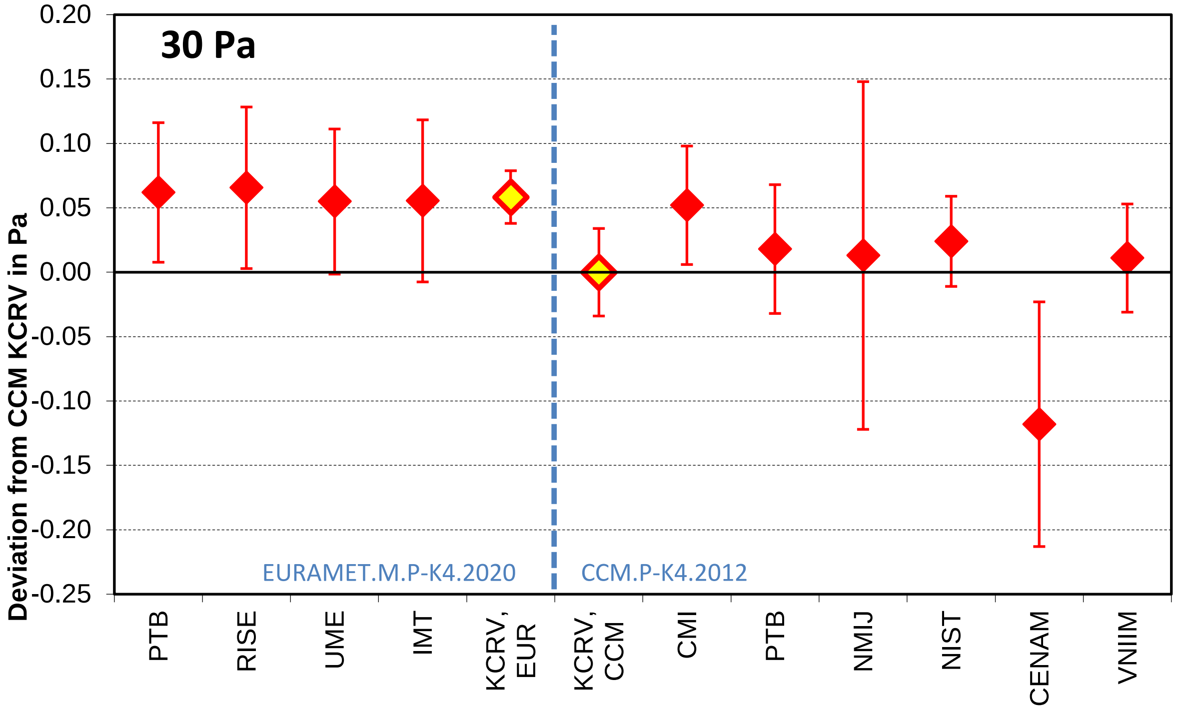

Figure 24. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 30 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

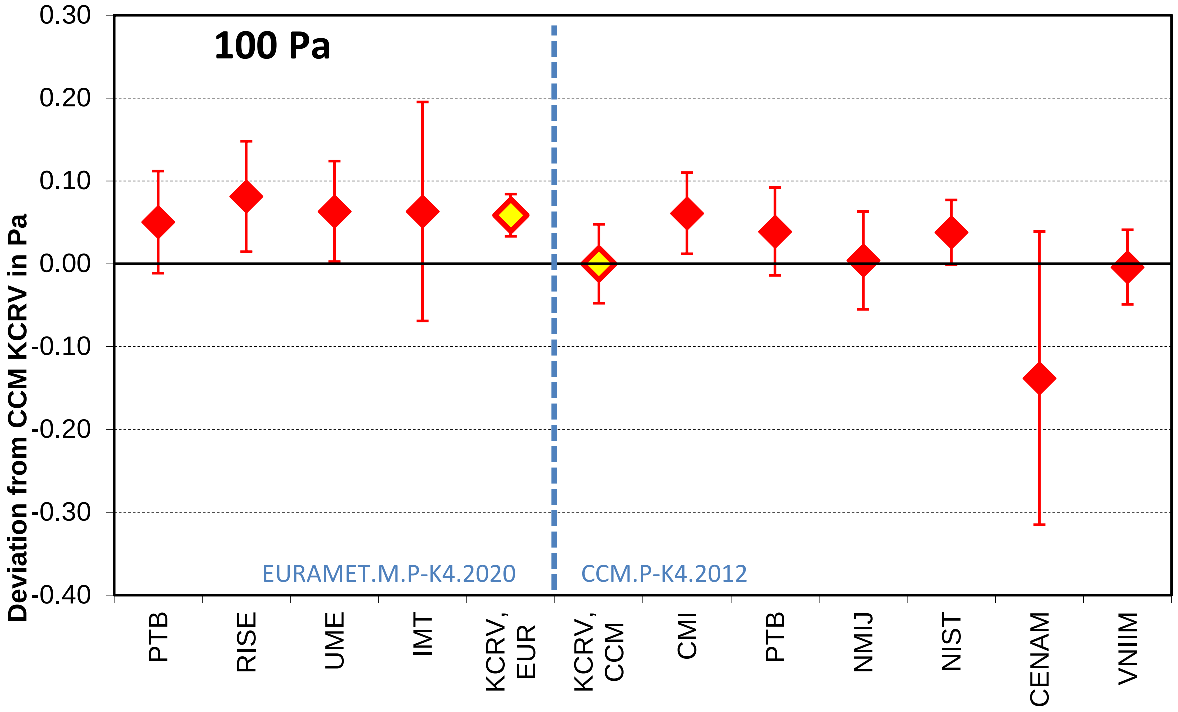

Figure 25. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 100 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

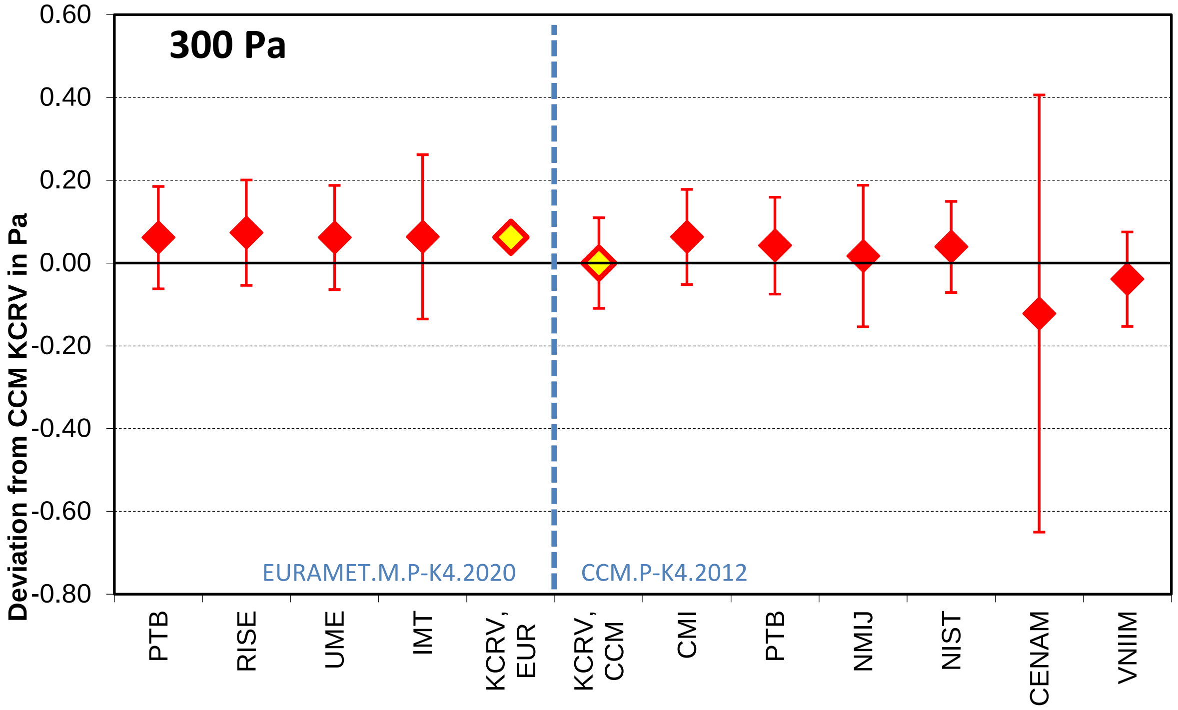

Figure 26. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 300 Pa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

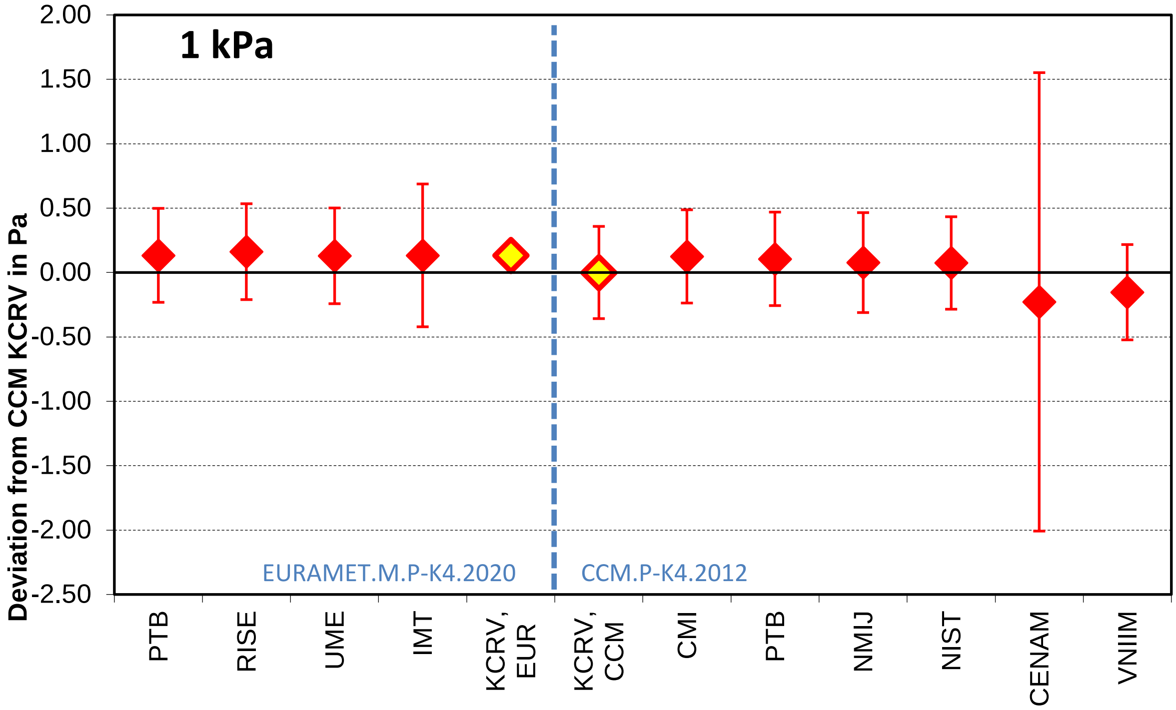

Figure 27. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 1 kPa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

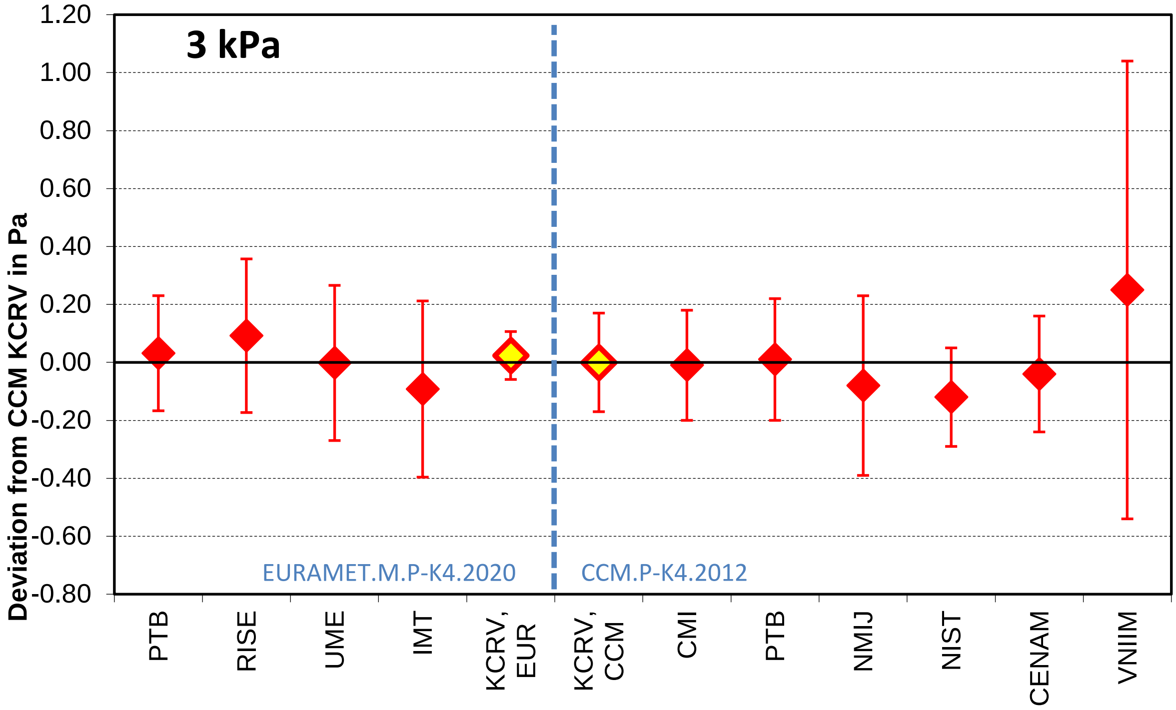

Figure 28. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 3 kPa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

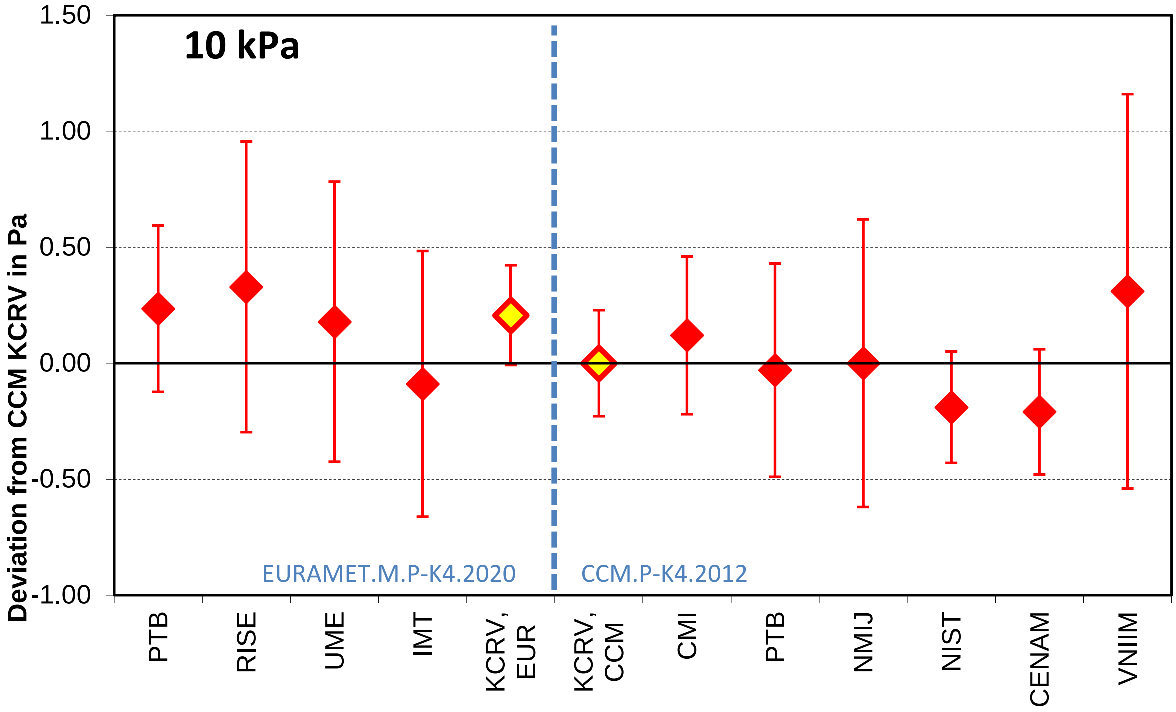

Figure 29. Deviations of NMIs results from KCRV of CCM.P-K4.2012 at 10 kPa of absolute pressure. Uncertainty bars show combined expanded (k = 2) uncertainties of the deviations.

9. DISCUSSION

According to Table 4, 4 of 36 reported results (of PTB, RISE and UME) show a marginal disagreement with the CCM KCRV at least for one of the pressures 30 Pa and 100 Pa. These deviations correlate with the deviations of the CMI results from the CCM KCRV within the CCM KC, which slightly violated the equivalence criterion at 30 Pa and 100 Pa (report [2], Table 5). This is clearly seen in the graphical presentation of the results in Figure 23, Figure 24, and Figure 25: the EURAMET KC results and the CMI result within the CCM KC always present a consistent group, which slightly deviates from the CCM KCRV, as the CMI results do this. At the same time, the observed non-equivalence is insignificant - with a k = 3 coverage factor all EURAMET results agree with the CCM KCRV. Statistically, the equivalences of the EURAMET and CCM KCs results in respect to the CCM KCRV are similar – the percentage of (marginally) non-equivalent results within CCM.P-K4.2012 is the same as for the EURAMET results, 4 of 36 results reported for the same target pressures as in the present EURAMET KC.

Additional information about relation of the EURAMET and CCM KCs results at (3, 10, and 30) Pa can be obtained from the results of a direct comparison of the PTB standard used in the EURAMET KC, the PTB FPG, and the PTB standard used in the CCM KC, the PTB static expansion system SE2, published in [11]. According to those results, the mean differences between the PTB EURAMET KC and PTB CCM KC pressures at (3, 10, and 30) Pa would be equal to (0.007, 0.009, and 0.015) Pa, respectively. In Annex 3, a supplementary table of the degrees of equivalence between the EURAMET and CCM KCs results is presented for the case when the link between the two KCs at (3, 10, and 30) Pa was produced based on the PTB measurements [11]. According to this alternative table, all EURAMET KC participants are equivalent with the CCM KCRV below 100 Pa.

The observed deviation of the EURAMET results from the CCM KCRV can, to some extent, be also explained by the calculation method of the CCM KCRV, taken as a non-weighted mean. In the CCM KC, the CENAM results at (10, 30 or 100) Pa deviate from the rest and pull the CCM KCRV downwards stronger than this would be when the participants results were weighted by their uncertainties. Especially at (30 and 100) Pa, Figure 24 and Figure 25, it is seen that all EURAMET and CCM results, without the

CENAM ones, present more homogeneous groups than the groups of the CCM results only including the CENAM results.

As for comparing the EURAMET KC NMIs results with those of the CCM KC NMIs in pairs, disagreement for 18 of 180 paired results is observed, with the percentage of 10 % which is not bigger than in the CCM KC group, where for 16 of 150 paired results a disagreement was observed. In most cases, the non-equivalence between the EURAMET and CCM KCs' participants is marginal. A significant non-equivalence, i.e. taking place even on a k = 3 coverage factor's level, is observed in 5 cases: for CENAM vs. PTB and RISE at 30 Pa, and for VNIIM vs. PTB, RISE and UME at 1 kPa. The same number 5 of significant non-equivalences was observed within CCM.P-K4.2012, however in all cases for the VNIIM results.

The comparison of the present EURAMET KC and CCM.P-K4.2012 results is also interesting under aspect of different traceability of the standards used in both KCs.
In CCM.P-K4.2012, 4 primary liquid column manometers, 2 force-balanced piston gauges traceable to primary liquid column manometers or dead-weight pressure balances, 2 resonant silicon pressure gauges traceable to dead-weight pressure balances, and 3 static expansion systems were used.
Within present EURAMET.M.P-K4.2020, 4 of 5 participants used force-balanced piston gauges, characterised as primary pressure standards or traceable to dead-weight pressure balances, and one participant used capacitance diaphragm gauges and a quartz bourdon gauge, traceable to a static expansion system and to a dead-weight pressure balance.
At pressures below 30 Pa, the uncertainty of the EURAMET KCRV is slightly bigger than that of the CCM KC, which expresses a better performance of the SES and oil-based liquid column manometer than of force-balanced piston gauges-based techniques in this pressure range. From 30 Pa upwards, the uncertainty of the EURAMET KCRV becomes lower than that of the CCM KC, because the force-balanced piston gauges perform better than several other standards applied within CCM.P-K4.2012.

10. CONCLUSIONS

The present comparison was successful as it demonstrates equivalence of the participants for gauge and absolute pressure, with the key comparison reference value and with each other at all pressure points of the comparison. A special way of the evaluation of the degrees of equivalence was required because the standard of CMI was used as a transfer standard and, simultaneously, as a standard under comparison. The key comparison reference value was calculated as the weighted mean, which is justified by a successful chi-squared test.

The results of this comparison were linked to those of CCM.P-K4.2012 using results of CMI obtained in both comparisons. Some participants of the present KC showed marginal disagreements with the CCM KCRV at 30 Pa or/and 100 Pa, which might deal with the uncertainty of the link of the two KCs, and which are not bigger and not more frequent as observed within CCM.P-K4.2012. Significant non-equivalences were observed only against CENAM results at 30 Pa and VNIIM results at 1 kPa, which also were conspicuous within the CCM.P-K4.2012 results.

In both, absolute and gauge modes, all results agree with the respective KCRVs of the present KC, and all laboratories can be considered equivalent.

In relation to the KCRV of CCM.P-K4.2012, overall 89 % of the data points are in agreement on the k = 2 coverage factor's level, and none were in disagreement at a k = 3 coverage factor.

Since there were only six labs determining the KCRV of CCM.P-K4.2012, the coverage factor is around 90 % for k = 2 [2] and additionally since there is 100 % agreement at k = 3, we can assume that all EURAMET KC labs with disagreements can be considered statistically equivalent with the KCRV of the CCM KC.

11. ACKNOWLEDGEMENTS

Contributions by the following colleagues, Ahmed Hashad (PTB), who essentially contributed to the PTB measurements within this KC and to characterisation of the PTB FPG, Zdeněk Krajíček (CMI), in his work and support of this KC on the CMI side, and D. Mehmet Demirel (UME), who essentially contributed to the UME measurements within this KC, are much appreciated.

12. REFERENCES

1. Krajíček Z., Bergoglio M., Jousten K., Otal P., Sabuga W., Saxholm S., Pražák D. and Vičar M. Final report on EURAMET.M.P-K4.2010: Key and supplementary comparison of national pressure standards in the range 1 Pa to 15 kPa of absolute and gauge pressure, *Metrologia* **51** (2014) Tech. Suppl. 07002
2. Ricker J., Hendricks J., Bock T., Pražák D., Kobata T., Torres J., Sadkovskaya I. Final report on the key comparison CCM.P-K4.2012 in absolute pressure from 1 Pa to 10 kPa, *Metrologia* **54** (2017) Tech. Suppl. 07002
3. Delajoud P., Girard M. Piston gauge with electronic balance for calibrations of very low pressures, *Vakuum in Forschung und Praxis* **15** (2003) 24-29
4. Tesar J., Repa P., Prazak D., Krajicek Z., Peksa L. The new method of traceability of a force balanced piston gauge used as primary vacuum standard, *Vacuum* **76** (2004) 491-499
5. Pražák D., Krajíček Z., Vičar M., Experience with force-balanced piston gauge as a transfer standard, Proc. of XXI IMEKO World Congress “Measurement in Research and Industry”, August 30 - September 4, 2015, Prague, Czech Republic, https://www.imeko.org/publications/wc-2015/IMEKO-WC-2015-TC16-338.pdf
6. EURAMET research project 14IND06 pres2vac: "Industrial standards in the intermediate pressure-to-vacuum range", https://www.euramet.org/research-innovation/search-research-projects/details/project/industrial-standards-in-the-intermediate-pressure-to-vacuum-range/
7. Hashad A., Ehlers S., Jusko O., Sabuga W., Characterization of a force-balanced piston gauge as a primary pressure standard, *Measurement* **131** (2019) 723-729
8. Naris S., Vasileiadis N., Valougeorgis D., Hashad A., Sabuga W., Computation of the effective area and associated uncertainties of non-rotating piston gauges FPG and FRS, *Metrologia* **56** (2019) 1-10
9. Jäger J., Use of a precision mercury manometer with capacitance sensing of the menisci, *Metrologia* **30** (1993/94) 553-558
10. Sabuga W., Priruenrom T., Haines R., Bair M., Design and evaluation of pressure balances with $1 \cdot 10^{-6}$ uncertainty for the Boltzmann constant project, *PTB-Mitteilungen* **121** (2011) 256-259
11. Hashad A.S., Sabuga W., Ehlers S., Bock T., Validation of a PTB force-balanced piston gauge - primary pressure standard, *Acta IMEKO* **10** (2021) 271-276
12. Šetina J., New approach to corrections for thermal transpiration effects in capacitance diaphragm gauges, *Metrologia*, **36** (1999) 623-626.
13. Fluke Calibration, Typical pressure measurement uncertainty defined by an FPG8601 Force Balanced Piston Gauge, Technical Note 2090TN05, Rev. 2004 March 26
14. Cox M.G., The evaluation of key comparison data, *Metrologia*, **39** (2002) 589-595.

13. Annex 1. Participants results

Main data reported by the participants with $p_{CMI} \equiv p_{Tij}$, $p_{Lab} \equiv p_{ij}$, $u_{CMI} \equiv u_{Tij}$, $u_{Lab} \equiv u_{ij}$ – pressures and their uncertainties of the laboratories measured at the reference levels of their standards, p_{CDG} - CDG differential pressure corrected for zero and calibration factor, s_{CDG} - standard deviation of the CDG reading.

CMI – PTB, absolute mode

p_{CMI}/Pa		p_{PTB}/Pa		p_{CDG}/Pa		u_{CMI}/Pa		u_{PTB}/Pa		s_{CDG}/Pa	
1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day
1.3015	1.2460	1.2799	1.2579	0.0404	-0.0015	0.0108	0.0101	0.0071	0.0071	0.001	0.002
1.3015	1.2460	1.2779	1.2599	0.0324	-0.0025	0.0122	0.0101	0.0071	0.0071	0.002	0.001
1.2995	1.2460	1.2799	1.2609	0.0354	-0.0025	0.0105	0.0101	0.0071	0.0071	0.001	0.001
1.3005	1.2450	1.2779	1.2619	0.0364	-0.0035	0.0105	0.0101	0.0071	0.0071	0.000	0.002
1.3015	1.2460	1.2779	1.2599	0.0364	-0.0025	0.0105	0.0105	0.0071	0.0071	0.001	0.001
3.0190	3.0075	3.0041	3.0026	0.0294	0.0245	0.0105	0.0102	0.0074	0.0074	0.001	0.001
3.0230	3.0075	3.0051	3.0016	0.0334	0.0254	0.0105	0.0101	0.0074	0.0074	0.001	0.001
3.0240	3.0065	3.0051	3.0006	0.0334	0.0284	0.0102	0.0101	0.0074	0.0074	0.001	0.002
3.0240	3.0075	3.0051	3.0016	0.0354	0.0284	0.0102	0.0101	0.0074	0.0074	0.001	0.002
3.0280	3.0075	3.0051	3.0016	0.0374	0.0274	0.0108	0.0101	0.0074	0.0074	0.002	0.001
9.9880	10.0005	9.9998	9.9998	0.0005	0.0035	0.0106	0.0102	0.0072	0.0072	0.001	0.004
9.9930	10.0015	10.0008	9.9998	0.0045	0.0075	0.0103	0.0102	0.0072	0.0072	0.002	0.002
9.9960	10.0015	9.9998	9.9988	0.0045	0.0095	0.0102	0.0109	0.0072	0.0072	0.001	0.003
9.9960	10.0015	9.9998	9.9998	0.0025	0.0105	0.0102	0.0103	0.0072	0.0072	0.001	0.004
9.9960	10.0015	9.9998	9.9978	0.0025	0.0145	0.0102	0.0102	0.0072	0.0072	0.003	0.002
29.9995	30.0025	29.9971	30.0000	0.0145	0.0055	0.0106	0.0105	0.0073	0.0073	0.002	0.004
29.9995	30.0025	29.9981	30.0010	0.0165	0.0065	0.0106	0.0105	0.0073	0.0073	0.002	0.003
30.0005	30.0035	29.9971	30.0000	0.0175	0.0075	0.0106	0.0105	0.0073	0.0073	0.002	0.003
30.0005	30.0045	29.9971	30.0010	0.0175	0.0085	0.0106	0.0105	0.0073	0.0073	0.002	0.003
30.0005	30.0045	29.9961	30.0000	0.0185	0.0095	0.0105	0.0105	0.0073	0.0073	0.002	0.003
99.9910	99.9905	100.0126	100.0220	-0.0309	-0.0429	0.0118	0.0121	0.0081	0.0082	0.009	0.011
99.9930	99.9925	100.0126	100.0160	-0.0289	-0.0349	0.0118	0.0124	0.0085	0.0085	0.013	0.011
99.9940	99.9975	100.0086	100.0160	-0.0250	-0.0299	0.0121	0.0121	0.0085	0.0085	0.012	0.016
99.9950	99.9985	100.0116	100.0180	-0.0269	-0.0329	0.0116	0.0121	0.0082	0.0083	0.011	0.010
99.9960	100.0015	100.0066	100.0180	-0.0200	-0.0279	0.0116	0.0118	0.0083	0.0083	0.010	0.010
300.0105	300.0150	300.0251	300.0180	-0.0055	-0.0175	0.0145	0.0186	0.0098	0.0098	0.002	0.012
300.0215	300.0060	300.0281	300.0160	0.0015	-0.0235	0.0199	0.0186	0.0098	0.0098	0.014	0.013
300.0095	299.9970	300.0241	300.0259	-0.0065	-0.0454	0.0207	0.0163	0.0098	0.0098	0.016	0.010
300.0095	300.0100	300.0250	300.0239	-0.0085	-0.0274	0.0193	0.0314	0.0098	0.0098	0.012	0.032
300.0095	300.0130	300.0161	300.0169	0.0005	-0.0205	0.0168	0.0237	0.0098	0.0098	0.009	0.015
1000.0360	1000.0455	1000.1759	1000.0607	-0.1337	-0.0040	0.0250	0.0247	0.0133	0.0132	0.011	0.002
1000.0290	1000.0575	1000.1479	1000.0717	-0.1267	-0.0040	0.0247	0.0256	0.0135	0.0133	0.163	0.002
1000.0360	1000.0425	1000.1290	1000.0556	-0.0878	-0.0050	0.0260	0.0253	0.0135	0.0133	0.018	0.002
1000.0330	1000.0425	1000.1080	1000.0786	-0.0709	-0.0250	0.0256	0.0250	0.0133	0.0133	0.021	0.013
1000.0240	1000.0375	1000.0969	1000.0616	-0.0669	-0.0150	0.0250	0.0260	0.0134	0.0133	0.017	0.017
3000.0425	3000.0975	3000.0722	3000.3330	0.0170	-0.2161	0.0532	0.0550	0.0237	0.0247	0.001	0.246
3000.0435	3000.1055	3000.0670	3000.3290	0.0210	-0.2051	0.0525	0.0600	0.0237	0.0240	0.001	0.230
3000.0385	3000.1005	3000.0578	3000.2898	0.0230	-0.1702	0.0547	0.0595	0.0238	0.0247	0.001	0.195
3000.0335	3000.0825	3000.0496	3000.2319	0.0250	-0.1113	0.0526	0.0539	0.0236	0.0244	0.001	0.041
3000.0255	3000.0585	3000.0343	3000.2316	0.0289	-0.1452	0.0528	0.0557	0.0237	0.0244	0.000	0.188
10000.1350	10000.6505	10000.2778	10001.6120	-0.0170	-0.8807	0.1572	0.1553	0.0627	0.0639	0.002	0.082
10000.1490	10000.6185	10000.2936	10001.3548	-0.0170	-0.6482	0.1705	0.1540	0.0639	0.0645	0.002	0.082
10000.1780	10000.6695	10000.3219	10001.2430	-0.0190	-0.5484	0.1524	0.1561	0.0623	0.0644	0.002	0.516
10000.1340	10000.6465	10000.2801	10001.3409	-0.0190	-0.6472	0.1612	0.1575	0.0631	0.0633	0.002	0.565
10000.1090	10000.5665	10000.2498	10001.3140	-0.0190	-0.7071	0.1552	0.1639	0.0625	0.0631	0.002	0.625
15000.5285	15001.6150	15000.7034	15002.2956	-0.0339	-0.5329	0.2270	0.2278	0.0905	0.0915	0.003	0.098
15000.5315	15001.5650	15000.7094	15002.4073	-0.0369	-0.7605	0.2256	0.2297	0.0903	0.0925	0.002	0.789
15000.4715	15001.3760	15000.6529	15001.9985	-0.0379	-0.4820	0.2223	0.2246	0.0901	0.0909	0.002	0.117
15000.4235	15001.3160	15000.6063	15001.8281	-0.0389	-0.3802	0.2263	0.2242	0.0904	0.0911	0.002	0.385
15000.4155	15001.0720	15000.6003	15001.5593	-0.0399	-0.3733	0.2280	0.2252	0.0905	0.0907	0.002	0.392

CMI – UME, absolute mode

p_{CMI}/Pa		p_{UME}/Pa		p_{CDG}/Pa		u_{CMI}/Pa		u_{UME}/Pa		s_{CDG}/Pa	
1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day

1.000	1.000	0.999	1.000	-0.0085	-0.0025	0.0101	0.0102	0.0102	0.0101	0.002	0.002
1.001	1.001	1.000	1.000	-0.0079	-0.0002	0.0101	0.0101	0.0101	0.0105	0.002	0.002
1.001	1.000	1.000	1.000	-0.0051	-0.0003	0.0101	0.0101	0.0101	0.0101	0.000	0.002
1.000	1.000	1.000	1.000	-0.0041	-0.0008	0.0102	0.0101	0.0102	0.0102	0.002	0.000
0.999	1.000	1.000	1.000	-0.0052	-0.0012	0.0101	0.0101	0.0101	0.0101	0.000	0.002
3.000	3.000	2.999	3.000	-0.0071	0.0007	0.0101	0.0101	0.0101	0.0101	0.000	0.000
3.000	3.000	3.000	3.000	-0.0056	-0.0004	0.0101	0.0101	0.0101	0.0101	0.000	0.000
3.001	3.001	3.000	3.000	-0.0064	-0.0012	0.0101	0.0101	0.0103	0.0101	0.000	0.002
3.000	3.000	3.000	3.000	-0.0055	-0.0001	0.0101	0.0101	0.0101	0.0101	0.000	0.000
3.000	3.001	3.000	2.999	-0.0055	0.0006	0.0101	0.0101	0.0101	0.0101	0.000	0.002
10.000	10.002	10.000	10.000	-0.0117	-0.0032	0.0102	0.0102	0.0102	0.0102	0.000	0.000
10.000	10.000	9.999	10.000	-0.0098	-0.0006	0.0102	0.0102	0.0104	0.0102	0.000	0.000
10.001	10.000	10.000	10.000	-0.0071	-0.0014	0.0103	0.0103	0.0102	0.0102	0.000	0.000
9.999	10.001	10.000	10.000	-0.0095	-0.0045	0.0102	0.0102	0.0102	0.0102	0.000	0.000
10.000	10.001	10.000	10.000	-0.0114	-0.0005	0.0102	0.0102	0.0102	0.0102	0.000	0.000
30.004	30.001	30.002	30.001	-0.0078	0.0018	0.0106	0.0106	0.0107	0.0107	0.002	0.002
30.002	30.001	30.003	30.000	-0.0032	0.0025	0.0106	0.0106	0.0110	0.0107	0.002	0.004
30.002	30.001	30.003	30.001	-0.0075	0.0006	0.0106	0.0105	0.0106	0.0106	0.002	0.002
30.001	30.000	30.003	30.001	-0.0067	0.0013	0.0106	0.0106	0.0106	0.0107	0.002	0.004
30.004	30.001	30.003	30.001	-0.0089	0.0000	0.0106	0.0106	0.0107	0.0107	0.002	0.002
100.001	99.996	100.007	100.004	-0.0008	0.0081	0.0124	0.0124	0.0120	0.0120	0.004	0.005
100.003	100.001	100.004	100.004	-0.0038	0.0036	0.0121	0.0118	0.0118	0.0118	0.004	0.004
100.002	99.998	100.006	100.003	0.0013	0.0052	0.0124	0.0121	0.0120	0.0122	0.005	0.005
100.000	99.999	100.005	100.005	0.0030	0.0060	0.0124	0.0121	0.0120	0.0120	0.004	0.004
100.000	100.000	100.005	100.004	-0.0007	0.0028	0.0118	0.0118	0.0120	0.0122	0.004	0.004
300.014	299.995	300.051	300.019	0.0413	0.0216	0.0143	0.0148	0.0184	0.0184	0.007	0.009
300.038	300.033	300.045	300.007	0.0105	-0.0290	0.0229	0.0174	0.0165	0.0178	0.021	0.016
300.034	300.012	300.032	300.022	0.0052	0.0081	0.0214	0.0163	0.0155	0.0215	0.013	0.013
300.006	300.008	300.029	300.027	0.0292	0.0153	0.0148	0.0158	0.0159	0.0174	0.004	0.005
300.029	300.030	300.029	300.015	0.0046	-0.0177	0.0199	0.0199	0.0154	0.0174	0.014	0.014
999.969	1000.005	999.956	1000.102	-0.0174	0.0919	0.0278	0.0347	0.0294	0.0289	0.014	0.021
999.926	999.987	999.977	1000.113	0.0474	0.1192	0.0268	0.0247	0.0333	0.0322	0.014	0.018
999.937	999.991	999.939	1000.093	-0.0021	0.0985	0.0278	0.0278	0.0350	0.0344	0.011	0.013
999.930	999.985	999.945	1000.108	0.0098	0.1192	0.0273	0.0319	0.0448	0.0369	0.036	0.011
999.921	999.973	999.943	1000.085	0.0203	0.1059	0.0278	0.0256	0.0375	0.0328	0.020	0.013
3000.032	2999.835	3000.014	3000.292	-0.0279	0.4598	0.0550	0.0656	0.0687	0.0699	0.036	0.055
3000.027	3000.035	3000.055	3000.313	0.0157	0.2675	0.0569	0.1363	0.0674	0.0744	0.039	0.098
3000.022	3000.012	3000.094	3000.351	0.0606	0.3517	0.0668	0.1682	0.0677	0.0671	0.059	0.143
3000.036	3000.002	3000.077	3000.368	0.0265	0.3625	0.0581	0.0764	0.0699	0.0662	0.041	0.054
2999.989	3000.330	3000.101	3000.338	0.1001	0.0068	0.0561	0.0743	0.0674	0.0671	0.034	0.064
10000.093	10000.244	10000.074	10000.249	-0.0692	-0.0530	0.1639	0.2093	0.2421	0.2484	0.129	0.063
10000.052	10000.291	10000.275	10000.096	0.1559	-0.2430	0.1547	0.1647	0.2176	0.2258	0.088	0.125
10000.065	10000.189	10000.284	10000.072	0.1447	-0.1630	0.1724	0.1584	0.2086	0.2005	0.116	0.063
10000.112	10000.220	10000.330	10000.140	0.1613	-0.1427	0.1837	0.1627	0.2018	0.3014	0.107	0.257
10000.096	10000.185	10000.265	10000.206	0.0965	-0.0317	0.1608	0.2128	0.2050	0.2081	0.109	0.104
14999.945	15000.605	15000.294	15000.934	0.2787	0.2248	0.2429	0.2385	0.3079	0.3205	0.116	0.131
15000.072	15000.603	15000.330	15000.985	0.1787	0.2962	0.2404	0.2545	0.2920	0.2872	0.072	0.120
15000.057	15000.654	15000.430	15000.956	0.2913	0.2114	0.2674	0.2393	0.3031	0.2852	0.104	0.107
15000.108	15000.573	15000.385	15000.797	0.1886	0.1260	0.2331	0.2413	0.2932	0.2983	0.080	0.116
15000.054	15000.629	15000.497	15000.769	0.3611	0.0429	0.2300	0.2231	0.3005	0.3058	0.061	0.107

CMI – RISE, absolute mode

p_{CMI}/Pa		p_{RISE}/Pa		p_{CDG}/Pa		u_{CMI}/Pa		u_{RISE}/Pa		s_{CDG}/Pa	
1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day
1.002	1.040	1.000	1.043	-0.0065	-0.0003	0.0101	0.0101	0.0151	0.0151	0.002	0.000
1.002	1.040	1.000	1.041	-0.0104	-0.0010	0.0101	0.0101	0.0151	0.0151	0.000	0.000
1.002	1.040	1.001	1.039	-0.0115	0.0005	0.0101	0.0102	0.0151	0.0151	0.002	0.000
1.002	1.041	1.002	1.038	-0.0103	-0.0023	0.0101	0.0101	0.0151	0.0151	0.000	0.000
1.002	1.039	0.998	1.036	-0.0092	-0.0019	0.0101	0.0101	0.0151	0.0151	0.000	0.002
3.002	3.000	2.999	3.000	-0.0268	0.0083	0.0117	0.0101	0.0152	0.0151	0.002	0.002
3.000	3.000	2.999	3.000	-0.0269	0.0077	0.0112	0.0102	0.0154	0.0151	0.002	0.002
3.002	3.000	2.999	3.000	-0.0175	0.0085	0.0108	0.0101	0.0152	0.0151	0.002	0.002
3.000	3.000	2.999	3.000	-0.0119	0.0126	0.0108	0.0102	0.0154	0.0151	0.002	0.002
3.001	3.000	3.000	3.000	-0.0097	0.0096	0.0112	0.0101	0.0154	0.0151	0.002	0.000
10.001	9.996	10.000	10.000	0.0308	-0.0142	0.0123	0.0103	0.0153	0.0152	0.004	0.000
10.000	9.997	10.000	10.000	0.0289	-0.0133	0.0118	0.0102	0.0153	0.0152	0.002	0.000
10.001	9.998	10.000	10.000	0.0295	-0.0118	0.0123	0.0102	0.0153	0.0152	0.004	0.002
10.000	9.998	10.000	10.000	0.0285	-0.0103	0.0129	0.0102	0.0153	0.0152	0.004	0.000
10.000	9.999	10.000	10.000	0.0309	-0.0086	0.0118	0.0102	0.0153	0.0152	0.002	0.002
29.999	29.999	29.999	29.999	-0.0330	0.0001	0.0116	0.0106	0.0159	0.0161	0.002	0.005
30.000	30.000	30.000	30.000	-0.0324	0.0000	0.0112	0.0106	0.0157	0.0156	0.002	0.002

30.000	30.002	30.000	30.000	-0.0292	0.0032	0.0112	0.0106	0.0159	0.0157	0.002	0.004
30.000	30.001	30.000	30.000	-0.0286	0.0070	0.0116	0.0108	0.0157	0.0156	0.002	0.004
29.999	30.001	30.000	30.000	-0.0271	0.0076	0.0112	0.0106	0.0157	0.0156	0.002	0.002
100.004	100.004	100.005	100.005	-0.0290	-0.0168	0.0134	0.0118	0.0175	0.0171	0.007	0.004
100.006	100.002	100.002	100.005	-0.0315	-0.0115	0.0124	0.0124	0.0180	0.0173	0.007	0.007
100.004	100.003	100.004	100.005	-0.0273	-0.0121	0.0124	0.0121	0.0175	0.0171	0.005	0.004
100.003	100.004	100.004	100.005	-0.0263	-0.0120	0.0129	0.0129	0.0173	0.0173	0.005	0.007
100.004	100.005	100.003	100.004	-0.0258	-0.0093	0.0129	0.0124	0.0175	0.0171	0.005	0.005
300.003	300.002	300.053	300.035	0.0209	0.0384	0.0163	0.0151	0.0211	0.0212	0.007	0.004
300.002	300.007	300.040	300.023	0.0074	0.0199	0.0168	0.0158	0.0212	0.0211	0.005	0.005
300.015	300.003	300.035	300.017	-0.0120	0.0203	0.0207	0.0143	0.0211	0.0211	0.014	0.002
300.011	300.007	300.029	300.017	-0.0122	0.0186	0.0180	0.0148	0.0214	0.0210	0.009	0.005
300.007	300.008	300.023	300.016	-0.0133	0.0174	0.0158	0.0158	0.0212	0.0211	0.005	0.007
1000.020	1000.026	1000.012	1000.016	-0.0629	-0.0528	0.0278	0.0250	0.0373	0.0377	0.013	0.016
1000.024	1000.024	1000.015	1000.036	-0.0562	-0.0211	0.0260	0.0268	0.0381	0.0367	0.025	0.018
1000.019	1000.032	1000.033	1000.041	-0.0279	-0.0213	0.0256	0.0260	0.0381	0.0389	0.020	0.023
1000.032	1000.026	1000.042	1000.046	-0.0261	-0.0084	0.0256	0.0283	0.0359	0.0385	0.009	0.014
1000.019	1000.020	1000.034	1000.034	-0.0182	-0.0091	0.0253	0.0260	0.0355	0.0359	0.009	0.013
3000.037	3000.072	3000.078	3000.287	-0.0644	0.1002	0.0573	0.0581	0.0794	0.0841	0.029	0.039
3000.076	3000.077	3000.130	3000.310	-0.0495	0.1250	0.0605	0.0534	0.0782	0.0850	0.021	0.041
3000.068	3000.062	3000.084	3000.282	-0.0868	0.1202	0.0611	0.0557	0.0776	0.0860	0.038	0.046
3000.054	3000.084	3000.108	3000.242	-0.0466	0.0640	0.0595	0.0577	0.0776	0.0828	0.030	0.041
3000.064	3000.051	3000.080	3000.228	-0.0810	0.0855	0.0565	0.0621	0.0823	0.0901	0.034	0.059
10000.574	10000.271	10000.329	10000.346	-0.4170	-0.1778	0.1744	0.1860	0.2174	0.2210	0.111	0.122
10000.401	10000.285	10000.283	10000.251	-0.2901	-0.2815	0.1714	0.1591	0.2199	0.2487	0.097	0.132
10000.330	10000.298	10000.264	10000.278	-0.2378	-0.2695	0.1765	0.2093	0.2183	0.2291	0.114	0.138
10000.335	10000.151	10000.240	10000.148	-0.2762	-0.2477	0.1896	0.1872	0.2264	0.2178	0.118	0.136
10000.250	10000.189	10000.259	10000.089	-0.1499	-0.3403	0.2237	0.1591	0.2227	0.2189	0.159	0.061
15001.728	15001.045	15001.982	15002.001	0.0313	0.6270	0.2862	0.2417	0.3195	0.3255	0.154	0.129
15001.628	15000.890	15001.904	15001.923	0.0486	0.7001	0.2478	0.2233	0.3288	0.3296	0.170	0.098
15001.364	15000.767	15001.774	15001.772	0.1735	0.6763	0.2242	0.2409	0.3296	0.3234	0.114	0.123
15001.359	15000.713	15001.595	15001.602	0.0108	0.5616	0.2811	0.2421	0.3271	0.3268	0.195	0.120
15001.224	15000.696	15001.489	15001.451	0.0211	0.4256	0.2602	0.2355	0.3268	0.3305	0.195	0.075

CMI – IMT, absolute mode

p_{CMI}/Pa		p_{IMT}/Pa		u_{CMI}/Pa		u_{IMT}/Pa	
1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day
1.1358	1.1132	1.1321	1.1030	0.0101	0.0102	0.0016	0.0017
1.1275	1.1060	1.1267	1.0979	0.0102	0.0102	0.0016	0.0016
1.1273	1.1029	1.1240	1.0942	0.0102	0.0102	0.0016	0.0016
1.1210	1.0987	1.1211	1.0910	0.0102	0.0102	0.0016	0.0016
1.1188	1.0976	1.1188	1.0884	0.0102	0.0102	0.0016	0.0016
2.9980	2.9743	3.0012	2.9726	0.0101	0.0102	0.0023	0.0024
2.9979	2.9724	3.0023	2.9720	0.0101	0.0102	0.0024	0.0023
2.9968	2.9723	3.0007	2.9709	0.0102	0.0102	0.0024	0.0023
2.9977	2.9714	3.0000	2.9699	0.0102	0.0102	0.0024	0.0024
2.9956	2.9704	2.9975	2.9697	0.0101	0.0101	0.0024	0.0023
9.9822	9.9550	9.9916	9.9653	0.0102	0.0102	0.0062	0.0062
9.9828	9.9549	9.9937	9.9649	0.0102	0.0102	0.0062	0.0062
9.9834	9.9549	9.9946	9.9646	0.0102	0.0102	0.0062	0.0062
9.9850	9.9539	9.9948	9.9668	0.0102	0.0102	0.0062	0.0062
9.9836	9.9529	9.9938	9.9647	0.0102	0.0102	0.0062	0.0062
29.9800	29.9031	29.9793	29.9098	0.0106	0.0106	0.0181	0.0181
29.9825	29.9114	29.9832	29.9179	0.0106	0.0106	0.0181	0.0181
29.9860	29.9116	29.9876	29.9191	0.0105	0.0106	0.0181	0.0181
29.9835	29.9169	29.9844	29.9218	0.0105	0.0106	0.0181	0.0181
29.9830	29.9191	29.9869	29.9259	0.0105	0.0106	0.0181	0.0181
99.9864	99.9185	99.9966	99.9121	0.0121	0.0118	0.0600	0.0600
99.9892	99.9228	99.9995	99.9158	0.0121	0.0118	0.0600	0.0600
99.9841	99.9235	99.9994	99.9153	0.0118	0.0116	0.0600	0.0600
99.9859	99.9247	100.0052	99.9176	0.0121	0.0118	0.0600	0.0600
99.9848	99.9237	100.0034	99.9154	0.0121	0.0118	0.0600	0.0600
300.0200	299.9690	300.0082	299.9425	0.0148	0.0168	0.0785	0.0784
300.0147	299.9488	300.0521	299.9183	0.0148	0.0151	0.0782	0.0788
300.0153	299.9477	300.0663	299.9020	0.0148	0.0151	0.0783	0.0783
300.0150	299.9405	300.0678	299.9247	0.0151	0.0151	0.0783	0.0784
300.0137	299.9404	300.0810	299.9110	0.0154	0.0151	0.0783	0.0785
1000.1163	1000.0028	1000.2097	999.9366	0.0260	0.0288	0.2062	0.2063
1000.1010	1000.0176	1000.2245	999.9457	0.0294	0.0260	0.2063	0.2062
1000.0867	1000.0075	1000.2282	999.9406	0.0264	0.0256	0.2062	0.2062
1000.0673	1000.0003	1000.2066	999.9334	0.0278	0.0250	0.2063	0.2063

1000.0670	999.9992	1000.1602	999.9174	0.0264	0.0260	0.2063	0.2063
3000.0807	3000.012	3000.1008	2999.9507	0.0565	0.0544	0.1168	0.1168
3000.0663	3000.0054	3000.0720	2999.9398	0.0557	0.0544	0.1168	0.1168
3000.0450	2999.9873	3000.0541	2999.9173	0.0600	0.0565	0.1170	0.1170
3000.0567	2999.9811	3000.0474	2999.8747	0.0565	0.0554	0.1168	0.1169
3000.0523	2999.9740	3000.0796	2999.8769	0.0554	0.0550	0.1168	0.1168
10000.1670	10000.1414	10000.2015	9999.9210	0.1714	0.1739	0.2244	0.2244
10000.1757	10000.0132	10000.2432	9999.8323	0.1946	0.1547	0.2252	0.2238
10000.1853	10000.0681	10000.2598	9999.8960	0.2025	0.1563	0.2255	0.2240
10000.1940	10000.0749	10000.2965	9999.9154	0.1627	0.1673	0.2241	0.2242
10000.1657	10000.0335	10000.2723	9999.8991	0.1635	0.1598	0.2241	0.2240
15000.1323	15000.0099	15000.2856	14999.8172	0.2425	0.2252	0.3169	0.3164
15000.1580	14999.9747	15000.3222	14999.8328	0.3271	0.2225	0.3207	0.3165
15000.1956	14999.9886	15000.3964	14999.8659	0.2297	0.2226	0.3166	0.3164
15000.1573	15000.0414	15000.3581	14999.9222	0.2294	0.2261	0.3166	0.3165
15000.2240	15000.0152	15000.4214	14999.8815	0.2366	0.2265	0.3169	0.3165

CMI – PTB, gauge mode

p_{CMI}/Pa		p_{PTB}/Pa		p_{CDG}/Pa		u_{CMI}/Pa		u_{PTB}/Pa		s_{CDG}/Pa	
1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day
0.9980	0.9995	1.0017	1.0087	-0.0055	-0.0025	0.0112	0.0108	0.0084	0.0082	0.010	0.011
0.9990	0.9995	1.0007	1.0077	-0.0045	0.0005	0.0128	0.0108	0.0084	0.0082	0.010	0.010
0.9990	1.0005	1.0007	1.0077	-0.0035	-0.0015	0.0117	0.0108	0.0084	0.0082	0.010	0.010
0.9970	1.0005	1.0027	1.0077	-0.0055	-0.0075	0.0112	0.0128	0.0082	0.0082	0.010	0.011
0.9980	0.9995	1.0007	1.0097	-0.0045	-0.0065	0.0112	0.0122	0.0082	0.0082	0.009	0.010
3.0005	3.0000	2.9976	2.9966	-0.0050	0.0070	0.0108	0.0117	0.0074	0.0074	0.005	0.138
3.0005	2.9970	2.9986	2.9966	-0.0060	0.0060	0.0108	0.0112	0.0074	0.0074	0.005	0.126
3.0015	2.9990	2.9986	2.9956	-0.0060	0.0040	0.0112	0.0112	0.0074	0.0074	0.005	0.010
2.9995	2.9990	3.0006	2.9966	-0.0010	0.0030	0.0112	0.0108	0.0074	0.0074	0.005	0.008
3.0005	2.9990	2.9976	2.9966	0.0010	-0.0010	0.0112	0.0108	0.0074	0.0074	0.005	0.010
10.0005	10.0050	10.0013	10.0019	-0.0005	0.0040	0.0109	0.0106	0.0072	0.0072	0.002	0.010
9.9995	10.0050	10.0013	10.0019	0.0015	0.0090	0.0113	0.0118	0.0072	0.0074	0.002	0.020
9.9995	10.0050	10.0013	9.9999	0.0035	0.0050	0.0109	0.0113	0.0072	0.0074	0.002	0.016
9.9995	10.0060	10.0003	10.0019	0.0055	0.0050	0.0109	0.0113	0.0072	0.0072	0.002	0.011
10.0015	10.0050	9.9983	10.0009	0.0055	0.0220	0.0113	0.0109	0.0072	0.0072	0.002	0.127
29.9970	29.9920	29.9986	30.0007	-0.0035	-0.0115	0.0120	0.0126	0.0078	0.0078	0.010	0.020
29.9990	29.9910	29.9976	29.9957	-0.0015	-0.0145	0.0120	0.0131	0.0078	0.0078	0.011	0.013
29.9970	29.9920	29.9986	29.9977	-0.0035	-0.0125	0.0126	0.0116	0.0078	0.0078	0.010	0.009
29.9970	29.9930	29.9976	29.9987	-0.0005	-0.0055	0.0120	0.0120	0.0078	0.0078	0.010	0.010
29.9970	29.9930	29.9976	30.0017	-0.0015	-0.0065	0.0126	0.0116	0.0078	0.0077	0.009	0.009
100.0020	100.0005	100.0141	100.0051	-0.0165	-0.0055	0.0134	0.0196	0.0079	0.0083	0.012	0.002
100.0020	99.9965	100.0061	100.0041	-0.0115	-0.0045	0.0139	0.0257	0.0080	0.0088	0.012	0.002
100.0030	100.0035	100.0091	100.0111	-0.0115	-0.0045	0.0134	0.0188	0.0079	0.0081	0.012	0.002
100.0010	99.9955	100.0091	100.0031	-0.0125	-0.0015	0.0145	0.0188	0.0081	0.0082	0.014	0.003
100.0000	100.0015	100.0091	100.0061	-0.0195	0.0005	0.0166	0.0222	0.0084	0.0084	0.014	0.003
300.0130	300.0245	300.0084	300.0234	-0.0165	-0.0055	0.0207	0.0279	0.0094	0.0098	0.021	0.001
300.0000	300.0175	300.0014	300.0184	-0.0135	-0.0055	0.0222	0.0214	0.0094	0.0093	0.025	0.001
300.0090	300.0185	300.0114	300.0184	-0.0105	-0.0045	0.0207	0.0270	0.0095	0.0097	0.023	0.001
300.0180	300.0165	299.9974	300.0154	-0.0015	-0.0025	0.0443	0.0245	0.0133	0.0095	0.030	0.001
300.0140	300.0015	299.9994	300.0024	0.0045	-0.0025	0.0341	0.0163	0.0109	0.0090	0.024	0.004
1000.0505	1000.0480	1000.1091	1000.0625	-0.0679	-0.0085	0.0441	0.0273	0.0143	0.0132	0.031	0.020
1000.0515	1000.0400	1000.0901	1000.0415	-0.0469	0.0045	0.0278	0.0319	0.0132	0.0136	0.027	0.020
1000.0465	1000.0340	1000.0671	1000.0584	-0.0180	-0.0095	0.0283	0.0268	0.0138	0.0130	0.030	0.020
1000.0545	1000.0410	1000.0710	1000.0384	-0.0190	0.0165	0.0306	0.0319	0.0137	0.0136	0.034	0.020
1000.0455	1000.0380	1000.0580	1000.0484	-0.0070	0.0065	0.0306	0.0384	0.0142	0.0140	0.042	0.024
3000.1475	3000.144	3000.2783	3000.1928	-0.1153	-0.0165	0.0701	0.0688	0.0259	0.0250	0.056	0.002
3000.1825	3000.2190	3000.2843	3000.2735	-0.0953	-0.0195	0.0688	0.0611	0.0265	0.0244	0.062	0.002
3000.1765	3000.1440	3000.2862	3000.1975	-0.0963	-0.0205	0.0600	0.0638	0.0244	0.0244	0.046	0.002
3000.1435	3000.1740	3000.2311	3000.2252	-0.0763	-0.0205	0.0708	0.0611	0.0257	0.0244	0.048	0.002
3000.1555	3000.1300	3000.2161	3000.1810	-0.0404	-0.0175	0.0586	0.0627	0.0252	0.0244	0.062	0.002
10000.6970	10001.0705	10000.7719	10001.1777	0.0135	0.0105	0.1953	0.1915	0.0698	0.0642	0.183	0.013
10000.5440	10001.0255	10000.6718	10001.0912	-0.0294	0.0414	0.1755	0.1744	0.0695	0.0624	0.211	0.013
10000.7120	10000.9265	10000.6119	10000.9485	0.2061	0.0933	0.2646	0.1755	0.0715	0.0626	0.119	0.103
10000.6710	10000.6815	10000.6958	10000.6858	0.1053	0.1173	0.1965	0.2107	0.0772	0.0668	0.220	0.110
10000.6320	10000.5875	10000.6547	10000.5407	0.0744	0.1642	0.1921	0.2275	0.0668	0.0677	0.123	0.015
15002.6310	15002.6295	15002.8840	15003.0212	-0.0818	-0.2305	0.2824	0.2973	0.0915	0.0915	0.104	0.125
15001.8780	15002.4115	15002.0826	15002.7840	-0.0359	-0.2066	0.2818	0.2914	0.0951	0.0967	0.090	0.153
15001.9760	15002.1345	15002.1459	15002.3693	-0.0160	-0.0609	0.3154	0.2556	0.0977	0.0909	0.069	0.089
15001.7560	15002.0115	15001.7757	15002.0671	0.1477	0.1118	0.3429	0.2571	0.1020	0.0928	0.111	0.285
15001.7310	15001.7375	15001.7257	15001.9166	0.1796	-0.0040	0.2973	0.2994	0.0993	0.0991	0.202	0.175

CMI – UME, gauge mode

p_{CMI}/Pa		p_{UME}/Pa		p_{CDG}/Pa		u_{CMI}/Pa		u_{UME}/Pa		s_{CDG}/Pa	
1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day
1.000	1.000	0.999	1.000	0.0066	0.0014	0.0117	0.0112	0.0117	0.0122	0.007	0.007
1.000	0.998	1.001	1.001	0.0093	0.0004	0.0105	0.0117	0.0112	0.0108	0.007	0.009
1.001	1.000	0.998	1.000	0.0035	0.0020	0.0112	0.0105	0.0112	0.0112	0.005	0.005
0.999	1.001	1.003	0.998	0.0111	-0.0025	0.0112	0.0122	0.0128	0.0122	0.007	0.007
1.002	1.000	0.998	0.999	0.0010	0.0005	0.0122	0.0117	0.0117	0.0117	0.009	0.005
2.999	2.999	3.000	3.000	0.0078	0.0006	0.0117	0.0128	0.0135	0.0135	0.007	0.011
2.999	3.000	2.999	2.999	0.0066	-0.0009	0.0105	0.0117	0.0128	0.0164	0.007	0.014
3.001	3.000	3.001	3.000	0.0058	0.0015	0.0108	0.0117	0.0128	0.0149	0.007	0.011
3.001	3.002	3.002	3.001	0.0065	0.0029	0.0117	0.0142	0.0112	0.0142	0.005	0.018
2.999	3.002	2.999	3.000	0.0071	0.0017	0.0108	0.0112	0.0128	0.0117	0.007	0.007
9.999	10.000	9.999	9.999	0.0015	0.0023	0.0113	0.0113	0.0143	0.0118	0.009	0.005
9.999	10.001	10.000	10.001	0.0025	0.0042	0.0106	0.0106	0.0109	0.0113	0.004	0.004
10.001	9.999	10.001	9.999	0.0017	0.0013	0.0109	0.0113	0.0109	0.0118	0.005	0.005
10.001	10.000	10.001	9.998	0.0000	-0.0011	0.0123	0.0106	0.0129	0.0113	0.007	0.005
10.000	10.002	10.000	10.002	0.0024	0.0030	0.0109	0.0106	0.0118	0.0113	0.007	0.005
29.998	30.002	29.998	29.999	-0.0015	-0.0039	0.0138	0.0152	0.0183	0.0226	0.013	0.016
30.000	30.001	30.001	30.001	0.0004	-0.0009	0.0120	0.0144	0.0209	0.0139	0.020	0.011
30.002	30.001	29.998	30.000	-0.0060	-0.0044	0.0159	0.0152	0.0209	0.0327	0.014	0.030
30.003	30.004	30.002	30.003	-0.0023	-0.0019	0.0152	0.0126	0.0152	0.0139	0.011	0.007
30.003	30.002	30.004	30.001	-0.0016	-0.0015	0.0152	0.0131	0.0145	0.0139	0.013	0.008
100.009	100.002	100.003	100.003	-0.0118	0.0041	0.0257	0.0158	0.0207	0.0241	0.023	0.021
100.007	100.003	100.009	100.006	-0.0022	0.0064	0.0139	0.0166	0.0176	0.0215	0.013	0.013
100.005	100.002	100.005	100.002	-0.0032	0.0037	0.0152	0.0145	0.0199	0.0241	0.020	0.021
100.007	100.003	100.009	100.004	-0.0016	0.0045	0.0181	0.0145	0.0207	0.0148	0.014	0.013
100.003	100.002	100.006	100.003	0.0011	0.0018	0.0139	0.0158	0.0168	0.0183	0.013	0.020
299.994	300.019	300.008	299.970	0.0015	-0.0474	0.0549	0.0617	0.0668	0.0903	0.082	0.059
300.002	300.012	299.996	300.037	-0.0169	0.0259	0.0529	0.0587	0.0562	0.0668	0.046	0.064
300.003	300.008	300.011	300.000	-0.0001	-0.0011	0.0443	0.0443	0.0485	0.1012	0.055	0.082
300.015	300.011	300.009	299.964	-0.0080	-0.0400	0.0636	0.0734	0.1200	0.0775	0.118	0.070
300.025	300.013	299.962	300.019	-0.0716	0.0174	0.0520	0.0617	0.0864	0.0756	0.114	0.061
999.987	1000.020	999.994	1000.017	0.0065	-0.0157	0.0835	0.0731	0.0726	0.0754	0.093	0.068
1000.048	1000.031	1000.044	1000.012	-0.0043	-0.0284	0.1283	0.0618	0.1058	0.0573	0.145	0.070
1000.027	1000.068	1000.014	1000.088	-0.0069	0.0053	0.0702	0.0826	0.1038	0.0644	0.145	0.068
1000.044	1000.029	1000.033	999.985	-0.0264	-0.0456	0.0449	0.0528	0.1193	0.1428	0.122	0.111
1000.012	1000.047	1000.054	1000.044	0.0441	-0.0037	0.0609	0.0807	0.0635	0.0990	0.043	0.059
3000.157	3000.060	3000.149	2999.979	0.0224	-0.1051	0.1271	0.1163	0.1238	0.2931	0.159	0.329
3000.128	3000.056	3000.208	3000.095	0.0807	-0.0071	0.1806	0.1031	0.1751	0.1585	0.172	0.213
3000.241	3000.078	3000.206	3000.081	-0.0177	-0.0405	0.1663	0.0996	0.2071	0.2291	0.229	0.232
3000.199	3000.091	3000.196	3000.073	0.0298	-0.0622	0.2047	0.1391	0.1230	0.1967	0.213	0.175
3000.117	3000.082	3000.096	3000.056	-0.0067	-0.0708	0.1127	0.1092	0.1816	0.2005	0.206	0.215
10001.657	10000.745	10000.495	10000.479	-1.3213	-0.4543	0.4743	0.2924	0.7708	0.5433	0.749	0.642
10000.512	10000.732	10001.750	10000.311	1.1346	-0.4935	0.6915	0.3845	0.5452	0.6647	0.570	0.703
10000.896	10000.649	10000.943	10000.712	0.0277	-0.0725	0.3762	0.3725	1.2080	0.5828	1.500	0.767
10000.453	10000.371	10000.694	10000.784	0.1985	0.2124	0.6321	0.5662	1.6271	0.5228	1.520	0.726
10000.562	10000.673	10000.756	10000.148	0.1116	-0.6660	0.4972	0.3265	0.6256	0.8690	0.769	1.048
15001.821	15002.482	15002.455	15002.643	0.4994	-0.0524	0.4160	0.2973	0.7502	0.6849	0.497	0.783
14999.889	15002.232	14999.877	15002.818	-0.1831	0.3492	0.6100	0.3338	1.0192	0.4474	0.667	0.456
15001.338	15002.098	15001.251	15002.204	-0.2940	-0.1550	0.6241	0.3491	0.5023	0.5445	0.377	0.679
15000.652	15001.633	15000.520	15002.041	-0.2649	0.1596	0.3712	0.2686	0.6030	0.5098	0.640	0.411
15000.335	15001.526	15001.101	15001.399	0.4764	-0.3905	0.5536	0.2887	0.5428	0.6387	0.840	0.644

CMI – RISE, gauge mode

p_{CMI}/Pa		p_{RISE}/Pa		p_{CDG}/Pa		u_{CMI}/Pa		u_{RISE}/Pa		s_{CDG}/Pa	
1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day
0.999	1.000	1.000	1.000	-0.0105	-0.0069	0.0215	0.0189	0.0180	0.0122	0.007	0.005
1.000	0.999	0.999	1.000	-0.0079	-0.0039	0.0189	0.0156	0.0164	0.0108	0.007	0.005
1.001	1.001	1.001	1.000	-0.0074	-0.0089	0.0156	0.0189	0.0142	0.0108	0.005	0.005
0.999	1.000	0.999	1.002	-0.0068	-0.0169	0.0142	0.0164	0.0135	0.0112	0.005	0.005
1.000	1.000	1.000	0.999	-0.0076	-0.0139	0.0180	0.0164	0.0180	0.0135	0.005	0.005
3.000	2.998	3.001	2.999	-0.0099	-0.0083	0.0135	0.0128	0.0117	0.0105	0.007	0.007
2.999	3.001	3.000	3.001	-0.0125	-0.0138	0.0135	0.0156	0.0123	0.0105	0.009	0.004
3.001	2.998	3.001	3.000	-0.0142	-0.0198	0.0122	0.0156	0.0117	0.0117	0.005	0.005
2.999	3.001	3.001	3.000	-0.0089	-0.0178	0.0128	0.0164	0.0135	0.0123	0.005	0.005
2.999	2.999	3.000	3.000	-0.0139	-0.0166	0.0189	0.0164	0.0164	0.0129	0.005	0.005
10.001	10.001	10.001	10.000	-0.0104	-0.0261	0.0129	0.0173	0.0110	0.0118	0.005	0.007

10.001	9.999	10.000	9.998	-0.0086	-0.0261	0.0165	0.0150	0.0130	0.0130	0.007	0.005
9.999	9.999	10.001	10.000	-0.0047	-0.0281	0.0157	0.0165	0.0143	0.0136	0.005	0.005
10.001	10.000	10.000	10.001	-0.0067	-0.0211	0.0129	0.0189	0.0114	0.0130	0.005	0.005
10.001	10.000	10.002	10.001	-0.0057	-0.0291	0.0129	0.0150	0.0118	0.0114	0.004	0.007
29.995	30.003	29.999	30.000	0.0107	-0.0283	0.0346	0.0191	0.0226	0.0146	0.020	0.007
30.002	30.004	30.001	30.001	0.0023	-0.0273	0.0299	0.0191	0.0192	0.0133	0.020	0.009
30.003	30.005	30.001	30.001	0.0043	-0.0293	0.0327	0.0262	0.0226	0.0184	0.014	0.013
30.002	30.010	30.003	30.005	0.0050	-0.0333	0.0346	0.0299	0.0218	0.0192	0.020	0.014
30.002	30.002	30.000	30.001	0.0047	-0.0253	0.0191	0.0394	0.0153	0.0244	0.009	0.020
100.000	100.027	100.000	100.004	-0.0062	-0.0384	0.0359	0.0947	0.0192	0.0156	0.027	0.093
100.004	100.034	100.004	100.007	-0.0122	-0.0443	0.0284	0.2183	0.0192	0.0295	0.014	0.238
100.004	99.999	100.002	100.005	-0.0042	-0.0188	0.0230	0.1674	0.0156	0.0233	0.014	0.159
100.003	99.990	100.003	100.004	-0.0042	0.0023	0.0349	0.0640	0.0233	0.0144	0.021	0.063
100.002	99.993	100.002	100.004	-0.0012	-0.0051	0.0284	0.1484	0.0192	0.0200	0.016	0.145
300.000	299.986	299.996	299.999	-0.0128	-0.0175	0.1537	0.0862	0.0894	0.0459	0.089	0.052
300.033	300.023	300.006	300.012	-0.0288	-0.0406	0.1437	0.0783	0.0806	0.0385	0.098	0.061
300.013	300.014	300.007	300.012	-0.0048	-0.0342	0.1437	0.0773	0.0767	0.0440	0.093	0.052
300.017	300.008	300.004	299.999	-0.0160	-0.0395	0.1427	0.0520	0.0525	0.0280	0.111	0.041
299.962	300.009	299.981	300.011	0.0213	-0.0320	0.0882	0.0882	0.0478	0.0468	0.064	0.059
1000.032	1000.021	1000.027	1000.048	-0.0273	-0.0139	0.3010	0.0749	0.0873	0.0476	0.247	0.048
999.981	1000.030	1000.016	1000.048	-0.0019	-0.0217	0.2860	0.1136	0.0836	0.0762	0.234	0.072
1000.090	1000.037	1000.043	1000.064	-0.0690	-0.0126	0.3967	0.1145	0.1131	0.0698	0.308	0.088
1000.014	1000.010	1000.021	1000.048	-0.0250	-0.0044	0.4546	0.0693	0.1549	0.0461	0.370	0.054
999.985	1000.026	1000.011	1000.054	0.0120	-0.0150	0.4297	0.1038	0.1334	0.0541	0.361	0.072
3000.298	3000.124	3000.281	3000.101	-0.0582	-0.0844	0.2154	0.1578	0.1450	0.1109	0.129	0.104
3000.259	3000.107	3000.237	3000.088	-0.0602	-0.0789	0.1673	0.1031	0.1109	0.0843	0.118	0.093
3000.285	3000.084	3000.269	3000.092	-0.0542	-0.0573	0.3114	0.1456	0.1922	0.1071	0.181	0.093
3000.274	3000.078	3000.232	3000.094	-0.0832	-0.0405	0.2505	0.2583	0.1574	0.1503	0.152	0.182
3000.191	3000.139	3000.176	3000.102	-0.0342	-0.0842	0.5236	0.1235	0.3256	0.0822	0.252	0.102
10000.954	10001.225	10001.336	10000.604	0.2551	-0.7104	0.3716	0.5144	0.3945	0.3107	0.238	0.367
10000.039	10000.535	10000.737	10000.464	0.5405	-0.1886	0.7188	0.3698	0.3920	0.2439	0.472	0.422
10000.494	10000.922	10000.938	10000.610	0.3175	-0.4546	0.3643	0.4800	0.4732	0.2414	0.408	0.460
10001.418	10000.634	10001.422	10000.491	-0.1326	-0.2234	0.5595	0.6418	0.3540	0.3687	0.402	0.406
10000.037	10000.772	10000.685	10000.569	0.4925	-0.3308	0.5633	0.3534	0.4903	0.2766	0.204	0.318
15002.662	15002.438	15002.094	15002.445	-0.6991	-0.1350	0.3437	0.4671	0.5815	0.4218	0.547	0.417
15003.055	15002.887	15002.671	15002.415	-0.4680	-0.6337	0.5426	0.3429	1.0699	0.3231	0.553	0.266
15002.590	15002.011	15001.944	15002.077	-0.6790	-0.0850	0.3530	0.3769	0.4943	0.3915	0.368	0.125
15002.648	15002.318	15002.607	15002.057	-0.1520	-0.4020	0.6035	0.4556	1.1150	0.3449	0.701	0.324
15002.211	15002.221	15002.069	15001.846	-0.1795	-0.5350	0.5190	0.6035	0.8935	0.3745	0.715	0.392

CMI – IMT, gauge mode

p_{CMI}/Pa		p_{IMT}/Pa		u_{CMI}/Pa		u_{IMT}/Pa	
1st day	2nd day	1st day	2nd day	1st day	2nd day	1st day	2nd day
1.0030	0.9996	1.0014	1.0041	0.0156	0.0260	0.0206	0.0211
1.0024	1.0077	0.9948	1.0107	0.0180	0.0335	0.0206	0.0213
1.0028	1.0027	1.0065	1.0030	0.0180	0.0269	0.0209	0.0209
1.0042	0.9847	1.0185	0.9959	0.0164	0.0345	0.0207	0.0217
1.0055	0.9827	1.0135	0.9866	0.0233	0.0393	0.0211	0.0217
3.0041	3.0094	3.0070	3.0088	0.0251	0.0279	0.0205	0.0210
3.0042	3.0093	3.0118	3.0090	0.0307	0.0233	0.0218	0.0207
2.9984	3.0123	3.0035	3.0116	0.0539	0.0164	0.0228	0.0202
3.0005	3.0073	3.0125	3.0111	0.0412	0.0189	0.0236	0.0204
2.9975	3.0063	3.0159	3.0112	0.0260	0.0251	0.0220	0.0205
10.0030	10.0107	10.0165	10.0129	0.0207	0.0251	0.0208	0.0208
10.0011	10.0089	10.0055	10.0132	0.0173	0.0242	0.0204	0.0208
10.0073	10.0072	10.0266	10.0104	0.0481	0.0207	0.0249	0.0206
10.0034	10.0084	10.0158	10.0109	0.0198	0.0157	0.0211	0.0204
10.0066	10.0077	10.0201	10.0150	0.0189	0.0279	0.0208	0.0212
30.0053	30.0072	30.0107	30.0029	0.0629	0.0452	0.0277	0.0235
30.0087	30.0090	30.0139	30.0081	0.0404	0.0787	0.0255	0.0279
30.0012	30.0098	30.0163	30.0032	0.0668	0.0570	0.0304	0.0263
30.0176	30.0105	30.0018	30.0075	0.1105	0.0442	0.0359	0.0242
30.0141	30.0163	30.0044	30.0178	0.0856	0.0609	0.0324	0.0246
100.0183	100.0216	100.0372	99.9995	0.0513	0.1066	0.0347	0.0386
100.0151	100.0089	100.0176	100.0036	0.0601	0.0650	0.0353	0.0346
100.0148	100.0041	100.0236	99.9992	0.0406	0.0699	0.0358	0.0353
100.0225	100.0224	100.0351	100.0124	0.0778	0.0689	0.0384	0.0357
100.0082	100.0066	100.0164	99.9935	0.0552	0.0719	0.0377	0.0350
300.0322	299.9356	300.0702	299.9040	0.4252	0.3773	0.1015	0.0916
300.0249	299.9625	300.0721	299.9412	0.2913	0.4822	0.0727	0.1108
300.0577	300.0534	300.0836	300.0651	0.2764	0.2764	0.0755	0.0716

300.0054	300.0553	300.0264	300.0724	0.2075	0.5332	0.0632	0.1262
300.0411	300.0691	300.0947	300.0654	0.2384	0.3393	0.0728	0.0935
1000.0389	1000.0684	1000.0533	1000.0661	0.3059	0.8583	0.0917	0.1779
1000.0386	1000.0155	1000.0903	1000.0185	0.2721	0.7984	0.0865	0.1783
1000.0553	1000.0057	1000.1036	999.9804	0.2611	0.3119	0.0858	0.0997
1000.0060	1000.0898	1000.0359	1000.1149	0.3967	0.5975	0.1062	0.1456
1000.0287	1000.0080	1000.0531	999.9786	0.3877	0.5176	0.1050	0.1346
3000.1166	3000.046	3000.0549	2999.9954	0.8017	0.9145	0.1993	0.2079
3000.1344	3000.0126	3000.0649	3000.0120	0.6142	0.4937	0.1659	0.1565
3000.0861	3000.0587	3000.0270	3000.0234	0.3736	0.5863	0.1393	0.1677
3000.0649	2999.9669	3000.0493	3000.0210	0.5126	1.0683	0.1547	0.2015
3000.0816	3000.0990	3000.0356	3000.0554	0.4153	0.6032	0.1451	0.1730
9999.4880	10000.1720	9999.3762	10000.1510	1.6857	1.5184	0.4410	0.4080
10000.6410	10000.1042	10000.5861	9999.9847	1.5403	2.2979	0.4083	0.5427
9999.8680	10000.0764	9999.7917	9999.9547	1.3404	1.9956	0.3653	0.4770
10000.5510	10000.3005	10000.4376	10000.2422	1.0122	2.0505	0.3128	0.5131
9999.7160	9999.9267	9999.6092	9999.8791	1.6458	1.2312	0.4266	0.3507
15000.5743	14999.5982	15000.6176	14999.6972	1.4211	0.7280	0.4410	0.3530
15000.6176	14999.9463	15000.6675	15000.0203	0.8509	1.1012	0.3606	0.3901
14999.8296	14999.4705	14999.8856	14999.5385	1.2810	1.3491	0.4279	0.4304
15000.1187	15000.7786	15000.1956	15000.9196	1.5378	1.3116	0.4619	0.4294
14999.7367	15001.3268	14999.8181	15001.5133	1.2988	1.5358	0.4275	0.4695

14. Annex 2. Differences between Laboratory and Transfer Standards

Mean differences between LS and TS pressures (d_i), their uncertainties (u_{d_i}), and mean uncertainties of LS pressures (u_{PTB}, u_{UME}, u_{RISE}, u_{IMT}) and TS pressure (u_{CMI}) at nominal pressure (p)

<u>Absolute mode</u>

	PTB - CMI		UME - CMI		RISE - CMI		IMT - CMI						
p / Pa	d_i / Pa	u_{d_i} / Pa	d_i / Pa	u_{d_i} / Pa	d_i / Pa	u_{d_i} / Pa	d_i / Pa	u_{d_i} / Pa	u_{PTB} / Pa	u_{UME} / Pa	u_{RISE} / Pa	u_{IMT} / Pa	u_{CMI} / Pa
1	0.013	0.013	0.003	0.015	0.004	0.018	-0.005	0.010	0.007	0.010	0.015	0.002	0.010
3	0.019	0.013	0.003	0.015	0.004	0.020	0.001	0.010	0.007	0.010	0.015	0.002	0.010
10	0.009	0.013	0.006	0.015	-0.005	0.021	0.010	0.012	0.007	0.010	0.015	0.006	0.010
30	0.010	0.014	0.003	0.016	0.014	0.021	0.003	0.021	0.007	0.011	0.016	0.018	0.011
100	-0.011	0.019	0.002	0.018	0.020	0.023	0.002	0.061	0.008	0.012	0.017	0.060	0.012
300	-0.002	0.024	-0.001	0.027	0.010	0.028	0.000	0.081	0.010	0.017	0.021	0.078	0.016
1000	0.008	0.031	0.004	0.047	0.037	0.048	0.008	0.211	0.013	0.034	0.037	0.206	0.026
3000	0.042	0.062	0.008	0.109	0.102	0.108	-0.082	0.131	0.024	0.068	0.082	0.117	0.058
10000	0.115	0.178	0.059	0.301	0.209	0.312	-0.209	0.285	0.063	0.220	0.223	0.224	0.168
15000	0.144	0.256	0.088	0.398	0.284	0.434	-0.221	0.400	0.091	0.299	0.327	0.317	0.236

<u>Gauge mode</u>

	PTB - CMI		UME - CMI		RISE - CMI		IMT - CMI						
p / Pa	d_i / Pa	u_{d_i} / Pa	d_i / Pa	u_{d_i} / Pa	d_i / Pa	u_{d_i} / Pa	d_i / Pa	u_{d_i} / Pa	u_{PTB} / Pa	u_{UME} / Pa	u_{RISE} / Pa	u_{IMT} / Pa	u_{CMI} / Pa
1	0.001	0.018	-0.004	0.018	0.009	0.023	0.050	0.031	0.008	0.012	0.013	0.021	0.013
3	-0.004	0.015	-0.004	0.020	0.014	0.020	0.050	0.033	0.007	0.013	0.012	0.021	0.013
10	0.002	0.015	-0.002	0.017	0.015	0.021	0.053	0.030	0.007	0.012	0.012	0.021	0.013
30	-0.003	0.018	0.001	0.025	0.012	0.033	0.046	0.062	0.008	0.016	0.017	0.027	0.015
100	-0.002	0.021	0.000	0.030	0.006	0.044	0.047	0.071	0.008	0.019	0.019	0.036	0.019
300	-0.007	0.027	0.003	0.113	0.023	0.112	0.063	0.304	0.010	0.069	0.045	0.081	0.032
1000	0.005	0.042	0.005	0.132	0.040	0.141	0.053	0.367	0.014	0.077	0.058	0.106	0.043
3000	0.026	0.073	0.008	0.302	0.052	0.228	-0.040	0.556	0.025	0.166	0.112	0.165	0.090
10000	0.112	0.228	0.131	1.115	0.125	0.678	-0.194	1.513	0.067	0.643	0.343	0.403	0.277
15000	0.171	0.333	0.220	0.896	0.129	0.716	-0.107	1.180	0.095	0.569	0.461	0.412	0.360

15. Annex 3. Equivalence between EURAMET and CCM KCs – supplementary results

Degrees of equivalence for absolute pressure of the results of the present EURAMET.M.P-K4.2020 and the CCM.P-K4.2012 comparison at nominal pressures (p_{nom}): Deviations of the EURAMET KC NMIs (i) results from the CCM KCRV ($D_{i,\mathrm{CCM}}$) with their expanded uncertainties ($U_{i,\mathrm{CCM}}$) and differences between the EURAMET KC NMIs (i) and the CCM KC NMIs (m) results (D_{im}) with their expanded uncertainties (U_{im}), all given in Pa.

The link between EURAMET.M.P-K4.2020 and the CCM.P-K4.2012 at (3, 10, and 30) Pa was produced based on the results of a direct comparison of the PTB standards used in both KCs [11].

NMI i	p_{nom} / Pa	CCM KCRV		NMI m									
				PTB, CCM [1)]		NMIJ		NIST		CENAM		VNIIM	
		$D_{i,\mathrm{CCM}}$	$U_{i,\mathrm{CCM}}$	D_{im}	U_{im}	D_{im}	U_{im}	D_{im}	U_{im}	D_{im}	U_{im}	D_{im}	U_{im}
PTB	1	0.016	0.043	0.016	0.047	0.015	0.047	0.010	0.046	0.026	0.053	0.017	0.054
	3	0.007	0.043	0.007	0.047	0.005	0.048	0.001	0.046	0.022	0.054	0.012	0.054
	10	0.013	0.044	0.009	0.049	0.008	0.072	0.004	0.046	0.057	0.065	0.016	0.054
	30	0.033	0.054	0.015	0.065	0.019	0.167	0.008	0.046	0.151	0.117	0.022	0.055
	100	0.050	0.062	0.010	0.069	0.046	0.187	0.012	0.053	0.187	0.218	0.054	0.060
	300	0.061	0.124	0.019	0.078	0.044	0.171	0.022	0.061	0.183	0.634	0.100	0.071
	1000	0.133	0.365	0.027	0.100	0.056	0.195	0.059	0.076	0.361	2.137	0.285	0.133
	3000	0.032	0.199	0.022	0.190	0.112	0.340	0.152	0.120	0.072	0.170	-0.218	0.950
	10000	0.235	0.359	0.265	0.557	0.235	0.761	0.435	0.296	0.445	0.339	-0.065	1.043
RISE	1	0.007	0.050	0.007	0.054	0.006	0.054	0.001	0.053	0.017	0.059	0.008	0.060
	3	-0.008	0.052	-0.008	0.055	-0.010	0.056	-0.014	0.055	0.007	0.061	-0.003	0.061
	10	-0.001	0.055	-0.005	0.059	-0.006	0.079	-0.010	0.056	0.043	0.073	0.002	0.063
	30	0.037	0.063	0.019	0.072	0.023	0.170	0.012	0.056	0.155	0.121	0.026	0.063
	100	0.081	0.067	0.041	0.073	0.077	0.189	0.043	0.059	0.218	0.219	0.085	0.065
	300	0.073	0.127	0.031	0.083	0.056	0.174	0.034	0.068	0.195	0.635	0.112	0.077
	1000	0.162	0.372	0.056	0.124	0.085	0.209	0.088	0.106	0.390	2.139	0.314	0.152
	3000	0.092	0.265	0.082	0.259	0.172	0.383	0.212	0.213	0.132	0.244	-0.158	0.966
	10000	0.329	0.626	0.359	0.758	0.329	0.918	0.529	0.593	0.539	0.615	0.029	1.163
UME	1	0.006	0.045	0.006	0.049	0.005	0.049	0.000	0.048	0.016	0.054	0.007	0.055
	3	-0.009	0.045	-0.009	0.049	-0.011	0.049	-0.015	0.048	0.006	0.055	-0.004	0.055
	10	0.010	0.046	0.006	0.051	0.005	0.073	0.001	0.048	0.054	0.067	0.013	0.055
	30	0.026	0.056	0.008	0.066	0.012	0.168	0.001	0.049	0.144	0.118	0.015	0.057
	100	0.063	0.061	0.023	0.068	0.059	0.187	0.025	0.052	0.200	0.218	0.067	0.059
	300	0.062	0.126	0.020	0.081	0.045	0.173	0.023	0.065	0.184	0.635	0.101	0.075
	1000	0.129	0.372	0.023	0.123	0.052	0.208	0.055	0.104	0.357	2.138	0.281	0.151
	3000	-0.002	0.268	-0.012	0.262	0.078	0.385	0.118	0.216	0.038	0.247	-0.252	0.967
	10000	0.179	0.604	0.069	0.739	0.179	0.902	0.379	0.569	0.389	0.592	-0.121	1.151
IMT	1	-0.002	0.040	-0.002	0.044	-0.003	0.044	-0.008	0.043	0.008	0.050	-0.001	0.051
	3	-0.011	0.040	-0.011	0.044	-0.013	0.045	-0.017	0.043	0.004	0.051	-0.006	0.051
	10	0.014	0.043	0.010	0.048	0.009	0.071	0.005	0.045	0.058	0.064	0.017	0.053
	30	0.027	0.063	0.009	0.072	0.013	0.170	0.002	0.056	0.145	0.121	0.016	0.063
	100	0.063	0.132	0.023	0.136	0.059	0.221	0.025	0.128	0.200	0.247	0.067	0.131
	300	0.063	0.198	0.021	0.174	0.046	0.231	0.024	0.167	0.185	0.653	0.102	0.171
	1000	0.133	0.554	0.027	0.429	0.056	0.461	0.059	0.424	0.361	2.178	0.285	0.438
	3000	-0.092	0.304	-0.102	0.299	-0.012	0.411	0.028	0.260	-0.052	0.286	-0.342	0.978
	10000	-0.089	0.573	-0.059	0.714	-0.089	0.882	0.111	0.536	0.121	0.561	-0.389	1.135