

LINKING SIM MASS COMPARISONS TO THE KCRV ON 1 kg

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Abstract. Within the frame of SIM (Sistema Interamericano de Metrología), inter laboratory mass comparisons have been performed in different nominal values. The main objective of these comparisons was to assess the equivalence level of SIM laboratories, among themselves and with other national metrology institutes from other metrological regions. The present work shows the degree of equivalence in 1 kg, of SIM laboratories with the Key Comparison Reference Value (KCRV), of CCM.M-K1 and therefore with those NMIs participants of the CCM.M-K1 by simple differences.

Keywords: Mass, Mass comparisons

1. Introduction

In the frame of SIM, mass comparisons were performed among SIM NMIs where the travelling standards were stainless steel mass standards of different nominal values.

An important goal of these comparisons was to evaluate the degree of consistency among SIM laboratories in mass measurement.

The present work expounds the evaluation of consistency at the 1 kg level among SIM laboratories and between SIM laboratories and the KCRV (Key Comparison Reference Value) of CCM.M-K1 and therefore with those NMIs participants of the CCM.M-K1 by simple differences.

2. Mass Comparisons used for this analysis

For the purpose of this paper were analysed the reported values in 1 kg of three comparisons performed in the frame of SIM and the reported values of the key comparison of CCM in 1 kg too.

- **SIM.7.16a** [1]
Nominal value: 1 kg
Participant NMIs: CENAM-Mexico, LANAMET-Nicaragua, CONACYT-EI Salvador, LNMG-Guatemala, LACOMET-Costa Rica, CENAMEP-Panama,
Pilot Laboratory: CENAM
Date: May 2003 - Nov 2003
- **SIM.7.29 (SIM.M.M-S1)** [2]
Nominal values: 1 kg, 100 g, 20 g, 5 g and 100 mg
Participant NMIs: CEM-España, CENAM-Mexico, IBMETRO-Bolivia,
INDECOPI-Peru, INEN-Ecuador, SIC-Colombia, SENCAMER-Venezuela

Pilot Laboratories: CEM, CENAM
Date: Jul 2004 – Jul 2005

- **SIM.7.31a (SIM.M.M-S2) [3]**
Nominal values: 1 kg
Participant NMIs: CENAM-Mexico, BSJ-Jamaica, LACOMET-Costa Rica, IBMETRO-Bolivia, CESMEC-Chile, INDECOPI-Peru, INTN-Paraguay
Pilot Laboratory: CENAM
Date: Apr 2005 - Jan 2006
- **CMM.M-K1 [4]**
Nominal value: 1 kg
Participant NMIs: BIPM-International (BIPM is an International laboratory not a NMI), CSIRO-Australia, NRC-Canada, NIM-China, BNM-INM/CNAM-France, PTB-Germany, IMGCI-Italy, NMIJ/AIST-Japan, KRISS-Republic of Korea, CENAM-Mexico, VSL-Netherlands, VNIIM-Russia, SMU-Slovakia, NPL-United Kingdom, NIST-USA
Pilot Laboratory: BIPM
Date: Feb 1995 - Nov 1997

All reports were published. For the Mass comparison SIM.7.29, only the reported results for 1 kg were used for the purpose of this paper.

Tables 1 to 3 report the mass differences between the participant laboratories and CENAM in SIM comparisons. Mass differences between participant laboratories and CENAM in CCM.M.K1 comparison are reported in table 4.

For CCM.M-K1, mass difference between participant laboratories and the KCRV are reported in table 5.

Table 1. Mass difference between NMI *i* and CENAM, in SIM.7.16a.

NMI	diff. mg	Unc. (k=2) mg
CENAM	---	0.15
LANAMET	0.17	0.54
CENAMEP	-0.06	0.43
LACOMET	-0.93	0.34
LNMG	0.4	1.0
CONACYT	0.4	1.0

Table 2. Mass difference between NMI *i* and CENAM, in SIM.7.29.

NMI	diff. mg	Unc. (k=2) mg
CENAM	---	0.020
CEM	-0.020	0.086
SIC	-0.14	0.18
SENCAMER	1.19	0.25
INEN	-0.01	0.19
INDECOPI	-0.04	0.30
IBMETRO	-0.08	0.15

Table 3. Mass difference between NMI *i* and CENAM, in SIM.7.31a.

NMI	diff. mg	Unc. (k=2) mg
CENAM	---	0.030
BSJ	0.1	1.3
LACOMET	-0.054	0.055
IBMETRO	0.03	0.16
INDECOPI	-0.04	0.26
INTN	0.1	1.6
CESMEC	0.02	0.50

Table 4. Mass difference between NMI *i* and CENAM, in CCM.M-K1

NMI	diff. mg	Unc. (k=2) mg
CENAM	---	0.026
BIPM	0.001	0.036
VSL	-0.017	0.045
NIST	-0.020	0.047
NPL	0.001	0.041
NRC	-0.019	0.043
NMIJ	-0.022	0.038
VNIIM	0.047	0.055
CSIRO	0.003	0.039
PTB	-0.003	0.037
NIM	-0.003	0.053
SMU	0.058	0.052
KRISS	-0.003	0.039
IMGC	-0.002	0.038
BNM	0.004	0.034

Table 5. Mass difference between NMI i and KCRV, in CCM.M-K1

NMI	diff. mg	Unc. (k=2) mg
BIPM	0.003	0.024
VSL	-0.015	0.037
NIST	-0.018	0.039
NPL	0.002	0.032
NRC	-0.017	0.034
NMIJ	-0.020	0.028
VNIIM	0.049	0.048
CSIRO	0.005	0.029
PTB	-0.001	0.026
NIM	-0.001	0.046
SMU	0.060	0.044
KRISS	-0.001	0.029
IMGC	0.000	0.027
BNM	0.006	0.022
CENAM	0.002	0.027

All differences reported in tables 1 to 5, were assessed for each particular comparison.

The uncertainty associated to each difference comprises the reported uncertainty for the corresponding participants and the stability of the standards used.

3. Evaluation of the degree of equivalence between SIM NMIs and KCRV in 1 kg

CENAM was the key linkage between SIM participant laboratories and the KCRV. The mass differences obtained between CENAM and SIM participant laboratories in corresponding comparison were used in order to link the results of SIM laboratories with those of the KCRV of CCM.M-K1.

It is assumed that all results have systematic differences among them within the uncertainty interval of such differences.

The mass difference between SIM's laboratory i and KCRV of CCM.M-K1 is calculated by,

$$diff(NMI_{ij} - KCRV) = diff(NMI_{ij} - CENAM_j) - diff(CENAM_{CCM} - KCRV) \quad (1)$$

where,

$diff(NMI_{ij} - CENAM_j)$ is the mass difference between the NMI i and CENAM in the comparison j ,

$diff(CENAM_{CCM} - KCRV)$ is the mass difference between CENAM and the KCRV of CCM.M-K1

The uncertainty of these mass difference is evaluated by combination of the standard uncertainty of the mass difference between SIM's laboratory and CENAM, the standard uncertainty of the mass difference between CENAM and the KCRV, a component of uncertainty due to the CENAM's reproducibility, minus CENAM's reported uncertainties for the corresponding comparisons.

$$u(\text{diff}(NMI_i - KCRV)) = [u^2(\text{diff}(NMI_{ij} - CENAM_j)) - u^2(CENAM_j) + u^2(\text{diff}(CENAM - KCRV)) - u^2(CENAM_{CCM}) + u^2(CENAM')]^{1/2} \quad (2)$$

where,

$u(\text{diff}(NMI_{ij} - CENAM_j))$ is the standard uncertainty of the mass difference between the NMI i and CENAM for the comparison j ,

$u(\text{diff}(CENAM - KCRV))$ is the standard uncertainty of the mass difference between CENAM and the KCRV of the CCM.M-K1,

$u(CENAM_j)$ is the reported uncertainty by CENAM in the comparison j ,

$u(CENAM_{CCM})$ is the reported uncertainty by CENAM in the CCM.M-K1.

$u(CENAM')$ is the component due to the CENAM's reproducibility, which was estimated as 7 μg ,

In table 6, are reported the calculated mass differences between SIM's NMIs and the KCRV of the CCM.M-K1, and the expanded uncertainties evaluated for those mass differences.

Table 6. Mass difference between NMI i and the KCRV of CCM.M-K1.

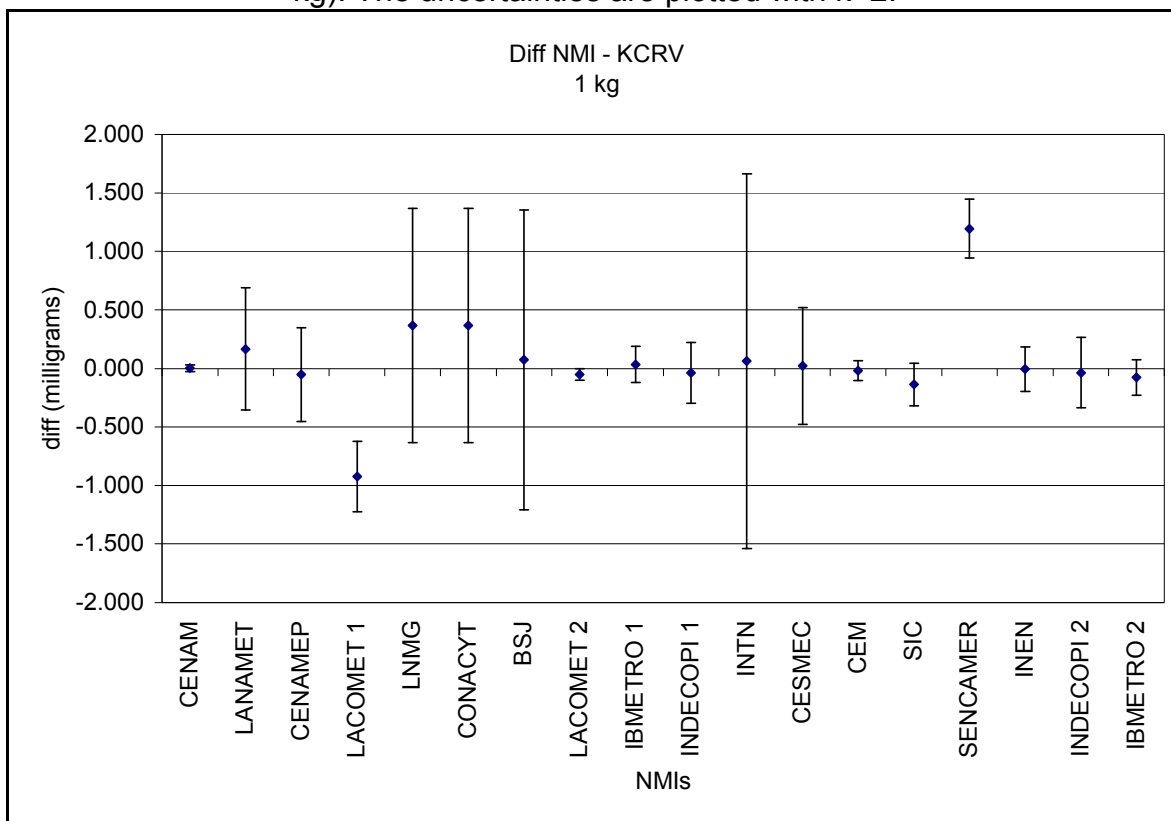
Comparison	NMI	Diff mg	U, k=2 mg
	CENAM	0.002	0.027
SIM.7.16a	LANAMET	0.17	0.52
	CENAMEP	-0.05	0.40
	LACOMET	-0.92	0.30
	LNMG	0.4	1.0
	CONACYT	0.4	1.0
SIM.7.31a (SIM.M-S2)	BSJ	0.1	1.3
	LACOMET	-0.052	0.049
	IBMETRO	0.03	0.15
	INDECOPI	-0.04	0.26
	INTN	0.1	1.6
	CESMEC	0.02	0.50
SIM.7.29, (SIM.M.M-S1)	CEM	-0.018	0.085
	SIC	-0.14	0.18
	SENCAMER	1.19	0.25
	INEN	-0.01	0.19
	INDECOPI	-0.04	0.30
	IBMETRO	-0.08	0.15

In figure 1, LACOMET 1 was calculated from its participation in SIM.7.16a and LACOMET 2 was calculated from its participation in SIM.7.31a.

Changes were reported in the traceability system of LACOMET between its participations in SIM.7.16a and SIM.7.31a.

IBMETRO 1 and INDECOPI 1 were calculated from SIM.7.31a results, and IBMETRO 2 and INDECOPI 2 were calculated from SIM.7.29 results.

Figure 1. Mass differences between SIM's NMIs and the KCRV of CCM.M-K1 (1 kg). The uncertainties are plotted with $k=2$.



4. Evaluation of the degree of equivalence between SIM laboratories and participant laboratories of CCM.M-K1

The mass difference between two laboratories that did not participate in the same comparison could be estimated using the corresponding difference of each laboratory and CENAM.

$$diff(NMI_{ij} - NMI_{kl}) = diff(NMI_{ij} - CENAM_j) + diff(NMI_{kl} - CENAM_l) \quad (3)$$

where,

$diff(NMI_{ij} - CENAM_j)$ is the mass difference between the laboratory i and CENAM in the comparison j ,

$diff(NMI_{kl} - CENAM_l)$ is the mass difference between the laboratory k and CENAM in the comparison l ,

the standard uncertainty of this difference is calculated from,

$$u(diff(NMI_{ij} - NMI_{kl})) = [u^2(diff(NMI_{ij} - CENAM_j)) - u^2(CENAM_j) + u^2(diff(NMI_{kl} - CENAM_l)) - u^2(CENAM_l) + u^2(CENAM_l)]^{1/2} \quad (4)$$

where,

$u(diff(NMI_{kl} - CENAM_l))$ is the standard uncertainty of the mass difference between the NMI k and CENAM for the comparison l ,

$u(CENAM_l)$ is the reported uncertainty by CENAM in the comparison l .

From formula 4, it is possible to estimate the degree of equivalence among SIM laboratories and between SIM laboratories and participant laboratories of CCM.M-K1, see tables 7, 8 and 9.

5. Conclusions

From this evaluation it is possible to estimate the degree of equivalence of SIM laboratories with the KCRV of CCM.M-K1, and the degree of equivalence among SIM laboratories and between SIM laboratories and participant laboratories of CCM.M-K1.

LACOMET, IBMETRO and INDECOPI participated in two of the comparisons analysed, and from these results it is possible to confirm that IBMETRO and INDECOPI participations throw differences against the KCRV consistent within the uncertainty intervals.

LACOMET participations show on the other hand, differences that are not consistent within the uncertainty intervals. This situation is mainly due to LACOMET's significant changes in its traceability chain.

References

- [1] J. Nava et al. - Interlaboratory mass comparison between laboratories belonging to SIM – CAMET region coordinated by CENAM (SIM.7.16a, SIM.7.16b)- 2005 NCSL International Workshop and Symposium
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- [3] J. Nava et al. - Interlaboratory mass comparison between laboratories belonging to SIM – sub-regions coordinated by CENAM (SIM.7.31a & SIM.7.31b) - Simposio de Metrología, Oct 2006, Querétaro, Mexico.
- [4] C. Aupetit, et al. - Draft B, Final Report on CIPM key comparison of 1 kg standards in stainless steel (CCM.M.-K1)

Table 7. Mass differences between NMI A minus NMI B and the expanded uncertainty. Values in milligrams.

		SIM.7.16a											
	A\B	CENAM		LANAMET		CENAMEP		LACOMET		LNMG		CONACYT	
		diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2
SIM.7.31a	SIM.M.M.-S2												
	BSJ	0.1	1.3	-0.1	1.4	0.1	1.3	1.0	1.3	-0.3	1.6	-0.3	1.6
	LACOMET	-0.054	0.055	-0.22	0.52	0.00	0.40	0.87	0.30	-0.4	1.0	-0.4	1.0
	IBMETRO	0.03	0.16	-0.13	0.54	0.09	0.43	0.96	0.34	-0.3	1.0	-0.3	1.0
	INDECOPI	-0.04	0.26	-0.21	0.58	0.02	0.48	0.89	0.40	-0.4	1.0	-0.4	1.0
	INTN	0.1	1.6	-0.1	1.7	0.1	1.6	1.0	1.6	-0.3	1.9	-0.3	1.9
	CESMEC	0.02	0.50	-0.15	0.72	0.08	0.64	0.95	0.58	-0.3	1.1	-0.3	1.1
SIM.7.29	SIM.M.M.-S1												
	CEM	-0.020	0.086	-0.19	0.53	0.04	0.41	0.91	0.31	-0.4	1.0	-0.4	1.0
	SIC	-0.14	0.18	-0.30	0.55	-0.08	0.44	0.79	0.35	-0.5	1.0	-0.5	1.0
	SENCAMER	1.19	0.25	1.03	0.58	1.25	0.47	2.12	0.39	0.8	1.0	0.8	1.0
	INEN	-0.01	0.19	-0.17	0.55	0.05	0.44	0.92	0.36	-0.4	1.0	-0.4	1.0
	INDECOPI	-0.04	0.30	-0.20	0.60	0.02	0.50	0.89	0.42	-0.4	1.0	-0.4	1.0
	IBMETRO	-0.08	0.15	-0.24	0.54	-0.02	0.43	0.85	0.34	-0.4	1.0	-0.4	1.0
CCM.M.K1	BIPM	0.001	0.036	-0.16	0.52	0.06	0.40	0.93	0.30	-0.4	1.0	-0.4	1.0
	VSL	-0.017	0.045	-0.18	0.52	0.04	0.40	0.91	0.30	-0.4	1.0	-0.4	1.0
	NIST	-0.020	0.047	-0.19	0.52	0.04	0.40	0.91	0.30	-0.4	1.0	-0.4	1.0
	NPL	0.001	0.041	-0.16	0.52	0.06	0.40	0.93	0.30	-0.4	1.0	-0.4	1.0
	NRC	-0.019	0.043	-0.18	0.52	0.04	0.40	0.91	0.30	-0.4	1.0	-0.4	1.0
	NMIJ	-0.022	0.038	-0.19	0.52	0.03	0.40	0.90	0.30	-0.4	1.0	-0.4	1.0
	VNIIM	0.047	0.055	-0.12	0.52	0.10	0.40	0.97	0.30	-0.3	1.0	-0.3	1.0
	CSIRO	0.003	0.039	-0.16	0.52	0.06	0.40	0.93	0.30	-0.4	1.0	-0.4	1.0
	PTB	-0.003	0.037	-0.17	0.52	0.05	0.40	0.92	0.30	-0.4	1.0	-0.4	1.0
	NIM	-0.003	0.053	-0.17	0.52	0.05	0.40	0.92	0.30	-0.4	1.0	-0.4	1.0
	SMU	0.058	0.052	-0.11	0.52	0.11	0.40	0.98	0.30	-0.3	1.0	-0.3	1.0
	KRISS	-0.003	0.039	-0.17	0.52	0.05	0.40	0.92	0.30	-0.4	1.0	-0.4	1.0
	IMGC	-0.002	0.038	-0.17	0.52	0.05	0.40	0.92	0.30	-0.4	1.0	-0.4	1.0
BNM	0.004	0.034	-0.16	0.52	0.06	0.40	0.93	0.30	-0.4	1.0	-0.4	1.0	

Table 8. Mass differences between NMI A minus NMI B and the expanded uncertainty. Values in milligrams.

		SIM.7.29 (SIM.M.M-S1)											
	AIB	CEM		SIC		SENCAMER		INEN		INDECOPI		IBMETRO	
		diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2
SIM.7.16a	LANAMET	0.19	0.53	0.30	0.55	-1.03	0.58	0.17	0.55	0.20	0.60	0.24	0.54
	CENAMEP	-0.04	0.41	0.08	0.44	-1.25	0.47	-0.05	0.44	-0.02	0.50	0.02	0.43
	LACOMET	-0.91	0.31	-0.79	0.35	-2.12	0.39	-0.92	0.36	-0.89	0.42	-0.85	0.34
	LNMG	0.4	1.0	0.5	1.0	-0.8	1.0	0.4	1.0	0.4	1.0	0.4	1.0
	CONACYT	0.4	1.0	0.5	1.0	-0.8	1.0	0.4	1.0	0.4	1.0	0.4	1.0
SIM.7.31a SIM.M.M.-S2	BSJ	0.1	1.3	0.2	1.3	-1.1	1.3	0.1	1.3	0.1	1.3	0.1	1.3
	LACOMET	-0.03	0.10	0.09	0.19	-1.25	0.25	-0.04	0.20	-0.01	0.30	0.03	0.16
	IBMETRO	0.05	0.18	0.17	0.24	-1.16	0.29	0.04	0.25	0.07	0.34	0.11	0.22
	INDECOPI	-0.02	0.27	0.10	0.32	-1.23	0.36	-0.03	0.32	0.00	0.40	0.04	0.30
	INTN	0.1	1.6	0.2	1.6	-1.1	1.6	0.1	1.6	0.1	1.6	0.1	1.6
	CESMEC	0.04	0.51	0.16	0.53	-1.17	0.56	0.03	0.54	0.06	0.58	0.10	0.52
CCM.M.K1	BIPM	0.021	0.088	0.14	0.18	-1.19	0.25	0.01	0.19	0.04	0.30	0.08	0.15
	VSL	0.003	0.092	0.12	0.18	-1.21	0.25	-0.01	0.19	0.02	0.30	0.06	0.16
	NIST	0.000	0.093	0.12	0.19	-1.21	0.25	-0.01	0.19	0.02	0.30	0.06	0.16
	NPL	0.021	0.091	0.14	0.18	-1.19	0.25	0.01	0.19	0.04	0.30	0.08	0.15
	NRC	0.001	0.091	0.12	0.18	-1.21	0.25	-0.01	0.19	0.02	0.30	0.06	0.15
	NMIJ	-0.002	0.089	0.12	0.18	-1.21	0.25	-0.01	0.19	0.02	0.30	0.06	0.15
	VNIIM	0.067	0.098	0.19	0.19	-1.14	0.26	0.06	0.20	0.09	0.30	0.13	0.16
	CSIRO	0.023	0.090	0.14	0.18	-1.19	0.25	0.01	0.19	0.04	0.30	0.08	0.15
	PTB	0.017	0.089	0.14	0.18	-1.19	0.25	0.01	0.19	0.04	0.30	0.08	0.15
	NIM	0.017	0.097	0.14	0.19	-1.19	0.25	0.01	0.20	0.04	0.30	0.08	0.16
	SMU	0.078	0.096	0.20	0.19	-1.13	0.25	0.07	0.20	0.10	0.30	0.14	0.16
	KRISS	0.017	0.090	0.14	0.18	-1.19	0.25	0.01	0.19	0.04	0.30	0.08	0.15
	IMGC	0.018	0.089	0.14	0.18	-1.19	0.25	0.01	0.19	0.04	0.30	0.08	0.15
	BNM	0.024	0.088	0.14	0.18	-1.19	0.25	0.01	0.19	0.04	0.30	0.08	0.15

Table 9. Mass differences between NMI A minus NMI B and the expanded uncertainty. Values in milligrams.

		SIM.7.31a (SIM.M.M.-S2)											
	A\B	BSJ		LACOMET		IBMETRO		INDECOPI		INTN		CESMEC	
		diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2	diff	Unc k=2
SIM.7.16a	LANAMET	0.1	1.4	0.22	0.52	0.13	0.54	0.21	0.58	0.1	1.7	0.15	0.72
	CENAMEP	-0.1	1.3	0.00	0.40	-0.09	0.43	-0.02	0.48	-0.1	1.6	-0.08	0.64
	LACOMET	-1.0	1.3	-0.87	0.30	-0.96	0.34	-0.89	0.40	-1.0	1.6	-0.95	0.58
	LNMG	0.3	1.6	0.4	1.0	0.3	1.0	0.4	1.0	0.3	1.9	0.3	1.1
	CONACYT	0.3	1.6	0.4	1.0	0.3	1.0	0.4	1.0	0.3	1.9	0.3	1.1
SIM.7.29 SIM.M.M-S1	CEM	-0.1	1.3	0.03	0.10	-0.05	0.18	0.02	0.27	-0.1	1.6	-0.04	0.51
	SIC	-0.2	1.3	-0.09	0.19	-0.17	0.24	-0.10	0.32	-0.2	1.6	-0.16	0.53
	SENCAMER	1.1	1.3	1.25	0.25	1.16	0.29	1.23	0.36	1.1	1.6	1.17	0.56
	INEN	-0.1	1.3	0.04	0.20	-0.04	0.25	0.03	0.32	-0.1	1.6	-0.03	0.54
	INDECOPI	-0.1	1.3	0.01	0.30	-0.07	0.34	0.00	0.40	-0.1	1.6	-0.06	0.58
	IBMETRO	-0.1	1.3	-0.03	0.16	-0.11	0.22	-0.04	0.30	-0.1	1.6	-0.10	0.52
CCM.M.K1	BIPM	-0.1	1.3	0.055	0.054	-0.03	0.16	0.04	0.26	-0.1	1.6	-0.02	0.50
	VSL	-0.1	1.3	0.037	0.061	-0.05	0.16	0.02	0.26	-0.1	1.6	-0.04	0.50
	NIST	-0.1	1.3	0.034	0.062	-0.05	0.16	0.02	0.26	-0.1	1.6	-0.04	0.50
	NPL	-0.1	1.3	0.055	0.058	-0.03	0.16	0.04	0.26	-0.1	1.6	-0.02	0.50
	NRC	-0.1	1.3	0.035	0.059	-0.05	0.16	0.02	0.26	-0.1	1.6	-0.04	0.50
	NMIJ	-0.1	1.3	0.032	0.055	-0.05	0.16	0.02	0.26	-0.1	1.6	-0.04	0.50
	VNIIM	0.0	1.3	0.101	0.068	0.02	0.16	0.09	0.26	0.0	1.6	0.03	0.50
	CSIRO	-0.1	1.3	0.057	0.056	-0.03	0.16	0.04	0.26	-0.1	1.6	-0.02	0.50
	PTB	-0.1	1.3	0.051	0.055	-0.04	0.16	0.04	0.26	-0.1	1.6	-0.02	0.50
	NIM	-0.1	1.3	0.051	0.067	-0.04	0.16	0.04	0.26	-0.1	1.6	-0.02	0.50
	SMU	0.0	1.3	0.112	0.066	0.03	0.16	0.10	0.26	0.0	1.6	0.04	0.50
	KRISS	-0.1	1.3	0.051	0.056	-0.04	0.16	0.04	0.26	-0.1	1.6	-0.02	0.50
	IMGC	-0.1	1.3	0.052	0.055	-0.03	0.16	0.04	0.26	-0.1	1.6	-0.02	0.50
BNM	-0.1	1.3	0.058	0.053	-0.03	0.16	0.04	0.26	-0.1	1.6	-0.02	0.50	

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