Report on the SIM Photometry and Radiometry Key Comparison of Spectral Regular Transmittance (SIM.PR-K6.2010)

Final Report
November 2020

Catherine Cooksey
Blaza Toman

Table of Contents

Introduction

The Consultative Committee for Photometry and Radiometry (CCPR) organizes measurement comparisons of several 'key' measurement scales in support of the Mutual Recognition Arrangement (MRA). Because participation in CCPR key comparisons is limited to 12 laboratories, the Regional Metrology Organizations (RMOs) facilitate corresponding key comparisons at a smaller scale to allow its participants' results to be linked to those of the CCPR comparison in terms of equivalence (through the key comparison reference value). In this way, RMOs assist national metrology institutes in fulfilling their obligations under the MRA.

The CCPR initiated planning in 2008 for a key comparison of spectral regular transmittance, later designated CCPR-K6.2010. While CCPR-K6.2010 was still in progress, the SIM Photometry and Radiometry (PR) Technical Committee began planning the SIM.PR-K6.2010 comparison in 2012, and the committee appointed the National Institute of Standards and Technology (NIST) of USA as the pilot laboratory and NIST and the National Research Council (NRC) of Canada as the link laboratories.

The announcement of the SIM.PR-K6.2010 comparison was posted on the BIPM KCDB in November 2016. The list of participant laboratories is provided in Table 1. Initiation of the SIM.PR-K6.2010 comparison began promptly following approval of the final report for CCPR-K6.2010 [1].

Table 1. Participating laboratories in SIM.PR-K6.2010 for spectral regular transmittance

RMO	Participating Laboratories	Economy	Primary Contact
SIM	National Institute of Standards and Technology (NIST)	USA	Catherine Cooksey
	National Research Council of Canada (NRC)	Canada	Joanne Zwinkels
	Centro Nacional de Metrología (CENAM)	Mexico	Carlos Matamoros Garcia
	Instituto Nacional de Metrología de Colombia (INM)	Colombia	Juliana Serna Saiz
	Instituto Nacional de Metrologia, Inovação e Tecnologia (INMETRO)	Brazil	Giovanna Borghi
APMP	Center for Measurement Standards/ Industrial Technology Research Institute (CMS/ITRI)	Chinese Taipei	Wen-Chun Liu
	National Institute of Metrology (NIM)	China	Zheng Chundi
	National Institute of Metrology (NIMT)	Thailand	Rojana Leecharoen

Comparison Measurements

The technical protocol for SIM.PR-K6.2010 (see Appendix A) was based on the technical protocol for CCPR-K6.2010 [2]. The comparison was accomplished through measurements of sets of standard filters, and the measurement sequence followed a star pattern: pilot-participant-pilot. Accordingly, the pilot measured all sets of comparison standards first. Then, each participant measured a single set of comparison standards. Finally, the pilot measured all sets a second time. Thus, the total number of measurement rounds is three. The schedule for the comparison is detailed in Table 2.

Table 2. Schedule for comparison measurements

Dates	Activity
December 2016 to March 2017	First measurements by pilot (Round 1)
March 2017	Comparison standards shipped to each participant
March 2017 to June 2017	Measurements by participants (Round 2)
April 2017 to June 2017	Comparison standards return from each participant
August 2017 to November 2017*	Second measurement by pilot (Round 3)

*Select filters and wavelengths were re-measured by the pilot in February 2018.

It is noted that the CCPR-K6.2010 comparison included an extra two rounds of measurements involving both the pilot and participants. The number of rounds for SIM.PR-K6.2010 was reduced from CCPR-K6.2010 to ease the burden on the pilot and speed the time of the comparison.

The pilot and the participants measured the spectral transmittance of each comparison standard according to the parameters listed in Table 3. When the measurement parameters deviated from those listed in the table, participants were expected to make appropriate corrections to their transmittance values and/or account for the deviations in their uncertainty budgets. The pilot provided participants with the temperature coefficients for the comparison standards and their corresponding uncertainties [3].

Table 3. Parameters for the comparison measurements.

Parameter	Comparison Value
Angle of Incidence (°)	0
Diameter of Beam (mm)	17
Wavelength (nm)	380, 400, 500, 600, 700, 800, 900, 1000
Bandwidth (nm)	1
Temperature (°C)	23
Relative Humidity (%)	< 60

Each laboratory measured the transmittance of the comparison standards independently several times during its measurement round. The number of measurements completed was consistent with the

laboratory's usual process and was stated in each laboratory's report (see Appendix B). The reported transmittance values were the average of these measurements.

Each laboratory estimated its measurement uncertainty according to the ISO Guide to the Expression of Uncertainty in Measurement [4]. For optimal comparability, each laboratory evaluated uncertainty contributions for a list of principal influence parameters provided in the SIM.PR-K6.2010 Technical Protocol (see Appendix A). The laboratory included contributions for additional parameters as needed based on its specific facility. All values were reported as absolute uncertainties with a coverage factor of $k = 1$.

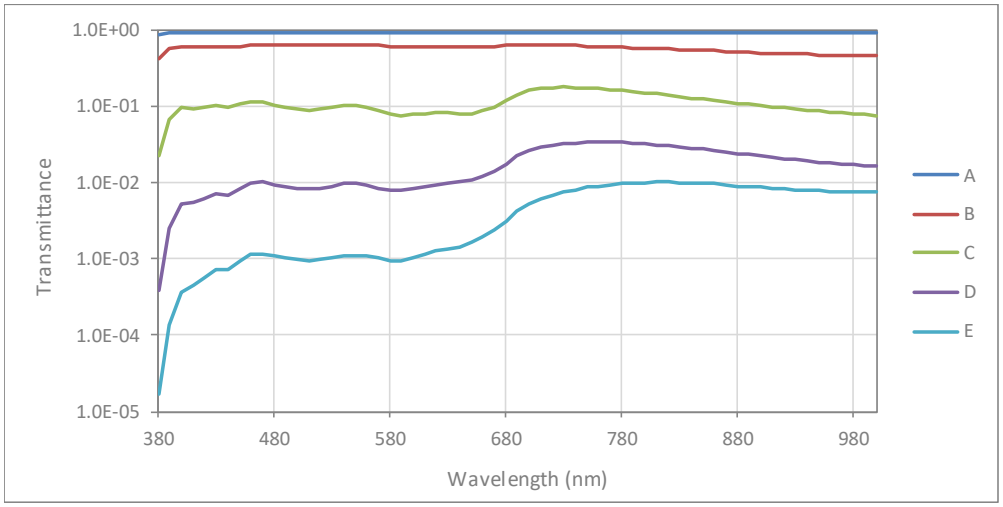
Description of Comparison Standards

The sets of comparison standards used in this comparison were previously used in both the original CCPR-K6 and the CCPR-K6.2010 comparisons [1,5]. Each participant received a separate set of standards to minimize the time needed for the completion of the comparison. Each set consisted of 5 neutral coloured glass filters, which have dimensions of 50 mm by 50 mm. Table 4 summarizes the main characteristics of each filter, and the nominal transmittance spectra of the filters are shown in Figure 1.

Table 4. Characteristics of the comparison filters

Filter Identifier	Type of Glass	Nominal Thickness (mm)	Nominal Transmittance (%) at 546 nm
A	BK 7	4.0	92
B	NG 11	2.0	50
C	NG 5	3.9	10
D	NG 4	3.9	1.0
E	NG 3	3.1	0.1

Figure 1. Nominal transmittance spectra of the comparison filters



Each filter was identified by a letter (filter identifier) and a number (set number) engraved in the top left corner outside the area used for measurement. To allow for the comparison standards to be used again in future comparisons, with a low risk of the results of this comparison being referred to by future participants, the set numbers of filters used are not published in this report.

Laboratories were permitted to remove dust from the filters using a stream of dry gas. However, participants were instructed not to clean the filters without approval from the pilot.

The pilot and participants commonly reported the appearance of dust on the filters following shipping. One participant reported the appearance of fingerprints along the edges of several filters in the set. None of the fingerprints occurred within the measurement area, so measurement of that filter set proceeded as planned. Another participant reported the appearance of a fingerprint in the measurement area of filter A and a fingerprint and nonuniform surface film in the measurement area of filter D. The pilot sent replacement A and D filters to the participant.

Participant Facilities

All participants provided descriptions of their facilities and these are included with the participant reports in Appendix B.

Pre-Draft A Process

The pre-Draft A process serves several purposes. First, it allows participants to review their own reported results to determine if the pilot has made any clerical errors. Second, it allows all participants to review each other's uncertainty budgets and send comments or ask questions about a participant's budget. Finally, it allows participants the opportunity to review relative data and assess the stability of the comparison standards and the internal consistency of a laboratory's measurements.

No laboratories made changes to their results, and no comments on the uncertainty budgets were received.

The relative data for the pilot can be found in Appendix C. The relative data is intended to show the stability of the comparison standards before and after travel between laboratories and the internal consistency of measurements for each laboratory. Because the SIM.PR-K6.2010 Technical Protocol (see Appendix A) specifies two rounds of measurements by the pilot and only one round of measurements by the participant, the plots in Appendix C show only the relative data of the pilot for each participant's comparison set.

The final reported data and uncertainty budgets for the pilot and participants can be found in Appendices D and E, respectively.

Analysis Method

The degrees of equivalence (DoE) for NIST (pilot, link) and NRC (non-pilot, link) to the key comparison reference value (KCRV) were determined during CCPR-K6.2010 [1]. The analysis technique used in SIM.PR-K6.2010 served to link the measurement results of this comparison to those of the CCPR-K6.2010, thereby, producing DoE's for each participant to the CCPR-K6.2010's KCRV.

Each of the 40 transmittance measurements (5 filters × 8 wavelengths) was considered an independent comparison of standards. Thus, each participant has, at most, 40 DoE's. These DoE's are the best estimate of a systematic offset of that participant's measurements has from the KCRV.

The analysis technique used in SIM.PR-K6.2010 was a combination of the recommended approach in CCPR G6, Appendix A.2.3, *For the link of non-link laboratories when the pilot is a link laboratory* [6] and a Monte Carlo calculation as described in JCGM 101:2008, *Evaluation of measurement data – Supplement 1 to the "Guide to the expression of uncertainty in measurement" – Propagation of distributions using a Monte Carlo method* [7].

First, the degree of equivalence for each non-link participant D_α was calculated with respect to the link laboratories, NIST and NRC, using:

$$D_{\alpha(NIST)} = D_{NIST} + (\tau_\alpha - \tau_{NIST}) \tag{1}$$

$$D_{\alpha(NRC)} = D_{NRC} + (\tau_{NIST} - \tau_{NRC}) + (\tau_\alpha - \tau_{NIST}) \tag{2}$$

Where D_{NIST} and D_{NRC} were the degree of equivalences for NIST and NRC, respectively, as reported in the CCPR-K6.2010 final report [1]. The transmittance values τ were the values measured by the laboratories during the SIM.PR-K6.2010 comparison (see Appendix D).

Second, the uncertainties for these DoE's, $u(D_{\alpha(NIST)})$ and $u(D_{\alpha(NRC)})$, were obtained using Monte Carlo propagation. This calculation included the total uncertainties and covariances of D_{NIST} and D_{NRC} as reported in the CCPR-K6.2010 final report [1] as well as the total uncertainty (including both Type A and Type B uncertainties) of each transmittance value measured during the SIM.PR-K6.2010 comparison (see Appendix E).

Next, weights W_{NIST} and W_{NRC} for the link laboratories were calculated such that the following condition was met:

$$W_{NIST} + W_{NRC} = 1 \tag{3}$$

The weights were defined as:

$$W_{NIST} = \frac{\bar{W}}{\bar{\sigma}^2_{NIST} - u^2_{NIST,r,RMO} - s^2_{RMO}} \tag{4}$$

$$W_{NRC} = \frac{\bar{W}}{\bar{\sigma}^2_{NRC} + u^2_{NIST,r,RMO}} \tag{5}$$

Where

$$\bar{W} = \frac{(\bar{\sigma}^2_{NRC} + u^2_{NIST,r,RMO})(\bar{\sigma}^2_{NIST} - u^2_{NIST,r,RMO} - s^2_{RMO})}{\bar{\sigma}^2_{NIST} + \bar{\sigma}^2_{NRC} - s^2_{RMO}} \tag{6}$$

$$\bar{\sigma}^2_{NIST} = s^2_{KC} + s^2_{RMO} + u^2_{NIST,st} + u^2_{NIST,r,KC} + u^2_{NIST,r,RMO} \tag{7}$$

$$\bar{\sigma}^2_{NRC} = s^2_{KC} + s^2_{RMO} + u^2_{NRC,st} + u^2_{NRC,r,KC} + u^2_{NRC,r,RMO} \tag{8}$$

Equations 4 through 8 depended on the following uncertainties. The standard uncertainties associated with uncorrelated (random) effects for NIST and NRC during CCPR-K6.2010 were $u_{NIST,r,KC}$ and $u_{NRC,r,KC}$, respectively, and were determined from the values reported in the CCPR-K6.2010 final report [1]. The corresponding uncertainties for NIST and NRC during SIM.PR-K6.2010 were $u_{NIST,r,RMO}$ and $u_{NRC,r,RMO}$, respectively, and were determined from the values reported in Appendix E. The standard transfer uncertainty for CCPR-K6.2010, s_{KC}, was the uncertainty added during the key comparison to obtain consistency between the comparison results using the Mandel-Paule approach. Similarly, the standard transfer uncertainty for SIM.PR-K6.2010, s_{RMO}, was the uncertainty added during this comparison to obtain consistency between the NIST results. For these calculations, $s_{RMO} = 0$. The standard uncertainties associated with the reproducibility of NIST's and NRC's scales between the CCPR-K6.2010 and SIM.PR-K6.2010 comparisons were $u_{NIST,st}$ and $u_{NRC,st}$. The values for all the standard uncertainties mentioned above can be found in Appendix F.

Finally, the degree of equivalence for each non-link participant D_α was calculated according to the absolute-difference model:

$$D_\alpha = W_{NIST} D_{\alpha(NIST)} + W_{NRC} D_{\alpha(NRC)} \tag{9}$$

The combined standard uncertainty of the DoE, $u(D_\alpha)$, was calculated by standard propagation of the uncertainties $u(D_{\alpha(NIST)})$ and $u(D_{\alpha(NRC)})$. In this way, all the uncertainties and covariances contributing to $D_{\alpha(NIST)}$ and $D_{\alpha(NRC)}$ were accounted for in the evaluation of the uncertainty of D_α.

The final uncertainty is given as an expanded uncertainty with a coverage factor of $k = 2$:

$$U(D_\alpha) = 2u(D_\alpha) \tag{10}$$

The Monte Carlo calculation was programmed in OpenBUGS, a software application for Bayesian modelling [8].

Comparison Results

The comparison results, DoE and its expanded uncertainty, for all non-link participants are shown for all filters and wavelengths in Figures 1 through 5 and tabulated in Tables 5 through 9.

Conclusion

According to the Technical Supplement of the Mutual Recognition Arrangement (MRA) [9], key comparisons provide the technical basis for the arrangement. The technical deliverables of an RMO key comparison are the DoE of each participating laboratory to the KCRV of the CCPR comparison and its expanded uncertainty. These results then form the basis upon which entries in the Calibration and Measurement Capabilities (CMC) database are evaluated and validated.

The results indicate that most of the participants have the capability to measure spectral regular transmittance and evaluate their uncertainty budgets adequately. There are some cases of non-equivalence that will require further investigation on the part of the participants.

It is important to note that the CCPR-K6.2010 comparison included an extra two rounds of measurements involving both the pilot and participants, while the number of rounds for SIM.PR-K6.2010 was reduced to ease the burden on the pilot and speed the time of the comparison. The

relative data found in Appendix C show that the comparison standards were stable throughout the period of comparison measurements. However, because the participants were only able to measure their comparison set once, participants were unable to evaluate the internal consistency of their measurements. Thus, it is recognized that reducing the number of rounds of measurements has precluded information that is potentially useful for participants in evaluating their results and estimating their uncertainties.

Figure 2. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter A

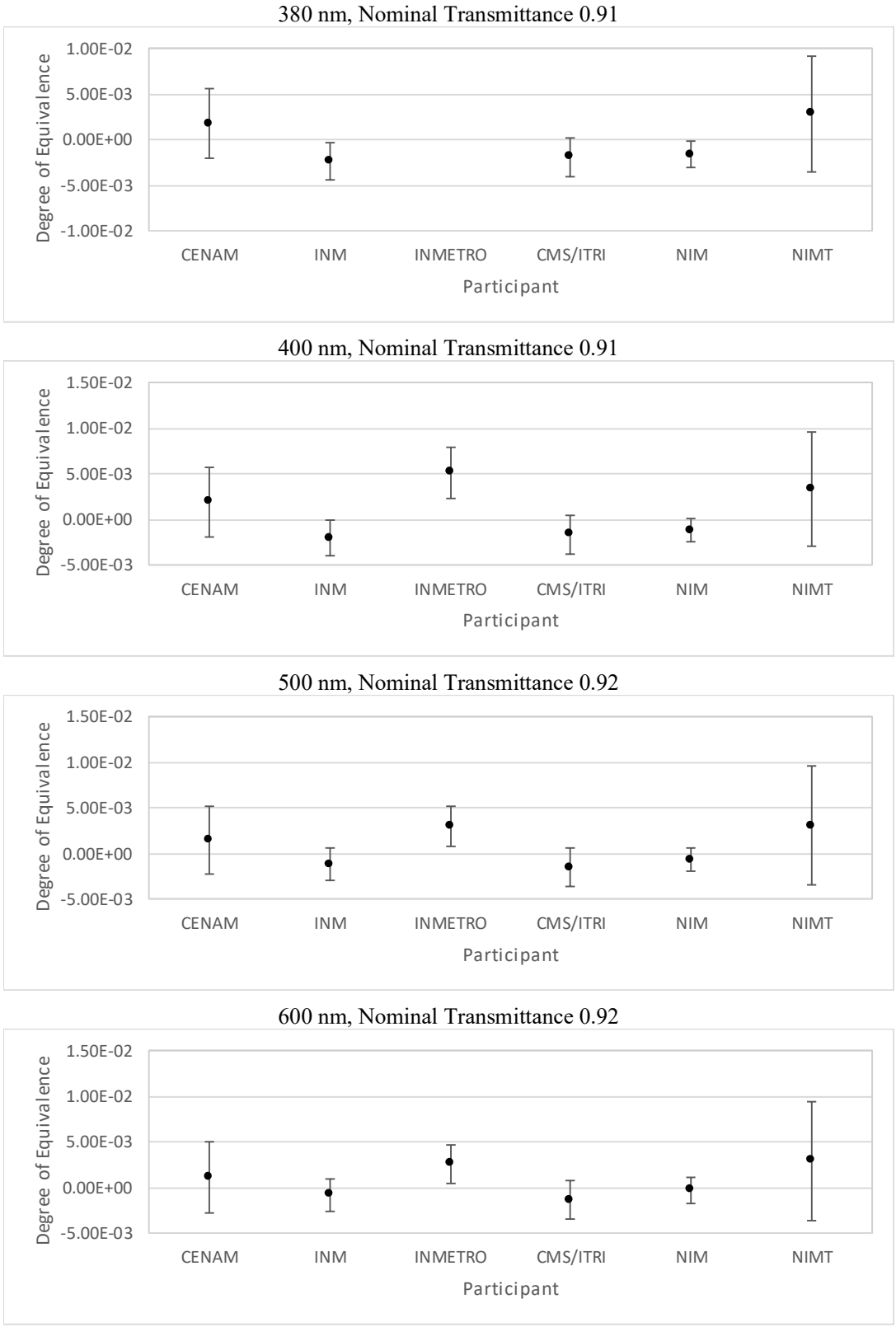


Figure 2. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter A

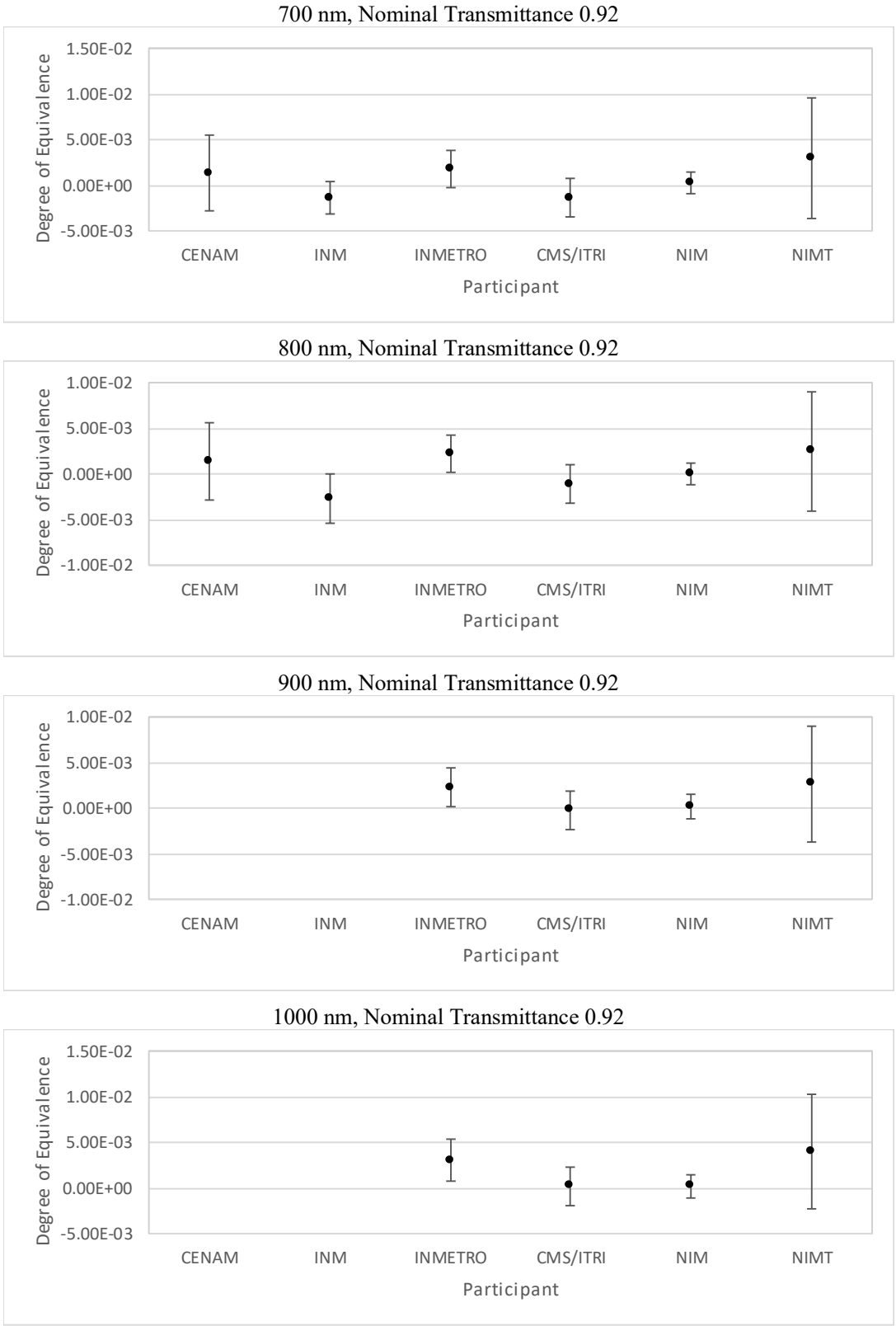


Figure 3. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter B

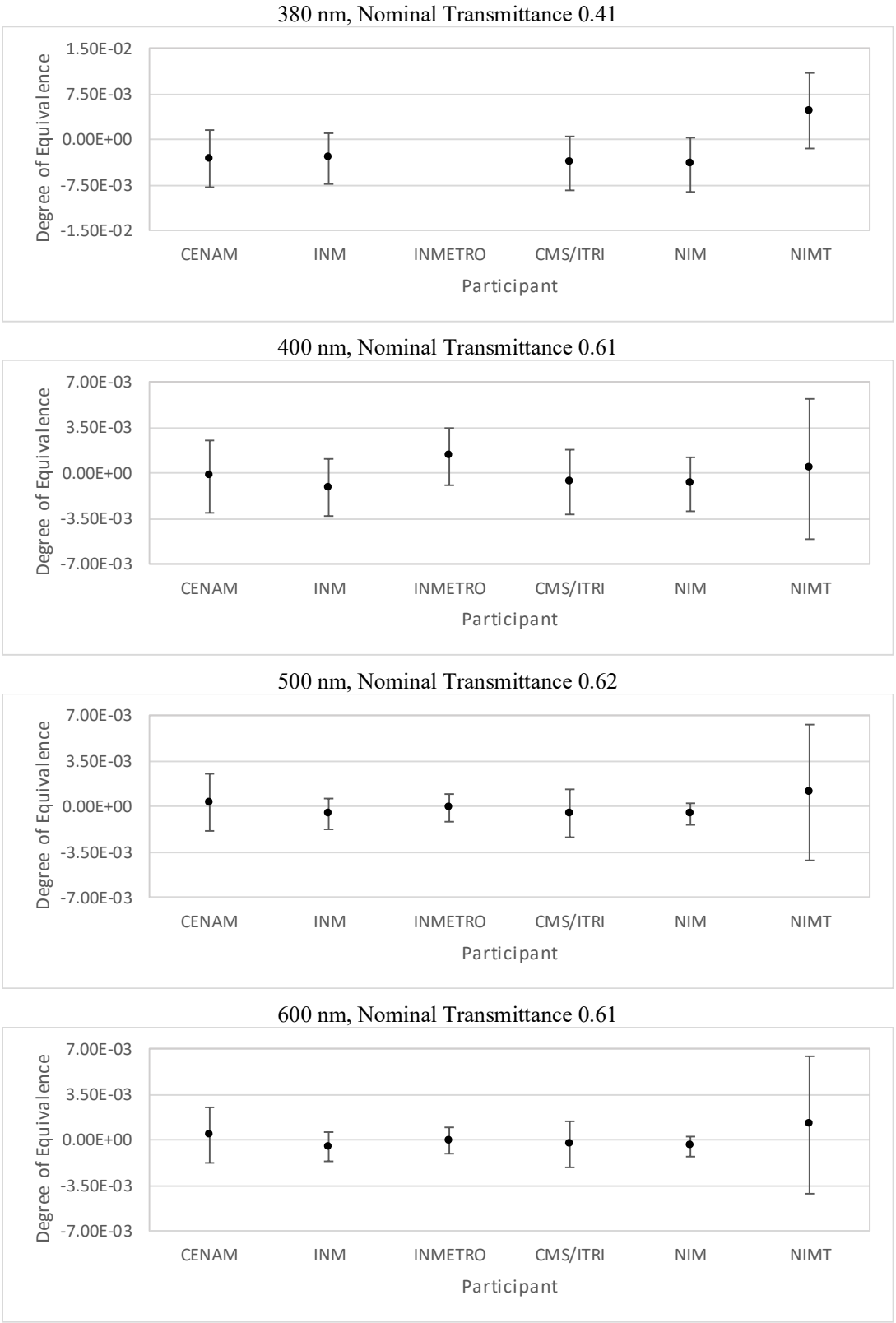


Figure 3. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter B

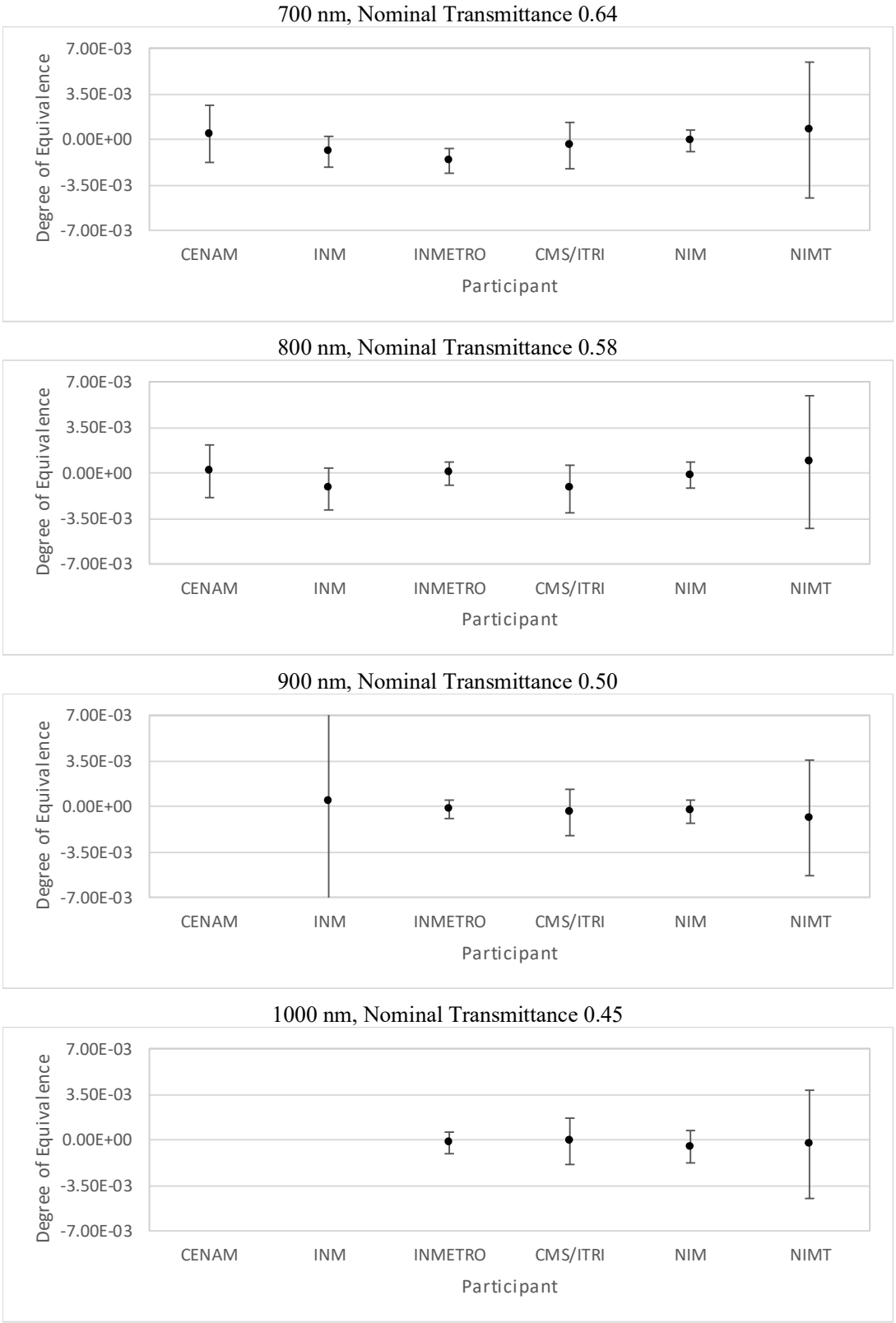


Figure 4. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter C

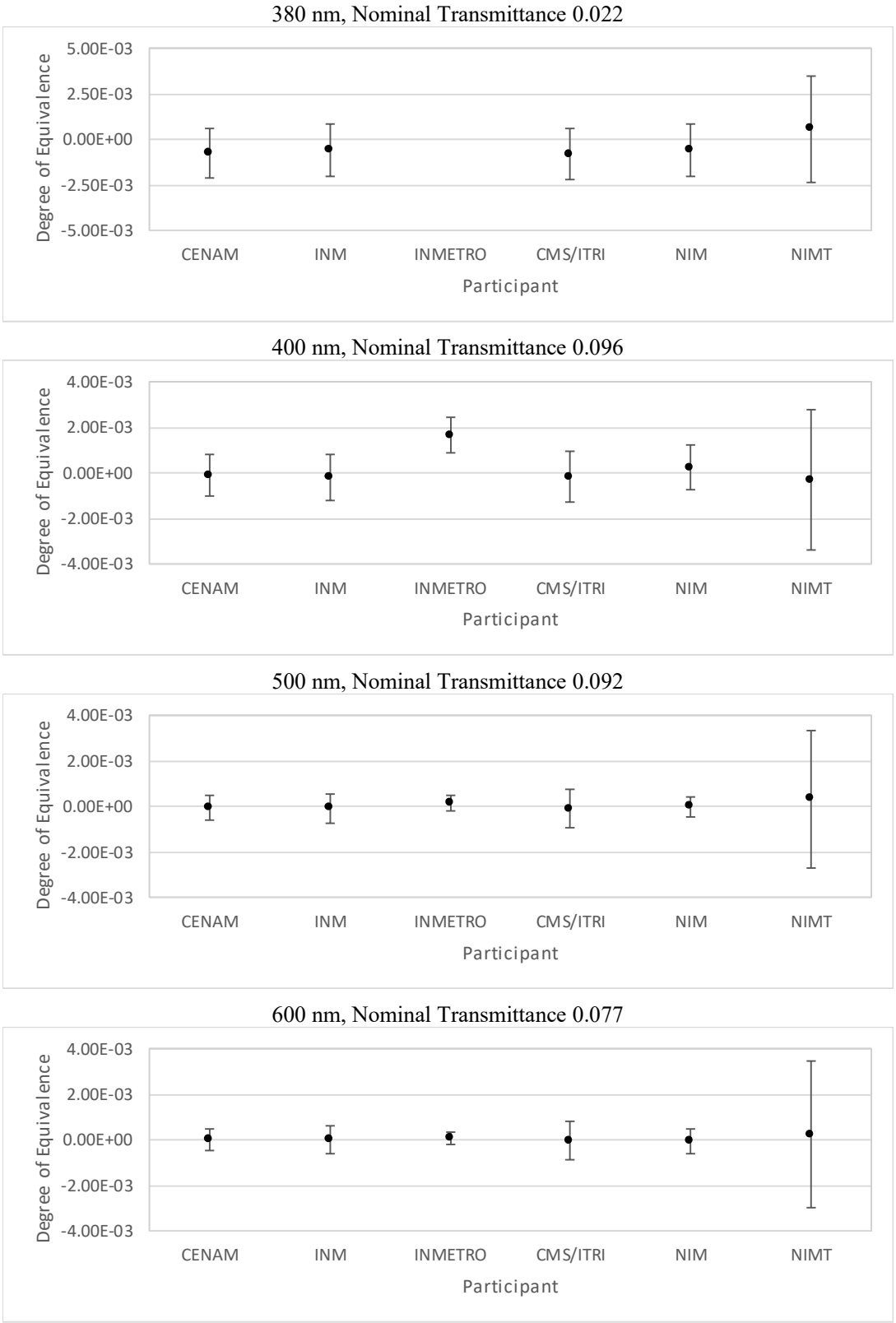


Figure 4. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter C

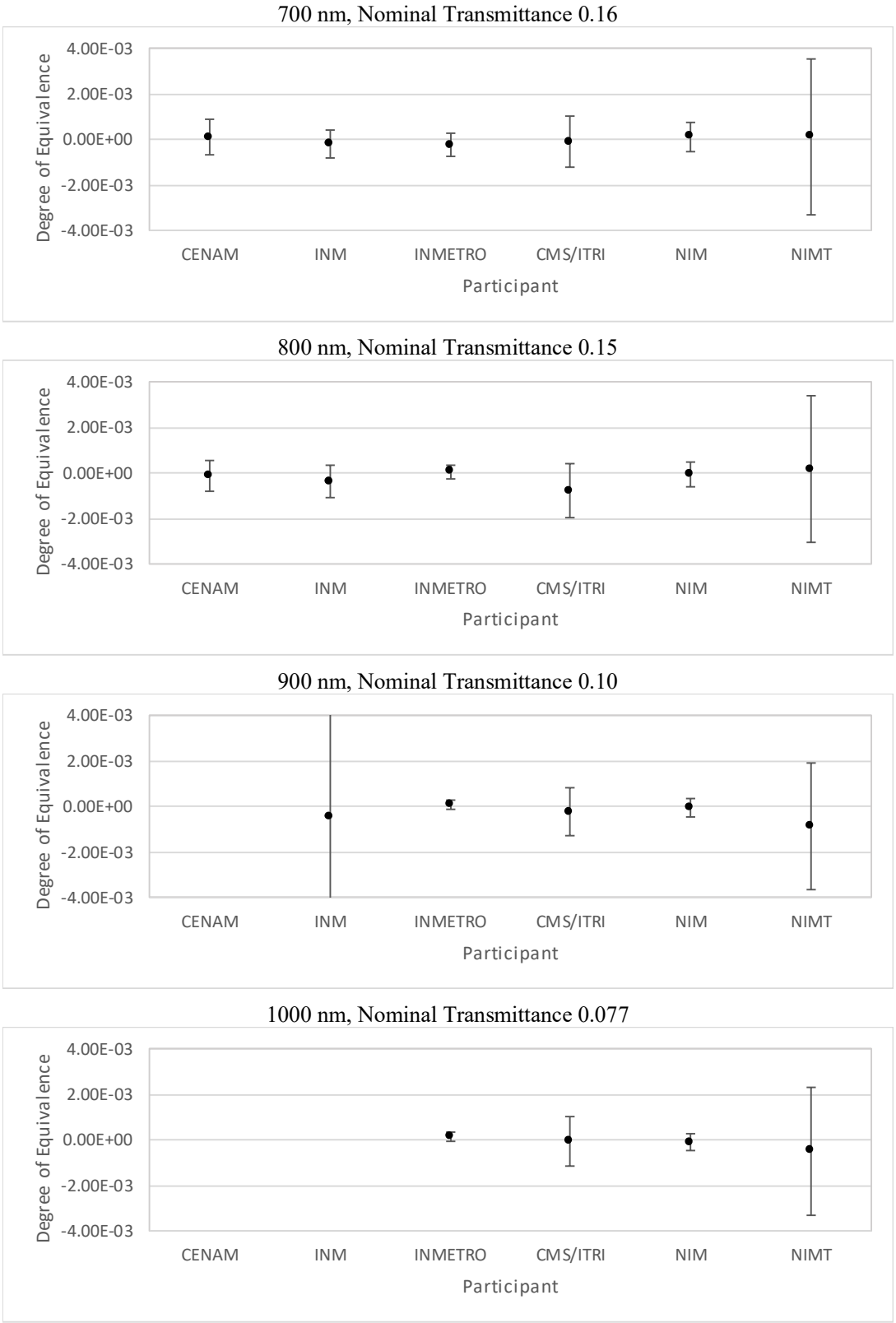


Figure 5. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter D

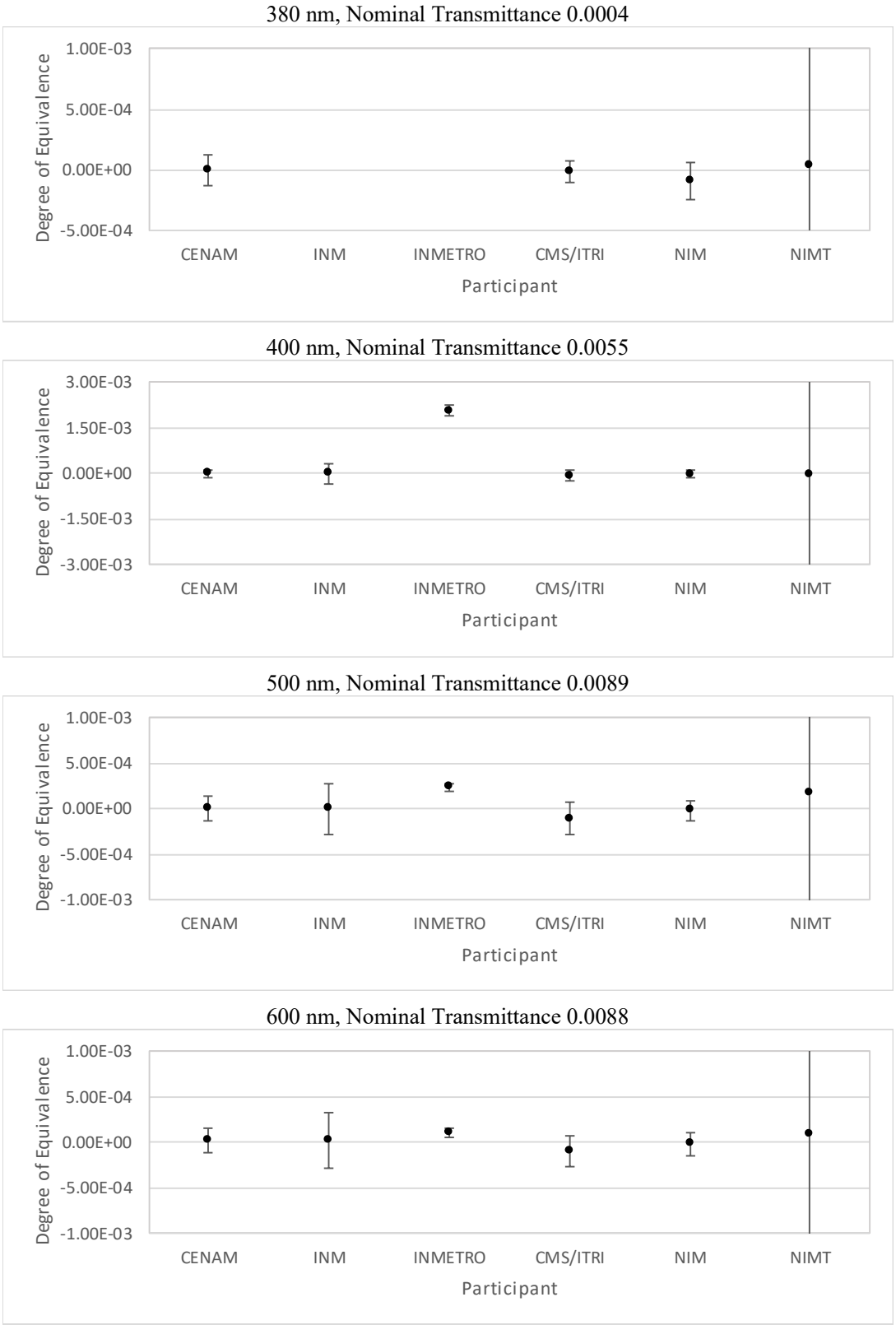


Figure 5. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter D

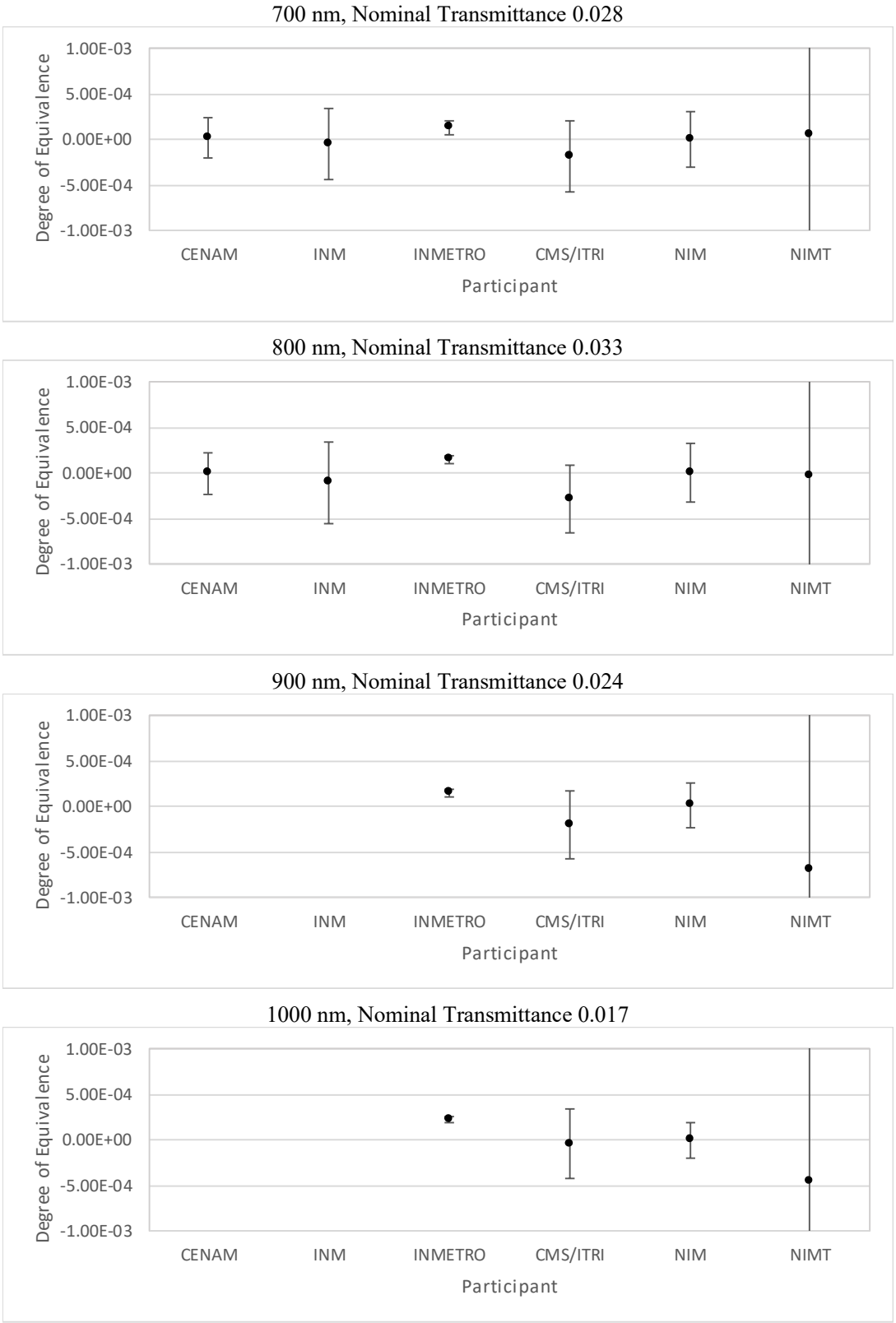


Figure 6. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter E

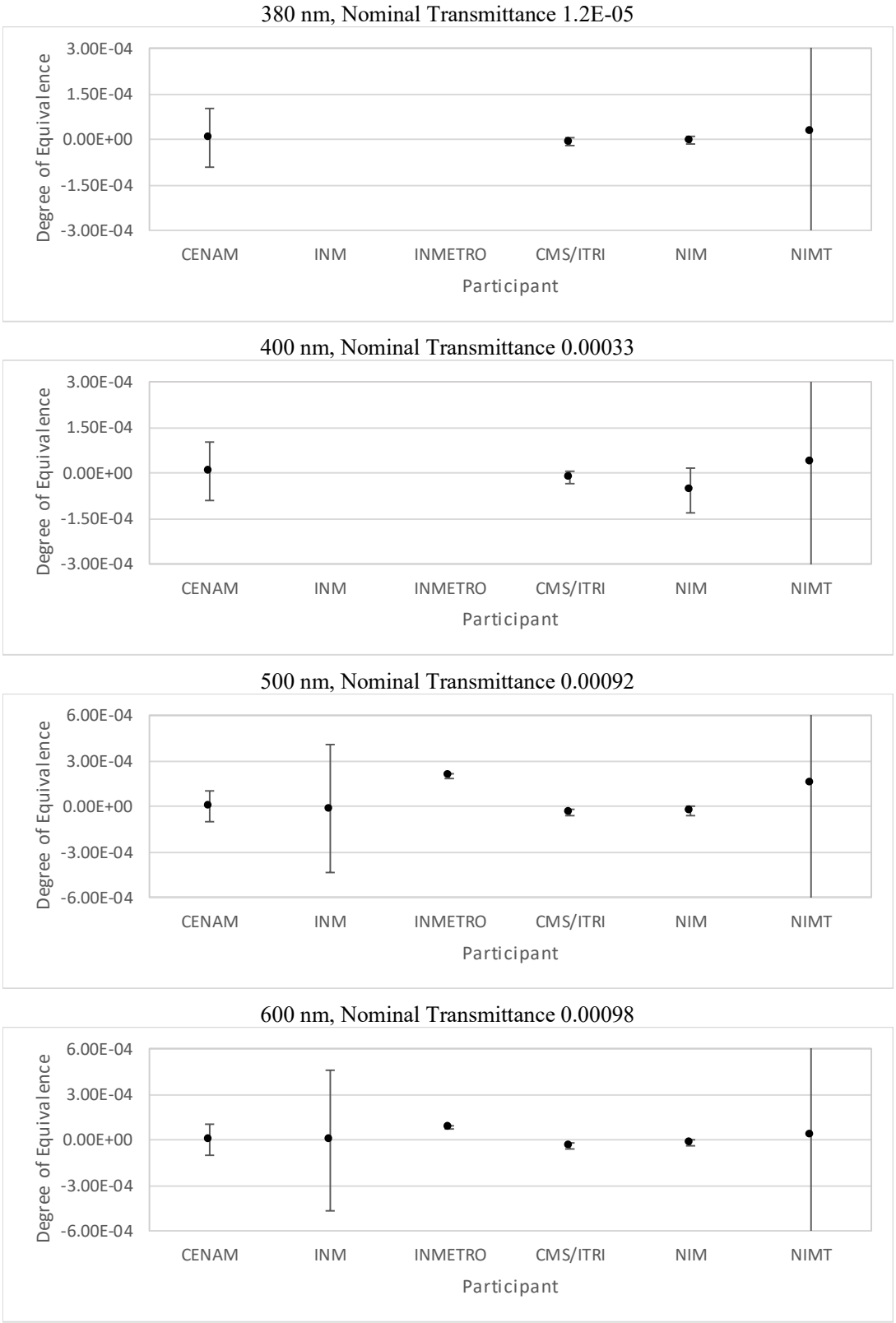


Figure 6. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter E

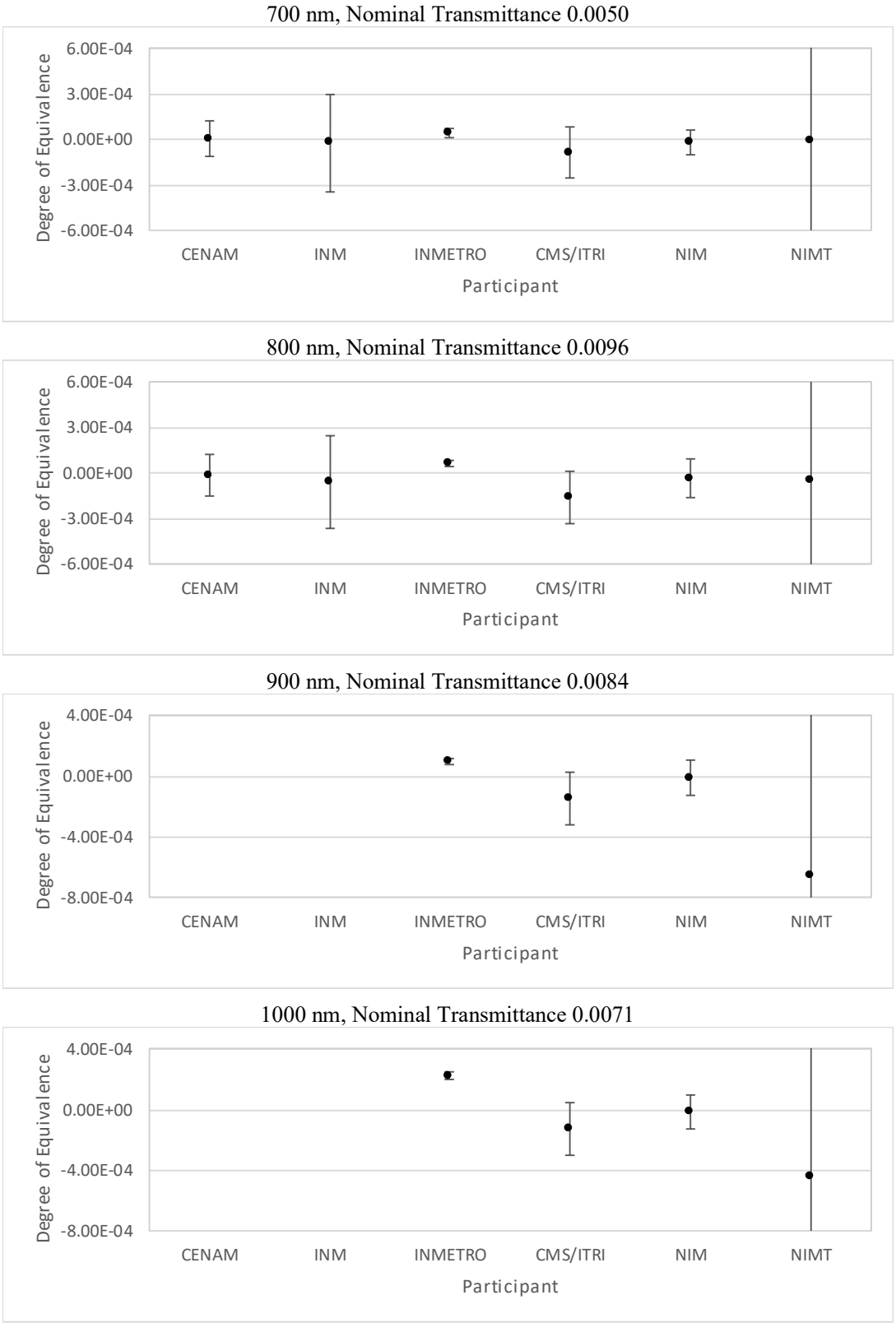


Table 5. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter A

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		0.91	0.91	0.92	0.92	0.92	0.92	0.92	0.92
CENAM	DoE	1.80E-03	1.95E-03	1.48E-03	1.12E-03	1.34E-03	1.34E-03	-	-
	U(DoE)	3.83E-03	3.82E-03	3.80E-03	3.88E-03	4.15E-03	4.22E-03	-	-
INM	DoE	-2.32E-03	-2.03E-03	-1.16E-03	-7.90E-04	-1.36E-03	-2.65E-03	-	-
	U(DoE)	2.01E-03	1.96E-03	1.76E-03	1.72E-03	1.74E-03	2.77E-03	-	-
INMETRO	DoE	-	5.14E-03	2.99E-03	2.61E-03	1.82E-03	2.19E-03	2.30E-03	3.07E-03
	U(DoE)	-	2.75E-03	2.21E-03	2.16E-03	2.05E-03	2.03E-03	2.06E-03	2.24E-03
CMS/ITRI	DoE	-1.89E-03	-1.64E-03	-1.52E-03	-1.37E-03	-1.39E-03	-1.11E-03	-1.80E-04	2.39E-04
	U(DoE)	2.18E-03	2.17E-03	2.11E-03	2.12E-03	2.12E-03	2.14E-03	2.15E-03	2.15E-03
NIM	DoE	-1.60E-03	-1.18E-03	-6.38E-04	-2.62E-04	3.08E-04	1.43E-05	2.07E-04	2.79E-04
	U(DoE)	1.44E-03	1.31E-03	1.25E-03	1.45E-03	1.23E-03	1.24E-03	1.29E-03	1.26E-03
NIMT	DoE	2.87E-03	3.36E-03	3.09E-03	2.95E-03	3.01E-03	2.52E-03	2.70E-03	4.01E-03
	U(DoE)	6.34E-03	6.34E-03	6.55E-03	6.48E-03	6.56E-03	6.56E-03	6.31E-03	6.28E-03

Table 6. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter B

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		0.41	0.61	0.62	0.61	0.64	0.58	0.50	0.45
CENAM	DoE	-3.13E-03	-2.20E-04	3.12E-04	3.76E-04	3.99E-04	1.68E-04	-	-
	U(DoE)	4.58E-03	2.79E-03	2.21E-03	2.14E-03	2.21E-03	2.03E-03	-	-
INM	DoE	-3.09E-03	-1.14E-03	-5.74E-04	-5.16E-04	-9.35E-04	-1.20E-03	3.64E-04	-
	U(DoE)	4.27E-03	2.19E-03	1.19E-03	1.15E-03	1.15E-03	1.59E-03	1.98E-02	-
INMETRO	DoE	-	1.30E-03	-9.13E-05	-4.19E-05	-1.64E-03	-2.96E-05	-2.10E-04	-1.58E-04
	U(DoE)	-	2.20E-03	1.12E-03	9.92E-04	9.83E-04	8.48E-04	7.33E-04	8.36E-04
CMS/ITRI	DoE	-3.85E-03	-6.95E-04	-5.22E-04	-3.51E-04	-4.46E-04	-1.22E-03	-4.32E-04	-5.22E-05
	U(DoE)	4.45E-03	2.47E-03	1.80E-03	1.75E-03	1.72E-03	1.85E-03	1.74E-03	1.76E-03
NIM	DoE	-4.09E-03	-8.28E-04	-5.31E-04	-4.58E-04	-1.33E-04	-1.63E-04	-3.30E-04	-5.08E-04
	U(DoE)	4.51E-03	2.09E-03	8.47E-04	7.70E-04	8.37E-04	1.04E-03	8.88E-04	1.22E-03
NIMT	DoE	4.70E-03	3.28E-04	1.09E-03	1.16E-03	7.28E-04	8.51E-04	-8.79E-04	-3.28E-04
	U(DoE)	-3.85E-03	5.41E-03	5.25E-03	5.23E-03	5.18E-03	5.05E-03	4.45E-03	4.20E-03

Table 7. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter C

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		0.022	0.096	0.092	0.077	0.16	0.15	0.10	0.077
CENAM	DoE	-7.49E-04	-9.14E-05	-7.49E-05	2.57E-05	1.13E-04	-1.37E-04	-	-
	U(DoE)	1.37E-03	8.92E-04	5.36E-04	4.58E-04	7.79E-04	6.80E-04	-	-
INM	DoE	-5.72E-04	-1.83E-04	-5.48E-05	1.36E-05	-1.66E-04	-3.77E-04	-4.71E-04	-
	U(DoE)	1.41E-03	1.04E-03	6.41E-04	6.19E-04	6.04E-04	7.23E-04	7.47E-03	-
INMETRO	DoE	-	1.65E-03	1.66E-04	6.67E-05	-2.51E-04	7.09E-05	5.71E-05	1.31E-04
	U(DoE)	-	7.70E-04	3.33E-04	2.64E-04	5.07E-04	2.97E-04	2.10E-04	1.92E-04
CMS/ITRI	DoE	-8.03E-04	-1.71E-04	-1.04E-04	-2.52E-05	-1.04E-04	-7.78E-04	-2.25E-04	-6.61E-05
	U(DoE)	1.40E-03	1.13E-03	8.62E-04	8.42E-04	1.13E-03	1.19E-03	1.07E-03	1.08E-03
NIM	DoE	-5.48E-04	2.49E-04	2.95E-06	-5.10E-05	1.26E-04	-2.63E-05	-3.91E-05	-9.26E-05
	U(DoE)	1.43E-03	9.67E-04	4.52E-04	5.19E-04	6.39E-04	5.45E-04	4.01E-04	3.84E-04
NIMT	DoE	5.89E-04	-2.99E-04	3.36E-04	2.45E-04	1.18E-04	1.72E-04	-8.80E-04	-4.72E-04
	U(DoE)	2.92E-03	3.09E-03	3.01E-03	3.24E-03	3.42E-03	3.22E-03	2.76E-03	2.80E-03

Table 8. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter D

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		0.0004	0.0055	0.0089	0.0088	0.028	0.033	0.024	0.017
CENAM	DoE	2.26E-06	1.17E-06	1.97E-06	1.73E-05	2.33E-05	-8.49E-07	-	-
	U(DoE)	1.25E-04	1.31E-04	1.31E-04	1.35E-04	2.14E-04	2.26E-04	-	-
INM	DoE	-	-7.51E-06	-2.66E-06	2.17E-05	-4.52E-05	-1.06E-04	-	-
	U(DoE)	-	3.31E-04	2.84E-04	3.11E-04	3.86E-04	4.56E-04	-	-
INMETRO	DoE	-	2.07E-03	2.34E-04	1.08E-04	1.33E-04	1.54E-04	1.48E-04	2.28E-04
	U(DoE)	-	1.67E-04	4.21E-05	5.34E-05	8.02E-05	4.18E-05	4.27E-05	3.20E-05
CMS/ITRI	DoE	-1.35E-05	-7.18E-05	-1.09E-04	-9.76E-05	-1.79E-04	-2.81E-04	-2.02E-04	-4.54E-05
	U(DoE)	8.28E-05	1.76E-04	1.73E-04	1.77E-04	3.86E-04	3.76E-04	3.78E-04	3.81E-04
NIM	DoE	-9.49E-05	-1.31E-05	-2.00E-05	-2.14E-05	2.90E-06	5.99E-06	1.35E-05	-2.60E-06
	U(DoE)	1.53E-04	1.38E-04	1.12E-04	1.35E-04	3.03E-04	3.23E-04	2.49E-04	1.96E-04
NIMT	DoE	4.03E-05	-3.96E-05	1.75E-04	8.40E-05	4.90E-05	-2.43E-05	-6.85E-04	-4.51E-04
	U(DoE)	2.98E-03	3.60E-03	3.02E-03	3.54E-03	2.99E-03	2.99E-03	2.59E-03	2.57E-03

Table 9. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter E

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		1.2E-05	0.00033	0.00092	0.0050	0.0050	0.0096	0.0084	0.0071
CENAM	DoE	6.28E-06	7.87E-06	2.30E-06	4.03E-06	6.02E-06	-1.31E-05	-	-
	U(DoE)	9.62E-05	9.71E-05	9.81E-05	9.89E-05	1.16E-04	1.33E-04	-	-
INM	DoE	-	-	-1.34E-05	-1.16E-06	-2.09E-05	-5.64E-05	-	-
	U(DoE)	-	-	4.24E-04	4.60E-04	3.22E-04	3.04E-04	-	-
INMETRO	DoE	-	-	2.01E-04	8.10E-05	4.64E-05	6.40E-05	9.62E-05	2.21E-04
	U(DoE)	-	-	1.37E-05	1.05E-05	2.89E-05	2.30E-05	1.97E-05	2.42E-05
CMS/ITRI	DoE	-7.09E-06	-1.53E-05	-3.58E-05	-3.49E-05	-8.43E-05	-1.60E-04	-1.48E-04	-1.26E-04
	U(DoE)	1.25E-05	2.02E-05	1.80E-05	2.12E-05	1.68E-04	1.75E-04	1.71E-04	1.69E-04
NIM	DoE	-3.07E-06	-5.66E-05	-2.47E-05	-1.86E-05	-1.70E-05	-3.44E-05	-1.10E-05	-1.69E-05
	U(DoE)	1.30E-05	7.29E-05	2.92E-05	2.26E-05	8.07E-05	1.30E-04	1.17E-04	1.11E-04
NIMT	DoE	2.69E-05	3.77E-05	1.51E-04	3.37E-05	-1.24E-05	-4.89E-05	-6.53E-04	-4.44E-04
	U(DoE)	3.20E-03	4.63E-03	2.96E-03	4.40E-03	3.21E-03	2.78E-03	2.61E-03	2.80E-03

Notes:

a) Columns with dashes indicate that transmittance values at these wavelengths were either not measured or not reported.

Acknowledgements

Many thanks to all participants for their timely responses to communications and submissions of measurement results. Thanks also to Annette Koo of the Measurement Standards Laboratory in New Zealand for her helpful advice.

Disclaimer

Certain commercial equipment, instruments, or materials are identified in this report and its appendices in order to specify the measurement procedure adequately. Such identification is not intended to imply recommendation or endorsement by NIST, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

References

[1] Koo A 2017 "Report on the consultative committee for photometry and radiometry key comparison of regular spectral transmittance 2010 (CCPR-K6.2010)" *Metrologia* **54** Tech. Suppl. 02001. http://iopscience.iop.org/article/10.1088/0026-1394/54/1A/02001

[2] Koo A 2010 "CCPR-K6.2010 Key Comparison Spectral Regular Transmittance. Technical Protocol". https://kcdb.bipm.org/AppendixB/AppBResults/CCPR-K6.2010/CCPR-K6.2010_Technical_Protocol.pdf

[3] Koo A 2017 "CCPR-K6.2010 Key Comparison Spectral Regular Transmittance. Appendix C – Temperature Coefficients". https://kcdb.bipm.org/AppendixB/appbresults/CCPR-K6.2010/2017/Appendix_C_Temperature_Coefficients.PDF

[4] BIPM IEC IFCC ILAC ISO IUPAC IUPAP and OIML 2008, "*Guide to the Expression of Uncertainty in Measurement*," (Geneva: International Organization for Standardization) available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf

[5] Obein G and Bastie J 2009 "Report on the CCPR Key Comparison K6: Spectral Regular Transmittance" *Metrologia* **46** Tech. Suppl. 02002. http://iopscience.iop.org/article/10.1088/0026-1394/46/1A/02002

[6] Consultative Committee on Photometry and Radiometry Key Comparison Working Group "Guidelines for RMO PR Key Comparisons," CCPR-G6 Version 1.0, 2014, available at http://www.bipm.org/utils/common/pdf/CC/CCPR/CCPR-G6.pdf

[7] BIPM IEC IFCC ILAC ISO IUPAC IUPAP and OIML 2008, "*Supplement 1 to the* '*Guide to the Expression of Uncertainty in Measurement' – Propagation of distributions using a Monte Carlo method*," (Geneva: International Organization for Standardization) available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_101_2008_E.pdf

[8] Lunn DJ, Spiegelhalter D, Thomas A, Best N 2009 "The BUGS project: Evolution, critique and future directions" *Statistics in Medicine* **28** 3049–3082.

[9] Technical Supplement to the CIPM MRA, CIPM revision 2003, available at https://www.bipm.org/utils/en/pdf/CIPM-MRA-TechnicalSupplement2003.pdf

Appendix A: Technical Protocol

SIM.PR-K6 Key Comparison
Spectral Regular Transmittance
Technical Protocol

1. Introduction

1.1 Under the Mutual Recognition Arrangement (MRA) the metrological equivalence of national measurement standards will be determined by a set of key comparisons chosen and organized by the Consultative Committees of the CIPM working closely with the Regional Metrology Organizations (RMOs).

1.2 At its meeting in June 2007, the Consultative Committee for Photometry and Radiometry, CCPR, instigated a new series of key comparisons in the field of optical radiation metrology. In particular, it decided that a key comparison of spectral regular transmittance would be carried out, and subsequently appointed MSL (New Zealand) to act as pilot laboratory.

1.3 The SIM Photometry and Radiometry (PR) Technical Committee (TC) met in February 2012 and decided to plan for a SIM K6 comparison. In addition, it was decided that the SIM K6 comparison would be carried out as close as possible to the CCPR K6:2010 comparison, and appointed NIST (USA) to be the pilot laboratory and NRC (Canada) and NIST (USA) to be the link laboratories.

1.4 This technical protocol has been drawn up by the participants of this comparison.

The procedures outlined in this document, which follows the guidelines established by the BIPM [1], CCPR G6 [2], and the CCPR comparison protocol "CCPR-K6.2010 Key Comparison Spectral Regular Transmittance" [3] defines the measurands and measurement/calibration procedure to be followed in this comparison. These procedures cover the technical procedure to be followed during measurement of the transfer standard filters and is based on current best practice in the use of standard filters and takes account the experience gained from the previous comparisons organised in this field [4, 5, and 6].

2 Organization

2.1 Participants

2.1.1 The list of participants was initially agreed via email from March 23, 2011 to May 31, 2013.

2.1.2 On November 11, 2014, the National Metrology Institute from Colombia, INM, requested participation in this comparison. All participants accepted this request by November 17, 2014.

2.1.3 Two additional participants were added in October 2015 as requested and agreed during the 2015 CCPR-WG-KC meeting.

2.1.4 By their declared intention to participate in this comparison, the laboratories accept the general instructions and the technical protocols written in this document and commit themselves to follow the procedures strictly.

2.1.5 Once the protocol and list of participants has been agreed, no change to the protocol or list of participants may be made.

2.1.6 All participants must either demonstrate independent traceability [7, 8, 9, 10] to the realization of the quantity, or make clear the route of traceability to the quantity via another named laboratory.

2.2 Participants' details

National Institute of Standards and Technology, NIST	Dr. Catherine Cooksey National Institute of Standards and Technology 100 Bureau Drive Gaithersburg, MD 20899-8442 USA	Phone: + 1 301-975-6208 catherine.cooksey@nist.gov
Centro Nacional de Metrologia, CENAM	Mr. Carlos H. Matamoros Garcia Area de Metrologia Fisica Centro Nacional de Metrologia km 4.5 carretera a los Cues, Municipio El Marques, Queretaro, Mexico, C.P. 76246	Phone: +52-442-2110552 cmatamor@cenam.mx
Instituto Nacional de Metrologia, Inovação e Tecnologia, INMETRO	Giovanna Borghi Optical Metrology Division Av. N. Sra. das Graças, 50, Xerém, Duque de Caxias, RJ, Brazil	Phone: + 55 21 2679 9051 gbalmeida@inmetro.gov.br
Center for Measurement Standards/Industrial Technology Research Institute, CMS/ITRI	Ms. Wen-Chun Liu Center for Measurement Standards / Industrial Technology Research Institute Bldg. 16, 321, Kuang Fu Rd., Sec. 2, Hsinchu, Taiwan	Phone: +886-3-5743859 liuwenchun@itri.org.tw
National Research Council of Canada, NRC	Dr. Joanne Zwinkels National Research Council of Canada Measurement Science and Standards 1200 Montreal Road Ottawa, Ontario K1A 0R6 CANADA Attention: Joanne Zwinkels, Bldg. M-36, Room 1141	Phone: +1 (613) 993-9363 Joanne.zwinkels@nrc-cnrc.gc.ca

Instituto Nacional de Metrología de Colombia, INM	Mrs. Juliana Serna Saiz Instituto Nacional Metrología de Colombia Avenida Carrera 50 No 26-55 Int. 2 Bogotá, D.C., Colombia	Phone: 2542222 ext 1512 jserna@inm.gov.co
National Institute of Metrology (Thailand), NIMT	3/4-5 Moo 3 Klong 5 Klong Laung Pathumthani 12120 Thailand	Phone: 6625775100 ext 2311 rojana@nimt.or.th
National Institute of Metrology, NIM	No.18 Bei San Huan Dong Lu, Beijing P.R. China	Phone: +86 10 64524806 zhengchundi@nim.ac.cn

2.3 Form of comparison

2.3.1 The comparison will be carried out through the measurements of transfer standard filters. Each participant will use a separate set of filters to minimize the time needed for the completion of the comparison.

2.3.2 A full description of the transfer standard filters is given in section 3 of this protocol.

2.3.3 The measurement sequence for this comparison is a star type: Pilot-Participant-Pilot. Transfer standards are first measured by the pilot laboratory, sent to each participant for their measurement, and then sent back to the pilot laboratory for the second measurement. The pilot will notify to each participant when transfer standard filters have been shipped out.

2.3.4 Each participating laboratory must notify to the pilot as soon as they have received the filters. Then, the participating laboratory has 6 weeks for measurements and shipping out the filters back to the pilot laboratory. The participant must notify to the pilot when they have shipped out the filters back to pilot laboratory.

2.3.5 Final results must be submitted directly to the pilot laboratory within four weeks from completion of the measurements (or the deadline date of return shipping) by each participating laboratory. The deadline for submitting results will also be notified when the filters have arrived to participants.

2.3.6 Exclusion of a participant's results from the report may occur if the results are not submitted before the deadline stated above.

2.3.7 Draft Timetable

Activity	**Time Required**
Pilot laboratory receives filters from LNE-CNAM	
First measurement by pilot laboratory	4 months
Shipping the filters to participants	2 weeks

Measurement by participants	6 weeks
All measurement reports, results, and uncertainty budgets due to NIST	4 weeks
Second measurement by pilot laboratory	3 months
NIST sends relative data and reported values to participants for checking (pre-Draft A)	3 months
Participants provide comments on their own and other's reports and uncertainties	2 months
Participants respond to comments on uncertainty statements and pre-Draft A discussion is closed	6 weeks
Pilot distributes Draft A	3 months
Comments on Draft A	4 weeks
Draft A-2 sent to participants for approval	2 months
Draft B sent to CCPR WG-KC for comments	4 weeks
Final Report published	2 months

2.4 Handling the artefacts (filters)

2.4.1 The transfer standard filters should be examined immediately upon receipt at final destination. The condition of the filters and associated packaging should be noted and communicated to the pilot laboratory. The form in appendix A.1 should be filled in and sent to the pilot laboratory.

2.4.2 The transfer standard filters should only be handled by authorized persons wearing powder-free gloves and stored in such a way as to prevent damage and contamination.

2.4.3 Cleaning should not be carried out unless there is clear evidence of filter contamination. Dust could be removed with a stream of dry gas (avoid cans with liquid propellants). Should further cleaning be required, the laboratory should consult with the pilot laboratory and if cleaning is approved

- make a measurement before cleaning
- use their own standard cleaning method, which must be described in their measurement report.
- make a measurement after cleaning

If cleaning is done, it must be reported in the measurement report and documented using the form in appendix A.2. If a filter appears damaged, a replacement may be available from the pilot laboratory.

2.4.4 After the measurements, the form in appendix A.2 must be filled in and sent to the pilot laboratory before the filters are packaged in their original transit cases for transportation. Ensure that the content of the package is complete.

2.5 Transport of artefacts (filters)

2.5.1 It is of the utmost importance that the artefacts be transported in a manner in which they will not be lost, damaged or handled by unauthorized persons.

2.5.2 Artefacts should be marked as “fragile”.

2.5.3 The pilot laboratory covers the costs for transportation to the participant laboratory. Transportation back to the pilot laboratory is each participant laboratory’s responsibility and cost. Each participating laboratory covers the costs for its own measurements, and any customs charges. The pilot laboratory has limited insurance for any loss of or damage to the standards during transportation. If damage occurs in the USA or in transit from the pilot laboratory to the participant, then the pilot laboratory will replace the set of artefacts at its own cost. If damage occurs after delivery to participant, the participant will pay the cost for replacement.

3 Description of the standards

3.1 The filter sets to be used in this comparison were previously used in both the original CCPR K6 and the CCPR K6:2010 comparisons. The sets consist of 5 neutral coloured glass filter plates 50 mm x 50 mm with nominal transmittance, at the wavelength of 546 nm, of 92 %, 50 %, 10 %, 1 % and 0.1 %.

3.2 Each filter is identified by a reference engraved in the top left corner outside the area used for measurement. This reference has two parts. One is a number indicating the set to which the filter belongs, the other is a letter indicating the filter type (see table below).

3.3 The main characteristics of the filters are summarised in the following table:

Nominal transmittance %	Type of glass	Nominal thickness mm	Filter Type Identifier
92	BK 7	4.0	A
50	NG 11	2.0	B
10	NG 5	3.9	C
1.0	NG 4	3.9	D
0.1	NG 3	3.1	E

4 Measurement instructions

4.1 Traceability

Temperature measurements should be made using the International Temperature Scale of 1990 (ITS-90)

4.2 Measurand

The measurand is the average spectral transmittance of each filter

- over a circular area of approximately 17 mm diameter centred on the middle of the filter
- over a bandwidth of 1 nm centred on the wavelengths (380, 400, 500, 600, 700, 800, 900 and 1000) nm
- for a parallel beam with normal angle of incidence
- at a temperature of 23 °C
- and at a relative humidity not exceeding 60 %.

4.3 Measurement instructions

4.3.1 Before measurement each filter should be inspected for damage or contamination. Any initial or subsequent damage or cleaning should be documented using the appropriate form in appendix A.1 or A.2.

4.3.2 The measurement should be performed in suitable laboratory accommodation maintained at a temperature as close as possible to 23 °C and at a relative humidity not exceeding 60 %. The temperature and relative humidity of the laboratory during the time of the measurements should be reported. It is the responsibility of the individual laboratory to correct the measurement for the deviation of the temperature from 23 °C. The pilot laboratory will provide the participants with temperature coefficients and their uncertainties for the filters.

4.3.3 The filter transmittance must be measured independently several times. The number of measurements should be that normally used by the participating laboratory to obtain the appropriate accuracy of their specific measurement facility. The number of measurements used should be stated in the measurement report but only the mean or final declared value of each filter of the set is required to be included.

4.3.4 The transmittance measurement of the filters should be made at wavelengths of (380, 400, 500, 600, 700, 800, 900 and 1000) nm.

4.3.5 The measurement of interest in this comparison is the average transmittance of each filter over a circular area of approximate 17 mm diameter centred on the middle of the filter as determined from the edges of the filter. The ideal beam is therefore a circular beam of 17 mm diameter. Should the measurement beam be different to this then the participant laboratory should incorporate an uncertainty to account for this when estimating the average transmittance over the area of interest for this comparison.

4.3.6 The beam geometry shall be as close as possible to a parallel beam with normal angle of incidence. Any deviation from these conditions should be reported. Any influence on transmittance as defined by 4.2.1 caused by such deviations should be handled as either a correction with associated uncertainty or solely as an uncertainty, whichever is the participant laboratory's regular practice.

4.3.7 The preferred bandwidth for the measurements is 1 nm; the bandwidth used should be stated in the report. Should the participant laboratory make measurements using some

different bandwidth then any bandwidth effects should be accounted for by the participant in their uncertainty budget.

4.3.8 No information relating to the comparison, such as measurement results, obtained by a participant during the course of the comparison shall be communicated to any party other than the pilot laboratory. The pilot laboratory will be responsible for disseminating information to other participants and any other release of information. In the latter case the pilot laboratory will seek permission of all the participants before releasing information.

5 Measurement uncertainty

5.1 Measurement uncertainty shall be estimated according to the ISO Guide to the Expression of Uncertainty in Measurement [10]. To achieve optimum comparability, a list containing the principal influence parameters for measurement of spectral transmittance is given below. The participating laboratories are encouraged to follow this breakdown as closely as possible and adapt it to their instruments and procedures if necessary. Other additional parameters that it may be felt appropriate can be added to the list; these include dependence on specific measurement facilities and should be added with an appropriate explanation and/or reference. As well as the value associated with the uncertainty, participants should give an indication of the basis for their estimate. All values should be given as absolute uncertainties for a coverage factor of k=1.

5.2 The reproducibility of measurements can be determined by calculating the standard deviation of a set of measurements with realignment and repositioning of the filter between each individual measurement. It characterises the whole process of the measurement. It is this value which has to be taken into account for the uncertainty evaluated according the type A method.

5.3 Type B uncertainty components may include the following:

- temperature of the filter during measurement,
- non-linearity of the detector over the dynamic range of the detector used for the measurements,
- that due to the uncertainty in the wavelength setting of the monochromator,
- stray light,
- beam size and position,
- inter-reflection between the filter and the various optical and mechanical components of the experimental set-up,
- obliquity effects (changes to path length and Fresnel reflection) due to a non-parallel beam or the imperfect alignment of the filter,
- polarization of the light,
- drift of the sources during the measurements,
- bandwidth,
- any other uncertainty components specific to the apparatus used for the measurements.

6 Reporting of results

6.1 The final results should be submitted to the pilot laboratory at the latest within four weeks from completion of measurements. The tables in appendices B.1, B.2, and B.3 should be completed at that time. The measurement report tables (appendices B.1, B.2, and B.3) of this document will be sent by e-mail (as a Microsoft word document) to all participants to be filled in. It would be appreciated if the completed form could be sent back electronically to the pilot. **In any case, the signed report including the results must also be sent in paper form by mail, or in PDF or JPG format of the signed report scanned and sent by email.** In case of any differences, the paper versions are considered to be the definitive version.

6.2 In completing the description of the participant's measurement facility, Appendix B.1, a schematic diagram of the facility should be included.

6.3 Following receipt of all measurement reports from the participating laboratories, the pilot laboratory will follow section 1, 2, and 3 of the Guidelines for CCPR Comparison Report Preparation (CCPR G2) to write the Pre-Draft A. Section 4 is not required for RMO comparisons linking to the KCRV of a CCPR key comparison [7].

7 Analysis of Comparison Results

7.1 Introduction

In the Technical Supplement to the Mutual Recognition Arrangement (MRA) [8], key comparisons are identified as the technical basis for the arrangement. The technical deliverables of a RMO key comparison are outlined in the CCPR-G6 [2] as:

> the unilateral degree of equivalence (DOE) of each participating laboratory (except the link laboratories) including the deviation from the KCRV of the CCPR comparison and associated expanded uncertainty of the deviation.

As the key comparisons are the technical basis for the MRA, the results reported should be the basis upon which CMCs are validated and subsequently evaluated. The CCPR Guidelines state that all participants should "check the consistency of their CMCs with the KC results" ([6], §8.1) after the comparison.

7.2 Data Analysis Model

The analysis technique to be used in the SIM K6 follows the recommended analysis approach in Appendix A.2.3, *For the link of non-link laboratories when the pilot is a link laboratory*, of the CCPR G6 [2].

Each of the 40 y_i measurements (5 filters x 8 wavelengths) is considered an independent comparison of standards.

The absolute-difference model is used. The KCRV (in the CCPR KC) has units of the key comparison quantity. All uncertainty components have the same units.

The DoE of the participants will be the best estimate of the systematic offset of that participant's measurements from the KCRV.

The value component of the unilateral Degree of Equivalence (DoE) of the non-link laboratory α is calculated from the unilateral DoE of the link laboratory *i* in the CCPR KC and the difference between the measurement results of the participants.

References

[1] T.J. Quinn, "Guidelines for CIPM key comparisons," BIPM, Paris, (1999, modified 2003).

[2] Consultative Committee on Photometry and Radiometry Key Comparison Working, "Guidelines for RMO PR Key Comparisons," CCPR-G6 Version 1.0, 2014, available at http://www.bipm.org/utils/common/pdf/CC/CCPR/CCPR-G6.pdf.

[3] "CCPR-K6.2010 Key Comparison Spectral Regular Transmittance. Technical Protocol," May 2013.

[4] K.L. Eckerle, J. Bastie, J. Zwinkels, V. Sapritsky and A. Ulyanov, "Comparison of regular transmittance scales of four national standardizing laboratories," Col. Res. Appl. 18 35 (1993).

[5] J.F. Verrill, "Intercomparison of spectrophotometric measurements of regular transmittance," Report contract N°. MAT1-CT940021, (1996).

[6] G. Obein and J. Bastie, "2008 *Report on the CCPR Key Comparison K6 Spectral regular transmittance,*" available at http://kcdb.bipm.org/AppendixB/appbresults/ccpr-k6/ccpr-k6_final_report.pdf.

G. Obein and J. Bastie "*Report on the CCPR Key Comparison K6: Spectral Regular Transmittance,*" Metrologia 46, Tech. Suppl., 02002 (2009).

[7] BIPM database: http://kcdb.bipm.org/appendixB/default.asp

[8] Mutual recognition arrangement: BIPM - CIPM MRA

[9] "ISO 17025: Practical Benefits of Implementing a Quality System". *Journal of AOAC International* ***86*** *(5): 1038–1044*. 2012.

[10] BIPM IEC IFCC ILAC ISO IUPAC IUPAP and OIML 2008, "*Guide to the Expression of Uncertainty in Measurement*," (Geneva: International Organization for Standardization) available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf.

[11] Consultative Committee on Photometry and Radiometry Key Comparison Working Group, "Guidelines for CCPR Key Comparison Report Preparation," CCPR-G2 (rev. 3), 2013, available at http://www.bipm.org/utils/common/pdf/CC/CCPR/CCPR-G2.pdf .

[12] International Committee for Weights and Measures, 2003, Mutual Recognition of National Measurement Standards and of Calibration and Measurement Certificates Issued by National Measurement Institutes (Paris: Comité International des Poids et Mesures), available at http://www.bipm.org/utils/en/pdf/mra_2003.pdf.

[13] Consultative Committee on Photometry and Radiometry Key Comparison Working, "Guidelines for CCPR and RMO bilateral key comparisons", CCPR-G5, 2014, available at http://www.bipm.org/utils/common/pdf/CC/CCPR/CCPR-G5.pdf .

Appendix A.1 Receipt of standards of the SIM K6:2016

To Laboratory:

From Pilot Laboratory:

Has the filter transportation package been opened during transit? e.g; Customs Y / N

If yes please give details:

Is there any damage to the packaging? Y / N

If yes please give details:

Are there any visible signs of damage or contamination on the filters? Y / N

If yes please give details:

We confirm receipt of the standards of the SIM K6:2016 Comparison.

Signature : **Date :**

Appendix A.2 Condition of the standards of the SIM K6:2016 comparison on departure from participant laboratory

Laboratory:

Were the filters contaminated or damaged in any way while at your laboratory? Y / N

If yes please give details:

Was any cleaning of filters undertaken while at your laboratory? Y / N

If yes please give details:

Has the filter container been flushed with dry nitrogen and sealed? Y / N

Signature : **Date :**

Appendix B.1 Description of measurement facility and measurement method

Laboratory:

Table B-1 Details of Measurement Setup

Make and Type of Spectrophotometer	
Additional Stray Light Rejection	
Source Drift Monitoring	
Source	
Detector	
Temperature[(a)]	
Humidity	
Beam Size	
Beam Collimation	
Measurement Sequence[(b)]	
Bandwidth	

[(a)] i.e. describe method of temperature monitoring of filters and range of temperatures [(b)] i.e. describe number of measurements and whether filter orientation with respect to beam changes between measurements

Description of measuring technique (please include a diagram)

If any damage, contamination or cleaning of the filters was carried out, please give details

Signature : **Date :**

Appendix B.2 Measurement Results

Please reproduce the following tables for each of the five filters measured at the completion of the measurements. All uncertainties should be reported as absolute uncertainties.

Laboratory: Filter Identifier:

Table B2 Measurement Results

Wavelength□ (nm)	380	400	500	600	700	800	900	1000
Spectral Transmittance[(a)]								
Number of Measurements								
Temperature								
Type A Uncertainty[(b)]								
Type B Uncertainty[(c)]								
Total Uncertainty[(d)]								
Degrees of Freedom								

[(a)]**Spectral transmittance.** The value of the spectral transmittance of the central 17 mm diameter of the filter as measured by the participant laboratory. [(b)]**Type A Uncertainty.** The combined uncertainties associated with the spectral transmittance values attributed to reproducibility of the measurement. [(c)]**Type B Uncertainty.** The combined uncertainties associated with the spectral transmittance values attributed to all type B components. [(d)]**Total Uncertainty.** The combined standard uncertainty of Type A and Type B components above.

Table B.3 Type B Uncertainty Budget[a]

Fill out the table below for the uncertainty contributions in the measurements. All uncertainties should be reported as absolute uncertainties.

Wavelength (nm)	380	400	500	600	700	800	900	1000
Nonlinearity								
Temperature								
Wavelength								
Stray Light								
Beam Size & Position								
Inter-reflection								
Obliquity								
Polarization								
Source Drift & Fluctuation								
Bandwidth								
Other[b]								
Total Type B Uncertainty								
Degrees of Freedom								

[a] Please record any uncertainties considered negligible as zero (rather than e.g. < some value) [b]Add lines to the table as necessary, itemising other components of uncertainty considered

Signature : **Date :**

Appendix B: Facility Descriptions

CENAM's Measurement Technique:
The measurement sequence is detailed in Table B1. Measurements at 900 nm and 1000 nm were not reported because of the noise of our lead sulfide photodiode.

Figure B1. Schematic diagram of CENAM's spectrophotometer.

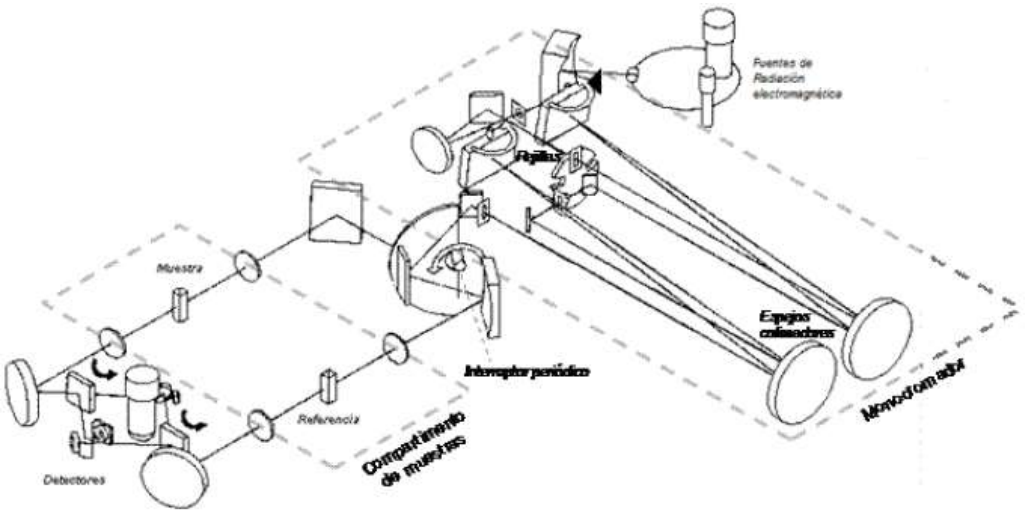


Table B1. Details of CENAM's Measurement Setup

Make and Type of Spectrophotometer	Spectrophotometer UV-VIS-NIR, Varian Cary 5e
Additional Stray Light Rejection	ASTM E 387, The Opaque filter method
Source Drift Monitoring	Signal Stability by 10 minutes
Source	Tungsten Halogen Lamp
Detector	R928 PMT
Temperature	Place near to spectrophotometer (23.2 °C; max. variation: 0.3 °C)
Humidity	Place near to spectrophotometer (RH 48.7 %; max. variation: 8.7 %)
Beam Size	1 mm x 10 mm (W x H)
Beam Collimation	Unchanged, Factory default
Measurement Sequence	For each filter: 4 measurements, Filter rotation of 90 degrees, sense clockwise; three times
Bandwidth	1 nm

INM's Measurement Technique:
The transmittance measurements were performed on a Cary 4000 (Agilent Technlogies) double bean spectrophotometer, with suitable photometric performance in the 175 nm to 900 nm range.

At each wavelength the following measurements were performed:

1. Set the zero of the measurement
2. Measurement of the transmittance at 100% (clear beam) (τ_z)
3. Blocking the sample beam and measurement of the transmittance (τ_0)
4. Measurement of the filter (τ_m)
5. Blocking the sample beam and measurement of the transmittance (τ_0)
6. Measurement of the transmittance al 100% (clear beam) (τ_z)
7. The spectral transmittance was obtained from:

$$\tau = \frac{\tau_m - \tau_0}{\tau_z - \tau_0}$$

Figure B2. Schematic diagram of INM's spectrophotometer. (Adapted from: Fundamentos de la espectroscopía UV- Visible moderna. Conceptos básicos AGILENT TECHNOLOGIES.)

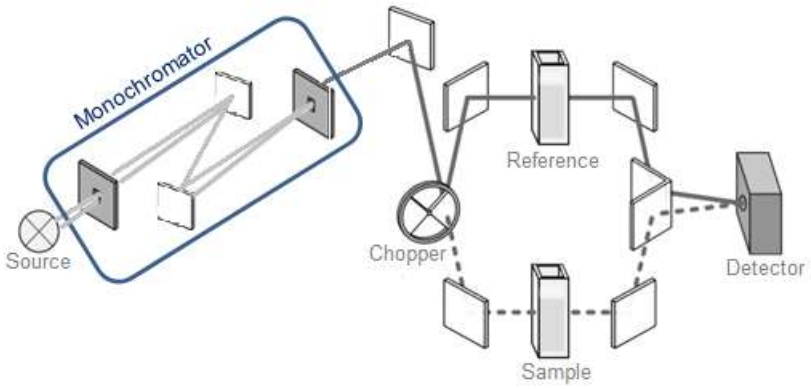


Table B2. Details of INM's Measurement Setup

Make and Type of Spectrophotometer	The measurements were done with the reference spectrophotometer Agilent Cary 4000 UV-Vis. This spectrophotometer has a double beam, a double out of plane Littrow monochromator, a 2 mm by 400 mm focal length and two gratings with 1200 lines/mm. The detector is a R928 photomultiplier tube. The instrument has three sources, a tungsten halogen visible source with quartz window, a deuterium arc UV source, and a mercury lamp used for wavelength accuracy validation. The spectrophotometer has a beam splitter, with a speed of 300 Hz. The wavelength range is 175 nm to 900 nm. Variable spectral bandwidth between 0.01 nm to 5.00 nm with 0.01 nm steps.
Additional Stray Light Rejection	At 220 nm, the spectrophotometer has a stray light < 0.00007%. At 370 nm. it has a stray light < 0.00007%.
Source Drift Monitoring	In order to monitor the drift, we did three measurements per point: clear beam, blocked beam, and the filter, and we corrected each transmittance (see Description of measuring technique)
Source	All measurements were performed with the tungsten halogen visible source.
Detector	R928 photomultiplier tube.
Temperature	The measurements were done between 22.5 °C and 23.2 °C.
Humidity	The relative humidity during the measurements was within 39.6 % RH and 52.4% RH.
Beam Size	Slit at full height (5 nm SBW): 13.35 mm high by 5.11 mm wide Slit at reduced height (5 nm SBW): 9.08 mm high by 5.1 mm wide
Beam Collimation	The spectrophotometer has 2 collimating mirrors, one in each monochromator.
Measurement Sequence	For each filter, we performed the following sequence: 1. We removed dust with dry nitrogen. 2. The filter was placed in the sample holder with its identification number in front of the incident beam and upright with a normal angle of incident. 3. The measurements were done at 380 nm, 400 nm, 500 nm, 600 nm, 700 nm, 800 nm, and 900 nm. 4. The filter was measured 30 times. 5. After these measurements, the filter was rotated 90° and measured 30 times more. Each filter was measured in two different days. The regular transmittance reported is the mean of all the measurements. The filters were measured in the following order A, E, D, C, B.
Bandwidth	The measurements were done with a bandwidth of 1 nm.

INMETRO's Measurement Technique:
Inmetro transmittance measurement system (TMS) is designed for the measurement of absolute regular spectral transmittance above 0.1 in the wavelength range from 400 nm to 1000 nm. The system consists of a 24 V/250 W quartz-tungsten-halogen lamp, a Czerny-Turner monochromator (Jobin Yvon HR 250 M), a light-tight box with the sample and a silicon photodiode (Hamamatsu S1227), as shown in Figure B3.

The quartz-tungsten-halogen lamp mounted inside the housing and operated in current-mode (10 A) is focused onto the entrance slit of the monochromator. A cut-off filter (Schott OG 550) is placed in front of the entrance slit to reject higher order wavelengths in measures above 590 nm. The light exiting the monochromator is collimated by a concave mirror and directed onto an iris that adjusts the beam diameter to about 17 mm. After the sample, the beam is focused by a concave mirror on the surface of the detector. A translation stage is used to interchange the sample (filter) and the reference (empty) in the beam path. The photocurrent is amplified by a transimpedance amplifier (LabKinetics SP042) and read with a digital voltmeter (Agilent 34420A).

Figure B3. Schematic diagram of INMETRO's transmittance measurement system.

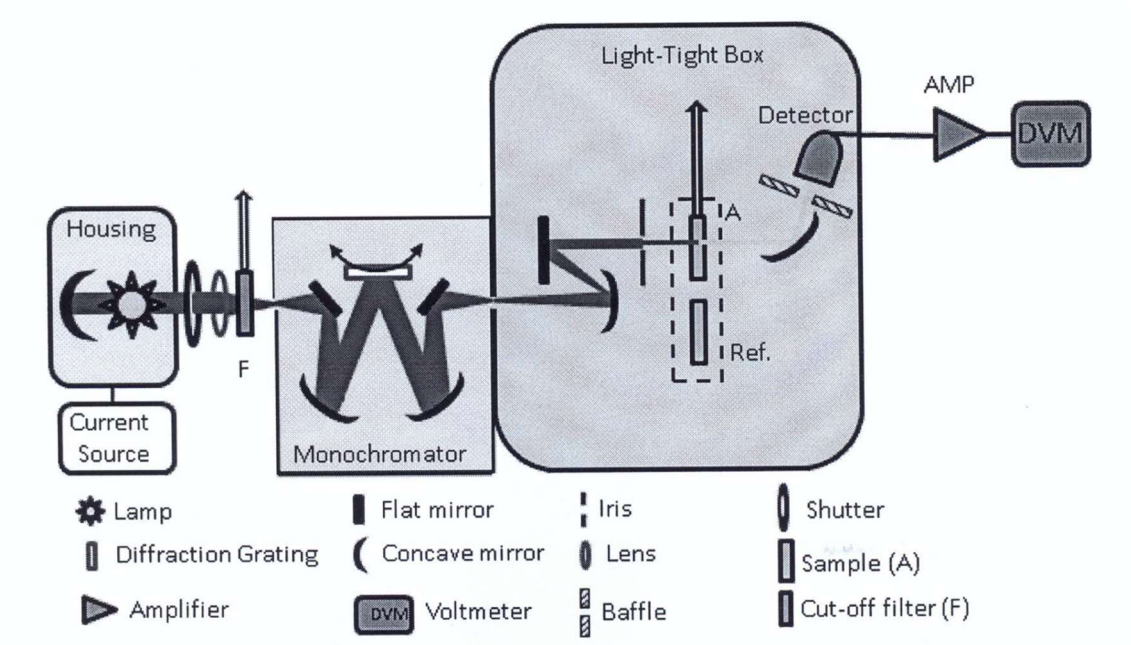


Table B3. Details of INMETRO's Measurement Setup

Make and Type of Spectrophotometer	Custom-made spectrophotometer based on a single beam Czerny-Turner monochromator (Jobin Yvon HR 250 M).
Additional Stray Light Rejection	Cut-off filter in front of the entrance to the monochromator to minimize high order in measurements above 590 nm. Sample and detector are placed in a light-tight box.
Source Drift Monitoring	Source drift is corrected along measurement by measuring the reference signal prior and after the measurement with the filters.
Source	24 V/250 W quartz-tungsten-halogen lamp
Detector	Silicon photodiode (Hamamatsu S1227)
Temperature	(24.5 ± 0.4) °C measured inside the light-tight box with a thermo-hygrometer traced to national metrology standards.
Humidity	< 60.0 % measured inside the light-tight box with a thermos-hygrometer traced to national metrology standards.
Beam Size	17 mm in diameter, rounded beam
Beam Collimation	Beam divergence < 0.7° at the sample
Measurement Sequence	Measurements were taken for each filter following the sequence: 0 % T (blocked beam), 100 % T (no filter), filter positioned 0°, and filter positioned 90°. At each wavelength measurement follows the sequence: reference (no filter), with filter, reference.
Bandwidth	Approximately 1 nm

CMS/ITRI's Measurement Technique:
CMS uses a double beam spectrometer to measure the transmittance of samples. The light passes through the filters vertically. The transmittance of the filters is calculated with respect to the reference beam and is corrected by separate baseline measurements.

The baseline measurements consist of 100% and 0% transmittance measurements. For 100% transmittance measurement, the sample beam passes through an empty sample holder. For the 0% transmittance measurement, the sample beam is blocked by an opaque sample.

To increase the sensitivity of low transmittance samples, the reference beam was attenuated. Specifically, the C filter was used to attenuate the reference beam when measuring the D filter, and the D filter was used to attenuate the reference beam when measuring the E filters. No filters were used in the reference beam during measurement of the A, B, and C filters.

Figure B5. Schematic diagram of the CMS/ITRI's spectrophotometer.

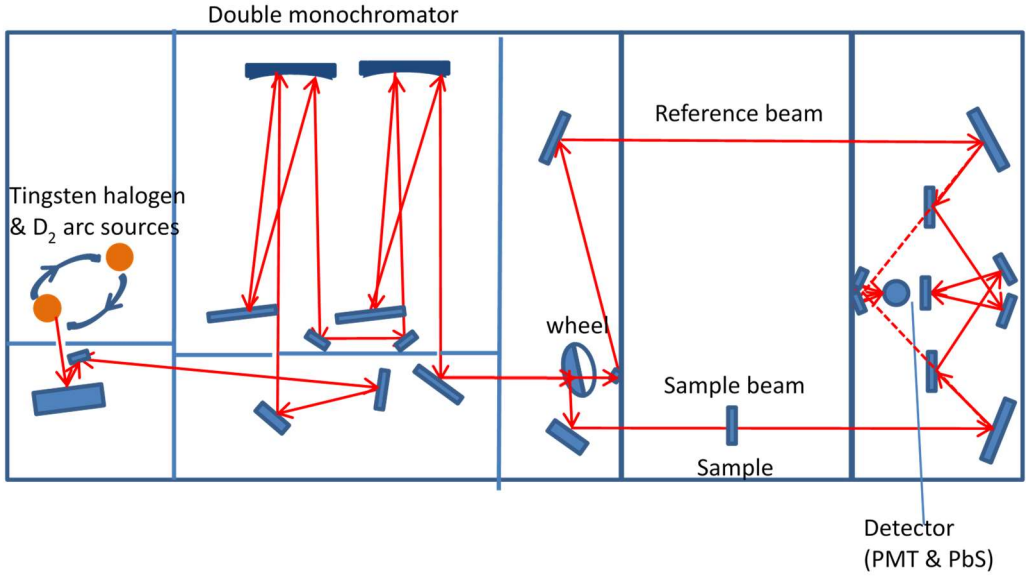


Table B4. Details of CMS/ITRI's Measurement Setup

Make and Type of Spectrophotometer	Agilent/Cary 5000: A UV-Vis-NIR spectrophotometer with photometric performance in the 200 nm to 3000 nm range.
Additional Stray Light Rejection	The signal of the solution of NaI at 220 nm and of $K_2Cr_2O_7$ at 370 nm was measured to determine the stray light effect. Stray light contribution was added to measurement uncertainty.
Source Drift Monitoring	A double-beam spectrophotometer was used. The reference and sample beam are continually compared to produce final measurement results, and the chopper cycle is 0.033 s.
Source	QTH lamp
Detector	The detector was PMT (Hamamatsu/R928) for the measurement below 800 nm, and cooled PbS for the measurement at 900 nm and 1000 nm
Temperature	(23.0 ± 1.5) °C
Humidity	(45 ± 10) %
Beam Size	An around 13 mm by 1 mm rectangular area
Beam Collimation	Maximum half angle of cone in the incident angle beam: 3.8°
Measurement Sequence	Each filter has been measured within three days and been repeated three times in each day.
Bandwidth	1 nm

NIM's Measurement Technique:
The measurements were conducted using a spectrophotometer based on a single beam, single monochromator (Type 2061, McPherson) with 2400 g/mm diffraction gratings. A tungsten halogen lamp (Type Osram 300 W) was used as the light source for the measurements over the whole spectral range. A series of band-pass filters were placed at the exit slit of the monochromator. A small portion of the light from the band-pass filters was directed onto a monitor detector (silicon detector, Type S1337-1010BQ, Hamamatsu) using a beam splitter. A silicon detector of the same type was used as the main detector. The monitor detector was used to minimize the impact from the drift of the source. The photocurrents of both detectors were measured using two Keithley 6485 Picoammeters synchronously. The filter was mounted with a sample holder on a translation and rotary stage.

Figure B6. Schematic diagram of the spectrophotometer at NIM.

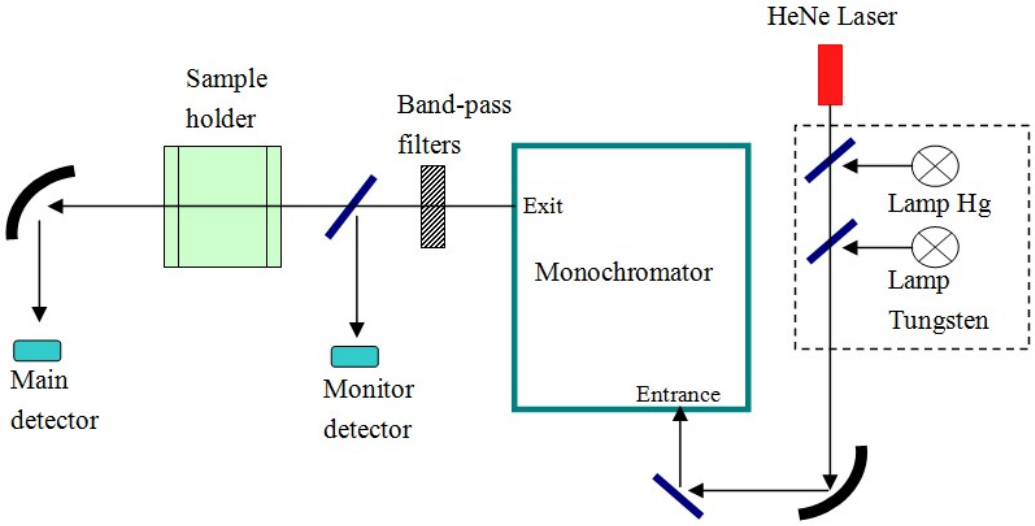


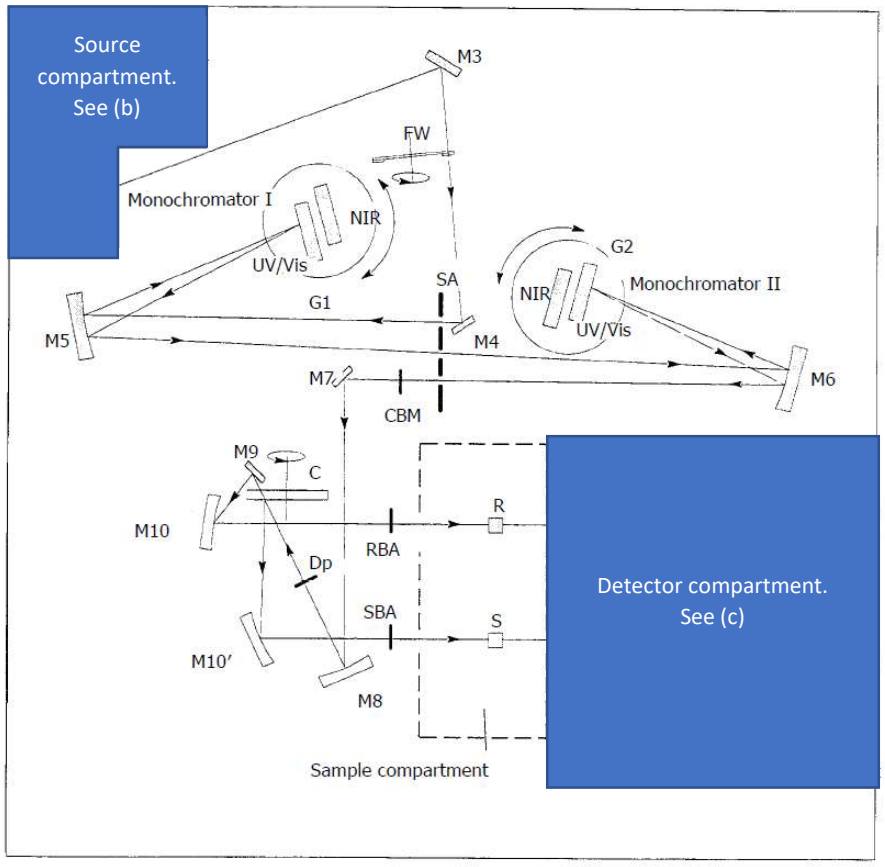
Table B5. Details of NIM's Measurement Setup

Make and Type of Spectrophotometer	Made by NIM
Additional Stray Light Rejection	Stray Light Filter
Source Drift Monitoring	Yes
Source	QTH Lamp, 300 W
Detector	Si, 1337
Temperature	(23 ± 1) ºC (4 Wire, PT100)
Humidity	< 40 % RH
Beam Size	Φ17 mm
Beam Collimation	0.3º
Measurement Sequence	100 %, Sample, Zero (Six times, no changes between measurements)
Bandwidth	1 nm

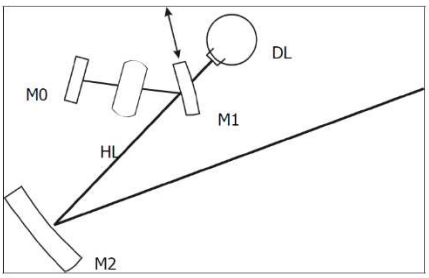
NIMT's Measurement Technique:
Even though the spectrophotometer used for the measurement is a double-beam spectrophotometer, the single beam method is adopted. In each series (round), the signal (which is the ratio of the sample beam to the reference beam) is measured in the series: dark, sample, blank, sample. The transmittance is calculated for each round of measurement by dividing the average dark corrected signal of the sample by the dark corrected signal of the blank. The diagrams of the spectrophotometer used are as followed:

Figure B7. (a) Schematic diagram of NIMT's spectrophotometer. (b) Source compartment showing the source doubling mirror M0. (c) Detector module with 3 detectors.

(a)



(b)



(c)

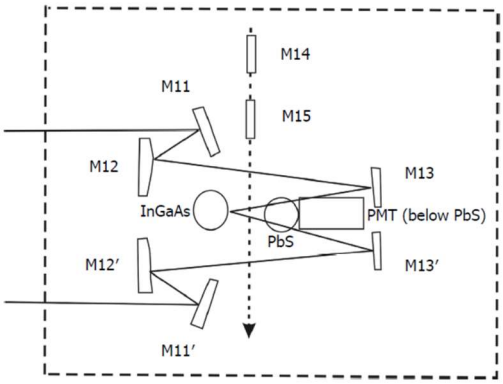


Table B6. Details of NIMT's Measurement Setup

Make and Type of Spectrophotometer	Perkin Elmer Lambda 1050
Additional Stray Light Rejection	10^{-8}
Source Drift Monitoring	Yes, using the ratio of the sample beam to the reference beam.
Source	100 W Tungsten Halogen Lamp 1
Detector	PMT
Temperature[(a)]	The temperature on the filter was not monitored. Only the ambient temperature of the room (near the spectrophotometer) was controlled and monitored to be within (23 ± 2) ºC.
Humidity	(50±15) % RH
Beam Size	Approx. 1 mm width by 13 mm height
Beam Collimation	No, the beam is a focusing one
Measurement Sequence[(b)]	Measurement were performed in total 12 rounds. In each round, the signals were measured in the sequence, dark→Sample→Blank (Ref)→Sample. Eight rounds were measured with the mark on the filter facing the beam while the other four rounds were measured with the other side of the filter facing the beam. For the first eight rounds, the filter was oriented in four different directions, north, south, east, and west with respect to the beam, two rounds for each orientation. Similar orientations were applied for the other four rounds.
Bandwidth	1 nm

NRC's Measurement Technique:
The filters were mounted in an automated 6-position filter wheel sample holder. A precision aperture was mounted in front of the filter wheel to limit the beam size to 17 mm diameter at the sample position, as specified in the technical protocol. In general, three filters were measured in any given measurement cycle at a given set of experimental conditions, with 2 open beam positions for the 100 % reference readings bracketing each filter reading. A dark signal (0 % reading) with the shutter closed was also recorded before each reference reading and the mean dark signal for each measurement cycle was subtracted from each raw signal measurement. For the higher density filters, D and E, a reference beam attenuation technique was used to reduce the uncertainty measurement. When using the reference beam attenuation technique, the automated measurement sequence was modified so that the measurement of the attenuating filter (and dark signal) bracketed the measurement of the filter under test in a time-symmetrical sequence and the filter wheel was rotated first in a clockwise and then a counter-clockwise direction. The measured signal for the filter under test was then referenced to the average of the two time-bracketing measurements of the attenuating filter, after each reading had been corrected for the mean dark signal. The transmittance of the filter under test was then calculated by multiplying this apparent transmittance by the known transmittance of the attenuating filter calibrated on the Reference Spectrophotometer under the same measurement conditions.

For the SIM.PR-K6 measurements, the filters D and E were measured at all wavelengths from 380 nm to 800 nm using a reference beam attenuation technique. Filter D was measured against filter C and Filter E was measured against filter D. For the wavelengths of 900 nm and 1000 nm, these two filters were measured relative to an open beam position.

The Type A uncertainty due to long-term measurement reproducibility and influence of sample non-uniformity were assessed from the experimental standard deviation of the mean of a minimum of 3 independent runs recorded on different days over a two month period and for which the filter was repositioned and/or the detection system was changed. This uncertainty component includes the influence of short term repeatability, where the result of one measurement run was typically obtained from the mean of 8 repeat measurement cycles recorded over a total elapsed time of 20 minutes.

All five filters were calibrated at the eight specified wavelengths from 380 nm to 1000 nm, with a bandwidth of (1.0 ± 0.03) nm. The measurements were performed using a 200 W tungsten-halogen lamp, and a minimum of two different types of the detectors identified above. For the wavelengths of 900 nm and 1000 nm, only the two different types of silicon photodiode detectors were used, whereas for the intermediate wavelengths of 400 nm to 700 nm, all 4 different types of detectors were used (two PMTs and the two Si detectors). For the wavelength of 380 nm, only the two PMTs were used for the highest density filter E.

The relative humidity during the measurements varied from a minimum of about 25 % RH to a maximum of about 45 % RH. The NRC Reference Spectrophotometer has a calibrated RTD element installed in the sample compartment. The temperature of the sample compartment was recorded with a calibrated digital thermometer Fluke Model 1529-R (uncertainty is ± 0.0025 °C at 25 °C) during the filter measurements and was used to correct the transmittance results with the relative temperature coefficients, κ, and the equation provide in the technical protocol. The

laboratory is equipped with an electronic air cleaner and a positive air flow system. Prior to each measurement run, a jet of purified nitrogen gas was used to blow any dust off the surfaces of the filters. No other cleaning of the filters was carried out.

The NRC Reference spectrophotometer was used for this comparison. It is a single-beam instrument with a highly-collimated beam design using all-reflective optics and a prism-grating monochromator in conjunction with a deuterium and tungsten-halogen source to cover the spectral range 200 nm to 2500 nm. The detectors that have been used for this key comparison over the spectral range 380 nm to 1000 nm are two different side-on PMTs: a Hamamatsu R6872 and Hamamatsu R928; and two different types of silicon photodiode detectors: a custom-designed silicon sphere detector comprising two Hamamatsu S1337 photodiodes mounted in a sintered PTFE integrating sphere; and a large area silicon photodiode (LASD) detector, a Hamamatsu S6337. To minimize inter-reflection errors and improve spatial uniformity of response, the Hamamatsu R6872 and R928 PMTs are used behind a ground quartz diffuser and the Hamamatsu S6337 photodiode is slightly tilted. The PMTs are thermoelectrically cooled to (-13 ±1) °C to increase measurement sensitivity and to lower dark current signal. The linearity of the PMTs and the silicon photodiode detection systems has been tested over more than 3 decades using the NRC automated high-precision variable aperture device.

Figure B4. Schematic diagram of the NRC Reference Spectrophotometer.

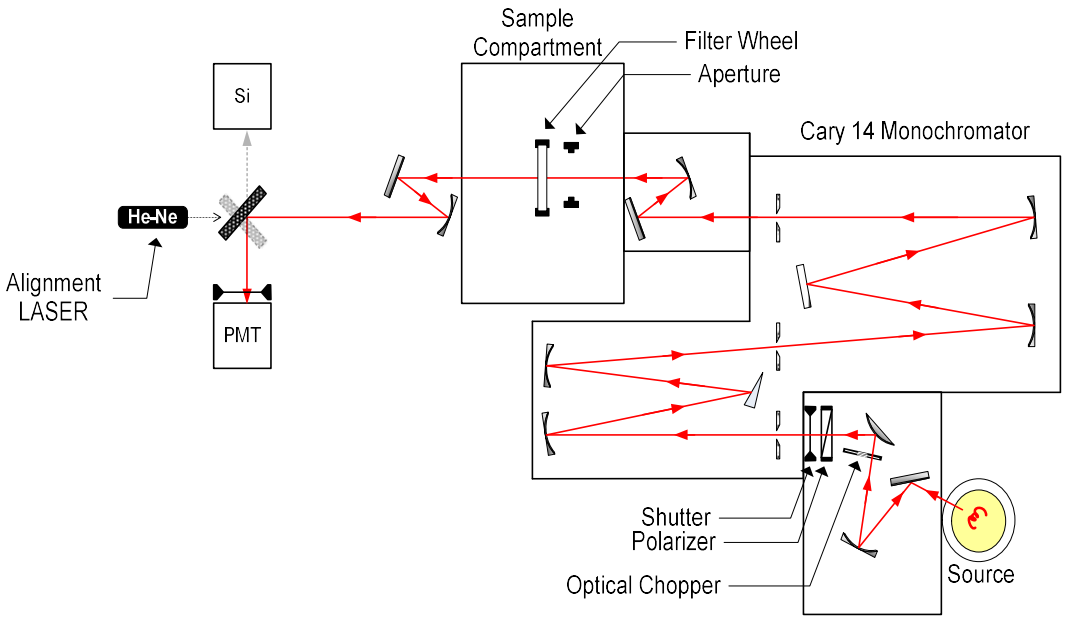


Table B7. Details of NRC's Measurement Setup

Make and Type of Spectrophotometer	Custom-built (J.C. Zwinkels and D.S. Gignac, "Design and testing of a new high-accuracy ultraviolet-visible-near-infrared spectrophotometer" *Appl. Opt.*, **31**, 1557-1567 (1992))
Additional Stray Light Rejection	Fused-silica prism predisperser, minimum monochromator slit height of 7 mm, and instrument operated in fully darkened room.
Source Drift Monitoring	Automated time-symmetrical measurements of sample and reference (either open beam or calibrated attenuator filter).
Source	200 W tungsten-halogen lamp (Q6.6A/T4/1CL) in a custom-designed and built chimney-type lamp housing.
Detector	Custom-designed and built silicon sphere detector (2x HMT 1337), large-area silicon detector (HMT S6337), two different thermoelectrically-cooled (-13° C) PMTs used behind a Suprasil quartz diffuser (HMT R928, HMT R6872).
Temperature	Monitoring with a calibrated digital thermometer (Fluke Model 1525-R) mounted in the sample compartment; range of measured temperatures: 22.91° C to 23.67° C, corrected to 23° C using temperature coefficients for the filters provided by pilot lab.
Humidity	25 % RH to 45 % RH
Beam Size	17 mm diameter (using a precision diaphragm mounted in front of the sample wheel)
Beam Collimation	Maximum degree of convergence is 0.7°.
Measurement Sequence	8 repeat measurements of filter in a time-symmetrical sequence, bracketing filter measurements with open beam measurements for each repeat measurement run.
Bandwidth	1.0 nm

NIST's Measurement Technique:
The transmittance measurements were performed on a custom-made spectrophotometer, which consists of a lamp-based source, a prism-grating monochromator, a sample carriage, and an optical detector attached to an integrating sphere. Details concerning the source, monochromator and detector are provided in Table B8. A schematic of the instrument is provided in the figure below.

After cleaning with an air bulb, each sample was mounted in a holder on the sample carriage with the identification number facing the incident beam in one of two possible sample orientations (see Table B8 Measurement Sequence). The sample was centered on the incident beam and aligned normal to the beam by retroreflecting a laser beam collinear with the axis of the incident beam. The maximum deviation from normal was 0.1º. The diameter of the incident beam was 17 mm.

The sample carriage consists of two incident positions for the beam: clear and sample. In each position, a shutter is used as a light trap for a dark signal. For each wavelength, the following signals were measured in this order: signal in the clear position, dark signal in the clear position, signal in the sample position, dark signal in the sample position, and signal in the clear position.

Net signals for the clear and sample positions are obtained by subtracting the dark signals, and the net clear signals, the first taken before the sample signal and the second taken after the sample signal, are averaged to minimize the effects of source drift and fluctuations on the timescale of a single transmittance measurement. The spectral transmittance of the sample was given by the net sample signal divided by the average net clear signal. Measurements were performed at wavelengths of 380 nm, 400 nm, 500 nm, 600 nm, 700 nm, 800 nm, 900 nm, and 1000 nm.

Figure B8. Schematic diagram of the NIST Reference Transmittance Spectrophotometer.

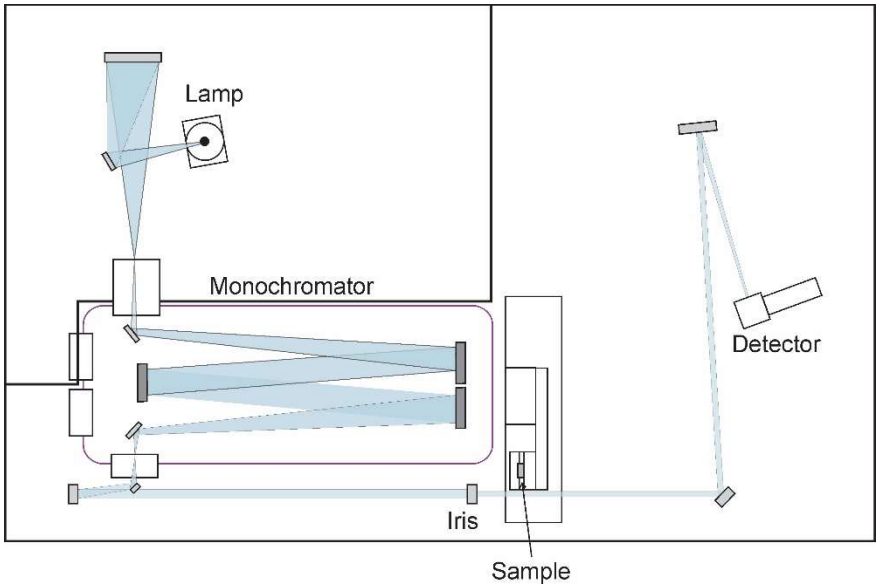


Table B8. Details of NIST's Measurement Setup

Make and Type of Spectrophotometer	Custom-made spectrophotometer consisting of a 1 m, prism-grating monochromator (McPherson 2051). Light from the source is focused by a spherical mirror onto the 1 mm entrance slit of the monochromator. The grating has 600 lines/mm and is blazed at 200 nm. The exit aperture of the monochromator is 1 mm diameter circle. The slit, apertures, and grating yield a triangular slit function with a nominal bandwidth of 1.5 nm. The light exiting the monochromator is collimated by an off-axis parabolic mirror, reduced in diameter by an iris, and is incident upon the sample plane. Light passing through the sample plane is focused by a spherical mirror into an averaging sphere attached to a detector. The current from the detector is amplified and read by a digital voltmeter.
Additional Stray Light Rejection	None
Source Drift Monitoring	The incident beam is measured in the clear position before and after measurement in the sample position at each wavelength. The average clear signal is used to minimize the effects of source drift on the timescale of a single transmittance measurement.
Source	150 W quartz-tungsten-halogen incandescent lamp
Detector	Silicon photodiode
Temperature	Calibrated temperature probe (Fluke 1620A Thermo-hygrometer). The average temperature was 23.98 °C.
Humidity	Calibrated hygrometer probe (Fluke 1620A Thermo-hygrometer). The range was from 5.3 % RH to 49.5 % RH.
Beam Size	17 mm diameter
Beam Collimation	Collimated (maximum deviation from collimation at the sample is 0.2°)
Measurement Sequence	The spectral transmittance of each sample was measured at two different orientations to remove any effects from the slight polarization of the incident beam: (1) upright, with the filter identifier facing the incident beam and located at the upper right corner and (2) rotated 90º about its normal so that the filter identifier was facing the incident beam and was located at the lower right corner. In each orientation, the transmittance was measured 3 times at each wavelength and averaged. The unpolarized transmittance is the average of transmittance at each orientation. Measurements were repeated on 3 different days for each sample over 14 weeks.
Bandwidth	1.5 nm

Disclaimer

Certain commercial equipment, instruments, or materials are identified in this appendix in order to specify the measurement procedure adequately. Such identification is not intended to imply recommendation or endorsement by NIST, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

Appendix C: Relative Data

Figure C1a. Relative Data for CENAM, Filter A

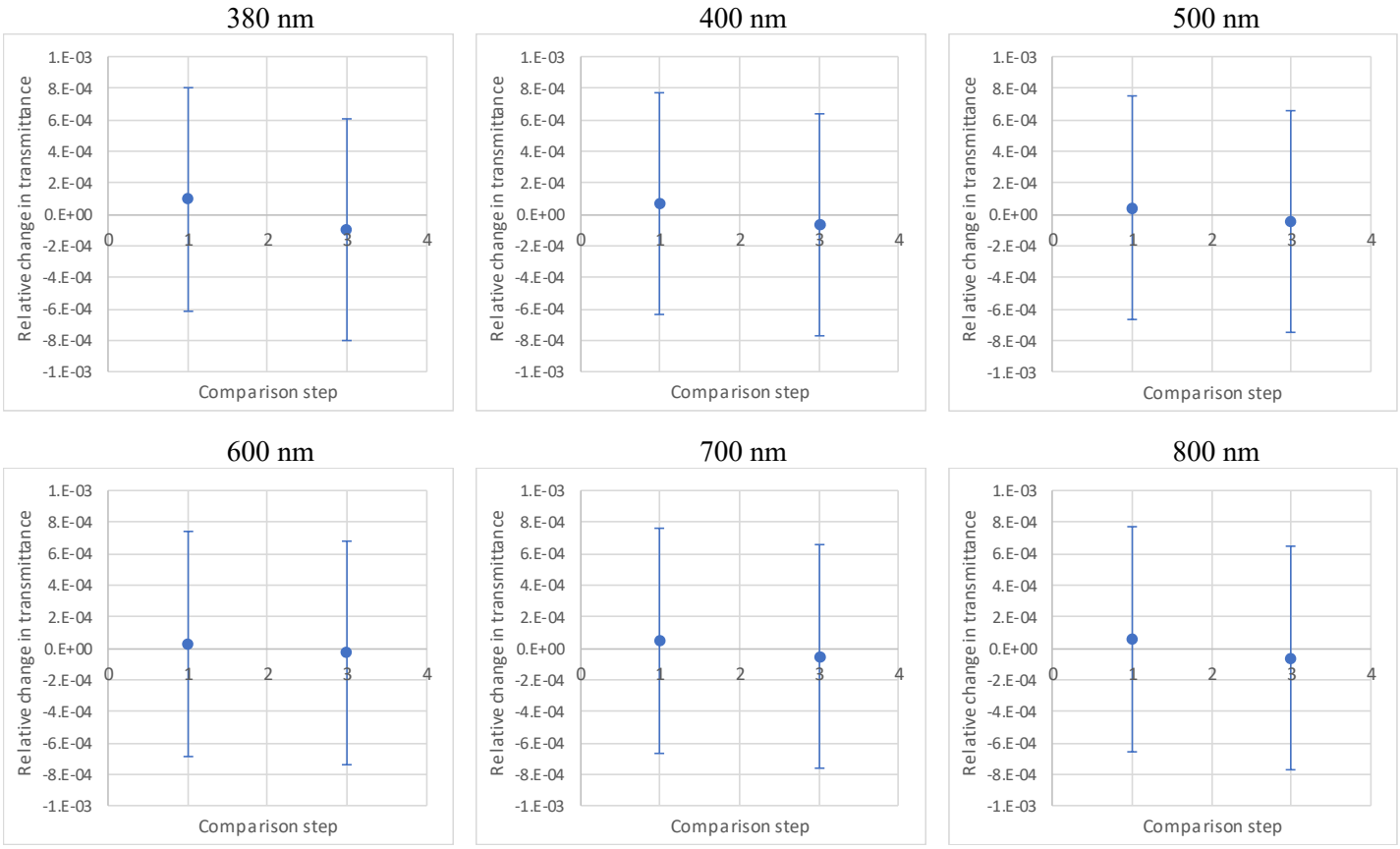


Figure C1b. Relative Data for CENAM, Filter B

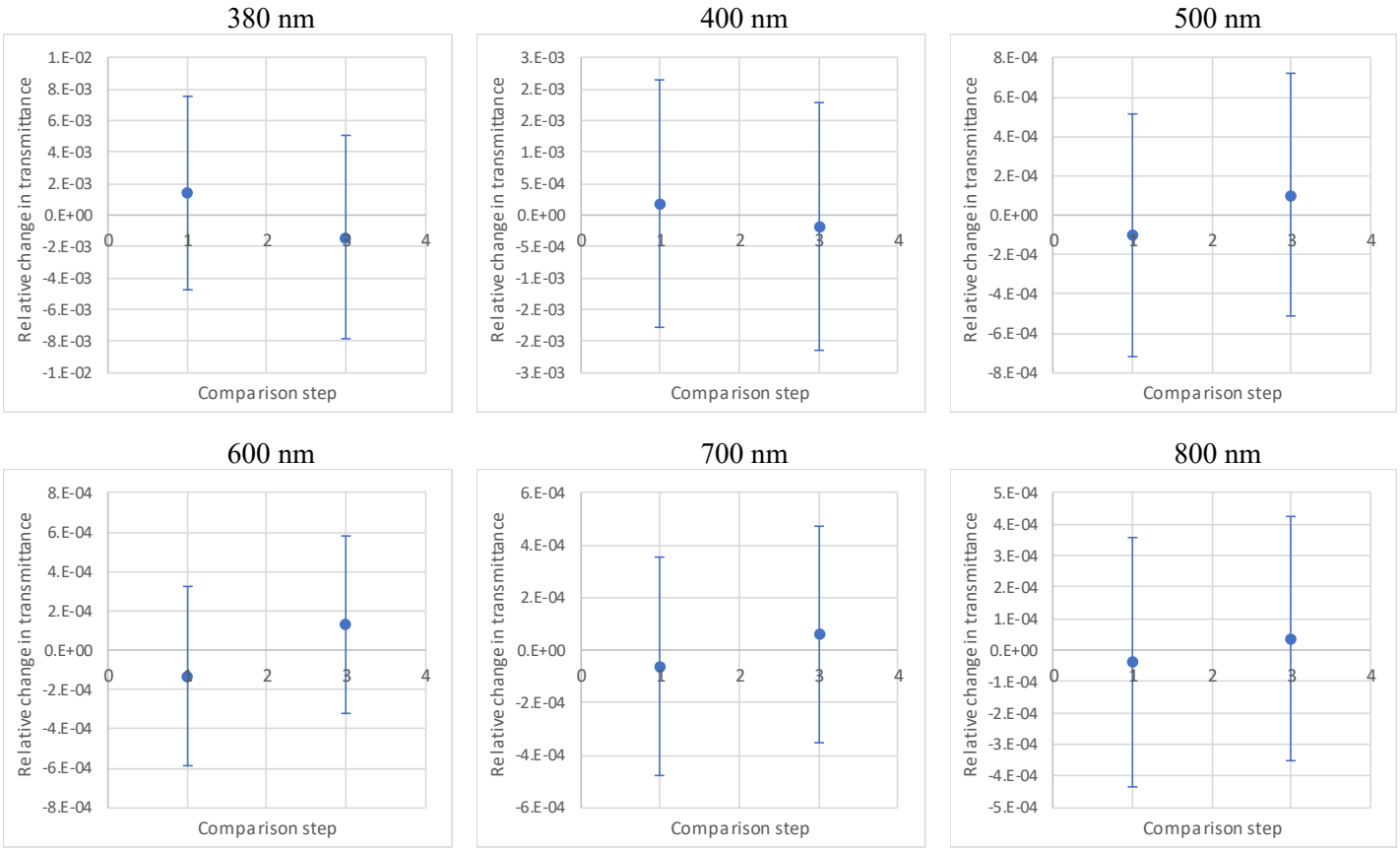


Figure C1c. Relative Data for CENAM, Filter C

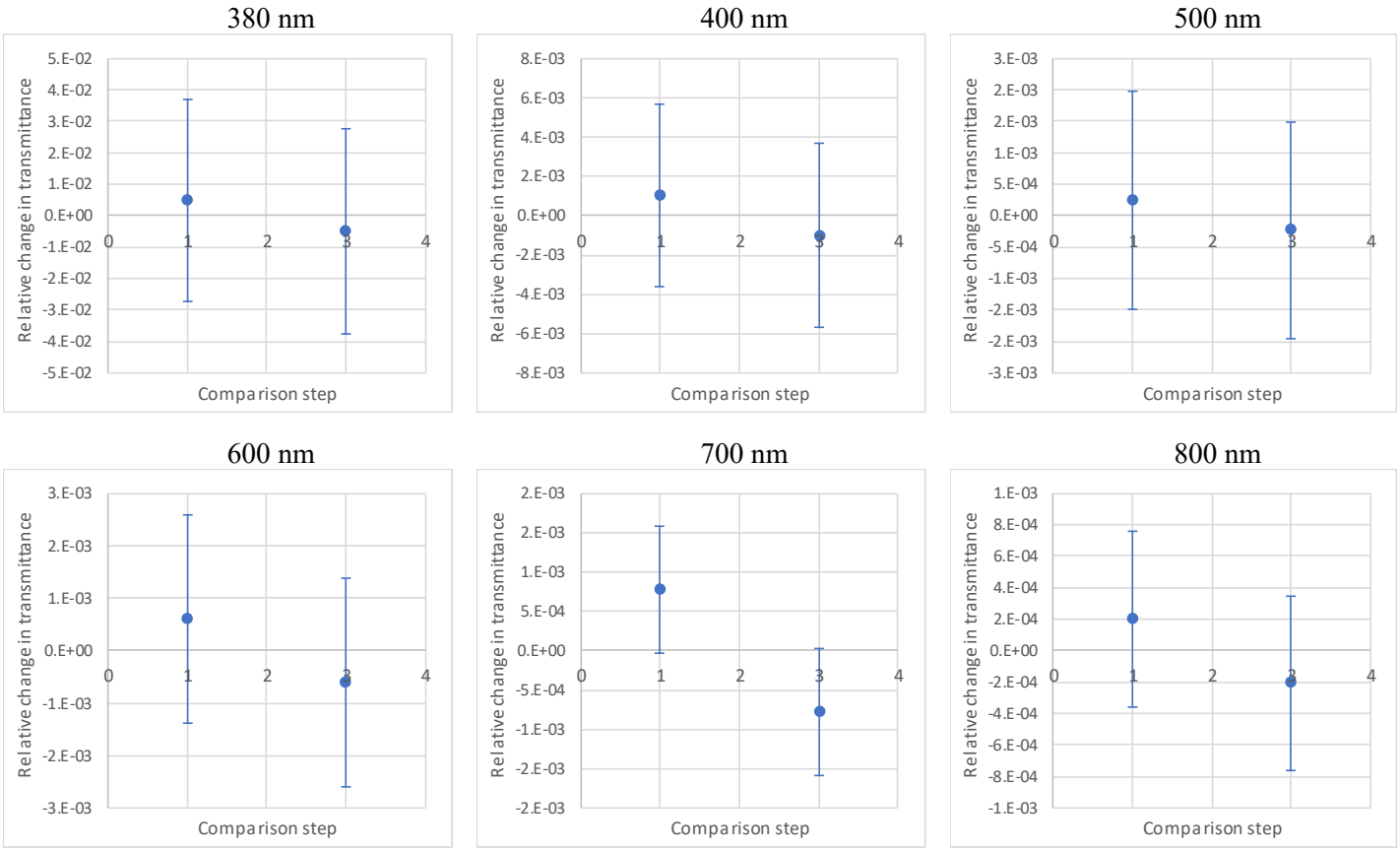


Figure C1d. Relative Data for CENAM, Filter D

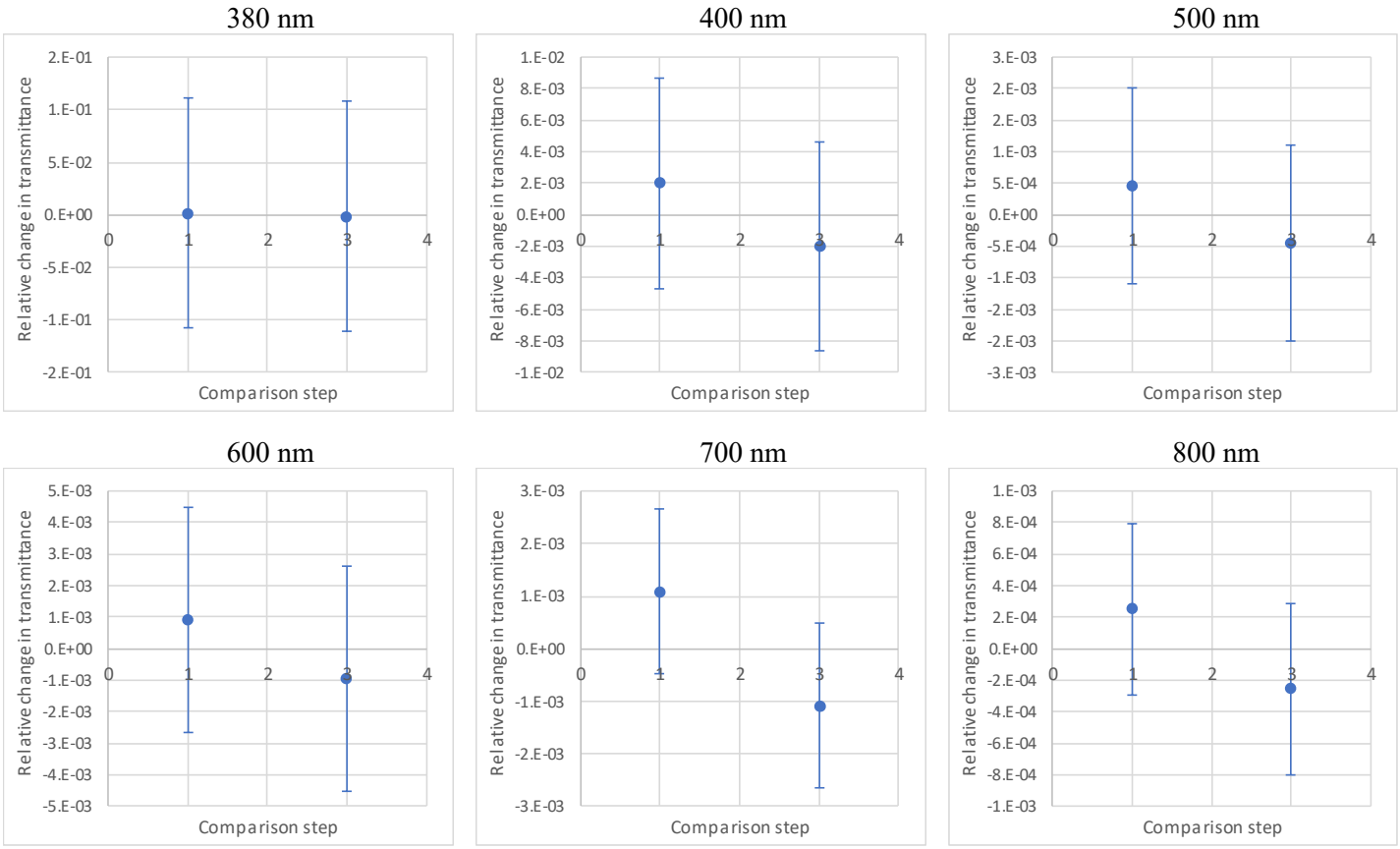


Figure C1e. Relative Data for CENAM, Filter E

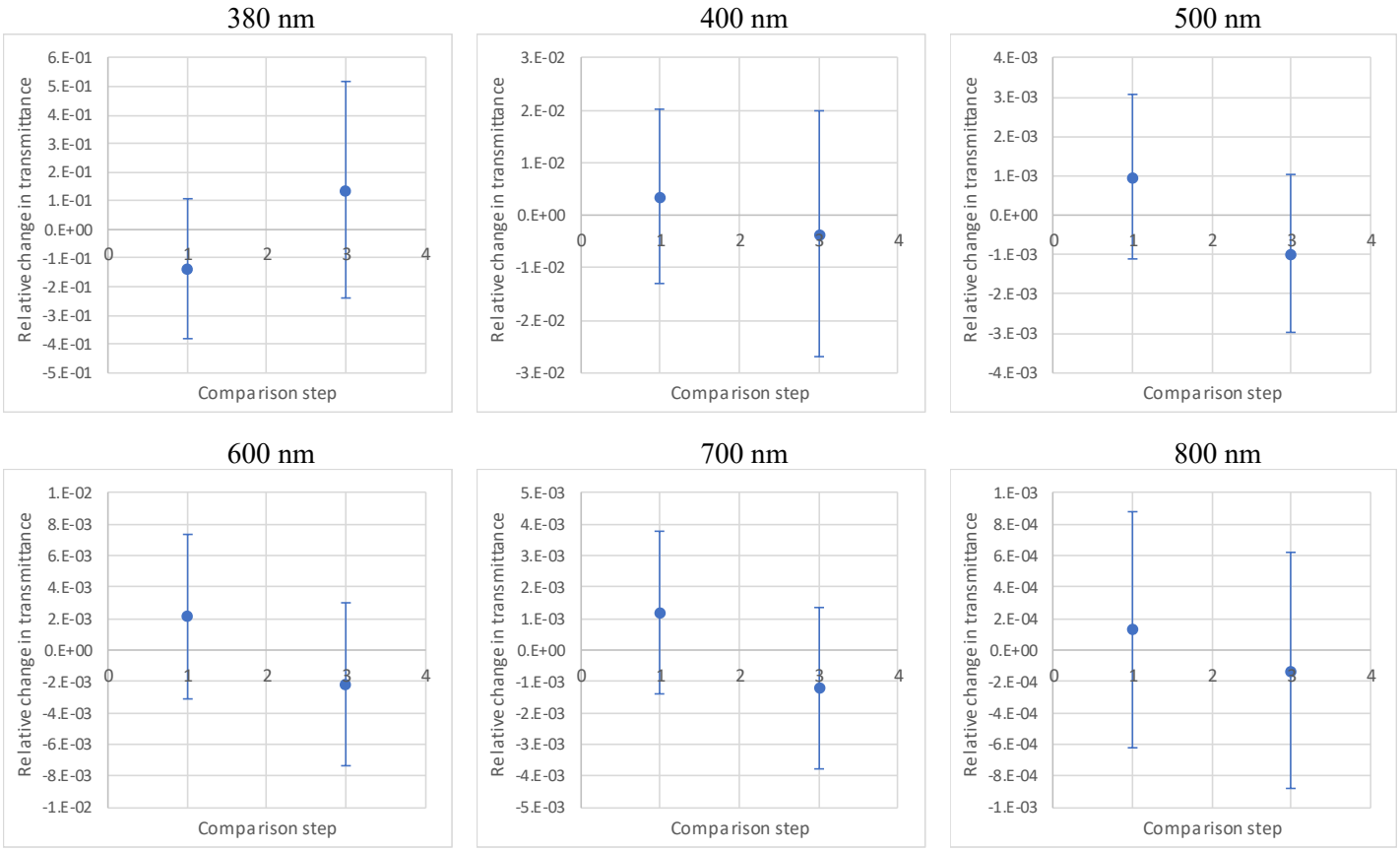


Figure C2a. Relative Data for INM, Filter A

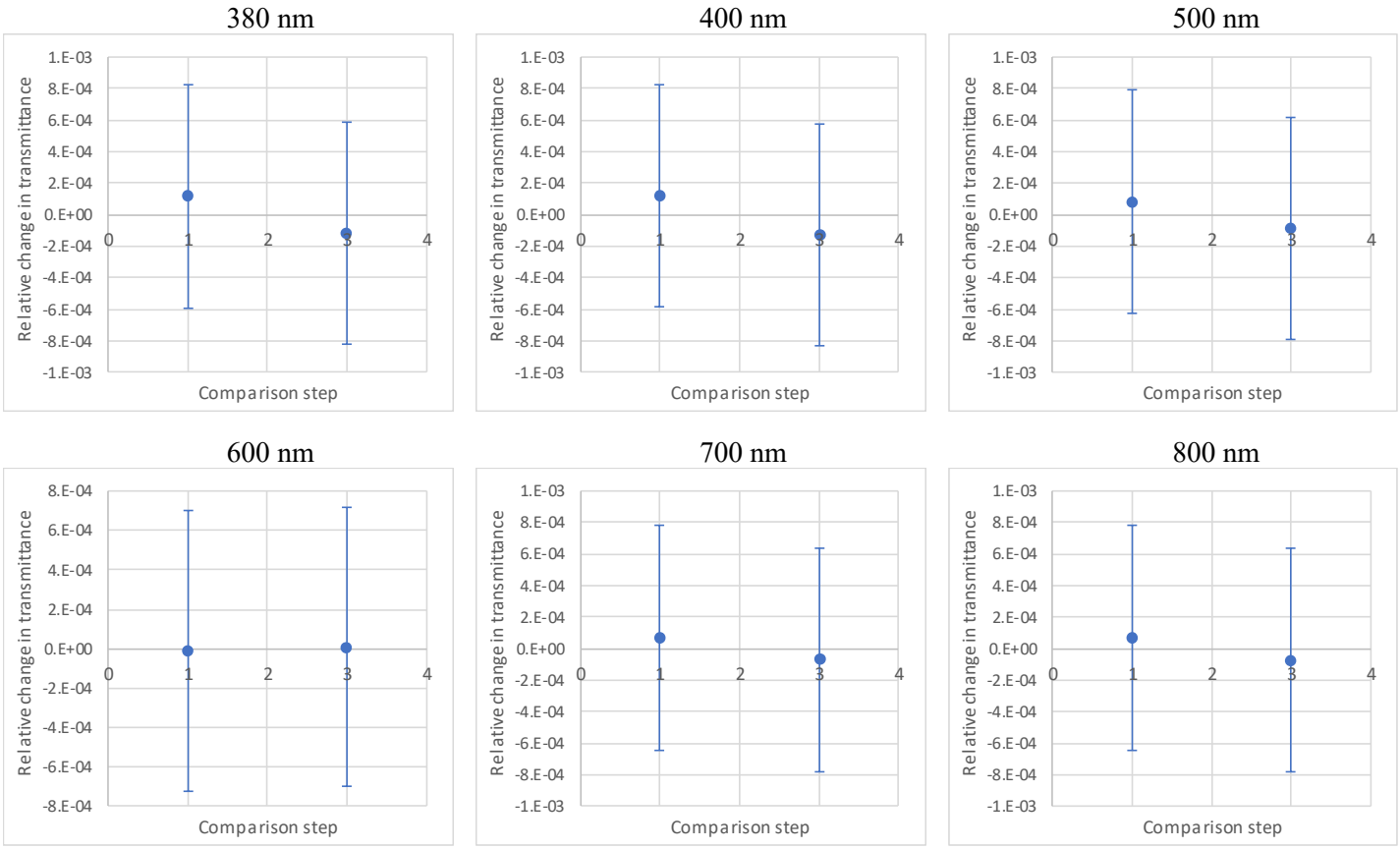


Figure C2b. Relative Data for INM, Filter B

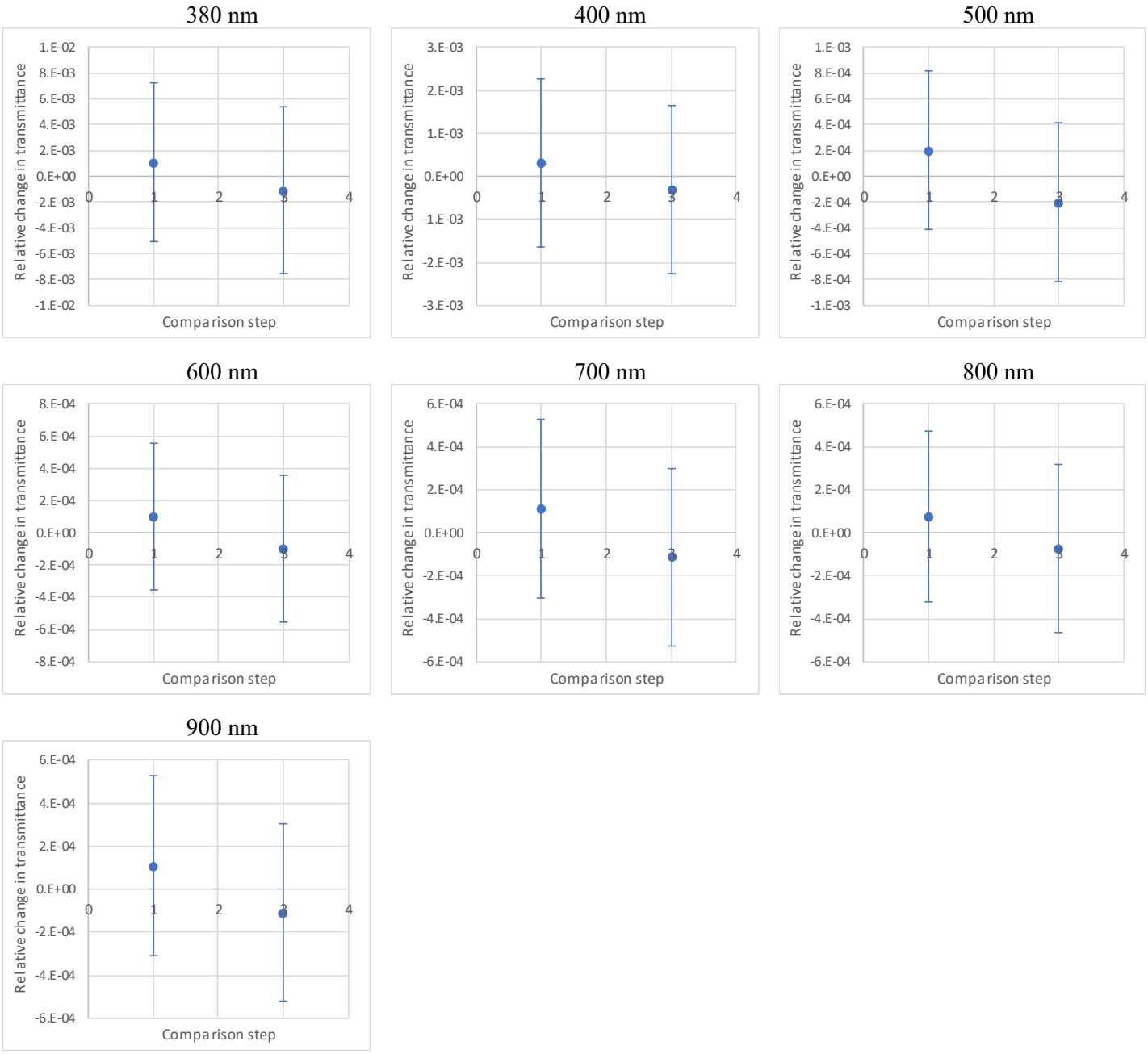


Figure C2c. Relative Data for INM, Filter C

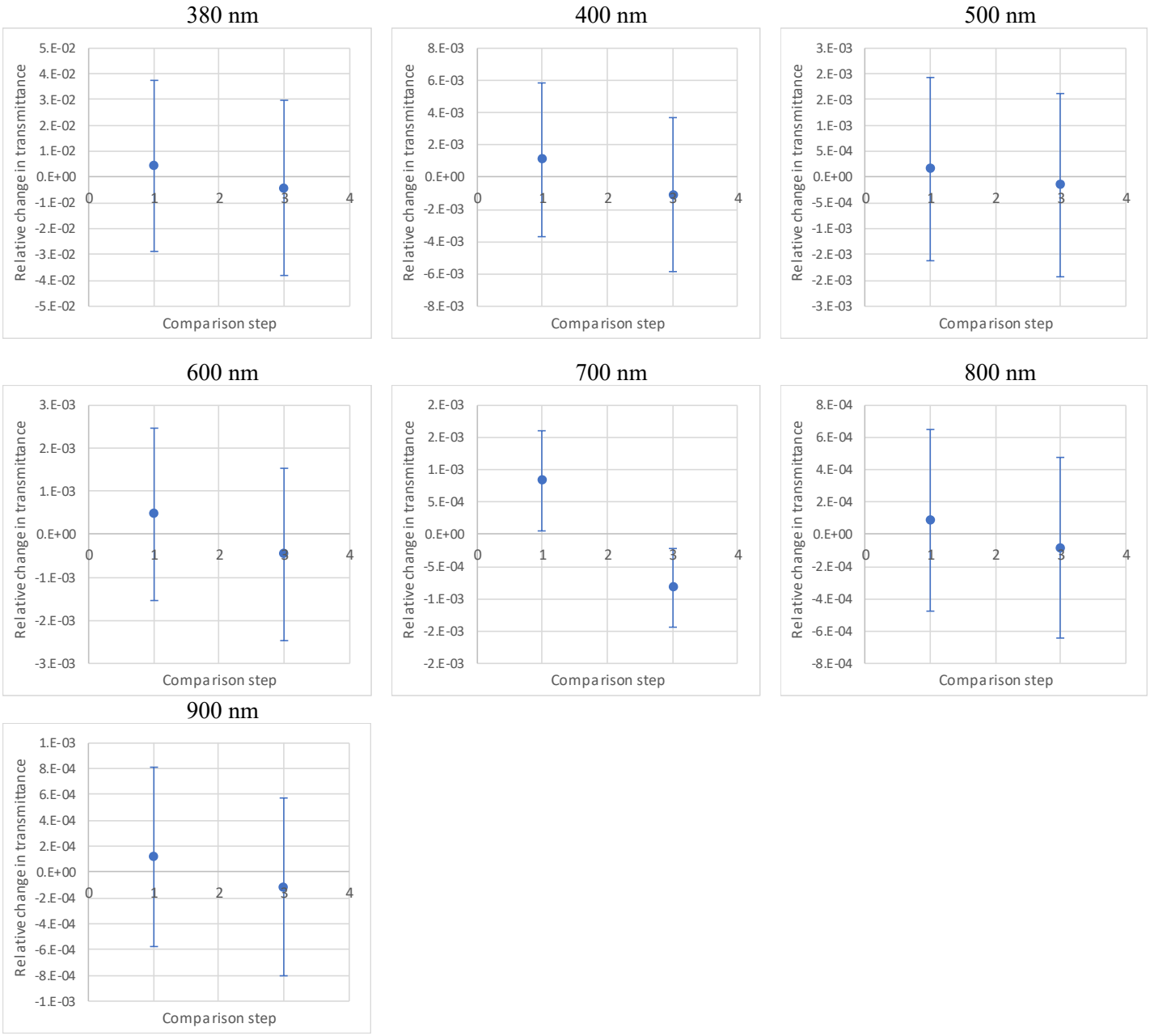


Figure C2d. Relative Data for INM, Filter D

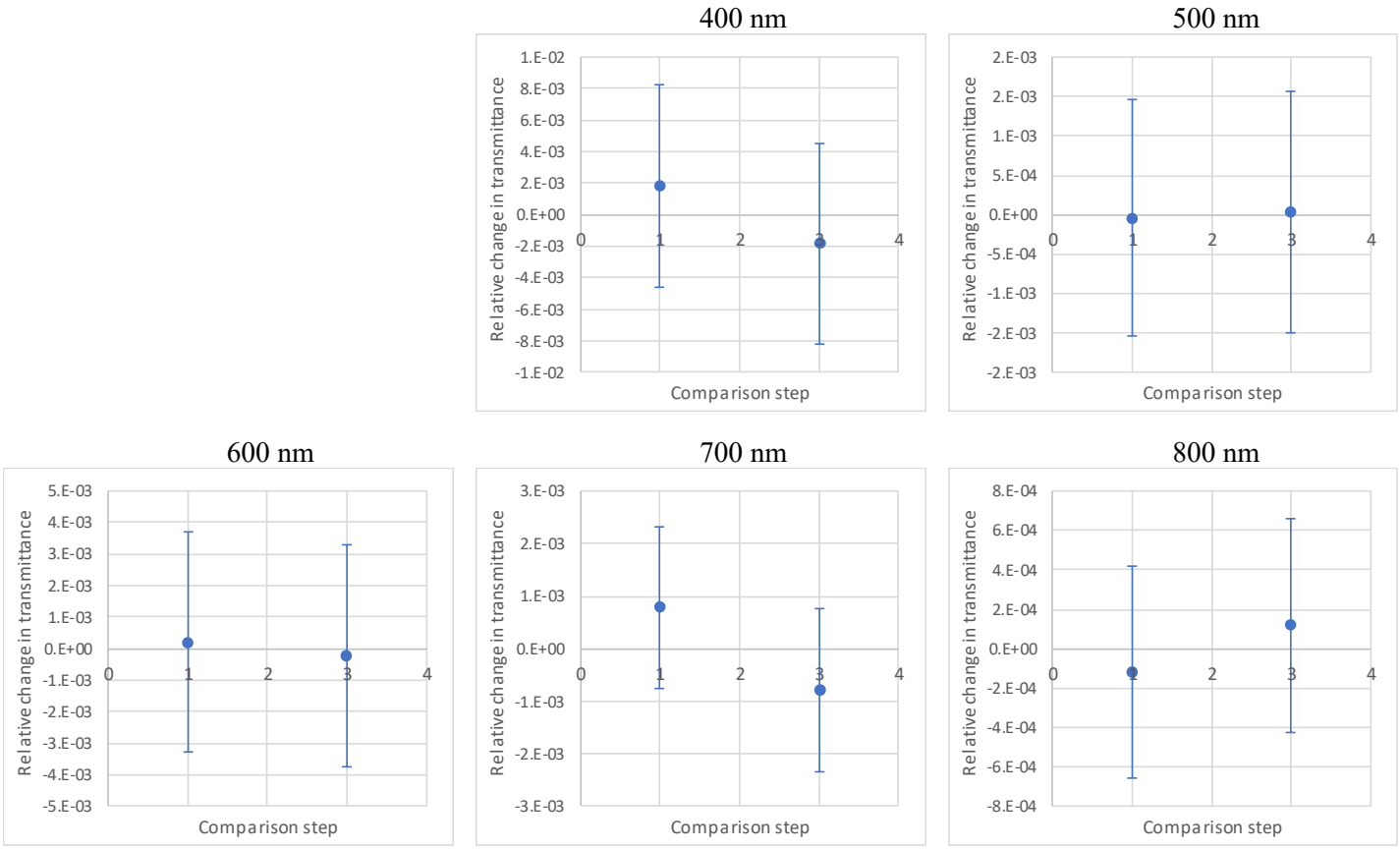


Figure C2e. Relative Data for INM, Filter E

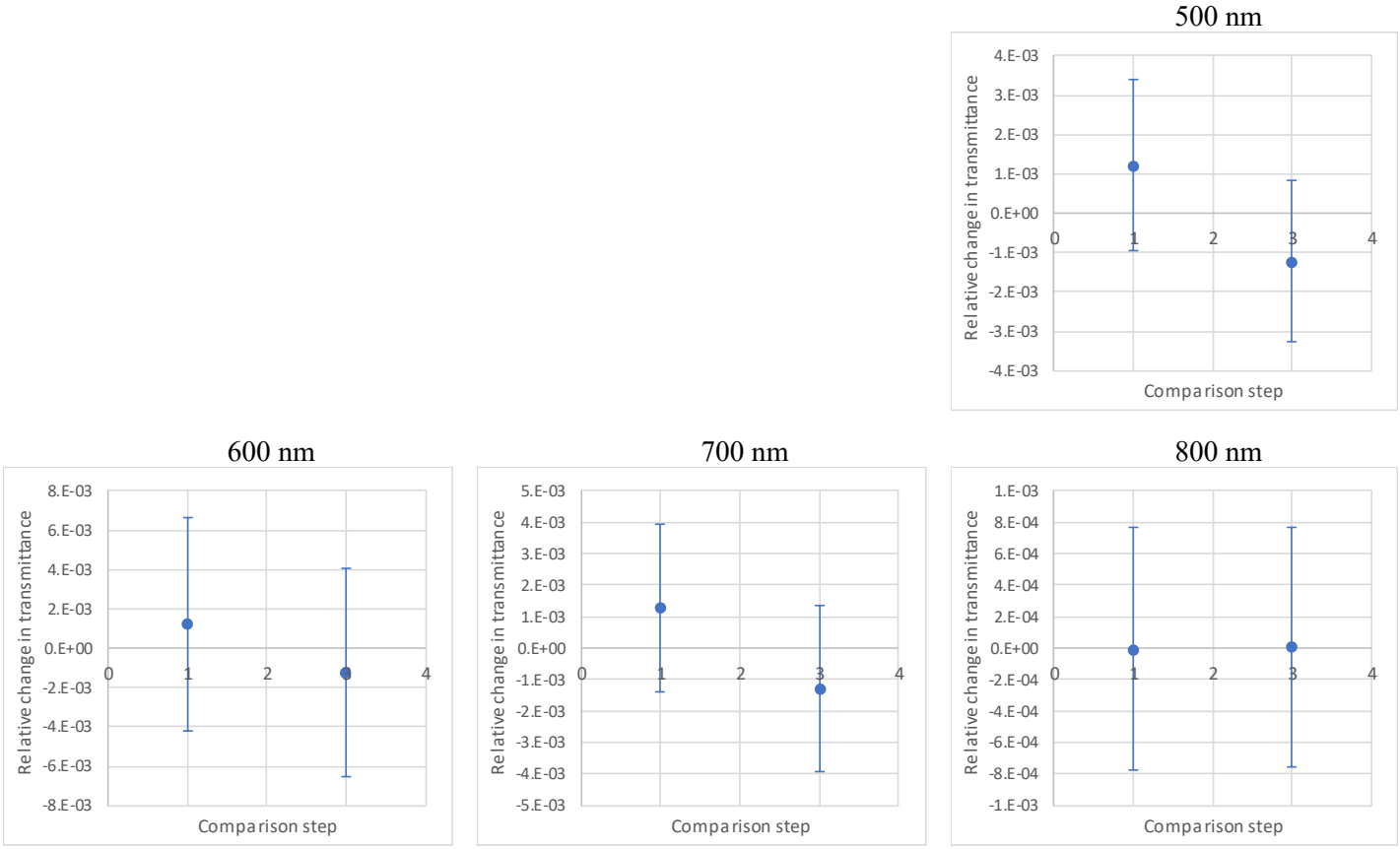


Figure C3a. Relative Data for INMETRO, Filter A

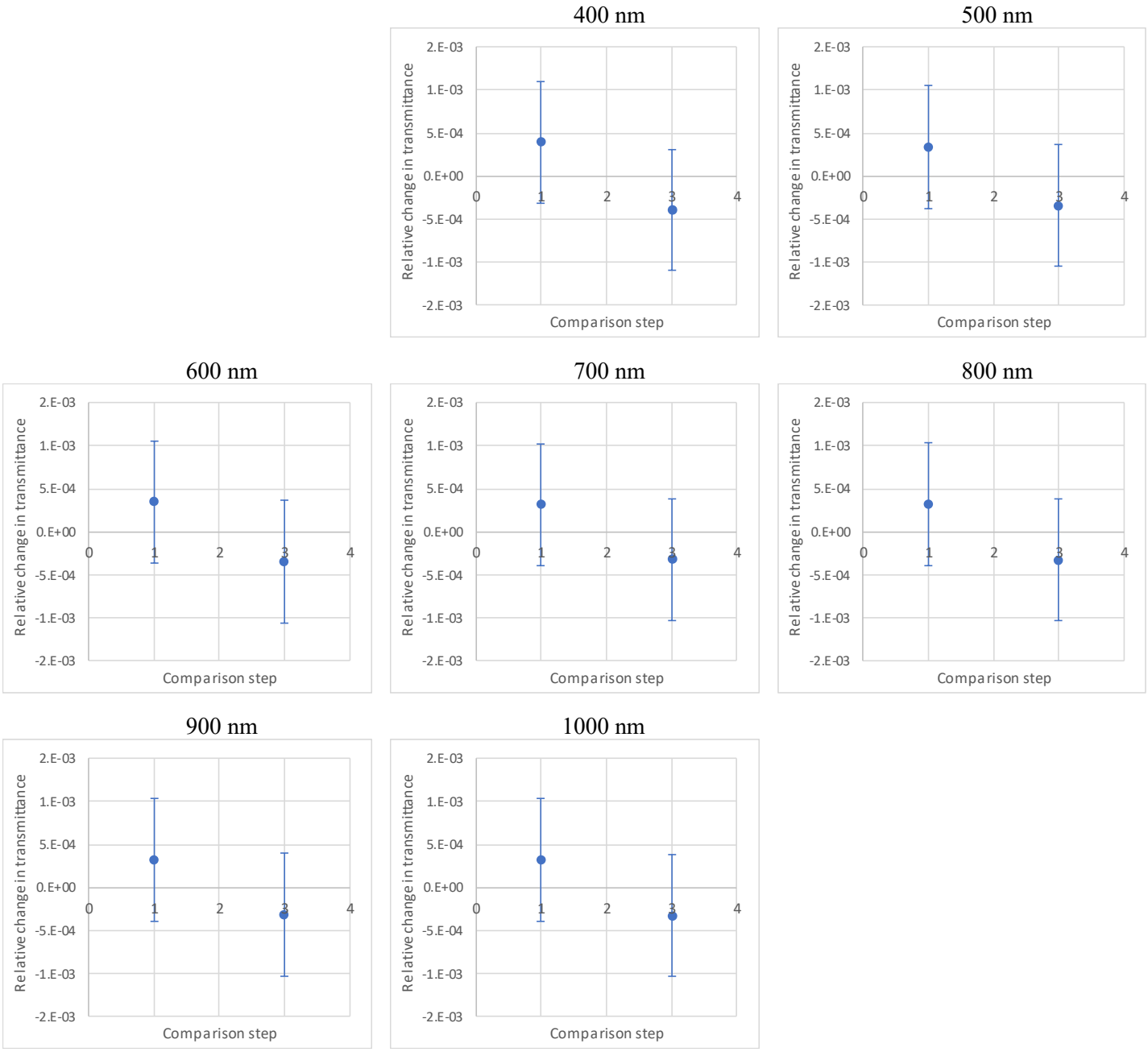


Figure C3b. Relative Data for INMETRO, Filter B

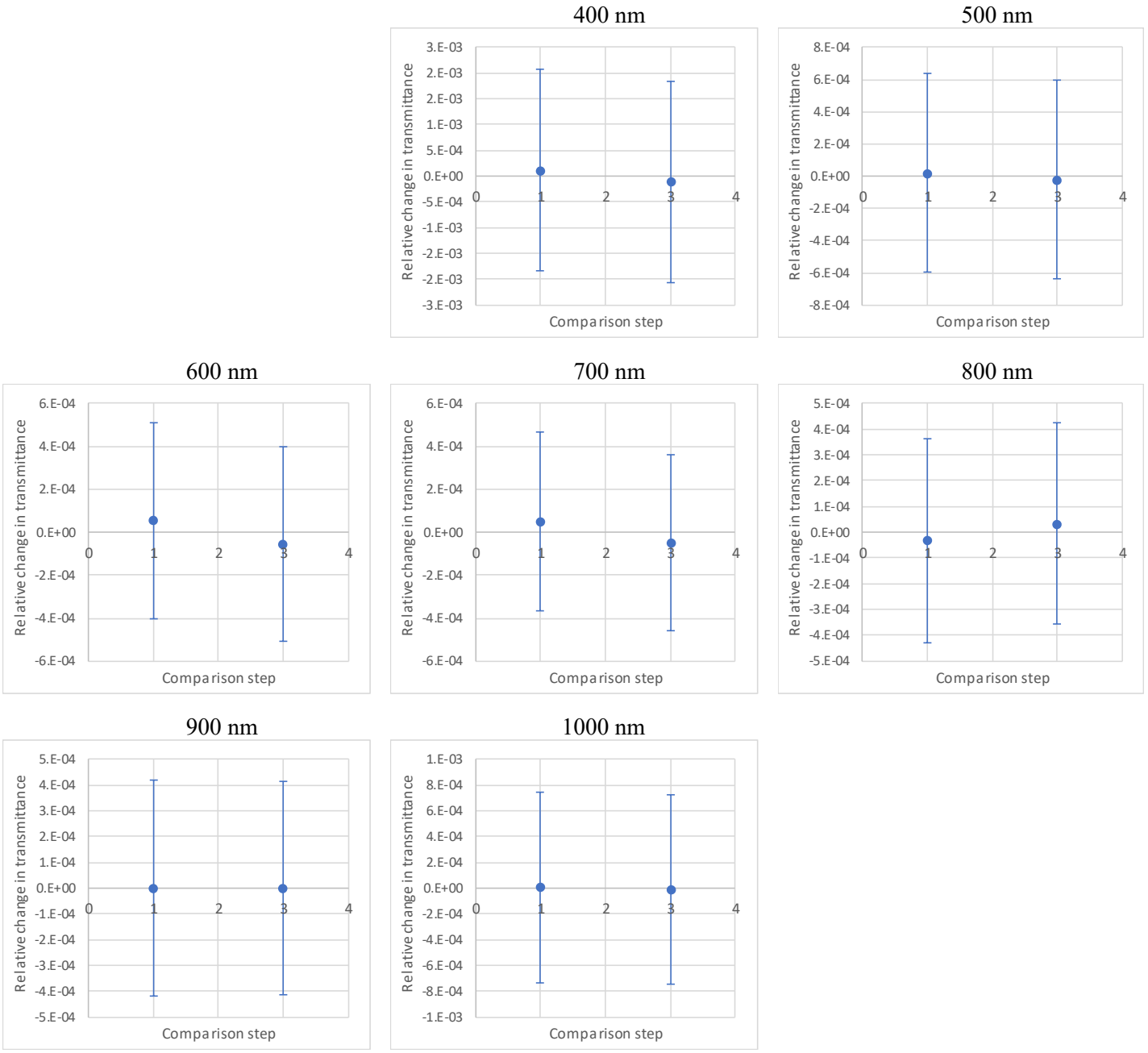


Figure C3c. Relative Data for INMETRO, Filter C

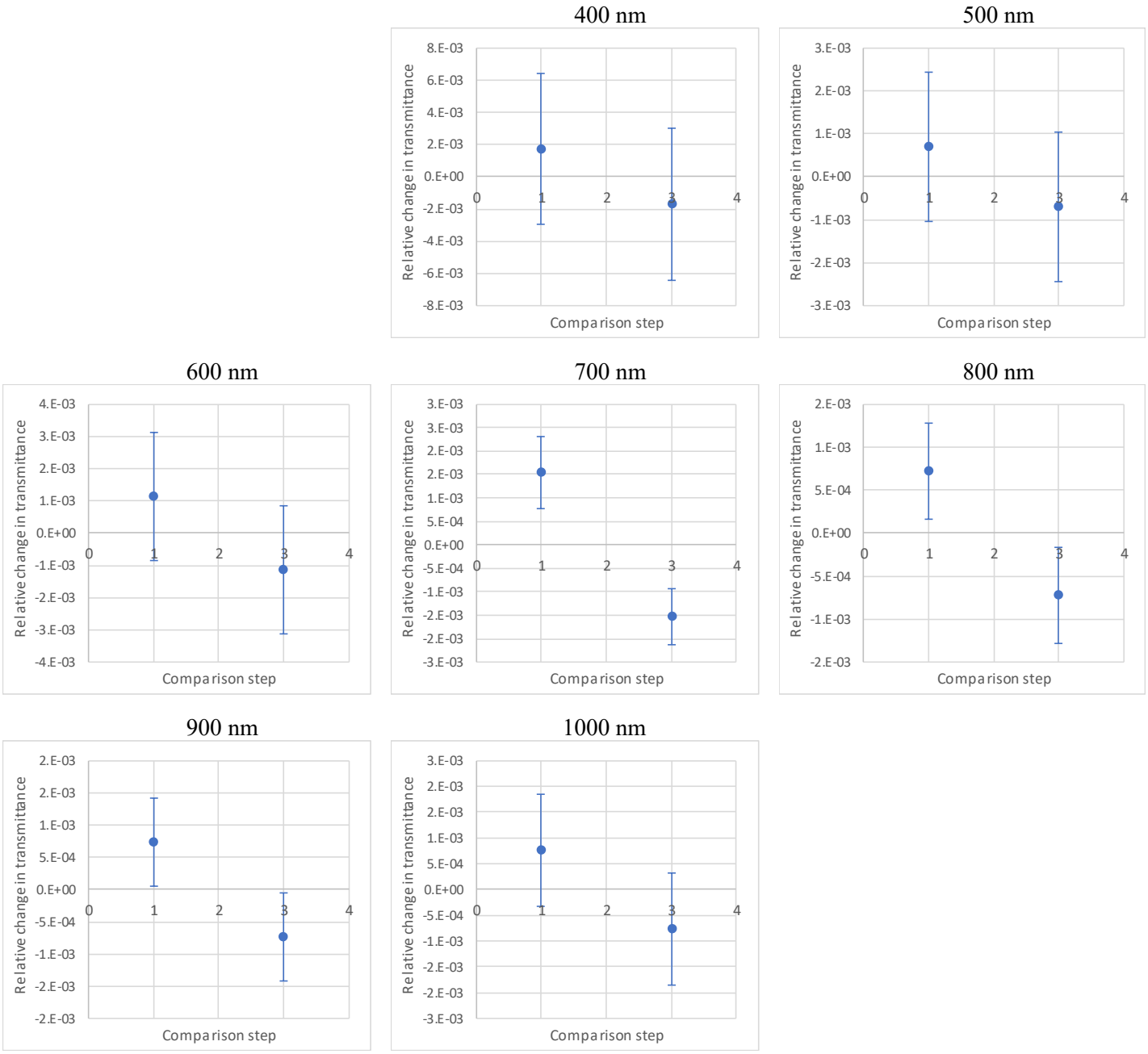


Figure C3d. Relative Data for INMETRO, Filter D

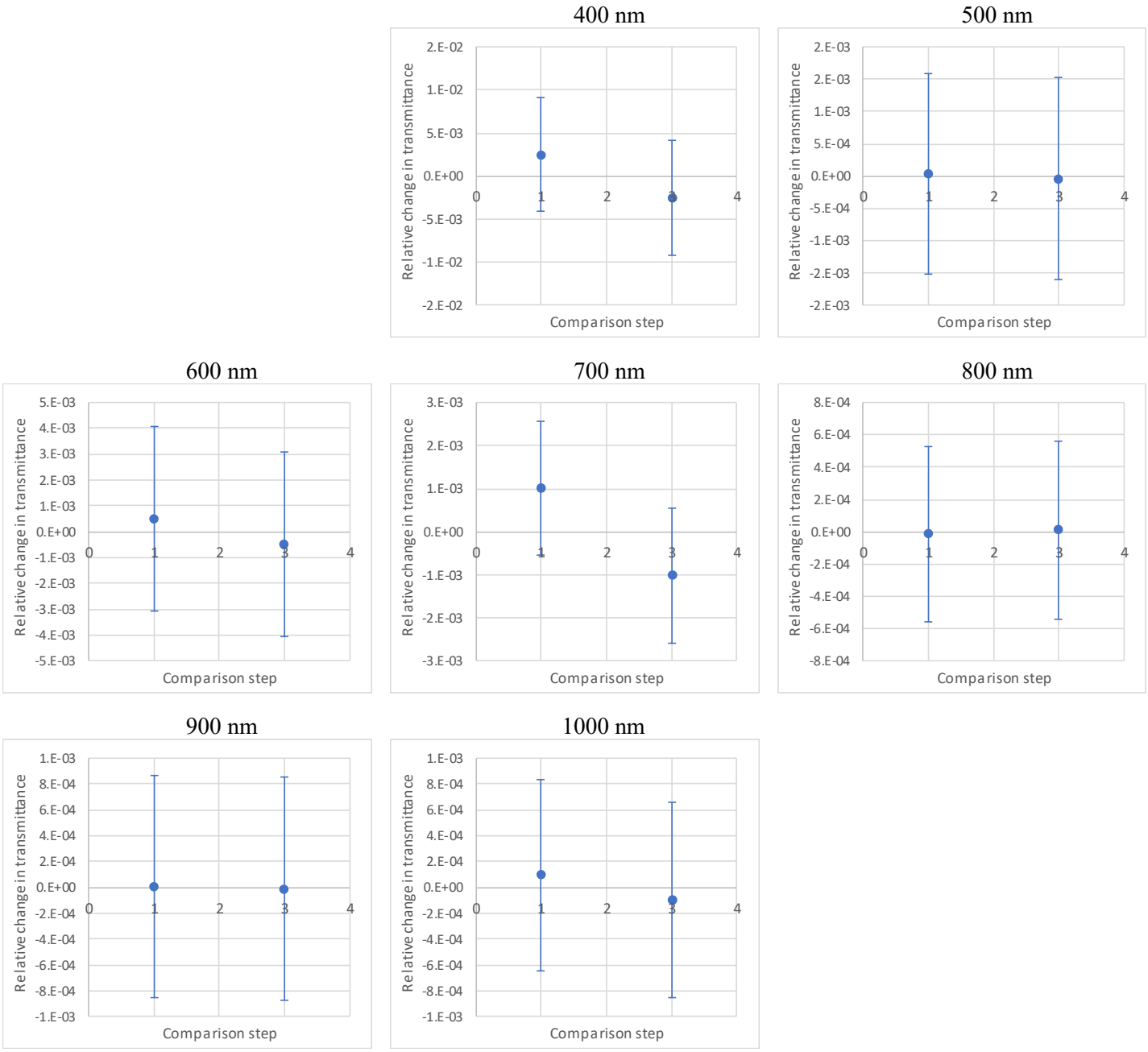


Figure C3e. Relative Data for INMETRO, Filter E

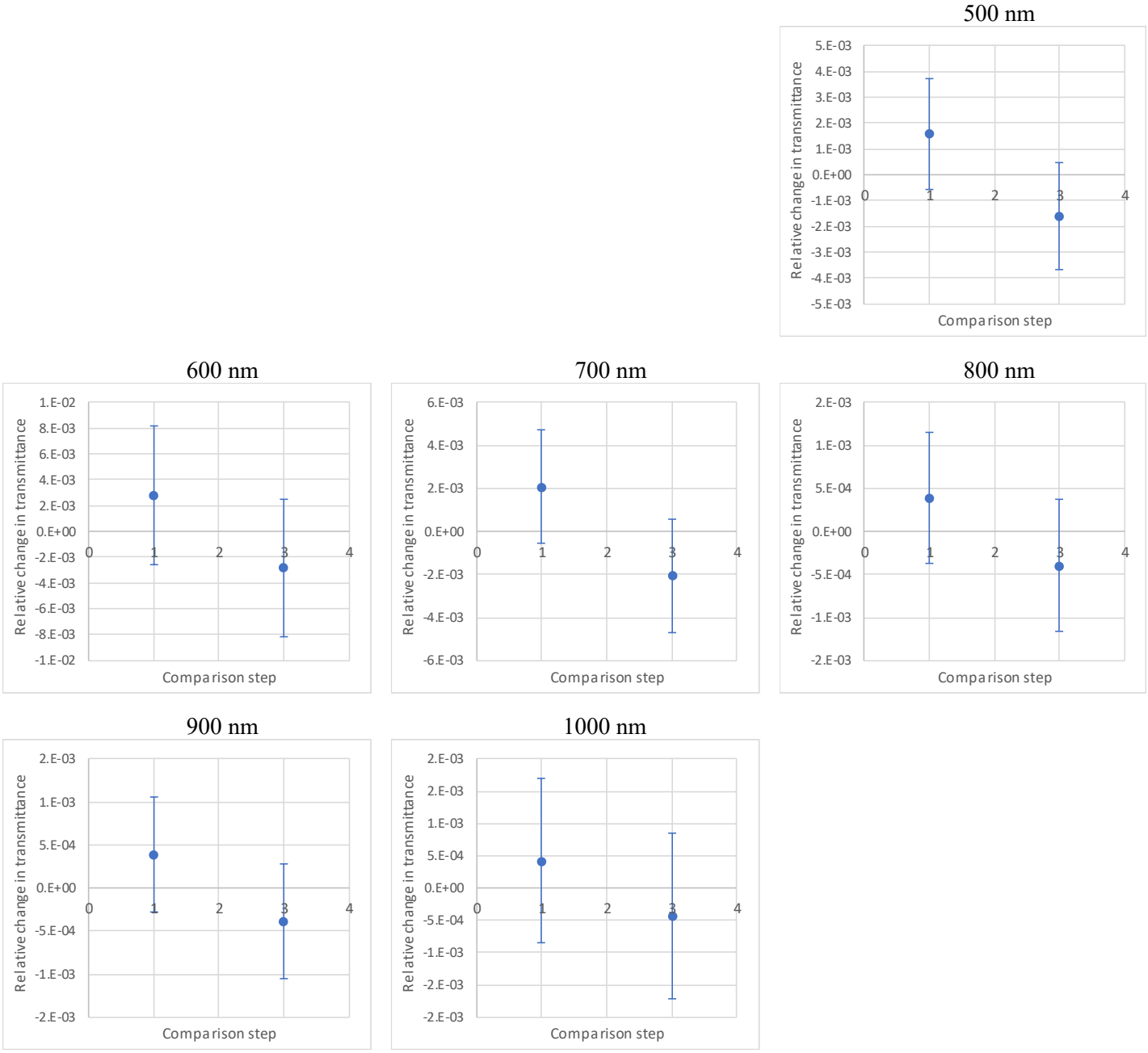


Figure C4a. Relative Data for CMS/ITRI, Filter A

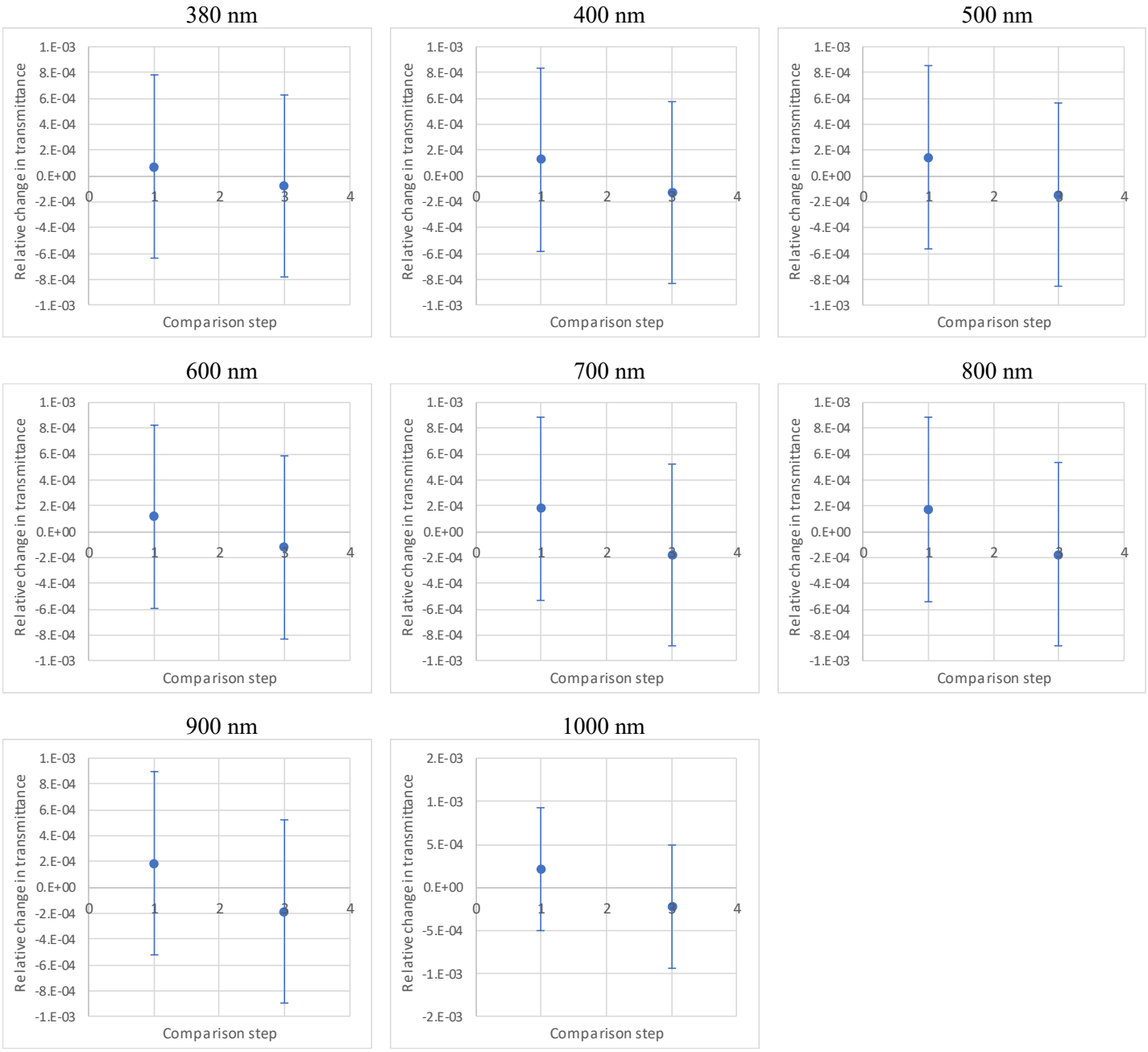


Figure C4b. Relative Data for CMS/ITRI, Filter B

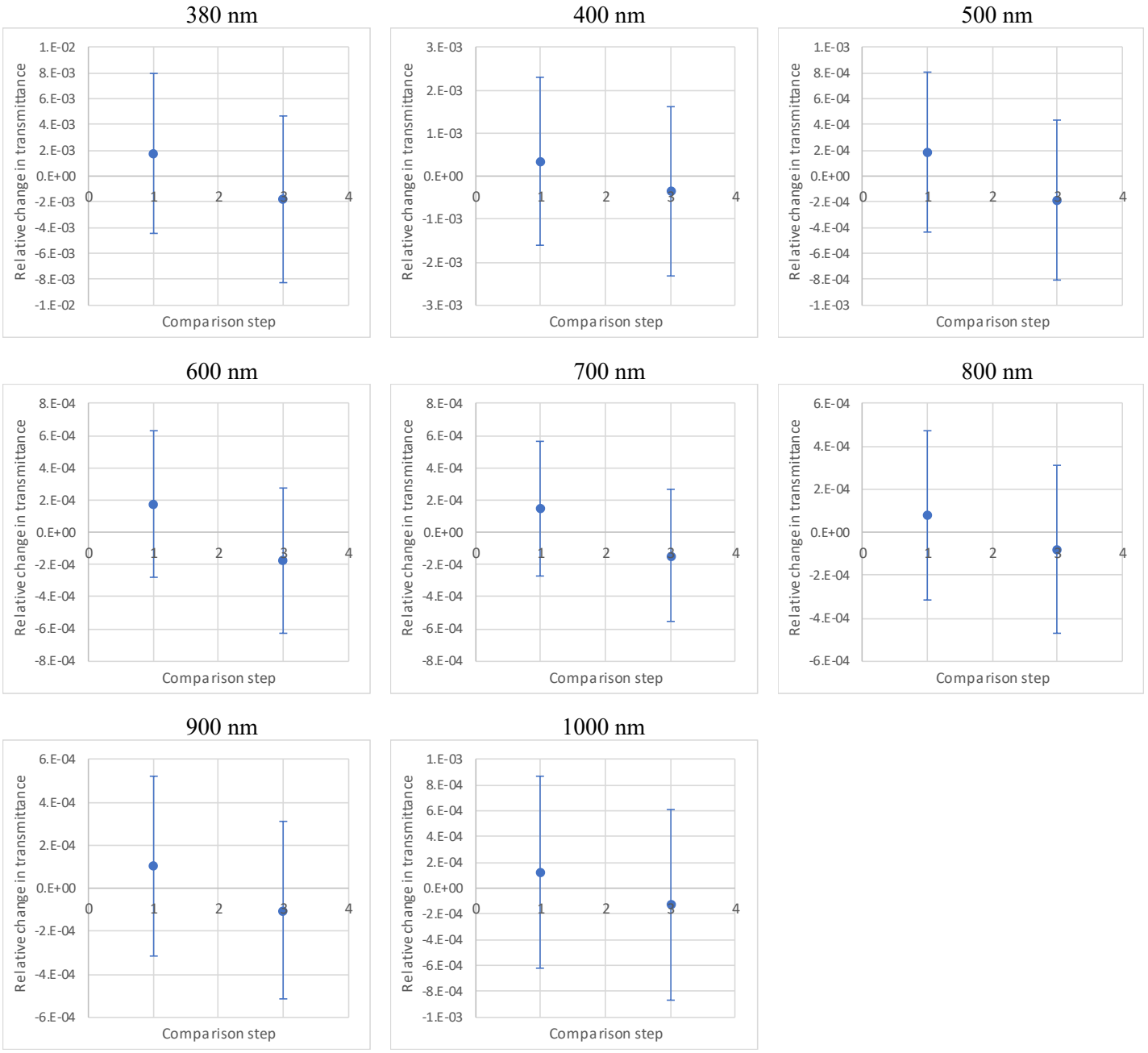


Figure C4c. Relative Data for CMS/ITRI, Filter C

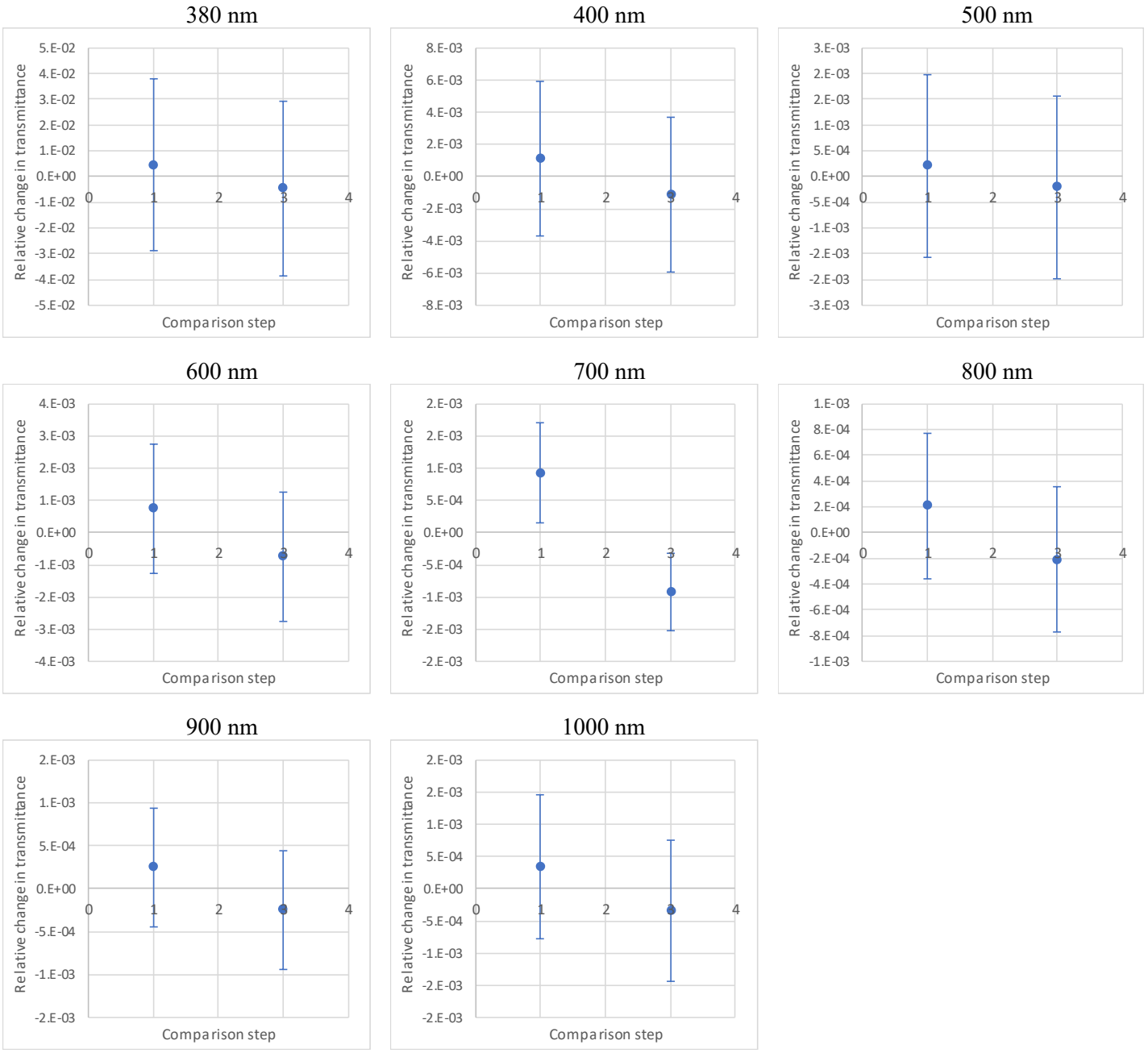


Figure C4d. Relative Data for CMS/ITRI, Filter D

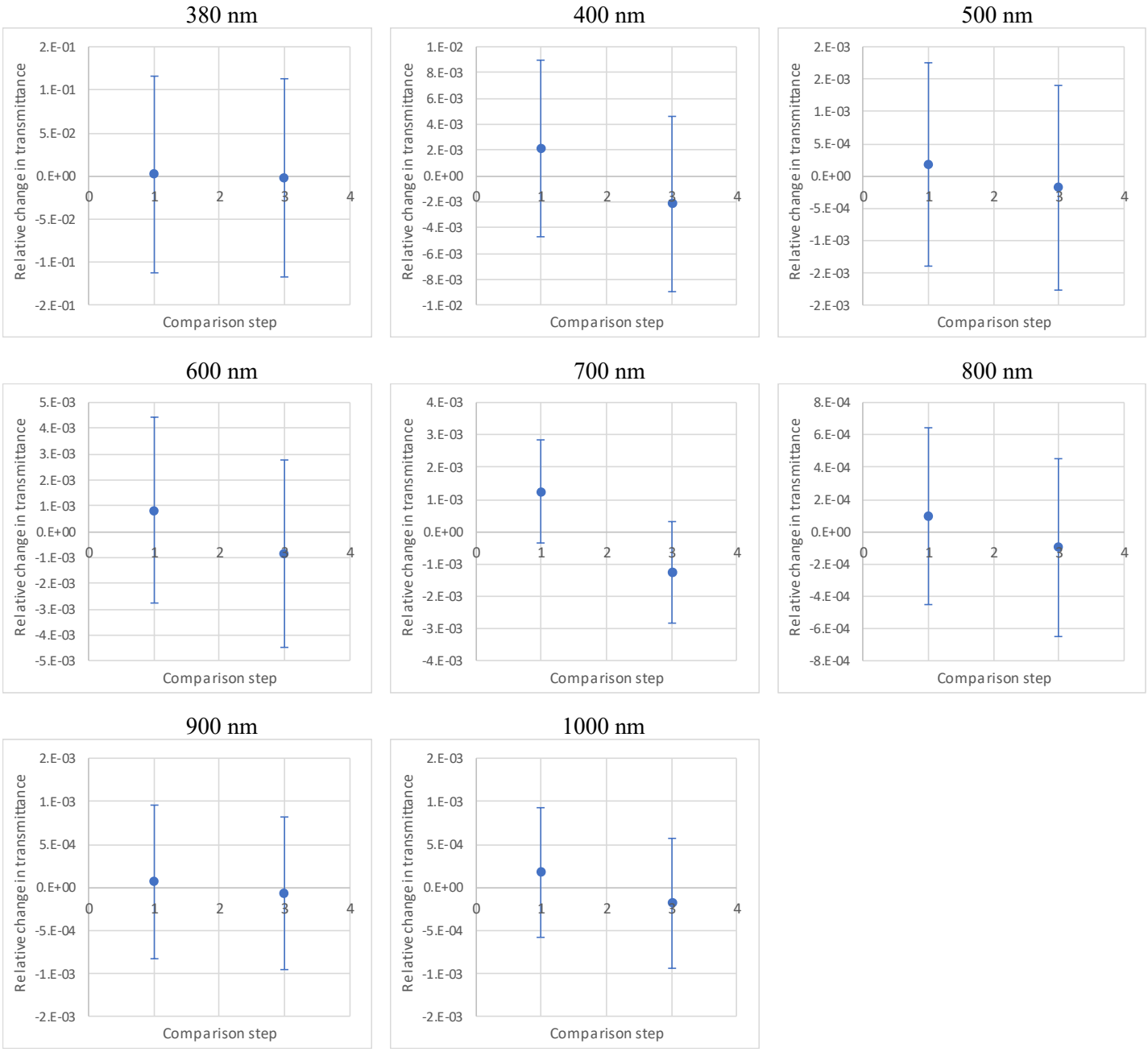


Figure C4e. Relative Data for CMS/ITRI, Filter E

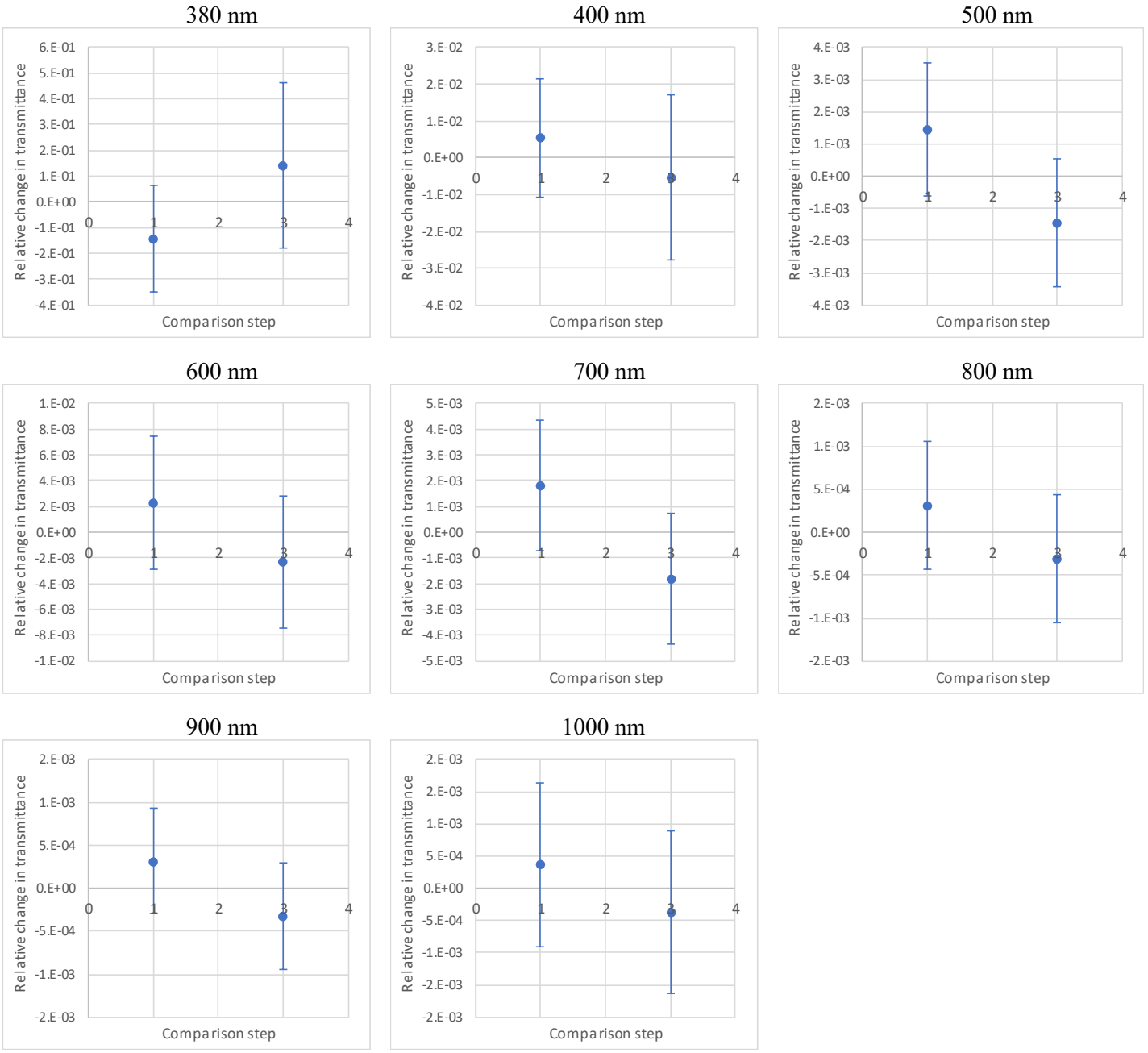


Figure C5a. Relative Data for NIM, Filter A

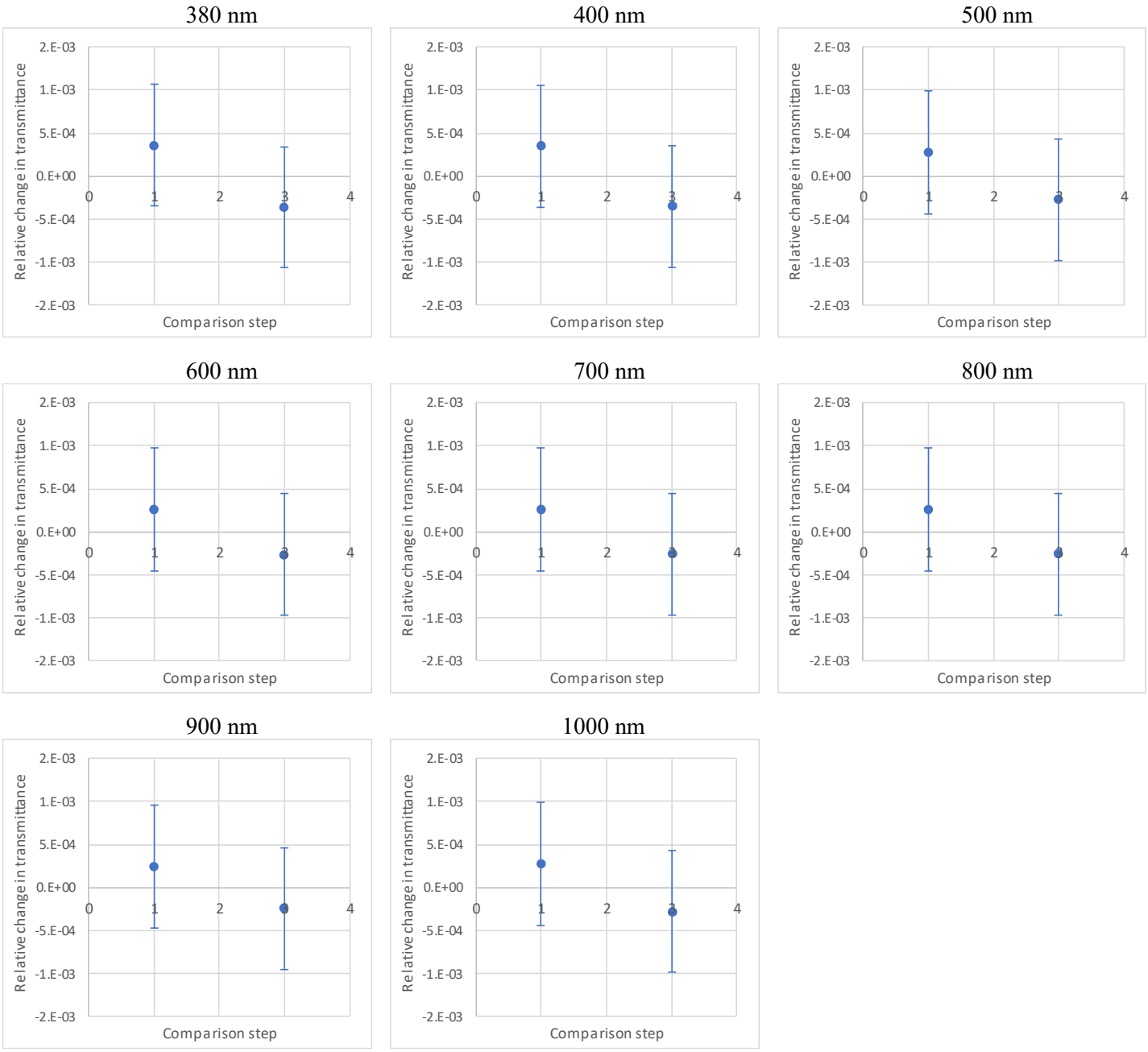


Figure C5b. Relative Data for NIM, Filter B

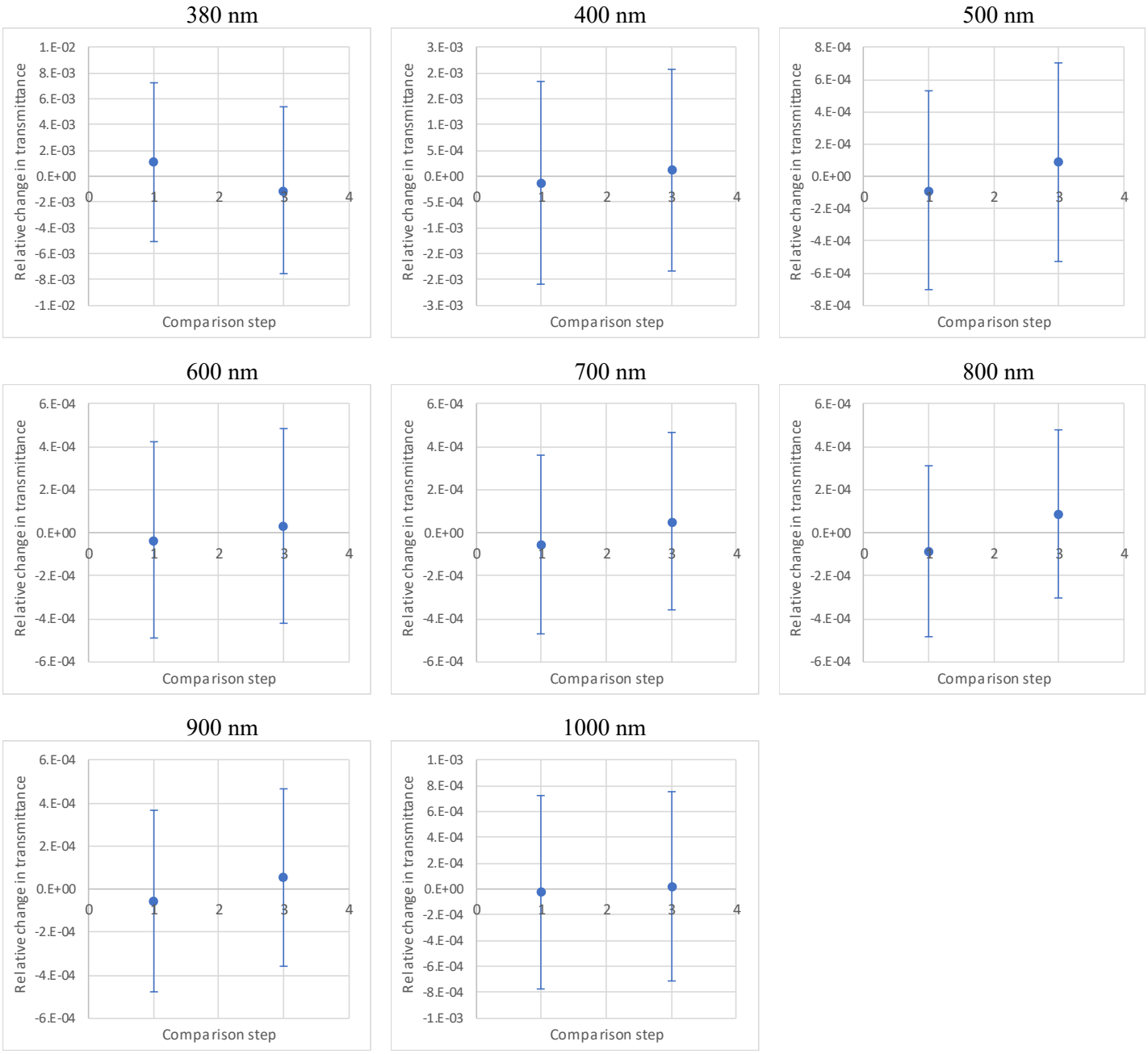


Figure C5c. Relative Data for NIM, Filter C

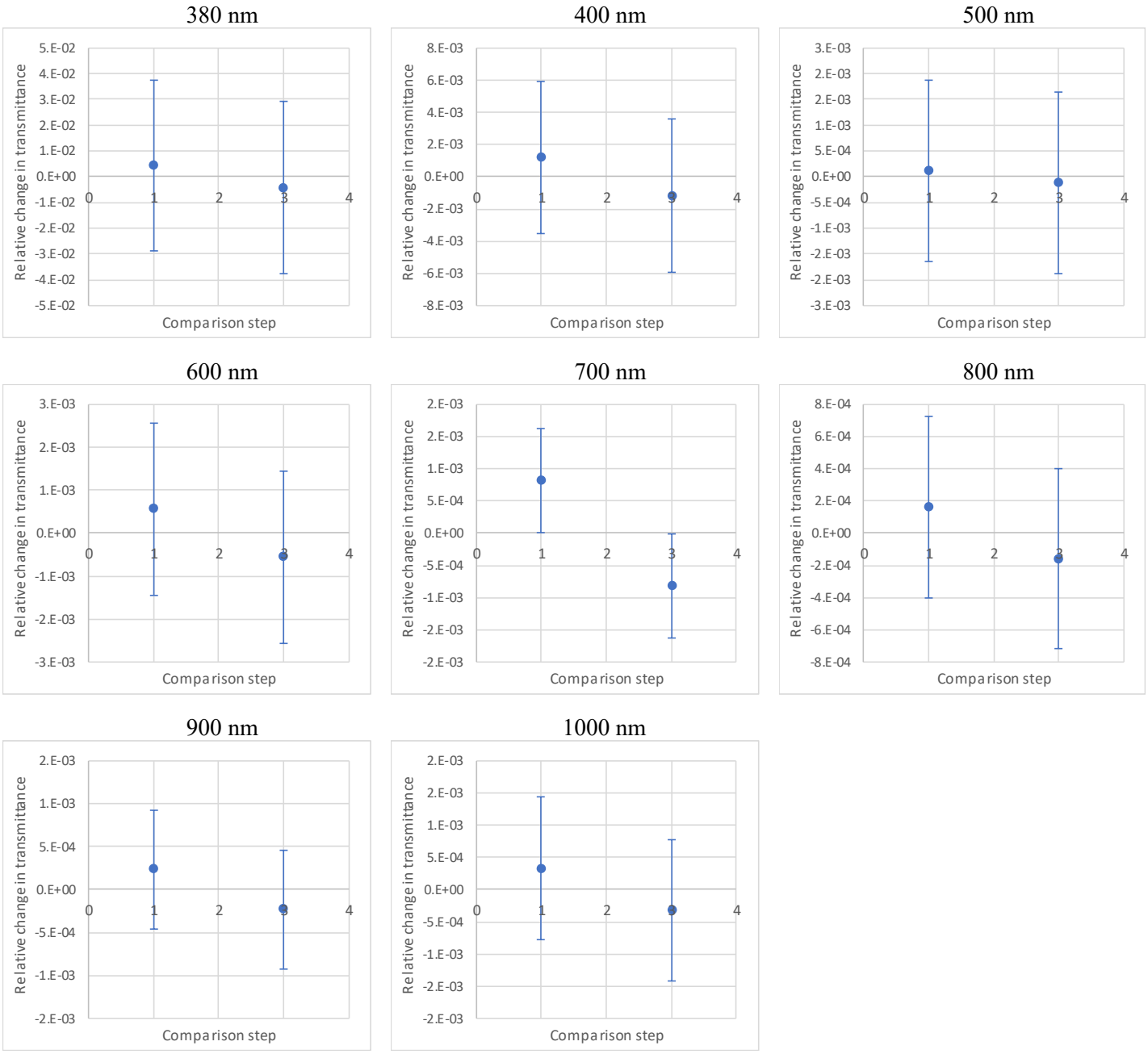


Figure C5d. Relative Data for NIM, Filter D

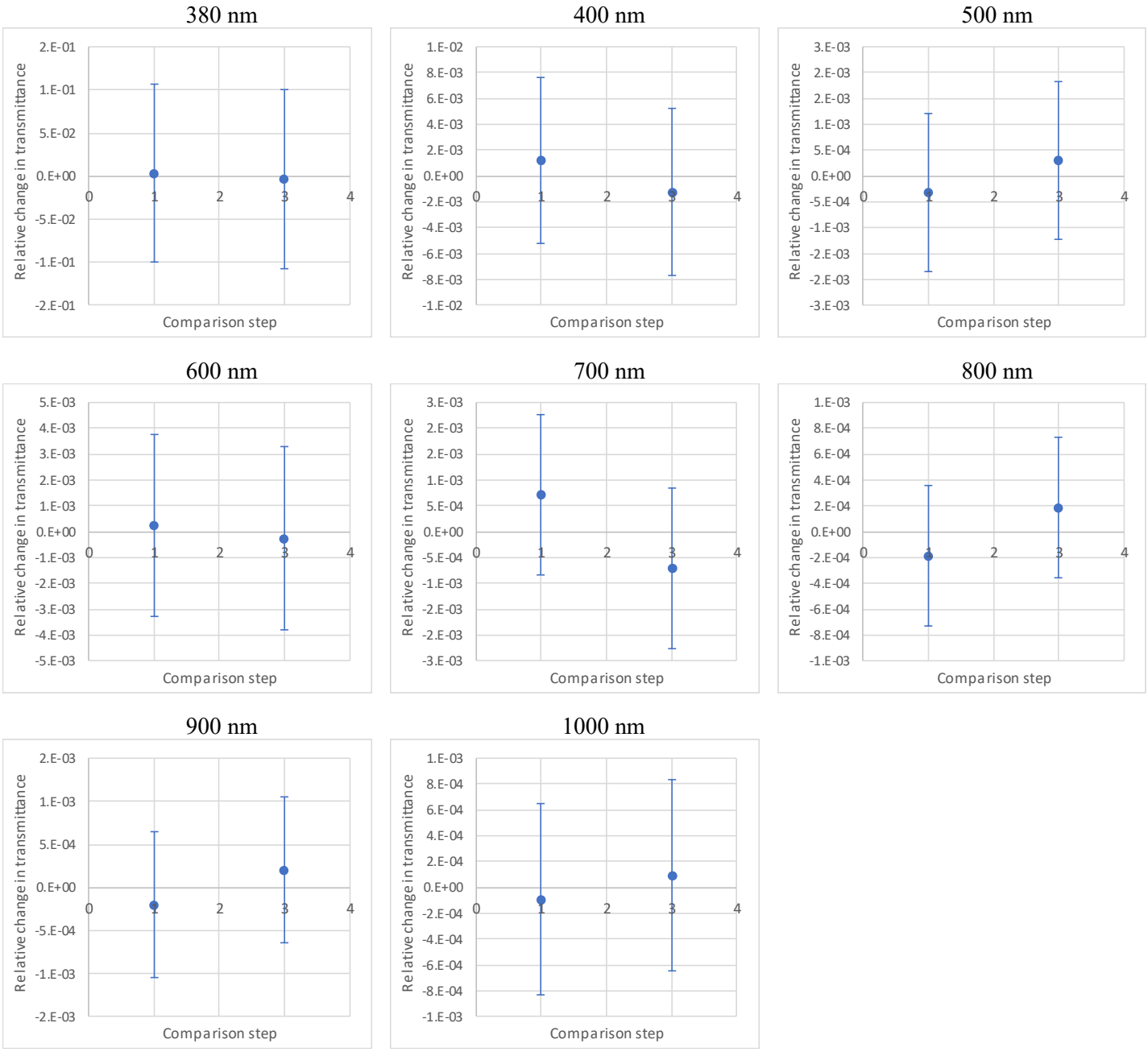


Figure C5e. Relative Data for NIM, Filter E

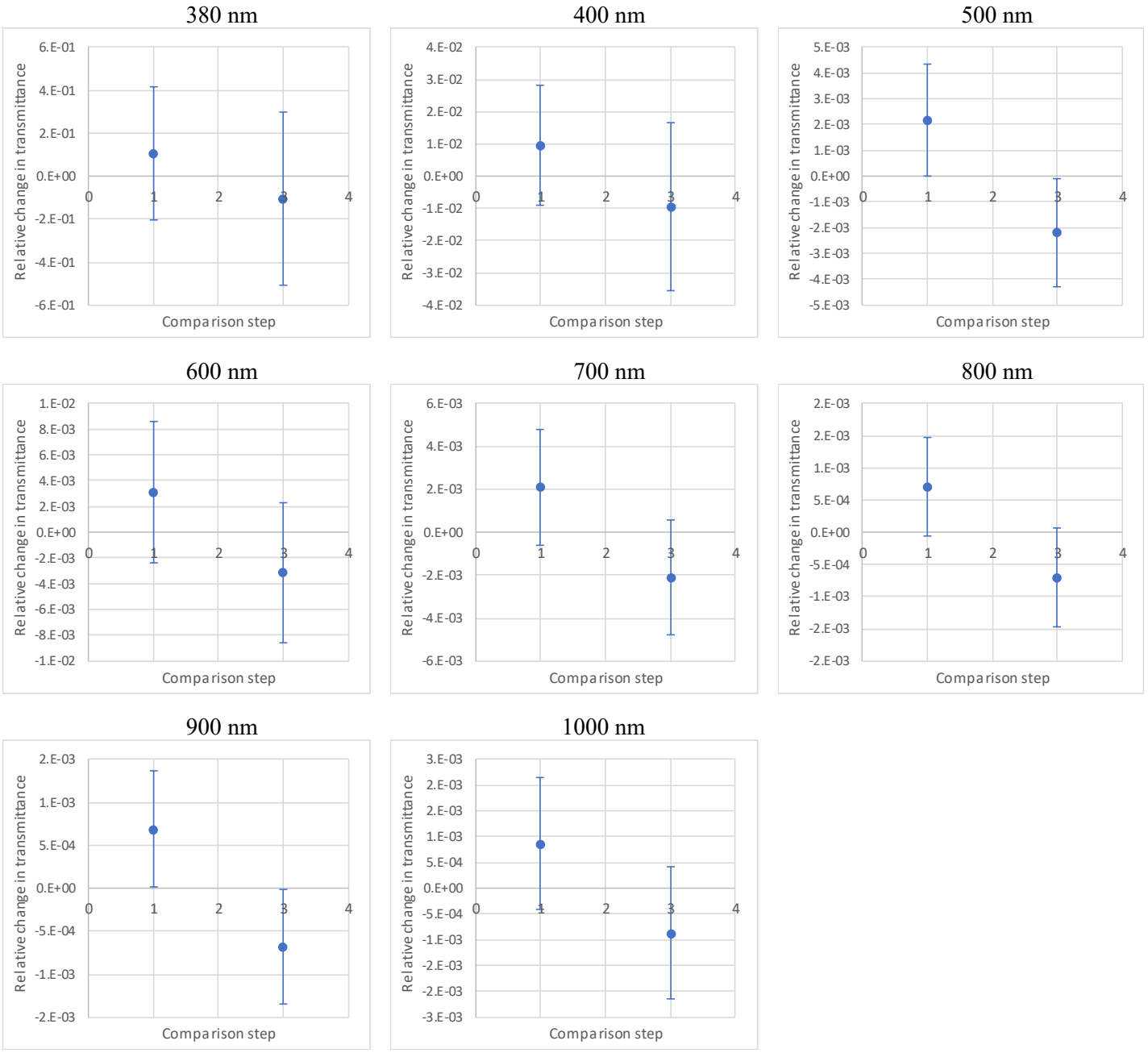


Figure C6a. Relative Data for NIMT, Filter A

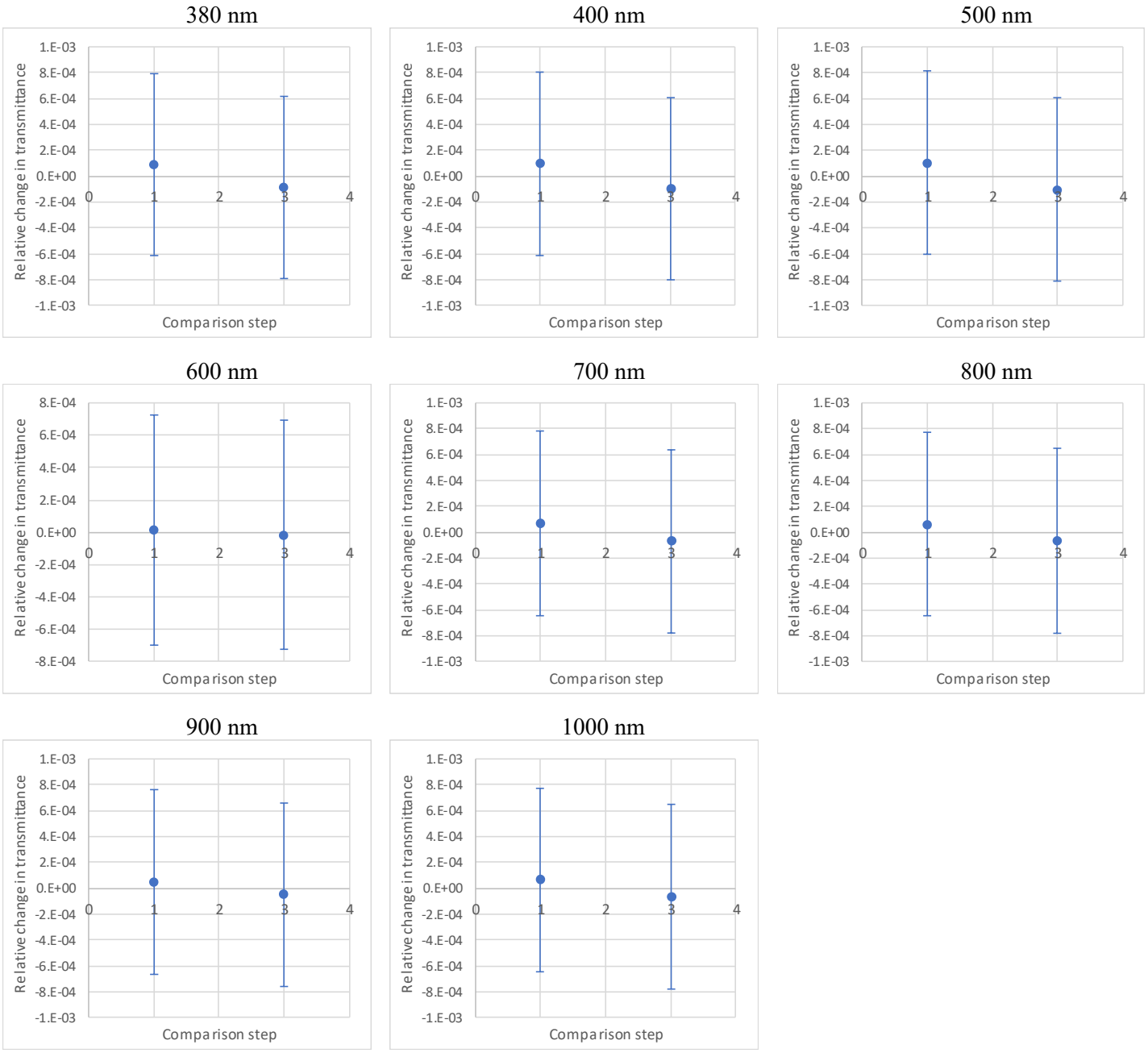


Figure C6b. Relative Data for NIMT, Filter B

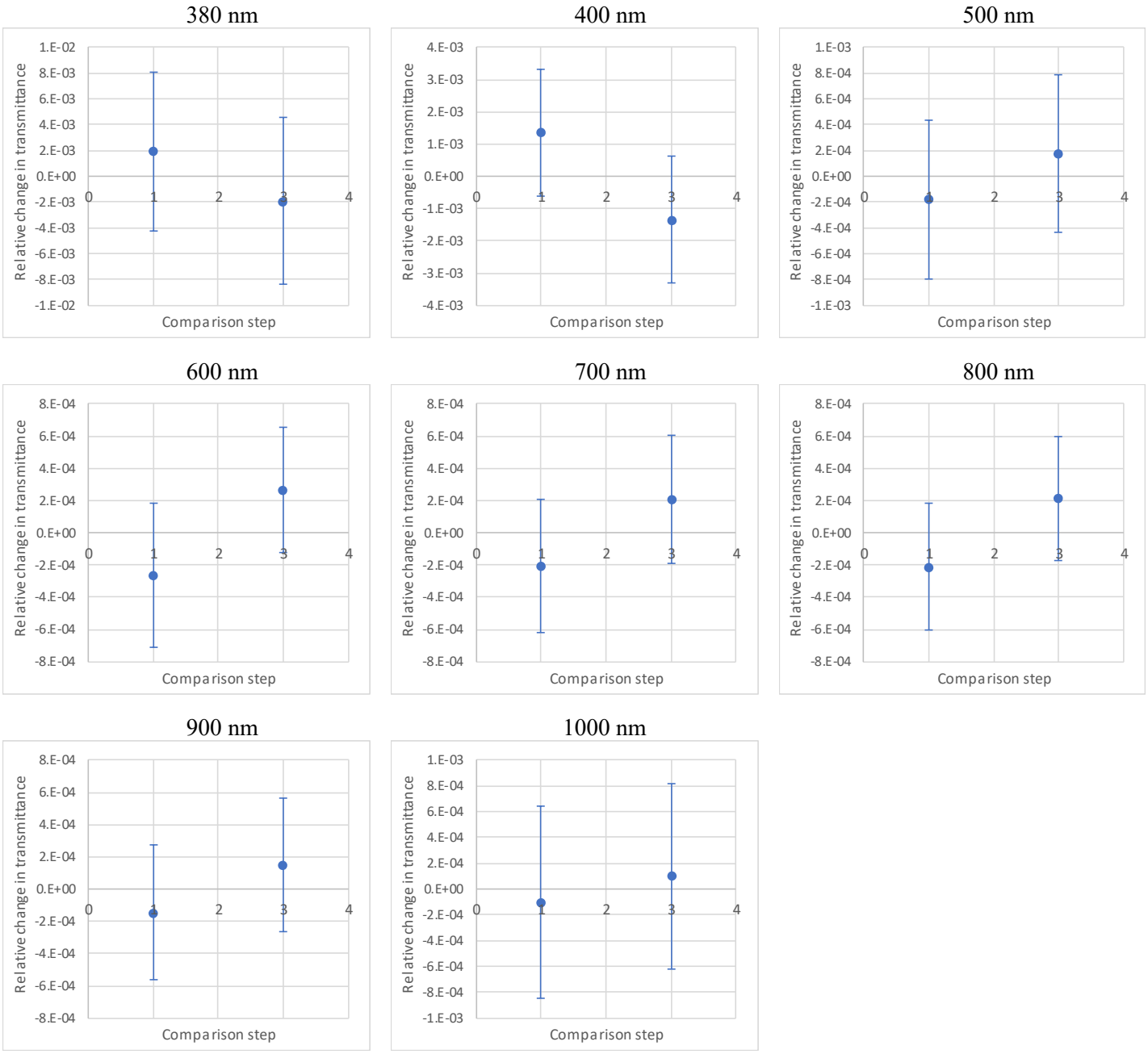


Figure C6c. Relative Data for NIMT, Filter C

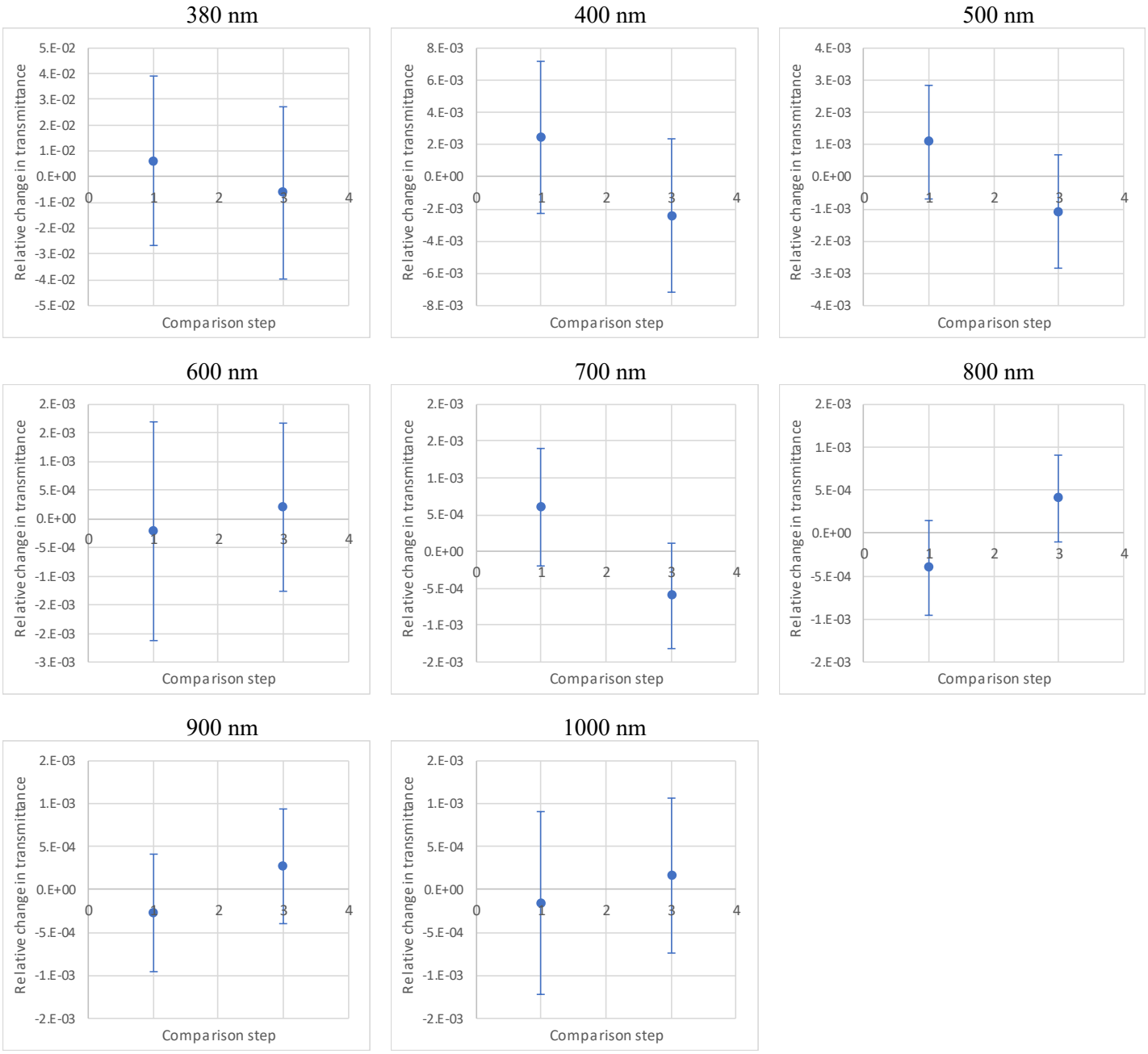


Figure C6d. Relative Data for NIMT, Filter D

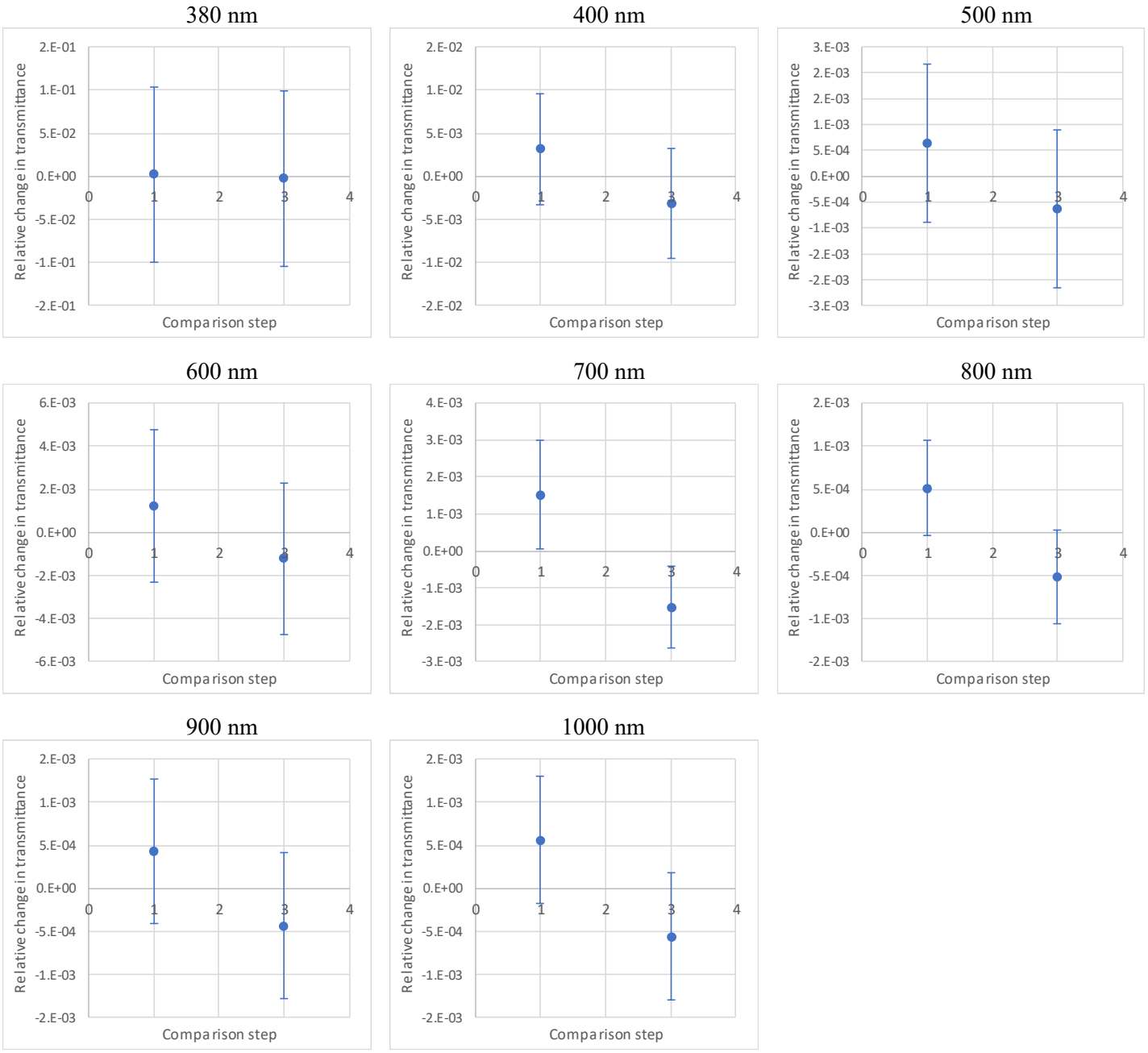


Figure C6e. Relative Data for NIMT, Filter E

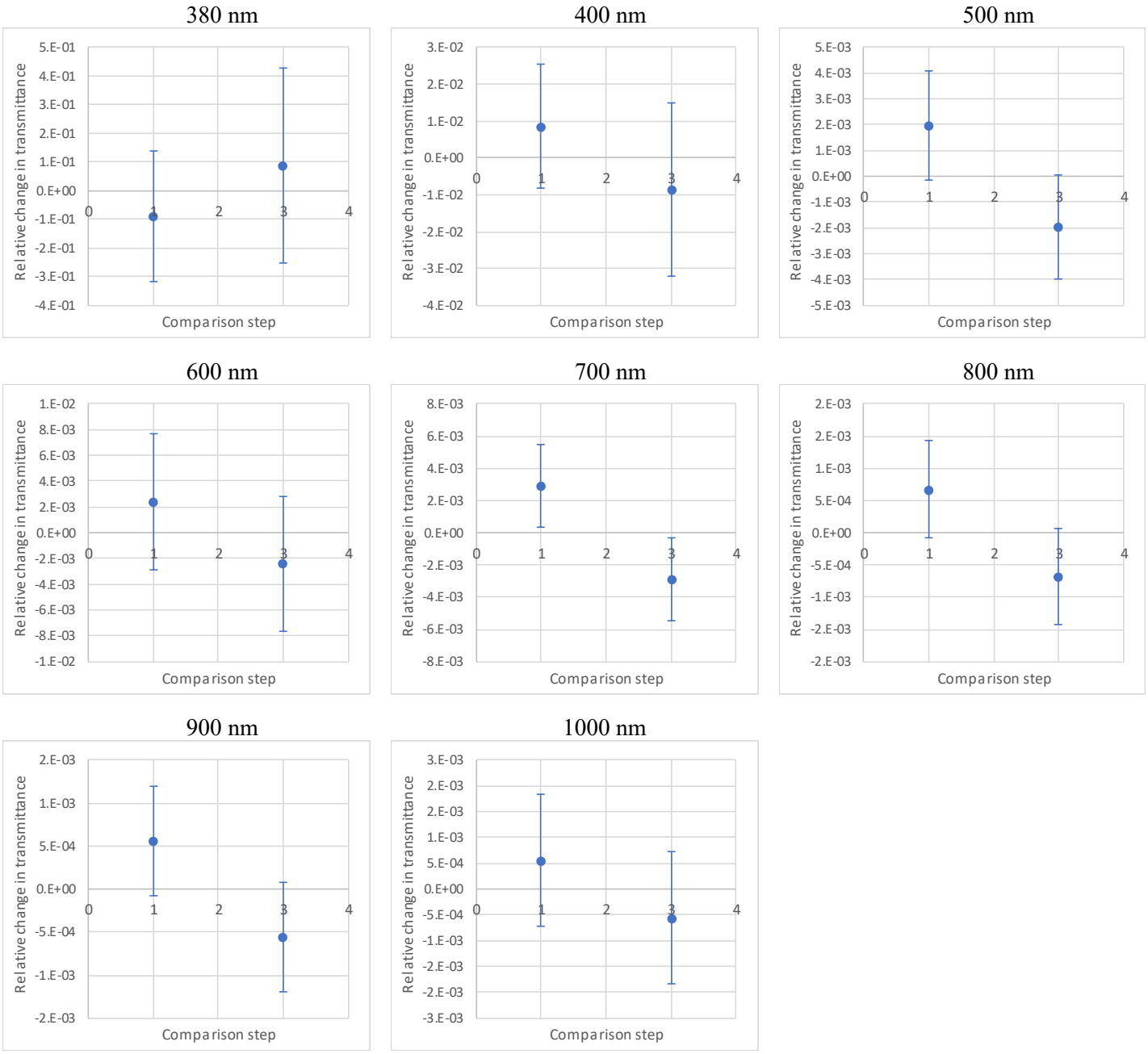


Figure C7a. Relative Data for NRC, Filter A

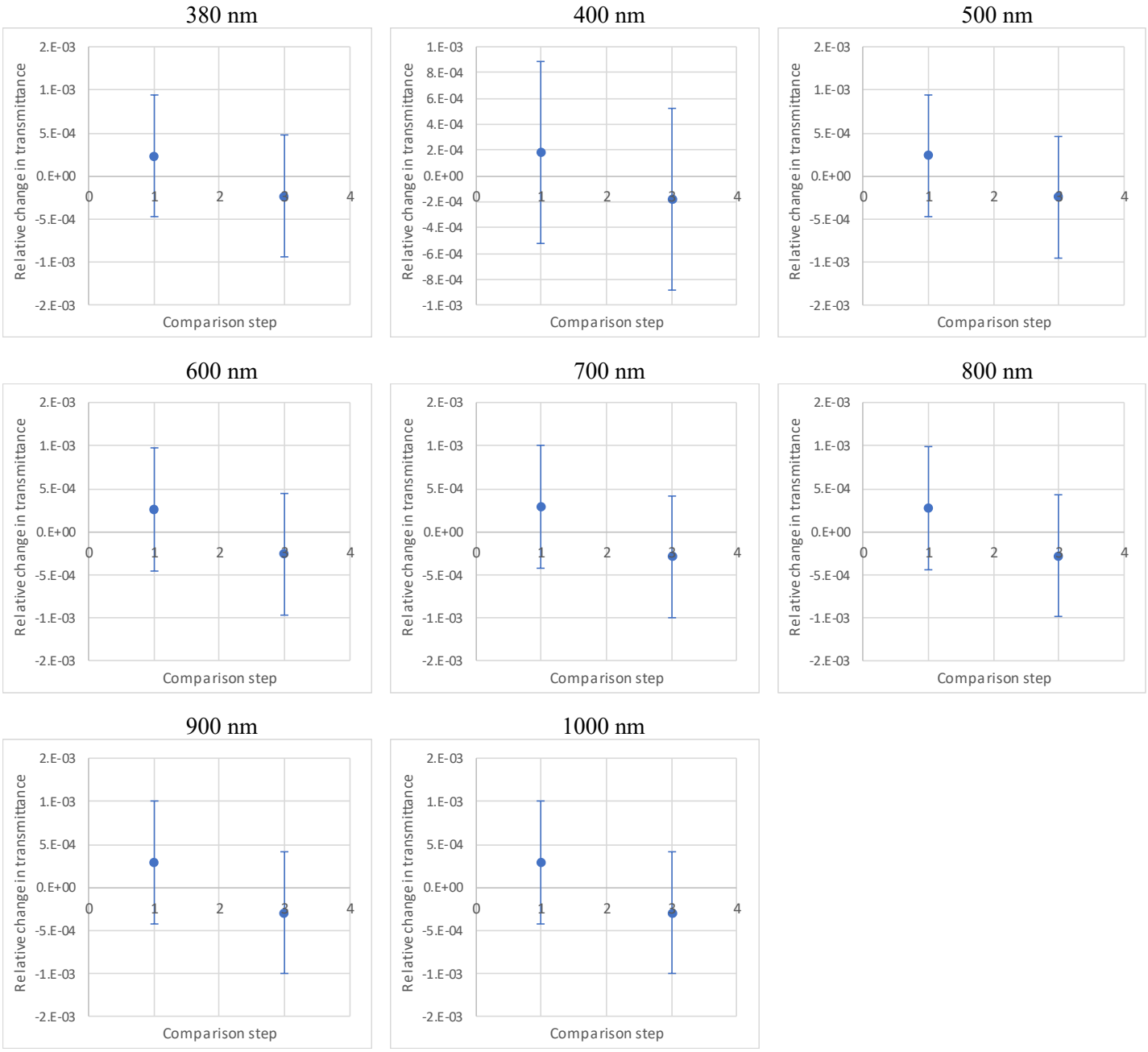


Figure C7b. Relative Data for NRC, Filter B

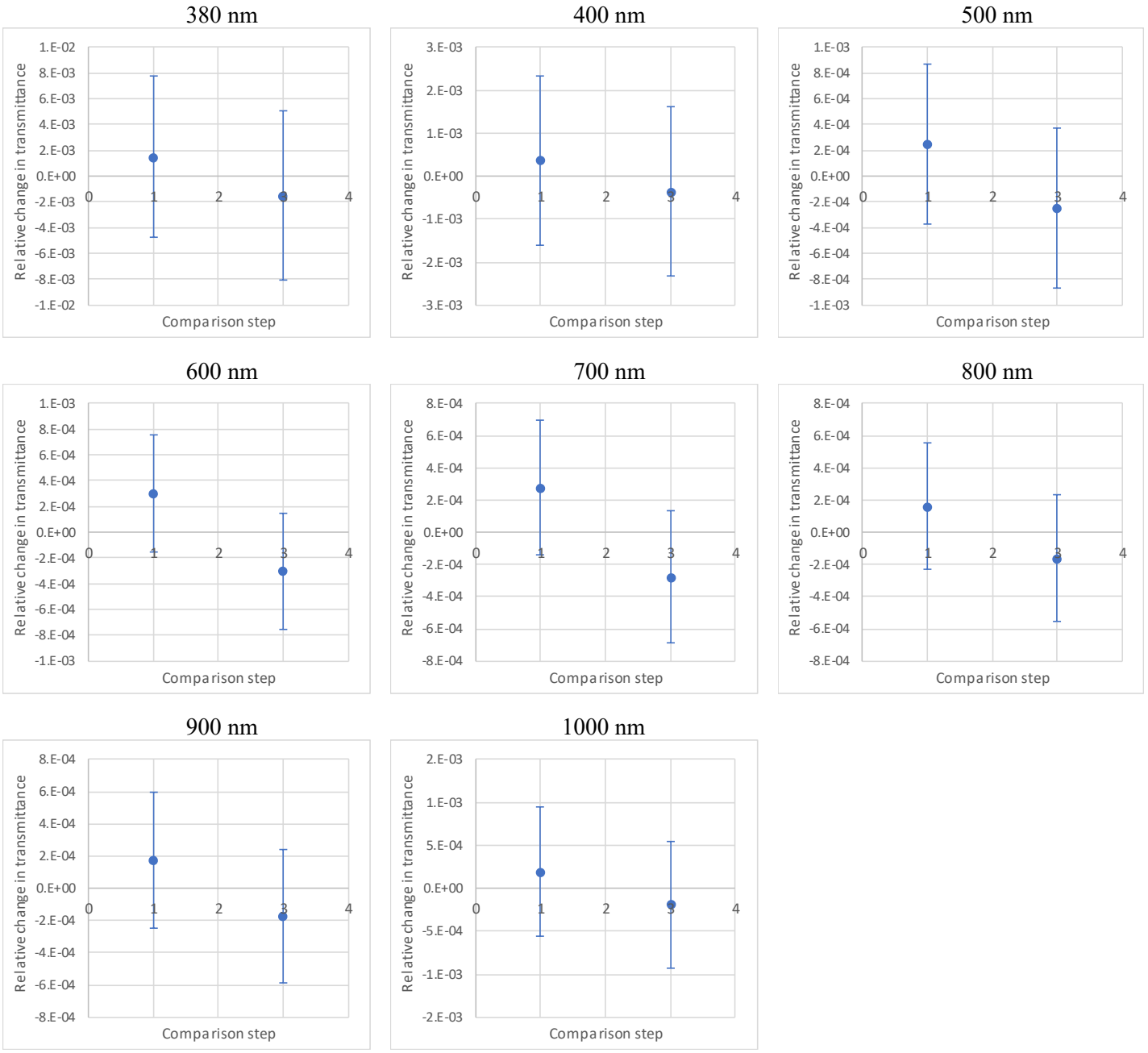


Figure C7c. Relative Data for NRC, Filter C

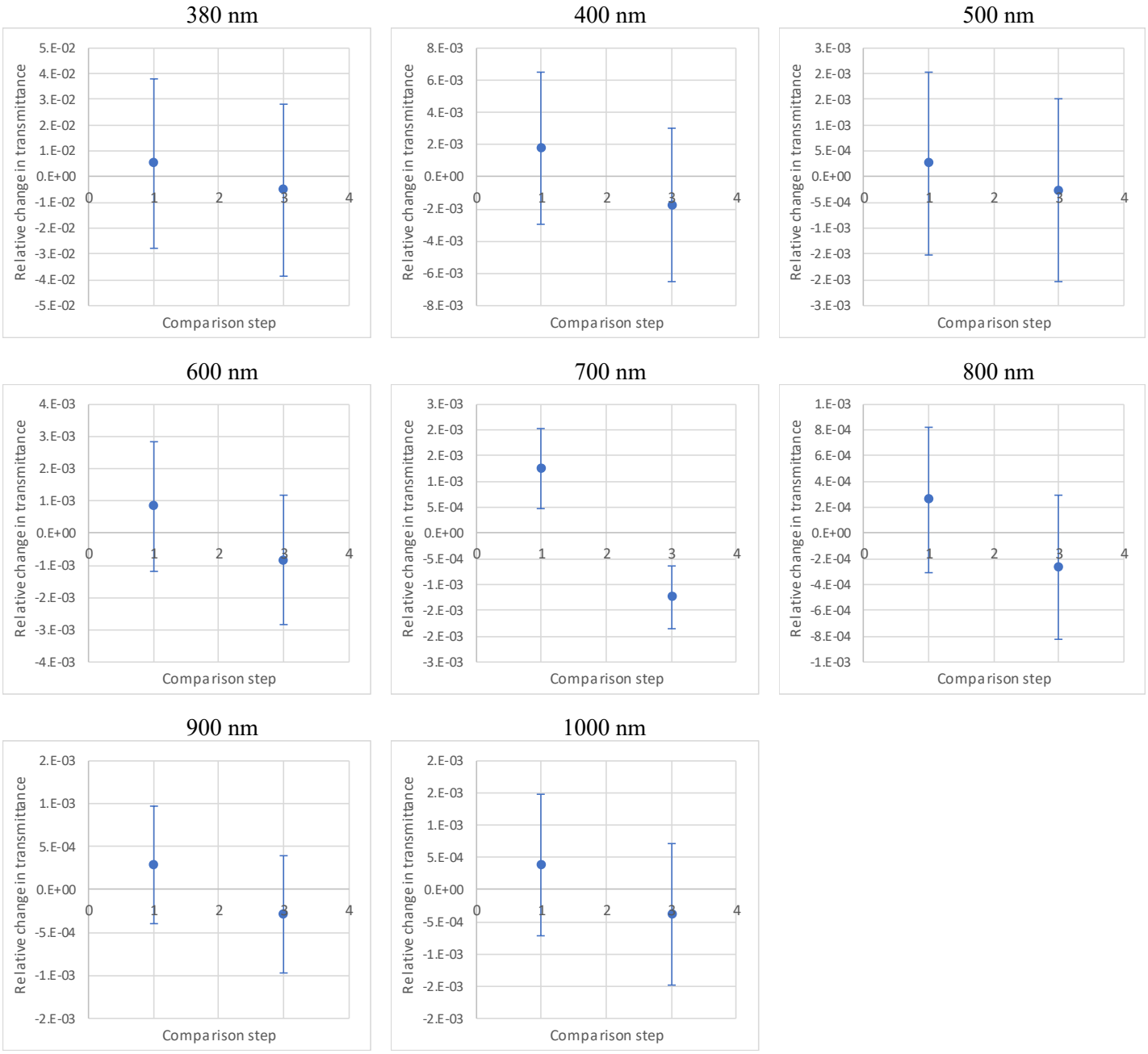


Figure C7d. Relative Data for NRC, Filter D

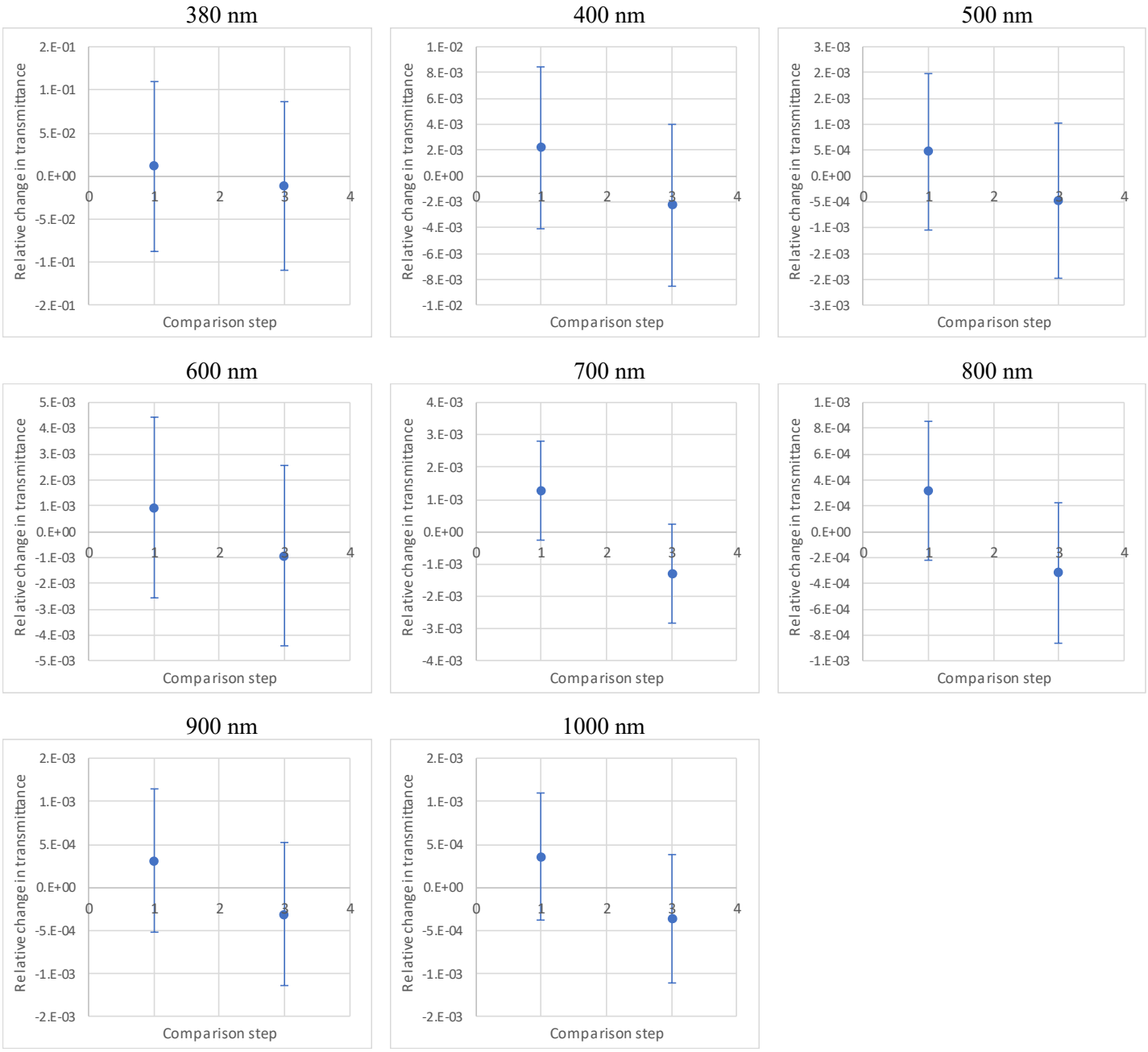
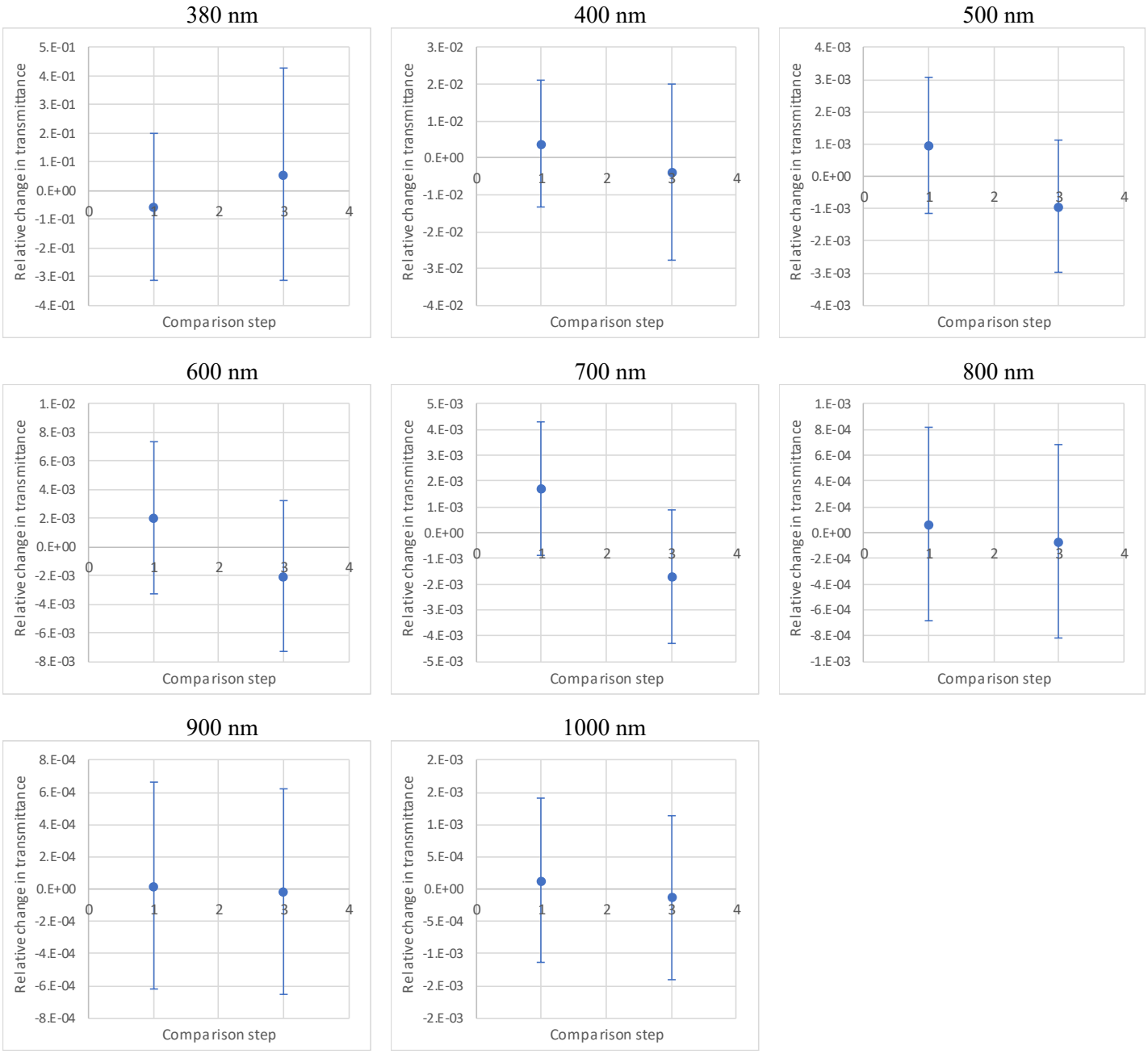


Figure C7e. Relative Data for NRC, Filter E



Appendix D: Reported Values for All Laboratories

Table D1. Reported spectral transmittance for CENAM

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1287E-01	9.1454E-01	9.1728E-01	9.1893E-01	9.2015E-01	9.2101E-01	-	-
B	4.0820E-01	6.0793E-01	6.2170E-01	6.1025E-01	6.3792E-01	5.7710E-01	-	-
C	2.2059E-02	9.7218E-02	9.3808E-02	7.8727E-02	1.6392E-01	1.5241E-01	-	-
D	3.5790E-04	5.1106E-03	8.3348E-03	8.2531E-03	2.6281E-02	3.1945E-02	-	-
E	1.8200E-05	3.3980E-04	9.3510E-04	1.0007E-03	5.0309E-03	9.6383E-03	-	-

Table D2. Reported spectral transmittance for INM

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1268E-01	9.1436E-01	9.1659E-01	9.1767E-01	9.1753E-01	9.1690E-01	-	-
B	4.0721E-01	6.0710E-01	6.2078E-01	6.0890E-01	6.3600E-01	5.7451E-01	5.0096E-01	-
C	2.1289E-02	9.4779E-02	9.1488E-02	7.6569E-02	1.6055E-01	1.4912E-01	1.0172E-01	-
D	-	5.3470E-03	8.6980E-03	8.6200E-03	2.7094E-02	3.2856E-02	-	-
E	-	-	8.9200E-04	9.5800E-04	4.8680E-03	9.3670E-03	-	-

Table D3. Reported spectral transmittance for INMETRO

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	-	9.1901E-01	9.1936E-01	9.2052E-01	9.2054E-01	9.2170E-01	9.2222E-01	9.2308E-01
B	-	6.1093E-01	6.2277E-01	6.1120E-01	6.3711E-01	5.7800E-01	5.0317E-01	4.5497E-01
C	-	9.8286E-02	9.3434E-02	7.8283E-02	1.6270E-01	1.5178E-01	1.0421E-01	7.7787E-02
D	-	7.1943E-03	8.5992E-03	8.3807E-03	2.6485E-02	3.2237E-02	2.2593E-02	1.6851E-02
E	-	-	1.0707E-03	1.0101E-03	4.8117E-03	9.2730E-03	8.1049E-03	6.9796E-03

Table D4. Reported spectral transmittance for CMS/ITRI

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1246E-01	9.1410E-01	9.1604E-01	9.1728E-01	9.1782E-01	9.1881E-01	9.2010E-01	9.2062E-01
B	4.0604E-01	6.0725E-01	6.2042E-01	6.0868E-01	6.3616E-01	5.7410E-01	4.9970E-01	4.5156E-01
C	2.1010E-02	9.4522E-02	9.1108E-02	7.6328E-02	1.6006E-01	1.4840E-01	1.0191E-01	7.5912E-02
D	3.2300E-04	4.8856E-03	8.0022E-03	7.9155E-03	2.5537E-02	3.1061E-02	2.1654E-02	1.6095E-02
E	8.7108E-06	3.3197E-04	9.3248E-04	9.9855E-04	5.0814E-03	9.7281E-03	8.4704E-03	7.1643E-03

Table D5. Reported spectral transmittance for NIM

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1229E-01	9.1413E-01	9.1670E-01	9.1821E-01	9.1943E-01	9.1986E-01	9.2041E-01	9.2058E-01
B	4.0649E-01	6.0734E-01	6.2067E-01	6.0882E-01	6.3659E-01	5.7567E-01	5.0062E-01	4.5206E-01
C	2.1506E-02	9.5760E-02	9.2104E-02	7.7039E-02	1.6143E-01	1.5014E-01	1.0281E-01	7.6445E-02
D	2.8496E-04	5.3050E-03	8.6249E-03	8.5218E-03	2.6992E-02	3.2786E-02	2.2982E-02	1.7026E-02
E	6.3733E-06	2.3800E-04	8.1397E-04	8.7693E-04	4.6152E-03	8.9547E-03	7.8020E-03	6.5709E-03

Table D6. Reported spectral transmittance for NIMT

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1494E-01	9.1692E-01	9.1958E-01	9.2105E-01	9.2191E-01	9.2232E-01	9.2291E-01	9.2442E-01
B	4.1554E-01	6.0888E-01	6.2358E-01	6.1159E-01	6.3864E-01	5.7753E-01	5.0059E-01	4.5265E-01
C	2.2804E-02	9.5383E-02	9.2657E-02	7.7670E-02	1.6210E-01	1.5101E-01	1.0242E-01	7.6428E-02
D	4.3335E-04	5.3297E-03	8.8825E-03	8.6611E-03	2.7178E-02	3.2942E-02	2.2391E-02	1.6687E-02
E	6.0646E-05	3.5667E-04	1.0734E-03	9.8652E-04	4.9871E-03	9.5189E-03	7.6857E-03	6.6246E-03

Table D7. Reported spectral transmittance for NRC

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1071E-01	9.1229E-01	9.1503E-01	9.1690E-01	9.1791E-01	9.1873E-01	9.1919E-01	9.1929E-01
B	4.0022E-01	6.0397E-01	6.1733E-01	6.0530E-01	6.3308E-01	5.7107E-01	4.9522E-01	4.4635E-01
C	2.1105E-02	9.5111E-02	9.1810E-02	7.6937E-02	1.6081E-01	1.4980E-01	1.0267E-01	7.6420E-02
D	3.8594E-04	5.5012E-03	8.9144E-03	8.8018E-03	2.7577E-02	3.3492E-02	2.3519E-02	1.7465E-02
E	1.1797E-05	3.2170E-04	9.0669E-04	9.6865E-04	4.9138E-03	9.4695E-03	8.2555E-03	6.9712E-03

Table D8a. Reported spectral transmittance for NIST, CENAM filter set, Round 1

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1027E-01	9.1198E-01	9.1558E-01	9.1781E-01	9.1920E-01	9.2007E-01	9.2064E-01	9.2101E-01
B	4.1817E-01	6.0776E-01	6.2143E-01	6.0982E-01	6.3738E-01	5.7691E-01	5.0203E-01	4.5384E-01
C	2.4222E-02	9.7475E-02	9.3953E-02	7.8841E-02	1.6406E-01	1.5264E-01	1.0481E-01	7.8210E-02
D	4.2290E-04	5.1451E-03	8.3439E-03	8.2626E-03	2.6300E-02	3.1969E-02	2.2348E-02	1.6538E-02
E	1.8901E-05	3.4337E-04	9.3664E-04	1.0041E-03	5.0335E-03	9.6439E-03	8.4068E-03	7.1092E-03

Table D8b. Reported spectral transmittance for NIST, INM filter set, Round 1

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1421E-01	9.1585E-01	9.1755E-01	9.1842E-01	9.1932E-01	9.1998E-01	9.2037E-01	9.2062E-01
B	4.1699E-01	6.0796E-01	6.2159E-01	6.0949E-01	6.3691E-01	5.7574E-01	5.0043E-01	4.5206E-01
C	2.3255E-02	9.5131E-02	9.1615E-02	7.6682E-02	1.6097E-01	1.4957E-01	1.0227E-01	7.6060E-02
D	4.5549E-04	5.3896E-03	8.7063E-03	8.6216E-03	2.7172E-02	3.2970E-02	2.3127E-02	1.7166E-02
E	2.3719E-05	3.3270E-04	9.0401E-04	9.6718E-04	4.8980E-03	9.4130E-03	8.1995E-03	6.9289E-03

Table D8c. Reported spectral transmittance for NIST, INMETRO filter set, Round 1

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1185E-01	9.1357E-01	9.1642E-01	9.1821E-01	9.1937E-01	9.2017E-01	9.2065E-01	9.2099E-01
B	4.1978E-01	6.0922E-01	6.2298E-01	6.1130E-01	6.3869E-01	5.7800E-01	5.0315E-01	4.5496E-01
C	2.3995E-02	9.6856E-02	9.3383E-02	7.8401E-02	1.6333E-01	1.5189E-01	1.0425E-01	7.7762E-02
D	4.2801E-04	5.1625E-03	8.3722E-03	8.2965E-03	2.6393E-02	3.2097E-02	2.2465E-02	1.6644E-02
E	1.8298E-05	3.1788E-04	8.7416E-04	9.3727E-04	4.7770E-03	9.2041E-03	8.0098E-03	6.7623E-03

Table D8d. Reported spectral transmittance for NIST, CMS/ITRI filter set, Round 1

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1352E-01	9.1521E-01	9.1746E-01	9.1873E-01	9.1973E-01	9.2043E-01	9.2090E-01	9.2125E-01
B	4.1691E-01	6.0768E-01	6.2118E-01	6.0918E-01	6.3660E-01	5.7535E-01	4.9994E-01	4.5151E-01
C	2.3216E-02	9.4854E-02	9.1284E-02	7.6507E-02	1.6044E-01	1.4927E-01	1.0218E-01	7.6047E-02
D	4.0378E-04	4.9935E-03	8.1198E-03	8.0391E-03	2.5764E-02	3.1359E-02	2.1876E-02	1.6164E-02
E	2.2110E-05	3.5910E-04	9.7246E-04	1.0412E-03	5.1765E-03	9.8819E-03	8.6201E-03	7.2942E-03

Table D8e. Reported spectral transmittance for NIST, NIM filter set, Round 1

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1332E-01	9.1499E-01	9.1734E-01	9.1870E-01	9.1971E-01	9.2043E-01	9.2085E-01	9.2123E-01
B	4.1731E-01	6.0762E-01	6.2126E-01	6.0929E-01	6.3660E-01	5.7579E-01	5.0069E-01	4.5240E-01
C	2.3441E-02	9.5685E-02	9.2161E-02	7.7228E-02	1.6156E-01	1.5025E-01	1.0289E-01	7.6611E-02
D	4.4741E-04	5.3494E-03	8.6489E-03	8.5655E-03	2.7020E-02	3.2792E-02	2.2983E-02	1.7047E-02
E	2.1370E-05	3.0708E-04	8.4334E-04	9.0389E-04	4.6434E-03	8.9873E-03	7.8173E-03	6.5938E-03

Table D8f. Reported spectral transmittance for NIST, NIMT filter set, Round 1

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1123E-01	9.1302E-01	9.1626E-01	9.1805E-01	9.1936E-01	9.2019E-01	9.2069E-01	9.2112E-01
B	4.1790E-01	6.0893E-01	6.2248E-01	6.1031E-01	6.3768E-01	5.7652E-01	5.0118E-01	4.5276E-01
C	2.3646E-02	9.5958E-02	9.2467E-02	7.7517E-02	1.6220E-01	1.5080E-01	1.0331E-01	7.6943E-02
D	4.5556E-04	5.3997E-03	8.7167E-03	8.6286E-03	2.7184E-02	3.2975E-02	2.3122E-02	1.7160E-02
E	2.1913E-05	3.4050E-04	9.2717E-04	9.9153E-04	4.9950E-03	9.5762E-03	8.3478E-03	7.0583E-03

Table D8g. Reported spectral transmittance for NIST, NRC filter set, Round 1

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1005E-01	9.1179E-01	9.1521E-01	9.1719E-01	9.1854E-01	9.1936E-01	9.1996E-01	9.2037E-01
B	4.1121E-01	6.0330E-01	6.1752E-01	6.0546E-01	6.3311E-01	5.7110E-01	4.9508E-01	4.4636E-01
C	2.3496E-02	9.5379E-02	9.1889E-02	7.7135E-02	1.6121E-01	1.4993E-01	1.0273E-01	7.6520E-02
D	4.7502E-04	5.5522E-03	8.9325E-03	8.8398E-03	2.7677E-02	3.3518E-02	2.3536E-02	1.7487E-02
E	2.0559E-05	3.3344E-04	9.1100E-04	9.7706E-04	4.9328E-03	9.4685E-03	8.2495E-03	6.9717E-03

Table D9a. Reported spectral transmittance for NIST, CENAM filter set, Round 3

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1009E-01	9.1186E-01	9.1550E-01	9.1776E-01	9.1910E-01	9.1996E-01	9.2054E-01	9.2094E-01
B	4.1698E-01	6.0754E-01	6.2155E-01	6.0998E-01	6.3746E-01	5.7695E-01	5.0202E-01	4.5381E-01
C	2.3978E-02	9.7276E-02	9.3910E-02	7.8744E-02	1.6381E-01	1.5258E-01	1.0476E-01	7.8164E-02
D	4.2167E-04	5.1245E-03	8.3364E-03	8.2473E-03	2.6242E-02	3.1953E-02	2.2337E-02	1.6530E-02
E	2.4866E-05	3.4094E-04	9.3483E-04	9.9981E-04	5.0214E-03	9.6414E-03	8.4051E-03	7.1067E-03

Table D9b. Reported spectral transmittance for NIST, INM filter set, Round 3

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1400E-01	9.1562E-01	9.1740E-01	9.1844E-01	9.1920E-01	9.1985E-01	9.2023E-01	9.2051E-01
B	4.1609E-01	6.0758E-01	6.2134E-01	6.0938E-01	6.3676E-01	5.7565E-01	5.0033E-01	4.5193E-01
C	2.3052E-02	9.4921E-02	9.1587E-02	7.6610E-02	1.6071E-01	1.4955E-01	1.0224E-01	7.6029E-02
D	4.5219E-04	5.3699E-03	8.7069E-03	8.6178E-03	2.7129E-02	3.2977E-02	2.3131E-02	1.7168E-02
E	2.2396E-05	3.2739E-04	9.0181E-04	9.6485E-04	4.8854E-03	9.4132E-03	8.1997E-03	6.9283E-03

Table D9c. Reported spectral transmittance for NIST, INMETRO filter set, Round 3

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1109E-01	9.1285E-01	9.1580E-01	9.1758E-01	9.1879E-01	9.1957E-01	9.2007E-01	9.2039E-01
B	4.1833E-01	6.0908E-01	6.2296E-01	6.1124E-01	6.3863E-01	5.7804E-01	5.0315E-01	4.5496E-01
C	2.3786E-02	9.6527E-02	9.3254E-02	7.8224E-02	1.6283E-01	1.5167E-01	1.0410E-01	7.7643E-02
D	4.2427E-04	5.1366E-03	8.3716E-03	8.2885E-03	2.6339E-02	3.2098E-02	2.2465E-02	1.6640E-02
E	2.2716E-05	3.1573E-04	8.7138E-04	9.3204E-04	4.7572E-03	9.1968E-03	8.0036E-03	6.7565E-03

Table D9d. Reported spectral transmittance for NIST, CMS/ITRI filter set, Round 3

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1338E-01	9.1497E-01	9.1720E-01	9.1851E-01	9.1940E-01	9.2011E-01	9.2055E-01	9.2085E-01
B	4.1543E-01	6.0725E-01	6.2095E-01	6.0897E-01	6.3642E-01	5.7526E-01	4.9984E-01	4.5140E-01
C	2.3003E-02	9.4645E-02	9.1246E-02	7.6393E-02	1.6014E-01	1.4921E-01	1.0213E-01	7.5996E-02
D	4.0218E-04	4.9724E-03	8.1169E-03	8.0257E-03	2.5700E-02	3.1353E-02	2.1873E-02	1.6158E-02
E	2.9360E-05	3.5528E-04	9.6966E-04	1.0364E-03	5.1579E-03	9.8757E-03	8.6146E-03	7.2889E-03

Table D9e. Reported spectral transmittance for NIST, NIM filter set, Round 3

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1267E-01	9.1435E-01	9.1684E-01	9.1821E-01	9.1924E-01	9.1996E-01	9.2040E-01	9.2072E-01
B	4.1639E-01	6.0776E-01	6.2137E-01	6.0933E-01	6.3666E-01	5.7589E-01	5.0075E-01	4.5242E-01
C	2.3245E-02	9.5456E-02	9.2141E-02	7.7141E-02	1.6130E-01	1.5020E-01	1.0285E-01	7.6561E-02
D	4.4449E-04	5.3363E-03	8.6542E-03	8.5612E-03	2.6981E-02	3.2805E-02	2.2992E-02	1.7050E-02
E	1.7342E-05	3.0121E-04	8.3966E-04	8.9825E-04	4.6240E-03	8.9747E-03	7.8066E-03	6.5824E-03

Table D9f. Reported spectral transmittance for NIST, NIMT filter set, Round 3

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.1107E-01	9.1284E-01	9.1607E-01	9.1802E-01	9.1924E-01	9.2007E-01	9.2060E-01	9.2100E-01
B	4.1630E-01	6.0729E-01	6.2270E-01	6.1063E-01	6.3794E-01	5.7677E-01	5.0133E-01	4.5285E-01
C	2.3360E-02	9.5496E-02	9.2266E-02	7.7549E-02	1.6201E-01	1.5092E-01	1.0337E-01	7.6967E-02
D	4.5366E-04	5.3657E-03	8.7056E-03	8.6076E-03	2.7101E-02	3.2941E-02	2.3102E-02	1.7140E-02
E	2.6150E-05	3.3472E-04	9.2353E-04	9.8674E-04	4.9660E-03	9.5633E-03	8.3384E-03	7.0504E-03

Table D9g. Reported spectral transmittance for NIST, NRC filter set, Round 3

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	9.0963E-01	9.1145E-01	9.1477E-01	9.1672E-01	9.1801E-01	9.1885E-01	9.1942E-01	9.1982E-01
B	4.0998E-01	6.0286E-01	6.1721E-01	6.0509E-01	6.3276E-01	5.7091E-01	4.9491E-01	4.4619E-01
C	2.3253E-02	9.5042E-02	9.1841E-02	7.7006E-02	1.6081E-01	1.4985E-01	1.0267E-01	7.6462E-02
D	4.6428E-04	5.5273E-03	8.9240E-03	8.8233E-03	2.7606E-02	3.3497E-02	2.3521E-02	1.7475E-02
E	2.3058E-05	3.3086E-04	9.0929E-04	9.7311E-04	4.9160E-03	9.4673E-03	8.2492E-03	6.9699E-03

Notes:

a) Columns with dashes indicate that transmittance values at these wavelengths were either not measured or not reported.

Appendix E: Uncertainty Budgets for All Laboratories

Table E1a. Uncertainty budget for CENAM, Filter A

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.20E-03	1.21E-03	1.21E-03	1.21E-03	1.22E-03	1.22E-03	-	-
Temperature	nc	nc	nc	nc	nc	nc	-	-
Wavelength	6.10E-06	7.40E-06	4.90E-06	5.50E-06	4.60E-06	2.04E-05	-	-
Stray Light	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	-	-
Beam Size & Position	nc	nc	nc	nc	nc	nc	-	-
Inter-reflection	nc	nc	nc	nc	nc	nc	-	-
Obliquity	nc	nc	nc	nc	nc	nc	-	-
Polarization	nc	nc	nc	nc	nc	nc	-	-
Source Drift & Fluctuation	1.12E-03	1.13E-03	1.13E-03	1.14E-03	1.14E-03	1.14E-03	-	-
Bandwidth	nc	nc	nc	nc	nc	nc	-	-
Instrument Resolution	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	-	-
Total Type B Uncertainty	1.65E-03	1.65E-03	1.66E-03	1.66E-03	1.67E-03	1.67E-03	-	-
Degrees of Freedom	64	64	64	64	64	64	-	-
Type A Uncertainty	7.44E-04	7.81E-04	8.16E-04	8.45E-04	1.09E-03	1.15E-03	-	-
Total Uncertainty	1.81E-03	1.83E-03	1.85E-03	1.87E-03	1.99E-03	2.03E-03	-	-
Degrees of Freedom	74	74	73	73	63	60	-	-

Table E1b. Uncertainty budget for CENAM, Filter B

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	4.89E-04	7.54E-04	7.73E-04	7.57E-04	7.96E-04	7.12E-04	-	-
Temperature	nc	nc	nc	nc	nc	nc	-	-
Wavelength	6.56E-04	3.70E-05	8.80E-06	4.00E-06	1.16E-05	5.29E-05	-	-
Stray Light	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	-	-
Beam Size & Position	nc	nc	nc	nc	nc	nc	-	-
Inter-reflection	nc	nc	nc	nc	nc	nc	-	-
Obliquity	nc	nc	nc	nc	nc	nc	-	-
Polarization	nc	nc	nc	nc	nc	nc	-	-
Source Drift & Fluctuation	5.13E-04	6.73E-04	6.86E-04	6.75E-04	7.02E-04	6.45E-04	-	-
Bandwidth	nc	nc	nc	nc	nc	nc	-	-
Instrument Resolution	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	-	-
Total Type B Uncertainty	9.66E-04	1.01E-03	1.03E-03	1.01E-03	1.06E-03	9.62E-04	-	-
Degrees of Freedom	32	67	67	67	66	68	-	-
Type A Uncertainty	9.02E-05	1.54E-04	1.78E-04	1.60E-04	1.57E-04	1.75E-04	-	-
Total Uncertainty	9.70E-04	1.02E-03	1.05E-03	1.03E-03	1.07E-03	9.78E-04	-	-
Degrees of Freedom	32	69	70	70	68	72	-	-

Table E1c. Uncertainty budget for CENAM, Filter C

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	3.48E-05	1.05E-04	1.01E-04	8.71E-05	1.69E-04	1.58E-04	-	-
Temperature	nc	nc	nc	nc	nc	nc	-	-
Wavelength	1.26E-04	5.20E-05	1.81E-05	1.01E-05	7.37E-05	3.12E-05	-	-
Stray Light	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	-	-
Beam Size & Position	nc	nc	nc	nc	nc	nc	-	-
Inter-reflection	nc	nc	nc	nc	nc	nc	-	-
Obliquity	nc	nc	nc	nc	nc	nc	-	-
Polarization	nc	nc	nc	nc	nc	nc	-	-
Source Drift & Fluctuation	7.48E-05	1.98E-04	1.93E-04	1.70E-04	2.88E-04	2.73E-04	-	-
Bandwidth	nc	nc	nc	nc	nc	nc	-	-
Instrument Resolution	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	-	-
Total Type B Uncertainty	1.53E-04	2.32E-04	2.21E-04	1.94E-04	3.43E-04	3.18E-04	-	-
Degrees of Freedom	17	66	61	61	69	64	-	-
Type A Uncertainty	9.90E-06	2.33E-05	2.09E-05	2.34E-05	2.69E-05	4.60E-05	-	-
Total Uncertainty	1.53E-04	2.33E-04	2.22E-04	1.95E-04	3.44E-04	3.22E-04	-	-
Degrees of Freedom	17	67	62	62	69	66	-	-

Table E1d. Uncertainty budget for CENAM, Filter D

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.75E-05	2.25E-05	2.58E-05	2.57E-05	4.46E-05	5.06E-05	-	-
Temperature	nc	nc	nc	nc	nc	nc	-	-
Wavelength	3.30E-06	7.90E-06	1.40E-06	2.10E-06	1.64E-05	5.10E-06	-	-
Stray Light	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	-	-
Beam Size & Position	nc	nc	nc	nc	nc	nc	-	-
Inter-reflection	nc	nc	nc	nc	nc	nc	-	-
Obliquity	nc	nc	nc	nc	nc	nc	-	-
Polarization	nc	nc	nc	nc	nc	nc	-	-
Source Drift & Fluctuation	3.41E-05	4.31E-05	4.93E-05	4.91E-05	8.25E-05	9.26E-05	-	-
Bandwidth	nc	nc	nc	nc	nc	nc	-	-
Instrument Resolution	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	-	-
Total Type B Uncertainty	4.82E-05	5.72E-05	6.27E-05	6.26E-05	9.95E-05	1.10E-04	-	-
Degrees of Freedom	98	98	90	90	76	70	-	-
Type A Uncertainty	2.20E-06	5.20E-06	4.90E-06	4.80E-06	1.28E-05	2.47E-05	-	-
Total Uncertainty	4.83E-05	5.75E-05	6.30E-05	6.29E-05	1.00E-04	1.12E-04	-	-
Degrees of Freedom	99	100	91	91	78	76	-	-

Table E1e. Uncertainty budget for CENAM, Filter E

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.72E-05	1.75E-05	1.81E-05	1.82E-05	2.24E-05	2.72E-05	-	-
Temperature	nc	nc	nc	nc	nc	nc	-	-
Wavelength	1.00E-07	7.00E-07	4.00E-07	4.00E-07	4.80E-06	4.00E-07	-	-
Stray Light	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	2.89E-05	-	-
Beam Size & Position	nc	nc	nc	nc	nc	nc	-	-
Inter-reflection	nc	nc	nc	nc	nc	nc	-	-
Obliquity	nc	nc	nc	nc	nc	nc	-	-
Polarization	nc	nc	nc	nc	nc	nc	-	-
Source Drift & Fluctuation	3.34E-05	3.40E-05	3.52E-05	3.53E-05	4.30E-05	5.17E-05	-	-
Bandwidth	nc	nc	nc	nc	nc	nc	-	-
Instrument Resolution	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	2.90E-06	-	-
Total Type B Uncertainty	4.75E-05	4.80E-05	4.91E-05	4.92E-05	5.67E-05	6.52E-05	-	-
Degrees of Freedom	97	98	98	98	96	88	-	-
Type A Uncertainty	2.40E-06	3.20E-06	2.10E-06	2.30E-06	5.70E-06	6.40E-06	-	-
Total Uncertainty	4.75E-05	4.81E-05	4.91E-05	4.92E-05	5.70E-05	6.56E-05	-	-
Degrees of Freedom	98	99	99	99	99	91	-	-

Table E2a. Uncertainty budget for INM, Filter A

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	4.83E-04	4.84E-04	4.85E-04	4.86E-04	4.86E-04	4.86E-04	-	-
Temperature	4.73E-06	1.58E-05	3.84E-06	2.84E-06	1.07E-07	6.11E-06	-	-
Wavelength	1.00E-04	1.82E-05	3.06E-05	2.40E-05	6.39E-05	6.50E-04	-	-
Stray Light	1.62E-06	1.60E-06	7.24E-06	1.15E-06	1.25E-06	1.02E-05	-	-
Beam Size & Position	1.42E-04	2.18E-04	1.78E-04	1.54E-04	2.03E-04	4.04E-04	-	-
Inter-reflection	2.20E-05	9.01E-05	5.73E-05	1.14E-04	1.68E-04	9.76E-05	-	-
Obliquity	8.47E-05	7.14E-05	9.62E-05	8.62E-05	9.92E-05	1.57E-04	-	-
Polarization	6.06E-05	7.24E-05	5.34E-05	8.63E-06	3.28E-05	1.33E-04	-	-
Source Drift & Fluctuation	4.22E-04	4.33E-04	2.88E-04	2.93E-04	2.92E-04	6.83E-04	-	-
Bandwidth	1.30E-04	3.67E-05	1.78E-05	4.32E-05	4.33E-05	1.94E-04	-	-
Resolution	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	-	-
Total Type B Uncertainty	6.85E-04	6.99E-04	6.06E-04	6.07E-04	6.38E-04	1.17E-03	-	-
Degrees of Freedom	26	32	57	103	115	59	-	-
Type A Uncertainty	3.37E-04	3.21E-04	2.29E-04	1.88E-04	1.93E-04	4.46E-04	-	-
Total Uncertainty	7.64E-04	7.70E-04	6.48E-04	6.36E-04	6.67E-04	1.26E-03	-	-
Degrees of Freedom	26	32	57	103	115	59	-	-

Table E2b. Uncertainty budget for INM, Filter B

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	3.62E-04	3.61E-04	3.58E-04	3.61E-04	3.54E-04	3.69E-04	3.87E-04	-
Temperature	2.50E-05	1.40E-05	1.20E-05	1.40E-05	1.20E-05	1.40E-05	1.80E-05	-
Wavelength	1.71E-04	1.44E-05	5.79E-05	2.48E-05	1.75E-04	3.07E-04	1.95E-03	-
Stray Light	1.65E-06	1.31E-06	8.04E-06	1.13E-06	1.69E-06	1.22E-05	7.03E-06	-
Beam Size & Position	6.12E-05	2.08E-05	2.36E-05	5.87E-05	7.05E-05	7.12E-05	7.93E-04	-
Inter-reflection	2.53E-05	6.85E-05	3.19E-05	2.05E-05	8.69E-05	1.34E-04	2.53E-03	-
Obliquity	7.27E-05	1.46E-04	1.49E-04	1.59E-04	1.50E-04	1.44E-04	5.00E-04	-
Polarization	4.75E-05	1.39E-04	1.07E-04	1.04E-04	4.43E-05	5.21E-05	2.69E-04	-
Source Drift & Fluctuation	2.81E-04	2.97E-04	2.00E-04	2.25E-04	1.91E-04	4.38E-04	7.49E-03	-
Bandwidth	5.59E-05	9.57E-05	2.37E-05	2.77E-05	4.95E-05	2.81E-05	4.90E-04	-
Resolution	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	-
Total Type B Uncertainty	5.04E-04	5.23E-04	4.55E-04	4.72E-04	4.81E-04	6.86E-04	8.22E-03	-
Degrees of Freedom	36	62	61	62	116	47	11	-
Type A Uncertainty	2.23E-04	1.95E-04	1.69E-04	1.75E-04	1.47E-04	2.79E-04	5.32E-03	-
Total Uncertainty	5.51E-04	5.58E-04	4.86E-04	5.03E-04	5.03E-04	7.41E-04	9.79E-03	-
Degrees of Freedom	36	62	61	62	116	47	11	-

Table E2c. Uncertainty budget for INM, Filter C

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.22E-04	2.42E-04	2.44E-04	2.53E-04	1.75E-04	1.91E-04	2.38E-04	-
Temperature	1.10E-04	7.20E-05	7.00E-05	7.90E-05	5.40E-05	5.50E-05	6.60E-05	-
Wavelength	4.02E-05	8.34E-06	1.28E-05	6.65E-07	4.41E-05	7.12E-05	8.89E-04	-
Stray Light	1.96E-06	1.61E-06	5.44E-06	1.48E-06	1.45E-06	1.25E-05	1.78E-05	-
Beam Size & Position	3.26E-05	7.03E-05	2.72E-05	1.43E-05	6.11E-05	5.28E-06	7.52E-04	-
Inter-reflection	2.83E-05	1.07E-04	1.62E-05	5.72E-06	2.23E-05	7.72E-05	5.43E-04	-
Obliquity	1.71E-05	5.94E-05	3.30E-05	2.74E-05	6.53E-05	7.45E-05	7.33E-05	-
Polarization	3.26E-05	1.04E-04	6.26E-05	4.84E-05	6.98E-05	4.40E-05	2.33E-04	-
Source Drift & Fluctuation	6.48E-05	1.15E-04	6.33E-05	6.63E-05	8.91E-05	2.08E-04	2.84E-03	-
Bandwidth	2.39E-05	8.59E-05	3.58E-05	5.20E-05	1.19E-05	3.80E-05	8.12E-04	-
Resolution	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	-
Total Type B Uncertainty	1.91E-04	3.39E-04	2.76E-04	2.84E-04	2.38E-04	3.21E-04	3.24E-03	-
Degrees of Freedom	64	266	224	234	163	40	16	-
Type A Uncertainty	5.02E-05	7.53E-05	5.14E-05	4.55E-05	6.37E-05	1.38E-04	1.85E-03	-
Total Uncertainty	1.98E-04	3.48E-04	2.80E-04	2.88E-04	2.47E-04	3.49E-04	3.73E-03	-
Degrees of Freedom	64	266	224	234	163	40	16	-

Table E2d. Uncertainty budget for INM, Filter D

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	-	9.41E-06	9.41E-06	9.41E-06	1.50E-04	1.73E-04	-	-
Temperature	-	1.60E-04	1.40E-04	1.50E-04	1.10E-04	1.00E-04	-	-
Wavelength	-	8.87E-07	1.43E-06	7.89E-07	5.94E-06	2.60E-05	-	-
Stray Light	-	1.42E-06	6.12E-06	1.15E-06	7.33E-07	1.11E-05	-	-
Beam Size & Position	-	1.20E-05	5.87E-06	7.09E-06	1.59E-05	1.37E-05	-	-
Inter-reflection	-	7.14E-06	2.58E-06	4.34E-06	7.22E-06	2.17E-05	-	-
Obliquity	-	4.77E-06	3.84E-06	2.52E-06	8.64E-06	1.81E-05	-	-
Polarization	-	5.37E-06	8.11E-06	4.81E-06	1.13E-05	1.24E-05	-	-
Source Drift & Fluctuation	-	2.00E-05	1.45E-05	1.72E-05	3.07E-05	8.20E-05	-	-
Bandwidth	-	6.96E-06	1.39E-06	6.86E-06	9.34E-06	1.92E-05	-	-
Resolution	-	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	-	-
Total Type B Uncertainty	-	1.62E-04	1.42E-04	1.52E-04	1.90E-04	2.21E-04	-	-
Degrees of Freedom	-	10	10	10	70	114	-	-
Type A Uncertainty	-	1.31E-05	1.05E-05	1.32E-05	2.23E-05	5.24E-05	-	-
Total Uncertainty	-	1.63E-04	1.42E-04	1.52E-04	1.91E-04	2.27E-04	-	-
Degrees of Freedom	-	10	10	10	70	114	-	-

Table E2e. Uncertainty budget for INM, Filter E

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	-	-	9.41E-06	9.41E-06	9.41E-06	9.41E-06	-	-
Temperature	-	-	2.10E-04	2.30E-04	1.60E-04	1.40E-04	-	-
Wavelength	-	-	3.55E-07	8.58E-08	2.50E-06	1.29E-05	-	-
Stray Light	-	-	5.95E-06	1.42E-06	3.49E-07	9.66E-06	-	-
Beam Size & Position	-	-	1.55E-06	1.28E-06	6.46E-06	9.35E-06	-	-
Inter-reflection	-	-	1.61E-06	1.01E-06	4.29E-06	8.19E-06	-	-
Obliquity	-	-	2.77E-07	3.04E-07	1.06E-06	3.79E-06	-	-
Polarization	-	-	9.89E-07	7.74E-07	2.72E-06	5.66E-06	-	-
Source Drift & Fluctuation	-	-	5.21E-06	5.74E-06	1.26E-05	4.29E-05	-	-
Bandwidth	-	-	2.17E-06	1.25E-06	5.87E-06	7.43E-06	-	-
Resolution	-	-	2.89E-07	2.89E-07	2.89E-07	2.89E-07	-	-
Total Type B Uncertainty	-	-	2.10E-04	2.30E-04	1.61E-04	1.48E-04	-	-
Degrees of Freedom	-	-	9	9	9	12	-	-
Type A Uncertainty	-	-	4.30E-06	4.32E-06	8.41E-06	3.04E-05	-	-
Total Uncertainty	-	-	2.10E-04	2.30E-04	1.61E-04	1.52E-04	-	-
Degrees of Freedom	-	-	9	9	9	12	-	-

Table E3a. Uncertainty budget for INMETRO, Filter A

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	-	2.4E-05	2.4E-05	2.4E-05	2.4E-05	2.4E-05	2.4E-05	2.4E-05
Temperature	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wavelength	-	6.4E-06	6.0E-06	5.6E-06	5.5E-06	1.4E-05	2.8E-05	1.7E-05
Stray Light	-	5.2E-06	5.2E-06	5.2E-06	5.2E-06	5.2E-06	5.2E-06	5.2E-06
Beam Size & Position	-	2.4E-06	2.4E-06	2.4E-06	2.4E-06	2.4E-06	2.4E-06	2.4E-06
Inter-reflection	-	6.1E-06	8.9E-08	5.1E-08	5.1E-08	5.1E-08	5.3E-08	1.2E-07
Obliquity	-	7.8E-06	7.8E-06	7.8E-06	7.8E-06	7.9E-06	7.9E-06	7.9E-06
Polarization	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	-	1.7E-05	1.2E-05	1.1E-05	1.0E-05	9.1E-06	8.9E-06	1.5E-05
Bandwidth	-	3.5E-06	2.0E-06	2.4E-06	2.5E-06	1.1E-05	1.2E-05	1.5E-05
System Fluctuation	-	2.0E-05	1.2E-05	1.1E-05	1.0E-05	1.0E-05	1.3E-05	1.1E-05
Total Type B Uncertainty	-	3.8E-05	3.1E-05	3.1E-05	3.0E-05	3.4E-05	4.3E-05	3.9E-05
Degrees of Freedom	-	8.2E+03	1.7E+04	2.5E+04	2.9E+04	7.2E+04	1.9E+05	1.8E+04
Type A Uncertainty	-	1.3E-03	9.5E-04	9.2E-04	8.7E-04	8.4E-04	8.5E-04	9.5E-04
Total Uncertainty	-	1.3E-03	9.5E-04	9.2E-04	8.7E-04	8.4E-04	8.5E-04	9.5E-04
Degrees of Freedom	-	901	901	901	901	902	904	902

Table E3b. Uncertainty budget for INMETRO, Filter B

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	-	1.8E-05	1.8E-05	1.8E-05	1.8E-05	1.7E-05	1.5E-05	1.3E-05
Temperature	-	6.7E-06	3.8E-06	6.8E-06	4.4E-06	3.6E-06	3.8E-06	4.5E-06
Wavelength	-	1.5E-05	1.0E-05	1.6E-06	4.6E-06	1.5E-05	1.4E-05	8.2E-06
Stray Light	-	3.9E-06	3.9E-06	3.9E-06	4.0E-06	3.7E-06	3.2E-06	2.9E-06
Beam Size & Position	-	1.8E-06	1.8E-06	1.8E-06	1.8E-06	1.7E-06	1.5E-06	1.3E-06
Inter-reflection	-	3.1E-06	1.5E-07	5.3E-08	1.5E-07	5.8E-08	1.3E-07	1.3E-07
Obliquity	-	5.8E-06	5.9E-06	5.8E-06	6.1E-06	5.5E-06	4.8E-06	4.3E-06
Polarization	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	-	1.5E-05	8.6E-06	9.0E-06	7.0E-06	6.5E-06	5.6E-06	4.9E-06
Bandwidth	-	3.0E-06	8.6E-07	1.5E-06	6.5E-07	1.1E-06	1.1E-06	8.2E-07
System Fluctuation	-	1.7E-05	8.6E-06	8.6E-06	8.5E-06	7.4E-06	6.0E-06	5.8E-06
Total Type B Uncertainty	-	3.4E-05	2.5E-05	2.4E-05	2.4E-05	2.5E-05	2.3E-05	1.9E-05
Degrees of Freedom	-	9.6E+03	2.8E+04	1.7E+04	4.5E+04	8.4E+04	9.9E+04	7.4E+04
Type A Uncertainty	-	5.5E-04	4.3E-04	4.1E-04	4.1E-04	3.2E-04	2.8E-04	2.8E-04
Total Uncertainty	-	5.6E-04	4.3E-04	4.1E-04	4.1E-04	3.3E-04	2.8E-04	2.8E-04
Degrees of Freedom	-	906	905	905	905	910	912	907

Table E3c. Uncertainty budget for INMETRO, Filter C

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	-	2.0E-06	1.9E-06	1.6E-06	3.3E-06	3.1E-06	2.1E-06	1.6E-06
Temperature	-	3.5E-06	2.1E-06	3.1E-06	3.2E-06	2.4E-06	1.8E-06	1.7E-06
Wavelength	-	1.5E-05	1.1E-05	3.6E-06	2.2E-05	7.0E-06	5.9E-06	2.4E-06
Stray Light	-	4.4E-07	4.2E-07	3.5E-07	7.3E-07	6.8E-07	4.7E-07	3.5E-07
Beam Size & Position	-	2.0E-07	1.9E-07	1.6E-07	3.3E-07	3.1E-07	2.1E-07	1.6E-07
Inter-reflection	-	4.1E-06	8.3E-08	4.5E-08	5.2E-08	4.4E-08	4.9E-08	2.7E-07
Obliquity	-	6.6E-07	6.3E-07	5.3E-07	1.1E-06	1.0E-06	7.0E-07	5.2E-07
Polarization	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	-	2.1E-06	1.2E-06	7.1E-07	9.3E-07	1.2E-06	7.0E-07	5.5E-07
Bandwidth	-	3.3E-07	3.2E-07	2.4E-07	8.8E-07	2.1E-07	1.3E-07	8.2E-08
System Fluctuation	-	2.7E-06	1.2E-06	7.5E-07	1.2E-06	1.3E-06	8.2E-07	6.3E-07
Total Type B Uncertainty	-	1.7E-05	1.2E-05	5.2E-06	2.3E-05	8.3E-06	6.7E-06	3.5E-06
Degrees of Freedom	-	2.6E+04	3.6E+06	1.0E+06	1.3E+08	7.5E+05	2.9E+06	5.1E+05
Type A Uncertainty	-	7.2E-05	7.1E-05	5.9E-05	1.9E-04	1.1E-04	7.2E-05	5.8E-05
Total Uncertainty	-	7.4E-05	7.2E-05	5.9E-05	1.9E-04	1.1E-04	7.2E-05	5.8E-05
Degrees of Freedom	-	1.6E+03	1.5E+03	1.5E+03	1.5E+03	1.5E+03	1.5E+03	1.4E+03

Table E3d. Uncertainty budget for INMETRO, Filter D

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	-	1.4E-07	1.7E-07	1.6E-07	5.1E-07	6.2E-07	4.3E-07	3.2E-07
Temperature	-	5.6E-07	3.7E-07	6.2E-07	1.0E-06	9.6E-07	7.0E-07	2.4E-07
Wavelength	-	1.2E-06	6.9E-07	7.5E-07	4.7E-06	1.0E-06	1.3E-06	4.1E-07
Stray Light	-	3.0E-08	3.6E-08	3.5E-08	1.1E-07	1.4E-07	9.5E-08	7.1E-08
Beam Size & Position	-	1.4E-08	1.7E-08	1.6E-08	5.1E-08	6.2E-08	4.3E-08	3.2E-08
Inter-reflection	-	5.4E-06	7.0E-08	4.2E-08	5.0E-08	4.8E-08	4.9E-08	9.1E-08
Obliquity	-	4.6E-08	5.5E-08	5.3E-08	1.7E-07	2.0E-07	1.4E-07	1.1E-07
Polarization	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	-	1.8E-07	1.6E-07	1.2E-07	1.8E-07	4.9E-07	2.6E-07	2.2E-07
Bandwidth	-	2.4E-07	4.2E-08	2.8E-08	1.5E-07	8.0E-08	4.9E-08	5.1E-08
System Fluctuation	-	1.1E-06	2.0E-07	1.4E-07	3.2E-07	4.1E-07	2.8E-07	2.4E-07
Total Type B Uncertainty	-	5.7E-06	8.5E-07	1.0E-06	4.8E-06	1.7E-06	1.6E-06	6.8E-07
Degrees of Freedom	-	109	2.6E+05	1.8E+06	1.9E+08	5.0E+04	4.4E+05	3.0E+04
Type A Uncertainty	-	7.7E-05	1.4E-05	1.2E-05	1.2E-05	8.6E-06	7.2E-06	9.2E-06
Total Uncertainty	-	7.7E-05	1.4E-05	1.2E-05	1.3E-05	8.8E-06	7.4E-06	9.2E-06
Degrees of Freedom	-	1.6E+03	1.6E+03	1.6E+03	2.2E+03	1.7E+03	1.8E+03	1.6E+03

Table E3e. Uncertainty budget for INMETRO, Filter E

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	-	-	2.0E-08	1.8E-08	8.8E-08	1.7E-07	1.5E-07	1.3E-07
Temperature	-	-	7.0E-08	1.1E-07	2.7E-07	3.6E-07	2.9E-07	1.4E-06
Wavelength	-	-	1.7E-07	1.1E-07	1.1E-06	1.1E-07	3.2E-07	2.6E-07
Stray Light	-	-	4.3E-09	4.0E-09	1.9E-08	3.7E-08	3.2E-08	2.8E-08
Beam Size & Position	-	-	2.0E-09	1.8E-09	8.8E-09	1.7E-08	1.5E-08	1.3E-08
Inter-reflection	-	-	8.4E-08	3.8E-08	9.1E-08	1.2E-07	7.3E-08	1.5E-07
Obliquity	-	-	6.5E-09	6.1E-09	2.9E-08	5.6E-08	4.9E-08	4.2E-08
Polarization	-	-	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	-	-	1.4E-08	9.3E-09	5.1E-08	6.7E-08	7.3E-08	5.7E-08
Bandwidth	-	-	6.7E-08	3.6E-08	2.7E-08	2.3E-08	2.0E-08	5.6E-08
System Fluctuation	-	-	9.0E-08	4.0E-08	6.5E-08	9.2E-08	1.0E-07	2.0E-07
Total Type B Uncertainty	-	-	2.3E-07	1.7E-07	1.2E-06	4.5E-07	4.8E-07	1.5E-06
Degrees of Freedom	-	-	5.4E+03	3.8E+04	2.3E+06	1.5E+04	1.4E+05	8.2E+05
Type A Uncertainty	-	-	6.5E-06	3.0E-06	5.1E-06	3.5E-06	3.8E-06	8.1E-06
Total Uncertainty	-	-	6.5E-06	3.0E-06	5.2E-06	3.5E-06	3.8E-06	8.2E-06
Degrees of Freedom	-	-	1.8E+03	1.8E+03	2.0E+03	1.9E+03	1.9E+03	1.9E+03

Table E4a. Uncertainty budget for CMS/ITRI, Filter A

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Temperature	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Wavelength	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Stray Light	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Beam Size & Position	3.14E-04	3.14E-04	3.14E-04	3.14E-04	3.14E-04	3.14E-04	3.14E-04	3.14E-04
Inter-reflection	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Obliquity	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Polarization	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
Source Drift & Fluctuation	4.23E-04	4.23E-04	4.23E-04	4.23E-04	4.23E-04	4.23E-04	4.23E-04	4.23E-04
Bandwidth	4.27E-04	4.27E-04	4.27E-04	4.27E-04	4.27E-04	4.27E-04	4.27E-04	4.27E-04
Total Type B Uncertainty	8.78E-04	8.78E-04	8.78E-04	8.78E-04	8.78E-04	8.78E-04	8.78E-04	8.78E-04
Degrees of Freedom	215	215	215	215	215	215	215	215
Type A Uncertainty	7.43E-05	1.58E-04	8.74E-05	1.08E-04	7.27E-05	2.11E-04	2.06E-04	2.55E-04
Total Uncertainty	8.82E-04	8.93E-04	8.83E-04	8.85E-04	8.82E-04	9.03E-04	9.02E-04	9.15E-04
Degrees of Freedom	219	220	219	220	219	211	212	194

Table E4b. Uncertainty budget for CMS/ITRI, Filter B

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Temperature	4.01E-05	8.78E-05	3.45E-05	9.07E-05	4.70E-05	2.22E-05	8.35E-06	2.86E-05
Wavelength	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Stray Light	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Beam Size & Position	3.14E-04	3.14E-04	3.14E-04	3.14E-04	3.14E-04	3.14E-04	3.14E-04	3.14E-04
Inter-reflection	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Obliquity	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Polarization	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04
Source Drift & Fluctuation	4.23E-04	4.23E-04	4.23E-04	4.23E-04	4.23E-04	4.23E-04	4.23E-04	4.23E-04
Bandwidth	4.27E-04	4.27E-04	4.27E-04	4.27E-04	4.27E-04	4.27E-04	4.27E-04	4.27E-04
Total Type B Uncertainty	8.20E-04	8.24E-04	8.20E-04	8.24E-04	8.20E-04	8.19E-04	8.19E-04	8.19E-04
Degrees of Freedom	224	228	224	228	224	223	223	223
Type A Uncertainty	6.91E-05	8.13E-05	7.92E-05	6.04E-05	5.44E-05	3.34E-04	1.18E-04	8.34E-05
Total Uncertainty	8.23E-04	8.29E-04	8.24E-04	8.27E-04	8.22E-04	8.85E-04	8.28E-04	8.24E-04
Degrees of Freedom	226	232	227	231	226	136	228	227

Table E4c. Uncertainty budget for CMS/ITRI, Filter C

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Temperature	9.52E-06	7.37E-05	2.94E-05	6.74E-05	5.54E-05	2.21E-05	6.12E-06	9.97E-06
Wavelength	1.00E-05	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Stray Light	1.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05
Beam Size & Position	8.50E-05	2.00E-04	2.00E-04	2.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04
Inter-reflection	5.00E-05	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Obliquity	5.00E-05	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Polarization	1.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04
Source Drift & Fluctuation	8.50E-05	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04
Bandwidth	7.00E-05	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Total Type B Uncertainty	1.87E-04	4.10E-04	4.05E-04	4.09E-04	5.35E-04	5.33E-04	5.32E-04	5.32E-04
Degrees of Freedom	254	270	258	268	140	138	137	137
Type A Uncertainty	9.29E-06	1.52E-05	1.29E-05	1.40E-05	2.12E-05	2.26E-04	2.23E-05	1.05E-05
Total Uncertainty	1.88E-04	4.11E-04	4.06E-04	4.10E-04	5.36E-04	5.80E-04	5.33E-04	5.33E-04
Degrees of Freedom	259	272	261	270	141	102	138	138

Table E4d. Uncertainty budget for CMS/ITRI, Filter D

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Temperature	3.05E-07	8.67E-06	5.25E-06	1.33E-05	1.80E-05	8.53E-06	2.19E-06	5.71E-06
Wavelength	1.00E-06	5.00E-06	5.00E-06	5.00E-06	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Stray Light	1.00E-06	3.00E-06	3.00E-06	3.00E-06	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Beam Size & Position	7.00E-07	1.00E-05	1.00E-05	1.00E-05	8.50E-05	8.50E-05	8.50E-05	8.50E-05
Inter-reflection	3.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-05	5.00E-05	5.00E-05	5.00E-05
Obliquity	1.50E-06	3.00E-05	3.00E-05	3.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05
Polarization	7.50E-06	7.50E-05	7.50E-05	7.50E-05	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Source Drift & Fluctuation	3.00E-06	3.00E-06	3.00E-06	3.00E-06	8.50E-05	8.50E-05	8.50E-05	8.50E-05
Bandwidth	1.50E-06	1.00E-05	2.00E-05	2.00E-05	7.00E-05	7.00E-05	7.00E-05	7.00E-05
Total Type B Uncertainty	9.08E-06	8.29E-05	8.44E-05	8.53E-05	1.88E-04	1.87E-04	1.87E-04	1.87E-04
Degrees of Freedom	102	73	78	81	259	254	254	254
Type A Uncertainty	1.18E-06	1.53E-06	3.60E-06	3.97E-06	1.31E-05	8.82E-06	1.39E-06	1.16E-06
Total Uncertainty	9.16E-06	8.30E-05	8.45E-05	8.54E-05	1.89E-04	1.88E-04	1.88E-04	1.88E-04
Degrees of Freedom	105	73	78	81	264	259	259	259

Table E4e. Uncertainty budget for CMS/ITRI, Filter E

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.00E-07	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
Temperature	1.19E-08	9.08E-07	9.04E-07	2.46E-06	5.32E-06	3.67E-06	1.10E-06	4.96E-06
Wavelength	1.00E-07	1.00E-06	1.00E-06	1.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06
Stray Light	2.00E-07	1.00E-06	1.00E-06	1.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06
Beam Size & Position	7.00E-07	7.00E-07	7.00E-07	1.00E-06	1.00E-06	1.00E-05	1.00E-05	1.00E-05
Inter-reflection	5.00E-07	1.00E-06	3.00E-06	3.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06
Obliquity	5.00E-07	1.50E-06	1.50E-06	1.50E-06	3.00E-05	3.00E-05	3.00E-05	3.00E-05
Polarization	1.00E-06	7.50E-06	7.50E-06	7.50E-06	7.50E-05	7.50E-05	7.50E-05	7.50E-05
Source Drift & Fluctuation	7.00E-07	1.00E-06	1.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06
Bandwidth	1.50E-06	1.50E-06	1.50E-06	1.50E-06	1.00E-05	2.00E-05	2.00E-05	2.00E-05
Total Type B Uncertainty	2.19E-06	8.19E-06	8.67E-06	9.43E-06	8.20E-05	8.44E-05	8.43E-05	8.44E-05
Degrees of Freedom	172	71	87	117	70	78	77	78
Type A Uncertainty	2.59E-07	1.23E-07	1.17E-06	1.66E-06	4.57E-06	1.82E-05	1.17E-06	2.34E-06
Total Uncertainty	2.21E-06	8.20E-06	8.75E-06	9.58E-06	8.22E-05	8.64E-05	8.44E-05	8.45E-05
Degrees of Freedom	178	71	89	122	70	83	78	78

Table E5a. Uncertainty budget for NIM, Filter A

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.31E-05	3.29E-05	9.83E-06	1.81E-05	2.55E-05	7.66E-05	4.27E-05	1.10E-04
Temperature	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wavelength	7.00E-06	3.89E-06	1.44E-06	4.81E-09	9.16E-07	8.96E-07	2.52E-07	1.34E-06
Stray Light	1.91E-04	1.31E-04	1.32E-04	2.78E-04	1.30E-04	1.40E-04	1.79E-04	7.78E-05
Beam Size & Position	1.37E-04	1.16E-04	1.02E-04	1.40E-04	7.58E-05	4.16E-05	1.21E-04	1.31E-04
Inter-reflection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Obliquity	1.91E-05	2.54E-05	6.35E-06	1.02E-04	3.23E-05	3.12E-05	8.54E-05	2.60E-05
Polarization	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7
Source Drift & Fluctuation	7.51E-05	8.08E-06	3.81E-05	1.05E-04	5.83E-05	5.20E-06	9.18E-05	6.47E-05
Bandwidth	6.99E-08	3.85E-08	1.44E-08	5.93E-09	9.16E-09	8.96E-09	2.51E-09	1.26E-08
Total Type B Uncertainty	2.48E-04	1.80E-04	1.71E-04	3.45E-04	1.67E-04	1.68E-04	2.54E-04	2.00E-04
Degrees of Freedom	14	18	14	12	13	10	20	220
Type A Uncertainty	1.92E-04	1.32E-04	1.32E-04	2.78E-04	1.32E-04	1.40E-04	1.80E-04	7.79E-05
Total Uncertainty	3.13E-04	2.24E-04	2.16E-04	4.43E-04	2.13E-04	2.18E-04	3.11E-04	2.15E-04
Degrees of Freedom	18	21	18	16	18	15	23	146

Table E5b. Uncertainty budget for NIM, Filter B

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	3.66E-05	1.37E-04	4.16E-05	7.49E-05	1.10E-04	2.99E-04	1.45E-04	3.38E-04
Temperature	2.18E-04	2.27E-04	9.87E-05	1.07E-04	1.30E-04	1.29E-04	1.12E-04	1.21E-04
Wavelength	7.58E-04	2.35E-05	1.61E-05	2.71E-06	1.27E-05	5.04E-05	1.66E-05	1.61E-05
Stray Light	2.18E-04	2.27E-04	9.84E-05	1.07E-04	1.30E-04	1.29E-04	1.11E-04	1.20E-04
Beam Size & Position	2.39E-04	1.46E-04	1.51E-04	1.70E-04	1.68E-04	2.17E-04	2.51E-04	2.77E-04
Inter-reflection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Obliquity	6.47E-05	6.12E-05	6.35E-06	1.21E-05	1.91E-05	3.46E-05	1.05E-04	1.93E-04
Polarization	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7
Source Drift & Fluctuation	1.15E-05	5.77E-07	2.02E-05	5.77E-05	4.73E-05	8.14E-05	4.04E-06	8.08E-06
Bandwidth	7.58E-06	3.54E-07	1.60E-07	1.77E-07	1.27E-07	5.04E-07	4.18E-07	1.62E-07
Total Type B Uncertainty	8.55E-04	3.84E-04	2.12E-04	2.47E-04	2.78E-04	4.25E-04	3.47E-04	5.08E-04
Degrees of Freedom	21	26	68	91	67	373	300	1.02E+03
Type A Uncertainty	2.18E-04	2.27E-04	9.87E-05	1.07E-04	1.31E-04	1.29E-04	1.12E-04	1.20E-04
Total Uncertainty	8.83E-04	4.46E-04	2.33E-04	2.69E-04	3.07E-04	4.44E-04	3.64E-04	5.22E-04
Degrees of Freedom	16	29	62	79	61	271	223	693

Table E5c. Uncertainty budget for NIM, Filter C

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	8.68E-06	7.19E-05	4.59E-05	4.10E-05	1.71E-04	1.69E-04	1.16E-04	1.40E-04
Temperature	1.00E-04	1.50E-04	3.87E-05	9.46E-05	5.62E-05	6.15E-05	4.23E-05	1.19E-05
Wavelength	1.43E-04	6.13E-05	2.14E-05	5.83E-06	4.31E-05	2.79E-05	2.38E-05	8.64E-06
Stray Light	1.00E-04	1.50E-04	3.82E-05	9.45E-05	5.55E-05	6.10E-05	4.17E-05	1.04E-05
Beam Size & Position	4.40E-05	1.17E-04	1.42E-04	1.51E-04	1.73E-04	1.54E-04	1.22E-04	1.02E-04
Inter-reflection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Obliquity	4.85E-06	1.03E-05	2.16E-05	3.38E-05	2.54E-05	2.54E-05	2.08E-05	1.84E-05
Polarization	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7
Source Drift & Fluctuation	1.75E-05	1.98E-05	9.99E-06	1.76E-05	9.81E-06	1.62E-05	5.77E-06	6.18E-06
Bandwidth	1.43E-06	6.13E-07	2.14E-07	1.21E-07	8.57E-07	2.79E-07	2.38E-07	1.46E-07
Total Type B Uncertainty	2.07E-04	2.61E-04	1.62E-04	2.09E-04	2.61E-04	2.48E-04	1.82E-04	1.76E-04
Degrees of Freedom	29	29	992	77	1.42E+03	857	1.11E+03	1.91E+05
Type A Uncertainty	1.00E-04	1.50E-04	3.83E-05	9.46E-05	5.55E-05	6.10E-05	4.18E-05	1.37E-05
Total Uncertainty	2.30E-04	3.01E-04	1.66E-04	2.29E-04	2.67E-04	2.55E-04	1.87E-04	1.76E-04
Degrees of Freedom	29	32	681	68	962	591	755	1.09E+05

Table E5d. Uncertainty budget for NIM, Filter D

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	3.45E-07	5.90E-06	1.09E-05	1.16E-05	4.72E-05	6.21E-05	4.62E-05	4.50E-05
Temperature	3.57E-05	2.78E-05	8.37E-06	1.86E-05	2.18E-05	6.74E-06	7.65E-06	1.05E-05
Wavelength	4.37E-06	9.64E-06	9.14E-07	2.56E-06	2.00E-05	4.70E-06	7.80E-06	2.28E-06
Stray Light	3.57E-05	2.78E-05	8.29E-06	1.86E-05	2.16E-05	5.88E-06	7.22E-06	1.03E-05
Beam Size & Position	1.31E-05	3.66E-05	5.11E-05	5.38E-05	1.33E-04	1.47E-04	1.13E-04	8.44E-05
Inter-reflection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Obliquity	1.24E-05	4.40E-06	8.08E-08	1.56E-06	4.50E-06	8.72E-06	3.12E-06	6.70E-06
Polarization	<1E-7	< 1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7
Source Drift & Fluctuation	4.54E-06	2.40E-06	1.54E-06	8.66E-07	3.58E-06	4.62E-07	6.00E-06	3.70E-06
Bandwidth	4.37E-08	9.64E-08	9.18E-09	2.56E-08	2.00E-07	4.70E-08	7.80E-08	1.56E-07
Total Type B Uncertainty	5.40E-05	5.51E-05	5.36E-05	6.10E-05	1.46E-04	1.60E-04	1.23E-04	9.71E-05
Degrees of Freedom	17	49	5.55E+03	371	5.62E+03	1.30E+06	1.88E+05	2.49E+04
Type A Uncertainty	3.59E-05	2.79E-05	8.31E-06	1.86E-05	2.17E-05	6.10E-06	7.30E-06	1.03E-05
Total Uncertainty	6.48E-05	6.18E-05	5.42E-05	6.38E-05	1.48E-04	1.60E-04	1.23E-04	9.77E-05
Degrees of Freedom	21	48	3.56E+03	270	3.66E+03	8.67E+05	1.22E+05	1.57E+04

Table E5e. Uncertainty budget for NIM, Filter E

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	3.97E-08	9.86E-07	2.94E-06	1.64E-06	1.15E-05	1.97E-05	1.85E-05	2.13E-05
Temperature	9.23E-07	2.01E-05	6.52E-06	3.25E-06	4.59E-06	4.09E-06	4.33E-06	9.47E-06
Wavelength	2.61E-07	8.44E-07	1.56E-07	4.36E-07	4.94E-06	7.14E-07	1.16E-06	2.01E-07
Stray Light	9.23E-07	2.01E-05	6.53E-06	3.25E-06	4.55E-06	3.89E-06	4.19E-06	9.41E-06
Beam Size & Position	1.80E-06	6.68E-06	8.50E-06	8.58E-06	3.46E-05	5.94E-05	5.34E-05	4.73E-05
Inter-reflection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Obliquity	1.25E-06	3.20E-07	1.50E-06	9.24E-07	5.14E-06	9.23E-06	8.13E-06	6.60E-06
Polarization	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7	<1E-7
Source Drift & Fluctuation	5.14E-07	2.70E-06	4.94E-07	2.89E-09	1.15E-07	1.13E-06	1.10E-07	8.08E-08
Bandwidth	2.63E-09	8.43E-09	1.56E-09	4.36E-09	4.94E-08	7.14E-09	1.98E-08	2.07E-09
Total Type B Uncertainty	2.62E-06	2.94E-05	1.30E-05	9.93E-06	3.77E-05	6.36E-05	5.75E-05	5.40E-05
Degrees of Freedom	207	15	50	279	1.12E+04	2.12E+05	1.08E+05	3.44E+03
Type A Uncertainty	1.11E-06	2.03E-05	6.59E-06	3.37E-06	4.54E-06	3.94E-06	4.21E-06	9.42E-06
Total Uncertainty	2.84E-06	3.57E-05	1.46E-05	1.05E-05	3.79E-05	6.37E-05	5.76E-05	5.48E-05
Degrees of Freedom	163	19	49	211	7.26E+03	1.34E+05	6.76E+04	2.23E+03

Table E6a. Uncertainty budget for NIMT, Filter A

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	4.00E-04	4.00E-04
Temperature	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Wavelength	1.13E-05	4.77E-06	4.19E-06	1.22E-06	1.50E-06	4.10E-06	8.31E-06	5.83E-06
Stray Light	nc	nc	nc	nc	nc	nc	nc	nc
Beam Size & Position	6.86E-04	6.88E-04	6.90E-04	6.91E-04	6.91E-04	6.92E-04	6.92E-04	6.93E-04
Inter-reflection	nc	nc	nc	nc	nc	nc	nc	nc
Obliquity	nc	nc	nc	nc	nc	nc	nc	nc
Polarization	nc	nc	nc	nc	nc	nc	nc	nc
Source Drift & Fluctuation	1.93E-04	1.77E-04	5.41E-04	5.38E-04	5.36E-04	5.36E-04	5.37E-04	5.38E-04
Bandwidth	nc	nc	nc	nc	nc	nc	nc	nc
Scale Bias	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.91E-03
Total Type B Uncertainty	3.06E-03	3.06E-03	3.10E-03	3.10E-03	3.10E-03	3.10E-03	3.07E-03	3.07E-03
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	4.17E-04	4.05E-04	3.55E-04	3.67E-04	3.46E-04	3.22E-04	3.35E-04	3.59E-04
Total Uncertainty	3.10E-03	3.10E-03	3.20E-03	3.20E-03	3.20E-03	3.20E-03	3.10E-03	3.10E-03
Degrees of Freedom	3.36E+04	3.78E+04	7.26E+04	6.36E+04	8.05E+04	1.07E+05	8.07E+04	6.12E+04

Table E6b. Uncertainty budget for NIMT, Filter B

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	4.00E-04	4.00E-04
Temperature	7.04E-05	9.74E-05	3.90E-05	1.00E-04	5.07E-05	2.94E-05	2.12E-05	4.76E-05
Wavelength	8.80E-04	8.61E-05	1.07E-05	6.88E-06	2.19E-05	2.09E-04	1.72E-04	9.06E-05
Stray Light	nc	nc	nc	nc	nc	nc	nc	nc
Beam Size & Position	5.40E-04	7.92E-04	8.11E-04	7.95E-04	8.30E-04	7.51E-04	6.51E-04	5.88E-04
Inter-reflection	nc	nc	nc	nc	nc	nc	nc	nc
Obliquity	nc	nc	nc	nc	nc	nc	nc	nc
Polarization	nc	nc	nc	nc	nc	nc	nc	nc
Source Drift & Fluctuation	1.52E-04	1.62E-04	5.37E-04	5.28E-04	5.31E-04	5.31E-04	5.29E-04	5.28E-04
Bandwidth	nc	nc	nc	nc	nc	nc	nc	nc
Scale Bias	1.79E-03	2.25E-03	2.25E-03	2.25E-03	2.25E-03	2.15E-03	1.97E-03	1.88E-03
Total Type B Uncertainty	2.16E-03	2.47E-03	2.52E-03	2.52E-03	2.53E-03	2.43E-03	2.18E-03	2.08E-03
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	5.71E-04	1.75E-04	1.80E-04	1.70E-04	1.63E-04	1.39E-04	1.32E-04	1.07E-04
Total Uncertainty	2.30E-03	2.50E-03	2.60E-03	2.60E-03	2.60E-03	2.50E-03	2.20E-03	2.10E-03
Degrees of Freedom	2.90E+03	4.58E+05	4.79E+05	6.02E+05	7.12E+05	1.15E+06	8.49E+05	1.63E+06

Table E6c. Uncertainty budget for NIMT, Filter C

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	4.00E-04	4.00E-04
Temperature	3.21E-04	5.25E-04	2.26E-04	5.94E-04	2.37E-04	1.14E-04	7.72E-05	1.65E-04
Wavelength	2.22E-04	1.02E-04	3.34E-05	1.94E-05	1.41E-04	1.33E-04	1.07E-04	4.04E-05
Stray Light	nc	nc	nc	nc	nc	nc	nc	nc
Beam Size & Position	1.60E-05	6.68E-05	6.49E-05	5.44E-05	1.13E-04	1.06E-04	7.17E-05	5.35E-05
Inter-reflection	nc	nc	nc	nc	nc	nc	nc	nc
Obliquity	nc	nc	nc	nc	nc	nc	nc	nc
Polarization	nc	nc	nc	nc	nc	nc	nc	nc
Source Drift & Fluctuation	1.29E-04	1.30E-04	5.24E-04	5.24E-04	5.24E-04	5.24E-04	5.25E-04	5.24E-04
Bandwidth	nc	nc	nc	nc	nc	nc	nc	nc
Scale Bias	1.06E-03	1.20E-03	1.20E-03	1.20E-03	1.36E-03	1.28E-03	1.20E-03	1.20E-03
Total Type B Uncertainty	1.29E-03	1.45E-03	1.46E-03	1.56E-03	1.60E-03	1.52E-03	1.38E-03	1.38E-03
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	1.12E-04	8.70E-05	5.20E-05	6.30E-05	1.07E-04	7.00E-05	7.80E-05	6.00E-05
Total Uncertainty	1.30E-03	1.50E-03	1.50E-03	1.60E-03	1.70E-03	1.60E-03	1.40E-03	1.40E-03
Degrees of Freedom	2.00E+05	9.72E+05	7.62E+06	4.58E+06	7.01E+05	3.00E+06	1.14E+06	3.26E+06

Table E6d. Uncertainty budget for NIMT, Filter D

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	4.00E-04	4.00E-04
Temperature	6.74E-04	1.19E-03	4.59E-04	1.13E-03	4.82E-04	2.09E-04	1.29E-04	2.65E-04
Wavelength	8.44E-06	1.52E-05	2.13E-06	5.05E-06	3.29E-05	1.79E-05	2.15E-05	6.13E-06
Stray Light	nc	nc	nc	nc	nc	nc	nc	nc
Beam Size & Position	1.00E-06	4.53E-06	7.55E-06	7.36E-06	2.31E-05	2.80E-05	1.90E-05	1.42E-05
Inter-reflection	nc	nc	nc	nc	nc	nc	nc	nc
Obliquity	nc	nc	nc	nc	nc	nc	nc	nc
Polarization	nc	nc	nc	nc	nc	nc	nc	nc
Source Drift & Fluctuation	1.28E-04	1.28E-04	5.23E-04	5.23E-04	5.23E-04	5.24E-04	5.25E-04	5.24E-04
Bandwidth	nc	nc	nc	nc	nc	nc	nc	nc
Scale Bias	1.06E-03	1.06E-03	1.06E-03	1.06E-03	1.06E-03	1.13E-03	1.06E-03	1.06E-03
Total Type B Uncertainty	1.40E-03	1.71E-03	1.41E-03	1.74E-03	1.41E-03	1.40E-03	1.26E-03	1.28E-03
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	6.00E-06	7.00E-06	1.00E-05	1.20E-05	1.30E-05	2.00E-05	6.50E-05	5.90E-05
Total Uncertainty	1.50E-03	1.80E-03	1.50E-03	1.80E-03	1.50E-03	1.50E-03	1.30E-03	1.30E-03
Degrees of Freedom	4.30E+10	4.81E+10	5.57E+09	5.57E+09	1.95E+09	3.48E+08	1.76E+06	2.59E+06

Table E6e. Uncertainty budget for NIMT, Filter E

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04	4.00E-04	4.00E-04
Temperature	9.77E-04	1.84E-03	6.80E-04	1.66E-03	7.17E-04	2.88E-04	1.65E-04	4.86E-04
Wavelength	5.47E-07	1.56E-06	5.97E-07	1.36E-06	8.79E-06	4.22E-06	1.80E-05	6.74E-06
Stray Light	nc	nc	nc	nc	nc	nc	nc	nc
Beam Size & Position	1.00E-06	1.00E-06	9.66E-07	8.88E-07	4.49E-06	8.57E-06	6.92E-06	5.96E-06
Inter-reflection	nc	nc	nc	nc	nc	nc	nc	nc
Obliquity	nc	nc	nc	nc	nc	nc	nc	nc
Polarization	nc	nc	nc	nc	nc	nc	nc	nc
Source Drift & Fluctuation	1.28E-04	1.28E-04	5.23E-04	5.23E-04	5.23E-04	5.23E-04	5.27E-04	5.24E-04
Bandwidth	nc	nc	nc	nc	nc	nc	nc	nc
Scale Bias	1.06E-03	1.06E-03	1.06E-03	1.06E-03	1.06E-03	1.06E-03	1.06E-03	1.06E-03
Total Type B Uncertainty	1.57E-03	2.21E-03	1.49E-03	2.12E-03	1.51E-03	1.36E-03	1.26E-03	1.34E-03
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	1.10E-05	1.20E-05	1.10E-05	1.20E-05	1.80E-05	1.30E-05	5.10E-05	3.60E-05
Total Uncertainty	1.60E-03	2.30E-03	1.50E-03	2.20E-03	1.60E-03	1.40E-03	1.30E-03	1.40E-03
Degrees of Freedom	4.92E+09	1.48E+10	3.80E+09	1.24E+10	6.87E+08	1.48E+09	4.64E+06	2.52E+07

Table E7a. Uncertainty budget for NRC, Filter A

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.21E-05	1.19E-05	1.16E-05	1.14E-05	1.12E-05	1.11E-05	1.11E-05	1.10E-05
Temperature	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wavelength	1.49E-06	5.80E-07	2.48E-06	4.93E-07	5.47E-07	6.97E-07	2.59E-07	9.00E-07
Stray Light	8.05E-06	7.91E-06	7.71E-06	7.57E-06	7.48E-06	7.40E-06	7.37E-06	7.34E-06
Beam Size & Position	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inter-reflection	9.20E-05	8.23E-05	6.72E-05	7.36E-05	7.47E-05	7.50E-05	5.42E-05	7.25E-05
Obliquity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	8.17E-08	7.23E-08	8.08E-10	1.81E-09	4.14E-09	1.37E-08	9.28E-09	1.47E-08
Total Type B Uncertainty	9.37E-05	8.41E-05	6.94E-05	7.55E-05	7.66E-05	7.68E-05	5.67E-05	7.44E-05
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	2.03E-04	1.43E-04	1.37E-04	1.30E-04	1.36E-04	1.54E-04	1.08E-04	9.55E-05
Total Uncertainty	2.23E-04	1.66E-04	1.53E-04	1.50E-04	1.56E-04	1.72E-04	1.22E-04	1.21E-04
Degrees of Freedom	10	13	11	13	12	11	11	11

Table E7b. Uncertainty budget for NRC, Filter B

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	3.63E-05	3.57E-05	3.52E-05	3.57E-05	3.46E-05	3.66E-05	3.75E-05	3.72E-05
Temperature	3.33E-06	2.11E-06	2.13E-06	2.65E-06	1.60E-06	1.69E-06	2.89E-06	3.19E-06
Wavelength	1.17E-04	6.87E-06	1.42E-05	3.82E-06	1.13E-05	4.78E-05	3.86E-05	2.24E-05
Stray Light	2.42E-05	2.38E-05	2.35E-05	2.38E-05	2.31E-05	2.44E-05	2.50E-05	2.48E-05
Beam Size & Position	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inter-reflection	8.69E-06	3.27E-05	3.51E-05	4.35E-05	4.31E-05	7.71E-06	6.87E-06	1.88E-05
Obliquity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	1.16E-04	1.99E-05	5.93E-07	1.04E-07	1.59E-06	1.04E-07	1.14E-07	2.19E-06
Total Type B Uncertainty	1.71E-04	5.88E-05	5.77E-05	6.21E-05	6.18E-05	6.62E-05	6.06E-05	5.45E-05
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	7.08E-05	4.65E-05	4.80E-05	3.61E-05	7.24E-05	6.40E-05	3.58E-05	4.79E-05
Total Uncertainty	1.85E-04	7.50E-05	7.51E-05	7.18E-05	9.52E-05	9.21E-05	7.04E-05	7.26E-05
Degrees of Freedom	328	47	42	110	21	30	104	37

Table E7c. Uncertainty budget for NRC, Filter C

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	3.18E-06	1.31E-05	1.26E-05	1.08E-05	2.04E-05	1.93E-05	1.39E-05	1.07E-05
Temperature	7.74E-07	1.71E-06	1.85E-06	1.90E-06	1.84E-06	1.74E-06	2.18E-06	1.85E-06
Wavelength	2.30E-05	1.06E-05	4.08E-05	1.08E-05	7.57E-05	3.07E-05	2.27E-05	9.41E-06
Stray Light	2.12E-06	8.71E-06	8.43E-06	7.18E-06	1.36E-05	1.28E-05	9.29E-06	7.13E-06
Beam Size & Position	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inter-reflection	7.98E-05	7.48E-05	4.07E-05	1.24E-05	2.89E-05	1.71E-05	5.39E-06	3.58E-06
Obliquity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization	2.00E-06	2.00E-06	2.00E-06	2.00E-06	3.00E-06	3.00E-06	3.00E-06	4.00E-06
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	2.63E-05	1.10E-05	7.42E-07	3.49E-07	2.64E-06	4.83E-08	4.28E-08	1.46E-07
Total Type B Uncertainty	8.72E-05	7.80E-05	5.97E-05	2.11E-05	8.48E-05	4.22E-05	2.89E-05	1.69E-05
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	8.80E-06	1.48E-05	8.96E-06	7.22E-06	9.33E-06	1.05E-05	1.08E-05	4.88E-06
Total Uncertainty	8.76E-05	7.94E-05	6.04E-05	2.23E-05	8.53E-05	4.35E-05	3.09E-05	1.76E-05
Degrees of Freedom	694	5.83E+03	1.44E+04	6.39E+02	4.89E+04	2.05E+03	463	1.18E+03

Table E7d. Uncertainty budget for NRC, Filter D

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	1.13E-09	7.04E-08	1.06E-07	8.64E-08	5.38E-07	5.73E-07	2.73E-07	1.51E-07
Temperature	2.94E-08	3.55E-07	5.05E-07	5.46E-07	9.98E-07	1.05E-06	1.25E-06	1.02E-06
Wavelength	7.24E-07	1.57E-06	2.70E-06	2.44E-06	1.74E-05	4.39E-06	4.14E-06	5.61E-07
Stray Light	7.52E-10	4.69E-08	7.07E-08	5.76E-08	3.59E-07	3.82E-07	1.82E-07	1.01E-07
Beam Size & Position	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inter-reflection	7.51E-07	8.24E-06	5.36E-06	4.15E-06	5.89E-06	4.59E-07	3.07E-06	2.26E-06
Obliquity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	8.57E-07	8.85E-07	7.27E-08	5.18E-08	3.64E-08	3.43E-08	2.87E-08	4.61E-08
Total Type B Uncertainty	1.35E-06	8.44E-06	6.02E-06	4.85E-06	1.84E-05	4.59E-06	5.31E-06	2.55E-06
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	6.65E-07	1.87E-06	1.41E-06	1.38E-06	3.28E-06	4.14E-06	5.38E-06	2.53E-06
Total Uncertainty	1.50E-06	8.64E-06	6.18E-06	5.04E-06	1.87E-05	6.18E-06	7.56E-06	3.59E-06
Degrees of Freedom	184	3.20E+03	2.59E+03	1.25E+03	7.38E+03	35	27	28

Table E7e. Uncertainty budget for NRC, Filter E

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	6.38E-13	2.41E-10	1.04E-09	1.09E-09	1.60E-08	3.24E-08	1.77E-08	1.01E-08
Temperature	1.07E-09	3.98E-08	1.58E-07	1.69E-07	4.19E-07	5.19E-07	5.89E-07	4.96E-07
Wavelength	2.73E-08	1.72E-07	3.46E-07	4.50E-07	4.69E-06	5.52E-07	9.18E-07	5.92E-07
Stray Light	4.25E-13	1.60E-10	6.92E-10	7.24E-10	1.07E-08	2.16E-08	8.35E-07	7.06E-07
Beam Size & Position	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inter-reflection	0.0	0.0	0.0	0.0	1.83E-06	4.47E-06	2.64E-06	1.55E-06
Obliquity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	1.00E-08	4.45E-08	8.48E-09	1.05E-08	4.31E-08	1.95E-08	9.09E-09	7.17E-08
Total Type B Uncertainty	2.91E-08	1.82E-07	3.80E-07	4.81E-07	5.05E-06	4.53E-06	2.98E-06	1.87E-06
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	4.53E-08	5.12E-07	3.52E-07	2.65E-07	9.13E-07	1.72E-06	9.23E-07	1.07E-06
Total Uncertainty	5.38E-08	5.43E-07	5.18E-07	5.49E-07	5.13E-06	4.85E-06	3.12E-06	2.16E-06
Degrees of Freedom	14	9	33	129	6.99E+03	441	914	114

Table E8a. Uncertainty budget for NIST, Filter A, Round 1

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	4.56E-05	4.57E-05	4.58E-05	4.59E-05	4.60E-05	4.60E-05	4.60E-05	4.60E-05
Temperature Correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wavelength	1.38E-05	9.76E-06	1.95E-06	2.32E-06	1.25E-06	8.68E-07	7.36E-07	8.68E-07
Stray Light	1.28E-05	5.85E-06	4.24E-07	4.49E-08	2.74E-08	6.61E-08	1.97E-07	2.66E-07
Beam Size & Position	6.11E-05	6.13E-05	6.15E-05	6.16E-05	6.16E-05	6.17E-05	6.17E-05	6.18E-05
Inter-reflection	4.68E-04	4.69E-04	4.71E-04	4.71E-04	4.72E-04	4.72E-04	4.73E-04	4.73E-04
Obliquity	2.59E-07	2.59E-07	2.59E-07	2.59E-07	2.59E-07	2.59E-07	2.59E-07	2.59E-07
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	3.65E-06	3.65E-06	3.67E-06	3.67E-06	3.68E-06	3.68E-06	3.68E-06	3.68E-06
Detector range ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	3.19E-04	3.20E-04	3.21E-04	3.21E-04	3.22E-04	3.22E-04	3.22E-04	3.22E-04
Total Type B Uncertainty	5.72E-04	5.73E-04	5.75E-04	5.76E-04	5.76E-04	5.77E-04	5.77E-04	5.77E-04
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	6.58E-05	6.58E-05	6.58E-05	6.58E-05	6.58E-05	6.58E-05	6.58E-05	6.58E-05
Total Uncertainty	5.76E-04	5.77E-04	5.78E-04	5.79E-04	5.80E-04	5.81E-04	5.81E-04	5.81E-04
Degrees of Freedom	2.34E+04	2.36E+04	2.39E+04	2.40E+04	2.42E+04	2.42E+04	2.43E+04	2.43E+04

Table E8b. Uncertainty budget for NIST, Filter B, Round 1

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	4.16E-05	0.0	6.21E-05	6.09E-05	6.36E-05	5.75E-05	5.00E-05	4.52E-05
Temperature Correction	1.09E-05	8.92E-06	7.82E-06	8.95E-06	8.02E-06	8.46E-06	9.45E-06	1.04E-05
Temperature Fluctuation	1.01E-05	2.16E-05	8.50E-06	2.23E-05	1.16E-05	5.48E-06	2.06E-06	7.04E-06
Wavelength	1.66E-03	9.48E-04	2.56E-04	8.59E-05	9.51E-05	1.04E-04	8.60E-05	3.45E-05
Stray Light	2.44E-04	1.89E-05	5.18E-06	1.85E-06	3.48E-06	9.10E-07	8.25E-06	1.92E-05
Beam Size & Position	7.27E-05	1.06E-04	1.08E-04	1.06E-04	1.11E-04	1.00E-04	8.73E-05	7.89E-05
Inter-reflection	7.27E-05	1.06E-04	1.08E-04	1.06E-04	1.11E-04	1.00E-04	8.73E-05	7.88E-05
Obliquity	1.11E-06	1.11E-06	1.11E-06	1.11E-06	1.11E-06	1.11E-06	1.11E-06	1.11E-06
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	5.00E-06	7.28E-06	7.45E-06	7.31E-06	7.64E-06	6.90E-06	6.00E-06	5.42E-06
Detector range ratio	0.0	1.21E-04	0.0	0.0	0.0	0.0	0.0	0.0
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	1.46E-04	2.12E-04	2.17E-04	2.13E-04	2.23E-04	2.01E-04	1.75E-04	1.58E-04
Total Type B Uncertainty	1.69E-03	9.91E-04	3.75E-04	2.82E-04	2.96E-04	2.74E-04	2.37E-04	2.03E-04
Degrees of Freedom	5.00E+09	6.36E+08	4.54E+07	3.88E+06	1.46E+07	9.85E+06	3.54E+06	1.28E+06
Type A Uncertainty	5.64E-04	3.98E-05	3.98E-05	3.98E-05	3.98E-05	3.98E-05	3.98E-05	3.98E-05
Total Uncertainty	2.10E-03*	9.92E-04	3.77E-04	2.85E-04	2.99E-04	2.77E-04	2.66E-04*	3.71E-04*
Degrees of Freedom	769	1.54E+06	3.22E+04	1.05E+04	1.27E+04	9.37E+03	7.97E+03	3.01E+04

Table E8c. Uncertainty budget for NIST, Filter C, Round 1

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	0.0	0.0	0.0	0.0	1.61E-05	0.0	0.0	0.0
Temperature Correction	2.71E-06	7.21E-06	6.76E-06	6.40E-06	9.15E-06	8.67E-06	7.12E-06	6.02E-06
Temperature Fluctuation	2.61E-06	1.83E-05	7.29E-06	1.68E-05	1.38E-05	5.50E-06	1.52E-06	4.16E-06
Wavelength	6.11E-04	3.49E-04	1.25E-04	8.23E-05	6.53E-05	5.90E-05	5.57E-05	4.69E-06
Stray Light	1.38E-04	1.68E-05	3.24E-06	2.80E-06	3.05E-06	3.86E-06	1.23E-06	5.64E-06
Beam Size & Position	3.75E-06	1.53E-05	1.47E-05	1.23E-05	2.58E-05	2.40E-05	1.64E-05	1.22E-05
Inter-reflection	4.46E-06	1.82E-05	1.75E-05	1.47E-05	3.07E-05	2.86E-05	1.96E-05	1.46E-05
Obliquity	8.95E-07	8.95E-07	8.95E-07	8.95E-07	8.95E-07	8.95E-07	8.95E-07	8.95E-07
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	2.16E-06	8.78E-06	8.46E-06	7.09E-06	1.48E-05	1.38E-05	9.45E-06	7.04E-06
Detector range ratio	0.0	1.91E-05	0.0	0.0	0.0	4.50E-06	0.0	0.0
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	8.21E-06	3.34E-05	3.22E-05	2.70E-05	5.65E-05	5.25E-05	3.60E-05	2.68E-05
Total Type B Uncertainty	6.27E-04	3.53E-04	1.32E-04	9.08E-05	9.91E-05	8.92E-05	7.21E-05	3.52E-05
Degrees of Freedom	2.52E+10	2.17E+07	1.25E+06	1.41E+05	1.06E+05	1.01E+05	9.45E+04	1.04E+04
Type A Uncertainty	1.32E-04	5.26E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05
Total Uncertainty	6.41E-04	3.57E-04	1.32E-04	9.14E-05	1.04E-04*	8.98E-05	7.28E-05	7.88E-05*
Degrees of Freedom	2.24E+03	8.53E+03	9.67E+04	2.04E+04	2.99E+04	1.82E+04	8.72E+03	1.25E+04

Table E8d. Uncertainty budget for NIST, Filter D, Round 1

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature Correction	1.11E-07	8.84E-07	1.25E-06	1.33E-06	3.09E-06	3.41E-06	2.63E-06	2.12E-06
Temperature Fluctuation	1.02E-07	2.30E-06	1.38E-06	3.49E-06	4.64E-06	2.20E-06	5.67E-07	1.47E-06
Wavelength	3.75E-05	2.45E-05	6.48E-06	1.39E-05	2.11E-05	5.42E-06	1.50E-05	4.46E-06
Stray Light	3.12E-05	1.18E-05	1.52E-06	8.08E-07	4.85E-07	1.45E-06	3.28E-07	3.85E-07
Beam Size & Position	6.33E-07	7.59E-06	1.23E-05	1.22E-05	3.85E-05	4.68E-05	3.28E-05	2.43E-05
Inter-reflection	1.55E-07	1.86E-06	3.00E-06	2.97E-06	9.41E-06	1.14E-05	8.01E-06	5.93E-06
Obliquity	3.37E-07	3.37E-07	3.37E-07	3.37E-07	3.37E-07	3.37E-07	3.37E-07	3.37E-07
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	4.62E-08	5.54E-07	8.96E-07	8.87E-07	2.81E-06	3.41E-06	2.39E-06	1.77E-06
Detector range ratio	8.79E-08	1.05E-06	1.71E-06	1.69E-06	5.35E-06	6.50E-06	4.55E-06	3.37E-06
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	1.54E-07	1.85E-06	2.99E-06	2.96E-06	9.36E-06	1.14E-05	7.96E-06	5.90E-06
Total Type B Uncertainty	4.88E-05	2.85E-05	1.48E-05	1.95E-05	4.66E-05	5.05E-05	3.82E-05	2.65E-05
Degrees of Freedom	3.33E+11	3.80E+06	1.68E+05	1.58E+05	3.97E+05	4.30E+05	4.01E+05	2.16E+05
Type A Uncertainty	3.03E-06	3.03E-06	3.03E-06	3.03E-06	3.03E-06	3.03E-06	3.03E-06	3.03E-06
Total Uncertainty	4.89E-05	2.86E-05	1.52E-05	1.97E-05	4.67E-05	5.06E-05	3.83E-05	2.67E-05
Degrees of Freedom	2.70E+05	3.15E+04	2.46E+03	6.80E+03	1.44E+05	1.80E+05	8.13E+04	2.15E+04

Table E8e. Uncertainty budget for NIST, Filter E, Round 1

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature Correction	7.67E-09	9.22E-08	2.04E-07	2.40E-07	8.37E-07	1.40E-06	1.22E-06	1.11E-06
Temperature Fluctuation	7.05E-09	2.28E-07	2.20E-07	5.99E-07	1.28E-06	8.87E-07	2.66E-07	1.20E-06
Wavelength	2.48E-06	2.02E-06	4.12E-07	2.39E-06	7.53E-06	2.44E-06	3.75E-06	2.27E-06
Stray Light	4.45E-06	3.93E-06	5.32E-07	2.74E-07	1.11E-08	5.22E-07	3.44E-07	3.18E-07
Beam Size & Position	7.97E-08	1.29E-06	3.52E-06	3.77E-06	1.90E-05	3.64E-05	3.17E-05	2.68E-05
Inter-reflection	2.13E-08	3.46E-07	9.42E-07	1.01E-06	5.08E-06	9.74E-06	8.49E-06	7.18E-06
Obliquity	1.41E-07	1.41E-07	1.41E-07	1.41E-07	1.41E-07	1.41E-07	1.41E-07	1.41E-07
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	2.72E-09	4.40E-08	1.20E-07	1.29E-07	6.47E-07	1.24E-06	1.08E-06	9.14E-07
Detector range ratio	4.18E-09	6.78E-08	1.85E-07	1.98E-07	9.96E-07	1.91E-06	1.66E-06	1.41E-06
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	7.32E-09	1.19E-07	3.23E-07	3.46E-07	1.74E-06	3.34E-06	2.91E-06	2.46E-06
Total Type B Uncertainty	5.09E-06	4.63E-06	3.74E-06	4.65E-06	2.12E-05	3.80E-05	3.32E-05	2.80E-05
Degrees of Freedom	1.70E+12	2.53E+07	9.73E+05	5.52E+05	3.11E+06	4.80E+06	4.91E+06	3.54E+06
Type A Uncertainty	3.21E-06	8.66E-07	8.66E-07	8.66E-07	8.66E-07	8.66E-07	8.66E-07	8.66E-07
Total Uncertainty	6.02E-06	4.71E-06	3.84E-06	4.73E-06	2.12E-05	3.80E-05	3.32E-05	2.80E-05
Degrees of Freedom	50	3.50E+03	1.54E+03	3.53E+03	9.84E+05	3.63E+06	3.14E+06	1.96E+06

Table E9a. Uncertainty budget for NIST, Filter A, Round 3

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	4.56E-05	4.57E-05	4.58E-05	4.59E-05	4.59E-05	4.60E-05	4.60E-05	4.60E-05
Temperature Correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wavelength	1.38E-05	9.76E-06	1.95E-06	2.32E-06	1.25E-06	8.68E-07	7.36E-07	8.68E-07
Stray Light	1.28E-05	5.84E-06	4.24E-07	4.49E-08	2.74E-08	6.60E-08	1.97E-07	2.66E-07
Beam Size & Position	6.11E-05	6.12E-05	6.14E-05	6.16E-05	6.16E-05	6.17E-05	6.17E-05	6.17E-05
Inter-reflection	4.68E-04	4.69E-04	4.70E-04	4.71E-04	4.72E-04	4.72E-04	4.73E-04	4.73E-04
Obliquity	2.59E-07	2.59E-07	2.59E-07	2.59E-07	2.59E-07	2.59E-07	2.59E-07	2.59E-07
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	3.65E-06	3.65E-06	3.66E-06	3.67E-06	3.68E-06	3.68E-06	3.68E-06	3.68E-06
Detector range ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	3.19E-04	3.20E-04	3.21E-04	3.21E-04	3.22E-04	3.22E-04	3.22E-04	3.22E-04
Total Type B Uncertainty	5.72E-04	5.73E-04	5.74E-04	5.76E-04	5.76E-04	5.77E-04	5.77E-04	5.77E-04
Degrees of Freedom	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.	Inf.
Type A Uncertainty	1.78E-05	1.78E-05	1.78E-05	1.78E-05	1.78E-05	1.78E-05	1.78E-05	1.78E-05
Total Uncertainty	5.72E-04	5.73E-04	5.75E-04	5.76E-04	5.76E-04	5.77E-04	5.77E-04	5.78E-04
Degrees of Freedom	4.28E+06	4.30E+06	4.35E+06	4.39E+06	4.41E+06	4.42E+06	4.43E+06	4.44E+06

Table E9b. Uncertainty budget for NIST, Filter B, Round 3

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	4.15E-05	0.0	6.21E-05	6.09E-05	6.36E-05	5.75E-05	5.00E-05	4.51E-05
Temperature Correction	1.13E-05	9.23E-06	8.10E-06	9.27E-06	8.30E-06	8.75E-06	9.78E-06	1.08E-05
Temperature Fluctuation	8.32E-06	1.78E-05	7.00E-06	1.84E-05	9.55E-06	4.52E-06	1.70E-06	5.80E-06
Wavelength	1.66E-03	9.48E-04	2.56E-04	8.59E-05	9.51E-05	1.04E-04	8.60E-05	3.45E-05
Stray Light	2.43E-04	1.89E-05	5.18E-06	1.85E-06	3.48E-06	9.11E-07	8.25E-06	1.92E-05
Beam Size & Position	7.25E-05	1.06E-04	1.08E-04	1.06E-04	1.11E-04	1.00E-04	8.73E-05	7.88E-05
Inter-reflection	7.25E-05	1.06E-04	1.08E-04	1.06E-04	1.11E-04	1.00E-04	8.73E-05	7.88E-05
Obliquity	1.11E-06	1.11E-06	1.11E-06	1.11E-06	1.11E-06	1.11E-06	1.11E-06	1.11E-06
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	4.98E-06	7.28E-06	7.45E-06	7.31E-06	7.63E-06	6.90E-06	6.00E-06	5.42E-06
Detector range ratio	0.0	1.21E-04	0.0	0.0	0.0	0.0	0.0	0.0
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	1.45E-04	2.12E-04	2.17E-04	2.13E-04	2.23E-04	2.01E-04	1.75E-04	1.58E-04
Total Type B Uncertainty	1.69E-03	9.91E-04	3.75E-04	2.82E-04	2.96E-04	2.74E-04	2.37E-04	2.03E-04
Degrees of Freedom	4.46E+09	8.16E+08	4.06E+07	5.08E+06	1.37E+07	8.60E+06	3.08E+06	1.12E+06
Type A Uncertainty	9.29E-04	1.53E-05	1.53E-05	1.53E-05	1.53E-05	1.53E-05	1.53E-05	1.53E-05
Total Uncertainty	2.25E-03*	9.91E-04	3.75E-04	2.82E-04	2.96E-04	2.74E-04	2.63E-04*	3.68E-04*
Degrees of Freedom	137	6.50E+07	1.40E+06	4.27E+05	5.43E+05	3.96E+05	3.26E+05	1.20E+06

Table E9c. Uncertainty budget for NIST, Filter C, Round 3

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	0.0	0.0	0.0	0.0	1.61E-05	0.0	0.0	0.0
Temperature Correction	2.77E-06	7.44E-06	6.99E-06	6.62E-06	9.46E-06	8.97E-06	7.37E-06	6.23E-06
Temperature Fluctuation	2.13E-06	1.51E-05	6.01E-06	1.38E-05	1.13E-05	4.54E-06	1.25E-06	3.43E-06
Wavelength	6.11E-04	3.49E-04	1.25E-04	8.23E-05	6.53E-05	5.90E-05	5.57E-05	4.69E-06
Stray Light	1.37E-04	1.67E-05	3.24E-06	2.79E-06	3.04E-06	3.86E-06	1.23E-06	5.64E-06
Beam Size & Position	3.71E-06	1.52E-05	1.47E-05	1.23E-05	2.57E-05	2.40E-05	1.64E-05	1.22E-05
Inter-reflection	4.42E-06	1.81E-05	1.75E-05	1.47E-05	3.07E-05	2.86E-05	1.96E-05	1.46E-05
Obliquity	8.95E-07	8.95E-07	8.95E-07	8.95E-07	8.95E-07	8.95E-07	8.95E-07	8.95E-07
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	2.13E-06	8.75E-06	8.45E-06	7.08E-06	1.48E-05	1.38E-05	9.45E-06	7.04E-06
Detector range ratio	0.0	1.90E-05	0.0	0.0	0.0	4.50E-06	0.0	0.0
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	8.12E-06	3.33E-05	3.22E-05	2.69E-05	5.64E-05	5.25E-05	3.60E-05	2.68E-05
Total Type B Uncertainty	6.27E-04	3.53E-04	1.32E-04	9.03E-05	9.87E-05	8.92E-05	7.21E-05	3.51E-05
Degrees of Freedom	2.32E+10	2.93E+07	1.12E+06	1.91E+05	1.00E+05	8.79E+04	8.24E+04	9.03E+03
Type A Uncertainty	2.00E-04	6.68E-05	7.07E-06	7.07E-06	7.07E-06	7.07E-06	7.07E-06	7.07E-06
Total Uncertainty	6.58E-04	3.60E-04	1.32E-04	9.06E-05	1.03E-04*	8.95E-05	7.24E-05	7.79E-05*
Degrees of Freedom	467	3.35E+03	3.41E+05	6.92E+04	7.14E+04	4.77E+04	2.89E+04	4.65E+04

Table E9d. Uncertainty budget for NIST, Filter D, Round 3

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature Correction	1.14E-07	9.11E-07	1.30E-06	1.38E-06	3.19E-06	3.53E-06	2.72E-06	2.20E-06
Temperature Fluctuation	8.36E-08	1.89E-06	1.14E-06	2.88E-06	3.81E-06	1.81E-06	4.68E-07	1.22E-06
Wavelength	3.75E-05	2.45E-05	6.48E-06	1.39E-05	2.11E-05	5.42E-06	1.50E-05	4.46E-06
Stray Light	3.10E-05	1.18E-05	1.52E-06	8.07E-07	4.84E-07	1.45E-06	3.28E-07	3.85E-07
Beam Size & Position	6.28E-07	7.56E-06	1.23E-05	1.21E-05	3.84E-05	4.68E-05	3.28E-05	2.43E-05
Inter-reflection	1.53E-07	1.85E-06	3.00E-06	2.97E-06	9.39E-06	1.14E-05	8.00E-06	5.93E-06
Obliquity	3.37E-07	3.37E-07	3.37E-07	3.37E-07	3.37E-07	3.37E-07	3.37E-07	3.37E-07
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	4.58E-08	5.51E-07	8.95E-07	8.86E-07	2.80E-06	3.41E-06	2.39E-06	1.77E-06
Detector range ratio	8.72E-08	1.05E-06	1.71E-06	1.69E-06	5.34E-06	6.50E-06	4.55E-06	3.37E-06
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	1.53E-07	1.84E-06	2.98E-06	2.95E-06	9.34E-06	1.14E-05	7.96E-06	5.90E-06
Total Type B Uncertainty	4.87E-05	2.84E-05	1.48E-05	1.93E-05	4.65E-05	5.05E-05	3.82E-05	2.65E-05
Degrees of Freedom	2.99E+11	5.25E+06	1.50E+05	2.13E+05	3.77E+05	3.75E+05	3.50E+05	1.89E+05
Type A Uncertainty	3.31E-06	3.31E-06	3.31E-06	3.31E-06	3.31E-06	3.31E-06	3.31E-06	3.31E-06
Total Uncertainty	4.88E-05	2.86E-05	1.52E-05	1.96E-05	4.66E-05	5.06E-05	3.83E-05	2.67E-05
Degrees of Freedom	1.88E+05	2.22E+04	1.75E+03	4.83E+03	1.11E+05	1.38E+05	5.98E+04	1.55E+04

Table E9e. Uncertainty budget for NIST, Filter E, Round 3

Uncertainty Component	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
Nonlinearity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature Correction	9.10E-09	9.44E-08	2.10E-07	2.47E-07	8.64E-07	1.45E-06	1.27E-06	1.14E-06
Temperature Fluctuation	6.65E-09	1.86E-07	1.81E-07	4.92E-07	1.06E-06	7.31E-07	2.19E-07	9.88E-07
Wavelength	2.48E-06	2.02E-06	4.12E-07	2.39E-06	7.53E-06	2.44E-06	3.75E-06	2.27E-06
Stray Light	5.09E-06	3.89E-06	5.30E-07	2.73E-07	1.10E-08	5.22E-07	3.44E-07	3.18E-07
Beam Size & Position	9.12E-08	1.28E-06	3.51E-06	3.75E-06	1.89E-05	3.63E-05	3.17E-05	2.68E-05
Inter-reflection	2.44E-08	3.42E-07	9.39E-07	1.00E-06	5.06E-06	9.73E-06	8.48E-06	7.17E-06
Obliquity	1.41E-07	1.41E-07	1.41E-07	1.41E-07	1.41E-07	1.41E-07	1.41E-07	1.41E-07
Polarization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Source Drift & Fluctuation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bandwidth	3.11E-09	4.36E-08	1.20E-07	1.28E-07	6.45E-07	1.24E-06	1.08E-06	9.14E-07
Detector range ratio	4.79E-09	6.70E-08	1.84E-07	1.97E-07	9.92E-07	1.91E-06	1.66E-06	1.41E-06
Detector gain ratio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector reproducibility	8.38E-09	1.17E-07	3.22E-07	3.45E-07	1.74E-06	3.34E-06	2.91E-06	2.46E-06
Total Type B Uncertainty	5.66E-06	4.59E-06	3.73E-06	4.62E-06	2.11E-05	3.80E-05	3.32E-05	2.80E-05
Degrees of Freedom	1.34E+12	3.33E+07	8.69E+05	7.22E+05	2.99E+06	4.19E+06	4.27E+06	3.16E+06
Type A Uncertainty	6.44E-06	6.44E-06	7.15E-07	7.15E-07	7.15E-07	7.15E-07	7.15E-07	7.15E-07
Total Uncertainty	8.58E-06	7.91E-06	3.79E-06	4.68E-06	2.11E-05	3.80E-05	3.32E-05	2.80E-05
Degrees of Freedom	13	9	3.17E+03	7.26E+03	1.51E+06	3.70E+06	3.48E+06	2.37E+06

Notes:

a) Columns with dashes indicate that transmittance values at these wavelengths were either not measured or not reported.

b) Uncertainty contributions labeled as “nc” indicates that this uncertainty contribution was not individually characterized.

c) Uncertainties listed as 0.0 are considered by the participant as negligible.

d) Values shown for NIST are representative of the average transmittance for all filter sets.

e) A few of NIST values for Total Uncertainty, as denoted with asterisks (*), have been expanded to achieve consistency with NIST’s Calibration and Measurement Capability (CMC) claims. The expansion is based on NIST’s results in CCPR-K6.2010 and follows the guidance provided in CCPR-G8, Guidelines for the evaluation of CMC claims in light of comparison results (https://www.bipm.org/utils/common/pdf/CC/CCPR/CCPR-G8.pdf).

Appendix F: Uncertainty Components for Analysis

Table F1. Standard uncertainty for NIST's uncorrelated effects during the CCPR-K6.2010 comparison, $u_{NIST,r,KC}$

Filter Identifier	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	2.16E-04	2.16E-04	2.16E-04	2.17E-04	2.18E-04	2.18E-04	2.18E-04	2.19E-04
B	1.66E-03	9.48E-04	2.57E-04	8.75E-05	9.61E-05	1.05E-04	8.71E-05	3.70E-05
C	6.12E-04	3.50E-04	1.26E-04	8.37E-05	6.69E-05	6.06E-05	5.73E-05	1.43E-05
D	4.61E-05	3.21E-05	1.48E-05	1.94E-05	2.50E-05	1.44E-05	2.00E-05	1.41E-05
E	2.68E-05	2.09E-05	1.34E-05	1.36E-05	1.53E-05	1.36E-05	1.39E-05	1.36E-05

Table F2. Standard uncertainty for NRC's uncorrelated effects during the CCPR-K6.2010 comparison, $u_{NRC,r,KC}$

Filter Identifier	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	1.18E-04	1.08E-04	1.08E-04	8.49E-05	7.55E-05	8.62E-05	9.58E-05	1.15E-04
B	1.66E-04	1.23E-04	8.68E-05	6.12E-05	7.42E-05	6.57E-05	7.15E-05	6.27E-05
C	6.55E-05	4.64E-05	1.71E-05	1.15E-05	2.90E-05	2.48E-05	1.51E-05	8.04E-06
D	1.78E-06	3.21E-06	2.00E-06	1.60E-06	6.02E-06	7.38E-06	4.60E-06	2.95E-06
E	1.52E-07	9.44E-07	6.57E-07	4.15E-07	1.7eE-06	2.98E-06	6.58E-06	3.52E-06

Table F3. Standard uncertainty for NIST's uncorrelated effects during the SIM.PR-K6.2010 comparison, $u_{NIST,r,RMO}$

Filter Identifier	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	2.39E-04	2.40E-04	2.40E-04	2.41E-04	2.41E-04	2.41E-04	2.41E-04	2.41E-04
B	1.83E-03	9.49E-04	2.58E-04	9.32E-05	1.00E-04	1.08E-04	9.10E-05	4.55E-05
C	6.34E-04	3.55E-04	1.26E-04	8.42E-05	6.71E-05	5.99E-05	5.65E-05	1.07E-05
D	3.77E-05	2.48E-05	7.32E-06	1.47E-05	2.17E-05	6.59E-06	1.53E-05	5.64E-06
E	5.48E-06	5.28E-06	9.15E-07	2.58E-06	7.66E-06	2.69E-06	3.84E-06	2.64E-06

Table F4. Standard uncertainty for NRC's uncorrelated effects during the SIM.PR-K6.2010 comparison, $u_{NRC,r,RMO}$

Filter Identifier	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	2.03E-04	1.43E-04	1.37E-04	1.30E-04	1.36E-04	1.54E-04	1.08E-04	9.55E-05
B	7.08E-05	4.66E-05	4.81E-05	3.61E-05	7.24E-05	6.41E-05	3.58E-05	4.79E-05
C	8.81E-06	1.48E-05	9.00E-06	7.28E-06	9.38E-06	1.05E-05	1.09E-05	4.97E-06
D	6.65E-07	1.88E-06	1.43E-06	1.41E-06	3.32E-06	4.17E-06	5.42E-06	2.58E-06
E	4.53E-08	5.12E-07	3.61E-07	2.78E-07	9.37E-07	1.74E-06	9.69E-07	1.10E-06

Table F5. Standard transfer uncertainty for CCPR-K6.2010 comparison, s_{KC}

Filter Identifier	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0	2.90E-05	0.0	1.70E-05	1.70E-05
C	0.0	0.0	0.0	1.70E-06	0.0	0.0	5.60E-06	2.90E-06
D	0.0	0.0	0.0	0.0	1.10E-06	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table F6. Standard uncertainty for reproducibility of NIST's scale, $u_{NIST,st}$

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	2.19E-03	2.20E-03	1.07E-03	1.07E-03	1.07E-03	1.07E-03	1.08E-03	1.08E-03
B	9.87E-04	1.46E-03	7.17E-04	7.02E-04	7.35E-04	6.62E-04	5.72E-04	5.13E-04
C	5.58E-05	2.32E-04	8.02E-05	6.24E-05	1.63E-04	1.50E-04	9.32E-05	6.17E-05
D	4.96E-06	1.63E-05	1.36E-05	1.36E-05	1.75E-06	8.60E-06	1.36E-05	1.36E-05
E	4.03E-06	4.86E-06	1.14E-06	1.14E-06	1.36E-05	1.36E-05	1.36E-05	1.36E-05

Table F7. Standard uncertainty for reproducibility of NRC's scale, $u_{NRC,st}$

Filter	Wavelength (nm)							
	380	400	500	600	700	800	900	1000
A	7.37E-05	5.23E-05	8.92E-05	1.01E-04	1.14E-04	1.18E-04	9.85E-05	5.33E-05
B	7.95E-05	4.93E-05	1.06E-05	4.18E-05	4.84E-05	4.17E-05	3.64E-05	2.76E-05
C	1.08E-05	8.39E-06	4.55E-06	3.75E-06	4.52E-06	4.95E-06	8.31E-06	7.78E-06
D	3.05E-07	1.88E-06	1.41E-06	1.81E-06	6.41E-06	7.33E-06	3.37E-06	2.28E-06
E	2.53E-08	1.48E-07	1.60E-07	2.23E-07	1.28E-06	2.32E-06	1.34E-06	7.14E-07