**Type of spectrophotometer:**

The NRC Reference spectrophotometer was used for this comparison. The instrument is shown schematically in Figure 1. 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°C (±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.

Reference SpectroPhotometer

Figure 1 Schematic diagram of the NRC Reference Spectrophotometer

**Description of the measuring 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, four 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.

In Round 1 of the NRC measurements (Step 2), the filter --D was measured against filter --C at a wavelength of 380 nm only. The filter --E was measured against filter --D at the wavelengths of 380, 400, 500, 600, 700 and 800 nm. For all other wavelengths, the filters --D and --E were measured relative to an open beam position.

In Round 2 of the NRC measurements (Step 4), the filters –D and --E were measured at all wavelengths using a reference beam attenuation technique. Filter --E was measured against filter --D and filter --D was measured against filter --C.

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 4 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 nm ± 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 higher density filters (--D and --E).

**Description of calibration laboratory conditions:**

The relative humidity during the measurements varied from a minimum of about 20% RH (for Step 2) to a maximum of about 45% RH (for Step 4). 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, , 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.

**Uncertainties**

The uncertainties reported in the following spreadsheets are absolute uncertainties.