A Review of Reproducibility and Accuracy of the DMS500 Over 10 Years

Introduction

It is now 10 years (2007) since Cambustion pioneered and introduced traceable calibrations for both spherical ("compact") and agglomerate ("soot") particles for fast particle analysers, on the DMS500. More detail is available in a presentation given at the National Physical Laboratory in 2010: http://www.npl.co.uk/upload/pdf/20100608_mansa_symonds.pdf.

This long history of traceable calibration offers the opportunity to examine in detail the consistency ("reproducibility") and accuracy of the instrument, in both the first generation *Mk I* (2002–2009) and updated *MkII* versions (2009–).

Methodology

The summary below is derived by analysing all the data from the final calibration check of every DMS500 since 2007. This uses data taken with real aerosols against standard reference instruments – a mixture of new and serviced DMS500s. More information on the calibration process is available: http://www.cambustion.com/sites/default/files/instruments/DMS500/dms_calibrationv3.pdf.

In summary, salt and CAST propane soot aerosols are classified with a Differential Mobility Analyzer (DMA) set to a known size, dividing the flow into the DMS500 and a reference aerosol electrometer. The DMS500 size is checked against the DMA setpoint, and the DMS500 number concentration against an aerosol electrometer.

The choice of a DMA and aerosol electrometer is made (vs, for example a Scanning Mobility Particle Sizer and Condensation Particle Counter) since the DMA and aerosol electrometer are generally agreed to be the closer to primary standards, clearly traceable back to more fundamental standards. The SMPS involves uncertain factors such as charging efficiency / correction and data inversion. The CPC is material sensitive to some degree, and besides is poorly matched in measureable concentration range when in single particle counting mode against electrometer based instruments like the DMS500. Indeed an electrometer standard is ultimately used for CPC calibration. At larger sizes, reference Polystyrene Latex (PSL) spheres of known size are aerosolised and sampled with the DMS.

Results

Firstly, for the spherical / “compact” calibration, Figure 1 shows a box and whisker plot of the sizing accuracy of DMS500s leaving Cambustion over the last 10 years, challenged with 100 nm DMA classified NaCl aerosol. The Y-axis is the fractional difference from the DMA size. The dotted lines show the current internal pass limit of +/- 5%.

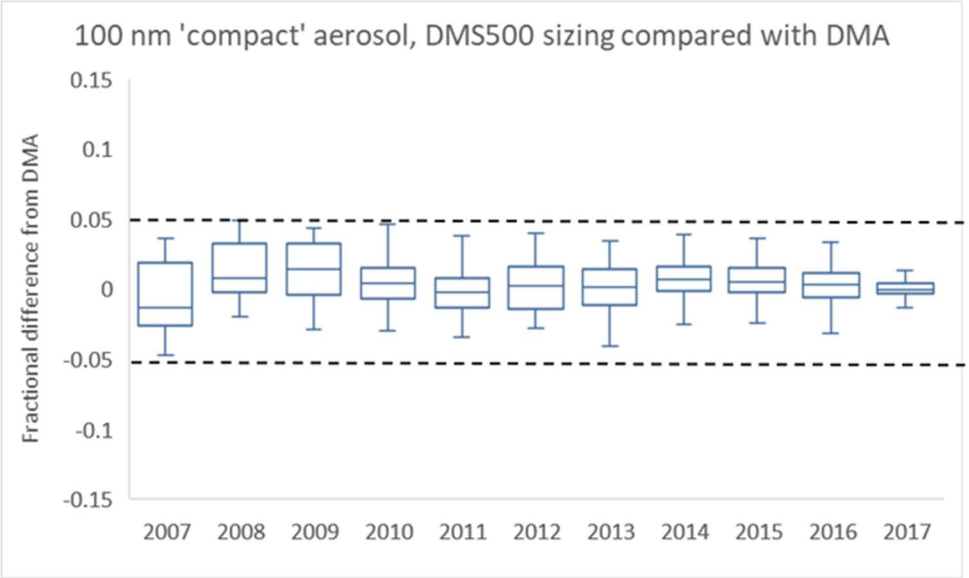

Figure 1

Derived from the same data set, Figure 2 shows the particle number agreement with the standard electrometer, again as a fraction. The dotted lines show our current internal pass limit of 10% difference from the standard.

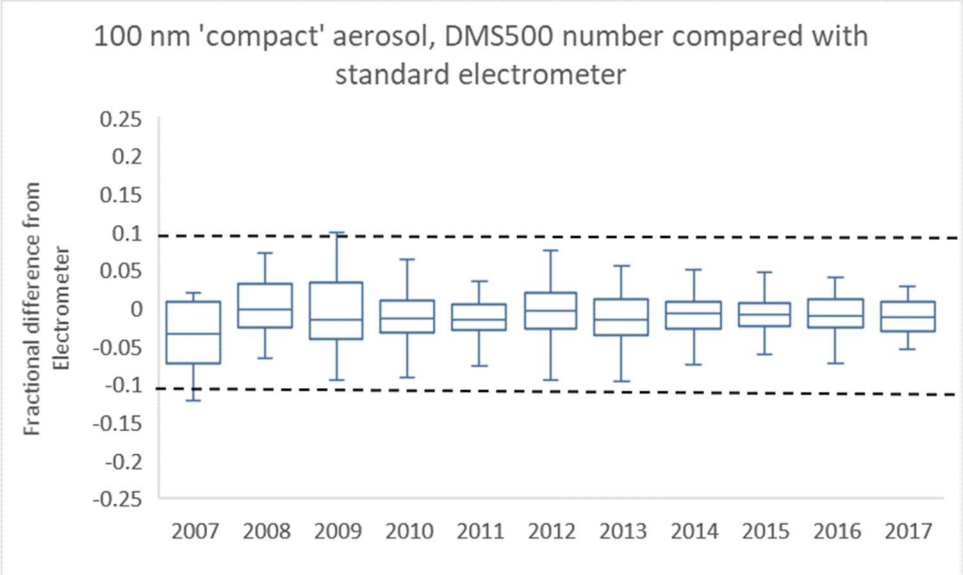

Figure 2

Figure 3 and Figure 4 show the equivalent plots for CAST propane soot, using the soot / agglomerate calibration matrix:

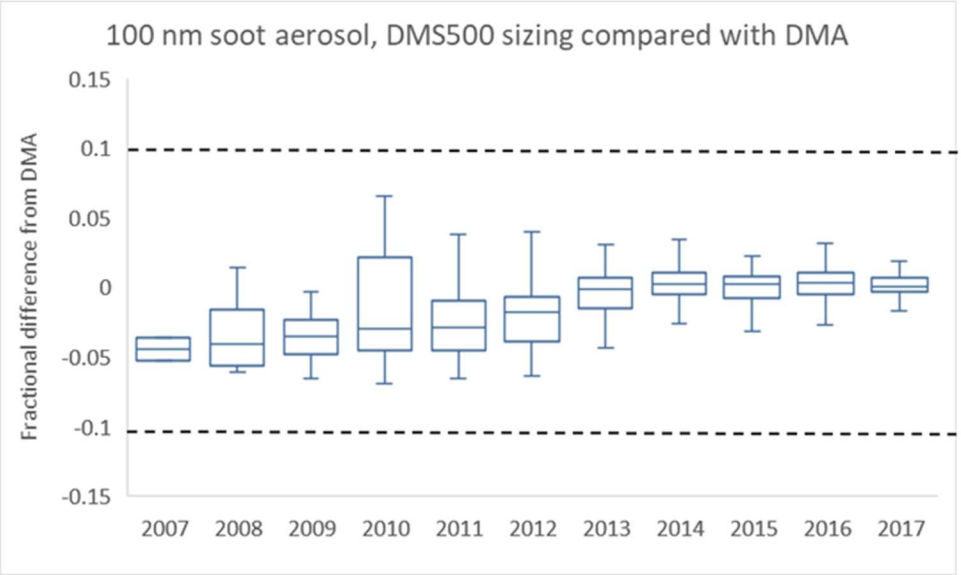

Figure 3

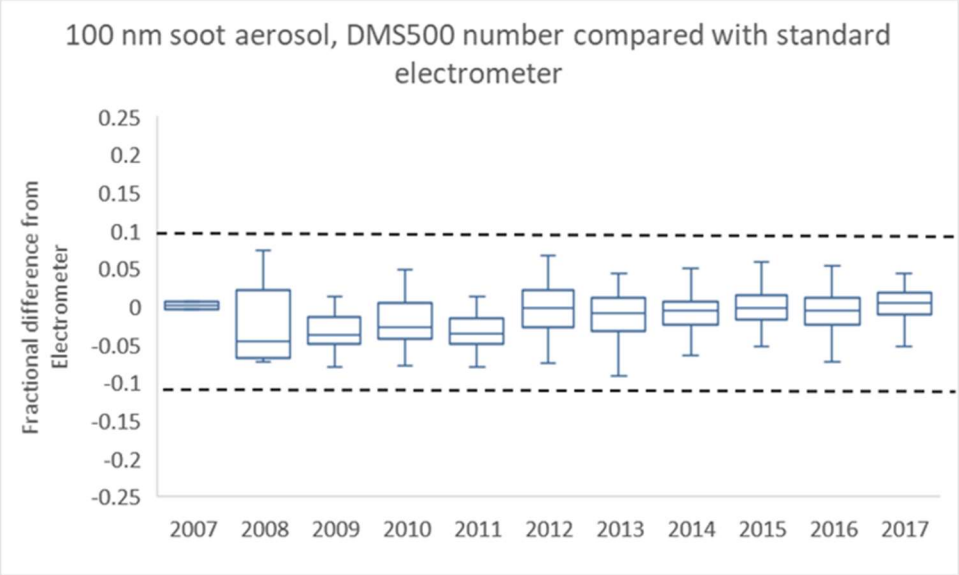

Figure 4

Each new DMS500 undergoes calibration at several sizes. For brevity, we now consider only calibrations performed in the last 3 years (several hundred). This coincides with the most recent minor update to calibration procedures, so is representative of the current calibration.

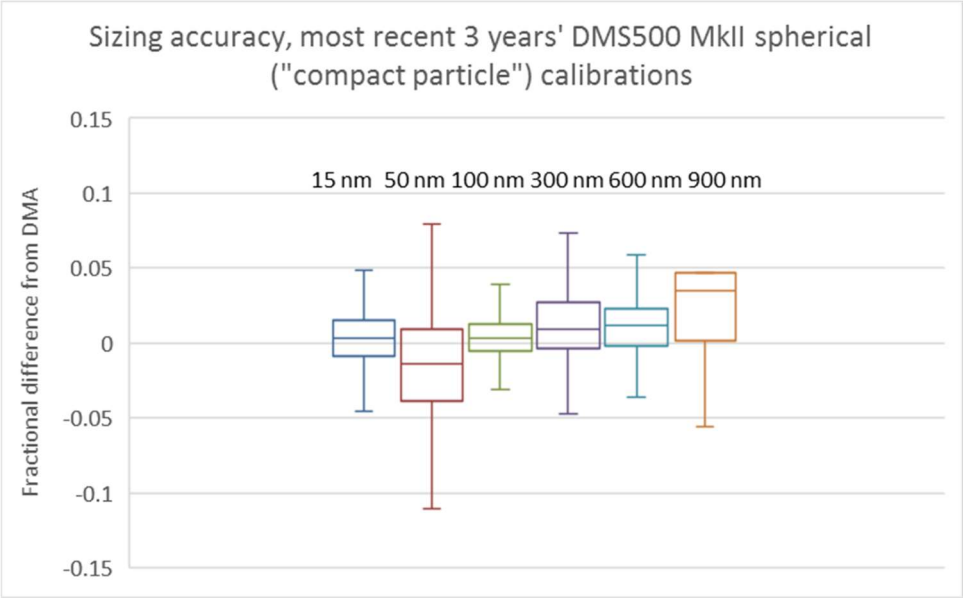

Figure 5

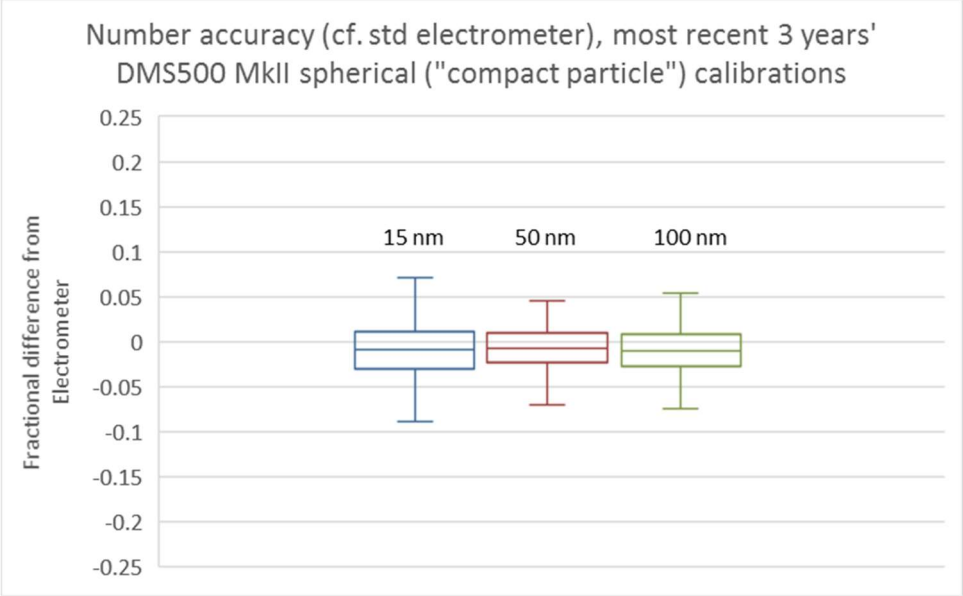

Figure 6

And for soot particles:

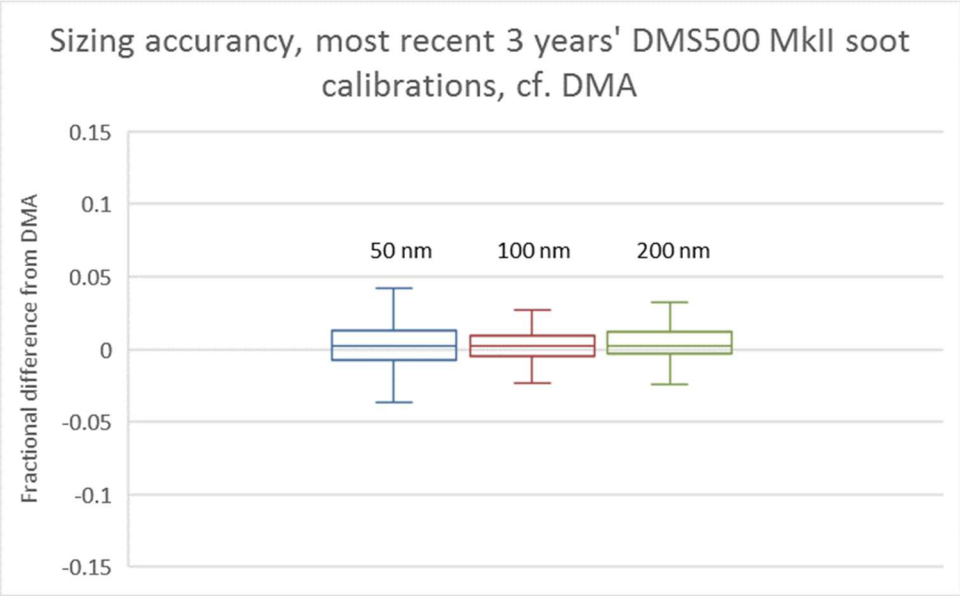

Figure 7

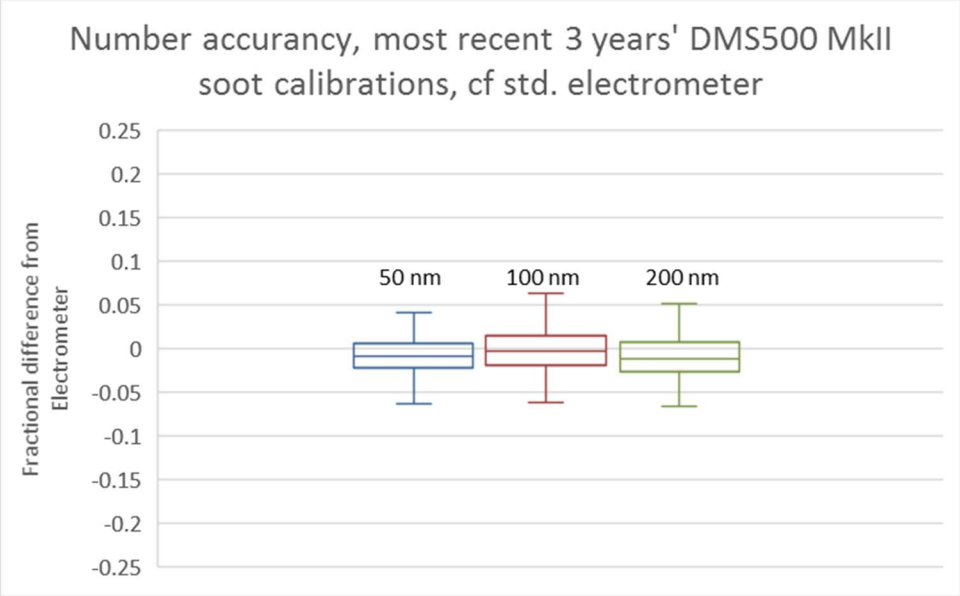

Figure 8

Conclusions

These data show that DMS500 *MkIIs* have been very consistent over the last decade, and thus conducive to good experimental reproducibility, in the sense that calibrated units do fall within a tight band of variation on the box and whisker plots. A gradual improvement over time has been observed (as would be expected with the process subject to continual improvement), but was already remarkably good back in 2007 (the last years of the first generation DMS500).

Arguably, accuracy is more important than consistency – it is even more important that an instrument gives the correct answer, as well as historically the same answer.

The most important revelation from these data is **how close the median results** (central horizontal bar) **are to zero** – there's no perceptible systematic bias to these results for the DMS from the traceable standards (with the possible exception of the size at 900 nm).

Having pioneered the separate compact and soot calibrations a decade ago, any sudden discontinuities in these plots in future are unlikely. Accurate calibration was implemented ten years ago, in response to experience and inter-comparisons in the field which showed that some of the very first *MkI* DMS500 units were not well aligned or accurate.

Just one reason why DMS500 is the instrument of choice for (amongst others) automotive OEMs, where both reproducibility and accuracy are important, especially for those who have bought multiple DMS500s.