

**MEASUREMENT OF
SURFACE TEXTURE IN CBTLM:
A THREE-YEAR REVIEW
OF INSTRUMENT CAPABILITIES**

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ABSTRACT

As part of the 1999 to 2002 National Measurement System Length Programme a review of the various surface texture measuring instruments and procedures in CBTLM was carried out on an annual basis. The review consisted of a series of measurement comparisons of the instruments and a review of all documented procedures and other related quality systems documentation. This report only presents the results of the measurement comparisons. The comparison involved five instruments: NPL NanoSurfs I, II and IV; a Taylor-Hobson Form Talysurf and the NPL Metrological Atomic Force Microscope, and two material measure geometries: type A1 (depth) and type C1 (sinusoidal). It is intended that the annual review and the production of a programme level report be repeated in future Length programmes.

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1. INTRODUCTION

As part of the 1999 to 2002 National Measurement System Length Programme an annual review exercise has been conducted to investigate the measurement consistency between surface texture measuring instruments used in the Dimensional and Optical Metrology Team of the Centre for Basic, Thermal & Length Metrology. The review is an ongoing comparison exercise designed to highlight any drift or anomalies in the results from the various instruments. Four material measures have been chosen to cover the measurement ranges of the instruments. The report includes the results from 2000 to 2002 inclusive.

2. INSTRUMENTS USED

The following instruments were used in the comparison:

NPL NanoSurfs I and II

NanoSurf I is an NPL-developed stylus instrument that incorporates the vertical sensitivity and low noise of the Taylor-Hobson Talystep transducer/stylus system (Garratt and Bottomley 1990) with a precision linear tracking arrangement (Lindsey 1986a). NanoSurf I has a theoretical resolution of less than 1 nm and a transverse range of 20 mm. Development of NanoSurf I was followed by development of NanoSurf II that had a greater horizontal range, improved linear motion accuracy and lower susceptibility to thermal and mechanical fluctuations (Lindsey 1986b).

NPL NanoSurf IV

The NanoSurfs I and II have one main drawback: lack of direct traceability. NanoSurf IV is a stylus instrument that employs laser interferometers to determine the position of a stylus tip in both the vertical and horizontal axes (Leach 2000). This gives the instrument traceability via the wavelength of the laser source. NanoSurf IV has a dry-bearing prismatic slideway with a range of 100 mm and uses a modified Taylor-Hobson Talystep transducer with a vertical range of 10 μm . The uncertainty in a length measurement in both the horizontal and vertical axes is ± 1.3 nm at a level of confidence of 95% (Leach 1999).

NPL Metrological AFM

The Metrological Atomic Force Microscope (MAFM) employs three laser interferometers to measure the position of an AFM tip in the x , y and z axes and utilises a flexure stage to provide planar motion in the x and y co-ordinate directions (Haycocks and Jackson 2001). The MAFM has a range of 100 μm in the x and y directions and 5 μm in the z direction with an uncertainty in position of 5 nm at a level of confidence of 95%.

Taylor-Hobson Form Talysurf

The Form Talysurf is an arcuate action stylus instrument that uses laser interferometry to measure the x and z co-ordinates of the stylus as it traverses the surface. The instrument has a cylindrical metal bar slideway reference and always samples 1000 points irrespective of the traverse length. The instrument has a resolution in z of 10 nm and is calibrated by traversing a type E reference hemisphere that has in-turn been calibrated by using the NPL modified Zeiss Horizontal Metroscope.

3. MATERIAL MEASURES

In order to compare the horizontal and vertical performance of the instruments, three type C1 (ISO 5436-1: 2001) sinusoid material measures were chosen. Two of these were manufactured from glass and one from nickel (this was included as it was small enough to fit into the working volume of the MAFM).

Table 1 gives the identification of each sinusoid together with its nominal amplitude and wavelength.

Identification	Nominal amplitude (nm)	Nominal wavelength (μm)
Glass sin 4b	350	25
Glass sin 4d	50	25
Nickel sin α^+	150	10

Table 1

To calibrate the vertical performance of the instruments two type A1 (ISO 5437-1: 2001) material measures were used. These consisted of two glass samples, one sample with two sets of three parallel lines etched at each side of the centre, orthogonal to its long axis. The nominal depths of the two sets of lines are 3000 nm and 300 nm. The other sample had one set of three parallel lines etched at the centre, orthogonal to its long axis with a nominal depth of 30 nm. Only the central lines of the three were used in these measurements.

4. MEASUREMENT PROCEDURE

Before any measurement the samples were first examined under a Nomarski microscope for damage or deposits of dirt on the surface. Where necessary the samples were cleaned with alcohol. Where possible all measurements were made

according to NPL Good Practice Guide No. 37 (Leach 2001) and to NPL Procedure QPCLM/B/288 and its associated desk instructions.

When the first two comparisons took place in June 2000 and June 2001 only one measurement of each material measure was made. However, in June 2002 the number of measurements taken on each material measure was increased to either four or five and the mean of these measurements was calculated and plotted on the figures shown in §5. The exception to this was the measurement of the nickel sinusoid on the MAFM - the instrument was set to take a series of measurements and then produce one mean result from the data. NanoSurf II was not used in 2002 due to a component failure on the instrument.

Table 2 shows the instruments used in the comparison and on which instrument each material measure was measured.

	DSS1 3000 nm	DSS1 300 nm	DSS1 30 nm	Glass sin No. 4b	Glass sin No. 4d	Nickel sin α^+
Form Talysurf	✓	✓	-	✓	✓	✓
NanoSurf I	✓	✓	✓ 2001 onwards	✓	✓	✓
NanoSurf II	✓ 2000/2001 only	✓ 2000/2001 only	✓ 2001 only	-	-	-
NanoSurf IV	✓	✓	✓	✓	✓	✓
MAFM	-	-	-	-	-	✓

Table 2

Table 3 lists the instruments used and the measurement parameters used for each material measure.

Glass sinusoid 4b		
NanoSurf I	Measuring speed Stylus	0.53 mm/min 2 μm conisphere
NanoSurf IV	Measuring speed Stylus	0.2 mm/min 2 μm conisphere
Form Talysurf	Measuring speed Stylus	0.5 mm/sec 20 μm conisphere
Glass sinusoid 4d		
NanoSurf I	Measuring speed Stylus	0.53 mm/min 2 μm conisphere
NanoSurf IV	Measuring speed Stylus	0.2 mm/min 2 μm conisphere
Form Talysurf	Measuring speed Stylus	0.5 mm/sec 20 μm conisphere
Nickel sinusoid α+		
NanoSurf I	Measuring speed Stylus	0.89 mm/min 2 μm conisphere
NanoSurf IV	Measuring speed Stylus	0.1 mm/min 2 μm conisphere
Form Talysurf	Measuring speed Stylus	0.5 mm/sec 20 μm conisphere
MAFM	Effective speed 8 μm/sec	
DSS1 3000 nm, 300 nm and 30 nm		
NanoSurf I	Measuring speed Stylus	0.42 mm/min 2 μm conisphere
NanoSurf II	Measuring speed Stylus	0.65 mm/min 12.5 μm conisphere
NanoSurf IV	Measuring speed Stylus	2 mm/min 2 μm conisphere
Form Talysurf	Measuring speed Stylus	0.5 mm/sec 20 μm conisphere

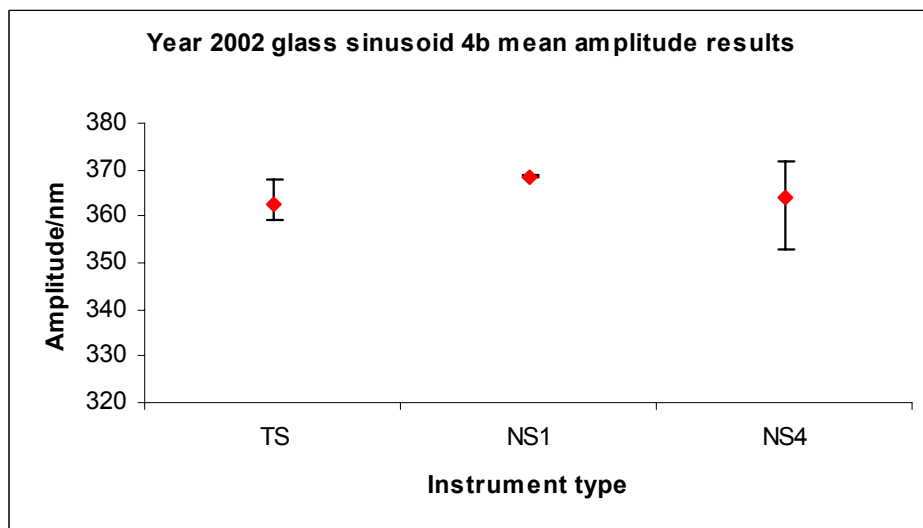
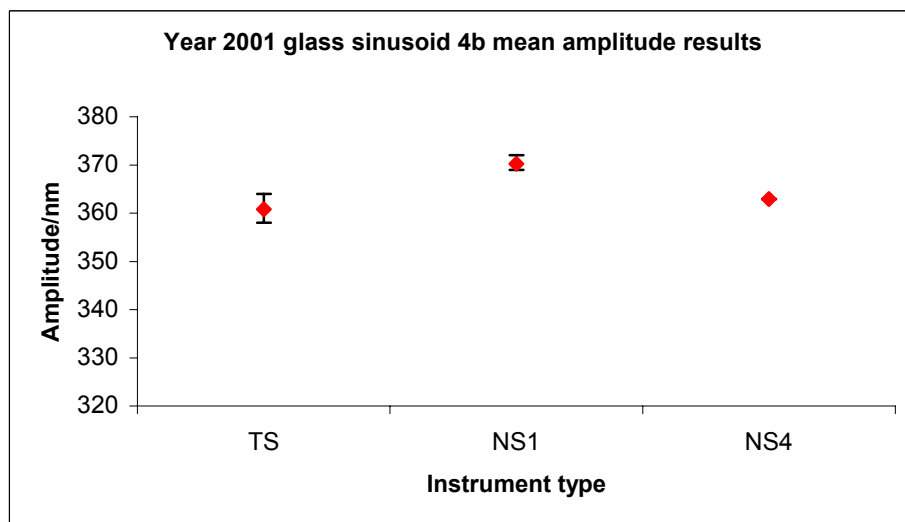
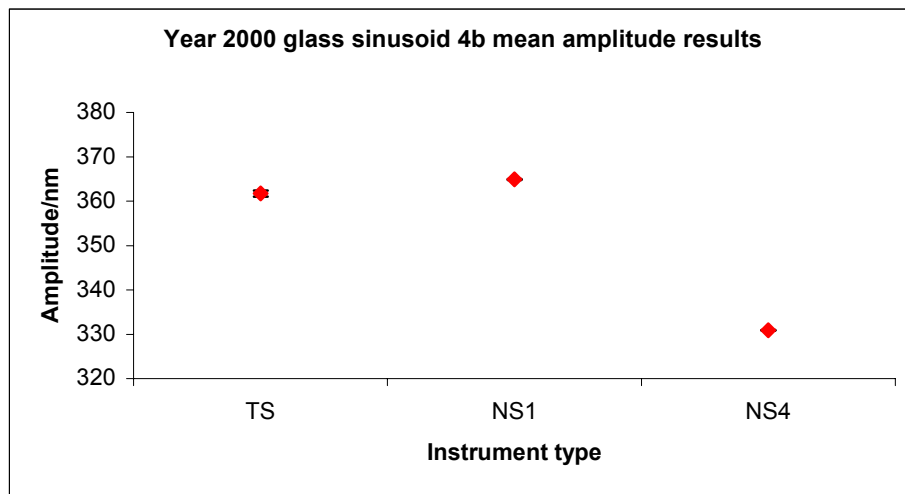
Table 3

5. RESULTS

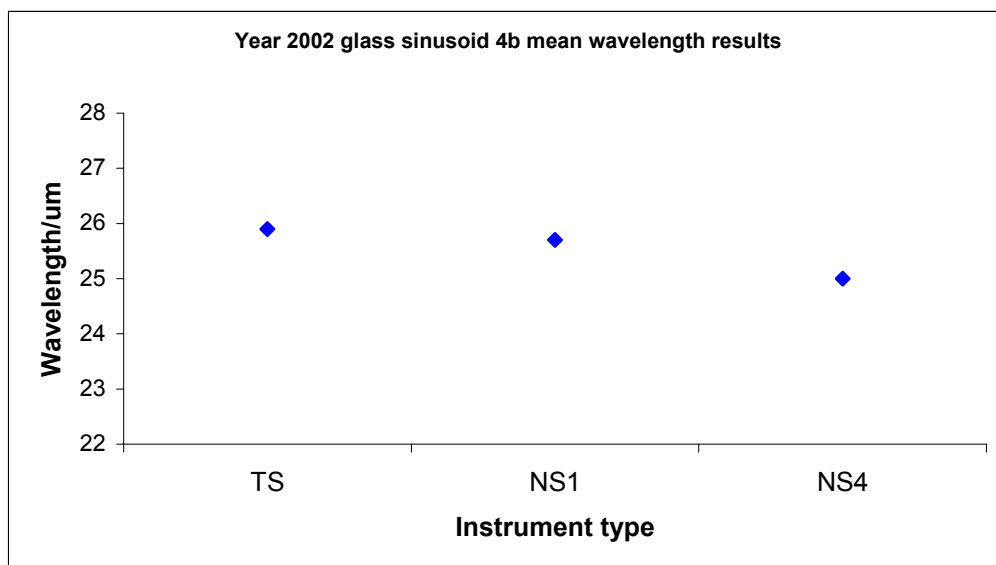
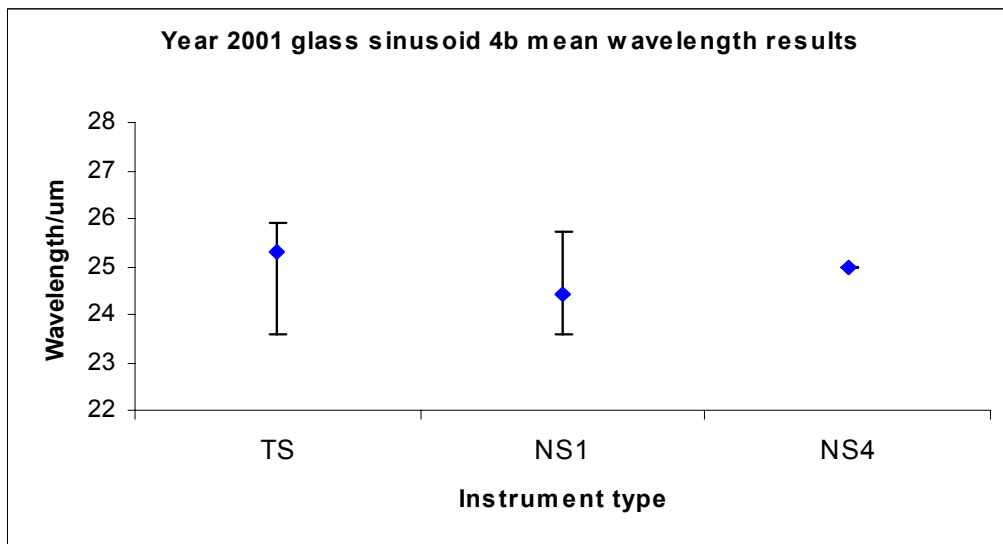
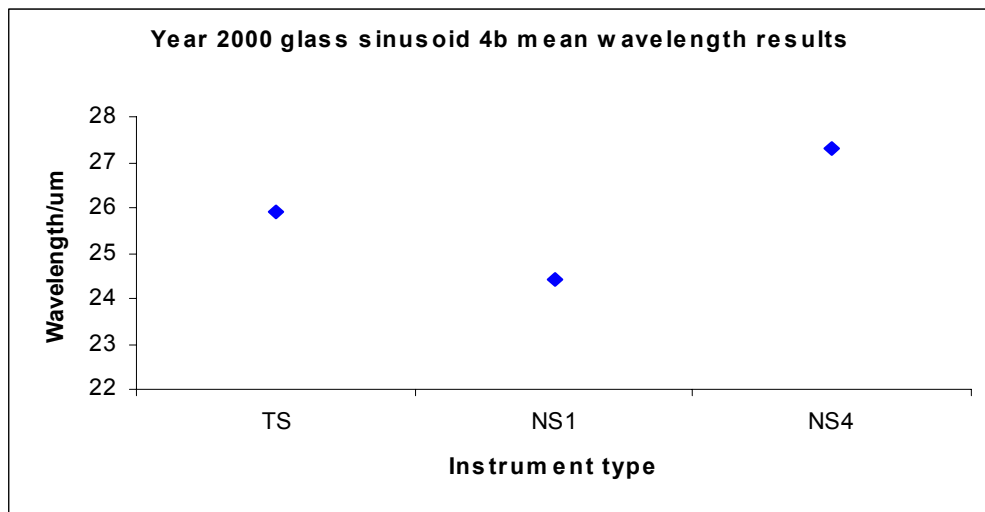
The calculation of the amplitude and wavelength measurement results involved the use of both computer software and manual methods. Dedicated computer software written in Matlab V6.1 (The MathWorks Inc.) was used to calculate the results obtained on the MAFM and Nanosurf IV. The amplitude and the wavelength results on NanoSurfs I, NanoSurf II and the Form Talysurf were obtained by manual calculation from a printed copy of the profile. NanoSurf IV data was analysed using a dedicated Matlab script called Mainscreen.m to calculate parameters from the raw data. The MAFM uses software called MAFMcontrol version 1.0.0 and two additional software programs for data correction, correctafm.m and nano2step.m. NanoSurf I and NanoSurf II also have their own dedicated data analysis software, called NS1 version 1.0.1 and NS2 version 1.0.2 respectively.

The following graphs show the mean results for each material measure. Where error bars are shown they represent the spread in the results due to repeated measurements across the surface, *i.e.* they run from the minimum to the maximum measured values and do not show statistical variation.

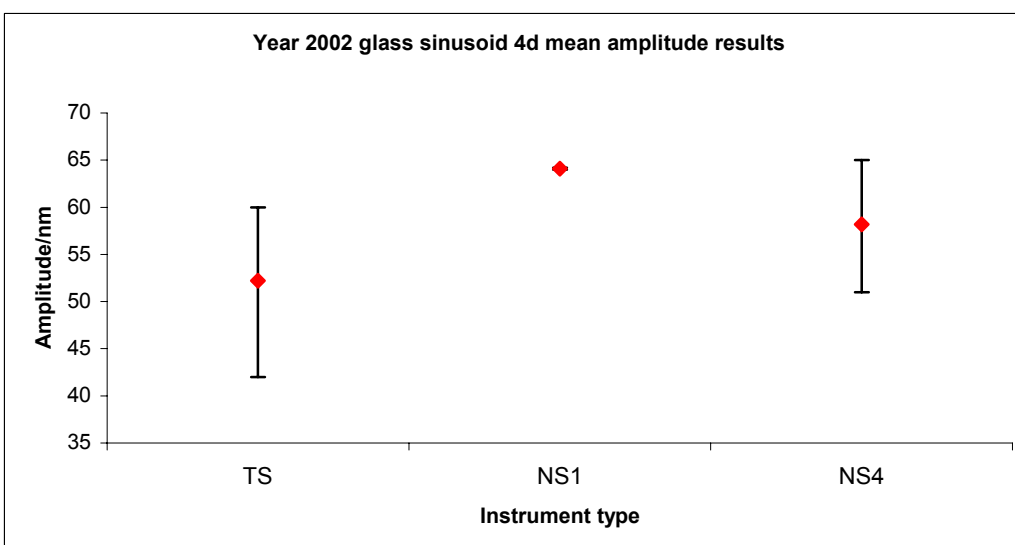
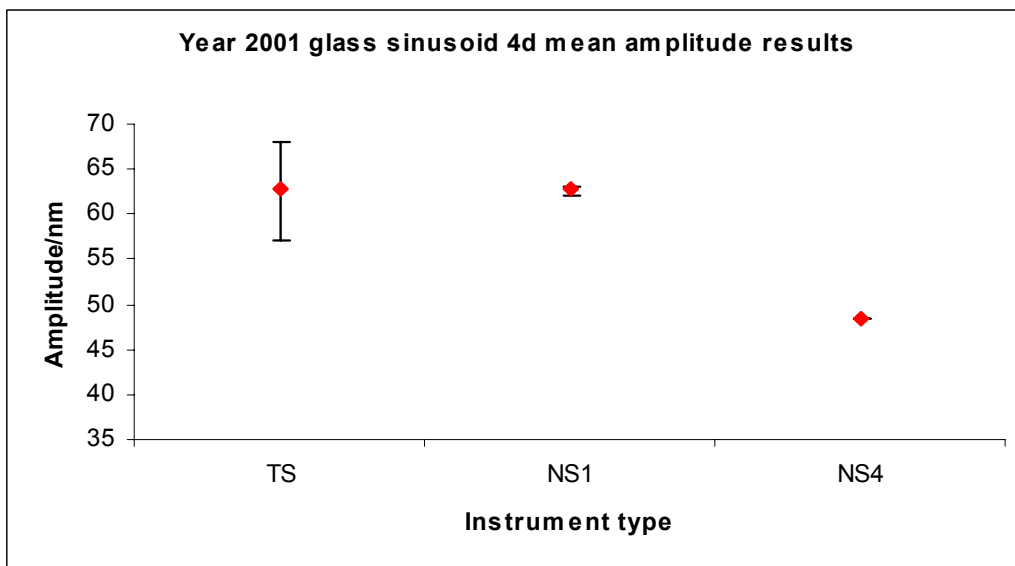
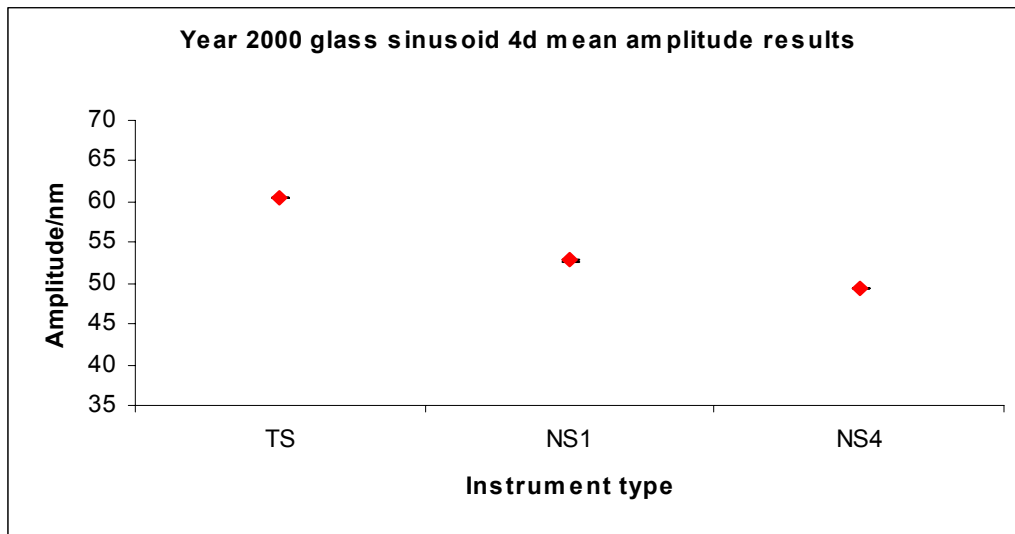
5.1 SINUSOID 4B AMPLITUDE RESULTS



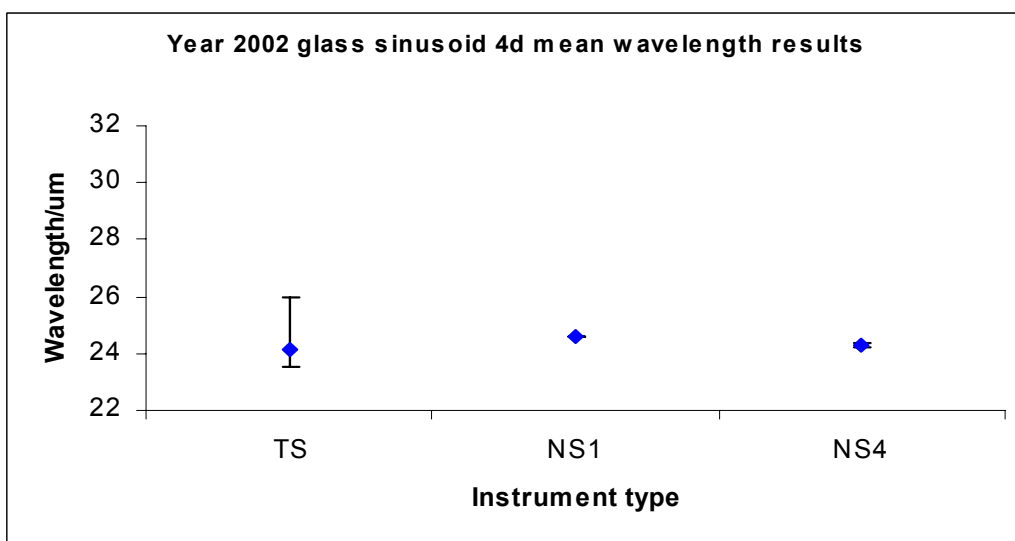
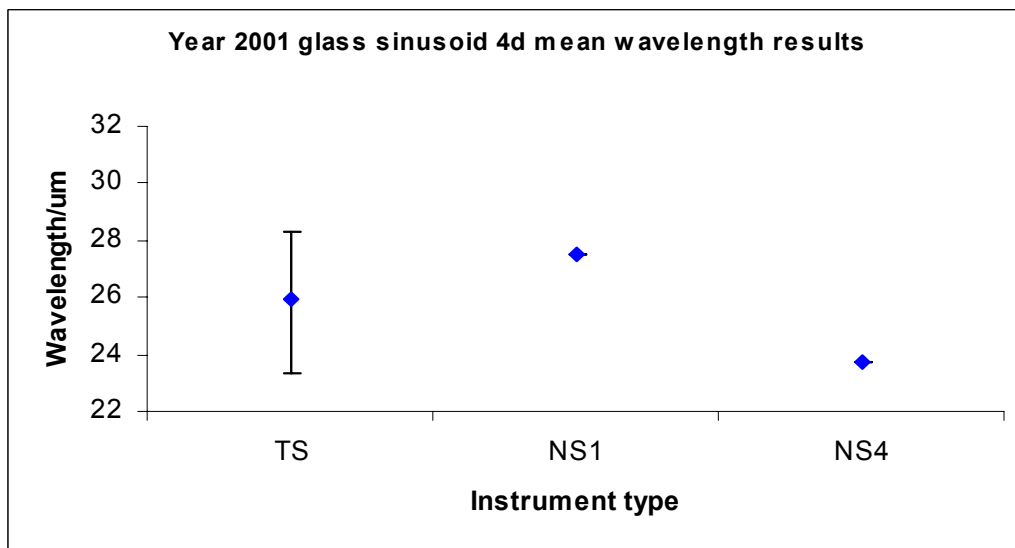
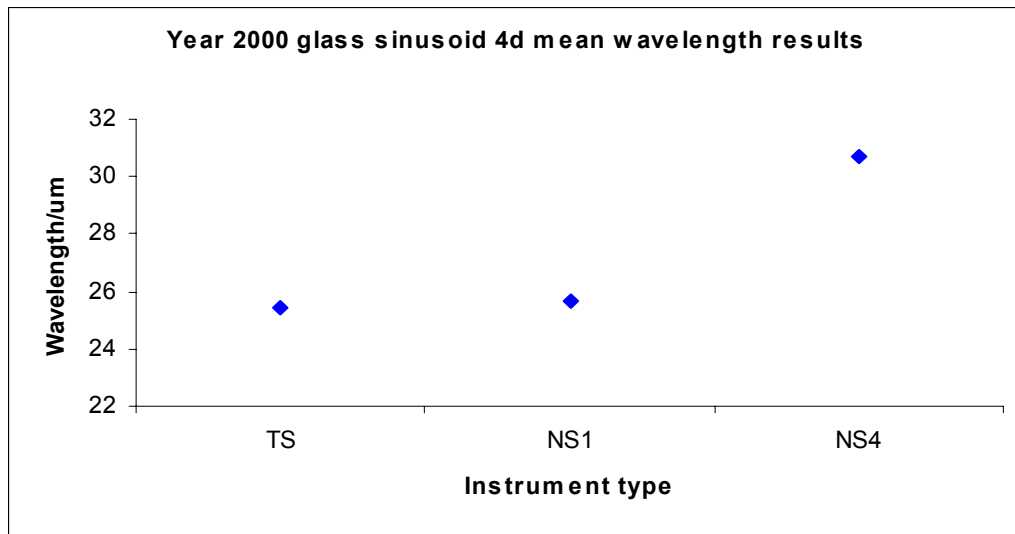
5.2 SINUSOID 4B WAVELENGTH RESULTS



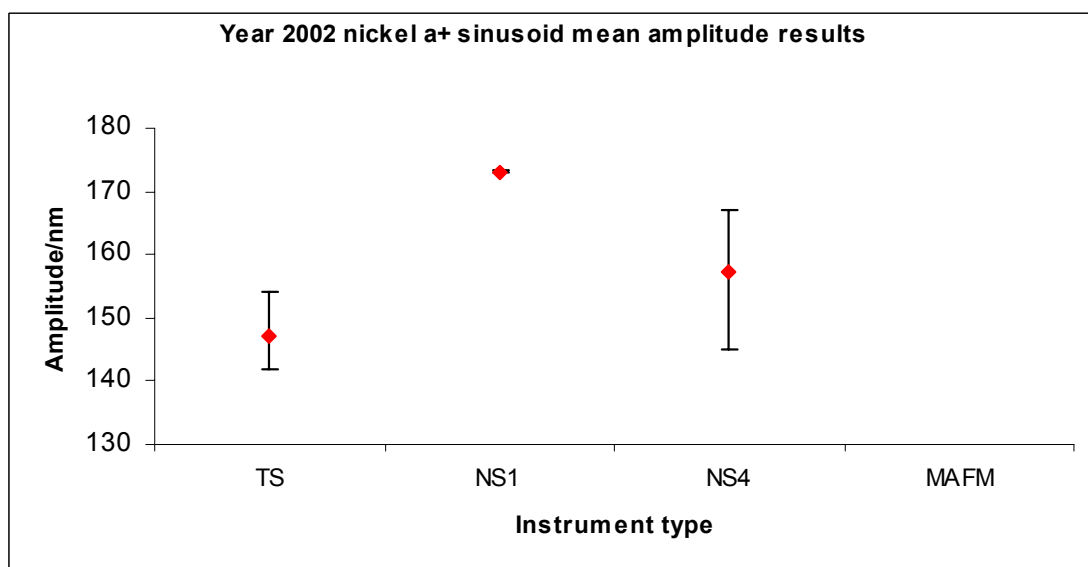
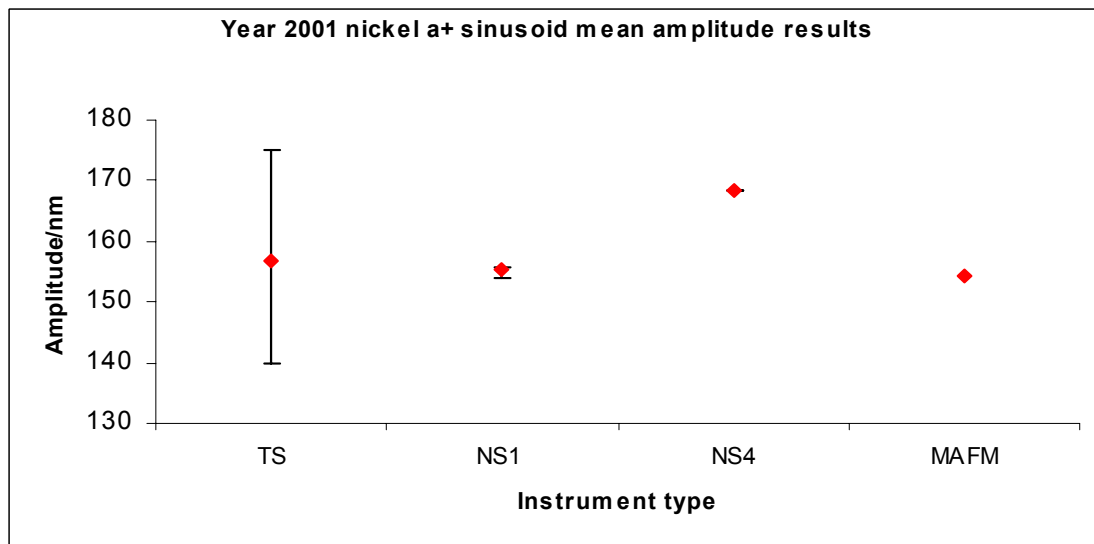
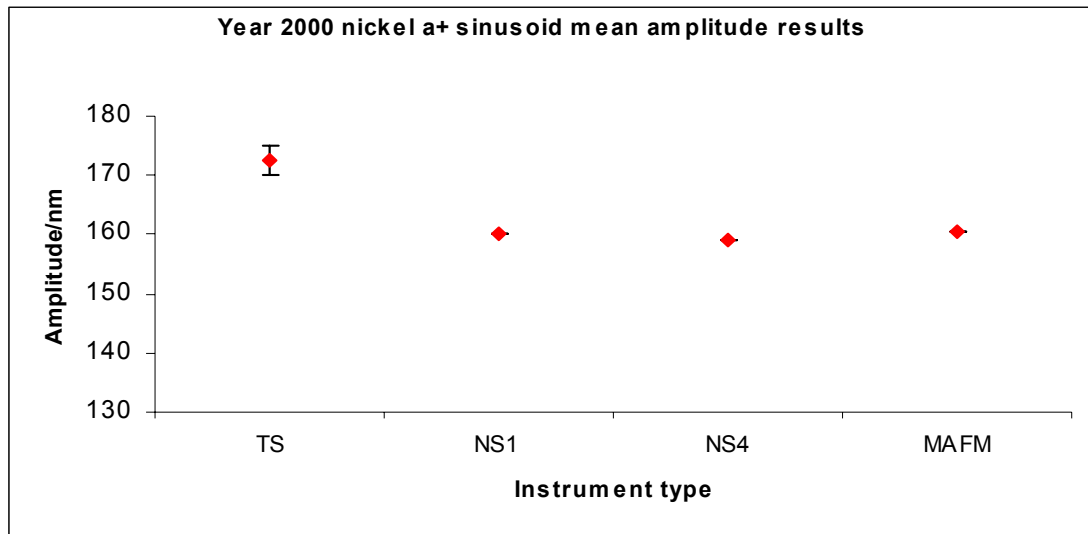
5.3 SINUSOID 4D AMPLITUDE RESULTS



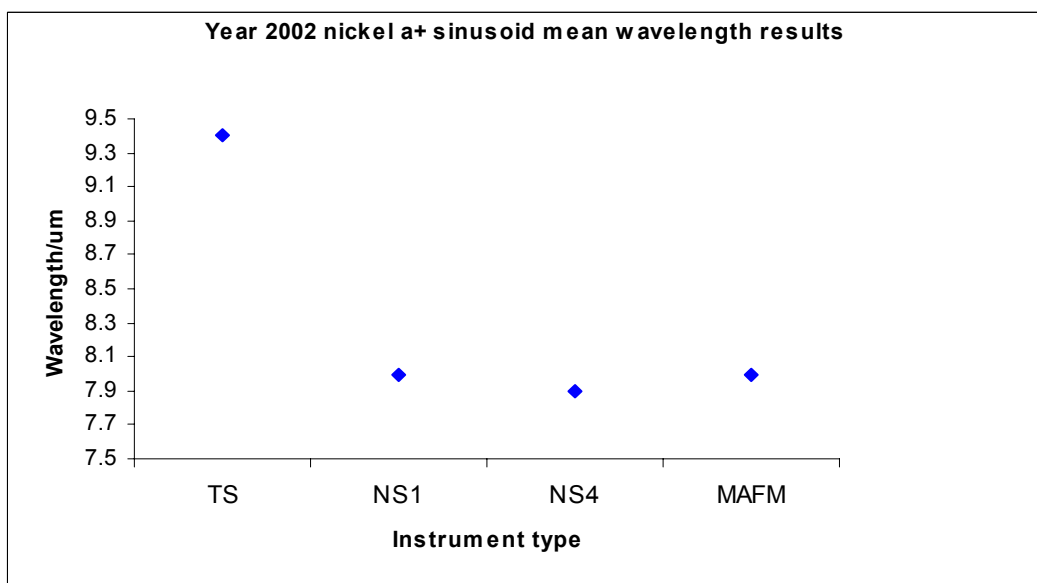
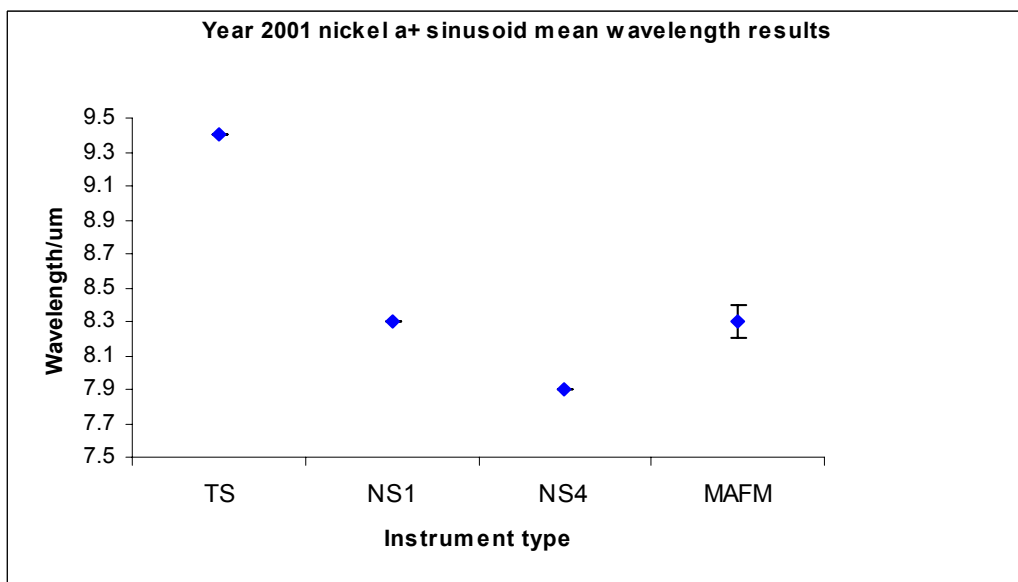
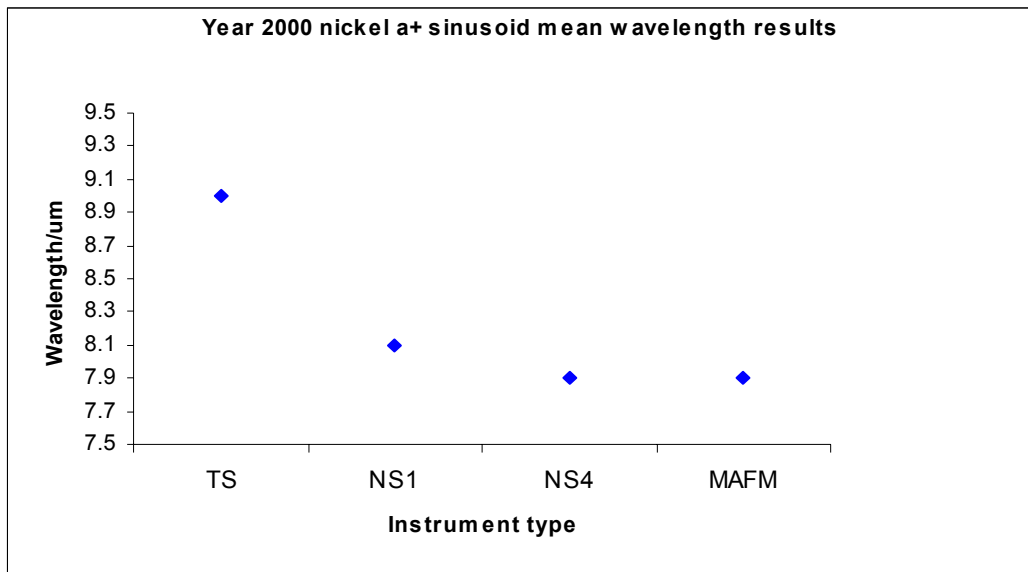
5.4 SINUSOID 4D WAVELENGTH RESULTS



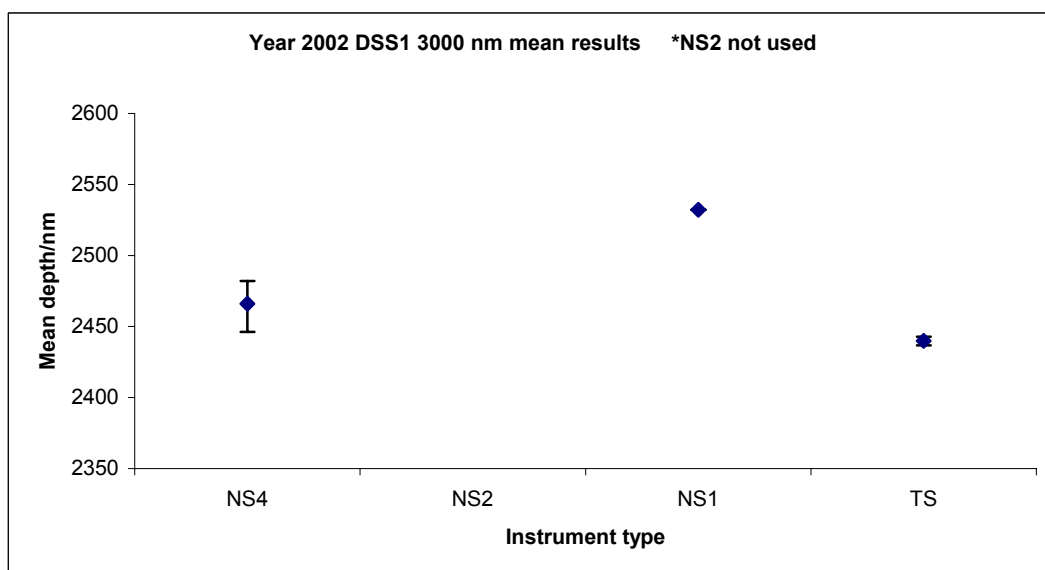
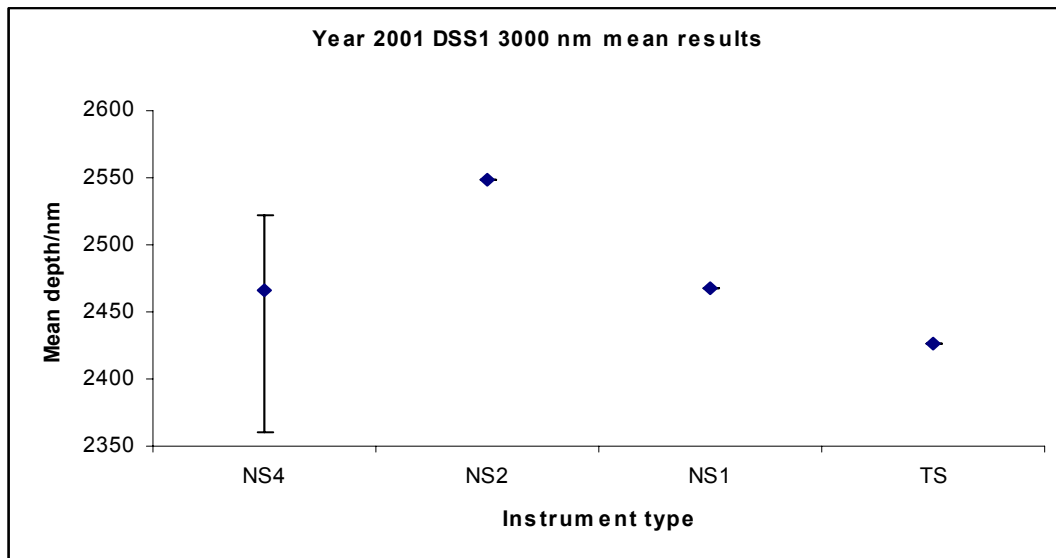
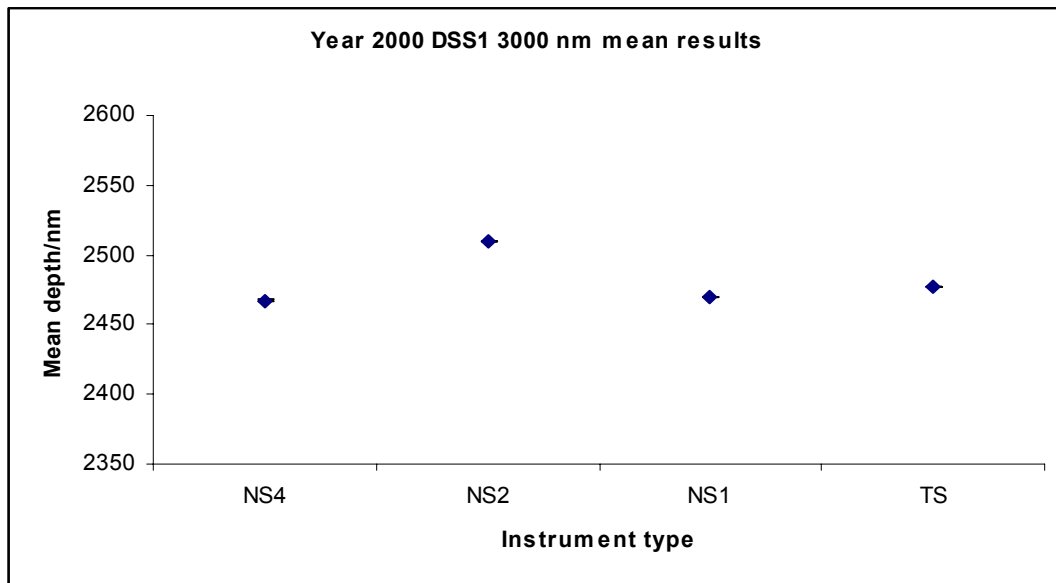
5.5 SINUSOID A+ AMPLITUDE RESULTS



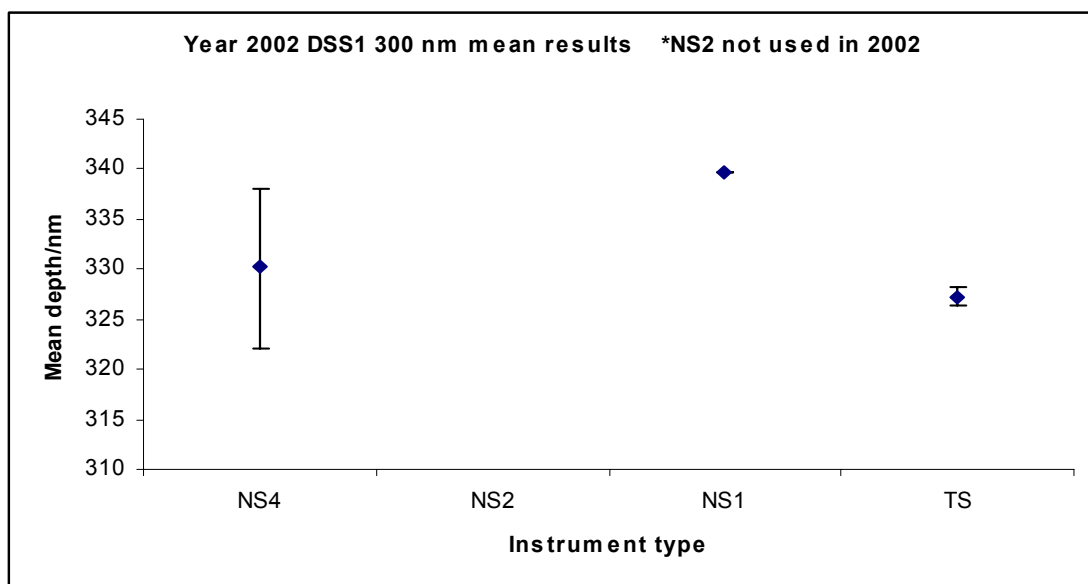
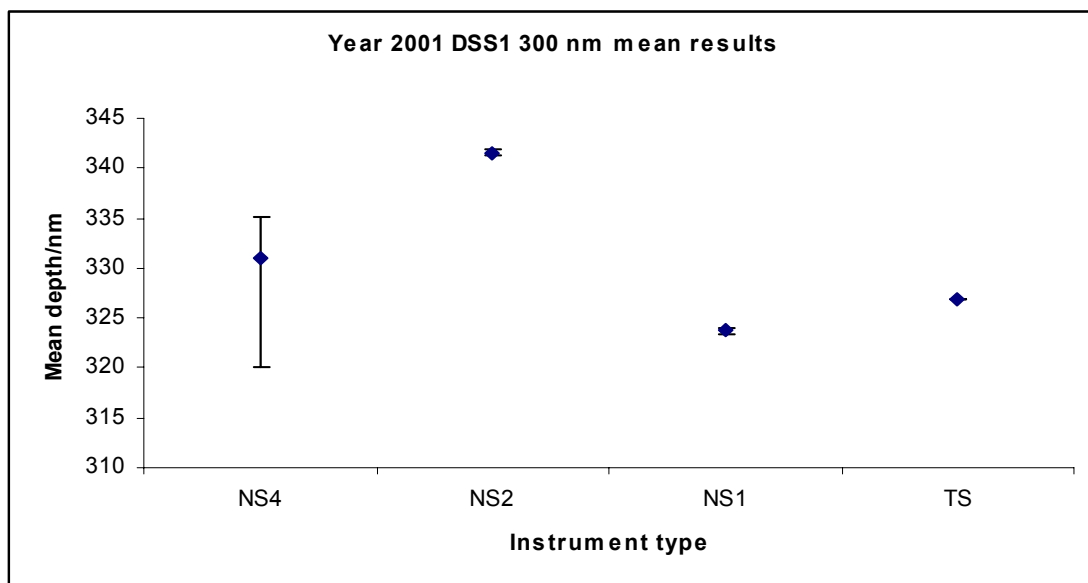
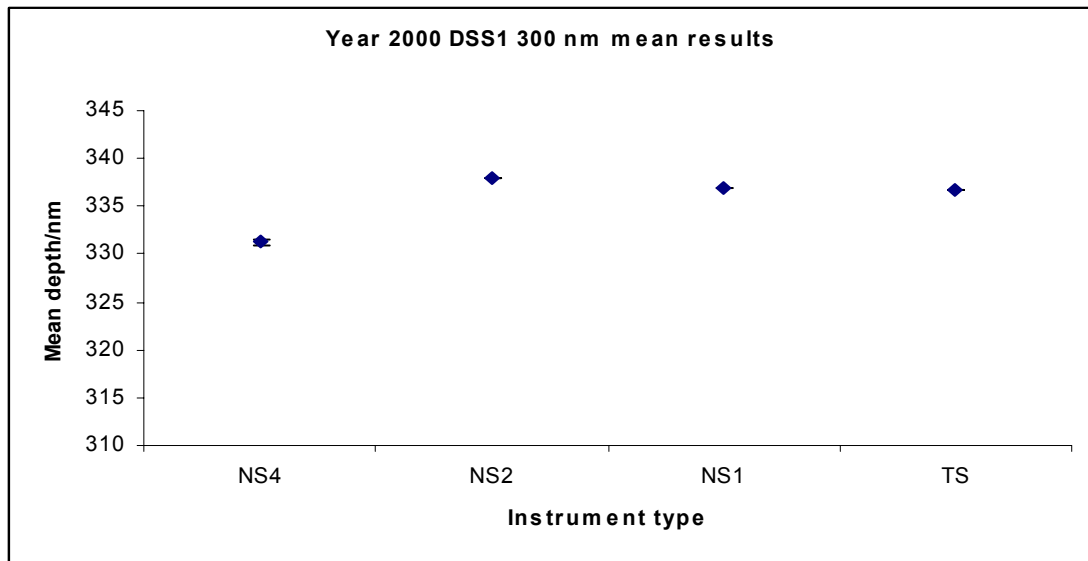
5.6 SINUSOID A+ WAVELENGTH RESULTS



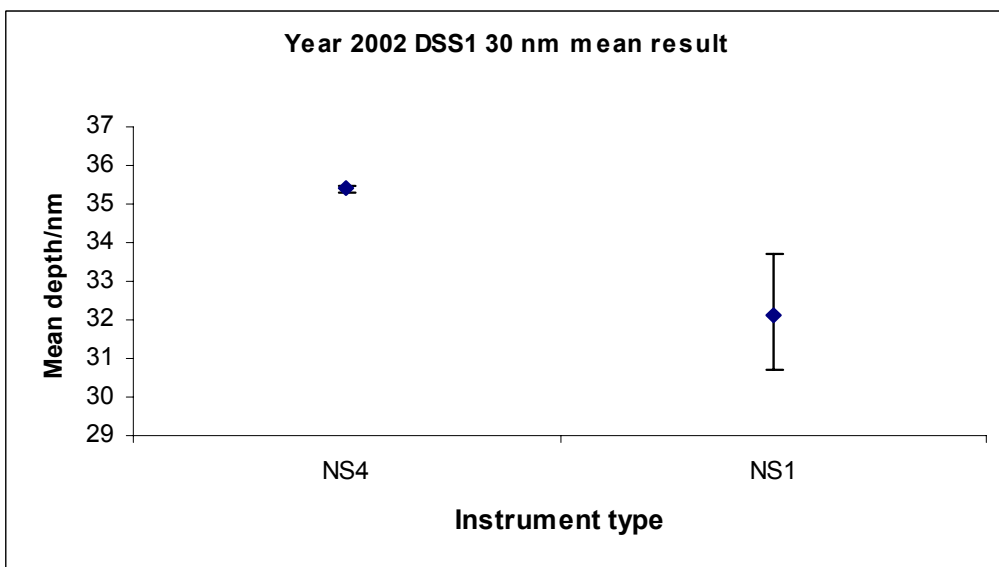
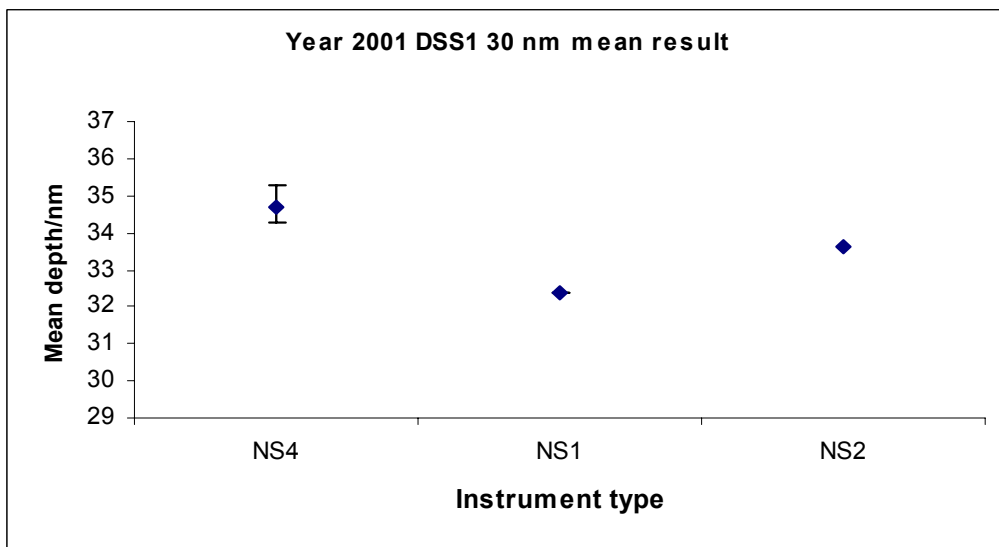
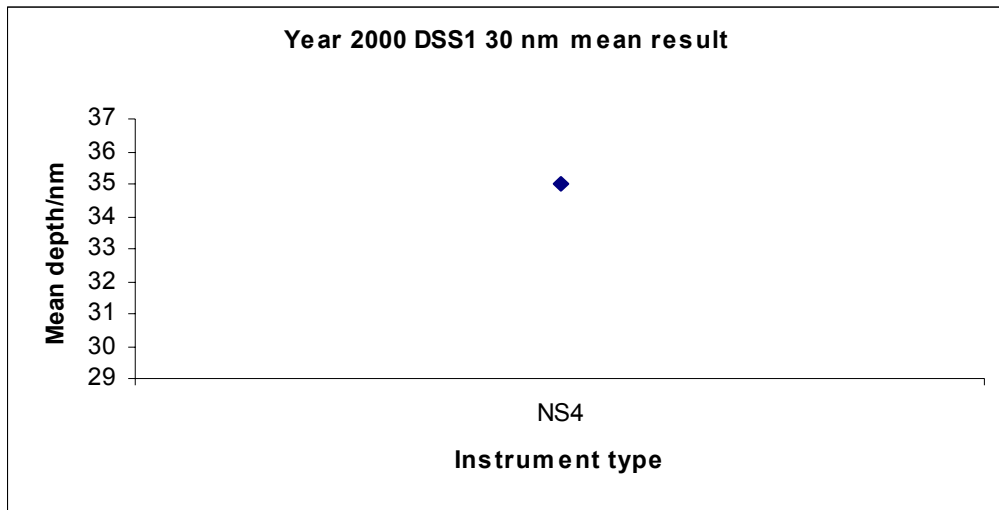
5.7 DSS1 3000 NM RESULTS



5.8 DSS1 300 NM RESULTS



5.9 DSS1 30 NM RESULTS



6. ANALYSIS

The amplitude results with the nominal 25 μm period, 350 nm amplitude sinusoidal glass material measure (4b) are in good agreement (within a few nanometres) with the exception of year 2000 where NanoSurf IV disagrees with the other results by around 30 nm. The wavelength results are all within 2 μm and fall within the spread in results that can be seen from the error bars on the year 2001 plot. Again there is a discrepancy with the year 2000 NanoSurf IV result. The discrepancy was explained when the stylus used by NanoSurf IV was subjected to a number of measurements as part of another milestone in Project 5.3 (5.3.1.9). These latter results (Leach and Hart 2001) showed that the nominal radius of curvature of the styli used by NanoSurf IV (and indeed many commercial surface texture measuring instruments) can be subject to a great deal of variation. Only the styli with radii of curvature that closely matched their nominal values were used in future years and NPL now has an annual policy of checking all styli.

The same conclusions as above can be attributed to the nominal 25 μm , 50 nm amplitude sinusoidal glass material measure (4d). However, when looking at the amplitude graphs the variations seem more pronounced because of the more magnified ordinate scale.

With the nickel sinusoid the amplitude results all agree to within ± 10 nm. This would be expected due to the variation over the surface of this specimen. The wavelength results measured by the Talysurf do not agree with the other instruments and are consistently high by around 1 μm . This was explained at the time by the lack of sound metrology on the traverse axis of the Talysurf and later improvements can only be explained as being due to the annual maintenance of the instrument by the manufacturer.

The results with the nominal 3000 nm type A1 material measure were in good agreement in year 2000 and 2001 with the exception of the NanoSurf II results that are consistently high (there is no result for year 2002 - see §4). This discrepancy has not been explained, but Nanosurf II is no longer used as part of the measurement service. NanoSurf I also gave a high result in year 2002. It must be remembered that the results for NanoSurfs I and II and the Talysurf are taken from manual calculations on printed profiles.

For the nominal 300 nm type A1 material measure the results are within the measured spread across the specimen (with the exception of the results from NanoSurf II) and agree well from year to year. With the nominal 30 nm material measure the results are all within a few nanometres and well within the uncertainties in the methods used to measure the data and calculate the results. NanoSurf IV shows excellent (± 1 nm) agreement from year to year.

7. CONCLUSIONS

An annual review of systems has proved to be a very useful and informative method for checking the performance of the instruments used as part of the surface texture measurement service at NPL. It is expected that this review methodology will be extended and employed in subsequent Length Programmes. In the future material measures will be employed that are more accessible to a wider range of instruments. For example, the performance of the Metrological AFM needs to be compared more rigorously with the performance of the other stylus instruments.

8. ACKNOWLEDGEMENTS

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