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Comparison between the Regional Association V and the Malaysian Standard Barometers

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Introduction:

Throughout this report the Malaysian standard barometer will be referred to as the Hass or Hass 3356, the Malaysian secondary standard as the Kew or Kew M/10081 and the WMO Regional Association V Standard barometer as the RA V.

The Malaysian Standard barometer (Hass No. 3356) and the Malaysian secondary standard barometer (Kew M/10081) were compared, using transfer standard barometers, with the Standard barometer of Regional Association V (Hass No. 3063) during the period 13th September to 4th October 1995.

Comparison Method:

The method used was based on Observations Instruction 88/6 [1]. Three aneroid barometers were used as transfer standards (CBM 106, 115 and 120). A Paroscientific 760 Digital barometer (s/n 55745) was also included in the comparison to determine its reliability as a transfer standard barometer.

The offset corrections for all four transfer standards were obtained by comparison against the RA V standard for a period of approximately one month before and one month after their use in Malaysia. Data relating to the offset corrections are shown in table 1. The offset corrections during the comparison in Malaysia are calculated on the basis of a linear change with time.

Barometer	Before Comparison (7/7/95 to 27/7/95)			After Comparison (23/11/95 to 4/12/95)			During Comparison (27/9/95 to 13/10/95)
	hPa			hPa			hPa
	X	σ	N	X	σ	N	X_c
DA 106	-0.01	0.050	20	+0.01	0.035	20	0.00
DA 120	-0.01	0.046	20	+0.08	0.032	20	+0.04
DA 115	-0.01	0.042	20	+0.06	0.040	20	+0.03
PS-760	+0.12	0.028	18	+0.12	0.023	20	+0.12

Table 1 - Offset corrections of Transfer Barometers to the RA V Standard

where:
X is the mean offset correction of the transfer standard to the RA V Standard.
σ is the sample standard deviation of the mean offset correction.
X_c is the interpolated offset correction of the transfer standard to the RA V Standard.
N is the number of samples.

In Malaysia, 79 readings were taken of the Transfer standards against both the Malaysian standard and secondary standard.

The data from the transfer standard barometers were corrected for pressure, temperature and for the interpolated offset correction. This yields a value of corrected pressure of the transfer standard to the RA V standard.

These corrected pressures were subtracted from each reading of the Malaysian standards. The results were then analysed.

Analysis of Results:

The Hass observations were analysed immediately upon receipt of the data. As part of the quality control of the observations, the ratio of the Main scale reading to the Cistern reading for each observation was calculated. The ratio of the diameters of the cistern and main tube is approximately 50:1, the exact ratio will depend on the actual tubes of the barometer and varies from instrument to instrument. These ratios were plotted against observation number (see figure 1).

The graph shows two observations deviating from the normal variation (circled); Investigation of the difference between the Hass and the transfer standard barometers also shows a large difference. Therefore this pair of observations was not used in determining the accuracy of the Hass.

A plot of the pressure difference between the corrected transfer standards and the standard barometers was plotted for the Hass and Kew standard barometers (see figures 2 & 3). A plot of standard barometer absolute pressure as measured by the Hass or Kew was overlaid on the ordinate.

Groups of observations where all four transfer barometers agreed and were different to the Hass by ±0.25 hPa or greater were compared with the same set of observations for the Kew barometer. If there was no discrepancy between the transfer standards and the Kew barometer then the errant Hass observations were not used in the calculation of the Hass accuracy and uncertainty. This quality control process was repeated for the Kew barometer, using the Hass as a reference. As a consequence five groups of readings were removed from the comparison with the Hass and three groups were removed from the Kew comparison.

Scatter plots of the pressure difference between the Malaysian standard barometers and corrected transfer standard barometers versus Malaysian standard barometer's pressure are shown in figures 4 & 5.

Results of the Malaysian Primary standard (Hass 3356) Comparison:

Table 2 contains the statistical summary of the differences between the Malaysian standard Hass and the RA V standard. The mean difference between the Malaysian standard Hass and the RA V standard was calculated both excluding and including the results from the Paroscientific 760 barometer.

Barometer	Difference (hPa) Hass 3356 - RAV	Standard Deviation (hPa)	Number of Observations
CBM 106	-0.039	0.056	74
CBM 120	-0.013	0.064	74
CBM 115	+0.002	0.054	74
PS - 760	-0.093	0.055	74
Mean Difference	-0.02 (excluding PS-760)		
Mean Difference	-0.04 (including PS-760)		

Table 2 - Summary of comparison with Hass 3356

The combined uncertainty of the comparison may now be derived from the individual contributions to the uncertainty (see Appendix A, Table A1). Each value listed in the table is the estimated or calculated uncertainty at the 95% confidence level[1].

The total uncertainty for the Hass 3356 is ±0.089 hPa excluding the Paroscientific 760 and ±0.075 hPa including the Paroscientific 760.

Results of Malaysian Secondary standard (Kew M/10081) Comparison:

The Kew barometer comparison data shows a correlation between the Kew pressure and the difference between the Kew and the RAV standard (see figure 5). This slope in the data is possibly due to either: (a) the method of generating index correction tables which may not take into consideration non linearities in the performance of the barometer, or (b) the barometer is faulty.

Table 3 contains the statistical summary of the differences between the Malaysian secondary standard Kew and the RA V standard. Table A2, in appendix A, contains the calculation of the combined uncertainty in the mean difference between the Kew and the RAV.

[1] These calculations are based on "Processing of Data Obtained During International Barometer Comparisons", A.Young, Nov. 1988, Folio 364, File 30/1510/10.

Barometer	Difference (hPa) Kew - RAV	Standard Deviation (hPa)	Number of Observations
CBM 106	-0.012	0.123	76
CBM 120	+0.013	0.132	76
CBM 115	+0.029	0.119	76
PS - 760	-0.066	0.128	76
Mean Difference	+0.010 (excluding PS-760)		
Mean Difference	-0.009 (including PS-760)		

Table 3 - Kew comparison results summary.

The total uncertainty for the Kew M/10081 is ±0.098 hPa excluding the Paroscientific 760 and ±0.086 hPa including the Paroscientific 760.

Performance of Paroscientific 760 barometer in comparison.

The offset correction for the Paroscientific barometer before the comparison was compared to the offset correction after the comparison. Performing a hypothesis test on the data showed that to a 95% confidence level, there is no difference between the offset corrections. This suggests that there was no significant change to the barometer caused by its transport to and from Malaysia.

The uncorrected data from the 760 was then compared directly against the corrected transfer standard barometers. In this way the data can be analysed in the same way both the Hass 3356 and Kew M/10081 were. Table 4 contains a summary of the average differences.

Barometer	Difference (hPa) PS-760 (uncorrected) - RAV	Standard Deviation (hPa)	Number of Observations
CBM 106	-0.064	0.050	79
CBM 120	-0.041	0.056	79
CBM 115	-0.026	0.036	79
Mean Difference	-0.044		

Table 4 - Comparison of Paroscientific 760 to RA V (in Malaysia)

This result indicates that the Paroscientific read, on average, 0.044 hPa low compared to the RAV standard whilst it was in Malaysia (compared to 0.12 hPa low in Australia). This could mean that there was some change in the offset correction to the Paroscientific 760 whilst the barometer was in Malaysia.

To determine the significance of this result, the uncertainty in this result must be calculated. This is shown in Appendix A, Table A3.

The uncertainty in the difference was found to be ±0.084 hPa. This result was compared to the interpolated offset correction for the Paroscientific using a two sample hypothesis test. The result of this test indicated that to a 95% confidence level there is no significant difference between the interpolated offset correction and the offset correction calculated whilst in Malaysia.

Summary of the Results of Standards Comparison:

Barometer	Difference (barometer - RAV Std.) hPa	Uncertainty ±hPa	Notes
Hass 3356	-0.02	0.109	
	-0.04	0.090	Including PS-760
Kew M/10081	-0.01	0.118	
	-0.03	0.099	Including PS-760

Conclusion:

The Malaysian Met. Service standard barometer (Hass 3356) is reading lower than the RAV standard by 0.02 ± 0.12 hPa. Since the uncertainty in the difference is larger than the difference no correction to the barometer is necessary.

The Malaysian Met. Service secondary standard barometer (Kew M/10081) is reading lower than the RAV standard by 0.01 ± 0.12 hPa. However the tests have shown that this barometer has a slope in its response between 1000 to 1010 hPa (see figure 5). Further tests should be performed over a wider pressure range, against the Malaysian standard, to determine if new correction tables need to be drawn up[2], or if the barometer is faulty.

The tests on the Paroscientific 760 barometer have shown that it is stable after air transport and thus suitable for use in comparisons. This barometer also shows a smaller scatter in its results, is easier to read and handle compared to Digital Aneroid barometers and thus improves the accuracy of the comparison. However there is a suggestion from the data that the Paroscientific may have undergone some reversible change whilst in Malaysia, or the barometer was sensitive to small differences in observational practice between Australia and Malaysia. These questions will require further investigation.

[2] The method of determing index corrections for the Kew should take into account the response of the barometer over several pressure points.

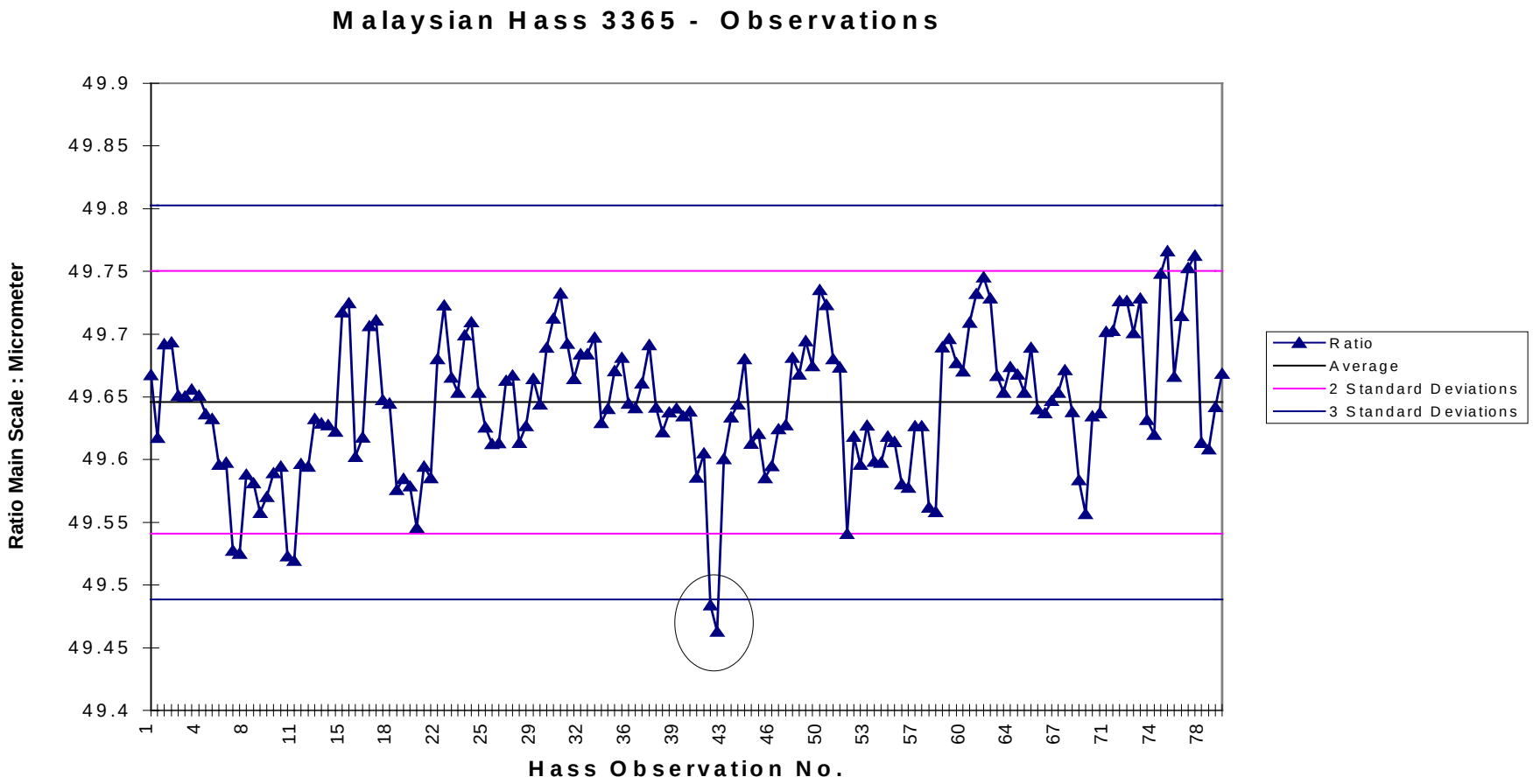

Figure 1 - Malaysian Hass Ratio Check.

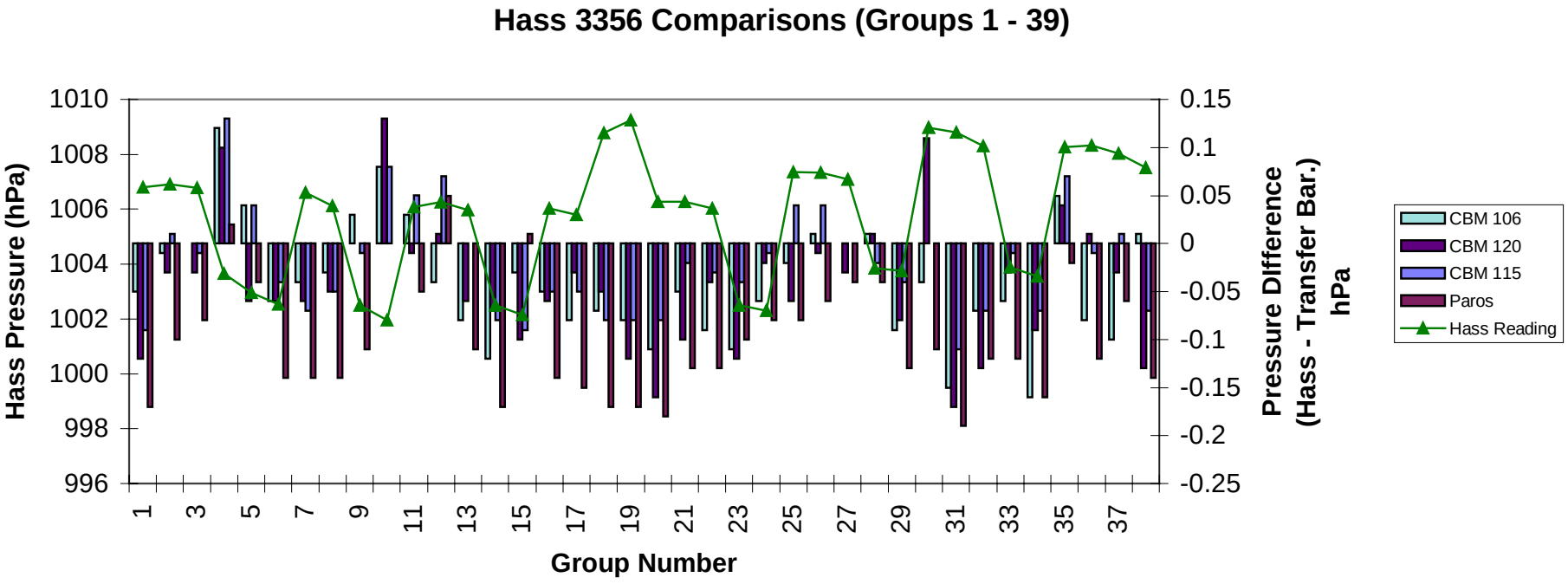

Figure 2(a) - Hass 3356 Comparisons (Groups 1 - 39)

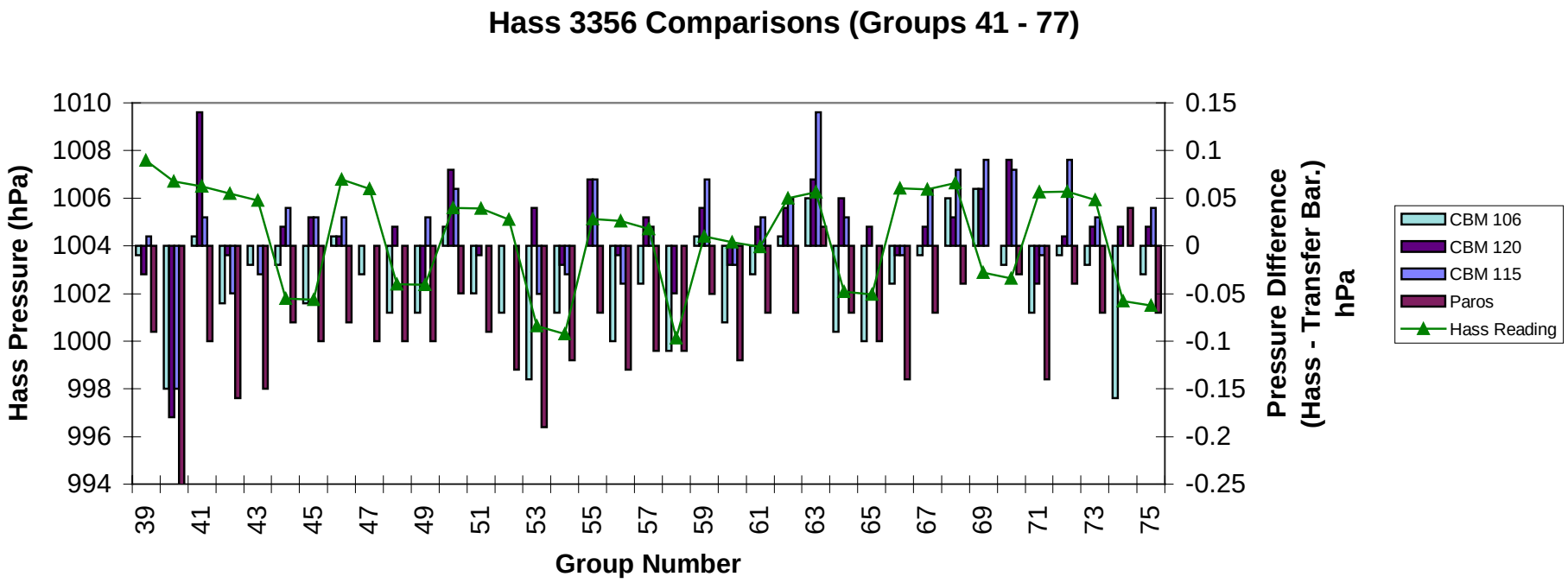

Figure 2(b) - Hass 3356 Comparisons (Groups 40 - 46)

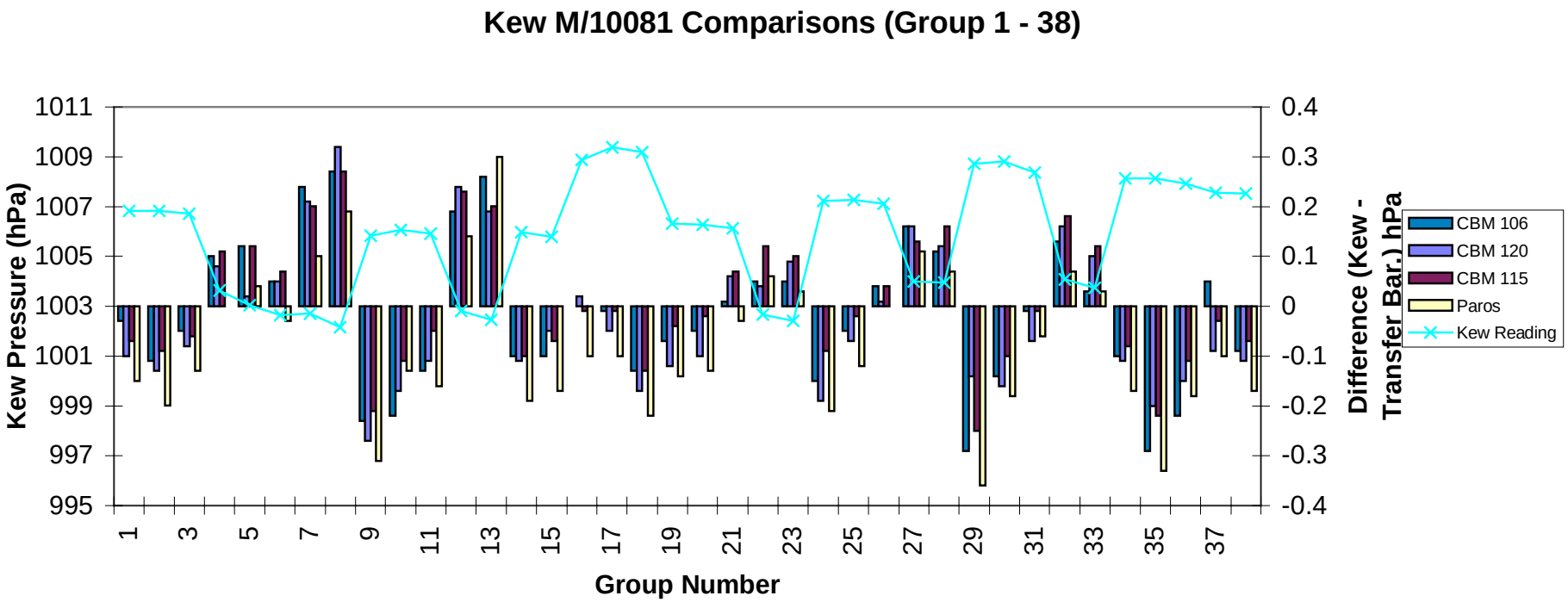

Figure 3(a) - Kew M/10081 Comparisons (Groups 1 - 38)

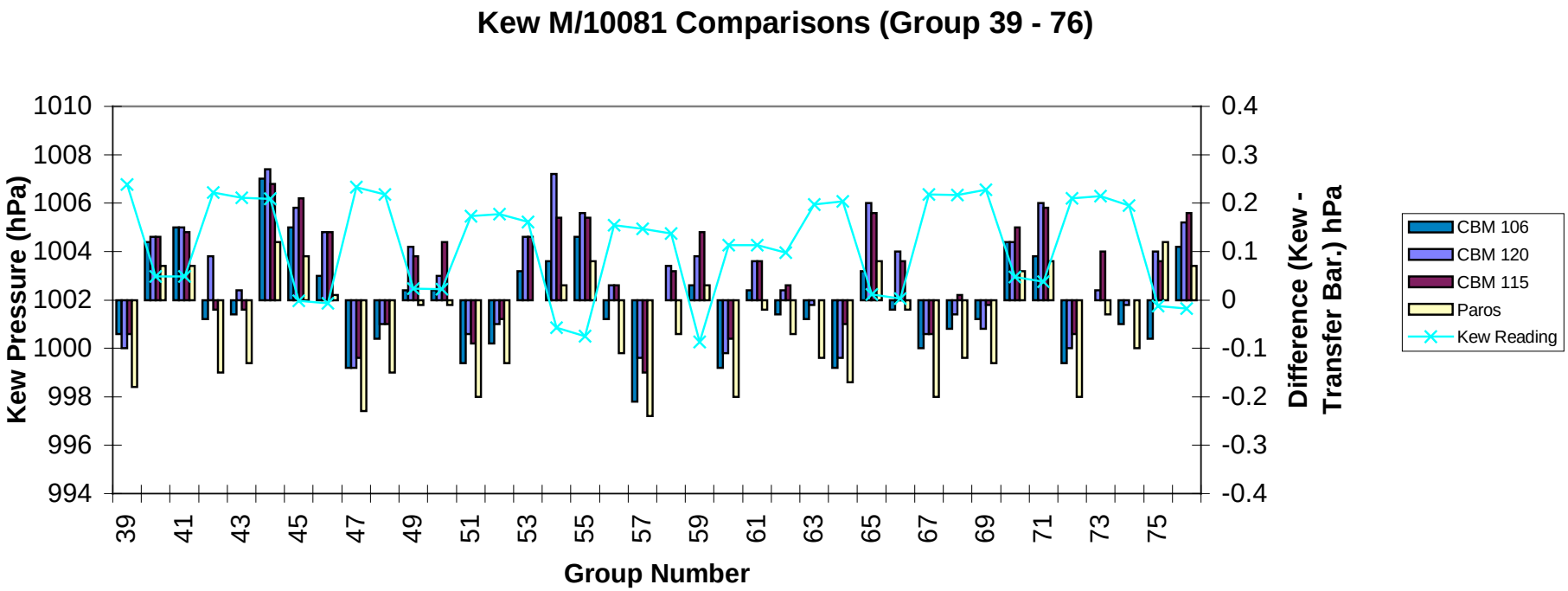

Figure 3(b) - Kew M/10081 Comparisons (Groups 39 - 76)

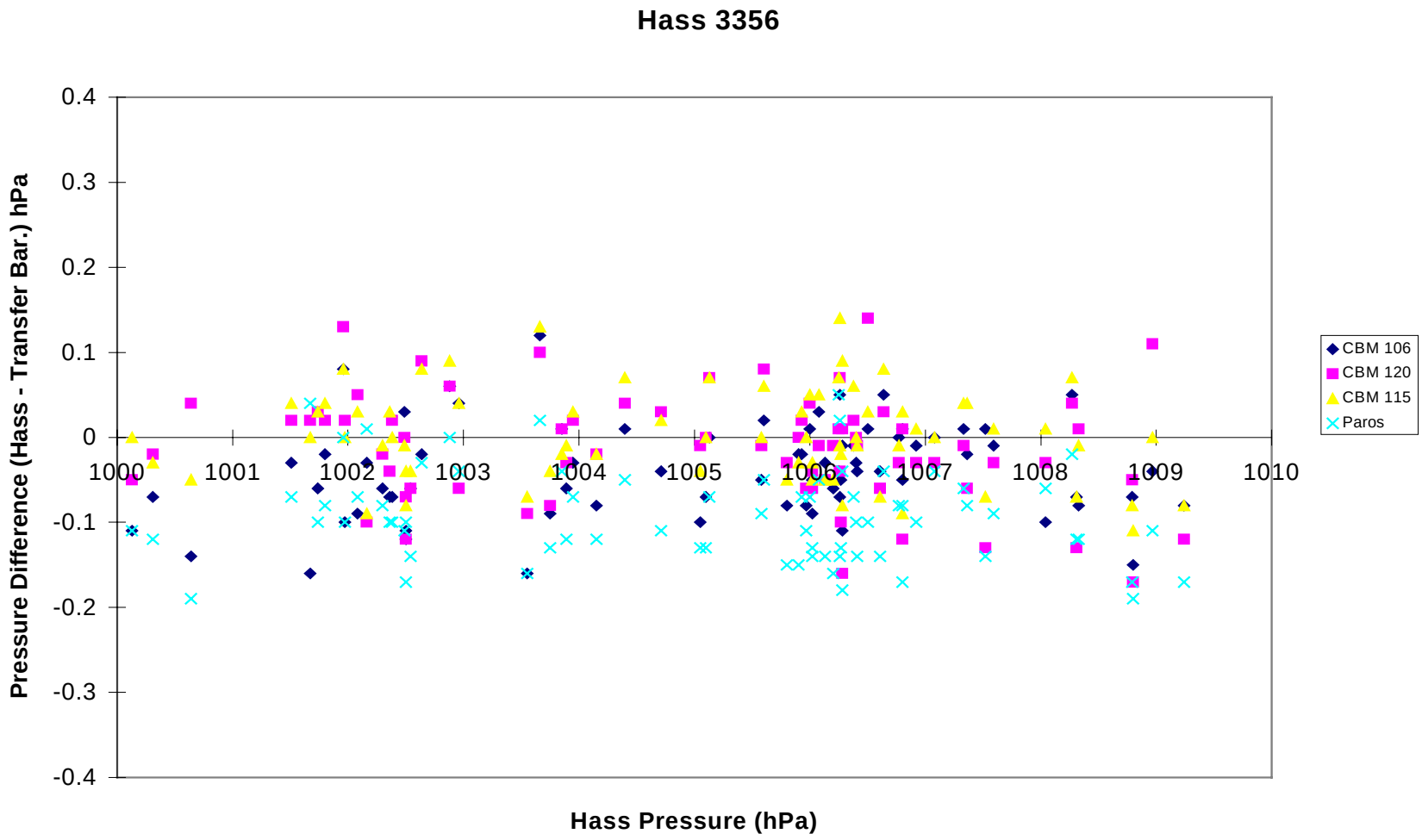

Figure 4 - Scatter plot of Hass 3365 Pressure Vs Transfer Std. Difference

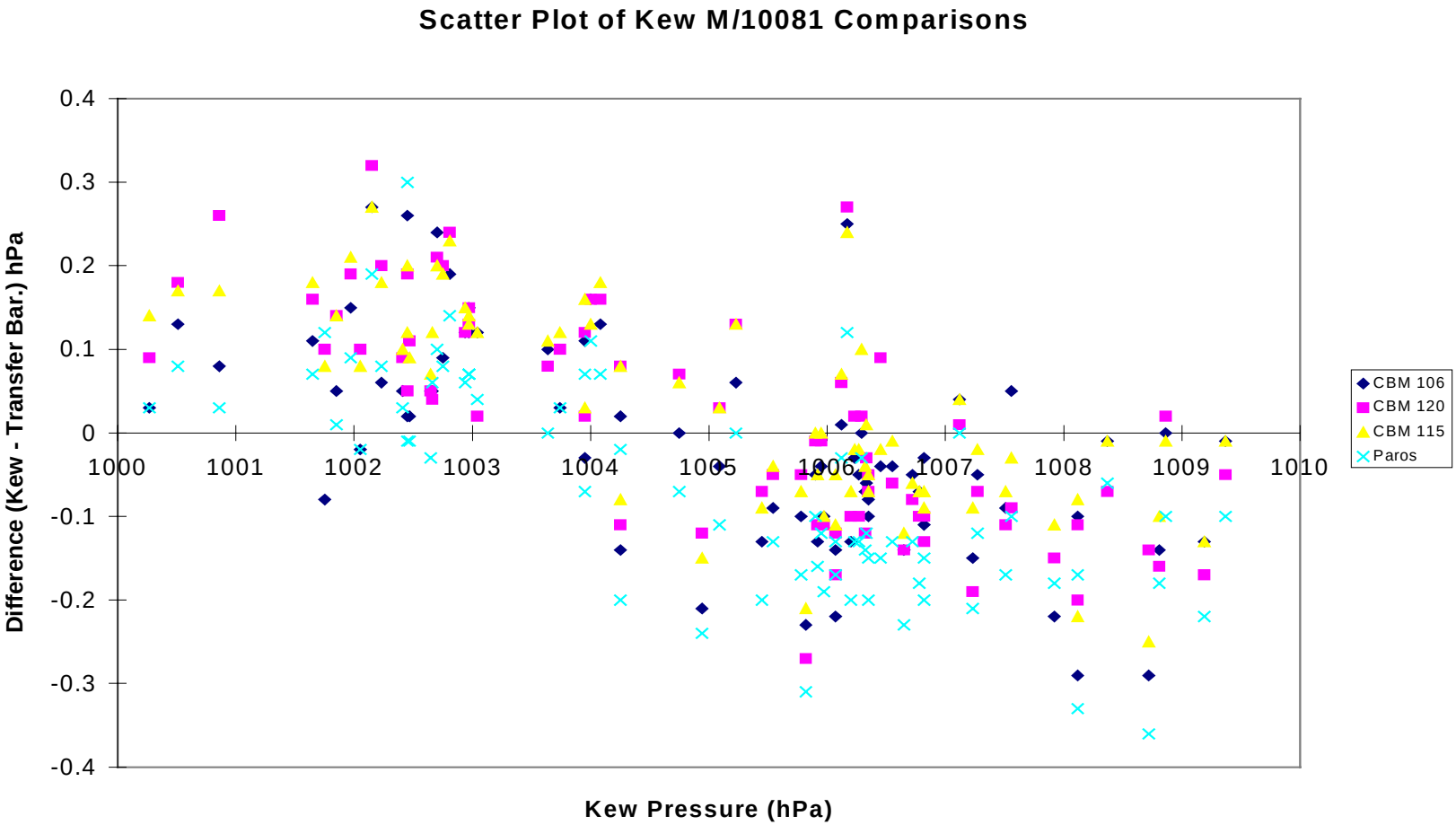

Figure 5 - Scatter plot of Kew M/10081 Pressure Vs Transfer Std. Difference

Appendix A

Uncertainty	CBM 106 (±hPa)	CBM 120 (±hPa)	CBM 115 (±hPa)	Paros-cientific 760 (±hPa)
in the offset correction of the transfer standards, determined by pooling the standard deviations before and after comparison.	0.014	0.013	0.013	0.008
in the mean differences between the transfer standards and the Hass 3356.	0.013	0.015	0.013	0.016
estimated, due to the use of the transfer standards in conditions different from the calibration against the RA V standard.	0.05	0.05	0.05	0.05
estimated, uncertainty due to drift in offset correction.	0.08	0.08	0.08	0.04
estimated, due to air transportation.	0.10	0.10	0.10	0.08
in observer reading of transfer standard.	0.02	0.02	0.02	0.005
Uncertainty in each transfer barometer.	0.140	0.140	0.140	0.104
Combined Uncertainty (excluding Paroscientific 760)	0.081			
Combined Uncertainty (including Paroscientific 760)	0.066			
Uncertainty in the observers reading of the RAV standard	0.02			
Estimated uncertainty in the observers reading of the Malaysian Standard	0.03			
Uncertainty in the comparison results. (Excluding Paroscientific 760)	±0.089			
Uncertainty in the comparison results. (Including Paroscientific 760)	±0.075			

Table A1. - Hass 3356: Calculation of combined uncertainty.

Uncertainty	CBM 106 (±hPa)	CBM 120 (±hPa)	CBM 115 (±hPa)	Paros-cientific 760 (±hPa)
in the offset correction of the transfer standards, determined by pooling the standard deviations before and after comparison.	0.014	0.013	0.013	0.008
in the mean differences between the transfer standards and the Kew M/10081	0.028	0.031	0.028	0.030
estimated, due to the use of the transfer standards in conditions different from the calibration against the RA V standard.	0.05	0.05	0.05	0.05
estimated uncertainty due to drift in offset correction.	0.08	0.08	0.08	0.04
estimated, due to air transportation.	0.10	0.10	0.10	0.08
in observer reading of transfer standard.	0.02	0.02	0.02	0.005
Uncertainty in each transfer barometer.	0.142	0.143	0.142	0.107
Combined Uncertainty (excluding Paroscientific 760)	0.082			
Combined Uncertainty (including Paroscientific 760)	0.067			
Uncertainty in the observers reading of the RAV standard	0.02			
Estimated uncertainty in the observers reading of the Malaysian Standard	0.05			
Uncertainty in the comparison results. (Excluding Paroscientific 760)	±0.098			
Uncertainty in the comparison results. (Including Paroscientific 760)	±0.086			

Table A2 - Kew M/10081: Calculation of combined uncertainty.

Uncertainty	CBM 106 (±hPa)	CBM 120 (±hPa)	CBM 115 (±hPa)
in the offset correction of the transfer standards, determined by pooling the standard deviations before and after comparison.	0.014	0.013	0.013
in the mean differences between the transfer standards and the PS-760.	0.011	0.013	0.008
estimated, due to the use of the transfer standards in conditions different from the calibration against the RA V standard.	0.05	0.05	0.05
estimated, uncertainty due to drift in offset correction.	0.08	0.08	0.08
estimated, due to air transportation.	0.10	0.10	0.10
in observer reading of transfer standard.	0.02	0.02	0.02
Uncertainty in each transfer barometer.	0.140	0.140	0.140
Combined Uncertainty	0.081		
Uncertainty in the observers reading of the RAV standard	0.02		
Estimated, uncertainty in the observers reading of the PS-760	0.01		
Uncertainty in the comparison results.	±0.084		

Table A3 - Paroscientific 760: Calculation of combined uncertainty