ELECTRONIC MEASUREMENT OF BAROMETRIC PRESSURE: A Comparison of Omega Model EWS-BP-A, Setra Model 276, Setra Model 278, and Vaisala Model PTB101B

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INTRODUCTION

Barometric pressure (or atmospheric pressure) is the force exerted on the ground surface by the atmosphere. Barometric pressure is expressed in many different units:

1 atmosphere = 14.7 lb/in^2 = 760 mm Hg = 760 torr = 1.013 bars = 101.3 kPa

The SI unit of pressure is the Pascal (Pa) and barometric pressure is best expressed in kilopascals (kPa). The standard barometric pressure (101.3 kPa) is the pressure at sea level at 15°C and 45° latitude. Barometric pressure decreases with increasing elevation. To compare pressure conditions among locations, meteorologists correct pressure to its sea-level equivalent (Eq. 1),

$$dP = 1013.25\{1-[1-(E/44307.69231)]^{5.25328}\} \qquad (1)$$

where *dP* is the reduction in pressure (in millibars) resulting from the site elevation and *E* is meters above sea level.

The first measurements of barometric pressure were made centuries ago using a mercury manometer, and even now mercury barometers are a standard reference instrument due to their inherent accuracy. Liquid manometers, however, have three disadvantages: 1) they are delicate and require perfectly vertical and level mounting, 2) their readings must be manually temperature-corrected, and 3) they do not have an electronic output.

Electronic barometric pressure transducers can be interfaced with a datalogging system for continuous measurement and recording. Better quality transducers are fully temperature compensated. We tested four electronic barometric pressure transducers in our laboratory (Table 1). Two of the sensors are available either directly from the manufacturer or from Campbell Scientific (model numbers in parentheses).

Table 1. Specifications of three barometric pressure sensors tested at the USU Crop Physiology Laboratory.

	Omega EWS-BP-A	Setra 276	Setra 278 (CS100)	Vaisala PTB101B (CS105)
Price	$145	$357	$578 ($540)	($580)
Range (kPa)	70 to 108	80 to 110[a]	60 to 110[b]	60 to 106
Accuracy at room temp.	*±0.36 kPa*	*±0.075 kPa*[c]	*±0.05 kPa*	*±0.05 kPa*
Temperature Range (^{o}C)	0 to 60	-18 to 79	-40 to 60	-40 to 60
Output (VDC)	1 to 5	0.5 to 4.5[d]	0 to 2.5	0 to 2.5
Supply (VDC)	8 to 24	4.9 to 7.1[e]	9.5 to 28	10 to 30

[a]Also available in 60 to 110 kPa range for same price
[b]Also available from Setra in 50 to 110 and 80 to 110 kPa range for same price
[c]±0.25% of the full scale range (30 kPa in this case)
[d]Also available in 0.1 to 5.1 VDC output range
[e]Also available in 9.0 to 14.5 and 21.6 to 26.0 VDC ranges

DIFFERENCES AMONG THE TRANSDUCERS

Four sensors are compared ranging in price from $145 to $580 (Table 1). The specified accuracies of the three more expensive sensors (Setra and Vaisala) are similar at room temperature. The Setra 278 and Vaisala PTB101B sensors are similar in design and circuitry and are carefully calibrated to self-correct for hysteresis and for temperature, zero, and span changes. They are expected to perform better than the Setra 276 over a range of temperatures and through time. The Setra 276 has one internal electrode while the Setra 278 and Vaisala PTB101B have a dual electrode design. The addition of a second, reference electrode enables more precise temperature compensation.

SENSOR TESTING AT THE CROP PHYSIOLOGY LABORATORY

Comparison of Setra and Vaisala Sensors

The three Setra and Vaisala sensors were connected to a Campbell Scientific 21X datalogger in the laboratory. Multipliers and offset values were provided by the manufacturer. Readings were taken over the course of 40 days (Figure 1).

Manual readings of the mercury barometer located in the USU Chemistry department were made and compared to the readings of each of the three sensors (Table 2). The Hg-barometer measures pressure with a resolution of 0.1 mm Hg (0.013 kPa). The 182-ft. (55.5-m) elevation difference between the Crop Physiology Lab and the chemistry lab on campus were accounted for using an online calculator: http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/barfor.html

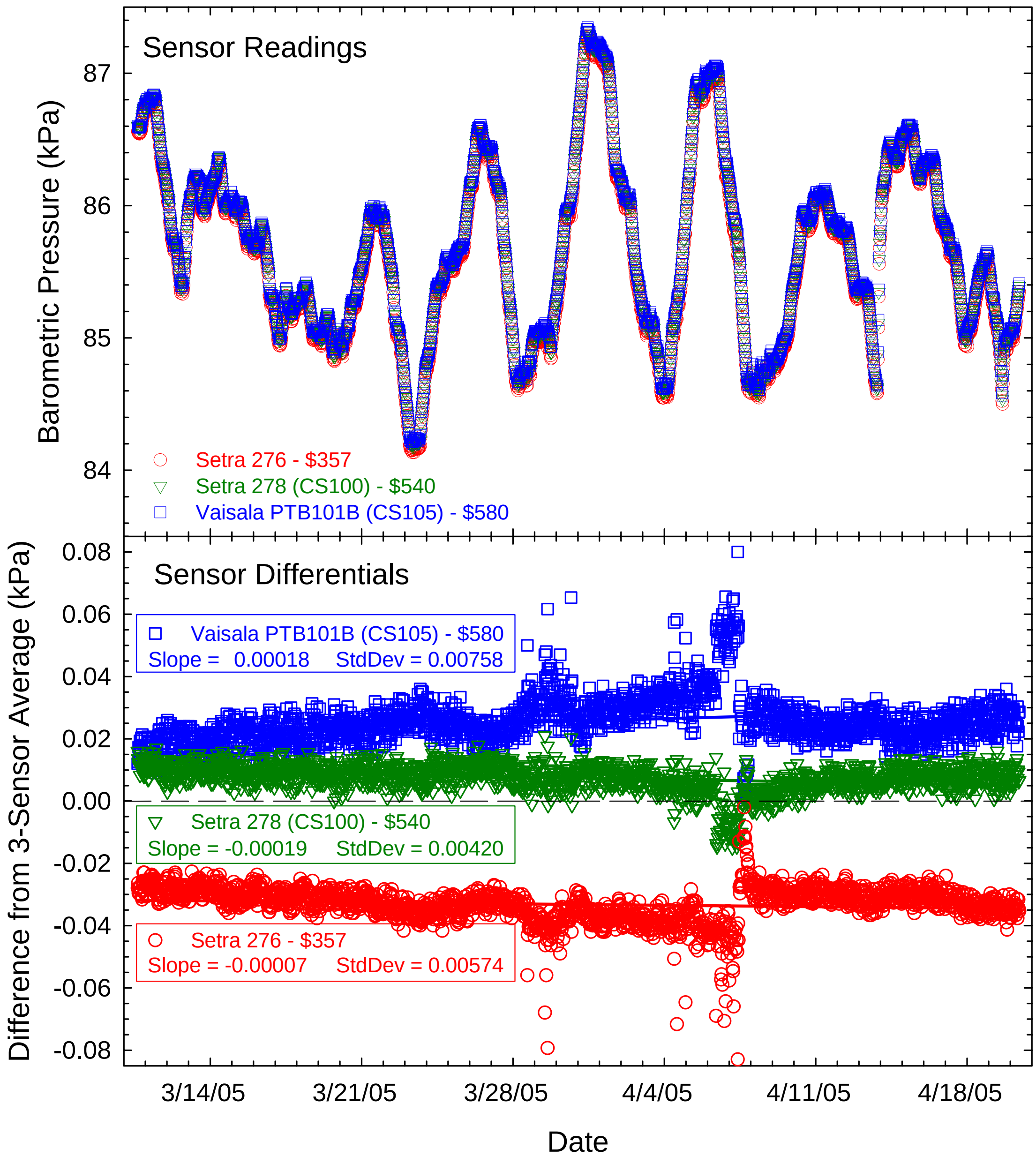

Figure 1. ***Top:*** **One-second barometric pressure readings at 30-minute intervals over a 40-day period.** ***Bottom:*** **Sensor differentials were calculated by subtracting the average of the three sensor readings from each individual sensor reading. The slope of each line indicates the sensor's stability over time. The standard deviation of the points from the line indicates the random noise in the sensor. Deviations were greatest during the period of temperature response testing, 3/28/05 to 4/9/05.**

Table 2. Comparison of barometric sensor outputs to Hg-manometer/barometer readings made on March 30, 2005 at 11:40 (reading #1) and on April 7, 2005 at 14:50 (reading #2).

Barometer/Sensor	Reading #1 (kPa)	Difference #1 from Hg-manometer (kPa)	Reading #2 (kPa)	Difference #2 from Hg-manometer (kPa)
Hg-manometer	85.939	0.000	85.155	0.000
Setra 276	85.903	-0.036	85.159	+0.004
Setra 278	85.948	+0.009	85.182	+0.027
Vaisala PTB101B	85.962	+0.023	85.207	+0.052
Mean of the Differences		*-0.001*		*+0.028*

The temperature response of the sensors was tested by varying the temperature of the sensor environment between 10 and 51°C over a 2-week period. All three sensors were affected by temperature (Figure 2), but the Setra 278 had a smaller temperature coefficient (slope of the line) than the other two sensors over the range of temperatures tested.

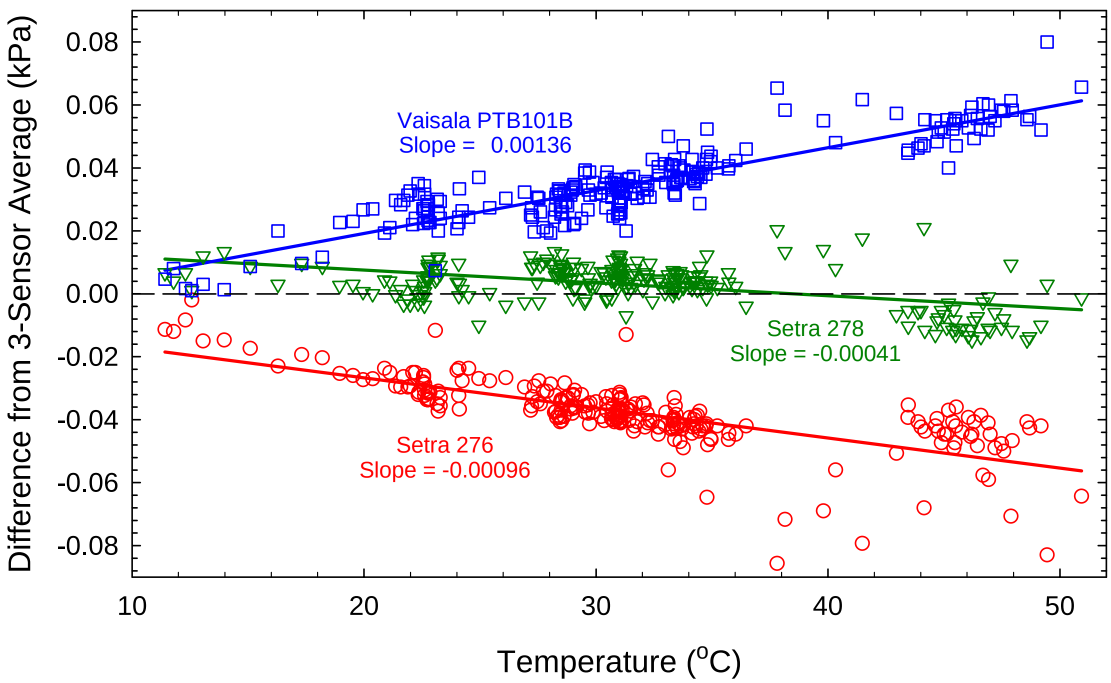

Figure 2. Sensor differentials across a temperature range from 10 to 51°C. Sensor differentials were calculated by subtracting the average of the three sensor readings form each individual sensor reading. The slope of each line indicates the influence of temperature on sensor output.

Comparison of Omega Sensor to Setra and Vaisala Sensors

The Omega EWS-BP-A is a low-cost alternative to the Setra and Vaisala sensors. It is designed to be wall mounted indoors, and is temperature compensated. The multiplier and offset were for the EWS were calculated based on the measurement and output ranges. Barometric pressure data were collected from all four sensors using the 21X logger for 33 days (Figure 3).

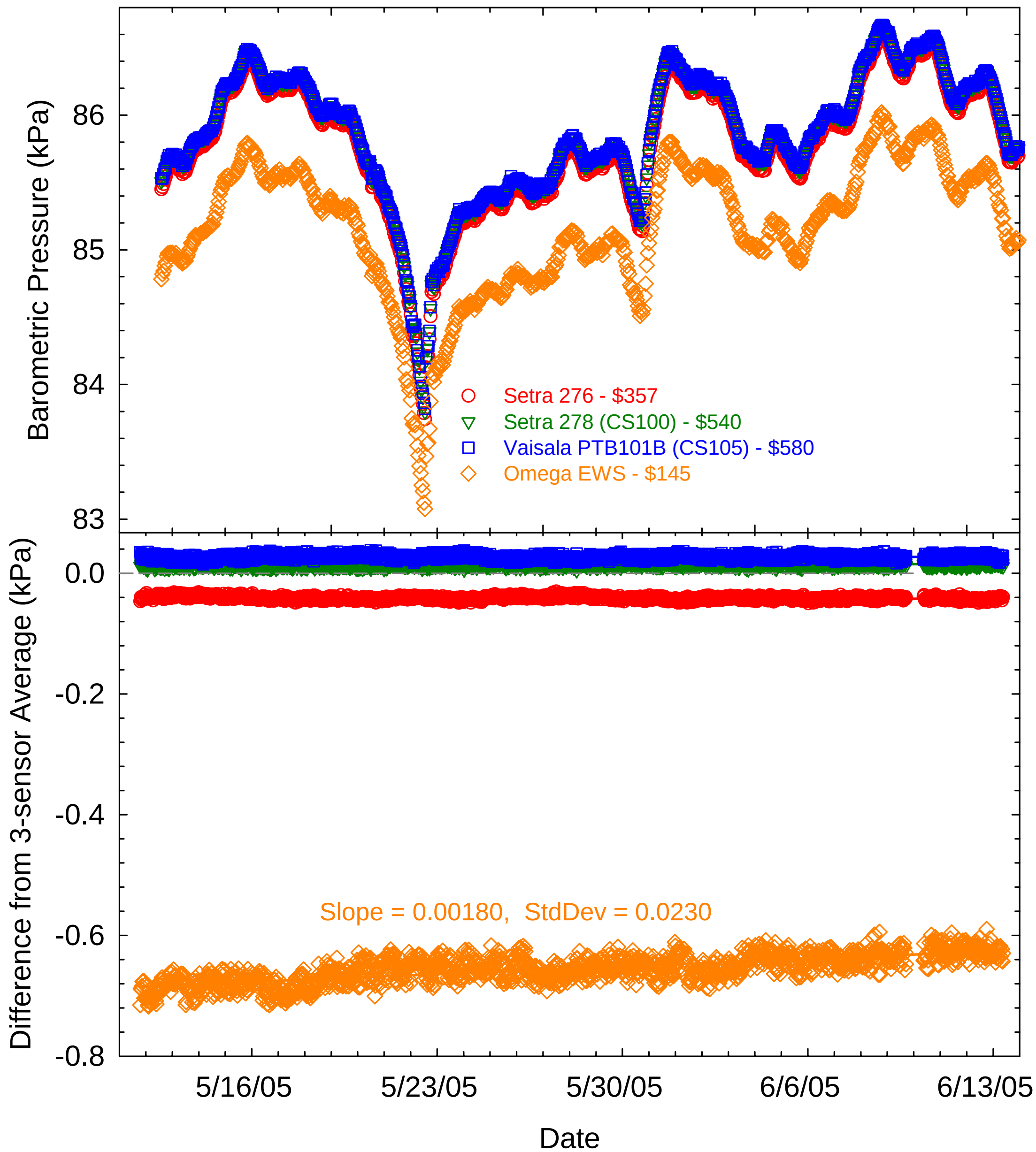

Figure 3. ***Top:*** **One-second barometric pressure readings at 30-minute intervals over a 33-day period.** ***Bottom:*** **Sensor differentials were calculated by subtracting the average of the three sensor readings from each individual sensor reading. The slope of each line indicates the sensor's stability over time. The standard deviation of the points from the line indicates the random noise in the sensor.**

DISCUSSION

All of the transducers performed satisfactorily in our lab environment over the time periods and the range of temperatures tested. The Setra 278 was the most stable sensor, as indicated by the smaller standard deviation from of the average line (Figure 1, bottom) and the smaller temperature response (Figure 2). The Setra 276 is good for measurements at room temperature, but its operating range of -18 to 79^{o}C may not be suitable for outdoor use in cold environments. The Omega EWS-BP-A is a cost-effective alternative that is suitable for laboratory use. We will continue to monitor the performance of these sensors to evaluate long-term drift of their output.

ACKNOWLEDGEMENTS

We wish to thank Campbell Scientific, Inc. for loaning us the Setra 278 (CS100) and Vaisala PTB101B (CS105) sensors for these tests.

APPENDIX

Wiring the transducers to a CSI 21X datalogger:

All four transducers can be connected to a Campbell Scientific 21X datalogger for excitation and differential measurement (Table A1). The Omega EWS, Setra 278 and Vaisala PTB101B require 12V power. The datalogger switches 12 VDC power to the sensor before measurement, then powers down the sensor after the measurement to conserve power. The three Setra and Vaisala sensors require an external trigger which can be powered by either an excitation or a control port. CR21X dataloggers supply 5 V excitation, but excitation from CR10X and CR1000 dataloggers is limited to 2.5 V. With CR10X or CR1000 dataloggers, a control port can supply the external trigger and a separate instruction is then used to read the sensors (see "Wiring the transducers to a CSI CR1000 datalogger" below).

Table A1. Campbell Scientific 21X datalogger wiring for the four barometric pressure transducers.

Sensor	Black to	White or Yellow to	Green to	Red to	Brown or Blue to	Clear or Silver to
Omega EWS	High port	Jumper H to L with 250Ω resistor.		12V power	Jumper L to ⏚.	
Setra 276	⏚	Low port	High port	Ex channel	none	⏚
Setra 278	⏚	Low port	High port	12V power	Ex channel	none
Vaisala PTB101B	⏚	Low port	Ex channel	12V power	High port	Case

Programming a 21X datalogger:

For excitation and differential measurement of each sensor, a P8 instruction (**`Ex-Del-Diff`**) is used. A brief delay between the excitation and the differential measurement is necessary for the Setra 278 and Vaisala PTB101B sensors, but is not necessary for the Setra 276 sensor. With the following multipliers and offsets the sensors will output barometric pressure in kPa.

Example 21X program:

```
; Read the Setra 276 Barometric Pressure Sensor
1:      Ex-Del-Diff  (P8)
   1:   1          Reps
   2:   5          5000 mV slow range
   3:   1          DIFF Channel
   4:   1          Excite all reps w/ Exchan1
   5:   1          Delay (0.01 sec units)
   6:   5000       mV excitation
   7:   1          Loc [ Setra_276 ]
   8:   0.0075     Mult
   9:   76.25      Offset

; Read the Setra 278 Barometric Pressure Sensor
2:      Ex-Del-Diff  (P8)
   1:   1          Reps
   2:   5          5000 mV slow range
   3:   2          DIFF Channel
   4:   2          Excite all reps w/ Exchan2
   5:   10         Delay (0.01 sec units)
   6:   5000       mV excitation
   7:   2          Loc [ Setra_278 ]
   8:   0.02       Mult
   9:   60         Offset

; Read the Vaisala PTB101B Barometric Pressure Sensor
3:      Ex-Del-Diff  (P8)
   1:   1          Reps
   2:   5          5000 mV slow range
   3:   3          DIFF Channel
   4:   3          Excite all reps w/ Exchan3
   5:   100        Delay (0.01 sec units)
   6:   5000       mV excitation
   7:   3          Loc [ Vaisala ]
   8:   0.0814     Mult
   9:   60         Offset

; Read the Omega EWS-BP-A Barometric Pressure Sensor
3:      Volt  (Diff) (P2)
   1:   1          Reps
   2:   5          5000 mV slow range
   3:   4          DIFF Channel
   4:   3          Loc [ Omega ]
   5:   .00949     Mult
   6:   60.95      Offset
```

Wiring the transducers to a CSI CR1000 datalogger:

All four transducers can be connected to a Campbell Scientific CR1000 datalogger (Table A2). The Omega EWS, Setra 278 and Vaisala PTB101B require 12V power. The datalogger switches 12 VDC power to the sensor before measurement, then powers down the sensor after the measurement to conserve power. With the CR1000 either a control port or the Switched 12V port can supply the external trigger to switch power to the sensors. A separate instruction is then used to read the sensors (see “Wiring the transducers to a CSI CR1000 datalogger” below).

Table A2. Campbell Scientific 21X datalogger wiring for the four barometric pressure transducers.

Sensor	Black to	White or Yellow to	Green to	Red to	Brown or Blue to	Clear or Silver to
Omega EWS	DIFF H1	Jumper H1 to L1 with 250Ω resistor.		SW12V power	Jumper L1 to ⏚ .	
Setra 276	G	DIFF L2	DIFF H2	5V power	none	⏚
Setra 278	G	⏚	SE Channel 5	12V power	Control Port 1	none
Vaisala PTB101B	G	⏚	Control Port 2	12V power	SE Channel 6	⏚

Programming a CR1000 datalogger:

The CR1000 can be programmed using the CRBasic Editor software within Loggernet version 3.1 or later. In Table A2 and in the programming example below, the Omega EWS sensor is wired to switched 12V power. The Setra 278 and Vaisala PTB101B are wired to 12V power and a control port is used to switch power on and off. The Setra 276 requires only 5V power, and is wired to the constant 5V power supply. The multipliers and offsets used in the example program convert sensor output to barometric pressure in kPa.

Example CR1000 program:

```
'Main Program
BeginProg
	Scan(1,Sec,1,0)
		'Omega EWS Barometric Pressure Sensor measurement Omega_EWS:
		SW12 (1 )
		VoltDiff (Omega_EWS,1,mV5000,1,True ,0,250,0.00949,60.95)
		'Setra 276 Barometric Pressure Sensor measurement Setra_276:
		VoltDiff(Setra_276,1,mV5000,2,True,0,250,0.0075,76.25)
		'CS100 Barometric Pressure Sensor measurement Setra_278:
		PortSet(1,1)
		VoltSE(Setra_278,1,mV5000,5,1,0,_60Hz,0.02,60)
		'CS105 Barometric Pressure Sensor measurement Vaisala:
		PortSet(2,1)
		VoltSE(Vaisala,1,mV5000,6,1,0,_60Hz,0.0184,60)
		'Call Data Tables and Store Data
		CallTable(Table1)
	NextScan
EndProg
```