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Investigation of the Usability of Mobile Sensors for Weather Forecasting

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Abstract

Crowd sourcing is a popular method for providing data from people by the use of mobile sensor, internet and communication technologies. However efficient use of the raw data provided by the sensors with different characteristics in order to obtain accurate results is not investigated in detail. This study aims to investigate the data collected by mobile sensors integrated in the smartphones for scientific purposes such as weather forecasting. In this context, accuracy of the data provided mobile humidity, pressure and temperature sensors was examined in this study. Data provided by 5 smart phones and 3 Bluetooth sensors were tested in this context. Accuracy assessment process was performed by calculating the Root Mean Square Errors of the data with respect to reference data collected by TST Sensor simultaneously. This study shows that accuracy of the data collected with the mobile sensors is affected by several external parameters such as climatic conditions, handling habits of the user, and etc. Although it is possible to calculate correction constant for each sensor separately, it is not possible to calculate a unique and universal correction constant in order to increase the accuracy of the raw data collected by the mobile sensors. Therefore further studies should be executed for improving the accuracy of the mobile sensor data for scientific purposes.

Keywords: Mobile sensors, weather forecast, accuracy assessment, smartphone

Introduction

The weather monitoring and forecasting holds great importance and is used in several areas ranging from keeping track of agricultural field weather conditions to that of industrial conditions monitoring. Weather forecast is made by the use of subjective and objective methods based on the observations and analysis meteorological events (Ladd and Driscoll, 1980; Murphy and Brown, 1984). Stated meteorological observations are mainly based on the field measurements at meteorological observation stations. In this context, many meteorological parameters such as wind (direction, speed and gust), air (ground) temperature, air (ground) pressure, evaporation, precipitation and etc. are observed by using several methods (URL 1).

In recent years, usage of mobile sensors has become rapidly widespread in diversified disciplines such as meteorology for weather forecasting and wildfire detection, urban planning for traffic management, satellite imaging for earth and space observation, medical purposes for patient care with the help of biometric sensors and homeland security for radiation and biochemical detection at ports (Sheth, A. and Henson, C, 2008).

Sensor use in smart phones has increased due to its beneficial uses in daily life. Even cardiac rhythm can be measured by using mobile sensors integrated in the current smart phones. Most of the smartphones are currently on the market have equipped with the various mobile sensor such as Global Positioning System (GPS), magnetometer, gyro, accelerometer, proximity and light sensor (Liu, 2013; URL 2).

However; pressure, humidity and temperature sensors are not available in all smart phones.

As the use of sensor technology is increased, many researchers have started to investigate in order to understand the usability of smartphone sensors for scientific purposes such as weather forecasting, health detection, early warning in case of hazards and etc. An atmosphere data and software intelligence company had a mission to dramatically improve weather and climate forecasting by the use of mobile sensors and an android application called PressureNet was developed for this purpose (URL 3). The data collected with PressureNet Application has been shared with the scientists for the reason to improve the studies about more accurate weather forecast models. With this application, instantaneous and local data about the Earth atmosphere can be provided (see Figure 1).

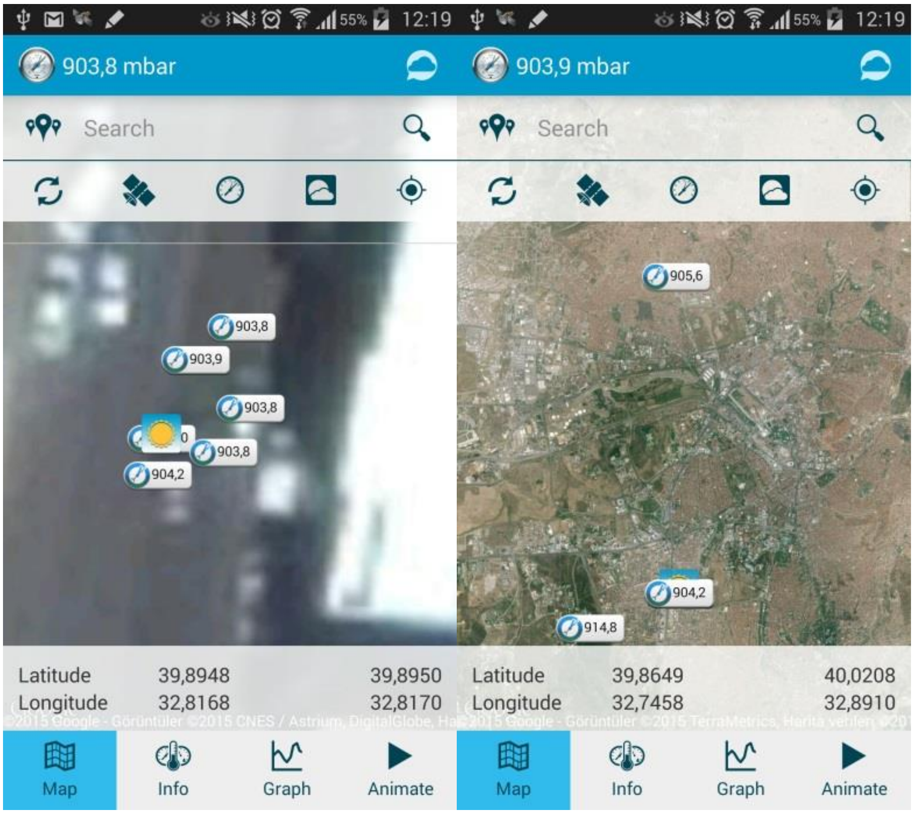

Fig. 1. PressureNet Application.

As it is seen Figure 2, PressureNet application used during Sandy Hurricane by thousands of people (URL 4). Figure 3 shows the results of two week-long observation at the same position which includes pressure, temperature and humidity records depending on the weather phenomena. As it may be seen on Figure 3, the values, which would be constant under normal conditions, are affected by weather events.

Between the dates 09 – 10 February, snowfall has been observed and the weather has warmed up after 12th of February. Pressure values designated with green color in Figure 3 point out this change in weather conditions. Pressure descended up to the 10th of February has risen up again due to the positive change in weather conditions. From this point of view, a relationship can be built up between rapid change in pressure and heavy rainfall.

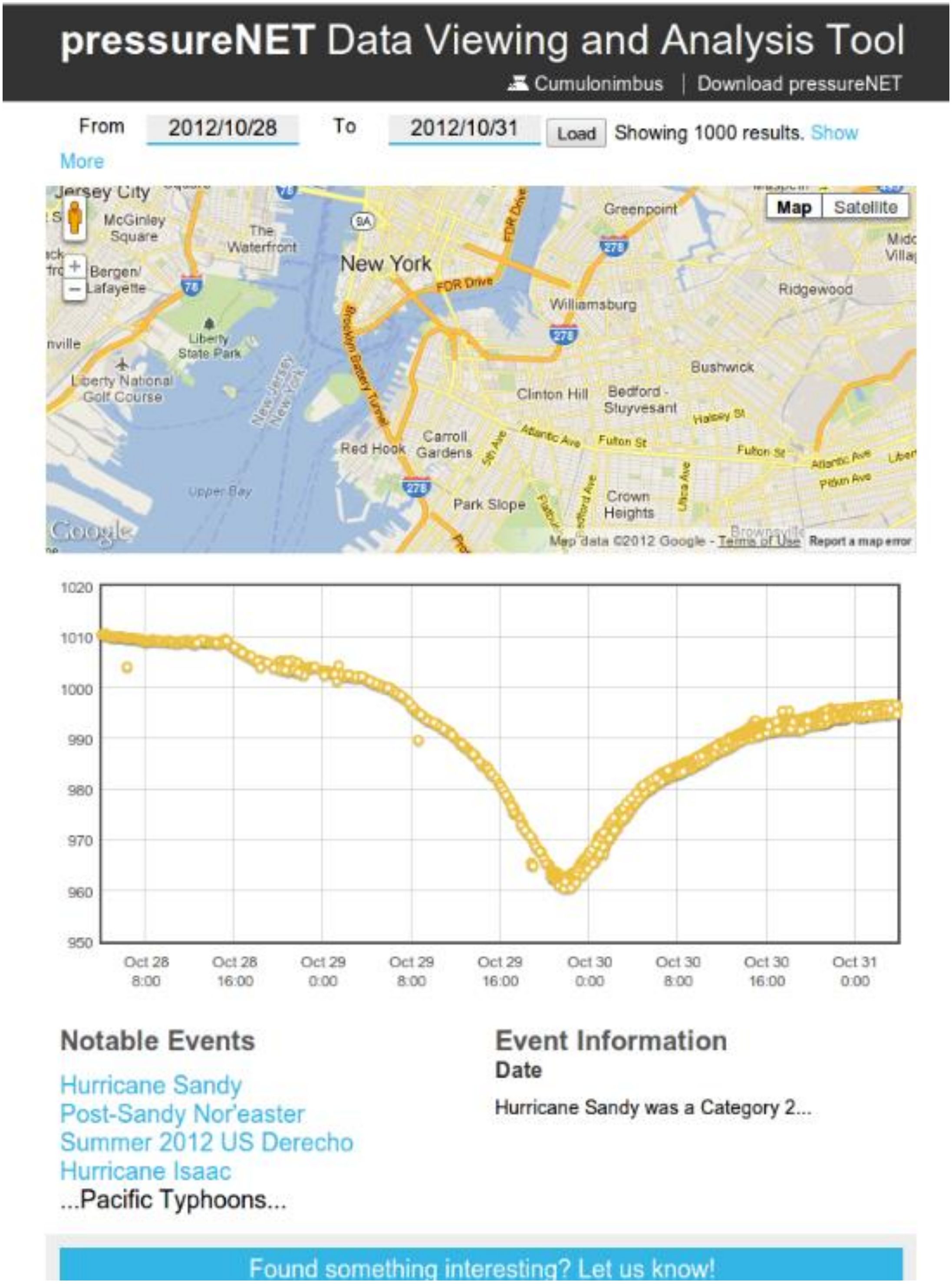

Fig.2. Application used during Sandy Hurricane (URL 4)

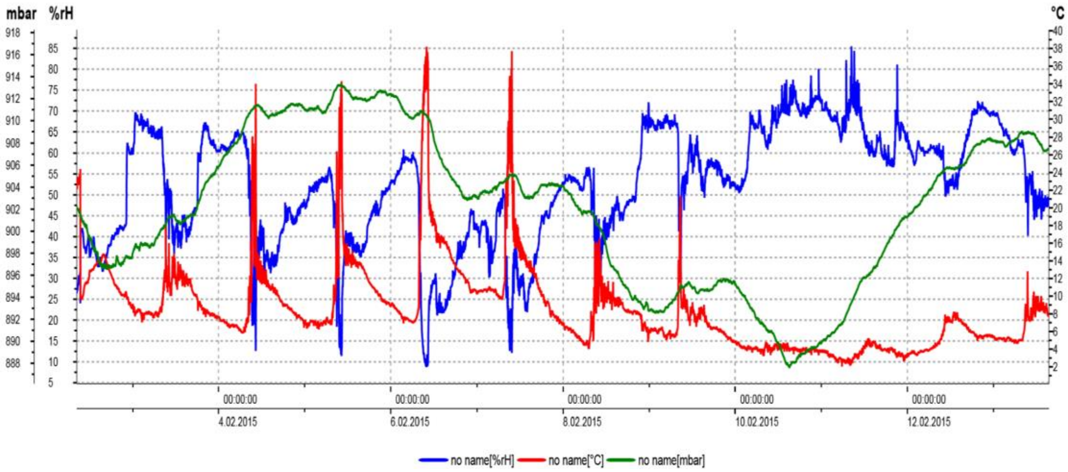

Fig.3. Pressure values designated (green color)

This study is inspired by the studies executed by PressureNet Team and aims to investigate usability of the mobile sensors for weather forecasting. In this context, 3 different model types of smart phone equipped with mobile sensors, 3 Bluetooth sensors and a professional sensor (TST) have been used. The accuracy of values derived from the Bluetooth sensor and 3 different smart phone sensors are checked by comparing them with the values of the professional sensor. Additionally accuracy and consistency of the data collected by the use of same smartphones were also examined in order to introduce the potential effects caused by the use of different smartphones. Finally, effect of the handling conditions of the smartphone on recorded sensor data were also examined within this study.

Data and Methodology

In this study humidity, temperature, and pressure data simultaneously collected in indoors by using 3 different types of smart phone (totally 5 smartphones) with integrated sensors, 3 Bluetooth sensors (TI-1, TI-2, TI-3) and a professional sensor (TST) have been used. Smart phones used in this study have different sensor capabilities as stated in Table 1. Since all of the smartphones have the same sensor capabilities, pressure sensors data collected by all data sensors was basically considered as the main data of this study. Humidity and temperature data were considered for examining the external factors affecting practical sensor accuracy.

Table 1: Sensor types used in the test models

	Model A	Model B	Model C
Pressure Sensor	+	+	+
Temperature Sensor	-	+	+
Humidity Sensor	-	+	+

Technical specifications of the smart phone sensors, TST and the Bluetooth sensor are presented in Table 2, Table 3 and Table 4 respectively. As the methodology of this study all sensors are placed at the same level under the same circumstances and data collected by that sensors was compared with the data provided by TST which is considered as reference data in order to determine the sensors' accuracy. The Root Mean Square Errors (RMSE) of the collected data was calculated in order to evaluate the accuracy of the sensors. Additional examinations of the collected data were performed in order to determine the external and/or internal parameters affecting the accuracy of the data recorded by mobile sensors such as

Table 2: Technical Specifications of the Smartphone Sensors

	Model A	Model B	Model C
Name	LPS331AP	BMP182	LPS25H
Max. Range	1260	1000	1013.25
Min. Delay	40000	66700	66700
Power	0.045	1	1.0
Resolution	2.4×10^{-4}	1	1.0
Vendor	STMicroelectronics	Bosch	STMicroelectronics
Absolute Accuracy P = 260 to 1260 hPa T = 0+80 °C	± 0.2 - 2	- 4 - +2	± 0.2 - 1

Table 3: Technical Specifications of the TST

Sensor Information		Humidity Sensor	
Memory	2 000 000	**Measurement Interval**	0 … 100 %RH
Storage Temperature	-40 … +85 °C	**Resolution**	0.1 %RH
Working Temperature	-20 … +70 °C		
NTC		**Pressure Probe**	
Measurement Interval	-20 … +70 °C	**Measurement Interval**	600 … 1100 mbar
Accuracy	± 0.2 °C (-20 … +70 °C) ± 0.4 °C	**Accuracy**	± 3 mbar (0 … +50°C)
Resolution	0.1 °C	**Resolution**	1 mbar

Table 4: Technical Specifications of the Bluetooth Sensor

Pressure Sensor	
Pressure Measurement Interval	300 … 1100 hPa
Relative Accuracy	± 0,15 (p= 950 hPa … 1050 hPa T=25 °C) ± 0,14 (p= 500 hPa … 1100 hPa T=25 °C … 40°C)
Absolute Accuracy	± 3 mbar (0 … +65oC)
Humidity Sensor	
Measurement Interval	0 … 100 %RH
Accuracy	± %3 RH
Temperature Sensor	
Measurement Interval	0 … +60°C
Accuracy	± 3 °C

use of different or same type of devices or handling habits of the user. The reference device TST, Model A, Model B and Bluetooth sensors were located in the same room and considered as the stationary while Model C is travelling in the building. 733 of the total 814 data records of Model C device were collected in the same room with the other devices.

Results

Daily measurements performed on 06-07 November 2014 are presented in Table 5. As it is shown in the table, totally 814 measurements were recorded for each sensor. RMSEs calculated by using reference data collected by using TST are also presented in Table 5. An additional RMSE were also calculated for the data, which was recorded in the same room with the other devices, of Model C and presented in Table 6.

According to the result of the analysis, accuracies of the pressure data of Model B and C were slightly different than the normal pressure values with a constant value for both. Therefore based on the detected constant error, 'Pressure Correction Values' were calculated as 3.1 and 3.6 for Model B and Model C, respectively. These pressure corrections were applied on records and corrected data were also presented in Table 5 and Table 6. The RMSEs were calculated again by using corrected records of Model B and C devices. Accuracies were calculated at reasonable levels for the pressure data obtained by Model A, TI-1 and TI-2 sensors.

Table 5: Sensor Accuracies in 06-07 November 2014

		Num. of Measurements	RMSE
Model A	**Pressure**	814	0.21
Model B	**Pressure**	814	3.11
	Corrected Pressure	814	0.06
	Temperature	814	0.84
	Humidity	814	1.55
Model C	**Pressure**	814	3.60
	Corrected Pressure	814	0.38
	Temperature	814	2.05
	Humidity	814	7.04
TI-1 Model A	**Pressure**	814	0.38
	Temperature	814	0.69
	Humidity	814	2.19
TI-2 Model A	**Pressure**	814	0.27
	Temperature	814	0.68
	Humidity	814	1.96

Table 6: Model C Sensor Accuracies

		Num. of Measurements	RMSE
Model C	**Pressure**	733	3.67
	Pressure Correction	733	0.11
	Temperature	733	1.66
	Humidity	733	6.79

As analysis was carried out, correction constants have been determined for the data of Model A, B and C devices. These correction constants are 0, 3.1 and 3.6 for Model A, B and C devices respectively. Consequently it is introduced that a single correction constant cannot be applied for all sensors. Therefore absolute pressure values cannot be used for any purposes unless a correction constant were determined and considered in calculations.

Further examinations were executed in order to determine a single correction constant for two different smartphone with the same model. The results are presented in Table 7. As it is seen in the Table 7, it is not possible to determine a single correction constant for same model devices. Consequently, it is introduced that errors of collected data is model independent.

Table 7: Sensor Accuracies on 19 December 2014

		RMSE
Model B - 1	**Pressure**	3.19
	Temperature	1.28
	Humidity	2.93
Model B - 2	**Pressure**	4.57
	Temperature	2.64
	Humidity	3.89
Model C – 1	**Pressure**	3.67
	Temperature	1.66
	Humidity	6.79
Model C – 2	**Pressure**	1.99
	Temperature	2.76
	Humidity	5.86

The effect of the handling habits of the user on sensor records were also examined by comparing humidity, pressure and temperature records of two sensors, one carried on hand and the other carried in pocket of the user. In this context, Model B device and TI Bluetooth sensor were used. In this test, both of the sensors were stationary and TI Sensor recorded its values in the pocket of the user until 12:00 while Model B device was recording on the table. After 12:00, TI Sensor position was changed and both sensors continued recording on the table. Line charts indicating the alteration of circumstances were presented in Figures 4-6. Y axis of these charts indicates sensor records and where X axis indicates time. Vertical line in each chart represents the time (at 12:00) when the handling method of the TI sensor is changed. As it is presented in Figure 4 Humidity records are directly affected by the handling habit of the user. Because humidity values of TI sensor were significantly higher than the values recorded by Model B Device until 12:00. This difference was made up after handling conditions of the sensors were consistent.

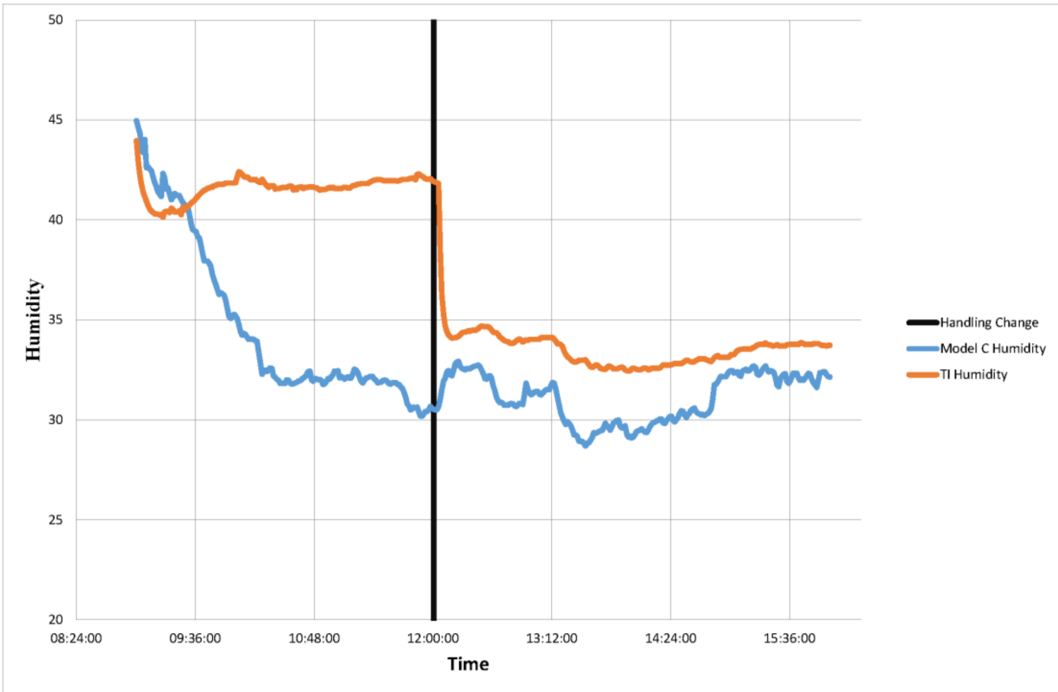

Fig. 4. The Effects of Handling Method on Humidity Records

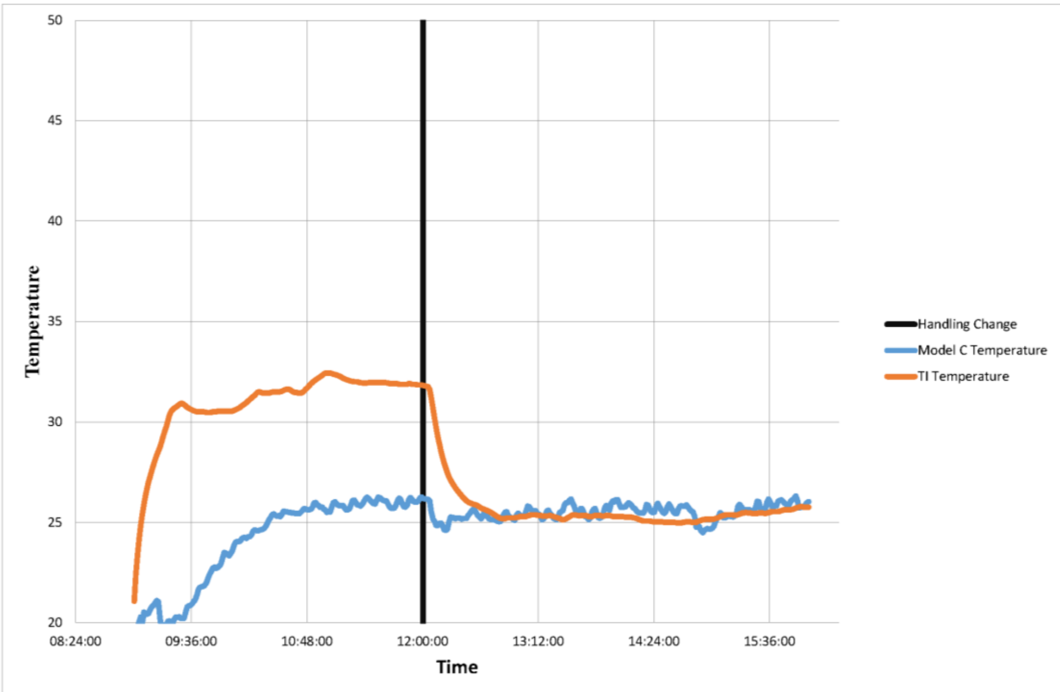

Fig. 5: The Effects of Handling Method on Temperature Records

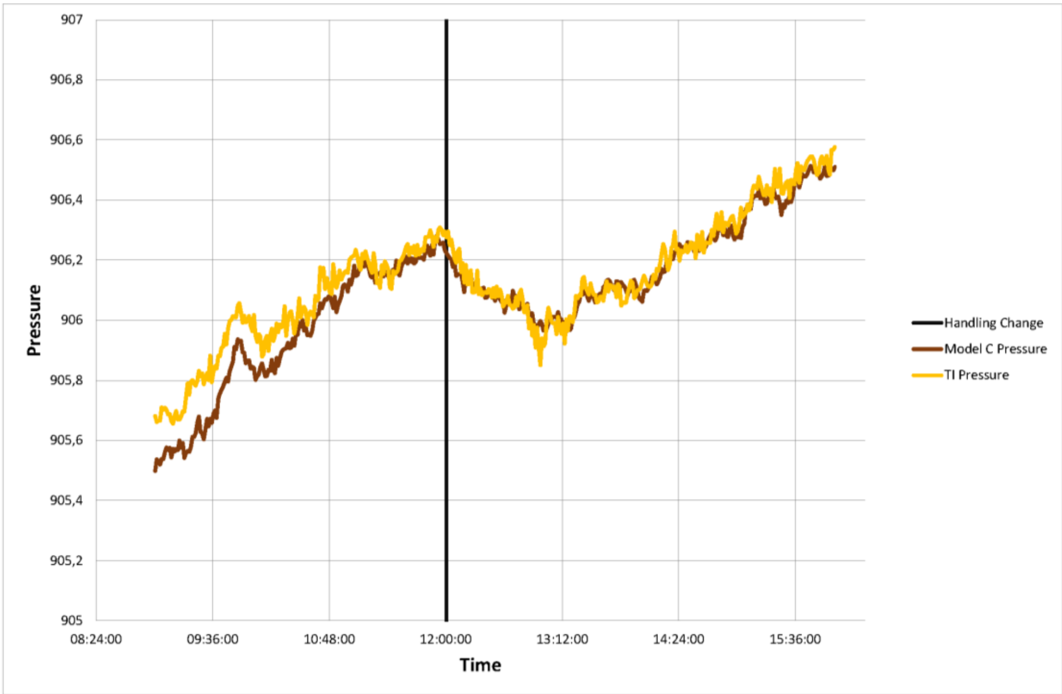

Fig. 6: The Effects of Handling Method on Pressure Records

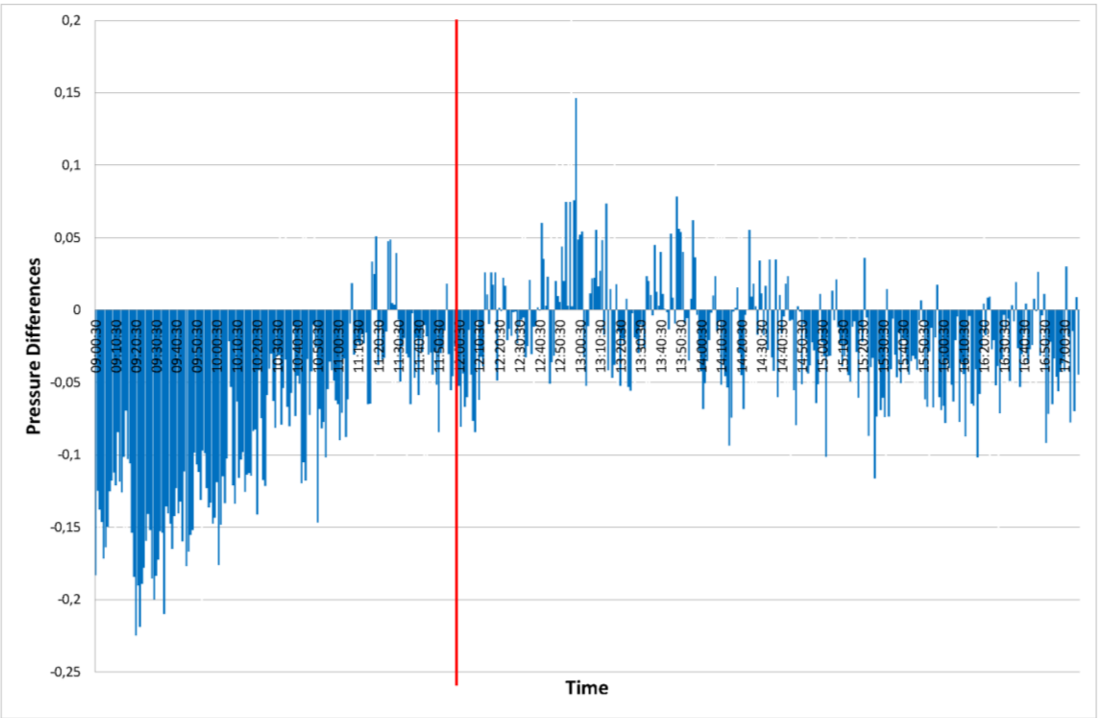

Fig. 7: Differences in pressure records

Figure 5 and Figure 6 represent the results of the test for temperature and pressure records respectively. As it is seen in the charts presented in the figures, handling method has a similar effect on temperature and pressure records with humidity records. Changes in pressure records are clearly presented in Figure 7. The bar chart presented in the figure indicates differences between the pressure records obtained from both of the sensors in time. Vertical line in the chart represents the time (at 12:00) when the handling method of the TI sensor is changed as in the other charts. As presented in the Figure 7, the differences between the pressure records significantly decrease after 12:00. Consequently, using a mobile sensor (smart phone) with a cover or in pocket has an effect on the sensor records.

Conclusion and Future Works

As a consequence, mobile sensors with today's technology are not capable of using for weather forecast since there are several parameters affecting the sensor measurements. Further studies should be executed in order to determine universal correction constants to be used for preprocessing of the raw data provided by the sensors used in different conditions. However, for the places with limited internet access, end-users can be warned at least with a low accuracy by means of the time series analysis obtained by data derived from the sensors. In the upcoming studies, prospective weather forecast would be able to perform in a test region with time series analysis and using sensor values.

This study shows that many factors such as handling methods of the sensor, type of smart phone use (with or without cover), and the conditions of the sensor location (air-condition, sunshine location and duration etc.) where the measurements are carried out could affect the accuracy of the sensors' data. Therefore methods should be developed in order to minimize and/or standardize these affects. Integration of the sensors in to wearable devices could minimize the effects caused by the handling habits of the users. In the near future, it could be probable to keep the correction constants of sensor values unique with the help of technological developments.

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