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Making a micro-barometer using a MEMS sensor and a Raspberry Pi

Raspberry Piと高感度気圧センサを用いた微気圧計の製作

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BACKGROUND （研究の背景）

In Jan.2022, the news of a sea floor volcanic eruption of Hunga-Tonga and the spreading barometric pressure changes over worldwide are exciting and surprising. In general, Mercury or Aneroid barometers are standard for school use. However, to use these old-fashioned types, we need some know-how to treat them. On the other hand, some electronic handheld barometers (e.g., "Ondotori" TR73-U, T&D) have become available, but few specialize in microbarometry, as described below. Therefore, we developed a new conceptual micro-barometer using a MEMS sensor. The purposes are: 1) To demonstrate a barometer in a classroom, 2) To record dairy barometric pressure changes, 3) To detect a pressure wave from the future big volcanic eruption

APPARATUS （研究器材）

As the sensor of the microbarometer, we chose DPS310 (MEMS sensor, Infineon The DPS310 (Infineon Technology, Inc.). A Raspberry Pi (RasPi) and a 7-inch color LCD were used as the logging device. Arduino Uno R3 was used for the AD converter. A block diagram (Fig. 1) and a photograph (Fig. 2) show the overall configuration. The sensor and Arduino are shown in Fig. 3. A 3-D printed plate is used to contain the sensor and Arduino. Soldering is not required for Grove connection and jumper plug connection. Due to the space limitation of this poster, the details of the system are available on the author's Web site (http://www.yossi-okamoto.net/).

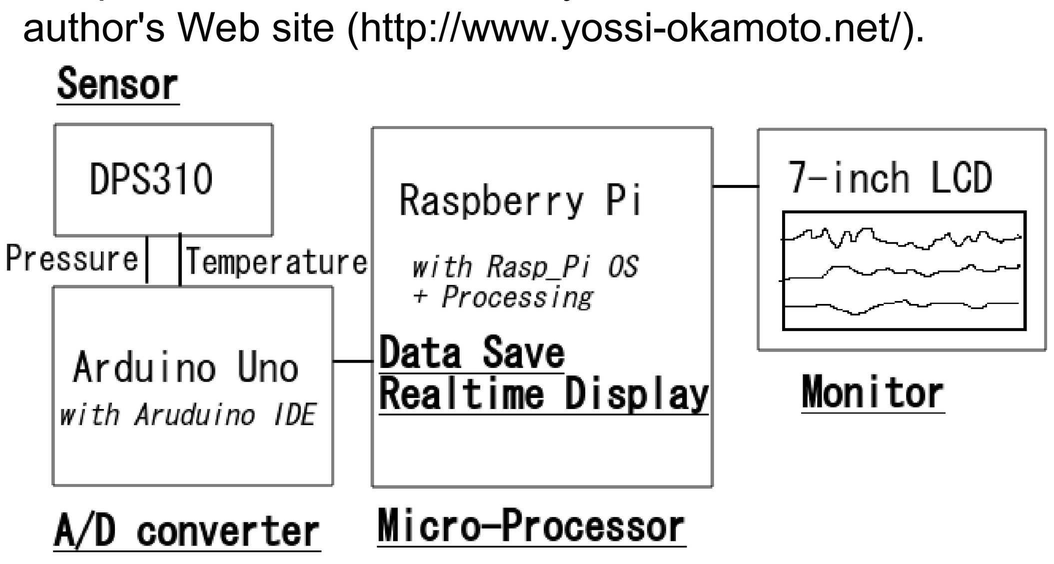

Fig. 1 Block diagram

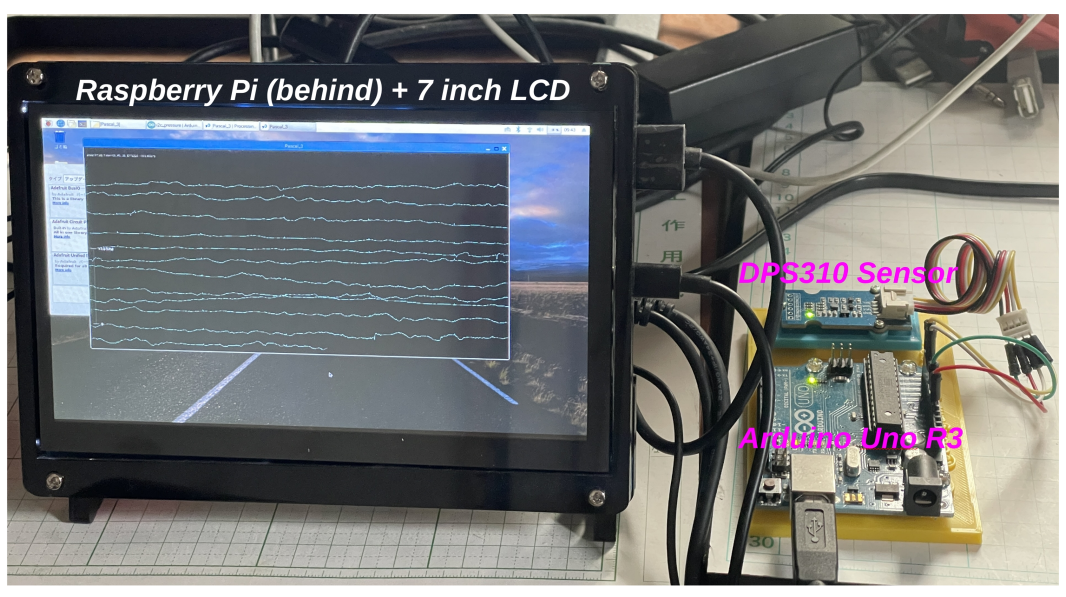

Fig.2 Whole system Prototype

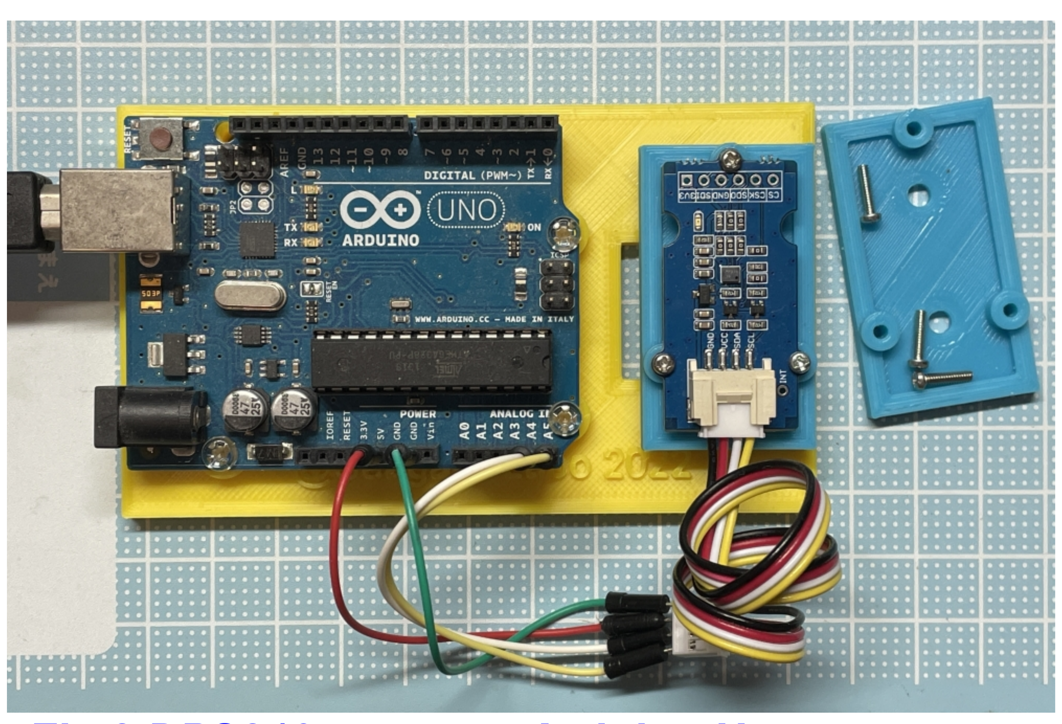

Fig.3 DPS310 sensor + Arduino Uno with sensor holders 3D-printed

1.DPS310 (above right, 3D printed base)

A variable capacitance type device with diaphragm mechanics, minimum resolution up to ±0.002 hPa (catalog value, equivalent to ±0.02 m in elevation, or a height difference of 2 cm!) The sensor is mounted on a 3D printed board. The sensor can detect the difference in atmospheric pressure caused by 10 cm up or down the sensor above the desk. It is also interesting to note that the changes in air pressure caused by the opening and closing of my room door (Fig. 4). The pressure change recorded in Japan during the eruption of Funga Tonga was reported to be about two hPa, so the sensitivity is more than sufficient.

2. Arduino Uno R3

Arduino Uno R3 is used for the AD converter. Infineon Technology, the sensor manufacturer, provides a library (i2_command) that can be used in the Arduino IDE. The output is connected to the Arduino with a Grove standard 4-wire i2c jumper wire (see photo). There are two sensor outputs, air pressure, and air temperature, but only air pressure is used here.

3. Raspberry Pi (here we refer to as "RasPi")

A RasPi and a 7-inch LCD were used for automatic data acquisition, storage, and real-time display. The LCD monitor can be altered existing PC for the logging system instead of RasPi. In Fig. 3, the RasPi is fixed behind the LCD monitor and is not visible.

4. Logging Software

Arduino IDE to control the sensor and Arduino is used on Ras Pi's Debian OS. The monitoring pressure waves and data saving are by Processing code. See the author's website for details.

RECORDING EXAMPLES （観測例）

Examples of short-time observation

The prototype is currently undergoing test observations on a desk in the author's home (2F of a wooden house) (Fig. 2). Some short-term observation records are shown below (examples of long-term observations will be in the last section). The source code is written in Processing, a modified version of the author's seismograph system, with 5 Hz sampling and a horizontal axis of 5 minutes, with a short time mark every minute. 5min x12 signal lines consist of a one-hour recording. The vertical barometric scale shows +1 hPa on the left end of the screen. After one hour of recording, the screen image and the pressure data are stored on a micro SD card in RasPi.

First, the vertical movement of the sensor on the desk (up and down by several to several tens of centimeters) and the noises of spike-like pressure fluctuations (maximum ±0.2 hPa) caused by opening and closing the room door are shown. The second is a record under strong winds during a cold wave. Finally, the micro-pressure fluctuations of a few to tens of seconds are recorded. The values in this paper are measured values instead of applied sea level calibration.

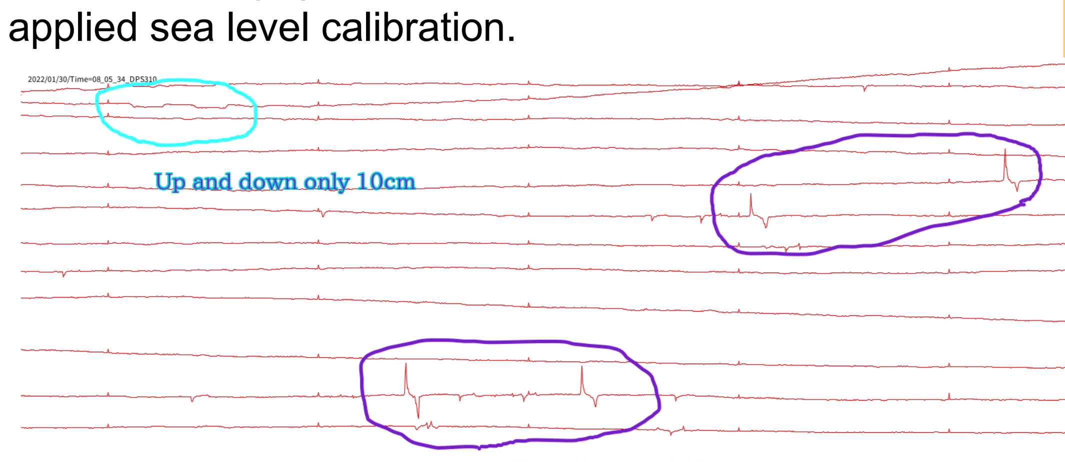

Fig.4 Dairy noise of door opens and closes with up-down sensor movement.

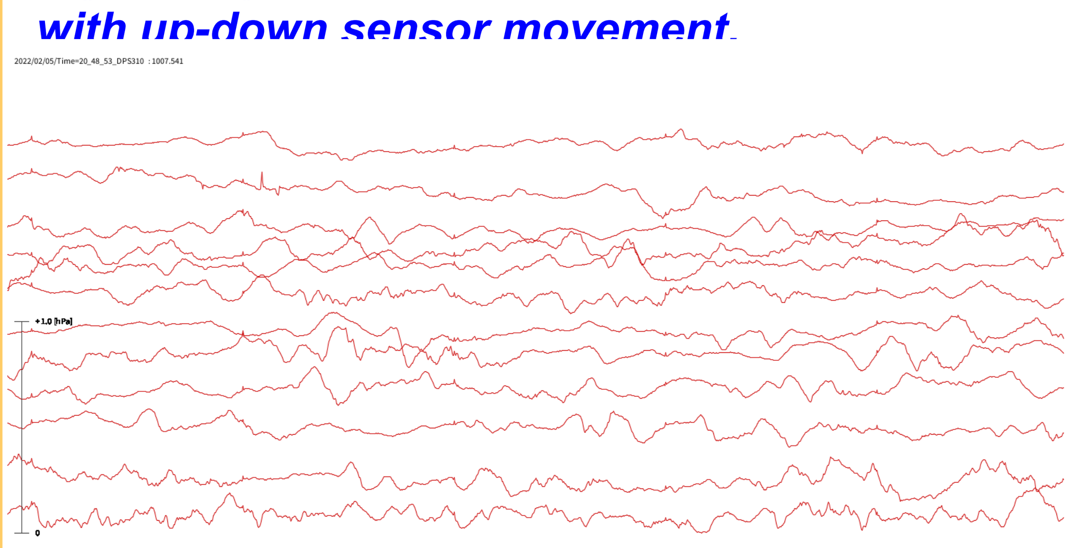

Fig.5 Strong windy night under cold storm. One hour record.

COMPARISON （比較観測）

Comparison of existing barometers and individual sensors

<With existing barometers>

1) Old mercury barometer (placed in the geoscience room on the 4th floor of OKU High School Tennoji Building, 23m above sea level)
2) Two "Ondotori-" TR-73U: A and B (same height)
3) Barometer application of iPhone12Pro (same height)
4) AMeDAS Osaka (elevation 83m, about 4km north)

<Date of measurement>
Around 11:14 a.m. on April 13, 2022
Around 11:00 a.m. on June 27, 2022

Table 1 shows the measured values from these barometers. The values from the Osaka AMeDAS are those at 11:00 a.m. The mercury barometer was read by three persons and averaged. We can see that DPS310 shows a value of about one hPa higher than that of AMeDAS, two "Ondotori", and of the iPhone device. The difference between the two sensors is about 1 hPa. While the mercury barometer shows about 5 hPa higher value than that of the iPhone's device.

Calibrated Osaka AMeDAS shows good agreement with the geoscience room on the 4F of Tennoji high school, 4 km south of the AMEDAS station. On the other hand, the mercury barometer in the geoscience room has a considerably significant error of over +10 hPa due to aging, so it is not suitable for comparison.

Table.1 Comparison of barometers

	2022/04/13 11;14		2022/6/27 11;00	
devices	Obs_P	sea level P	Obs_P	sea level P
iPhone			1005.7	1008.3
TR-73U_A	1008.9	1011.6	1004.6	1007.2
TR-73U_B	1009.4	1012.1	1005.5	1008.1
DPS310（本機）	1010.9	1013.6	1006.4	1009.0
Osaka-AmeDAS	1003.4	1013.0	998.7	1008.1
Hg-Barometer	1015.0	1017.7	1010.8	1013.4

<Among DPS310 Sensors>

Comparison between individual DPS310 sensors
Two recording PCs were added to the desk in my room. The data of the three sensors were plotted for three days irregularly spaced timings(Fig.8). The observed values of the three sensors lay within 0.1 to 0.3 hPa, and the difference between the iPhone is about 0.7hPa and the trend is quite fit each other, which also shows the high performance of the iPhone device.

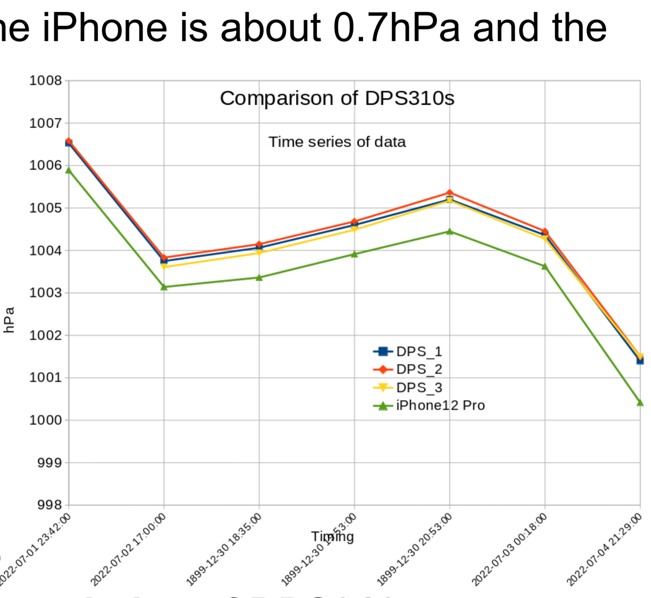

Fig.6 Comparison of three DPS310s With iPhone12Pro

<Temperature characteristics of DPS310>

Some quick cooling and heating tests were carried out to check the affected performance of the device by ambient temperature. The results are quite strange, showing delayed response and 'hysteresis'. Therefore we checked the datasheet, and found that they declare a temperature compensation algorithm, applied to the output signal.

LONGTIME RECORDS （長期観測例）

Long-term Observations

The first is a one-day record (Fig.7), and the second was pressure fluctuations during a half-month period in the latter half of April, with no missing observation, and the air conditioner was never used (Fig.8).

In Fig.7, some increases in barometric pressure caused by the timing of the air conditioner ON/OFF in my room become more frequent in the summer (blue circles). These are not by temperature drop but maybe by the air blowing. Looking at the long-term observations in Fig.8, the atmospheric pressure rises before noon and falls before evening on many days. We believe that we observe "atmospheric tides." In addition, we can see a sharp pressure drop due to the passage of a low-pressure system at the end of April.

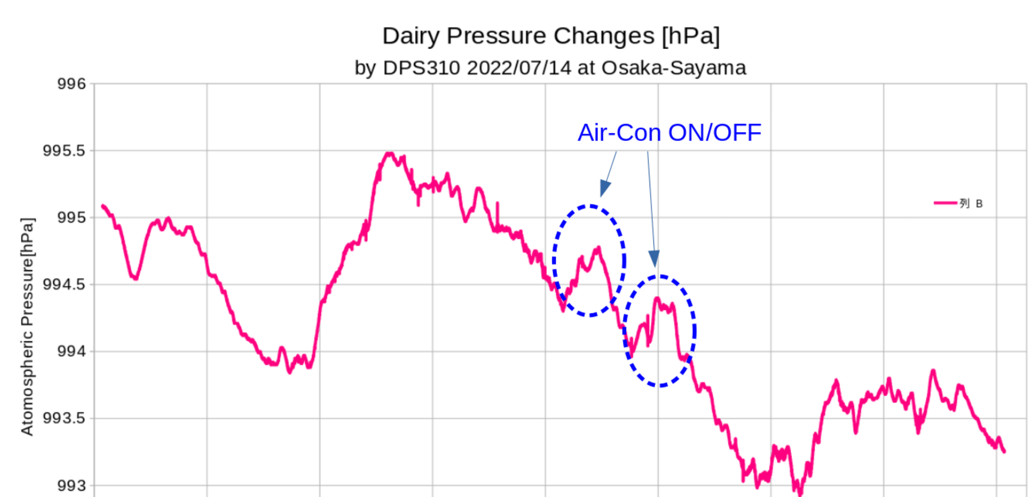

Fig.7 Dairy Barometric Pressure changes

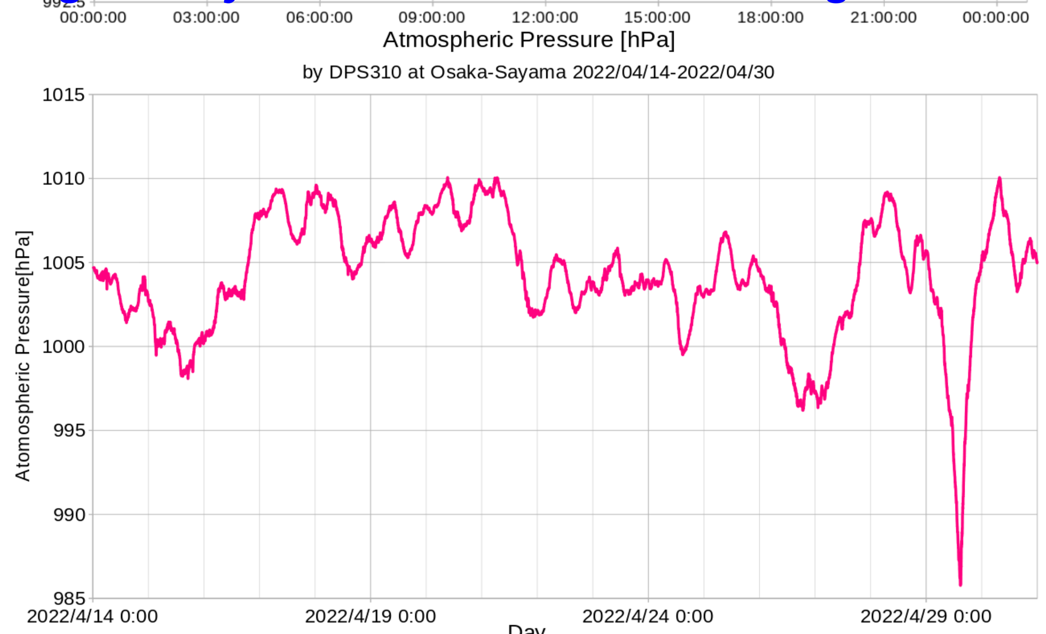

Fig.8 A half-Monthly Pressure changes

DISCUSSION（議論）

One of the features of this sensor is its temperature compensation algorithm. If the ambient temperature suddenly changes, the pressure value is limited to around ±0.02 hPa/°C. This behavior is complicated; however, we can neglect it for long-range observation. This sensor can respond sufficiently by 5 Hz sampling; the most significant advantage of this sensor. Unfortunately, the package of our present system is a bit big to use on mobile. Therefore, we are now developing a smaller, all-in-one device using M5Stack for mobile

SUMMARY（まとめ）

A simple microbarometer using an inexpensive DPS310 micro-pressure sensor was assembled. Due to the mechanics of this device, it is not suitable for absolute pressure measurement. However, we confirm that it can measure absolute pressure with a small error (within ±1hPa) compared with the AMeDAS data of the Osaka District Meteorological Observatory.

The fast response speed of the sensor is a notable advantage of this system, which can record short time pressure changes in less than one second, which is not possible with conventional "Ondotori" sensors or smartphone devices, as described above. This is one of the most crucial features, so we can used it in the classroom to show real-time signals of air pressure changes caused by vertical shifts of only a few 10 cm on the desk in front of the students.

We believe these features can open up a new observation field from the conventional barometric pressure observation. For example, it has the potential to capture changes in atmospheric pressure caused by strong storms, powerful explosions in the vicinity, and pressure changes associated with ground shaking during earthquakes (Nemoto, personal communication). Evaluating convenience, compared with smartphone devices such as the iPhone, which are rapidly developing in the field of measurement, is a future issue. Now, the DPS310 is superior in time response and storage capacity. However, the difference may close in the future. As mentioned at the beginning, the primary motivation for developing this device was to capture pressure fluctuations caused by large-scale volcanic eruptions that will occur somewhere in the world in the future. As the developer of this device, we would be pleased if we could inspire students' interest through this project; By measuring the somewhat boring natural phenomenon such as barometric pressure changes.

REFERENCES （参考文献）

Please refer my following web site;
http://www.yossi-okamoto.net/index_e.html

ACKNOWLEDGMENTS （謝辞）

Ms.Sayoko Furuta of the Osaka District Meteorological Observatory gave us helpful information about AMeDAS stations. Hiroo Nemoto, Professor of Ritsumeikan University, discussed the relationship between earthquakes and atmospheric pressure changes. Dr.Yuri Imura, geoscience teacher of Tennoji senior high-dchool at OKU, offered her classroom for the observation. Mr.Rei Mitsuhashi (same school) assisted with the observations. I thank them for their help.