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Short-time variation in atmospheric pressure, humidity, and temperature during the annular solar eclipse of December 2019 in Sri Lanka

Hansana Madushan[1], Chandana Jayaratne[1] and Ajith Wijemannage[2]*

[1] Astronomy and Space Science Unit, Department of Physics, University of Colombo, Colombo 00300, Sri Lanka
[2] Department of Meteorology, Bauddhaloka Mawatha, Colombo 00700, Sri Lanka

***Corresponding author**:*
Hansana Madushan
hansana2madushan@gmail.com

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ABSTRACT

Considering the annular solar eclipse on December 26, 2019, atmospheric pressure, humidity, and temperature were investigated at the ground level in two locations in Sri Lanka: Jaffna (9.6897°N, 80.0232°E, with 93.4% of solar disk coverage) and Colombo (6.9008°N, 79.8602°E, with 85.5% of solar disk coverage). A temperature drop was recorded at both sites, Jaffna and Colombo, with the lowest temperature values observed in 11 and 8 min, respectively, after the maximum eclipse phase. The temperature dropped by 4.2℃ and 0.8℃ with average falling rates of 0.0425°C/min and 0.0082℃/min in Jaffna and Colombo, respectively. The relative humidity increased by 12.0% and 1.1% with average increasing rates of 0.12 and 0.01%/min in Jaffna and Colombo, respectively. The Jaffna site reported an increasing trend in atmospheric pressure until the maximum eclipse phase; the maximum pressure occurred near the full phase during the annularity and started decreasing a few minutes after the full phase. The Colombo pressure sensor showed no such variation.

Keywords: solar eclipse; annular solar eclipse; sun–moon relative position; air temperature; humidity; atmospheric pressure

1. INTRODUCTION

An eclipse is a natural phenomenon that occurs when the sun, moon, and earth are aligned. Eclipses occur on new moon days, but are relatively rare, occurring twice a year on average. There are three different types of solar eclipses: total, annular, and partial. The moon completely blocks the sunlight in a total solar eclipse, whereas the moon is near its farthest point from the earth in an annular solar eclipse, which is called apogee. Because of the apogee, the outer edge of the sun appears as a bright ring of fire. A partial solar eclipse occurs when the sun-moon-earth system is not exactly aligned in a straight line. As such, the sun is partially covered sun by the moon (Hocken and Kher, 2020).

When any type of solar eclipse occurs, the moon blocks part or all of the sun's radiation from reaching the earth. Solar radiation significantly influences the changes in the earth's weather. A solar eclipse process causes a sudden cutoff of solar radiation for a few minutes, which might disturb the thermal stability of the atmosphere.

Numerous studies have been conducted to understand the response of the atmosphere during a solar eclipse. Kimball and Fergusson (1919) reported a slight increase in atmospheric pressure (AP) within 10-15 min before the first contact and a slight decrease after the first contact near the central line in a 1916 solar eclipse. Szałowski (2002) discussed a temperature drop of 11°C 25 min after the maximum eclipse phase. Founda et al. (2007) reported that solar radiation reduction during a 2006 total eclipse over Greece was proportional to sun obscuration, and the minimum temperature occurred 12-14 min after the maximum eclipse phase. Muraleedharan et al. (2011) reported a solar eclipse that did not leave any observable changes in surface pressure. Peñaloza-Murillo et al. (2020) noticed a 15-min time lag from the maximum eclipse phase to reach the minimum temperature in the annular solar eclipse over Riyadh on June 21, 2020.

Further, there are several recent articles regarding atmospheric behavior during the annular solar eclipse on December 26, 2019. Pakkattil et al. (2020) reported a surface air temperature drop of 0.7°C, weakened wind speed, and an increase in relative humidity (RH) by 5.1% during an eclipse (eclipse magnitude = 0.9676) over Calicut city, India. They also reported a gradual decrease in surface O_3 and NO_2 during this period. Moreover, Lokeswara Reddy et al. (2020) reported a near-surface temperature drop of 1.12°C, an RH lift of 14.63%, and an air pressure reduction of 0.9 hPa in Anantapur (eclipse magnitude = 0.885), India. Manoj et al. (2021) reported a temperature drop of 4°C, an RH lift of 39.6%, and a pressure reduction of 0.62 hPa on an eclipse day (eclipse magnitude = 0.94) compared with the average values of the neighboring control days at Cochin, India.

Owing to the sudden cutoff of solar energy, a solar eclipse provides a chance to examine short-term meteorological changes and atmospheric responses. Therefore, the objective of this study was to investigate the meteorological changes during on annular solar eclipse of December 26, 2019 in Sri Lanka.

2. MATERIALS AND METHODS

2.1 General information

On December 26, 2019, from around 8:09 to 11.21 local time (UTC+5.30), Sri Lankans witnessed an annular solar eclipse. The eclipse was seen as an annular eclipse in the northern part of Sri Lanka, in the Jaffna area, with the moon covering 93.4% of the solar disk at the annularity. Meanwhile, the eclipse was seen as a partial eclipse in the southern part, around Colombo city, with the moon covering 85.5% of the solar disk. This annular solar eclipse was also visible in Saudi Arabia, Oman, southern India, and some parts of Indonesia. An eclipse of this nature is very rare. Therefore, the eclipse is considered significant, and several scientific experiments have been performed regarding it. The duration of the annular phase of the eclipse was 3 min 14 s, and the duration of the partial eclipse was 3 h 12 m 9 s (Table 1).

2.2 Instrumentation and background condition

There were two measuring sites located at the University of Jaffna (on the central line of the eclipse) and the University of Colombo. Figure 1 shows the eclipse path and measuring site locations. The altitudes of the Colombo and Jaffna measuring sites were 6.7 and 10.0 m, respectively. The sky was clear and cloudless at both sites. The measuring sites were located 310.46 km away from each other. In the eclipse, the central line going across the Jaffna site was 128-km wide path of umbra falling on the earth. The meteorological variables were monitored using microcontroller-based automated and calibrated sensor systems from 07:38:36 to 11:38:36 local time (UTC+5:30) during the eclipse period. Initially, the meteorological parameters were recorded at 30-s intervals and then averaged for 2 min. The resolutions (sensitivities) of output data of all sensors according to the respective manufacturers are listed in Table 2. All sensors were calibrated using standard instruments with the help of the Department of Meteorology, Sri Lanka, and error coefficients were added to the readings.

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Table 1. Measuring sites and Eclipse information (National Aeronautics and Space Administration, 2020)

Location	Coordinates	Eclipse Type	P1	P2	Max	P4	P5	Magnitude	Annular eclipse duration
Jaffna	9.6897° N, 80.0232° E	Annular	08:08:58	09:33:49	09:35:26	09:37:03	11:21:07	0.966	3m 14s
Colombo	6.9008° N, 79.8602° E	Partial	08:10:00	-	09:36:28	-	11:22:10	0.913	-

Note: P1 = first contact (partial eclipse begins), P2 = bright rings start to appear or annularity starts, Max = maximum eclipse, P4 = the moon starts to move away or annularity ends, P5 = last contact (partial eclipse ends)

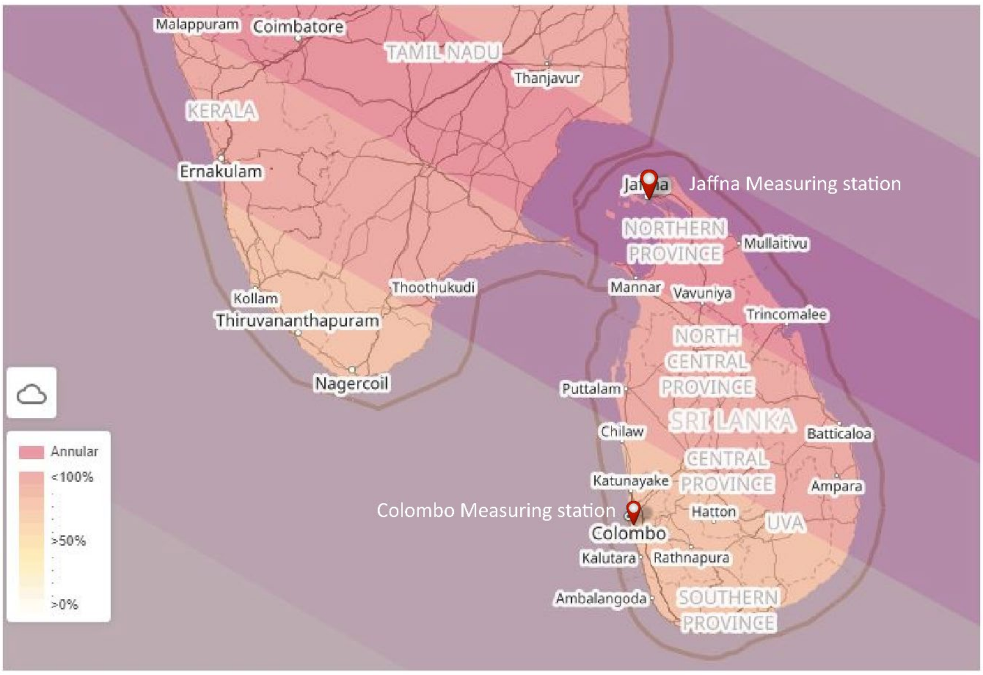

Figure 1. The path of December 26, 2019, solar eclipse and measuring points (Time and Date AS, 2019)

Table 2. Sensor specifications

Parameter	Sensor	Resolution of output data
Air temperature	bmp180	0.1°C
Pressure (Barometer)	bmp180	0.01 hPa
Relative humidity	dht 22	0.1%

3. RESULTS AND DISCUSSION

3.1 Temperature variation

For both the measuring sites, the ambient air temperature (Figures 2 and 3) dropped dramatically after the beginning of the partial eclipse (P1). Some noises were recorded by the Jaffna sensor due to the occasional operational problems of the sensor and some background problems, including the wind. However, most of the noises were eliminated using noise reduction techniques. Both measuring sites followed the same general temperature variation pattern, but the magnitude of the temperature drops at the Jaffna site was higher than that at the Colombo site. The minimum temperature recorded at the Colombo site was 26.7°C, which occurred 96 min after the beginning of the partial eclipse and 8 min after the maximum eclipse. Meanwhile, at the Jaffna site, the recorded minimum temperature was 27.1°C, which occurred 98 min after the beginning of the partial eclipse and 11 min after the maximum phase. A similar range of time lags from mid-eclipse to the time when the temperature reaches its minimum was reported by Anderson (1999) in another total solar eclipse that occurred in Hecla, Manitoba, Canada. The average rates of change of temperature drop for Colombo and Jaffna were 0.0082°C/min and 0.0425°C/min, respectively (Table 3). Founda et al. (2007) reported a similar temperature falling rate of 0.044°C/min in a total solar eclipse that occurred on March 29, 2006, in Kastelorizo, Greece. In this study, the maximum ambient air temperature drop during the annular eclipse at the Jaffna site was found to be 4.2°C. This finding is consistent with Anderson (1999) who reported air temperature drops observed in the 1994 annular solar eclipse that range of 3.3-9.7°C at various locations in the USA. Further, Pakkattil et al. (2020), Lokeswara Reddy et al. (2020), and Manoj et al. (2021) reported temperature drops between 0.7°C and 4°C during the annular eclipse of December 26, 2019, at different locations in India, which also agree with the findings of this study.

3.2 RH variation

The timeseries of the RH variation during the solar eclipse at the Jaffna and Colombo sites are shown in Figures 4 and 5, respectively. Some noises were recorded in the original dataset, as already discussed in the temperature variation section, and were eliminated using noise reduction methods. Similar to the temperature variation, both sites mostly followed the same general pattern for RH variation. At the central line of the eclipse maximum, the RH reached a maximum of 75.0% 11 min after the maximum eclipse phase in Jaffna, whereas the RH reached a maximum of 78.0% 8 min after the maximum eclipse phase in Colombo. The RH lifting rate at the central line (Jaffna, Sri Lanka) was 0.12%/min. Other relevant information is shown in Table 4.

A few minutes after the maximum RH, at both sites, a decrease in RH occurred, and the minimum RH reading was reported a few minutes before the fourth contact (eclipse end). The minimum RH readings, RH range (max-min), time lag from the maximum eclipse, and average drop rates are shown in Table 5. During the same eclipse, India reported an RH lift between 5.1% and 39.6% (Manoj et al. 2021; Pakkattil et al. 2020; Lokeswara Reddy et al. (2020)).

3.3 AP variation

The timeseries of AP variation during the solar eclipse in Jaffna and Colombo are shown in Figures 6 and 7, respectively. In Jaffna, the AP followed an increasing trend until the maximum annular eclipse phase. A maximum could be found during the annular eclipse period and another maximum of the AP could be found a few minutes before the eclipse ends. However, in Colombo, the AP variation (Figure 7) did not show the same variation pattern as in Jaffna. The AP was almost constant during the eclipse period in Colombo. The AP only varied by 1 hPa. A few minutes before the partial eclipse ended, the AP returned to the early value. However, because Sri Lanka is a tropical country, the daily AP variation is supposed to be followed by the diurnal AP variation, which has two peaks around 10:00 and 22:00 local time. This seemed to be a deviation from the expected daily AP variation. Moreover, it was impossible to conclude, by using a single measurement, that the pressure variation was a result of the eclipse, as AP depends on several factors.

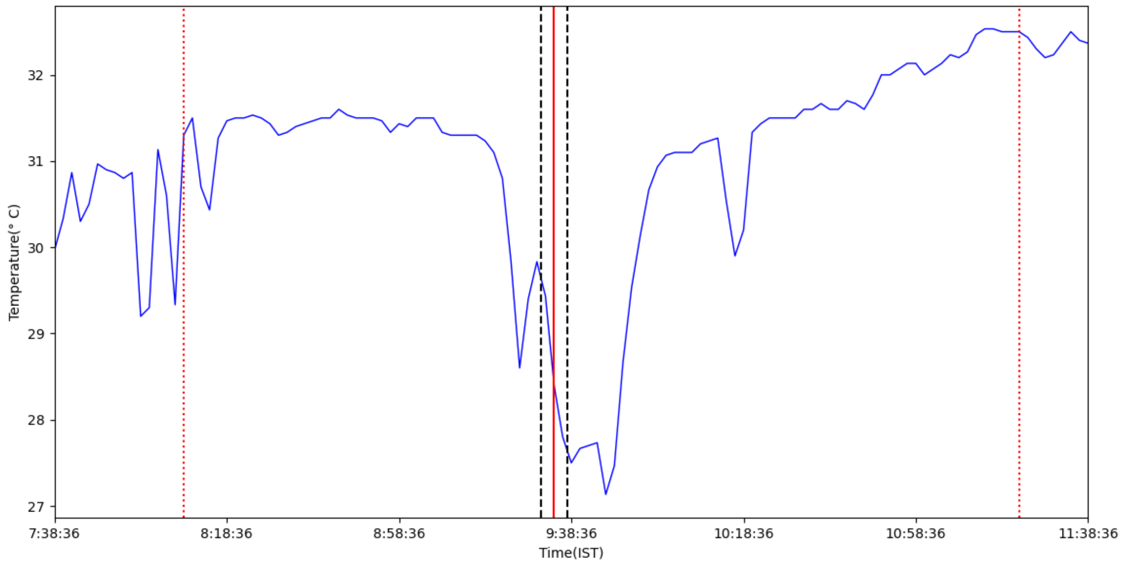

Figure 2. Ambient air temperature variation during the annular solar eclipse of December 26, 2019, in Jaffna, Sri Lanka
Note: Vertical lines represent the beginning of the partial eclipse, beginning of the annular eclipse, maximum eclipse, end of the annular eclipse, and end of the partial eclipse phases, respectively.

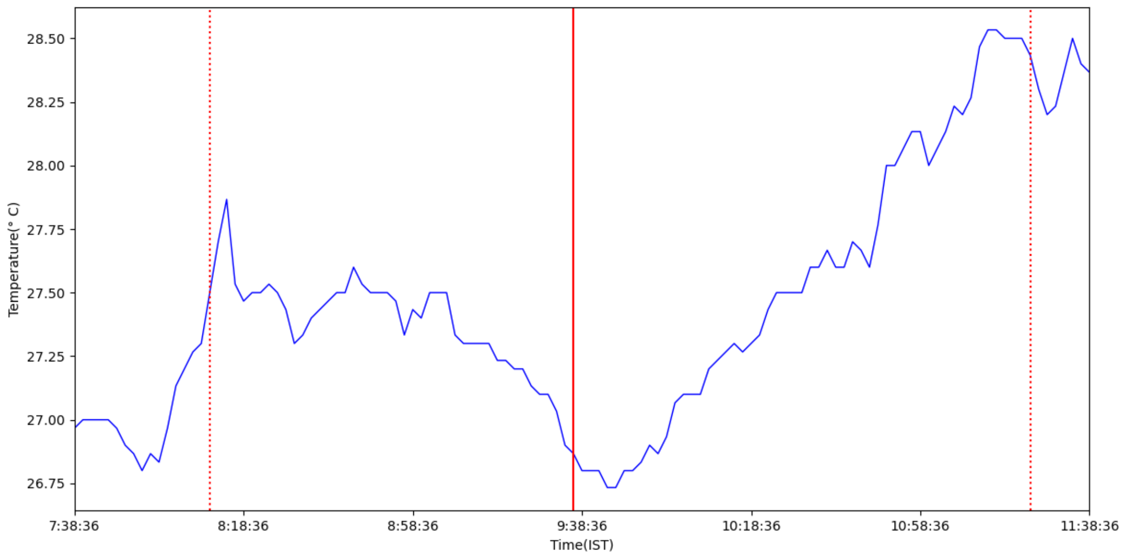

Figure 3. Ambient air temperature variation during the annular solar eclipse of December 26, 2019, in Colombo, Sri Lanka
Note: Vertical lines represent the beginning of the partial eclipse, maximum eclipse, and end of the partial eclipse phases, respectively.

Table 3. The minimum ambient air temperature, temperature drop, time lag from the beginning of the partial eclipse, time lag from maximum eclipse, and average temperature falling rate

Measuring site	Minimum temperature (°C)	Maximum temperature drop from partial eclipse begins (°C)	Time lag from partial eclipse begins (min)	Time lag from maximum eclipse (min)	Average temperature falling rate (°C/min)
Colombo	26.7	0.8	96	8	0.0082
Jaffna	27.1	4.2	98	11	0.0425

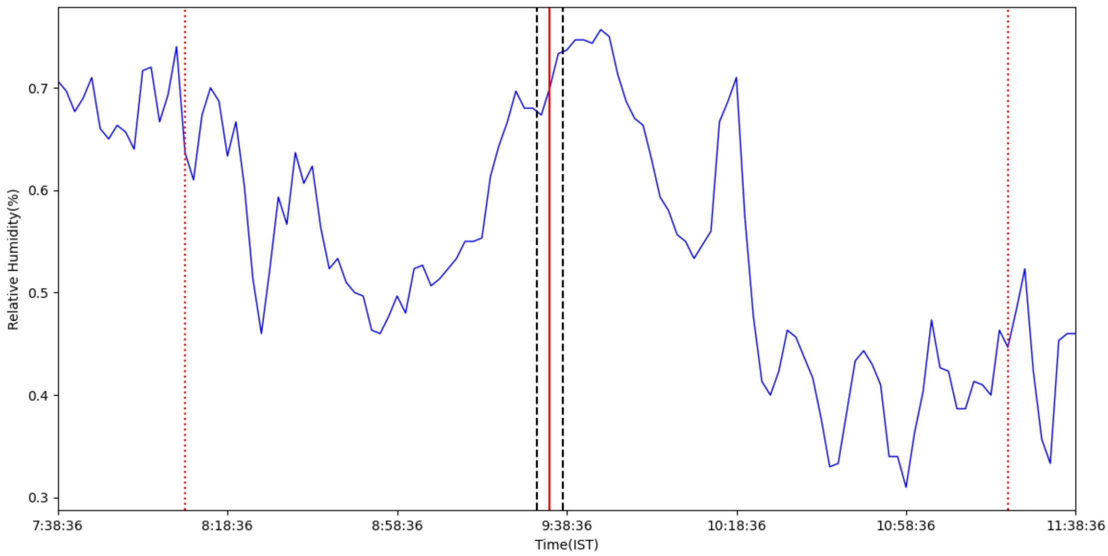

Figure 4. Relative humidity (RH) variation during the annular solar eclipse of December 26, 2019, in Jaffna, Sri Lanka
Note: Vertical lines represent the beginning of the partial eclipse, beginning of the annular eclipse, maximum eclipse, end of the annular eclipse, and end of the partial eclipse phases, respectively.

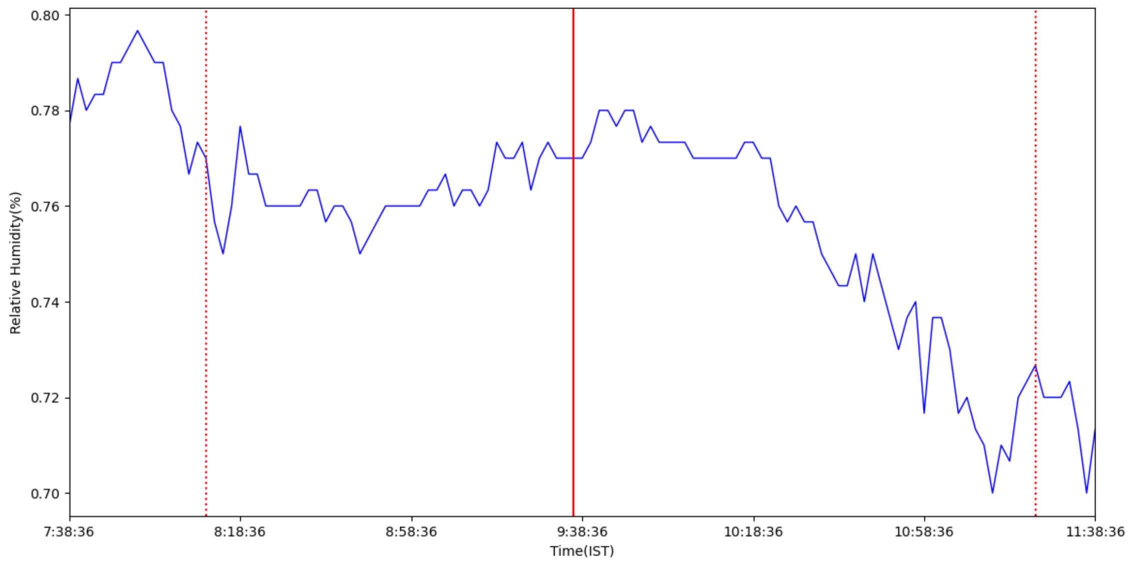

Figure 5. RH variation during the annular solar eclipse of December 26, 2019, in Colombo, Sri Lanka
Note: Vertical lines represent the beginning of the partial eclipse, maximum eclipse, and end of the partial eclipse phases, respectively.

Table 4. Maximum RH, maximum RH lift, time lag from the beginning of the partial eclipse, time lag from maximum eclipse, and average RH lifting rate

Measuring site	Maximum RH value (%)	Maximum RH lift from partial eclipse begins (%)	Time lag from partial eclipse begins (min)	Time lag from maximum eclipse (min)	Average RH lifting rate (%/min)
Colombo	78.0	1.1	96	8	0.01
Jaffna	75.7	12.0	98	11	0.12

Table 5. Minimum RH readings, RH range, time lag from the maximum RH, and average RH falling rate

Measuring site	Min RH (%)	RH range (max-min) (%)	Time lag from the max RH (min)	Average RH falling rate (%/min)
Colombo	70.0	8.0	92	0.09
Jaffna	31.0	44.7	72	0.62

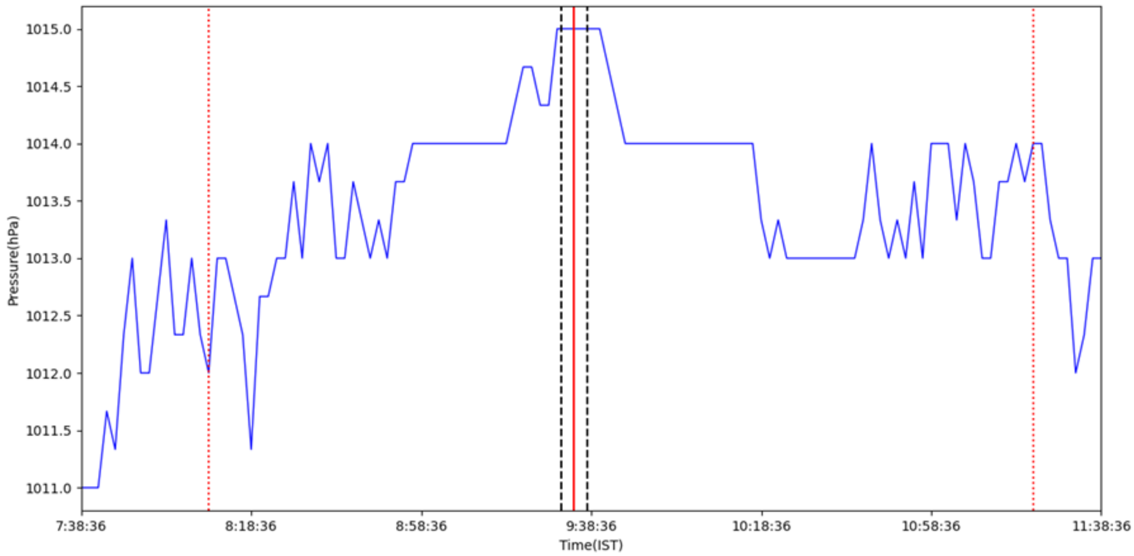

Figure 6. AP variation during the annular solar eclipse of December 26, 2019, in Jaffna, Sri Lanka
Note: Vertical lines represent the beginning of the partial eclipse, beginning of the annular eclipse, maximum eclipse, end of the annular eclipse, and end of the partial eclipse phases, respectively.

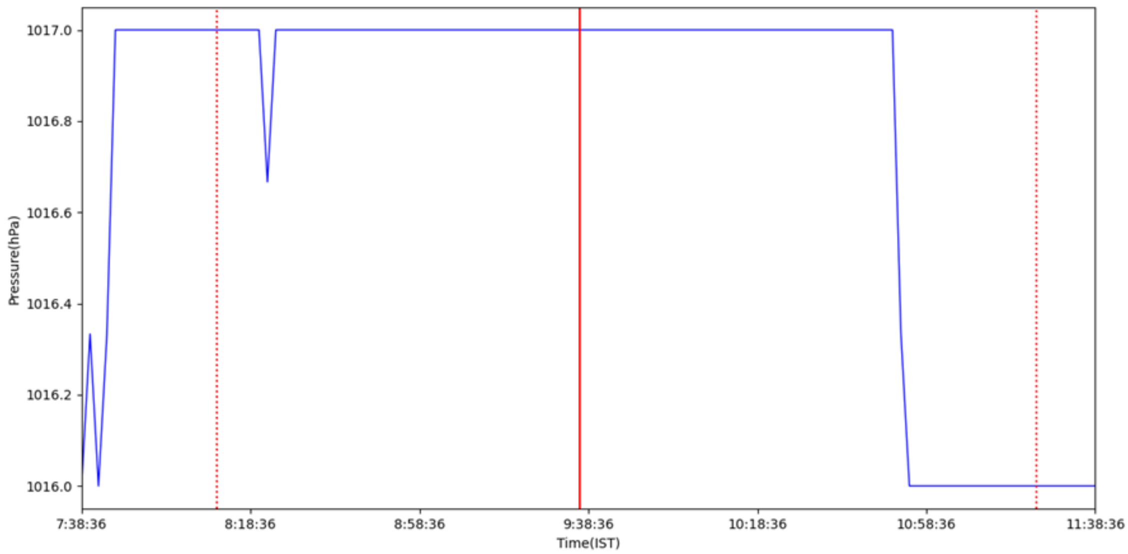

Figure 7. AP variation during the annular solar eclipse of December 26, 2019, in Colombo, Sri Lanka
Note: Vertical lines represent the beginning of the partial eclipse, maximum eclipse, and end of the partial eclipse phases, respectively.

4. CONCLUSION

We conducted this study to understand the effect of a solar eclipse on the behavior of terrestrial meteorological parameters, particularly at locations in Sri Lanka. The measurements of ambient air temperature, RH, and AP were performed at two sites 310.46 km apart during the annular solar eclipse of December 26, 2019. The effect of the eclipse on the behavior of meteorological parameters differed significantly between the full and partial eclipses. Unfortunately, there was insufficient information to prove the AP variation that occurred due to the solar eclipse because the AP in Sri Lanka, which is surrounded by an ocean, depends on several factors.

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