ISSN No:-2456-2165

Infrasonic Observation of Microbarom Signals in the Coastal of Equatorial Indonesia: An Investigation in the Southern and Northern Parts of West Java, Indonesia

Mario Batubara, Musthofa Lathif
Research Center for Space,
National Research and Innovation Agency (BRIN),
Bandung, Indonesia

Ibnu Fathrio
Research Center for Climate and Atmosphere,
National Research and Innovation Agency (BRIN),
Bandung, Indonesia

Masa-yuki Yamamoto
Department of Engineering,
Kochi University of Technology (KUT) Kochi, Japan

Islam Hamama
National Research Institute of Astronomy and Geophysics Department of Egyptian

Abstract:- We report 2023 infrasound observations derived from ambient noise of the microbaroms between the north and south coasts of West Java province, Indonesia. Measurements were conducted out serially between May and August 2023, utilizing embedded infrasound sensors. Our microbaroms studies demonstrate that infrasound from the oceanic field causes frequent atmospheric pressure fluctuations of several millipascals at about 0.4 Hz. As a result, their amplitude appears to be quite dominant from twilight until the following morning, which is supposed to be dependent on the emergence of the atmospheric sound channels between the ground and the atmospheric level at a specific altitude. Theses channels are affected by the wind structure at top reflection point and atmospheric vertical temperature. The structure of wind and temperature in our geographical study, in the equatorial region, were proven to explain and distinguish the observed microbaroms by direct measurement of standard meteorology. Finally, we propose that the usage of our infrasound sensor will offer global complementary results for monitoring upper atmospheric dynamics.

***Keywords**:- Microbaroms, infrasound, equatorial, vertical profile.*

I. INTRODUCTION

Infrasound refers to sound waves that are below the threshold of human hearing, or in the sub-audible spectrum. Because of its superiority in terms of attenuation by the propagation medium, as well as the role and refraction by the structure of the atmospheric layer, this wave can propagate to a very long distance from its point of origin. These waves are commonly generated by diverse geophysical and anthropogenic activities (1).

Efforts are being made to investigate the characteristic and utilization of wave compression through the use of infrasound detection systems operated on the ground based on array systems and campaign activities. Studying the dynamics of the Earth's upper atmosphere using wave propagation mechanisms is an ongoing research topic (2,3,4).

Infrasound monitoring is a novel technique approach for studying atmospheric dynamics. The structure of the atmospheric layers, such as temperature and wind, refracts these waves back to the ground. Knowing the properties of infrasound signals from different locations provides useful information about the structure of the atmosphere and its dynamics.

The infrasound monitoring is a new verification technique to study the dynamics of the atmosphere. These waves are refracted back to the ground by the structure of the atmospheric layers which is depend on their vertical profile such as temperature and wind (6,7). Knowing the characteristics of infrasound signals from different location give a benefit information of the atmospheric structure as well as their dynamics. Our activity first aims to investigate the background noise around the southern and northern coastal area of West Java province, Indonesia in order to enhance our knowledge on the long wave atmospheric propagation and the dynamics of the middle and upper atmosphere in the equatorial region. An organized field campaign at above location equipped with the Automatic Weather Station (AWS) near the infrasound station was used to investigate the background infrasonic noise.

Microbarom, a nonlinear interaction of ocean surface waves that produces a natural source of infrasound (5). They oscillate at a constant frequency o between 0.1 and 0.5 Hz. Because of low absorption and efficient ducting between the ground and the refractive layer of the atmosphere, microbaroms can travel hundreds of kilometers in the atmosphere. In term of wave propagation, the conditions of the refractive mechanism are met. In this case, the components of wind speed (e.g., strong jet stream in the stratosphere) and temperature gradient play an important role. Changes in wind components due to daily changes in standard meteorology conditions and tidal migration cause

ISSN No:-2456-2165

refraction and sound channels in the atmosphere (2,8). This depicts how observations of atmospheric infrasound arrival are influenced by diurnal condition of standard meteorology at the coastal area. This paper was aims to better understand diurnal variation in the characteristics of microbarom signals, such as amplitude and spectrum observed in southern and northern West Java.

The structure of the paper is as follows: in section 2 we describe measurement with an approaching method for this study by using the infrasonic signals recorded over West Java province, Indonesia. The diurnal variation of microbarom arrivals retrieved from the recorded infrasound signals are analyzed and discussed in section 6. The last section summarizes for our findings.

II. INFRASOUND OBSERVATION

The infrasound sensors are being installed equitably over West Java and continually operational during the campaign between May and August 2023. Figure 1 depicts the location of infrasound campaign and will be planned for infrasound station in Indonesia.

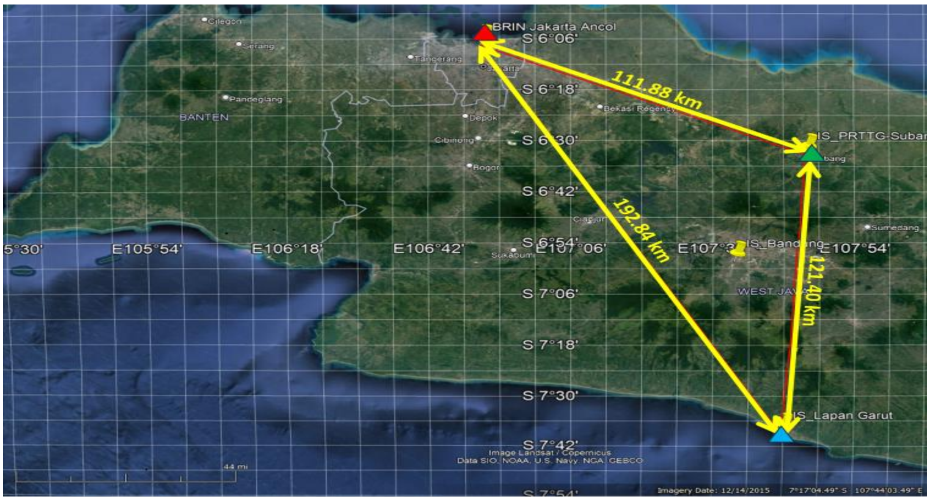

Fig. 1: Spatial distribution of the infrasound stations consist of Ancol Jakarta (red triangle), Subang (Green triangle), and Pamengpeuk (blue triangle).

All sensor data is delivered through File Transfer Protocol (FTP) to a local disc drive and our database repository where it is archived. This study focus on observation data from Ancol (red triangle in figure 1) and Pameungpeuk (blue triangle in figure 1), both of which are located near the coast of West Java, Indonesia.

In more detail, signal packets are grouped separately for individual filtering processes using different frequency bands based on previous Power Spectral Density (PSD) results. Next, each group is processed by several operations. 1. Both ends of the data in each group are tested for coherence and the implementation of cosine taper to minimize the effects of discontinuity. 2. The signal source is identified with a coherent peak estimated value. Finally, in the spectral domain processing of each packet, a cosine-tapered window of 120 seconds is applied with 90 percent overlap. The width of the signal packet envelope should proportionate to window width of cosine taper.

III. EQUATORIAL WINDS STRUCTURE IN THE ATMOSPHERE

The fluctuation of tidal components eventually modulates the wind in the atmosphere. In addition, the vertical profile of the atmosphere, especially wind and temperature, plays an important role in variations in microbaroms detection at locations. This structure should be understood in order to comprehend their contribution to sound refractions.

A. The Diurnal Wind Profile

The daily wind variance is primarily caused by heat variations at lower altitudes (e.g., the troposphere). Direct insolation absorption and ozone absorption both play a part in this variation at higher altitudes, in the stratosphere and lower mesosphere. The response to the absorption of solar energy by water vapor and ozone is important and is the main characteristic that needs to be observed at each altitude. At mid-latitudes, the absorption of ozone becomes significant, giving rise to trapping modes that decay exponentially with altitude.

ISSN No:-2456-2165

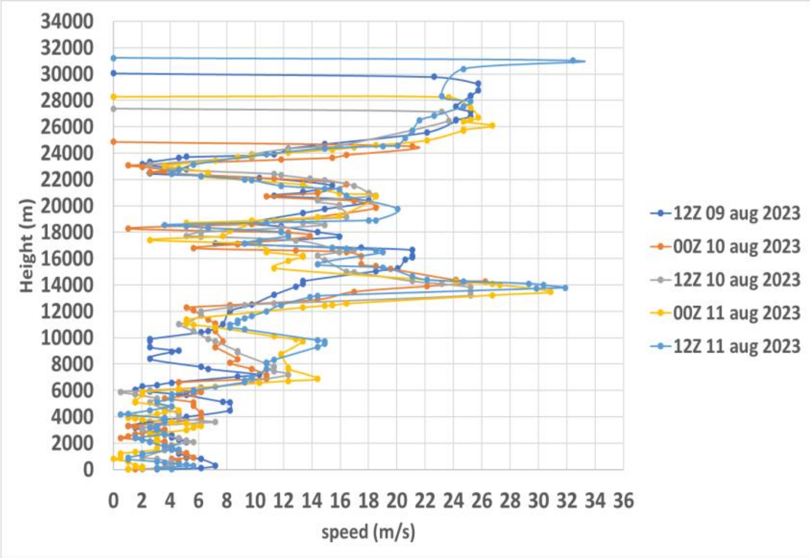

Fig. 2: Vertical profile of wind speed observed by Radiosonde at North of Jakarta on Aug 9th 2023 to Aug 11th 2023.

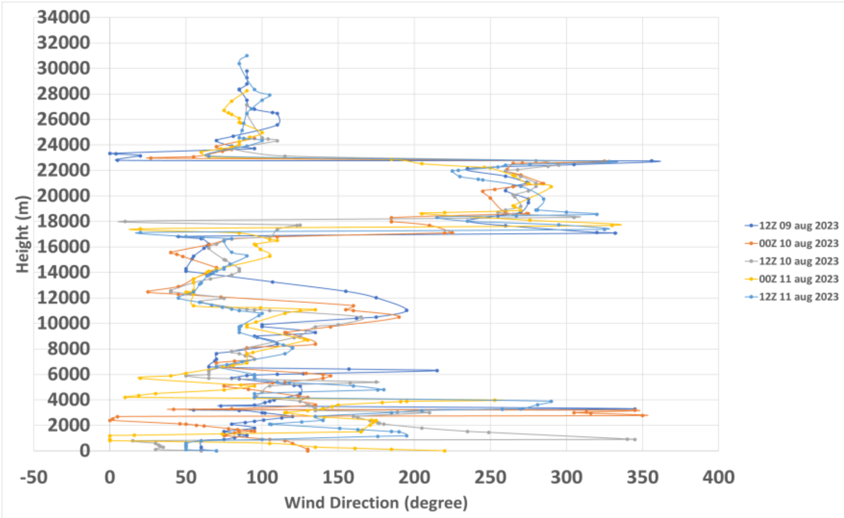

Fig. 3: Vertical profile of wind direction observed by Radiosonde at North of Jakarta on Aug 9th 2023 to Aug 11th 2023.

Figure 2-3 depicts the vertical profile of wind speed measured by radiosonde in the Northern Jakarta every 12 hours between 9 and 11 August 2023. Horizontal wind components and temperature gradients with respect to altitude, time, and geographic location are the primary determinants of long-range sound propagation. Positive temperature gradients ($dT/dz > 0$) refract sound downwards, and the sound speed at the refraction layer is greater and equal to the sound speed at the ground in the windless condition. Strong wind shear, for example, may have an essential role in the refraction process in the case of wind.

Figure 2 shows the wind speed blowing in three areas with altitudes of 6-10 km, 12-16, and 24-30 km, each with a speed of 14 m/s, 32 m/s and 26 m/s. The strong jet streams at stratopause and tropopause may have contributed to the formation of a ducting layer that refracted sound propagate down to the ground. Moreover, the winds were characterized by a relatively strong tropospheric and stratospheric jet stream, with peak velocities of ~14 m/s and 32 m/s at 10 km and 14 km altitude, respectively. Figure 3 shows the vertical profile of wind direction that the wind at troposphere had a strong positive direction caused southward jet stream. On the other hand, in the stratosphere at altitude about 14 km, the winds cause sound are expected to propagate eastward. The key point of the wind specification during the radiosonde launch period was the predominance of strong south and east jet streams, with tropospheric and stratospheric jet peaks at 10 km and ~14 km, respectively.

IV. EQUATORIAL TEMPERATURE PROFILES IN THE ATMOSPHERE

A. Diurnal Temperature

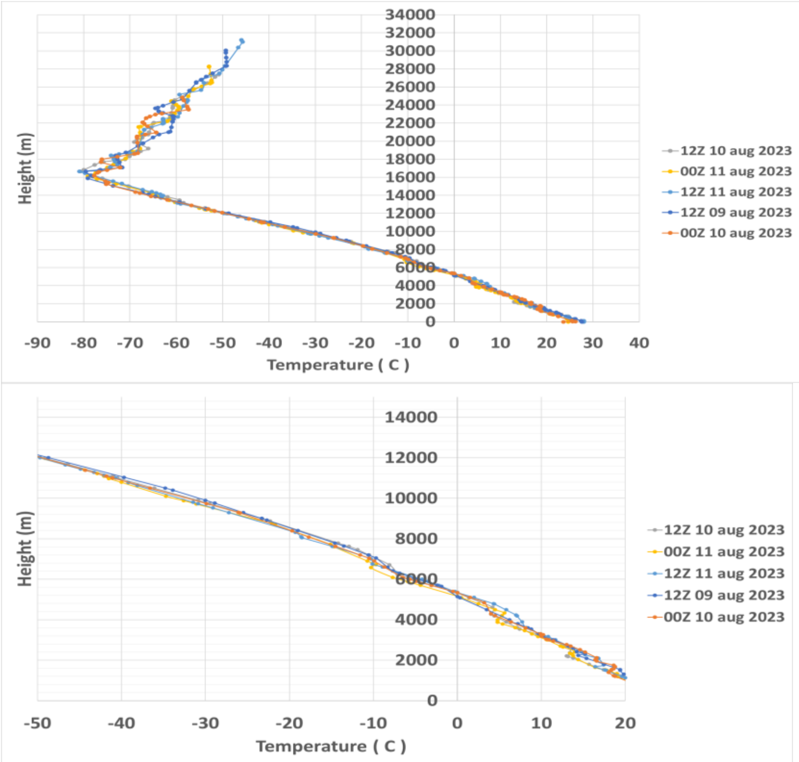

Fig. 4: Vertical profile of temperature observed by Radiosonde at North of Jakarta on Aug 9th 2023 to Aug 11th 2023. Full vertical coverage up to 32 km (top panel).

Figure 4 upper and lower panels show the vertical profile of temperature over the entire radiosonde height range and is clarified up to a height of 15 km, respectively. The temperature on the surface up to an altitude of 16 km tends to have a negative gradient, but before reaching a height of 15 km, the atmospheric temperature experiences a positive gradient twice at an altitude of ~2 km and ~4 km (Bottom panel of Figure 4). Above this layer, strong positive gradient of temperature measured at the stratosphere, mainly due to the solar energy absorption. The starting point of the positive gradient temperature is measured at an altitude of 16 km, the wind blows towards the northeast.

V. RESULT ON VARIATION OF MICROBAROMS

A. Measurement at Pameungpeuk, West Java Indonesia

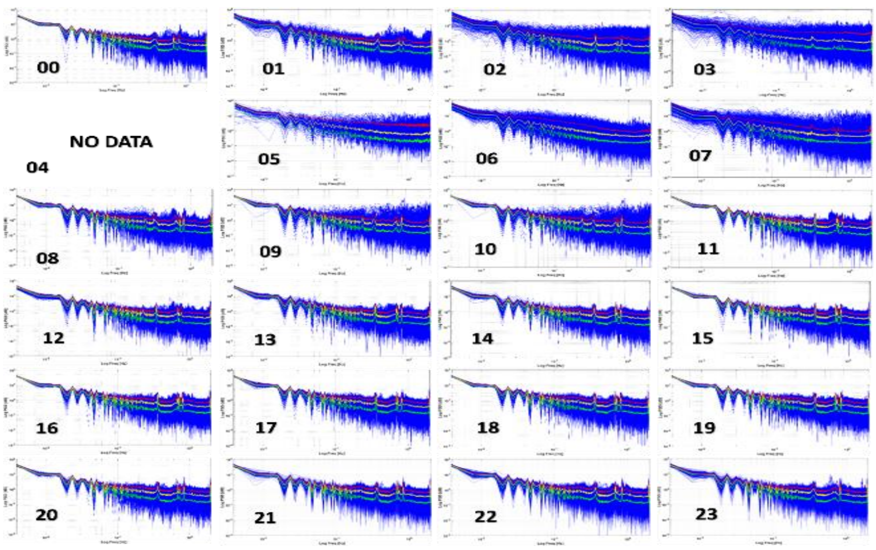

Fig. 5: Power Spectral Density of Infrasound signals observed at Pameungpeuk, West Java on 15 May 2023 (00 – 23 UTC) with 0.9 percentile (red line), 0.5 percentile (yellow line), and 0.1 percentile (green line).

Figure 5 shows the power spectral density profile of the infrasound signal recorded for 24 hours at Pameungpeuk on May 15, 2023. The image shows that the spectrum at 0.4 Hz (microbarom frequency) begins to appear between 10 and 23 UTC. However, the spectrum at this range began to distruct at 19 UTC, affected by the ambient temperature and local wind structure (Figure-6).

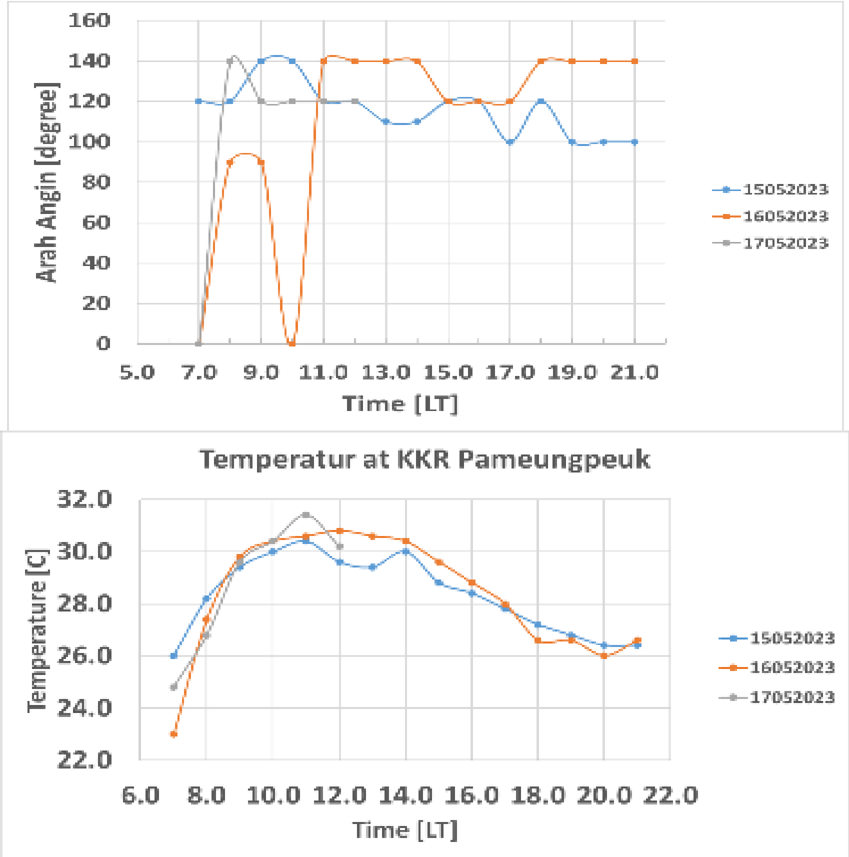

Fig. 6: Two surface meteorology profiles using AWS in the Pameungpeuk area. Profile of wind direction (left) and temperature (right) for 3 (three) days.

B. Measurement at Ancol, Jakarta Indonesia

The power spectral density profile of the infrasound waves on 09-11 August 2023 is shown in Figure-7. The microbarom frequency spectrum appears around 0.4 Hz starting at 10 UTC to 02 UTC. This appearance is also in the same condition as the previous results of infrasound wave observations conducted in Pameungpeuk, West Java. The components of wind speed and temperature are important factors that influence the appearance of this spectrum.

Figures 8 and 9 respectively show the air temperature profile along with humidity and wind speed along with its direction based on AWS measurements at Ancol, Jakarta in the period 9-11 August 2023. Specifically for wind speed, where at 10 UTC the wind began to change direction to the south, which was followed by a weakening of the strength of the gusts so that the propagation speed of the microbial column increased towards the observation location.

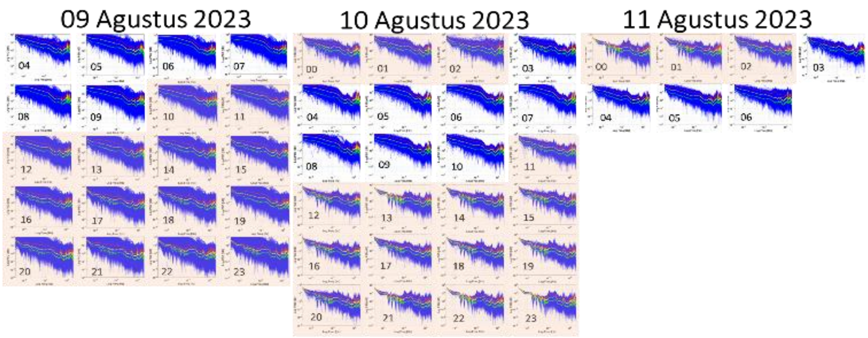

Fig. 7: Power Spectral Density of Infrasound signals observed at Ancol, North Jakarta on 09 August 2023 04UTC – 11 August 2023 06UTC) with 0.9 percentile (red line), 0.5 percentile (yellow line), and 0.1 percentile (green line).

10 Agustus 2023 11 Agustus 2023

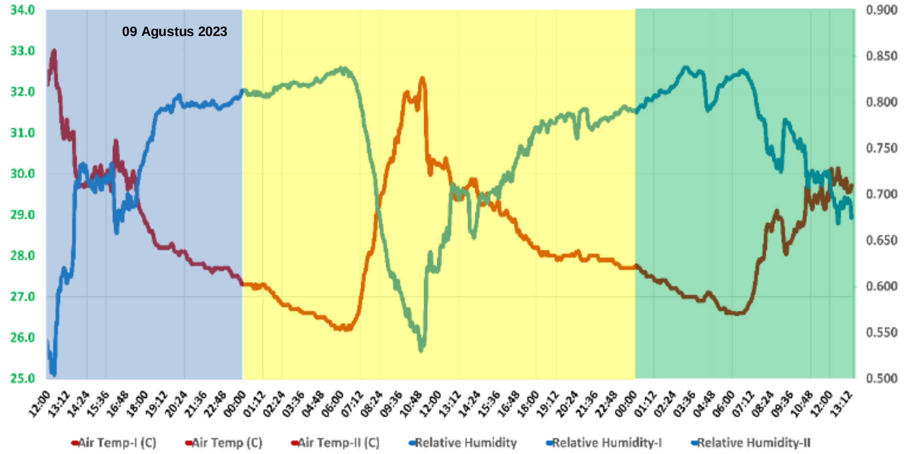

Fig. 8: Profile of standard meteorology at KS Ancol Jakarta for the period 09-11 August 2023 using AWS. Air temperature in Celcius and relative humidity are shown in red and blue lines, respectively

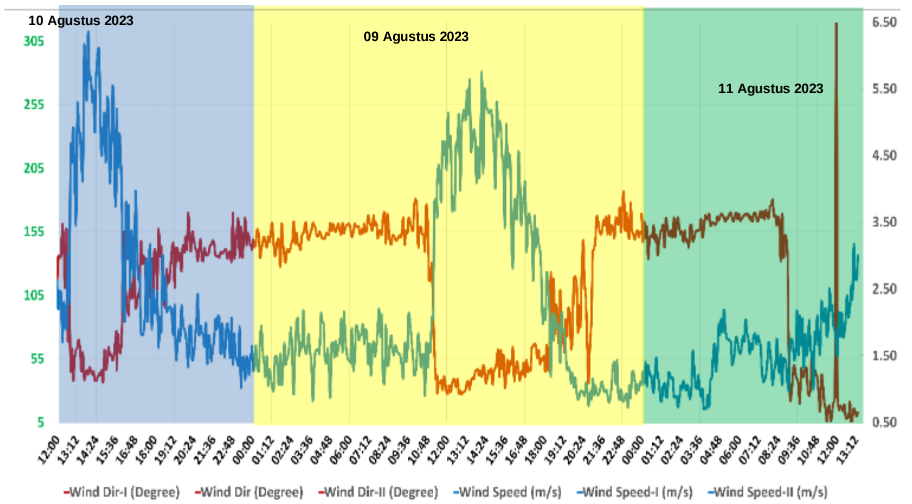

Fig. 9: Profile of standard meteorology at KS Ancol Jakarta for the period 09-11 August 2023 using AWS. Wind direction in degree unit and Wind speed in m/s are shown in blue and red lines, respectively.

VI. CONCLUSIONS

We carried out an infrasound wave observation campaign in two areas close to sea waters in West Java province. Campaign activities were carried out during the period May and August 2023. We analyzed infrasound signals for suspected evidence of low-frequency atmospheric pressure disturbances generated by continuous oscillations of microbaroms waves from the ocean field. Infrasound data from two observation areas are specifically evaluated to obtain information on the spectral power characteristics of certain waves. We therefore conclude, based on infrasound characteristic, that the wind component in the atmosphere plays an important role in the propagation of infrasound waves. This indicates that the microbaroms spectrum was already clearly observed beginning at dusk. At the same time, the wind component in the atmosphere, particularly the wind at the ground, are propagating strongly southwards towards the sensor site. Furthermore, the influence of jet streams in the troposphere also plays an important role in sound refraction downward to the ground. The atmospheric structure at an altitude of 10 km tends to be more dominant in the formation of ducting layers which cause the propagation of microbaroms towards the sensor location.

ACKNOWLEDGMENT

The authors would like to thank to Laboratory member at Kochi University of Technology (KUT), Japan, who initially built the infrasound sensor. This work was supported by research grant of the National Research and Innovation Agency (BRIN). The research grants are provided by the Research Organization of Aeronautics and Space as well as the Research Organization of Disaster and Maritim – BRIN. Finally, the author thanks all those who helped prepare field observations, especially the Coordinator of the Ancol Science Area, Jakarta; and the Pameungpeuk Botanical Garden Area, West Java.

REFERENCES

[1.] Campus, P., Christie, D.R. (2010). Worldwide Observations of Infrasonic Waves. In: Le Pichon, A., Blanc, E., Hauchecorne, A. (eds) Infrasound Monitoring for Atmospheric Studies. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9508-5_6

[2.] Donn, W. L., and D. H. Rind (1972), Microbaroms and the temperature and wind of the upper atmosphere, J. Atmos. Sci., 29, 156–172, https://doi.org/10.1175/1520-0469(1972)029<0156:MATTAW>2.0.CO;2

[3.] Le Pichon, A., Herry, P., Mialle, P., Vergoz, J., Brachet, N., Garcés, M., Drob, D., and Ceranna, L. (2005), Infrasound associated with 2004–2005 large Sumatra earthquakes and tsunami, Geophys. Res. Lett., 32, L19802, https://doi:10.1029/2005GL023893.

[4.] Assink, J. D., Waxler, R., Frazier, W. G., and Lonzaga, J. (2013), The estimation of upper atmospheric wind model updates from infrasound data, J. Geophys. Res. Atmos., 118, 10,707–10,724, https://doi:10.1002/jgrd.50833.

[5.] Donn, W. L., and Naini, B. (1973), Sea wave origin of microbaroms and microseisms, J. Geophys. Res., 78(21), 4482–4488, https://doi:10.1029/JC078i021p04482.

[6.] Garcés, M., Willis, M., Hetzer, C., Le Pichon, A., and Drob, D. (2004), On using ocean swells for continuous infrasonic measurements of winds and temperature in the lower, middle, and upper atmosphere, Geophys. Res. Lett., 31, L19304, https://doi:10.1029/2004GL020696.

[7.] Willis, M., Garcés, M., Hetzer, C., and Businger, S. (2004), Infrasonic observations of open ocean swells in the Pacific: Deciphering the song of the sea, Geophys. Res. Lett., 31, L19303, https://doi:10.1029/2004GL020684.

[8.] Hagan, M.; Forbes, J.M.; Vial, F. On modeling migrating solar tides. Geophys. Res. Lett. 1995, 22, 893–896, https://doi.org/10.1029/95GL00783.