UAD Universitas Ahmad Dahlan
Bulletin of Applied Mathematics and Mathematics Education
Volume 3, Number 1, 2021 pp. 45-54
https://dx.doi.org/10.12928/bamme.v3i1.7340
e-ISSN 2776-1029, p-ISSN 2776-1002

Identification of cross-equatorial northerly surge (CENS) relationship to very heavy rain events in Jakarta

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ARTICLE INFO

Article History
Received 15 January 2023
Revised 6 November 2023
Accepted 29 December 2023

Keywords
CENS
NCS
Very heavy rain

How to cite this article:
Lestari, T. A., Athallah, M. S. B., Haryanto, Y. D. (2023). Identification of cross-equatorial northerly surge (CENS) relationship to very heavy rain events in Jakarta. *Bulletin of Applied Mathematics and Mathematics Education*, *3*(1), 45-54.

ABSTRACT

CENS is a meteorological phenomenon in the form of surface wind flow originating from the South China Sea (SCS), very strongly across the equator. CENS is closely related to the increase in average rainfall in parts of Indonesia. There has been very heavy rainfall on January 18, 2022 in the Jakarta area which resulted in flooding. Therefore, this study focuses on seeing if there is a CENS relationship that is factor in increasing rainfall in the Jakarta area on January 18, 2022. The results showed that the NCS began to form on January 16-17, 2022 with a Siberian High of 1040.6 hPa and the propagation of cold air masses from Asia to the south which was an indicator of CENS. The next day, the CENS phenomenon began to occur, characterized by meridional wind speeds in the 105°- 115°BT region of less than -5 m/s. This phenomenon triggers the strengthening of the northeast Asian monsoon flow so that the area south of the equator, including Jakarta, gets a large moisture transport from the SCS. This causes the potential for the formation of high convective clouds to trigger very heavy rain and cause flooding in the Jakarta area on January 18, 2022.

Introduction

The pressure difference is caused by the difference in radiation received by high latitudes and the equator, causing airflow to move from high pressure to low pressure. There is an increase in convectivity in October-March in the Indonesian region (especially the western part) because the wind pattern blows from the north which carries water vapor after passing through vast warm waters (Moron et al., 2010; Chang et al., 2016). The flow of air from the Northern Hemisphere that passes through the equator is called cross equatorial flow. Previous research explains that cross equatorial flow can be characterized by the dominant wind direction from the north in the equatorial region so it is called cross equatorial northerlu surge (CENS) (Hattori et al., 2011). Cross equatorial flow is seen as a wind direction from northwest to west in the Southern Hemisphere due to the coriolis force (Swarinoto, 1996).

CENS is a meteorological phenomenon in the form of surface wind flow originating from the South China Sea (SCS) very strongly across the equator. CENS is closely related to the increase in average rainfall in parts of Indonesia (Hattori et al., 2011; Mori et al., 2016; Mori et al., 2018). Strengthening CENS can strengthen the Asian winter monsoon flow which plays a role in the formation of rain in the Indonesian region during the rainy season period from November to March (Yulihastin, 2015). Cross equatorial flow originating from mid-latitudes in the northern hemisphere is an important environmental factor associated with high rainfall in Jakarta (Wu et al. 2007).

Wu et al. (2007) showed that strong northerly wind events strong northerly winds occurred five times over the South China Sea in 2007, and in the South China Sea in 2007, and in the strongest strongest event, the northerly winds blew across the equator and penetrated into the northern part of Java penetrated the northern part of Java Island. This strong flow persisted for more than a week and coincided with the formation of heavy rains that repeatedly caused widespread flooding. Therefore, the strengthening CENS has the potential to cause persistent rainfall. This is as happened in the years that recorded major flood events in Jabodetabek. Based on previous research (Wu et al., 2007; Hattori et al., 2011; Yulihastin et al., 2020) states that CENS is associated with heavy rain events over Java Island. In addition, Van Bemmelen (1922) first conducted research on the diurnal variation of local winds over Jakarta scientifically using hot air balloon observations in 1905-1915 and found a clear land-sea circulation in the lower troposphere showing a dominant northerly sea breeze during the day below 1 km altitude with an opposing southerly flow above and a relatively weak southerly land breeze in reverse during the night to early morning period. Consequently, the land-sea circulation and its relationship with convective activity over Jakarta has been widely studied by Hashiguchi et al. (1995), Hadi et al. (2000, 2002), Renggono et al. (2001), and Araki et al. (2006).

Several studies examined the relationship between cold surges in the northern South China Sea and convective variations in the equatorial region. Compo et al. (1999) showed a strong correlation between cold surge and convective activity in southern Indonesia using 11 years of data from the European Center for Medium-range Weather Forecasts (ECMWF) reanalysis and Outgoing Longwave Radiation (OLR) data. Chang et al. (2003) stated that the environment was a strong cold surge factor in producing the nearequatorial cyclone Vamei in 2001. Chang et al. (2005) examined the long-term variation in convective activity over the Maritime Continent and its relationship with cold surge. The results suggest that a strong cold surge phenomenon can enhance convective activity over the Indo-China Peninsula and northern Sumatra. In addition, one of the problems with previous studies is that there is no uniform quantitative definition of cold surge with definitions varying depending on the purpose of the study. For example, Wu and Chan (1995, 1997) defined cold surge using surface meteorological data as negative temperature anomalies (<2 K), changes in wind direction (>60) and a northerly wind component greater than 8.1 m s1 over Hong Kong (22.4N, 114.1E).

Meanwhile, Compo et al. (1999) stated that a pressure surge using ECMWF reanalysis data as a positive sea level pressure anomaly (>3 hPa) at 15N, 115E. Chang et al. (2005) defined cold surge as a northerly wind component at 925 hPa that averages more than 8 m s1 between 110-117.5E, 15N. These previous definitions do not take into account the intensity of cold surge in the equatorial region (10S-10N).

Based on surface observations from Soekarno Hatta Meteorological Station, rain with an intensity of 150.2 mm/day was recorded. In addition, at the Maritime Meteorological Station recorded 129.5 mm/day and at Meteorological Station 745 Kemayoran recorded 191.8 mm/day. Rainfall intensity criteria based on the Meteorology Climatology and Geophysics Agency (BMKG, 2010) explains that rainfall intensity >20 mm/hour or >100 mm/day is categorized as very heavy rain. This rainfall is the highest rainfall in Jakarta during the period November 2021-18 January 2022 which has an impact on inundation in 77 RTs out of 30470 RTs in Jakarta with inundation

10.12928/bamme.v3i1.7340

heights ranging from 40-85 cm and the number of refugees as many as 1194 people from 310 family cards (BPBD, 2022). Therefore, this research focuses on seeing if there is a CENS relationship that is a factor in increasing rainfall in the Jakarta area on January 18, 2022.

Method

The research location is in the DKI Jakarta area on January 18, 2022, with coordinates 5°19' 12" - 6°23' 54" LS 106° 22' 42" - 106° 58' 18" EAST (See Figure 1).

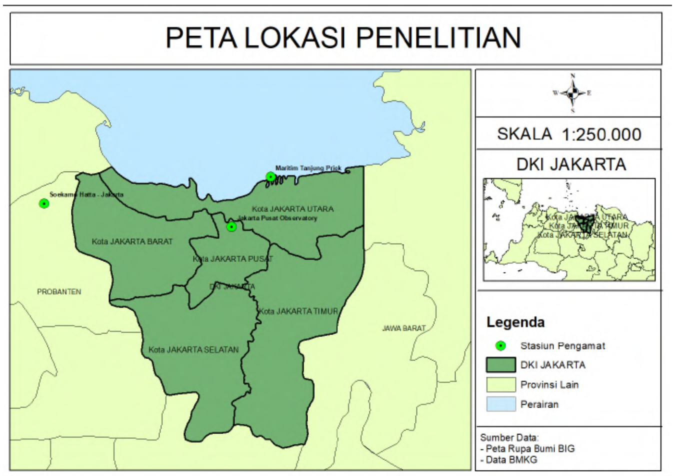

Figure 1. Research location

The data used in this study are as follows.

Synoptic observation data

Synoptic observation data is surface weather observation data sent from weather observation stations throughout Indonesia every three hours (Mujiasih, 2011). Synoptic observation data used in this study is the accumulated rainfall (mm) on January 18, 2022, at 00-23 UTC from three meteorological stations namely Soekarno Hatta Meteorological Station, Tanjung Priok Meteorological Station, and 745 Kemayoran Meteorological Station. This data is taken from the BMKG database, BMKGSoft, which is used as verification of very heavy rain events that cause some inundation in parts of Jakarta.

ERA-5 reanalysis data

ERA5 is an ECMWF reanalysis with a resolution of 0.125° x 0.125° which is the fifth generation for global climate and weather for the last 4 to 7 decades. Data are currently available from 1950, with Climate Data Store entries for 1950-1978 (early reanalysis) and from 1959 to the present. This data is retrieved from https://cds.climate.copernicus.eu/. The parameters used are Mean Sea Level Pressure (MSLP), 2m surface temperature, zonal wind speed (U), meridional wind speed (V), and specific humidity (q). This data is used to analyze the effect of CENS on rainfall in Jakarta on January 18, 2022. The analyzed layer is in a representative layer to see atmospheric symptoms without interference from the lower and upper layers of the atmosphere so that each parameter is selected in the layer at 925 mb (Aldrian, 2007). This data is processed using The Grid Analysis and Display System (GrADS) application to facilitate analysis, Climate Data Operators (CDO) to determine the value of parameters from certain coordinates, and Microsoft Excel to process data from CDO results.

Satellite imagery

The satellite imagery used is the himawari-8 satellite with the IR band every 6 hours on January 17-18, 2022. This image is accessed from the BMKG satellite database. The image is used to determine the presence of rain-producing clouds and the rain rate estimated by the satellite.

This study was conducted by identifying the Northerly Cold Surge (NCS) which is characterized by increased pressure in the Siberian region which causes the flow of air masses to southern Asia and the pressure difference between Gushi and Hong Kong, which is >10 hPa which causes a temperature drop of up to 6°C in Hong Kong. After that, analyzing moisture transport is carried out to determine the effect of CENS on atmospheric dynamics in Jakarta which refers to the method of Zhou and Yu (2005) using the following equation.

$$Q = \frac{1}{g}\int_{pt}^{ps} qV\, dp \quad (1)$$

where Q is Water Vapor Transport (kg/m/s), g is Earth's Gravitational Acceleration (m/s2), ps is Surface Pressure (1000 hPa), pt is Pressure at Upper Level (300 hPa), q is Specific Humidity (g/kg), V is Zonal-Meridional Wind Vector, and dp is Pressure Change (hPa). Furthermore, it identifies CENS events that refer to Hattori's (2011) research by looking at north wind speeds of more than 5 m/s that blow in the region between 105˚BT to 115˚BT. In addition, this research also identifies NCS first because this is a precursor to the CENS phenomenon.

Results and discussion

Identification of NCS

NCS is an indicator of the occurrence of CENS where NCS is the transmission of cold air masses from high latitudes to the equatorial region. NCS is identified by looking at the increase in air pressure in the Tibetan plateau region commonly known as the Siberian High so that MSLP analysis can be carried out as a cusor of NCS and CENS. Figure 2 shows the MSLP values on January 16-18, 2022 in the Asia, South China Sea, and Indonesia regions.

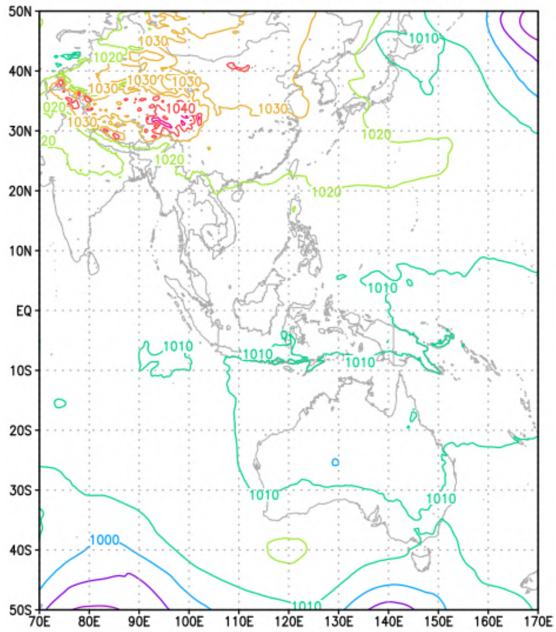

Figure 2. MSLP on January 16-18, 2022

10.12928/bamme.v3i1.7340

The figure shows that there is a high pressure area in mainland Asia, with a value of 1040 hPa which indicates the presence of a Siberian High, as an indicator of NCS. This allows the formation of CENS. The pressure difference between mainland Asia with high pressure and Australia with lower pressure results in these conditions supporting the strengthening of the Asian monsoon flow moving into the Indonesian region.

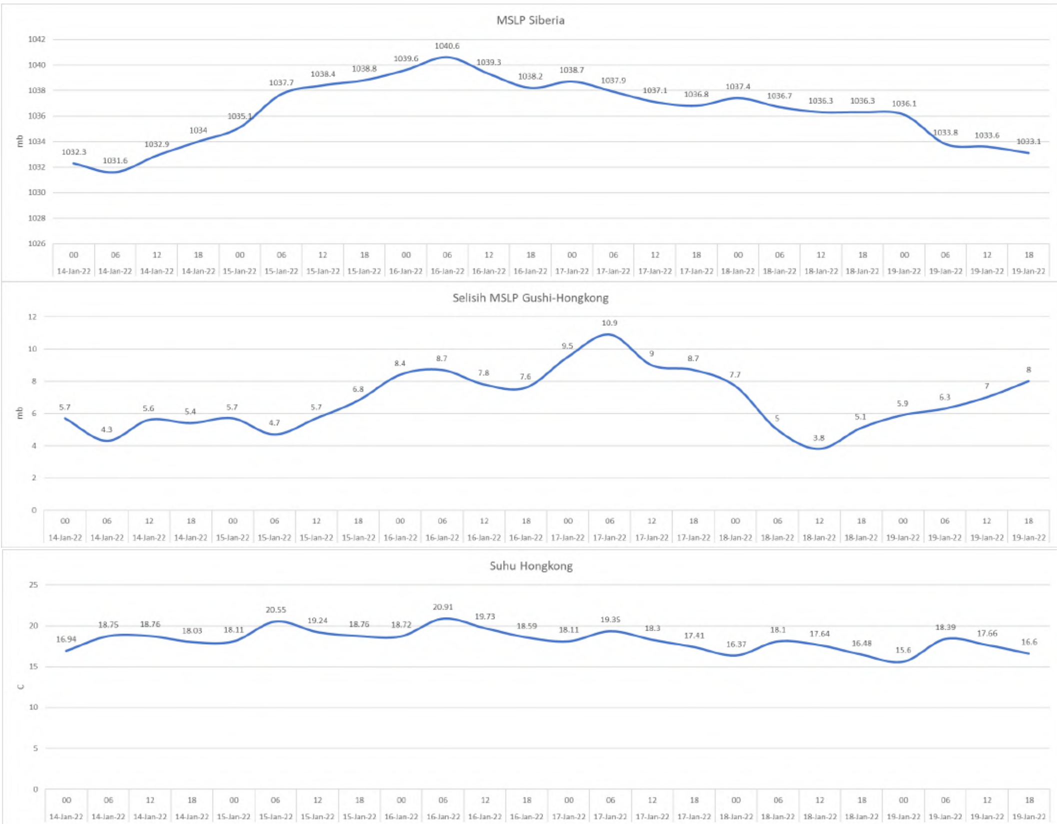

Figure 3. MSLP and temperature values to identify NCS

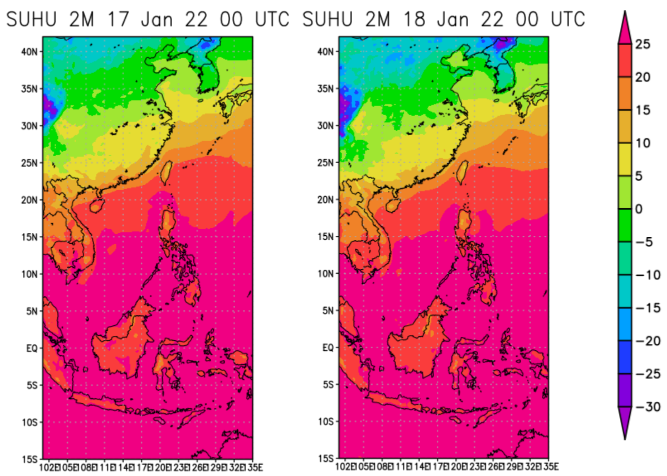

Figure 4. Cold air mass propagation

Figure 3 shows a Siberian high of 1040.6 mb on January 16, 2022. It can be said that there is a Siberian High which is the initial precursor of the NCS. In addition, the MSLP difference between Gushi and Hong Kong exceeded 10 hPa on January 17, 2022, which amounted to 10.9 hPa, thus reinforcing that the NCS had formed on that date. Based on this, it is known that the NCS occurred from January 16-17, 2022. The event was also marked by a decrease in temperature in Hong Kong starting from January 16, 2022, due to the movement of the NCS towards the South China Sea. However, the temperature drop is less than 6°C, which is only about 2°C.

In addition, there is the transmission of cold air masses from Asia to the south to latitude 22°8'-22°35'LU which can be seen in Figure 4. NCS is an indication of the occurrence of CENS so it is possible that CENS will occur a few days after NCS is formed.

Moisture transport analysis

Moisture transport is one of the most dominant factors that explain CENS can increase rainfall in the region. Therefore, moisture transport analysis was made from January 17-18, 2022 at the single level data layer.

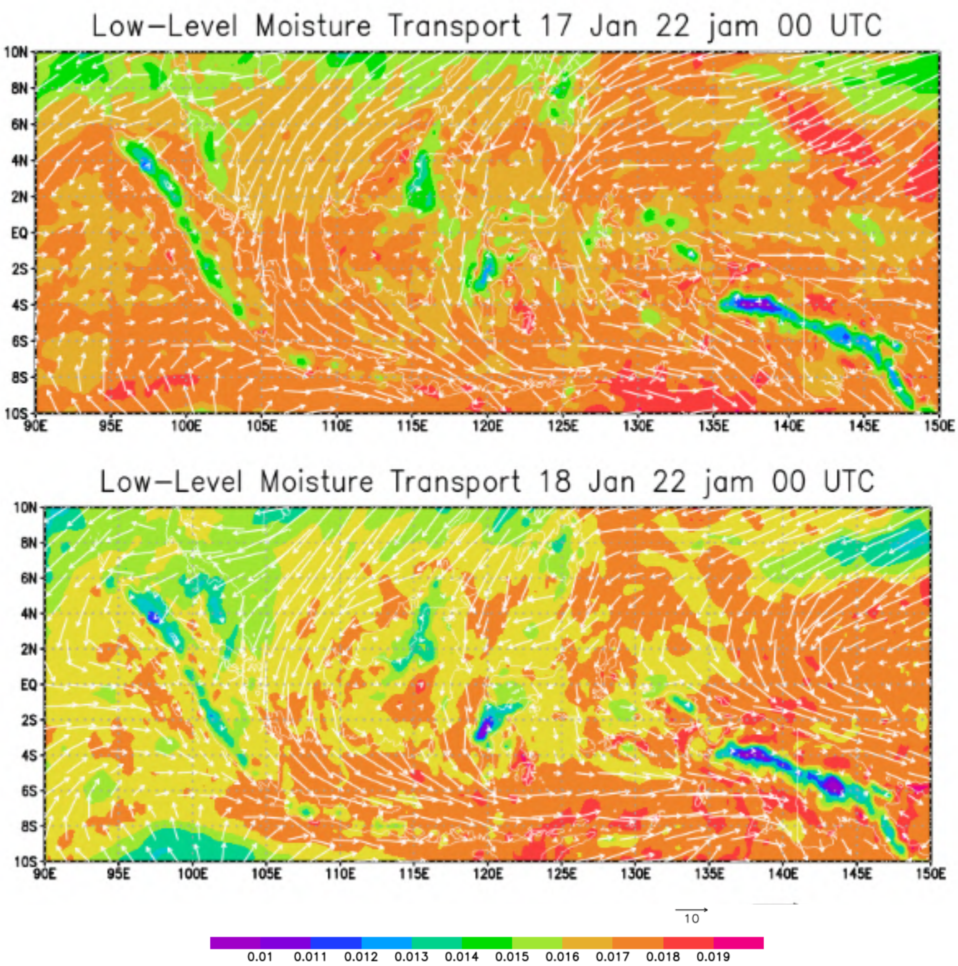

Figure 5. Moisture Transport January 17-18, 2022 (kg/kg)

Based on Figure 5, it can be seen that the formation of CENS began which caused the strengthening of the northeast Asian monsoon flow so that the western part of Indonesia, especially Jabodetabek, received a large supply of water vapor from the South China Sea. In

10.12928/bamme.v3i1.7340

addition, there is also the transmission of cold air masses (NCS) from high latitudes to equatorial regions with the nature of dry air masses that meet with warm air masses in the South China Sea. This allows the formation of fronts in the South China Sea region, increasing the potential for the formation of convective clouds in the area through which it passes. If the flow passes through the equator, the impact can reach the southern equatorial region.

Identification of CENS

Based on the method of Hattori (2011), CENS can be identified when the northerly wind speed at the 925 hPa layer in the region between 105˚BT to 115˚BT is more than 5 m/s or the meridional wind speed is less than -5 m/s. Therefore, the Hovmoller diagram was used to look at the cross-section of time for the average longitude of 105˚-115˚BT from January 17-18, 2022.

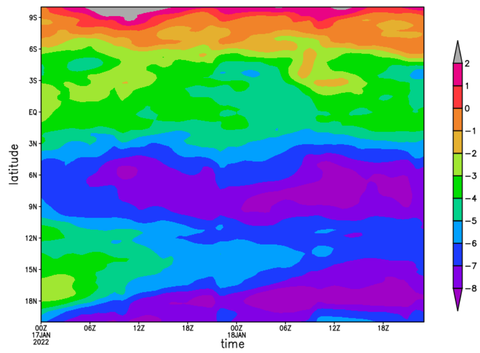

Figure 6. Meridional Wind Hovmoller diagram on January 17-18, 2022 (m/s).

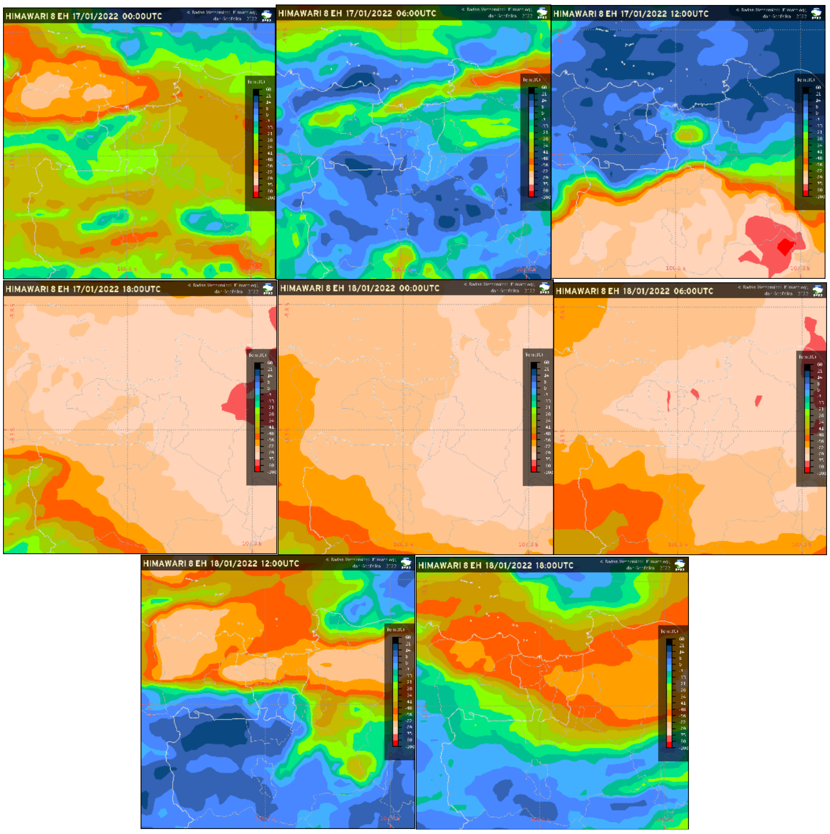

Figure 7. Himawari-8 Enhanced Satellite Imagery on January 17-18, 2022.

Based on Figure 6, it can be seen that the CENS phenomenon occurred on January 17-18, 2022 with meridional wind speeds in the 105˚- 115˚BT region less than -5 m/s.

Satellite image analysis

Figure 7 shows that there is a spread of convective cloud systems in the Greater Jakarta area from January 17, 2022 at 18 UTC resulting in very heavy rain that causes flooding in Jakarta and surrounding areas. The clouds are getting lower in temperature so that there is very strong convection in the Jakarta area, especially on January 18, 2022. The cloud is a mature cloud that shifts from the South to the North (Jakarta) on January 17, 2022 at 12 UTC. There was an expansion of cloud coverage and a decrease in cloud temperature (>-60°c) on January 17, 2022 at 18 UTC to January 18, 2022 at 06 UTC, indicating that convective clouds were very mature and rain occurred. The strengthening of the Asian monsoon flow due to the presence of CENS, thus providing a large supply of water vapor in the Jabodetabek area, the convective cloud system is persistent. The cloud range began to shrink and the cloud temperature began to rise on January 18, 2022 at 12-18 UTC.

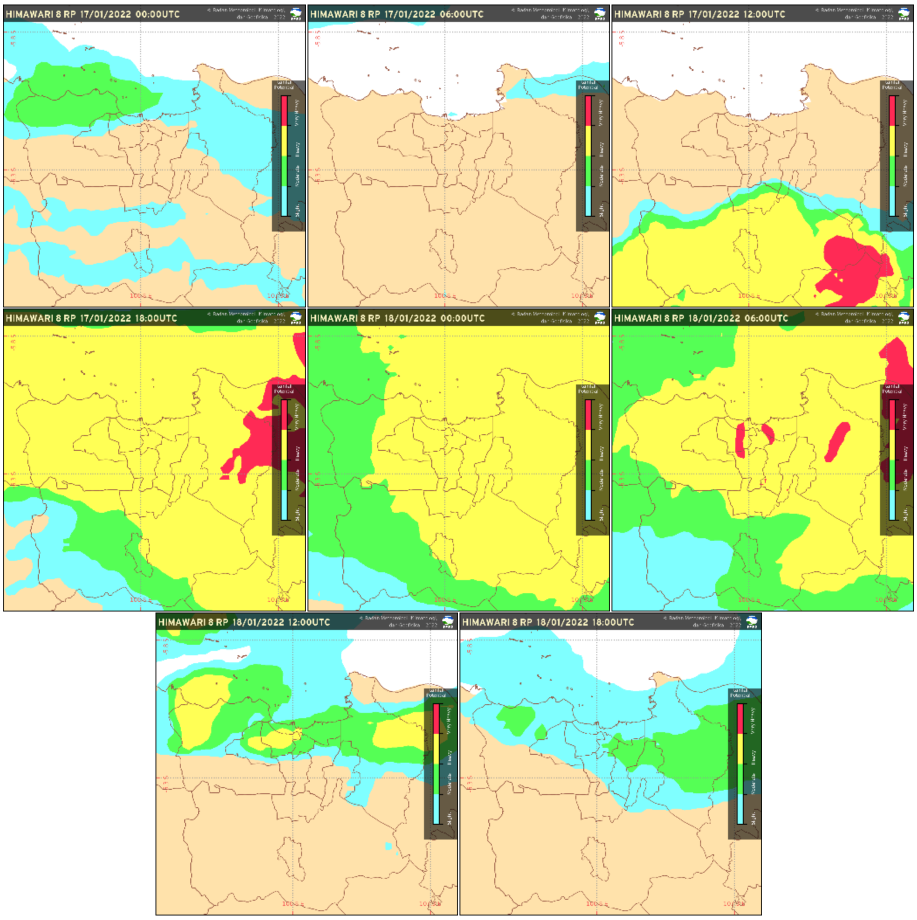

Figure 8. Himawari-8 Satellite Image of Rain Precipitation on January 17-18, 2022.

Figure 8 shows the estimated spatial rainfall from Himawari-8 satellite data on January 17-18, 2022. The movement of air masses triggers the convective cloud system to shift from south to north (Jakarta) so that rain occurs on January 17, 2022 at 18 UTC until January 18, 2022 at 06 UTC in the Jakarta area. The cloud shift also caused a decrease in rainfall in the Jakarta area starting January 18, 2022 at 12 UTC. From the station rainfall data that has been explained in the

 10.12928/bamme.v3i1.7340

background, it shows that there was rain with very heavy intensity on January 17-18, 2022 which resulted in flooding in the Jakarta area as a result of CENS.

Conclusion

Based on the results and discussion, it is concluded that.

- The NCS began to form on January 16-17, 2022 with the presence of a Siberian High of 1040.6 hPa and the propagation of cold air masses from the Asian region to the south which is an indicator of the occurrence of CENS.
- Based on the Hattori method (2011), the CENS phenomenon occurred on January 17-18, 2022 with meridional wind speeds in the 105°- 115°BT region less than -5 m/s.
- CENS triggers the strengthening of the northeast Asian monsoon flow so that the area south of the equator including Jakarta gets a large moisture transport from the South China Sea. This causes the potential for the formation of high convective clouds to trigger very heavy rain and cause flooding in the Jakarta area on January 18, 2022.

References

Aldrian, E., Utama, G.S.A. (2007). Identifikasi dan Karakteristik Seruakan Dingin (Cold Surge) Tahun 1995-2003. *Jurnal Sains Dirgantara*, 4(2), 107-127.

Araki R, Yamanaka MD, Murata F, Hashiguchi H, Oku Y, Sribimawati T, Kudsy M, Renggono F. (2006). Seasonal and interannual variations of diurnal cycles of wind and cloud activity observed at Serpong, west Jawa, Indonesia. *J Meteor Soc Japan*, 84A:171–194 https://doi.org/10.2151/jmsj.84A.171.

BMKG. (2010). *Peraturan KBMKG Nomor: Kep. 009 Tahun 2010 tentang Prosedur Standar Operasional Pelaksanaan Peringatan Dini, Pelaporan, Dan Diseminasi Informasi Cuaca Ekstrim*.

BPBD. (2022). *Curah Hujan Ekstrem di DKI Jakarta, Genangan Mampu Terrtangani Cepat.* Retrieved from https://bpbd.jakarta.go.id/

Chang, C. P., C. H. Liu, and H. C. Kuo. (2003). Typhoon Vamei: An equatorial tropical cyclone formation. Geophys. *Res. Lett.*, 30(1150), doi:10.1029/ 2002GL016365.

Chang, C. P., P. A. Harr, and H. J. Chen. (2005). Synoptic disturbances over the equatorial South China Sea and western maritime continent during boreal winter. *Mon. Wea. Rev*., 133, 489–503.

Chang, C.P., Lu, M.M., Lim, H. (2016). Monsoon Convection in the Maritime Continent: Interaction of Large-Scale Motion and Complex Terrain. *Meteorological Monographs*, Chapter 6. doi: 10.1175/AMSMONOGRAPHS-D-15- 0011.1.

Compo, G. P., G. N. Kiladis, and P. J. Webster. (1999). The horizontal and vertical structure of east Asian winter monsoon pressure surges. *Quart. J. Roy. Meteor. Soc*., 125, 29–54.

Hadi TW, Horinouchi T, Tsuda T, Hashiguchi H, Fukao S. (2002). Sea-breeze circulation over Jakarta, Indonesia: a climatology based on boundary layer radar observations. *Mon Wea Rev.* 130, 2153–2166, https://doi.org/10.1175/ 1520-0493(2002)130<2153:SBCOJI>2.0.CO;2

Hadi TW, Tsuda T, Hashiguchi H, Fukao S. (2000). Tropical sea-breeze circulation and related atmospheric phenomena observed with L-band boundary layer radar in Indonesia*. J Meteor Soc Japan,* 78:123–140, https://doi.org/10.2151/ jmsj1965.78.2_123

Hashiguchi H, Fukao S, Tsuda T, Yamanaka MD, Tobing DL, Sribimawati T, Harijono SWB, Wiryosumarto H. (1995). Observations of the planetary boundary layer over equatorial Indonesia with an L-band clear-air Doppler radar: initial results. *Radio Sci,* 30:1043–1054 https://doi.org/10. 1029/95RS00653

Hashiguchi H, Tsuda T, Fukao S, Yamanaka MD, Harijono SWB, Wiryosumarto H. (1995).Boundary layer radar observations of the passage of the convection center over Serpong, Indonesia (6°S, 107°E) during the TOGA-COARE intensive observation period. *J Meteor Soc Japan,* 73:535–548 https://doi.org/ 10.2151/jmsj1965.73.2B_535

Hashiguchi H, Yamanaka MD, Tsuda T, Yamamoto M, Nakamura T, Adachi T, Fukao S, Sato T, Tobing DL. (1995). Diurnal variations of the planetary boundary layer observed with an L-band clear-air Doppler radar. *BoundaryLayer Meteor,* 74:419–424 https://doi.org/10.1007/BF00712381

Hattori, M., Mori, S., Matsumoto, J. (2011). The Cross-Equatorial Northerly Surge over the Maritime Continent and Its Relationship to Precipitation Patterns. *Journal of the Meteorological Society of Japan*, 89A, 27- 47. doi: 10.2151/jmsj.2011-A02

Mori, S., Wu, P., Yamanaka, M.D., Hattori, M., Hamada, J.I., Arbain, A.A., Lestari, S., Sulistyowati, R., Syamsudin, F. (2016). Lightning Climatology over Jakarta, Indonesia, Based on Long-Term Surface Operational, Satellite, and Campaign Observations*. Geophysical Research Abstracts,* 18, EGU2016-5307-2, EGU General Assembly 2016.

Mori, S., Hamada, J.I., Hattori, M., Wu, P.M., Katsumata, M., Endo, N., Ichiyanagi, K., Hashiguchi, H., Arbain, A.A., Sulistyowati, R., Lestari, S., Syamsudin, F., Manik, T., Yamanaka, M.D. (2018). Meridional March of Diurnal Rainfall over Jakarta, Indonesia, Observed with a C-band Doppler Radar: An Overview of the HARIMAU2010 Campaign. *Progress in Earth and Planetary Science*, 5, 47. doi:10.1186/s40645-018-0202-9

Moron, V., Robertson, A.W., Qian, J.H. (2010). Local versus Large-Scale Characteristics of Monsoon Onset and Post-Onset Rainfall over Indonesia. *Climate Dynamics*, 34, 281–299. doi: 10.1007/s00382-009-0547-2.

Renggono F, Hashiguchi H, Fukao S, Yamanaka MD, Ogino SY, Okamoto N, Murata F, Harijono SWB, Kudsy M, Kartasasmita M, Ibrahim G. (2001). Precipitating clouds observed by 1.3-GHz L-band boundary layer radars in equatorial Indonesia. *Ann Geophys,* 19:889–897 https://doi.org/10.5194/angeo-19-889-2001

Swarinoto, Y.S. (1996). Studi tentang Aliran Lintas Ekuator pada Paras 850mb di Daerah Sekitar Laut Jawa*. Skripsi*. Universitas Indonesia: Depok.

Van Bemmelen W. (1922). Land- und Seebrise in Batavia. *Beitr Phys Frei Atmos 10*, 169–177 (in German)

Wu, M. C., and J. C. L. Chan. (1995). Surface-features of winter monsoon surges over South China. *Mon. Wea. Rev.*, 123, 662–680.

Wu, M. C., and J. C. L. Chan. (1997) Upper-level features associated with winter monsoon surges over south China. *Mon. Wea. Rev*., 125, 317–340.

Wu, P., M. Hara, H. Fudeyasu, M. D. Yamanaka, J. Matsumoto, F. Syamsudin, R. Sulistyowati, and Y. S. Djajadihardja. (2007). The impact of transequatorial monsoon flow on the formation of repeated torrential rains over Java Island. *SOLA*, 3, 93–96.

Yulihastin, E. (2015). Pengaruh Cross-Equatorial Northerly Surge (CENS) terhadap Presipitasi pada Kasus Banjir Jakarta 2013. *Tesis*, Institut Teknologi Bandung: Bandung.

Yulihastin, E., T. W. Hadi, N. S. Ningsih, M. R. Syahputra. (2020). Early morning peaks in the diurnal cycle of precipitation over the northern coast of West Java and possible influencing factors. *Ann. Geophys*, 38: 231–242.

Zhou, J., & Yu, J. L. (2005). Influences Affecting the Soil-Water Characteristic Curve. *Journal of Zhejiang University Science*, 6, 797-804.

 10.12928/bamme.v3i1.7340