Seasonal Windstorm Pattern and Damages in Peninsular Malaysia 2018

N H Zakaria¹, S A Salleh¹,²*, Arnis Asmat¹, and M A Islam³
¹Centre of Studies of Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.
²Applied Remote Sensing and Geospatial Research Group, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia.
³Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), 40450, Shah Alam, Selangor, Malaysia.
⁴Faculty of Engineering, Department of Civil Engineering, University of Nottingham, Malaysia Campus, Jalan Broga, Semenyih, Selangor, Malaysia, 43500.

Email: aekbal@salam.uitm.edu.my & nur1812@gmail.com

Abstract Natural disasters cause damages, losses and social problems. Windstorm has been a major contributor to the losses and damages to the sustainability of human lives and built environment. The formation of seasonality in Southeast Asian countries are affected by the monsoon which brings large scale seasonal interchance of wind pattern. The trend of windstorm events is not properly recorded in any recent or previous studies. This paper analyses the windstorm pattern in Peninsular Malaysia. NCEP FNL Operational Model Global Tropospheric Analyses and Meteorological Operational (MeTOP) datasets were used to retrieve the wind speed and the direction during the study period. Both datasets show approximate value of wind pattern based on reported events. Southeast-monsoon (SM), Northeast-monsoon (NM) and Inter-monsoon (IM) impacts are considered in this study. The result exhibited the highest windstorm event was Southeast-monsoon, and the highest wind speed is from NS that is 5.96 m/s to 6.23 m/s. While the highest wind speed outside of peninsula that blows and impacts the land is from SM and the value calibrates in between 9.20 m/s to 10.96 m/s

1. Background

Windstorm classified as tropical cyclone, thunderstorm, tornadoes, monsoon and gale [1]. The increase of windstorm event leads to loss of public and private properties and causes death. Centre for Research on the Epidemiology of Disasters (CRED) in Emergency Events Database (EM-DAT) reported that there is increased of total damage by storm events in 2017 as compared to the previous year [2]. Seasonal monsoon event takes place in existence with windstorm events. Malaysia experiences four types of monsoon known as Northeast Monsoon (NM) occurs from December to March, Southeast Monsoon (SM) occurs from June till September, Inter-monsoon (IM) from April to May and also from October to November [3]. The highest wind speed value during NM is recorded 15 knots during SM it is 10-20 knots [3].

Malaysian Meteorological Department (MMD) is the organization in Malaysia that responsible to deliver and alert the citizen about upcoming weather condition including windstorm events through news, social media and website. Malaysia currently does not have any complete database of windstorm occurrence and resulting damage [4]. The complete information about windstorm will benefits the society especially in planning the emergency response, as well as for future planning and development.

The windstorm event impact has cause big impact to the urban metropolitan society. 80% damages of roofing system in Peninsular Malaysia caused by windstorm event. Study in Pulau Pinang on 2010 to 2013 shows, the damages breakdown is about 47% damages targeted the steel sheet roofing, 30% the truss system, 13% the roof tiles and 20% other related component [5]. Figure 1 shows the number of
houses damaged during windstorm events from 2010 to 2013 in five districts of Pulau Pinang. The district was divided to island portion and mainland. Northeast Penang Island (TL) and Southwest Penang Island (BD) in the island portion and three (Northern Seberang Perai (SPU), Central Seberang Perai (SPT) and Southeast Seberang Perai (SPS) on the mainland. During the period, the highest number of houses damaged recorded in SPU with 538 cases (47%) and the lowest number houses damaged in BD with 111 cases (10%) respectively. [5]

With the emergence of geomatics technology such as Meteorological Operational (MetOp), Geographical Information System (GIS) and numerical simulation Advanced Research Weather Research and Forecasting Model (WRF-ARW), the analysis about windstorm event has become reliable. The limitation of ground data to recording windstorm event in Malaysia can be resolve with the used of geomatics technology as mentioned before. MetOp data give wind speed and direction reading as well as WRF-ARW which is the data is approximately as the ground data. For analysis and illustrate the data, the use of GIS was implementing to mapping the wind speed and direction associates with the windstorm event data.

The wind speed and direction of wind was retrieve using NCEP FNL Operational Model Global Tropospheric Analyses (1° x 1°) that is under Global Data Assimilation System (GDAS). GDAS continuously collects observational data for required analyses [6] and parameters include surface pressure, relative humidity, geopotential height, temperature, sea level pressure, sea surface temperature, soil values, ice cover, u component (East-West) and v component (North-South) of winds, vertical motion, ozone and vorticity.

MetOp satellite carries the Advanced Scatterometer (ASCAT) onboard as its sensor is the lastest satelitte that provides wind data. MetOp is a satellite from the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). ASCAT is a C band radar, which is operated by measuring the wind field over global ocean [7]. The wind speed and wind direction are collected using C band radar in ASCAT on board of the MetOp platform [8].

Hence, this paper aim collecting and compile the data of windstorm event in Peninsular Malaysia on 2018. The data was compile based on the MetOp data was used to explore the wind speed and wind direction pattern from ocean into the land of Peninsular Malaysia. The use of numerical simulation was implementing to see the wind speed and direction in Peninsular Malaysia. These three results were analyzing to see the wind speed and direction compare to real event reported.

2. Methods
This study integrates MetOp data with numerical simulation to analyze the windstorm event in Peninsular Malaysia on 2018. Hence, the method and data use are WRF-ARW Simulation, ASCAT MetOp, Remote Sensing data extraction and collection of past windstorm event.
2.1 WRF-ARW Simulation

| Specification / Data             | Data LBC Specification                                                                 |
|---------------------------------|-----------------------------------------------------------------------------------------|
| Data type                       | NCEP FNL Operational Model Global Tropospheric Analyses, continuing from July 1999      |
| Data Format                     | Grid                                                                                     |
|                                 | WMO_GRIB1                                                                                |
|                                 | WMO_GRIB2                                                                                |
| Temporal Resolution             | 6 hours                                                                                  |
| Spatial Grid Resolution         | 1° × 1°                                                                                  |
| Data Coverage                   | From 0E to 359E and 90N to 90S                                                           |

The dataset NCEP FNL Operational Model for Global Tropospheric Analyses which provides data from 1999 until now. Table 1 shows the specification of the lateral boundary condition (LBC) of the simulation settings. The dataset is employed due to their common applications in representing the wind speed and direction for simulation modelling [10][11][12]. The dataset used are based on monsoon event on NM (December to March), SM (June to September) and IM (April to May and October to November) for year 2018. The data is simulated for 1 km resolution to cover peninsular Malaysia.

![Figure 2. Domain design and coverage area.](image)

The regional dynamic downscaling is conducted using Advanced Research Weather Research and Forecasting Model (WRF-ARW) version 3.8 nested domains are used with the grid size approximately 30 km, 10 km and 1 km the near surface wind. The domains are focused on Peninsular Malaysia. The largest domain cover Southeast Asia region and the smallest domain covers the Peninsular Malaysia. Figure 2 shows the domain covering the study area. WRF-ARW default physics scheme is used for this study.

2.2 ASCAT MetOp

This study uses datasets from MetOp satellite for wind speed and direction retrieval. The data is requested from EUMESAT official webpage. The spatial resolution MetOp datasets provide is 12.5 km x 12.5 km.
ASCAT is an active microwave sensor and its main operational objective is designed to detect surface wind speed and wind direction over global ocean with the consideration of measured winds speed with accuracy less than 2 m/s [7]. Besides that, the data is available in real-time with a correctness retrieval enhanced within 3 hours and below for assessment. Moreover, ASCAT data gives information about eastward and northward wind, wind speed, surface downward, eastward and northward stress, wind stress, sampling length and land ice mask. The characteristics of ASCAT, MetOp satellite is shown in Table 2. MetOp-A stopped functioning after October 2006 and later replaced with MetOp-B launched in 2012 working till now.

The ASCAT data is provided with multiple variables in the form of Network Common Data Form (netCDF) data type. The variables are added as fields in feature attribute table. For this study, wind speed data was used to retrieve the average wind speed. Meanwhile, eastward wind and northward wind data was used to retrieve wind direction. The data was processing to retrieve wind speed and wind direction. Theorem Pythagoras’s equation stated in later part of this article is applied to produce the final output.

### Table 2. MetOp data specification

| Satellite | ASCAT satellite MetOp |
|-----------|-----------------------|
| a) MetOp-A launched 19 October 2006 |
| b) MetOp-B launched 17 September 2012 till now |
| Product Name | Wind speed data |
| Data Format | Grid |
| Data Type | NetCDF-CF |
| Accuracy | RMS error = > 2 m/s |
| | Bias = >0.5 m/s |
| Variables | a) Longitude (degree) |
| | b) Latitude (degree) |
| | c) Wind Speed (meter per second) |
| | d) Northward wind |
| | e) Eastward wind |
| Sampling | a) 50km resolution product with 25km cell spacing. |
| (Resolution) | b) 25km resolution product with 12.5km cell spacing |

### 2.3 Data Extraction for Remote Sensing

The equation 1 to 5, study from Grange on 2014 were used in this study to calculate the wind speed and direction from the MetOp satellite image [12] [13]. The wind speed can be directly obtained from equation 1, where $\vec{u}$ is scalar average wind speed and $u_i$ is defined as wind speed. This is the standard arithmetic mean for wind speed. Wind is represented in vector and specified as speed and direction. Wind speed is defined as the air motion of kinetic energy with respect to the earth surface. The equation 1 shows the average value of the wind speed. The monthly average wind speed data are calculated according to the monsoon seasonal periods.

$$\vec{u} = -u_i \times sin \left[ \frac{2\pi \times \theta_i}{360} \right]$$

To retrieve the velocity amplitude or resultant vector, Pythagoras's theorem and trigonometry formula are used to obtain wind direction. The meridional and zonal ($u$ and $v$ respectively) represent
the two wind components namely the east-west and north-south to be calculated using the formula to measure the average vectors for horizontal wind [14].

The two wind components \((u\text{ and } v)\) in equation 2 and equation 3 need to be calculated first before the average value is calculated [12]. The negative sign is calculated along with wind speed \((u_i)\). Wind direction, by meteorological convention, is defined as from where the wind is blowing from, while the vectors are defined as the direction where the flow is heading to. Wind direction \((\theta)\) measured in degrees and the units for the components in radians [13].

\[
\bar{u} = -u_i \times \sin \left[2\pi \times \frac{\theta_i}{360}\right] \quad (2)
\]
\[
\bar{v} = -u_i \times \cos \left[2\pi \times \frac{\theta_i}{360}\right] \quad (3)
\]

To calculate the resultant vector average wind speed \((\bar{U}_{RV})\) and direction \((\bar{\theta}_{RV})\) the following equation 4 and equation 5 are used:

\[
\bar{U}_{RV} = \left(\bar{u}^2 + \bar{v}^2\right)^{1/2} \quad (4)
\]
\[
\bar{\theta}_{RV} = \arctan \left(\frac{u}{v}\right) + \text{flow} \quad (5)
\]

2.4 Past Windstorm event and damages

For this study, data of windstorm event were collected based on reports and social media[15][16]. The use of big analytic data has given a lot of information for windstorm event from side of human that faced the situation. The picture and video collected from social media proven the case of windstorm event even the case not reported by related state authority [17]. Due to a very limited resources of storm data, this study opted to use these methods and same study by Majid [18] in Penang have also used this method for windstorm event data collection.

The collection of the data need be done manually since a reliable windstorm database in Malaysia still unavailable because lack of funding, recent advance monitoring technologies, and unrecorded data [4]. The development of a database is crucial to provide information on windstorm distribution and the damaged. The use of big analytic data was utilized to gather the windstorm event and damages. The data was collected based on related keyword that refer to event. In Malaysia, the study about damages by windstorm focused on roof structure [19]. For this study, the considered damage was falling trees, building damage, car damage, accidents and human death. Those damages were selected based on cases damages reported.

3. Result and analysis

3.1 Windstorm event and damages on 2018

Figure 3 shows the total windstorm cases reported and recorded in newspaper and article [15], [16]. Total cases recorded in this study is 53. The bar chart shows the highest windstorm event reported in Southeast Monsoon with 17 cases, followed by Northeast monsoon 15 cases, Inter-monsoon 10 and 2 cases each. Figure 4 shows the total cases based on state in Peninsular Malaysia. It is shown that the highest windstorm impacted Kedah with 21 cases, follow by Selangor with 14 cases and other state less than 10 cases.
Figure 5 shows the total damages by windstorm event in 2018. The highest damage was caused by tree falling with 30 cases, building damage of 19 cases, car damage, accident and death 1 cases each. Kedah shows 21 cases of damages by windstorm followed by Selangor with 17 cases. Perlis with five cases, Pahang and Penang three cases, while Perak, Johor and Kelantan one cases and no cases in Kuala Lumpur, Negeri Sembilan and Terengganu. In Perlis, the windstorm event has causes car accident and death reported. Figure 6 shows the map of windstorm event reported in 2018.
Figure 6. Maps of windstorm event in Peninsular Malaysia on 2018

Figure 5. Statistics of total damage based on State
3.2 WRF simulation for wind speed and wind direction

Figure 7 show the maps of wind speed and direction stimulated by WRF-ARW for seasonal monsoon in Malaysia in 2018. The highest wind speed occurred on NM that is 6.23 m/s and the lowest wind speed occurred in SM 0.78 m/s.

Figure 7 (a) show the wind speed and direction for SM. The wind speed recorded between 0.7 m/s to 1.7 m/s. The highest wind speed focused on northern-region which is in Perlis, Kedah, Pulau Pinang and Perak. While in centre Peninsular of Malaysia shows the wind speed reading was between 1.2 m/s to 1.4 m/s impact the Selangor and Pahang state. The reason Selangor is impacted by windstorm event hazard because the increases of urban area and the orientation of building in Selangor is very typical which causes damage to the building in this area during windstorm event. Hence the intensity of vertical and orientation of building has affecting the formation of wind in the urban area. Building orientation has strong correlation with wind direction [20].

In NM as shown in figure 7 (b), the highest wind speed at 5.96 m/s to 6.23 m/s. The lowest value lies in between 3.07 m/s to 4.21 m/s. The high wind speed occurs at the centre of Peninsular Malaysia [21] and causes the windstorm event that brings damages. The area impacted by windstorm and damages are Selangor, Pahang, Negeri Sembilan and Johor. In the northern-region in Perlis, Kedah and Pulau Pinang the wind speed is less than in the centre of Peninsular and there is no event of windstorm and damages reported from the collected data of windstorm event.

While in the IM, less cases were reported. Figure 7 (c) show the IM wind speed on April to May 2018. The highest and lowest wind speed recorded are 2.90 m/s to 3.37 m/s and 1.81 m/s to 2.07 m/s. The highest wind speed at north-region and the lowest wind speed at central region of Peninsular Malaysia. Only 2 cases were reported and recorded by newspaper and article.

Figure 7 (d) shows the IM wind speed on October to November 2018. The highest wind speed is 3.04 m/s to 4.02 m/s while the lowest is 1.69 m/s to 2.16 m/s. For this IM, the highest wind speed recorded in north-region while the lowest wind speed at Southeast region. In Selangor, the wind speed range between 2.57 m/s to 2.95 m/s, which is higher comparatively with the other states. The impact of unplanned urban expansion caused Selangor to become prone area for windstorm impact although the wind speed is medium and is not supposed to cause any damage.
3.3 Wind speed and direction pattern from MetOp satellite image

The transboundary wind circulation flows from one place to another has caused the winds fluctuation on the land surface. Figure 8 shows the wind speed and direction map from MetOps satellite images. The highest wind was on SM at 9.20 m/s to 10.96 m/s and the lowest wind speed was 0.99 m/s to 2.01 m/s in IM in October to November.

The high SM wind speed was 9.20 m/s to 10.96 m/s and blows from outside of Johor as shown in Figure 8 (a). But no windstorm cases are reported even though the wind speed in the land surface is high. It is because type of landuse in Johor 73% of total area was green area and only 27% was developed area [22]. Different cases are observed in northern region and Perlis where the wind speed from outside areas are 6.84 m/s to 8.29 m/s which forms the windstorm event and causes death reported by online Astro Awani on 18 September 2018 [23].

Figure 8 (b) shows the wind speed of NM from MetOps. The highest wind speed is 7.3 m/s to 8.93 m/s that comes from Straits of Melaka and circulates into the land surface. The highest wind speed also comes from outside next to Selangor state and intensifies the windstorm event. While the other impacted areas are in Pahang where the outer wind comes into Pahang at 5.57 m/s to 6.38 m/s.

In IM as shown in figure 8 (c) and 8 (d), the highest reading for wind speed on April-May and October-November are approximately same. The lowest wind speed for IM April-May was 1.76 m/s to 3.38 m/s and for IM October-November was and 0.99 m/s to 2.01 m/s. For IM in April-May the highest wind speed blows from outside of western region (Terengganu and Kelantan) and from outside of Selangor, while for IM in October-November the highest wind speed blows from southeast region (Johor). The IM in October-November causes bigger windstorm impact at Selangor state.

4. Conclusion

The wind pattern changes during windstorm events and causes damages to the public and private property. This study analyzed the wind speed and direction using WRF-ARW simulation and MetOp satellites images. It has been determined, that the highest impact by windstorm is spotted on SM and NM. The highest wind speed occurs on NM. The circulation of wind from ocean has causes the stronger or weaker circulation of wind patterns inside the Peninsular Malaysia. The type of land use also impacts the development of windstorm events. The numbers of event do not cover all Peninsular Malaysia because weak windstorm detection network. The limitations of ground stations to retrieve wind data spatially leads to the use of WRF-ARW and MetOp in this study. Future study needs to be conducted to examine the impact of wind coming from outside to a certain boundary layer and change the impact.
of wind pattern locally causing windstorms. As the study in Penang on 2016, the impact of windstorm event has been recorded. The total cases show the windstorm event, destruction, and total loss for the study area. But there is no study causes of windstorm event that might be associate with the other related parameter such as rain, humidity, temperature and orientation of building.

Acknowledgements
The authors would like to express their gratitude to the Universiti Teknologi MARA (UiTM) for funding this project under Geran Bestari Perdana 600-IRMI/DANA 5/3 BESTARI (P) (074/2018).

References
[1] D. Henderson and J. Ginger, “Role of building codes and construction standards in windstorm disaster mitigation,” Aust. J. Emerg. Manag., vol. 23, no. 2, pp. 40–46, 2008.
[2] N. Kishore et al., “Mortality in Puerto Rico after Hurricane Maria,” N. Engl. J. Med., vol. 379, no. 2, pp. 162–170, 2018.
[3] M. O. F. Science, “General Information Natural Hazard in Malaysia Dissemination of weather information / forecast / warning Additional Utilisation of Weather / Climate Information.”
[4] F. A. Wan Chik, C. D. S. N. A, N. I. Ramli, M. K. A. Muhammad, T. A. Majid, and N. Z. Zulkarnain, “Development of Windstorm Database System for Wind Damages in Malaysia,” J. Civ. Eng. Res., vol. 4, pp. 214–217, 2014.
[5] T. A. Majid, S. A. S. Zakaria, F. A. Wan Chik, S. N. C. Deraman, and M. K. A. Muhammad, “Past windstorm occurrence trend, damage, and losses in Penang, Malaysia,” J. Eng. Sci. Technol., vol. 11, no. 3, pp. 397–406, 2016.
[6] Y. Dong, G. Li, M. Yuan, and X. Xie, “Evaluation of five grid datasets against radiosonde data over the eastern and downstream regions of the tibetan plateau in summer,” Atmosphere (Basel), vol. 8, no. 3, pp. 1–19, 2017.
[7] A. Bentamy, S. A. Grodsky, J. A. Carton, D. Croizé-Fillon, and B. Chapron, “Matching ASCAT and QuikSCAT winds,” J. Geophys. Res. Ocean., vol. 117, no. 2, 2012.
[8] A. S. J. Figu-saldaña, J. w. Wilson, Evert Attema, R. Gelshorpe , Mark R Drinkwater, “The Advanced Scatterometer (ASCAT) on the Meteorological Operational (MetOp) platform: A follow on for European wind scatterometers,” Curr. Sci., vol. 107, no. 4, pp. 589–595, 2014.
[9] H. Zhang, Z. Pu, X. Zhang, H. Zhang, Z. Pu, and X. Zhang, “Examination of Errors in Near-Surface Temperature and Wind from WRF Numerical Simulations in Regions of Complex Terrain,” Weather Forecast., vol. 28, no. 3, pp. 893–914, Jun. 2013.
[10] Y. Takeyama, T. Ohsawa, K. Kozaï, C. B. Hasager, and M. Badger, “Effectiveness of WRF wind direction for retrieving coastal sea surface wind from synthetic aperture radar,” Wind Energy, vol. 16, no. 6, pp. 865–878, Sep. 2013.
[11] D. Carvalho, A. Rocha, M. Gómez-Gesteira, and C. Silva Santos, “WRF wind simulation and wind energy production estimates forced by different reanalyses: Comparison with observed data for Portugal,” Appl. Energy, vol. 117, pp. 116–126, Mar. 2014.
[12] S. K. Grange, “Technical note : Averaging wind speeds and directions Technical note : Averaging wind speeds and directions,” no. June 2014, 2015.
[13] S. K. Grange, “Averaging wind speeds and directions,” no. October, p. 12, 2014.
[14] S. K. Grange, “Technical note : Averaging wind speeds and directions Technical note ;,” no. June 2014, p. 12, 2014.
[15] “Plaza Tol Bukit Raja gempar dilanda ribut | Kes | Berita Harian.” [Online]. Available: https://www.bharian.com.my/berita/kes/2018/08/465683/plaza-tol-bukit-raja-gempar-dilanda-ribut. [Accessed: 09-Jan-2019].
[16] “Tiga lelaki nyaris maut, ribut landa Bachok | Astro Awani.” [Online]. Available: http://www.astroawani.com/berita-malaysia/tiga-lelaki-nyaris-maut-ribut-landa-bachok-182838. [Accessed: 09-Jan-2019].
[17] “Malaysia Country Report | GardaWorld.” [Online]. Available: https://www.garda.com/crisis24/country-reports/malaysia. [Accessed: 09-Jan-2019].
[18] T. A. Majid, S. A. S. Zakaria, F. A. Wan Chik, S. N. C. Deraman, and M. K. A. Muhammad, “Past windstorm occurrence trend, damage, and losses in Penang, Malaysia,” J. Eng. Sci. Technol., vol. 11, no. 3, pp. 397–406, 2016.
[19] N. I. Ramli, M. I. Ali, T. A. Majid, W. C. F. A, D. S. N.C., and M. M. K. A, “Wind-related Disasters in Malaysia and Changes in Regulations and Practice,” Wind Eng. J.AWE, vol. 40, no. 3, pp. 290–293, 2015.
[20] E. Prianto, F. Bonneaud, P. Depecker, and J.-P. Peneau, “TROPICAL-HUMID ARCHITECTURE IN NATURAL VENTILATION EFFICIENT POINT OF VIEW A Reference of Traditional Architecture in
Indonesia,” 2000.

[21] P. Malaysia, A. M. Razali, M. S. Sapuan, K. Ibrahim, A. Zaharim, and K. Sopian, *Mapping of Annual Extreme Wind Speed Analysis from 12 Stations in* .

[22] Jabatan Perancangan Bandar dan Desa Negeri Johor (JPBD), “Draf Rancangan Struktur Negeri Johor 2030,” 2016.

[23] Salim Aziz (ASTRO AWANI), “Tiga maut, kereta bertembung ketika ribut di Padang Besar | Astro Awani,” 2018. [Online]. Available: http://www.astroawani.com/berita-malaysia/tiga-maut-kereta-bertembung-ketika-ribut-di-padang-besar-185845. [Accessed: 04-Mar-2019].