Research in Marine Sciences
Volume 3, Issue 1, 2018
Pages 231-244

Extreme weather and floods in Kelantan state, Malaysia in December 2014

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Received: 2017-10-13 *Accepted: 2018-01-08*

Abstract

This paper described the event of weather activities and flooding in the affected areas of Kelantan State in Malaysia during the Dec 2014 to January 2015. This is the worst flooding in Kelantan since 1927 with approximately the return period of rainfall of 1: 1000 years. The scenarios of flooding, rainfall amount on land and rainfall rate in the atmosphere were discussed. The factors contributing to this flood in 2014 are similar to the 2006 worst Johor flood which also occurred in the December and January.

Keywords: Extreme weather; Flood; Kelantan; NCEP data; Malaysia.

1. Introduction

With the changing in climate scenario all over the world we have seen changes along with it the changing pattern of hydrology and weather pattern. Global warming over the last century means heat extremes that previously only occurred once every 1,000 days are happening four to five times more often (Fischer and Knutti, 2015). Extreme weather seem to be on the increase and similarly affecting the water availability and thus sometimes the abundance of water. Climate change includes not only changes in mean climate but also in weather extremes. A few prominent heat waves and heavy precipitation events was attributed to the human contribution to their occurrence and has been demonstrated by some researchers (Stott *et al*., 2004; Pall *et al*., 2011; Otto *et al*., 2012; Lewis and Karoly, 2013; Sippel and Otto, 2014). The climate change were found to have impacted the extreme weather in 2015 for example the searing summer heat wave in Europe, sunny day flooding in Miami, one of Alaska's worst wildfire seasons and heavy rainfall in China (https://www.ncdc. noaa.

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gov/bams/2015). The extreme weather was also reported to be on the rise, citing some example of the events in China, Europe and the Americas. This is related to the consequences from the extreme weather where most hurricanes and storms, flooding, landslides occurrences; mudslides were among the cases related to weather extremes (http://www.ssec.wisc.edu/~kossin/articles/Chapter_2.pdf).

Floods are a common occurrence in Malaysia, but the recent monsoon flood from December 2014 to January 2015 was regarded as one of the more devastating floods to hit Malaysia in recent decades, with more than 100,000 flood victims evacuated from their homes (Reuters, 2014). The flood in Kelantan was mainly due to the continuous heavy rainfall from 21-23 December 2014 which was equivalent to more than 60 days of rainfall, whereby the water level in the river exceeded those of recorded floods of 1967 and 2004 (Nurul Farahen *et al*., 2017). Jaafar *et al*., (2016) reported that the accumulated rainfall on December and whole year of 2014 at Gagau station shows that contribution of rainfall on December is roughly 50 % of all of 2014.

On 17th December 2014, there were 3390 people in Kelantan and 4209 in Terengganu evacuated (Khaosod English, 2014). The persistence of precipitations raised the water level on most of the rivers in Kelantan, Pahang, Perak and Terengganu beyond safety levees, which caused the evacuation of approximately 60,000 people on the following day. The aftermath of flooding damages estimated by the Malaysian government mounted to 1 billion ringgits ($284 million USD), from which, 100 million ringgits disposed to repair roads in Kelantan and 132 million ringgits to repair roads in Terengganu (INQUIRERNET, 2015).

Figure 1. The Kelantan State showing Kelantan river system (DOA, 2013)

2. Materials and methods

The study area is the Kelantan State (Figure 1). Kelantan State is located on the east coast of Peninsular Malaysia (Figure 2). This paper is written based on secondary data from several report and articles on the 2014 floods. Additional data analyses of the passage of cold surge from China affecting precipitation rate (Prate) from 14 Dec 2017- 4 Jan 2015 were reanalysed using NCEP reanalysis data (Kalnay *et al*., 1996) available from the Climate Prediction Center (CDC). The global dataset has a horizontal grid spacing (resolution) of 2.5º × 2.5º. The dataset is valuable for investigating extreme weather events and forecasting (Grumm, 2005; Hamill *et al*., 2005). The daily maps were visualized by Grid Analysis and Display System (GrADS) software (2.0.2).

3. Results and Discussion

3.1. The 2014 Flood

Over the years, flood has become one of the most destructive phenomena all over the world. It's included Malaysia and Kelantan State located at the east coast of Peninsular Malaysia is one of the prone areas to flooding (Figures 1 and 2). Flood in Kelantan is mainly caused by heavy rainfall brought by the Northeast monsoon starting from November to March every year. It is categorized as annual flood as it occurs every year during the Monsoon season.

Figure 2. Flood prone areas in Malaysia, the east coast of Peninsular Malaysia include almost all states from Kelantan to Johor is prone to flooding

The 2014 flood in Kelantan is the worst since 1967. Kuala Krai is the worst area hit by the floods. Crossing the river from upstream systems that meet at the confluence Kuala Krai quickly cause overflow of irrigation and drainage, rain of 850mm for 10 days in Kelantan is more than the normal rate of 100 mm. Coupled with a static clouds situation that should move to Johor brought heavier rain than usual (http://www.met.gov.my). Besides heavier rain factor, there is also deforestation factor. Some deforestation even occurred in the catchment area or waterway. Logging activities from the deforestation explained why a lot of facilities damaged (Wardah, 2015).

This devastating flood event occurring at the north-east coast of Peninsular Malaysia was called by locals as the "Kelantan Big Yellow Flood 2014". Yellow is due to the colour of murky water that brought with it the suspended sediment from the catchment areas being eroded away by the rainfall. Kelantan is located in the East-coast of the peninsular exposing it to high rainfalls during the North-east monsoon season. In December 2014, Kelantan was hit by the worst flood ever recorded in history where flood levels reaches up to 5 to 10 meters. Buildings were inundated up to the 3rd and 4th floor. Many people could not evacuate from their homes and people sheltering in evacuation centres such as school were left helpless due to lack of supplies and necessities.

On record, this flood was considered among the worst that hit the country in 200 years. It

Figure 3. The effect of the 2014 flood where trees were uprooted, cars and houses destroyed and flood water everywhere including in the Kota Bharu stadium (Baharuddin *et al*., 2015)

was assumed that flood of this nature could only occur once in a blue moon (possibly a return period of in 1000 years). For the state of Kelantan, the phenomenon was unprecedented in the history of its existence. The occurrence of the flood was blamed squarely on the extraordinary rainfall occurring within a short duration and massive agricultural as well as logging activities (Azuhan, 2015; Sathiamurthy and Kong, 2015).

It was made worse by extensive soil erosion in the upland areas and the subsequent siltation of sediments on riverbed with muddy and sandy materials (Nurul Akma *et al*., 2015), containing some heavy metals, because of the uncontrolled land development in the upstream areas. It was believed that soil erosion in the upper reaches of Kelantan River prior to the flood was already 100 times more than normal because the land uses in the upper catchment were mostly converted to agriculture. Adnan and Atkinson (2011) reported that the changing land uses to agriculture was almost 400% in the 12 years period, from 1988-2000, whereby most of the changes were conversion to oil palm (152%) and mixed agriculture (158%), and most of the changes are due to deforestation (9.3%). During the height of the flood, trees were uprooted, abandoned logs were transported and the subsoil was eroded, which was subsequently silted in the lower reaches of the river (flood plains), causing untold damages to homes and agricultural lands alike (Figure 3).

3.2. The Hydrological Chronology

The hydrological chronology of the Kelantan flood in 2014 was described by Baharuddin *et al*. (2015). The flood begin with torrential rains beginning on the 17 th December 2014, led to flash flooding and forced 3390 people in Kuala Krai, Kelantan, to flee their homes (Sapa-dpa Midrand, 2015). Later, three days of continuous heavy rain fell from the 21st to the 23rd of December, 2014, in Gua Musang. This was a record-setting rainfall of 1,295 mm, equivalent to the amount of rain usually seen in a span of 64 days. As a result, the water levels of three major rivers, the Galas River at Dabong, the Lebir River at Tualang and the Kelantan River, rose drastically above the water levels considered dangerous (Murty, 2015). The highest recorded level of the Galas River at Dabong, Gua Musang was 46.47 metres (danger level: 38 metres), the highest recorded level of the Lebir River at Tualang, Kuala Krai was 42.17 metres (danger level: 35 metres), and the highest recorded level of the Kelantan River was 34.17 metres at Tangga Krai, Kuala Krai (danger level: 25 metres) and 22.74 metres (danger level: 16 metres) at the Guillemard Bridge in Tanah Merah. The highest level of the Sungai Golok at Rantau Panjang was 10.84 metres, which was over the danger level of nine metres (Portal Rasmi eBanjir, 2015). Table 1 showed the comparison between Kelantan River level in 1967, 2004 and 2014.

Table 1. The highest recorded river level between 2014 and 1967 flood of Kelantan River

River	Gauging Site	Danger level (m)	1967	2004	2014
Kelantan	Tangga Krai	25.0	33.61	29.70	34.17
Kelantan	Tambatan Diraja	5.0	6.22	6.70	7.03

Source: DID (2014)

The recorded water levels were highest in 2014 at 34.17 m and 33.61 m in 1967.

3.3. Spatial rainfall distribution - isohyet

Spatial rainfall distribution analysed by Alias *et al*. (2016) described a general view on the rainfall distribution prior to the flood are made based on the rainfall distribution plots (isohyets) published by the department of irrigation and drainage (DID) Malaysia (Figure 4).

High rainfall distribution began at the upstream eastern side of the Kelantan river basin on 16 December 2014. Two hundred fifty five (255) mm rainfall was recorded in Gunung Gagau station. High rainfall was also recorded in the western side of the basin which is around the Ulu Sekor and Kampung Jeli stations with the recorded rainfalls of 163.4 mm and 199.1 mm. The rainfalls on both locations could influence the Kelantan River water levels in Kuala Krai as the rains contributed to the volume of flow in Sungai Galas and Sungai Lebir. Accordingly heavy rainfalls fell in the east-coast from 15 to 29 December 2014. The rainfalls which may contribute to the flood occur in two phases. Phase one begins from 15 December to 21 December 2014 with daily rainfall reaching up to 100 mm to 300 mm. During this time most of the rainfall was concentrated to the east-coast of Peninsular Malaysia, especially the coastlines of Kelantan, Terengganu and Pahang (Figure 4).

Phase 2 begins from 22 to 24 of December 2014 were higher intensities of rainfall occurred. The daily rainfall during this phase reaches up to 500 mm and were more concentrated in the middle of the peninsular especially areas centre of Kelantan, Terengganu and Perak States.

3.4. Spatial pattern of cumulative rainfall

A detail assessment of the rainfall distribution in Kelantan River Basin was made using spatial rainfall distribution constructed from data observed in stations within the basin and

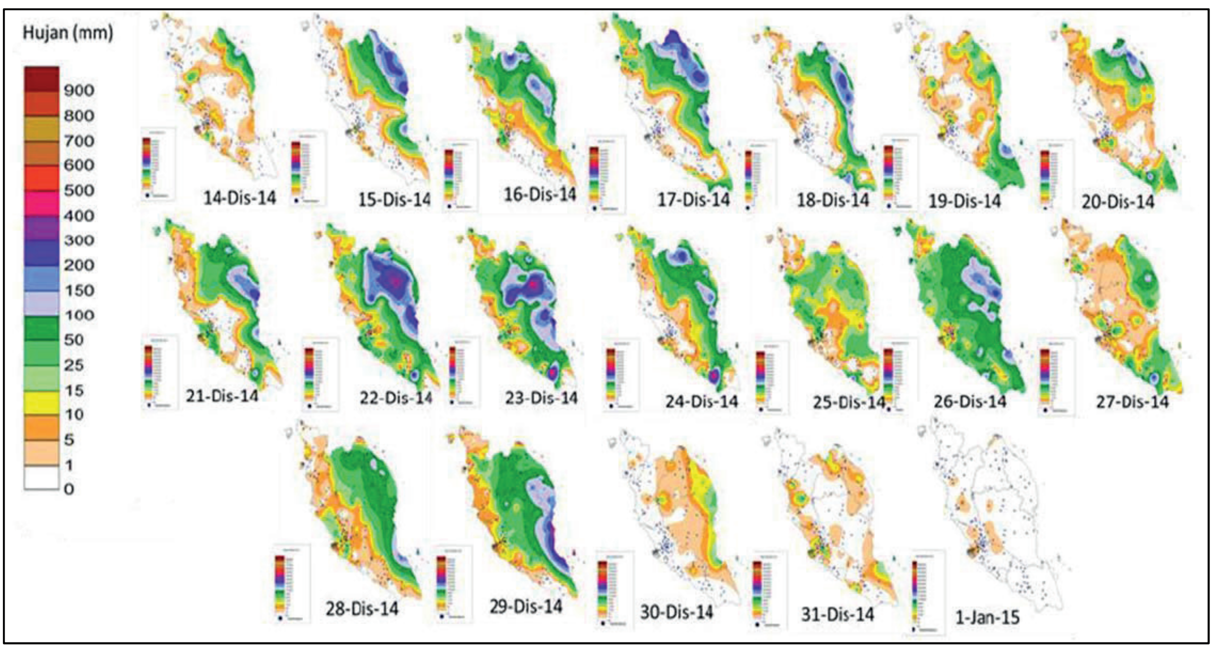

Figure 4. Rainfall isohyetal map from 14 Dec 2014- 1 Jan 2015 (Alias *et al*., 2016)

its surrounding borders (Figure 5). The analysis was conducted using rainfall data from 16 to 26 December 2014. Heavy rains (more than 200 mm per day) were observed to fall during this period. By assessing the cumulated rainfalls by stages, we can assess the patterns of the spatial rainfall distribution across the river basin (Alias *et al*., 2016).

During the second phase (20-24 December 2014), very high rainfall in the middle of Kelantan and Terengganu, the 7-day total rainfall (16-22 December 2014) in Gunung Gagau reaches to 1237.5 mm. This rainfall value exceeds very far from the historical record. Similar observation can be seen for the cumulated 9-day rainfall (16-24 December 2014) where Gunung Gagau station records a total of 1866.9 mm rainfall and 10-day rainfall of 2099.1 mm, half of its annual rainfall (Alias *et al*., 2016) (Figure 5).

3.5. The effect of cold surge on precipitation

Eyeball analysis of the maps in Figure 6, shows the variations of the precipitation rate during the event and over the area from 14 Dec 2017 to 1 January 2015. From 14 Dec 2014, the precipitation rate (prong or tongue) comes from north of the South China Sea toward the south and on 16 Dec 2014 touch the Peninsular Malaysia with maximum amount of precipitation rate of 0.0003 $Kg/m^2/s$. The precipitation rate increased to 0.0005 $Kg/m^2/s$ on 21 Dec 2014. The values

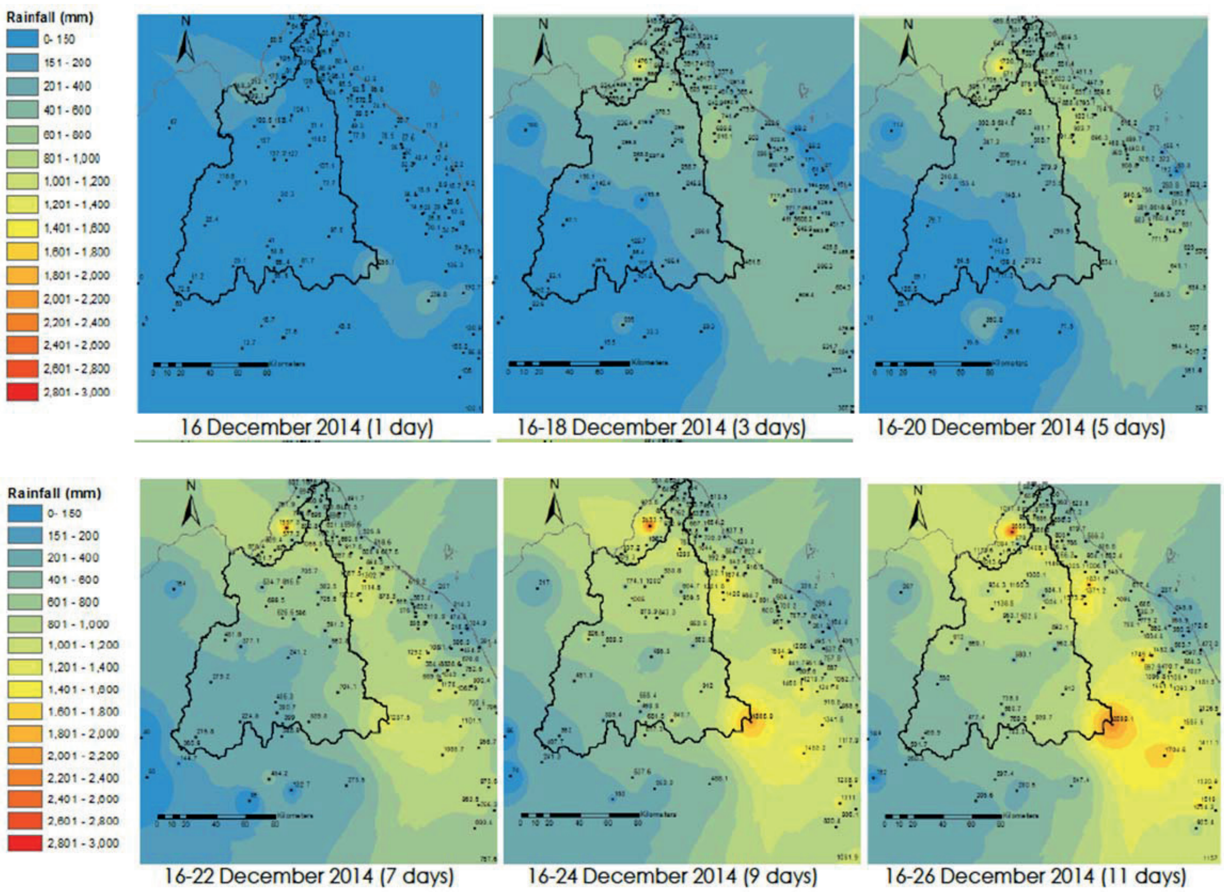

Figure 5. Spatial distribution of the cumulated rainfall depths (Alias *et al*., 2016)

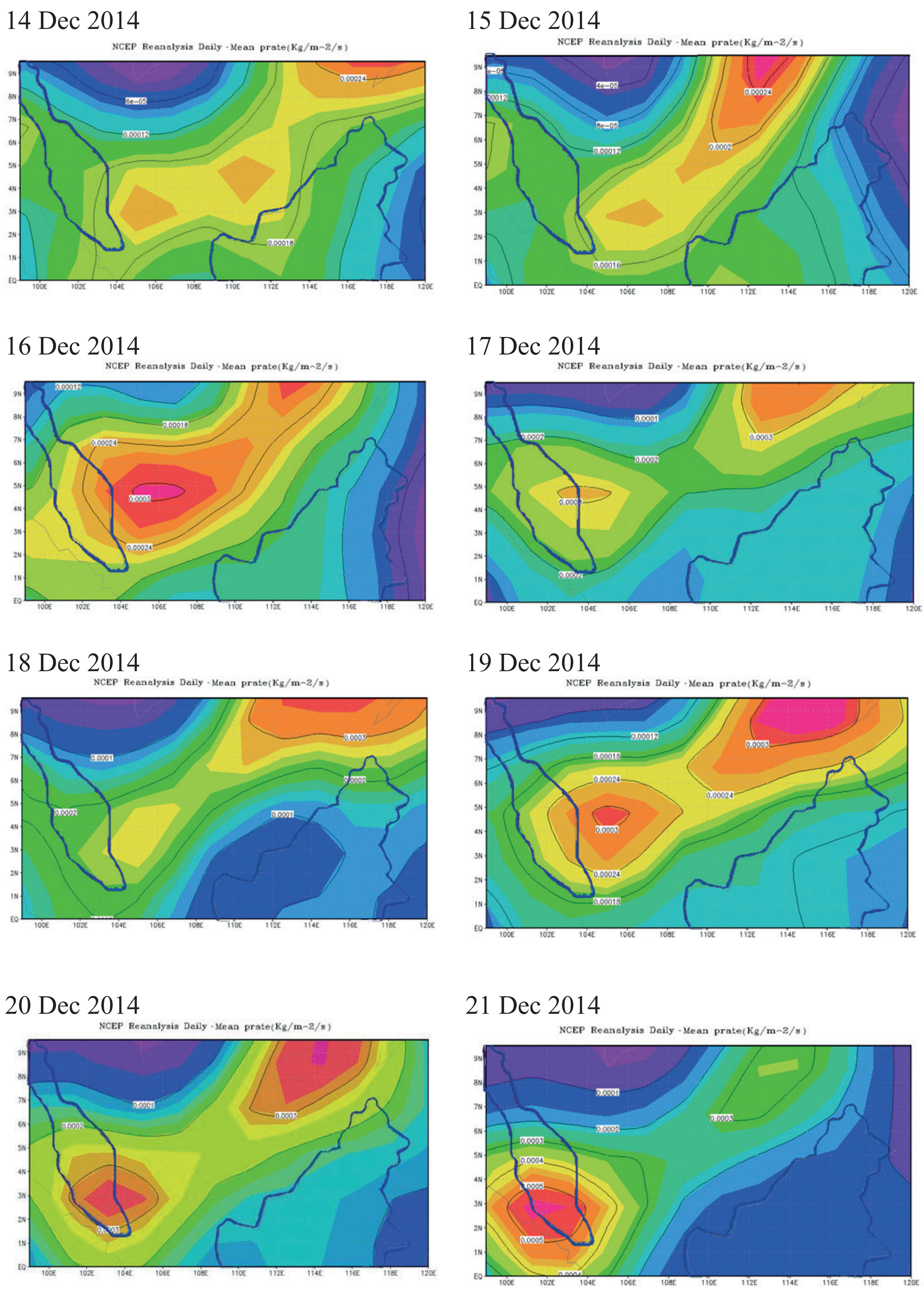

Figure 6. The precipitation rate in (Kg/m^2/s) during the passage of cold surge in the South China Sea

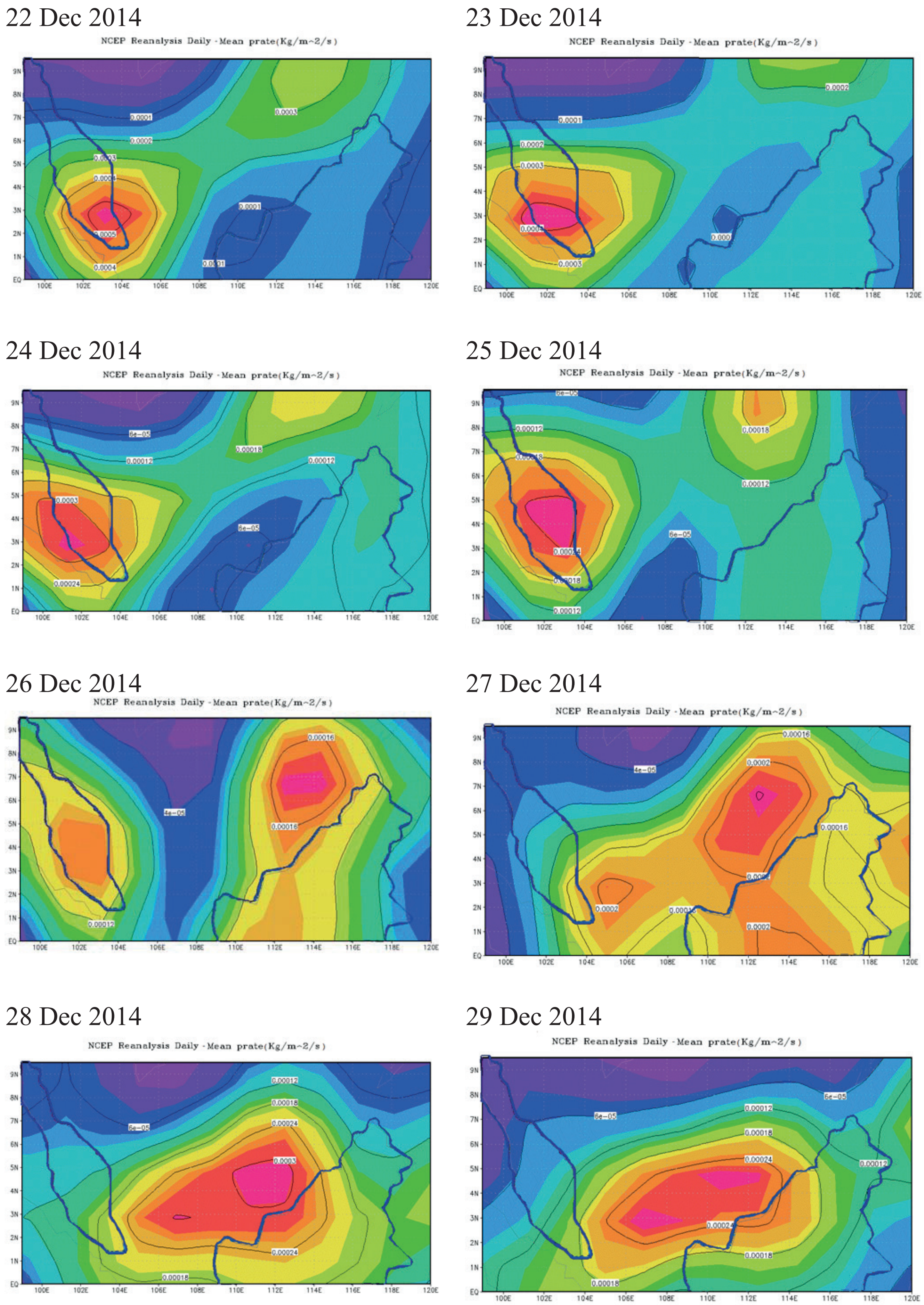

Figure 6 Continued

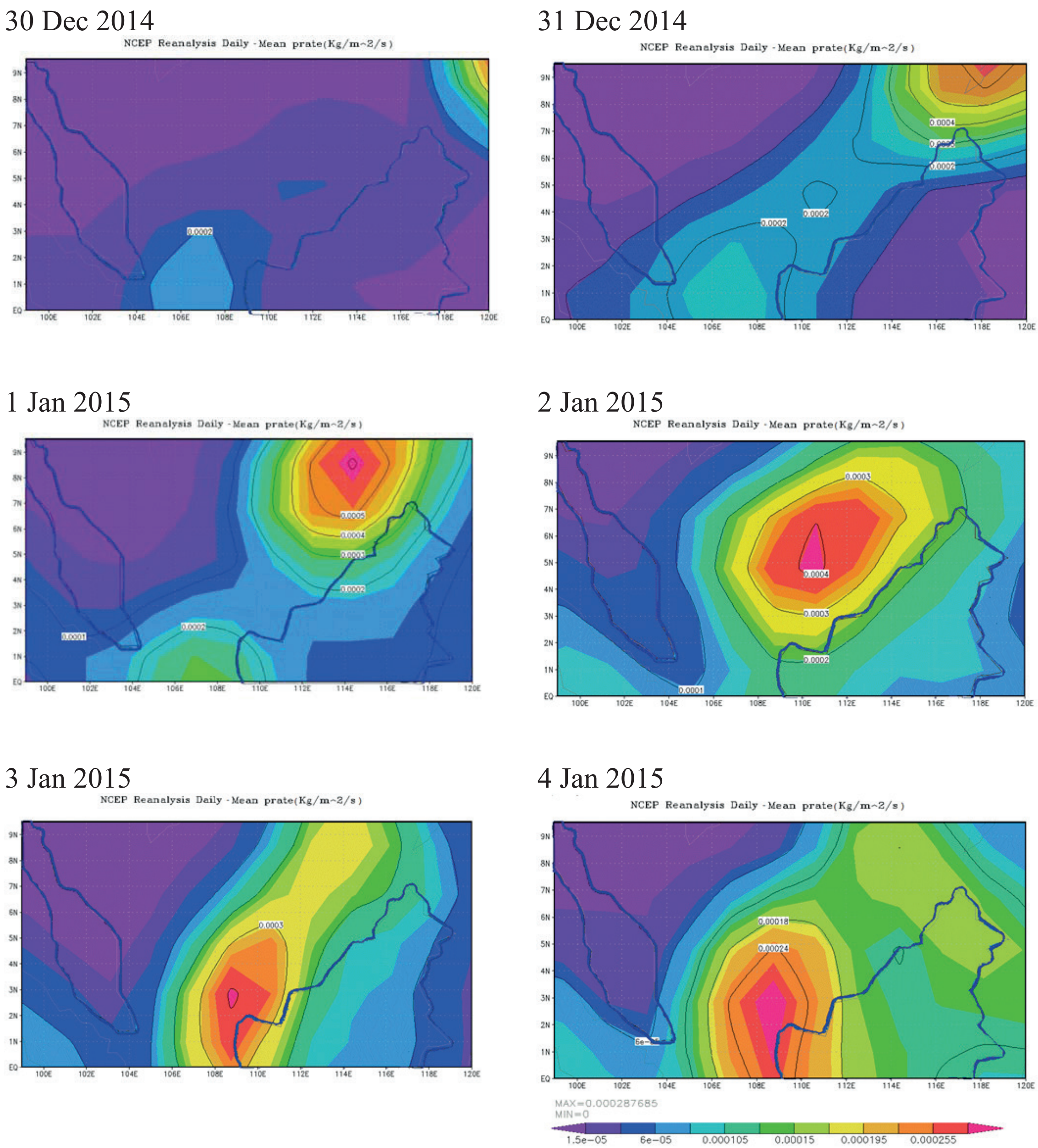

Figure 6 Continued

started to reduction and the precipitation front left the Peninsular on 26 Dec 2014. The values had the lowest amount of about 0.00015 Kg/m^2/s. The maps shows that from 26 Dec to 29 Dec 2014 the front located over the South China Sea and East Malaysia with maximum precipittion rate of 0.0003 Kg/m^2/s. The front shows the movement over the South China Sea, between Peninsular Malaysia and East Malaysia.

Table 2 shows the comparison between precipitation rate using NCEP analysis and the rainfall amount (mm) recorded on the ground analysed from the isohyetal map from Alias *et al*., (2016). The highest rainfall were recorded on the 15-18 Dec 2014, 20-24 Dec 2014 and 26 Dec 2014. These 3 periods of highest rainfalls were shown on both the NCEP analyses and the isohyetal rainfall.

Table 2. Comparison between precipitation rate analyzed NCEP and the ranges of rainfall amount from isohyetal map.

Date	Range of Rainfall amount (mm) from isohyetal map	Range of Rainfall amount in the atmosphere ($Kg/m^2/s$) using NCEP
14 Dec 2014	15-50	0.00012-0.00018
15 Dec 2014	50-300	0.00012-0.00016
16 Dec 2014	50-300	0.00018-0.00024
17 Dec 2014	100-300	0.00020-0.00030
18 Dec 2014	50-300	0.00010-0.00020
19 Dec 2014	10-50	0.00012-0.00024
20 Dec 2014	20-200	0.00016-0.00020
21 Dec 2014	25-150	0.00015-0.00030
22 Dec 2014	20-400	0.00013-0.00020
23 Dec 2014	20-400	0.00010-0.00020
24 Dec 2014	25-300	0.00012-0.00018
25 Dec 2014	5-50	0.00018-0.00024
26 Dec 2014	50-200	0.00012-0.00018
27 Dec 2014	10-50	0.00007-0.00010
28 Dec 2014	15-100	0.00006-0.00009
29 Dec 2014	15-200	0.00006-0.00009
30 Dec 2014	1-15	< 0.000013
31 Dec 2014	1-10	<0.000012
1 Jan 2015	0-5	<0.000010

Based on the studies carried out by the Special Task Force Study on the Devastating Flood 2014 (Isahak, 2015) the flood was the worst flooding ever experienced in 200 years, causing losses of up to RM2.85 billion. The number of peoples displaced was also the highest ever recorded at 500,000 peoples (Komoo, 2015).

The worst affected area of Kelantan State in Dec 2014 and early January 2015 was due to a meteorological disturbance called Maiden-Julian Oscillation (MJO) (Shamshuddin *et al.*, 2016) that occurred between December and January. Analysing almost similar worst case flood event in Johor State in 2006/07 which also occurs in December and January, Tangang *et al*. (2008) stated that the influence of the Borneo Vortex, MJO, and the Indian Ocean Dipole play an important role in contributing to the massive floods during the periods Dec 2006 to January 2007. The occurrence of the three heavy precipitation episodes was associated with three dominant factors namely, the strong northeast cold surge; the absence of the Borneo vortex; and the influence of eastward propagating Madden-Julian Oscillation (MJO) disturbances. These extreme precipitation episodes were basically part of the deep cumulus and heavy precipitation system in the Maritime Continent during the boreal winter. The interaction between these systems i.e. the synoptic-scale Borneo vortex, the northeast cold surge and the MJO, largely determines the variability of the organized convection, particularly over the western part of the region (Chang *et al*., 2005). Similar dominant factors in Johor flood could also be use to explain this 2014 worst flood in Kelantan according to Tangang (pers. comm.) and Shamshuddin *et al*., (2016).

Conclusion

This paper discussed the chronology of the flood event in terms of meteorology, hydrology and rainfall of the worst floods of Kelantan State in December 2014 and January 2015, which had caused severe damages to the infrastructures and death. This study showed that the local weather phenomena in the tropics are largely influenced by atmospheric conditions and they could be explained by dominant factors such as the MJO, cold surges and the existence of Borneo Vortex. Knowing these factors is one thing, but how do we use these factors to prepare for the coming flood which was expected to return with heavier rainfall and more frequent.

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