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THE IMPACT OF GLOBAL WARMING ON STORMS AND STORM PREPAREDNESS IN SOUTHEAST ASIA

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According to the latest report by the Intergovernmental Panel on Climate Change (IPCC), "[w]arming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures" (IPCC, 2007: 5) by about 0.8–1.0°C over the last 160 years. Based on a survey of literature on global warming and precipitation, there is agreement that the frequency of extreme precipitation events in Southeast Asia will increase with global warming. At the regional level, densely populated countries in Southeast Asia are vulnerable to these changes in precipitation events. This article provides a review of the potential changes to storm events in Southeast Asia, based on the understanding of existing scientific discourse. The article also presents two case studies of anomalous storm event in Southeast Asia, Typhoon Vamei and the extreme high rainfall event in December 2006 in Peninsular Malaysia, as indication of the potential impacts of global warming related changes to storm activities, highlighting the need for preparedness in adapting to the impact of global warming.

Keywords: global warming, storms, Southeast Asia, mitigation, moral hazard, safe development, storm preparedness

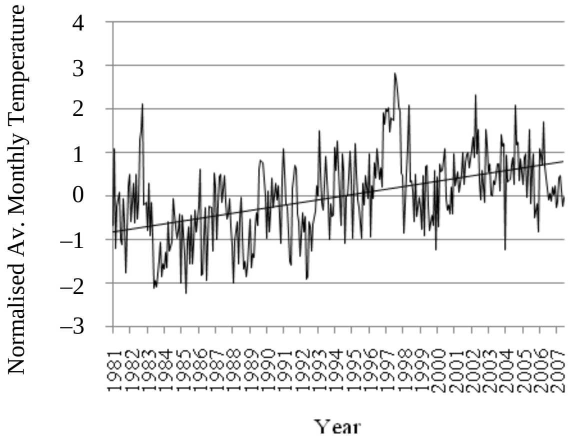
INTRODUCTION

While global surface temperatures have increased by close to 1 degree Centigrade over the last 160 years (IPCC, 2007) there is regional variation in this increase. Southeast Asia as a region, has an area of approximately 4,000,000 km² with more than 600 million people. It is pertinent to consider the region-specific impacts of global warming for Southeast Asia. One potential impact of global warming is the change to storm characteristics in the region. This raises several questions. How much warming has Southeast Asia experienced? To what extent are storm characteristics changing in Southeast Asia due to global warming, and what are the implications for people in this region?

To answer the first question of how much warming Southeast Asia has experienced, this paper examined the existing literature on global warming. A literature survey of various works from on storms in Asia was done to determine if storms are on the rise in Asia and a trend series analysis of data collected for the Johor Straits sub-region was conducted to provide some preliminary empirics on the issue. Two case studies of severe storms were used to illustrate the impacts of storms and a conceptual critique of storm preparedness with respect to the two cases presented to answer the question of how people in Southeast Asia are affected.

The IPCC (2007) reported an average of 1°C increase in recorded temperature over the last 100 years for Asia, which was derived from the results for 58 simulations from 14 climate models (IPCC, 2007: 11). Indeed, (Cruz et al., 2007) summarised the following warming trends for the region in the IPCC Assessment Report 4 (AR4). "Warming is least rapid, similar to the global mean warming, in Southeast Asia, stronger over South Asia and East Asia and greatest in the continental interior of Asia (Central, West and North Asia). In general, projected warming over all sub-regions of Asia is higher during northern hemispheric winter than during summer for all time periods. The most pronounced warming is projected at high latitudes in North Asia" (Cruz et al., 2007: 487).

Found mostly between the tropics of Cancer and Capricorn, countries in Southeast Asia experienced the least rapid warming on the average. However, even for this region where warming is the least rapid, Easterling et al. (1997) reported that minimum temperatures have increased some 2.16°C in the last century while maximum temperatures did not change significantly from 1950 to 1997 (Easterling et al., 1997: 366).



Note: Solid black line shows the linear trend for the entire period.

Figure 1: Normalised average monthly temperature recorded at Changi Meteorological Station, Singapore between 1981 to 2008 (Compiled from National Oceanic and Atmospheric Administration, n.d.)

A preliminary time series analysis of the data collected at the Changi Meteorological Station, Singapore has shown an approximate 1°C increase trend over the last 27 years. This corroborates the general warming trend proposed by Easterling et al. (1997) but shows higher temperature increase than IPCC (2007) for the Southeast Asian region.

Apparently, Southern Johor and Singapore have been experiencing more warm events even in the light of the moderate warming trends projected by IPCC (2007).

LITERATURE REVIEW ON GLOBAL WARMING AND PRECIPITATION CHANGES IN SOUTHEAST ASIA

Having established that the region is indeed warming, does empirical evidence exist to prove that storm characteristics are changing in Southeast Asia due to global warming? At the global level, increase in atmosphere and ocean temperatures will affect the hydrological cycle as the way water moves through the earth-atmosphere system changes. For instance, Brahic (2007) reported that the Asian Monsoons are strengthening. This is corroborated from paleoclimatic data from corals in the mid-Holocene, showing more intense East Asian summer and winter monsoons during a warmer mid-Holocene (Morimoto et al., 2007).

Based on the projected patterns of precipitation change by IPCC AR4, while the increase in average global temperatures generally increases the amount of water vapour in the atmosphere, it did not lead to increases in precipitation for the entire globe. Indeed, since the IPCC Third Assessment Report (TAR) in 2001, "there is an improving understanding of projected patterns of precipitation. Increases in the amount of precipitation [will] very likely [occur] in high-latitudes, while decreases are likely [to occur] in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100), continuing [the] observed patterns in recent trends" (IPCC, 2007: 16).

Droughts and floods will increase in intensity, duration and frequency in many areas. "There will be more rain at high latitudes, less rain in the dry subtropics, and uncertain but probably substantial changes in tropical areas" (Stern, 2007: 62). The main reason for this has been attributed to the widening of the Hadley circulation in the tropics. The IPCC AR4 proposed that a consistent weakening and poleward expansion of the Hadley circulation is diagnosed in the climate change simulations (Lu, Vecchi and Reichler, 2007). Consequently, differences in water availability between regions will become increasingly pronounced. In other words, storms and droughts will become more pronounced.

Kharin et al. (2007) and Trenberth et al. (2003) suggested that the occurrence of heavy precipitation events should increase by about 6 to 7 percent for every Kelvin increase in global average temperatures. In fact, Kharin et al. (2007) predicted a spread in extreme precipitation events simulated by models occurring in the tropics, especially over the tropical Pacific. For the Western Pacific, specifically over the East Java region in

Indonesia, rainfall data from 1955 to 2005 showed that there has been an increased ratio of rainfall in the wet to the dry season (Aldrian and Djamil, 2008, 435). In other words, this has lead to the increased threat of droughts during the dry season and extreme weather in the wet season during the recent decades.

The summer monsoon over East Asia and Southeast Asia (both the East Asian Summer monsoon and the Western North Pacific Summer monsoon) have shown increasing occurrence of variability, especially in terms of extreme dry and wet conditions over the past few decades (Chen, Yen and Weng, 2000; Zhou and Chan, 2005; Sun and Ding, 2008; Yim et al., 2008).

During the period 1979 to 2003, Lau and Wu (2007) reported that the probability distribution functions of tropical rainfall has significantly shifted such that extreme high (top 10%) and low (bottom 5%) precipitation events are occurring more often than before. On the contrary, moderate precipitation events have reduced during the same period (Lau and Wu, 2007: 979). In addition, the total accumulated precipitation for the Southeast Asian region has increased some 2000 to 4000 mm between the decades 1980s to 1990s (Lau and Wu 2007: 985). There is also spatial variation in the increase of high precipitation events. According to Lau and Wu (2007) who analysed data from the Global Precipitation Climatology Project (GPCP), the increase in amounts and frequency of high precipitation was experienced over the Inter-tropical Convergence Zone, the Indian Ocean and monsoon regions.

In a study of the Southeast Asian monsoon region, Bhaskaran and Mitchell (1998) found that the return periods of extreme precipitation events has been reduced due to greenhouse warming. In their modelling, greenhouse forcing results in a 10 fold increase in frequency of 1 in 100 year events (Bhaskaran and Mitchell, 1998: 1460). The increase in frequency was reduced to five times when aerosols were included in their model. A summary of the discussion so far is included in Table 1.

Table 1: Changes in Southeast Asian precipitation in a warming world

Works cited	Frequency of low precipitation events	Frequency of moderate precipitation events	Frequency of extreme high precipitation events	Intensity of extreme events	Period of study	Study area/ Region
Aldrain and Djamil (2008)	Increase	Decrease	Increase	Droughts and storms are more pronounced	1955–2005	Java, Indonesia
Bhaskaran and Mitchell (1998)	–	Increased	Decreased	–	1860–1990; modelled for 1990–2070	Southeast Asia
Brahic (2007)	–	–	–	Monsoons strengthened	6500 BP	Western Indonesia
Chen, Yen and Weng (2000)	Increase	–	Increase	Heavy rainfall events in Eastern China	1979–1993	East & Southeast Asia
Kharin et al. (2007)	–	–	Increase	–	2046–2065; 2081–2100	Tropical Pacific
Lau and Wu (2007)	Increase	Decrease	Increase	Total precipitation amount increased two folds from 1980s to 1990s	1979–2003	Tropics
Yim et al. (2008)	Increase	–	Increase	–	1979–2005	East Asia and Southeast Asia
Zhou and Chan (2005)	Increase	–	Increase	–	1979–2001	South China Sea
This study	Decrease	–	Increase	–	1978–2007	Southeast Asian Cities

METHODOLOGY TO EXAMINE CHANGES IN PRECIPITATION IN THE SOUTHEAST ASIAN REGION

In an analysis of the rainfall records from 10 stations in Southeast Asian countries from 1978 to 2008, the author has found an increase in extreme wet events in Southeast Asia, which is in general agreement with Lau and Wu (2007). In order to analyse the extreme events in precipitation, the monthly precipitation between January 1978 to December 2007 were normalised for the 30 year average monthly precipitation and its standard deviation. The values of $Z_{m,y}$ indicate the extent of deviation from the distribution of monthly rainfall. As the data is normalised with mean 0 and standard deviation 1, higher $Z_{m,y}$ values indicate more extreme precipitation. Conversely, $Z_{m,y}$ values lower than –1 indicate extreme dry months.

$$Z_{m,y} = \frac{p_{m,y} - \bar{p}_m}{S_m}$$

where,

$Z_{m,y}$	=	Normalised monthly precipitation for month *m* in year *y*
$p_{m,y}$	=	Precipitation for month *m* in year *y*
$\bar{p}_m$	=	Mean monthly precipitation for month *m* over a 30-year period
S_m	=	Standard deviation of monthly precipitation for month *m* over a 30-year period

In order to examine the frequency of extreme wet months, the proportion of $Z_{m,y}$ to its absolute value was used. For the period 2003 to 2007, $Z_{m,y} / |Z_{m,y}|$ or proportion of extreme wet months were generally higher than the preceding periods.

With the exception of Jakarta, all the stations recorded a higher proportion of wet months in 2003 to 2007 compared to the period from 1998 to 2002. The values were generally in the range of 0.8 for the 2003–2007 period, indicating that more than 80% of the events of standard deviation greater than 1 were wet events.

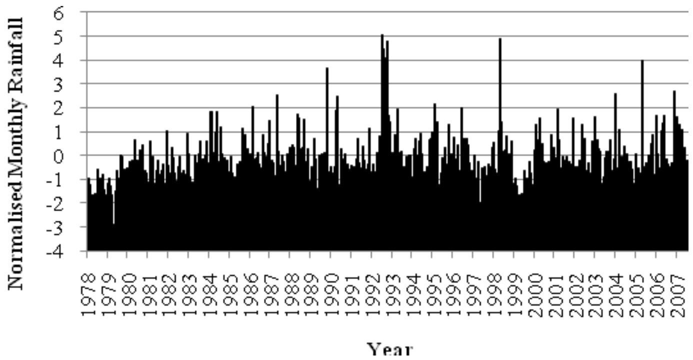
Table 2: Number of months in a year where $Z_{m,y} > 1$, for selected ASEAN cities

Year	Bangkok	Hanoi	Jakarta	Kuala Lumpur	Manila	Singapore	Vientiane
1978–1982	6	0	8	8	0	1	4
1983–1987	3	0	2	4	3	8	3
1988–1992	1	2	0	12	9	13	1
1993–1997	5	14	2	9	16	5	0
1998–2002	4	7	1	3	11	8	2
2003–2007	5	11	5	8	12	12	28

Table 3: $\frac{Z_{m,y}}{|Z_{m,y}|}$ values for selected ASEAN cities

Year	Bangkok	Hanoi	Jakarta	Kuala Lumpur	Manila	Singapore	Vientiane
1978–1982	0.75	0.00	1.00	0.35	0.00	0.06	0.50
1983–1987	0.50	0.00	1.00	0.31	0.17	0.67	0.50
1988–1992	0.25	0.18	0.00	0.80	0.50	0.72	0.20
1993–1997	0.63	1.00	1.00	0.69	0.84	0.63	0.00
1998–2002	0.33	0.78	1.00	0.21	0.55	0.57	0.29
2003–2007	0.83	1.00	1.00	0.62	0.86	0.80	0.97

In fact, Singapore has experienced more extreme wet events than extreme low precipitation events in the last 10 years. Figure 2 shows the normalised monthly rainfall for Singapore in the last 30 years. Notice that there were more months from 2 to 5 standard deviations higher than the mean monthly rainfall after 1992. In fact the number of months more than 1 standard deviation lower than the mean monthly rainfall has become negligible, after 2005. While preliminary empirics show that the precipitation characteristics have changed, more stations for Southeast Asia need to be analysed before a more conclusive statement can be made about the incidences of more wet months due to global warming.



Note: The area within 1 standard deviation from the mean monthly rainfall (values of –1 to 1).

Figure 2: Normalised average monthly rainfall recorded at Changi Meteorological Station, Singapore between 1981 to 2008 (Compiled from National Oceanic and Atmospheric Administration, n.d.)

IMPACT OF CHANGES IN PRECIPITATION ON SOUTHEAST ASIA

According to Stern, 1–5 billion people, mostly in South and East Asia, may receive more water. However, much of the extra water will come during the wet season and will only be useful for alleviating shortages in the dry season if storage could be created (at a cost). The additional [volume of] water could also give rise to more serious flooding during the wet season (Stern, 2007: 63) especially in cases where the local drainage basins may not have sufficient storage to hold the extra water for use during the dry season, and there may be more frequent floods (Milly et al., 2002). Stern (2007) suggested that any changes in rainfall patterns across Monsoon Asia would "severely affect" millions of lives. While the summer monsoon brings the much needed rain for agriculture and other economic activities (close to 90% of total annual rainfall), a sharp increase or decrease could spell trouble (Stern, 2007: 82). The problem with changing precipitation patterns is not in the change in the average amounts received but with the duration, frequency and intensity of each precipitation event; in particular, storms.

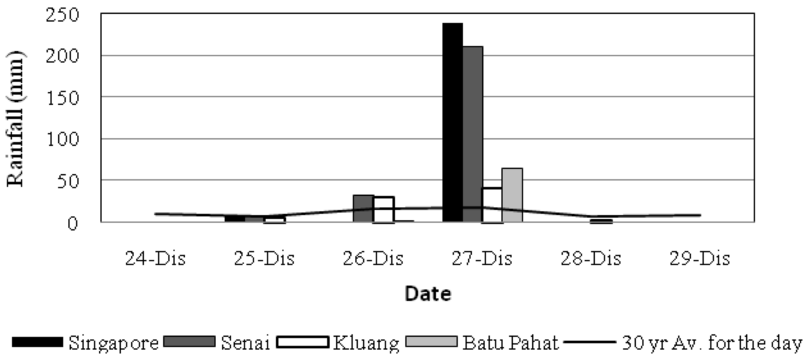
The focus of this article is on potential disruption to human activities due to storms. According to Cruz and others, intense tropical cyclone activity is "likely" to increase with projected impacts such as damage to crops, damage to coral reefs, power outages, disruption of public water supply, increased risk of water borne diseases, floods, high winds and loss of property (Cruz et al., 2007: 18). For Southeast Asia, tropical cyclones have increased in frequency and intensity in the Pacific basin (Fan and Li, 2005). On the other hand, a literature review by Pielke et al. (2005) showed that while there were considerably fewer large tropical cyclones in the 1970s, 1980s and 1990s, in comparison with the 2000s, the period during the 1940s and 1950s experienced quite a large number of tropical cyclones as well, indicating no obvious trend in hurricane intensity and frequency. Indeed, researchers like Vecchi et al. (2006) reported that the Walker circulation over the Pacific has weakened and that hurricane activity was lower in the twenty first century. In fact, Landsea suggested that "it is difficult to separate out any anthropogenic signal from the substantial natural multidecadal oscillations with a relatively short record of tropical-cyclone activity" (Landsea, 2006: E12). Of the eleven pieces of work cited in Table 1, ten studies affirm the view that the frequency of extreme precipitation events will increase in Southeast Asia in a global warming world. While we cannot be sure if there will be more tropical cyclones due to human induced global warming in the next few decades, there are already cases of unprecedented extreme precipitation events in Southeast Asia. The author has selected two cases of high precipitation events that hit Southern Johor and Singapore in 2001 and 2006, respectively, as discussion on the implications of global changes extreme storms events in Southeast Asia.

The Lessons from Typhoon Vamei and The 2006 Heavy Precipitation Event in South Johor

The term "typhoon", is a region specific name which refers to a tropical cyclone found in the Pacific Ocean basin. Theoretically, tropical cyclones do not form near the equator as there is an absence of *Coriolis* force, which is partly responsible for its formation. On 27 December 2001, Typhoon Vamei made landfall in Singapore, just barely one and a half degree north of the equator (Dybas, 2003; Padgett, 2001). A main reason cited for its abnormal formation so near to the equator was the persistence of a meridional pressure gradient across the equator created by a storm surge of extended duration over the South China Sea.

From the months of November to January, Singapore and Southern Johor experience the Northeast monsoon winds which bring with it heavy rainfall. The events leading to the formation of Typhoon Vamei started on 19 December 2001, when a cold surge developed rapidly over the South China Sea. At that same time, the Borneo vortex was located near 3°N on the northwest coast, moving southwest towards the equator. By 21 December, the centre of the vortex had moved off the coast of Borneo over the sea. At this point, the open sea region in the southern end of the South China Sea narrows to about 500 km with Borneo to the east and the Malay Peninsula and Sumatra to the west (Dybas, 2003). The vortex hovered over this location for several days (Chang, Ching and Kuo, 2003). During the few days leading up to 26 December 2001, the Borneo vortex centre remained in the narrow equatorial sea region (Padgett, 2001) while the strong northeasterly surge persisted. The presence of the vortex acted as a barrier which deflected the northeast surge slightly to the northwest of the vortex. Together with the existing northwesterly wind blowing across the equator, these two flows "wrapped around the vortex and the net result was a spinning up of a rapid counter-clockwise circulation that is similar to the spinning of a top played by a child, and this led to the development of Typhoon Vamei" (Chang, Ching and Kuo, 2003). The observations and proposed explanation of the formation was verified by (Koh and Lim, 2005) in a simulation using a Coupled Ocean/Atmosphere Mesoscale Prediction System.

Was this a meteorological extreme event triggered by global warming? The movement of the Borneo vortex onto the narrow equatorial sea and the intensity of the northeasterly surge are the two key ingredients to the genesis of Typhoon Vamei. Intensified monsoon in a global warming scenario can account for the persistent and strong northeasterly surge while higher sea surface temperature can explain the contribution of latent heat that sustained the persistence of the Borneo vortex over the sea. However, the hypothesis above needs to be tested further before we can conclude that the theoretical proposition is true. While one of the direct impact of Typhoon Vamei was on the understanding of how tropical cyclones form in equatorial regions, a greater and more tangible impact was the heavy rainfall it brought to Singapore and South Johor.



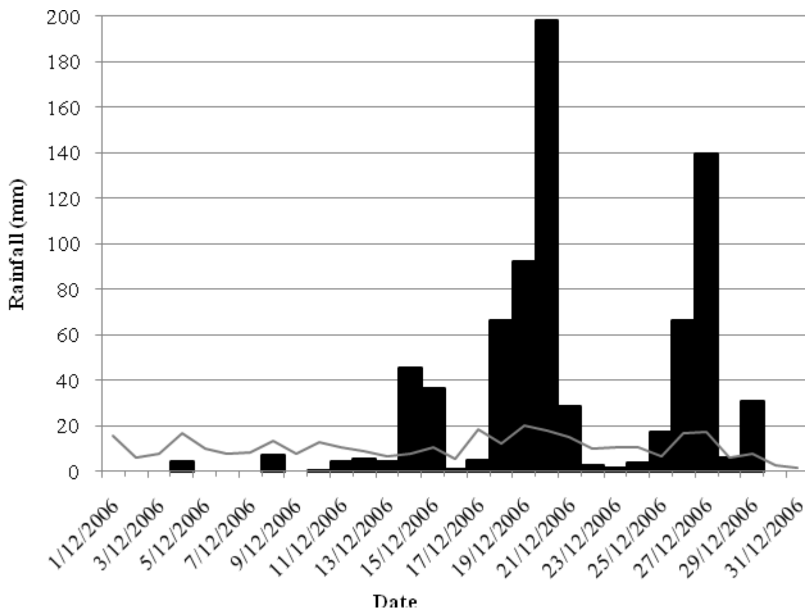
Source: Adapted from National Oceanic and Atmospheric Administration (n.d.) and Malaysian Meteorological Department (n.d.)

Figure 2: Rainfall for South Johor and Singapore during Typhoon Vamei in 2001

Within a single day, the rainfall received at Singapore was 240 mm or 10% of the entire 2001 precipitation amount. While it was only a category one storm on the Saffir-Simpson scale, "it still wreaked havoc" as two U.S. Navy ships were damaged by the typhoon, and storm surges from the winds flooded areas in southern Peninsular Malaysia (Dybas, 2003). Ground wind speeds of 9.4 ms^{-1} were recorded at Changi station, Singapore, while the storm has sustained speed of 140kmh^{-1} or close to 40 ms^{-1}. This was based on an observation from a U.S. naval ship located within the eyewall of Typhoon Vamei (Padgett, 2001). In addition, heavy rainfall was received in the states of Johor, Kelantan, Terengganu and Pahang (Malaysian Meteorological Department, n.d.). In Johor and Singapore, the stations of Senai and Changi Airport (Singapore) recorded rainfall exceeding 210 mm and 240 mm, respectively on 27 December 2001 (Malaysian Meteorological Department, n.d.); National Oceanic and Atmospheric Administration, n.d.). This amount exceeded the average climatic rainfall of 225.5 mm for the month of December in the region. In other words, all the rain that is expected for the whole month was received in a single day when Vamei made landfall. This peak in rainfall is shown in Figure 3. This resulted in flooding and mudslides in the Johor and Pahang States where more than 17,000 people were evacuated and 5 lives were lost (Johnson and Chang, 2007). The heavy rain caused a landslide at Gunung Pulai, which destroyed four houses and killed five people. Together with rainfall from the previous storms, the precipitation of Vamei resulted in river flooding that led to an estimated RM13.7 million damage to crops, transportation, education, and health-care facilities (Bernama, 2002).

The main culprit of the losses was not the typhoon but rather the lack of preparedness for such an unusual event. In this case, the storm was a theoretical impossibility until it happened. While the northeast monsoon season brought high volumes of rainfall to the affected areas annually, the freak storm added abnormal amounts of water into the local hydrological system, which made it a surprise. One can argue that preparing for a surprise might be paradoxical, in that if it was foreseeable, then it will not be a surprise. One might have thought that the event in 2001 would send alarm bells, but in December 2006, floods once again hit Johor and this time the hazardous event displaced no less than 100,000 people (Lee, 2007).

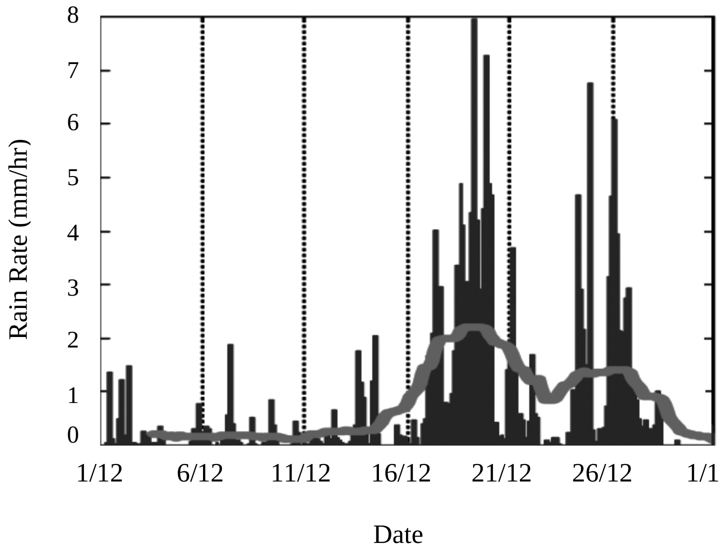
There were three episodes of high rainfall event in December 2006 (see Figure 3) and January 2007 over South Johor and Singapore. These extreme precipitation events were mainly associated with strong northeasterly winds over the South China Sea (Tangang et al., 2008). These events occurred between 17 to 20 and 24 to 28 December 2006 and from 11 to 14 January 2007. The three events were preceded by an event on 14 December, which recorded slightly more than 40 mm of rainfall in one 24-hour period, but the subsequent three events dwarfed this event in terms of the amount of precipitation received and the range of impact caused. The highest recorded rainfall was on 20 December with rainfall 10 times the average daily rainfall for a 30-year period.



Note: The histogram refers to actual recorded rainfall and the solid grey line refers to the 30 year average daily rainfall

Figure 3: Rainfall for December 2006 over Singapore (Data compiled from National Oceanic and Atmospheric Administration, n.d.)

Chatterjea (2009), reports that the 24-hour (8 PM to 8 PM) rainfall on 19 December 2006 was 366 mm in Singapore. This exceeded the 30-year average (1978–2007) monthly rainfall of 299 mm for December by almost 50% in Singapore. In Johor, the station at Air Panas recorded about 782 mm of rainfall from 18–21 December, some 4 times the December average (Tangang et al., 2008: 1). Chatterjea (2009) further suggests that the impact of this event, compounded by high tide and strong winds, included disruption to traffic, flooding, damaged buildings, uprooted trees, over-spilled reservoirs, collapsed quarry walls, disrupted train services, etc. This event caused as many as 35 fresh slope failures along the roads in her study area, which encompassed the major roads in the Western half of the main island of Singapore (Chatterjea, 2009: 8). The next episode was in the last week of December with single day rainfall exceeding 7 times the average daily rainfall at 140 mm on 26 December. Compounded by the 19–20 December episode, this caused further disruption to urban life (Chatterjea, 2009: 9).



Note: Area-averaged (1°N–2.5°N, 102.5°E–105°E) precipitation rate (mm/hr) for December 2006. The thick grey line indicates the five-day running means.

Figure 4: Rainfall rate per hour over South Johor and Singapore (Adapted from Tangang et al., 2008: 2)

Chatterjea (2009) reported that Singapore experienced a record 765.9 mm of rain from 1 to 28 December, the highest ever recorded for December since 1869. Tangang et al. (2008) reported more than 200,000 people evacuated and 16 deaths, with total economic loss estimated at USD500 million. Due to unusually high rainfall, the first wave of floods hit Johor in mid-December. While flooding is common in Peninsular Malaysia during the Northeast monsoon season, floods are usually found in the northeastern parts of the peninsula and not in the south. It also coincided with the 2006/2007 El Nino event during which Peninsular Malaysia experiences higher than normal rainfall (Tangang et al., 2008). Officials cited it as a one in a hundred year flood and as reason for not being able to cope with the abnormally high levels of river discharge. In just three weeks, another flood of similar intensity and magnitude hit Johor but no one seems to be making statements about another one hundred year flood "returning in a space of three weeks" (Lee, 2007). Further to the west, North Sumatra and Aceh experienced abnormal rainfall which also caused flooding starting 22 December 2006 (Mail & Guardian Online, 2006). This led to 200,000 people being displaced by the floods and landslides in the Indonesian provinces of Aceh and North Sumatra and at least 118 people dead with 155 people missing as of 29 December 2006 (International Herald Tribune, 2006).

The lesson from Typhoon Vamei in which all the rain that was expected for the whole month was received within a single day, was not well learnt by the time the floods of December 2006 occurred. While global warming may not be a direct cause of the increase frequency of extreme precipitation events, the fact that a theoretical impossibility was debunked did not send sufficient alarm bells ringing to local and national governments. As the literature survey in this article has shown, there is general consensus on the increase in frequency of extreme high precipitation events in Southeast Asia even though the agreement on the intensity of such events is lacking. Given the potential disruption to the biophysical, social and economic aspects of human life, it would be intuitive to take measures, in advance, to ensure effective response to the impact of high precipitation events in Southeast Asia. Logically, these measures should include timely and effective early warnings, temporary evacuation of people and property from threatened locations.

RESPONDING TO INCREASED FREQUENCY OF HIGH PRECIPITATION EVENTS

One can argue that Vamei is probably a one in four hundred year storm (Chang, Ching and Kuo, 2003) and the storm in December 2006 was a one in a hundred year storm, and that the chances that such storms will strike again are low. There are numerous examples of communities badly affected by extreme precipitation events, even when these storms occur on a yearly basis. Much can be learned from such lessons. Hurricane Katrina is one such example. Drawing from the lessons of Hurricane Katrina, it was ranked one of the deadliest hurricane as it killed thousands of people, displaced many more and resulted in a "massive relief and evacuation effort" (Travis, 2005). The sad reality is that while impacts of storms like Katrina have been simulated prior to the event, almost 1 in 4 persons ignored evacuation orders and were unable to flee the path of destruction (Travis, 2005: 1656). What went awry? Perhaps the community was not sufficiently prepared for the onslaught of this particular storm, despite the efforts in information dissemination and evacuation plans.

To understand the problem, the author argues for the following conceptual approach to storm preparedness based primarily on the Tyndall Center for Climate Change Research's paper on "The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation" (Brooks, Adger and Kelly, 2005). The approach proposes that preparedness for storms events should be based on assessment of risk, building adaptive capacity and adaptation. While "risk is viewed in terms of outcome, and is a function of physically defined climate hazards and socially constructed vulnerability" (Brooks, Adger and Kelly, 2005), adaptive capacity refers to the "ability or capacity of a system to modify or change its characteristics or behaviour so as to cope better with existing or anticipated external stresses" (Brooks, 2003) and adaptation refers to the actual change or modification of the system.

In determining the risks involved in preparing for the increased storm activities due to global warming, the concepts of hazard and social vulnerability must be considered. The International Strategy for Disaster Reduction disambiguates risk factors between "hazard" (determines geographical location, intensity and statistical probability) and "vulnerability" (determines susceptibilities and capacities) (United Nations, 2002: 66). In other words, the biophysical risks and the socialcultural conditions of the people in the geographical region determine the risk to which they are subjected to by these storms.

In the Southern Johor cases above, this paper has provided empirical evidence to corroborate the IPCC (2007) reports of increase in frequency and intensity of storms. In fact, the Malaysian Meteorological Department has already documented extreme weather events in various parts of Malaysia the year before, including Kedah (19 December 2005), Kelantan (17–20 December 2005), Perlis (18 December 2005) and Terengganu (13 February 2006). This was in addition to the information they have about the 2001 Vamei event (MMD, 2007). In fact the MMD acknowledges that since the 1980s, there has been "increasing number of days of extreme rainfall event (exceeding 90th percentile of total rainfall) for several stations over the Peninsular Malaysia" (MMD, 2007).

In terms of adaptive capacity and adaptation, the MMD has in place weather prediction systems. However, up till September 2007, some 9 months after the 2006/2007 storm events, the Malaysian Ministry of Natural Resources and Environment (MNRE) did not have a national level risk assessment. It was only at the UNDP-Ministry of Natural Resource and Environment (MNRE) Conference on Climate Change Preparedness: Towards Policy Changes on 11 September 2007 that the Minister for MNRE called for ministries and agencies to coordinate in their efforts to produce "risk maps for vulnerable areas" (Khalid, 2007). It is heartening to note that a national level effort was undertaken to increase the adaptive capacity of the country through improved risk assessment, in order to craft effective adaptation strategies to combat the impacts of increased storms due to global warming.

However, preparedness in itself is not a simple three-step process of identifying risks and vulnerabilities, building adaptive capacity and implementing effective adaptation strategies. In adopting adaptation strategies, there is a risk of complacency resulting in preparedness paradox. While areas such as Southern Johor are beginning to build adaptive capacity and hence may have suffered the consequences of low preparedness, despite the apparent preparedness for the storm in terms of adaptive capacity, hurricane Katrina still topped the charts with over USD200 billion worth of damage. According to Burby (2006) this was due to two storm preparedness paradoxes, at the federal and local government levels, respectively. The federal level paradox is the safe development paradox, in that by making hazardous areas safer, it has increased the potential for property damages and economic loss (Burby, 2006). The concept of safe development is that the federal government considers that if steps are taken to make it safe for human occupancy then land exposed to natural hazards can be used profitably. These steps usually include measures to mitigate the likelihood of damage by offering federal financial support for flood and hurricane protection works, beach nourishment, and federal requirements through the "National Flood Insurance Program for safe building practices such as elevation of construction in flood hazard areas" (Burby, 2006: 173). "Supposedly safe development in New Orleans (and elsewhere) has proven to be unsafe for several reasons including limitations of flood and hurricane protection works and limitations of the National Flood Insurance Program’s efforts to control losses through floodplain mapping and regulation of construction practices" (Burby, 2006: 176). However, it is the illusion of such "safety" that contributed to the unprecedented life and economic losses.

On the other hand, the local government paradox is that while their citizens bear the burden of deaths, displacement and economic loss in disasters, policies to limit vulnerability are given inadequate attention (Burby, 2006). Only a relatively small proportion of the $500 billion in losses from natural disasters in the United States between 1975 and 1994 (Burby, 2006: 178), was covered by federal disaster relief. In fact, most losses were not insured and were borne by victims. "Given that the incidence of disaster losses is primarily borne by local residents and businesses, one would expect that avoidance of losses would be a high priority for local officials. The paradox is that this is typically not the case" (Burby, 2006: 178). Apparently the political apathy stems in part from the lack of citizen concern about hazards, resulting in a "policies without publics" dilemma that smothers local policy initiatives. The federal level safe development concept results in a kind of "moral hazard" in which "the availability of insurance protection lowers an insured party's incentive to avoid risk" (Burby, 2006: 179). This discourages both the local governments and individuals from taking actions to decrease the risk of loss.

In summary the concepts discussed above about storm preparedness can be illustrated in Figure 6.

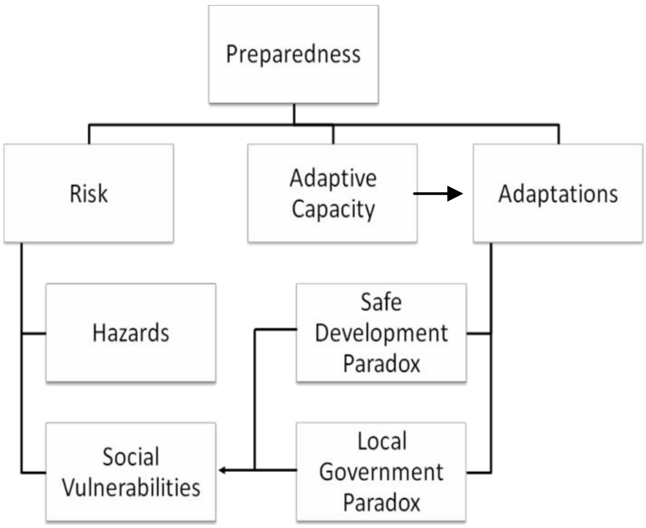


Figure 5: Proposed conceptual framework of storm preparedness

While risk assessment is an important component of storm preparedness, with building adaptive capacity, the two paradoxes may present a negative feedback loop to the social vulnerabilities of the community in question. In implementing storm preparedness, it is important to be cognizant of these two paradoxes.

RECOMMENDATIONS AND CONCLUSION

Much can be done in terms of preparedness for storms arising from changing weather patterns. Like the Asian Tsunami of 2006, Typhoon Vamei and the December 2006 South Johor storms came as surprise. The surprise was largely created by a lack of preparedness. This lack of preparedness for the 2001 and 2006 incidents is possibly admissible on the grounds that in 2001, the IPCC TAR could not commit itself to predicting impacts of global warming as certainly as the AR4. By 2007, the AR4 used terms like "virtually certain" which replaced the less confident terms like "likely". There is little excuse now for nations not to get prepared for Vamei-like storms or storms of greater magnitude. The literature survey in this article has shown general agreement that high precipitation events will occur more frequently.

For a start, governments need to develop storm preparedness strategies. At the moment, countries like the United States have well placed Severe Local Storm Warning (SLSW) and Preparedness Programs developed by the National Weather Service (NWS) since the 1970s and Hurricane Preparedness Programs (HPP) by Federal Emergency Management Agency (FEMA). The author proposes a detailed examination of these two programs to derive a relevant and effective preparedness program for extreme precipitation events in Southeast Asia. The SLSW focus on the three steps formula of severe weather monitoring, warning and dissemination (Mogil and Groper, 1977) while FEMA HPPs focus on facility/property protection, personal/family disaster plan, evacuation and insurance (FEMA, 2004). While the UNDP-MNRE conference laid the foundations for building adaptive capacity in Malaysia, the lessons learnt from hurricane Katrina will be important for consideration.

While mitigation refers to actions taken to reduce or eliminate the negative impacts largely through tackling the root cause of climate change, Mitchell and Tanner (2006) defined adaptation as an understanding of how individuals, groups and natural systems can prepare for and respond to changes in climate or their environment. Storm preparedness programs should take into consideration the concept of adaptation over and above the need for mitigation. The SLSW formula of monitoring-warning-dissemination is at the core of adaptation strategies. This is not different from the Brooks (2003) concepts of risk-adaptive capacity-adaptation framework. They provide information for institutions and individuals to react and respond to. While international institutions are able to provide a network of information for monitoring and warning, information dissemination is usually poor. This is evidently the case in Cyclone Nargis.

Cyclone Nargis made landfall in Myanmar on 2 May 2008 (Indian Meteorological Department, 2008) and left in its path more than 22,000 dead and up to 40,000 missing. The tragedy is unexpected as it is an "unprecedented event in Myanmar's history" (British Broadcasting Corporation, 2008) which brought winds reaching 190 kmh^{-1} and waves of up to 3.5 metres. The storm was already looming over the Bay of Bengal since 26 April 2008. Cyclone Nargis was officially declared a category one cyclone on 28 April (Joint Typhoon Warning Center, 2008) and farmers in Bangladesh were warned to hasten their harvesting (Herman, 2008) when Nargis was still some 1,000 kilometers from the coast. While the fresh memories of Cyclone Sidr generated some degree of preparedness in Bangladesh, the country was spared as the cyclone made an eastward turn on 1 May 2008.

According to WMO, Director for Weather and Disaster Risk Reduction Activities Department, Dieter Schiessl, a cyclone hits Myanmar once every 40 years, and being an infrequent disaster, "governments have no incentives to prepare themselves thoroughly" Although the information about the cyclone was "amply available and timely provided, and distributed in the ways and means for reaching the general public", the WMO was unsure "what really reached individuals in the country". Information dissemination is a crucial step to consider in crafting storm prepadreness programs. In addition there is a need to consider the FEMA HPPs focus on facility/property protection, personal/family disaster plan, evacuation and insurance in areas lying in the tacks of tropical cyclones. Indeed, Schiessl suggests that in Myanmar’s "rural areas with undeveloped infrastructure", there are "significant challenges" to implementing any evacuation (Channel News Asia, 2008).

Extra care must be taken to address the two storm preparedness paradoxes discussed above. Indeed, while getting prepared for future storms, the local as well as national level governments must consider the safe development and local government paradoxes. While getting ready for the next 400 year storm entails concepts from safe development practices and hazard insurance cover, there is always the danger of complacency and moral hazard which contributed to the problems which are faced by victims, for example in the case of hurricane Katrina.

Some meteorologists (Kunston and Tuleya, 2004; Vecchi et al., 2006; Landsea, 2006) argue that a link between global warming and storm frequencies and intensities may not exist. However, this article has shown unequivocal agreement that there is increased frequency in high precipitation events over Southeast Asia. Extreme high precipitation events like Vamei and even intense hurricanes like Katrina have caught humans off-guard. The lesson to be learnt is one of maintaining preparedness. When we examine natural hazards like storms, we often focus on the causes and the consequences. Mitigation and adaptation are often viewed as measures to ameliorate the impacts of these hazards. Effective monitoring, warning and information dissemination, together with property protection and insurance, family disaster plans, and evacuation drills make up hazard preparedness. The issue of preparedness is crucial in a global warming world where changes in the frequency of storm events are predicted to happen for regions like Southeast Asia.

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