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Preparedness and storm hazards in a global warming world: Lessons from Southeast Asia.

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Abstract
The 2007 Intergovernmental Panel on Climate Change (IPCC) Assessment Report 4 found an average increase in global surface temperature of 0.74°C between 1906 and 2005. There is general agreement in the literature that the frequency of extreme precipitation events in Southeast Asia will increase with global warming. In particular, the potential impact of associated storm hazards will render the densely populated countries in Southeast Asia vulnerable to such changes in precipitation events. One main adaptation strategy given such impending changes is preparedness. Using existing literature and historical meteorological data, this paper establishes that Southeast Asia is indeed experiencing storms of higher intensities and more frequently. Two case of extreme storm event in Southeast Asia, the extreme high rainfall event in December 2006 in Southern Johor and Typhoon Vamei, are presented to consider the implications of the increased storm activities due to global warming. These two examples also discuss the need for preparedness in adapting to the impact of global warming.

Keywords
Global Warming, Storms, Southeast Asia, Storm Preparedness

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Introduction: Two cases of extreme precipitation events in Southeast Asia.

In a global warming world, it has been suggested that storms will become more intense and frequent. As such, this paper argues a need for better storm preparedness. Two cases are first presented here to show how storms can affect human lives and activities.

Typhoons, or tropical cyclones as they are known in the Pacific basin, normally do not form near the equator as there is an absence of *Coriolis* force to "turn" the storm system. Typhoon Vamei made landfall in Singapore on 27 December 2001, less than one and a half degree north of the equator (Dybas 2003; Padgett 2001). This abnormal formation so near to the equator was the interaction between a north-south pressure gradient across the equator created by a storm surge over the South China Sea that persisted for days as well as the topographical conditions of the region over which it formed (Chang, Ching and Kuo 2003). This theory was verified in a simulation using a Coupled Ocean/Atmosphere Mesoscale Prediction System (Koh and Lim 2005). As an extremely rare storm event, the question as to whether global warming has any part to play arises. According to (Chang, Ching and Kuo 2003), 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 formation of Typhoon Vamei.

Higher than normal sea surface temperatures in a global warming world can explain the contribution of latent heat that sustained the persistence of the Borneo vortex over the sea, while intensified monsoons due to warming can explain the persistent and strong northeasterly surge. While this proposed hypothesis in the literature needs to be tested further, one of the direct impact of Typhoon Vamei was the anomalously heavy precipitation it brought to South Johor and Singapore.

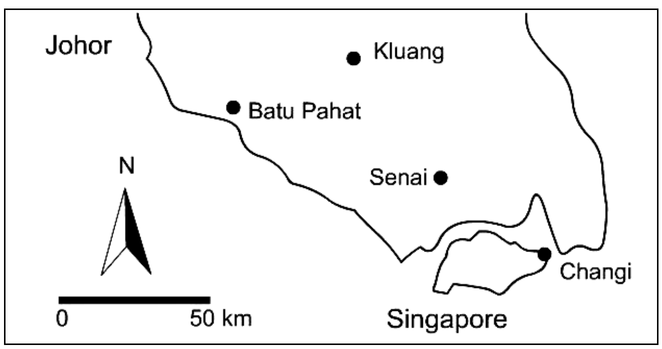
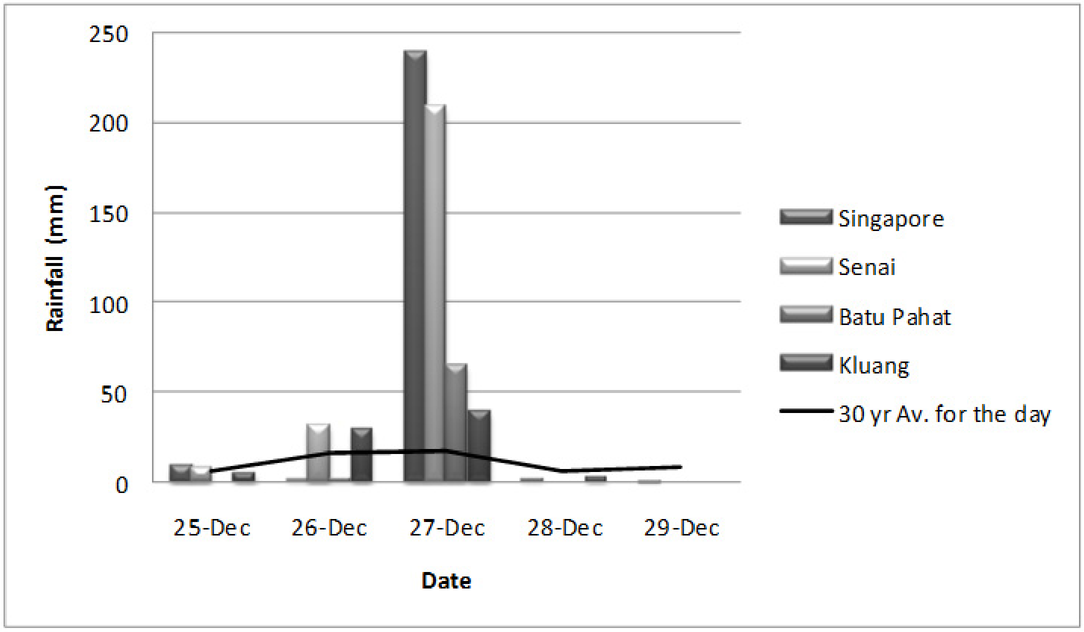


Figure 1: Location of Meteorological Stations in Southern Johor and Singapore cited in this study.

Based on observation from a U. S. naval ship located within the eye-wall of Typhoon Vamei (Padgett 2001), the typhoon has a sustained speed of close to 40m/s with surface wind speeds of 9.4 m/s were recorded at Changi station, Singapore. Further, storm surges from the winds flooded areas in southern Peninsular Malaysia (Dybas 2003).

The precipitation received at Singapore was 240 mm or 10% of the entire 2001 precipitation amount in a 24 hour period. Even though it was only a category one typhoon, "it still wreaked havoc" as two U.S. Navy ships were damaged by the cyclone In addition, heavy rainfall was received in the states of Johor, Kelantan, Terengganu and Pahang (Malaysian Meteorological Department n.d.). Precipitation exceeding 210 mm and 240 mm were recorded at the stations of Senai (Johor) and Changi Airport (Singapore), respectively on 27 December 2001 (Malaysian Meteorological Department n.d.) and (National Oceanic and Atmospheric Administration n.d.). All the rain that is expected for the whole month was received in a single day when Vamei made landfall. The rainfall received exceeded the average climatic rainfall of 225.5 mm for the month of December in the region, shown in Figure 2. Consequently, flooding and mudslides in the Johor and Pahang States resulted in more than 17,000 people being evacuated and 5 lives (at Gunung Pulai) were lost (Johnson and Chang 2007). Together with antecedent precipitation from previous storms, Vamei resulted in flooding that cost approximately, 13.7 million Malaysian

Ringgit (Dr Mahathir Told 2002) in damage to crops, transportation, education, and health-care facilities to Southern Johor.

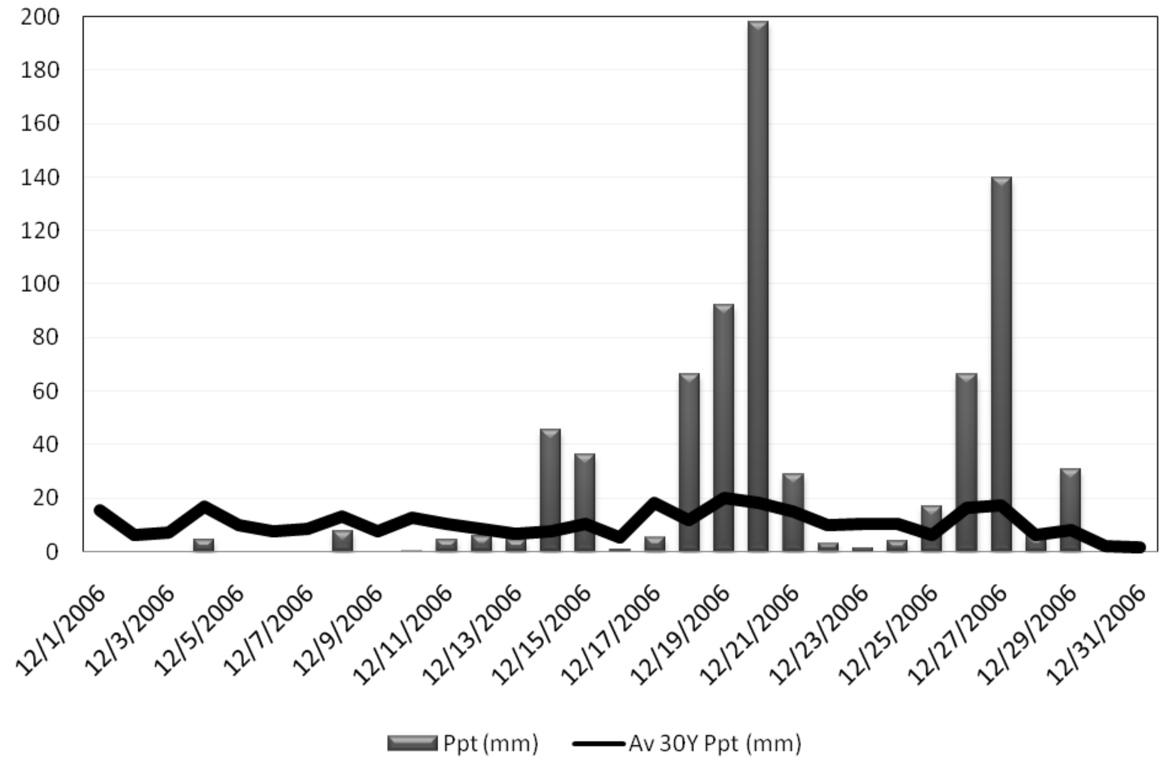


Source: Compiled from (National Oceanic and Atmospheric Administration n.d.) and (Malaysian Meteorological Department n.d.)

Figure 2: Precipitation for South Johor and Singapore from 25 Dec to 29 Dec 2001.

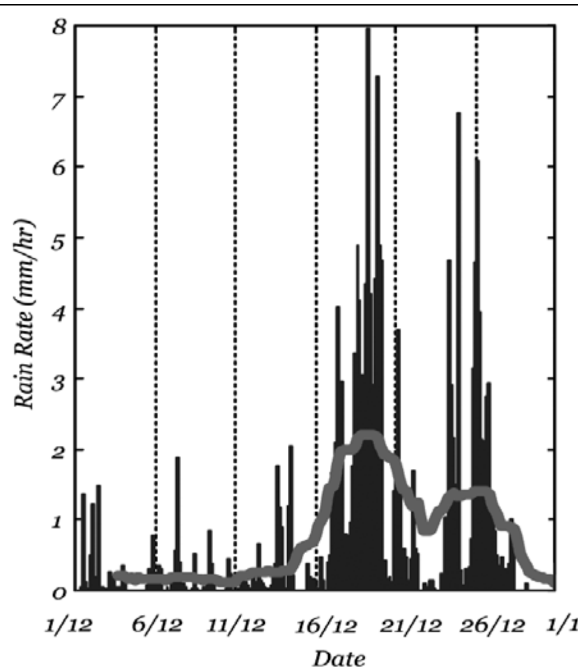
A main cause for the losses was not the direct impact of the tropical cyclone but rather the lack of preparedness for such an anomalous event. Normally, the northeast monsoon season would bring high volumes of rainfall to the affected areas annually, this unusual and unexpected storm added anomalous amounts of water overloading the local hydrological system. It is paradoxical to prepare for something unexpected, in that if it was prepare-able and foreseeable, then it will not be unexpected. With the event in 2001, one would expect the local and national governments to get prepared, but in December 2006, Johor once again experienced a hazardous flood event that displaced more than 100,000 people (Lee 2007).

Between December 2006 and January 2007, there were three of high rainfall events over South Johor and Singapore (see Figure 3). These extreme precipitation events were mainly associated with winds of northeast monsoon season brining in moisture from the South China Sea (Tangang et al. 2008). 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 40mm of precipitation over a 24 hour period. However, the subsequent three events dwarfed this event in terms of the range of impact caused and the amount of precipitation received. Air Panas (in Johor) recorded about 782 mm of precipitation from 18-21 December, 4 times the December average (Tangang 2008, 1). The maximum precipitation recorded on 20 December was 10 times the average daily rainfall for a 30 year period. The 24-hour (0800 to 2000 hrs) precipitation on 19 December 2006 was 366 mm in Singapore (Chattereja, 2008). This exceeded the 30-year average (1978 – 2007) monthly precipitation of 299 mm for December by close to 50% in Singapore. Chatterjea (2008) further suggested that the impact of this event, compounded by high tide and strong winds, included flooding, disruption to traffic, uprooted trees, over-spilled reservoirs, collapsed quarry walls, disrupted train services, damaged buildings, etc. The next storm episode was in the last week of December with a single day precipitation exceeding 7 times the average daily precipitation at 140 mm on 26 December. Compounded by the 19-20 December episode, this caused further disruption to urban life (Chatterjea, 2008, 9).



Data compiled from (National Oceanic and Atmospheric Administration n.d.)

Figure 3: Precipitation for December 2006 over Changi Airport Station, Singapore.



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.

(Adapted from Tangang et al. 2008, 2)

Figure 4: Precipitation rate per hour over South Johor and Singapore

A record 765.9 mm of rain from 1 to 28 December for Singapore, the highest ever recorded for December since 1869 was reported (Chatterjea, 2008). More than 200,000 people were evacuated and 16 people died, with a total economic loss estimated at USD 500 million (Tangang, 2008). By mid-December, the first wave of floods hit Johor in mid-December, which is unusual for that part of Malaysia. While flooding is common in Peninsular Malaysia during the Northeast monsoon season, they are usually found in the northeastern parts of the peninsula and not in the south. Tangang (2008) also suggested that the floods arising from higher than normal precipitation coincided with the 2006/2007 ENSO event. The local government called it in a hundred year flood and as reason for not being able to respond to the anomalously high levels of river discharge. However, in just three weeks, another flood of similar intensity and magnitude hit Johor but no one seems to be making statement about another one hundred year flood "returning in a space of three weeks" (Lee 2007).

Apparently the potential impact of unexpected storms from the lesson with Typhoon Vamei was not well learnt by the time the floods of December 2006 occurred. Precipitation that was expected for the whole month was received within a single day. Was this the work of global warming? If indeed this was due to global warming, then it is useful to understand how global warming has changed precipitation patterns, which will shed light on how storm preparedness programmes should be designed.

Precipitation changes due to Global Warming in Southeast Asia

Eleven of the twelve years between 1995 and 2006 were the twelve warmest years in the recorded global surface temperature since 1850 (IPCC, 2007). The increase in global surface temperature from 1906 to 2005 ranged from 0.56 to 0.92°C, averaging 0.74°C (IPCC, 2007). Moreover, there is uneven regional variation to this warming. It is important to consider the region-specific impacts of global warming. In the IPCC Assessment Report 4 (AR4). "[w]arming is least rapid … 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). Countries in Southeast Asia, mostly in the low latitudes, experienced the least rapid warming on the average. However, even for this region where warming is the least rapid, Easterling et al. (1997) reports that minimum temperatures have increased by about 2.16 °C in the last century while maximum temperatures did not change significantly from the period 1950 to 1997 (Easterling et al. 1997, 366). Using data from one meteorological station alone, there is an approximate one degree Centigrade increase in the average monthly temperature for Singapore 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.

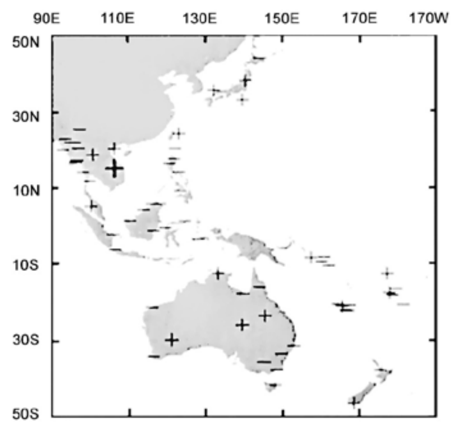
Increases in atmospheric and oceanic temperatures will affect the hydrological cycle as the way water moves through the earth-atmosphere system changes. For example, plaeoclimatic data from corals in the mid-Holocene, has shown that the East Asian summer and winter monsoons were more intense during a warmer mid-Holocene (Morimoto, et al. 2007).

IPCC AR4 suggests that while global warming tends to raise the amount of water vapour in the atmosphere, it does not necessarily lead to increases in precipitation for the entire globe. In fact, "increases in the amount of precipitation are very likely in high-latitudes, while decreases are likely in most subtropical land regions" (IPCC 2007, 16). In addition to the spatial variation in the amount of precipitation, 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). One explanation given has been the consistent weakening and poleward expansion of the Hadley circulation (Lu et al. 2007) resulting in more pronounced differences in moisture availability between regions. Indeed, the occurrence of heavy precipitation events will increase by about 6 to 7 percent for every Kelvin increase in global average temperatures based on the works by Kharin et al. (2007) and Trenberth et al. (2003).In particular, Kharin et al. (2007) reported increasing extreme precipitation events over tropical Pacific. For the Western Pacific, (East Java region in Indonesia), precipitation data from 1955 to 2005 indicated that there has been an increased ratio of precipitation between the wet and dry season (Aldrain and Djamil 2008, 435). This has lead to the increased threat of meteorological hazards such as extreme weather during the wet season and droughts during the dry season in the recent decades.

Increasing occurrence of variability in the summer monsoon over East Asia and Southeast Asia (both the East Asian Summer monsoon and the Western North Pacific Summer monsoon) has occurred, 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). For the period between 1979 and 2003, the total accumulated precipitation for the Southeast Asian region has increased from 2000 to 4000 mm (Lau and Wu, 2007, 985). Further, Lau and Wu (2007) reported that the extreme high (top 10%) and low (bottom 5%) precipitation events are occurring more often than before. During the same period, moderate precipitation events have reduced (Lau and Wu, 2007, 979). The same study also proposed that there is increase in amounts and frequency of high precipitation experienced over the Inter-tropical Convergence Zone, the Indian Ocean and monsoon regions during the 1980s and 1990s (Lau and Wu, 2007, 979).

However, there are contradicting studies that found that the return periods of extreme precipitation events has been reduced due to greenhouse warming in the Southeast Asian monsoon region (Bhaskaran and Mitchell, 1998). In their modeling, greenhouse forcing results in a 10 fold increase in frequency of 1 in 100 year events (Bhaskaran and Mitchell, 1998, 1460).

One of the most comprehensive studies done was by Manton et al. (2001). They analyzed the extreme daily temperature and rainfall from 1961 to 1998 for 91 stations in Southeast Asia. While the study confirmed that there were more hot days and warm nights, the conclusion for extreme rainfall events was "less spatially coherent", to quote them.



The sign of the linear trend is indicated by +/- : symbols at each site; bold indicates significant trends (95%).
(Source: Manton et al. p. 274)

Figure 5: Trend in the frequency of daily rainfall exceeding the 1961–1990 mean 99th

Regions like Vietnam, Laos, Northeast Thailand and Peninsular Malaysia have show an increasing trend in the frequency of extreme event while places like archipelago Southeast Asia and Myanmar have shown a decreasing trend.

Given the range of conclusions found in the literature, a summary of the discussion so far is included in Table 1 below. While there are exceptions, the overall conclusion from the review is that the frequency of extreme high and low precipitation events will increase, while there is a relatively weak consensus that the intensity of extreme events will increase.

Table 1: A summary of changes to Precipitation in a global warming world (focus on Tropics and Southeast Asia)

Works cited	Basis of conclusion	Frequency of extreme high precipitation events	Frequency of moderate precipitation events	Frequency of low precipitation events	Intensity of extreme events	Study Area/Region	Period of study
Aldrain & Djamil, 2008	Past records	Increase	Decrease	Increase	Droughts and storms are more pronounced	Java, Indonesia	1955 - 2005
Bhaskaran & Mitchell, 1998	Modelling	Decreased	Increased	-	-	Southeast Asia	1860 -1990; modeled for 1990 - 2070
Brahic, 2007	Past records	-	-	-	Monsoons strengthened	Western Indonesia	6500 BP
Chen, Yen & Weng, 2000	Past records	Increase	-	Increase	Heavy precipitation events in Eastern China	East & Southeast Asia	1979 - 1993
Kharin et al. 2007	Modelling	Increase	-	-	-	Tropical Pacific	2046-2065 2081 - 2100
Lau & Wu, 2007	Past records	Increase	Decrease	Increase	Total precipitation amount increased two folds from 1980s to 1990s for some areas	Tropics	1979 - 2003
Manton et al. 2001	Past records	Decrease	-	Reduced raindays in Malaysia, Philippines and Thailand. No significant treand in other stations	Proportion of annual rainfall from extreme events has increased	Southeast Asia	1961 -1 998
Yim et al. 2008	Past records	Increase		Increase		East Asia and Southeast Asia	1979 - 2005
Zhou & Chan, 2005	Past records	-		Increase		South China Sea	1979 - 2001
This study	Past records	Increase	-	Decrease	-	Southeast Asian Cities	1978 - 2007

Determining changes in precipitation in the Southeast Asian region

While the conclusion drawn from the range of literature reviewed provided an overview of the occurrence of single extreme event, there is no consensus on the middle to long term precipitation changes for the region. A simple analysis of the precipitation records from 7 stations in Southeast Asian countries from 1978 to 2008 was conducted. The author has found that high precipitation months in Southeast Asia have increased.

In order to analyze the extreme events in precipitation, the monthly precipitation between January 1978 and December 2007 was examined for reach of the stations in the 7 cities studies. While the probability of precipitation amount is not a pure statistical distribution, but is dependent on a complex combination of physical processes, the precipitation data was used to determine the mean, median and 90th percentile value for a 30 year average monthly precipitation for each station. In the Manton et al. (2001) study, he used a 99th percentile to denote intense one-off events. Here the author proposes using the 90th percentile to review the long term trend of the monthly rainfall data. Months where by the average month rainfall exceeds the 90th percentile in each 5 year period were then tabulated.

Table 2: Number of months in a 5 year period where rainfall is greater than 90th percentile over a 30 year period, for selected ASEAN cities.

Year	Bangkok	Hanoi	Jakarta	Kuala Lumpur	Manila	Singapore	Vientiane
1978 - 1982	3	0	12	5	1	2	4
1983 - 1987	8	0	3	2	2	8	2
1988 - 1992	7	2	0	9	5	9	0
1993 - 1997	10	11	10	6	9	4	0
1998 - 2002	4	6	2	6	9	6	3
2003 - 2007	4	17	9	8	9	7	27
Mean Monthly Rainfall **(over 360 months)**	126.16	63.35	38.47	203.89	104.12	174.63	27.48
Median Monthly Rainfall **(over 360 months)**	89.66	8.128	2.032	193.55	33.27	138.56	0

Except for Bangkok, all stations recorded a higher proportion of months wetter than the 30 year 90th percentile, in 2003 to 2007 compare to the period 1998 to 2002. In some cases, Vientiane and Hanoi for example, the value was more than doubled. This is consistent with the single storm intensities spatial trend in Manton et al. (2001), where the increases were in Indochina. Another wet period was between 1993 and 1997 where some of the stations recorded more months that had rainfall greater than the 90th percentile value. This simple analysis showed that places with increasing trend in wetter months coincided with the places in Manton et al (2001). However, more stations for Southeast Asia need to be studied before we can conclude that there are more wet months due to global warming.

Implications of precipitation changes on Southeast Asia

Increasing frequency and intensity of extreme events translate into potential hazards. Stern (2007) posits that "South and East Asia, may receive more water. However, much of the extra water will come during the wet season … 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). Any changes in precipitation patterns across Monsoon Asia would "severely affect" millions of lives (Stern, 2007). While the summer monsoon brings the much needed rain for agriculture and other economic activities (close to 90% of total annual precipitation), a radical increase or decrease could be disastrous (Stern 2007, 82). Thus, 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 two cases of high precipitation events that hit Southern Johor and Singapore in 2001 and 2006 presented at the beginning of this paper illustrate the potential impacts. Of the two examples, tropical cyclones tend to be more destructive due to its higher wind speeds and precipitation. Tropical cyclones have increased in frequency and intensity in the Pacific basin (Fan and Li 2005). 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). Of the nine pieces of work cited in Table 1, eight studies suggest that the frequency of extreme precipitation events will increase in Southeast Asia. There are already cases of unprecedented extreme precipitation events in Southeast Asia although we cannot be sure if there will be more tropical cyclones due to human induced global warming in the next few decades.

Responding to increased frequency of high precipitation events.

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. Regardless of whether global warming is a direct cause of the increased frequency in extreme precipitation events, Typhoon Vamei, which was a theoretical impossibility until it happened, did not send sufficient warning to local and national governments.

One can argue that the storms cited in the cases here are rare, with Vamei being a one in four hundred year storm (Chang, Ching and Kuo 2003) and the storm in December 2006 being a one in a hundred year storm. The chances that such storms will strike again are low.

However, even in communities when such extreme precipitation events occur on a yearly basis, there are numerous examples of communities badly affected by extreme precipitation events. The classic example is the case of Hurricane Katrina, which killed thousands of people, displaced many more and resulted in a "massive relief and evacuation effort" (Travis 2005). Despite the fact that impacts of a Category 5 hurricane 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 were the reasons for this lack of preparedness, despite the efforts in dinformation dissemination and evacuation procedures?

Brooks, Adger and Kelly's (2005) approach to explain adaptive capacity may be used to understand the conceptual approach to storm preparedness. In order to be prepared for storms, an assessment of risk, the building of adaptive capacity and the actual adaptation strategies must be included. While "risk is viewed in terms of outcome, and is a function of physically defined climate hazards and socially constructed vulnerability" (Brooks, Adger & 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) while adaptation refers to the actual procedures.

The concepts of hazard and social vulnerability must be considered in determining the risks involved in preparing for the increased storm activities due to global warming. There is a need to distinguish risk factors between "hazard" (determines geographical location, intensity and statistical probability) and "vulnerability" (determines susceptibilities and capacities)" (United Nations 2002: 66). Indeed, the social-cultural conditions of the people and the biophysical risks in the geographical region determine the storm-related risk they are subjected to.

The two cases in this paper have provided empirical evidence to corroborate the increase in frequency and intensity of storms as suggested by the literature. Paradoxically, the Malaysian Meteorological Department (MMD) has already documented anomalous storms in Malaysia the year before, including Kelantan, 17-20 Dec 2005, Perlis, 18 Dec 2005, Kedah, 19 Dec 2005, and Terengganu, 13 Feb 2006, in addition to the data collected for the 2001 Vamei event (MMD 2007). In fact MMD acknowledges that there has been "increasing number of days of extreme rainfall event (exceeding 90th percentile of total rainfall) for several stations over the Peninsular Malaysia" since the 1980s (MMD 2007). While information is available for historical events, there is still a need to develop adaptive capacity.

MMD has in place weather prediction systems as part of its adaptive capacity. However, even 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. In fact, the Minister for MNRE called for ministries and agencies to coordinate in their efforts to produce "risk maps for vulnerable areas" at the UNDP-MNRE Conference on Climate Change Preparedness: Towards Policy Changes on 11 September 2007 that (Khalid 2007). Since then, the national level effort was undertaken to increase the adaptive capacity of the country through improving risk assessment, in order to formulate effective adaptation strategies to respond to the impacts of increased storms due to global warming.

Recommendations and Conclusion

Much can be learned from Typhoon Vamei and the December 2006 storm that came as surprise. It was the lack of preparedness that resulted in the surprise. As the IPCC AR4 was not published until February 2007, the lack of preparedness for the 2001 and 2006 incidents can be admissible on the grounds that the IPCC TAR (published in 2001) could not commit itself to predicting impacts of global warming as certainly as the AR4. In AR4 terms such as “virtually certain” replaced the less confident terms like “likely” of TAR. Based on the virtual certainty and detail of information available now, there is little excuse for governments not to get prepared for Vamei-like storms. There is general agreement in the literature survey that high precipitation events will occur more frequently.

Governments need to develop storm preparedness strategies. While mitigation seeks to ameliorate or eliminate the negative impact mainly through engaging 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. 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. The SLSW focuses on the three step formula of severe weather monitoring, warning and dissemination (Mogil and Groper 1977). The SLSW formula of monitoring-warning-dissemination is at the core of adaptation and preparedness strategies. It provides information for governments, civil society and individuals to react and respond to. While international institutions are able to provide a network of information for monitoring and warning, information dissemination locally may be unsurprisingly poor. Cyclone Nargis is a case in point.

On 2 May 2008, cyclone Nargis made landfall in Myanmar (Indian Meteorological Department 2008) leaving more than 22,000 dead and up to 40,000 people missing. Like Typhoon Vamei, this tragedy was unexpected as it is “unprecedented” (British Broadcasting Corporation 2008). The storm brought winds reaching 190 km/h and waves of up to 3.5 metres. While 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 1000 kilometers from the coast. However the country was tentatively spared as the cyclone made an eastward turn on 1 May 2008. Ironically, the storm made another unexpected turn and headed towards Myanmar, bringing with it a swath of destruction as a Category 4 cyclone.

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”, it was unsure “what really reached individuals in the country” (Channel NewsAsia, 2008). Information dissemination is critical to storm preparedness programs. Due to Myanmar’s "rural areas with undeveloped infrastructure", there are "significant challenges" to implementing any evacuation (Channel NewsAsia, 2008).

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 evacuation drills make up hazard preparedness. In region slike Southeast Asia where changes in the frequency of storm events are predicted to happen, preparedness is crucial in a global warming world. While some meteorologists (Kunston Tuleya 2004; Vecchi, et al. 2006; Landsea 2006) argue on the link between global warming and storm frequencies and intensities, this paper has provided evidence to show that there is indeed increased frequency in high precipitation events over Southeast Asia. Storms like Vamei and Nargis have caught humans off-guard. It is pertinent to maintaining preparedness as an important step to adapting to the virtually certain occurrence of storm hazards.

Bibliography

Aldrian E and Djamil YS (2008) Spatio-temporal climatic change of rainfall in East Java Indonesia. International Journal Of Climatology 28.: 435–448.Doi: 10.1002/joc.1543

Bhaskaran B and Mitchell JFB (1998) Simulated changes in Southeast Asian Monsoon precipitation resulting from anthropogenic emissions. International Journal Of Climatology 18: 1455 – 1462

Brahic C (2007) Climate change may boost monsoon and worsen droughts. New Scientist Environment. Available via http://environment.newscientist.com/article/dn10978. Accessed 20 March 2008

British Broadcasting Corporation (2008) Aid call as Burma casualties rise. Available via BBC News: http://news.bbc.co.uk/2/hi/asia-pacific/7384858.stm. Accessed 7 May 2008
Brooks N (2003) Vulnerability, risk and adaptation: A conceptual framework, Tyndall Centre Working Paper 38
Brooks N, ADger W N and Kelly P M (2005) The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change 15(2): 151 - 163
Chang CP, Ching HL and Kuo HC (2003) Typhoon Vamei: An equatorial tropical cyclone formation. Geophysical Reserach letters. Available via http://www.weather.nps.navy.mil/cpchang/papers-pdf/vamei.pdf . Accessed 20 December 2005
Channel NewsAsia (2008) Myanmar claims warning issued ahead of cyclone. Available via Channel NewsAsia.com: http://www.channelnewsasia.com/stories/afp_asiapacific/view/346189/1/.html. Accessed 8 May 2008
Chatterjea K (2008) Severe Wet Spells and Vulnerability of Urban Slopes: Case of Singapore. Natural Hazards DOI: 10.1007/s11069-009-9362-7
Chen TS, Yen MC and Weng SP (2000) Interaction between the Summer Monsoons in East Asia and the South China Sea: Intraseasonal Monsoon modes. Journal of the Atmospheric Sciences 57(9): 1373 – 1392
Cruz RV, Harasawa H, Lai M, Wu S, et al (2007) Asia. Climate Change 2007: Impacts, Adaptation and Vulnerability. In Contribution of Working Group II to the Fourth Assessment Report of the IPCC, by ML Parry, OF Canziani, JP Palutikof, PJ. van der Linden and CE Hanson (Eds.), 469 - 506. Cambridge: Cambridge University Press.
Dr Mahathir Told (2002) Recent floods claimed five lives and casued substantial damage. Bernama: The Malaysian National News Agency. 8 January 8 2002. Available via www.bernama.com. Accessed 14 October 2007
Dybas C (2003) Hurricanes at the Equator: Impossible Perfect Storm. National Science Foundation. 12 May 12 2003. Available via http://www.nsf.gov/od/lpa/news/03/tip030512.htm. Accessed 3 October 2007
Easterling DR, Horton B, Jones PD, Peterson TC, Karl TR, Parker DE, Salinger MJ, Razuvayev V, Plummer N, Jamason P and Folland CK (1997) Maximum and Minimum Temperature Trends for the Globe. Science, New Series 277(5324): 364 - 367
Fan DD, and Li CX (2005) Complexities of Chinese Coast in response to Climate Change. Advance in Research on Climate Change 1:111 -114
Herman S (2008) Bangladesh's Farmers Told not to Panic About Approaching Cyclone. Available via Voice of America News: http://voanews.com/english/2008-04-29-voa19.cfm. Accessed 7 May 2008
Indian Meteorological Department (2008) May 2 2008 Shipping Bulletin for Met. Area VIII North of Equator. Available via National Ocean and Atmospheric Administration: National Weather Service: http://weather.noaa.gov/pub/data/raw/fq/fqin01.dems.txt. Accessed 7 May 2008
Intergovernmental Panel on Climate Change (2007) Working Group I Report - The Physical Sciecne Basis: Summary for policy makers. Intergovernmental Panel on Climate Change. February 2007.Available via http://www.ipcc.ch. Accessed 1 March 2007
Johnson RH and Chang CP (2007) Winter MONEX: A quater century and beyond. American Meteorological Society. Available via http://www.wmo.int/pages/prog/arep/tmrp/documents/WinterMONEX25MeetingReport.pdf . Accessed 5 Oct 2007
Joint Typhoon Warning Center (2008) Cyclone Nargis Warning NR 004. Available via National Ocean and Atmospheric Administration National Weather Service: http://www.webcitation.org/5XPe7ByM8. Accessed 7 May 2008
Khalid, A. (2007). Opening remarks, Conference on Climate Change Preparedness: Towards Policy Changes, 11 September 2007. Available via http://www.undp.org.my/index.php?option=com_content&view=article&id=161. Accessed 20 Jan 2009
Kharin VV, Zwiers FW, Zhang X and Hegerl GC (2007) Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations. Journal of Climate 20 (18): 1419-1444. Doi: 10.1175/JCLI4066.1
Koh TY and Lim H (2005) Verification of a mesoscale simulation of Tropical Cyclone Vamei. Geophysical Research Abstracts 7 Available via http://www.asiaoceania.org/abstract/oa/58-OA-A1253.pdf. Accessed 1March 2007
Kunston TR and Tuleya RE (2004) Impact of CO@ induced warming on simulated hurrican intensity and precipitation: Sensitivity to the choice of climate model and convective parameterization. Journal of Climate 17(18): 3477 - 3495
Landsea CW (2006) Meteorology: Hurricanes and global Warming. Nature 438: E11 - E12

Lau KM and Wu HT (2007) Detecting trends in tropical rtainfall characteristics, 1979 – 2003. International Journal of Climatology 27: 979 – 988. Doi: 10.1002/joc.1454.

Lee LC (2007) Johor Floods: Once in 100 yeras, twice in three weeks? Malaysiakini. 16 Jan 2007. Available via http://www.malaysiakini.com/letters/62176. Accessed 1 April 2008

Lu J, Vecchi GA and Reichler T (2007) Expansion of the Hadley cell under global warming. Geophysical Research Letters Doi:10.1029/2006GL028443.

Malaysian Meteorological Department (n.d.) Tropical Storm Vamei causes widespread floods in Johor. Available via http://www.kjc.gov.my/people/research/webpages/sigwx/dis2701_e.htm Accessed 5 October 2007.

Manton MJ, Della-Marta PM, Haylock MR et al. (2001) Trends in Extreme daily rainfall and temperature in Southeast Asia and the South Pacific: 1961 – 1998. International Journal of Climatology, 21:269-284.

Milly PCD, Dunne RT, Wetherald KA and Delworth TL (2002) Increasing risk of great floods in a changing climate. Nature 415: 514 - 517

Mitchell T and Tanner TM (2006) Adapting to Climate Change: challenges and opportunities for the development community. Tearfund, Teddington.

Mogil HM and GroperHS (1977) NWS's Severe Local Storm Warning and Disaster Preparedness Programs. Bulletin of the American Meteorological Society, 58(4): 318 - 324

Morimoto M, Kayanne H, Abe O and McCulloch MT (2007) Intensified mid-Holocene Asian monsoon recorded in corals from Kikai Island, subtropical northwestern Pacific. Quaternary Research 67: 204 - 214

National Oceanic and Atmospheric Administration (n.d.) Global Summary of the day, 2001. National Climate Data Center, National Oceanic and Atmospheric Administration: Climatic Data OnLine. Available via http://www7.ncdc.noaa.gov/CDO/cdoselect.cmd?datasetabbv=GSOD . Accessed 30 March 2008

Padgett G (2001) December 2001 Wordlwide Tropical Weather Summary. Available via http://www.australiasevereweather.com/cyclones/2002/summ0112.htm. Accessed 15 September 2007

Stern N (2007) The Economics of Climate Change: The Stern Review. Cambridge: Cambridge Univeristy Press

Sun Y and Ding Y (2008) Effects of intraseasonal oscillation on the anomalous East Asian summer monsoon during 1999. Advances in Atmospheric Sciences 25(2): 279 – 296

Tangang FT, Juneng L, Salimun E, Vinayachandran PN, Yap KS, Reason CJC, Behera SK and Yasunari T (2008) On the roles of the northeast cold surge, the Borneo vortex, the Madden-Julian Oscillation, and the Indian ocean Dipole during the extreme 2006/2007 flood in southern Peninsular Malaysia. Geophysical Research Letters. Doi: 10.1029/2008GL033429

Travis J (2005) Hurricane Katrina: Scientists' fear come true as Hurricane floods New Orleans. Science 309(5741): 1656 - 1659

Trenberth KE, Dai A, Rasmussen RM and Parsons DB (2003) The changing character of precipitation. Bulletin of the American Meteorological Society 84:1205-1217

United Nations (2002) Risk awareness and assessment, in Living with Risk, ISDR, UN, WMO and Asian, Disaster Reduction Centre, Geneva, 39-78.

Vecchi GA, Soden BJ, Wittenberg AT, Held IM, Leetmaa A and Harrison MJ (2006) Weakening of tropical Pacific atmospheric circulation due to anthropogenic forcing. Nature 441(4): 73 - 76

Yim SY, Yeh SW, Wu R and Jhun JG (2008) The Influence of ENSO on Decadal Variations in the Relationship between the East Asian and Western North Pacific Summer Monsoons. Journal of Climate 21(13): 3165 – 3179

Zhou W and Chan JCL (2005) Intraseasonal Osciallations and the South China Sea Summer monsoon onset. International Journal of Climatology 25: 1585 – 1609