# CLIMATE PROFILE

## *Climate Variabilities, Extremes and Trends in Central Dry, Coastal and Hilly Zones*

# MYANMAR

*This has been prepared by the Regional Integrated Multi-Hazard Early Warning System (RIMES), as a technical partner to United Nations Human Settlements Programme (UN-Habitat), as part of the Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) Programme, in Myanmar.*

*The completion of this Climate Profile has been possible through RIMES' collaboration with Myanmar's Department of Meteorology and Hydrology (DMH) and support from United Kingdom's Department for International Development (DFID), through the BRACED Consortium.*

# Table of Contents

# Definition of Key Terminologies

| Terminology | Definition |
|---|---|
| Average | Average in rainfall, temperature and wet days values in 30 years (1981-2010) |
| Dry season | The period of minimal rainfall, from November to April |
| Maximum temperature | Daytime temperature, usually measured from 12:00-14:00, for identifying the hottest temperature in a day |
| Minimum temperature | Nighttime temperature, usually measured from 18:30 – 6:30, for determining the coolest temperature in a day |
| Normal | Averages in rainfall and temperature values, utilizing data from 1981-2010 baseline period |
| Wet season | Also referred to as the Southwest Monsoon Season, in Myanmar, where copious rainfall is usually observed in the country, from May to October |

## List of Figures

# List of Tables

# List of Acronyms

| | |
|---|---|
| **BRACED** | Building Resilience and Adaptation to Climate Extremes and Disasters |
| **DFID** | Department for International Development |
| **DMH** | Department of Meteorology and Hydrology |
| **RIMES** | Regional Integrated Multi-Hazard Early Warning System |
| **UN-Habitat** | United Nations Human Settlements Programme |
| **WMO** | World Meteorological Organization |

# 1 INTRODUCTION

## 1.1. Background

Understanding climate – its drivers, variabilities, extremes, and trends – is essential for facilitating better risks and resources management, and development of planning initiatives. Historical climate data, which is a record of past climate, can reinforce short-term, medium-term, and long-term preparedness. Historical climate data, along with other variables, provides a range of utility, viz:

- identification of climate's location-specific seasonality, variations and trends, and climate correlation to other relevant variables (e.g. rainfall and/or temperature and crop growth, crop yield and/or crop damage; rainfall and/or temperature and insect infestation; rainfall and/or temperature and disease outbreak; rainfall and/or temperature and drought; rainfall and flooding; temperature and/or rainfall and energy generation and consumption; rainfall and temperature and reservoir operation; and wind speed and wind energy generation, etc.), for guiding effective planning and decision-making in various sectors, pricing premiums and identification of incentive packages to clients in insurance industry, and better analysis and presentation of reports by media
- validation of community experiences, for fostering national, sub-national and local stakeholders' understanding of climate risks and strengthening design of interventions for resilience
- development and updating of location-specific hazard and/or risk maps, for guiding disaster risk reduction decisions
- refining weather/climate forecasting models
- providing reference for analysis of forecast of various timescales, and generation of advisories for risks and resources management
- providing reference against which to compare current climate, and a baseline for anticipating potential future scenarios

The key focus of this analysis is to provide evidence to/support community climate-related experiences and perceptions, in key townships in Myanmar's Central Dry, coastal and hilly zones; and develop inferences vis-à-vis opportunities and risks offered by location-specific climate variabilities, extremes, and trends.

## 1.2. Objectives

While providing opportunities for various uses of analysis outputs, this study is undertaken to provide evidence to/support community experiences and perceptions on climate variabilities, extremes and observable trends in select priority areas in different climate zones, in Table 1, for evolving better understanding of past, current and potential future climate opportunities and risks:

**Table 1. Priority Areas for Climate Analysis**

| Zone | Region/State | Township |
|---|---|---|
| Central Dry | Mandalay | Meiktila |
| Coastal | Ayeyarwady | Bogale<br>Labutta<br>Pyapon |
| | Kayin | Hpa-An |
| | Rakhine | Kyaukpyu<br>Tangoup |
| | Mon | Mawlamyine |
| | Yangon | Dagon Seik Kan |
| Hilly/Mountain | Shan | Kengtung |

Specifically, this study is aimed at undertaking:

- analysis of location-specific variabilities, extremes and trends in rainfall and temperature using historical data from DMH observation stations
- inferences vis-à-vis opportunities and risks associated with location-specific variabilities, extremes and trends to societies and livelihoods

## 1.3. Methodology

The analysis takes advantage of review of available literature and analysis of compiled and quality-checked long-term historical data from DMH. This study adopts the World Meteorological Organization's (WMO's) recommended baseline period, of 1981-2010, for deriving climate normals and for other relevant historical data analysis. Utilizing the recommended baseline period, the analysis also provides connectivity and synergy to other analyses available, using the same baseline period.

## 1.4 Scope and Limitations

There are 10 townships targeted for the development of Climate Profile. Due, however, to the availability of DMH observation stations in priority townships, this Climate Profile is focused on seven (7) townships. In townships where DMH observation stations are not established, or where stations were established recently such that historical data are inadequate, historical observations from nearest stations are used, in the assumption that patterns of climate would be similar, given the proximity of the areas and the similarity in other geophysical conditions:

- In Ayeryarwady, the townships of study are Bogale, Labutta and Pyapon. Historical data from Labutta has been analyzed to also represent climate in Bogale and Pyapon;
- In Rakhine, long-term observation data from Kyaukpyu has been analyzed in the absence of an observation station in Tangoup; the analysis outputs for Kyaukpyu is hence taken to represent the climate in Tangoup;
- In Yangon, 30 years data from Mingaladon station has been analyzed to represent the climate of Dagon Seik Kan township

Wet season, in this analysis, refers to May to October; the dry season is from November to April.

Averages, in rainfall and temperature, are referenced to the baseline period of 1981-2010. The updating of this Climate Profile is required regularly, for capturing most recent variabilities, trends, and extremes. For deeper understanding of long-term variabilities, trends, and extremes, it would be beneficial to undertake an analysis of observed climate of 50-100 years, or more, if data is available. In Myanmar, however, data quality and gaps present lingering challenges in thoroughly understanding and appreciating the behavior of climate in various areas.

While this study provides insights into broad climate-society inferences, detailed sector-specific studies, capturing sectoral sensitivities to rainfall and temperature fluctuations, has to be conducted.

# 2 National Climate Overview

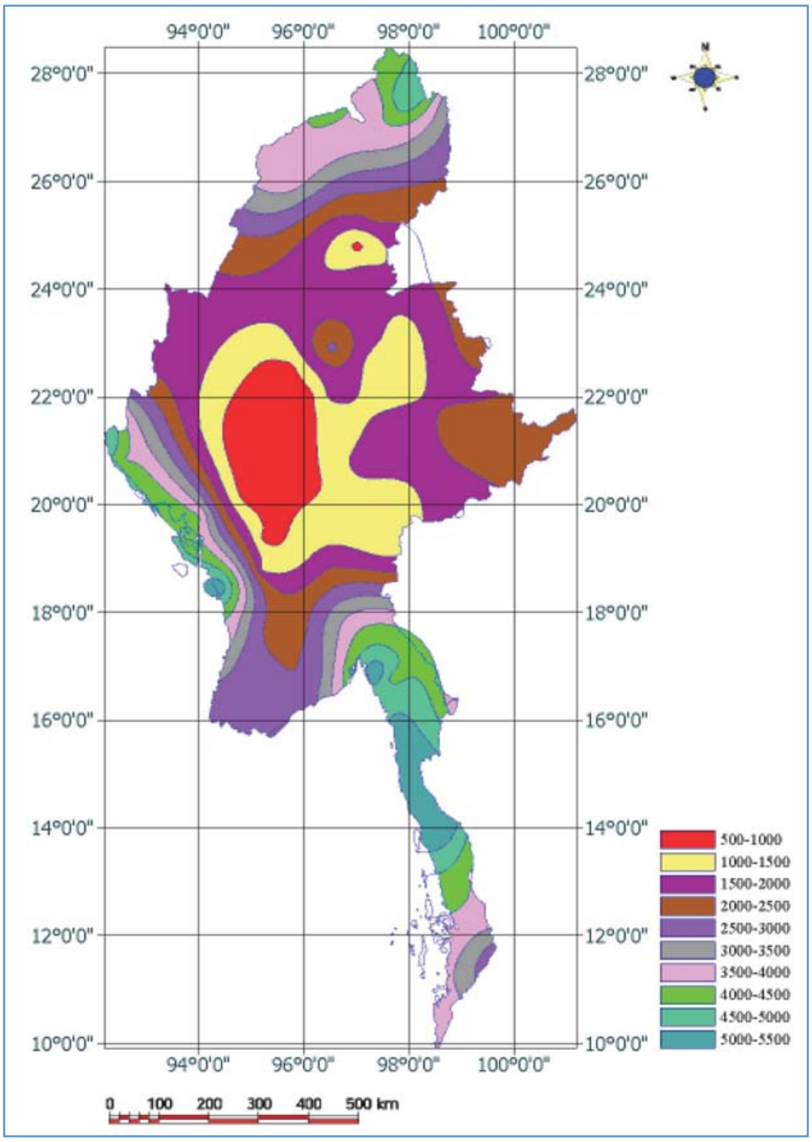
## 2.1 Country Climate Context

Myanmar’s climate is influenced by many factors. The country, lying along 9° 55”, 28°15”N and 92° 10', 101° 10”E, is positioned in Western Southeast Asia, along the path of the Asian monsoon circulation. Corollarily, Myanmar’s climate pattern is highly influenced by the monsoon – about 95% of its annual national average rainfall is received from the Southwest Monsoon, from May to October, with spatial and temporal variability. The Central Dry Zone has the least benefit from the Southwest Monsoon, due to high mountains surrounding the area (rain shadow effect).

The Southwest Monsoon, typically established in the whole country by June, has the following normal onset dates in various parts:

- 18 May in Southern Myanmar
- 23 May in Deltaic areas
- 31 May in Central Myanmar
- 6 June in Northern Myanmar

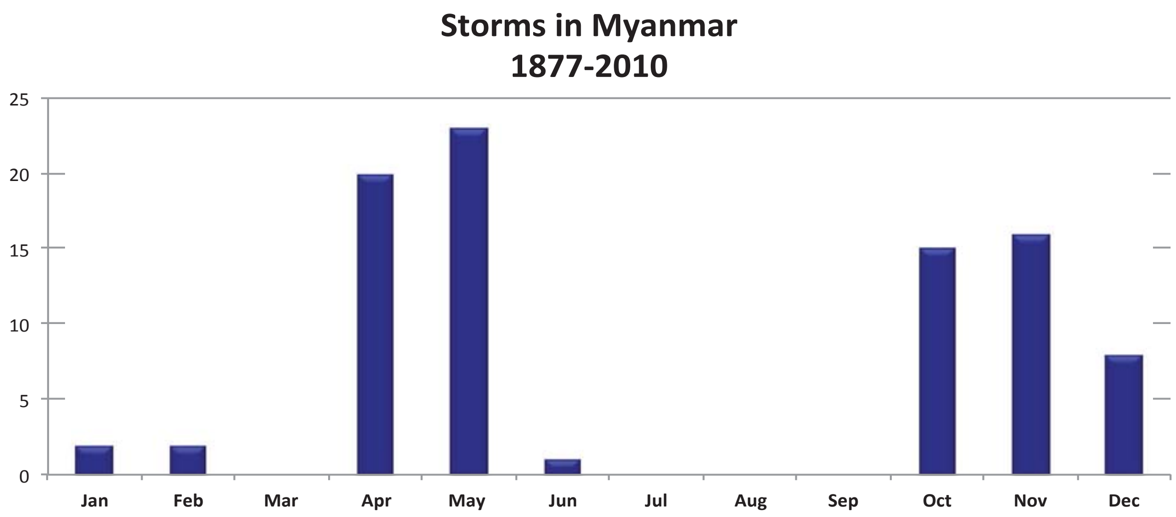
The reversal of the wind patterns, from November to February (Northeast Monsoon), brings dry, cool climate to Myanmar. Although the period is typically dry, weather disturbances from the Bay of Bengal and Andaman Sea, on the Southwest and South of the country, respectively, could bring rainfall to coastal zones and other areas; disturbances/remnants of typhoons from the South China Sea could bring rainfall especially to the Eastern parts. Disturbances over the Bay of Bengal and Andaman Sea, and localized thunderstorms, could also bring rainfall to the normally dry and warm months of March and April. Figure 1 shows the rainfall zones in Myanmar (right).




*Source: DMH*

*Figure 1. Spatial variability in average annual rainfall over Myanmar, as influenced by various climate drivers.*

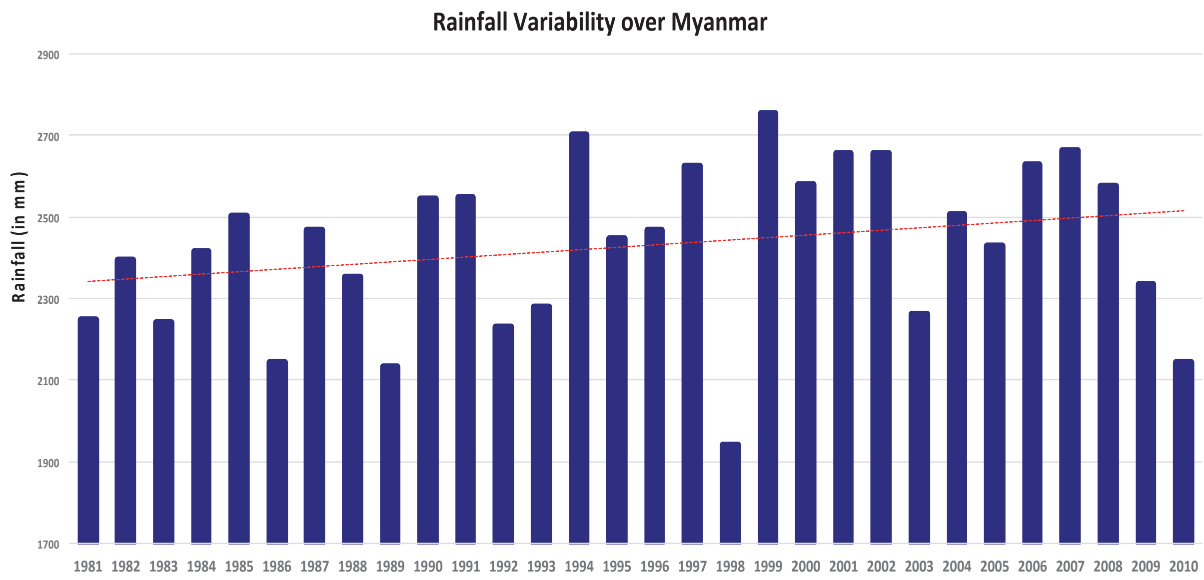
Tropical storms are most frequent in April, May, October, November and December per DMH data from 1877 to 2010 (refer to Figure 2).




*Source: DMH*

*Figure 2. Storms that crossed Myanmar from 1877-2010.*

Though manifesting an increasing trend, strong inter-annual rainfall variability has been recorded over Myanmar (in Figure 3). On a national average, within the 1981-2010 baseline period, 1998 has been recorded to receive the lowest rainfall of only around 1800mm. On the other hand, 1999 recorded the highest observed average rainfall of over 2700 mm. These fluctuations in rainfall are driven by synoptic and local climate systems. These drivers of climate, and their implications for Myanmar, in a location-specific context, requires thorough research/investigation to be well understood.




*Source: DMH*

*Figure 3. Inter-annual rainfall variability over Myanmar, from 1981-2010.*

Temperature, in the country, is warmest in March and April; and coolest from December to February.

## 2.2 Climate Zones

This analysis is focused on three (3) climate zones in Myanmar: Central Dry, coastal and hilly. Comparison of annual average rainfall, over the locations of analysis (in Figure 4), shows that the coastal townships of Kyaukpyu, Mawlamyine, Hpa-An, Labutta, and Mingaladon receive the highest average annual rainfall. Kengtung and Meiktila stations, in the hilly and Central Dry zones, respectively, receive much less rainfall comparative to stations in the coastal zones.

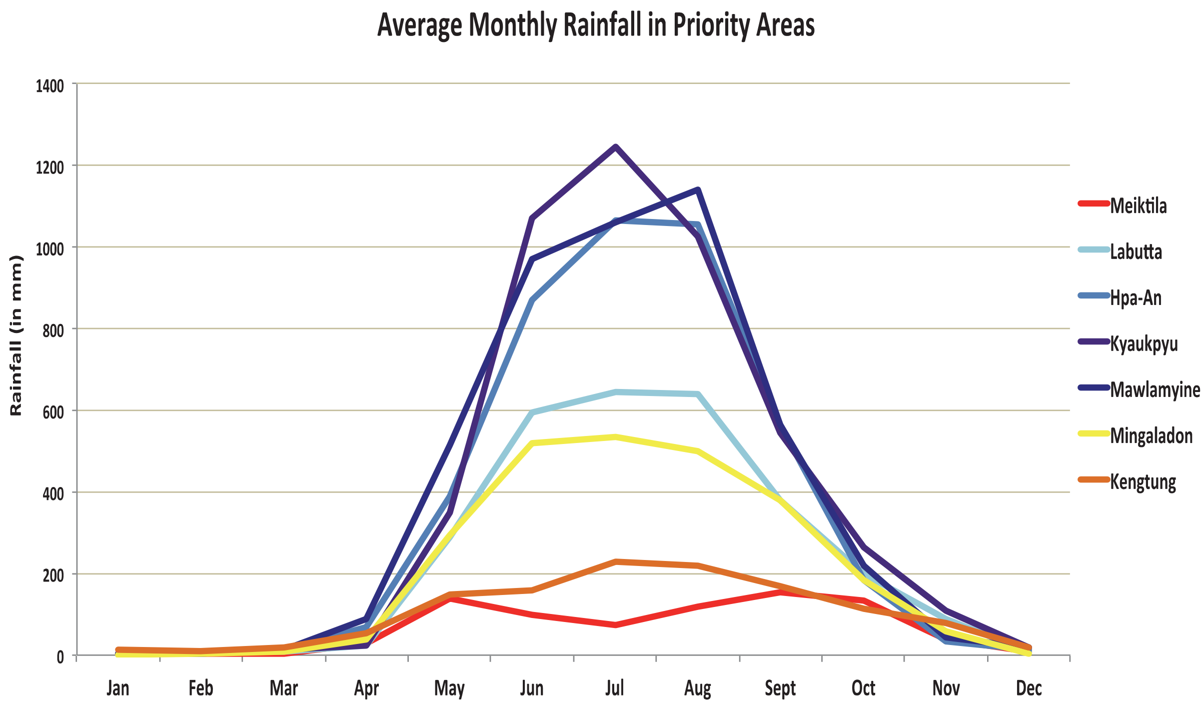



*Figure 4. Average monthly rainfall in Kyaukpyu, Mawlamyine, Hpa-An, Labutta, Mingaladon, Kentung, and Meiktila stations. Areas in the coastal zone receive the highest amount of rainfall, annually, compared to areas in the hilly and Central Dry zones.*

Of the stations studied, Meiktila recorded the warmest average temperature; Kengtung registered the coolest.

As mentioned in the outset, the differences in rainfall and temperature are influenced by many factors of global, synoptic, and meso- or inter-mediate scales. The topography of specific area, its distance from the sea, its distance from the equator, among others, contribute to spatial variations in climate.

# 3 Climate Variabilities, Extremes and Trends

## 3.1 CENTRAL DRY ZONE

### 3.1.1 Meiktila Township, Mandalay Region

#### 3.1.1.1 General Climatic Features

Meiktila Township is located at the heart of Mandalay, in Figure 5, along 20°53’N and 95°53’E. As with other areas in Myanmar’s Dry Zone, the township receives less rainfall compared to other areas in the country, due to the orographic effect of mountains enveloping the zone.


*Figure 5. Meiktila Township, in Mandalay Region, in Myanmar’s Central Dry Zone*

Rainfall in Meiktila demonstrates bimodal rainfall pattern (dual peak; observable in stations located in the Central Dry Zone). With annual average rainfall of about 800mm, rainfall is normally heaviest in May and September (in Figure 6).

The average annual maximum temperature is around 33°C. April records the warmest daytime temperature, averaging at 38.2°C; December has the coolest at around 28.8°C.

On the other hand, minimum or nighttime temperature is warmest in May at an average of around 25.20°C and in April at around 25°C. Coolest nights are in January and December, at 14.6°C and 16°C, respectively.

Extreme maximum temperature has been recorded in Meiktila during the 30 years period of analysis. The warmest being 46°C in 13 April 2010; the coolest (19°C) was recorded in 3 February 2007 and 7 December 1992.

Average maximum and minimum temperatures in Meiktila, and the monthly highest and lowest recorded, for both maximum and minimum temperatures, are provided in Figures 7 and 8.

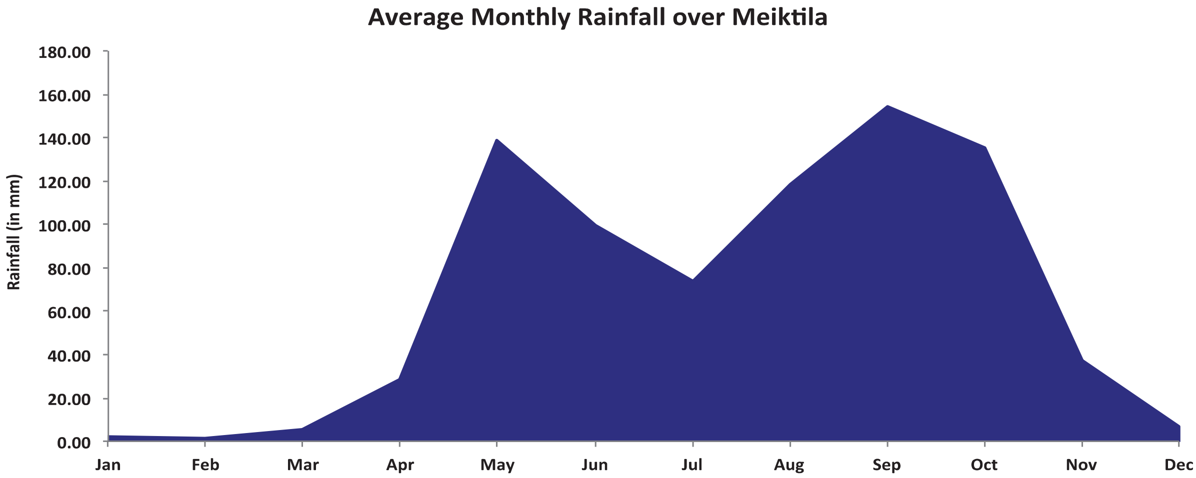



*Figure 6. Rainfall pattern in Meiktila exhibits dual peak – in May and September. On an annual average, the township receives only about 800mm and is the most water-stressed among the stations/townships inclusive of this report.*

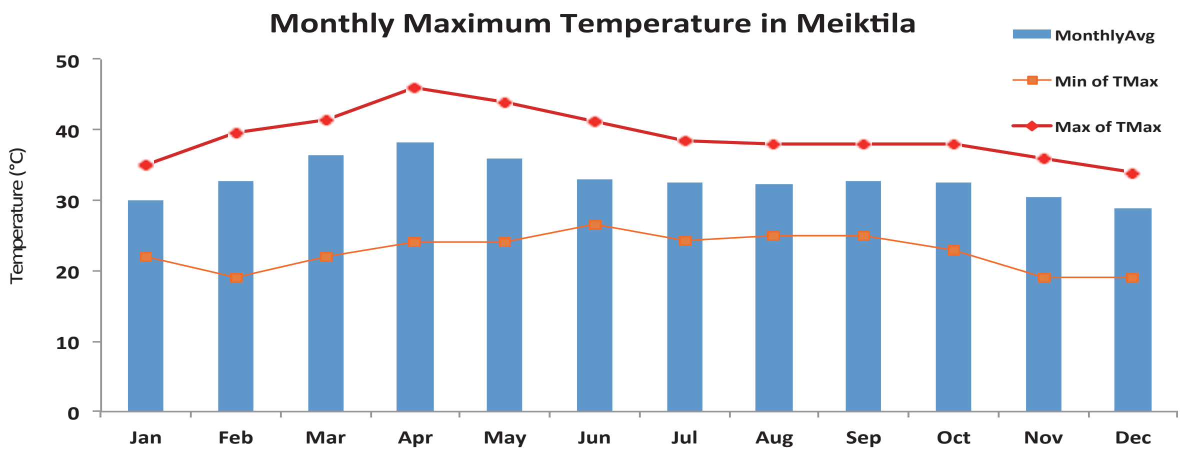



*Figure 7. Average monthly daytime temperature in Meiktila, based on historical data from 1981-2010. April has warmest daytime temperature, while December has the coolest. Extremely hot daytime temperature, in 30 years, was recorded in April 2010.*

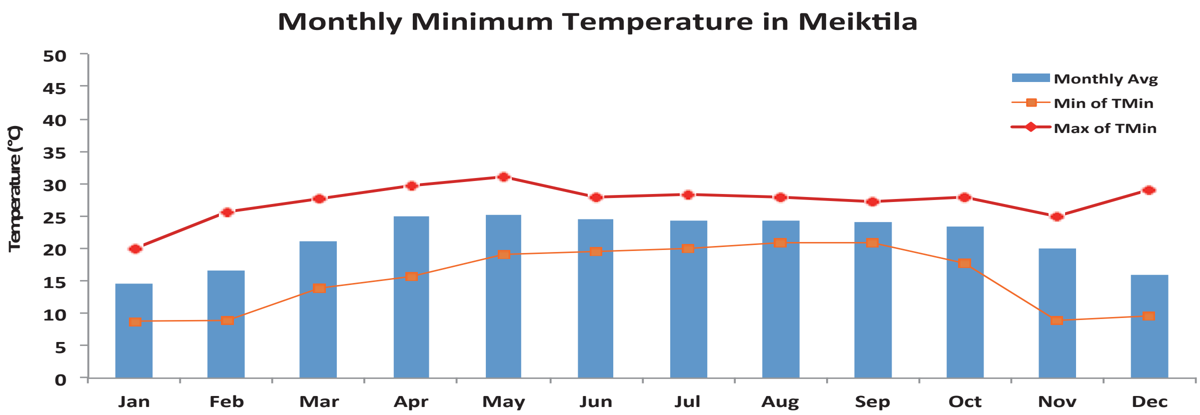



*Figure 8. Average monthly nighttime temperature in Meiktila, per 1981-2010 baseline period. Warmest nights are in May and April; coolest nights are in January and December. Extremely warm nights, exceeding 30°C were recorded in May; nighttime temperature below 10°C were recorded in in January, February, November and December.*

### 3.1.1.2 Rainfall Variabilities, Extremes and Trends

### Annual Rainfall

High inter-annual rainfall variability is observed in Meiktila, with annual rainfall fluctuating, both positively and negatively (in Figure 9), from its average annual rainfall of 800mm.

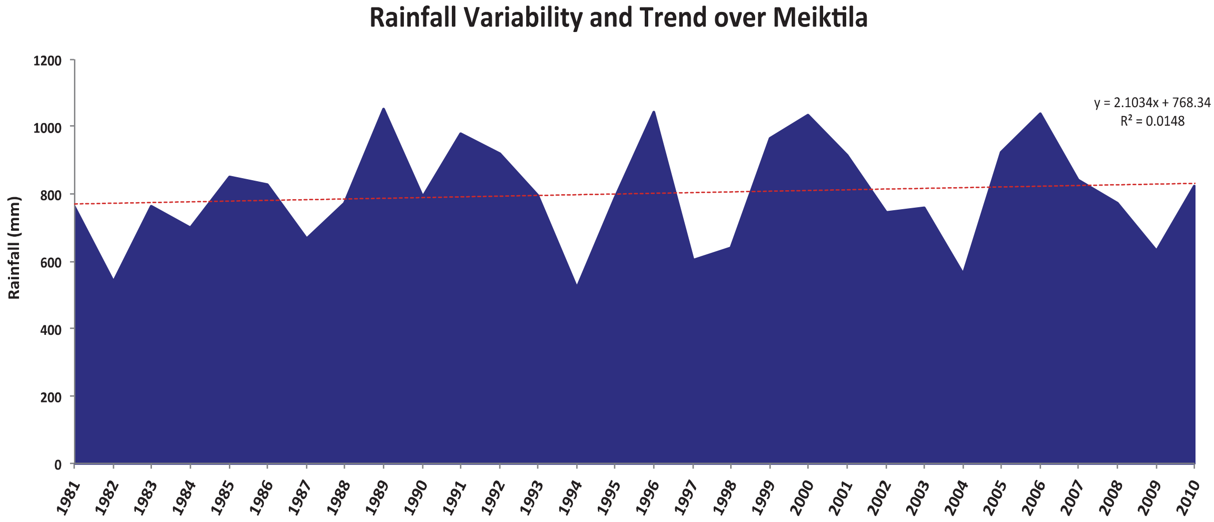



*Figure 9. Annual rainfall, over Meiktila, from 1981-2010, showing notable inter-annual variability. The driest year was in 1994 and the wettest year was in 1999; average annual rainfall is about 800mm. The trend in annual rainfall is increasing.*

Annual rainfall suggests an increasing trend. While there were equal number of years exceeding and falling short of the annual average rainfall, significant positive anomaly was recorded in 1989 (1053mm), 1996 (1043mm), 2006 (1037mm) and 2000 (1033mm).

### Wet and Dry Season Rainfall

On the average, about 90% of the annual rainfall in Meiktila is contributed by the Southwest monsoon – or wet season – at about 720mm; dry season contribution is around 82mm. Year-on-year variability is, however, manifest (Figure 10).

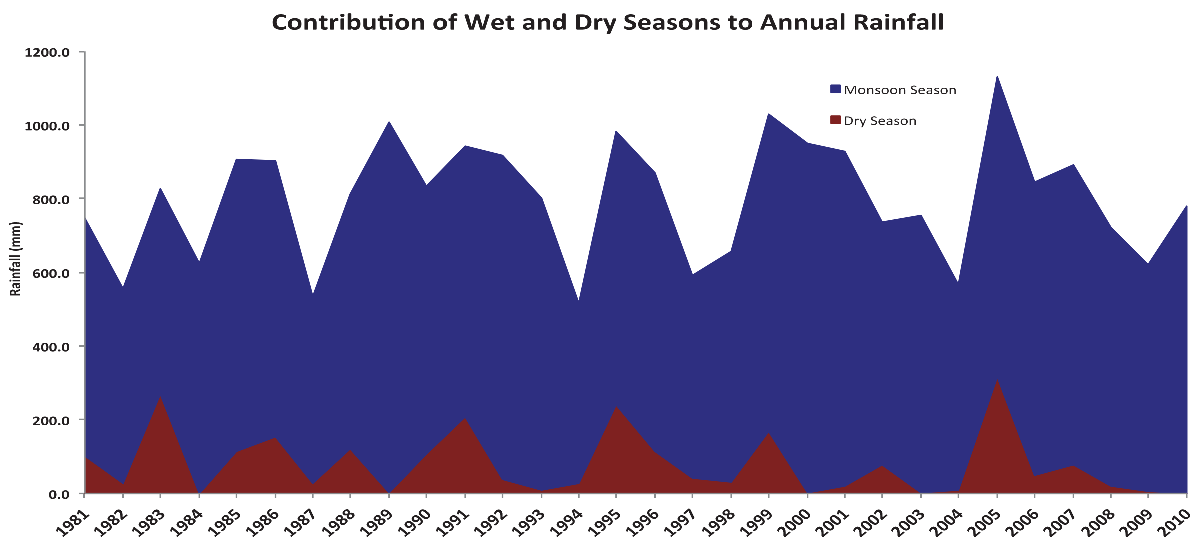



*Figure 10. Contribution of rainfall, from wet and dry seasons, during the years of analysis.*

Significantly wetter wet seasons were recorded in 1989 (1006mm), 2000 (946mm), 2001 (909mm) and 1992 (880mm). Mirroring the annual rainfall, the wet season of 1994 recorded the least (491mm). It can be noted that the dry season of 2005, 1983, 1995 and 1991 recorded rainfall of more than 200mm, owing to severe weather events within the usually dry period.

Wet season rainfall suggests an increasing trend, amid a backdrop of shorter Southwest Monsoon season. Observed wet season rainfall in 17 years surpassed the average wet season rainfall. Dry season rainfall manifests a decreasing trend.

## Extreme Rainfall Events

1989 – the wettest year – recorded 1053mm of rainfall. During the year, extreme 24-hour rainfall events were recorded in 13 May (194mm) and in 12 July (114mm). Other 24-hour heavy rainfall events recorded were in 7 October (63mm); 26 August (60mm); 9 September (55mm); 18 September (51mm); 30 April (38mm); 1 June (30mm); 15 October (27mm) and 23 October (26mm); 10 September (21 mm); and 21 August (20mm). Other rainfall events were below 20mm.

In 30 years, 130 heavy rainfall events – of ≥40mm in 24 hours – have been recorded in Meiktila. Of these events, nine (9) were more than 100mm in 24 hours (194mm in 13 May 1989; 180mm in 23 May 2003; 121mm in 2 June 2001; 114mm in 12 July 1989 and in 24 September 2006; 111mm in 20 September 1993; 104mm in 3 November 1991; 102mm in 24 August 1987; and 101mm in 31 August 2002.

It should be clarified that extreme rainfall events have been also recorded in wet seasons with accumulated rainfall that fell below average – 100mm, in 24 hours, was recorded in 2002 (31 August). The second driest wet season, in 1987, recorded extreme rainfall event of over 100mm, also in August. These suggest multiple stresses experienced in Meiktila during these years, with water-stressed conditions interspersed with extreme rainfall, and possibly, flooding in some areas.

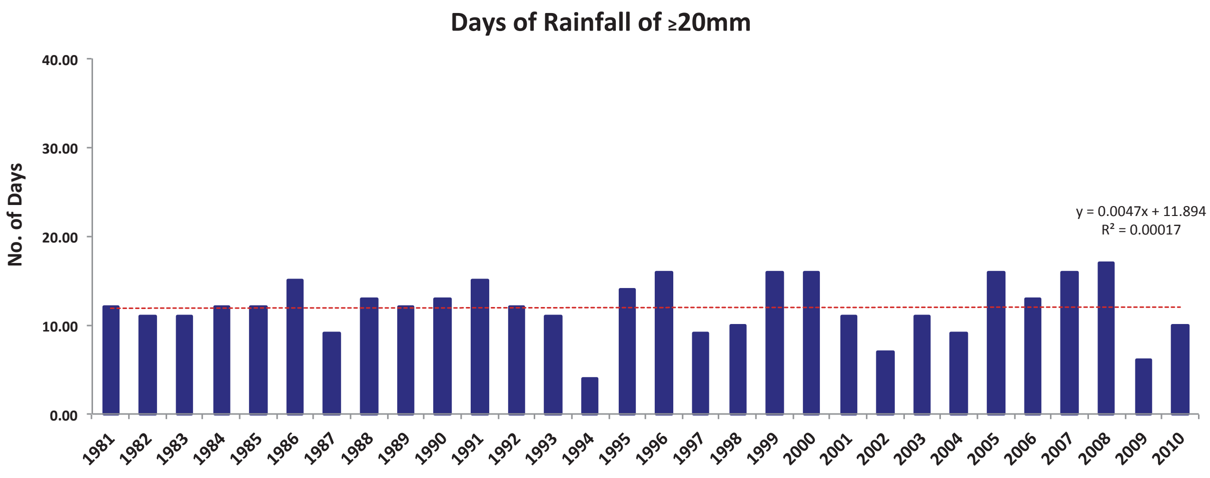
While most extreme rainfall events have occurred within the wet season, these are not isolated therein. Table 2 highlights extreme rainfall events, exceeding 40mm, during the dry season in Meiktila.

**Table 2. Extreme Rainfall Events during the Dry Season in Meiktila**

| 24-Hour Extreme Rainfall | Date Recorded |
|---|---|
| 104mm | 3 November 1991 |
| 66mm | 4 November 1996 |
| 56mm | 21 November 1981 |
| 55mm | 19 November 1988 |
| 50mm | 23 April 1996 |
| 47mm | 9 April 2006 |
| 43mm | 26 March 2008 |
| 41mm | 2 November 1984 |

Further analysis shows that 24-hour heavy rainfall events, of ≥20mm and ≥40mm, are slightly increasing (in Figure 11).

In 30 years, 1994 was the driest, which received only 522mm. Highest 24-hour rainfall events during the year were in 11 June (41mm); 6 August (35mm); 30 May (32mm); and 28 May (29mm). The remaining wet days registered rainfall lower than 20mm.



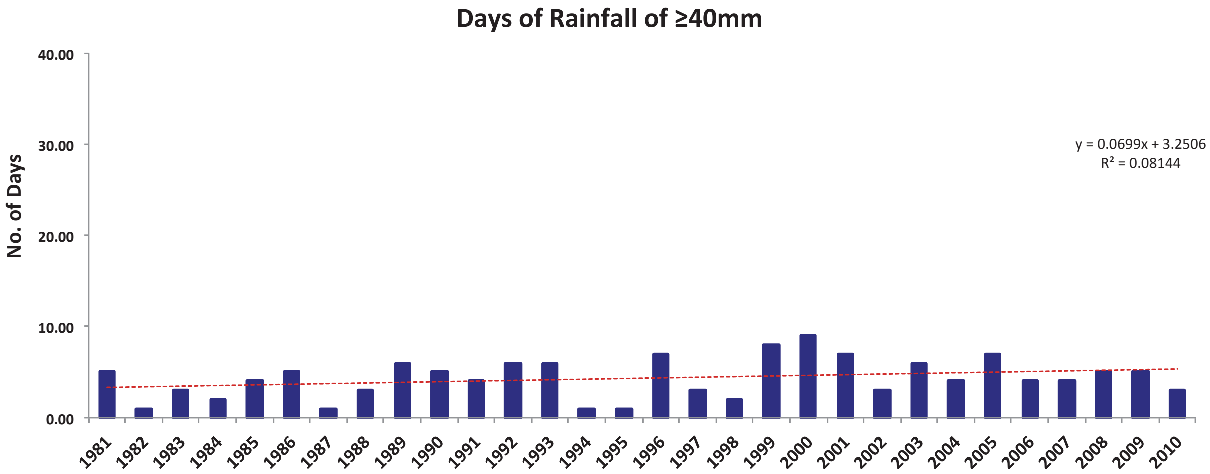




*Figure 11. Heavy rainfall events of ≥20mm (above) and ≥40mm (below), indicate a slightly increasing trend in Meiktila. The slightly increasingly trend is more notable in rainfall of ≥40mm, suggesting more events of higher intensity experienced over Meiktila.*

### 3.1.1.3 Temperature Variabilities, Extremes and Trends

### Maximum Temperature

The warmest location included in the analysis, the average maximum or daytime temperature is about 33°C. Figure 12 shows high variability in average daytime temperature in the area, with the year of warmest days (1998) recording an average temperature of 34.49°C. 2010, with an average temperature of 33.82°C, ranks 2nd warmest in 30 years.

In 2008, 247 days exceeded the average maximum temperature of 33°C; of these, 27 days recorded daytime temperature of ≥40°C. The most extreme daytime temperature recorded during the year was 43.20°C.

2010 (13 April; 46°C) recorded the warmest day in 30 years. Other very warm temperatures were 44°C (14 May 2010), 43.50°C (18 May 2010), 43.20°C (10 May 1998); 43°C was recorded five (5) times, 4 of which in 2010 (17 May 2005; and 25 April, 13 May, 15 May, and 17 May 2010).

Compared to 2008, however, 2010 recorded only 176 days that exceeded the average maximum temperature of 33°C; 39 days registered temperature of ≥40°C.

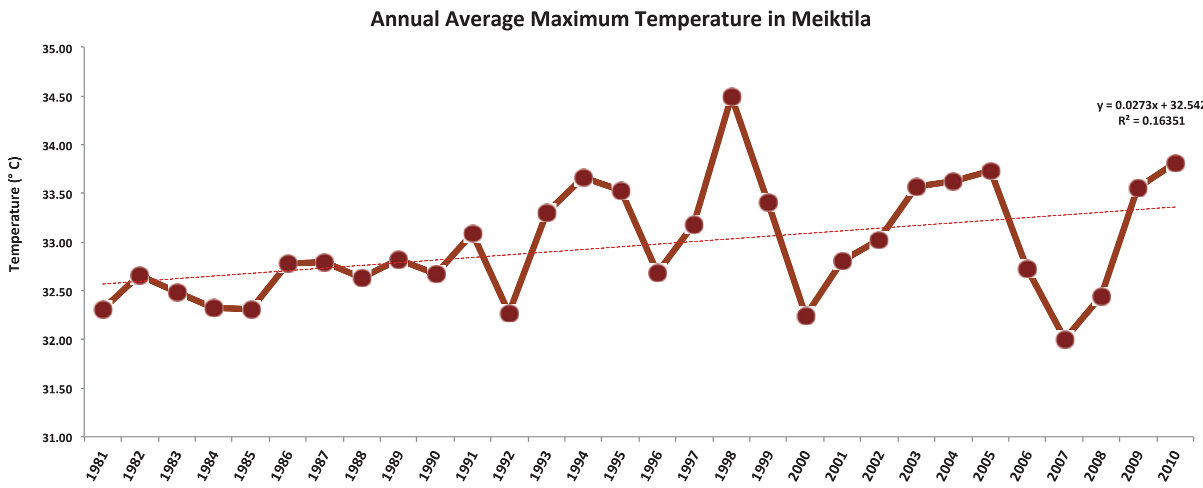



*Figure 12. Year-on-year variability in average daytime temperature in Meiktila. 1998 recorded the warmest days; 2007 observed the least warm days in 30 years.*

Within the study period of 30 years, a total of 452 days observed temperature of ≥40°C, all recorded in March, April, and May except for one (1) event which was recorded in 1 June 1983 (41.10°C). On the other hand, the lowest daytime temperature in Meiktila is 19°C, recorded in 7 December 1992 and 3 February 1997.

2007, the year of lowest average daytime temperature, registered 41°C as its warmest (31 March); only 8 days recorded temperature of ≥40°C (in March, April and May) and only 112 days exceeded the average temperature of 33°C. About 70% of the days in 2007 recorded daytime temperature of 33°C and below. Lowest maximum temperature was 21°C.

Average maximum temperature is manifesting an increasing trend, suggesting higher occurrences of temperatures warmer than average, in 30 years.

## Minimum Temperature

Nighttime temperature, usually measured from 18:30 to 6:30, is presented under this section. Figure 13 shows the variability in minimum temperature in Meiktila, which is averaged at around 21.60°C.

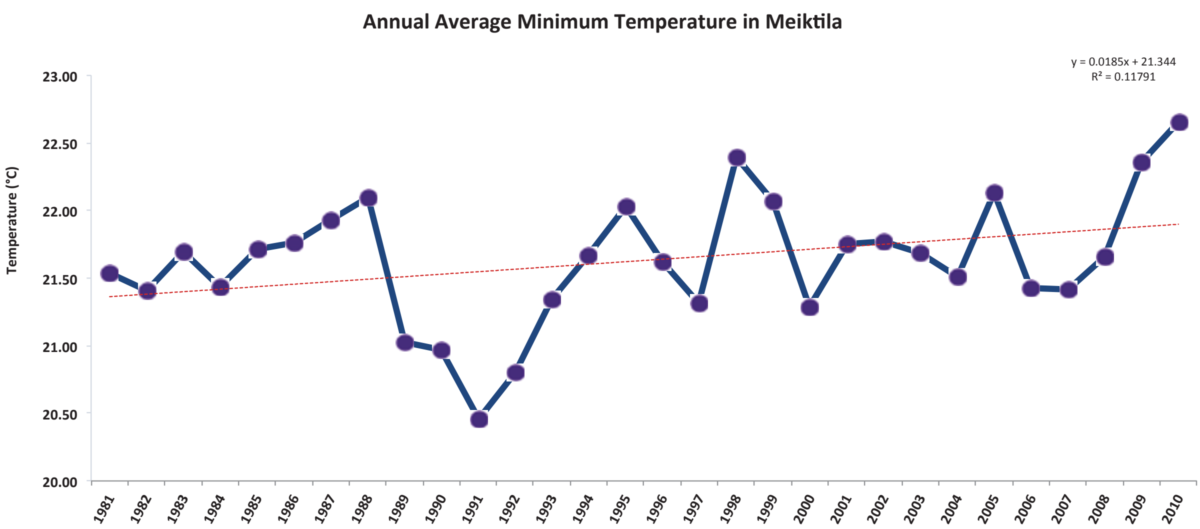



*Figure 13. Variability in average nighttime temperature in Meiktila, from 1981-2010. Warmest nights were recorded in 2010; the coolest nights were in 1991.*

2010, with night time temperature averaged at 22.65°C, was the warmest in 30 years. 242 nights, within the year, exceeded the average nighttime temperature. Six (6) nights exceeded 30°C, all in May. Warmest nighttime temperature, during the year, was recorded on 14 May (31.10°C; also the warmest in 30 years). The lowest nighttime temperature for the year was 11.10°C on 3 January.

On the other hand, 1991 recorded the coolest average nighttime temperature, at 20.46°C. 207 nights were warmer than average, with the warmest at 28°C (19 April). Lowest recorded nighttime temperature, in 1991, was 11°C (21 and 22 January).

Moreover, the coolest minimum temperature recorded, in 30 years, were in 6 January 1992 (8.80°C); 21 November 1981 (8.90°C); 9 February 1997 (9°C); 9.40°C was recorded in 23 and 24 January 1997; 9.50°C was registered in 25 January 1997 and 23 December 1983; and 26 and 27 December 1999 recorded 9.70°C.

The minimum temperature shows an increasing trend, suggesting that more nights of warmer temperatures (against average), had been experienced in 30 years.

### 3.2. COASTAL ZONE

### 3.2.1 Kyaukpyu Township, Rakhine Region

### 3.2.1.1 General Climatic Features

Kyaukpyu, in Rakhine Region, is located in Western Myanmar. Straddling 19°26'0"N and 93°33'0"E, Kyaukpyu is facing the Bay of Bengal (in Figure 14).

Receiving most of the rainfall from the Southwest Monsoon and from weather systems over the Bay of Bengal, Kyaukpyu is the wettest of the stations studied, with average annual rainfall of about 4,655mm.

Like many areas with dominance of Southwest Monsoon influence, Kyaukpyu receives significant rainfall from May to October, with unimodal peak (in July; refer to Figure 15).

Average annual daytime temperature, in Kyaukpyu, is around 29.8°C. The warmest months, in terms of daytime temperature, are April and May at around 32.4°C; coolest months are January (about 26.6°C) and December (at about 27.6°C).

Nighttime temperature, on the other hand, is warmest in May (25.74°C) and coolest in January (around 17°C) and February (18.4°C).

In the 30 years of analysis, the most extreme maximum temperature observed was 39.7°C, on 19 September 1988; lowest maximum temperature was in 31 December 1997 (19.1°C).

Warmest minimum temperature was recorded in 26 May 1983 (30°C); coolest minimum temperature was in 24 December 1983 (10°C).

Figures 16 and 17 provide details of daytime and nighttime temperature in Kyaukpyu.


*Figure 14. Kyaukpyu Township, in Rakhine Region, is positioned in front of the Bay of Bengal.*

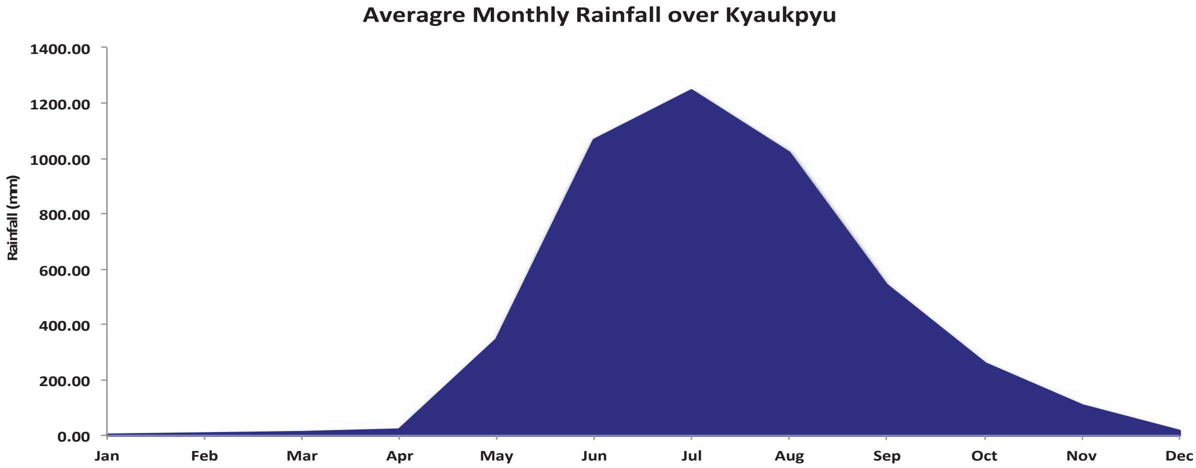



*Figure 15. Rainfall in Kyaukpyu is concentrated during the Southwest Monsoon months of May to October; rainfall peak is usually in July.*

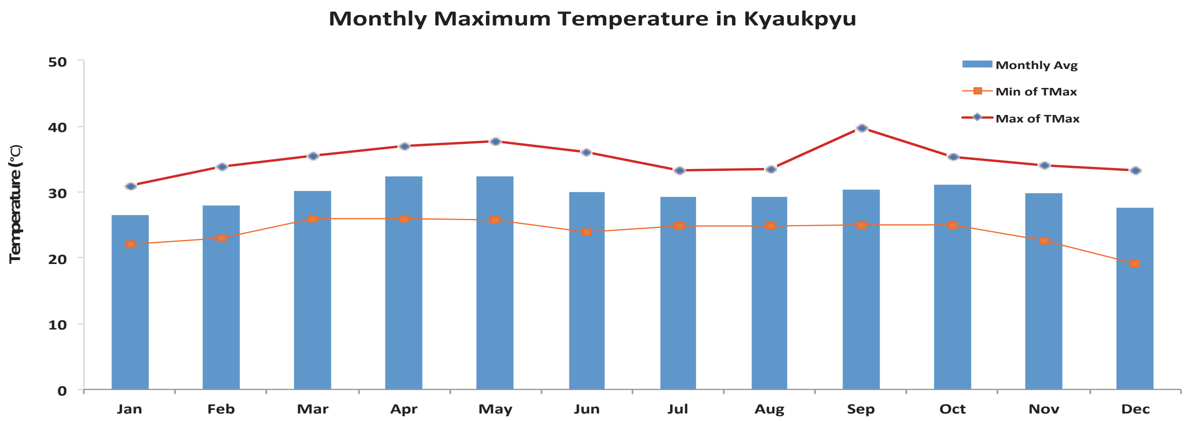



*Figure 16. Warmest daytime temperature in Kyaukpyu is normally in April and May, averaged at 32.4°C. Months of coolest average daytime temperature are January and December. Red marked lines indicate the warmest daytime temperature, for each month, recorded over 30 years; orange marked lines, on the other hand, provide the coolest daytime temperature, within the same period.*

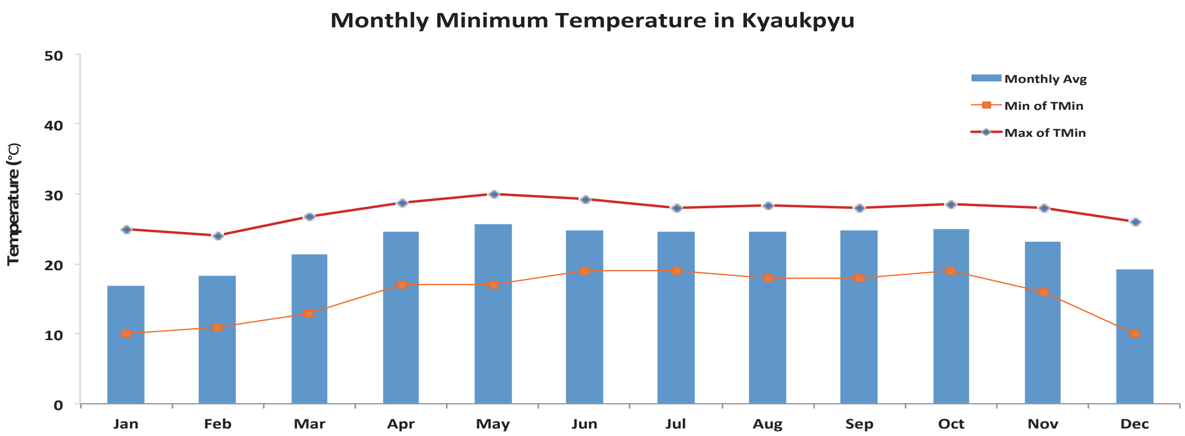



*Figure 17. Nighttime temperature in Kyaukpyu is normally warmest in May and coolest in January. Warmest and coolest temperatures recorded, for each month, are indicated by red and orange marked lines,*

### 3.2.1.2 Rainfall Variabilities, Extremes and Trends

#### Annual Rainfall

In contrast to Meiktila, which receives only 800mm of rainfall on an annual average, the coastal township of Kyaukpyu – the wettest of the townships studied – receives average annual rainfall of about 4655mm. Inter-annual variability is highly notable, with the wettest year, in 30 years (2001) observing 6511mm, which is exceeding the average by more than 1800mm. The lowest annual rainfall, on the other hand, was in 1981 (2821mm), with a negative anomaly of over 1800mm against the average (in Figure 18).

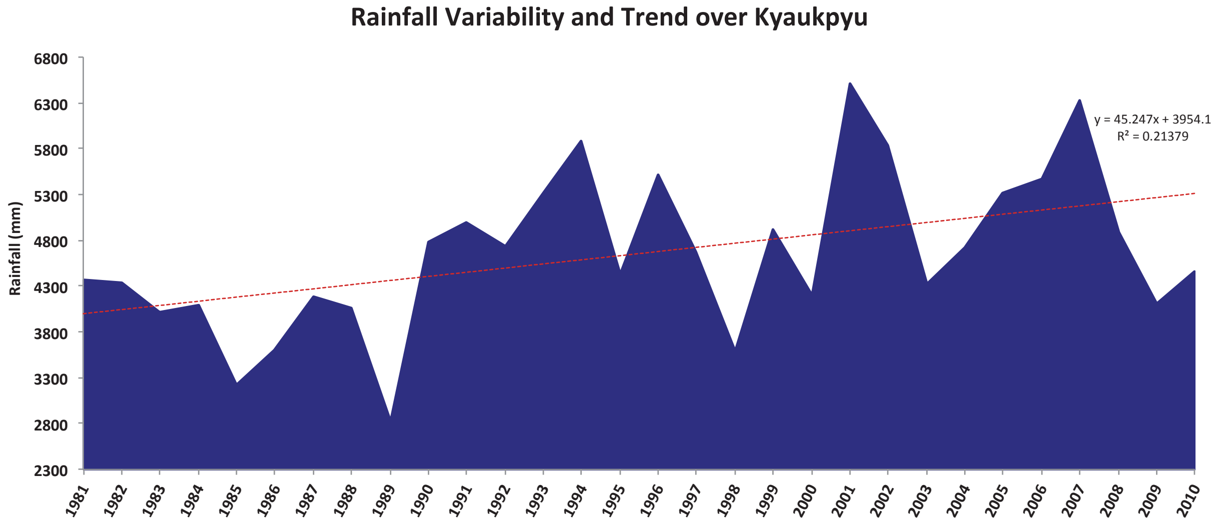



*Figure 18. Rainfall variability and trend over Kyaukpyu, from 1981-2010.*

Annual rainfall shows an increasing trend, indicative of significant positive deviation of observed rainfall, from average, within the period of study.

#### Wet and Dry Season Rainfall

Over-all, in Kyaukpyu, about 96% of annual rainfall is contributed by the wet season (Figure 19). Excursion from this pattern is noticeable in 1991, 2005, 1995, and 1990. In 1991, contribution of the wet season to annual rainfall was below 90%. This indicates that significant rainfall events have been recorded during the dry season.

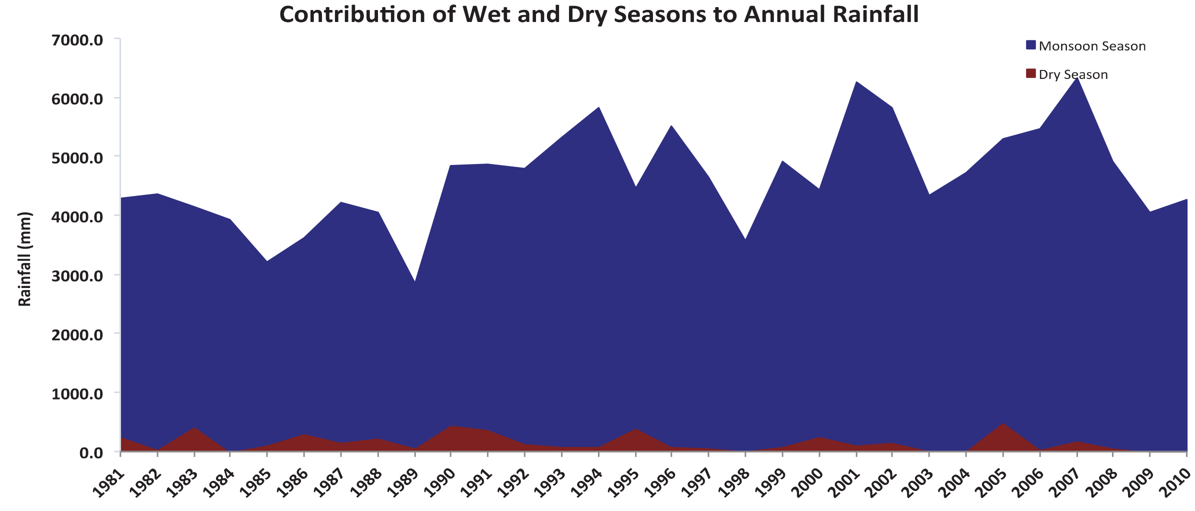



*Figure 19. Rainfall contributions, from wet and dry seasons in Kyaukpyu*

Wet season rainfall shows an increasing trend, mirroring the increasing trend in the annual average rainfall, against shorter wet season. The trend, in dry season rainfall, is decreasing.

### Extreme Rainfall Events

In the wettest year of 2001, four (4) days recorded extreme rainfall events of more than 200mm (21 June with 289mm; 31 March with 248mm; 13 August with 242mm; and 22 July with 209mm). 14 other events within the year recorded heavy rainfall events within the range of 100mm to 185mm, all happening within the wet season. It can be noted that 31 March 2001 recorded the 2nd highest extreme event within the period.

On the other hand, in the driest year of 1981, there was only one (1) rainfall event that exceeded 200mm (22 June 1981 with 212mm). Seven (7) days recorded rainfall within the range of 109mm to 142mm, all during the wet season, except in 20 November which recorded 123mm.

It should be noted that dry season months, during the wettest and driest years, have registered extreme rainfall events. While rainfall could be a resource to mainly rainfed areas during the dry season, these extreme rainfall events could also cause floods and other secondary hazards in different areas, depending on location-specific thresholds and other local conditions.

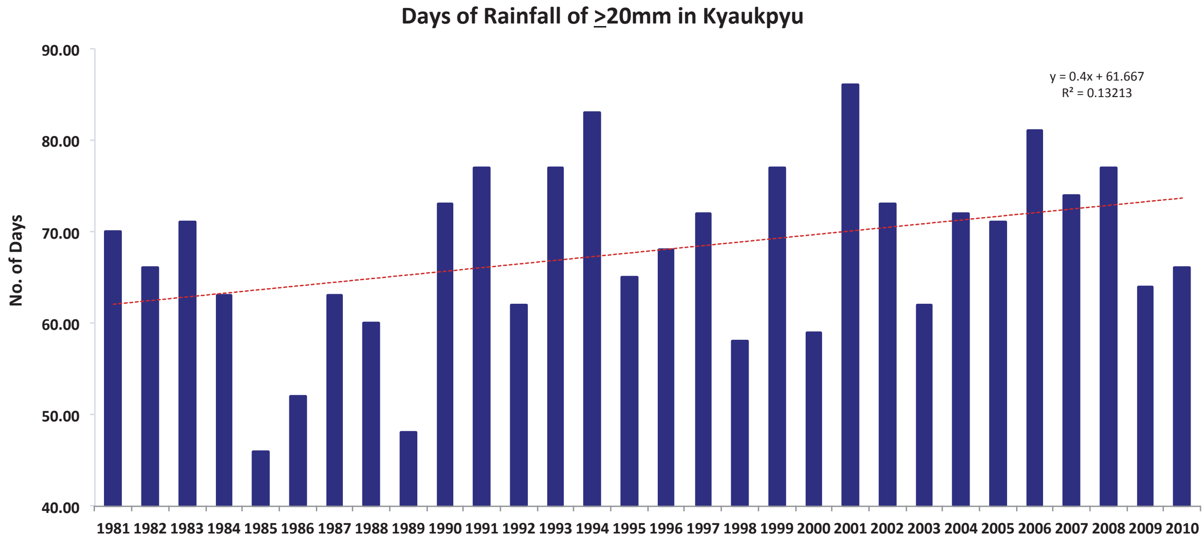
In 30 years, 1212 rainfall events were ≥40mm. Of this number, 295 24-hour events were ≥ 100mm. The most extreme 24-hour rainfall events were: 411mm on 6 July 2007; 394mm in 22 October 1992; and 344mm in 23 October 2010. 33 events were within the range of 200mm to 289mm and 259 24-hour events were within the range of 100mm-199mm.

While most of the extreme rainfall events in Kyaukpyu were recorded in the wet season, excursions have been recorded in the dry season - 10 rainfall events (1 in March, 8 in November and 1 in December) recorded rainfall events exceeding 100mm (Table 3). As mentioned in the outset, 31 March 2001 recorded 248mm rainfall.

The occurrences of heavy rainfall events are increasing, as provided in Figure 20.

**Table 3. Extreme Rainfall Events during the Dry Season in Kyaukpyu**

| 24-Hour Extreme Rainfall | Date Recorded |
|---|---|
| 248mm | 31 March 2001 |
| 166mm | 20 November 1995 |
| 144mm | 10 December 2010 |
| 138mm | 9 November 2005 |
| 134mm | 5 November 1991 |
| 130mm | 5 November 1990 |
| 123mm | 20 November 1981 |
| 113mm | 9 November 1986 |
| 104mm | 10 November 1983 |
| 103mm | 18 November 1988 |



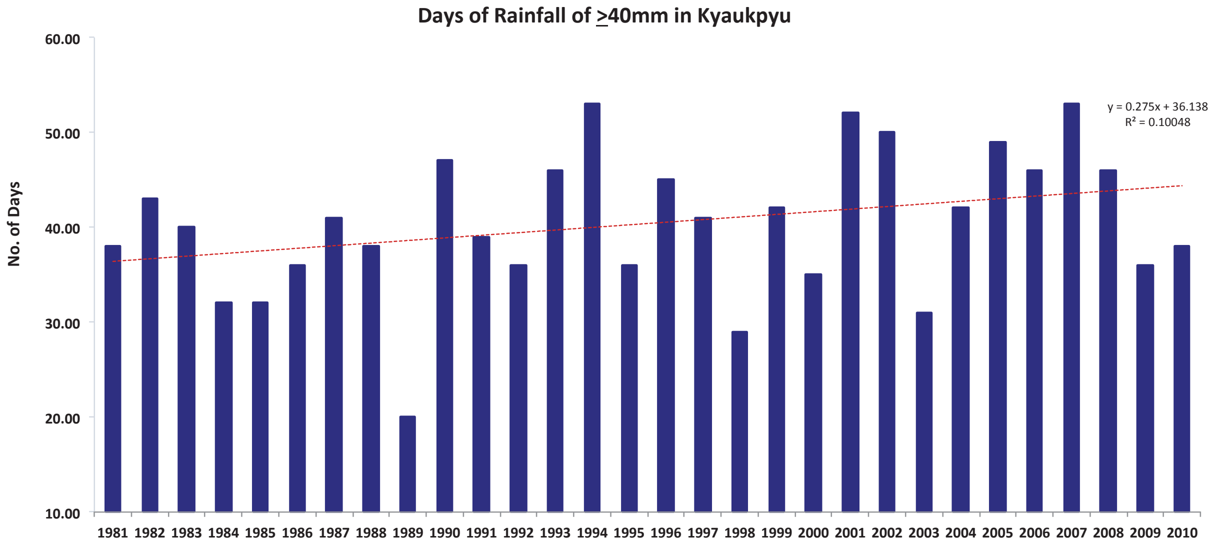




*Figure 20. Heavy rainfall events, of ≥20mm and ≥40mm (above and below, respectively) manifesting an increasing trend.*

### 3.2.1.3 Temperature Variabilities, Extremes and Trends

### Maximum Temperature

Maximum temperature, in Kyaukyu, is averaged at 29.76°C. The highest average annual temperature recorded was in 2010, at 30.59°C. In this year, 238 days exceeded the average temperature. The highest recorded temperature, within the year (36°C), was recorded 12 times, both in April and May. The lowest maximum temperature during the year was 25°C, recorded 2 times (both in December).

The lowest average maximum temperature was in 1983, at 29.34°C. Within this year, only 187 days were having maximum temperature over the average. Warmest temperature recorded, in 1983, was 35°C, on 24 April. 16 days recorded maximum temperature of 34°C, all in April and May. The lowest maximum temperature recorded was in 7 January and 31 December, at 23°C. Within 30 years, about 54% of the days registered maximum temperature above average. Of this, 43 days exceeded 35°C.

Kyaukpyu's average annual maximum temperature is provided in Figure 21. The annual maximum temperature suggests an increasing trend.

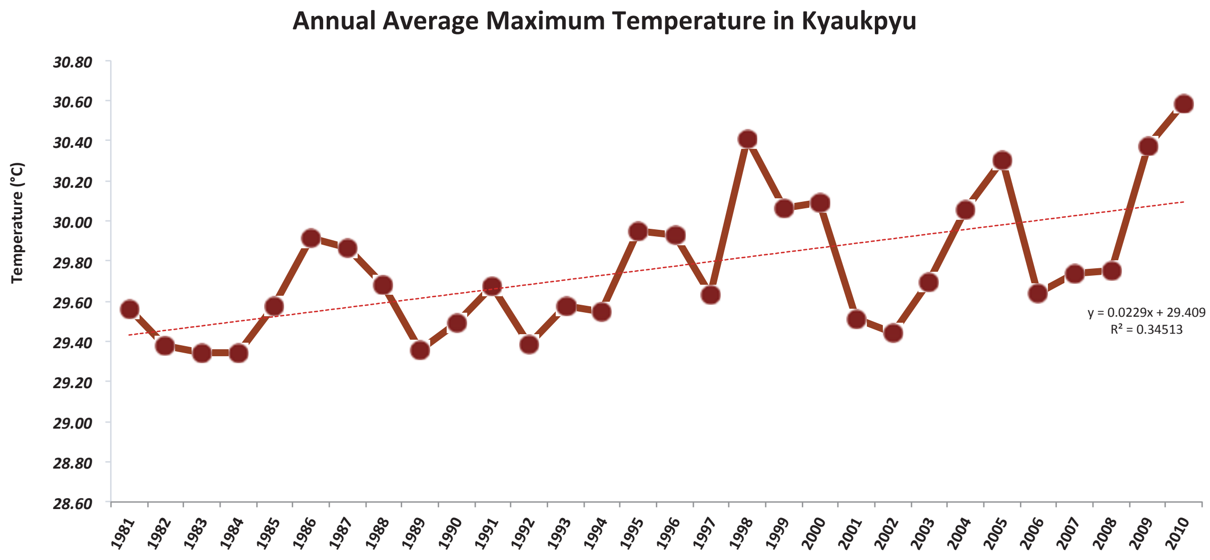



*Figure 21. Annual average maximum temperature, in Kyaukpyu, from 1981-2010 showing inter-annual variability and increasing trend.*

In 30 years, the highest temperature recorded was in 19 September 1988, at 39.7°C. The next warmest temperatures recorded were in 11 May 1986 (37.7°C) and in 3 April 1989 (37°C).

## Minimum Temperature

The coolest average minimum temperature was in 2004 at 20.49°C. Averaged at 22.79°C, the highest minimum temperature was in 1987, at 24°C. In 1987, the highest recorded minimum temperature of 29.5°C was in 23, 27 and 29 May. 263 days recorded minimum temperature above the average, with 168 nights exceeding 25°C.

In 2004, the highest minimum temperature (27°C) was in 11 June and 16 November; the lowest minimum temperature recorded was 10°C, recorded 14 times, all in the month of January. 176 days recorded minimum temperature higher than the average, with 26 days exceeding 25°C. About 52% of the nights in 2004 recorded minimum temperature below the average. Figure 22 presents the variability in annual average minimum temperature in Kyaukpyu.

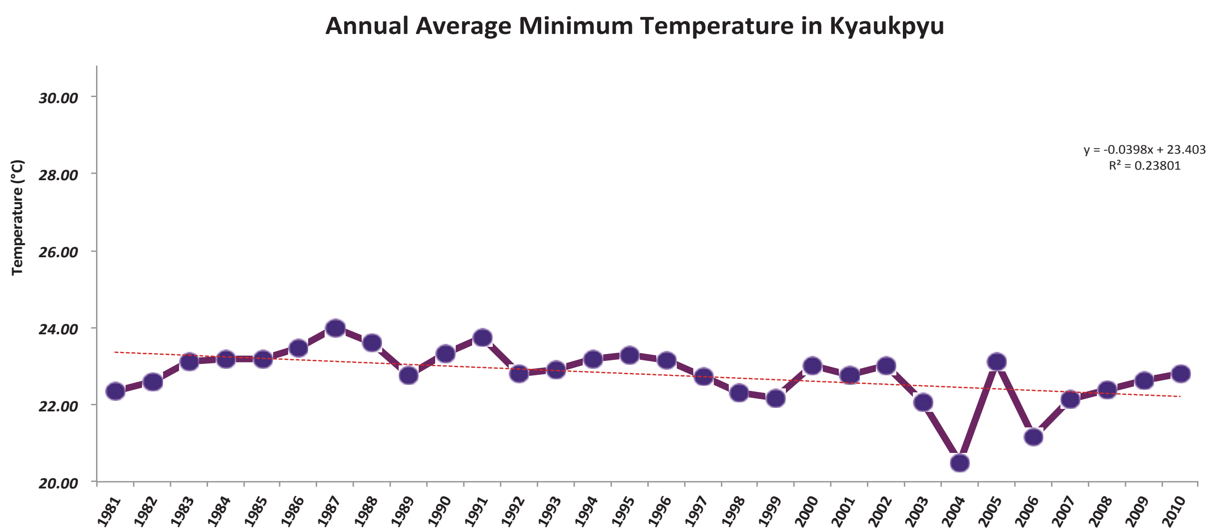



*Figure 22. Variability in annual minimum temperature in Kyaukpyu, from 1981-2010*

In 30 years, the warmest night was in 26 May 1983 (30°C); 29.5°C was recorded four (4) times, all in the month of May (in 1986, and thrice in 1987). About 23% of the nights in 30 years recorded minimum temperature exceeding 25°C and about 64% of the nights exceeded the average minimum temperature. Annual average minimum temperature suggests a decreasing trend, mainly due to night time temperatures below 20°C (about 27% of the total number of nights), with 10°C as the lowest recorded minimum temperature.

The data suggests nights have been cooler in Kyaukpyu.

### 3.2.2 Maylamyine Township, Mon State

#### 3.2.2.1 General Climatic Features

The township of Mawlamyine, in Mon State, is located in the Southern Myanmar (in Figure 23). Mawlamyine, strategically located at 16°29'N and 97°37"E, receives rainfall from both Southwest Monsoon and weather systems over the Bay of Bengal and Andaman Sea. Average annual rainfall is around 4638mm; Mawlamyine, as with many other areas in the coastal zone, is one of the very high rainfall receiving areas in the country.


*Figure 23. Mawlamyine Township in Mon State*

Highly influenced by the Monsoon, the wet season establishes in May, peaks in August and starts to recede by September (in Figure 24). Average rainfall in August, is around 1140mm.

The warmest days in the township are normally in March and April, averaging at 35.5°C and 35.6°C, respectively. On the average, the days in January are the coolest, at 18.4°C. The average monthly daytime temperature is supplied in Figure 25.

Extremely warm daytime temperature, of 37.70°C was recorded twice in Mawlamyine, both in April 1992. Coolest daytime temperature is 21°C (18 October 1992).

On the other hand, nighttime temperatures are warmest in April (24.7°C) and in May (24.3°C). Warmest night time temperature recorded in 30 years was 29.20°C (19 April 1991); coolest was in 26 December 1999, at 8°C.

Details on Mawlamyine's nighttime temperature is provided in Figure 26.

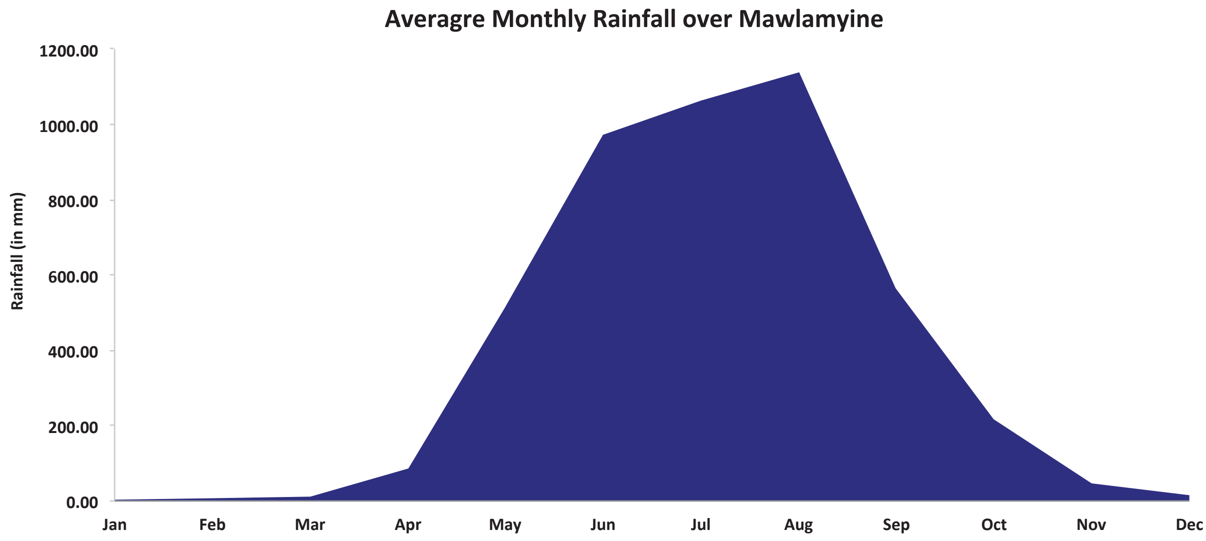



*Figure 24. Average monthly rainfall in Maylamyine showing rainfall being generally confined within the months of May to October, as with many other areas in the country influenced by the Southwest Monsoon*

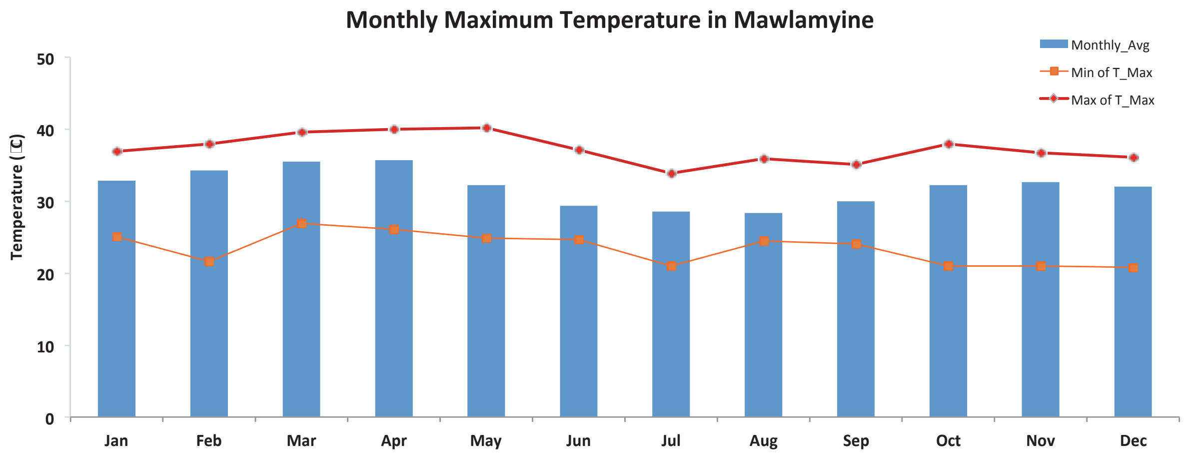



*Figure 25. Maximum temperature in Mawlamyine, averaged monthly, in blue bars; the red marked lines indicate the highest recorded maximum temperature; the orange marked lines provide the lowest observed maximum temperatures.*

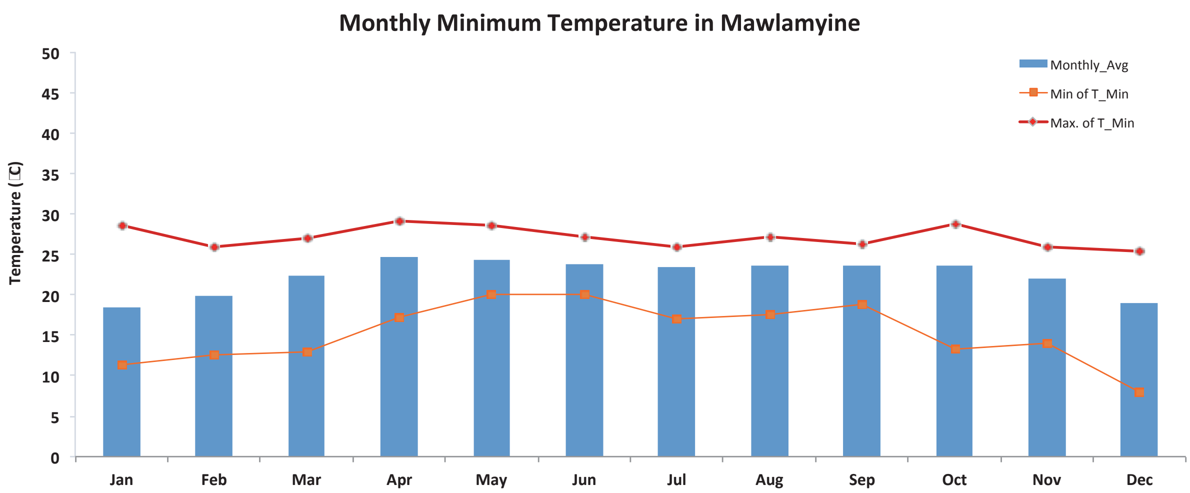



*Figure 26. Average monthly minimum temperature in Mawlamyine, in blue bars; the red marked lines indicate the highest recorded minimum temperature; the orange marked lines shows the lowest observed minimum temperatures.*

### 3.2.2.2 Rainfall Variabilities, Extremes and Trends

#### Annual Rainfall

Mawlamyine, with annual average rainfall of 4638mm, exhibits strong inter-annual variability. Figure 27 shows that the highest observed rainfall in 30 years was in 1999, with 6455mm – a positive anomaly of about 40% against average annual rainfall. The year with the lowest rainfall was in 1983, registering only 50% of average annual rainfall (2158.60m).

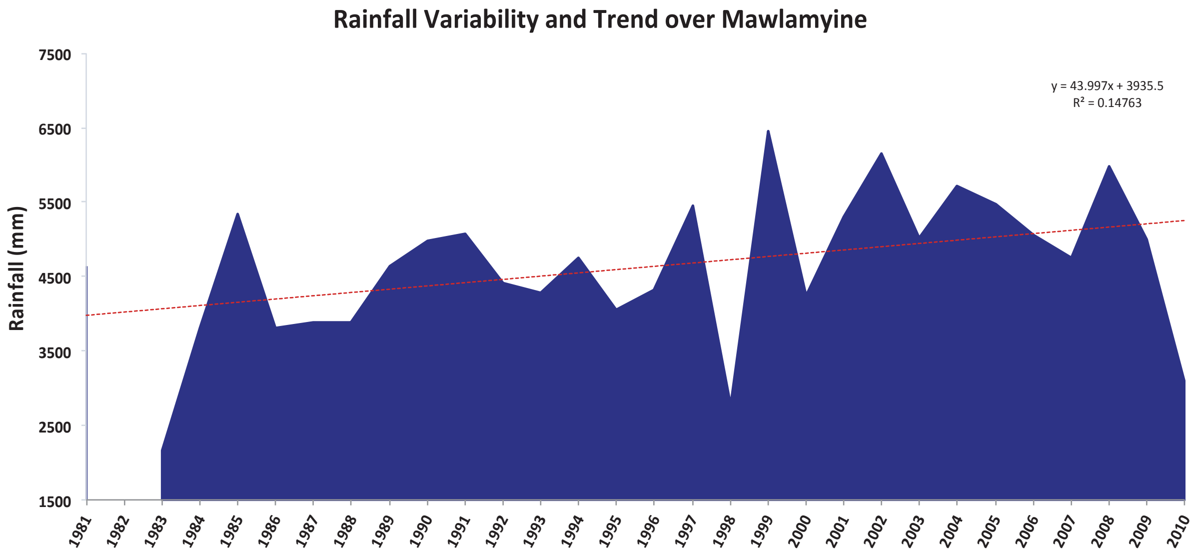



*Figure 27. Rainfall variability and trend over Mawlamyine, from 1981-2010; data, for 1982, is not available.*

Increasing trend is manifest in annual rainfall.

#### Wet and Dry Season Rainfall

As with many coastal areas, the wet season in Mawlamyine contributes tremendously to annual rainfall (Figure 28). Averaged over the baseline period, 96% of the annual average rainfall is attributed to the wet season; inter-annual variability, however, is high.

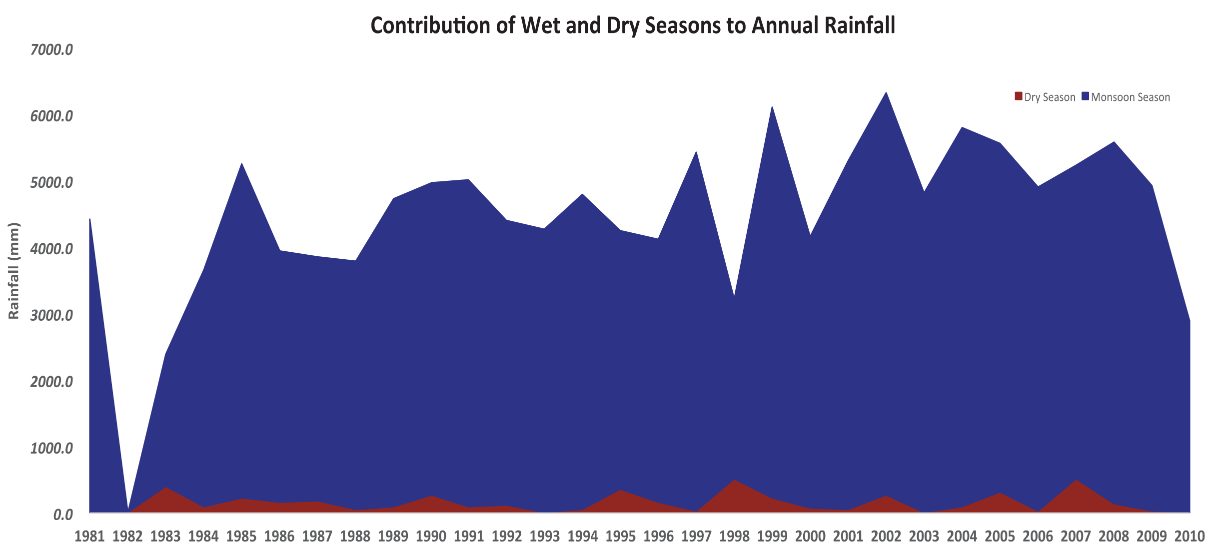



*Figure 28. Contribution of wet and dry seasons to annual rainfall in Mawlamyine.*

As mentioned previously, 1999 is the wettest year in Mawlamyine. It should be noted that the lowest contribution from the wet season (91%), to annual rainfall, was recorded in 1999; contribution of the dry season rainfall, during the year, was about 579mm.

On the other hand, 1994 recorded the highest wet season contribution to annual rainfall, at around 99.9% - observed rainfall was 4757; only 6mm was observed during the dry season.

The wet season in Mawlamyine is showing an increasing trend.

## Extreme Rainfall Events

Evaluation of observation data, for 1999, shows that 53 events exceeded 40mm; 16 events were very heavy rainfall events exceeding 100mm. All of the rainfall events ≥40mm have been recorded within the wet season, except two (2) events in April which registered among the highest rainfall events for the year: 165mm in 25 April and 231mm in 26 April. The highest recorded rainfall within the year, was 290mm, in 16 September. Four (4) other rainfall events exceeded 200 mm (269mm in 2 July; 247mm in 1 July; 231mm in 26 April, 207mm in 26 July).

On the other hand, the driest year of 1983 had 19 events above 40mm; very extreme rainfall events, of more than 100mm were recorded in 5 October (121mm, the highest amount of rainfall received during the year); 8 September (115mm); and 4 October (101mm). All rainfall events exceeding 40mm were during the wet season except for 30 December which recorded 66.80mm.

Of the years of record, within the baseline period, the highest 24-hour rainfall was in 15 June 2004 (481mm). 232 rainfall events were ≥100; of these, 27 events exceeded 200mm. Six (6) events of ≥100 were recorded in the dry months April, November and December, in Table 4.

| Table 4. Extreme Rainfall Events during the Dry Season in Mawlamyine | |
|---|---|
| **24-Hour Extreme Rainfall** | **Date Recorded** |
| 236mm | 30 April 2008 |
| 231mm | 26 April 1999 |
| 164mm | 25 April 1999 |
| 152mm | 29 April 2008 |
| 110mm | 15 November 1995 |
| 104mm | 10 December 2010 |

Heavy rainfall events of ≥20mm and ≥40mm suggest an increasing trend, indicative of the increasing occurrences of extreme 24-hour rainfall (Figures 29 and 30)

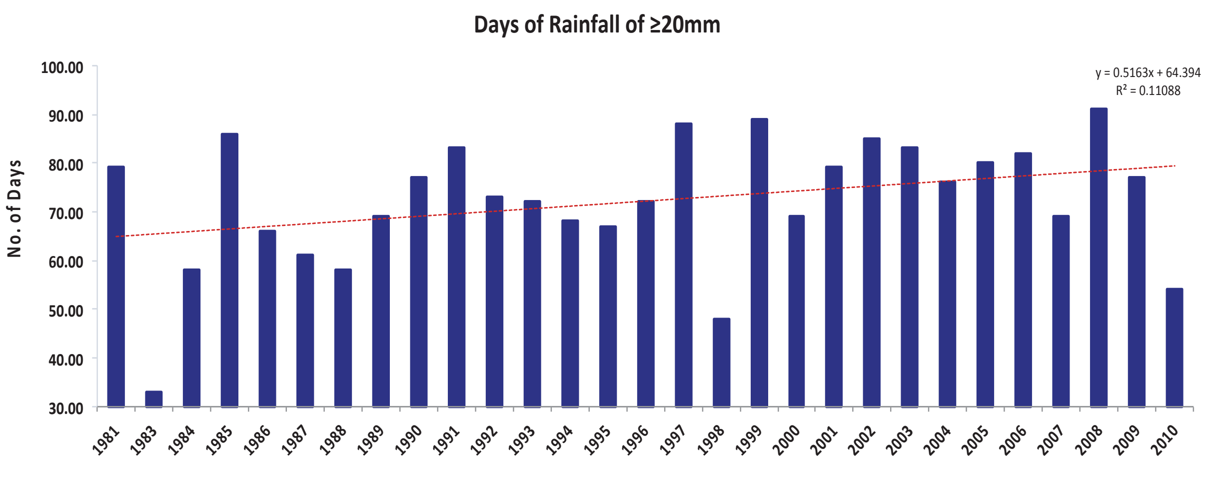



*Figure 29. Heavy rainfall events of* ≥20mm, from 1981-2010, indicating an increasing trend.

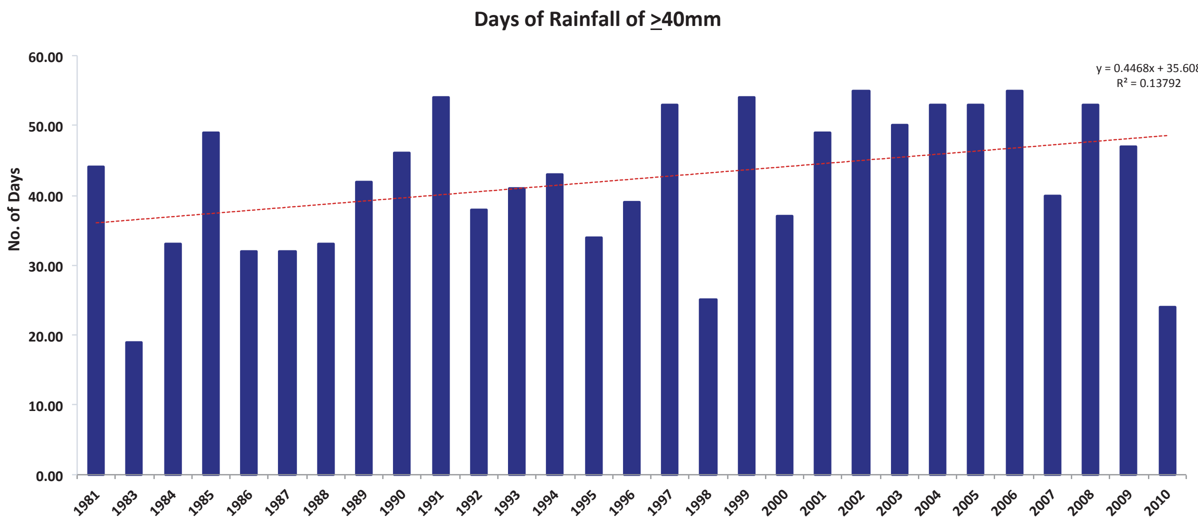



*Figure 30. Heavy rainfall events ≥40mm manifest an increasing trend in Mawlamyine.*

### 3.2.2.3 Temperature Variabilities, Extremes and Trends

#### Maximum Temperature

The average maximum temperature, in Mawlamyine, is 31.97°C. 1998 recorded the warmest days, on the average, at 33.11°C; the lowest average daytime temperature was in 1992 (31.15°C). This variability in annual average maximum temperature is provided in Figure 31.

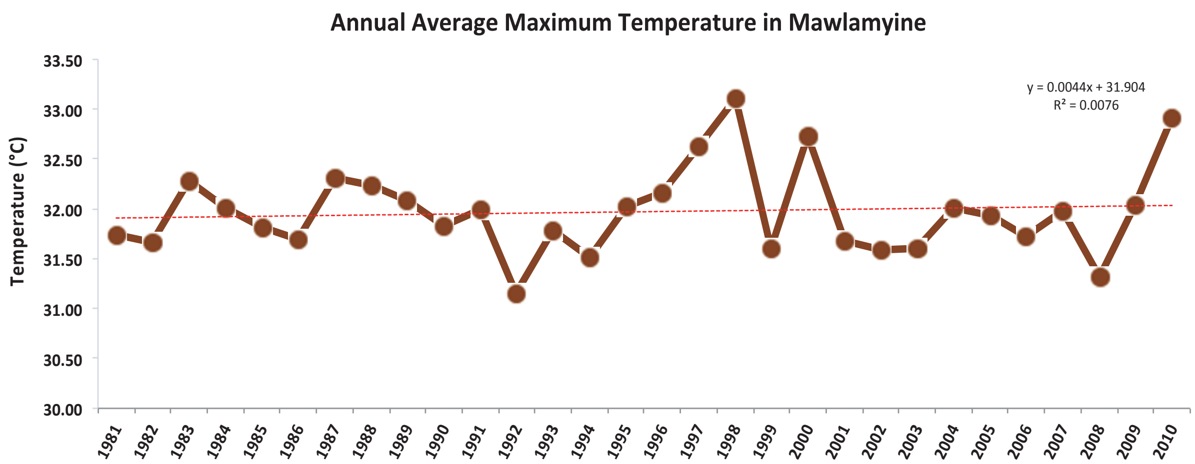



*Figure 31. Variability in annual average maximum temperature in Mawlamyine. 1998 has recorded the highest average maximum temperature; the day time temperatures in 1992 averaged to be the lowest from 1981-2010.*

In 1998, the highest maximum temperature observed was 40.20°C (in 8 May; also the highest observed maximum temperature in 30 years). 247 days had temperature exceeding the average; of these, 86 days had temperature exceeding 35°C. Day time temperature of ≥40 was recorded twice, on the consecutive days of 7 and 8 May.

1992, on the other hand, observed 37.70°C as its warmest day time temperature (in 26 April). 162 days recorded temperatures exceeding the average; of the number, 30 days had temperatures higher than the average. The lowest maximum temperature, in 30 years, of 21°C was recorded during the year (18 October).

In 30 years, three (3) days had maximum temperature of ≥40°C, recorded in April and May. 57% of the days, from 1981 – 2010, exceeded the average; 15% of the days, in 30 years, had maximum temperature exceeding 35°C. The slightly increasing trend of maximum temperature is also indicated in Figure 31.

## Minimum Temperature

Nighttime temperature, in Mawlamyine, is averaged at 22.38°C. The highest average night time temperature was in 1981 (23.03°C). On the other hand, the coolest average nighttime temperature was in 1992 (21.01°C). The average minimum temperature, from 1981-2010, is provided in Figure 32.

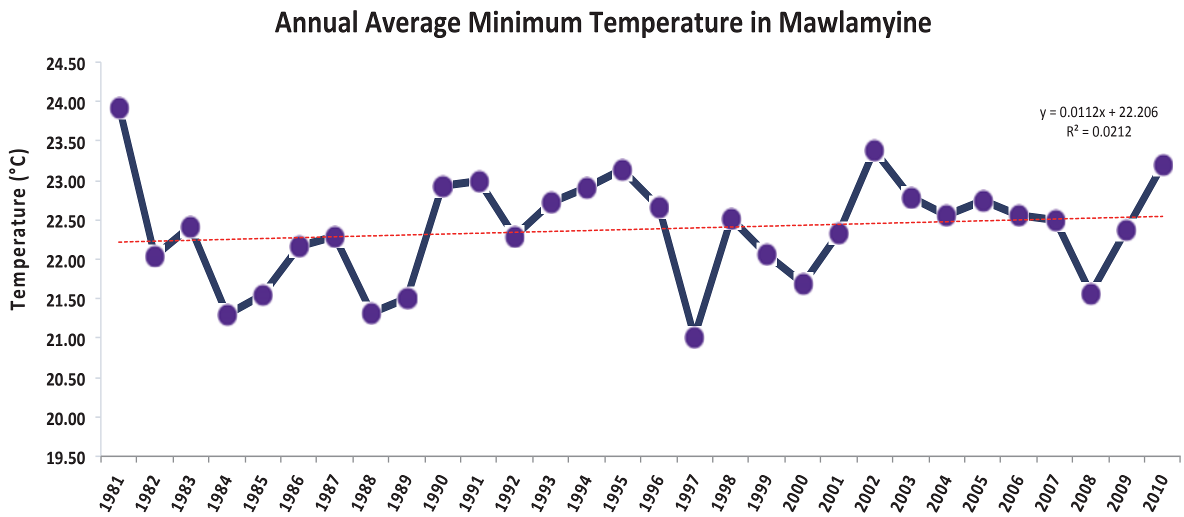



*Figure 32. Annual average minimum temperature in Mawlamyine. On the average, the warmest nights were recorded in 1981; the coolest nights were in 1997.*

In 1981, about 86% of the nights observed temperatures higher than the average; 82 nights had temperature higher than 25°C. The highest nighttime temperature, during the year, was 27°C, recorded 13 times – all in the months of March, April and May. The lowest nighttime temperature observed in 1981 was 14.70°C.

It can be noted that while 1992 was the year of coolest nights, on the average, it registered minimum temperature (29°C, in 18 April) exceeding the highest minimum temperature in 1981. In 1992, however, only 219 nights (about 60% of the nights during the year) had temperatures that exceed the average; 54 nights observed temperatures higher than 25°C. The lowest night temperature recorded within the year was 13°C, in 29 February.

Both day time and night time temperatures are exhibiting increasing trends, suggesting that in general, warmer daytime and nighttime temperatures had been experienced in the period of analysis.

### 3.2.3 Hpa-An Township, Kayin Region

#### 3.2.3.1 General Climatic Features

Hpa-An Towship, in Kayin Region, is situated close to Mawlamyine (in Figure 33). The rainfall pattern, which is unimodal, is similar that of other coastal areas. The rainfall in Hpa-An, on the average, is lower compared to Kyaukpyu and Mawlamyine. Average annual rainfall is around 4,270mm, with peak in July and August (Figure 34).

The hottest months are March (37.13°C) and April (37.45°C), in both daytime and nighttime average temperature.

The coolest daytime average temperature is in the wet months of July (29.01°C) and August (28.95°C). The coolest nights are in January (18.45°C) and February (19.32°C). Daytime temperature, however, in January and February are high, both averaged at over 33°C.

Extremely hot daytime temperature was in 6 May 1998 (43.6°C); Consecutively, the 2nd and 3rd warmest days (43°C and 42.5°C) were 7 May and 8 May 1998, respectively. Coolest daytime temperature was in 21.6°C, recorded in 17 and 18 November 1988.

On the other hand, extremely warm nighttime temperatures were in 19 April 1991 and 4 May 1995 (28.6°C). 28.5 °C and 28.4°C were observed in 31 March and 9 May, both in 1998. Coolest nighttime temperature was in 25 and 26 December 1999 (10.7°C and 10.8°C, respectively).

Average monthly maximum and minimum temperatures, with highest and lowest recorded maximum and minimum temperatures in various months, are provided in Figures 35 and 36.


*Figure 33. Hpa-An Township in Kayin State*

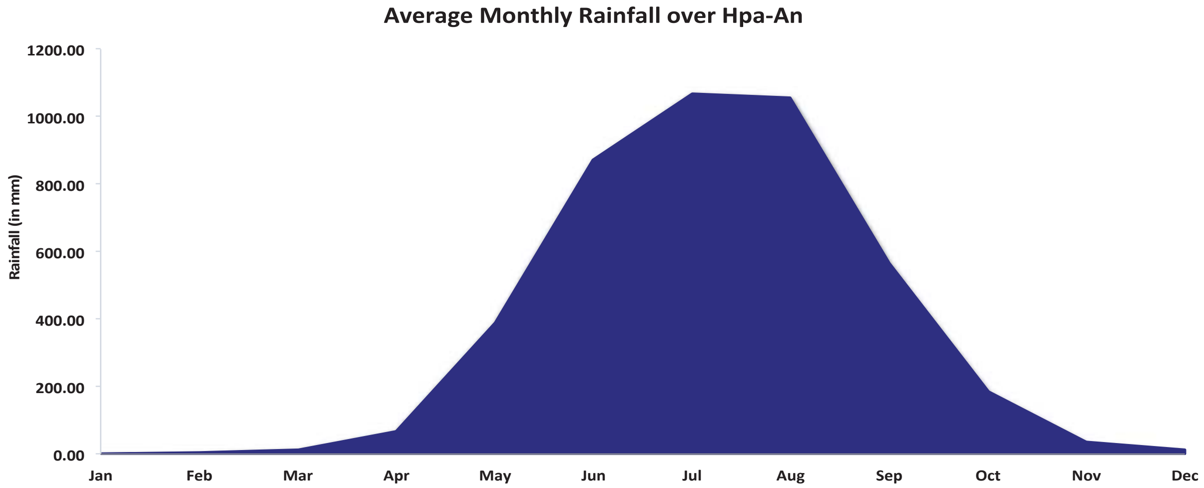



*Figure 34. Monthly average rainfall in Hpa-An vis-à-vis the 1981-2010 baseline period. The unimodal rainfall pattern, peaking in July and August, indicates the influence of the Southwest Monsoon over the rainfall in the area.*

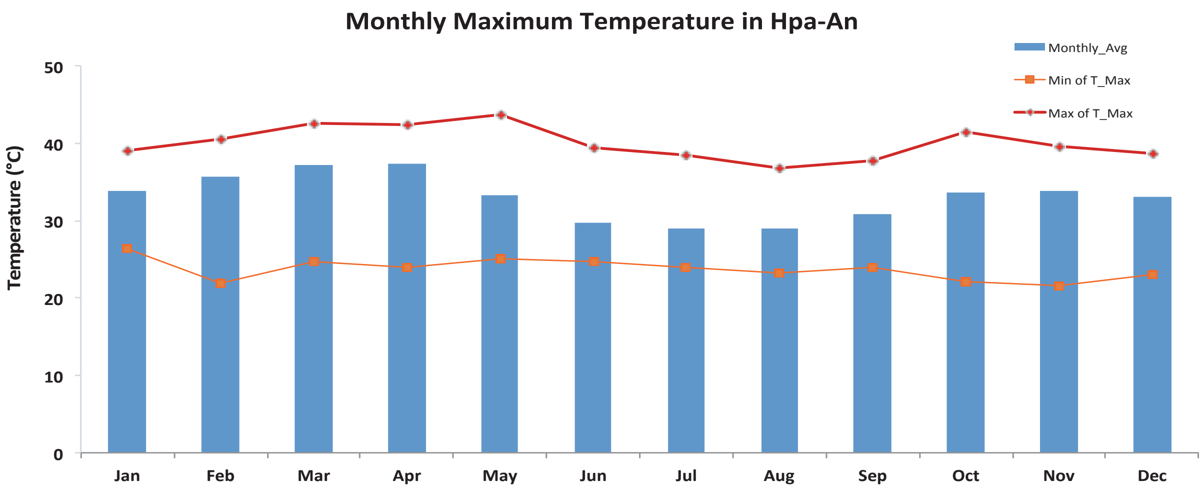



*Figure 35. Monthly average maximum temperature in Hpa-An (blue bars). Highest and lowest maximum temperatures, monthly, are indicated in red and orange marked lines, respectively*

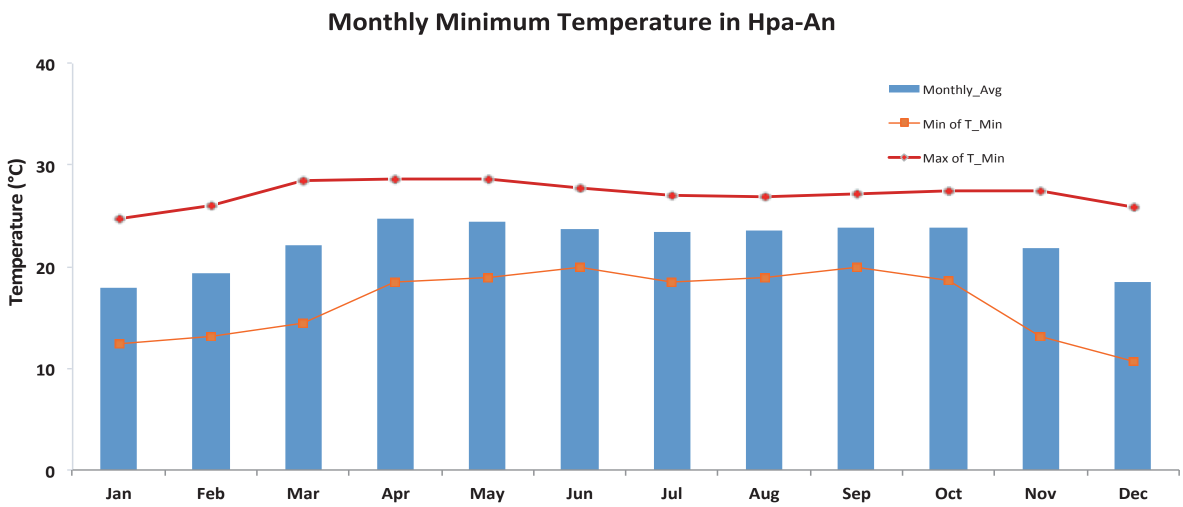



*Figure 36. Monthly average minimum temperature in Hpa-An, based on 1981-2010 baseline data (indicated in blue bars. The red marked line shows the highest minimum temperature recorded, while the orange marked line identifies the lowest minimum temperature recorded, monthly.*

### 3.2.3.2 Rainfall Variabilities, Extremes and Trends

#### Annual Rainfall

Inter-annual rainfall variability is highly marked in Hpa-An (Figure 37). Averaging at 4267mm annually, the highest observed rainfall was recorded in 1994 at 5472mm – a positive anomaly of more than 1,200mm against the average. Four (4) other years recorded observed rainfall of more than 5000mm (5283mm in 1997; 5244mm in 1982; 5232mm in 1999; and 5108mm in 2008). 1998 was the driest year, recording only 2669mm, nearly 1600mm below the average.

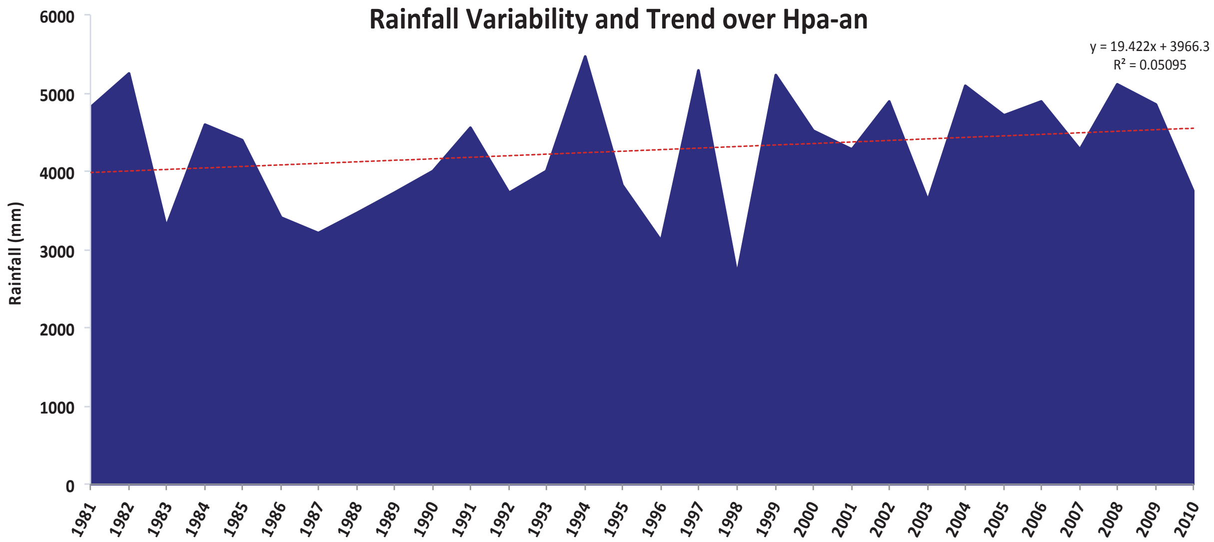



*Figure 37. Rainfall variability, over Hpa-An, from 1981-2010. The wettest year was in 1994; while 1998 recorded the least amount of rainfall. The annual rainfall shows an increasing trend.*

The trend in annual rainfall is increasing, with wet days averaged at 132 annually. 15 years recorded wet days that exceeded the average; equal number of years recorded wet days under the average.

#### Wet and Dry Season Rainfall

In Hpa-An, almost 97% of annual rainfall is contributed by the wet season. The highest excursion in terms of quantity was in 2008, where the dry season recorded 547mm (more than 10% contribution to the annual rainfall of 5108mm). It can be noted from Table 6 that 2008 recorded three (3) rainfall events of ≥55mm, all in April. Percentage-wise, 2007 recorded about 11% dry season contribution to annual rainfall.

The driest dry season was in 2004, contributing only 4mm to an annual rainfall of 5101mm; almost 100% of the annual rainfall was contributed by the wet season. The contribution of the wet season to the annual rainfall, from 1981 to 2010, is provided in Figure 38.

Rainfall in both the wet and dry seasons manifest an increasing trend.

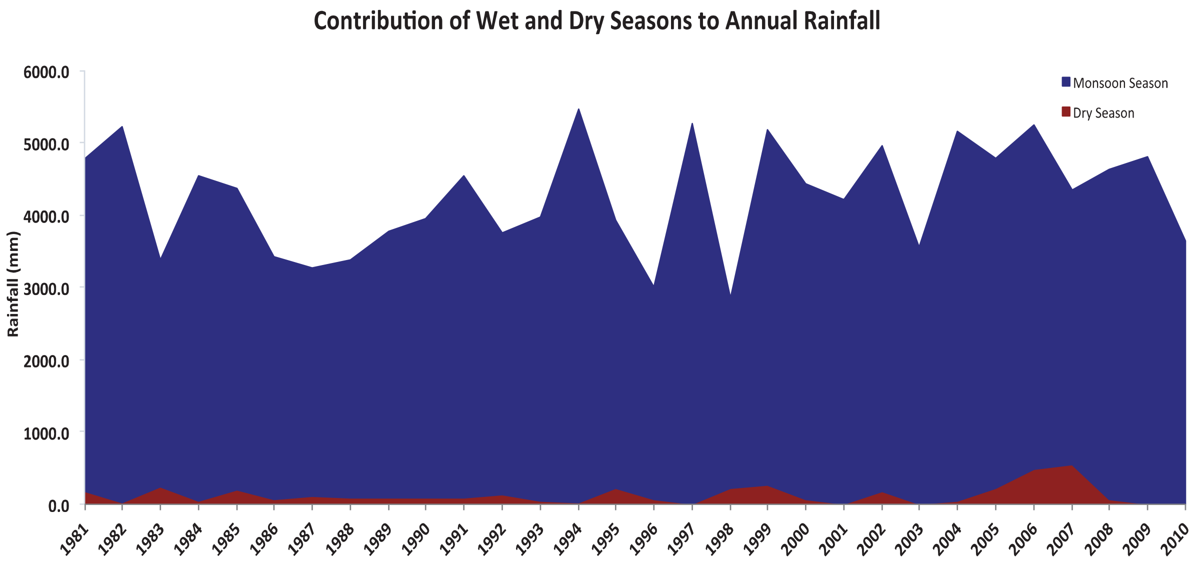



*Figure 38. Wet and dry seasons contribution to annual rainfall in Hpa-An, from 1981-2010.*

## Extreme Rainfall Events

In the wettest year of 1994, 54 rainfall events exceeded 40mm; six (6) events exceeded 100mm (159mm in 15 August; 150mm in 6 July; 136mm in 16 August; 135mm in 19 July; and 133mm in 8 July; and 123mm in 7 July). Within the year, all rainfall events ≥40mm took place within the wet season.

The driest year of 1998 recorded 20 events exceeding 40mm. The most extreme rainfall during the year was 111mm, in 9 August 1998. Two (2) other events exceeded 100mm (103mm in 11 September; and 102mm in 10 June). All rainfall events ≥40mm were recorded within the wet season.

About 10.4% of the days of record (1138 days), in 30 years, registered rainfall ≥40mm. 175 events exceeded 100mm. The most extreme 24-hour rainfall observed was in 6 July 2006, at 349mm. Eight (8) events, during the period exceeded 200mm of rainfall, in Table 5.

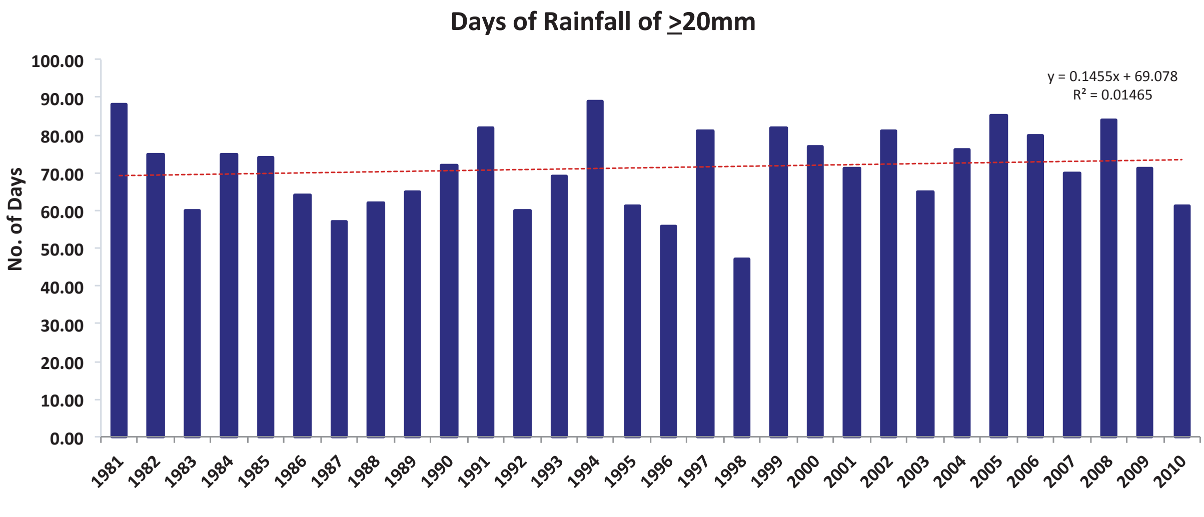
| **Table 5. Most Extreme Rainfall Events in Hpa-An from 1981-2010** | |
|---|---|
| **24-Hour Extreme Rainfall** | **Date Recorded** |
| 349mm | 6 July 2006 |
| 316mm | 24 June 2004 |
| 246mm | 4 July 2009 |
| 239mm | 1 July 1997 |
| 238mm | 24 August 1997 |
| 234mm | 10 September 1982 |
| 216mm | 29 July 2008 |
| 203mm | 30 July 1995 |

In the inclusive period of analysis, significant heavy rainfall events were recorded during the dry season. Specifically, 14 events exceeded 40mm in the dry season, in Table 6.

| **Table 6. Most Extreme Rainfall Events in the Dry Season in Hpa-An from 1981-2010** | |
|---|---|
| **24-Hour Extreme Rainfall** | **Date Recorded** |
| 135mm | 21 April 2008 |
| 130mm | 26 April 2007 |
| 107mm | 20 April 2008 |
| 105mm | 14 November 1985 |
| 69mm | 4 November 1981 |

| | |
|---|---|
| 65mm | 1 December 2010 |
| 62mm | 13 November 1999 |
| 55mm | 15 April 2008 |
| 48mm | 25 December 1992 |
| 45mm | 29 December 1983 |
| 44mm | 13 April 1981, |
| 44mm | 12 November 1985 |
| 41mm | 27 April 1996 |
| 41mm | 23 April 2007 |

Analysis, of heavy rainfall events (≥20mm and ≥40mm), suggests increasing trend (Figure 39).



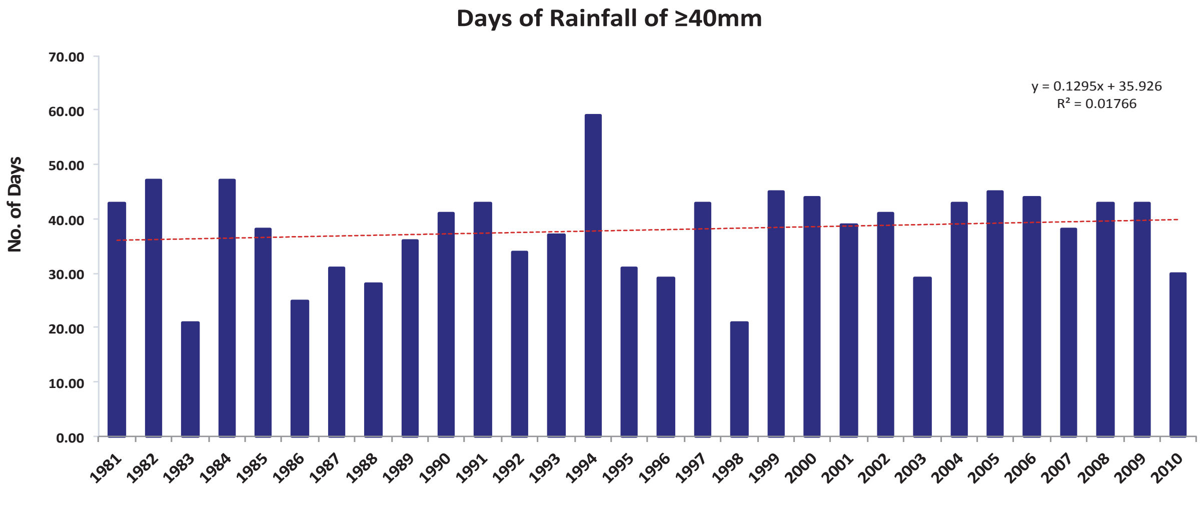




*Figure 39. Heavy rainfall events of ≥20mm and ≥40mm in Hpa-An suggesting increasing trend.*

### 3.2.3.3 Temperature Variabilities, Extremes and Trends

#### Maximum Temperature

Maximum temperature in Hpa-An is averaged at 33.05°C. 30 years record of maximum temperature shows inter-annual variability (in Figure 40). The highest average maximum temperature was in 1998 (35.03°C); the lowest average day time temperature, on the other hand, was in 1982 (31.69°C).

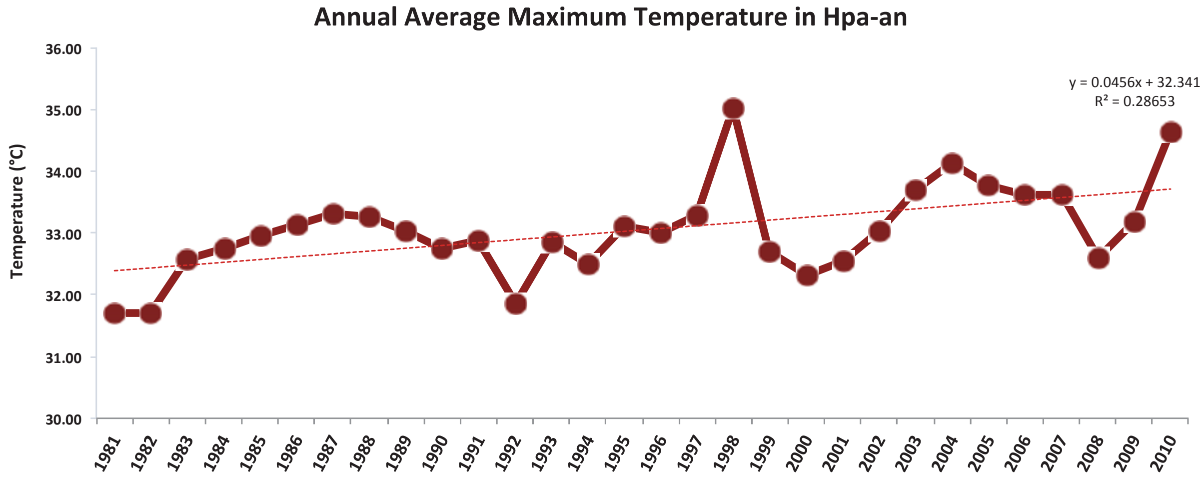



*Figure 40. Variability and trend in annual average maximum temperature, in Hpa-An, from 1981-2010*

1998 observed the warmest day in 6 May (43.6°C, also the warmest recorded in 30 years); 43°C was recorded the following day, 7 May. During the year, about 55% of the days had maximum temperature exceeding the average. Very warm daytime temperature, exceeding 40°C, was recorded in 32 days within the year.

1982, recording the lowest average maximum temperature, has 78 days (about 21% of the days in the year) with temperature higher than the average. Six (6) days recorded maximum temperature of ≥38°C. The highest maximum temperature observed during the year was 38.7°C (11 November).

In 30 years, about 32% of the days had temperature that exceeded the average. Maximum temperature in 151 days exceeded 40°C. As mentioned in the outset, the highest temperature observed, over the 30 years, was 43.6°C, in 1998. The lowest maximum temperature recorded was 21.6°C, recorded in 17 and 18 November 1988.

The maximum temperature, from 1981-2010, indicates an increasing trend, suggesting that warmer days had been experienced during the period.

**Minimum Temperature**

The highest nighttime temperature in Hpa-An was in also in 1998, indicating that both the warmest day time and night time temperatures had been recorded during the same year.

The average minimum temperature is 22.28°C. In 1998, about 74% of the nights exceeded the average; 42% of the nights had temperature exceeding 25°C. The warmest night, during the year, was in 31 March at 28.5°C.

The lowest average nighttime temperature in Hpa-An was in 2004 (20.68°C). Evaluation of nighttime temperature data, during the year, indicated that about 94 nights exceeded the average; and only one (1) night exceeded 25°C (25.5°C, which is also the highest night time temperature during the year).

In 30 years, the warmest nights were in 19 April 1991 and 4 May 1995, both at 28.6°C. About 64% of the nights exceeded the average minimum temperature; and about 12% of the nights had temperature that exceeded 25°C. There were only six (6) nights where temperature was within the range of 28°C to 28.6°C.

The annual average minimum temperature in Hpa-An, from 1981-2010, is provided in Figure 41.

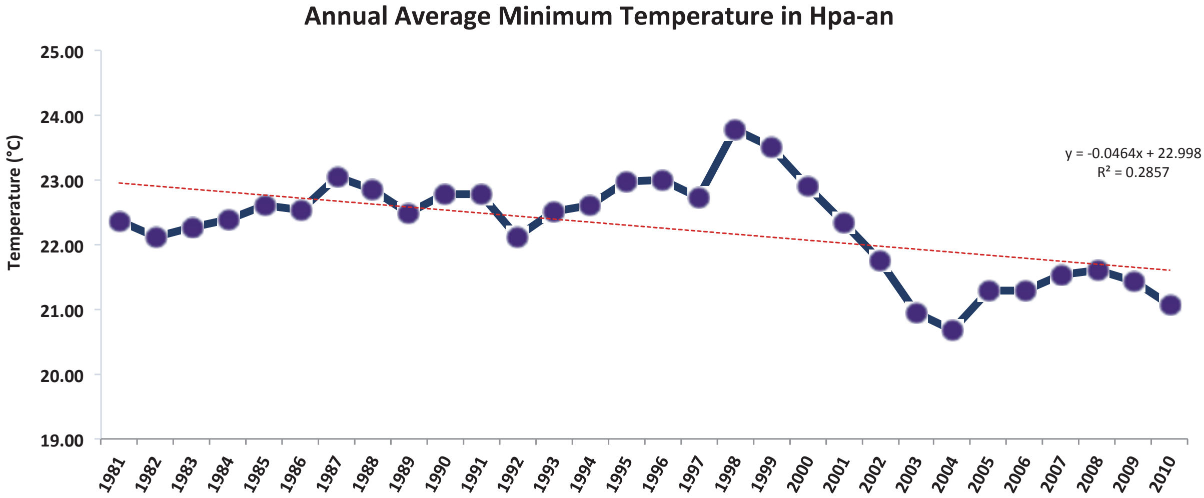



*Figure 41. Annual average minimum temperature in Hpa-an, from 1981-2010. The warmest nights, on the average, were in 1998 and the coolest nights were in 2004.*

Analysis of the occurrence of very warm nights indicates a decreasing trend, opposing the increasing tendency of very hot daytime temperature. This implies warmer days and cooler nights in Hpa-An.

### 3.2.4 Labutta Township, Ayeyarwady Region

### 3.2.4.1 General Climatic Features

Labutta Township in Myanmar's delta (Figure 42), is flanked by the Bay of Bengal to the West and the Andaman Sea to the South. The position of the township exposes it to the Southwest Monsoon and other weather systems over the Bay of Bengal and Andaman Sea.


*Figure 42. Labutta Township in Ayeyarwady Region*

Rainfall in Labutta exhibits a unimodal behavior (in Figure 43), with the wet season starting in May, peaking in July and August, and starts receding from September; November-April records minuscule amounts of rainfall. This rainfall pattern suggests high influence of Southwest Monsoon over rainfall in the township.

Excursion, however, from this pattern could occur in cases where severe weather events, along the Bay of Bengal and/or Andaman Sea, affect Labutta in the dry season.

Labutta is typically warmest in April (maximum temperature averaged at 36.09°C; average minimum temperature at 24.40°C) and March (with average maximum temperature at 35.62°C; average minimum temperature at 21.77°C). January records the lowest average minimum temperature, at 17.53°C; followed by December (18.84°C); and February (19.26°C)

Most extreme maximum temperature recorded was 41.5°C, on 2 May 2002 and 1 May 2004. Coolest maximum temperature was 20°C (31 December 2010).

On the other hand, warmest minimum temperature was 28°C recorded 15 times (14 times in May and once in June); coolest nighttime temperature was in 18 December 1990 and 28 December 1993 (10°C).

Diurnal variation (i.e. difference between day time and night time temperature) is notable in Labutta, especially from December to February; the wet months of June, July, August and September have the least diurnal variation. In these months, maximum temperature is at its lowest; August records the lowest average maximum temperature.

Figures 44 and 45 provide information on the average maximum and minimum temperature, and the range of the observed maximum and minimum temperatures in Labutta.

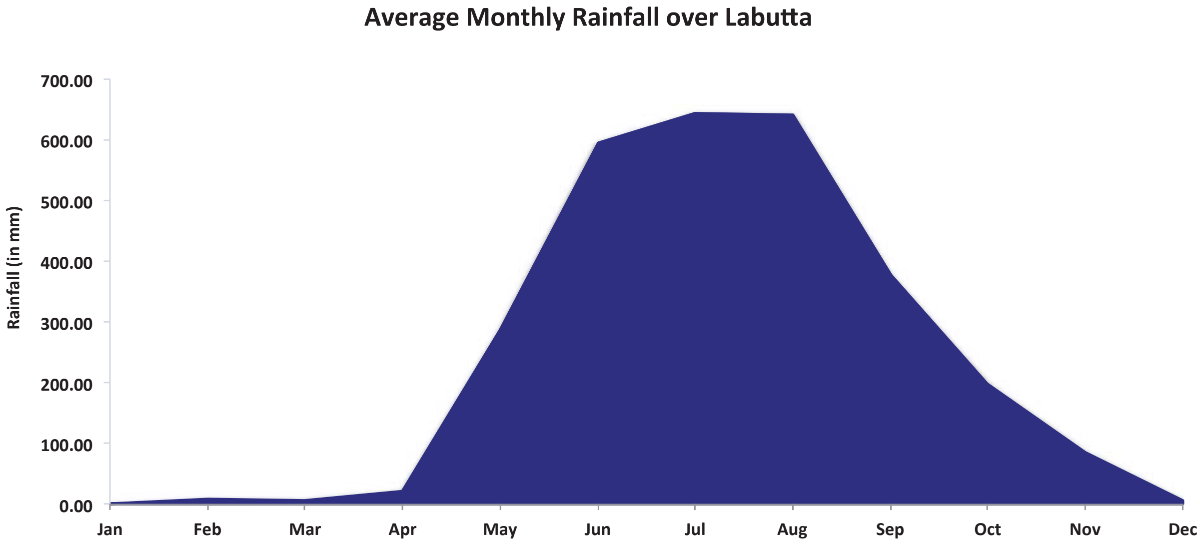



*Figure 43. Average monthly rainfall in Labutta. The wet season, from May to October, is highly influenced by the Southwest Monsoon*

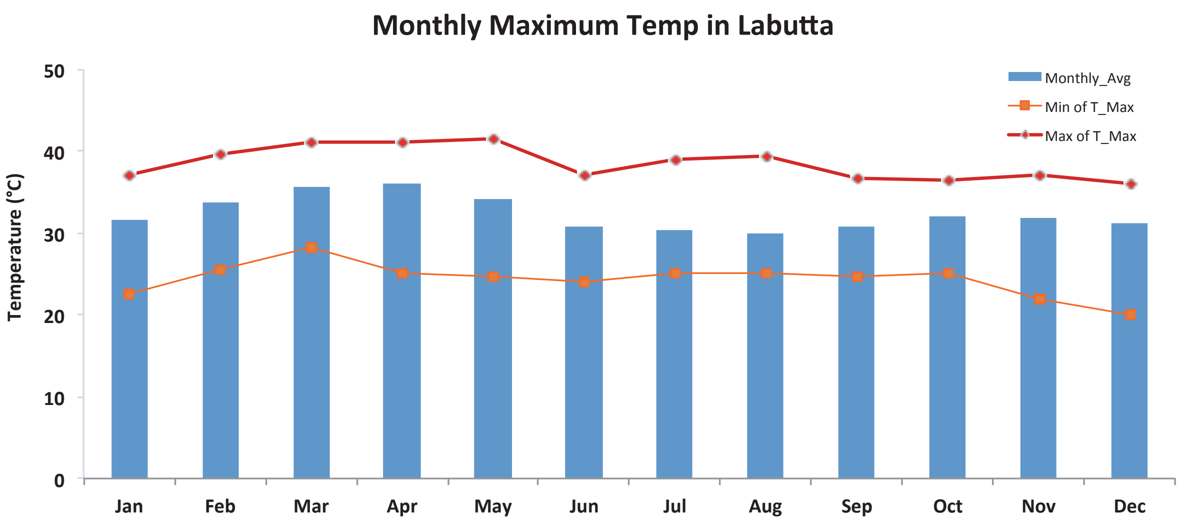



*Figure 44. The blue bars show the monthly average maximum temperature in Labutta, based on data from 1981-2010. The red marked lines indicate the highest observed maximum temperature in particular months; the orange marked lines identify the lowest observed maximum temperature.*

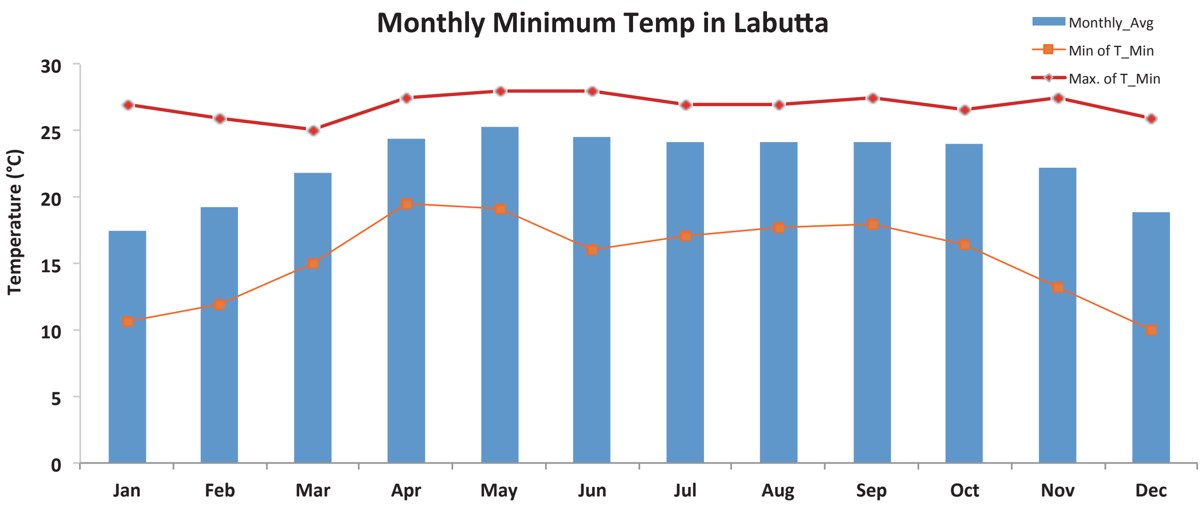



*Figure 45. The blue bars show the monthly average minimum temperature in Labutta, based on data from 1981-2010. The red marked lines indicate the highest observed minimum temperature in particular months; the orange marked lines show the lowest observed minimum temperature.*

### 3.2.4.2 Rainfall Variabilities, Trends and Extremes

### Annual Rainfall

Labutta, also located in the coastal zone, has average annual rainfall of about 2,900mm. Inter-annual variability, however, is highly notable (Figure 46).

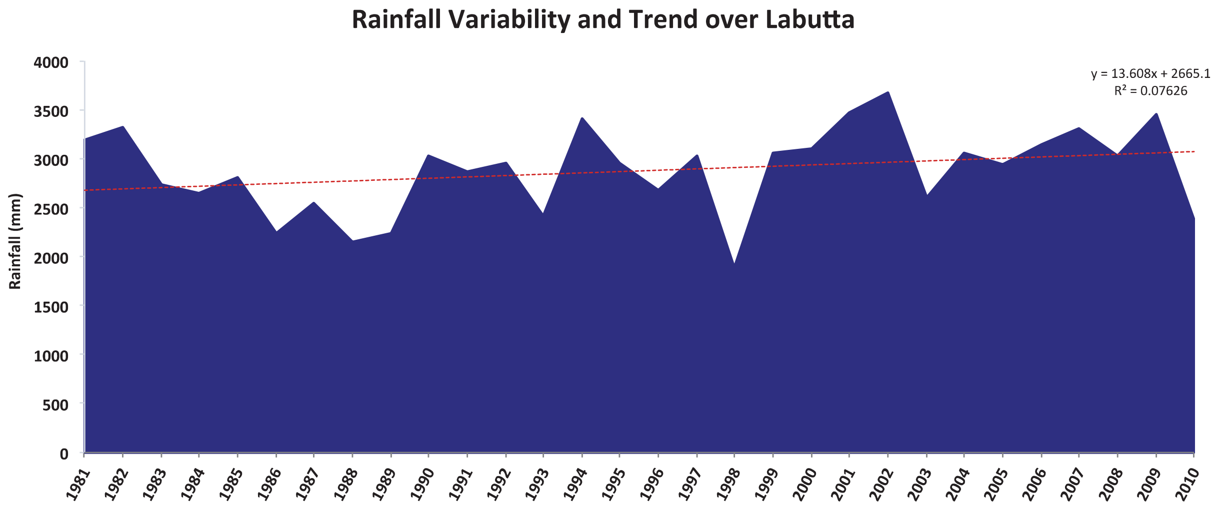



*Figure 46. Rainfall variability and trend, over Labutta, based on observed data from 1981-2010.*

The lowest annual rainfall was recorded in 1998 (1888mm); highest observed rainfall was 3677mm, in 2002.

1998 recorded 29 events exceeding 20mm and 8 days exceeding 40mm. The highest 24-hour rainfall during the year was in 28 May (89mm) and12 September (88mm).

Annual rainfall implies an increasing trend.

## Wet and Dry Season Rainfall

On average, the wet season in Labutta contributes about 95% to annual rainfall. Excursions from this pattern, however, is notable in Figure 47.

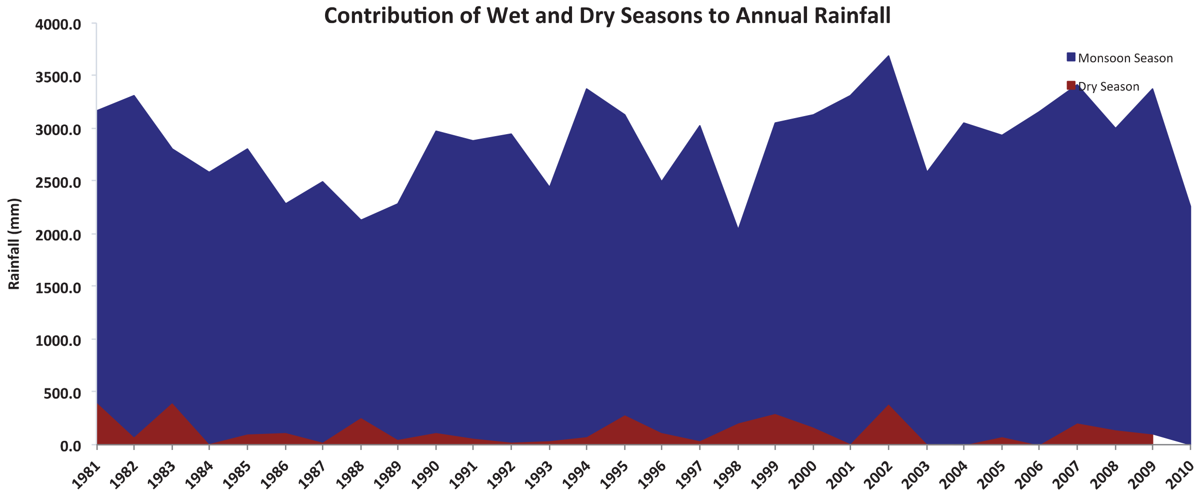



*Figure 47. Contribution of wet and dry seasons to annual rainfall in Labutta.*

Very wet seasons were recorded in 2002 (3302mm), 2001 (3291mm), 1994 (3293mm), 2009 (3271mm), 1982 (3244mm), 2007 (3214mm), 2006 (3149mm), and 2004 (3052mm). The highest 24-hour rainfall in Labutta was recorded in 20 May 2002 (240mm).

The number of wet days, in Labutta, is averaged at around 118 over the study period of 1981-2010. The variability is high, ranging from having the least number of rainy days 1987 (94), and the most number of rainy days in 1999 (141).

Trend in annual and wet season rainfall is increasing; wetter wet seasons are implied in 30 years of record. Decreasing trend, however, is suggested in the dry season.

## Extreme Rainfall Events

In 2002, 54 events exceeded 20mm; 30 rainfall events exceeded 40mm. Six (6) very heavy rainfall events, exceeding 100mm were recorded during the year. The most intense 24-hour rainfall was recorded in 20 May (240mm, the only rainfall event exceeding 200mm during the year; also the highest rainfall amount recorded in 30 years).

In 30 years, about 626 events exceeded 40mm; of these, 73 events exceeded 100mm in 24 hours. Two events exceeded 200mm (240mm in 20 May 2002; 216mm in 18 June 1987).

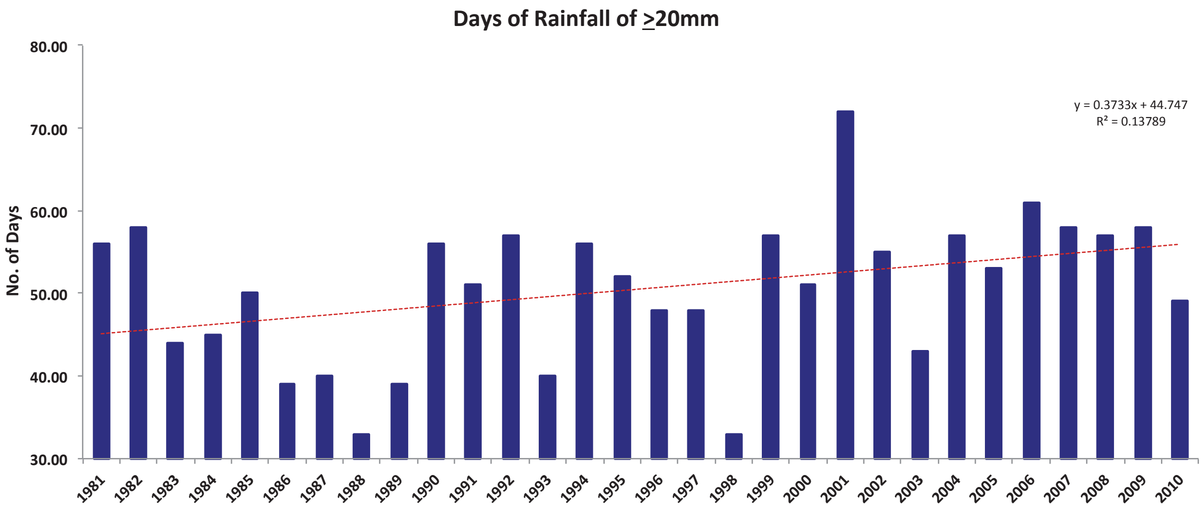
November, a typically dry month, received the 3$^{rd}$ most intense rainfall in 30 years in Labutta (198mm in 28 November 2002). Table 7 presents extreme rainfall events exceeding 100mm, during the dry season.

**Table 7. Extreme Events Exceeding 100mm During the Dry Season in Labutta, from 1981-2010**

| 24-Hour Extreme Rainfall | Date Recorded |
|---|---|
| 198mm | 28 November 2002 |
| 135mm | 29 November 2002 |
| 125mm | 3 November 1983 |
| 123mm | 12 December 2010 |

| | |
|---|---|
| 118mm | 20 November 1988 |

Analysis, of extremes, further suggests increasing occurrences of high intensity rainfall events in the township (Figure 48).



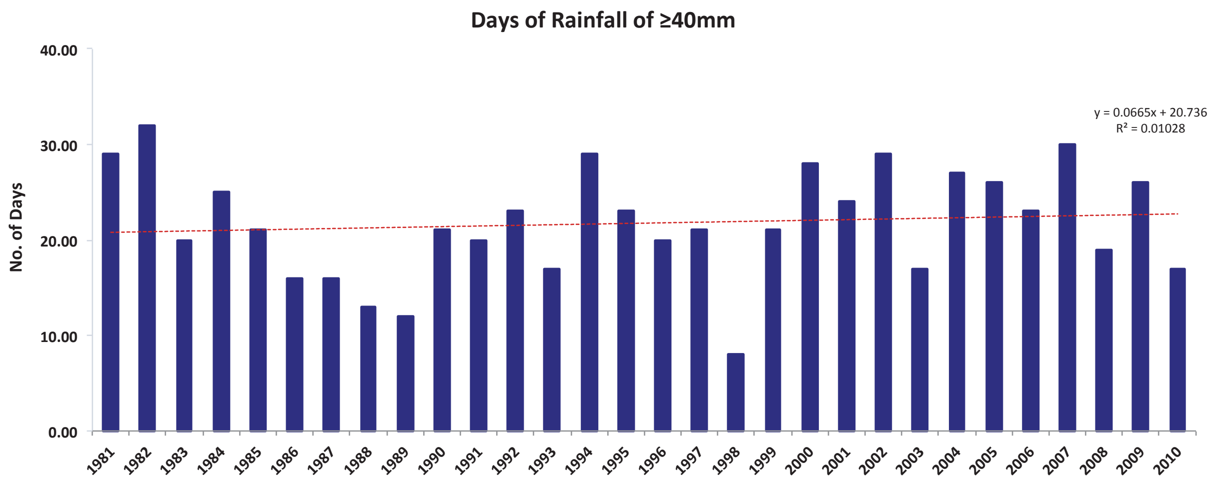




*Figure 48. Heavy rainfall events of ≥20mm and ≥40mm suggesting an increasing trend in Labutta.*

### 3.2.4.3 Temperature Variabilities, Trends and Extremes

### Maximum Temperature

In 30 years, the maximum temperature in Labutta is averaged at 32.30°C. 2005 is overall the warmest year with average maximum temperature of 33.8°C; 1994 recorded the lowest average maximum temperature at 29.57°C. These are indicated in Figure 49.

The warmest maximum temperature in Labutta was recorded in 2 May 2002 and 1 May 2004 at 41.5°C; the coolest maximum temperature was in 31 December 2010 at 20°C.

Analyses of average maximum temperature shows that while year-on-year temperature variability is evident, increasingly warmer days (in terms of both a) number of days with warmer than normal day time temperature and b) extreme temperature events) have been experienced over 30 years.

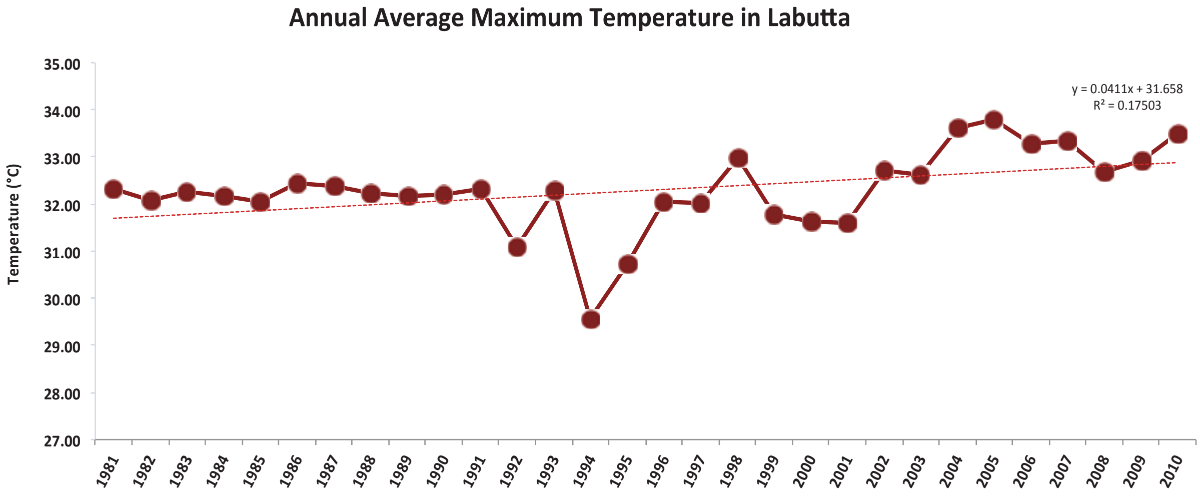



*Table 49. Variability and trend in annual average maximum temperature in Labutta*

## Minimum Temperature

Average minimum temperature in Labutta, from 1981 – 2010, is around 22.27°C. As with the maximum temperature, the minimum temperature is marked by year-on-year variations. Highest average minimum temperature is in 1998, at 23.36°C. Warmest nighttime temperature in Labutta is at 28°C, recorded 15 times within 1981-2010[1] - 13 times in May; and one (1) in June. Lowest minimum temperature, on the other hand, was 10°C; this was recorded twice (18 December 1990 and 28 December 1993).

A notable drop in average minimum temperature was recorded in 2001 at 19.35°C; and in 2003 at 21.28°C (refer to Figure 50).

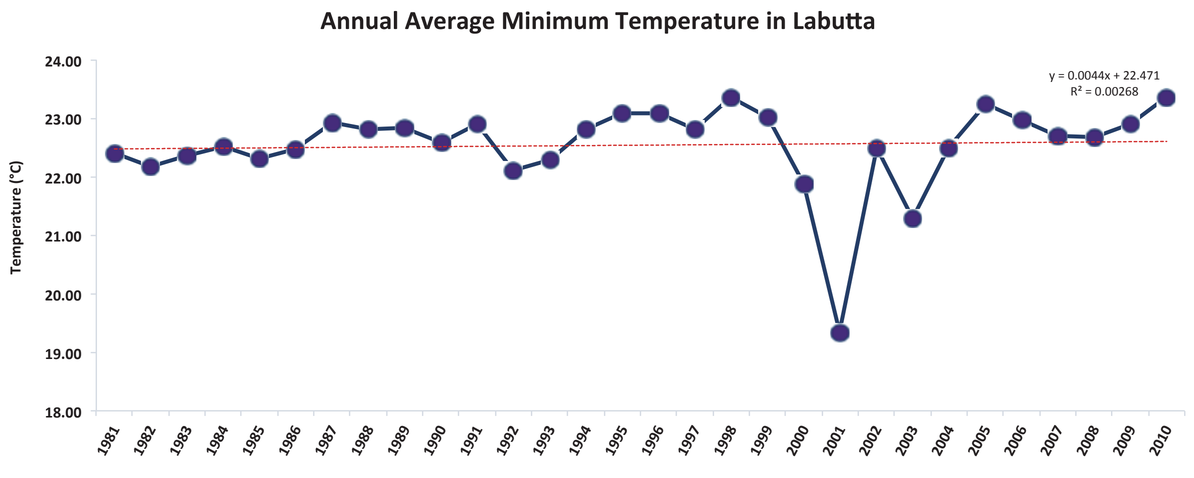



*Figure 50. Variability and trend of minimum temperature in Labutta, based on 1981-2010 temperature data.*

Minimum temperature data indicates that despite a slightly increasing trend in average minimum temperature, the occurrence of very warm nights is decreasing.

[1] 28°C was recorded in 25 and 26 May 1983; 16 May 1985; 23 and 24 May 1987; 26 and 27 May 1987; 12 and 13 May 1988; 12 and 13 May 1989; 9 May 1990; 5 June 1992; 16 May 1998; and 29 May 1998.

### 3.2.5 Mingaladon Township, Yangon Region

#### 3.2.5.1 General Climatic Features

Among the stations studied in the coastal zone, Mingaladon registers the lowest average annual rainfall of around 2530mm. Located at 16°54’26”N and 96°08’0”E (in Figure 51), the township receives significant amount of rainfall from the Southwest Monsoon and severe weather disturbances, but lesser than other stations closer to the coast.

Rainfall peaks in June (521.40mm) and July (535.13mm); December to March are typically very dry months. The township receives rainfall from severe weather disturbances over the Bay of Bengal and Andaman Sea, which peaks in April and November. The average monthly rainfall, over Mingaladon, is presented in Figure 52.

Warmest average daytime temperature is experienced in March (36.6°C) and April (37.4°C). Nighttime temperature, in these months, are also warm, at 21.2°C and 23.7°C, respectively. The warmest average nighttime temperature, however, is in May at 24.6°C.

The coolest daytime average temperature is experienced in the wet season months, particularly August (29.9°C) and July (30.1°C). Nighttime temperature for these months are high at 23.9°C and 24.1°C, respectively. The coolest nighttime temperature is in January (17.5°C) and in December (18.6°C). It is notable, however, that these months have high diurnal variation – day time temperature remains warm at an average of 32.6°C and 31.8°C, respectively.

Warmest daytime temperature recorded in 30 years was in 26 April 2004; and in 8 and 9 May 1998 (42°C). Coolest daytime temperature was in 29 April 2000 (20.3°C).


*Figure 51. Mingaladon Township in Yangon Region*

Moreover, warmest nighttime temperature was observed in 1 April 1998 (32.6°C); coolest was in 5 January 1994 (10°C). The average monthly maximum and minimum temperature, over 30 years, with the highest and lowest recorded temperature for each category, is provided in Figure 53.

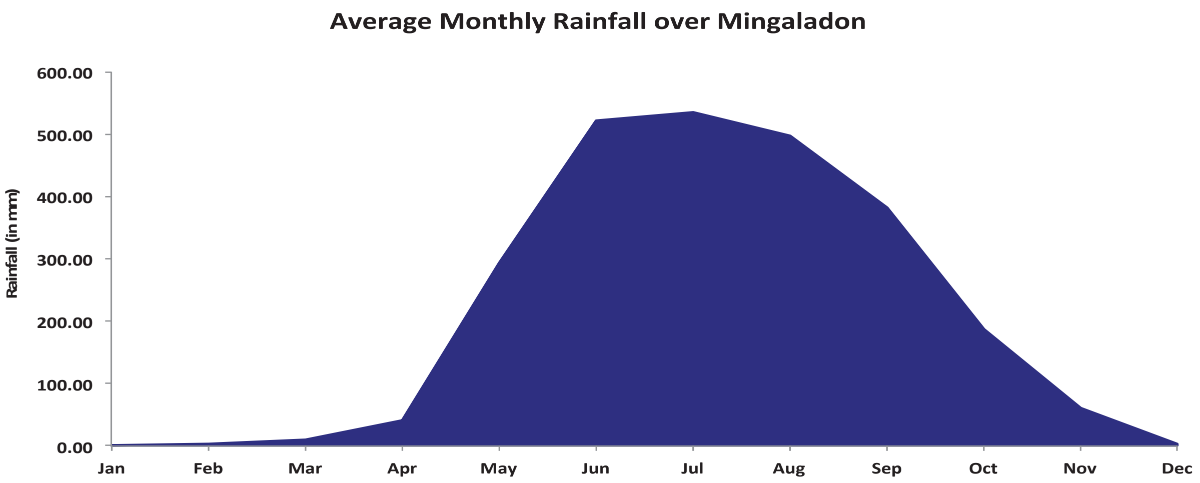
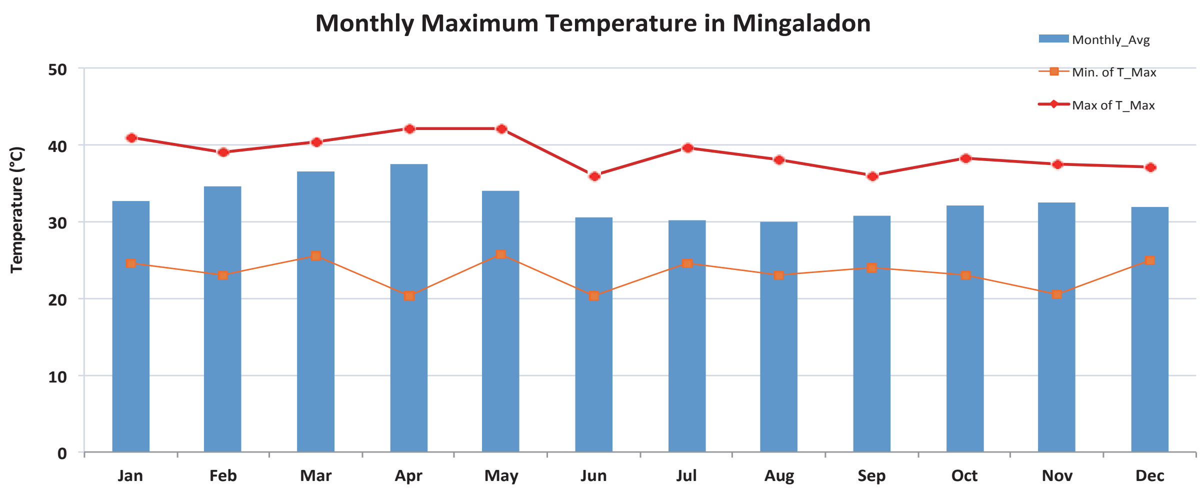



*Figure 52. Average monthly rainfall in Mingaladon. The wet season normally peaks in June and July*



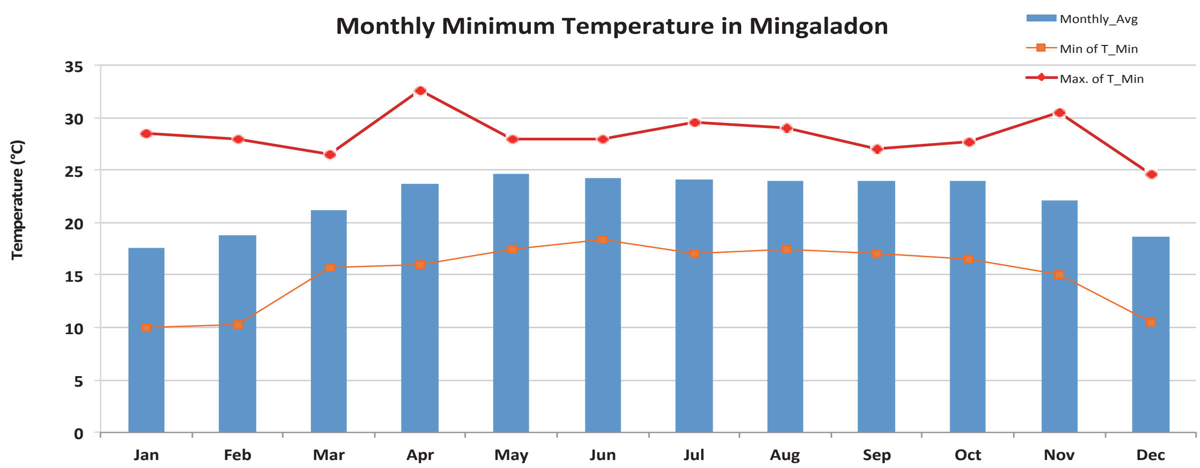




*Figure 53. Monthly maximum (above) and minimum (below) temperature (in blue bars); the marked red line shows the highest maximum and minimum temperature recorded in various months; while the orange marked line indicates the lowest maximum and minimum temperatures in various months.*

### 3.2.5.2 Rainfall Variabilities, Extremes and Trends

### Annual Rainfall

Per rainfall data from 1981-2010, the wettest year in Mingaladon was in 2007, recording 3450mm (about 136% of annual average rainfall of around 2532mm). On the other hand, the driest year was in 1998, which recorded only 1478mm or only about 58% of the annual average rainfall, the negative anomaly being more than 1000mm. Figure 54 presents the inter-annual variability in annual rainfall, from 1981-2010.

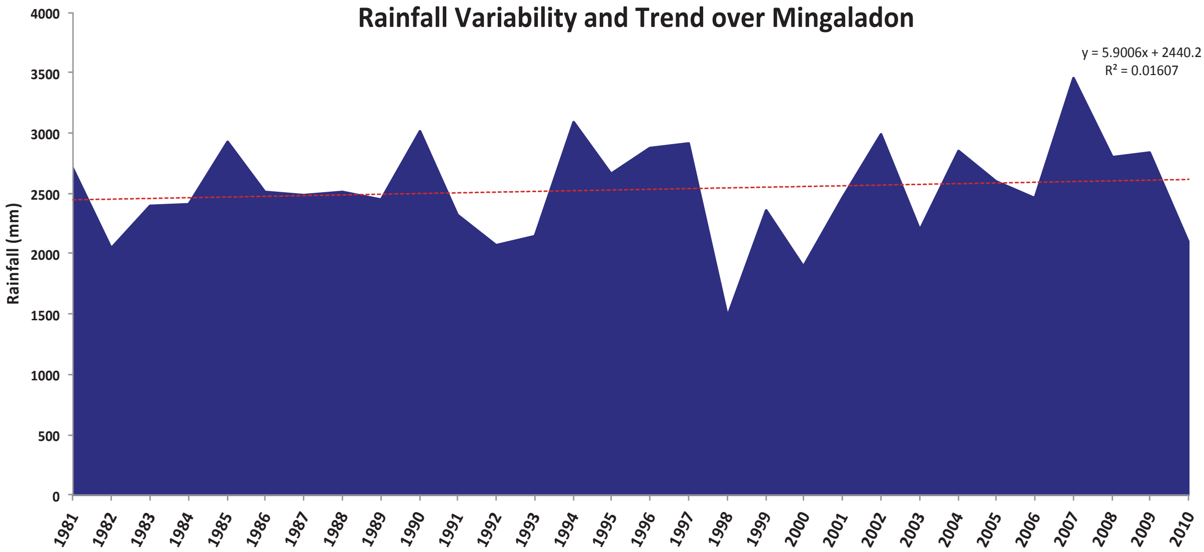



*Figure 54. Variability and trend of annual rainfall in Mingaladon, from 1981-2010*

The analysis of annual rainfall suggests an increasing trend.

### Wet and Dry Season Rainfall

The wet season rainfall, in Mingaladon, contributes around 94% to annual average rainfall. Of the 30 years of record, the wet season contribution of 1992 is the highest, being 100% of the annual rainfall of 2040mm. The least wet season contribution was in 1999, which was nearly 83%.

The variability of the contribution of the wet season to annual rainfall is presented in Figure 55.

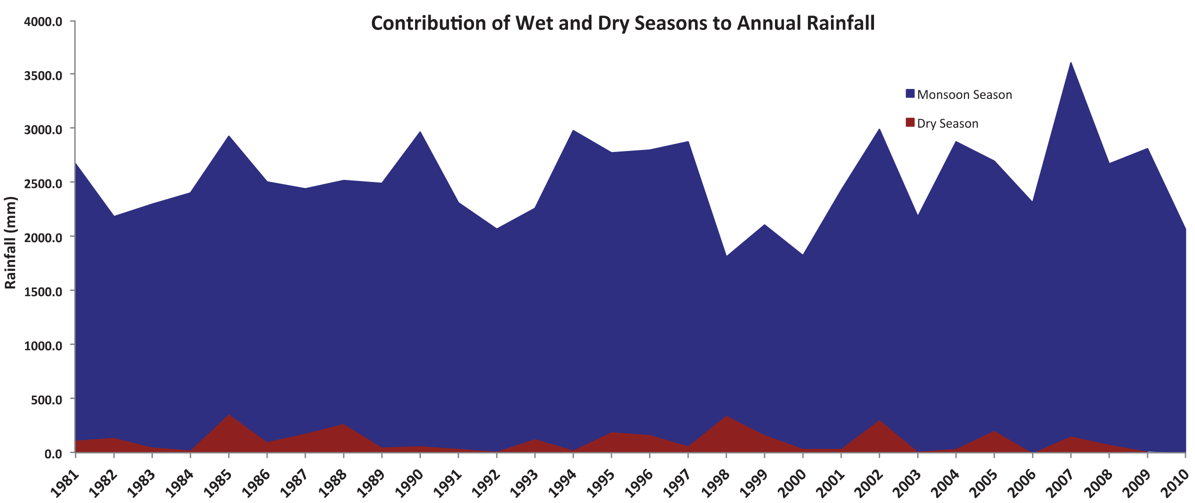



*Figure 55. Wet and dry season contribution to annual rainfall in Mingaladon.*

In 1999, 406mm of rainfall was recorded during the dry season. The dry season rainfall, during the year, had seven (7) events exceeding 20mm. April 14 recorded 118mm (also the highest 24-hour rainfall in 1999). Other significant rainfall events in April 1999 included: 84mm in 15 April; 36mm in 16 April; and 25mm in 19 April. On the other hand, significant rainfall events in November 1999 were: 27mm in 11 November and 22mm in 7 November at 22mm.

The increasing trend in rainfall, during the wet season, influences the increasing trend of annual rainfall; dry season rainfall implies a decreasing trend.

### Extreme Rainfall Events

In 2007, 25 days observed rainfall of ≥40mm, all in the wet season. Four (4) days recorded rainfall exceeding 100mm, with the highest 24-hour rainfall recorded on 5 May (283mm). 22 September recorded the other event exceeding 200mm during the year, at 214mm.

In the driest year of 1998, seven (7) events exceeded 40mm, with 96mm as the highest 24-hour rainfall. All events exceeding 40mm occurred during the wet season.

In the period of 30 years, the highest 24-hour rainfall was in 5 May 2007. Only 4.8% (531 days) of the total number of days recorded rainfall of ≥40mm; 25 events exceeded 100mm. The highest recorded rainfall events, exceeding 140mm, in Mingaladon are provided in Table 8.

**Table 8. Most Extreme Rainfall Events Recorded in Mingaladon**

| 24-Hour Extreme Rainfall | Date Recorded |
|---|---|
| 283mm | 5 May 2007 |
| 245mm | 3 May 2008 |
| 214mm | 22 September 2007 |
| 158mm | 19 November 1988 |
| 146mm | 14 November 1985 |
| 142mm | 7 July 2007 |

It should be noted that of the most extreme rainfall events recorded in Mingaladon, as presented in Table 8, two (2) were recorded in November. Of the wet days of ≥40mm, in 30 years, 14 events were observed during the typically dry months of April, November and December. Of this number, five (5) events exceed 100mm, in Table 9. Analysis indicates that extreme rainfall events are in increasing trend.

**Table 9. Extreme Rainfall Events Recorded in Dry Season**

| 24-Hour Extreme Rainfall | Date Recorded |
|---|---|
| 158mm | 19 November 1988 |
| 146 | 14 November 1985 |
| 123 | 29 April 2006 |
| 118 | 14 April 1999 |
| 101 | 25 November 2002 |

## 3.2.5.3 Temperature Variabilities, Extremes and Trends

### Maximum Temperature

Analysis of 30 years data, in Mingaladon, shows variability in annual average maximum temperature (in Figure 56). The average maximum temperature is 32.73°C.

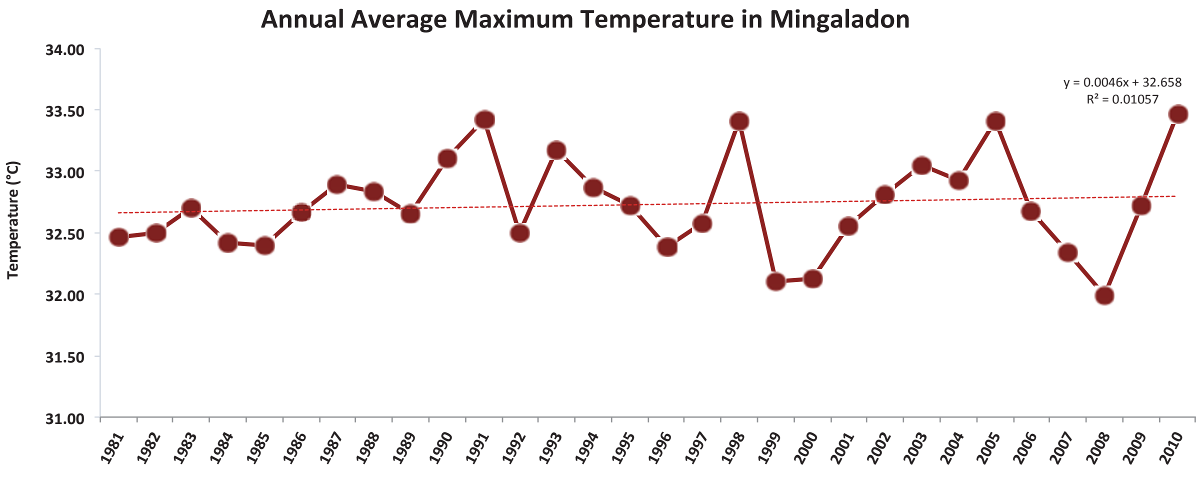



*Figure 56. Annual average maximum temperature in Mingaladon, from 1981-2010. On the average, the warmest day time temperatures were in 2010; the coolest were in 2008.*

In 2010, the year recording the warmest average maximum temperature, the hottest day was in 10 May (41.2°C). During the year, 197 days recorded temperature exceeding the average; 98 days exceeded 35°C. Very hot days, of temperature ≥40, were recorded 24 times during the year, all in the months of April and May.

The warmest day in 2004 (42°C in 26 April) exceeded the temperature during the warmest day in 2010. In 2004, however, only 189 days recorded maximum temperature exceeding the average; and 80 days exceeding 35°C. Six (6) days recorded temperature of ≥40°C (all in April).

The annual average maximum temperature shows an increasing trend, implying that more number of days, over the period of study, were warmer than the average. Based, however, on percentile analysis, the occurrence of very hot daytime temperature is decreasing.

## Minimum Temperature

Nighttime temperature in Mingaladon indicates significant inter-annual variations, from 1981-2010 (refer to Figure 57). In the township, 1998 recorded the warmest nights, on the average. 2008, however, exhibited a significant drop in average nighttime temperature, at 19.69°C. The average nighttime temperature, in 30 years, is 22.24°C.

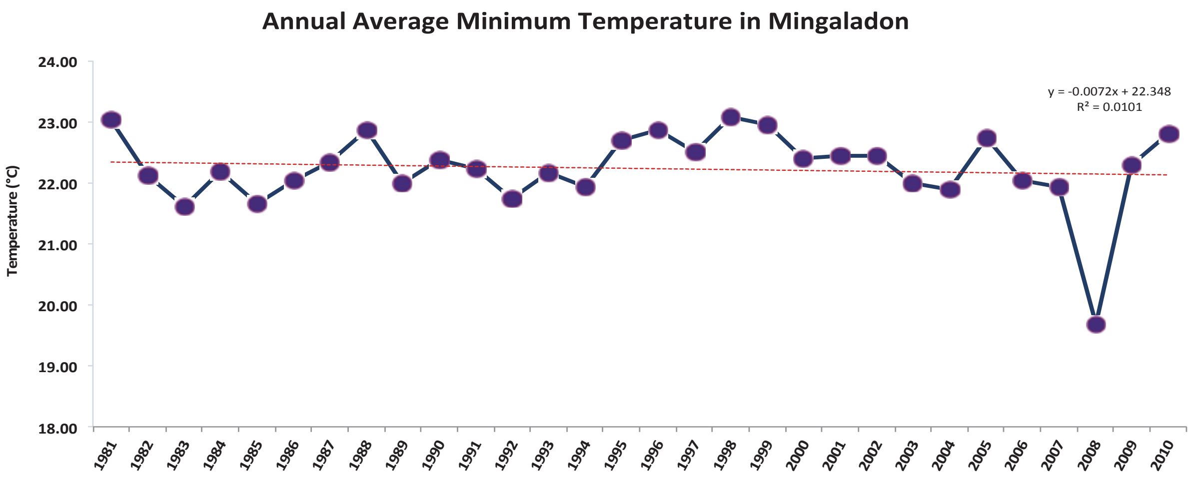



*Figure 57. Annual average minimum temperature in Mingaladon. The warmest nights, on average, were in 1998 while the coolest were in 2008.*

In 1998, the warmest nighttime temperature was in 1 April (32.6°C, the only nighttime exceeding 30°C; also the warmest night within 30 years). 252 nights exceeded the average minimum temperature; of these, 85 nights exceeded 25°C.

On the other hand, in 2008, the warmest night was recorded at 25.8°C; only five (5) nights registered temperature of ≥25°C. 49 nights within the year had temperature exceeding the average.

In 30 years, two (2) nights recorded temperature of >30°C (32.6°C in 1 April 1998; 30.5°C in 19 November 1984). About 62% of the nights, in 30 years, exceeded the average minimum temperature; about 11% of the nights exceeded 25°C.

The average minimum temperature suggests a slightly decreasing trend; percentile analysis also indicates a decreasing trend. Both suggest that the number of very warm nights are occurring less frequently in Mingaladon.

## 3.3 HILLY/MOUNTAIN ZONE

### 3.3.1 Kengtung Township, Shan State

#### 3.3.1.1 General Climatic Features

Kengtung Township, in Eastern Myanmar, is a township in the hilly state of Shan (in Figure 58). Located along 21°17'30"N and 99°36'30"E, Kengtung has an annual average rainfall of 1232 mm. Also exhibiting unimodal pattern, the rainfall is concentrated during the wet season (May to October), with July and August being the wettest months (receiving about 231mm and 219mm, respectively, on the average).

Kengtung receives lesser rainfall compared to townships in the coastal zone, but more compared to townships in the Central Dry Zone. Located inland, it receives less rainfall from the Southwest Monsoon but benefits from rainfall from remnants of severe weather disturbances from the South China Sea. The average monthly rainfall, in Kengtung, is provided in Figure 59.

The warmest average daytime temperature is in April (33.5°C). The diurnal variation in April is significant, with its average nighttime temperature at 17.8°C. The lowest average maximum temperature is in December, at 25.5°C, and January at 27.1°C. Both are also the coolest months in terms of average nighttime temperature (January at 10°C and December at 11°C). February registers as among the months with coolest nighttime temperature, averaging at 11.1°C.

Highest nighttime temperature is in the wet months of June (21.7°C), July (21.5°C), August (21.3°C). Daytime temperature, for these months, averages at 30.7°C (June), 29.5°C (July) and 29.6°C (August).


*Figure 54. Kengtung Township in Shan State*

Extremely hot daytime temperature was registered in 18 and 19 April 1983 (40°C); coolest daytime temperature was in 3 March 1986 (10°C). On the other hand, warmest nighttime temperature was in 12 June 1992 (29.2°C); coolest night was in 28 December 1999 (2°C).

The average monthly maximum and minimum temperatures, with the highest and lowest recorded temperatures per month, are provided in Figures 60 and 61.

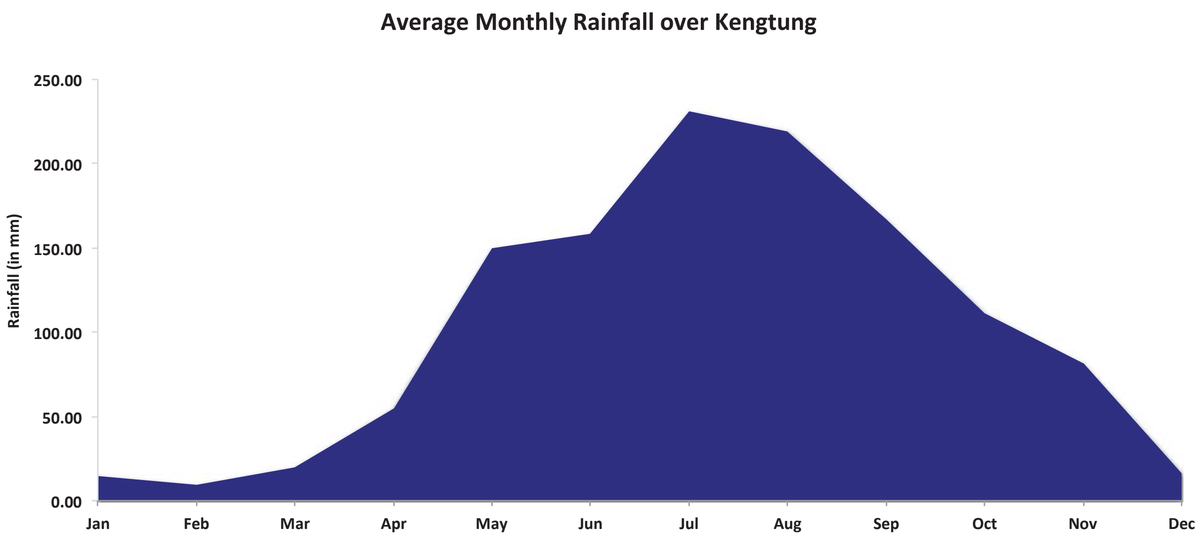



*Figure 59. Average monthly rainfall over Kengtung Township in Shan State. The rainfall concentration is from May to October. In November, Kengtung also receives rainfall from remnants of weather systems over the South China Sea*

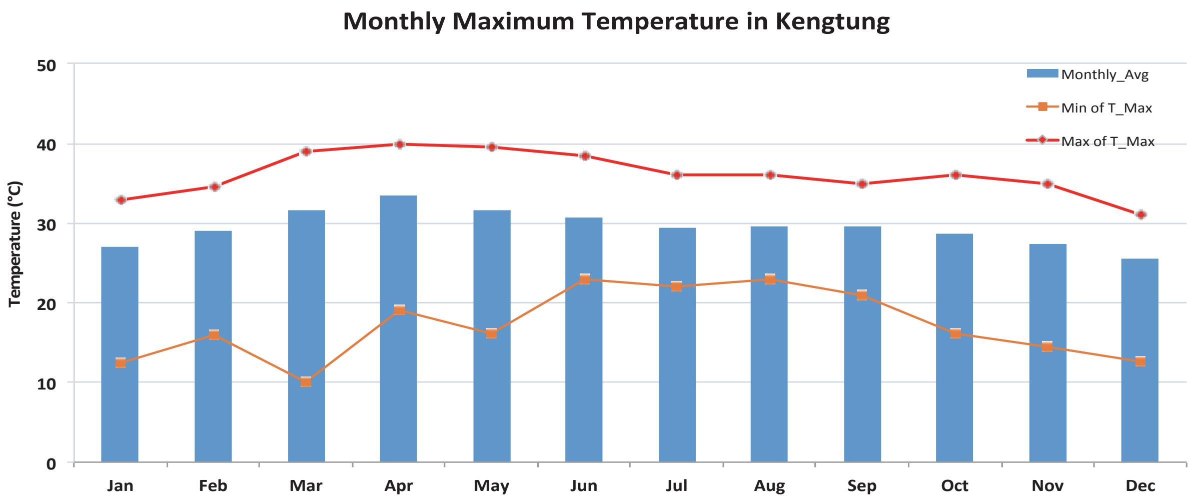



*Figure 60. Average monthly maximum temperature in Kengtung indicated in blue bars. The red marked line shows the warmest recorded daytime temperature per month; orange marked lines identifies the coolest recorded daytime temperature.*

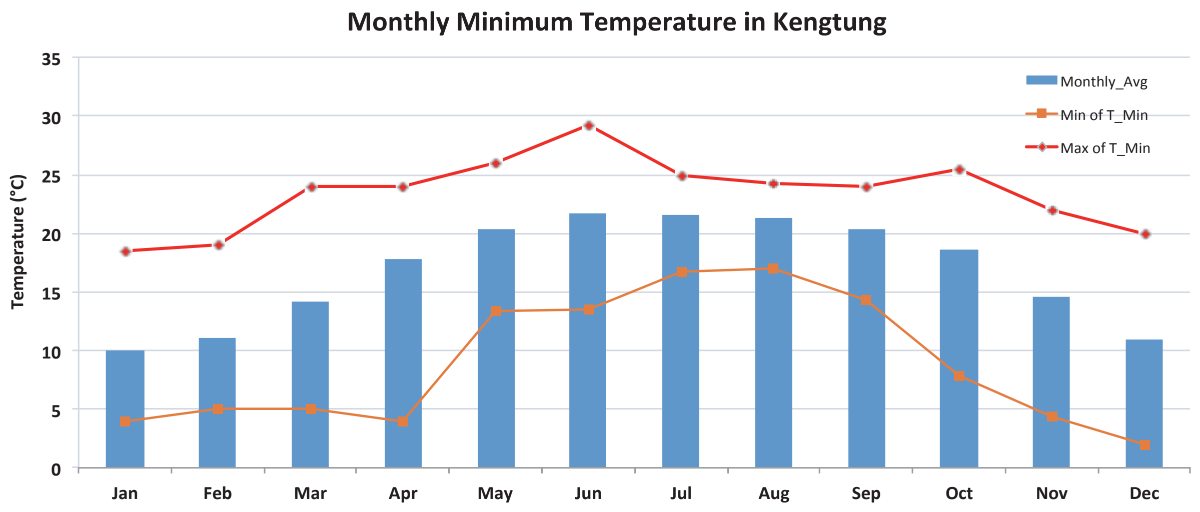



*Figure 61. Average monthly minimum temperature, in Kengtung, in blue bars; the red marked lines indicate the highest minimum temperatures recorded while the orange marked lines represent the lowest minimum temperature recorded in various months.*

### 3.3.1.2 Rainfall Variabilities, Extremes and Trends

### Annual Rainfall

Kengtung's rainfall is averaged at 1231mm annually. Located inland in the eastern part of Myanmar, it receives less rainfall from the Southwest monsoon compared to areas in the coastal zone. It can be noted that in Kengtung, November receives significant rainfall, from the influence of remnants of weather systems from the South China Sea.

Per available data within 30 years, the wettest year was in 2002, which recorded 1507mm of rainfall. On the other hand, 1998 recorded the lowest rainfall of 950mm (in Figure 62).

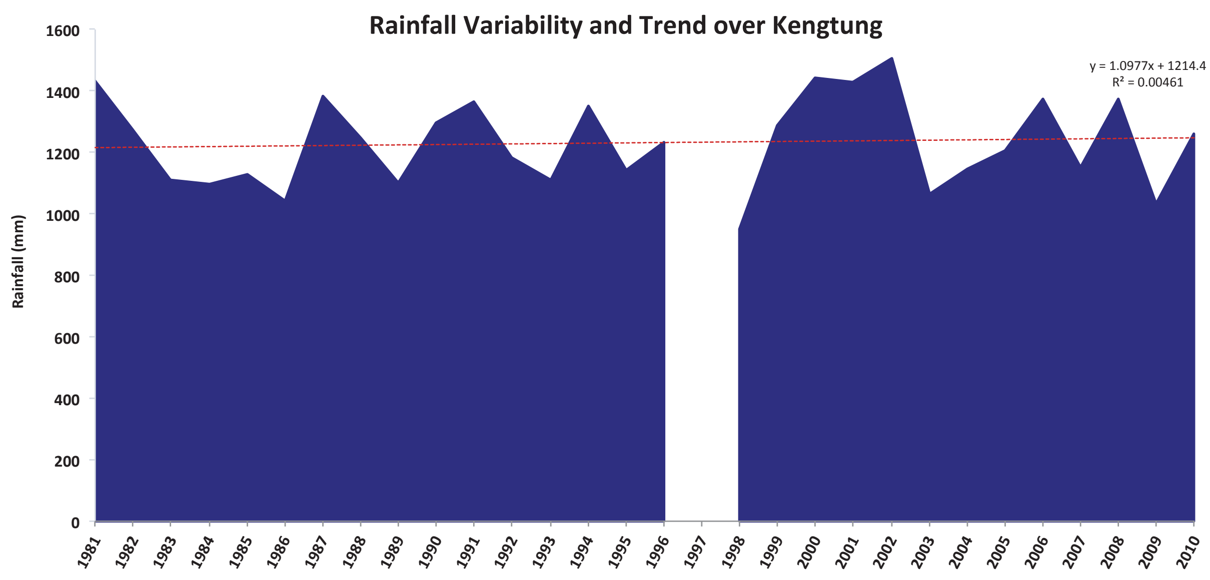



*Figure 62. Rainfall variability and trend over Kengtung, from 1981-2010. Rainfall data for 1997 is not available; the analysis of rainfall variabilities, extremes and trends is hampered by missing data.*

Increasing trend, in annual rainfall, is suggested based on available data from 1981-2010.

**Wet and Dry Season Rainfall**

The wet season in Kengtung, averaging at 1036mm, contributes to about 84% to annual rainfall – the lowest average wet season contribution to annual rainfall compared to other parts of the country included in the analysis.

It can be noted from Figure 63 that substantial amount of rainfall is received outside the May-October period. The wet season of 1981 has the lowest contribution to annual rainfall, at only around 74%; dry season rainfall in 1981 recorded 371mm. In terms of amount, the highest recorded dry season rainfall in Kengtung is in 2002, at 378mm.

The wet season rainfall shows an increasing trend, similar to annual rainfall.

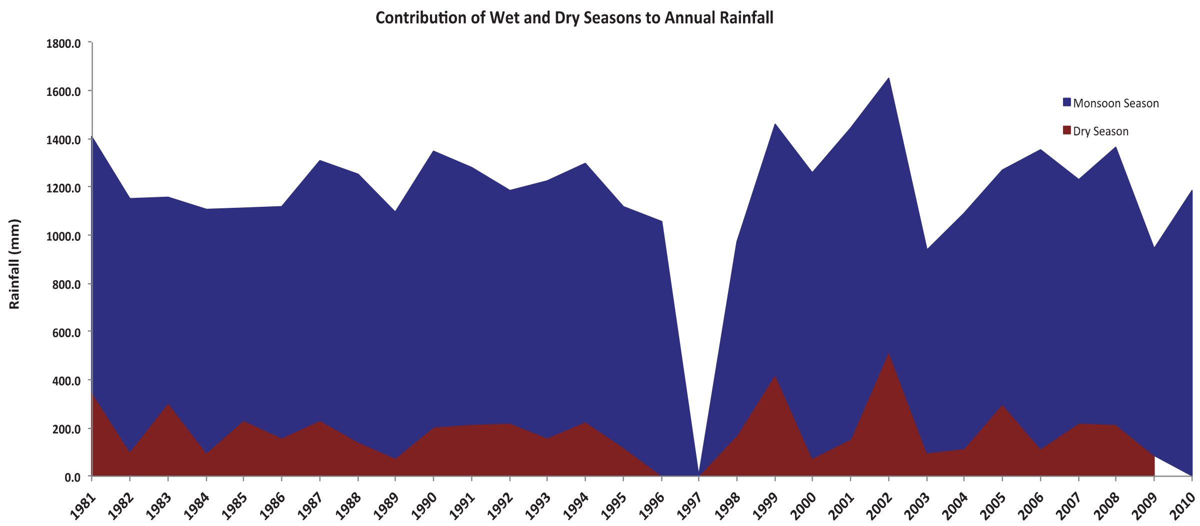



*Figure 63. Wet and dry seasons contribution to annual rainfall in Kengtung. The data shows significant rainfall from months outside of the May to October period.*

## Extreme Rainfall Events

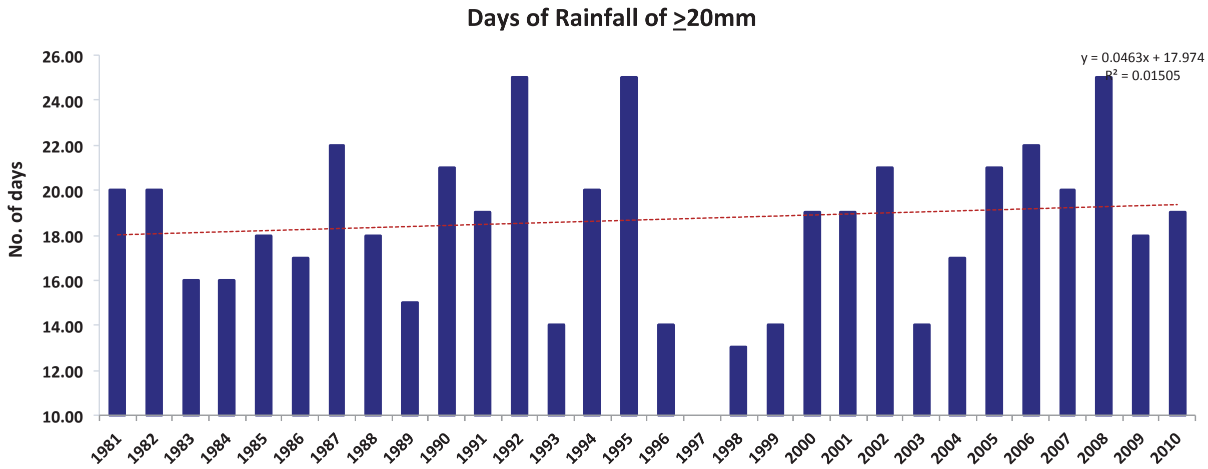
In 2002, four (4) events exceeded 40mm; the highest 24-hour rainfall amount, during the year, was 71mm (27 November). On the other hand, 1998 recorded its highest 24-hour rainfall on 3 November, at 47mm. Only two (2) events exceeded 40mm.

Of the available records, the most extreme rainfall event was 108mm, recorded in 16 August 1991. 121 events recorded rainfall of ≥40mm. Four (4) events exceeded 80mm, in Table 10.

**Table 10. Most Extreme Rainfall Events in Kengtung**

| 24-Hour Extreme Rainfall | Date Recorded |
|---|---|
| 108mm | 16 August 1991 |
| 98mm | 22 July 1996 |
| 91mm | 3 November 1991 |
| 91mm | 17 July 2000 |

In Kengtung, while rainfall events of ≥20mm show an increasing trend, rainfall events of ≥40mm shows a decreasing trend (Figure 64). This indicates the decreasing occurrences of very extreme rainfall events of 40mm and above.



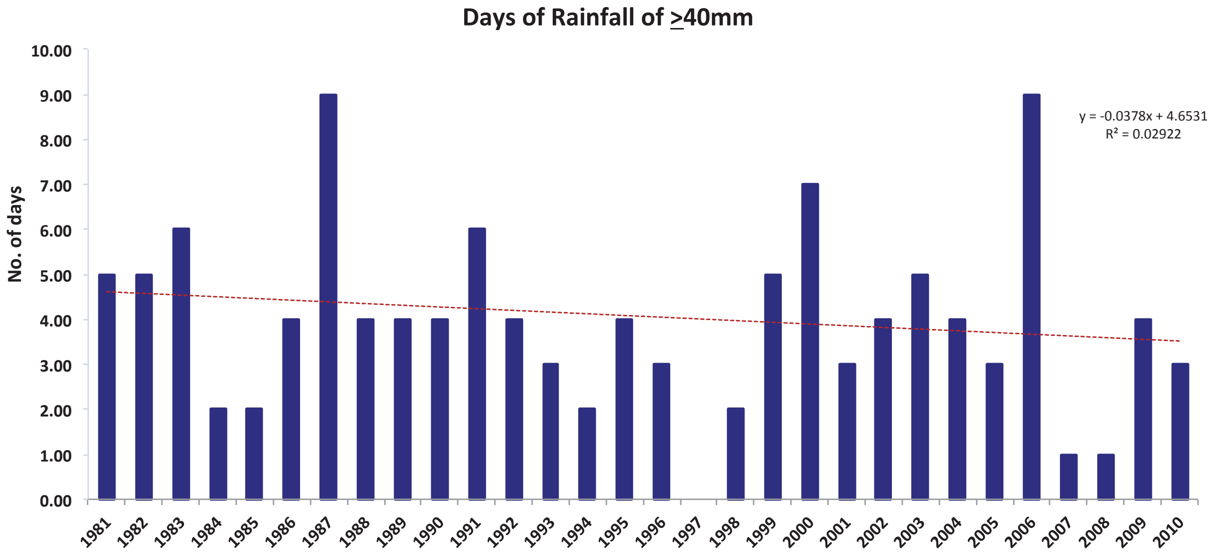




*Figure 64. Above: rainfall events of ≥20mm implies an increasing trend. This opposes the decreasing trend in rainfall events of ≥40mm (below).*

### 3.3.1.3 Temperature Variabilities, Extremes and Trends

### Maximum Temperature

Of the years of record, the highest average maximum temperature was in 2010 (30.41°C). On the other hand, the year with the lowest average maximum temperature was in 1981 (28.52°C). Figure 65 presents this.

In 2010, 205 days had temperatures that exceeded the average maximum temperature of 29.58°C; 39 days exceeded 35°C. The highest maximum temperature was in 15 May 2010, at 39.6°C. The lowest daytime temperature during the year was 20.6°C.

In 1981, the warmest maximum temperature recorded in Kengtung was 38°C, in 12 May. 150 days had temperature that exceeded the average; of these, seven (7) days exceeded 35°C. The lowest daytime temperature during the year was 17°C, on 11 November.

In 30 years, the warmest days were in 18 and 19 April 1983 (40°C; the only two days that exceeded the next warmest temperature of 39.6°C in 15 May 2010). About 48% of the days exceeded the average temperature; about 5% of the days exceeded 35°C. The lowest maximum temperature during the 30 year period was 10°C, in 3 March 1986.

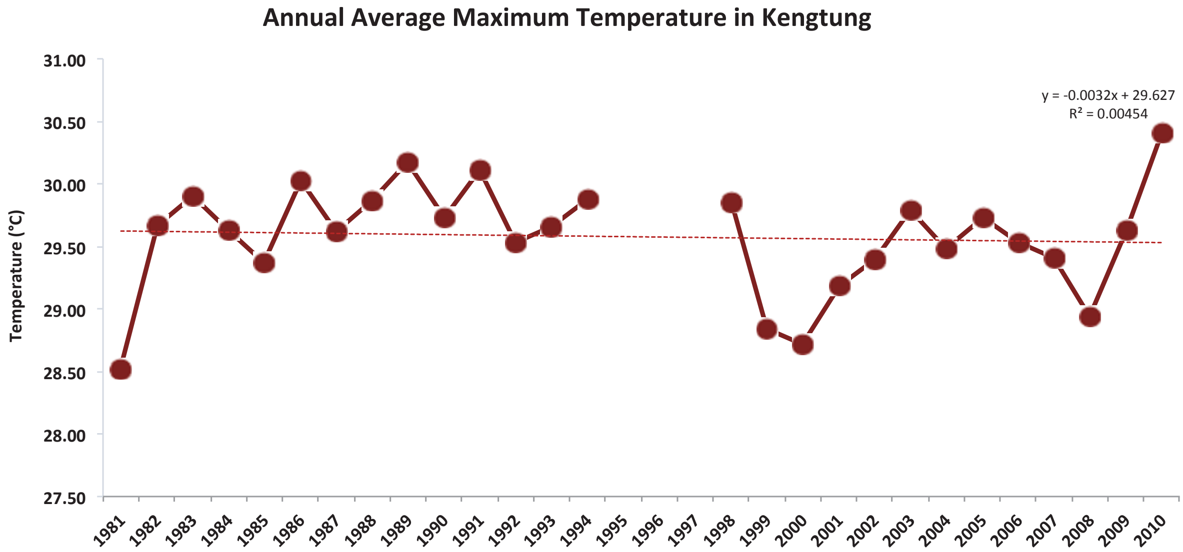



*Figure 65. Variability in annual average maximum temperature, in Kengtung, from 1981-2010. The warmest days, on the average, were in 2010; the coolest days, in 1981.*

The annual average maximum temperature shows a decreasing trend; percentile analysis also shows decreasing trend, which suggests that the occurrence of very warm daytime temperature is decreasing.

## Minimum Temperature

2010, which recorded the warmest average maximum temperature, also recorded the warmest average minimum temperature. The year registered the average minimum temperature of 18.13°C. 2004 recorded, on the average, the coolest nights at 15.19°C.

The average minimum temperature, over the baseline period, is 16.91°C. In 2010, 228 nights exceeded the average temperature; 169 nights exceeded 20°C. The warmest night, in 2010, was in 20 May (25.8°C), followed by 22 May (25.5°C).

During the year with the lowest average minimum temperature, in 2004, 171 nights exceeded the average; 63 nights exceeded 20°C. The highest minimum temperature was in 30 June 2004 (22°C). The coolest night recorded was in 19 January (4°C).

The variability of annual average minimum temperature in Kengtung is presented in Figure 66. The trend, based on available data, is decreasing.

In 30 years, the warmest night was in 12 June 1992 (29.2°C). About 52% of the nights exceeded the average; of this, about 32% of the nights exceeded 20°C. Six (6) nights registered temperature exceeding 25°C.

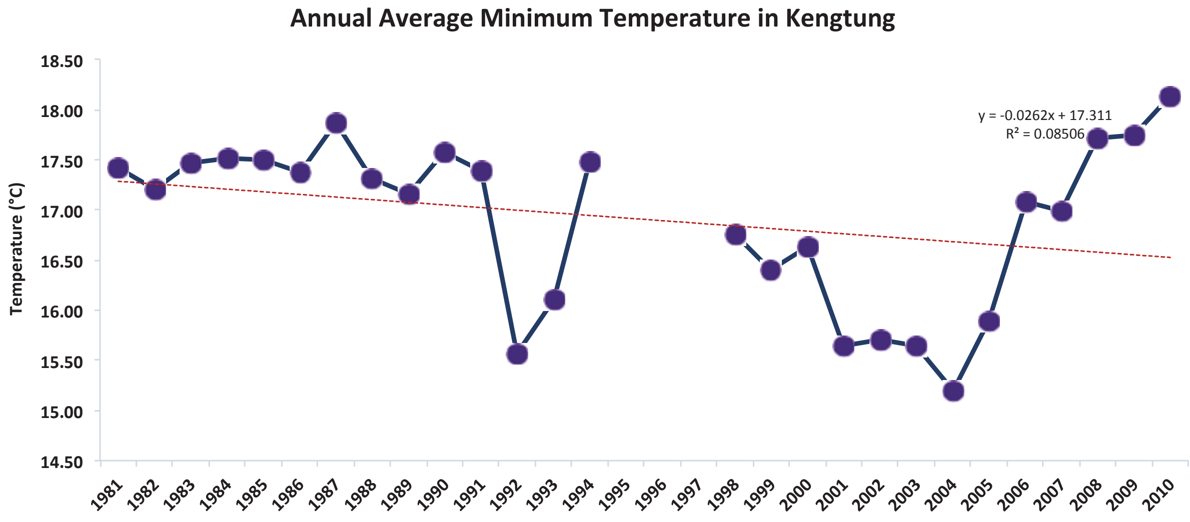



*Figure 66. Annual average minimum temperature in Kengtung, from 1981-2010. The warmest nights, on the average, were in 2010; on the other hand, the coolest nights were in 2004. Temperature data, from 1995-1997, is unavailable.*

# 4 Key Inferences

## 4.1 Central Dry Zone

The increasing trend in annual and wet season rainfall, opposing shorter wet season duration and dryer dry seasons, strongly suggests occurrence of more heavy rainfall events. Corroborating this is the increasing trend in the analysis of extreme rainfall. On the other hand, warmer days and nights are implied from the analysis of temperature data.

The implications of these trends are enormous in various fronts, in Meiktila:

- **For domestic activities**, the increased tendency of wet season rainfall offers tremendous opportunity for increased water availability for domestic activities, given effective water collecting facilities, in a water-stressed locality like Meiktila. This increasing wet season rainfall tendency, however, against shorter wet season is highly suggestive of occurrence of more intense rainfall over shorter periods, which could trigger floods and disrupt regular domestic activities. Dryer dry seasons could potentially expose households to more stress, especially the poor, due to recurring heavy rainfall events and drier periods.
- **In human health**, increased occurrences of heavy rainfall events (and secondary hazards like floods) could be associated to more incidence of waterborne diseases. Extended dry periods, coupled with very hot temperatures, on the hand, implies exacerbation of problems related to water availability and quality for domestic use, especially in areas where households are highly dependent on rainfall and underground water. Higher daytime temperatures could point to incidence of heat wave and its impacts on the vulnerable; health impacts from warmer nights are also implied. Wetter and warmer days favor reproduction of mosquitos, which could cascade to increased incidence of mosquito-borne diseases.
- **In agriculture**, the tendency of occurrences of more rainfall and temperature extremes, punctuated by shorter wet season, exposes the sector to higher risks of floods and droughts, even within the same year. The stress could be higher in areas that are rainfed, compared to those with existing water resources support facilities. Moreover, extremely hot temperature could curb the growth and productivity of various crops.
- **Livestock** could be exposed to higher incidence of waterborne and temperature-related diseases. The availability and quality of grass and fodder could further impact on livestock health. Further, extremely hot daytime temperature could drive changes in grazing patterns.
- **In infrastructures**, such as roads, deterioration could be exacerbated due to repeated exposures to floods and extreme temperature.

## 4.2 Coastal Zone

With copious amounts of rainfall concentrated from May to October, the wet season in coastal areas provides very significant support to domestic activities, livelihoods, health, construction, and inland transportation, among others. The data from observation stations in Kyaukpyu, Mawlamyine, Hpa-An, Labutta and Mingaladon all suggest increasing tendency in annual and wet season rainfall, with the dry season – in all stations, except Hpa-An – implying decreasing tendency. Analysis of extreme rainfall events, in all stations, indicate increasing tendency. Temperature-wise, data from all stations in the coastal zone suggest increasing trend in daytime temperature. The behavior of nighttime temperature is variable: increasing trend in Mawlamyine; slightly increasing tendency in Labutta, with decreasing tendency for extremely warm nighttime temperature; decreasing tendency in Kyaukpyu, Hpa-An, and Mingaladon.

The following are key implications, vis-à-vis the tendencies of rainfall and temperature in priority areas in Myanmar's coastal zone:

- **For domestic activities**, the tendency for wetter wet seasons and dryer dry seasons is indicative of potential for enhanced surplus water during the wet season, and exacerbated water stress during the dry season. The tremendous rainfall resource, during the wet season, could be tapped through rainwater harvesting facilities. With unimodal rainfall mode, water stress during the dry season could especially be significant, in cases where there is considerable shortfall from the wet season rainfall. The tendency for wetter wet seasons and increased occurrences of extreme rainfall events could expose households to increased frequencies of flooding and landslides, while dryer dry seasons could lead to reduced access to potable water and water for domestic use, even from underground sources due to salt water intrusion and contamination, among others. Increasing tendency in daytime temperature could be equated to enhanced evaporation, which could additionally impact on water availability. Increasing nighttime temperature could increase utilization of electricity, for ventilation purposes. This could further stress already stressed energy availability in Myanmar.
- **For human health and life**, the increased occurrences of floods and landslides, spiked with dry conditions, could cascade to injuries, damage to properties and assets, potential deaths, and increases in water-related diseases.
- **For agriculture,** the unimodal pattern concentrates rainfall from May to October. This strongly suggests that farmers in the coastal zone, sans irrigation support facilities, could cultivate water-intensive crops (e.g. rice) only once a year. Increasing tendency in rainfall, during the wet season, and the decreasing tendency of dry season rainfall suggests intensification of hazards experienced in coastal areas, which could impact on agricultural production. Extreme daytime temperature, in addition to impacts on water resources availability, could curb growth and productivity, due inherent sensitivity of crops to extreme temperatures.
- **In livestock,** stresses from occurrences of more heavy rainfall events and extremely hot day time temperature, could be exacerbated by the potential increase in diurnal variation, which could aggravate health concerns in livestock.
- **In infrastructures**, the implications for both rainfall and temperature trends could exacerbate stress to facilities like roads, through constant exposures to extremes. These facilities have to be constructed robustly to withstand such extremes occurring more frequently. Noting the concentration of rainfall during the wet season, efficient water catching facility may be required for storing this resource which can be used during the dry season. As discussed earlier, significant shortfall in rainfall, during the wet season, could potentially result to extreme water scarcity, in the dry season.
- **In energy**, higher demand for power, for homes, business establishments and critical infrastructures, for regulating temperature during days and nights, could be anticipated.
- **In fishing**, a range of temperature is required for optimal abundance of various fish species; below and beyond the optimum temperature range could generate physiological stress in fish species. Increased rainfall is beneficial for infusing nutrients to rivers and seas, and reducing saline concentration; drier conditions could increase water toxicity levels which is not optimum for fish reproduction and cultivation.
- **Traiding** is highly linked to agricultural and fish production. As productivity in agriculture and fisheries are linked to rainfall and temperature, inter-annual climate variabilities also impact trading.
- **Inland water transport** is essential for in- and out-transporting of goods and people, and variability in water level, and as well as severe weather events, have impacts on inland water transport. While rainfall is highly required for facilitating good conduciveness of inland water transport, excessive events leading to floods could disrupt this service. On the other hand, extreme paucity in rainfall could render serious issues in navigation.

### 4.3 Hilly Zone

Like other priority stations inclusive of the analysis, the trend in wet and annual rainfall, in Kentung, is increasing, against a slightly decreasing trend in dry season rainfall. Both daytime and nighttime temperature suggest a decreasing tendency.

Key inferences, for Kengtung, are:

- **For household activities**, the increasing wet season rainfall, coupled with the tendency for decreased occurrence of very heavy rainfall events, could be beneficial for the largely rainfed area. Better availability of water could enhance households activities.
- The positive implication is also deduced for **agriculture**, especially in terms of cultivation of crops with high water requirement. Heavy rainfall events, which may lead to floods and landslides in some areas, could disrupt agricultural activities.
- While the temporal distribution of rainfall (April and November receiving significant rainfall) may be advantageous for **various sectors** in Kengtung, extreme rainfall events could expose the area into floods and landslides, which could lead to cascading concerns.
- The decreasing tendency in daytime and nighttime temperature could be beneficial **across sectors**, except in incidence of extremely hot daytime temperature and extremely cold nighttime temperature, which may be associated to health and other relevant concerns.

# 5 References


Brunet and Jones, 2011. Data rescue initiatives: bringing historical climate data into the 21st century. Contribution to CR Special 25 "Climate services for sustainable development". Vol. 47: 29-40, 2011.

DMH. Historical rainfall and temperature observation data, 1981-2010.

Driel, W.F. van & T.A. Nauta, 2013. Vulnerability and Resilience Assessment of the Ayeyarwady Delta in Myanmar, Scoping phase. Bay of Bengal Large Marine Ecosystem (BOBLME) Project, Global Water Partnership (GWP) and Delta Alliance, Delft-Wageningen, The Netherlands.

Hoguane, et al., 2012. Influence of rainfall on tropical coastal artisanal fisheries – a case study of Northern Mozambique. Journal of Integrated Coastal Zone Management 12(4):477-482 (2012).

Htay, 2013. Study of Cyclonic Storms which Crossed Myanmar Coast from 1877-2012.

WMO, 2009. Guidelines on analysis of extremes in a changing climate in support of informed decisions for adaptation. Climate and Data Monitoring. WCDMP-No.72.