Songklanakarin J. Sci. Technol.
37 (1), 81-88, Jan. - Feb. 2015

http://www.sjst.psu.ac.th

Original Article

Analysis of daily rainfall during 2001-2012 in Thailand

Mayuening Eso[1,2], Metta Kuning[1,2]*, and Somporn Chuai-Aree[1,2]

[1] *Department of Mathematics and Computer Science, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus, Mueang, Pattani, 94000 Thailand.*

[2] *Centre of Excellence in Mathematics, Commission on Higher Education, Ratchathewi, Bangkok, 10400 Thailand.*

Received: 21 June 2014; Accepted: 3 November 2014

Abstract

The presented study aims to classify precipitation regions, analyze trends, and fit an appropriate model for daily precipitation in Thailand. Factor analysis and generalized linear model (GLM) with gamma regression are performed on the historical records of daily rainfall amounts from 114 weather stations during 2001 to 2012. The study shows that the factor analysis divides the area of Thailand into seven regions with explanation of 58.9% of the total variance. The conducted gamma models reveal a good fit for the upper part, south-east, and south-west of the examined regions. The deviance residual plots from these models also provide a reasonable fit.

Keywords: daily rainfall, daily precipitation, factor analysis, gamma regression, GLM

1. Introduction

Rainfall in Thailand is under the influence of the monsoon seasonal winds i.e. southwest monsoon and northeast monsoon. The southwest monsoon starts in mid-May and continues to mid-October, and the northeast monsoon occurs from mid-October until mid-February. Moreover, the precipitation in Thailand is affected by other winds such as cyclone coming from Pacific Ocean, South China Sea, Bay of Bengal, and Andaman Sea. Typically, the cyclone comes through Thailand at an annual average of 3-4 times, between April and December for each year (Leewatchanaku, 2000; Wangwongwiroj, 2008).

The phenomenon of El Niño and La Niña also influence the amount of rainfall. These events occur every three to eight years as a part of a natural cycle. The term El Niño refers to the situation when sea surface temperatures in the east-central equatorial Pacific Ocean are significantly warmer than normal, and La Niña effects are opposite to those of El Niño and refer to a period when the eastern Pacific Ocean is much cooler than the normal sea surface temperature (Australian Government Bureau of Meteorology, 2005). The damage caused by El Niño is normally quite extensive. For example, it can involve drought and bush fires in Australia, Southeast Asia (especially in Indonesia), and southern Africa. High rainfalls are also observed over parts of Peru, Ecuador, and areas around the Gulf of Mexico from El Niño effect. The impact of La Niña on the world's weather is a tendency to heavy rainfall and flooding in Australia, Indonesia, Philippines, and southern Africa. It also causes a significant drought event occurring in east Africa and southern region of South America. From 2001 to 2012, El Niño occurred in May 2002 to March 2003 (11 months), June 2004 to February 2005 (9 months), August 2005 to January 2006 (6 months), and June 2009 to January 2010 (8 months). For the corresponding period, La Niña occurred in January to February 2001 (2 months) and in September 2007 to May 2008 (9 months) (Jutakorn, 2010), and also between late 2010 and early 2011 (Davey *et al.*, 2011). According to the Australian Government Bureau of Meteorology (2014), the La Niña during 2010-2011 occurred in October and December 2010, and in February and March 2011.

* Corresponding author.
Email address: metta.kuning@gmail.com

There are many advantages from water and rainfall, but excessive water supply might result in natural disasters such as landslides and floods. Thailand has been badly flooded many times due to heavy rainfall, which has contributed to costly damage of assets and agriculture, and significant loss of life. Therefore, it is important to find an appropriate statistical model for forecasting daily precipitation amounts.

In Thailand, precipitation trend analysis as part of climate change for the past several decades has been the topic of many studies. In 2005, Singhrattna *et al.* developed a statistical forecasting method for summer monsoon rainfall (August-October) over Thailand using traditional linear regression and a local polynomial-based nonparametric method in the west central region and in the Chao Phraya River basin. Hung *et al.* (2009) used an Artificial Neural Network (ANN) technique to improve rainfall forecast performance in Bangkok. Szyniszewska and Waylen (2012) studied daily rainfall characteristics from the monthly rainfall totals in central and northeastern Thailand (Lopburi, Chachoengsao, Buriram and Sisaket province). Phien *et al.* (1980) fitted the distribution in time of the monthly rainfall sequences at various stations in northeast Thailand. This study aims to figure out more precisely how daily rainfall varied over the period 2001-2012, to classify rainfall regions in Thailand and to develop an appropriate generalized linear model.

2. Data and Methodology

Daily precipitation for Thailand for the period 2001-2012 (12 years) was obtained from Thai Meteorology Department (TMD). The dataset contains 122 stations starting from January 1, 2001 to February 7, 2013. The criterion is set up to overcome the station with a large amount of missing values. The data in which the values are missing for more than 13% are removed. Eight stations which meet these criteria are Bang Khen, Burirum, Khanom, Krabi, Mae Jo, Nongbualumphu, Sukhothai, and Suwanabhum Airport. Thirty two stations are observed to have incomplete data for January 2001, and are also excluded from the analysis. The rain falling on February, 29 for each leap year, 2004, 2008, and 2012, are simply omitted. As a result, data from February 5, 2001 to February 4, 2013 for 114 stations are used for the study.

The spatial distribution of those 114 stations is shown in Figure 1. It is found that 11 provinces have no stations from this data set. They are Amnat Charoen, Yasothon, Saraburi, Ang Thong, Sing Buri, Nonthaburi, Uthai Thani, Samut Sakhon, Samut Songkhram, Nakhon Nayok, and Nong Bua Lam Phu. Provinces have different numbers of stations. For instance, there are 35 provinces with only one station, 19 provinces with two stations, five provinces with three stations, four provinces with four stations, and two provinces with five stations.

However, rainfalls on successive days are serially correlated. Since conventional statistical models assume independent errors, we effectively reduce these serial correlations by restructuring the data as 5-day averages, thus reducing the data to 73 periods in each year. The autocorrelation function (ACF) is applied for checking the independence assumption (Shumway and Stoffer, 2011; Venables and Ripley, 2002).

Rainfalls in closely clustered stations are also spatially correlated. In this study, factor analysis is used to allocate the 114 stations to a smaller number of clusters with similar patterns. The model for factor analysis can be written in matrix notation as

$$y - \mu = \Lambda f + \varepsilon \tag{1}$$

where

$$y = (y_1, y_2, \ldots, y_p)', \; \mu = (\mu_1, \mu_2, \ldots, \mu_p)',$$

$$f = (f_1, f_2, \ldots, f_m), \; \varepsilon = (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_p)', \text{ and}$$

$$\Lambda = \begin{pmatrix} \lambda_{11} & \lambda_{12} & \cdots & \lambda_{1m} \\ \lambda_{21} & \lambda_{22} & \cdots & \lambda_{2m} \\ \vdots & \vdots & \cdots & \vdots \\ \lambda_{p1} & \lambda_{p2} & \cdots & \lambda_{pm} \end{pmatrix}.$$

Likewise, $y_1, y_2, \ldots, y_p$ are 5-day average of rainfall, $\mu_1, \mu_2, \ldots,$ μ_p are the mean rainfall amount of each station, $f_1, f_2, \ldots, f_m$ are common factors, and $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_p$ are unique factors (Johnson and Wichern, 2007; Rencher, 2002). In this study,

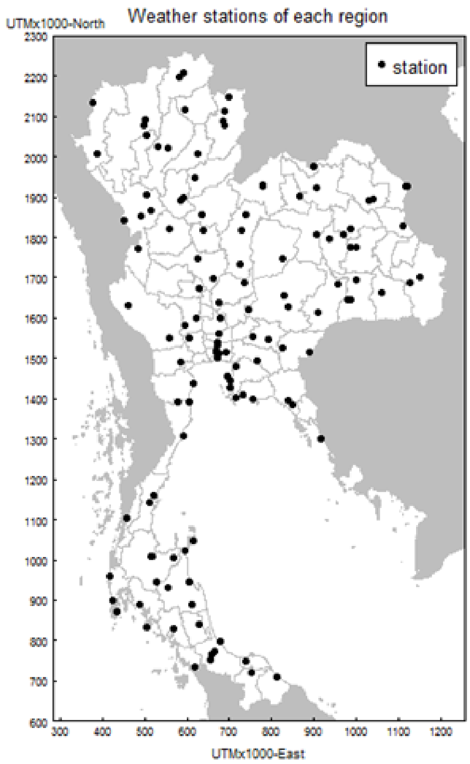

Figure 1. Geographical distribution of the 114 meteorological stations in Thailand

the covariance matrix is used to fit the factor model. Maximum likelihood and promax are used for factor extraction and factor rotation, respectively, to estimate factor loadings. Then, the average daily rainfall from the stations in each factor is computed.

Rainfall measurements have skewed distributions, even when only rainy days (R), with over 4.43 mm/day are selected, and therefore violating the statistical assumption of normally distributed errors. The generalized linear model (GLM) with gamma distributions is fitted for this skewed data. The function is most commonly written as

$$f\left(y|\alpha,\beta\right)=\frac{1}{\Gamma(\alpha)}\beta^{\alpha}y^{\alpha-1}e^{-\beta y}\ \ ,y,\alpha,\beta>0 \qquad (2)$$

where y is a random sample from the gamma distribution, α is an inverse-scale parameter, β is a shape parameter, and $\Gamma(\alpha)$ is a gamma function.

For GLM, the canonical link for the gamma family is $-1/\mu$. Mean for gamma distribution is μ and variance is μ^2 (Gill, 2001). The analyzed multiple regression model is shown as follows;

$$1/\text{mean}[R] = \text{constant - factor(year) - factor(month)} \qquad (3)$$

To check the goodness of fit, deviance residual is used to evaluate models. A 95% confidence interval plot can be used to show the pattern of rainfall amounts for each factor. These confidence intervals are based on standard errors to present the differences between the average rainfall and its overall mean by sum contrasts (Tongkumchum and McNeil, 2009; Venables and Ripley, 2002). The dependent variable of this research is the rainfall amount as 5-day average, and the determinants are months and years. R programming language is used for data analysis and graphical displays (R Development Core Team, 2013).

3. Results

3.1 Factor analysis

Factor analysis is used to produce the rainfall regions in Thailand. This technique is useful for a very large dataset and data reduction with minimum loss of information in order to have a good understanding and interpretation of the data results (Baeriswyl and Rebetez, 1997).

The loading values from factor analysis in Table 1 denote correlations between factors and stations. This technique reduces the number of meteorological stations from 114 to 7 regions and can be explain 58.9% of the total variance. When taking into account the loadings above 0.30, 87 of the 114 stations are correlated with a single factor, and 26 stations are correlated with two factors.

Figure 2 demonstrates the seven regions identified by factor analysis, which comprises of the following regions. The first region (F1) covers the area of the northeastern part of Thailand for 32 stations. The second region (F2) includes the central and eastern part of Thailand with 34 stations, and therefore is defined as central. The third region (F3) consists of 13 stations from the area of the south-east. The fourth region (F4) represents the upper northern part of Thailand with 14 stations. The fifth region (F5) combines 10 stations from the lower north. The sixth region (F6) comprises of nine stations from the south-west, and the last region (F7) covers the area of the upper south including two stations.

3.2 The pattern of daily rainfall

The annual daily average rainfall of each region during 2001-2012 is shown in Figure 3. The daily average rainfall of the upper north, lower north, northeastern, and central region range from 2.99 to 5.01 mm/day. The highest daily average rainfall is in the year 2011 for these regions. These are around 5.01, 4.96, 4.99 and 4.29 mm/day for each region, respectively. In 2009, the upper north has approximately 3.13 mm/day of rainfall on the average, the lowest amount compared to other regions. For the south-west, the daily average rainfall is more than 5.5 mm/day for all years; it reaches its peak of 7.99 mm/day in 2012. For the upper south, the rainfall fluctuates from 4.61 to 6.61 mm/day. There are obvious peaks in 2002 and 2011 with 6.30 and 6.61 mm/day, respectively. The rainfalls of the south-east varies from 4.37 to 8.64 mm/day. Unusual heavy rainfall is also observed in 2005, 2008, 2010, and 2011 with the average of 6.57, 6.86, 7.22, and 8.64 mm/day, respectively.

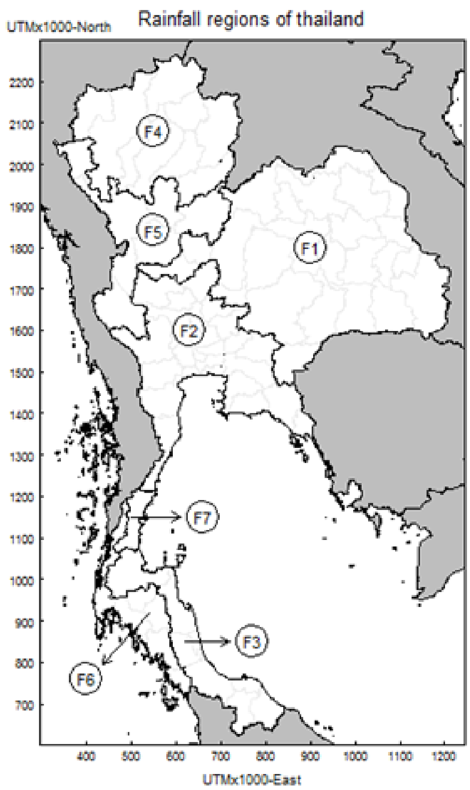

Figure 2. The rainfall regions from factor analysis over Thailand

Table 1. Loading scores from factor analysis

Station	F1	F2	F3	F4	F5	F6	F7	Uniq
NPnomA	**1.133**	-0.125			-0.237		0.191	0.189
MDahan	**1.105**				-0.155		0.133	0.202
SNakhon	**1.100**				-0.240			0.189
NPnom	**1.087**	-0.123			-0.206		0.209	0.175
SNakhonA	**1.082**				-0.238			0.238
RoiEt	**1.008**							0.194
KMlasai	**1.007**					-0.120		0.184
RoiEtA	**1.005**							0.232
KSPhiSai	**0.949**							0.209
TPhraA	**0.905**							0.234
KKaen	**0.859**	0.113			-0.120			0.234
UBRthani	**0.843**						0.164	0.227
Uthani	**0.835**			0.220				0.226
ThaTum	**0.799**			-0.110				0.249
SurinA	**0.779**			-0.127				0.278
Nkhai	**0.778**			0.255				0.244
Surin	**0.767**			-0.122	0.114			0.278
UBRthaniA	**0.765**				0.127		0.181	0.270
SSKetA	**0.754**				0.157		0.103	0.259
ChPhum	**0.566**	0.183					-0.188	0.253
Loei	**0.565**	0.107		0.228			-0.192	0.242
LoeiA	**0.546**	0.118		0.238			-0.191	0.234
LomSak	**0.487**			0.170	0.284			0.239
WiBuri	**0.438**	0.214			0.174		-0.158	0.272
NRong	**0.618**	**0.342**		-0.172				0.298
NRsima	**0.569**	**0.317**					-0.176	0.281
ChChai	**0.492**	**0.424**		-0.105			-0.121	0.319
SKaew	**0.476**	**0.460**					0.100	0.300
BChum	**0.423**	**0.320**			0.111		-0.129	0.290
Pchabun	**0.441**			0.158	**0.314**			0.267
PichitA	**0.367**	0.110		0.129	**0.356**			0.280
Nsawan	**0.299**	0.277			0.281			0.268
KHongA			**0.856**					0.317
Skhla			**0.830**					0.372
NSTA	-0.112		**0.809**					0.337
YalaA	0.186		**0.791**					0.446
NST			**0.788**					0.367
PTlungA	-0.155		**0.773**					0.393
HYaiAir			**0.765**					0.392
PTNAir			**0.765**					0.411
NRTwat			**0.733**			-0.146		0.535
SDao			**0.618**			0.248		0.486
SRThaniA			**0.615**			0.107	0.200	0.425
SRThani			**0.561**			0.187	0.203	0.404
KSmui	-0.105	0.190	**0.551**				0.228	0.520
ChRaiA	0.187	0.118		**0.698**				0.207
ChRai	0.215	0.118		**0.671**				0.225
Pyao	0.113	0.126		**0.666**				0.228
ChMai	0.117			**0.522**	0.257			0.229
Lphun				**0.508**	0.296			0.243
Lpang		0.121		**0.502**	0.295			0.224
MaeHS	0.278			**0.442**	0.193		0.169	0.279
TChang	**0.318**			**0.698**	-0.172			0.192
ThaWP	**0.323**			**0.697**	-0.124			0.160
NanA	**0.362**			**0.660**				0.158
Nan	**0.394**			**0.621**	-0.110			0.176
LpangA				**0.518**	**0.367**			0.201
Phrae	0.161			**0.496**	**0.314**			0.225
Udit	0.160	0.122		**0.411**	**0.327**			0.202

Station	F1	F2	F3	F4	F5	F6	F7	Uniq
HPongA	-0.185	**1.052**			-0.193			0.302
SThip	-0.253	**1.050**			-0.127			0.289
Lbang		**1.042**			-0.183			0.260
PTya	-0.140	**1.035**			-0.134			0.295
RYong	-0.124	**0.969**			-0.158			0.333
KSchang		**0.941**			-0.102			0.283
Pilot		**0.905**						0.312
KToey	0.123	**0.885**				-0.148		0.229
ChBuri		**0.874**						0.276
BNa	0.110	**0.870**				-0.119		0.217
BkokM	0.108	**0.862**				-0.129		0.235
Pburi		**0.775**					0.230	0.311
KPSaenA		**0.739**			0.147			0.263
Ratburi		**0.702**			0.143		0.155	0.279
DMuang	0.138	**0.681**						0.271
HuaHin		**0.663**					0.253	0.369
Kanburi		**0.656**			0.157			0.337
ChChsaoA	0.197	**0.654**				0.113		0.356
PTthaniA	0.136	**0.637**			0.125			0.287
NPhlupA		**0.629**					0.158	0.384
UThongA		**0.616**			0.230			0.262
SuPBuri	0.129	**0.610**			0.213			0.276
PhriuA	0.281	**0.571**	-0.161			0.159	0.146	0.245
AtayaA	0.204	**0.552**			0.183			0.287
LBuri	0.233	**0.438**			0.240			0.278
PChongA	0.265	**0.393**		-0.103	0.167	0.154	-0.172	0.349
TakFaA	0.240	**0.345**			0.244		-0.103	0.268
ChTburi	**0.364**	**0.561**	-0.111				0.144	0.238
Aprathet	**0.356**	**0.469**						0.375
KBBurin	**0.346**	**0.450**						0.301
PrBuri	**0.369**	**0.433**						0.262
KLYai	**0.392**	**0.376**	-0.247			0.203	0.262	0.283
PRKhan		**0.595**			0.105		**0.337**	0.429
ChNat	0.210	**0.413**			**0.316**			0.268
Tak	-0.100	0.109		0.183	**0.738**			0.203
BmbolDam	-0.149	0.147		0.229	**0.685**			0.262
DoiMSA	0.135			0.222	**0.649**		0.190	0.149
MaeSot	0.285			0.243	**0.553**	-0.136	0.287	0.163
SSrongA	0.168	0.108		0.252	**0.451**			0.256
Umphang	0.211		-0.101	0.149	**0.449**		0.135	0.276
TPPhum	0.218	0.176	-0.140	0.120	**0.420**		0.224	0.239
KPPhet	0.171	0.188		0.146	**0.413**			0.288
MaeSr	0.207	0.107		0.292	**0.381**		0.200	0.237
Pnulok	**0.314**	0.151		0.154	**0.374**			0.268
PKetAir	-0.175		0.108			**0.839**		0.276
TKPa						**0.824**		0.265
Pket			0.169			**0.778**		0.322
KLanta			0.181			**0.722**		0.317
Satun			0.270		-0.130	**0.637**		0.464
TrangAir		-0.147	**0.334**			**0.648**		0.353
PSang		-0.128	**0.336**			**0.576**	0.106	0.418
Chawang		-0.154	**0.334**			**0.556**	0.168	0.377
RNong	0.276					**0.490**	**0.371**	0.206
SawiA		0.249	0.251			0.129	**0.396**	0.519
Chphon		0.252	0.274				**0.393**	0.501

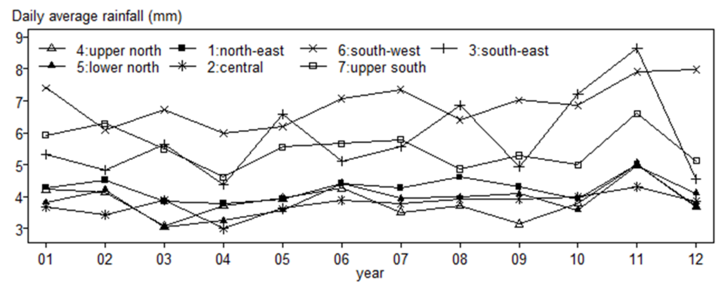

Figure 3. the average of daily rainfall

3.3 Rainy season

The rainy season is defined here as the successive days with an average of daily rainfall of at least 4.43 mm/day. The rainy season is showed by the dark grey color in Figure 4. In the upper part of Thailand, the rainy season for upper north is in the period between April and September, which lasts six months. The lower north region also has the rainy season around six months starting from May to early October. In the north-east, the rainy season occurs in late April to early October, and lasts roughly for seven months. In the central region, the rainy month starts one month after that of north-east from May to October and it lasts six months.

In contrast to rainy seasons in the south of Thailand, the south-west has a quite longer rainy season around nine months starting from late March to November. The upper north has four rainy months during September to December, and there are five months of a rainy season for the south-east starting from September to January.

The overall mean of daily average rainfall during the rainy season are 10.71, 9.16, 8.19, 7.90, 7.40, 7.24, and 6.25 mm/day for the region of south-east, south-west, upper south, north-east, upper north, lower north, and central, respectively.

3.4 Generalized linear model: gamma regression

Gamma regression is fitted to the data using *glm*() function in R. The four regions in the upper part of Thailand have correlation coefficients of over 0.60 (Figure 5), and thus these regions are grouped into one region. In the southern part, the upper south and south-east are also combined because there is a lower number of stations in the upper south region. Gamma regression is thus fitted into three regions; upper, south-west and south-east in the period of rainy seasons.

The autocorrelation function of deviance residuals from gamma model is analyzed to ensure the independence assumption has been handled properly. The ACF plots for each factor show that no statistically significant correlations are at lag 1, and all autocorrelation are below 0.2 as shown in Figure 6.

Figure 7 shows the confidence intervals from the fitted gamma model. For the region of upper part of Thailand, it is found that there are discrepancies for the month of June, August and September from the overall mean of 7.05 mm/day. For these months, the average rainfalls are 6.17, 7.98, and 9.34 mm/day, and 95% confidence intervals are 5.60-6.87, 7.22-8.92, and 8.36-10.59 mm/day, respectively. The daily rainfall in June is under the overall mean and different from other months. In the south-east, the month of November is evidently different from the overall mean of 10.25 mm/day. The average rainfall in this region is 14.89 mm/day and 95% confidence interval is 11.56-20.94 mm/day. In the south-west, there are six months that are statistically significantly different from its overall mean of 9.16 mm/day. It is shown that the averages of rainfall in both April and November are less than the overall mean by having 5.04 mm/day with 4.38-5.93 mm/day of 95% confidence interval, and 6.32 mm/day with 5.34-7.75 mm/day of 95% confidence interval, respectively. For the remaining four months, July, August, September, and

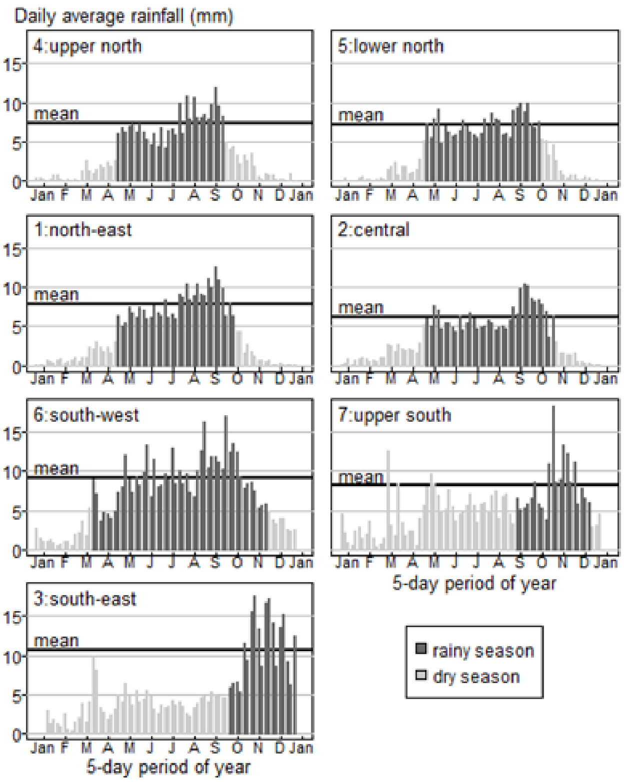

Figure 4. The rainy season of seven regions

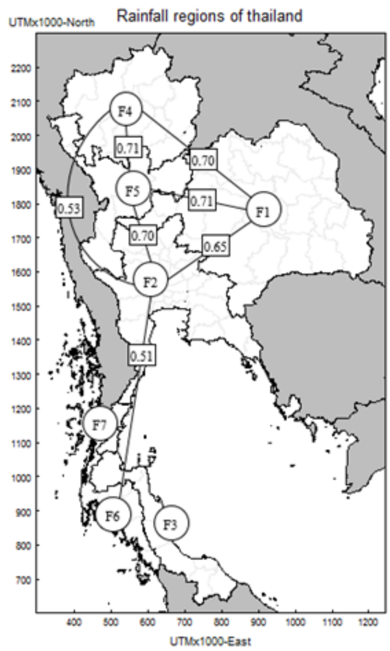

Figure 5. The correlation coefficients between regions

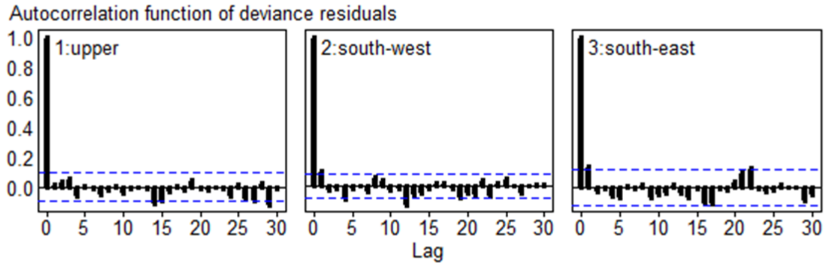

Figure 6. The autocorrelation function of residuals

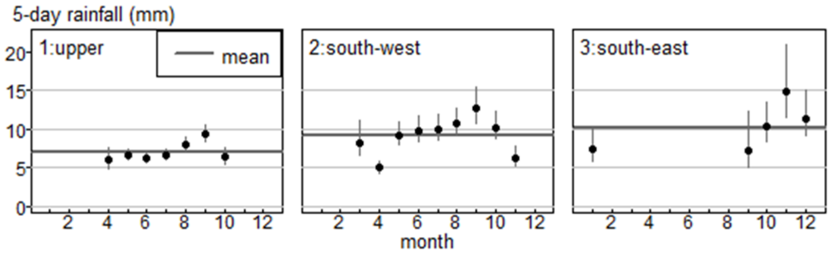

Figure 7. Confidence interval from gamma models of each month

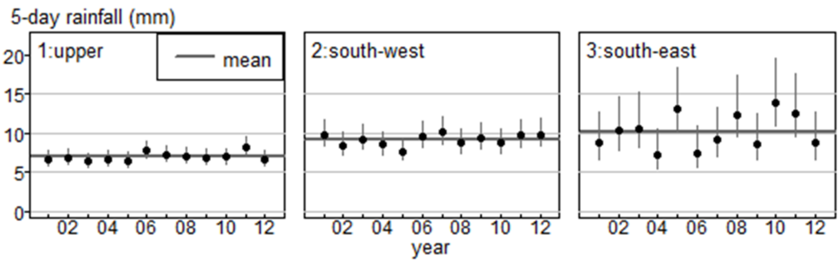

Figure 8. Confidence interval from gamma models of each year

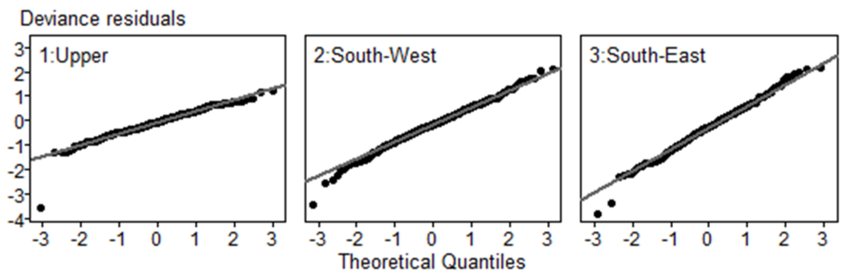

Figure 9. Deviance residuals of three regions from gamma model

October, the averages of rainfall are 10.00, 10.71, 12.73, and 10.27 mm/day with 95% confidence interval of 8.60-11.96, 9.26-12.70, 10.85-15.40, and 8.82-12.29 mm/day, respectively.

When considering year variables (Figure 8), the average of rainfall in the year 2011 is different from the overall mean for the region of the upper part of Thailand. The average of rainfall is 8.30 mm/day, and 95% confidence interval is 7.31-9.60 mm/day. In the south-east, the average rainfalls are different from their overall mean in 2005 and 2010, the average rainfall of 13.14 and 13.99 mm/day and 95% confidence interval of 10.21-18.44 and 10.90-19.51 mm/day, respectively. However, the rainfall in the south-west is not different from its overall mean in each year.

The deviance residual plots from the model are shown in Figure 9, and indicate that the model provides a reasonable fit for all regions.

4. Conclusions and Discussion

The approach of factor analysis is able to separate the regions of Thailand with overall 114 weather stations into seven clusters, comprising of upper north, lower north, northeast, central, upper north, south-west and south-east with the total variance of 58.9%. The successive days with an average rainfall over 4.43 mm/day are specified as a rainy season for each region. Finally, after investigating the correlation coefficient between regions, the seven regions are further reduced into three regions, namely the upper part of Thailand, south-west, and south-east.

The result shows that three models are capable of fitting data reasonably well. The average of rainfall in June, August, and September of the upper part region are statistically significantly different from its overall mean. For the south-west, there are six months that the amounts of rainfall are different from its overall mean starting from April to December excluding May and June, and only the one month of November for the south-east. The amounts of rainfall in the year 2001 of the upper part of Thailand are different from the overall mean and for the south-east, the levels of rainfall in the year 2005 and 2010 are also different from its overall mean.

It is evident that the rainy season of the region in the upper part of Thailand is in the period of the southwest monsoon and also for the south-east in the period of the northeast monsoon. When considering the phenomenon of the La Niña, it seems that the La Niña has no effect on the levels of rainfall in Thailand. The reason for this can be seen from the final model in which the upper part is statistically significantly different from the overall mean in September 2011 when there was no La Niña. Likewise, for the south-east, there was no La Niña event in November 2005 and November 2010.

In addition, the result of year variable from the gamma model for the central region is not different from other years, but in 2011 the area around Bangkok suffered severe flooding starting around the end of July. During June to October in 2011, Thailand experienced five categories of storms. These include 'Hai Ma', 'Nok Ten', 'Hai Tang', 'Nesat', and 'Nalgae'. They caused heavy rainfall in the upper part of Thailand, which then resulted in the worst flood affecting 684 districts of 65 provinces around and in Bangkok (IPSR, 2012).

Acknowledgments

We gratefully acknowledge the Thai Meteorological Department (TMD) for providing the daily rainfall data. We are also grateful to Emeritus Professor Don McNeil for his helpful suggestions. This research was supported by grant funds from the program of Strategic Scholarships Fellowships Frontier Research Networks (Specific for Southern Region) for the Ph.D. Program Thai Doctoral degree from the Office of the Higher Education Commission, Thailand, and also by the Centre of Excellence in Mathematics, the Commission on Higher Education, Thailand.

References

Australian Government Bureau of Meteorology. 2005. El Nino, La Nina and Australia's Climate. Available from: http://www.bom.gov.au/info/leaflets/nino-nina.pdf. [March 27, 2014].

Australian Government Bureau of Meteorology. 2014. Record-breaking La Niña events: An analysis of the La Niña life cycle and the impacts and significance of the 2010-11 and 2011-12 La Niña events in Australia. Available from: http://www.bom.gov.au/climate/enso/history/ln-2010-12/index.shtml. [April 3, 2014]

Baeriswyl, P.A. and Rebetez, M. 1997. Regionalization of precipitation in Switzerland by means of principal component analysis. Theoretical and Applied Climatology. 58, 31-41.

Davey, M., Huddleston, M. and Brookshaw, A. 2011. Global impact of El Niña and La Niña. Available from: http://www.changingclimate.org.uk/uploads/content_documents/361/Global_Impact_of_ElNino_and_LaNina_Implications_for_Financial_Markets.pdf. [April 1, 2014].

Gill, J. 2001. Generalized Linear Models: A Unified Approach, Sage Publications, Inc., Thousand Oaks, U.S.A., pp. 30-39.

Hung, N.Q., Babel, M.S., Weesakul, S. and Tripathi, N.K. 2009. An artificial neural network model for rainfall forecasting in Bangkok Thailand. Hydrology and Earth System Sciences. 13, 1413-1425.

Institute for Population and Social Research, Mahidol University (IPSR). 2012. Food Security the Illusion of Money VS the Reality of Food. Thai Health. 9, 34-40.

Johnson, R.A. and Wichern, D.W. 2007. Applied Multivariate Statistical Analysis, Pearson Prentice Hall, New Jersey, U.S.A., pp. 481-526.

Jutakorn, J. 2010. El Niño and La Niña phenomenon effected on southwest monsoon in Thailand. Meteorological department. Weather report no. 551.557-21-01-2010.

Leewatchanaku, K. 2000. Hydrolog, Siam Stationery Supplies Ltd. Part, Bangkok, Thailand, pp. 3.10-3.23.

Phien, H.N., Arbhabhirama, A. and Sunchindah, A. 1980. Distribution of monthly rainfall in northeast Thailand. Southeast Asian Studies. 18, 110-123.

R Development Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Austria: R Foundation for Statistical Computing. Available from: http://www.R-project.org. [April 18, 2014].

Rencher, A.C. 2002. Methods of Multivariate Analysis, John Wiley and Sons, Inc., New York, U.S.A., pp. 408-447.

Shumway, R.H. and Stoffer, D.S. 2011. Time Series Analysis and Its Applications with R Examples, Springer Science and Business Media, LLC, New York, U.S.A., pp. 21.

Singhrattna, N., Rajagopalan, B., Clark, M. and Kumar, K.K. 2005. Seasonal forecasting of Thailand summer monsoon rainfall. International Journal of Climatology. 25, 649-664.

Szyniszewska, A.M. and Waylen, P.R. 2012. Determining the daily rainfall characteristics from the monthly rainfall totals in central and northeastern Thailand. Applied Geography. 35, 377-393.

Tongkumchum, P. and McNeil, D. 2009. Confidence intervals using contrasts for regression model. Songklanakarin Journal of Science and Technology. 31, 151-156.

Venables, W.N. and Ripley, B.D. 2002. Modern Applied Statistics with S, Springer Science and Business Media, LLC, New York, U.S.A., pp. 183-189, 389-391.

Wangwongwiroj, N. 2008. Hydrology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand, pp. 57-71.