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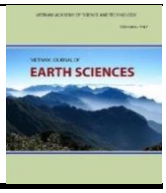

Spatial distribution of hot days in north central region, Vietnam in the period of 1980-2013

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ABSTRACT

Based on the data of daily maximum temperature of 26 meteorological stations in the North Center Region, Vietnam over the period of 1980-2013, the authors conducted the research on spatial distribution of the number of hot days. The initial result shows that in general, in the north of the study area, the large number of hot days occurred in the plain, the hot days tend to decrease moving from the plain to the west and the east. In the south, the number tends to increase from the west to the east. Especially, the largest number occurred in two areas: Ma and Ca Rivers valleys (Thanh Hoa and Nghe An provinces) and coastal areas (Thua Thien Hue province) creating two hot centers in Tuong Duong district (Nghe An province) and Nam Dong district (Thua Thien Hue province).

Keywords: Heat wave; hot day; spatial distribution; North Center Region.

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1. Introduction

Heat waves are among the extreme weather events with extreme temperature significantly affecting on human being, environment and social-economic activities. Heat waves are direct causes of some disasters such as drought and usually associated with variety of calamities influencing society in term of water quality and quantity, human health, mortality, to name but a few (Nairn and Fawcett, 2013; Unal et al., 2013; Liu et al., 2015). For example, more Australians die every year due to extreme heat events than other natural hazards (Will Steffen, 2015) and increased risk of heat-related deaths in many populated areas of the United States (Peterson et al., 2013), Europe (D'Ippoliti et al., 2010). Moreover, numerous studies underscored that there are many negative effects on wide range of sectors caused by heat waves including agriculture, aquaculture, tourism, etc (Unal et al., 2013).

Although there is no single agreed upon definition of a heat wave, but in general, it is considered as a period of consecutive days with unusual high temperatures that potentially can harm human health (Hay hoe et al., 2004).

The ground-breaking research have indicated that extreme heat is closely associated to climate change. Due to climate change, it is noticed that the Earth's surface has experienced the successfully warmer at the recent three decades than any preceding decades since 1950 (IPCC, 2014). The report

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also indicated that it is more likely to increase the number of warm days and nights; by contract, decline the cold days and nights figure on the global scale. Moreover, many characteristics of heat wave have varied in term of frequency, intensity and duration over the period of 1950-2013 across Australia (Perkins and Alexander 2013; Climate Council 2014b). For example, it is observed in Australia that the record of hot days have double in the last 50 years, while record cold days have declined by a similar fractions (CSIRO and BoM, 2012) and hot weather records were set three times more often than those of cold weather over the last decade (Trewin and Smalley, 2013). In many regions of Europe, especially Hungarian Plain and Southern Romania, the summers have experienced longer, more frequent, severe and intensive hot weather (Spinoni et al., 2015). Besides, according to Croitoruin which western and central regions of Romania are the most exposed to an increase of heat waves (Adina-Eliza Croitoru et al., 2016). In Italy, three heat variables including daily average temperature, daily average maximum and minimum temperature tended to go down in early stage from 1961 to 1981 and go up in the late stage (Toreti A. and Desiaton F., 2008). In Pacific Asian countries, over the period of 1961-1998, the number of warm days and nights was shown the tendency to rise, by contrast, the figure of cool days and nights declined (Manton M.J, 2001).

Heat waves can occur at various periods of time in different geographical areas all over the world. For Vietnam, virtual regions of the country are subject to heat waves, especially in the summer or dry season. In the country, a heat wave which occurs in particular region refers to a period of at least two days in succession with daily maximum temperature is equal or more than 35°C (Tx ≥ 35°C) in more than half of stations in the region. Besides, the day with Tx ≥ 35°C is considered a hot day (National Central for Hydro-Meteorological Forecasting).

Due to the location (located in the belt of tropical monsoon climate, strongly affected by Western Pacific subtropical-high pressure and Western hot low pressure in summer) and terrain's diversification (the terrain is tilted in the northwest-southeast direction), the country has experienced a large number of hot days in general. Besides, in this period, the number tended to increase gradually by decades in most regions of the nation that is cut out for global warming and makes the climate condition more severe.

In recent years, heat wave has occurred more frequently and intensively than the past on a large scale and its effects are so increasingly severe and unpredictable. According to reliable researches, there were more hot days in the decades (1991-2000) than some previous decades, especially in the Center and the South of Vietnam. This has significant relationship with the rise of some extreme weather events such as drought.

It is true that local topography conditions consisting of elevation and terrain form play an important role in accelerating temperature and therefore, heat waves. For instance, the moisture air is forced up by slope, the air cools, moisture condenses, rainfall and latent heating occur with consequences similar to those associated with convection heating (Gerald A. Meehl, 1992). As a result, dry air comes down and its temperature goes up.

Turning to North Central Region, there are high ranges of mountain in the west that facilitates Fohn effect in the summer. Fohn is hot and dry wind blowing in waves from the mountains to the valleys creating hot and dry condition with maximum temperature reaching at 35°C at noon and relative humidity dropping below 45%.

The main objective of this study is to divide the hot day belts based on observed data, vertical temperature variation and Fohn

effect in the North Central Region during 1980-2013.

2. Data and Method

2.1. Data

The data consists of daily maximum temperature (Tx) of 26 stations in the region observed in 34 years (1980-2013) that is provided by Centre of Information and Hydro-meteorological Data. The specification of the stations is presented in the following table (table 1).

Table 1. Technical specification of meteorological stations in the North Central region

No.	Stations	Longitude	Latitude	Height (m)	No.	Stations	Longitude	Latitude	Height (m)
	Thanh Hoa province					Ha Tinh province			
1	Hoi Xuan	105°07’	20°22’	87	15	Kim Cuong	105°16’	18°27’	10
2	Bai Thuong	105°23’	19°54’	21	16	Huong Khe	105°42’	18°11’	10
3	Yen Dinh	105°39’	19°58’	9	17	Ha Tinh	105°54’	18°21’	3
4	Thanh Hoa	105°46’	19°49’	5	18	Ky Anh	106°17’	18°05’	3
5	Phu Xuan	105°34’	19°38’	10		Quang Binh province			
6	Tinh Gia	105°47’	19°32’	5	19	Tuyen Hoa	106°08’	17°50’	25
	Nghe An province				20	Ba Don	106°25’	17°45’	8
7	Quy Chau	105°07’	19°33’	87	21	Dong Hoi	106°37’	17°28’	7
8	Quy Hop	105°07’	19°19’	88		Quang Tri province			
9	Tay Hieu	105°24’	19°19’	72	22	Dong Ha	107°50’	16°50’	4.16
10	Quynh Luu	105°38’	19°08’	3	23	Khe Sanh	106°50’	16°38’	367
11	Tuong Duong	104°26’	19°19’	97		Thua Thien Hue province			
12	Con Cuong	105°53’	19°03’	27	24	Hue	107°41’	16°24’	10.5
13	Do Luong	105°18’	18°54’	4	25	A Luoi	107°25’	16°12’	600
14	Vinh	105°40’	18°40’	6	26	Nam Dong	107°43’	16°09’	59.7

2.2. Methods

In order to carry out the research, the authors use some methods including:

- Statistic is used to determine the number of yearly average hot days over 34 years depending on Tx in each station.

- Mapping is used to set up the map of Tx and hot day distributions in the region, scale 1:250,000.

To produce the zones of Tx and number of hot days, we drew the contours. However, due to limitation of the stations, the authors densified the data based on two reasons: vertical temperature variation (average temperature decreases about 0.6°C when elevation increases 100 m) and Fohn effect (this factor intensifies the temperature that has lifted the contours up). It means, for example, there are more hot days in the region affected by Fohn effect than other regions with same elevation).

3. Results

3.1. The monthly and yearly maximum temperature

In general, monthly maximum temperature over the 34 years fluctuated from 20°C to 34.9°C reaching the highest values in the summer (June, July, August) and lowest points in the winter (December, January, February) as a general picture in Vietnam. There was a range of yearly maximum temperature by 3.6°C with highest and lowest values were 30.2°C and 26.6°C in Nam Dong and A Luoi station, respectively (Table 2).

The monthly temperature in six stations represented for the provinces is displayed in Fig. 1 to clarify the temporal and spatial changes of temperature in the region in the period (1980-2013) (Fig. 1).

As is shown in the Fig. 1, the temperature figure tended to hit a peak in the summer and reach a bottom in the winter asmentioned above. Spatially, in the whole period, the

temperature value was highest in Hue, closely followed by Dong Ha station. Thanh Hoa recorded a period with the lowest value of maximum temperature of the six stations.

Table 2. The monthly and yearly maximum temperature in the period from 1980 to 2013

No.	Month / Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
1	Hoi Xuan	21.7	23.1	26.1	30.5	33.3	34.2	33.8	33.2	31.7	29.2	26.6	23.2	**28.9**
2	Bai Thuong	20.9	21.8	24.3	28.5	32.1	33.7	33.6	32.5	31.2	29	26.4	22.6	**28.1**
3	Yen Dinh	20.4	21.1	23.5	27.6	31.5	33.5	33.1	32.1	30.8	28.8	25.9	22.3	**27.6**
4	Thanh Hoa	20.0	20.6	22.9	27.1	31.2	33.4	33.2	32.3	30.8	28.5	25.7	22.0	27.3
5	Nhu Xuan	20.4	21.0	23.6	27.9	31.5	33.9	33.7	32.4	30.8	28.7	26.0	22.2	28.2
6	Tinh Gia	20.1	20.7	23	27.4	31.5	33.9	33.8	32.6	30.8	28.4	25.6	22	**27.5**
7	Quy Chau	22.2	23.4	26.5	31.1	33.5	34.2	34.2	33.2	31.6	29.1	26.6	23.2	**29.1**
8	Quy Hop	21.8	23	26.1	30.8	33.4	34.3	34.4	33.3	31.5	29	26.5	23	**28.9**
9	Tay Hieu	21.2	22.4	25.4	30.1	33.2	34.3	34.3	33	31.2	28.7	26.1	22.7	**28.6**
10	Quynh Luu	20.4	21.1	23.4	27.5	31.3	33.3	33.1	32.2	30.6	28.2	25.5	22	**27.4**
11	Tuong Duong	23.1	24.9	28.5	32.5	34.3	34.7	34.6	33.7	32.2	29.5	27.1	23.9	**29.9**
12	Con Cuong	21.7	22.9	26.1	30.6	33.5	34.6	34.5	33.6	31.6	28.8	26.3	22.8	**28.9**
13	Do Luong	20.8	21.9	24.6	29.1	32.6	34.2	34	32.9	31.1	28.4	25.8	22.3	**28.1**
14	Vinh	**20.5**	**21.3**	**23.8**	**28.3**	**32.3**	**34.2**	**34.3**	**33.1**	**30.9**	**27.9**	**25.1**	**21.7**	27.8
15	Kim Cuong	21.1	22.2	25.4	30	33.1	34.2	34.2	33.3	31.3	28.1	25.3	22	**28.4**
16	Huong Khe	21.6	22.9	25.9	30.7	33.6	34.6	34.9	33.7	31.3	28.2	25.4	22.1	**28.7**
17	Ha Tinh	20.6	21.4	24.1	28.4	32.4	34.2	34.3	33.2	30.8	27.9	25	21.6	**27.8**
18	Ky Anh	20.4	20.9	23.8	28.3	32.2	33.7	33.9	33.0	30.6	27.1	24.3	21.4	**27.5**
19	Tuyen Hoa	21.7	23.2	26.8	31.3	33.7	34.4	34.1	33.6	31.2	28	25.2	21.9	**28.8**
20	Ba Don	21.8	22.7	25.4	29.3	32.7	34.3	34.3	33.5	31.2	28.4	25.6	22.5	**28.5**
21	Dong Hoi	22	22.6	25.1	29	32.2	34	34.1	33.4	30.9	28.3	25.8	22.7	**28.3**
22	Dong Ha	22.9	24.2	27.2	31.3	33.8	34.8	34.7	33.9	31.6	28.7	26.2	23.2	**29.4**
23	Khe Sanh	22	24.2	27.5	30.8	31.3	30.2	29.6	29	28.8	26.8	24.3	21.5	**27.2**
24	Hue	23.5	24.9	27.6	31.1	33.4	34.6	34.7	34.2	31.6	28.9	26.5	23.4	**29.5**
25	A Luoi	21.3	23.5	26.2	29.3	30.3	30.6	30.4	29.8	28.2	25.5	23	20.5	**26.6**
26	Nam Dong	24.4	26.4	29.3	32.8	34.3	34.9	34.7	34.3	31.9	29	26.5	23.7	**30.2**
	Average	**21.5**	**22.6**	**25.5**	**29.7**	**32.6**	**33.9**	**33.8**	**32.9**	**31.0**	**28.4**	**25.7**	**22.4**	**28.3**

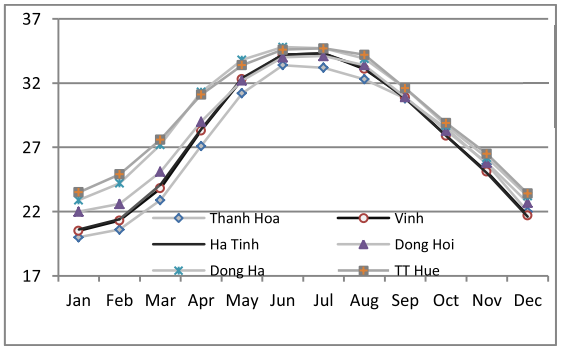

Figure 1. The average monthly maximum temperature in the period of 1980-2013

3.2. Setting up a map of average annual maximum temperature in the region in the period of 1980-2013

The map shows spatial variation of inter-annual maximum temperature in the North Central region. There are four belts of the temperature including: less than 26°C, from 26°C to 28°C, from 28°C to 30°C and greater than 30°C. In the North of the region (Thanh Hoa, Nghe An and Ha Tinh province), in general, the temperature tended to increase from the west to the middle and from the east to the middle as well. In other words, the highest temperature was in the middle and decreases from the middle to the east and the west. There was one heat center located surrounding Tuong Duong district, Nghe An province. In the South (3 remaining provinces), the temperature tended to increase from the west to the east. The vicinity of Nam Dong, Thua Thien Hue province became the heat center of the South or the second heat center of whole region (Fig. 2).

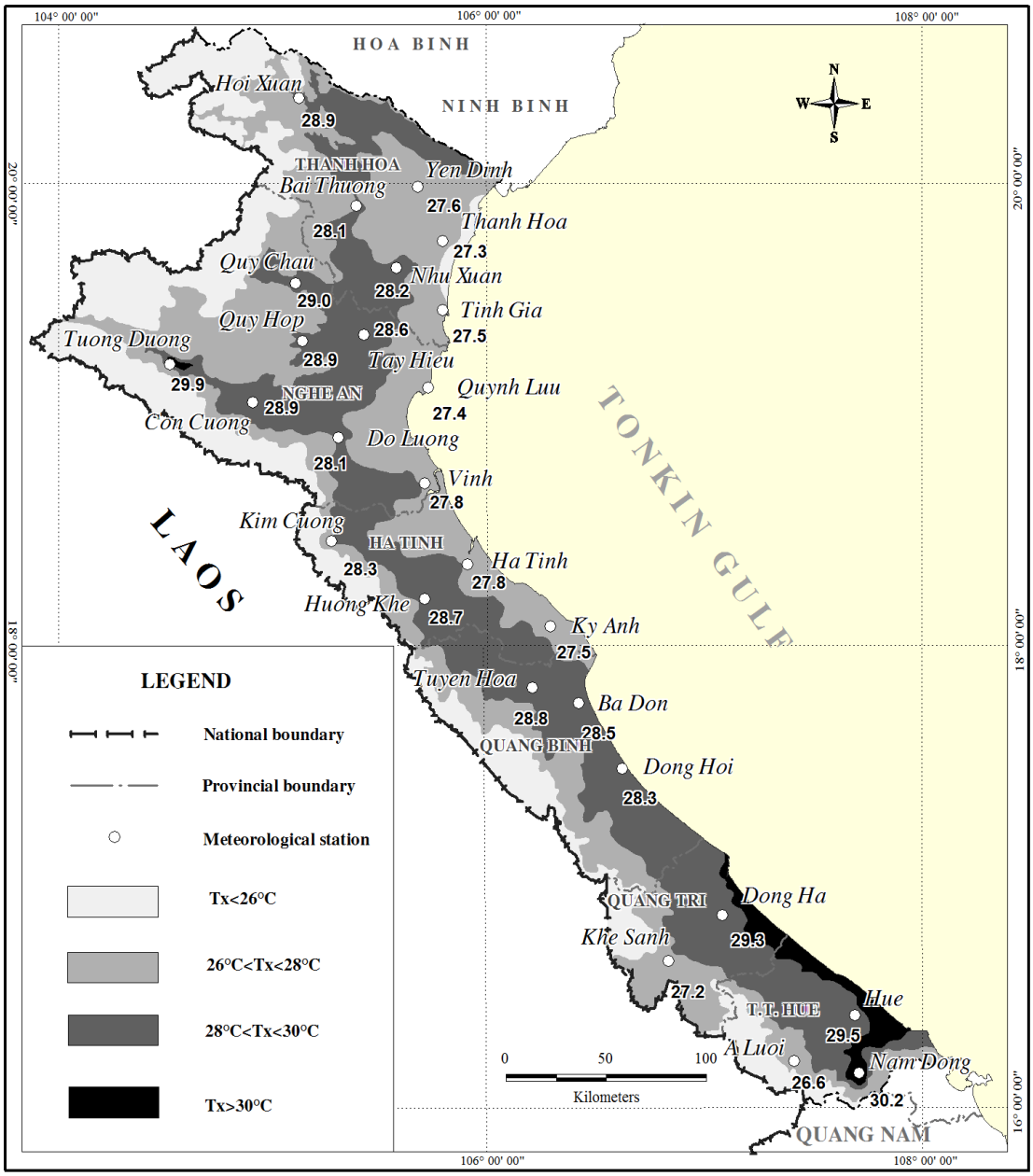

Figure 2. Average annual maximum temperature map in the North Central Region

Regarding daily maximum temperature in the period of 34 years, it fluctuates from 38.1 to 43°C as shown in Fig. 2. in each station, daily maximum temperature tended to reach the peak at most El Nino years (Table 3).

Table 3. Daily maximum temperature in period of 1980-2013

Stations	Daily Tx	Year	Stations	Daily Tx	Year
Hoi Xuan	41.7	2003	Vinh	40.7	2010
Bai Thuong	41.5	1983	Kim Cuong	41	2010
Yen Dinh	40.5	1983	Huong Khe	42	2007
Thanh Hoa	40.3	1987	Ha Tinh	40.2	1994
Nhu Xuan	41.8	2010	Ky Anh	39.5	1987
Tinh Gia	42.4	2003	Tuyen Hoa	41.6	2010
Quy Chau	42.5	2005	Ba Don	40.7	2007
Quy Hop	42.1	2011	Dong Hoi	40.7	1980
Tay Hieu	43	2007	Dong Ha	42.1	1980
Quynh Luu	39.5	1987	Khe Sanh	38.7	1988
Tuong Duong	42.2	2007	Hue	41.3	1983
Con Cuong	42.2	2010	A Luoi	38.1	1983
Do Luong	40.6	2010	Nam Dong	41.1	2013

3.2. Number of hot days in the period from 1980 to 2013

As is shown in the Fig. 2, the number of hot days in the region ranges widely from 1.8 to 85.1 days between 1980 and 2013.

In comparison with the other regions of the country, North Central Region has a large number of hot days since more than half station (18 stations) had over 40 days per year. Especially, in some stations belong to the western areas such as Quy Chau, Quy Hop, Tay Hieu stations (Nghe An province), Huong Khe, Kim Cuong stations (Ha Tinh province), Ba Don station (Quang Binh province), there were more than 52 hot days. However, there was a wide range of hot day in two south provinces, fluctuating from the smallest number such as A Luoi: 1.8 days, Khe Sanh: 10.1 days to the greatest number (Dong Ha: 70.4 day, Hue: 63.5 days, Nam Dong: 85.1 days).

Moreover, it is clearly seen that in north four provinces of the study area, the hot days tended to occur with a large number in the west and decreased moving to the east (toward the sea). The largest number of hot days occurred in Tuong Duong station (Nghe An province) and this place became the first hot center. By contrast, in the other provinces, hot days appeared virtually in the east and reduced moving to the west. The greatest number occurred in Nam Dong station and thus, this place became the second hot center. The number of hot day also dramatically changed in these two provinces as against the whole region.

Regarding reason for the figure, in the one hand, the elevation is one of the important causes of changing the hot days. For example, two stations (A Luoi and Khe Sanh) with the least number are located at highest elevation at 600 m and 367 m, respectively. The equal important reason is Fohn effect.

As a result, spatial distribution of the hot days for the whole region is shown in Fig. 4.

3.3. The number of hot day map in the North Central Region

3.3.1. Method of mapping

The map is established based on the hot day contours with particular number of hot days. Dividing the number is based on the observed data, elevation and Fohn effect. The observed data shows that the number ranged widely from 1.8 to 85,5 days in the stations at elevation around 10m to 600 m and thus, there are no hot days in the areas with elevation being equal or more than 700 m. This assertion is content with vertical temperature variation as maximum temperature cannot reach 35°C at around 700 m.

In order to make distribution of hot days as detailed as possible, the number of hot days is divided into 6 levels: level 1 (no hot days),

level 2 (0-20 hot days), level 3 (20-40 hot days), level 4 (40-60 hot days), level 5 (60-80 hot days) and level 6 (more than 80 hot days) (Fig. 3).

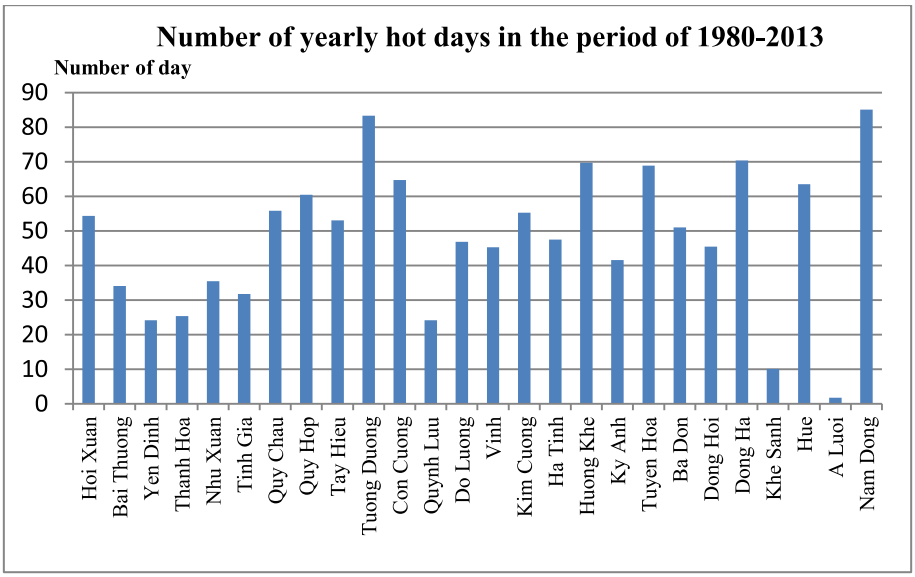

Figure 3. The number of average yearly hot day in the North Central Region

3.3.2. Spatial distribution of hot days

It is clearly to see that the largest area of the North Central Region is at level 4 with yearly average hot days between 40 and 60 days. If only considered the temperature, level 4 (40-60 hot days) is just available in the plains and valleys with elevations less than 200 meters. However, due to Fohn effect, this level extends to the higher elevations occupying a large area including a part of Thanh Hoa and Nghe An province, almost areas of Ha Tinh province, the coastal plain area of Quang Binh province, the plain of Quang Tri and Thua Thien Hue province (Fig. 4). In addition, the level also occurs in hidden valleys of the high mountain range such as Muong Lat valley, Ma and Ca rivers valleys.

Level 3 (20 to 40 hot days) occupies the second largest area of the region. The level has been at altitude from 200 to 500 meters located in the west of all the provinces in the study area. The level occupies the most area of Thanh Hoa and Nghe An provinces, the least area of Ha Tinh and Quang Binh province. Besides, the level was also available in the coastal zone belonging to Nghe An and Thanh Hoa.

Level 2 (0-20 hot days) occupies the third largest area of the region that distributes at the elevation from 500 to 700 meters belonging to west hills. Particularly, small coastal areas of Thanh Hoa city (Thanh Hoa province) and Quynh Luu district (Nghe An province) have been in this level.

From 700 meters and above, there is no hot day because of vertical temperature variation. Therefore, the area without hot day appears in high mountains in the west of the North Central region. Exception, the mountain pass of Ha Tinh province (Ngang mountain pass) with height around 250m had no hot day in the whole period.

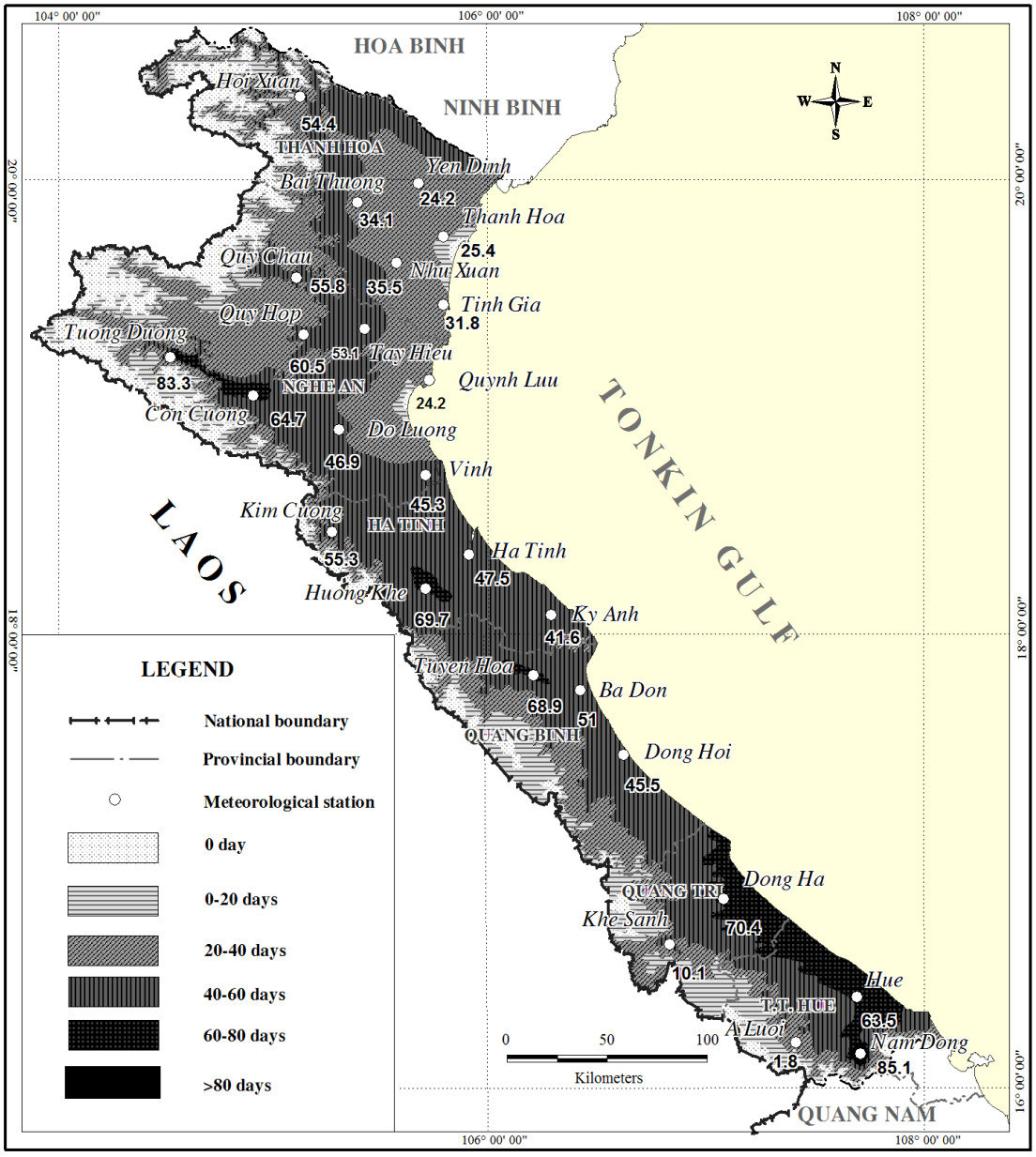

Figure 4. The number of hot day map in the North Central Region, scale 1:250,000

Level 5 (60-80 hot days) appears in the small areas of the whole region including the coastal area of Thua Thien Hue (this level occupies almost the entire area of this province), vicinity of Hoi Xuan station belonging to Ma river valley, a part of Tuong Duong, Muong Xen and Con Cuong districts belonging to Ca river valley, surrounding Huong Khe station (Ha Tinh province) and Tuyen Hoa station (Quang Binh province). The reason of high number of hot day in these areas is high local temperature combined with strong Fohn effect due to steep terrain and narrow land that facilitate Fohn to penetrate into the area.

Specially, there are two areas with the largest number of hot day in the North Central

Region (more than 80 hot days) such as Nam Dong district (Thua Thien Hue province) and Tuong Duong district (Nghe An province). These places lie in valleys which are strongest influenced by Fohn effect compared to all parts of the region.

To sum up, the number of hot day in North Central Region is divided into 6 levels (no hot day, 0-20 hot days, 20-40 hot days, 40-60 hot days, 60-80 hot days and more than 80 hot days). The level of 40-60 hot days appeared in the largest area; the level of more than 80 days appeared in the smallest area and formed the heat centers. Spatially, in the north, the hot day tends to appear more frequently in the plain and reduces moving to the west and the east. There is a hot center in Tuong Duong district (Nghe An province) surrounding Ma and Ca rivers valleys. In the south, the number tends to increase moving from the west to the east and formed the second hot center in Nam Dong district (Thua Thien Hue province).

4. Discussions

The hot day appears in the North Central Region due to complex mechanism but it can be categorized into 3 main causes: the local temperatures, topography and Fohn effect.

In the north of the region, the largest number of hot days occurs in Ma and Ca rivers valleys creating the first hot center (Tuong Duong district, Nghe An province) because they locate in hidden side of the mountain range where are strongly exposed to Fohn effect. There are large number of hot days in the plain and from the plain, frequency of heat wave decreases gradually moving to the west and the east. For the reason, the temperature at high elevation in the west is lower than in the plain; the temperature in the east also low since Fohn effect in the coastal area reduces when the wind passes a long road from the west to the east.

In the south, due to steep slopes and short road between west and east, Fohn effect is still strong in the entire region. Besides, because the terrain is steep gradually from west to east, the temperature increases steadily by this way. Thus, frequency of hot day goes up from west to east and reaches the largest number in Nam Dong district, Thua Thien Hue province creating the second hot center.

The heat wave is a consequence of the complicated combination of many reasons. To identify the particular reason, it should be divided the region into some small parts such as mountainous, coastal area, plain, etc as each part has different causes of hot days. In the research, we have not analyzed the all reasons for the hot days.

5. Conclusions

The study of the spatial distribution of hot days in the North Central Region during 1980-2013, the author gives some following conclusions:

- There is a similarity between the spatial distribution of the average annual maximum temperature and the number of hot days.

- The annual number of hot day from 40-60 days appears in the largest area of the region.

- There is unequal distribution in the region: In the Northern provinces, the hot days appear mostly in the plains and decrease moving from plain to the west and the east. In the southern provinces, the hot days tends to rise from the west to the east. There is the large number of hot days in Ma and Ca rivers valleys (Thanh Hoa, Nghe An provinces) and coastal areas (Thua Thien Hue province) creating two hot centers in Tuong Duong district (Nghe An province) and Nam Dong district (Thua Thien Hue province).

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