Research Paper

# STUDY ON A CASE STUDY OF ABNORMAL HEAT WAVES IN THE WINTER IN THE NORTHERN AREAS OF VIET NAM IN 2010 AND 2015

**Vo Van Hoa[1],Vu Anh Tuan[2], Du Duc Tien[2], Mai Khanh Hung[2], Luong Thi Thanh Huyen[2], Luu Khanh Huyen[2]**

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**ABSTRACT**

*Under the condition of climate change, the abnormal extreme weather phenomena has been increasing in both of frequency and intensity, especially the abnormal heat waves in the winter. The paper shows the results of thermodynamic analysis that caused two abnormal heat waves in the winter in northern areas of Viet Nam (one case occurred in the early winter, the other occurred at the end of winter). Based on the large-scale synoptic pattern analysis, we found that the key reason that caused abnormal heat waves in the winter in northern areas of Viet Nam is due to the unusual activities of western hot low pressure and western Pacific subtropical high pressure in combination with "foehn" effect caused by Hoang Lien Son high rock mountain . In some cases, the combination between strong cold surge that descending from the south China and western hot low pressure also caused an abnormal heat wave in the winter.*

**Keywords**: *Abnormal heat wave, western hot low pressure, foehn effect.*

## 1. Introduction

In recent years, weather and climate conditions have become increasingly complex. The abnormal changes of weather and climate, such as droughts, storms and heavy rain, have caused many difficulties and even great losses for production and business in many fields of socio-seconomic development activities. On the other hand, the fluctuations of climate and weather have made difficult to forecast. The lack of long-term climate and weather forecasts is a major constraint for policy makers and managers in proposing, planning and developing national-wide and local socio-economic development plans. At the national and local levels, leaders and even local people have to deal passively with nature. That really has a great impact on the economic and social life of the country.

In Viet Nam, in the past 10 years, due to the effects of climate change, the weather regime in most parts of Viet Nam has changed considerably. Heat wave is also an abnormal increase in the highest temperature value as well as the duration of a period of heat wave. Based on observation data, the everage temperature of 2010 is considered as the hottest year in the series of ob-

VO VAN HOA
vovanhoa80@yahoo.com
[1]Red-river Delta Regional Hydro-Meteorological Center
[2]National Center for Hydro-Meteorological Forecasting

served data. However, the year 2015 broke the record. However, the most typical example of climate change is the unusually winter. Specifically, the phenomenon of snow, ice, frost, ... occurred on a large scale. Unbelievable snow is observed in recent years. Even in the middle of the winter, the maximum daily temperature in the northern mountainous provinces observed 32 - 34$^0$C, making it feel like as in the summer. Due to the influence of El Nino phenomenon 2015 - 2016, in the middle of winter, the northern provinces still have hot days as summer, the daily temperature was up to 32 - 33$^0$C. Therefore, the winter 2015 - 2016 was identified as an unusually warm winter. Specifically, during the period from February 12 - 14, 2016, due to the impact of the low pressure is compressed by the cold surge in the north combined with the field of divergence on the 5000 meters, the northern provinces appeared relatively high temperature 31 - 33$^0$C, some higher places such as Lac Son: 35.2$^0$C; Hoa Binh: 34.5$^0$C; Bac Me: 33.7$^0$C; ... in the center of Hanoi, the temperature was also 33.3$^0$C. Apart from high temperature, the humidity in the day was also very low, only 30-35%. This is a rare event in recent years because of the climate phenomenon that must occur in October and November every year.

In fact, there were a lot of national researchs that mentioned to winter moonson in Asia. Wallace and Gutzler (1981) ultilized 500hPa geopotential height anomalous in the winter of North hemisphere in order to build a forecast equation of change of Siberia high-pressure based on 3 impact centers including Scandinava center (55$^0$N, 20$^0$E), Seberia center (55$^0$N, 75$^0$E) and Japan center (40$^0$N, 145$^0$E). The result verification pointed out that the positve value of forecasting equation mean that the significant change of Siberia high-pressure in comparison with the normal. Yi Zhang and et al (1997) had paid attention to climatology and annual cycle of winter moonson in Asia from 1979 to 1995 based on NCAR's reanalysis dataset. The temporal and spatial distribution of winter moonson in Asia is belong to the cold mass's origin, path and progress. These results was pointed out in Sirapong and et al (2014). In average, there are 2 extreme cold surges in the winter. The extreme cold surge usually occurred in 7 to 9 days with the highest pressure at Seberia center around 1060 hPa. The intensity of Siberia high-pressure usually change according to season and reach to maximum in January. However, the extreme cold surges usually occurred in October and March. Hansen and et al (1999) pointed out the temperature increasing in Siberia region is faster than the increasing of global average temperature. Moreover, the temperature increasing on the land is higher than the ocean that caused the re-distributing of global pressure system. This caused the annual intensity change of Siberia high-pressure such as another large-scale pressure system. Bingiyi Wu and Jia Wang (2002) studied the impact of pole oscillation and Siberia high-pressure on the change of East Asia winter moonson and found that Siberia high-pressure is direct and key impact factor. The affect of Siberia high-pressure on surface temperature mainly impacted to the south of 50$^0$N, Pacific northwest and south of China. The similar results were found in research of Bin Wang and et al (2001).

It can be seen that under the influence of climate change, many weather and climate phenomena in Viet Nam have changed in a more extreme and unusual trend, including abnormal heat wave in winter in the northern mountainous provinces. In order to understand and predict these changes, it is necessary to have studies to evaluate the magnitude, trend and behavior of abnormal heat wave in the winter in the northern mountainous areas as well as their impact in recent decades. The paper shows out the results

of thermodynamic analysis that caused two abnormal heat waves in the winter in northern areas of Viet Nam (one case occurred in the early winter, the other occurred at the end of winter). The next section will give out the dataset is used in the analysis. The large-scale synoptic pattern analysis results that caused the abnormal heat waves in 16 to 19 November 2015 and 25 to 27 Feb 2010 presents in third section. Finally, is some key findings and remarks.

## 2. Dataset and analysis methodology

To have sufficient scientific basis to analyze the anomalies of winter heat waves in the northern mountainous areas as well as to show the dynamic thermodynamic mechanisms that govern the abnormal activity of heat waves. In this study, we conducted two abnormal heat waves, including heat wave from 16 to 19 November 2015 (early winter) and heat wave from 25 to 27 February 2010 (late winter). In order to serve the analysis, we collected the following dataset:

- Daily maximum temperature of 21 surface meteorological observation stations in the north region of Viet Nam from 25 to 27 February 2010 and 16 to 19 November 2015. These daily maximum temperatures are checked by QC system prior to using in analysis (logic, physical and climatology checks)

- The climatological monthly average temperature in November and February that is calculated from period of 1971 - 2010 at 21 surface meteorological observation stations in the north region of Viet Nam.

- JRA55 reanalysis data of JMA (ftp://ds.data.jma.go.jp/ JRA-55/Hist/Daily) from 23 to 29 February 2010 and 14 to 21 November 2015 including presssure of mean sea level, 10 meters wind, 2 meters temperature at surface level. At upper standard pressures of 925, 850, 700 and 500hPa, the geopotential height and wind field were collected.

The abnormal factor determined according to the large different between the daily maximum temperature of these days that heat wave occurring with climatological monthly average temperature. In order to find out the synoptic patterns that drive the abnormal heat waves, the weather maps from surface up to 500hPa level derived from JRA55 reanalysis data is analyzed by synoptic resonance analysis method.

## 3. The large-scale weather pattern analysis that caused the abnormal heat waves in the winter in the northern areas of Viet Nam

### *3.1. The abnormal heat wave from 16 to 19 November 2015*

From 16 to 19 November 2015, there was an abnormal heat wave spell occurring in the northern mountainous. The maximum temperature reached $31^0$- $33^0$C, and achieved an excess of $33^0$C in some areas such as Phu Yen (Son La) 35,$1^0$C; Hoa Binh 35-$36^0$C; Van Chan (Yen Bai) 34.$5^0$C; Bac Me (Ha Giang) 33.$7^0$C; Vinh Yen (Vinh Phuc) 34.$4^0$C; Tp. Cao Bang 33.$0^0$C; Hiep Hoa (Bac Giang) 34.$2^0$C; …. The above observed maximum temperatures is larger about 2 to 2.5 times than climatological standard deviation of monthly average temperature in November (climatological monthly average temperature of northern region of Viet Nam is 21.$5^0$C in November). The daily maximum temperature distribution at 00UTC from 16 -19 November 2015 was shown in the Fig. 1. Different from the abnormal heat wave spell in February 2010, the maximum temperature in this spell tended to deflect towards the east and concentrated on the Viet Bac and Dong Bac mountainous areas. The heat wave focused on the period from 16 to 18, and then significantly decreased in 19 November 2015.

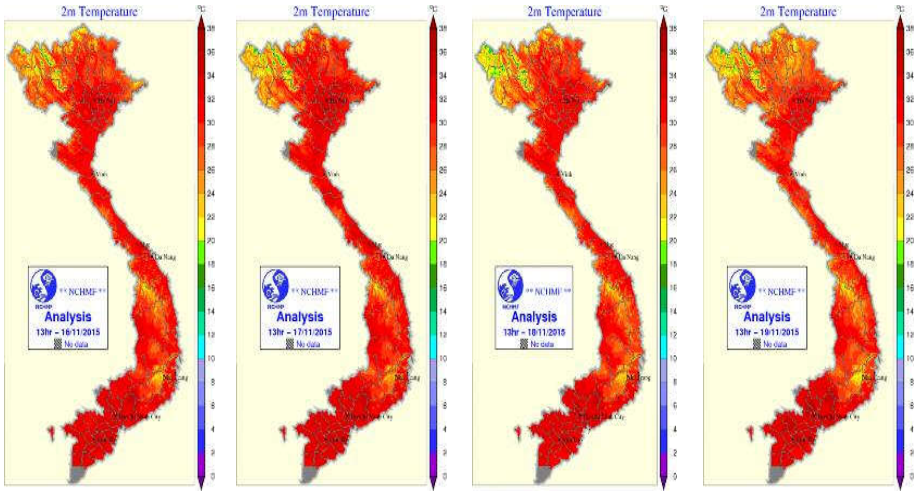
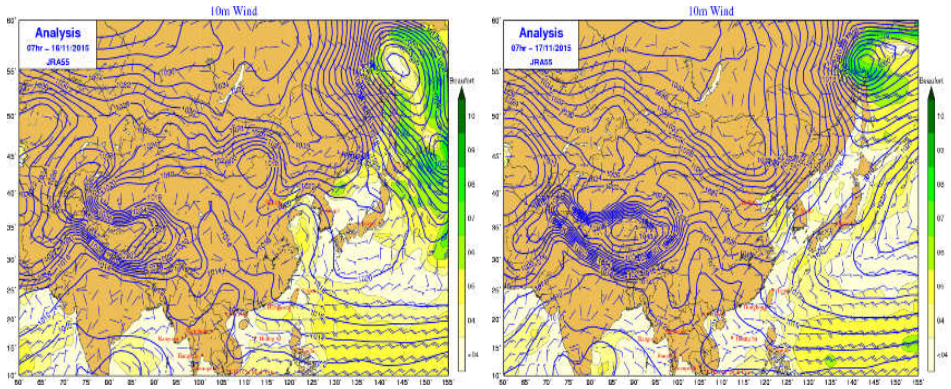



**Fig. 1.** The maximum temperature distribution at 00UTC from 16-19 November 2015 (from left to right)

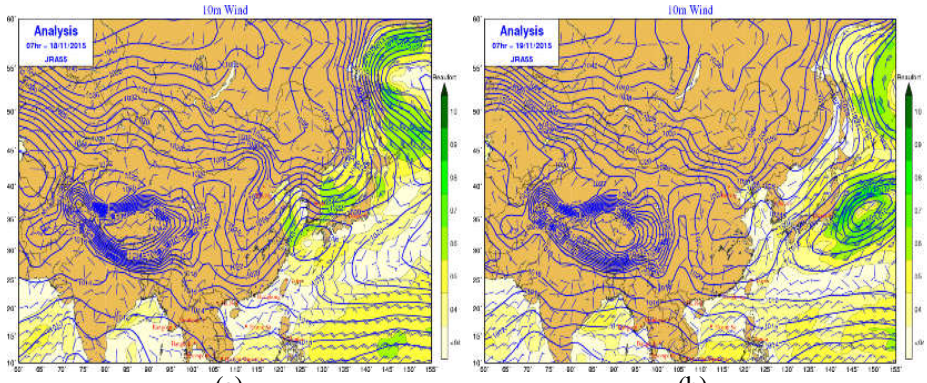
In Fig. 2, the reanalysis map illustrates 10m wind and sea level pressure on 16 November (onset) and 17 November (date of occurence). The left figure shows an unfully-developed low pressure in the north of North Viet Nam along the longitude of 103 -112$^0$E, a high pressure in the north of India and a developing low-pressure in northeast China. The prevailing winds in the north Viet Nam was changing from east winds to southeast winds with average speed of 3 - 5m/s. On 17 November 2015, this high pressure moved eastwards quickly and located in north Bangladesh, while the low pressure in the northeast China disappeared completely and was replaced by a high continent pressure. Also, the low pressure in the north of Northern Viet Nam moved towards the south and located in the north border regions. The winds in Tonkin Gulf remained south winds and reached 7-10m/s.

The distribution of pressure of mean sea level at 00UTC in 18 and 19 November 2015 respectively shown in Fig. 3. The Fig. 3a shows the clear cold surge in the northeast region of China which was extending to the northeast border region of Viet Nam. The mentioned low-pressure was forced westward gradually with incomplete shape. The wind speed of the prevailing south-winds over the north of Viet Nam was decreased. In 18 November 2015 (the Fig. 3b) the low-pressure area was squeezed by the continental high from China. In the west of Northern Viet Nam, the wind direction changed to north-east and the temperature was decreased for ending this unusual heat wave.




(a) (b)

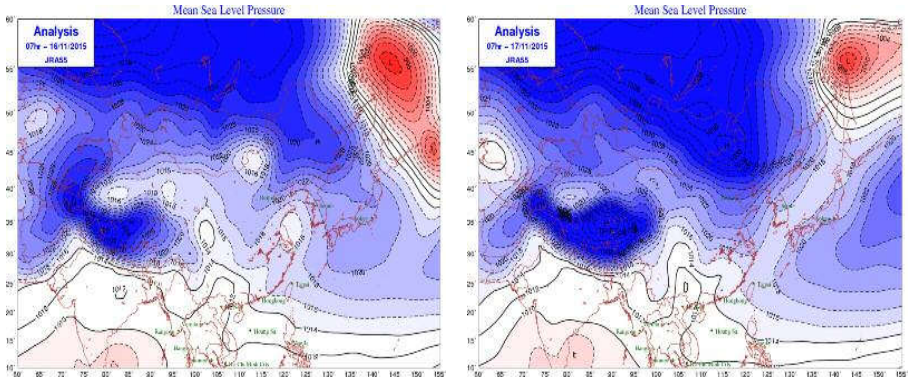
**Fig. 2.** The 10 meters wind and pressure distribution at 00UTC 16 (a) and 17 (b) November 2015




(a) (b)

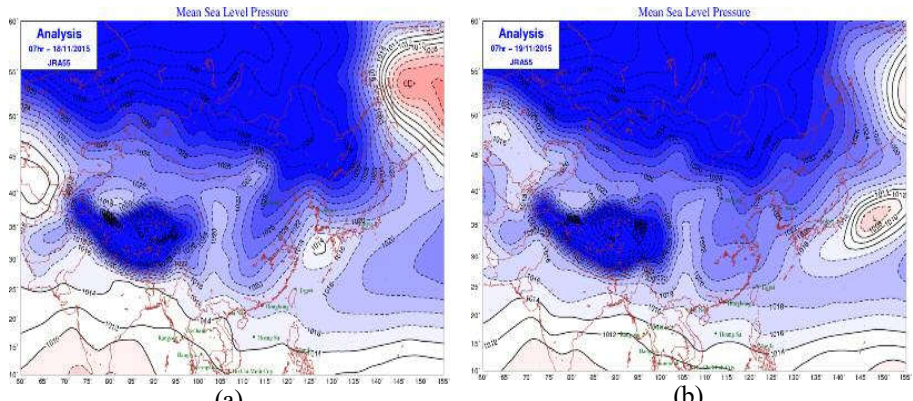
**Fig. 3.** The 10 meters wind and pressure distribution at 00UTC 18 (a) and 19 (b) November 2015

The Fig. 4 shows the strong continental high area with center at the north of Indian and two high pressure areas in China (cleared close isobaric line). These two high areas over China have maximum pressure values about 1014hPa and 1016hPa. A low pressure area in the Bay of Bengal is forecasted to enhance and move to north-east and then a trough will be formed over Northern Viet Nam. In 17 November, the continental high pressure was strengthened and the isobaric line 1020hPa was extended to the north of China. After that, the low pressure area moved southward and covered the north of Viet Nam. The Fig. 5a shows the continental high (in the northeast China) was extending to south-west and close to the boundary of Northern Viet Nam and then we cannot observe the low pressure area over the North Viet Nam anymore. The Fig. 5b shows the continental high over China and the isobaric 1020hPa was closed to the boundary of the east of Northern Viet Nam. The temperature was more decreased after 19 November 2015 (Fig. 1).




(a) (b)

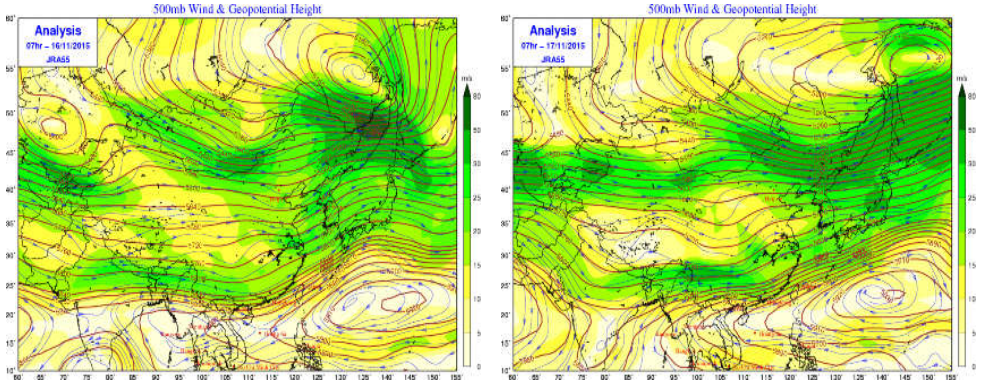
**Fig. 4**. Mean sea pressure level at 00UTC on 16 (a) and 17 (b) November 2015




(a) (b)

**Fig. 5.** Mean sea pressure level at 00UTC on 18 (a) and 19 November 2015 (b)

The Fig. 6a shows the subtropical high (at level 500hPa) with axis $17^0$N-$18^0$N, over Central Viet Nam. Over this subtropical high, there was a high pressure (in the northwest Thailand). In upper level, dry north-west wind from the subtropical high which is also located over the mountainous area in Northern Viet Nam has speed about 20 - 25m/s and 15m/s in the north of Bangladesh and the north of Northern Viet Nam respectively. In 17th November 2015, the subtropical high moved northward and the high-pressure area in the northwest Thailand was disappeared. Therefore, the winds in the north of Northern Viet Nam changed to southwest winds with speed about 10 -15m/s. This is clear that before the heat wave, there was a weak divergence in 500hPa pressure level and after that there was no divergence anymore

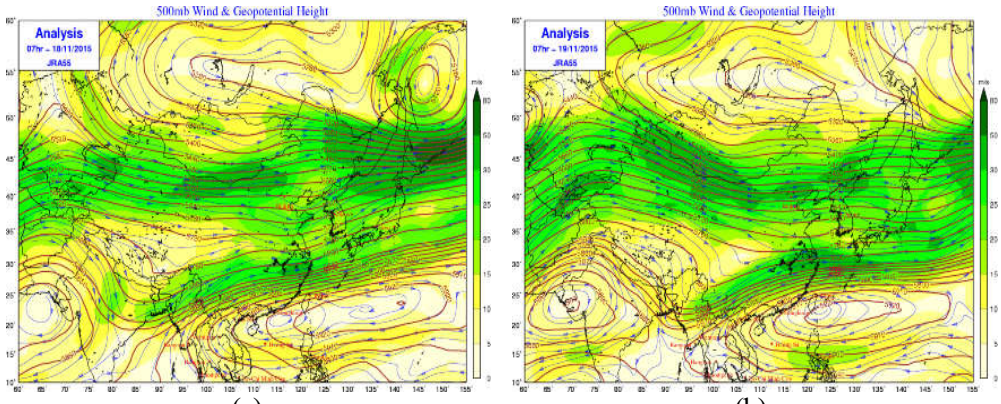



(a) (b)

**Fig. 6.** Wind and pressure in 500hPa at 00UTC on 16 (a) and 17 (b) November 2015

Fig. 7a shows the north Pacific high is moving eastward and the southwest winds over Northern Viet Nam with speed around 10 - 15m/s. In the north of the Bay of Bengal, a westerly disturbance moves eastward. Fig. 7b shows the wind stronger convergence in the north of Northern Viet Nam, wind speed increased by 15 - 20m/s, some wind speed about 25m/s. In the afternoon, it was raining in the north of Northern Viet Nam, this is a sign ending the heat wave.

In summary, the reason for the unusually heat wave from 16 -19 November 2015 was the effect of the heat low pressure area in the north of Northern Viet Nam. The enhanced continental high from China and convergence wind over 500hPa level caused the ending of the heat wave.




(a) (b)

**Fig. 7.** Wind and pressure in 500hPa at 00UTC on 18 (a) and 19 (b) November 2015

***3.2. The abnormal heat wave from 25 to 27 February 2010***

From 25 to 27 Feb 2010 in the mountainous provinces of North Viet Nam, there was an unusually heat wave. The highest temperature of the day has rosen around 33 - 35°C. Daily max-

imum temperatures have passed the heat wave threshold (≥ 35$^0$C): Muong La, Quynh Nhai (Son La) 36.5$^0$C; Hoa Binh 36- 37$^0$C; Lao Cai 36.6$^0$C; Dinh Hoa (Thai Nguyen) 36.6$^0$C; Minh Dai (Phu Tho) 36.4$^0$C; Cao Bang 35.4$^0$C; That Khe (Lang Son) 35.6$^0$C; ... The above obsserved maximum temperatures is larger about 2.5 to 3 times than climatological standard deviation of monthly average temperature in February. The climatological monthly average temperature of northern region of Viet Nam in February is 17-18$^0$C.

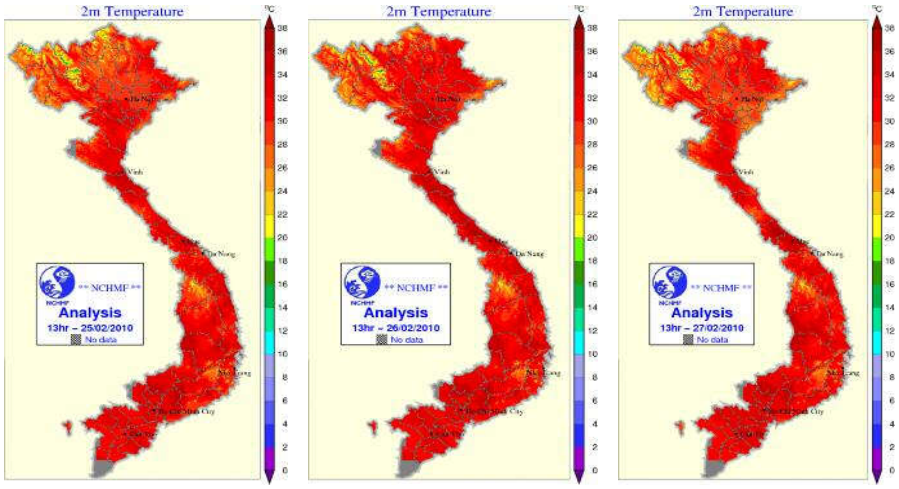
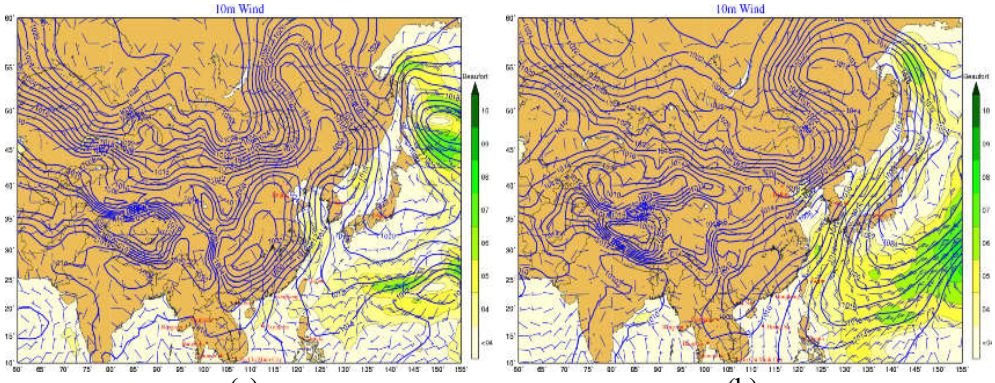



**Fig. 8.** The temperature at 00UTC on the 25, 26 and 27 February 2010 (in order from left to right)

Fig. 8 shows the highest temperature distribution at 00UTC on 25, 26 and 27 Feb 2017 in the northern mountainous provinces. Unlike the unusually heat wave in the northern mountainous area as above analyzed, the highest temperature distribution in this heat wave is quite similar to the North West, Viet Bac and Northeast areas. The hottest area is still in the northern midland provinces and it is very clear in the February 26th temperature distribution. The highest temperature distribution in the Northeast mountainous provinces was the same for all three days of 25, 26 and 27 February. It means that the intensity of given heat wave is more prolonged in comparison with the normal in February.

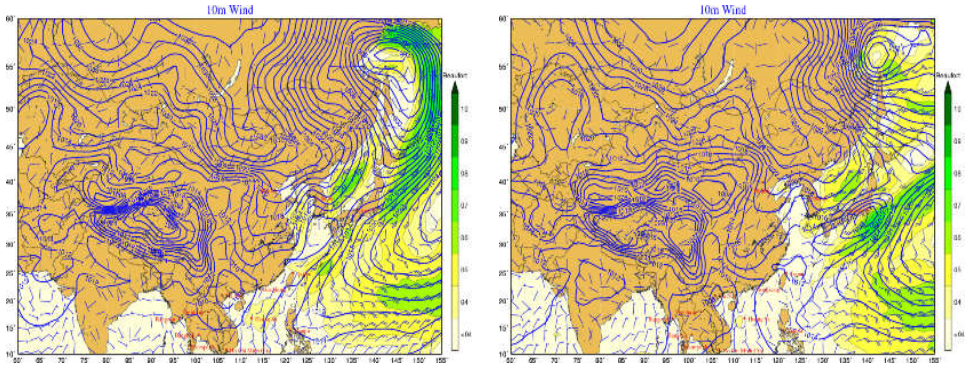



(a) (b)

**Fig. 9.** The 10 meters wind and pressure of mean sea level fields at 00UTC on 24 (a) and 25 (b) February 2010

Fig. 9 illustrates 10m - wind and surface pressure reanalysis on 24 February 2010 (before the onset of unusually heat wave) and February 25, 2010 (the onset of unusually heat wave). Fig. 9a shows a low-pressure area below 1000hPa. This low-pressure circulation covers a large area of

mainland China. The prevailing wind direction throughout the northern mountainous provinces is the southwest. Wind intensity is not strong and located in the impact zone at the southwestern edge of the low pressure zone. On Feb 25, the low-pressure shape changed to the compressed elliptical form and expanded over the Southwest. The whole of the North for this moment was covered by the southwestern part of the low-pressure area.



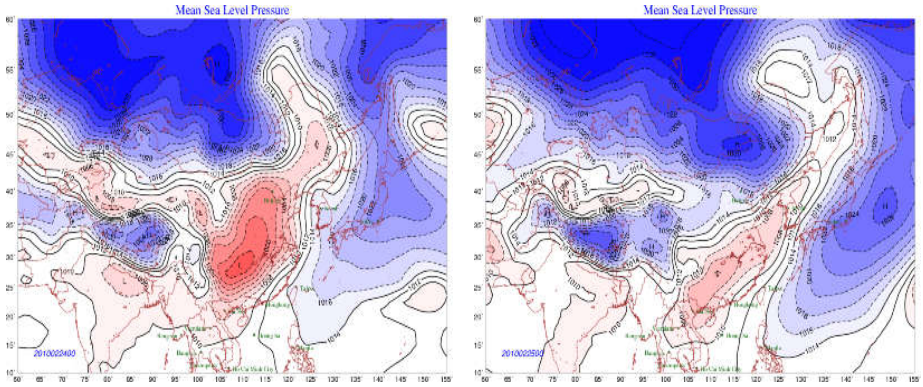

(a) (b)

**Fig. 10.** The 10 meters wind and pressure of mean sea level fields at 00UTC on 26 (a) and 27 (b) February 2010

On February 26 (Fig. 10a), the low-pressure center moved south and covered the Northern provinces. The low-pressure center is located in the Northeast region. In the northern part of China, there was a high-pressure ridge that was stretching southward. This is the reason why a large low-pressure area two days before was narrowed rapidly. In the northern mountainous area, the wind direction was changed towards the lower center of the low area. The next day (Fig. 10b), the low-pressure area became smaller and covered a relatively narrow area in the northern coastal provinces (the low-pressure center also located on this area). The continental high-pressure ridge also expanded to the northeastern border of Viet Nam.

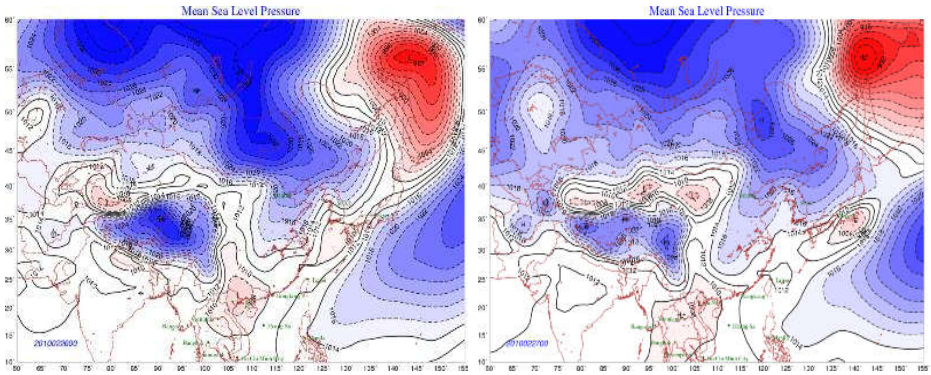
Fig. 11 represents the pressure mean sea level reanalysis map at 00UTC on February 24 and 25, 2010 (before and after beginning of the unusually heat wave). Fig. 11a indicates a low-pressure region with relatively low atmospheric pressure at the center (red colored region). At this time, the low-pressure center located at about 30$^{o}$N - 110$^{o}$E. It has small impact on the northern mountainous provinces. The 1008hPa line run through the northern mountainous area has proven itself. On 25 February 2010, the low-pressure region in northeastern China moved closer to the northeastern mountainous provinces. The intensity of the low-pressure has weakened considerably while the central pressure has increased (shown in light pink shaded color). The low-pressure circulation now covers the whole of the northwestern and northeastern parts of Viet Nam which provided the evidence that there is an impact of the above-mentioned low-pressure region.

In Fig.12, the reanalysis map illustrates pressure distribution which was calculated to sea level pressure at 00UTC of 26 and 27 February in 2010 when abnormal heat wave occurred. In these sea level pressure reanalysis maps (Fig.12a), it is clear that the low-pressure area moved towards the northeast mountainous areas of Viet Nam and its center located over the Northeast Viet Nam. The circulation of this low pressure covered the northern part. However, the center pressure is significantly high at 1006hPa. Turning to 27 February, while the maximum temperature decreased in the north mountainous part, this low-pressure center was pushed back to the Northern Plain and intensified to 1008hPa. This could be a signal for the cessation of this anomal heat wave.




(a) (b)

**Fig. 11.** The pressure of mean sea level at 00UTC on 24 (a) and 25 (b) February 2010



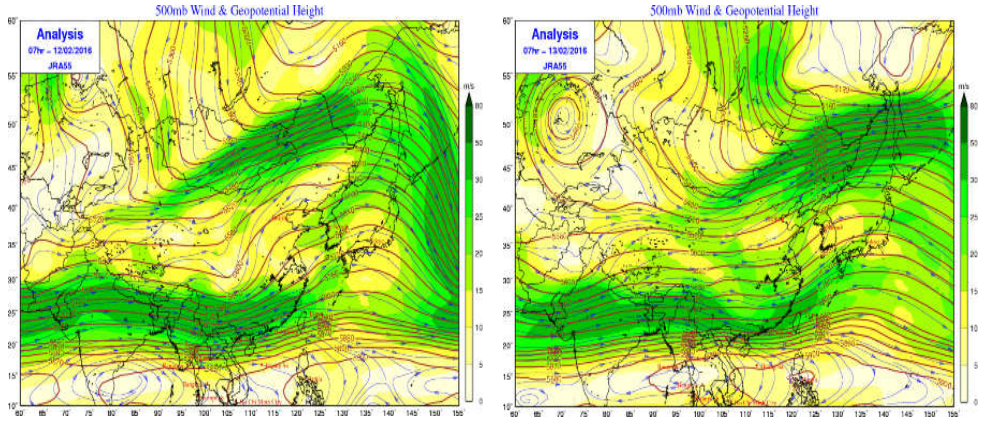

(a) (b)

**Fig. 12.** The pressure of mean sea level at 00UTC on 26 (a) and 27 (b) February 2010

Considering Fig. 13 showing the reanalysis map of 500hPa wind and geopotential height before and after the period of anomal heat wave, the left map illustrates the subtropical high pressure located in low-latitude ran along the latitude of 100N though Southern Viet Nam. At the same time, Northern Viet Nam in general and mountainous areas in specific experienced high-velocity southwest winds with an average of 25 to 30 m/s and 30 to 40 m/s in some mountainous area in the north. Turning to 25 Feb 2010, the axis of this subtropical high was move to the north, whereas the north mountainous part still suffered from southwest wind, however, with slightly decreased wind velocity at an average of 20 to 30 m/s. This could explain that there was no effect of divergence field to the weather of north mountainous area both before and after the occurrence of abnormal heat wave.

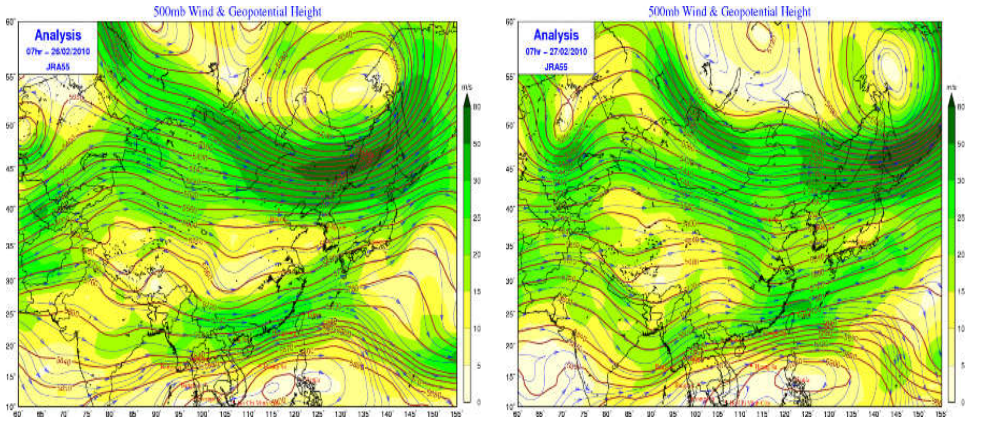
Fig. 14 shows the reanalysis map of 500hPa wind and geographical height in 26 and 27 February 2010 before and after the period of anomal heat wave. In the Fig. 14a, there was northeast to southwest subtropical high forming a high pressure in South China sea - East sea of Viet Nam. Meanwhile, the north part was covered by the southwest winds prevailing in the area from Belgan Bay through northern Viet Nam to South China. The southwest wind was at 20-25m/s. In 27 February, while there was a sharp decrease in the temperature in Northern Viet Nam, the north mountainous area still suffered from Southwest to West winds with a decrease in its intensity to 15 to 20 m/s.

We can see that with reanalysis maps for the abnormal heat wave in northern Viet Nam and north mountainous area during the period from 25 to 27 February 2010, the key element had caused this phenomenon was the direct effect of heat low pressure located in China since it was pushed back to the northern Viet Nam. The southward movement of cold surge in the north facilitated for ending this abnormal heat wave




(a) (b)

**Fig 13.** The wind and geopotential height field of 500hPa pressure level at 00UTC of 24 (a) and 25 (b) February 2010




(a) (b)

**Fig. 14.** The wind and geopotential height field of 500hPa pressure level at 00UTC of 26 (a) and 27 (b) February 2010

## 4. Conclusion

Under the climate change, the abnormal extreme weather phenomena had been increasing in both of occurring frequency and intensity, specially the abnormal heat waves in the winter. The paper shows out the results of thermodynamic analysis that caused two abnormal heat waves in the winter in northern areas of Viet Nam (one case occurred in the early winter, the other occurred at the end of winter) based on the dataset of obsserved daily maximum temperature, the climatological monthly average temperature in November and February that is calculated from period of 1971 - 2010 and JRA55 reanalysis data of JMA from 25 to 27 February 2010 and 16 to 19 November 2015. The abnornal factor determined according to the large different between the daily maximum temperature of these days that heat wave occurring with climatological monthly average temperature. In order to find out the synoptic patterns that drive the abnormal heat waves, the weather maps from surface up to 500hPa level derived from JRA55 reanalysis data is analyzed by synoptic resonance analysis method. We found out the main cause of the unusual activities of the heat wave in winter is that the heat low pressure area in the north of Northern Viet Nam had been moving southward by the continental high pressure from China and in combining with the effect of the wind divergent at levels 3000 - 5000 meters over Northern Viet Nam. In addition, unusual activies of westhern Pacific subtropical high pressure, southwest moonsoon in combination with "foehn" effect caused by Hoang Lien Son high rock moutain

chain is also significantly considered. In some cases, the combination between strong cold surge that desending from the south China and western hot low-pressure is also caused an abnormal heat wave in the winter. Finally, the effect of urban heating is significantly contributed to abnormal heat wave in northern urban areas, speacially is in early winter period.

**Acknowledgments:** *This work was supported by the Ministry of Natural Resources and Environment through the national Project "The impact of climate change on abnormal cold surge and heat wave in the winter at the Viet Nam northern mountain areas to serve for socio-economic development" (code: BDKH.25/16-20)*

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