Research Paper

RESEARCH ON THE CRITERIA TO DETERMINING ABNORMAL MID-WINTER WARM SPELLS IN THE NORTHERN PART OF VIET NAM

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ABSTRACT

The objective of the paper was to characterise the climatology of surface temperature in the mid-winter months (DJF) in the northern part of Vietnam in the years 1971-2016 and determine the abnormal mid-winter warm spells and their statistic characteristics basing given criteria. The results shown that abnormal warm spells occur in January when the daily average air temperature is greater than 3°C in comparison with the given standard threshold (the sum of the climatological everage and standard deviation values of monthly mean temperature). Meanwhile, this threshold for December and February is only 1.5°C. The daily average air temperature during the period of active of abnormal mid-winter warm spells is in the range of 22-25°C, while the daily maximum air temperature is about 26-29°C, eventhrough can be reached to 30-33°C.

Keywords*: Abnormal warm spells in mid-winter, Northern part of Vietnam.*

1. Introduction

In the last few years, due to the effects of climate change, the climate regime on almost all regions of Vietnam had been significantly changing. The heat wave activities also abnormally increases in terms of the highest temperature value as well as the active period of a heat wave. The year 2010 was considered to be the hottest year in the series of observed dataset from the beginning of the monitoring, until 2015 this record was broken. Even in the middle of winter, in the northern mountainous provinces, the high temperature of 32-34°C was observed. This caused a very hot weather in the middle of winter. The abnormal mid-winter warm spells has caused many impacts on agricultural production, transportation, tourism and so on.

So far, there were been a number of researches around the world about abnormal mid-winter warm spells. Wibig (2007) related periods of mid-winter warm spells in central Ploand to macroscale circulation indices. She proved that positive temperature anomalies were positively correlated to with the Zonal Circulation Index and with the East Atlantic and North Atlantic Oscillation circulation types. Synoptic situations

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responsible for the occurrence of warm spells in winter are related to the advection of relatively warm air from over the Atlantic as a result of the simultaneous occurrence of a high-pressure over South Europe and a centre of low pressure over North Europe. According to Francis and Vavrus (2012), these anomalous periods should be more persistent due to an increased amplitude of Rossby waves and their slower progression eastward. Such modifications in global circulation are an effect of the observed enhanced warming at high northern latitudes relative to mid-latitudes (Artic amplification) and the relaxation of poleward 1000 to 500hPa thickness gradients. Weakening zonal winds and slowing planetary waves translate into more persistent weather patterns at mid-latitudes, which are often extreme and are associated with upper troposhperic pressure and air flow patterns. Recently, Arkadiusz et al. (2019) had been studied to characterise the temporal and spatial variability of winter warm spells in Central Europe in the year 1966-1967 to 2015-2016. and to determine the circulation conditions of their occurrence. In this research, a warm spell was defined as a sequence of at least three warm days, i.e. when the maximum air temperature is higher than the 95th percentile of the probability density function designated from observation. The research has been proven that over the study period the air temperature increased in the winter season in Central Europe and this translated into an increase in number of warm days. An average of 3-5 warm spells was recorded per 10 years. The most numerous warm spells occurred during three winter season, i.e. 1989-1990, 2006-2007 and 2015-2016. The occurrence of warm spells was related to positive anomalies of geopotential heights over the study area in the cross section of the entire troposphere. Maximum anomalies appeared at 250hPa geopotential height, and they developed on average 9 days before the commencement of warm spells over the study area.

In Vietnam, there were some reseaches on heat waves (Phan et al., 2010, 2011; Kieu et al., 2015; Do, 2014). However, these studies only paid attention to find out climatological characteristics based on given past observation datasets, changing trend in the past and future projection according to climate change scenarios. Meanwhile, research on abnormal warm spell phenomena in mid-winter in northern part of Vietnam have not been implemented. The objective of the paper was to characterise the climatology of surface temperature in the mid-winter months (DJF) in the northern part of Vietnam in the years 1971-2016 and determine the abnormal mid-winter warm spells and their statistic characteristics basing given criteria. The next sections of the paper will present the dataset and research methods used. Finally, we will give out some initial research result, discussion and recommendations for further research.

2. Data and Methods

The 2 meters air temperature (T_{2m}) at all of daily observation times and daily maximum temperature (T_m) in period 1971-2016 is collected at 8 manually surface meteorological stations in North part of Vietnam. The basic information of used 8 manually surface meteorological stations is shown on Table 1. The quality of these dataset is physically and climatologically checked before putting into account.

As according to climate, the mid-winter (from December to February) is the coldest time of the year in the North part of Vietnam. The statistics for many years shown that the climatological value of mid-winter monthly average temperature is popularly below 18^{o}C. During these months, there may be strong cold surges with daily average air temperatures lower than 15^{o}C, even falling below 13^{o}C. The highest daily average temperature in many years is only popular

Table 1. List of manually surface meteorological stations in North part of Vietnam.

Order	Station name	Longitude (deg.)	Latitude (deg.)	Height (meters)	Area name
1	Lai Chau	103.150	22.067	243.2	North-West
2	Dien Bien	103.000	21.367	475.1	North-West
3	Thai Nguyen	105.833	21.600	35.3	Central North
4	Tuyen Quang	105.217	21.817	40.8	Central North
5	Bac Giang	106.120	21.170	7.5	North-East
6	Phu Lien	106.633	20.800	112.4	North-East
7	Ha Noi	105.800	21.017	6.0	Northern delta
8	Nam Dinh	106.150	20.433	1.9	Northern delta

from 20-22^{o}C. However, there are a number of years, alternating cold surges that appear more warm days, daily average temperatures can exceed the cold weather threshold (daily average temperature is below 20-22^{o}C). The highest daily air temperature can reach 27-28^{o}C. Even in the North-Western part of Vietnam, at Lai Chau and Dien Bien station also occurred warm spell with the highest daily air temperature can reach 35-36^{o}C. The question is how to identify these unusual warm spell in mid-winter.

In order to determine abnormal warm spells in mid-winter months, we proposed the checking method as following:

- The climatological average of monthly average air temperature ($T^{i,j}_{TBNN}$) and standard deviation of monthly average air temperature ($\sigma^{i,j}_{TBN}$) is calculated basing on T_{2m} dataset in period 1971-2016 in which i get values of 12, 1 and 2 corresponding to December, Jannuary and February, j varies from 1 to 8 corresponding to 8 surface meteorological stations as shown in Table 1. The sum of $T^{i,j}_{TBNN}$ and $\sigma^{i,j}_{TBN}$ is called as standard threshold ($T^i_j = T^{i,j}_{TBNN} + \sigma^{i,j}_{TBN}$) and this sum is used to determine whether given month is unusual warm in comparison with the normal.

- Calculate the deviation $\Delta T^{i,j}_{TBT} = T^{i,j}_{TBT} - T^i_j$ if the deviation is positive, then the monthly average air temperature of given month is considered warmer than the climate. In other words, there is the possibility of warm spells alternating with cold surges. Conversely, if the deviation is negative, it indicates that the monthly average air temperature of given month is suitable for the climate standard. The process of calculating above mentioned deviation is done separately for each mid-winter month in the period of 1971-2016 and each surface meteorological stations is studied. Supposing that there were N is found in given M months of the period 1971-2016 ($N \leq M$) satisfied the criteria, i.e the monthly average air temperature higher than the standard threshold (T^i_j). The procedure to determine warm spells will be implemented for each of N months.

- For each of N, continously calculate the deviation between daily average air temperatiure of each day in given month ($T^{i,j,k}_{tb}$) with standard threshold (T^i_j): $\Delta T^{i,j,k}_{tb} = T^{i,j,k}_{tb} - T^i_j$ in which k is index of day in given month. A warm spell is determined to occur when satisfying the following 2 criteria:

According to the above method, the deviation between the daily average temperature ($T^{i,j,k}_{tb}$) and the standard threshold (T^i_j) is the criterion for determining an abnormal warm spell in mid-winter. Specifically, the positive value of the deviation $\Delta T^{i,j,k}_{tb}$ is the threshold that indicates whether the abnormal warm spell occurs or does not occur in the given months. The variation of the threshold determined by this deviation will

change the number of mid-winter warm spell found during 1971-2016. The question of how much is the threshold for deviation is appropriate to determine an abnormal warm spell in mid-winter. In this study, the concept of "*abnormal*" of the warm spell is understood acccording to two meanings: 1) having daily average temperature higher than the standard threshold (T_j^i) and 2) must be rare event (low occurrence frequency).

In order to select the appropriate threshold, in this study we propose a survey based on a fixed number of thresholds based on deviations $\Delta T_{tb}^{i,j,k}$ including: 1.5°C, 2.0°C, 2.5°C, 3.0°C, 3.5°C and 4.0°C. Based on the results of determining the number of abnormal warm spell in mid-winter according to the above defined thresholds, the analysis process will be carried out to make the selection of the appropriate threshold. The next section will detail the results of this survey as well as the results of calculating some of the climitological average characteristics of temperature field in the mid-winter months of the period 1971-2016 in the northern region of Vietnam.

3. Results

Fig. 1 show out the spatial distribution of climatological mean of monthly average air temperature T_{TBNN}^{2m} (left) and monthly maximum air temperature T_{TBNN}^{max} (right) for January. It can be seen that the distribution of T_{TBNN}^{2m} is quite homogeneous and fluctuate in the range of 16.0-16.5°C. Particularly in Lai Chau and Dien Bien stations, T_{TBNN}^{2m} is higher than the other station. Meanwhile, the T_{TBNN}^{max} ranges from 19.0-20.0°C, only two Lai Chau and Dien Bien stations range from 23.0-24.0°C.

Based on the method of determining the number of abnormal warm spells, the statistical results for January point out a lot of found warm spells when the $\Delta T_{tb}^{i,j,k}$ thresholds of 1.5°C, 2.0°C, 2.5°C is applied. Therefore, these thresholds do not meet the requirement for rare occurrence frequency. Table 2 shows the results of the determination of abnormal warm spells in January based on threshold of 3°C. A total of 23 abnormal warm spells occurred in January during the period of 1971-2016 and only occurred in 17 years/46 years. The length of abnormal warm spell lasts 2-3 days on average. The year that recorded 2 abnormal warm spells occurred in January including 1980, 1993, 1998, 2001, 2006, and 2016. During these abnormal warm spells, the daily maximum temperature (T_m) was popular from 26-28°C (T_m fluctuates in the range of 19-20°C on average). The longest abnormal warm spell is up to 7 days was found in 2000 (from 9 to 16 January). However, this year was not the hottest year in period of 1971-2016. The highest daily average air temperature recorded at abnormal warm spell from 9 to 10 January, 1998 was 24.4°C and deviation was up to 5.4°C in comparison with climate mean. The highest T_m value recorded at Tuyen Quang station during the abnormal warm spell from January 22-25, 2001 was 32°C. The survey results for the thresholds of 3.5°C and 4.0°C show that there are very few abnormal warm spells found (about 6 events/46 years) because many warm spells do not meet the criteria of 2 consecutive days that $\Delta T_{tb}^{i,j,k}$ is greater than the given threshold.

The spatial distribution of T_{TBNN}^{2m} and T_{TBNN}^{max} for February is similar to January (Fig. 2). It can be seen that in February, T_{TBNN}^{2m} ranges from 17.5-17.8°C in the North-East, Central North and Northern delta regions and varies 18.3-19.0°C in the North-West region. Similary, T_{TBNN}^{max} in the North-East, Central North and Northern delta regions only ranges from 20-22°C. However, T_{TBNN}^{max} fluctuated in the range of 26°C in the North-West region. For December, spatial distribution of climatological mean T_{TBNN}^{2m} and T_{TBNN}^{max} is very homogeneous and fluctuate in the range

of 17.5-18.5°C. The T^{max}_{TBNN} fluctuated in the range of 21.5-22.5°C in the North-East, Central North and Northern delta regions. For North-West region, T^{max}_{TBNN} fluctuated in the range of 23.5-24.0°C. However, the daily maximum temperature is more higher than normal during occurrence days of abnormal warm spells.

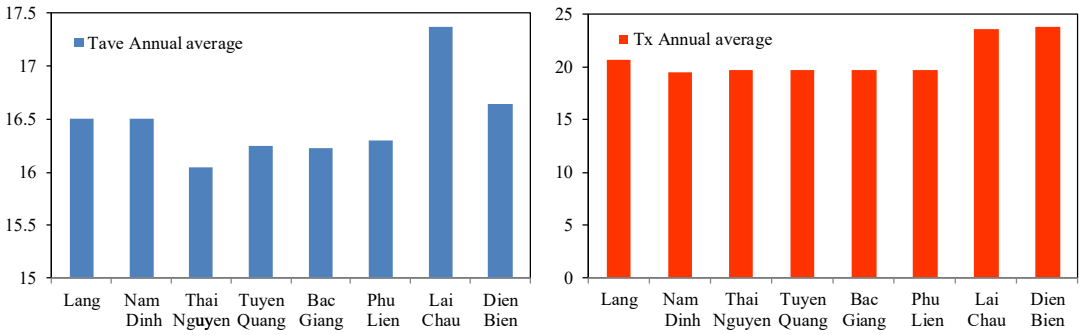

Fig.1. The spatial distribution of climatological mean of monthly average air temperature (left) and monthly maximum air temperature (right) for January.

Table 2. The number of abnormal warm spells recorded in January from 1971-2016 based on 3oC threshold and their characteristics.

Order	Year	Day	T^i_j	$\Delta T^{i,j,k}_{tb}$	Station name							
					Lang	Nam Đinh	Thai Nguyen	Tuyen Quang	Bac Giang	Phu Lien	Lai Chau	Đien Bien
	1979	**11**	19.0	**3.1**	22.1	21.9	22.1	21.5	21.4	21.4	17.4	16.8
1	**1979**	**12**	19.0	**3.3**	22.3	22.4	22.6	21.5	22.6	21.9	16.9	16.3
	1979	**13**	19.0	**3.8**	22.8	22.5	22.3	22.7	22.1	21.7	16.5	16.0
	1980	**1**	19.0	**3.6**	22.6	22.8	23.0	23.0	22.3	21.8	17.4	16.3
2	**1980**	**2**	19.0	**3.9**	22.9	23.0	22.8	23.6	23.0	22.2	17.4	16.8
	1980	**3**	19.0	**3.5**	22.5	22.5	22.7	23.2	22.4	21.2	17.5	16.9
	1980	**28**	19.0	**3.7**	22.7	21.4	22.4	22.0	22.6	21.4	19.1	18.2
3	**1980**	**29**	19.0	**3.7**	22.7	21.3	22.5	20.5	21.7	21.0	18.5	17.0
	1987	**2**	19.0	**3.9**	22.9	22.3	22.5	21.1	22.2	21.1	18.7	18.4
4	**1987**	**3**	19.0	**3.1**	22.1	22.2	22.0	22.8	22.5	21.0	19.1	18.6
	1987	**4**	19.0	**3.2**	22.2	21.5	20.9	22.4	21.0	21.1	19.2	19.6
	1991	**20**	19.0	**3.4**	22.4	22.1	21.4	20.6	21.5	20.2	19.9	20.9
5	**1991**	**21**	19.0	**3.8**	22.8	21.8	23.0	23.0	22.7	21.4	18.6	20.1
	1991	**22**	19.0	**3.5**	22.5	21.6	22.6	22.7	23.0	21.1	17.6	19.9
	1991	**23**	19.0	**3.5**	22.5	22.2	21.5	23.0	22.3	20.9	18.8	20.7
6	**1993**	**3**	19.0	**3.6**	22.6	22.5	22.4	21.4	22.7	21.6	18.7	20.5
	1993	**4**	19.0	**4.1**	23.1	22.4	22.5	23.3	22.6	21.3	18.4	20.7
7	**1993**	**9**	19.0	**3.4**	22.4	22.3	21.4	22.6	21.4	21.1	19.7	20.3
	1993	**10**	19.0	**3.1**	22.1	21.9	21.2	22.3	21.2	21.1	19.2	20.0
8	**1994**	**11**	19.0	**3.5**	22.5	21.9	22.5	22.7	21.8	20.8	17.7	20.8
	1994	**12**	19.0	**4.2**	23.2	22.9	23.0	23.3	23.2	21.5	17.8	20.1
	1998	**2**	19.0	**3.8**	22.8	22.4	22.8	22.9	22.3	22.2	18.6	19.9
9	**1998**	**3**	19.0	**4.0**	23.0	22.3	22.0	21.9	22.4	22.0	19.7	20.1
	1998	**4**	19.0	**3.3**	22.3	21.8	22.6	23.1	21.7	21.4	19.8	20.1
	1998	**8**	19.0	**3.8**	22.8	22.7	22.9	21.6	23.3	23.0	19.4	21.1
	1998	**9**	19.0	**5.4**	24.4	23.8	23.9	23.7	24.4	23.8	19.7	22.8

10	**1998**	**10**	19.0	**5.4**	24.4	24.8	25.1	24.3	24.9	24.0	19.1	21.4
	1998	**11**	19.0	**4.2**	23.2	23.0	22.1	23.6	21.7	23.1	18.8	20.3
11	**1999**	**30**	19.0	**3.3**	22.3	21.1	23.1	23.3	22.9	21.4	19.0	20.9
	1999	**31**	19.0	**5.4**	24.4	23.1	22.9	24.3	23.0	21.4	22.6	24.4
	2000	**9**	19.0	**3.8**	22.8	22.1	22.3	23.3	22.7	21.4	17.2	21.0
	2000	**10**	19.0	**3.3**	22.3	21.6	21.6	22.0	22.2	20.6	19.6	21.6
	2000	**11**	19.0	**4.2**	23.2	22.8	22.3	23.0	22.8	21.0	19.5	21.9
12	**2000**	**12**	19.0	**5.2**	24.2	23.5	23.5	23.9	23.5	21.6	19.2	21.2
	2000	**13**	19.0	**3.6**	22.6	20.9	22.9	24.3	22.4	20.2	17.6	20.5
	2000	**14**	19.0	**4.8**	23.8	23.5	23.2	23.0	23.2	22.0	16.4	19.7
	2000	**15**	19.0	**4.4**	23.4	22.4	23.0	23.3	22.9	21.4	16.4	19.4
	2001	**6**	19.0	**3.1**	22.1	21.8	22.0	20.8	19.7	16.8	18.7	21.0
13	**2001**	**7**	19.0	**4.4**	23.4	23.1	22.4	22.6	22.3	21.7	18.8	20.0
	2001	**8**	19.0	**4.5**	23.5	23.7	23.5	23.7	23.8	21.5	18.5	17.8
	2001	**22**	19.0	**4.1**	23.1	22.9	22.3	22.7	22.8	21.5	19.2	21.6
	2001	**23**	19.0	**4.6**	23.6	23.1	23.5	24.6	22.8	21.7	19.3	19.8
14	**2001**	**24**	19.0	**4.6**	23.6	23.0	22.7	24.5	22.9	21.8	21.1	22.5
	2001	**25**	19.0	**4.2**	23.2	23.2	22.8	25.5	22.7	21.5	21.1	21.8
	2002	**17**	19.0	**4.2**	23.2	22.6	22.1	22.3	22.6	21.9	17.6	17.8
15	**2002**	**18**	19.0	**3.9**	22.9	22.6	22.4	22.1	22.4	22.5	18.5	17.8
16	**2003**	**25**	19.0	**4.3**	23.3	23.2	22.7	21.8	23.2	22.0	18.8	17.6
	2003	**26**	19.0	**4.7**	23.7	22.9	23.7	23.3	23.3	22.5	19.5	18.5
	2005	**25**	19.0	**3.7**	22.7	21.8	22.1	22.4	22.3	20.3	19.8	19.0
17	**2005**	**26**	19.0	**4.1**	23.1	22.3	23.1	23.3	23.0	21.3	19.3	18.9
	2005	**27**	19.0	**3.8**	22.8	21.4	23.0	23.8	22.9	20.5	19.6	18.9
18	**2006**	**3**	19.0	**3.4**	22.4	21.7	21.7	22.2	21.7	20.6	16.9	16.3
	2006	**4**	19.0	**4.4**	23.4	23.1	22.9	23.1	22.7	21.8	17.4	16.6
19	**2006**	**18**	19.0	**4.9**	23.9	23.2	22.9	24.4	22.9	21.5	19.4	18.4
	2006	**19**	19.0	**4.7**	23.7	22.9	23.3	23.4	23.1	21.4	17.9	18.2
	2008	**11**	19.0	**4.8**	23.8	23.2	23.4	23.4	23.5	22.0	19.8	17.9
20	**2008**	**12**	19.0	**4.2**	23.2	22.9	23.2	21.7	22.8	22.5	18.7	17.9
	2008	**13**	19.0	**3.7**	22.7	22.0	22.0	23.4	21.4	20.9	18.3	18.0
	2010	**30**	19.0	**3.7**	22.7	22.0	21.7	22.2	21.9	20.8	19.5	19.2
21	**2010**	**31**	19.0	**4.9**	23.9	23.7	23.5	24.2	23.6	22.0	20.0	19.6
	2016	**5**	19.0	**3.5**	22.5	22.2	21.1	21.2	20.5	20.9	19.8	18.8
22	**2016**	**6**	19.0	**3.7**	22.7	22.1	21.6	20.8	21.7	21.6	17.9	17.8
	2016	**10**	19.0	**5.6**	24.6	23.9	23.0	23.6	23.5	22.5	20.1	20.1
23	**2016**	**11**	19.0	**3.2**	22.2	22.4	21.2	20.9	20.4	20.8	16.3	16.0

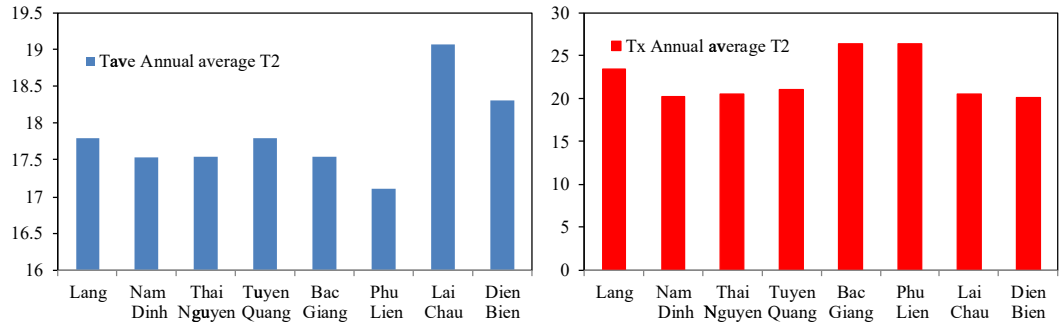

Fig. 2. The spatial distribution of climatological mean of monthly average air temperature (left) and monthly maximum air temperature (right) for February.

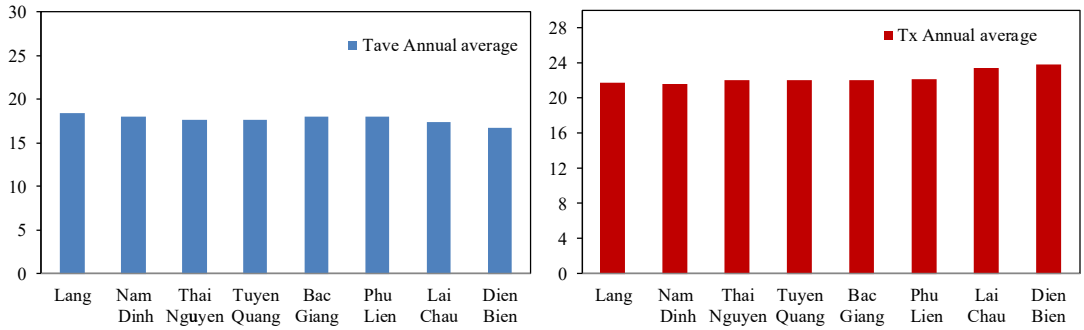

Fig. 3. The spatial distribution of climatological mean of monthly average air temperature (left) and monthly maximum air temperature (right) for December.

With the same survey method for January, the results of determining the number of abnormal warm spells in period of 1971-2016 in December and February show that suitable threshold $\Delta T_{tb}^{i,j,k}$ is 1.5°C. In particular, there were 22 abnormal warm spells was occurred in February. The abnormal warm spells recorded in 2003, 2007, 2009 and 2010 had the longest length. Especially, there was a warm spell lasting up to 14 days from 13-25 February 2007 and up to 11 days from 1-11 February 2010. The daily mean air temperature and daily maximum air temperature are respectively popular in the range of 23-25°C and 27-29°C during occurrence of abnormal warm spells (daily maximum air temperature is higher from 5-7°C than normal). The daily maximum air temperature was observed up to 30-32°C during abnormal warm spells occurred in 1973, 1979, 1991, 2003. Specially, daily maximum air temperature at the Lai Chau and Dien Bien stations were usually recorded 31-33°C and more than 35°C in some days.

For December, a total of 26 abnormal warm spells were identified during the period of 1971-2016. Unlike January and February, abnormal warm spells recorded in February are common last in a short length of 2-4 days. There was only one abnormal warm spell lasting 6 days in 1975 (occurred from 3 to 8 December), and there were 3 abnormal warm spells lasting 5 days in 2001, 2002 and 2009. The daily average air temperature and the daily maximum temperature was respectively normal around 23-25°C and 26-28°C (higher than 6°C in comparison with the normal). There was only two abnormal warm spells occurred in 2002. Table 3 summarizes the results of the determination of abnormal warm spells in the DJF months according to the above selected thresholds.

Table 3. The number of abnormal warm spells recorded in DFJ from 1971-2016 based on selected thresholds and their characteristics.

Month	Total number of warm spells	List of years that warm spells occurred	List of years that had 2 warm spells occurred	daily average temperature in normal (°C)	daily maximum temperature in normal (°C)	Longest warm spell	Duration in days	Date
January	23	1979, 1980, 1987, 1991, 1993, 1994, 1998, 1999, 2000, 2001, 2002, 2003, 2005, 2006, 2008, 2010, 2016	1980, 1993, 1998, 2001, 2006, 2016	22-23	26-28	2000	7	9-16
February	22	1973, 1978, 1979, 1981, 1987, 1990, 1991, 1998, 1999, 2003, 2007, 2009, 2010, 2013, 2015, 2016	2009, 2010	23-25	27-29	2007	14	13-25
December	26	1975, 1976, 1980, 1984, 1990, 1991, 1992, 1993, 1994, 1997, 1998, 2000, 2001, 2002, 2005, 2009, 2010, 2012, 2016.	2002	23-24	26-28	1975	6	3-8

4. Summary and Discussion

The multi-year average statistical characteristics of the temperature field in the mid-winter month (DJF) in the northern part of Vietnam during the period of 1971-2016 were investigated in this study. At the same time, based on these climatological characteristics, the method of identifying in DJF months has been proposed. The survey and evaluation results show that suitable threshold for determining abnormal warm spell in January is 3^{o}C and 1.5^{o}C for December and February (monthly average temperature compare with standard threshold). Basing on these given threshold, there respectively were 23, 22 and 26 abnormal warm spells in January, February and December. The daily average temperature varies from 22 to 25^{o}C, while the daily maximum temperature flactuate in the range of 26-29^{o}C. However, the daily maximum temperature reached 30-33^{o}C in some days. In average, the length of abnormal warm spells in DJF lasts from 2-4 days. In some special cases, the duration of warm spells can be last up to more than 6 days. The longest warm spell last up to 14 days in 2007.

Although encouraging results have been achieved, there are still some shortcomings in this research such as the role of driven weather patterns, atmospheric circulation and urban effects, the impact of topography on the occurrence of abnormal warm spells in the mid-winter months was not considered. Besides, the application of found thresholds in determining abnormal warm spells in operation is still difficult. In subsequent studies, we will step by step focus on addressing these shortcomings to improve criteria in determining abnormal warm spells as well as.

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