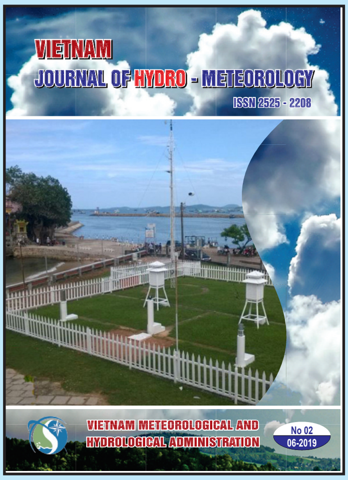
VIETNAM JOURNAL OF HYDRO - METEOROLOGY

ISSN 2525 - 2208

VIETNAM METEOROLOGICAL AND HYDROLOGICAL ADMINISTRATION

No 02
06-2019



Publishing licence
No: 166/GP-BTTTT - Ministry of Information and Communication dated 17/04/2018

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Engraving and printing
Thien Ha Joint Stock Company
Tel: 04.3990.3769 - 0912.565.222

VIETNAM JOURNAL OF HYDROMETEOROLOGY
Volume 02 - 06/2019

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Research Paper

A POPULAR SCIENCE VIDEO PROGRAM PROPOSED FOR PROMOTING SCIENTIFIC LITERACY IN WATER DISASTER SOLUTIONS ADAPTING CLIMATE CHANGE

Yi-Ching Chen[1], Michelle Hui Lee[2], Fu-Ming Chang[3], Mei-Xiu Lai[4]

ARTICLE HISTORY

Received: February 12, 2019 Accepted: May 22, 2019
Publish on: June 25, 2019

ABSTRACT

Under climate changes, the traditional water control thinking has long been obsolete. "Adaptation" has been considered as one of the strategies for climate change. In addition to the adjustment of engineering technology and water management strategies, there are still non-engineering aspects considerations, too. Climate change has never been a simple question to wait for a simple answer. The sustainable development of water management strategy requires not only good scientific research and good communication, but also trustworthy science, clear policies, creative business opportunities and public participation. Sometimes, after damage, quarrel provoked by the people's grievances and public opinion also caused disaster, too. The reason behind this is that people have lack sufficient knowledge in science, let alone scientific literacy and the recognition of scientific value under extreme climate. The expression of the story in this popular science video will allow people to experience the universal value of the life community in which people and water are closely interdependent.

Keywords: *Climate change, adaptation, water control, non-engineering aspect, popular science video.*

1. Introduction

Scientific knowledge is such a medium which leads people to look at the world from different angles. In addition to its practical value, it is more aesthetic. Popular science is an interpretation of science intended for a general public. It is presented in many forms, including books, magazine articles, video (film and television documentaries), and web pages (Wikipedia, 2019). It is hoped that the general public can have basic scientific literacy, can read and listen to science, and basically understand current affairs or news related to science. Science and technology must rely on popular science to spread the public. If scientific concepts can spread to the public, the quality of the people can be improved and social development can be promoted.

When scientists are able to communicate effectively beyond their peers to broader, non-scientist audiences, it builds support for science, promotes understanding of its wider relevance to society, and encourages more

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informed decision-making at all levels, from government to communities to individuals. It can also make science accessible to audiences that traditionally have been excluded from the process of science. It can help make science more diverse and inclusive (Feliú-Mójer, 2015). Contemporary scientific communication is the "science education of the public", which is aimed at the whole society and enables those people finishing normal school education still be able to contact scientific knowledge and scientific methods, and people can use rational thinking to understand the living environment of human beings and apply science to life.

The water disaster problems under climate change are seriously concerned now. The natural reversal of climate change is likely to trigger a human catastrophe at any time. The "water" closest to human life and property is the most important. At present, the flood and drought situation in various countries has become more and more serious, and even more the water pollution and reclaimed water have become the priority issue of all countries. In fact, the World Economic Forum (2018) published a global risk assessment report that has pointed out that climate change, extreme rainfall and water resources crisis have ranked among the top five risks in the world and deserve the attention to all people. Adaptation and mitigation are two major national action strategies today for all countries. It is also necessary to formulate short-term to long-term action strategies to cope with water disaster caused by climate change.

However, people always thinks that the government can solve the problems in drought and flood by investing abundant money in engineering works. This is a serious fallacy: we cannot look at the drought and flood problems as traditional technical projects only, such as construction of dikes and dams. The reason behind it is that people lack sufficient scientific knowledge in dealing with water disaster, let alone the scientific literacy in the treatment of water problems.

2. Scientific literacy, Scientific communication, and Popular science video

2.1. Scientific literacy

When the word "science" is no longer a "stuff for exams", it needs to start from everyday life, then science literacy becomes one of the most important. Only when individuals have the ability to acquire, process, and understand basic scientific information can they choose the right response, and even have curiosity and interest in knowledge, from which they can reflect, think dialectically, and participate. Orzel (2014) in his excellent book "Eureka: Discovering Your Inner Scientist" said, "science is what makes us human". As a human, a scientific literate person is expected to be able to do the following (Allian, 2015):

- Build a model based on experimental evidence (physical model, conceptual model, mathematical model).
- Use and understand some existing models (you can't build everything yourself).
- Understand the limitations of science.
- Think of an experiment to test a particular model.

Scientific literacy has received attention over the years, but there is virtually no consensus on its definition and a number of different factors that influence interpretations of this concept (Laugksch, 2000). Ogunkola (2013) collected explanations offered for importance of scientific literacy to conclude that it helps citizens to comprehend the potentials and abuses of science. It also helps citizens to make informed decisions about basic everyday problems and vote on the numerous issues that require some scientific acknowledge.

2.2. Scientific communication

In 2011 a "Popular Science Communication Industry Development Plan" was promoted in Taiwan and scientific communication, here, is defined as a communication activity that transmits technology and scientific knowledge, methods, thinking and spirit, and cultivates the scientific literacy of the whole people. With the embarrassment of the economic era, in addition to school education, the communication media has become the most important channel of scientific knowledge for the people. Nowadays, communications technology is advancing by leaps and bounds, the impact of media information on the social environment is ubiquitous. Undoubtedly, when the media has become the most important source of people to establish a worldview and values, media literacy education is also particularly important.

Science communication is defined as the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science (the AEIOU vowel analogy, Burns et al., 2003):

- Awareness: access to scientific information;
- Enjoyment: appreciate the various processes and performances of science;
- Interest: inspired by the spontaneous participation of science;
- Opinion-forming: encourage to take the initiative to generate opinions;
- Understanding: to understand scientific content, scientific processes, and social factors.

2.3. Popular science video

The communication media can be books, magazines, newspapers, and furthermore, digital video and animations. Google has predicted that after 2020, 90% of the network stream flow will come from the video, and 92% of people will look through the Internet for their own information or answers, then after videos become the best solution choice. Some great popular science videos are common on BBC, National Geographic, Discovery Channel, but why are these videos so attractive? The characteristics of these videos may be (1) there is a solid team, including science, scriptwriting, animation, photography and other production staff, (2) sufficient funds, (3) presenting capabilities with good writing, speaking, images, (4) proper background music, (5) video with clear target, main scope, structure, and intention of the whole piece.

To communicate scientific information adequately, the mass media need to provide suitable information and channels so the community can acquire new information, and thus innovations can be generated. In addition, new media have become quite important and convenient for a new generation. Using videos or graphic images would be easier for an audience to understand scientific concepts (Tsai, 2017).

3. Video Production Planning for "2025 Asking Water"

3.1. Background for water disaster solutions

The ancient Chinese poet Qu Yuan's "Ask Heaven" of "Li Sao": "Why is winter warmer, why is summer colder?" which pointed out the anomaly of the weather and predicted the phenomena that human beings are currently facing. The year of 2025 is a key number in IPCC to remind us that there should be specific actions to mitigate and adapt the climate change. Therefore, a topic of popular science video program with "2025 Asking Water" Figure 1 is proposed to match the subject to find the solutions for water disaster.

Fig. 1. Part scene of "2025 Asking Water"

Under the constant extreme changes in the climate, the traditional water control thinking has long been obsolete. Climate change is not a simple question to be coped with a simple answer. A sustainable development strategy for climate change and water management requires not only good scientific research and good communication, but also trustworthy science, clear policies, creative opportunities and public participation. Even William D. Nordhaus and Paul M. Romer, the 2018 Nobel Prize winners in Economic Sciences, try to integrate climate change and technological innovation into long-term overall economic analysis based on science concepts. Many scientists also predict that the "water resources" competition will be the biggest international crisis after the end of the Cold War.

Many water topics are concerned and 13 episodes are planned in this popular science video program as list of Table 1.

Table 1. Planned episodes in popular science video program

(1) Global water disaster under climate change	The impact of climate change on water disasters is global, not just Taiwan. There were many heavy rain events occurred in the world just only in 2018: Japan, India, Laos, Vietnam, South Korea, etc. Such heavy rains never occurred. It will remind us that every country must be prepared and take action on water disasters under climate change!
(2) Wisdom of coexistence with water	In recent years, the extreme rains, super hurricanes or typhoon have continuously tested the ability of each country to prevent, respond and treat disasters. In Taiwan, before we can solve the problem, you must understand our own terrain and culture, and face different problems and resources before we can propose a suitable solution.
(3) Water resources of Taiwan	In recent years, global climate anomalies and the frequency of droughts and floods have increased year by year. Due to the large changes in the topography of Taiwan and the steep terrain of the catchment area, conserving water is truly difficult. Also the uneven distribution of rainfall and dryness make much efforts to prevent and control floods and droughts. Taiwan faces the difficulty in developing and deploying of water resources, and it needs to take into account the diversified challenges of natural and hydrophilic environment.

(4) Water depletion in Taiwan	In response to climate change, which brings extreme rainfall and possible water supply risks, the Taiwan government has a forward-looking strategy and complete planning for solving water resources problems, and actively promotes various facilities and management efforts to ensure that all water is without depletion. Opening new water sources, saving water, dispatch and backup are the four major measures of effective strategies for solving water problems.
(5) Discolored rive-water pollution	In recent years, population has increased and urban expansion, industrial development, coupled with deforestation, poor conservation make that the mountains are no longer green and the rivers are dirty. Understanding water pollution, what we should do is to face and solve it under climate change.
(6) Urbanization water environment	As result of urbanization, costs of preventing flood are rising and people's tolerance for flooding is reduced. Restricted traffic and underground pipeline problems cause difficulties in improving existing rainwater sewer. Integrated water management can make city becoming a city of "water conserving, permeable, flood preventing and ecology".
(7) Floodplain in the city	Floodplain management is a decision-making process that aims to achieve the wise use of the city floodplains. "Wise use" means both reduced flood losses and protection of the natural resources and function of floodplains.
(8) Storm like typhoon	In 2018 a torrential rain in southern Taiwan caused city's flood problems. The rainfall was about 694 mm within 72 hours due to tropical depression and its peripheral circulation. A storm just like typhoon, The 24 hours of rainfall in this storm was more than it on the most terrible Typhoon Morakot ever happened in Taiwan. The concept of detention pond is to regulate floods, delay flood peaks, increase infiltration, and reduce flooding, etc.

(9) Black water becomes gold	Following the increasing of domestic water consumption, and the further depletion and pollution of freshwater resources, the use of water has become the focus of attention around the world. Reclaimed water can take on the role of stabilizing water resources. Reclaimed water will also integrate the renewable water-related industrial chain with the business opportunity of "black water becoming gold"
(10) Reborn of strata subsidence area	Strata subsidence is one of the causes of flooding, and another challenge dealing with extreme climate change. There are engineering and non-engineering aspects in flood prevention at strata subsidence area. Besides the drainage improvement in engineering works, enhanced early warning evacuation and runoff sharing are proposed in non-engineering works at land development.
(11) Separation line of flood and drought	Under climate change, many cities are likely to face dangerous conditions lust standing on separation line of flood and drought. With the natural terrain of Taiwan, several cities have been tested in this way.
(12) Green agriculture	According to the United Nations, green agriculture incorporates ideas and guidelines from different conceptual areas. These are fair trade, ecological agriculture, organic or biodynamic agriculture, as well as conservation agriculture. Green Agriculture: will be foundations for biodiverse, resilient and productive agricultural systems.
(13) City ark	Facing the water disaster under climate change, many countries think about the urban planning concept of "city ark" to remind humans that this is a "catastrophe"! We must re-examine the fragile ecological balance between mankind and nature with a serious attitude.

3.2.The importance of scientific communication in this video program

- Strengthen the necessary knowledge through the truth that must be faced. Through this video program, the project intends to let the public know the cross-domain science of water control. It is easy to understand that popular science will make it no longer "unreachable" and easy to accept and absorb.

- Remind the people to be prepared for danger, to respect the heavens, and to recognize the meaning of science in civilization developing. The concept of new thinking and pluralistic water control through the design of video program, when the public understands that the adjustment measures for water control with scientific evidence, it will enhance people to concern about water control issues, and present enthusiasm to join the mission.

- Inspire a new dialogue between people and "water". Crisis is a turning point. The seriousness of the "water" crisis and the urgency of response have led to the research and development of new technologies, engineering and non-engineering thinking, and stimulated the new generation to further explore in science.

- Allow the concept of popular science to take root through far-reaching digital convergence. The dissemination of video production through the digital convergence can improve the understanding the popular science knowledge as well as being an important reference for exploring relevant issues.

4. Conclusion

Therefore, an in-depth popular science video program with complete information is proposed to: (1) strengthen the necessary knowledge through the truth that must be faced; (2) remind the people to be prepared for danger, to respect the heavens, and to recognize the meaning of science in civilization developing; (3) inspire a new dialogue between people and "water"; (4) allow the concept of popular science to take root through far-reaching digital convergence.

This project is not only a popular science video program, but also has the following features and other added value. Trough attractive streaming media to create a rich audio-visual feast this video program can be a most vivid teaching material for popular science textbooks in climate change to feel the natural wonders of the knowledge of earth science. The expression of the story in video allows people to experience the universal value of the life community in which people and everything, such as water are closely interdependent. Also, the narrative style of situational aesthetics makes people have true feel about water disaster and solutions under climate change.

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Vietnam Journal of Hydrometeorology, ISSN 2525-2208, 2019 (02): 9-15

Research Paper

METHOD OF CALCULATION & APPLICATION OF WQI INDEX TO ASSESS THE STATUS WATER QUALITY AND PROPOSAL OF MANAGEMENT LUY RIVER BINH THUAN PROVINCE

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ARTICLE HISTORY

Received: Feburary 8, 2019 Accepted: April 25, 2019
Publish on: June 25, 2019

ABSTRACT

The objective of this study is to apply the WQI index to assess the quality of Luy river surface water flows through Binh Thuan province and propose solutions to improve surface water quality in accordance with the society economic development Binh Thuan. Quality of Luy river water most of the parameters in the upstream areas reach A2 column; QCVN 08-MT: 2015/BTNMT, except BOD_5 and COD exceeding 1.07 - 2.83 times, while downstream only meets the level of B1 column. WQI values have large fluctuations in space and time, WQI in monitoring positions from 53 to 91 (June, 2018).

How to manage and protect water resources both in quantity and quality, to ensure the society economic development with the protection of water resources . To solve this problem it is necessary to assess the needs of water use, identifying the factors likely to impact water resources, pollution assessment based on existing standards or models Vietnam and proposed environmental protection measures to ensure appropriate quality water for society economic development - Binh Thuan province. This paper focuses on assessing water quality Luy river from 2016 to present.

Keywords*: Luy River Binh Thuan, water quality index, assessment, evaluate.*

1. Introduction

In order to assess and determine the level of pollution of surface water resources in the river Luy in Binh Thuan province, the paper presents the selection and application of WQI water quality assessment method according to Decision No. 879/QĐ - TCMT July 1, 2011 of the General Department of Environment on promulgating a manual to calculate water quality index to assess the pollution level of surface water resources, and evaluated according to QCVN 08:2015/BTNMT.

Calculation and application of WQI index to assess the changes in Luy river water quality, propose solutions to sustainable management of water resources for Binh Thuan socio-economic development.

2. Materials and methods

2.1. Concept

The Water Quality Index (WQI) (Decision, 2011), is one of the types of environmental indicators (Environment Index), classified by arithmetic or according to the ability to describe a large number of data and information about Water Environment.

2.2. Advantages of WQI in evaluating water quality developments

The use of WQI overcomes the limitations in the way of evaluating the study of water quality

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according to the traditional method is to apply standards and norms for each individual parameter. From the references on water quality research method using WQI index, it is possible to synthesize and evaluate the advantages and limitations of this method compared with the method of comparison with standards and norms.

2.3. Overview of development history of water quality index method

WQI was first proposed in the US in the years 1956-1970 and is widely applied in many states. Currently many WQI models have been studied and applied in many countries such as India, Chile, England, Wales, Taiwan, Australia, Malaysia and so on. WQI is considered an effective tool for environmental management. in water quality monitoring, water resource management (Huynh, 2018).

From the 70s to the present, in the world, there have been hundreds of works of research and development and application of the WQI model for their country or locality in one of three directions:

- Apply the available WQI model to your country or locality;
- Applying to improve a new WQI model for your country or locality;
- Research and develop a new WQI model for your country or locality.

In which, the first two directions are suitable for application in developing countries because they are less expensive in terms of manpower, time and finance.

2.4. Calculating water quality index

There are many methods for calculating water quality indicators such as the basic model of Bhargava (Bhargava - WQI), the basic model of the US National Sanitation Fund (NSF - WQI), NFS Model - WQI adjusting pressure. for Ho Chi Minh City (NFS-WQI/HCM) (MONRE, 2008) (Huynh, 2018). However, in the article, choosing how to calculate the water quality index according to the manual of calculating the water quality index of the General Department of Environment (Decision, 2011; MONRE, 2008; Huynh, 2018).

2.4.1. Collect and gather monitoring data

+ Monitoring data used to calculate WQI are data of intermittent continental surface water monitoring for periodic monitoring or average value of parameters in a defined period for continuous monitoring (from 2016 to 2018)

+ The parameters used to calculate WQI usually include the numbers: pH, temperature, degree opaque, TSS, DO, BOD_5, COD, $N\text{-}NH_4^+$, $P\text{-}PO_4$, Total Coliform.

+ Monitoring data is included in the calculation and processing, eliminating false values, satisfying the normative process of data quality.

2.4.2. WQI calculation is as follows

+ WQI parameters (WQISI) are calculated for parameters BOD_5, COD, $N\text{-}NH_4^+$, $P\text{-}PO_4^{2}$-, TSS, turbidity, Total Coliform by the following formula:

$$WQI_{SI} = \frac{q_i - q_{i+1}}{BP_{i+1} - BP_i}\left(BP_{i+1} - C_p\right) + q_{i+1} \quad (1)$$

where BP_i is the lower limit concentration of the observed parameter values specified in Table 2 corresponds to the level i; BP_{i+1} is the upper limit concentration of the observed parameter values is specified in Table 2 corresponding to the i + 1 level; q_i: WQI value at level i given in the table corresponding to BPi value; q_{i+1} is WQI value at i + 1 in the table corresponding to BP_{i+1} value; C_p is the value of the monitoring parameter is taken into account.

Calculate WQI value for DO parameter (WQI_{DO}): calculated through saturation % value.

- Step 1: Calculate saturation % DO

Calculate saturation DO

T: water environment temperature at the time of monitoring (unit: ^oC).

Calculate saturation % DO

$DO\%_{\text{bão hòa}} = DO_{\text{hòa tan}} / DO_{\text{bão hòa}} * 100$

Dissolution:Value of observed DO (unit: mg/l)

Table 1. Table of q_i and BP_i values

i	q_i	BPi value convention for each parameter						
		BOD_5 (mg/l)	COD (mg/l)	$N\text{-}NH_4^+$ (mg/l)	$P\text{-}PO_4^{2-}$ (mg/l)	Turbidity (NTU)	TSS (mg/l)	Coliform (MPN/100ml)
1	100	≤4	≤10	≤0.1	≤0.1	≤5	≤20	≤2500
2	75	6	15	0.2	0.2	20	30	5000
3	50	15	30	0.5	0.3	30	50	7500
4	25	25	50	1	0.5	70	100	10.000
5	1	≥50	≥80	≥5	≥6	≥100	>100	>10.000

Step 2: Calculate the value of WQIDO:

$$WQI_{SI} = \frac{q_{i+1} - q_i}{BP_{i+1} - BP_i}\left(C_p - BP_i\right) + q_i \quad (2)$$

where Cp is saturated% DO; BP_i, BP_{i+1}, q_i, q_{i+1} are values corresponding to i, i + 1 in Table 2.

Table 2. Table specifying BP_i and q_i values for saturated DO%

i	1	2	3	4	5	6	7	8	9	10
BP_i	≤20	20	50	75	88	112	125	150	200	≥200
q_i	1	25	50	75	100	100	75	50	25	1

Table 3. Table of values for BPi and q_i for pH coefficient

I	1	2	3	4	5	6
BP_i	≤5.5	5.5	6	8.5	9	≥9
q_i	1	50	100	100	50	1

If saturated DO% ≤ 20, WQIDO equals 1.

If 20 < saturation DO value < 88, WQIDO calculated according to formula 2 and use Table 3. If 88 ≤ saturation% DO value 112, then WQIDO equals 100.

If 112 < saturation DO value < 200, WQIDO calculated according to formula 1 and use Table 3. If the value of saturation DO% ≥ 200, then WQIDO equals 1.

- Calculate WQI value for pH coefficient

If the pH value is ≤ 5.5 then WQI_{pH} is equal to 1.

If 5.5 < pH value < then WQI_pH is calculated according to formula 2 and use table 4.

If 6 pH value of pH ≤ 8.5 then WQI_{pH} is equal to 100.

If 8.5 < pH value < 9 then WQI_{pH} is calculated according to formula 1 and use Table 4.

If the pH value is ≥ 9, then WQI_{pH} is equal to 1.

After calculating WQI for each of the above numbers, the calculation of WQI is applied according to the following formula:

$$WQI = \frac{WQI_{pH}}{100}\left[\frac{1}{5}\sum_{a=1}^{5} WQI_a \times \frac{1}{2}\sum_{b=1}^{2} WQI_b \times WQI_c\right]^{1/3} \quad (3)$$

where WQIa: The value of WQI has been calculated for 05 parameters: DO, BOD_5, COD, $N\text{-}NH_4^+$, $P\text{-}PO_4^{2-}$; WQIb: WQI value calculated for 02 numbers: TSS, turbidity; WQIc: WQI value calculated for Total Coliform count; WQI_{pH}: WQI has calculated for pH coefficient.

Note: The WQI value after calculating will be rounded to an integer.

After calculating WQI, use the WQI value determination table corresponding to the water quality assessment for comparison (Decision, 2011; MONRE, 2008; Huynh, 2018).

Table 4. Level of water quality assessment

WQI	Water quality assessment	Pollution level	Color
91 - 100	Good use for domestic water supply purposes	Unpolluted	Blue
76 - 90	Use for domestic water supply purposes but need appropriate treatment measures	Less pollution	Green
51 - 75	Use for irrigation purposes and other similar purposes	medium	yellow
26 - 50	Used for water way and other similar purposes	heavy pollution	Orange
0 - 25	Heavy polluted water, requiring future treatment measures	High pollution	Red

3. Results and disscution

3.1. Evolutions of water quality of Luy river from 2016 to present

At the monitoring points across the Luy river, the water quality varies from DO, BOD_5, COD, pH, temperature, nitrate, nitrite and phosphate, total iron), turbidity and coliform.

Temperature: At different monitoring sites, the temperature varies and tends to increase. The temperature at the same monitoring location over the years has a difference of about 1 - 2.9°C. All monitoring positions on the whole route over the years have temperatures ranging from 26.1°C to 29°C and average temperature of about 27.1°C. QCVN08:2008/BTNMT-National technical regulation on surface water quality has no regulation on temperature parameters.

pH: At monitoring locations, pH at the same monitoring point over the years has a difference of about 0.45-0.76. All monitoring positions on the whole route over the years have pH fluctuating between 7.02-8.45 and within the limits of the regulation. In 2016 - 2018, the pH decrease due to the influence of rain promotes the acidification of compounds in the soil.

Variable suspended solids and turbidity

Suspended solids: Suspended solids content at the same monitoring location over the years has a difference of 0.29 - 12.6 mg/l and all monitoring positions across the route over the years exceed the limit of the standard from 1.3 to 1.9 times.

Turbidity: At the same monitoring position over the years there is a difference in turbidity from 7 to 63.9 mg/l and tends to increase from 2016 to 2018. Turbidity on the entire Luy river is over for the purpose of use.

Evolution of metal pollution

Total iron: The total iron content of the rainy season is usually higher than the dry season, the same location monitored over the years has the difference of the total iron content of about 2 - 2.9 mg/l, most of the locations monitoring has an increasing trend from 2016 to 2018 and gradually decreases from 2016 to 2018, most of them exceed the limit of the standard from 1.72 to 4.4 times.

The evolution of organic pollution

DO: At the monitoring sites, the DO content tends to decrease, the survey shows that it is affected by domestic waste of riverine inhabitants and agricultural production activities. At the same location monitoring over the years there is a difference of DO content from 0.8 to 1.6 mg/l, Over the years there is DO content fluctuating between 5.1-6.7 mg/l and within the limits of the norm.

BOD_5: At the monitoring locations tend to increase BOD_5 content, due to the impact of domestic waste of riverine inhabitants and agricultural production activities. At the same monitoring position over the years with the difference of BOD_5 content from 8 to 18 mg/l, all monitoring positions over the years have BOD5 content fluctuating in the range of 0.9 - 7 mg/l and within the limits of the regulation. In 2016 - 2018, BOD_5 content showed signs of increase due to the influence of rain and organic compounds

COD: At monitoring sites there is a tendency to increase due to the impact of domestic waste of people living along canals and agricultural production. At the same monitoring position over the years there is a difference of COD content from 10-22 mg/l and most of the monitoring positions (53-91 mg/l). WQI in monitoring positions from 53 to 91 (Huynh, 2018). On the whole route over the years, COD content is within the limits of the regulation

Changes in nutrient pollution (Ammonium, nitrite, nitrate and phosphate).

Ammonium: At the monitoring locations tend to increase the content of ammonium. At the same monitoring point over the years, there is a difference of ammonium content from 0.019 to 0.89 mg/l and most of the monitoring positions across the route over the years have ammonium content within the limits of the standard. QCVN 08: 2008/BTNMT.

Nitrite: At the monitoring sites, there is a tendency to increase, at the same monitoring point over the years, there is a difference of nitrite content from 0.008 - 0.061 mg/l and all monitoring positions on the whole route have the function Nitrite content is within the limits of the norm.

Nitrate: All the important positions on the whole route over the years have nitrate content ranging from 0.09 to 0.788 mg/l and within the limits of the regulation. In 2016 - 2018, nitrate content showed signs of increasing due to the effects of rain, which led to nutrient compounds into the river.

Phosphate: At the same monitoring point over the years there is a high difference in phosphate content and over phosphate monitoring years within the limits of the norm, and from 2016 - 2018, phosphate tends to decrease.

Microbial contamination

Coliform: At locations of rainy monitoring, coliform content is often higher than dry season. Coliform, most of the monitoring points over the years exceed the norm

3.2. Evaluate surface water quality changes according to WQI index

If comparing and evaluating each parameter at monitoring points in the Luy river with QCVN 08:2008/BTNMT, only the Luy river basin water source can be identified.

The Luy River Binh Thuan is polluted with any parameters, not determined how pollution is. This is a limited issue in comparing each parameter in the current QCVN. Therefore, it is necessary to have a combination with WQI calculation method to compare and evaluate immediately the level of water pollution.

The zoning map of water quality of Luy river basin as shown in Figure 1 shows that the water source in the downstream area of Luy river which flows through Phan Ri Cua - Tuy Phong town has been polluted. This result is consistent with the spatial evolution, the farther away from the concentration area of population and the

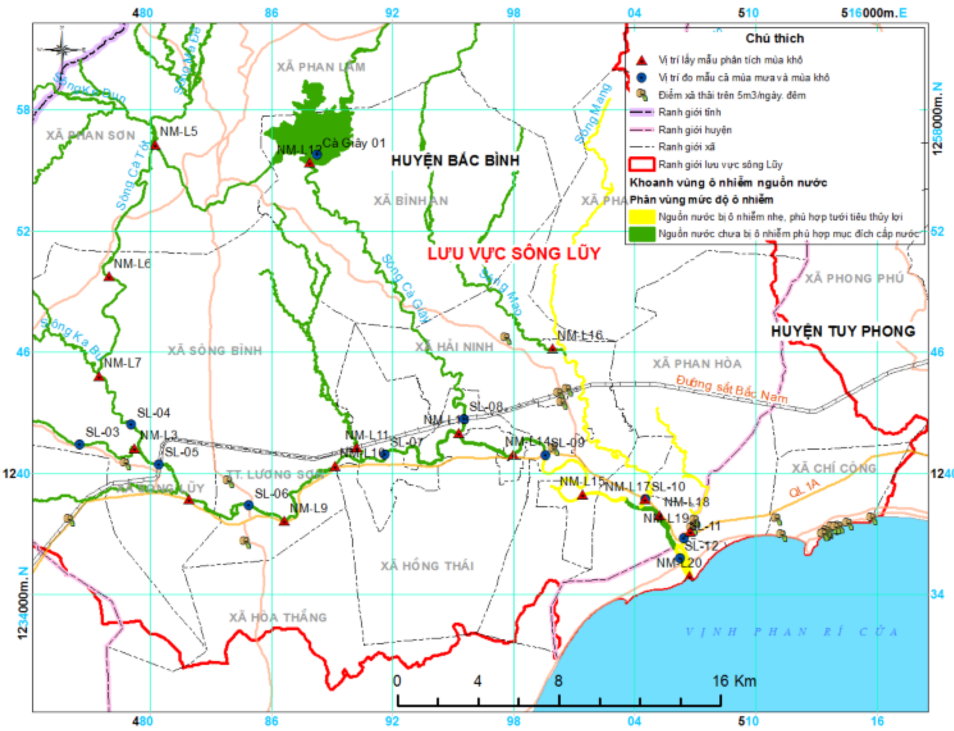

Fig.1. Water quality maps are established by WQI index for Luy river basin

source of waste, the better the quality of water, at the same time, under the influence of flow, the content of pollutants decreases gradually when away from the discharge location. From the results of assessing the current situation in the basin, it is possible to identify the quality of the river Luy has negative developments by pollutants in domestic wastewater; shrimp farming wastewater.

4. Conclution

The speed of economic development in Binh Thuan province has affected the water quality of Luy river basin, the level of water pollution through WQI water quality assessment method.

The use of QCVN 08:2008/BTNMT to assess water quality is only possible to identify the pollution level of each parameter, while using the WQI water quality assessment method (MONRE, 2008) provides an overview of water quality through a scale of pollution assessment. The highest average WQI rainy season is 76 and low is 13, the highest WQI dry season is 91 and the lowest is 16, the dry season is higher than the rainy season. The combination of the WQI index with QCVN 08:2008/BTNMT allows to accurately assess the water quality as data.

Data helps leaders at all levels to promptly adjust and make accurate decisions on solutions to minimize water quality pollution.

The results of assessment of Luy river basin water quality are mainly polluted with suspended solids, turbidity and coliform. Over time, the water quality of Luy river basin is not stable over the years and tends to be worse in the rainy season. According to space, the water quality of Luy river basin is being polluted at medium level for the upstream, heavily polluted in the middle and very heavy pollution in the downstream.

Management of water resources in the Luy river basin needs to focus on water quality to ensure water resources to meet the objectives and orientation of socio-economic development in Binh Thuan province, especially water for domestic use. and agricultural production.

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Research Paper

VULNERABILITY ASSESSMENT OF WATER RESOURCES SYSTEMS IN LAM DONG PROVINCE

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ARTICLE HISTORY

Received: January 16, 2019 Accepted: April 08, 2019
Publish on: June 25, 2019

ABSTRACT

In recent years, Lam Dong's water resources have not only changed in terms of quality and quantity of water, but this has affected the economic, social and living environment in the region. Based on UNEP guidelines, the vulnerability of water resources in the study area has been explored by isolating important issues related to the different functions of the water resource systems in a storage facility. area. At present, the vulnerability index for the river basin in Lam Dong (VI) reaches 0.29 in the river basin with a vulnerability index for medium water resources. Assessing the vulnerability of basin water resources is the basis for scientists to provide appropriate management solutions in the direction of sustainable development.

Keywords: *Vulnerability assessment, Lam Dong.*

1. Introduction

Water is the most important resource of the river basin. The use of water is closely related to land use and the impact on the watershed, therefore, water management by river basin will support better protect land and environmental resources. In order to implement an effective management policy of water resources, it is necessary to understand and assess the vulnerability of water resources. Assessing the vulnerability of water resources is a process of investigating, surveying and analyzing the water resources system, thereby assessing the sensitivity of the water resource system to changes of water resources to propose risk mitigation measures.

Intergrated river basin management is one of the most nescessary tasks. Vulnerability Assessment of Water Resources Systems is a basis for scientists generate adequate management methods in order to subtainable development. This paper presents the result of vulnerabilty indicators of water resources for river basin in Lam Dong province.The assessment of water resource vulnerability of this river basin is based on the premise of four components of the water resource system, including: Management challenges, Resource stress, Development pressures, Ecological insecurity.

2. Methodology and Data

2.1. Theoretical basis for determining parameters to assess the vulnerability of water resources

Based on UNEP and Peking University guidelines (UNEPPKU, 2008). The vulnerability of water resources has been explored by isolating important issues related to the various functions (uses) of water resource systems in a basin. Therefore, this analysis is based on the premise of assessing the vulnerability of water resources in a river basin to be linked by four

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components of the water resource system, including: Total water resources, developing water resources and pressure to use water resources, ecosystems and water resources management.

According to this approach and assessment, a sustainable water resource system can only operate in an integrated operational framework that combines both natural systems and management systems.

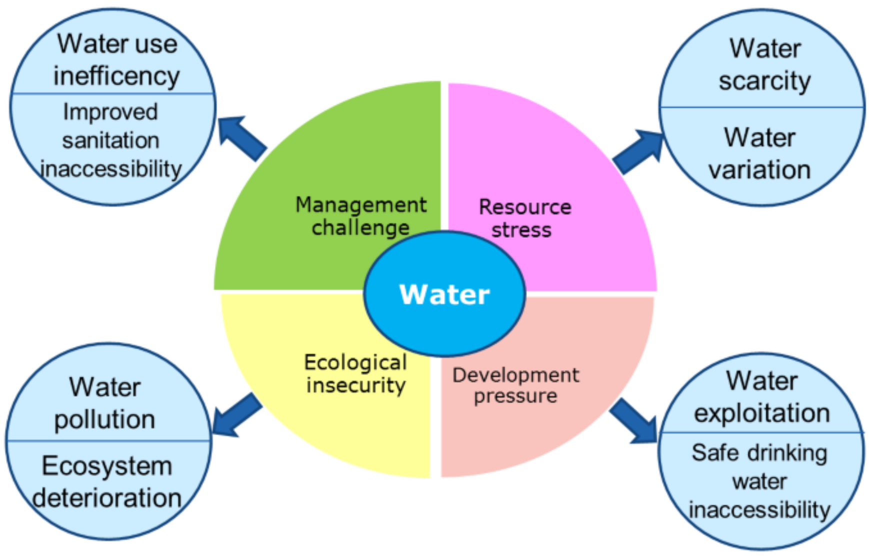

Fig. 1. Vulnerability to freshwater resources and indicators

2.2. Resource Stress (RS)

Water resources of a river basin are the total amount of fresh water available for maintaining ecosystems and socio-economic development, the water resources of a river basin may be characterized by water scarcity coefficient. and precipitation fluctuations in the basin.

Water Stress parameter (RSs): can be expressed by per capita water and compared to the average per capita water volume worldwide (1,700m^3/year) and determined as follows:

$$RS_S = \begin{cases} \frac{1700 - R}{1700} (R \le 1700) \\ 0\, (R > 1700) \end{cases} \quad (1)$$

where R is per capita water resources (m^3.person-1).

Water Resources Variation parameter (RSv): The variation of the water resources can be expressed by the coefficient of variation (CV) of total annual average precipitationof whole the basinand determined by the formula:

$$RS_V = \begin{cases} \frac{C_V}{0.3} (C_V < 0.3) \\ 1 (C_V \ge 0.3) \end{cases} \quad (2)$$

where CV is the coefficient of variation (CV) of precipitation.

2.3. Water Development Pressures (DP)

Development pressures (DPs): Freshwater resources are recharged through a natural hydrological process. Over-exploitation of water resources will disrupt the normal hydrologic process, ultimately causing difficulties for the recharge of the water resourcebase. Thus, the water resourcesdevelopment rate (i.e: per cent of water supply, compared to the total water resource), can be used to demonstrate the capacity of a river basin for a healthy renewable process. Thus:

$$DP_S = \frac{W_u}{W} \quad (3)$$

where W_u is the total water supply (capacity); and W is the total water resource

Safe Drinking Water Inaccessibility Parameter (DP_d): The ability to access clean water sources is also developed to indicate the status of adaptation to social factors. This is a comprehensive parameter reflecting the impact of capacity of all households using water as well as available techniques. This coefficient can be determined by the ratio of the total population able to receive clean water compared to the total population in the basin:

$$DP_d = \frac{P_d}{P} \quad (4)$$

where P_d is the population without access to improved drinking water sources; and P is the total Population.

2.4. Ecological Health (EH)

Ecosystem Deterioration Parameter (EH_e): As a result of the population expansion, the natural landscape was modified by the consequent urbanization and other socioeconomic development activities. Removing vegetation from landscapes changed the hydrological properties of the land surface, and can cause severe problems in supporting the functioning of ecosystems, in terms of water resources conservation, and contributed to the vulnerability of the region's water resources. Thus, the land ratio without vegetation coverage can be used to represent the contribution of ecosystemdeterioration to the vulnerability of water resources, expressed as:

$$EH_e = \frac{A_d}{A} \quad (5)$$

where A_d is the land area without vegetation coverage (i.e., total land area, except that covered with forests and wetland,expressed in km^2); and A is the total land area (km^2).

Water Pollution Parameter (EH_p): Vietnam is a country with relatively abundant surface and groundwater resources. However, the management, use and protection are not good, causing surface water sources to be increasingly polluted due to a large amount of industrial and domestic waste, and the source of groundwater is contaminated with persistent organic matter. In addition to their influence on the hydrologic process, water development and use activities will produce wastes, polluting the water resources base. Thus, another very important factor influencing the vulnerability of water resources is the total wastewater produced within the basin. The contribution of water pollution to water resources vulnerability, therefore, can be represented by the ratio between the total untreated wastewater discharge and the total water resources of a river basin.

$$EH_p = \frac{W_W}{W} \quad (6)$$

where W_w is the total wastewater discharge (m^3); and WR = total water resources (m^3).

This component will assess the vulnerability of freshwater by evaluation of the current management capacity to cope with 3 types of critical issues, including: (i) efficiency of water resources use; (ii) human health condition closely dependent on, and heavily influenced by, accessibility to freshwater resources; and (iii) overall capacity in dealing with conflicts.

Water Use Inefficiency parameter (MC_e): This can be represented by the GDP value of $1m^3$ of water, compared to the world average for selected countries, as follows:

$$MC_E = \begin{cases} \frac{WE_{WM} - WE}{WE_{WM}} & (WE < WE_{WM}) \\ 0 & (WE \geq WE_{WM}) \end{cases} \quad (7)$$

where WE is the GDP value produced from $1m^3$ of water; WEWM is the WE of selected countries.

Lack of information, or weak specific regulations on management, directives and human capacity institutions create a threat to the implementation of people, communities, where the public expects demand. when it comes to water supply. Water use policies and techniques determine the efficiency of water use. Therefore, the effectiveness of the water resource management system can be expressed through the difference between the water efficiency of the basin and the average water efficiency in the world.

Improved Sanitation Inaccessibility Parameter (MC_s): The ability to receive sanitation depends on the availability of clean water in the basin. Actual environmental pollution caused by community consciousness. Therefore, the best way to manage water resources is to create favorable conditions for people to receive and be aware of environmental sanitation conditions. Therefore, a management system must meet the above criteria is to strengthen the water supply to the community to meet the water demand for production life and at the same time be aware of the protection of water resources of me With the criterion on environmental sanitation parameters MC_s can be used as a typical parameter to assess management capacity in terms of ensuring improvement for human livelihood activities. and is calculated by the proportion of people not receiving sanitation with the total population calculated. With P_s is the total number of people not receiving sanitation and P is the total population of the basin. The formula for calculating MC_s is as follows:

$$MC_s = \frac{P_S}{P} \quad (8)$$

where P_d is the population without access to improved sanitation; and P is the total population.

Management Capacity (MC_c): In fact, any problems have any conflicts. Solution is always an important issue to determine the effectiveness of a job. Conflict management capacity parameters (MC_c) represent river basin management capacity for different types of conflicts. A good management system can be assessed through its effectiveness in aligning mechanisms and establishing effective management policies. Conflict management capacity, can be assessed through the matrix of contradictory management capacity parameters:

Table 1. Conflict management capacity parameter assessment matrix

Category of capacity	**Description**	**Scoring Criteria** 0,0 →		0,25
Institutional capacity	Transboundary institutional arrangement for coordinated water resources management	Solid institutional arrangements	Loose institutional arrangements	No existing institutions
Agreement capacity	Writing/ signed policy/ agreement water resources management	Concrete/ detailed agreement	General agreement only	No agreement
Communication capacity	Routine communication mechanism for water resources management	Communication at policy and operational levels	Communication only at policy level or operational level	No communication mechanism
Implementation capacity	water resources management cooperation actions	Effective implementation of basin – wide river projects/programs	With joint project/program but poor management	No joint project/program

2.6. Vulnerability Index (VI)

To determine the vulnerability index of water resources (VI), it is necessary to determine the above parameters by weight. In each type of parameters their weights must have a sum equal to 1.

VI = 0,25RS + 0,25DP + 0,25EH + 0,25MC (9)

Once the vulnerability index of the water resource has been identified, it is necessary to assess the situation of water resources based on the following criteria:

Table 2: Reference sheet for interpretation of Vulnerability Index

Vulnerability Index	Interpretation
Low($VI \leq 0,2$)	This indicates a healthy basin, in terms of resource richness, development practices, ecological state, and management capacity. No serious policy change is needed.
Moderate ($0,2 < VI < 0,4$)	This indicates the river basin is generally in a good condition in regard to realization of sustainable water resources management. It may still face major challenges, however, in regard to either technical support or management capacity-building. Thus, the basin's policy design should focus on the main challenges identified after examining the VI structure, and strong policy interventions should be designed to overcome key constraints for the river basin.
High ($0,4 \leq VI < 0,7$)	This indicates the river basin is experiencing high stresses, and great efforts should be made to design policy to provide technical support and policy backup to mitigate the pressures. A longer-term and appropriate strategic development plan should be made, with a focus on rebuilding management capacity to deal with the main threatening factors.
Severe ($0,7 \leq VI \leq 1,0$)	This indicates the river basin is highly degraded in regard to being a water resources system with a poor management structure. Restoration of the river basin's water resources management will require major commitment from both government and general public. Restoration will be a long process, and an integrated plan should be made at the basin level, with involvement from international, national and local level agencies.

3. Results and discussion

3.1. Resource Stress

Water Stress parameter (RS_s): The rivers and streams in Lam Dong are plentiful, the average per capita is 168,345 m^3/day, compared to the one-person water standard in the world, the water resources in the river basin of Lam Dong province are evaluated. At a very plentiful level and can meet the demand for residential and some economic sectors. Therefore the water scarcity coefficient RSs of the basin are zero.

Water Resources Variation parameter (RS_v): According to average rainfall statistics from 1980 to 2015, Lien Khuong, Bao Loc, and Da Lat stations calculated the average Cv coefficient of 0.123 in the whole basin. Accordingly, the calculation of the coefficient of RS water pressure on the average of the entire basin is 0.207.

3.2. Development pressures

Development pressures (DP_S): The average total water demand of all industries in rural and urban areas in Lam Dong is 1610,12x106 m^3. At that time, calculate the average DPs of Lam Dong province by 0.039.

Safe Drinking Water Inaccessibility Parameter (DP_d): From the statistics of the number of households using clean water in Lam Dong province, in Da Lat and Bao Loc, the districts with households using clean water have a high rate. Lam Ha district has the lowest percentage of people using clean water in the province only accounting for 35.73%.

According to the statistics of Lam Dong Statistical Yearbook in 2015, on average of Lam Dong Province, the proportion of people not using clean water is 10.77%.

After that, calculating the coefficient of receiving clean water in Lam Dong province is 0.11.

3.3.Ecosystem Deterioration Parameter (EH)

Water Pollution Parameter (EH_p): Climate change and many changes such as population growth, industrial development and increasing demand make water pollution and land degradation affect ecosystems. Calculating the total amount of industrial wastewater, animal husbandry and living is very difficult to collect as much as possible. According to the experience of experts, the calculation of domestic wastewater will be equal to 85% of the amount of water used, the amount of wastewater produced by livestock depends on the livestock. According to the data collected from Lam Dong province in 2010, from the calculation of water use needs of the sectors (calculated in detail in the calculation of water balance in Lam Dong province, calculating the coefficient of water pollution pollution $EH_p = 0.03116$.

Ecosystem Deterioration Parameter (EH_e):In Lam Dong, the land is mainly used for agriculture, accounting for 93.05%, non-agricultural land accounts for 5.58% and unused land accounts for only 1.39%. According to the statistics, the districts calculated the ecosystem decline coefficient of this area of 0.93.

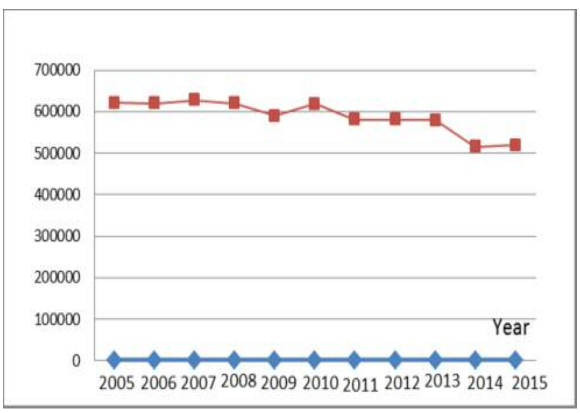

Fig. 2. Fluctuation of forest area in the past time in Lam Dong (ha)

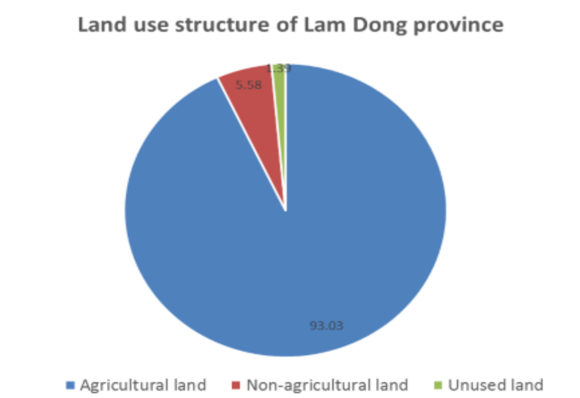

Fig. 3. Allocation of land use rates in Lam Dong

3.4. Management Capacity(MC)

Water Use Inefficiency parameter (MC_e)

Parameters used to calculate are investigated and surveyed in some areas in the basin. GDP income of regions calculated on average by Lam Dong province in 2015: (With the conversion of 1 USD = 23.000 VND), urban areas: 3137.4 thousand VND/month, equivalent to 49789,17 USD/year; rural areas: 2325,05 thousand VND/month, equivalent to 36897.53 USD/year.

According to the Decision No. 48/2013/QD-UBND dated the 18th October 2013 of Lam Dong Provincial People's Committee on regulating clean water consumption price of Lam Dong Water Supply and Sewerage Company Limited, the average of the region is 12100 VND/m^3 equivalent to 0.53USD/m^3. Meanwhile, in China, France, Mexico, the US is 23.8 USD/m^3. The average water use efficiency is 8.6.

The results of calculating the efficiency parameters of water use in Lam Dong are: MC_e= 0.94.

Improved Sanitation Inaccessibility Parameter (MC_s)

According to the global report of the United Nations Development Program (UNDP), Vietnam's human development index has increased by 41% over the past two decades. In 2012, Vietnam ranked 127th out of 187 countries - within the average category of human development with the Human Development Index (HDI) of 0.617 (China is 0.699, Thailand is 0.690).

According to the statistical data of Lam Dong province, by 2015, the proportion of households using hygienic drinking water accounted for 89.23%, of which 97.66% in urban areas and in rural areas was 85.45%. About 96.36% of households have hygienic toilets, of which urban areas account for 99.61%, and rural areas account for 93.23%.

According to Decision No. 1404/QD-UBND dated June 30, 2015, approving the rural water supply and environmental sanitation planning of Lam Dong province by 2020 as follows:

- Regarding clean water supply: 99% of rural population use hygienic water; 73% of rural population use clean water to meet QCVN 02/2009 standards of the Ministry of Health; 100% of schools and commune health stations in rural areas have enough hygienic water (completed before 2018); 99% of the rural population uses hygienic toilets and performs well personal hygiene, keeping the village and commune environmental sanitation clean; 100% of preschool and general education schools and health stations in rural communes have hygienic latrines (completed before 2017).

- Rural sanitation: 71.77% of rural households have hygienic latrines. 100% of preschool and general education schools and rural health stations have adequate hygienic latrines. 58% of breeding households have hygienic breeding facilities.

With the statistics of the province, calculating the number of people with access to sanitation in the basin of the province is: $MC_s = 0.0364$.

Management Capacity (MC_c)

Currently, in the basin, there are many investment projects for industrial and agricultural development, especially high-tech agriculture, with priority given to development. However, there are areas that are interested in investing and developing synchronously, ensuring sustainable economic development, such as Bao Loc and Da Lat. In parallel, with this problem, there are areas of incomplete development, there are still many agricultural production companies but no wastewater treatment system and environmental protection, causing pollution to the environment, aquatic ecosystems are strongly affected by population growth and economic development. These are very sensitive and pressing issues of society.

Management is the center for water resources issues in the river basin of Lam Dong province as well as the water quality and environment of the province. This also creates challenges in management. In general, the current status of water resources management in the river basin can see some points:

Rivers in Lam Dong province many rivers do not fit in the territory of Vietnam (located on the territory of neighboring Cambodia) and go through many provinces and cities (Dong Nai, Dak Nong, Dak Lak) so the problem to Developing an integrated water resource management program here is not easy to implement.

There is currently no institutional management of water resources here.

Community mechanism issue: there has been concern about the community in the use of water resources, there is a waste charge to limit discharge but there is no strict and effective.

Regarding the use of water in combination with environmental sanitation is not synchronized across the province, areas, residential areas in general, the poor in particular.

Regarding implementation capacity: there have been projects in operation but so far, in general the implementation capacity for the locality is still limited.

Through the basis to determine the capacity of conflict management capacity, there are results for river basins in the scope of Lam Dong province as follows: Institutional capacity: 0.25; policy capacity: 0.25; Community mechanism capacity: 0.2 and enforcement capacity: 0.2. Accordingly, calculate the conflict management capacity MCc = 0.225.

3.5. Vulnerability and indicators for river basins in Lam Dong province

Based on the results of calculation of water pressure parameters, pressure on water exploitation and use, ecosystem parameters, management capacity, and calculated value of damage to water resources in Lam Dong province as follows: VI = 0.2903. That is, the index of water resource vulnerability of the basin of medium and basin level with good conditions for sustainable management of water resources still faces technical pressure and management policy. Therefore, it is necessary to develop a new management policy to match the water resource challenge.

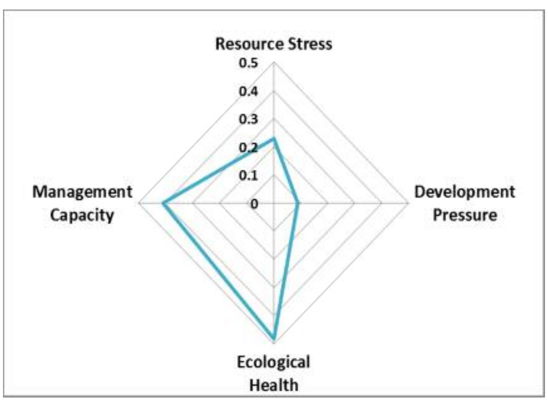

Fig. 4. Vulnerability Index of Water Resources Systems in Lam Dong province

Through these vulnerability values, the province should have a priority plan for higher vulnerability values to reduce the level of vulnerability. Since then, reducing the index of water resource vulnerability for each region as well as for the whole study area.

Results of calculation of vulnerability coefficient for water resources in river basins in Lam Dong province gives an overview of the situation of environmental sanitation and water resources in the basin. Since then, managers have a policy of integrated management of water resources for the basin within their scope more effectively. The problem of rational use of water is useful, the use is associated with very important protection. Not only can the waste source be grasped, but also to minimize the waste source into the environment, affecting water resources.

Ecosystems represent the survival of a river basin. The percentage of non-vegetation land (1.39%) indicates vulnerability to water resources. Parameters of conflict management capacity are social and not mathematically and natural with high accuracy and concretization, so the final calculation value has not reached absolute.

4. Conclusion

Integrated management of water resources by river basins is an urgent issue. Assessing the vulnerability of basin water resources is the basis for scientists to devise appropriate management measures towards sustainable development. The study results show that the current index of water resource vulnerability in the river basin in Lam Dong (VI) reaches 0.29 in the river basin with a vulnerability index for medium water resources. Although this index has not reached the absolute level, due to its social nature, it has partly shown the situation of environmental sanitation and water resources in the basin, especially Lam Ha and Don Duong districts. Since then, managers have a policy of integrated management of water resources for river basins that is better and more efficient.

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Research Paper

THE EFFECT OF CLIMATE CHANGE ON THE SURFACE WATER RESOURCES OF THE LAM DONG PROVINCE

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ARTICLE HISTORY

Received: February 12, 2019 Accepted: May 22, 2019
Publish on: June 25, 2019

ABSTRACT

Lam Dong is a province located upstream of the Dong Nai river system. Although not as complicated as the downstream provinces affected by natural disasters related to sea level rise, Lam Dong suffers from typical disasters such as droughts and floods. This study focused on assessing the impact of precipitation on flow changes by Mike NAM model. Under the impact of climate change, the results of river basin flow calculations according to climate change scenarios show that the flow of river basins has a marked change in stages, and in particular , under the influence of climate change, the trend tends to increase. Annual flow, in the period 2016- 2035, the Dong Nai river basin increases by 1.75% on average, the Krong No river basin increases by 1.63%, the La Nga river basin increases by 1.79% and the Luy river area Cai Phan Thiet river increased by 2.2%. Research results can serve as a basis for local reference in water resource planning and socio-economic development.

Keywords: *Climate change, water resources, Lam Dong, Mike NAM.*

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1. Introduction

Climate change (CC) is one of the biggest challenges in the 21st century. In the fourth report of the Intergovernmental Panel on Climate Change (IPCC-AR4), it was emphasized that global warming and CC are an inevitable phenomenon. Climate change can lead to changes in the hydrological cycle and has a great impact on water resources. In recent years, research on the impacts of climate change on water resources, especially surface water, has attracted the attention of researchers around the world. In these studies, hydrological models are often combined with climate scenarios from global circulation models (GCMs) to examine the possible effects of climate change on water resources and hydrological cycle. The climate change scenarios used in these studies are mainly used from climate change scenarios of the Ministry of Natural Resources and Environment in 2016 (MONRE, 2016).

The objective of this study is to assess the impacts of climate change on changes in the flow of river basins in Lam Dong province. To accomplish this goal, the author used the hydrological model NAM.

The results of this study provide a clearer view of the change in river flow in Lam Dong at present and in the future and help managers to plan water resources management and planning. for this basin.

2. Materials and methods

2.1. Materials

2.1.1 Introduction of the study area

Lam Dong is one of five provinces in the Central Highlands region of Vietnam, having a geographical location located in the 11°12'30" – 12°26'00" north latitude and 107°15'00" – 108°45'00" east longitude. The total natural land area of Lam Dong is 977,219.6 ha, accounting for 3.1% of the national area and 17.9% of the Central Highlands.

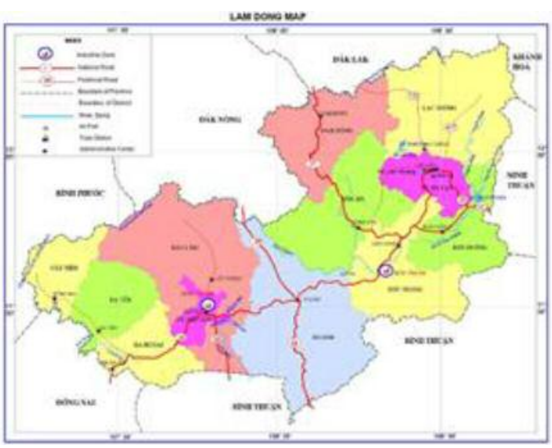

Fig. 1. Administrative map of Lam Dong province

Lam Dong is the watershed of two major river and stream systems: the system consists of the Krong No river - Srepok - Me Cong river with a basin area of 1,248 km^2 and the system of Dong Nai - La Nga river with basin area of 8,524 km^2 includes Da Dang, Da Nhim, Dai Nga, Da Huoai rivers and some tributaries on the left bank of Dong Nai Thuong river, flowing to the Southeast region. The rivers of Lam Dong province play an important role in supplying water to downstream areas of Dong Nai River and Binh Thuan Province.

2.1.2 The expression of climate change in Lam Dong

a. The expression of climate change

The expression of climate change is most evident in the characteristics of temperature and precipitation. Calculating and analyzing the series of data from 1980 - 2017 stations shows,

Assessing the trend of temperature factors from 1980 - 2017 shows that the average temperature of many years of Da Lat station is about 17.9°C, Lien Khuong is 21.3°C, Bao Loc is 21.9°C. The temperature trend of the area increased, in Da Lat the annual average temperature increased by 0.0184°C/year, Lien Khuong increased by 0.0223°C/year, Bao Loc increased by 0.0199°C/year.

Regarding precipitation factors, analyzing the data series from 1980 to 2017 showed that the average annual precipitation at Da Lat meteorological station is 1806.1mm, Lien Khuong station is 1602.4mm, Bao Loc station is 3834.9 mm. The annual precipitation trend increased, at 4.9575 mm/year at Da Lat station, at 2.3037 mm/year at Lien Khuong station, at Bao Loc station increased by 7,1698 mm/year.

Lam Dong also occurs many extreme climatic phenomena such as being strongly affected by ENSO phenomena causing droughts and floods.

b. Climate change scenario in Lam Dong province

Temperature

According to the climate change scenario of the Ministry of Natural Resources and Environment in 2016, the scenario RCP4.5, the annual average temperature in Lam Dong in the period of 2016 - 2035 increased about 0.7°C; in the period of 2046 - 2065, the temperature increases about 1.5°C; the period of 2080 - 2090 temperature increased about 1.9°C.

Thermal distribution in the year, the temperature increase in each month, different seasons, from October to December, the average temperature increases by 0.8°C in the period of 2016 - 2035, increases by 1.5°C in the period of 2046 - 2065 and an increase of 1.8°C in the period 2080 - 2090. In January to March, the average temperature increased by 0.7°C in the period of 2016 - 2035, increased by 1.5°C in the period of 2046-2065, increased by 2°C in the period 2080 - 2090. From July to September, the average temperature increases 0.7°C in the period of 2016 - 2035, increases by 1.5°C in the period of 2046-2065, increases by 1.9°C in the period of 2080-2090 [6].

Precipitation

According to the CC scenario, the average scenario of RCP4.5, precipitation in Lam Dong in the period of 2016 - 2035 increased 3.9%, the period 2046 - 2065 increased by 6.5% and the period 2080 - 2099 increased by 7, 8%.

Seasonally, from October to December, the average precipitation increases by 32.5% in the period of 2016 - 2035, an increase of 35.1% in the period of 2046 - 2065, an increase of 54.4% in the period of 2080 - 2090. From January to March, the average precipitation increased by 3.1% in the period of 2016 - 2035, down by 1.1% in the period of 2046 - 2065, increasing by 6.1% in the period of 2080 - 2090. From January IV to VI average increase of 3.8% in the period 2016 - 2035, up 4.6% in the period 2046 - 2065, increasing 4.1% in the period 2080 - 2090. And from July to October IX average precipitation increased by 10.4% in the period of 2046 - 2065, an increase of 3% in the period 2080 - 2090.

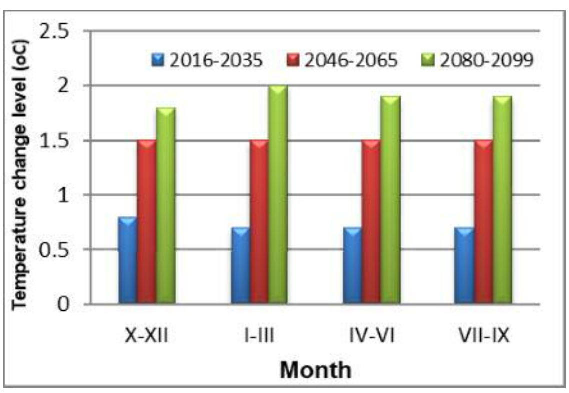

Fig. 2. Temperature changes for months of the year according to RCP4.5 scenario

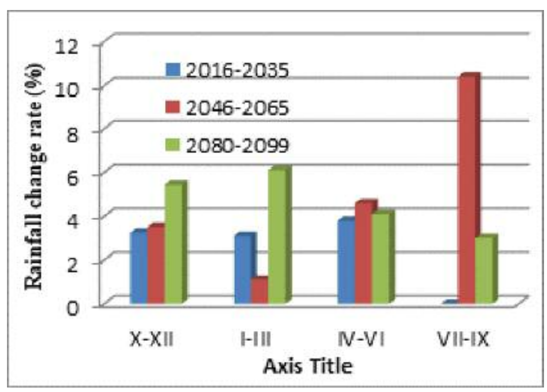

Fig. 3. The change in precipitation in months of the year according to RCP4.5 scenario

2.2. Methods

NAM model structure is built on the principle of vertical reservoirs and linear reservoirs, including 5 vertical tanks as shown in Fig. 4.

- Melted snow storage tanks are controlled by temperature conditions. For tropical climatic conditions in our country, this tank is not considered.

- Surface tank: the amount of water in this tank includes the amount of rain water blocked by the vegetation cover, the amount of water remaining in the depressions and the amount of water in the floor close to the face. The upper limit of this tank is denoted by Umax.

- Lower storage tank: is a land with roots, so plants can absorb water for evaporation and evaporation. The upper limit of the amount of water in this tank is denoted by Lmax, the current amount of water is denoted by L and the ratio L / Lmax represents the moisture state of the reservoir.

- Upper water storage tank.
- Underground water tank.

Input data of the model

The required input data of the model is represented in two forms: spatial data and non-spatial data.

- Spatial data in the form of maps includes:

River basin topographic map: using elevation digitization model with ARCVIEW software to convert topographic map into DEM form;

Map of networks of rivers and streams, reservoirs in the river basin;

Map of land use;

- Non-spatial data in the form of Database include:

Data on meteorology: rain, evaporation, temperature, ...

Hydrological data: water flow, reservoir parameters;

Data on land include: soil type, soil characteristics, ...

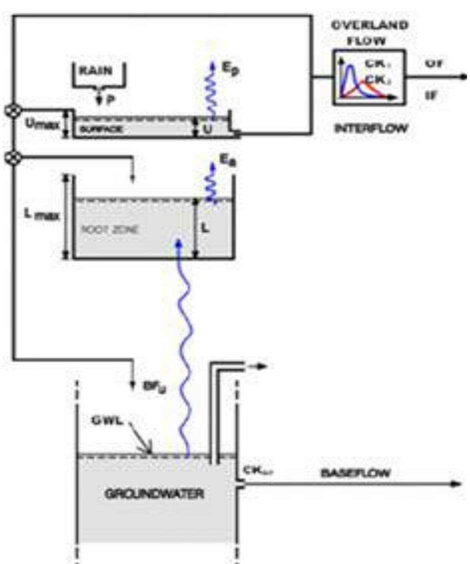

Fig. 4. NAM model structure

Output data of the model

- Calculate and evaluate the water flow, the total amount of incoming water in each sub-region by time (month, season, year);
- Restoring missing monitoring data at monitoring stations.

Edit model parameters to determine the model parameters so that the calculation process line is best suited to the actual process line. Correction of model parameters can be carried out by two methods: wrong test method or optimal method.

In summary, the NAM model is used to determine the process flow path at the watershed section of the basin from rain data by finding a set of parameters that are suitable for the characteristics of the study basin. In order to determine the required parameters, we need to have real flow metrics to measure a few years for model calibration and verification.

3.Results and discussion

3.1. Calculation of river basin flow in Lam Dong province

To assess the impact of climate change on river flows in Lam Dong province. Within the scope of this study, Mike Nam model will be used to calculate the current flow as well as the climate change scenarios.

- Input data of the rain flow model

For the NAM rainfall - flow model, the input of the model, including, spatial data and attribute data. As follows:

Spatial data include: DEM river basin map (90x90); Map of river and stream network in Lam Dong province; Map of grid system of meteorological and hydrological stations in Lam Dong and neighboring provinces.

Attribute data include: Control area of hydrological station; Meteorological data include rainfall, average evapotranspiration daily; Hydrological data include daily average flow.

Meteorological and hydrological data are used with time-of-day steps to allow the study of the flow in detail over time in the basin. Document of daily rainfall including meteorological stations: Lien Khuong, Bao Loc, Da Lat from 1980 - 2015, in which, data for calculation of baseline scenario are compared with simulation results under the impact of Climate change is 1986 - 2005. In addition, rainfall data at the stations measured rain: Lac Duong, Di Linh, Da Chay, Dam Rong ...

Document on rainfall flow at Dai Ninh, Thanh Binh, Ta Lai, Duc Xuyen and Dai Nga stations.

Document on evaporation is taken from Lien Khuong, Bao Loc and Da Lat stations.

The DEM digitized elevation map combined with the river network map, the hydro-meteorological station network was included in ArcGis 9.3 to determine the topographical characteristics and determine the hydrological parameters of the basin as basin slope, flow direction for the purpose of dividing the basins for the analysis and calculation of flow in the river basin of Lam Dong province.

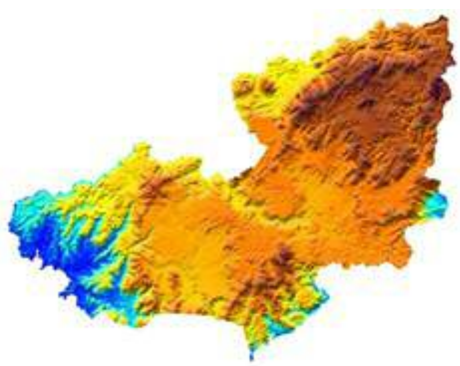

Fig. 5. DEM map of the study area

Based on a map of sub-basins, administrative maps, a network of rivers and streams, reservoirs, all of Lam Dong province is divided into 53 small sub-regions and the main river basins are Krong No river basin (Srepok) and La Nga. Thuong Dong Nai 1, Thuong Dong Nai 2, Da Nhim, Da Dang, and LVS Cai Phan Thiet - Luy river.

Fig. 6. Hydrological calculation section of Lam Dong province

At the same time, area data controlled by the hydrological measuring station are used to re-examine the divided basin area with ArcGis tool. The base basin map is exported as shape or txt as input to the NAM model.

Results of calculation of flow for river basins in Lam Dong province are as follows:

Results of flow simulation from 1980 - 2017, averaged over many years, the results are as follows:

The Krong No river basin,at Duc Xuyen station, has an average annual flow of 102 m^3/s, the average annual volume is 3216 million m^3. The average flow module for many years in the basin is calculated at 31.5 $l/s.km^2$, the maximum flow module is 222.7 $l/s.km^2$ appears in October/ 2010, the minimum flow module is 4, 2 $l/s.km^2$ appeared in March 2005. Flow regime in the Krong No river basin is divided into 2 seasons: flood season and dry season. The flood season lasts from August to November, the dry season lasts from December to July next year. The total surface flow generated in the entire Krong No and adjacent basin in the period of 1980 - 2017 is 1266.1 million m^3, accounting for 11.6% of the total surface flow in Lam Dong province.

The Dong Nai 1 upstream river basinis calculated from the retention section between Da

Dang River and Da Nhim River, the outlet of the basin up to the section running through Loc Bao Commune - Bao Loc City adjacent to Village 7 - Dak Commune Nia - Gia Nghia town - Dak Nong province, the main river in the basin is Dong Nai river, the length of the main river is 110 km. The average flow module for many years in the basin is calculated at 29.9 $l/s.km^2$. Flow regime in Thuong Dong Nai 1 basin is divided into 2 seasons: flood season and dry season. The flood season lasts from July to October, the dry season lasts from November to June next year. The total annual average flow of surface water generated over the entire basin of the Upper Dong Nai 1 is 1,174.6 million m^3. The total amount of water in the flood season is 824.6 million m^3, accounting for 70.2% of the average annual water volume, the dry season is 350.0, accounting for 29.8% of the average annual water volume.

Upstream of Thuong Dong Nai 2 river basinis calculated from the retention section between Dong Nai river and Dak Buk So river to the confluence between Dong Nai river and Da Huoai river (village 6 area - Da Kho commune - Da Teh district). - Lam Dong, the length of Dong Nai main river in the basin is estimated about 125 km Based on the calculation results of the above table, the average flow module for many years in the basin is calculated at 43.0 $l/s.km^2$. The largest monthly flow module is 161.4 $l/s.km^2$ appearing in August, 2006, the minimum monthly flow module is 2.7 $l/s.km^2$ appearing in March 2005. The flood season lasts from July to October, and the dry season lasts from November to June of the following year, the total annual average flow of many years arising over the entire Upper Dong Nai 2 basin is 2,726.0 million m^3, accounting for 25.0% of the total surface flow in Lam Dong province The total amount of water in the flood season is 1,913.7 million m^3, accounting for 70.2% of the average annual water volume, the dry season is 812.3 million m^3, accounting for 29.8 % of total average water for many years. In the period 1986 - 2005, the total flow of flood season was 1914 million m^3, the dry season was 812 million m^3 and the year was 2773 million m^3.

Da Dang river basin has 2 main rivers: Da Dang river and Cam Ly river, Da Dang river originating from Xa Lat area, Lac Duong town - Lac Duong district, then entering with Cam Ly river in Tan Van commune - Lam Ha district, the length of Da Dang river, taking into account the outlet of the basin about 70 km, Cam Ly river is about 64.1 km long. Calculating the flow of Da Dang river basin, the basin with average flow module in many years in the basin is calculated at 32.2 $l/s.km^2$. Flow in Da Dang basin is divided into 2 seasons, flood season and dry season. The flood season lasts from December to November, and the dry season lasts from December to July next year. The total annual surface flow generated in the entire Da Dang and adjacent basin is 1,272.2 million m^3, accounting for 11.7% of the total surface flow in Lam Dong province. The total amount of water in the flood season is 714.0 million m^3, accounting for 56.1%, the dry season is 558.2 million m^3, accounting for 43.9%.

The Da Nhim river basinhas the main stream of Da Nhim river, the river originates from the north of Gia Rich mountain (1,923m), Lac Duong district, Lam Dong province, near the border with Khanh Hoa and Ninh Thuan provinces, the river flows through Don Duong and Duc Trong districts and pouring into Da Dang river near Pongour waterfall, the length of the main river to the entry point with Da Dang river is about 130km. Based on the calculation results from the model, the average flow module for many years in the basin is calculated at 29.2 l/s.km^2. According to the calculation results of the experience frequency of the calculation year, the flow regime in the basin of Da Nhim and adjacent rivers is divided into 2 seasons: flood season and dry season. The flood season lasts from August to November, the dry season lasts from December to July next year. The total average flow of surface water for many years in the entire Da Nhim and adjacent basin is 1,992.5 million m^3, accounting for 18.3% of the total surface flow in Lam Dong province. The total amount of water in the flood season is 1,118.2 million m^3, accounting for 56.1% of the average water volume in many years, the dry season is 874.3million m^3, accounting for 43.9% of the total average water volume for many years. In the period 1986 - 2005, the total annual flow generated in the basin was 1889 million m^3, the flood season was 1118 million m^3, the dry season was 874 million m^3. In terms of flow, the average water flow in the flood season is 106.1 m^3/s, the largest average water flow in the flood season is 187.9 m^3/s (in 2007), the smallest average water flow in the flood season is 57.7 m^3/s (2010). The dry season has an average water flow of 41.6 m^3/s, the largest water flow in the dry season is 87.2 m^3/s, the minimum flow in the dry season is 24.4 m^3/s.

La Nga River originates from Di Linh plateau, Bao Loc, the confluence of three small streams named: Roha, Dak Toren and Dak No at an average height of over 1,000m, the highest place to 1,460m. The basin of the river includes most of Bao Loc district (Lam Dong), Tanh Linh (Binh Thuan), Tan Phu and Dinh Quan (Dong Nai). The length of the river from source to destination is about 210km. The section running through Dong Nai province is 70km long. The length of the main river in the basin is estimated at 70 km, taking into account the outlet of the basin (Da Mi lake area - Loc Nam commune - Bao Lam district bordering Binh Thuan province). Based on the calculation results of the above table, the average flow module for many years in the basin is calculated at 51.4l/s.km^2. Moderate flow module in flood season is 101.6 l/s.km^2. Moderate flow module in dry season is 26.3l/s.km^2. The total average flow of surface water for many years in the whole La Nga and adjacent basin is 2,100.2 million m^3, accounting for 19.3% of the total surface flow in Lam Dong province. The total amount of water in the flood season is 1,391.7 million m^3, the dry season is 708.5 million m^3.

3.2. Impact of climate change on river basin flows in Lam Dong province

Within the scope of this study, only focus on assessing the impact of climate change on river flows according to RCP scenario 4.5.

Calculation of river basin flow according to climate change scenario RCP 4.5 shows that the flow of river basins has changed markedly in stages, and especially with the effects of climate change shows that the flow tends to increase.

a.The average annual flow

In the period of 2016-2035, the annual flow of Dong Nai river basin (Thuong Dong Nai 1, Thuong Dong Nai 2, Da Dang river basin and Da Nhim river basin) increases by 1.75% on average, the flow of Krong No river basin increases 1 , 63%, La Nga river basin increased by 1.79% and Luy river area of Cai Phan Thiet river increased by 2.2%. By the end of the century, the flow of Dong Nai river basin (Thuong Dong Nai 1, Thuong Dong Nai 2, Da Dang river basin and Da Nhim river basin) increased by 3.39% on average, the flow of Krong No river basin increased by 3.12 %, La Nga river basin increased by 3.39% and Luy river area of Cai Phan Thiet river increased by 2.17%.

Period of 2046 - 2065: total annual flow of Thuong Dong Nai 1 river basin is 1195 million m^3, Thuong Dong Nai 2 river basin is 2771 million m^3, Krong No river basin is 1287 million m3, Da Dang river basin is 1295 million m^3, Da Nhim river basin 2022 million m^3, Luy river basin - Cai Phan Thiet about 378 million m^3.

Period 2080 - 2099: By the end of the century, the total flow in Thuong Dong Nai 1 river basin is 1212 million m^3, Thuong Dong Nai 2 river basin is 2808 million m^3, Krong No river basin is 1304 million m^3, Da Dang river basin is 1315 million m^3, Da Nhim river basin 2043 million m^3, the total flow in La Nga river basin is about 2168 million m^3, Luy river basin - Cai Phan Thiet about 382 million m^3.

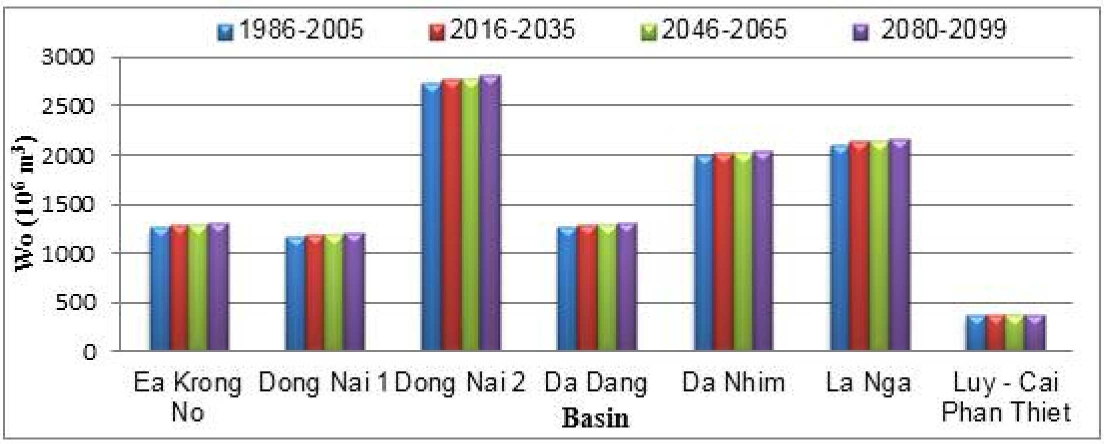

Fig. 7. Total flow of river basins according to RCP4.5 scenario (106 m^3)

b.The average flow in the flood season

The flow of flood season has many changes, in the period of 2016 - 2035, the flood season in Dong Nai river basin (Upper Dong Nai 1, Thuong Dong Nai 2, Da Dang river basin and Da Nhim river basin) increases by 1.13% on average. The basin of the Krong No river in the flood season increases by 1.2%, the La Nga river basin increases by 1.11% and the area of Luy river in Cai Phan Thiet river increases by 2.78%. By the end of the century, the flood season in Dong Nai river basin increased by an average of 2.89%, the river basin of Krong No flow increased 2.62%, La Nga river basin increased 2.94% and Luy river area Cai Phan Thiet river increased by 2.86%.

Period 2046 - 2065: total flow of flood season Thuong Dong Nai 1 river basin is 837million m^3, Thuong Dong Nai 2 river basin is 1941 million m^3, Krong No river basin is 774 million m^3, Da Dang river basin is 724 million m^3, Da river basin Nhim 1129 million m^3, La Nga river basin is 1412 million m^3, Luy river basin - Cai Phan Thiet about 173 million m^3.

Period 2080 - 2099: By the end of the century, the total flow of flood season in Upper Dong Nai 1 river basin is 848 million m^3, Thuong Dong Nai 2 river basin is 1964 million m^3, Krong No river basin is 783 million m^3, Da Dang river basin is 735 million m^3, Da Nhim river basin is 1135 million m^3, the total flow in La Nga river basin is about 1433 million m^3, Luy river basin - Cai Phan Thiet is about 176 million m^3.

c. The average flow in dry season

The dry season flow according to the RCP4.5 scenario tends to increase, especially in the period of 2016 - 2035 and the period of 2080 -

2099. In the dry season, the Dong Nai river basin (Upper Dong Nai 1, Thuong Dong Nai 2, Da Dang river basin and Da Nhim river basin) increases about 2.37%, the basin of Krong No river in dry season flows increases by 2.06% La Nga river basin increased by 2.47% and Luy river area of Cai Phan Thiet river increased by 1.62%

2016 -2035   2046 - 2065   2080 - 2099

Fig. 8. River basin flow module according to RCP scenario 4.5 (l/s.km^2)

4. Conclusion

Climate change scenarios for the Lam Dong river basin developed for the period 2016-2035, 2046-2065, 2080-2099 show an increase in temperature and increase in precipitation in the future. Rainy season has reduced but not significantly.

Under the impact of climate change, river basin flow calculations according to climate change scenarios show that the flow of river basins has markedly changed in stages, and in particular, under impacts of flow climate change tend to increase, especially, the flow in dry season also tends to increase slightly.

In general, the forecasted results of future flow changes may not be completely accurate due to uncertaimty in the forecast of the comprehensive climate models (GCM). However, the results achieved here can be referenced in the management of water resources in the river basin of Lam Dong province. In subsequent studies, the author will continue to consider the effects of climate change in conjunction with the effect of changing vegetation cover on flow changes.

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Vietnam Journal of Hydrometeorology, ISSN 2525-2208, 2019 (02): 35-44

Research Paper

DYNAMICAL ESTUARINE ECOSYSTEM MODELING OF PHYTOPLANKTON SIZE STRUCTURE USING STELLA

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ARTICLE HISTORY

Received: March 06, 2019 Accepted: May 12, 2019
Publish on: June 25, 2019

ABSTRACT

An ecosystem model was developed for size-structured phytoplankton dynamics of coastal bay. State variables of the model include major inorganic nutrients (NO_2^-+NO_3^-, NH_4^+, PO_4^{3-}, Si), size classes of phytoplankton (microphytoplankton (>20µm), nanophytoplankton (<20µm), two classes of zooplankton (mesozooplankton, microzooplankton), and organic matters (POC, DOC). The iconographic interface of STELLA model was used to facilitate construction of the dynamic ecosystem model. The ecosystem model was integrated with STELLA 7.0 using a 4th order Runge-Kutta method (a numerical variable time step). The developed method suggested that the dynamical model using STELLA software can be useful to study phytoplankton dynamics in the pelagic coastal ecosystem.

Keywords: *Ecosystem model, Phytoplankton, Zooplankton, STELLA.*

1. Introduction

In microbial food web, the different sized phytoplankton can be affected differently by nutrient uptakes and light utilization as well as grazing in water column (Sin et al., 2000; Varela et al., 2005; Kriest and Oschlies, 2007; Chen et al., 2008). The growth of each phytoplankton size class is also different depending on seasons (Wilkerson et al., 2006; Marquis et al., 2007; Garcia et al., 2008; Weston et al., 2008).

In estuaries, the variability of plankton is associated with complex physical forcing including deterministic (tides), stochastic (wind, turbulence) components and nutrient enrichments (Allen et al., 2008; Lee et al., 2008; Pannard et al. 2008; Vallières et al., 2008). A better understanding of estuarine ecosystems becomes a key issue in environmental research for coastal waters as well as freshwater environments. Dynamical model is a useful tool for understanding plankton in estuarine coastal ecosystem (Flynn, 2005; Dube and Jayaraman, 2008; Rogachev et al., 2008). Size-structured phytoplankton dynamics were incorporated in estuarine coastal ecosystem model developed by Sin and Wetzel (2002).

The spring blooms were observed by many studies in coastal estuaries, major mechanisms of spring bloom included (1) high number of germinable diatoms in sediment during spring (Hansen and Josefson, 2003), (2) germination at the surface forced from resuspension of the sediment during winter mixing of the water column

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(Ishikawa and Furuya, 2004).

STELLA was developed as tool for ecological and economic system modeling (Costanza et al., 1998; Costanza and Gottlieb, 1998; Costanza and Voinov, 2001). STELLA was also applied for germination and vertical transport of cyst forming dinoflagellate model by Anderson (1998) and reservoir plankton system model by Angelini and Petrere (2000).

2. Methodologies

2.1 Model description

The ecosystem model includes 10 state variables (Fig. 1) nano- (< 20 μm), net- (> 20 μm) phytoplankton; microzooplankton (> 200 μm and < 330 μm), mesozooplankton (>330 μm); nutrients NO_2^-+NO_3^-, NH_4^+, PO_4^{3-} dissolved Si, and non-living organic materials, DOC and POC. Large and small phytoplankton are differentiated in their ability for nutrients, light limitations, temperature dependent metabolism and assimilation rate. Germination of netphytoplankton was considered together with wind forcing effect.

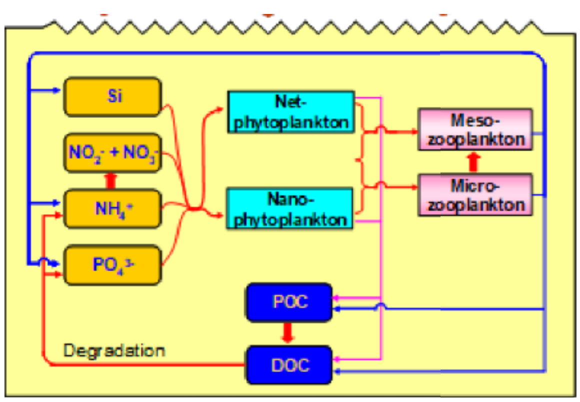

Fig. 1. The general scheme describing model structure for plankton in estuaries

The grazer variables were differentiated by the size structure of potential prey, as well as their half-saturation foods and assimilation rates (at 10°C) and affected by temperature response factor. POC, DOC were released from phytoplankton accumulation and zooplankton excretion and mortality. Nutrients were enriched by bacterial degradation of organic matter and grazer excretion. The ecosystem model was integrated with STELLA 7.0 using the function (a numerical variable time step differential equation solver using a 4th order Runge-Kutta method).

2.2 Mathematical structure of biological and chemical processes

Producers

Phytoplankton biomass (Phy) is determined by growth rate, germination rate (netphytoplankton), respiration rate, mortality rate and grazing rate (Tables 1-2).

Phytoplankton growth, G_P (Eq. 1) can be affected by assimilation rate at 10°C (ass), temperature response factor ( ), light limitation (f_L) and nutrient limitation (f_{NU}) and phytoplankton biomass (Phy) for each size-structure.

$$G_P = ass \cdot \tau \cdot f_L \cdot f_{NU} \cdot Phy \quad (1)$$

Temperature response factor ( ) was presented by Blackford et al. (2004)

$$\tau = Q_{10}^{((Temp-10)/10)} - Q_{10}^{((Temp-30)/4)} \quad (2)$$

Light limitation (f_L) in Eq. 3 (DiToro et al., 1971) is determined by f, k_d, z, I_m, I_o, where f is the photo-period, kd is light attenuation coefficient (m^{-1}), z is the depth (m), and I_m and I_o are incident average and optimal light (E m^{-2} d^{-1}), respectively. Light attenuation (k_d) was measured over the annual cycle. Daily k_d values were interpolated based on the field data.

Table 1. Symbol and unit for state variables

Variables	Symbol	Unit
Nanophytoplankton	NP	g C m^{-3}
Netphytoplankton	MP	g C m^{-3}
Microzooplankton	Z1	g C m^{-3}
Mesozooplankton	Z2	g C m^{-3}
Particulate organic carbon	POC	g C m^{-3}
Dissolved organic carbon	DOC	g C m^{-3}
Ammonium	N1	μM
Nitrite+nitrate	N2	μM
Orthophosphate	P	μM
Silicate	Si	μM

Table 2. Differential equations employed for 10 state variables

No.	Variable
1	Nanophytoplankton $\frac{dNP}{dt} = G_P - R_P - M_P - p \cdot G_Z$
2	Netphytoplankton $\frac{dMP}{dt} = G_P + G_{GM} - R_P - M_P - p \cdot G_Z$
3	Microzooplankton $\frac{dZ1}{dt} = G_Z - R_Z - M_Z - E_Z - L_Z$
4	Mesozooplankton $\frac{dZ2}{dt} = G_Z - R_Z - M_Z - E_Z - L_Z$
5	Particulate organic carbon $\frac{dPOC}{dt} = f_{Ez} \cdot \sum E_Z + f_{Mz} \cdot \sum M_Z + f_{Mp} \cdot \sum M_P - POC \cdot r_{hyd}$
6	Dissolved organic carbon $\frac{dDOC}{dt} = k_{Ez} \cdot \sum E_Z + k_{Mz} \cdot \sum M_Z + k_{Mp} \cdot \sum M_P + POC \cdot r_{hyd} - DOC \cdot r_{deg}$
7	Ammonium $\frac{dN1}{dt} = \left(DOC \cdot r_{deg} + \sum E_Z\right) / r_{C:N} - \left(Nitrif + \sum G_P\right) / r_{C:N}$
8	Nitrite+nitrate $\frac{dN2}{dt} = Nitrif + NO_{FW} - \left(\sum G_P\right) / r_{C:N} - L_{N2L}$
9	Ortho-phosphate $\frac{dP}{dt} = \left(DOC \cdot r_{deg} + \sum E_Z\right) / r_{C:P} - \left(\sum G_P\right) / r_{C:P} - L_{PB}$
10	Silicate $\frac{dS_i}{dt} = \left(POC \cdot r_{hyd} + \sum E_Z + \sum M_P\right) \cdot d_{Si} / r_{C:Si} - \left(\sum G_P\right) / r_{C:Si}$

$$f_L = \frac{e \times f}{k_d \times z}\left(e^{-\frac{I_m}{I_o}.e^{-k_d z}} - e^{-\frac{I_m}{I_o}}\right) \quad (3)$$

Monod (1942) model is applied for nutrient limitation f_{NU} (Eq. 4). The half-saturation constant (K_N) for nitrogen based on mean cell size (biovolume, µm3) is used Moloney and Field (1991) equations (Eq. 5). The half-saturation constant (K_P) for phosphorus is determined by dividing K_N by the N:P ratio (Eq. 5).

$$f_{NU} = MIN\left(\frac{N}{N + K_N}, \frac{P}{P + K_P}, \frac{Si}{Si + K_{Si}}\right) \quad (4)$$

where K_N, K_P, K_{Si} are half-saturation constant of nutrients.

$$K_N = 2M^{0.38} \quad K_P = \frac{K_N}{r_{N:P}} \quad (5)$$

G_{GM} is germination enhancement incorporated for netphytoplankton. Germination is assumed by the maximum germination rate, wind mixing factor and germination potential over annual cycle in Eq. 6.

$$G_{GM} = r_{gm} \cdot W_{sp} \cdot p_{gm} \quad (6)$$

where r_{gm} is the maximum germination rate, W_{sp} is wind mixing factor and pgm is germination potential (ranging from 0% to 100%).

Respiration of each size class is shown in (Eq. 7) by Blackford et al. (2004).

$$R_P = r_{BR} \cdot \tau \cdot Phy + (G_P - (G_P \cdot (f_{exu} + (1 - a_N) \cdot (1 - f_{exu}) \cdot r_{ar}) \quad (7)$$

where r_{BR} is basal respiration of phytoplankton, f_{exu} is exudation under nutrient stress, a_N is nutrient limitation factor, r_{ar} is activity respiration.

$$M_P = r_{PM} \cdot Phy \quad (8)$$

Phytoplankton mortality is described by Eq. 8

$$G_i = p \cdot G_Z \quad (9)$$

where is mortality rate of phytoplankton

Loss of phytoplankton by grazer (Gi) is Eq. 9

where p is parameters describing the relative prey availability for each consumer, (G_Z) is grazing by zooplankton.

Consumers

The zooplankton community including mesozooplankton, microzooplankton is considered. The consumer productions (Z) are determined by grazing, respiration, mortality, egestion and loss by predation (Tables 1-2).

Grazing of zooplankton is the uptake food from producers applied ERSEM model (Blackford et al., 2004) equation and described in Eq. 10.

$$G_Z = r_{Za} \times \tau \times F_{lim} \times Z \quad (10)$$

where r_{Za} is zooplankton assimilation rate at 10ºC, τ is temperature response factor, Z is zooplankton biomass, F_{lim} is food limitation for grazers and described as

$$F_{lim} = \frac{f_Z}{f_Z + K_F} \quad (11)$$

where K_F is half saturate food concentration.

$$f_Z = \sum_{F_Z=1}^{n} p \cdot F_Z \cdot \frac{F_Z}{F_Z + C_{\min F}} \quad (12)$$

where p is parameters of the relative prey for each consumer (described in Eq. 9), F_Z is biomass for each consumer, C_{minF} is lower threshold for feeding.

Respiration of zooplankton (R_Z) is shown in Eq. 13.

$$R_Z = r_{Basal} \cdot \tau \cdot Z + Gz \cdot (1 - eff_{ass}) \cdot (1 - f_{exc}) \quad (13)$$

where r_{Basal}, eff_{ass} f_{exc} are basal respiration rate, efficiency of assimilation, fraction of excretion.

Mortality of zooplankton (MZ) is related to mortality rate (m_Z) and biomass of each zooplankton (Z) (Eq. 14).

$$M_Z = m_Z \cdot Z \quad (14)$$

where m_Z is mortality rate of zooplankton.

Zooplankton excretion is related to grazing (GZ), efficiency of assimilation ( ) and fraction of excretion f_{exc} in Eq. 15.

$$E_Z = Gz \cdot (1 - eff_{ass}) \cdot f_{exc} \quad (15)$$

LZ is loss of zooplankton by predation

$$L_Z = p_Z \cdot Z \quad (16)$$

where p_z is loss rate of each zooplankton by predation, Z is zooplankton biomass.

Organic matter

Particulate organic matter (POC) was expressed by supporting processes (POC_{sup}), (Eq. 17) and hydrolysis process (POC_{hyd}), (Eq. 18).

$$POC_{sup} = f_{Ez} \cdot \sum E_Z + f_{Mz} \cdot \sum M_Z + f_{Mp} \cdot \sum M_P \cdot \quad (17)$$

where f_{Ez} is fraction zooplankton excretion (E_Z) in POC; f_{Mz} is fraction zooplankton mortality (M_Z) in POC; f_{Mp} is fraction phytoplankton mortality (M_P) in POC.

$$POC_{hyd} = POC \cdot r_{hyd} \quad (18)$$

where r_{hyd} is hydrolysis rate of POC.

Dissolved organic matter (DOC) was expressed by supporting processes (DOC_{sup}) (Eq. 19) and degradation process (DOC_{deg}) (Eq. 20).

$$DOC_{sup} = k_{Ez} \cdot \sum E_Z + k_{Mz} \cdot \sum M_Z + k_{Mp} \cdot \sum M_P + POC_{hyd} \quad (19)$$

where k_{Ez} is fraction zooplankton excretion (E_Z) in DOC; k_{Mz} is fraction zooplankton mortality (M_Z) in DOC; k_{Mp} is fraction phytoplankton mortality (M_P) in DOC.

$$DOC_{deg} = DOC \cdot r_{deg} \quad (20)$$

where r_{deg} is degradation rate by heterotrophic bacteria.

Ambient Nutrients

Ammonium

Ambient ammonium was released by heterotrophic processes $\left[NH_4^+\right]_u$ (Eq. 21) and uptake by nitrification process and phytoplankton growth $\left[NH_4^+\right]_{uptake}$ (Eq. 22).

$$\left[NH_4^+\right]_{in} = \left(DOC_{deg} + \sum E_Z\right) / r_{C:N} \quad (21)$$

$$\left[NH_4^+\right]_{uptake} = \left(Nitrif + \sum G_P\right) / r_{C:N} \quad (22)$$

where $r_{C:N}$ is ratio carbon and nitrogen in biomass.

Nitrification process

The excretion processes produce ammonium and nitrification process converts ammonium to nitrite + nitrate (Jaworski et al., 1972).

$$Nitrif = [NH_4^+] \cdot e^{(k_t \times time)} \quad (23)$$

$$k_t = k_{20} \times \theta^{(temp-20)} \quad (24)$$

where k_{20} is nitrification rate at 20°C, θ is constant (1.188) for temperature adjustment of the nitrification rate.

Nitrite and nitrate

Ambient nitrite + nitrate was supplied by nitrification and freshwater input process, $\left[NO_2^- + NO_3^-\right]_{in}$ (Eq. 25) and uptake of phytoplankton, $\left[NO_2^- + NO_3^-\right]_{uptake}$ (Eq. 27).

$$\left[NO_2^- + NO_3^-\right]_{in} = Nitrif + NO_{FW} \quad (25)$$

where NO_{FW} is nitrite+nitrate input from freshwater through embankments (Eq. 26).

$$NO_{FW} = e_{N2} \cdot TN_F \cdot per_{N2} \cdot (1 - Sal_{dif}) \quad (26)$$

where e_{N2} is efficiency for nitrite+nitrate input, TN_F is concentration of TN in freshwater input, per N_2 is percentage of nitrite+nitrate in freshwater TN, Sal_{dif} is salinity decrease factor.

$$\left[NO_2^- + NO_3^-\right]_{uptake} = \left(\sum G_P\right) / r_{C:N} + L_{N2L} \quad (27)$$

$$L_{N2L} = \left[NO_2^- + NO_3^-\right] \cdot r_{N2L} \quad (28)$$

where L_{N2L} is loss of nitrite + nitrate by bacterial uptake, $r_{C:N}$ is ratio carbon and nitrogen in biomass, r_{N2L} is loss rate of nitrite + nitrate by bacterial uptake.

Ortho-phosphate

Ortho-phosphate was related to processes such as excretion of zooplankton (E_Z) and bacterial degradation from DOC (DOC_{deg}) $\left[PO_4^{3-}\right]_{in}$ (Eq. 29) and phytoplankton uptake (GP) is $\left[PO_4^{3-}\right]_{uptake}$ (Eq. 30).

$$\left[PO_4^{3-}\right]_{in} = \left(DOC_{deg} + \sum E_Z\right) / r_{C:P} \quad (29)$$

$$\left[PO_4^{3-}\right]_{uptake} = \left(\sum G_P\right) / r_{C:P} + L_{PB} \quad (30)$$

$$L_{PB} = \left[PO_4^{3-}\right] \cdot r_{PL} \quad (31)$$

where L_{PB} is loss of orthophosphate by bacterial uptake; r_{PL} is loss rate of bacterial orthophosphate uptake; $r_{C:P}$ is ratio carbon and phosphorus in biomass.

Silicate

Silicate was obtained by POC hydrolysis (POC_{hyd}), excretion of zooplankton (E_Z), mortality of phytoplankton (M_P) in $\left[DS_i\right]_{in}$ (Eq. 32) and it was uptake by phytoplankton growth (G_P) $\left[DS_i\right]_{uptake}$ (Eq. 33).

$$\left[DS_i\right]_{in} = \left(POC_{hyd} + \sum E_Z + \sum M_P\right) \cdot d_{Si} / r_{C:Si} \quad (32)$$

where d_{Si} is dissolved S_i parameter from organic matter lysis.

$$\left[DS_i\right]_{uptake} = \left(\sum G_P\right) / r_{C:Si} \quad (33)$$

where $r_{C:Si}$ is ratio carbon and silic in biomass.

3. Results

3.1 Environmental change effect and predictions of model

Effects of temperature, attenuation coefficient and germination potential to size classes of phytoplankton by sensitivity analysis were observed in Fig. 2 to Fig. 6. The increase of temperature affected netphytoplankton in late spring. The increase enhanced nanophytoplankton in early spring and decreased them in late spring (Fig. 2). The change of attenuation coefficient (+10%) did not affect netphytoplankton, however nanophytoplankton were declined and total chl a decreased (Fig. 3).

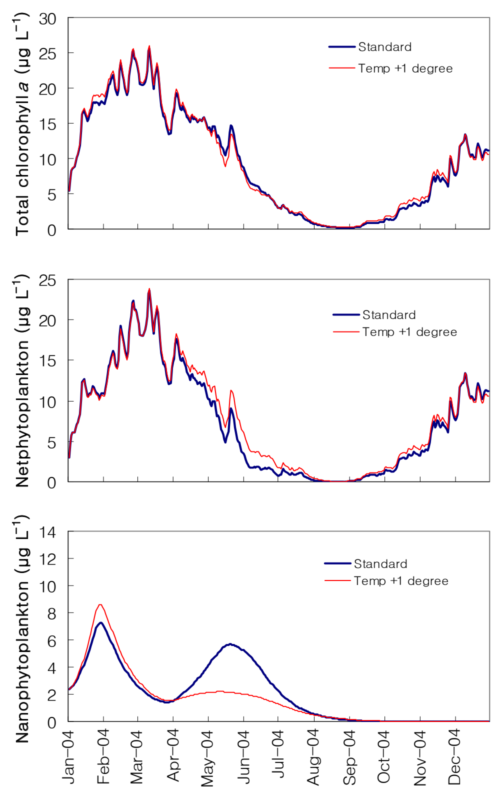

Fig. 2. Effect of temperature change to total chlorophyll a, net- and nanophytoplankton.

Germination potential has positive effect on netphytoplankton in cold season (winter and early spring) and total chl a concentration was increased during spring. Nanophytoplankton increased during late spring by enhancing germination potential (Fig. 4). P enrichment contributed to increase of nanophytoplankton as well as total chl a (Fig. 5). However, the combination of temperature (+ 1°C) attenuation coefficient (+10%) and P (+10%) reduced nanophytoplankton and enhanced netphytoplankton during late spring (Fig. 6).

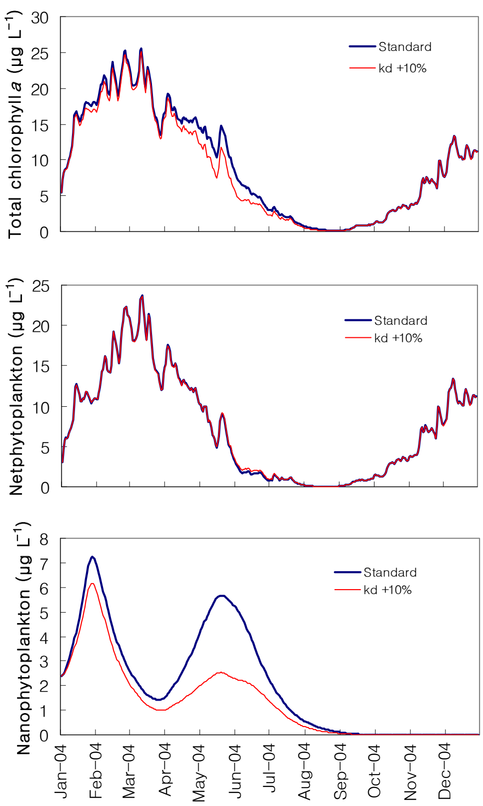

Fig. 3. Effect of attenuation coefficient change to total chlorophyll a, net- and nanophyto lankton

The annual mean percentage changes of state variables by changing environmental parameters were shown in Table 3. Nanophytoplankton were decreased with increase of temperature and attenuation coefficient. Netphytoplankton and nanophytoplankton were enhanced by increase of germination (Table 4). Nanophytoplankton were significant increase (30%) with increase of orthophosphate whereas netphytoplankton were insensitive to the change. Meso- and microzooplankton responded negatively to the changes of temperature and attenuation coefficient. However, they responded positively to increases of germination potential and wind mixing and orthophosphate. POC and DOC were enhanced by increases in germination potential and wind mixing. Ammonium, orthophosphate and silicate were enhanced when temperature increased. Nitrite+nitrate was increased when salinity decreased.

3.2 Discussion

Size-based ecosystem models provide a simulation tool for understanding the structure and function of pelagic ecosystems. The ecosystem-based approach is also required to a range of environmental conditions. The variation of dynamics and community structures are produced by a variety of physical and chemical scenarios. The forcing factors defined by wind mixing, temperature, turbidity, germination potential, orthophosphate were used in the model.

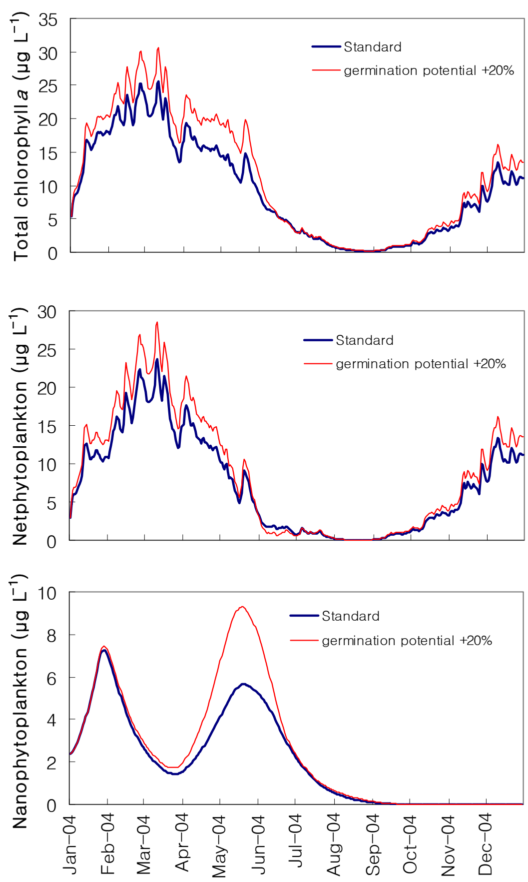

Fig. 4. Effect of germination potential change to total chlorophyll a, net- and nanophytoplankton

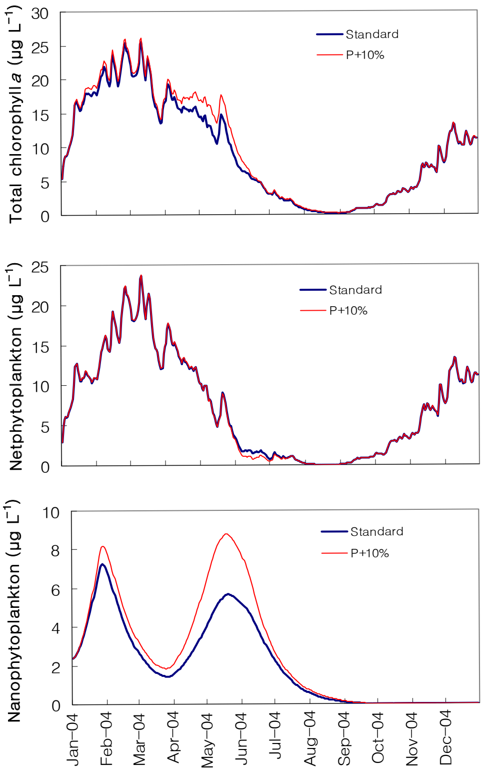

Fig. 5. Effect of phosphorus change to total chlorophyll a, net- and nanophytoplankton

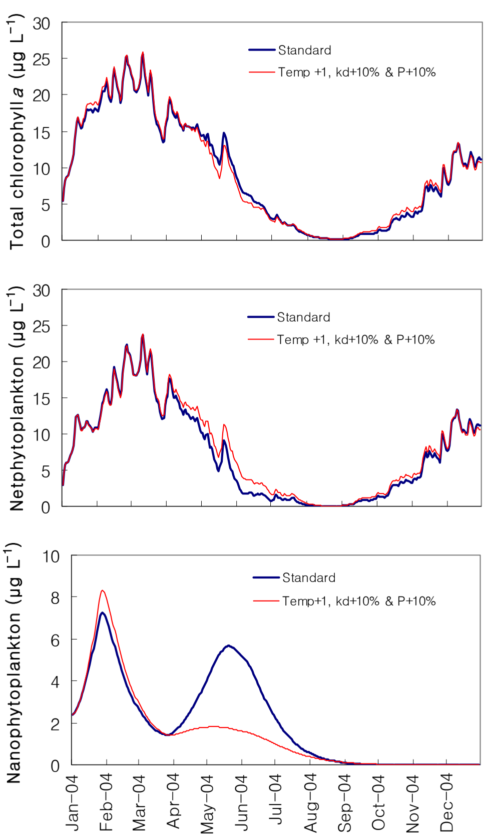

Fig. 6. Effect of temperature + attenuation coefficient + phosphorus change to total chlorophyll a, net- and nanophytoplankton

The simulation results showed a good agreement with ranges of observations suggesting that the model was plausibly linked to variations in mixing by wind, germination, temperature, turbidity and phosphorus supply.

The spring bloom period in each case is characterized by a succession of blooms, generally led by diatoms accounting netphytoplankton (data not shown). The diatom bloom was displayed over the seasonally maximum period of winter and early spring when wind speed increased. The wind mixing effect on phytoplankton (diatoms) germination at the surface during the cold season has been documented by Ishikawa and Furuya (2004). Diatom bloom such as Skeletonema costatum from resting stages occurred under wide range of water temperature in the coastal water (Shikata et al. 2008). Low temperature contributed to the spring bloom of diatoms (Andersson et al. 1994). In this model, netphytoplankton were dominant during early spring whilst nanophytoplankton dominated the production during late spring. The grazers exhibited a response after the spring bloom. Mesozooplankton and microzooplankton were typically responded to netphytoplanton bloom during spring.

The results of model simulations (Figs. 2-6) and sensitivity analysis (Table 4) demonstrated that the abiotic environmental parameters and variables: light, temperature, wind mixing, germination potential and orthophosphate play the major roles for phytoplankton dynamics in estuarine and coastal bay. The sensitivity analysis of ecosystem model showed that netphytoplankton are sensitive to change of wind mixing or germination potential, however nanophytoplankton were affected by not only these parameters but also by temperature, turbidity, and phosphorus. The size structures of phytoplankton were controlled by seasonality due to the wind mixing enhanced germination at the surface water from resting stage in the sediment. Phosphorus input also enhanced phytoplankton biomass, especially nanophytoplankton. It appeared that phosphorus could also drive phytoplankton growth and change in size structure of this ecosystem. The model could be useful to examine phytoplankton dynamics in relations to physical factors and nutrient dynamics.

4. Conclusion

Model validation for state variables suggested that the ecosystem model captures the phytoplankton and nutrient dynamics, and can be useful tool for analyses and management of an estuarine and coastal ecosystem which suffers nutrient enrichments and change of hydrology. The model also demonstrates that physical processes including wind mixing, water transparency, temperature as well as nutrients affect phytoplankton dynamics and response of phytoplankton can be related to the environmental changes in the coastal estuarine area.

Table 4. Results percentage change of sensitivity analysis for state variables given +1 degree change in temperature; -10% in salinity; +10% in attenuation coefficient, germination potential, wind speed, ammonium, nitrite+nitrate, orthophosphate, silicate. MP: netphytoplankton; NP: nanophytoplankton; Z_1: mircozooplankton; Z_2: mesozooplankton; DOC: dissolved organic matter; POC: particulate organic matter; N_1: ammonium; N_2: nitrite+nitrate; P: orthophosphate, S_i: silicate; –: % change <8%.

Parameters	State variables									
	MP	NP	Z_1	Z_2	DOC	POC	N_1	N_2	P	Si
Temperature +1°C	–	-19.0	-66.3	-42.6	–	–	19.5	–	16.2	45.2
Attenuation coefficient k_d +10%	–	-34.3	-24.9	-19.7	–	–	–	–	–	35.2
Germination potential +10%	9.6	13.4	43.6	33.7	8.4	9.1	–	–	–	- 11.3
Salinity -10%	–	–	–	–	–	–	–	30.6	–	–
Wind speed +10%	9.6	13.4	43.6	33.7	8.4	9.1	–	–	–	-11.3
Ammonium +10%	–	–	–	–	–	–	12.7	–	–	–
Nitrite+nitrate +10%	–	–	–	–	–	–	–	10.3	–	–
Orthophosphate +10%	–	30.8	46.0	33.19	–	–	–	–	–	-35.3
Silicate +10%	–	–	–	–	–	–	–	8.9	–	13.6

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Vietnam Journal of Hydrometeorology, ISSN 2525-2208, 2019 (02): 45-50

Research Paper

POWER DISSIPATION INDEX OF TROPICAL CYCLONES IN THE EAST SEA

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ARTICLE HISTORY

Received: February 21, 2019 Accepted: May 28, 2019
Publish on: June 25, 2019

ABSTRACT

In this paper, through statistics of tropical cyclones in the East Sea from 1961 to 2017, the research team calculate Tropical Cyclone Power Dissipation (PDI), defined the maximum wind speed and the life time of tropical cyclones, compare with some other indicators that have been used by other authors such as NetTC in the East Sea to see the correlation between indicators and factors related to climate change such as sea surface temperature, Nino 3-4. Since then, the tendency of PDI increase, the correlation coefficient with Nino 3-4 is positive in the East Sea region, but this correlation is small.

Keywords: *PDI, NetTC.*

1. Introduction

The changes of tropical cyclones (TC) including storms and depressions in the East Sea are the more important consequences of climate change (Kossin et al., 2013; Doocy et al., 2013; Wu et al., 2014). The understanding of activities of TC, the characteristics of TC in the past is very important role for forecasters to grasp the rules of TC and forecast better in the future. The changes of frequency and intensity of TC affect to the economic and social activities, so the study of the nature and trend of TC changes is particularly important.

Human impact is one of the reasons affecting the number and intensity of landfalling storms, but other potential energy such as Accumulated Cyclone Energy (ACE) index is also one of the factors affecting the quantity and intensity of TC (Emanuel, 2005, 2007; Free et al., 2004; Nordhaus, 2010; Walsh et al., 2016). For the purpose of detecting climate signals, such integral measures will be preferable, owing to the much larger amount of information available for storms throughout their lifetimes compared to landfall. In this study will focus on the change of the Power Dissipation Index (PDI), defined by the author (Emanuel, 2005).

$$PDI = \int_0^{\tau} V_{max}^3 dt \qquad (1)$$

where V_{max} is the maximum surface wind at any given time in a storm, and τ is the lifetime of the event. For the purposes of this paper, the PDI is also accumulated over each year.

Annually accumulated integral metrics such as ACE and PDI show striking variations from year to year and on longer time scales (Bell et al., 2000). In the western portion of the North Pacific, ACE is significantly affected by ENSO (Camargo and Sobel, 2005). Emanuel (2005) showed that, in the Atlantic, the PDI is strongly

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correlated with SST in the later summer and early fall in the tropical Atlantic between Africa and the Caribbean, while in the western North Pacific region, the correlation, though significant, is weaker. The PDI, a measure of the total energy consumption by tropical cyclones, has been empirically related to a small set of environmental predictors selected on the basis of both theoretical and empirical considerations. The resulting index depends on ambient low-level vorticity, potential intensity, and vertical shear of the horizontal wind. The variability of all three of these factors has contributed significantly to the observed variability of the PDI over the last 25 year from 1980 to 2004, during which time they have relatively high confidence in both the tropical cyclone record and the reanalysis data. These results suggest that future changes in PDI will depend on changes not only in surface radiative flux, but in tropopause temperature, surface wind speed, low-level vorticity, and vertical wind shear, as well. These variables are among those simulated by global climate models, which can then be used, in principle, to project future changes in PDI using by:

$$PDI \sim \eta_{850}^{5/2} V_p^{7} (1+0.3S)^{-4} \qquad (2)$$

where η850 is absolute vorticity at 850 hPa, Vp is potential intensity and S is shear at 850-250 hPa. They are in the process of estimating these changes in the suite of global models being used for the 2007 Intergovernmental Panel on Climate Change (IPCC) report.

In addition to the PDI, the other authors such as Phan Van Tan (2010) also calculated the relationship between NetTC index and sea surface temperature (SST) during the TC season, in which NetTC index is calculated by:

$$NetTC = (\%Dp + \%TC8\text{-}9 + \%TC10\text{-}11 + \%TC12\,up + \%NTCDa)/5 \qquad (3)$$

where %Dp, %TC8-9, %TC10-11, %TC-12up, %NTCDa is the percentage of tropical depressions, storms with 8-9 force, 10-11 force, upper 12 force and number of stormy days in each year of the year compared to the average of the whole time series. The results showed a positive correlation between sea surface temperature in the regions (5°N-25°N, 150°E-165°E) and (0°N-30°N, 100°E-180°E) with NetTC index from 1981 to 2007.

From the above bases, this study will analysis and evaluate indicators with some of the factors affecting the external environment such as SST, NiNo3-4 to see variation of TC in the East Sea and the relationship between the number of tropical cyclones with environmental factors. Comparison between indicators also to find appropriate indicator that characterize the impact on variation of TC in the East Sea.

2. Data and Method

The number of tropical cyclones is collected in the East Sea from the National Center for Meteorological and Hydrological Forecasting (NCHMF) from 1961 to 2017. However, the data on maximum wind speed and lifetime in the East Sea are taken from the Joint Typhoon Warning Center (JTWC) at:

https://metoc.ndbc.noaa.gov/JTWC.

Reanalysis data of factors such as SST, Nino3-4 from Tokyo Climate Center (TCC) at: *https://extreme.kishou.go.jp/itacs5/.*

In addition to the statistical method, the PDI index is calculated according to Emanuel (2005) and NetTC index is calculated according to Phan Van Tan (2010).

3. Results and discussion

3.1. Activity of TC in the East Sea and landfalling in Viet Nam

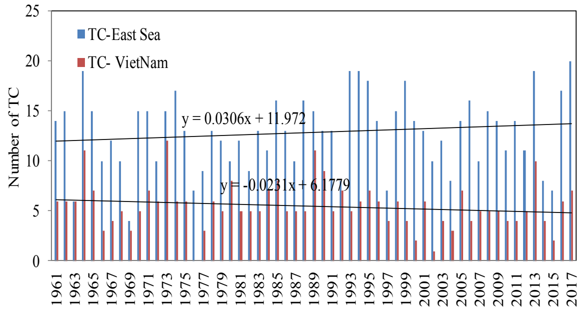

Fig. 1. Number of TC in the East Sea (blue) and landfalling in Viet Nam (red) from 1961-2017

Fig. 1 shows the number of TC in the East Sea and the number of TC that landfall Vietnam in the period from 1961 to 2017, showing a slight increase of TC in the East Sea with coefficient a = 0.03. Meanwhile, in contrast, the number of TC landfallind in Vietnam decrease in this series time.

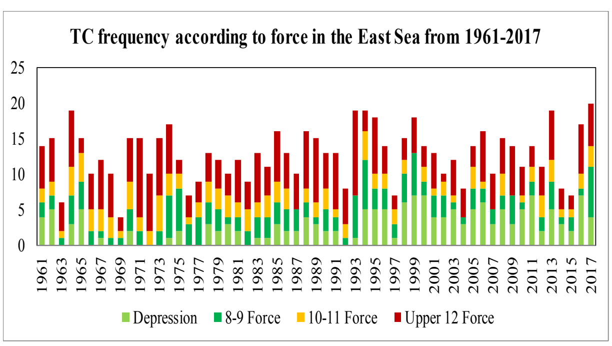

Fig. 2. TC frequency according to force in the East Sea from 1961-2017

The frequency of TC from tropical depression, TC with 8-9 force, TC with 10-11 force and sTC with upper 12 force is shown by Figure 2. It can be seen that the number of TC with upper 12 force is biggest, about 40%, following by the activity of tropical depression with 22% and the number of TC with 8-9 force and 10-11 force with 21% and 16% respectively. Frequency by 5 years, found that from 1991 to 1995, the number of TC in the East Sea is biggest with average of 15.9 times, of which the number of TC with upper 12 force is also more frequency with average of 7 times per year. However, considering this period, the number of TC effecting to Vietnam is only from 5 to 7 times, approximately with the normal.

Frequency by 10 years, the 1991-2000 decade is biggest with average of about 14.5 times per year, in which from 1993 to 1995 and 1999, there are 18 to 19 times in the East Sea. According by force, there are about 2.9 number of tropical depression, 2.7 number of TC with 8-9 force, 2.2 number of TC with 10-11 force and 5.2 number of TC with upper 12 force per year in the East Sea.

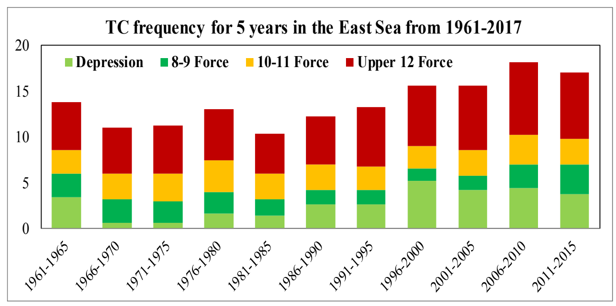

Fig. 3. TC frequency by 5 years in the East Sea from 1961 to 2017

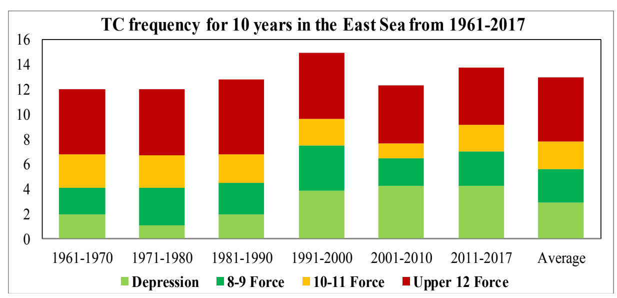

Fig. 4. TC frequency by 10 years in the East Sea from 1961 to 2017

3.2. Power dissipation index and NetTC

PDI in the East Sea tends to increase slightly in the series time with coefficient a = 0.0032 (Fig. 5), similar to that, Nino 3-4 index also tends to increase slightly in this series time from the year 1961 to 2017 with coefficient a = 0.0038 (Fig. 6). Considering the correlation coefficients between these two series of data, the positive correlation is 0.2 (Fig. 7).

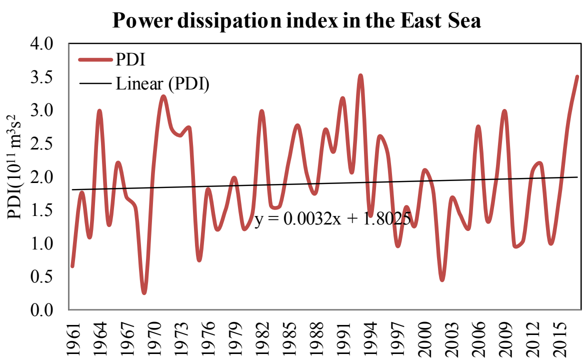

Fig. 5. Power dissipation index (PDI) tin the East Sea

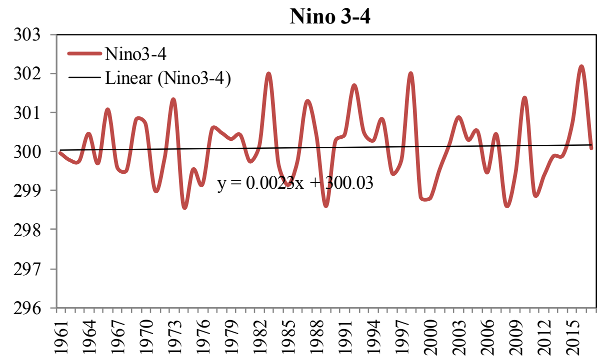

Fig. 6. Nino 3-4 index from 1961 to 2017

Table 1. Average number of TC by 10 years according to force

Year	Dpression	8-9 Force	10-11 Force	Upper 12 Force
1961-1965	3.4	2.6	2.6	5.2
1966-1970	0.6	2.6	2.8	5
1971-1975	0.6	2.4	3	5.2
1976-1980	1.6	2.4	3.4	5.6
1981-1985	1.4	1.8	2.8	4.4
1986-1990	2.6	1.6	2.8	5.2
1991-1995	2.6	1.6	2.6	6.4
1996-2000	5.2	1.4	2.4	6.6
2001-2005	4.2	1.6	2.8	7
2006-2010	4.4	2.6	3.2	8
2011-2015	3.8	3.2	2.8	7.2

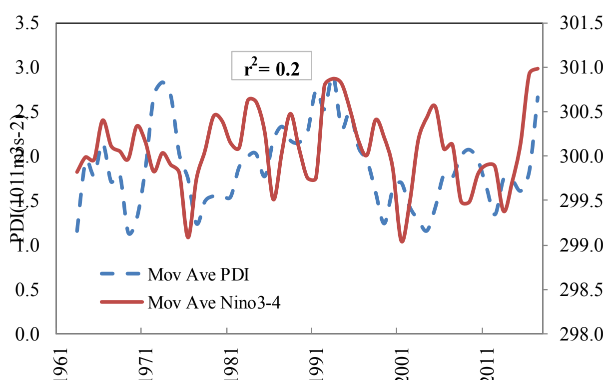

Fig. 7. PDI (blue) and Nino 3-4 index (red) in the East Sea. The time series have been smoothed using moving average with 3 year to reduce effect of interannual variability and fluctuation on time scales

In general, there is a similarity between the PDI and Nino 3-4 from 1961 to 1970 and from 2011 to 2017 (Fig. 8). However, from 1981 to 1990, the correlation is bigger but it is negative, as the year of strong ElNino like 1983, 1988, 1998, PDI index in the East Sea is smaller than the normal, with $1.6*10^{11}m^3.s^{-2}$, $1.8*10^{11}m^3.s^{-2}$, $1.5*10^{11}m^3.s^{-2}$, respectively. In these years, the number of TC are bigger than the normal with 13 to 16 times and effecting to Vietnam with 5 to 7 times. With strong Lanina like 1989, 2000 and 2011, the PDI is $2.7*10^{11}m^3.s^{-2}$, $2.1*10^{11}m^3.s^{-2}$ and $2.1*10^{11}m^3.s^{-2}$, bigger than the normal, the number of TC are also bigger than the normal, from 14 to 15 times; however, landfalling in Vietnam has not been uniform, there were 11 TC in 1989 but there were only from 2 to 4 number of TC in 2000 and 2001. In general, PDI depends on three factors: maximum wind speed, lifetime of TC. PDI correlates with the Nino3-4 index, but this correlation is small.

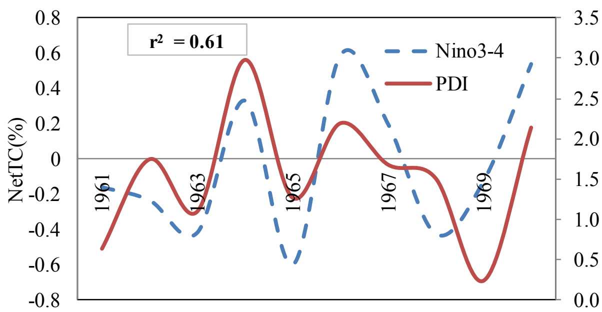

Fig. 8. Correlation between PDI (blue) and Nino 3-4 (red) from 1961 to 1970

We also calculate the NetTC index, finding that this index also tends to increase in the series time from 1961 to 2017 with coefficient a = 0.28 (Fig. 9). The correlation between the NetTC index and SST in the region (0-30°N; 100-180°E) has a positive correlation (Fig. 10, Fig. 11). In general, there is a similar between the NetTC index and SST in this area, especially from 1981 to 2003, this correlation is stronger that means SST in the region (0 - 30°N; 100 - 180°E) increasing related to the increasing of NetTC index in the East Sea (Fig. 12). Considering the two hottest years of 2016 and 2017 with SST in the East Sea, it is approximately 28.9°C, the NetTC index is 126.3 and 170.6% respectively, the number of TC in the East Sea is bigger than the normal, from 17 to 20 number of TC per year. Meanwhile, in the three coldest years, 1972, 1976 and 1992, SST in the East Sea is approximately 28.1°C, NetTC index is smaller, 74.7%, 63 % and 64.2%, respectively. The number of TC in the East Sea in these years is also smaller than the normal, about 7 to 10 number of TC per year.

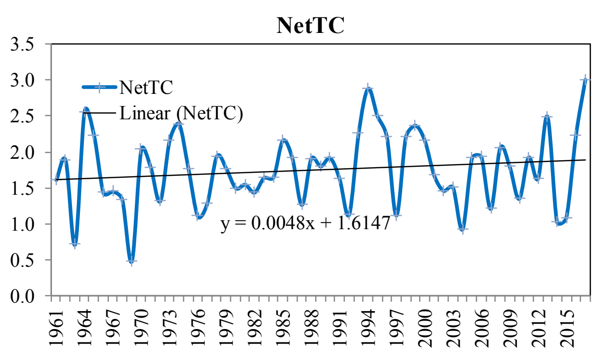

Fig. 9. The NetTC index (blue) and linear (black) in the East Sea from 1961 to 2017

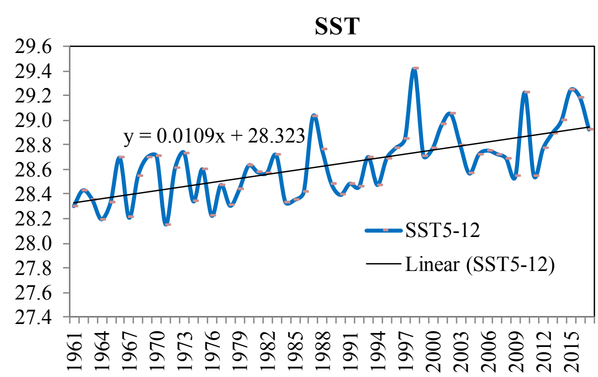

Fig. 10. The SST (red) and linear (black) in the East Sea from 1961 to 2017

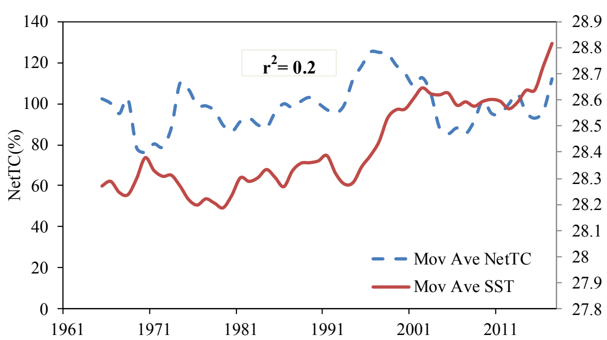

Fig. 11. NetTC index (blue) and SST (red) in the East Sea. The time series have been smoothed using moving average with 3 year to reduce effect of interannual variability and fluctuation on time scales

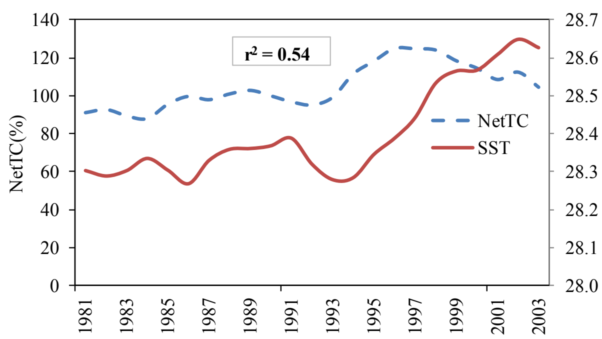

Fig. 12. Correlation between NetTC (blue) and SST (red) from 1981 to 2003

4. Conclusion

In the series time from 1961 to 2017, TC in the East Sea tends to increase slightly. Meanwhile, in contrast, the number of TC landfalling in Vietnam tends to decrease. The number of TC with upper 12 force is biggest, about 40%, following by the activity of tropical depression with 22% and the number of TC with 8-9 force and 10-11 force with 21% and 16% respectively. Frequency by 10 years, the 1991-2000 decade is biggest with average number of TC about 14.5 times per year.

The indicator of PDI depends on three factors: maximum wind speed, lifetime and number of TC. PDI correlates with the Nino3-4 index, but this correlation is weak. Similarly, the correlation beween the NetTC index and SST is positive. In general, indicators related to the changes of TC in the East Sea have correlation with factors related to climate change, but this correlation is not strong and it only shows clearly in extreme years such as in the strong ENSO phase or hottest years.

Acknowledgements

This study is supported by the funding of the government project titled “Study of the scientific argumentation of the climate change impact monitoring system on extreme characteristics of hydro-meteorological factors and severe meteorological phenomena for sustainable social and economic development in Vietnam” grant number: BDKH.24/16-20.

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Vietnam Journal of Hydrometeorology, ISSN 2525-2208, 2019 (02): 51-63

Research Paper

OBSERVED PRECIPITATION CHARACTERISTICS IN MJO PHASES OF VIET NAM

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ARTICLE HISTORY

Received: March 12, 2019 Accepted: June 08, 2019
Publish on: June 25, 2019

ABSTRACT

The research uses synoptic station data and MJO index to analyse the precipitation distribution all over Viet Nam. The mean rainfall amount in the Northern region tends to increase in MJO phases 1 and 2; the rainfall anomalies in the North Central provinces are positive in phases 3, 4 and 5; from Middle Central to Southern provinces, MJO increases the rainfall, especially in phases 4 and 5. During transitional seasons (MAM and SON), positive rainfall anomalies in those wet phases tend to be higher than those in summer and winter, especially in SON.

Keywords: *Rainfall anomaly, MJO, wet phases.*

1. Introduction

The MJO is a tropical large-scale oscillation that is dominated by periods of 30-60 days and the zonal wave number one propagating eastward (Madden and Julian, 1971). It is the low frequency variation in the intensity of the wind in the upper atmosphere and the variation of temperature at different levels combined with the surface pressure. The longest oscillation period is at about 41-53 days and has the largest frequency at about 45 days. The 40-50 day fluctuation is the basis for explaining some of the low frequency fluctuations of tropical circulation and climate fluctuations. Among these characteristics, the movement from west to east of the 40-50 day oscillation has the greatest significance. This movement is expressed as an atmospheric wave, most of which is related to the movement of intense convection. These convections move at speeds of 10-30 m/s from the Indian Ocean to the western Pacific Ocean and across the Pacific Ocean to South America. The surface effects of convection movement to the east can be seen in some equatorial regions suitable for temperature and surface pressure changes with a 40-50 day cycle.

In addition to the above-mentioned spatial characteristics, oscillations of 40-50 days also have varying characteristics over noticeable time. For example, the variation between seasons is reflected in the nature of this oscillation. Sub-seasonal variation, including 10-20 days, 30-50 days and a week fluctuations (Ding, 1994) is the most important because this oscillation has major implications for the active and inactive phases of the monsoon. The oscillation has its own intensity variation with the weakest in the Western Pacific and the strongest in the Indian Ocean. The figure below gives an example of phase space diagram (Wheeler and Hendron,

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2004) of MJO representing position (areas from 1 to 8) and intensity (distance to the center of simplicity map) of MJO. Based on the two characteristics RMM1 and RMM2 in phase space, we will determine the current MJO location and intensity.

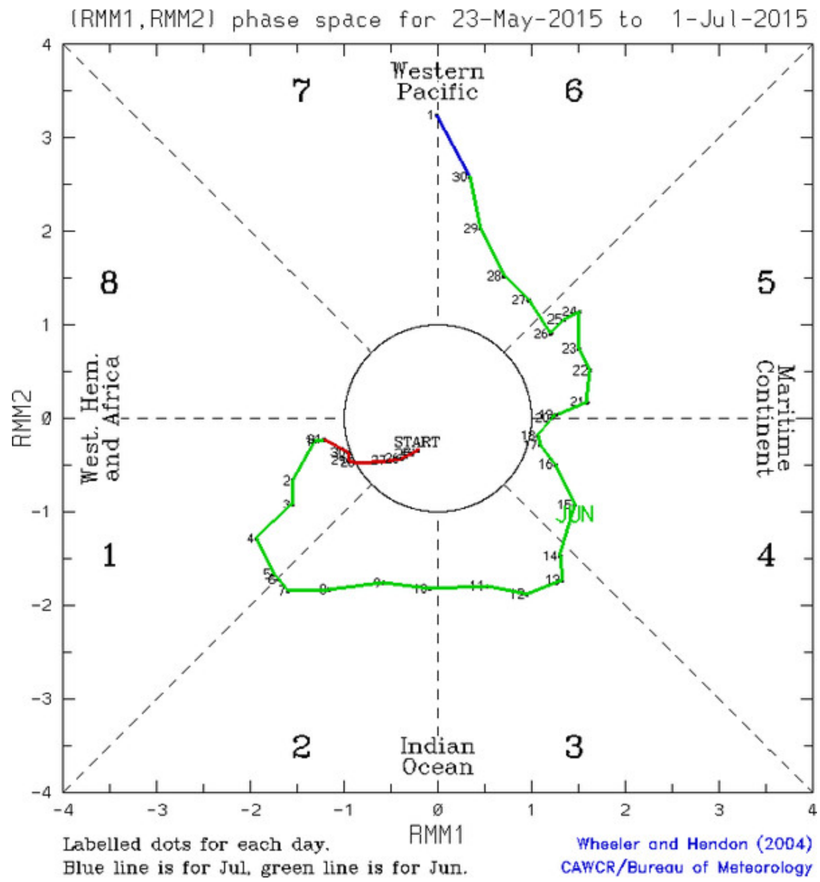

Fig. 1. Schematic representation of phase space of MJO with values of two characteristics RMM1 (horizontal axis) and RMM2 (vertical axis), global ocean areas (represented by numbers from 1 to 8) in which the Western Pacific region are two regions 6 and 7. Colors represent the months (red-May, Green - June and Blue - July).

Donald et al. (2006) evaluated the effect of the MJO on global-scale rainfall and found that MJO is an important phenomenon that may affect the daily rainfall distribution, even in high latitudes, through teleconection to large-scale sea level atmospheric pressure. Donald et al. (2006) also emphasized that MJO could be the mechanism and a predictor to bridge the weather forecast (usually only within the 5-day limit) and climate forecast (often highly skilled in 3-6 month forecasts). Through the composite of anomalies in the summer of the Northern Hemisphere in different MJO phases (2, 4, 6, and 8), there is a close relationship between the positive anomalies of precipitation and negative anomalies of mean sea level pressure and vice versa.

The MJO has a direct impact on the weather in the tropical region, as it organizes convection and precipitation. There have been many studies on the impact of the MJO on the South and East Asian (EA) region. Most of them, however, are for the boreal summer season (Zhu et al., 2003a, 2003b; Zhan et al., 2006). In summer, the MJO related intraseasonal disturbances tend to propagate northeastward that significantly influence the “active” and “break” monsoon rainfall fluctuations (Yasunari, 1979; Murakami et al., 1984; Wang et al., 2006). The disturbances associated with the MJO directly modulate the rainfall over the Asian continent through its influence on the genesis of higher frequency monsoon lows and depressions. As revealed by Goswami et al. (2003), a majority of such monsoon lows and depressions develop during the wet phase of the MJO. A recent study of Zhang et al. (2009) reported a significant impact of the MJO on summer rainfall in southeast China. The impact of the MJO on wintertime weather in East Asia, especially in its midlatitude region, is less well documented.

2. Data and method

The present study is based primarily on two data sources: observation rainfall data from 59 synoptic stations along Viet Nam that was provided by the National Centre for Hydro-Meteorological Forecasting, Viet Nam.

To identify phases of the MJO, we use the real-time multivariate MJO (RMM) index of Wheeler and Hendon (2004), which was downloaded from the Australian Bureau of Meteorology and is currently available from http://www.bom.gov.au/climate/mjo. All data collected from 1997 to 2015.

To analyse the characteristic of Viet Nam's precipitation in MJO phases, we extract days which is the same MJO phases to calculate anomaly of precipitation for 59 synoptic stations. For instance, rainfall anomaly of MJO phase 1 in January will be calculated by rainfall average of phase 1 minus rainfall average in January. Other phase anomalies are calculated similarly as above.

3. Characteristic of precipitation in Viet Nam in MJO phases

3.1. Characteristic of precipitation in MJO phase

Before examining the details of rainfall distribution in each MJO phase in each month, we analyzed the average rainfall characteristics in each phase in climate regions. Daily rainfall of 59 synoptic stations will be averaged for each phase in the period from 1997-2015. In which, it is divided into 3 main areas: Northern region; Central region and Central Highlands - Southern regions.

Fig. 2 shows the average rainfall in each phase in the Northern region. The graph shows that the daily mean rainfall in the Northern region is slightly different between phases, about 3-5mm/day, except for those stations have higher daily mean rainfall in most phases such as Lai Chau, Hoa Binh (Tay Bac), Sa Pa, Ha Giang (Viet Bac), Thai Nguyen, Tien Yen (Dong Bac).

It can be recognized that, the daily mean rainfall in phase 1 and phase 2 tends to be higher than other phases; additionally, in the delta region, the rainfall in phase 4 is also higher. The MJO is likely to increase rainfall in the Northern provinces in phase 1, phase 2 and in the delta region in phase 4.

In the Central region (Fig. 3), the difference in daily mean rainfall between phases is higher. The North Central provinces have the highest daily mean rainfall in phase 3, phase 4, phase 5 of which phase 4 is highest; Central and South Central provinces are phase 4, phase 5 (phase 5 is highest). There are also a number of stations that recorded remarkable rainfall in most phases such as Ky Anh, Hue, Quang Ngai, Quy Nhon and Truong Sa.

The Central Highlands-Southern region is the most southern region of Vietnam, the daily mean rainfall in this region is strongly modulated by the MJO, especially in the phase 5 and phase 4, especially at stations like Phu Quoc, Ca Mau and Pleiku (Fig. 3).

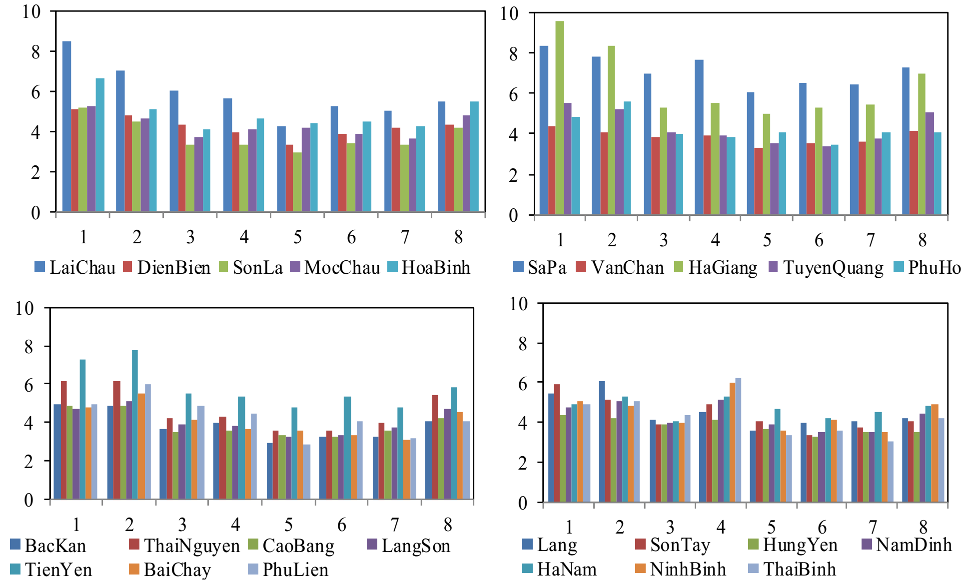

Fig. 2. The mean rainfall in each phase of the Northern region (Y axis is the daily mean rainfall; X axis is the MJO phases).

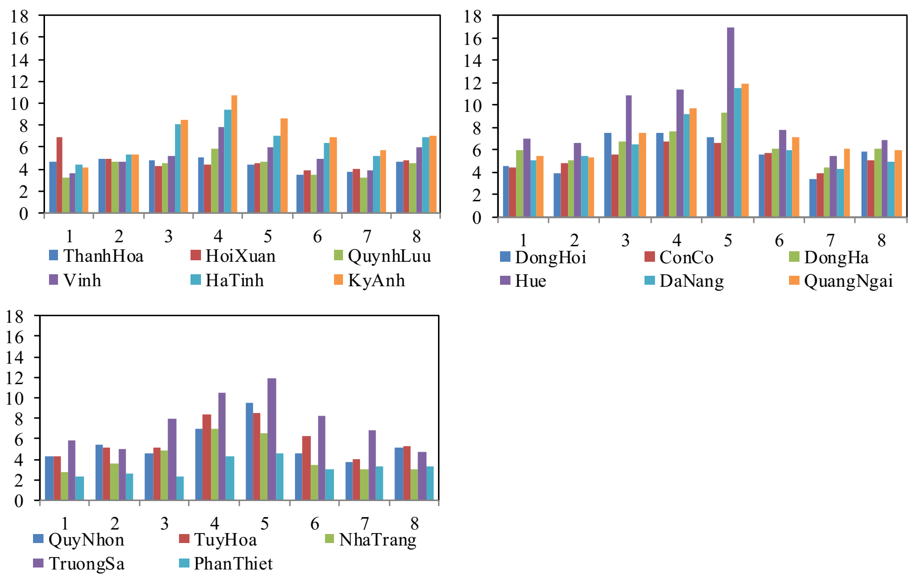

Fig. 3. The mean rainfall in each phase of the Central region (Y axis is the daily mean rainfall; X axis is the MJO phases).

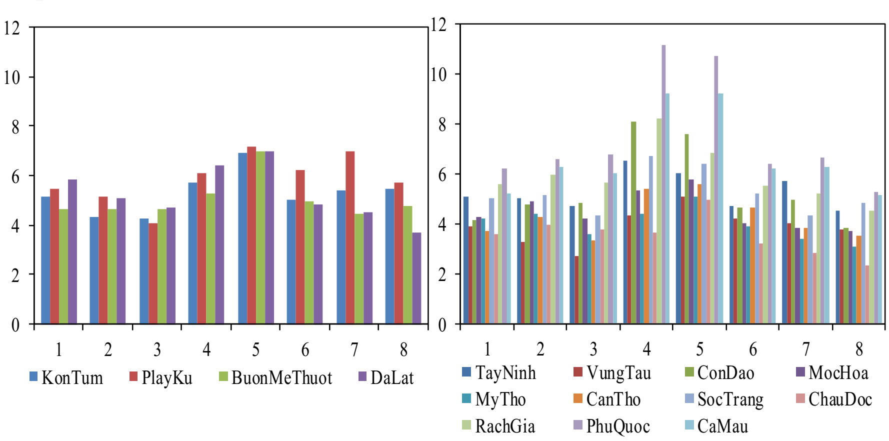

Fig. 4. The mean rainfall in each phase of the Central Highland- Southern region (Y axis is the daily mean rainfall; X axis is the MJO phases).).

By analyzing the daily mean rainfall distribution characteristics in each MJO phase, the higher daily mean rainfall is concentrated in phases 1 and 2 in the Northern region, phase 3, 4 and 5 in the Central region and Central Highlands - Southern provinces. However, the difference in rainfall between highest and lowest phases is not much.

In the next section, we will investigate the characteristics of rainfall distribution in each month by calculating the phased rainfall anomaly (i.e average rainfall minus monthly average rainfall in the period from 1997-2015). From the above characteristics, in the analysis of rainfall characteristics in each month, we will mostly focus on considering phase-averaged rainfall anomaly in phases 1, 2, 3, 4, 5 and some phases which have mean rainfall is higher than monthly mean rainfall.

3.2. Characteristic of precipitation in summers

In summer season (JJA), large-scale systems that have major impacts on Vietnam's weather are subtropical high pressure, Intertropical Convergence Zone (ITCZ), hot and dry low-pressure-area, tropical cyclones in the north and the southwest monsoon in the southern provinces. In this study, we analyzed the relationship between the MJO and the distribution of rainfall in Vietnam through rain characteristics in the MJO phases.

The observed rainfall anomalies in June and August in most of the stations are negative the phase 1 of the MJO, whereas in July, the observed anomaly are positive in the Northern provinces and negative elsewhere.

In phase 2, rainfall anomalies tend to be positive in the coastal stations of the Northern region in June and August. In July, rainfall anomaly is slightly positive in the north of Central provinces Vietnam. The southern provinces still maintain lower rainfall than the corresponding monthly mean rainfall (Fig. 5).

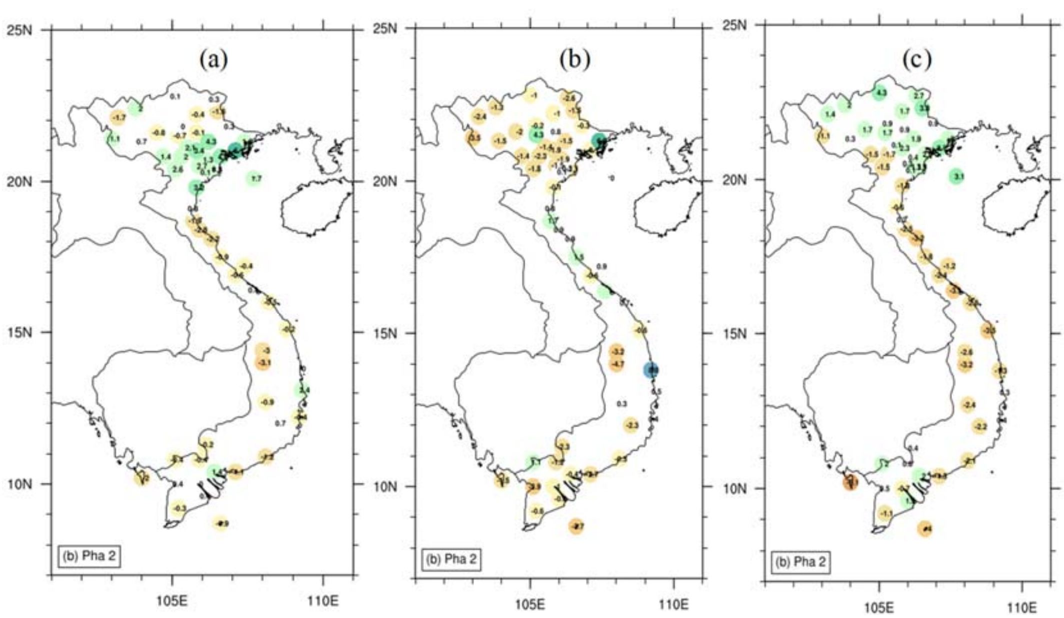

Fig. 5. The rainfall anomaly of phase 2 in Viet Nam in summer months (JJA), including: (a) June, (b) July and (c) August.

In June and August, positive rainfall anomalies in phase 3 are higher and expand further south (Fig. 6). In June, positive rain anomaly area is concentrated in the mountainous and highland areas of the North and Center of the Central provinces (from Quang Tri to around Quang Ngai). By August, rainfall anomaly has increased, especially in the northeast provinces of Northern Vietnam, then extended to the Mid-Central provinces. Rainfall anomaly in phase 3 is almost the same as phase 2 in July.

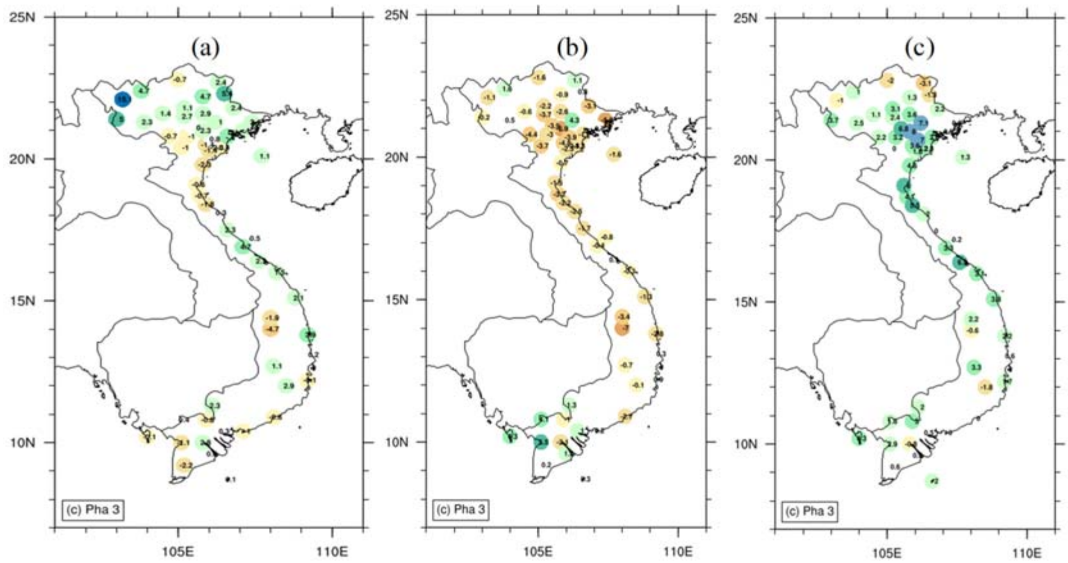

Fig. 6. The rainfall anomaly of phase 3 in Viet Nam in JJA months, including: (a) June, (b) July and (c) August.

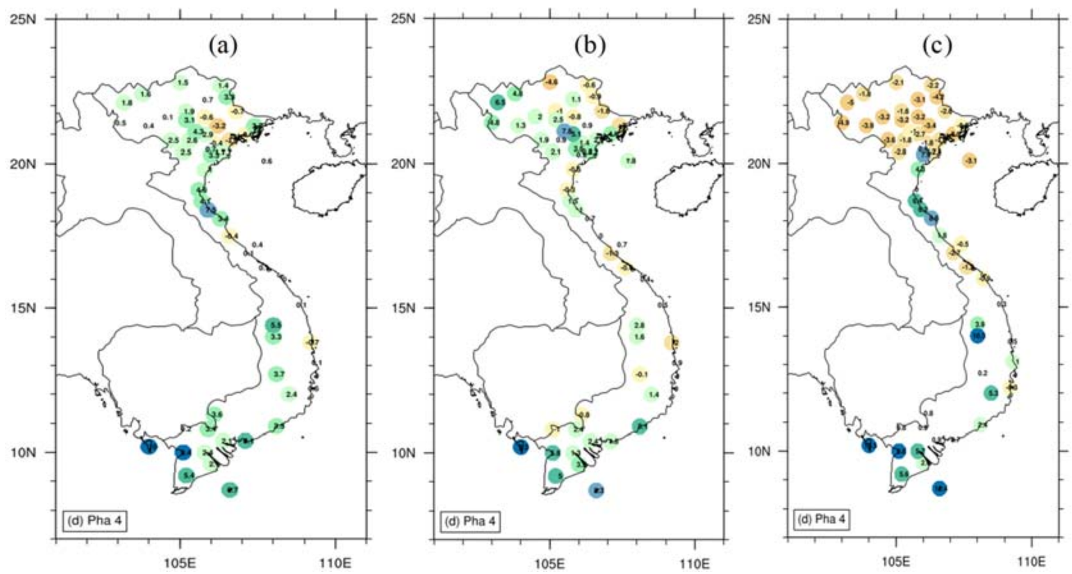

Fig. 7. The rainfall anomaly of phase 4 in Viet Nam in JJA months, including: (a) June, (b) July and (c) August.

The rainfall anomalies in phase 4 of June and July are clearly above normal for most of the stations in Vietnam, especially for the southern stations. However, in August, the rainfall anomaly Northern provinces shifted to negative, whereas the positive observed rainfall anomalies remained in the north central and southern provinces (Fig. 7).

The rainfall anomaly in phase 5 (Fig. 8) has increased rapidly in August, especially in the Mid-Central provinces. Meanwhile, in June and July, the rainfall anomaly in this phase decreased gradually in the Northern provinces, of which many stations turned to negative anomaly compared to phase 4. The positive rainfall anomaly in the southern provinces also tends to decrease slightly but still be positive.

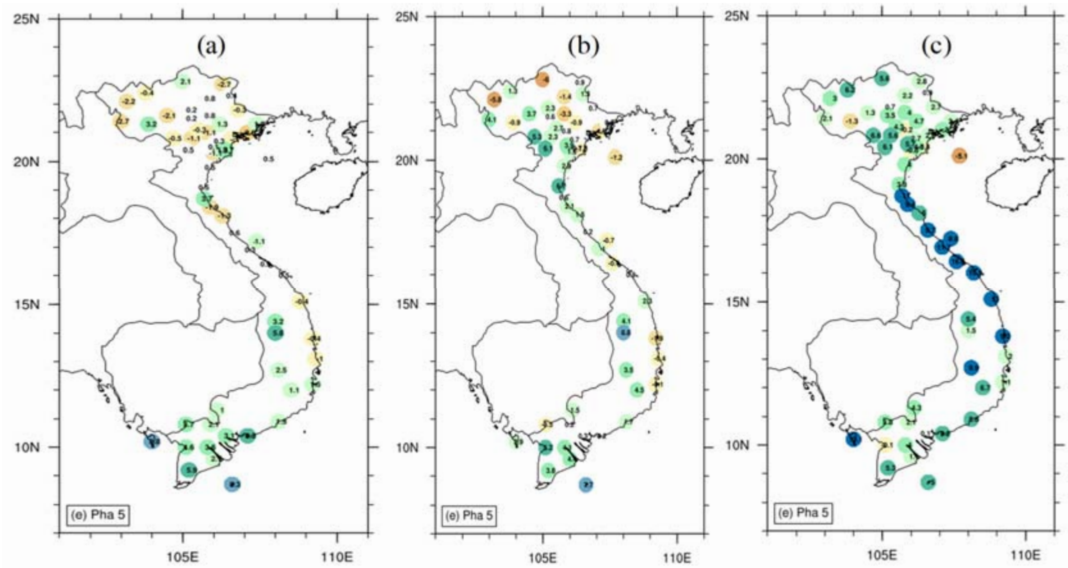

Fig. 8. The rainfall anomaly of phase 5 in Viet Nam in JJA months, including: (a) June, (b) July and (c) August.

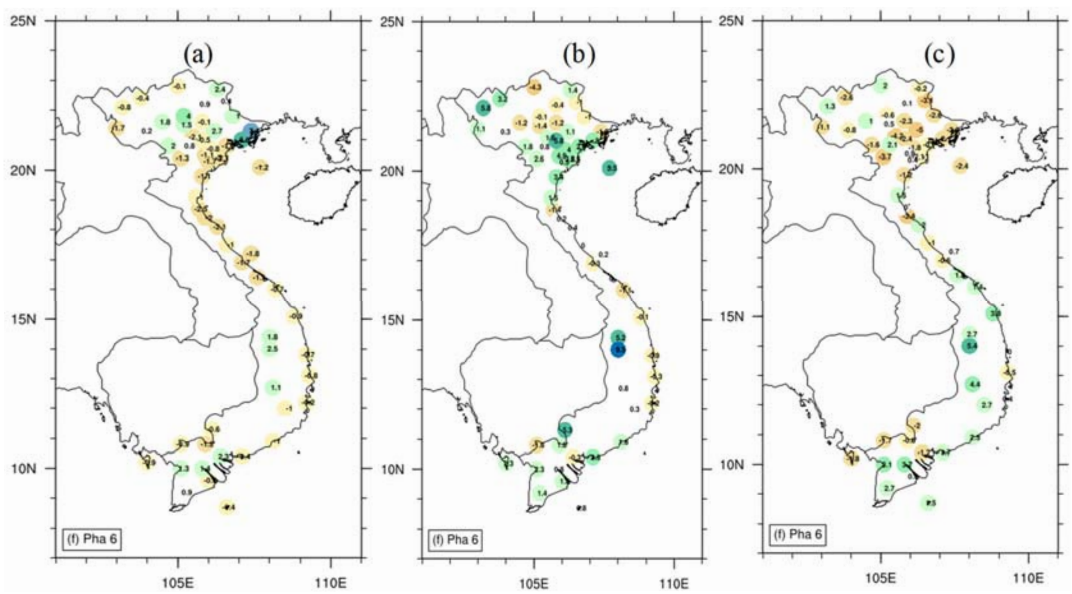

Fig. 9. The rainfall anomaly of phase 6 in Viet Nam in JJA months, including: (a) June, (b) July and (c) August.

In phase 6 (Fig. 9), the mean rainfall decreased rapidly in JJA months, in which August had the most decrease compared to previous phase 4 and 5. This decrease trend of the rainfall anomaly continues in phase 7 and 8 resulting the wide-spread negative rainfall anomaly in phase 7 all over Vietnam. The exception was observed in phase 8 rainfall anomaly in August with the dipole pattern of positive rainfall anomaly in the north and negative anomaly in the south.

The analysis of rain distribution in each MJO phase in the JJA shows that: in phase 4 and phase 5, the rainfall anomaly tends to be higher than monthly mean rainfall mostly all over Vietnam, with maximum positive anomaly in the Mid-Central, South-Central, Highlands and Southern provinces. In addition, in phase 3 and phase 6, in the Northern provinces, the near or above normal mean rainfall are also observed. Phase 1 and phase 7 in summer months are dry phase and phase 8 shows a dipole pattern of rainfall anomaly along Vietnam.

3.3. Characteristic of precipitation in Winters

In DJF months, the large-scale systems controlling Vietnamese weather are mainly cold surge, upper westerly jet stream in the north or equatorial trough and subtropical high in the south. Therefore, the activity of MJO could be one of the factors directly or indirectly associated with these large-scale systems and affecting the weather including the rainfall distribution in Vietnam during this time.

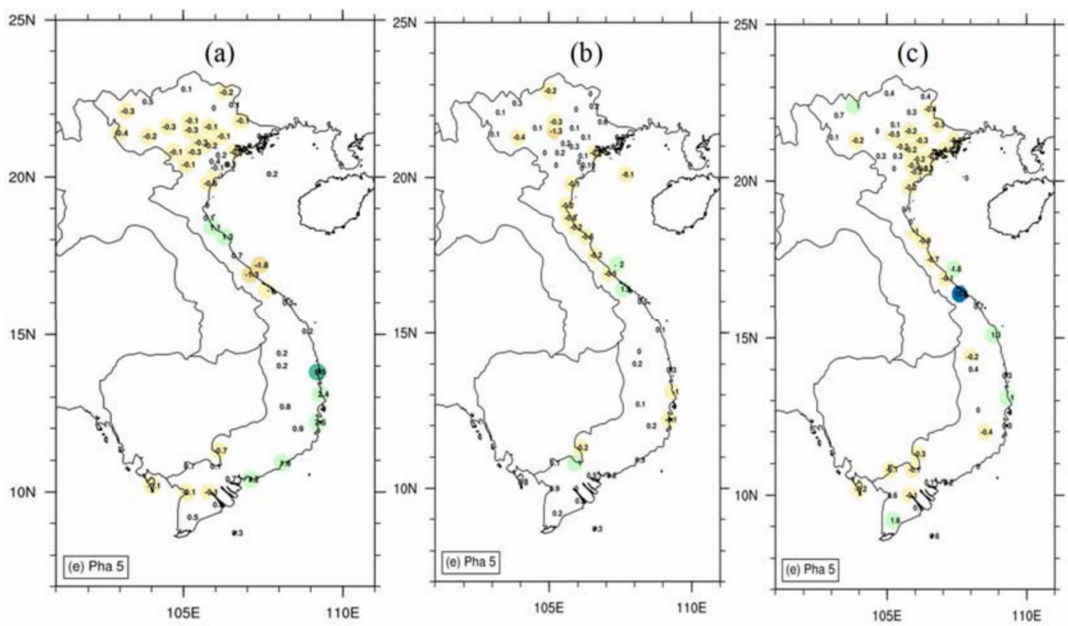

Fig. 10. The rainfall anomaly of phase 4 in Viet Nam in DJF months, including: (a) December, (b) January and (c) February.

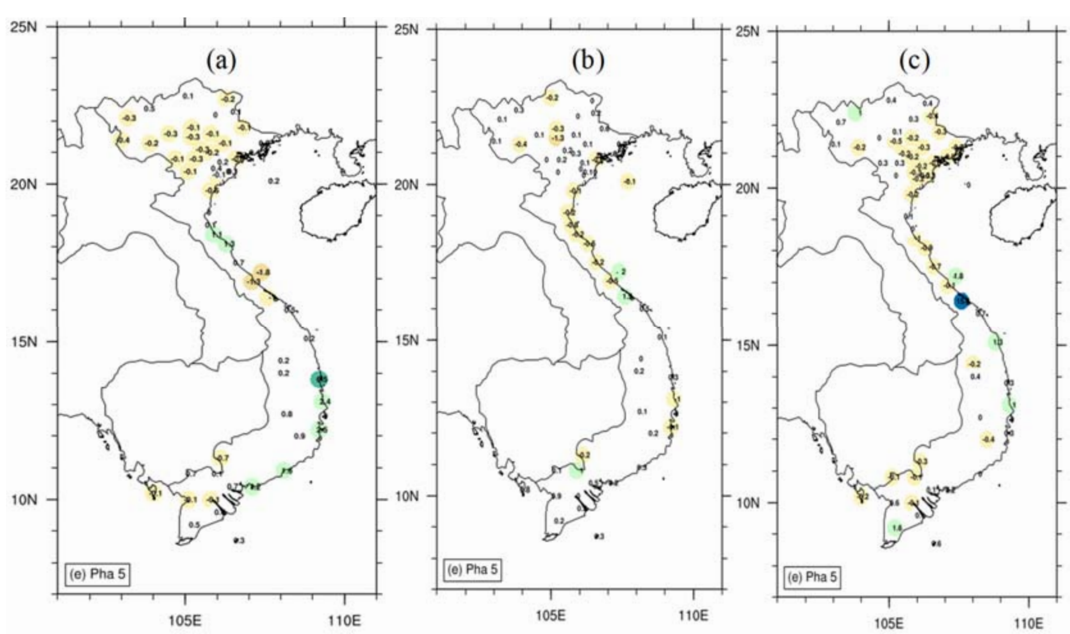

Fig. 11. The rainfall anomaly of phase 5 in Viet Nam in DJF months, including: (a) December, (b) January and (c) February

The rainfall anomalies in phase 4 are positive in December and February whereas the phase 4 rainfall anomaly in January is negative countrywide (Fig. 10).

During DJF, the positive rainfall anomaly in phase 5 is less than in JJA. The mean rainfall is only slight higher than normal in some coastal stations in the south-Central and Highlands in December and January. In February, most rainfall anomalies have negative values (Fig. 11).

Thus, in DJF months, the positive rainfall anomalies are often observed in phase 4, especially in December and February. In other phases, the rainfall anomalies are negative.

3.4. Characteristic of precipitation in transition period

During transition months, the dominate large-scale weather systems in Vietnam tend to weaken or dispute each other so the weather forecast in general and rainfall in particular is extremely difficult, especially in medium, extended range forecasts and beyond. Considering the characteristics of rain distribution in MJO phases of transition months is also one of the important factors to help forecasters have more reference tools before making a final official forecast.

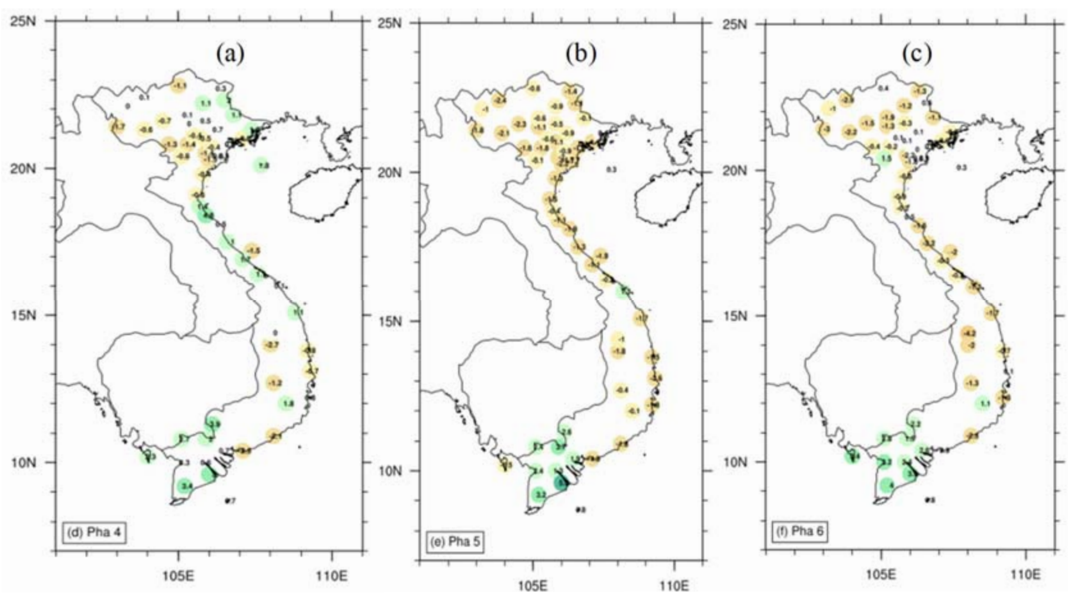

Fig. 12. The rainfall anomaly of April in Viet Nam in DJF months, including: (a) Phase 4, (b) Phase 5 and (c) Phase 6

In April (Fig. 12), the observed rain anomalies in the phases 4, 5 and 6 shows positive values in the Southern region. Therefore, it can be seen that the activity of MJO during this period also partly affects the rainfall distribution in the Southern provinces where as negative elsewhere in Vietnam.

Phase 7 of the MJO in April and May cause the mean rainfall anomaly (Figs. 13a-13b) to be positive most of Vietnam, except for some stations in the west of the Southern region in April and in the North of Vietnam in May.

Considering the transition period from summer to winter, including September, October and November. Fig. 14 shows that the positive rainfall anomalies appear more frequently during this period. The mean rainfall in phase 4, phase 5, phase 6 tend to be higher than corresponding monthly mean rainfall. In phase 4 (Fig. 14), positive rain anomalies focus mainly on the provinces from the south of the Northern Delta to the Highlands -Southern in September, October. In November, the positive rainfall anomalies continued to cover all Northern provinces; In addition, the rainfall anomaly values also tends to be higher in the Central coast region. This shows that MJO is likely in increasing rainfall anomaly in phase 4 in Vietnam in general and in the Middle Central provinces in particular.

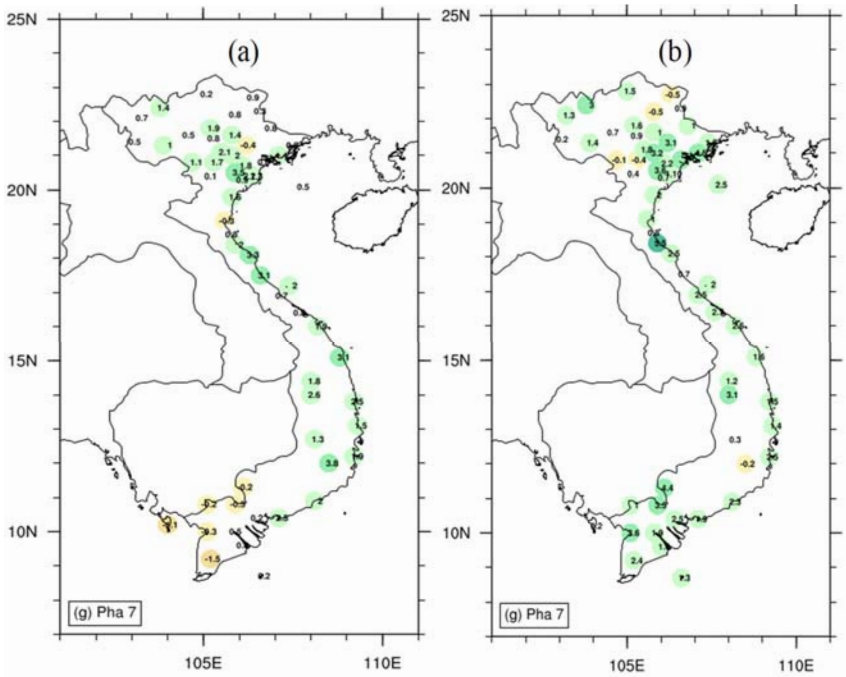

Fig. 13. The rainfall anomaly of phase 7 in Viet Nam in DJF months, including: (a) April, (b) May**.**

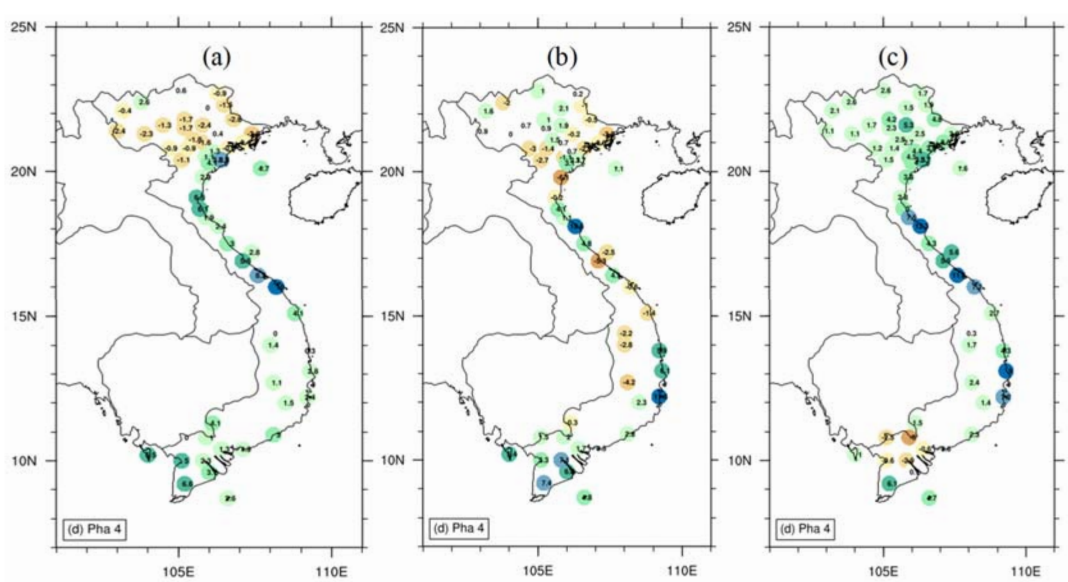

Fig. 14. The rainfall anomaly of phase 4 in Viet Nam in transition months, including: (a) September, (b) October and (c) November.

In phase 5 (Fig. 15), the positive rainfall anomalies are gradually narrowed to the south, concentrate on Central and Highland-Southern provinces. Specially, in November, it is still the highest positive rainfall anomaly in the Central coastal provinces.

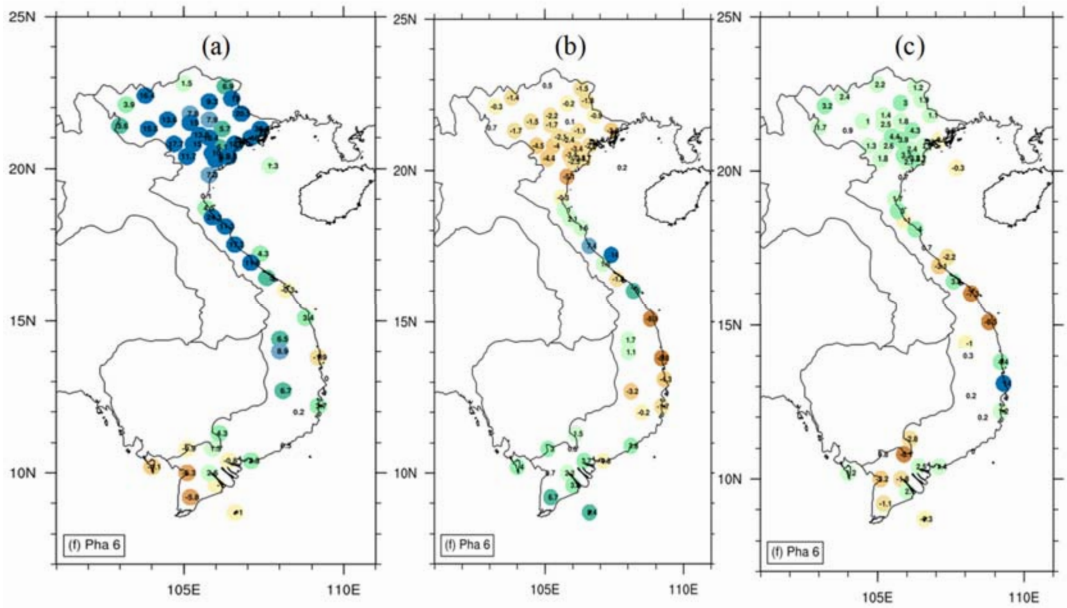

Fig. 15. The rainfall anomaly of phase 5 in Viet Nam in transition months, including: (a) September, (b) October and (c) November.

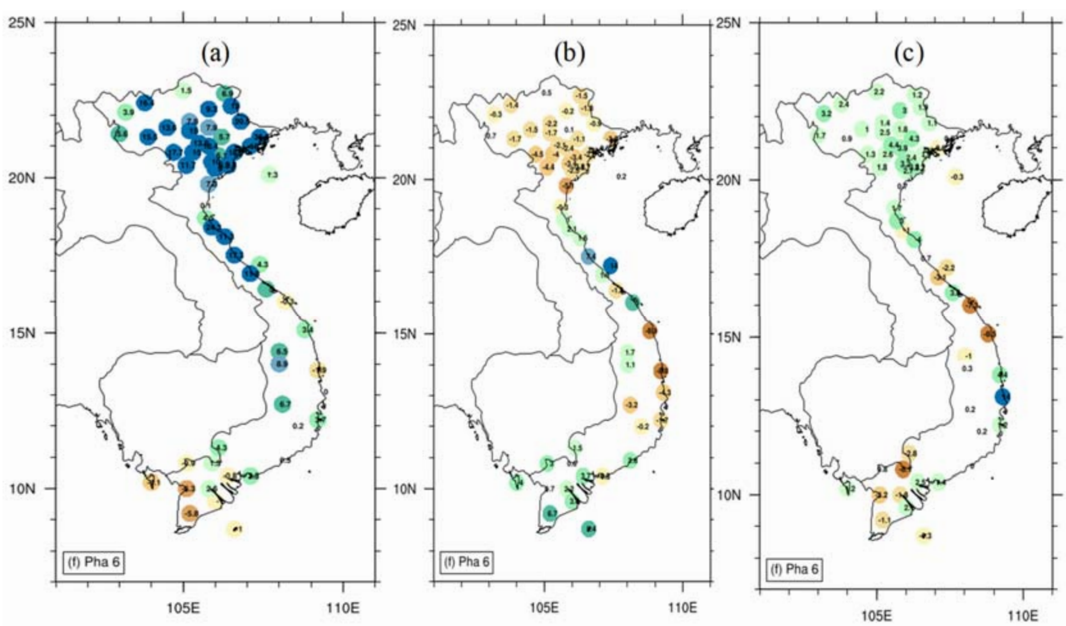

Fig. 16. The rainfall anomaly of phase 6 in Viet Nam in transition months, including: (a) September, (b) October and (c) November.

In phase 6 (Fig. 16), the mean rainfall anomalies tend to decrease in October and November. But in September, the rainfall anomalies show the highest positive values, especially in the Northern and North Central provinces.

Thus, in transition months, the mean rainfall in each phase tends to be higher than corresponding monthly mean rainfall. It is also higher than DJF or JJA months. The higher rainfall anomalies are often concentrated in phases 4, 5 and then phase 6. In other phases, the rainfall anomalies are more mostly negative.

4. Conclusion

In the Northern provinces, the mean rainfall anomalies in phases 1 and 2 of MJO are higher than in other phases. In the North Central regions, the higher rainfall are in phases 3, 4 and 5. From Middle Central to the Southern provinces, phases 4 and 5 are considered as the wettest phases. However, there are not much differences between phases which have the highest and lowest positive rainfall anomalies.

Although MJO is a tropical oscillation, its influence on rainfall distribution in Vietnam is not only in the Southern provinces but also in the Northern provinces. Phase 4 and phase 5 are two phases where the MJO increases rainfall anomalies in Vietnam; the next wet phases are 3, 6 and 7. During transitional seasons, positive rainfall anomalies tend to be higher than summer and winter, especially in September, October and November.

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Research Paper

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

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ARTICLE HISTORY

Received: March 20, 2019 Accepted: June 18, 2019
Publish on: June 25, 2019

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 midwinter, Northern part of Vietnam.*

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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 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 ($T^{i,j}_{TBN}$) 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 $T^{i,j}_{TBN}$ and $\sigma^{i,j}_{TBN}$ is called as standard threshold ($T^i_j = T^{i,j}_{TBN} + \sigma^{i,j}_{TBN}$) 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 ≤ 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_{TBNN}^{max} 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_{TBNN}^{max} 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.

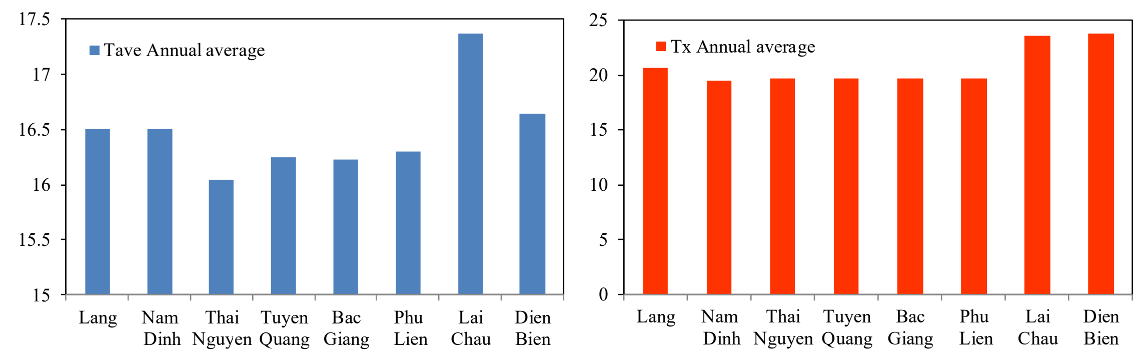

Fig.1. The spatial distribution of climatological mean of monthly average air temperature (left) and monthly maximum air temperature (right) for January.

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_j^i	$\Delta T_{tb}^{i,j,k}$	Station name							
					Lang	Nam Đinh	Thai Nguyen	Tuyen Quang	Bac Giang	Phu Lien	Lai Chau	Đien Bien
1	**1979**	**11**	19.0	**3.1**	22.1	21.9	22.1	21.5	21.4	21.4	17.4	16.8
	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
2	**1980**	**1**	19.0	**3.6**	22.6	22.8	23.0	23.0	22.3	21.8	17.4	16.3
	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
3	**1980**	**28**	19.0	**3.7**	22.7	21.4	22.4	22.0	22.6	21.4	19.1	18.2
	1980	**29**	19.0	**3.7**	22.7	21.3	22.5	20.5	21.7	21.0	18.5	17.0
4	**1987**	**2**	19.0	**3.9**	22.9	22.3	22.5	21.1	22.2	21.1	18.7	18.4
	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
5	**1991**	**20**	19.0	**3.4**	22.4	22.1	21.4	20.6	21.5	20.2	19.9	20.9
	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
9	**1998**	**2**	19.0	**3.8**	22.8	22.4	22.8	22.9	22.3	22.2	18.6	19.9
	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
	1999	30	19.0	3.3	22.3	21.1	23.1	23.3	22.9	21.4	19.0	20.9
11	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
	2006	3	19.0	3.4	22.4	21.7	21.7	22.2	21.7	20.6	16.9	16.3
18	2006	4	19.0	4.4	23.4	23.1	22.9	23.1	22.7	21.8	17.4	16.6
	2006	18	19.0	4.9	23.9	23.2	22.9	24.4	22.9	21.5	19.4	18.4
19	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

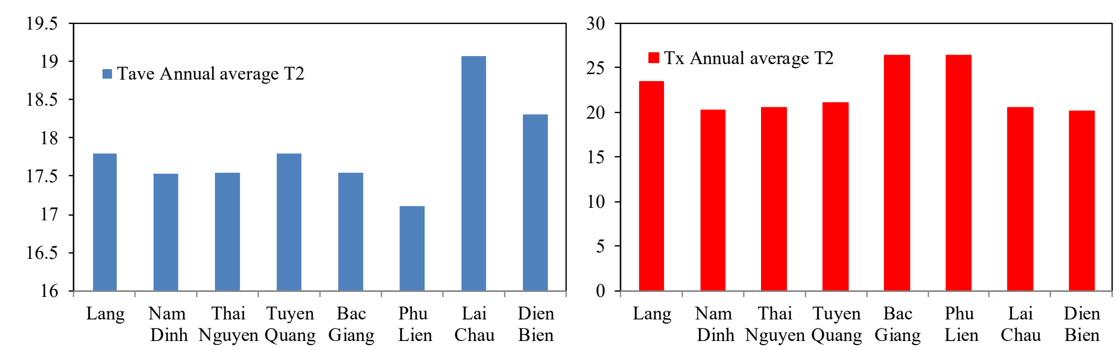

Fig. 2. The spatial distribution of climatological mean of monthly average air temperature (left) and monthly maximum air temperature (right) for February.

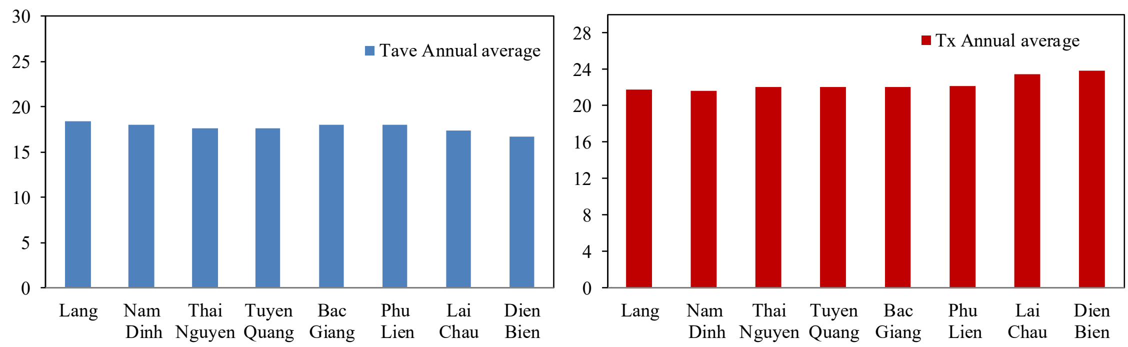

Fig. 3. The spatial distribution of climatological mean of monthly average air temperature (left) and monthly maximum air temperature (right) for December.

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^oC and 1.5^oC 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^oC, while the daily maximum temperature flactuate in the range of 26-29^oC. However, the daily maximum temperature reached 30-33^oC 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.

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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