EWATEC-COAST: Technologies for Environmental and Water Protection of Coastal Zones in Vietnam

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Dear readers,

We are glad to present hereby the scientific and technical contributions of the EWATEC-COAST working groups to the 4th VNU - HCM International Conference for Environment and Natural Resources ICENR 2014 with a focus on “green growth, climate change and protection of the coastal environment”. This conference was held in June 2014 in Ho-Chi-Minh City (HCMC), Vietnam, and hosted by the Institute for Environment and Resources (IER) of the Vietnam National University Ho-Chi-Minh City (VNU-HCMC).

EWATEC-COAST is the name of our German-Vietnamese joint project dealing with “technologies for environmental and water protection of coastal zones in Vietnam under climate change conditions”. The project is coordinated by the University of Braunschweig, Germany. Main Vietnamese partner is the IER. The project is funded by the German Federal Ministry of Education and Research (BMBF) as a part of the funding initiative CLIENT, and by the VNU-HCMC. The project is financed for a period of three years. It started in fall 2012.

Presentations of the project scope and of intermediate results were embedded in the scientific programme of the ICENR 2014. More than 200 scientists, government officials, national and international experts and the engineering practice joined the conference. The excellent development of German-Vietnamese cooperation was appreciated by the Vietnamese Deputy Minister of Natural Resources and Environment (MONRE), Assoc. Prof. Bui Cach Tuyen, and the Consul General, German Consulate General of Ho-Chi-Minh City, Dr. Hans-Dieter Stell, in their welcome notes.

It is the rapid growth of economy and population that puts massive environmental pressure on river catchments in Vietnam. The joint project EWATEC-COAST focuses on one of the most jeopardized zones of Vietnam, the highly polluted inland water and estuary system of the Thi Vai river basin and the adjacent Can Gio mangrove forest, an UNESCO world biosphere reserve.

Both areas are located south-eastern of Ho-Chi-Minh City. In the past, various companies, which are mostly located in industrial zones along the river, discharged wastewater without treatment into the river system.
The Thi Vai river was therefore considered as ecologically dead. Most recently, the water quality of the river has been slightly improved because first control initiatives have been realized. A comprehensive strategy for the sustainable rehabilitation is still missing.

EWATEC-COAST will significantly contribute to find ecologically and economically sound solutions for the rehabilitation of the affected water bodies, the fauna and the flora with focus on mangroves. Climate change impacts, in particular the impact of the sea water level on coastal protection and the inland water system will be considered. Main task is the development and application of a model-based "management system" for sustainable water and environmental protection of the affected coastal zone. The system will serve for decision making. Another important task is the development and optimization of innovative process technology for industrial waste water treatment in the industrial zones of the Thi Vai river basin.

The management system will be implemented at provincial and municipal authorities as well as research institutions and primarily serve as a planning framework. The project concept can be transferred to other regions of Vietnam and to other countries. First project results are very promising and confirm the suitability of the overall project strategy. Excellent perspectives for economic, scientific and technical exploitation of results are expected.

In this book we have compiled the contributions of nearly all German and Vietnamese project partners of EWATEC-COAST presented at the ICENR and hence present a comprehensive overview about the preliminarily findings that have been gained throughout focused research work since the beginning of the project.

We hope you enjoy reading this issue.

Yours sincerely

Günter Meon, Matthias Pätsch, Nguyen Van Phuoc and Nguyen Hong Quan

(Editors)

Braunschweig, Germany, and Ho-Chi-Minh City, Vietnam,
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Observed Climate Variations and Change in Vietnam

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Abstract

In this study, observed changes of temperature, rainfall, and some extreme climate indices in Vietnam were investigated by using daily observations during the period 1961-2012. The observed data were collected from 80 meteorological stations for temperature, and from 170 stations for rainfall over the seven climatological sub-regions of Vietnam. Results show that there were insignificant differences between the trends of changes obtained from the 1961-2011 and 1979-2012 periods. Near-surface temperature, including mean (T2m), maximum (Tx) and minimum temperature (Tm), increased consistently at almost all stations. Tm increased faster than Tx. Temperature also increased faster in winter than in summer. Consequently, the number of hot days and warm nights increased whereas the number of cold days, cold nights and cool days decreased. In the northern regions, temperature tended to slightly decrease in May but significantly increased in June.

Annual rainfall decreased in the northern area of Vietnam, while it increased at almost all stations in the central regions, and had insignificant trends in the southern sub-region. Changes in some extreme rainfall indices were likely consistent with changes in annual rainfall. Monthly rainfall in the central regions significantly increased from August to December. Rainfall generally increased in May and decreased in June over almost all country.

Key Words: climate change, extreme events, trend analysis
1. Introduction

From the late 19th century, the average near-surface temperature has globally increased by about 0.74ºC (IPCC, 2007). However the warming was not uniform for all places on the globe; some places were even slightly colder than before (IPCC, 2007). In some arid areas such as the Southwest United States, Southwest Asia, Central Asia, or Australia, the rate of warming was believed to be slightly higher than the warming rate over the continents, therefore higher than the global average rate (Hulme, 1996). The rise of global temperatures might lead to changes in atmospheric and oceanic circulations that consequently cause changes in rainfall patterns and other extreme climate phenomena. Global warming could also alter bio-climatic conditions. Agricultural production in some areas might be heavily impacted due to the increase in the frequency and intensity of droughts that could occur even in the areas with increasing precipitation. Therefore, in the context of the current global warming, assessing climate change (CC) is of particular importance. The results of the assessment provide a scientific basis for evaluating the impacts of CC, hence mitigation and adaption measures can be designed and implemented. At regional and national scales, the assessments of climate change were usually conducted following two steps: 1) Assessing climate change based on the observed data; and 2) Projecting future climate.

Vietnam’s climate is mainly influenced by summer monsoon (also called southwest monsoon, from May to October) and winter monsoon (or northeast monsoon, from November-April). Additionally, the impact of the Inter-Tropical Convergence Zone as well as other tropical disturbances in the interaction with the topography also play an important role. In the past recent years, several studies about the changes of climate conditions in Vietnam have been conducted (eg. Ho et al., 2009; Phan et al., 2009; Phan et al., 2010; Ho et al., 2011; Ngo-Duc et al., 2012; Nguyen, 2008). However, further evaluations of the changes of temperature, rainfall and their mechanism of changes are still needed. In this study, observed daily data during the period 1961-2012 are used to examine the changes of temperature and rainfall characteristics for the whole territory of Vietnam. Detailed description of the data and methodology are presented in Section 2. Sections 3 and 4 present the analysis results and conclusions, respectively.
2. Data and methods

The following daily observed variables were collected from the meteorological station network of Vietnam: 1) rainfall (R); 2) near-surface air temperature (T2m); 3) daily maximum near-surface air temperature (Tx); and 4) daily minimum near-surface air temperature (Tm). Figure 1 shows the number of stations where data were available. The collected data were sparse before 1979. There are totally about only 60 stations in the network with more than 50 years of data. In truth, there are about 120 to 170 stations in Vietnam with more than 60 years of data but their use for research purposes was still limited because the data had not been fully digitized. Since 1978, the number of meteorological stations with available data has significantly increased. There are about 80 and 150 stations for temperature and rainfall, respectively. Therefore in order to compare the spatial distribution as well as the changes of temperature and rainfall over time, two periods were separately used in this study: 1) 1961-2012 for stations with at least 45 years of data; and 2) 1979-2012 for stations with at least 30 years of data.

![Figure 1. Number of meteorological stations used in this study over time. The vertical axis indicates the number of stations; the horizontal axis indicates the observed period from 1961 to 2012.](image)

The data were provided by the Data Center of the National Hydro-Meteorological Service of Vietnam, which belongs to the Ministry of Natural Resources and Environment. The missing data and the data with detected errors are excluded in the analysis. Monthly (annual) temperature
and rainfall are only estimated if there are more than 25 (330) days in the month (year) with available data. This is equivalent to 80% (90%) of data availability.

The trends of changes of climate characteristics are estimated using the Sen’s slope (Sen, 1968) and the non-parametric Mann-Kendall test (Kendall, 1975).

Table 1 shows several climate variables derived from temperature and rainfall. Those variables are analysed and discussed in Section 3.

**Table 1. Climate variables derived from temperature and rainfall. A rainy day is the day where its total rainfall is greater than or equal to 0.1 mm.**

<table>
<thead>
<tr>
<th>No</th>
<th>Variables</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Annual average near-surface temperature</td>
<td>T2m</td>
</tr>
<tr>
<td>2</td>
<td>Monthly average near-surface temperature</td>
<td>Tmon</td>
</tr>
<tr>
<td>3</td>
<td>Annual average value of daily maximum near-surface temperature</td>
<td>Tx</td>
</tr>
<tr>
<td>4</td>
<td>Annual maximum value of daily maximum near-surface temperature</td>
<td>TXx</td>
</tr>
<tr>
<td>5</td>
<td>Annual average value of daily minimum near-surface temperature</td>
<td>Tm</td>
</tr>
<tr>
<td>6</td>
<td>Annual minimum value of daily minimum near-surface temperature</td>
<td>TNn</td>
</tr>
<tr>
<td>7</td>
<td>Number of hot days (days with Tx≥35°C)</td>
<td>Tx35</td>
</tr>
<tr>
<td>8</td>
<td>Number of cold days (days with Tm≤15°C)</td>
<td>T2m15</td>
</tr>
<tr>
<td>9</td>
<td>Annual count of days when Tx &gt; 90 percentile</td>
<td>TX90p</td>
</tr>
<tr>
<td>10</td>
<td>Annual count of days when Tm &lt; 10 percentile</td>
<td>TN10p</td>
</tr>
<tr>
<td>11</td>
<td>Total annual rainfall</td>
<td>R</td>
</tr>
<tr>
<td>12</td>
<td>Total monthly rainfall</td>
<td>Rmon</td>
</tr>
<tr>
<td>13</td>
<td>Annual count of rainy days</td>
<td>R01Ann</td>
</tr>
<tr>
<td>14</td>
<td>Total rainfall during the summer monsoon season (May-October)</td>
<td>RSum</td>
</tr>
<tr>
<td>15</td>
<td>Total rainfall during the winter monsoon season (November-April)</td>
<td>RWin</td>
</tr>
<tr>
<td>16</td>
<td>Number of rainy days during the summer monsoon season (May-October)</td>
<td>R01Sum</td>
</tr>
<tr>
<td>17</td>
<td>Number of rainy days during the winter monsoon season (November-April)</td>
<td>R01Win</td>
</tr>
<tr>
<td>18</td>
<td>Annual maximum 1 day rainfall</td>
<td>Rx1day</td>
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<td>19</td>
<td>Number of days when rainfall &gt; 50mm</td>
<td>R50</td>
</tr>
<tr>
<td>20</td>
<td>Number of days when rainfall &gt; 95 percentile</td>
<td>R95p</td>
</tr>
</tbody>
</table>
3. Observed climate variability and change for Vietnam

3.1. Changes in temperature characteristics

Figure 2 shows the Sen’s slope for the trends of T2m, Tx and Tm for both periods 1961-2012 and 1979-2012. Over the whole territory of Vietnam, temperature has increased steadily and substantially in the last decades. Most uptrends satisfied the 10% significance level. Except Hue station, the increase of T2m and Tm agreed well over all climate zones as well as for the two periods. Tx had decreasing tendencies at about one third of the stations in Central Highlands, South and South Central Vietnam during 1979-2012 although the trends hardly satisfied the 10% significance level. Figure 3 shows in more detail the changing tendencies of T2m at each station. The trends of T2m averaged over Vietnam were almost equal to 0.18°C per decade for both periods. However, the trend of T2m and Tm in the southern part of Vietnam was significantly greater during the 1979-2012 period compared with 1961-2012 while in the northern part, the temperature increase in the period 1961-2012 seemed a little larger than that in the period 1979-2012.

The trend of annual minimum value of daily minimum temperature (TNn) was entirely consistent with that of annual T2m, whereas annual maximum value of daily maximum temperature (TXx) had some decreasing trends at a number of stations in the northwest region, and in the southern area, especially in the Central Highlands (Figure 4). It was previously reported that TXx in the southern region (from 16.0°N equatorward) was usually identified during March-April together with severe drought conditions. The decreasing trend of TXx in these regions was probably related to the extended impacts of winter monsoon activities to the lower latitudes. Yet another possibility could be linked to the occurrences of abnormal rainfall events and/or other in the corresponding period, which consequently reduced the maximum daily temperature.

The trends of annual count of days with maximum temperature greater than 90 percentile (TX90p) and annual count of days with minimum temperature less than 10 percentile (TN10p) had insignificant differences between the two data periods. TN10p decreased for both periods with a higher decreasing rate in the southern part compared with that in the North. These North-South differences in the trends of TN10p were signifi-
cantly greater for the period 1979-2012 compared with 1961-2012. The changes of TX90p were consistent with those of TXx, which showed increasing trends in the northern regions and significant decreases in the Central Highlands and at some stations in the southern areas. The trends of number of hot days (Tx35) and number of cold days (T2m15) were essentially similar to those of TX90p and TN10p, respectively, except for the southern region where most T2m15 had zero values.

Figure 2. Sen's slopes of annual average near-surface temperature (T2m), annual average value of daily maximum temperature (Tx) and annual value of daily minimum temperature (Tm) for the period 1961-2012 (a), b), c)) and 1979-2012 (d), e), f)) in °C per decade. The dots with circles indicate where the trends satisfy the 10% significance test.
Figure 3. Sen’s slopes of T2m (°C/decade) of the two phases from 1961 to 2012 and from 1979 to 2012. R1-R7 are sub-regions: R1: North West; R2: North East; R3: North Delta; R4: North Central; R5: South Central; R6: Central Highlands; R7: South.

Figure 4. Similar to Figure 2 but for the annual maximum value of maximum daily temperature (TXx) in °C per decade, annual count of days with maximum temperatures greater than 90 percentile (TX90p) and annual count of days with minimum temperatures less than 10 percentile (TN10p) in days per decade.
Figure 5 represents the trends of T2m for each month, reflected in the value of the Sen’s slope averaged over all stations for both 1961-2012 and 1979-2012 periods. Results for the period 1961-2012 indicated that the trend of temperature in May in Vietnam was almost unchanged and the stations of the northern part showed some decreasing trends (Figure 6). The temperature increase in summer was less than that in winter. The decrease in May temperature and strong increase in June temperature detected in the northern stations (Figure 5-6) might be related to seasonal changes or shifts in modes of monsoon activities over the area.

There was a noticeable difference in temperature trends in January and December between the period 1979-2012 and the period 1961-2012. While the trend of January-T2m during the 1979-2012 period was near zero, the trend of December-T2m was surprisingly high (greater than 0.4°C per decade). The differences in the T2m trends between the two periods are more clearly shown in Figure 6. One should note that these differences mainly occurred in the northern stations. The near-zero trend of January-temperature might be related to an increase in the frequency of cold events in recent years. The strong upward trend of T2m in the first half of the winter months (October-December) could be an indicator for the delayed activities of winter monsoon. This hypothesis deserves will be further investigated in the near future.

![Figure 5. Seasonal variation of the Sen’s slopes of T2m (°C/decade) averaged over all stations.](image)
3.2. Changes in rainfall characteristics

The changes of rainfall, including annual rainfall and rainfall in the monsoon seasons were fairly consistent, showing that rainfall tended to decrease in the northern climates (from 16°N northward) and increased in the southern area, especially in the South Central region (R5) for both periods (Figure 7, Figure 9). The decrease (increase) rates of rainfall in the northern (southern) regions were generally small with a majority of stations having the absolute changing rate of less than 5% per decade. The trends of rainfall estimated for the two periods were also of notable differences. The 1961-2012 trend was relatively less than that of the period 1979-2012. During the later period, there were a number of northern stations with decreasing rates (reaching -10% per decade), while the upward trends in some southern stations are detected (up to 10 to 15% per decade). From 1979 to 2012, there were a number of rainfall stations in the South having a decreasing trend of rainfall in the summer monsoon season but a sharply increasing trend in the winter monsoon season.

The changing tendencies of the annual count of rainy days (R01Ann), of the rainy days within the summer monsoon season (R01Sum) and of the rainy days within the winter monsoon season (R01Win) were basically consistent with the change of rainfall (Figure 8), except for the North (South) Central region where rainfall tended to decrease (increase) while the number of rainy days increased (decreased). The upward trend in
rainfall together with the downward trend in the number of rainy days in the rainy season in some parts of the South Central Coast and Highlands of Vietnam may lead to increased risks of flooding. As will be shown below, days and periods with intense rainfall indeed increased in southern Vietnam. On the other hand, an increase in rainfall and in number of rainy days in the dry season might not contribute much to the increase in annual rainfall but could have an important impact on crop structuring in agriculture and aquaculture.

Figure 7. Same as Figure 2 but for annual rainfall amount (R), summer monsoon rainfall amount (RSum) and winter monsoon rainfall amount (RWin) in % per decade.
Figure 10 shows the seasonal variability of the rainfall trend at each station. The order of the stations is arranged on the Y axis from R7 to R1 and from South to North. One can realize the consistency of the trends estimated from the two different periods. The alternating increase and decrease in the trend of rainfall across the months suggest a shift in seasonal rainfall regimes that could be associated with the monsoon activities over Vietnam. Averaging over Vietnam, the trends (for both increasing and decreasing ones) during the period 1979-2012 were stronger than that of the period 1961-2012. The difference was most pronounced in December, of which the trend for the period 1961-2012 was near zero, while that for the later period tended to increase by more than 8% per decade. Except for December, both periods indicated upward trends in January, March, May and July and decreasing trends in February, June and October.

The changes in rainfall regime can also be realized through the trends Rx1day, R50 and R95p (Figure 11). In Vietnam, a heavy rainy day is defined when daily rainfall is greater than or equal to 50mm. When daily rainfall exceeds 95 percentile (R95p) or 99 percentile (R99p), it is considered as an extreme rainy day. In this study, only R95p was analyzed. One can see that the trends of RX1day, R95p and R50 were basically similar to the trend of annual rainfall, i.e. all three variables had downward trends in the northern regions and upward trends in the southern part, particularly in the South Central region of Vietnam (Figure 11). Results based on the 1979-2012 data series showed that most of the additional stations (compared with the period 1961-2012) in the southern part had decreasing trends for all three variables. However, those decreasing trends were generally small.
Figure 8. Same as Figure 2 but for number of annual rainfall days (R01Ann), summer monsoon rainfall days (R01Sum) and winter monsoon rainfall days (R01Win) in % per decade.

Figure 9. Same as Figure 3 but for annual rainfall amount (%/decade).
Figure 10. Same as Figure 6 but for annual rainfall amount (%/decade).

Figure 11. Same as Figure 2 but for maximum daily rainfall (Rx1day) in % per decade, number of heavy rainfall days (R50) and number of extreme rainfall days (R95p) in days per decade.
4. Summary and future plans

In this study, it was shown that near-surface temperatures including mean (T2m), maximum (Tx) and minimum temperature (Tm) have increased consistently at almost all stations in Vietnam in the last decades. The increasing rate was faster in winter than in summer, and faster for T2m and Tm than for Tx. Consequently, the number of hot days increased whereas the number of cold nights decreased. In the northern regions, temperature tended to slightly decrease in May but significantly increased in June. Between the two periods 1979-2012 and 1961-2012, there was a noticeable difference in temperature trends in January and December, which could be an indicator for the delayed activities of winter monsoon in recent decades. This hypothesis deserves further detailed investigations in the near future.

This study also confirmed that annual rainfall decreased in the northern area of Vietnam, while it increased at almost all stations in the central regions, and had insignificant trends in the southern sub-region. The trends of rainfall estimated for 1961-2012 were relatively less than that of the period 1979-2012. Rainfall generally increased in May and decreased in June over almost all Vietnam. Changes in some extreme rainfall indices were likely consistent with changes in annual rainfall.

The unusual change of temperature in May over the northern part of Vietnam might be related to the changes of the summer monsoon and/or the extension of the winter monsoon over Vietnam. These and other aspects will be explored in future studies, focussing on the driving mechanisms for the identified changes.

References


