Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2019-425-AC2, 2020

Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on "Simulation of storm surge inundation under different typhoon intensity scenarios: Case study of Pingyang County, China" *by* Xianwu Shi et al.

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Received and published: 19 June 2020

The paper aims at quantifying the inundation range and water depth distribution due to storm surges for different typhoon scenarios for the Pingyang County in China. The typhoon scenarios are constructed in a consistent way to reflect variations in tracks and intensity. The storm surges are estimated with the hydrodynamical model. In combination with the peak river runoff values the water level scenarios are used for the estimation of the coastal flooding magnitude in case of a seawall breach. The study provides an insight into the spatial distribution of the areas potentially endangered by the typhoon related flooding. It can be helpful for further hazard and risk assessments

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for urban planning, emergency procedures or insurance. The paper is well structured and mostly easy to follow. Here are some points requiring clarification and some suggestions: Response: We greatly appreciate your kind help in reviewing the manuscript and all constructive comments. We substantially revised the paper based on these comments.

Section 3.1: Concerning the data sources and DEM, I agree with the first reviewer. Please include the response you gave, at least partially, into the paper. Response: Thanks for your suggestion. we have added the DEM as shown in Fig 1.

Fig. 2 in the review response: Please include this figure into the paper with (1) better quality (2) color code for the land elevation, so the orography of the potentially flooded area can be deduced. Response: Thanks for your suggestion. we have modified Fig. 2b and Fig. 2c according to your advice.

Section 3.3 and Tables 1 and 2: 1ïijL'139 – table content is specified as "error statistics". (1) Are these values the differences between two values: observed and modeled max high water (or max storm surge) for each typhoon and location? (2) What are the "average errors" discussed in lines 142-150 and shown in the last column and line of the Tables? These values seem not to be the average (mean) of the values in the Tables. E.g. Table 1, event 9015 – Average value 8 is not equal to the mean of (3, 2, -23), similar is true for many other lines and columns. Please either specify in the text how these "average" values were obtained or correct the average values in the Tables and discussion in the Section 3.3 accordingly. Response: Thanks for noting this error. we have modified the manuscript according to your advice. (1)These values are the differences between observed and modeled max high water (or max storm surge) for each typhoon and location. (2)The "average errors" indicates the mean absolute error of the differences between observed and modeled value in each station, and we have corrected the value in TABLE 1 and 2.

2ïijL'142-143: the locations of the tidal stations on the map (either Fig. 1 of figure with

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DEM) would be helpful. They could also help to understand the significant differences in the storm surges on Fig. 4. Response: Thanks for your suggestion. The locations of the tidal stations have been added in Fig 3.

3ïijL'144: "storm surge high tide" please reformulate because by definition "surge" is a residual of water level and the tide and has no tidal component. Response: Thanks for your suggestion. "storm surge high tide" has been changed to "water level" in the revised manuscript.

4ïijL'146: "10surge and which maximum storm surge is meant here? Is it at any particular location or/and event or averaged maximum? Please specify in the text. Also, if the 10about 10cm as mentioned in the text, then the maximum storm surge should be about 1m, however at the Fig. 4 there are storm surges reaching over 3m. Response: Thanks for your comments. the maximum storm surge means the max value for each tidal station in a typhoon storm surge event process. To avoid ambiguity, the sentences"10

Sections 3.3: The information about the tidal signal used at the open boundaries during validation is missing. Approximate tidal range at the coast is worth mentioning in this section because the discussed errors of 15-30 cm have different weight when they occur for the tidal range of e.g. 1m or 6m. Also, how the astronomical tides were estimated for calculation of storm surges is interesting, especially in connection with Fig.3 and Fig.4. Response: Thanks for your comments and question. The monthly averaged high tide levels of the previous 19 years during June–October at the Dongtou tidal stations in the study area were selected as the astronomical tide levels to simulate the inundation range and water depth of storm surges under different typhoon intensities in this study. The tidal range at Pingyang Coast is about 4m. In Fig.3 and Fig.4, the astronomical tides are computed based on observational water level data using harmonic analysis method during validation.

1ïijL'Fig. 3 and Fig. 4: Please include the dates on the x-axis additionally to the time.

The axis are different between Fig. 3 and Fig. 4 and it is difficult to recognize the corresponding water level and storm surge. For example, for Ruian on Fig.4 there is a storm surge of 3m, however on Fig.3 for the same location and same typhoon it is really hard to deduce when such high surge has taken place. Response: Thanks for your suggestion. We have modified Fig 3 and Fig 4 in the revised manuscript.

2ïijL'189: Please provide a quantitative example of the highest water level during this typhoon for any location of your choice in the area of investigation. Response: Thanks for your suggestion. the tidal level at Aojiang Station caused by Typhoon Fred was presented in the manuscript as below: This typhoon landed at the time of the highest astronomical tide and it generated the highest tide level ever recorded in the coastal area, causing the tidal level at Aojiang Station up to 6.56m.

3ïijL'197-198: (1) does "constant direction of movement" mean that the modified typhoon moves in a straight line? If not, please reformulate. If yes, please explain how this constant direction correspond to original typhoon track. (2) "track... was translated to the landing site..." – meaning the track was shifted so that landing points coincide? (3) the map with the original tracks of the two typhoons and the "designed typhoon" track described in the line 202 would be very helpful here Response: Thanks for your suggestion and comments. (1) "constant direction of movement" mean that the designed typhoon" track move in the same direction and are parallel to the track of 0608 "Saomei". (2) yes, "track... was translated tothe landing site..." means the track was shifted so that landing points coincide. (3ïijL'the map with the original tracks of the two typhoons and the "designed typhoon" track were presented in the revised manuscript as shown in Fig 6 and 7. 4ïijL'215: "36 and 36 km" please correct Response: Thanks for noting this. We have carefully checked it, and there is nothing wrong. Where the central air pressure ($P_0) wassetto915or925hPa, theradiusofmaximumwindspeed(R)bothobtainthevalueof36kmcomputingbyFormula4.$

5ïijL'220: change "coupled" to "linearly added" - as far as I understood, the high tide values were linearly added to the peak surge heights at the coast Response: Thanks

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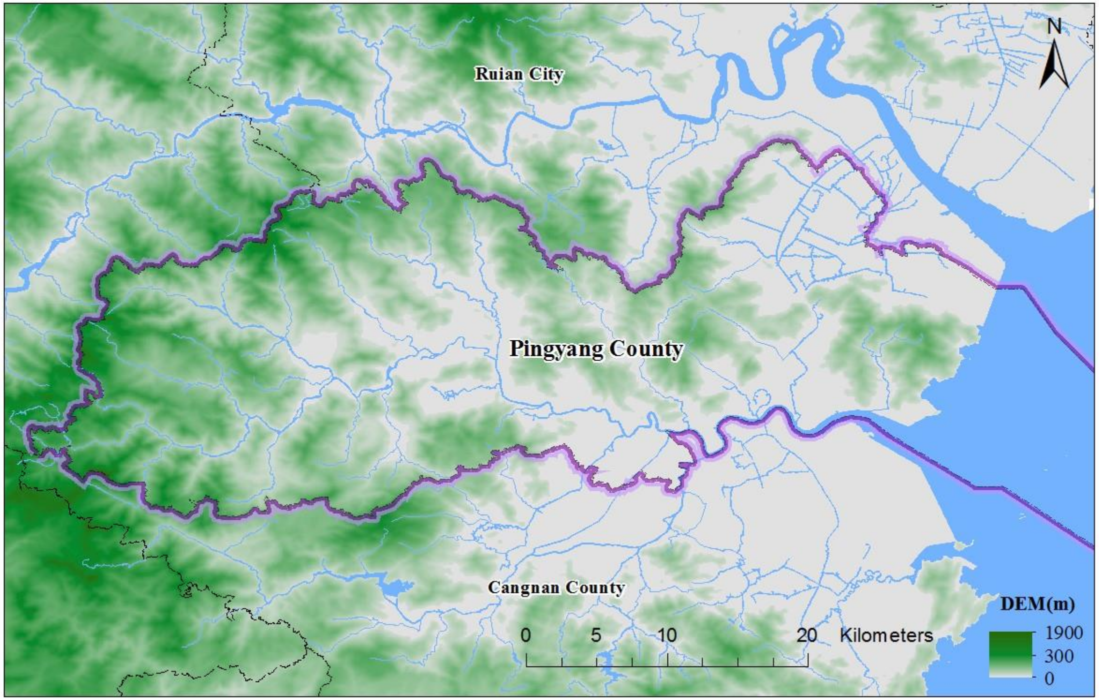
for your suggestion. We have changed "coupled" to "linearly added" in the revised manuscript.

6ïijĽ229: "peak flow in an estuary has no obvious influence..." - Does it mean the peak flow does not influence water levels during the typhoon OFF the estuary or IN the estuary? If the former, please add this to the sentence. If the later, then it contradicts with the next two sentences, where it is stated that "storm surge-runoff interaction...increases the tidal level...". Response: Thanks for your suggestion. It means the peak flow does not influence water levels during the typhoon off the estuary after we looked up the reference (Sun et al., 2017). This sentence has been modified as below in the revised manuscript: The peak flow in an estuary has obvious influence on the high-water level during the passage of a typhoon (Sun et al., 2017).

7ïijĽ245-246: Where the wave overtopping rate came from in the numerical simulations for this study? Was the wave model additionally used to estimate the overtopping? Or how the wave overtopping was found based on the results from the storm surge model? Please specify. Response: Thanks for your question. The typhoon-astronomical-flood-wave coupled numerical model was used to perform the storm surge simulation in this study (Chen et al, 2019). Waves caused by typhoon are simulated by SWAN model, which can describe the evolution of wave fields under specific wind, flow and underwater terrain conditions in shallow waters. The governing equation is as follows. $\partial/\partial_t N+\partial/\partial_x C_x N+\partial/\partial_y C_y N+\partial/\partial\sigma$ Cσ N+$\partial/\partial\theta$ Cθ N=S/σ In the equation, N is wave action, σ is relative frequency of waves, θ is wave direction, and S is source item. C$_x andC_y arewavepropagationspeedinxandydirection, respectively.C\sigma$is propagation speed of wave action in frequency space, and Cθ is the propagation speed of wave action in wave direction space. Based on the wave elements and the structural parameters of the seawall, the overtopping discharge is calculated by the empirical formula. In the simulation of dike-breaching, the varying dike top elevation is applied according to overtopping discharge to simulate the process of dike-breaching. Discussion: Discuss the limitations and sources of uncertainty originating in e.g. linear combination of averaged high tides instead of dynamically simulated surge and tide with their interaction; simplified seawall collapse scenarios and how this can affect the estimates of inundated areas (for example, in this study inundation is independent on the duration of the storm surge event). Response: Thanks for your suggestion. According to your advice, the sections of Discussion and Conclusion has been modified in the revised manuscript. The limitation and sources of uncertainty of this study have been modified in the revised manuscript This study presents a framework of calculation of inundated areas under different typhoon intensity scenarios. The proposed framework was composed by four parts: model configuration, model validation, parameters setting and inundation simulation. Based on the historical observational data, the key parameters (e.g., typhoon track, radius of maximum wind speed, astronomical tide, and upstream flood runoff) could be set to drive the storm surge numerical model. A high-precision numerical model was established and validated for simulating storm surges within the study area. Using these key parameters as driving factors, the inundation range and water depth distribution in Pingyang County corresponding to the storm surges under different typhoon intensity scenarios were simulated in combination with the storm surge numerical model. The obtained results could serve as a basis for developing a methodology aimed at storm surge disaster risk assessment in coastal areas. The proposed method could be easily adopted in various coastal areas and serves as an effective tool for the decision making in storm surge disaster risk reduction practices. The inundation range of a storm surge is related to many factors (Petroliagkis, 2018), linear combination of averaged high tides instead of dynamically simulated surge and tide with their interaction would cause uncertainty of the simulated results. In this study, the process of inundation is independent on the duration of the storm surge event, and the seawall collapse scenarios is simplified in a sudden, which could increase the inundation range of the simulated result.The high-water level in the towns of Shuitou and Xiaojiang in Pingyang County is mainly caused by the upstream flood of the Aojiang River. Consequently, the inundation situation in these two areas is directly related to upstream flood runoff. In this study, the impact of the upstream flood was only considered as the average of the flood peak flow during the storm surge. The water level and inundation range caused by the large astronomical tide due to the superposition of the extreme flood scenarios might be more unfavorable than the simulated storm surge with the superimposed average of the flood peak runoff, which might result in uncertainty in the calculation results. In our next study, we will further analyze the quantitative response relationship between typhoon intensity at landfall and upstream flood runoff, and propose a method for setting flood runoff upstream of the estuary area. This paper presents a deterministic method for setting key parameters under typhoon intensity scenarios assuming that these factors (e.g., typhoon track, radius of maximum wind speed, astronomical tide, and upstream flood runoff) are independent; however, any correlation between these parameters is ignored. The occurrence probability of parameter combinations is difficult to evaluate. The joint probability method is an efficient way to determine the base flood elevation due to storm surge (Yang et al. 2019), and the joint probability among these factors could be established (e.g., using the Copula method) to calculate the occurrence of extreme storm surge events. This study contributed to the methodology of quantitative assessment of storm surge hazards for coastal counties. If combined with a vulnerability curve between the loss ratio of typical exposure influenced by storm surges and the water depth induced by flooding in coastal areas, a quantitative storm surge risk could be evaluated in future research. The results of a quantitative assessment of storm surge risk could provide a theoretical basis for urban planning, development of emergency evacuation procedures, and disaster insurance.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2019-425/nhess-2019-425-AC2-supplement.pdf

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2019-425, 2020.



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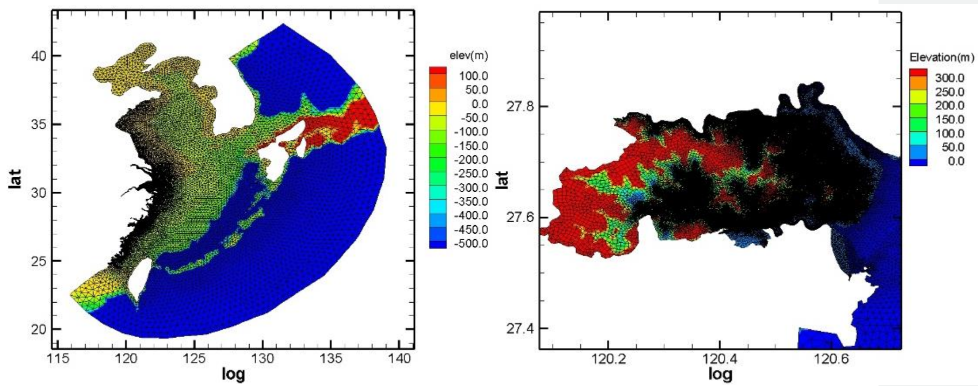
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50.0
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-50.0
-100.0
-150.0
-200.0
-250.0
-300.0
-350.0
-400.0
-450.0
-500.0
lat
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Elevation(m)
300.0
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Fig. 3. the distribution of tidal station along the coastal Zhejing Province

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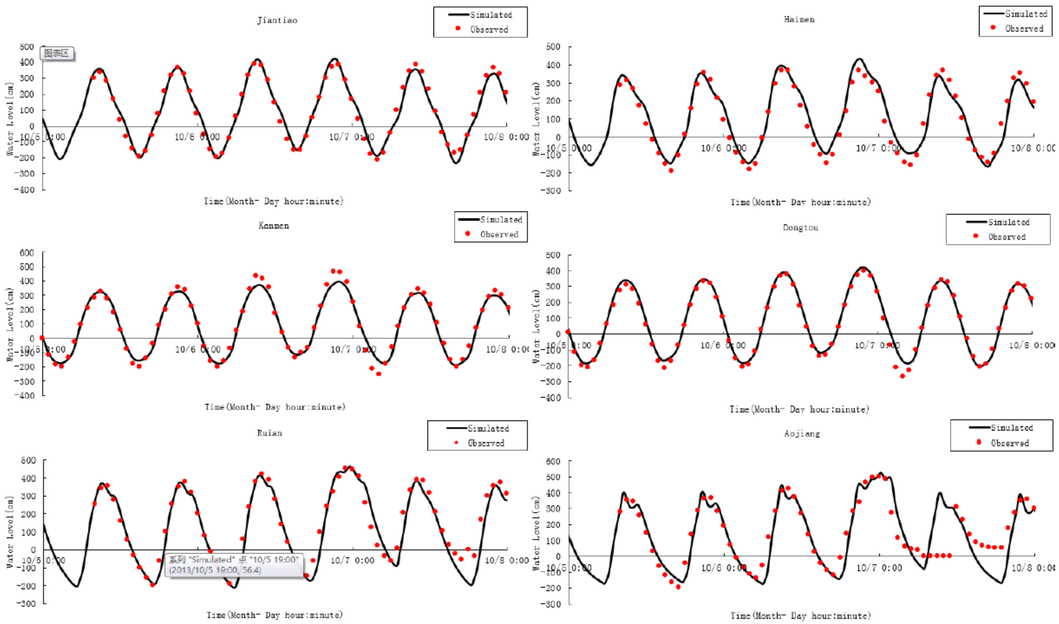

Fig. 4. Verification of the water level for tidal stations affected by the storm surge caused by Typhoon Fitow (No. 1323)

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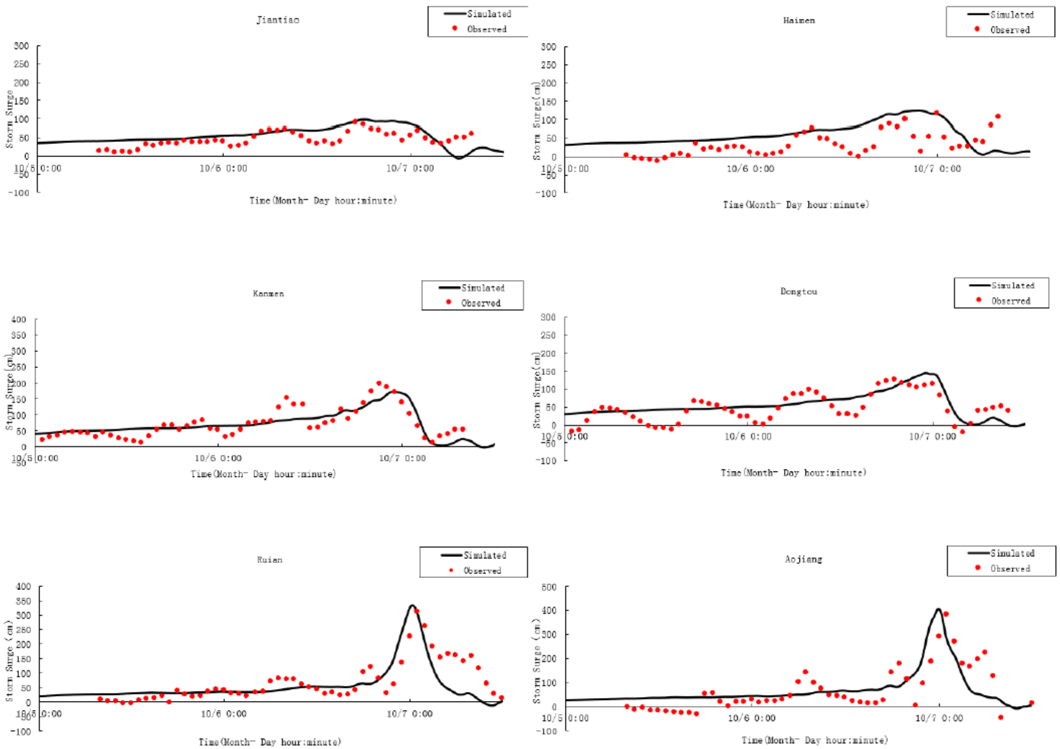

Fig. 5. Verification of the storm surge for tidal stations affected by the storm surge caused by Typhoon Fitow (No. 1323)

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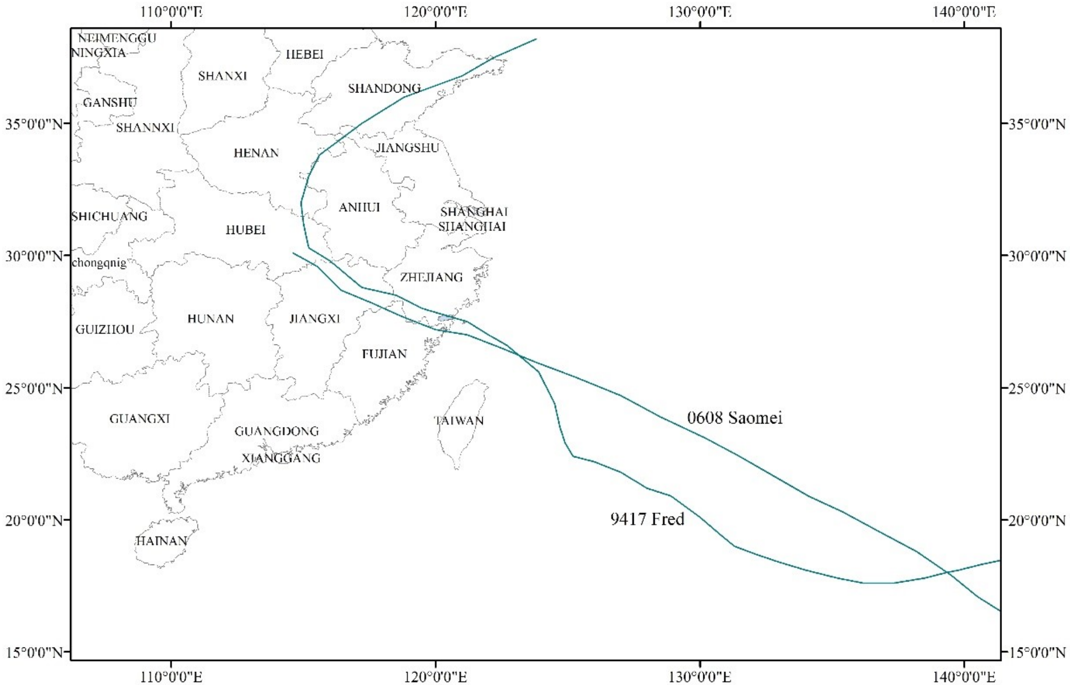

Fig. 6. Typhoon track of 9417 “Fred” and 0608“Saomei”

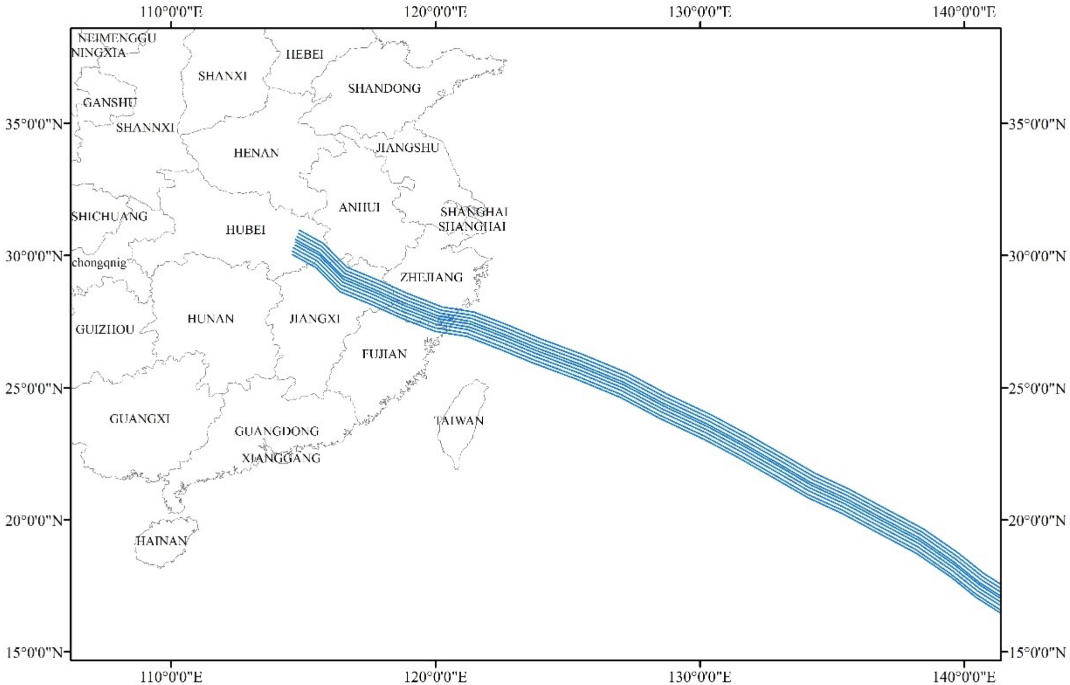

Fig. 7. "designed typhoon" track set over Pingyang County