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Reconstruction Assessment of the Paleo-inundation Condition in the Nile River Basin Part I: Basic Process

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Synopsis

Paleo-inundation condition assessment is the study of the historical inundation under the past flood events which occurred prior to direct measurement of hydrologic parameters using modern methods. The ultimate objectives of this study are to estimate paleo-inundation under the extreme floods using historical literature and incomplete data records. This paper focuses on showing an application example for estimating the historical inundation conditions under the paleo-floods using modern technologies at the river basin scale.

Keywords: Paleo-inundation, Nile River basin, Flo-2D, flood risk management

1. Introduction

Inundation simulation is very import for flood risk management to reduce the damage and economic loss and provide escape information of flood disaster. Paleo-inundation study which is a part of paleo-flood hydrology study is to calculate the inundation conditions under the historical events by using the historical information and modern methods. Paleo-inundation analysis play an important role on reconstructing the flooding and damage conditions, evaluating the historical flood control policy, providing the experiences of historical flood risk management and escape technology.

Paleo-flood hydrology is the study of past flood events which occurred prior to direct measurement of hydrologic parameters using modern methods(Baker et al., 1987). Although there is some ambiguity between the terms ‘paleo-floods’ and ‘historical floods’, we use the terms here to refer to any past flood that must be recreated due to a lack of direct measurements (Baker et al., 1987). The most popular technique of paleo-flood hydrology is the analysis of slack water deposits and paleo-stage indicators (SWD-PSI). Research in this area has focused on: (1) geochronology, (2) hydraulic modeling, (3) flood-frequency analysis, and (4) climate impacts (Baker et al., 2002). Paleo-hydrology is increasingly studied world-wide. In recent studies, a three-dimensional coupled climate model consisting of three components describing the atmosphere, ocean and vegetation (ECBilt-CLIOVECODE) (Brovkin et al., 2002; Goosse and Fichefet, 1999; Opsteegh et al., 1998) was developed and used to model the paleo-climate. The hydrologic model STREAM (Aerts et al., 1999) has been used to simulate paleo-discharge (Ward et al., 2007, 2008 and 2011) using paleoclimate data from ECBilt-CLIOVECODE.

The hydrology and paleo-hydrology studies in Nile river basin have been studied in many previous researches. The Nile river recorded flood level in Roda island have been studied to find the multiscale detection of abrupt climate change by using Mann-Kendall rank test (Fraedrich et al., 1997;Jiang et al., 2002). Oscillatory modes have been used to extend the Nile river records from 622 A.D. to 1922 A.D.(Kondrashov et al., 2005). The deep Mediterranean sediments have been observed to find the Nile flood records and provide a direct link between the deep-marine sedimentary records and climate change(Ducassou et al., 2008). The relationships between the paleo-climate variability and paleo-flood have been presented (Hassan, 2007;Eltahir, 1996). There are many researches in the Nile river basin focus on the sediments isotope to find the paleo-flood records and paleo-climate conditions(Beuning et al., 2002;Ducassou et al., 2009), climate change impacts on hydrology (Elshamy et al., 2009), Sediment transport(Billi and el Badri Ali, 2010;Khalifa, 2012;Ya, 2011), and Hydrological modeling(Setegn et al., 2008;Chebud and Melesse, 2009;Petersen and Fohrer, 2010). It is important to simulate the paleo-inundation conditions for the paleo-hydrology study in the Nile river basin.

In this study, the main objectives are to build the basic process for the paleo-inundation reconstruction analysis, to provide a case study for the paleo-inundation reconstruction assessment, and give a discussion on the basic process.

2. General

Nile river is the one of the longest river in the world with 6740km from the source to the sea. The Nile river basin is extends from 4°S to 32°N and covering an area of 3 million km2.It is including two main branches (Blue Nile and White Nile), a main Nile and lakes(Victoria, Albert, Kayoga, Edward).The climate in the upstream of Nile river basin is tropical, and the climate in the downstream of Nile river basin is arid and semi-arid. The mean annual rainfall in the upstream is 1200 mm, but that in the downstream is less than 10 mm. In this study, we will focus on the main Nile river basin in the Egypt. The detail location is shown in the Figure 1.

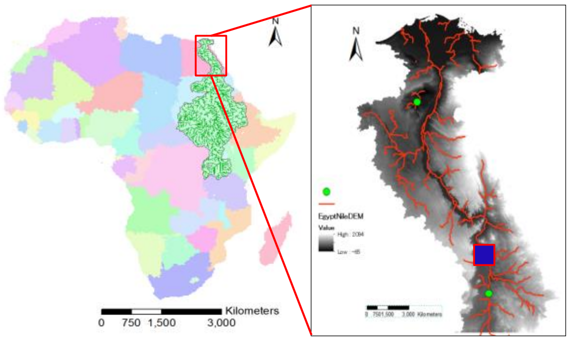

Figure 1 Location of study area with the blue square in the left DEM map.

3. Methods

3.1 Process of scenario paleo-hydrology study

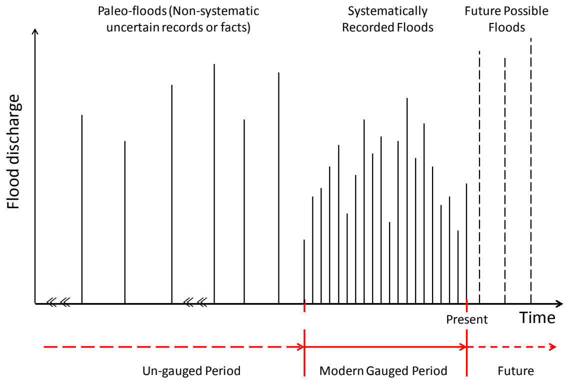

Figure 2 Paleo-floods, systematically recorded floods and future possible floods (Luo et al., 2013)

In this section, it is descripted the basic process of paleo-hydrology reconstruction. Figure 2 show the time series of the hydrological studies. The main target of this study is to reconstruct the paleo-inundation condition in the past period. The detail framework of this study is presented in Figure 3. The process of this study is described as follow:

(1)We collected the observed data in present period such as digtilized inundation maps, systematical recorded discharge, rainfall and water depth, and DEM, land use, soil type, river channel. The present observed data can be get from the online database, books and websites.

(2)The historical recorded data of rainfall, discharge, water level, environment conditions and so on will be collected from the old maps, books, pictures and drawers in the paleo-period. The paleo-period is the past period which is lack of the systematical recorded data (Figure2).

(3)Based on the collected data in present period and paleo-period, we will construct the historical scenario condition for paleo-inundation simulation.
(4)The climate model, hydrological model, and environment construction model will be calibrated and validated by using the collected data in present period and paleo-period.
(5)The paleo-inundation condition is reconstructed by using the historical scenario condition from step 3, the simulated data and calibrated models from step 4.

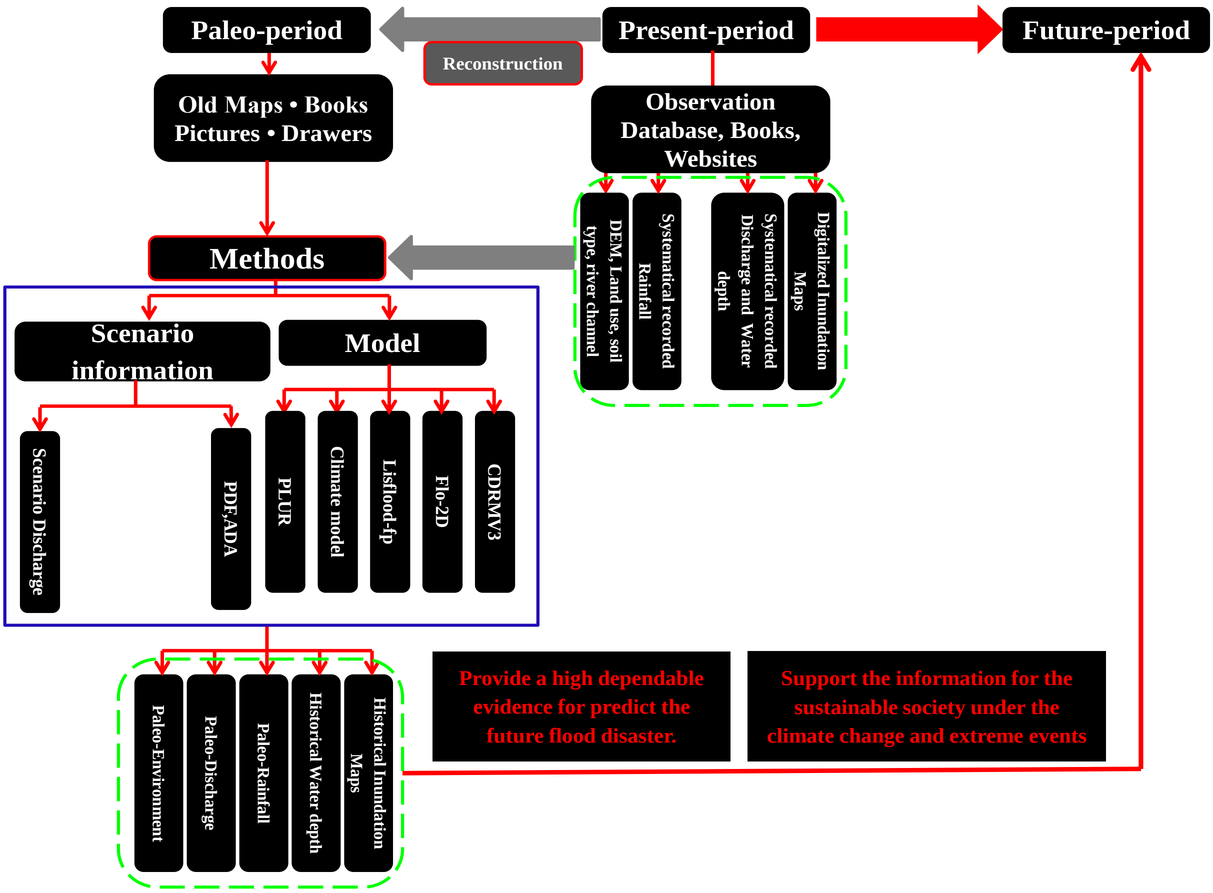

Figure 3 Process of paleo-hydrology study

3.2 Flo-2D model

FLO-2D is a two-dimensional finite difference model that simulates clear-water flood hazards, mudflows, and debris flows on alluvial fans and urban floodplains. Interactive flood or mudflow routing between channel, street, and floodplain flow is performed using a uniform grid system to describe complex floodplain topography.

In this study, we used the Flo-2D software to reconstruct the paleo-inundation condition. The detail steps are described as follow:
(1)We use the data from step 1 of section 3.1 to process the DEM, land use and river boundary in ArcGIS, and converse the raster file to ASCII file.
(2)The transferred ASCII files from step 1 are used as the input in GDS of Flo-2D software.
(3)In the GDS, we need to create the grid by using the grid size 100m, define the simulation boundary using polyline shape file, and interpolate the elevation points.
(4)The paleo-informations such as paleo-land use, paleo-dykes and paleo-channel will input in the simulation area which is defined in step 3.
(5)We will define the input flow point and output elements for calibration.
(6)The inundation condition will be presented in Mapper of Flo-2D software.

4. Results and Discussion

The case study results are presented in this section. We chose two case studies, the first one is the inundation condition over bank flow, and the second one is the inundation in the floodplain under the historical basin scale flood prevention method.

For the first case study, we used the historical discharge without Aswan dam to reconstruct the scenario discharge (Figure 4).

In Figure 5, we found the highest water level is located inside the river channel close to the input point, and it overflow to the floodplain. The most water lever of the inundation condition in the flood plain is less than 2.5 meter, but there are two areas have the high water level in the flood plain which is the area close to the input point, and the area in the middle of river channel with green color.

For the second case study, we simulated the basin scale method for flood prevention based on the historical information. The input scenario discharge is presented in Figure 6. In this case study, we make the boundary dykes with 150 meter elevation, No.1 dykes are 100 meter elevation, and No.2 dykes are 120 meters elevation (Figure 7). The paleo-inundation condition using the basin scale method is shown in Figure 8. The highest water level is 34.3 meter which appears in the area close to the input point. The flood is overflowing from Dyke No.1 to Dyke No.2, and it is stopped by the Dyke No.2.

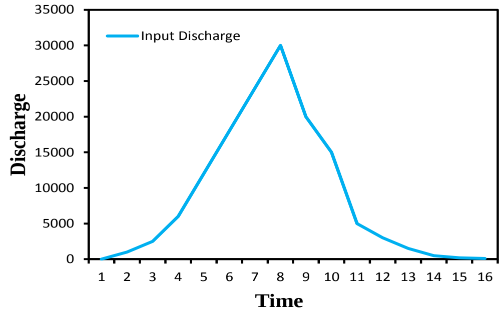

Figure 6 Scenario Discharge for case study 2

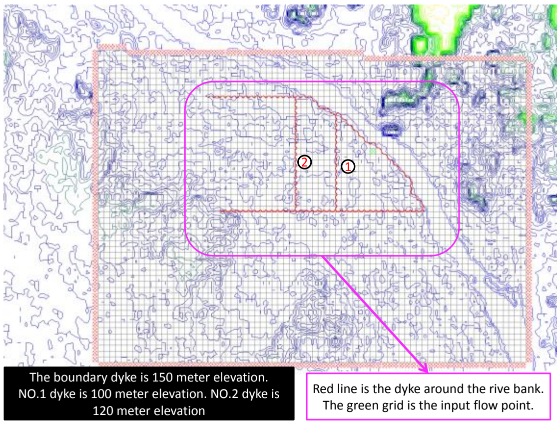

Figure 7 Structure of paleo-condition for case study 2.

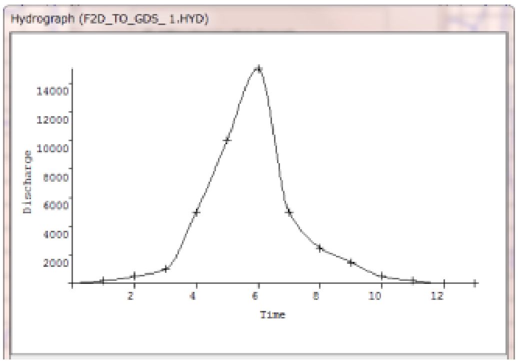

Figure 4 Scenario Discharge for case study 1

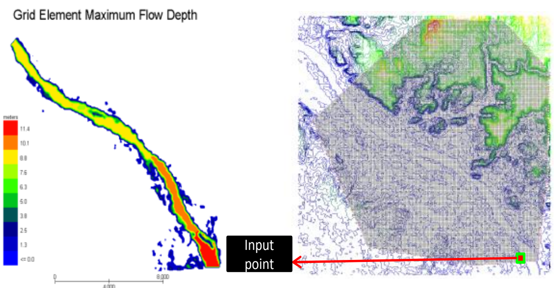

Figure 5 Inundation condition of case study 1

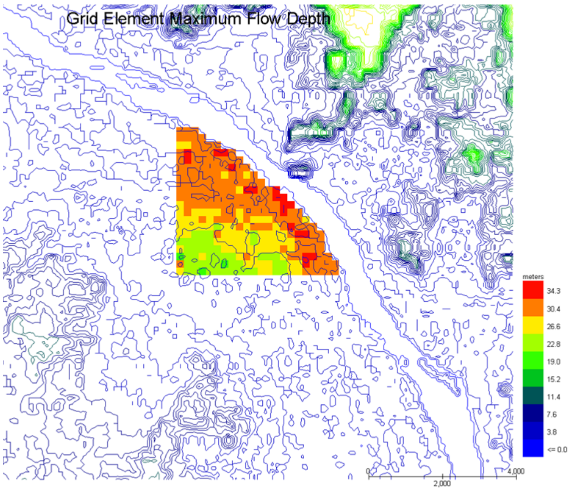

Figure 8 Paleo-inundation condition using basin scale method.

This paleo-inundation reconstruction is important to evaluate the past flood control policies and get the experience from the paleo-flood events. However this study is basically introducing the process of the paleo-inundation and paleo-hydrology simulation. Due to the lack of detail historical data and information, it is necessary to have a further research focus on the paleo-inundation and paleo-hydrology with the historical calibration and historical input data.

5. Conclusions

The basic process of paleo-inundation and paleo-hydrology reconstruction in the Nile river basin is developed in this study. A detail steps for paleo-inundation reconstruction assessment using Flo-2D is also described. Two case study of paleo-inundation condition have been study using Flo-2D software under the histrocial scenario discharge and basin scale method. A further study of the paleo-inundation and paleo-hydrology reconstruction using the historical recorded data is necessary.

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