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Application of Google Earth in Modern River Sedimentology Research*

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Abstract

Google Earth, a software based on satellite's images and database of navigation, gains features of high resolution, integrated images, quick update, convenience, simpleness and free cost. Practice of this software shows that it plays an important role in mapping, construction and river research. Based on the fundamental features of Google Earth, this passage makes an introduction to its application in studying modern river sedimentology through the case study of the Yellow River. The results show that Google Earth satellite's high-resolution images and image overlay functions make it easy for users to quickly navigate river, determine the type of river, track the river flows and measure the terrain slope; the software's "Ruler" and "Add Path" functions make it easy for users to measure channel width, curvature, amplitude, wavelength, size, morphology of point-bar and other river parameters; the software's "Historical Image" function has important significance in the study of modern river migration, sedimentary evolution and river geomorphological shape during different seasons.

Keywords

Google Earth, River Type, Terrain Slope, River Parameters, Modern River Evaluation

1. Introduction

Google Earth is a set of software based on satellite and GPS data, which allows users to view satellite image, maps, terrain and 3D buildings on a 3D interactive sphere [1], and to measure the length and height of target objects as well. As one of the most popular digital earth platforms at present, it has characteristics of high resolution, integrated images, quick update, convenience, simpleness and free cost. Practice of the software found that

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it can play an important role in many previous studies, including application in construction [1]-[4], surveying and mapping [5]-[7], setting up the database [8] and visualization model [9]. In the study of rivers, Alice Goudie [10] used Google Earth to measure the stream distribution and geomorphological characteristics of salt marsh in England and Wales. Result shows that the density and the bending of a stream are closely related with tidal range. Shi Shuyuan [11] put forward the method to build geological knowledge database of meandering river based on the Google Earth software. Li Yupeng [12] used Google Earth software to measure modern rivers and concluded that the river width had a positive correlation with the length of point-bar. He pointed out that it had a function of guiding the quantitative analysis of reservoir configuration under the point-bar of meandering river. Zhang bin [13] measured and defined the parameters of meandering river based on the Google Earth software. He pointed out that the deep meander of Jialing River was one of the world's most complex, irregular and curved channels. Zhang Changmin [14] used Google Earth software to study modern deposition of Dongting Lake and Poyang Lake. He found two types of delta. The application of Google Earth to river geomorphology and sedimentology shows that it does have a lot of uses, especially in the study of sedimentary and geomorphic features of rivers in macro. However, when the previous uses Google Earth to study the modern river sedimentology, they often only focus on a single aspect. So on the basis of characteristics of Google Earth software, this paper uses the Yellow River as an example, introducing the application of Google Earth software to the measurement of river types, terrain slope, river parameters and analysis about evolution of modern rivers.

2. Google Earth Overview

2.1. Software Introduction

Google Earth is virtual globe software which was first launched by Google Company in 2005. It decorates the satellite images, aerial photography and GIS on a 3D model of the earth [15]. Users can get free high-resolution satellite images around the world through the Google Earth software.

2.2. Image Accuracy

Google Earth integrates satellite images with aerial data. Parts of satellite images are from the Digital Globe and Earth Sat companies. Aerial images are derived from the Blue Sky, Sanborn, IKONOS and SPOT5 companies. The SPOT5 Company can provide images with the resolution of 2.5 m. The IKONOS Company can provide image with the resolution of 1 m, and the Quick Bird Company can offer 0.61 m high-precision image which is the highest level of global business [3] [16]. High-precision images are advantageous to the meticulous research of river types and sedimentary characteristics. Although there is a certain error when using the Google Earth software to extract related parameters of the river, the influence to macro geomorphology research can be ignored.

2.3. Platform Interaction

Google Earth is not only a satellite image browsing software, but also an interactive platform which combines satellite images, maps with related information and communication. The interaction of this platform shows in two aspects: "Layer" and "Landmark" function. The "Layer" function is similar to the layer management function of AutoCAD software. It can classify and manage information through different layers. Each layer can be displayed on and off in need to maintain a clear and clean interface. The "Landmark" is the address label, it can be inserted to the map in order to make annotations, reminders. The "Landmark" can be saved and exported as a separate file [5] [17].

3 Application of Google Earth in the Study of Modern River Sedimentology

3.1. River Classification

In the study of modern river sedimentology, different types of river have different features of depositional model and geomorphologic shape. With the launch of Google Earth software, users can quickly determine the river types by observing sedimentary and geomorphological features of rivers through high-resolution satellite images. In the field of sedimentology, rivers are divided into braided river, meandering river, anastomosing river and Straight River. There is great difference in their macro geomorphological and sedimentary characteristics (**Table 1**).

Braided River (**Figure 1(a)**) has features of flat valley, low curvature, and high terrain slope. It has many channel bars in the whole valley and its channel branches off around diara. It is like intertwined "braid" in the valley and the channels and bars are very unstable, constantly migrating its path in the deposition process.

Meandering River (**Figure 1(b)**) has features of single channel, high curvature, and low terrain slope. Its riverbank can resist strong corrosion. The entire deposition process is that the concave bank constantly being eroded while the convex bank keeps accumulating deposition. Point bars can see clearly on the Google Earth satellite images.

Anastomosing River (**Figure 1(c)**) has features of multi-channel, straight or curved, low terrain slope. It has stable riverbank composed of fine-grained sediments (silt or clay) and vegetation. These channels are separated by river flood plain composed of natural levee, Vegetation Island and wetland. The difference between the braided river and the anastomosing river is that the anastomosing channels are stable while the braided channels are unstable.

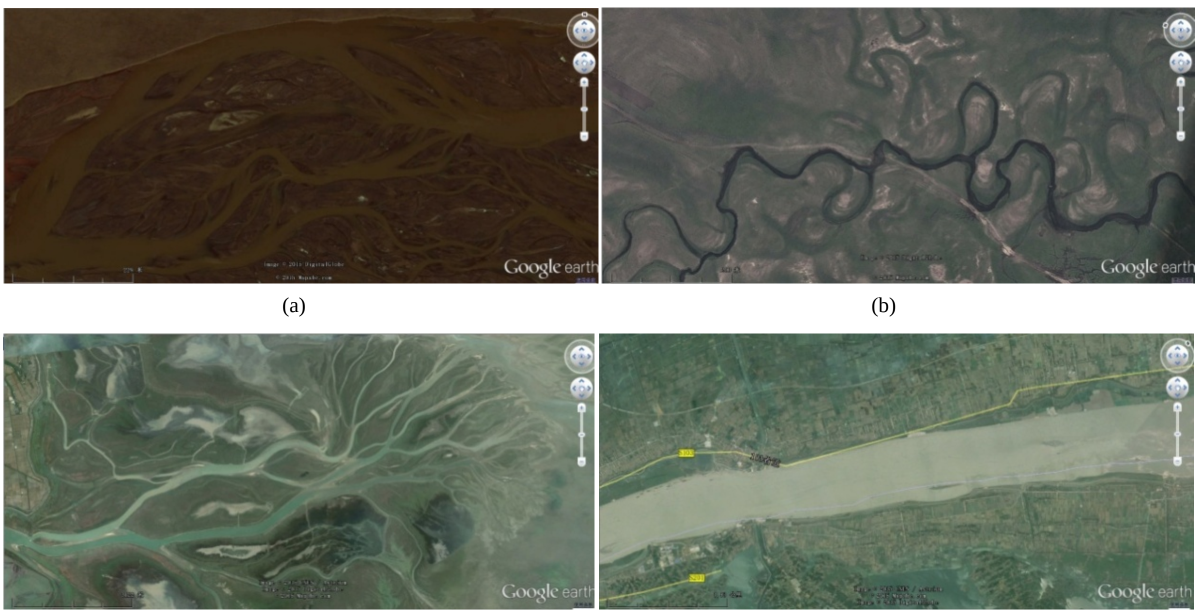
Straight River (**Figure 1(d)**) has features of single channel, low curvature. If the channel's curved index < 1.5, it is Straight River. It can be used as criteria to distinguish Straight River and braided river.

In the actual study, steps of using Google Earth to divide river types are as follows:

1) Open client software, type the name of the river or place that river flowing through in the upper left corner

Table 1. Comparison table of geomorphological and sedimentary characteristics of different rivers.

River Type	Curvature	Channel Morphology	Channel Stability	Channel Sand	Abandoned Channel Characteristics
Braided River	Low	Two or More Channels; Sand Islands and Sandbanks	Very Unstable, Rapid Migration	Channel Bar	No Oxbow Lake
Meandering River	High	Single Channel	Gradually Lateral Migration	Point Bar	Oxbow Lake
Anastomosing River	Low-Medium	Two or More Channels; Large Stable Sand Islands	Stable	No Channel Sandbanks; Little Point Bar	No Oxbow Lake; Abandoned Channel
Straight River	Very Low-Low	Single Channel	Unstable	Unstable Point Bar; Alternate Distribution	No Oxbow Lake



(a) (b) (c) (d)

Figure 1. Satellite's image of different types of river. (a) Braided river has many channel bars in the whole valley and its channel branches off around diara; (b) Meandering River has features of single channel, high curvature, low terrain slope; (c) Anastomosing River has features of multi-channel, straight or curved, and has stable riverbank composed of fine-grained sediments (silt or clay) and vegetation; (d) Straight River has features of single channel, low curvature.

of the search field to locate river (Figure 2). At the same time, users can also create corresponding landmarks in order to find it again quickly if necessary;

2) Find the research section of the river on Google Earth satellite images, combine geomorphological and sedimentary characteristics of different types of river (Figure 1 and Table 1) to determine the its type.

According to the methods above, the river type of the Yellow River from Baihe Town (34˚51'35.74"N, 112˚33'41.26"E) to Zhengzhou City, Garden Town (34˚54'20.40"N, 113˚42'4.78"E) is braided river. The bifurcation index of the river is high, and its channel bar is significant (Figure 3).

3.2. Terrain Slope Measurement

In the study of fluvial sedimentology and geomorphology, the terrain slope is one of the significant factors controlling river types. In general, the terrain slope of braided river is big, while that of meandering river and anastomosing river is small. Measuring the terrain slope can be used to explore the relationship between different types of river and terrain slope in different river basins. The terrain slope, one of the basic parameters of the river, can provide data for the development of water conservancy projects directly when it converted to basin slope. However, the lack of data of early aerial photo limits some scholars' research and measuring work. With the launch of the Google Earth software, users can quickly locate rivers, track the flow direction and batch obtaining altitude data via Google Earth online images. It provides great convenience for the measurement of terrain slope.

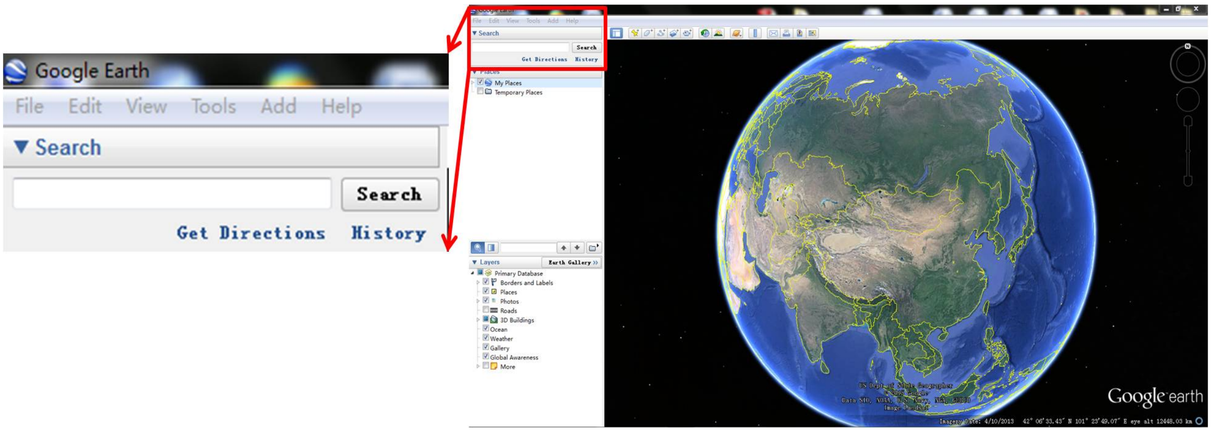


Figure 2. Schematic diagram of searching and navigating river. The red box of the image shows the window of searching for places.

Figure 3. Analysis chart of river type of Yellow River from Baihe town to Zhengzhou city, garden town. the channel bars of the braided river can be seen clearly in the red box of the image.

In the actual study, steps of using Google Earth to measure terrain slope are as follows:

1) Use the search tool to find the selected rivers, and then observe the flow direction and characteristics of the river basin before selecting target parts of river for measurement. The Google Earth software does not display the rivers' name, which brings great inconvenience to the researchers when tracking the rivers. So users can use layer overlay function to superpose third-party street map directly on the Google Earth image to improve efficiency;

2) Create the starting "Landmark a" and ending "Landmark b" on the Google Earth image of the selected river;

3) Read latitude, longitude and altitude Ha, Hb of the two landmarks respectively and measure the "Distance L" between the two landmarks through the "Ruler" function in tool bar (**Figure 4**);

4) Calculate the corresponding terrain slope θ based on the relationship of trigonometric functions:

$$\theta = \arcsin\left(\frac{Ha - Hb}{L}\right).$$

Firstly, use one braided reach of the Yellow River from Zhengzhou City, Sun Village to Garden Town as an example (**Figure 4**, **Table 2**) and measure the terrain slope of this braided river. The altitude of starting "Landmark a" (113˚34'32.69"E, 34˚56'57.39"N) is 94.368 m and that of ending "Landmark b" (113˚41'53.64"E, 34˚55'1.34"N) is 91.102 m. Secondly, use the "Ruler" tool to measure the "Distance L" between two landmarks and the result is 11.73 km. Lastly, put the measured data into topographic gradient calculation formula in the step 4) to calculate the terrain slope and the result is 0.016˚.

3.3. River Parameters Measurement

Google Earth satellite images gain features of high resolution, high precision. So in modern river sedimentology research, using Google Earth software "Add Path", "Ruler" tool, can directly measure the river's width, curva-

Table 2. Calculation table of terrain slope of braided river in the yellow river from Zhengzhou city, sun village to garden town.

River Length L (km)	Landmark a			Landmark b			Height difference Ha-Hb (m)	Slope (˚)
	Longitude (E)	Latitude (N)	Altitude (m)	Longitude (E)	Latitude (N)	Altitude (m)		
11.73	113˚34'32.69"E	34˚56'57.39"N	94.368	113˚41'53.64"E	34˚55'1.34"N	91.102	3.266	0.016

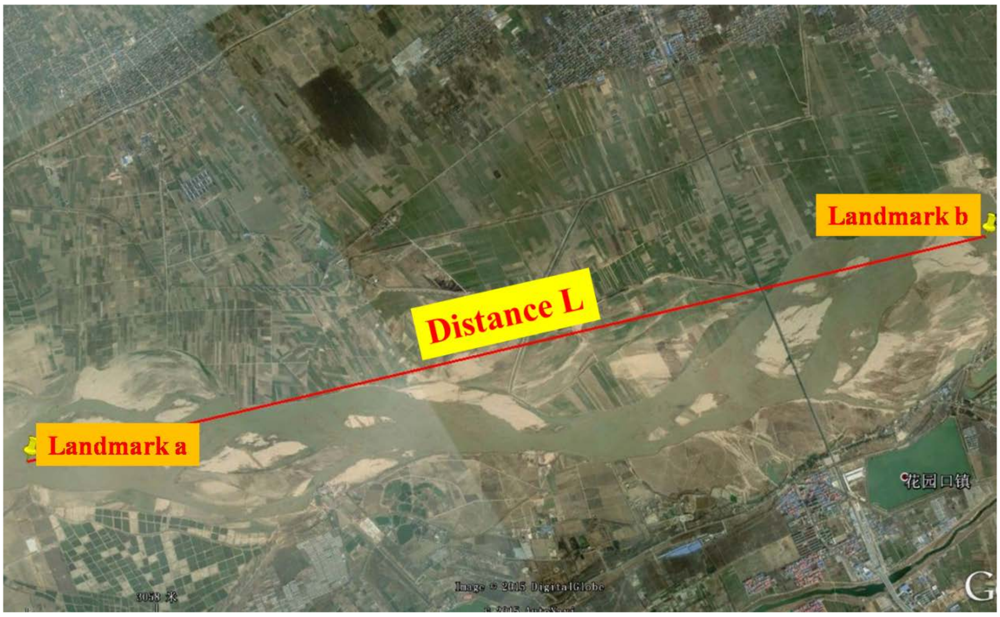


Figure 4. Schematic diagram of measuring terrain slope, the red line connecting two yellow landmarks is the "Distance L" that needs to be measured.

ture, amplitude, wavelength, point bar size and shape and other river parameters.

In the actual study, the main measurement steps of measuring the meandering river's point bar parameters are as follows:

1) Find the meandering river's fluvial deposits point which is need to be measured on the Google Earth satellite image and select the appropriate resolution;

2) Use the "Add Path" tool to delineate river unit which is under measurement on Google Earth satellite images;

3) Use "Distance Measurement" function in "Ruler" tool under the model of measurement tool, add an anchor point-by-point along the curve with the mouse and finally measure the length of the curve.

According to the methods above, use a point bar (37˚45'28.04"N, 119˚8'57.74"E) near the Yellow River estuary as an example (**Figure 5**). Then use Google Earth software to select the appropriate set of measurement points. The result of the measurement is that the channel width is 0.29 km, the length of point bar's arc is 2.19 km and the diameter of it is 0.97 km.

3.4. Modern River Evolution Analysis

Google Earth has the function of checking the historical satellite images. This function is of great importance to the study of modern rivers changes, sedimentary evolution and the river geomorphology in different seasons. At present, the Google Earth can check the earliest historical images in 2000. However, there will be a slight difference in the time of year when checking the historical images in different regions.

In the actual study, the steps of checking historical images are as follows:

1) Find the river on the Google Earth satellite image, and keep the interface stable;

2) Click the "View" column, find the "Historical Image", and check the item;

3) The time axis will appear in the upper left corner, and the two sides of the axis are the earliest and the latest year's images of Google Earth respectively. Move the axis pointer to view the corresponding year's historical images.

Use one meandering reach of the Yellow River near Fengqiu County, Yangzhai Village (34˚56'35.32"N, 114˚27'14.83"E) as an example. The red lines in the figure are the stable dams fixed on the both sides of the Yellow River, so they are used as the reference in the study of modern river evolution. According to the Google Earth's historical images of this meandering reach in different years from 2000, it can be found that the meander near the dam which is built on the upper left side migrated towards east from 2002 (**Figure 6(a)**) to 2006 (**Figure 6(b)**).There was little changes to the dam on the upper left side while the two meanders near the lower

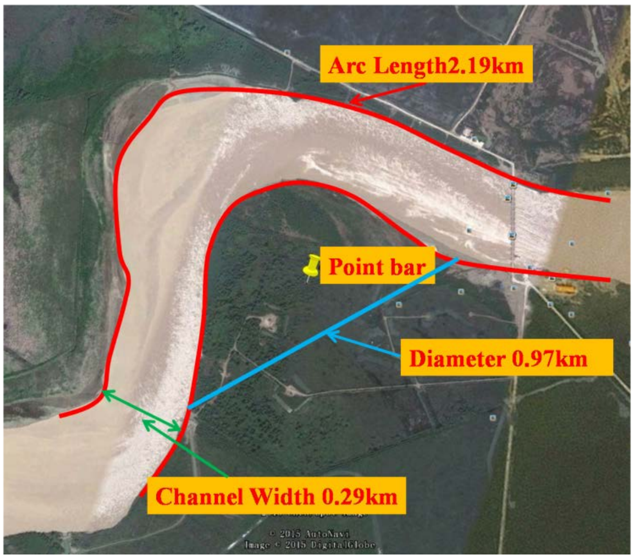
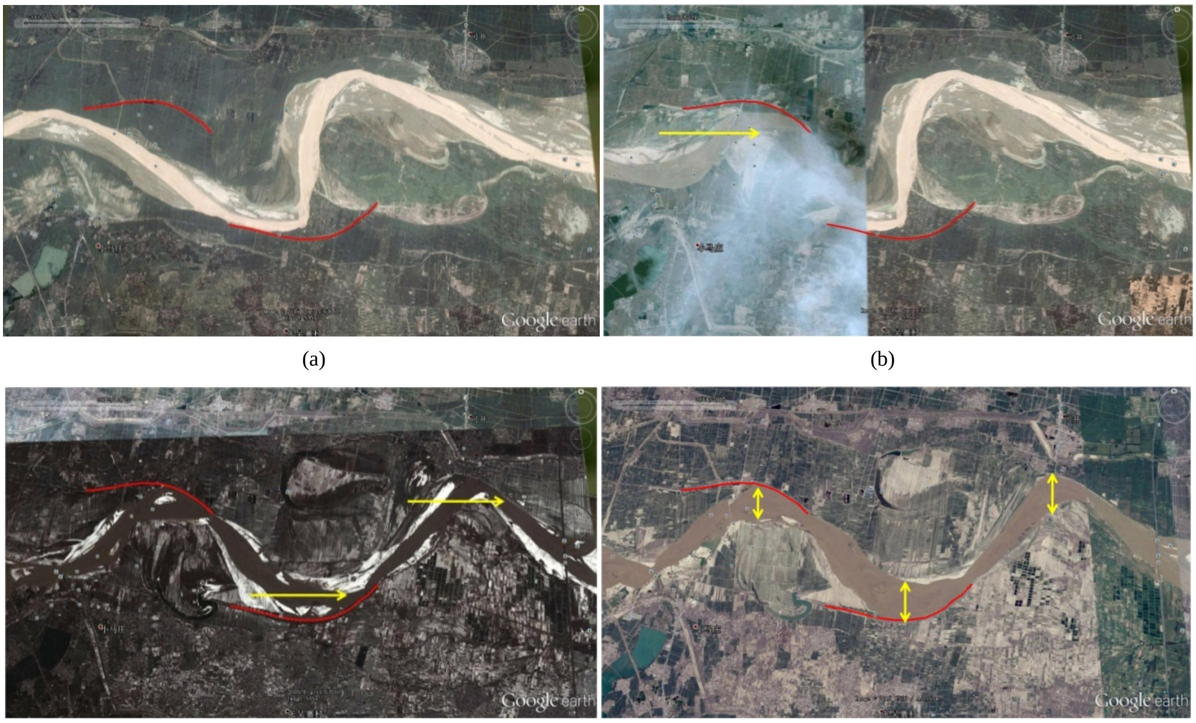


Figure 5. Schematic diagram of measuring point bar's parameters of the Yellow River. The red line is the arc length. The yellow landmark is the position of the point bar. The green arrow is the channel width. The blue line is the diameter of the point bar.



(a) (b) (c) (d)

Figure 6. Schematic diagram of modern river evolutionary analysis. (a)The image was taken in August 2002 (the two red lines were the dams built on the two river banks; (b) The image was taken in May 2006 (the yellow arrow means the flow direction and the left meander apparently migrated towards east during 2002-2006); (c) The image was taken in December 2012 (the two yellow arrows mean the water flow direction and the meander apparently migrated towards east during 2006-2012); (d)The image was taken in March 2015 (the three yellow arrows mean the extension of the river width during 2012-2015).

right side both migrated towards east from 2006 (**Figure 6(b)**) to 2012 (**Figure 6(c)**). There was no apparent migration occurred to the position of the meanders, however, the channel width became significantly wider from 2012 (**Figure 6(c)**) to 2015 (**Figure 6(d)**). In summary, the whole meandering river migrated towards east and its channel gradually widened from 2002 to 2015.

4. Conclusions

1) The resolution of satellite images from Google Earth software is high; users can study the sedimentary and geomorphological features of the rivers and quickly determine their types by observing the high-resolution satellite images;

2) Users can superimpose appropriate layers on the Google Earth's satellite images to quickly locate the river, track river flow, obtain batch elevation data and easily measure the terrain slope;

3) The Google Earth software's "Ruler", "Add Path" and other functions make it easy for users to directly measure the channel width, radian, amplitude, wavelength and some dam parameters such as size and shape;

4) Google Earth software's "Historical Image" function has important significance in studying modern river migration, sedimentary evolution and topography of river in different seasons.

Therefore, the use of Google Earth can greatly improve the efficiency of modern river sedimentology research.

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