The Design and Development of the Hainan Province "Digital Ocean" Platform and Applications on Natural Disasters Prevention and Reduction

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Abstract: Since the Hainan Province is located at the south end of China, it is the key province to implement the Belt and Road initiative. In order to support the construction of international tourism island and Digital Hainan Province, it is required to build Hainan Province "Digital Ocean" platform to integrate ocean environment three-dimensional (3D) monitoring data, including sea, land and air data, to support ocean information visualization and decision-making support. Because of the complex of ocean data, such as spatio-temporal, 3D and dynamics, new technical framework of "Digital Ocean" platform and new techniques, such as multisource spatial data organization and management and self-adaptive visualization, need to be developed. This paper introduces the design and development of Hainan Province "Digital Ocean" platform, with characteristics of "software, data and services all-in-one integration" and "dynamic, high-resolution, automatic ocean information procession", and its applications on natural disasters prevention and reduction. The technical framework and development method of ocean 3D visualization model based on earth sphere model are introduced. The key techniques, such as multisource, mass spatial data organization and management, mass spatial information self-adaptive visualization, submarine, seacoast, island 3-D visualization, and the multi-layer, multi-time information visualization, are developed. The Super Typhoon Sarika, which happened in Sanya city on October 2016, is used as a case study to demonstrate the whole process of forecasting, risk prediction, and disaster assessment of typhoon storm surge. This platform will be a base to integrate ocean environment 3D monitoring data and other ocean information resources of Hainan Province. The construction of Hainan Province "Digital Ocean" platform will boost the development of ocean informatization and ocean economic industry, and help to build a "Strong Ocean Province".

1 INTRODUCTION

The Hainan Province is the biggest province in China, with around 204 square kilometres areas, including around 200 square kilometres ocean areas. Since it is located at the south end of China, it is the key province to implement the Belt and Road initiative. However, Hainan Province is also one of the most serious provinces of ocean disaster in China. In 2016, 16 people was dead and the economic loss is around 0.569 billion Yuan due to the ocean disaster. The main disasters are storm surge, sea wave and coast erosion. The 3D monitoring data from buoy, submerged buoy, ground wave radar and monitoring station are important for ocean disaster monitoring and forecasting and have the characteristics of networking acquire, distributed storage and spatial-temporal dynamics. "Digital Ocean" platform is the base for ocean information acquire and processing, ocean disaster monitoring and forecasting, ocean information production and services of ocean pollution forecasting and loss evaluation, it is an important support of ocean disasters prevention and reduction.

There are a lot of studies on Digital Earth (Chen and Genderen, 2008; Goodchild, 200; Guo et al., 2009; Guo et al., 2010) and Digital Ocean (Hou, 1999; Su et al., 2006; Zhang et al., 2011; Dong et al., 2010; Patrikalakis et al., 2000; Zhang et al., 2017), however, few studies were focus on province or city

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level. In order to support the construction of international tourism island and Digital Hainan Province, it is required to build Hainan Province "Digital Ocean" platform to integrate all ocean environment 3D monitoring data, including sea, land and air data to support ocean information visualization and decision-making support. Because of the complex of ocean data, such as spatio-temporal, 3D and dynamics, new technical framework of "Digital Ocean" platform and new techniques such as multisource spatial data organization and management and self-adaptive visualization need to be developed.

This paper introduces the design and development of Hainan Province "Digital Ocean" platform, with characteristic of “software, data and services all-in-one integration” and “dynamic, high-resolution, automatic ocean information procession”, and its applications on natural disasters prevention and reduction.

2 SYSTEM DESIGN

The Hainan Province "Digital Ocean" Platform is an integrated system that integrates ocean factor visualization and ocean phenomenon visualization models, databases, graphical user interfaces, and ocean information services to help the public and decision makers for ocean information sharing (Figure 1). It also can be used for natural disasters prevention and reduction for forecasting, risk prediction, and disaster loss assessment of typhoon storm surge.

This system has a multi-tier architecture consisting of presentation, business logic, and data tiers. Figure 1 provides an overview of system architecture. The presentation tier is the interface for users to interact with system, users can submit requests from the presentation tier, and it also can be used as the system client viewer for accessing 3D ocean factor and phenomenon visualization information. The business tier copes with the requests from the presentation tier. The business tier has three parts, including spatial database engine and metadata management, ocean information 3D visualization model and ocean information services. The data tier includes all available data sources, such as basic geographic database, remote sensing image database, ocean basic geographic database and 3D and dynamic ocean database. The database server is used to manage those sharing databases in this system, and it also supplies data services for the application server and spatial analysis and model analysis server.

3 THE CONSTRUCTION OF 3D VISUALIZATION MODEL BASED ON EARTH SPHERE MODEL

As the base of Hainan Province "Digital Ocean" platform, the construction of 3D visualization model based on earth sphere model is very important, the technical realizations are as following: firstly, the reference datum of earth sphere model is defined as: the model is based on the 3D coordinate system of the earth centroid as the original point O, it is a right-handed Cartesian coordinate system with Z axis pointing north direction, Y axis is from west to east, and the X axis is the orthogonal basis of Z and Y axis; secondly, the Digital Orthophoto Maps (DOM) is fused with Digital Elevation Model (DEM) to create real 3D terrain model by project transformation, geometric transformation (including pan, rotation, zoom in and zoom out etc.) and texture mapping using DirectX; then through the overlay of vector data with DEM and integration of building model, scene model and facility model with terrain model to implement 3D visualization model based on earth sphere model. Finally, navigation operations such as rotation, pan, zoom in and zoom out, and spatial query are implemented by using free Active X in client side.

The construction of 3D visualization model includes the following 5 steps.

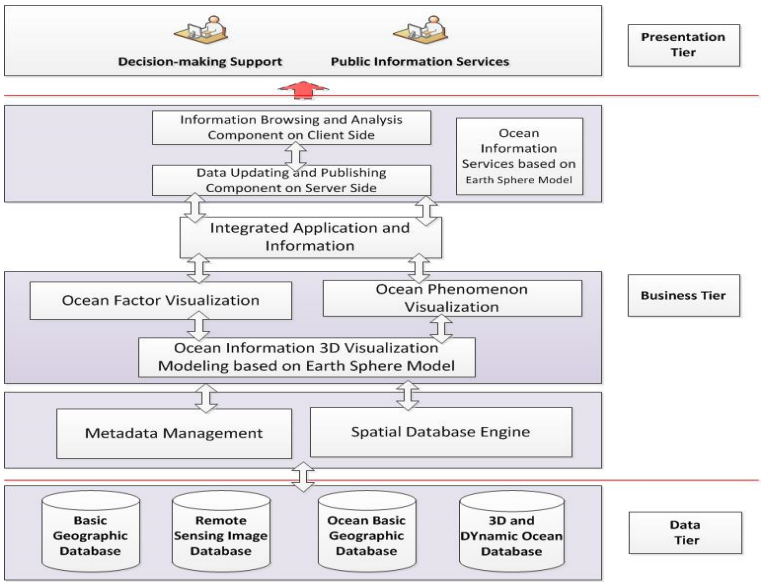

Figure 1: System design.

3.1 The Modeling of Earth Sphere

The modeling of earth sphere includes the following steps, the establishment of earth sphere model, the calculation of sphere parameter, and sphere surface grid generation.

3.2 The Construction of Terrain Field

The data used in "Digital Ocean" system include terrain data, remote sensing images, and texture data etc. The construction of terrain field means integration, merging, and overlay of remote sensing images, texture and DEM data to implement 3D visualization model based on earth sphere model and exporting to terrain field files.

3.3 Vector Data Overlay and Visualization.

The vector data used in "Digital Ocean" system include basic geographic data (administrative boundary, river, water course and road) and thematic data (ocean resources distribution, biochemistry factor distribution and water-depth distribution etc.) consisting of point, line and polygon, all of these data need to be integrated in "Digital Ocean" system. Vector data overlay and visualization mean the overlay of these vector data into 3D terrain field based on earth sphere model and exporting to vector field files.

3.4 3D Modeling and Integration

The 3D models in the "Digital Ocean" system consist of building models, scene models and facility models. Among them, building models include port, dock, observation station etc. models; scene models include trees, fish, dam, light tower and seabed pipeline models; facility models include airplane and ship models. 3D modeling and integration mean building, scene and facility modeling and overlay these models into vector data and 3D terrain field to implement 3D visualization model based on earth sphere model. There are two ways of modeling: one is modeling using 3D modeling software such as 3dMax, another is modeling in vector and terrain fields based on earth sphere model.

3.5 Navigation Operations Based on Earth Sphere Model

The navigation operations based on earth sphere model include rolling, zoom in, zoom out, pan, attribute queries, length and area measure etc., which are the base of sphere operation.

3.6 Publishing of Field Data

The publishing of field data includes publishing of terrain field, vector field and model field data. When these field data are published, users in the client side could select any of vector field and model field data

and load them into terrain field. Among them, a tool need to be developed to publish the terrain field data and Internet Information Services (IIS) could be used to publish the vector field and model field data.

4 KEY TECHNIQUES DEVELOPMENT

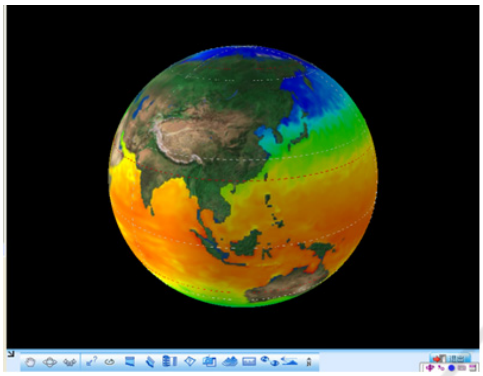

Figure 2: Sea temperature visualization on 3D visualization model.

The key techniques, such as multisource, mass spatial data organization and management and mass spatial information self-adaptive visualization oriented "Digital Ocean", are developed. Furthermore, the key techniques of submarine, seacoast, island 3-D visualization are developed to implement submarine roaming based on DEM and topographical and physiognomic data. Finally, the multi-layer, multi-time information (e.g. hydrology and meteorology information) visualization techniques are developed to implement visualization and information queries of ocean disasters information field (Figure 2).

5 SYSTEM DEVELOPMENT AND APPLICATIONS ON NATURAL DISASTERS PREVENTION AND REDUCTION

The Skyline software is used to implement the Hainan Province "Digital Ocean" platform and applications on natural disasters prevention and reduction. The Super Typhoon Sarika, which happened in Sanya city on October 2016, is used as a case study to demonstrate the whole process of forecasting, risk prediction, and disaster assessment of typhoon storm surge.

The Super Typhoon Sarika, which happened October 17-18 2016, made lots of economic loss in Sanya city. The tidal level data collected in three tidal stations in Sanya city were used to show the whole process of tidal up and down caused by the Super Typhoon Sarika. The flood submerge areas with different tidal levels were showed on the 3D visualization model based on earth sphere model with the help of the key techniques developed such as 3-D visualization and multi-layer, multi-time information visualization (Figure 3). The "Digital Ocean" platform will be a very useful tool for the city management decision makers, such as department of ocean of Sanya City, to use for forecasting, risk prediction, and disaster assessment of typhoon storm surge. The spatial query tool will be used to query the tidal level information of each tidal station during the whole process of the Super Typhoon Sarika. The spatial analysis and query tools will be used to create and show the flood risk and disaster assessment maps on the 3D visualization model, which will help the decision makers to query flood submerge areas, flood risk, flood loss information and decision making support for storm surges disasters prevention and reduction.

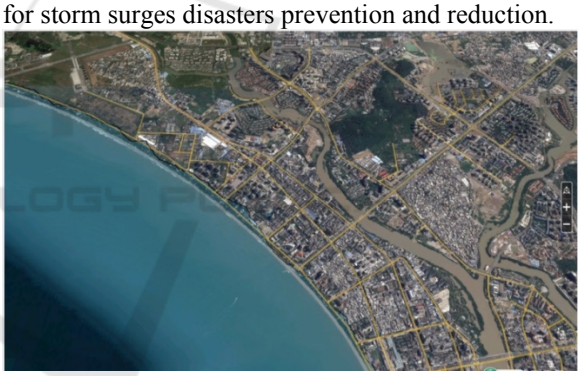

Figure 3: Flood submerge areas simulation with 3m tidal levels on 3D visualization model.

6 CONCLUSIONS

This paper introduces the design and development of Hainan Province "Digital Ocean" platform, with characteristics of “software, data and services all-in-one integration” and “dynamic, high-resolution, automatic ocean information procession”, and its applications on natural disasters prevention and reduction. The technical framework and development method of ocean 3D visualization model based on earth sphere model are introduced. The key techniques, such as multisource, mass spatial data organization and management and mass

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