Chapter 1
Introduction

Xin Zhang, Lei Wang, Xiaoyi Jiang, and Changming Zhu

Abstract The oceans are an important part of the earth that is a treasure house of resources and an important regulator of the global environment. There is a great part of the human being living in the coastal region all over the world. Oceans and coastal regions are changing at faster rates, over broader scales, than ever before and in fundamentally new ways. Digital analysis based on multisource data can greatly improve the cognition about the oceans and coasts, which are from diverse observing approaches such as satellites, airplane, ship, high frequency ground wave radar, buoys (moored and drifting) and land-based stations. This chapter briefly describes the concepts of the digital ocean and digital coast (DO&DC), discusses the modeling and visualization technologies for the realization of the DO&DC system, and notes the important roles of the DO&DC in digital earth development.

Keywords Digital ocean • Digital coast • Digital earth • Modeling

X. Zhang (✉)
State Key Laboratory of Remote Sensing Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100101, China
e-mail: zhangxin@radi.ac.cn

L. Wang
Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100101, China

Hainan Province Key Laboratory of Earth Observation, Sanya Institute of Remote Sensing, Sanya 572029, Hainan Province, China
e-mail: wanglei98@radi.ac.cn

X. Jiang
National Marine Data and Information Service, State Oceanic Administration of China, Tianjin 300171, China
e-mail: andyjiangxy@126.com

C. Zhu
Department of Geography and Environment, Jiangsu Normal University, Xuzhou 221116, Jiangsu, China
e-mail: ablezhu@163.com

X. Zhang et al. (eds.), *Modeling with Digital Ocean and Digital Coast*, Coastal Research Library 18, DOI 10.1007/978-3-319-42710-2_1

1.1 Digital Earth

Advances in the past few years have demonstrated that many aspects of the Digital Earth (DE) that Al Gore envisioned in 1992 and later described in his 1998 speech are now technically feasible (Goodchild 2008). Chen and Genderen (2008) state that DE is an integrated approach to build the next level of scientific infrastructure to support global change research. They present a number of examples, including cover forest and grassland fires, desertification and sandstorms, deforestation, forest carbon sequestration, wetlands conservation, the observation of migratory birds for the spread of avian influenza (bird flu), the Tibet Plateau uplift, the rise of sea levels, and underground coal fires. In terms of DE's potential fields of applications, Guo et al. (2009, 2010) studied the DE prototype system DEPS/CAS and, through this research, defined DE systems as either scientific systems (such as the World Wind of the USA, the DE Prototype system/Chinese Academy of Sciences (DEPS/CAS) of China, the Blue Link and the Glass Earth of Australia, and the Earth Simulator (ES) of Japan, among others) or commercial systems (such as Skyline and Google Earth) and proposed that DE is a comprehensive platform for the integration of future information resources. Wright et al. (2010) presented a methodology for visualizing reconstructed plumes using virtual globes, such as that of Google Earth, which allows the animation of the evolution of a gas plume to be easily displayed and shared on a common platform. Yasuko et al. (2010) developed a visualization system (KML generators) for multidisciplinary geoscience data that visualizes seismic tomographic models, geochemical datasets of rocks, and geomagnetic field models by exploiting Google Earth technologies. Chen et al. (2009) put forward a solution to render the vertical profiles of atmospheric data from the A-Train satellite formation in Google Earth, using data from the NASA Cloud satellite as a proof-of-concept. However, these authors have not yet solved the problems facing the exploration and visualization of three-dimensional ocean data on visual globes.

DE is a powerful digital information world that can be accessed of space-time data of the earth in a virtual form (Vahidnia and Alesheikh 2013). With the development of technology, science has entered into an era of big data in which early research on the earth does not meet development of the earth's needs (Chaowei Yanga et al. 2013; Guo 2013). In the digital information era, huge volumes of geo-referenced data can be transformed into useful information that can be analyzed, visualized and shared and is of great interest to scientists (Manfred Ehlers and Peter Woodgate 2014). Guo (2013, 2014) noted that the use of DE technology can address real world human challenges (e.g., climate change, natural disasters, and urban expansion, and in the cloud computing platform), support dust storm forecasting, soil erosion monitoring, and forest disaster prevention (Peng Yue and HongxiuZhou 2013; Ick-Hoi Kim and Ming-Hsiang Tsou 2013). Lars Bernard and Stephan Mäs (2014) noted that scientific GDI (geodata infrastructures) could become one of the core components in the future DE. Yingjie Hu and Zhenhua (2015) proposed making 3D models, virtual earth map layers, remote sensing images, digital elevation models (DEMs), and other data formats to build the DE system in a unified virtual environment.

DE is becoming a global challenge and a widespread leading field in science and technology. It is a comprehensive embodiment of a country's science and technology, economic strength, and national security safeguarding ability is and also one of the important signs of a country's comprehensive national strength. DE has a very vigorous life-force and is a global strategic goal of science and technology development. DE is a comprehensive platform and integration of future information resources. In many ways, DE, as a collection of technologies, has integrated the huge and valuable body of geo-data resources. It will prove to be an important area of research in the coming years (de By and Yola Georgiadou 2014; Yingjie Hu and Zhenhua 2015), but we are also facing a series of challenges such as big data storage, communication and processing (Guo 2014, 2015; Chris Pettit and Arzu Coltekin 2015).

1.2 Digital Ocean

The Earth is the only known blue planet in the universe. Approximately 71 % of the earth's surface is covered by ocean, which operates as an elementary component of the global life support system and acts as a balance for the human resource treasury and environment. Oceans and, indeed, the entire planet, are changing at faster rates, over broader scales, than ever before and in fundamentally new ways. In a very short period of time, the bounty of oceans has been depleted, and the ocean ecosystems have become seriously disrupted (Wright et al. 2007). The bounty and circulation of the oceans makes the study of the problems of rising sea levels, warming seawater, increasing storm intensities and other issues important from a global perspective. Since 2005, the Global Earth Observation System of Systems (GEOSS) has been implemented to achieve comprehensive, coordinated and sustained observations of the Earth to increase our understanding of the Earth's processes and to enhance the prediction of the behavior of the Earth system (GEO 2005). As the oceanographic component of GEOSS, one objective of the Global Ocean Observing System (GOOS) is to foster the development of data management systems that allow users to exploit multiple data sets from many different sources through "one-stop shopping" (Thomas 2003). The purpose of the Integrated Ocean Observing System (IOOS) is to make a more effective use of existing resources, new knowledge and advances in technology to provide the data and information required for global or regional scientific studies (Ocean.US 2002). As the National Science Foundation's contribution to the U.S. IOOS, the Ocean Observatories Initiative (OOI) will construct a networked infrastructure of science-driven sensor systems to measure the physical, chemical, geological and biological variables of the ocean and seafloor. Greater knowledge of these variables is vital for the improved detection and forecasting of environmental changes and their effects on biodiversity, coastal ecosystems and climate (COL 2009). In the future, ocean information will become an increasingly valuable commodity worldwide because of the role of maritime commerce and new ocean-related investments, vulnerability to ocean-related natural disasters, the need to provide security for coastal populations, and the challenges of providing food and water to more people (Interagency Ocean Observation Committee 2013).

The term of DO emerged after the DE program was proposed by Al Gore (1998). The DO is the embodiment and re-innovation of "DE" theory and technology for the oceans of the world (Hou 1999). Patrikalakis et al. (2000) studied a knowledge network of distributed heterogeneous data and software resources for multidisciplinary ocean research that brought together advanced modeling, observation tools and field estimation methods. However, these authors did not discuss the integration of the technologies based on the global visualization of the Earth. Su et al. (2006a, b, c) studied the technologies of ocean GIS and proposed the benchmarks and the key technologies of a China DO Prototype System. As a public application platform, Google Ocean (www.googleearth.com) can provide much educational information, such as videos of ocean life, and allow the public to watch unseen footage of historic ocean expeditions, but the site has many shortcomings for scientific research and governmental applications. There have been many visualization systems for regional ocean data developed using OpenSceneGraph, including the Regional Ocean Modeling System (ROMS) (Shen et al. 2007), but there are many other technologies that can be researched from the DO perspective.

Based on various types of data about the ocean, including survey and evaluation data, historic data, basic geographic data, remote sensing data and business data, the specific content of the DO includes the researching and developing the DO sphere system for social and business management services based on the earth sphere model to achieve the interactive 3D visualization, reproduction and prediction of various ocean subsystems (such as the seabed, water, and sea surface) and phenomena. The DO system can be divided into two versions, "management" and "public service", based on the analysis of the demand characteristics and application modes of different user groups.

The DO system can complete the integration of small-scale geographic data and thematic data of the ocean based on the earth sphere model. It can also realize the dynamic update of the ocean monitoring and forecasting information. The DO system can be used to achieve a variety of expressions of regional data and query and retrieval of ocean information and data. It can also display and distribute business information generated in the process of ocean management.

The DO public service system is designed to satisfy public information inquiries and share science knowledge and information products on Internet. They depend on the data integration of large-scale ocean basic geographic data, thematic data and real-time updated observing and forecasting information. The DO public service system applications span a variety of aspects, including sea and island management, ocean environmental protection, disaster prevention and mitigation, economy planning, law enforcement monitoring, rights and interests maintenance, science and technology management, and fisheries.

1.3 Digital Coast

The coastal zone is a special area that is under the effect and interaction of land and sea. Under the background of the global sea level rising, the coastal disasters seriously threaten the survival and living environment of the coastal zone living things. The dynamic monitoring of the coastal zone has gradually become a hot research topic in related research fields.

The coastal zone has abundant energy resources such as tidal energy, wave energy, and wind energy et al. It also has many biological resources such as reeds, seaweed, ocean microorganisms, mangroves and fish and many natural resources such as groundwater, seawater, minerals, beaches, and shoreline et al. However, the coastal zone can be subject to many natural disasters such as storm surge, typhoons and slow-onset disasters including coastal erosion, sea water intrusion, land subsidence, sea surface elevation, and estuary and harbor sediment deposition. It is difficult to use traditional methods to monitor the environment, especially large-scale coastal monitoring because of the characteristics of uncertainty in the surrounding coastal environment. With the development of remote sensing technology, more and more fields have been introduced. Remote sensing technology is large-range, short period and multi time phase, making coastal zone dynamic monitored in convenient and quick style.

Digital coast is an extension and application of the DE theory and technologies in the coastal zone, and it is a product of information technology development and application.

Under a broadband, high-speed computer information network environment as an information infrastructure, Digital Coast system takes a mass storage and distributed computing system to manage and process the ocean data.

As for the theory study, Digital Coast should study the method of water quality monitoring and analysis technologies systematically. It should research the change and development trends of coral reefs, mangroves and coastline, as well as the ocean oil spill pollution monitoring.

Digital Coast system can realize 3D visual expression and localization of high-precision satellite images, vectors data and terrain data of the offshore area and islands. It can take advantage of the ocean scene simulation function to show the real-world islands by integrating ocean water, ocean scene, coastal landscape, seabed topography and so on.

From the query and display of ocean usage information about the current situation, historical situation, statistics, and functional region division information in the different theme modules, we can achieve the functions of query, retrieval, location and statistical analysis of all types of information.

Based on the survey data from the islands and coastal zones in the ocean island theme, we can fulfill a variety of island information queries (such as location, area, length of coastline, and population), as well as the visualization of island images and terrain. Aimed at the ocean rights and interests, we can demonstrate the political, economic and military interests of a country and its neighboring countries from the aspects of the political situation, economic situation, military situation. We can also browse and view the interests of the island terrain, high-precision images, profile information, multimedia information and its relevant attribute information. For the polar ocean theme, we can achieve the display, query and 3D landscape simulation of the polar expeditions. The previous tracking information, thematic polar information, and research stations visualization can also be viewed.

1.4 Modeling with DO&DC

Modeling with DO&DC is the important content to build a digital information system. The process of using a model to describe the causal and interrelation is called modeling. The means and methods to achieve this process are varied, as there are different ways of describing the relationship.

Modeling with DO&DC mainly focuses on system applications and data modeling. The main contents of the modeling include determining the data and related processes, defining the data structure, numerical simulation and forecasting modeling, data organization and storage modeling, system application modeling, and so on.

Modeling with DO&DC relate to a number of related research areas on the technical level, such as remote sensing, GIS, virtual reality, scientific data visualization, computer network, geodesy, and data warehouse.

Modeling with the DO&DC includes:

1. DO&DC is a new concept and application model from the application level of the earth sphere model. It requires DO&DC transition from theory to practice and a break from concept to engineering application entity;
2. From the perspective of data integration in the global sphere, DO&DC cover the major data types in the ocean areas, such as ocean survey data, model forecast data, pattern prediction data, space remote sensing data, aerial remote sensing data, basic geographic data, business approval data, and statistical data;
3. In the space region, DO&DC covers oceans, the polar regions, key ocean areas, the islands and coastal zones, and the vertical dimension of the space related to the expression of the main elements (seabed, water, sea surface, and sea islands);
4. In the application services, DO&DC covers the major areas, including ocean comprehensive management and macro decision-making, the ocean economy, ocean disaster prevention and mitigation, ocean fisheries, ocean dynamic environment, and ocean homeland security and maintenance;
5. Aimed at the two demand groups of ocean thematic business and information services groups from the perspective of application service groups, it needs to put forward unique system programs of research and development, which have a strong relevance and practicality;

6. The system development should be based on the requirements of business applications. It has realized the development of various elements' multi-dimensional expression to study the visual expression of different types of ocean and ocean phenomena;
7. Research on the true 3D Earth sphere model space parameters integrated the feature in electronic chat and its construction technology;
8. Research on ocean real-time monitoring data management is based on the earth sphere model and application integration technology to achieve a unified space-time management and application integration of multi-source monitoring data;
9. Study of the data model of the process of the typical EI Nino phenomenon and the sea level rise based on the earth sphere model;
10. Research data loading and sphere integration techniques based on the cloud service architecture under a distributed network environment;
11. Research on the integration, process analysis, feature mining, and application service technology of large ocean space-time data.

1.5 Virtual Visualization Application in DO&DC

Virtual visualization is the interactive processing theory, algorithm and technology research branch of visualization technology, which is based on computer image processing and graphics technology converting the scientific computing data, engineering calculation data and measurement data into graphics or images drawn on the screen. Using virtual visualization technology, we can transform the spatial data into a graphic image, to help people to address and identify its characteristics and rules and to understand the nature of laws. The virtual visualization can be applied in many areas of ocean research.

1.5.1 Research of Global Climate Change

The visual simulation of ocean circulation phenomena is crucial for the analysis and prediction of global climate change and the effect on the oceans. The oceans regulate the climate of the earth's land and the height of the oceans, the air dry or wet effect, and control of the wind speed and direction. Thus, the modeling and visualization of ocean temperature changes can help scientists understand the impact of climate change and predict future impacts on human activities. The research results of the modeling, simulation and visualization of the spatial analysis of global warming, El Niño, sea level change, carbon cycle, ocean circulation variability and other global climate changes in the research field could provide support services for international negotiations on climate change.

1.5.2 Management of Fisheries and Ocean Biology

The DO is capable of showing the ocean nature to reveal the living environment and ocean organism behavior. It can also be used to study the ocean habitats and explore the ocean resources.

1.5.3 Ocean Emergency Decision-Making

Under the information of wind field, flow field and the temperature field emergency incident background information, real-time monitoring information, all kinds of statistical information (surrounding economic losses, casualties and ecology destruction), we can build all types of ocean emergency (oil spill, hazardous chemicals leakage, leakage of nuclear, maritime) contingency plans and impact assessment models to realize the dynamic visualization expression to evaluate the emergency influence and assess the thematic information products made from the impact of unexpected events. By assessing the impact of emergency situation, it is possible to make an assessment of thematic information products.

1.5.4 Ocean Scientific Research Field

Using DO&DC data resources and computing resources integrated ocean numerical model, GIS spatial analysis model, ocean phenomena visualization model and other ocean research and development model to provide a virtual platform for scientific research users to load and test the mechanism of the ocean phenomenon, simulation and comprehensive analysis of scientific research results.

1.6 Conclusions

DE could provide support to social and economic development. On the one hand, it can support the overall sustainable development of a country, and on the other hand, it is closely linked to the integration of research on global change, resources, and environment as well as on global economic unifying processes.

DO&DC construction is a long-term engineering with strategic and prospective, and the modeling theories and technologies research is the core of the whole engineering. In future work, we should actively carry out strategic planning on DO development and establish the management and service system of ocean and coast information resources, as well as build up the information exchange and share channels.

Acknowledgments The study is funded by the Free Exploring Program of the State Key Laboratory of Remote Sensing Science of China (No. 14ZY-03), the Special Research Project for the Commonweal of the Ministry of Water Resources of the People's Republic of China (grant no. 201201092), the 908 Project of the State Oceanic Administration, China (No. 908-03-03-02), the National Natural Science Foundation of China (grant no. 61473286 and 61375002), and the National Science & Technology Pillar Program (2015BAJ02B01, 2015BAJ02B02). All memberers of the Research Team are gratefully acknowledged for their contributions to the work carried out in this chapter in recent years. In particular, special thanks are given to Miss Qiong Zheng, Mr. Yongxin Chen and Mr. Yuqi Liu for their contributions in the document revision.

References

Al Gore (1998) The DE: understanding our planet in the 21st century [online]. Available from: http://portal.opengeospatial.org/files/?artifact_id=6210. Accessed 14 July 2010

Chaowei Yanga, Yan Xu, Douglas Nebert (2013) Redefining the possibility of digital Earth and geosciences with spatial cloud computing. Int J Digital Earth 6(4):297–312

Chen SP, Genderen J (2008) Digital Earth in support of global change research. Int J Digital Earth 1(1):43–65

Chen AJ, Leptoukh G, Kempler S, Lynnes C, Savtchenko A, Nadeau S, Farley J (2009) Visualization of A-Train vertical profiles using Google Earth. Comput Geosci 35(2):419–427

Chris Pettit, Arzu Coltekin (2015) Geovisual analytics: design and implementation. Int J Digital Earth 8(7):517–521

Consortium for Ocean Leadership (COL) (2009) Project execution plan [online]. Available from: http://www.oceanleadership.org/wp-content/uploads/2009/04/. Accessed 14 July 2010

de By* RA, Georgiadou Y (2014) Digital earth applications in the twenty-first century. Int J Digit Earth 7(7):511–515

GEO (2005) The Global Earth Observation System of Systems (GEOSS) 10-year implementation plan [online]. Available from: http://www.earthobservations.org/documents/. Accessed 14 July 2010

Goodchild MF (2008) The use cases of digital Earth. Int J Digital Earth 1(1):31–42

Guo HD (2013) Making digital Earth on Earth. Int J Digital Earth 6(1):1–2

Guo HD (2014) Digital Earth: big Earth data. Int J Digital Earth 7(1):1–2

Guo HD (2015) Big data for scientific research and discovery. Int J Digital Earth 8(1):1–2

Guo HD, Fan XT, Wang CL (2009) A digital Earth prototype system: DEPS/CAS. Int J Digital Earth 2(1):3–15

Guo HD, Liu Z, Zhu LW (2010) Digital Earth: decadal experiences and some thoughts. Int J Digital Earth 3(1):31–46

Hou WF (1999) Tentative idea for development of "Digital Ocean". Aviso of Ocean 18(6):1–10

Ick-Hoi Kim, Ming-Hsiang Tsou (2013) Enabling digital Earth simulation models using cloud computing or grid computing-two approaches supporting high-performance GIS simulation frameworks. Int J Digital Earth 6(4):383–403

Interagency Ocean Observation Committee (2013) U.S. IOOS Summit Report: A new decade for the Integrated Ocean Observing System, [online]. Available from: http://www.iooc.us/wp-content/uploads/2013/01/U.S.-IOOS-Summit-Report.pdf. Accessed 14 Nov 2013

Lars Bernard, Stephan Mäs (2014) Scientific geodata infrastructures: challenges, approaches and directions. Int J Digital Earth 7(7):613–633

Manfred Ehlers, Peter Woodgate (2014) Advancing digital Earth: beyond the next generation. Int J Digital Earth 7(1):3–16

Ocean. US (2002) Building consensus: toward an integrated and sustained ocean observing system [online]. Available from: http://www.ocean.us/documents/docs/Core_lores.pdf. Accessed 14 July 2010

Patrikalakis NM, Bellingham JG, Mihanetzis KP (2000) The Digital Ocean. Computer Graphics International 2000 (CGI'00) (1):45–48

Peng Yue, HongxiuZhou (2013) Geoprocessing in cloud computing platforms-a comparative analysis. Int J Digital Earth 404(4)

Shen YZ, Austin JA, Crouch JR, Dinniman MS (2007) Interactive visualization of regional ocean modeling system. In: Proceedings of the IASTED International Conference on Graphics and Visualization in Engineering., pp 74–82

Su FZ, Du YY, Pei XB (2006a) Constructing digital sea of China with the Datum of coastal line. Geo-Inf Sci 8(1):12–15

Su FZ, Yang XM, Xu J (2006b) Basic theory and key technologies for ocean geographic information system. Acta Oceanol Sin 25(2):80–86

Su FZ, Zhou CH, Zhang TY (2006c) Constructing a raster-based spatial-temporal hierarchical data model for ocean fisheries application. Acta Oceanol Sin 25(1):57–63

Thomas CM (2003) The coastal module of the Global Ocean Observing System (GOOS): an assessment of current capabilities to detect change. Ocean Policy 27(3):295–302

Vahidnia MH, Alesheikh AA (2013) Modeling the spread of spatio-temporal phenomena through the incorporation of ANFIS and genetically controlled cellular automata: a case study on forest fire. Int J Digital Earth 6(1):51–75

Wright DJ, Blongewicz MJ, Halpin PN, Breman J (2007) Arc Ocean: GIS for a Blue Planet. ESRI Press, Redlands

Wright TE, Burton M, Pyle DM, Caltabiano T (2010) Visualising volcanic gas plumes with virtual globes. Comput Geosci 35(3):1837–1842

Yasuko Y, Yanaka H, Suzuki K, Tsuboi S, Isse T, Obayashi M, Tamura H, Nagao H (2010) Visualization of geoscience data on Google Earth: development of a data converter system for seismictomographic models. Comput Geosci 36(2):373–382

Yingjie Hu, Zhenhua LV (2015) A multistage collaborative 3D GIS to support public participation. Int J Digital Earth 8(3):212–234