Paper presented at the 22nd Asian Conference on Remote Sensing, 5 - 9 November 2001, Singapore.
Copyright (c) 2001 Centre for Remote Imaging, Sensing and Processing (CRISP), National University of Singapore;
Singapore Institute of Surveyors and Valuers (SISV); Asian Association on Remote Sensing (AARS)

THE STUDIES ON OCEAN DYNAMIC MONITORING AND THEIR UNPRECEDENTED AMOUNT OF INFORMATION MANAGEMENT WITH SATELLITE REMOTE SENSING AND FRACTAL APPROACH*

Changbao ZHOU, Weigen HUANG, Dongling LI, Huaguo ZHANG, Qinmei XIAO,
Jingsong YANG, Bin FU, Aiqin SHI, Xiu lin LOU

Key Lab. of Ocean Dynamic Processes and Satellite Oceanography Second Institute of Oceanography,
State Oceanic Administration, Hangzhou, 310012, Zhejiang Province,
Tel: (86)-0571-88076924-2552,2399
Fax: (86)-0571-88071539, 88839374
Email: cbzhou@mail.hz.zj.cn
P. R. China

KEY WORDS: Remote Sensing, Fractal Approach, Ocean Dynamics, Monitor, Manage

ABSTRACT The new needs for quantitative and precise detection for marine dynamic features and environmental factors are addressed with the fast development of satellite remote sensing techniques and applications. The magnitudes of remote sensing data, various in-situ observed data, and the different scale mapping data are increased quickly. So the problems on capture, store, process, display and management of an unprecedented amount of information have became a very important. Satellite remote sensing associated with fractal approaches presented here are new methodologies in order to solve related scientific problems.

The requirements of ocean remote sensing information applications are briefly introduced in the paper at the first. The theories and models of fractal system and the possibility of their ocean application as well as the examples of multi-scale management on oceanic features are described in detail. The potential of a remote sensing associated with fractal approach in detecting and manage of ocean is discussed and concluded at the final of the paper.

1. INTRODUCTION

The new needs for quantitative and precise detection for marine dynamic features and environmental factors are addressed with the fast development of satellite remote sensing techniques and applications. The data magnitudes from satellite and airborne remote sensing information, including visible radiometer, infrared radiometer, synthetic aperture radar (SAR), altimeter, scatterometer and microwave radiometer and so on, and various in-situ observed data are more and more, and the different scale mapping, such as coastline, sea surface features and environmental factors as well as objects over or under seawater, and the changes of multi-dimension are complex, so the problems on capture, store, process, display and management of an unprecedented amount of information have became a very important. Satellite remote sensing associated with fractal approaches presented here are new methodologies in order to solve related scientific problems. It is known that the coastline, coastal zone changing, wind, surface wave, currents and fronts, tidal flows, mesoscale eddies, internal waves, shallow bottom topography and water depth., the objects over and under see water, sea surface oil pollution and other environmental pollutions, sea disaster such as flood and storm surge and so on information are obtained successfully using satellite remote sensing methods. Remote sensing approaches also have been used to monitor the time-space dynamic changes of oceanic phenomena, and fractal approaches may solve the store of an unprecedented amount of remote sensing information and permit to perform the infinite scale manage of coast and ocean dimension.

The ocean and its environments are considered to the most complex objects. They are furthermore characterized by the interaction of complex and coupled physical and biochemical upper ocean and atmospheric boundary-layer processes at spatial and temporal scale ranging from meters to hundreds of kilometers and seconds to several days and longer. Therefore, many of these processes and their interaction are still not well known, primarily as a result of lack of observations. Validations of physical or coupled biophysical numerical ocean models are consequently important. In monitoring and prediction system of the ocean, satellite multi-sensor remote sensing and in-situ observations must be integrated and combined with fine-resolution numerical ocean models and fractal approaches are significant methodologies. Only via such an integrated system will be a realistic representation of the initial state to provide reliable and accurate forecasts of oceanic dynamic changes.

*The paper is supported by 863-818-06-02 and 9609 projects

2. THE METHODS OF THE STUDIES

The construction of marine geographic information system is powerful tool for oceanic monitoring and management. A very great database, including remote sensing information base, image base, map base and field observed database etc, is build at the system. The data of different period terms and various multi-scale images and maps are collected based on the requirements of all users, and store and management for an unprecedented amount of information in the database bring difficulty, and new requirements for hardware system are advanced. Only these problems are solved using fractal methods. The larger scale map is stored, or a larger scale image is compressed and stored, and then from these maps, multi-scale maps can be produced or repeated according to application needs.

2.1 Remote sensing methods

The high resolution and multi-phases remote sensing images, for example SPOT, IRS, TM, or IKONOS and SAR images, are chose according to requirement of oceanic dynamic changing monitoring and manage needs for national and province as well as local position.

The acquire of rich information from multi-sensor, multi-band and multi-source remote sensing images, data processing, extraction of characteristic information and parameter interpreting and producing of special maps. The processing and translating on remote sensing images don't deal with in detail here.

2.2 Fractal approaches

Fractal theories, physical mechanisms of the fractal and fractal applications in many areas have achieved new progresses. There are a series of advantage for fractal approach. Main features on a set of fractals (F) are as follows: (i) F has a fine structure, i.e., detail on arbitrarily small scales. (ii). F is too irregular to the described in traditional geometrical language, both locally and globally. (iii) Often F has some form of self-similarity, perhaps approximate or statistical. (iv) Usually the fractal dimension of a set of F (defined in some way) is greater than its topological dimension. (v) In the most cases of interest F is defined in a very simple way, perhaps recursively

It is known coastlines are fractal objects. Larger map scale is, more detail structures of the line is. So they kindly represent the real geographic objects. Several algorithms are simply described as follows:

2.2.1 Fractal approach of line interpolation: Dounlas-Peuker(D-P) algorithm is used to estimate fractal dimensions of curves. It is a good automatic map generalization approach. The signatures of the algorithm are as following: (a) Draw a feint line between first and end points of the digital curve, and calculate the distances from all the points to the feint line. (b) Compare the biggest distance with the give threshold. If the biggest distance smaller than the thres hold, remove all the points between two points for whole line. Otherwise, keep down all the points with biggest distance and then divide the curve into two sections, and repeat that. (c) The new curve formed by linking the remained points sequentially. Fractal dimension can be estimated based on a series on the points obtained by the scale and the line length linked corresponding curve.

Random midpoint displacement method (RMDM) is a recursion algorithm (Yiwen Jin et al. 1998). RMDM is a good method to generate Brownwain curve, and it now is used as an interpolation algorithm. First, make a straight line between the two points. Put the midpoint of the line up or down with a random distance to get an insert point. Consequently, the three points form a curve with two beelines, and the old straight line is replaced by the curve. Then the same thing is done on the each part of the curve, till the each beeline is enough short. The result is a complex and self-similar curve with fractal properties.

Thus, it is seen that Dounlas-Peuker algorithm means to predigest curve by removing the points whose displace distance is less than the threshold, and RMDM is to expand curve through adding some points. Thereby, these two algorithms are mutual contradictorily processes, but which is consistent on geometry.

Therefore, the new approach first estimates the fractal dimension and the range of fractal patterns by Dounlas-Peuker algorithm, then educes the amount of insert points on the base of the interplay between curve length and scale (Qiao Wang et al. 1998). The next step is to find positions for every insert point with RMDM. Final step is to join all points in order and complete interpolation process. However, due to the shortcoming of RMDM that the direction of displacing is always up or down and fail to reflect isotropy of movement of geography line, this paper revises the displacing direction of RMDM from up-down to left-right which is perpendicular to the given line.

This new method first calculates insert depth by Dounlas-Peuker algorithm and RMDM based on Beckett formula, then obtain the range of non-scale to limit the shift distance. We have built the relation between amount of insert point and complexity of curve, scale change, and length of beeline Summarily, the main steps are as following:

- To give the original curve as coordinates points and denominators of original scale M1 and target scale M2.
- To calculate fractal dimension and range of non-scale by Dounlas-Peuker algorithm.
- To calculate average displacement and average length of beeline, then obtain shift coefficient.
- To calculate the number of insert points
- To insert coordinates points for every beeline sequentially, till the present displacement is less than minimum of the range of non-scale or the present insert level equals to the number of insert points
- After completing first one beeline, sequentially do the next one up to last one.
- To draw the new curves.

and then the management of an unprecedented amount of information and infinite scale mapping are performed by using a new fractal theory and approach.

2.2.2 Fractal approach of coastline generalization: Fractal approach of line generalization still uses Douglas-Peuker algorithm, it not only remains the various natures of automatic generalization based on fractal analysis, but also kindly keeps the characteristic points of the patters. Its algorithm is simply described as follows:

- To input a series of points from original line and the denominators M1 and M2 for different scales.
- To decide the range of non-scale and fractal dimension D.
- To calculate threshold of displacement.
- To remove the points that the size of displacement is less than threshold by using Douglas-Peuker algorithm.
- To link the remain points and output generalization patterns.

2.2.3 Fractal approach of surface area-measure relationship: It is known that contour of land surface is considered as connect of terrestrial surface and vertical surface. The terrestrial contour from the vertical direction is easily got if terrain is indicated by DEM. To suggest terrestrial surface express as a square and then divide the square into 4 or n of small squares with one side is equals to r. the center point of a small square is estimated by using second-fine mid-point method. The area of every square is calculated and fractal dimension is got. The zoom fine constructing map of terrain is obtained.

2.2.4 Fractal approaches of image compress: The data magnitude of a remote sensing image is about 100 mbit in general. For example, a 512x512 subimage is chosen, its magnitude is equal to 0.267 mbit (512x512x8). The transmission and storage for so much large of images and maps become very difficulty. Therefore the fractal image compress is very important. The base for fractal image compress is the fractal transfomation. Its essential method is fractal image encoding technologies. The advantages of the method include: (a) The quality of retrieving image is high. (b) Reconstructing images is independent of image resolution. (c) The efficiency of decode is high. (d) Quite a large compress ratio is performed.

The related fractal encoding and decoding algorithm includes: (a) To build the reduce-image. (b) To divide the image into a group of unoverlap {Ri} parts. (c) To form the Domain pool in the reduce-images that is in order from up to down, and then calculates average image gray value. (d) To search the Domain pools for every Ri, and find the most optimal matching Di part. The graphic for encode and decode can be designed.

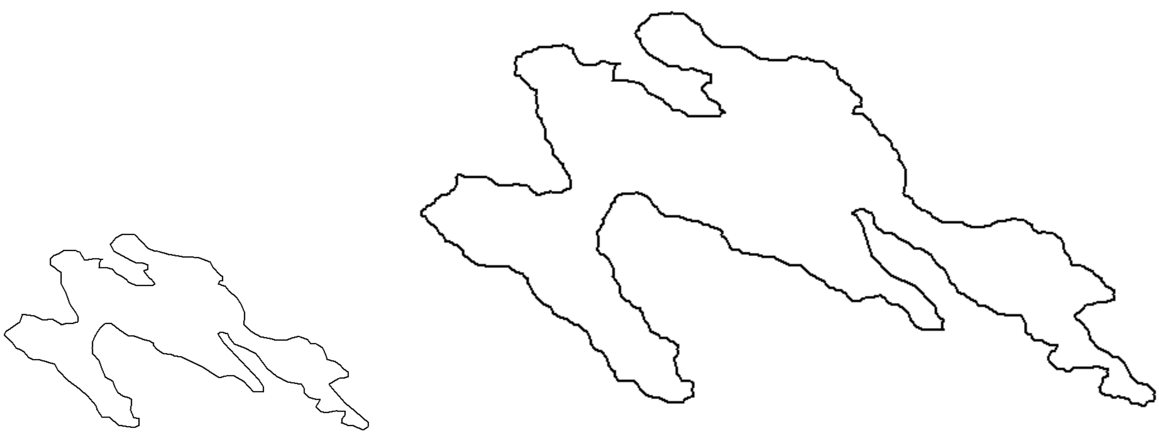
3. SOME RESULTS OF THE COMBINING REMOTE SENSING WITH FRACTAL APPROACHES

The studies on fractal interpolation and image compress and so on are to solve the transforming problems that maps are from small scales to large that, or from large scale to small that, and they are an important parts for the infinite scale management of ocean features, and the storage for an unprecedented amount of database. The combining remote sensing with fractal methods are studying by many scientists and have achieved new progress.

Fig.1shows shoreline map of some small island from remote sensing image, of them, Fig.1 (a) is a compress map with a small scale of 1/200,000, and Fig.1 (b) is a map with the large scale of 1/50,000. From Fig.1, we can see that Fig.1 (a) is the coastline map with small scale of 1/200,000, and Fig.1 (b) is a coastline map with larger 4 times than Fig.1a, which is that obtained through fractal interpolation approach.

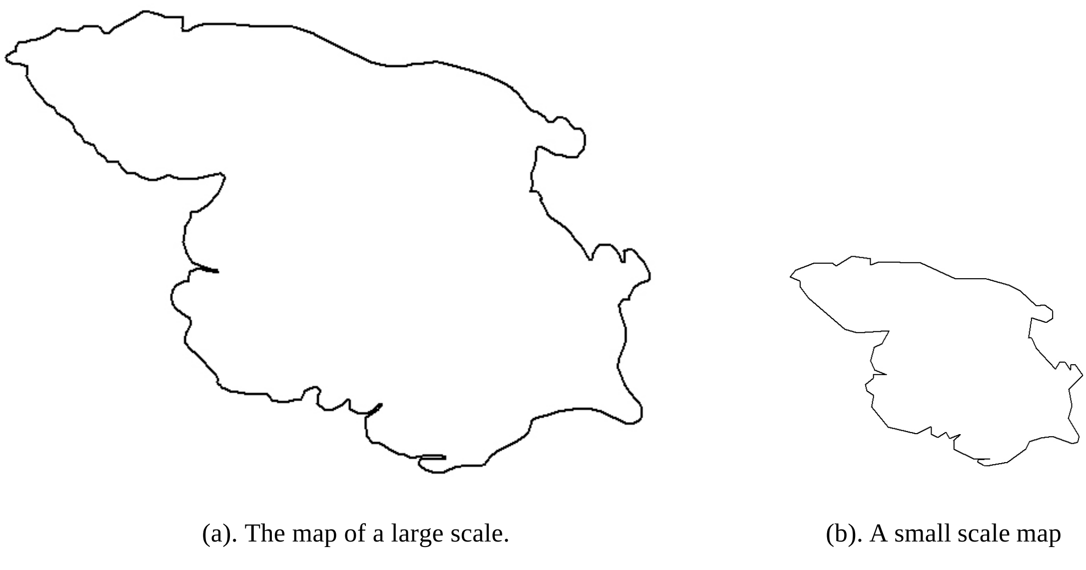
Fig. 2 shows another example of different scale coastline. Fig.2 (a) is a map with large scale of 1/10,000, and Fig.2 (b) is the shoreline map with mid-scale of 1/50,000 using fractal integrated method.

Fig.3 shows the shallow bottom topography of some sea areas from SAR subimage. Fig.3 (a) is processed SAR subimage, Fig.3 (b) shows a underwater bathymetry from a part of Fig.3 (a). Fig.3 (c) is the sallow topographic map with the scale larger 4 times than the map of Fig.3 (b).. From the map of Fig.3, we can see that the fine structures of the shallow topography may be more obvious by using fractal transformation.



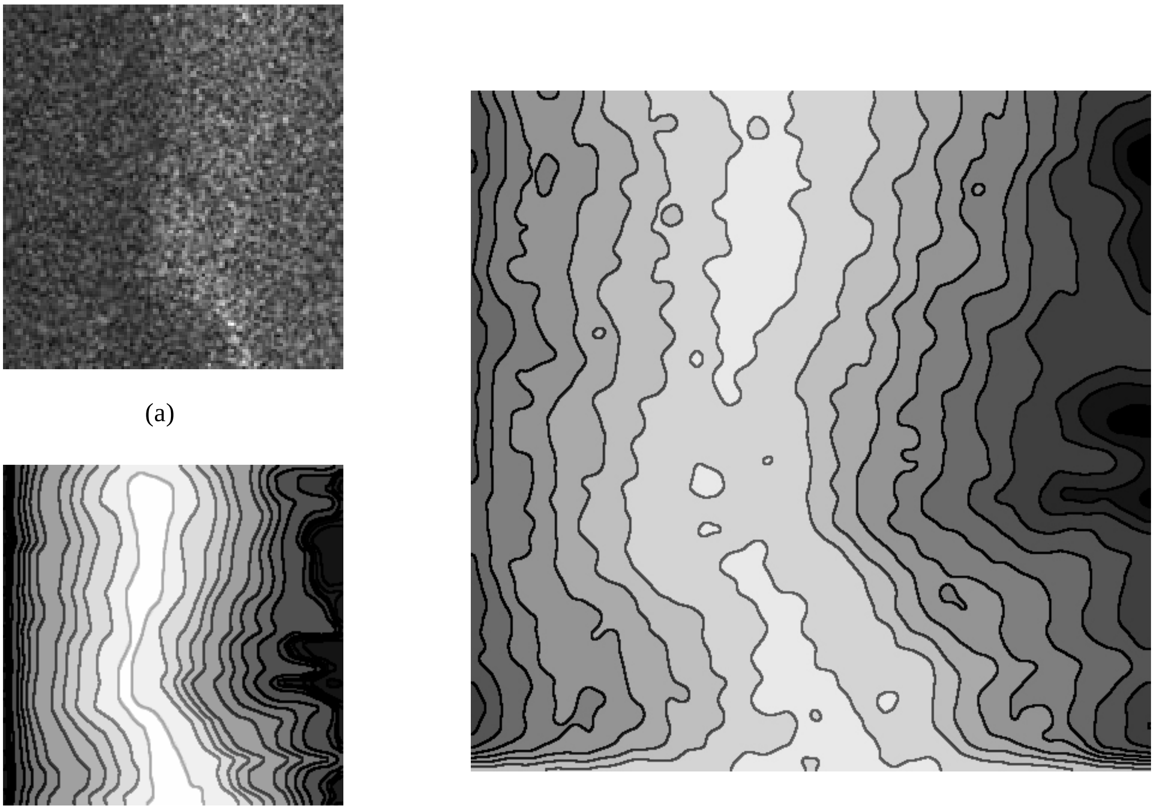
(a) (b)

Fig.1 The example of different scale maps of coastline
(a). The map of a small scale. (b). A large scale map



(a). The map of a large scale. (b). A small scale map

Fig.2 Another example of different scale maps of coastline



(a) (b) (c)

Fig.3 The maps of shallow bottom topography. (a) SAR subimage. (b) the bottom topographic map. (c) a new shallow topography obtained by fractal approaches.

The results indicate that multi-scale maps of coastline and shallow topography can get by using remote sensing associated with fractal approaches. The infinite scale management and the stores of an unprecedented amount of information are implemented.

From figure 1, 2 and 3, we can see that shapes of curves are almost the same. There are differences in their fine structures. Dynamic monitoring and their infinite scale manage of coastzone and oceanic phenomena provides powerful tools.

4. DISCUSSIONS AND CONCLUSION

The studies indicate that fractal approaches in the application of coastal and oceanic dynamic monitoring and their infinite scale managements are of the important supplement action with fast development and widely applications of remotely sensing technologies. Thus the closed combinations of remote sensing and fractal methods are of the great potential in oceanic applications. The preliminary results from the paper have been demonstrated.

Remote sensing and fractal theories and models as well as the wide application of ocean and coastal zone will be studied in the future.

REFERENCE

Hehai Wu, 2000. Research on fundamental theory and technical approaches of automated map generalization. Journal of Wuhan technical university of surveying and mapping, 25(5): 377-386.(in Chinese).

Hongyi Lin, Yingxie Li, 1992. Fractal theory—exploring of oddity. Beijing science and technical university Press.(In Chinese).

Huadong Guo etal., 2000. The theory and Applications for Radar Observing earth. Science Press.(In Chinese).

I.S.Robinson, 1985. Satellite Oceangraphy. Ellis Horwood Limited.

Qiao Wang, Hehai Wu, 1998. Study on fractal description of geographic information and automatic generalization. Wuhan technical university of surveying and mapping Press.(In Chinese).

Shupeng Chen etal., 1998. The Research on Remote Sensing interaction mechanisms. Science Press.(In Chinese).

Yiwen Jin etal, 1998.The Principle and Application for Fractal Geometry. Zhejiang University press. (In Chinese).

Zhaochong Wu and Zhenhui Fang, 2000. Edge detection of SAR images based on the fractal theory. Journal of Wuhan technical university of surveying and mapping, 25(4): 334-337. (In Chinese).