

PAPER • OPEN ACCESS

Implementation of ocean element curves and profiles on GIS

To cite this article: Zengjian Zhang *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1171** 012039

View the [article online](#) for updates and enhancements.

You may also like

- [Ocean Dynamics and the Inner Edge of the Habitable Zone for Tidally Locked Terrestrial Planets](#)

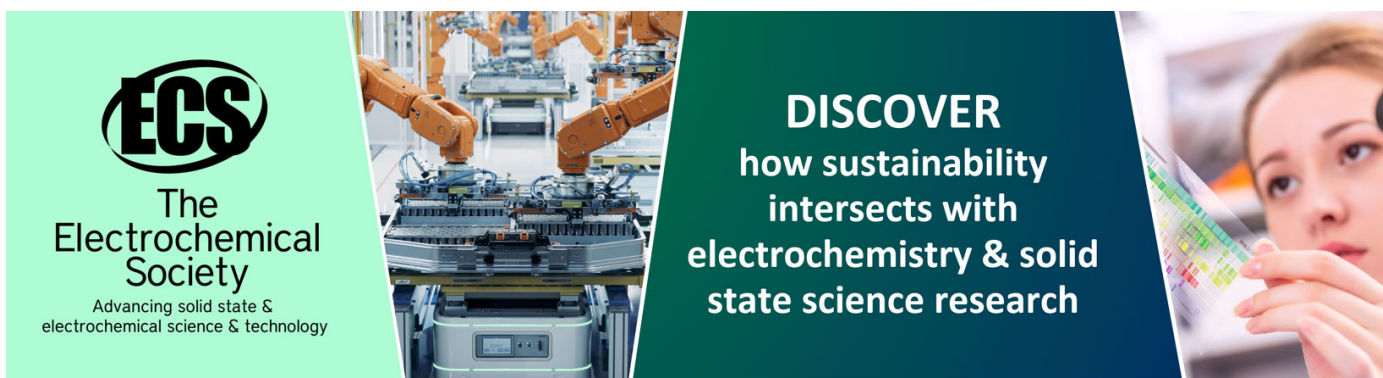
Jun Yang, Dorian S. Abbot, Daniel D. B. Koll et al.

- [Global distribution and cleanup opportunities for macro ocean litter: a quarter century of accumulation dynamics under windage effects](#)

Chia-Ying Ko, Yi-Chia Hsin and Ming-Shiou Jeng

- [Thin-shell Tidal Dynamics of Ocean Worlds](#)

Marc Rovira-Navarro, Isamu Matsuyama and Hamish C. F. C Hay



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Implementation of ocean element curves and profiles on GIS

Zengjian Zhang, Shanshan Xu¹, Shanshan Geng, Kaiyue Wang, Fei Chen and Pengfei Ning

National Marine Data and Information Service, Tianjin 300171, China

¹ E-mail: xss_nmdis@163.com

Abstract. This paper introduces the realization algorithm of ocean element curves and profiles on GIS. The algorithm projects the curves and profiles of ocean elements onto the geographic map. It realizes the combination of two-dimensional spatial geographic location, time dimension of curve change and spatial dimension of vertical profile, and displays three-dimensional information on a two-dimensional plane map. It can well express the actual survey data, statistical analysis data, and realize the comprehensive visualization of marine elements. The algorithm is useful in the visualization of ocean data. The algorithm has good application prospects in the visualization display of marine data, quality control of survey data, joint analysis of different elements or disciplines, and scientific research.

1. Introduction

Geographic Information System (GIS) is a cross discipline integrating computer science, geography, surveying and mapping, environmental science, space science, information and management science. With its intuitive application interface, powerful data management and spatial analysis functions, it has formed a multi-field, multi-level and multi-scale application pattern [1]. In recent years, the application of GIS in the marine field has been explored and practiced, from the spatio-temporal model of marine GIS [2, 3], centralized data management [4, 5], to the analysis and evaluation of data [6, 7], the development and management of the ocean [8, 9], to the two- and three-dimensional visualization of marine information and phenomena [10, 11], marine mapping [12, 13], and the sharing services of marine information and products [14-21], the coverage of its application is getting wider and wider, the level of application is getting higher and higher, and the objects benefited are getting more and more.

But at the same time, we must also see that with the construction of marine GIS standards, spatio-temporal models, databases and 2D/3D systems, the marine GIS products released by network sharing are still mainly based on raster data of remote sensing images, while the GIS marine phenomenon products made from measured data are poor, showing a relatively poor state. This has created obstacles for us to quantitatively describe the ocean and study the ocean. The main reason for this phenomenon is that we lack of research on the underlying calculation and projection methods of ocean phenomenon products.

In this paper, through the analysis of the drawing methods of ocean element curves and ocean element profiles, and the construction of the drawing algorithm, the visualization of ocean elements on GIS geographic maps is realized, and the four-dimensional data is intuitively displayed on the maps. This helps scientific researchers to know the changes of elements in different geographical locations over time through element curves, and further understand the changes of elements in different



geographical locations with depth through element profiles, providing intuitive reference for scientific researchers to analyze and judge marine phenomena.

2. Significance of ocean element curves and profiles

Ocean element curves are used to represent the trend of ocean element properties of a station or region over time, such as daily and monthly profiles of temperature and salinity of a station. Vertical profiles are used to represent the vertical distribution of marine element objects at a single station or region, such as the vertical profiles of temperature and salinity at a station [22].

Generally, researchers draw element profile maps, profile maps and station maps separately and then put them together to characterize the elements. The station maps are used to illustrate the geographical location where the data are collected, and the element profile maps and maps are used to illustrate the temporal variation and vertical distribution of the elements, and few people combine the two to describe them. The significance of this paper is to combine the geographic location in two dimensions with the temporal dimension of curve variation or the spatial dimension of vertical profile to show the three-dimensional information on a two-dimensional plan, which is convenient for researchers to analyze the spatial distribution of elements jointly with the temporal and vertical variation in a comprehensive way.

3. Projection algorithm of ocean element curves

The ocean element curve map consists of 6 parts: X-axis scale, X-axis scale value, Y-axis scale, Y-axis scale value, border, and change curve. This study carried out the projection of the element curves to the GIS geographic map, that is, to project these 6 parts from the original coordinate system to the area specified in the GIS geographic map.

The specific algorithm is as follows:

Step 1, the initial calculation parameters of the element curve to be projected are obtained. These include the lower left longitude lon and latitude lat of the longitude and latitude square area, the size gsize of the longitude and latitude square area, the data value sequence l of the element, the time sequence z of the element, the X-axis label Xlab, the X-axis unit xStr, and the Y-axis unit yStr, where the number of z values is set to nz and the number of l is set to nv.

Step 2, Set the basic information of the drawing area. The drawing area is located in the longitude and latitude square area where the vertical section to be projected is located, and its edge should be reserved with four directions of blank area (lScale, rScale, bScale, tScale), X axis scale area (xtickScale), Y axis scale area (ytickScale), X axis label area (xlabScale), and Y axis label area (ylabScale). These settings are proportional to the size of the longitude and latitude square area.

Step 3, the coordinates of the lower left corner of the curve axis of the element to be projected (x0, y0) are calculated based on the initial calculation parameters and the basic information of the plotted area.

$x0 = lon + (lScale + xtickScale + xlabScale) * gsize;$

$y0 = lat + (bScale + ytickScale + ylabScale) * gsize;$

Step 4, calculate the ratio of each scale pitch on the X and Y axes.

The formula for calculating the ratio of the scale spacing on the X-axis is as follows:

$monScale = (1 - lScale - rScale - ytickScale - xlabScale) * gsize / (nz - 1);$

The formula for calculating the Y-axis scale pitch ratio is as follows.

$zScale = (1 - tScale - bScale - xtickScale - ylabScale) * gsize / (nv - 1).$

Step 5, the coordinates of the values of each element in the element to be projected are calculated as follows:

$xn(k) = x0 + (k - 1) * monScale;$

$yn(k) = y0 + (l(k) - l(1)) * zScale;$

$k \in (1, nz);$

(xn(k), yn(k)) denotes the coordinates of the kth element value of the element to be projected; l(k) denotes the kth scale value of the Y-axis; l(1) denotes the first scale of the axis.

Step 6, calculate the quadrangular coordinates of the drawing border with the following formula.

```
xmin=xn(1);
ymin=y0;
xmax=xn(nz);
ymax=y0+(l(end)-l(1))*zScale;
```

The top-left (xmin,ymax), bottom-left (xmin,ymin), bottom-right (xmax,ymin) and top-right (xmax,ymax) coordinates of the plotted borders are obtained.

Step 7, the X-axis scale coordinates and Y-axis scale coordinates after the projection of the element change curve are calculated as follows.

```
xt=x0+(n-1)*monScale;
yt1=y0;
yt2=y0-xtickScale*gsz;
```

The starting coordinates of the nth x-axis scale short are (xt,yt1) and the ending coordinates are (xt,yt2).

$n \in (1, nv)$.

The Y-axis scale is calculated as follows.

```
xt1=x0;
xt2=x0-ytickScale*gsz;
yt=y0+(l(k)-l(1))*zScale;
```

The starting coordinates of the kth Y-axis scale short are (xt1,yt) and the ending coordinates are (xt2,yt).

$k \in (1, nz)$.

Step 8, the coordinates of each scale value labeling and unit labeling coordinates of X-axis and Y-axis are calculated with the following formula.

```
xb=x0+(k-1)*monScale;
yb=y0-xtickScale*gsz;
```

X-axis scale values labeled with coordinates(xb,yb) and labeled with values Xlab(k). where $k \in (1, nz)$.

The formula for calculating the X-axis unit labeling coordinates is as follows.

```
xbn=x0+(nz-1)*monScale;
ybn=y0-5*xtickScale*gsz;
```

The coordinates of the X-axis unit labeled as(xbn,ybn), with the labeled value xStr. The formula for calculating the coordinates of the scale value labeling of the Y-axis is as follows.

```
xc=x0-ytickScale*gsz;
yc=y0+(l(n)-l(1))*zScale;
```

The coordinates of the scale values of the Y-axis labeled as (xc,yc) and the labeled values as l(n).where $n \in (1, nv)$. The formula for calculating the coordinates of the Y-axis unit labeling is as follows.

```
xcn=x0(n);
ycn=y0(n)+(l(end)-l(1))*zScale+4*ytickScale*gsz;
```

The Y-axis unit is labeled with the coordinates(xcn,ycn) and the labeled value is yStr.

The calculation results of the above 8 steps are sorted and organized, and the calculation results are output. The output results include element curves, plot border lines, scale lines and marker points; among them, element curves are generated by connecting the coordinates of each element value in step 5; plot border lines are generated by connecting the coordinates of the plot border corners in step 6; scale lines are generated by cyclically connecting the starting and ending points of the X-axis and Y-axis scales calculated in step 7; marker points are generated by the X-axis and Y-axis scale markers and unit. The marker points are generated from the X- and Y-axis scale markers and unit markers calculated in step 8.

4. Projection algorithm of marine element profiles

The ocean element profile is similar to the ocean element curve, which consists of 6 parts: X-axis scale, X-axis scale value, Y-axis scale, Y-axis scale value, border, and profile. This section carried out the projection of the element profile to the GIS geographic map, that is, to project these 6 parts from the original coordinate system to the area specified in the GIS geographic map.

Step 1, the initial calculation parameters of the vertical profile element to be projected are obtained. These include the longitude lon and latitude lat of the lower left corner of the longitude and latitude square area where the vertical profile is to be projected, the size of the longitude and latitude square area gsize, the depth value d of the vertical profile element, the data value z and the number of data values mk of the vertical profile element, the depth value scale dlevel and the number of scales md, the data value scale zlevel and the number of scales mz, the X-axis unit xStr and the Y-axis unit yStr.

Step 2, Set the basic information of the drawing area. The drawing area is located in the longitude and latitude square area where the vertical section to be projected is located, and its edge should be reserved with four directions of blank area (lScale, rScale, bScale, tScale), X axis scale area (xtickScale), Y axis scale area (ytickScale), X axis label area (xlabScale), and Y axis label area (ylabScale). These settings are proportional to the size of the longitude and latitude square area.

Step 3, the drawing border coordinates are calculated based on the initial calculation parameters and basic information with the following formula.

```
xstart=lon+lScale*gsiz;
xend=xstart+(1-rScale)*gsiz;
ystart=lat+bScale*gsiz;
yend=ystart+(1-tScale)*gsiz;
```

where lScale denotes the ratio of the left margin area relative to the size of the latitude/longitude square; rScale denotes the ratio of the right margin area relative to the size of the latitude/longitude square; bScale denotes the ratio of the lower margin area relative to the size of the latitude/longitude square; and tScale denotes the ratio of the upper margin area relative to the size of the latitude/longitude square.

The coordinates of the lower left corner (xstart,ystart), upper left corner (xstart,yend) and upper right corner (xend,yend) of the plotted border are derived from the above equation.

Step 4, the depth values and data values after projection of the vertical profile elements are calculated; the calculation formula is as follows.

```
zmin=min(zlevel);
zmax=max(zlevel);
dmin=min(dlevel);
dmax=max(dlevel);
dscale=(yend-ystart)/(dmax-dmin);
zscale=(xend-xstart)/(zmax-zmin);
dp=(dmax-di)*dscale+ystart;
zp=(zi-zmin)*zscale+xstart;
i ∈ (1,mz)
```

zmin denotes the minimum value of the data value scale of the vertical profile element; zmax denotes the maximum value of the data value scale of the vertical profile element; dmin denotes the minimum value of the depth value scale of the vertical profile element; dmax denotes the maximum value of the depth value scale of the vertical profile element; dscale denotes the ratio of the plotting scale frame relative to the depth value scale of the vertical profile element; zscale denotes the ratio of the plotting scale frame relative to the data value scale of the vertical profile element; dp denotes the depth value of the projected vertical profile element; zp denotes the data value of the projected vertical profile element.

Step 5, the X-axis scale coordinates and Y-axis scale coordinates after projection of the vertical profile elements are calculated as follows.

```
xtn(k)=(zlevel(k)-zmin)*zscale+xstart;
```

$xtny1=yend;$

$xtny2=xtny1+(yend-ystart)*xScale;$

The starting coordinates of the k th scale are $(xtn(k),xtny1)$ and the ending coordinates are $(xtn(k),xtny2)$. Where $k \in (1,mk)$ and $xScale$ denotes the ratio of the x-axis scale relative to the size of the square area. The Y-axis scale is calculated as follows.

$ytn(j)=(dmax-dlevel(j))*dscale+ystart;$

$ytnx1=xstart;$

$ytnx2=ytnx1-(xend-xstart)*yScale;$

The starting coordinates of the j th scale are $(ytnx1,ytn(j))$ and the ending coordinates are $(ytnx2,ytn(j))$.

Where $j \in (1,md)$ and $yScale$ denotes the ratio of the y-axis scale relative to the size of the square area.

Step 6, calculate the coordinates of each scale value labeling and unit labeling coordinates of X-axis and Y-axis with the following calculation formula.

$xtny3(k)=xtny2+(yend-ystart)*xlabScale;$

Where $k \in (1,mk)$; $xlabScale$ denotes the ratio of X-axis labeling relative to the size of the square area; the labeling coordinates of the X-axis scale values are $(xtn(k),xtny3(k))$, and the labeling value of the X-axis scale values is $zlevel(k)$.

The formula for calculating the X-axis unit labeling coordinates is as follows.

$dxtn=xtn(mk);$

$dxtny3=xtny3(mk)+(yend-ystart)*0.035;$

The coordinates of the X-axis unit labeled as $(dxtn,dxtny3)$ with the labeled value $xStr$. The formula for calculating the coordinates of the scale value labeling of the Y-axis is as follows.

$ytnx22(j)=ytnx2(j)-(xend-xstart)*ylabScale;$

$j \in (1,md);$

$ylabScale$ denotes the ratio of the Y-axis annotation relative to the size of the square area; the coordinates of the Y-axis scale value annotation are $(ytnx22(j),ytn)$ and the annotation value is $dlevel(j)$.

The calculation formula of Y-axis unit labeling coordinates is as follows.

$dytn=ytn(md);$

$dytnx22=ytnx22(md)-(xend-xstart)*0.035;$

The Y-axis unit is labeled with the coordinates $(dytn,dytnx22)$ and the labeled value is $yStr$.

The calculation results of the above 6 steps are sorted and organized, and the calculation results are output, including the drawing border line file, the vertical profile element data point file, the line file, the scale line file and the annotation point file. Among them, the drawing border line file is obtained by connecting the lower left corner coordinates, upper left corner coordinates and upper right corner coordinates calculated and outputted in step 3; the vertical profile element data point file is generated from the depth value and data value of the vertical profile element calculated in step 4, which is connected as the profile element line file; the X-axis scale line file and Y-axis scale line file are obtained from the starting coordinates of the X-axis scale calculated in step 5 $(xtn(k),xtny1)$ and end coordinates $(xtn(k),xtny2)$ of the X-axis scale and the start coordinates $(ytnx1,ytn(j))$ and end coordinates $(ytnx2,ytn(j))$ of the Y-axis scale are formed; the annotation point file is formed by the X-axis scale value annotation value, unit annotation value, Y-axis scale value annotation value and unit annotation value calculated in step 6.

5. GIS-based implementation of marine element curves and profiles

Using the above algorithm, this study visualized the statistical results of the $5^\circ \times 5^\circ$ latitude and longitude grid of WOA18 (WORLD OCEAN ATLAS 2018) [23, 24] to obtain the cumulative yearly and monthly temperature variation curves of the 0m layer of the $5^\circ \times 5^\circ$ grid and the cumulative yearly temperature and salinity vertical profiles of the $5^\circ \times 5^\circ$ grid. The generated GIS format files are loaded

into ARCGIS to obtain GIS-based ocean element profiles and curves, as shown in Figure 1 and Figure 2.

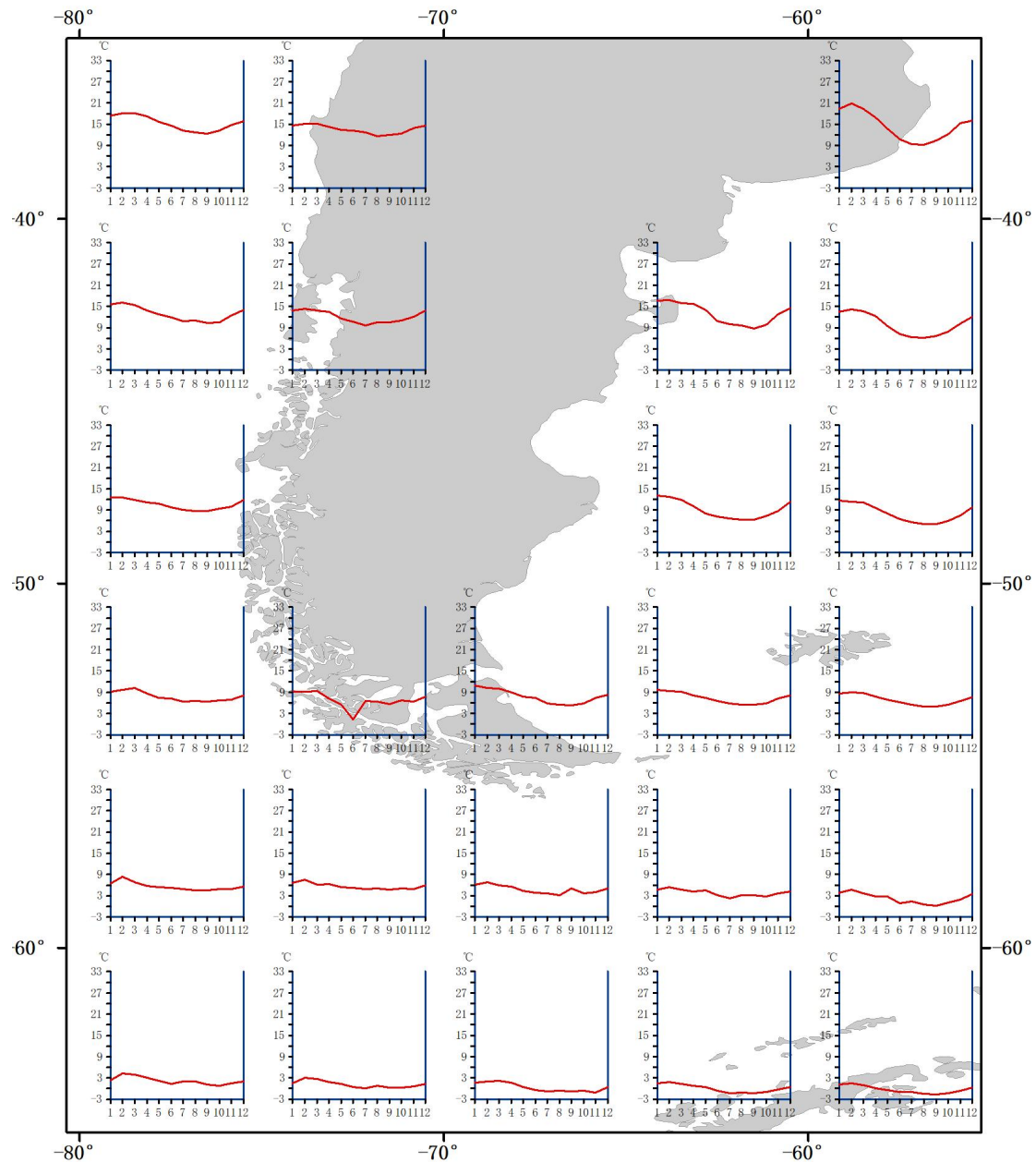


Figure 1. Cumulative yearly and monthly temperature variation curve of 0m layer of $5^{\circ} \times 5^{\circ}$ degree grid.

Figure 1 shows the projection results of the cumulative yearly and monthly temperature variation curve of the 0m layer of the $5^{\circ} \times 5^{\circ}$ degree grid, which shows the monthly variation of the surface SST in the southern South American sea. From the figure, we can see that the highest temperature in this sea generally occurs in February, and the lowest temperature occurs in August, September, and its highest temperature is below 20°C throughout the year, and the lowest temperature is about -3°C , which occurs in the sea south of 60°S . The temperature variation curve in the 5-degree grid of (75°W - 70°W , 55°S - 50°S) is obviously different from that of the surrounding grid, and the water temperature

takes a sharp turn in June, with a monthly average temperature of 0°C, much lower than the surrounding 3°C-6°C.

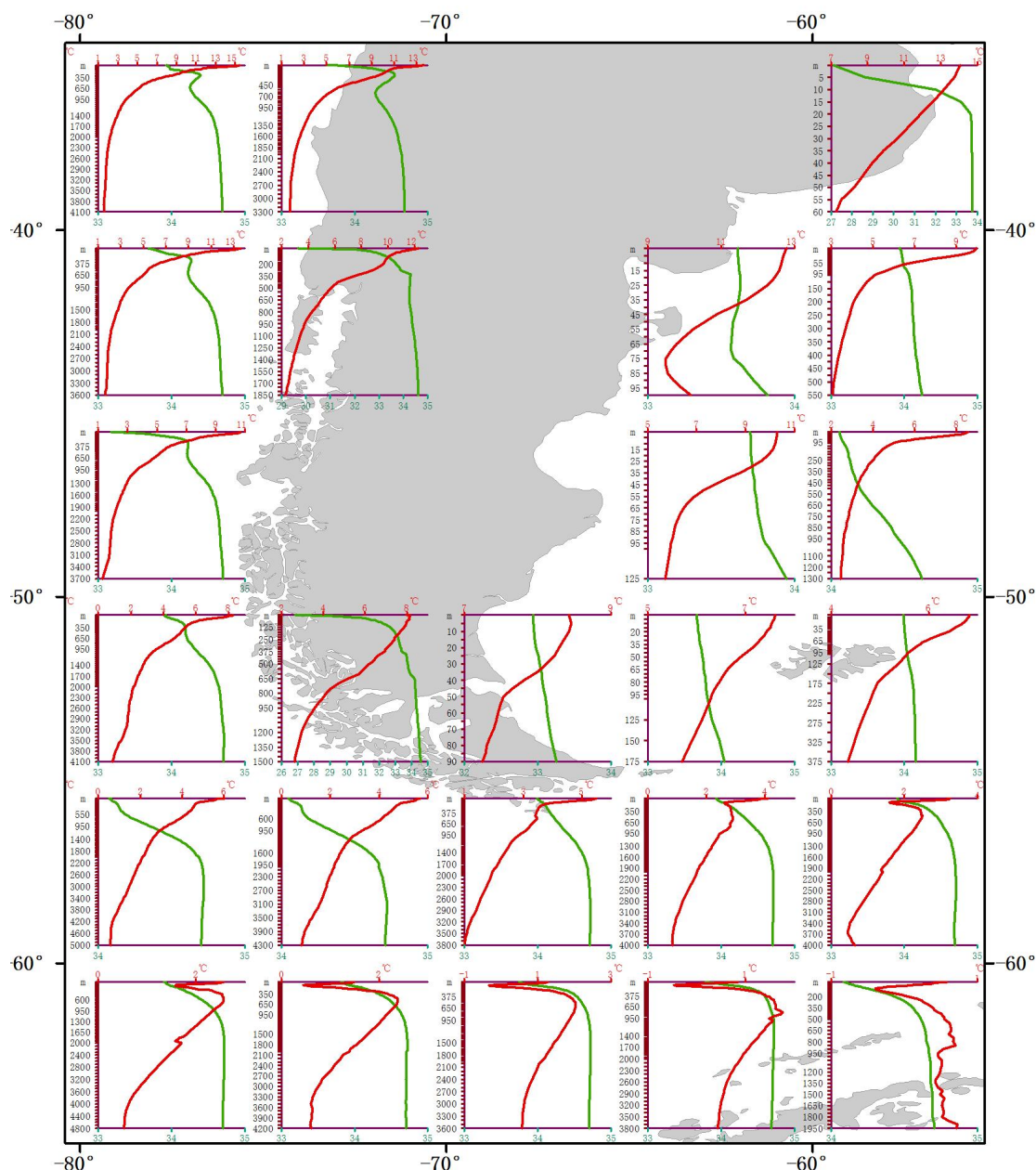


Figure 2. Cumulative annual temperature and salinity vertical profiles of 5°×5° degree grid.

Figure 2 shows the vertical profiles of temperature and salinity for a 5°×5° degree grid, which shows the vertical temperature and salinity distribution in the southern part of South America.

From the figure, we can see that the depth is deep in the west and south of South America, and shallow in the east. The temperature distribution north of 60°S is characterized by high temperature in the surface layer and low temperature in the middle and lower layers. There is an obvious thermocline in the subsurface. From the temperature profile curve south of 60°S, we can see that the water temperature decreases from the surface layer to about 100m layer. The water temperature from 100m to 600m layer increases again, and the water temperature from 600m layer to bottom decreases. We

can guess that there must be a stream of cold water around the 100m layer, which makes the temperature reverse.

The salinity distribution shows that salinity is low in the surface layer, and the salinity is high in the middle and deep layers. The salinity is between 33 and 35 in most sea areas. The minimum salinity about 27 occurs near the shore. The salinity about 34 to 35 is below 1000m.

6. Analysis of the application prospects

The GIS based marine element curve map and profile map combine the geographical position of two-dimensional space with the time dimension of curve change and the spatial dimension of vertical profile to display three-dimensional information on a two-dimensional plane map. This method can well express the actual survey data, statistical analysis data, and realize the comprehensive visualization of marine elements. The curves and profiles of marine elements based on GIS have good application prospects in the visual display of marine data, quality control of survey data, joint analysis of different elements or disciplines, and scientific research [25].

In terms of ocean data visualization, the ocean data of measured and statistical analysis disciplines and elements can be effectively visualized, so that users can clearly observe and analyze the time variation characteristics and vertical distribution characteristics of specific geographical location elements, as shown in Figure 1 and Figure 2.

In terms of data quality control, the difference between the field survey data and the climate state data can be clearly seen by projecting the field survey data onto the drawn climate state element curve and profile results. If we add the control of the maximum and minimum isocurves, we can quickly analyze whether there are certain anomalies in the survey data.

In terms of joint analysis of different elements or disciplines, the change curves and profiles of different disciplines can be drawn together, and the isolines, change curves and profiles can be superimposed together for joint analysis, so that users can analyze the distribution and interrelationships between different elements. As shown in Figure 2, superposition of temperature and salinity profiles can clearly show the different trends of temperature and salinity with depth, so as to analyze the depth of cold water.

In terms of scientific research, GIS based marine element curves and profiles provide researchers with a more intuitive map representation. It directly displays the changes and vertical characteristics of the elements on the geographical map, making the joint analysis between the target elements and other elements, and the overlapping analysis with the terrain and other elements simpler and more understandable.

References

- [1] Wang Hongmei and Zhu Zhenhai 1999 *Remote Sensing Technology and Application* **14(3)** 49
- [2] Zhang Tianyu, Zhou Chenghu and Shao Quanqin 2003 *GEO-Information Science* **4** 25
- [3] Liu Xiansan, Zhang Xin, Liang Bimiao and Chi Tianhe 2010 *Science of Surveying and Mapping* **35(6)** 142
- [4] Jiang Fenghui, Li Shujun, Zhou Dandan and Gao Shiliang 2011 *Geomatics & Spatial Information Technology* **34(3)** 146
- [5] Yang Zhonghua and Li Hongping 2013 *Geospatial Information* **11(5)** 65
- [6] Bu Zhiguo, Gao Xiaohui and Li Zhongqiang 2012 *Periodical of Ocean University of China* **42(1)** 36
- [7] Li Zhen, Ai Bo and Tao Huaxue 2007 *Marine Geology Letters* **23(8)** 35
- [8] Xu Xiaobo, Li Guozhong, Huang Jinhua, Cao Jian and Sun Xiaoru 2008 *Urban Geotechnical Investigation & Surveying* **6** 56
- [9] Yang Kai and Zhou Mei 2007 *Journal of Guangxi University for Nationalities (Natural Science Edition)* **13(4)** 67
- [10] Wang Xianghong, Liu Jiping, Wang Liang, Wang Yong and Xu Shenghua 2013 *Marine Sciences* **37(7)** 90

- [11] Yang Nai, Zhu Xiaodong, Yang Bin and Guo Qingsheng 2009 *Geospatial Information* **11(5)** 65
- [12] Cao Lijuan, Zhang Li and Chen Feng 2012 *Geospatial Information* **10(1)** 164
- [13] Fan Miao, Xing Zhe and Jin Jiye 2010 *Geography and Geo-Information Science* **26(4)** 109
- [14] Zhang Feng, Li Sihai and Wei Hongyu 2008 *Geospatial Information* **6(4)** 81
- [15] Zhou Yiwen, Shi Shilong and Wei Fang 2009 *Geomatics & Spatial Information Technology* **32(1)** 51
- [16] Zhang Qiufeng, Niu Fuxin and Li Xibin 2014 *Ocean Development and Management* **3** 13
- [17] Liang Zhong, Lin Qiaomu and Yao Zhongshan 2007 *Ocean Technology* **36(4)** 102
- [18] Liu Zhenmin, Zhang Renqun and Chen Jixiang 2003 *Ocean Technology* **22(4)** 27
- [19] Yang Feng, Du Yunyan, Cui Majun and Xiao Ruli 2011 *Bulletin of Surveying and Mapping* **10** 35
- [20] Yuan Xuemei, Jiang Yongguo and Guo Zhongwen 2010 *Periodical of Ocean University of China* **40(12)** 147
- [21] Li Li, Zeng Lan, Zhu Xiuli and Li Haochuan 2006 *Geomatics World* **6** 6
- [22] Lynne D. Talley, George L. Pickard, William J. Emery and James H. Swift 2011 *Descriptive Physical Oceanography: An Introduction, Sixth edition* 160
- [23] Locarnini R. A., A. V. Mishonov, O. K. Baranova, T. P. Boyer, M. M. Zweng, H. E. Garcia, J. R. Reagan, D. Seidov, K. Weathers, C. R. Paver and I. Smolyar 2018 *World Ocean Atlas 2018 Volume 1: Temperature. A. Mishonov Technical Ed.; NOAA Atlas NESDIS* **81** 52
- [24] Zweng M. M., J. R. Reagan, D. Seidov, T. P. Boyer, R. A. Locarnini, H. E. Garcia, A. V. Mishonov, O. K. Baranova, K. Weathers, C. R. Paver and I. Smolyar 2018 *World Ocean Atlas 2018, Volume 2: Salinity. A. Mishonov Technical Ed.; NOAA Atlas NESDIS* **82** 50
- [25] Fang Yinxia and Yu Xiajun 2000 *Marine Science Bulletin* **19(3)** 85