A Photomap of China with NOAA AVHRR Data *

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ABSTRACT

A low-cost and quick mapping technique on near-synchronous, small-scale and macrocosm is developed using digital NOAA/AVHRR data. The photomap of China on the scale of 1:4,000,000, is made from imagery and symbol base maps according to cartographic techniques strictly. The false color composite of AVHRR thermal infrared, near infrared and visible red channels is used to provide much information and colourful tones. The data processing include map projection transformation, image enhancement both on contrast stretch and image sharpening, color balance adjustment, cloud removing, separated processing of land and sea, modification of image seasonal aspect with vegetation index image and mosaic. The data was received by the meteorological satellite ground station in Guangzhou in the late autumn and the early winter from 1988 to 1991. This is the first small-scale, integrated and standard color photomap in China, especially it contains the whole South China Sea that is rather difficult or expensive to use other remotely sensed data such as Landsat or SPOT. Geographic element, map symbol and lettering were selected and designed carefully considering the finial load of the photomap content and vision effect. This photomap is very useful not only in remote sensing or geosciences application but also in many other fields.

Key words: Cartography Image Processing Mapping Space Imagery NOAA/AVHRR Photomap

INTRDUCTION

Photomap is an important field in cartography. Most of photomap were made with erath resource satellite system, such as Landsat or SPOT. But, for mapping a small-scale photomap, it is often neglected that NOAA AVHRR, sometimes, is a suitable and low-cost mapping data source of remote sensing. In China, it is impossible to use Landsat MSS or TM data for mapping the integral China. There are two reasons: The first is absence of the data of South China Sea and the parts of Northwest and Southwest China because of the limited ground receiving radius of the remote sensing satellite ground station in Beijing. The second is higher cost for processing so much data if a digital mosaic operation is performed. AVHRR is an easy-obtained, low-cost and high view frequency remote sensing data although its ground resolution is lower (1100 meters in nadir). Its larg view field and related small data volume are advantageous to the digital mapping operation economically. Also, the high view frequency of AVHRR is useful to get a high quality and cloud-free image with a cloud removing technology. Therefore, a high quality, near-synchronous and low-cost photomap on small scale can be achieved. The photomap was designed and made according to the national cartographic standard strickly. Albers equal-area projection was used as the mathematical foundation. The two parallel latitudes were located in northern latitude 25 and 47 degrees respectively as well as most published map of China. Geographic elements, map symbols and letterings were selected and designed carefully considering the finial load of the map content and vision effect. Three of AVHRR channels, thermal infrared channel 4, near infrared channel 2 and visible red channel 1, that were assigned to red, green and blue color respectively, were used to form a false color composite image. This composite fashion is more colorful than the general standard composite with near infrared and visible bands only. The process of digital image processing ensured a smooth mosaic without any artificial marks and the precise, artistic image base map (See Fig.1).

DATA COLLECTION AND PREPROCESSING

This is the first step in cartography of photomap. The most of image data was collected by Guangzhou satellite meteorological ground station and the other was from Xinjiang and Beijing ground stations. The receiving period was selected in the autumn and the early winter from the end of 1988 to the early 1991. In consideration of the ground resolution of AVHRR and the finial image subjective quality of the photomap on the scale of 1:4,000,000, China was divided into 64 subimages that each was the size of 512 by 512 pixels and 32 pixels overlap to adjacent ones. These subimages were encoded according to their geographic locations so that the multitemporal and registered image data were obtained to remove cloud cover or improve the image quality by combination. Most of the image were restricted within about 1024 pixels wide on a satellite nadir path in order to avoid the degradation of the image resolution on the sides of a path. The original AVHRR data was converted from 10-bit to 8-bit byte for display. Normally, the lower 8 bits of the original data

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were selected in AVHRR channel 1 and channel 2. A related range of brightness level was extracted from the original AVHRR thermal infrared channel 4 according to the ground temperature range except that of cloud, snow and ice. Sometimes, it was necessary to adjust the selected level range slightly for some special objective such as bright desert which has a higher spectral albedo to cause a brightness saturation in the lower 8 bits data of channel 1 and channel 2. The major part of the data preprocessing was a map projection transformation of AVHRR data on the basis of Albers equal-area projection. Satellite orbital parameters and the time code were used to execute the map projection transformation. The products of the preprocessing were placed in file to provide to the data processing of mapping.

DATA PROCESSING OF MAPPING

Data processing of mapping or image base map making is the most important step in mapping of photomap. An IIS digital image processing system was used to perform a precise geometric correction, image enhancement, color adjustment, digital mosaic and a series of special processings. The image base map as an output was made by a color film recorder and a normal darkroom processing.

Precise Geometric Correction

Although the preprocessed images were transformed into an Albers equal-area projection form, there were still a little errors that would cause the errors of the points position on the finial photomap to be larger than one millimeter. So it was necessary to perform a precise geometric correction to ensure the geometric precision of the photomap. A published standard map which was devided into 64 subsections was inputted to the system as a basis of the geometric control. Using the general image-register programm on the four quadrants of a subimage, displacement vectors in each quadrant were determined and a control points file could be created with these data. Then a geometric correction was operated with the normal polynomial correction for every subimages. For some images, a simple translation was satisfactory enough to the required precision. The resultant precision of points position on the photomap was less than one millimeter under the scale of 1:4,000,000.

Image False Color Composite And Enhancement

In order to get colorful tones, rich information and the best vision effect, a false color composite which included a thermal infrared band was taken. This composite scheme may be the best one in the composites of AVHRR data, although the degree of difficulty of color adjustment in a image mosaic is increased extremely. With the three channels which are the least correlation in a spectral space, thermal infrared (assigned as red), near infrared (green) and visible red (blue), the best color balance and the richest information can be achieved. Before the composite action, the original channel 4 data was processed by a negative operation so that the image brightness was in proportion to the ground radiant temperature. As a result, the higher the radiant temperature is, the bright the red color is. Therefore, the color rule in the composite fits the human subjective vision habit psychologically. A controlled linear stretching for the three components respectively, other than a scale based on the statistics of a subimage, was used so as to control the image color for mosaic and keep a appropriate image contrast and a color balance.

Digital Mosaic Operation

A high quality and satisfactory digital mosaic is a difficult, time-consuming and experience-needed thing. In this digital mosaic operation, there were 64 subimages to be mosaic together in the main part of China and 12 subimages in South China Sea. We classified the total 76 subimages into 6 parts according to the similarity of geographic landscape and image characteristic, Xinjiang area, Tibet area, Central China, South China, Northeast China and South China Sea. Mosaic was operated first in these parts with about 12 to 16 subimages for each one. Finially, a compeleted mosaic of the 64 subimages with the 5 parts except South China Sea was taken to form a embryonic form of the image base map. Color adjustment is a careful work. Although the histogram matching technique usually is useful in digital mosaic, it is just satisfactory on the condition of the similar geographic landscape and image character. Therefore, this method is effective for a limited and related harmonious area. In our mosaic procedure, histogram matching just effected in the overlap part of the adjacent images as a color reference and a interactive color adjustment was used in the other part of a image. A feather transition was used to smooth the color change and remove any artificial marks.

Some Special Processing Procedures

Cloud Removing Operation: With a series of multi-temporal and registered images, a cloud removing operation can be done. Two kinds of image detection algorithm were needed to extract cloud and cloud-shadow as the Range Of Interest (ROI) information to be stored. Cloud detection based on the lower temperature or lower brightness in channel 4 and higher brightness in channel 1 and channel 2 simultaneously. The shadow detection was only from the lower brightness in channel 1 and channel 2 simultaneously. These can be expressed as a logical relation as below;

$$\text{CLOUD} = (\text{LOWCH4}).\text{AND}.(\text{HIGHCH1}).\text{AND}.(\text{HIGHCH2}) \quad (1)$$

$$\text{SHADOW} = (\text{LOWCH1}).\text{AND}.(\text{LOWCH2}) \quad (2)$$

$$(\text{CLOUD}).\text{OR}.(\text{SHADOW}) = \phi \quad (3)$$

The CLOUD and SHADOW are the detected area of cloud and cloud-shadow in a image respectively. The LOWCHn and HIGHCHn are the lower and higher brightness of channel n in a image respectively. Both the detections were needed a proper threshold from a image. Cloud and shadow removing were done by a minimum and a maximum operation of multi-temporal images for the detected cloud and shadow area respectively. After the operation above, adjust the brightness of the substituted area slightly to eliminate the difference in brightness between the substituted parts and the background. A interactive adjustment should be used for some area if necessary.

Modification of Image Seasonal Aspect: It is well known that one of the most important facters which effects a image color directely is seasonal change of vegetation. Because the images were received duing a period of nearly 4 months, the seasonal change of vegetation in some images was obvious and could cause a problem in the mosaic especially in Northwest China. So, a modification must be done. Using the vegetation index, such as (CH2-CH1)/(CH2+CH1) or (CH2-CH1), we got a vegetation index image (VI). Then a simple arithmetic operation was used with the near infrared data (CH2) and the VI images to form a new image to substitute the original CH2 image.

$$\text{NEWNIR} = A * (\text{NIR}) + B * (\text{VI}) \quad (4)$$

$$(\ |B| < |A|,\ A > 0\ )$$

NIR is a near infrared image (CH2). A and B are

weighted coefficients determined according to a actual image. If we want to rise the vegetation information, B should be positive, otherwise, B should be negative. With this modification, the vegetation information between the different temporal adjacent images tended to the same and the other area kept the original state.

Change the Color of Snow or Odd Cloud: As the thermal infrared channel assigned as a red color had been negatived, the lower temperature objects appeared as a cyan color in the composite. This goes against the human habit and results a decrement of color contrast or a destruction of color balance also. To restore the snow or odd cloud to white, Use the snow or could detection method as the same as that in could removing step and take a negative operation for CH4 on snow part of a image and increase the brightness of CH1 and CH2 properly so that the snow is pure white.

Change the Color of Sea: Like the color change of snow, the color of sea in the original composite image appeared as red because of its related higher temperature compared with the land in winter. Although the thermal infrared data shows the cold and warm currents clearly, but that may be beyond the comprehension for most readers who does not have the enough knowledge about geosciences. Therefore, it is necessary to change the color of sea to fit an overwhelming majority reader's habit. A land mask was created by a bands arithmetic operation and a piecewise linear transform was used on the sea area to change the color from red to dark blue and remove thermal infrared information. In the illustration of South China Sea, thermal infrared information was kept but its contrastv and brightness was reduced extremely.

Image Sharpening Processing: The goal of this processing was to improve the image subjective quality. A Laplace transform for extraction of the edge feature was used to form a enhanced edge image. The resultant sharpening image was achieved by the means of a weighted addition of the original image and its enhanced edge image. This can be expressed as below:

$$NEWIMAGE = A * IMAGE + B * EDGEIMAGE \qquad (5)$$

$$(B << A,\ A,B > 0,\ A + B = 1)$$

A and B are the weighted coefficients.

Integral Processing of the Image Base Map: With the advantage of digital image processing, a integral image base map was made. Because the images outside China were not collected compeletely, the area outside China in the image base map was assigned a grey tone instead of image except a zone along the international boundaries of China. A white contour along the continental edge, including the islands, was added using a erosion algorithm of mathmorphology. A mini cross mark was located at the point of intersection of latitude and longitude every 5 degrees for the purpose of register with other geographic elements maps. The legends, margins and the illustration of South China Sea were inserted at once according to the design.

PHOTOMAP DESIGNING AND MAPPING

After image processing, the satellite image mosaic is not a real map, only the following steps are finished. There are four parts in photomap design; expression of geographic elements, lettering, legend design and preliminary layout. Geographic elements are very important for photomap. Expression of geographic elements involves mainly three problems: i.e., selection, location, design of color and symbol of geographic elements. Satellit photomap is a new type of maps with providing a lot of information. For general readers, a photomap itself provides a color photography reflecting native land so that they are interested in reading and interpreting; For readers with geographic knowledge, it provides much more information than many general-purpose maps, so that they can analyse and "taste" it. There is no doubt that geographic elements are first of all contents. It is necessary and confined to express them. In this photomap, geographic elements included rivers, lakes, reservoirs, settlements, railways, highways, the tops of mountain and internaional boundaries and so on. In the river system, all first-level branches and some secondary branches in China were selected, such as Han Shui river, Xiang Shui river; large lakes and reservoirs were selected, such as Boyang lake, Dongting lake and Danjang reservoir, so that the structure and density of rivers were represented. Cities above regional level were selected in principle, but parts of them were deleted in the east part of China with high density of population. On the contrary, in the west part of with low density besides regional cities, some county cities were also represented properly. In road nets, main lines of railways and national level highways (in western China, trunk highways) were selected. The grades of all social elements of selection were based on up-to-date published maps from China Cartographic Publishing House. For mountain elements, some famous and typic ones were selected (for example, Zhumulangma peak, Hangeli peak and yellow mountain and so on). With geographic elements of objective reality, however, it is difficult to display geographic elements because of the limited resolution of image. To display the selected position correctly, we used visual interpretion and overlaping depiction to locate geographic elements with the same scale and the same projection overlaping on the map of the image. In order to enhance the accuracy of depiction, it was necessary to depict correctively 5 by 5 degrees geographic grids in the overlaped map one by one. As a matter of fact, even though some rivers and settlements, railways and highways were too small and unclear, there was no problem to locate them. International boundaries were based on standard national boundaries published by China Cartographic Publishing House and refered to correlation of image information. That were examined and approved by National Surveying and Mapping Service. In order to stress on the geographic elements, we must apply symbols to express some trivial linear geographic elements (such as rivers, railways and highways) and very small settlements, some famous peaks and so on. Because the main color backgrounds of the image base map were blue, green and yellow, we decided to use violet for stream system, black and white sharply contrasted lines for railways, pinkish red lines for highways, black isosceles triangle symbols for the tops of mountain. In settlements, some important cities were exaggerated by their outline figures and the rest were represented by circle pinkish symbols, like red flowers on the background. International boundaries were decorated with violet bands so that the main area was reinforced. Lettering is an important part in " map languages ". Because of big chinese characters, lettering in number restricts the selection of geographic elements to a great extent. In the photomap, lettering of first level rivers, a part of secondary level rivers and large lakes were selected in principle. All of selected settlements and the tops of mountain had lettering. Railways and highways were not lettered. Great geographic units (such as Huabei plain, Dongbei plain and Sichuan Basin and so on) and some mountain ranges (such as Ximalaya Range, Tanggula Range and

Tianshan Range) were lettered. For the sake of sticking out letterings in the photomap, we taken on a way which made chinese characters with shadows of white rim. At present, the software with shadow chinese characters has not yet been manufactured, we taken on map-making way which color and white characters were overlapped and staggered each other. As respects of legend design, photomap is different from general-purpose map in content, because it is provided with dominant position of plantiful geographic information. The legend illustrates and interprets fully contents of photomap to readers. The legend was divided into three sections; The first section consisted of hydro-elements such as rivers, lakes, reservoirs, islands, coral reefs and so on. The second section consisted of physical elements such as deserts, loess landform, coniferous forest, marshes and so on. The third section consisted of social and economic elements such as cities, railways, international boundaries, Great Wall and so on. To distinguish snow from cloud in the photomap, a legend of cloud layers was added to prevent readers from misunderstanding. It is emphasised that the first and the third sections could be seen in a general map and the second section is only on the photomap. It is very useful to the high level readers. In order to differ from the legend in conventional maps, all contents of the legend were represented as a scheme of legend with "enviromantal mode", or a window of the images to reveal the main part (to contain its geographic background) that had been illustrated in the legend. Thus, readers can understand and read the legend in the organic way not a isolated way. By contrasting legend, it is easy to understand main part of the map in depth for readers. Particularly, by reading the groud elements, readers could relate enviroment to law of geographic distribution and make it have high value reading. It is necessary to discuss map layout. The photomap is on the scale of 1:4,000,000. The full margin size is 150 by 100 centimetres, which needed to use two standard-sized sheets to print, and regard 110 E as the central meridian line. According to the size, the northern most Mohe Town and the southern most Hainan Island lay basically in the edges of the sheet margin. In Comparison to above montioned, there were some distances from the eastern most and the western most international boundaries of China to the sheet margins. Thus it is passable to make use of the blank of East China Sea and the Pacific for arranging the illustration of South China Sea. In the photomap, the beautiful South China Sea image is seldom seen in other maps. The coral reefs, scattered the ocean like stars in the sky, were likely to inlay beautiful sapphires in the dark blue ocean, exquisitely carved. And so its scale was increased to 1:7,000,000. The whole South China Sea was laid in the lower right and the legend corresponded with South China Sea was laid in lower left, that made use of the area of the map out of China. They distributed symmetrically in right and left of the whole map and played an important role in balancing and steading the photomap. Owing to limitation of collection of satellite images, there were not sufficient images out of China. For the cake of uniting and sticking out main area, a part out of China was processed as grey. The ocean was a dark blue color and formed a sharp contrast with the land. Saturation was harmonized each other and it played a very harmonious role in the colorful main area.

CONCLUSION

A high quality, low cost and rapid mapping method of photomap has been developed for the macroscopic and small scale mapping using the full resolution AVHRR data. Digital image processing technique ensurse the high quality and the map accuracy. This is the first integral photomap of China with the digital image processing and also the first standard national photomap in China. Mapping of the small scale photomap is a potential aspect in NOAA AVHRR application. This photomap is very useful not only in the remote sensing or geoscience applications but also in many other fields such as education, planning, popular science and art appreciation. A better improved photomap, the second edition, in which the area outside China will be filled with image is going to be done.

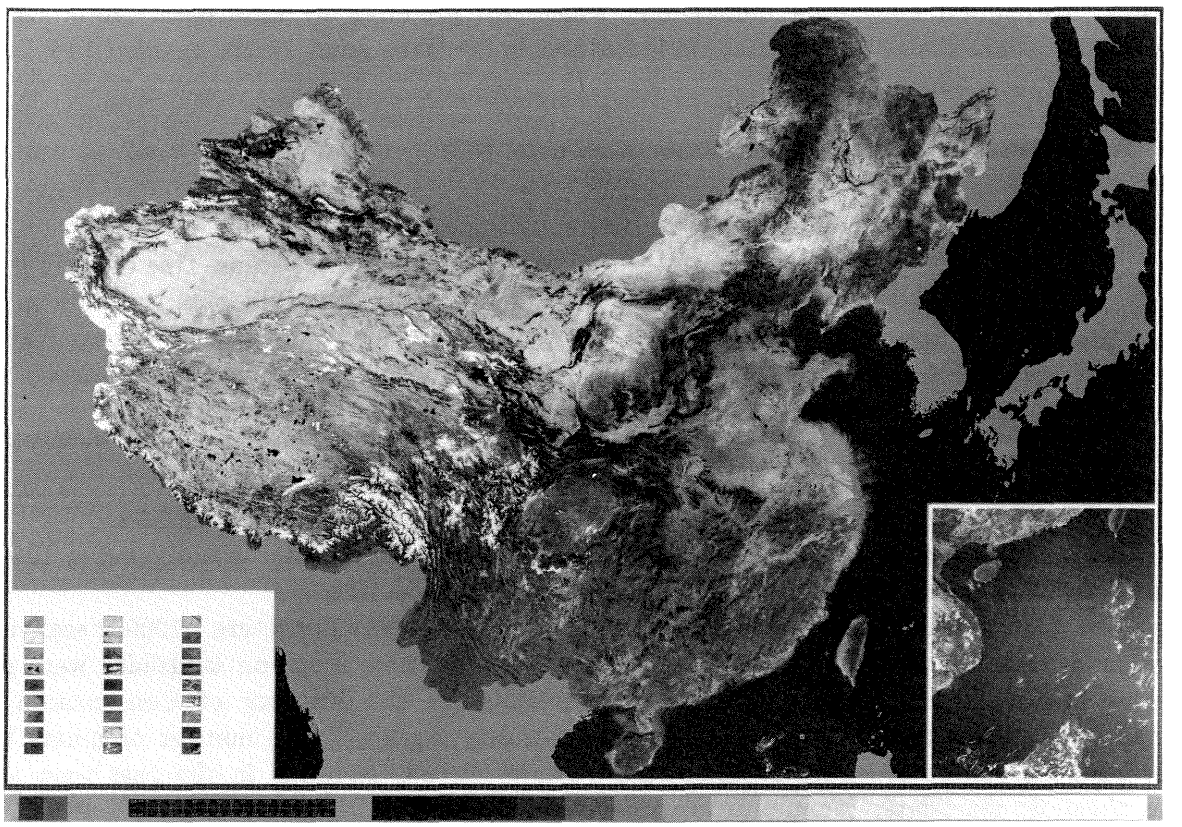

Fig.1 Image base map of the photomap of China