Cloud-removing Algorithm of Short-period Terms for Geostationary Satellite

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***Abstract*—The quality of the thermal infrared surface brightness temperature data has been the first limitation to the research of seismicity by thermal infrared anomalies. The interference of the cloud layer is one of the problems to be solved. If the earth surface is covered by the cloud layer, the thermal infrared information probed by the satellite will be the information of the cloud layer instead of the earth surface. The development of cloud removal algorithm for geostationary satellite short-period terms is conducive to capturing the changes of seismic precursor in a few days before the earthquake. Based on the characters of high time resolution and broad covering scope of the geostationary satellite, this work makes use of the pixel of a larger value to replace the pixel of a smaller value according the 2nd thermal channel with the suitable data of time and period, and realize the concrete algorithm.**

***Index Terms*—geostationary satellite, remote sensing, infrared, cloud removal algorithm, Short-period**

I. INTRODUCTION

Satellite thermal infrared remote sensing has become a promising technique for monitoring fault activities and earthquake precursors for its many advantages, such as a wide field of vision, high spatial resolution, short observation period, and also owing to its good reflection to thermal infrared anomalies of some major earthquakes. However, the thermal thermal infrared radiation of the earth's surface is influenced by the external non-seismic factors, such as cloud layers, terrain, object styles, and weathe. All the non-seismic factors cannot be excluded only with the satellite data in a period around the earthquake. A general research on the historic satellite data of at least two years using temporal and spatial compositive analysis of statistics is of great necessity to find out the universal features. For seismic thermal infrared remote sensing, the time resolution of the geostationary satellite is higher than that of the polar-orbiting satellite (a panorama graph which covers about 1/3 of the whole earth can be captured each half hour during the flood season or each hour during the non-flood season), which is favorable to generating short period and high quality brightness temperature data over all the surface of China and capturing the earthquake precursor information. Nevertheless, the lack of the seismology oriented extensive satellite data processing system and a massive professional data warehouse needed by seismologists has seriously restricted the research. The interference of the cloud layer is one of the problems to be solved. If the earth surface is covered by the cloud layer, the thermal infrared information probed by the satellite will be the information of the cloud layer instead of the earth surface. At present, the main means for eliminating the interference of the cloud layer is to compare and analyze the multi-temporal graphs of the same region during a period (e.g. 10 days). Assuming that a region has the weather of cloudless during this period, the image of this period can be used as a part to generate a composite image. For the polar-orbiting satellite used for seismic thermal infrared monitoring, only two-night images (with a remote possibility of three images) for the same region in China one day can be used because of its long revisiting period (the revisiting period is 24 hour for a single satellite). So it will take 10 days to synthesize a large area cloud-eliminated land surface Brightness temperature image, such as the whole China area(for the same receiving point), but hardly including the western region(because the elevation angle of the receiving antenna is small). Meanwhile, a fewer images for some local areas for pixel comparing lead to the lower quality of cloud-eliminated synthetic image. Thus the consecutive national synthetic land surface brightness temperature images with high quality and a short period are hard to be made.

During the acquisition of optical satellite images, clouds diversify the color and brightness of different image regions. Light transmission and scattering attenuation of clouds result in blurring and reduced contrast among ground objects. Images of objects cannot be obtained when clouds are too thick. The cloud removal problem of remote sensing image, has been a hotspot in the field of remote sensing image processing. So cloud removal from satellite images can improve the capability and accuracy of applications that use satellite images. At present, many domestic and international scholars carried on a great deal of method and algorithm research to cloud removal problem. For the thin cloud removal from single satellite images, there are common methods including histogram matching method, remote sensing image method of Multi-spectral information and homomorphic filtering. Histogram matching method use the gray histogram of image to represent the probability of the gray level appearing in the image[6] [7] [12]. The cloud removal method for Multi-spectral images detects and removes clouds according to the principle of spectral sensitivity[10] [17]. By filtering out the low-frequency information, the image can filter the cloud information interference in the method of homomorphic filtering[3] [14]. The problem of removal cloud in remote sensing images is not only the removal of the thin cloud, but also the removal of the thick cloud, which is also a hot topic in the research of cloud removal. The first method bases on image restoration, which combines the image theory of transformation and restoration realizes the cloud removal[16]. Multi-source image interpolation method, which compares the images of the same area obtained at different time periods, realizes the cloud removal in remote sensing images according to the image interpolation[15]. The preferable way to removal of thick cloud is the fusion of multi-source data, and in this way, the data obtained through different sensors or same source will be fused to remove the cloud[13].

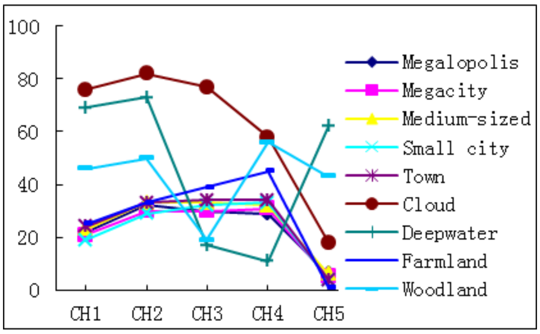
II. PROPOSED CLOUD REMOVAL ALGORITHM FOR GEOSTATIONARY SATELLITE SHORT-PERIOD TERMS

A. *Source of data*

Compared with polar-orbiting meteorological satellite, geostationary meteorological satellite has a low revisit period and large observation range. It can gets a global disk data every hour (half an hour of encryption time), so the infrared band of geostationary meteorological satellite is suitable for large-scale long-term dynamic seismicity thermal anomaly monitoring. The satellites gets a global disk data every hour, enabling seismicity thermal anomaly could be monitored in a large range by infrared band of geostationary meteorological satellite long-term dynamic.

B. *Infrared channel selection*

Comparing the distribution of the spectral mean, which from the atmospheric channel and each channel of all land surface types[8, 11], the second infrared channel of FY-2C satellite is sensitive to the cloud (The wavelength range is 11.5-12.5 microns). It is not obvious that the channel can distinguish various types of land surface such as vegetation, bare land and water, but it is suitable as an distinguish indicator of the clouds because of a clear difference between the land feature and the clouds(The spectral mean in each channel of all land surface types is shown in Fig.1). In the same way, the radiation value of the same land surface target is also different in the absence of cloud or shadow of cloud. Solar radiation from the earth's surface decreases with the solar radiation which is reduced by the effect of cloud shadow. Meanwhile, because the surface temperature that is continuously under the cloud shadow is lower than the land surface temperature of direct sunlight, the surface radiation value is decreased. Therefore, the method of cloud removal using channel 5 radiation can achieve better results during the day and there is no cloud interference problem in the night.



The spectral values in the figure are the results of the original sensor values of 0~100 normalized(Normalized channel values)

Figure 1. The spectral mean chart in each channel of all land surface types.

C. *Data processing and algorithm implementation*

Through the research of the annual variation law of brightness temperature in 9 test areas, the experiment selected suitable data between 0:00 and 3:00 a.m. every 3-5 days for synthesis. Choosing this time period is order to make the influence of sun elevation angle, relative azimuth angle, sunshine and cooling down time have roughly the same effect. Method of comparison using the second thermal infrared channel radiation values and replacing a small grayscale pixel with a large grayscale pixel remove the cloud. After the above experiment, synthesizing data every 5 days to remove the cloud can get better results.

Algorithm refer to the flow diagram 3-6-2. First, there are three arrays named A1, A2 and A3 that need to be set, the format is:

WORD A1[1024] [912], A2[1024] [912], A3[1024] [912];

For array A1[I][J], A2[I][J], A3[I][J], I, J are row and column number.

Next, for the first disk data, its UTC time need to be converted to the Beijing time, and its scaling, radiometric correction and geographical projection has been processed in the satellite data quasi-real-time processing business system. The brightness temperature value of the second thermal infrared channel is stored in memory M, and A2 is the pixel array of China regional projection template file. Comparing the pixel-level of M and A2, the brightness temperature value could be searched for its pixel row and column number in M, and this value could be stored in array A1.

For the second disk data, its UTC time need to be converted to the Beijing time in the same way, and its scaling, radiometric correction and geographical projection has been processed in the satellite data quasi-real-time processing business system. The brightness temperature value of the second thermal infrared channel is stored in memory M. Comparing the pixel-level of M and A2, the brightness temperature value could be searched for its pixel row and column number in M, and this value could be stored in array A3. Subsequently, array A1 and array A3 is compare by pixel, when the NE of a particular pixel in A1is bigger than another NE in A3, the pixel in A1 remain the same, and on the contrary, the pixel in A1 will be replaced by the value of the corresponding pixels in A3. Then, the third strip data is still stored in address A3, and A1 is a composite result of the first and second strip data at this time, so the above operations need to be repeated until the synthesis is completed.

Acting in accordance with above methods of work, images which is limited by selected time period and region will perform the same operation until all images are processed.

Ultimately, A1 will be stored as a HDF format and export.

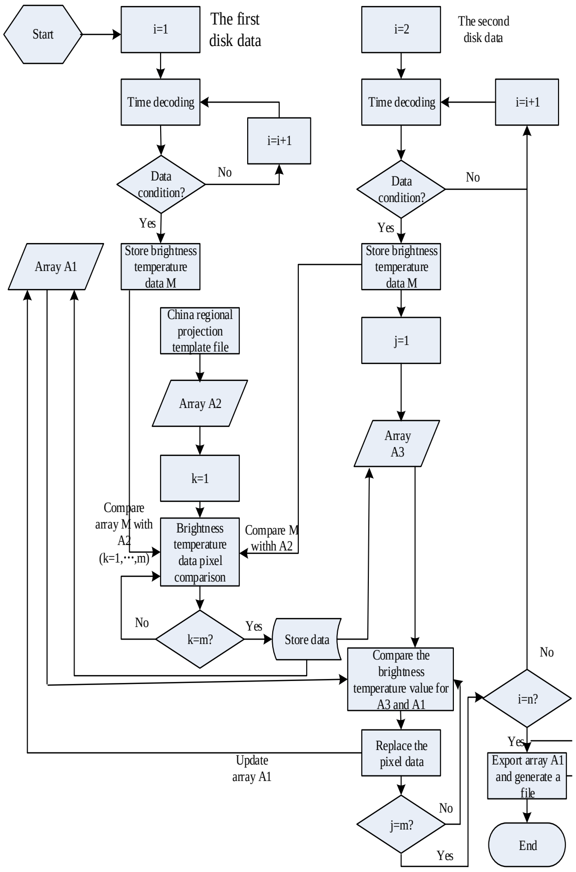
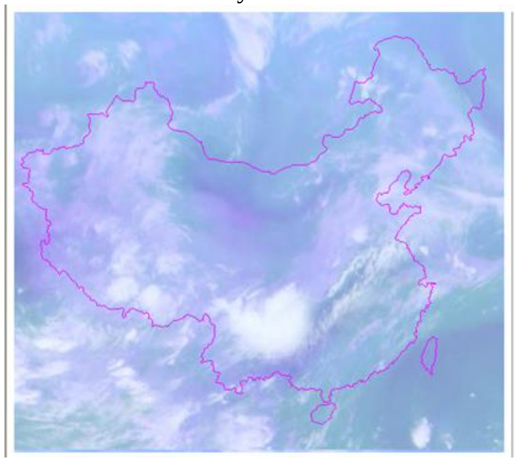


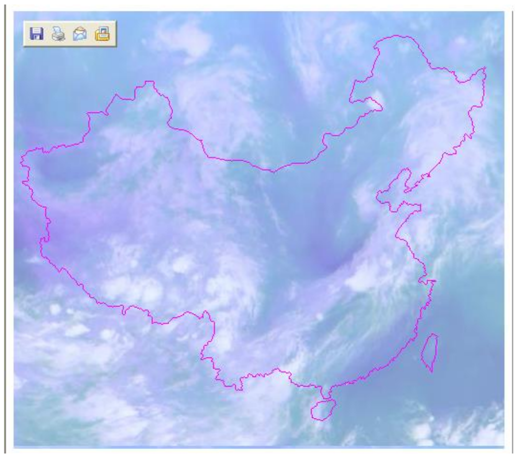
Figure 2. Flow diagram of composite cloud removal algorithm of geostationary satellite in 5 days.

III. CLOUD REMOVAL ALGORITHM'S PROCESSING RESULTS OF GEOSTATIONARY SATELLITE

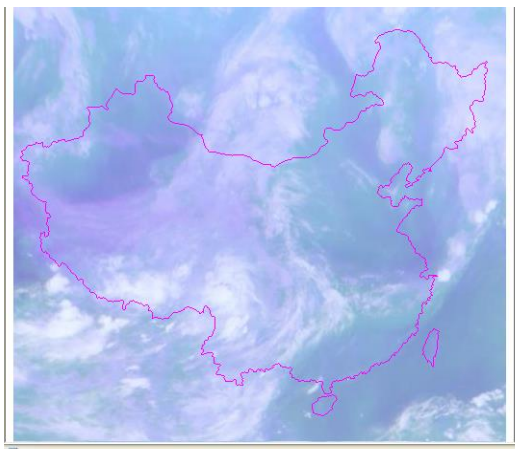
Fig.3 shows the result of FY-2C nighttime data which is disposed by cloud removal method of the 1 to 5 in July 2008(11:00-3:00 am), and the data time is expressed in UTC time. The first five charts are false color composite images which are disposed by three channels, and the white part of the graph is the cloud before removing the cloud. From the cloud removal brightness temperature map after the synthesis in 1st to 5th in July 2008, the mazarine blue part has been almost removed, furthermore the color from mazarine blue to orange red is used to indicate a gradual increase in temperature. In generally, the cloud top temperature is very low, so it can be seen that the clouds are clearly eliminated.



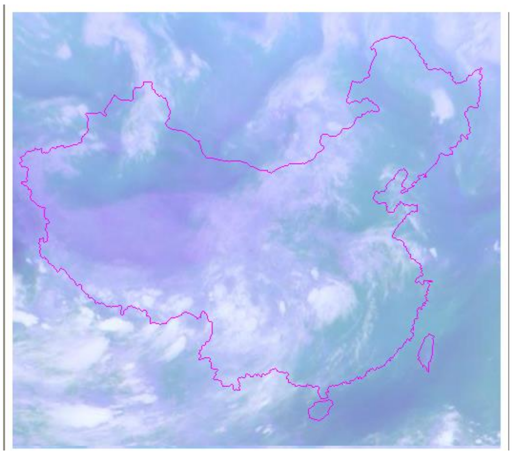
20080630_1732 false color composite map



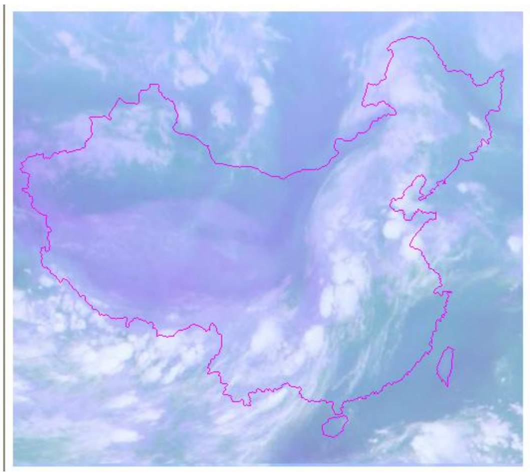
20080701_1732 false color composite map



20080702_1732 false color composite map



20080703_1732 false color composite map



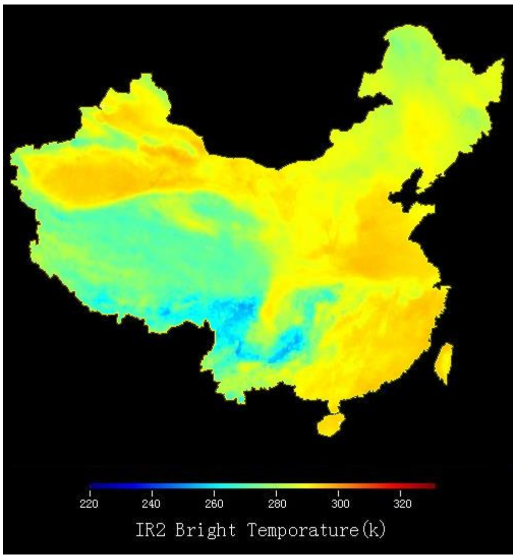
20080704_1732 false color composite map

Figure 3. False color composite map of a single image before removing the cloud.

IV. CONCLUDING REMARKS

FY-2C meteorological satellite receiving system has been established since August 2007, and the satellite data received everyday is up to 3G. Hence, about 1000G original data will be received every year which are a large database in addition with 3TB original data received from January 2006 to August 2007. The workload would be extensive if these data were preprocessed in receiving, correcting, backup, and generating images for specific purposes only by manual guard, so it is difficult to ensure the timeliness and reliability of satellite data. This thesis suggests for a model of calibrating the differences of the surface brightness temperature of the geostationary satellite generated by time.

Cloud removal composite map



the brightness temperature map from 1st to 5th in July 2008

Figure 4. Composite brightness temperature map of removal cloud in five days.

Based on the characters of high time resolution and broad covering scope of the geostationary satellite, this work makes use of the pixel of a larger NE value to replace the pixel of a smaller NE value according the 2nd thermal channel with the satellite data between 0:00 and 3:00 a.m. every 3-5 days (the influences from sun elevation angle, relative azimuth angle, sunshine and cooling down time are generally the same), and realize the concrete algorithm. The result shows that it is better to synthesize a cloud-eliminated image with every 5 days' satellite data (The results are shown in fig.4).

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