Interpolation method of HIRS/2 image using AVHRR image

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ABSTRACT

It is becoming increasingly important to integrate images collected by different remote sensors, but difficult because of different resolutions.

In this paper, interpolation method of low resolution image using correlation to other higher resolution image has been proposed and applied to the meteorological satellite NOAA AVHRR and HIRS/2 images. Using this method, the resolution of HIRS/2 images is improved equivalent to that of AVHRR image.

As an example, these interpolated images were applied to the precise atmospheric correction method using the combination of AVHRR data and HIRS/2 data to correct atmospheric effects at the area which is smaller than one original pixel of HIRS/2.

1. Introduction

Remotely sensed data from meteorological satellite NOAA can provide very useful and important information in meteorology, oceanography and other scientific fields because of its instantaneous and periodic observation of broad area of the earth surface.

The Advanced Very High Resolution Radiometer (AVHRR) has 5 channel scanning radiometer sensitive in visible, near infrared and infrared window regions. The horizontal resolution is 1.1km at the nadir. So, AVHRR images are very useful to derive quantitative meteorological and surface variables.

The High resolution Infrared Radiation Sounder (HIRS/2) has 20 channels primary in the infrared region. The instrument is designed to provide data for the calculation of vertical temperature profile. Air mass types, temperature profile, geopotential thickness, thermal winds, cloud heights, cloud amounts, surface emission and so on can be derived using data from HIRS/2. In addition, sea surface temperature can be corrected with the combination of AVHRR data and HIRS/2 data. But the resolution presented by HIRS/2 is 17km at the nadir and the data is not appropriate to the analysis of small areas and local phenomena.

Integrating images collected by AVHRR and HIRS/2 is important to derive more information from NOAA. However, there are two difficulties to integrate these data sets.

(1) Pixel to pixel registration between images is difficult.
(2) The resolution of HIRS/2 is low compared to that of AVHRR. So one pixel of HIRS/2 image is too large to analyze small area and local phenomenon.

In this paper, in order to integrate AVHRR and HIRS/2, the method which solve these two problems is proposed and an example of the applications of the integrated images is presented.

2. Matching between AVHRR image and HIRS/2 image

To integrate images collected by different remote sensors, it is necessary to know the positional relationship between images.

The angle of AVHRR between the satellite track and direction of the scan line is different from that of HIRS/2. Further, the nadir of AVHRR is not exactly the same as that of HIRS/2.

The positional relationship of two images is represented by the affine transformation coefficients. The central wavelength of HIRS/2 channel 8 is approximately equivalent to that of AVHRR channel 4. So, the HIRS/2 channel 8
image is similar to the AVHRR channel 4 image. Using this similarity, we can
derive the affine transformation coefficients. We use the template matching
method. Details about this method are given as below.
First, we select the images for template matching. We use the images which
were collected at the clear winter day. It is because there are much differences
between sea temperature and land temperature and so, it is easy to match
accurately. We format the two data sets to approximately the same pixel size before
template matching is performed. This is accomplished by enlarging the HIRS/2
image. The templates are selected from the regions which contain the coastlines
in order to derive error vectors accurately. If a reliable match is obtained, the
error vector is detected. It is done for more than 15 templates in one image. We
repeat this for some images. The error vectors between AVHRR image and HIRS/2
image are translated into affine transformation coefficients by the method of
least squares. In order to get more precise coefficients, we translate HIRS/2
images using these affine transformation coefficients. Using these images, we
repeat the process mentioned above over again and update the affine
transformation coefficients.
... The result is shown as Fig. 1. The affine transformation coefficients is
translated into the three parameters, ΔI, ΔJ, θAH as shown in Fig. 1. θAH is the angle
difference of the direction of HIRS/2 scanning from that of AVHRR. ΔI and ΔJ are
the displacements of HIRS/2 image from the nominal position that is obtained for
given θAH.

\[ θAH = -0.101 \]
\[ ΔJ = 3.51 \]
\[ ΔI = 1.44 \]

Fig. 1 Positional relationship between AVHRR and HIRS/2 images for NOAA10

3. Interpolation method of HIRS/2 images using AVHRR data
For multispectral images, the spectral bands have high correlation in spatial
characteristics. AVHRR channel 4 observes the earth surface temperature from
the space, so it is influenced by the atmospheric effects including clouds. In
addition, the temperature on the upper atmosphere is affected by that of lower
atmosphere, so AVHRR channel 4 image correlates with HIRS/2 images. By using
this correlation, interpolation of the HIRS/2 data can be performed.
After deriving affine transformation coefficients, we interpolate HIRS/2
image using correlation to AVHRR data. A primary assumption in interpolating is
that the local average and variance of the interpolated data are approximately
kept the same value as that of HIRS/2 data. It is because these parameters
represent the main and broad conditions of the atmosphere. We use interpolation
method using correlation to other high resolution image. this method is as
follows.

3.1 Interpolation method using correlation to the high resolution
image
The image to be interpolated is O1. Taking 2x2 average of the high resolution
image called RN, the image RN-1 is generated. We repeat this process until the
resolution is equivalent to that of O1. this image is called R1. Then, we get the
images of pyramidal structure.
Using O1, R1 and R2, we get the interpolated image O2.(See Fig 2) If all the
signs of 4 neighbors' gradient at O1 pixel are the same as those of R1 pixel, it is
considered that R1 and O1 are high correlated around this pixel. Then, the data for
pixels V - VIII are calculated. We get the local average and variance of R1 and O1
(r1-r9, o1-o9). Using these parameters, the interpolated data is obtained as follows:
If the signs are not the same, it is considered that these images are not correlated around this pixel. Then, we create the data by bi-linear interpolation of 01.

By applying these processes to each pixel, we get the image called O2 whose resolution is twice equivalent to O1's one. We repeat these step until we get the image whose resolution is equivalent to RN.

3.2 Interpolation method of HIRS/2

We interpolate the HIRS/2 channel 8 image at first using AVHRR channel 4 image by the method mentioned above. It is because that it represents the earth surface temperature and it has the highest correlation to AVHRR channel 4 image. Using this interpolated image, HIRS/2 channel 13 image which is designed to represent the temperature of 1000mb high, is interpolated. In this way, interpolation is performed in ascending order of observation height. As mentioned before, temperature of upper atmosphere is affected by that of the lower one, and this method reflects the temperature vertical profile. Fig.3 is the HIRS/2 channel 8 image which is enlarged to the AVHRR size and Fig.4 is the result of this interpolation method.

4. Atmospheric correction for AVHRR infrared data using interpolated data

As an example of the applications of these interpolated images, we correct the atmospheric effects for AVHRR infrared data at Mutsu Bay.

Remotely sensed sea surface temperature (SST) is distorted by the atmospheric effects. So the data must be corrected to compensate the atmospheric effects for SST observation. Minowa et al. proposed a method using the data of HIRS/2 sensors to correct the atmospheric effects for AVHRR infrared data. (1) This method can be applied only to the HIRS/2 pixel with little clouds and land. Because of the low resolution of HIRS/2 sensors, the region where this method can be applied is limited to widely cloud free sea surface. But using this interpolated images, the resolution of HIRS/2 data become high. Then, this method can be applied to a...
small region, if cloud free pixels are found within the low resolution HIRS/2 pixels.

Mutsu Bay is situated on the northern end of Honshu, Japan. It has a size of about 50kmx40km with a rather flat floor and is surrounded by the Tsugaru, Shimokita and Natsudomari Peninsulas. Since one pixel of HIRS/2 is larger than Mutsu Bay and represents the mixture of sea, land, and clouds, this method cannot be applied to Mutsu Bay. (see Fig. 3) But using the interpolated data, this method can be applied to a small region such as Mutsu Bay. The interpolated image of HIRS/2 channel 8 is shown in Fig. 4.

The result of this experiment is shown in Fig. 5 and Fig. 6. In the results of atmospheric correction, average error is 0.108K, standard deviation is 0.765 and correlation is 0.993 for all points. Average error means average of the difference between remotely observed temperature and observed temperature by buoys. This result can be used for many kinds of research work.

![Fig. 5 Relation between the remotely observed temperature (uncorrected) and sea truth](image)

![Fig. 6 Relation between the remotely observed temperature (corrected) and sea truth](image)

5. Conclusion

In this paper, an interpolation method of low resolution image using its correlation to other high resolution image is proposed and applied to the images from meteorological satellite NOAA. And then, as an example of the applications of the interpolated images, we correct the atmospheric effects at Mutsu Bay and it has been shown that this interpolation method is quite effective.

Moreover, this interpolated data can be useful for many analyses using HIRS/2 data. AVHRR data and HIRS/2 data whose resolution are the same as that of AVHRR data are useful to understand the three dimensional phenomena more accurately. By using three dimensional technique, many approaches of meteorological analysis can be performed. Three dimensional edge detectors will make it possible to grasp the shape of clouds, air masses and so on. By extracting skeletons and branch points of them, we will be able to track their changes more clearly and understand much information dynamically.

This interpolation method will be effective for not only AVHRR and HIRS/2 data but also the data collected by other remote sensors. To integrate multi-source and multi-resolution images, this interpolation method will be available.

Reference

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