A Review on Detection and Correction of Satellite Image using RSGIS

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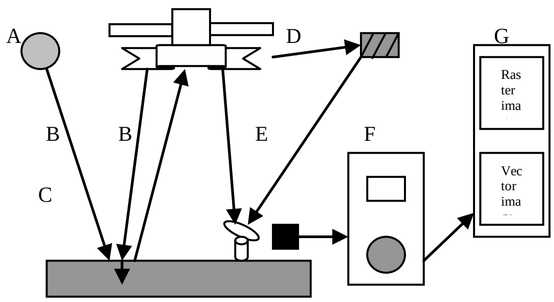
Abstract

The principles of remote sensing are based on the properties of the electromagnetic spectrum and the geometry of airborne or satellite platforms relative to their targets.

Remote Sensing is a technology used for obtaining information about a target though the analysis of data acquired from the target at a distance with a device that is not in contact with the object. In other words, it is the science and art of acquiring information (spectral, spatial, and temporal) about material objects, area or phenomenon, without coming into physical contact with the object it is composed of three parts such as:

1. The target – Objects, or phenomena in an area
2. The data acquisition – through certain instruments and
3. The data analysis – through some device.



A – Energy source or Electromagnetic energy
B – Radiation and the atmosphere
C – Interaction with the target
D – Recording of energy by the sensor
E – Transmission, reception and processing
F – Interpretation and analysis
G – Application modified form

More commonly the term remote sensing refers to imagery and image information derived by both airborne and satellite platforms that house sensor equipment. The data collected by the sensor are in the form of electromagnetic energy (EM).

Sensors carried by platforms are engineered to detect variations of emitted and reflected electromagnetic radiation. An essential component in geomatics, natural resources and environmental studies is the measurement and mapping of the earth surface – land and water bodies.

Basic Components of Remote Sensing

In much of remote sensing, the process involves an interaction between incident radiation and the target of interest. This is exemplified by the use of imaging systems where the following seven elements are involved.

1. Energy source or illumination (A): The first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.
2. Radiation and the atmosphere (B): The energy travel from source to the target, it will come in contact with and interact with the atmosphere it passes though. This interaction may take place a second time as the energy travels from the target to the sensor.
3. Interaction with the Target (C): Once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
4. Recording of energy by the Sensor (D): After the energy has been scattered by, or emitted from the target, we require a sensor to collect and record the electromagnetic radiation.
5. Transmission, Reception and Processing (E): The energy recorded by the sensor has to be transmitted, often in electronic form to a receiving and processing station where the data are processed into an image.

6. Interpretation and Analysis (F): The processed image is interpreted, visually and/or digitally or electrically, to extract information about the target which was illuminated.

7. Application (G): The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

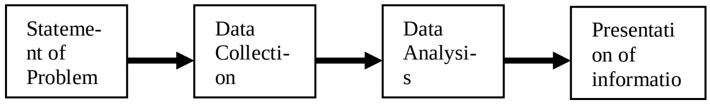


Fig: Remote Sensing Process

Atmospheric Effects

Remote sensing requires that EMR travel some distance through the earth's atmosphere from the source to the sensor. Radiation from the sun on an active sensor will initially travel through the atmosphere, strike the ground target, and pass through the atmosphere a second time before it reaches a sensor. The total distance is called the path length. For EMR emitted from the earth, the path length will be half the path length of the radiation from the sun or an active source. The atmospheres have a profound effect on intensity, direction and wavelength size of the radiation that reaches a remote sensing system. These effects are caused primarily by the atmospheric scattering and absorption.

Scattering

The redirection of EM energy by the suspended particles in the air. Different particles sizes will have different effects on the EM energy propagation. Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. There are three different types of scatter that occur as radiation passes through the atmosphere as:

1. Rayleigh scattering
2. Mie scattering and
3. Selective scattering

Atmospheric Correction:

The path radiation coming from the sun to the ground pixel and then being reflected to the sensor. In this on going process absorption by atmospheric molecules takes place that converts incoming energy into heat. Scattering by the atmospheric particles is also the dominant mechanism that leads to radiometric distortion in image data.

Need of Atmospheric Correction:

When an image is to be utilized, it is frequently necessary to make corrections in brightness and geometry for accuracy during interpretation and also some of the application may require correction to evaluate the image accurately. The various reason for which correction should be done:

- Derive ratios in 2 bands of multi spectral image since the effect of atmospheric scattering depends on the wavelength, the two channels will be unequally affected and the computed ratio will not accurately reflect the true ratio leaving the earth's surface.
- When land surface reflectance or sea surface temperature is to be determined.
- When two images taken at different times and needed to be compared or mosaic the images.

Correction Methods

Rectifying the image data for the degrading effects of the atmospheric entails modeling the scattering and absorption processes that take place. There are numbers of ways of correcting the image data for atmospheric correction

- Collecting the ground truth measurements of target temperature, reflectance etc. and calibrating these values or quantities on the ground and the radiance values by the sensor.
- Modeling the absorption or scattering effects for the measurements of the composition and temperature profile of the atmosphere.
- Utilizing the information about the atmospheric inherent to remotely sensed data i.e., use the image to correct it-self.

A) Random Cloud Detection Method

Random Cloud occurs as individual pixels with DNs that are much higher or lower than the surrounding pixels. Odd pixels that have spurious DN crop up frequently in image – if they are particularly distracting, they can be suppressed by spatial filtering. These defects can be identified by their marked differences in DN from adjacent pixels in the affected band; cloudy pixels can be replaced by substituting for an average value of the neighborhood DN. Moving windows of 3 X 3 or 5 X 5 pixels are typically used in such procedures.

In the image the pixel produce bright and dark spots. These spots also interfere with information extracting procedures such as classification. Random cloud pixels may be removed by digital filters. These spots mat be eliminated by a moving average filter.

Algorithm

Step 1: Design a filter kernel, which is a two-dimensional array of pixels with an odd number of pixels in both the x and y dimension. The odd-number requirement means that the kernel has a central pixel, which will be modified by the operation.

Step 2: Calculate the average of the nine pixels in the kernel; for the initial location, the average is 43.

Step 3: If the central pixel deviates from the average DN of the kernel by more than a threshold value, replace the central pixel by the average value.

Step 4: Move the kernel to the right by one column of pixels and repeat the operation. If the new central pixel is within the threshold limit of the new average and remains unchanged.

Step 5: When the right margin of the kernel reaches the right margin of the pixel array, the kernel returns to the left margin, drops down one row of pixels, and the operation continues until the entire image has been subjected to the moving average filter.

Average values for successive 3X3 pixels kernel

53

49

43

40	60	50	40	50
40	43	40	53	60
40	60	60	40	50

Original data set showing
Outline of filter kernel

40	60	50	40	50
40	0	40	90	60
40	60	60	40	50

Filtered data set with cloud
pixels replaced by average values
(3 X 3 Pixels)

Fig: Filtering to remove random cloudy pixels.

B) Cloud Field Detection by Variance ratio of Single-Band image

The intensity also depends on cloud droplet's radius, wavelength and other factors such as solar zenith angle and satellite observing angle. Therefore, the common threshold methods, as they are narrow in threshold range, result in un-welcomed cloud detection error. In this paper, single-band image bright-ness(or reflectance or thermal infrared brightness temperature) method is adopted, by its characteristics of variance ratio scaling, to position the cloud field to the level of pixel.

Formula 1 is variance ratio of single-band image brightness:

$$\frac{dy}{dx} = \lim_{x \to 0} \frac{f(x+\Delta x) - f(x)}{\Delta x} \qquad (1)$$

Where in practical situations, x is column coordinate, $\Delta x \neq 0$ is a constant, so the equation equals to:

$$\frac{dy}{dx} = \frac{f(x+\Delta x) - f(x)}{\Delta x} = \frac{\Delta y}{\Delta x} \qquad (2)$$

Where $\Delta x = | x_{next} - x|$ is difference of ambient value.

When considering image brightness process, Δy is difference of ambient brightness value. When considering image reflectance process, Δy is difference of ambient reflectance value. When considering brightness temperature process of thermal infrared image, Δy is difference of ambient brightness temperature value.

When cloud field emerges, a sharp change appears accordingly at two ambient points in brightness image, and this change could be precisely calculated and amplified. For instance, when the original spectral curve changes suddenly, the derivative curve's tendency changes inversely. When original curve smoothly passes inflexion point, derivative curve changes closely. When original curve is stable, and the derivative curve is stable as a line, too. In tracing variance ratio of image's brightness, combining with normalized brightness value of ground target detection, cloud-field interference could be exactly positioned. Cloud's absorption capability in different band is different, so combining brightness variance ratio of several bands could help to position and eliminate interference of cloud field.

The method of single-band variance ratio processes data mainly in three ways.

(1) Calculating the variance ratio of brightness image
(2) Calculating the variance ratio of reflectance image
(3) Calculating the variance ratio of brightness temperature image of thermal infrared spectral band

According to different bands, one from the above three can acquire cloud interference components.

- Variance ratio of brightness image formula:

$$db / dx = \begin{vmatrix} \Delta b_{11} & \Delta b_{12} & \ldots\ldots & \Delta b_{1n-1} \\ \Delta b_{21} & \Delta b_{22} & \ldots\ldots & \Delta b_{2n-1} \\ \vdots & \vdots & & \vdots \\ \Delta b_{m1} & \Delta b_{m2} & \ldots\ldots & \Delta b_{mn-1} \end{vmatrix}$$

Where *db/dx* is variance ratio of brightness image, Δb_{mn} is the difference of adjacent brightness value，Δx is adjacent difference on coordinate X.

- Variance ratio of reflectance image formula:

$$d(R_{B,T,FS}) / dx = \begin{vmatrix} \Delta R_{11} & \Delta R_{12} & \ldots\ldots & \Delta R_{1n-1} \\ \Delta R_{21} & \Delta R_{22} & \ldots\ldots & \Delta R_{2n-1} \\ \vdots & \vdots & & \vdots \\ \Delta R_{m1} & \Delta R_{m2} & \ldots\ldots & \Delta R_{mn-1} \end{vmatrix}$$

$$R_{mn} = \text{reflectance\_scale}_{B}(b - \text{reflectance\_offset}_{B}) / \cos(\Theta)$$

Where $R_{B,T,FS}$ is reflectance, ΔR_{mn} is the difference of adjacent reflectance value, Δx is adjacent difference on coordinate X, b is image's DN. cos (ϴ) is cosine of the solar zenith angle, reflectance_scale $_B$ is reflectance scale ratio, reflectance_offset $_B$ is reflectance zoom intercept.

- Variance ratio formula of brightness temperature image of thermal infrared spectral band To describe it, the first step is to use the reflectance of thermal infrared spectral band, reflectance scale ratio, reflectance zoom intercept, and cosine of the solar zenith angle to produce a radiance-and- brightness matrix. Then use Plank function in band's interval integral and get a brightness-and-temperature matrix.

C) The principal component transformation split-and-merge clustering method (PCTSMC):

The algorithm processed data from every other pixel in order to reduce the data volume for computational efficiency. Thus, the basic spatial resolution of the pixel in this study is 2.2 km at nadir. For most of the studies discussed below, the images consist of 512 X 512 pixels. First, the land areas in the image are carefully masked by inserting special values into the land area data. The present cloud-detection algorithm is then applied to the remaining data. The present algorithm is characterized by the following two points. One is that the algorithm has a recovery function. In previous algorithms, the pixel was identified as cloud-free only if all the tests proved negative. However, there are usually no complete threshold values. If severe threshold values are adopted, cloudy pixels will certainly be removed. However, this procedure will even remove some cloud-free pixels, which is undesirable. Choice of a severe threshold value is the safest way to ensure that no cloudy pixels escape detection. As a result, a large number of cloud-free pixels may be lost. The present algorithm allows a cloud free pixel to be recovered even when one of the tests show the pixel to be cloudy. The other point of difference from previous algorithms is that a two-dimensional histogram is used in the present algorithm to detect cloudy pixels. The present algorithm can be explained by the use of AVHRR data obtained from satellite passes over the Japan Sea for 9 April 1988 at 0334. A flow diagram of the present algorithm is shown in Fig. 1.

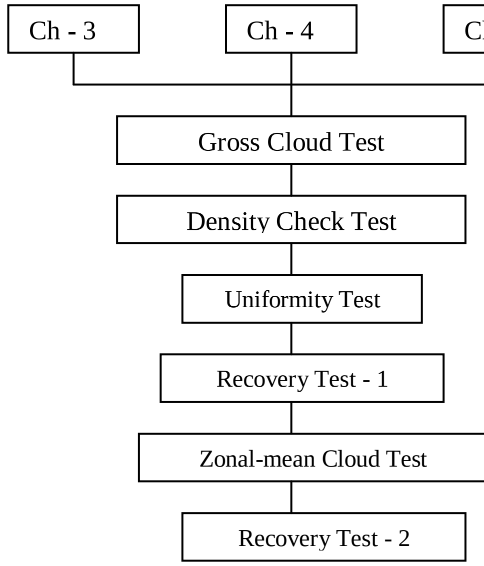


Fig: A flow chart to detect nighttime cloudy pixels

i) *The gross cloud test*

The first test is the gross cloud test (GCT) which uses the brightness temperatures from Channel-4. This test is very simple and common to other algorithms. In this test, all pixels with brightness temperatures from Channel-4 of less than a pre-defined threshold value are rejected as cloudy. The threshold value of 268 K is adopted here.

ii) *The density check test*

The density check test (DCT) is the most important test in the present algorithm. The brightness temperatures from Channels-3, -4, and -5 are used in this test. Originally, an attempt was made to examine the inter-channel relationships expected under cloud-free conditions, obtaining regression coefficients and interceptions between the brightness temperatures for each channel.

iii) *The uniformity check test (UCT)*

Spatial variations in observed temperature fields are generally smaller for cloud-free areas than those in cloudy areas. Here, examinations are made of the 3 × 3 constructions of element unit arrays where the center pixel was judged as cloud-free in the previous tests. If the maximum temperature difference between the central pixel and the four neighboring pixels is more than 1 K, the central pixel is flagged as cloudy. Generally, cloud-free pixels corresponding to an oceanic front are often removed as cloudy in this test because the threshold value of 1 K is fairly small. This is a severe problem since oceanic fronts are very important in oceanography studies.

iv) *Recovery test 1 (RT-1)*

The pixels judged as cloud-free by the previous UCT. The remaining pixels are sure to be cloud-free since the threshold value of the UCT is considerably severe. Even if a pixel was judged as cloudy by the UCT, the pixels existing in the area surrounded by the contour line might be considered as corresponding to oceanic fronts when the pixels existing in the high density area. Therefore, pixels which are located in the high density area and judged to be cloudy by the UCT are recovered as cloud-free pixels. The remaining pixels are then identified as cloudy. The threshold value of the frequency in the grid is set at 15% of the maximum frequency. This value of 15% was empirically determined.

v) *The zonal-mean cloud test (ZCT)*

Spatial variations of sea surface temperature in the zonal direction are much weaker than those in the meridian direction. Thus, if the brightness temperature from Channel-4 differs from the average value in the zonal direction by more than 10 K, the pixel identified as cloud-free in the previous tests is now classified as cloudy.

vi) *Recovery test 2 (RT-2)*

This test consists of two separate tests. In the first test, an array of 5 × 5 element units of which the center was a pixel judged as cloudy in previous tests (except by the GCT) was constructed. If more than eighteen pixels among the surrounding twenty-four pixels were judged as cloud-free, the center pixel was recovered as cloud-free. In the second test, an array of 5 × 5 element units in which the center is a pixel judged as cloud-free in previous tests is also constructed. If more than twelve pixels among the surrounding twenty-four have been judged as cloudy, the center pixel is determined as cloudy and rejected.

Result and comparison

The cloud field separation, auto registration, resampling with brightness modification and dark background equilibrium, the data fusion satisfies consistency in two ways.

(1) Band 6 data exactly come into the position where cloud field and cloud pixel of band 1 used to be and the original cloud-free field of band 1 remains the clear-sky data unvaried.

(2) The post-fusion band 1 cloud field and pixels are properly uncensored in details, and no pixel overlapping around fusion suture, the exactitude level to pixel.

The re-sampling ratio relies on the two confining points at the edge of a certain cloud field, thus re-sampling ratio on the whole is dynamic, making a consistent difference on the overall band 1 data, and the hue being much closer. The least square fitting between the selected band 1 and band 6 gives waveband relevance and, post-fusion data bear consistent relevance. Here R equals to 0.78. It is noticeable that after data fusion the normalized mean reduces from 0.239 to 0.179 and normalized standard difference reduces from 0.16098 to 0.0573633, statistically proving a great refinement. There might be horizontal stripes in the image, due to one-dimensional cloud field dealings, which can be attenuated by LEE filter, mid-value smooth filter, and mean smooth filter.

Conclusion

1. The clouds are processed in different ways based on the thickness of the clouds. In the concept, it is agreeable to common sense. The accuracy of classification does not be promoted after finishing cloud filtration because the methods of the cloud filtration destroy the original pixel values of the images extensively. Because the filters remove the noise in the images systematically and the cloudy noise distributes over the images randomly, the effect of filters is limited. It is the reason that the accuracy is lower than before instead of increase.
2. In this method of brightness variance ratio is adopted to exactly position the cloud boundary in satellite data. By setting brightness threshold and tracing cloud field tag it is efficient to detect cloud pixel, and large-scale cloud field as well.
3. By relocation, resampling, confine the multi-band fusion dealing only to the cloud field and cloud pixel, thus clear-sky data of the original band immune from it. At the same time, resampling data in fusion region and transmission band data are of consistent rule in changing.
4. By brightness equilibriums and contrast control, the fusion data and clear-sky data are close in hue, no overlay-area between them, and finally to prove high fedelity in data.
5. There was a tendency for many cloud-free pixels to be misjudged as cloudy and rejected from analysis. These rejected pixels can possibly be retained allowing many cloud-free pixels to be free from misjudgment. A more reliable and effective cloud detection algorithm should be developed in the future.

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