CHAPTER 4

Limitations of RS Data

4.1 Introduction

With the increasing use of Remote Sensing (RS) products and techniques, more and more challenges and opportunities came out. Here in our research area, we focus on one of the significant aspects of satellite imagery which are clouds and cloud shadows that affect the RS data.

4.1.1 Clouds and Cloud Shadows

Remote sensing always provide a high quality of performance in many applications on account of global and repetitive measurement capability, such as scene analysis, land use classification, landscape ecological change detection, etc. However, keeping in view the various uses for remote sensing images, the first goal is to extract earth observation information from the satellite images [29]. Unfortunately, two-thirds of the Earth's surface is always covered by clouds throughout the year [30], causing serious problems in optical wavelength remote sensing [30]. Since approximately 50% of the earth is covered by cloud at any given time, one of the most significant challenges in creating repeatable and robust classifications is understanding and appropriately addressing cloud contamination [28, 31]. For example, cloud cover affects the accuracy of vegetation estimates, and cloud cover affects the climate system over a broad range of time and space scales [28, 32].

Many researchers have attempted to detect clouds and the corresponding cloud shadows so as to eliminate cloud contamination producing cloud-free imagery [29, 30]. However, numerous obstacles still exist. For example, the thin cloud and cloud shadow pixels had similar reflectance ranges to the cloud-free pixels; in particular, both cloud shadow and water pixels had a very similar reflectance range, indicated that bright surface features such as snow, ice, and sand can easily be mistaken for cloud features in the visible portion of the spectrum. Even though the locations of clouds can be detected, it is still difficult to estimate the locations of their corresponding shadows [30]. This is because, in some cases, the clouds and their shadows are likely to be separated by a considerable distance. The locations of shadows in the image depend on the distances of the corresponding clouds from the ground and the incidence angle of the sunlight at that time [30]. In addition the location of clouds in the scene may have an impact on the classification algorithm [28, 31].

4.2 Remote Sensing Image Resolution

The Earth observation satellites provide a wide variety of image data with different characteristics such as spatial, spectral, radiometric, and temporal resolutions. Resolution is defined as the potential of an entire remote sensing system to render a clearly defined image. Resolutions of a remote sensing are of different types. Nature of each of resolution should be understood in order to extract meaningful biophysical information from the remotely sensed imagery [33].

4.2.1 Spatial Resolution

The spatial resolution of an imaging system is not an easy concept to define. It can be measured in a number of different ways, depending on the user's purpose. The most commonly used measure, based on the geometric properties of the imaging system is the instantaneous field of view (IFOV) of sensor [35]. The IFOV is the ground area sensed by the sensor at a given instant of time. The spatial resolution is dependent on the IFOV. The dimension of the ground-projected is given by IFOV, which is dependent on the altitude and the viewing angle of sensor [34]. The finer the IFOV is, the higher the spatial resolution will be. However, this intrinsic resolution can often be degraded by other factors, which introduce blurring of the image, such as improper focusing, atmospheric scattering and target motion. Other methods of measuring the spatial resolving power of an imaging system are based upon the ability of the system to distinguish between specified targets [35]. Then we can say that a spatial resolution is necessarily a measure of the smallest features that can be observed on an image [34]. For instance, a spatial resolution of 79 meters is coarser than a spatial resolution of 10 meters. Generally, the better the spatial resolution is the greater is the resolving power of the sensor system [34]. Other meaning of spatial resolution is the clarity of the high frequency detail information available in an image. Spatial resolution is usually expressed in meters in remote sensing and in document scanning or printing it is expressed as dots per inch (dpi).

Images where only large features are visible are said to have coarse or low resolution. In fine or high resolution images, small objects can be detected. Military sensors for example, are designed to view as much detail as possible, and therefore have very fine resolution. Commercial satellite provides imagery with resolutions varying from a few meters to several kilometers. Generally speaking, the finer the resolution, the less total ground area can be seen.

4.2.2 Spectral Resolution and Reflectance

When solar radiation hits a target on the earth surface, the radiation may be transmitted, absorbed or reflected. Different objects reflect and absorb in various ways at different wavelengths. Some radiation are reflected away from the target at different angles (depending in part on surface "roughness" as well as on the angle of the sun's direct rays relative to surface inclination), and some being directed back in line with the observing sensor. Most of the remote sensing systems were designed to monitor the reflected radiation from the object. The reflectance spectrum of an object is a plot of the fraction of radiation reflected as a function of the incident wavelength and serves as a unique signature for the material. An object may be identified from its spectral reflectance signature if the sensing system has sufficient spectral resolution to distinguish its spectrum from that of other object. This feature provides the basis for multispectral remote sensing. The following graph shows the typical reflectance spectra of five materials: clear water, turbid water, bare soil and two types of vegetation.

The reflectance of clear water is generally low. However, the reflectance is maximum at the blue end of the spectrum and decreases as the wavelength increases. Hence, clear water appears dark-bluish. Turbid water has some sediment suspension which increases the reflectance in the red end of the spectrum, accounting for its brownish appearance. The reflectance of bare soil generally depends on its composition. In the example shown below, the reflectance increases monotonically with increasing wavelength. Hence, it should appear yellowish-red to the eye. Vegetation has a unique spectral signature which enables it to be distinguished readily from other types of land cover in an optical/near-infrared image. The reflectance is low in both the blue and red regions of the spectrum, due to absorption by chlorophyll for photosynthesis. It has a peak at the green region which gives rise to the green color of vegetation. In the near infrared (NIR) region, the reflectance is much higher than that in the visible band due to the cellular structure in the leaves. Hence, vegetation can be identified by the high NIR but generally low visible reflectance.

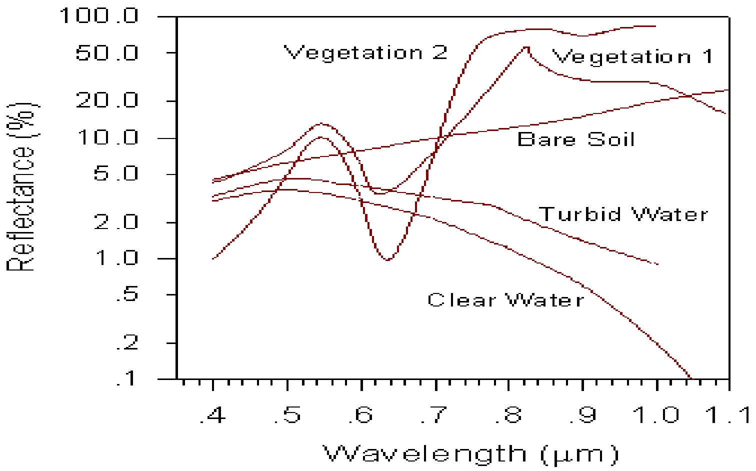

Fig: 4.1 Reflectance Spectra of Five Types of Land cover

The shape of the reflectance spectrum can be used for identification of vegetation type. For example, the reflectance spectra of vegetation 1 and 2 in the above figures can be distinguished although they exhibit the general characteristics of high NIR but low visible reflectance. Vegetation 1 has higher reflectance in the visible region but lower reflectance in the NIR region. For the same vegetation type, the reflectance spectrum also depends on other factors such as the leaf moisture content and health of the plants [22].

4.2.3 Radiometric Resolution

The radiometric resolution of a remote sensing system is a measurement of total number of gray levels which is measured between pure black and pure white [34]. The number of gray levels that can be represented by a gray scale image is equal to 2n, where n is the number of bits in each pixel [37]. Frequently the radiometric resolution is expressed in terms of the number of binary digits, or bits necessary to represent the range of available brightness values [36, 37]. A larger dynamic range for a sensor results in more details being discernible in the image. The Landsat sensor records 8-bit images; thus, it can measure 256 unique gray values of the reflected energy while Ikonos-2 has an 11-bit radiometric resolution (2048 gray values). In other words, a higher radiometric resolution allows for simultaneous observation of high and low contrast objects in the scene [38, 39].

A digital image comprises of a two-dimensional array of individual picture elements called pixels arranged in columns and rows. Each pixel represents an area on the Earth's surface. A pixel has an intensity value and a location address in the two dimensional image.

The intensity value represents the measured physical quantity such as the solar radiance in a given wavelength band reflected from the ground, emitted infrared radiation or backscattered radar intensity. This value is normally the average value for the whole ground area covered by the pixel.

The intensity of a pixel is digitized and recorded as a digital number. Due to the finite storage capacity, a digital number is stored with a finite number of bits (binary digits). The number of bits determines the radiometric resolution of the image. For example, an 8-bit digital number ranges from 0 to 255 (i.e. 2^8 - 1), while an 11-bit digital number ranges from 0 to 2047. The detected intensity value needs to be scaled and quantized to fit within this range of value. In a Radio metrically Calibrated Image, the actual intensity value can be derived from the pixel digital number [22, 33].

4.2.4 Temporal Resolution

Temporal resolution is the frequency with which images of a given geographic location can be acquired. Satellites not only offer the best chances of frequent data coverage but also of regular coverage. The temporal resolution is determined by orbital characteristics and the width of the imaged area.

The frequency of flyovers by the satellite or plane is only relevant in time-series studies or those requiring an averaged or mosaic image as in deforesting monitoring. This was first used by the intelligence community where repeated coverage revealed changes in infrastructure, the deployment of units or the modification/introduction of equipment. Cloud cover over a given area or object makes it necessary to repeat the collection of said location [22].

Temporal resolution, often referred to as the "revisit interval", is the time between opportunities to obtain imagery over a given earth observation. Temporal resolution is a key attribute even when only one image is required, especially when adverse atmospheric conditions are in place during much of the time when one wishes to obtain imagery. The probability of obtaining an image with clear sky conditions in a place like the Pacific Northwest of the U.S. Or the Brazilian Amazon is directly related to the number of viewing opportunities, and therefore to temporal resolution. While one image per area of interest is the norm for most studies, the ability to capture phonological changes [40, 42] and, in passive optical images the changing interaction of the Sun with the geometry of a forest canopy, can lead to substantial improvement in the prediction of earth attributes [43,41].

4.3 Technical Limitations of Remote Sensing Data

4.3.1 Radiometric Corrections

Radiometric correction of remotely sensed data normally involves the processing of digital images to improve the fidelity of the brightness value magnitudes (as opposed to geometric correction which involves improving the fidelity of relative spatial or absolute locational aspects of image brightness values). The main purpose for applying radiometric corrections is to reduce the influence of errors or inconsistencies in image brightness values that may limit one's ability to interpret or quantitatively process and analyze digital remotely sensed images [44].

When a sensor records the solar energy on Earth's surface, the atmosphere affects both target radiance and irradiance. As sunlight pierces through atmosphere, it is both attenuated and scattered, reducing target illumination and making it diffuse. The atmosphere also acts as a scattering reflector, adding extra radiance directed back to sensor. When expressing these two atmospheric effects mathematically, total radiance recorded for the sensor can be related to object's reflectance at the surface and to irradiance:

$$L_T = \frac{R}{\pi} T_R E_T + L_P \qquad (1)$$

Where,

L_T = Total radiance is measured by sensor

T_R = Atmospheric transmittance

L_P = The radiance of atmosphere the target to sensor trajectory (and not of the object) from the scattering effect

R = The object reflectance

E_T = Total irradiance reaching the earth

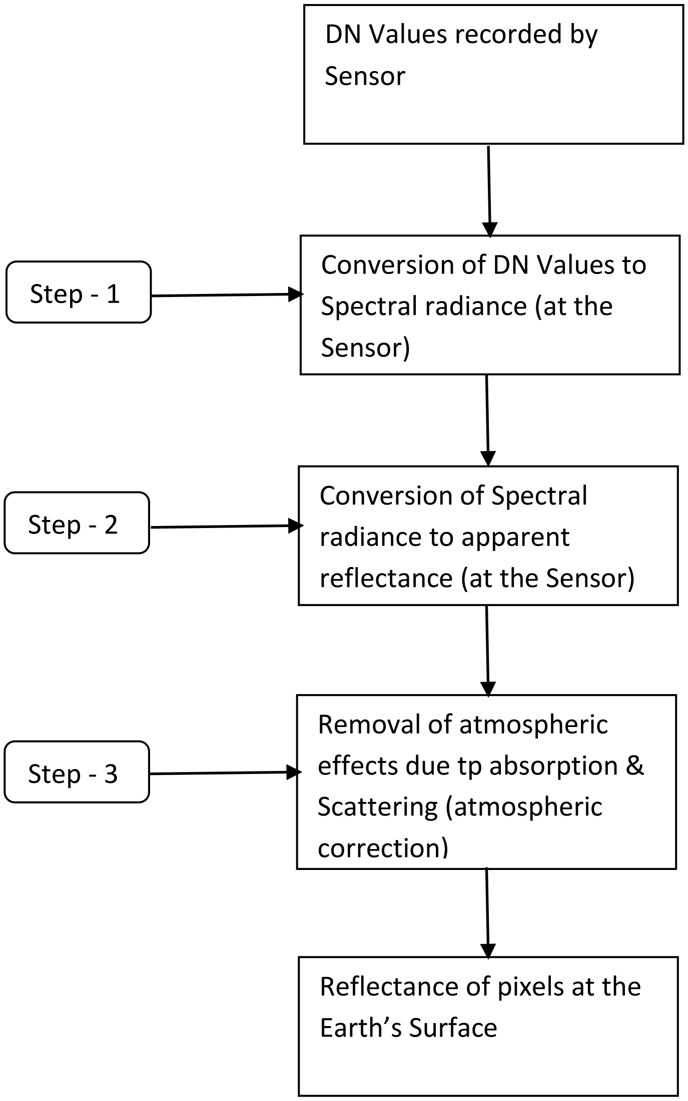

Fig 4.2: Steps of Radiometric Correction

4.3.2 Atmospheric Corrections

The solar radiation is absorbed or scattered by the atmosphere during transmission to the ground surface, while the reflected or emitted radiation from the target is also absorbed or scattered by the atmosphere before it reaches a sensor. The ground surface receives not only the direct solar radiation but also sky light, or scattered radiation from the atmosphere. A sensor will receive not only the direct reflected or emitted radiation from a target, but also the scattered radiation from a target and the scattered radiation from the atmosphere, which is called path radiance. Atmospheric correction is used to remove these effects. The atmospheric correction method is classified into the method using the radiative transfer equation, the method using ground truth data and other methods.

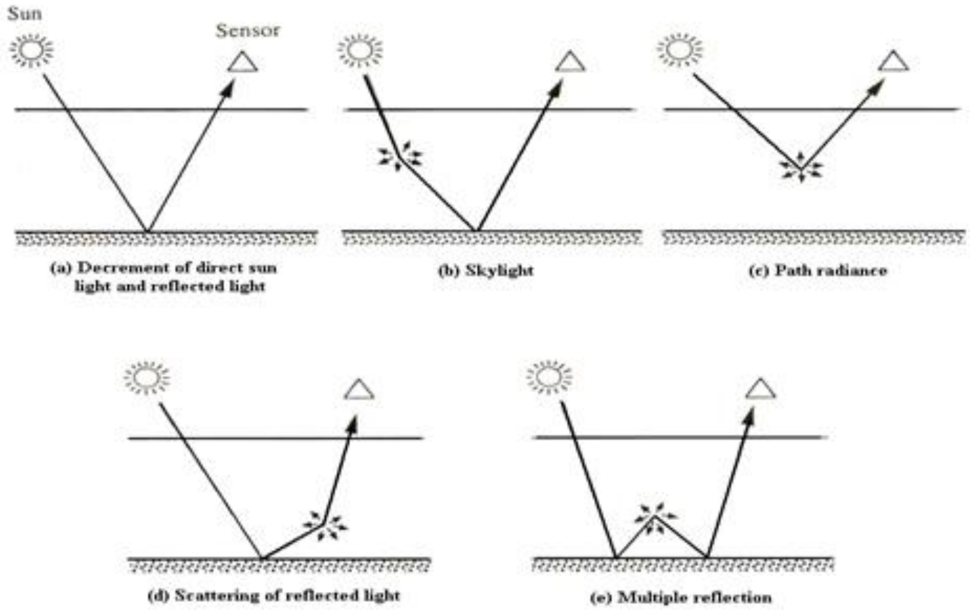

Fig 4.3: Atmospheric Effect

- ***The Method using the Radiative Transfer Equation***

An approximate solution is usually determined for the radiative transfer equation. For atmospheric correction, aerosol density in the visible and near infrared region and water vapor density in the thermal infrared region should be estimated. Because these values cannot be determined from image data, a rigorous solution cannot be used.

- ***The Method with Ground Truth Data***

At the time of data acquisition, those targets with known or measured reflectance will be identified in the image. Atmospheric correction can be made by comparison between the known value of the target and the image data (output signal). However the method can only be applied to the specific site with targets or a specific season.

- ***Other Method***

A special sensor to measure aerosol density or water vapor density is utilized together with an imaging sensor for atmospheric correction. For example, the NOAA satellite has not only an imaging sensor of AVHRR (Advanced Very high Resolution Radiometer) but also HIRS (High Resolution Infrared Radiometer Sounder) for atmospheric correction.

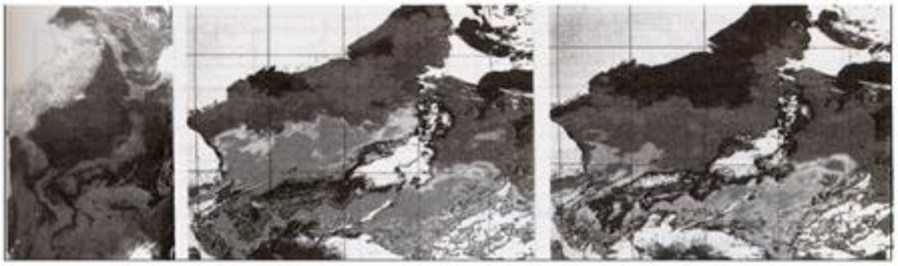

Fig 4.4: Atmospheric Corrections

4.3.3 Geometric Corrections

Geometric correction is undertaken to avoid geometric distortions from a distorted image, and is achieved by establishing the relationship between the image coordinate system and the geographic coordinate system using calibration data of the sensor, measured data of position and attitude, ground control points, atmospheric condition etc.

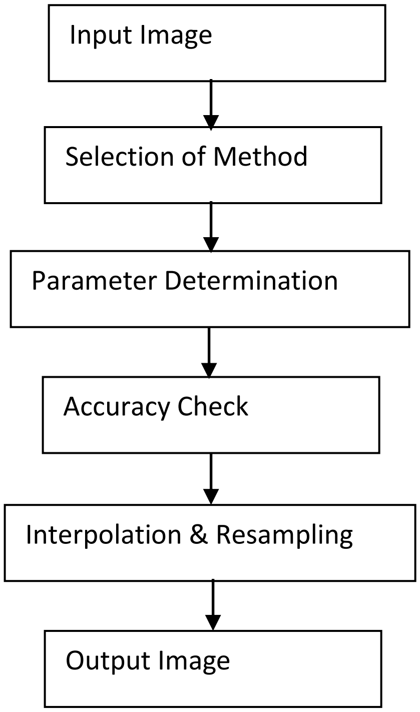

Fig 4.5: Geometric Correction

1) Selection of Method

After consideration of the characteristics of the geometric distortion as well as the available reference data, a proper method should be selected such as:

➢ Systematic Correction

When the geometric reference data or the geometry of sensor are given or measured, the geometric distortion can be theoretically or systematically avoided. For example, the geometry of a lens camera is given by the collinearity equation with calibrated focal length, parameters of lens distortions, coordinates of fiducially marks etc. The tangent correction for an optical mechanical scanner is a type of system correction. Generally systematic correction is sufficient to remove all errors.

➢ Non-Systematic Correction

Polynomials to transform from a geographic coordinate system to an image coordinate system, or vice versa, will be determined with given coordinates of ground control points using the least square method. The accuracy depends on the order of the polynomials, and the number and distribution of ground control points.

➢ Combined Method

Firstly the systematic correction is applied, and then the residual errors will be reduced using lower order polynomials. Usually the goal of geometric correction is to obtain an error within plus or minus one pixel of its true position

2) Determination of Parameters

Unknown parameters which define the mathematical equation between the image coordinate system and the geographic coordinate system should be determined with calibration data and/or ground control points.

3) Accuracy Check

Accuracy of the geometric correction should be checked and verified. If the accuracy does not meet the criteria, the method or the data used should be checked and corrected in order to avoid the errors.

4) Interpolation and Resampling

Geo-coded image should be produced by the technique of resampling and interpolation. There are three methods of geometric correction as mentioned below.

For geometric correction with the help of image transformation, the pixels of the original image and the target raster are not superimposed upon each other. Therefore, the grey-scale values of the pixels have to be re-calculated during the transformation process. This process is called resampling.

4.4 Chapter Summary

The preprocessing of remotely sensed image is very important to improve the quality and to remove the errors. It consists of three corrections such as geometric, atmospheric and radiometric correction. The atmospheric correction is needed because wind affects airborne remote sensing systems, the rotation of the earth affects satellites, as well as relief and the bird's eye perspective affect the sensors and all can cause distortions. After the image has been geometrically corrected, image projection and real projection match.