Abstract—Compared with the traditional remote sensing, multi-angular observation could get the detailed three-dimensional structural information of forest through different directional observations, which provides a new method for quantitative remote sensing. In this paper the look-up table was constructed according with the different kinds of remote sensing model. The mixed pixel model was used as TM/ETM+ data was used, and the appropriate physical model was used according to the different forest sense as CHRIS data was used. Base on the model the look-up tables were constructed, and the leaf area index was retrieved from the different kinds of data making use of interpolation. Comparing the LAI(Leaf Area Index) with MODIS 15A2 LAI, the result shows that the result compares well with the measured LAI in Changbai sample plots, and the multi-angle remote sensing can improve the precision of retrieval of conifer LAI, so there is a certain theoretical research and practical application value.

Keywords—multi-type; remote sensing; LAI; look-up table; physical model

I. INTRODUCTION

Multi-angle remote sensing observations as a new method, is a research focus now. In theory, multi-angle optical remote sensing is based on the single point of observation in the traditional mode, adding with the information of angle dimensions. It contains not only looking down observation from above, but also the slope observation from the side-view above. So it is possible to get more information from the forest sensing, also provide useful information in the forest scene. So it provides guarantee for the inversion of forest leaf area index and other spatial information. With true multi-angle satellite remote sensing data, the multi-angle remote sensing applications are also booming.

The objects of remote sensing observations are usually mixed-pixel that contains a variety of components. The pixel spectral structure, are composed of pixel structures, components spectra, light condition and observation condition in common decision. In order to describe the relationship between remote sensing signals and properties of ground objects, it established variety of models to compute the reflection coefficient of a two-way surface features of ground objects. Currently, there have been many physical models, their theory can be summarized into four categories: The geometric optical model is represented by Li Xiaowen and Strahler [1,2], radioactive transfer model mixed models and computer simulation model[4,5], in which SAIL is represented. And they are all presented by Verhoef [3]. Each model has its own advantages and disadvantages in the scope of application: geometric optical model is more suitable to handle non-uniform vegetation, particularly low density, large sparse groups of individuals. But the attenuation processing of radiation crowns plant is too simple, scattering light of the sky and multiple scattering effect groups did not be considered which makes the accuracy of geometrical optics model are affected; radioactive transfer models for vegetation composition in the general population density compared to small groups, and other dense, uniform level of groups, but did not consider the role of non-leaf organs of vegetation distance between components and non-random distribution of the phenomenon Hybrid model is applicable to any non-uniformity of groups, However, the calculation is very large; computer simulation model thoroughly reflect the true characteristics of natural vegetation, but this method has a large calculation and repeat. Also be restrictions on the number of population structure variables.

In this paper, LAI data products as a true value, and the use of multi-angle CHRIS data, the traditional single point of TM / ETM + data inversion of leaf area index, by comparing the advantages and disadvantages of two inversion methods, the results show that as the multi-angle remote sensing can detect three-dimensional surface objects for multi-direction information, compared with traditional single-angle remote sensing, quantitative inversion has certain advantages. Before comparing, because the resolution of three different sensors, it is needed invert CHRIS data which the spatial resolution is 18 * 18m to LAI, and invert the TM/ETM+ data which the resolution is 30*30 m to LAI data with 1km resolution.

II. STUDY AREA

Study area is located in Lu Shuihe Forestry Bureau in Jilin Province. It is in the northern of Chang Bai Mountain, address is the Lu Shuihe town of Fu song county in Jilin Province. General geographic longitude 127020'-128009 in the 'north latitude 42018'-42052', global east to west 40 km, north-south length of 50 km, total area of 12.1295 million hectares. Its eastern part borders on the White River Forestry Bureau, Southwest connected with Quanyang Forestry bureau, appearing in the Northwest across the River with Hongshi Forestry Bureau, northern part adjacent Dun Hua Forestry Bureau of water, as shown in Figure 1.

Highest point of Lu shuihe Forestry is the “Laotudingzi” mountain, with the elevation of 1359 m. The lowest point in located besides Songhua River at the junction of Lushuihe and the Quanyang side with the elevation of only 369 m, the
global average altitude of 600-800 m, only few areas above the elevation of 1000m. The southern part is fluctuant lava hathpace ground, and northern part is fluctuant middle mountains, with the average grade of 15 degrees. The region is temperate continental climate, summer and winter winds change significantly, the average year, as the westerly dominant wind direction, maximum wind speed is 18 m/s. Significant seasonal variation of precipitation is mainly in the higher summer temperatures, abundant rainfall, with annual rainfall of 800-1400 mm. In winter the snow is about 0.5m deep, with the average relative humidity of 70-75%, and the low temperature. The maximum frozen layer of the mountains is in the depth of 1.8m. Early frost begins in mid-September. And late frost ends in late May, approximately 110 days of plant growth period. For the low temperature, small evaporation, humid air and other factors, the region is conducive to the growth of dense deciduous broad-leaved forest and coniferous mixed forest.

III THE ESTABLISHMENT OF LOOKUP TABLE

Physical model is the description and expression of the physical mechanism of the transmission of the Sun ray in the vegetation canopy, and due to the complexity of the process, the model parameters expressing the process are often more than one. The amount of information carried by the current remote sensing data is not enough to support the inversion of so many surface parameters, so the lack of the amount of information, that is ill-posed inversion problem, must be solved for the correct inversion of the model. One way is on the basis of the forward of the sensitive and interest parameters to establish the lookup table and to consider the effect of the all the sensitive parameters’ change in a certain step within the value range on the reflective of the canopy. Since too many parameters are involved in the physical model, this study determines some parameters for the specified research area to simplify the lookup table.

To ascertain the surface parameter inversion right or not there are two main factors: one is that the related model accurately describe the physical process of the target or not, and the other is that the inversion method is reliable and feasible or not. Leaf area index (LAI) inversion is just the case[6]. This paper studies the coniferous forest in Changbai Mountain area. The different remote sensing models are taken on the basis of the different forest stand intensity, for instance, the crown density of the open forest is relatively small, generally less than 0.2, and the vegetation group showing such characteristics as non-uniform state, low density, large individual is suitable for the geometric optics model, so we choose the Improved MG eoSail model[7,8], the thick forest with crown density greater than 0.2 show with canopy density of the growing level of uniformity of the structure presented at this time, so select the appropriate level of uniformity in vegetation radioactive transfer mode (Sail model).

We studied the precision by comparing the traditional TM/ETM+ remote sensing data with multi-angle CHRIS data inversion leaf area index, this work required inversion leaf area index based on the corresponding look-up table from different model. Here introduced the establishment method of the lookup table:

(1) How to establish the TM/ETM+ look-up table

The traditional model applied the Boolean principle to the mixed pixel posed by the vegetation - soil system [9], then

$$R_h = R_{s,\mu,\lambda} K \int_{-1}^{0} (e^{K_{LAIh}} - e^{K_{LAIh}}) LAI dh + R_{s,\mu,\lambda} K \int_{0}^{1} e^{K_{LAIh}} - e^{K_{LAIh}} LAI dh$$

(1)

$$R_{s,\mu,\lambda}$$ is the vegetation canopy reflectance when the vegetation canopy is very dense (for the background of all the cover off the soil), or the vegetation thick is infinite, $$R_{s,\mu,\lambda}$$ is the Two-way launch rate of the soil, $$k$$ is Extinction coefficient, Obvious $$k$$ is the function of $$\Omega^o$$ (Eye position), $$\Omega$$ (Position of the sun), $$LAD$$ (Leaf angle distribution) ,and so on. it can expressed by next formula:

$$K = (2/\pi) LAI[\beta_0 - \pi/2] \cos \theta_i + \sin \beta_0 \tan \theta_i \sin \theta_i$$

(2)
In the paper \( \theta_0 \) is \( 0^\circ \) and \( \theta_s \) is \( 44.543^\circ \) calculated from image time and center longitude and latitude. The \( k \) from formula (2) is simulated with SAIL model according the coniferous forest leaf angle distribution characteristics (in this paper LAD is uniform), and LAI is changed by step 0.1. The reflection of sense is simulated with the parameters change \( d \) and the look-up table is constructed.

(2) To introduce the model for multi-angle look-up table, vegetation BRDF is a complex function distributed in the hemisphere with the space of \( 2\pi \), there are many factors and so complex. If you want to learn parameters of each factor influence and through model inversion accurately estimate each parameter, you must select this model for sensitivity analysis. The analysis of BRDF changes with the main parameters is in the literature, it analyze the following nine parameters of the sensitivity: (a) the spatial distribution of leaf type. (b) the rate of scattering light in the sky. (c) groups of leaf angle distribution. (d) groups of total leaf area index. (e) leaf reflection and transmission coefficients. (f) the vertical reflection coefficient of soil. (g) the reflection coefficient of stem.

Because of these nine parameters in their respective sensitive areas have significantly effects on the BRDF and the changes are significant in different regions and different forest, so it is hard to establish a unified look-up table (which takes into account the impact of each parameter on the BRDF) to each parameter is very tedious. Therefore, this article only build the lookup table for the coniferous forest in Changbai Mountain area. It can reduce the impact of other parameters to establish efficient and convenient look-up table. Table is constituted by six variables as following: the solar zenith angle, line of sight zenith angle, azimuth, band, canopy closure, leaf area index.

Groups of leaf angle distribution can be set to a fixed region and the value of species, these parameters, such as leaf reflection, transmission coefficients, the vertical reflection coefficient of the soil, and the stem of the reflection coefficient is responded by the band parameters in the lookup table, the spatial distribution of leaves is responded by canopy density from the lookup table, the role of scattering light the sky generally set at 0.5.

IV LOOKUP TABLE INVERSION AND ANALYSIS

For TM/ETM+ data inversion, we used equation (1) to establish a lookup table, which only contain the relationship of 3, 4-band reflectance and LAI, other parameters was always fixed. According to the formula (1), we established a lookup table, LAI was achieved by inversion, this result was compared with the result by using multi-angle remote sensing CHRIS data, during this process, we transform by the spatial resolution of 30m in the TM/ETM to 1km, and then it was compared with MODIS 15A2 LAI products. As the three kinds of data with different spatial resolution, after scaling all of them has the same resolution can used to comparison. This paper targeted the same species, so we take these methods such as the average of pixels increases, and demand approach. Figure 4 is the averaging results from 3 available MODIS 15A2 LAI chart in 8 months.
canopy density, the structure is horizontal homogeneous, so forest stand density is relatively high, with the growing of MGeoSail model has been chosen; In the condition that homogeneous state of individual highlights, so the improved condition of the sparse forest stand, trees showed non-physical models to different scenarios of forests. In the mixed models, for CHRIS data, use different remote sensing data. For TM / ETM + data, use decomposition of relative look-up table based on different classes of remote sensing. First, choose the right model and build the traditional single-angle and advantages of multi-angle compare LAI inversion result.

This paper aims to highlight the inadequacies of traditional single-angle and advantages of multi-angle remote sensing. First, choose the right model and build the relative look-up table based on different classes of remote sensing data. For TM / ETM + data, use decomposition of mixed models, for CHRIS data, use different remote sensing physical models to different scenarios of forests. In the condition of the sparse forest stand, trees showed non-homogeneous state of individual highlights, so the improved MGeoSail model has been chosen; In the condition that forest stand density is relatively high, with the growing of canopy density, the structure is horizontal homogeneous, so the model which is appropriate for the horizontal homogeneous, (Sail model) has been chosen. Second, in the base of the selection of suitable models, according to the different sensitivity parameters to the models and the features of different test area, the parameters of look-up tables have been designed. The look-up tables has been built by the forward modeling, then according to the method of interpolation, using reflectivity values of remote sensing images to inverse the value of LAI.

Finally, make a comparative analysis with the traditional single method of LAI inversion and MODIS 15A2 LAI product. The result shows that the accuracy of multi-angle remote sensing has been improved, but the effective is not very clear after analysis the possible two reasons. It also reminds us of the need to find more stable, more accurate and better indicators of structural parameters to reflect the forest vegetation. These parameters may be a combination of the angles which are similar to band combinations between parameters. These parameters are used to describe some certain parameters of vegetation.

REFERENCES