FRACTIONAL VEGETATION COVER RETRIEVAL USING MULTI-SPATIAL RESOLUTION DATA AND PLANT GROWTH MODEL

Xihan Mu, Yaokai Liu, Guangjian Yan*

State Key Laboratory of Remote Sensing Science, School of Geography, Beijing Normal University, Beijing, China, 100875

*Email: muxihan@bnu.edu.cn

1. INTRODUCTION

Fractional Vegetation Cover (FVC) is an essential bio-physical parameter in Soil-Vegetation-Atmosphere Transfer (SVAT) schemes to simulate the exchanges between the surface and the atmospheric boundary layer [1]. It characterizes the fraction of vegetation on a flat background covered by vegetation, thereby accounting for the amount of vegetation distributed in a horizontal perspective.

Although great effort has been paid on the estimation of FVC, more research progress is still needed, especially when various types of satellite data acquired at different local times, resolutions and viewing geometries are jointly used. In this paper, an algorithm is addressed on FVC retrieval, with the combination of MODIS and Huan Jing satellite (HJ), which is a newly launched constellation by China. In the developed model, we considered angular effect and utilised spatial and temporal information to a great extent. It is noticed that MODIS has relatively coarse spatial resolution and rich angular information and HJ, in contrast, is likely to distinguish more spatial details with view zenith angle less than 30 degrees. MODIS and HJ surface reflectance products provide data supply for the algorithm and play cooperative roles. For the reason that the MODIS and HJ data have compensated the shortages of each other in the framework of designed algorithm, the joint use of two types of data is expected to generate more accurate results. A vegetation growth model was introduced to constrain the relative worse quality of HJ data in a temporal scale [4]. Uncertainty was assessed by error propagation theory and field experiments. Retrieved FVC became more reasonable after consideration of the correlation among time series observations.

2. METHODS

In the case of dense and non-dense vegetation, FVC of remote sensing pixel could be expressed as a linear function of NDVI [3]:

$$FVC = (NDVI - NDVI_{min})/(NDVI_{max} - NDVI_{min}) \quad (1)$$

where $NDVI_{max}$ and $NDVI_{min}$ are the NDVIs of full cover vegetation and bare soil, respectively. For the directional observations, the FVC defined in a viewing angle simply keeps the same formulation as follows:

$$\mathrm{FVC}(\theta) = (\mathrm{NDVI}(\theta) - \mathrm{NDVI}_{\min}(\theta))/(\mathrm{NDVI}_{\max}(\theta) - \mathrm{NDVI}_{\min}(\theta)) \tag{2}$$

Here the FVC is defined as the fraction of vegetation cover in the perpendicular plane to the viewing line. Consequently, FVC is supposed to vary as a linear function of NDVI:

$$\mathrm{FVC}(\theta) = a \cdot \mathrm{NDVI}(\theta) - b \tag{3}$$

In the heterogeneous surfaces, a remotely sensed pixel could be decomposed as bare soil and dense vegetation. In the homogeneous vegetation fraction, soil uniformly distribute in the gaps among leaves, Therefore, in this part, vegetation-soil system could be described by a 1-D radiative transfer model. *S* represents the fraction of homogeneous vegetation calculated from satellite image with a higher spatial resolution, and 1-*S* is the bare soil part (Fig.1). According to the traditional Beer-Lambert Law, directional fraction of vegetation cover reads:

$$\mathrm{FVC}(\theta) = S(1 - e^{-LAI \cdot G(\theta) \cdot \Omega / \cos\theta}) \tag{4}$$

where LAI is defined only in the part of S. Ω is the Clumping index, and G is the projection [2]. If assumed that leaf angle spherically inclined, we can define LAI_e =0.5·LAI·Ω. Equation for multi-angular observations can be defined as:

$$\begin{aligned} a \cdot NDVI\ (\theta_1) - b &= S(1 - e^{-LAI \cdot G(\theta_1) \cdot \Omega / \cos\theta_1}) \\ a \cdot NDVI\ (\theta_2) - b &= S(1 - e^{-LAI \cdot G(\theta_2) \cdot \Omega / \cos\theta_2}) \\ &.\bullet\bullet\bullet\bullet \\ a \cdot NDVI\ (\theta_m) - b &= S(1 - e^{-LAI \cdot G(\theta_m) \cdot \Omega / \cos\theta_m}) \end{aligned} \tag{5}$$

Where S is speculated from the classification map of a higher resolution sensor like that is onboard HJ-1 small satellite. There are three unkown variables which are a, b and LAIe in the equation (5). LAIe could be retrieved by solving equation (5), with the constraints $0 \le a, b \le 1$, $LAI_e > 0$, then $FVC(\theta)$ is easy to obtain. Assuming the independence of each variable, the variance of FVC estimation error σ_F^2 is related to LAIe and S:

$$\sigma_F^2 = \sigma_{NDVI}^2 (e^{-LAI_e} a^2) + \sigma_S^2 (\frac{e^{-LAI_e} F^2}{S^2} - e^{-LAI_e} + 1) \tag{6}$$

where a and F/S are generally close to 1 with F stands for FVC. Thus the variance of S-σ_S^2 would exert great influence on the final FVC error σ_F^2. So an accurate estimation of S is very important. As the use of HJ-1 data may increase error in data acquisition and successive operations would cause error in estimating parameter S, a Logistic model of vegetation growth is incorporated to get rid of these uncertainties [4]:

$$NDVI = \frac{c}{1+e^{a+bt}} + d \tag{7}$$

where a and b are fitting parameters, c+d is the maximum NDVI value, d is the initial background NDVI value, and NDVI is the normalization difference vegetation index value at the observational time t (Fig. 2). Phenological dates t1 and t2 denote the onset dates of leaf growth and onset of maximum leaf area. The transition date t1 determines whether the land in a HJ-1 pixel has been covered by green vegetation, hereby can be used to calculate fractions of HJ-1 pixels that have vegetation in a MODIS pixel, say, the S in equation (5).

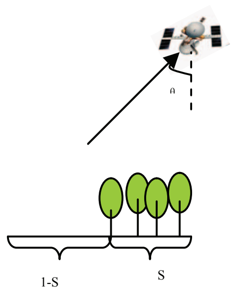

Fig.1. Fraction of uniform vegetation in a pixel of coarse resolution

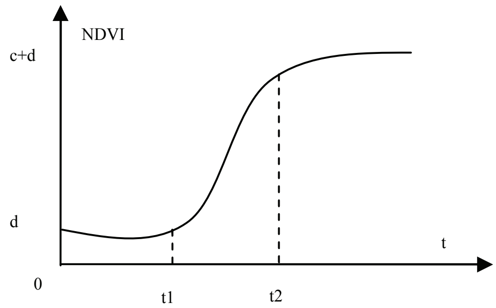

Fig.2. A dash line showing the NDVI vary with observational times.

3. CONCLUSIONS

The main goal of our work is to retrieve FVC by using a new algorithm regarding angular effect, combining spatial and temporal information. During this process, a logistic model of vegetation growth is introduced to retrieve green-up onset date. Fig.3 shows the onset date of every pixel in experimental area. Then we calculate the fraction of vegetation covered HJ-1 pixels in a single MODIS pixel. Finally the FVC series are obtained of the study area. Fig.4 shows the preliminary results of fractional vegetation cover retrieved from the addressed algorithm in this paper. Further studies are under going.

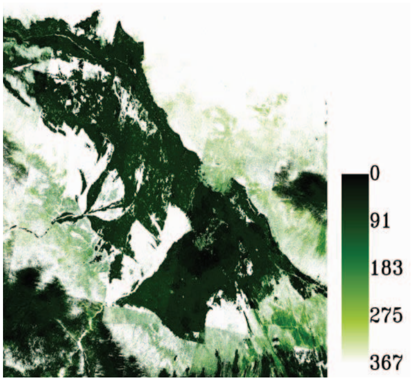

Fig.3. the onset date of every pixel in time series. (Julian day)

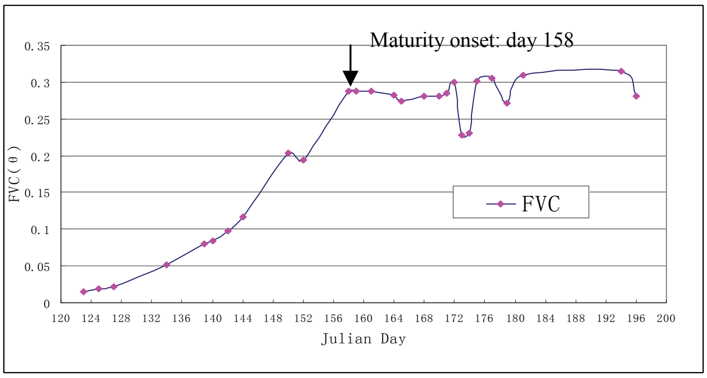

Fig.4. time series of FVC retrieved from a new algorithm regarding angular effect, spatial and temporal information.

4. REFERENCES

[1] Chen, T.H. and co-authors, Cabauw experimental results from the project for inter-comparison of and-surface parameterization schemes, *Journal of Climate*, vol.10, no.7, pp. 1194-1215, 1997.

[2] Ross, J.K, The radiation regime and architecture of plant stands, Dr W. *Junk Publishers, Boston*, 1981.

[3] Gutman, G. Ignatov, A, The derivation of the green vegetation fraction from NOAA/ AVHRR data for use in numerical weather prediction model. *International Journal of Remote Sensing*, vol.19, no.8, pp. 1533-1543, 1998.

[4] Xiaoyang Zhang, Mark A, Friedl et al. Monitoring vegetation phenology using MODIS. *Remote Sensing of Environment*, vol. 84, pp. 471-475, 2003.