Continental Land Cover Mapping/Monitoring and Ground Truth Database

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Abstract

Land cover map of 30 arc-second grid by NOAA AVHRR data for the whole Asia was produced by the authors as the project of the Asian Association on Remote Sensing(AARS). Land cover change monitoring of continental scale by satellite data needs preprocessing to remove undesirable factors due to noises, atmosphere, or the effect by solar zenith angle. The paper describes the method to remove these factors. The most important thing for better mapping/monitoring in the future is the accumulation of ground truth data by many land cover related researchers. The project of the development of Global Land Cover Ground Truth Database(GLCGT-DB) is proposed.

KEY WORDS : LAND COVER, AVHRR, GROUND TRUTH DATABASE

1. Introduction

Land cover is one of the key parameters for the understanding of global environment. Since global land cover has high diversity, continental or regional approach is practical. Therefore the author focused on Asia. Time series low resolution, high temporal resolution satellite such as NOAA AVHRR provides suitable phenological information for broad area. This paper presents two studies and one proposal. One study is land cover mapping of the whole Asia using AVHRR data in one year(April 1992 – March 1993). The other study is land cover change monitoring for global land area using AVHRR from 1981 to 1994. In order to pursue better and more reliable land cover map and land cover change map, ground truth data is crucial. However, the collection of ground truth data is time consuming and difficult, the author proposes here the development of Global Land Cover Ground Truth Database(GLCGT-DB) by the cooperation of many researchers and projects.

2. Land cover mapping of Asia

The Land Cover Working Group(LCWG) (Chairman: R. Tateishi) of the Asian Association on Remote Sensing(AARS) initiated the project to map land cover of the whole in 1993. The land cover mapping has done by the following steps.

- development of land cover classification system
- collection of ground truth
- data processing for classification using AVHRR NDVI and channel 4 and 5, and elevation data

The final product is distributed by CD-ROM (LCWG/AARS and CEReS/Chiba University, 1999) which includes the following data sets.

- 30-second land cover data set of the whole Asia
- ground truth data set

- full description of the methodology
- introduction of LCWG/AARS

3. Land cover change monitoring of global land area

Detection and monitoring of land cover change in global scale provides an important input to global change studies. Time series AVHRR data have potential to extract large land cover change areas. To pursue this potential, undesirable effects/components in time series AVHRR data should be removed. These undesirable effects can be divided into the following two types. The first one is high temporal frequency effects such as cloud effects and signal noises in data transmission. The other one is low temporal frequency effects such as the effect by solar zenith angle(SZA). This paper describes the preprocessing method to remove these effects for the use of NOAA/NASA Pathfinder AVHRR Land Data Set. In order to remove high temporal frequency effects, "Temporal Window Operation (TWO) method" was developed. This method is applicable for time series 10-day composite NDVI data. The investigation of the effect by SZA to NDVI reveals that the SZA less than 60 degree has little effect and that this range of SZA is recommended for the use of AVHRR NDVI data.

3.1 Necessity of preprocessing of time series AVHRR NDVI

The data used for this study are NOAA/NASA Pathfinder AVHRR Land(PAL) Data Set 10-day composite NDVI data. The PAL data are 8 km resampled data from Global Area Coverage(GAC) data with nominal resolution of 4 km. The period of the data authors used for this study is for 13 years from August, 1981 to September, 1994. Though these data have potential for global land cover change monitoring, the PAL NDVI data have undesirable components to be removed. In this study, authors divided these components into two categories. One is high temporal frequency effects such as cloud effects and signal noises in data transmission. The other is low temporal frequency effects such as the effect by solar zenith angle(SZA). In order to remove high temporal frequency effects, authors refined the Temporal Window Operation(TWO) method(Park 1998). In order to investigate low temporal frequency effects, homogeneous land cover area were selected and the mode NDVI values of the area were extracted and analyzed because the mode value is free from the effect of misregistration.

3.2 Removal of high temporal frequency effects

- Temporal Window Operation(TWO) method -

The TWO method consists of the following three steps

(Step 1) Search and the removal of high value noise (preprocessing of the TWO method)

AVHRR channel 1 and 2 data may have high or low value noises at the time of transmission and reception when the angle of an antenna becomes low. Though NDVI value becomes high or low due to this reason, only high NDVI noises remains after Maximum Value Composite(MVC) processing. Therefore the problem is how to eliminate high value noises. The proposed method is the combination of temporal threshold and spatial threshold.

The temporal threshold is the 115% of the maximum NDVI from three consecutive NDVIs before and after the examined 10-day composite NDVI. If the examined NDVI is larger than 115% value, it is considered as a noise.

The spatial threshold is calculated from mean(M) and standard deviation(SD) of the surrounding 24 NDVI values in 5 by 5 matrix region with the examined pixel as a center. The threshold value is M + 1.5*SD. If the examined NDVI is larger than the threshold, it is considered as a noise.

The threshold values were decided empirically.

(Step 2) Temporal Window Operation(TWO) method

The TWO method is based on the assumption that the real NDVI without noises changes smoothly in a year with one or two peaks(local maximums) and bottoms(local minimums). In this case, NDVI changes monotonously between a peak and a bottom. The TWO method is carried out in a moving temporal windows with a predetermined temporal period(window size). Longer the window size is, there are more chance to have a real NDVI free from noises in the window. However, a window size longer than a period between a peak and a bottom is not suitable because monotonous NDVI change occurs only within this period. Figure 1 shows the NDVI value conversion by TWO method. The TWO method is carried out for time series 10-day NDVI data as follows.

(1) Find the NDVI value at the start(first) point in a temporal window.

(2) Search the nearest temporal point with larger NDVI than the start point in a temporal window.

If there is such a point, this point will be the next start point. If there is not such a point, the point with maximum NDVI in a window will be the next start point.

(3) NDVI at points between the former start point and a new start point are converted by linear interpolation of two NDVIs of these consecutive start points.

(4) iteration to (2)

(Step 3) Correction of NDVI bottom part (Post TWO processing)

At the bottom part of time series NDVI, TWO method may convert NDVI values higher than actual values. In order to eliminate this effect, NDVI is corrected after TWO processing based on the assumption that, coming close to NDVI bottom, the decrease width of NDVI is diminishing. This assumption just means that NDVI temporal curve at its bottom is convex downward. If NDVI value near bottom was converted by TWO method and also satisfies this assumption, conversion by TWO method was canceled and this NDVI value is considered as an actual NDVI without noise.

3.3 Investigation of low temporal frequency effects

The potential cause of low temporal frequency effects is the change of solar zenith angle(SZA) at the time of observation. In order to investigate these effects, NDVI for the same land cover condition with different SZA must be analyzed. These NDVI values after the conversion by TWO method were prepared by the following ways.

- homogeneous land cover areas consisting of approximately three hundred 4-minute pixels(approx. 1.5 by 1.5 degree) were extracted from global land cover dataset (LCWG/AARS and CEReS/Chiba University, 1997). The extracted land cover types are evergreen forest, deciduous forest, shrubland, Taklimakan desert, White Sand desert, and vegetation.
- The mode NDVI at a certain time for the extracted area was used.
- The maximum NDVI, minimum NDVI, NDVI at the maximum SZA, NDVI at the minimum SZA, in a temporal NDVI mode curve, were used.

By the above method, effects by misregistration and yearly shift of season were removed.

Before examining the effect by SZA, whether the effect by the change of satellite exists or not must be examined. In order to examine effect by the change of satellite from NOAA-7 to -9 and -11, the mode NDVI values at the above mentioned five types of land cover at the time of minimum Solar Zenith Angle(MinSZA), spring Solar Zenith Angle(Mid1SZA), fall Solar Zenith Angle(Mid2SZA), and maximum NDVI(MaxNDVI) for 12 years(1982-1993) were compared. Though we found the case of NDVI change due to the change of SZA at the time of satellite change, we could not find clear NDVI change for the same SZA value, the same land cover, the same season but the different satellites. That is, we cannot recognize the effect by the change of satellite.

Then, the relationship between NDVI and SZA was examined using 12 year's data. Similarly to the above investigation, the mode NDVI values for five types of land cover at the same season such as the time of minimum Solar Zenith Angle(MinSZA), maximum Solar Zenith Angle(MaxSZA), spring Solar Zenith Angle(Mid1SZA), fall Solar Zenith Angle(Mid2SZA), minimum NDVI(MinNDVI), and maximum NDVI(MaxNDVI) were investigated. Lines in Figure 2 show approximated lines from (SZA, NDVI) plots for the same land cover and same season for 12 years. When SZA is less than 60 degrees, no apparent NDVI decrease was found. But when SZA exceeds 60 degrees, there are some NDVI decreases. Since the rate of these NDVI decrease varies area by area, correction of NDVI decrease is not possible using only SZA value. One of the reason of NDVI decrease at large SZA can be assumed by terrain shade effect.

4. Proposal of establishing Global Land Cover Ground Truth Data Base (GLCGT-DB)

For the better land cover mapping and monitoring, the preparation of ground truth data is a crucial issue. Here, the ground truth data means training sample data for classification and validation data for accuracy assessment after mapping and monitoring. Since the collection of ground truth data is difficult, the development of common ground truth database by the cooperation of many researchers is the solution to cope with this difficulty.

Here the authors propose to develop the Global Land Cover Ground Truth Data Base (GLCGT-DB) as follows.

- Develop global ground truth data base for land cover/ land use
- Inputs of ground truth data are from existing land cover/land use related projects or missions and from individual contributors.
- Developed data base will be open to any projects and researchers.
- Developed data base will serve to make better land cover/land use map for global/ continental/ regional scale in the future.
- The global land cover ground truth data base (GLCGT-DB) consists of original ground truth data and generalized ground truth data.
- Original ground truth data include the following information: geographic location(lat/long), time, land cover class/land use definition of land cover/land use classification system
- Generalized ground truth data will be produced from original ground truth data. Generalized ground truth data will be produced by harmonizing different classification systems

5. Conclusions

As the project of Asian Association on Remote Sensing(AARS) the authors produced land cover data set of the whole Asia. For the purpose of land cover monitoring using time series AVHRR data, authors developed Temporal Window Operation(TWO) method to remove high temporal frequency noises in AVHRR NDVI. Authors corrected NOAA/NASA Pathfinder AVHRR Land(PAL) 10-day composite NDVI data from 1981 to 1994 by the TWO method. The investigation using 12 years AVHRR NDVI results that the use of the NDVI data only within 60 degree SZA is recommended for temporal analysis. The most part of lands in the north hemisphere have less than 60 degree SZA from February to October, which is the recommended period for temporal analysis using PAL

NDVI.

References

Cihlar,J., and J. Howarth, Detection and Removal of Cloud Contamination from AVHRR Images , IEEE Trans.Geosci.and remote sensing, Vol. 32, pp. 58- 589, 1994

Holben,B., Characteristics of maximum-value composite images from temporal AVHRR data , International Journal of Remote Sensing, Vol. 7, pp. 1417-1434, 1986

James, M. E., Kalluri, S. N. V.,"The Pathfinder AVHRR land data set: An improved coarse resolution data set for terrestrial monitoring," International Journal of Remote Sensing, Vol. 15, pp. 3347-3363,1994

LCWG/AARS and CEReS/Chiba University, 1997, (CD-ROM) AARS Global 4-minute Land Cover Data Set

LCWG/AARS and CEReS/Chiba University, 1999, (CD-ROM), AARS Asia 30-second land cover data set

Los, S. O.,"Estimation of the Ratio of Sensor Degradation Between NOAA AVHRR Channels 1 and 2 from Monthly NDVI Composites," IEEE Transactions on geoscience and remote sensing, Vol. 36, No. 1, pp. 206-213,1998

Price, J. C.,"Timing of NOAA afternoon passes," International Journal of Remote Sensing, Vol. 12, pp. 193-198, 1991

Rao, C. R. N., Chen, J.,"Inter-satellite calibration linkages for the visible and near-infrared channels of the Advanced Very High Resolution Radiometer on the NOAA-7, -9, and -11 spacecraft," International Journal of Remote Sensing, Vol. 16, No. 11, pp. 1931-1942,1995

Singh, S. M.,"Simulation of solar zenith angle effect on Global Vegetation Index(GVI) data," International Journal of Remote Sensing, Vol. 9, pp. 237-248,1988a

Singh, S. M.,"Lowest order correction for solar zenith angle to Global Vegetation Index(GVI) data," International Journal of Remote Sensing, Vol. 9, pp. 1565-1572,1988b

Singh, S. M.,"Lowest-order correction to GVI data for solar zenith angle effect," International Journal of Remote Sensing, Vol. 10, pp. 819-825,1989

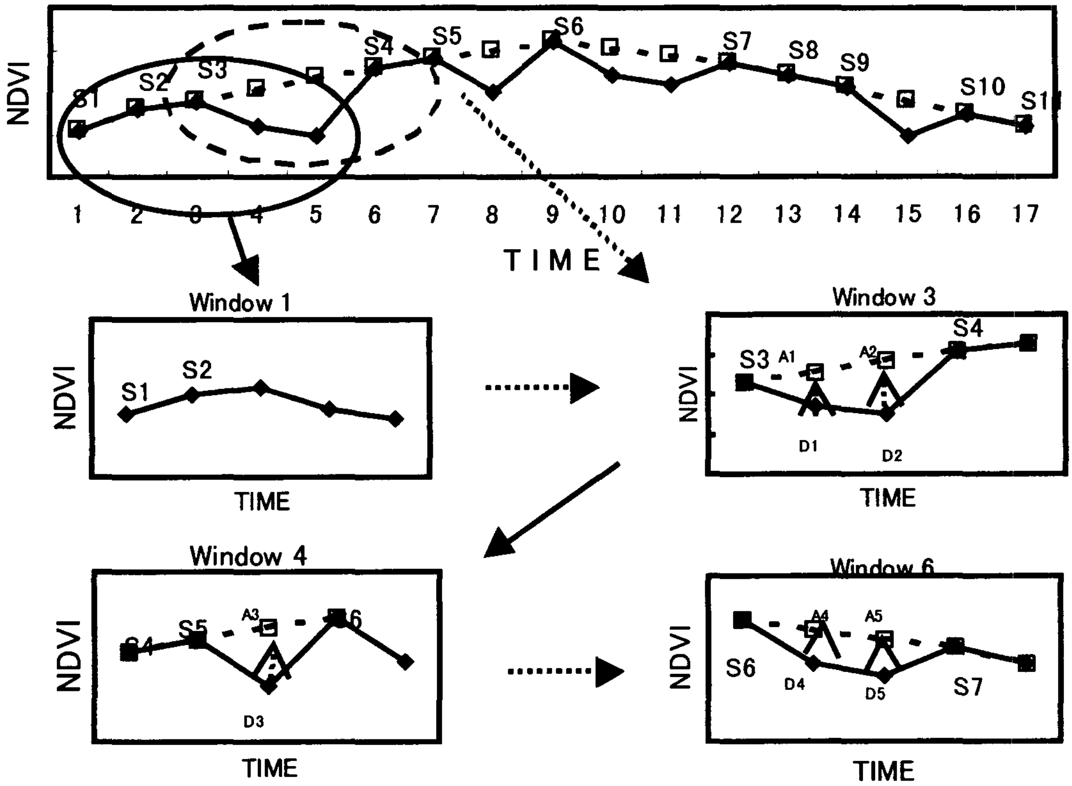

Figure 1. Temporal Window Operation (TWO) STEP2

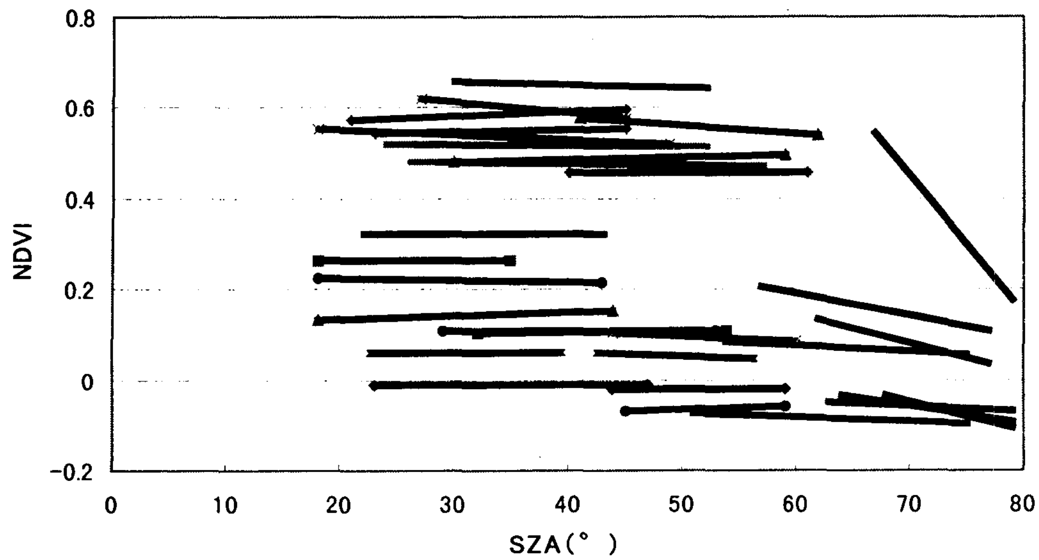

Figure 2. PAL NDVI data for solar zenith angle effect