Retrieving leaf area index and fraction of absorbed photosynthetically active radiation using GCOM-C/SGLI data

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The Japan Aerospace Exploration Agency (JAXA) will launch the Global Change Observation Mission - Climate (GCOM-C) satellite. We developed the algorithms for retrieving the Leaf Area Index (LAI) and the fraction of Absorbed Photosynthetically Active Radiation (fAPAR), which will be produced and distributed as one of the GCOM-C standard land products by JAXA. In this document, we introduce the methods for retrieving them.

LAI and fAPAR were estimated based on the look-up tables showing the relationships between Normalized Difference Vegetation Index (NDVI) data and the LAI or fAPAR. They were retrieved by comparing the values of multi-angle NDVIs derived from satellite and from the look-up tables for each sun and satellite geometries. The multidirectional observation capability is one of the feature of the Second generation GLobal Imager (SGLI) onboard the GCOM-C satellite. The look-up tables were produced for each solar and view zenith angles and relative azimuth angle. The relationships among LAI, fAPAR and multi-angle NDVIs were estimated for 6 kinds of land cover types. They were adjusted to fit with the collected in-situ reference data. The data from several databases such as VALERI and BIGFOOT were used as in-situ reference data.

The relationships among LAI, fAPAR and NDVIs were simulated using a radiative transfer simulator, the Forest Light Environmental Simulator (FLiES) [1]. It simulates radiative transfers in the forests and grasslands based on the Monte Carlo method. The inputs of the FLiES were the reflectance and the transmittance of canopy leaves and understory vegetation, the reflectance of stems and soils, the leaf area density (LAD) of tree canopies, the non-photosynthetic bark area density (BAD) of trees, and the forest landscape data. The forest landscape data were the total number of trees, the geometric shapes of the trees, and the positions, radius and the heights of the trees.

The accuracy of the retrieved LAI and fAPAR will be assessed using the in-situ observation data which will be collected at several sites on global after the launch of the GCOM-C satellite. In this research, the MODIS reflectance data were used for the satellite data for producing the look-up tables, because the GCOM-C satellite has not been launched yet. The look-up tables will be revised to fit with the SGLI data after the launch of the GCOM-C satellite.

[1] H. Kobayashi *et al.*, A coupled 1-D atmosphere and 3-D canopy radiative transfer model for canopy reflectance, light environment, and photosynthesis simulation in a heterogeneous landscape, *Remote Sensing of Environment*, **112** (2008), 173-185.

Keywords: LAI, fAPAR, NDVI, MODIS

Atmospheric Correction Inter-comparison Exercise (ACIX)

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The free and open data access policy to Landsat-8 (L-8) and Sentinel-2 (S-2) satellite imagery has encouraged the development of atmospheric correction (AC) approaches for generating Bottom-of-Atmosphere (BOA) products. Several entities have started to generate (or plan to generate in the short term) BOA reflectance products at global scale for L-8 and S-2 missions. To this end, the European Space Agency (ESA) and National Aeronautics and Space Administration (NASA) have initiated an exercise on the inter-comparison of the available AC processors. The results of the exercise are expected to point out the strengths and weaknesses, as well as communalities and discrepancies of various AC processors, in order to suggest and define ways for their further improvement.
In particular, 11 atmospheric processors from five different countries participate in ACIX with the aim to inter-compare their performance when applied to L-8 and S-2 data. All the processors should be operational without requiring parametrization when applied on different areas. A protocol describing in details the inter-comparison metrics and the test dataset based on the AERONET sites has been agreed unanimously during the 1st ACIX workshop in June 2016. In particular, a basic and an advanced run of each of the processor were requested in the frame of ACIX, with the aim to draw robust and reliable conclusions on the processors' performance. The basic run includes the correction of Rayleigh and aerosol scattering, gas absorption and adjacency effects (only for the processors, it could not be omitted). In the optional run, the participating teams can include all the corrections involved in their AC approaches. The protocol also describes the comparison metrics of the aerosol optical thickness and water vapour products of the processors with the corresponding AERONET measurements. Moreover, concerning the surface reflectances, the inter-comparison among the processors is defined, as well as the comparison with the MODIS surface reflectance and with a reference surface reflectance product. Such a reference product will be obtained using the AERONET characterization of the aerosol (size distribution and refractive indices) and an accurate radiative transfer code. The inter-comparison outcomes will be presented and discussed among the ACIX participants in the 2nd ACIX workshop, which will be held on 11-12 April 2017 (ESRIN/ESA). The proposed presentation is an opportunity for the user community to be informed about the ACIX results and conclusions.

Spatial Representativeness and Scaling of Spectral Vegetation Indices Across Landsat, MODIS, and VIIRS

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A large number of tower sites are equipped with optical sensors, acquiring high-quality, continuous remote sensing data. High-temporal resolution vegetation index (VI) time series data are often derived from these near-surface remote sensing data and used for characterizing seasonal changes in site-level leaf area index and evaluating the quality of satellite products such as land surface phenology or VIs by inter-comparison of their temporal trends. One issue associated with these inter-comparisons is the spatial representativeness of in situ (Tower) VI data. Tower optical sensors' field-of-views (FOVs) are often smaller than the spatial resolution of coarse resolution satellite sensors, such as Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS). Likewise, "ratio-based" VIs such as the normalized difference vegetation index (NDVI) are not scale-invariant as they involve a non-linear transformation of band reflectances. In this study, we assessed the spatial representativeness and scaling uncertainty of Tower VI data for their inter-comparisons with MODIS and VIIRS VI time series data. Two contrasting AmeriFlux sites in terms of vegetative cover conditions were selected, for which Landsat Operational Land Imager (OLI) data were obtained along with USGS National Land Cover Data (NLCD). The OLI image data and NLCD land cover data were spatially aggregated to produce VIs and major vegetation cover types, respectively, at various pixel sizes, including Tower ground FOV footprint, 250 m, 375 m, 500 m, 750 m, and 1 km. Several statistical measures were employed to quantify the spatial representativeness of Tower VIs for MODIS and VIIRS pixels and to quantify the magnitude of VI scaling uncertainties across these pixel sizes. Preliminary results of the analysis will be presented.

Keywords: NDVI, EVI, EVI2, scaling uncertainties, spatial representativeness

A Generic Approach For Inversion And Validation Of Surface Reflectance Over Land: Application To Landsat 8 And Sentinel 2.

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This paper presents a generic approach developed to derive surface reflectance over land from a variety of sensors. This method relies on the inversion of the radiative transfer equation in the Lambertian case, with no adjacency effects, that account for a simplified coupling of the absorption by atmospheric gases and scattering by molecules and aerosols as implemented in the 6SV radiative transfer code. The processing code relies on look-up tables generated by 6SV, for which the accuracy (~1%) has been well documented in several papers. The code uses ancillary data such as pressure and gas concentrations but relies on a per pixel inversion of the aerosol properties to assure the best possible accuracy for the surface reflectance, as aerosols can be highly variable both in space and time. This new aerosol inversion builds on the extensive dataset acquired by the Terra platform, combining MODIS and MISR to derive an explicit and dynamic map of band ratio’s between blue and red channels and is a refinement of the operational approach used for MODIS and LANDSAT over the past 15 years. The aerosol inversion is generic and applicable to a variety of sensors. We use this approach to derive Landsat 8 and Sentinel 2 surface reflectance products. We then present the validation approach and results using AERONET data. Finally, we conclude by analyzing the consistency of the time-series of surface reflectance combining both sensors over agricultural areas and exploring the potential application of this new product.

Keywords: radiative transfer, aerosol, surface reflectance

GEOGLAM Asia-RiCE initiative

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The Asia-RiCE initiative (http://www.asia-rice.org) has been organized to enhance rice production estimates through the use of Earth observation satellites data, and seeks to ensure that Asian rice crops are appropriately represented within GEO Global Agriculture Monitoring (GEO-GLAM) to support FAO Agriculture Market Information System (FAO-AMIS). Asia-RiCE is composed of national teams that are actively contributing to the Crop Monitor for AMIS and developing technical demonstrations of rice crop monitoring activities using both Synthetic Aperture Radar (SAR) data (Radarsat-2 from 2013; Sentinel-1 and ALOS-2 from 2015; TerraSAR-X, Cosmo-SkyMed, RISAT, and others) and optical imagery (such as from MODIS, SPOT-5, Landsat, and Sentinel-2) for 100x100km Technical Demonstration Sites (TDS) as a phase 1 (2013-2015) in Asia. with satellite –based cultivated area and growing stage map.

The Asia-RiCE teams are also developing satellite-based agro-met information for rice crop outlook, crop calendars and damage assessment in cooperation with ASEAN food security information system (AFSIS) for selected countries (currently Indonesia, Thailand, Vietnam, Philippine, and Japan; http://www.afsisnc.org/blog), using JAXA's Satellite-based MonItoring Network system as a contribution to the FAO AMIS outlook (JASMIN) with University of Tokyo (http://suzaku.eorc.jaxa.jp/cgi-bin/gcomw/jasm/jasm_top.cgi).

From 2016 as a phase 2, Asia-RiCE initiative deploy up-scaling activity from a province (100x100km) to major crop areas or entire country to implement operational use for rice crop production information in low Mekong, Vietnam and top 10 provinces in Indonesia using space based technology in cooperation with VAST, VNSC, CESBIO, MOA/Indoensia, LAPAN and JAXA.

This paper reports this year activity of 2016 accomplishment and way forward.

Keywords: GEOGLAM, Asia Rice, ALOS-2, food security

A Big Data Approach for Situation-Aware correction and estimation of NDVI, based on Landsat8 OLI/TIRS (Surface Reflectance) time series data

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The Landsat8 Surface Reflectance Higher-Level Data provided by USGS corrected from medium resolution MODIS Terra /Aqua Satellites data, contain Cloud QA, CFmask, CFmask Cloud Confidence and Interpolation Flag bands corresponding to prior single Quality Assessment(QA) Band of OLI/TIRS data. These corrected band data, when used for deriving vegetation indices such as Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Soil Adjusted Vegetation Index (SAVI) still exposes limitations in presence of atmospheric artifacts such as aerosol, cloud, cirrus cloud etc. The effect of occlusion by these artifacts imposes an important challenge for estimation of accurate vegetation indices, adequately affecting application areas such as digital precision agriculture: Where recommendation applications developed for farmers largely depend on these indices(e.g. Spatio-temporal irrigation recommendations to farmers based on NDVI based estimation of crop evapotranspiration - ETc). Our approach corrects the surface reflectance band values in the case of occlusion by cloud and other artifacts, defusing Spatio-temporal correlations and regressions. The Big Data process pipeline consisting correlation and regression techniques developed on Apache Spark can easily scale for large data sets including many tiles(scenes) and over widened time-scale.

Keywords: Normalized Difference Vegetation Index (NDVI), Situation-Aware, Big Data, Apache Spark, Landsat8

Rice Crop Monitoring by using Multiple Satellite Sensors

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Rapid population and economic growth, and the increase in extreme weather events, are destabilizing global food security. In Asia, rice is a staple cereal crop, and the continent accounts for about 90% of global rice production and consumption. The Group on Earth Observations (GEO) Global Agricultural Monitoring (GLAM) was launched in 2011 to utilize remote sensing tools to enhance crop production projections in order to promote food security and foster sustainable economic growth. Asia-Rice Crop Estimation & Monitoring (Asia-RiCE) is a component of GEOGLAM, and aims to use remote sensing tools to develop rice-related information such as maps of paddy fields, rice growing conditions, yield, and production. Rice is mainly cultivated in the rainy season, and the high density of cloud cover during that season limits the observations that can be made from space using only optical sensors. In contrast, Synthetic Aperture Radar (SAR) is a robust tool because it penetrates cloud cover; however, the revisit frequency of a single SAR satellite is limited, making it difficult to capture the complicated rice crop calendar in Asia. In this research, SAR data (ALOS-2 PALSAR-2 etc.), and optical global imager data (MODIS) were utilized to monitor rice crops in Asia. Rice crop growth can be estimated from backscattering coefficient measured by ALOS-2 or vegetation index such as NDVI or EVI by MODIS. In addition, microwave radiometer (AMSR2) was also used to identify surface water condition because AMSR2 36.5GHz data has high sensitivity to water, and it can penetrate cloud and capture surface water condition on a 2-3 days basis with 10 km spatial resolution. The integrated use of these satellite data enables us to capture rice growing and surface water condition during whole rice cropping cycle consists of planting, vegetative, reproductive, ripening, harvesting, and fallow seasons. These information can improve our ability to estimate rice crop yield/production and quantify the carbon or water balance in paddy fields and the methane emission from paddy fields.

Keywords: rice paddy, SAR, Microwave radiometer, Optical sensor

Crop mapping and crop production estimation using multi-source remote sensing data

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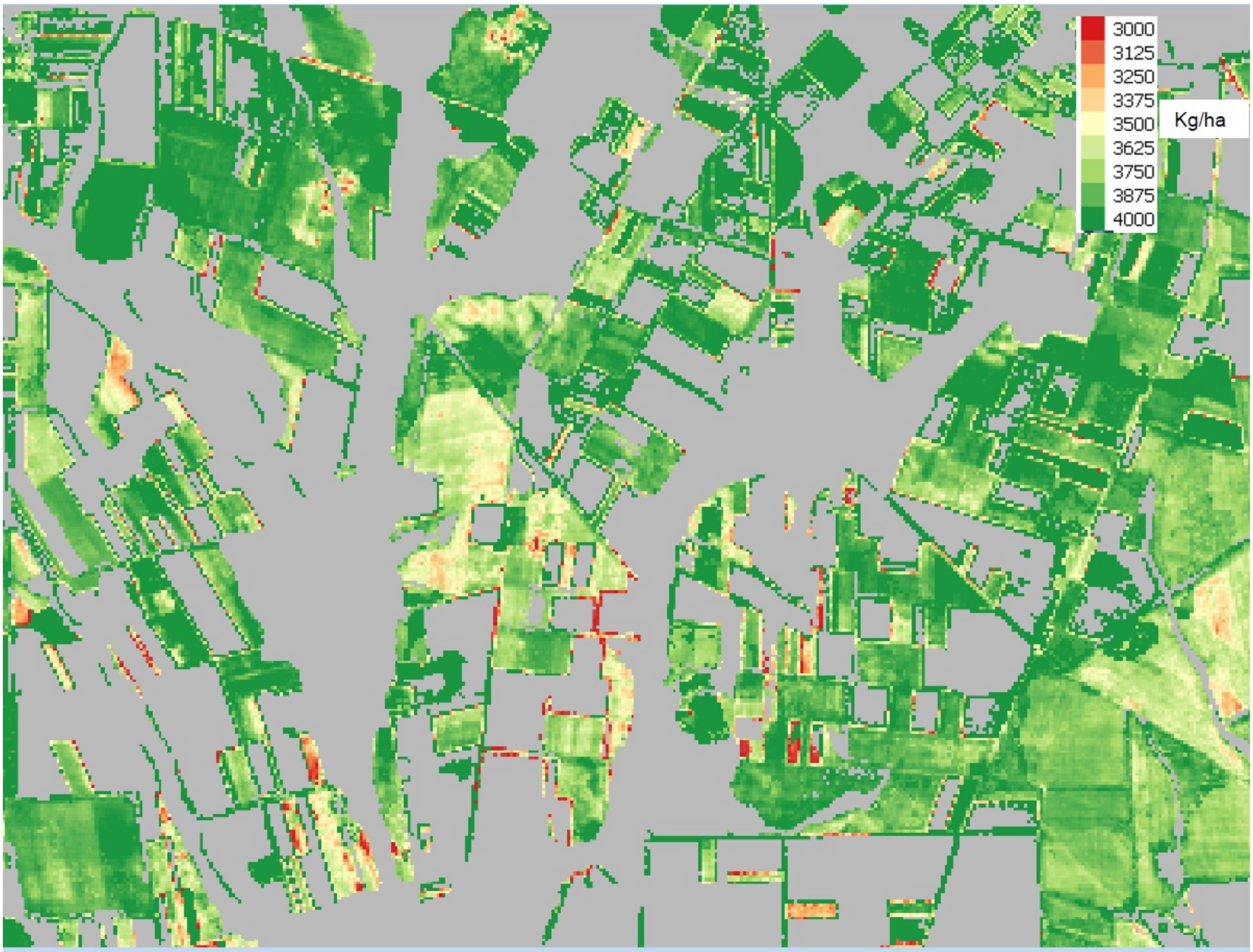
Remote sensing data from space is the essential source of information for enabling continous monitoring and quantification of crop state at global and regional scales. Crop mapping, state assessment, area estimation, yield forecasting and eventually crop production estimation are the main tasks being addressed within the Group on Earth Observation (GEO) Global Agricultire Monitoring Initiative (GEOGLAM). Efficiency of agriculture monitoring can be improved when heterogeneous multi-source remote sensing datasets are exploited. Here, we present several case studies of utilizing MODIS, Landsat-8 and Sentinel-2 data along with meteorological data for winter wheat yield forecasting, mapping and area estimation. Historical coarse spatial resolution data, such as MODIS, VIIRS and AVHRR, can provide daily global observations that coupled with statistical data on crop yield can enable the development of empirical models for timely yield forecasting at national level. With the availability of high-temporal and high spatial resolution Landsat-8 and Sentinel-2A imagery, course resolution empirical yield models can be downscaled to provide yield estimates at regional and field scale. In particular, we present the case study of downscaling the MODIS CMG based generalized winter wheat yield forecasting model to high spatial resolution data sets, namely harmonized Landsat-8 –Sentinel-2A surface reflectance product (HLS). Since the yield model requires corresponding in season crop masks, we propose an automatic approach to extract winter crop maps from MODIS NDVI and MERRA2 derived growing degree days (GDD) using the Gaussian mixture model (GMM). Validation for the state of Kansas (US) and Ukraine showed that the approach can provide accuracies > 90% without using reference (ground truth) data sets. Another application of yearly derived winter crop maps is their use for stratification purposes within area frame sampling for crop area estimation. In particular, one can simulate the dependence of error (coefficient of variation) on the number of samples and strata size. This approach was used for estimating the area of winter crops in Ukraine for 2013-2016. The GMM-GDD approach is further extended for HLS data to provide automatic winter crop mapping at 30 m resolution for crop yield model and area estimation.

Keywords: agriculture, crop mapping, crop yield, MODIS, Landsat-8, Sentinel-2



Winter wheat yield map derived from Landsat-8

Evaluation of The Landsat-8/Sentienl-2 Land Surface Reflectance

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The land surface reflectance is a fundamental climate data record at the basis of the derivation of other climate data records (Albedo, LAI/Fpar, Vegetation indices) and has been recognized as a key parameter in the understanding of the land-surface-climate processes. Here, we present the validation of the Land surface reflectance used for Landsat-8 and Sentinel-2 data. This methodology uses the 6SV Code and data from the AERONET network.
The first part was to define a protocol to use the AERONET data. To correctly take into account the aerosol model, we used the aerosol microphysical properties provided by the AERONET network including size-distribution (%C_f, %C_c, r_f, r_c, σ_r, σ_c), complex refractive indices and sphericity. Over the 670 available AERONET sites, we selected 230 sites with sufficient data. To be useful for validation, the aerosol model should be readily available anytime, which is rarely the case. We then used regressions for each microphysical parameter using the aerosol optical thickness at 440nm and the *Angström* coefficient as parameters. Comparisons with the AERONET dataset give good APU (Accuracy-Precision-Uncertainties) for each parameter.
The second part of the study relies on the theoretical land surface retrieval. We generated TOA synthetic data using aerosol models from AERONET and determined APU on the surface reflectance retrieval while applying the Landsat-8 and Sentinel-2 Atmospheric correction software. Over 250 AERONET sites, the global uncertainties are for MODIS band 1 (red) is always lower than 0.0015 (when surface reflectance is > 0.04). This very good result shows the validity of our reference. Then, we used this reference for validating the Landsat-8 and Sentinel-2 surface reflectance products. The overall accuracy clearly reaches specifications.
Finally, we will present an error budget of the surface reflectance retrieval. Indeed, to better understand how to improve the methodology, we defined an exhaustive error budget. We included all inputs i.e. sensor, calibration, aerosol properties, atmospheric conditions… This latter work provides a lot of information, such as the aerosol optical thickness obviously drives the uncertainties of the retrieval, the absorption and the volume concentration of the fine aerosol mode have an important impact as well…

Keywords: Atmospheric correction, validation, land surface reflectance

LANDSAT AND SENTINEL 2A SURFACE ALBEDO ESTIMATION. APPLICATION TO EVAPOTRANSPIRATION RETRIEVAL

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Surface albedo is an essential parameter not only for developing climate models, but also for most energy balance studies. While climate models are usually applied at coarse resolution, the energy balance studies, which are mainly focused on agricultural applications, require a high spatial resolution. The albedo, estimated through the angular integration of the BRDF, requires an appropriate angular sampling of the surface. However, Landsat and Sentinel 2A sampling characteristics, with nearly constant observation geometry and low illumination variation, prevent from deriving a surface albedo product.
In this work we apply an algorithm developed to derive a Landsat and Sentinel 2 surface albedo. It is based on the BRDF parameters estimated from the MODerate Resolution Imaging Spectroradiometer (MODIS) CMG surface reflectance product (M{O,Y}D09) using the VJB method (Vermote et al., 2009). Landsat and Sentinel 2 unsupervised classification images are used to disaggregate the BRDF parameters to their spatial resolution. Using these albedo values with field measurements we apply the S-SEBI method to estimate the evapotranspiration.

Keywords: Landsat, Sentinel 2, Surface albedo, Evapotranspiration

Inversion of forest structure parameters using multi-source remote sensing data

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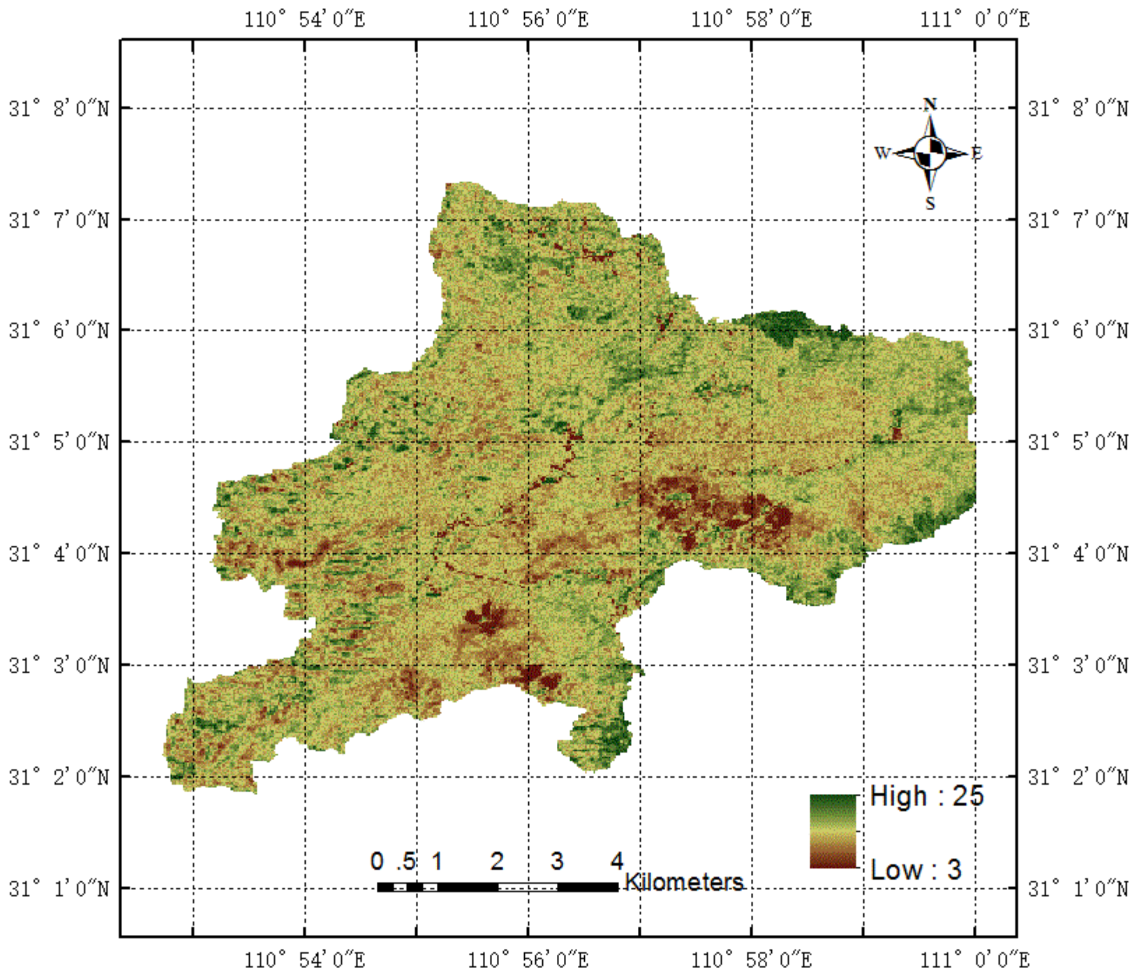
The inversion of forest structure parameters, which are needed in forest management planning, is carried out through the joint use of Sentinel-1A, Sentinel-2A, Landsat-8, GF-2 and field survey data. After atmosphere and terrain correction, Optical bands' reflectance value, intensity of C-band SAR and a series of extracted vegetation index were used in the construction of random forest regression model, terrain factors of slope and aspect were also within consideration. 1 m resolution GF-2 panchromatic imageries were used as the data source of texture analysis and the influences of different size of convolution window were analyzed. We introduce the concept of Normalized Difference Time Index (NDTI) to reflect the impact seasonal changes, which is proved to be an influential variable in our regression model. Through the above work, this article is dedicated to explore the possibility of a practical forest structure remote sensing inversion solution in mountain areas around Three Gorges basin of Yangtze River, which was previously thought as one of two most difficult regions for remote sensing in China.
Vegetation indexes used in this article include Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Soil Adjusted Vegetation Index (SAVI), Modified Soil Adjusted Vegetation Index (MSAVI), Normalized Difference Moisture Index (NDMI). Normalized Difference Time Index is expressed in the following form:
NDTI = (Band X_{summer} –Band X_{winter}) / (Band X_{summer} + Band X_{winter})
Texture factors include Mean, Variance, Homogeneity, Contrast, Dissimilarity, Entropy, Second Moment and Correlation of different convolution window.
The correlation coefficient of the model for average tree height is 0.377, with a standard error of 1.1024 m, for average diameter at breast height(DBH) is 0.422, with a standard error of 1.8684 cm, for volume per hectare is 0.556, with a standard error of 11.8606 m^3/ha.This work is still refining according to the needs of forestry production sector.

Keywords: Forest structure parameters, Multi-source, NDTI, Texture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Land cover classification of the Mongolian Plateau using multi-temporal MODIS data

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The Mongolian Plateau is part of the Central Asian Plateau and it mainly consists of Inner Mongolia of China and Republic of Mongolia. Previous studies have shown that this region has been experiencing rapid land cover and land use change such as lake shrinkage and land degradation due to human activities and climate change. In this study, we aimed to produce high reliable regional land cover map of the Mongolian Plateau using 500 m resolution multi-temporal MODIS data of 2016. The classification method is as below: First, we implement classification to each scene of the MODIS data of different seasons in year 2016. Second, we integrate these multi-temporal classification results. In the per-scene classification, we conduct a kernel density estimation (KDE), and then use the densities in a Bayesian inference to obtain the class posterior probability. After the multi-temporal per-scene classification, we calculate the classification score by integrating class posterior probabilities in multi-temporal scenes. In addition, we applied night light data such as SUOMI NPP to correctly estimate urban area. Also, digital elevation model data was used for detecting the wrong estimation of water or paddy class which located on the slope of mountain. For validation of the map, we mainly relied on the ground truth photo database which named SACLAJ (Site-based dataset for Assessment of Changing Landcover by JAXA) as well as higher resolution satellite images from ALOS and Landsat-8. Our studies demonstrated that combining such variety of satellite data and ground truth data, we can produce a high reliable regional land cover map which can be used as base input data for other researchers.

Keywords: Land use, Inner Mongolia, Kernel density estimation

ALGORITHM DEVELOPMENT AND VALIDATION METHOROLOGY FOR GCOM-C/SGLI AVOBE GROUND BIOMASS PRODUCT

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Japan Aerospace Exploration Agency (JAXA) will launch new Earth observation satellite GCOM-C in this fiscal year. GCOM-C equips Second-generation Global Land Imager (SGLI) as core sensor. Since SGLI can observe nadir and offnadir angle with along track direction simultaneously, it is expected to retrieve forest Above Ground Biomass (AGB) using bi-directional spectral data.

For the estimation of forest AGB, difference of bi-directional reflectance of each observation angle caused by forest canopy structure will be key information. Authors have been developed basic AGB estimation algorithm for SGLI. This algorithm is based on the empirical model related to the relationship between reflectance shift on the Red-NIR plane for different viewing angle and AGB. Since the algorithm requires the bi-directional reflectance on fixed observation geometry, we have also developed bi-directional reflectance simulator, BiRS, which employ not only sun-target-sensor geometry but also forest structure based on canopy structure model.

In this paper, a preliminary result of ARG estimation using MODIS multipass composite data is described. The preliminary result meets good estimation accuracy on the area that has Biomass validation data. As the result of comparison between NDVI value and normalized AGB shows the fact that NDVI cannot describe forest AGB.

Furthermore, validation plans of SGLI AGB product will be introduced including non-direct AGB measurements using terrestrial / aerial LiDAR and Structure from Motion technology.

Keywords: Second Generation Global Imager (SGLI), Multi-angular observation, Forest canopy, Biomass Estimation

