A PHYSICALLY BASED APPROACH IN RETRIEVING VEGETATION LEAF AREA INDEX FROM LANDSAT SURFACE REFLECTANCE DATA

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1. INTRODUCTION

The monitoring and modeling of the terrestrial biosphere within the larger context of climate variability and change studies requires global multi-decadal time series of key variables characteristic of vegetation structure and functioning [1]. Leaf Area Index (LAI) is a key biophysical variable that controls the exchange of energy, mass (e.g. water and CO2) and momentum between the Earth surface and atmosphere [2]. In this study, we aim to generate global 30-m LAI from Landsat surface reflectance data using the radiative transfer theory of canopy spectral invariants which facilitates parameterization of the canopy spectral bidirectional reflectance factor (BRF) [3][4][5]. This methodology permits decoupling of the structural and radiometric components and obeys the energy conservation law. According to this theory, the single scattering albedo is a function of spatial scale, thus accounting for variation in BRF with sensor spatial resolution and also accounts for variation in spectral BRF with sensor bandwidth [5]. The other parameter is input reflectance data uncertainty that accounts for varying information content from measurements (spectral BRF from multiple bands). Furthermore, canopy spectral invariants introduce an efficient way for incorporating multiple bands for retrieving LAI. We incorporate a 3-band retrieval scheme including the Red, NIR and SWIR bands, the SWIR band being specifically useful in low LAI regions and thus compensating for background effects. The initial results have satisfactory agreement with MODIS LAI, although with spatially more detailed structure and variability. A future exercise will be to introduce field measured LAI estimates to minimize the differences between model simulated LAI's and in-situ observations.

2. RESULTS AND DISCUSSION

2.1 Parameterization of canopy spectral reflectance

Retrievals of LAI from a satellite sensor require parameterization of the retrieval algorithm that can be adjusted for the specific features of the BRF measurements (spatial resolution, bandwidth, calibration, atmospheric correction, information content, etc.). The radiative transfer theory of canopy spectral invariants provides the required BRF parameterization via a small set of well-defined measurable variables that specify the relationship between the spectral response of vegetation canopy bounded by a non-reflecting surface to the incident radiation at the leaf and canopy scales [5][6][7]. In modeling the framework, the canopy spectral BRF is parameterized in terms of a compact set of parameters – spectrally varying soil reflectances, single-scattering albedo, spectrally invariant canopy interceptance, recollision probability and the directional escape probability [5]. The algorithm supports a flexible mode of operation, wherein retrievals of LAI can be obtained based on any number of given bands. A input landcover map is used (MODIS 500m landcover map resampled to 30-m) for creating biome-specific Look-up-tables (LUTs) which stores the simulated spectral BRF at the red, NIR and SWIR bands as a function of soil reflectance, LAI and view/azimuth angles.

2.2 Retrieval of the 3-band and 2-band LAI

Following the modeling framework outlined in Secton 2.1, we implemented a 3-band (Red, NIR and SWIR) and 2-band (Red and NIR) inversion scheme for each 30-m Landsat pixel, whereby if a 3-band retrieval fails to localize an LAI solution set, the algorithm will automatically switch to a 2-band retrieval method. If both fail, a backup LUT, based on NDVI-LAI empirical relationship, is utilized for the retrieving the LAI. Based on results and from previous studies [8], the SWIR certainly adds a significant bit of information related to background effects (dark/ wet background vs. bright background). The background can relate to soil effects, shadows and understory presence. The 3-band retrieval effects are observed in the low LAI regions (Fig. 1b), where we see a significant decrease in NDVI variation for a constant LAI. The 2-band retrieval is unable to capture this effect (Fig. 1a). This retrieval strategy will be an important aspect of the global LAI production, where accurate LAI numbers will eventually lead to more accurate GPP/NPP and leaf-biomass estimates, especially for landcover types like needleleaf forests, savannas and shrubs. The effect of background can significantly bias the LAI estimates for these biomes. As an example, we show an initial result displaying the Landsat LAI map around the California region (Landsite tile row:42/col:32, Fig. 2a & 2b) and the corresponding MODIS 1Km LAI map resampled to 30-m (Fig. 2c). The difference map shows agreeable results with LAI differences for most biomes within +-0.5 LAI (Fig. 2d). The conifers show a higher difference (0-1 LAI) and is due to the fact that the surface reflectances between Landsat and MODIS are consistent but varies in magnitude, especially in the NIR region for most of the forest biomes. This introduces a magnitude shift in the LAI estimates too. Future work will introduce field measured LAI estimates to minimize the differences between model simulated LAI's and in-situ observations.

3. FIGURES

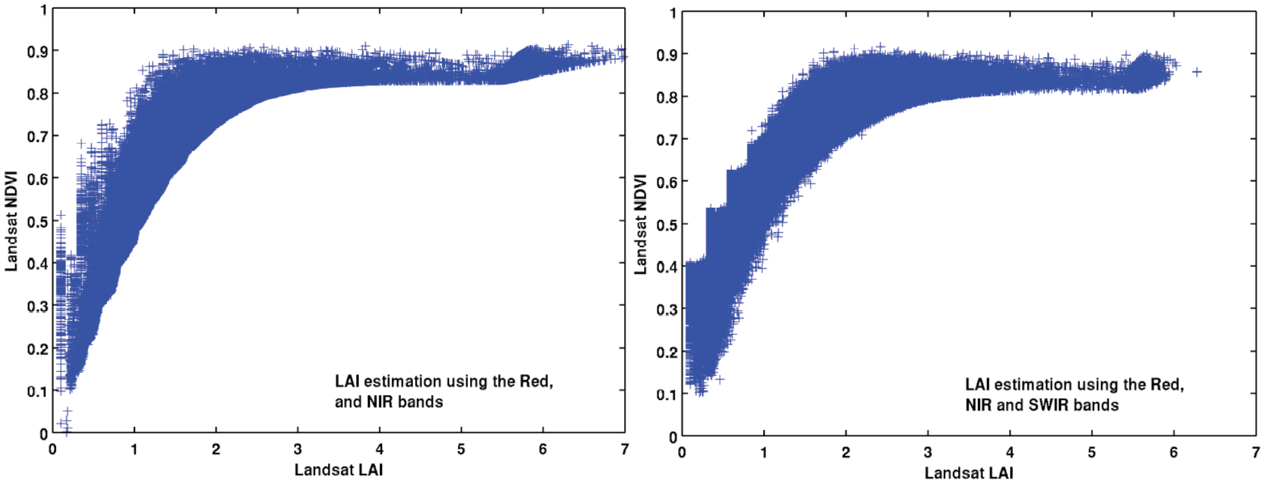

Figure 1. (a) Landsat NDVI vs. Landsat rerieved LAI using 2-band only for needleleaf forests (all needleleaf pixels from Fig. 2 below). (b) Same as (a) but using a 3-band retrieval scheme.

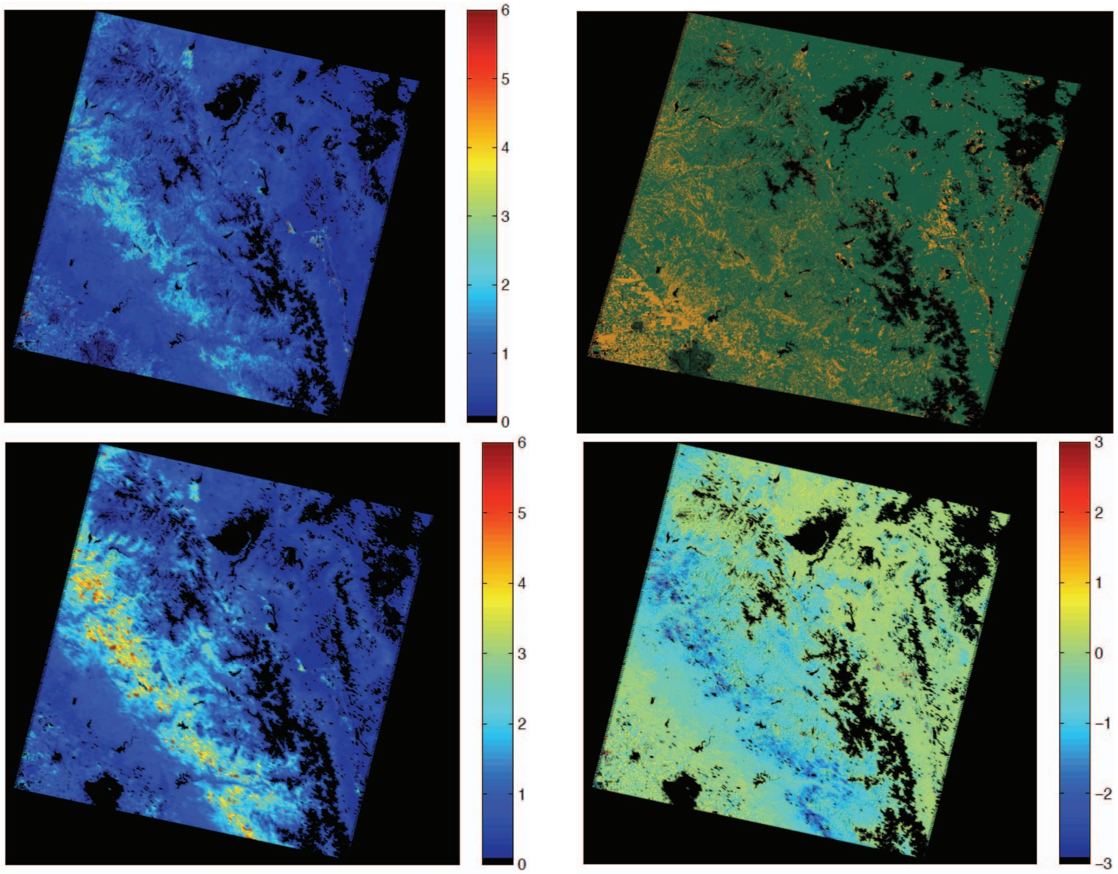

Figure 2. (a) Landsat derived 30-m LAI map using the 3-band and 2-band retrieval scheme. (b) Landsat Quality layer displaying pixels that are retrieved using 3-band (green in color) and 2-band (yellow in color) (c) MODIS 1Km LAI map resampled to 30-m. (c) LAI difference map (Landsat – MODIS).

4. CONCLUDING REMARKS

This study establishes the framework in generating a 30-m LAI product from the Landsat surface reflectance data. Long-term Global products of LAI at 30-m will prove to be of significant use in mapping global vegetation dynamics in the context of climate change and in specific application areas of mapping GPP/NPP and carbon sequestration. Creation of Global 30-m LAI maps from the 1970s till present will be the immediate aim of this study.

5. REFERENCES

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