Physically-based Canopy Reflectance Model Inversion of Forest Structure from MODIS Imagery in Boreal and Mountainous Terrain using the BIOPHYS-MFM Algorithm

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ABSTRACT

The BIOPHYS algorithm provides innovative and flexible methods for the inversion of canopy reflectance models (CRM) to derive essential biophysical structural information (BSI) for monitoring, inventory and quantifying vegetation state and disturbance, and for input to ecosystem, climate and carbon models [1-9]. Based on spectral, angular, temporal and scene geometry inputs that can be provided or automatically derived, the BIOPHYS Multiple-Forward Mode (MFM) approach generates look-up tables (LUTs) that comprise reflectance data, structural inputs over specified or computed ranges, and the associated CRM output from forward mode runs. Image pixel and model LUT

spectral values are then matched and retrieved, with the corresponding BSI associated with the matches output as the vegetation BSI results.

BIOPHYS-MFM has been extensively used and validated over a range of applications in collaboration with agencies in the USA and Canada over the past decade, such as CCRS, CFS, AICWR, NASA LEDAPS, BOREAS and MODIS Science Teams, and as a contribution to the North American Carbon Program [1-7]. The algorithm generates a variety of BSI products, such as land cover, biomass, stand and crown volume, stem density, height, crown closure, leaf area index (LAI) and branch area, crown dimension, productivity, topographic correction and validation, structural change from harvest, forest fires and mountain pine beetle damage assessment, and water / hydrology applications. BIOPHYS-MFM has been applied in different locations and ecosystems in Canada (six provinces from Newfoundland to British Columbia) and USA (NASA COVER, MODIS and LEDAPS sites) using 7 different canopy reflectance models and a variety of airborne and satellite remote sensing systems (e.g. MODIS, Landsat, SPOT, IKONOS, airborne MSV, MMR, casi, Probe-1, AISA).

In this paper we summarise the BIOPHYS-MFM algorithm and results from Terra-MODIS imagery from MODIS validation sites at Kananaskis Alberta in the Canadian Rocky Mountains, and from the Boreal Ecosystem Atmosphere Study (BOREAS) in Saskatchewan Canada. At the montane Rocky Mountain site, BIOPHYS-MFM density estimates were within ±380 stems/hectare (ha), with horizontal crown radius (HCR) ±0.4m, vertical crown radius (VCR) ±0.6m, and height (HGT) ±0.8m. At the BOREAS site, BIOPHYS-MFM analysis of single-date MODIS imagery yielded density estimates within ±210 stems/ha, HCR ±0.3m, VCR ±0.5m, and HGT ±0.9m. Higher accuracies at BOREAS compared to the Rocky Mountain site were attributed primarily to the more complex terrain in the mountains, for which the results obtained were quite good given the steep environmental, ecosystem, terrain and biophysical gradients. Further assessment at BOREAS involved integrated BIOPHYS-MFM analysis of multiple MODIS scenes with different view zenith angles to provide convergence of BSI on aggregation. Improvements were found for density (±42 stems/ha) and HCR (±0.2m), with VCR and HGT results unchanged (with ±0.5m and ±0.9m, respectively).

We concluded that good results from MODIS were obtained for both boreal and montane ecosystems. From this and other studies, BIOPHYS-MFM is well suited for large-area, multi-temporal applications involving multiple image sets and mosaics for assessing vegetation disturbance and quantifying biophysical structural dynamics and change for carbon and other models. It is also suitable for integration with forest inventory, monitoring and update needs, and other programs.

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