Evaluation of Collection 5 MODIS Terra, Aqua and Combined LAI Products

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Abstract

Suite of Collection 5 MODIS LAI/FPAR products include 8-day Terra and Aqua products, 8-days Combined Terra and Aqua product, and 4-day Combined Terra and Aqua product. In this study we analyzed Collection 5 LAI/FPAR products over the range of spatial scales: North America continent (single composite during the growing season), at scale of MODIS tile (annual time series for three MODIS tiles) , and at scale of validation sites (annual time series for three sites). For analysis we used Collection 4 Terra and Aqua surface reflectances, Collection 4 Land Cover and Collection 5 LAI/FPAR algorithm. To maintain consistency, we use the same daily retrievals algorithm and compositing algorithm for Terra, Aqua and combined products. Daily LAI retrievals algorithm consist of two parts: main (Radiative Transfer based) and back-up (empirical). Compositing algorithm selects best quality retrievals over the compositing period (main algorithm, if available), followed by maximum FPAR compositing. In this study we address the following set of MODIS LAI/FPAR research questions. 1) Is there any systematic difference in statistical properties of Terra and Aqua surface reflectances? How do they depend on the scale of analysis? 2) Is there any systematic difference in LAI and quality (QC) between Terra and Aqua retrievals? How do they depend on spatial scale? 3) What is the difference in spatial coverage of Terra and Aqua based retrievals in the combined product? 4) Influence of what kind of environmental factors (such as clouds, aerosols, snow) can be reduced by implementing Combined product? Do these improvements depend on vegetation type and season? 5) How does the Combined product help to reduce problem of saturation of surface reflectances over the dense forests (such as broadleaf forests)?

Results

Continental Scale

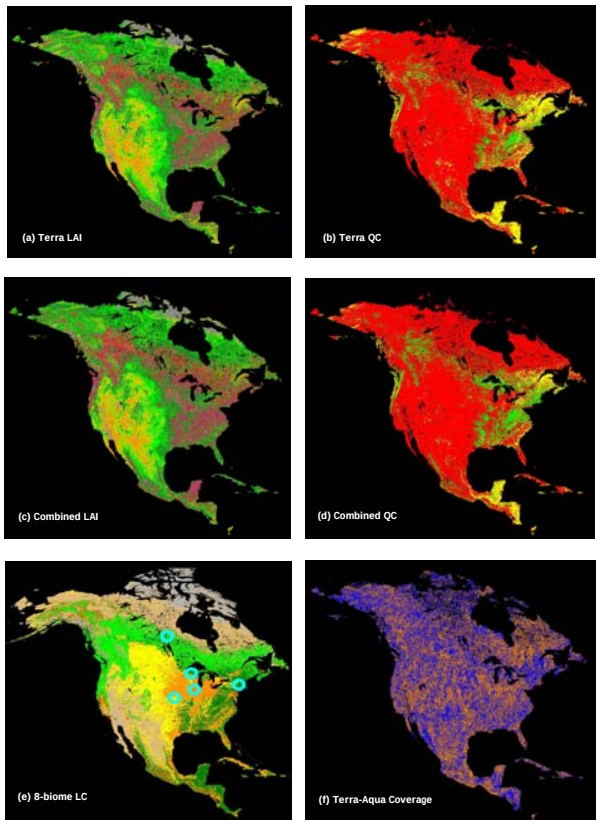

Figure 1. Spatial distribution of 8-day Terra, Aqua and Combined products. Collection 4 MODIS Terra and Aqua Surface Reflectance products for days 201-208.2003, Collection 4 Terra Land Cover product and Collection 5 LAI/FPAR algorithm were used in retrievals over North America continent: (a) Terra LAI; (b) Terra QC; (c) Combined LAI; (d) Combined QC; (e) Terra Land Cover, overlaid with location of validation sites; (f) Spatial distribution of Terra and Aqua coverage in Combined product. Based on the above: spatial distribution of LAI from Terra and Combined products is similar; there is no spatial patterns of predominant Terra or Aqua retrievals- essentially random coverage; Overall retrieval rate of the main algorithm is high (80% for Terra and 85% for Combined); Back-Up algorithm retrievals are mostly concentrated over woody vegetation and combined product helps to improve retrieval rate over woody vegetation by about 15%.

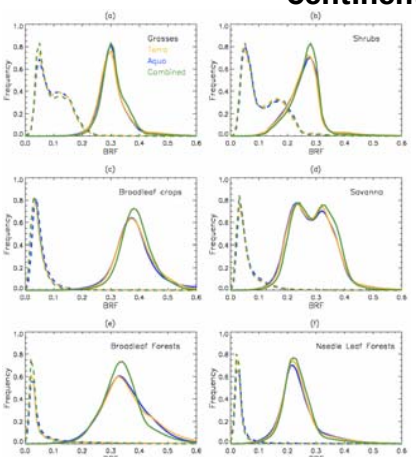

Figure 2. Comparison of histograms of Red (dotted line) and NIR (solid line) surface reflectance from Terra, Aqua, and Combined data sets. Data sources are the same as for Figure 1. In general, histograms are similar, which confirm large scale similarity of Terra and Aqua data. The difference between combined and Terra or Aqua data is due to compositing, which reduces variance in data.

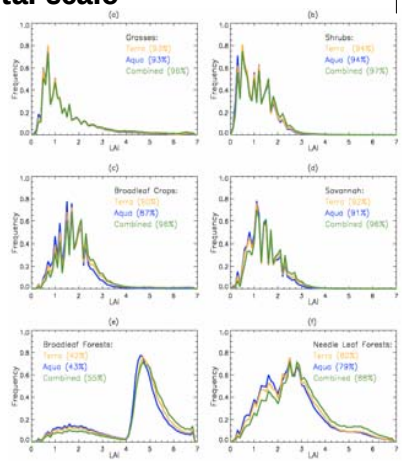

Figure 3. Comparison of histograms of LAI derived from Terra, Aqua, and Combined data sets. Data source are the same as for Figure 1. Similarity of histograms confirms stability of Terra, Aqua and Combined LAI products. Percentages of main algorithm retrievals are shown for all three products.

Tile Scale

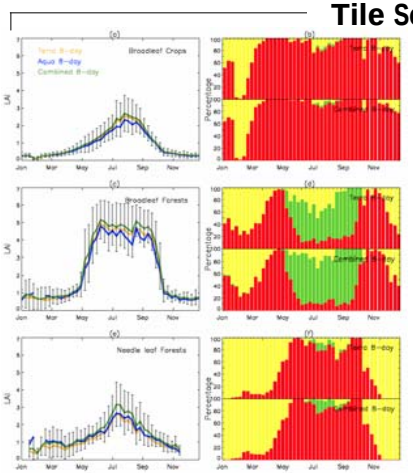

Figure 4. Time series of 8-day Terra, Aqua and Combined LAI and QC data over broadleaf crops in tile h11v04, broadleaf forests at tile h12v04 and needle leaf forests at tile h12v03. LAI profiles indicate agreement within product specifications (0.5 LAI), however Aqua LAI is systematically lower. Combined product demonstrate increase of main algorithm coverage over broadleaf forests by 15-20%.

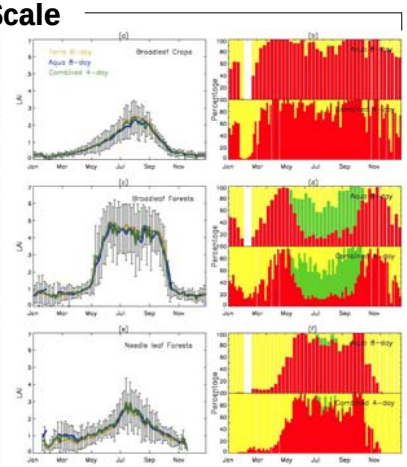

Figure 5. Time series of 8-day Terra and Aqua and 4-day Combined products. Spatial coverage of data sets is the same as in Figure 4. Comparison of LAI and QC indicates that 4-day Combined product have similar statistical properties as 8-day single sensor product: similar retrieval rate of the main algorithm and similar LAI values.

Site Scale

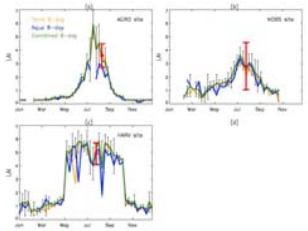

Figure 6. Validation of MODIS LAI product is generally performed at small scales of 1x1 km to 10x10 km sites. Here we evaluated time series of 8-day Terra, Aqua, and Combined retrievals for three 7x7 km sites, where BigFoot field data were available: AGRO (broadleaf crops in tile h11v04), NOBS (needle leaf forests in tile h12v03) and HARV (broadleaf forests in tile h12v04). MODIS products agrees with field measurements within uncertainties of both data sets. Retrievals over broadleaf crops and broadleaf forests demonstrate correct seasonality. However, seasonality over needle leaf forests during the summer time is overestimated. Also, compared to continental and tile scale retrievals, both Terra and Aqua retrievals demonstrate higher level of noise. Aqua LAI is somewhat lower than Terra LAI. Sudden drops in Aqua LAI are more pronounced.

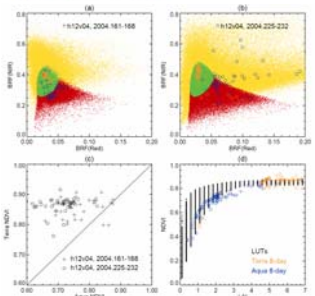

Figure 7. To understand the reasons for the noise in LAI retrievals we analyzed Terra and Aqua surface reflectances over HARV broadleaf forests site during two composites: 161-168.2004 and 225-232.2004. For the above composites Terra reports correct LAI (~5), while Aqua LAI is substantially underestimated (~2-3). Retrieval domain of the MODIS LAI/FPAR algorithm overlaid with surface reflectances over HARV site is shown for both composites, (a)-(b). For both composites Terra surface reflectances belong to domain of saturation (resulting in retreival of high LAI). However, Aqua surface reflectances over the site are positioned beyond the saturation domain, closer to soil line, which results in LAI underestimation. Also, NDVI of Terra is higher than NDVI of Aqua: 0.85 vs. 0.7 (c), which is inconsistent with LUTs of the algorithm and RT theory, which predicts nearly constant NDVI at high LAI regardless of view-illumination conditions, (d). Possible reason for the noise in Aqua data is that retrievals are performed at higher VZA, which reduces the accuracy of atmospheric correction.

Conclusions

- Suite of Collection 5 MODIS LAI and FPAR products will include the following: a) 8-day Terra (MOD15A2), b) 8-day Aqua (MYD15A2), c) 8-day Combined Terra and Aqua (MCD15A2), d) 4-day Combined Terra and Aqua (MCD15A3)
- We analyzed prototypes of the above products using Collection 4 Aqua and Terra Surface Reflectance products, Collection 4 Land Cover product, and Collection 5 LAI/FPAR algorithm
- For completeness and generality of results three spatial scales were used in analysis: continental (North America), MODIS tile scale (1200x1200 km), and scale of validation sites (7x7 km)
- Terra has the longest time series. Collection 4 LAI/FPAR data were validated over all vegetation types. Collection 5 Terra LAI poses the best stability (lowest day-to-day variations) compared to Aqua data
- Aqua data have shorter time series. Aqua LAI/FPAR data were not validated. In general we see more noise in Aqua LAI retrievals based on limited case studies. We also found that Aqua NDVI is quite often lower than Terra, which results in similar difference between Aqua and Terra LAI. The difference is within product specifications (0.5LAI) at continental and tile scale, however could be large at the local scale of validation sites. We attribute this due to noise in surface reflectances
- Combined Terra and Aqua LAI product selects best retrievals from two data sets. Contribution of Terra and Aqua retrievals are equal at the continental scale for all vegetation types. Locally contribution may vary as function of space and time. Single sensor retrievals (Aqua or Terra) have high retrieval rate of main algorithm during the growing season at continental scale: 85% overall, 95% for herbaceous vegetation and 70% for woody vegetation. Combined 8-day product helps to improve retreival rate over woody vegetation by about 15%. Combined 4-day product generally have similar retrieval rate of main algorithm as single sensor 8-day product, but improve temporal resolution of the product- 4-days instead of 8-days. This property is valuable for various phenological studies
- Our study suggests that for Collection 5 and future reprocessing of the suite of MODIS land products the atmospheric correction and calibration of Terra and Aqua should be improved to reduce noise in high lever MODIS products, such as LAI/FPAR
- Reference: Yang, W., Shabanov, N.V., Huang, D., Tan, B., Knyazikhin, Y., and Myneni, R.B. "Evaluation of LAI Retrievals from MODIS Terra, Aqua and Combined Data", Remote Sensing of Environment, in preparation.