

NORMALIZING ASTER DATA USING MODIS PRODUCTS FOR LAND COVER CLASSIFICATION

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ABSTRACT:

ASTER has similar bandwidths and spatial resolution to Landsat and is an important component of the mid-resolution data archive. However, the limited duty cycle of ASTER and relatively small scene size has resulted in a “patchwork” archive of global imagery. The changes of solar geometries (BRDF) and phenology complicate land cover classification and change detection especially when comparing to the historical Landsat data archive. In this paper, we use the improved general empirical relation model (GERM) approach to normalize ASTER images acquired from different dates to one reference MODIS data. The resulting MODIS-like surface reflectance from different ASTER scenes can be mosaiced for land cover classification. Land cover change detection also becomes possible while comparing ASTER images to other mid-resolution data produced from same approach.

1. INTRODUCTION

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) instrument aboard the Terra platform acquires Earth imagery at a resolution of 15-90m resolution using 14 VNIR-SWIR-TIR bands (Abrams, 2000). The mission has now acquired about 2x global cloud-free coverage since launch in December 1999. ASTER is critical for characterizing land cover changes during the 2003-2010+ period especially while Landsat 7 ETM+ has encountered the Scan-Line Corrector problem since May 2003 and the age of Landsat 5 are threatening the continuity of Landsat data record before a new Landsat mission starts operation in 2011 (Wulder et al., 2008). ASTER data among other mid-resolution (10-60m) sensors such as the Advanced Wide Field Sensor (AWiFS) and Linear Imaging Self-Scanner (LISS) III sensors aboard Indian Remote Sensing Satellite (IRS) and the Charge Coupled Device (CCD) camera aboard China-Brazil Earth Resources Satellite (CBERS) have been considered as a potential substitute for Landsat data continuity if Landsat data gap starts (Powell et al., 2007).

However, the limited duty cycle of ASTER and relative small scene size (60kmx 60km) has resulted in a “patchwork” archive of imagery acquired from different points in the growing season. Images acquired from different dates are affected by changing solar geometry (BRDF) and vegetation seasonal changes (phenology), which complicates land cover classification and change detection. The lack of a blue band limits its abilities in retrieving consistent surface reflectance using standard “dense dark vegetation” approaches for aerosol extraction, and thus limits biophysical estimation. A consistent data stream from different mid-resolution satellites (such as ASTER and Landsat) is a key to combining data sources for integrated analysis.

A general empirical relation model (GERM) approach was recently developed to correct mid-resolution satellite digital number (DN) to surface reflectance using MODIS surface reflectance as a reference data set in one step processing (Gao et al., 2008). Different from the physical atmospheric correction

approach, GERM approach is a relative atmospheric correction approach and therefore the corrected surface reflectance is a MODIS-like surface reflectance. Results from GERM approach shows that it can achieve the similar accuracy to the physical model approach. Data from Landsat TM/ ETM+, IRS-P6 AWiFS and TERRA ASTER were integrated in one consistent mid-resolution data set for time-series data analysis by using MODIS (Moderate Resolution Imaging Spectroradiometer) observations acquired from close dates (Gao et al., 2008).

The GERM approach uses linear transformations between mid-resolution data and MODIS surface reflectance and requires the close acquisition dates between Landsat-like data and MODIS data. It needs adjustment if acquisition dates between mid-resolution data and MODIS data are different especially when land cover or phenology changes. A general form of GERM approach needs to incorporate different relations based on land cover type. Each land cover type may present different changes (relations) between mid-resolution data and MODIS surface reflectance.

In this paper, we present an improved GERM approach and normalized ASTER data that were acquired from different dates and locations to one target date using MODIS data as references, thus the ASTER “patchwork” can be mosaiced in a consistent MODIS-like surface reflectance for land cover classification.

2. APPROACH

The basis of this approach is that homogeneous pixels of the same land cover type have the same surface reflectance regardless of patch size. Thus the BRDF/seasonality changes of homogeneous pixels should also be the same for different patch sizes given each land cover type does not split (1 to n, change in one direction is fine) during a short period. The relationship of each land cover type between acquisition date and target date will stay same for different resolution images. Therefore, the relationships built on the MODIS data and aggregated coarse

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resolution ASTER data can be applied to fine resolution ASTER to produce ASTER surface reflectance at a target date (e.g. MODIS acquisition date).

Figure 1 illustrates a processing flow from mid-resolution sensor digital number or radiance to MODIS-like surface reflectance at MODIS acquisition date. In this process, the mid-resolution data are first precision registered and orthorectified, reprojected and resampled to MODIS coarse resolution. An unsupervised classification is applied to the mid-resolution data. A majority spectral cluster type of each MODIS pixel based on ASTER pixels is computed and also used as criteria to determine homogeneity of MODIS pixel. Relationships between ASTER data and MODIS surface reflectance for each cluster are then built using “pure” coarse-resolution homogeneous pixels. The “pure” pixel at MODIS resolution for each cluster type is determined by the percentage of majority cluster (> defined threshold). Only cloud-free pixels on both MODIS and ASTER image can be selected as samples. The MODIS-like surface reflectance is then produced at fine resolution using the resulting relationship from “pure” samples for the same cluster type. For small clusters that have not enough good samples to work on, a global relation regardless of cluster type will be used as backup algorithm.

The GERM approach processes ASTER DN to MODIS-like surface reflectance band by band. ASTER and MODIS have similar bandwidths as Landsat ETM+. As shown in Table 1, ASTER instrument characteristics are nearly identical to Landsat ETM+ on band 2 to 5 except for a narrower swath width. The MODIS land bands have bandwidths corresponding to the ASTER and Landsat ETM+ sensor except that they are somewhat narrower than either. Many studies have shown that MODIS and ETM+ surface reflectance are very consistent and directly comparable (Vermote et al., 2002; Masek et al., 2006). Therefore it is feasible to make consistent ASTER and ETM+ surface reflectance through high temporal MODIS observations.

MODIS surface reflectance product is an appropriate data source as a reference data set not only because of the similar bandwidth but also because: 1) MODIS provides daily global coverage; 2) MODIS products have been partially validated and provide associated quality control flags and 3) MODIS products are freely available on-line and easy to access.

3. APPLICATION EXAMPLE

Using GERM approach, several ASTER images from different acquisition dates can be normalized to any clear MODIS acquisition date in MODIS-like surface reflectance. Figure 2 illustrates the processing result over central Virginia. In the test, we used ASTER scenes that were acquired from Fall 2005 to Spring 2006 (10/23/05, 11/10/05, 1/27/06 and 4/10/06) and a MODIS image acquired on 4/10/2006. Figure 2(a) shows map stitched from original L1B ASTER data with different acquisition dates (b). The differences of seasonality/BRDF are obvious on this map. However, those differences have been reduced in the mosaic map (d) of the BRDF/seasonality corrected ASTER images by using MODIS surface reflectance (c) as a correction reference. The remaining differences between adjacent ASTER paths may reflect diverging land cover conditions through the growing season (e.g., same land cover on the ASTER acquisition date but different on the MODIS acquisition date thus causing a “1:n” non-function relationship) or heterogeneous aerosol loading within an

ASTER scene (MODIS aerosol information was not used in this example). Results can be improved by including MODIS aerosol information in normalization and using additional ASTER images to distinguish land cover types and avoid “1:n” relationship in models.

The original GERM approach doesn’t distinguish among different land cover types. It can normalize mid-resolution data using MODIS data with close acquisition dates such that land cover changes can be neglected during a short period. Figure 3a shows the subset of normalized ASTER surface reflectance from original GERM approach. The right part of image from scene boundary (dash red line) is the adjusted ASTER data of April 10, 2006 using same day MODIS surface reflectance. Figure 3b is the subset of normalized ASTER surface reflectance from the improved GERM approach in this paper. The right part of image (ASTER scene on April 10) in Figure 4b shows almost identical values to Figure 3b. However, the left part of mosaic is the ASTER scene acquired on January 27, 2006 but normalized to the April 10, 2006 target date. The improved GERM approach (Figure 3b) shows more consistent results in the mosaic ASTER image. The lower reflectance such as river from original GERM approach seems too high in Figure 3a, which may due to the inappropriate global relations from all samples without distinguishing different land cover types.

Figure 4 shows the supervised classification (maximum likelihood) results from original DN image and the normalized MODIS-like surface reflectance using same training samples. Figure 4a is the classification result from Figure 2a and Figure 4b is the classification map from Figure 2d. Figure 4b is obviously more reasonable than Figure 4a. The differences between different ASTER scenes have been greatly reduced in Figure 4b.

4. CONCLUSION

The improved GERM approach allows computation of surface reflectance from satellite digital number directly despite different acquisition dates between the mid-resolution data and MODIS data. It corrects atmospheric, BRDF and phenology effects through one step processing. ASTER images acquired from different dates can be normalized to a “standard” date by using MODIS data as reference. Therefore, the mosaiced ASTER surface reflectance can be used for a large area land cover classification. In the meanwhile, the resulting MODIS-like surface reflectance is also comparable to other mid-resolution MODIS-like surface reflectance produced from this approach. This will allow the further land cover changes study and time-series analysis using data from multiple mid-resolution sensors.

There are two major advantages for GERM model using MODIS surface reflectance as a reference data set. First, the MODIS-like surface reflectance provides a way to standardize surface reflectance from different mid-resolution sensors to one “standard” and thus data from different sensors will be consistent and comparable. Second, in theory, the MODIS-like mid-resolution surface reflectance data may be used to retrieve mid-resolution biophysical parameters by using MODIS algorithm directly.

The approach is better for ASTER images that were acquired during same season to the MODIS acquisition (target) such that land cover and phenology changes are all point to one direction

(i.e., in 1 to 1 or n to 1 relation) during the period. It's a very reasonable assumption for forest type. However, it may not work for cropland which may break our assumption because of different crop calendar. For example, if two patches of bare soil are similar in the ASTER image but different in MODIS target date (i.e., in 1 to n relation such as one grows vs. one not), this model will not be able to capture different changes unless additional information are introduced. Therefore, it is more appropriate to use more informative leave-on images and normalize it to a leaf-on or leaf-off MODIS target date.

5. ACKNOWLEDGEMENTS

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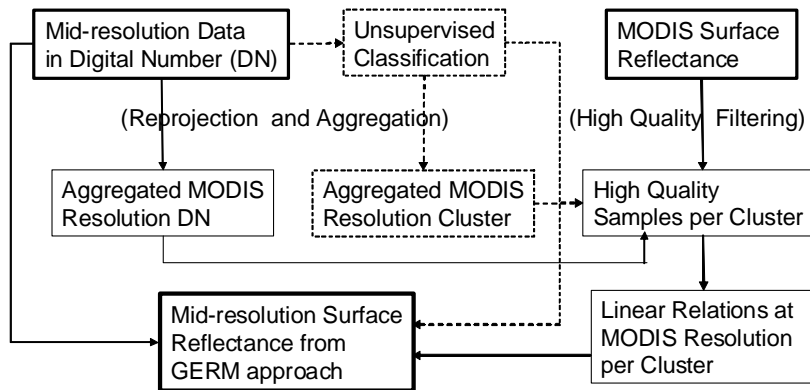
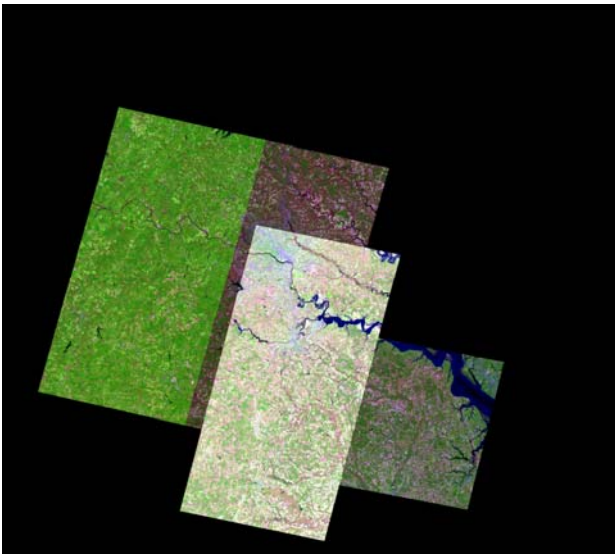


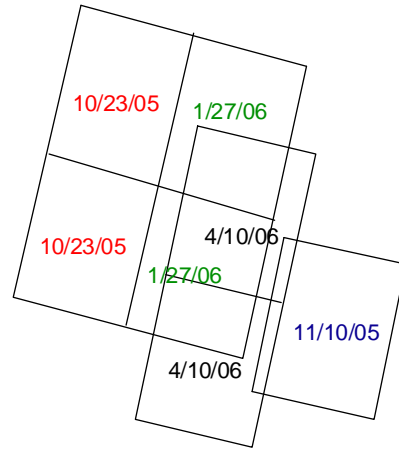
Figure 1. Processing flow chart of the improved GERM approach. Solid lines and rectangles show the design of original GERM approach. Dashed lines and rectangles shows the improvements.

| ASTER | Spectral Bandwidth (μ) | | Ground Resolution | | SwathWidth/Repeat | |
|------------------|------------------------------|------------------|-------------------|------|-------------------|-----------------|
| | ETM+ | MODIS | ASTER | ETM+ | ASTER | ETM+ |
| B1: 0.52-0.60 | B1: 0.45-0.52 | B3: 0.459-0.479 | 15 m | 30 m | 60 km /16 days | 185 km /16 days |
| B2: 0.63-0.69 | B2: 0.52-0.60 | B4: 0.545-0.565 | | | | |
| B3: 0.76-0.86 | B3: 0.63-0.69 | B1: 0.620-0.670 | | | | |
| B4: 1.60-1.70 | B4: 0.76-0.90 | B2: 0.841-0.876 | | | | |
| B5: 2.145-2.185 | B7: 2.09-2.35 | B7: 2.105-2.155 | 30m | 60 m | | |
| B6: 2.185-2.225 | | | | | | |
| B7: 2.235-2.285 | | | | | | |
| B8: 2.295-2.365 | | | | | | |
| B13: 10.25-10.95 | B6: 10.4-12.5 | B31: 10.78-11.28 | 90 m | | | |
| B14: 10.95-11.65 | | B32: 11.77-12.27 | | | | |

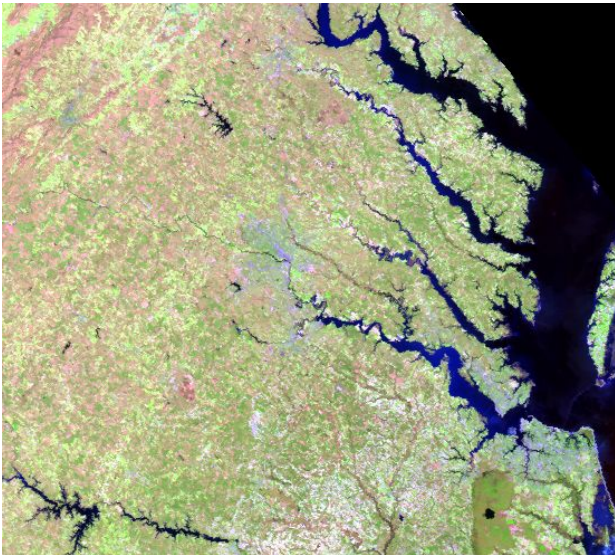
Table 1. Sensor characteristics among ASTER (black), ETM+ (blue) and MODIS (green)



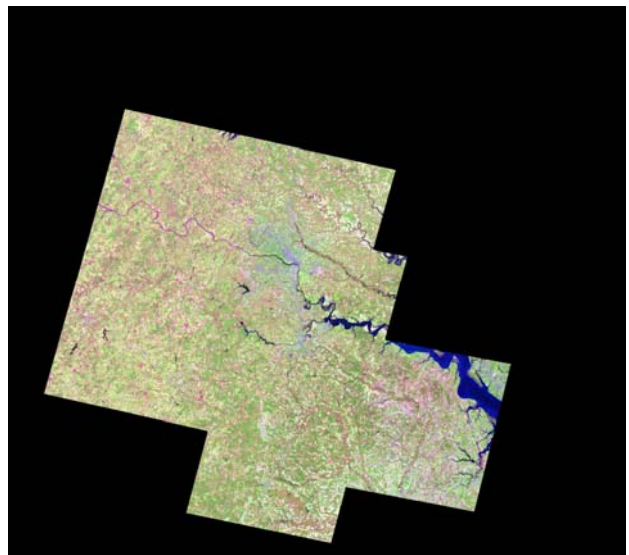
(a) ASTER Digital Number



(b) ASTER Acquisition Date



(c) MODIS Surface Reflectance



(d) Normalized MODIS-like Surface Reflectance

Figure 2. Seven ASTER scenes in digital number (a) acquired from different dates (b) are normalized to the MODIS-like surface reflectance (d) by using a MODIS surface reflectance (c) acquired on April 10, 2006 as reference.

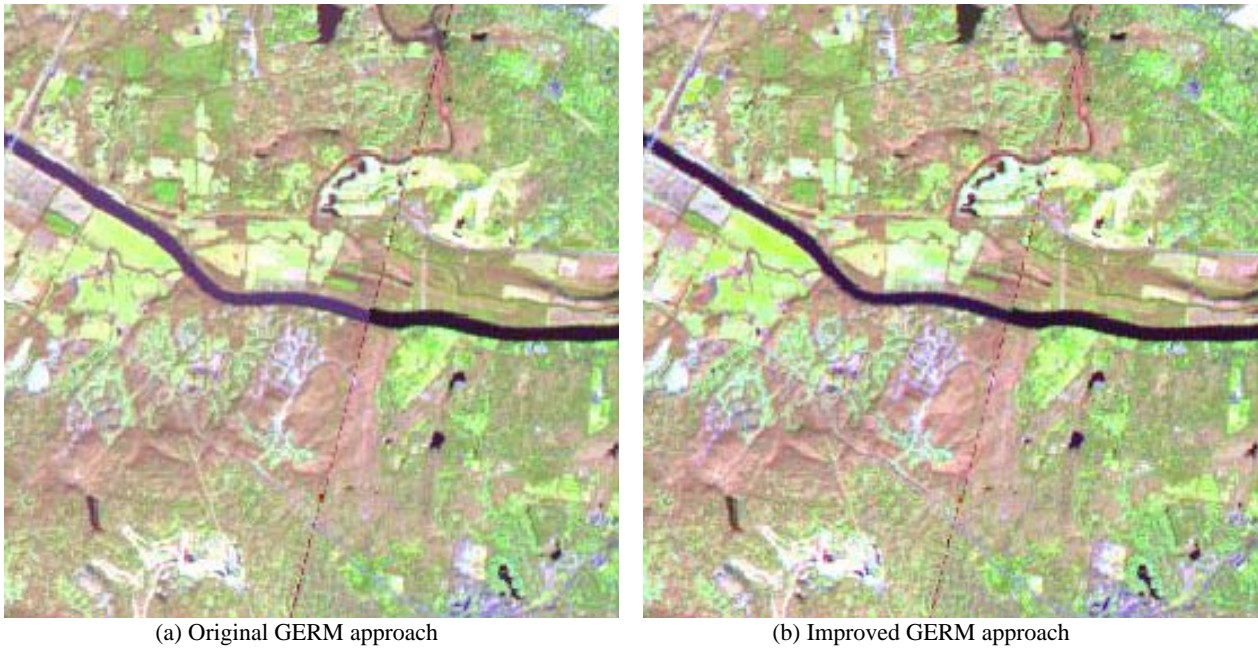


Figure 3. The improved cluster based GERM approach (b) shows more consistent results in the mosaic comparing to the original GERM approach (a). Note that right side of ASTER mosaic (separated by red dash line) has same acquisition date to MODIS target date (on April 10, 2006), thus results from (a) and (b) are almost identical for the right side. The cluster based GERM approach shows better result when ASTER acquisition date (left side ASTER scene acquired on January 27, 2006) is different from MODIS target date (April 10, 2006). The lower reflectance such as river in (a) seems too high from original GERM approach.

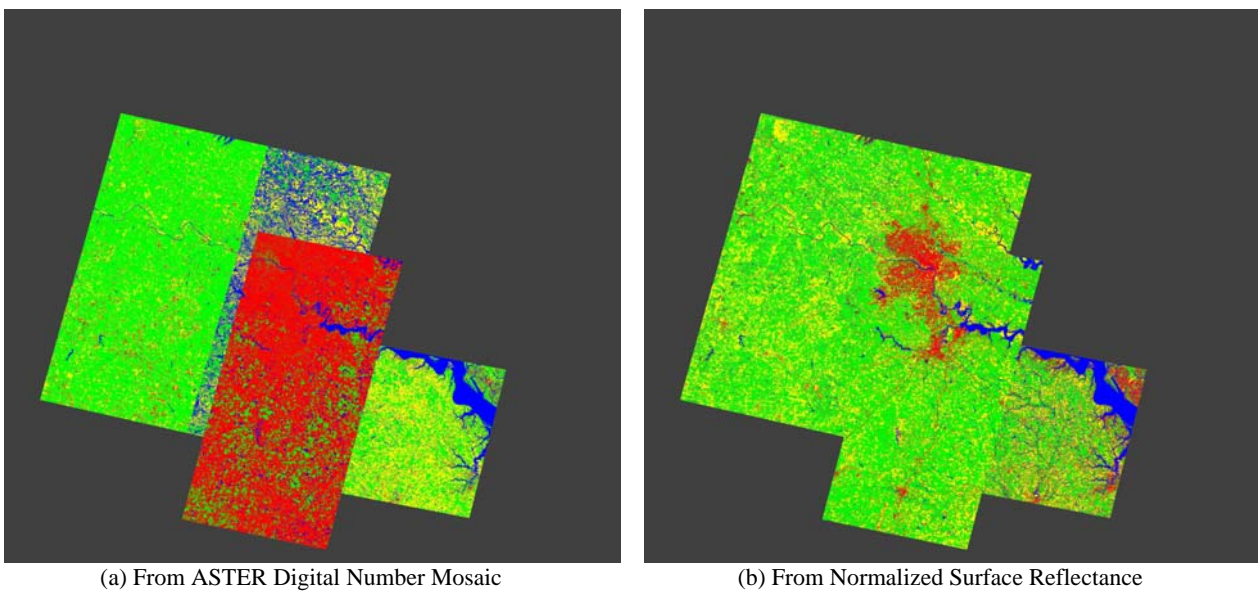


Figure 4. Maximum likelihood classification results from original DN images (a) and the normalized surface reflectance (b). The classification based on the normalized surface reflectance image shows more consistent results across different ASTER scenes. (green=forest; yellow=crops/grass; red=urban/built-up; blue=water)

