

Notes on GA-CSIRO BRDF Shape Tiff Files

There are five TIFF files (provided as Google Earth Superoverlay and network linked presentations through the TERN system) that represent an exploratory presentation of BRDF shape for the Australian continent. It is part of a project aimed at providing a rational default BRDF shape for Landsat correction outside of the time MODIS is available and to understand how the BRDF time series relates to land cover type and condition. This document describes the background and some notes to help with their interpretation.

Background:

An 11 year time series 2001-2011 of BRDF models developed from MODIS MOD43 data for the Australian continent is available through TERN and has been reprojected to a geographical graticule for a standard mapping region with 500m spatial resolution and “weekly” samples. “Weekly” means 8 day samples based of the previous 16 days compositing. There are 46 such “weeks” in a year of data. Data are available by spectral band as well. For this study, six spectral bands were used corresponding to the 6 reflective Landsat bands.

The data contain considerable variance, some of which is noise, some environmental and some sampling and estimation variance. It is unlikely that all of the variance represents a similar level of variance in land surface properties. For land cover work, the data should therefore be pre-processed. These data were pre-processed using time series cleaning taking BRDF quality flags into account, and water covered area masking. It will be reported in more detail later. The data were also averaged using different strategies to investigate inter- (ie trend) and intra-annual (ie seasonal) variations and are presently being compared with some standard land cover products.

The kernel model has the form:

$$\rho_{brf}(\lambda, t) = f_{iso}(\lambda) + f_{vol}(\lambda)K_{vol}(t) + f_{geo}(\lambda)K_{geo}(t)$$

Where “t” represents the triple of values $(\theta_s, \theta_o, \phi_d)$ (θ_s is solar zenith angle, θ_o is view zenith angle and ϕ_d is the relative azimuth angle between sun and view directions) and λ is waveband. The data provided by the MODIS team are the triple $(f_{iso}(\lambda), f_{vol}(\lambda), f_{geo}(\lambda))$ by band for each time sample and potentially at most of the 500m pixels as indicated by quality flags.

The shape function is defined as:

$$s_{brf}(t) = \rho_{brf}(\lambda, t) / f_{iso}(\lambda) = 1 + \alpha_{vol}K_{vol}(t) + \alpha_{geo}K_{geo}(t)$$

We will use an indicator called “RMS” to measure differences between shapes defined as:

$$RMS = \left(\frac{4}{\pi} \int_0^\pi \int_0^{\pi/2} \int_0^{\pi/2} \cos \theta_s \sin \theta_s \cos \theta_o \sin \theta_o |s_1 - s_2|^2 d\theta_o d\theta_s d\phi_t \right)^{1/2}$$

The RMS was developed to measure the “distance” between two shape functions, indicated by s_1 and s_2 . For a single shape function, the second is taken as the “Lambertian” shape function where $\alpha_{vol} = \alpha_{geo} = 0$. So, RMS becomes the “distance” of the shape function from Lambertian which is a measure of asymmetry.

The present data sets were developed by averaging the complete series of (potentially) 506 samples at 500m pixel resolution for each of the 6 spectral bands over the Australian continent. These were transformed to BRDF shape Parameters and to some Shape Indicators that need not be listed in detail here except for RMS above. A 9-band image was formed from the data set made up from three shape parameters ($\alpha_{vol}, \alpha_{geo}, RMS$) from three spectral bands, RED (0620_0670nm), NIR (0841_0876nm) and SWIR1 (1628_1652nm). The 6 alphas can be selected when the effect of including or leaving out the RMS information is investigated.

One way to explore such an image is to use Principal Component Analysis (PCA) or Minimum Noise Fraction (MNF) transformations. These indicate how many significant independent components exist in the data compared with the nominal dimension (in this case the nominal dimension is 9 if all bands are used or 6 if only the alphas are used). Spatial presentation of the components allows interpretation as land covers or conditions. MNF is, in theory, a “better” tool than PCA in the situation here as the shift difference covariance matrix will be quite a good estimate of the fine scale noise covariance and will also naturally scale the analysis. This is important, as we have combined differently scaled bands into a single image. We also know that many of the bands are correlated and also that the noise is correlated – possibly differently in the various bands and types of parameter. The results will be presented by the images in Google Earth format with a brief discussion to follow.

Images-

There are 5 Tiff images in the presentation. They are:

- 9 Feature MNF Band 1 as a gray scale;
- 9 Feature MNF Bands 2, 3 and 4 as a colour composite;
- 3 Feature MNF Bands 1, 2 and 3 as a colour composite
- 9 Feature MNF Bands 1, 2 and 3 as a colour composite;
- 9 Feature PCA Bands 1, 2 and 3 as a colour composite.

Things to note:

MNF band 1 of the 9 Feature image (the MNF Band 1 grayscale image) dominates the variance of the signal relative to the noise. Its image (the first in the list above) shows a very strong gradient from bright in the centre of the continent to very dark in the mountainous

forests of the rim. This is a gradient of BDRF anisotropy with the deserts being most “Lambertian” and the forest-covered mountains being most “anisotropic”.

An outcome of this work has been to show that a significant component of the variation in RMS is due only to terrain roughness. The hills are anisotropic to a significant degree only through the patterns of shading that they create over the year. For land covers it is useful to normalise this out. That can be done to some degree by leaving Band 1 out and using Bands 2, 3 and 4 so that the colour composite of MNF Bands 2, 3 and 4 represents one main product in this presentation. It is the second image in the list above.

The third image is an MNF component analysis based on the 6 alphas without RMS included. It seems in this case that there are four independent components and the first MNF is also the gradient that is seen in RMS perhaps not as dominating. So that the effect is strong in the data even if you do not underline it. This colour composite represents an interesting contrast with the MNF 234 image. The MNF 234 image shows a lot of “patch” separation but due to missing MNF1 the comparisons between patches in different places may not be as simple. In the third image the same colour in different places is also similarity in shape. That is the MNF 234 represents what is possible and MNF 123 of 6 bands is what is most practical!

Both 9 component analyses show there are only 4 or possibly 5 main independent components in the data with 9 Features. The 6 component case has about 3 independent components. This is consistent with expectations. The other products presented as the second group of images (the fourth and fifth) listed above are PCA using the first three bands and MNF using the first 3 bands. They are provided as contrasts with the MNF discussion above but perhaps they are not as informative. The products are all here for comment and interaction.

Both the composite MNF 2,3,4 of the 9 feature image of alphas and RMS statistics and the MNF 1,2,3 of the 6 feature alphas image are clearly structured image with distinct spatial patterns that are quite different from each other in colour. Colour differences represent significant differences in BRDF shape between patches both spatially and spectrally. The question is whether these distinctions represent land cover differences or represent variations in land cover roughness that are not presently part of land cover taxonomy?

Feedback is welcome.

Contact Information for feedback or troubleshooting:

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If there are any problems with access to or display of the images please contact Matt.Paget@csiro.au

[NOTE: The files provided are Google Earth KMZ files. You will need Google Earth to display them.]