On the Blending of the MODIS and Landsat ETM+ Surface Reflectance

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PURPOSE

The 16-day revisit cycle of Landsat has long limited its use for studying global biophysical processes, which evolve rapidly during the growing season. In cloudy areas of the Earth the problem is compounded, and researchers are fortunate to get 2-3 clear images per year. At the same time, the coarse resolution of sensors such as AVHRR and MODIS limit their ability to quantify biophysical processes in heterogenous landscapes.

This study illustrates our efforts to blend high-frequency temporal information from MODIS and high spatial resolution information from Landsat for applications which require high resolution in both time and space. The MODIS daily 500m surface reflectance and the 16-day repeat cycle Landsat ETM+ 30m surface reflectance are used to produce a synthetic "daily" surface reflectance product at ETM+ spatial resolution.

ALGORITHM

Suppose we have: 1) MODIS surface reflectance $M(x_i,y_j,t_k)$, 2) Landsat surface reflectance $L(x_i,y_j,t_k)$, where k>=1 and k<=n, and 3) MODIS surface reflectance $M(x_i,y_j,t_0)$, then we can predict surface reflectance at time t_0 with

$$L(x_{w/2}, y_{w/2}, t_0) = \sum_{i=1}^{w}\sum_{j=1}^{w}\sum_{k=1}^{n} W_{ijk} * (L(x_i, y_j, t_k) - M(x_i, y_j, t_k) + M(x_i, y_j, t_0))$$

Where w is a search window. Only spectrally similar and cloud free pixels within this window are used as candidates to calculate the final surface reflectance. Weight W_{ijk} is determined by: 1) the spectral distance between MODIS and ETM+ data at the given location; 2) the temporal difference between input and predicted MODIS data and 3) location distance between the predicted pixel and candidate pixel.

If $M(x_i,y_j,t_k) = M(x_i,y_j,t_0)$ then W_{ijk}=maximum and $L(x_{w/2},y_{w/2},t_0) = L(x_i,y_j,t_k)$
=> basic assumption1: if no change in MODIS surface reflectance, then no change in ETM+ surface reflectance
If $L(x_i,y_j,t_k) = M(x_i,y_j,t_k)$ then W_{ijk}=maximum and $L(x_{w/2},y_{w/2},t_0) = M(x_i,y_j,t_0)$
=> basic assumption2: if MODIS and EMT+ surface reflectance are equal at time t_k, then they should be equal at t_0

DATA SOURCES AND STUDY AREAS

A selection of MODIS and Landsat data was acquired for the BOREAS Southern Study Area (54N, 104W), where the growing season is short and phenology changes are extreme. MODIS daily surface reflectance (MOD09GHK) products were acquired for late-May through late-September 2001. Landsat ETM+ images were acquired for four dates during this period: 5/24/2001, 7/11/2001, 8/12/2001, and 9/29/2001. Scene subsets are shown below, using a NIR-Red-Green RGB composite.

PROCESSING

The Landsat ETM+ data were calibrated, precisely geolocated, and atmospherically corrected using the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) at the NASA GSFC. The MODIS daily surface reflectance (MOD09GHK) were reprojected to the UTM projection at the ETM+ spatial resolution. The data blender algorithm accepts multiple inputs of the MODIS and ETM+ data.

DISCUSSION

In general, the data blending algorithm shows good promise for producing image time series that preserve the high spatial resolution of Landsat, and replicate the phenology observed in MODIS. Detailed statistical comparisons are in progress using Landsat data "withheld" from the training. As expected, the synthetic images have lost some spatial resolution relative to the 30m Landsat images, although detailed features (such as roads and shorelines) are still preserved.

Prediction is improved if Landsat imagery is available at the beginning (greenup), middle (maturity), and end (senescence) of the growing season (3 images per year). Thus the Landsat data act as phenology "transition points" that bracket the temporal interpolation.

We are currently expanding the study to focus on instances of land-cover change during the growing season. If changes are "permanent" during the growing season (burn scars, land cover conversion) then the algorithm should be able to record the transition from one state to another. If however changes are transient, and not recorded in any of the bracketing Landsat images (e.g. clouds) then it may not be possible to capture them.