MRLC 2001 IMAGE PREPROCESSING PROCEDURE

The core dataset of the MRLC 2001 database consists of Landsat 7 ETM+ images. Image selection is based on vegetation greenness profiles defined by a multi-year normalized difference vegetation index (NDVI) data set derived from the Advanced Very High Resolution Radiometer (Yang, Homer, and others, 2001). Specifically, the conterminous U.S. is divided into 66 mapping zones. For each mapping zone, the temporal NDVI profiles of major land cover types within that mapping zone are used to define ideal time windows for acquiring images in early, peak and late growing seasons, and three images are acquired for each Landsat path/row. When no reasonably clear and cloud free ETM+ image is available within the ideal time windows, the Landsat 5 image archive is searched for a replacement. This document first details the procedures for preprocessing selected Landsat 7 images for the MRLC 2001 database, most of which are also applied to Landsat 5 images because the TM sensor and the ETM+ sensor are geometrically and radiometrically compatible. Differences between the procedures for preprocessing Landsat 5 and Landsat 7 are discussed in section 8.

1. Document list

The following documents are produced and included in the MRLC 2001 database for each Landsat ETM+/TM image processed:

sceneid_refl_b*i*.tif – band *i* at-satellite reflectance image
sceneid_tc1.tif – at-satellite reflectance based tasseled cap brightness
sceneid_tc2.tif – at-satellite reflectance based tasseled cap greenness
sceneid_tc3.tif – at-satellite reflectance based tasseled cap wetness
sceneid.h1 – NLAPS header file for bands 1 – 5 and 7
sceneid.h2 – NLAPS header file for the thermal band

All image files are byte (8-bit) files. A scene ID (sceneid) contains information on the following items: Landsat number, WRS path and row, year and Julian date, etc.

2. Standard geometric and radiometric corrections

All MRLC 2001 images are geometrically and radiometrically corrected using standard methods at the USGS EROS Data Center (EDC) using the National Landsat Archive Production System (NLAPS). Possible geolocation errors due to terrain effect are corrected using the 1-arc second National Elevation Dataset (NED). Bands 1 to 5 and 7 are resampled to a 30 m spatial resolution using the cubical convolution method. The thermal band has a pixel size of 60 m after being processed using the standard geometric and radiometric correction methods, but is resampled to 30 m to match the pixel size of the spectral bands. The panchromatic band has a pixel size of 15 m. More details on the standard geometric and radiometric correction methods are given at http://edc.usgs.gov/glis/hyper/guide/nlapssys3.html.

3. Image resampling and projection

All MRLC 2001 images have the Albers Conical Equal Area projection with projection parameters defined below:

For conterminous US,

Projection Type:	Albers Conical Equal Area
Spheroid Name:	GRS 1980
Datum Name:	NAD83
Latitude of 1st standard parallel:	29:30:00.00000 N
Latitude of 2nd standard parallel:	45:30:00.00000 N
Longitude of Central Meridian:	96:00:00.00000 W
Latitude of origin of projection:	23:00:00.000000 N
False easting at central meridian:	0.0000000 meters
False northing at origin:	0.0000000 meters

For Alaska,

Projection Type:	Albers Conical Equal Area
Spheroid Name:	WGS 84
Datum Name:	WGS 84
Latitude of 1st standard parallel:	55:00:00.00000 N
Latitude of 2nd standard parallel:	65:00:00.00000 N
Longitude of Central Meridian:	154:00:00.00000 W
Latitude of origin of projection:	50:00:00.000000 N
False easting at central meridian:	0.0000000 meters
False northing at origin:	0.0000000 meters

For Hawaii,

Projection Type:	Albers Conical Equal Area
Spheroid Name:	WGS 84
Datum Name:	WGS 84
Latitude of 1st standard parallel:	08:00:00.00000 N
Latitude of 2nd standard parallel:	18:00:00.00000 N
Longitude of Central Meridian:	157:00:00.00000 W
Latitude of origin of projection:	03:00:00.000000 N
False easting at central meridian:	0.0000000 meters
False northing at origin:	0.0000000 meters

4. Converting DN to at-satellite reflectance

The above standard geometric and radiometric correction results in digital number (DN) images. DN is a measure of at-satellite radiance. To further standardize the impact of illumination geometry, the DN images are converted first to at-satellite radiance and then to at-satellite reflectance using the following equations:

$$L_\lambda = Gain_\lambda \cdot DN_\lambda + Bias_\lambda \quad (1)$$

$$\rho_\lambda = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda \cdot \sin(\theta)} \quad (2)$$

where:

λ	=	ETM+/TM band number
L	=	at-satellite radiance
gain	=	band specific, provided in the header file sceneid.h1
bias	=	band specific, provided in the header file sceneid.h1
ρ	=	at-satellite reflectance, unitless
d	=	Earth-Sun distance in astronomical unit
ESUN	=	Mean solar exoatmospheric irradiance from Table 1
θ	=	Sun elevation angle, provided in the header file sceneid.h1

The Earth-Sun distance can be derived from table 2 or calculated according to Iqbal (1983).

TABLE 1. ETM+ SOLAR SPECTRAL IRRADIANCES

Band	watts/(meter squared * µm)
1	1969.000
2	1840.000
3	1551.000
4	1044.000
5	225.700
7	82.070
8	1368.000

TABLE 2. EARTH-SUN DISTANCE IN ASTRONOMICAL UNIT

Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance
1	.9832	74	.9945	152	1.0140	227	1.0128	305	.9925
15	.9836	91	.9993	166	1.0158	242	1.0092	319	.9892
32	.9853	106	1.0033	182	1.0167	258	1.0057	335	.9860
46	.9878	121	1.0076	196	1.0165	274	1.0011	349	.9843
60	.9909	135	1.0109	213	1.0149	288	.9972	365	.9833

At-satellite reflectance values range from 0 to 1. To save disk space, the values are multiplied by 400 and then truncated to produce 8-bit data. As a result of truncation, reflectance values higher than 0.6375 are set to 0.6375. This should not degrade the data quality significantly for land cover purpose, because most land targets, especially vegetated surfaces, have reflectance values less than 0.6375.

More details on how to convert DN to at-satellite reflectance are provided by Markham and Barker (1986), Irish (2000, at http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_toc.html), and Huang et al. (2002).

5. At-satellite reflectance based tasseled cap transformation

The 8-bit, at-satellite reflectance images (bands 1 to 5 and 7) produced in section 4 are used to calculate tasseled cap brightness, greenness and wetness using the following coefficients:

	band 1	band 2	band 3	band 4	band 5	band 7
brightness:	0.35612057	0.39722874	0.39040367	0.69658643	0.22862755	0.15959082
greenness:	-0.33438846	-0.35444216	-0.45557981	0.69660177	-0.02421353	-0.26298637
wetness:	0.26261884	0.21406704	0.09260517	0.06560172	-0.76286850	-0.53884970

The following equation is used to rescale the tasseled cap values (tc_value) to fit in the 8-bit data range (tc_8bit):

$$tc\_8bit = round[(tc\_value + offset) * 255 / range] \quad (3)$$

Offset and range are defined as follows:

	offset	range
brightness	-20	380

greenness	100	255
wetness	170	320

Most land targets have tasseled cap values between 0 and 255 after being rescaled using (3). Theoretical background of tasseled cap transformation is given by Crist and Cicone (1984). The at-satellite reflectance based coefficients listed above are derived by Huang et al. (2002).

6. Preprocessing of the thermal band

Landsat 7 produces two thermal images, one acquired using a low gain setting (often referred to as band 6L, saturating at 347.5K) and the other using a high gain setting (often referred to as band 6H or band 9, saturating at 322K). Band 6H, or band 9, is used in the MRLC 2001 database because it is more sensitive to most land targets, especially vegetated targets. While the temperature of some land surfaces like desert, sand beach and impervious surface can be higher than 322K (saturation temperature for band 6H), this problem should not be a major concern for most land cover studies, as these targets are relatively easy to discern in Landsat images.

The thermal band is first converted from DN to at-satellite radiance using equation (1), and then to effective at-satellite temperature (T) using the following equation:

$$T = K2 / Ln(K1/L + 1) \qquad (4)$$

where:

T = Effective at-satellite temperature in Kelvin
K2 = Calibration constant 2 from Table 3
K1 = Calibration constant 1 from Table 3
L = Spectral radiance in watts/(meter squared * ster * µm)

Notice the gain and bias values required for equation (1) are provided in the sceneid.h2 file for the thermal band.

Table 3. ETM+ Thermal Band Calibration Constants

	K1 watts/(meter squared * ster * µm)	**K2** Kelvin	**Source**
Landsat 7	666.09	1282.71	Irish (2000)
Landsat 5	607.76	1260.56	Markham and Barker (1986)

The above equations assume unity emissivity and use pre-launch calibration constants.

The temperature image (T_float) is resampled to have a spatial resolution of 30 m, and is rescaled to produce 8-bit data (T_8bit) as follows:

$$T\_8bit = (T\_float - 240) * 3 \quad (5)$$

7. The panchromatic band

The pan band (band 8) is processed using standard geometric and radiometric correction methods described in section 2 to produce DN image. No further processing is performed.

8. Preprocessing Landsat 5 TM image

As are the ETM+ images, Landsat 5 TM images are processed using standard geometric and radiometric correction methods and are corrected for possible geolocation errors due to terrain effect using the 1-arc second NED data set, yielding TM DN images. With the TM sensor and the ETM+ sensor being geometrically and radiometrically compatible, the above Landsat 7 preprocessing procedures (including converting DN to at-satellite reflectance and tasseled cap transformation) are also applied to Landsat 5 TM images. To take advantage of the superior radiometric calibration of ETM+, however, TM DN (DN5) is first converted to ETM+ DN (DN7) using the following equation:

$$DN7 = DN5 \times slope + intercept \quad (6)$$

where the slope and intercept values are as follows according to Vogelmann et al. (2001):

Band #	Slope	Intercept
1	0.9398	4.2934
2	1.7731	4.7289
3	1.5348	3.9796
4	1.4239	7.032
5	0.9828	7.0185
7	1.3017	7.6568

Using the following set of gain and bias values, the derived image is then treated as an ETM+ DN image in calculating at-satellite reflectance and tasseled cap transformation:

Band#	gain	bias
1	0.7756863	-6.1999969

2	0.7956862	-6.3999939
3	0.6192157	-5.0000000
4	0.6372549	-5.1000061
5	0.1257255	-0.9999981
7	0.0437255	-0.3500004

While the equations for converting the thermal band DN to at-satellite temperature and then rescaling the image to produce 8-bit data are the same as those for ETM+ images, the gain and bias values are provided in the sceneid.h1 header file, and the constants K1 and K2 are provided in table 3. The two constants were derived by Markham and Barker (1986). However, the unit used in Markham and Barker (1986) for K1 is different from that used in processing current Landsat 5 data. As a result, K1's value as listed in table 3 is 10 times of that provided by Markham and Barker (1986). The at-satellite temperature image is resampled from the original 120 m resolution to 30 m.

All Landsat 5 TM image products are rescaled to produce 8-bit data the same ways ETM+ image products are generated.

9. Contact information

For further information, please contact:

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10. References

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