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eMODIS: A User-Friendly Data Source

Open-File Report 2010–1055

U.S. Department of the Interior
U.S. Geological Survey

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By Calli Jenkerson, Thomas Maiersperger, and Gail Schmidt

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Inch/Pound to International System of Units (SI)

Multiply	By	To obtain
	Length	
inch	2.54	centimeter (cm)
inch	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)

Vertical coordinate information is referenced to the World Geodetic System 1984 (WGS 84).

Horizontal coordinate information is referenced to the World Geodetic System 1984 (WGS 84).

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)

Vertical coordinate information is referenced to the World Geodetic System 1984 (WGS 84).

Horizontal coordinate information is referenced to the World Geodetic System 1984 (WGS 84).

Abbreviations and Acronyms

ASCII	American Standard Code for Information Interchange
AVHRR	Advanced Very High Resolution Radiometer
CM	Centimeter
CONUS	Continental United States
DBS	Direct Broadcast System
DD	Decimal Degrees
DOY	Day of Year
EOS	Earth Observing System
EROS	Earth Resources Observation and Science
FOV	Field of View
FT	Foot
FTP	File Transfer Protocol
GeoTIFF	Georeferenced Tagged Image File Format
HDF-EOS	Hierarchical Data Format for EOS
KB	Kilobyte
KM	Kilometer
LAADS	Level-1 and Atmospheres Archive and Distribution System
LAEA	Lambert Azimuthal Equal Area
M	Meter
MB	Megabyte
MI	Mile
MM	Millimeter
MODAPS	MODIS Adaptive Processing System
MODIS	Moderate Resolution Imaging Spectroradiometer
MODLAND	MODIS Land Discipline Team
MVC	Maximum Value Composite
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NM	Nanometer
NMI	Mile, Nautical
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
PGE	Product Generation Executable

QA	Quality Assessment
SI	International System of Units
USGS	U.S. Geological Survey
VI	Vegetation Index
WGS	World Geodetic System
YD	Yard

eMODIS: A User-Friendly Data Source

By Calli Jenkerson,[1] Thomas Maiersperger,[2] and Gail Schmidt[3]

Introduction

The U.S. Geological Survey's (USGS) Earth Resources Observation and Science (EROS) Center is generating a suite of products called "eMODIS" based on Moderate Resolution Imaging Spectroradiometer (MODIS) data acquired by the National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS). With a more frequent repeat cycle than Landsat and higher spatial resolutions than the Advanced Very High Resolution Spectroradiometer (AVHRR), MODIS is well suited for vegetation studies. For operational monitoring, however, the benefits of MODIS are counteracted by usability issues with the standard map projection, file format, composite interval, high-latitude "bow-tie" effects, and production latency. eMODIS responds to a community-specific need for alternatively packaged MODIS data, addressing each of these factors for real-time monitoring and historical trend analysis.

eMODIS processes calibrated radiance data (level-1B) acquired by the MODIS sensors on the EOS Terra and Aqua satellites by combining MODIS Land Science Collection 5 Atmospherically Corrected Surface Reflectance production code and USGS EROS MODIS Direct Broadcast System (DBS) software to create surface reflectance and Normalized Difference Vegetation Index (NDVI) products. eMODIS is produced over the continental United States and over Alaska extending into Canada to cover the Yukon River Basin. The 250-meter (m), 500-m, and 1,000-m products are delivered in Geostationary Earth Orbit Tagged Image File Format (GeoTIFF) and composited in 7-day intervals. eMODIS composites are projected to non-Sinusoidal mapping grids that best suit the geography in their areas of application (see *eMODIS Product Description* below).

For eMODIS products generated over the continental United States (eMODIS CONUS), the Terra (from 2000) and Aqua (from 2002) records are available and continue through present time. eMODIS CONUS also is generated in an expedited process that delivers a 7-day rolling composite, created daily with the most recent 7 days of acquisition, to users monitoring real-time vegetation conditions. eMODIS Alaska is not part of expedited processing, but does cover the Terra mission life (2000–present). A simple file transfer protocol (FTP) distribution site currently is enabled on the Internet for direct download of eMODIS products (*ftp://emodisftp.cr.usgs.gov/eMODIS*), with plans to expand into an interactive portal environment.

eMODIS Rationale

Background

NASA–EOS MODIS products provide NDVI and surface reflectance data with a more frequent overpass than Landsat and at higher spatial resolution than AVHRR. Vegetation monitoring studies benefit from these features, and the land science community has engaged MODIS data since its release in 2000 to enhance the accuracy of existing tools and to facilitate a link with the AVHRR record.

Despite the benefits of MODIS products, real-time applications were immediately challenged with making those products directly useful because of difficulties with reprojection, format conversion, mosaicking, and subsetting. Within the EROS science community, some users turned to the USGS EROS MODIS DBS to generate more user-friendly products and developed a reliance on them as input to their monitoring activities. When the USGS discontinued the EROS MODIS DBS in 2006, users pursued alternative data sources and solicited the USGS Land Remote Sensing Program for a prototype eMODIS system. "eMODIS" thus represents "enhanced," "expedited," and "expandable" MODIS data from EROS.

Requirements

The initial production design for eMODIS was based on prototyping a replacement for the EROS MODIS DBS. Table 1 outlines the conceptualized similarities and differences between eMODIS and its parent DBS specifications.

[1]ADNET Systems, Inc., contractor to the U.S. Geological Survey Earth Resources Observation and Science Center, Sioux Falls, S. Dak, work performed under contract 08HQCN0005.

[2]Stinger Ghaffarian Technologies (SGT), contractor to the U.S. Geological Survey Earth Resources Observation and Science Center, Sioux Falls, S. Dak., work performed under contract 08HQCN0005.

[3]Science Applications International Corporation (SAIC).

Table 1. Specifications comparison between eMODIS and U.S. Geological Survey Earth Resources Observation and Science Center Moderate Resolution Imaging Spectroradiometer Direct Broadcast System.

[MODIS, Moderate Resolution Imaging Spectroradiometer; EROS, Earth Resources Observation and Science; DBS, Direct Broadcast System; NOAA, National Oceanic and Atmospheric Administration; NRT, Near Real Time; GDAS_OZF, Global Data Assimilation System Ozone; OZONEEP, Total Ozone Mapping Spectrometer Column Ozone Earth Probe; NISE, National Snow and Ice Data Center, Near Real Time Global Ice and Snow Extent; SEA_ICE, National Centers for Environmental Prediction Ice Concentration; REYNSST, Reynolds Weekly Sea Surface Temperature from National Oceanic and Atmospheric Administration, National Centers for Environmental Prediction; GBLAV, Global Operational Aviation Analyses and Forecasts; avn_ozone, Aviation Run Total Ozone; PGE, Product Generation Executable; NDVI, Normalized Difference Vegetation Index; CONUS, Continental United States; ~, approximately; LAEA/GeoTIFF, Lambert Azimuthal Equal Area/Geostationary Earth Orbit Tagged Image File Format]

	eMODIS	EROS Center MODIS DBS (end April 2006)
Data source	NOAA NRT system	EROS antennae
Instruments	Terra and Aqua MODIS	Terra and Aqua MODIS
Ingested processing level	Level 1B Swath	Level 0 Swath
Ancillary inputs	GDAS_OZF (OZONEEP), NISE, SEA_ICE, REYNSST	GBLAV, avn_ozone, NISE, SEA_ICE
Algorithms	Collection 5 MODIS PGE 03, PGE 11	Collection 4 MODIS PGE 03, PGE 11
Output layers	NDVI, Surface Reflectance Bands, Quality, Acquisition Date	NDVI, Surface Reflectance Bands, Quality, Acquisition Date
Geographic extent	CONUS	CONUS
Product latency	~1 day after last input	~1 day after last input
Composite schedule	Daily rolling 7-day	Daily rolling 7-day
Output projection/format	LAEA/GeoTIFF	LAEA/GeoTIFF
Archive capability	Yes	No
Historic reprocessing capability	Yes	No

The USGS collaborated with the NASA EOS Project to complete a prototype eMODIS system. In December 2007, a system was in place to accomplish the following:

- Ingest real-time MODIS L1B data over continental United States from National Oceanic and Atmospheric Administration's (NOAA) Near Real Time (NRT) system.
- Archive ancillary and intermediate products needed for processing expedited data.
- Use the latest (May 2007) Collection 5 Product Generation Executable (PGE) 11 code and recycled EROS MODIS DBS code to process L1B files into surface reflectance and NDVI composites.
- Provide expedited 7-day rolling composites over continental United States at 250-m, 500-m, and 1,000-m resolutions, Lambert Azimuthal Equal Area (LAEA) projection, GeoTIFF format.
- Distribute from a nominal 30-day archive hosted from a direct FTP access Internet site.

Data validation was included in the prototype activity to verify the general consistency of processing artifacts, geolocation, data quality, and data accuracy. The evaluation is summarized in the unpublished eMODIS "readme" file distributed from the FTP site and describes satisfactory production output (*ftp://emodisftp.cr.usgs.gov/eMODIS/CONUS/)*.

The success of the prototype effort prompted the addition of historical production to the eMODIS system. Enhancements for historical production include the use of a definitive source for precision L1B inputs, the use of EROS AVHRR weeks to describe a 7-day interval (*http://ivm.cr.usgs.gov/links.php*), and permanent retention of the products. Both expedited and historical processing have been supported over the continental United States since January 2008, and coverage over Alaska (including that portion of the Yukon River Basin extending into Canada) was added later that year. The core product requirements are listed in table 2. Because eMODIS is designed as an extensible system, augmentations satisfying future temporal, geographic, or geophysical requirements will be easily integrated.

Table 2. eMODIS requirements.

[CONUS, Continental United States; ~, approximately; <, less than; MODIS, Moderate Resolution Imaging Spectroradiometer; LAEA/GeoTIFF, Lambert Azimuthal Equal Area/ Geostationary Earth Orbit Tagged Image File Format; m, meter; NDVI, Normalized Difference Vegetation Index; Advanced Very High Resolution Radiometer; AVHRR]

	Expedited	Historical CONUS	Historical Alaska
Timeliness	~1 day after last input	<30 days after last input	<30 days after last input
Temporal extent	Current week	2000 – present	February – October 2000 – present
Instruments	MODIS	Terra and Aqua MODIS	Terra MODIS
Geographic extent	CONUS	CONUS	Alaska including Yukon River Basin, excluding Aleutian Islands
Projection/Format	LAEA/GeoTIFF	LAEA/GeoTIFF	Alaska Albers Equal Area/GeoTIFF
Spatial resolution	250-m, 500-m, 1,000-m	250-m, 500-m, 1,000-m	250-m, 500-m, 1,000-m
Layers	NDVI, Surface Reflectance Bands, Quality, Date	NDVI, Surface Reflectance Bands, Quality, Date	NDVI, Surface Reflectance Bands, Quality, Date
Composite period	7-day rolling	7-day interval according to AVHRR calendar	7-day interval starting January 1
Archive persistence	30 days	Long term	Long term

eMODIS Product Description

The eMODIS suite of products includes eMODIS CONUS and eMODIS Alaska. eMODIS enhancements for both include distribution of 7-day composites as GeoTIFFs, rejection of pixels on the east and west edges of a swath to mitigate the "bow-tie" effect, and use of a snow filter to tag snowy pixels when no other pixels are available. Each dataset includes reflectance, acquisition, quality, and NDVI information at 250-m, 500-m, and 1,000-m spatial resolutions.

The historically produced data over the continental United States are composited within a 7-day interval matching the historical EROS AVHRR compositing scheme. Expedited production runs daily, using the last 7 days of acquisitions as input to the composites. The products, generated independently for both Terra and Aqua MODIS, are projected to a LAEA sphere. Figure 1 shows examples of the eMODIS CONUS product.

eMODIS Alaska products are composited over 7-day weeks, defined from January 1, but are produced only during the growing season (February–October). There is no expedited production in Alaska. The composites represent the entire geographic region on the Alaska Albers Equal Area mapping grid and are produced only for Terra. An additional enhancement specific to eMODIS Alaska is the implementation of a sun angle threshold (83º). Figure 2 shows examples of the eMODIS Alaska product.

Both eMODIS CONUS and eMODIS Alaska distribute the following files:

- NDVI (band 2 – band 1 / band 2 + band 1)
- Atmospherically corrected surface reflectance
  - Band 1 (620–670 nanometer (nm)) red
  - Band 2 (841–876 nm) near infrared
  - Band 3 (459–479 nm)
  - Band 4 (545–565 nm)
  - Band 5 (1,230–1,250 nm)
  - Band 6 (1,628–1,652 nm)
  - Band 7 (2,105–2,155 nm)
- Quality of reflectance and NDVI
- Day of acquisition
- Metadata

Native spatial resolution for the reflectance bands is 250-m in bands 1 and 2 and 500-m in bands 3-7. All bands are aggregated accordingly for the eMODIS 500-m and 1,000-m products; that is, bands 1 and 2 are resampled to 500-m in the 500-m product, and all bands are resampled to 1,000-m in

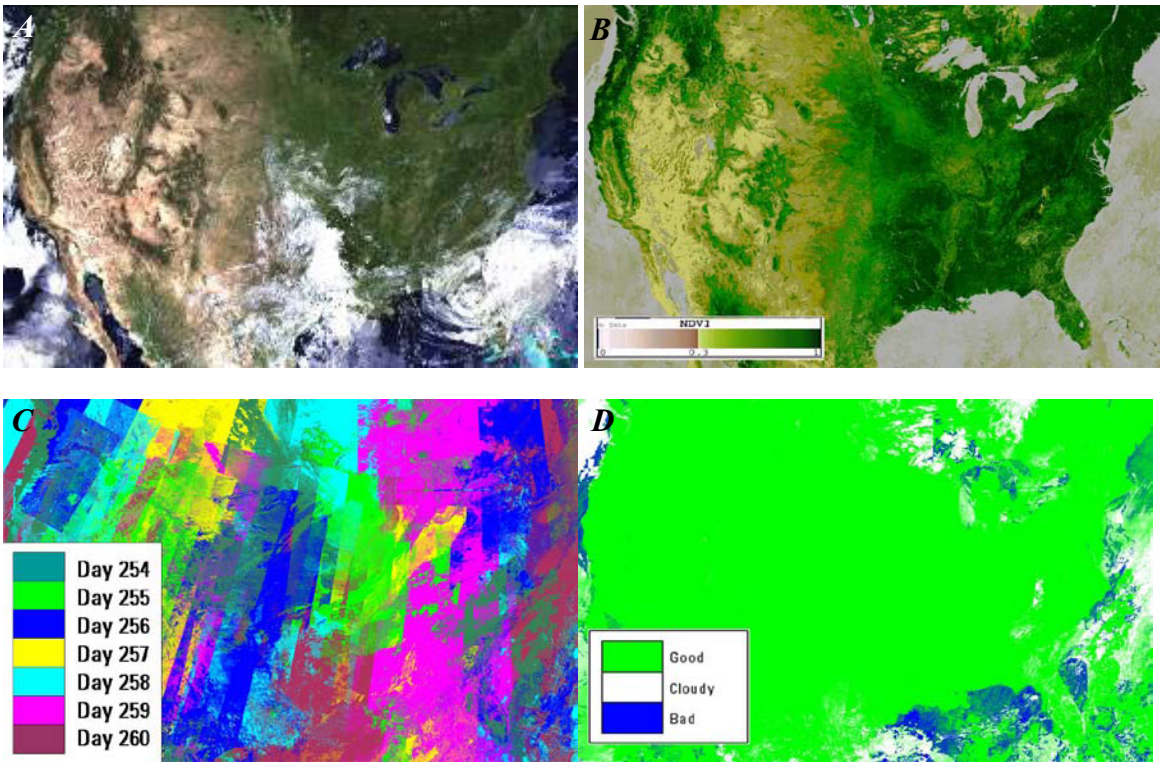

Figure 1. Samples of the eMODIS product suite. *A*, RGB image created with Bands 1, 4, and 3 from 500-meter data acquired August 15–21, 2008, showing Hurricane Fay moving into the southeast United States. *B*, False-colored 250-meter Normalized Difference Vegetation Index calculated with data from September 11–17, 2007. *C*, Corresponding images for the same interval in 2007 depicting per-pixel day of acquisition. *D*, Corresponding images for the same interval in 2007 depicting per-pixel quality.

the 1,000-m product. The 250-m product, however, includes only bands 1 and 2 as original 250-m pixels. Table 3 contains the image dimensions for each product, and the geographic dimensions of the composites are defined in table 4 with the output map projection parameters for CONUS and Alaska respectively. Center of pixel is exclusive to spatial resolution, so coordinates may vary slightly between the 250-m, 500-m, and 1,000-m lower right corners.

In contrast to the NASA-EOS MODIS Vegetation Indices (VI) that layer VI, reflectance, and quality information in a single Hierarchical Data Format for Earth Observing Systems (HDF-EOS) file, eMODIS provides separate GeoTIFF files for each product in a 7-day interval, allowing the users to download only the files they need. The NDVI and every reflectance band have five associated files: data, quality, metadata, acquisitions image, and an acquisitions table (see *eMODIS Product Generation, Acquisition Files* below). Consequently, 45 files can be expected per 500-m and 1,000-m data set whereas the 250-m product will have only 20. All associated files (GeoTIFFs, ".met," and ".txt") are packaged into a ".zip" file which is coupled with a checksum (".sum.") for distribution. There is one zip file and one checksum for NDVI and a separate zip and checksum for reflectance. The average volume for each zip is shown in table 5.

A typical dataset includes the products listed below compressed into two zip files, the contents of which are stated in table 6. File volumes and further specifications are detailed in tables 7 and 8.

The NDVI data are specified with a valid range "-1,999 – 10,000." The value "-1,999" is assigned to any VI computation between "-1,998" and "-10,000." VI computations between "-1" and "-1,997" are assigned face value. When surface reflectance input pixels contain negative or fill values, the pixel will have a "-2,000" for NDVI and a corresponding "10" in the band quality layer.

Table 3. Seven-day composite image dimensions.

[MODIS, Moderate Resolution Imaging Spectroradiometer; CONUS, Continental United States; m, meter]

Product	eMODIS CONUS X (samples)	eMODIS CONUS Y (lines)	eMODIS Alaska X (samples)	eMODIS Alaska Y (lines)
250-m	18,348	11,556	9,322	7,064
500-m	9,174	5,778	4,661	3,532
1,000-m	4,587	2,889	2,330	1,766

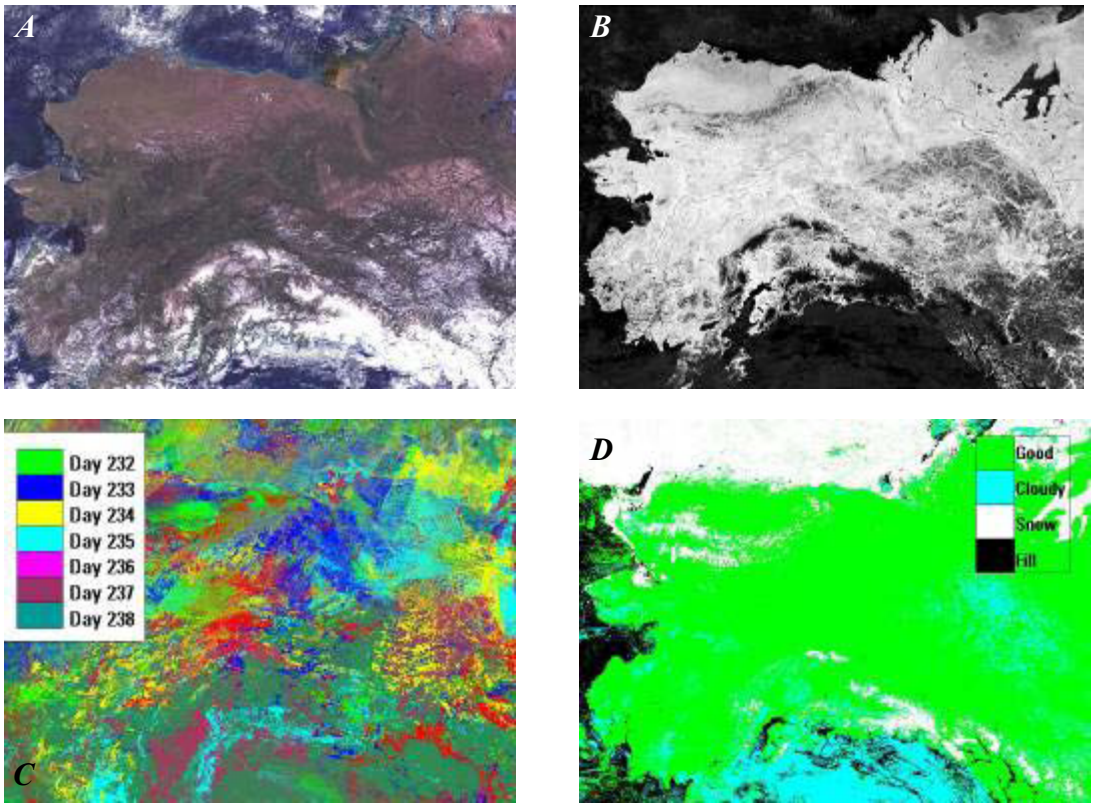

Figure 2. Samples of the eMODIS Alaska product suite. *A*, RGB image created with Bands 1, 4, and 3 from 500-meter data acquired from August 20–26, 2007. *B*, Grey-scaled 250-meter Normalized Difference Vegetation Index calculated with data from the same interval. *C*, Corresponding images for the same interval depicting per-pixel day of acquisition. *D*, An example from June 11–17, 2003, depicting per-pixel quality.

Table 4. Seven-day composite mapping grid parameters.

[MODIS, Moderate Resolution Imaging Spectroradiometer; CONUS, Continental United States; LAEA, Lambert Azimuthal Equal Area; WGS, World Geodetic System; DD, Decimal Degrees; NA, not applicable; Lat, latitude; Lon, longitude]

	eMODIS CONUS	eMODIS Alaska
Projection	LAEA	Alaska Albers Equal Area
Sphere/Datum	6370997.00 (Sphere 19)	WGS 84
Central Longitude/Meridian DD	-100.00	-154.0000000
Central Latitude/Latitude of Origin DD	45.00	50.0000000
Standard Parallel 1 DD	NA	55.0000000
Standard Parallel 2 DD	NA	65.0000000
Semimajor Axis	NA	6378137
Semiminor Axis	NA	6356752.31
*Upper Left Lat,Lon DD (center of pixel)	48.4030555, -128.5300591	72.0000000, -173.0000000
*Lower Right Lat,Lon DD (center of pixel)	22.4793919, -75.4163527	54.0029556, -128.9981667
*Upper Left Output X,Y (center of pixel)	-2050500, 752500	2538877.50, -666333.75
*Lower Right Output X,Y (center of pixel)	2536500, -2136500	773127.50, 1663916.25

*Coordinates apply to 500-meter and 1,000-meter composites. Because of center of pixel designation, 250-meter coordinates will vary slightly from these reported.

Table 5. Seven-day composite zip file volumes in megabytes.

[CONUS, Continental United States; NDVI, Normalized Difference Vegetation Index; MB, megabyte; m, meter]

Product	eMODIS CONUS NDVI ZIP (MB)	eMODIS CONUS REFLECTANCE ZIP (MB)	eMODIS Alaska NDVI ZIP (MB)	eMODIS Alaska REFLECTANCE ZIP (MB)
250-m	352.9	715.6	112.4	237.1
500-m	89.7	634.6	28.9	211.1
1,000-m	22.9	161.9	6.6	53.9

Table 6. Seven-day composite zip file contents.

[m, meter; NDVI, Normalized Difference Vegetation Index]

Filename	Description
composite500m_AQUA_NDVI_2005_7.zip	
500m_composite_ndvi.tif	NDVI data
500m_composite_ndvi_bq.tif	NDVI data quality
500m_composite_ndvi.met	NDVI data metadata
500m_composite_ndvi_acq.tif	NDVI data acquisitions image
500m_composite_ndvi_acq_table.txt	NDVI data acquisitions table
composite500m_AQUA_REFL_2005_7.zip	
500m_composite_b*.tif	reflectance data
500m_composite_b*_bq.tif	reflectance data quality
500m_composite_b*.met	reflectance data metadata
500m_composite_b*_acq.tif	reflectance data acquisitions image
500m_composite_b*_acq_table.txt	reflectance data acquisitions table
*Repeated per band (1–7)	all of the above

Table 7. Seven-day composite output file volumes in megabytes.

[m, meter; MB, megabyte; CONUS, Continental United States; NDVI, Normalized Difference Vegetation Index; KB, kilobyte]

File	250-m Average (MB)		500-m Average (MB)		1,000-m Average (MB)	
	eMODIS CONUS	eMODIS Alaska	eMODIS CONUS	eMODIS Alaska	eMODIS CONUS	eMODIS Alaska
Reflectance bands 1–7	405	126	101	32	25	8
NDVI	405	126	101	32	25	8
Quality	202	63	51	16	13	4
Acquisitions image	405	126	101	32	25	8
Acquisitions table	.004	.02	.004	.02	.004	.02
Metadata	.003	3 KB	.003	3 KB	.003	3 KB

Table 8. Seven-day composite output file specifications.

[NDVI, Normalized Difference Vegetation Index; NA, not applicable; ASCII, American Standard Code for Information Interchange]

File	Data type	Valid range	Fill value	Scale factor
Reflectance bands 1–7	16-bit signed integer	-100 – 16,000	-28,672	0.0001
NDVI	16-bit signed integer	-1,999 – 10,000	-2,000	.0001
Quality	8-bit unsigned integer	0 – good 1 – cloudy 2 – bad band quality 3 – negative reflectance 4 – snow 10 – fill	10	NA
Acquisitions image	16-bit unsigned integer	101 – 36699	NA	NA
Acquisitions table	Delimited text	101 – 36699	NA	NA
Metadata	ASCII	NA	NA	NA

eMODIS Product Generation

The eMODIS 7-day composites are produced with a combination of the software used to create standard NASA-EOS MODIS products and software from the former EROS MODIS DBS. Collection 5 MODIS code acquired from MODIS Adaptive Processing System (MODAPS) Services Software Distribution (*http://modaps.nascom.nasa.gov:9500/*) is implemented as the eMODIS "house" algorithm. It is used to generate atmospherically corrected level-2 surface reflectance swaths, from which USGS EROS MODIS DBS software processes the final composites. The input level-1B data are downloaded from the Level 1 and Atmosphere Archive and Distribution System (LAADS) into historical processing, whereas expedited production uses data from the NOAA NRT system.

The compositing process begins with all level-2 surface reflectance swaths relevant to the CONUS or Alaska extent. The first step strips the outer 150,000-m of data from the east and west borders of the level-2 surface reflectance data in order to remove the pixels located at a distance from nadir that is likely to cause a "bow-tie effect." Next, the algorithm grids the needed swath products (stripped surface reflectance, geolocation, and cloud mask) within the mapping coordinates listed in table 4.

A simple NDVI calculation achieved by using band 1 (red) and band 2 (near infrared) is then made for each gridded surface reflectance file. The resulting gridded NDVI files, representing all available coverage, are fed into an enhanced maximum value composite (MVC) algorithm. A traditional MVC would be populated by using the highest NDVI chosen from all available values for a pixel in the 7-day period. For the eMODIS composites, the MVC algorithm is modified to incorporate band quality, negative surface reflectance, cloud mask, snow cover, view angle, and for Alaska, sun angle, as described in the section on *Composite Selection Process*.

The MVC outputs finally are stitched together by an EROS MODIS DBS compositing process to create the eMODIS 7-day NDVI composites. The surface reflectance and acquisitions composites are put together by using the pixels selected as MVC input.

Composite Selection Process

The pixels populating the final eMODIS product are selected through an enhanced MVC algorithm by using a five-step (CONUS) or six-step (Alaska) process to filter through input surface reflectance with bad quality, negative values, clouds, snow cover, low view angles, or low sun angles (Alaska).

1. The band quality information in the level-2 surface reflectance data are used to determine if a certain pixel is of "bad quality." The standard MODIS Land Science Team (MODLAND) Quality Assessment (QA) bits are carried into the production of the 250-m, 500-m, and 1,000-m surface reflectance data. Bad or less than ideal quality surface reflectance pixels are not used in eMODIS production, leaving pixels with QA values of "00" as the only input candidates.

MODLAND QA bits 0–1	
corrected product produced at	00—ideal quality all bands
	01—less than ideal quality some or all bands
corrected product not produced due to	10—cloud effects all bands
	11—other reasons some or all bands may be fill value. [Note that a value of (11) overrides a value of (01)]

2. Pixels with negative surface reflectance values are immediately flagged to exclude them as potential input to the gridded NDVI files, unless there are no positive values available. In the rare case that a negative surface reflectance value is retained, the resulting gridded NDVI value is flagged as "-3,000" so that the pixel for that day in the period will be ignored in the MVC process.

3. CONUS processing continues with the next step, but at this point, eMODIS Alaska extracts the solar zenith angle from the 1,000-m geolocation product and resamples it for the 250-m and 500-m products. Any pixels acquired at sun angles greater than 83º are eliminated as composite candidates.

4. The level-2 cloud mask product is used to minimize the overall presence of cloudy pixels in the production stream. Data from the first byte (band) in the cloud mask are used for cloud assessment. If bit 0 (see below) is "not determined," then the associated pixel is treated as cloudy. If bit 0 is "determined" and bits 1-2 indicate a "cloudy" pixel, the pixel is excluded unless there are no suitable pixels available in the 7-day record and data for the pixel were from the most recent acquisition (see *Quality Assignment*)

   If bit 0 is "determined" and bits 1-2 indicate "probably clear" or "confident clear," then the corresponding surface reflectance pixel is eligible in the MVC process. The following bit interepretation legend includes information on the field of view (FOV).

Bit field	Description	Key
0	Cloud Mask Flag	0 = Not determined
		1 = Determined
2, 1	Unobstructed FOV Quality Flag	00 = Cloudy
		01 = Uncertain
		10 = Probably Clear
		11 = Confident Clear

5. At this point in the filtering process, the two highest NDVI values in the remaining ideal-quality, nonnegative, noncloudy pixels are checked for snow cover, which is read from the first byte in the level-2 cloud mask product.

Bit field	Description	Key
5	Snow Flag	0 = Snow/Ice
		1 = No Snow/Ice

   If one of the two highest NDVI values is flagged as snowy, it is eliminated from the selection process, and the single remaining pixel is used in the final composite. If neither or both values are snowy, the pixels are finally examined for their position from nadir.

6. The view angle (distance from nadir) finally determines which gridded NDVI pixel is used in the composite. The sensor zenith angle taken from the 1,000-m geolocation product is used to determine the view angle and is resampled for the 250-m and 500-m products. The two highest NDVI values in the remaining ideal-quality, nonnegative, noncloudy, nonsnowy pixels are assessed for their position from nadir by using the geolocation information. Whichever of these two pixels is closest to nadir will be used to populate the final composite.

NOTE: It is possible for off-nadir pixels to be selected for the composite since in some cases the off-nadir pixels may have a higher NDVI than those closer to nadir.

The composite resulting from the MVC process is then stitched inside CONUS or Alaska space to provide the eMODIS 7-day composites.

Quality Assignment

A quality file is produced by the eMODIS software to track each pixel in the composite. The highest quality pixels are filtered through the *Composite Selection Process*, but there can be situations when no good quality surface reflectance values were acquired for a particular pixel. The best available pixel is always preferred for the final composite but in cases when the "best" is snowy, cloudy, or negative, the accompanying QA product will describe its condition. In the worst case, in which all available pixels have negative surface reflectance, are cloudy, snow-covered, and at unacceptable view or sun angles, MVC will use the most recently acquired pixel that does not carry an original fill value (-28,672).

The following values are used in the QA band:

0 = good quality
1 = cloudy pixel
2 = bad band quality
3 = negative surface reflectance
4 = snow
10 = fill

Acquisition Files

Because the composites are created from up to 56 files for CONUS and well over 100 files for Alaska, the eMODIS products include acquisitions files to identify which of the possible inputs were used to populate the final composite. As stated in the section on *eMODIS Product Characteristics*, there is a composite image of dates (acq.tif), as well as an American Standard Code for Information Interchange (ASCII) file (acq.txt), listing the dates for each pixel. The acquisitions image and acquisitions table contain the same information in different formats. The original acquisition used in the composite production is identified in an integer formatted as "DOY AQ."

Day of year is "DOY," and "AQ" is the acquisition number, which in this case represents the order of capture rather than the time of acquisition and is one-based. For example, an acquisitions value of "11702" identifies the second capture (02) from April 27 (117) as the input selected for the composite. Likewise, an acquisition value of "1001" represents day 10 (January 10), first capture.

Metadata Files

The metadata accompanying the data files summarize geographic bounds, projection parameters, and product contact information.

eMODIS Product Delivery

eMODIS NDVI and reflectance zip files are delivered immediately after production to a direct access FTP site, along with calculated checksum files for each zip. Users navigate a simple directory tree to download eMODIS output.

ftp://emodisftp.cr.usgs.gov/eMODIS
<extent>/
<productionstream>/
<SENSOR>/
<year>/
comp_<endday>/
composite<resolution>m_<SENSOR>_NDVI_<year>_<endday>.zip
composite<resolution>m_<SENSOR>_REFL_<year>_<endday>.zip

where <extent> is "CONUS" or "Alaska"

<productionstream>	is "expedited" or "historical"
<SENSOR>	is "AQUA" or "TERRA"
<year>	is acquisition year, e.g., 2005
<endday>	is the Julian date for the last day of a 7-day interval
<resolution>	is "250," "500," or "1000"

For example, ftp://emodisftp.cr.usgs.gov/eMODIS/CONUS/expedited/TERRA/2008/comp_249/

09/05/2008 06:31PM 23,300,786	composite1000m_TERRA_NDVI_2008_249.zip
09/05/2008 06:31PM 159,691,723	composite1000m_TERRA_REFL_2008_249.zip
09/06/2008 12:40AM 360,246,011	composite250m_TERRA_NDVI_2008_249.zip
09/06/2008 12:38AM 709,872,934	composite250m_TERRA_REFL_2008_249.zip
09/05/2008 08:41PM 91,472,635	composite500m_TERRA_NDVI_2008_249.zip
09/05/2008 08:40PM 629,760,762	composite500m_TERRA_REFL_2008_249.zip

In the expedited production stream, the output zip files are delivered within 24 hours of the last input acquisition. Note in the directory listing above that the files for the 7-day interval ending on Julian day 2008249 (September 5, 2008) completed production by 12:40AM the next day (September 6).

Production in the historical stream generally is well within 30 days of the last input acquisition for current data and is dependent on the availability of well-defined ancillary data, including spacecraft location and climatology. Historical production for the Terra mission has been completed over the continental United States and Alaska from February 2000 to the present, and for the Aqua mission, over the continental United States from July 2002 to the present. Production continues with the current MODIS record.

The eMODIS FTP site provides very basic access to the product suite. The user community has requirements to enhance this delivery vehicle in order to maximize the applications-ready appeal of the products. Development is underway to provide an attractive and intuitive Web interface through which interactive services will be used to visualize, subset, and reformat eMODIS data if desired. This capability will add flexibility to the eMODIS products, expanding their relevance in the user community.

eMODIS Product Validation

A full scale validation of eMODIS was planned in 2009, with subsequent publications expected. A general characterization of data consistency in terms of processing artifacts, geolocation, data quality, and data accuracy accompanies the "readme" documents on the eMODIS FTP site (*ftp://emodisftp.cr.usgs.gov/eMODIS*). Requests for further information and publication references may be directed to the author (see *eMODIS Contact Information*).

eMODIS Contact Information

Calli Jenkerson
jenkerson@usgs.gov
(605) 594-2638

Selected References

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(605) 594-6151

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