Existing Satellite Land Data Products

a non-comprehensive review

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Introduction

We want to look at some existing satellite land products to highlight issues for HyspIRI products

- How do data products relate to each other?
- How are data organized spatially?
- How are data grouped temporally?
- What are approaches are used to calculate data products?
- How are data distributed?

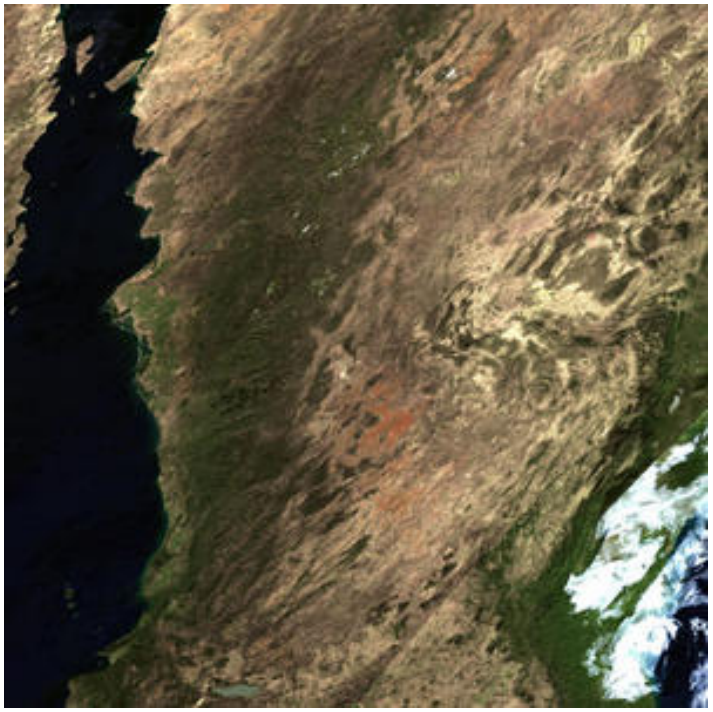
Overview of MODIS Processing Levels

- Level 0 data - raw satellite feeds
- Level 1 data - radiometrically calibrated, but not otherwise altered
- Level 2 data - atmospherically corrected to yield a surface reflectance product
- Level 3 data - level 2 data gridded into a map projection
  - usually have also been temporally composited or averaged
  - The advantage of level 3 data is that each pixel of L3 data is precisely geolocated
  - a disadvantage is that the process of compositing may compromise data
- Level 4 data - products that have been put through additional processing

MODIS Surface Reflectance

The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmospheric scattering or absorption.

- level-2 and -3 data
- gridded 250 m (Bands 1 & 2), 500 m, 5600 m (climate grid)
- Daily, 8-day
- Utilizes 6S atmosphere radiative transfer model



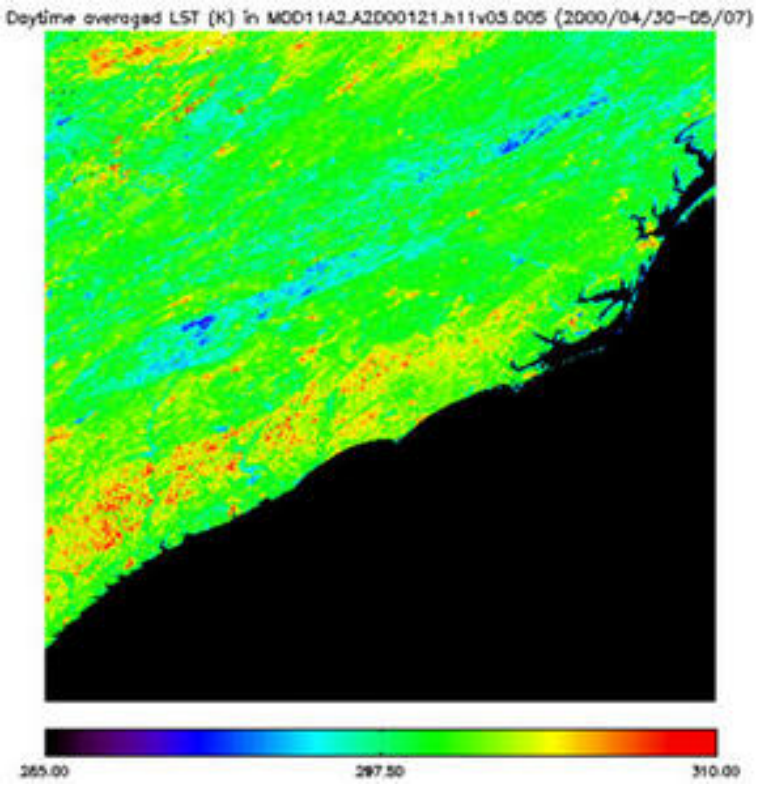
A combination of Bands 1, 4, 3 displays an R, G, B Surface Reflectance image using 500-m data acquired between January 1 - 8, 2007 over much of Mexico (h08v06), giving a clear view of the pine-oak forests defining the Sierra Madre Occidental in the west, across the altiplano region occupying much of the Mexican interior.

https://lpdaac.usgs.gov/products/modis_products_table/surface_reflectance/8_day_l3_global_500m/mod09a1

MODIS Land Surface Temperature & Emissivity

The MODIS Land Surface Temperature and Emissivity (LST/E) products provide per-pixel temperature and emissivity values

- level-2 and -3 data
- gridded 1000 m, 6000 m, 5600 m (climate grid)
- Daily, 8-day, monthly
- Utilizes generalized split-window algorithm at 1 km and day/night algorithm at 6 km



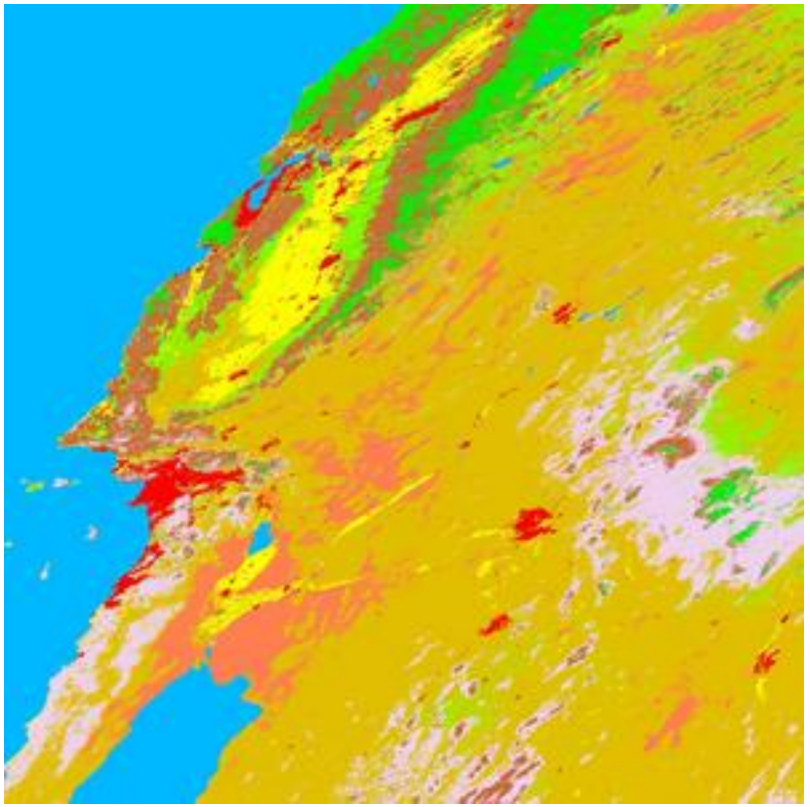
This false-colored MOD11A2 image shows the 8-day average values of daytime clear-sky LSTs retrieved from MODIS data in the period of April 30 May 7, 2000 over the eastern coast of the United States.

https://lpdaac.usgs.gov/products/modis_products_table/land_surface_temperature_emissivity/8_day_l3_global_1km/mod11a2

MODIS Land Cover Type and Dynamics

MODIS Land Cover product porvides five different land cover classification schemes and the Land Cover Dynamics product includes layers on the timing of vegetation growth, maturity, and senescence that mark the seasonal cycles

- level-3 data
- gridded 500 m, 1000 m, 5600 m (climate grid)
- yearly
- uses supervised decision-tree classification
- uses vegetation indices for dynamics



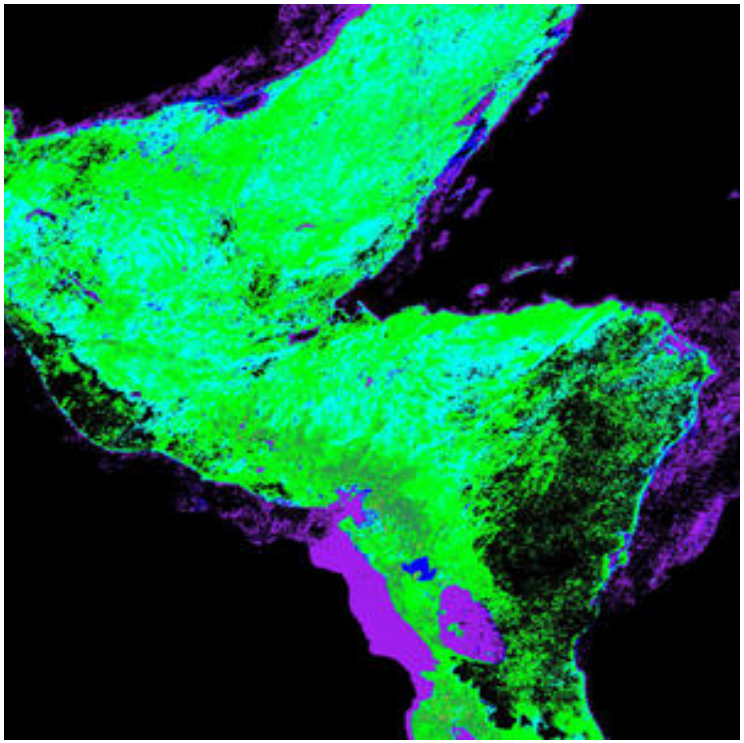
This image represents the 2005 land cover types for the western United States (h08/v05). This first SDS layer depicts the IGBP classification. The predominant light brown color represents the open shrublands. Varying shades of green portray the evergreen and deciduous forests. Sienna shades are areas of woody savannas, and savannas. Closed shrublands are characterized in thistle, and yellow indicates croplands. Red represents urban and built-up areas, while coral indicates barren and sparse vegetation.

https://lpdaac.usgs.gov/products/modis_products_table/land_cover/yearly_l3_global_500_m/mcd12q1

MODIS Land Bidirectional Reflectance Distribution Function (BRDF) and Albedo

The MODIS Albedo product describes both directional hemispherical reflectance (black-sky albedo) and bihemispherical reflectance (white-sky albedo), model weighting parameters (fiso, fvol, fgeo), and modeled nadir view reflectance

- level-3 data
- gridded 500 m, 1000 m, 5600 m (climate grid)
- 16-day sampled at 8-days
- Combines both Aqua and Terra data
- Uses RossThick-LiSparseReciprocal kernel semiempirical model



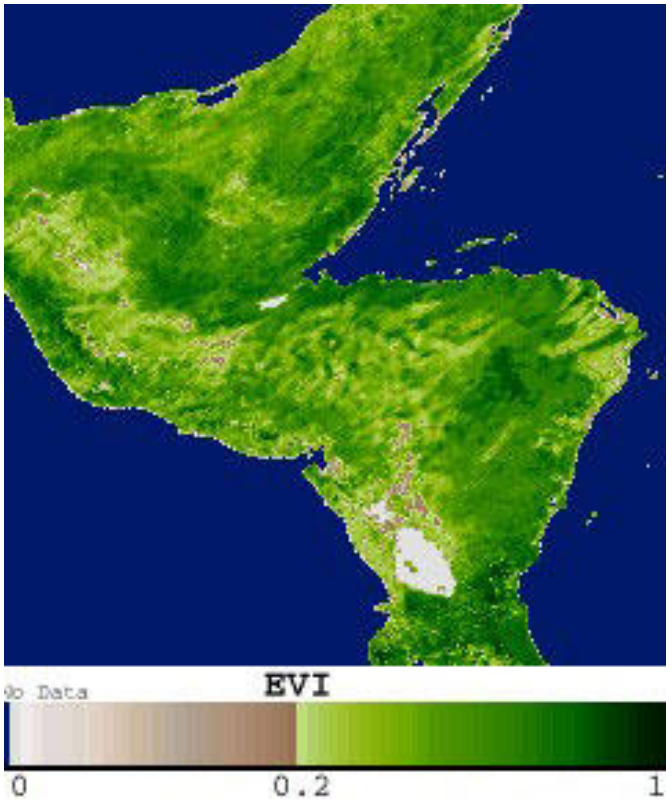
This is a representation of the first of the three model parameters used to reconstruct surface anisotropic effects and thus correct directional reflectences to a common view geometry, or to compute integrated albedos. The colors describe isotropic weighting parameters for data acquired between February 26 and March 13, 2001 over Central America including the Yucatan Peninsula, El Salvador, Honduras, Nicaragua, and some of Costa Rica (h09v07).

https://lpdaac.usgs.gov/products/modis_products_table/albedo/16_day_l3_global_500m/mcd43a3

MODIS Vegetation Indices

The MODIS Vegetation Indices product provides Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI)

- level-3 data
- gridded 250 m, 500 m, 1000 m, 5600 m (climate grid)
- 16-day, monthly
- Vegetation index



The MYD13A2 images shown are samples of the MODIS/ Aqua Vegetation Indices 16-Day L3 Global 1km SIN Grid. EVI has been pseudo-colored to represent the biomass health of the Yucatan Peninsula using tile h09v07 from May 1 16, 2007.

https://lpdaac.usgs.gov/content/view/full/6657

MODIS Thermal Anomalies/Fire Products

MODIS Thermal Anomalies/Fire products include fire occurrence (day/night), fire location, the criteria used for the fire selection, detection confidence, and a calculation of Fire Radiative Power. It distinguishes between fire, no fire and no observation.

- level-3 data
- gridded 1000 m
- daily, 8-day
- Derived from MODIS 4- and 11-micrometer radiances.
- The fire detection strategy is based on both absolute detection and on detection relative to its background

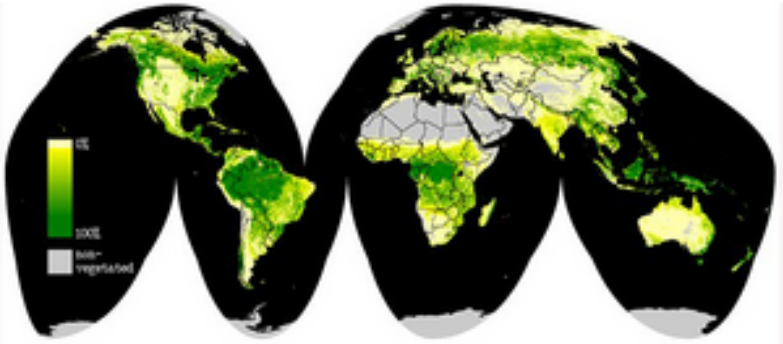
Using the MOD14A2 Fire Mask a color code was applied to highlight fires in yellow, water bodies in blue, and leaving land area in black. Each yellow pixel is 1km2.

https://lpdaac.usgs.gov/products/modis_products_table/thermal_anomalies_fire/8_day_l3_global_1km/mod14a2

MODIS Vegetation Continuous Fields

MODIS Vegetation Continuous Fields (VCF) product is a sub-pixel-level description of surface vegetation cover as proportions of: tree cover, non-tree cover, and bare.

- level-3 data
- gridded 250 m
- yearly
- uses a semi-automated process to generate regression trees with machine learning software
- uses surface reflectance and surface temperature



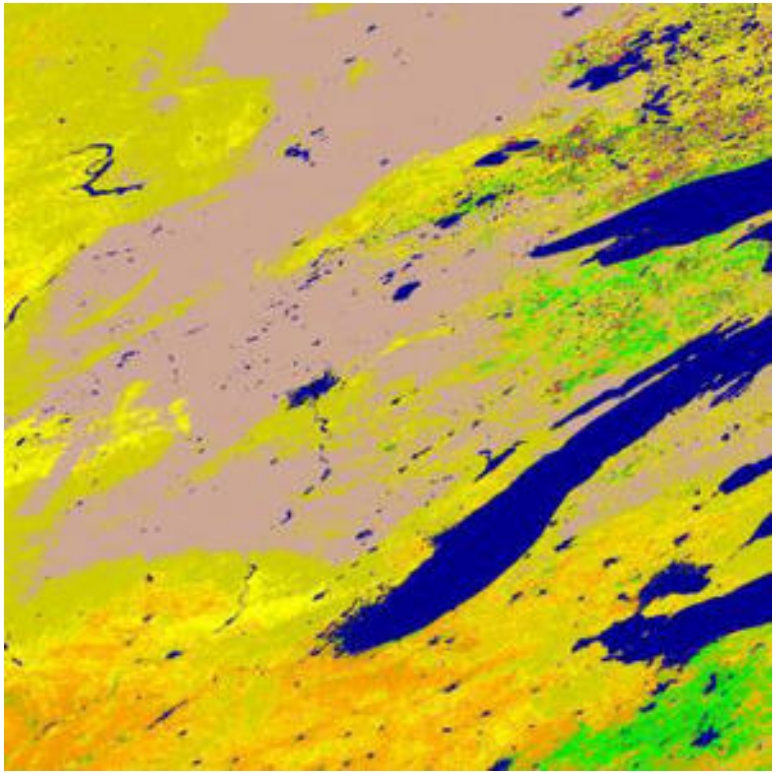
Global Vegetation Continuous Fields percent tree cover for 2001. Darker greens indicate denser tree cover, pale colors indicate light tree cover, and gray indicates completely bare.

https://lpdaac.usgs.gov/products/modis_products_table/vegetation_continuous_fields/yearly_l3_global_500m/mod44b

MODIS Leaf Area Index and *f*PAR

The MODIS leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (*f*PAR) provides LAI, the number of equivalent layers of leaves relative to a unit of ground area, and *f*PAR, the photosynthetically active radiation absorbed by a canopy

- level-4 data
- gridded 1000 m
- 8-day
- uses MODIS surface reflectance data and land cover inputs
- Uses canopy reflectance model inversion with vegetation indices as a backup



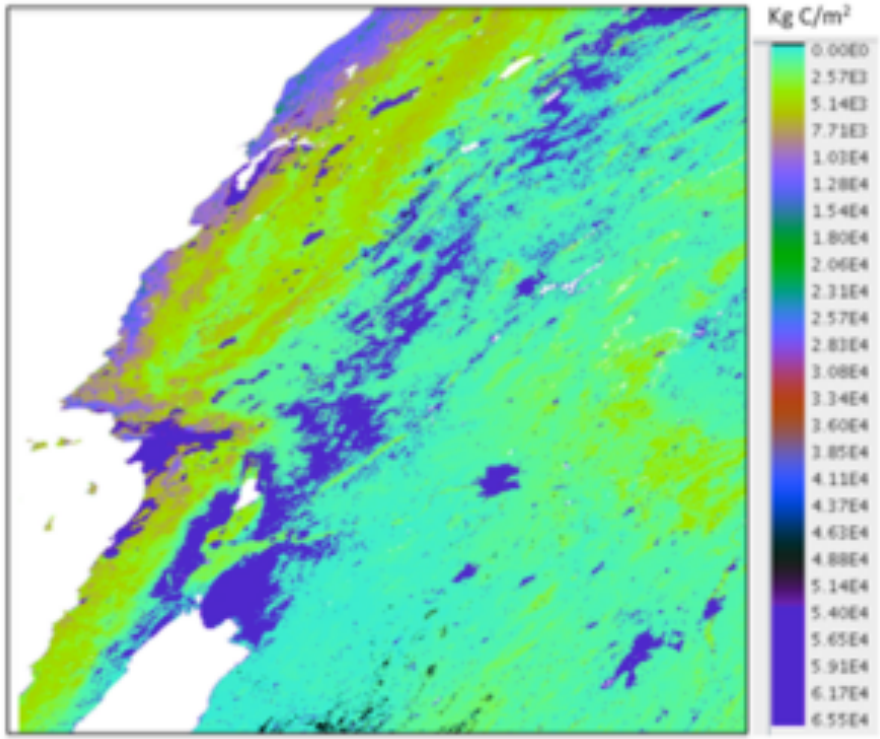
This image is pseudo-colored to display the Fraction of Photosynthetically Active Radiation (FPAR) calculated over north-central U.S., from the Great Lakes westward across the Northern Great Plains. These data collected between March 6 13, 2007 indicate more vegetation growing furthest to the East, as expected during this time of the year.

https://lpdaac.usgs.gov/products/modis_products_table/leaf_area_index_fraction_of_photosynthetically_active_radiation/8_day_l4_global_1km/mod15a2

MODIS Gross Primary Productivity and Net Primary Productivity

The MODIS Gross Primary Productivity (GPP) product uses a radiation-use efficiency model. Net Primary Productivity (NPP) is the rate plants in an ecosystem produce net useful chemical energy. NPP is equal to the difference between the rate plants in an ecosystem produce useful chemical energy (or GPP), and the rate they expend energy for respiration.

- level-4 data
- gridded 1000 m
- 8-day GPP, annual NPP
- Uses MODIS fPAR, MODIS land cover, and meterological data inputs
- Uses ecosystem process model



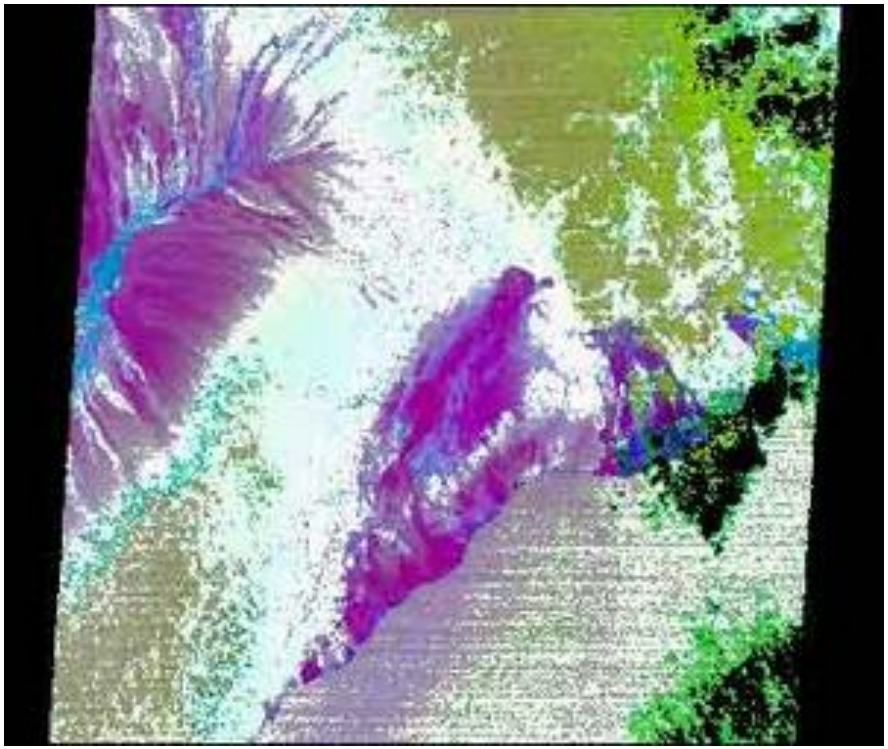
This image depicts the 2010 Terra MODIS 1-km annual Net Primary Productivity (in Kg C/m2) over the H08/V05 tile that covers much of the western/southwestern US.

https://lpdaac.usgs.gov/products/modis_products_table/gross_primary_productivity/8_day_l4_global_1km/mod17a2

ASTER Surface Emissivity

The ASTER Surface Emissivity is generated using the five thermal infrared (TIR) bands (acquired either during the day or night time). The Temperature/Emissivity Separation (TES) algorithm derives both E (emissivity) and T (surface temperature) taking into account the land-leaving radiance and down-welling irradiance vectors for each pixel

- 90 m resolution
- 5 thermal IR bands
- uses ASTER Level-2 Surface Radiance (TIR)
- Emissivity is estimated using the Normalized Emissivity Method (NEM),
- On-demand product



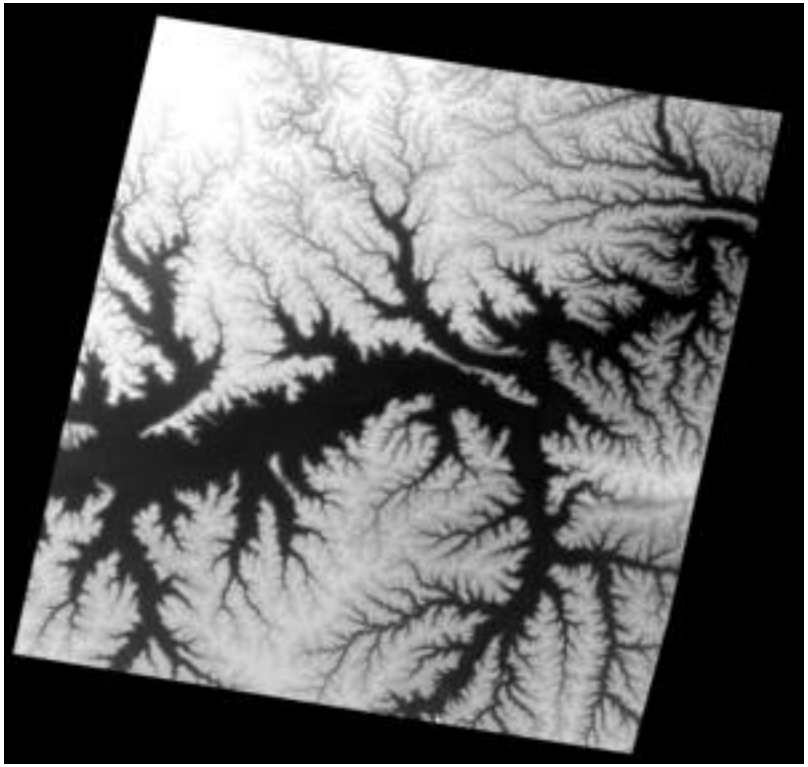
Sample ASTER surface emissivity scene.

https://lpdaac.usgs.gov/products/aster_products_table/on_demand/surface_emissivity/v1/ast_05

ASTER Digital Elevation Model

ASTER stereo pairs from nadir and backward views are used to produce single-scene (60x60 km) digital elevation models (DEM) having vertical (RMSE) accuracies between 10- and 25-m. Data from multiple scenes are grouped to make global DEM. Global data partitioning into 1° x 1° tiles.

- 30 m resolution
- automated stereo-correlation method
- cloud masked



Sample ASTER DEM scene.

https://lpdaac.usgs.gov/content/view/full/11033

Landsat Ecosystem Disturbance Adaptive Processing System

The LEDAPS project processes Landsat data to surface reflectance and uses change-detection techniques to map disturbance, regrowth, and permanent forest conversion across the continent.

- –Scene based
- –Starts with global calibrated TOA reflectance from Global Land Survey dataset
  - Orthorectified, low cloud cover, during leaf-on conditions
- – Processed to surface reflectance using MODIS algorithm
  - Also does cloud and cloud shadow masking
- –Disturbance Index calculated from Kauth-Thomas tassled-cap transform
- –Uses land cover map to identify forest pixels

Landsat-5 image of Eastern Virginia, showing "patchwork" of land-cover types

http://ledaps.nascom.nasa.gov/overview/overview.html

Web Enabled Landsat Data (WELD) Products

WELD creates reflectance composites of TOA reflectance. Brightness temperature are resampled to 30 m.

- Uses NDVI compositing and cloud and cloud shadow masking
- Annual, seasonal (3-month), monthly, weekly
- 30 m pixels
- Broken into 5000x5000 tiles

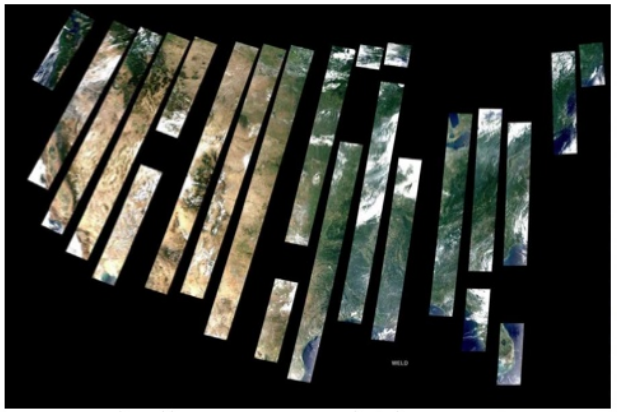


Figure 4 Example weekly WELD CONUS composite (July 15 - 21, 2008)

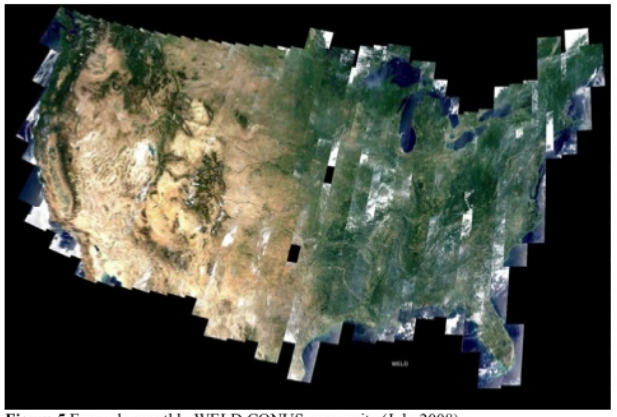


Figure 5 Example monthly WELD CONUS composite (July 2008)

Figure 6 Example seasonal WELD CONUS composite (Summer 2008)

http://globalmonitoring.sdstate.edu/projects/weld/

Prototype USGS Essential Climate Variables from Landsat

- Based on MODIS product concepts
- WELD/LEDAPS Surface Reflectance
- Land Surface Temperature
- Land Cover
  - Uses surface reflectance
  - for end-users and for modeling/algorithm stratification
  - Global land cover – annual continuous fields and 5-year thematic classifications
- LAI / fPAR
  - Uses surface reflectance and land cover
  - Based on Landsat scenes
    - Must consider phenology when using composites
- On demand processing?

Conclusions

There are a number of issues for HyspIRI products

- Data products are connected
  - Multiple levels of processing
  - Data from lower levels are inputs to higher level products
- Swath or Scene vs. Gridded Data
  - How to scale to climate grids?
  - What approach best suits applications?
- Temporal compositing approaches
  - Frequent views vs. data quality
- How to merge VSWIR and Thermal Data?

Conclusions

- Data products may be produced using a number of different approaches
  - Simple calculations (e.g. vegetation indices)
  - Empirical relationships (e.g. regression trees)
  - Models and model inversions
- Data archive vs. on-demand processing?

MODIS	Surface Reflectance	8-day surface reflectance for land bands	500 m
MODIS	Snow Cover/Sea Ice	daily/8-day/monthly Normalized Difference Snow Index	500 m
		Sea ice from NDSI	1km/4km
MODIS	Land Surface Temperature (LST) and Emissivity	Daytime and nighttime LST/emissivity	1km/6km
MODIS	Landcover	Landcover type	500 m
		Landcover dynamics	1 km
		Onset_Greenness_Increase	
		Onset_Greenness_Maximum	
		Onset_Greenness_Decrease	
		Onset_Greenness_Minimum	
		NBAR_EVI_Onset_Greenness_Min	
		NBAR_EVI_Onset_Greenness_Max	
		NBAR_EVI_Area	
MODIS	Vegetation Indices	16 day NDVI, EVI	250 m/500 m
MODIS	Thermal Anomalies/Fire	Daily/8-day fire products	1 km
		fire occurrence (day/night)	
		fire location	
		fire radiative power	
MODIS	LAI/fPAR	8 day LAI/fPAR	1 km
MODIS	Gross Primary Production	8 day GPP	1 km
		annual NPP	
		8-day ET (prototype)	
MODIS	BRDF/Albedo	16 day Albedo	500 m/1 km
		BRDF adjusted reflectance	
		Albedo model parameters	
MODIS	Vegetation Continuous Fields	Tree Cover	500 m
MODIS	Burned Area	Burn date/burned area	500 m

Landsat	Orthorectified at-sensor radiance		30 m
Landsat	TOA reflectance		30 m
Landsat	Surface reflectance		30 m
Landsat	Surface temperature		60 m
Landsat	global land cover		30 m
Landsat	LAI/fPAR		30 m
Landsat	MRLC National Land Cover Dataset	roughly every 5 years	30 m
Landsat	Landfire US forest disturbance		30 m
Landsat	MTBS burn severity history for the US		30 m
Landsat	USDA National Cropland Data Layer (crop type for the US)		30 m
Landsat	NGA/MDA-Federal "cultural (ie. urban)" growth monitoring		30 m