Getting the Big Picture

Land Processes Distributed Active Archive Center

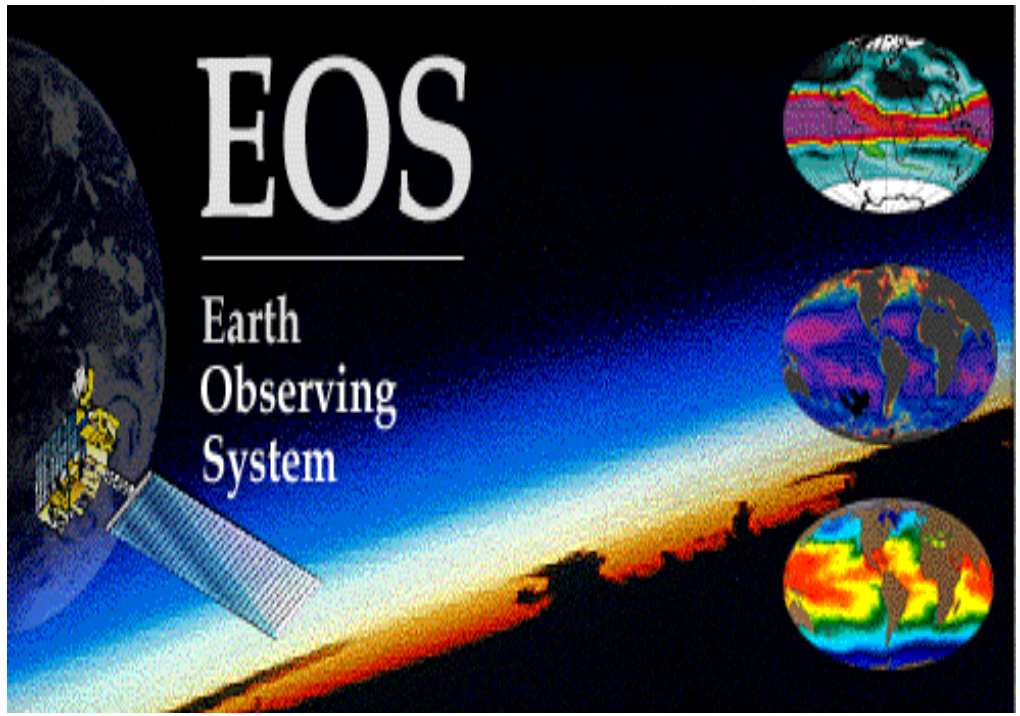
Calli Jenkerson

Earth Observing System Mission

Part of the Earth Science Enterprise as NASA's Contribution to the U.S. Global Change Research Program

EOS GOAL:

- 15 continuous years of Satellite Measurement
- Scientific Research
- Accessible Data



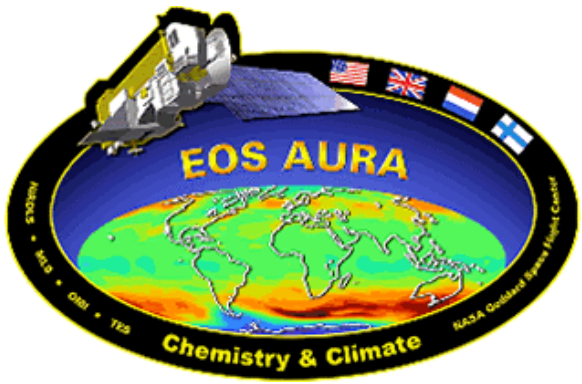
Earth Observing System Mission

EOS GOAL:

15 continuous years of Satellite Measurement

1999

2002



2004

MODIS INSTRUMENTATION

- 100% duty cycle
- Sun-synchronous, near-polar orbit (705 km)
- 2330 x 10 km scan
- 250, 500, or 1000 meter spatial resolution
- GLOBAL COVERAGE EVERY 1-2 DAYS

MODIS INSTRUMENTATION: CALIBRATION

ON-BOARD CALIBRATORS (OBC's)

1. Blackbody (BB)
2. Spectroradiometric Calibration Assembly (SRCA)
3. Solar Diffuser (SD)
4. Solar Diffuser Stability Monitor (SDSM)

SPATIAL AND RADIOMETRIC FIDELITY

MODIS INSTRUMENTATION: BROAD SPECTRAL COVERAGE

Band	Λ (μm)	Res.(m)	Band	Λ (μm)	Res.(m)	Band	Λ (μm)	Res.(m)
1	0.62-0.67	250	**13**	0.662-0.672	1000	**25**	4.482-4.549	1000
2	0.841-0.876	250	**14**	0.673-0.683	1000	**26**	1.360-1.390	1000
3	**0.459**-0.479	500	**15**	0.743-0.753	1000	**27**	6.535-6.895	1000
4	0.545-0.565	500	**16**	0.862-0.877	1000	**28**	7.175-7.475	1000
5	1.230-1.250	500	**17**	0.890-0.920	1000	**29**	8.400-8.700	1000
6	1.628-1.652	500	**18**	0.931-0.941	1000	**30**	9.580-9.880	1000
7	2.105-2.155	500	**19**	0.915-0.965	1000	**31**	10.780-11.280	1000
8	0.405-0.420	1000	**20**	3.660-3.840	1000	**32**	11.770-12.270	1000
9	0.438-0.448	1000	**21**	3.929-3.989	1000	**33**	13.185-13.485	1000
10	0.483-0.493	1000	**22**	3.929-3.989	1000	**34**	13.485-13.785	1000
11	0.526-0.536	1000	**23**	4.020-4.080	1000	**35**	13.785-14.085	1000
12	0.546-0.556	1000	**24**	4.433-4.498	1000	**36**	14.085-**14.385**	1000

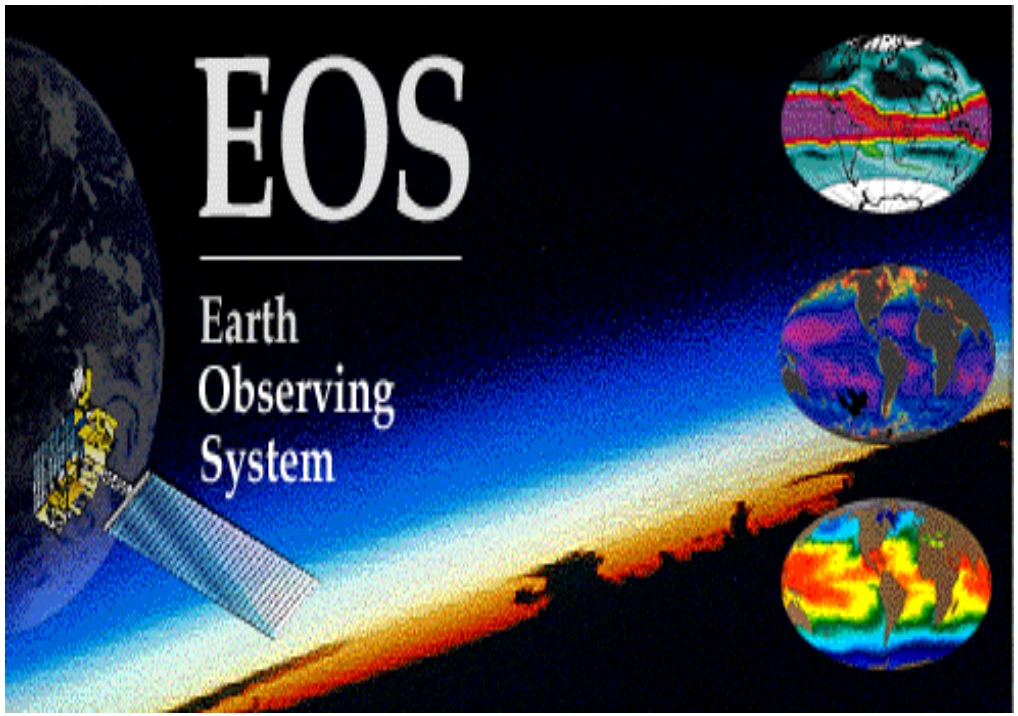
EOS SCIENCE Challenge

Moderate resolution remote sensing for quantifying land surface characteristics

- land cover type/extent
- snow cover extent
- surface temperature
- leaf area index
- fire occurrence

…input of parameters to climate and ecosystem process models

FULFILLING EOS MISSION GOALS



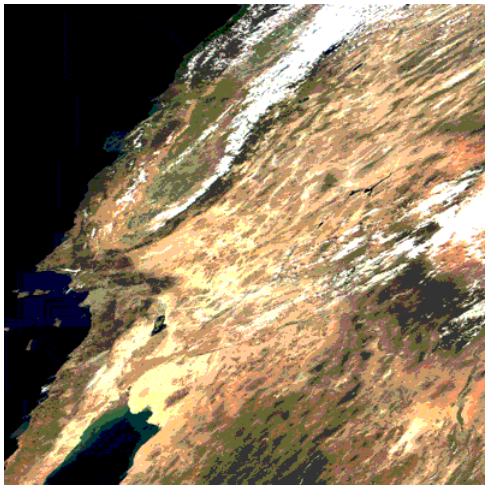
- Superior Instrumentation
- Synergistic Science
- *Relevant Science Data*

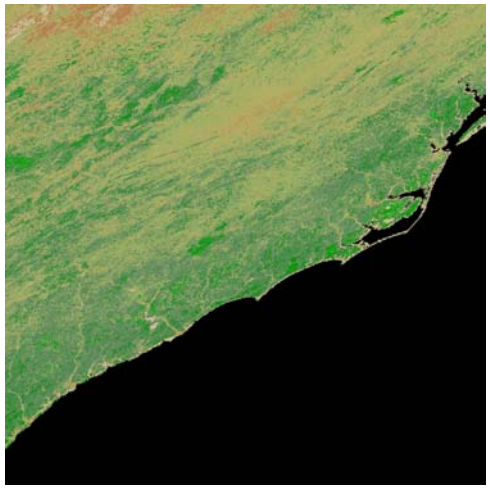
SCIENCE TEAM TASKS:

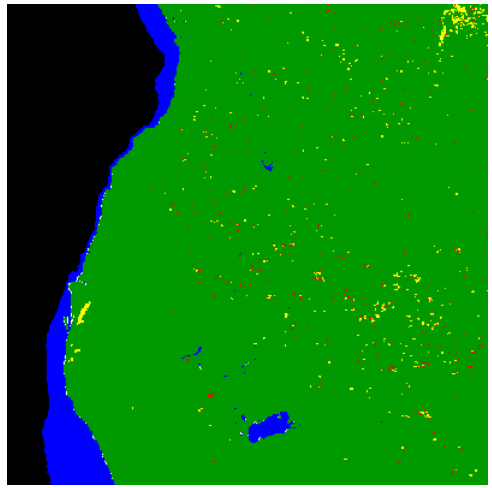
- Develop algorithms suitable for global-to-regional monitoring, modeling, and assessment

- Generate and validate high level products that remove the burden of certain types of data processing from the user community

MODIS LAND DATA OVERVIEW







Energy Budget

Vegetation Parameters

Land Cover/Use

Surface Reflectance

BRDF/Albedo

Temperature/Emissivity

Vegetation Index

LAI/FPAR

NPP

Thermal Anomalies/Fire

Land Cover

VCC/VCF

LAND PRODUCTS at LP DAAC

MOD/MYD 09 Surface Reflectance

MOD/MCD 43 BRDF / Albedo

MOD/MYD 11 Land Surf. Temp. / Emissivity

MOD/MYD 14 Thermal Anomalies / Fire

MOD/MYD 12 Land Cover / Change

MOD/MYD 13 Vegetation Indices

MOD/MYD 15 Leaf Area Index / FPAR

MOD/MYD 17 Veg.Net Primary Production

MOD 44 Vegetation Cov. Conv/Cont. Fields

LAND PRODUCTS at LP DAAC:
Data Characteristics

Temporal	1-, 8-, 16-, 32-day, monthly, quarterly, yearly
Spatial	250m, 500m, 1000m, 5600m
Level 2	Derived geophysical variables at the same resolution and location as Level 1 source data
Level 2G	Level 2 data mapped on uniform space-time grid scales
Level 3	Variables mapped on uniform space-time grid scales in derived spatial and/or temporal resolutions
Level 4	Model output or results from analyses of lower-level data.

MODIS LAND PRODUCTS at LP DAAC: Quality Assurance

- Quality assurance is an integral part of the MODIS production chain
- Each PI is responsible for producing QA fields for their particular product
- QA fields vary, depending on the product characteristics

DATA MATURITY STATUS

<u>Provisional products</u> Version 003

- product quality may not be optimal
- incremental product improvements are still occurring
- general research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
- users are urged to contact science team representatives prior to use of the data in publications
- may be replaced in the archive when the validated product becomes available

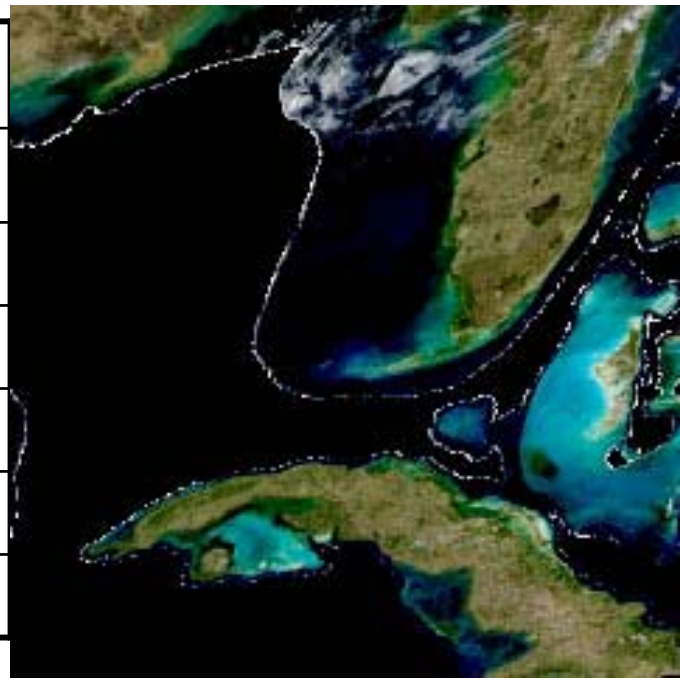
DATA MATURITY STATUS

Validated products Version 004

- formally validated product, although validation is still ongoing
- uncertainties are well defined
- ready for use in scientific publications, and by other agencies
- there are three successive stages of validation dependent on number and types of field site comparisons

MODIS Surface Reflectance

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD09GHK	2G	DAILY	500M
MOD09GQK	2G	DAILY	250M
MOD09GST	2G	DAILY	1000M
MOD09A1	3	8-DAY	500M
MOD09Q1	3	8-DAY	250M
MOD09CMG	*3*	*DAILY*	*0.05 deg*



- Surface reflectance for 7 spectral bands as if measured at ground level with no atmospheric scattering or absorption.
- Corrections for gases, aerosols, cirrus clouds

MODIS Surface Reflectance

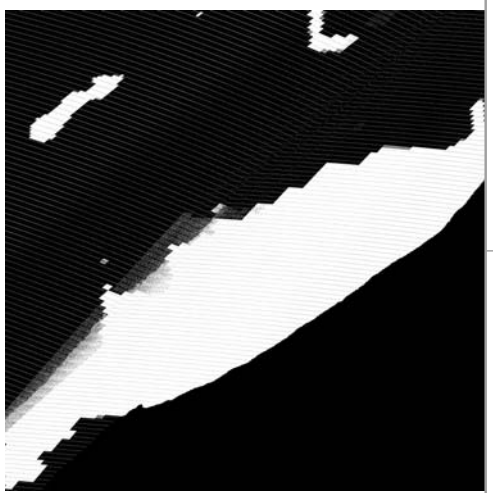
Data Set Characteristics	**MOD09A1 8Day 500m**
Area	~ 10° x 10° lat/long
Image Dimensions	2400 x 2400
File Size	~161 MB
Resolution	500 meters
Projection	Sinusoidal
Data type	16-bit Integer
Science Data Sets (Bands)	13

MODIS Surface Reflectance

SDS	Units	Data Type-bit	Fill Value	Valid Range	Multiply by Scale Factor
Surface Reflectance for band 1 (620-670 nm)	reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
Surface Reflectance for band 2 (841-876 nm)	reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
Surface Reflectance for band 3 (459-479 nm)	reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
Surface Reflectance for band 4 (545-565 nm)	reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
Surface Reflectance for band 5 (1230-1250 nm)	reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
Surface Reflectance for band 6 (1628-1652 nm)	reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
Surface Reflectance for band 7 (2105-2155 nm)	reflectance	16-bit signed integer	-28672	-100 - 16000	0.0001
* Surface reflectance 500m quality control flags	bit field	32-bit unsigned integer	4294967295	0-4294966531	na
Solar zenith	degree	16-bit signed integer	0	0 - 18000	0.01
View zenith	degree	16-bit signed integer	0	0 - 18000	0.01
Relative azimuth	degree	16-bit signed integer	0	-18000 - 18000	0.01
**Surface reflectance 500m state flags	bit field	16-bit unsigned integer	65535	0	na
Surface reflectance day of year	Julian day	16-bit unsigned integer	65535	0 – 366	na

MODIS Surface Reflectance

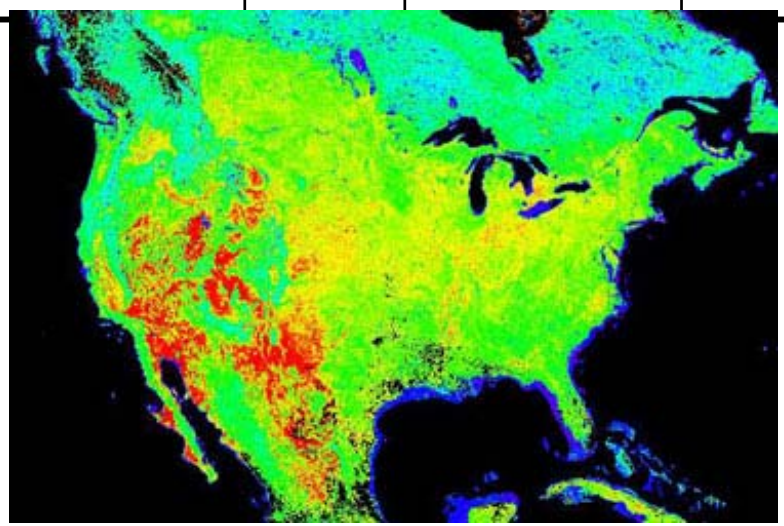
MOD09GHK Science Data Sets: Quality Flags



0	1 -- adjacency correction performed 2 –- no adjacency correction performed
1	1 -- atmospheric correction performed 2 -- atmospheric correction performed
2-5, 6-9, 10-13, 14-17, 18-21, 22-25, 26-29	band X data quality four bit range 0000 -- highest quality 1000 -- dead detector; data interpolated in L1B 1001 -- solar zenith >= 86 degrees 1010 -- solar zenith >= 85 and < 86 degrees 1011 -- missing input 1100 -- internal constant used in place of climatological data 1101 -- correction out of bounds pixel constrained to extreme allowable 1110 -- L1B data faulty 1111 -- not processed due to deep ocean or clouds
30-31	MODLAND QA bits; 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)].

BRDF/Albedo

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD43B1- Model BRDF/Albedo	3	16-DAY	1000M
MOD43B3-Albedo	3	16-DAY	1000M
MOD43B4-NBAR	3	16-DAY	1000M
MOD43C1-**Global Albedo**	3	16-DAY	0.05º
MOD43C2-**Global BRDF/Albedo Parameters**	3	16-DAY	0.05º
MOD43C3-**Global NBAR**	3	16-DAY	0.05º



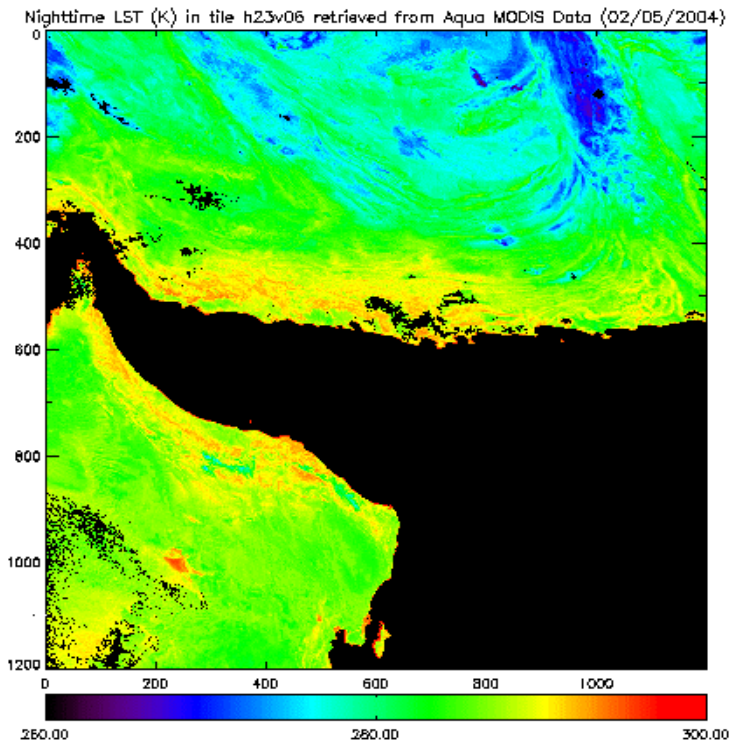
- Coefficients for mathematical description of pixel BRDF used to simultaneously derive albedo measurements

Removes geometric effects from multi-date images

- Quantifies directional information in signal
- Provides a surface radiation-scattering model

Land Surface Temperature/Emissivity

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD11_L2	2	1-DAY	1000M
MOD11A1	3	1-DAY	1000M
MOD11A2	3	8-DAY	1000M
MOD11B1	3	DAILY	5000M
MOD11C1	3	DAILY	0.05deg
MOD11C2	3	8-DAY	0.05deg
MOD11C3	3	MONTHLY	0.05deg



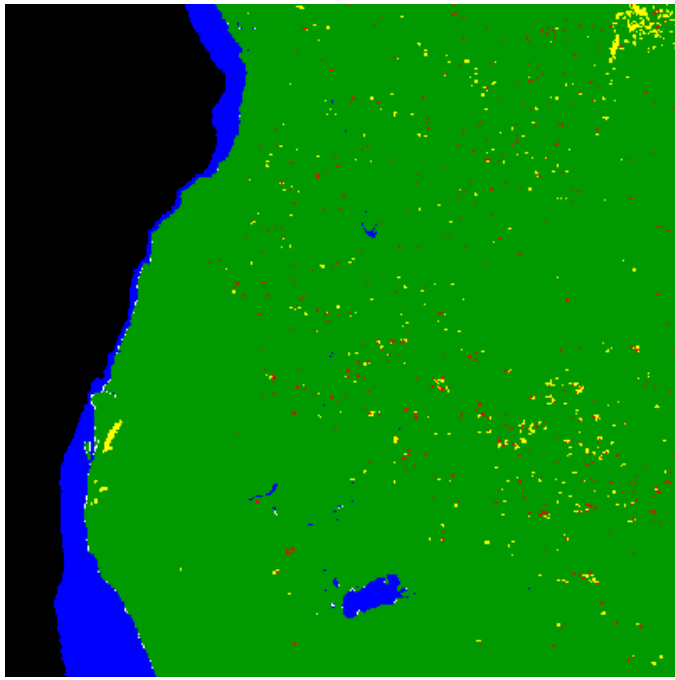
•Temperatures are extracted in Kelvin with a view-angle dependent algorithm applied to direct observations.

•Emissivities are estimates derived from applying algorithm output to database information

• **1º K accuracy**

Thermal Anomalies/Fire

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD14	2	1-DAY	1000M
MOD14A1	3	1-DAY	1000M
MOD14A2	3	8-DAY	1000M
MOD40A	*3*	*8-DAY*	*500M*

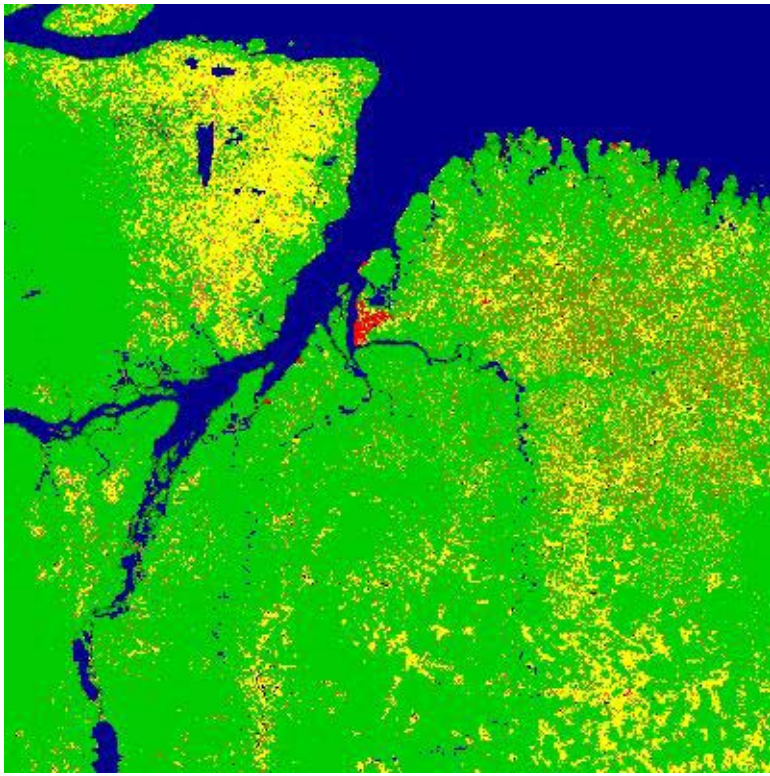


- Fire location and Energy calculation
- Smoldering/flaming ratio
- Volcano alerts / monitoring
- Burn scars

Effects related to deforestation, gas release, particulate release, ecological biomes

Land Cover/Phenology

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD12Q1	3	96-DAY	1000M
MOD12Q2	*3*	*YEARLY*	*1000M*



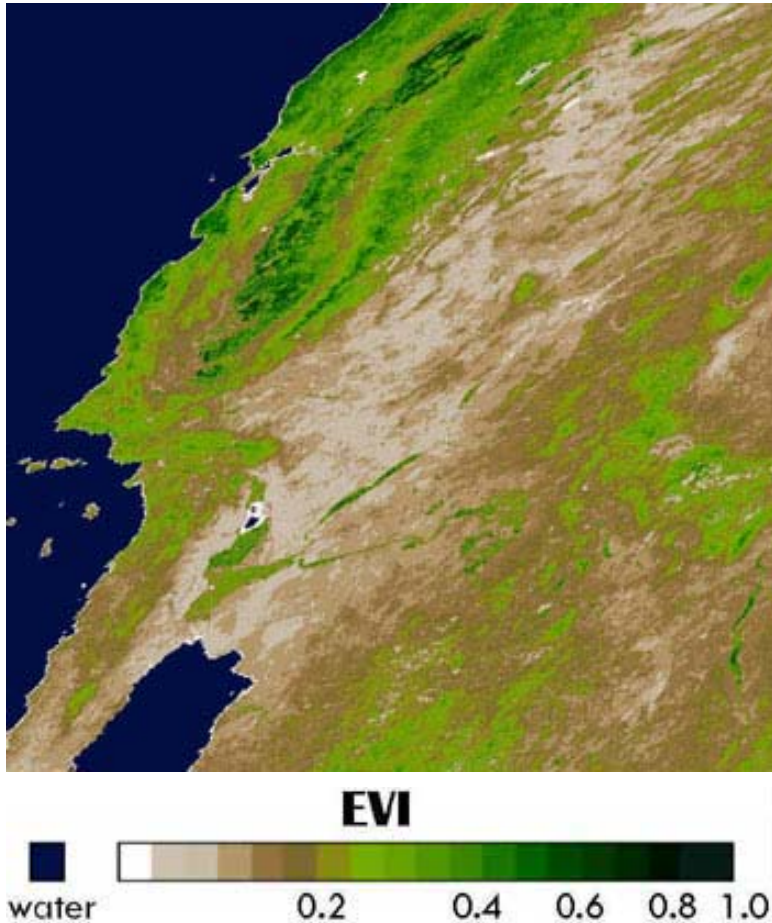
- **Identifies land cover using 5 different classification schemes**

IGBP; UMD; LAI/FPAR; BCC; PFT

- Supervised decision-tree method
- Natural vs. Human induced changes

Vegetation Indices

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD13A1	3	16-DAY	500M
MOD13A2	3	16-DAY	1000M
MOD13Q1	3	16-DAY	250M
MOD13A3	3	MONTHLY	1000M



NDVI as continuity index with AVHRR NDVI

EVI Enhanced Vegetation Index

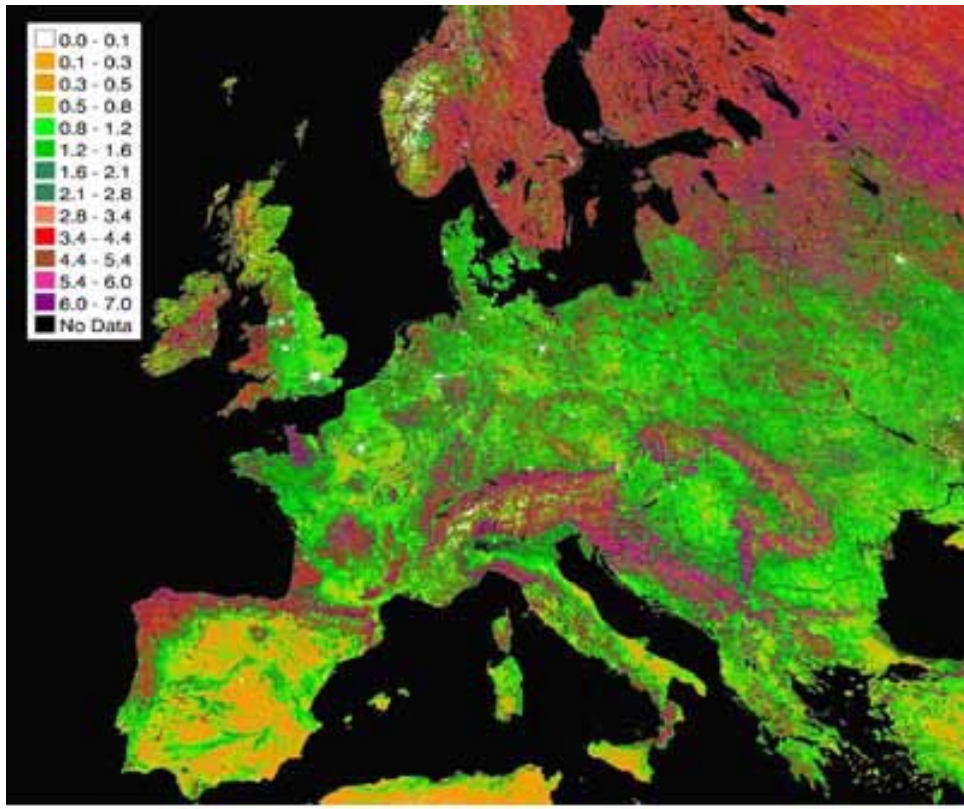
Band 3 Blue (470 nm)

remove smoke and sub-pixel/thin clouds
minimize background variations
enhance sensitivity to sparse vs. dense conditions.

Leaf Area Index/FPAR

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD15A2	4	8-DAY	1000M

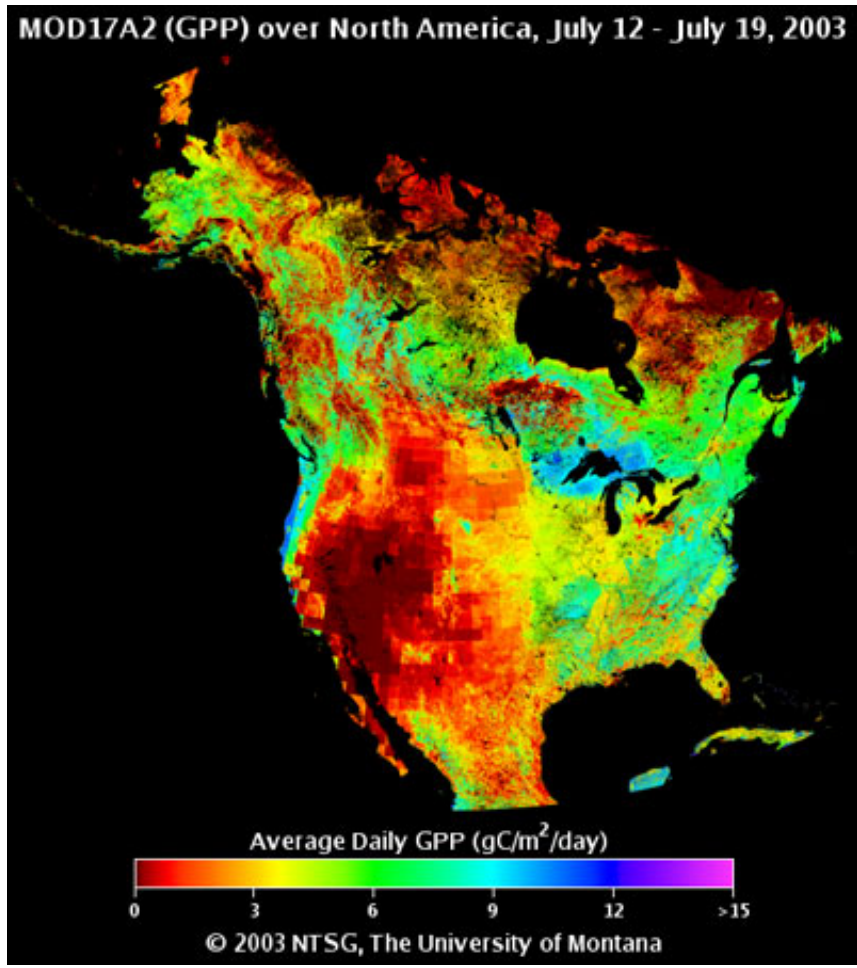
- Derived directly from EVI, land cover type, and background, which are combined using a 3-D radiative transfer model to produce values.
- These products are essential in calculating terrestrial energy, carbon, water cycle processes, and biogeochemistry of vegetation.



Leaf Area Index (LAI) over northern Europe, July 28 - August 4, 2003

Net Primary Production

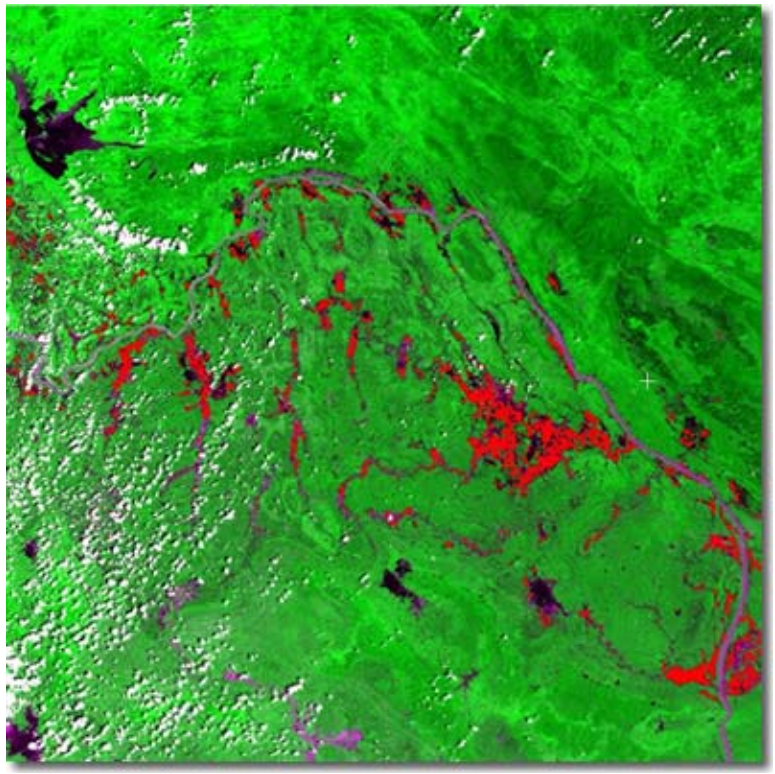
DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD17A2-GPP	4	8-DAY	1000M
MOD17A3-NPP	4	YEARLY	1000M



- EVI -> FPAR -> GPP -> NPP
- NPP=yearly integral of Net Photosynthesis
- Theoretical use defining seasonally dynamic flux of CO_2 for specific vegetation types
    - Practical use in estimating crop yield and forest production

Vegetation Cover Conversion

DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD44A	4	96-DAY	250M



MOD44A – Percentage of land cover change

0- No Change

1- Tree Cover Change

255 – Fill Value

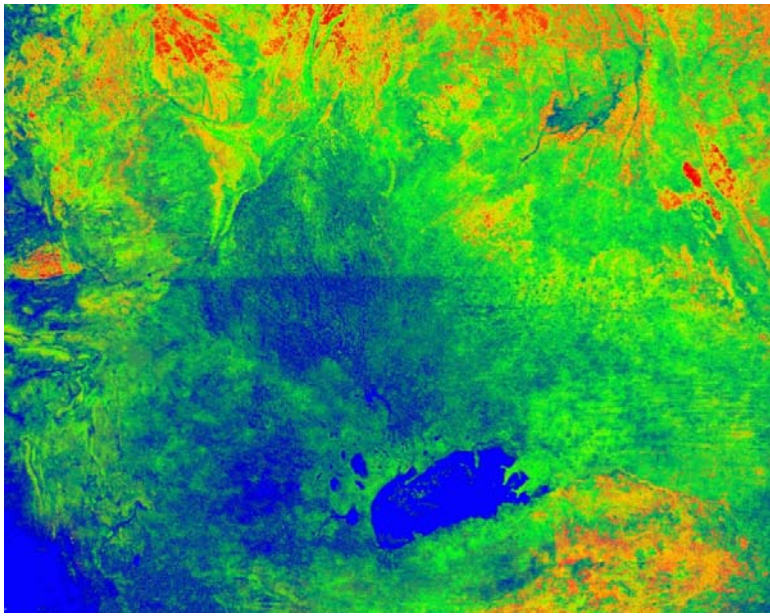
Vegetation Continuous Fields

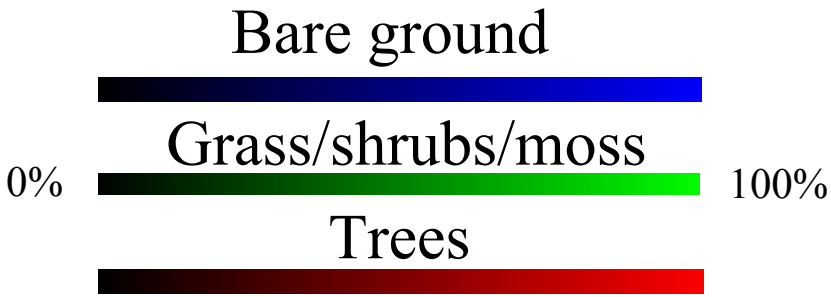
DATATYPE	LEVEL	TEMPORAL	SPATIAL
MOD44B	4	YEARLY	500m

The current version (V003) of the MODIS Vegetation Continuous Fields product contains only

- **percent tree cover**
- **percent nontree vegetation**
- **percent bare**

with the other layers to follow in later releases.



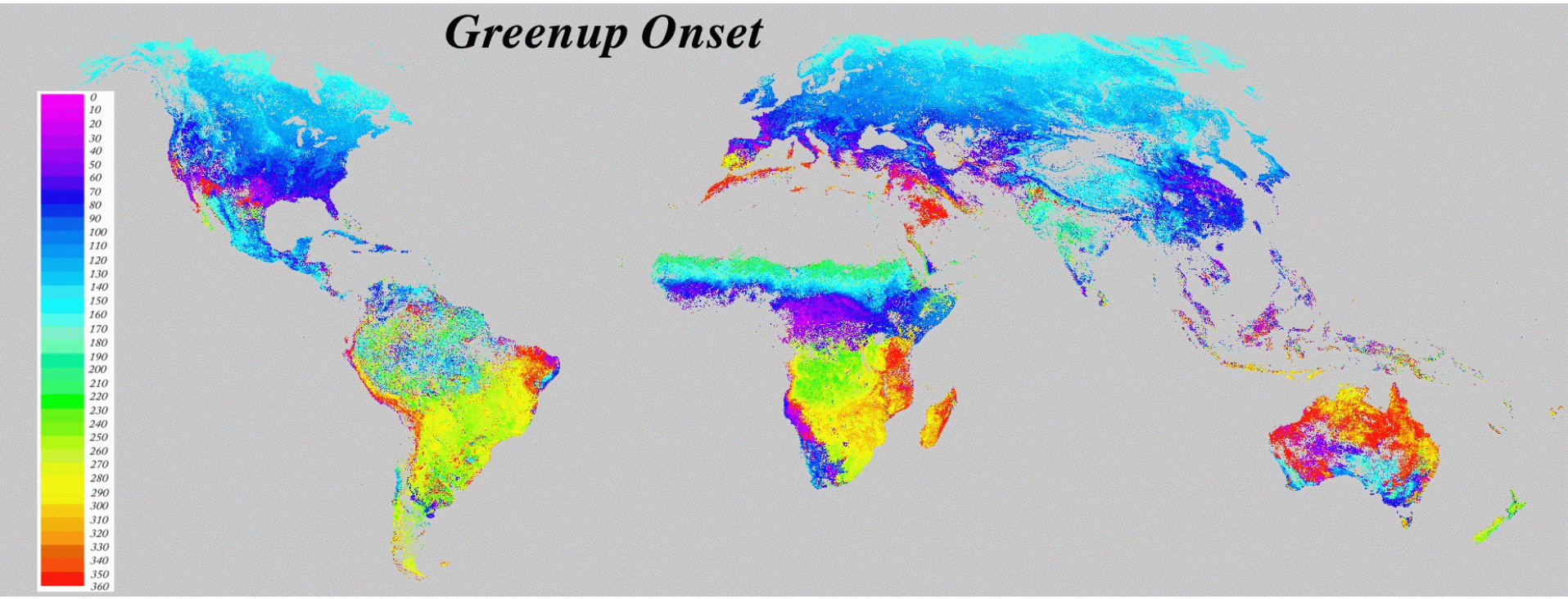


Future MODIS Land Products

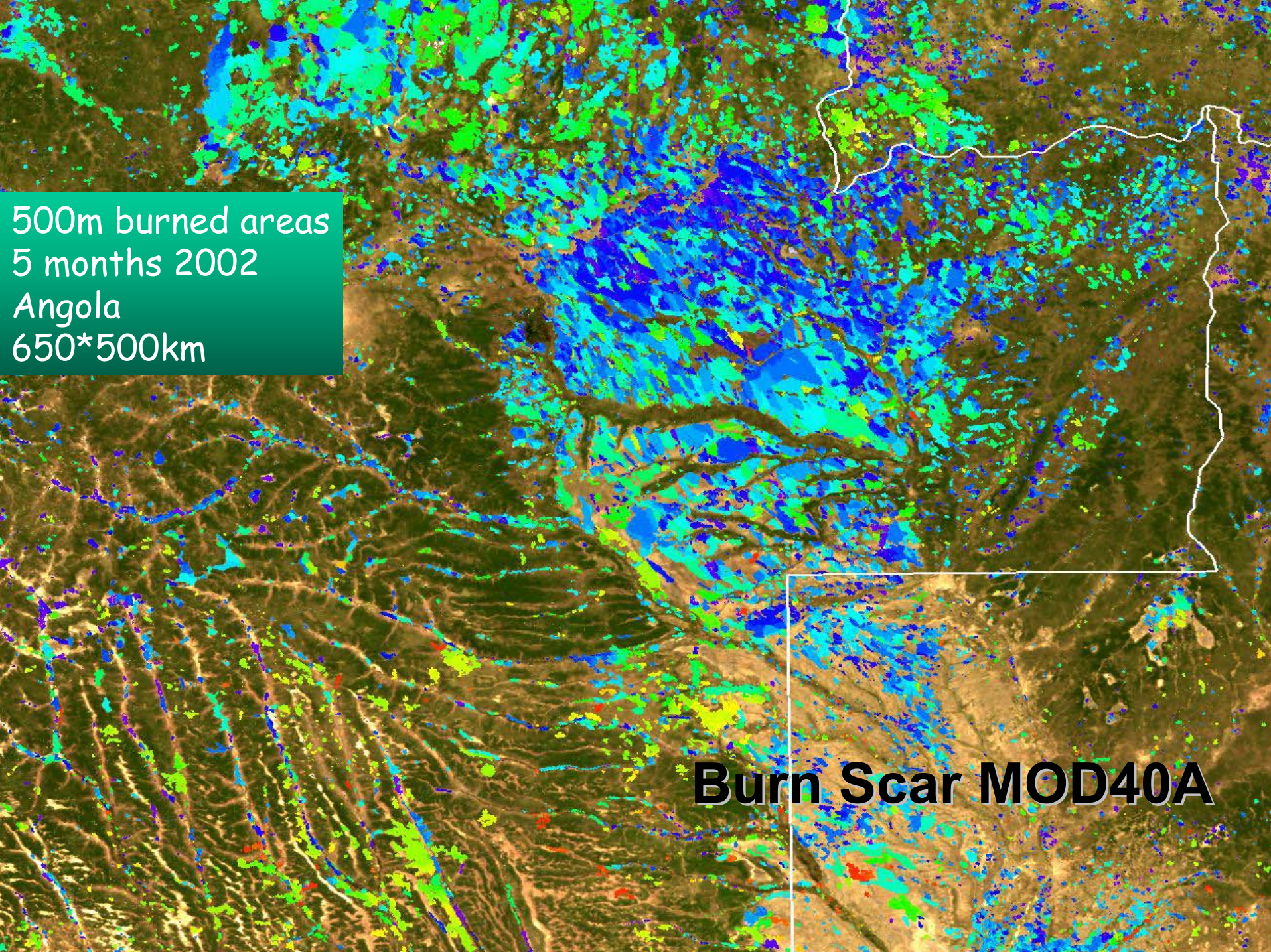
MOD12Q2	Phenology
MOD40A	Burn Scar
MOD16	Fraction Evaporative Water
MOD??	Canopy Water

Phenology MOD12Q2

Global Results -2001
(e.g., Northern Hemisphere Green Wave)



Credit: Xiaoyang Zhang


500m burned areas
5 months 2002
Angola
650*500km
Burn Scar MOD40A

MOD16 - Land Surface Evaporative Fraction

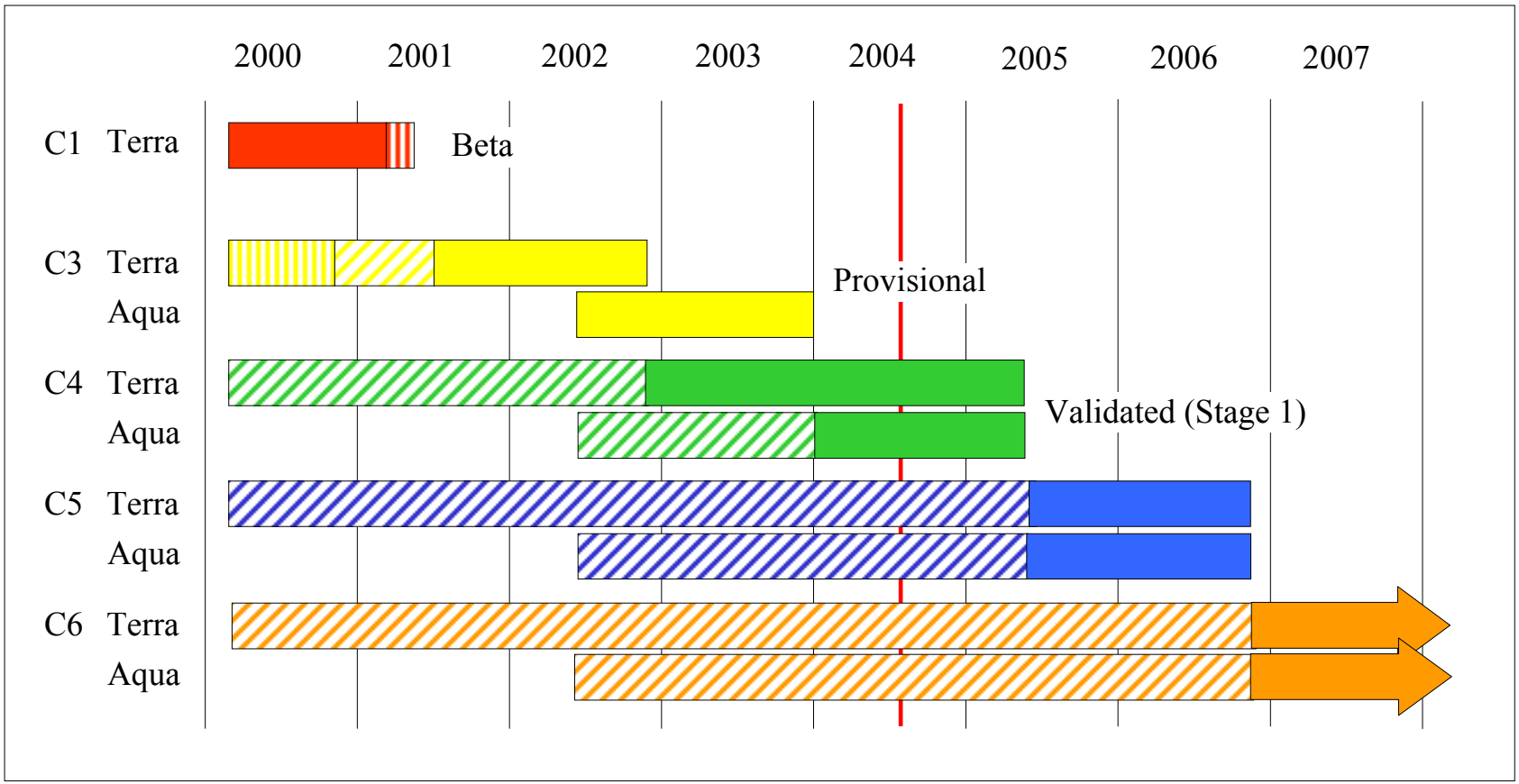
- transport of heat away from the surface
- MOD16 will be based on SEBS (Surface Energy Budget System)
  - Ground heat flux is parameterized using fractional vegetation and net radiation
  - Potential inputs: MOD11, MOD43, MOD15, MOD13, MOD12; meteorological and radiative forcing terms, surface pressure, air temperature, specific humidity, wind speed, insolation, downward longwave radiation

- Hoping to have sample products over a limited area in July 2005, routine regional production by July 2006

Canopy Water Content

- H2O absorption bands at 980 and 1240
- MODIS sees 858 and 1240 bands, which can be used to make a NDWI (normalized difference water index)
- Looking for seasonal changes
- Units will be mm/pixel of EWT (equivalent water thickness)
- Probably start with NBAR for input

DATA VERSIONS



C*n* – Collection Version *n*

Forward processing

Level 1 only

Reprocessing

NAMING CONVENTIONS: DATA SET NAMES

MOD09A1 MODIS/Terra Surface Reflectance 8-Day L3 Global 500m ISIN Grid

ShortName

Instrument

Platform

Parameter

Temporal Resolution

Processing Level

Global or Swath

Spatial Resolution

Grid or not

NAMING CONVENTIONS: FILE NAMES

MOD09A1.A2000185.h11v05.003.2000193081710.hdf

ShortName

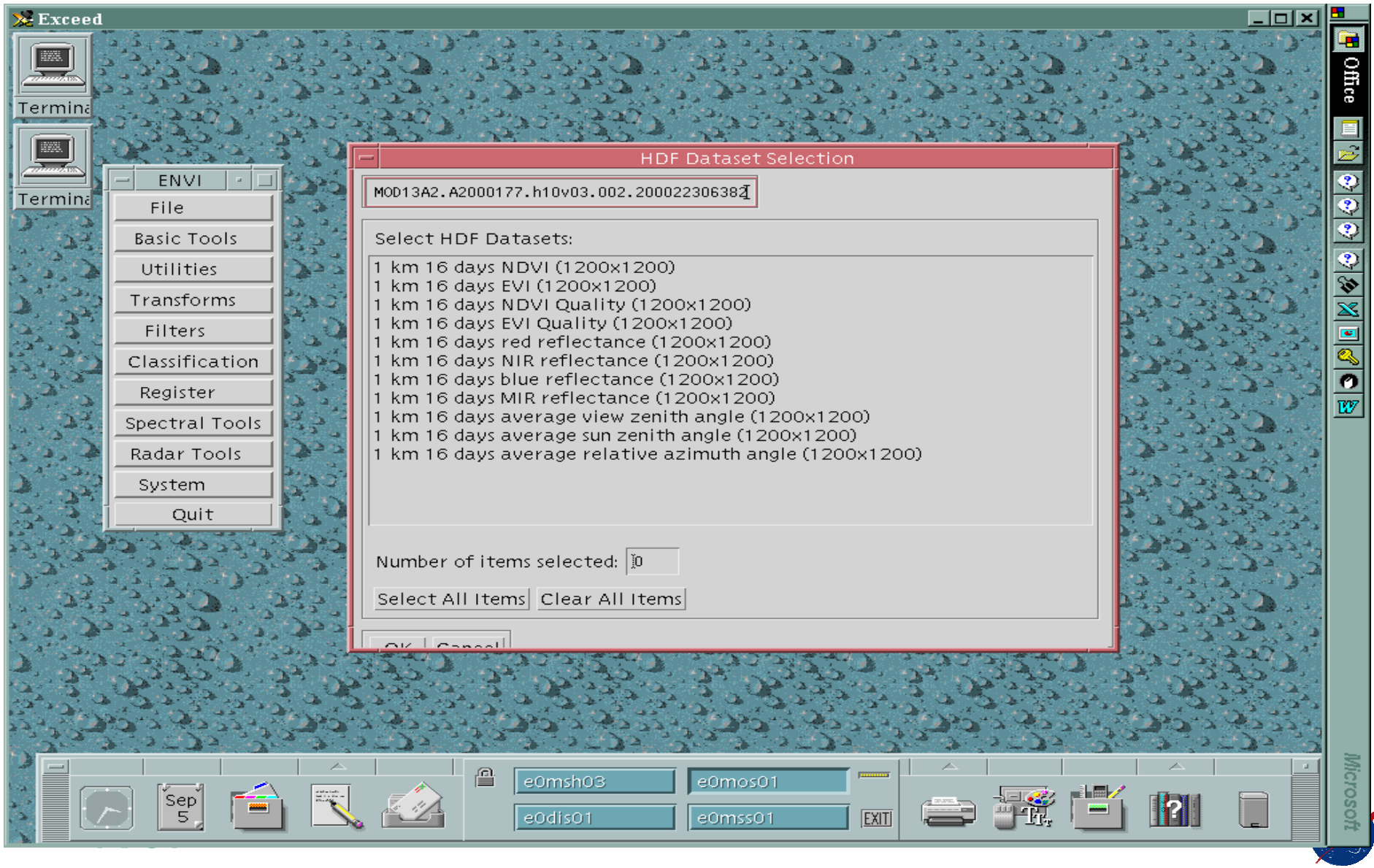
Julian Acquisition Date

TileID

Processing Version

Julian Processing Date

MODIS DATA FORMAT: HDF-EOS



LP-DAAC HDF-EOS HELP

No cost software options

EOSView - ftp://lake.nascom.nasa.gov/software/trmm_software/

JHV - http://hdf.ncsa.uiuc.edu/java-hdf-html/

view_hdf - http://eosweb.larc.nasa.gov/HPDOCS/view_hdf.html

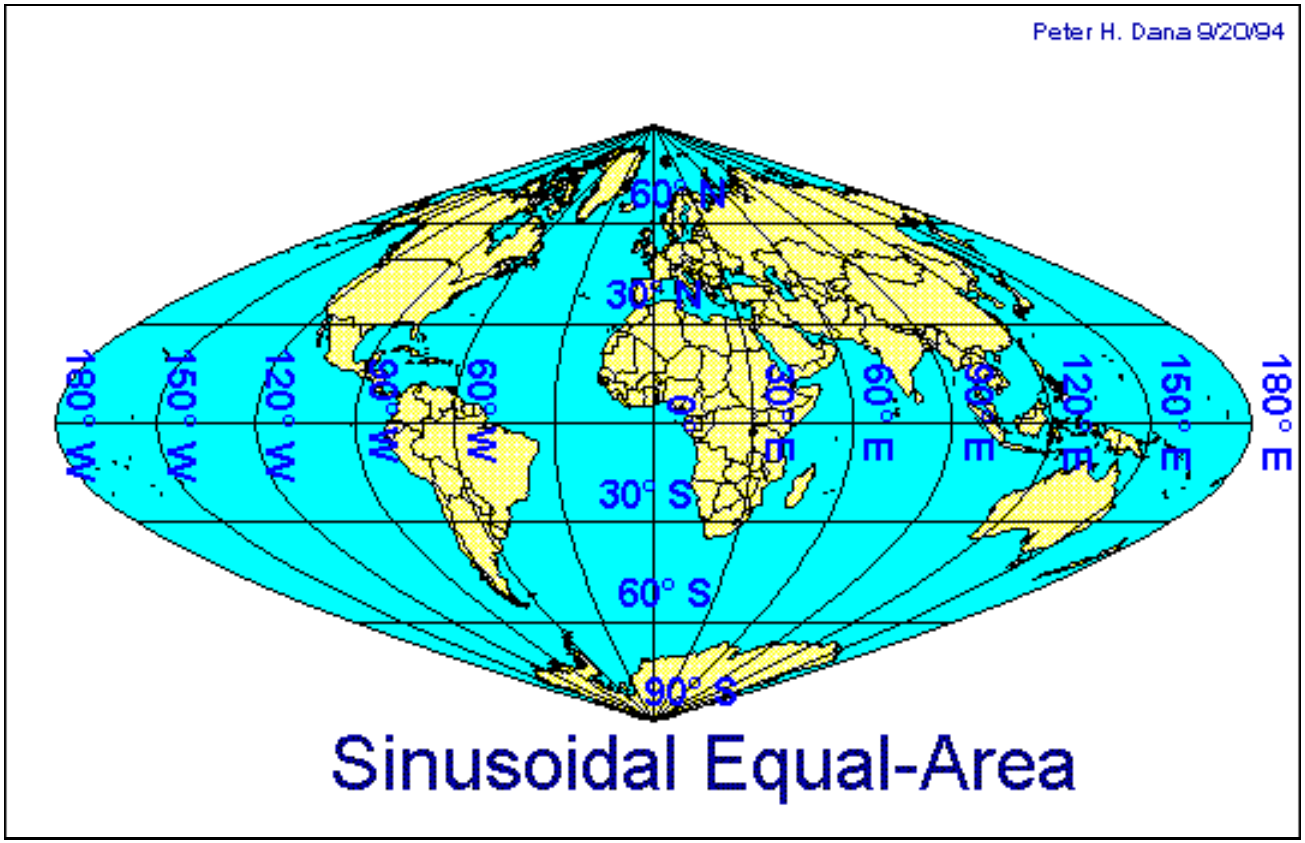
Web Winds - http://webwinds.jpl.nasa.gov/

HDFLook - http://www-loa.univ-lille1.fr/Hdflook/hdflook_gb.html

http://lpdaac.usgs.gov/dataformat.asp

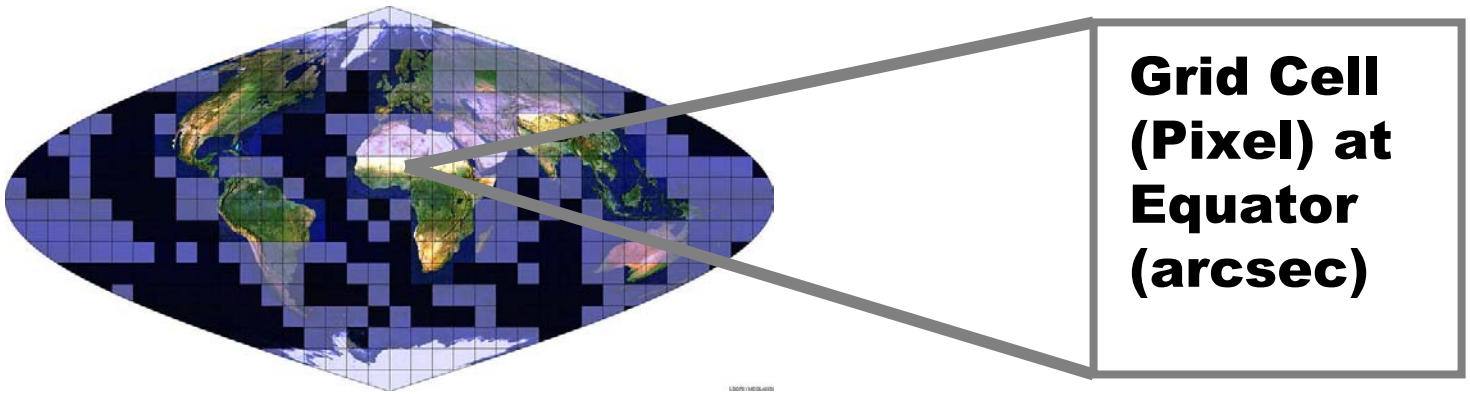
MODIS V004 Map Projection

All higher level products in most recent reprocessing (V004) are in conventional Sinusoidal projection.



Most image processing/conversion software handles the Sinusoidal projection with ease.

MODIS Actual Spatial Resolution

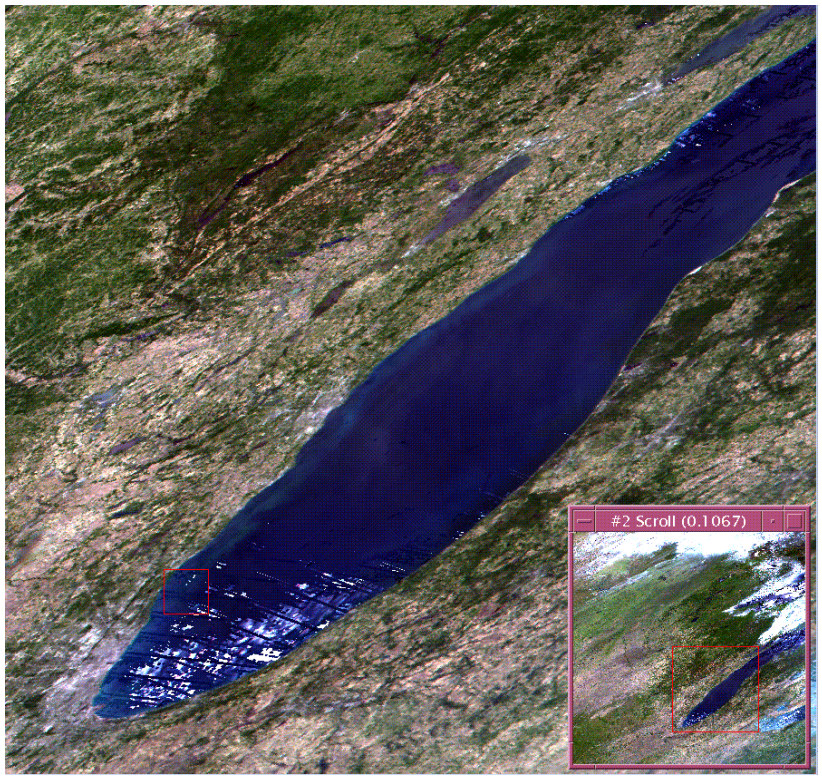


L1B pixel size		Projection calculation basis		Out pixel size
250 M	=	7.5 ARCSEC	=	230 M
500 M	=	15 ARCSEC	=	460 M
1000 M	=	30 ARCSEC	=	920 M

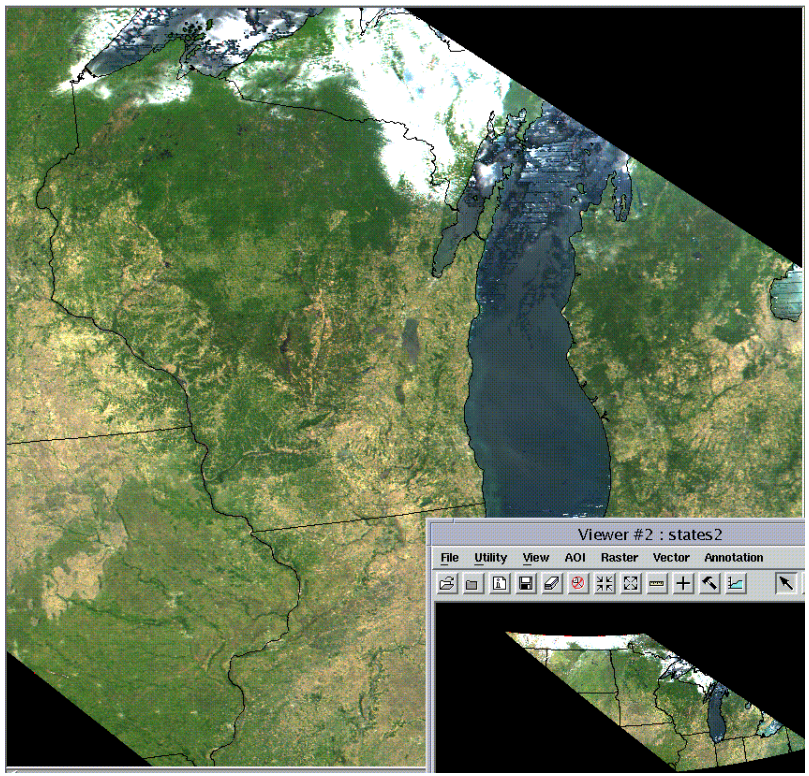
The processing of higher level MODIS products includes binning and projection operations. These operations reducing the pixel size slightly.

MODIS REPROJECTION TOOL

http://edcdaac.usgs.gov/landdaac/tools/modis/index.asp



BEFORE



AFTER

QABits – Science Data Sets in hdf files

8-32 bit integers describing the quality of geophysical parameters

bit	Long Name	Key
00-01	Mandatory QA flags	00=LST produced, good quality, not necessary to examine more detailed QA 01=LST produced, other quality, recommend examination of more detailed QA 10=LST not produced due to cloud effects 11=LST not produced primarily due to reasons other than cloud
02-03	Data quality flag	00=good data quality 01=other quality data 10=LST affected by nearby clouds and/or sub-grid clouds and/or ocean 11=LST screened off
04-05	Emis Error flag	00=average emissivity error <= 0.01 01=average emissivity error <= 0.02 10=average emissivity error <= 0.04 11=average emissivity error > 0.04
06-07	LST Error flag	00=average LST error <= 1K 01=average LST error <= 2K 10=average LST error <= 3K 11=average LST error > 3K

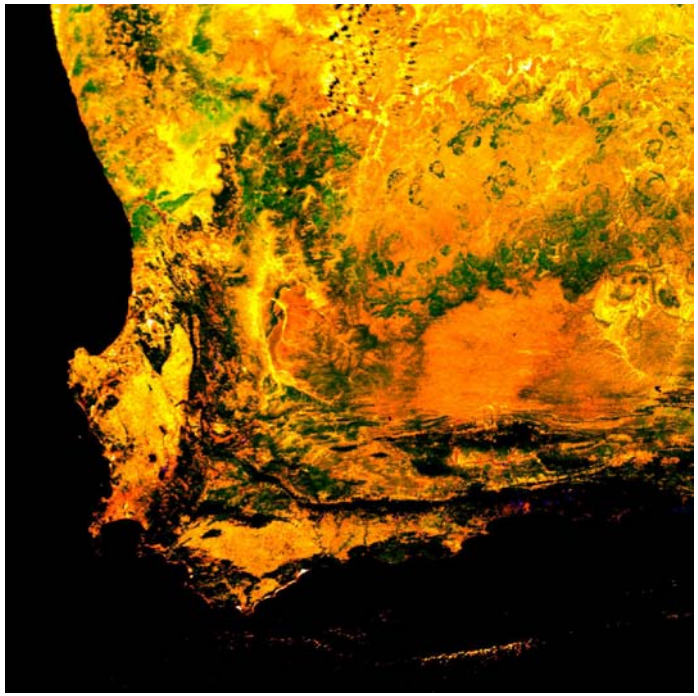
MODIS LDOPE Tools

Can perform any processing function necessary for manipulating MODIS Land data, except reprojection

QABits, mosaicking, subsetting, format conversion, multidimensionality, etc.

- stand-alone executables invoked from a command-line interface
- supported on Irix, Solaris, Linux, and Windows operating systems

MODIS CHALLENGES



Data Format

Map Projection

QABit Interpretation

Timeliness

- MODAPS production generally less than 1 week behind real time
- Goal to stay within 15 days of Level 1 production

MODIS DATA TOOLS

http://edcdaac.usgs.gov/datatools.asp

MRT
MRTSwath
LDOPE
HDF-EOS