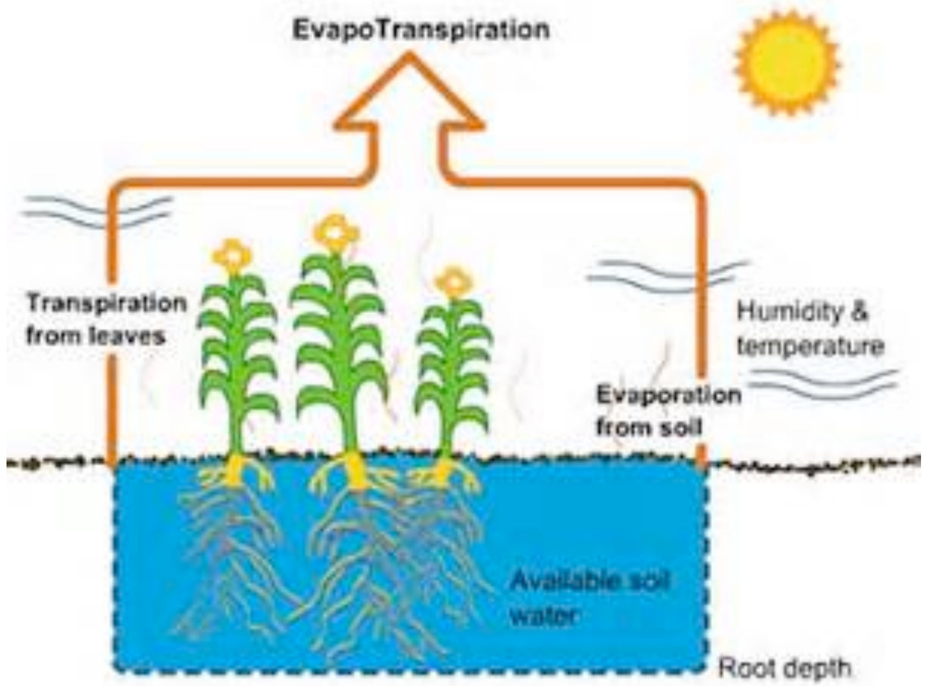
Overview of NASA Hydrological Data
Soil Moisture, Vegetation Index



Objective

To provide an overview of NASA remote sensing-based soil moisture, evapotranspiration, and vegetation index data information and access

Outline

- Soil Moisture from NASA Satellites and Models
- Soil Moisture Data and Access

  Overview of Soil Moisture Active-Passive

- Evapotranspiration (ET), Vegetation Index Data and Access

  Overview of ET data

  Presentation of Aqua/Terra Moderate Resolution Imaging Spectroradiometer (MODIS)Vegetation Index

Soil Moisture from NASA Satellites and Models

NASA's Satellites for Soil Moisture

Satellite	Sensors	Quantities
Aqua	Advanced Microwave Scanning Radiometer for EOS (AMSR-E) (May 2002 to October 2011) (Level-3 data at 25 km Equal area grids)	Snow Water Equivalent, Sea Ice, Soil Moisture, Rain Rate (not Available currently but can be used examine past variability and change in soil moisture)
TRMM (Tropical Rainfall Measuring Mission)	TRMM microwave Imager (TMI) (November 1997 to present – **but will end soon)** (Level-3 gridded data available at 0.25x0.25 degree)	Rainfall, Vertical Rain Profile, Soil Moisture
SMAP (Soil Moisture Active Passive)	Equal-area ridded data at 3 km and 9 km resolutions Launched in January 2015 Data will be available in late 2015	Soil Moisture, Freeze-Thaw State

NASA Models for Soil Moisture

Models	Quantities
GLDAS	Evapotraspiration, Multi-layer Soil Moisture, Rainfall, Snowfall Rate, Snow Melt, Snow-Water Equivalent, Surface and Sub-surface Runoff

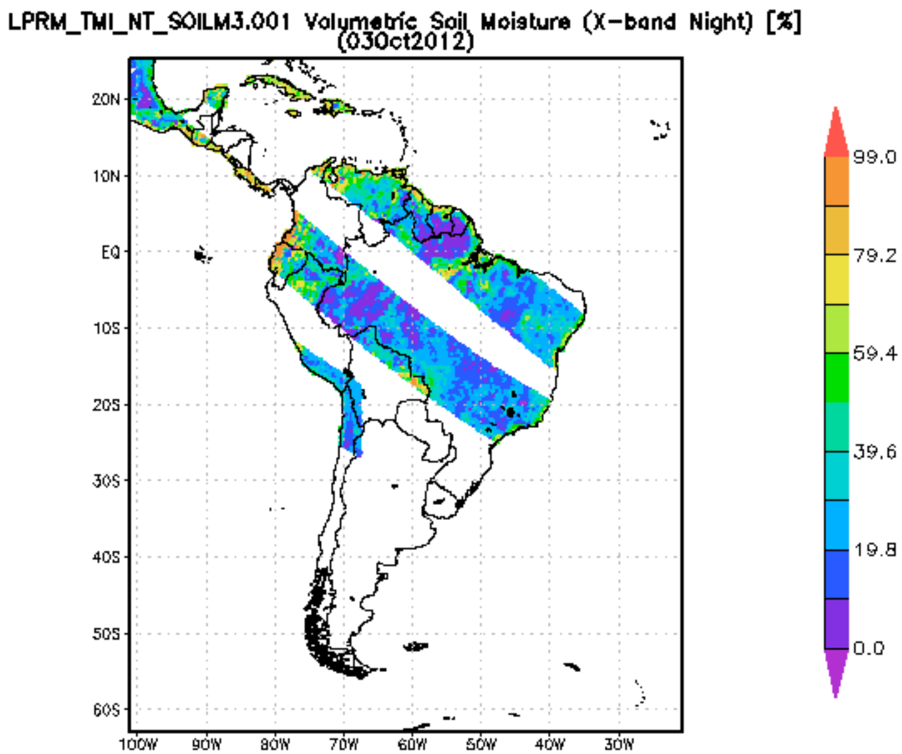
TMI **Soil Moisture Access from Giovanni-3**

http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=soilmoisture_daily

Day and Night Time Soil Moisture Derived from
TMI and Land Parameter Retrieval Model

Note:
Giovanni-3 may not be available after August 2015

TRMM will no longer be functional after a few months



Product limited to 38° S to 38° N

GLDAS from Giovanni-3

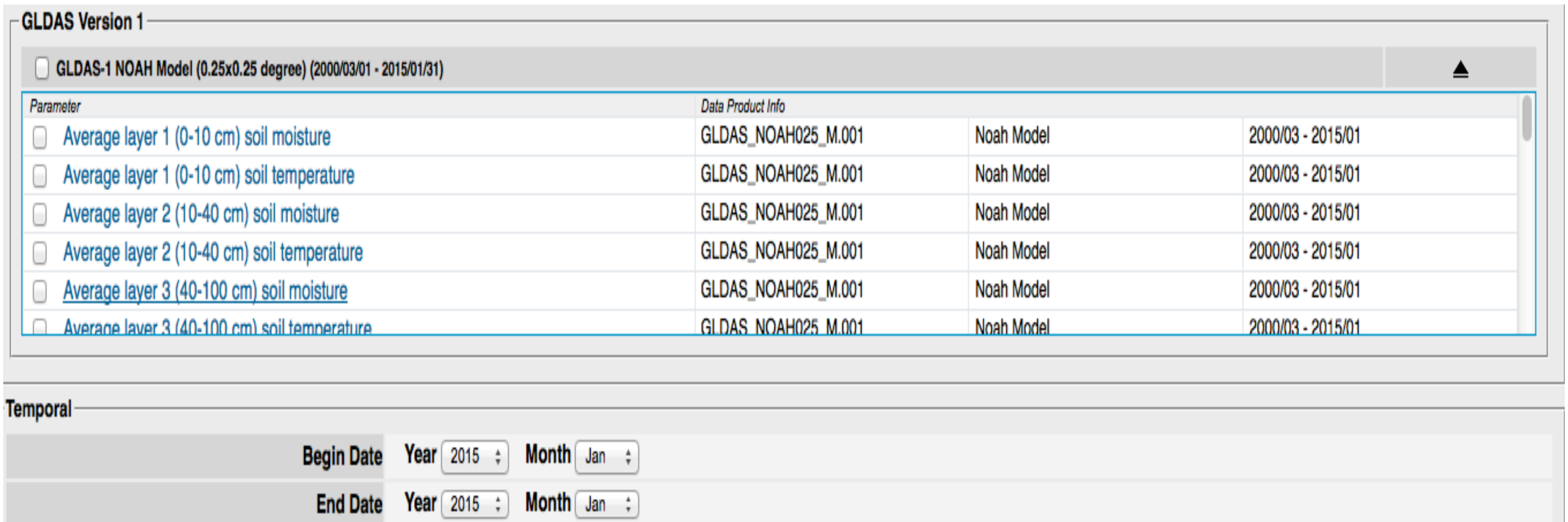
(Will Be available from Giovanni-4 after August 2015)

http://disc.sci.gsfc.nasa.gov/giovannii

i

GLDAS Data Available from the Giovanni-3 Hydrology Portal

Multi-layer Soil Moisture

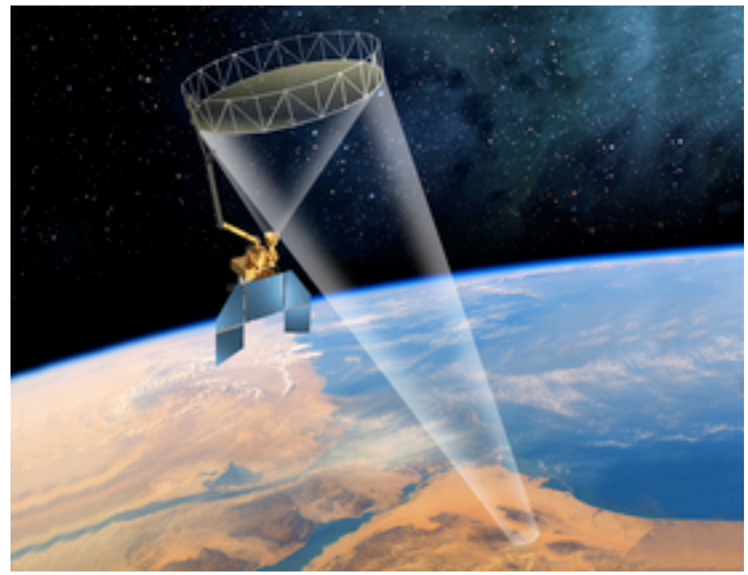


Overview of SMAP

SMAP Mission

http://smap.jpl.nasa.gov/mission

- SMAP is designed to measure the amount of water in **the top 5 cm (2 inches)** of soil everywhere on Earth's surface
- SMAP will also determine if the ground is frozen or thawed in colder areas of the world
- SMAP will produce global maps of soil moisture



SMAP was launched on
31 January 2015

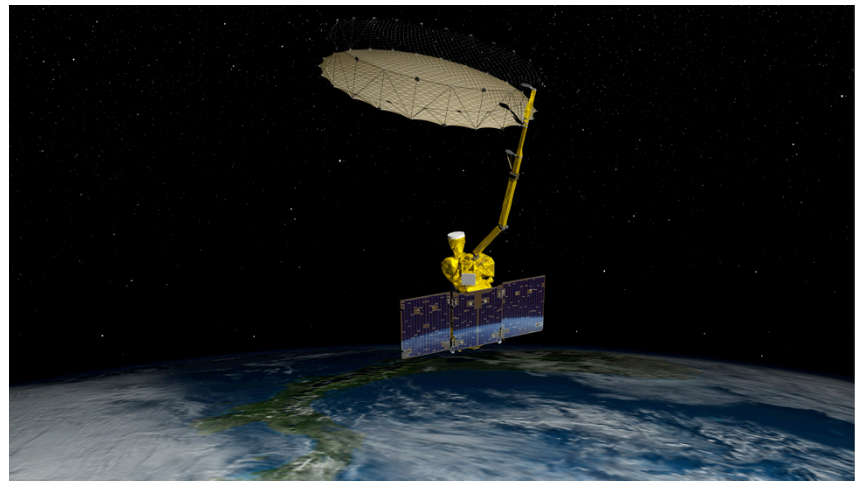
SMAP Mission

http://smap.jpl.nasa.gov/observatory/specifications/

- SMAP is in a near-polar orbit:

Altitude
685 km
Repeat Ground Track 8 Days
Measurements: 6 am/pm

- SMAP mission life is expected to be ~3 years
- SMAP coverage:
  Global land area at **three-day average intervals**,
  Land region above **45N at two-day average intervals**



20-foot (6-meter) reflector antenna on NASA's new Soil Moisture Active Passive (SMAP) observatory to begin spinning for the first time.

SMAP Sensors

http://smap.jpl.nasa.gov/observatory/specifications/

SMAP carries two sensors

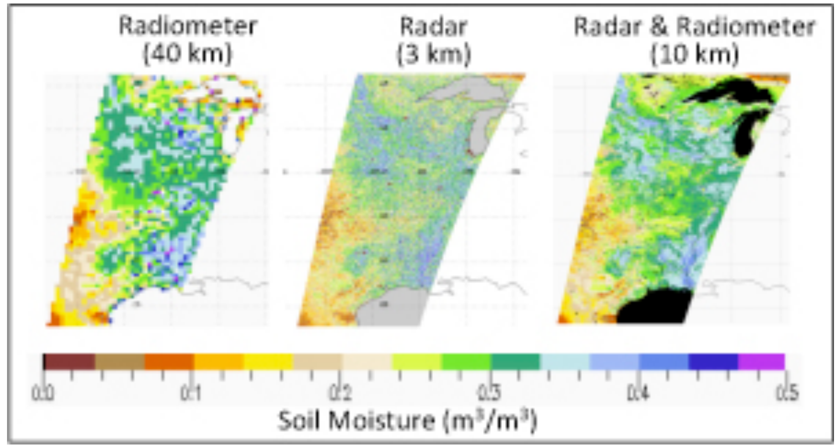
Sensor	Frequency (L-Band)	Spatial Resolution
Radar (Synthetic Aperture)	1.26 Ghz	10 km Soil Moisture 1-3 km Freeze-Thaw
Radiometer	1.41 Ghz	40 km (IFOV 38 km x 49 km)

SMAP Data Products

http://smap.jpl.nasa.gov/data/

SMAP Data Products Include Soil Moisture Content and Freeze-Thaw Sate

- More accurate soil moisture data from the radiometer with lower resolution (36 km) are combined with higher resolution (3 km) but less accurate moisture data from the radar
- The combined data provide accurate soil moisture (units m^3/m^3) maps with resolution of 9 km



SMAP algorithm details can be found at http://smap-archive.jpl.nasa.gov/science/dataproducts/ATBD/

SMAP Data Products

http://smap.jpl.nasa.gov/data/

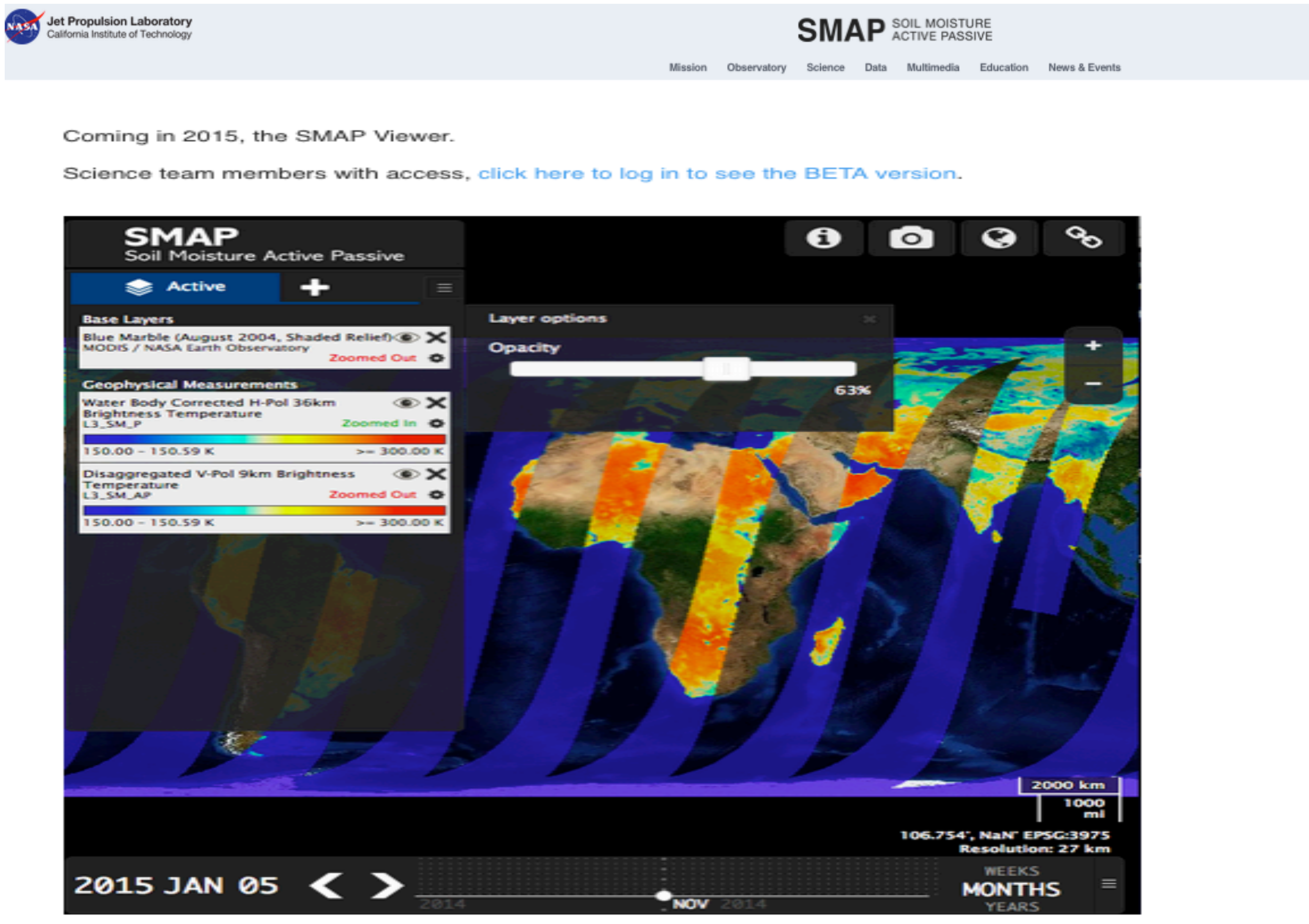
Product	Description	Gridding (Resolution)	Latency**	
L1A_Radiometer	Radiometer Data in Time-Order	-	12 hrs	Instrument Data
L1A_Radar	Radar Data in Time-Order	-	12 hrs	
L1B_TB	Radiometer T_B in Time-Order	(36×47 km)	12 hrs	
L1B_S0_LoRes	Low-Resolution Radar σ_o in Time-Order	(5×30 km)	12 hrs	
L1C_S0_HiRes	High-Resolution Radar σ_o in Half-Orbits	1 km (1–3 km)#	12 hrs	
L1C_TB	Radiometer T_B in Half-Orbits	36 km	12 hrs	
L2_SM_A	Soil Moisture (Radar)	3 km	24 hrs	Science Data (Half-Orbit)
L2_SM_P*	Soil Moisture (Radiometer)	36 km	24 hrs	
L2_SM_AP*	Soil Moisture (Radar + Radiometer)	9 km	24 hrs	
L3_FT_A*	Freeze/Thaw State (Radar)	3 km	50 hrs	Science Data (Daily Composite)
L3_SM_A	Soil Moisture (Radar)	3 km	50 hrs	
L3_SM_P*	Soil Moisture (Radiometer)	36 km	50 hrs	
L3_SM_AP*	Soil Moisture (Radar + Radiometer)	9 km	50 hrs	
L4_SM	Soil Moisture (Surface and Root Zone)	9 km	7 days	Science Value-Added
L4_C	Carbon Net Ecosystem Exchange (NEE)	9 km	14 days	

Over outer 70% of swath.
** The SMAP Project will make a best effort to reduce the data latencies beyond those shown in this table.
* Product directly addresses the mission L1 science requirements.

SMAP Data Merged with Land Surface Model

SMAP Data Viewer Coming Soon

http://smap.jpl.nasa.gov/map/



SMAP Data Products Portals

http://smap.jpl.nasa.gov/data/

- The SMAP data products will be available to the public through two NASA-designated Earth science data centers

  The Alaska Satellite Facility (Level 1 radar products)
  https://www.asf.alaska.edu/

  The National Snow and Ice Data Center (all other products) http://nsidc.org/

- Format: Hierarchical Data Format version 5 (HDF-5)

SMAP Data Products Availability

http://smap.jpl.nasa.gov/data/

- The SMAP mission is currently conducting a post-launch calibration and validation (Cal/Val)

- The duration of the Cal/Val phase:

  6 months for Level 1 products
  12 months for Level 2, Level 3, and Level 4 products

SMAP Data Products Strengths

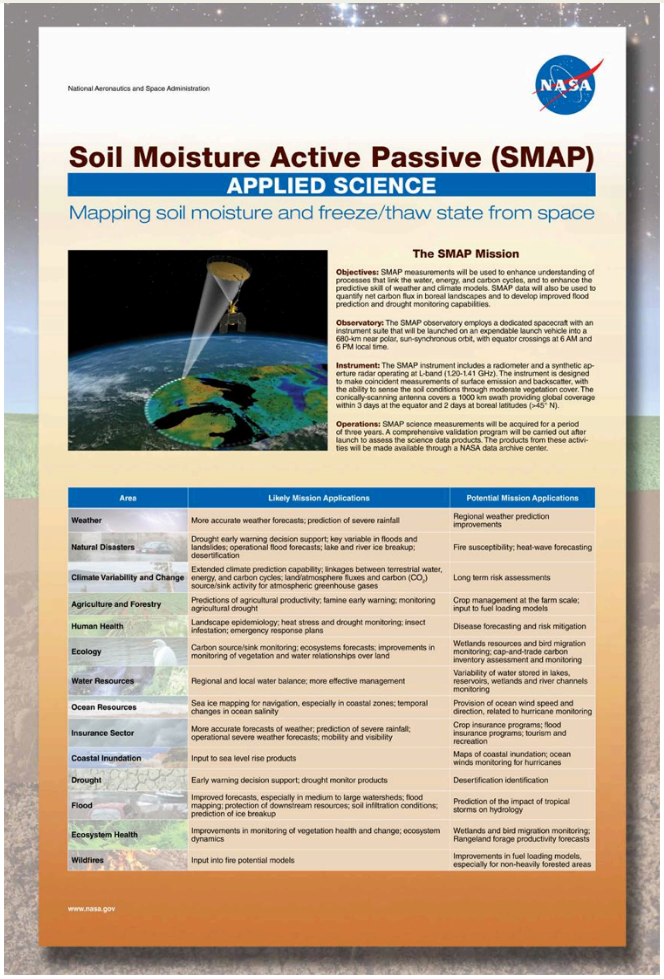
- High-resolution and high-accuracy than earlier soil moisture data from AMSR-E/TMI
- Better sensing over vegetated surface
- Deeper soil moisture (1-5 cm) available
- Freeze-Thaw state available

SMAP Applications

SMAP Application Areas

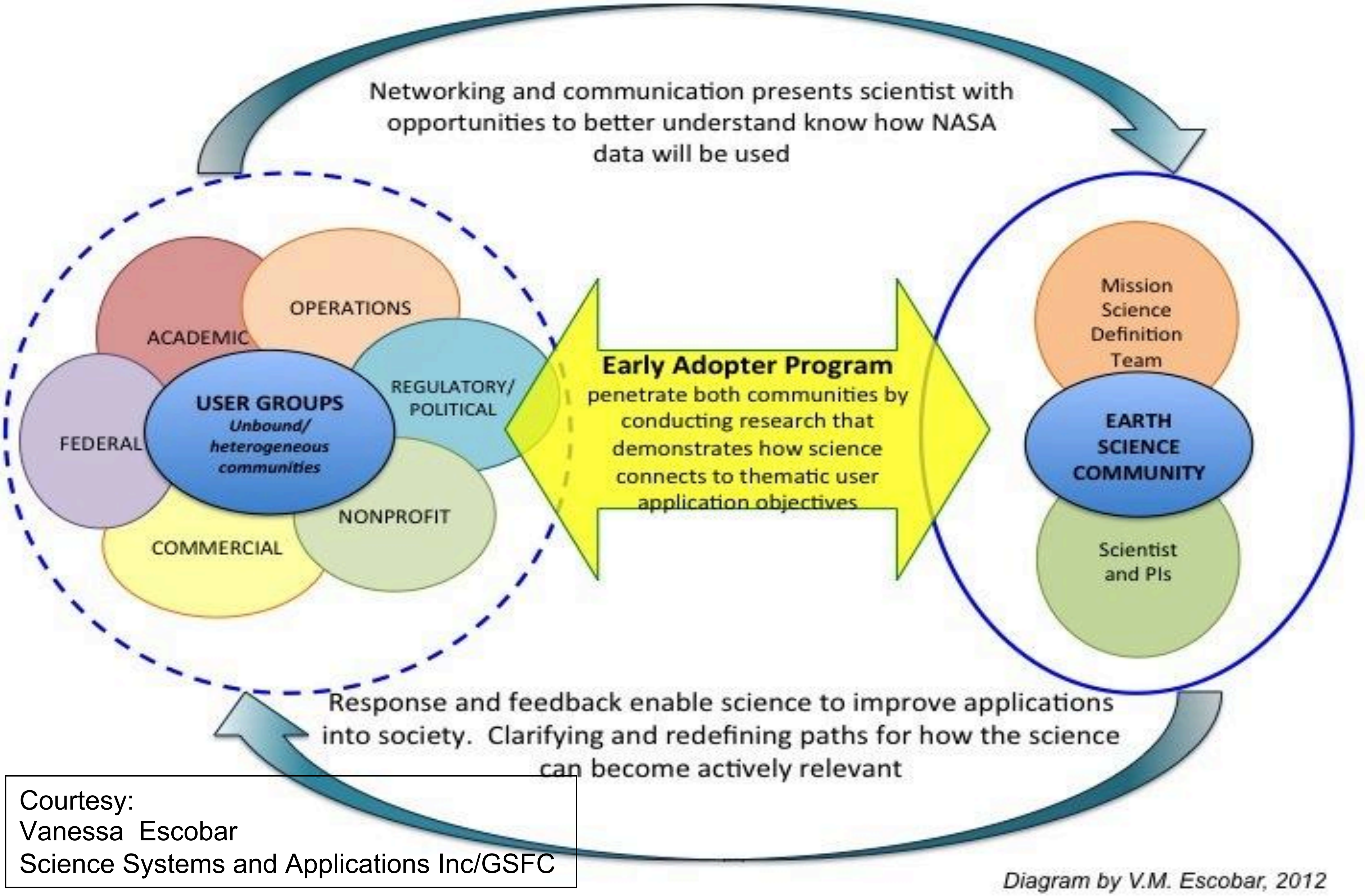
http://smap.jpl.nasa.gov/science/applications/

Applied Science Poster available from the SMAP Applications Web-site



- Weather and Climate Forecasting
- Droughts and Wildfires
- Floods and Landslides
- Agricultural Productivity
- Human Health
- National Security

SMAP Early Adopter Concept



Courtesy:
Vanessa Escobar
Science Systems and Applications Inc/GSFC

SMAP Early Adopters		
	Investigator and Institution	**Applications Research Topic**
Selected in 2011		
1	**Stephane Belair**, Meteorological Research Division, Environment Canada (EC)	*Assimilation and impact evaluation of observations from the SMAP mission in Environment Canada's Environmental Prediction Systems*
2	**Hosni Ghedira**, Masdar Institute, UAE	*Estimating and mapping the extent of Saharan dust emissions using SMAP-derived soil moisture data*
3	**Zhengwei Yang and Rick Mueller**, USDA National Agricultural Statistical Service (NASS)	*U.S. National cropland soil moisture monitoring using SMAP*
4	**Catherine Champagne**, Agriculture and Agri-Food Canada (AAFC)	*Soil moisture monitoring in Canada*
5	**Amor Ines and Stephen Zebiak,** International Research Institute for Climate and Society (IRI) Columbia University	*Seasonal climate forecasts with dynamic crop simulation models for crop forecasting and food security early warning applications*
6	**Lars Isaksen and Patricia de Rosnay**, European Centre for Medium-Range Weather Forecasts (ECMWF)	*Monitoring SMAP soil moisture and brightness temperature at ECMWF*
7	**Xiwu Zhan, Michael Ek and John Simko**, NOAA National Environmental Satellite Data and Information Service, Center for Satellite Applications and Research (NOAA-NESDIS-STAR)	*Transition of NASA SMAP research products to NOAA operational numerical weather and seasonal climate predictions and research hydrological forecasts*
Selected in 2012		
8	**Curt Reynolds**, USDA Foreign Agricultural Service (FAS)	*Enhancing USDA's global crop production moni SMAP soil moisture products*
9	**John Eylander**, U.S. Army Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL)	*U.S. Army Engineer Research and Development adoption for USACE civil and military tactical s*
10	**Jim Reardon and Gary Curcio**, US Forest Service (USFS)	*Wildfire danger and estimated smoldering pote soils of the North Carolina coastal plain*
11	**Gary McWilliams, Li Li, Andrew Jones and George Mason**, Dept. of Defense - Soil Moisture Applications Consortium (SMAC)	*Exploitation of SMAP data for Army and Marine assessment*
12	**Michael Ek, Marouane Temimi, Xiwu Zhan**, NOAA National Centers for Environmental Prediction (NCEP)	*Integration of SMAP freeze/thaw product into the NOAA NCEP weather forecast models*
13	**John Galantowicz**, Atmospheric and Environmental Research, Inc. (AER)	*Use of SMAP-derived inundation and soil moisture estimates in the quantification of biogenic greenhouse gas emissions*
14	**Jingfeng Wang, Rafael Bras and Aris Georgakakos**, Georgia Institute of Technology (GIT)	*Application of SMAP observations in modeling energy/water/carbon cycles and its impact on weather and climatic predictions*
15	**Kyle McDonald**, City College of New York (CUNY) and CREST Institute, and **Don Pierson**, New York City Dept. of Environmental Protection	*Application of SMAP freeze/thaw and soil moisture products for supporting management of New York City's potable water supply*
16	**Chris Funk, Amy McNally and James Verdin**, US Geological Survey & UC Santa Barbara	*Incorporating soil moisture retrievals into the Famine Early Warning System (FEWS) Land Data Assimilation System (FLDAS)*
17	**Fiona Shaw**, Willis, Global Analytics	*eNCOMPASS – A risk identification and analysis system for insurance; Multiple catastrophe risk models, risk rating tools and risk indices for insurance and reinsurance purposes including a Global Flood Model*
18	**Rafael Ameller**, StormCenter Communications, Inc.	*SMAP for enhanced decision making (emergency management)*
Selected in 2013		
19	**Jonathan Case and Clay Blankenship,** Marshall Space Flight Center and Universites Space Flight Center	*Application of Next-Generation Satellite Data to a High-Resolution, Real-Time Land Surface Model with SMAP.*
20	**Barbara S. Minske**, University of Illinois and sponsored by John Deere Inc.	*Comprehensive, Large-Scale Agriculture and Hydrologic data Synthesis*
21	**Thomas Harris,** Exelis Visual Information Solutions	*Utilization of SMAP Products in ENVI, IDL and SARscape-Products L1 to L4*

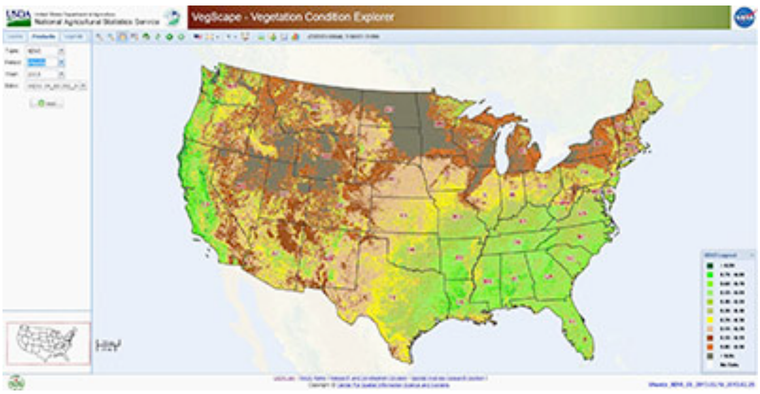
Courtesy:
Vanessa Escobar
Science Systems and Applications Inc/GSFC

SMAP Early Adopters through mid 2013

SMAP Early Adopters Examples

http://smap.jpl.nasa.gov/science/early-adopters/

USDA has VegScape for accessing, visualizing, assessing and disseminating crop soil moisture condition derivative data products produced using SMAP data



USDA VegScape Application

Global Insurance and Re-Insurance

Willis Global Analytics is merging satellite data from NASA into existing risk identification and analysis systems for insurance and reinsurance, engaging end users to enhance decision making with SMAP products.

Vegetation Index Data and Access

What is Vegetation Index ? Why is it Important?

http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php

- Vegetation plays an important role in the hydrology cycle **through the process of evapotranspiration**

- "Vegetation Index": quantifies the concentrations of green leaf **vegetation around the globe from remote sensing observations**

- To determine the density of green on a patch of land, the distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants are observed by the satellite sensors

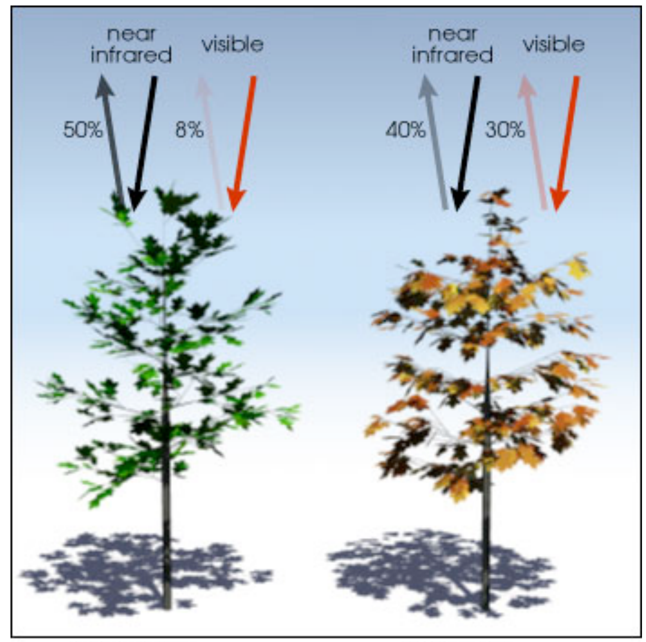
What is Vegetation Index

http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php

- Normalized Difference Vegetation Index (NDVI) is defined as :
  NDVI = (NIR — VIS)/(NIR + VIS)

[NIR is near-infrared and VIS is Visible radiation observed by remote sensing]

- NDVI is used as a drought indicator and to estimate land evapotranspiration



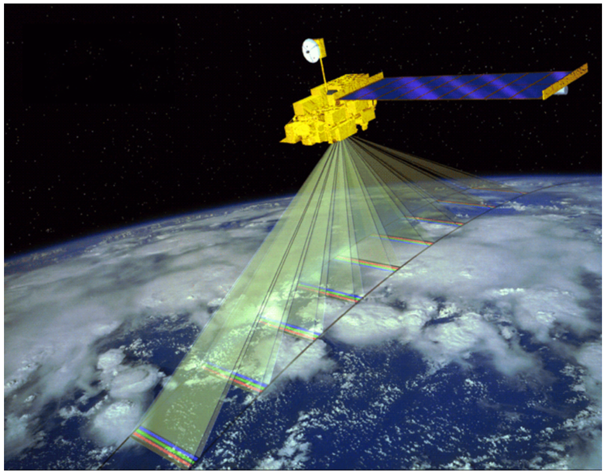
$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

NDVI is calculated from the visible and near-infrared light reflected by vegetation. Healthy vegetation (left) absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation (right) reflects more visible light and less near-infrared light.

We will focus on derived from Terra/Aqua MODIS

Review of MODIS
(Moderate Resolution Imaging Spectroradiometer)

http://modis.gsfc.nasa.gov



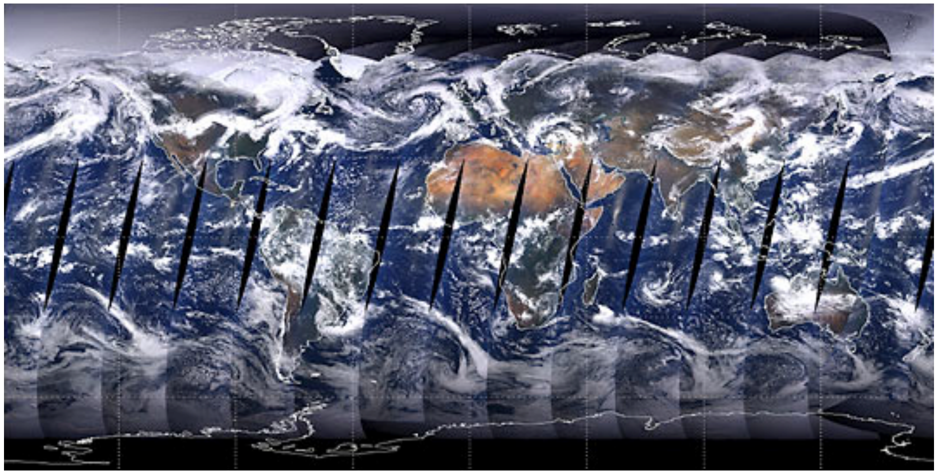
Flying on Terra and Aqua

Spatial Resolution

250m, 500m, 1km

Temporal Resolution

Daily, 8-day, 16-day, monthly, quarterly, year (2000-present)



Spectral Coverage

36 bands (major bands include Red, Blue, IR, NIR, MIR)

Bands 1-2: 250m

Bands 3-7: 500m

Bands 8-36: 1000m

MODIS NDVI Data Products and Access

http://modis-land.gsfc.nasa.gov/vi.htm

Data can be accessed through
Land Processes Distributed Active Archive (LP DAAC)
https://lpdaac.usgs.gov/products/modis_products_table

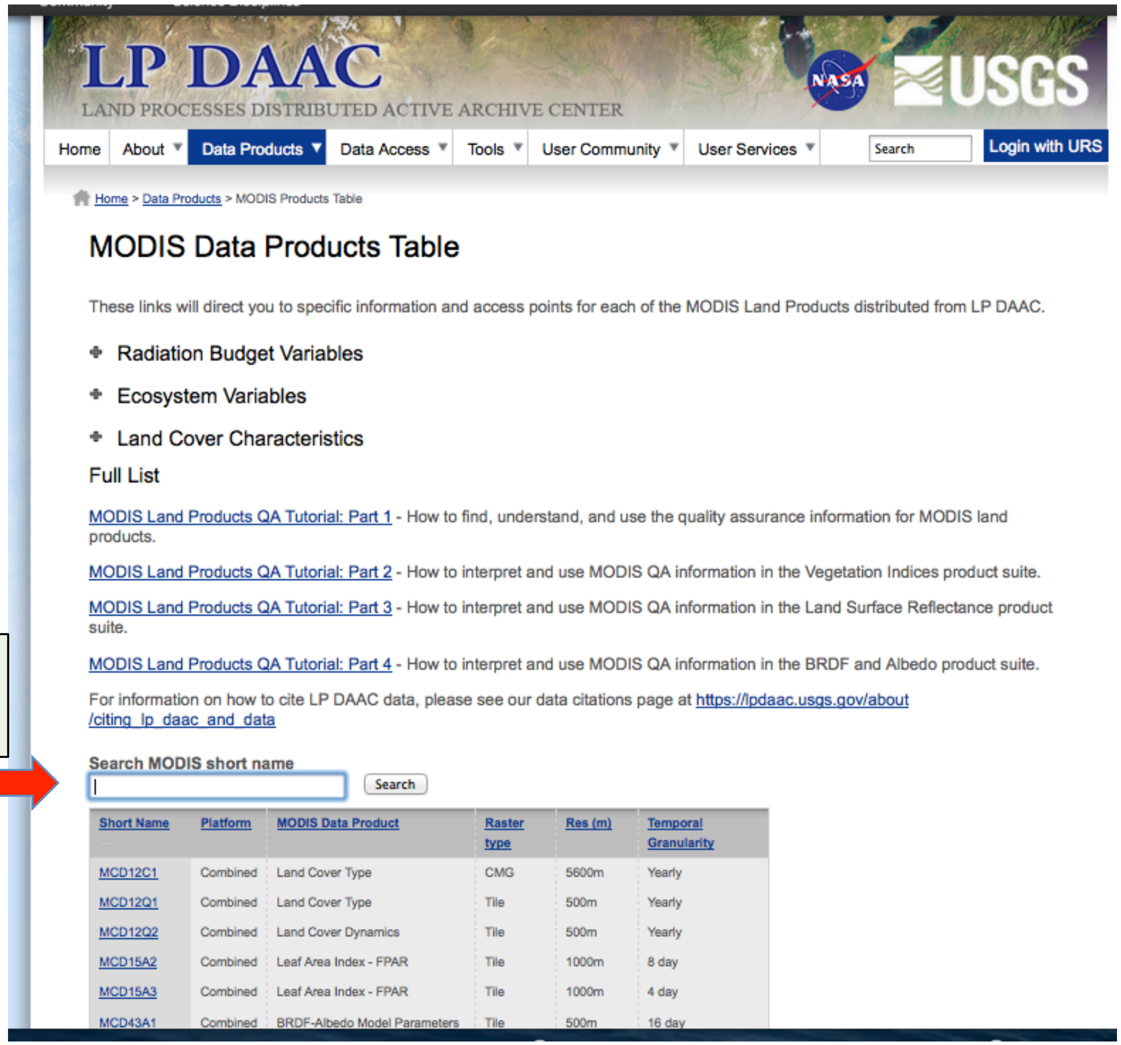
See links below to the Product Description pages posted at the LP DAAC (product details, data access links, and more....)

Product Name	Terra Product ID	Aqua Product ID
Vegetation Indices 16-Day L3 Global 250m	MOD13Q1	MYD13Q1
Vegetation Indices 16-Day L3 Global 500m	MOD13A1	MYD13A1
Vegetation Indices 16-Day L3 Global 1km	MOD13A2	MYD13A2
Vegetation Indices 16-Day L3 Global 0.05Deg CMG	MOD13C1	MYD13C1
Vegetation Indices Monthly L3 Global 1km	MOD13A3	MYD13A3
Vegetation Indices Monthly L3 Global 0.05Deg CMG	MOD13C2	MYD13C2

MODIS NDVI Data Products and Information

https://lpdaac.usgs.gov/products/modis_products_table

Product Search



MODIS NDVI Data Characteristics

Basic Info | Data Policies | Data Access | Help

Data Set Characteristics

Click to get the data will lead to multiple data download options

Temporal Coverage	
Area	~10 x 10 lat/long
File Size	~30 MB
Projection	Sinusoidal
Data Format	HDF-EOS
Dimensions	2400 x 2400 rows/columns
Resolution	500 meters
Science Data Sets (SDS HDF Layers)	12

MODIS NDVI Data Access

Data Access Tools

Data Pool: The Data Pool (On-line Archive) provides access to all MODIS products. https://lpdaac.usgs.gov/data_access/data_pool

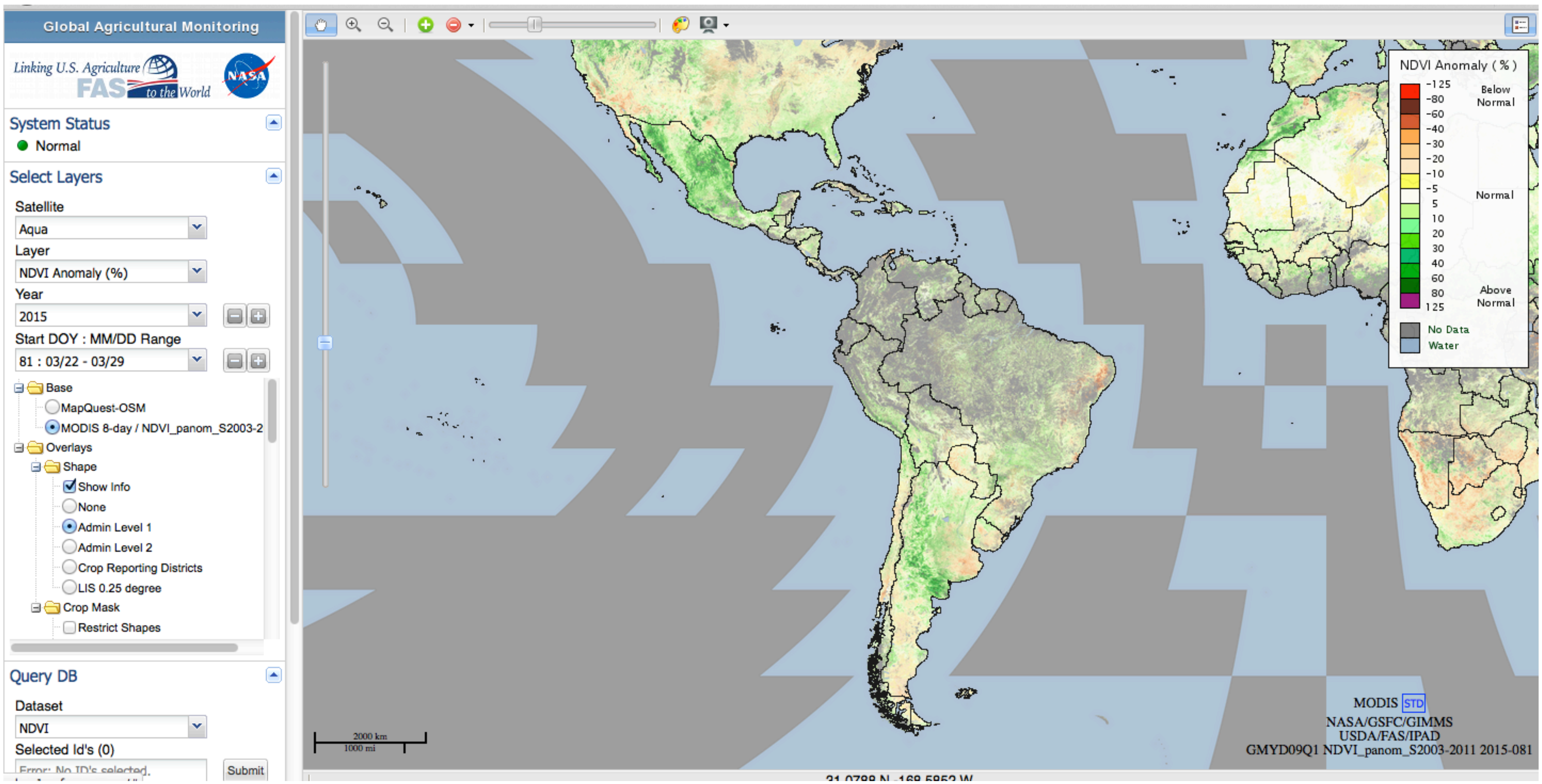
Reverb: This tool provides access to a complete data record of all MODIS products available from the LP DAAC. http://reverb.echo.nasa.gov

GloVis: The Global Visualization interface provides access to tiled MODIS products that have an associated browse image. http://glovis.usgs.gov

MRTWeb: The MODIS Reprojection Tool Web interface provides access to all MRT services offered by the stand-alone MRT. http://mrtweb.cr.usgs.gov

Visualize MODIS NDVI Anomalies Using Global Agriculture Monitoring

http://glam1.gsfc.nasa.gov/



Visualize MODIS NDVI Anomalies Using Global Agriculture Monitoring (GLAM)

http://glam1.gsfc.nasa.gov/

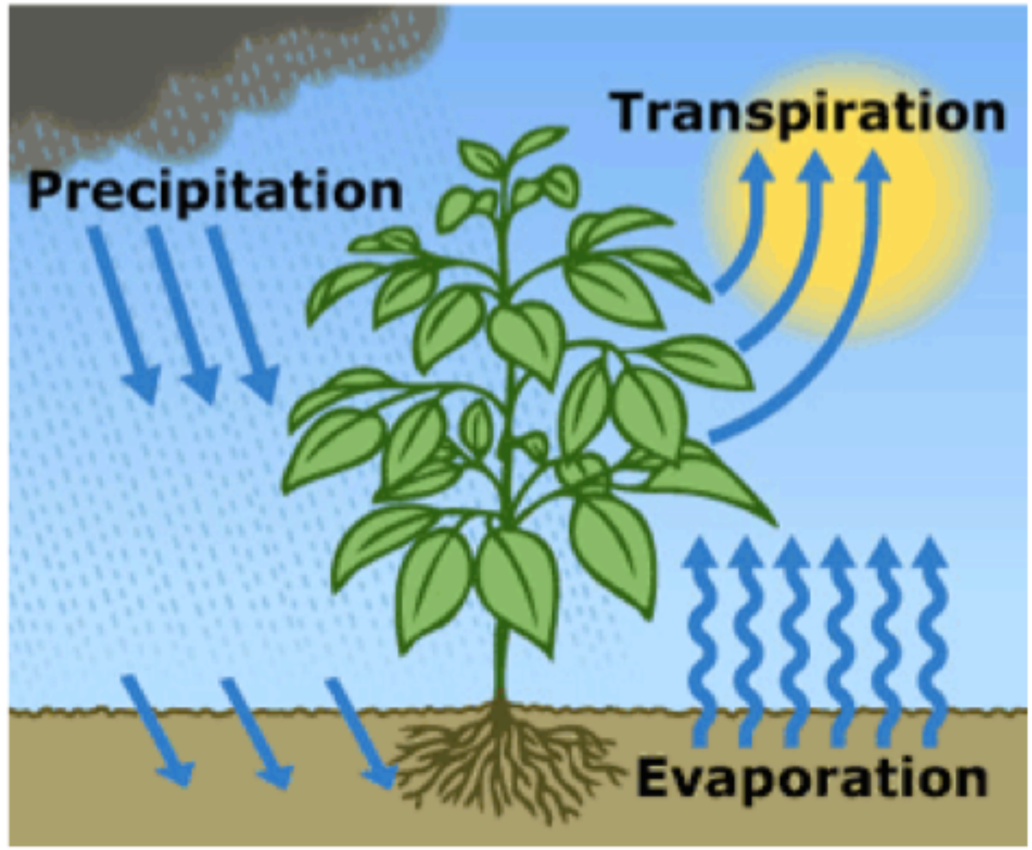
Live Demo of GLAM

Evapotranspiration

What is Evapotranspiration (ET)?

The sum of evaporation from the land surface plus transpiration from plants

ET is an important component of hydrology cycle -- represents loss of water to atmosphere from land and vegetation



Source: USGS

Evapotranspiration From Remote Sensing Data

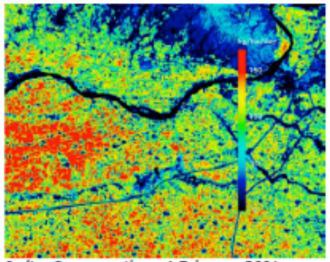
METHODS FOR DERIVING ET:

ENERGY BALANCE AND VEGETATION INDICES

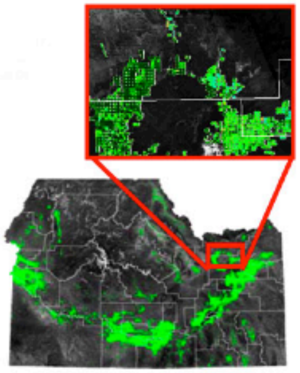
ET Obtained From Landsat Using Energy Balance

ET, Landsat and Energy Balance: SEBAL and *METRIC*tm

- SEBAL –
  - Surface-Energy Balance Algorithm for Land
  - Developed by Dr. Wim Bastiaanssen (Netherlands)
  - Applications: ET and crop productivity
- METRIC
  - Mapping Evapotranspiration with High Resolution and Internalized Calibration
  - Developed by Dr. Rick Allen, University of Idaho



India: Crop growth on 4 February 2001



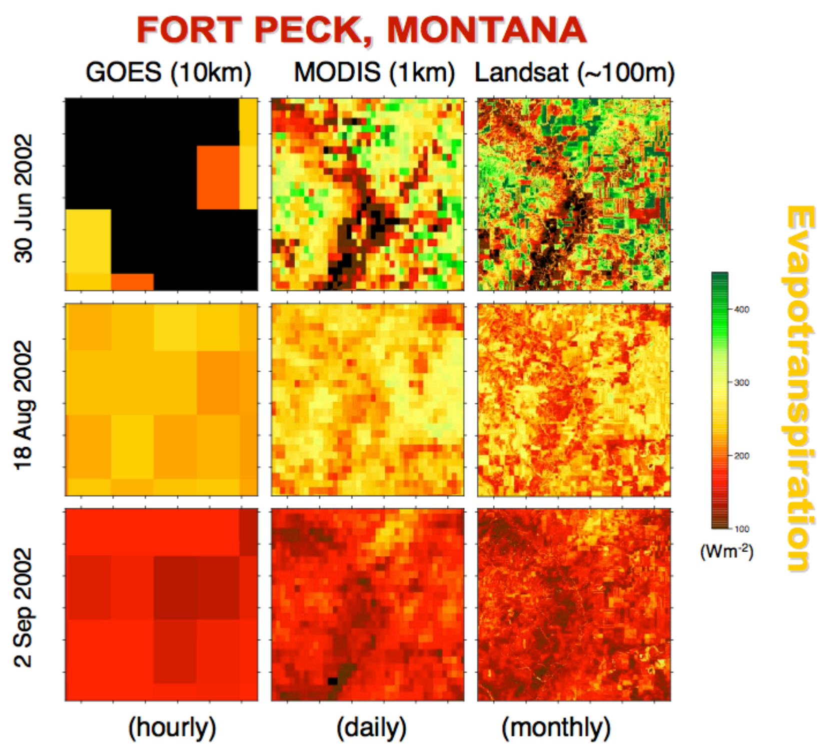
Agricultural evapotranspiration for southern Idaho. Image courtesy of IDWR.

Source: Rick Allen, University of Idaho

ET Obtained Using Energy Balance Approach With Landsat, MODIS, and GOES* Observations

The Atmosphere-Land Exchange Inverse (ALEXI) and Disaggregation ALEXI (DisALEXI)

http://hyspiri.jpl.nasa.gov/downloads/2010_workshop/day1/day1_13_anderson_hyspiri_2010_anderson.pdf



Available over US

*GOES – NOAA geostationary Satellite

ET Obtained From Vegetation Index

Application of ET Derived from NDVI

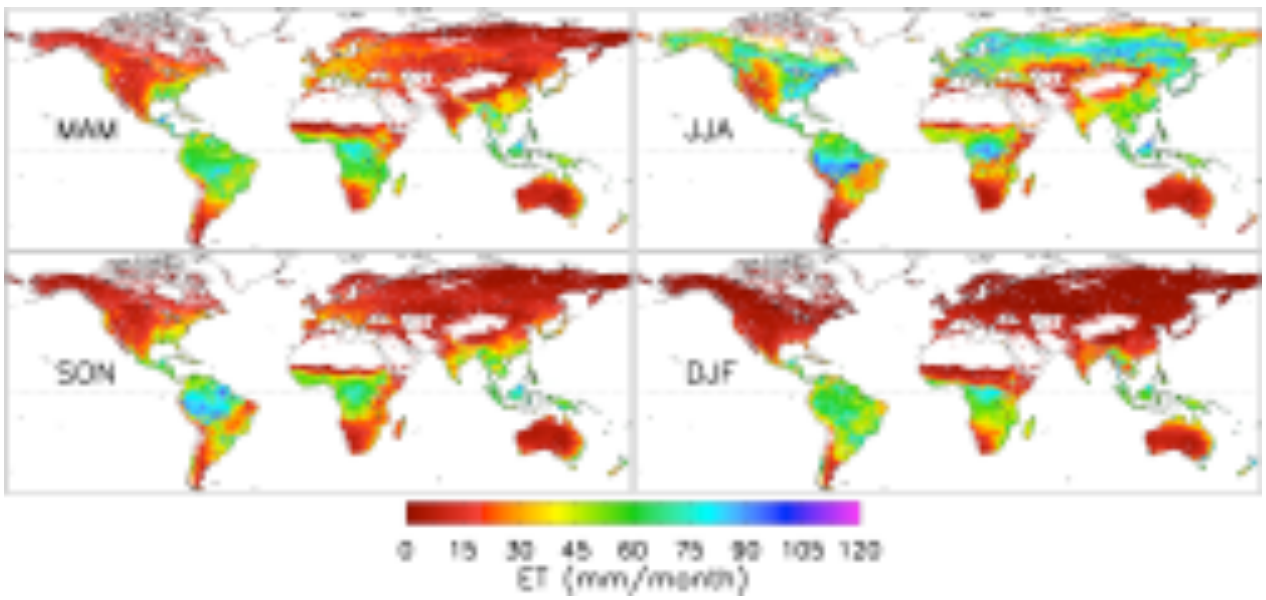
- Landsat imagery was used to map crop development and crop water demand throughout California's Central Valley, Central Coast, and North Coast at ¼ acre resolution from 2010-2012.
- A web-interface was developed for agricultural producers and water managers to understand crop canopy conditions and irrigation demand.
- This project was conducted by the Ecological Forecasting Lab at NASA Ames Research Center.

Available over California Central Valley

ET Obtained From MODIS Land Cover

MODIS Global Evapotranspiration Project (MOD16)

http://ntsg.umt.edu/project/mod16



Seasonality of Global ET:

1 km, 8-Day and Monthly

Next:

Hands-on Activity:

Learn to Import Remote Sensing Data into GIS