

Welcome to

NASA Applied Remote Sensing Training Program (ARSET) Webinar Series

27 November 2012 : Week-4

Introduction to Remote Sensing Data for Flood and Drought Monitoring

Course Dates: Every Tuesday, November 6 - December 4, 2012

ARSET

Applied Remote SEnsing Training

A project of NASA Applied Sciences



Webinar Presentations can be found on:

<http://water.gsfc.nasa.gov/webinars/>

For Webinar Recording Link :

Contact : Marines Martins

Email: marines.martins@ssaihq.com

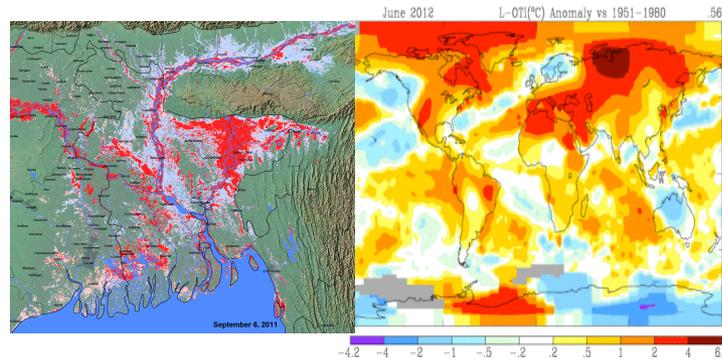
Course Outline

Week 1



**Intro. & Background:
Satellite Remote Sensing**

Week 2



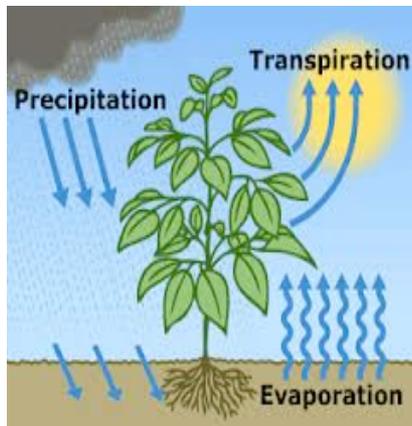
**Flood and Drought
[Rainfall, Weather and
Climate Data]**

Week 3



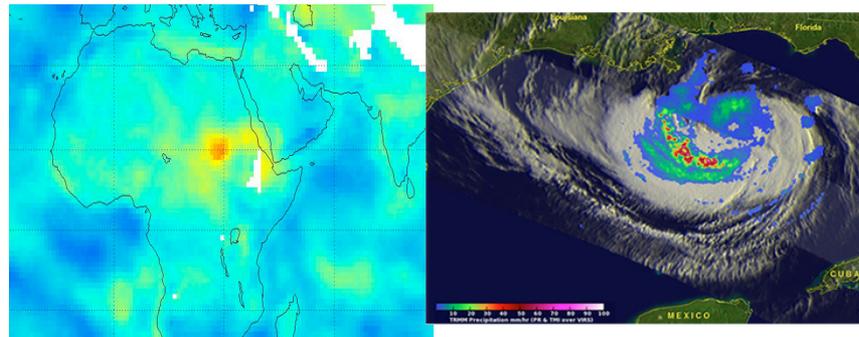
Web-tools

Week 4



Evapotranspiration

Week 5



Data Applications/ Case Studies

Satellite-Derived Evapotranspiration Mapping for Water Resource Management

NASA Remote Sensing Training
Presented by Cindy Schmidt (ARSET)
with contributions from
David Toll ,Rick Allen and Forrest Melton

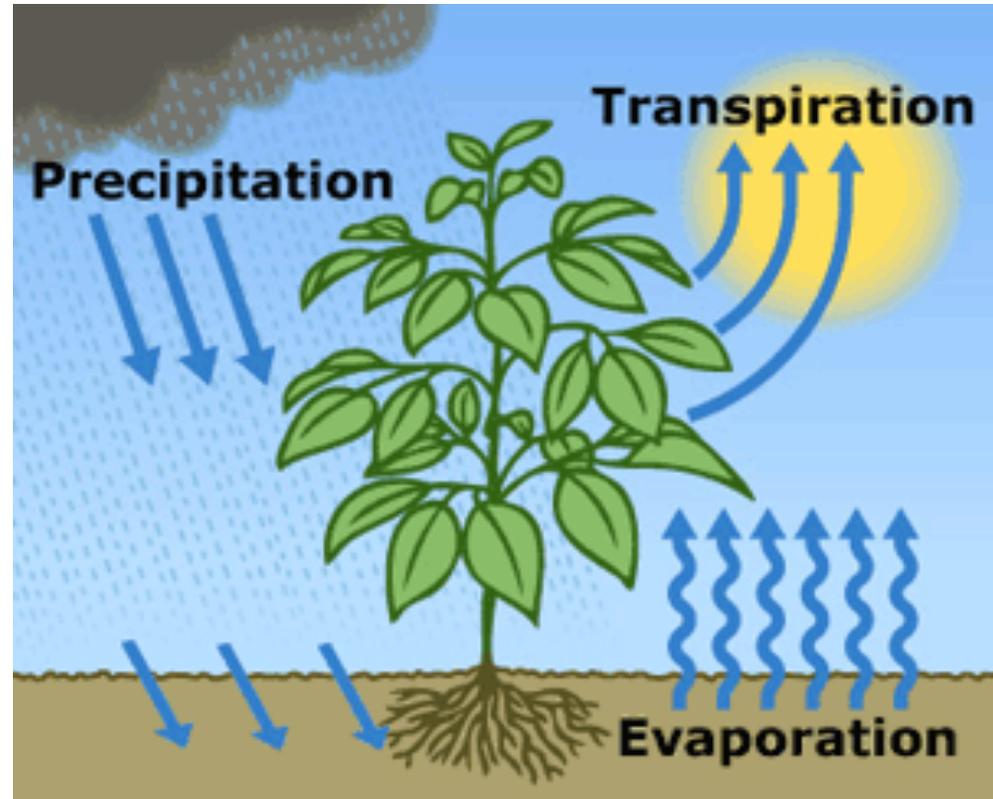
ARSET
Applied Remote **SE**nsing **T**rainig

A project of NASA Applied Sciences



What is Evapotranspiration?

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



Source: USGS

Overview

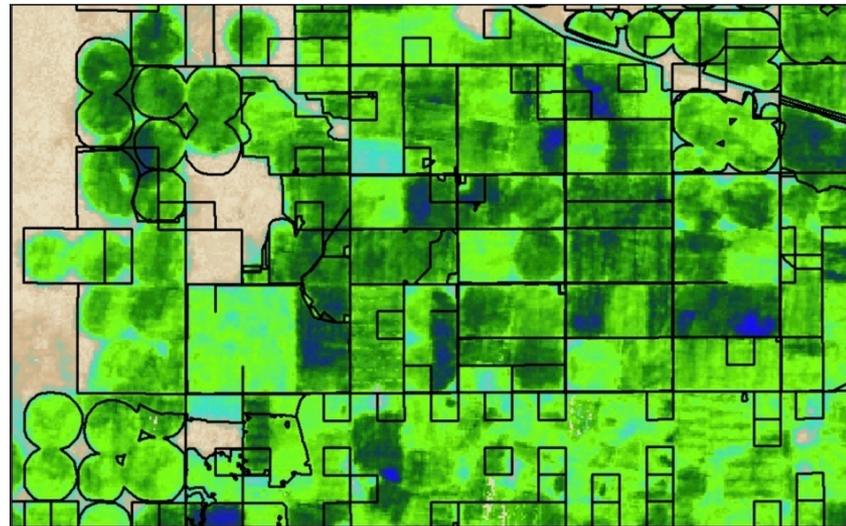
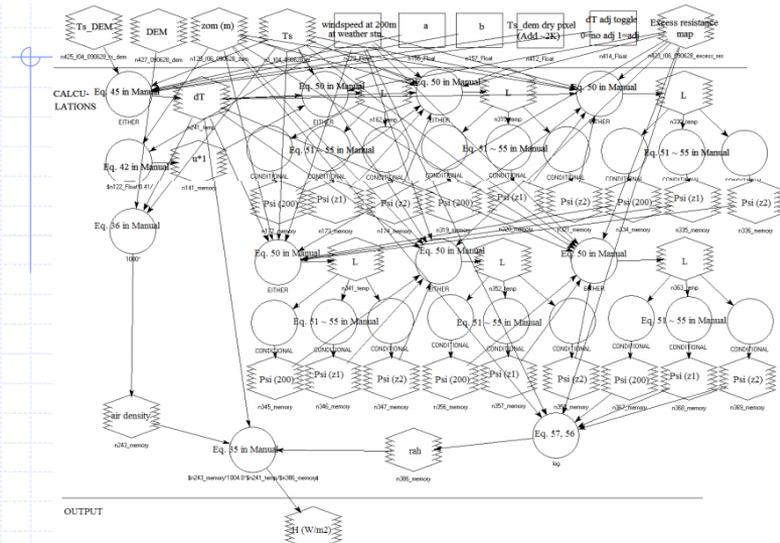
- Importance of ET
- Challenges of Measuring ET
- Benefits and opportunities of using remote sensing for ET
- Methods of deriving ET using remote sensing:
 - Pros and Cons
 - Applications of ET
- Summary

Importance of ET

- Critical component of water and energy balance of climate-soil-vegetation interactions.
- Used for
 - Determining agricultural water consumption
 - Assessing drought conditions
 - Develop water budgets
 - Monitor aquifer depletion
 - Etc....

Challenges of Measuring ET

- ET is complex (many variables)
- ET varies across time and space (A LOT!)



Main Limitation of ET Ground Measurements

They are point measurements and cannot capture spatial variability



Eddy Flux Towers

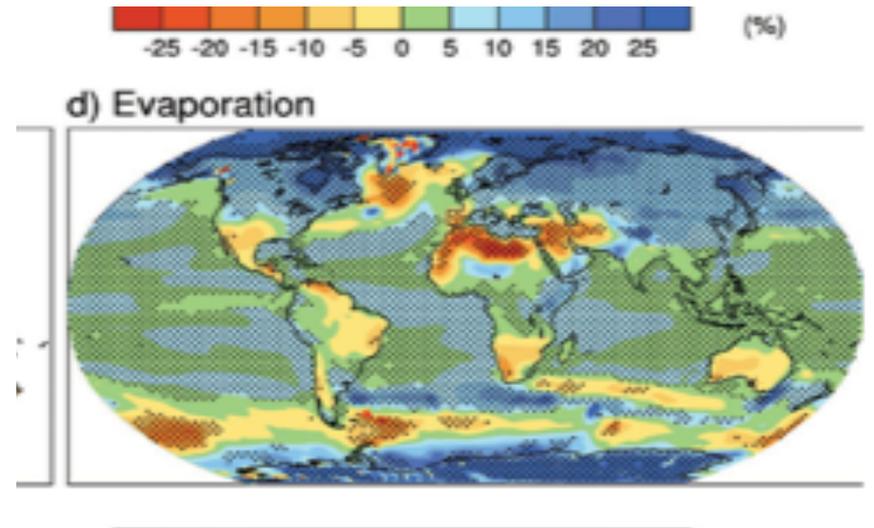
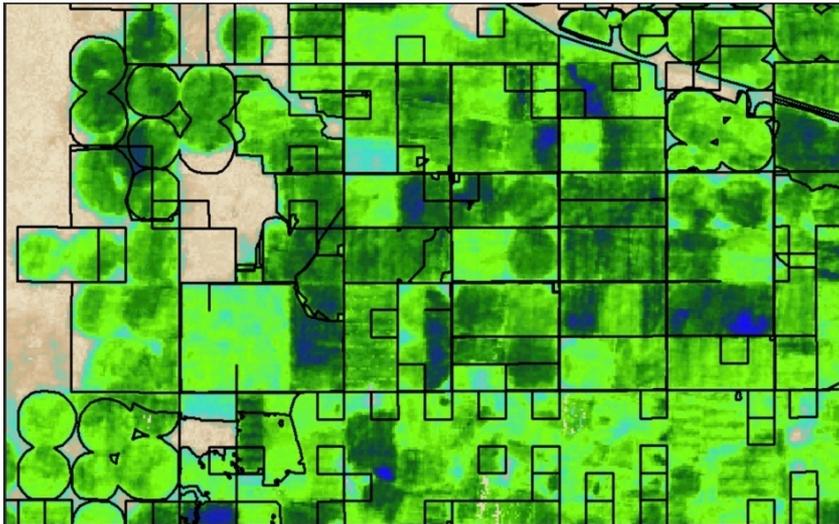


Lysimeters

Benefits of Using Remotely Sensed Satellite Data

Data

- Provides relatively frequent and spatially continuous measurement of biophysical variables at different spatial scales:
 - Radiation
 - Vegetation coverage and density



Methods for Deriving ET

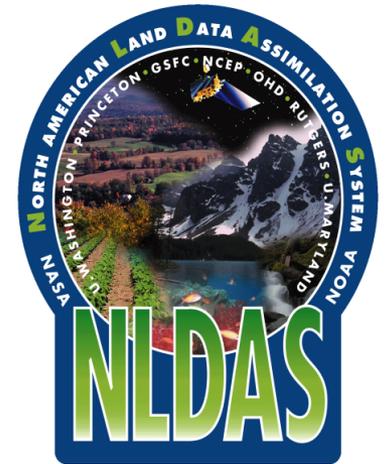
Method	Spatial Resolution	Source	Availability
Land Surface Models: NLDAS/GLDAS	1 - 1/8 degree (Global)	NASA/NOAA	Free/download
Other Physical Models: MODIS	1km (Global)	University of Montana	Free/download
Energy Balance: METRIC/SEBAL	30 m (Local, Regional)	Various	Not Free/contract
Vegetation/ET Relationships	30 m (Local, Regional)	Various	Free/Not Free
ALEXI	10 km – 30 m	USDA	Not yet available

METHODS FOR DERIVING ET:

**NASA'S LAND DATA ASSIMILATION
SYSTEM**

NASA's Land Data Assimilation System (LDAS)

- Use uncoupled land surface models forced with real time output from:
 - Numerical prediction models
 - Satellite data
 - Precipitation measurements
- Provides hourly information in 1/8th degree in near real-time
- Extends back to 1979
- GLDAS (global) and NLDAS (North America)
- Can access data through NLDAS Drought Monitor (NOAA), Giovanni



NLDAS Drought Monitor

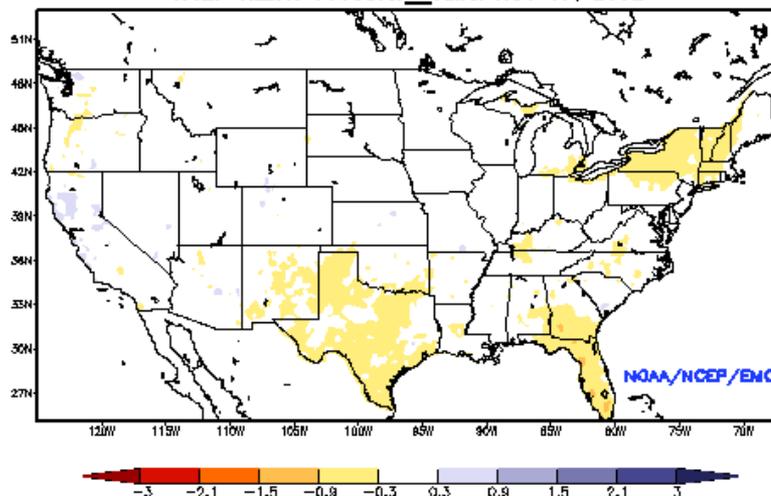
Evapotranspiration

NOTE: This page is best viewed with a screen resolution of at least 1024x768
DISCLAIMER: Any data provided on this server should be used for research or educational purposes only.
This data should NOT be relied on for any operational use as data gaps can occur due to hardware failure and/or model upgrading procedures.

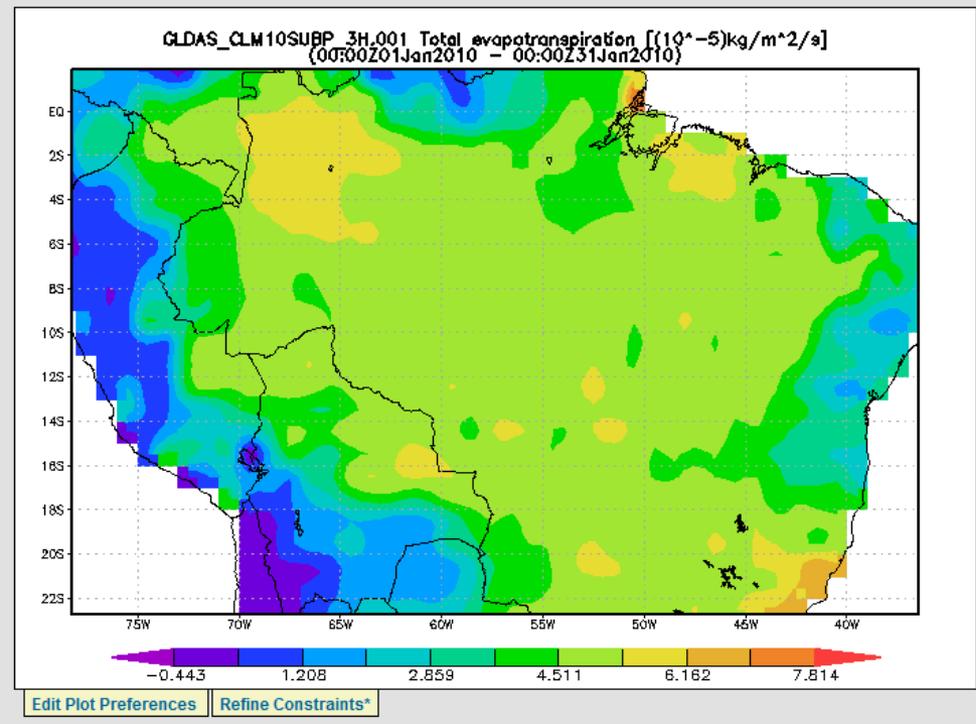
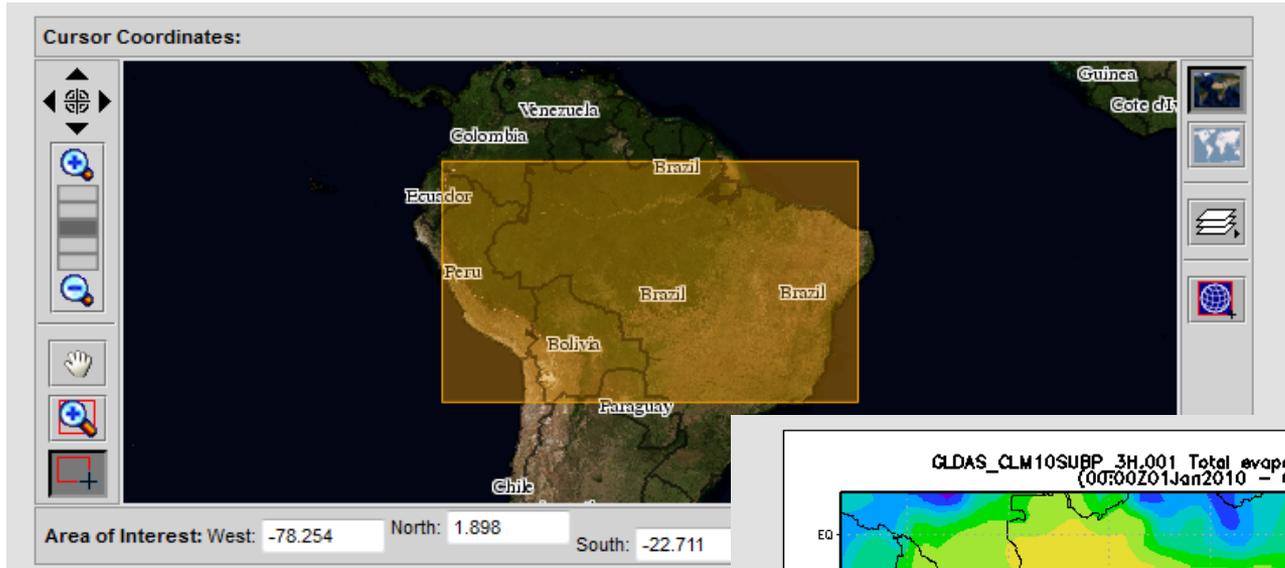
Ensemble Mean LSM OUTPUT:

Current Evapotranspiration Anomaly

Ensemble-Mean: Current Evaporation Anomaly (mm/day)
NCEP NLDAS Products Valid: NOV 17, 2012



ET Data From GLDAS Using Giovanni



Brazil

METHODS FOR DERIVING ET:

MODIS

MODIS-based Global Evapotranspiration and Drought Severity Index products

Qiaozhen Mu, Maosheng Zhao, Steven W. Running

Numerical Terradynamic Simulation Group (NTSG), College
of Forestry & Conservation, The University of Montana,
Missoula

What is MODIS????

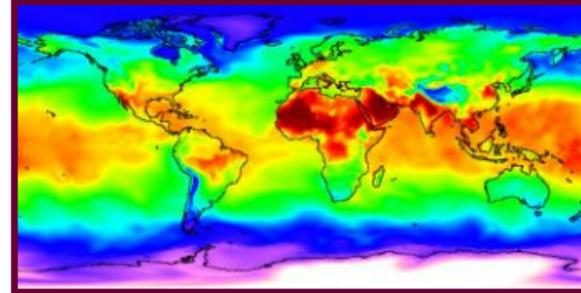
What Is MODIS?

- Moderate Resolution Imaging Spectrometer
- Launched on Terra: December 1999
- Launched on Aqua: May 2002
- Spatial Resolution: 250m, 500m, 1km
- Temporal Resolution: Daily, 8-day, 16-day, monthly, quarterly, yearly
- 36 bands:
 - Radiation Budget (Surface Reflectance, Temperature, Albedo)
 - Ecosystem Variables (Vegetation Indices, Leaf Area Index, etc.)
 - Land Cover Characteristics (Fire, Land Cover)

MODIS and ET



Input MODIS data (RS)
(Albedo, FPAR/LAI, Land cover)



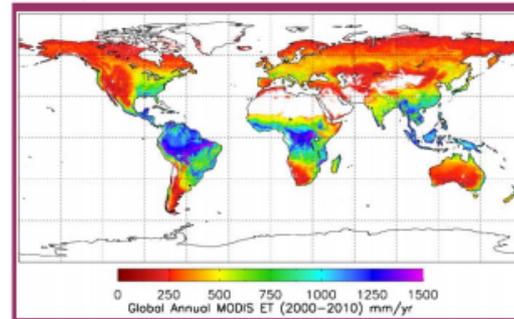
Daily Meteorological data (MET)
(S_{\downarrow} , VPD, Temperature. No Precp!)

Penman-Monteith equation

$$\lambda E = \frac{\Delta \cdot R_a \cdot (R_n - G) + \rho \cdot C_p \cdot VPD}{R_a \cdot (\gamma + \Delta) + \gamma \cdot R_s}$$

MODIS ET: soil evaporation, evaporation from intercepted water by canopy and plant transpiration.

$$ET = f(RS, MET)$$

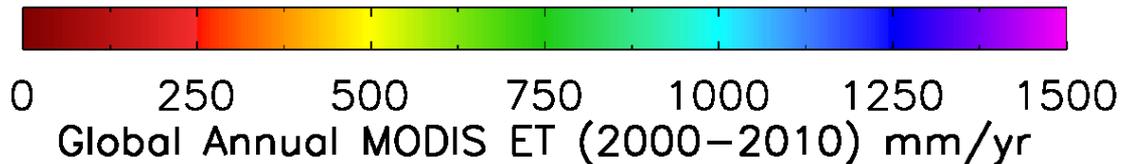
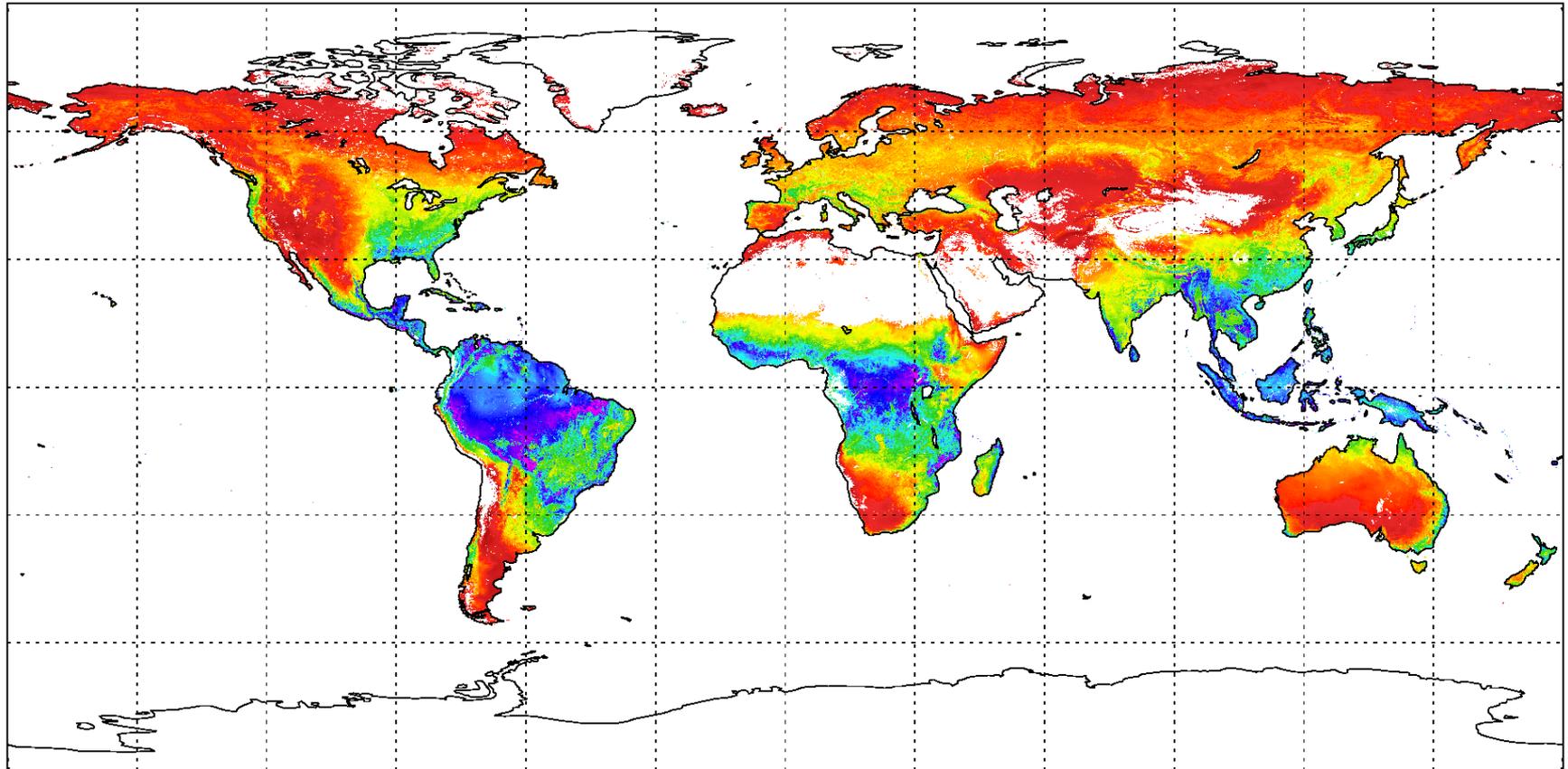


Characteristics of MODIS ET Products

- Spatial Resolution 1 km
- Spatial Coverage: Global
- Time frame: 8-day, monthly, annual
- Time period: 2000-2011

Global annual 1-km ET over 2000-2010

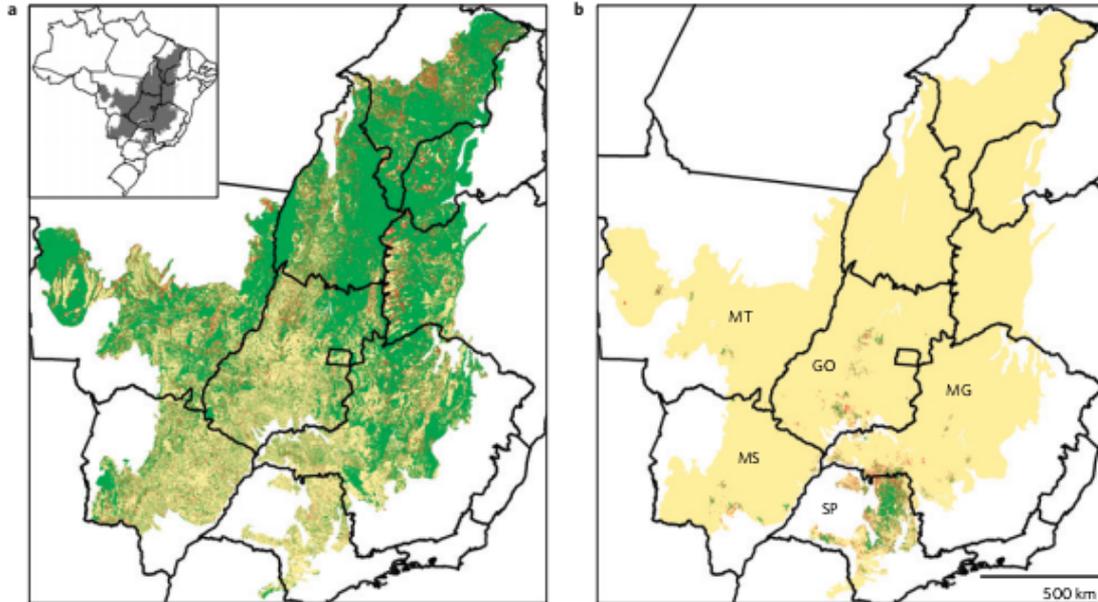
The Global average MODIS ET over vegetated land surface is 575.9 ± 381.6 mm yr⁻¹.



Application of MODIS ET

Direct impacts on local climate of sugarcane expansion in Brazil

Loarie, S. R, et al. (2011)



Natural vegetation in green
Cleared areas in red

Areas of planted sugar cane for biofuel

Conversion of natural vegetation to a crop/pasture mosaic warms the area an average of 1.55°C

Conversion of the crop pasture mosaic cools the region by an average of $.93^{\circ}\text{C}$. (changes the surface albedo and ET)

Where Can You Get MODIS ET Products?

- MODIS Global Evapotranspiration Project

The University of Montana



Numerical Terradynamic Simulation Group

Modeling and Monitoring Ecosystem Function at Multiple Scales

Projects Data Publications People Teaching Media Event Contact

MODIS Global Evapotranspiration Project (MOD16)

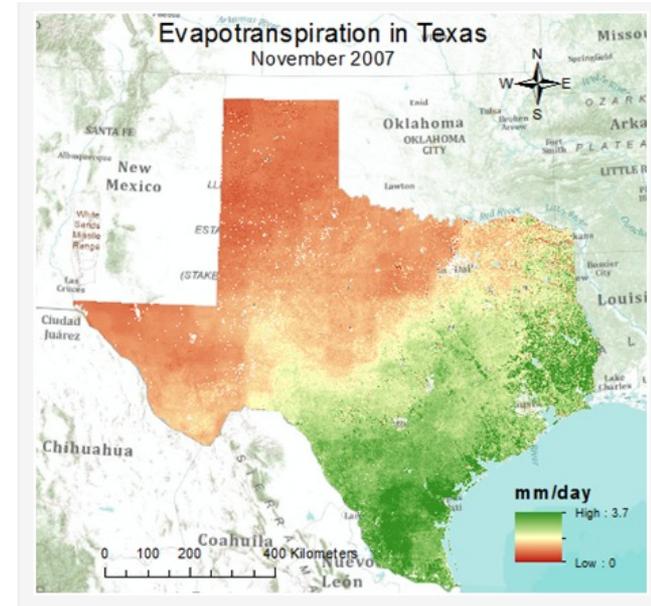
MODIS

Project Description Documentation Scientists Publications Data Product

<http://www.ntsg.umt.edu/project/mod16>

MODIS Toolbox (ArcGIS)

- Developed by Center for Research in Water Resources at University of Texas, Austin
- Download from ArcGIS Resource Center, Geoprocessing Model and Script Tool Gallery: <http://resources.arcgis.com/gallery/file/geoprocessing>



**METHODS FOR DERIVING ET:
ENERGY BALANCE AND VEGETATION
INDICES**

What Satellite Do These Two Methods Use?

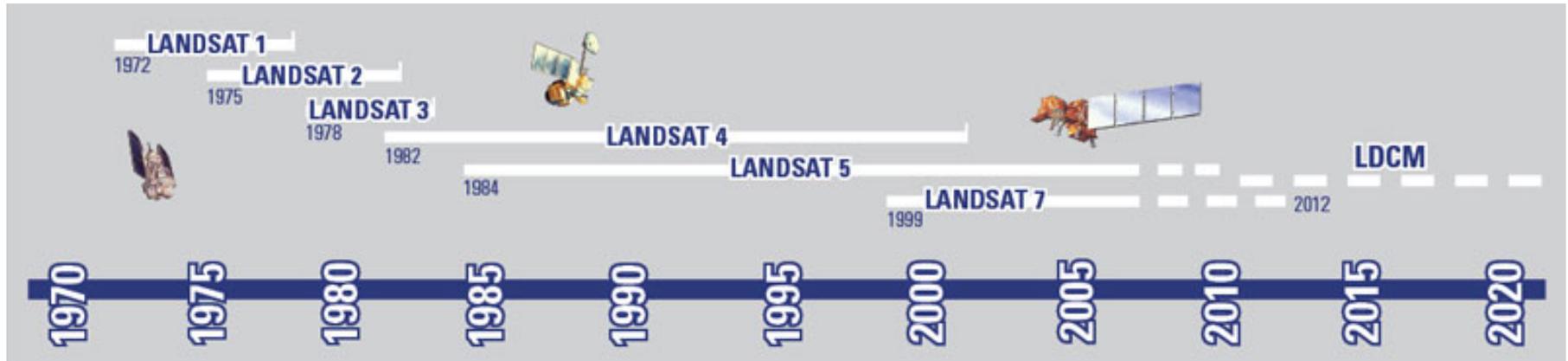
- *Energy Balance Method*
- *Vegetation Indices/ET Relationship*

Answer: The LANDSAT satellite

What is LANDSAT?

36+ Years of Continuous Landsat Global Land Observation

- Landsat 1 was launched July 23, 1972 (MSS)
- Landsat 2 was launched January 22, 1975 (MSS)
- Landsat 3 was launched March 5, 1978 (MSS)
- Landsat 4 was launched July 16, 1982 (TM)
- **Landsat 5** was launched March 1, 1984 (TM)
- Landsat 6 was launched October 5, 1993, but never reached orbit
- **Landsat 7** was launched April 15, 1999, May 2003 SLC-Off (ETM+)
- Landsat 8 is scheduled for launch in February 2013



And...

- On December 8, 2008, the USGS made the entire 36-year long Landsat archive available to anyone via the Internet at *no cost*.
 - **GeoTIFF format**
 - **Orthorectified “GIS-ready”**

USGS Global Visualization Viewer

System Notices (1)

Collection Resolution Map Layers Tools File Help



Downloadable

WRS-2 Path /Row: 29 30 Go
Lat/Long: 43.2 -97.1 Go

Max Cloud: 100% [Up Arrow] [Down Arrow] [Left Arrow] [Right Arrow]

Scene Information:

ID: LE70290302012135EDC00
CC: 0% Date: 2012/5/14
Qlty: 9 Product: ETM+ L1T

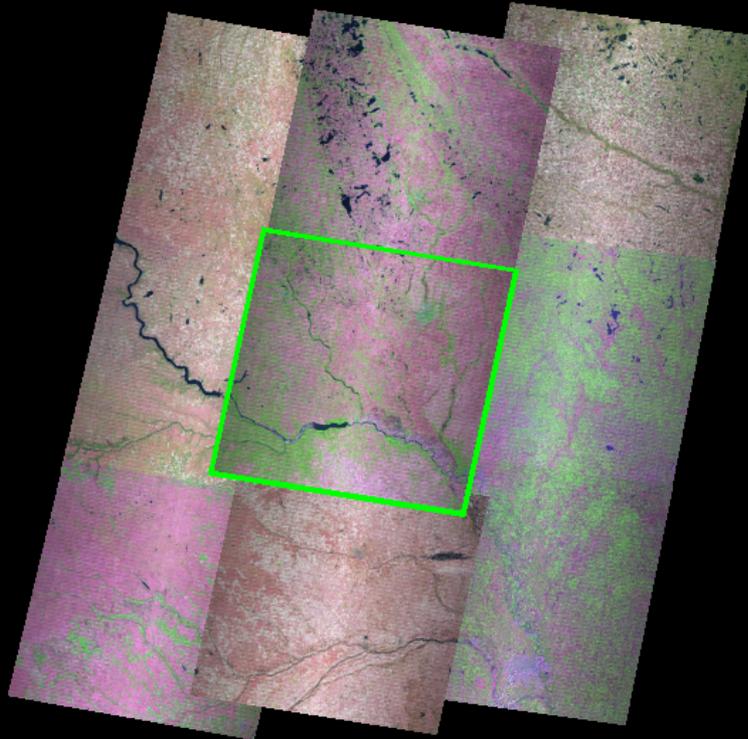
May 2012 Go

Prev Scene Next Scene

Landsat 4 - Present List

Add Delete Send to Cart

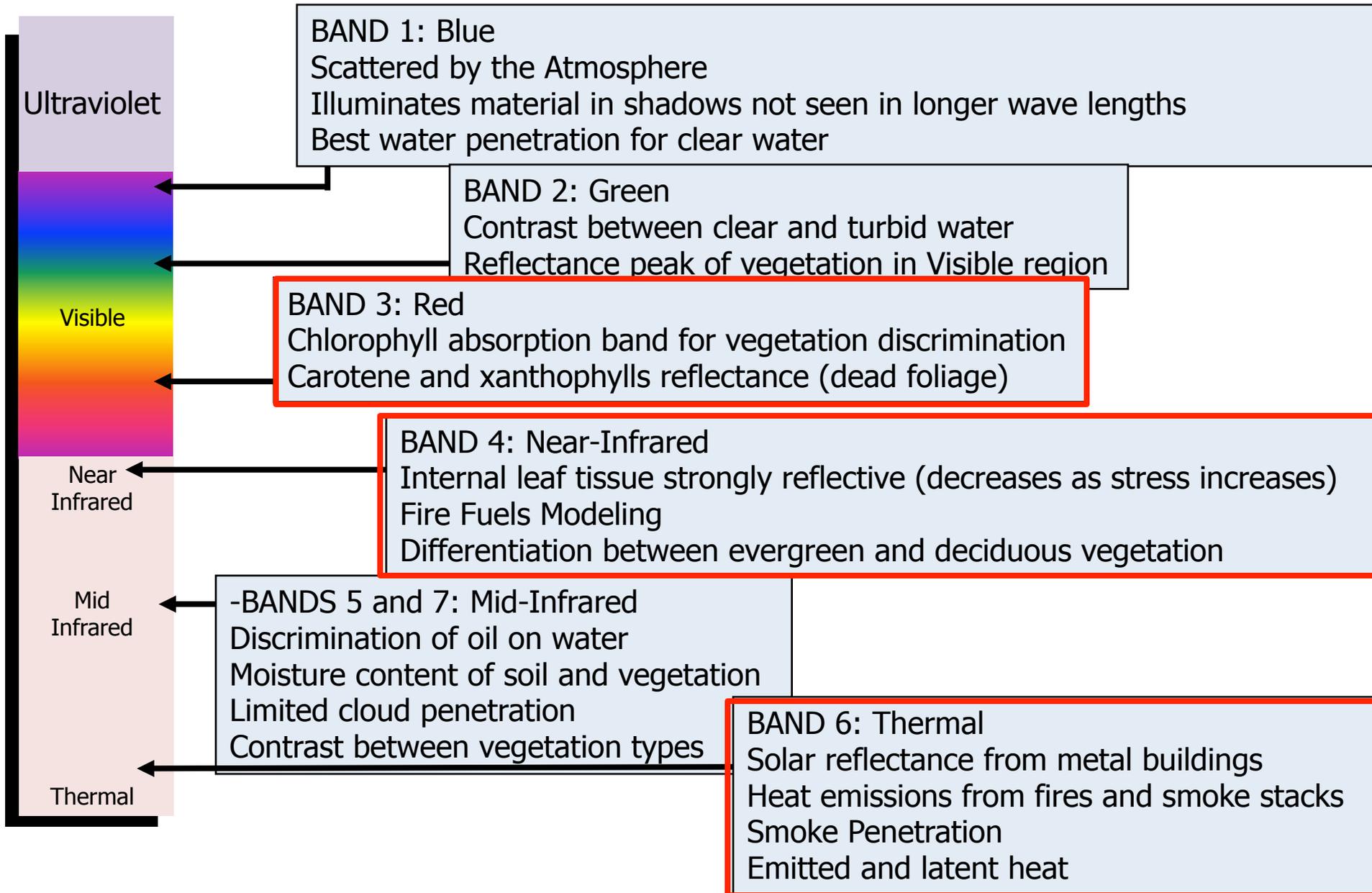
1000m No Limits Set



More on Landsat....

- 7 Spectral Bands (Visible, Near-Infrared, Mid-Infrared, Thermal)
- Spatial Resolution:
 - Landsat 5
 - All bands EXCEPT thermal: 30 meters
 - Thermal: 120 meters
 - Landsat 7
 - All bands EXCEPT thermal: 30 meters
 - Thermal: 60 meters
- Revisit Time: 16 days

Landsat Bands: What is Important for ET?

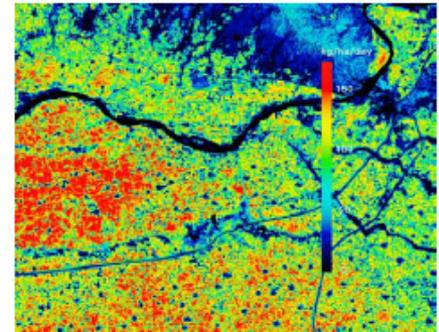


METHODS FOR DERIVING ET:

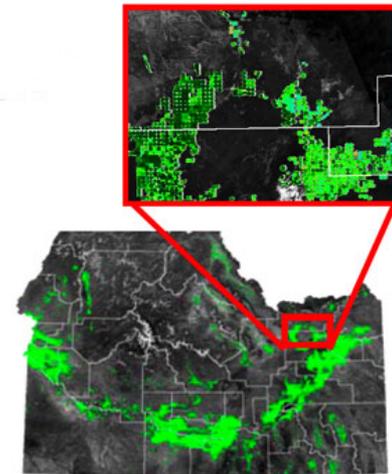
ENERGY BALANCE

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.

How METRIC Works

Requires satellites with Red, Near IR and Thermal IR

R_n: Landsat reflectances and surface temperature

G estimated from R_n, surface temp. and vegetation indices

H estimated from surface temp. ranges, surface roughness, and wind speed

R_n (radiation from sun and sky)



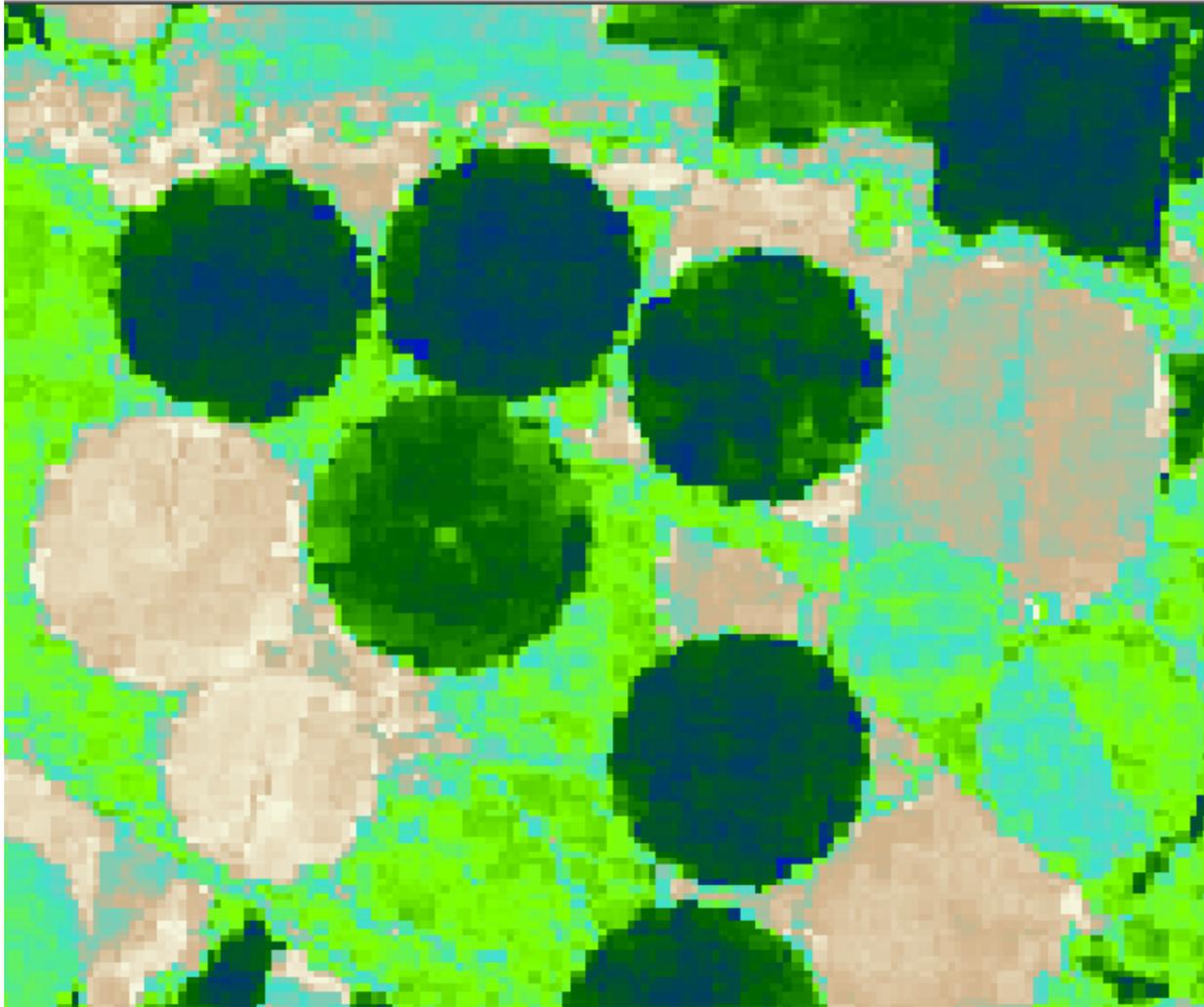
$$ET = R_n - G - H$$

Basic Truth:

Evaporation
consumes
Energy

G (heat to ground)

Why use Landsat Imagery?: Good Spatial Resolution



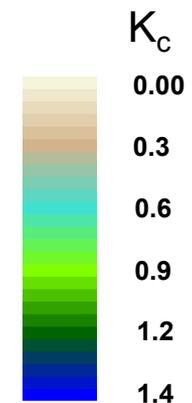
METRIC application in La Mancha, Spain, 2003

Source: Rick Allen, University of Idaho

ET from individual Fields is

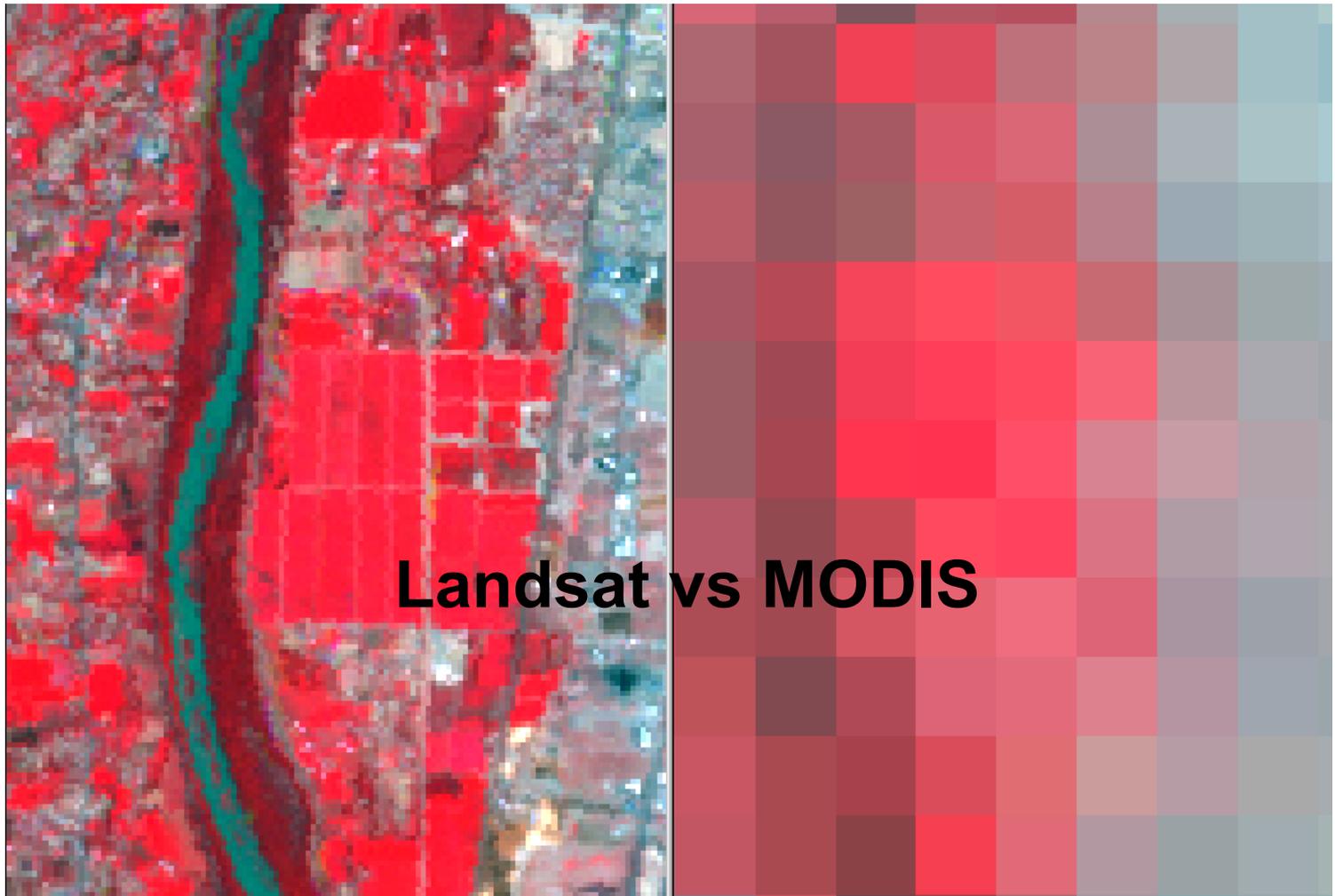
Critical for:

- ◆ Water Rights,
- ◆ Water Transfers,
- ◆ Farm Water Management



(K_c based on ET_0)

More on Spatial Resolution



Landsat False Color (MRG)
8/26/2002 10:33am

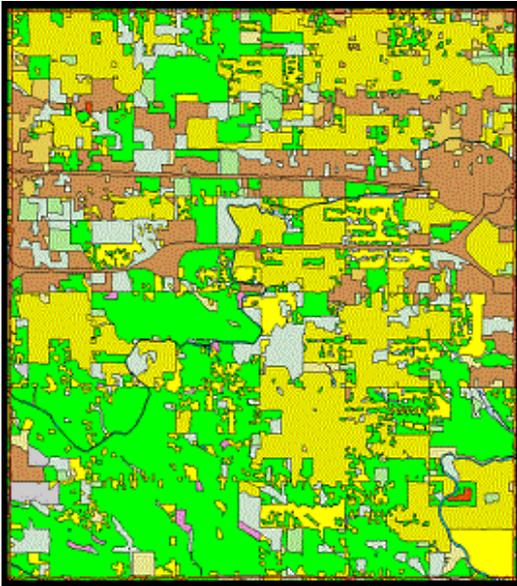
MODIS False Color (MRG)
8/26/2002 11:02am

METRIC ET Applications at the Idaho Department of Water Resources

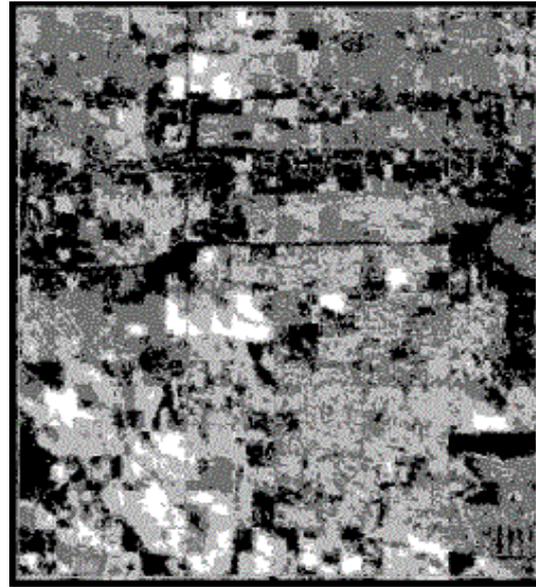
1. Aquifer depletion
2. Water rights buy-back
3. Planning: ET by land use class
4. Water use by irrigated agriculture
5. Water rights compliance monitoring
6. Modeling: ET for computing water budgets
7. Analysis of water-rights curtailment alternatives.

ET BY LAND USE CLASS

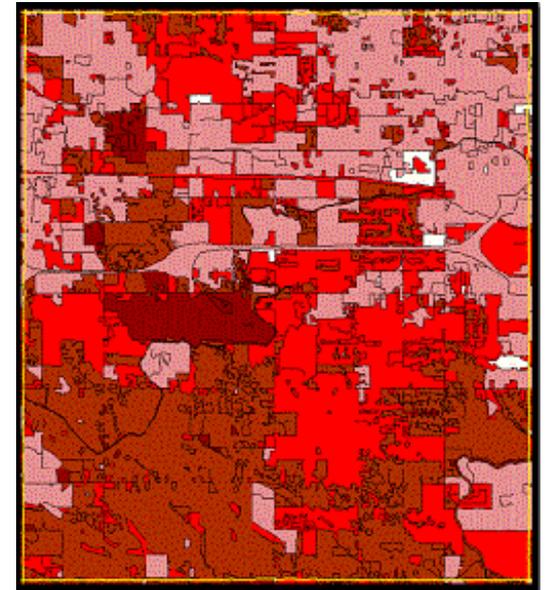
How Does Water Use Change as Land Use Changes?



Land Use / Land Cover



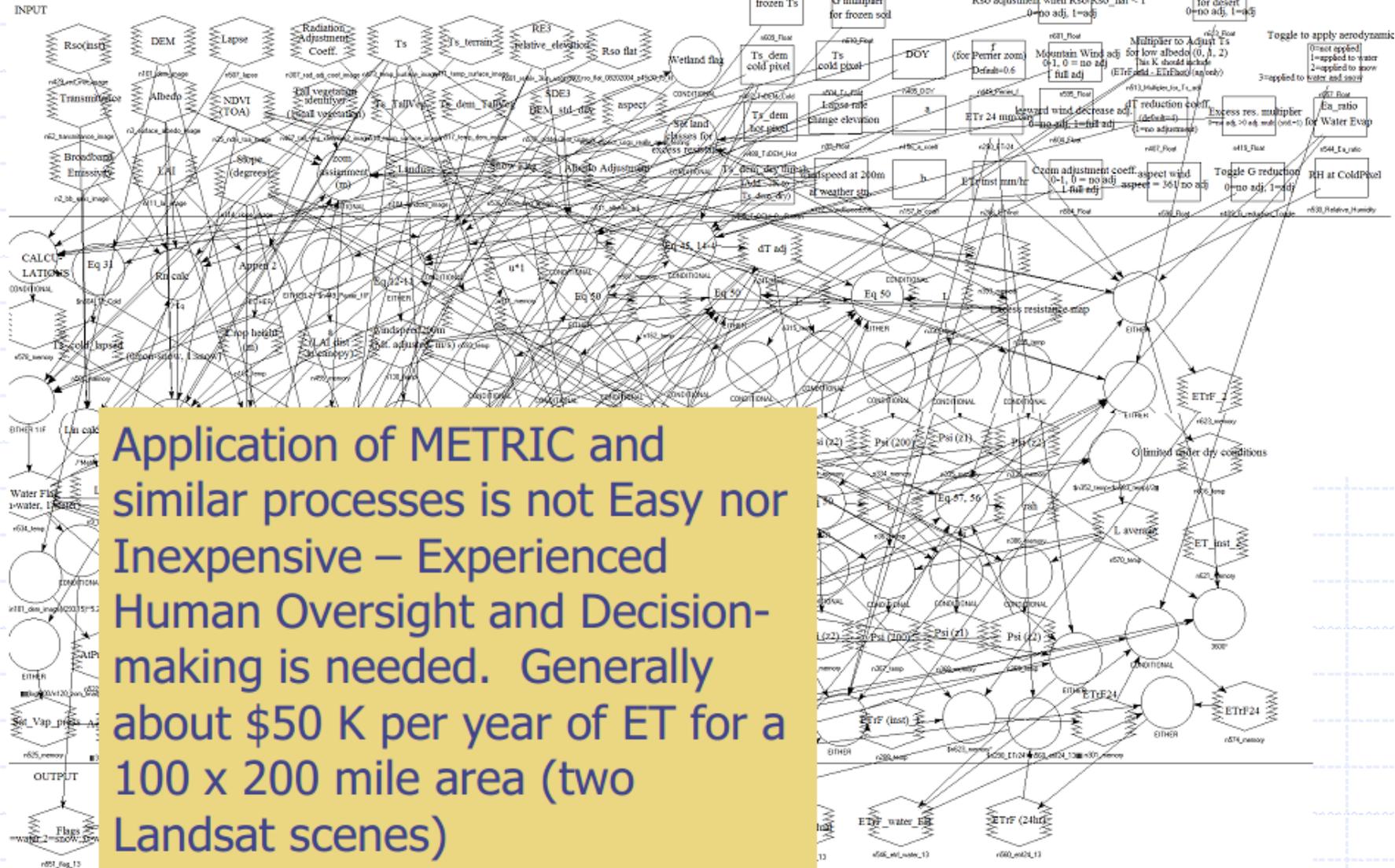
ET From METRIC



ET By Land Use / Land Cover

'full' METRICtm-ERDAS submodel for sensible heat and ETrF

v02, Main energy balance model for METRIC: Sensible heat flux, Net radiation, Ground heat flux, Reference ET fraction and ET. Last change: Sept 2011, RTreza for frozen soil and G-red, in desert
 Copyright (C) 2003-2011. R.G.Allen, M.Tasumi, R.Treza, J. Kjaersgaard, and University of Idaho. All rights reserved. --Populated by VBscript 9/13/2011 at 10:07:34 AM



Application of METRIC and similar processes is not Easy nor Inexpensive – Experienced Human Oversight and Decision-making is needed. Generally about \$50 K per year of ET for a 100 x 200 mile area (two Landsat scenes)

TAKE HOME MESSAGE

Although Landsat data are free,
using the energy balance method
to derive ET costs time and
money!

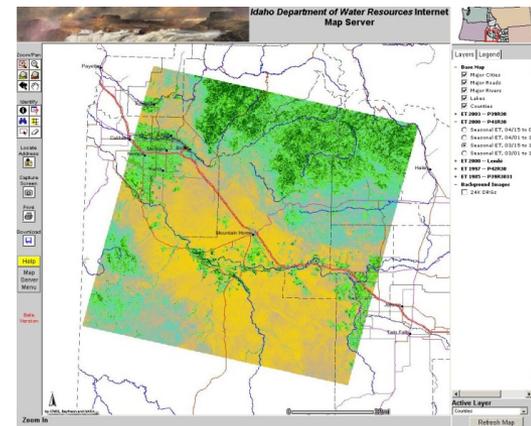
SEBAL and METRIC : Additional Information

◆ <http://www.sebal.us/>



◆ www.kimberly.uidaho.edu/water/ (METRICtm)

◆ <http://maps.idwr.idaho.gov/et/>

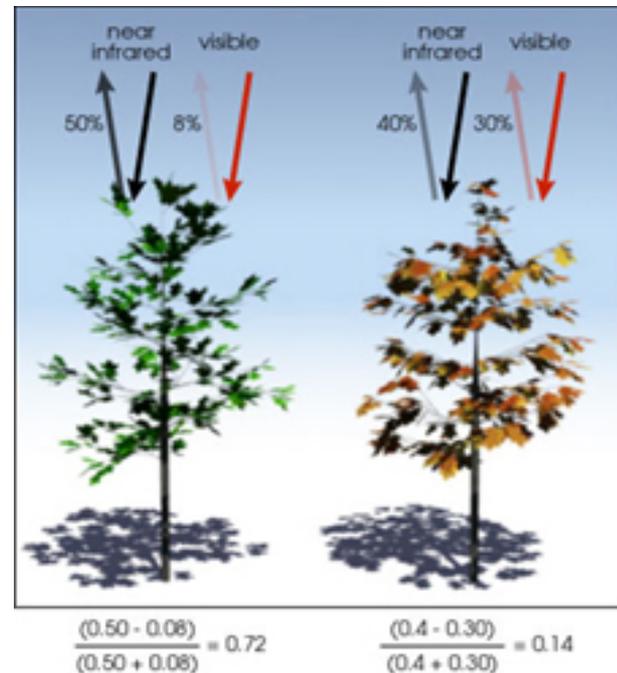


METHODS FOR DERIVING ET:

VEGETATION INDICES

Vegetation Index and ET Relationships

- *What is a vegetation index?*
 - *Based on the relationship between red and near-infrared wavelengths.*
 - *Chlorophyll strongly absorbs visible (red)*
 - *Plant structure strongly reflects near-infrared*



Normalized Difference Vegetation Index (NDVI)

Near Infrared – Red
Near Infrared + Red

Values represent varying levels of vegetation density



North America, July 2000

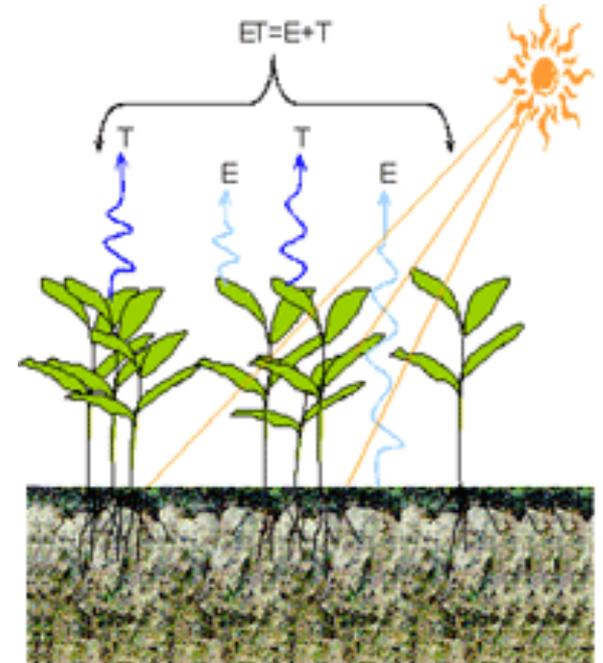


Africa, March 2000

Other terms you need to know....

Crop Evapotranspiration (ETc)

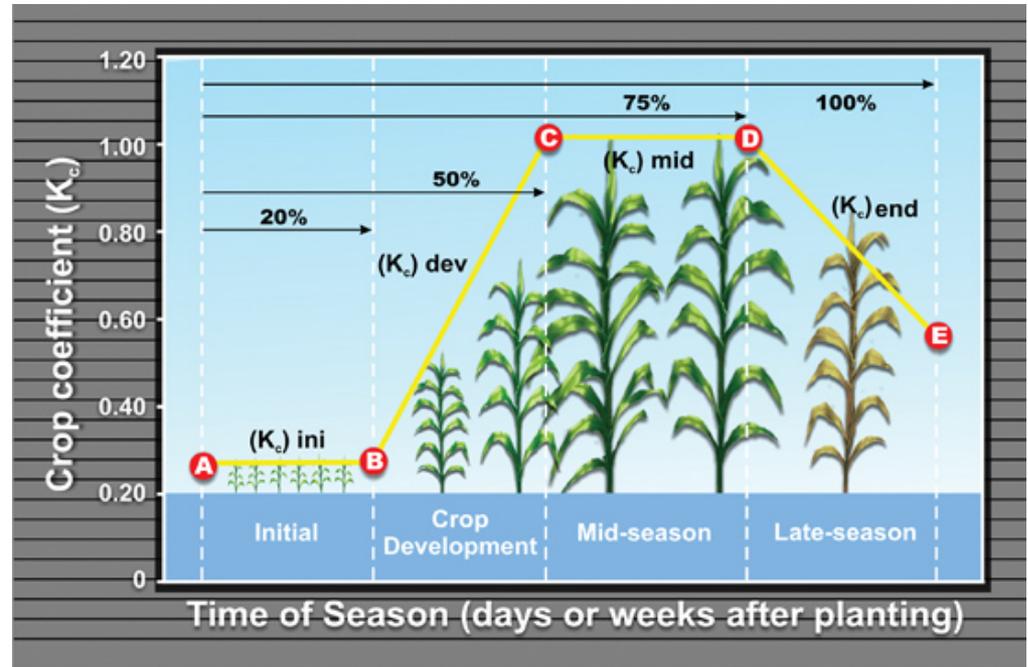
- ETc = the combined processes of crop transpiration (T) and evaporation from the soil surface (E) for a well-watered (non-stressed) crop
- ETo = reference ET (measure on the ground). Typically a well-watered grass surface.



Source: California Department of Water Resources

Crop Coefficient (K_c)

- Vary by type of crop, stage of growth of the crop, and some cultural practices.



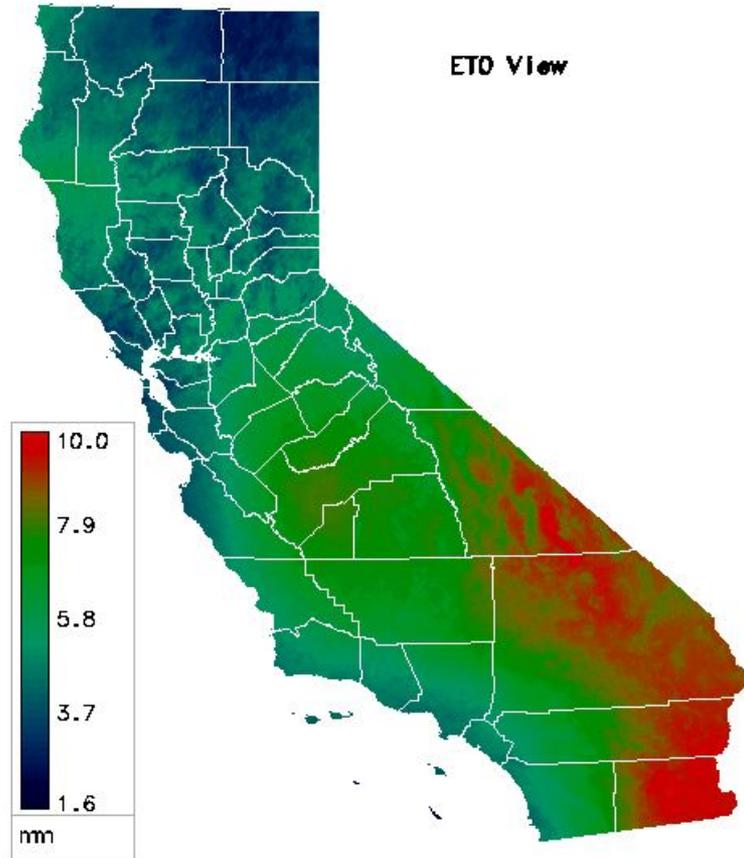
Source: University of Nebraska-Lincoln Extension

Calculating ETc

- Apply crop coefficient (Kc) to reference ET (ETo) : $ETc = ETo * Kc$
- In California, the California Irrigation Management Information System (CIMIS) provides daily ETo values, gridded across the entire state at 2km resolution.

Daily ETo Value from CIMIS

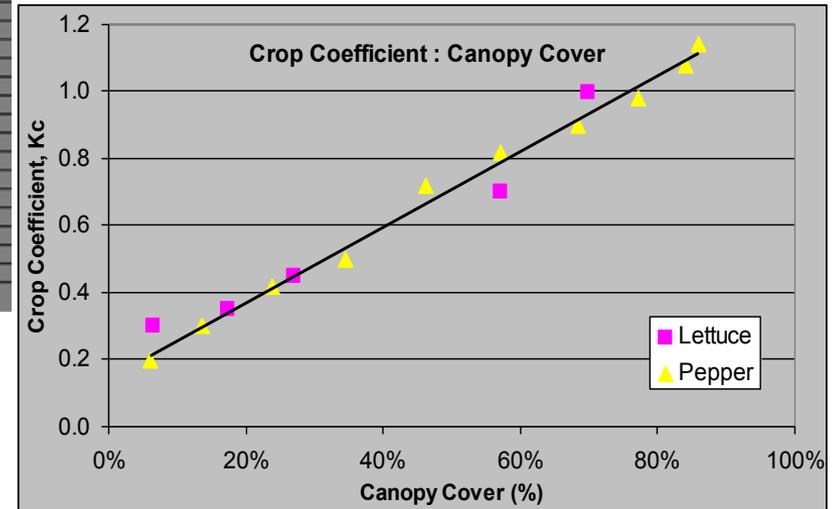
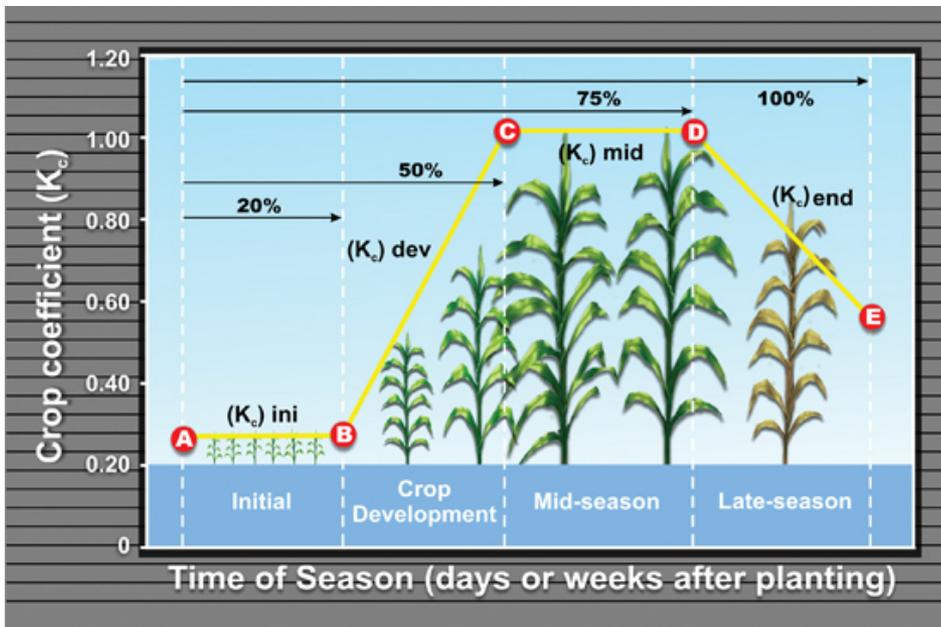
May 17, 2012



Crop Coefficients (Kc) vs. Vegetation Indices

Kc is related to light interception (ground cover)

There is a direct relationship between Kc and NDVI



Source: Tom Trout, USDA



TOPS Satellite Irrigation Management Support

TOPS Satellite Irrigation Management Support (SIMS)

Earth-resource satellites were used to map crop development and crop water demand throughout California's Central Valley, Central Coast, and North Coast at ¼ acre resolution during the 2010-2012 time period. Through this prototype interface, users may view maps and inspect/download time-series trends of selected data layers at user-specified locations. The datasets are intended to provide additional information about crop canopy conditions and irrigation demand for agricultural producers and water managers. This interface is being made available for review and evaluation by California growers and other interested stakeholders.



[SIMS beta web interface](#)



[Help](#)



[Additional project info](#)

Acknowledgment: These datasets were developed by the Ecological Forecasting Lab at NASA Ames Research Center in collaboration with the California State University, USDA Agricultural Research Service and California Department of Water Resources, and with support from the NASA Applied Sciences program.

Disclaimer: These datasets are distributed for research, evaluation and demonstration purposes only. The datasets are still under review and should be considered provisional.

Feedback: Kindly direct questions or feedback to Forrest Melton (forrest.s.melton@nasa.gov).



Last Update: 2012-10-24

NASA Official: Jennifer Dungan
Curator: Forrest Melton

NASA AMES | [PRIVACY](#)

<http://ecocast.arc.nasa.gov/sims/>

Beta website: <http://www.ecocast.org/dgw/sims>



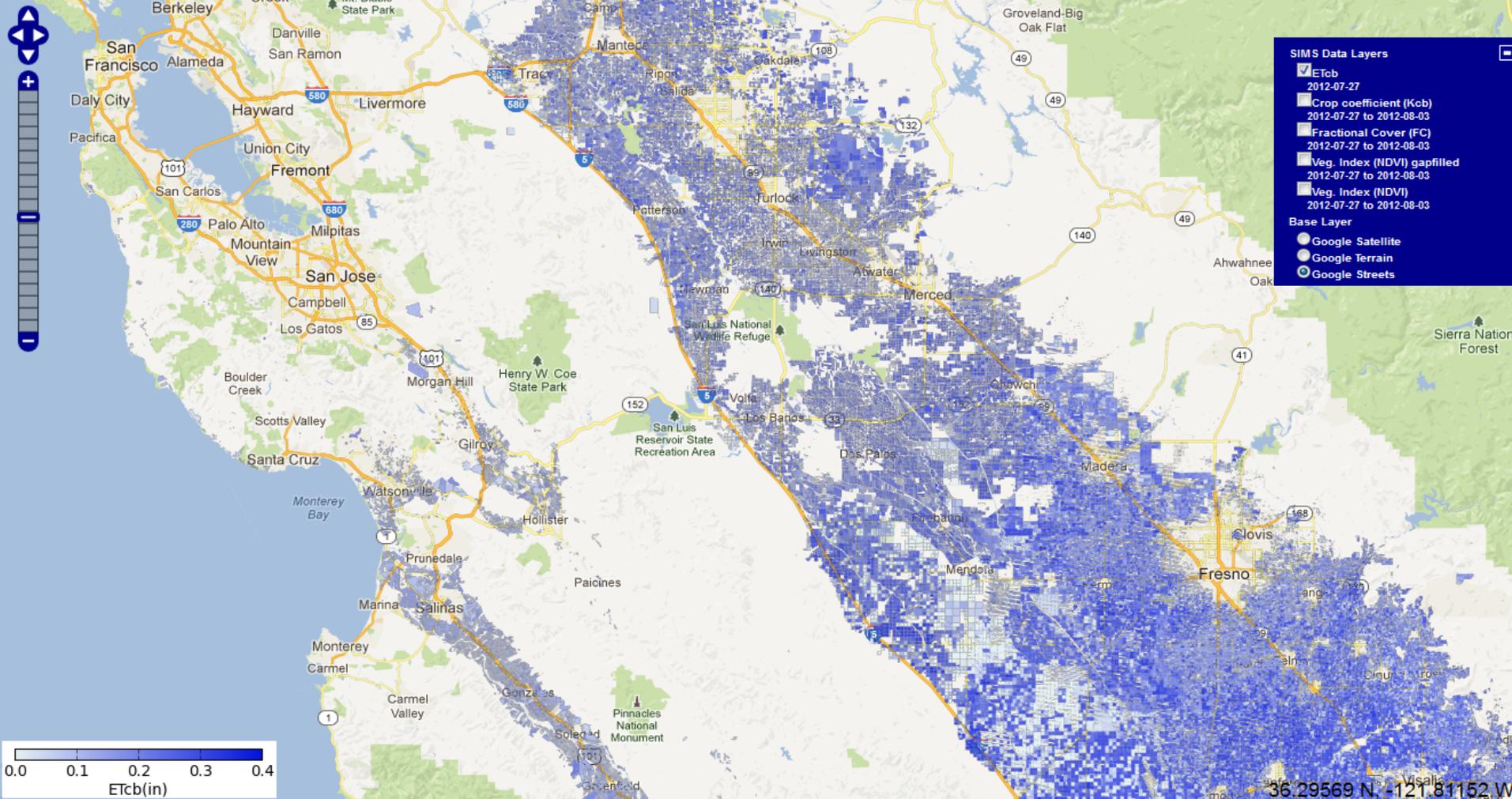
TOPS Satellite Irrigation Management Support

Username: Password: [Login](#)

Go to: [Search](#)

[About](#) [Help](#)

Select Date: 2012-07-27



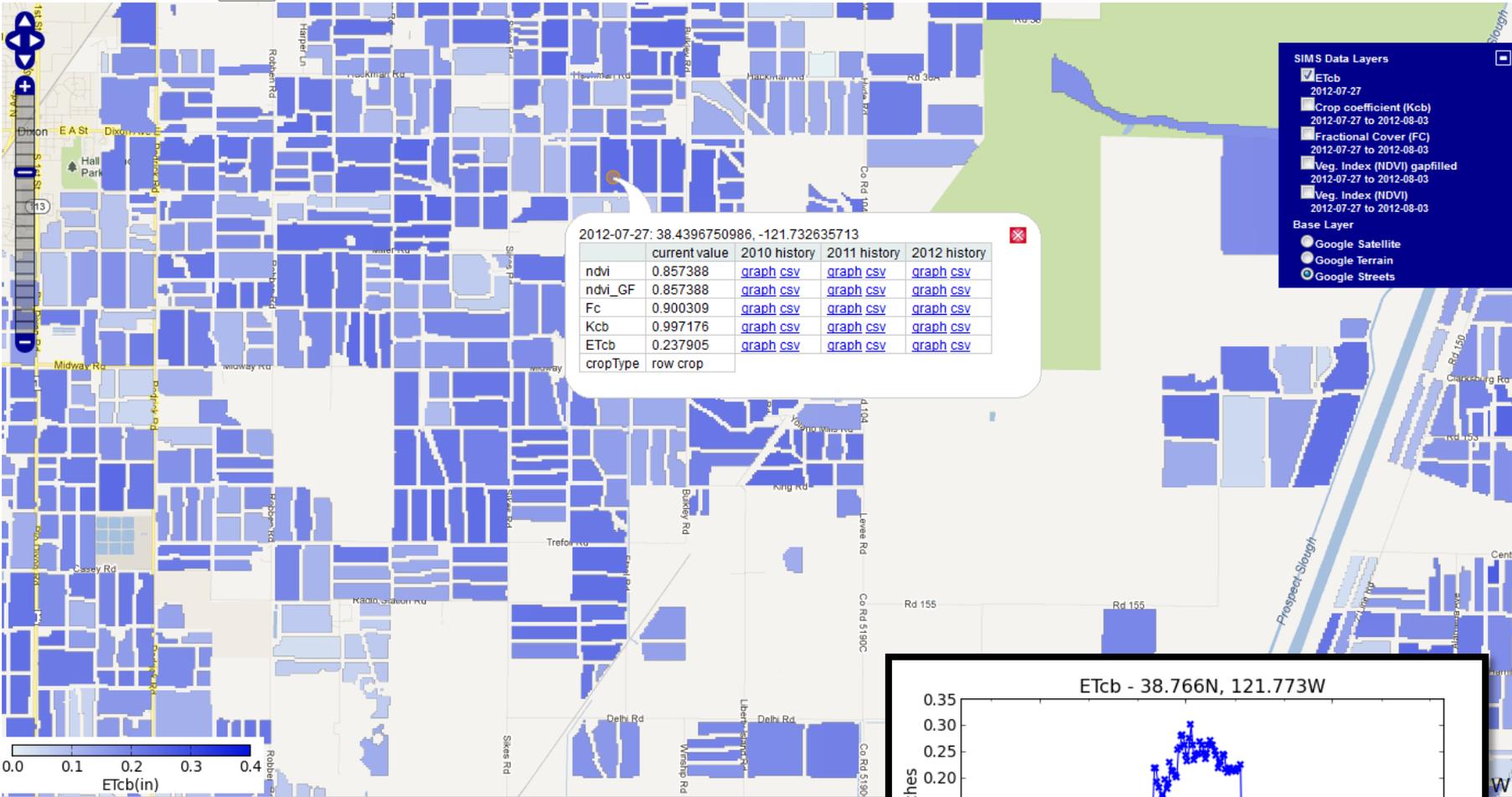
Disclaimer: This data is for research and evaluation purposes only.



Go to:

[About](#) [Help](#)

Select Date:



2012-07-27: 38.4396750986, -121.732635713

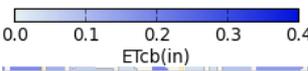
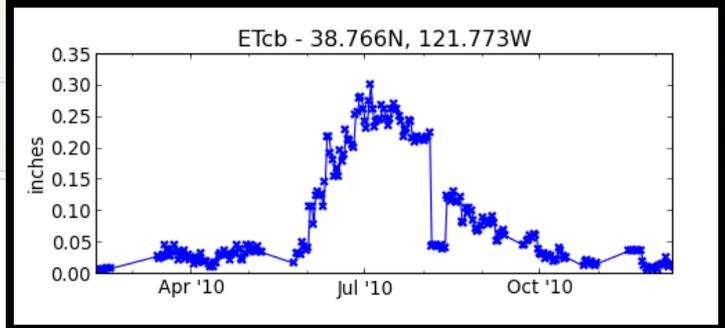
	current value	2010 history	2011 history	2012 history
ndvi	0.857388	graph csv	graph csv	graph csv
ndvi_GF	0.857388	graph csv	graph csv	graph csv
Fc	0.900309	graph csv	graph csv	graph csv
Kcb	0.997176	graph csv	graph csv	graph csv
ETcb	0.237905	graph csv	graph csv	graph csv
cropType	row crop			

SIMS Data Layers

- ETcb
- 2012-07-27
- Crop coefficient (Kcb) 2012-07-27 to 2012-08-03
- Fractional Cover (FC) 2012-07-27 to 2012-08-03
- Veg. Index (NDVI) gapfilled 2012-07-27 to 2012-08-03
- Veg. Index (NDVI) 2012-07-27 to 2012-08-03

Base Layer

- Google Satellite
- Google Terrain
- Google Streets



Summary: TOPS-SIMS

- TOPS-SIMS: Fully automated system for near real-time satellite data processing & mapping of NDVI, F_c , K_{cb} , & ET_{cb}
- Web interface for data access and retrieval
- Comparison against other ET models, surface renewal measurements / soil moisture data ongoing; initial results encouraging
- Next Steps:
 - Currently working with partner growers to test web interface and develop additional information tools
 - Continuing work on comparison with other models and surface observations of ET
 - Integration of other satellite-driven models and NOAA FRET data
 - Working with partners to develop plans for long term operational support

Advantages/Disadvantages for ET Derived from Vegetation Indices

- Primarily useful for estimating ET of a well-watered crop on a dry soil surface
- This method is simple and quick, and inexpensive.
- Can be used on other types of imagery – not just Landsat

Summary

- ET is not directly measured from satellites.
- Deriving ET is a complex process (some methods are more complex than others).
- There are multiple ET products available that utilize different approaches and remote sensing instruments at different temporal and spatial resolutions.
- You can download ET data from NLDAS, GLDAS, and the University of Montana (from MODIS)
- Any of the ET data derived from Landsat require special processing capabilities BUT you can view/download for California from SIMS website.

Thank You!