

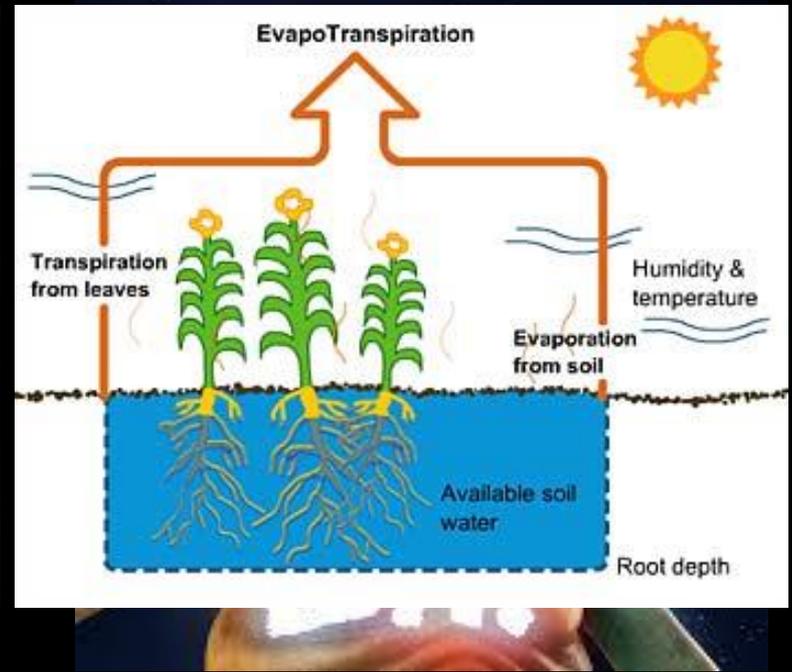
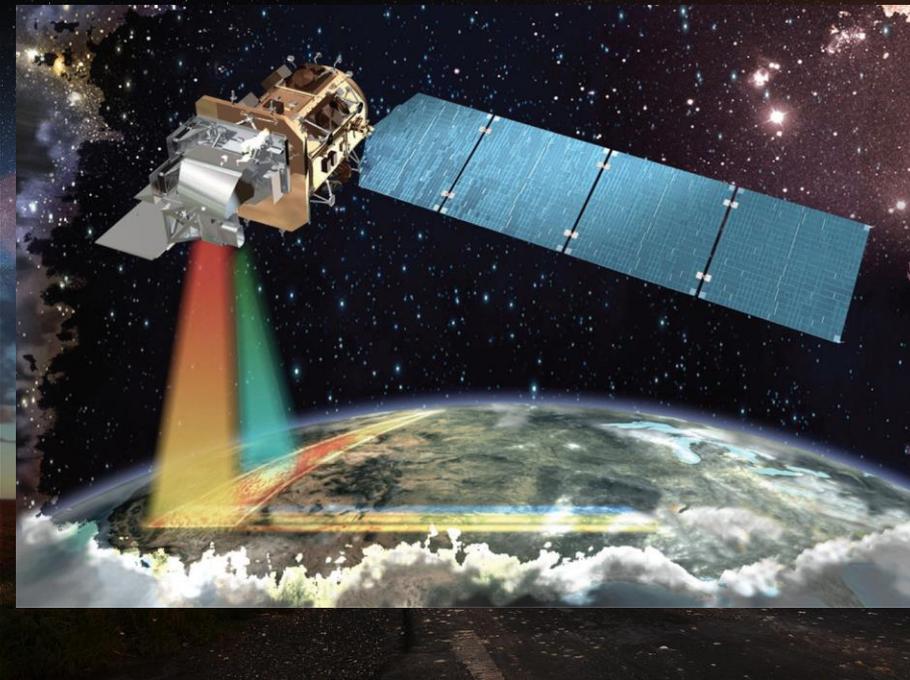


2015 International Workshop on Evapotranspiration Mapping for Water Security

Day 1 Summary

Forrest Melton
NASA ARC-CREST
forrest.s.melton@nasa.gov

NASA + ET?



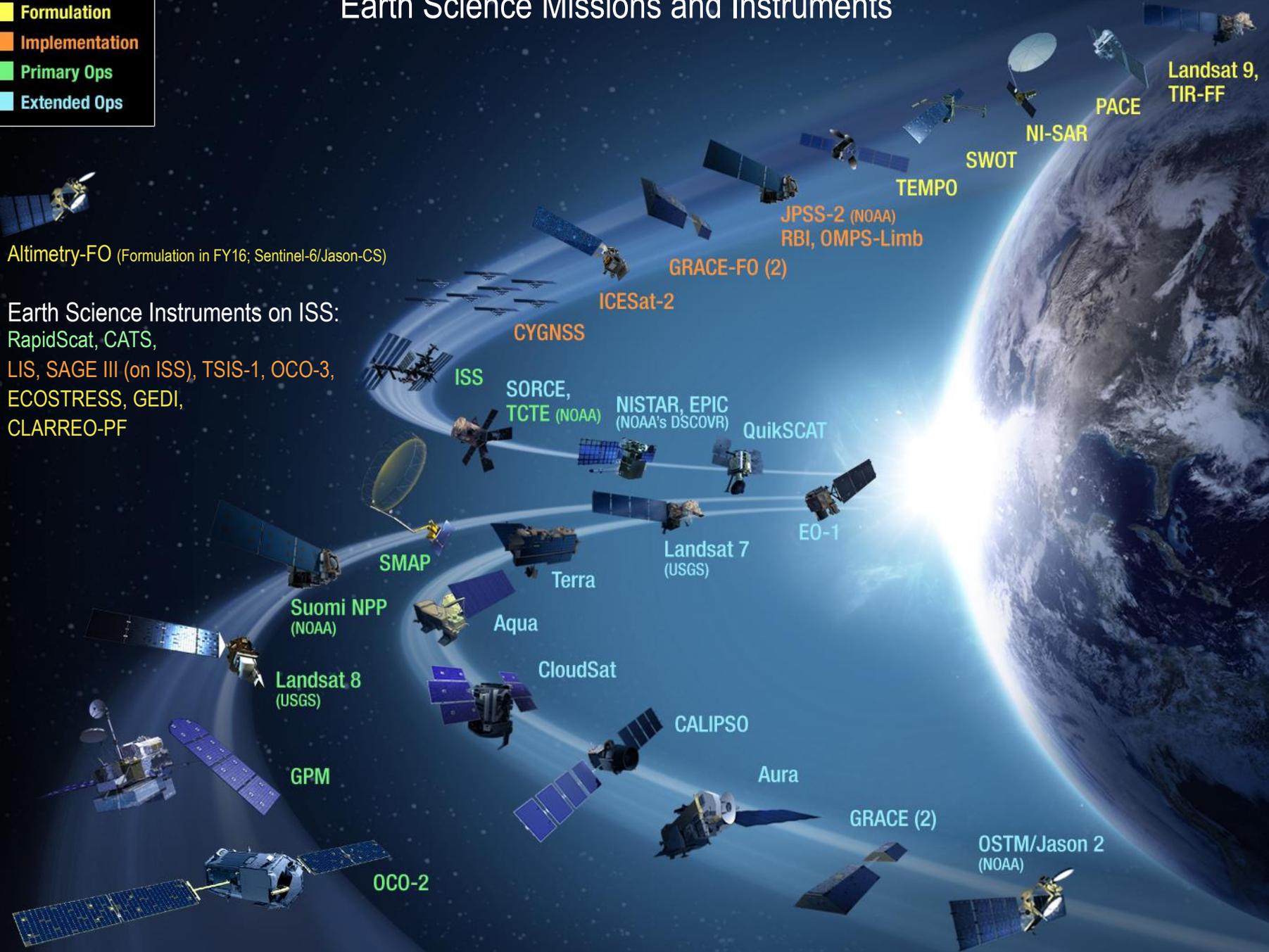
Evapotranspiration (ET): water consumed (lost to atmosphere) through the combined processes of soil evaporation & plant transpiration

Earth Science Missions and Instruments



Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)

Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF



Earth Science Missions and Instruments

- Formulation
- Implementation
- Primary Ops
- Extended Ops



Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)

Earth Science Instruments on ISS:

RapidScat, CATS,
 LIS, SAGE III (on ISS), TSIS-1, OCO-3,
 ECOSTRESS, GEDI,
 CLARREO-PF



★ Contributing to Water Cycle and Food Security Studies

OCO-2

GPM

Landsat 8 (USGS)

Suomi NPP (NOAA)

SMAP

CloudSat

Aqua

Terra

Landsat 7 (USGS)

EO-1

QuikSCAT

NISTAR, EPIC (NOAA's DSCOVR)

SORCE, TCTE (NOAA)

ISS

CYGNSS

ICESat-2

GRACE-FO (2)

JPSS-2 (NOAA)
 RBI, OMPS-Limb

TEMPO

SWOT

NI-SAR

PACE

Landsat 9, TIR-FF

Remote Sensing Platforms for Mapping ET



Landsat 7



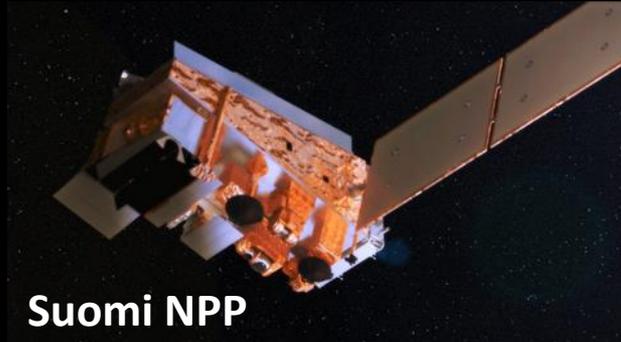
Terra



Aqua



Landsat 8



Suomi NPP



GOES-R



Intl. Space Station



Aircraft



UAVs

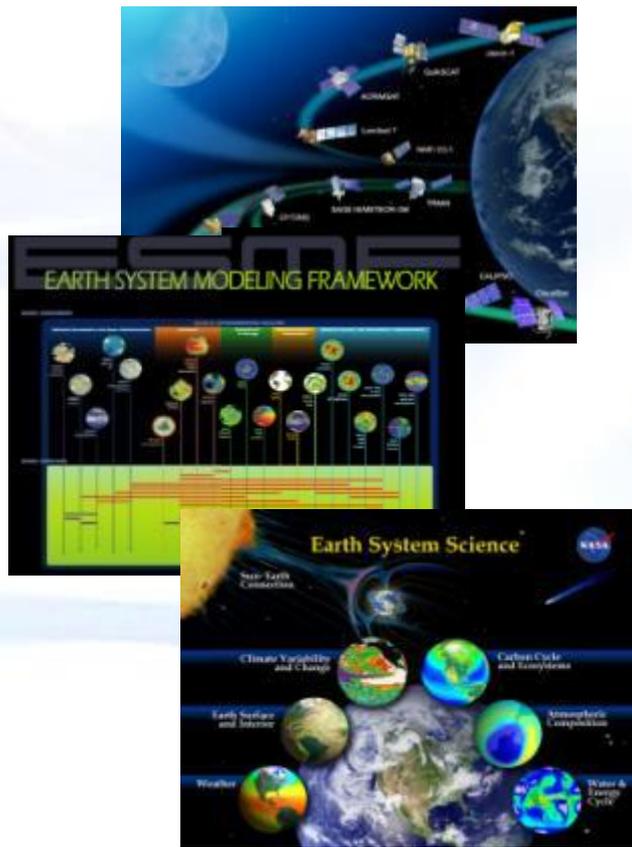
NASA Applied Sciences Program

A Pathway Between Earth Science & Society



**Results of
NASA Earth
Science Research**

**Uses by Partners
and Stakeholder
Communities**



**NASA
Applied Sciences
Program**

GEOSS Societal Benefit Areas



Perspectives on Value of Remotely-Sensed ET



?

????

The future growth and prosperity of the western states depend upon the availability of adequate quantities of water of suitable quality

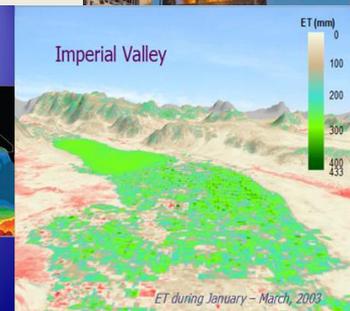
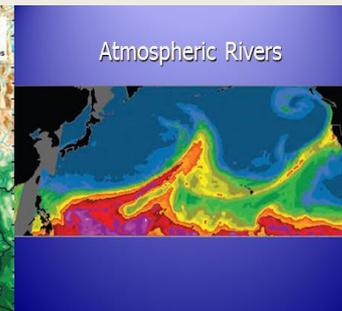
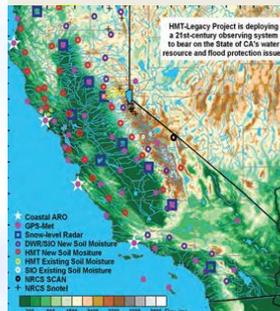


Priority State & Federal Actions

- Increase support/funding for data
- Identify and close data gaps
- Gather/disseminate real-time data
- Foster remote sensing capabilities
- Reduce costs through innovation



Tony Willardson,
Western States Water Council



Why use an “Energy balance”?

- ◆ ET is calculated as a “residual” of the energy balance – driven by THERMAL

R_n (radiation from sun and sky)

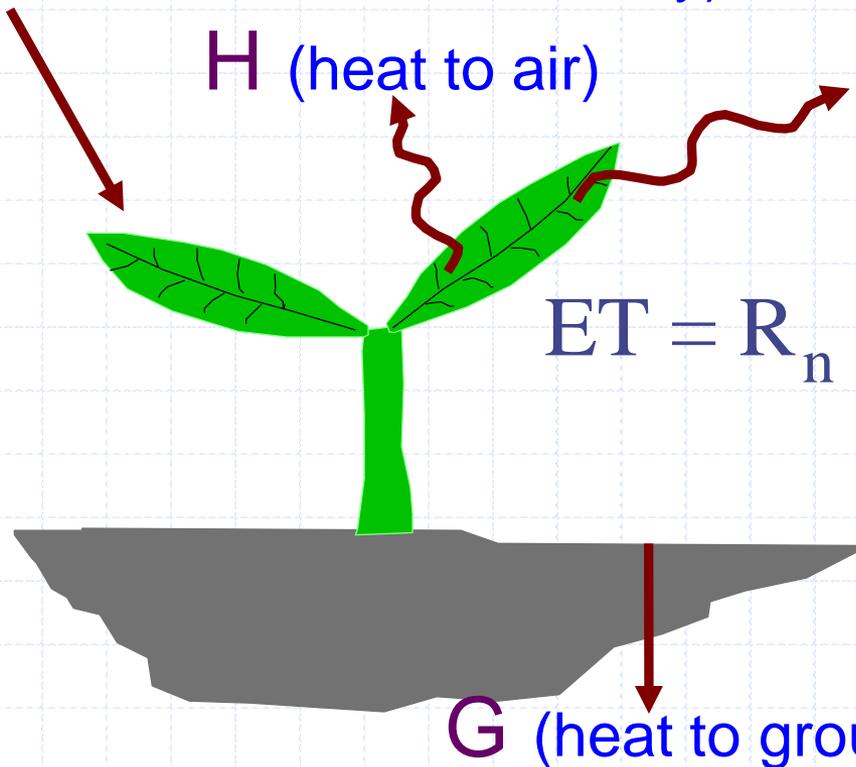
H (heat to air)

ET

$$ET = R_n - G - H$$

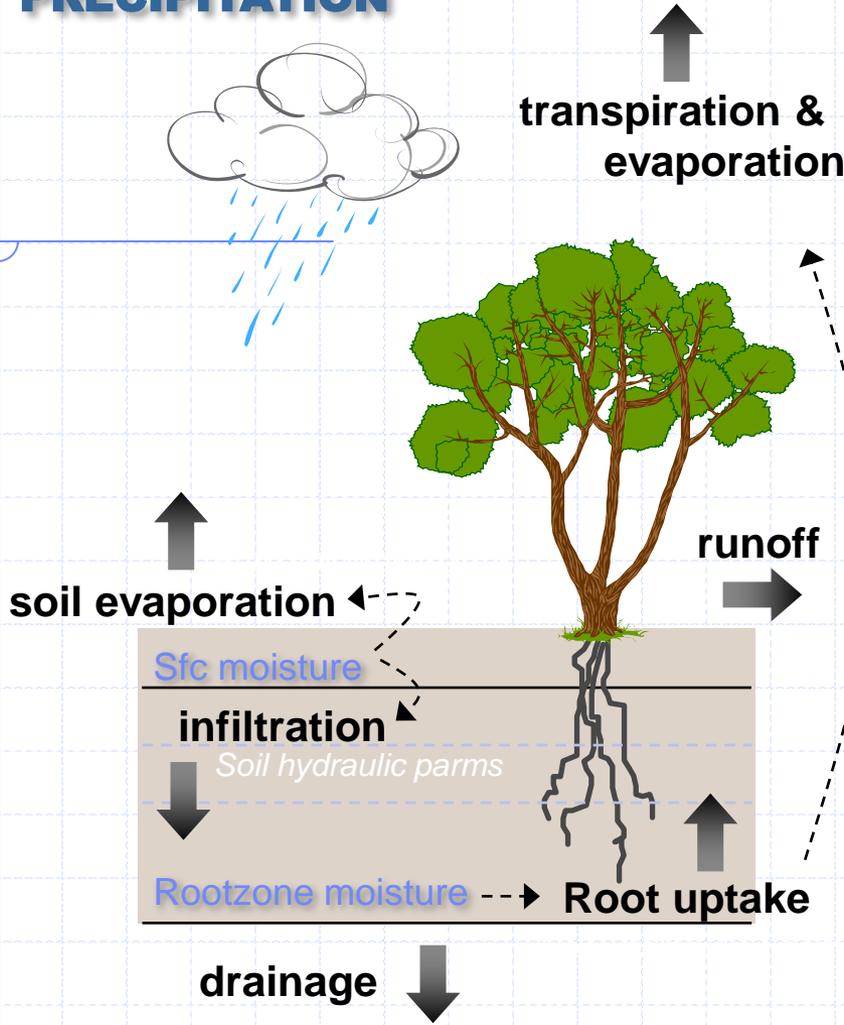
Basic Truth:

Evaporation
consumes
Energy



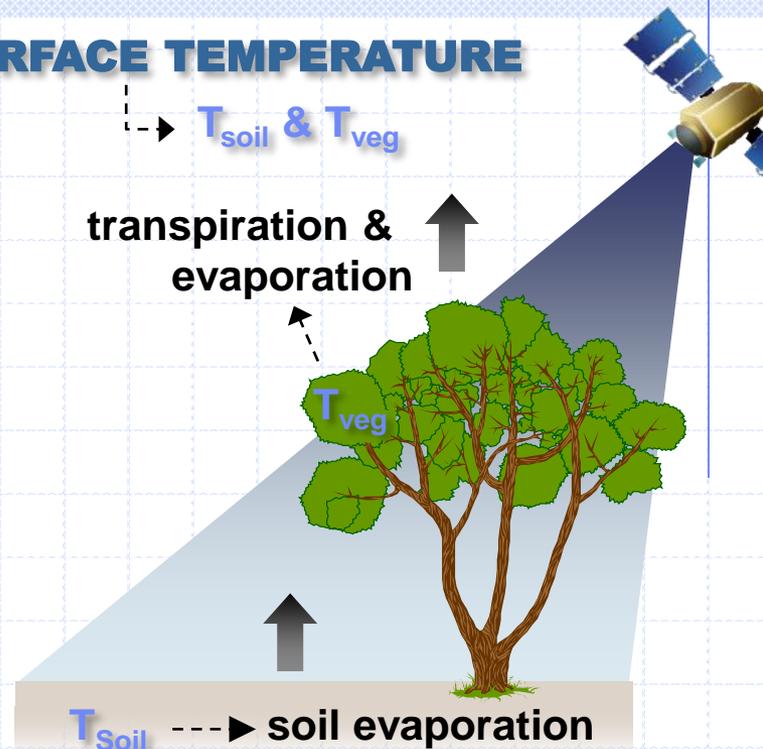
G (heat to ground)

PRECIPITATION



WATER BALANCE APPROACH
(prognostic modeling)

SURFACE TEMPERATURE



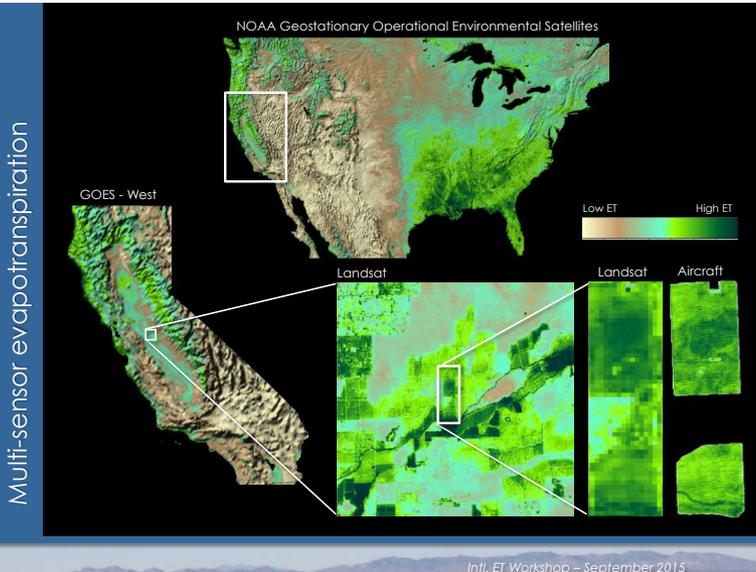
Given known radiative energy inputs, how much water loss is required to keep the soil and vegetation at the observed temperatures?

ENERGY BALANCE APPROACH
(diagnostic modeling)

US Applications at the National Scale

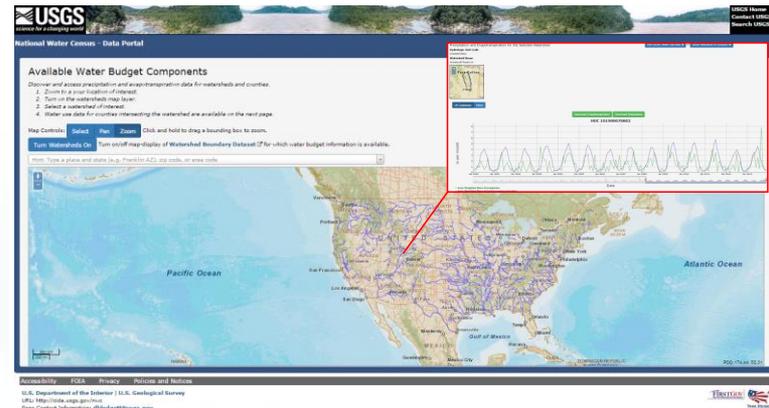


Martha Anderson, USDA ARS

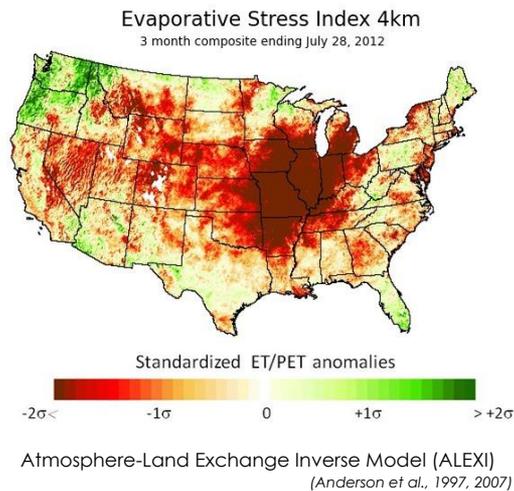


Jim Verdin, USGS

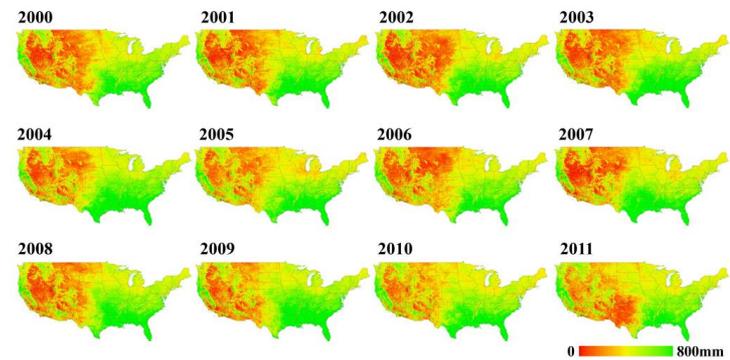
National Water Census – Data Portal



GOES ET and Drought Products (GET-D)



SSEBop Annual ETa Totals from MODIS

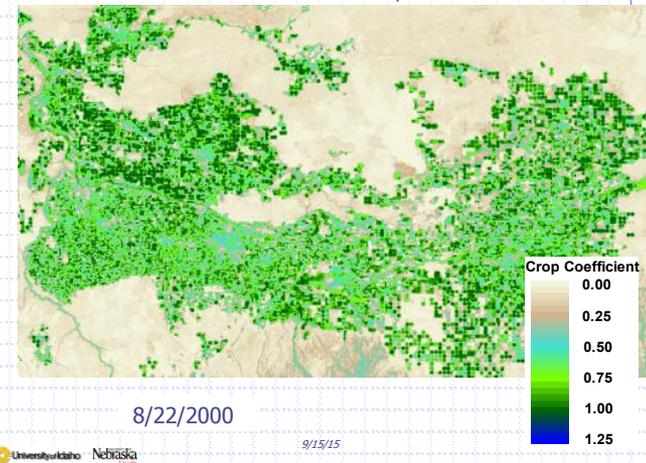


Rick Allen, University of Idaho

METRIC Applications in Idaho

Water Planning
Aquifer Depletion
Hydrologic Modeling
Endangered Species
Agricultural Water Use
Legal Finding-of-Fact
Water Rights Buy-Back
Water Rights Compliance
In-Season Water Demand
Tribal Water Rights Negotiations

Time Series of ET near Twin Falls, ID



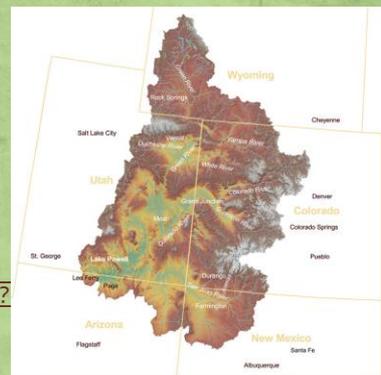
Applications of METRIC for Water Management



Steve Wolff, Wyoming State Eng. Office

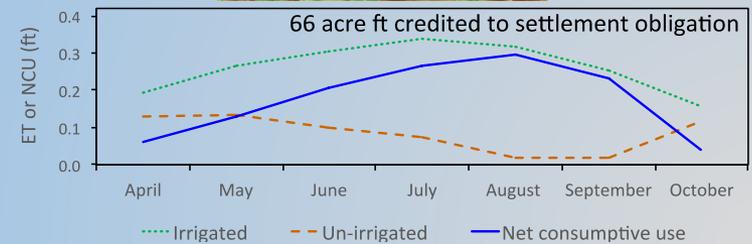
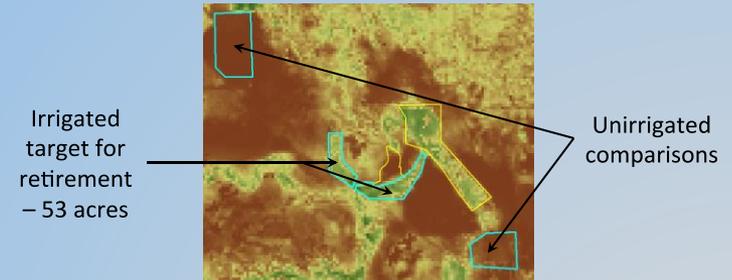
Using Remote Sensed Data in the Upper Colorado River Basin - Three Examples

1. Within Wyoming
2. To compare current (and differing) methodologies used to assess CU by the four Upper Basin States
3. System Conservation Pilot Program



Larry Dunsmore, Klamath Tribes

Using METRIC results to implement the agreement



Justin Huntington, DRI

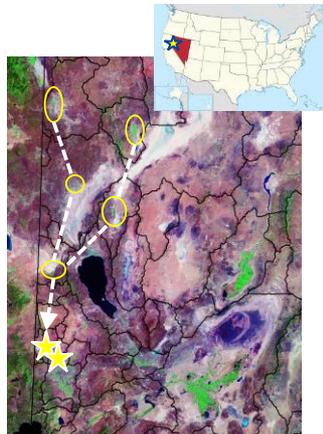
Consumptive Use and Water Transfers

- Western water law allows for existing groundwater rights to be transferred to a new location and/or use
- Following agriculture and capturing natural discharge
- Example: Export groundwater irrigation water rights out of a basin and use it for municipal purposes in a basin needing the water

~\$10K per ac-ft in 2015
~\$70,000 per ac-ft in 2007

One 125 acre center pivot @ 4ac-ft/acre

= \$5,000,000 per center pivot
= 35,000,000 !! per center pivot



Duane Woodward, Central Platte NRD

Nebraska

- Landsat 5, 7, 8 Applications in the Central Platte Natural Resources District (NRD).
- Objective: Manage water use from the High Plains Aquifer. ET from irrigators extracts substantial amounts of water from the aquifer and can lower the levels.
- LB962- Recognized that surface and ground water must be managed together for sustainability of water resources.
- They have to reduce ground water depletion to sustainable levels.
- Central Platte NRD has adopted the use of Landsat based ET



ET Applications for Irrigation Management

Sonia Salas, Western Growers

Use of ET



Challenges

- ET data gaps due to lack of local/ representative weather stations in certain locations
- Lack of local commodity specific irrigation scheduling calculators (Real-time crop, regional/site specific conditions should be considered when using ET)

Opportunities

- ET data enhancement. For example, CIMIS * is utilizing remotely sensed satellite data to generate ET maps and address data gaps.
- Support/continue successful efforts that consider crop, regional/site specific conditions (irrigation calculators for avocados, lettuce, almonds, wine grapes)

* California Irrigation Management Information System (CIMIS)



Forrest Melton, NASA ARC-CREST

Satellite Irrigation Management Support (SIMS) Web Services



Martin Mendez-Costabel, E & J Gallo



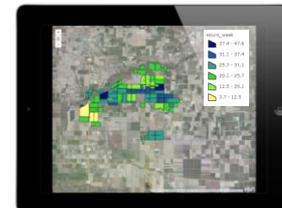
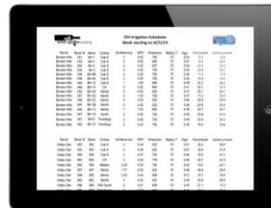
PRESENT Model for deployment of Satellite-Based applications

- Desktop and mobile based – information delivered to growers real time via mobile applications
- Use of 'Landsat web services' and cloud computing systems via:
 - Amazon S3
 - Google Earth Engine
- Custom mobile applications for:
 - Viewing
 - Editing
 - Collection
- 24-HOUR DELIVERY



Custom Irrigation Schedules

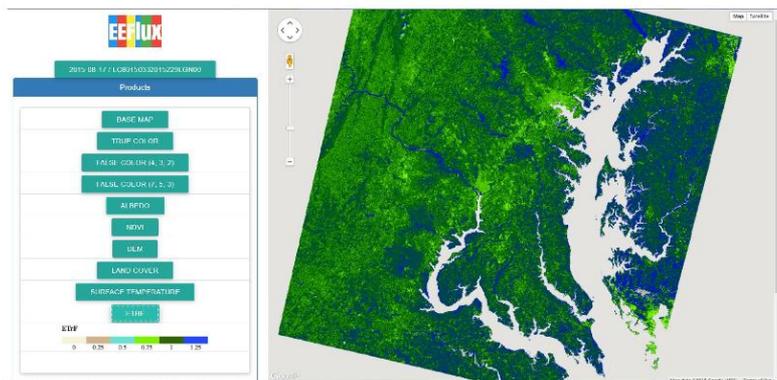
- Growers get access to authoritative content (Maps/Apps – real time information)
- Mobile-based
- Farming to tier & specific stress index



Ayse Kilic, Univ. of Nebraska

Google Earth Engine Evapotranspiration Flux - EEFlux

ET_rF--Fraction of Reference ET

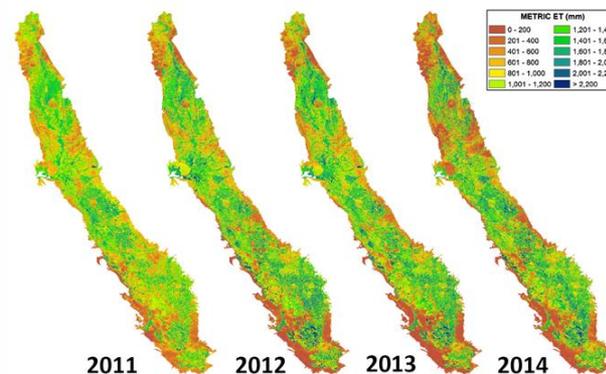


$$ET_rF = ET/ET_{ref}$$

ET_{ref} is reference ET- ASCE-Penman Monteith Alfalfa reference

Justin Huntington, DRI

Testing Large Area Applications of Automated METRIC Energy Balance on NEX



You can't Manage what you can't Measure!

NASA Earth Exchange

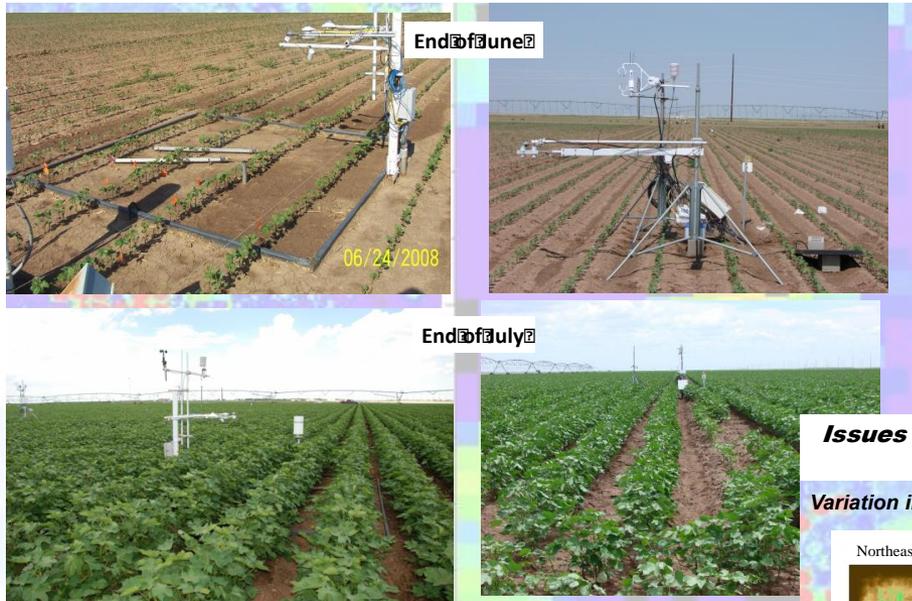


Collaboration with Forrest Melton

Evaluating ET Measurements



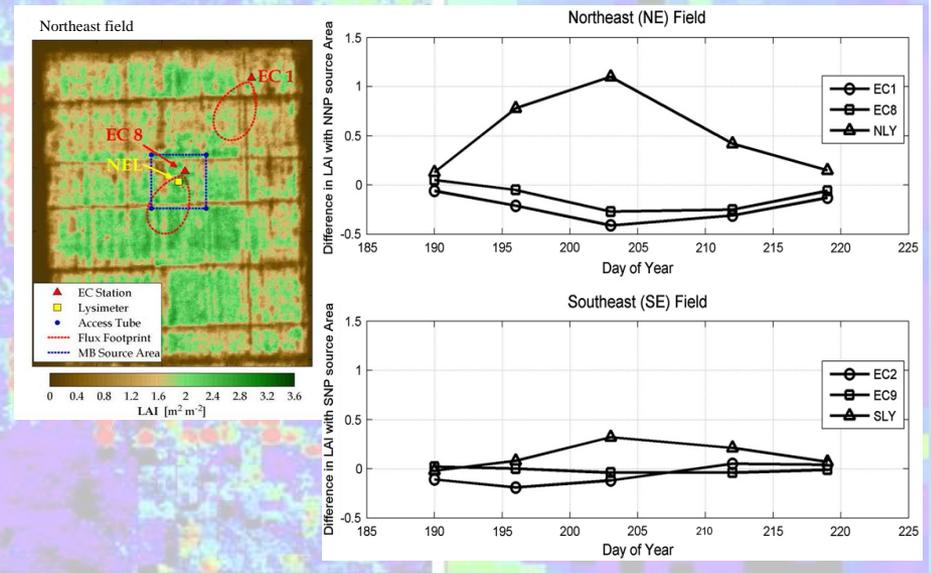
Issues in Evaluating ET Model Output Using Measurements and Model Inter-comparisons



Bill Kustas, USDA ARS

Issues in Evaluating ET Model Output Using Measurements and Model Inter-comparisons

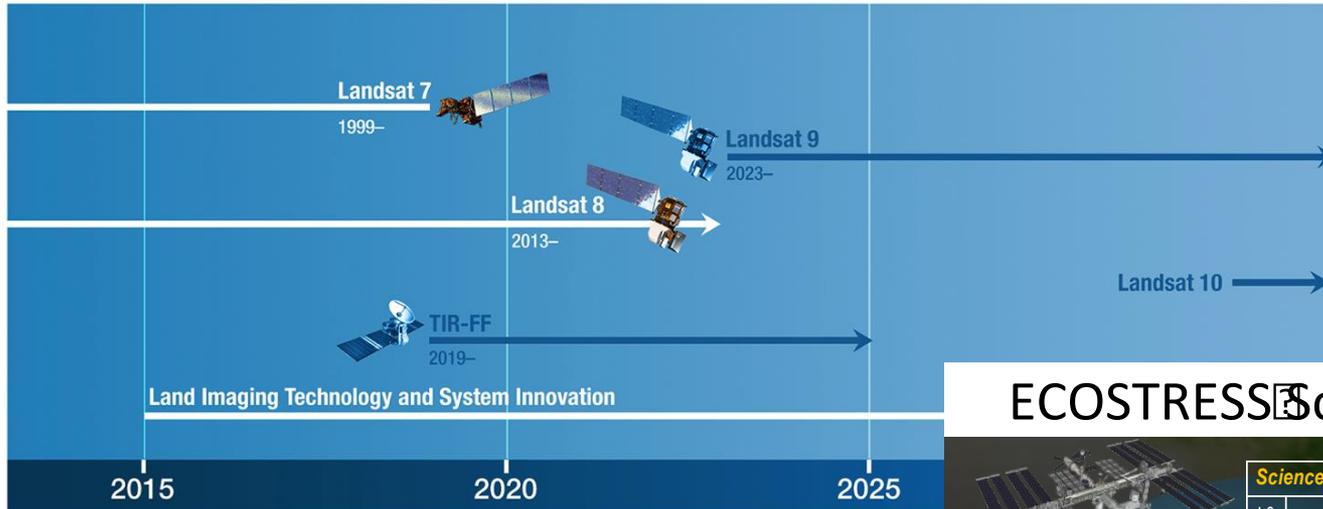
Variation in source area/flux footprint affecting the measurements by NP, LY and EC systems



Upcoming Missions to Support Water Management



Sustainable Land Imaging (SLI) Architecture



**Brad Doorn,
NASA HQ**

ECOSTRESS Science Overview (2/2)

**Josh Fisher,
NASA JPL**

Science Data Products	
L0	Raw data
L1	Radiometrically corrected Brightness Temperature
L2	Surface Temperature and Emissivity
L3	Evapotranspiration
L4	Water Use Efficiency, Evaporative Stress Index

Revisit Time versus Spatial Resolution
With sphere size indicating # of thermal infrared window bands

Science Team

Principal Investigator
Simon Hook, JPL

Co-Investigators
Rick Allen, Univ. of Idaho
Martha Anderson, USDA
Joshua Fisher, JPL
Andrew French, USDA
Glynn Hulley, JPL
Eric Wood, Princeton Univ.

Collaborators
Christopher Hain, Univ. Maryland



Other Topics

Mike Hobbins, NOAA

Estimating Reference Crop ET (ET₀)
Penman-Monteith ET₀ model

ASCE Standardized Reference ET equation
(identical to FAO-56 on a daily basis)

$$ET_0 = \frac{0.408 D (R_n - G) \frac{86400}{10^6} + \frac{9 C_p}{D + G} U_2 (e_w - e_a) \frac{86400}{10^6}}{D + G (1 + C_p U_2)}$$

Radiative forcing Advective forcing

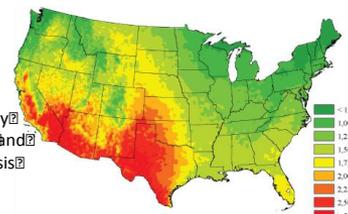
"Reference" crop is specified:

- 12-m grass in 50-m alfalfa
- well-watered actively growing
- completely shading the ground
- albedo of 0.23

Drivers from NDAS:

- temperature at surface (2m)
- specific humidity at surface
- downward W at surface
- 10-m wind speed at 2.0m
- daily, Jan, 1979 to present
- ~12-km, CONUS-wide

remotely sensed and reanalysis data



Mean Annual ET (mm), 1981-2010

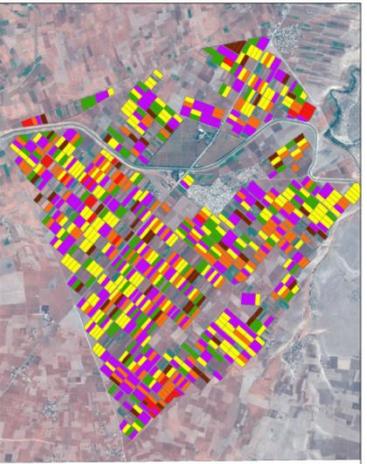
λ = latent heat of vaporization
R_n = net radiation (SW + LW) at crop surface
G = ground heat flux
U₂ = wind speed
e_w = saturated actual vapor pressure
Δe_s = air temperature
γ = psychrometric constant
Δt = time-step

CONUS-wide template for global product



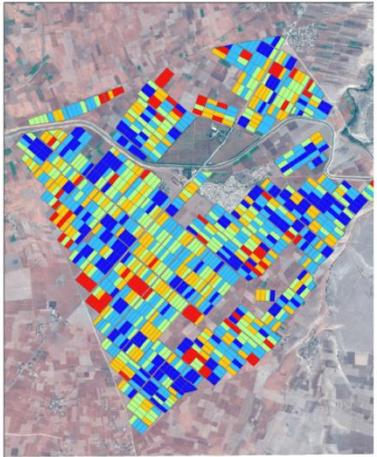
Mutlu Ozdogan, Univ. of Wisconsin

Cumulated ET (mm) from Jan 27 to Apr 17, 2015



Légende
14.91 - 28.96 28.96 - 45.05 45.05 - 61.51 61.51 - 82.57
28.67 - 38.95 45.05 - 51.50 60.98 - 73.01

Daily ET (mm) processing from Landsat image (25 August 2015)



Légo
0-1.5 1.5-3.0 3.0-4.5 4.5-6.0 > 6

Tim Newman, USGS

U.S. Geological Survey Stakeholder Outreach

- USGS Requirements, Capabilities & Analysis (RCA) activity
- Landsat Science Team
- National Geospatial Advisory Committee - Landsat Advisory Group
- USGS Fort Collins Science Center Surveys and Case Studies
- Department of the Interior Remote Sensing Working Group
- Office of Science & Technology Policy-led Earth Observation Assessment
- U.S. Group on Earth Observations (USGEO)
- National Research Council Earth Science Decadal Survey
- Landsat Ground Station Operators & Technical Working Groups
- AmericaView Nationwide Consortium for Remote Sensing
- Committee on Earth Observation Satellites (CEOS)
- Intergovernmental Group on Earth Observations (GEO)
- Joint Agency Commercial Evaluation (JACIE) Workshop
- Day-to-day interaction with users, meetings, conferences, workshops

Themes from Day 1



1. Remotely-sensed ET data products are currently used for water management applications in 22 states in the U.S., and for national-scale applications including drought monitoring and the U.S. Water Census
2. Advances in use of cloud computing and web services / mobile devices are increasing access to remotely sensed ET data
3. Improving frequency of 30-100m satellite observations would enhance water management applications in U.S. and internationally