HyspIRI TQ3: Water Use and Availability

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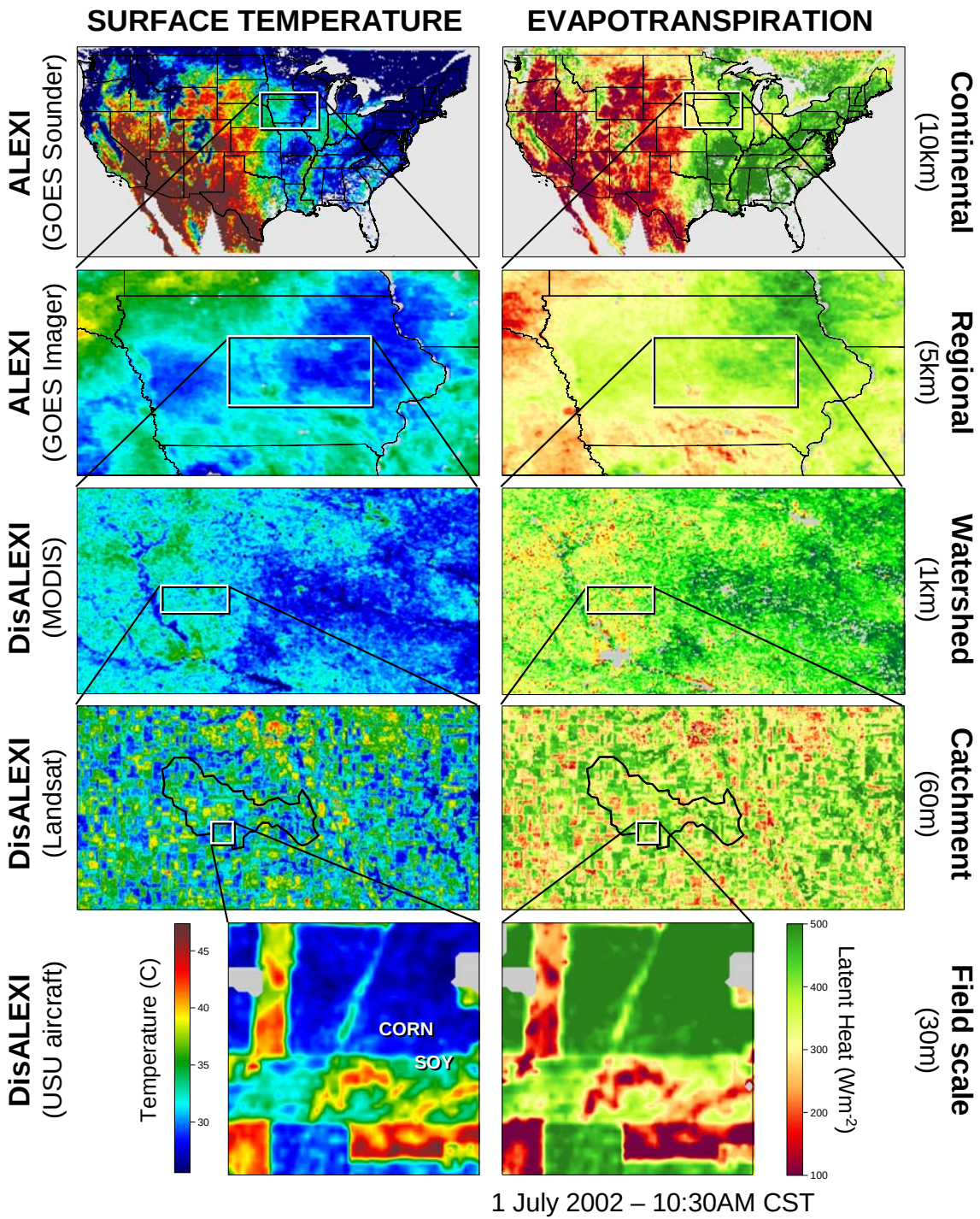
Earth *IS* the Water Planet

Quantifying and Managing Water Consumption is Crucial

TQ3: Water Use and Availability

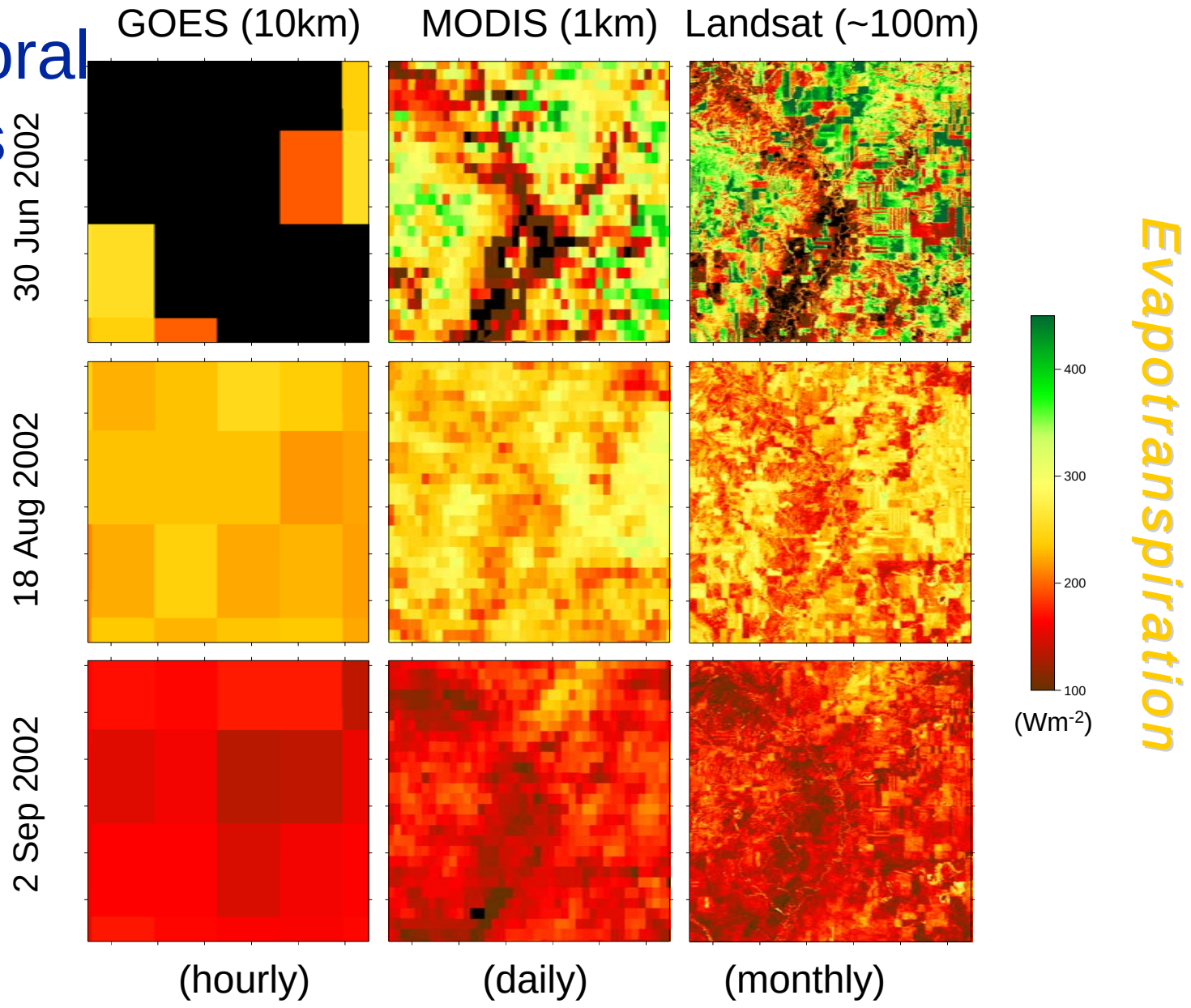
- *Response to climate change:*
  How is climate change impacting the evaporative component of the global water cycle over natural and managed landscapes?
- *Water management:*
  How can information about evapotranspiration and its relationship to land-use/landcover be used to facilitate better water management?
- *Drought:*
  How can we improve early detection, mitigation, and impact assessment of droughts at local to global scales?
- *Irrigated area:*
  What is the current global irrigated acreage, how is it changing with time, and are these changes in a sustainable balance with regional water availability?
- *Water use in food production:*
  Can we increase food production in water-scarce agricultural regions while improving or sustaining environmental access to water?

Spatial Scales of ET

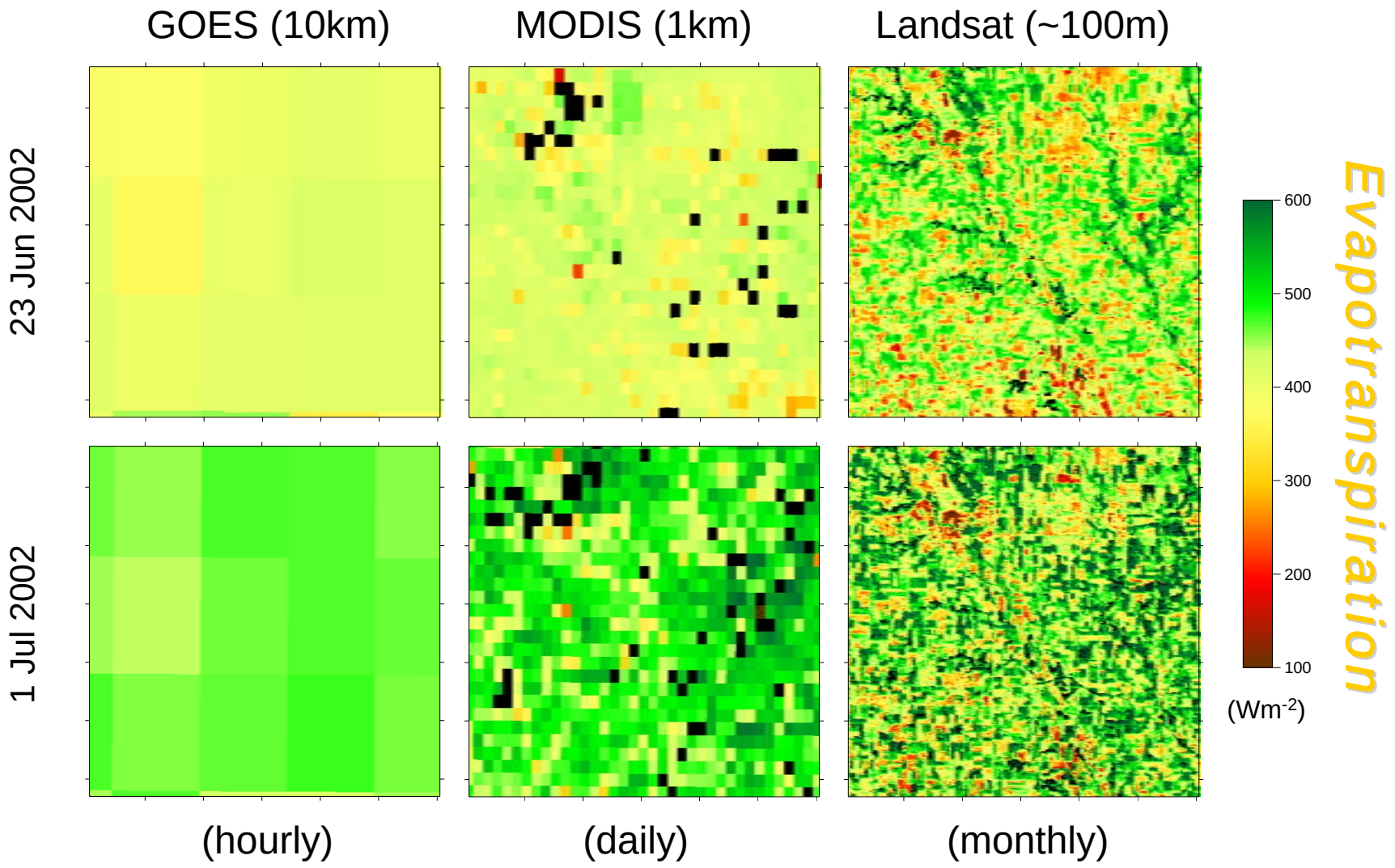


Temporal Scales of ET

FORT PECK, MONTANA

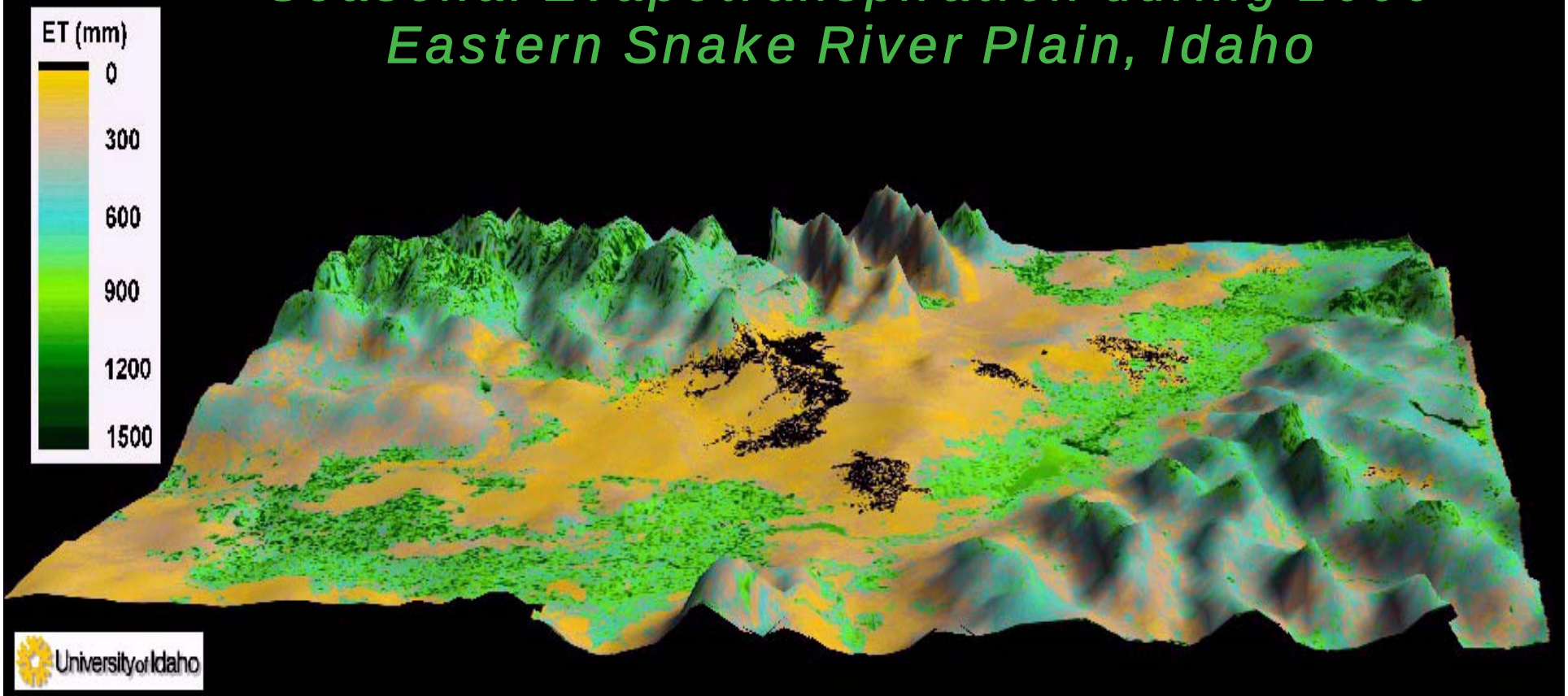


AMES, IOWA


GOES (10km)
MODIS (1km)
Landsat (~100m)
23 Jun 2002
1 Jul 2002
(hourly)
(daily)
(monthly)
600
500
400
300
200
100
(Wm-2)
Evapotranspiration

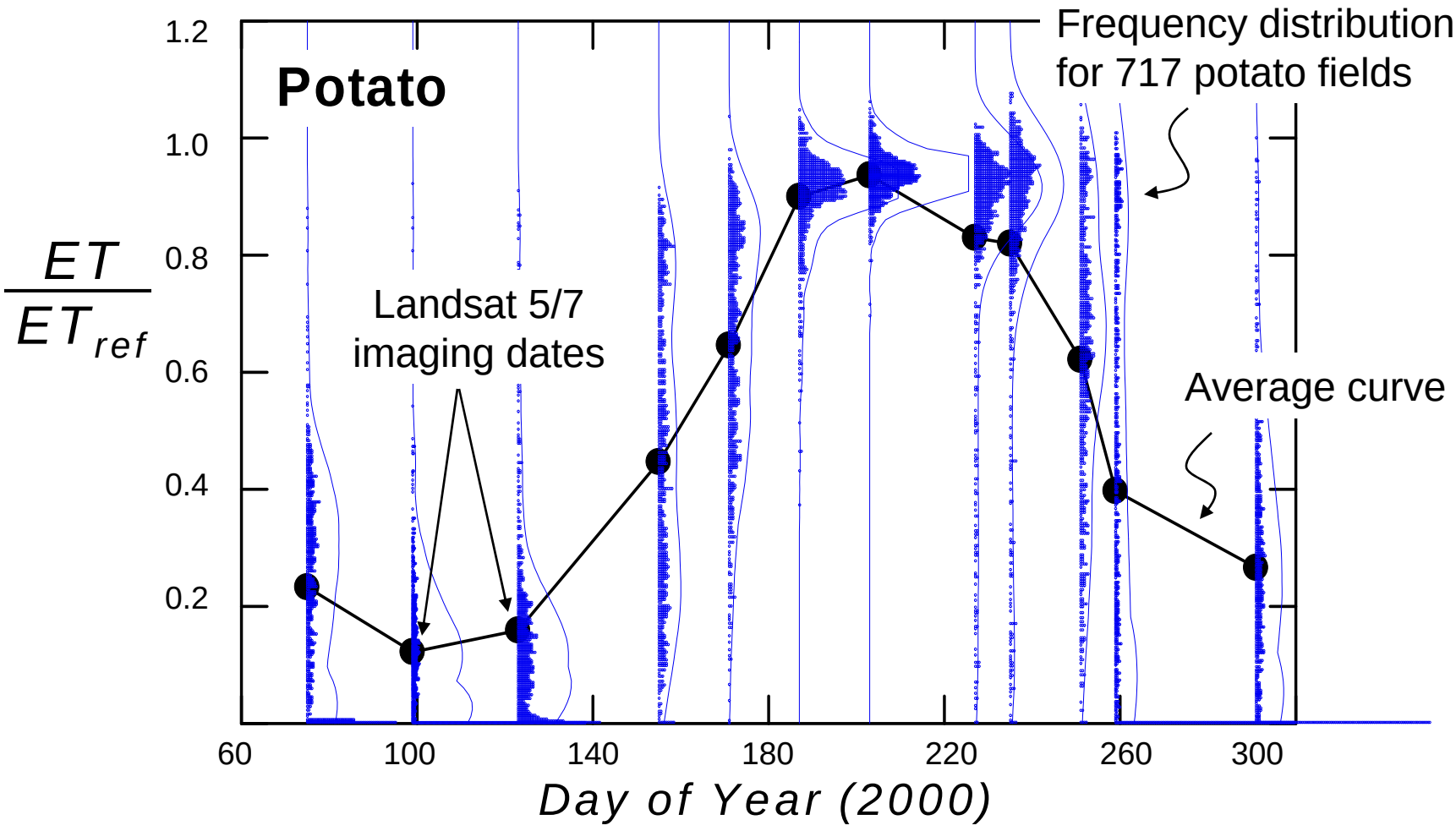
Impact of Irrigation on Water Consumption

Seasonal Evapotranspiration during 2000
Eastern Snake River Plain, Idaho



(R. Allen)

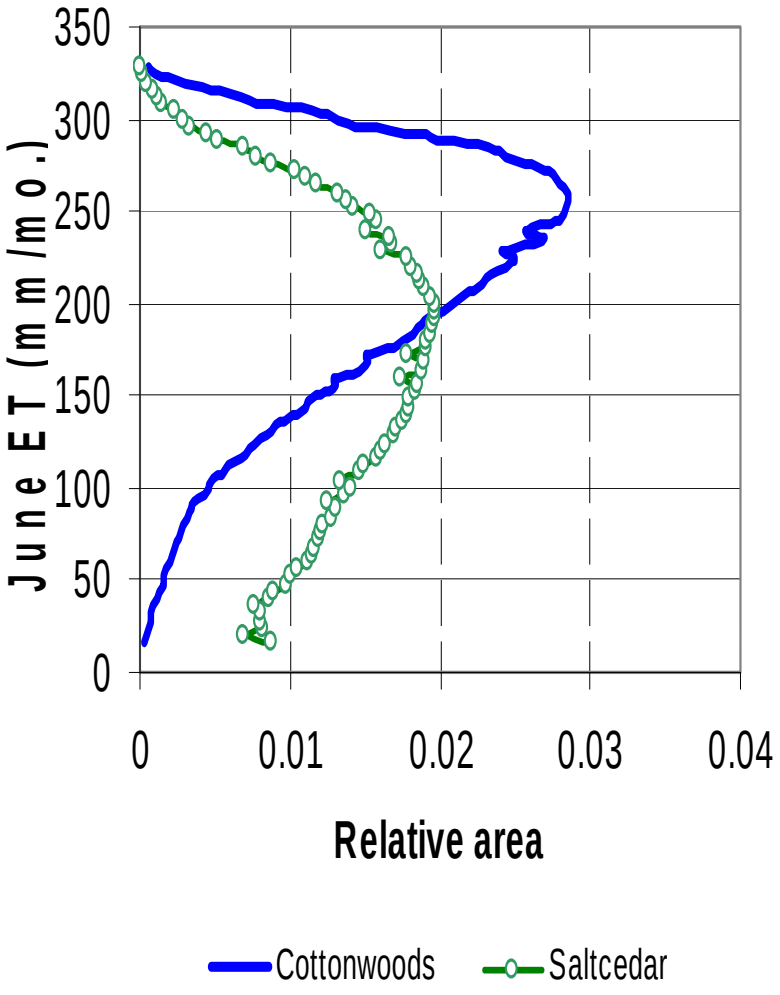
Variation among Fields of the Same Crop

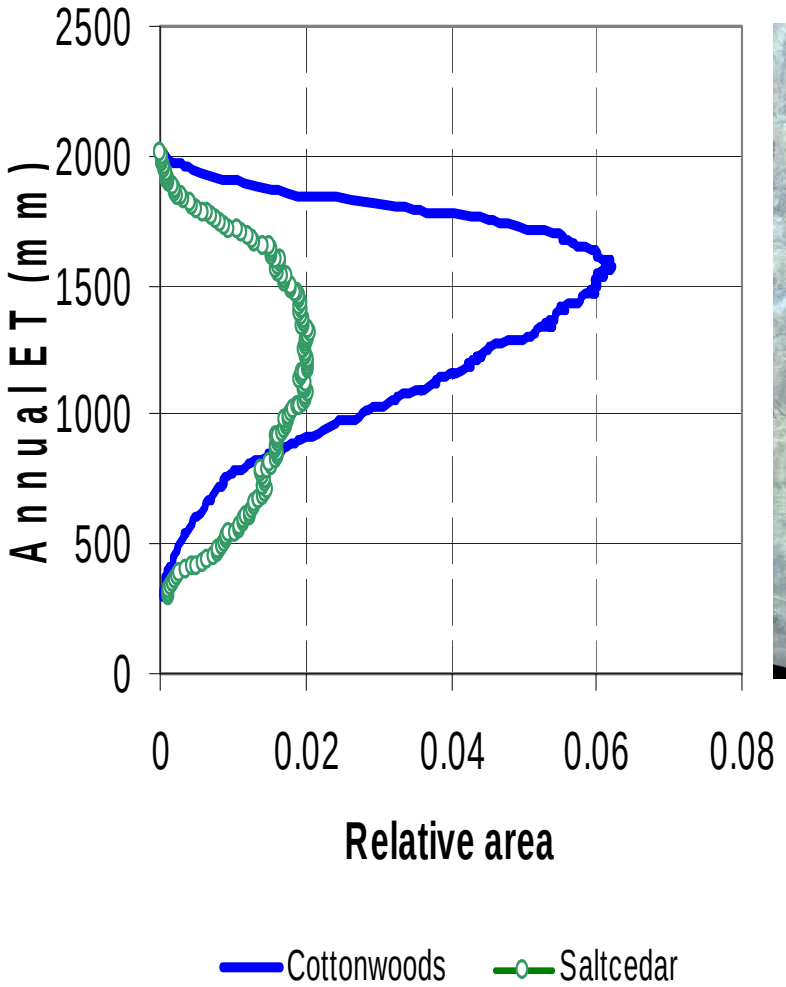


- **<100m TIR imaging allows sampling of individual fields**
- **weekly revisit will improve seasonal integration**

Variation among Populations of Wild Vegetation

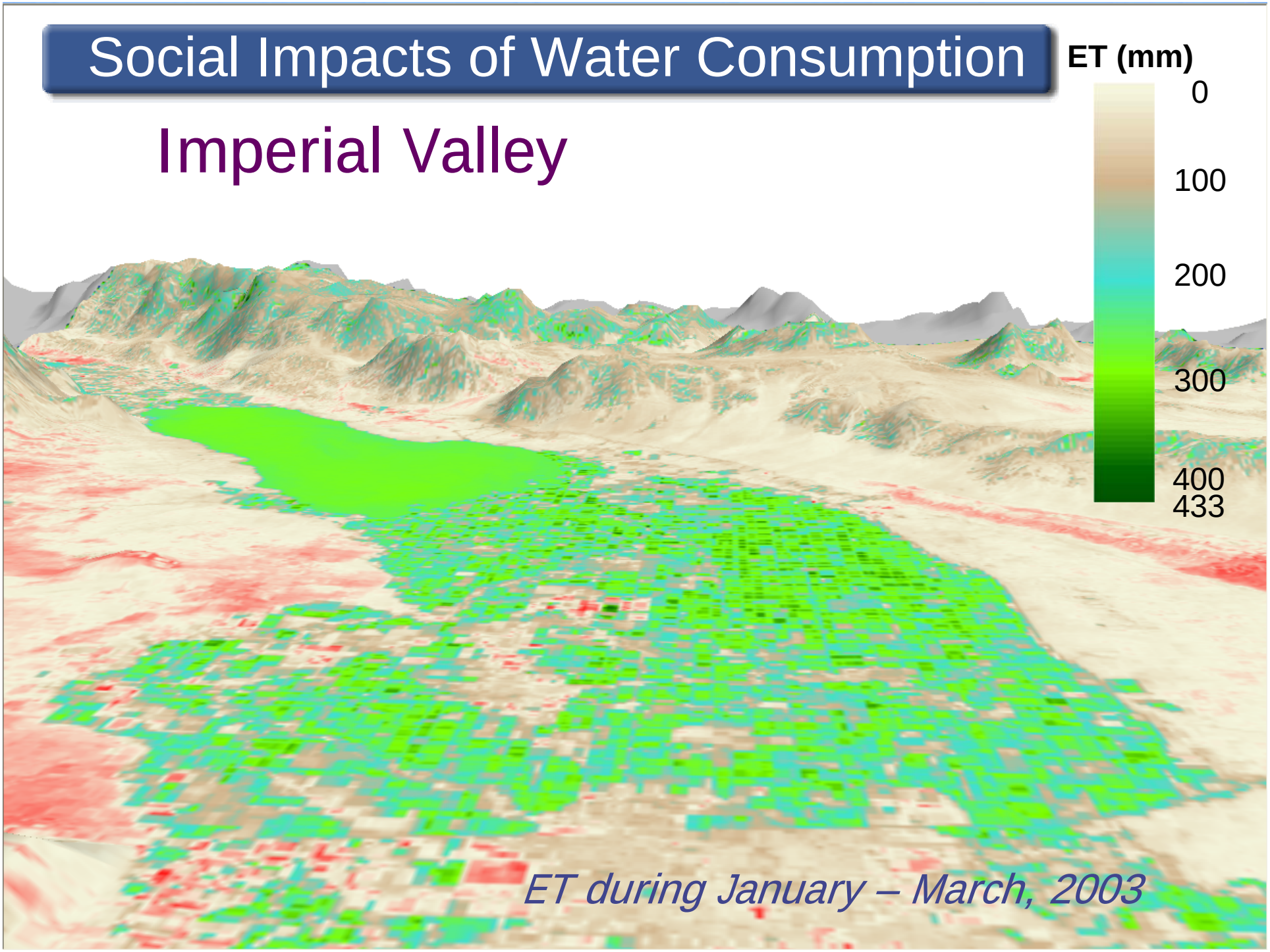
15,000 acres of cottonwood and salt cedar





Social Impacts of Water Consumption

Imperial Valley



ET during January – March, 2003

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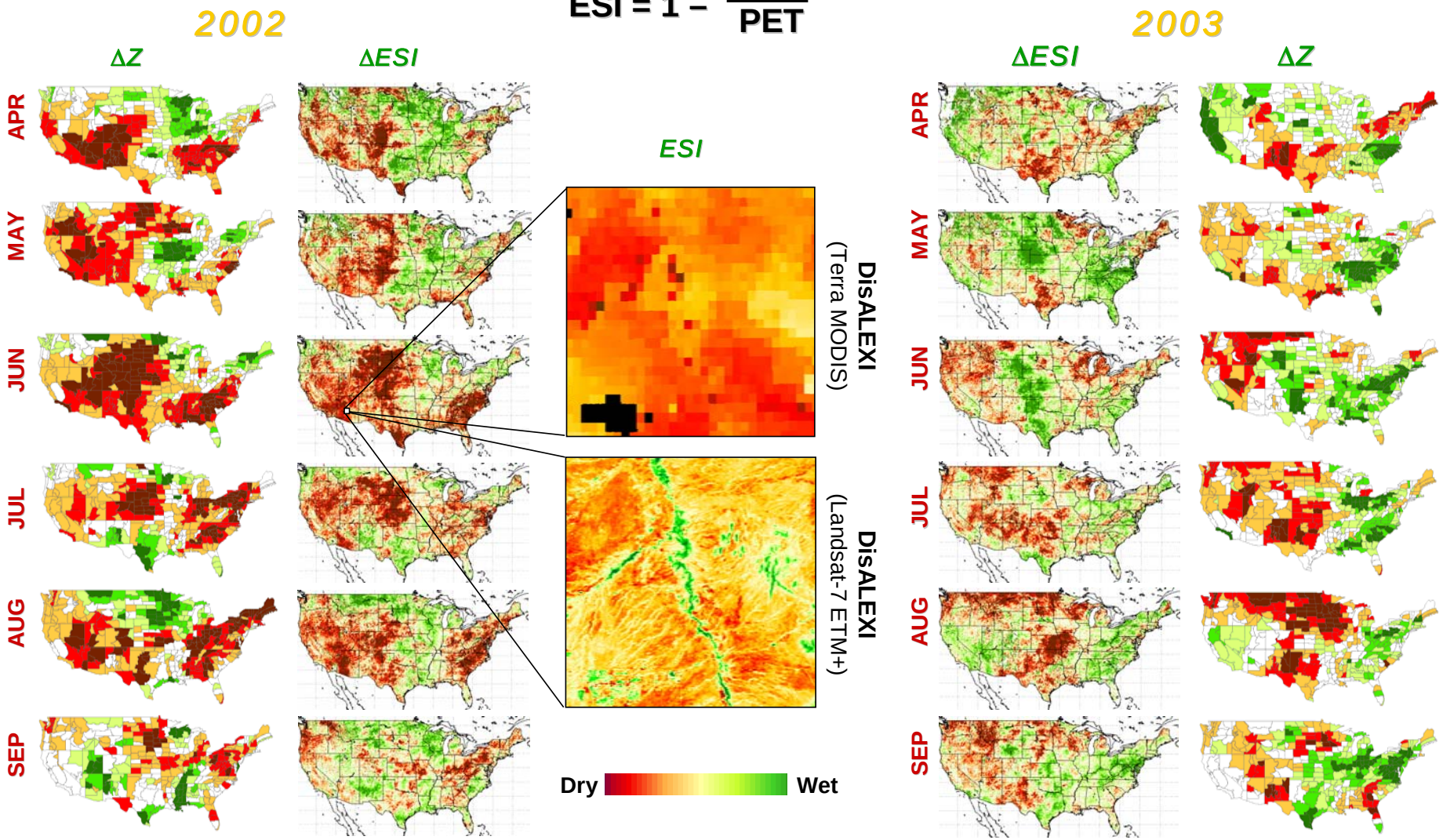
EVAPORATIVE STRESS INDEX

$$ESI = 1 - \frac{AET}{PET}$$



AET = ~f(LST)

PET = ~f(Veg.Index)

(Anderson et al., 2007)

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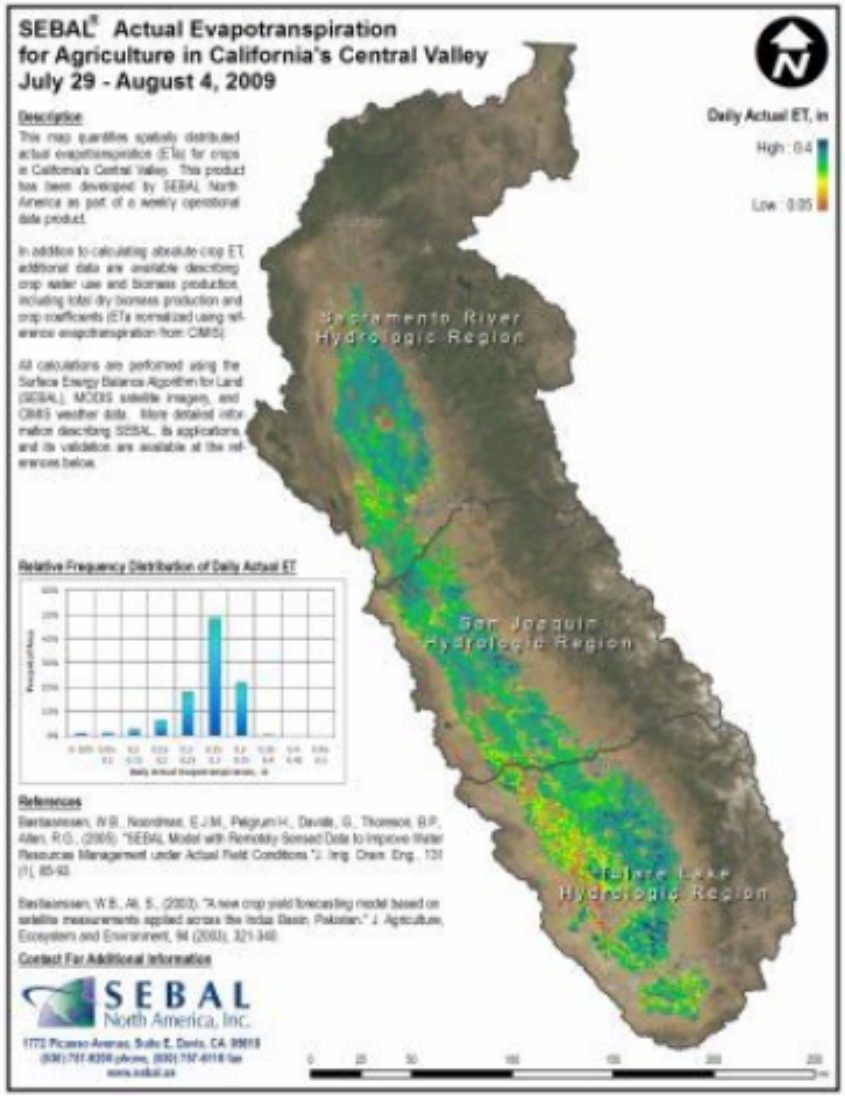
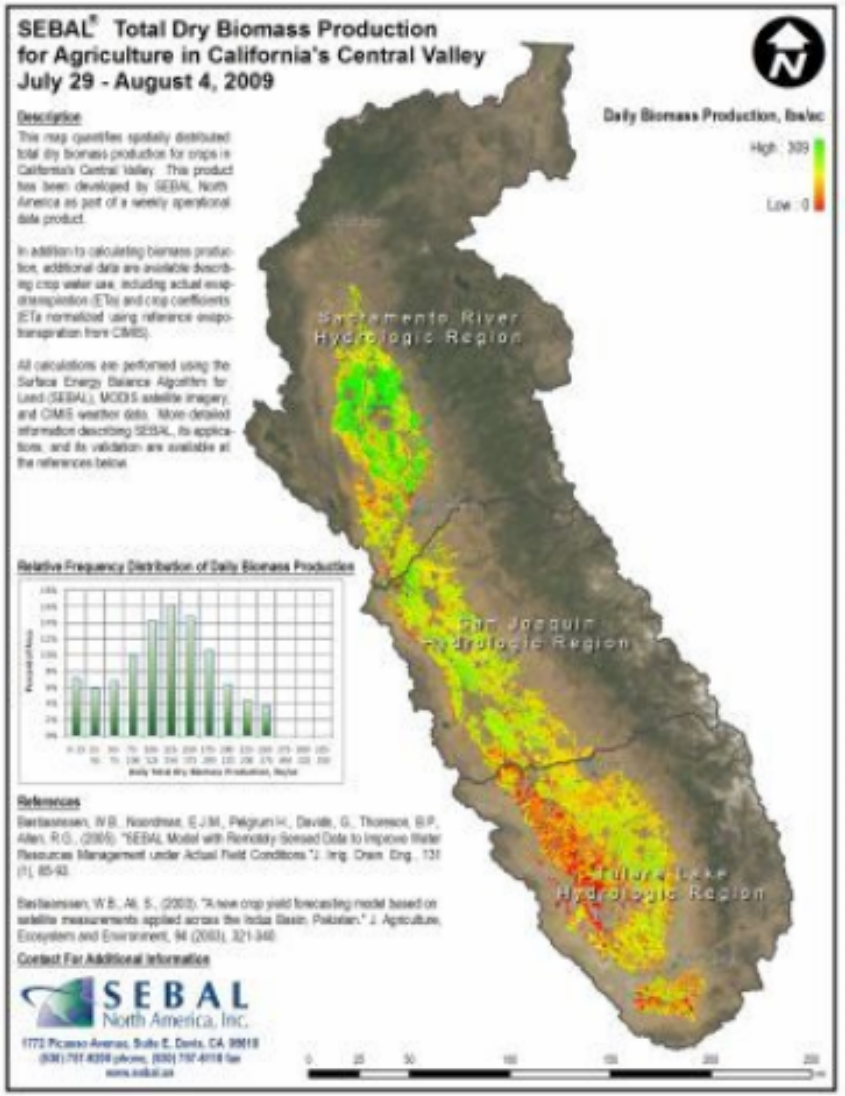
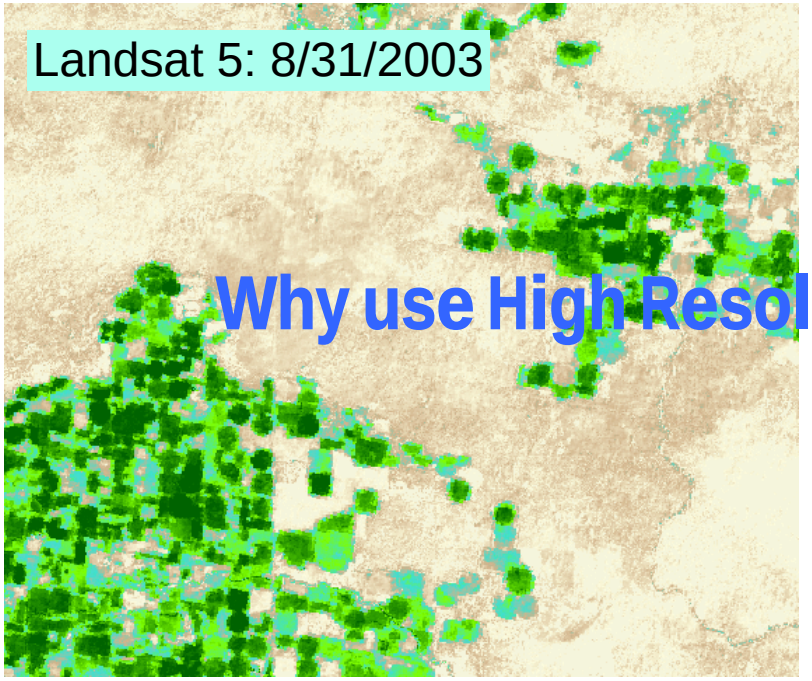
Water Consumption and Biomass from Satellite

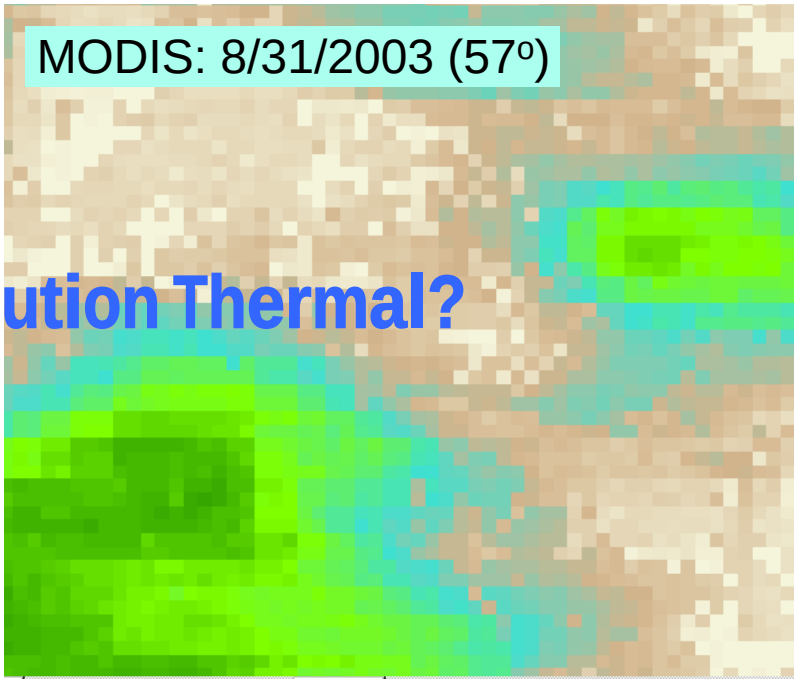


Actual Evapotranspiration

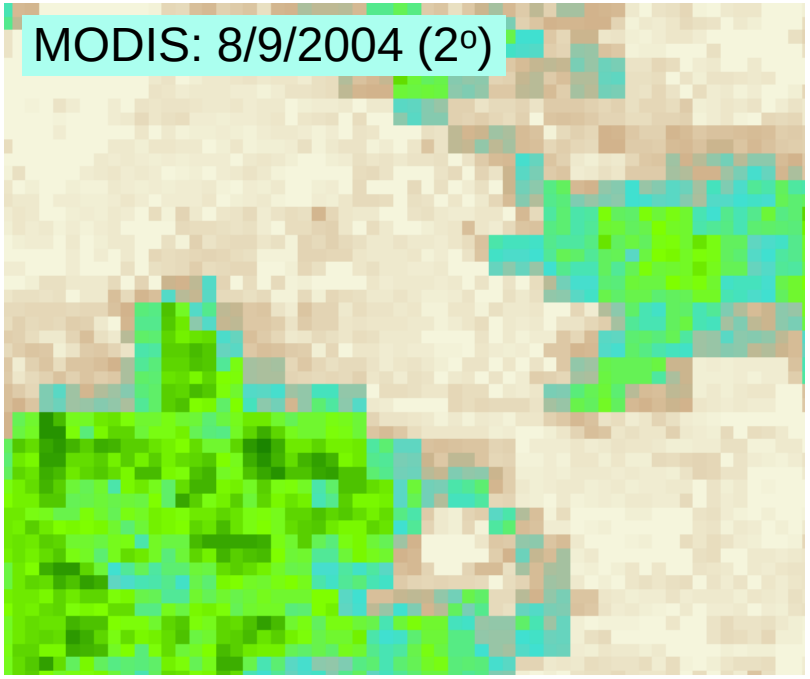


Total Dry Biomass production



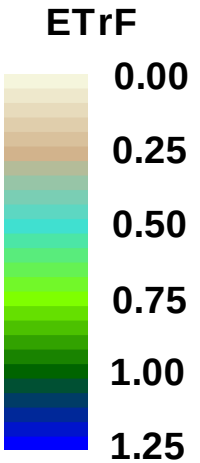


Why use High Resolution Thermal?



ET by METRIC

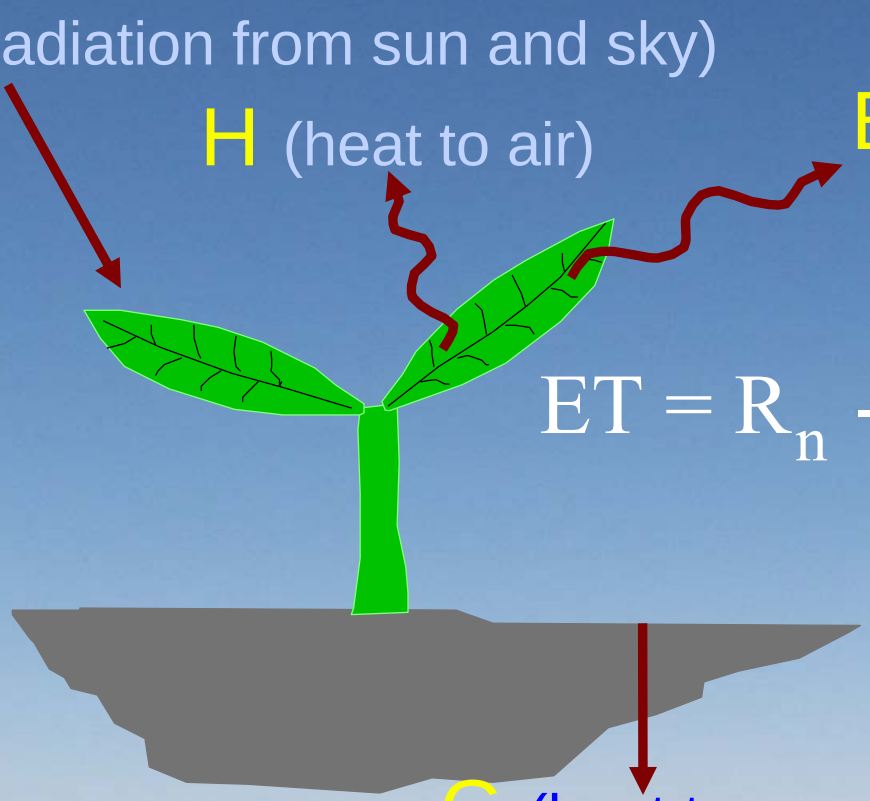
Minidoka, Idaho



$$ET_rF = \frac{ET}{ET_{reference}}$$

Why Energy balance?

- ET is calculated as a "residual" of the energy balance

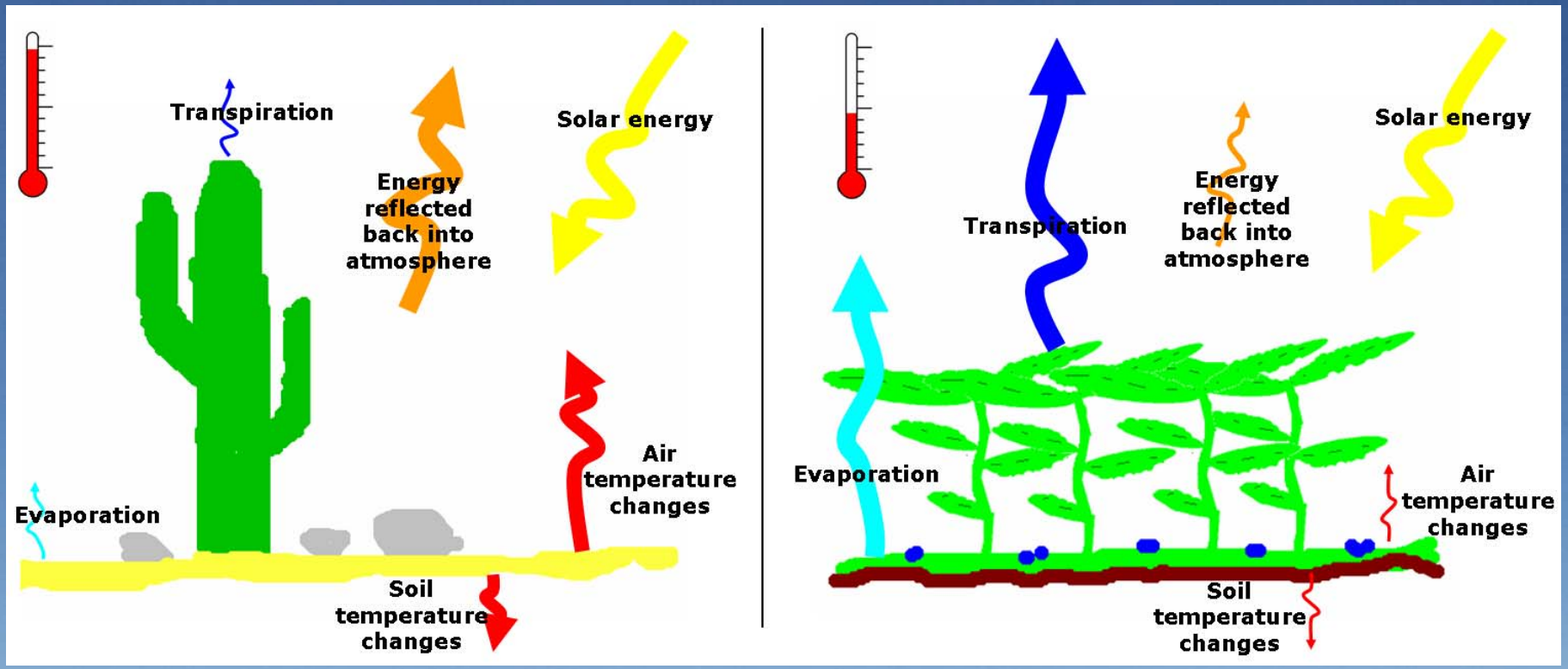


$$ET = R_n - G - H$$

Basic Truth: Evaporation consumes Energy

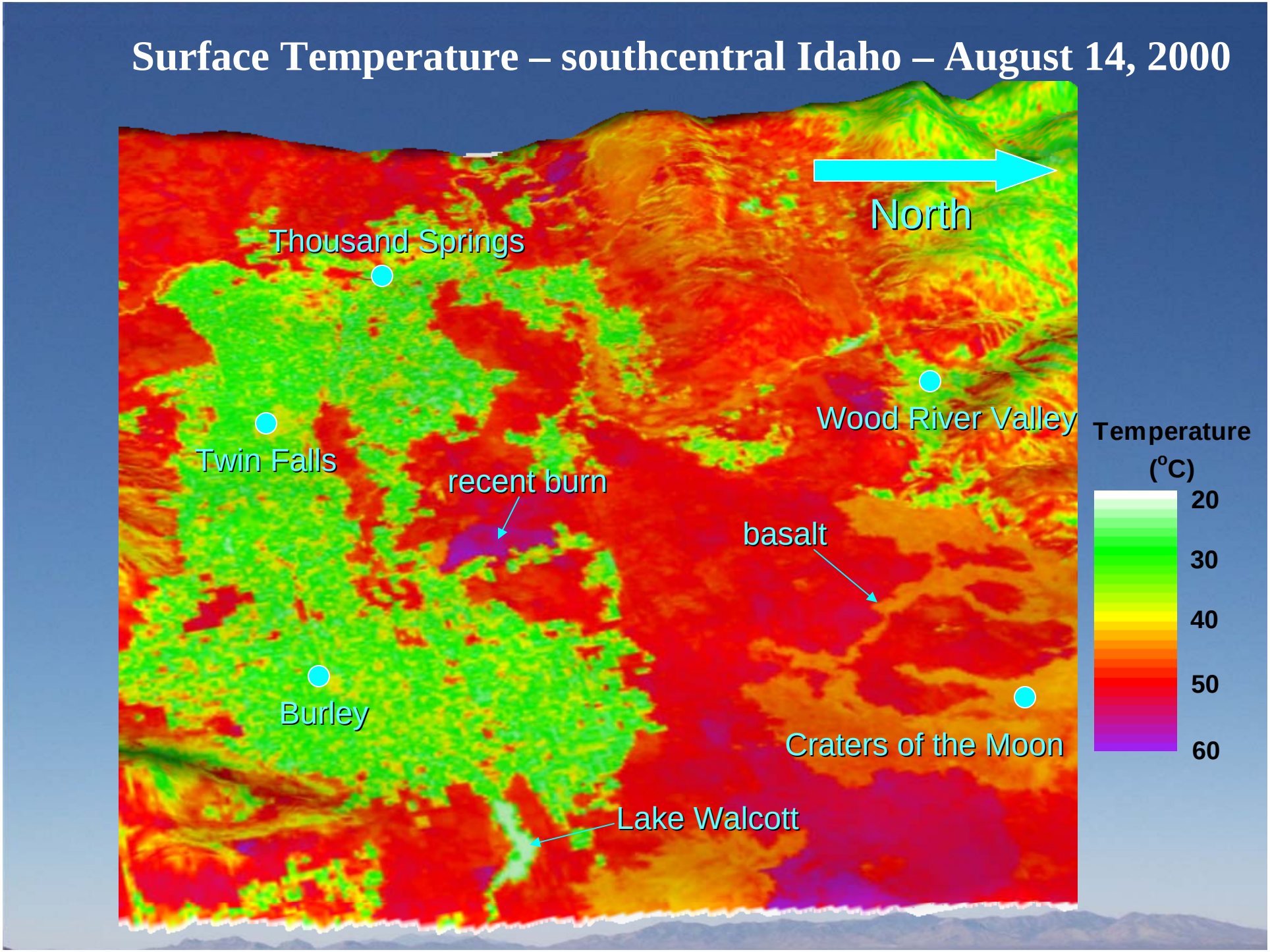
The energy balance includes all major sources (R_n) and consumers (ET, G, H) of energy

Why Land Surface Temperature?



Courtesy of W. Bastiaanssen, WaterWatch

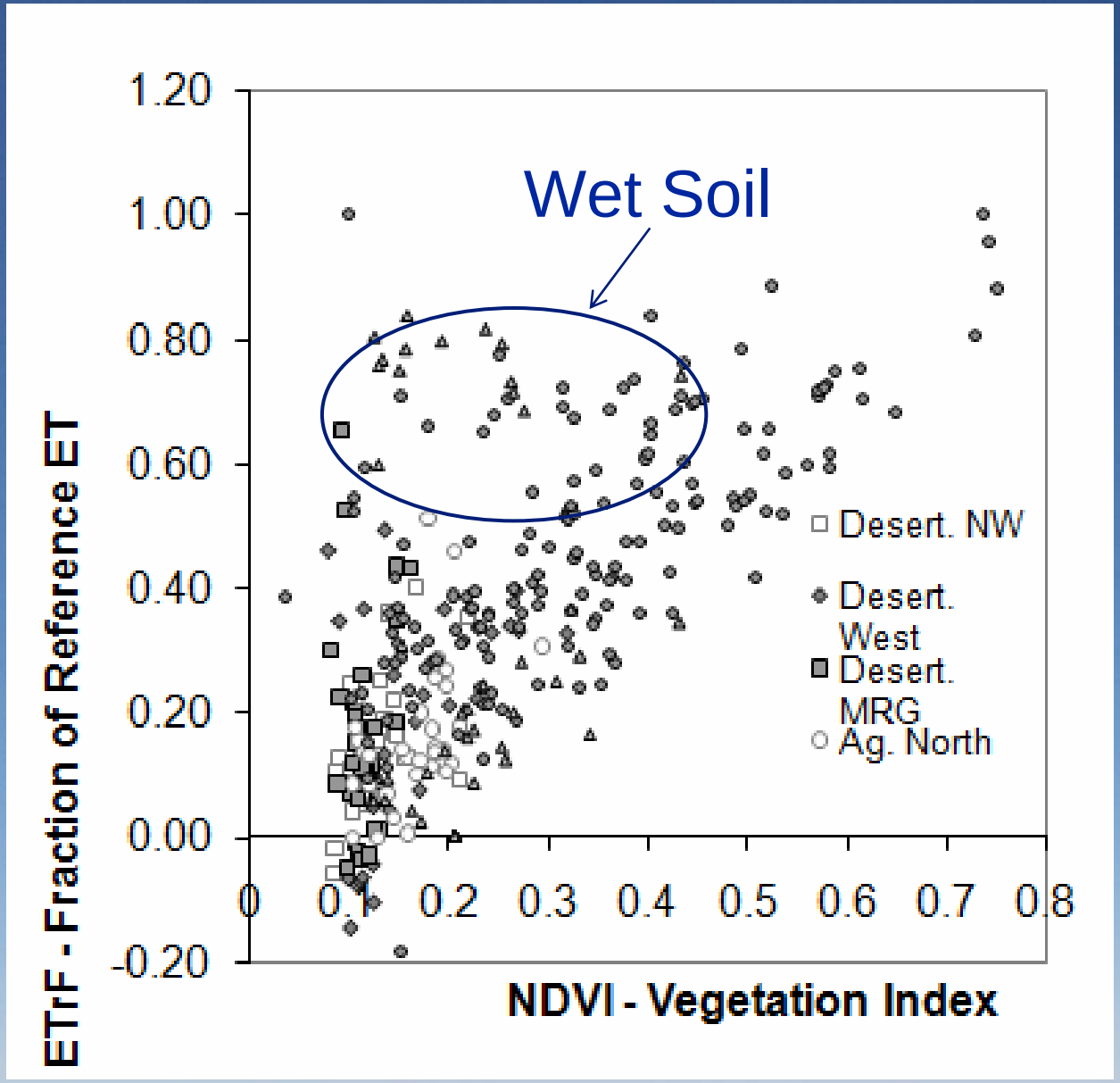
Surface Temperature – southcentral Idaho – August 14, 2000



ET is not just about Vegetation Amount

April 4, 2002
Landsat 7

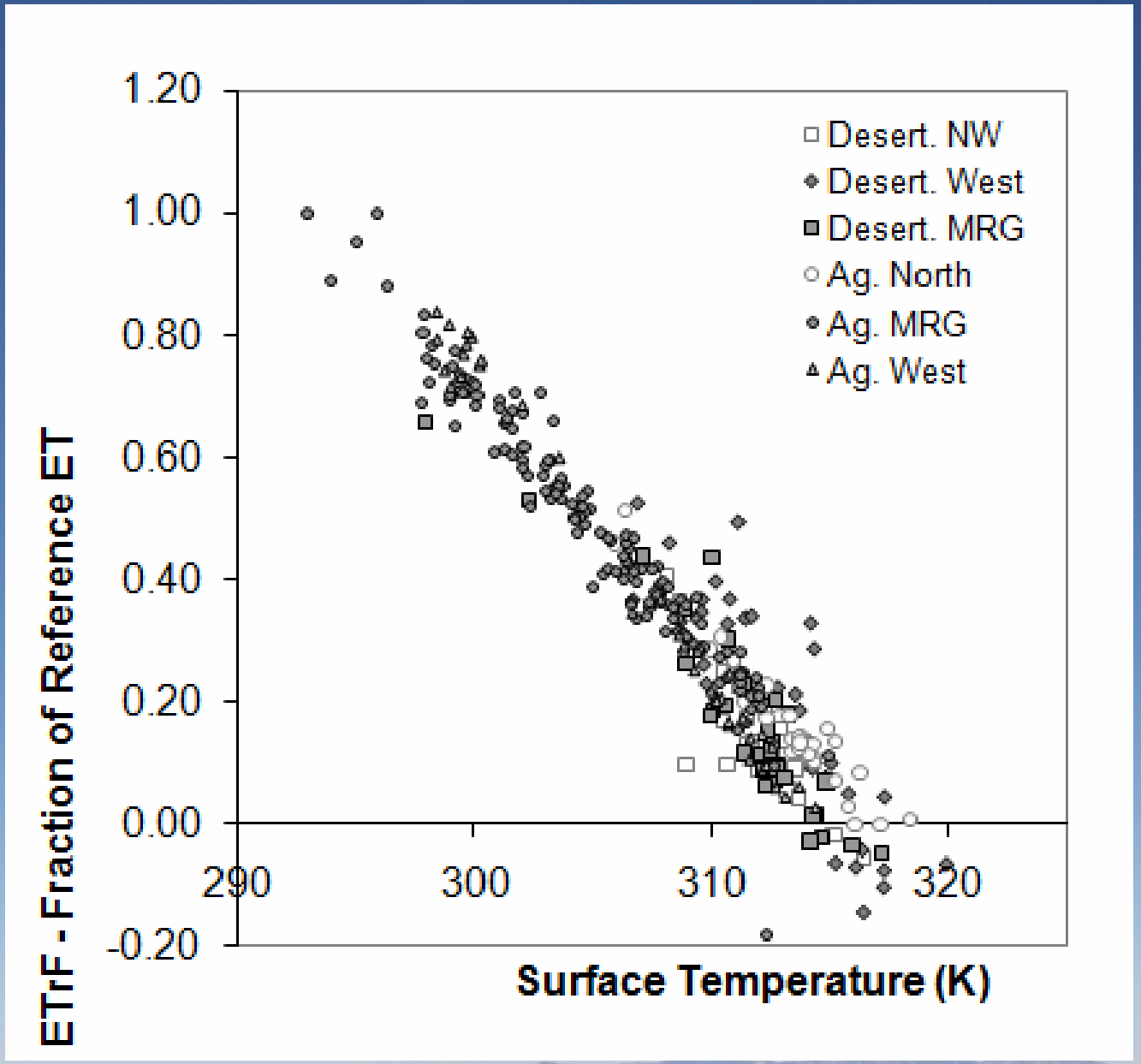
Rio Grande,
New Mexico



ET is not just about Surface Temperature (but almost)

April 4, 2002
Landsat 7

Rio Grande,
New Mexico

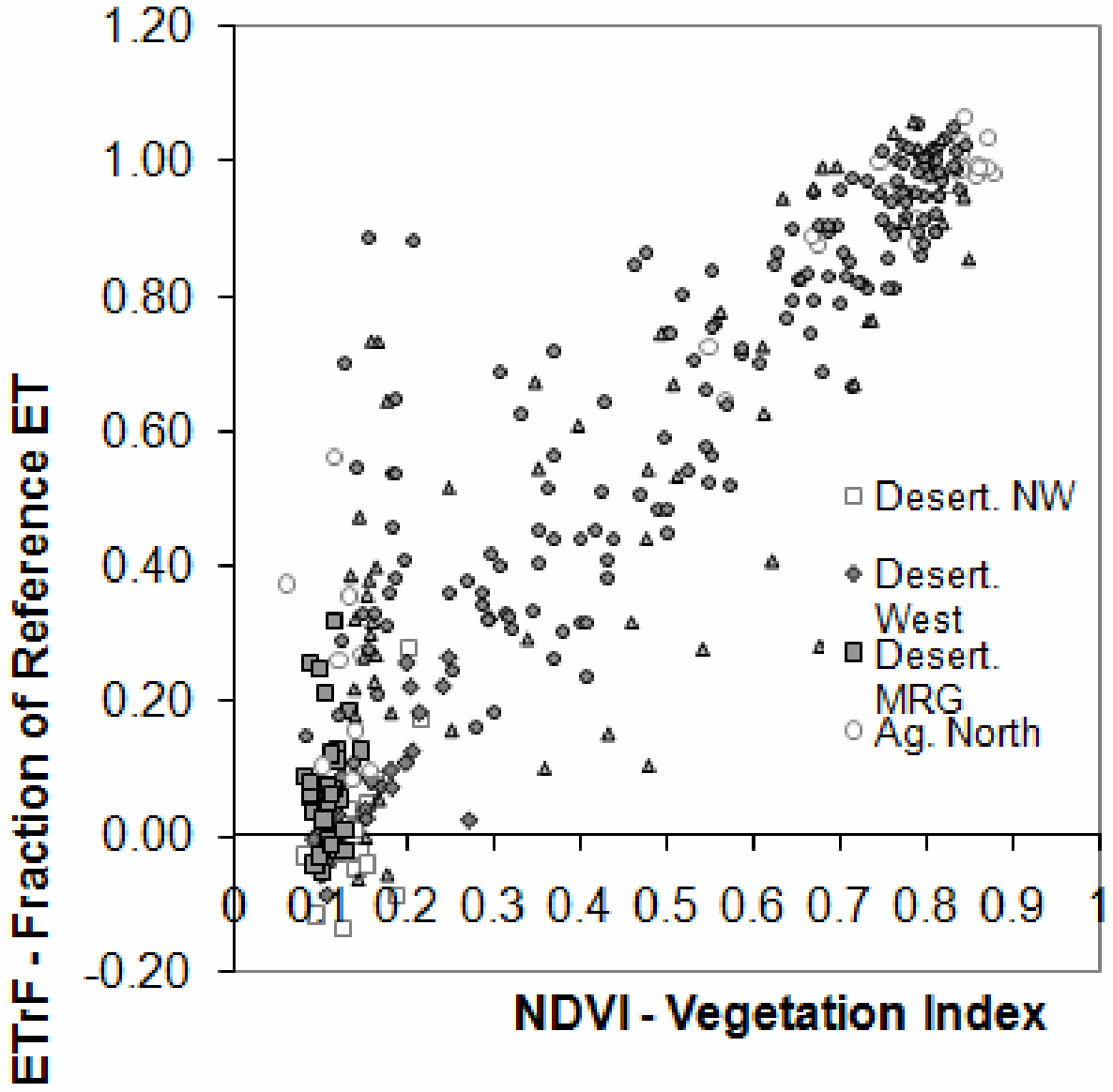


ET vs. NDVI

June 7, 2002
Landsat 7

Rio Grande,
New Mexico

Dry soil surface

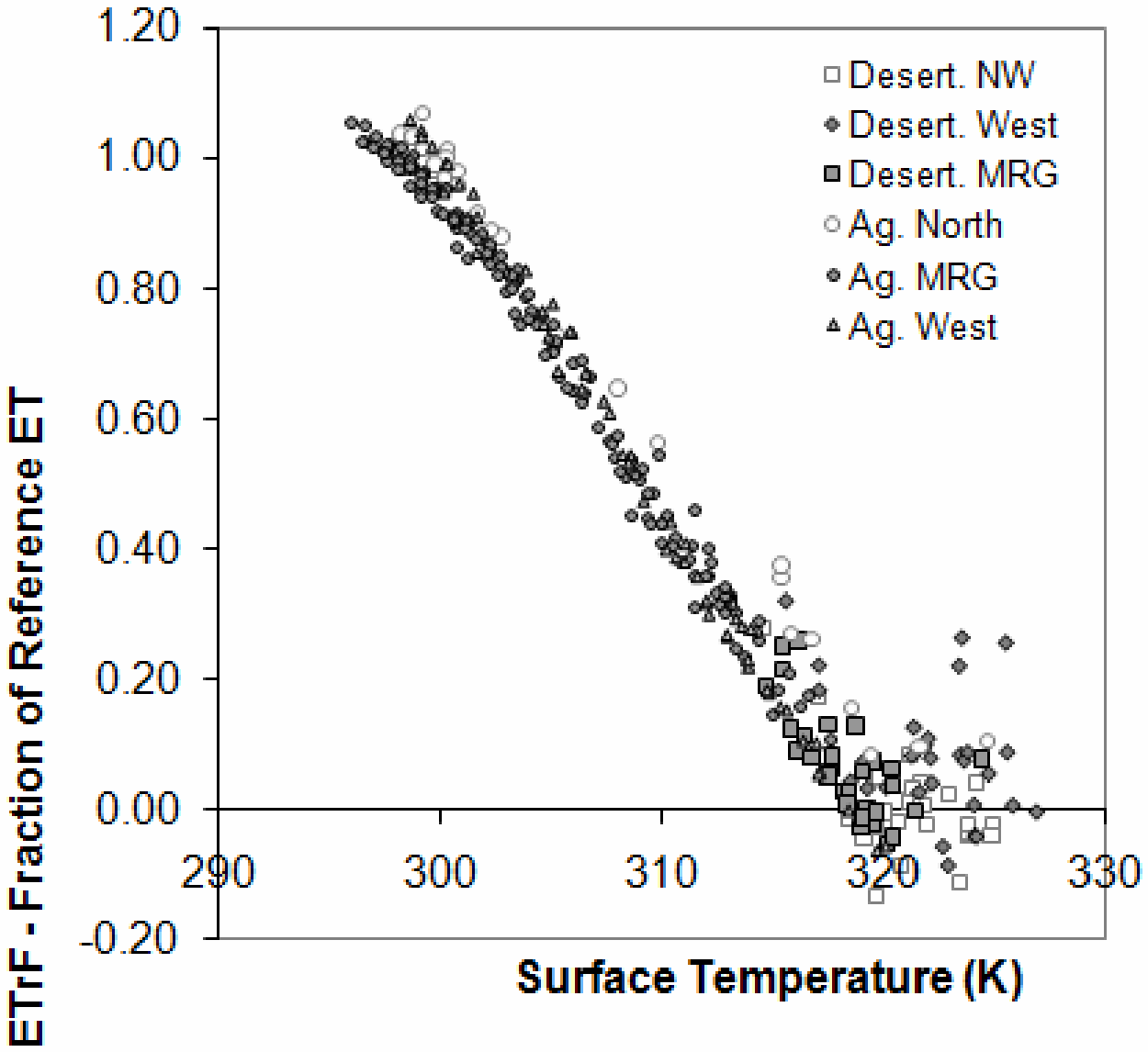


ET vs. LST

June 7, 2002
Landsat 7

Rio Grande,
New Mexico

Dry soil surface



Sensible Heat Flux -- Parameterization

$$H = \rho \, c_p \, T_* \, u_*$$

$$T_* = \frac{\Delta T}{\ln\left(\frac{z_2}{z_1}\right) - \psi_h(z_2, L) + \psi_h(z_1, L)}$$

$$u_* = \frac{k \, u_{z3}}{\ln\left(\frac{z_3}{z_{om}}\right) - \psi_m(z_2, L) + \psi_m(z_1, L)}$$

ΔT	=	near surface temperature gradient
u_{z3}	=	general wind speed at blending height
ψ	=	boundary layer stability functions

Science Traceability Matrix

Science Objectives (primary example→)	How is climate variability impacting the evaporative component of the global water cycle over natural and managed landscapes? (DS 166, 196, 203, 257, 368; WGA)
Measurement Objectives	Evapotranspiration (surface energy balance) at scales resolving the typical length scales of land-surface moisture Heterogeneity
Measurement Requirements	Global coverage; ~weekly revisit; resolving agricultural fields, riparian patches, reservoirs, water rights (tied to agricultural field-sized) polygons; LST accurate to 1 K; ~10-11 A.M. Overpass
Instrument Requirements	<100-m resolution; 3+ bands in the 8–12 micron region (for atmospheric and emissivity correction); Min/Max T 250/360 K; ~weekly revisit; Maximum view angle 20–30 deg from nadir
Other Mission and Measurement Requirements	Detailed land cover classification (can be improved using hyperspectral); vegetation indices; **coincident broadband albedo retrievals**; regional hydrologic water balances and stores

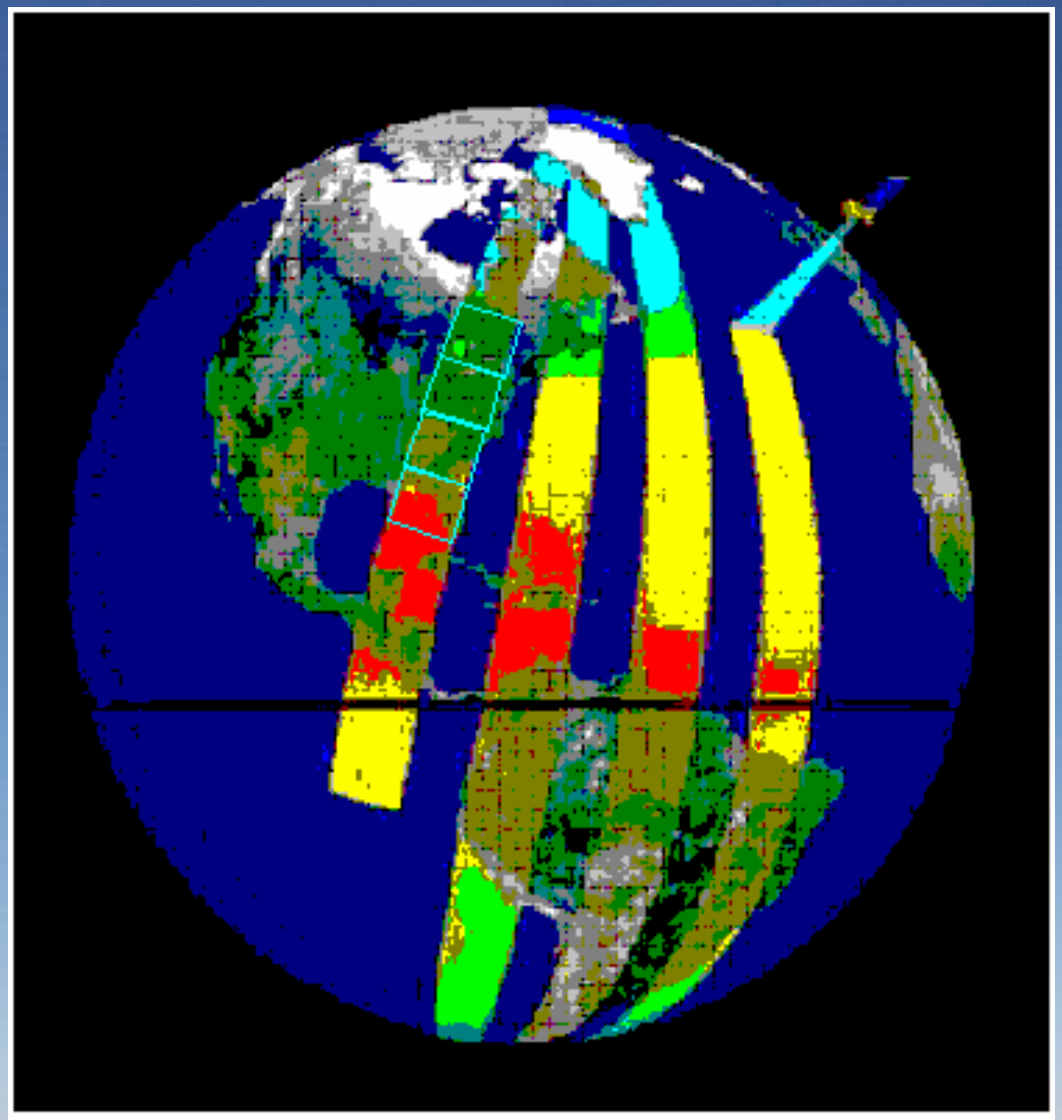
Validation Approaches

- ET from ground-based flux networks
  - Ameriflux / FLUXNET
  - NEON Long-term Ecological Research sites
  - NSF CUAHSI Hydrologic Study Watersheds
  - EOS validation sites
- Intensive Soil-Plant-Atmospheric modeling
- Other ET products (intensive, local scale remote sensing, etc.)

Level 3 Products

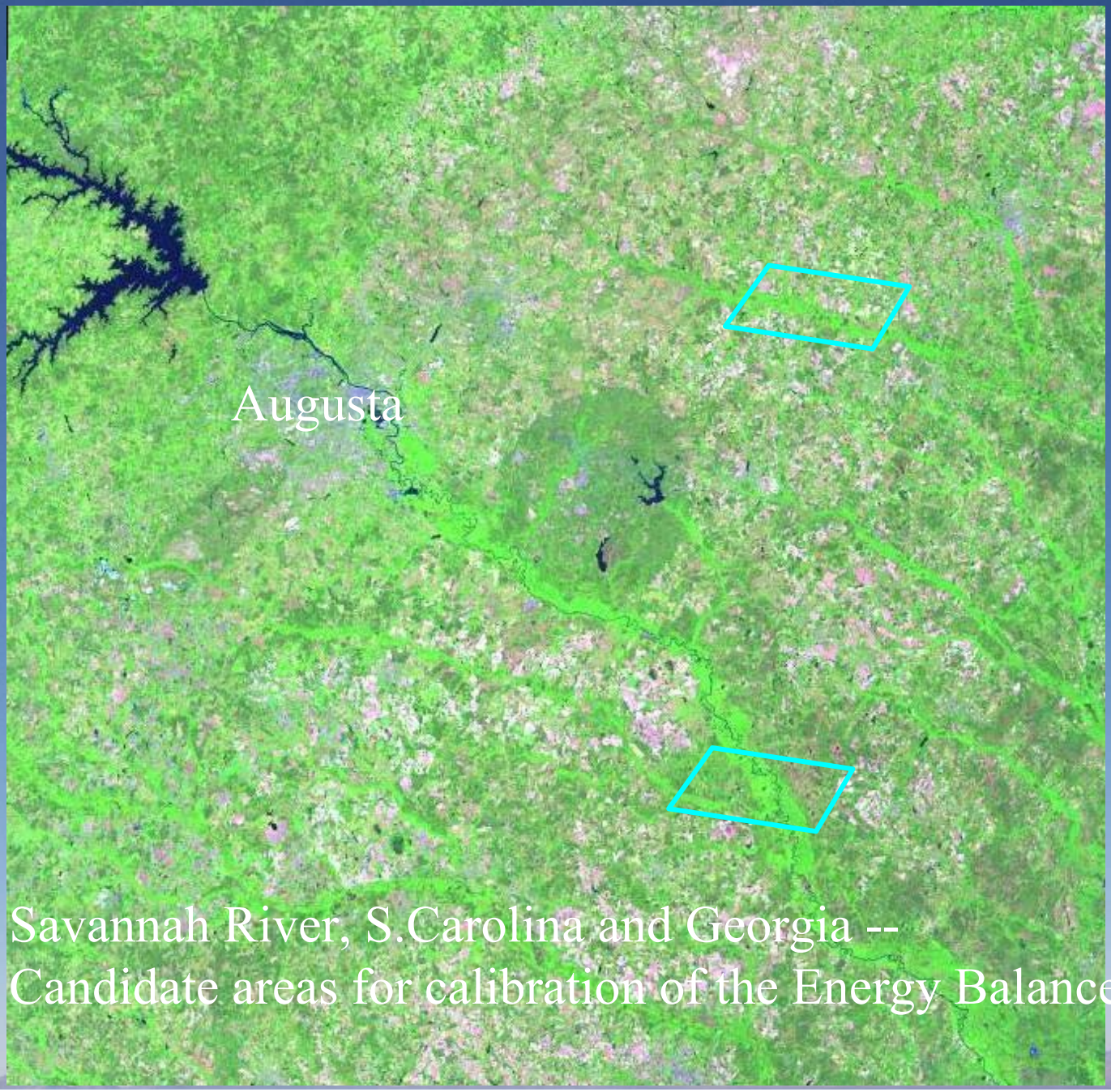
- High Resolution, Near Real Time Maps of Global Evapotranspiration and partitioning of H and LE
- High Resolution, Annual Maps of Global Evapotranspiration
- Global Maps of Irrigated Acreage
- Global Maps of Water Productivity (Crop per Drop)

Level 3 Product: Global Evapotranspiration



Pre-assign Calibration – Sampling areas each ~100 km

Use for automated calibration



Savannah River, S.Carolina and Georgia --
Candidate areas for calibration of the Energy Balance

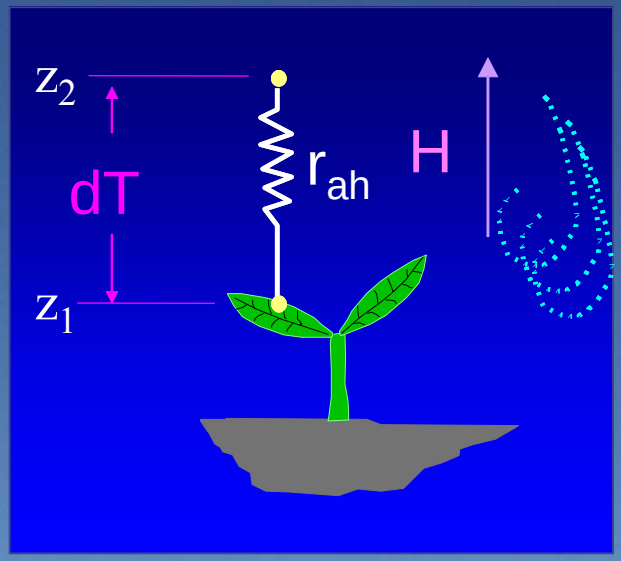
Calibration using **I**nverse **M**odeling of **E**xtreme **C**onditions – CIMEC -- used by *SEBAL, METRIC, SEBI*

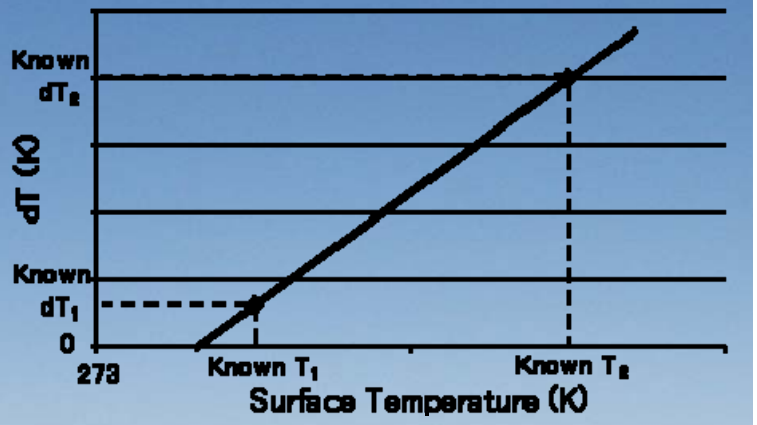
- Question: Are there 'conditions' in the image where we 'know' at least three components of the EB? *(R_n, G, H, LE)*
- Answer: Yes.
  - at a 'dry' condition:
    - LE ~ 0 so that $H = R_n - G$
  - At a 'wet' (vegetated condition):
    - For full cover, ET → ET_{ref} so that $H = R_n - G - c\ ET_{ref}$ (METRIC – at a specific location; SEBI – for each pixel, theoretical condition)

Challenge with Near Surface Temperature Difference (dT)

- T_{air} is *unknown* and *spatially variable* at the 60 m scale
- A linear relationship between T_s and dT generally holds:

$$dT = b + aT_s$$

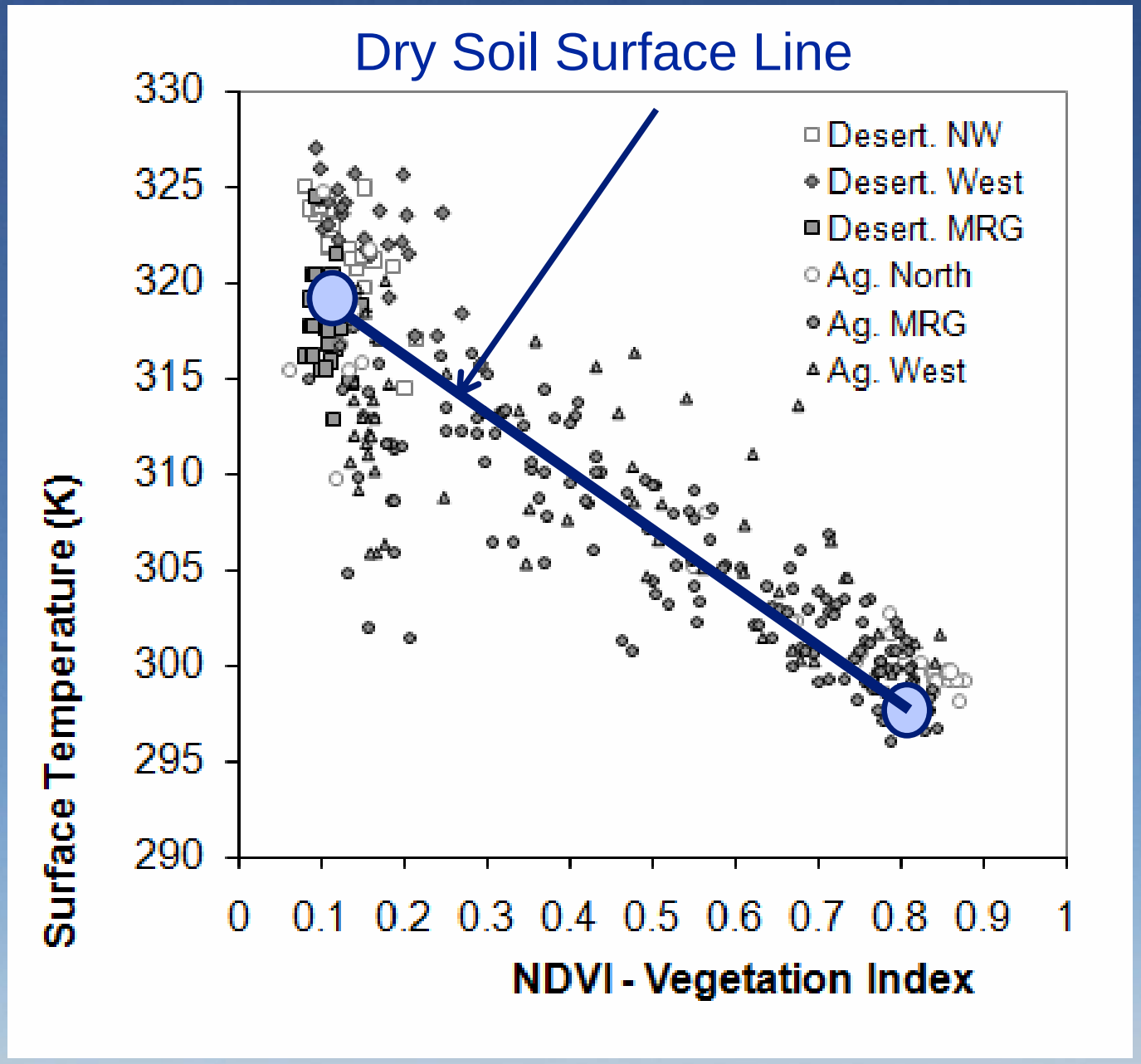




- T_s is *used only as an index* and *can have large bias*

Selection of Two Endpoint Temperatures for CIMEC Calibration

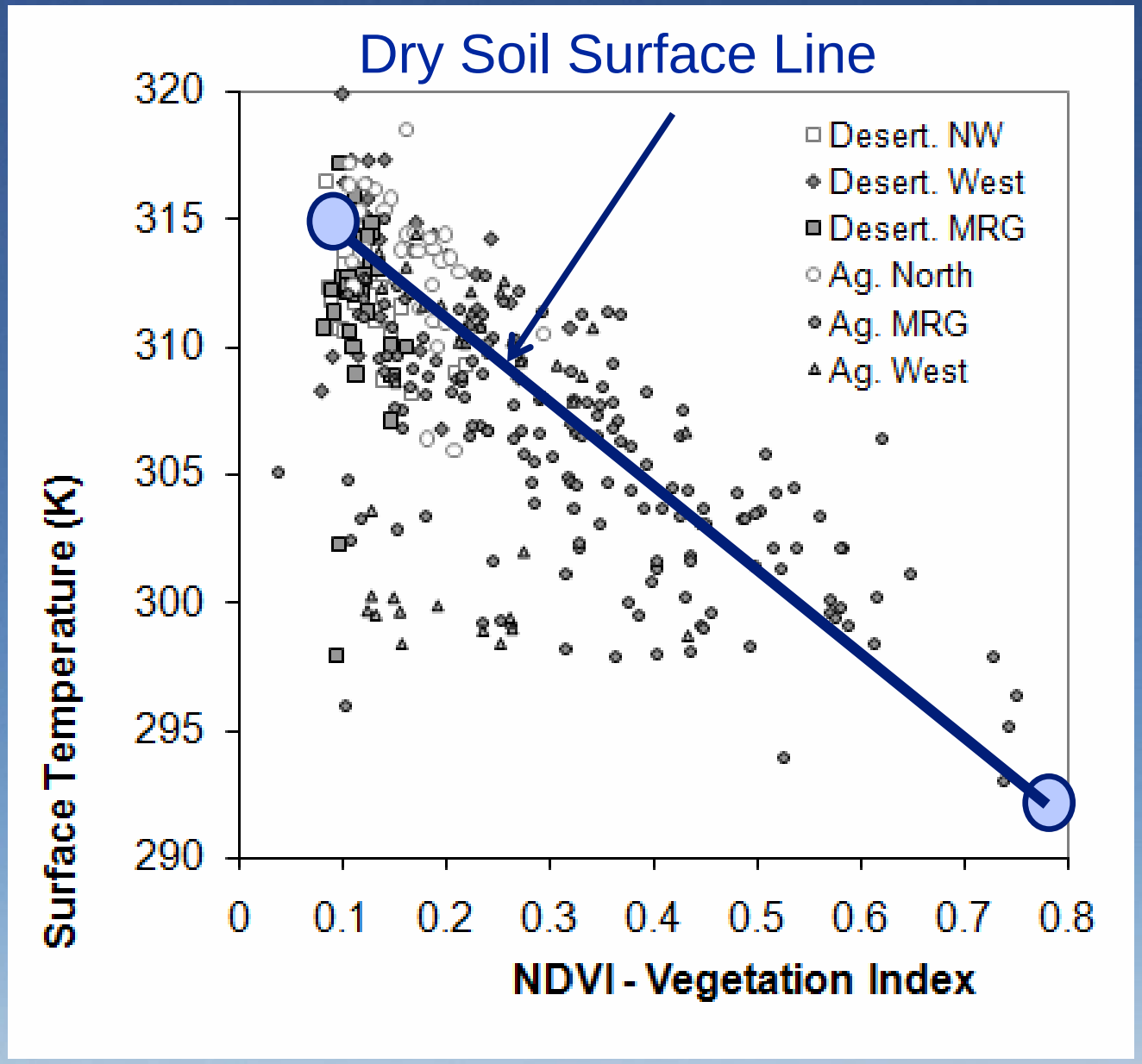
June 7, 2002
Landsat 7



CIMEC autocalibration minimizes biases in EB Components

Selection of Two Endpoint Temperatures for CIMEC Calibration

April 4, 2002
Landsat 7

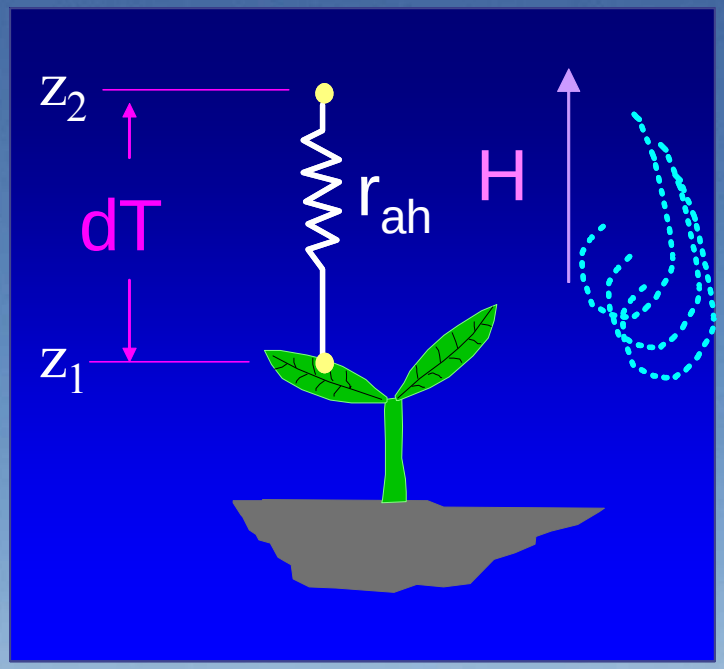


Calibration of *SEBAL* and *METRIC* CIMEC models:

Inversion of the H eqn:

$$dT_{cold} = \frac{H_{cold}\ r_{ah\ cold}}{\rho_{air\ cold}\ c_p}$$

$$dT_{hot} = \frac{H_{hot}\ r_{ah\ hot}}{\rho_{air\ hot}\ c_p}$$



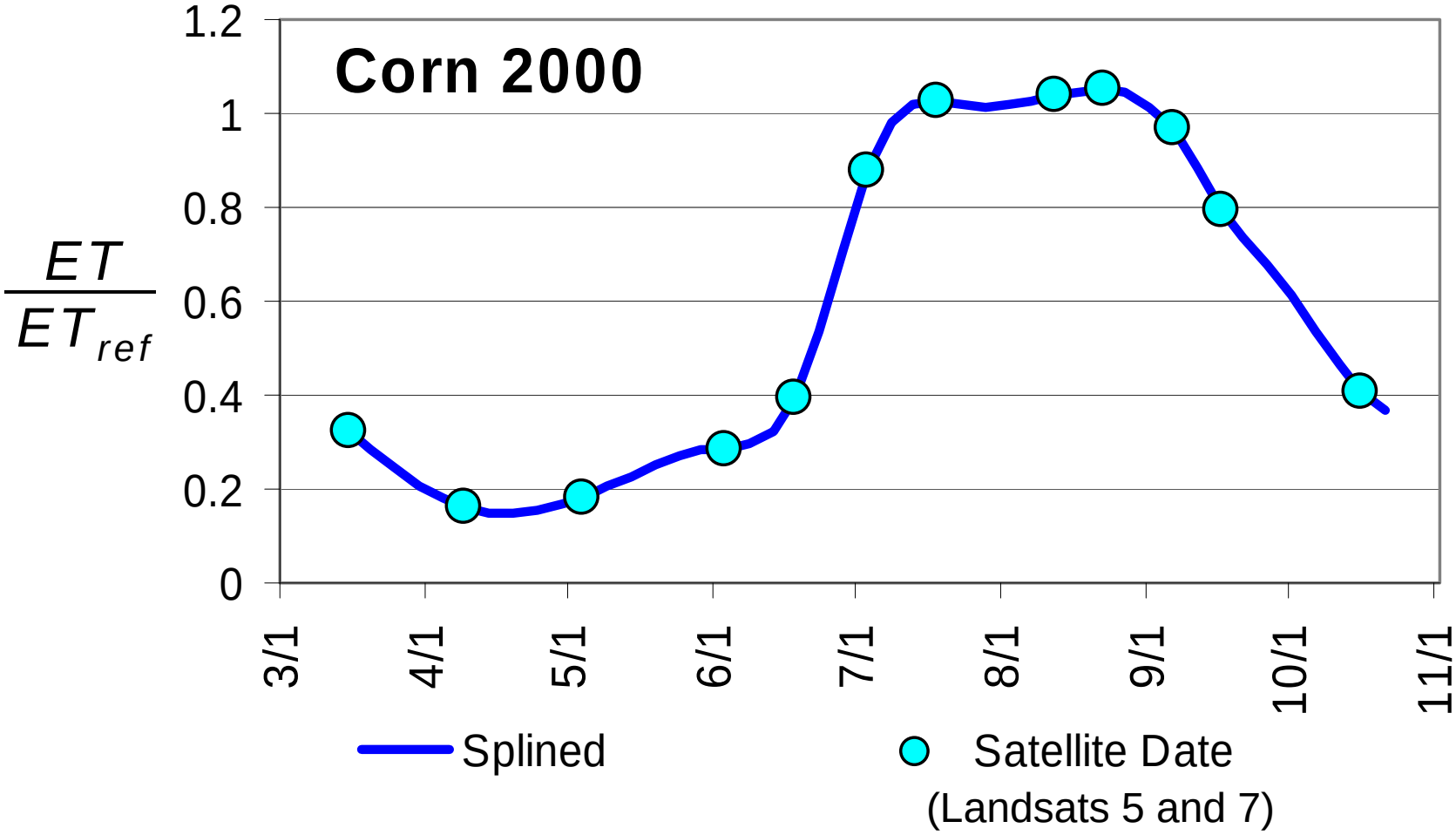
$R_n - G$

$R_n - G - 1.05\ ET_{ref\ alfalfa}$ *(METRIC)*
or 0 *(SEBAL – classical)*

Utility of Global ET Product

- Accuracy will be adequate for direct use by:
  - hydrology water balance models
  - estimation of irrigation performance
  - estimation of water stress and food production during drought
- Relative spatial accuracy will be even better

Interpolation between images for Seasonal ET



Interpolate fraction of reference ET between satellite imaging dates

Precursor Science

- Improve autocalibration of ET algorithms to compensate for energy balance component biases
- Develop means to best combine higher frequency TIRS (for H) with lower frequency VSWIR (for albedo, roughness)
- Adjustment of LST retrievals for tall vegetation canopies as f(view angle)m – leverage MODIS, airborne, etc.

Precursor Science

- Assimulate NCEP, GDAS etc. weather and rainfall grids with daily soil-water balance modeling to interpolate between overpass dates and as means to estimate potential (reference) ET
- Explore combinations of hyperspectral VSWIR and TIR to increase accuracy of mapping of irrigated agriculture