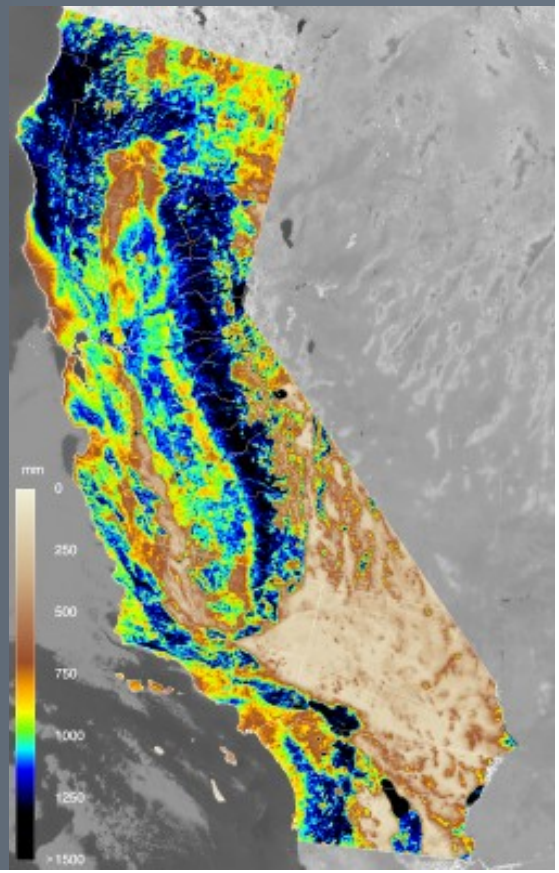
Using SEBAL to Understand ET Response to Climate Change

Linking Climate Change Impacts on ET and Agricultural Production to Water Resources Decision Making



Bryan Thoreson, PhD, PE
Davids Engineering, Inc.
SEBAL North America, Inc.

Outline

- Need for Monitoring
- Causes of ET Change
- SEBAL Theory and Methods
- SEBAL Accuracy
- Understanding ET Variability
- Water Use Measurement
- Questions

Need for Monitoring

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- DWR Climate Change White Paper
- Strategy 8: ***Preserve, Upgrade and Increase Monitoring, Data Analysis and Management***

  "For data to be useful in climate monitoring and climate change detection, there must be better and more consistent monitoring of critical variables such as temperature, precipitation, **evapotranspiration**…"

Causes of ET Change

- ET_a a function of:
  - Available Energy (Net Radiation)
  - Water Supply
  - Plant Characteristics
  - Many other factors
- Climate Changes:
  - Temperature (Increases)
  - Precipitation
  - Plant Characteristics

SEBAL Theory and Methods

- Physically-based
  - Validated over a wide range of climatic conditions
  - Handles climate change
- Retrospective
  - Diagnostic, not predictive tool

Energy Balance at Earth's Surface

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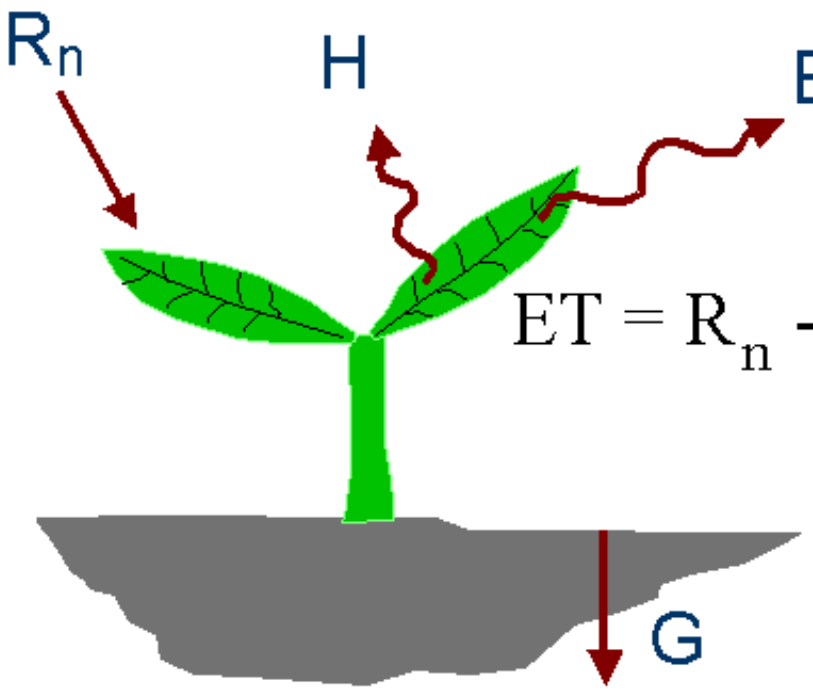
ET is calculated as a "residual" of the energy balance



$$ET = R_n - G - H$$

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

SEBAL Model

SEBAL's Internal "Self-calibration"

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The SEBAL process utilizes two "anchor" pixels to fix boundary conditions of the energy balance:

- **"Cold" pixel:** water body or well-irrigated crop surface with full cover:

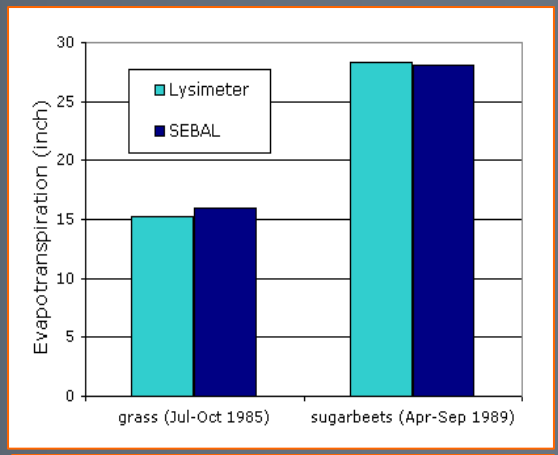
$T_s \cong T_{air}$; $H \cong 0$

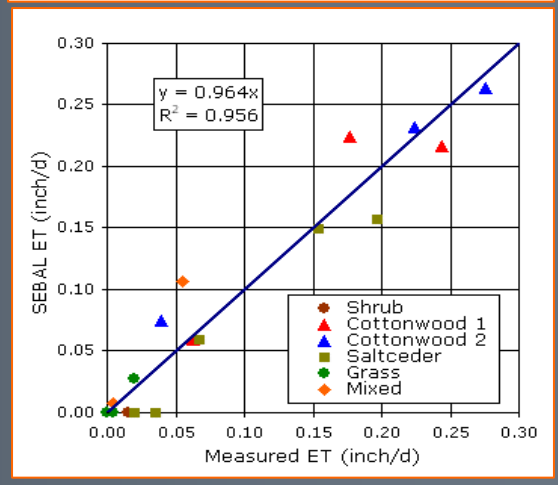
- **"Hot" pixel:** a dry, bare agricultural field

$T_s >> T_{air}$; $ET \cong 0$; $H \cong R_n - G_0$

SEBAL Validation

- Rigorous, Ongoing Validation
  - 6 ET Measurement (Estimation) Methods
  - 15 countries
  - 5 continents
  - 4 climate types and 9 subtypes
  - 15+ vegetation types
  - Various spatial scales (basin to pixel)

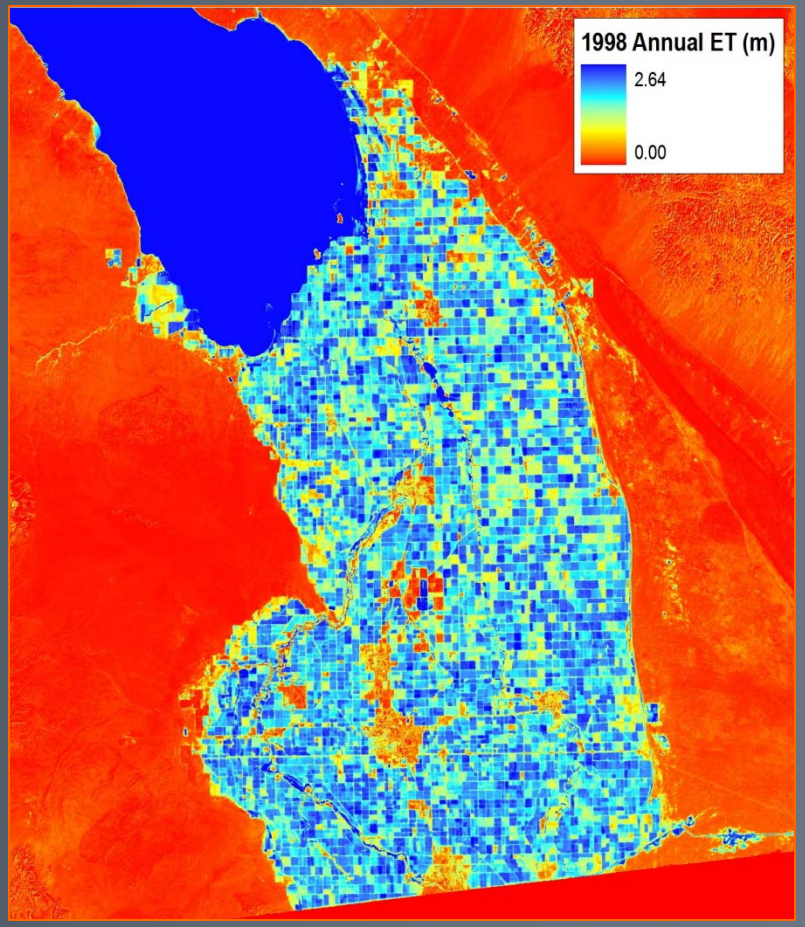




- ASCE Journal of Irrigation and Drainage Engineering, Vol. 131, No.1, pp. 85-93

SEBAL Validation in 2006

- Keller-Bliesner Engineering
  - WY98 Water Balance
  - 1999 taf
- SEBAL North America
  - WY98 SEBAL Analysis
  - 2010 taf
- Difference:
  - 11 kaf, 1%



SEBAL Accuracy--Summary

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Images Processed	Approximate Accuracy
1	+/- 15 to 20%
5 or more	+/- 5% or less

Accuracy of Kc x ETo methodology +/- 10 to 20 % when applied with expert judgment

(Allen et al., 2005, ASCE Journal of Irrigation and Drainage Engineering, Vol 131 "*Prediction Accuracy for Projectwide Evapotranspiration Using Crop Coefficients and Reference Evapotranspiration*")

ET Spatial Variability… Among Fields

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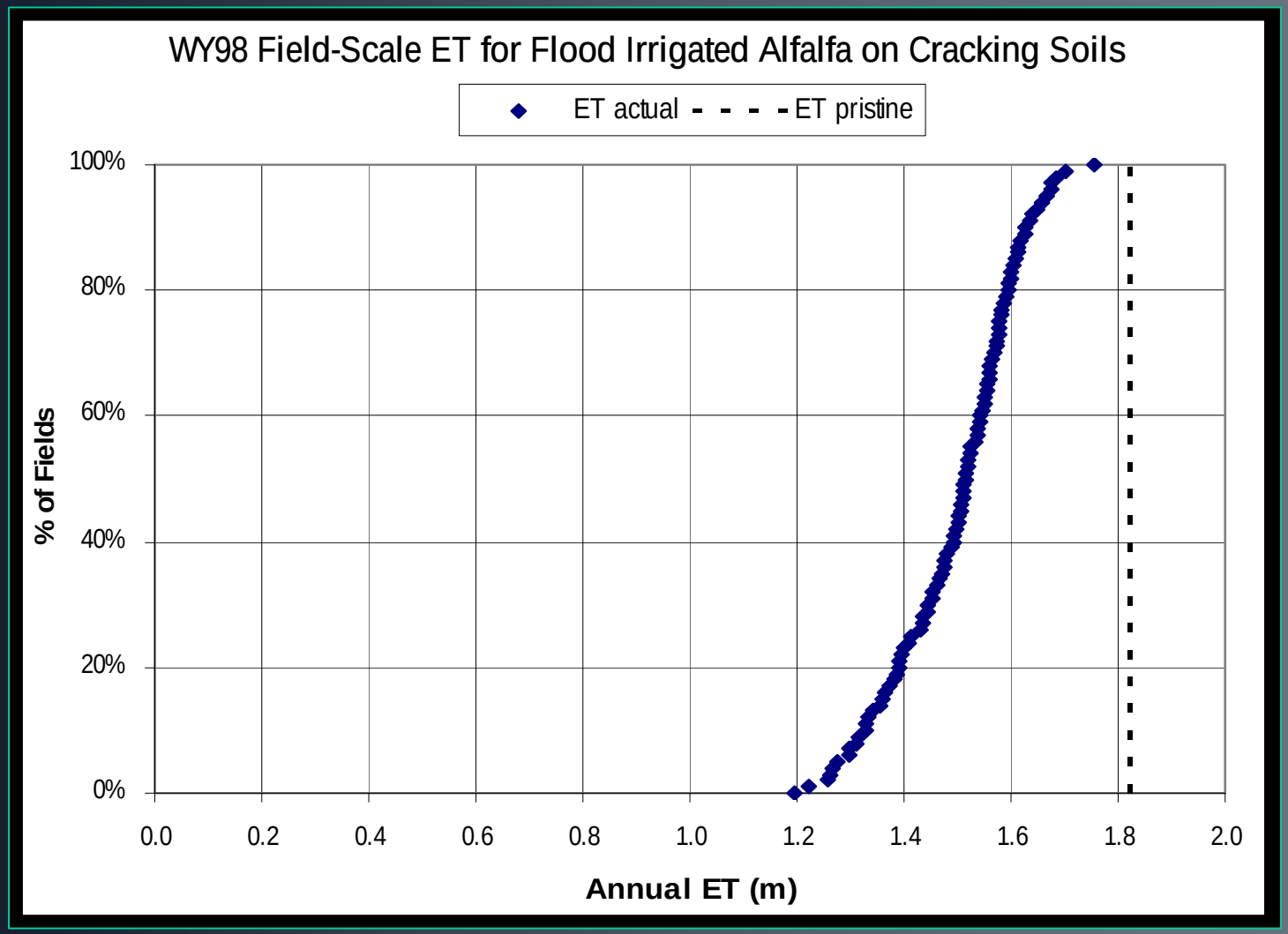

ET Spatial Variability... Within Fields

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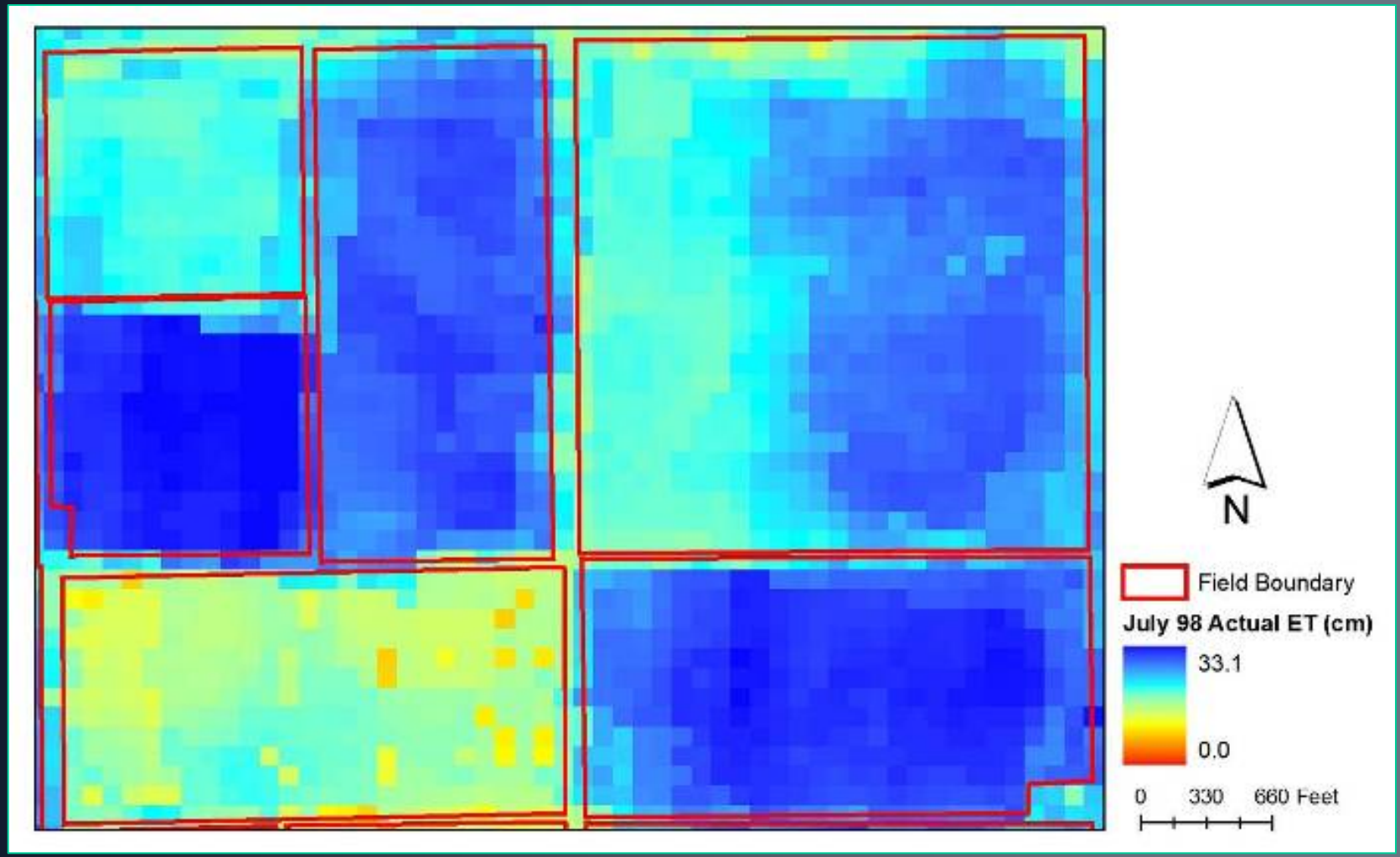

ET Temporal Variability

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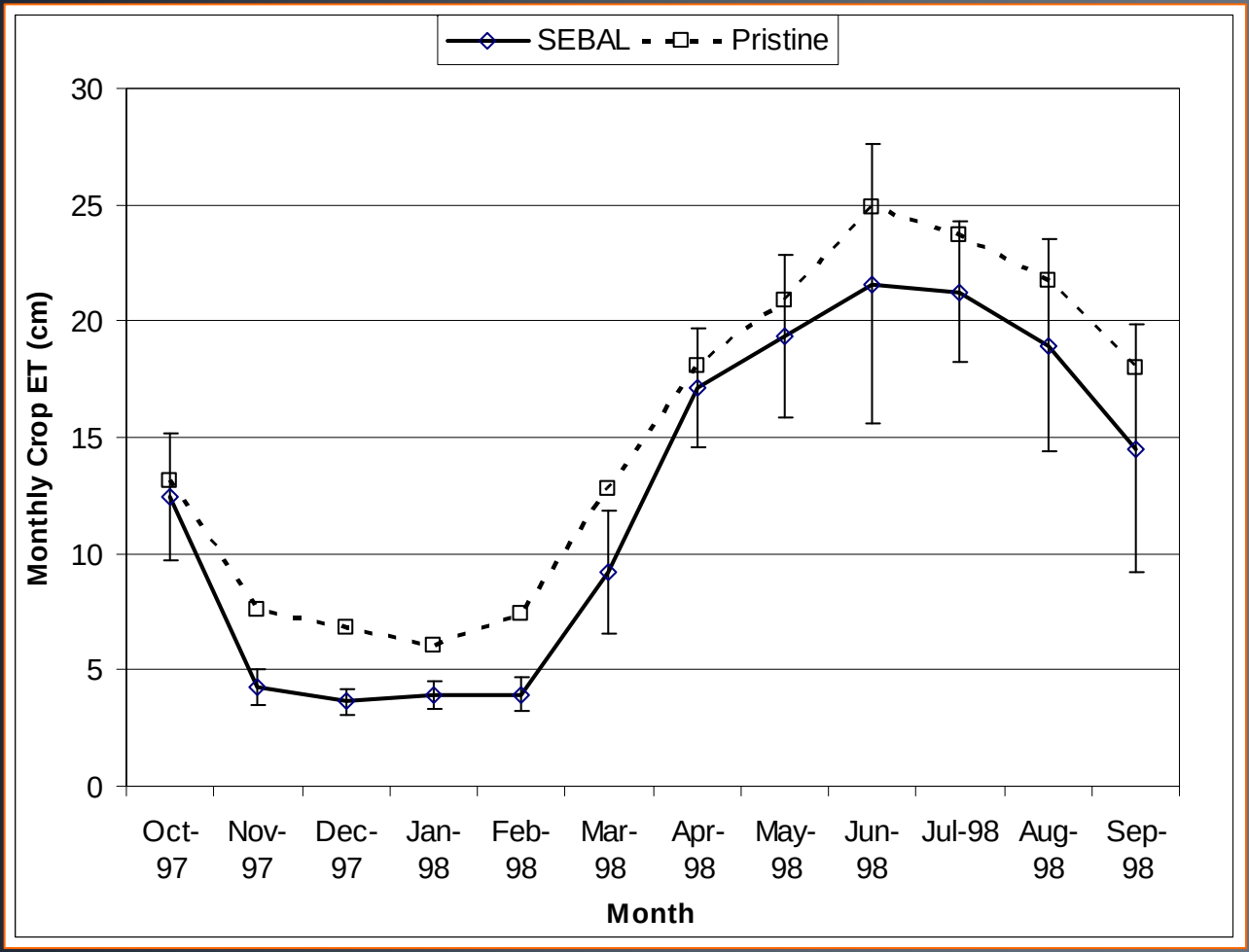
Comparison of monthly actual and pristine ET for flood irrigated alfalfa on heavy cracking soil



Limitations of ET by SEBAL

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- Not a real-time tool (thus not a replacement for CIMIS or scheduling services)
- Dependent on cloud-free images (generally not a problem in CA)
- Substantial cost:
  - Image purchase
  - Processing requires trained, expert operators

Possible Responses to Climate Change

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- *Reduced Water Availability*
  - *Actual* ET less than Potential ET
- *Increased Spatial Variability*
  - *Among and within irrigated fields*
- *Changing Crop Coefficients*

Possible Uses of SEBAL to Better Understand Climate Change

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- Behavioral Responses to Reduced SW Availability
  - ET Changes Little → GW Pumping
  - ET Decreases → Deficit Irrigation
- Hydrologic Responses through Accurate Basin Water Balances
- Broad-based Crop Coefficients for Real Time/Predictive Analyses

Water Use Measurement

- DWR Climate Change White Paper
- Strategy 8: ***Preserve, Upgrade and Increase Monitoring, Data Analysis and Management***

  "Information on water use is currently limited and often unreliable. Accurate measurement of water use can facilitate better water planning and management."

Water Use Measurement with SEBAL

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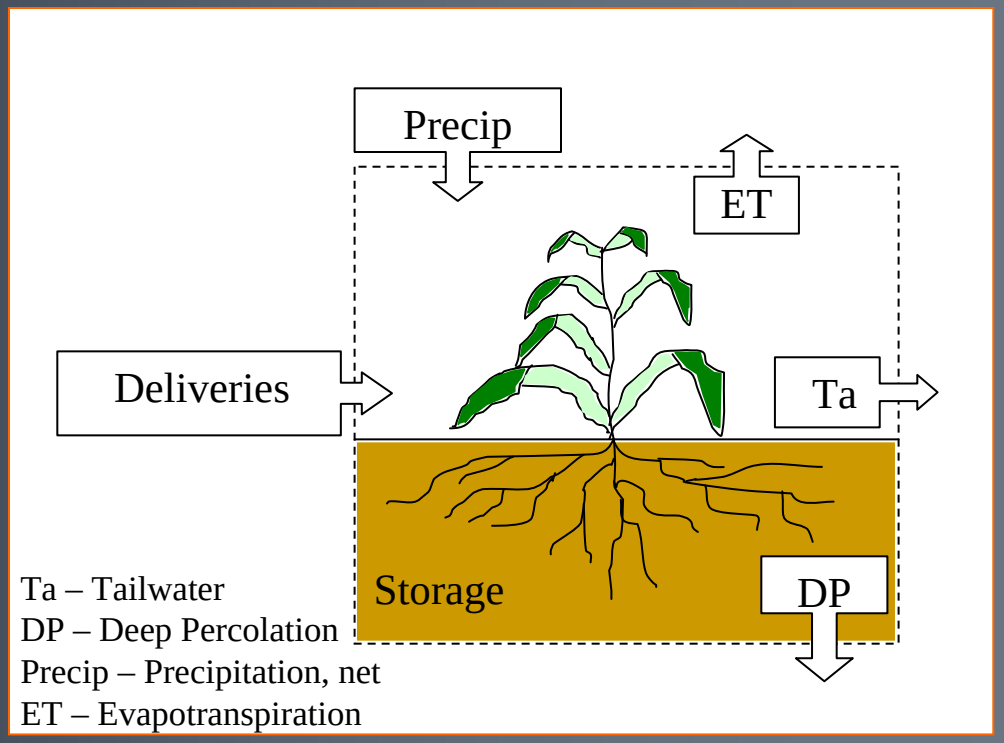
- Agriculture and Landscaping
- Root Zone Water Balance
- ET = Water Use
- Ta & DP =Water Available for Reuse



Measuring ET Under Changing Climates

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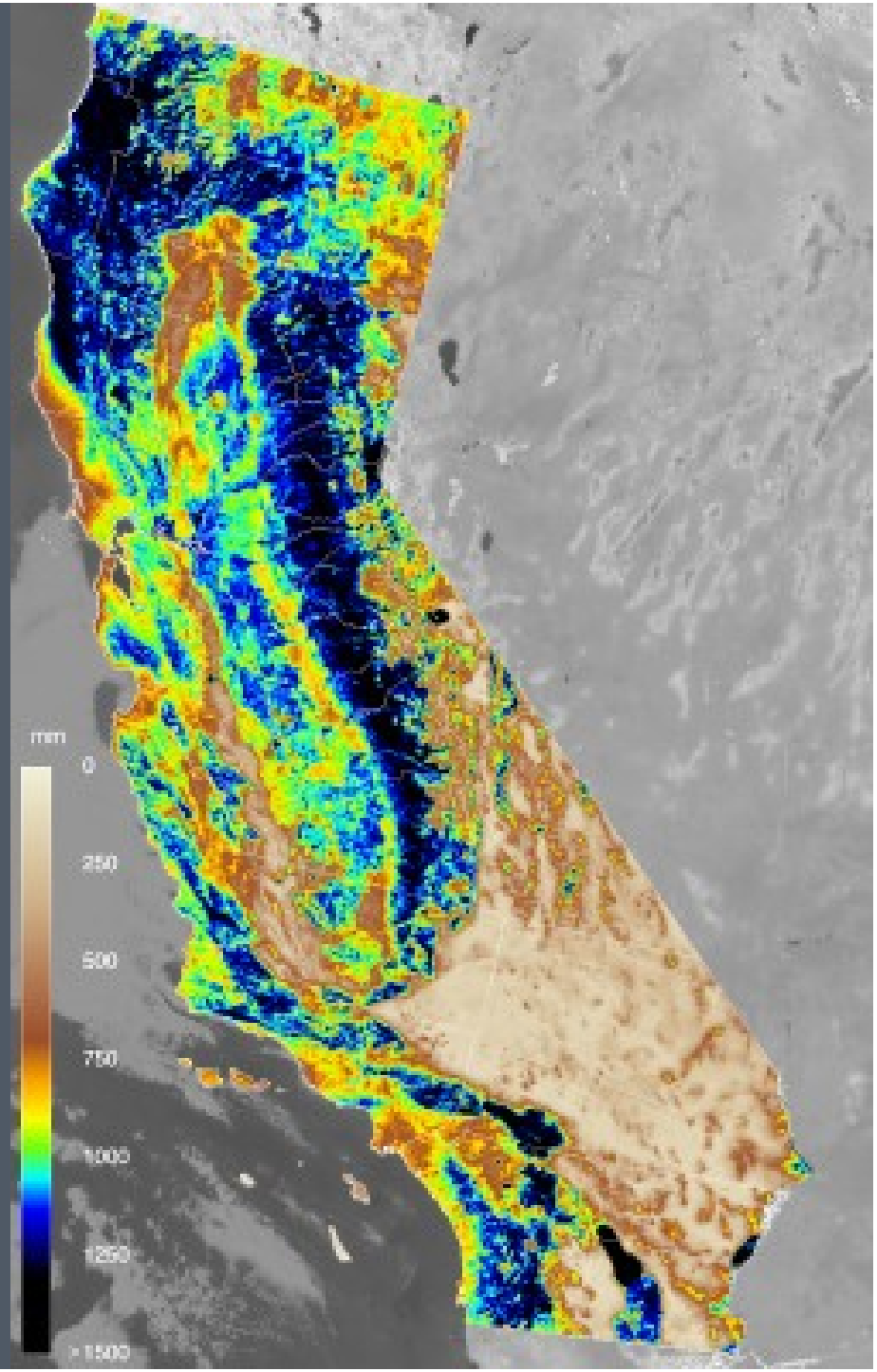
- SEBAL Quantifies ET (Water Use) Spatial and Temporal Variability
- Use SEBAL to:
  - Track ET (Water Use) Changes Over Time
  - Improve Water Balance Accuracies
  - Develop Crop Coefficients

- More information:

www.sebal.us

- Questions?



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SEBAL Accuracy

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Comparison Technique	State	Duration, Months	Landscape	Difference	Reference
Eddy correlation	NM	8	Riparian Vegetation	4%	Unpublished
Weighing Lysimeter	ID	8	Sugar beet & grass	3%	Allen et al. (2003)
Weighing Lysimeter	CA	7	Peach	5%	Cassel and Roberson (2006)
Weighing Lysimeter	CA	7	Alfalfa	2%	Cassel and Roberson (2006)
Water Balance	CA	12	Irrigated Agriculture	1%	Soppe, et al (2006)