Irrigation Water Use in the Harney

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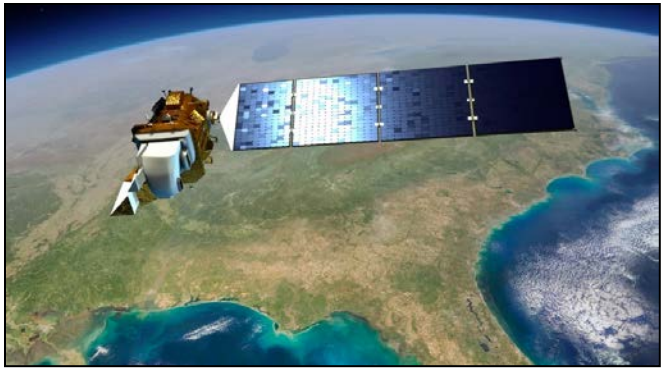

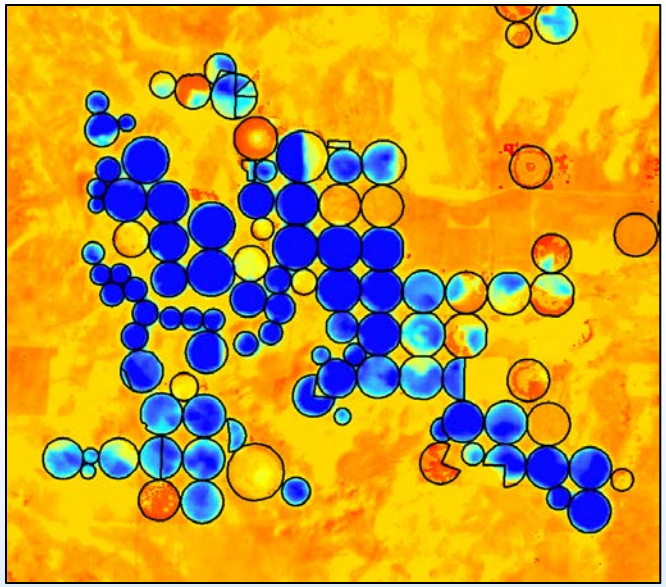

Jordan Beamer, Hydrologist

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Acknowledgements

- Dr. Brenda Bateman, OWRD
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- Clarence Robison, UI
- Dr. Ricardo Trezza, UI
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Outline

- Background on irrigation water use
- Methods to measure and model crop water use
- Existing data and data gaps
- NASA-ROSES grant and opportunity
- Data and models
  - Crop demands model
  - Remote sensing of ET
  - Direct ET measurement
- Initial results
- Discussion, next steps

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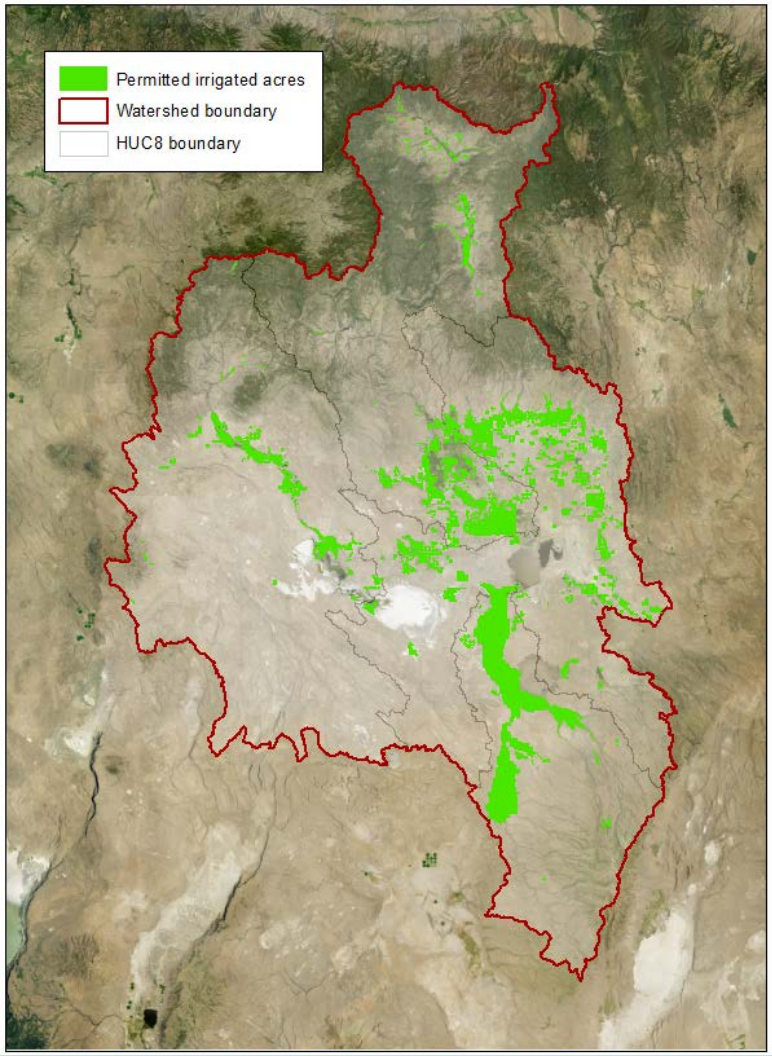
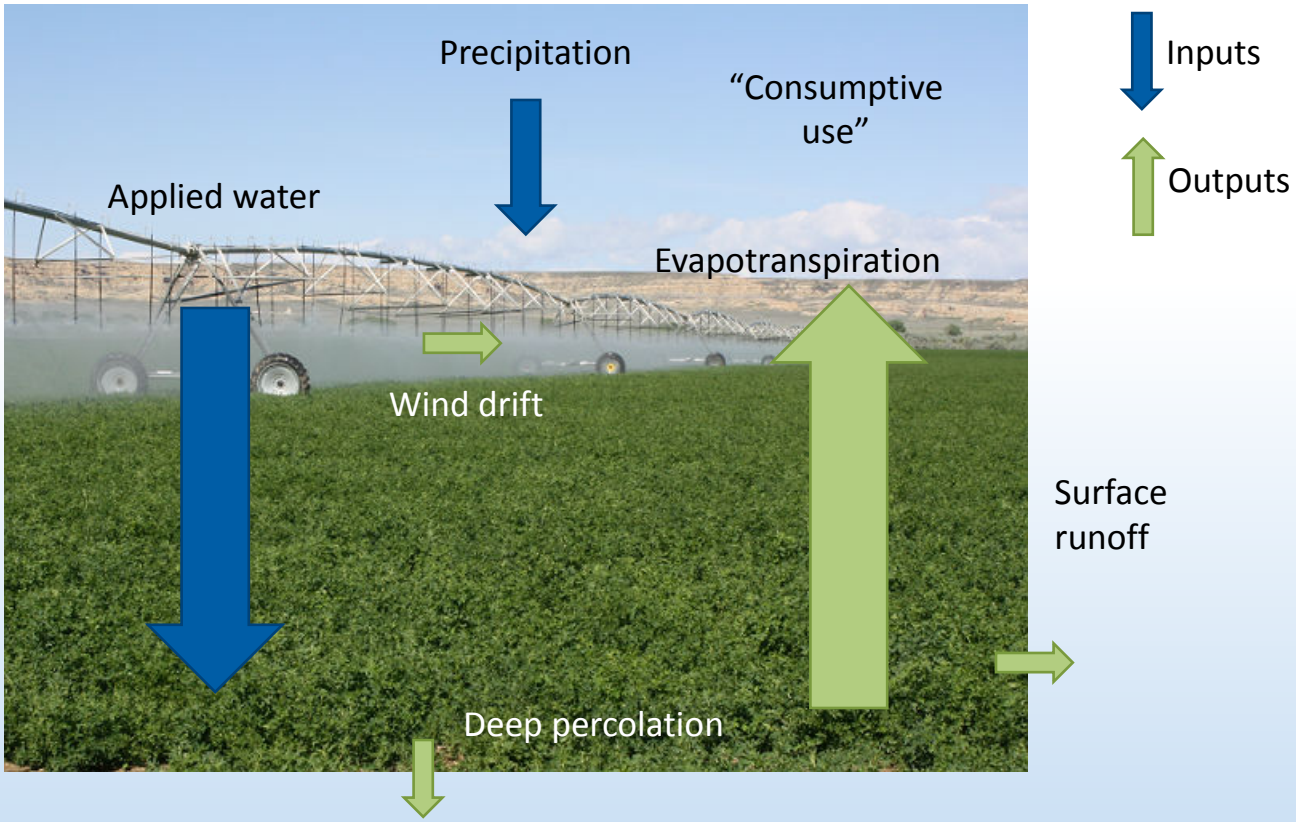
Introduction

- Irrigation accounts for majority of water use in the Harney basin budget
- Groundwater study needs accurate pumpage and irrigation use data
- Datasets with streamflow and GW levels exists, records about water use (diversions and withdrawals) is limited



Irrigation Water Use

- Evapotranspiration (ET) data used to estimate irrigation use and pumpage



Source: http://www.teachingfromthetractor.com/alfalfa-seed-established-fields/

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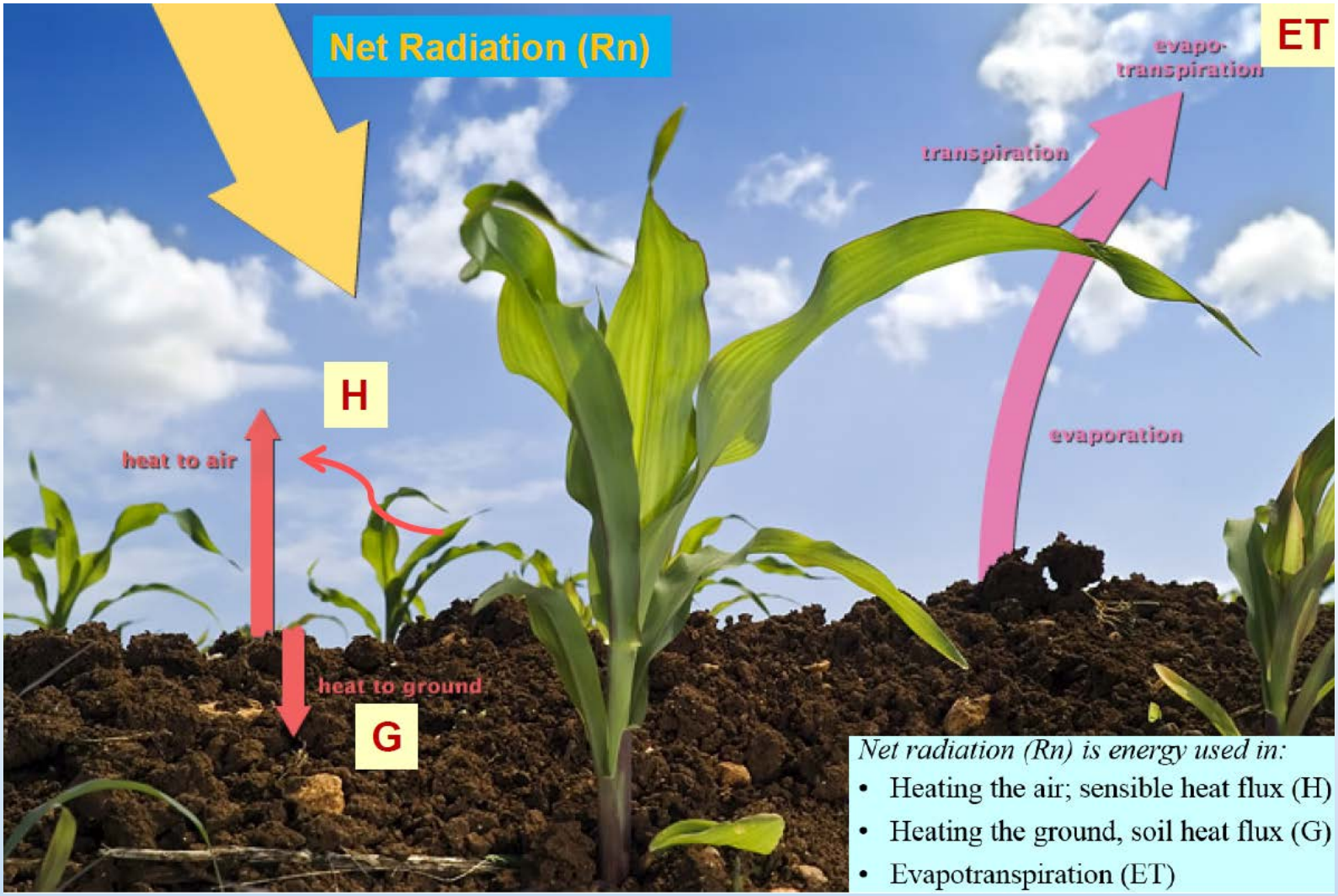
Evapotranspiration (ET)



Credit: R. Trezza

University of Idaho

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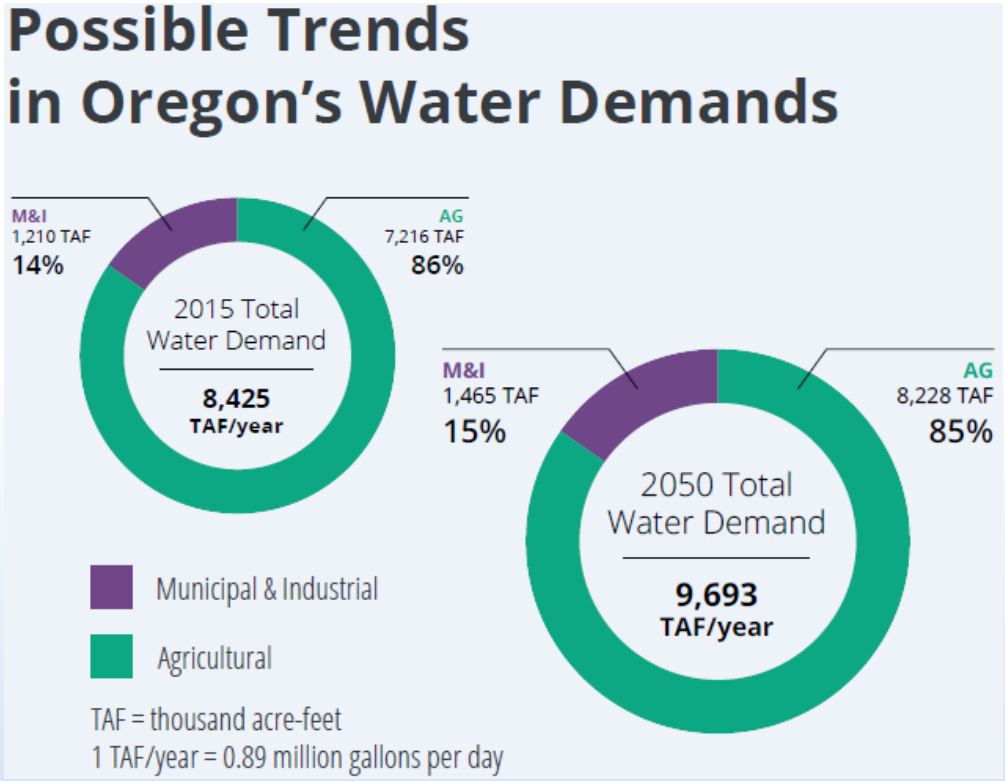
Information gap



- Estimated agricultural water demand currently accounts for 86% of the consumptive water use in Oregon (OWRD, 2015).
- But without ET and water use measurements from irrigated agriculture, the *actual* water use largely assumed.
- "Hard to manage what you don't measure"

Figure: OWRD, 2015

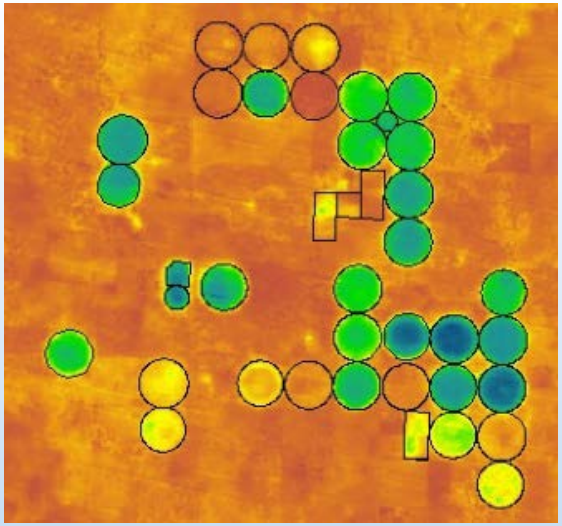
ET Terminology

- Need *actual* water use for basin study

- Potential Consumptive Use
  - Crop ET that occurs under optimal conditions (upper bound)
  - Traditional Reference ET * Crop Coefficient approaches
  - Data sources: AgriMet, COOP weather stations

- Actual Consumptive Use
  - ET that actually occurs, typically less than potential ET
  - Actual historical consumptive use from agriculture
  - Data sources: Lysimeters, Flux tower stations, remote sensing of ET

AgriMet station in Baker Valley



Actual ET varies by field!

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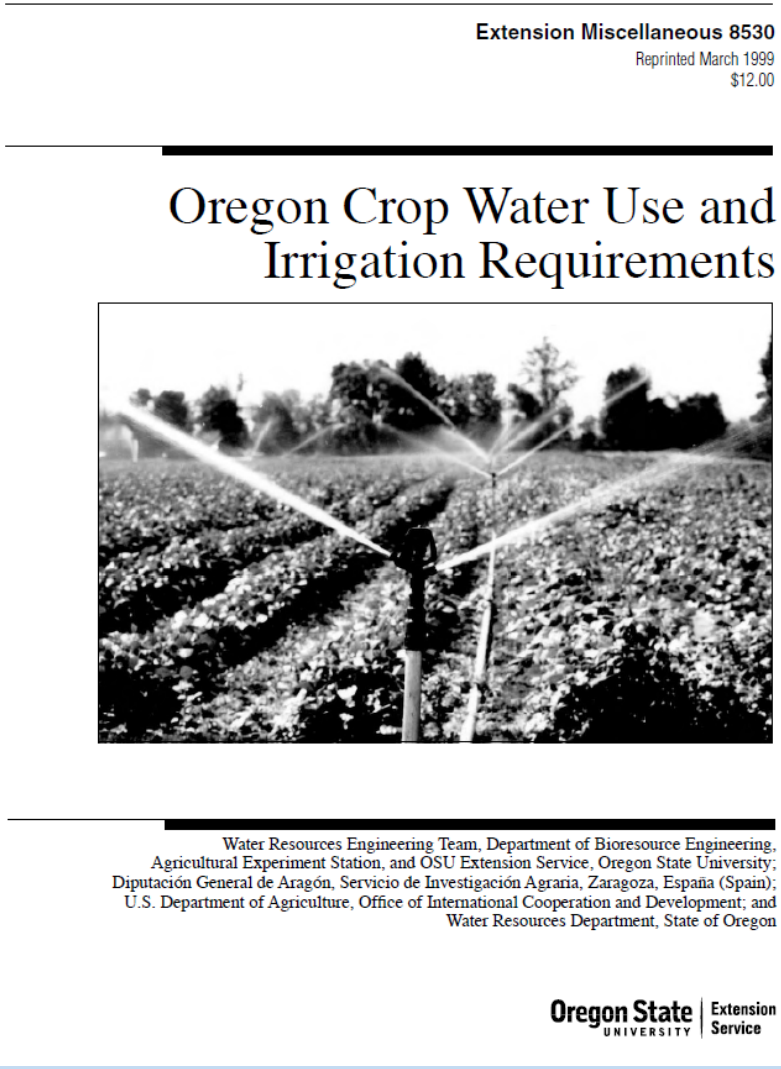
Irrigation Requirements



Extension Miscellaneous 8530
Reprinted March 1999
$12.00

Oregon Crop Water Use and Irrigation Requirements

Water Resources Engineering Team, Department of Bioresource Engineering, Agricultural Experiment Station, and OSU Extension Service, Oregon State University; Diputación General de Aragón, Servicio de Investigación Agraria, Zaragoza, España (Spain); U.S. Department of Agriculture, Office of International Cooperation and Development; and Water Resources Department, State of Oregon

Oregon State University | Extension Service

- Cuenca et al. (1992) - crop ET and NIWR for 17 crops in 27 hydro-climate regions
- Blaney-Criddle grass reference ET
- Single Crop Coefficient (Kc) curve
- Widely cited, used for irrigation planning

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Harney ET crop and NIWR

- Table of growing season, total crop ET and net irrigation requirements, for crops grown in region 20 (Harney county).

Crop type	Typical growing season	5 out of 10 years				9 out of 10 years			
		ET crop		Net IRR		ET crop		Net IRR	
		in.	ft.	in.	ft.	in.	ft.	in.	ft.
Alfalfa Hay	May 15 - Aug 30	18.9	1.57	17.1	1.42	20.6	1.72	20.0	1.66
Grain Spring	May 10 - Sep 15	20.6	1.71	18.7	1.56	22.4	1.87	21.7	1.81
Grain Winter	Apr 05 - Aug 10	19.4	1.61	16.8	1.40	21.3	1.77	20.0	1.67
Mint	Mar 30 - Aug 07	20.5	1.71	17.8	1.48	22.5	1.88	21.2	1.77
Pasture	Apr 01 - Oct 15	30.4	2.53	26.9	2.24	33.6	2.80	31.9	2.66

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AgriMet

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AgriMet crop ET

- FAO / ASCE Penman-Montieth Equation calculation

The Penman-Monteith combination equation for instantaneous energy flux (or averaged over a period of time, e.g. 1 hour) for a reference surface is given as,

$$ET_{ref} = \left[\frac{\Delta (R_n - G) \frac{K_{time}}{K_{energy}} + K_{time}\, \rho_{air}\, c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma \left(1 + \frac{r_s}{r_a}\right)} \right] \frac{K_{energy}}{K_{time}} \qquad (1)$$

where

ET_{ref}	=	reference evapotranspiration (W/m^2)
R_n	=	net radiation (W/m^2)
G	=	soil heat flux (W/m^2)
$(e_{sat} - e_{air})$	=	vapor pressure deficit of the air (kPa)
e_{sat}	=	saturation vapor pressure of the air (kPa)
e_{air}	=	actual vapor pressure of the air (kPa)
ρ_{air}	=	mean air density at constant pressure (kg/m^3) = 1.225
c_p	=	specific heat of the air (MJ/kg °C) = 0.001013
Δ	=	slope of saturation vapor pressure vs temperature (kPa/ °C)
γ	=	psychrometric constant (kPa/ °C)
r_s	=	(bulk) surface resistance (s/m)
r_a	=	aerodynamic resistance (s/m)
K_{time}	=	units conversion (3,600 s/h)
K_{energy}	=	units conversion (1,000,000 J/MJ)

AgriMet crop curves

- Generalized Crop Coefficients for Field and Row Crops

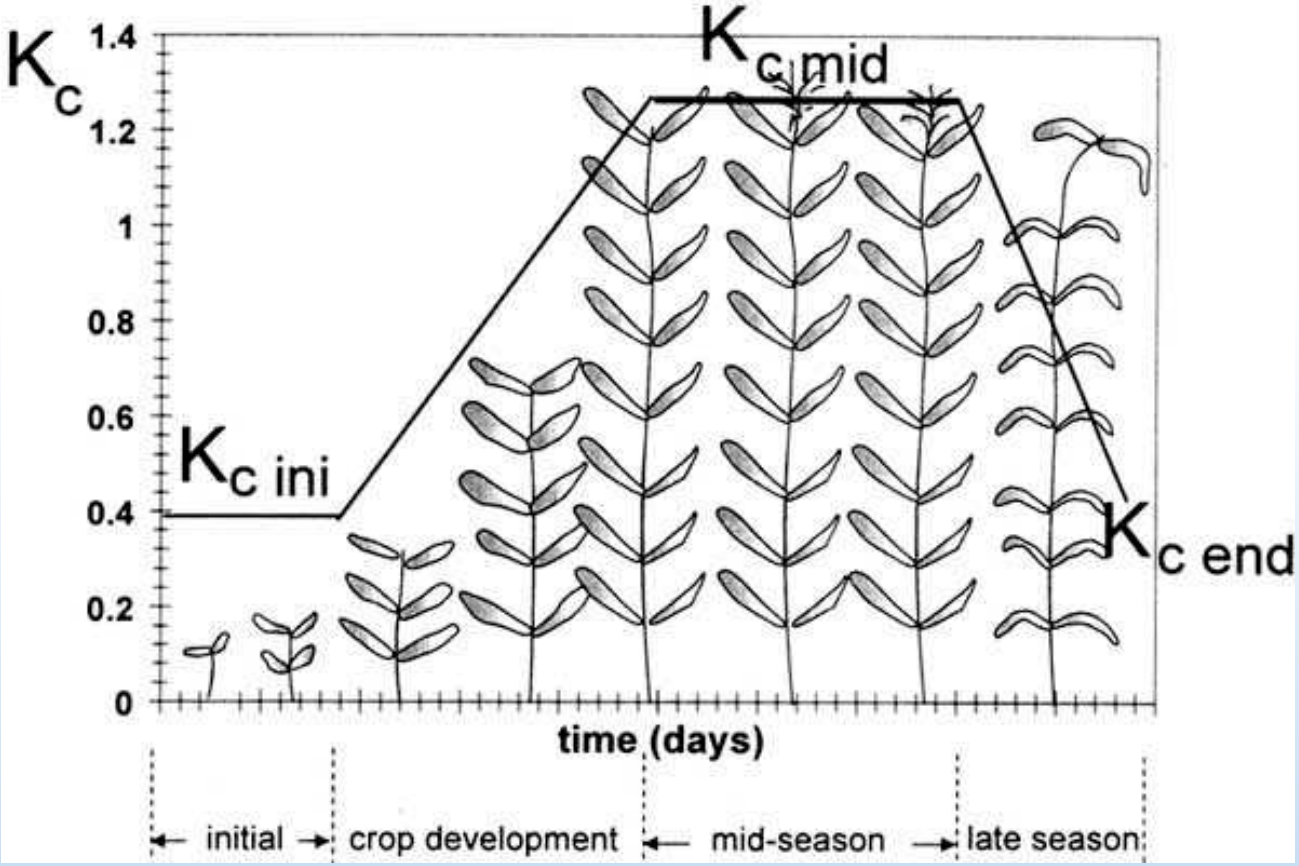

Figure: FAO 56

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AgriMet ET calculation

- Crop coefficients relate reference ET to crop specific ET

$$ET_c = ET_r \times K_c$$

ET_c	Specific Crop Consumptive Use
ET_r	Reference Evapotranspiration (Alfalfa)
K_c	Crop Coefficient (varies with time)

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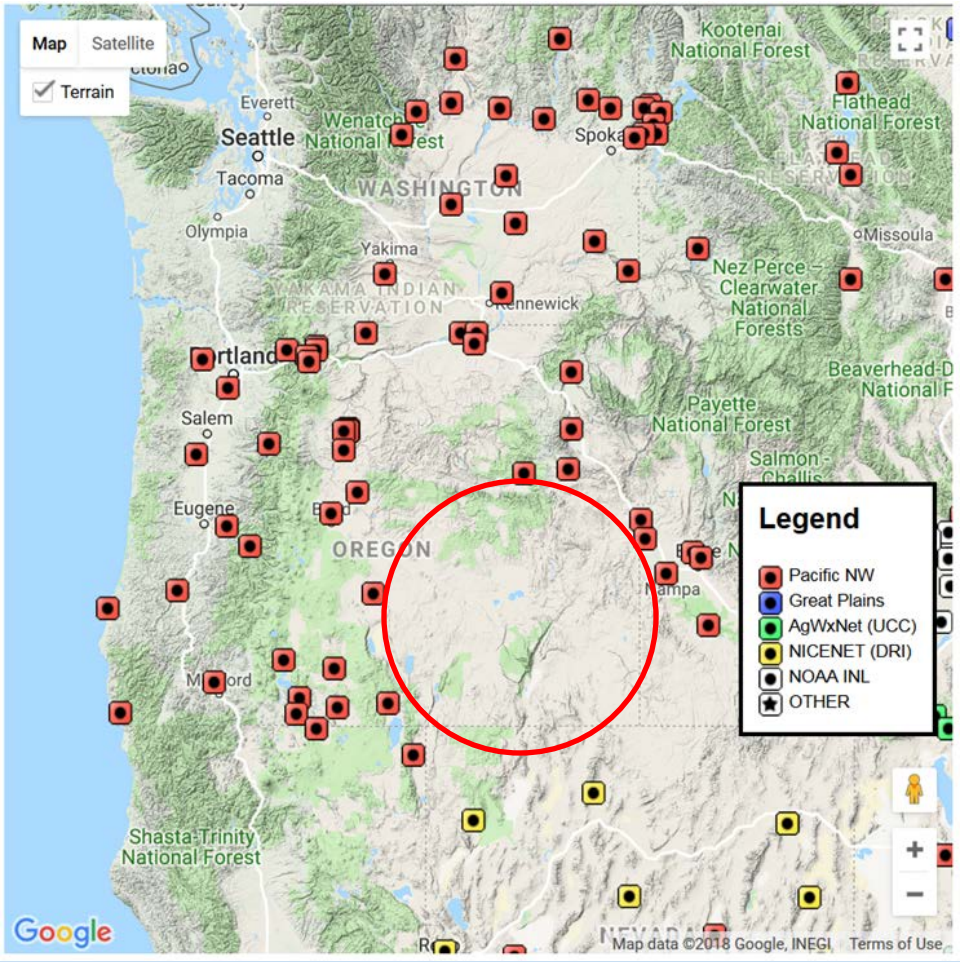
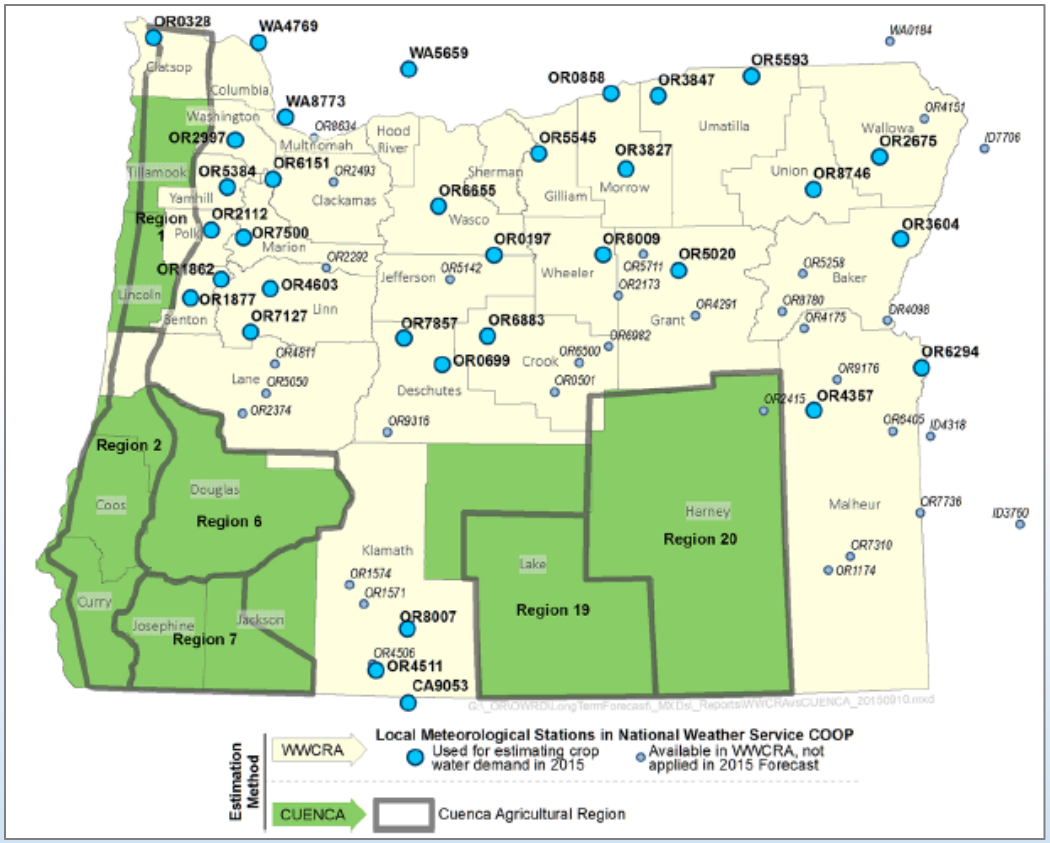
Coverage gap



OWRD Demand Forecast

- 2015 State-wide Long Term Water Demand Forecast (OWRD, 2015)
- The modern USBR ET-Demands model used for crop ET for current and projected future climates
- Unfortunately, no ET-Demands for parts of Oregon outside Columbia and Klamath drainages
- No AgriMet or ET-Demands ☹



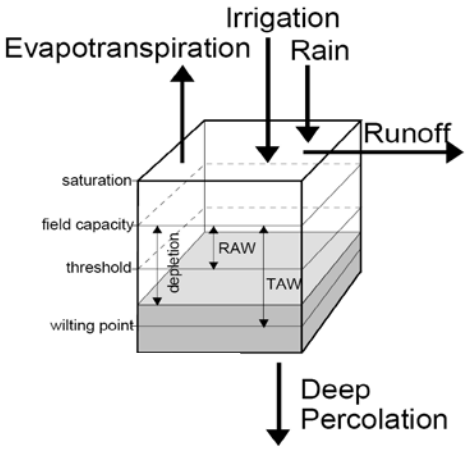
Map: OWRD, 2015

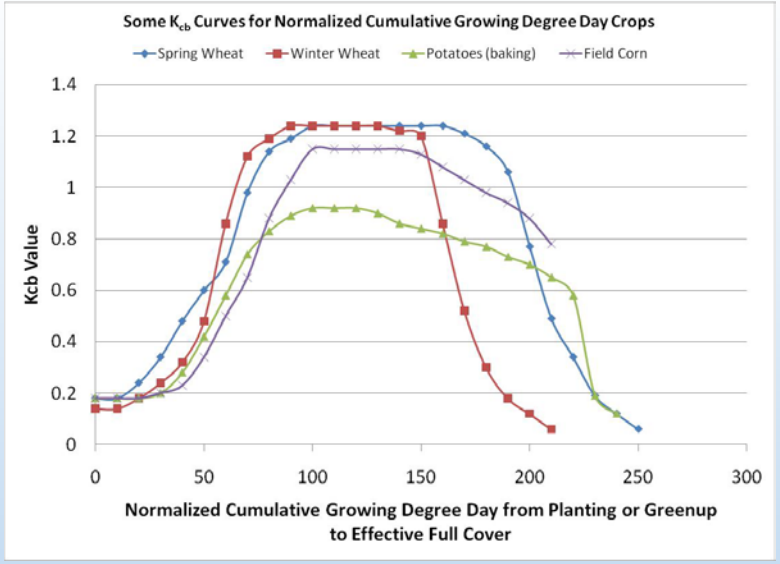
USBR ET-Demands Model

- In this study, we apply ET-Demands to the Harney Basin for updated crop ET and NIWR values.

- ET-Demands model – the ASCE-PM reference ET and *dual* crop coefficient model based on FAO-56 (Allen et al. 1998)

- Reference ET = f(solar rad, temp, humidity, winds)





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Actual ET measurement

Bowen Ratio station

Eddy covariance station

Photo: Doug Maurer; Maurer et al., 2005

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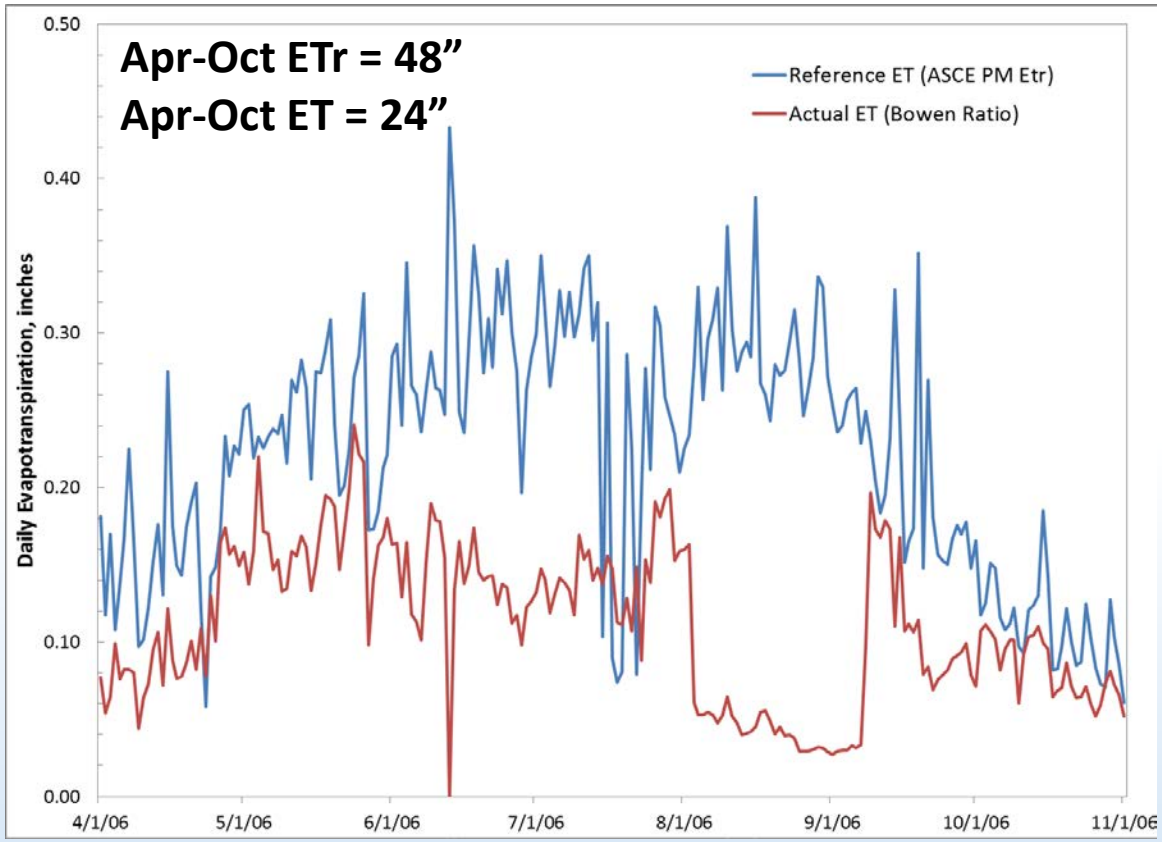
Actual ET data



Bowen Ratio ET station in a flood irrigated alfalfa field in Walker River Valley, NV

Flux towers “sense” impacts of plant and soil stress from lack of available water

Photo: Allander et al., 2009

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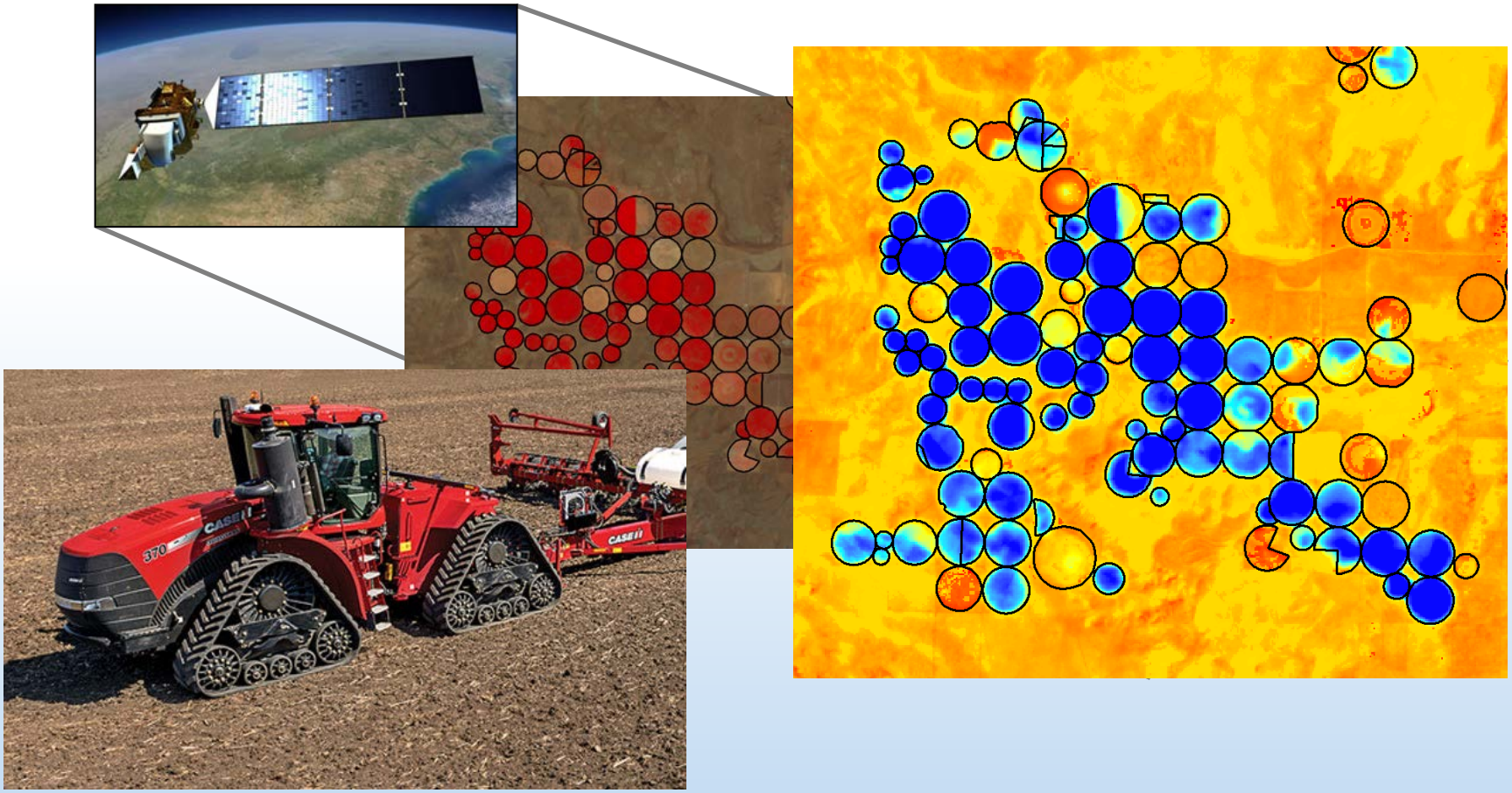
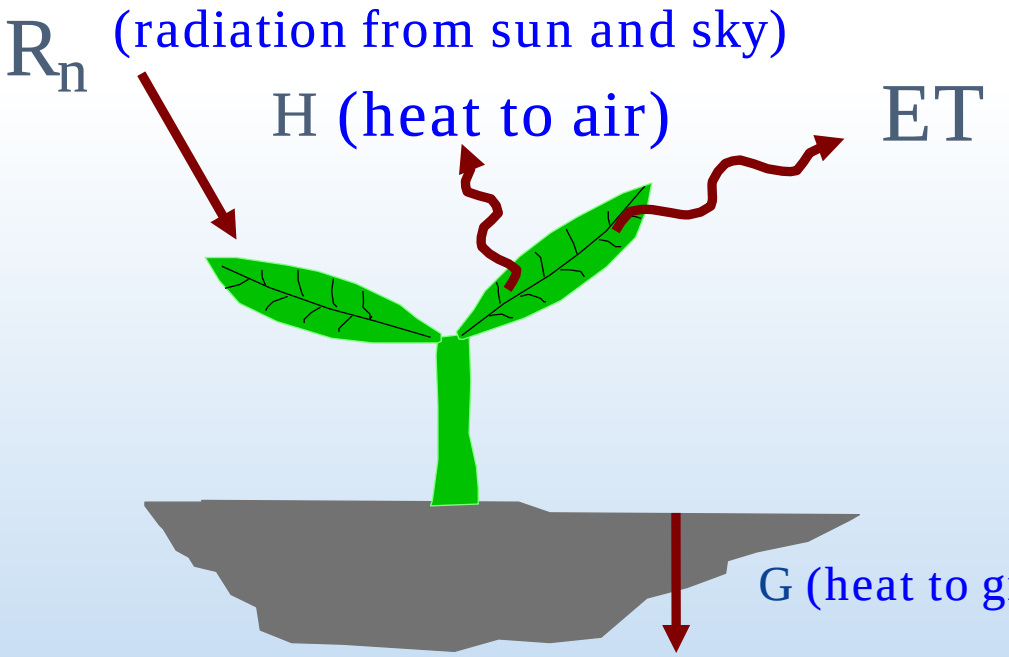
Remote sensing of ET

- Remote sensing can be used to estimate actual ET over large areas and long time histories



Satellite energy balance

- Basic truth: Evaporation consumes energy
- Satellite data used to compute the energy balance, including actual ET
  - METRIC Model – Mapping Evapotranspiration at high Resolution using Internalized Calibration (Allen et al., 2007)



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

Figure: Allen et al., 2014

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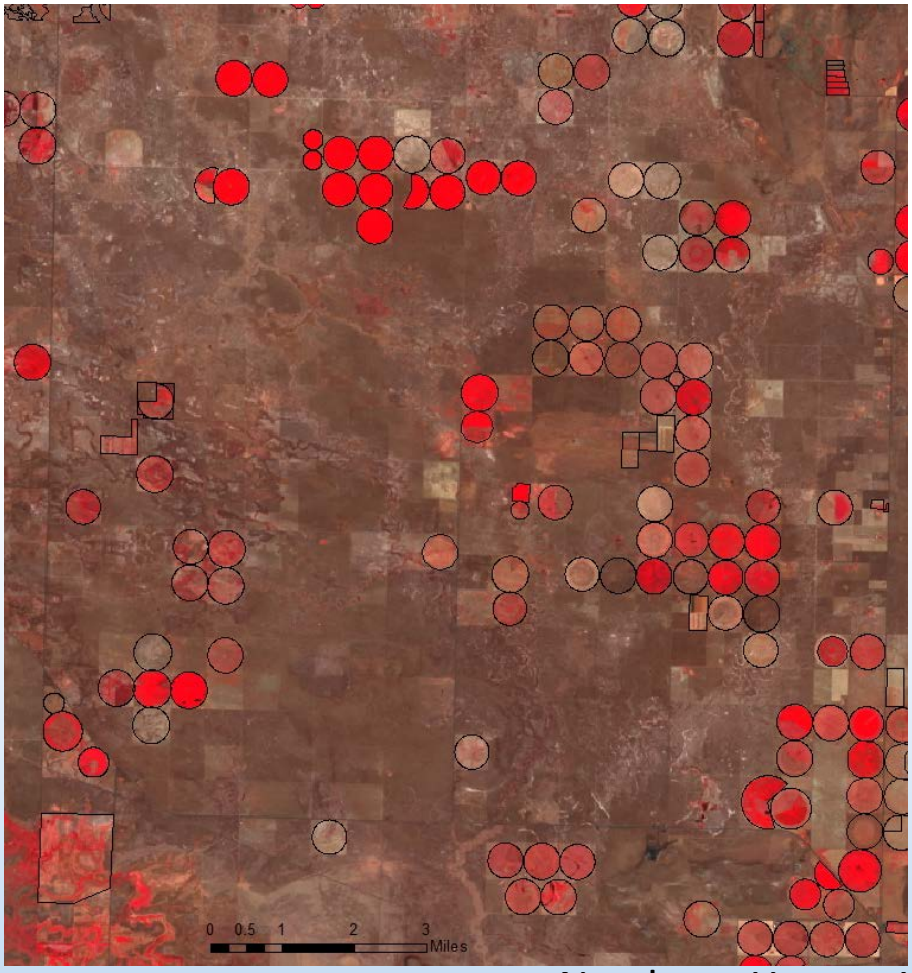
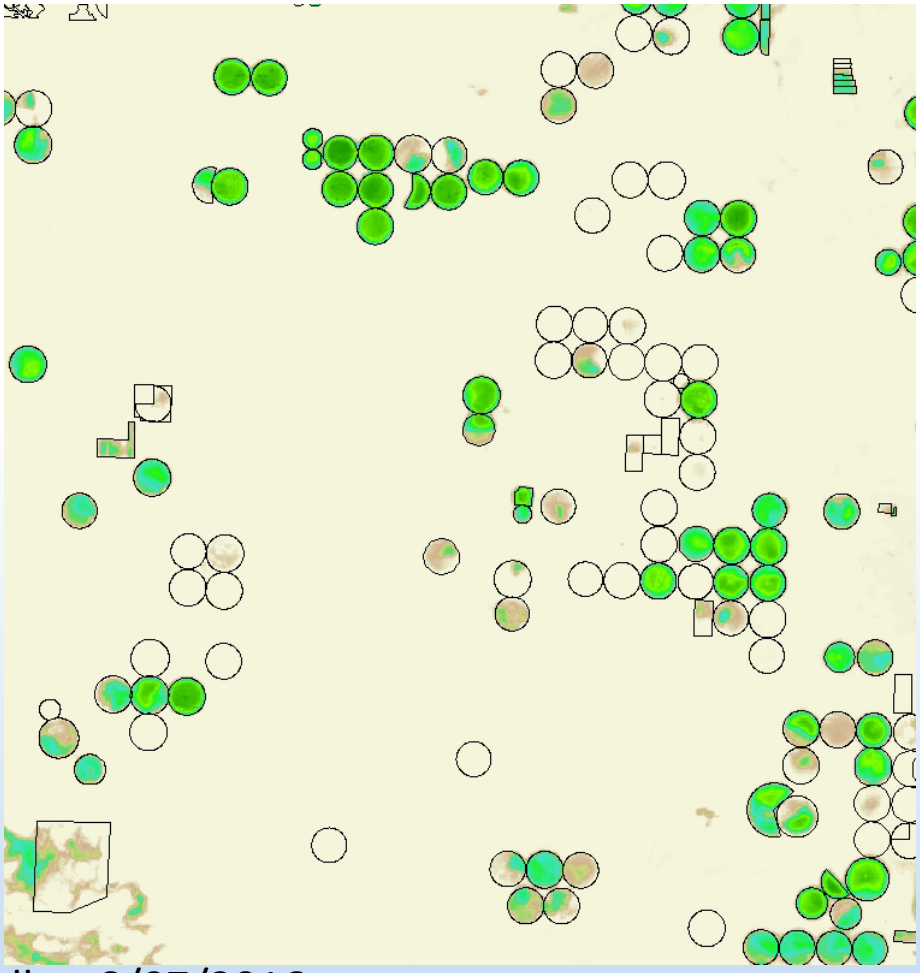
Energy balance ET

False Color Infrared



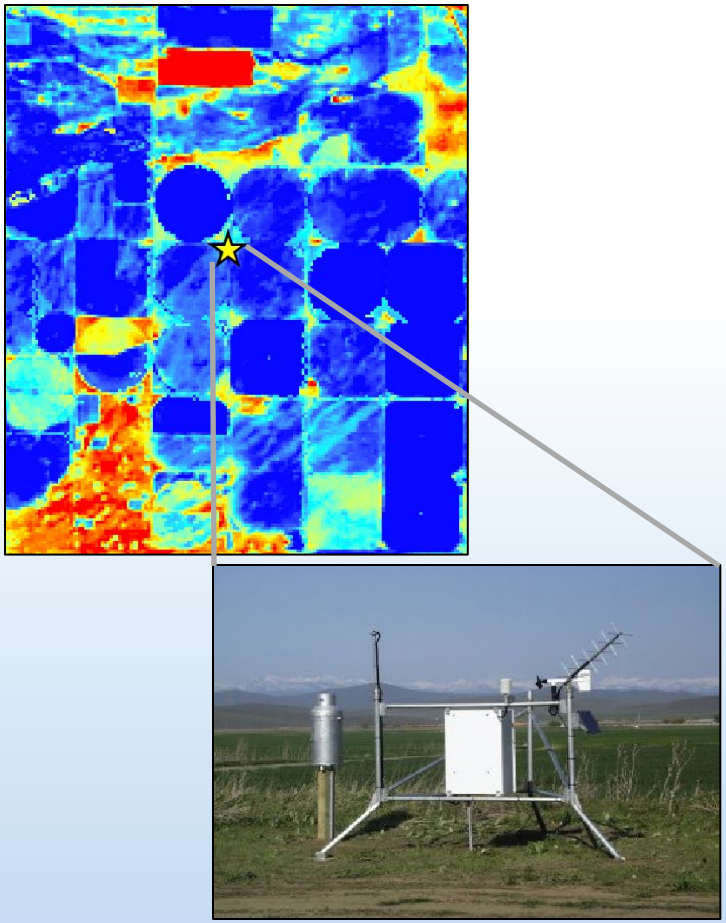
Evaporative Fraction (ETrF)



Northern Harney Valley, 8/07/2016

METRIC calibration

- **METRIC** combines the strengths of energy balance from satellite and accuracy of ground-based reference ET calculation



Satellite-based energy balance provides spatial information and distribution over large area (does the “heavy lifting”)

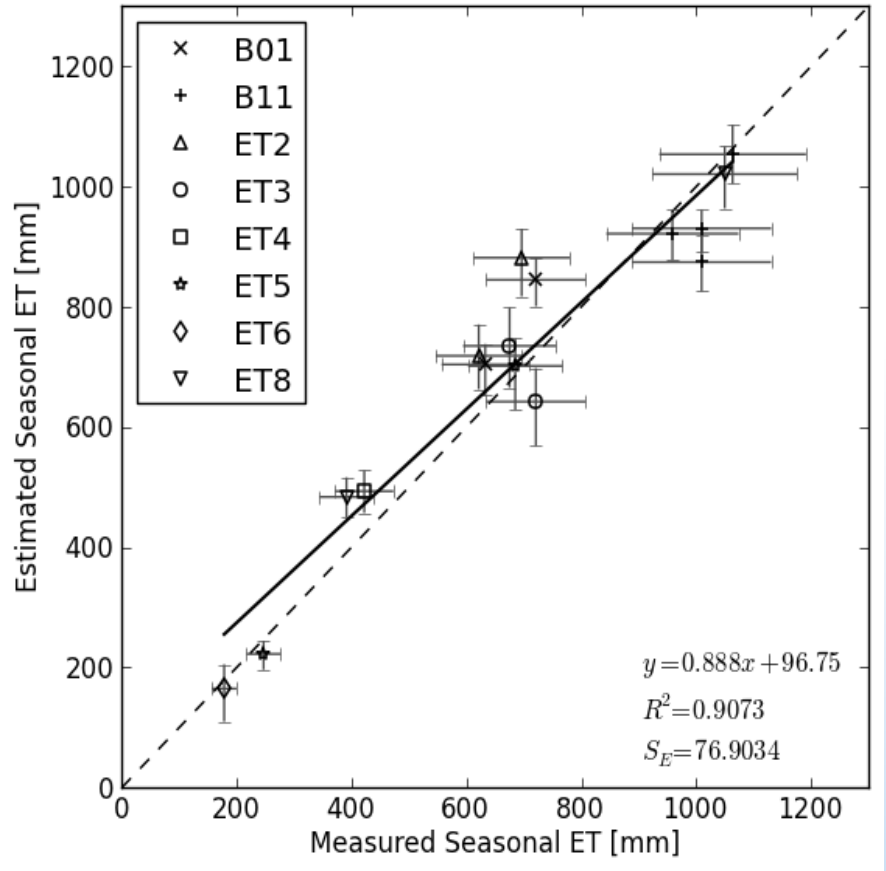
Experienced user selects upper bound (ET = ETr) and lower bound (ET = 0) to “constrain” ET estimates.

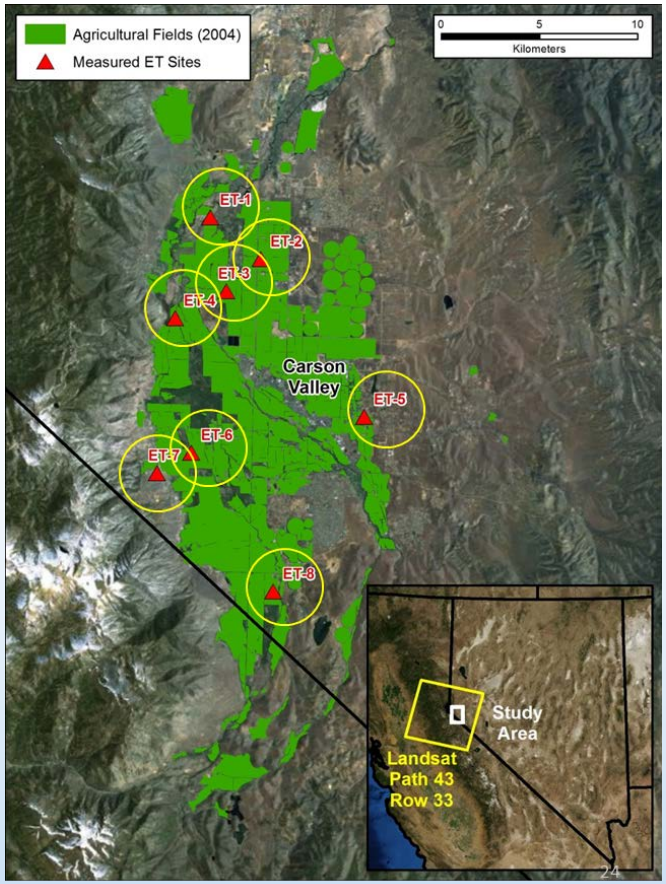
Reference ET calculation “anchors” the energy balance surface and provides “reality” to product.

Credit: R.G. Allen

METRIC validation

- Over a season the error in daily estimates largely cancels out





Morton, C.G., J.L. Huntington, G.M. Pohll, R.G. Allen, K.C. McGwire, and S.D. Bassett. (2013). Assessing Calibration Uncertainty and Automation for Estimating Evapotranspiration from Agricultural Areas Using METRIC. Journal of the American Water Resources Association (JAWRA) 49(3): 549-562.DOI: 10.1111/jawr.12054

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NASA-ROSES Project

Project Title: Operational Remote Sensing of Agricultural Water Use in Cooperation with Western State Water Resource Agencies for Improved Water Management

- **Problem:** METRIC very resource intensive, prohibits operation use
- **Project goal:** Develop software tools, ET maps, and databases for in-house use by agency staff

Project partners:

NASA

DRI Desert Research Institute

The University of Idaho 1889

IDWR

State of Nevada
Department of Conservation & Natural Resources
Division of Water Resources
Jason King, P.E., State Engineer

Wyoming State Engineer's Office

Utah DNR Water Resources

California Water Boards
State Water Resources Control Board
Regional Water Quality Control Boards

Texas Water Development Board

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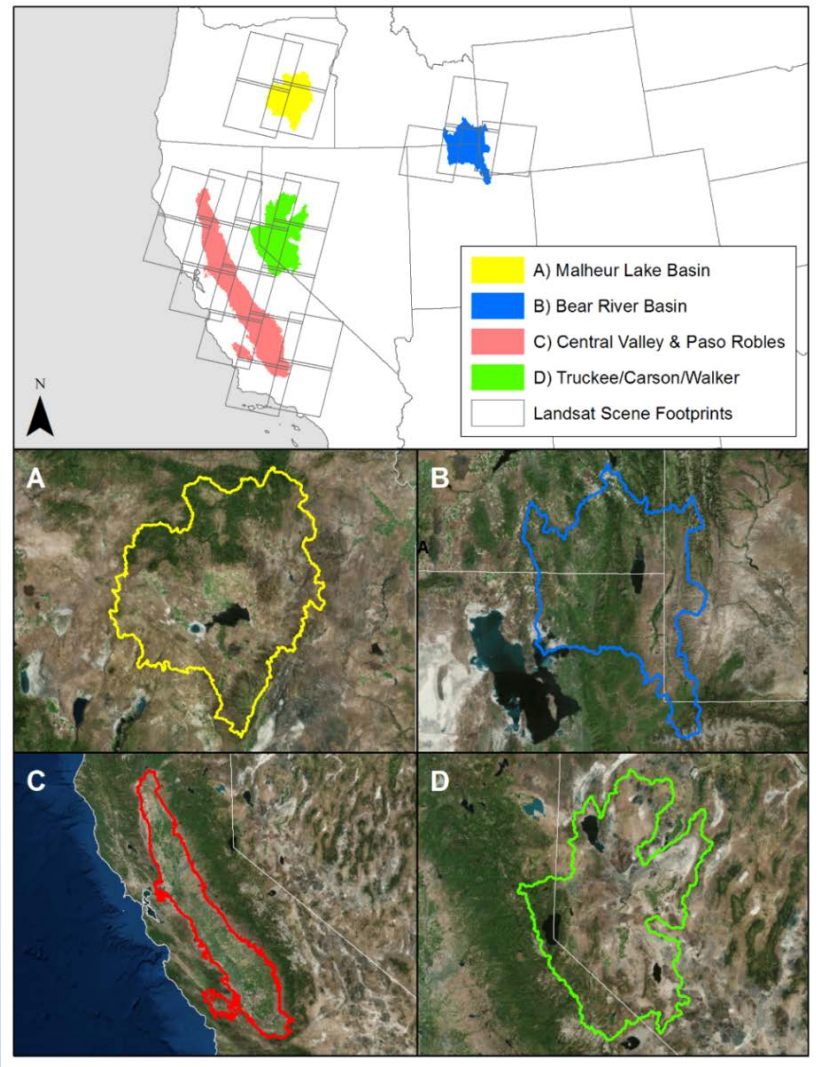
NASA-ROSES Project

- Each agency identified an area with data gaps in need of **accurate agricultural ET measurement and modeling**
- OWRD identified the **Harney Basin** as the study area
- Overlaps with **GW Study** and **Basin Planning** efforts
- Agency staff trained on **METRIC** and **ET-Demands**, test application in study area



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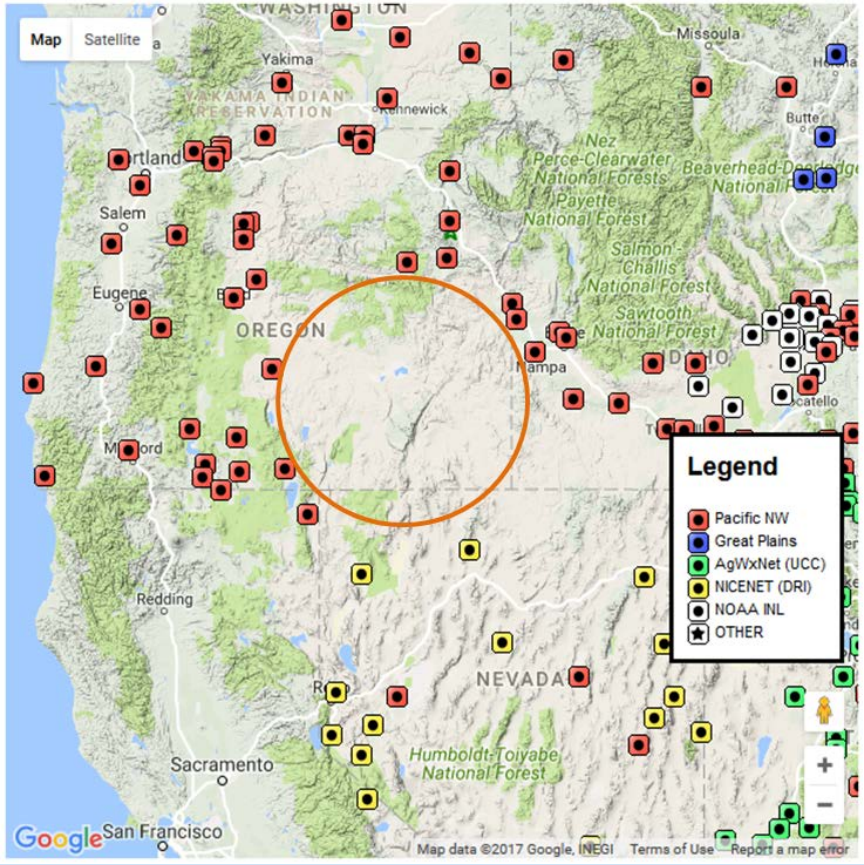
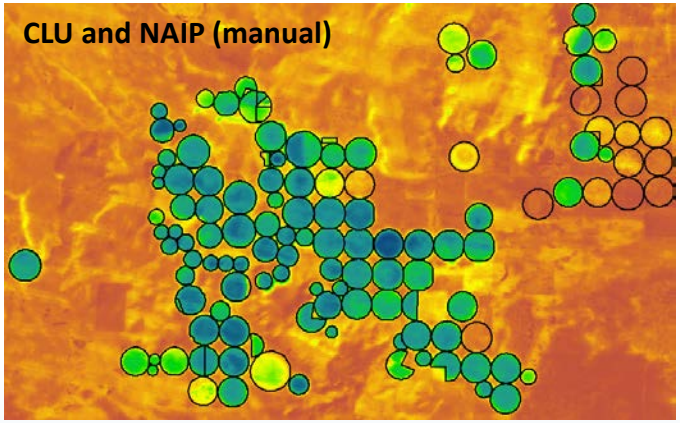
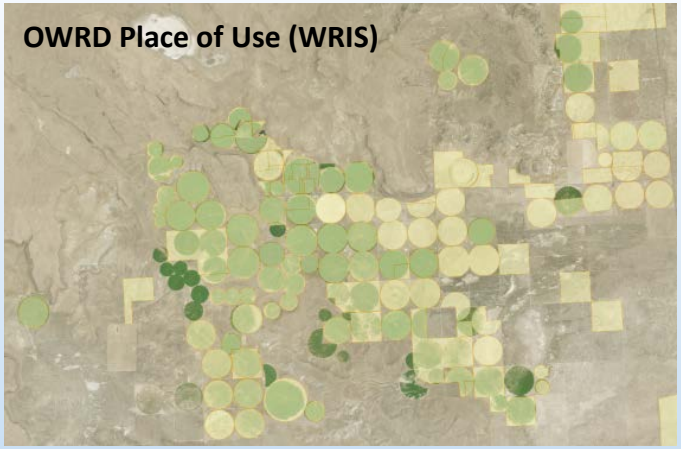
Initial challenges

Lack of reference ET station



Irrigated field boundary delineation





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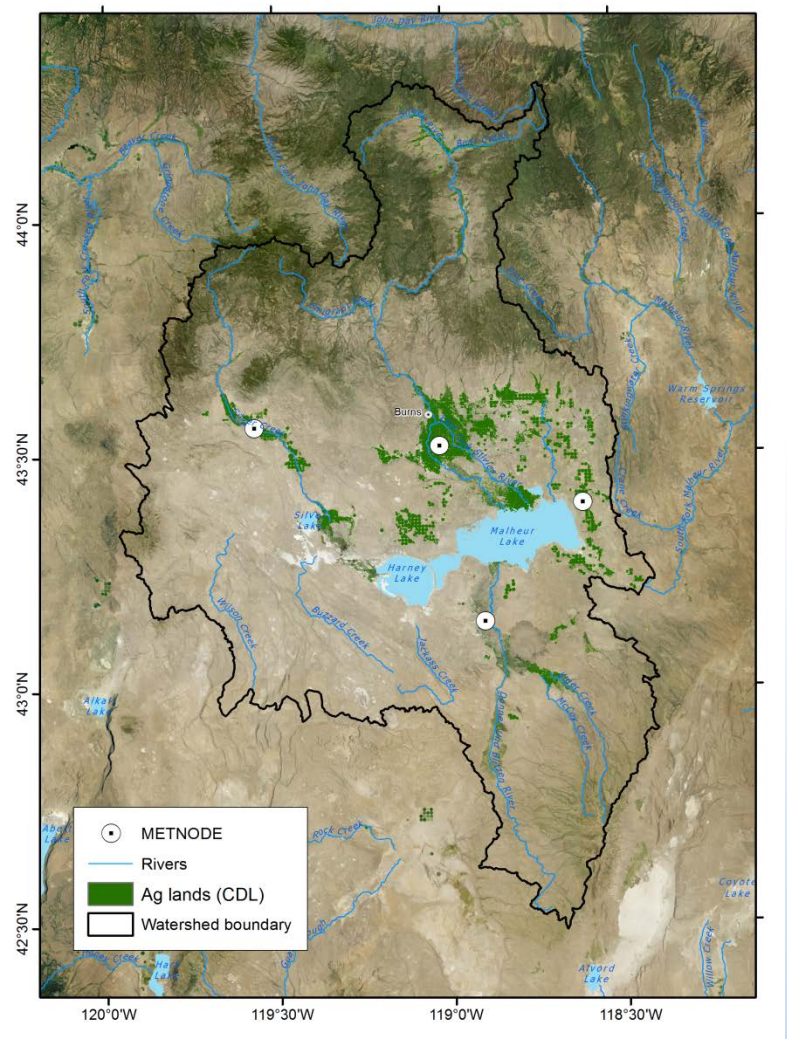
ET-Demands set-up



- Applied DRI Python ET-Demands model to get crop ET and NIWR in Harney basin
- Compare results to METRIC actual crop ET
- Model inputs:
  - Crop type from 2017 cropland data layer
  - Soil data from STATSGO
  - GridMET daily ETo and PPT 1979-2016
- Model parameters tuned to match typical growing season and number of cuttings

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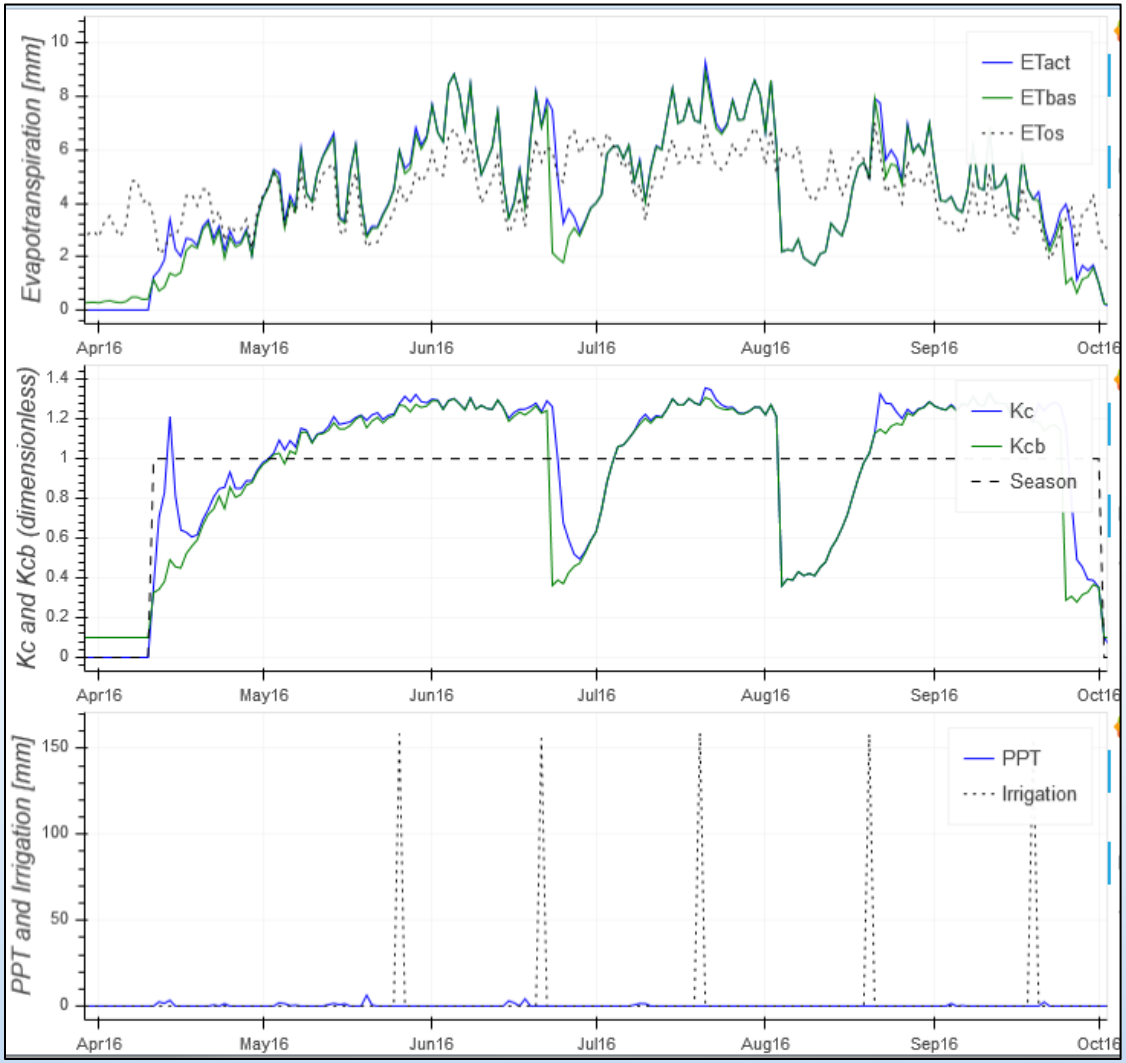
Sample daily output



- Example daily time series of crop ET for Alfalfa hay
- Crop coefficient curves show crop development, 3 cuttings
- Simulated sprinkler irrigation and PPT

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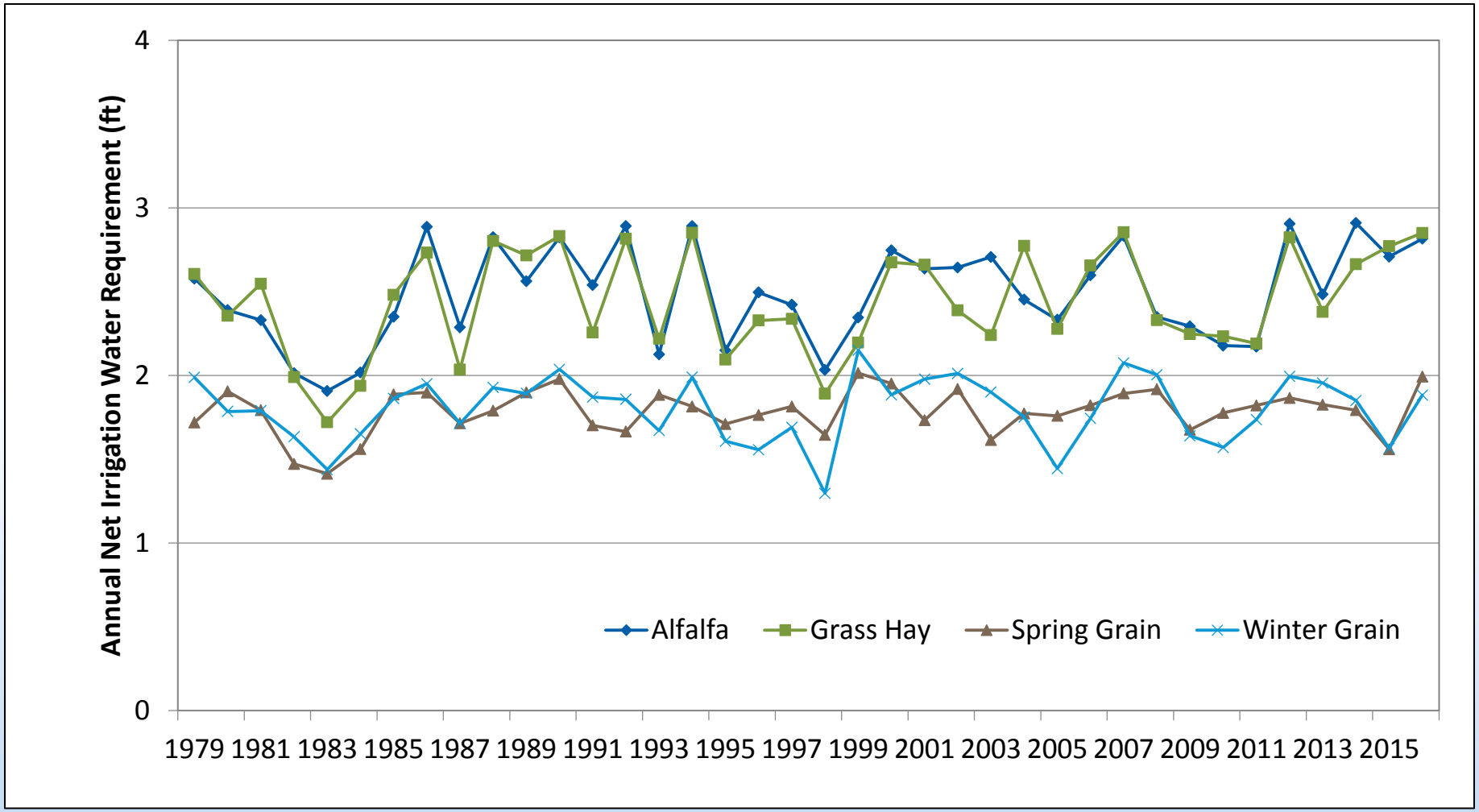
ET-Demands time series



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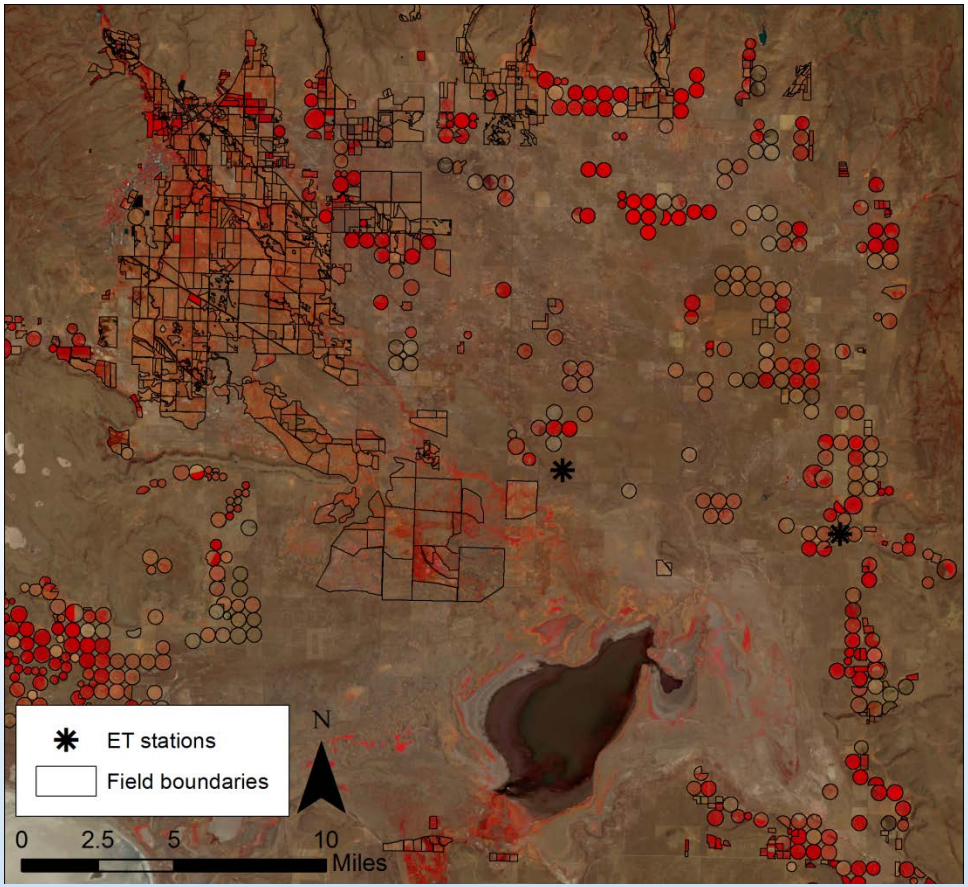
METRIC set-up



- Applied DRI pyMETRIC code to create ET maps for 2016
- Used 28 (mostly) clear Landsat 7 and 8 scenes from 1/20 to 12/05 (30-m res)
- Computed field-averaged ET and net ET (ET-PPT)

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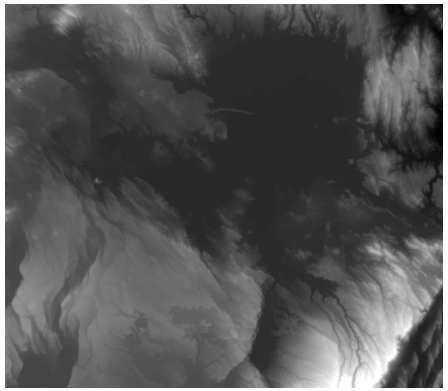
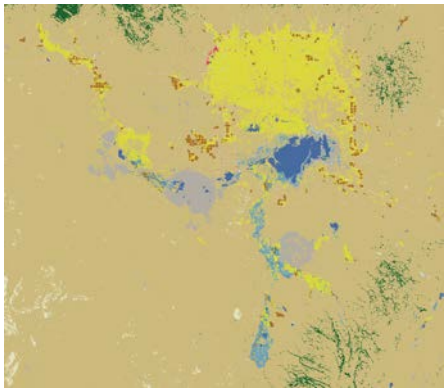
METRIC inputs

Static layers

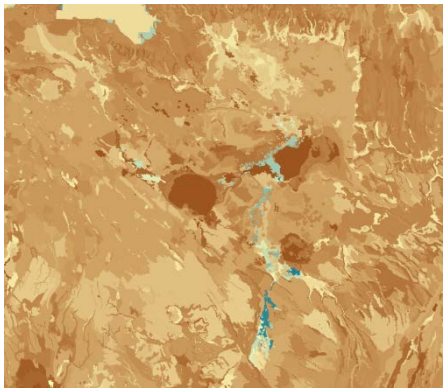
Elevation



Land cover

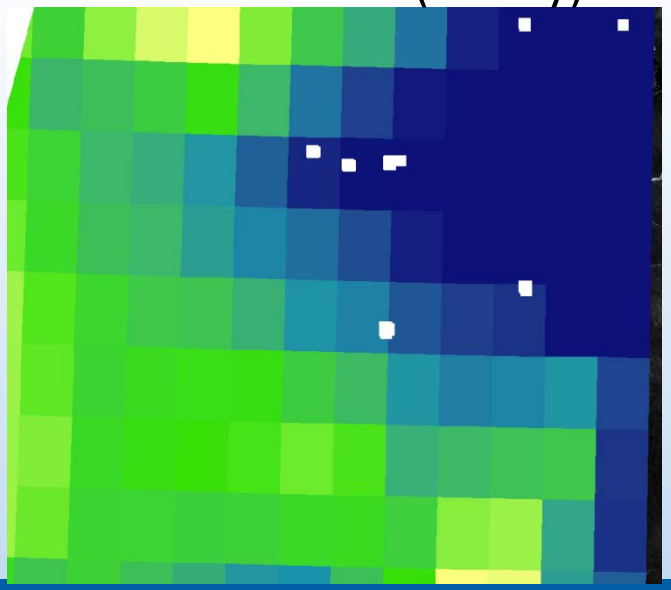


Soils

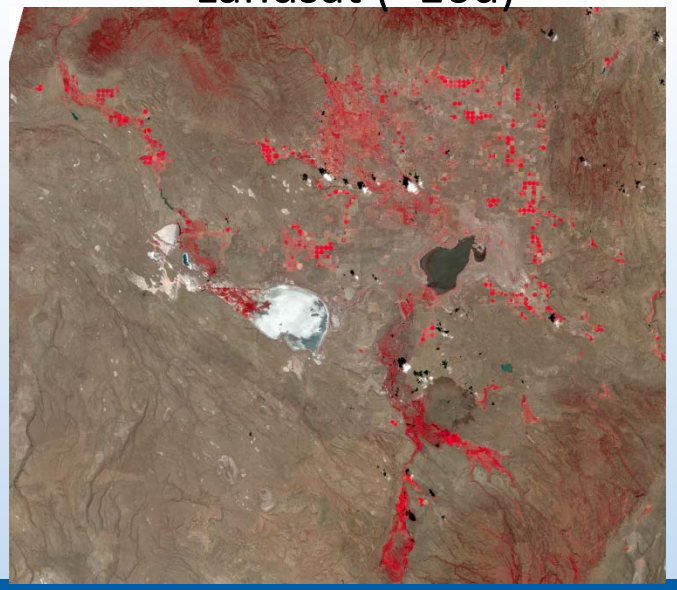


Time-varying layers

Reference ET (hourly)



Landsat (~16d)



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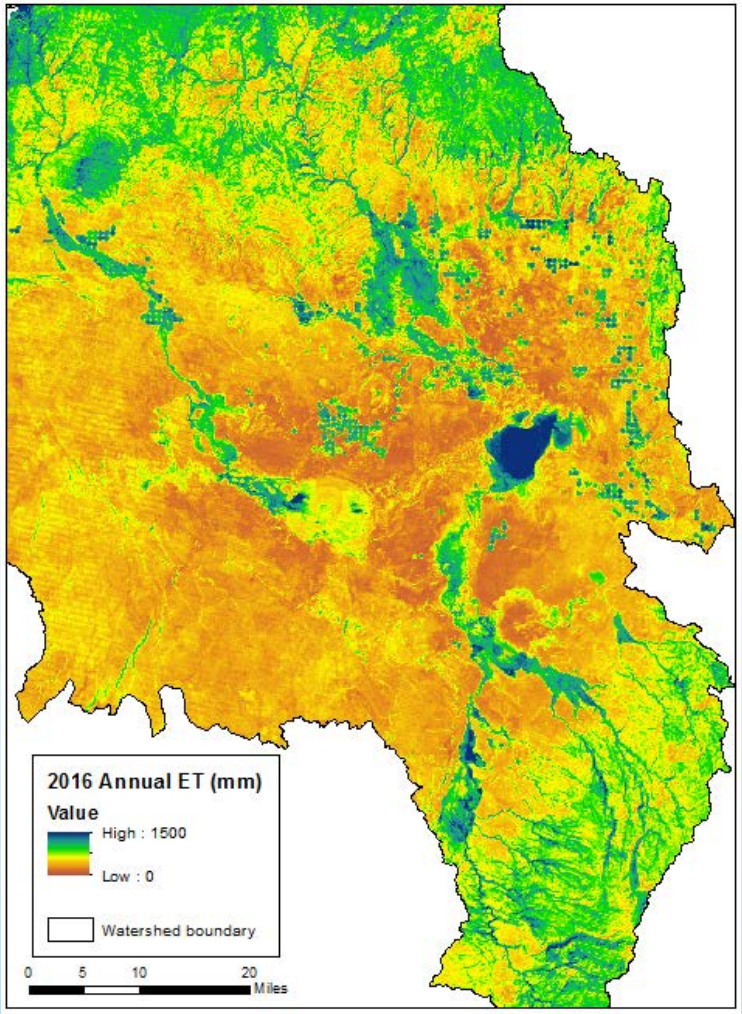
METRIC ET map

Annual 2016 Total Evapotranspiration (mm)



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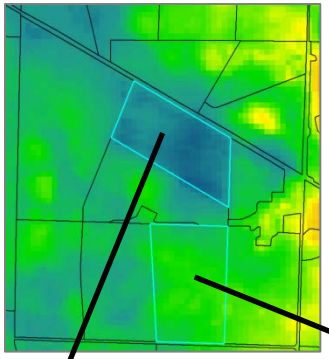
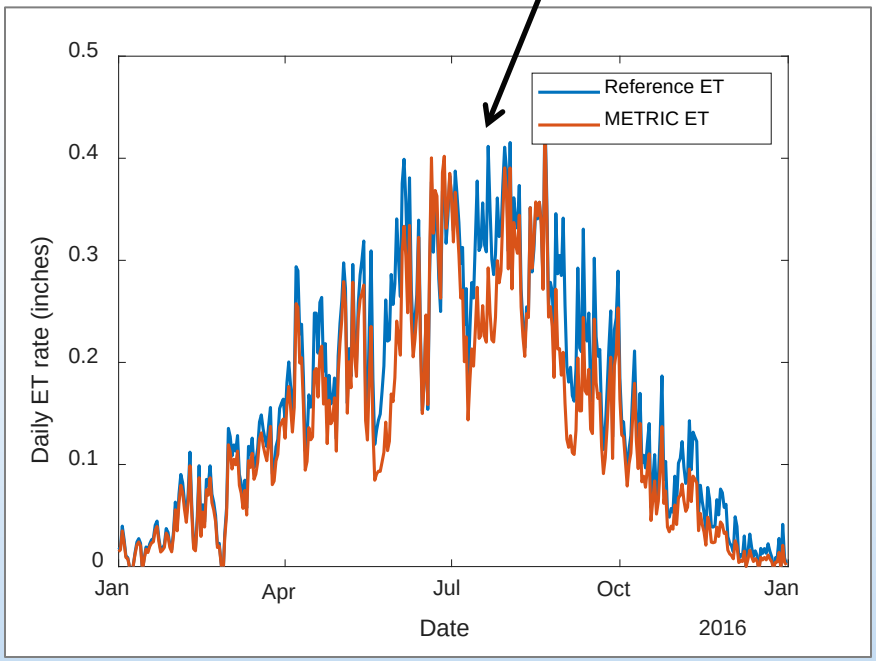
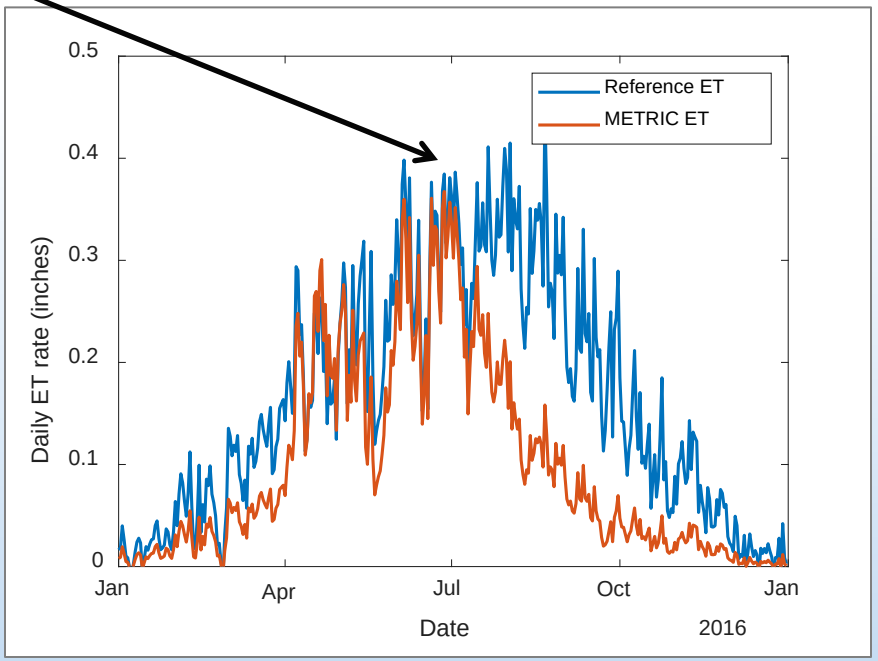
METRIC time series



- Daily time series of METRIC ET compared at two fields at EOARC
- Highlights difference between a fully irrigated and water-supply limited ET





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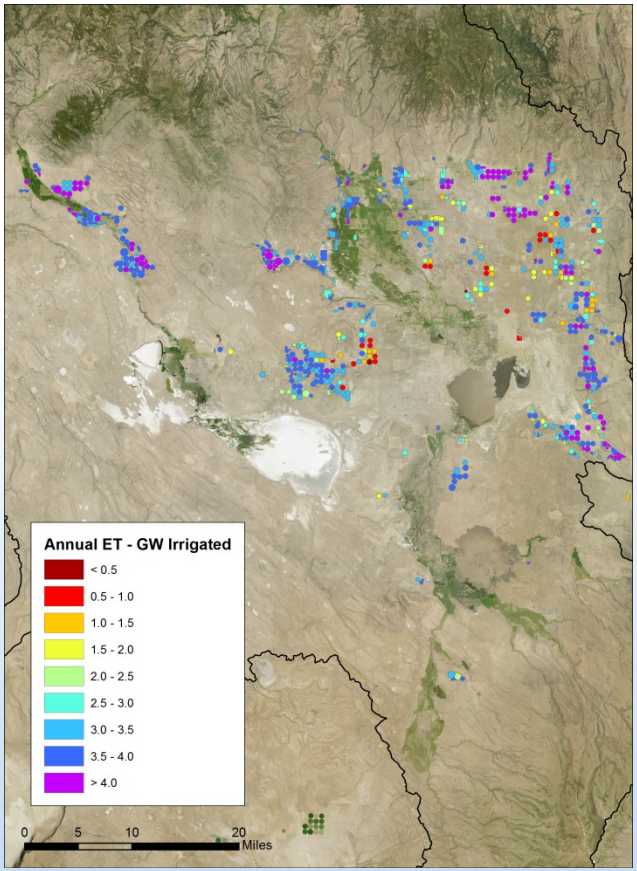
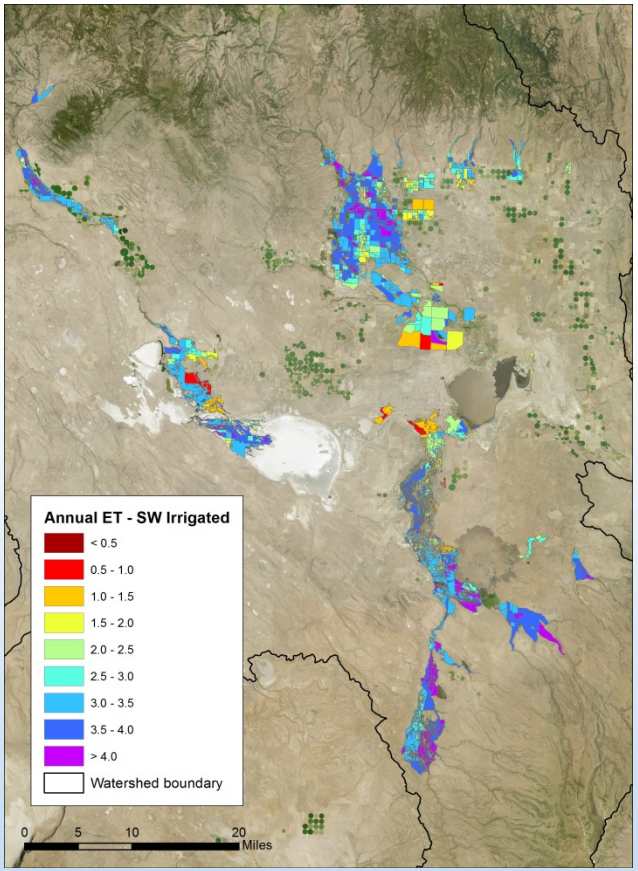
Field-averaged ET map

Field Averaged Annual Total ET (ft)

Groundwater Irrigated Fields



Surface Water Irrigated Fields + Refuge



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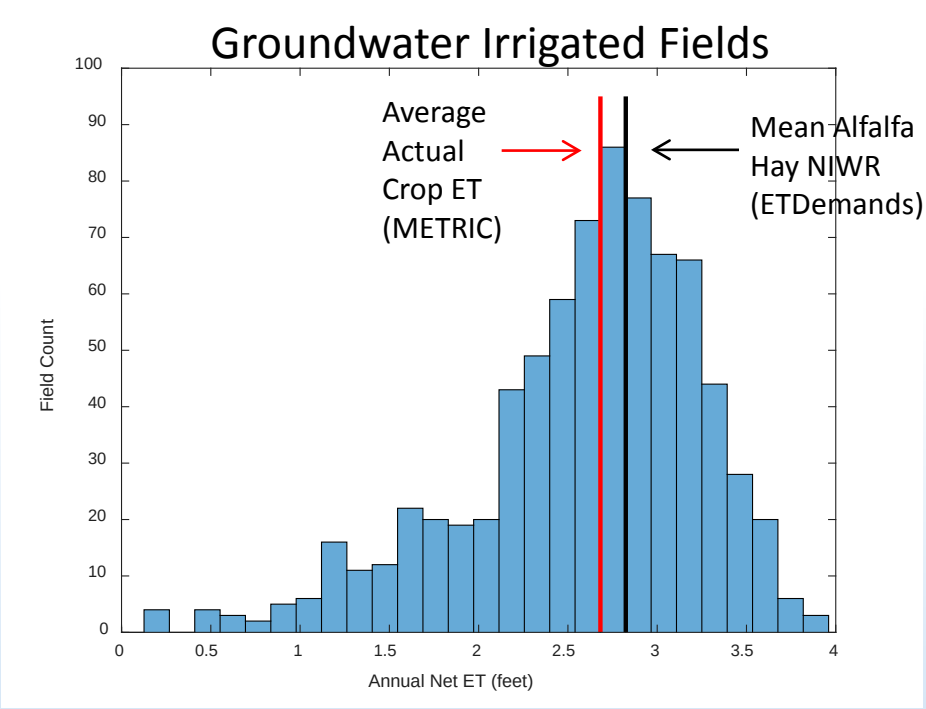
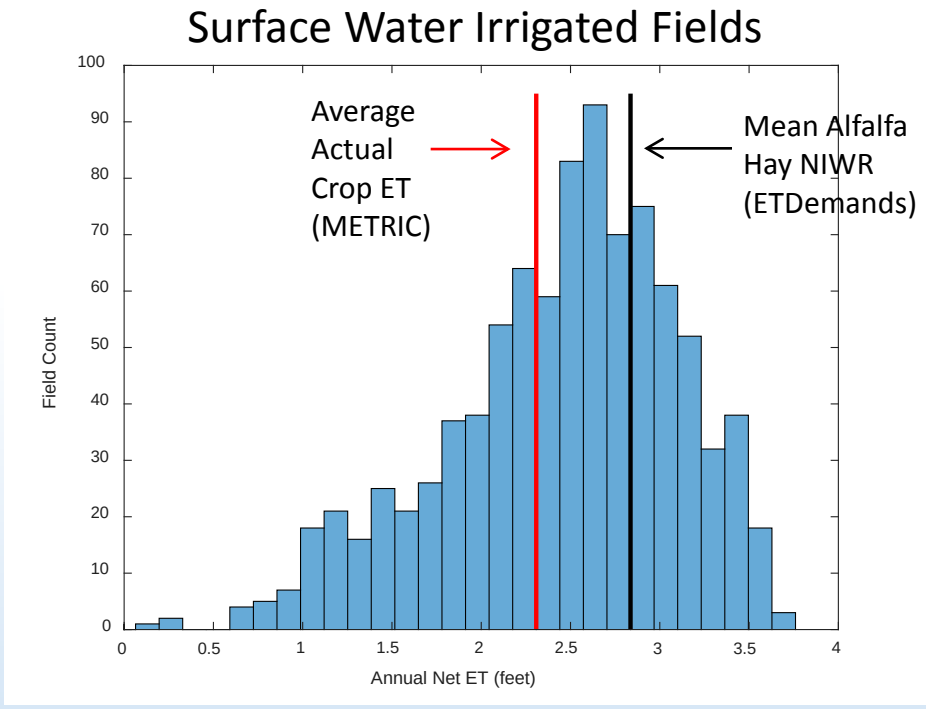
Actual vs. potential crop ET





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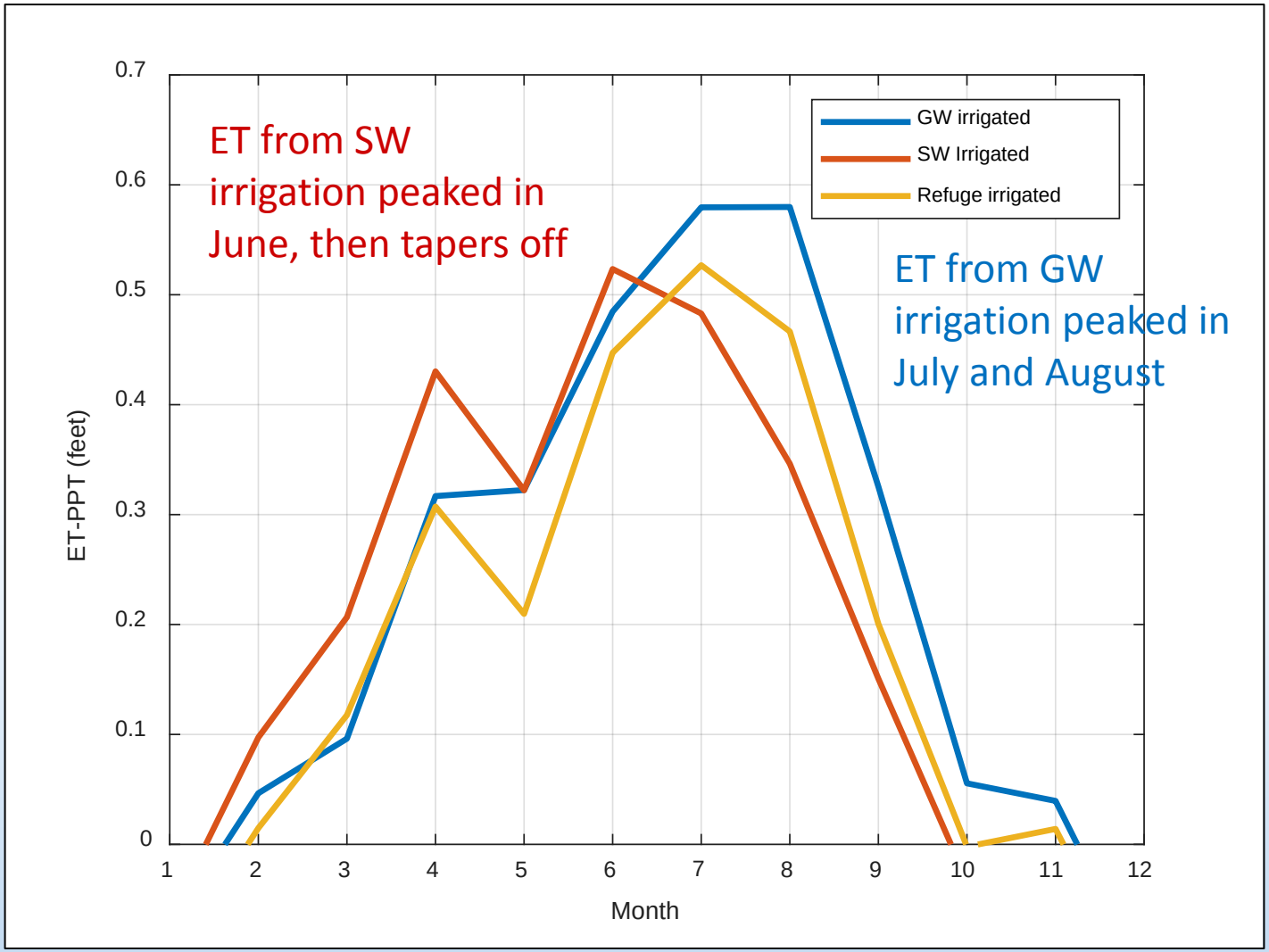
METRIC monthly ET



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METRIC ET volume

Source type	Irrigated area (acres)	Mean Net ET rate (ft)	Net ET volume (ac-ft)
Groundwater	62,200	2.64	164,100
Surface water	73,900	2.31	170,700
Refuge	47,200	2.05	96,800
Total	183,300	2.35	431,600

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Harney ET stations

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Discussion & next steps

- Promising initial results - the remote sensing of ET (METRIC) approach computes a mean net ET rate very similar to the NIWR from ET-Demands for 2016
- Our group will perform METRIC analysis for a total of 10 years of Landsat imagery in the basin
- Next steps are to tie the field level ET data to water rights and wells
- More field validation needed – ET stations and water use records provide ground-truth data for METRIC ET estimates

Station data access

Native Vegetation Site:

https://www.wrcc.dri.edu/cgi-bin/rawMAIN.pl?orolwn

Alfalfa Center Pivot Site:

https://wrcc.dri.edu/cgi-bin/rawMAIN.pl?orocrn

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Questions?