The GRAPEX Project: A Multi-scale Approach to Water and Energy Exchange in Vineyards

USDA ars

E&J Gallo Winery

USDA-ARS HRSL
Hydrology & Remote Sensing Lab
Beltsville, Maryland, USA

Many participants are contributing to the GRAPEX project……

GRAPEX=Grape Remote sensing Atmospheric Profile Evapotranspiration eXperiment

William Kustas[1], Martha Anderson[1], Kyle Knipper[1], Feng Gao[1], Joe Alfieri[1], Lynn McKee[1], John Prueger[2], Jerry Hatfield[2], Chris Parry[3], Andrew McElrone[3], Larry Hipps[4], Alfonso F Torres-Rua[5], Mac McKee[5], Luis Sanchez[6], Maria Mar Alsina[6], Nick Dokoozlian[6], Forrest Melton[7,8], Kirk Post[7], Christopher Hain[9] Héctor Nieto[10], Nurit Agam[11], Ting Xia[12]

[1]USDA-Agricultural Research Service, Hydrology and Remote Sensing Laboratory, Beltsville, MD
[2]USDA-ARS National Laboratory for Agriculture and the Environment, Ames, IA
[3]USDA-ARS Crops Pathology and Genetics Research Unit, Davis, CA
[4]Plants, Soils and Climate Department, Utah State University, Logan UT
[5]Department of Civil and Environmental Engineering, Utah State University, Logan, UT
[6]Viticulture Research, Ernest & Julio Gallo Winery, Modesto, CA
[7]School of Natural Resources California State University of Monterey Bay, Marina CA
[8]NASA Ames Research Center, Moffett Field, CA
[9]NASA Marshall Space Flight Center, Huntsville AL
[10]IRTA (Institute for Food and Agricultural Research and Technology) LLIEDA Spain
[11]Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of Negev, Israel
[12]Department of Hydraulic Engineering, Tsinghua University, Beijing, China

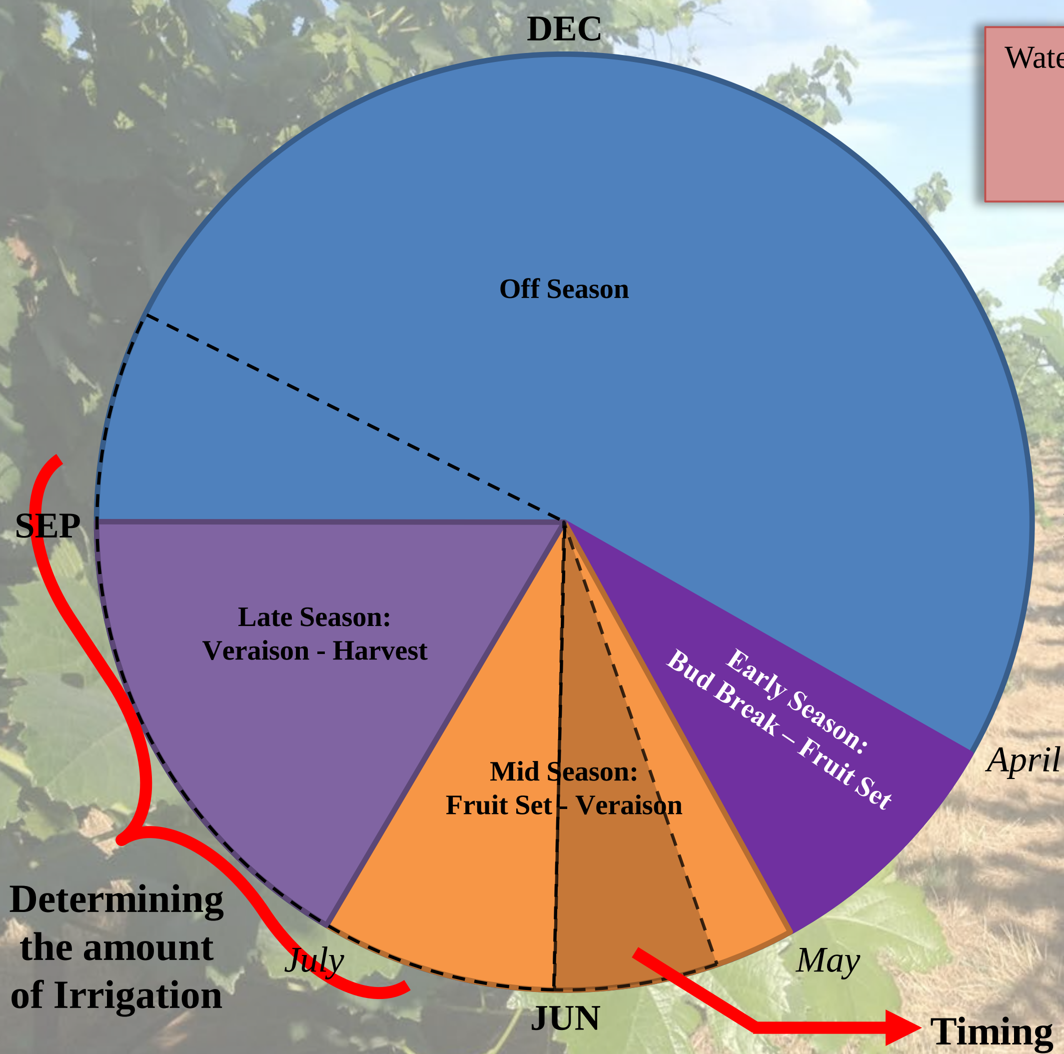
Irrigation Scheduling in Viticulture

Water management decisions focus on:

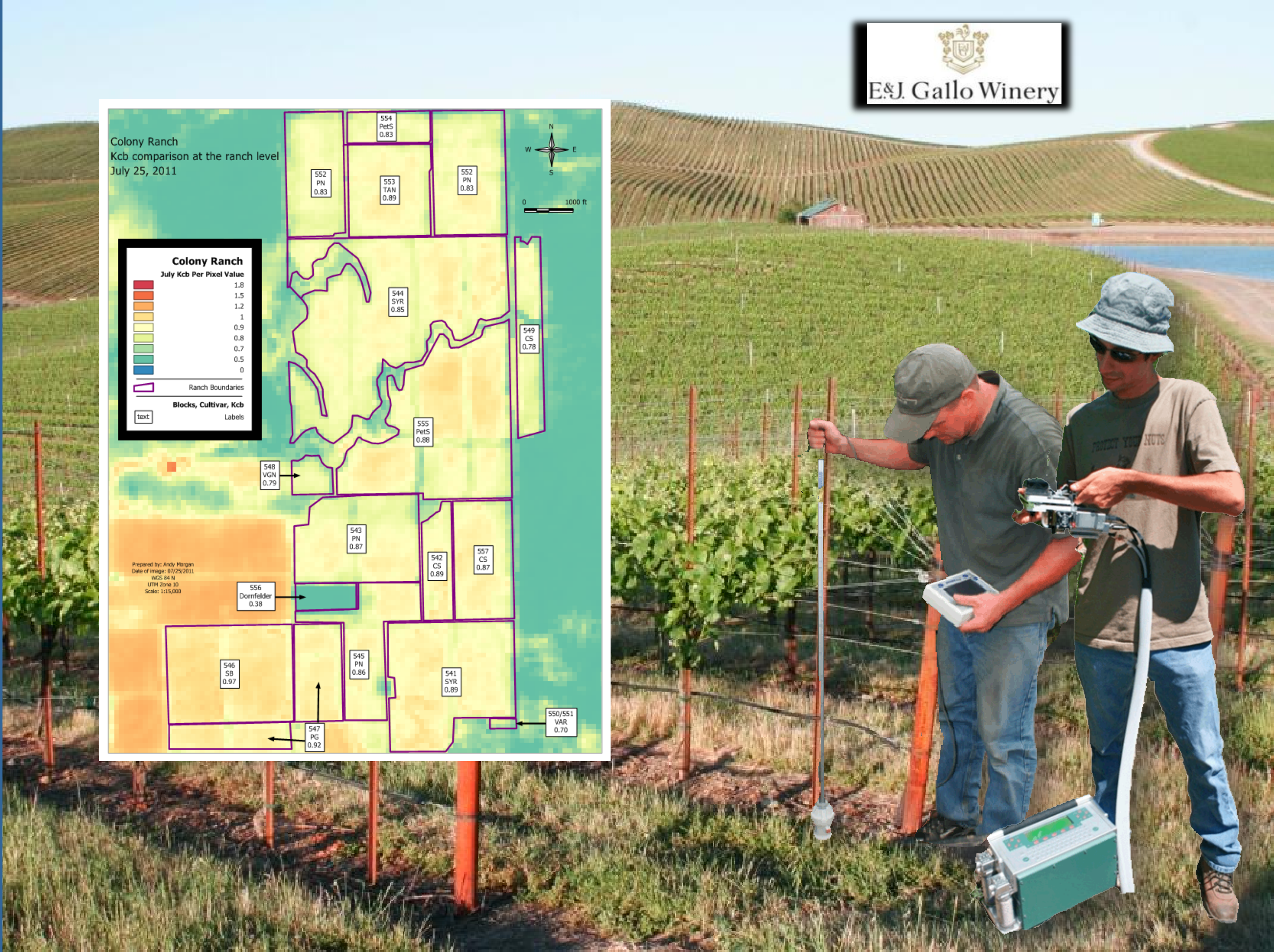
1) Timing of the start of irrigation in the spring
2) Manage the quantity of water applied during remainder of growing season

Complications arise from:

1) Changing Weather/Climate
2) Within field variations (soil texture, elevation)
3) Local/state government imposed mandatory water reductions



Monitoring Water Use in U.S. Vineyards



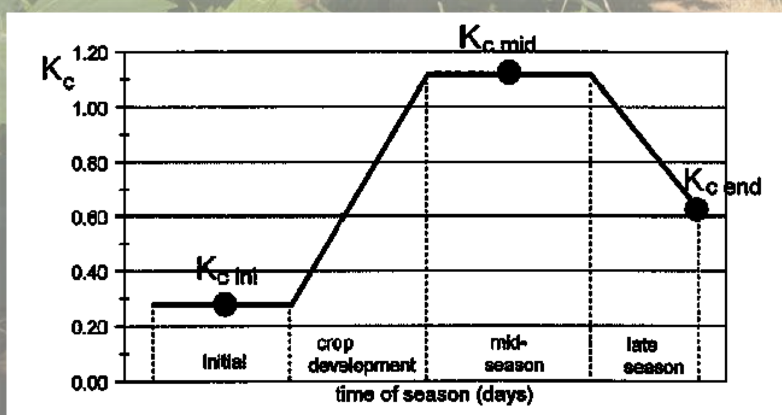
Monitoring Water Use in U.S. Vineyards

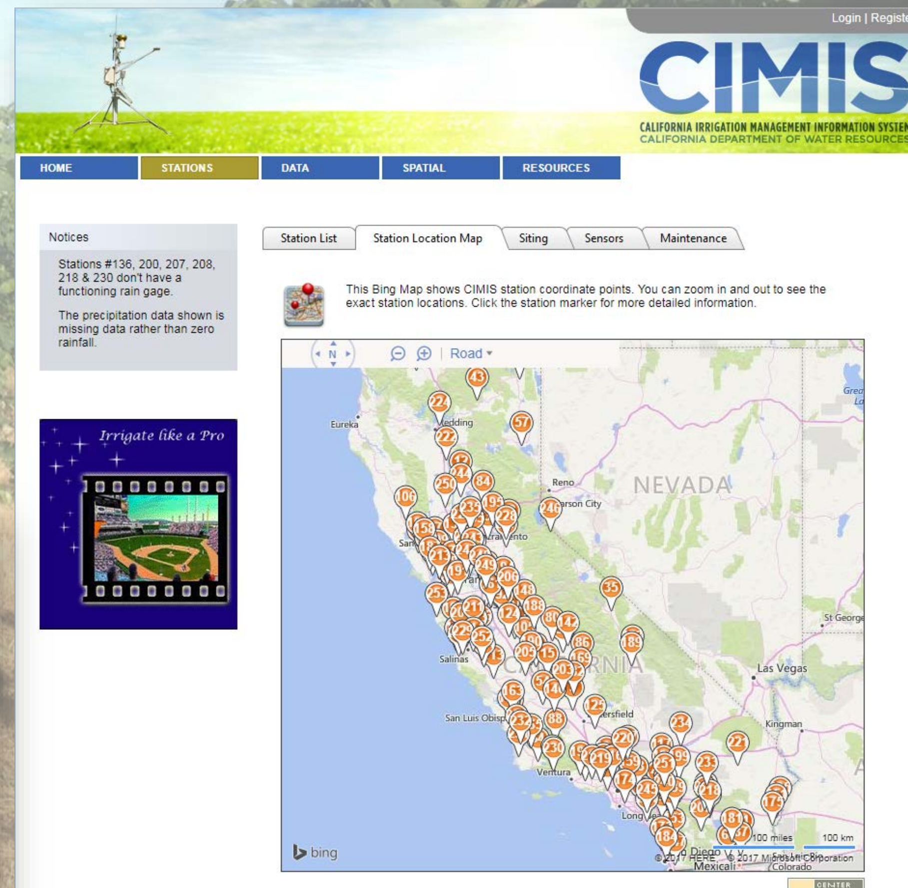
Current Operational ET Estimates for Irrigation Scheduling

$$ET = K_c(ET_0)$$

Crop Coefficient (~ NDVI)

Reference ET



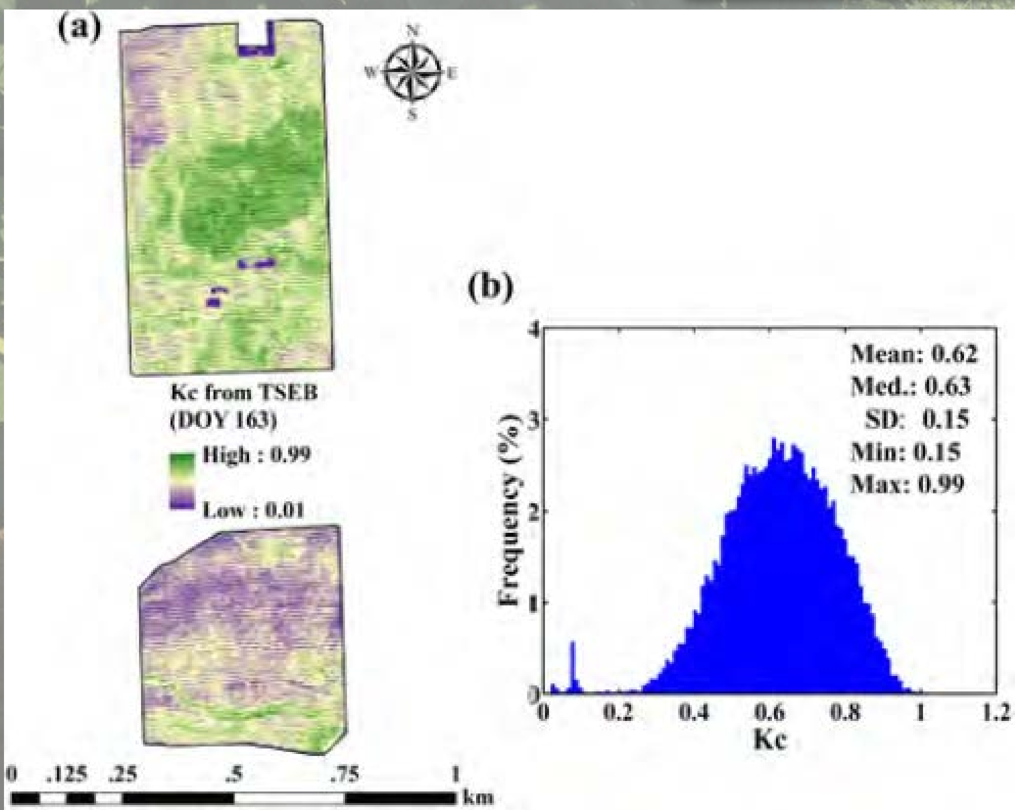


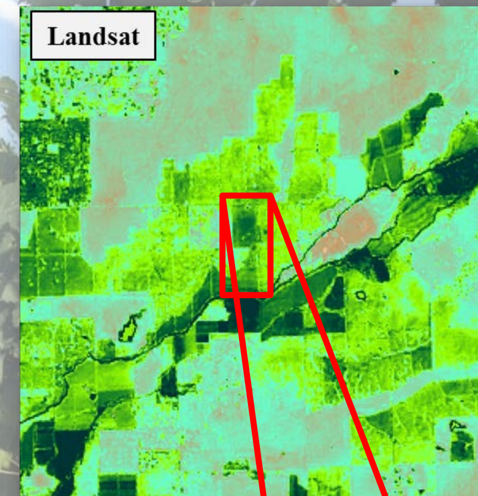
Limitations of Crop Coefficient for actual ET

$$K_c = ET/ET_0$$

ET from TSEB

FAO 56





GRAPEX Study site

The measurements were collected in two vineyards located approximately 32 km (~20 mi) northeast of Lodi, CA (38.29°N, 121.12°W).

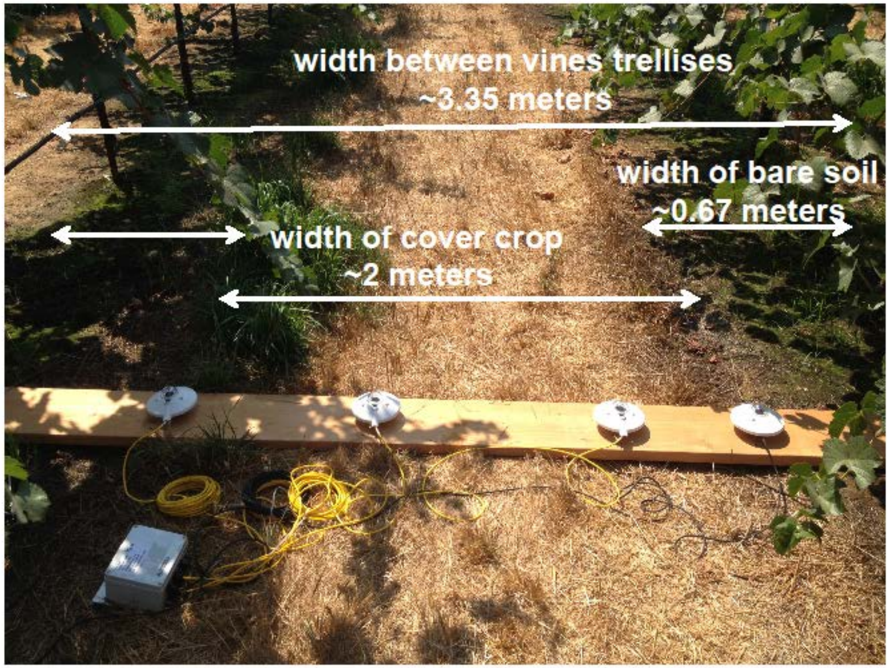
East-West Rows spaced ~3.3 m (11 ft).
Vines spaced ~1.5 m (5 ft).

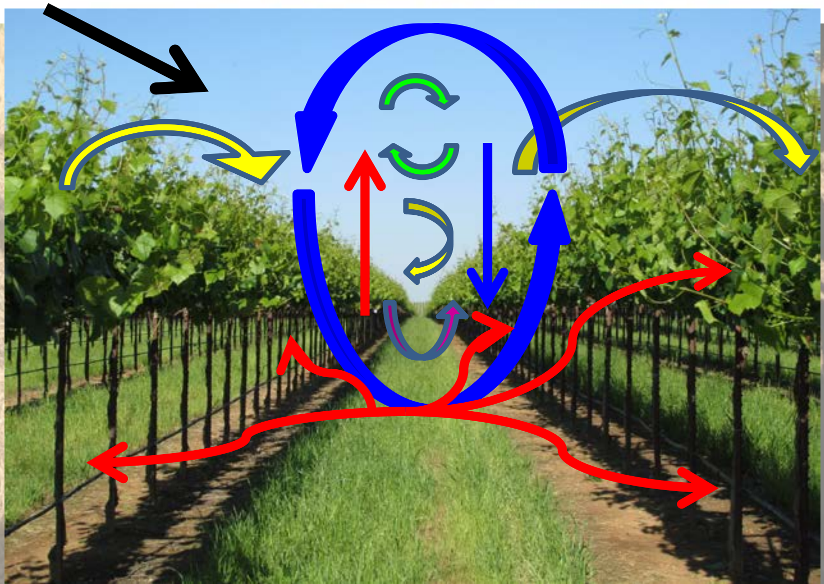
- **North Vineyard (site 1):**
  - **~ 34.4 ha (85 ac).**
  - **Mature vines.**

- **South Vineyard (site 2):**
  - **~21 ha (52 acre).**
  - **Young vines.**

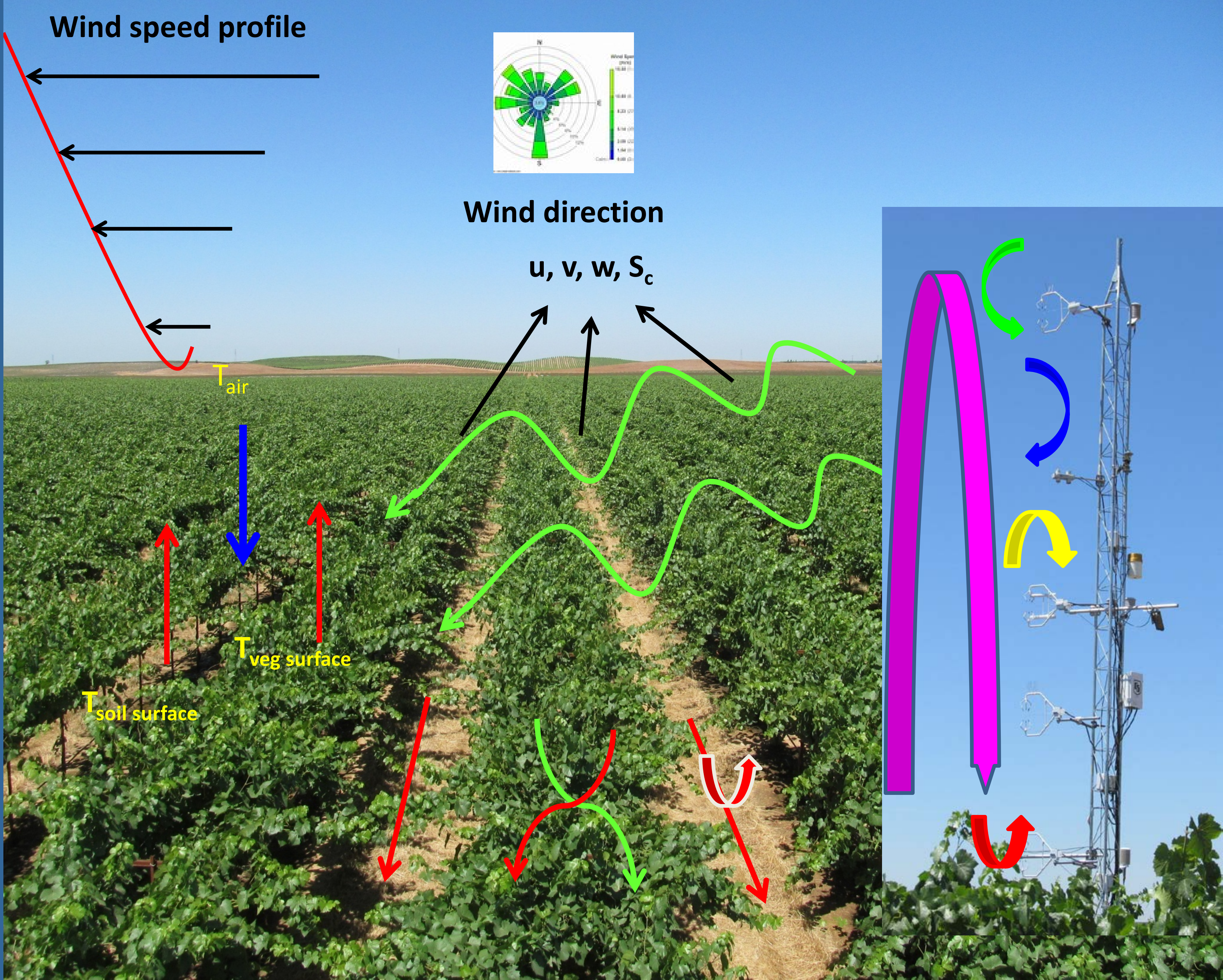
GRAPEX Study site

Bare soil, cover crop & vine canopy: 3 sources





Vine canopy structure affecting turbulent exchange

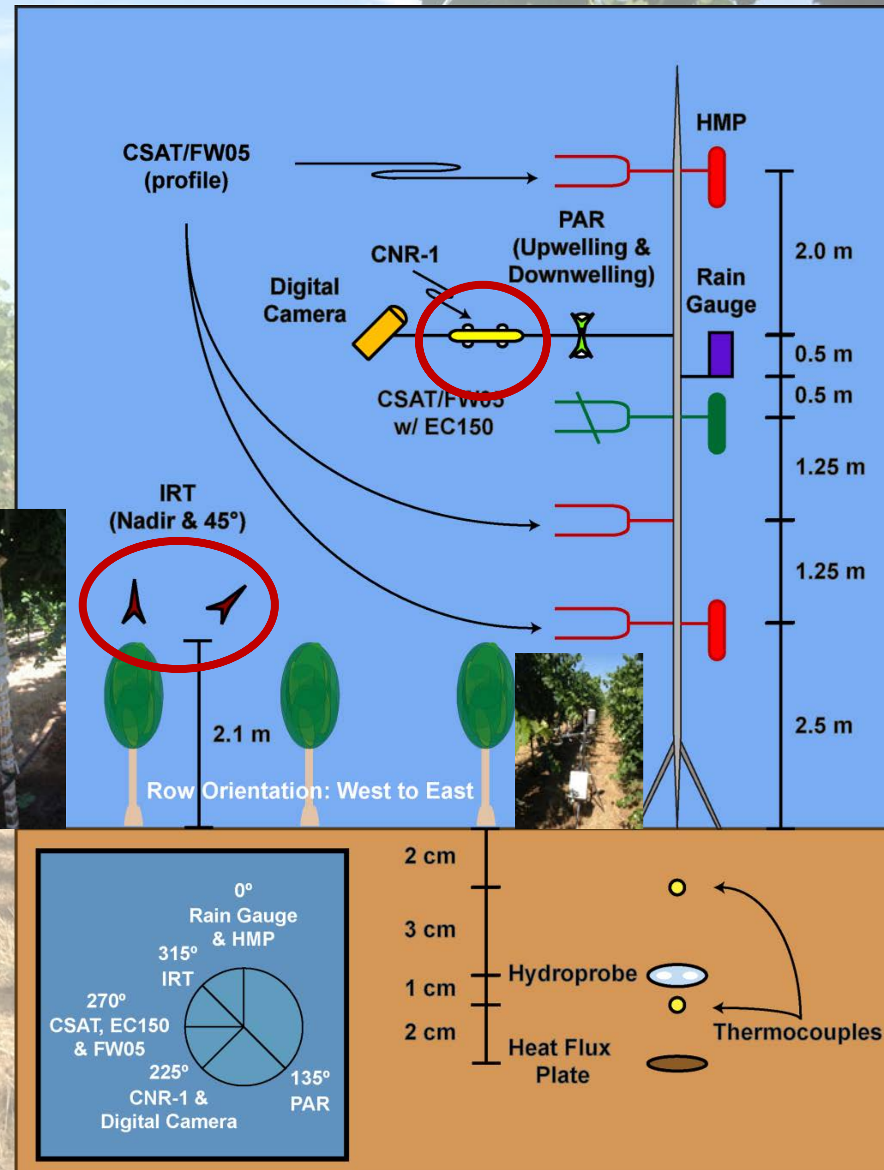


GRAPEX site measurements

The two vineyards were heavily instrumented to measure meteorological, vegetation, and soil conditions.

Measurements included:

- **meteorological quantities, *e.g.* wind speed, air temperature, and precipitation.**
- **surface energy balance.**
- **wind and friction velocity profiles at four† levels.**
- **surface/canopy temperature.**
- **vine water use via sap flow sensors.**
- **soil temperature/moisture at multiple depths.**



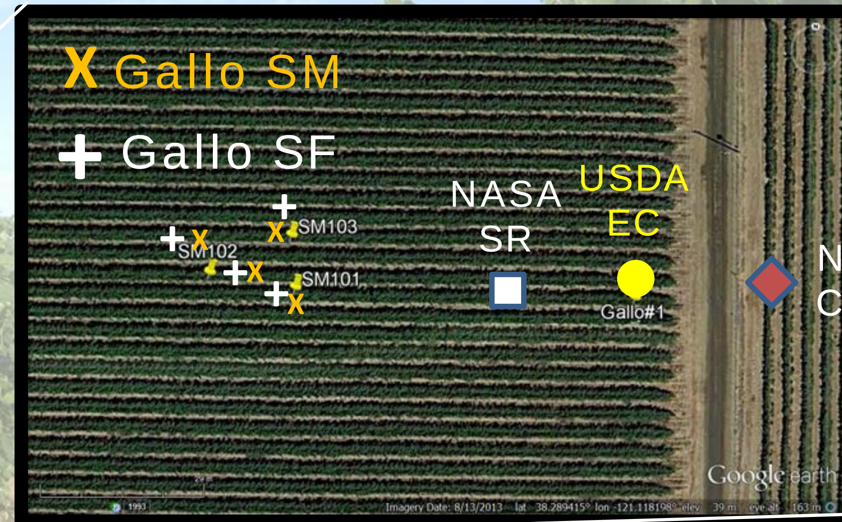
† † During IOPs, wind profile data was also collected at a fifth level (~1.5 m) , beneath the canopy.

GRAPEX site measurements

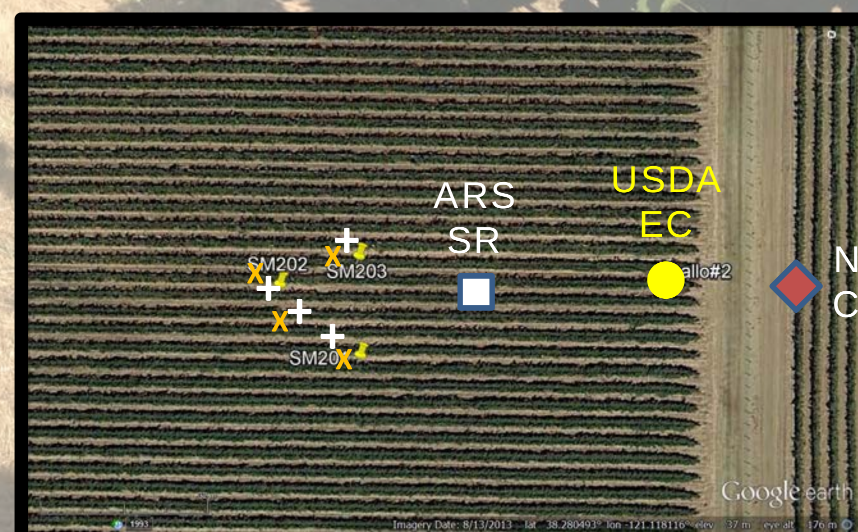
Profile Soil Moisture and Sapflow Network

NASA Soil Moisture Profile Network

North Vineyard
USDA/Gallo Soil Moisture Profiles



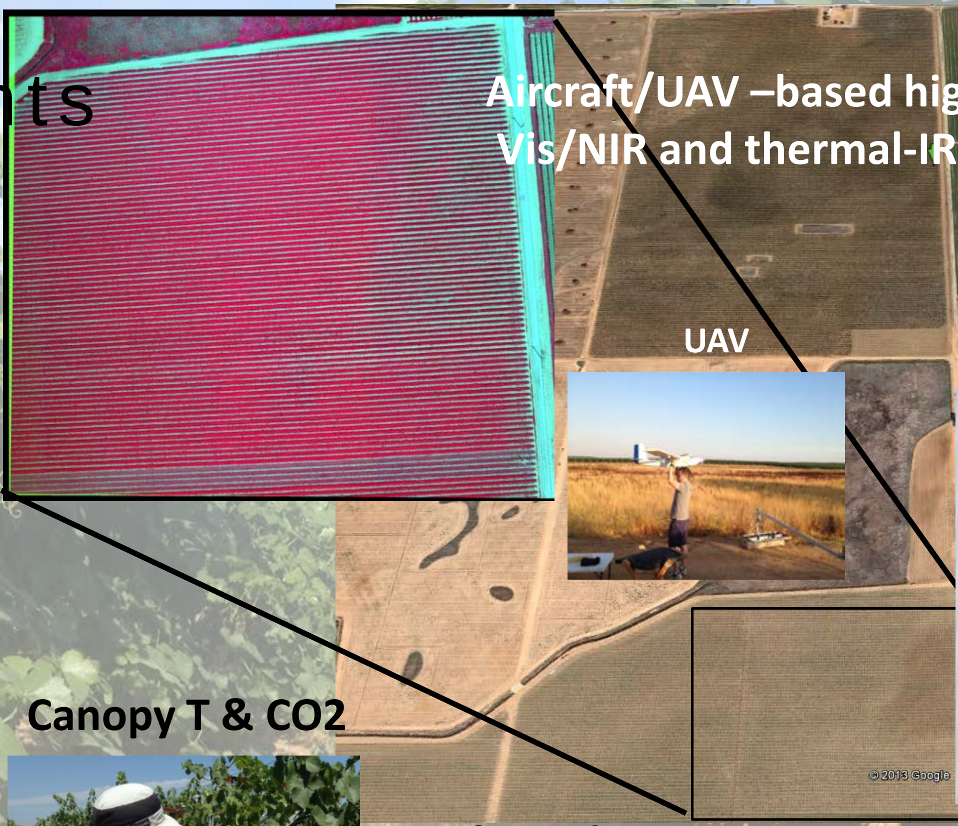
South Vineyard
USDA/Gallo Soil Moisture Profiles



GRAPEX Episodic Measurements

GRAPEX Measurements During IOPs

Aircraft/UAV –based high resolution Vis/NIR and thermal-IR



UAV

Tower-based Thermal/Optical Scanner

Below canopy wind & water vapor turbulence

Canopy T & CO2

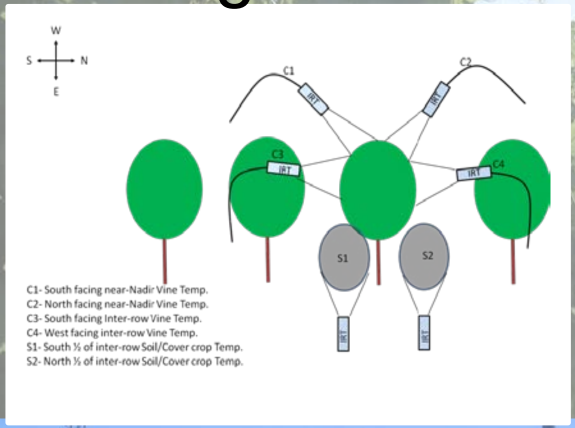
Spectral & LAI

solar radiation divergence

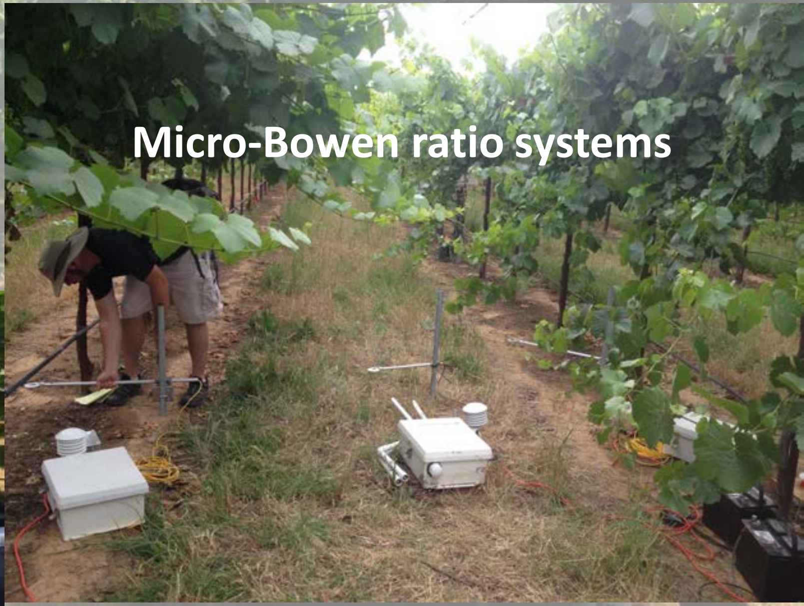
Scintillometry

GRAPEX Episodic Measurements

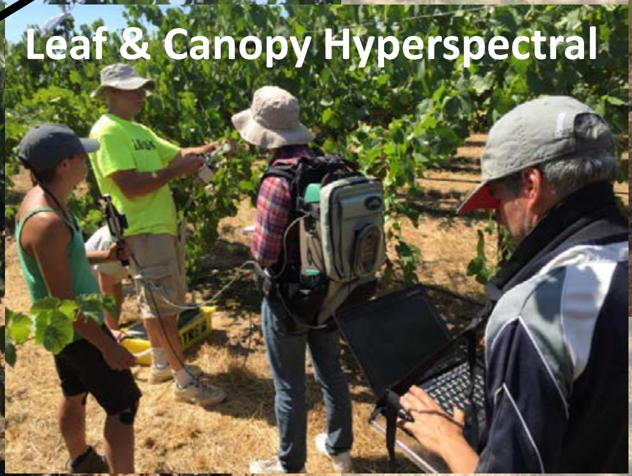
Additional GRAPEX Measurements During IOPs



IRT sensor network



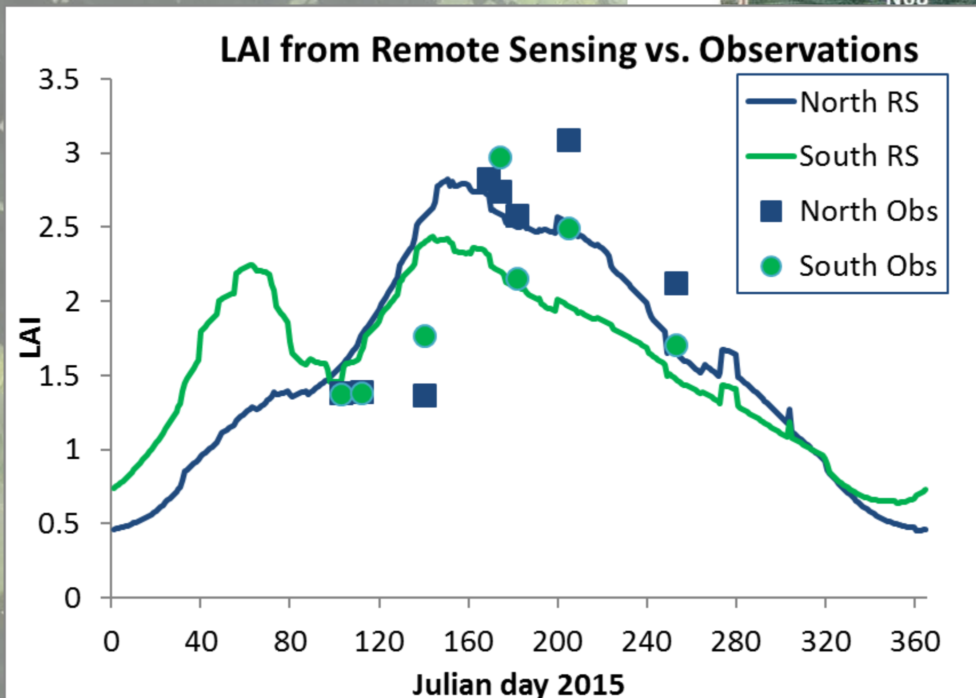
Micro-Bowen ratio systems

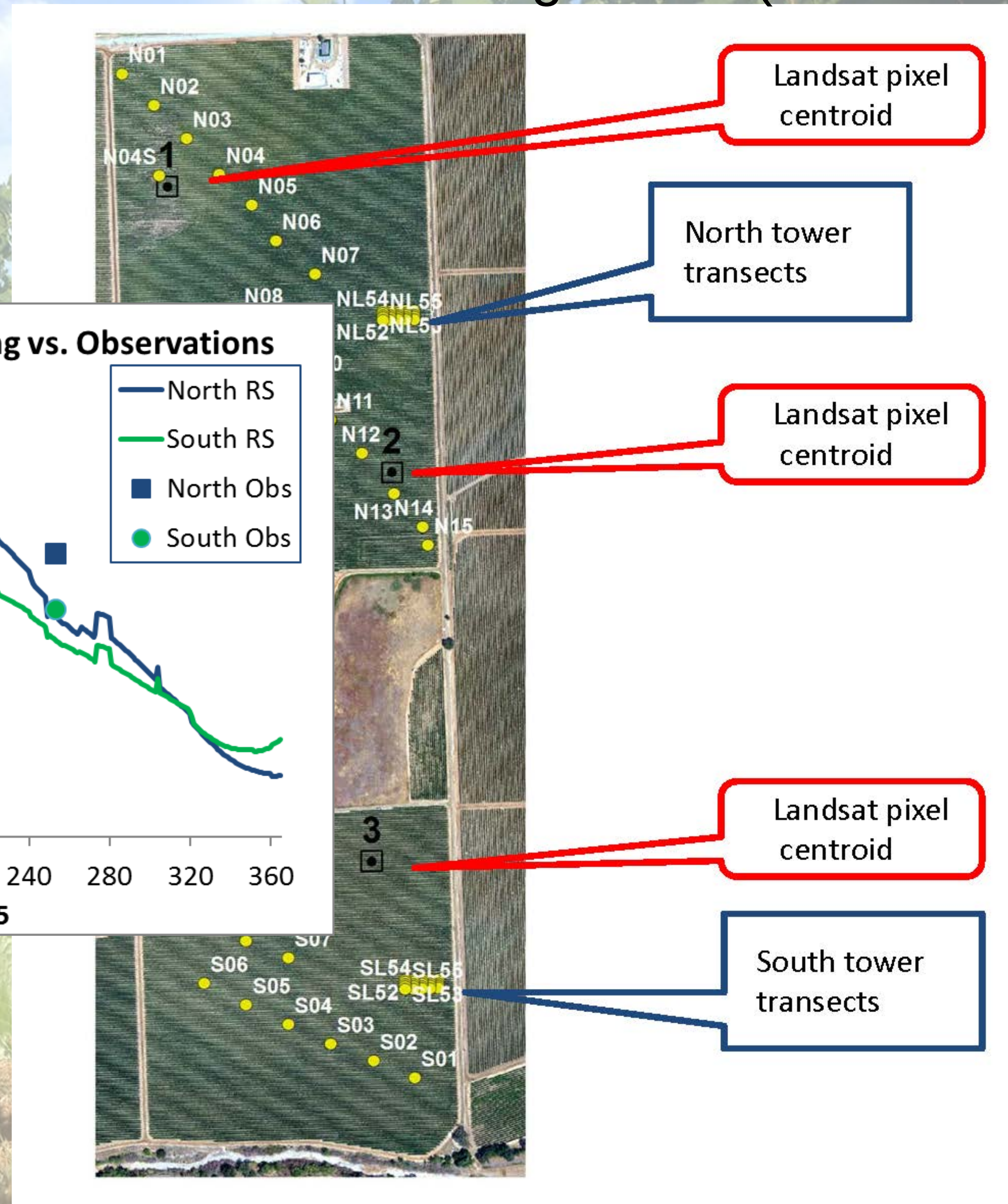


Leaf & Canopy Hyperspectral

GRAPEX LAI Measurements During IOPs (2014-16)

Leaf Area Index transects for GRAPEX





GRAPEX Intensive Observation Periods (IOPs)

GRAPEX IOPs

IOP 1 ~April/May	IOP 2 ~June/July	IOP 3 ~August
LAI ~ 0.5 to 2	LAI ~ 1.5	LAI ~ 2



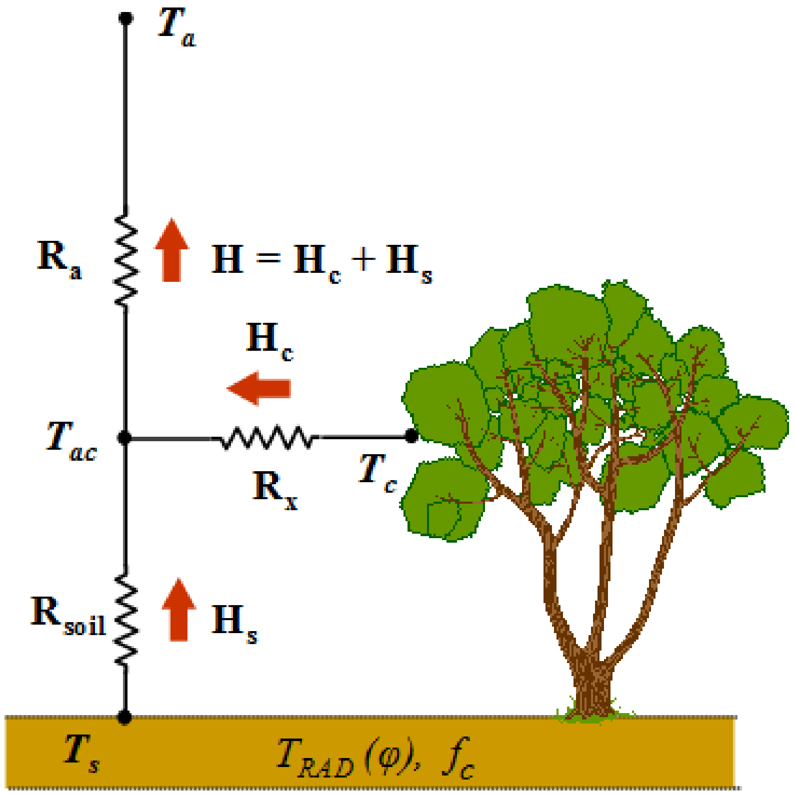
North Vineyard

LAI ~ 0.5 to 2	LAI ~ 1	LAI ~ 1.5



South Vineyard

TSEB Approach



SENSIBLE HEAT FLUX

Norman and Kustas, et al. (1995)

System, soil, canopy budgets

$RN = H + LE + G$

$RN_S = H_S + LE_S + G$

$RN_C = H_C + LE_C$

Two-source approximation

$T_{RAD}(\theta)^4 \sim f_C(\theta)\, T_C^4 + [1 - f_C(\theta)]\, T_S^4$

Temperature constraint

H_C, H_S, RN_C, RN_S, G

PT, PM or LUE R_C model

LE_C

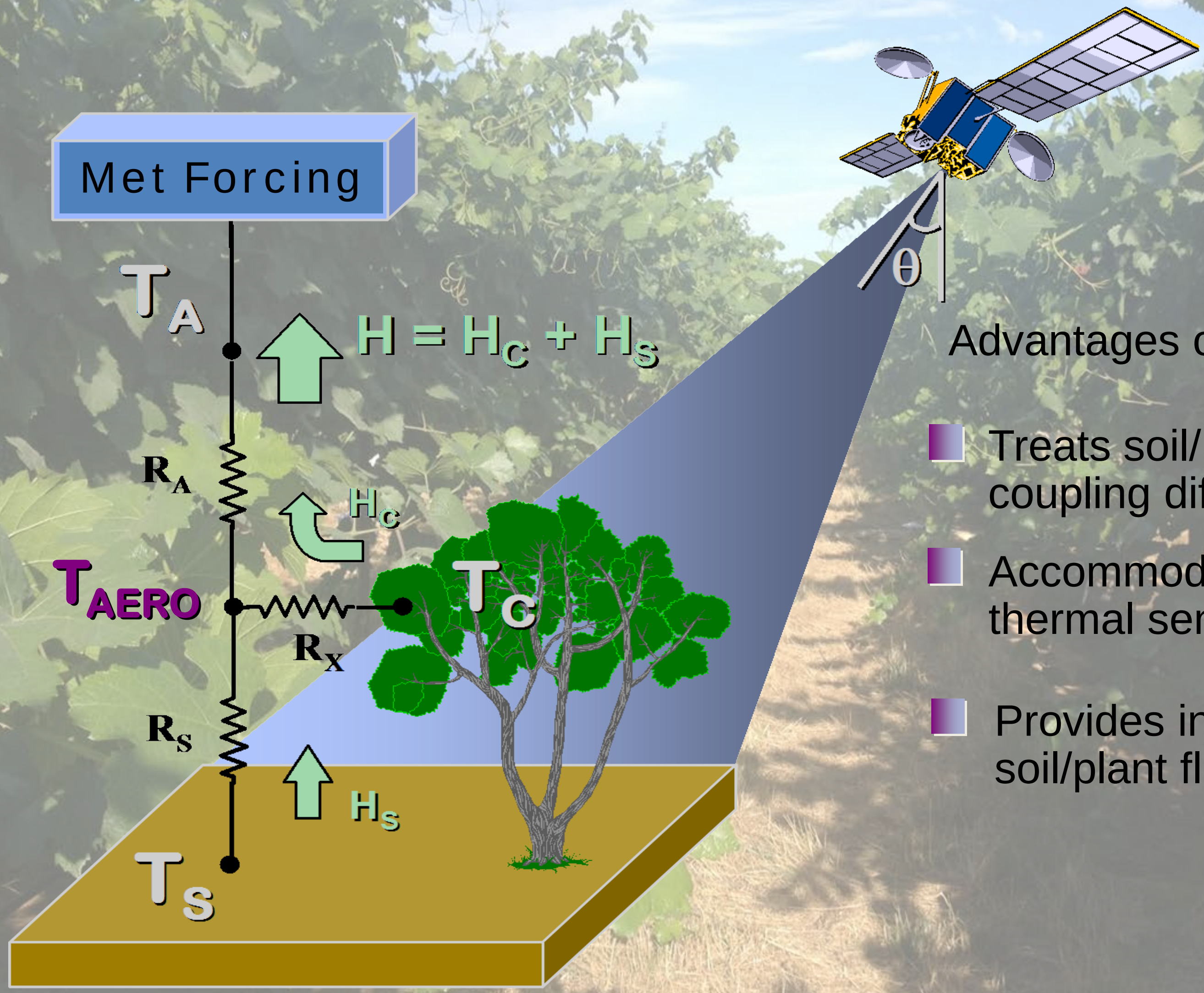
Residual

$LE_S = RN - H - G - LE_C$

Iterative solution

Two-Source Energy Balance Approach

Advantages of TSEB



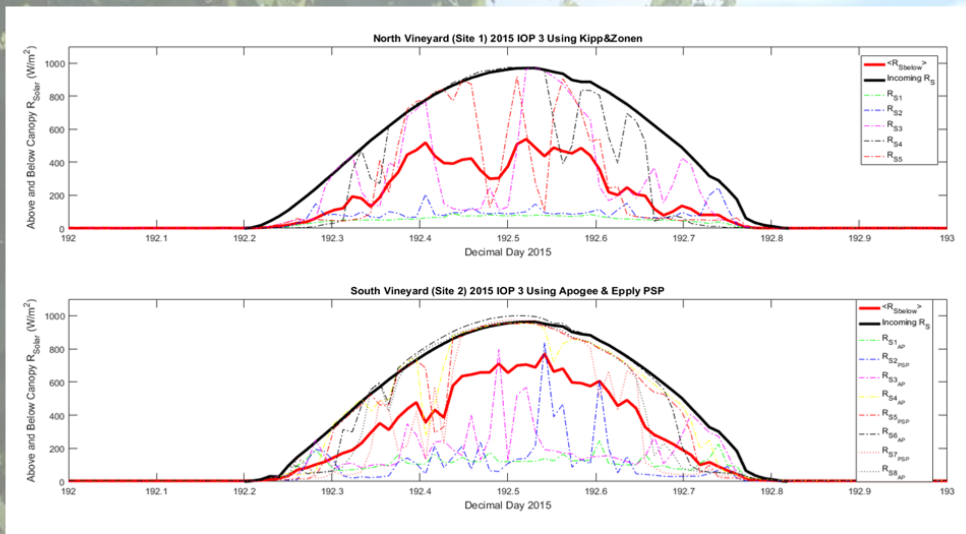
Advantages of TSEB

- Treats soil/plant-atmosphere coupling differences explicitly
- Accommodates off-nadir thermal sensor view angles
- Provides information on soil/plant fluxes and stress

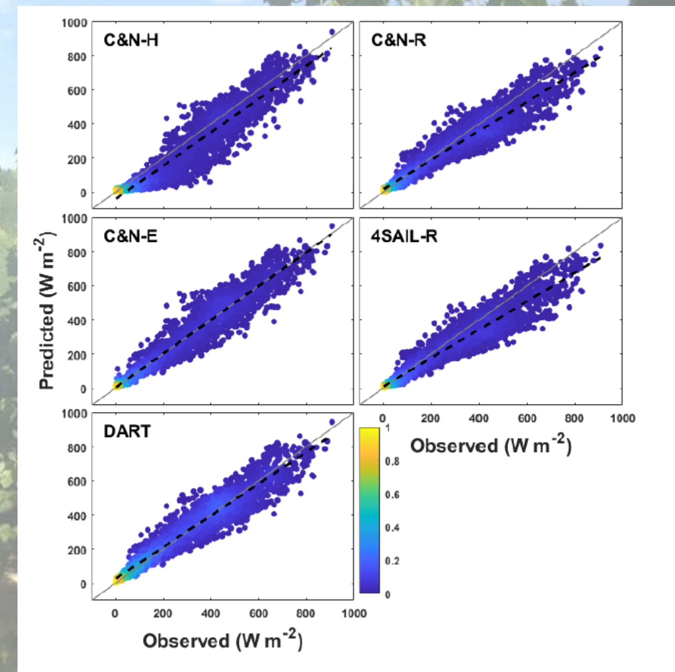
Radiation Modeling in Vineyards

Modification of radiation extinction for vine canopy architecture

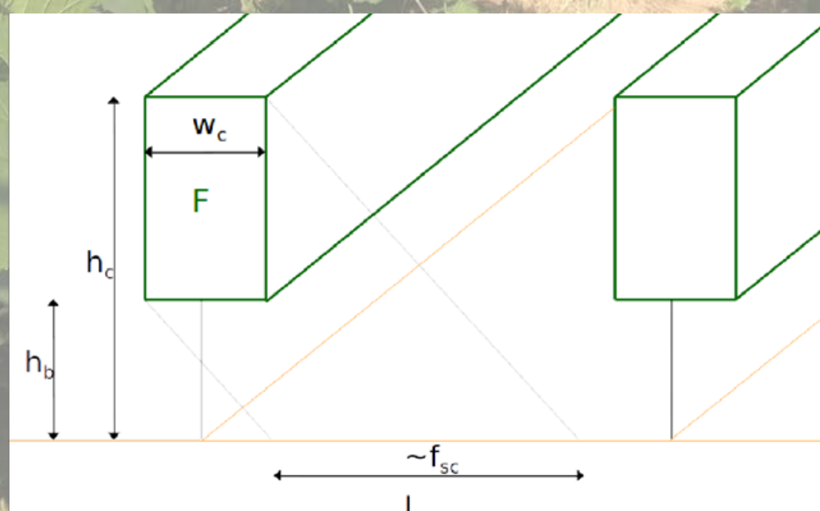
Measurements



Model validation

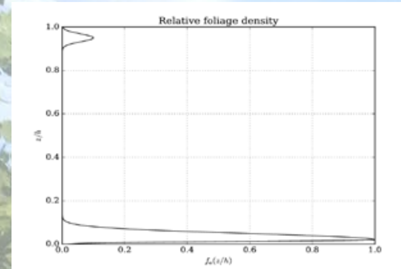


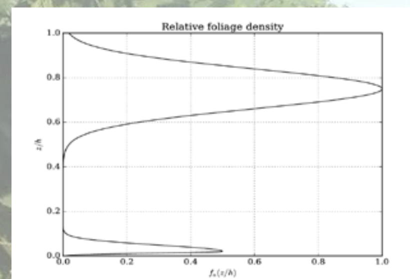
Refined radiation algorithm

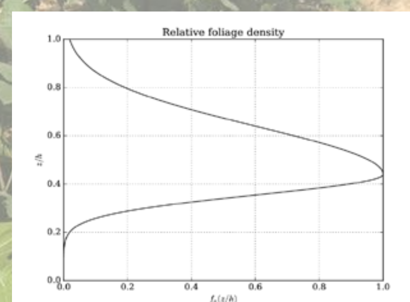


Modeling Below Canopy Winds in Vineyards

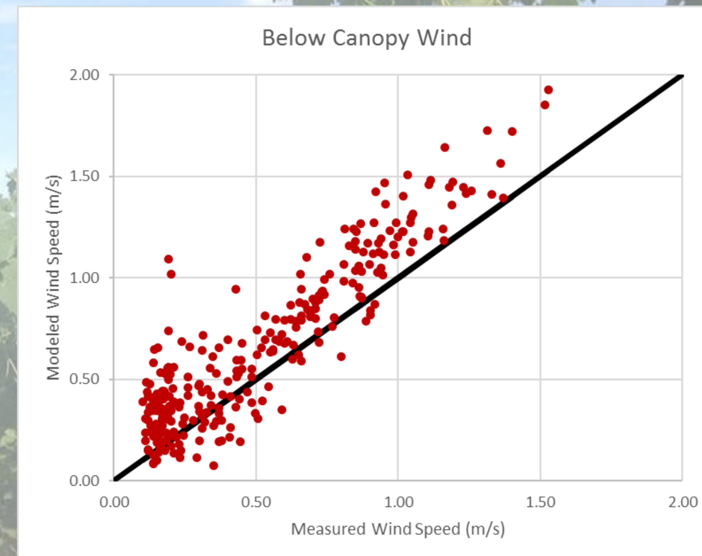
Modification of wind profile in the canopy air space for vine canopy for canopy architecture



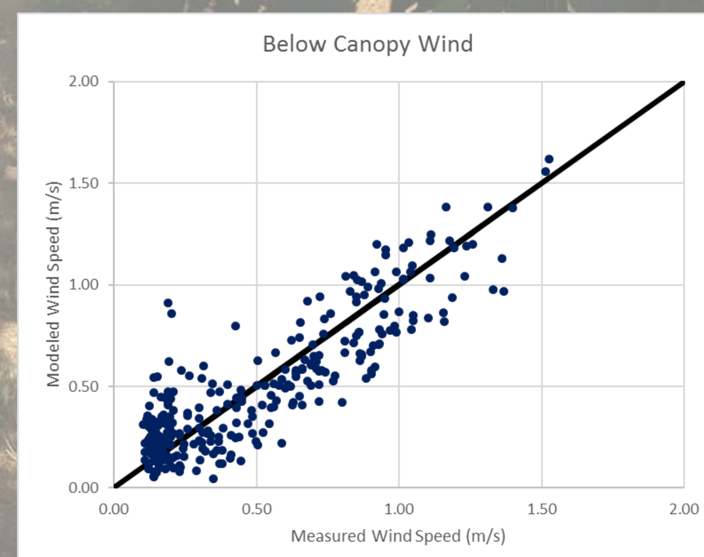




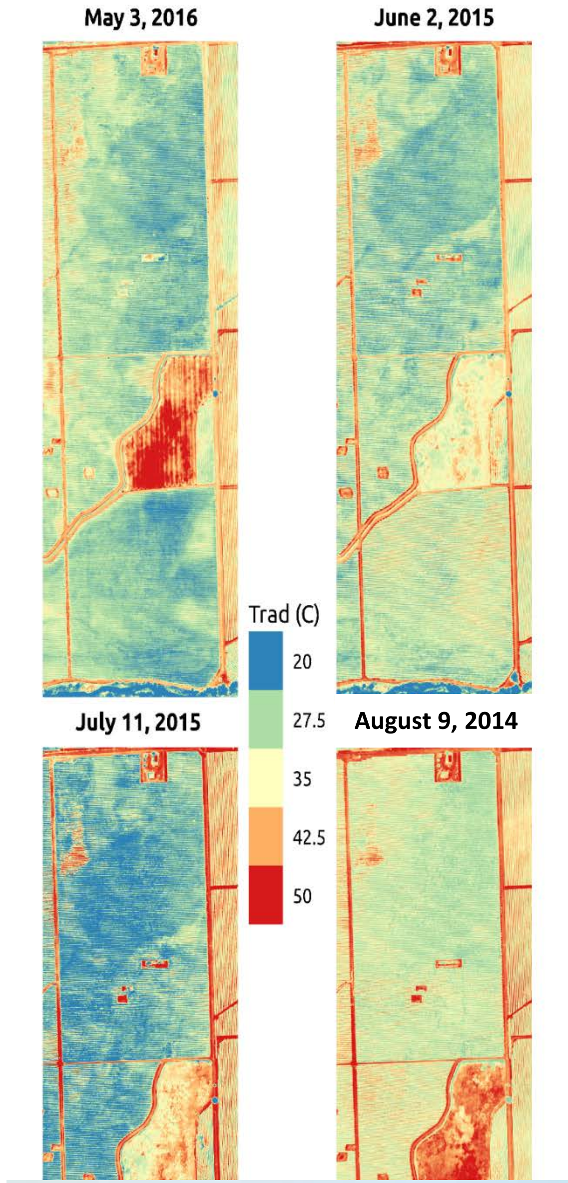
Original wind extinction algorithm

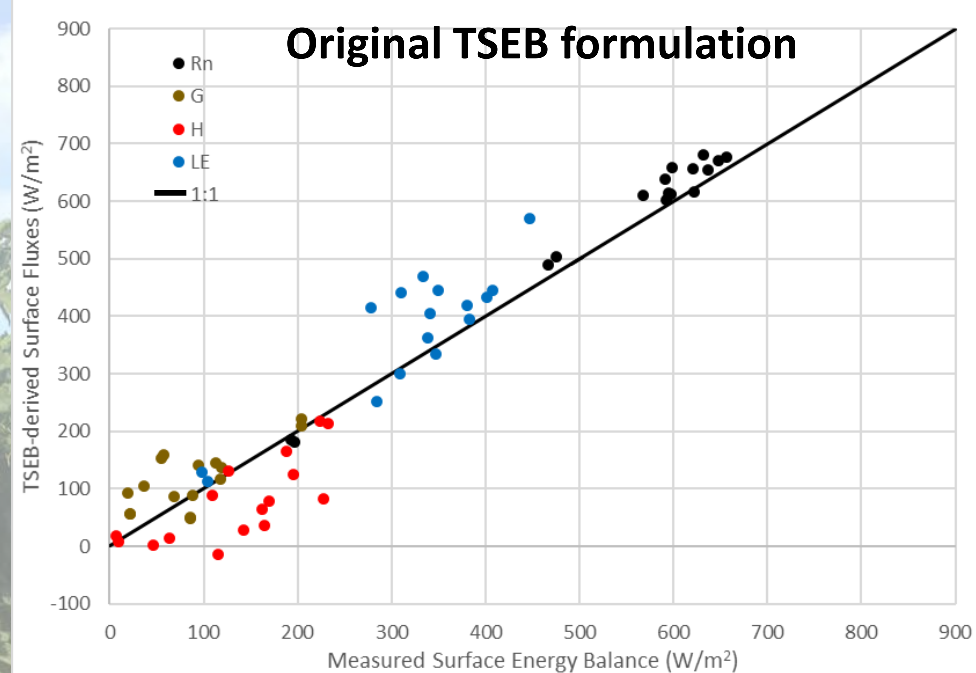


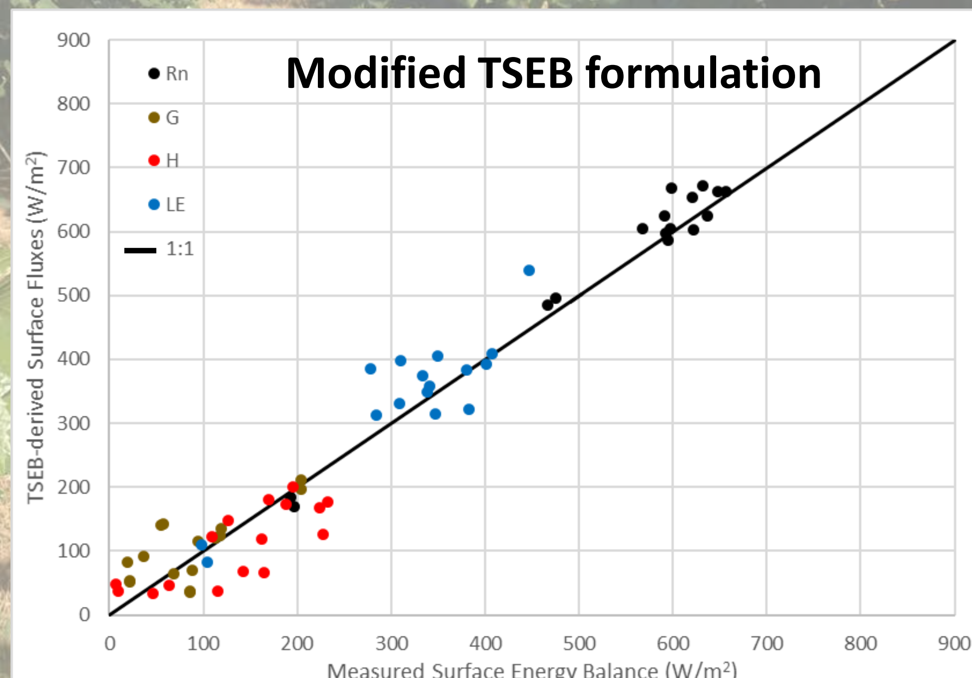
Revised wind extinction algorithm



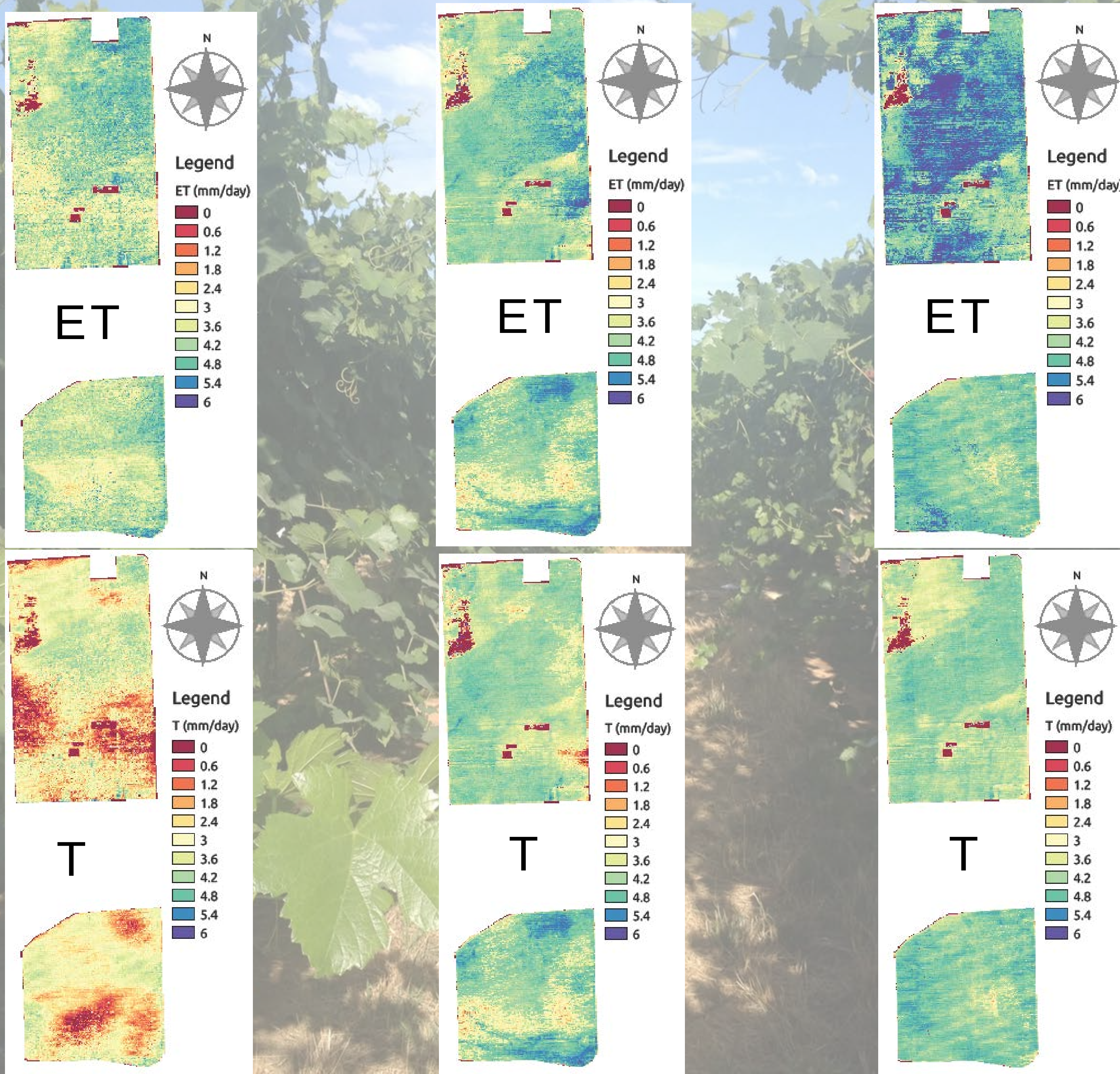
Using UAV Imagery in TSEB





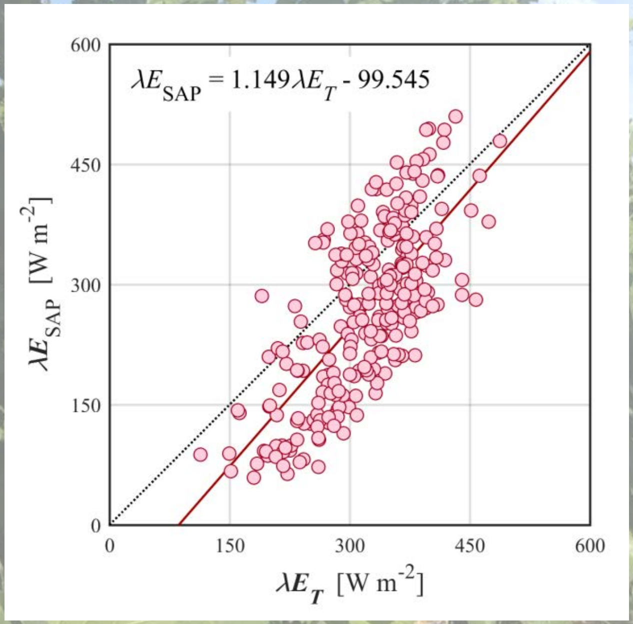


TSEB-derived ET and T Using UAV Imagery

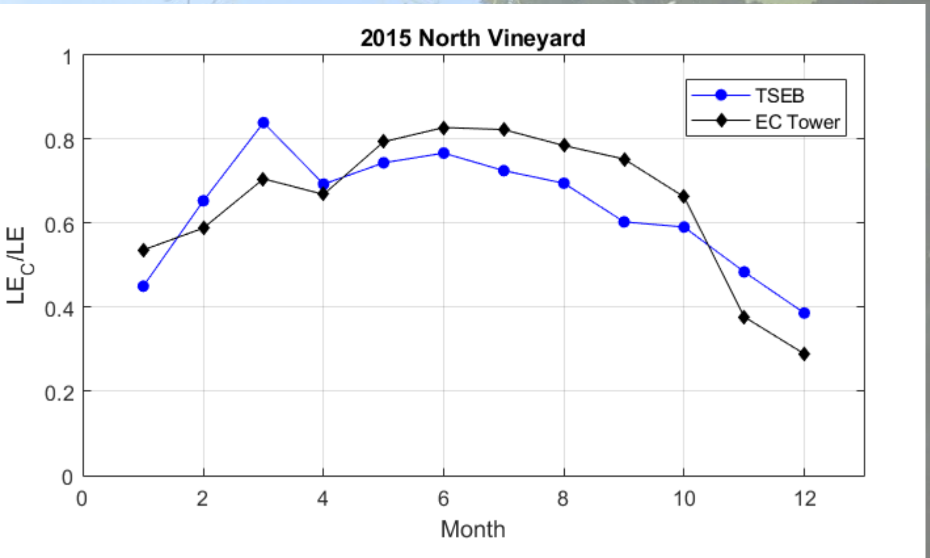


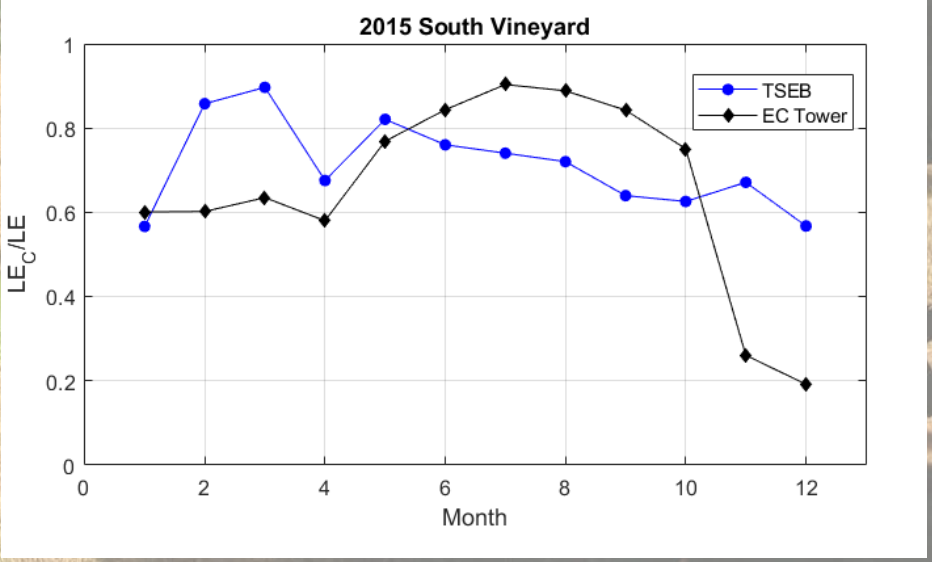
Partitioning of ET into T and E: Observations and Model Estimates

Sap-flow vs EC-Flux Partitioning

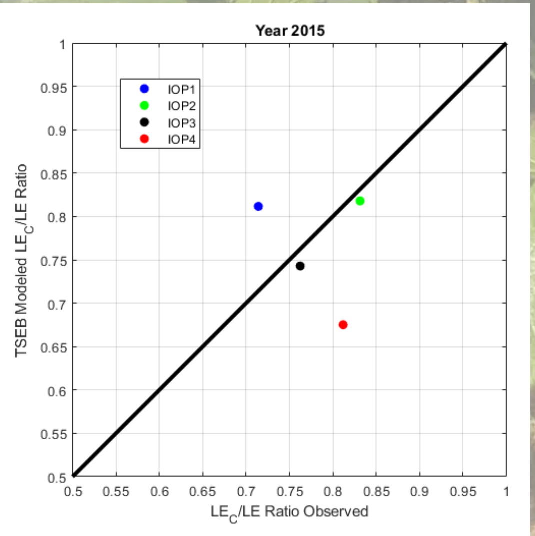


TSEB vs EC-Flux Partitioning



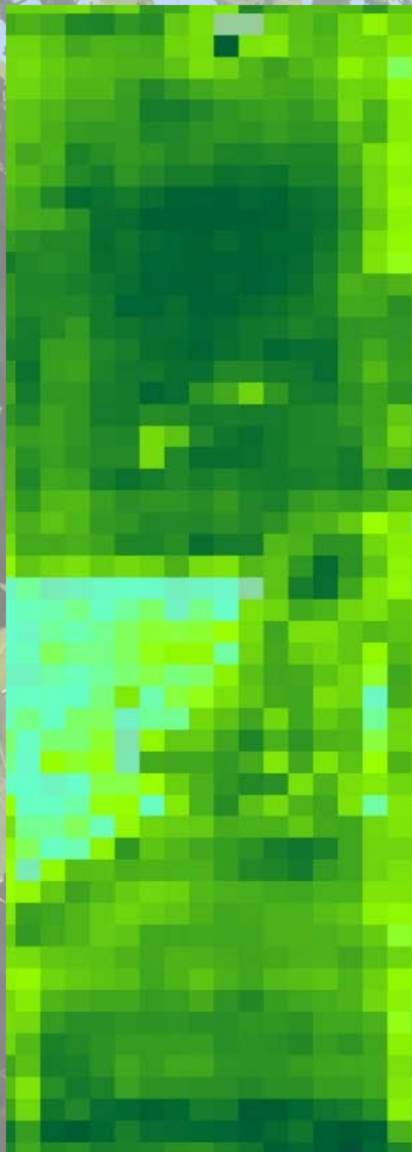


TSEB vs EC/Micro Bowen Ratio

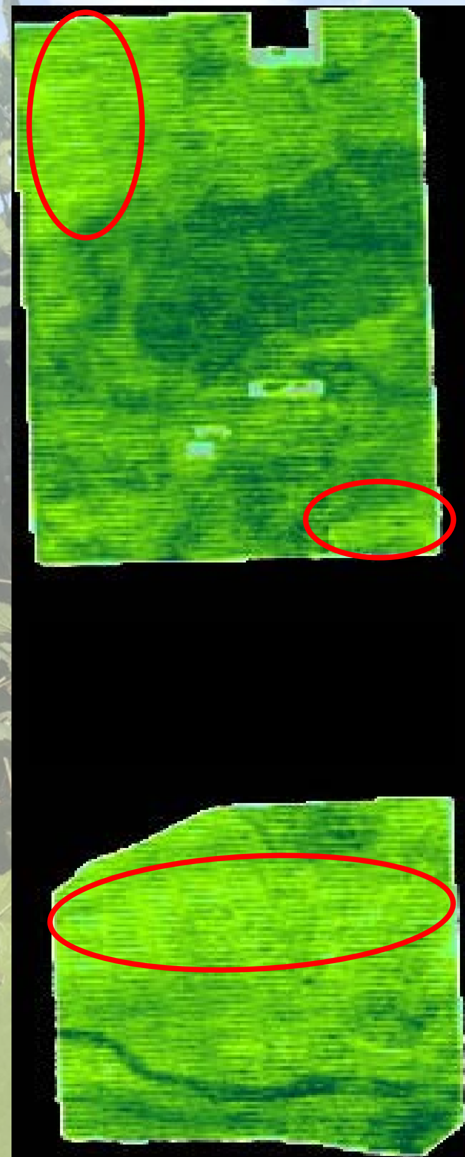


Effect of Resolution on Mapping ET Patterns

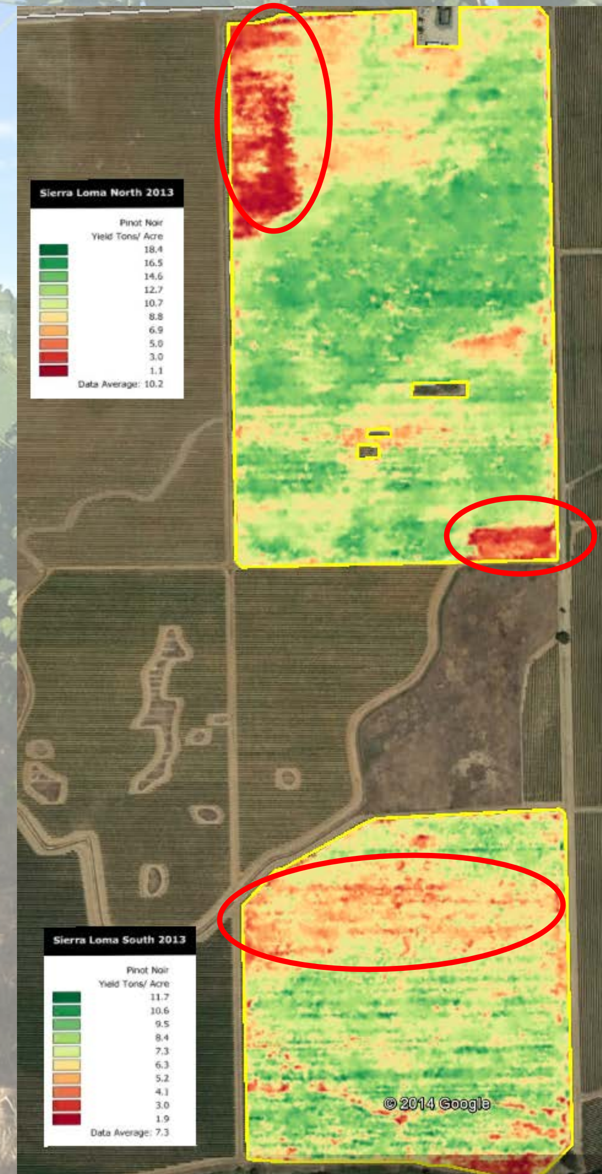
Landsat

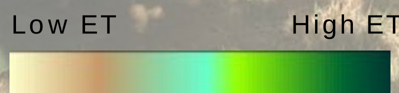


Aircraft



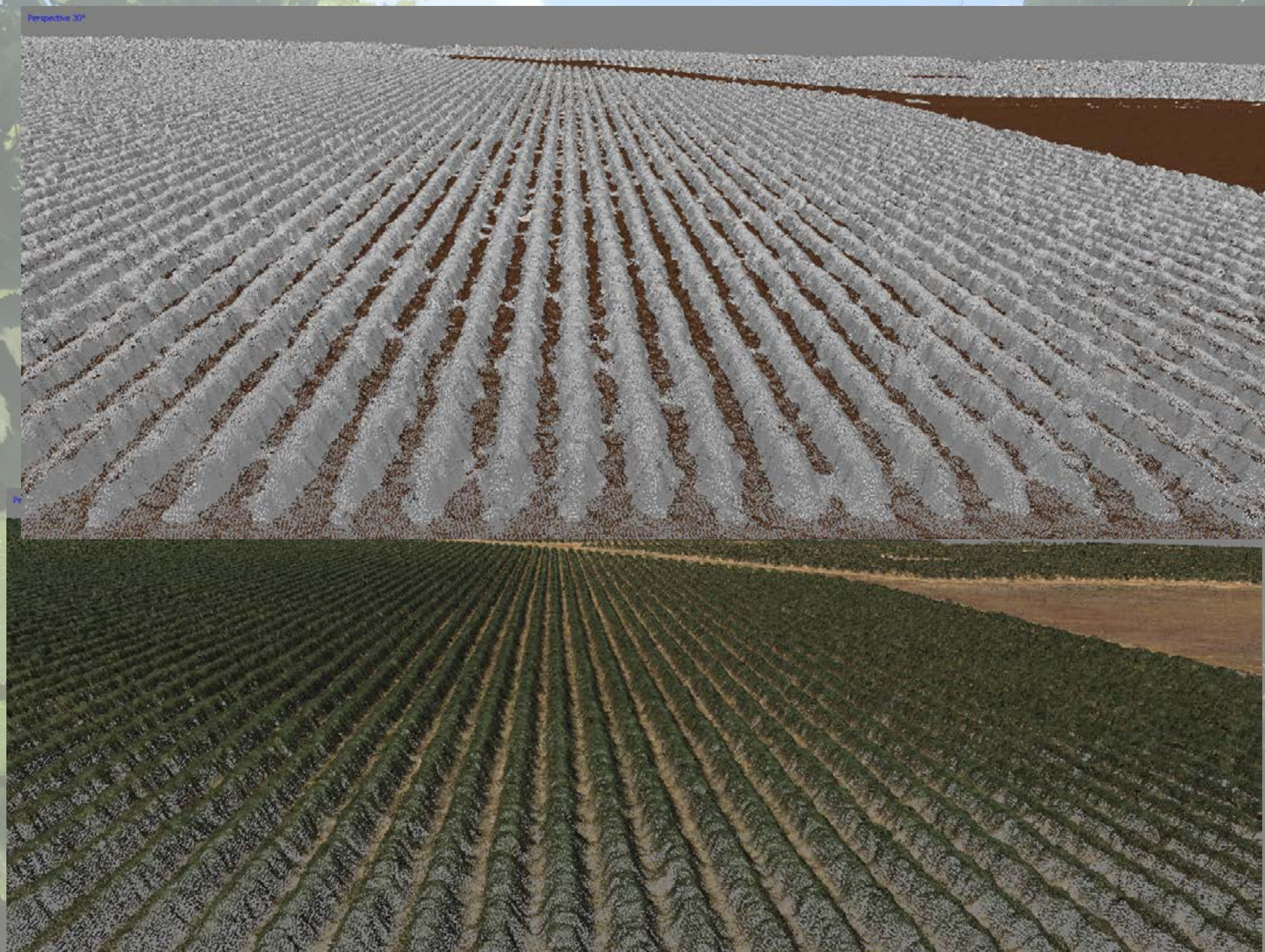
Yield map





PhoDAR (LIDAR-like) data

GRAPEX UAV canopy Volume



Automatic soil / vegetation discrimination, canopy volume relate to yield

Shadow Detection Algorithm

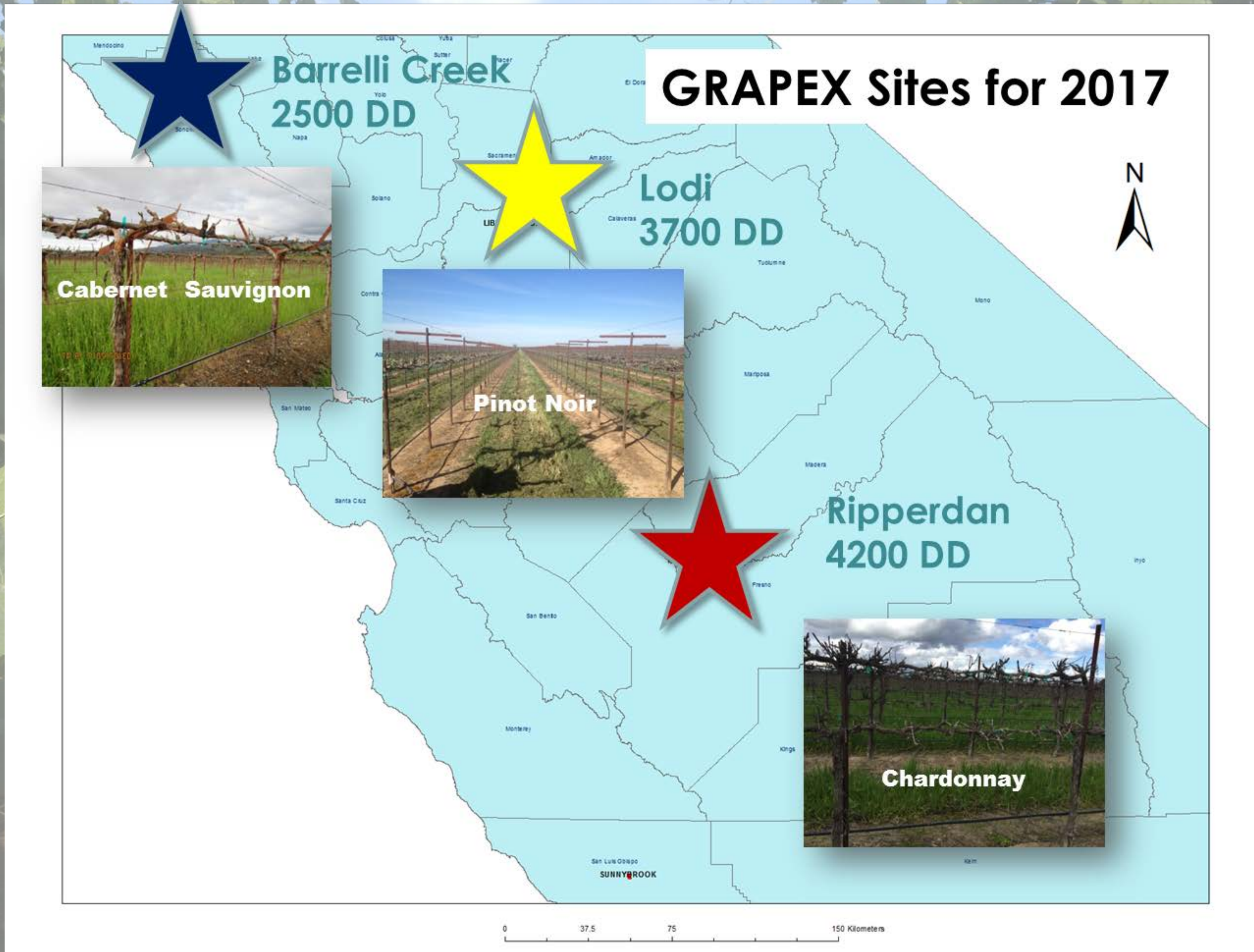
True Color Image

Shadowed areas highlighted

= shadowed pixels

GRAPEX Sites Expanded: to New Climate Zones & Varieties

Expanding GRAPEX Study Sites



Conclusions

Preliminary Results from GRAPEX

- Crop coefficient-based techniques have limited utility for estimating ET and stress in vineyards.

- Refinements to TSEB model parameterizations for unique canopy structure, architecture and row spacing/orientation using the data collected from GRAPEX is improving model performance.

- The capability of resolving vine transpiration from interrow evaporation/transpiration may depend on pixel resolution.

- Very high resolution imagery from UAVs may provide valuable information on landscape features and vine conditions not detectable at satellite resolutions.