

National Aeronautics and Space Administration



EVAPOTRANSPIRATION

ADVANCES IN AIRBORNE AND
SATELLITE TECHNOLOGY

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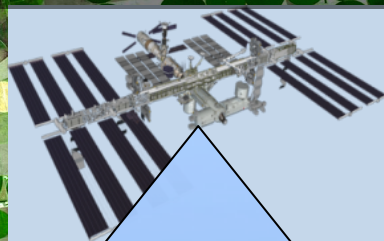
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Outline

- Is ET important to WSWC?
- A measurement framework for ET
 - Ground → UAV → Airborne → Spaceborne
- Pros and Cons of different vantage points
- Future capabilities and needs
- Summary

VANTAGE POINTS



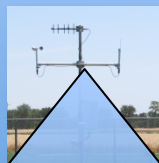
SPACEBORNE



AIRBORNE



UAV



GROUND/
TOWER

Russell Ranch

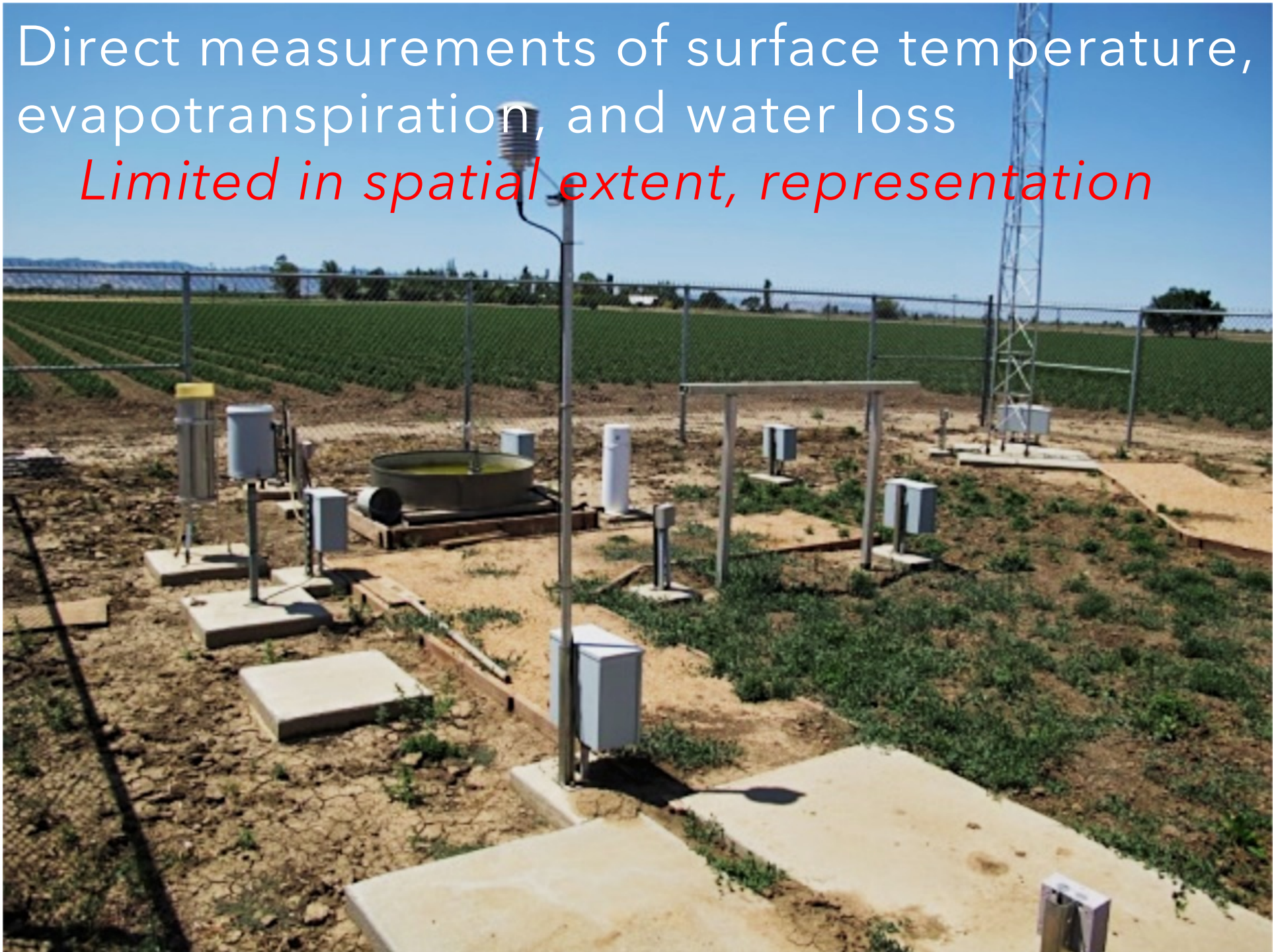
Davis, California

Experimental agricultural facility

Multiple crops, treatments (e.g., water, nutrients)



Direct measurements of surface temperature,
evapotranspiration, and water loss
Limited in spatial extent, representation



UAV Remote Sensing

- *Demonstrates remote measurement ability*
- *Still in development*
- *Limited in spatial extent, representation*



AIRBORNE (AD)VANTAGE

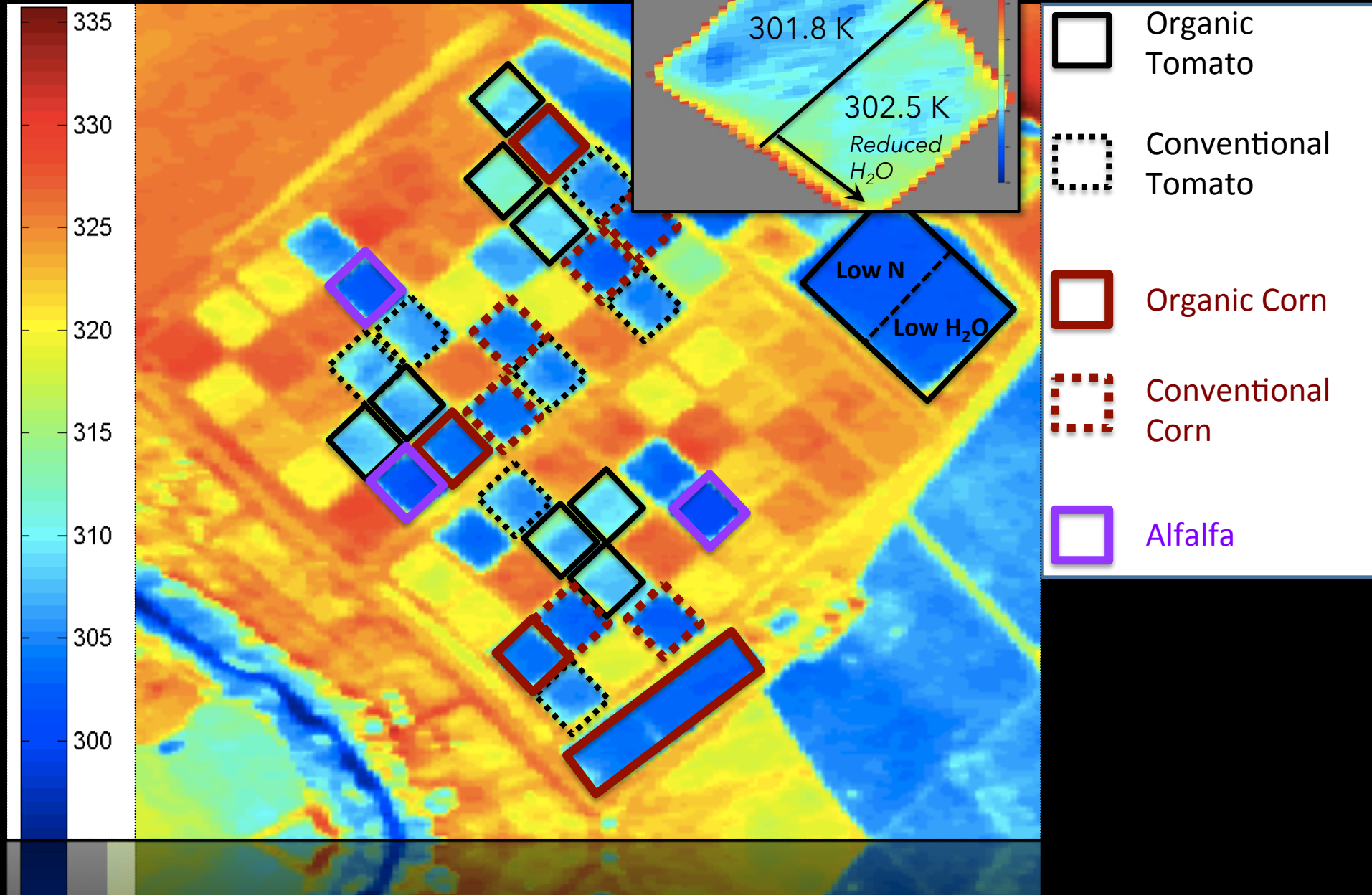


- Monitoring specific crop types
- Monitoring specific farms
- Concentrated observation of time-critical events

HyTES: Hyperspectral Thermal Emission Spectrometer

JPL Airborne Capability

Image Acquisition: 9 JUL 2014



4-DAY REVISIT

The probability of acquiring a cloud-free image at least once a month during the growing season from a 16-day revisit is **4%** over the past 26 years. This increases to **75%** with a 4-day revisit.

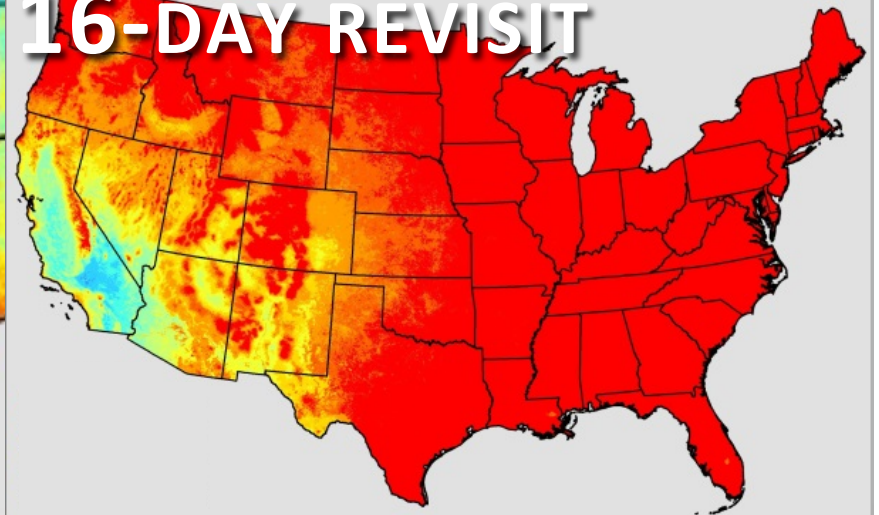
Allen et al. 2011

IMAGE ACQUISITION

HIGH PROBABILITY

LOW PROBABILITY

16-DAY REVISIT

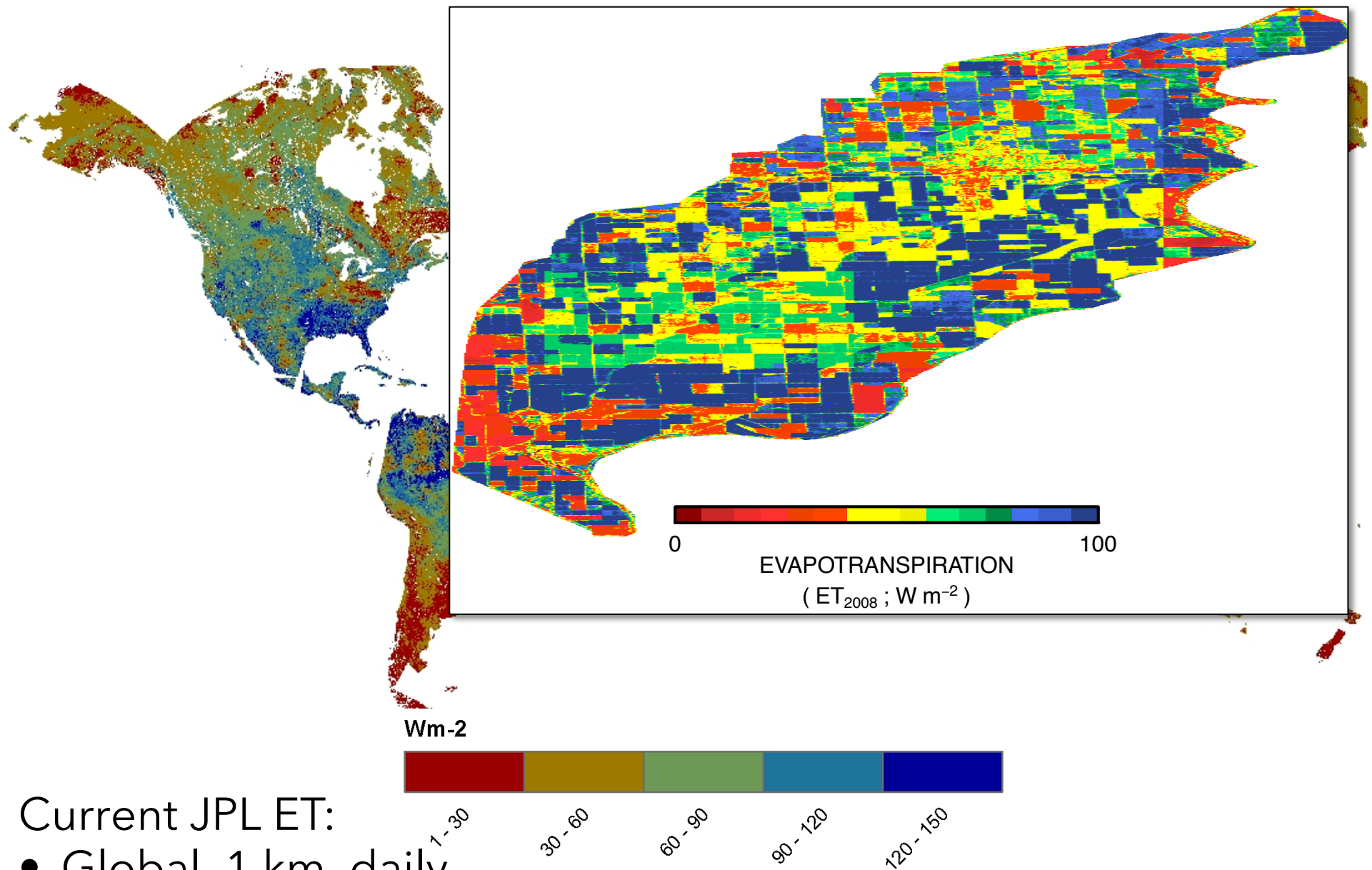


ET Spaceborne Measurements Requirements

Parameters	Minimal	Optimum	Landsat 8	MODIS	HyspIRI*	...?
Return Cycle (days)	≤8	≤4	16	1	5	...
Number of TIR bands	1	>2	2	3	8	...
Spatial resolution (m)	120	30	100	1000	60	...
Coverage	US always on	World always on	US always on	World always on	World always on	...

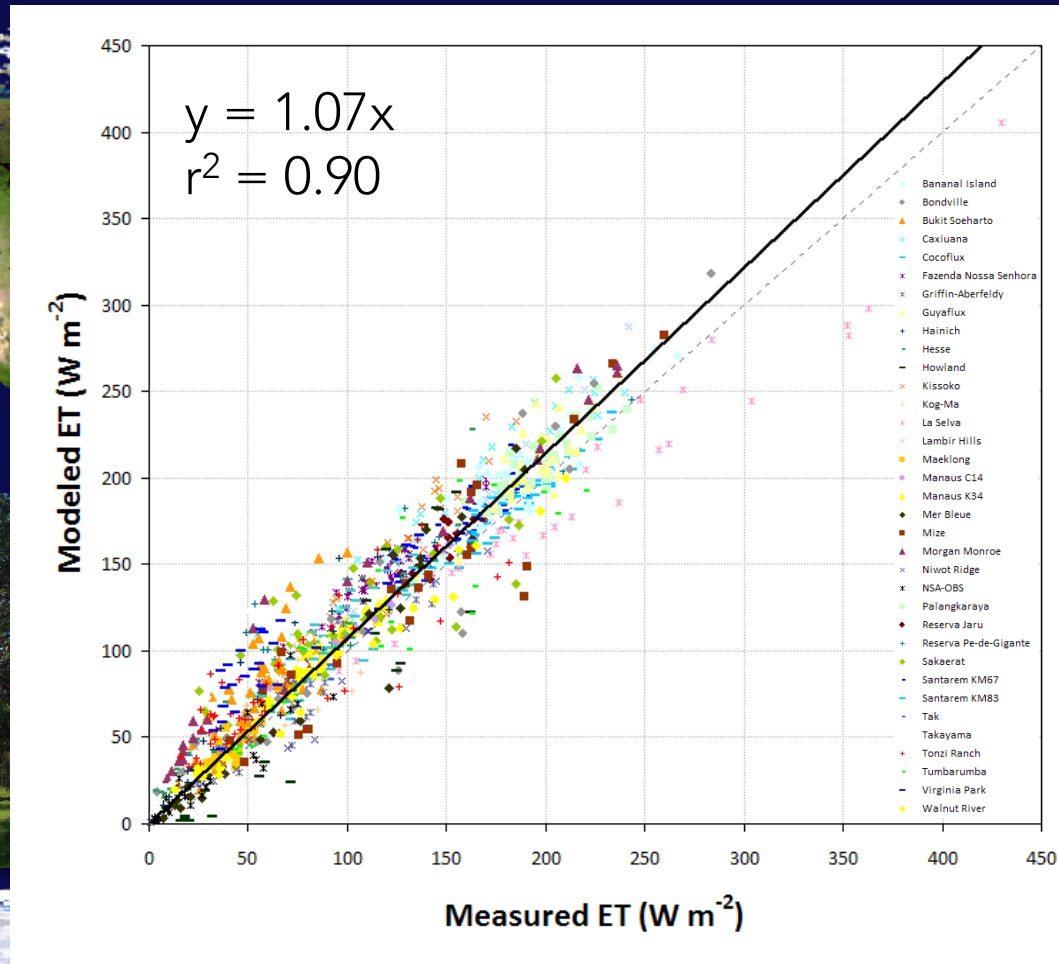
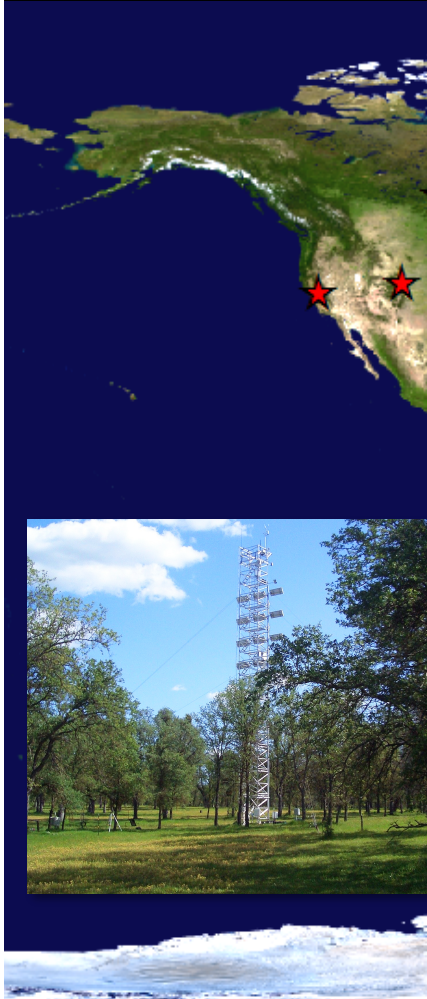
Source: Letter to Anne Castle on "Water Resources Needs" dated November 22, 2011, R. Allen, U. Idaho, referencing Allen 2010, Allen et al 2011.

* Proposed mission >2023.



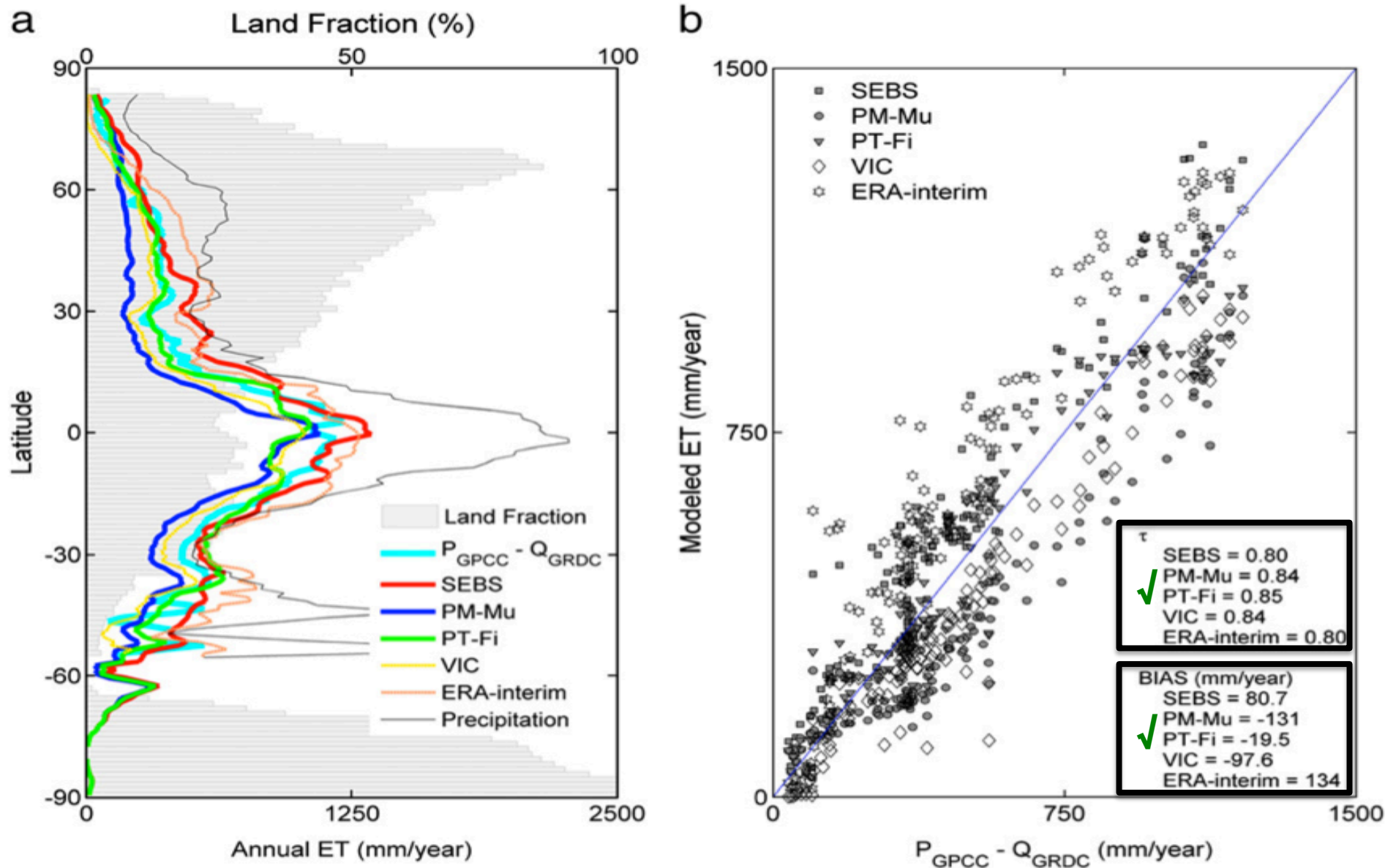
Current JPL ET:

- Global, 1 km, daily
- Running multiple algorithms: PT-JPL, PM-MOD16, SEBS, PMBL
- Validation at hundreds of FLUXNET eddy covariance sites



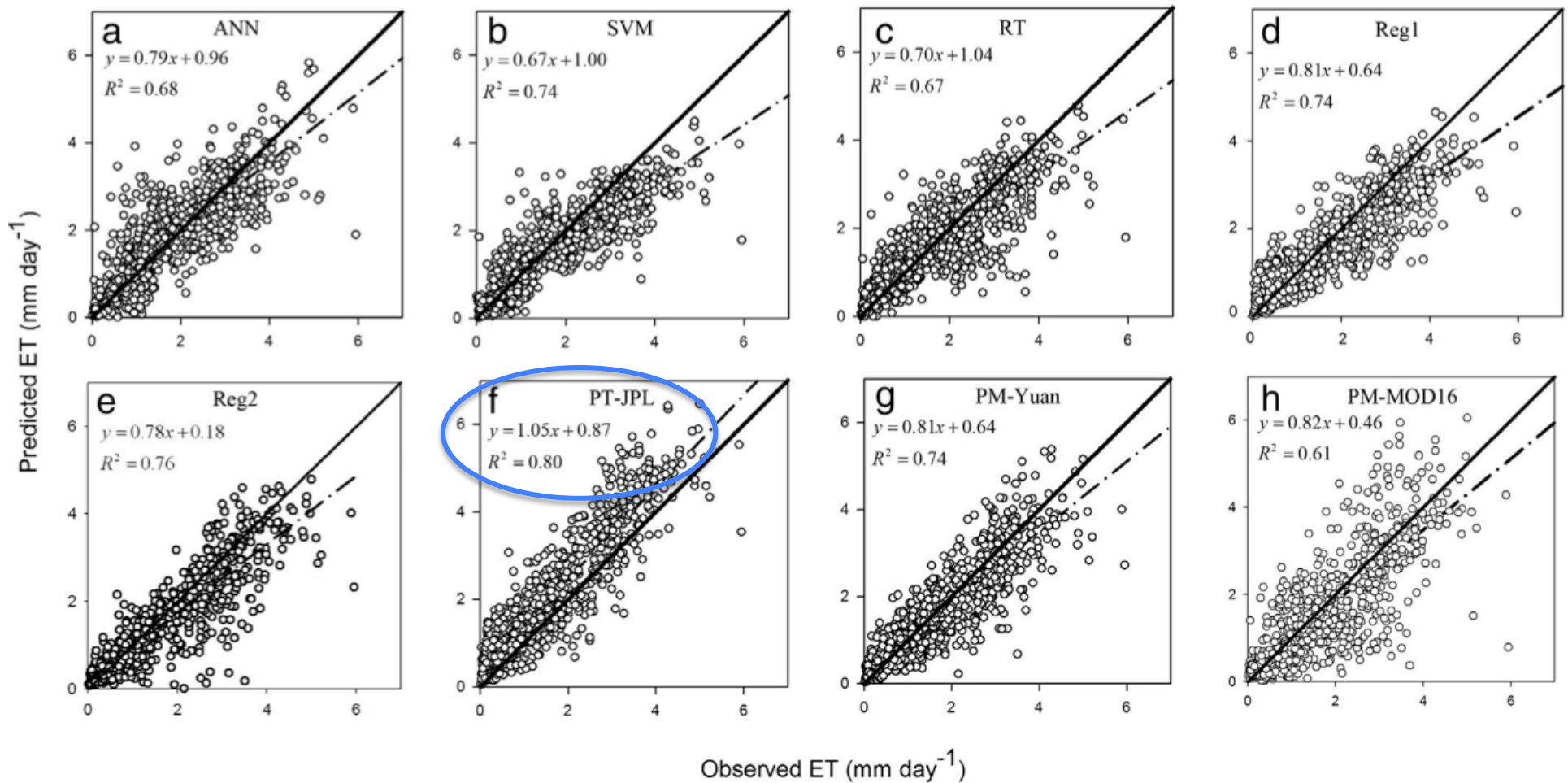
PT-JPL ET VALIDATION

INDEPENDENT EVALUATION (PRINCETON):



Vinukollu et al. 2011: *Remote Sensing of Environment*

INDEPENDENT EVALUATION (BEIJING):



INDEPENDENT EVALUATION (AUSTRALIA):

Agricultural and Forest Meteorology 187 (2014) 46–61



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Multi-site evaluation of terrestrial evaporation models using FLUXNET data

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ABSTRACT

We evaluated the performance of four commonly applied land surface evaporation models using a high-quality dataset of selected FLUXNET towers. The models that were examined include an energy balance approach (Surface Energy Balance System; SEBS), a combination-type technique (single-source Penman–Monteith; PM), a complementary method (advection–aridity; AA) and a radiation based approach (modified Priestley–Taylor; PT-JPL). Twenty FLUXNET towers were selected based upon satisfying stringent forcing data requirements and representing a wide range of biomes. These towers encompassed a number of grassland, cropland, shrubland, evergreen needleleaf forest and deciduous broadleaf forest sites. Based on the mean value of the Nash–Sutcliffe efficiency (NSE) and the root mean squared difference (RMSD), the order of overall performance of the models from best to worst were: ensemble mean of models (0.61, 64), PT-JPL (0.59, 66), SEBS (0.42, 84), PM (0.26, 105) and AA (0.18, 105) [statistics stated as (NSE, RMSD in W m^{-2})]. Although PT-JPL uses a relatively simple and largely empirical formulation of the evaporative process, the technique showed improved performance compared to PM, possibly due to its partitioning of total evaporation (canopy transpiration, soil evaporation, wet canopy evaporation) and lower uncertainties in the required forcing data. The SEBS model showed low performance over tall and heterogeneous canopies, which was likely a consequence of the effects of the roughness sub-layer parameterization employed in this scheme. However, SEBS performed well overall. Relative to PT-JPL and SEBS, the PM and AA showed low performance over the majority of sites, due to their sensitivity to the parameterization of resistances. Importantly, it should be noted that no single model was consistently best across all biomes. Indeed, this outcome highlights the need for further evaluation of each model's structure and parameterizations to identify sensitivities and their appropriate application to different surface types and conditions. It is expected that the results of this study can be used to inform decisions regarding model choice for water resources and agricultural management, as well as providing insight into model selection for global flux monitoring efforts.

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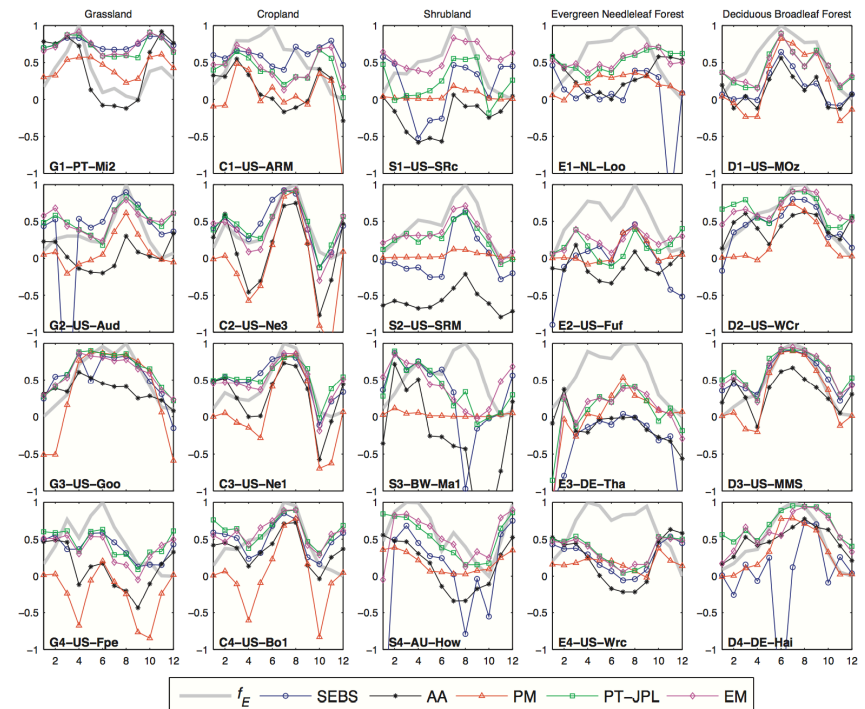
1. Introduction

Reliable estimates of evaporation (E) are required for the accurate representation of mass and energy exchanges at the land surface. In hydrological and water resource studies, an evaporation model is required to characterize the exchange of moisture between the surface and the overlying atmosphere. Not surprisingly, the choice of model can have considerable impact on water

resource planning and decision support across a range of temporal and spatial scales. Improved understanding of the influence of model choice on flux estimation is required in order to better characterize the fidelity of these simulations, particularly in light of an increasing number of regional and global scale efforts to produce land surface heat flux data products (Jiménez et al., 2011; Mueller et al., 2013).

A number of models have been developed for the estimation of either the reference, potential or actual values of evaporation (see reviews of Kalma et al., 2008 and Wang and Dickinson, 2012). The reference evaporation is defined as the evaporation from a hypothetical, well-watered ‘reference’ crop (Allen, 2000), while potential evaporation is the maximum evaporation for a given surface if moisture is not limiting (Penman, 1948; Irmak and Haman, 2003). Estimation of the reference and potential evaporation is

PT-JPL was the best performing ET retrieval algorithm.



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ECOSTRESS

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

An Earth Venture Instrument-2 Proposal
Submitted in response to
AO NNH12ZDA006O EVI2

Prepared for
National Aeronautics and
Space Administration
Science Mission Directorate

*ECOSTRESS will provide critical insight into **plant-water dynamics** and how **ecosystems change with climate** via **high spatiotemporal** resolution thermal infrared radiometer measurements of evapotranspiration from the International Space Station (ISS).*

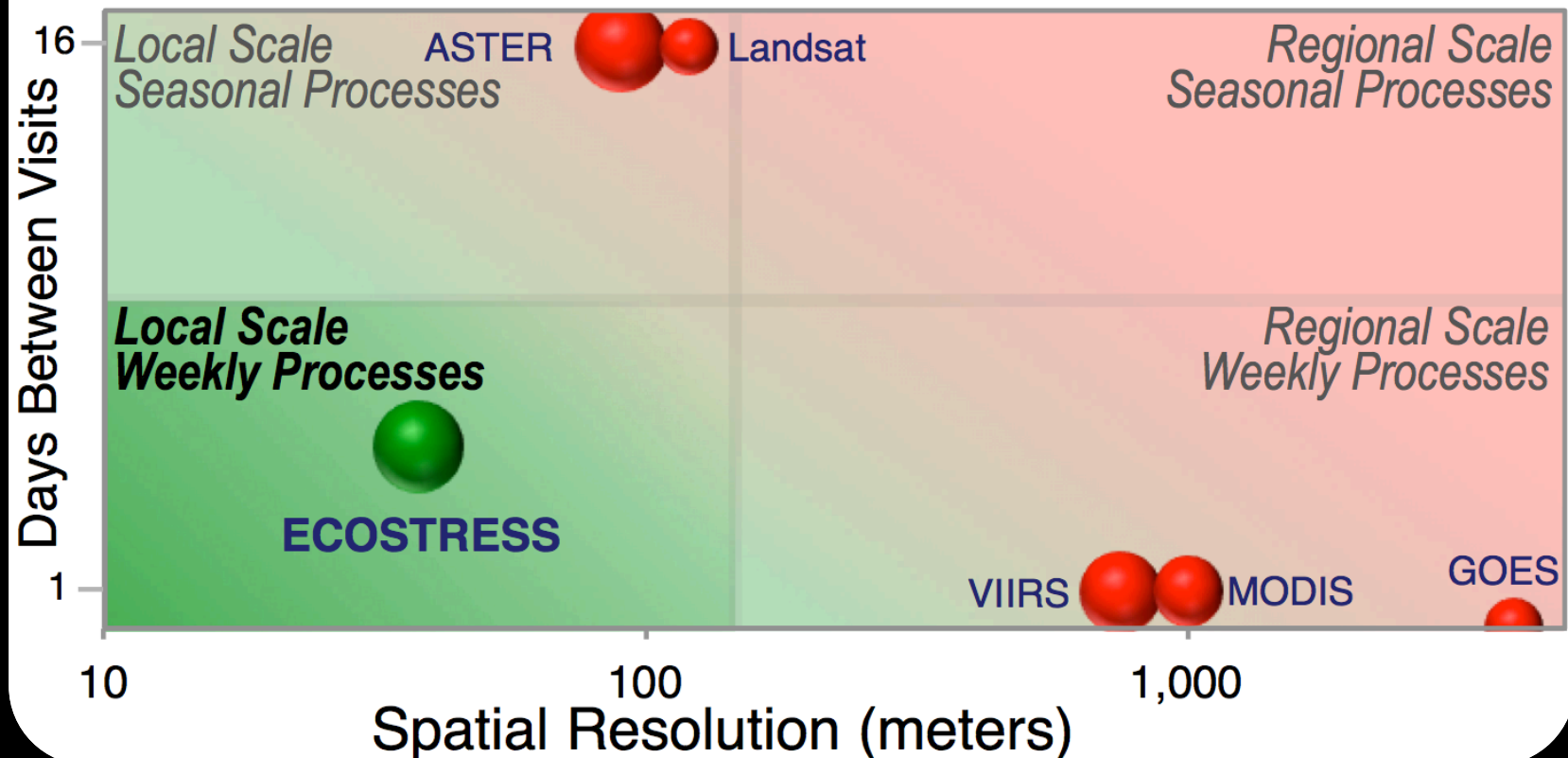
ECOSTRESS Science Data Products

L2	Surface Temperature Surface Emissivity
L3	Evapotranspiration
L4	Water Use Efficiency Evaporative Stress Index

November 25, 2013

Revisit Time versus Spatial Resolution

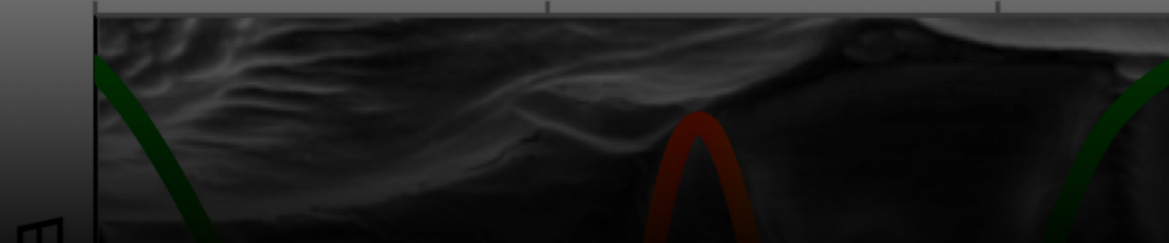
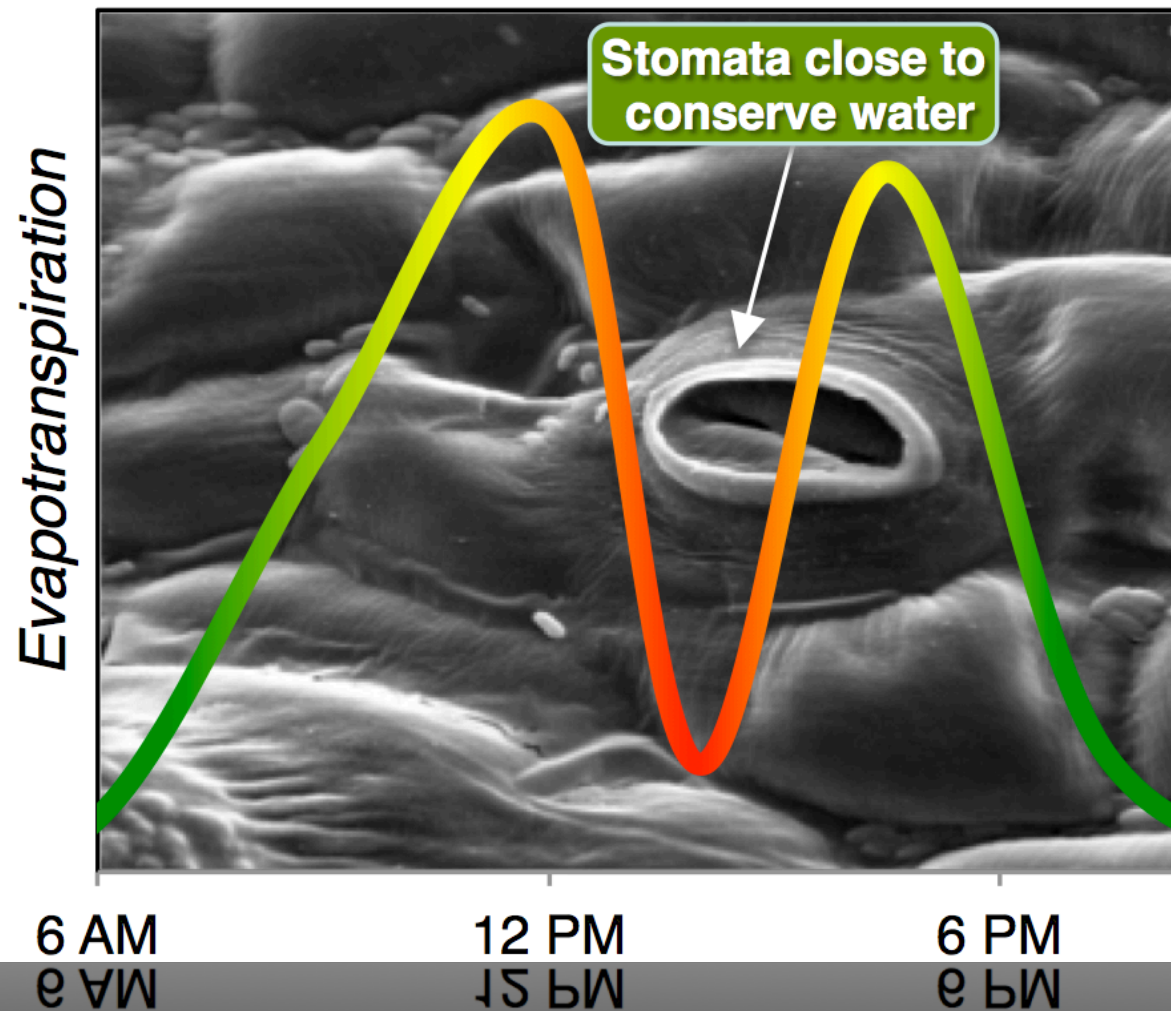
With sphere size indicating # of thermal infrared window bands



ET Spaceborne Measurements Requirements

Parameters	Minimal	Optimum	Landsat 8	MODIS	HyspIRI*	ECOSTRESS
Return Cycle (days)	≤8	≤4	16	1	5	3-5
Number of TIR bands	1	>2	2	3	8	5
Spatial resolution (m)	120	30	100	1000	60	38x57
Coverage	US always on	World always on	US always on	World always on	World always on	World always on*

Water Stress Drives Plant Behavior



ET Spaceborne Measurements Requirements

Parameters	Minimal	Optimum	Landsat	MODIS 8	HyspIRI*	ECOSTRESS	SLI?
Return Cycle (days)	≤8	≤4	16	1	5	3-5	?
Number of TIR bands	1	>2	2	3	8	5	?
Spatial resolution (m)	120	30	100	1000	60	38x57	?
Coverage	US always on	World always on	US always on	World always on	World always on	World always on*	?

Take Home Messages

- JPL is a strength in ET;
- Different vantage points provide different capabilities to monitor ET at the field scale;
- Airborne allows local to regional scale monitoring—JPL assets available;
- Spaceborne allows local to global scale observation;
- ECOSTRESS is a newly selected NASA Earth Ventures mission to capture ET and water stress at the field scale and over the diurnal cycle—JPL seeking partnerships/applications-prototyping!
- Future of Landsat continuity / Sustainable Land Imaging—role of WSWC.