ECOSTRESS ET Algorithms
Overview

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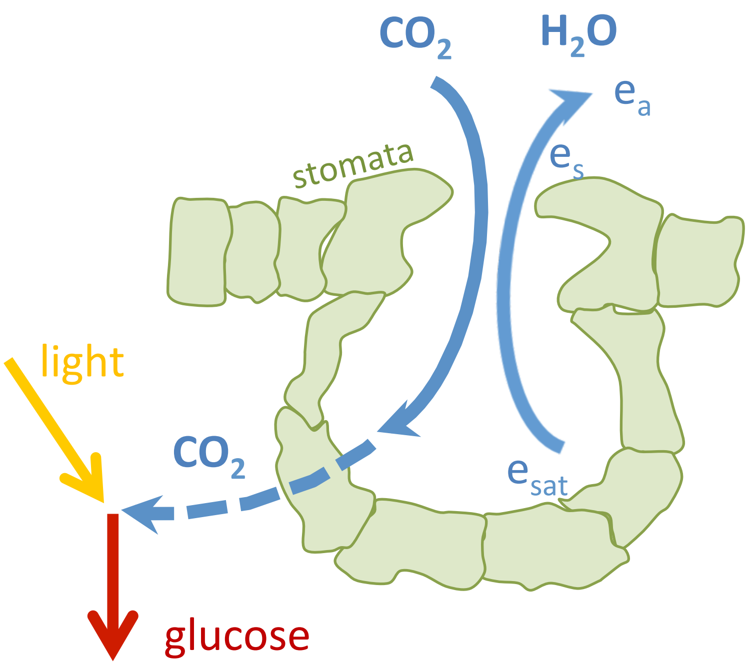
Evapotranspiration

- Soil evaporation and vegetation transpiration



Bottom-up: Big leaf model

$ET_{leaf} \sim \frac{g_s \, g_g}{g_s + g_b} (e_{sat} -$

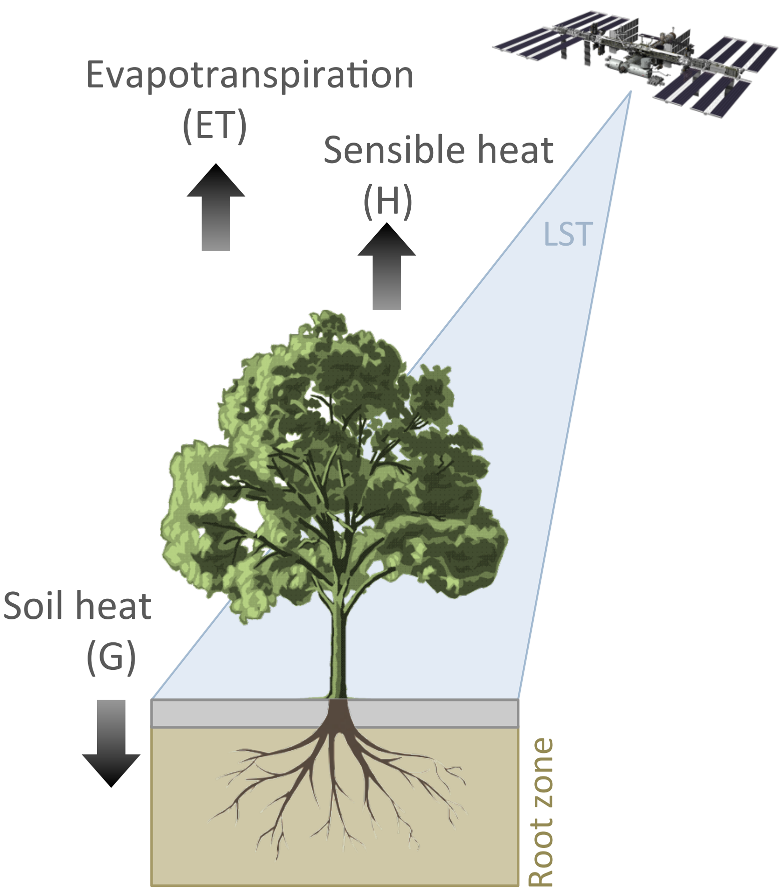
$g_s = g_{max}(fPAR) \, f_1(T_{leaf}) \, f_2(\Delta e) \, f_3(C_i) \, f_4(\psi_s)$

$ET = \int^{Canopy} ET_{leaf}$

Under stress conditions, plants close their stomata and leaf temperature increases

ECOSTRESS approaches to mapping ET

Relationship between LST and ET



$$ET = R_n - H - G$$

with
- R_n the net radiation
- H the sensible heat flux
- G the soil heat flux

} LST dependent

$$R_n = (1 - \text{albedo})R_{SW} - \varepsilon\sigma T_s^4 + \varepsilon R_{LW}$$

$$H = \rho C_p \frac{T_s - T_{air}}{r_a}$$?

Energy balance approach:

Given known radiative energy inputs (R_n), how much water loss is required to keep the soil and vegetation at the observed temperatures?

Outline

- ECOSTRESS ET requirements
- Impact of revisit period on ET
- Impact of LST uncertainties on ET
- Ensemble of ET models for ECOSTRESS:
  - ALEXI from USDA (Two-source Energy balance)
  - METRIC from U. of Idaho (In-scene approach)
  - PT-JPL from JPL (Radiation based model)

Requirements

- From observations: Instantaneous ET (at varying overpass time)
- Standard product: daily ET
- Requirements

	Evapotranspiration		Land Surface Temperature	
	Accuracy	Precision	Accuracy	Precision
Requirements	15%	5%	2K	0.3K
Capabilities	10%	1%	1K	0.2K

- Ancillary information
  - Meteorological data (Air temperature and humidity, wind speed)
  - Albedo from other missions

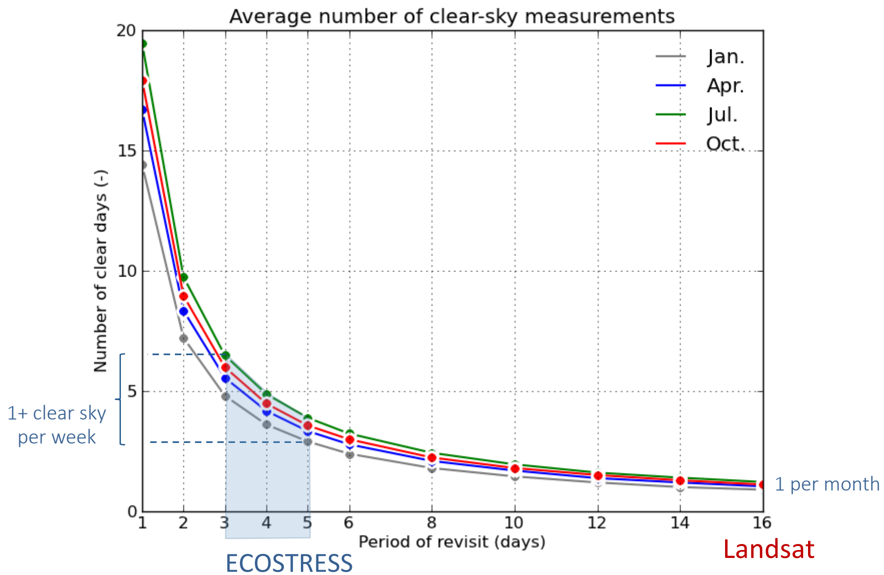
    Landsat 7 & 8: 8-day revisit, 30m resolution

    ESA/Sentinel 2: two satellites, 5-day revisit, 10 to 60m resolution, launch of first satellite in April 2015

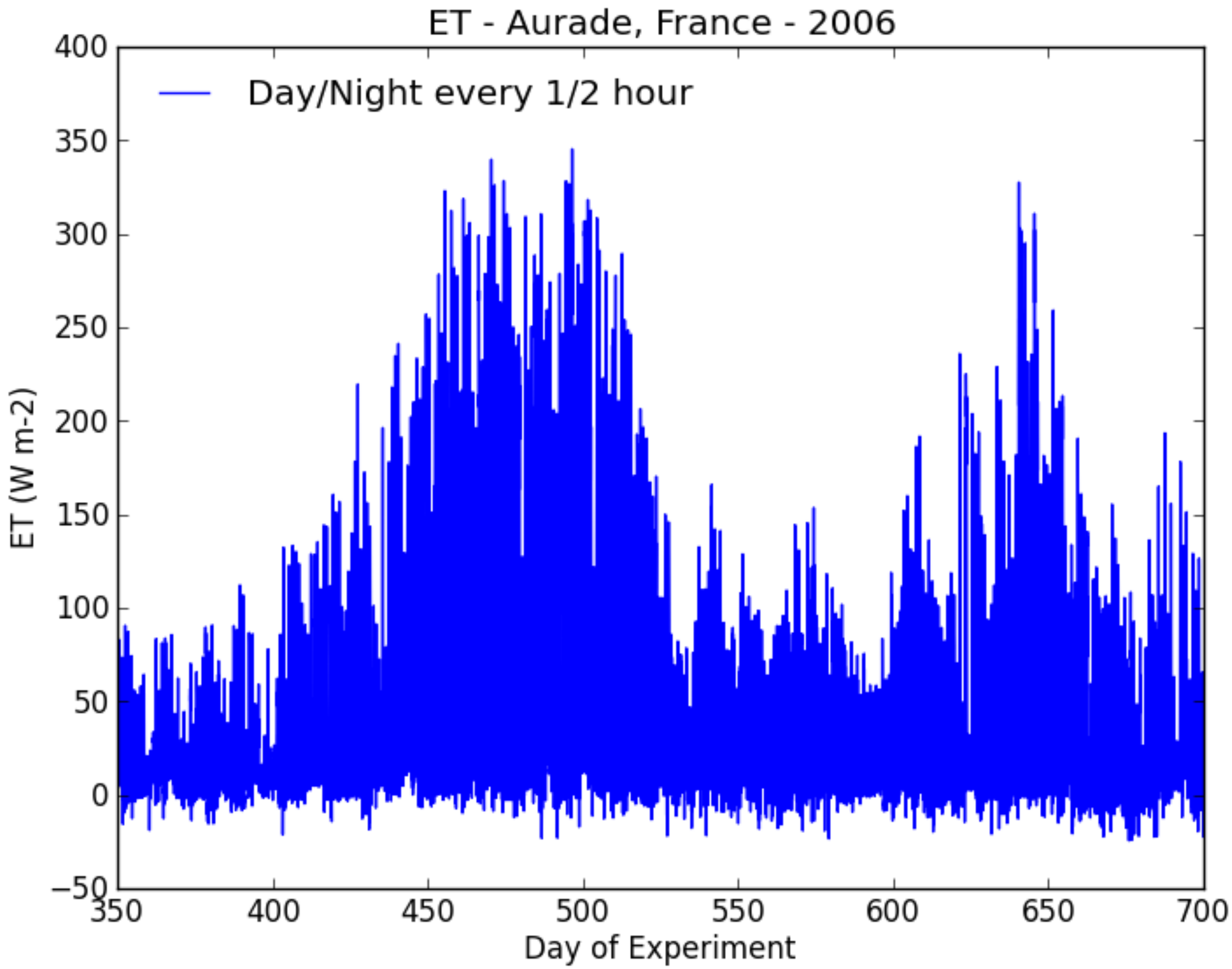
Impact of the revisit period on ET

ECOSTRESS revisit period is 3-5 days. What is the impact on monthly and seasonal fluxes?

- Empirical study based on 21 AmeriFlux sites over contiguous US (2125 months – ~9 years per sites)
- Only clear-sky conditions are considered
- Representativeness of different temporal samplings



Evapotranspiration (ET)



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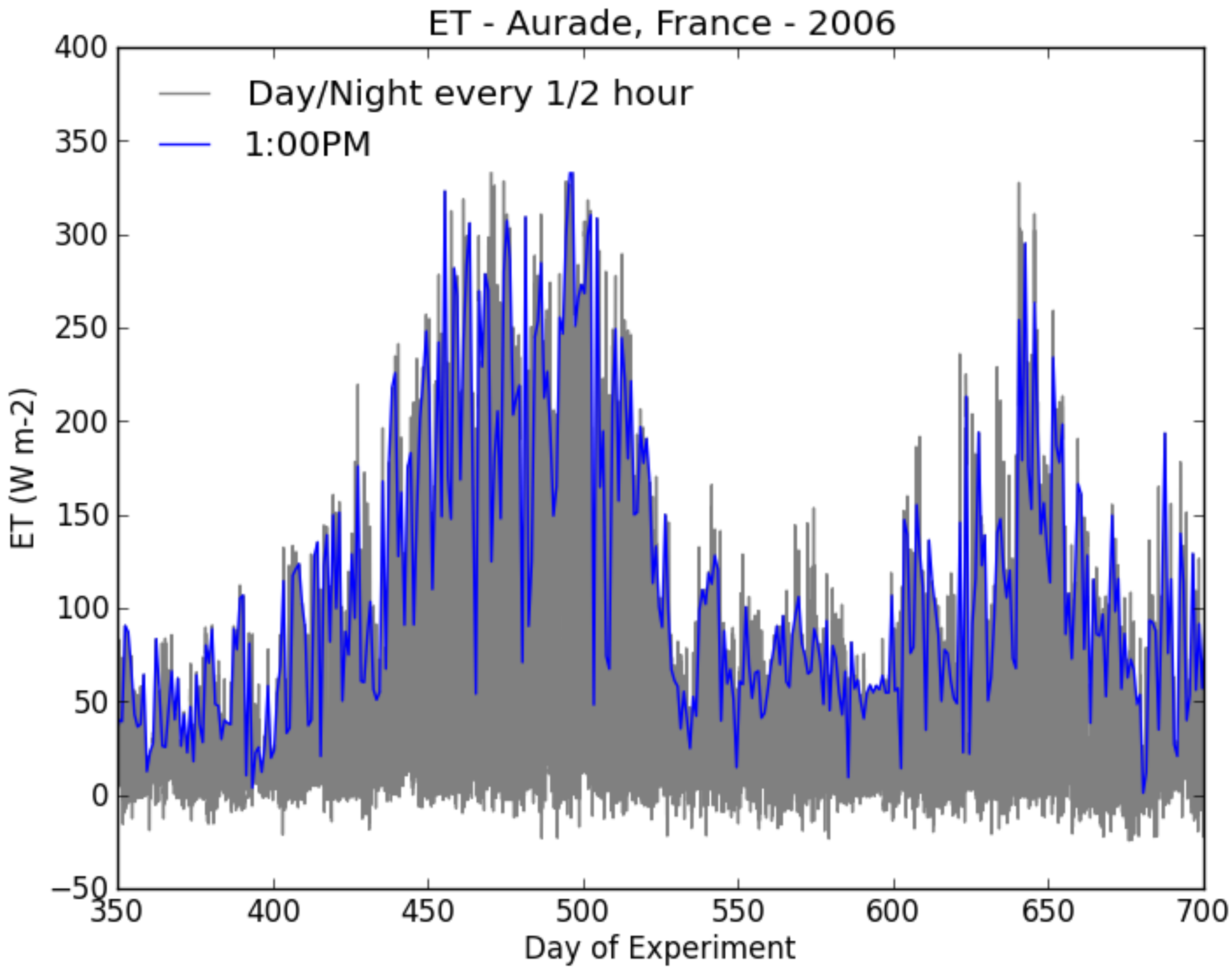

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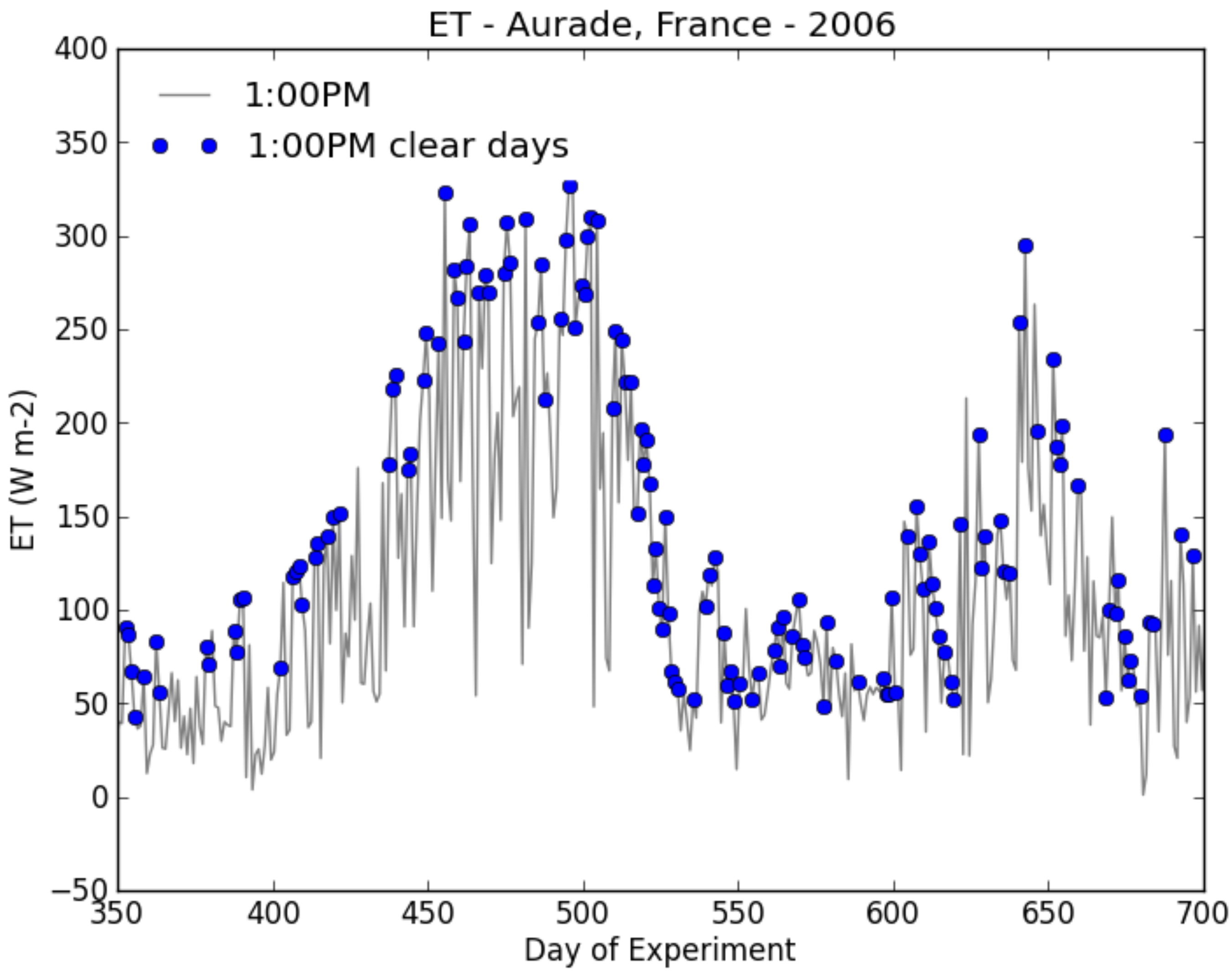

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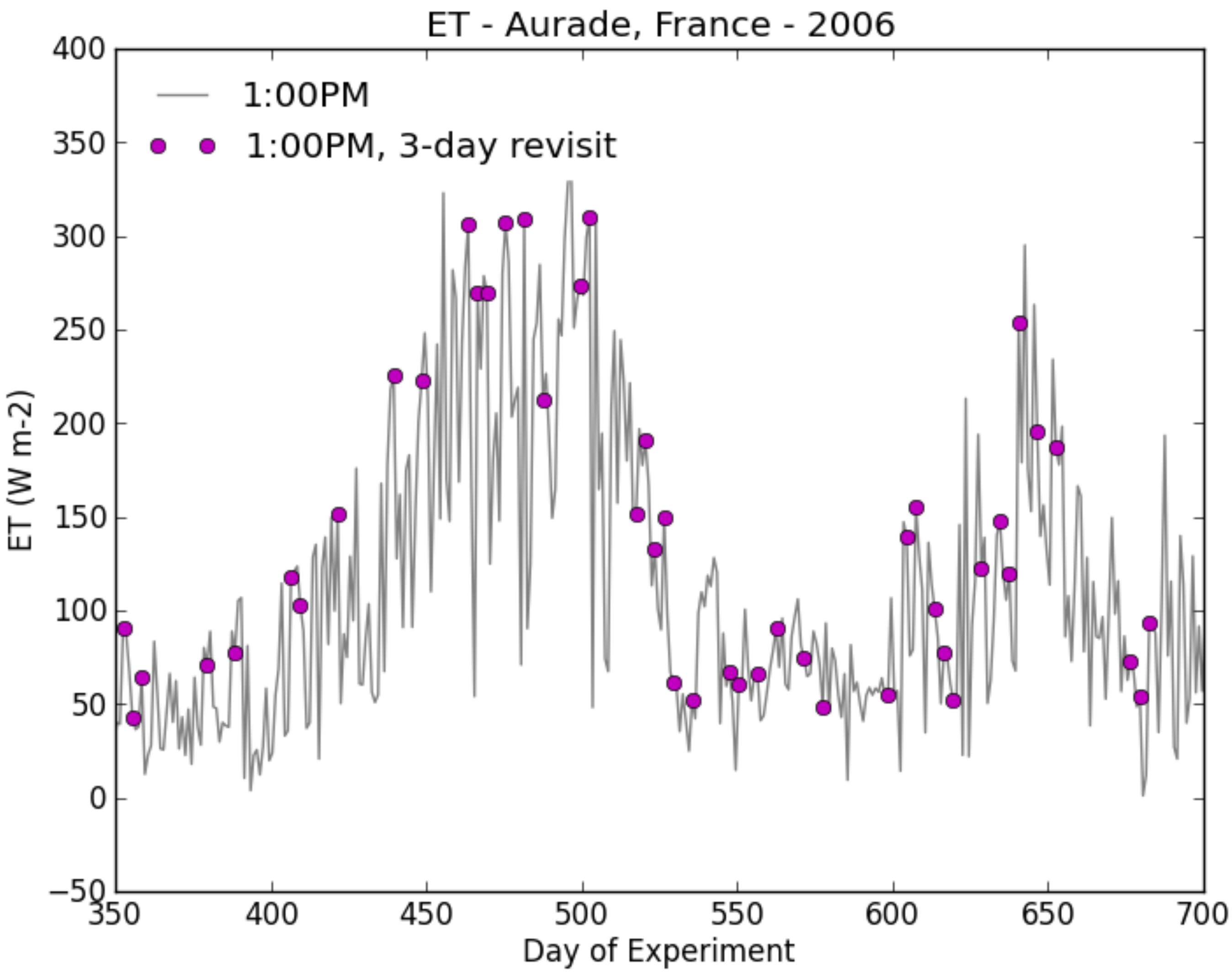

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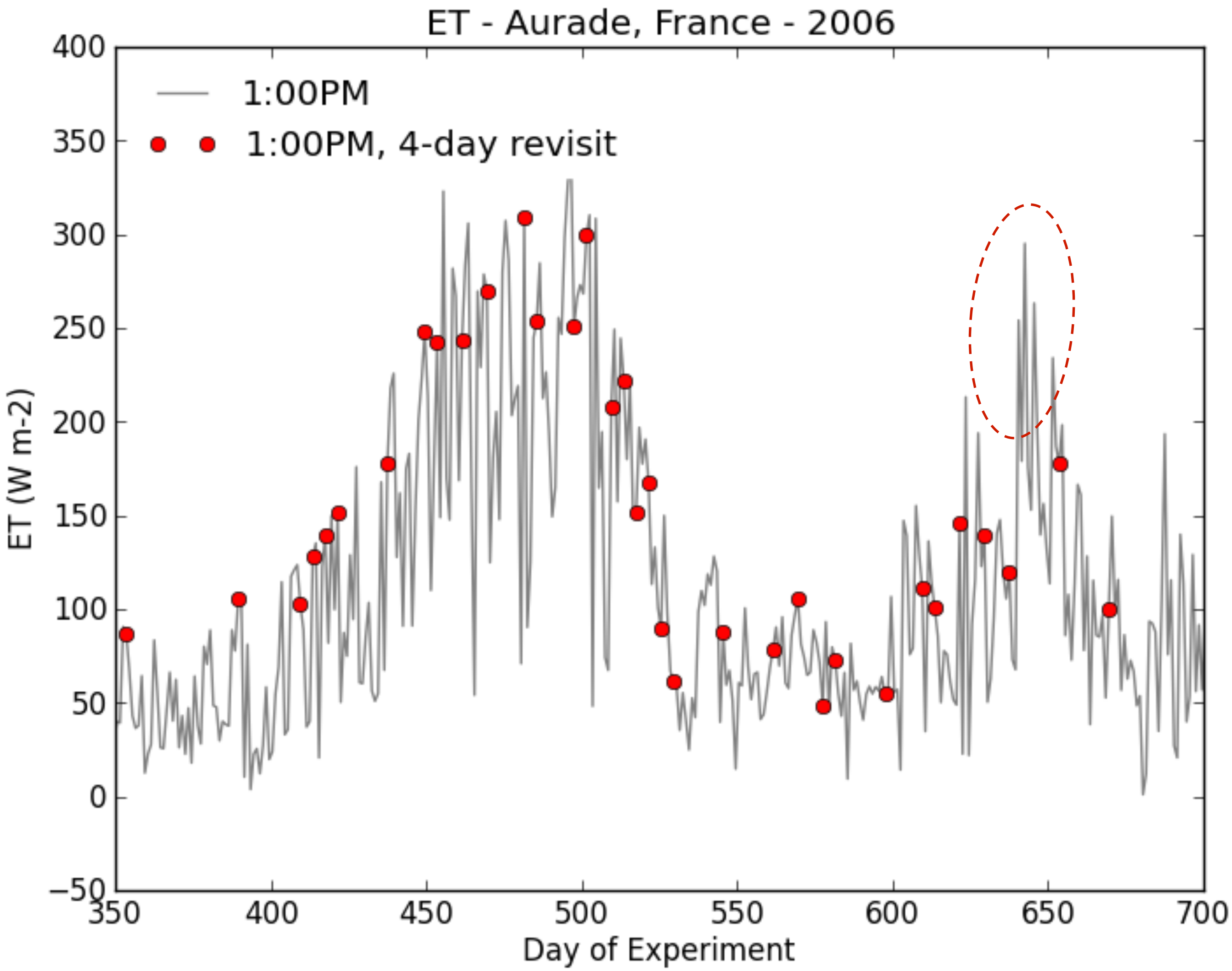

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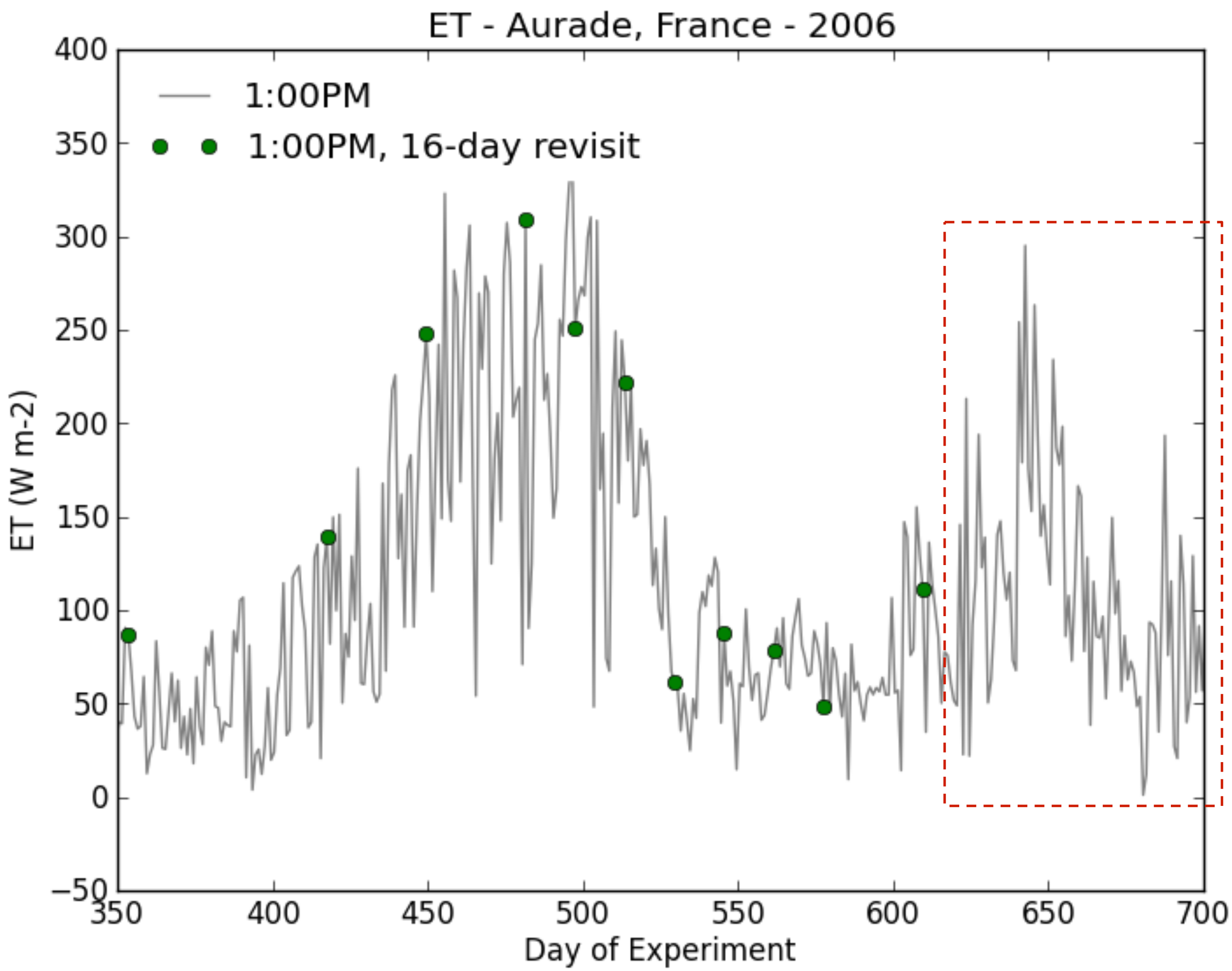
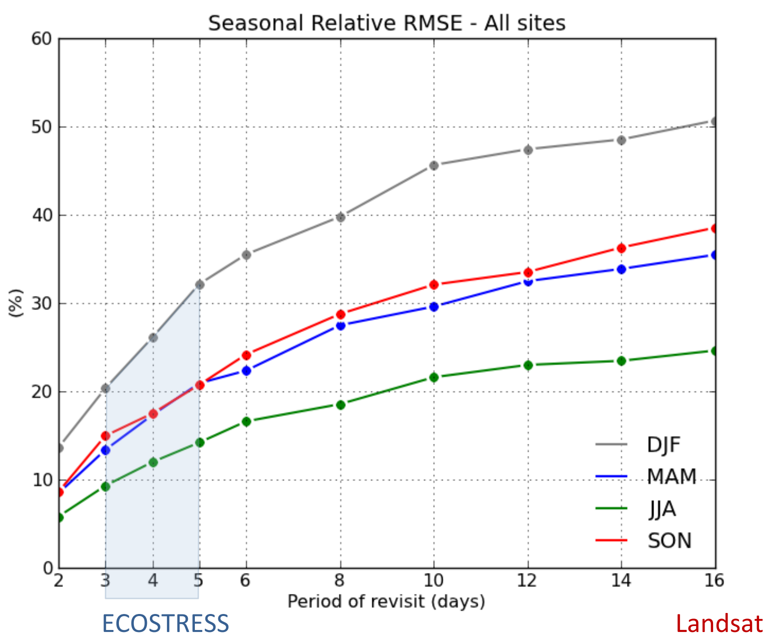


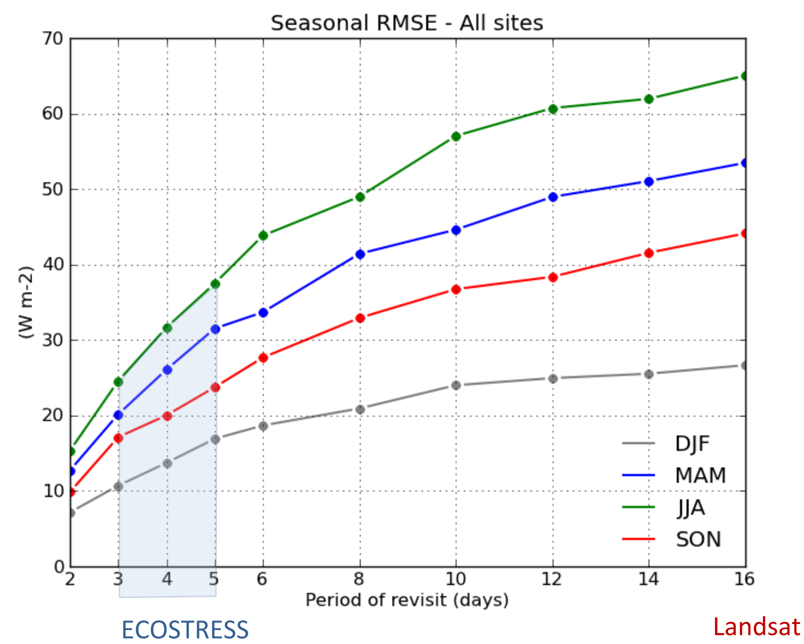
Impact of the revisit period on ET

Seasonal 13:00 ET RMSE (1-D revisit dataset as reference)

Relative



Absolute



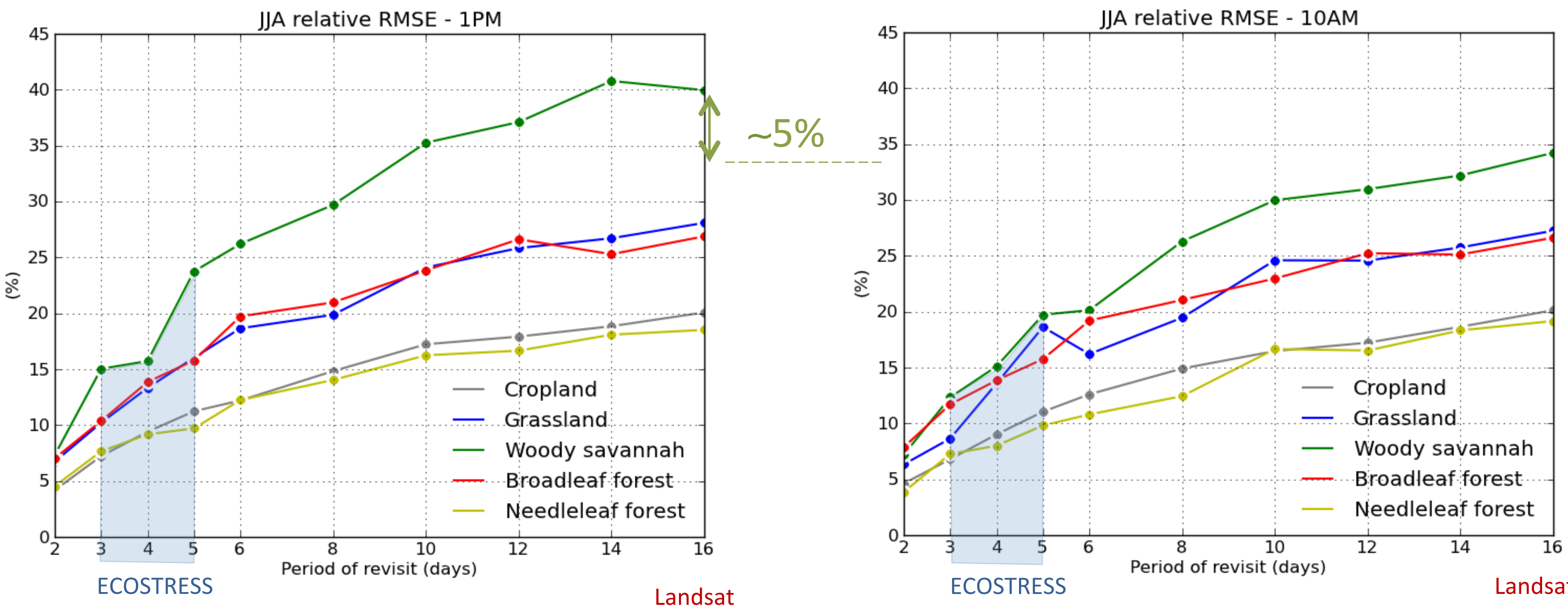
Differences with 1-D revisit (control dataset) are twice as large for a 16-day than a 4-day revisit period

Impact of the revisit period

Seasonal ET RMSE (1-D revisit dataset as reference)

1PM

10AM

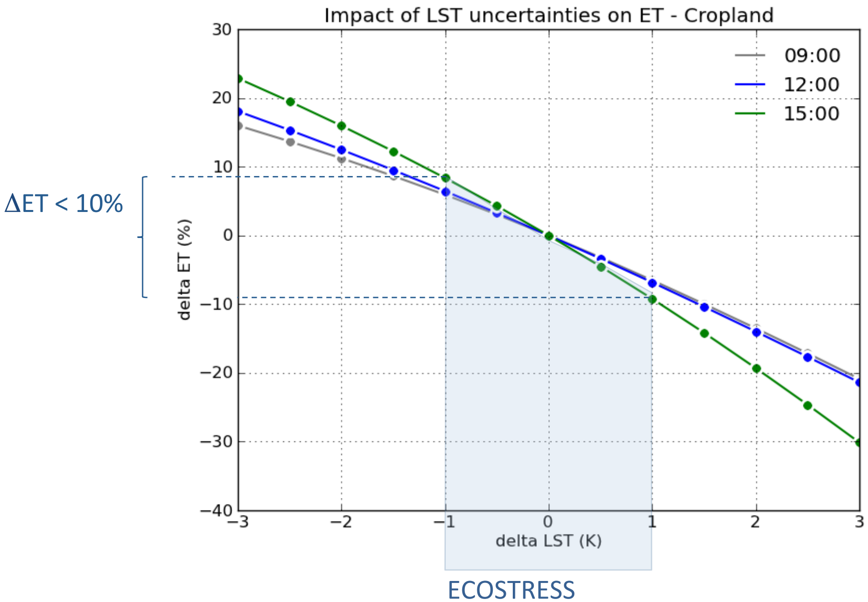


- Lowest differences for cropland and needleleaf forests (lower temporal variability)
- Similar differences at 10AM and 1PM – except for savannah

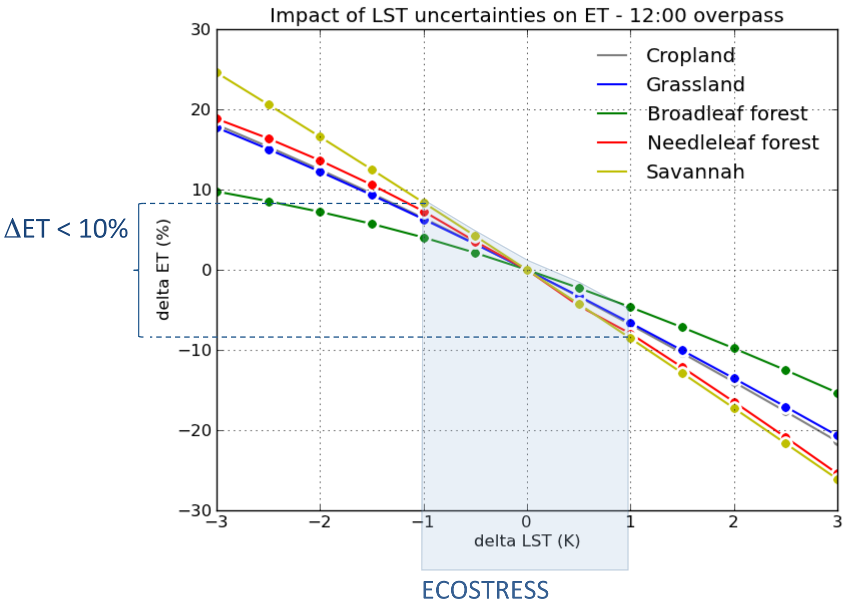
ET sensitivity to LST uncertainty

1. LST estimated from up and down-welling LW radiation
2. R_n and H calculated for LST + ΔLST
3. ΔET estimated using energy balance equation

Different overpass times



Different surface types



If LST meets requirements ⇨ ET meets requirements

ECOSTRESS ensemble of ET models

ECOSTRESS is gathering ET models that are commonly used for research and operational applications

The ensemble of model simulations is used to:

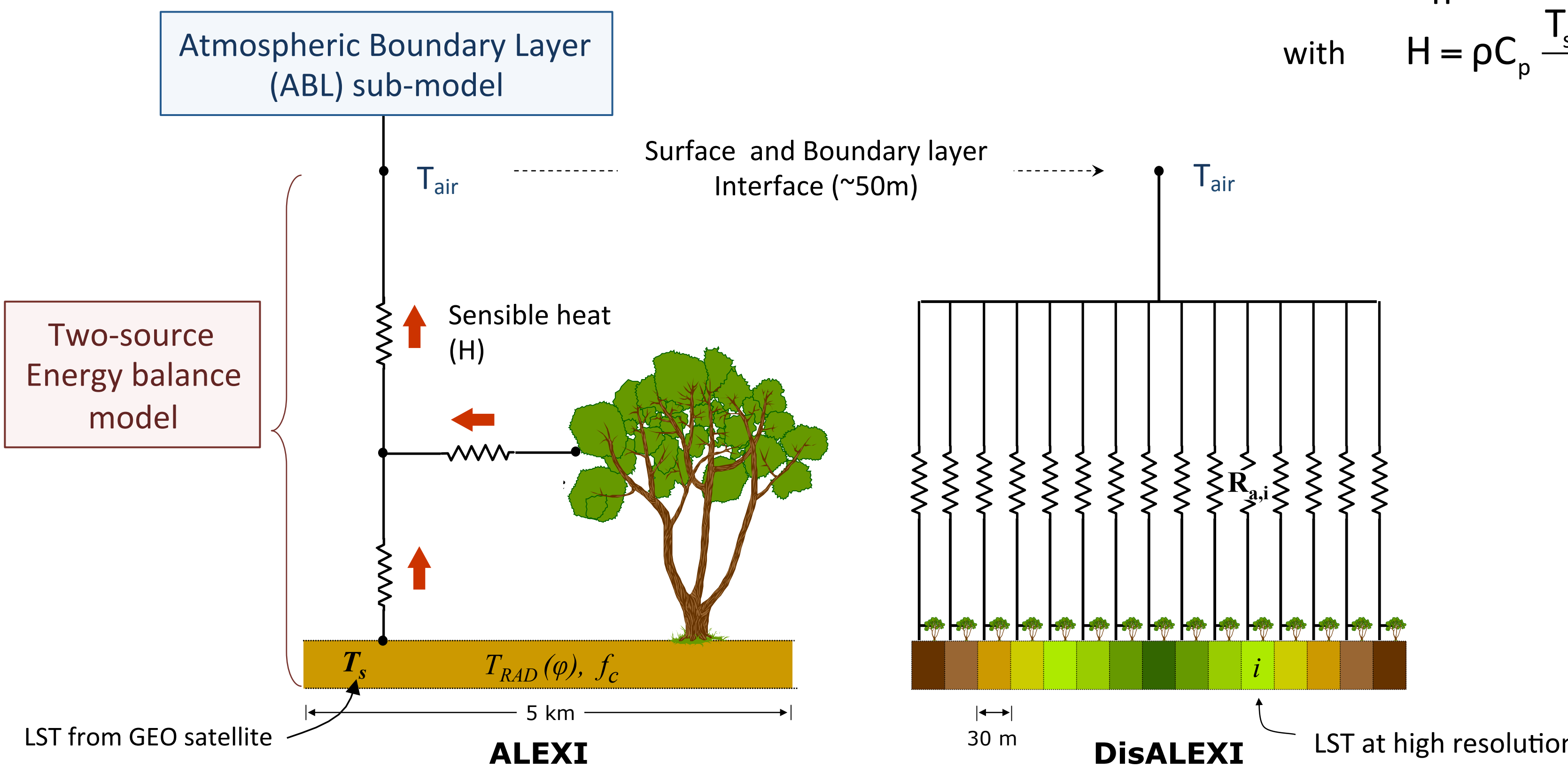
- Provide the best estimates of ET for a wide range of land cover types and climates
  - ALEXI and METRIC were initially developed for managed landscape
  - PT-JPL is more used for natural ecosystems
- Evaluate the uncertainties on ET due to model physics and model parameterizations – ECOSTRESS standard ET product could be a weighting average of outputs from different models

ALEXI - The Atmosphere Land-Exchange Inverse model

Co-I: Martha C. Anderson (USDA)

$$ET = R_n - H - G$$

with $H = \rho C_p \dfrac{T_s - T_{air}}{r_a}$?



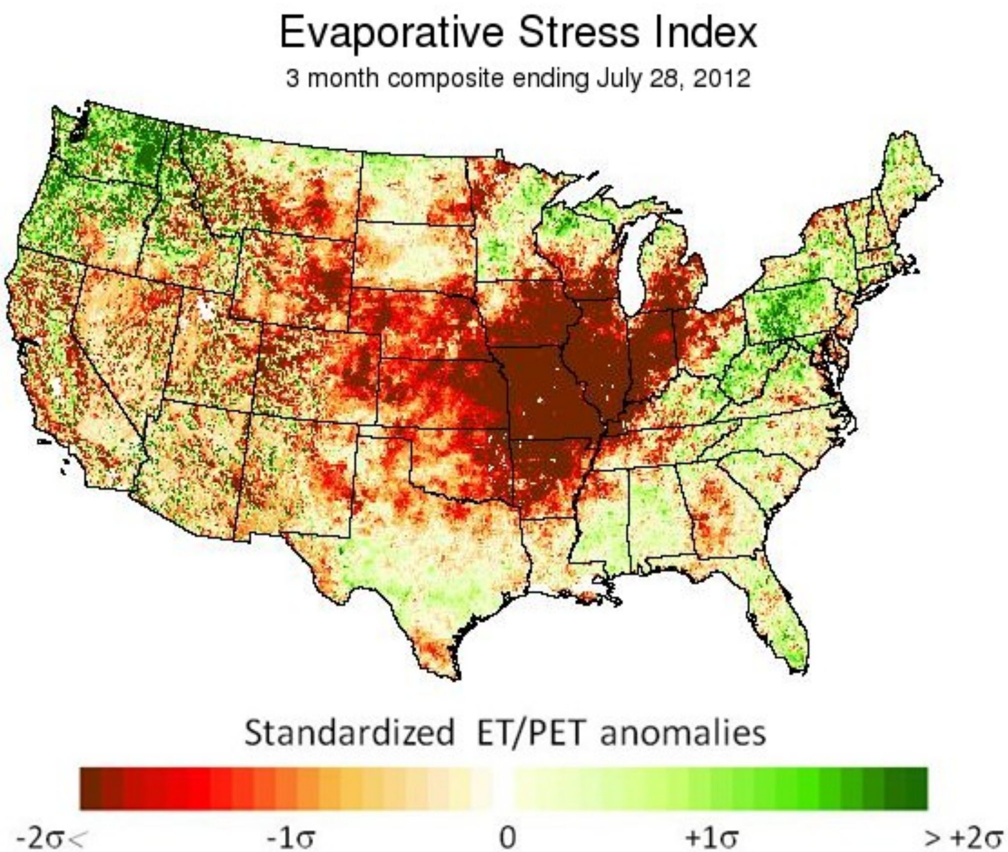
Step 1: ET at 5km resolution

Coupling surface energy with ABL model to simulate air temperature T_a at 50m

Step 2: ET at high spatial resolution

Downscaling ET at high resolution from step 1 using high resolution LST and VNIR

ALEXI – Advantage and applications



The Evaporative Stress Index from ALEXI is part of the National Integrated Drought Information System (NIDIS)

Applications of ALEXI

- Crop water use
- Crop phenology monitoring
- Drought early warning (water stress detection)

METRIC – Mapping ET with high Resolution and Internalized Calibration

Co-I: Rick G. Allen (U. of Idaho)

METRIC uses the in-scene information and ground reference from weather stations

$$ET = R_n - H - G$$

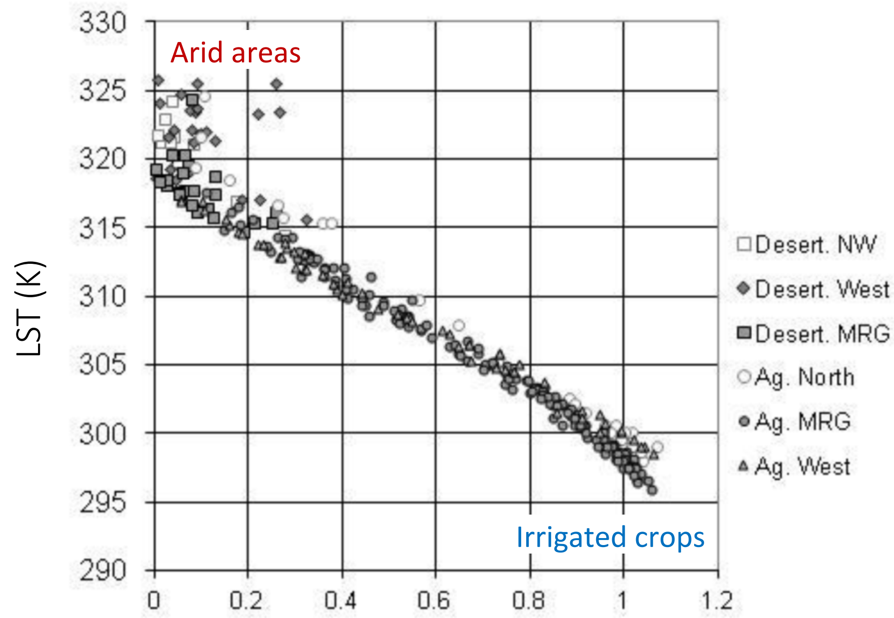
with $H = \rho C_p \frac{T_s - T_{air}}{r_a}$, where $T_s - T_{air} = \Delta T$

Assumption:

$$\Delta T = a\, T_s + b$$

with a, b are in-scene empirical coefficients calculated from energy balance applied to:

- "hot" pixel where ET = 0
- "cold" pixel where ET = 1.05 x potential ET



Fraction ET/potential ET

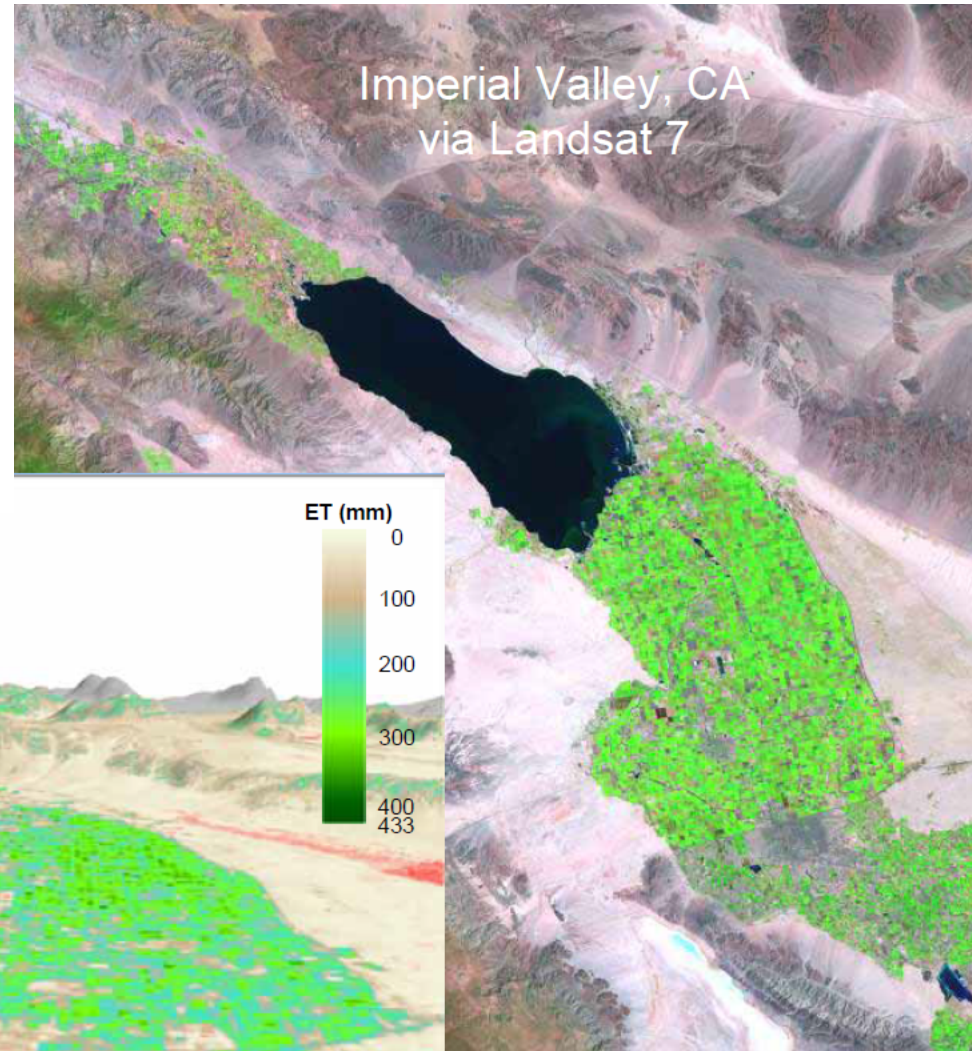
Designed for relatively small agricultural regions (100x100 miles)

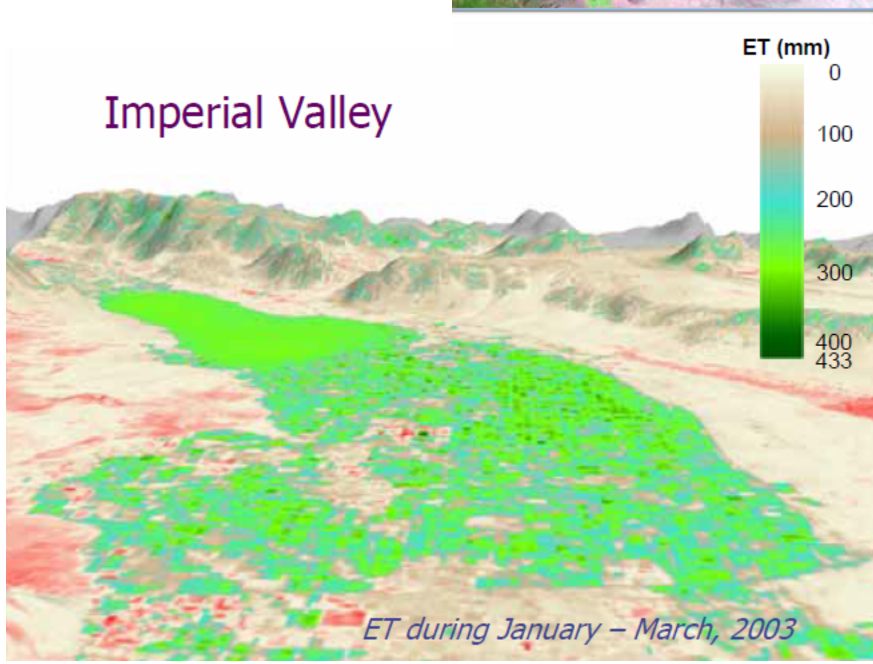
Each image provides internal and automatic calibration

METRIC – Advantage and applications

Operational applications of METRIC in Idaho:

- Quantify net depletion from ground water pumping
- Compare actual ET with water right
- Calculate natural and irrigation-induced recharge to aquifers
- Monitor crop phenology





Dedicated for high resolution imagery, METRIC is used by more western states

PT-JPL – Priestley and Taylor approach

Co-I: Joshua B. Fisher (JPL)

$$ET_{canopy} = f_g f_T f_M \alpha \frac{\Delta}{\Delta + \gamma} R_{nc}$$

bio-physiological constraints due to light, temperature and water stress limitations

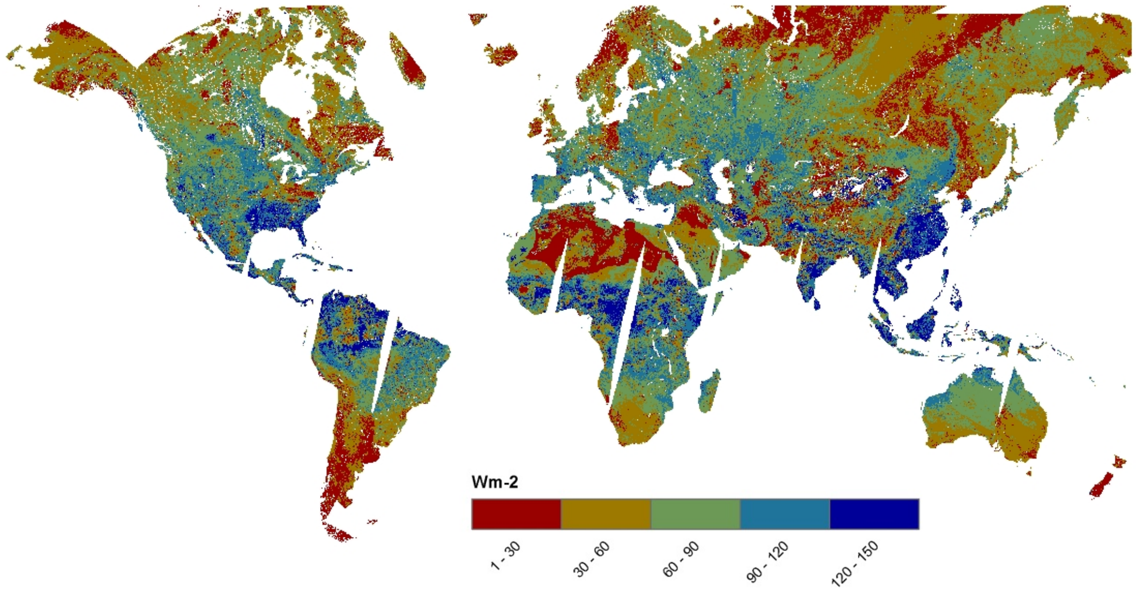
potential ET represents the atmospheric moisture demand

with $$R_{nc} = (1 - albedo)R_{SW} - \varepsilon\sigma T_s^4 + \varepsilon R_{LW}$$

the canopy net radiation

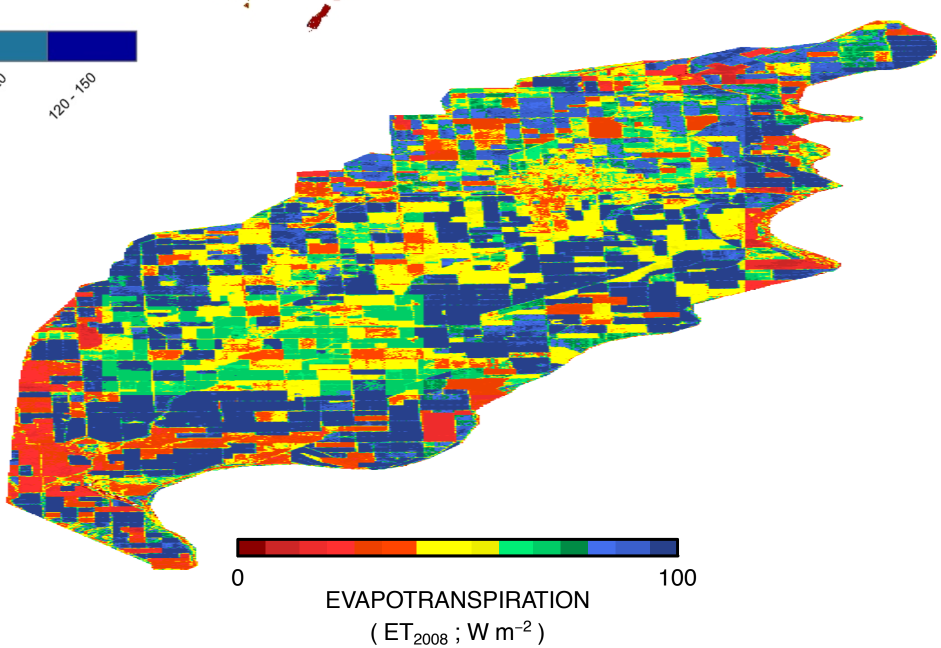
R_{SW}, R_{LW}	the shortwave and longwave incoming radiation
$\Delta = de_s/dT$	the slope of the saturation water vapor function
γ, σ	the psychrometric constant and the Steffan-Boltzmann
α	the Priestley-Taylor coefficient = 1.26 (empirical value)
ε	the surface emissivity

PT-JPL – Advantage and applications



PT-JPL is used to derive ET at various spatial resolutions:

- Global scale (MODIS)
- Field scale (Landsat)



PT-JPL has shown the **best performance** in simulating daily to monthly ET average in recent model comparison studies

Conclusion

- Next step will be focused on model uncertainty estimates and model intercomparison

- A detailed description of the models and the validation procedure of the ECOSTRESS ET product are coming after the break…