National Aeronautics and Space Administration

Resolving the diurnal cycle of Solar-Induced Chlorophyll Fluorescence (SIF) from stomate to landscape

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Strategic Focus Area: Water and carbon cycles

Objectives: Our SURP aims to develop predictive models to resolve the diurnal cycle of satellite solar induced fluorescence (SIF) using sporadic measurements of SIF from OCO-3 and land surface temperature (LST) and evapotranspiration (ET) from ECOSTRESS. The developed predictive models will be eventually used to generate an operational hourly SIF product from OCO-3.

Background: Spaceborne SIF is a major step towards measuring terrestrial GPP in real time, but achieving this goal currently relies on discrete measurements (single daily overpass on periodic dates). The actual SIF emission is highly dynamic; without properly accounting for diurnal change, the full potential of satellite SIF is limited for benefitting global ecology or agriculture applications. NASA's OCO-3 has potential to resolve SIF diurnal dynamics using the ISS orbit to provide repeated sampling every few days at different local overpass times, but day-to-day variations challenges efforts to reveal the actual SIF diurnal cycle and creates difficulties for directly applying OCO-3 SIF to evaluate ecosystem health and growth. A similar problem is faced by NASA's ECOSTRESS, also on the ISS, which aims to quantify diurnal ET.

Approach: We generate diurnally-resolved and high spatial resolution LST and ET products from the native ECOSTRESS sporadic measurements as a crucial first step for eventually generating diurnally resolved SIF, which will rely on ECOSTRESS based input. Our framework consists of two steps (**Fig 1**). First, we construct the diurnal cycle of ECOSTRESS LST using a diurnal temperature cycle (DTC, **Fig 2**) model. Second, we utilized the PT-JPL algorithm (PT-JPL), to construct diurnal ET from diurnally-resolved ECOSTRESS LST (**Fig 3**). We use 2 approaches to assess performance. First, we utilized leave-one-out cross validation to check the consistency with the native ECOSTRESS observations. Second, we evaluated the temporal variations of the diurnally-resolved ECOSTRESS LST and ET with independent flux tower measurements. We validate at two 0.3° × 0.3° domains with distinct vegetation types, landscape heterogeneities, and climate regimes, including a semi-arid grassland EC flux tower at the Sevilleta Wildlife Refuge in New Mexico (US-Seg) and a humid cropland EC flux tower in Lamont, Oklahoma (US-ARM).

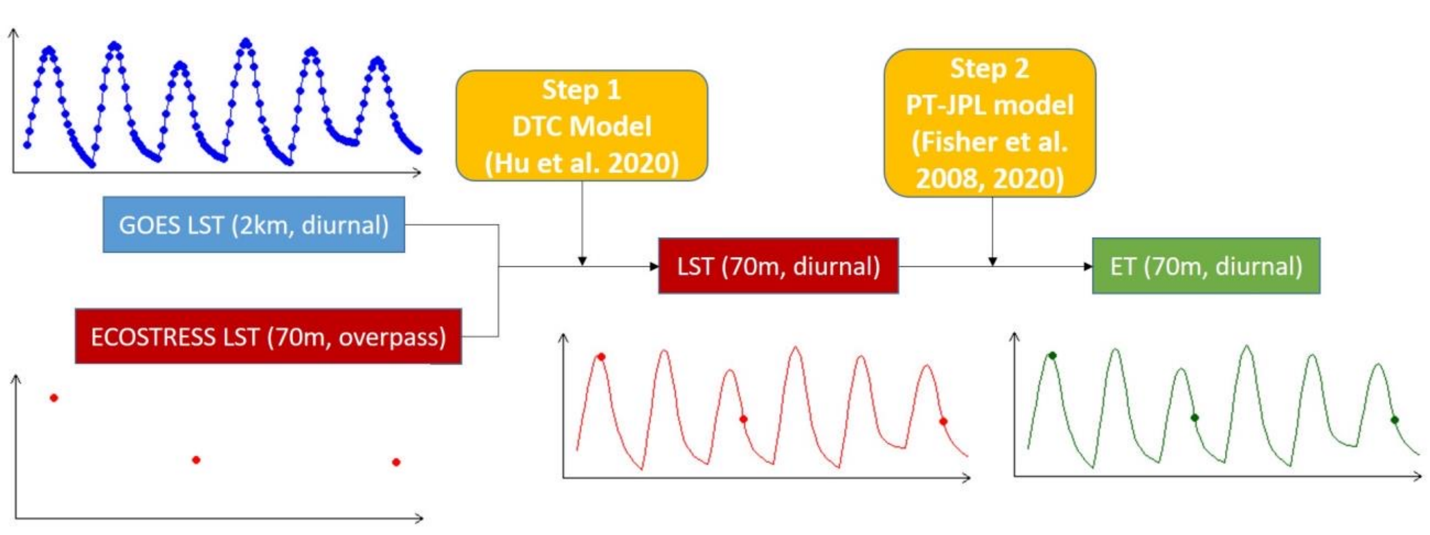

Figure 1. Framework for constructing the full diurnal cycle of LST and ET from sporadic ECOSTRESS measurements.

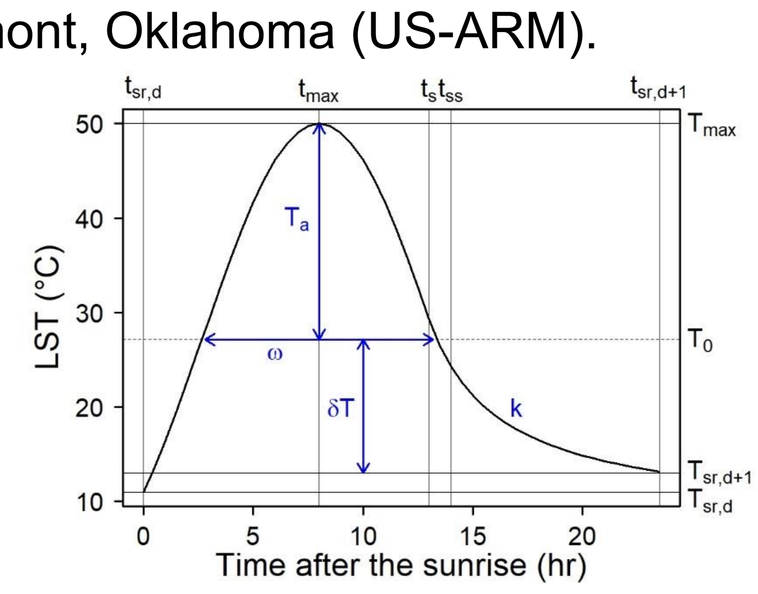

Figure 2. A schematic illustration of the DTC model.

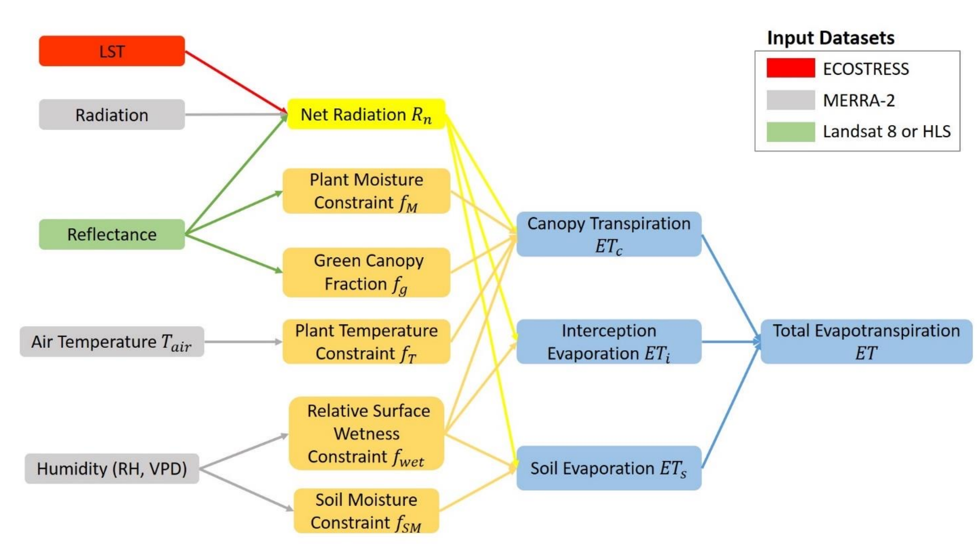

Figure 3. Diagram of the PT-JPL model.

Results: Comparison to ET and tower data at US-Seg indicate the physical LST and ET models offer reliable reconstruction of spatial LST and ET snapshots (**Figs 4a, 5a**), reliable reconstruction of diurnal pattern of tower LST and ET (**Figs 4b, 5b**), and low sensitivity to meteorological data sources. 70 m LST predictions resolve more spatial detail compared to 2 km GOES (**Fig 4a**), and capture diurnal LST observed across distinct phenological growth stages (peak growth, leaf-out, and senescence, corresponding to rows 1-3 in **Fig 4b**). 70 m ET predictions capture basic spatial structure of ECOSTRESS (**Fig 5a**), but struggle to capture amplitude of variability (**Fig 5b**).

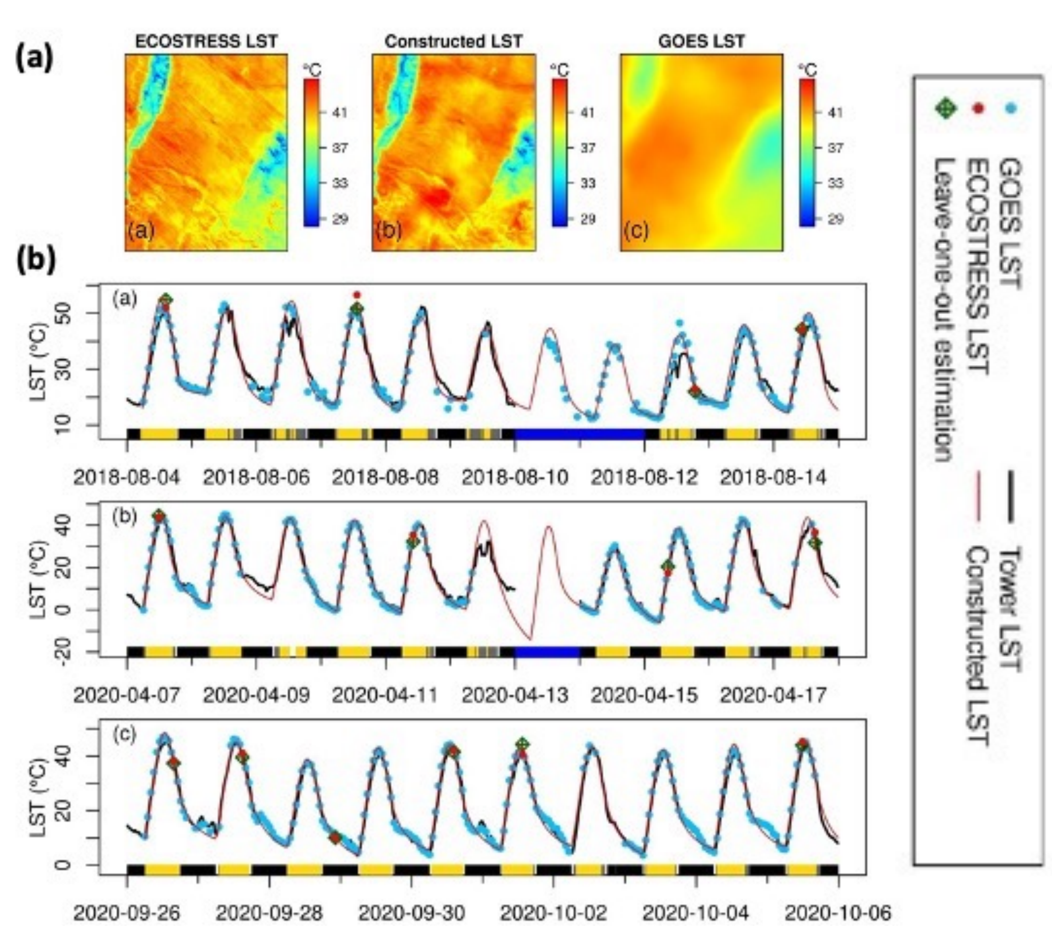

Figure 4. Evaluation of diurnally-resolved LST at US-Seg

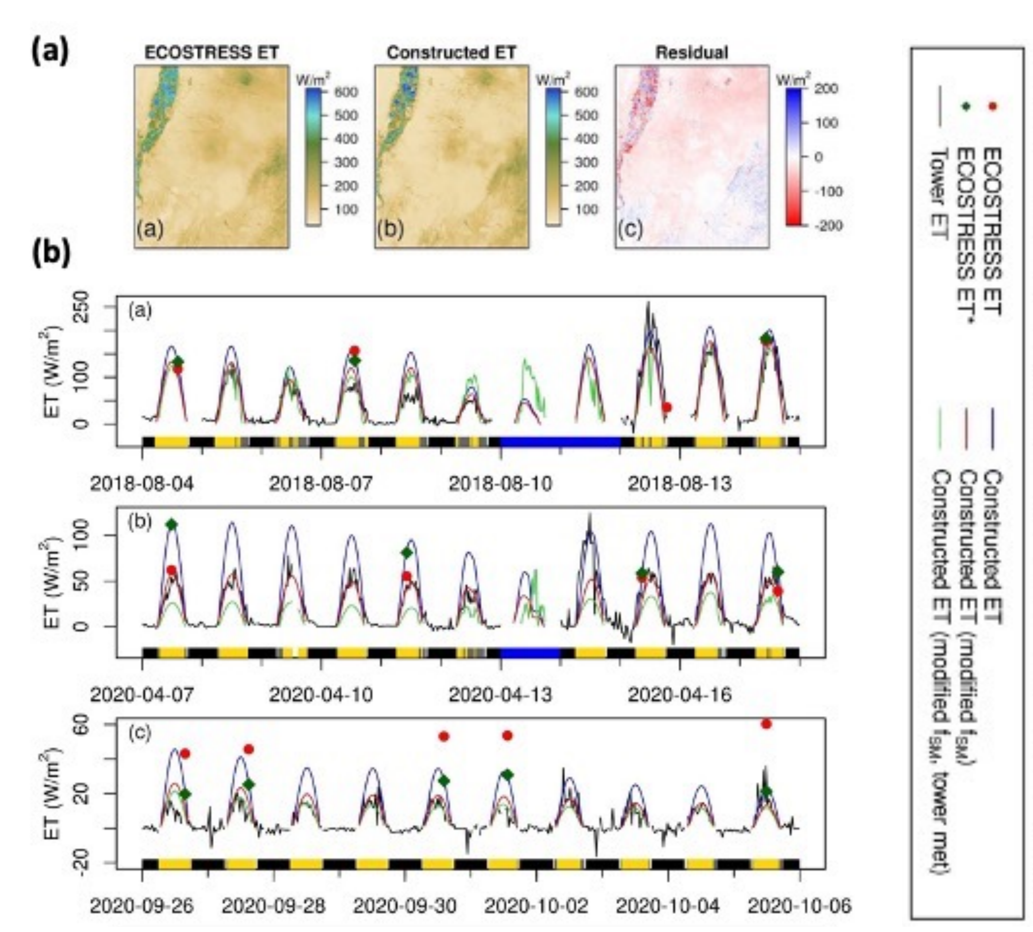

Figure 5. Evaluation of diurnally-resolved ET at US-Seg

Significance/Benefits to JPL and NASA: Our SURP has the following impacts: (1) Enhance ECOSTRESS cal/val opportunities through temporal extrapolation of sporadic tower measurements; (2) Direct use of ECOSTRESS LST and ET for data assimilation in land models will advance ECOSTRESS science goals to better quantify water exchange in natural and managed ecosystems; (3) Provide process-based framework for operational ECOSTRESS LST and ET products at JPL. Our SURP sets the stage for (a) testing and applying our framework to broader climates, biomes, and landscapes towards eventually generating diurnally resolved 70m global operational LST/ET products to enhance ecological/agricultural applications, and (b) generating diurnally resolved SIF from NASA OCO-2 midday and OCO-3 sporadic measurements.

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