National Aeronautics and Space Administration

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

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Objectives

This proposal develops predictive models to resolve the diurnal cycle of SIF using sporadic measurements from the Orbiting Carbon Observatory 3 (OCO-3), constrained by evapotranspiration (ET) from ECOSTRESS, both on board the ISS. The developed predictive models will be used to generate an operational hourly SIF product from OCO-3.

Background

Solar-Induced chlorophyll Fluorescence (SIF) observed from space-borne sensors represents a major step towards measuring terrestrial photosynthesis in real time. A major roadblock lies in its current data acquisition characteristics- a discrete measurement at a single daily overpass time on periodic dates. However, the actual SIF emission from plants is a highly dynamic signal that varies rapidly with ambient light conditions and physiological stress. 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 mission has potential to resolve SIF diurnal dynamics by leveraging the ISS orbit for repeated sampling every few days at different overpass times. However, day-to-day variations in SIF challenges efforts to reveal the actual SIF diurnal cycle and creates difficulties for directly applying OCO-3's sporadic SIF to evaluate terrestrial ecosystem health and growth. A similar problem is faced by NASA's ECOSTRESS, also on the ISS, which aims to quantify the diurnal evapotranspiration (ET). These limitations are of increasing importance as NASA turns to real-world applications to benefit stakeholders and/or farmers.

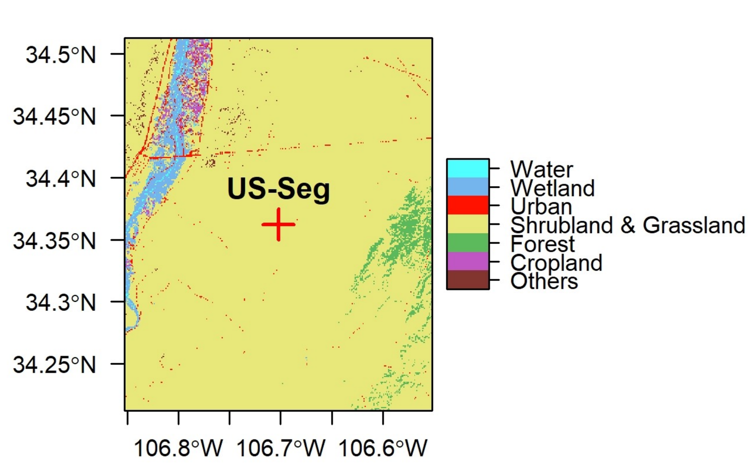

Figure 1. Land cover map of study domain, with US-Seg tower marked by red cross.

We are developing approaches to estimate diurnal SIF using ECOSTRESS and tower measurements at a desert grassland flux tower (US-Seg) at the Sevilleta Wildlife Refuge in New Mexico (Fig 1).

Our SURP funded research is currently in review at WRR (Wen et al., in review)

Approach

We first tested approaches to generate diurnally resolved and high spatial resolution ET from native ECOSTRESS sporadic measurements, serving simultaneously as it's own data product, and as a constraint for the data-driven SIF model. Our framework consists of two steps (illustrated in Fig 2). First, we construct the diurnal cycle of ECOSTRESS land surface temperature (LST) using a diurnal temperature cycle (DTC) machine learning model initially developed by Göttsche & Olesen (2001) and widely adopted and refined afterwards (Duan et al., 2014, Hu et al., 2020). Second, we utilize the PT-JPL algorithm (Fisher et al., 2008, 2020) employed by the ECOSTRESS team for operational ET product, to construct diurnal ET from diurnally-resolved ECOSTRESS LST.

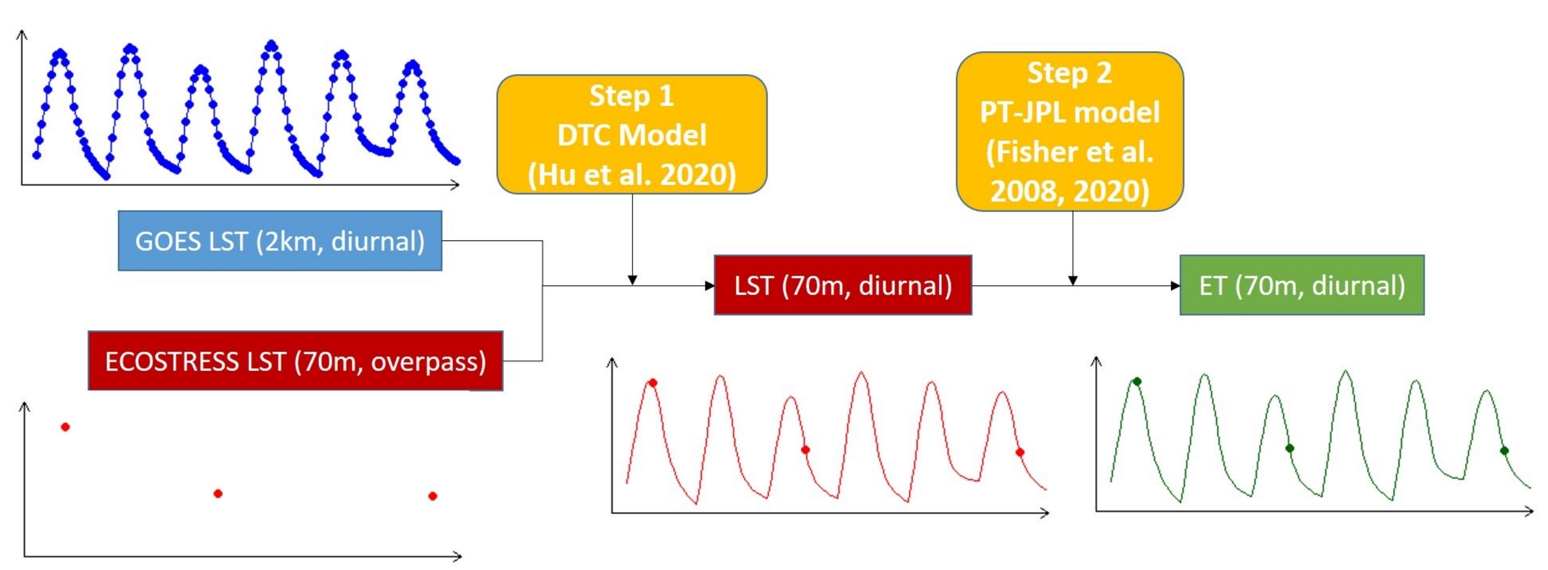

Figure 2. The overall framework for constructing the full diurnal cycle of LST and ET from the sporadic ECOSTRESS data.

Results

Current results at the Sevilleta Grassland tower in New Mexico indicate the DTC model offers reliable reconstruction of spatial LST and ET snapshots (Figs 3 and 4), and reliable reconstruction of the diurnal pattern of tower LST and ET (Fig 5).

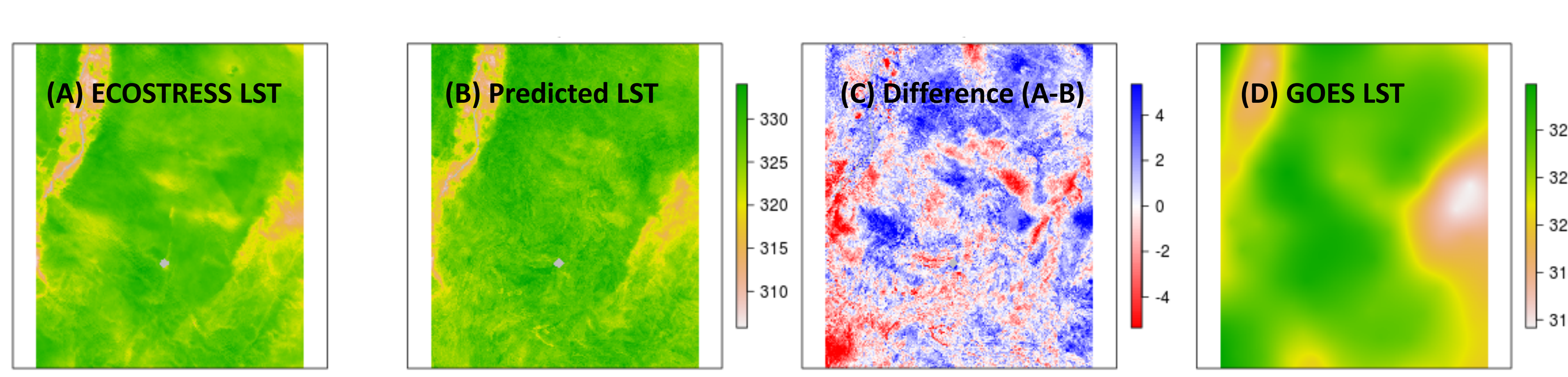

Figure 3: Reconstruct spatial LST using DTC model at US_Seg on Aug 4, 2018 at 2:20 PM local time. DTC Predictions (B) are in good agreement with ECOSTRESS estimates (A), capturing large scale spatial patterns and smaller scale features not present in coarse resolution measurements from GOES LST.

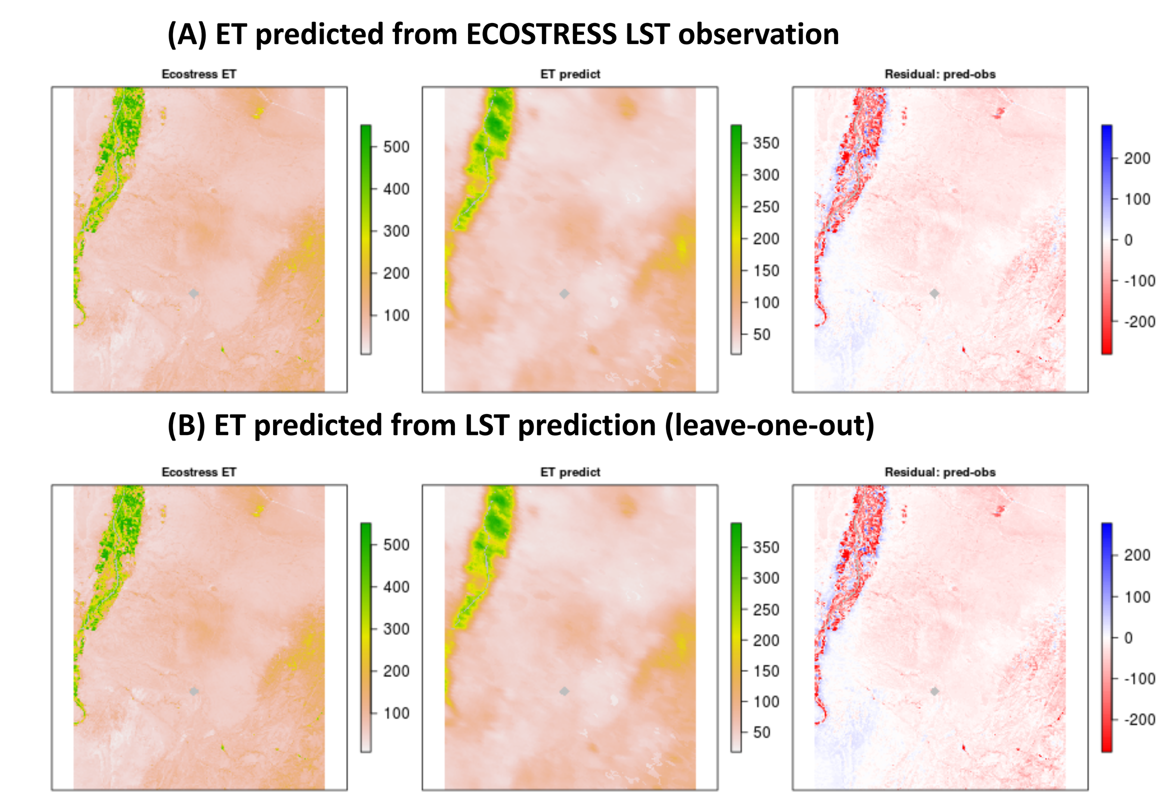

Figure 4: Reconstruct spatial ET using PT-JPL and LST values from Fig 3. (A) This shows successful reconstruction of operational ET using ECOSTRESS LST observations. (B) This shows excellent agreement between operational and predicted ET using LST predictions from the DTC machine learning model in Fig 3B.

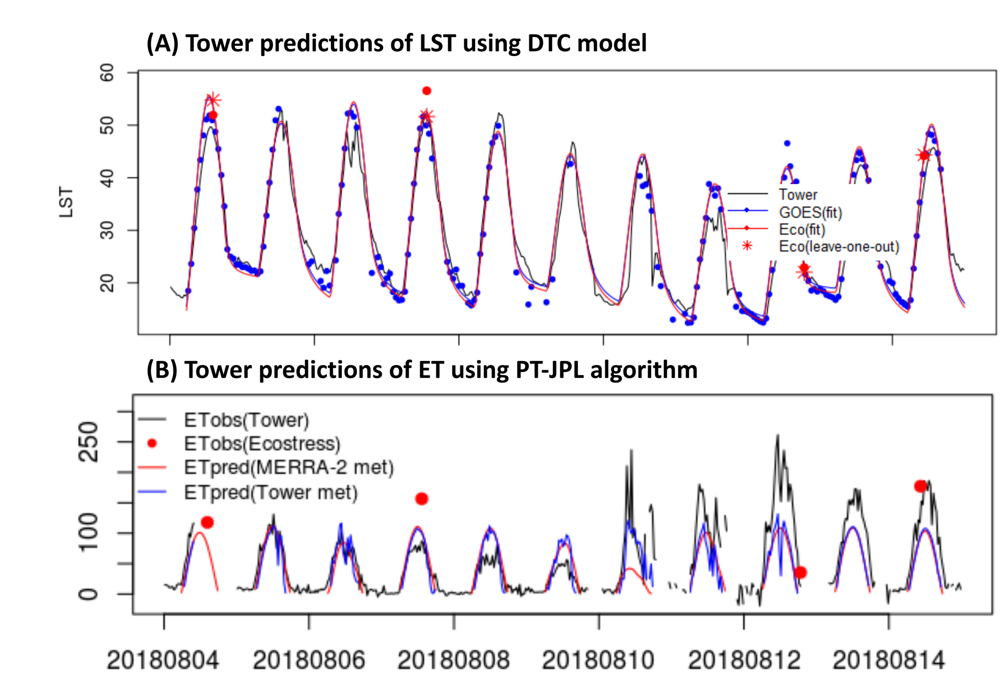

Figure 5: Reconstructed diurnal and day-to-day variations in (A) LST and (B) ET in comparison to observations at US-Seg from Aug 4-14, 2018. LST performance is exceptional. ET is consistent but shows magnitude mismatch after Aug 10.

Significance/Benefits to JPL and NASA

Our SURP will have the following impacts: (1) Enhance OCO-3 and ECOSTRESS cal/val opportunities through temporal extrapolation of sporadic tower measurements; (2) Direct use of OCO-2 SIF and ECOSTRESS ET for data assimilation in land models will advance OCO-2 and OCO-3 science goals to better quantify C uptake by natural processes; (3) Provide data assimilation framework for operational OCO-2/3 SIF products at JPL. Our new model-data fusion system, will enable incorporation of OCO-2/3 SIF observations for large-scale application.

Publications

Wen, J., J. B. Fisher, N. C. Parazoo, L. Hu, M. E. Litvak, Y. Sun, Resolve the continuous diurnal cycle of high-resolution ECOSTRESS Evapotranspiration and Land Surface Temperature, Water Resource Research, In Review

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