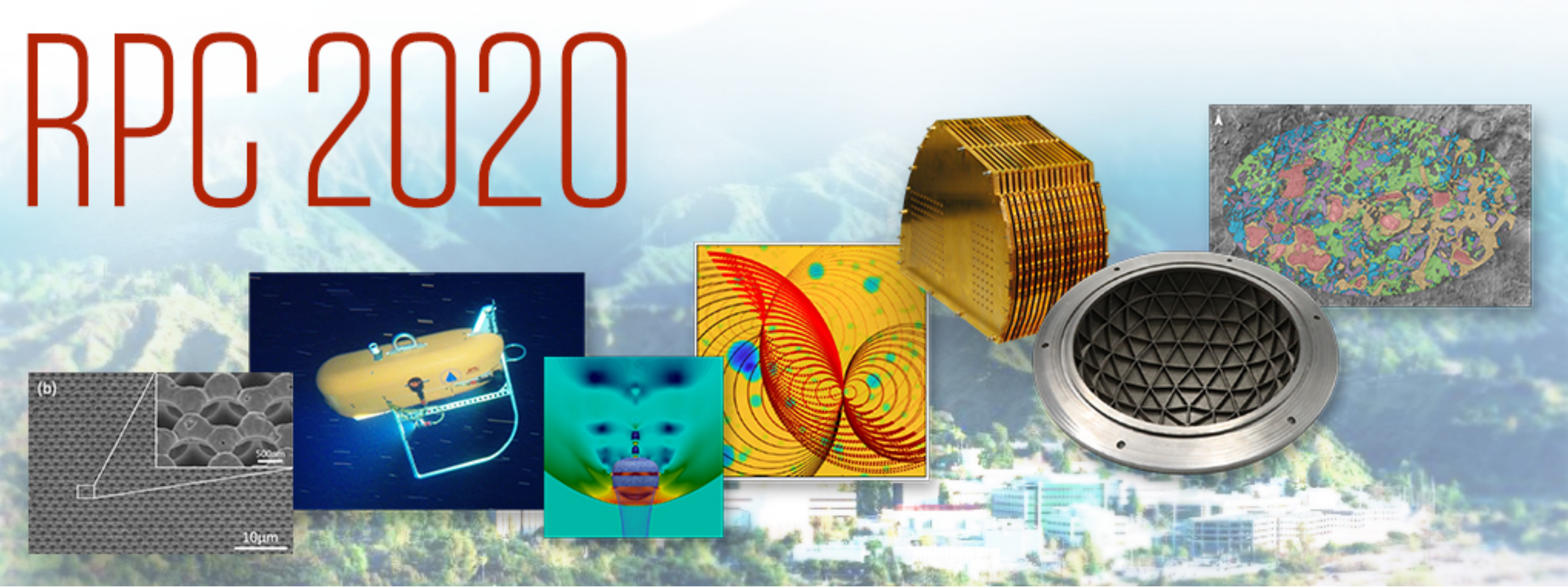

Virtual Research Presentation Conference

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

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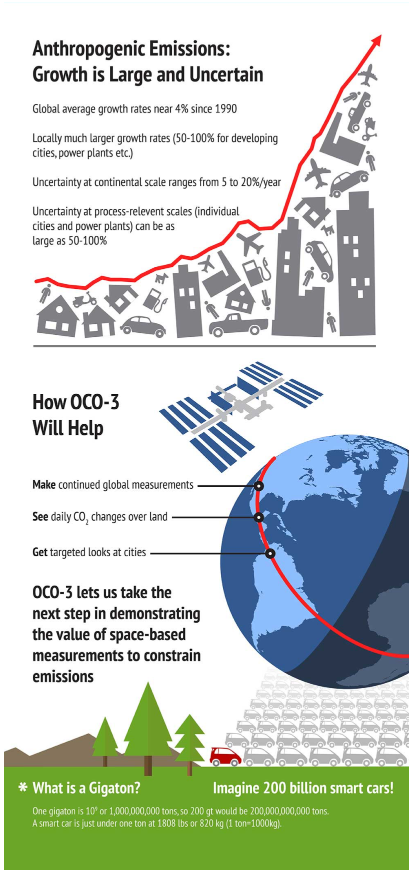
Program: SURP

Assigned Presentation #RPC-048

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

- Increasing CO2 from fossil fuel combustion are the main culprit of climate change and warming temperatures
- Plants use this extra CO2 to stimulate growth and storage in soils, and can therefore help slow rising CO2 and warming, and mitigate climate change
- Together, plants around the world remove about a quarter of CO2 emitted from tailpipes
- Scientists are concerned that warming may alter the ability of plants to remove CO2, but it's still not clear how global plants are responding
- NASA, and other agencies around the world interested in Earth Science, have figured out ways to observe changes in photosynthesis from space, and understand if, where, and why plants are responding
- Two key measurements help us figure out the where and why
- When plants absorb sunlight for photosynthesis, they re-emit light in a different form called solar induced fluorescence, or **SIF**, which can tell us about the rate of photosynthesis under different environmental conditions
- At the same time that plants absorb light and CO2 for photosynthesis, they lose water taken up from the soil, which cools leaf temperature through evapo-transpiration (**ET**)
- This light emission, and leaf cooling, are currently being measured globally from the International Space Station (ISS)



https://ocov3.jpl.nasa.gov/science/

Problem Description

- A major roadblock in achieving this goal lies in its current data acquisition characteristics- **a discrete measurement at a single daily overpass time on periodic dates**.
- However, the actual SIF emission and water loss from plants are highly dynamic signals that vary substantially and rapidly with ambient light conditions and plant physiological regulations due to 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 and ECOSTRESS missions possess the potential to resolve the SIF and ET diurnal dynamics by leveraging the ISS orbit to provide repeated sampling every few days at different times of day.
- However, changing weather drives day-to-day variations in SIF and ET, which challenges efforts to reveal the actual diurnal cycles and creates difficulties for directly applying sporadic ISS measurements to evaluate ecosystem health and growth.
- These limitations are of increasing importance as NASA turns its attention to real-world applications to benefit stakeholders and/or farmers

Methodology

- Our basic approach is to “fill in” gaps in the OCO-3 and ECOSTRESS records using models to predict SIF and ET when ISS sensors aren’t around
- We have two kinds of models: process-driven, and data-driven.
- The process-driven approach (Gu et al., 2019) uses theory to quantify the different ways plants use absorbed solar energy for photosynthesis, heat dissipation, and fluorescence (SIF). So, we build equations to predict the fate of sunlight once it is absorbed by chlorophyll receptors on the leaf surface
- The data-driven approach (Yu et al., 2018; Wen et al., 2020) uses machine learning to develop relationships between SIF or ET, and ancillary vegetation and meteorological datasets that are related to SIF and/or ET. The idea here is to develop these relationships when SIF or ET is observed (either from the ISS or field observations), and then use these ancillary data with the machine learning model to predict SIF or ET between ISS passes.
- The combined process- and data-driven approaches provides a way to fill gaps in operational datasets helpful for tracking vegetation health in real time, while at the same time helping to identify key predictors, and refine process understanding, for improved predictive capabilities in earth system models.

Results

a) Accomplishments versus goals

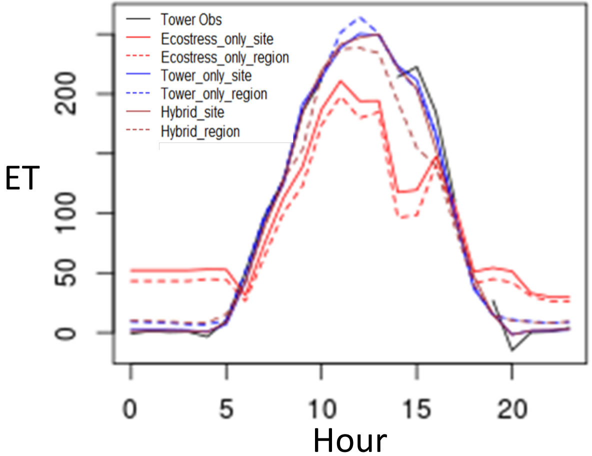
- Our focus in Year 1 shifted from SIF to ET prediction due to the longer record of available ECOSTRESS ET.
- ET spatial variability is controlled by slowly varying vegetation indicators. Temporal variability is controlled by rapidly varying environmental conditions (temperature, VPD, sunlight) which regulate stomatal closure at hourly time scales.
- The combination of vegetation and meteorological data with ECOSTRESS data captures a substantial amount of spatial variability, but sporadic and infrequent sampling can cause severe biases in diurnal structure.
- A hybrid approach combining temporally continuous tower ET and spatially continuous ECOSTRESS ET best reproduces withheld observations

b) Significance

- Our key finding is that diurnal ET prediction from ECOSTRESS data is possible but requires ancillary spatial and temporal vegetation, meteorological, and ground ET data for more accurate predictions over space and time.

c) Next steps

- Add more predictors to machine learning model, including geostationary data from weather satellites to improve diurnal information, and data fusion products that better address atmospheric scattering (clouds) and cross-sensor consistency



Publications and References

Yu, L., J. Wen, C.Y., Chang, C. Frankenberg, **Y. Sun** (2019), High Resolution Global Contiguous SIF of OCO-2, *Geophys. Res. Lett.,* 46(3), 1449-1458.

Wen, J., P. Köhler, G. Duveiller, **N.C. Parazoo**, T.S. Magney, G. Hooker, L. Yu, C. Y. Chang, and **Y. Sun** (2020), A framework for harmonizing multiple satellite instruments to generate a long-term global high spatial-resolution solar-induced chlorophyll fluorescence (SIF), *Remote Sens Env*., 239, 111644.

Gu, L., J. Han, J. Wood, C.Y. Chang, **Y. Sun** (2019), Sun-induced Chl fluorescence and its importance for modeling of photosynthesis based on light reactions, *New Phytologist*, 223(3), 1179-1191.