ECOSTRESS

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

An Earth Venture Instrument-2 Proposal
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 Prepared for
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Science Mission Directorate

PI

Simon Hook (JPL)

SCIENCE LEAD

Joshua B. Fisher (JPL)

SCIENCE TEAM

Rick Allen (U. Idaho)
Martha Anderson (USDA)
Andy French (USDA)
Chris Hain (UMD)
Glynn Hulley (JPL)
Eric Wood (Princeton U.)

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HOW DO DIFFERENT PLANTS RESPOND TO CHANGES IN WATER AVAILABILITY?
WHICH PLANTS DIE FIRST?
How plants respond to changes in water availability can be expressed in terms of Water Use Efficiency (WUE), defined as the amount of carbon fixed per unit water used (gross primary production, GPP, divided by ET). Some plants have high WUE and can fix a large amount of carbon using a small amount of water; other plants are less efficient. Low WUE plants risk replacement with increasing droughts.
What we need: accurate, high spatial, high temporal, diurnal cycle, global, ET.
Water Stress Drives Plant Behavior

Evapotranspiration

Stomata close to conserve water

Diurnal Cycle

6 AM 12 PM 6 PM
The International Space Station (ISS)
Gray shading represents mean diurnal variation in ET over 14-days. The afternoon decline in ET is related to water stress (clear day).

I Xylem refilling after initial water release.
II ET at maximum/potential rate in the morning.
III Stomata shut down water flux in the afternoon.
IV ET resumes at maximum/potential in early evening when demand is reduced.
Current JPL ET:
- Global, 1 km, daily
- Running multiple algorithms: PT-JPL, PM-MOD16, SEBS, PMBL
PT-JPL ET Validation

Evaporative Stress Index (ESI)

New global observations of the terrestrial carbon cycle from GOSAT: Patterns of plant fluorescence with gross primary productivity

Christian Frankenberg, 1, Joshua B. Fisher, 1, John Worden, 1, Grayson Badgley, 1, Sassan S. Saatchi, 1, Jung-Eun Lee, 1, Geoffrey C. Toon, 1, Andre Butz, 1 Martin Jung, 3, Akiko Kuze, 6 and Tatsuya Yokota 8

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[1.] Our ability to close the Earth’s carbon budget and predict feedbacks in a warming climate depends critically on knowing where, when and how carbon dioxide is exchanged between the land and atmosphere. Terrestrial gross primary production (GPP) constitutes the largest flux component in the global carbon budget, however significant uncertainties remain in GPP estimates and its seasonality. Empirically, we show that global spaceborne observations of solar induced chlorophyll fluorescence – occurring during photosynthesis – exhibit a strong linear correlation with GPP. We found that the fluorescence emission even without any additional climatic or model information has the same or better predictive skill in estimating GPP as those derived from traditional remotely-sensed vegetation indices using ancillary data and model assumptions. In general, the stronger the correlation between fluorescence and GPP, the better the prediction of GPP. This is because the fluorescence signal is more directly related to plant photosynthesis, which is the main process driving GPP, as shown by sophisticated data assimilation experiments. The results show significant improvements over traditional methods in the estimation of GPP at a global scale.

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[2.] Figure 1. The L3/L4 data flow diagram illustrates the steps involved in the retrieval of global vegetation indices from the Global Ozone Monitoring Experiment (GOME) measurements. The diagram highlights the key steps: 1) geolocation parameters, 2) surface temperature, surface emissivity, and cloud mask, 3) MODIS surface reflectance, 4) potential ET, 5) ETo components, 6) OCO-3 SIF, 7) water usage index. Each step is crucial for accurately estimating GPP and its seasonal variability. The diagram also shows the integration of various datasets and models to improve the accuracy of GPP estimation.

[3.] The L3/L4 data flow methodology provides a robust approach for quantifying GPP globally: 1) meteorology-driven full land surface carbon cycle models [Friedlingstein et al., 2006; Sitch et al., 2008]; and, 2) remote sensing-driven [Zhao and Running, 2010] and/or flux tower-based [Beer et al., 2010; Jung et al., 2011] semi-empirical models focused on GPP or net primary production (NPP). Significant uncertainties related to the first approach are due to differing model sensitivities to meteorological parameters and uncertain global meteorological data sets [Friedlingstein et al., 2006; Sitch et al., 2008]. Uncertainties with the second approach exist because GPP cannot be directly estimated from the remote sensing measurements but is also modeled as a function of leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (FAPAR) or vegetation indices such as the normalized difference or enhanced vegetation index (NDVI, EVI) [Zhao et al., 2011].

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[4.] Overall, the new satellite-based observations provide a comprehensive view of the Earth’s carbon cycle and offer a unique perspective on the role of vegetation in the global carbon cycle. The findings highlight the potential of remote sensing for improving our understanding of the biogeochemical processes that regulate the Earth’s carbon budget.
Nine land surface models were run with only a perturbed climate (i.e., CO$_2$, land use constant) over the 20$\text{th}$ century, representing the $\gamma$-response, or climate sensitivity to identify key WUE uncertainty hotspots.
ECOSTRESS KEY SCIENCE QUESTIONS

1. How is the terrestrial biosphere responding to changes in water availability?

1. How do changes in diurnal vegetation water stress impact the global carbon cycle?

1. Can agricultural vulnerability be reduced through advanced monitoring of agricultural consumptive use and improved drought detection?
ECOSTRESS SCIENCE OBJECTIVES

1. IDENTIFY CRITICAL THRESHOLDS OF WATER USE AND WATER STRESS IN KEY CLIMATE SENSITIVE BIOMES (E.G., TROPICAL/DRY TRANSITION FORESTS, BOREAL FORESTS);

1. DETECT THE TIMING, LOCATION, AND PREDICTIVE FACTORS LEADING TO PLANT WATER UPTAKE DECLINE AND/OR CESSATION OVER THE DIURNAL CYCLE;

1. MEASURE AGRICULTURAL WATER CONSUMPTIVE USE GLOBALLY AT SPATIOTEMPORAL SCALES APPLICABLE TO IMPROVING DROUGHT ESTIMATION ACCURACY.
COMMUNITY INVOLVEMENT

NASA ROSES

APPLIED SCIENCES

EARLY ADOPTERS
ECOSTRESS:

A technology that will help us understand how plants react to our changing planet

Olivia Mansion
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).

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ECOSTRESS AND BEYOND...

- 2017
- → HyspIRI →
- → Landsat/SLI →