Dr. DaNa L. Carlis

"I am interested in climate changes. Satellite data are the only means to monitor the spatial and temporal variations of essential environmental variables from regional to global scales. They are also the critical inputs to numerical models for assessing the impacts of environmental changes as well as the constraints to assist the models with predicting future changes."

— Shunlin Liang, University of Maryland, College Park

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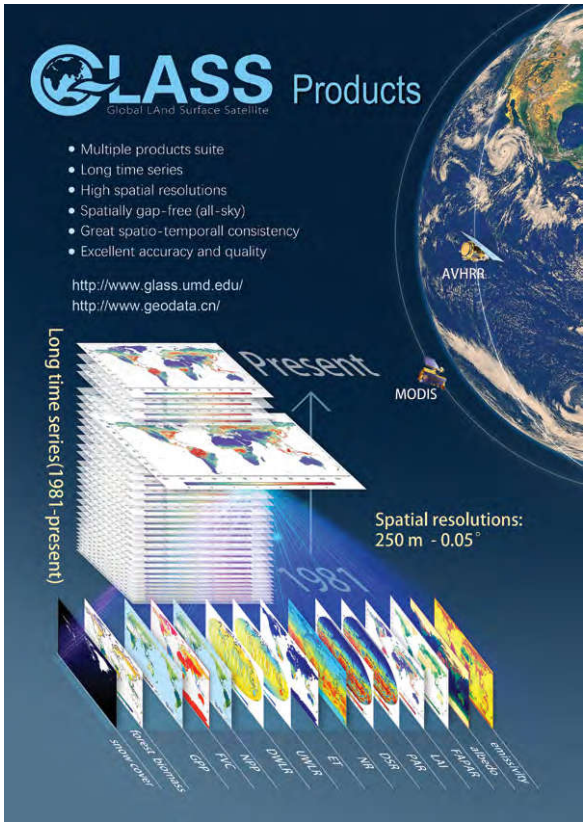
A Touch of Glass

Introducing the High-level Global Land Surface Satellite Products

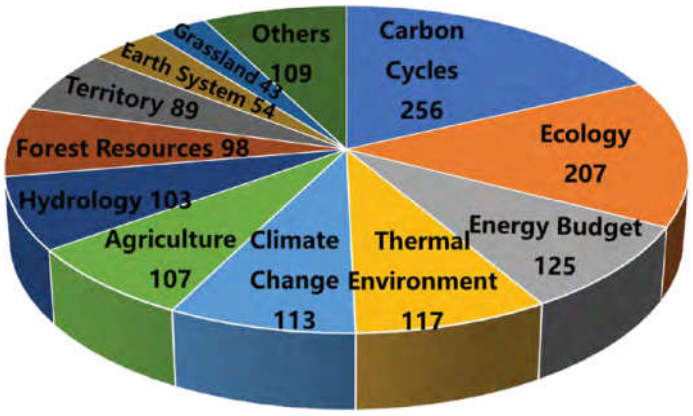
Key messages from "The Global Land Surface Satellite (GLASS) Product Suite," by **Shunlin Liang** (University of Maryland, College Park), **Jie Cheng**, **Kun Jia**, **Bo Jiang**, **Qiang Liu**, **Zhiqiang Xiao**, **Yunjun Yao**, **Wenping Yuan**, **Xiaotong Zhang**, **Xiang Zhao**, and **Ji Zhou**. Published online in *BAMS*, February 2021. For the full, citable article, see https://doi.org/10.1175/BAMS-D-18-0341.1.



A promotional yer for GLASS products.

To better understand, monitor, and predict environmental changes, including climate change, we need access to high-level satellite products of diffe ent environmental variables. The Global Land Surface Satellite (GLASS) products suite includes a set of high-level satellite products of land surface essential variables mainly from Advanced Very High-Resolution Radiometer (AVHRR) and Moderate-Resolution Imaging Spectroradiometer (MODIS) data. The GLASS products are mainly in three categories: surface radiation budget components, ecosystem structure and carbon cycle components, and water cycle and cryosphere components.

Estimating land surface variables from satellite observations is an "ill-posed" inversion problem. For each pixel, the number of multispectral bands is usually smaller than the number of environmental variables, and the values of many spectral bands are highly correlated. Some novel solutions have been proposed to solve the problem of insufficient information in generating reliable GLASS products. We can identify at least four approaches. The first is based on the temporal signature of the satellite observations. The typical example is the MODIS leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (FAPAR) products that are generated using two-year observations simultaneously. The second uses algorithm ensemble. The typical example is the evapotranspiration (ET) product that is based on integration of five estimation algorithms. The third uses multiple satellite observations. For example, the forest aboveground biomass product is based on optical, Lidar, and microwave data products. The last



Application areas of the GLASS products. The numbers indicate the quantity of peer-reviewed papers regarding GLASS products in the Web of Science database.

incorporates the physical model to generate the products, such as the gross primary production (GPP) product.

The GLASS products have several unique features compared to similar products, including the following:

1) Several products are unique, such as the high-resolution (1-km) broadband thermal emissivity and time series forest aboveground biomass products.
2) Most products have long time series (i.e., more than 40 years from 1981 to present), while most other similar global products start from the year 2000, with a time span of approximately 20 years.
3) The products of surface radiation budget components, covering the world's land and ocean surfaces, have a spatial resolution of 5 km (several products are at 1 km over land), which is an order of magnitude higher than other such products in wide use, such as the Global Energy and Water Exchanges (GEWEX), the Clouds and the Earth's Radiant Energy System (CERES), and the International Satellite Cloud Climatology Project (ISCCP), which have spatial resolutions at least 100 km.
4) Several of the long-time-series global products have the highest spatial resolution in the world, such as 250 m for the LAI, FAPAR, and shortwave albedo products and 5 km for snow cover extent. In addition, the all-weather land surface temperature and near-surface air temperature products have a 1-km resolution.
5) GLASS products are of high quality and accuracy.

So far, more than 1.7 PB of GLASS products data have been downloaded, and more than 2,000 peer-reviewed papers based on the GLASS products have been published. Their applications are distributed in many scientific disciplines and societal benefit areas.

The GLASS products can be freely downloaded at www.glass.umd.edu and www.geodata.cn.

METADATA

BAMS: What would you like readers to learn from this article?

Shunlin Liang (University of Maryland, College Park): *The Global Land Surface Satellite (GLASS) products suite of a dozen essential land variables are generated from MODIS and AVHRR satellite observations. The algorithms for generating these products were published in the top remote sensing journals. The GLASS products are spatially continuous with the valid estimates under cloudy conditions and are highly accurate based on extensive validation. Most products span from 1981 to the present and are suitable for long-term environmental change studies. Readers will learn about the algorithms, product characteristics, validation, and some preliminary applications.*

BAMS: How did you become interested in the topic of this article?

SL: *When I started to use satellite data, I had to spend a considerable amount of time and energy converting raw satellite data to high-level products characterizing the physical and biological properties of land surfaces. Every satellite data user is eventually repeating this same process. It would be hugely ef cient if some groups can produce these high-level satellite products and distribute them to the public so that users do not have to do so themselves.*

BAMS: What surprised you the most about the work you document in this article?

SL: *Repeatedly reprocessing. A small error in the algorithm or the computer program will lead to another reproduction.*

BAMS: What was the biggest challenge you encountered while doing this work?

SL: *Producing the global high-level satellite products requires high-performance computing, huge data storage, and adequate nancial support.*

"Now that we know that these monster ashes exist and where/when they occur, we can start to gure out what makes them tick. Detailed measurements with a ground-based Lightning Mapping Array and other radio-frequency lightning data will be instrumental in probing the physics of their extreme lateral development, documenting their associated hazards (i.e., cloud-to-ground strokes), and examining how they interact with the Earth–atmosphere system (for example, the generation of sprites and other types of transient luminous events). As an early-career scientist, I expect to see considerable progress on this topic before I retire—and hopefully even contribute a piece of it."

—Michael Peterson, Los Alamos National Laboratory

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"We will continuously increase the number of GLASS products (almost 20 at present). The current GLASS products have spatial resolutions from 250 meters to 5 kilometers, and we are developing the high-resolution GLASS (Hi-GLASS) products at 30 meters and will of cially distribute them to the public in early 2023."

—Shunlin Liang, University of Maryland, College Park

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