GLASS Products

Global LAnd Surface Satellite

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GLASS Products

Global LAnd Surface Satellite (GLASS) products are the result of over a decade of dedicated research and development. This initiative was supported by three major projects: the "Global Land Surface Parameters Generation and Application" under China's 11th Five-Year Plan (863 Program), the 12th Five-Year Plan (863 Program), and the "Global Climate Dataset Generation and Monitoring of Key Climate Change Processes and Elements" under the 13th Five-Year National Key Research and Development Plan. Constructed under the leadership and overall design of Professor Shunlin Liang, GLASS products have been developing from five initial products (in 2009) to more than a dozen products with improved accuracies and qualities over previous versions of the same products as well as other comparable products.

GLASS products currently contains multiple parameters of carbon cycle, water cycle and radiation budget, including leaf area index(LAI), fraction of absorbed photosynthetically active radiation(FAPAR), fraction vegetation cover(FVC), gross primary production(GPP), net primary production(NPP), broadband albedo, broadband emissivity(BBE), downward shortwave radiation(DSR), photosynthetically active radiation(PAR), land surface temperature(LST), longwave radiation, all-wave net radiation(Rn), evapotranspiration(ET), aboveground biomass (AGB), snow cover extent (SCE) and soil moisture(SM). These products are generated from the Advanced Very High Resolution Radiometer and Moderate Resolution Imaging Spectroradiometer satellite data. Their unique features include long-term temporal coverage (many from 1981 to present), high spatial resolutions of the surface radiation products (250m/500m/1km/0.05°), spatial continuities without missing pixels, and high quality and accuracy based on extensive validation using in situ measurements and intercomparisons with other existing satellite products.

Since its official release in 2012, the GLASS products have been highly recognized by peers globally for their distinct features of high accuracy, long time series, multiple spatial resolutions, and comprehensive global coverage without gaps. Until December 2023, the GLASS products have been downloaded more than 2 PB, serving nearly 300,000 researchers from over 1,000 scientific research institutions, and have produced abundant research results in various scientific fields. Users include not only numerous domestic research institutions and industrial departments but also internationally renowned organizations such as NASA, NOAA, and USDA. More than 3,000 SCI articles have been published using the GLASS products. Research based on the GLASS products has been featured in top international journals such as Nature, Science, and PNAS. The GLASS products have become the preferred mainstream dataset for researchers.

GLASS Products

Table 1 Characteristics of the GLASS products

No.	Product	Temporal range	Temporal resolution	Spatial resolution
1	leaf area index	1981-2022	8 days	250m/500m/1km/0.05°
2	broadband albedo	1981-2022	8 days	250m/500m/1km/0.05°
3	broadband emissivity	1981-2022	8 days	500m/1km/0.05°
4	photosynthetically active radiation	2000-2022	Daily	0.05°
5	downward shortwave radiation	2000-2022	Daily	0.05°
6	longwave radiation	2000-2022	Instantaneous/8 days	1km/0.05°
7	all-wave net radiation	1981-2022	Daily	0.05°
8	land surface temperature	1981-2022	Instantaneous/Daily	1km/0.05°
9	fraction of absorbed photosynthetically active radiation	1981-2022	8 days	250m/500m/1km/0.05°
10	fraction vegetation cover	1981-2022	8 days	500m/0.05°
11	evapotranspiration	1981-2022	8 days	1km/0.05°
12	gross primary production	1981-2022	8 days	500m/1km/0.05°
13	net primary production	1981-2022	8 days	500m/1km/0.05°
14	aboveground biomass	1985-2015	5 years	0.05°
15	snow cover extent	1982-2018	8 days	0.05°
16	soil moisture	2000-2020	Daily	1km

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Liang, S., Zhang, X., Xiao, Z., Cheng, J., Liu, Q., & Zhao, X. (2013b). Global LAnd Surface Satellite (GLASS) products: Algorithms, validation and analysis. Springer

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Leaf Area Index (LAI)

Leaf Area Index (LAI) has true LAI and effective LAI. True LAI is defined as half the total green leaf area per unit of horizontal ground area, while effective LAI is the true LAI multiplied by a clumping index. Most terrestrial numerical models and various applications mainly use true LAI.

Highlight

- The GLASS LAI product is true LAI;
- Highest spatial resolution; better represent the spatial details of the land surface; higher temporal and spatial (no blanks or missing values);
- It has good temporal consistency and accuracy in characterizing vegetation phenology, capturing vegetation disturbance changes, etc.

Major Algorithms

The latest version of the GLASS LAI product (V6) uses a new inversion method: a Bi-directional Long Short-Term Memory (Bi-LSTM) recurrent neural network model. Based on existing high-quality global LAI products, pixels that represent different land covers, different vegetation growth change types, and different satellite observation conditions are selected through cluster analysis. By using the principle of minimum difference, a variety of LAI products are fused to construct time series LAI samples. The Bi-LSTM algorithm model is trained, and finally, 22 years (2000~present) of LAI product data at 250 m and 500 m resolutions are generated.

Quality Assessments

After direct comparison validation with high-resolution reference maps, the accuracy of the products at 250 m and 500 m resolutions is better than other similar products.

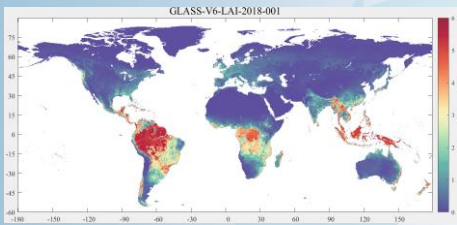

Fig. 1 Global map of GLASS LAI (V6).

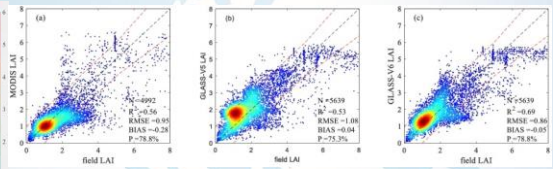

Fig. 2 Direct validation of (a) MODIS LAI, (b) GLASS LAI (V5), and (c) GLASS LAI (V6) product at a 500-m scale

Reference

Ma, H., & Liang, S. (2022). Development of the GLASS 250-m leaf area index product (version 6) from MODIS data using the bidirectional LSTM deep learning model. Remote Sensing of Environment, 273, 112985

Fraction of Absorbed Photosynthetically Active Radiation

Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) represents the proportion of photosynthetically active radiation incident on the top of the vegetation canopy that is absorbed by green vegetation. It is a key biophysical variable directly related to plant photosynthetic activity and is an indicator of the presence and productivity of live vegetation, as well as an indicator of the strength of terrestrial carbon sinks. The GLASS FAPAR product represents the instantaneous value at 10:30 local time, which is an approximation of the daily average.

Highlight

➢ It is consistent with the GLASS LAI product in temporal and spatial distribution.

Major Algorithms

It is derived from satellite data and existing FAPAR and LAI products. Based on high-quality global FAPAR products (MODIS C6, GLASS V5, and PROBA-V V1), it uses the principle of the smallest gap to fuse existing FAPAR products to construct FAPAR time series samples at globally representative sites. The Bi-LSTM model is used to train and obtain the mapping relationship between the time series MODIS reflectance (using only the first two bands of red and near-infrared and angle information), GLASS LAI (V6), and FAPAR sample values, thereby generating a global 250 m spatial resolution FAPAR product.

Quality Assessments

Compared with the existing 300 m and 500 m FAPAR products, the GLASS FAPAR (V6) product has higher accuracy and demonstrates better spatial and temporal consistency.

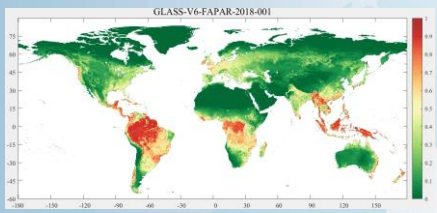

Fig. 1 Global map of GLASS FAPAR (V6).

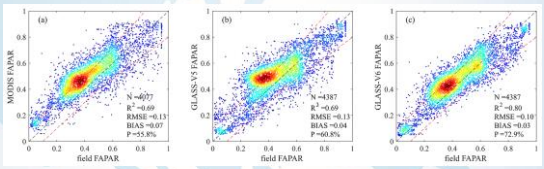

Fig. 2 Direct validation of (a) MODIS FAPAR, (b) GLASS FAPAR (V5), and (c) GLASS FAPAR (V6) product at a 500-m scale

Reference

Ma, H., Liang, S., Xiong, C., Wang, Q., Jia, A., & Li, B. (2022). Global land surface 250 m 8 d fraction of absorbed photosynthetically active radiation (FAPAR) product from 2000 to 2021. Earth System Science Data, 14, 5333-5347

GLASS Albedo

Land surface albedo, as a fundamental variable in determining land surface radiation budget, is defined as integral of surface reflectance in the sun/view hemisphere, and also in broad band wavelength ranges of SW (0.3~3μm), VIS (0.4~0.7μm) or NIR (0.7~3μm).

Highlight

- Global land and sea coverage, gap filled, more than 40 years time series, multiple spatial resolution of 0.05°/500m/250m;
- Special treatment for snow/ice and water surface to boost accuracy in the corresponding area.

Major Algorithms

Albedo is estimated in 2 steps:

1) The AB (angular bin) is direct-estimation algorithm based on 7 prebuild Look-Up Tables, corresponding to vegetation, bare ground, snow/ice, partial covered snow/ice, sea water, coast, mixed sea ice, respectively. It estimates broadband surface albedo from satellite-observed directional narrow band reflectance, and generate preliminary results.

2) The STF (statistics-based Temporal Filtering) is an algorithm which merges the preliminary results from AB algorithm, and fills the remaining gaps based on Bayes theory, so that the final GLASS product is continuous in space and time.

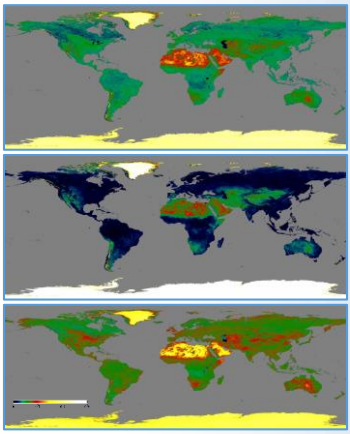

Fig. 1 Global map of GLASS albedo in SW, VIS and NIR bands.

Quality Assessments

The GLASS albedo product has been validated at homogeneous FLUXNET sites around the world, as well as through ground campaigns in China. It is also cross-compared with MODIS MCD43 albedo product. The results indicate that it has similar accuracy as MCD43 albedo product, with the advantages of long term and gapless.

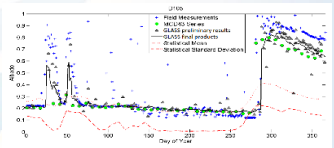

Fig. 2 Comparing GLASS albedo with MCD43 albedo and in situ data in D105 site.

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Liu, N., Liu, Q., et al. (2013). A statistics-based temporal filter algorithm to map spatiotemporally continuous shortwave albedo from MODIS data. Hydrology and Earth System Sciences, 17, 2121-2129

Qu, Y., Liu, Q., Liang, S., et al. (2014). Improved direct-estimation algorithm for mapping daily land-surface broadband albedo from MODIS data. IEEE Transactions on Geoscience and Remote Sensing, 52, 907-919

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Feng, Y., Liu, Q., Qu, Y., & Liang, S. (2016). Estimation of the Ocean Water Albedo From Remote Sensing and Meteorological Reanalysis Data. IEEE Transactions on Geoscience and Remote Sensing, 54, 850-868

Downward Shortwave Radiation (DSR)

The Sun is the only energy source for the climate system. Sunlight, which penetrates the atmosphere and reaches the Earth surfaces, is crucial for life on our planet. The incident shortwave solar radiation (300~3000 nm), also known as insolation, is referred to as total solar irradiance incident at Earth surface, which is an essential parameter in land surface radiation budget and many land surface process models.

Highlight

- GLASS-MODIS and GLASS-AVHRR DSR product is highly consistent, spatially complete, temporally continuous, and long-time.
- The GLASS DSR products are relatively accurate according to the ground measurements.

Major Algorithms

The main idea of this improved algorithm is to establish the relationship between the surface radiation flux and top-of-atmosphere radiance through radiation simulation. The Moderate Resolution Atmospheric Transmission (MODTRAN5) (Anderson et al. 1999) is used to simulate the radiative transfer of solar spectrum. we simulate the radiative transfer with selected aerosol model and cloud type at different view geometries. The downward spectral flux at surface resulting from MODTRAN4 simulation can be integrated from 300nm to 3000nm to calculate surface insolation using MODIS and AVHRR observations.

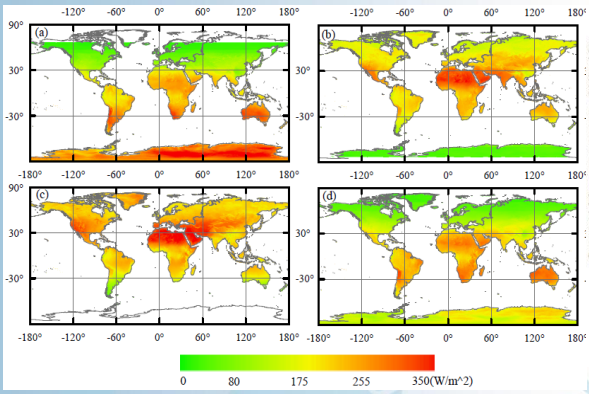

Fig. 1 Three-year (2003-2005) average global land distribution of DSR (in W/m2) at 5km spatial resolution

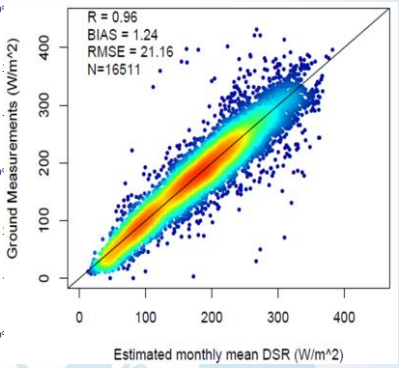

Fig. 2 Validation results of monthly GLASS DSR at more than 500 ground stations.

Reference

Zhang, X., Wang, D., Liu, Q., Yao, Y., Jia, K., He, T., Jiang, B., Wei, Y., Ma, H., Zhao, X., Li, W., & Liang, S. (2019). An Operational Approach for Generating the Global Land Surface Downward Shortwave Radiation Product From MODIS Data. IEEE Transactions on Geoscience and Remote Sensing, 57, 4636-4650

Photosynthetically Active Radiation (PAR)

The visible part (400–700nm) of insolation is called photosynthetically active radiation (PAR). PAR constitutes the basic source of energy for biomass by controlling the photosynthetic rate of organisms on land, thus directly affecting plant growth.

Highlight

- GLASS-MODIS and GLASS-AVHRR PAR product is highly consistent, spatially complete, temporally continuous, and long-time.
- The GLASS PAR products are relatively accurate according to the ground measurements.

Major Algorithms

The main idea of this improved algorithm is to establish the relationship between the surface radiation flux and top-of-atmosphere radiance through radiation simulation. The Moderate Resolution Atmospheric Transmission (MODTRAN5) (Anderson et al. 1999) is used to simulate the radiative transfer of solar spectrum. we simulate the radiative transfer with selected aerosol model and cloud type at different view geometries. The downward spectral flux at surface resulting from MODTRAN5 simulation can be integrated from 400nm to 700nm to calculate PAR using MODIS and AVHRR observations.

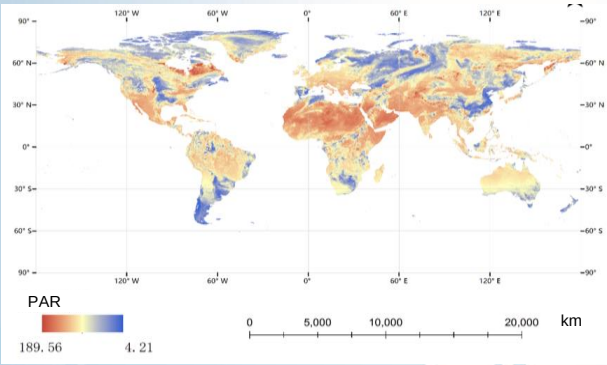

Fig. 1 The estimated GLASS daily mean PAR from MODIS observation on the Julian day 111 of 2011.

References

Zhang, X., Liang, S., Zhou, G., Wu, H., & Zhao, X. (2014). Generating Global Land Surface Satellite incident shortwave radiation and photosynthetically active radiation products from multiple satellite data. Remote Sensing of Environment, 152, 318-332

Zhang, X., Wang, D., Liu, Q., Yao, Y., Jia, K., He, T., Jiang, B., Wei, Y., Ma, H., Zhao, X., Li, W., & Liang, S. (2019). An Operational Approach for Generating the Global Land Surface Downward Shortwave Radiation Product From MODIS Data. IEEE Transactions on Geoscience and Remote Sensing, 57, 4636-4650

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Surface Longwave Radiation (GLASS-AVHRR)

Surface longwave radiation (SLR) is the electromagnetic radiation emitted by the surface, atmosphere, and clouds at wavelengths between 3 and 100 μm. It includes three components, namely downward, upward, and net longwave radiation.

Highlight

- GLASS-AVHRR SLR product is highly consistent, spatially complete, temporally continuous, and long-time.
- The accuracy of GLASS-AVHRR SLR product is superior to those of ERA5 and CERES SLR products, especially for DLR and NLR.

Major Algorithms

GLASS-AVHRR SLR product is retrieved from the AVHRR TOA shortwave and thermal radiances and ERA5 near-surface meteorological parameters using hybrid deep neural networks. The networks consist of densely connected convolutional neural network blocks and long short-term memory network blocks to exploit the spatiotemporal variations of SLR.

Quality Assessments

GLASS-AVHRR SLR product has been validated at globally distributed sites. It is also cross-compared with CERES, ERA5, and GLASS-MODIS SLR products. The results demonstrate that it has better accuracy than the other three products, with the advantages of higher spatial resolution, longer periods, and gapless.

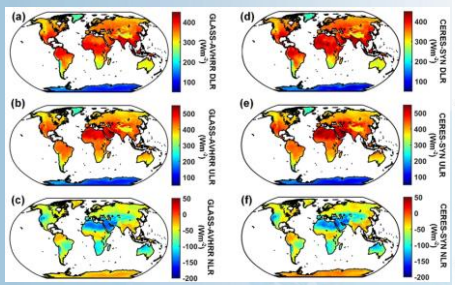

Fig. 1 Global SLR distributions in July, 2008 from GLASS-AVHRR product

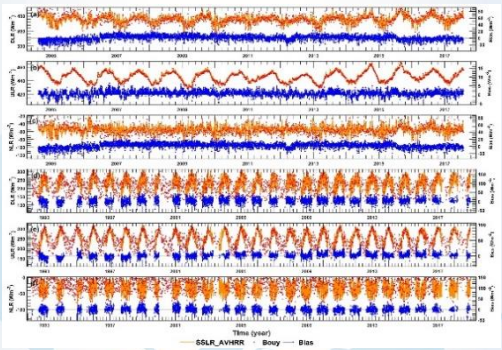

Fig. 2 Time series of GLASS-AVHRR SLR product and measurements at OS_WHOTS (22.75°N, 158°W) and (d-f) BSRN_GVN (70.65°S, 8.25°W) sites.

References

Xu, J., Liang, S., Ma, H., & He, T. (2022). Generating 5 km resolution 1981–2018 daily global land surface longwave radiation products from AVHRR shortwave and longwave observations using densely connected convolutional neural networks. Remote Sensing of Environment, 280, 113223

Xu, J., Liang, S., Ma, H., He, T., Zhang, Y., & Zhang, G. (2023). A daily 5-km all-sky sea-surface longwave radiation product based on statistically modified deep neural network and spatiotemporal analysis for 1981–2018. Remote Sensing of Environment, 290, 113550

Net Radiation (Rn)

Land surface all-wave net radiation (Rn), characterizing the available radiative energy at the Earth's surface and usually called surface radiation budget, is the difference between total upward and downward radiation. Rn controls the energy and water exchanges between the biosphere and the atmosphere, and has a major influence on the Earth's weather and climate.

Highlights

- The GLASS Rn products including GLASS-MODIS (2000-present) and GLASS-AVHRR (1982-2018), currently offer long-term land surface daily Rn products with the highest spatial resolution (5km).
- The two satellite-based GLASS Rn products performed superiority to most existing products, especially GLASS-MODIS.

Major Algorithms

At low-mid latitudes, GLASS Rn was produced by the DSR-based algorithm.

For high latitudes, GLASS-MODIS was produced by the LRD algorithm, while GLASS-AVHRR was filled with the corrected ERA5.

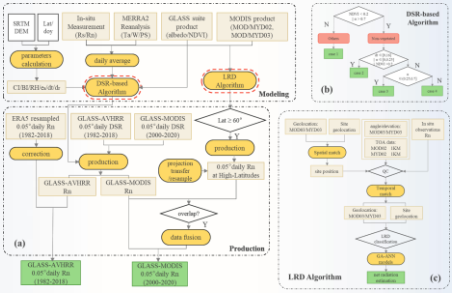

Fig. 1 Flowchart of GLASS daily Rn product generation.

Quality Assessments

The GLASS Rn products have been validated against the measurements from 584 sites in 26 measurement networks around the world and compared to other current Rn products at daily scale. The results shown in the Table indicated that the GLASS Rn is more accurate, robust and spatio-temporal consistent.

Product	Spatial resolution	Time Range	R^2	RMSE (Wm^{-2})	Bias (Wm^{-2})
GLASS-MODIS	5km	2000-2018	0.88	25.54	−1.26
GLASS-AVHRR	5km	1983-2018	0.79	33.08	3.48
		2000-2018	0.80	33.10	4.03
ERA5	0.25°	1983-2018	0.80	31.70	−4.56
		2000-2018	0.80	32.17	−4.88
CERES4A	1°	2000-2018	0.76	35.49	3.50
MERRA2	0.5°×0.625°	1983-2018	0.74	37.40	1.69
		2000-2018	0.76	37.61	1.04

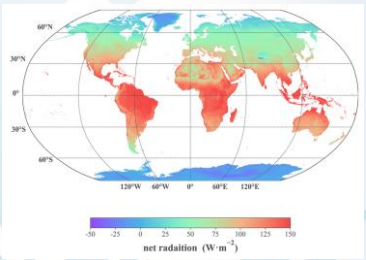

Fig. 2 Multi-annual average of GLASS-AVHRR Rn

References

Jiang, B., Liang, S.L., Jia, A.L., Xu, J.L., Zhang, X.T., Xiao, Z.Q., Zhao, X., Jia, K., & Yao, Y.J. (2019). Validation of the Surface Daytime Net Radiation Product From Version 4.0 GLASS Product Suite. IEEE Geoscience and Remote Sensing Letters, 16, 509-513

Jiang, B., Liang, S.L., Ma, H., Zhang, X.T., Xiao, Z.Q., Zhao, X., Jia, K., Yao, Y.J., & Jia, A.L. (2016). GLASS daytime all-wave net radiation product: algorithm development and preliminary validation. Remote Sensing, 8, 17

Yin, X., Jiang, B., Liang, S., Li, S., Zhao, X., Wang, Q., Xu, J., Han, J., Liang, H., Zhang, X., Liu, Q., Yao, Y., Jia, K., & Xie, X. (2023). Significant discrepancies of land surface daily net radiation among ten remotely sensed and reanalysis products. International Journal of Digital Earth, 16, 3726-3753

Land Surface Temperature (GLASS-AVHRR LST)

Land surface temperature (LST), the thermodynamic temperature of a thin layer in the interface between surface components and the atmosphere, is an important parameter for energy balance at regional as well as global scales.

Highlight

- GLASS-AVHRR LST product offers an extensive historical record spanning over 40 years.
- GLASS-AVHRR LST product includes an orbit-drift-corrected version, addressing a widespread challenge associated with AVHRR data.

Major Algorithms

GLASS LST product was derived using a non-linear generalized split-window (GSW) algorithm which improves the accuracy of GSW algorithm in wet and hot atmospheric conditions. Furthermore, a novel orbit drift correction (ODC) algorithm, based on diurnal temperature cycle (DTC) model and Bayesian optimization algorithm, was also proposed to normalize estimated LST to the same local time (14:30 local solar time).

Quality Assessments

The GLASS LST product has been validated at six SURFRAD sites, showing that the average accuracies of LST estimation varied from -0.4 K to 2.0 K and the RMSE variations introduced by ODC were within ±0.5 K.

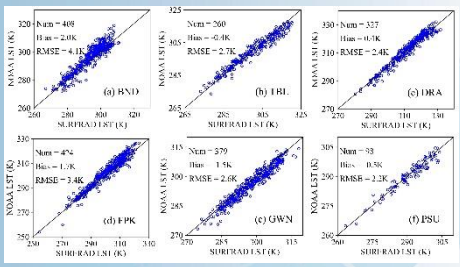

Fig. 1 Scatterplots of retrieved NOAA-14 LST versus in-situ SURFRAD LST for all matched days over (a) DRA, (b) TBL, (c) DRA, (d) FPK, (e) GWN, and (f) PSU.

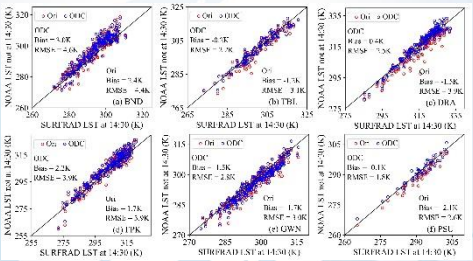

Fig. 2 The result of orbit drift correction over (a) DRA, (b) TBL, (c) DRA, (d) FPK, (e) GWN, and (f) PSU.

Reference

Liu, X., Tang, B., Yan, G., Li, Z., & Liang, S. (2019). Retrieval of Global Orbit Drift Corrected Land Surface Temperature from Long-term AVHRR Data, Remote Sensing, 11, 2843.

Land Surface Temperature (GLASS-AVHRR LST)

Land surface temperature (LST) is one of the most important parameter for energy exchange between Earth's surface and the atmosphere. It has been widely used in research and applications of land surface processes and models.

Highlight

- GLASS-AVHRR LST product integrates several classical LST retrieval algorithms through machine learning method, its accuracy has been significantly improved.
- GLASS-AVHRR LST product is highly consistent, complete, and temporally continuous since 1981.

Major Algorithms

GLASS-AVHRR LST product was generated from LTDR AVHRR thermal infrared data using the random forest method. The random forest method was used to integrate serval classical split-window algorithms, which were refined with the radiation transfer dataset based on the simulation with a global atmospheric profile dataset.

Quality Assessments

GLASS-AVHRR LST product has been validated against *in-situ* LST from SURFRAD, and globally distributed LSWT from NDBC. The result shows that the LST product achieved a good accuracy.

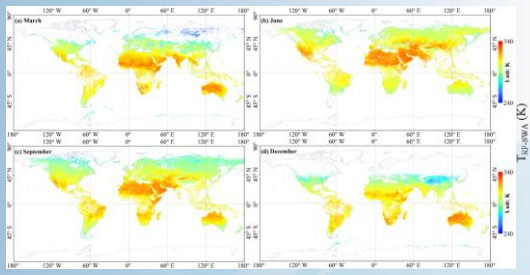

Fig 1 Monthly averaged LST retrieved from NOAA 14 AVHRR for 1999 : (a) March; (c) June; (c) September; (d) December.

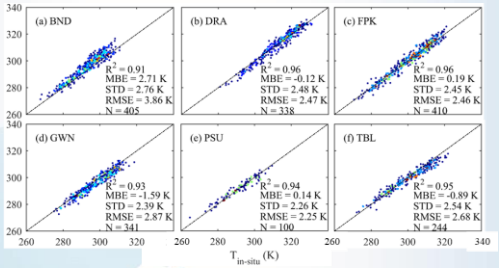

Fig 2 the retrieved LST plotted against *in-situ* LST from six SURFRAD sites

References

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Ma, J., Zhou, J., Göttsche, F.M., Liang, S., Wang, S., & Li, M. (2020). A global long-term (1981–2000) land surface temperature product for NOAA AVHRR. Earth System Science Data, 12, 3247-3268

Land Surface Temperature (GLASS-MODIS LST)

Land Surface Temperature (LST) characterizes the radiative temperature of the land surface, which is a key parameter in the land surface process and plays an important role in the energy interaction between the land surface and the atmosphere.

Highlight

- GLASS LST product provides high precision, long time series, and spatio-temporal seamless data.
- GLASS LST product has multiple time scales, comprising instantaneous LST as well as daily average LST data, catering to diverse application requirements.

Major Algorithms

GLASS LST product is developed based on multi-source data, including MODIS observation data, model data, other satellite products （e.g. LWDN, DSR, albedo, LAI), angle information, and in-situ measurements, etc., utilizing machine learning algorithms to achieve spatio-temporal continuous,all-weather instantaneous and daily average LST estimation at global scale, with a spatial resolution of 1 km.

Quality Assessments

GLASS LST product is similar to the official MODIS LST products in terms of spatial distribution pattern and verification accuracy, but GLASS LST fill in the missing pixels of MODIS products and correct the LST outliers caused by cloud misjudging pixels, especially in high-latitude areas.

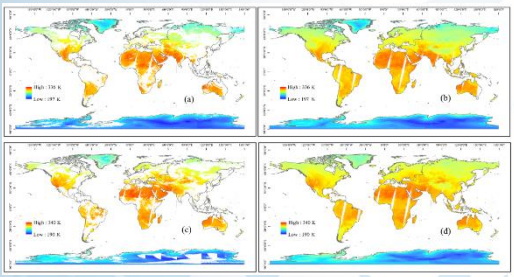

Fig. 1 Spatial patterns of MODIS LST (a, c) and estimated instantaneous LST (b, d) at a global scale on the Days 90 and 270 of 2010.

References

Li, B., Liang, S., Liu, X., Ma, H., Chen, Y., Liang, T., & He, T. (2021). Estimation of all-sky 1 km land surface temperature over the conterminous United States. Remote Sensing of Environment, 266, 112707

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Fractional Vegetation Cover (FVC)

Land Surface fractional vegetation cover (FVC) refers to the fraction of green vegetation as seen from nadir in the total statistical area. FVC is an important vegetation parameter that characterizes the vegetation coverage status of the Earth's surface and plays a key role in global change research, land surface process simulation, and hydro-ecological modeling.

Highlight

➢The GLASS FVC estimation method is developed based on globally distributed high spatial resolution samples

➢GLASS FVC product is complete spatially and temporally continuous, and the validation accuracy is superior to the traditional satellite-based FVC product

Major Algorithms

GLASS FVC product was generated using the multivariate adaptive regression splines (MARS) algorithm, which was trained based on globally distributed high spatial resolution samples extracted using Landsat data. The GLASS FVC product has an 8-day temporal resolution, and 500 m and 0.05° spatial resolution after and before the year 2000, respectively.

Quality Assessments

The GLASS FVC product has been validated with global distributed sample data and time series ground measured FVC data in Heihe agriculture regions of China for the whole growth periods of corn. It is also compared with GEOV1 global FVC product.

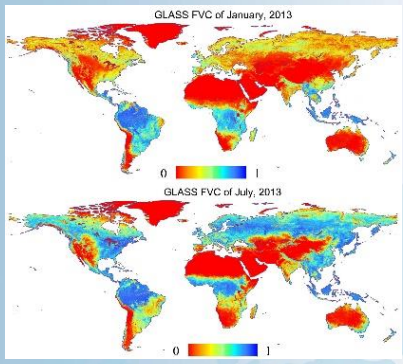

Fig 1. Monthly averaged global FVC maps in January and July of 2003

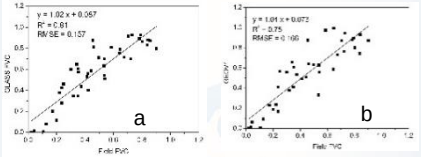

Fig 2. Validation of GLASS FVC (a) and GEOV1 FVC (b) with global distributed sample data

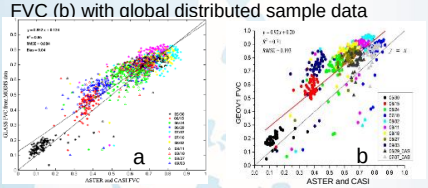

Fig 3.Validation of GLASS FVC (a) and GEOV1 FVC (b) in Heihe Agricultural Area

References

Jia K., Liang S., Liu S.,et al. (2015). Global land surface fractional vegetation cover estimation using general regression neural networks from MODIS surface reflectance. IEEE Transactions on Geoscience and Remote Sensing, 53(9), 4787-4796

Jia K., Liang S., Gu X., et al. (2016). Fractional vegetation cover estimation algorithm for Chinese GF-1 wide field view data. Remote Sensing of Environment, 177, 184-191

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Evapotranspiration (ET)

Evapotranspiration (ET), the loss of water from the Earth's surface to the atmosphere from soil evaporation, water bodies evaporation, canopy interception evaporation and vegetation transpiration, is a major component of the surface energy budget and water cycle.

Highlight

- GLASS ET product merges five traditional satellite-based ET products using deep neural networks (DNN) method.
- GLASS ET product is highly consistent, complete, and temporally continuous. The accuracy of GLASS ET product is superior to five traditional satellite-based ET product for different land cover types .

Major Algorithms

GLASS ET product version 5.0 was generated based on the DNN method, which merges five traditional satellite-based ET products [Moderate Resolution Imaging Spectroradiometer (MODIS) ET product (MOD16), Shuttleworth–Wallace dual-source ET product (SW), Priestley–Taylor-based ET product (PT-JPL), modified satellite-based Priestley–Taylor ET product (MS-PT) and simple hybrid ET product (SIM)] with a daily temporal resolution and 1 km spatial resolution.

Quality Assessments

The GLASS ET product has been validated at FLUXNET sites around world. It is also compared with FLUXCOM and MOD16A2 ET product.

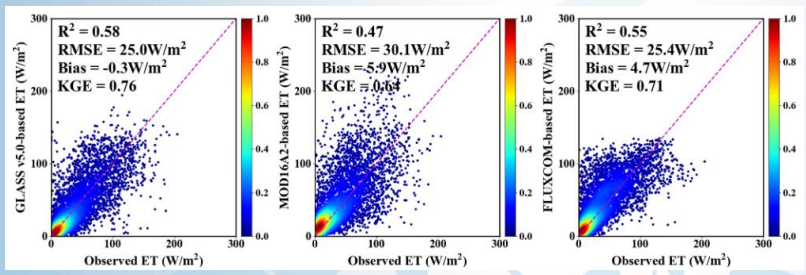


Fig 1. Validation of GLASS ET product v5.0, MOD16A2 ET product and FLUXCOM ET product based on EC observations at 63 validation flux tower sites.

Reference

Xie, Z., Yao, Y., Zhang, X., Liang, S., Fisher, J.B., Chen, J., Jia, K., Shang, K., Yang, J., Yu, R., Guo, X., Liu, L., Ning, J., & Zhang, L. (2022). The Global LAnd Surface Satellite (GLASS) evapotranspiration product Version 5.0: Algorithm development and preliminary validation. Journal of Hydrology, 610, 127990

Gross Primary Production (GPP)
Net Primary Production (NPP)

The gross primary production (GPP) is the total amount of plant photosynthesis by absorbing the CO_2 from atmosphere. The net primary production (NPP) is the GPP minus the plant autotrophic respiration.

Highlight

- The version of rEC-LUE model, incorporated the atmospheric CO_2 concentration, direct and diffuse radiation and VPD, which can reproduce the long-term change of GPP.
- The rEC-LUE model has been validated by the eddy covariance tower based carbon flux data at North America, Europe and East Asia, which characterized the spatio-temporal change of GPP.

Major Algorithms

In order to accurately simulate the long-term change of GPP, GLASS GPP products use the latest version of the rEC-LUE model, focused on the incorporation of several environmental variables including atmospheric CO_2 concentration, direct and diffuse radiation, and vapor pressure deficit, which affects the long-term trend of GPP. The GLASS NPP, generated from GLASS GPP multiply the ratio of plant autotrophic respiration to GPP from 10 dynamic vegetation models (TRENDY model)

Quality Assessments

The GLASS-GPP has good performance according to accuracy assessment based on global GPP observations.

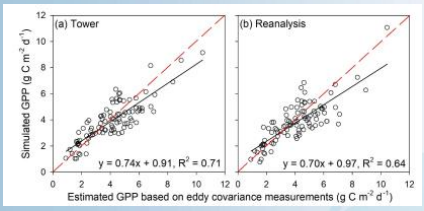
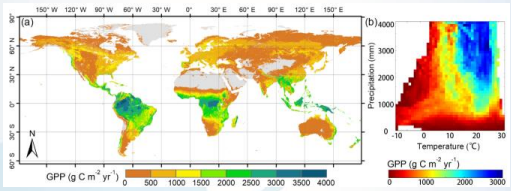


Fig.1 Accuracy validation based on GPP estimated from EC towers. The modeled GPP values were simulated using **(a)** tower derived meteorology and **(b)** global reanalysis meteorology.



Spatial pattern of global GPP simulated by the revised EC-LUE model during 1982–2017: **(a)** averaged annual GPP; **(b)** averaged annual GPP at different temperature and precipitation gradients.

References

Yuan, W., Liu, S., et al. (2010). Global estimates of evapotranspiration and gross primary production based on MODIS and global meteorology data. Remote Sensing of Environment, 114, 1416-1431

Yuan, W., Cai, W., et al. (2014). Global comparison of light use efficiency models for simulating terrestrial vegetation gross primary production based on the LaThuile database. Agricultural and Forest Meteorology, 192-193, 108-120

Zheng, Y., Shen, R., Wang, Y., Li, X., Liu, S., Liang, S., Chen, J.M., Ju, W., Zhang, L., & Yuan, W. (2020). Improved estimate of global gross primary production for reproducing its long-term variation, 1982–2017. Earth Syst. Sci. Data, 12, 2725-2746

Global Aboveground Biomass (AGB)

Aboveground biomass (AGB) is defined as the dry mass of living vegetation above the soil including stem, stump, branches, bark, seeds, and foliage, typically expressed as a per area density (e.g. Mg ha^{-1}).

Highlight

➢ GLASS AGB product integrates GLASS GPP, Albedo, FVC and FAPAR products.

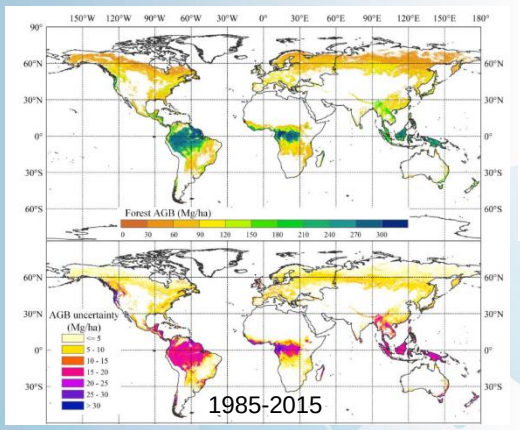
➢ GLASS AGB product has a long temporal coverage and is spatiotemporally continuous.

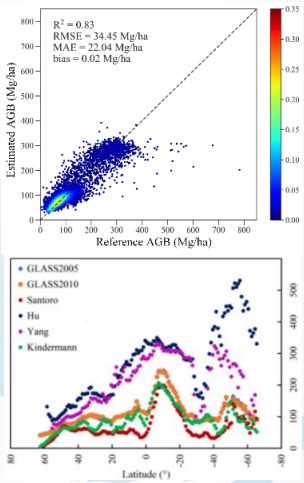
Major Algorithms

The GLASS AGB product (version 1.0) was generated based on ensemble machine learning algorithms, with training data compiled from field measurements, LiDAR-derived AGB, and some high resolution biomass maps. Predictor variables were derived from GLASS GPP, Albedo, FVC, and FAPAR, as well as VOD and slope data.

Quality Assessments

The GLASS AGB product has been evaluated by cross-validation and comparison with several global forest AGB maps.





References

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Snow Cover Extent (SCE)

Snow cover extent (SCE) refers to the extent of land covered by snow at any given time. Snow cover is vital for Earth climate system due to its high surface albedo, heat insulation, and contribution to soil moisture and runoff.

Highlight

- GLASS-AVHRR SCE is highly consistent, spatially complete, temporally continuous, and long-time
- the cross-comparisons between GLASS-AVHRR SCE and CLARA-A2-SAL for the period 1982–2018 ($r = 0.76$, $p < 0.05$) demonstrates that the reliability of GLASS-AVHRR SCE are reliable in climate change studies.

Major Algorithms

The algorithm of GLASS-AVHRR SCE consists five steps：First, by using the quality control flag, gridcells with valid observations were chosen from AVHRR-SR CDR. Second, the cloud detection was carried out to distinguish cloud cover with other land surface types. Third, the daily SCE (NHSCE-D) was retrieved by using a decision tree approach. Fourth, the NHSCE-D were combined with JASMES-GHR and ESA Snow-CCI SCFG to generate a daily combined SCE (HSCE-Dc). Fifth, the NHSCE-Dc was aggregated to produce an 8-day maximum SCE (NHSCE-8Dc). Finally, remaining gaps in NHSCE-8Dc were filled by using the snow cover probability to generate a spatial complete GLASS-AVHRR SCE .

Quality Assessments

GLASS-AVHRR SCE has the advantages of long time series, high spatial resolution, complete spatial coverage, compared with NOAA NHSSCE、Suomi-NPP, and MODIS.

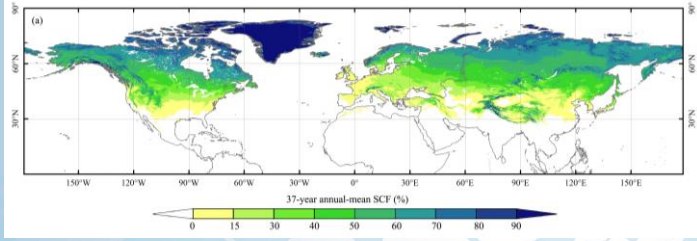

Fig.1 Distribution of 37-year annual-mean snow cover fraction (%) across the NH calculated from GLASS SCE from September 1981 to August 2019 (without 1994)

References

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https://doi.org/10.5281/zenodo.5775238

GLASS Soil Moisture (SM)

Soil moisture (SM) typically refers to the water stored in the unsaturated soil zone. As an essential climate variable specified by the Global Climate Observing System, it plays a critical role in terrestrial water, energy, and carbon cycles.

A long-term consistent SM product can benefit climate change-related studies, hydrological modeling, disaster monitoring and agricultural applications at both regional and global scales.

Highlight

➢ A long-term global SM product (GLASS SM) with reliable accuracy and high spatiotemporal resolution (1 km, daily)

Major Algorithms

The global 1-km, daily GLASS SM product is generated using an XGBoost machine learning model that integrates multi-source datasets, including albedo, LST, LAI from the GLASS product suit, as well as the ERA5-Land reanalysis product, MERIT DEM and SoilGrids datasets.

Quality Assessments

The GLASS SM product has been validated across independent dense SM networks and intercompared with microwave SM products. The results indicate that it can well capture the temporal dynamics of measured SM, and exhibits high spatiotemporal consistency with microwave SM products while maintaining a more complete spatial coverage.

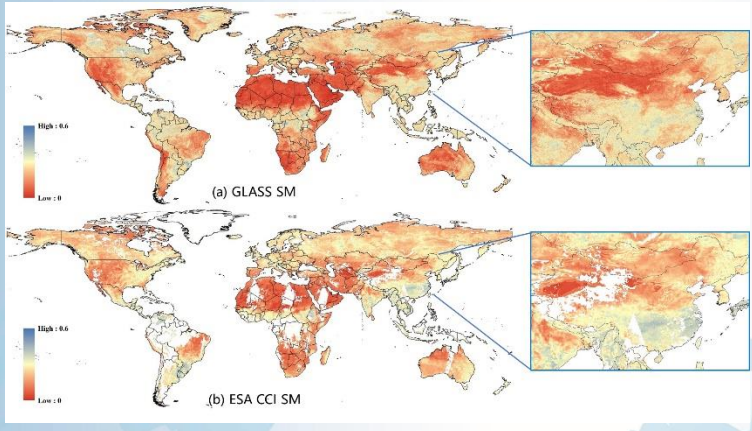

Fig. 1 Comparison between the (a) 1-km GLASS SM and (b) 25-km ESA CCI combined SM products on the 180th day of 2016

Reference

Zhang, Y., Liang, S., Ma, H., He, T., Wang, Q., Li, B., Xu, J., Zhang, G., Liu, X., & Xiong, C. (2023). Generation of global 1km daily soil moisture product from 2000 to 2020 using ensemble learning. Earth System Science Data, 15, 2055-2079

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