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Dataset Development of Yearly Phenological Parameters During Vegetation Growing Season in Northern Hemisphere based on Fengyun Satellites Images (2011–2019)

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Abstract: The vegetation growing season serves as a sensitive indicator of terrestrial ecosystem responses to climate change. Accurate monitoring of its key parameters is crucial for understanding vegetation-environment interactions, assessing carbon sink capacity, and evaluating the ecological impacts of global climate change. The yearly phenological parameters during the vegetation growing season in the Northern Hemisphere from Fengyun Satellites (from 2011 to 2019) were developed using a double-baseline dynamic threshold method, integrated with long-term NDVI time series data from Fengyun-3B satellite. The phenological parameters are the start date, end date, and length of the growing season. The dataset includes: (1) yearly vegetation growing season phenological parameters from 2011 to 2019; (2) multi-year average growing season phenological parameters. It has a spatial resolution of 0.05°. The dataset is archived in .tif data format, and consists of 30 data files with data size of 652 MB (compressed into one single file with 102 MB).

Keywords: Northern Hemisphere; vegetation growing season; Fengyun satellite; dynamic threshold method

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2025.12.05.V1.

1 Introduction

Vegetation phenology refers to the annual seasonal phenomena exhibited by plants during

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their growth process, influenced by the combined effects of climate and surrounding environmental factors such as temperature, precipitation, soil conditions, and human activities. It manifests as a cyclical process of vegetation transitioning from dormancy to growth, senescence, and back to dormancy[1]. As a sensitive indicator of terrestrial ecosystem responses to global climate change, the vegetation growing season phenology not only directly reflects the interaction mechanisms between vegetation and the environment but also serves as a critical biological indicator of ecosystem carbon and water cycles and energy balance[2]. Therefore, accurate monitoring of vegetation growing season phenological parameters (such as the start and end dates of the growing season) is essential for assessing ecosystem carbon sink functions and uncovering the pathways through which climate change impacts the biosphere[3].

Remote sensing technology, with its capacity for continuous and large-scale vegetation spectral monitoring, has become a crucial means for achieving large-scale, long-term time series vegetation phenology retrieval. For global and hemispheric scale studies, commonly used data sources include the SPOT-VGT sensor[4], Terra/Aqua Moderate Resolution Imaging Spectroradiometer (MODIS)[5], and the NOAA Advanced Very High Resolution Radiometer (AVHRR)[6]. At regional and local scales, the application of Landsat, Sentinel-2, and spatiotemporally fused data is more widespread. Currently, phenology extraction algorithms based on biophysical characteristics such as the Normalized Difference Vegetation Index (NDVI) are widely employed to derive phenological parameters including the start and end of the growing season.

The Fengyun-3 (FY-3) series, as China's second-generation polar-orbiting meteorological satellites, is equipped with the Visible Infrared Imaging Radiometer (VIRR), enabling the acquisition of global, all-weather remote sensing data. Among them, FY-3B an operational satellite inheriting and enhancing all core payloads from its predecessor has demonstrated significant efficacy in meteorological and oceanic applications, including sea surface temperature retrieval[7], soil moisture monitoring[8], and snow cover identification[9], since it became operational in 2011. However, its potential in terrestrial ecosystems, particularly for extracting vegetation phenological parameters, remains underexplored and inadequately validated, thus restricting the in-depth application of domestic satellite data in ecological remote sensing.

The Gross Primary Productivity (GPP), as the largest CO_2 flux in the global carbon cycle and closely linked to vegetation photosynthesis, has become an important reference for validating remotely sensed phenology results in recent years. Based on FY-3B satellite data (2011–2019), this study reconstructs vegetation index time series by integrating Hampel and Savitzky-Golay filters, and proposes an improved double-baseline dynamic threshold algorithm to systematically extract key phenological parameters across the Northern Hemisphere. Then authors use FLUXNET site-based GPP observations to validate the accuracy of the extracted vegetation phenological parameters in the Northern Hemisphere. The research aims to evaluate the potential of Fengyun satellites in vegetation phenology monitoring. Through comparative analysis with MODIS phenological products (MCD12Q2)[10], it reveals the spatiotemporal patterns and interannual variation characteristics of vegetation growing season phenological parameters in the Northern Hemisphere from 2011 to 2019, thereby providing a scientific basis for expanding the application of FY satellites in terrestrial ecosystem dynamic monitoring.

2 Metadata of the Dataset

The metadata of Yearly phenological parameters during vegetation growing season in Northern Hemisphere based on Fengyun satellites images (2011–2019)[11] dataset is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

Table 1 Metadata summary of the Yearly phenological parameters during vegetation growing season in Northern Hemisphere based on Fengyun satellites images (2011–2019)

Items	Description
Dataset full name	Yearly phenological parameters during vegetation growing season in Northern Hemisphere based on Fengyun satellites images (2011–2019)
Dataset short name	FY_GS_2011-2019
Authors	Wang, N., Aerospace Information Research Institute, Chinese Academy of Sciences, China University of Geosciences, wangning981229@163.com Wu, L., China University of Geosciences, wuling@cugb.edu.cn Jiao, Q. J., Aerospace Information Research Institute, Chinese Academy of Sciences, jiaoqj@aircas.ac.cn Huang, W. J., Aerospace Information Research Institute, Chinese Academy of Sciences, University of Chinese Academy of Sciences, huangwj@aircas.ac.cn Zhang, B., Aerospace Information Research Institute, Chinese Academy of Sciences, University of Chinese Academy of Sciences, zhangbing@aircas.ac.cn
Geographical region	0°N–90°N, –180°–180°
Year	2011–2019
Temporal resolution	Year
Spatial resolution	0.05°×0.05°
Data format	.tif
Data size	652 MB
Data files	Yearly vegetation growing season phenological parameters from 2011 to 2019; Multi-year average growing season phenological parameters
Foundations	Fengyun Application Pioneering Project of China Meteorological Administration (FY-APP); National Natural Science Foundation of China (42071330)
Data computing environment	Matlab 2021b
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the "ten percent principle" should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[12]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC, OARL

3 Methods

This dataset was primarily derived from the FY-3B VIRR NDVI product[13], which features a spatial resolution of 0.05°and a temporal resolution of 1 year. The data were acquired from the Fengyun Satellite Remote Sensing Data Service System of the National Meteorological

Center of China[1], covering the period from 2011 to 2019.

3.1 Algorithm

(1) Hampel filtering

The FY-3B NDVI data were first processed using Hampel filtering[14] to replace outliers. The core principle of the Hampel filter is to perform local anomaly detection for each data point using the median and median absolute deviation (MAD), and replace identified outliers. This approach effectively suppresses the influence of outliers while preserving the main characteristics of the signal.

(2) Savitzky-Golay filtering

This dataset employs the Savitzky-Golay (S-G) filter[15] method to fit the NDVI time series data. The S-G filter can maximally preserve the original shape of the curve and avoid over-smoothing. The calculation method of S-G filtering is as follows:

$$Y_j^* = \frac{\sum_{i=-m}^{i=m} C_i Y_{j+1}}{2m+1} \tag{1}$$

where Y denotes the original NDVI value, Y_j^* represents the smoothed NDVI, C_i refers to the filter coefficients, Y_{j+1} corresponds to the NDVI value of the j image within the sliding window, and $2m+1$ indicates the width of the sliding window. i represents the relative position within the sliding window, m is the half-width of the window.

(3) Double-baseline dynamic threshold method

Phenological parameter extraction commonly employs the dynamic threshold method[16]. This method calculates a single minimum vegetation index value for the entire year to identify all phenological parameters. However, it overlooks the fact that in practice, the background signals before and after the vegetation growing season (spring and autumn) are not identical. This discrepancy arises due to annual variations in factors such as residual green vegetation growth conditions, key temperature and precipitation patterns, snow cover, and soil moisture during the period corresponding to the minimum vegetation index value[17]. Therefore, this study proposes an improved double-baseline dynamic threshold method. Based on the distinct temporal changes in NDVI during vegetation green-up and senescence phases, the thresholds for the start and end of the growing season are calculated using their respective minimum values and amplitudes. Specifically, for the start of the growing season, the minimum NDVI value during the green-up phase is selected to calculate the amplitude and determine the start of the growing season (SOS). For the end of the growing season, the minimum NDVI value during the senescence phase is used to calculate the amplitude and determine the end of the growing season (EOS). The difference between the two gives the length of the growing season (LOS). In this study, the relative NDVI threshold is set at 40%, and the calculation formula is as follows:

$$NDVI_{ratio} = \frac{\left(NDVI_{t1} - NDVI_{S-Min}\right)}{\left(NDVI_{Max} - NDVI_{S-Min}\right)} \tag{2}$$

$$NDVI_{ratio} = \frac{\left(NDVI_{t2} - NDVI_{E-Min}\right)}{\left(NDVI_{Max} - NDVI_{E-Min}\right)} \tag{3}$$

where $NDVI_{ratio}$ denotes the threshold ratio, $NDVI_{t1}$ and $NDVI_{t2}$ represent the NDVI

[1] https://satellite.nsmc.org.cn/DataPortal/cn/home/index.html.

value during the periods from green-up to the growth peak $t1$ and from the growth peak to senescence $t2$, $NDVI_{Max}$ is the maximum annual NDVI value at the growth peak, $NDVI_{S-Min}$ / $NDVI_{E-Min}$ refer to the minimum NDVI values during the annual rising/falling phases, the differences between $NDVI_{Max}$ and $NDVI_{S-Min}$ / $NDVI_{E-Min}$ represent the amplitude of NDVI variation during vegetation growth and senescence phases, respectively, and t is the Julian day (d).

(4) Trend analysis

The Theil-Sen (TS) estimator and Mann-Kendall (MK) test, two non-parametric methods, were employed to investigate the spatiotemporal trends of vegetation growing season phenological parameters in the Northern Hemisphere[18]. The TS estimator was used to analyze the trend in time series data, while the MK test was applied to assess the significance of detected changes. Both methods offer strong resistance to noise and do not require the data to follow any specific distribution.

3.2 Technical Route

The dataset development process primarily involved 3 key steps: reconstruction of vegetation index time series, extraction of growing season phenological parameters, and analysis of their spatiotemporal trends (Figure 1).

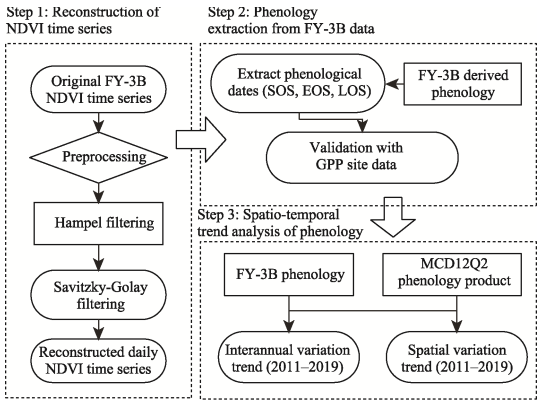


Figure 1 Flowchart of the dataset development

The raw data underwent initial preprocessing, during which pixels with NDVI values below 0.2 were removed, as such low-value areas typically represent non-vegetated regions[19]. To mitigate the impact of noise on the NDVI time series, the data were then interpolated and reconstructed. Specifically, Hampel filtering was applied for preliminary denoising to identify and replace outliers with the median value within the moving window. This step effectively suppressed the influence of outliers while preserving the primary signal characteristics. Subsequently, the interpolated time series data were smoothed using Savitzky-Golay filtering. Vegetation phenological parameters were then extracted using the double-baseline dynamic threshold method, with the threshold set as a dynamic value equal to 40% of the difference between the maximum and minimum NDVI. Finally, we compared the phenological information from this dataset with the MCD12Q2 product to investigate the spatiotemporal trends of vegetation growing season phenological parameters in the Northern Hemisphere from 2011 to 2019.

4 Data Results and Validation

4.1 Dataset Composition

The Yearly phenological parameters during vegetation growing season in Northern Hemisphere based on Fengyun satellites images (2011–2019) contains information on vegetation growing season phenological parameters in the Northern Hemisphere from 2011 to 2019, including the start day, end day, and length of the growing season. Specifically, it

comprises 30 data files, including yearly and multi-year averages of SOS, EOS, and LOS, archived in .tif format with a spatial resolution of 0.05° (Table 2).

In this dataset, the start of the growing season (SOS), end of the growing season (EOS), and length of the growing season (LOS) are respectively archived in files named FY_SOSyyyy.tif, FY_EOSyyyy.tif, and FY_LOSyyyy.tif. Their corresponding multi-year averages are named FY_SOSMean.tif, FY_EOSMean.tif, and FY_LOSMean.tif. Here, "FY" stands for the Fengyun Satellite Vegetation Phenology Dataset, "yyyy" denotes the specific year.

Table 2 List of files in the dataset

Composition file	Description	Number of files	Data size
FY_SOSyyyy.tif	SOS	9	224 MB
FY_EOSyyyy.tif	EOS	9	224 MB
FY_LOSyyyy.tif	LOS	9	42.9 MB
FY_SOSMean.tif	SOS	1	53.4 MB
FY_EOSMean.tif	EOS	1	53.4 MB
FY_LOSMean.tif	LOS	1	53.4 MB

4.2 Data Products

By applying the double-baseline dynamic threshold method to FY-3B NDVI time series data, the authors extracted a dataset of annual vegetation growing season phenological parameters for the Northern Hemisphere spanning 2011 to 2019. Based on these yearly results, the 9-year average spatial distribution of vegetation phenology was further calculated (Figure 2). The analysis reveals that, during the study period, the start of the vegetation growing season in the Northern Hemisphere primarily occurred between Julian days 105 and 125, while the end date mainly fell between days 265 and 305. Spatially, the phenology exhibits a clear latitudinal zonality and distinct land-sea differentiation. With increasing latitude, the start of the growing season is progressively delayed, whereas its end date advances significantly. This pattern results in a more compressed growing season window at high latitudes, leading to a progressive shortening of the overall growing season length from low to high latitudes. This spatial distribution suggests that the growing season length in high-latitude regions is more strongly constrained by temperature limitations. In terms of land-sea contrasts, vegetation phenological characteristics at similar latitudes show significant differences due to varying climate regimes. In Western Europe, moderated by a maritime climate characterized by milder winters and earlier spring warming, the start of the growing season generally occurs earlier than in inland East Asia, which is dominated by a continental climate. This reflects the buffering effect of the ocean on thermal conditions. Conversely, in maritime climate regions on the western edges of continents, where autumn cooling is gradual, the end of the growing season is notably later than in areas at the same latitude on the eastern continental margins. The difference in growing season length between western and eastern coastal regions further underscores the significant influence of land-sea thermal processes on the annual cycle dynamics of vegetation phenology.

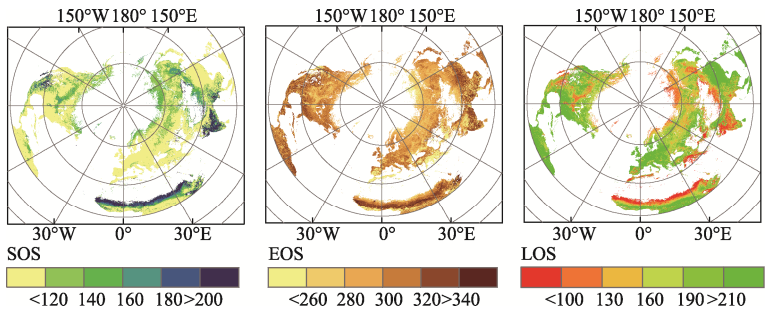


Figure 2 Mean phenological parameters of vegetation in the Northern Hemisphere (2011–2019)

4.3 Data Validation

The authors utilized the photosynthetic activity of Gross Primary Productivity (GPP) to evaluate and validate satellite-derived vegetation growing season phenology. The GPP data were obtained from the FLUXNET 2015 Tier 1 dataset[2], and we selected Eddy Covariance (EC) observations from flux tower sites in the Northern Hemisphere. This dataset enables long-term monitoring of ecosystem carbon fluxes, such as Net Ecosystem Exchange (NEE), through EC technology. Daily-scale daytime partitioned GPP data (GPP_DT_VUT_REF)[20] for the period 2011–2014 were estimated by applying the Daytime partitioning method (DT) and the Variable Ustar Threshold (VUT) filtering approach to the gap-filled NEE data. A comparison between FY-derived phenology extracted using different methods and ground-based GPP observations is presented in Figure 3. The results indicate that phenological metrics (particularly EOS and LOS) extracted by the double-baseline dynamic threshold method are significantly more accurate than those obtained from the traditional dynamic threshold method. Specifically, the method yielded a higher coefficient of determination (R^2) alongside notably lower Root Mean Square Error (RMSE) and Mean Absolute Error (MAE). These findings demonstrate that Northern Hemisphere vegetation phenology derived from the double-baseline dynamic threshold method exhibits better consistency with ground-based GPP phenology.

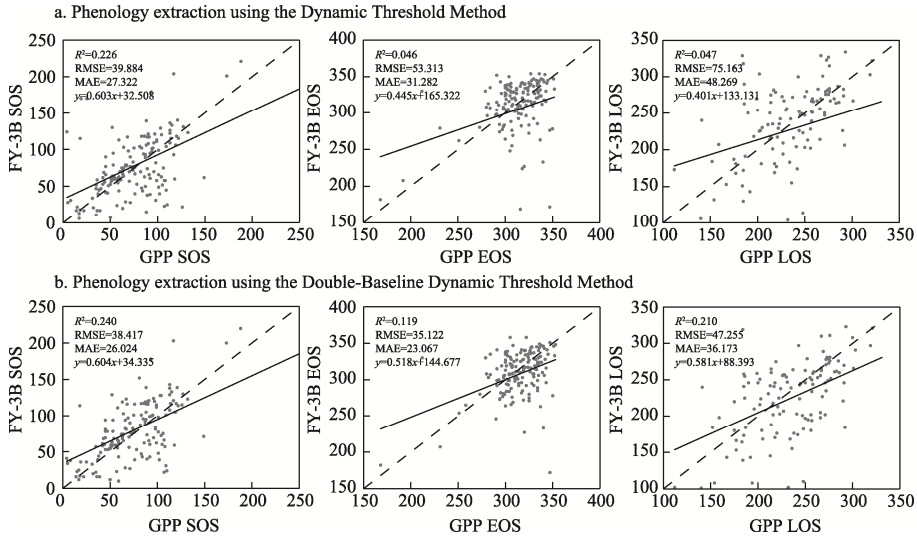


Figure 3 Accuracy verification chart of FY dataset based on GPP phenology data

In remote sensing studies of vegetation phenology, cross-comparison and validation using multi-source remote sensing data serve as a critical approach for assessing dataset reliability and understanding trend uncertainty. To evaluate the performance of the FY dataset in revealing long-term vegetation phenological trends, the authors conducted a comparative analysis with the widely used MCD12Q2 phenological product. Results based on trend analysis (Figure 4) show that both datasets indicate an overall advancing trend in vegetation growing season phenological parameters across the Northern Hemisphere from 2011 to 2019, a temporal pattern consistent with findings reported by Jiang, *et al*.[21]

As shown in the spatial distribution of Northern Hemisphere phenological trends (Figure 5), both the FY and MCD12Q2 datasets show generally low interannual variability in vegetation phenology across most mid-latitude to high-latitude regions. In contrast, more

[2] https://fluxnet.org/data/fluxnet2015-dataset/.

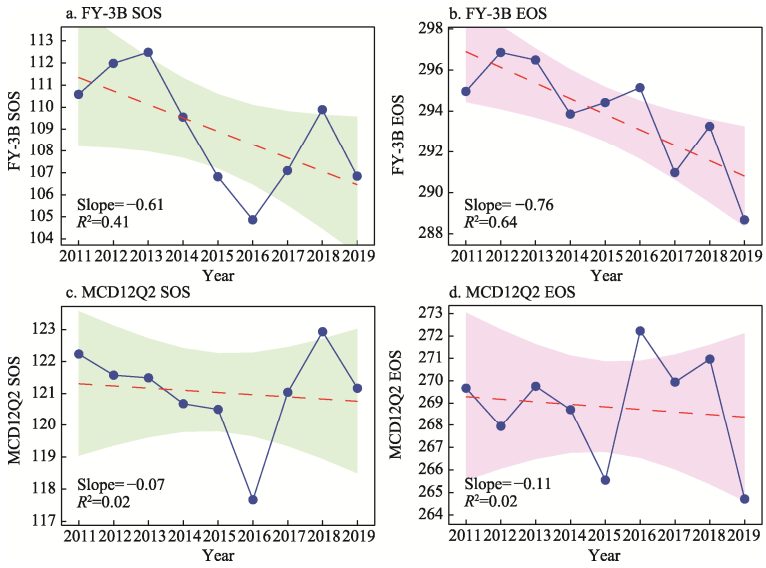


Figure 4 Interannual of trend comparison between FY and MCD12Q2 datasets (the shaded areas represent the 95% confidence intervals)

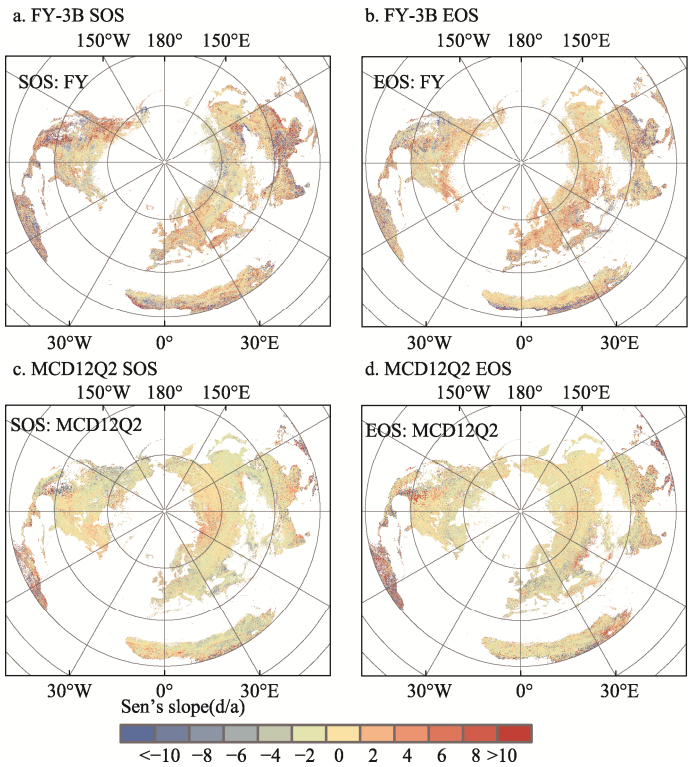


Figure 5 Comparison of spatial trends between FY and MCD12Q2 datasets

pronounced phenological variations are observed in mid-latitude areas such as the central-western United States, the Mediterranean region of Europe, and India, as well as in low-latitude regions including equatorial Africa and northern South America. These notable changes are likely linked to stronger vegetation dependence on precipitation and higher interannual rainfall variability in these regions. Overall, the FY satellite phenology dataset

and the MCD12Q2 product exhibit consistent spatial patterns in growing-season phenological trends, with their geographical differences reflecting the varying responses of vegetation phenology to climatic drivers across regions.

5 Discussion and Conclusion

This study developed a dataset of vegetation growing-season phenological parameters for the Northern Hemisphere (2011–2019) based on FY-3B satellite NDVI time series and an improved double-baseline dynamic threshold method. The results indicate that the double-baseline method achieves higher accuracy for key phenological parameters from Fengyun satellite data than the conventional dynamic threshold approach. The dataset validates the application potential of FY satellites in vegetation phenology remote sensing and provides data to support for understanding vegetation phenological patterns and their climatic drivers across the Northern Hemisphere. However, the study has several limitations. First, data gaps exist in certain regions, such as near the Arctic Circle and in subtropical coastal areas, largely due to persistent cloud cover. Second, in multi-cropping agricultural systems region (e.g., the winter wheat-summer maize rotation region of the North China Plain), the algorithm, which was designed for natural vegetation growing seasons, shows uncertainty in interpreting complex crop phenology signals. Future improvements could combine time-series interpolation with crop-stage-specific monitoring methods to enhance the dataset's completeness and regional applicability.

Author Contributions

Jiao, Q. J. conceived and designed the overall framework for the dataset algorithm, product development, and the study. Wu, L. optimized the technical solutions and revised the paper. Huang, W. J. guided the product application analysis. Zhang, B. defined the research scope for the product. Wang, N. implemented the algorithms, generated the data products, and authored the data paper.

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Conflicts of Interest

The authors declare no conflicts of interest.

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