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A Novel Method for Removing Snow Melting-Induced Fluctuation in GIMMS NDVI3g Data for Vegetation Phenology Monitoring: A Case Study in Deciduous Forests of North America

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***Abstract*—The normalized difference vegetation index (NDVI) has been widely used in recent decades to monitor vegetation phenology. However, interference from snow cover introduces a high degree of uncertainty in interpreting NDVI fluctuation, because snow melting increases NDVI value in a manner similar to vegetation growth, leading to false detection. In this study, we present a novel methodology to smooth out data noise caused by snow in the third generation NDVI dataset from Global Inventory Modeling and Mapping Studies (GIMMS NDVI3g). This method is developed to replace small values with a pixel-specific snow-free background NDVI estimate, based on the assumption that the existence of snow decrease NDVI value and the patterns of NDVI fluctuation after snow melting and that after initiation of vegetation growth are different. Using the daily gross primary production (GPP) data of 111 site-years from FLUXNET in nine North American sites and the GIMMS NDVI3g dataset, we found that the green-up onset day (GUD) derived from raw NDVI is 42.2 days earlier than that of GPP, on average. This difference decreases to 4.7 days when applying the newly developed method. Additionally, the root mean square error and Spearman's correlation coefficient between NDVI-derived GUD and GPP-derived GUD are improved from 46.8 to 12.8 days and 0.22 to 0.64, respectively. Our results indicate that this method could effectively improve the ability to monitor the vegetation phenology by NDVI time series in areas with seasonal snow cover.**

***Index Terms*—Climate change, remote sensing, snow cover, vegetation phenology.**

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I. Introduction

Vegetation indices such as normalized difference vegetation index (NDVI) characterize unique spectral characteristics of green vegetation [1]. They have been widely used to monitor vegetation phenology as the response of terrestrial ecosystems to climate change in the last decades [2]–[4]. A large number of studies based on NDVI time series have reported that climate warming during recent decades has caused considerable time shifts of spring vegetation phenology but with different magnitudes or even opposite trends at regional or global scales [2], [5], [6]. The results are mainly from substantial variability in the response of terrestrial ecosystems to climate change in different regions for various vegetation types. Besides, the quality of NDVI time series data also has an undeniable influence on the detection of phenology shift, because NDVI is severely affected by atmospheric conditions, satellite, and sensor degradation, along with background interferences from soil, snow cover, leaf litter, and dead branches. These interferences can lead to unstable NDVI fluctuation that is mismatched with vegetation growth [7], [8]. As a background interference, snow melting period is usually earlier than or partially overlaid with vegetation green-up event. Snow melting can increase NDVI values as vegetation grows (Fig. 1), leading to false detection of early green-up events in areas with seasonal snow cover [9]–[12]. It is thus necessary to remove the effects of snow melting from the NDVI data to precisely capture spring vegetation phenology shift [13].

In previous studies, several methods were used to remove the effects of snow by utilizing supplementary data such as land surface temperature [14], normalized difference water index [9], normalized difference phenology index [12] and "quality flags" provided by the NDVI dataset itself [3] as references. However, the effectiveness of these methods depends on the quality of these supplementary datasets and how they match with the NDVI dataset in spatial and temporal resolutions. Their effectiveness is significantly affected if such supplementary datasets are unavailable or contain larger errors. Due to the lack of an