Normalized Difference Greenness Index (NDGI): A new vegetation index for improved estimation of vegetation phenology

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Satellite monitoring of vegetation phenology is crucial to understanding the biological impacts of climate change. Nevertheless, satellite-based phenology estimation can be biased by effects of snow using conventional vegetation indices (VIs), such as the normalized difference vegetation index (NDVI). To eliminate effects of snow, snow-free VIs that take advantage of the shortwave infrared (SWIR) band have been proposed (i.e., phenology index [PI] and normalized difference phenology index [NDPI]). However, PI cannot properly capture the presence of sparse vegetation, and NDPI does not account for the influence of dry vegetation. Here, we propose a novel snow-free VI, designated the normalized difference greenness index (NDGI), using reflectance of green, red, and near-infrared (NIR) bands. NDGI is a semi-analytical index deduced based on the linear spectral mixture model and the spectral characteristics of vegetation, snow, soil, and dry grass. Its performance for estimating the start of growing season (SOS) and end of growing season (EOS) was evaluated using simulation datasets, time-lapse camera data of tundra sites, and flux tower gross primary production (GPP) data of grassland sites. Simulation results demonstrated that NDGI can exclude the influence of snow on SOS and EOS estimations. In the camera sites, NDGI markedly outperformed NDVI, PI, and NDPI for SOS estimation with RMSE=6.46 days and Bias=-1.32 days (vs. RMSE range 12.39–14.8 days and Bias>3.5 days for the other VIs), and for EOS estimation with RMSE=8.33 days and Bias=0.11 days (vs. RMSE range 8.00–26.74 days and Bias>2.67 days for the other VIs). In the GPP sites, NDGI also outperformed the other VIs for SOS estimation with RMSE=10.32 days and Bias=-4.91 days (vs. RMSE range 12.9–24.74 days and Bias>6.13 days for the other VIs). Although its performance was lower for monitoring EOS than SOS in GPP sites, it still outperformed the other VIs in EOS estimation. These results indicate the potential of NDGI for operational monitoring of plant phenology in the tundra and grassland ecosystems based on satellite observations.

Keywords: plant phenology, remote sensing, snow, MODIS

