Integrating Statistical and Expert Knowledge to Develop Phenoregions for the Continental United States

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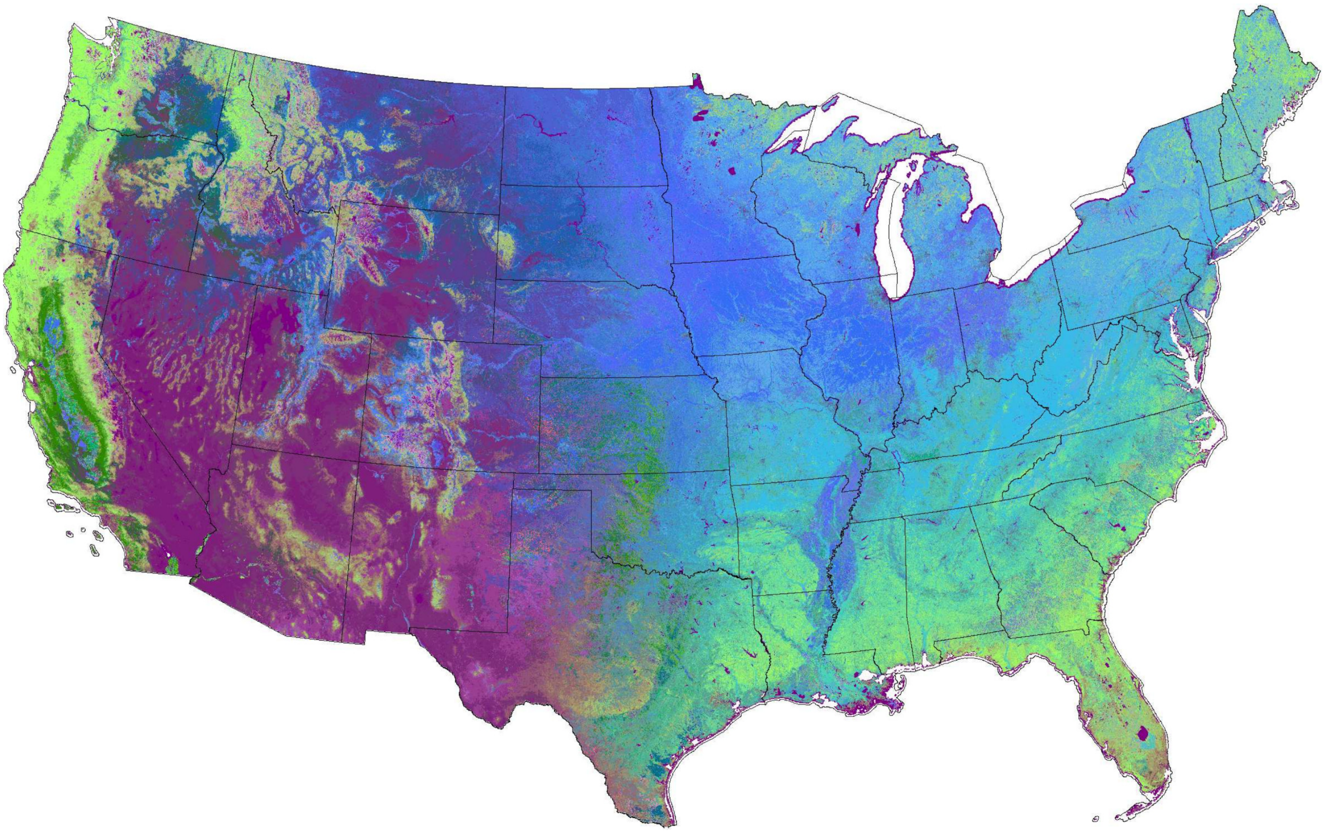
Vegetated ecosystems exhibit unique phenological behavior over the course of a year, suggesting that remotely sensed land surface phenology may be useful for characterizing land cover and ecoregions. However, phenology is also strongly influenced by temperature and water stress; insect, fire, and weather disturbances; and climate change over seasonal, interannual, decadal and longer time scales. Normalized difference vegetation index (NDVI), a remotely sensed measure of greenness, provides a useful proxy for land surface phenology. We used NDVI for the conterminous United States (CONUS) derived from the Moderate Resolution Spectroradiometer (MODIS) every eight days at 250 m resolution for the period 2000–2015 to develop phenological signatures of emergent ecological regimes called phenoregions. We employed a "Big Data" classification approach on a supercomputer, specifically applying an unsupervised data mining technique, to this large collection of NDVI measurements to develop annual maps of phenoregions. This technique produces a prescribed number of prototypical phenological states to which every location belongs in any year. To reduce the impact of short-term disturbances, we derived a single map of the mode of annual phenological states for the CONUS, assigning each map cell to the state with the largest integrated NDVI in cases where multiple states tie for the highest frequency of occurrence. Since the data mining technique is unsupervised, individual phenoregions are not associated with an ecologically understandable label. To add automated supervision to the process, we applied the method of Mapcurves, developed by Hargrove and Hoffman, to associate individual phenoregions with labeled polygons in expert-derived maps of biomes, land cover, and ecoregions. We will present the phenoregions methodology and resulting maps for the CONUS, describe the "label-stealing" technique for ascribing biome characteristics to phenoregions, and introduce a new polar plotting scheme for processing NDVI data by localized seasonality.

Figure: This map shows the 50 phenoregions derived from the MODIS NDVI at 250 m resolution data for years 2000–2012. The phenoregions are colored using a "similarity colors" technique that employs a principle components analysis to produce data-specific combinations of red, blue, and green for every phenoregion in the map.

Keywords: phenology, NDVI, MODIS, phenoregions, label stealing, cluster analysis



Development of plant phenological observation by using citizen science and historical archived data published on the web sites

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Accurate detection of plant phenology (e.g. timing of flowering, leaf-flush, and leaf-fall) is required to evaluate the spatio-temporal variability of ecosystem functions and service under rapid climate changes. Towards this aim, analysis of daily satellite-observed vegetation index with a coarse spatial resolution (e.g. 500m) and in situ-observed long-term historical biometeorological data set is useful. However, these approaches include many uncertainties and problems mainly caused by heterogeneity of plant species, spatial representativeness, and land cover changes. Here, (1) we examined the relationship between leaf-colouring information published on the meteorology service web site (http://www.tenki.jp) and the timing of end of growing season detected by daily Terra and Aqua/MODIS satellite-observed green-red vegetation index in Japan; (2) we evaluated the long-term historical flowering information published on the web sites; and (3) we examined the land cover change in the “Satoyama” landscape area by using aerial photographs published on the geographical survey web site (http://mapps.gsi.go.jp/maplibSearch.do#1). In this presentation, we will discuss the usability of citizen science and historical archived data published on the web sites for developing the detection of spatio-temporal variability of plant phenology in Japan.

Keywords: phenology, remote-sensing, citizen science, web site

Land Surface Phenology Changes in Central Asia

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Land surface phenology metrics allow for the summarization of long image time series into a set of annual observations that describe the vegetated growing season. These metrics have been shown to respond to both climatic and anthropogenic impacts. In this study we assembled a time series (2001-2016) of Moderate Resolution Imaging Spectroradiometer (MODIS) Nadir BRDF-Adjusted Reflectance (NBAR) data at two spatial resolutions (0.05º and 500m) and land surface temperature data at two spatial resolutions (0.05º and 1000m). We then derived land surface phenology metrics focusing on the peak of the growing season by fitting convex quadratic regression models connecting the NDVI time series with the progression of Accumulated Growing Degree-Days (AGDD) derived from the land surface temperature data. We linked the annual information on (1) peak timing, (2) thermal time to peak and (3) peak magnitude with three important climate oscillations—the Atlantic Multidecadal Oscillation (AMO); the North Atlantic Oscillation (NAO); and the East Atlantic / West Russia pattern (EAWR)—and evaluated the effects of the different spatial resolutions. We discovered several significant correlations between the climate oscillations and the land surface phenology peak metrics for a range of different bioclimatic regions in the drylands of Central Asia, and we linked these correlation results to changes in ambient population modeled by LandScan.

Keywords: Land Surface Phenology, Remote Sensing, Central Asia

Tracking and characterizing human impacts in tropical forests: Can Landsat go it alone?

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Representing a significant portion of the global carbon store as well as countless other ecosystem services, tropical forests have been under threat due to expansion of human activities in recent decades. Following the public release of the entire Landsat data archive - the longest record of earth observation data in existence - a veritable explosion of innovation in forest monitoring methods using Landsat time series (LTS) has occurred. New approaches have emerged allowing for the tracking of forest changes either retrospectively - supporting carbon accounting for REDD+ and other applications - or in near real-time - supporting operational monitoring and enforcement efforts. Methods exploiting all observations in particular have shown that accounting for seasonal fluctuations (ie. those arising from canopy phenology) can enhance the detection and characterization of human-driven changes. Despite the demonstrated promise of LTS in monitoring changes in tropical forests, limitations in the temporal, spectral and spatial resolution of Landsat data raise questions about extent to which methods based on LTS alone are adequate for addressing monitoring needs in tropical forests.

Here, we show that while LTS provide unprecedented detail in forest change studies, specific monitoring objectives in tropical forests call for the integration of LTS with other data sources. To demonstrate this need, we focus on two monitoring targets: (1) the timely detection of changes and (2) characterization of change dynamics over time. First, given that many tropical regions experience perpetual cloud-cover, generating large temporal gaps in LTS, recent research has shown that fusion of LTS with SAR data can improve the temporal accuracy of forest change alerts by up to 47 days. Fusion of LTS with the ESA-Copernicus Sentinel constellation of SAR and optical satellites thus has the potential to significantly improve the near real-time forest monitoring systems. Second, LTS-based methods face limitations when characterizing forest change processes like deforestation and forest degradation. Recent results integrating forest observations from community-based monitoring (CBM) project sites with LTS-based change indicators show that gradual, small-scale degradation of the forest canopy can be detected using LTS, but require regularly acquired *in situ* observations for adequate calibration and validation of change models. These insights show the promise of fusing LTS with other satellite data streams such as SAR image time series, as well as *in situ* observations and measurements, to enhance forest monitoring capabilities in the tropics to support such objectives as REDD+.

Keywords: Landsat, time series, tropical forests, SAR, deforestation, participatory monitoring

Interannual Variability in the Length of Growing Season across the Contiguous US as Observed from MODIS, VIIRS, and Tower Vegetation Index Time Series Data

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Vegetation phenology is considered one key variable to understand climate change impacts on plant productivity. Spectral vegetation index (VI) time series data from polar-orbiting satellites such as Moderate Resolution Imaging Spectroradiometer (MODIS), have widely been used to characterize vegetation phenology at various spatial and temporal scales. They have shown to be valuable tools in discerning various phenological metrics, such as the start and end of growing seasons (SOS and EOS), and have recently been used to quantify interannual variability in the length of growing season (GSL) at regional and global scales. Assuring the quality of satellite-derived GSL is critical to characterize directions and magnitudes of shifts in GSL, which are linked to the changes in plant productivity. The objective of this study was to assess the quality of satellite-derived GSL in characterizing the relative impacts of the SOS and EOS changes to the GSL interannual variability by an intercomparison with in-situ optical sensor data. The GSL derived from MODIS (2003-2015) and Visible Infrared Imaging Radiometer Suite (VIIRS) (2012-2015) VI time series data were compared with those derived from in-situ (Tower) VI time series data (2003-2015), which were derived from in-situ tower optical sensor data, at 11 AmeriFlux sites located across a range of biomes in the contiguous US (CONUS). The SOS and EOS metrics were obtained from all the three datasets by fitting logistic function for each year, and the GSL was calculated as the difference between the SOS and EOS. Relative contributions of the changes in SOS and EOS to the GSL interannual variability were evaluated using the ratios of the absolute changes in SOS to that of GSL. Year-to-year changes in MODIS and VIIRS GSLs corresponded well with those from the Tower GSL although some biases were observed for some sites ($R^2>0.68$, $p<0.01$). The relative contributions of the SOS and EOS varied across sites (SOS contribution=20~93%), which were seen in all the three datasets. The stronger SOS contributions (>50%) were seen at many of the sites located in the mid-latitudinal region (37.5°N~42.5°N), whereas EOS showed stronger contributions (>50%) at those sites located in the southwestern part of the CONUS. These relative contributions changed temporally but the observed spatial patterns were consistent. These results indicate that the satellite-derived GSL is capable of characterizing the interannual variability of GSL in the CONUS. Further analysis at additional locations may help to assure the quality of satellite-derived GSL and to better understand GSL interannual variability under climate change.

Keywords: vegetation phenology, growing season length, MODIS, VIIRS, in-situ radiation data

Impacts of changes in phenology on land-atmosphere interactions in temperate and boreal regions

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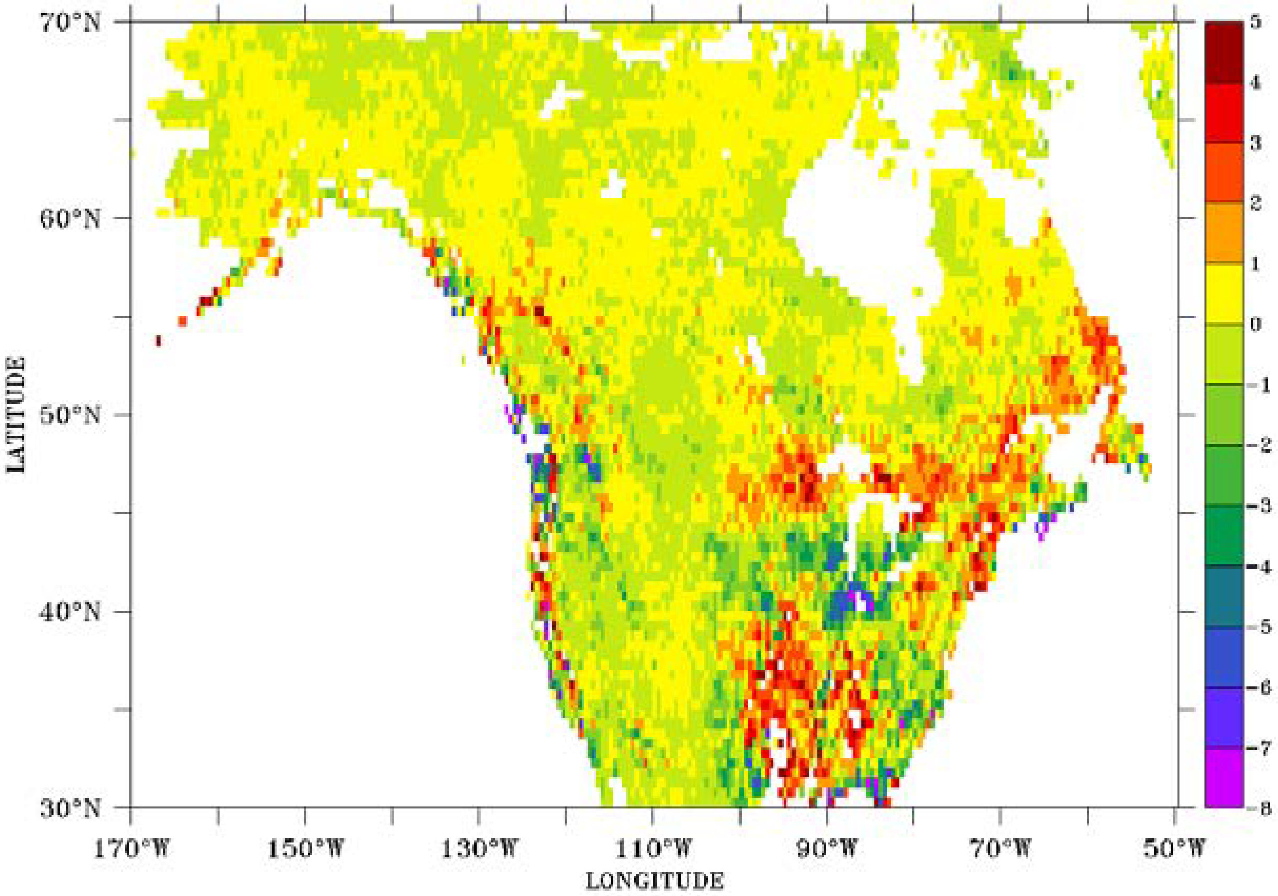
Recent remote sensing data and ground observations have shown earlier leaf out in spring in the northern hemisphere, which is believed to result from climate warming. The advance of leaf out would be expected to have impacts on the dynamics of the wider ecosystem processes such as primary production and evapotranspiration. Moreover, controlled experiments show that temperate and boreal trees require chilling in winter for rapid leaf out in spring. If the amount of chilling falls below a species specific threshold then an exponentially increasing amount of warming is required to initiate leaf out –potentially actually delaying it in a warmer climate. Implications of these chilling requirements for a delayed greening of vegetation at the biome level are not clear. Impacts of changes in the phenology in the past thirty years are explored by incorporating Leaf Area Index (LAI) data derived from satellite remote sensing observed Normalized Difference Vegetation Index (NDVI) into the Joint UK Land Environment Simulator (JULES), a numerical biosphere-atmosphere exchange simulation system. A 30 year model simulation using daily varying climate and monthly varying LAI is compared to a simulation with the varying climate but a fixed seasonal cycle. So, while the LAI varies between months in the second simulation, the LAI is the same for all 30 Januaries, for all 30 Februaries and so on. The first simulation shows the effects of varying climate and phenology over the last 30 years on the northern hemisphere, the second reflects only the climate variability. The analysis of the simulations shows that there are significant changes due to the changes in the phenology in the biosphere-atmosphere fluxes in some areas of the northern hemisphere. In particular the net primary productivity increases significantly for example in the South Eastern United States. Further changes in the biosphere-atmosphere fluxes are explored. The results highlight the necessity of including appropriate phenology models in climate models for improved predictions of land-atmosphere interactions.

Keywords: Plant Phenology, JULES, Biosphere-atmosphere exchange, Net Primary productivity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LATITUDE
170°W
150°W
130°W
110°W
90°W
70°W
50°W
LONGITUDE
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