

MONITORING SPATIAL PATTERNS OF VEGETATION PHENOLOGY IN AN AUSTRALIAN TROPICAL TRANSECT USING MODIS EVI

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ABSTRACT:

Phenology is receiving increasing interest in the area of climate change and vegetation adaptation to climate. The phenology of a landscape can be used as a key parameter in land surface models and dynamic global vegetation models to more accurately simulate carbon, water and energy exchanges between land cover and atmosphere. However, the characterisation of phenology is lacking in tropical savannas which cover more than 30% of global land area, and are highly vulnerable to climate change. The objective of this study is to investigate the spatial pattern of vegetation phenology along the Northern Australia Tropical Transect (NATT) where the major biomes are wet and dry tropical savannas. For this analysis we used more than 11 years Moderate Resolution Imaging Spectroradiometer (MODIS) Enhanced Vegetation Index (EVI) product from 2000 to 2011. Eight phenological metrics were derived: Start of Season (SOS), End of Season (EOS), Length of Season (LOS), Maximum EVI (MaxG), Minimum EVI (MinG), annual amplitude (AMP), large integral (LIG), and small integral (SIG) were generated for each year and each pixel. Our results showed there are significant spatial patterns and considerable interannual variations of vegetation phenology along the NATT study area. Generally speaking, vegetation growing season started and ended earlier in the north, and started and ended later in the south, resulting in a southward decrease of growing season length (LOS). Vegetation productivity, which was represented by annual integral EVI (LIG), showed a significant descending trend from the northern part of NATT to the southern part. Segmented regression analysis showed that there exists a distinguishable breakpoint along the latitudinal gradient, at least in terms of annual minimum EVI (EVI), which is located between 18.84°S to 20.04°S.

1 INTRODUCTION

Phenology as a subject to study the life cycles of vegetation and the interactions between vegetation and climate (White and Thornton, 1997) is receiving increasing interests in global change research. Vegetation phenology can be used as a key parameter in large scale ecosystem simulation models (Running and Hunt, 1993) and general circulation models (Sellers et al., 1996). At the same time, vegetation phenology is also an accurate indicator of influences by climate change on vegetation growth (Menzel et al., 2006).

Phenological studies of vegetation traditionally utilised ground based techniques (Jeffrey, 1960, Sparks and Jeffrey, 2000), however, increasing number of studies utilise remote sensing to study vegetation phenology on a large scale (Schwartz, 1999, Zhang et al., 2003, Stöckli, 2004). Compared with field based cameras or visual inspection, space borne optical sensors such as MERIS (MEdium Resolution Imaging Spectrometer) and MODIS (Moderate Resolution Imaging Spectroradiometer) are able to provide daily measurements of variety biophysical and biochemical information of the earth's surface with moderate spatial resolution.

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However, till now most remote sensing phenology studies focused on temperature and light limited systems (Beurs and Henebry, 2010), with few conducted on water limited systems (Brown and de Beurs, 2008), and rarely on tropical savannas. Tropical savannas are generally defined as a biome with discrete tree stratum and continuous grassy ground layer (Frost et al., 1986), which covers one-sixth of the global land surface, and contributes approximately 30% of the gross primary productivity (GPP) of all terrestrial ecosystems (House and Hall, 2001). Tropical savannas are also considered particularly vulnerable to climate change (Canadell et al., 2003). Despite the importance of tropical savannas, studies of its vegetation phenology are lacking regardless of the methods, thus restricting our capability to understand the impact of possible climate change scenarios on tropical savannas ecosystems.

Previous studies showed that a biogeographical boundary existed in the NATT area, which may distributed around 16-20 °S. 18-20 °S was considered as the south limit of the influences from monsoonal rainfall (Bowman, 1996, Burbidge, 1960), 15-16 °S was considered as the southern limit of wet season as well as the southern limit of monsoon tall-grass savannas (Cook and Heerden, 2001). Meanwhile, in terms of vegetation family and species, the major changes occur around 16-17 °S (Egan and Williams, 1996). Based on these findings, we hypothesised that, if such a virtual biogeographical

boundary exists, it might be reflected by vegetation phenology.

In this study, we mainly focused on two points: 1) using remote sensing to investigate the spatial patterns of vegetation phenology in the NATT area; 2) try to identify the abrupt change (breakpoint) in terms of the phenological metrics along the latitude in the NATT, thus providing a phenological perspective on the biogeographical boundary question. Our study showed that there were significant spatial patterns of vegetation phenology in the NATT during past decades, a north-south directional trend was identified. Meanwhile, breakpoint analysis showed that, there was a distinguishable 'breakpoint' located around 18 °S to 20°S,

2 DATA AND METHODS

2.1 Study area

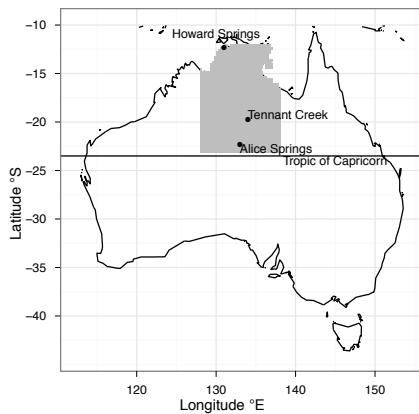


Figure 1: The spatial extent of the NATT study area (gray colour area)

This study focussed on Northern Australia Tropical Transect which was extended in this study as a 1.38 million km² area which located between latitude 12° S and 23° S and between longitude 128 ° E and 138 ° E (Fig. 1). The use of transects has been largely adopted by global change community over past two decades as a standard method to assess spatial patterns of biogeochemical processes (Koch et al., 1995). The spatial variation of long time constants along the transect can be used as an surrogate of predicted temporal variation to understand the future responses to global change (Koch et al., 1995). The Northern Australian Tropical Transect (NATT) was established under IGBP (International Geosphere Biosphere Programme) in the mid 1990s, and is one of three transects around world to study global savannas (Koch et al., 1995). Along the NATT, mean annual precipitation decreases from nearly 1700mm in the north wet end (Howard Springs) to 300mm in the south dry end (Alice Springs) (Hutley et al., 2011). The vegetation in NATT is a wet-dry savannas gradient where in northern half of NATT, the dominant vegetation is tropical savannas covered by overstorey evergreen Eucalyptus and understorey annual and perennial C4 grasses (Egan and Williams,

1996). However, in southern half of the NATT the dominance of savannas declines, and the dominance of Acacia woodlands and shrub lands and hummock grasslands increases. (Bowman and Connors, 1996).

2.2 Data

2.2.1 MOD13C1 EVI A total of more than 11 years (2000-2011) of MODIS Terra 16-day 0.05 ° spatial resolution collection 5 vegetation indices product (MOD13C1) were used in this study. This product is mainly designed to provide globally consistent vegetation conditions (Running et al., 1994, Justice and Vermote, 1998). In this study, the Enhanced Vegetation Index (EVI) was used as a surrogate for vegetation growth condition. EVI can effectively reduce the soil background and atmospheric noise while improving the sensitivity in high biomass regions (Huete et al., 2002). The equation of EVI is:

$$EVI = 2.5 \times \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + 6 \times \rho_{red} - 7.5 \times \rho_{blue} + 1} \quad (1)$$

where ρ_{NIR} , ρ_{red} , and ρ_{blue} are the wavelengths in the near infrared, red, and blue bands respectively (Huete et al., 2002).

The residual cloud and aerosol contamination in the original EVI time series were filtered out based on the quality assurance (QA) flags provided along with the MOD13C1 product.

For pixels without distinct seasonality, such as deserts and water-bodies, no phenology metrics were derived. QA filtered data was temporally gap filled by the average value of the six points before and after the gap. Remaining noise was removed by a Savitzky-Golay filter.

2.3 Methods

2.3.1 Phenological metrics retrieval method In this study, each increase (green-up) and decrease (brown-down) during a growing season was reproduced by two separate four parameters logistic function:

$$y = a + \frac{b - a}{1 + \exp\left(\frac{c-t}{d}\right)} \quad (2)$$

where, a is the background EVI before or after growing season, b is the maximum EVI during growing season, c is the inflection point when the fitted curve reached the maximum rising or decreasing speed, d is the scaling factor which determines the rate of increase or decrease of EVI at inflection point. The parameters were estimated based on nonlinear least squares criteria for each pixel and each phenological cycle during 2000-2011, a total of 11 growth cycles.

The phenological transition dates were determined based on the curvature change rate K' of the fitted curve followed Zhang's method (Zhang et al., 2003). Specifically, Start of Season (SOS) corresponded to the timing

