551.501 : 551.583

Characterization of vegetation fraction estimated using spot-vegetation NDVI data for regional climate modeling in India

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सार – एम. एम. 5 जैसे मेसोस्केल जलवायु निदर्शों द्वारा वनस्पति (वी. एफ.) की सूचना देने का कार्य महत्वपूर्ण है। निदर्शन (मॉडलिंग) में सामान्य रूप से सबसे अधिक प्रयुक्त की गई जलवायु संबंधी मासिक वी. एफ. है। वी. एफ. की सूचनाएँ एन. ओ. ए. ए. – ए. वी. एच. आर. आर. एन. डी. वी. आई. भूमंडलीय ऑंकड़ा सेटों का उपयोग करते हुए गुटमेन और इग्नाटोव (1988) (जी. आई.) द्वारा तैयार की गई है। इस शोध–पत्र में भारतीय क्षेत्र के अप्रैल 1998 से नवंबर 2003 की अवधि के स्पॉट– वेज़ीटेशन 10 दिवसीय मिश्रित एन. डी. वी. आई. के उत्पादों का उपयोग करते हुए 1 कि. मी. के वी. एफ. के ऑंकड़ा सेट तैयार करने के बारे में बताया गया है। स्पॉट–वेजीटेशन के 0 % और 100 % की वी. एफ. से संबंध एन. डी. वी. आई. की संवेदक विशिष्ट प्रभावसीमाएँ जी. आई. के 0.04 और 0.52 की तुलना में क्रमश: 0.04 और 0.804 पाई गईं। जी. आई. के जलवायु संबंधी वी. एफ के साथ प्राप्त किए गए वी. एफ के ऑंकड़ों की तुलना की गई है। तीन अक्षांशीय क्षेत्रों (<16, 16–24, > 24) के लिए वी. एफ. के विश्लेषण से जी. आई. से 15 % तक की भिन्नताओं का पता चला है। वर्षा–आधारित कृषि वाले क्षेत्र में उल्लेखनीय भिन्नता का पता चला है। वी. एफ. से प्राप्त किए गए मौसमी और वर्ष–प्रतिवर्ष की भिन्नताओं के परिणामों पर विचार–विमर्श किया गया है।

ABSTRACT. Vegetation fraction (VF) is an important input in mesoscale climate models, such as MM5. The most commonly used VF inputs in modeling is the climatic monthly VF generated by Gutman and Ignatov (1998) (GI) using NOAA-AVHRR NDVI global data sets. This paper reports the generation of 1 km VF data set using SPOT-VEGETATION 10-day composite NDVI products from April 1998 to November 2003 for the Indian region. Sensor-specific thresholds of NDVI associated with 0% and 100% VF for SPOT-VEGETATION were found to be 0.04 and 0.804, respectively, in contrast to 0.04 and 0.52 of GI. Comparison of derived VF with climatic VF of GI was carried out. Analysis of VF for three latitudinal zones (<16, 16-24, >24) indicated the differences up to 15 percent from GI. Significant difference was observed for the area having rain-fed agriculture. Results of the seasonal and year-to-year variations of derived VF are discussed.

Key words – Vegetation fraction, Climate model, Remote Sensing, NDVI.

1. Introduction

Land surface parameters such as land cover (Pineda *et al*. 2004), vegetation type, vegetation fraction (VF) and green leaf area index (LAI) controls surface processes of energy and water exchange. Thus Land surface plays a central role in climate (Pitman 2003). Vegetation fraction (Deardorff 1978) represents vegetation amounts in horizontal dimension and has been used in the mesoscale climate models, such as fifth generation Pennsylvania State University/NCAR Mesoscale Model (MM5) (Dudhia 1993), to weigh the evaporation flux for bare and vegetated surfaces. Estimation of VF has been carried out using remote sensing data (Asrar *et al*. 1984, Puevdorj *et al*. 1998) by number of techniques including spectral mixture analysis (McGwire *et al*. 2000), neural network (Barret *et al*. 1995) and using vegetation indices (VI) (Gitelson *et al*. 2002). The VF derived from spectral mixture and neural network analysis requires ancillary ground measurements and/or hyper spectral data and adopted for smaller regions and/or low temporal repetivity studies.

The VI based approaches are widely used as an indicator of temporal and spatial variations in vegetation structure (Bannari *et al*. 1995, Buschmann and Nagel 1993). Normalized Difference Vegetation Index (NDVI) has been generally preferred VI for global assessment of VF (Carlson and Ripley 1997). NDVI is derived from the combination of red (ρ_r) and near-infrared (ρ_n) reflectance and defined as NDVI = (ρ_n - ρ_r) / (ρ_n + ρ_r). Gutman and Ignatov (1998), referred as GI in this paper, had utilized the NOAA-AVHRR NDVI products of few kilometer resolutions for the generation of global monthly climatic VF inputs for mesoscale models. Efforts have also made to generate global VF dataset at 1 km scale using 10-day composite NOAA-AVHRR data (Zeng *et al*. 2000) and its effect on land surface climatology (Barlonge and Zeng, 2004). Very little work has been carried out for the generation of VF using SPOT-VEGETATION (VGT) NDVI data for Indian region.
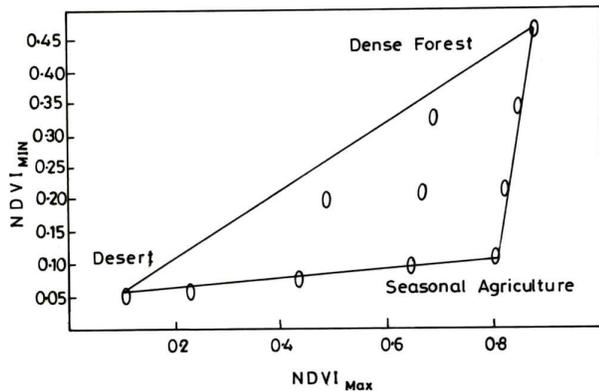
Fig. 1. Global triangle of surface types estimated using cluster analysis of SPOT-VGT NDVI (1998-2003)

The objective of the work was to derive and characterize the VF at 1 km resolution VGT NDVI data for as inputs for Regional Climate Models (RCM) over Indian domain in multi-institutional DOS-ISRO International Geosphere-Biosphere programme (D-IGBP) project. The dense vegetation approach followed in GI was adopted. The global constants, maximum NDVI associated with dense vegetation ($NDVI_v$) and minimum NDVI associated with exposed soil ($NDVI_s$), of GI were estimated for the VGT sensor. The new VF was compared with the climatic VF data of GI over Indian region and seasonal as well as inter-annual variations were investigated.

2.   Data used and methodology

The study area covers Indian domain of 65° - 105° E Longitudes and 5° - 45° N Latitudes. Ten-day composite VGT NDVI data for the period from April 1998 to November 2003 was obtained from the web site http://www.free.vito.beg. Climatic VF of GI was obtained from the site ftp://140.90.197.192/pub/ggutman/frveg for the comparison.

Images of pixel-level minimum and maximum NDVI were generated using the data set of five years (1998-2003). Two-dimensional feature space cluster analysis using Minimum NDVI ($NDVI_{min}$) and Maximum NDVI ($NDVI_{max}$) images was performed. $NDVI_v$ of dense vegetation and $NDVI_s$ of exposed soil were estimated from the triangle formed by plotting the centers of clusters.

Ten-day composition of satellite data minimizes the cloudy pixels, however some pixels may have cloud effect due to existence of persistent clouds. In the generation of VF, a two step cloud filtering was performed, comprising (*i*) replacement of cloudy pixels by the maximum NDVI using moving window of 3 composite images

(*ii*) remaining cloudy pixels in the mid-month (second composite of each month) were replaced by average of the NDVI values of previous and next mid-month composites. Mid-month VF images for the study period were generated using following equation

$$VF = (NDVI_i - NDVI_s)/ (NDVI_v - NDVI_s)$$

Where $NDVI_i$ is the NDVI of the ith pixel and $NDVI_v$, $NDVI_s$ are the constants associated with 100% and 0% VF, respectively.

For the comparison with GI data and investigation of seasonal as well as year-to-year variations, study area was divided in to three latitudinal zones *viz.*, <16°, 16° - 24° and >24°, respectively. The Zone 1 (Upper part of India) covers areas having desert, irrigated agriculture and forest. Zone 2 (central part of India) is dominated by rain-fed agriculture area. Zone 3 (lower part of India) covers the forest and irrigated agriculture area.

3.   Results and discussion

The result of two-dimensional feature space cluster analysis using $NDVI_{min}$ and $NDVI_{max}$ is shown in Fig. 1. Top right point of triangle, formed by centers of clusters, describes the characteristics of area having higher values for $NDVI_{min}$ and $NDVI_{max}$. These higher values refer to dense forest vegetation, which does not change significantly during the annual cycle. The value of $NDVI_{max}$ associated with the dense vegetation ($NDVI_v$) is 0.804. $NDVI_{min}$ value associated with bottom left cluster indicates the $NDVI_s$ for the desert like soils and the value is 0.048. The corresponding NOAA-AVHRR values of GI were 0.52 for $NDVI_v$ and 0.04 for $NDVI_s$.

The zonal comparison of average (1998-2003) monthly VF (VF_{av}), derived using VGT NDVI data, with climatic data of the GI is shown in Fig. 2. Zone1 has less than 5% difference, except in August, which could be due to drought years, *viz.*, 2000 and 2002 (Sikka 2003). The VF_{av} for Zone 2 and Zone 3 were greater than climatic VF by 8% and 12%, respectively. Fig. 3 showing spatial distribution of differences for February 2002 indicates that the differences are within 10 percent for the dense forest (S2 and S5), Irrigated agriculture (S1) or desert (S6). The significant differences, of the order of 10-30%, are observed for other regions due to year-to-year variation in agriculture area/condition. These differences can result in to different land surface energy flux partitioning when used in climate modeling.

Seasonal variations of VF_{av} for the months of June, October and February are shown in Figs. 4 (a-c). It is seen from these images that the northeastern forest of India,
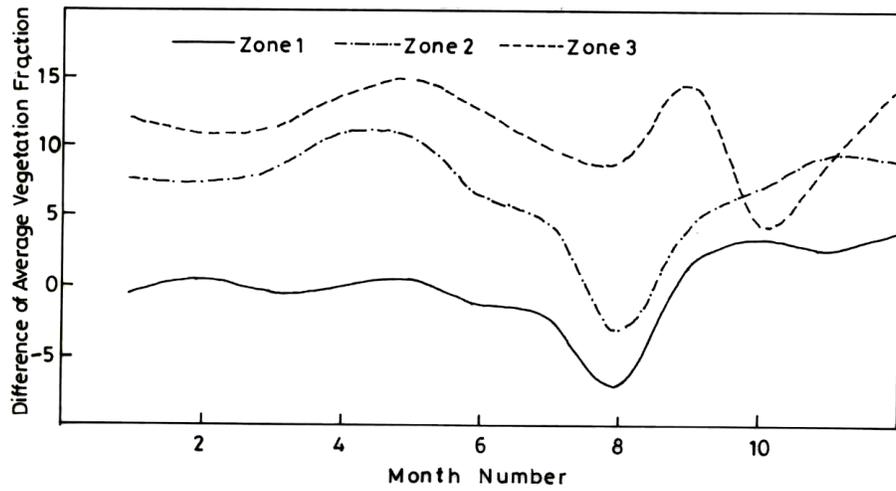
Fig. 2. Relative deviation from the fraction map of Gutman and Ignatov (1998); Differences up to 15% was observed by using SPOT data at regional scale
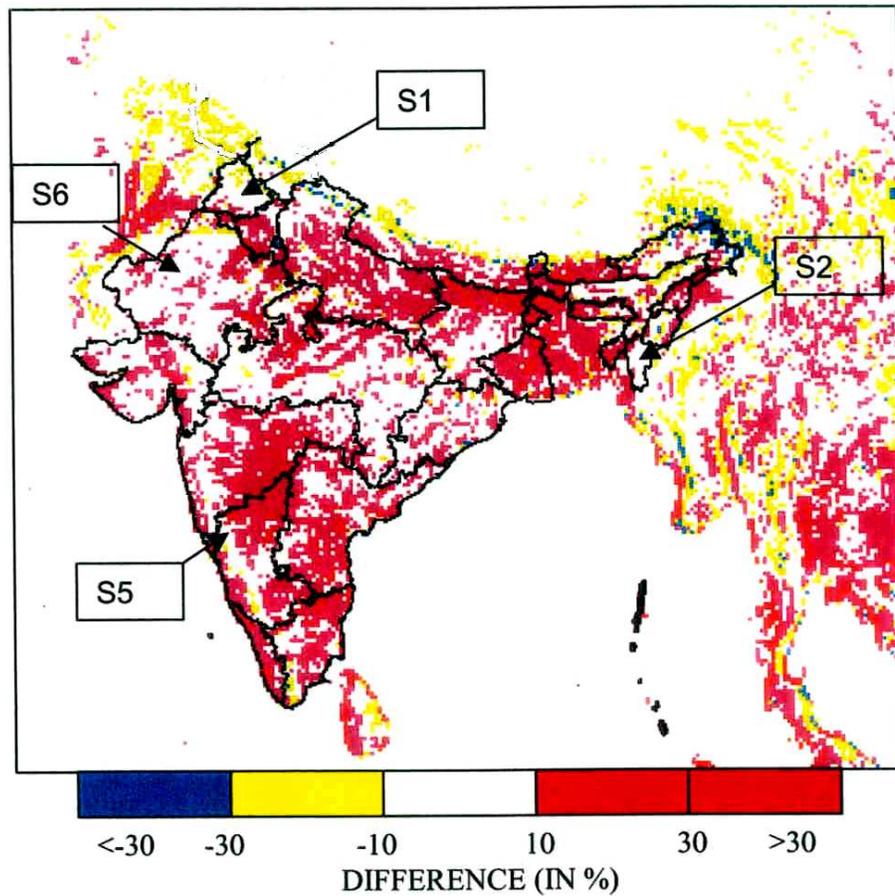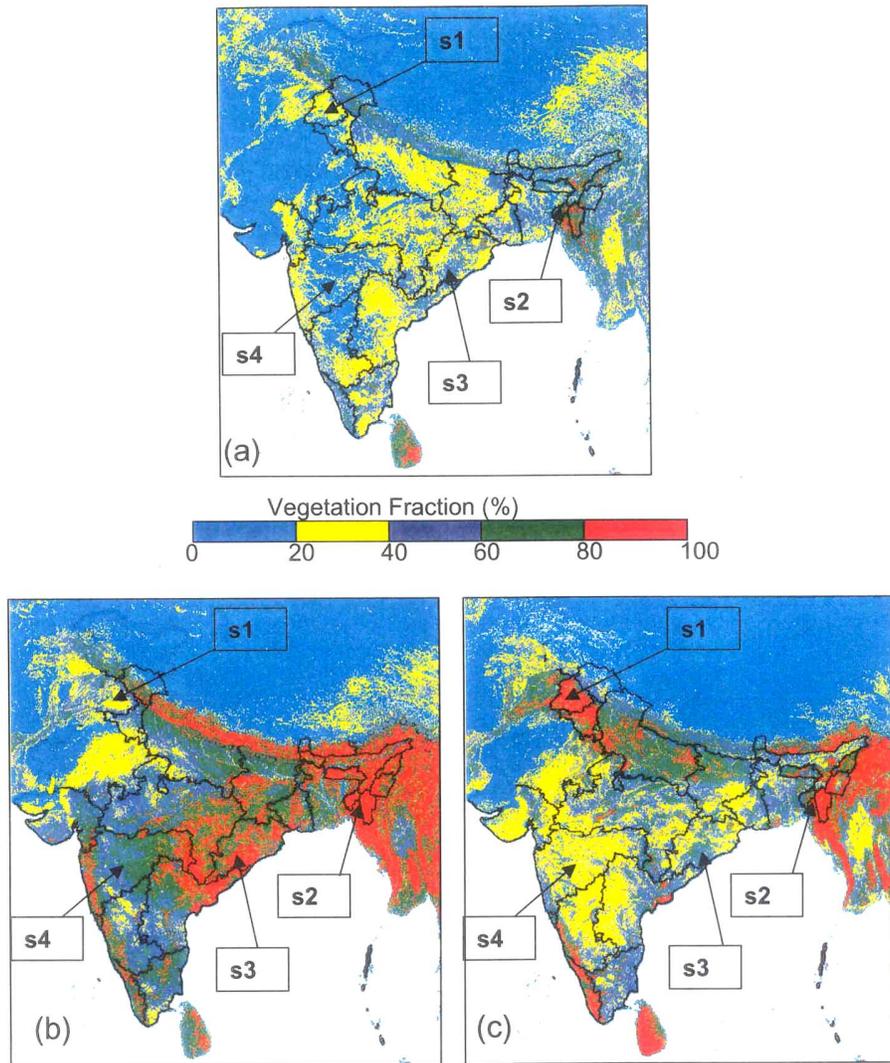

Fig. 3. Difference of vegetation fraction (VF) derived using SPOT-VGT NDVI of February 2002 and VF of Gutman-Ignatov (GI). Positive differences indicate the under estimation by GI. The vegetation structures such as dense forest (S2, S5), desert (S6) and irrigated agriculture area (S1) have lower differences

Figs. 4(a-c).   Climatic monthly average vegetation fraction (VF) of (a) June (b) October and (c) February. S1 represents irrigated agriculture area; S2 and S3 represents forest area and S3 is the representation of area having dominant rain-fed agriculture
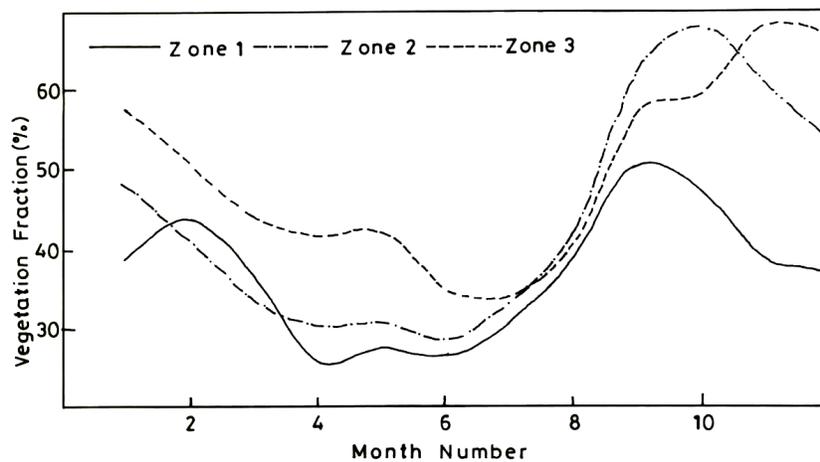
Fig. 5. Zone-wise average monthly vegetation fraction derived using SPOT NDVI (1998-2003)
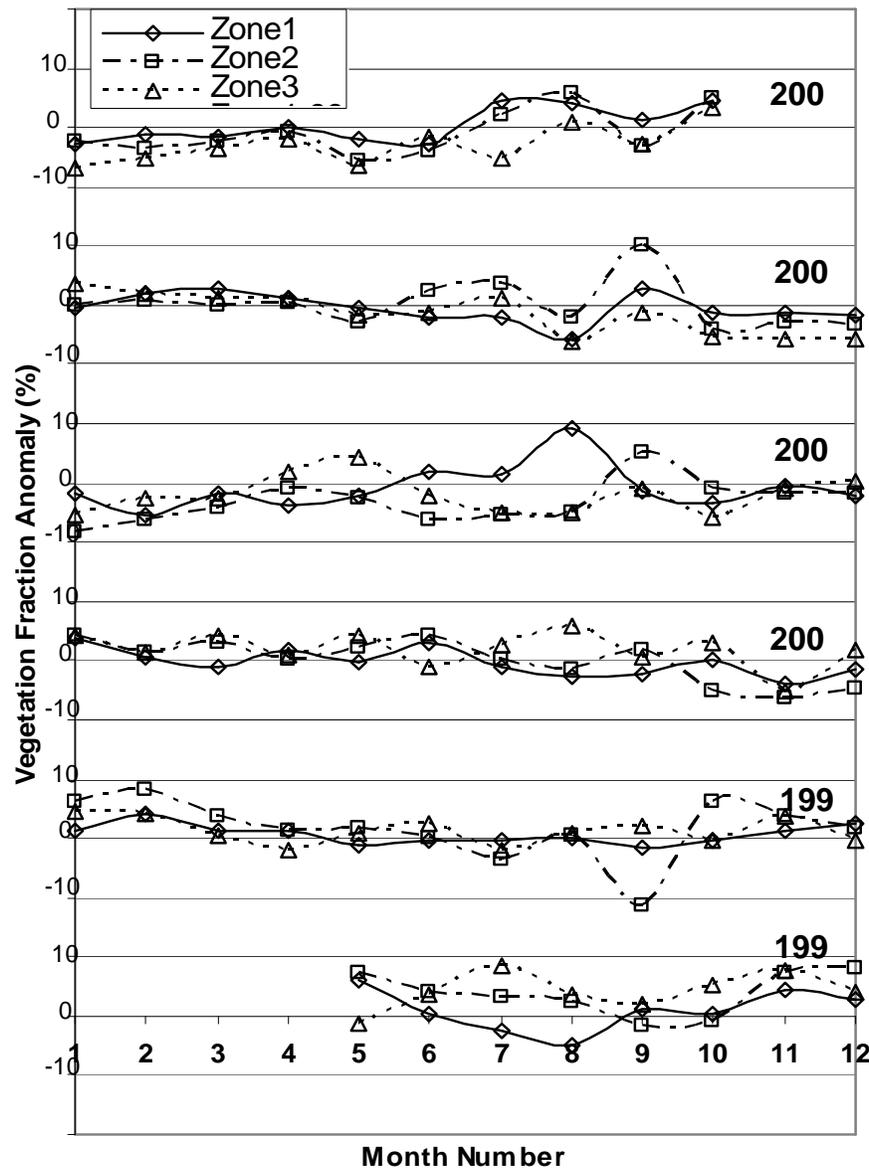
Fig. 6. Anomaly of monthly vegetation fraction from five years mean

labeled as S2, has more than 80 percent VF in all three months. However the hilly terrain of Orissa State (S3) has VF in the range of 40-60 percent in June and February months in contrast to 80-100% VF in October. This indicates the differences originated from the different seasonal dynamics of forest vegetation.

The parts of irrigated area of Indo-Gangetic plains (S1) had higher green vegetation fraction (20-40%) as compared to rain-fed agriculture area labeled as S4 (0-20%) in the month of June (pre-monsoon phase). In the month of October (post-monsoon phase), VF for S1 remained similar to June, where as that for S4 increased to

40-80%. S1 and S4 have VF in the range of 80-100% and 20-40% in the month of February, respectively, due to winter crops. This analysis brings out the distinct seasonal pattern of VF for different vegetation cover types in India.

The zone-wise profiles of VF_{av} are given in Fig. 5. It is observed that Zone1, in general, had lower VF compared to other two zones, since it covers hot desert (part of north-west India) and cold desert (part of north India). The low VF in summer in all three zones and increase during monsoon has contribution from both, agriculture and natural vegetation. The temporal profile of

VF of Zone 2 has the highest contrast, 28% to 68%, due to the contribution from dominant rain-fed agriculture area.

The highest VF observed for the Zone 1, Zone 2 and Zone 3 are in the months of September, October and November, respectively.

Inter-annual variations of the VF are shown in Fig. 6. It is seen that months from August to October and January to February have higher deviations due to monsoon and winter crop seasons. The effect of drought in 2000 and 2002 is distinctly observed for zones in terms of negative VF anomalies during the months of November to March for the years 2000-01 and 2002-03. The high seasonal and inter-annual variations of VF emphasize the need of using in-season VF inputs in contrast to climatic VF.

4. Conclusions

This study has (a) demonstrated use of 10-day composite NDVI of SPOT-VEGETATION for estimation and mapping of VF (b) reports estimated constants of NDVI associated 0% and 100% VF for VEGETATION sensor and (c) explains large seasonal and inter-annual variations in VF for Indian region. The difference between climatic VF and the VF for February 2002 clearly shows the large differences observed for agriculture areas, while high VF areas such as dense forest and low VF areas (desert) do not show large differences. Study using five-year data set over India indicates the need to use of in-season VF, in contrast to climatic VF, in the regional climate modeling.

Acknowledgements

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