Preliminary results of the BRF dependence of a subtropical semideciduous forest on angular and directional effects

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Abstract. Remote sensing data are commonly used for monitoring, measuring and detecting tropical forest dynamics and deforestation. However, only a few studies have been dedicated to examine the directional and angular effects on the spectral response of the Brazilian subtropical forest areas. Thus, the objective of this study was to present the preliminary results of an ongoing project to evaluate the bi-directional reflectance factor (BRF) response of a semideciduous forest (*Parque Estadual do Turvo* - PET) from South Brazil as a function of the directional and angular geometry of data acquisition. The PET was selected because it represents the most preserved and largest subtropical forest of the region. A field campaign was performed in September 2012 to acquire hemispherical photographs and to estimate the leaf area index (LAI) in 13 transects of 20 m x 100 m where six photographs were acquired on each transect. Multi-angle Imaging SpectroRadiometer (MISR) data acquired in January, March and August were used to evaluate the directional and angular effects on the BRF and on the nadir-normalized BRF (ANIF). A total of 57 pixels were averaged and analyzed. Results showed that view angle and directional effects became stronger from the summer (January) to the winter (August) due to decrease in LAI (leaf fall) of the highest deciduous trees and the changes in shadowing resultant from the increase in the solar zenith angle (SZA). As the sensor view zenith angle (VZA) and the SZA increased, the BRF and ANIF present more differences from the summer to the winter. ANIF results showed that the near-infrared (NIR) reflectance was less affected by the angular and directional effects when compared to the reflectance of the other MISR bands. This preliminary study requires more complete field data and long term MISR images analysis in order to validate the present results.

Keywords: remote sensing, LAI, GIS, vegetation, sensoriamento remoto, KIAF, SIG, vegetação.

1. Introduction

Traditional forest mapping methods based on field inspection has been complemented by indirect measurements through remote sensing techniques. This approach represents the lowest time consuming technique and allows near-instantaneous large area coverage. Besides the traditional mapping strategies (Franklin, 2001), several studies have tried to estimate biophysical and biochemical parameters of the vegetation based on physical and empirical models using reflectance and/or vegetation indices as input (Knyazikhin et al., 1998; Myneni et al., 2002; Jackson et al., 2004; Jiang et al., 2010; Govender et al., 2009; Roberts et al., 2011; Aguirre-Salado et al., 2012). In this context, directional and angular effects may play an important role in the accuracy of these estimates.

Directional and angular effects on vegetation are basically dependent on the wavelength, canopy architecture, phenological/development stage and on the scale under analysis (Gao et al., 2003; Doraiswamy et al., 2005; Jiang et al., 2010). When large field of view sensors like the Moderate Resolution Imaging Spectroradiometer (MODIS), *Satellite Pour l'Observation de la Terre* (SPOT) – Vegetation and the Advanced Very High Resolution Radiometer (AVHRR), or even side looking satellite data (Hyperion/EO-1) are used, these effects can

introduce a significant level of inaccuracy (Meyer et al., 1995; Galvão et al., 2009; Breunig et al., 2011a). The backscattering direction represents more sunlit canopy while the forward scattering direction indicates the predominance of the shadow fraction.

Data generated by the Multi-angle Imaging SpectroRadiometer (MISR) allows to evaluating directional and angular effects by acquiring images in four wavebands and nine view zenith angles (VZA) at nearly simultaneous time. This sensor is onboard the Terra satellite, launched in December of 1999. It was designed to measure the intensity of solar radiation reflected by the Earth system and has been used to evaluate the directional and angular effects considering the different scene components. MISR acquires images at four backscattering, one nadir and at four forward scattering view directions.

The subtropical semideciduous forest from South Brazil represents one of the largest remaining forest areas of the Rio Grande do Sul State. The current preserved areas are represented by two indigenous parks *Terra Indígena do Guarita* (TIG) and *Terra Indígena de Nonoai* (TIN) and one preservation area named *Parque Estatual do Turvo* (PET). In these forests, the highest trees present a loss of leaf in the winter drier season and a maximum of leaf area index (LAI) at the summer (February) (Breunig et al., 2011b). All these areas are useful for monitoring studies as well as to test the hypothesis that the directional effects are stronger in the winter season because of the decrease in LAI (leaf fall) and the increase in solar zenith angle (SZA).

The objective of this study was to evaluate the directional and angular effects on the spectral response of the subtropical semideciduous forest from the PET using MISR data acquired along one year.

2. Methodology

2.1. Study area characterization

The study area is the *Parque Estadual do Turvo* (PET), in northwestern of the *Rio Grande do Sul* State, in South Brazil (Figure 1). In Figure 1, two administrative micro-regions are highlighted: Três Passos (left) and Frederico Westphalen (right). The largest forest areas of the State are located in these regions. The study area has a subtropical climate (Cfa according to the Köppen classification) with an average temperature in the warmest month (January) of 22°C and a temperature range that varies between -3°C and 18°C in the coolest month (July). The total annual precipitation is around 1,665 mm well-distributed along the entire year (SEMA, 2005). The average altitude of the PET is 301 m with a gently undulated relief at the highest altitudes. Considering the legal difficulties to entry in the indigenous areas, only the PET was studied.

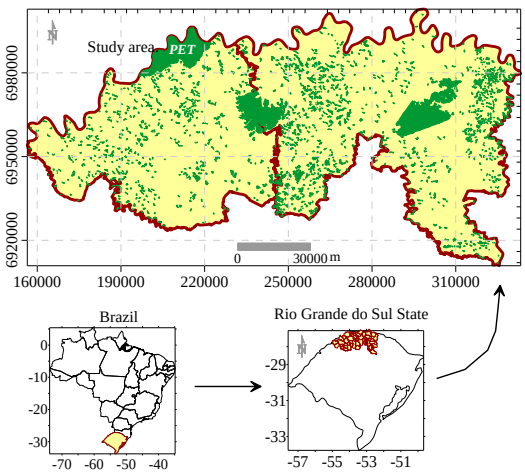


Figure 1. Study area location in northwestern of Rio Grande do Sul State in South Brazil.

2.2. Field campaign and data processing

Field campaign was performed in September 12, 2012 to acquire hemispherical photographs within the field transects. Transects were established along the main road in the PET, at 1000-m spaced intervals with a total of 13 transects of 20 x 100 m (Figure 2a). Photographs were acquired within each transect at every 20 m (Figure 2b). Results of LAI estimates in each transect were averaged. Summer acquisition was not possible because of legal restrictions to entry in the PET at that time, but it programmed for 2013.

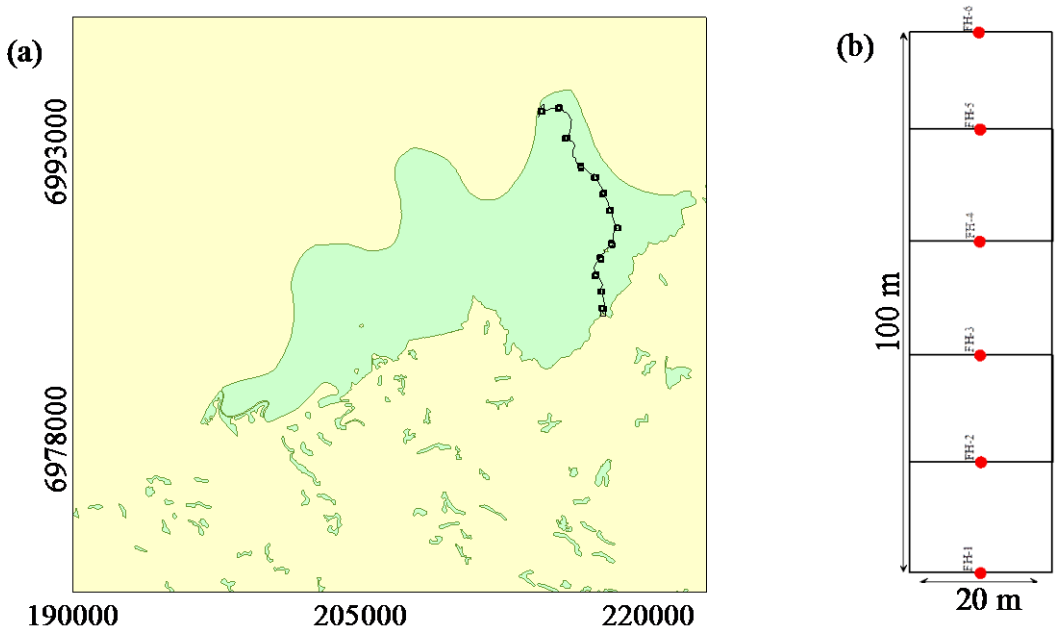


Figure 2. Distribution of the (a) field transects along the main road and (b) of the sample plots of photographs acquisition within each transect.

2.3. MISR data acquisition and processing

A total of 15 MISR acquired images from January to August 2012 were used to study the directional effects. MISR products were obtained by FTP protocol of data transfer (l4ftl01.larc.nasa.gov) and filtered to the path 223 (MISR_AM1_AS_LAND_P223…) within the server. The product MIANCAGP (Ancillary Geographic Product) was downloaded to perform the geometric correction of the bidirectional reflectance factor (BRF) product (MIL2ASLS). More detailed information of MISR products is presented by Lewicki *et al.* (2004) and by the MISR official website.

MISR BRF product was processed to 1.1 km x1.1 km, in the four bands (blue, green, red and near infrared – NIR) and to the nine relative VZA (0; ±26.1°; ±45.6°; ±60.0°; e ±70.5º) for the cameras An, Af/Aa, Bf/Ba, Cf/Ca and Df/Da with bands centered at 443, 555, 670 and 865 nm, respectively. In the present study, the cameras followed by "f" represent images acquired at backscattering direction, "a" represent images acquired at forward scattering direction and "n" the nadir acquired images.

Initially, only the 2012 data were processed using the MISR-View 5.31 algorithm. This software was used to evaluate data availability for the study area and cloud coverage. After selection of the images with good quality, MISR original data were imported using an ENVI-IDL add on (MISR L2 for BRF) (ITT, 2009).

After processing, only three images of 2012 year were retrieved and used to the seasonal analysis over the study area: January 6, 2012; March 30, 2012 and; August 17, 2012. All other dates showed low quality BRF values (atmospheric contamination).

2.4. Data analysis

Data analysis was performed over pixels extracted over the main forest area (PET) based on the three images of the 2012 year. The forest area was masked and the BRF values of high quality pixels were exported for graphing and statistics computation. MISR data were nadir-normalized by dividing the data from the off-nadir cameras (Af/Aa, Bf/Ba, Cf/Ca e Df/Da) by those of the nadir one (An). This is equivalent to obtain the anisotropic index "ANIF". A total of 57 pixels were used in the calculations.

In spite of the small number of images, these three dates allowed the evaluation of directional and angular effects seasonally from the summer, when the forest presents the maximum LAI (Breunig et al., 2011b), to the winter, when the forest presents the minimum LAI due to leaf fall by the highest trees (deciduous forest).

3. Results and discussion

Three quick looks of the MISR nadir data (camera "An") illustrate the seasonal differences in the studied period (Figure 3) associated with forest canopy changes face to view-illumination geometry.

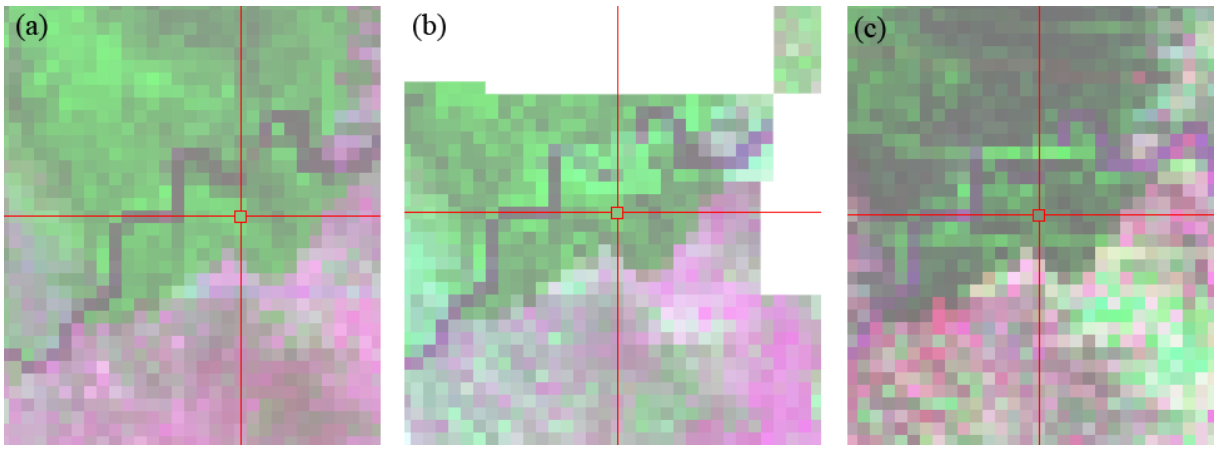


Figure 3. Quicklooks of nadir MISR false-color composites (RGB for bands at 670 nm, 865 nm and 555 nm, respectively) for (a) January 6, 2012, (b) March 10, 2012 and, (c) August 17, 2012. An automatic 2% linear enhancement contrast was applied to all images.

From the analysis of the mean BRF values of the 57 pixels in the four MISR bands as a function of the acquisition geometry, a notable difference in BRF was verified (Figure 4). All bands presented variability from the summer (January 6, 2012) to the winter (August 17, 2012). The directional effect seems more evident in the winter with low LAI values and large SZA. In this season, the largest trees present significant leaf fall (deciduous). On the other hand, in the summer, the directional effects were much smaller. These results suggest that PET semideciduals forest presents a gradual transition from a more isotropic canopy to a more anisotropic canopy from the summer to the winter due to changes in LAI and in the geometry of data acquisition (Figure 4).

Considering the magnitude of the BRF values, the blue band (Figure 5a) presented the lesser seasonal variability for a given VZA. The variation of SZA must be considered as it increased from January (≅ 25°) to the winter (≅ 48°) (Galvão *et al*., 2011; Moura *et al*., 2012). The green (Figure 5b) and red (Figure 5c) bands presented the highest variability of ANIF as a function of the VZA in the backscattering direction. From the normalized-nadir (ANIF) values, the NIR band (Figure 5d) seems lesser dependent of the angular and directional effects than the other bands.

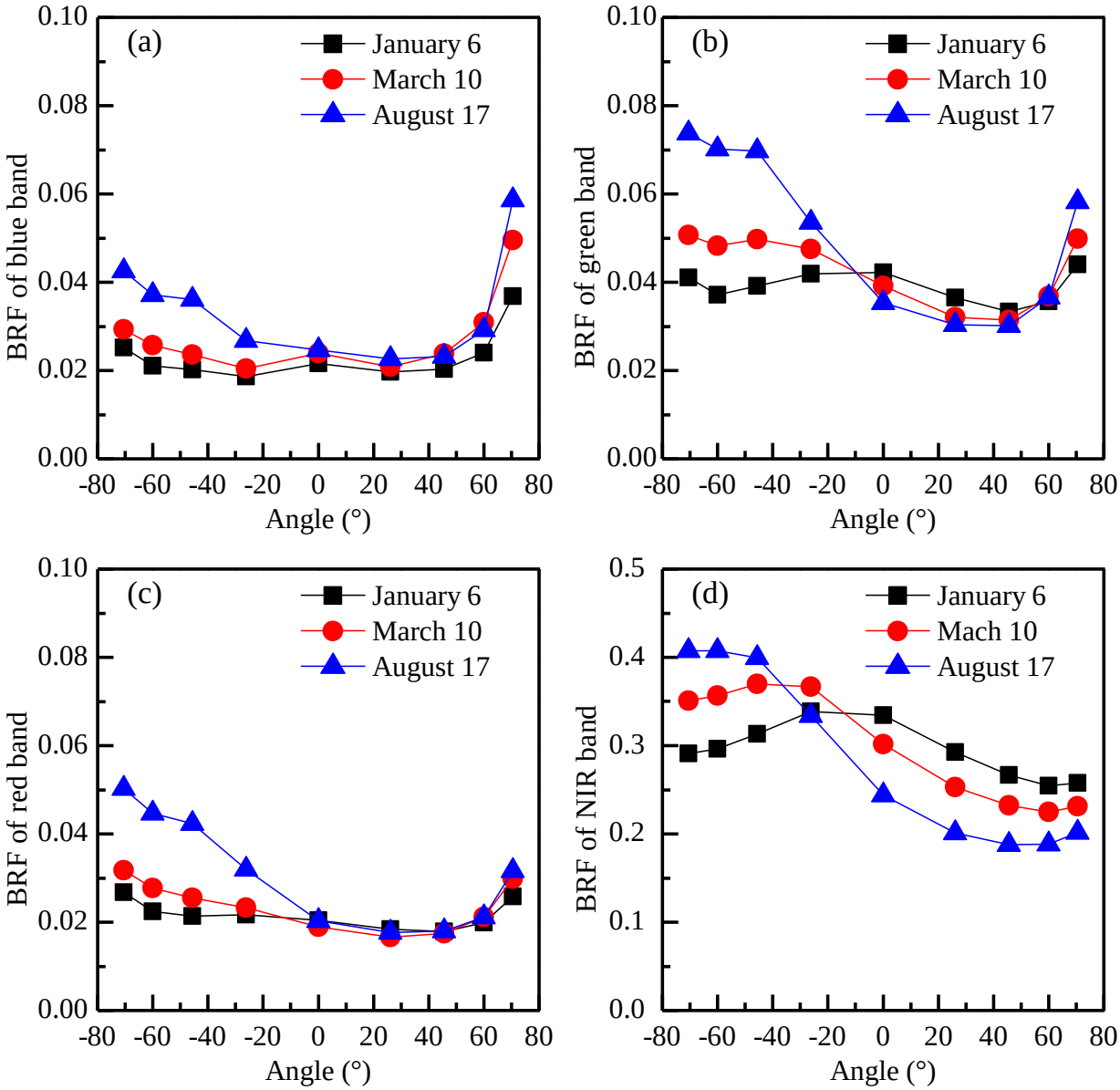


Figure 4. Angular and directional effects on the average BRF of 57 MISR pixels for the bands: (a) blue, (b) green, (c) red and (d) NIR. Negative view zenith angles (VZA) indicate backscattering direction, whereas positive VZA indicates forward scattering direction. All dates refer to 2012.

Results from Figure 5 can significantly affect the determination of vegetation indices such as the Normalized Difference Vegetation Index (NDVI) (Rouse *et al.*, 1973) and the Enhanced Vegetation Index (EVI) (Huete *et al*., 2002). These vegetation indices are usually used to monitor forest areas and can present a significant dependence on the directional and angular effects, as showed by Galvão *et al*. (2011) and Moura *et al*. (2012) in Amazonian tropical forest areas of Brazil.

Preliminary results of LAI (based on 10 hemispherical photographs) estimates from hemispherical photographs were obtained only in the winter (3.28 ±0.62) and will be compared to the summer estimates to be performed soon. Long term field LAI measurements will improve our understanding about canopy dynamics of subtropical forest areas located in South Brazil (Figure 1) as well its impact on BRF and ANIF of several sensors with pointing capability or large field of view angles.

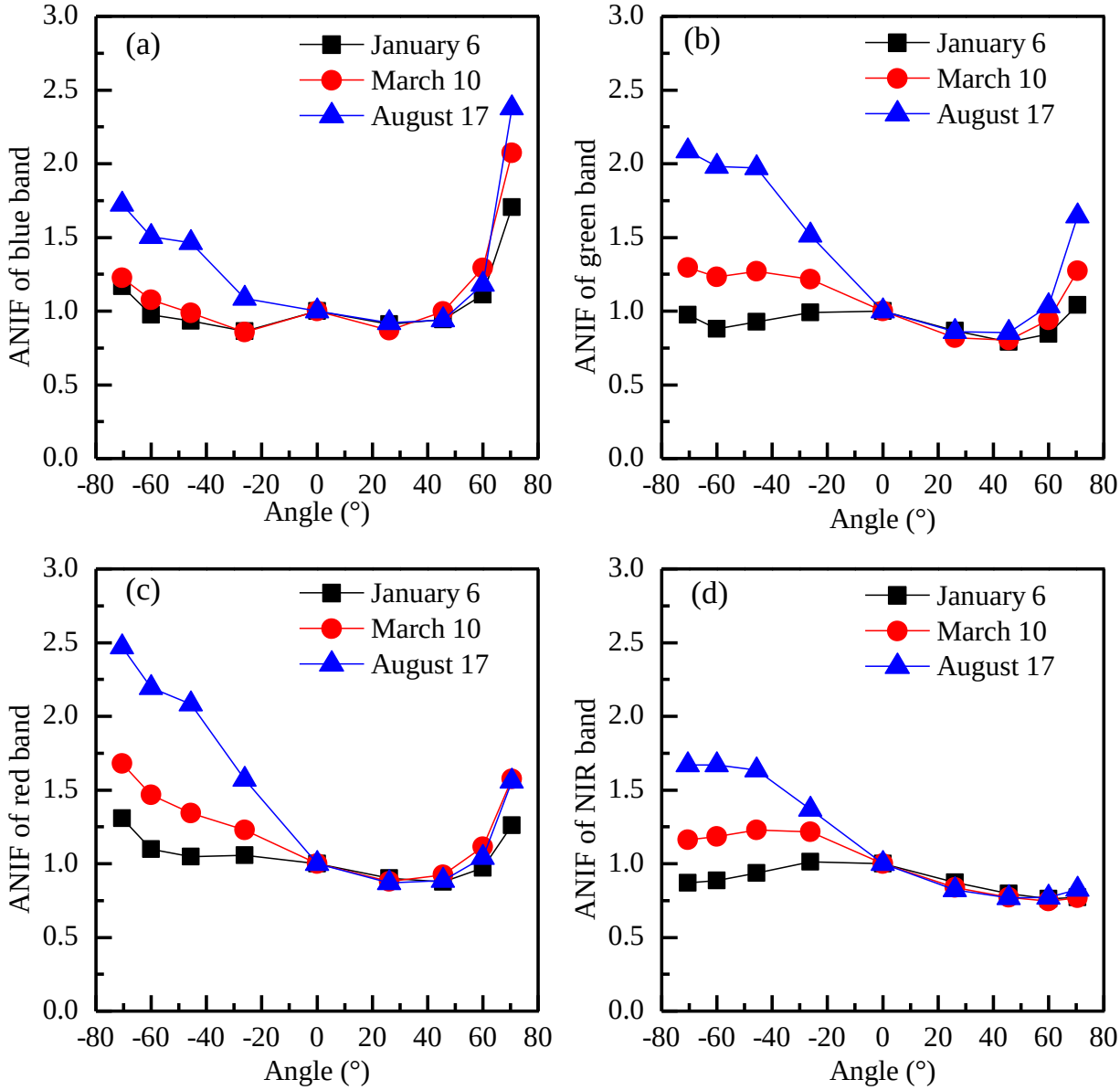


Figure 5. Angular and directional effects on the average nadir-normalized BRF (ANIF) of 57 MISR pixels for the bands in: (a) blue, (b) green, (c) red and (d) NIR. Negative view zenith angles (VZA) indicate backscattering direction, whereas positive VZA indicates forward scattering direction. All dates refer to 2012.

4. Conclusions

Results showed a gradual increase of the directional and angular effects from the summer (January) to the winter (August), in all nine MISR cameras. As the VZA increased, the BRF and the nadir-normalized data (ANIF) also increased. Results suggest that the greatest anisotropy observed in the winter for the subtropical semideciduous forest of the PET is explained by the lower LAI values due to leaf fall of the largest trees and by the resultant modifications in shadows from the large SZA during this period. These results suggest that carry is necessary when interpreting remote sensing time series if one considers using data acquired by large field-of-view sensors or by instruments with pointing capability.

Field and image data acquisition using different sensors will continue on the next years to better characterize the seasonal dynamics of the semideciduous forest of the study area and the impacts of the bi-directional effects on its spectral response.

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