ON THE ABILITY OF THE ERS SCATTEROMETER TO DETECT VEGETATION PROPERTIES

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ABSTRACT

The ability of the active microwave remote sensing to complement existing optical vegetation indices has been explored by variety of studies [1-4]. To demonstrate these complementarities, we investigate synergies between the slope parameter from the ERS scatterometer (ERS-SCAT) [5] and the Normalized Difference Vegetation Index (NDVI). While the NDVI is strongly linked to the absorption of photosynthetically active radiation (PAR), the active microwave signal has the ability to penetrate partially a vegetation canopy, bouncing back from its stalks and stems and so returning a signal (i.e. backscatter) that is influenced by the canopy structure. While this interaction is rather complicated and not fully understood, this study suggests the ability of the ERS-SCAT slope parameter to differentiate between varieties of structural vegetation properties and complement so to existing optical vegetation indices.

Keywords— Phenology, ERS, Great Plains, Scatterometer, NDVI

1. INTRODUCTION

Observations of vegetation characteristics are typically provided by the optical remote sensing data. These provide information on vegetation status (e.g., NDVI, Enhanced Vegetation Index or EVI), structure (Leaf Area Index or LAI), as well as net primary production (NPP) and have been applied across a range of fields from the phenological variability [6], land change [7] to detection of carbon sinks and sources. While the NDVI and the EVI have been well studied, the biomass and structural optical products lack deep understanding and thorough validation. Limitations of aboveground biomass estimates from optical data encouraged recent research in microwave remote sensing of vegetation. The ability of microwaves to partially penetrate vegetation has been explored [1-4], emphasizing estimates structural properties that complement measurements retrieved from optical data.

The sensitivity of active microwave sensors to vegetation properties has been demonstrated [1-3]. Wagner et al. [2] studied how ERS-SCAT might monitor seasonal vegetation development. Studying the slope—temporal change of the backscatter at a specific incidence angle (Figure 1)—they concluded that this information could be useful for discriminating among major vegetation regions across the globe. Currently, information about the slope at 40° incidence angle is implemented for the vegetation correction of the ASCAT soil moisture product [5].

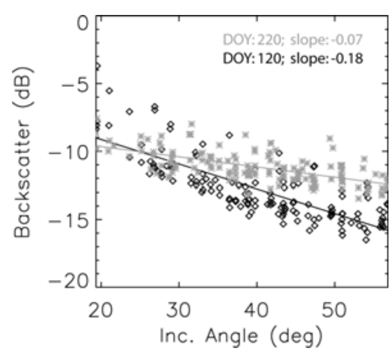

Figure 1. Change of ERS-SCAT backscatter with incidence angle at 40° incidence angle (Days Of Year 120 and 220).

In this study we investigate the vegetation response on two datasets retrieved from two independent technologies—backscatter from the ERS-SCAT and the NDVI derived from the 16-day MODIS Nadir BRDF-Adjusted Reflectance (NBAR) optical product.

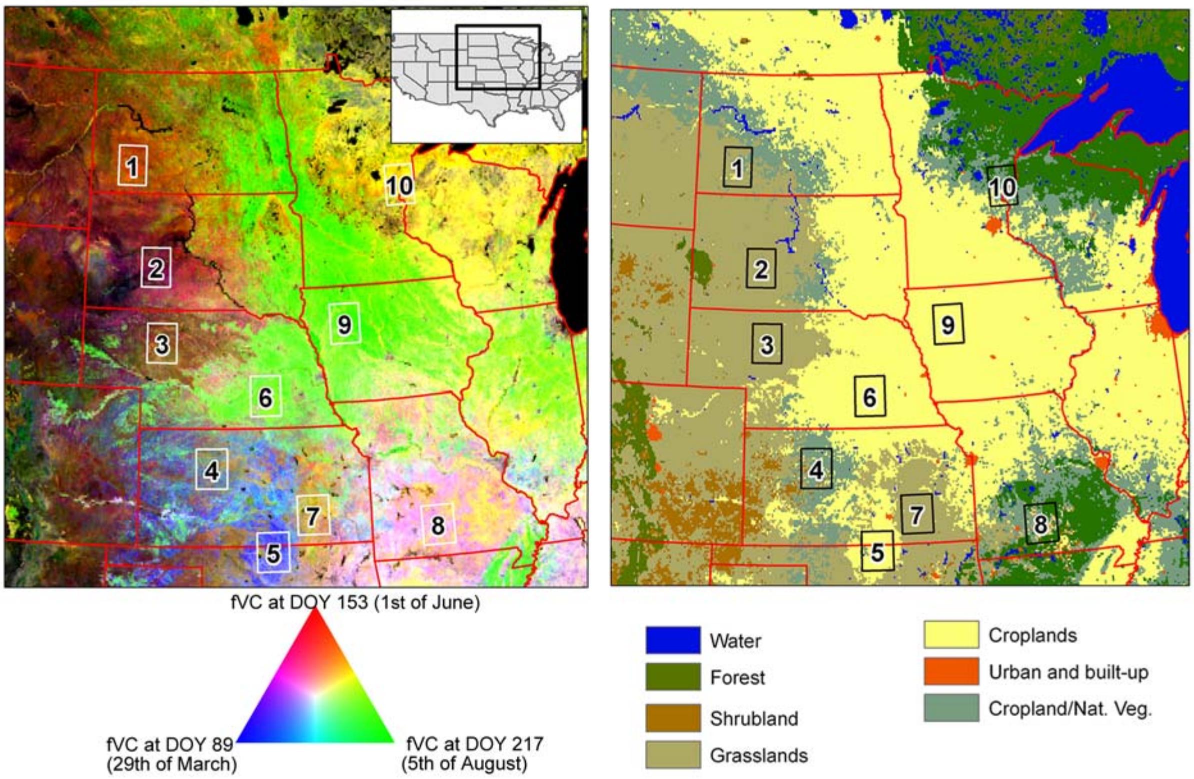

Figure 2. Location of the study area overlaid with selected 10 phenological targets. At the background: The color-composite of the fractional vegetation cover (fVC) for 2007 derived from the NBAR reflectance using the algorithm of Jiang et al. [8]. Color represents Day Of Year (DOY), with red=D Of Year 153, green=DOY 217, blue= DOY 89, respectively (left). The MODIS land cover characterization from https://wist.echo.nasa.gov/api/ – the IGBP global vegetation scheme (right).

The long time series of ERS-SCAT were processed at the Institute of Photogrammetry and Remote Sensing (IPF), Vienna University of Technology (TUWIEN), the MODIS NBAR (MCD43A4) product was acquired from the Land Processes Distributed Active Archive Center (LPDAAC: https://wist.echo.nasa.gov/api/). The temporal characteristics are investigated over key agricultural areas in the Great Plains, USA (Figure 2).

2. METHODOLOGY

The Great Plains of the USA were selected as the study area because of the presence of large and homogenous areas with diversity of land cover classes important for analyses of coarse resolution data such as the ERS-SCAT. The ten selected target areas represent different land surface phenologies according to the fractional vegetation cover composite (Figure 2). Each target area covers 1 by 1 degree (or 20x20 0.05 degree pixels of the NBAR product, 49 ERS-SCAT grid points). Targets 2, 3, and 7 represent variety of grasslands: mixed grass prairie (2), sandhills prairie (3), and tallgrass prairie (7). Crops dominate targets 5 (winter wheat), 6 (irrigated corn and soybean), and 9 (dryland corn and soybean). Targets 1, 4, and 10 are mixtures: cropland/grassland (1, 4) and woodland/cropland (10). Target 8 is dominated by deciduous forest.

We followed Wagner et al. [2] study and computed the ERS-SCAT daily slope—change of backscatter at 40° incidence angle (Figure 1). The slope is calculated for a given day *t* from the triplet backscatter measurements observed within a given centered time period [5]. A time period of 32 days was selected to filter the high frequency variation, while still capturing most of the phenological dynamics. The result is a set of daily slope values representing 32-day window. The NDVI derived from the 16-day MODIS NBAR product was masked for snow using the available snow flags. The yearly statistics (mean, median, and 10^{th}, 25^{th}, 75^{th}, and 90^{th} percentiles) of the ERS-SCAT slope and the NDVI were computed over each target, over time period ranging from September 2003 through May 2007 (the time period was limited by the availability of both the ERS-SCAT and the NBAR datasets over the study area). Spearman cross-correlations of the NDVI with the ERS-SCAT slope time-series were computed as function of the lag L. Analysis was restricted to NDVI values greater than 0.35 and the corresponding ERS-SCATslope values.

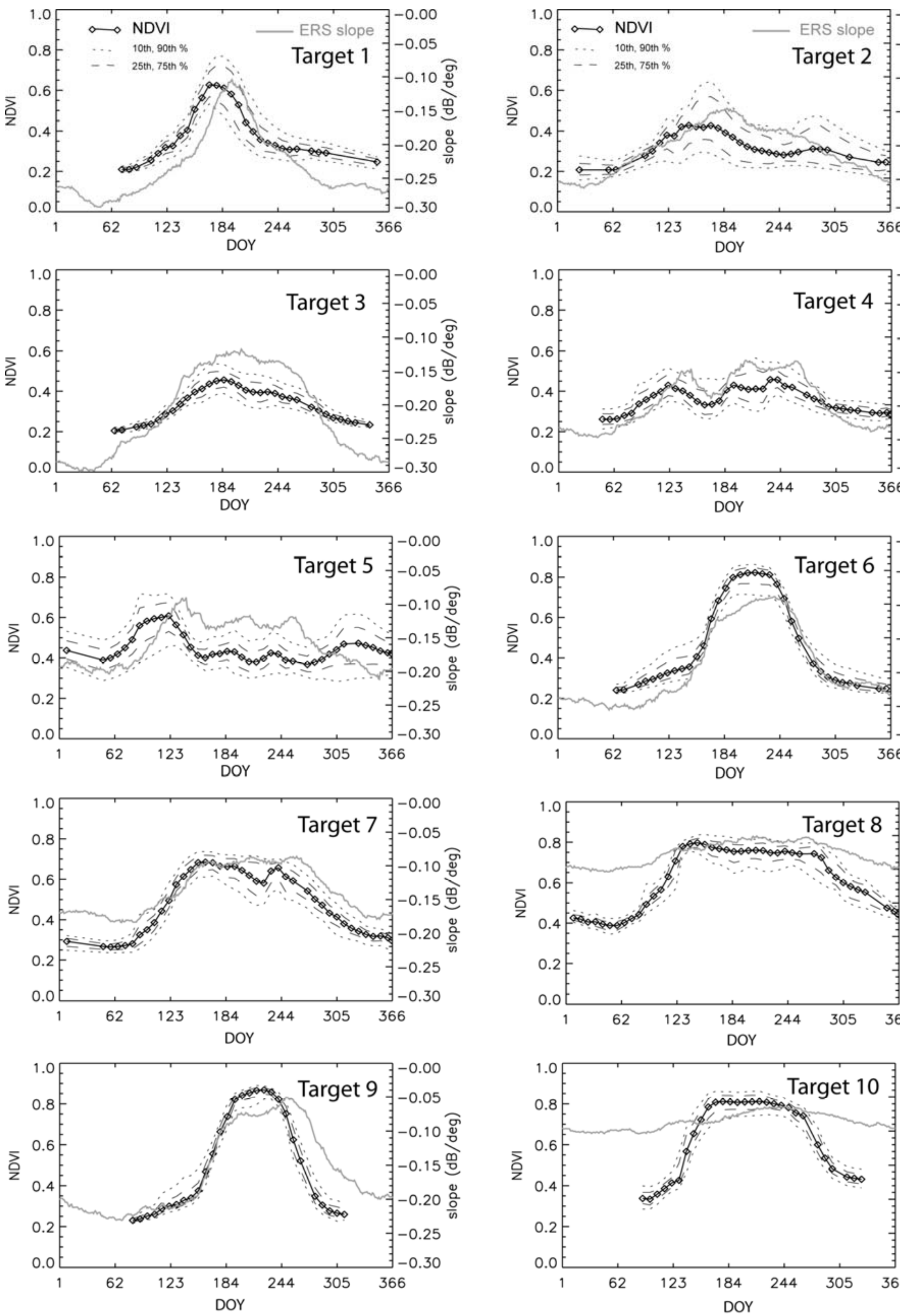

Figure 3. Mean NDVI and ERS-SCAT *slope* time series over 10 targets exhibiting different land surface phenologies.

5. RESULTS AND DISCUSSION

The seasonal development of the NDVI and ERS-SCAT slope averaged over 3.5 years is displayed in Figure 3. The variability of the NDVI within each target is illustrated by the percentile bands around the means (Fig. 3); the variability of the slope differed only minimally (data not shown). In general, the ERS-SCAT slope captured seasonal dynamics comparable to the NDVI, but with differences in phase and amplitude according to land cover. The lag values with maximum correlation representing the shift between analyzed time-series are provided in Table 1. Cross-correlations were not computed over forested targets due to the minimal seasonality of the slope time-series.

Target ➔	1	2	3	4	5	6	7	9
Lag (days)	-8	-24	0	0	-24	0	-8	-8

Table 1. The lag values with maximum rank correlation between the NDVI and slope time series.

The target responses can be regrouped to three classes according to the dominant land cover: (A) grasslands– 1, 2, 3, and 7, with 1 being mixed with summer crops; (B) croplands– 4, 5, 6, and 9, with 4 being mixed with winter wheat; and (C) woodlands– 8 and 10. The class A can be characterized by earlier vegetation onset and maximum NDVI lower than 0.5 (exceptions are targets mixed with croplands). The slope lag was equal to -8 days in tall-grass prairie (7) and grasslands/croplands (1), 0 in sandhills prairie (3), and -24 days in mixed-grass prairies (2). The slope offset in class B was equal to 0 for irrigated corn/soybean and mixture of cropland/grassland (6, 4), -8 for dryland corn/soybean (9), but -32 days for winter wheat. Finally, the class C demonstrated constant ERS-SCAT slope behavior compared to seasonal changes of NDVI. Lags were measured in periods of 8 days according to the MODIS NBAR temporal resolution.

These results are in agreement with Macelloni et al. [3] suggesting the large difference between the backscattering of canopies with broader versus narrower leaves and sparser versus denser canopies. Canopies that are less dense and/or composed of narrower leaves (drier mixed-grass prairies and winter wheat) show significant negative shifts between NDVI and slope time series. In contrast, the denser canopies of corn and soybean and tallgrass prairies result in no temporal shift. If the backscatter is mostly attenuated, whether by larger planophile leaves or denser canopies, the ERS slope performs similarly to optical indices. Sparser, narrower leafed canopies allow deeper penetration, enabling returns bouncing back from stalks and stems, thus capturing and additional structural aspect. This phenomenon is notable during times when chlorophyll is lower (during senescence and drydown) but the stem and stalks remain.

10. DISCUSSION AND CONCLUSIONS

In this study, vegetation influences on two remote sensing variables retrieved from independent technologies—microwave scatterometer and optical spectroradiometer—were studied over diverse phenological targets in the Great Plains, USA. While the backscatter interaction is rather complicated and not fully understood, this study illustrates the ability of the ERS-SCAT slope parameter to differentiate between land covers with sparser and denser canopies, thereby complementing optical monitoring.

11. REFERENCES

[1] E. Mougin, A. Lopes, P. L. Frison, and C. Proisy, "Preliminary analysis of ERS-1 wind scatterometer data over land surfaces," *International Journal of Remote Sensing*, vol. 16, pp. 391-398, 1995.

[2] W. Wagner, G. Lemoine, M. Borgeaud, and H. Rott, "A study of vegetation cover effects on ERS scatterometer data," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 37, pp. 938-948, 1999.

[3] G. Macelloni, S. Paloscia, P. Pampaloni, F. Marliani, and M. Gai, "The relationship between the backscattering coefficient and the biomass of narrow and broad leaf crops," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 39, pp. 873-884, 2001.

[4] J. Shi, T. Jackson, J. Tao, J. Du, R. Bindlish, L. Lu, and K. S. Chen, "Microwave vegetation indices for short vegetation covers from satellite passive microwave sensor AMSR-E," *Remote Sensi. of Environ.*, vol. 112, pp. 4285-4300, 2008.

[5] V. Naeimi, K. Scipal, Z. Bartalis, S. Hasenauer, and W. Wagner, "An improved soil moisture retrieval algorithm for ERS and Metop Scatterometer observations," *IEEE Transactions on Geoscience and Remote Sensing*, 2009.

[6] K. M. De Beurs and G. M. Henebry, "Land surface phenology, climatic variation, and institutional change: Analyzing agricultural land cover change in Kazakhstan," *Remote Sensing of Environment*, vol. 89, pp. 497-509, 2004.

[7] B. C. Reed, J. F. Brown, D. Vanderzee, T. R. Loveland, J. W. Merchant, and D. O. Ohlen, "Measuring phenological variability from satellite imagery," *Journal of Vegetation Science*, vol. 5, pp. 703-714, 1994.

[8] Z. Jiang, A. R. Huete, J. Chen, Y. Chen, J. Li, G. Yan, and X. Zhang, "Analysis of NDVI and scaled difference vegetation index retrievals of vegetation fraction," *Remote Sensing of Environment*, vol. 101, pp. 366-378, 2006.