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MONITORING VEGETATION DYNAMICS USING MERIS FUSED IMAGES

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ABSTRACT

The MEdium Resolution Imaging Spectrometer (MERIS) can be used to monitor vegetation dynamics at regional to global scales. However, the spatial resolutions provided by this sensor (300 or 1200 m) might not be appropriate to monitor fragmented landscapes. This is why the synergistic use of MERIS full resolution (300 m) and a high spatial resolution land use/land cover database (25 m) is studied in this paper. An unmixing-based data fusion approach was used to produce images that have the spectral and temporal resolutions provided by MERIS and a Landsat-like spatial resolution. The central part of The Netherlands was selected to illustrate this approach. Seven MERIS full resolution and one Landsat TM image were available over this area too. The radiometric characteristics of the fused images were evaluated at 25 and at 300 m. After this quantitative quality assessment, the best fused images were used to compute MTCI and MGVI profiles for the main land cover types present in the study area.

1. INTRODUCTION

Monitoring vegetation dynamics is crucial to fully understand the interactions between the biosphere and the atmosphere [1]. Earth observation satellites provide regular and synoptic data that can be used to monitor these dynamics at different spatial, spectral and temporal resolutions. Time series of vegetation indices are the most common approach to monitor greenness shifts [2].

Despite the good spatial and spectral resolution of MERIS an accurate characterization of heterogeneous landscapes still requires a higher spatial resolution. Landsat-like sensors (spatial resolution of 20 to 30 m) can be used to study heterogeneous landscapes, but their temporal resolution is, in general, not sufficient for monitoring purposes, especially in frequently clouded areas [3].

Data fusion techniques could facilitate the study of heterogeneous and frequently clouded areas by offering an efficient means to integrate different kinds of images [4]. In this study multitemporal MERIS FR data were combined with a high spatial resolution land use/land cover dataset using an unmixing-based data fusion approach.

2. METHODOLOGY

2.1 Data fusion

Recently, Zurita-Milla et al. [5] presented a detailed implementation of the unmixing-based data fusion approach to combine MERIS FR and Landsat TM data. In this implementation two parameters (namely, the size of the MERIS neighborhood and the number of classes used to classify the high spatial resolution image) need to be optimized. In a follow-up study, Zurita-Milla et al. [6] studied the applicability of such MERIS fused images for land cover mapping and for vegetation status assessment over heterogeneous landscapes.

Here we investigate the use of a high spatial resolution land use/land cover map to characterize the landscape. This allows us to apply the unmixing-based data fusion method to a time series of MERIS FR images and to use the resulting fused images to monitor vegetation seasonal dynamics with high spatial, spectral and temporal resolutions.

2.2 Study area and datasets

The study area covers approximately 2400 km2 of the central part of The Netherlands (centered at 52.19° N, 5.91° E). For the year 2003, three datasets are available over this area: (i) a Landsat TM-5 image acquired on 10 July 2003, (ii) a high spatial resolution land use database and (iii) a time series of seven MERIS full resolution level 1b images acquired the 18th of February, the 16th of April, the 31st of May, the 14th of July, the 6th of April, the 15th of October and the 8th of December.

The TM image was already geo-referenced to the Dutch national coordinate system and had a pixel size of 25 m. The MERIS FR images were corrected for the smile effect [7] and transformed into top of atmosphere radiances (L_{TOA}) using the metadata provided with the files. The land use/land cover database, known in Dutch as LGN, is a geographical database that describes the main land uses in The Netherlands. The latest version, LGN5, includes the main land use/land cover types present in the country and has a grid structure with a cell size of 25 m.

2.3 Image co-registration

Image co-registration is a critical step when combining multiple datasets. Here we compute the actual ground instantaneous field of view (GIFOV) of each MERIS FR pixel. The AMORGOS 3.0 software is used In order to use best possible MERIS geo-location values [8]. Based on the information derived from AMORGOS we

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determined the GIFOV of each MERIS pixel. After that, we calculated the fractional coverage of the LGN5 classes for each MERIS pixel. In this respect, Zhukov et al. [9] showed that the accuracy of the retrieved signal is inversely related to the fractional coverage of the class and they suggested aggregating small fractions to increase the reliability of the solutions. In our work, a threshold of 5% was selected. This is, classes that cover less than 5% of a MERIS pixel are aggregated into the spectrally most correlated LGN5 class present in the considered pixel.

3. RESULTS AND DISCUSSION

3.1 Co-registration accuracy

The LGN5 and the time series of MERIS images were co-registered without re-sampling the data. This means that there's neither a loss of geometrical accuracy (as resulting from nearest neighbor resampling) nor an alteration of the original pixel values, due to bi-cubic resampling for example.
Fig. 1 shows an overlay of the MERIS image from July (band 13, NIR) over the TM image of July (band 4, NIR). Notice that since the TM image used in this study was one of the images used to create the LGN5, the co-registration between this image and the LGN5 was perfect. The GIFOV of each MERIS pixel is represented as a polygon in Fig. 1.

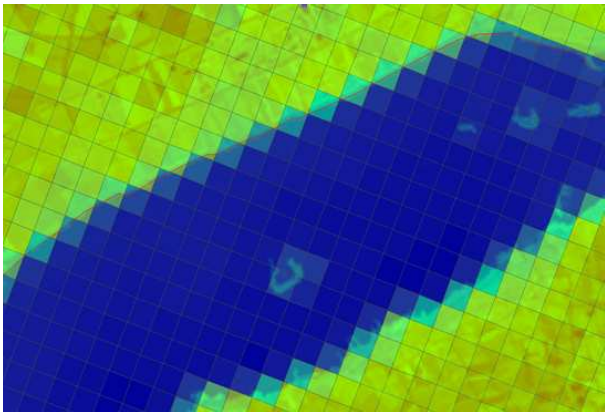

Figure. 1. Co-registration of the MERIS and TM images of July: MERIS band 13 is depicted using a blue-green-red color table and TM is shown as semi-transparent background.

The small irregularities that can be observed in the shape of these polygons are caused by topography and by the satellite position and look angle. In addition, an increase of the GIFOV was observed when moving from nadir to the edge of the swath. Accounting for this effect is, therefore, essential to properly determine the fractional composition of each MERIS pixel. Fig. 1 can also be used to visually assess the co-registration accuracy: the color gradient of the MERIS pixels corresponds well with the fraction of water within these pixels. It illustrates that the use of AMORGOS to compute the MERIS geo-location values resulted in a good co-registration accuracy.

3.2 Data fusion

The unmixing-based data fusion approach was first solved for the MERIS image of July. The ERGAS index [10] was computed at 25 and at 300 m to identify the best fused image [5]. In this case, the best fused image was obtained for a neighborhood size of 9 by 9 MERIS pixels (recall that the MERIS images were fused with the LGN5 and that therefore the number of classes do not need to be optimized in this case).

3.3 Vegetation dynamics

The series of fused images was used to compute the MERIS terrestrial chlorophyll index (MTCI) and the MERIS global vegetation index (MGVI). A 300 by 300 TM pixels subset located in the northwest of the study area was selected for illustration so that the spatial enhancement of the fused images could clearly be visualized. Fig. 2 shows the results for the MTCI whereas Fig. 3 shows the results for the MGVI. The large water body situated in the middle of the selected subset was masked out before computing the vegetation indices because its MTCI and MGVI values are meaningless. Some outlier pixels (i.e. pixels with unfeasible index values) were identified at the edges of field plots and for non-vegetated areas (e.g. roads etc). These values were masked out from the images (shown in dark blue).

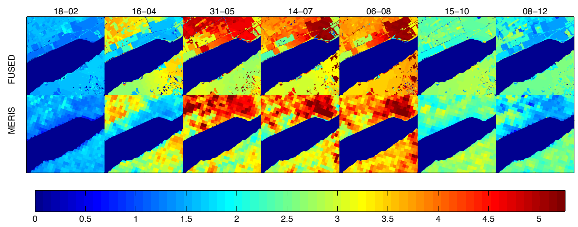

Figure 3. Temporal evolution of MTCI values for fused (top) and MERIS (bottom) data.

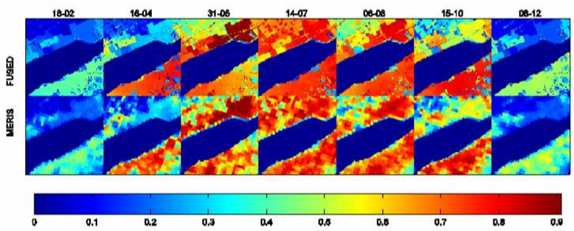

Figure 3. Temporal evolution of MGVI values for fused (top) and MERIS (bottom) data.

Vegetation dynamics are visible in both images: low vegetation index values are found at the beginning and at the end of the series (which correspond to the winter months) and high vegetation index values are found in the middle of the series (spring and summer). The fused images preserve the information contained in the original MERIS images (i.e. general spatial patterns are consistent at the original MERIS scale) whilst showing additional spatial details. This shows the potential of fused images for monitoring individual fields.

4. CONCLUSIONS

In this work the linear mixing model is used to downscale time series of MERIS FR images (300 m pixel size) to a Landsat-like spatial resolution (25 m). A heterogeneous and fragmented landscape located in the central part of The Netherlands was selected to illustrate the performance and applicability of the proposed method. Seven MERIS FR images were available over this area covering the period comprised between the months of February and December 2003. The Dutch land use/land cover database of the same year (LGN5) was used to derive the fractional composition of each MERIS pixel. To do so, the ground instantaneous field of view (GIFOV) of each MERIS pixel was computed using the AMORGOS software to obtain accurate MERIS geo-location values. Subsequently, each MERIS pixel was successively unmixed for each MERIS band using the corresponding LGN5 fractions.

Results showed that vegetation indices computed from the fused images yielded consistent spatial patterns as those found when computing the indices with original MERIS images. However, the use of fused images provided much more spatial details, showing the potential of fused images to monitor individual vegetation patches or agricultural fields.

These results are particularly relevant to map and monitor frequently clouded, heterogeneous and/or highly fragmented landscapes where the use of medium or low spatial resolution data is required in order to increase the chance of getting cloud free images.

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