Physical Measurements and Signatures in Remote Sensing, Guyot & Phulpin (eds)
© 1997 Balkema, Rotterdam, ISBN 90 5410 917 3

The use of NOAA-AVHRR 'overlapping' NDVI Maximum Value Composites for vegetation assessment in Scotland

A. R. S. Marçal
University of Dundee, UK

G. G. Wright
Macaulay Land Use Research Institute, Aberdeen, UK

ABSTRACT: NOAA-AVHRR data between April and September of 1995 and 1996 was processed to produce Normalised Difference Vegetation Index (NDVI) Maximum Value Composites (MVCs) for Scotland. The limitations of monthly NDVI MVCs are discussed for Scotland. Overlapping NDVI MVCs were produced from a fixed number of images and temporal NDVI plots were obtained for selected land cover classes. The date assigned to a NDVI MVC on a temporal plot is analysed and discussed.

1 INTRODUCTION

The amount and frequency of cloud cover is a limiting factor on the use of passive remote sensed satellite data. It is particularly important in northern Europe where the presence of cloud cover is abundant even during the Summer. In these areas, it is difficult to obtain sufficient data to produce vegetation temporal profiles from satellites with a long repetition period, such as Landsat or Spot. Although data from NOAA-AVHRR has a much lower spatial resolution (1.1 km at nadir) than Landsat and Spot satellite data, the temporal resolution is much higher. Each of the two operational NOAA satellites scans any specific location the Earth once every 12 hours. Due to unsuitable illumination and viewing conditions not all of these images can be used. The number of useful images is limited to around 5 on a 9 day period. This is further reduced by the presence of cloud. Nevertheless, a reasonable number of nearly cloud free images can be obtained from AVHRR for most places in one year.

The objective of this work is to develop a methodology which allows for AVHRR data to be used on a regular basis to monitor the vegetation biomass change in Scotland on a national and regional scale. This should be consistency achieved for the widest period possible.

1.1 *The Land Cover of Scotland 88 (LCS88) survey*

The Land Cover of Scotland 1988 (LCS88) survey (MLURI 1993a) was performed, using monochrome aerial photography, with the aim of assisting in developing and monitoring the effectiveness of countryside policies in Scotland. For this study, a 500 m ground resolution (pixel) dataset was produced, with classes being assigned to the predominant individual feature on the original raster (50 m) LCS88 dataset. The most common LCS88 classes are shown on Figure 1. For comprehensive information about the LCS88 survey readers are referred to the main project report (MLURI 1993b).

The LCS88 survey treats land cover classes uniformly throughout the country. However, as the growth of these cover features is affected by climate, there are substantial differences in their vegetation dynamics within Scotland. Satellites can provide data to monitor the vegetation biomass change on a regional and national scale, enhancing the information available on the LCS88 dataset.

Table 1. Number of AVHRR images used

Month	1995	1996
April	2	5
May	4	2
June	5	5
July	5	5
August	5	4
September	3	3

2 DATA PROCESSING

AVHRR data from NOAA 14 has been collected between the months of April and September 1995 and 1996. The number of images which used was limited by the satellite repetition period, very oblique images were not selected, and most importantly by the amount of cloud cover. The best 24 images from each year were chosen for processing. Table 1 shows the number of images used from each month of 1995 and 1996.

Normalised Difference Vegetation Index (NDVI) reflectance calibrated images (Rao and Chen 1996) were produced from the raw AVHRR channels 1 and 2. The 1995 NDVI images were rectified into 1 km pixel datasets using on average 45 well distributed Ground Control Points (GCPs) per image (Marçal and Wright 1997). The 1996 images were also rectified into 1 km pixel datasets using an automatic rectification system (Marçal 1997). The system performs an automatic image registration, based on the satellite orbital model (Brush 1985), with around 20 GCPs being identified on the automatic image. The final imagery is produced by a single image transformation from the raw data.

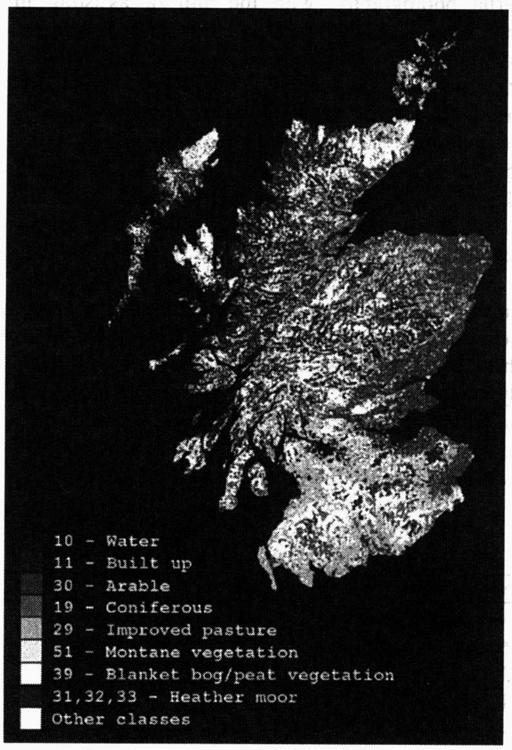

Figure 1. The Land Cover of Scotland 88 census.

2.1 *Monthly NDVI Maximum Value Composites*

The use of Maximum Value Composites (MVCs) is generally accepted as an effective way of eliminating the undesirable influence of factors, such as variable atmosphere and viewing and illumination geometry, on the NDVI values (Holben 1986). This is true when a reasonable number of cloud free images is available for compositing.

Monthly NDVI MVCs were produced for Scotland, between April and September for 1995 and 1996. The small number of images available from April (2) and September 1995 (3) did not allow for consistent MVCs to be obtained for these months. Similarly, only four monthly NDVI MVCs from 1996 were used, as the number of images available from May and September was only 2 and 3 respectively.

Assuming that the minimum number of cloud free images required to produce a consistent NDVI MVC is 4, only 4 monthly NDVI MVCs are available from 1995 and 1996. Increasing the requirement of cloud free images to 5 will reduce the number of monthly MVCs available to only 3 per year. The use of monthly NDVI MVCs can consequently be limited, in places like Scotland, to 3 or 4 months in one year.

2.2 *Overlapping NDVI MVCs*

A different method was used to analyse continuos vegetation biomass change in Scotland from early Spring to the end of Summer. Instead of producing a NDVI MVC from a fixed period of time (e.g. a month) regardless of the number of images available, NDVI MVCs from a fixed number of images were produced. The compositing periods will vary depending on the availability of data. Four independent NDVI MVCs were produced from the 24 images available from 1995 and 1996, with 6 images being used for each MVC. In order to obtain smoother NDVI temporal profiles, intermediate NDVI MVCs were also produced, with an overlap of 4 images between consecutive MVCs. The compositing periods ranged between 14 and 51 days in 1995 and between 22 and 57 days in 1996. Figure 2 shows the distribution of the NDVI images available from 1995 and 1996 and the corresponding MVC dates. The date assigned to a MVC was the mean Julian day of the 6 NDVI images used to produced it.

Table 2. Number of pixels from NDVI images (* image not used)

Julian day	MVC 1	MVC 2	MVC 3	MVC 4	MVC 5	MVC 6	MVC 7	MVC 8	MVC 9	MVC 10
96	343	*	*	*	*	*	*	*	*	*
97	11	*	*	*	*	*	*	*	*	*
98	135	77	*	*	*	*	*	*	*	*
100	172	49	*	*	*	*	*	*	*	*
118	936	785	523	*	*	*	*	*	*	*
134	2153	885	118	*	*	*	*	*	*	*
135	*	490	117	158	*	*	*	*	*	*
154	*	1464	798	825	*	*	*	*	*	*
160	*	*	1036	803	1086	*	*	*	*	*
167	*	*	1158	710	628	*	*	*	*	*
169	*	*	*	808	721	502	*	*	*	*
176	*	*	*	446	396	282	*	*	*	*
196	*	*	*	*	251	134	242	*	*	*
197	*	*	*	*	668	368	389	*	*	*
198	*	*	*	*	*	2038	2540	2880	*	*
199	*	*	*	*	*	426	517	628	*	*
202	*	*	*	*	*	*	30	106	1977	*
217	*	*	*	*	*	*	32	102	448	*
227	*	*	*	*	*	*	*	9	114	216
236	*	*	*	*	*	*	*	25	285	590
242	*	*	*	*	*	*	*	*	10	39
257	*	*	*	*	*	*	*	*	916	2414
263	*	*	*	*	*	*	*	*	*	381
267	*	*	*	*	*	*	*	*	*	110

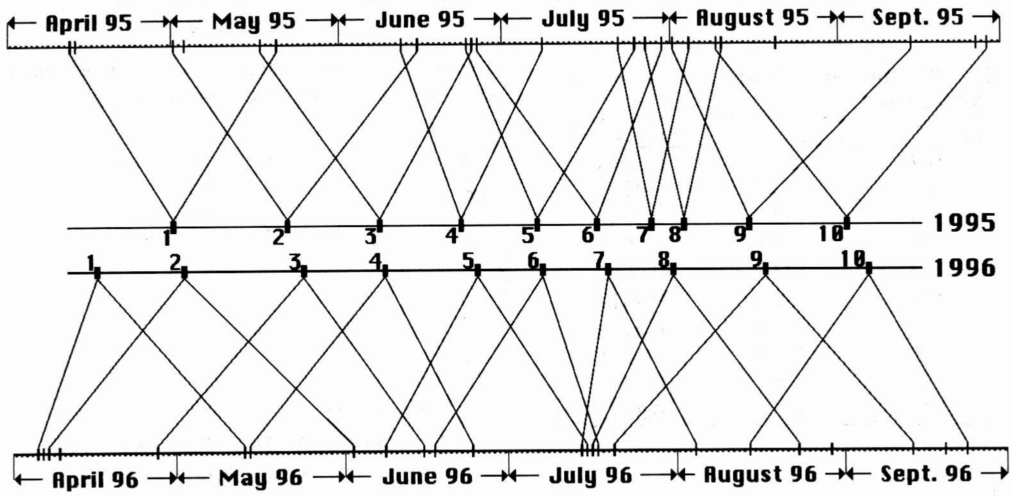

Figure 2. Temporal distribution of the NDVI images used to produce MVCs for 1995 and 1996.

2.3 *Date assigned to a NDVI MVCs*

The distribution of pixels contributing to the 1996 NDVI MVCs was investigated for areas of Improved Pasture. A total of 3750 1 km^2 pixels were available having all four 500m sub-pixels belonging to LCS88 class 29 (Improved Pasture). Table 2 shows the number of pixels from each image which were selected as maximum value to the NDVI MVCs. Most of the NDVI values on the 1st MVC come from images 134 (13 May) and 118 (27 April). However, the mean Julian day of the 6 images used to produce the 1st MVC is 107.

In a NDVI MVC there are images contributing with considerable more pixels than others to the MVC. This can be due to the atmospheric and geometric differences between the images but it can also be due to vegetation change within the compositing period. When NDVI temporal profiles are produced from a set of NDVI MVCs, the abscissa used for each MVC is normally the mean day of the compositing period or, alternatively, the mean day of the images used by the MVC. A different method can be used which includes sensitivity to the relative contribution of individual images to a MVC on the temporal plot. The MVC abscissa, of a particular set of pixels, is assigned to the weighted mean Julian day, calculated by the relative contribution of each NDVI image used in producing the MVC.

Table 3 shows the mean NDVI value of 'Improved Pasture' from the 1996 NDVI MVCs, as well as the corresponding mean and weighted mean Julian day. The weighted mean Julian day for the 1st MVC (123.6) is considerably higher than the mean Julian day (107) because most NDVI values come from the last two images (Table 2). The result of using the weighted mean Julian day for the first MVC is a 16.6 days shift on the NDVI temporal plot of 'Improved Pasture' abscissa. The other MVCs are similarly affected by using the weighted mean abscissa.

Table 3. 1996 Improved Pasture 'overlapping' NDVI MVCs

MVC	mean j. day	weight. j. day	mean NDVI
1	107	123.6	0.3788
2	123	137.4	0.4265
3	145	153.4	0.4682
4	160	162.8	0.4661
5	177	173.6	0.4695
6	189	192.4	0.4815
7	201	198.1	0.4773
8	213	199.1	0.4741
9	230	220.7	0.4237
10	249	252.7	0.3982

3 RESULTS

The NDVI temporal profile of Improved Pasture for 1995 and 1996, obtained from the 4 monthly MVCs available for each year, is presented on Figure 3. The monthly MVCs were plotted with the abscissa on the 15th day of the month. The small number of point available to produce the plot significantly limit the potential interpretation.

The NDVI temporal profile of Improved

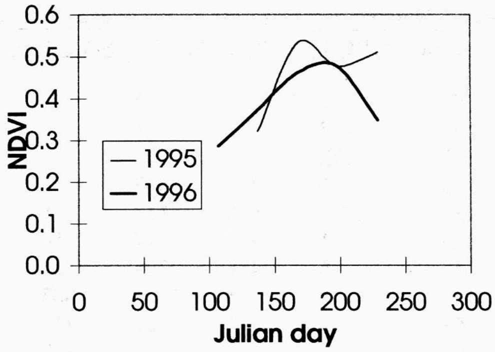

Figure 3. 'Improved Pasture' NDVI temporal plots obtained from monthly MVCs

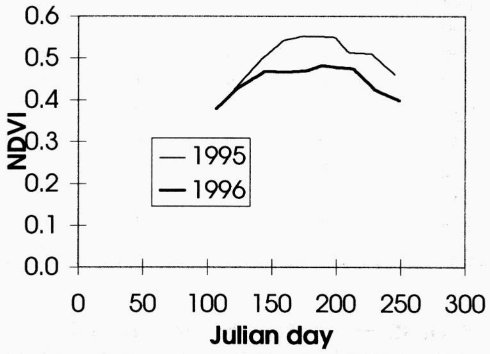

Figure 4. 'Improved Pasture' NDVI temporal plots from 'overlapping' MVCs (mean Julian day)

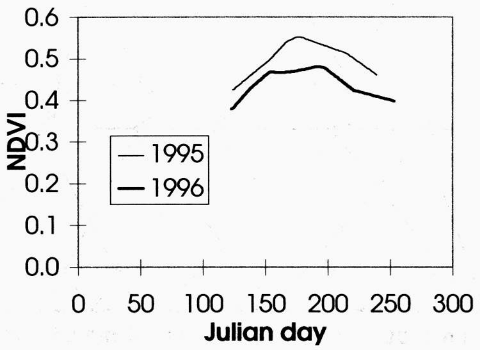

Figure 5. NDVI temporal plots of 'Improved Pasture' obtained from 'overlapping' MVCs (weighted mean Julian day)

Pasture obtained using the 10 'overlapping' MVCs is presented on Figure 4 and 5. The MVCs abscissa used for the plot on Figure 5 was the mean Julian day of the 6 NDVI images per MVC. The weighted

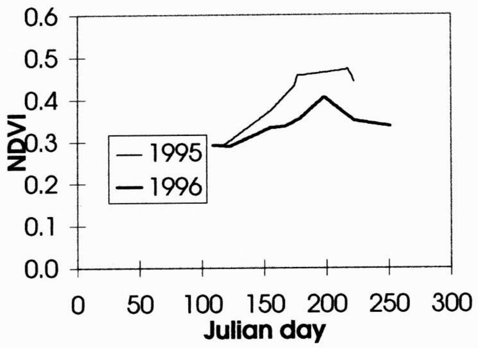

Figure 6. NDVI temporal plots for 'Coniferous'

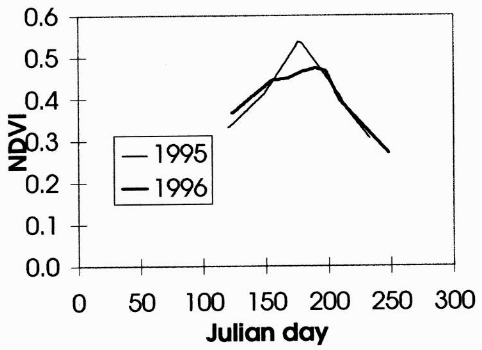

Figure 7. NDVI temporal plots for 'Arable'

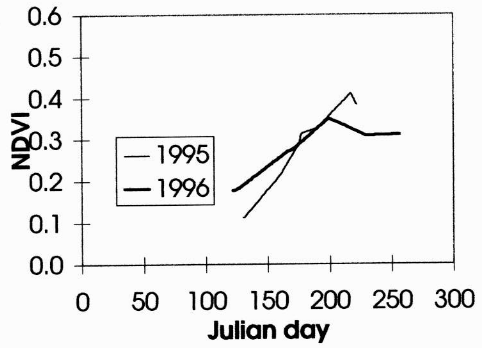

Figure 8. NDVI temporal plots for 'Montane Vegetation'

mean Julian day of the 6 NDVI images was used for the MVCs abscissa on Figure 5.

The 1996 NDVI plots on Figures 4 and 5 were produced using the same set of NDVI values, only the corresponding dates were different (Table 3). The use of weighted mean Julian day for abscissa provides shorter high NDVI periods. When a few consecutive images have high NDVI values, the abscissas get closer together by using the weighted mean method. This aspect can be observed on MVCs 7 and 8. Most of the maximum values were obtained from image 198 (16 July) on both MVC 7 and 8 (Table 2). The abscissas of these two MVCs are only 1 day apart on the weighted mean plot, but they are 12 days apart on the mean day plot.

NDVI temporal plots were produced for the most common land cover classes, using the weighted mean abscissa for the 'overlapping' MVCs. Figure 6 shows the 1995 and 1996 NDVI temporal profiles of Coniferous (1841 pixels). The NDVI values are generally lower than those of Improved Pasture and the rate of increase in NDVI during the Spring is also slower. The NDVI temporal profiles of Arable (4746 pixels) and Montane Vegetation (468 pixels) are shown on Figures 7 and 8. This two classes exhibit a considerably different behaviour than the previous classes. There is a sharp decline in NDVI for Arable pixels during the Summer, with an identical rate for both years. The NDVI of Montane Vegetation is very low during the Spring, but grows steadily during most of the Summer.

The NDVI temporal profiles of 1995 and 1996 are generally similar, for the four classes featured. The NDVI values from 1995 are, however, generally higher than those from 1996. This can be due to vegetation growth, probably due to climatic differences between the two years, or it can be due to the availability of AVHRR data. The production of temporal profiles for previous years, using archived data, could provide a 'typical' behaviour for each land cover class, which could be used as a reference value for subsequent years.

4 CONCLUSIONS

The use of 'overlapping' MVCs allows for NDVI temporal plots to be obtained on a regular basis, in areas where the presence of cloud is frequent throughout the year. The 'overlapping' NDVI MVCs are more suitable to continuously monitor vegetation during the Spring and Summer than the conventional monthly NDVI MVCs, which are limited in Scotland to 3 or 4 months per year. The 'overlapping' method provides consistent data, by compositing a fixed number of NDVI images, and good temporal resolution.

The use of the weighted mean Julian day as the MVC abscissa, on a temporal plot, provides a more accurate representation of the vegetation dynamics than using the mean Julian day. Temporal profiles of NDVI were obtained for the different land cover classes featured on the LCS88 census of Scotland, using 'overlapping' MVCs with weighted mean abscissa.

The 'overlapping' NDVI MVCs technique is currently being developed as an input to a grazing management model at the MLURI, which was previously based on historical coarse resolution climatic information.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the NERC Dundee Satellite Station for providing AVHRR data. ARSM would like to thank JNICT (Junta Nacional de Investigação Científica e Tecnológica) and the Remote Sensing Society for the financial support.

REFERENCES

Brush, R.J.H., 1985, A Method for Real-Time Navigation of AVHRR Imagery, *IEEE Transactions on Geoscience and Remote Sensing*, GE-23, 876-887

Holben, B., 1986, Characteristics of maximum-value composite images from temporal AVHRR data, *International Journal of Remote Sensing*, Vol. 7, No. 11, pp. 1417-1434

Marçal, A.R.S., Wright, G.G., 1997, The use of 'overlapping' NOAA-AVHRR NDVI Maximum Value Composites for Scotland and initial comparisons with the LCS88 data on a Scottish Regional and District basis, *International Journal of Remote Sensing*, Vol. 18, No.3, 491-503

Marçal, A.R.S., A new method for high accuracy navigation of NOAA AVHRR imagery, *International Journal of Remote Sensing*, submitted for publication in February 1997

MLURI, 1993a, The Land Cover of Scotland 1988, Executive Summary, *Macaulay Land Use Research Institute*, Aberdeen, 39pp

MLURI, 1993b, The Land Cover of Scotland 1988, Final Report, *Macaulay Land Use Research Institute*, Aberdeen, 81pp + Appendices

Rao, C.R.N., Chen, J., 1996, Post-Launch Calibration of the Visible and Near-infrared Channels of the Advanced Very High Resolution Radiometer on the NOAA-14 spacecraft, http://orbit-net.nesdis.noaa.gov/ora/