Introduction of the PHenology And Vegetation Earth Observation Service (PHAVEOS).

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Abstract

Monitoring vegetation biophysical variables, are key to understand the growth and functioning of vegetation and in turn, provide key inputs in the modelling of bio geochemical cycles. The PHenology And Vegetation EO Service realises the full spectral, spatial and temporal resolution of the MERIS instrument by generating of a range of biophysical variables on a daily basis. Level1b data undergoes geometric, radiometric and atmospheric correction before application of biophysical algorithms. The resulting Level 2 data is then resampled and composited to a 250m spatial grid to generate a daily Level 3 output products. Additional modelling steps are applied creating a time series of Level 4 biophysical maps which retain daily temporal resolution but with full spatial coverage. The development of advanced Web dissemination services should allow users to interactively assess, compare and download biophysical maps and phenology curves. PHAVEOS is laying the foundations for services that utilise the even higher spatial and temporal resolutions available from the upcoming Sentinel 2 and 3 series of EO platforms.

Keywords: *phenology, MTCI, LAI, fAPAR*

1. Introduction

Monitoring vegetation biophysical variables, such as Leaf Area Index (LAI) and pigment content, are key to understand the growth and functioning of vegetation and, in turn, provide key inputs in the modelling of bio-geochemical cycles. Development in satellite remote sensing over last three decades and algorithms to derive biophysical variables from these data, has provided a unique opportunity to measure these variables with increased temporal and spatial resolution.

Traditional approaches to obtain compete spatial coverage from optical EO composite observations from 8-day to monthly periods. This (Level 3) approach, however, has the side effect of reducing temporal resolution and can introduces temporal bias depending on the compositing method.

To address these issues, the European Space Agency (ESA) has funded the development of the PHenology And Vegetation Earth Observation Service (PHAVEOS) as part of the Value Adding Element (VAE) of the Earth Observation Market Development (EOMD) programme. The development, undertaken by Infoterra Ltd. in partnership with the University of Southampton and INRA, aims to utilise the unique spectral, spatial and temporal characteristics of the MEdium Resolution Imaging Spectrometer (MERIS).

In 2002 the European Space Agency (ESA) launched the ENVISAT platform carrying MERIS to provide super-spectral resolution in 15 wavebands at 1.2km spatial resolution on a systematic basis and at 300m on demand. The ability to downlink the full, 300m, resolution data was expanded in 2005 and systematic acquisition of full spectral and spatial resolution MERIS data commenced. This has enabled the monitoring of vegetation change using a variety of measures with spatio-temporal resolutions of 300m every 2-3 days.

MERIS has the ability to monitor the 'red edge' (Baret, et al. 1992, Curran and Steele, 2005) where the absorption of light by vegetation declines rapidly. As total canopy chlorophyll content increase, the absolute location of the red edge shifts to longer wavelengths in the spectrum. The MERIS Terrestrial Chlorophyll Index (MTCI) was developed (Dash and Curran, 2004) to capitalise on this phenomenon, so that MTCI remains responsive to productivity increases in high biomass settings (España-Boquera et al. 2006, Rossini et al. 2007) where more traditional vegetation indices become insensitive to change. MTCI

has also been shown to have a superior correlation with Gross Primary Productivity (GPP) than traditional measures (Wu et al. 2009, Harris and Dash, 2010). MERIS can also be used as the basis for the derivation of biophysical parameters such as Leaf Area Index (LAI) and fraction of Absorbed Photosynthetically Active Radiation (fAPAR) (Bacour, et al. 2006, Baret et al. 2006), which are classed as Essential Climate Variables (Anonymous, 2006).

2. Methodology

PHAVEOS employs a three stage approach to maximise the spatio-temporal resolution available. In the first processing stage, standard Level 1b data is geometrically, radiometrically and atmospherically corrected before a range of (Level 2) biophysical parameters and indices are derived.

In the second stage, the biophysical data are spatially composited and mapped to one or more geographic grids using a flux conserving (area weighted) algorithm (McGlynn, 2003). The compositing is carried out on a daily basis so that the resulting Level 3 vegetation maps retain temporal resolution.

The first and second stage processing steps are shown in more detail in Figure 1. Where possible, use is made of established MERIS processing tools such as the Accurate MERIS Ortho-Rectified Geo-location Operational Software (AMORGOS) and the Basic Envisat AATSR and MERIS toolkit (BEAM).

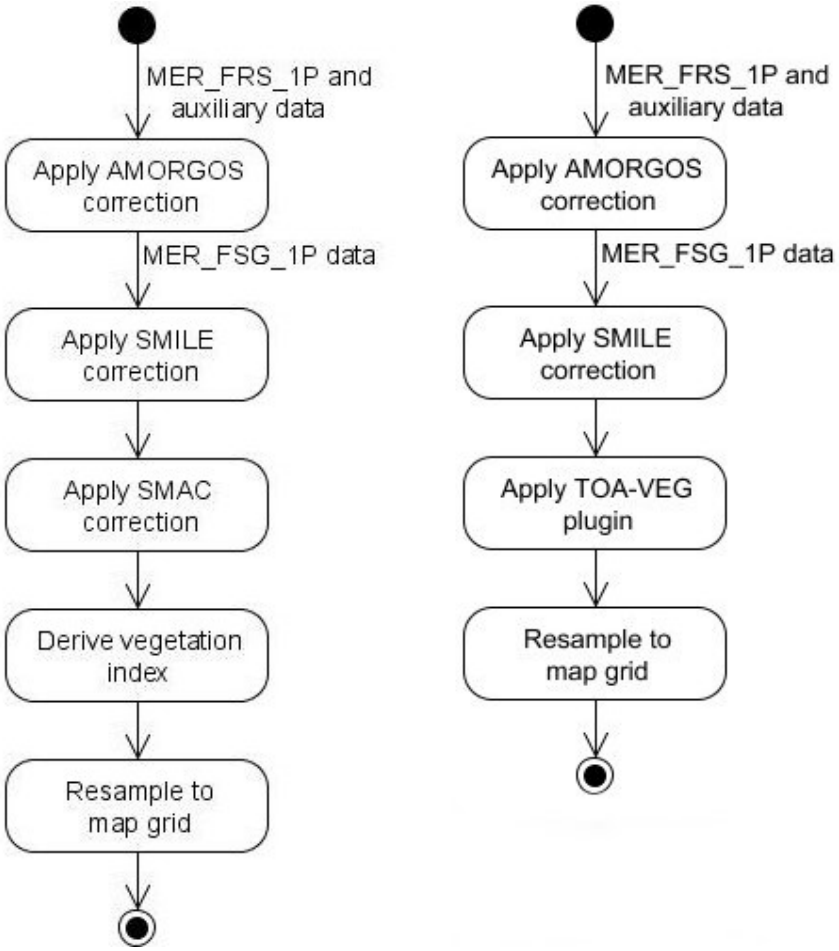

Figure 1: *activity diagrams showing the processing steps employed for the Level 1b to Level 3 data processing. The diagram on the left shows the processing chain used to derive MTCI and the one on the right, the processing applied to derive LAI, fractional green cover(fCover) and fAPAR parameter maps*[1].

In the final stage of processing, the Level 3 vegetation maps are used as the basis for a two step modelling exercise that applies temporal interpolation and smoothing to generate time series of vegetation biophysical variable maps with continuous 250m spatial resolution and daily coverage.

[1] Based on the Top Of Atmosphere VEGetation (TOA_VEG) processor for the BEAM toolkit (http://www.brockmann-consult.de/beam/software/repositories/4.6/beam-meris-veg-2.0.1/docs/MERIS_ATBD_TOA_VEG_03_06.pdf).

3. Results

Figures 2 and 3 show the range of vegetation maps generated by PHAVEOS.

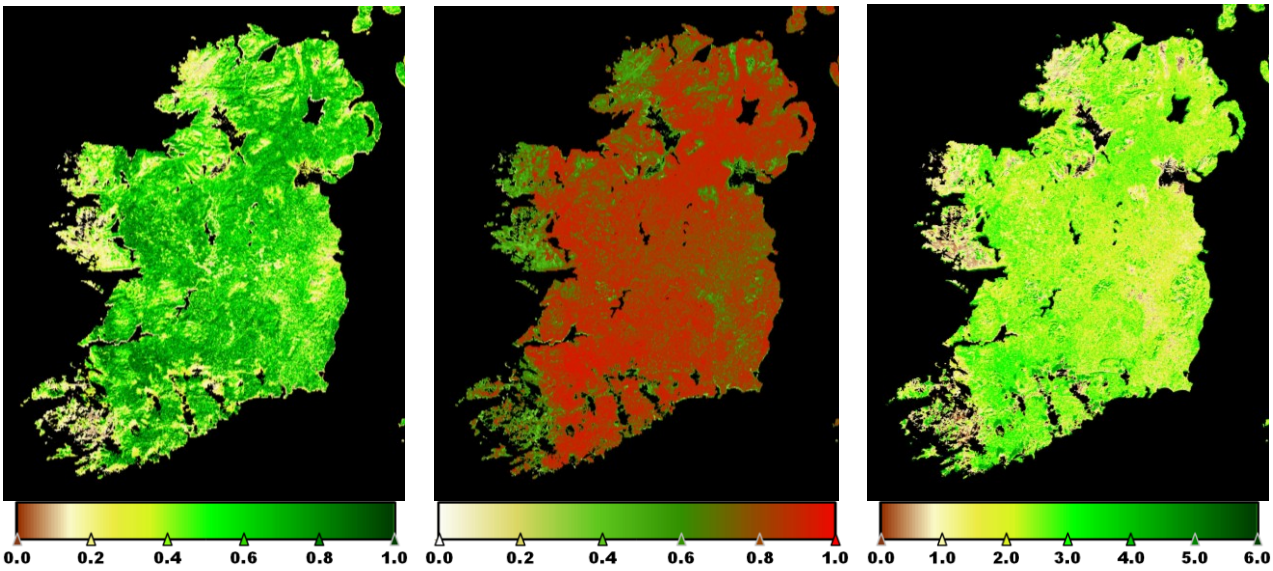

Figure 2: *Level 3(composite) maps of Ireland for 14th January 2006. From left to right: fCover, fAPAR and LAI. Note that the original Level 1b pixels are remapped directly to the Irish Grid using area weighted resampling to maximise the geospatial fidelity. Copyright ESA 2006, processed by Infoterra Ltd.*

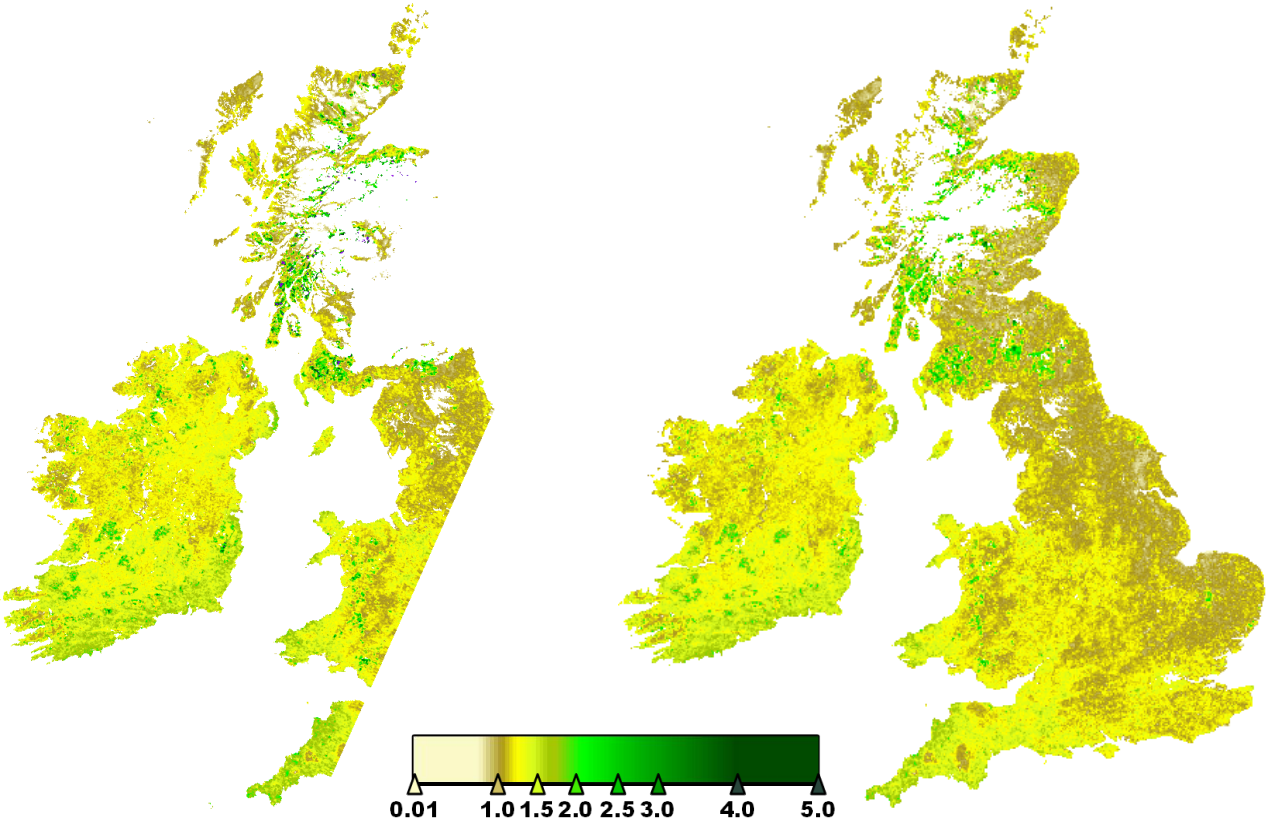

Figure 3: *comparison of daily Level 3 and Level 4 (modelled) MTCI maps of Great Britain and Ireland for 8th March 2010, at the height of the 'winter burn' of vegetation. The coverage provided in the Level 3 map on the left is constrained by the area of data acquisition, snow and cloud cover on the day. The coverage of the Level 4 map on the right is only constrained by persistent snow cover over high ground. Copyright ESA 2010, processed by Infoterra Ltd.*

The presentation of phenology information by PHAVEOS is still under development but Figure 4 illustrates how time series information, for each 250m map cell, would be presented via a Web Map Service.

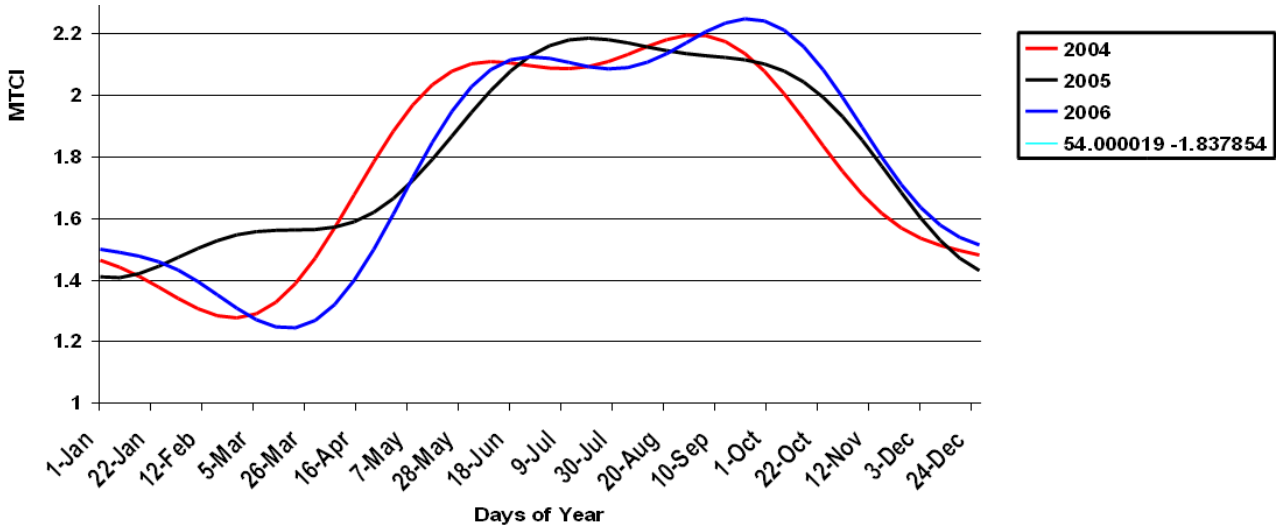

Figure 4: *dissemination concept, illustrating a continuous series of MTCI values covering 2004, 2005 and 2006 for a 250m map grid cell located at 54.000019 N and –1.837854 E (in the North York Moors). Note the lack of winter burn and late summer 'lush up' of vegetation revealed for 2005 by this comparison.*

5. Conclusions

Despite significant progress in estimating global carbon fluxes from large area field observations, a considerable amount of uncertainty about the magnitude, spatial pattern and causes of terrestrial ecosystem carbon uptake remains. Although season length is related to the degree of carbon sequestration its effects are spatially variable, therefore, accurate spatial and temporal manifestation of phenology should be investigated. Level 4 products from PHAVEOS, provide temporally continuous data at a much finer spatial resolution than existing satellite derived products, enabling researchers to monitor phenological variables more accurately and precisely.

Acknowledgements – *the authors would like to acknowledge the support of the ESA EODM .programme which has funded the PHAVEOS development, supplied data and generously donated access to the Grid Processing On-Demand data processing infrastructure. In particular, we would like to acknowledge the advice, guidance and encouragement provided by Dr B.Koetz, the ESA project officer.*

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