Evaluation of the MERIS Terrestrial Chlorophyll Index

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Remote sensing of vegetation

*What is it?*
MERIS: *individual bands*, classify

*How much is there?*
MERIS: *MGVI (fAPAR-LAI)* ESA level 2 product

*What condition is it in?*
MERIS: *MTCI (chlorophyll content)* ESA level 2 product
Red edge position (REP):

- links remotely sensed data and chlorophyll content
- is defined as the point of maximum slope of the curve in red / near infrared region
MEdium Resolution Imaging Spectrometer (MERIS)

- Onboard ESA’s Envisat
- 15 programmable bands in region of 390-1040nm
- Pushbroom imaging spectrometer
- 1150km swath on ground
- Two spatial resolutions
  - Full resolution (FR)-300m
  - Reduced resolution (RR)-1200m
- Global coverage in 3 days
**MERIS to estimate REP at a landscape scale**

We have

- *Large volumes* of discontinuous spectral data
- *High variation* in chlorophyll values

We require

- *Unique* value for an index
- *Automation*

Problems with REP estimation techniques in literature

- Designed for small volumes of continuous spectral data
- Insensitive to high chlorophyll values
- REP value depends on technique used
- Two-step process, requires user intervention
In some respects MERIS is well suited for high SNR (around 600:1 in blue wavelengths to around 250:1 in near-infrared wavelengths over vegetation) and well-placed wavebands.

<table>
<thead>
<tr>
<th>Band no</th>
<th>Central wavelength (nm)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>412.5</td>
</tr>
<tr>
<td>2</td>
<td>442.5</td>
</tr>
<tr>
<td>3</td>
<td>490</td>
</tr>
<tr>
<td>4</td>
<td>510</td>
</tr>
<tr>
<td>5</td>
<td>560</td>
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<tr>
<td>6</td>
<td>620</td>
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<td>7</td>
<td>665</td>
</tr>
<tr>
<td>8</td>
<td>681.25</td>
</tr>
<tr>
<td>9</td>
<td>708.75</td>
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<tr>
<td>10</td>
<td>753.75</td>
</tr>
<tr>
<td>11</td>
<td>760.625</td>
</tr>
<tr>
<td>12</td>
<td>778.75</td>
</tr>
<tr>
<td>13</td>
<td>865</td>
</tr>
<tr>
<td>14</td>
<td>885</td>
</tr>
<tr>
<td>15</td>
<td>900</td>
</tr>
</tbody>
</table>

Position of MERIS standard band setting on a vegetation reflectance spectrum.
Designing the MERIS Terrestrial Chlorophyll Index (MTCI)

Requirements:

(i) Easy to calculate from MERIS data

(ii) Sensitive to wide range of chlorophyll contents
Equation

\[ MTCl = \frac{R_{Band10} - R_{Band9}}{R_{Band9} - R_{Band8}} = \frac{R_{753.75} - R_{708.75}}{R_{708.75} - R_{681.25}} \]
Preliminary evaluation

**Model**
- LIBSAIL (LIBERTY + SAIL)
- Reflectance from 400-2500 nm
- Averaged to get the MERIS standard band setting

**Field**
- Collected for Maple and Douglas-fir (NASA ACCP 1992-93)
- Canopy spectral reflectance (400-2500nm)
- Canopy chlorophyll content

**MERIS**
- Study area: New Forest, Hampshire, UK
- Acquisition date 19 October 2002
- Top-of-canopy reflectance
Model results
Field results

Using MERIS standard band setting data for Douglas-fir
Using continuous spectra for Douglas-fir
Using MERIS standard band setting data for maple
Using continuous spectra for maple
MERIS results

- NDVI
- REP
- MTCI

Min | Max
--- | ---

Color scale for data representation.
MERIS results

The left side of the image shows a map with various land use categories: Woodland, Urban, Meadows & Agricultural land, and Heath. The right side displays a scatter plot with two distinct clusters representing Heath and Woodland, plotted against REP (nm) and NDVI.
Observed Issues and Recommendations

New L2 products

- Need for defining new L2 land products by fully exploiting the capabilities of the MERIS instrument not available from other sensors.
  - ESA response:
    - for the land community at present we have MGVI, NDVI, rectified reflectances at 665 and 865nm, DDV AOT, surface pressure.
    - **new MERIS Terrestrial Chlorophyll Index (MTCI) will be provided in the L2 product** replacing the NDVI.
    - algorithms for experimental MERIS products, i.e. LAI, fraction cover, chlorophyll content, surface reflectance under development; shall be made available in source code under the BEAM software.

- Need for defining new atmospheric L2 products:
  - Aerosol path radiance at 665 nm
  - Particular Matter: PM 10
  - Aktinic fluxes
Background to preliminary evaluation:


Four evaluations underway at Southampton University

*Experiments* – greenhouse, field  
*Time series* – four sites  
*Surrogate chlorophyll content* – Vietnam  
*Non-canopy variables* – simulations
Experiments – greenhouse experiment
spinach, low / medium / high levels of fertilization,
weekly chlorophyll content and MTCI measurement
field experiment
grassland, low / medium / high levels of fertilization,
monthly chlorophyll content and MERIS MTCI measurement

Time series – four sites (joint with JRC Ispra)
Hainich
Country: Germany
Site: Hardwood forest
Dominant species: Beech
Loobos
Country: Netherlands
Site: Coniferous forest
Dominant species: Scots Pine

![Graph of MTCI over Julian days](image-url)
New Forest
Country: United Kingdom
Site: Mixed forest
Dominant species: Oak, Pine, Heath
Pavia
Country: Italy
Site: Agriculture
Dominant species: Rice

MTCJ vs Julian days graph
Surrogate chlorophyll content

**Aims**

(i) Determine relationship between Agent Orange deposition and current MTCI in forests

(ii) Identify defoliation hotspots

**Inputs**

(i) MERIS images covering southern Vietnam

(ii) Agent Orange data (HERBS files)

(iii) Land cover and topography
Surrogate chlorophyll content
Surrogate chlorophyll content

- Initial results for 10 provinces: negative relationship between Agent Orange deposition and MTCI

- Further per-pixel investigation of the Agent Orange deposition / MTCI relationship is underway for large forest regions
**Non-canopy variables:** use a mix of leaf / vegetation canopy / atmospheric models and MERIS data to investigate the effects of the following on the MTCI / chlorophyll content relationship

- Spatial resolution
- Soil brightness
- Atmospheric scattering
- Atmospheric absorption
- Solar & sensor angle / azimuth
Conclusions

- The MTCI is the second of two land products from MERIS
- MTCI is conceptually simple and is related to chlorophyll content; chlorophyll content is, in turn, related to vegetation condition
- Evaluations, preliminary and ongoing are encouraging
- Prediction: remote sensing conferences in 2005 / 6 will see further evaluations of the MTCI