Monitoring vegetation dynamics using MERIS fused images

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Mapping and monitoring heterogeneous landscapes: spatial, spectral and temporal unmixing of MERIS data

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Overview

- Monitoring vegetation dynamics
- Data fusion
  - Complex landscapes
- Study area and datasets
- MERIS fused images
- Results
  - Image quality
  - MERIS vegetation indices
  - Validation
- Conclusions
Monitoring vegetation dynamics (I)

- Earth system
  - Carbon cycle
  - Biosphere ↔ Climate
- Time series of VIs
  - AVHRR
  - SPOT-VEGETATION
- Other applications
  - Forecasting crop yield
  - Monitoring habitats
  - Epidemiology
New sensors, new products

- **MODIS**
  - EVI (MOD13) → minimizes canopy background and atmospheric effects

- **MERIS**
  - MTCI → canopy chlorophyll content
  - MGVI → FAPAR

\[
\text{MGVI} = f\left(R8^*, R13^*\right)
\]

\[
\text{MTCI} = \frac{R10 - R9}{R9 - R8}
\]
Coarse and medium spatial resolution sensors cannot capture all the details/dynamics of complex landscapes.

Landsat-like sensors have a past track record in monitoring vegetation dynamics at sufficient spatial but, in general, not temporal resolution.
Complex landscapes (II)

Objective:
- Evaluate the synergetic use of MERIS FR images and (existing) high spatial resolution datasets for monitoring heterogeneous (and frequently cloudy) landscapes.

Landsat TM
10 July 2003
Materials: high spatial resolution

Landsat TM
10 July 2003

LGN5
Materials: MERIS FR data
Methodology (I)

18/02 16/04 31/05 14/07 06/08 15/10 08/12

fusion

18/02 16/04 31/05 14/07 06/08 15/10 08/12
Methodology (II): study area
Methodology (I)
Methodology (III): the LMM

\[ pv = m_1 \cdot f_1 + m_2 \cdot f_2 + m_3 \cdot f_3 + m_4 \cdot f_4 + e \]

\[ \vdots \]

\[ pv = m_1 \cdot f_1 + m_2 \cdot f_2 + m_3 \cdot f_3 + m_4 \cdot f_4 + e \]

\[ pv_i = \sum_{c=1}^{nc} (\mu_{ci} \cdot f_c) + e_i \quad i = 1,2,\ldots, nb \]

\[ 0 \leq f_c \leq 1 \quad \sum_{c=1}^{nc} f_c = 1.0 \]

\[ PV_{(nb \times 1)} = M_{(nb \times nc)} \cdot F_{(nc \times 1)} + E_{(nb \times 1)} \]

\( nb \): number of bands

\( nc \): number of classes (endmembers)
Methodology (IV): unmixing-based data fusion

Data fusion:

\[ \mathbf{PV}_{(k^2 \times 1)} = \mathbf{F}_{(k^2 \times nc)} \cdot \mathbf{M}_{(nc \times 1)} + \mathbf{E}_{(k^2 \times 1)} \]

Low Resolution (MERIS FR) \quad High Resolution (LGN)

“Energy Unconstrained”

\[ 0 < \mu_{ci} \leq L^i_{Sat} \]

k: neighborhood size
nc: number of classes

Zurita-Milla et al. (2008).
IEEE GRSL, 5, 453-457
Methodology (V): points of attention

- Image co-registration
  - Manual image-to-image → not operational
  - Re-projection issues

- Duplicates removal
  - Pixel size = f (swath)

Source: http://www.noc.soton.ac.uk/bilko/envisat/html/pop/mer_prodgrid.html
Methodology (V): points of attention

- Image co-registration
  - Manual image-to-image → not operational/ errors
  - Re-projection issues
  - AMORGOS (3.0)

- Duplicates removal
  - Pixel size = f (swath)

- Fractional cover estimation
  - \( PV_{(k^2 \times 1)} = F_{(k^2 \times nc)} \cdot M_{(nc \times 1)} + E_{(k^2 \times 1)} \)
  - Fraction aggregation threshold (5%)
  - PSF effects
Methodology (VI): image quality

- **At 300m**

\[
ERGAS = 100 \frac{h}{l} \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left( \frac{RMSE_i^2}{M_i^2} \right)}
\]

where: \( h \) and \( l \) are the resolutions of the high and the low spatial resolution images.

- \( N \) is the number of spectral bands involved in the fusion.
- \( M \) is the mean value of the MERIS band-\( i \).
- \( RMSE_i \) is the root mean square error computed between the band-\( i \) of the MERIS image and its corresponding band of the degraded fused image.

- **At 25m (only for July!)**

Where: \( M \) is the mean value of the TM band-\( i \).

\( RMSE_i \) is computed between the band-\( i \) of the TM image and its (spectrally) corresponding band of the fused image.
Results (I): a quick look

- RGB color composite of a subset of the MERIS FR image (a), fused image (b), and the TM image (c)
Results (II): image co-registration
Results (III): Quality assessment (25 m)

5% aggregation changed < 0.6% of the LGN5 pixels
Results (IV): Quality assessment (300 m)
Monitoring vegetation dynamics (I)

- **MTCI**

Fused images allow monitoring of individual fields and small patches of vegetation.
Monitoring vegetation dynamics (I)

- MTMI

Fused images allow monitoring of individual fields and small patches of vegetation.
Monitoring vegetation dynamics (I)

- MGVI
Monitoring vegetation dynamics (II)

- MGVI
Monitoring vegetation dynamics (III)

**MTCI**

“Quality check”
“Validation”
Monitoring vegetation dynamics (IV)

- MGVI
Conclusions

- The unmixing-based data fusion approach succeed in synthesizing MERIS fused images with a very good spectral quality.

- The NDVI, MTCI and MGVI profiles extracted from the temporal series of fused images show consistent patterns for each of the land cover types under study.

- Monitoring vegetation dynamics (phenology) at high spatial and temporal resolution is possible by combining time series of MERIS FR data with high spatial resolution images.
Thank you for your attention!