Monitoring vegetation dynamics using MERIS fused images

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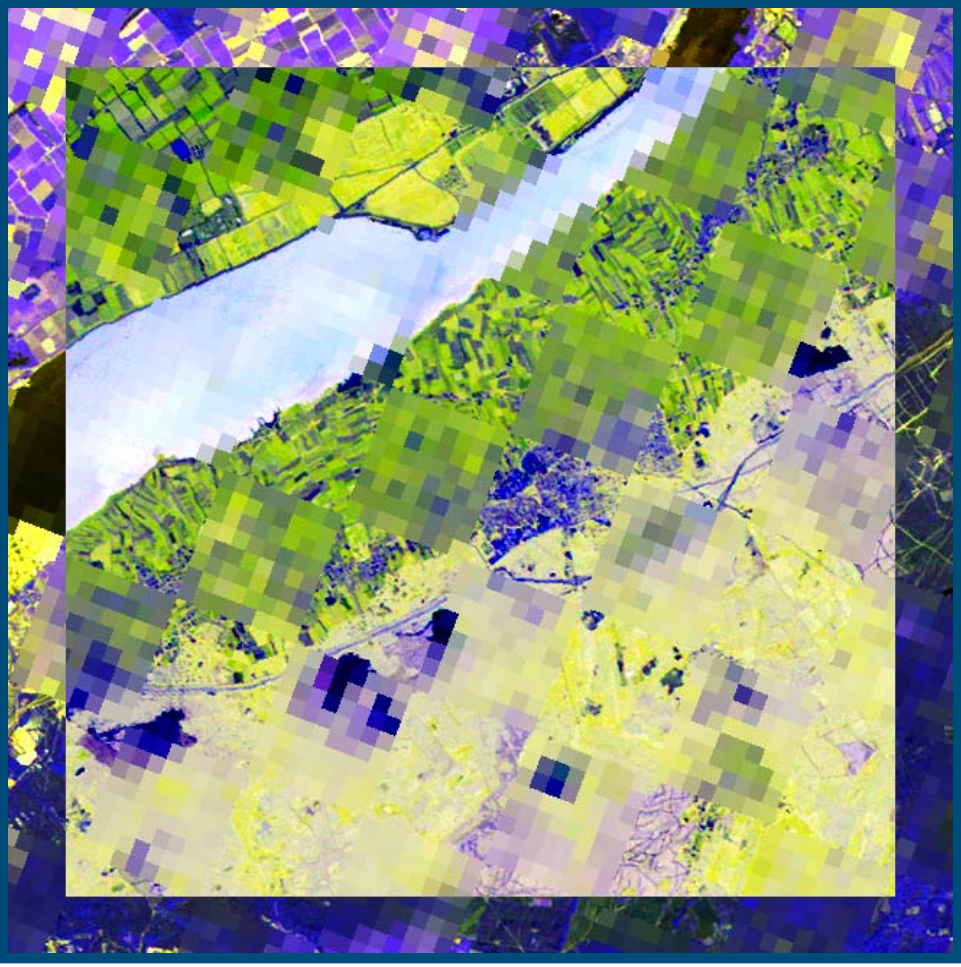
Mapping and monitoring heterogeneous landscapes: spatial, spectral and temporal unmixing of MERIS data



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Raúl Zurita-Milla

17th September 2008

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

$$MTCI = \frac{R10 - R9}{R9 - R8}$$

MGVI = *f* (R8*,R13*)

Complex landscapes (I)

- 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

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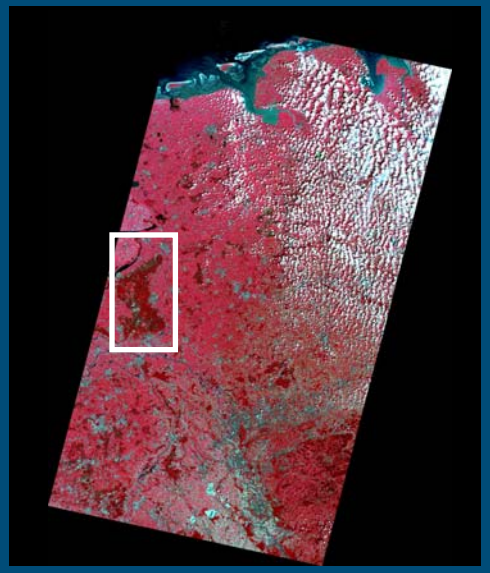
Complex landscapes (II)

Objective:

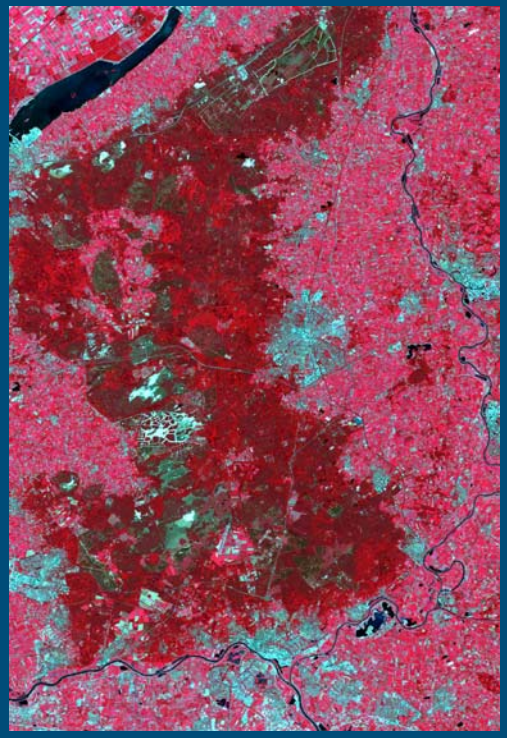
- Evaluate the synergetic use of MERIS FR images and (existing) high spatial resolution datasets for monitoring heterogeneous (and frequently cloudy) landscapes.



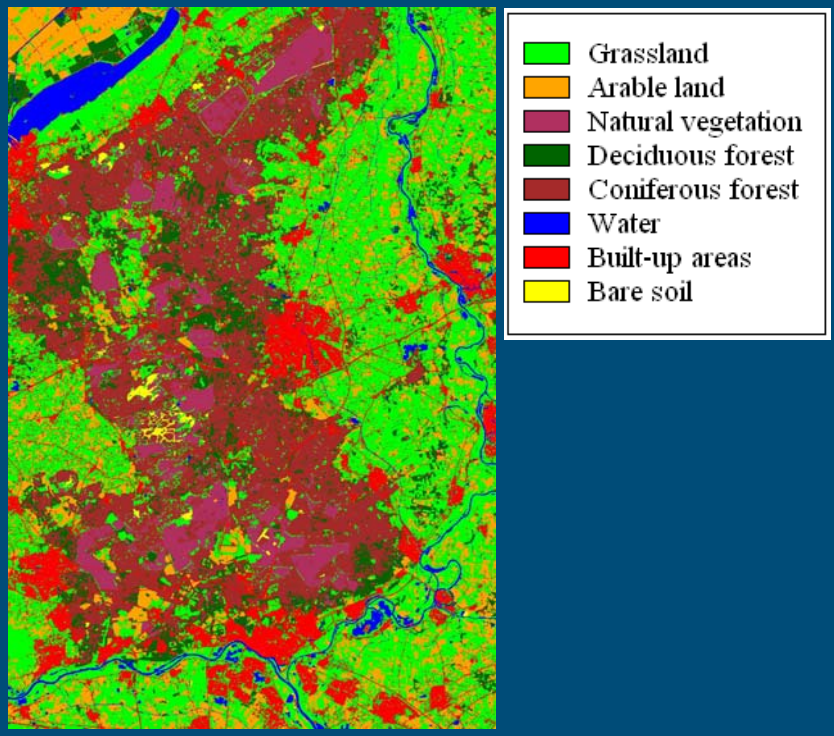
Landsat TM
10 July 2003

Materials: high spatial resolution

Landsat TM
10 July 2003

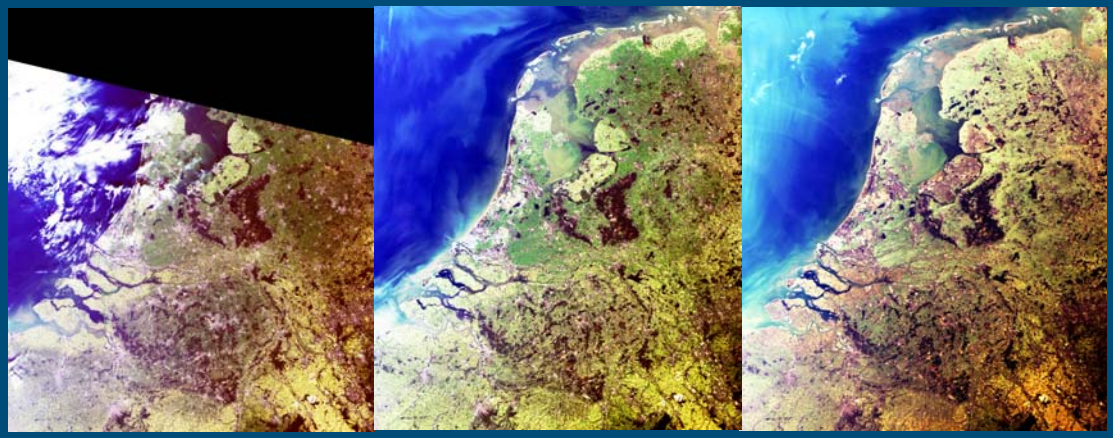


LGN5



Materials: MERIS FR data

18/02 16/04 31/05 14/07



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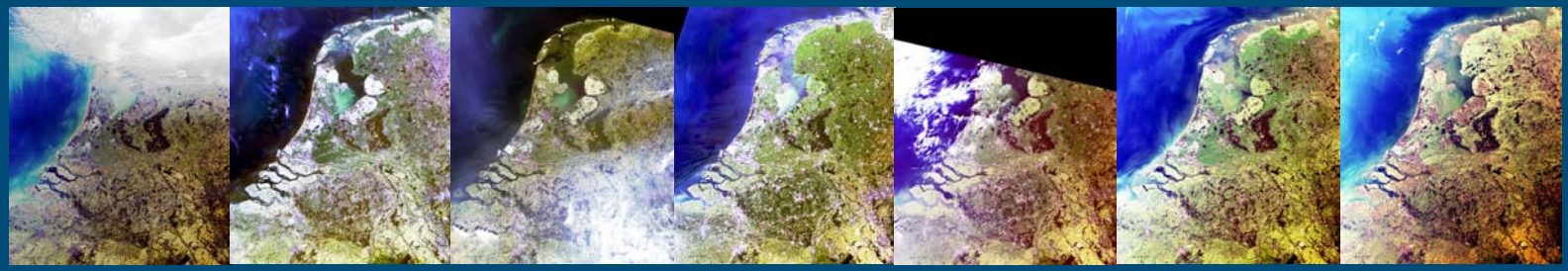
Methodology (I)



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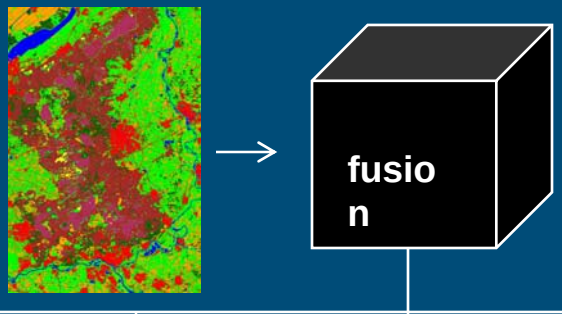

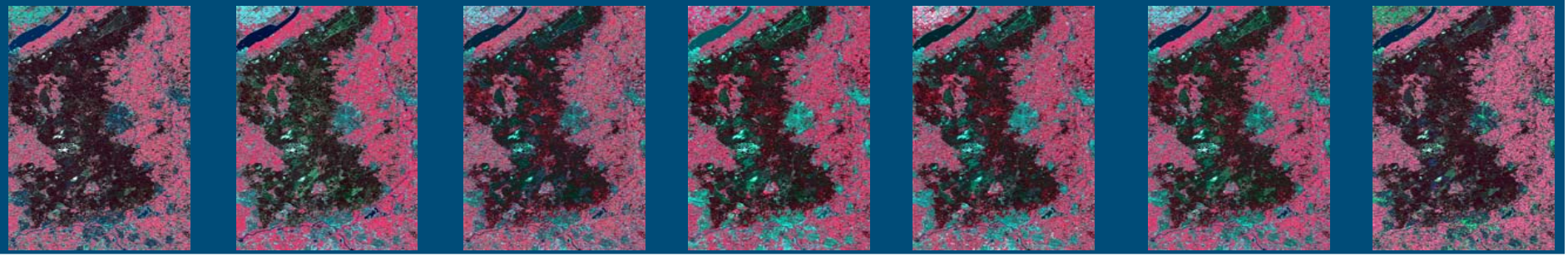

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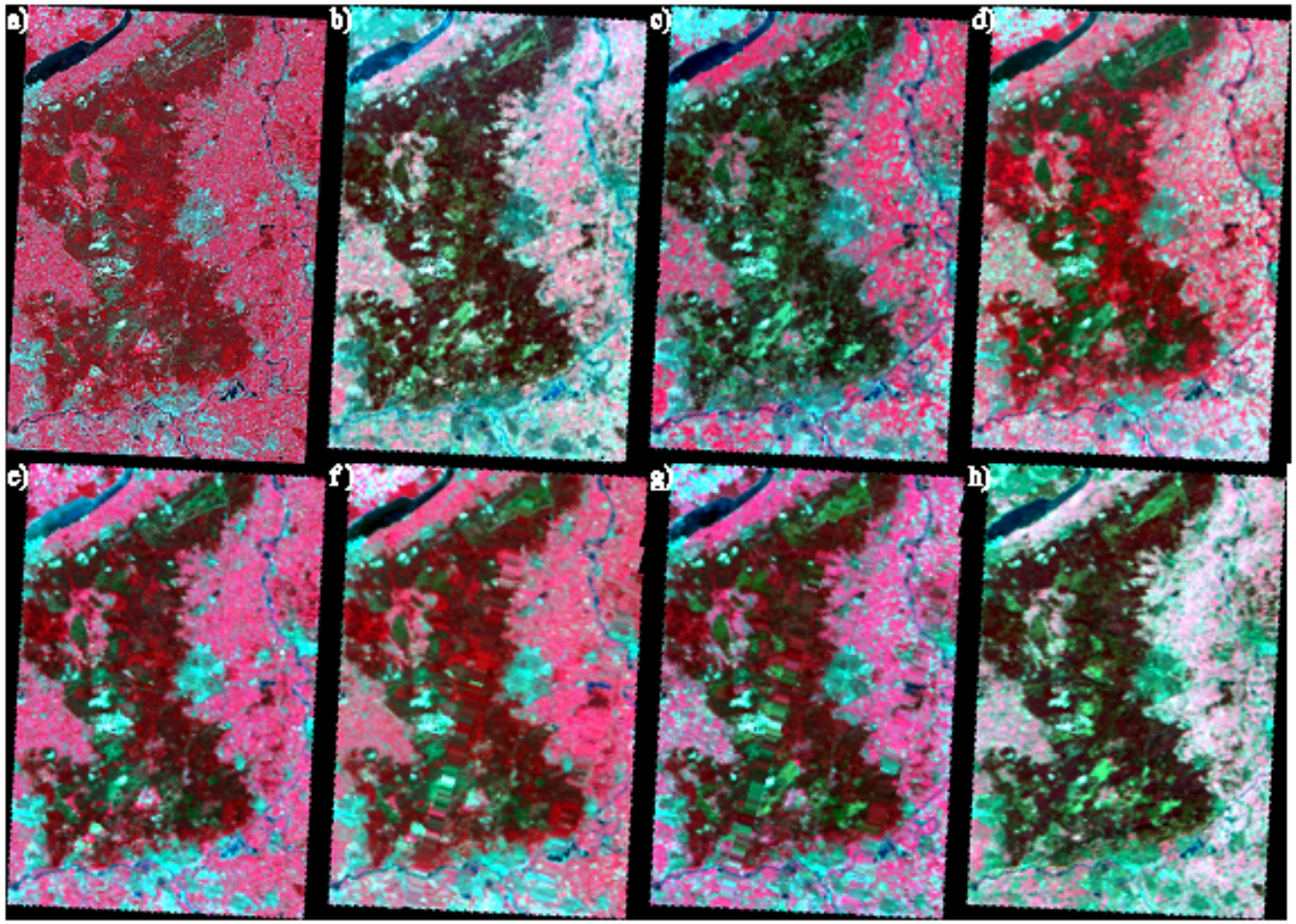
Methodology (II): study area



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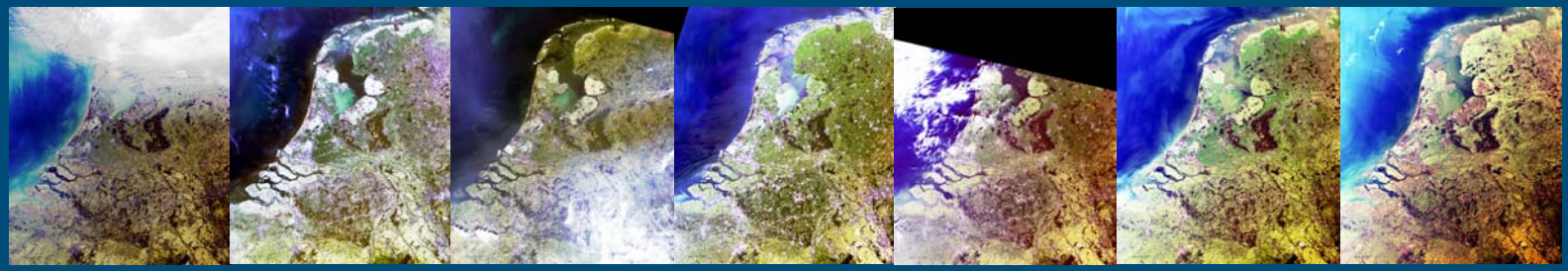
Methodology (I)



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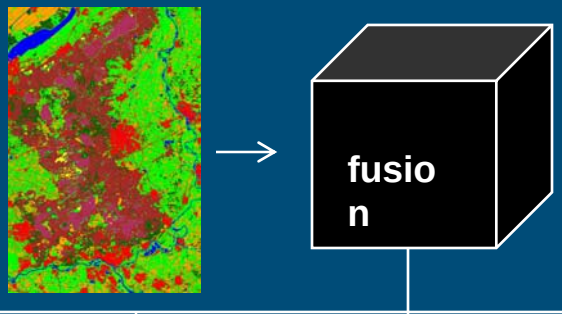

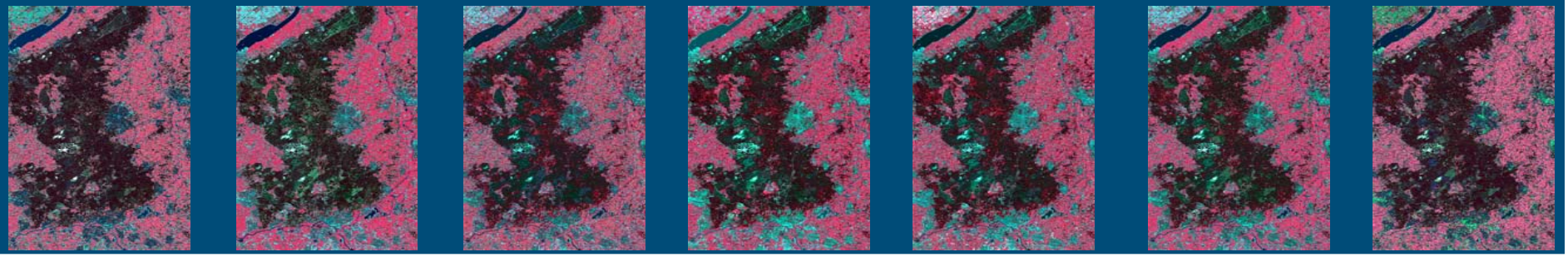

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Methodology (III): the LMM

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

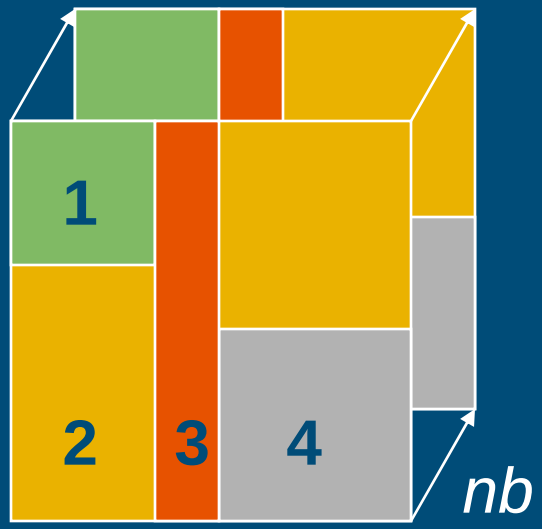
$$\vdots \qquad\qquad \vdots$$

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

$$pv_i = \sum_{c=1}^{nc} (\mu_{ci} \cdot f_c) + e_i \qquad i = 1,2,...,nb$$

$$0 \le f_c \le 1 \qquad \sum_{c=1}^{nc} f_c = 1.0$$

$$\mathbf{PV}_{(nbx1)} = \mathbf{M}_{(nbxnc)} \cdot \mathbf{F}_{(ncx1)} + \mathbf{E}_{(nbx1)}$$



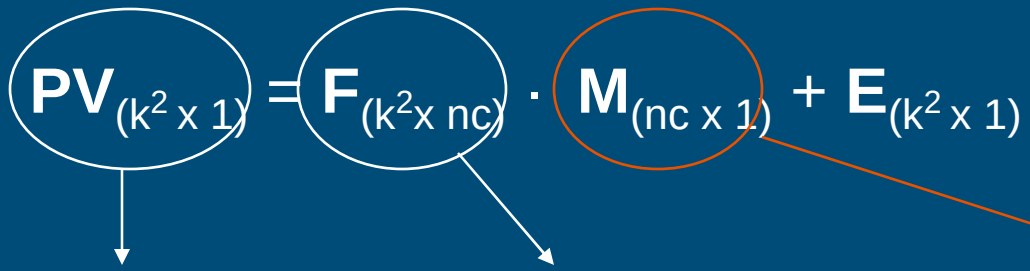
nb: number of bands

nc: number of classes (endmembers)

Methodology (IV): unmixing-based data fusion

- Data fusion:

k: neighborhood size
nc: number of classes



Low Resolution (MERIS FR)

High Resolution (LGN)

Low Resolution downscaled

"Energy Unconstrained"

$$0 < \mu_{ci} \leq L^{i}_{Sat}$$

Zurita-Milla et al. (2008). IEEE GRSL, 5, 453-457

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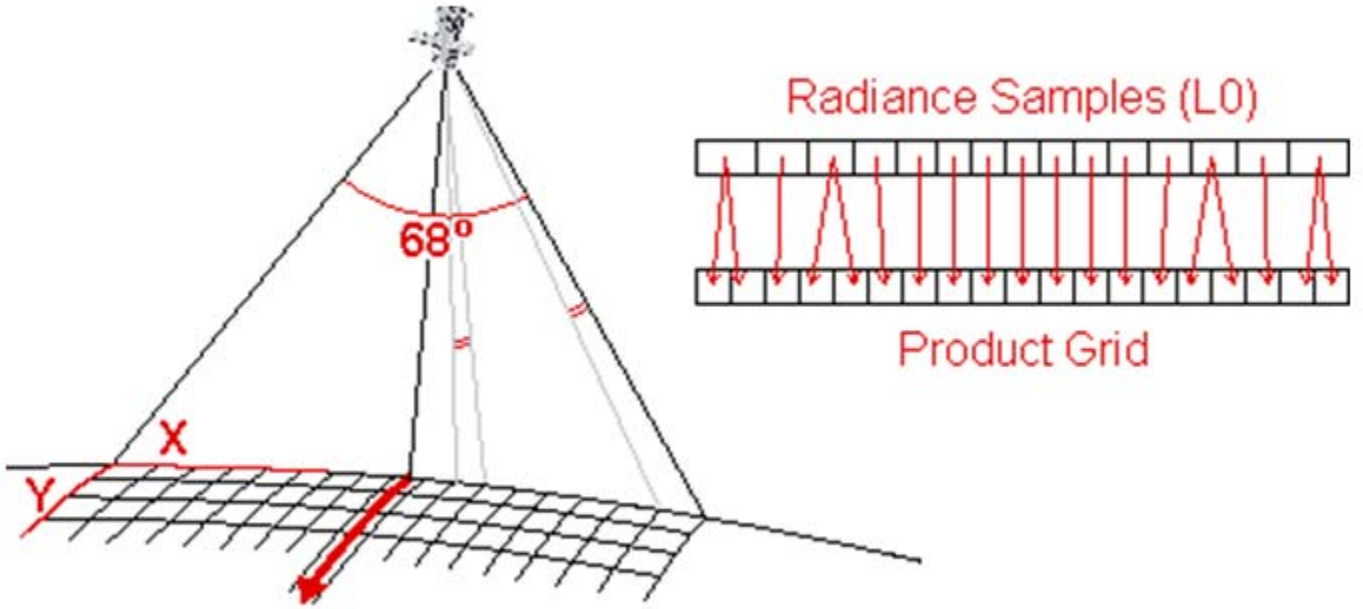
Methodology (V): points of attention

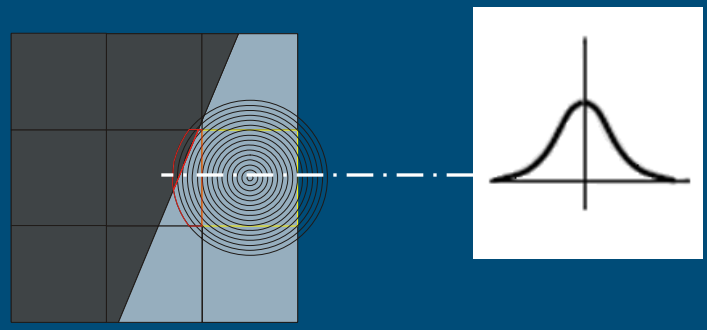
- Image co-registration
  - Manual image-to-image → not operational
  - Re-projection issues
  -
- Du
  -



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



  - $\mathbf{PV}_{(k^2 \times 1)} = \mathbf{F}_{(k^2 \times nc)} \cdot \mathbf{M}_{(nc \times 1)} + \mathbf{E}_{(k^2 \times 1)}$
  - Fraction aggregation threshold (5%)
  - PSF effects

Methodology (VI): image quality

- *At 300m*

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

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*.

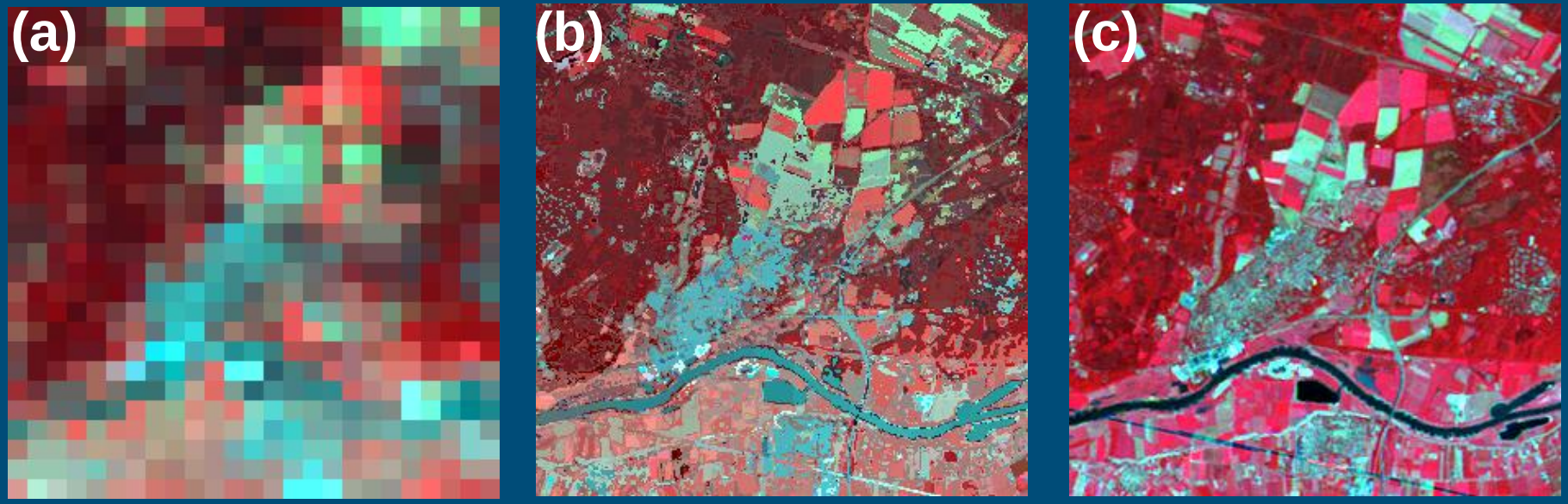
RMSEi is the root mean square error computed between the band-*i of the* MERIS image and its corresponding band of the degraded fused image.

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

Where: M is the mean value of the TM band-*i*.

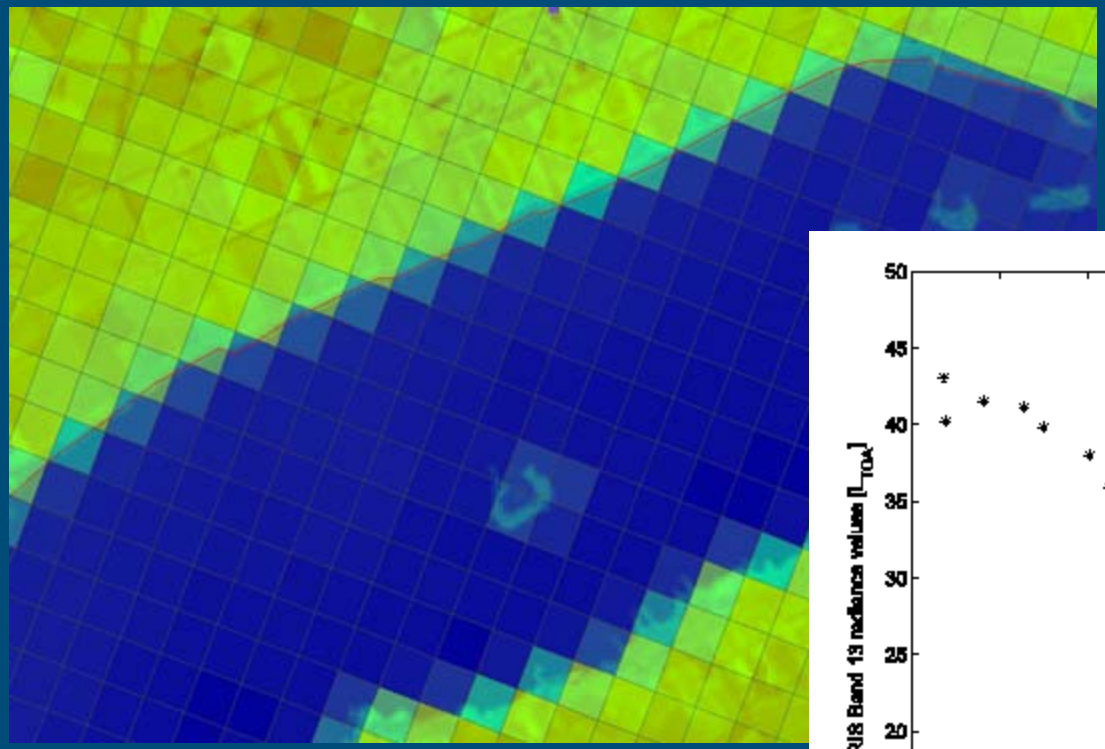
$RMSE_i$ is computed between the band-*i* of the TM image and its (spectrally) corresponding band of the fused image.

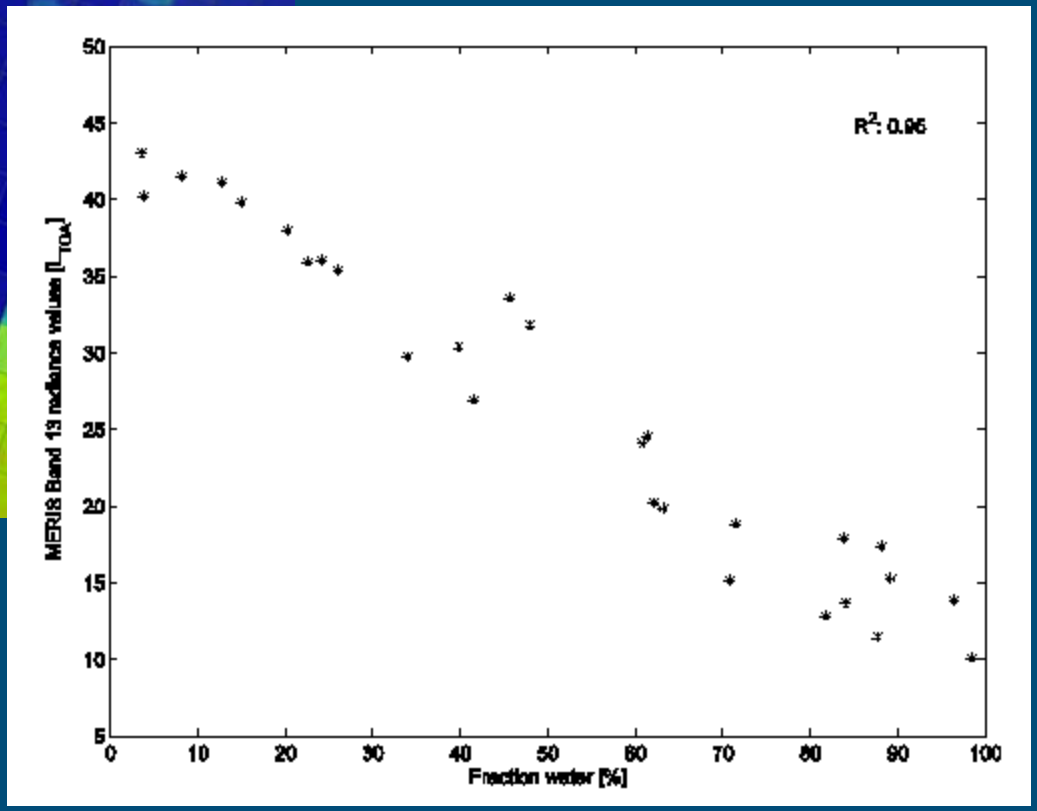
Results (I): a quick look



- 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





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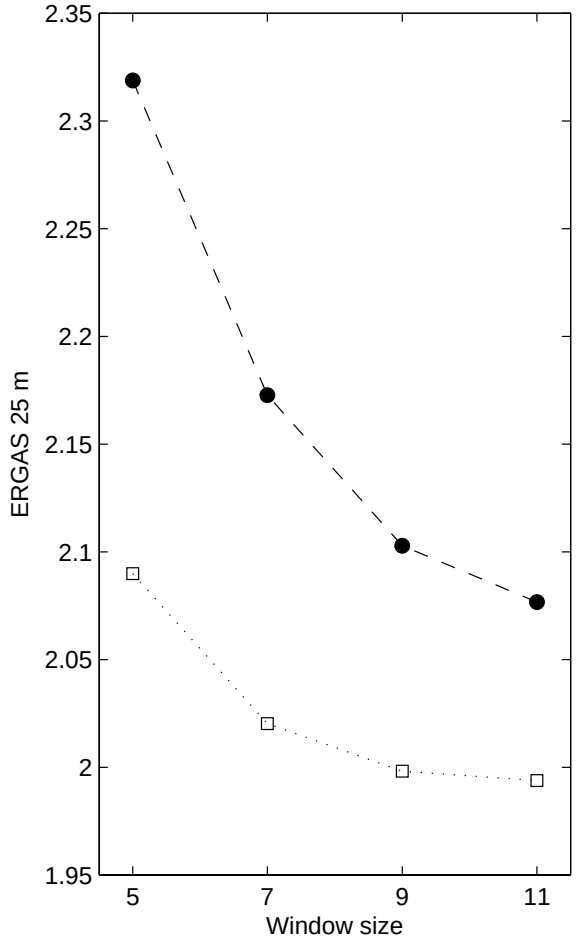
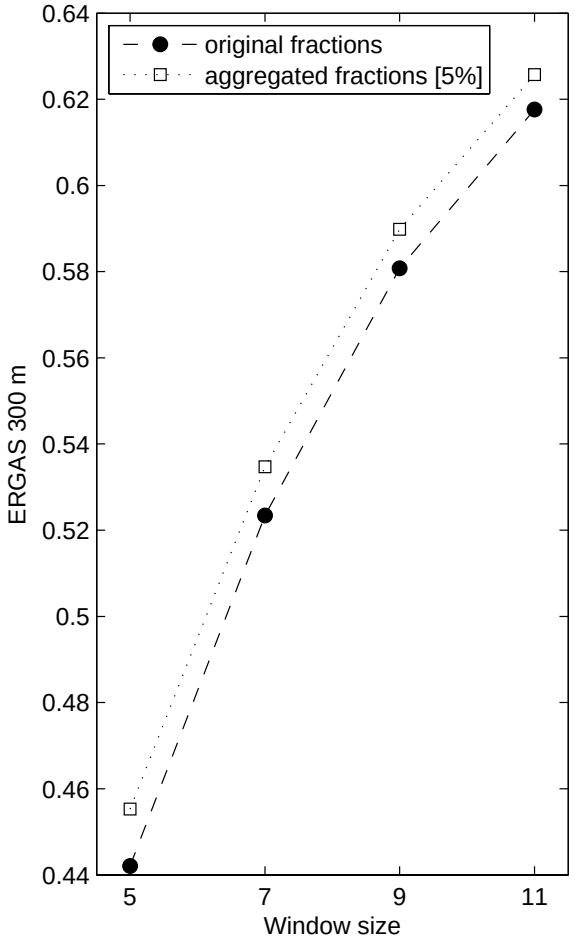
Results (III): Quality assessment (25 m)

5% aggregation changed < 0.6% of the LGN5 pixels





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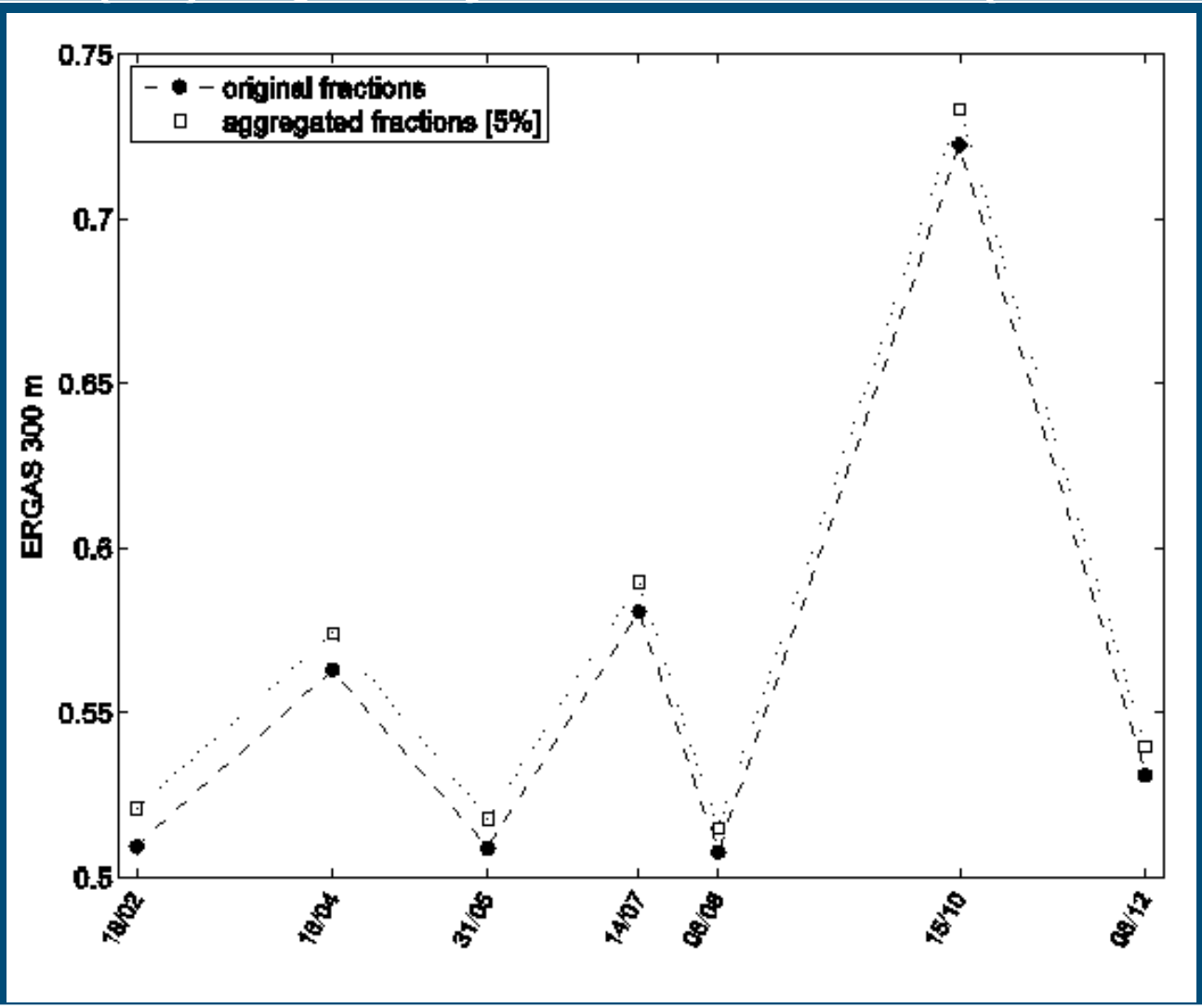
Results (IV): Quality assessment (300 m)



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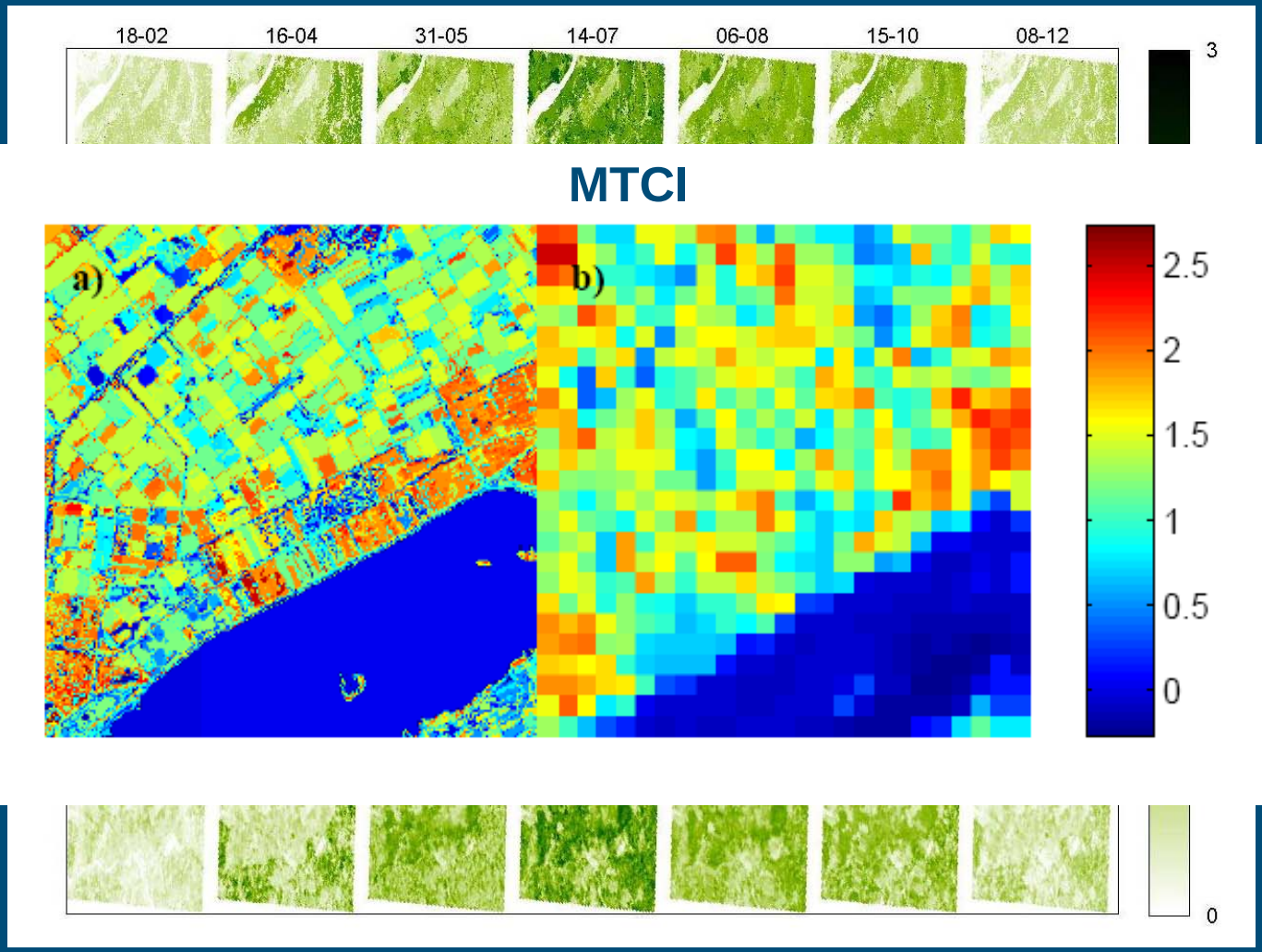
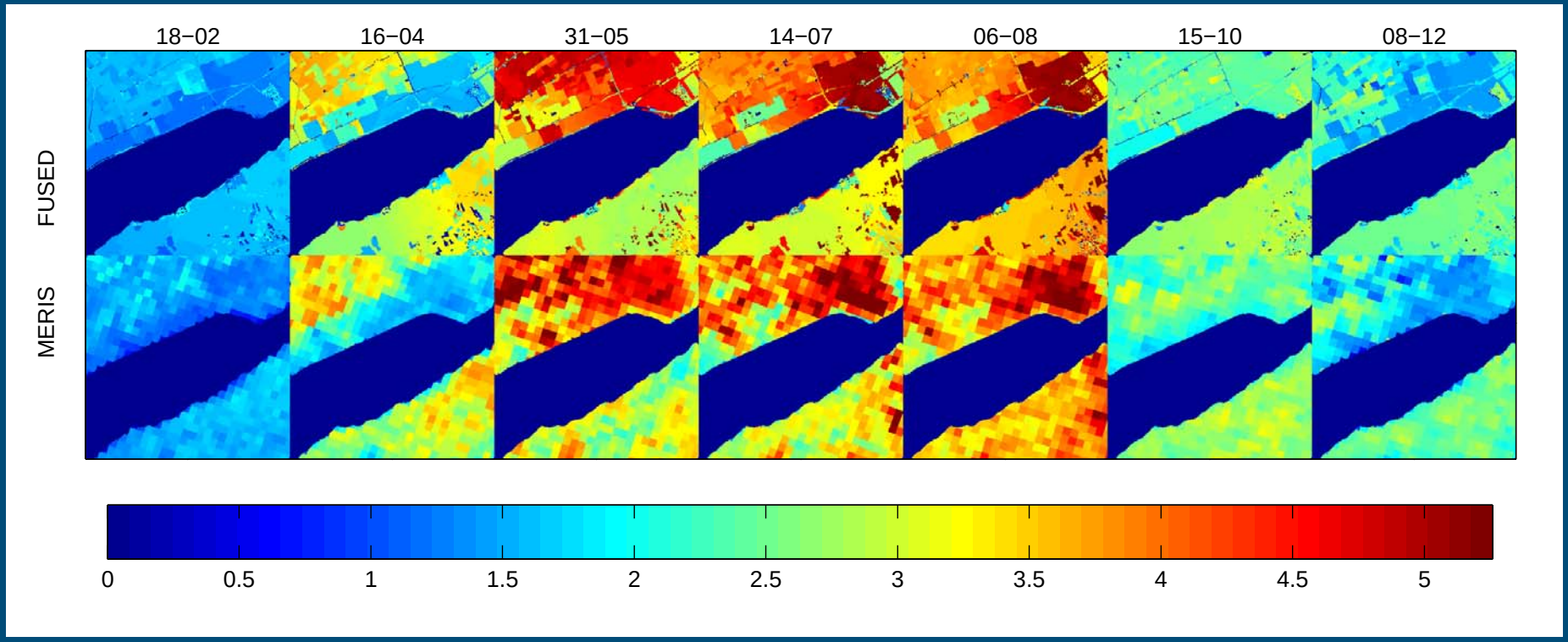
Monitoring vegetation dynamics (I)

- MTCI



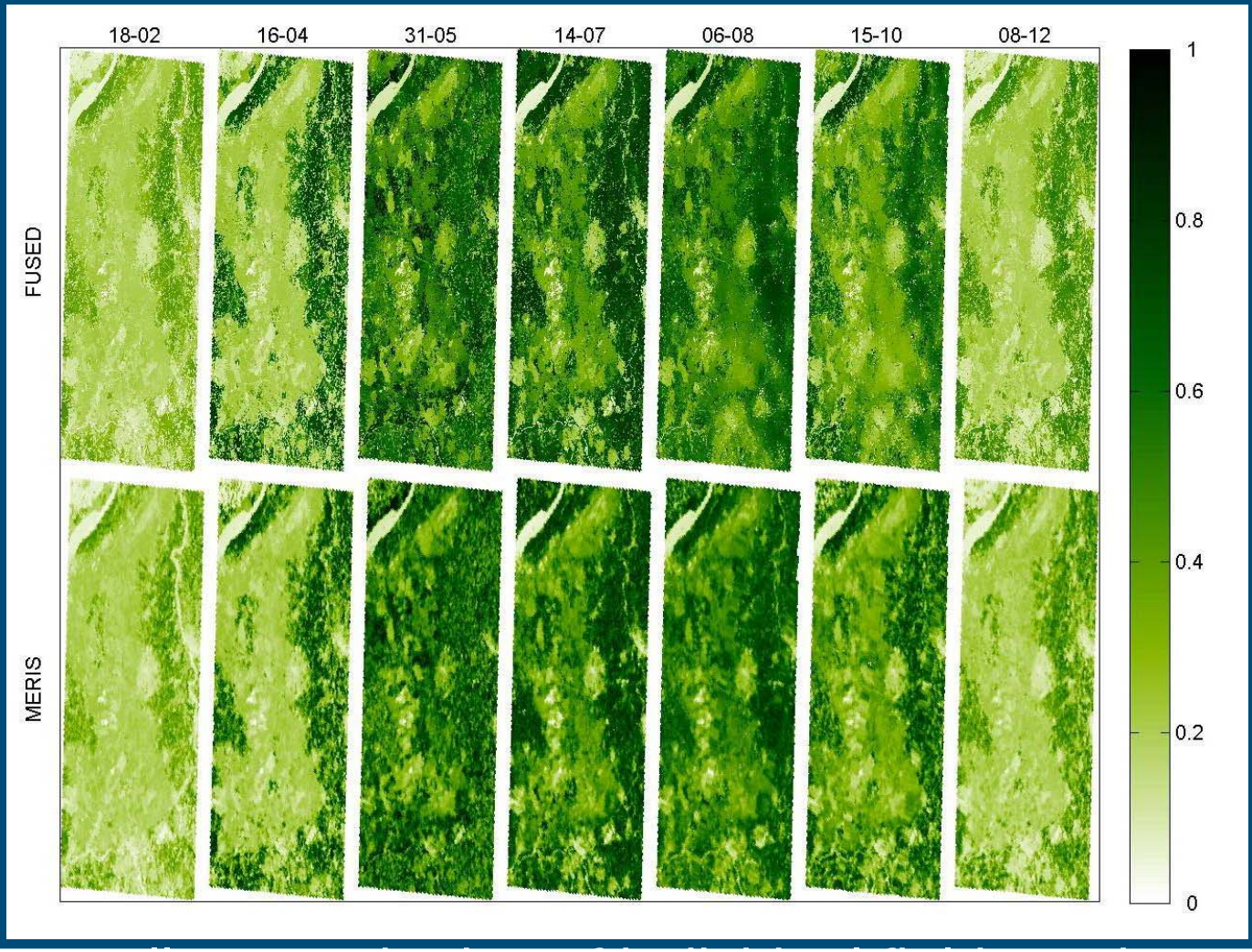
Monitoring vegetation dynamics (I)

- MTCI



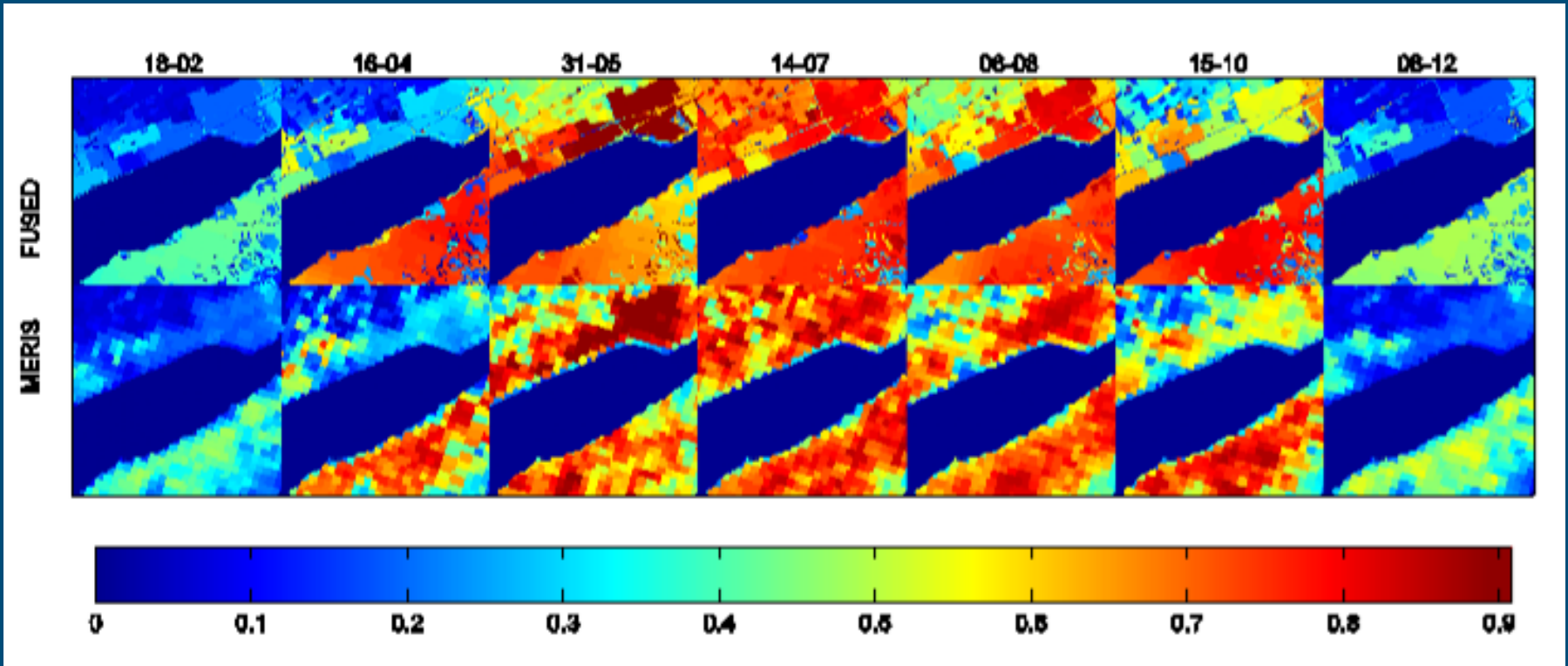
Monitoring vegetation dynamics (I)

- MGVI



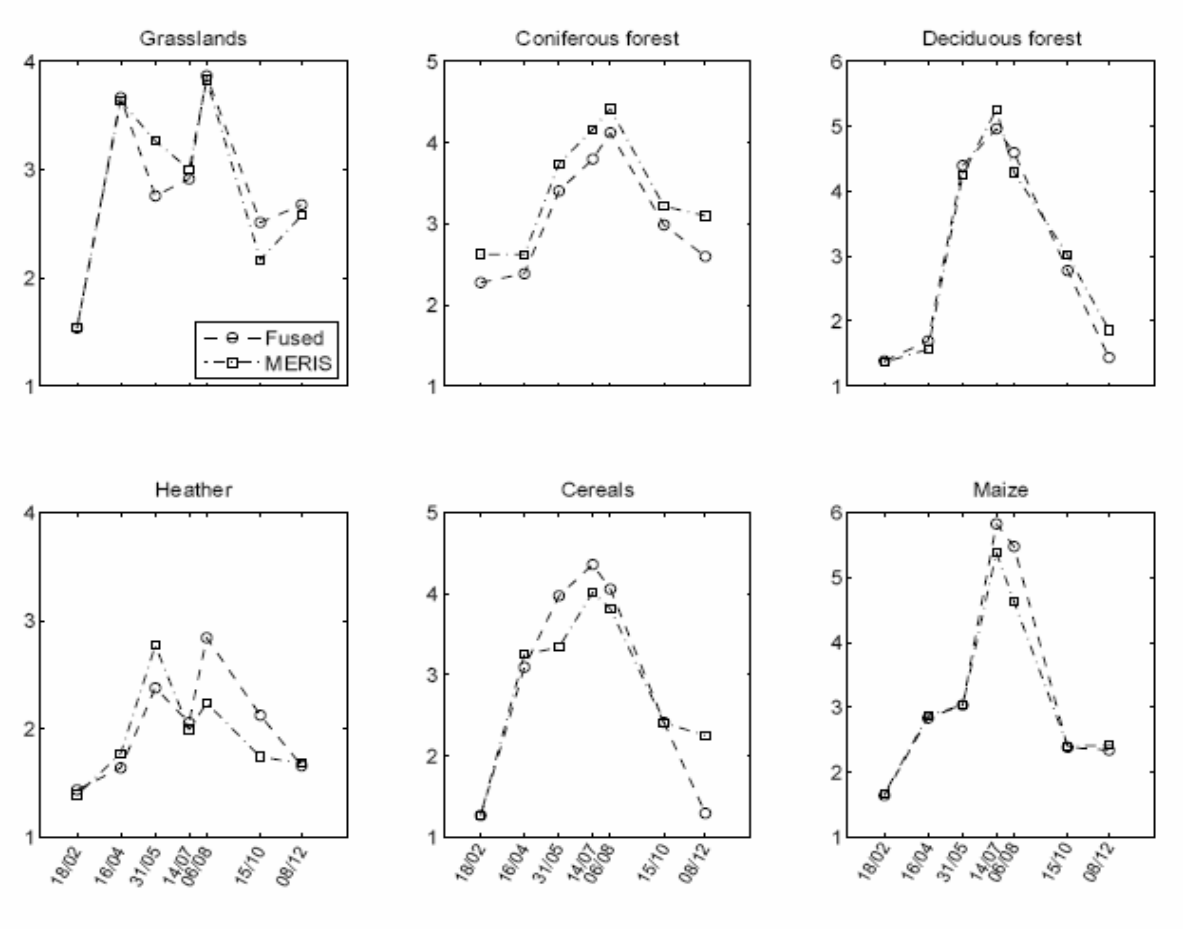
Monitoring vegetation dynamics (II)

- MGVI



Monitoring vegetation dynamics (III)

- MTCI

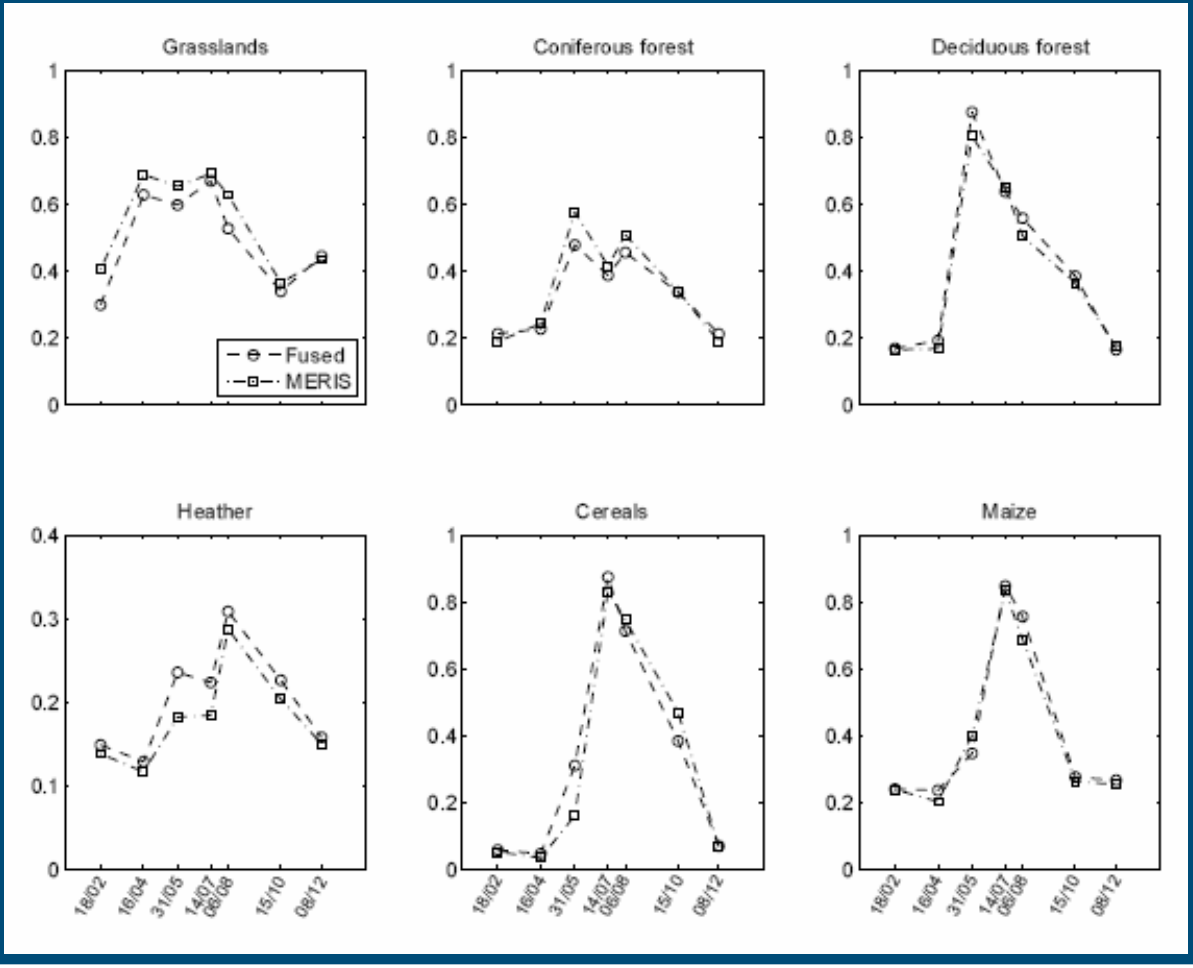


"Quality check"

"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!

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