Analisi di immagini iperspettrali satellitari multitemporali: metodi ed applicazioni

Francesca Bovolo

E-mail: bovolo@fbk.eu
Web page: http://rsde.fbk.eu

Outline

Multitemporal Image Analysis

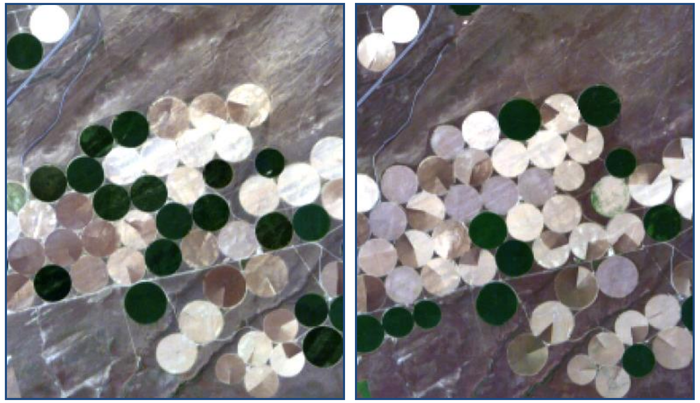
- Multitemporal image analysis: aims at analyzing two or more remote sensing images acquired on the same geographical area at different times for identifying changes or other kinds of relevant temporal patterns occurred between the considered acquisition dates.

- Several multitemporal problems exist:
  - Binary change detection.
  - Multiclass change detection.
  - Trend analysis in long time series.

Binary change detection
Tsunami damages

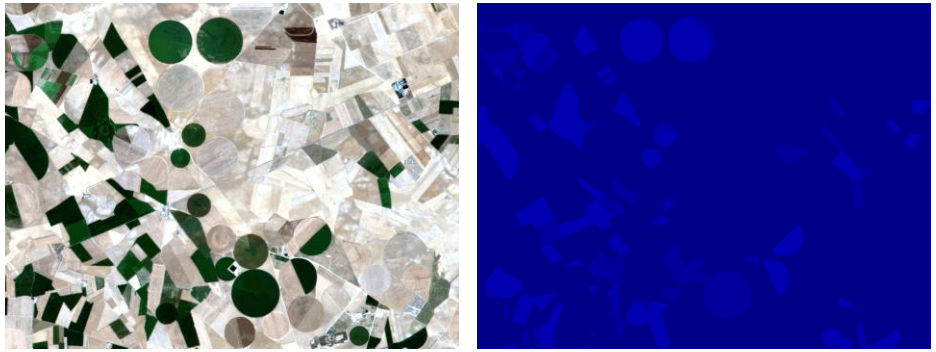
Before Change — After Change

Multiclass change detection
Crop rotation



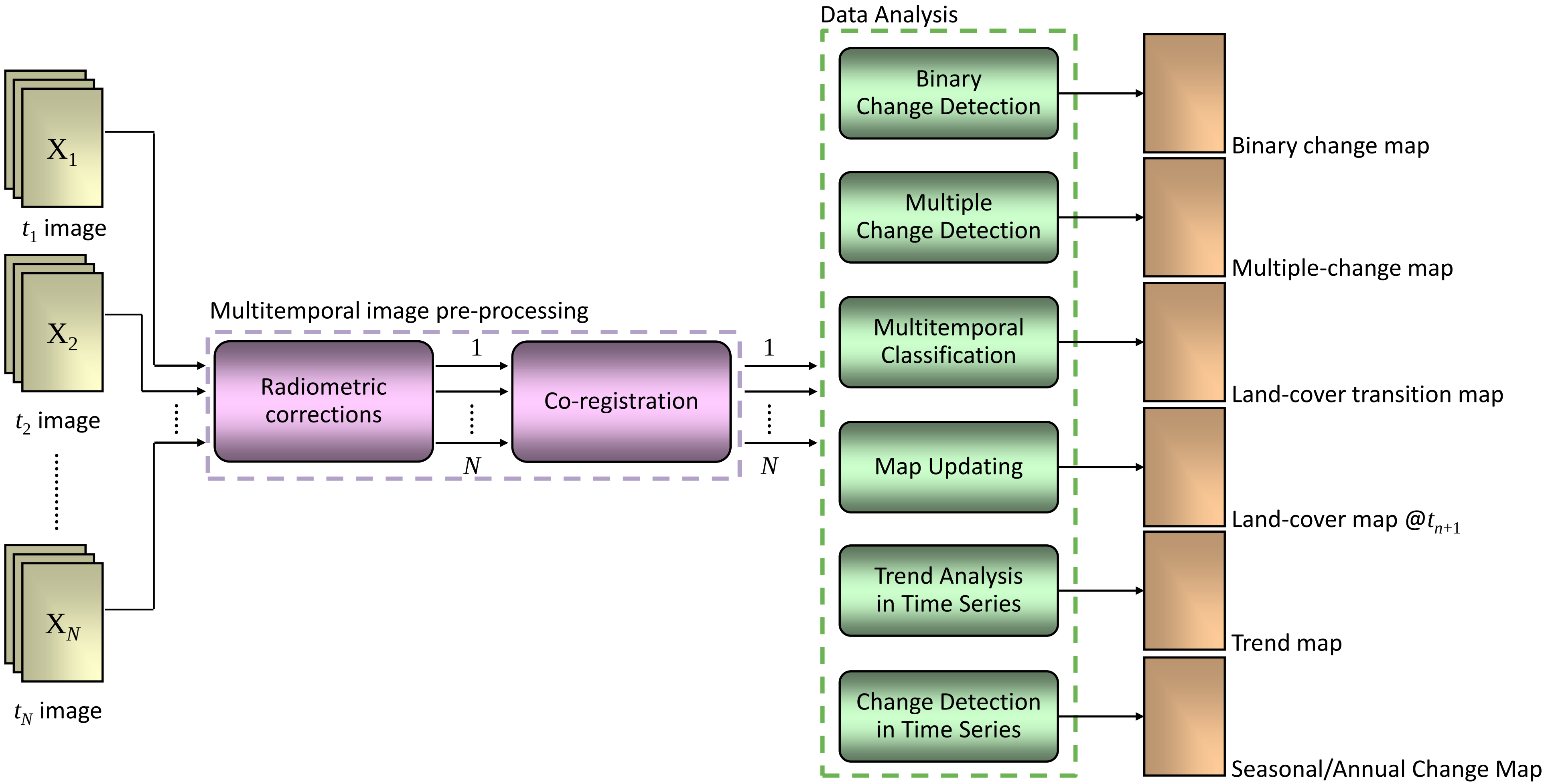
Before Change — After Change

Trend analysis in long time series



True Color Composite — NDVI

Multitemporal Analysis Block Scheme & Products



F. Bovolo, L. Bruzzone, "The Time Variable in Data Fusion: A Change Detection Perspective," IEEE Geoscience and Remote Sensing Magazine, Vol. 3, No. 3, pp. 8-26, 2015.

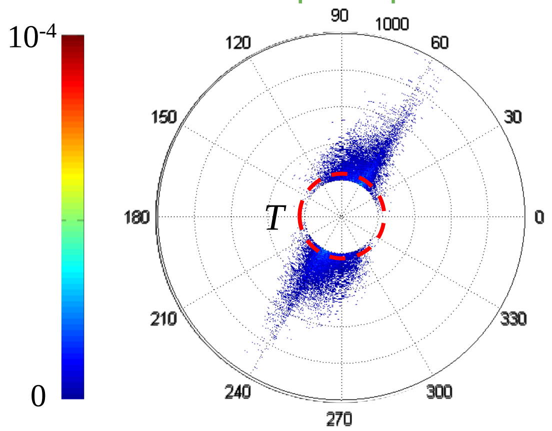
Multitemporal Images Co-registration

- In multitemporal image processing, poor co-registration is a source of errors and can be modeled as a noisy component.

- Registration noise statistical properties have been modeled by accounting for its multiscale behaviors in the difference image domain.

Multiscale CVA

RN polar plot

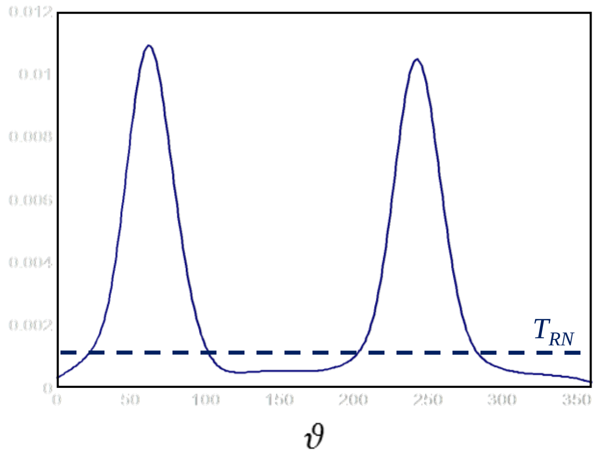


Difference Image Analysis

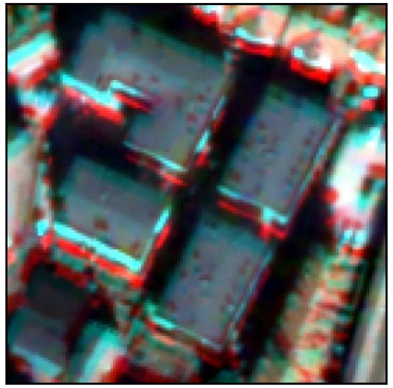
Level ϑ

$$X_D^{\vartheta} = X_2^{\vartheta} - X_1^{\vartheta}$$

RN probability density function



Multitemporal false-color composite of misaligned images



Registration noise map

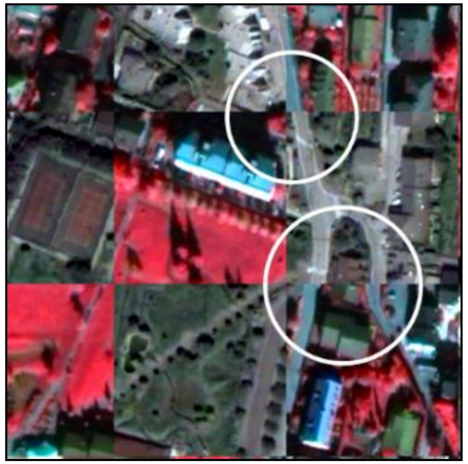
F. Bovolo, L. Bruzzone, S. Marchesi, “Analysis and Adaptive Estimation of the Registration Noise Distribution in Multitemporal VHR Images,” *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 47, No. 8, Part 1, pp. 2658-2671, 2009.

Multitemporal Images Co-registration

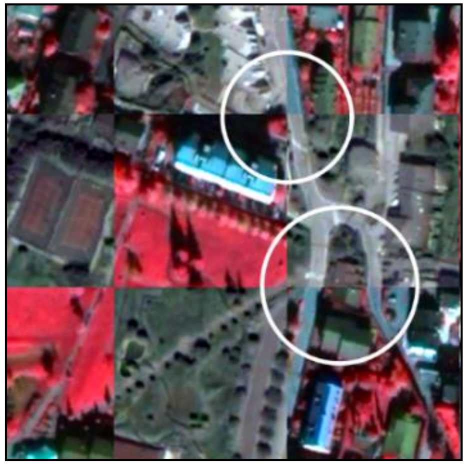
Registration noise information can be used to improve multitemporal analysis by:

- Removing noisy pixels in post-processing [1];
- Involving registration noise in the co-registration step [2]-[4];
- Other more complex paradigms.

Multitemporal chessboard images



Before co-registration



After co-registration

	RMSE (pixels)	STD (pixels)
Before co-registration	16.87	2.13
SoA	3.70	2.21
Registration noise – based co-registration	0.89	0.37

[1] S. Marchesi, F. Bovolo, L. Bruzzone, “A context-sensitive technique robust to registration noise for change detection in VHR multispectral images,” *IEEE Transactions on Image Processing*, Vol. 19, No. 7, pp. 1877-1889, 2010.
[2] Y. Han, F. Bovolo, L. Bruzzone, “An Approach to Fine Co-Registration Between Very High Resolution Multispectral Images Based on Registration Noise Distribution,” IEEE Transactions on Geoscience and Remote Sensing, Vol. 53, No. 12, pp. 6650 – 6662, 2015.
[3] Y. Han, F. Bovolo, L. Bruzzone, “Edge-Based Registration Noise Identification for VHR Multisensor Images,” IEEE Geoscience and Remote Sensing Letters, Vol. 13, pp. 1231 – 1235, 2016.
[4] Y. Han, F. Bovolo, L. Bruzzone, “Segmentation-based Fine Registration of Very High Resolution Multitemporal Images,” IEEE Trans. on Geoscience and Remote Sensing, in press 2017.

Hyperspectral Multitemporal Data Analysis: Challenges

- Multitemporal hyperspectral data are highly sensitive to detailed variations of the spectral signatures of land covers thus when multitemporal images are considered subtle changes/temporal variations can be detected.

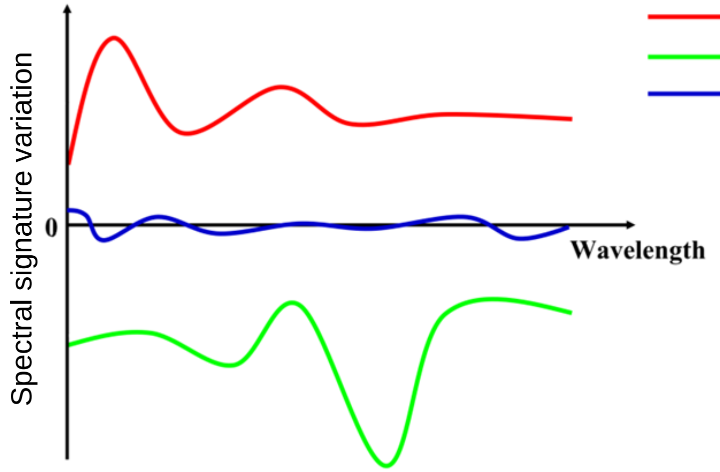
- The definition of the concept of change in hyperspectral (HS) images is not clear in the literature and represents the first challenge.

- Only few approaches to multitemporal in hyperspectral images exist in the literature.

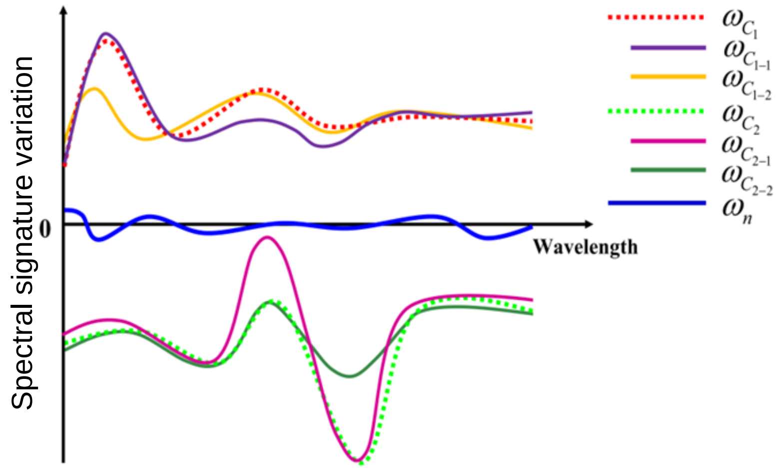
- State-of-the-art methods are mainly developed for multispectral images and do not explicitly handle the challenging issues that may arise due to the properties of hyperspectral images like:
  - the high dimensionality;
  - the presence of noisy channels and redundant information;
  - the increase of computational cost;
  - the increase of the possible number of changes;
  - the high complex change representation and identification;
  - the presence of changes at sub-pixel level (i.e., mixed pixels).

Hyperspectral Change Concept

Low spectral resolution



High spectral resolution



Hyperion data

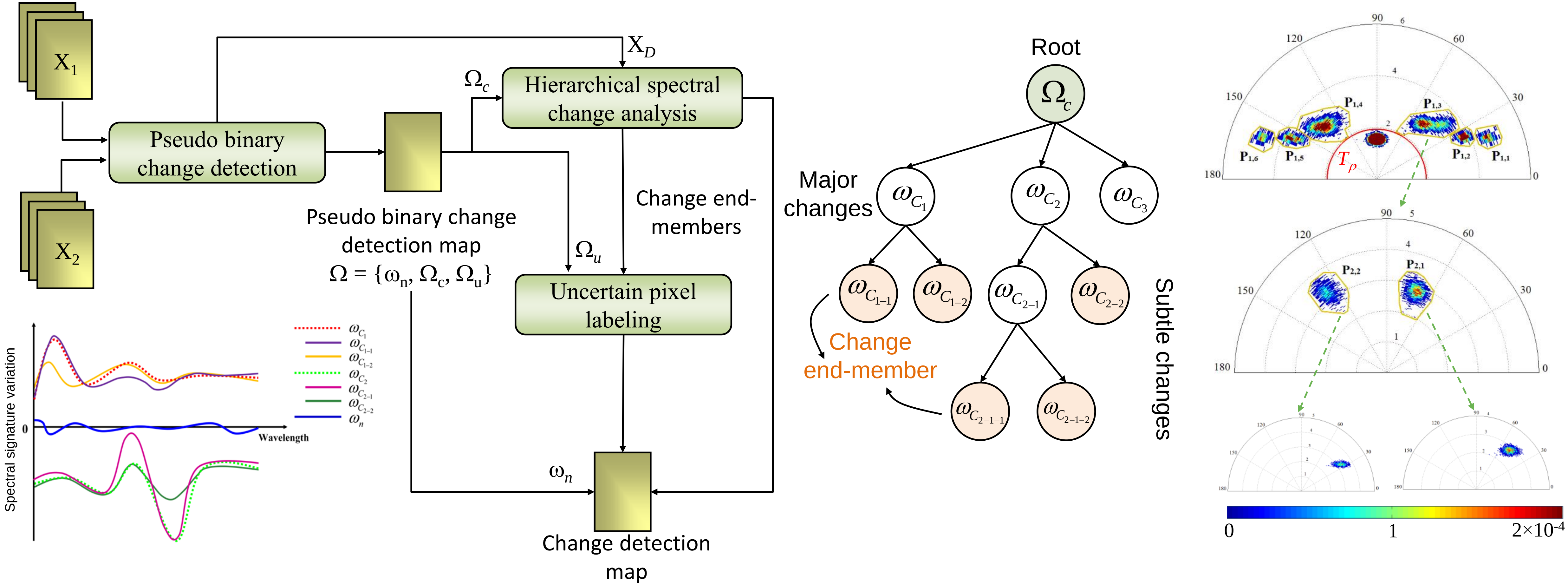
2004

2007

Multitemporal false color composite

R	823.65nm
G	721.90nm
B	620.15nm

Hyperspectral Information Visualization & Management

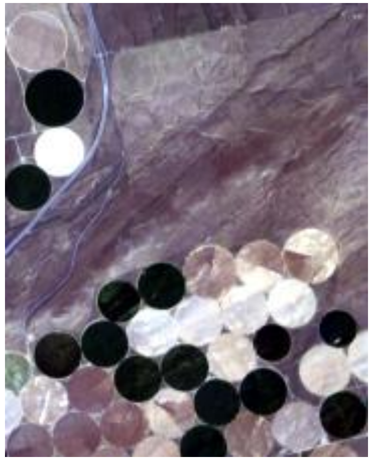


F. Bovolo, S. Marchesi, L. Bruzzone, “A Framework for Automatic and Unsupervised Detection of Multiple Changes in Multitemporal Images”, IEEE Transactions on Geoscience and Remote Sensing, Vol. 50, No. 6, pp. 2196-2212, 2012.

S. Liu, L. Bruzzone, F. Bovolo, P. Du, “Hierarchical unsupervised change detection in multitemporal hyperspectral images,” IEEE Transactions on Geoscience and Remote Sensing, Vol. 53, pp. 244 - 260, 2015. DOI 10.1109/TGRS.2014.2321277.

S. Liu, L. Bruzzone, F. Bovolo, M. Zanetti, P. Du, “Sequential Spectral Change Vector Analysis for Change Detection in Multitemporal Hyperspectral Images,” IEEE Transactions on Geoscience and Remote Sensing, Vol. 53, pp. 4363 – 4378, 2015.

Hyperspectral Information Visualization & Management

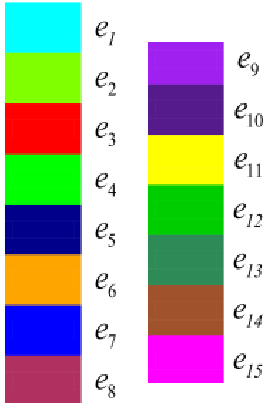


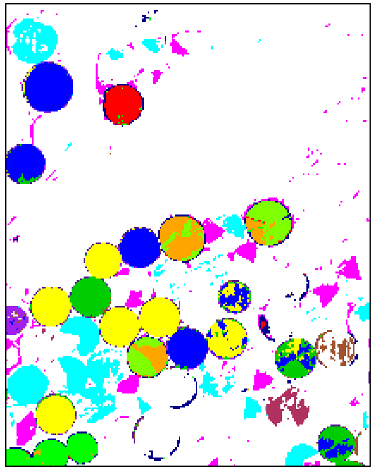
2004

2007

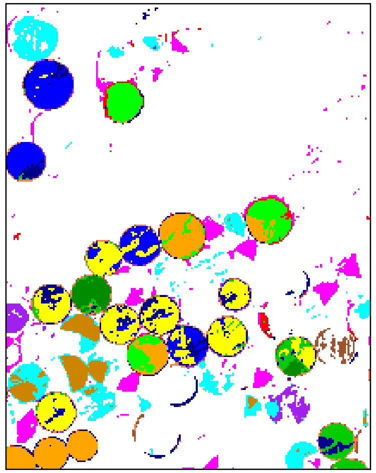
Multitemporal false color composite

R	823.65nm
G	721.90nm
B	620.15nm



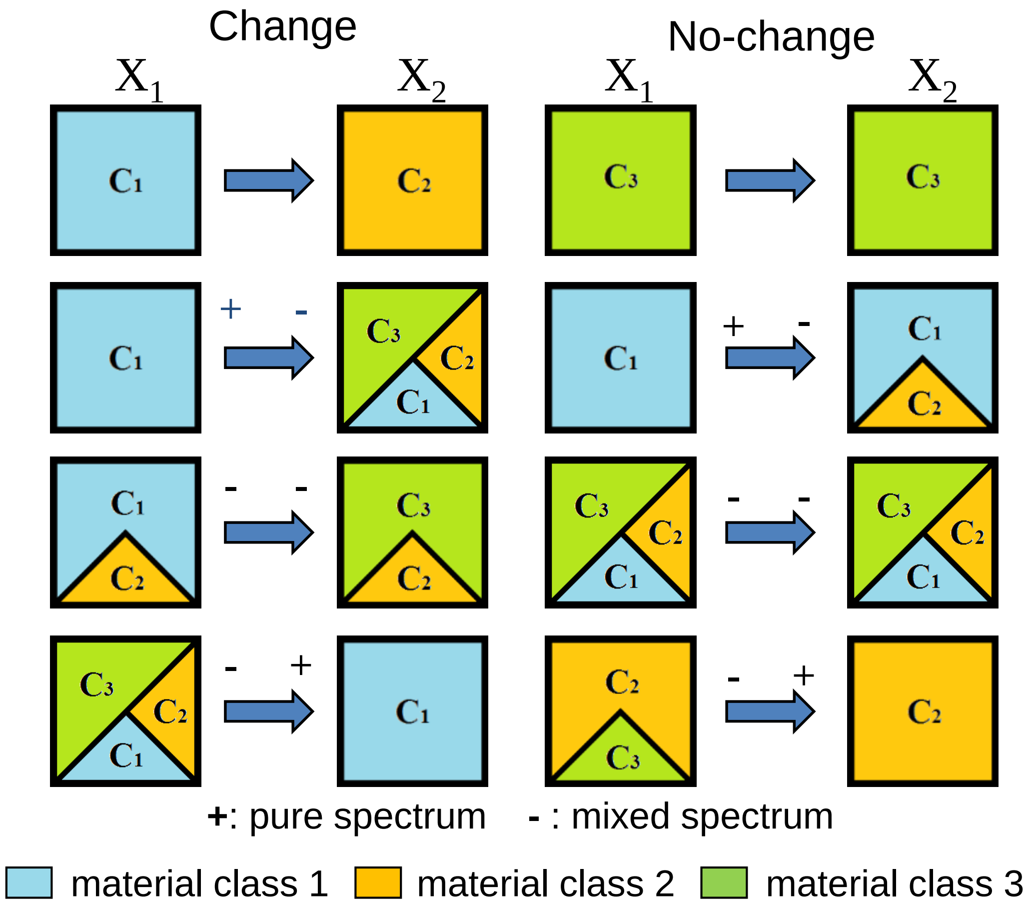


Proposed method

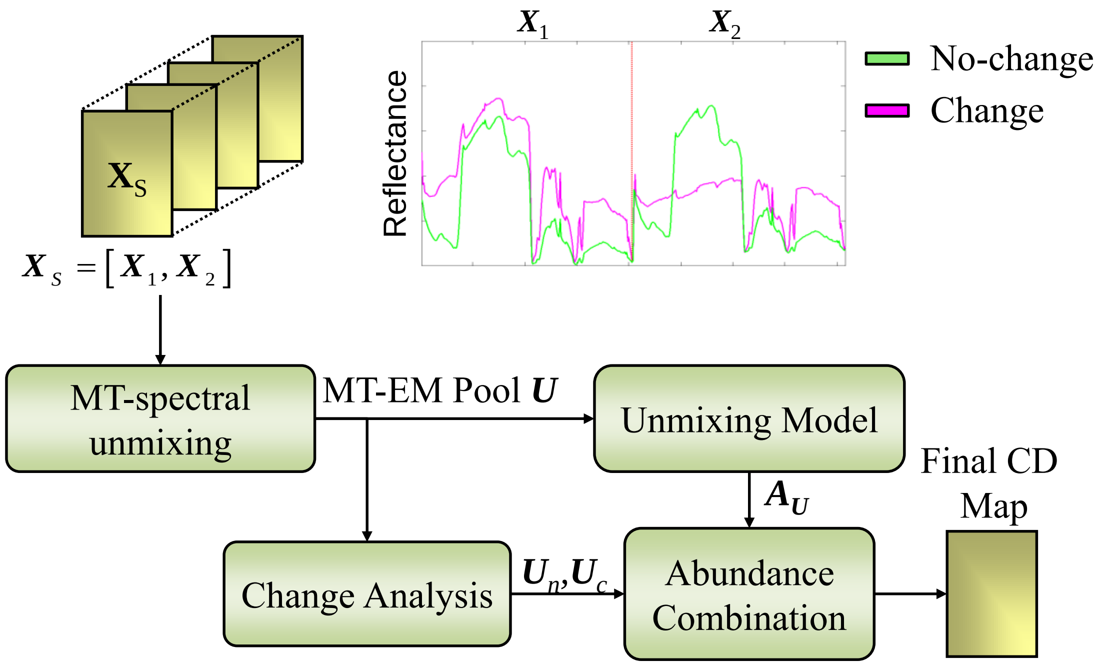


Standard clustering

Unmixing in Hyperspectral Multitemporal Images

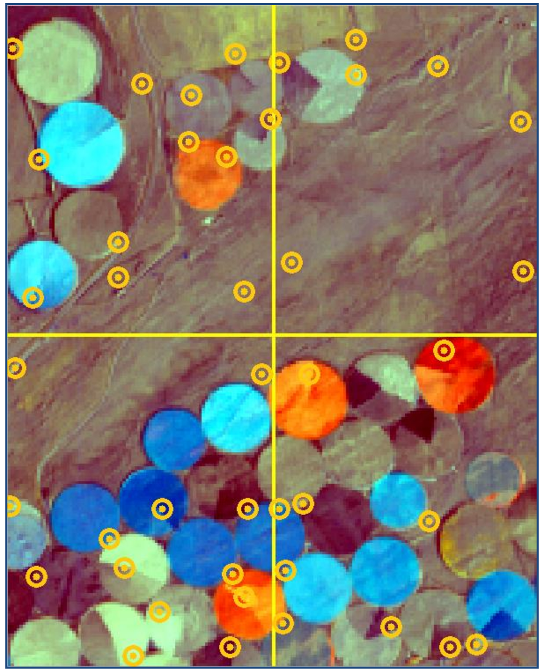


- Multiemporal information extraction can be designed as a multitemporal spectral unmixing problem at sub-pixel level.
- A pure multitemporal endmember (MT-EM) of either change or no change is a stacked feature vector composed by a pure spectral signature in both X_1 and X_2 components.



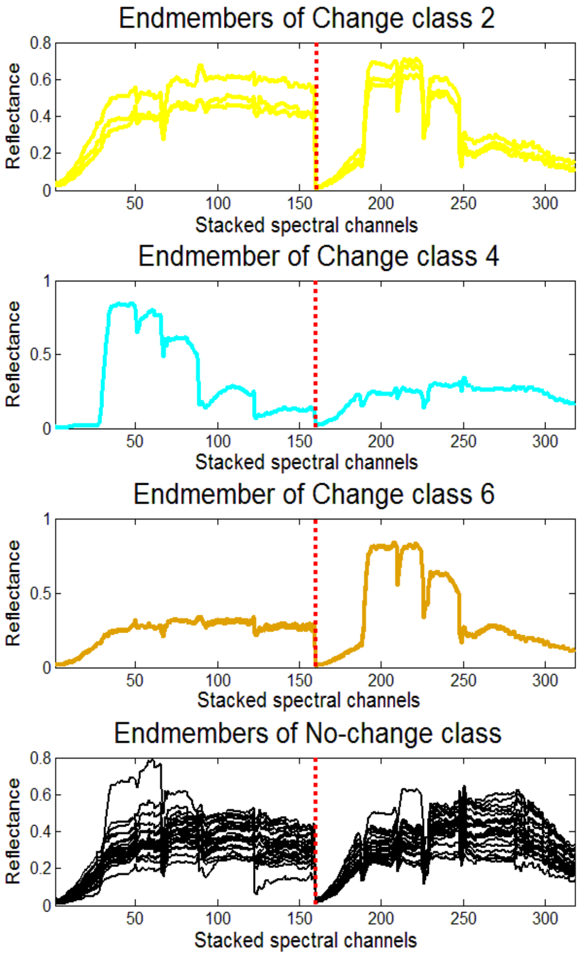
S. Liu, L. Bruzzone, F. Bovolo, P. Du, "Unsupervised Multitemporal Spectral Unmixing for Detecting Multiple Changes in Hyperspectral Images," IEEE Transactions on Geoscience and Remote Sensing, Vol. 54, pp. 2733 - 2748, 2016.

Unmixing in Hyperspectral Multitemporal Images

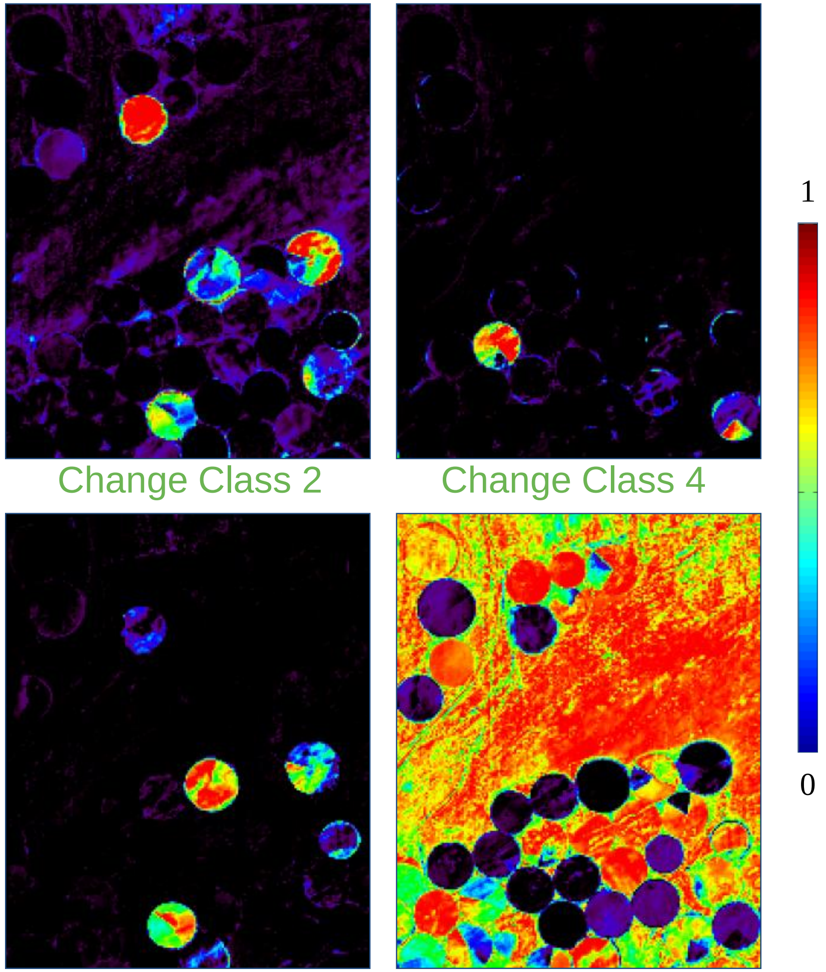


Extracted Endmembers

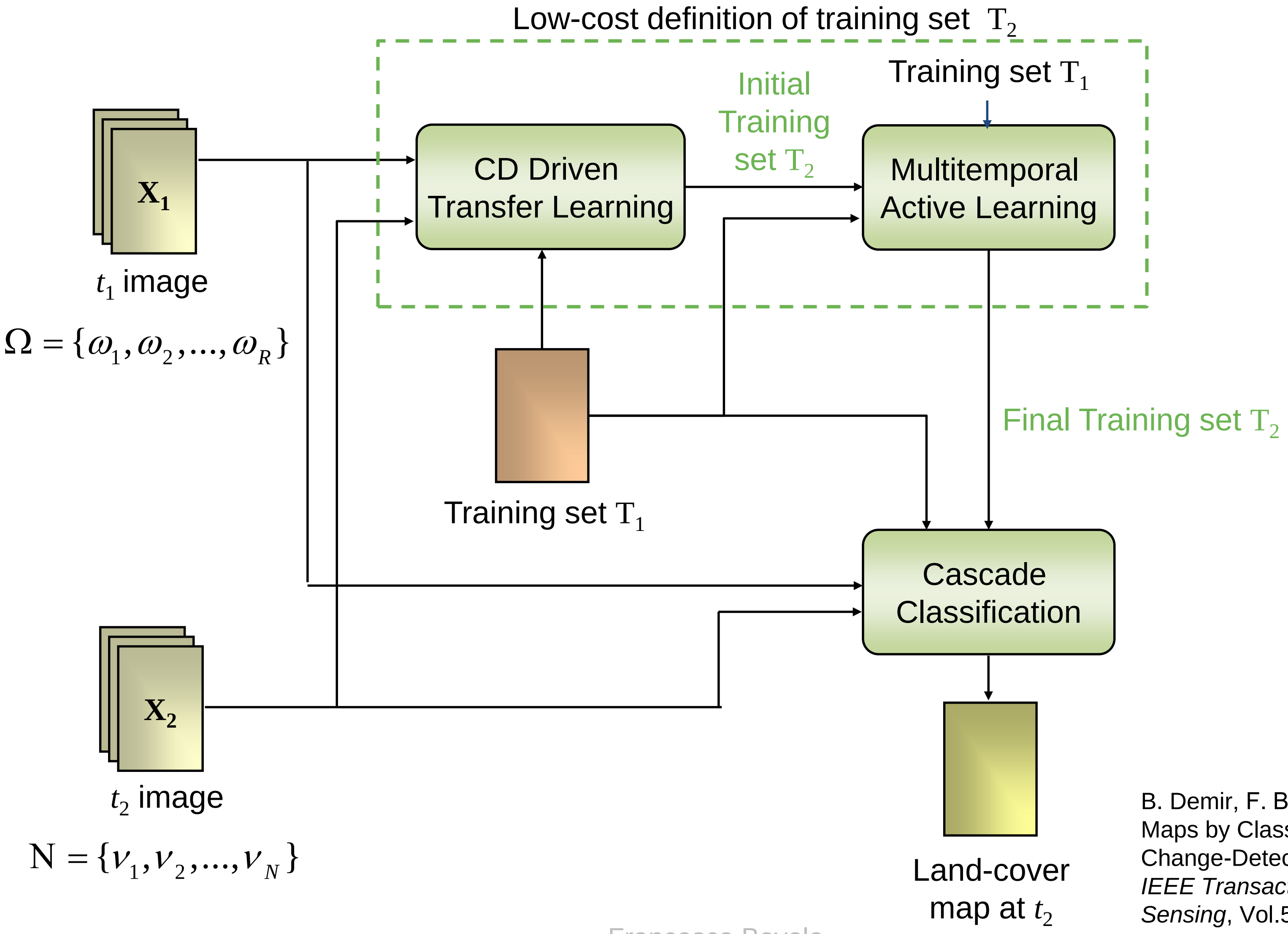
- 42 endmembers
- 16 change MT-EMs in $\boldsymbol{U}_c$
- 26 no-change MT-EMs in $\boldsymbol{U}_n$



Abundance Maps



Land-Cover Map Updating



B. Demir, F. Bovolo, L. Bruzzone "Updating Land-Cover Maps by Classification of Image Time Series: A Novel Change-Detection-Driven Transfer Learning Approach", *IEEE Transactions on Geoscience and Remote Sensing*, Vol.51, pp.300-312, 2013.

Applications

Multitemporal analysis of hyperspectral images can be relevant in many applications, among the others those where small intensity changes and/or changes slow in time may strongly benefit:

- Forest analysis (e.g., forest disturbance, forest fires, forest classification, biomass analysis);
- Precision agriculture (e.g., crop mapping, crop rotation, crop stress analysis, fertilization);
- Water quality (e.g., chlorophyll monitoring, alga bloom);
- Vegetation (e.g., desertification, deforestation, vegetation stress);
- Etc.

Conclusions

- PRISMA will guarantee regular multitemporal hyperspectral images.
- Several activities have been developed in multitemporal image processing in multispectral images (satellite and airborne).
- Automatic supervised/unsupervised methods are available including:
  - Multitemporal images preprocessing.
  - Binary change detection.
  - Multiclass change detection.
  - Trend analysis in long time series.
- These methods can been adapted to the characteristics of PRISMA hyperspectral multitemporal images to generate new products.