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THE TIME VARIABLE IN REMOTE SENSING: PAST, PRESENT AND FUTURE CHALLENGES

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Outline

1. Current Trends and Background on the Time Variable
2. Past: Medium and High Resolution Images
3. Present: VHR Multispectral and SAR Images
4. Future Challenges
5. Conclusion

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Introduction

In the last 15 years we had a significant increase in the interest on topics related to the time series and the analysis of multitemporal data:

- ✓ Sharp increase in the number of papers published on the major remote sensing journals (e.g., IEEE Transactions on Geoscience and Remote Sensing, IEEE Geoscience and Remote Sensing Letters, IEEE Journal on Selected Topics in Applied Earth Observation and Remote Sensing, Remote Sensing of Environment, International Journal of Remote Sensing).
- ✓ Increased number of related sessions in international conferences.
- ✓ Increased number of projects related to multitemporal images and data.

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Introduction

The increased interest in multitemporal data analysis is due to many issues:

- ✓ Increased number of satellites with increased revisitation time that allow the acquisition of either long time series or frequent bitemporal images.
- ✓ New policy for data distribution of archive data that makes it possible a retrospective analysis on large scale (e.g. the Landsat Thematic Mapper archive).
- ✓ New policies for the distribution of new satellites data (e.g. ESA Sentinel).

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MultiTemp History

MultiTemp 2001: Trento

UNIVERSITY OF TRENTO - Italy

First International Workshop on the Analysis of Multitemporal Remote Sensing Image
13-14 September 2001
University of Trento, Trento, Italy

Joint Research Centre European Commission

IEEE GRSS Geoscience and Remote Sensing Society

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MultiTemp Hystory

MultiTemp 2003: Ispra

Joint Research Centre European Commission

Second International Workshop on the Analysis of Multitemporal Remote Sensing Images

16-18 July 2003

European Commission Joint Research Centre, Ispra, Italy

UNIVERSITY OF TRENTO - Italy

IEEE GRSS Geoscience and Remote Sensing Society

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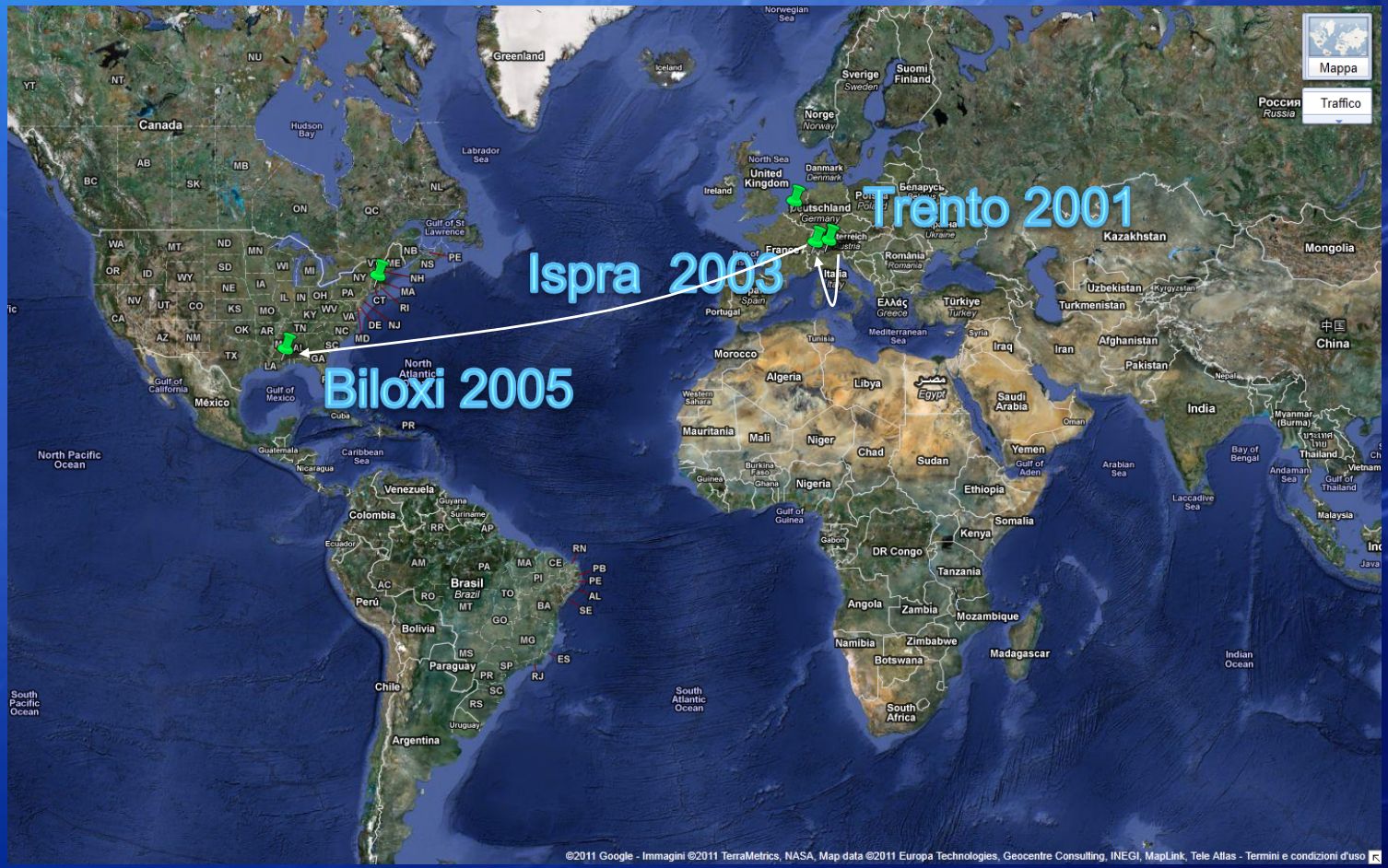
MultiTemp History



MultiTemp 2005: Biloxi

Third International Workshop on
the Analysis of Multitemporal Remote Sensing Images
16-18 May 2005
Biloxi, Mississippi USA

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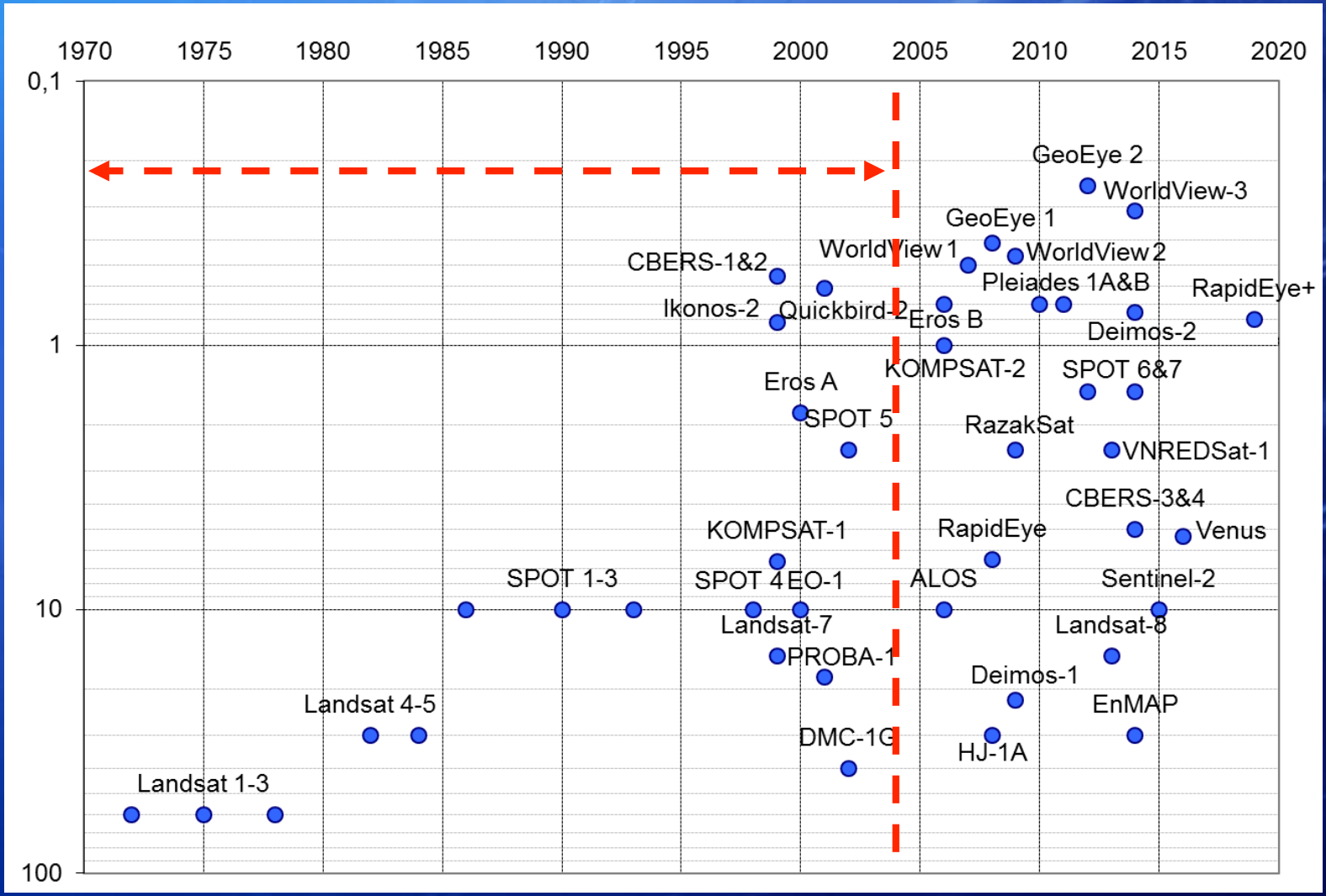
Optical Satellite Missions



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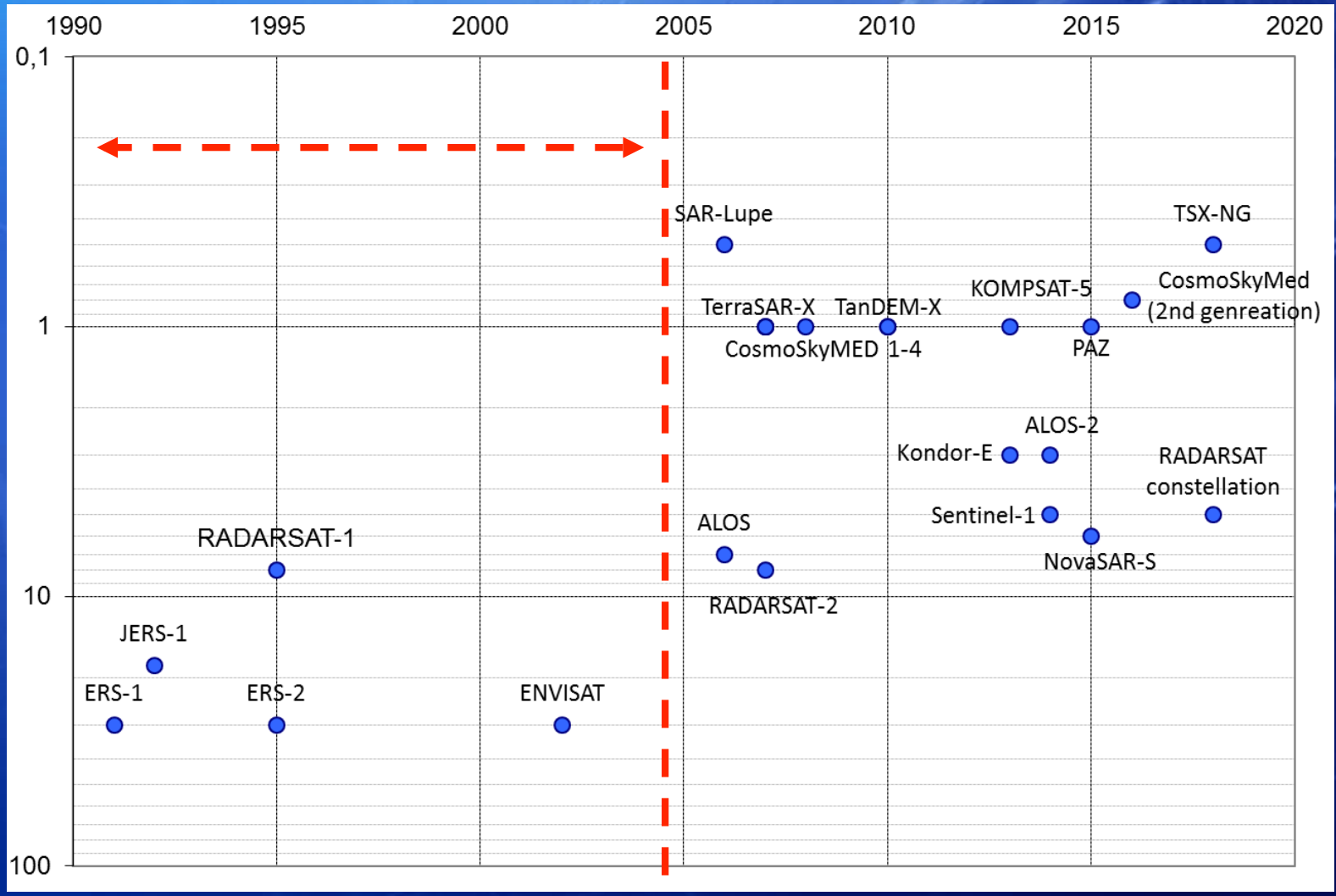
SAR Satellite Missions



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Time Variable: Medium/High Resolution Images

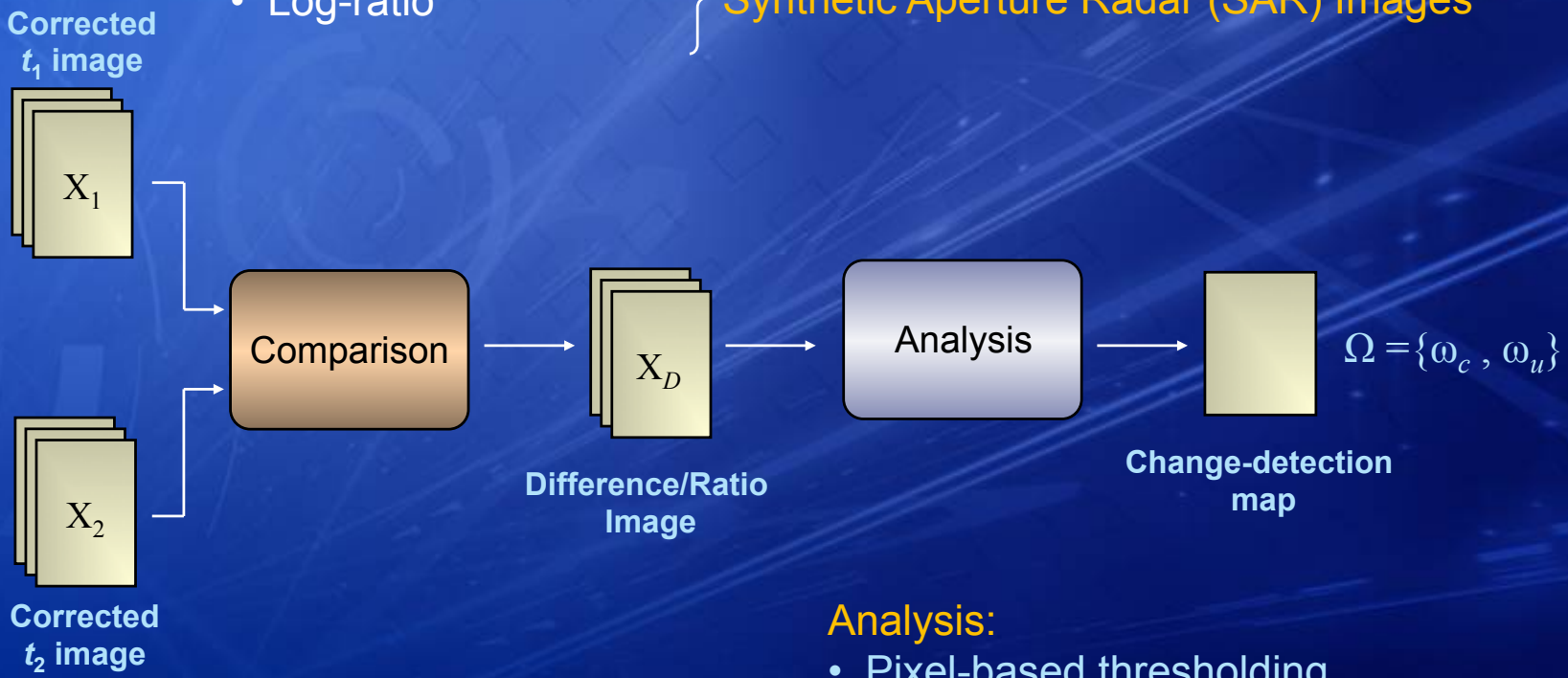
Binary change detection

Comparison Operators:

- Difference
- Vector difference
- Ratio
- Log-ratio

} Optical Images

} Synthetic Aperture Radar (SAR) Images



Analysis:

- Pixel-based thresholding
- Context-based approaches

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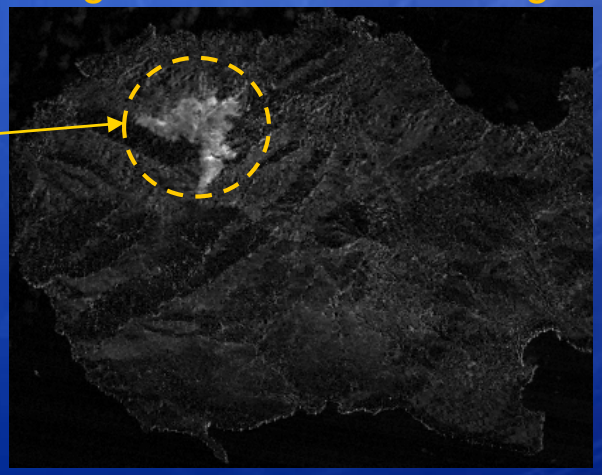
Example: Change Detection in Multispectral Images

Landsat TM, Pre-event

Landsat TM, Post-event

Magnitude Difference Image

Burned area



Change Detection Map (Burned Area)

Landsat 5 Thematic Mapper images of a forest fire in the Island of Elba, Italy

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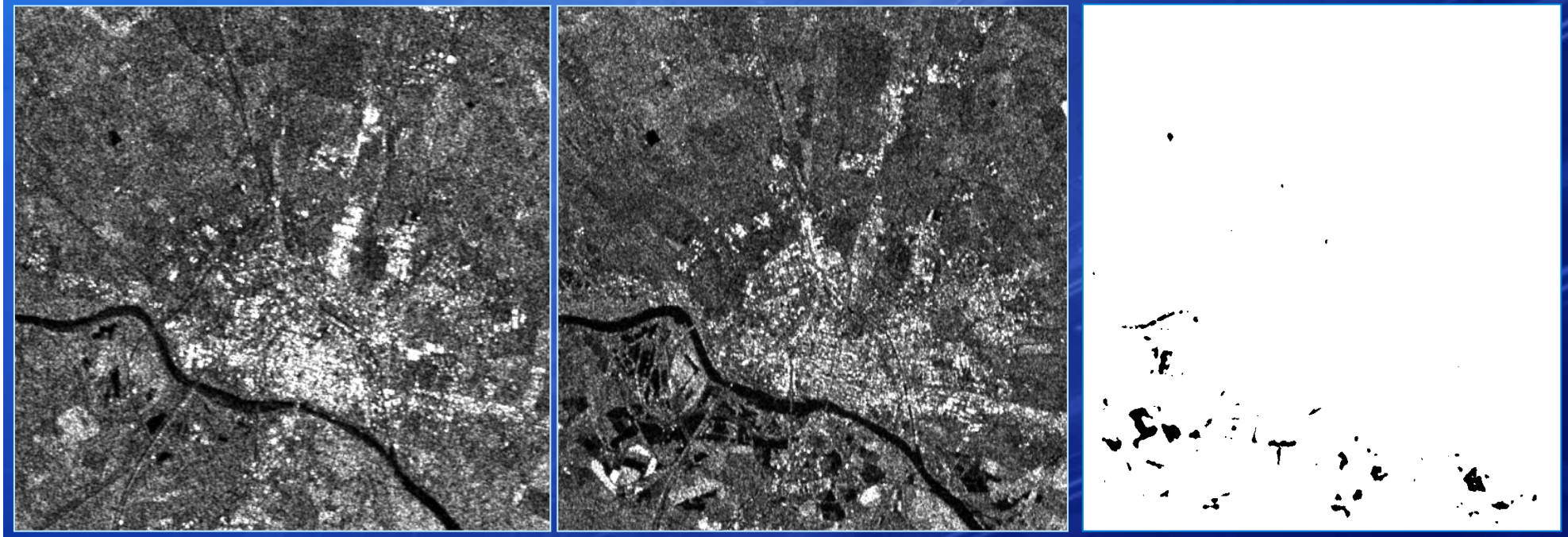
Example: Change Detection in SAR Images

ERS-2, Pre-event Image

ERS-2, Post-event Image

Change Detection Map
(Flooded Area)



ERS-2 SAR images of a flood in the City of Pavia, Italy

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Time Variable: Medium/High Resolution Images

Detection of land-cover transitions

- ✓ Goal: generation of a change-detection map in which land-cover transitions are explicitly identified;
- ✓ Number of images: 2 (or pairs of images extracted from a series);
- ✓ Application domain: updating thematic maps, detection of multiple changes.

May 1995 (Landsat)

July 1995 (Landsat)

Thematic Map

URBAN
URBAN

BARE SOIL
SUGAR BEET

WHEAT
BARE SOIL

BARE SOIL
CORN

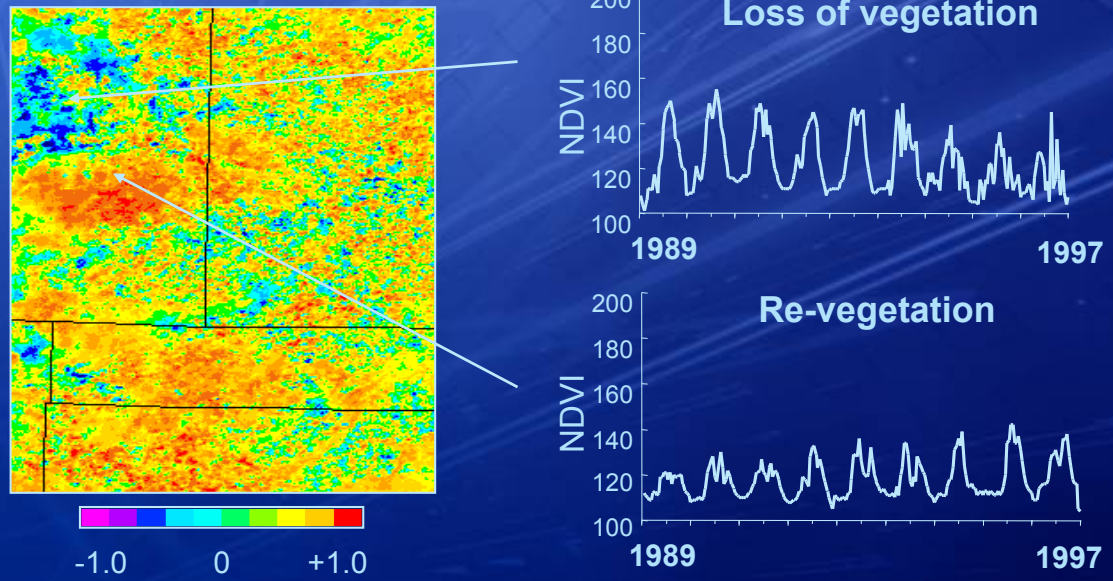
BARE SOIL
SOYBEAN

© Lorenzo Bruzzone

Time Variable: Medium/High Resolution Images

Analysis of long time series of medium resolution images

- ✓ Goal: analysis of the temporal signatures in long image time series;
- ✓ Number of images: 2 time series made up on n images (n>>2);
- ✓ Application domain: analysis of the dynamic of bio/geo-physical variables; monitoring seasonal/annual changes.



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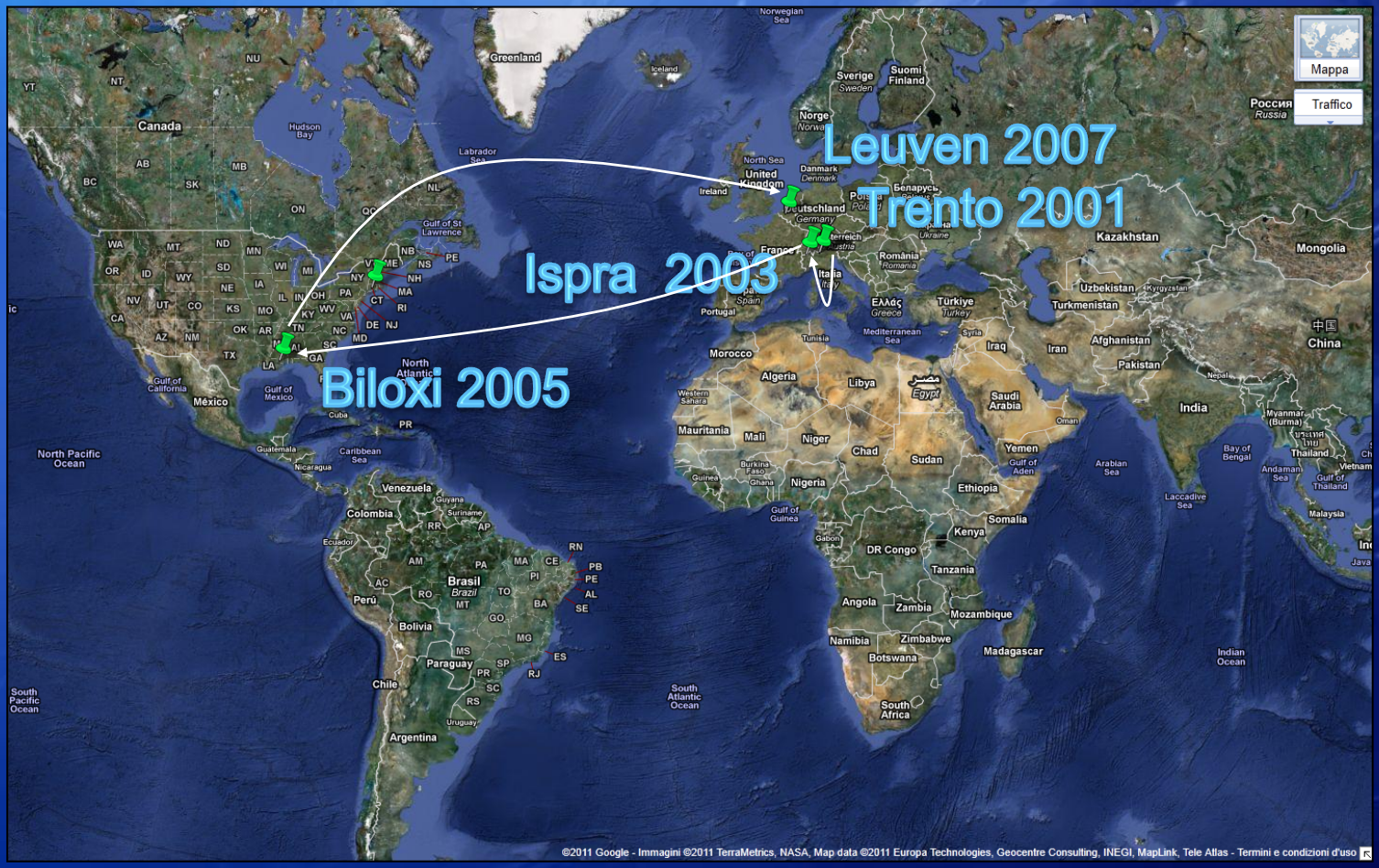
MultiTemp History



MultiTemp 2007: Leuven

Fourth International Workshop on the Analysis of Multitemporal Remote Sensing Images
18-20 July, 2007
Provinciehuis Leuven, Belgium

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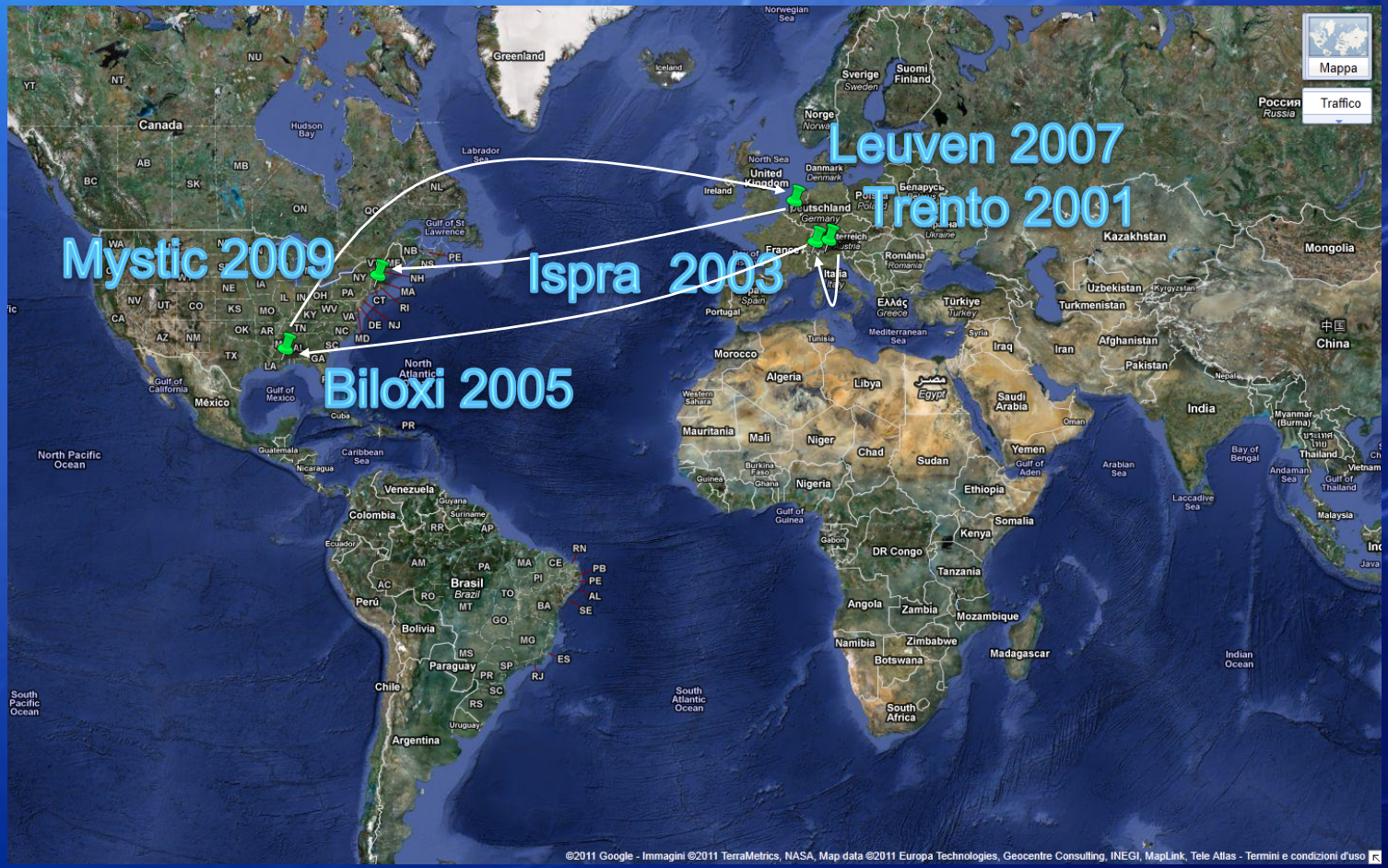
MultiTemp History



Multitemp 2009: Mystic

Fifth International Workshop on the Analysis of Multitemporal Remote Sensing Images

28-30 July, 2009

Mystic, Connecticut, USA

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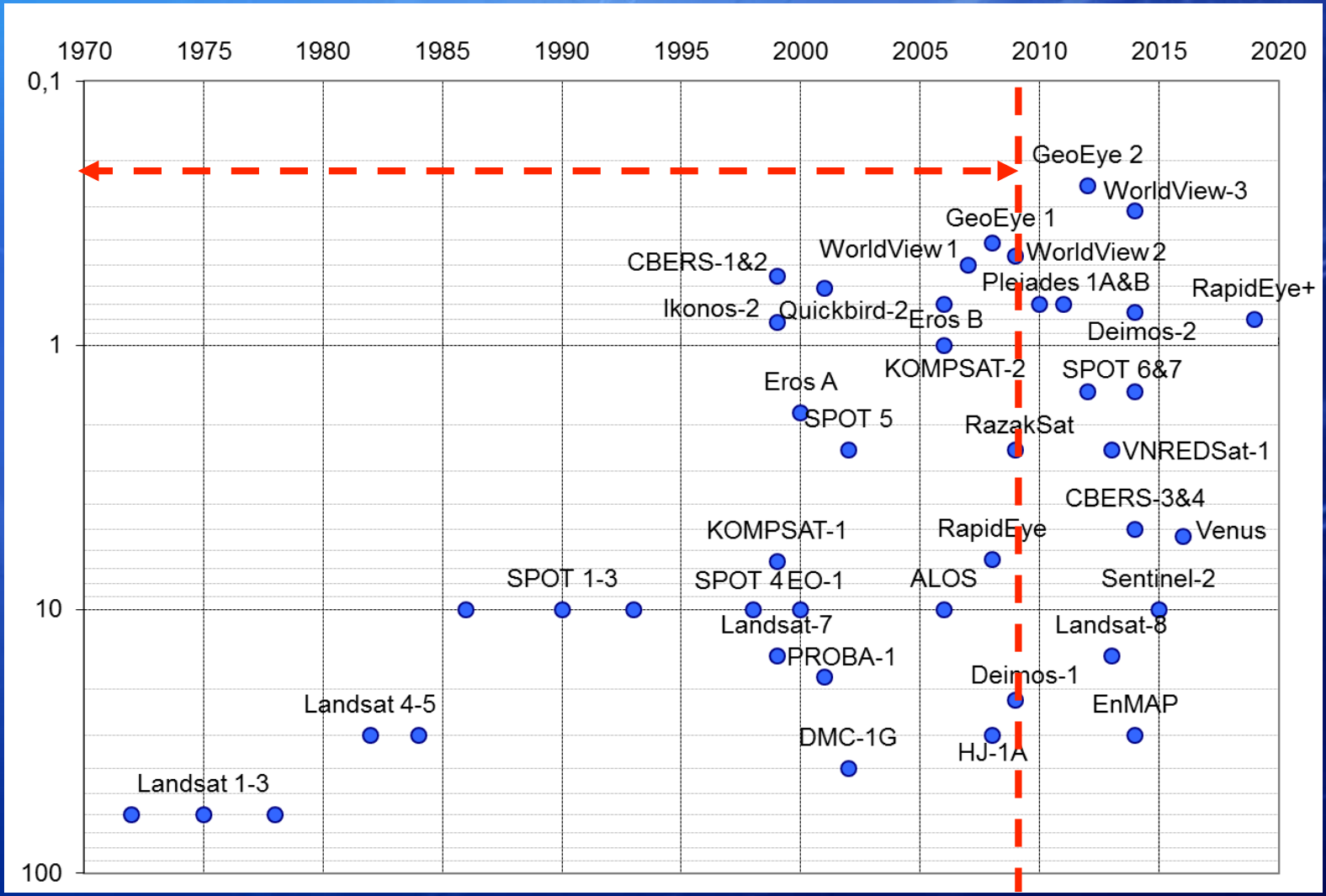
Time Variable: VHR Multispectral Images



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Time Variable: VHR Multispectral Images

July 2006 October 2005

Quickbird images of the city of Trento (Italy)

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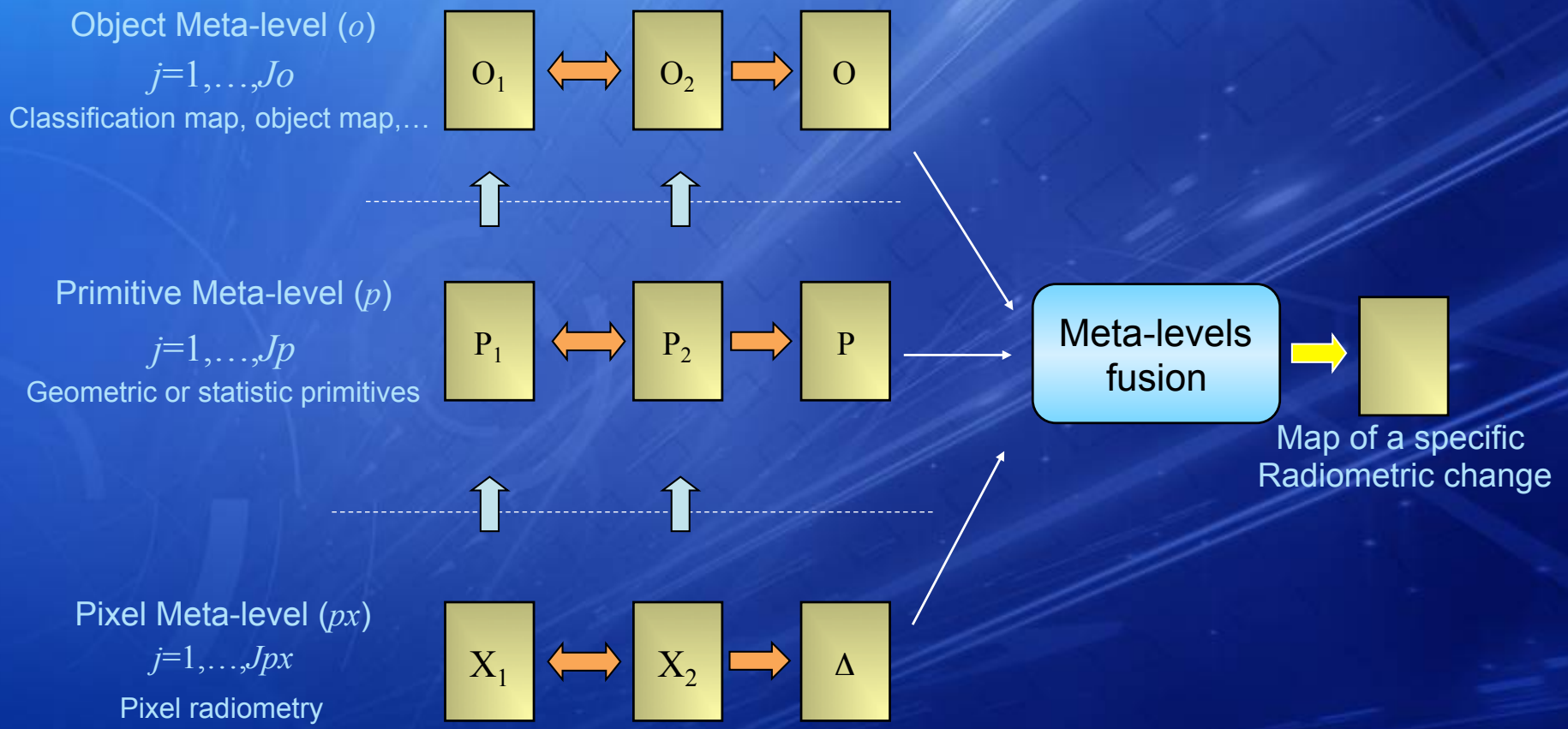
CD in Multitemporal VHR images

Change detection in VHR Images should exploit a top-down approach to the definition of the processing architecture. This approach should:

- ✓ explicitly model the presence of different radiometric changes on the basis of the properties of the considered images
- ✓ extract the semantic meaning of changes;
- ✓ identify changes of interest with strategies designed on the basis of the specific application;
- ✓ exploit the intrinsic multiscale properties of the objects and the high spatial correlation between pixels in a neighborhood.

CD in Multitemporal VHR images



L. Bruzzone, F. Bovolo, A Novel Framework for the Design of Change-Detection Systems for Very-High-Resolution Remote Sensing Images, *Proceedings of the IEEE*, Vol. 101, 2013, pp. 609-630.

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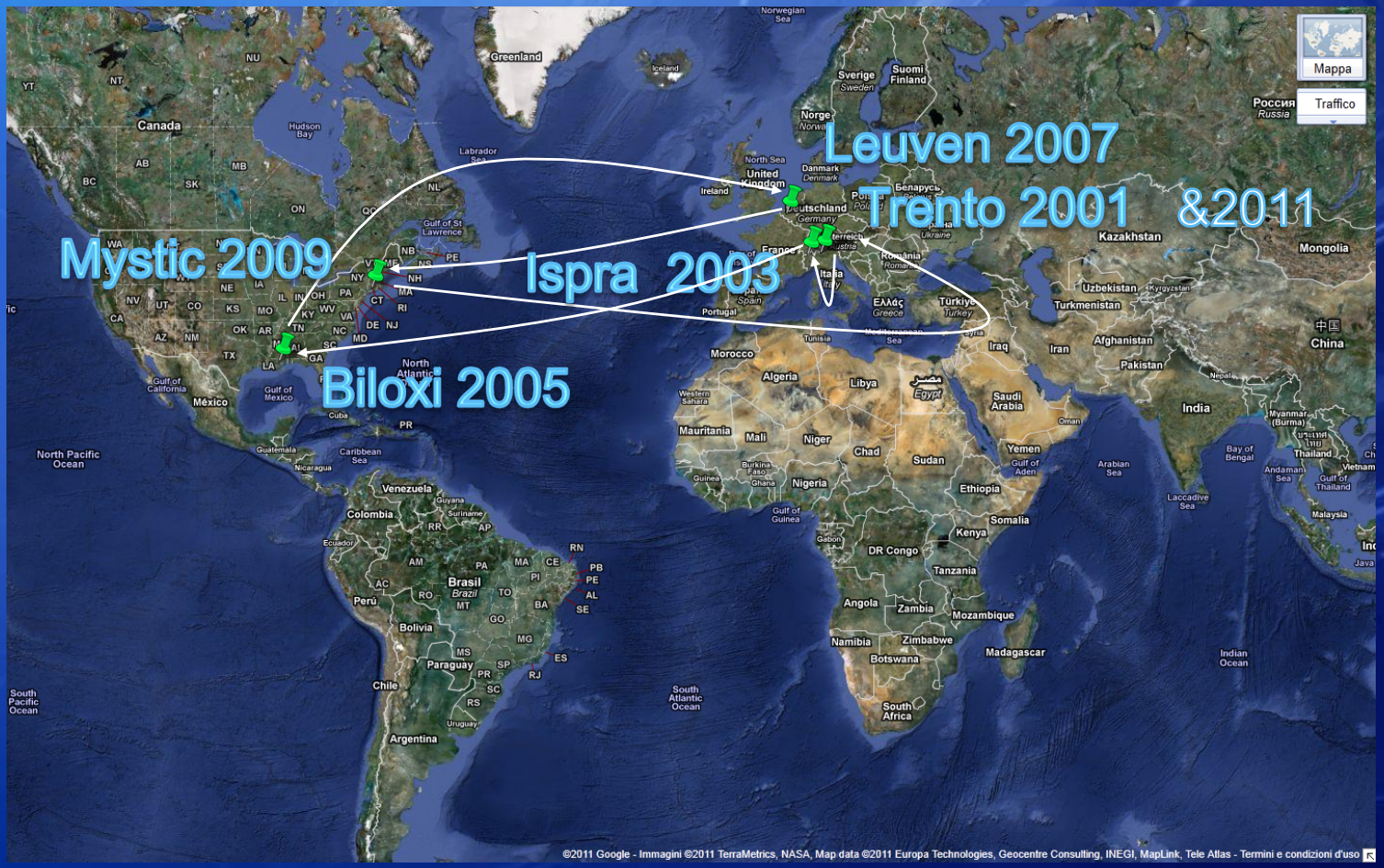
MultiTemp History



MultiTemp 2011: Trento

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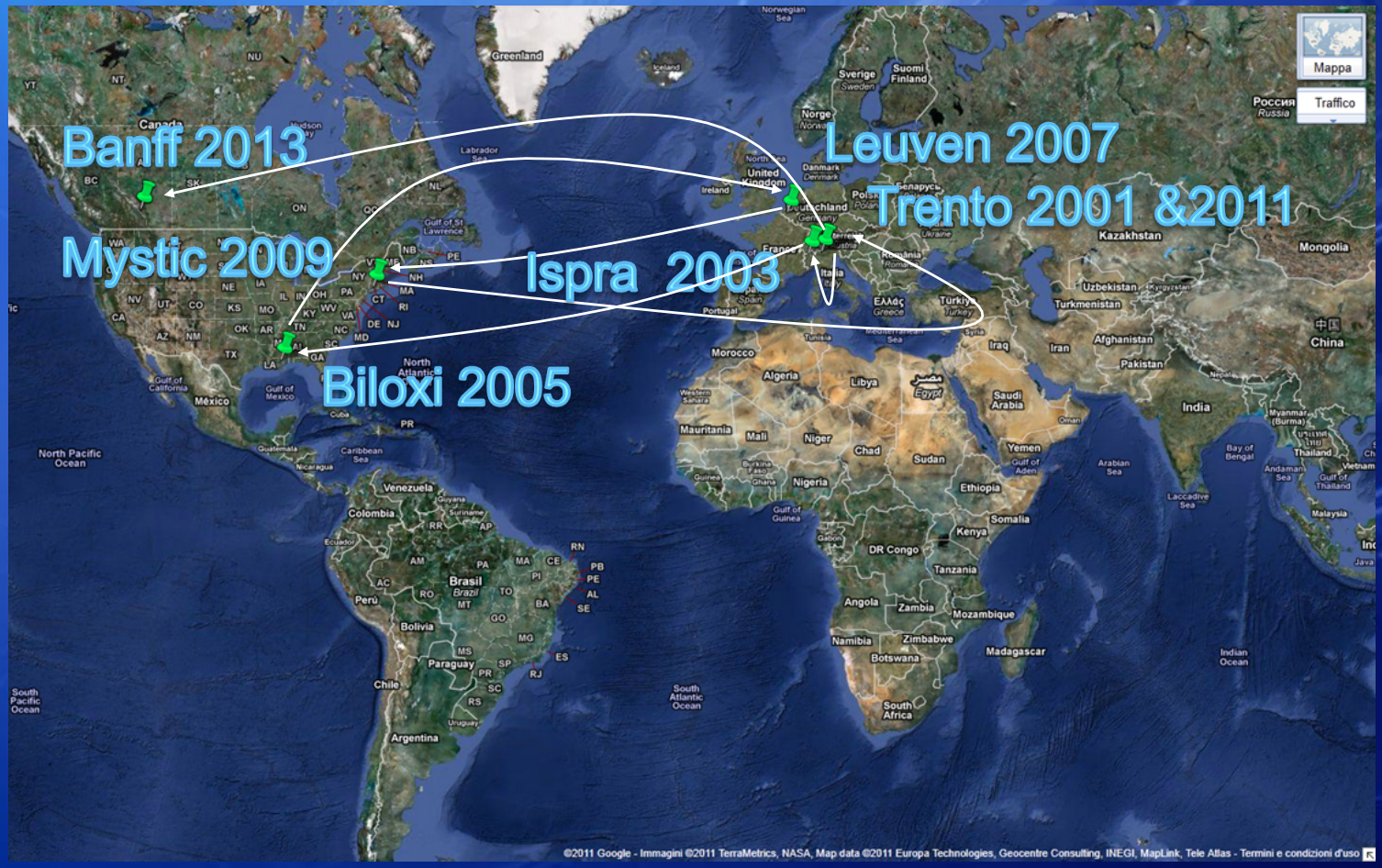
MultiTemp History



MultiTemp 2013: Banff

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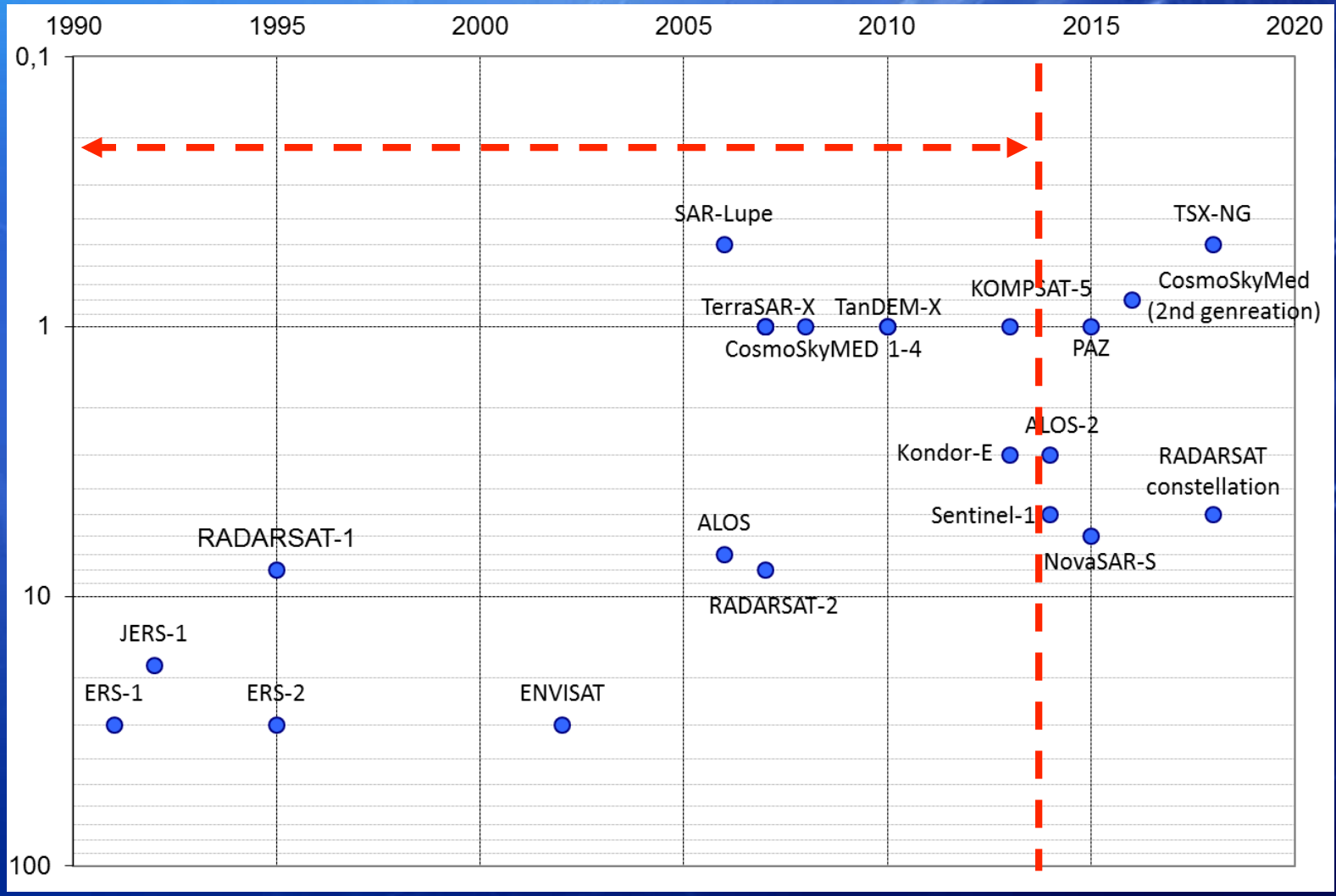
Time Variable: VHR SAR Sensors



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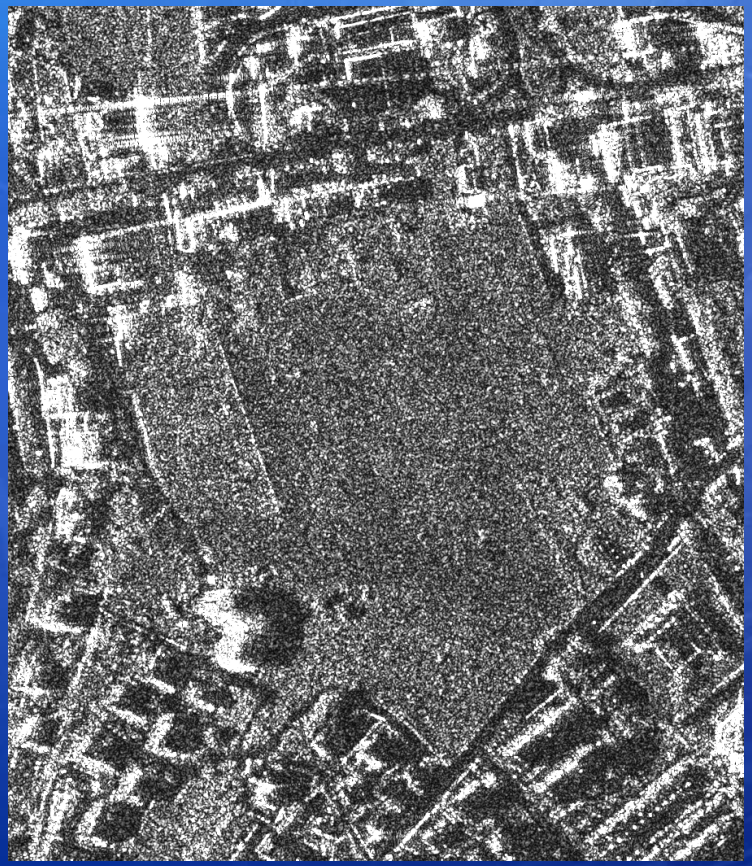
Time Variable: VHR SAR Sensors

April 2009



September 2009

Comso-Skymed SAR Images of the Earthquake of L'Aquila, Italy

COSMO-SkyMed Product – ©ASI – Agenzia Spaziale Italiana – (2010). All Rights Reserved.

Time Variable: VHR SAR Sensors

- ✓ In multitemporal SAR VHR images we have many sources of backscattering changes.
- ✓ Often backscattering changes associated with different sources exhibit characteristics similar to each other. They can be separated only by explicitly modeling the EM behavior of complex objects.
- ✓ To this end it is necessary to bridge the gap between low level features and semantic information:
  - Modelling the interaction between the EM waves and the imaged objects.
  - Extracting the different object components with proper detectors.
  - Combining object components for identifying the objects and the possible changes in their state.

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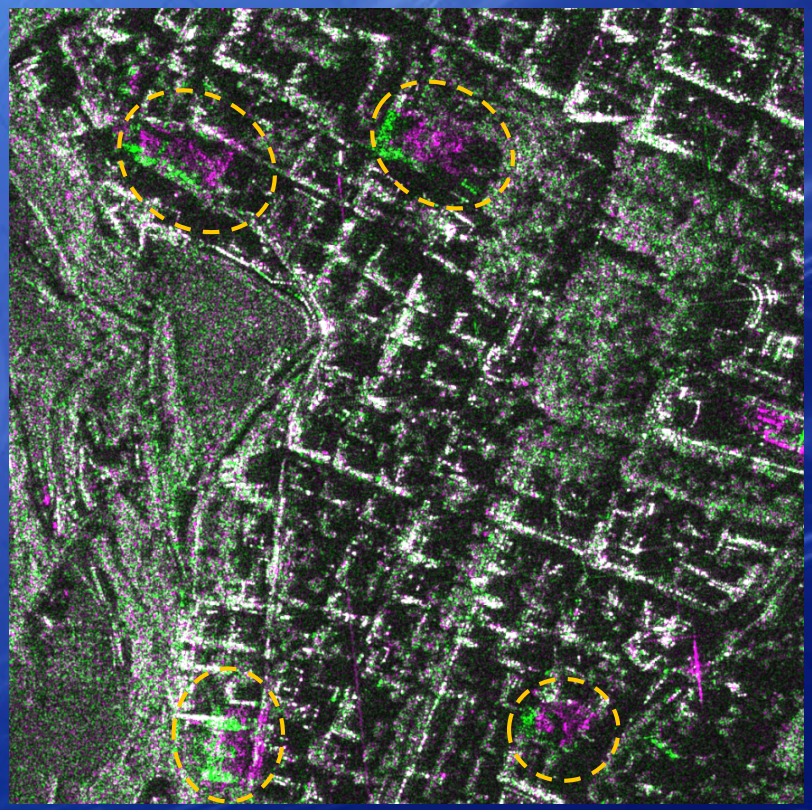
Example: L'Aquila Earthquake

Multitemporal data set: SpotLight (CSK®) images acquired before (5th April 2009) and after (21st April 2009) the earthquake of L'Aquila (Italy, 6th April 2009).

Optical image: GeoEye, Tele Atlas 2011
Google ©



RGB multitemporal composition
(R:04/21/2009, G:04/05/2009, B:04/21/2009)

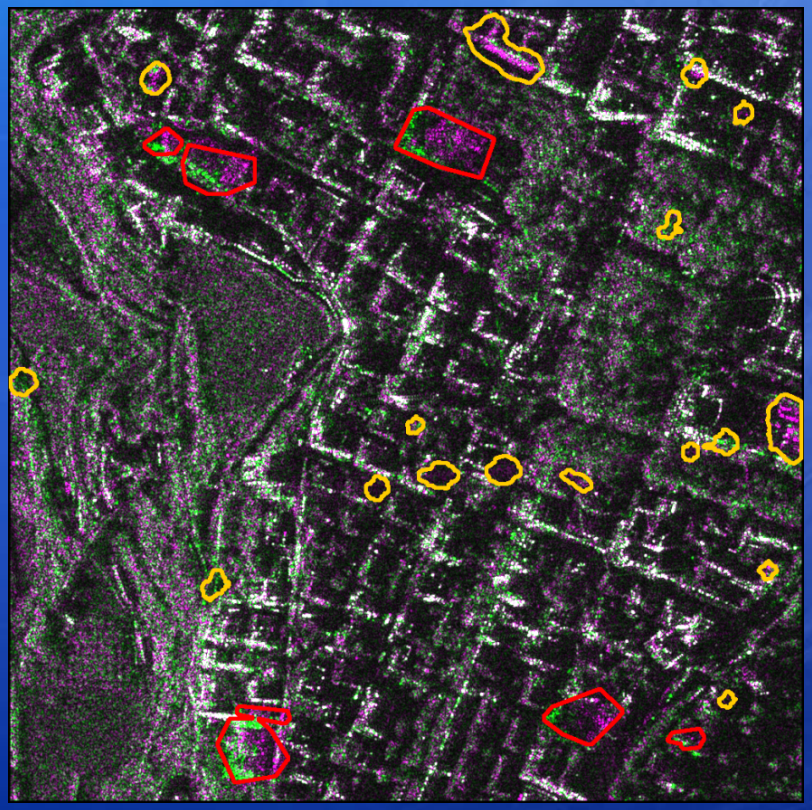
- 1m×1m resolution
- X-band
- 1-look
- Amplitude
- HH-polarization
- 57-58 degree incidence angle
- Ascending orbit
- Right look
- CSKS1
- Calibrated
- Co-registered
- Geo-referred

Backscattering decrease Backscattering increase Unchanged areas

COSMO-SkyMed Product – ©ASI – Agenzia Spaziale Italiana – (2009). All Rights Reserved.

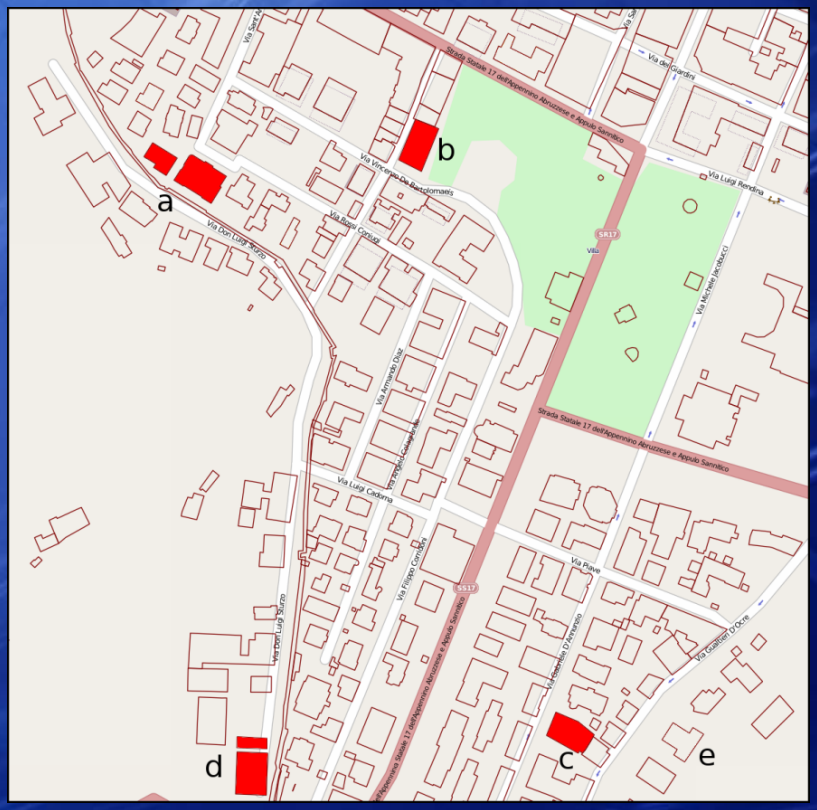
Example: L'Aquila Earthquake

Generation of the building change detection according to the output of fuzzy rules.



Overlay between RGB and the final buildings change detection map

Collapsed buildings Other changes



Ground Truth from orthophotos acquired on April 2009 by the civil protection (GeoPortale Abruzzo)

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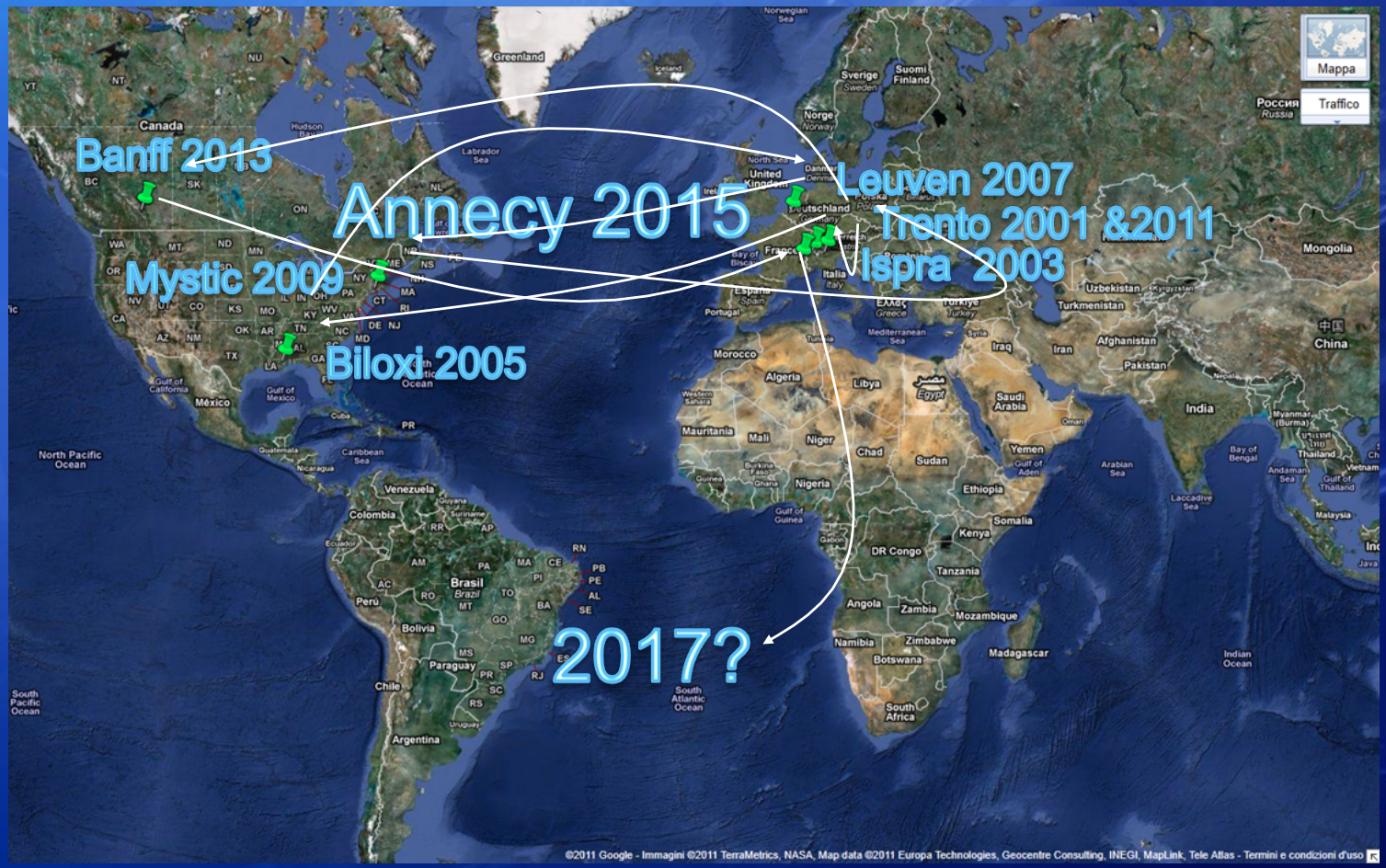
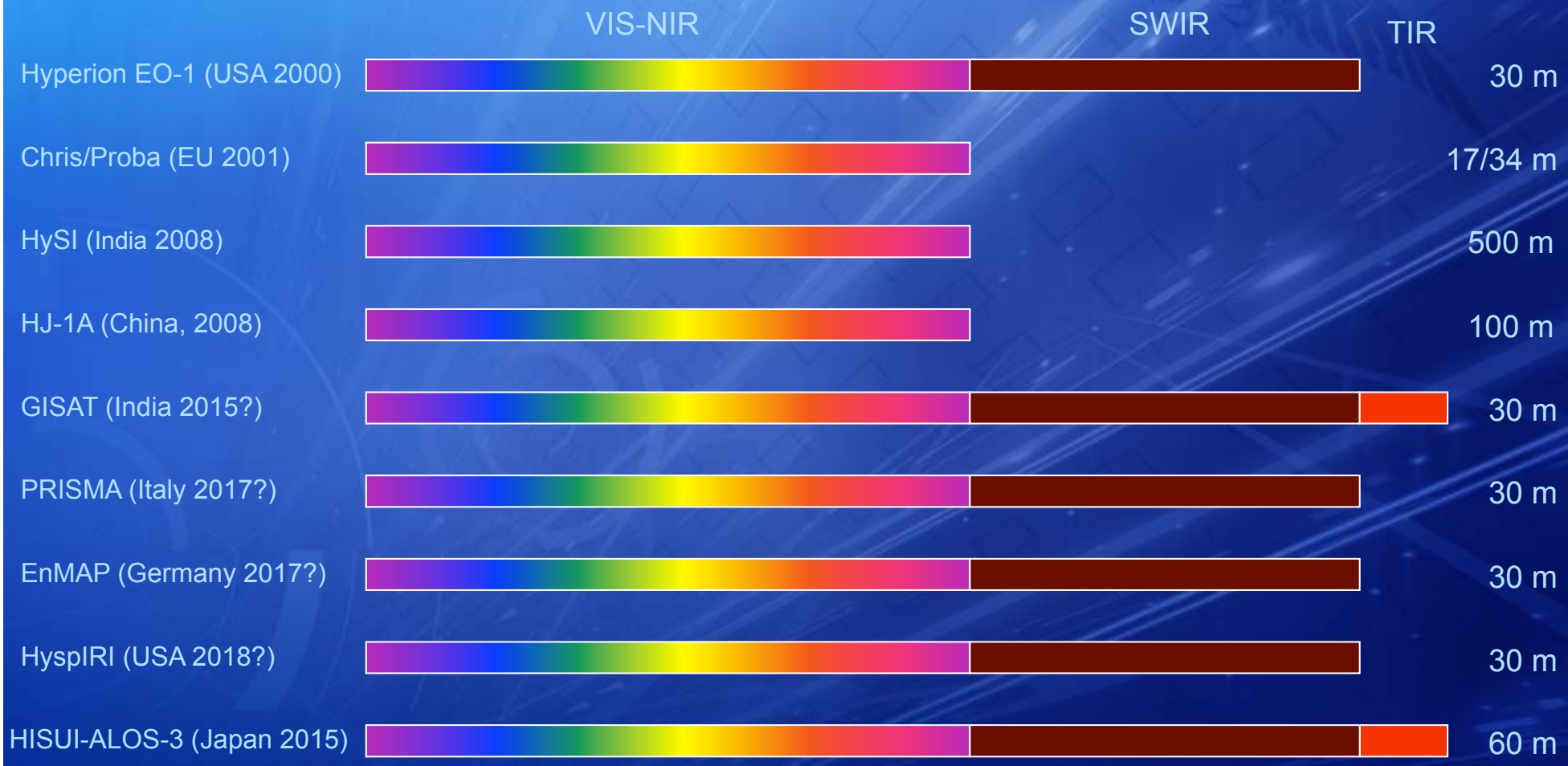
MultiTemp History



Future Challenges: Hyperspectral Images



Source of data: IEEE GRSS ISIS Technical Committee

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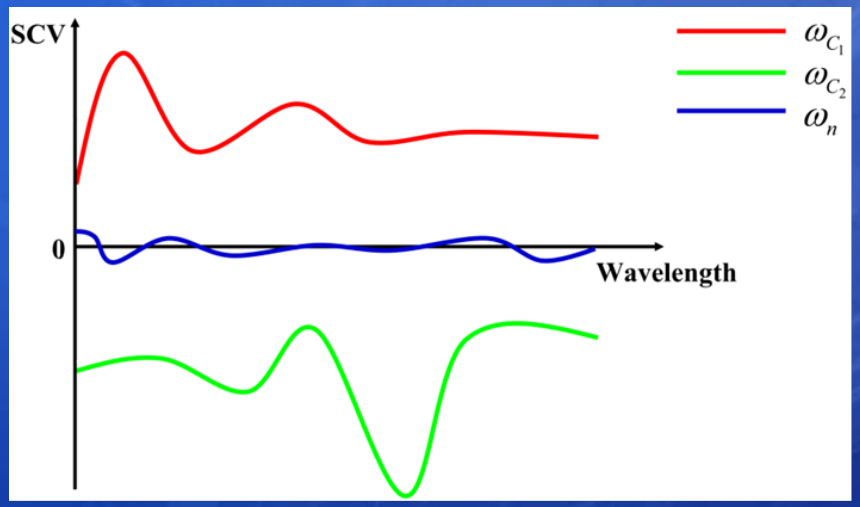
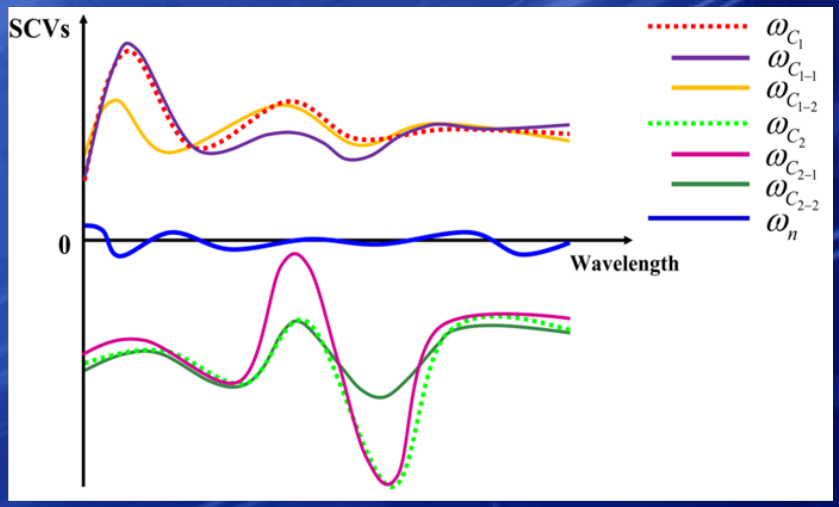
Future Challenges: Hyperspectral Images

Change detection in hyperspectral images:

- ✓ What is a change in hyperspectral images?
- ✓ How can changes of interest be isolated and extracted?



Major changes



Subtle changes

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, 2015, pp. 244 – 260.

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, 2015, pp. 4363 – 4378.

Future Challenges: Long Time Series

- ✓ Detection of spatio-temporal events on long time series.

- ✓ Exploit the large amount of freely available information of archives of image time series (e.g., Sentinel 1 and 2, Landsat) for a systematic information extraction also in few items of the time series. This can be done in different problems related to pairs of images:
  - Binary change detection;
  - Detection of land cover transitions;
  - Multitemporal classification.

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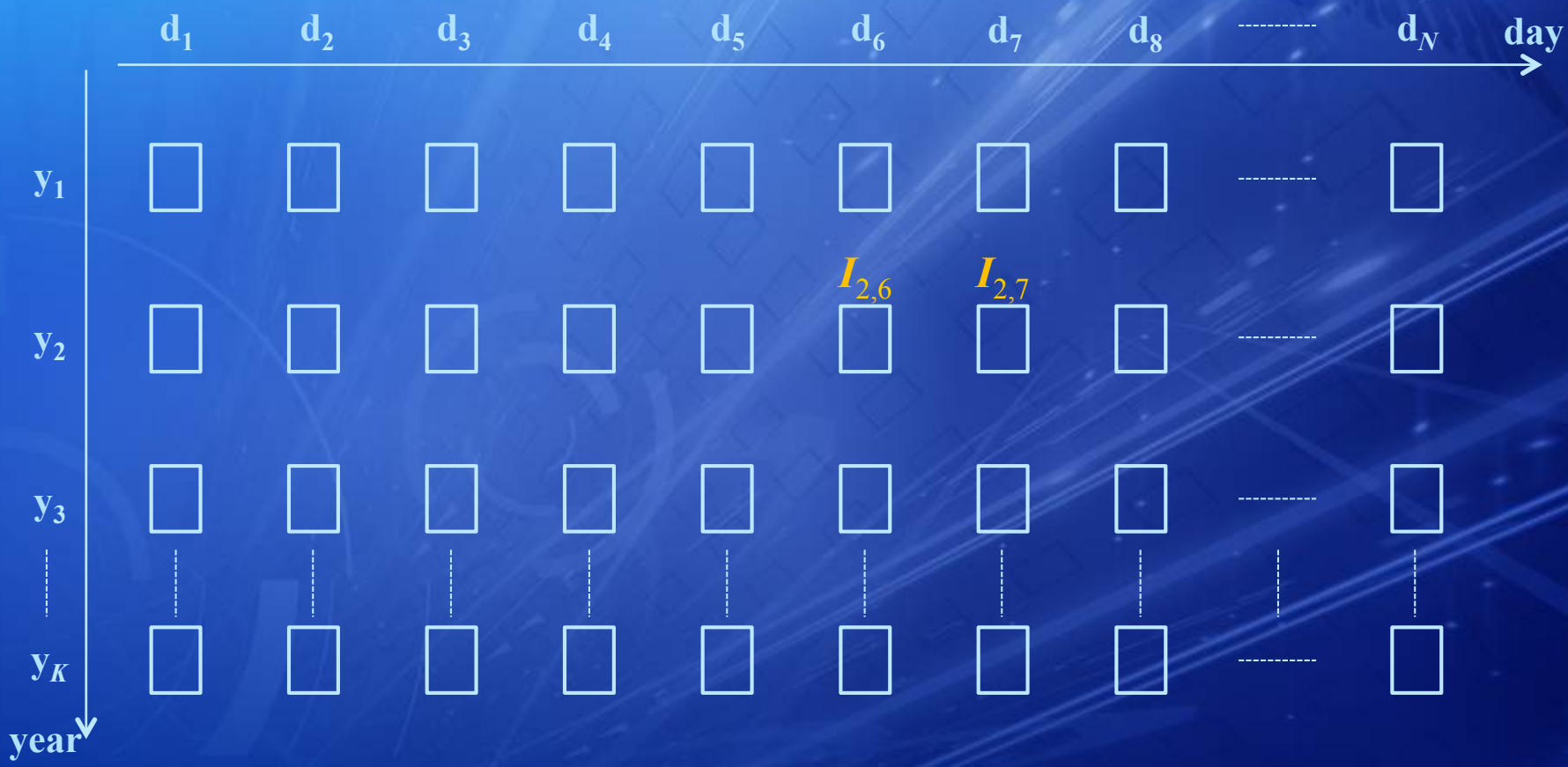
Future Challenges: Long Time Series



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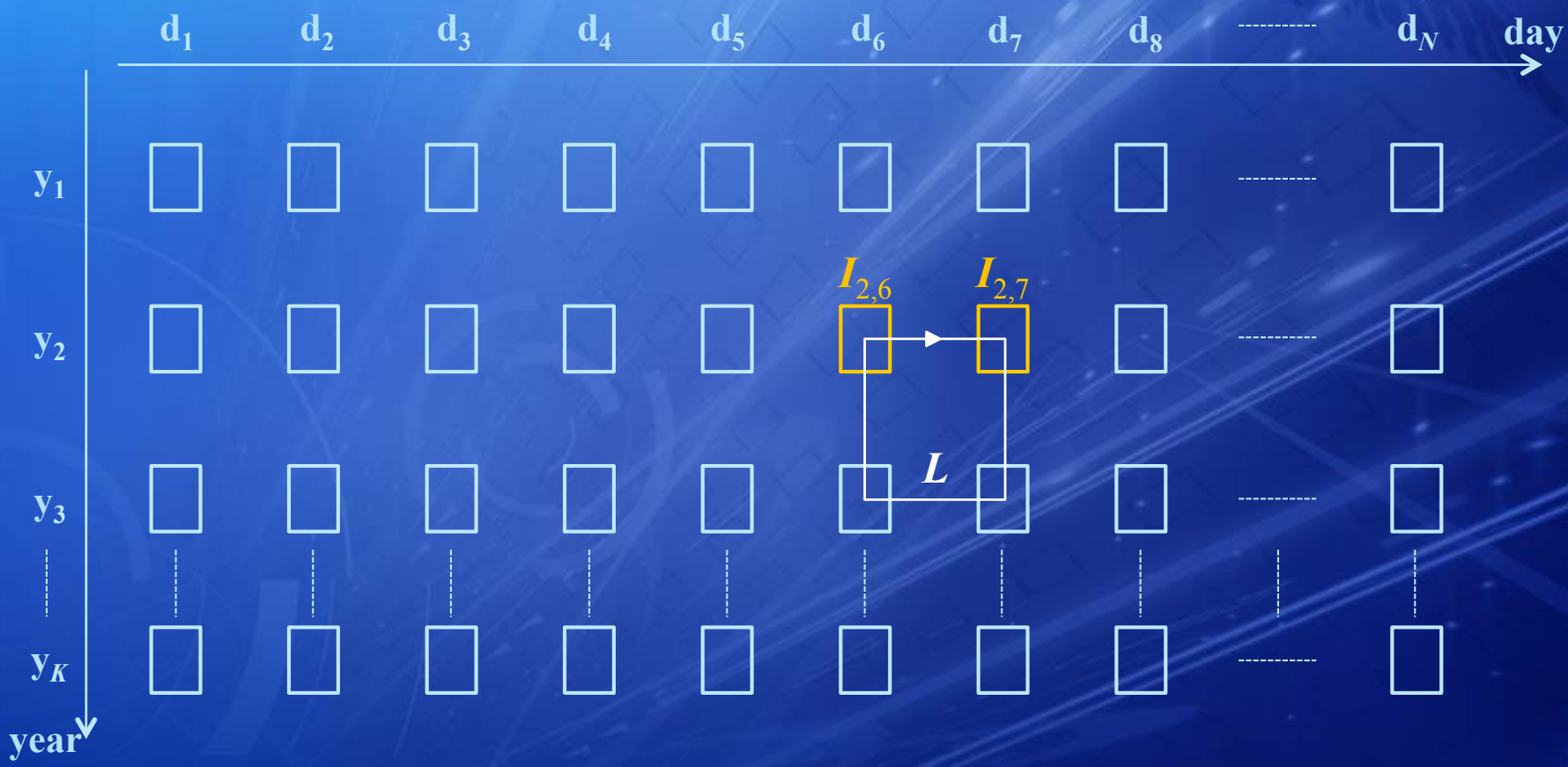
Future Challenges: Long Time Series



L. Bruzzone, F. Bovolo, "A Novel Circular Approach to Change Detection in Pair of Images Extracted from Image Time Series," IEEE 2014 Int. Geoscience and Remote Sensing Symposium, (IGARSS '14), Québec City, Québec, Canada, 13-18 July 2014.

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Conclusion

- ✓ Analysis and exploitation of time series and multitemporal images is a very important and timely topic both from the methodological and the application perspective.

- ✓ Many methodological challenges are related to the properties of new satellite data that require the development of a new generation of processing techniques for the analysis of:
  - VHR multispectral and SAR images.
  - Hyperspectral images.
  - Long time series.

- ✓ These properties open the possibility to develop also new applications that exploit either the very high geometrical (e.g. analysis of single buildings) or spectral (e.g. detection of subtle changes) resolution and the increased revisit time (e.g. monitoring and surveillance application).