Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

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Change Detection
for land cover analysis

An overview

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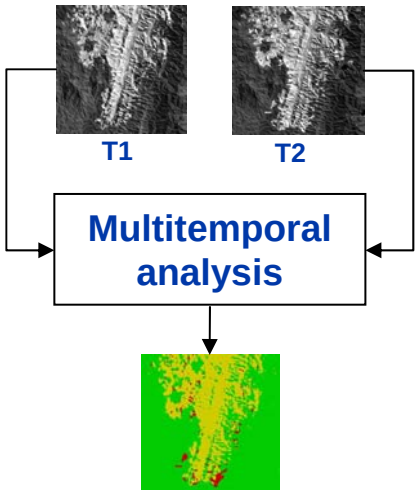
Agenda

- Overview of techniques
- Factors affecting the change detection
- Factors to consider when choosing a method
- Common choices of techniques
- Conclusion

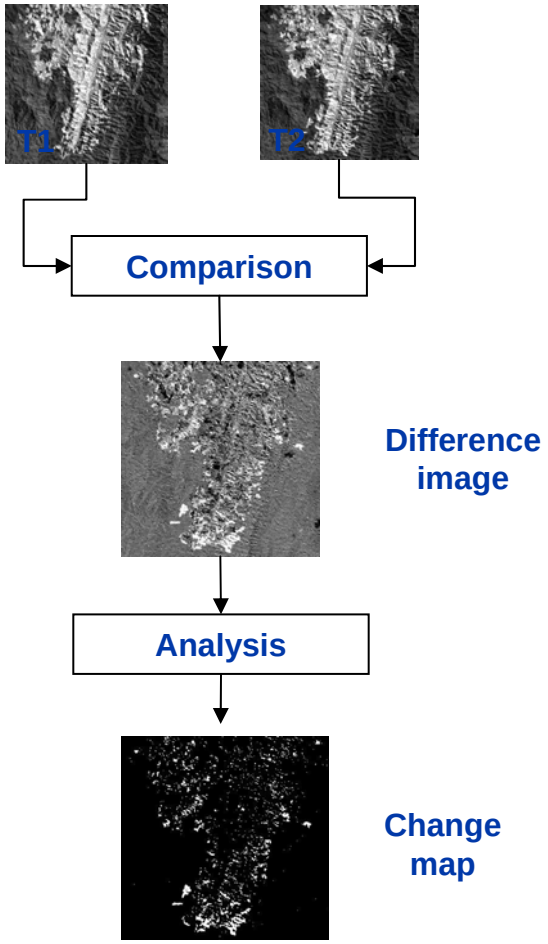
Change detection

- Two main categories of land cover changes:
  - Conversion of land cover from one category to a different category.
  - Modification of the condition of the land cover type within the same category (thinning of trees, selective cutting, pasture to cultivation, etc.)



- Two main approaches to change detection:
  - Unsupervised (no ground truth)
  - Supervised (ground truth)

Unsupervised techniques

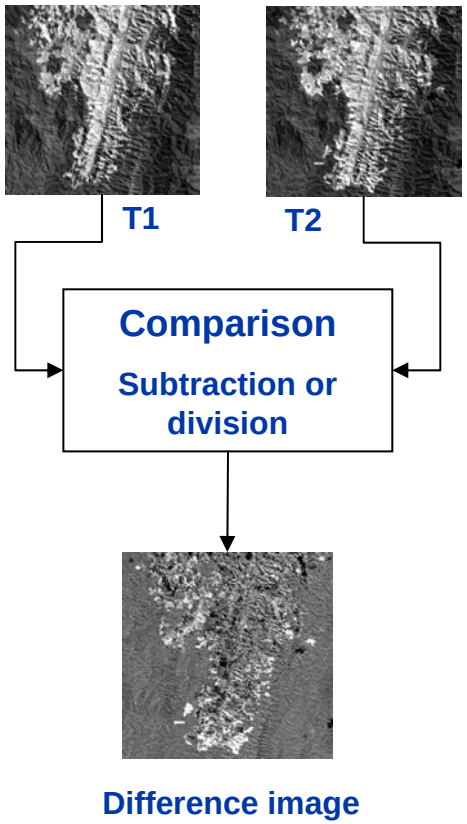


- Objective
  - Produce a change detection map in which changed areas are separated from unchanged ones.
- The changes sought are assumed to result in larger changes in radiance values than other factors.
- Comparison is performed directly on the spectral data.
- This results in a difference image which is analysed to separate insignificant from significant changes.

Unsupervised techniques

- Classes of techniques:
  - **Image math**
  - **Spectral change vectors**
  - **Transformations**
  - **Image regression**

Image math

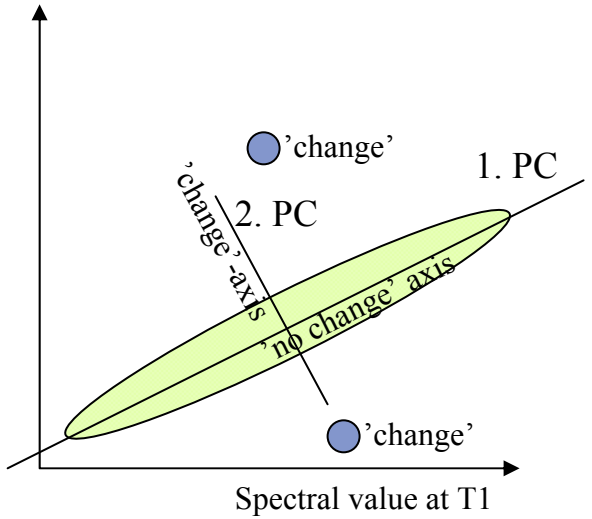


- Identifies change through computation of differences or ratios between image bands.
- Works on single bands (or derived vegetation indices).
- Produces a difference image.

- Advantage
  - Simple and fast.
- Drawback
  - Does not provide change matrix.
  - Sensitive to changes due to other factors.

Transformations

- Principal Component Analysis
- Alt1: Perform PCA on data from both dates and analyse the component images.
- Alt2: Perform PCA separately on each image and subtract the second-date PC image from that of the first date.



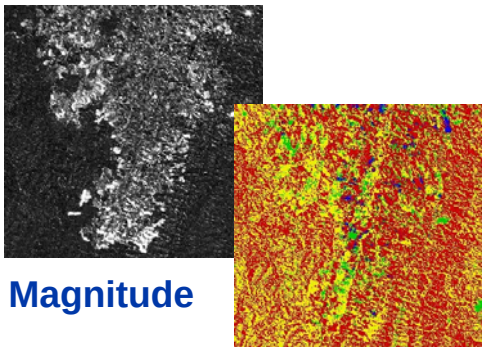
- Advantage
  - Reduces data redundancy.
- Drawback
  - Results are scene dependent and can be difficult to interpret.
  - Does not provide change matrix.

Image regression

- Relationship between pixel values of two dates is established by using a regression function.
- The dimension of the residuals is an indicator of where change occurred.

- Advantage
  - Reduces impact of atmospheric, sensor and environmental differences.
- Drawback
  - Requires development of accurate regression functions.
  - Does not provide change matrix.

Change vector analysis



- Determines in n-dimensional spectral space, the length and direction of the vector between Date 1 and Date 2.
- Produces an intensity image and a direction image of change. The direction image can be used to classify change.
- Typically used when all changes need to be investigated.

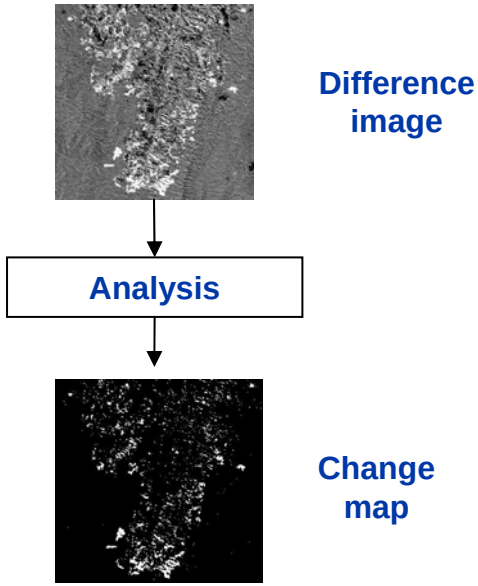
- Advantage
  - Works on multispectral data.
- Drawback
  - Shares some of the drawbacks of image math, but less severe.

Analysis of difference image

- All the unsupervised techniques produce a difference image. This image must be analysed to find the changes.

- Objective
  - Control variances caused by differences in variables that are not of interest.
  - Measure changes caused by variances in the variables of interest.

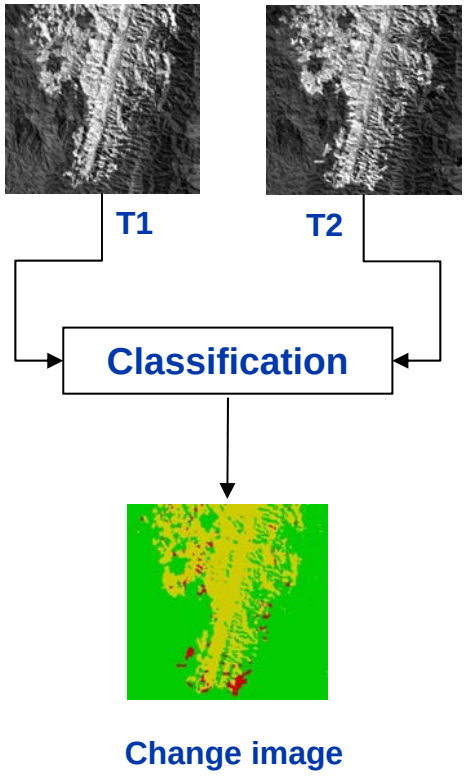
- Analysis of the difference image can be performed using:
  - Manual trial-and error.
  - Empirical thresholding techniques.
  - Bayesian decision theory.



Summary: Unsupervised change detection

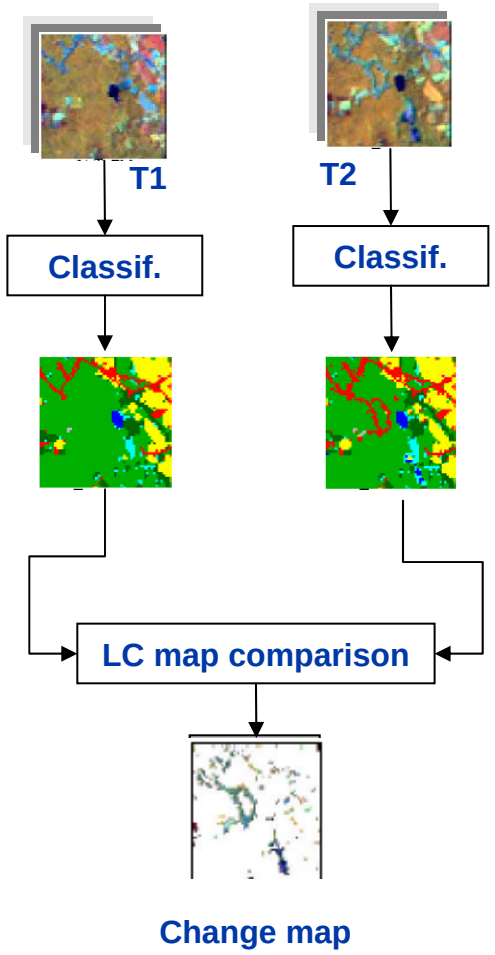
- Results in a change map in where changed areas are separated from unchanged ones.
- Can be sensitive to atmospheric effects, sensor differences etc.
- All techniques result in a difference image that require interpretation.
- Image math is simple, but easily affected by other effects.
- Transformations can be difficult to interpret.
- Image regression reduces impact of other effects, but requires development of accurate regression functions.
- Change vector analysis allows for multispectral change detection.

Supervised techniques



- Objective
  - Generate a change detection map where changed areas are identified and the land-cover transition type can be identified.
- The changes are detected and labelled using supervised classification approaches.
- Main techniques:
  - Post-classification comparison
  - Multidate direct classification

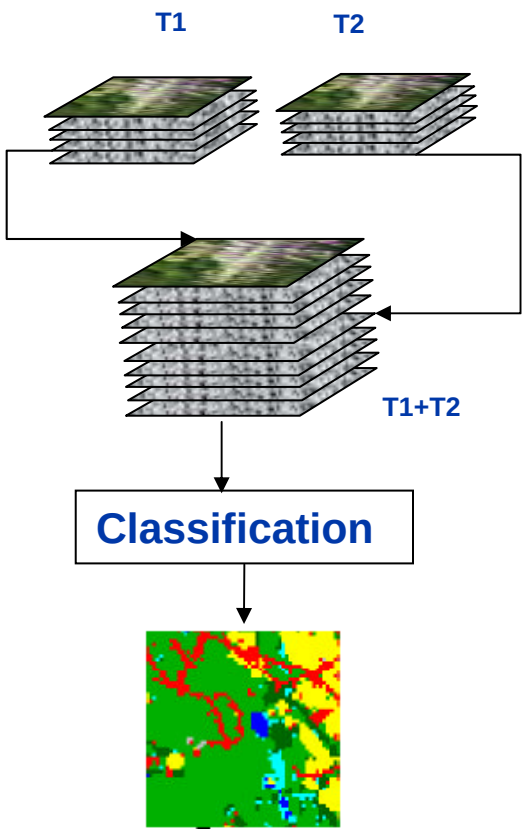
Post classification comparison



- Standard supervised classifiers are used to classify the two images independently.
- Changes are detected by comparing the two classified images.

- Advantage
  - Common and intuitive.
  - Provides change matrix.
- Drawback
  - Critically depends on the accuracy of the classification maps. Accuracy close to the product of the two results.
  - Does not exploit the dependence between the information from the two points in time.

Multidate direct classification



- Two dates are combined into one multitemporal image and classified.
- Performs joint classification of the two images by using a stacked feature vector.
- Change detection is performed by considering each transition as a class, and training the classifier to recognize all classes and all transitions.

- Advantage
  - Exploits the multitemporal information.
  - Error rate not cumulative.
  - Provides change matrix.
- Drawback
  - Ground truth required also for transitions.

Summary: Supervised change detection

- Explicit labelling of landcover transitions is obtained.
- Requires training data.
- Does not need to normalize the multitemporal images for atmospheric conditions, sensor differences etc.
- The (widely used) post-classification technique suffers from the fact that independent errors in the two classifications results in a decrease in accuracy.
- Multi-date direct classification is an effective method, but requires ground truth which is rarely available.

Supervised vs. Unsupervised

	Supervised	Unsupervised
Level of change detection	**Change detection at decision level.**	**Change detection at data level.**
Change information	**Provides explicit labelling of change and class transitions.**	**Separates 'change' from 'no change'.**
Change computation	**Obtained directly from the classified images.**	**Obtained through interpretation of the difference image.**
Ground truth	**Requires ground truth.**	**Requires no ground truth.**
Spectral information.	**Multispectral.**	**Most methods work on one spectral band.**
Data requirements	**Not sensitive to atmospheric conditions and sensor differences.**	**Sensitive to atmospheric conditions and sensor differences.**

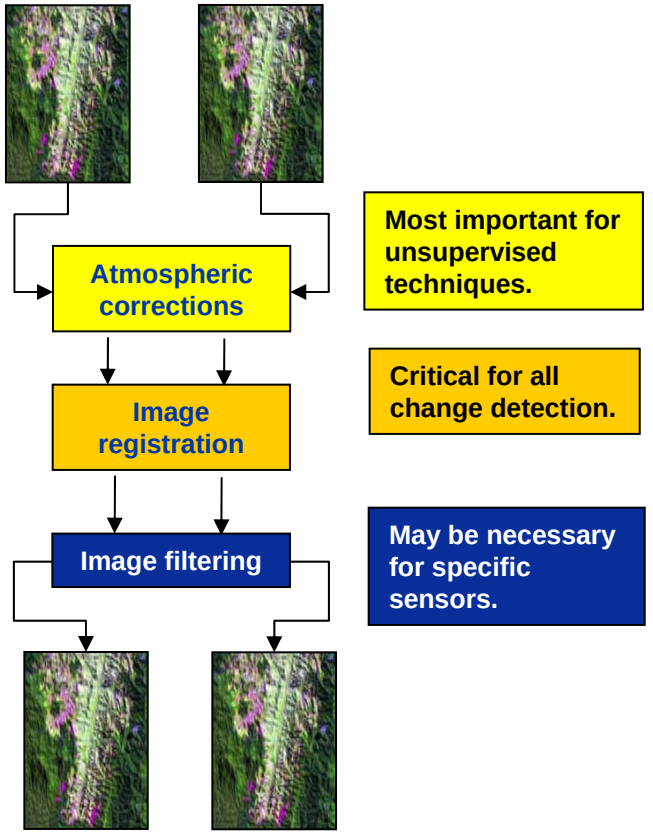
Factors affecting the change detection

- Ideal situation:
  - Precise registration.
  - Precise radiometric and atmospheric calibration/normalization.
  - Similar phenological states.
  - Same spatial and spectral resolution.

- In practice this can not be fully satisfied and this will affect the change detection.

Data selection/Preprocessing

- Data selection
  - For unsupervised approaches use images from comparable phenological dates.
- Image registration
  - Critical in all change detection
  - Perfect alignment difficult, some noise will often appear.
  - Approaches for reducing these effects have been proposed.
- Atmospheric correction
  - Unnecessary for supervised approaches.
  - Can be omitted for unsupervised approaches if the signal from changes studied can be separated from those caused by other factors.

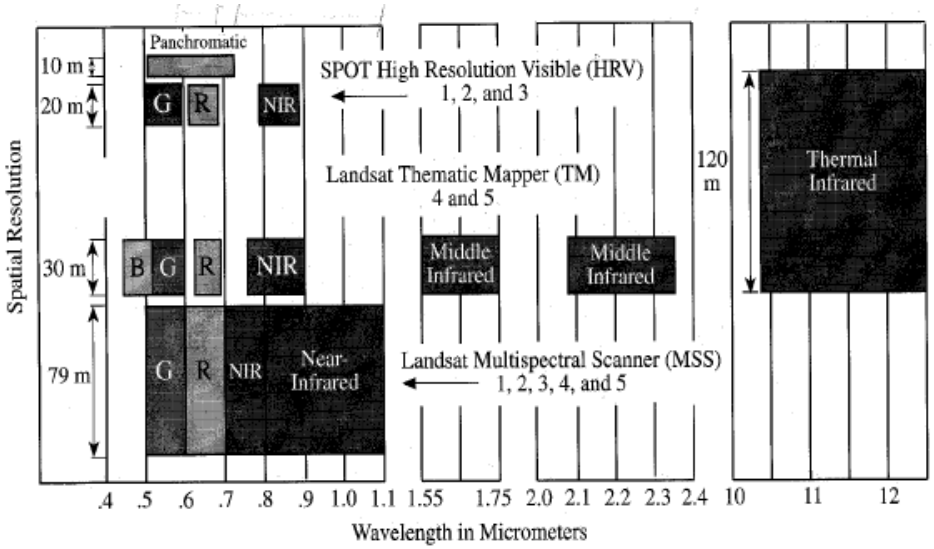


Multi-source

- In practice, acquiring the same sensor data in multi-temporal format is difficult, and data from different sensors have to be used.
- Mixing data types is a problem with change detection. The assumption that similar land covers look the same in both images will be invalid.
- Different spatial resolution can also be a problem as a given land cover is not necessarily seen in the same way at different resolutions.

Multi-source

- If the data are of a comparable nature, change detection can be determined at the data level (unsupervised approaches).



- When comparing very heterogeneous datasets, the change detection must generally be performed at decision level (supervised approaches).
- Application of multi-source data will become increasingly important, and more advanced techniques are needed.

Factors to consider when choosing a method

- Objective of the change detection?
  - Monitor/identify specific changes
  - More efficient mapping at T2
  - Improved quality of mapping at T2
- What type of change information to extract?
  - Spectral changes
  - Land cover transitions
  - Shape changes
  - Changes in long temporal series
- What type of changes to be considered?
  - Land use and land cover change
  - Forest and vegetation change
  - Wetland change
  - Urban change
  - Environmental change

Factors to consider…

- Expected amount of changes
- Available data at date 1 and date 2
  - Remote sensing data
    - Temporal, spatial and spectral characteristics.
    - Differences in characteristics btw. date 1 and date 2.
  - Classified maps
  - Ground truth
- Environmental considerations
  - Atmospheric conditions
  - Soil moisture conditions
  - Phenological states
- Accuracy requirements

Common choices of techniques

- A large number of change detection applications exist and different change detection techniques have been used.
- The most common techniques for change detection are:
  - Image differencing, PCA, CVA, Post-classification comparison.
- There is still no conclusions on which method is best suited for a specific application.
- Because of this different methods are often tested, and previous research has shown that a combination of two techniques can often improve the results.
- A parallel implementation of several change detection methods followed by an integration of the results may be the most effective way to detect change in a wide range of environments.

Conclusion

- Problem to be solved, available data and environmental factors must be considered when choosing an approach.
- There is no one best technique, a combination may be an alternative.
- If ground truth is not available, unsupervised techniques must be used.
- If data to be compared come from very different sources, supervised techniques must be used.
- Application of multi-source data will become increasingly important, and more advanced techniques are needed.