Pattern recognition techniques for time series

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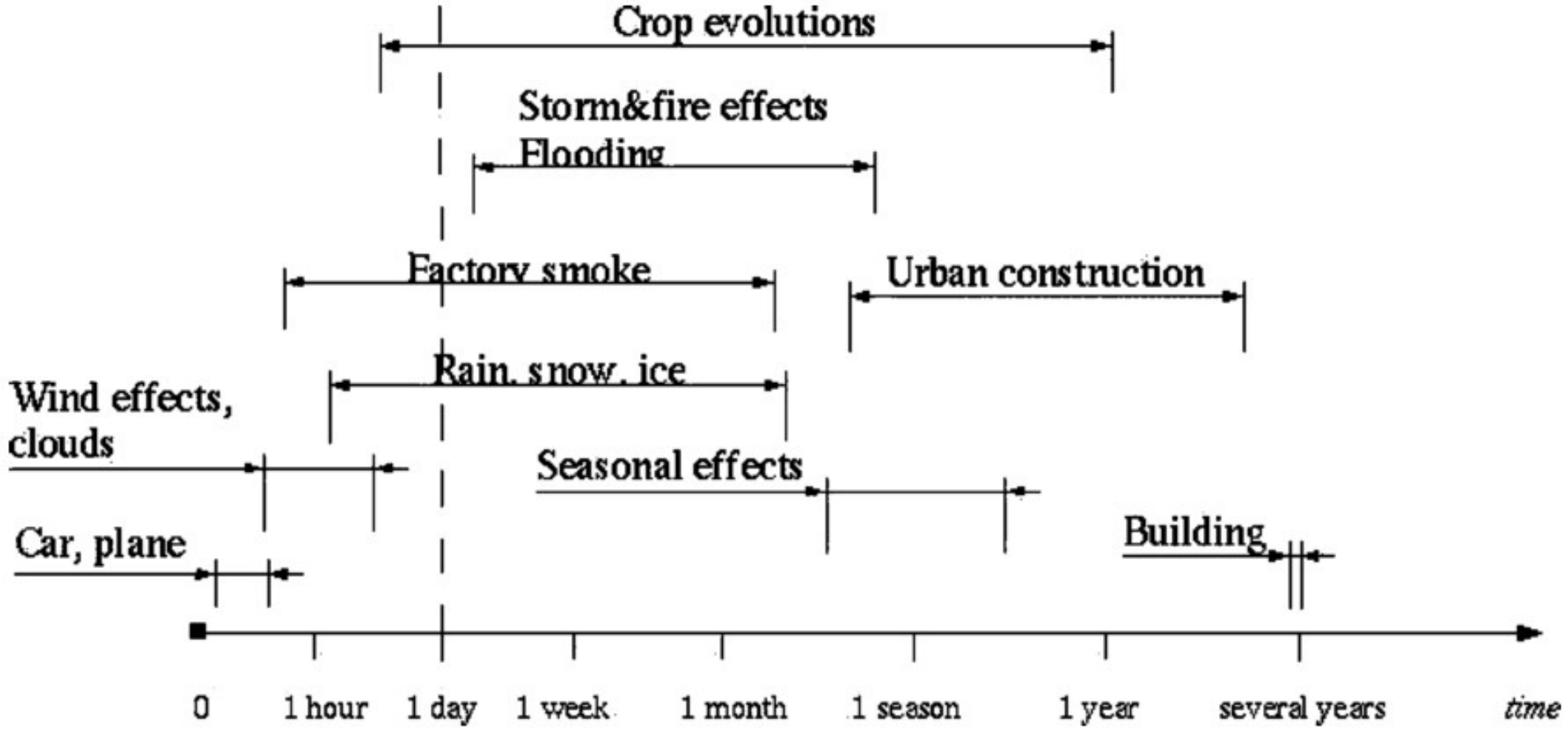
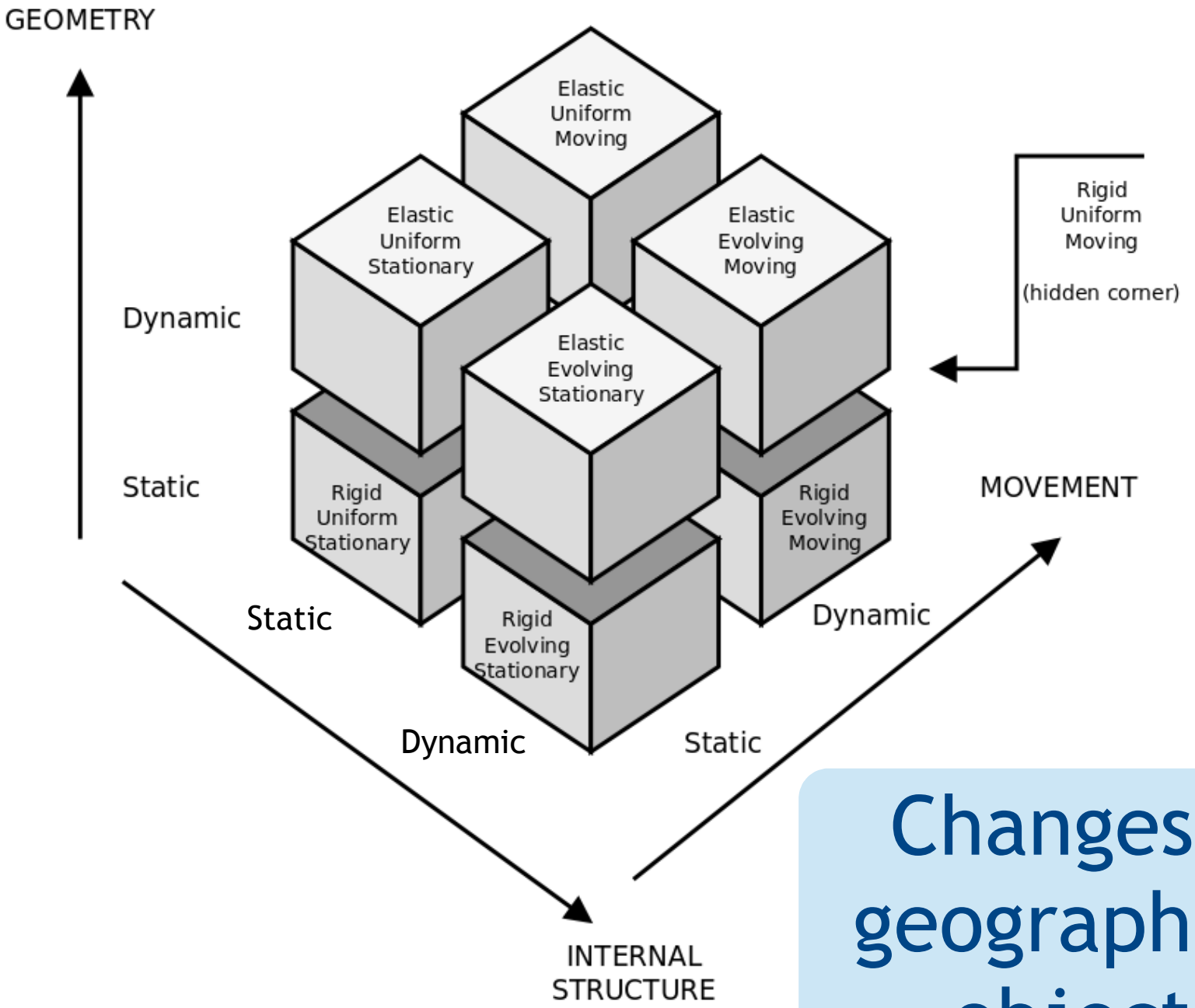
The Earth is constantly changing.

Changes in different time-scales

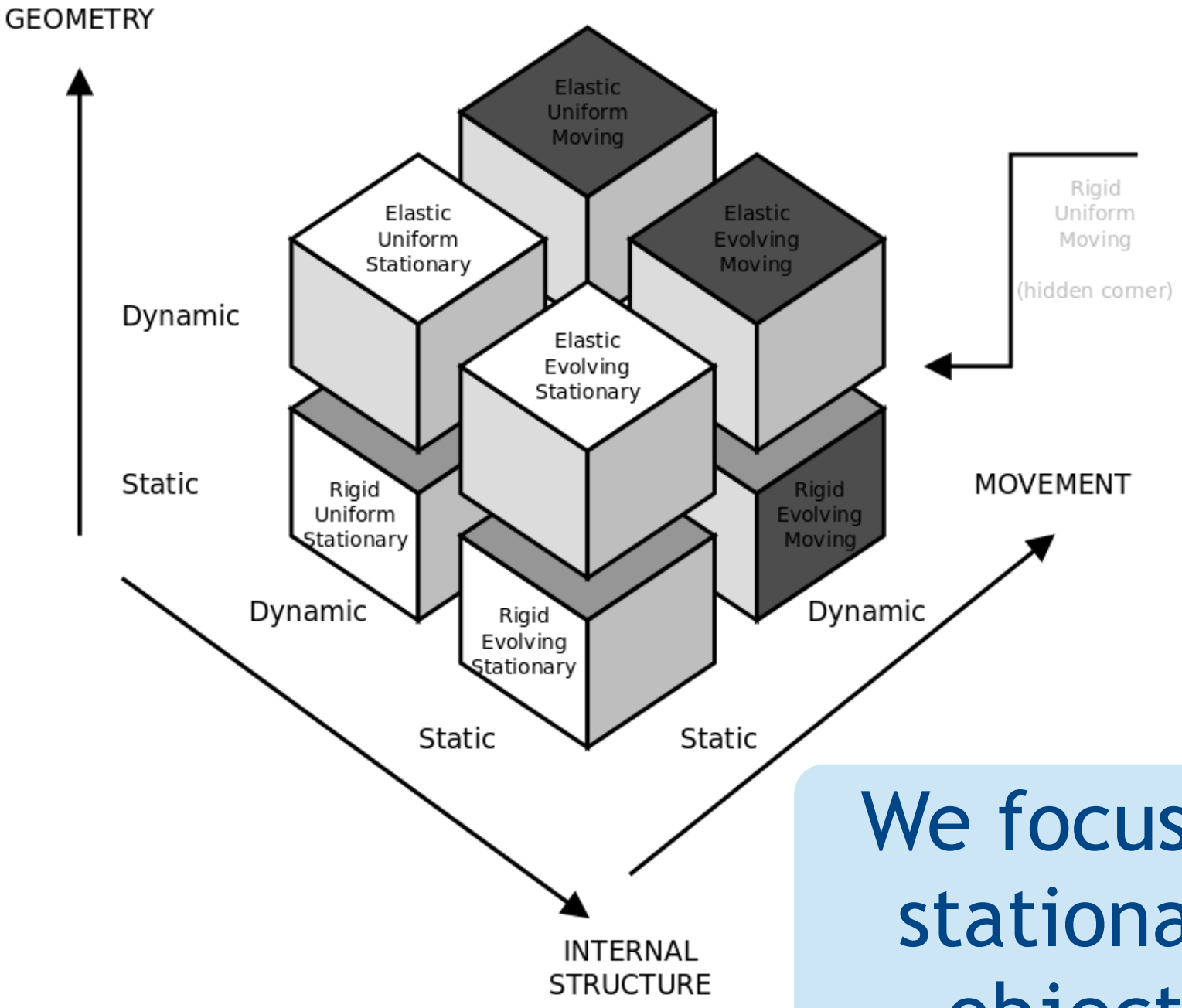


(Heas, 2005)



Changes in geographical objects

(Goodchild, 2007)

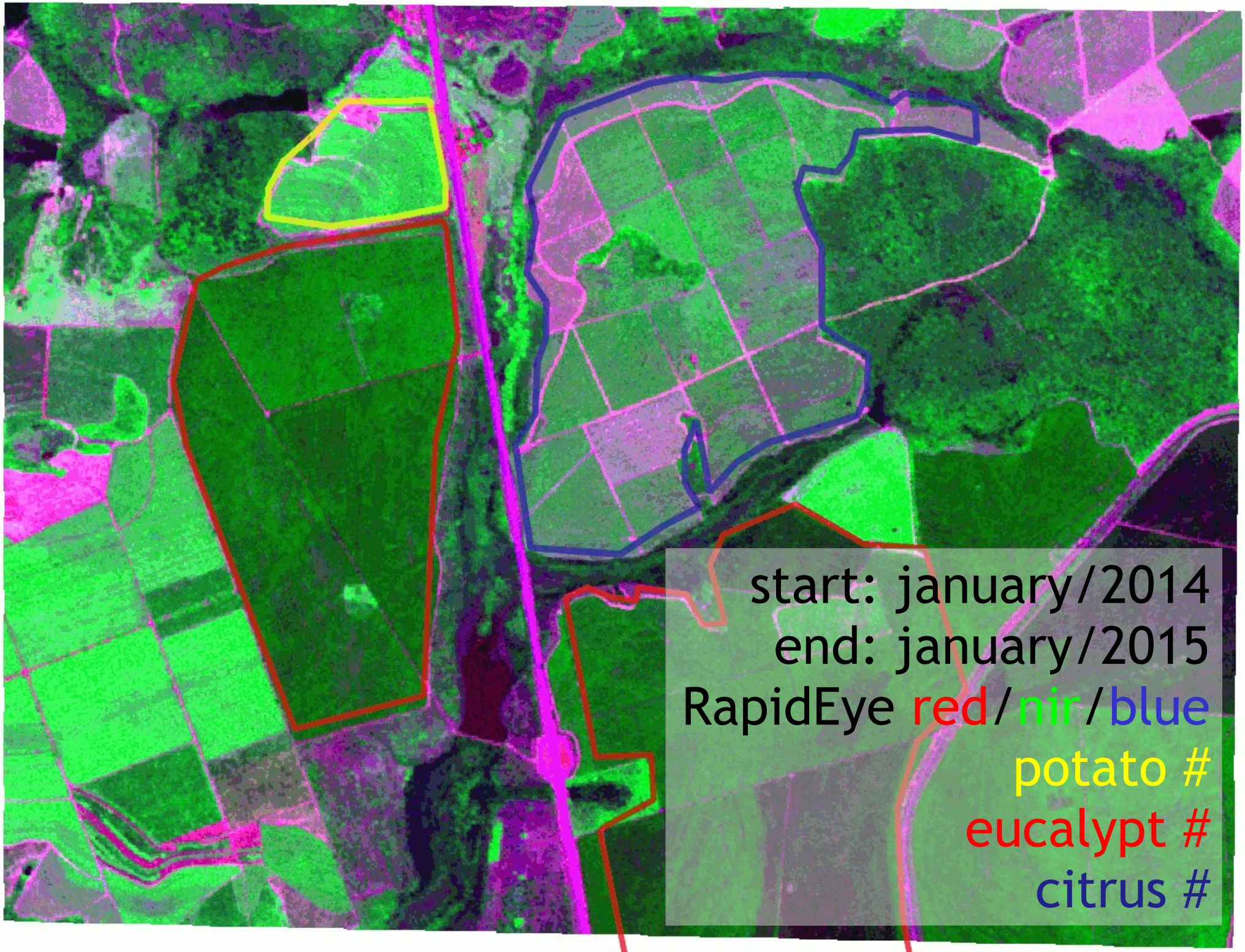


We focus on stationary objects

(Goodchild, 2007)

How to model changing patterns in land use/cover?

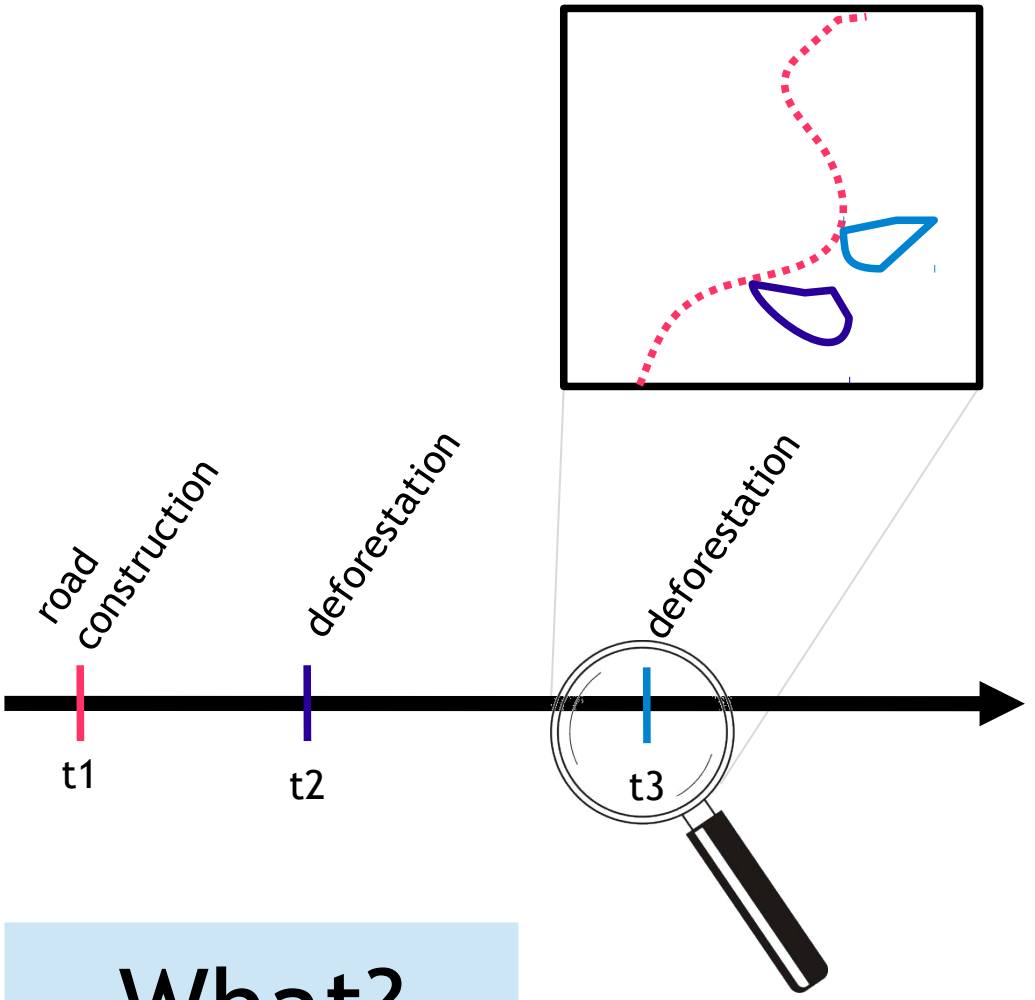
SITS - Satellite Image Time Series


start: january/2014
end: january/2015
RapidEye red/nir/blue
potato #
eucalypt #
citrus #

SITS

Detect changes

What?
When?
Where?



What attributes that best describe changing patterns?

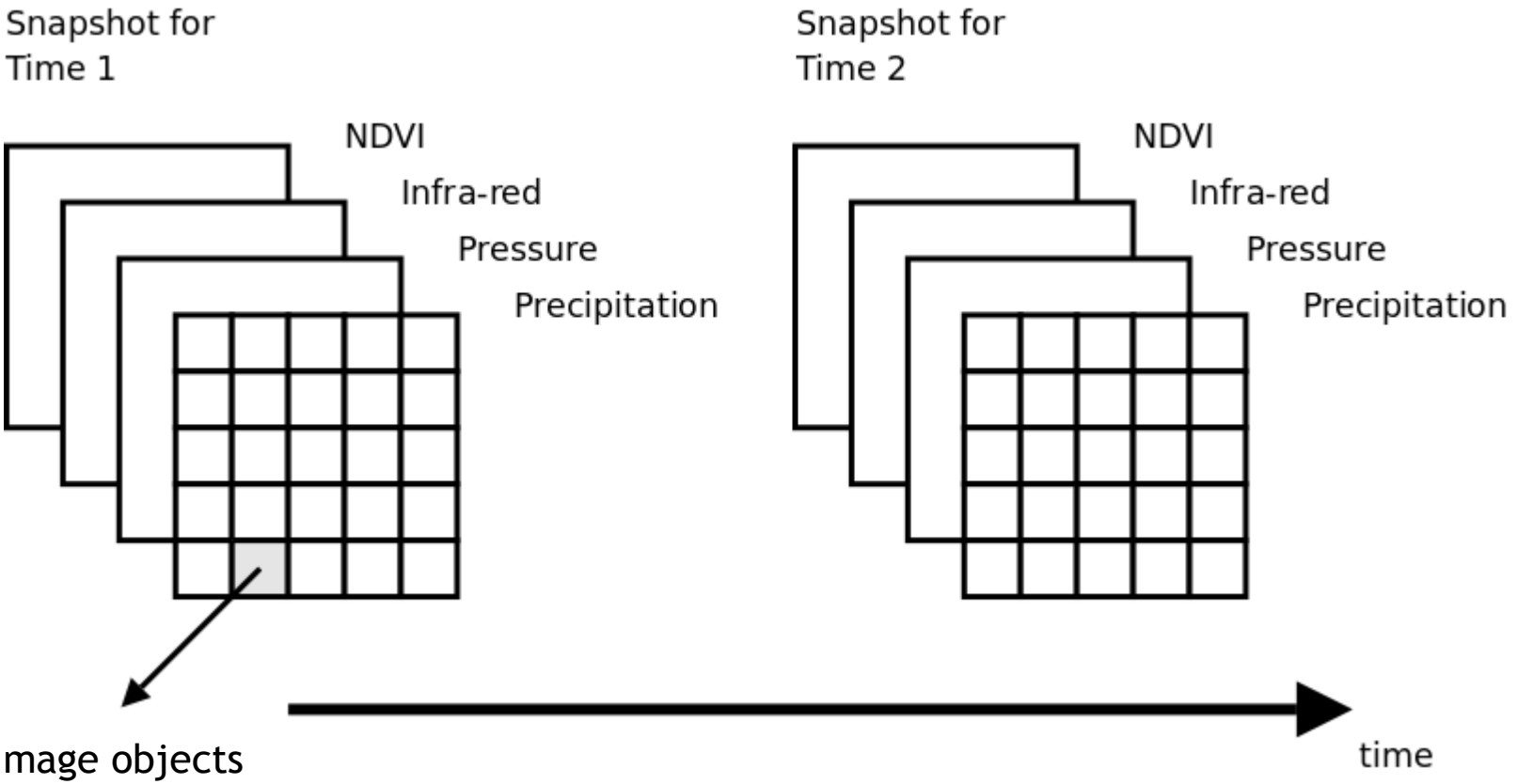
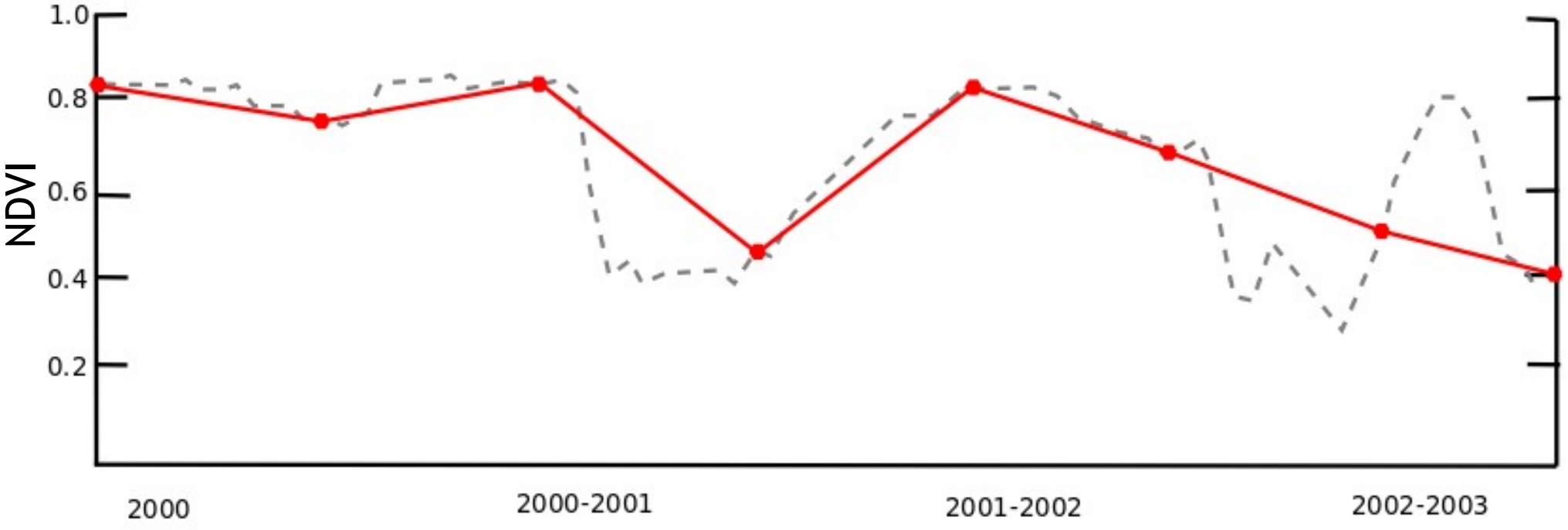


Image objects

- Pixels
- Cells
- Regions

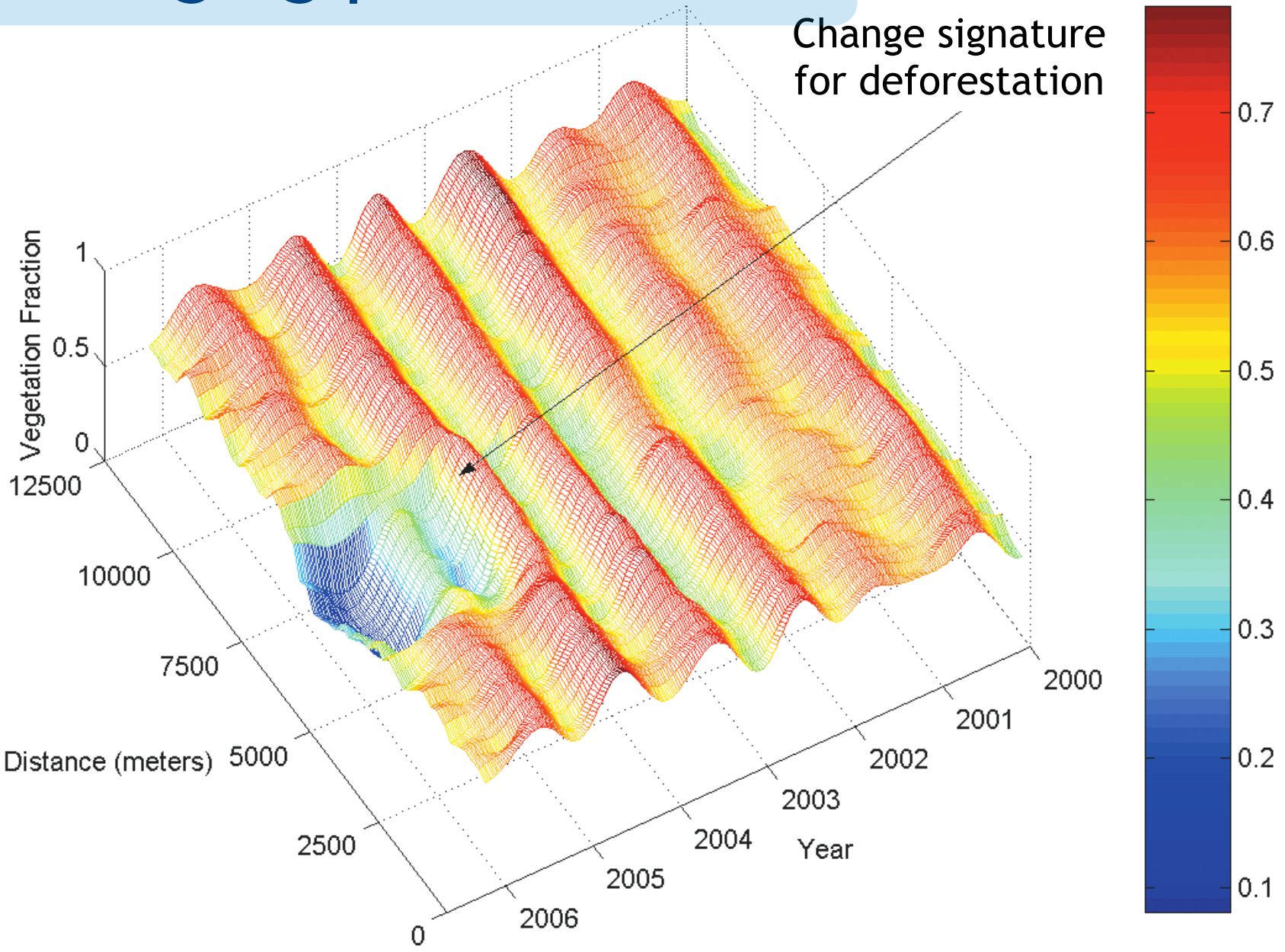
(Kumar, 2001)

Variations in image attributes define trajectories in time



≠ Temporal resolutions

Similar trajectories of change define changing patterns



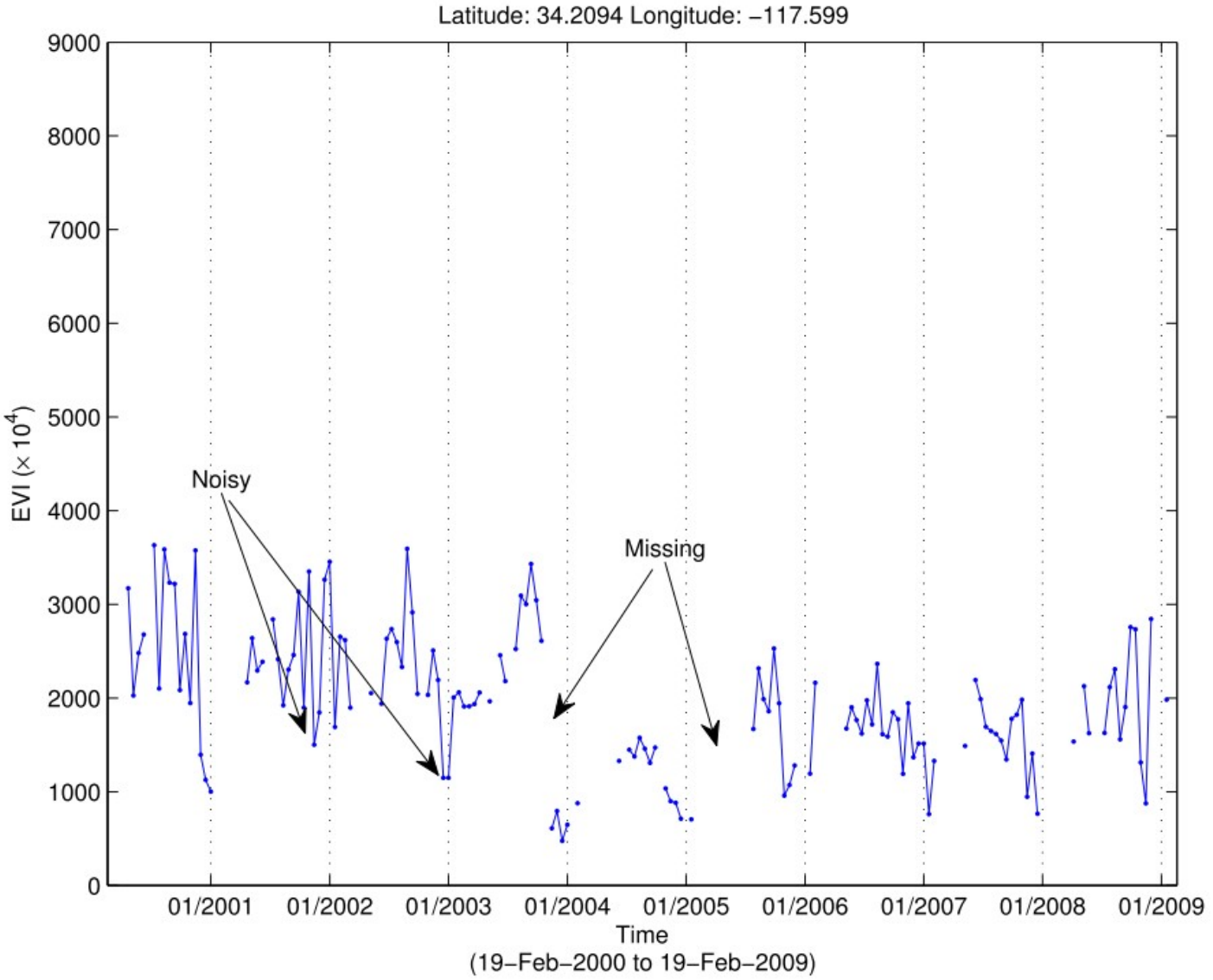
(Freitas, 2008)

Change Detection Challenges

- Massive data size
- High degree of geographic/inter-region variation
- Noisy/missing data
- Disparate land cover types
- Wide variety of changes that can occur

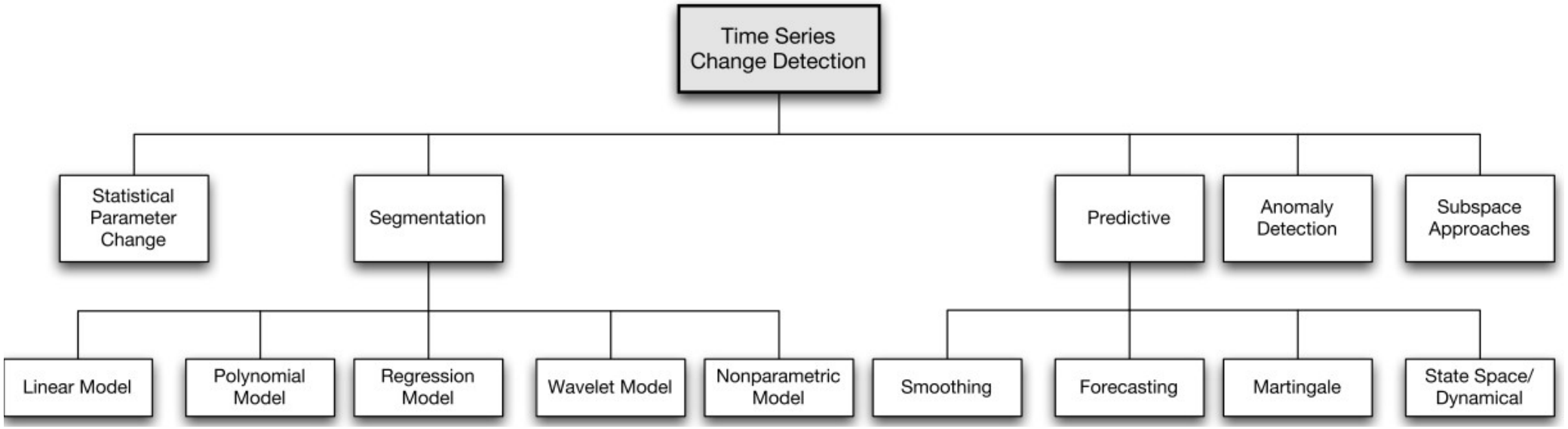
(Boriah, 2010)

Common Problem



Example of time series (BDC)

Taxonomy for change detection



(Boriah, 2010)

Statistical Parameter Change

- Data follows a parametric distribution
- Methods detect points where a distribution parameter change
- Estimate the value of the parameters before and after the change

Change detection using MODIS

- Begins by computing annual sums, and differences between consecutive years
- Resulting differences are assumed to follow normal distribution ($\mu = 0$, no change)
- The z-score of the difference of annual sums is computed
- If the z-score is above a threshold τ,a change is considered to have occurred between t1 and t2

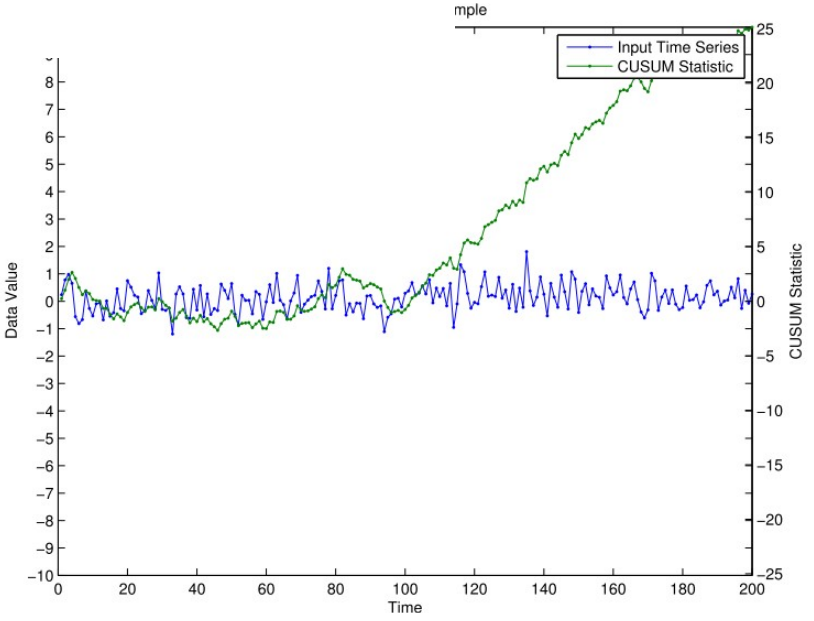
(Lunetta, 2006)

Revision - Cummulative Sum

- Given a time series $\{t_1, t_2, \ldots\}$ and the in-control mean μ, the statistic is defined as

$$CS_k = \sum_{i=0}^{\kappa} (t_i - \mu).$$

The basic algorithm sets μ to an apriori known value, or to the first value t_1 of the time series



(Page, 1954)

Segmentation

- Partition the input time series into homogeneous segments
- When successive segments are not homogenous, there is a change point between them

Recursive Merging

- A given time series can be partitioned into homogeneous segments
- Boundaries between segments are changes
- Two most similar consecutive annual cycles are merged until one annual cycle is left remaining
- Change score for this location is based on the dimension of the observed cycle distances

(Boriah, 2010)

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(Boriah, 2010)

Predictive

- Methods are based on the assumption that one can learn a model for a portion of the input time series
- Change is detected based on deviation from the model

Yearly Delta

- Looks for discrepant sequences in relation to a model of previous observations in the time series
  1. Build an initial projection model based on a short window at the beginning of the time series
  2. Compare subsequent windows to the model's
  3. Grow the model by incorporating subsequent values

(Fang, 2006)

Yearly Delta

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(Fang, 2006)

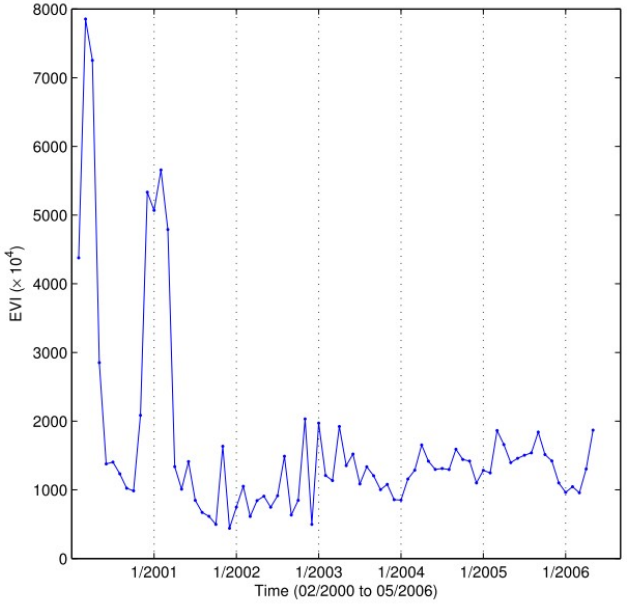
Anomaly Detection

- Methods find regions of a time series that are significantly different from the rest of the time series
- Anomaly detection is looking for a temporary departure from normal

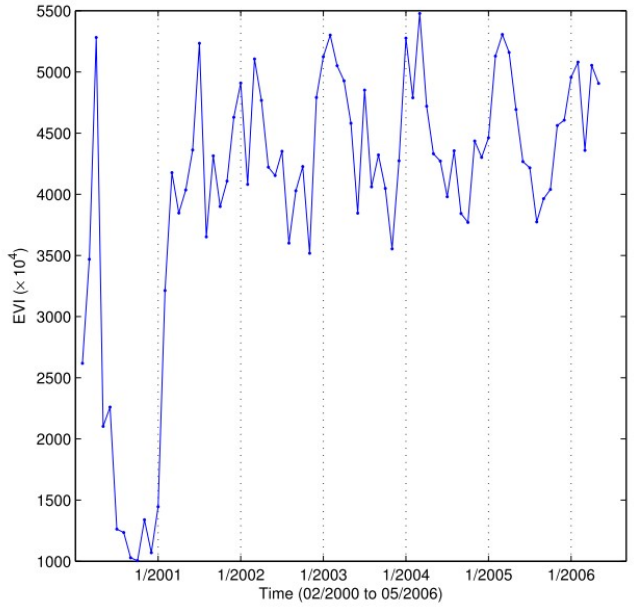
Subspace

- Methods encode the input time series into a matrix structure
- Employ spectral methods (e.g. PCA) and look for changes in the matrix structure

Applications

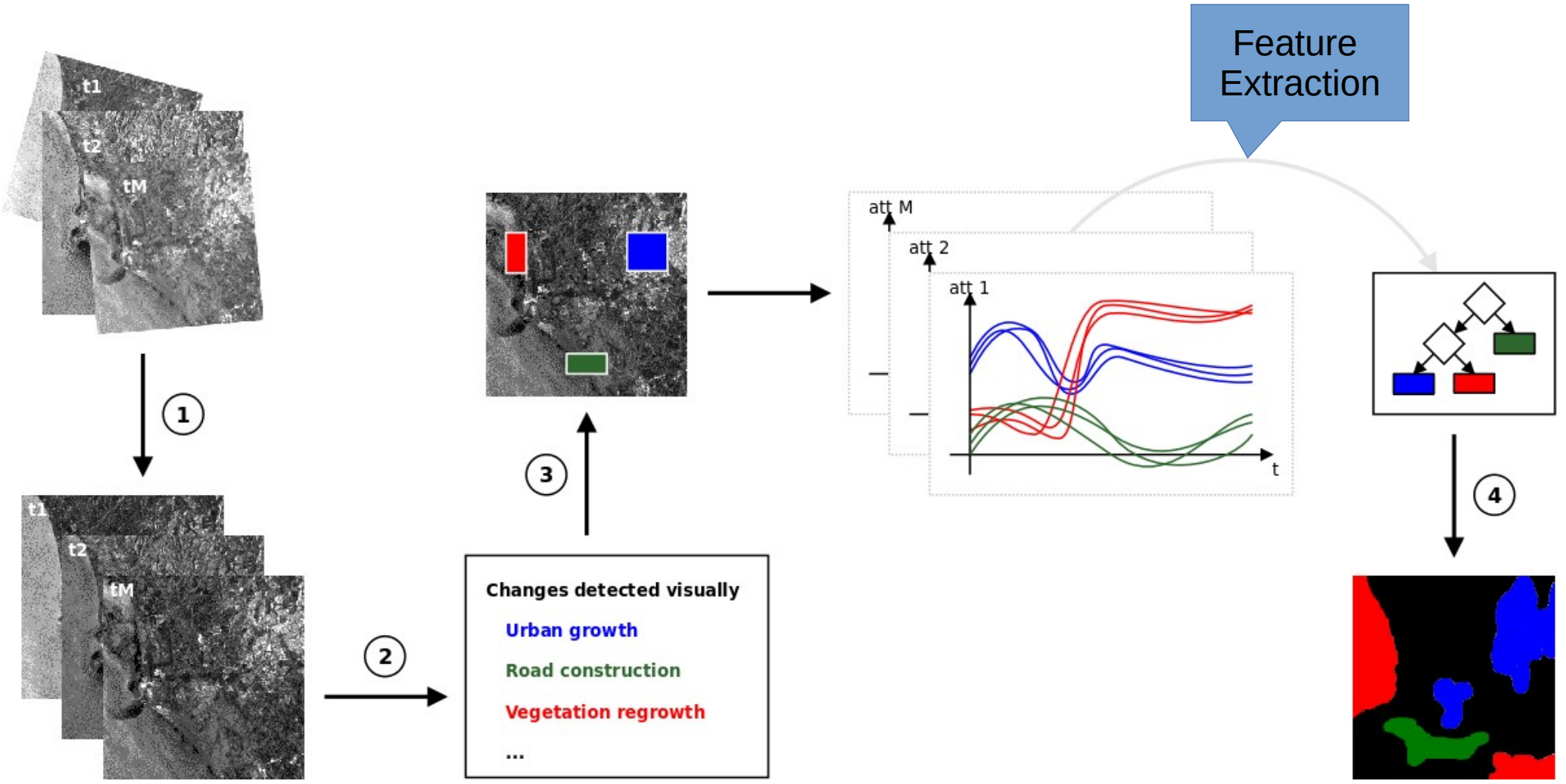


Source: Google Maps.



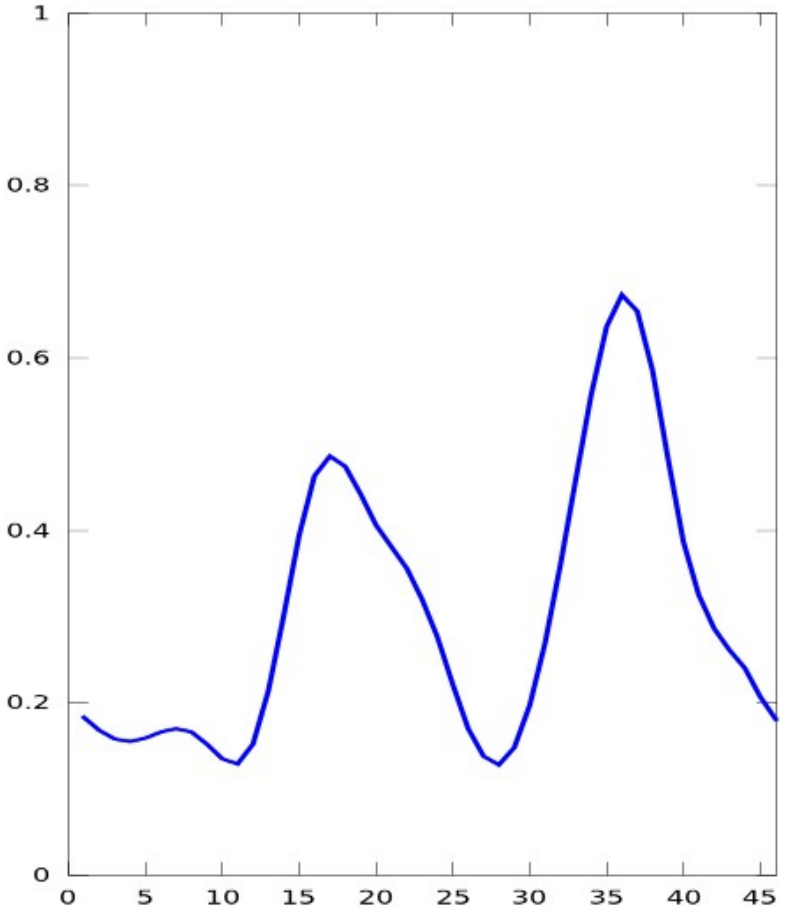
Source: Google Maps.

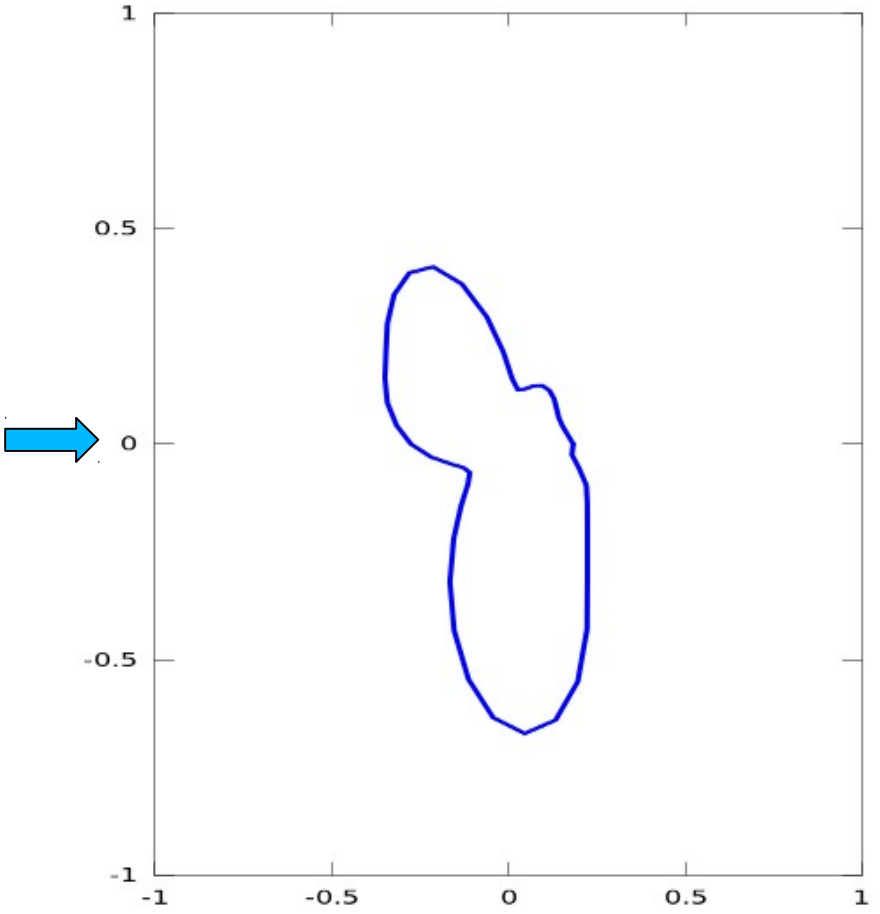
Classification scheme for RS



Slides: 46 to 47

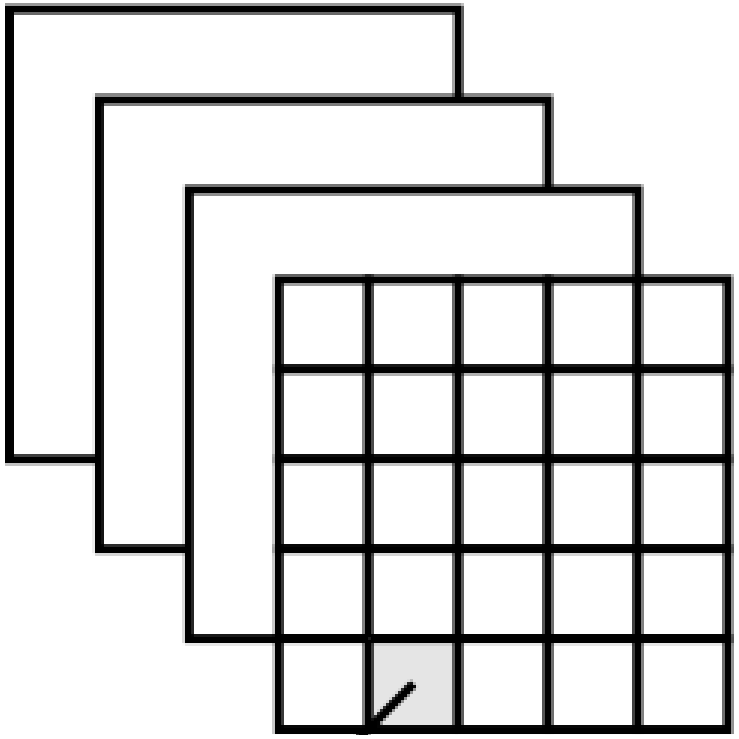
Using Polar Coordinates





Slides: 37 to 45
76 to 96

Time series data reduction

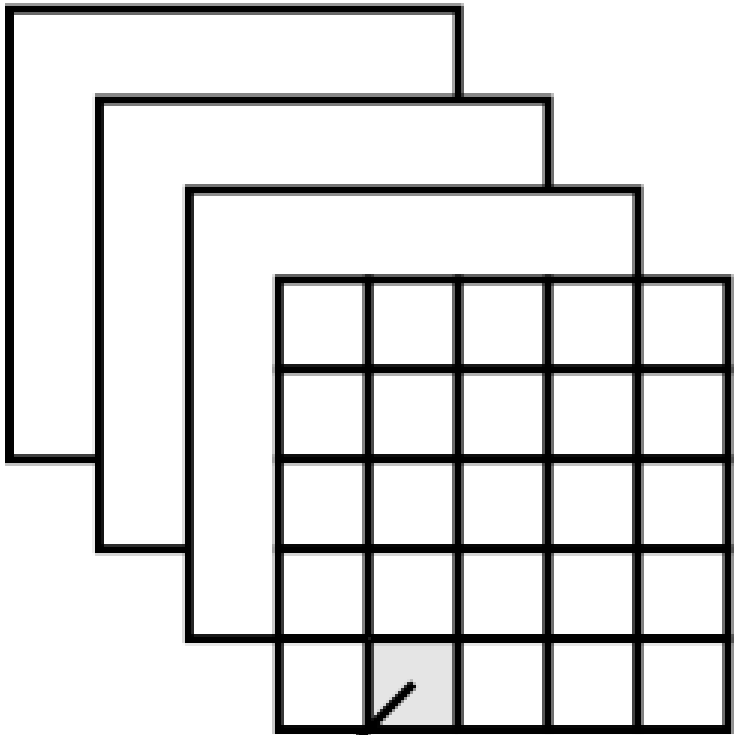


5000x5000 pixels
Spatial resolution 250m
Temporal resolution 15 days

24 images/year

600 million objects

Time series data reduction



Multitemporal segmentation

Average area of 2000 pixels

300 thousands objects

0.05% of 600 million

References

Goodchild, 1997. Towards a general theory of geographic representation in GIS.

Langran, 1998. A framework for temporal geographic information.

Kumar, 2001. Mining scientific data: Discovery of patterns in the global climate system.

Heas, 2005. Modeling trajectory of dynamic clusters in image time-series for spatio-temporal reasoning.

Freitas, 2008. Combining wavelets and linear spectral mixture model for MODIS satellite sensor time-series analysis.

Câmara, 2009. Earth Observation Information and Decision Making: An ongoing story.

DEGRAD, 2009. Available from: http://www.obt.inpe.br/degrad/.

Boriah, 2010. Time Series Change Detection: Algorithms for Land Cover Change. PhD Thesis.

Lunetta et al., 2006. Land-cover change detection using multi-temporal MODIS NDVI data. Remote Sensing of Environment.

Page, 1954. Continuous inspection schemes. Biometrika.

Fang et al., 2006. Online change detection: Monitoring land cover from remotely sensed data. ICDM Workshops.

Ratanamahatana & Keogh, 2004. Everything you know about dynamic time warping is wrong. 10th ACM SIGKDD.

Souza et al., 2009. Verificação de assinaturas offline utilizando Dynamic Time Warping. IX CBRN.