Near real-time disturbance monitoring using satellite images: Severe drought in Somalia

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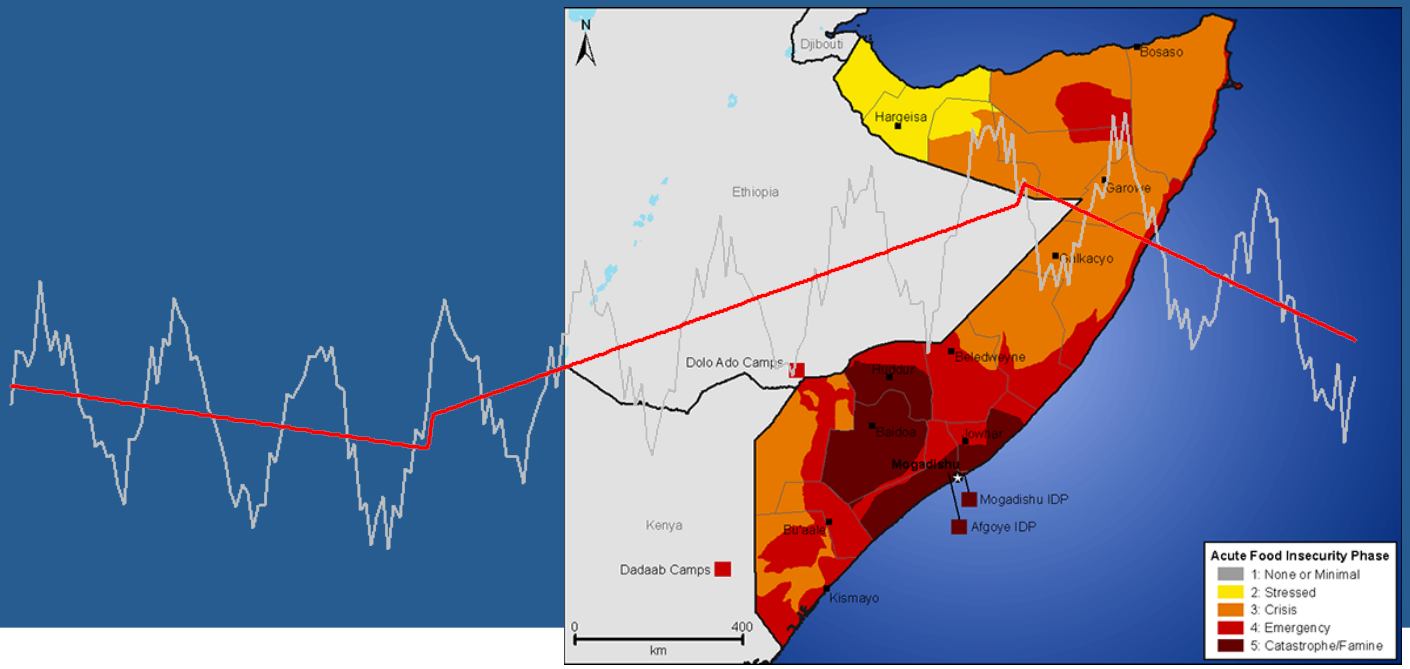

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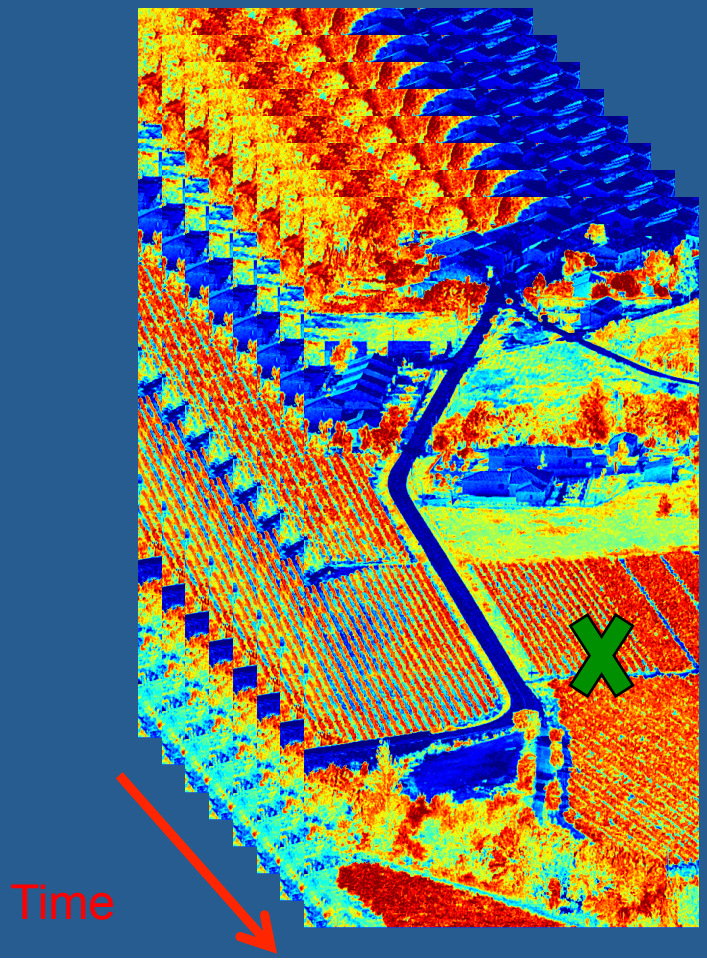
Overview

- Near real-time change monitoring?!
- Methodology
- Results
  - Disturbance detection in Wageningen, The Netherlands
  - Drought detection in Somalia
- Discuss and conclude

- Verbesselt et al., 2012, Near real-time disturbance detection using satellite image time series, RSE.

Introduction

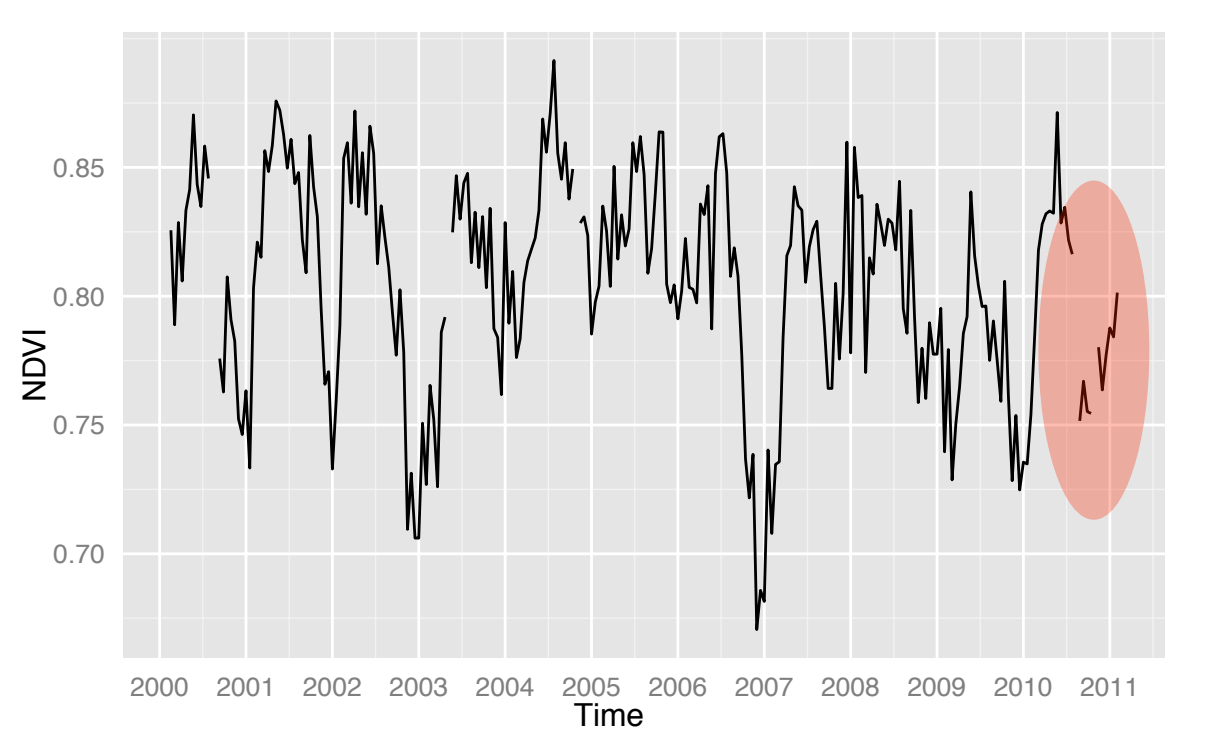
- Near real-time change monitoring



Are there changes in the last image?

Introduction

- Near real-time change monitoring

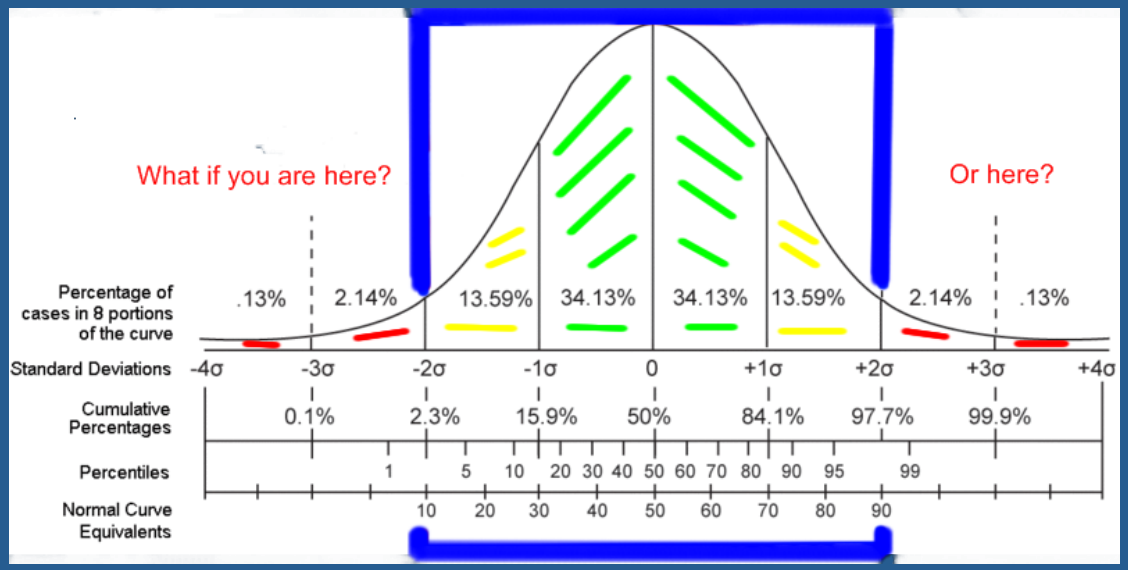


- Monitoring: Is there a change at the end of the time series?

Introduction

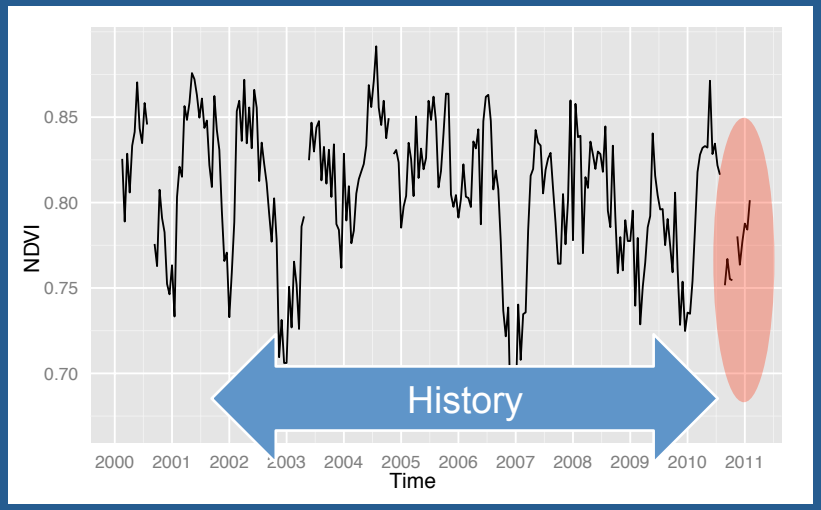
- How do we know something is abnormal?
  - What is normal?

- From a statistical perspective…



Introduction

- Temporal perspective
  - Using the history to determine what is normal



abnormal?

However, is the history representative?

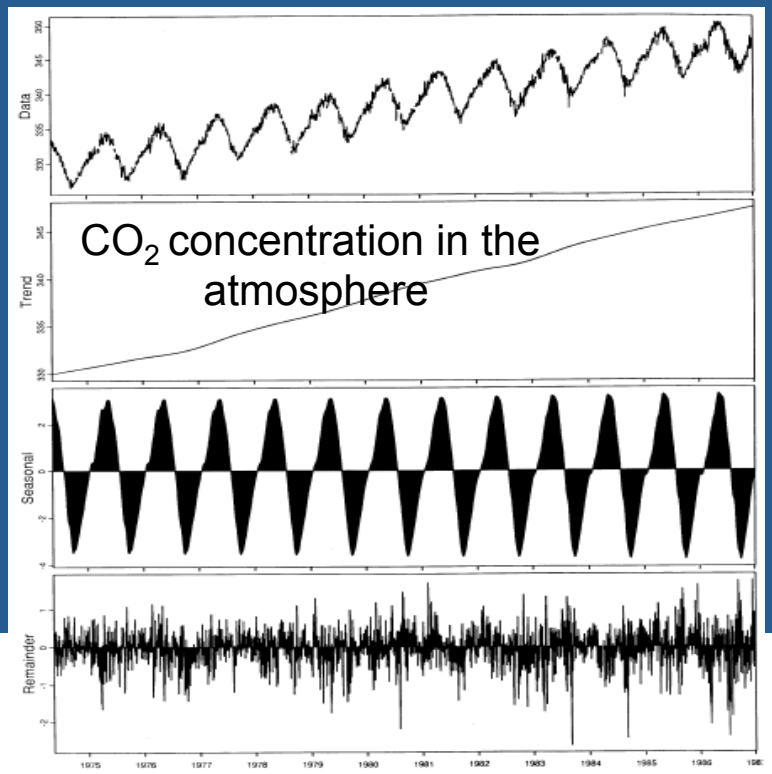
Introduction

- Stable history
  - without structural changes
  - to model normal data variation

- Breaks For Additive Seasonal Trend (BFAST)
  - Detect significant changes
  - Decomposition of a time series

$$Y_t = T_t + S_t + e_t$$

  - T_t using a piecewise linear model

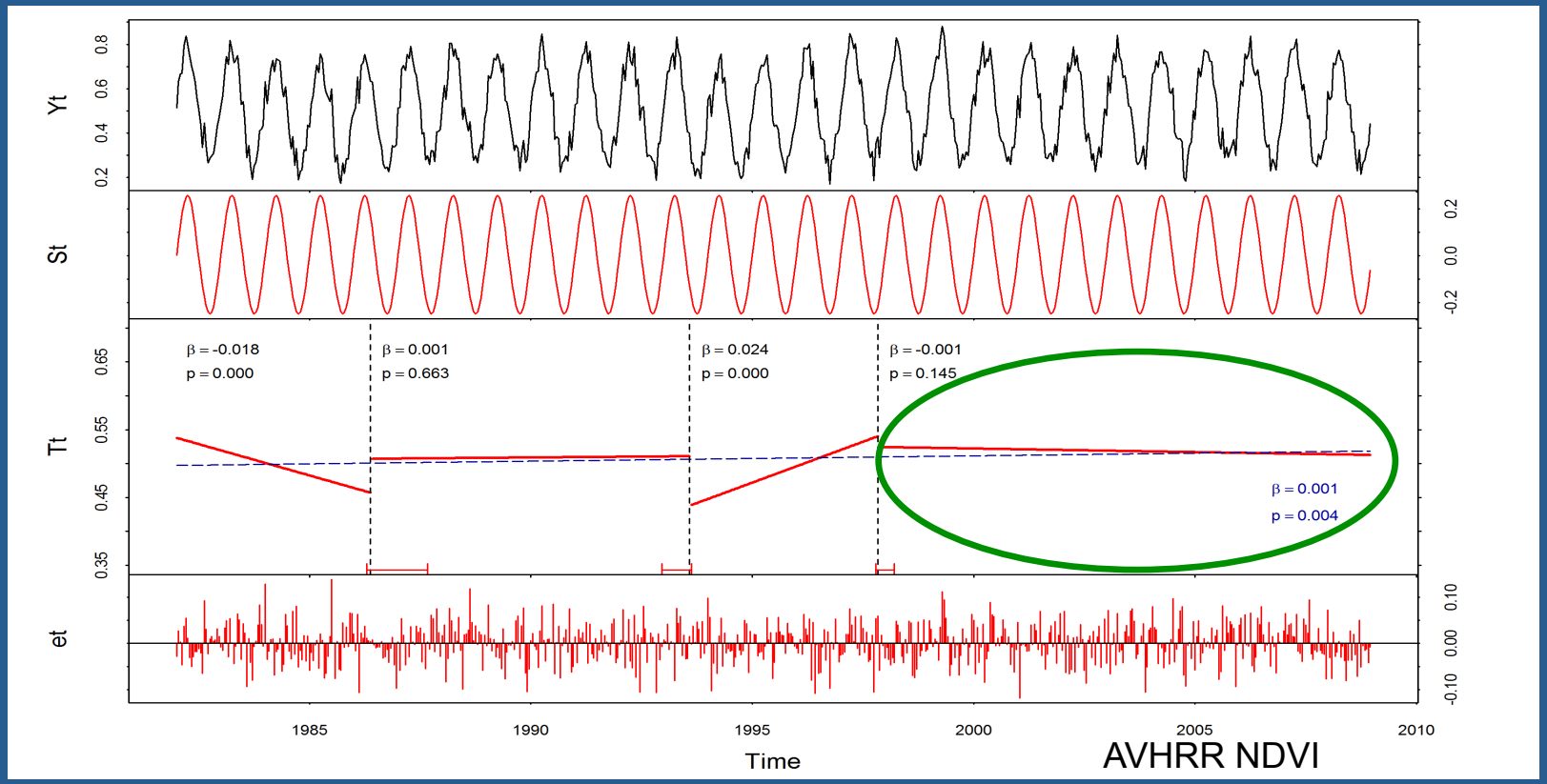


J. Verbesselt, R. Hyndman, G. Newnham, and D. Culvenor, Detecting trend and seasonal changes in satellite image time series, RSE, 2010.

Introduction

- BFAST to find a stable history period
  - a period without abrupt changes

$$Y_t = S_t + T_t + e_t$$



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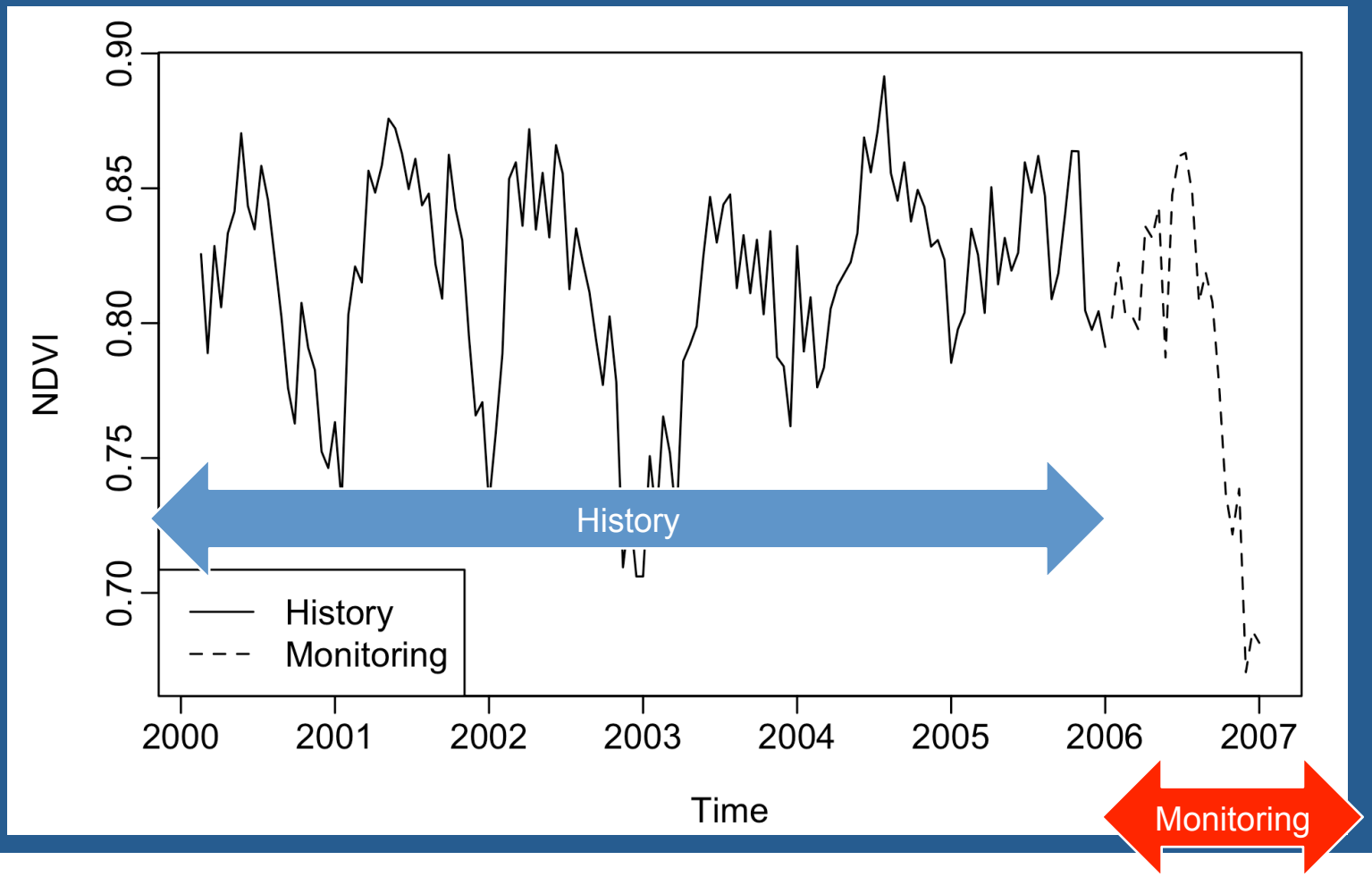
Jong, R., Verbesselt, J., Schaepman, M. E. & Bruin, S. Trend changes in global greening and browning: contribution of short-term trends to longer-term change. *Global Change Biol* ***18, 642–655 (2011).***

Methodology

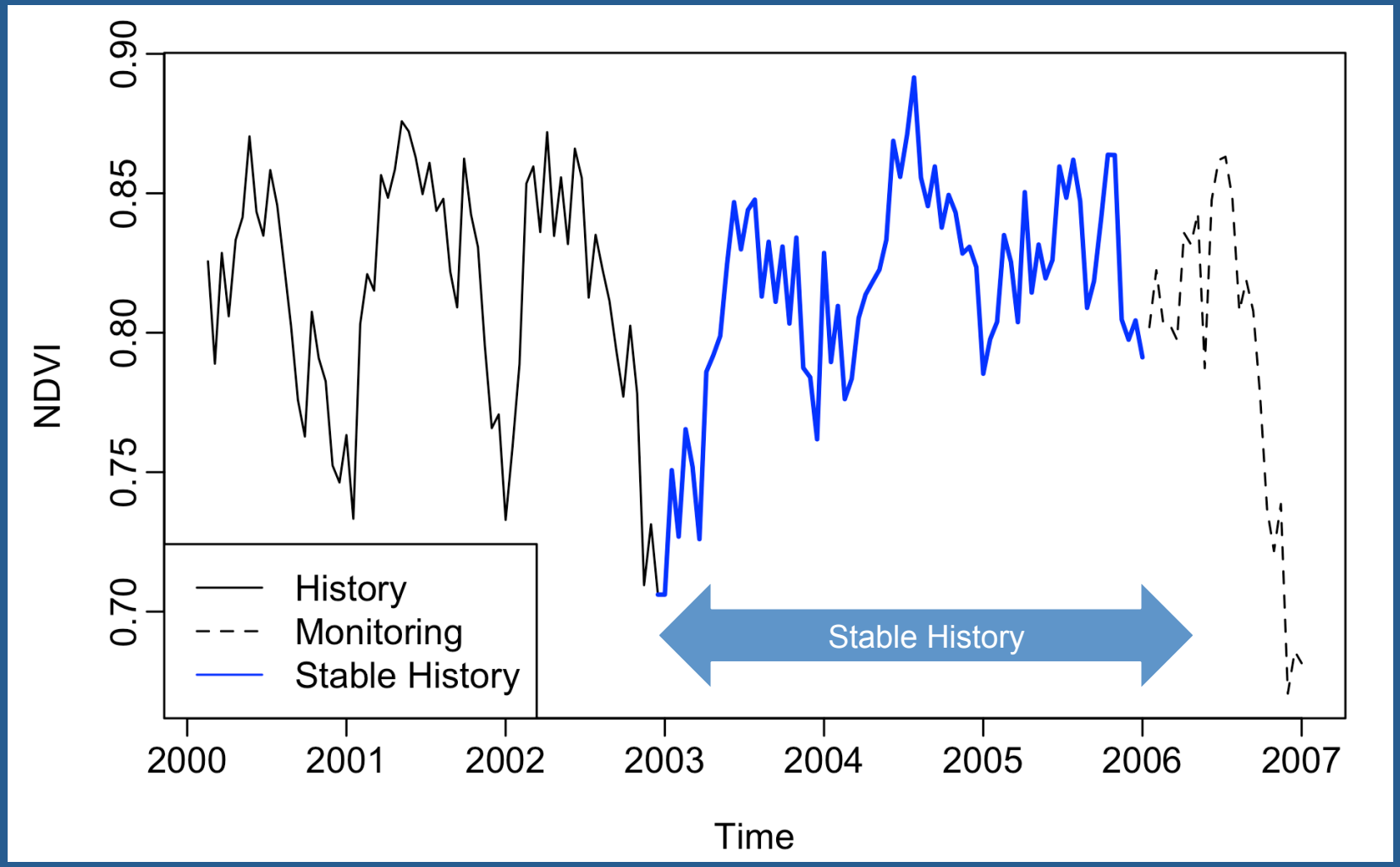
- 3 steps for near real-time monitoring:
  - Identify a stable *history period*
  - Model the stable *history period*
  - Do new observations in the *monitoring period* conform with the expected behaviour of the history sample?

Methodology

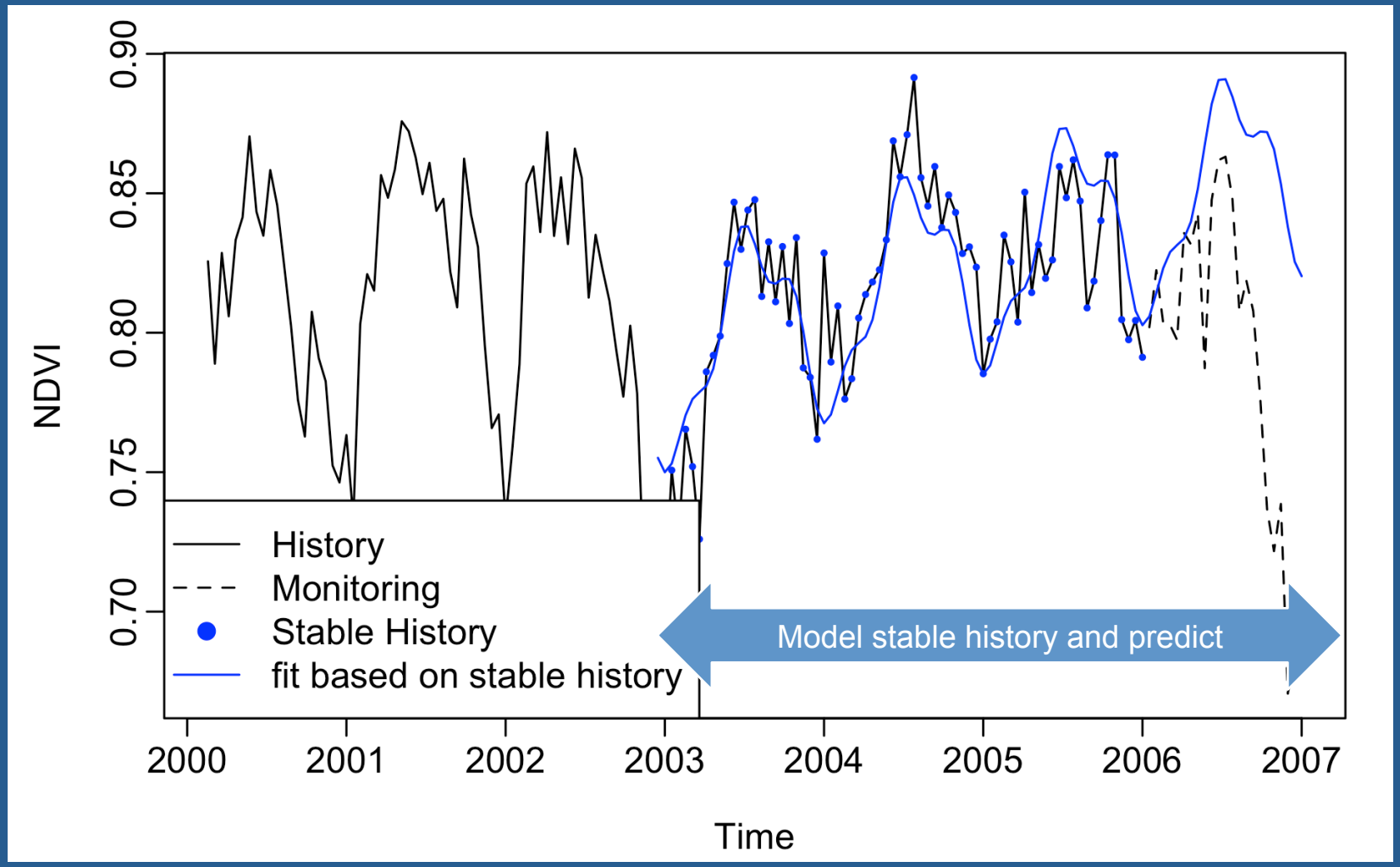
- The idea



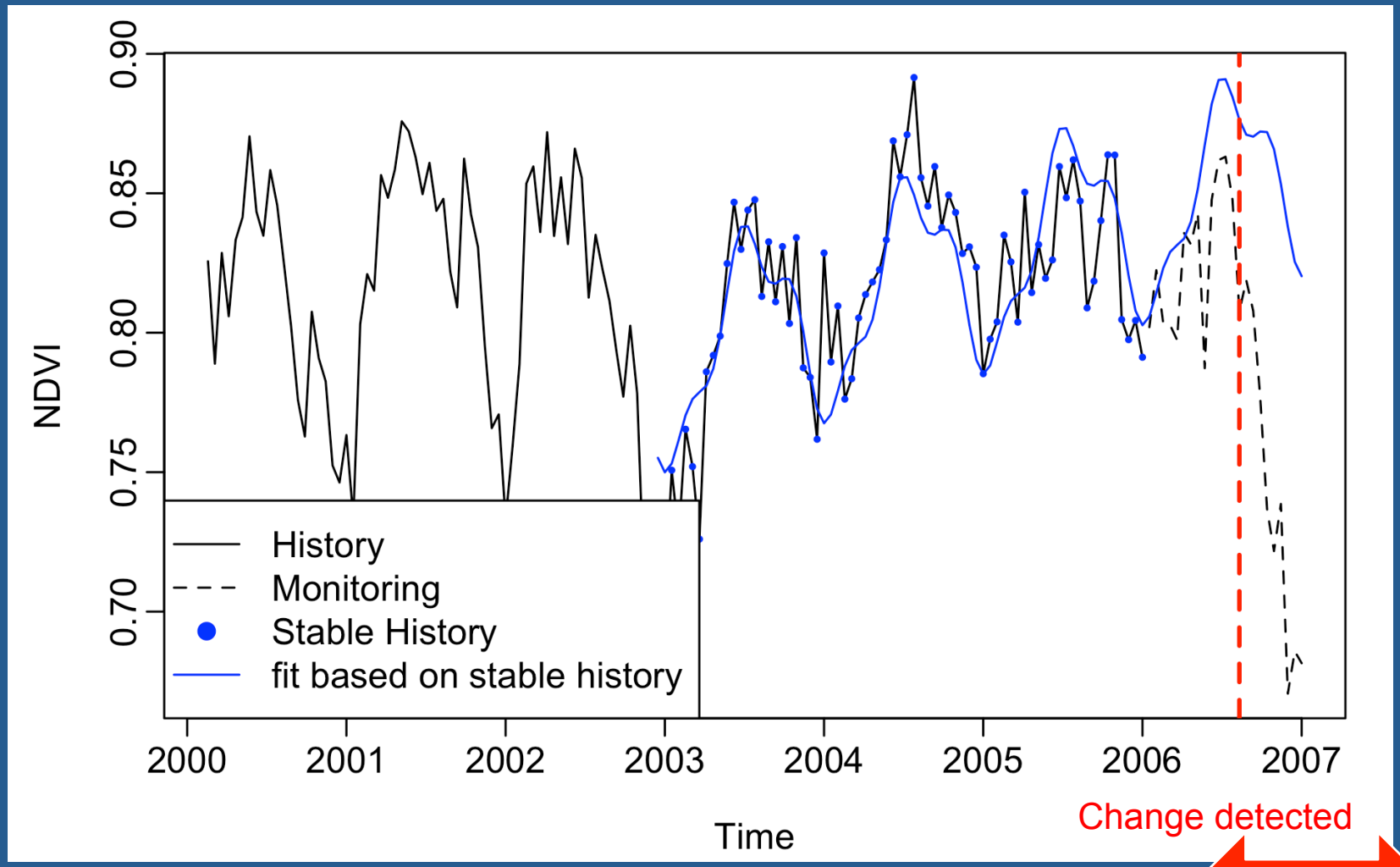
Methodology



Methodology



Methodology



Monitoring

Methodology

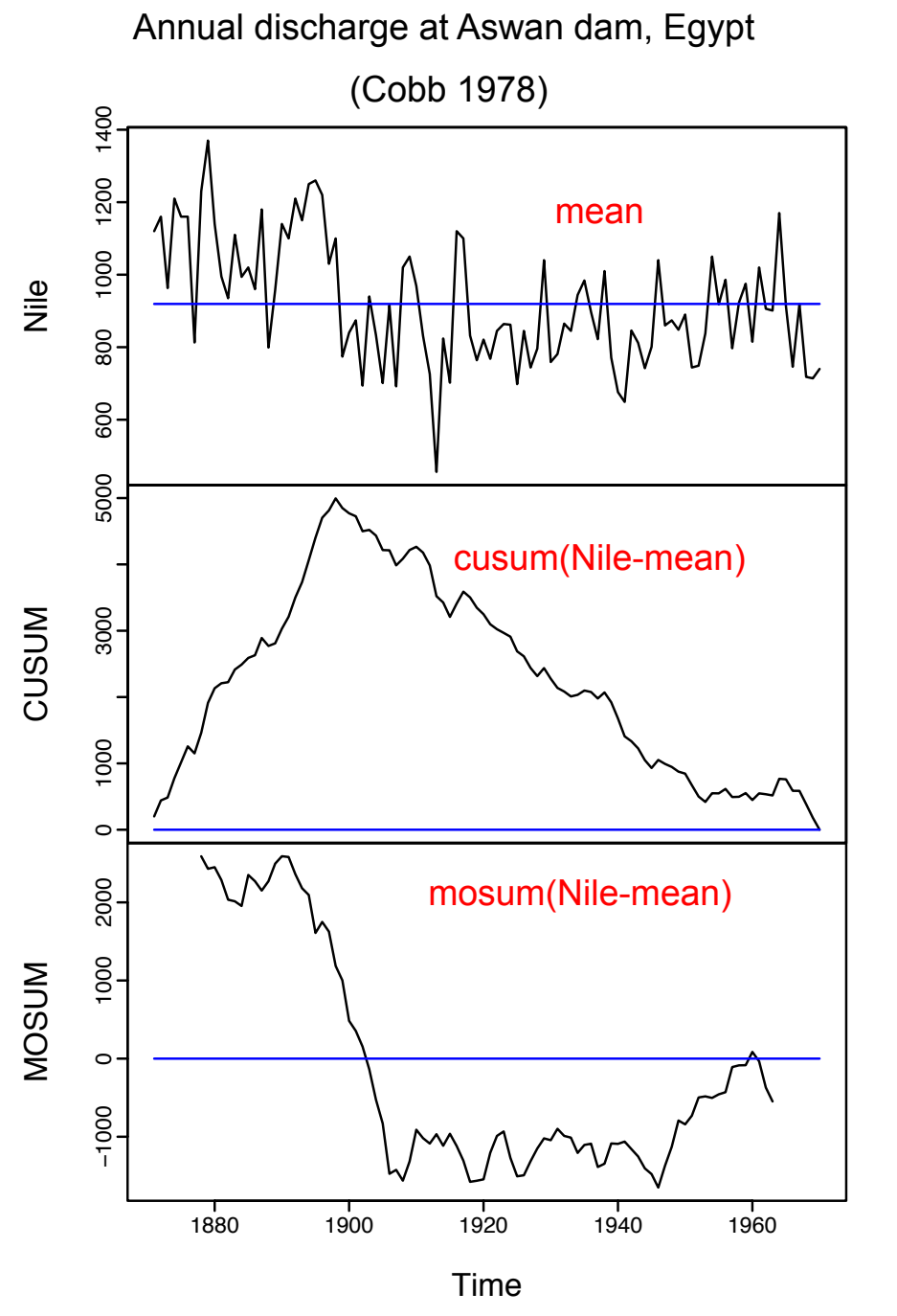
- Model
  - Trend + seasonal model
  - Ordinary least squares regression

$$y_t = \alpha_1 + \alpha_2 t + \sum_{j=1}^{k} \gamma_j \sin\left(\frac{2\pi jt}{f} + \delta_j\right) + \varepsilon_t$$

- Monitoring (Zeileis 2005)
  - Testing for change in model versus data (i.e. residuals)
    - Moving sum of the residuals (MOSUM)
    - Cumulative sum of the residuals (CUMSUM)

J. Verbesselt, R. Hyndman, A. Zeileis, and D. Culvenor, “Phenological change detection while accounting for abrupt and gradual trends in satellite image time series,” *Remote Sensing of Environment*, ***2010***.

- MOSUM and CUSUM tests
  - Test whether annual flow remains constant over the years?

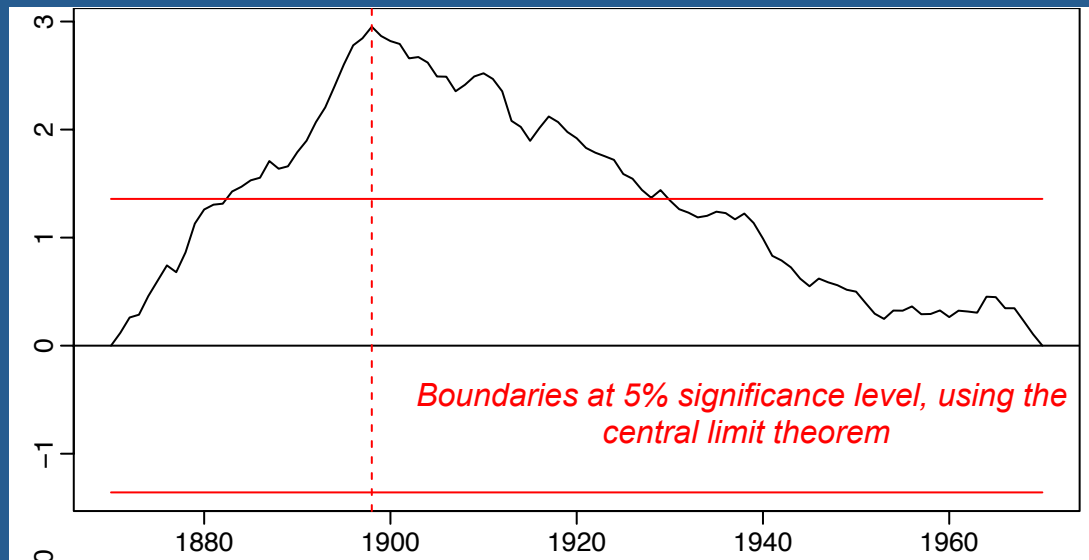


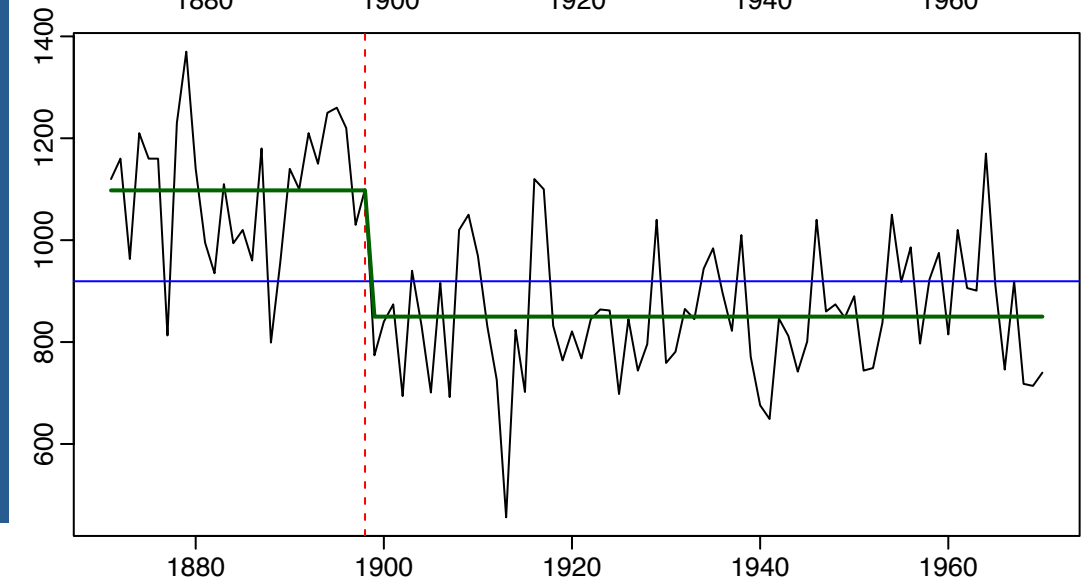
Method

- CUMSUM
- Empirical fluctuation of scaled cumulative sums

$$\frac{1}{\hat{\sigma}\sqrt{n}}\sum_{s=1}^{zn}(y_s - x_s^\top \hat{\beta})$$

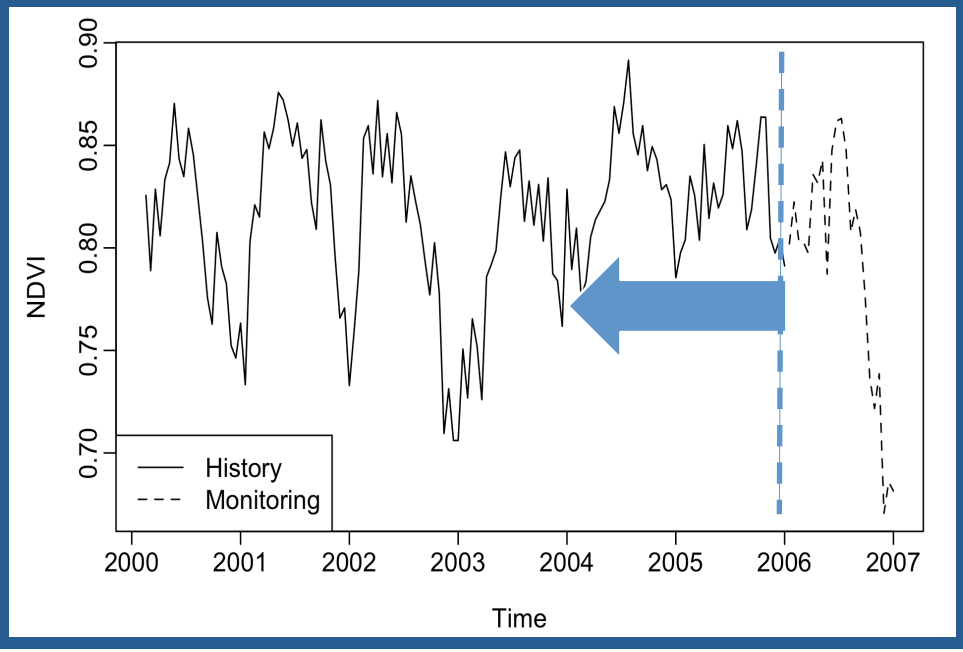
- Determine data of change
  - Piecewise linear model fit
  - minimizing the RSS
- Corresponds to the building of the dam in 1898!





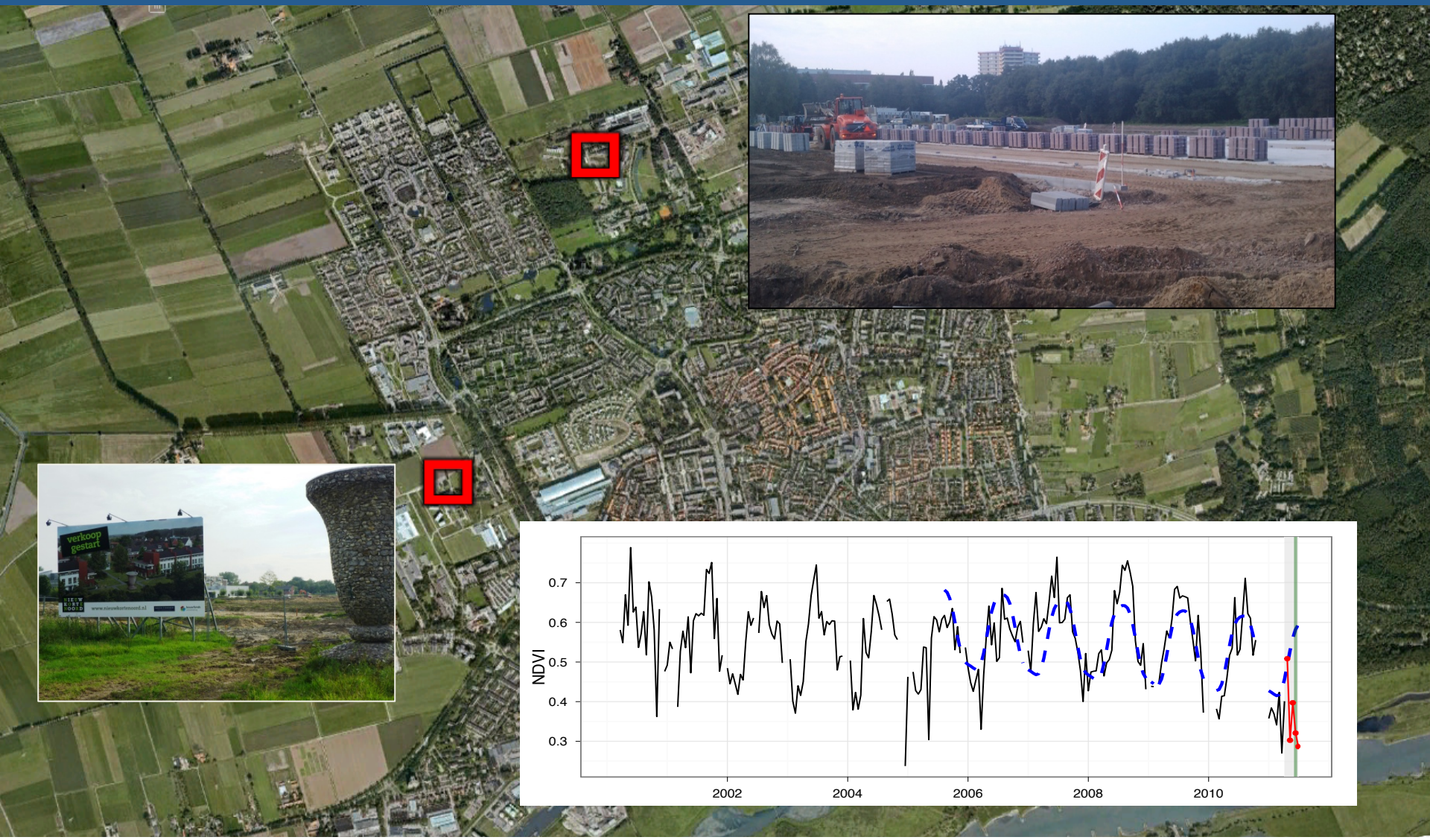
Methodology

- Stable history
  - BFAST
  - Reverse-ordered Cumulative SUM (ROC) of the residuals
    - Similar idea as the CUMSUM test
    - but going back in time



Results I: Wageningen example

Results I



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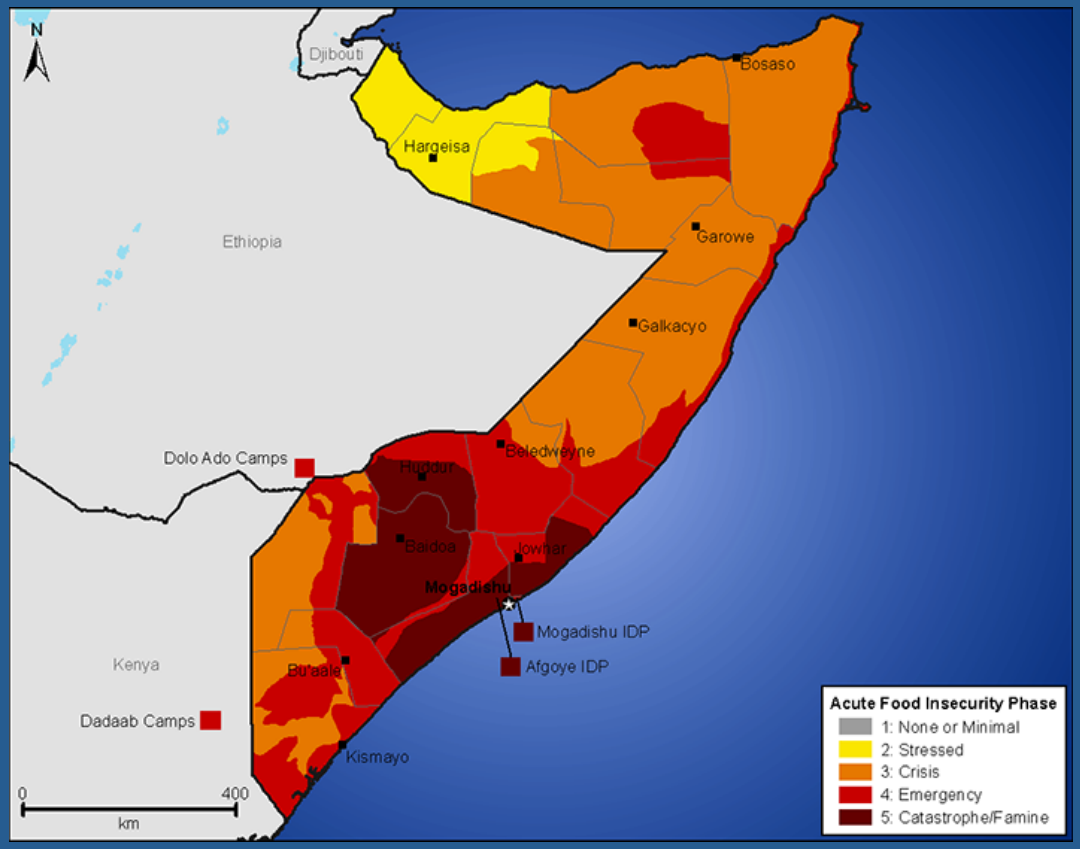
disaster monitoring?

Results II

- Early warning for drought in Somalia
  - Assess impact of the drought on vegetation



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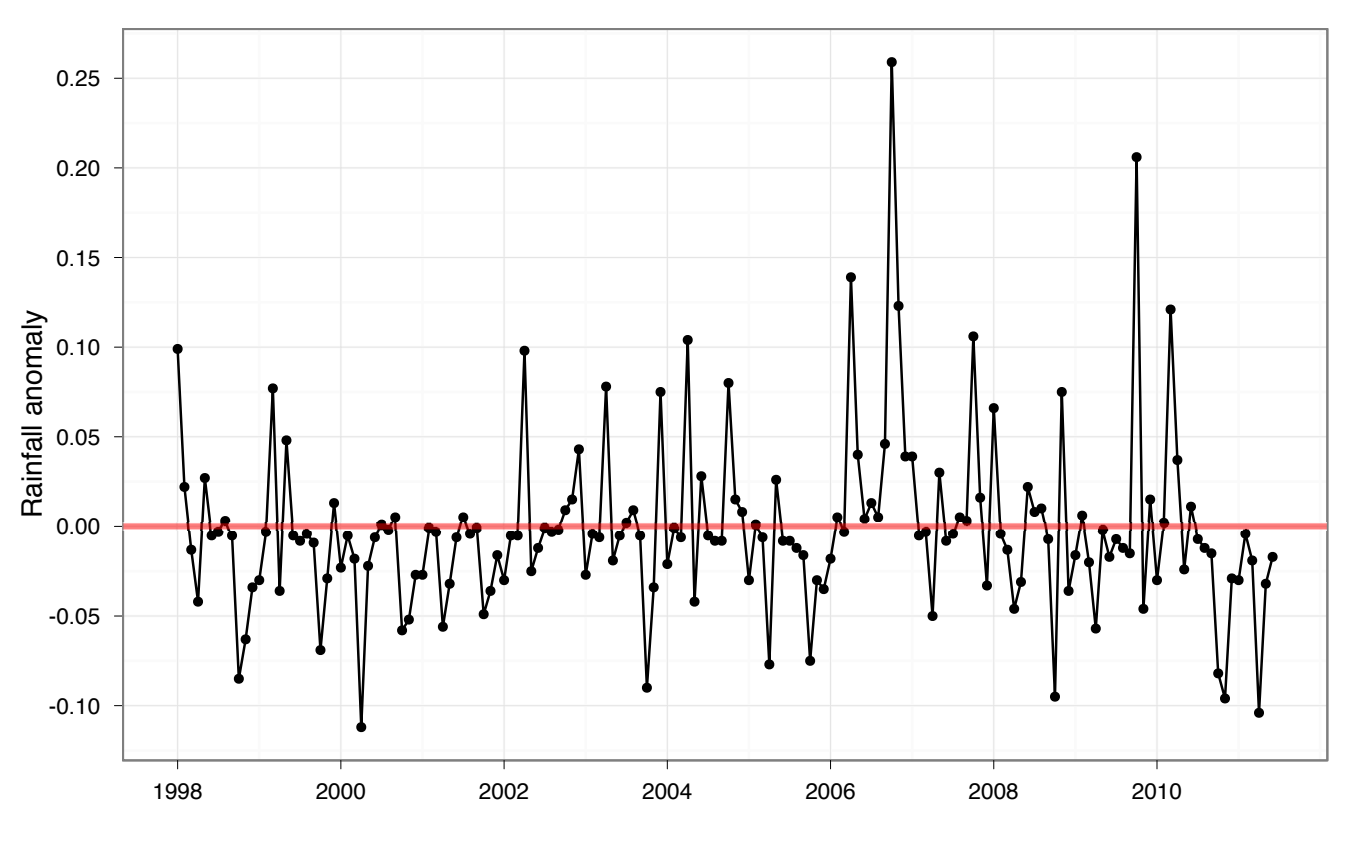
Verbesselt, A. Zeileis, and M. Herold, Near Real-Time Disturbance Detection using satellite Image Time Series: Drought Detection in Somalia (Accepted with revesions), Remote Sensing of Environment

Results II

- Early warning for drought in Somalia



Monthly Rainfall anomaly (mm/hr) measured by the tropical rainfall measuring mission (TRMM)

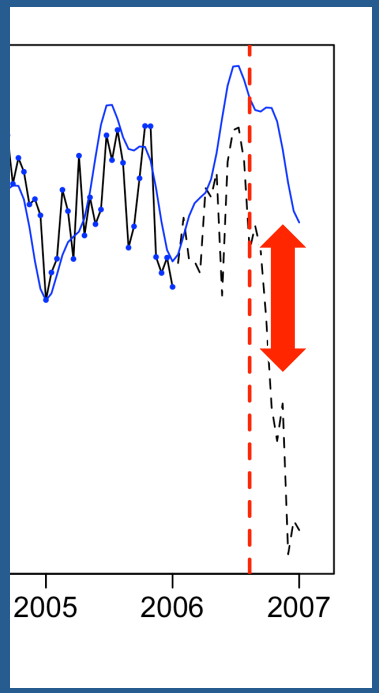
TRMM 3B43 climatology (version 6) data

Results II

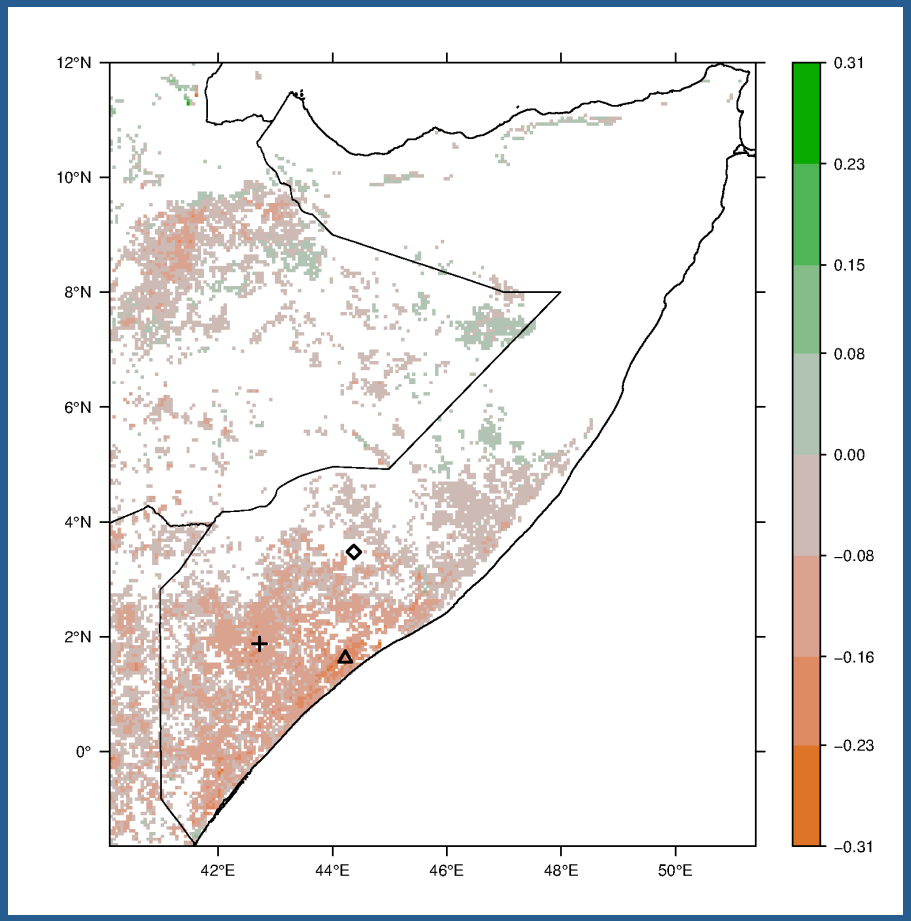
Monitoring period

mid 2011 – mid 2011

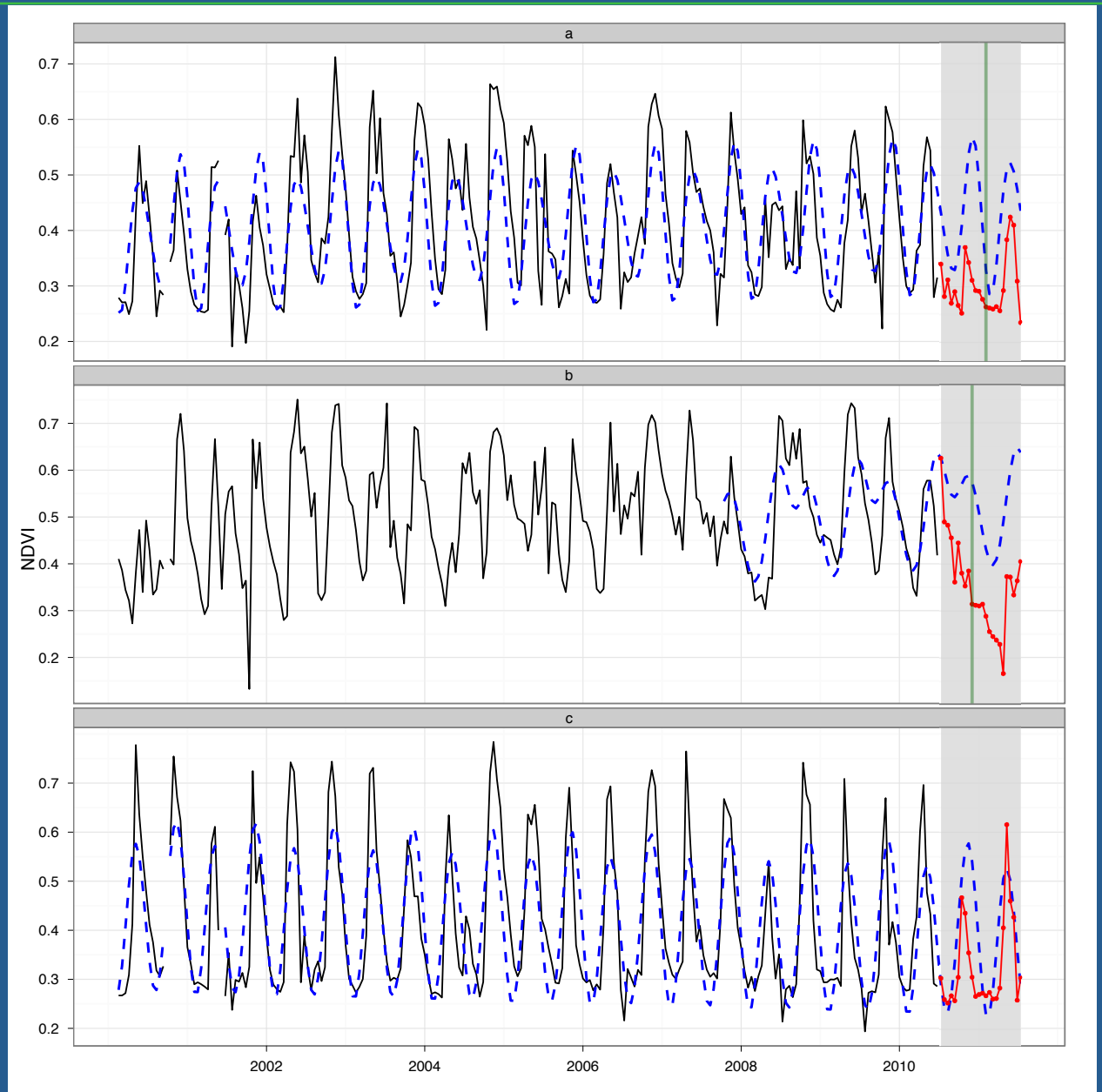
Magnitude of detected disturbance



NDVI



Results II



change

change

NO change

Discussion & conclusion

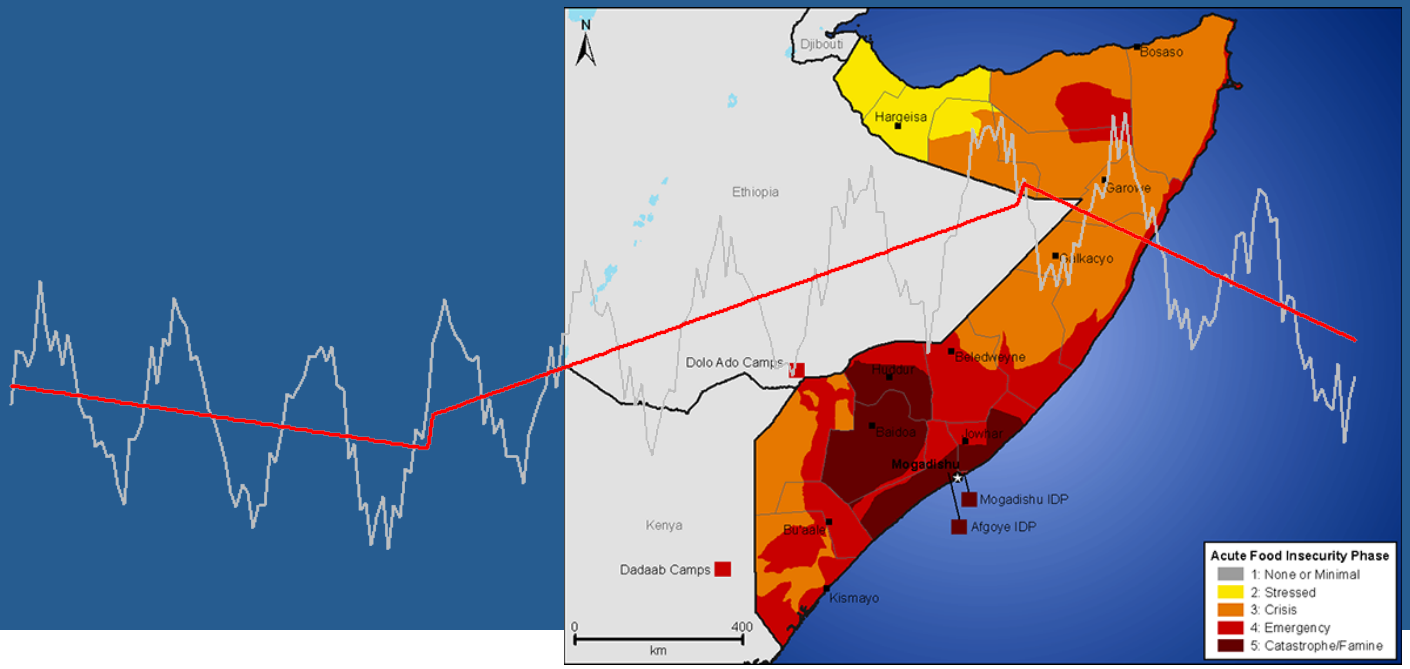
- Determining the stable history
  - ROC (reverse-ordered CUMSUM)
  - Expert knowledge
    - Always use the full length of the time series e.g. climate data – very long time series
- Near real-time anomaly detection
  - TRMM Monthly rainfall time series
  - Other variable provide by the Giovanni online data system
- Online processing and cloud computing
  - Anomaly detection for variables available via “Giovanni”.

Discussion & conclusion

- Near real-time change monitoring method
  - Available via the ‘bfast’ package for R – bfastmonitor()
    - no gap filling needed
    - fast and generic for different types of data
  - http://bfast.r-forge.r-project.org

Thanks for your attention!

- Check it out:
  - http://bfast.r-forge.r-project.org
  - Verbesselt et al., 2012, Near real-time disturbance detection using satellite image time series, RSE.



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