



GEOINFORMATION

in der Umweltplanung | Environmental Planning

Technische Universität Berlin



Frühwarnsignale aus Zeitreihenanalysen

Das Beispiel der Zentralasiatischen Tugai-Auwälder (MODIS NDVI)

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GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung



FONA
Forschung für Nachhaltige
Entwicklung
BMBF



DLR Projektträger



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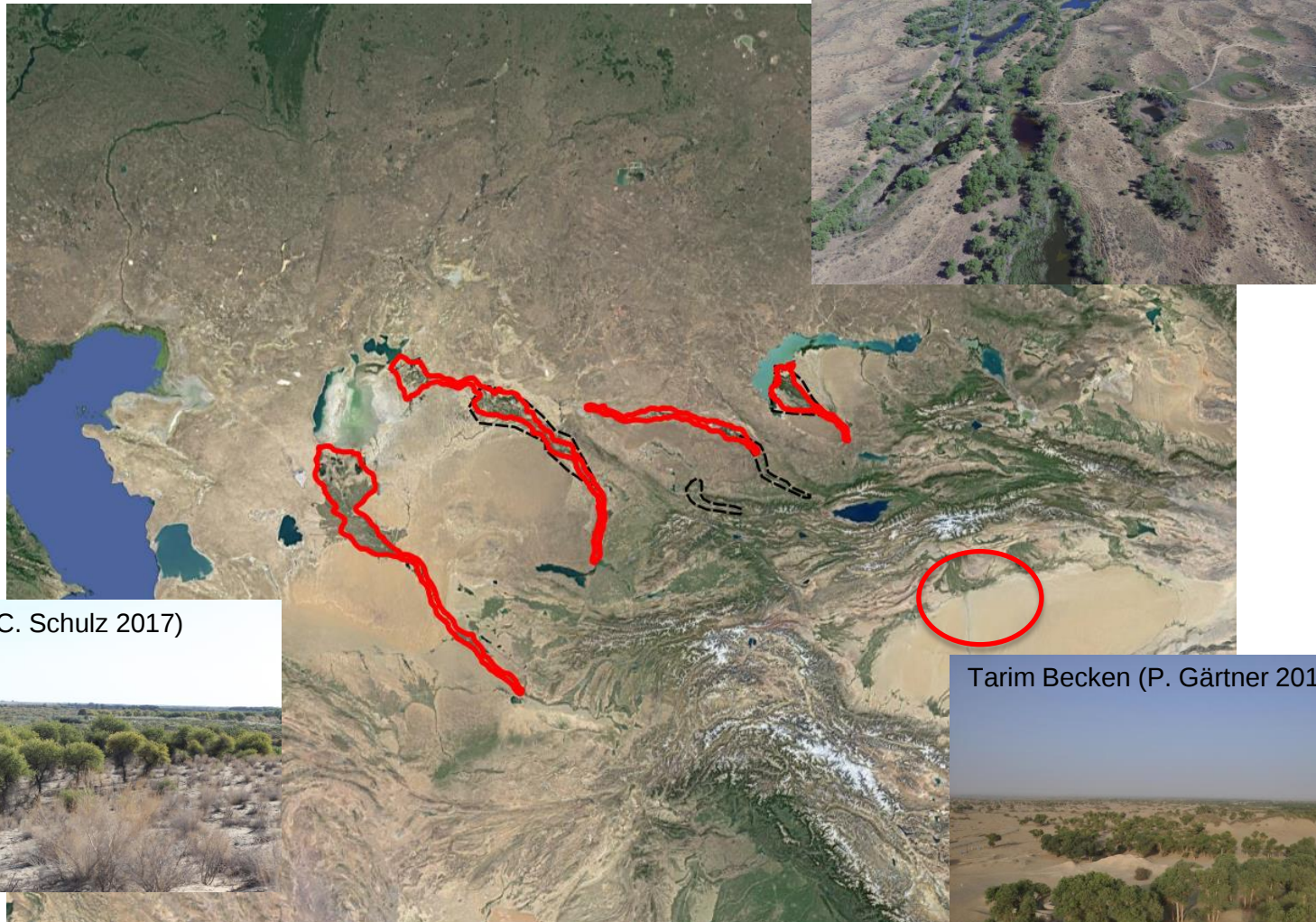
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7. Treffen des Arbeitskreises Fernerkundung | 05.-07.09.2018



Zentralasiatische Pappel-Auwälder



Syr Darya (C. Schulz 2017)

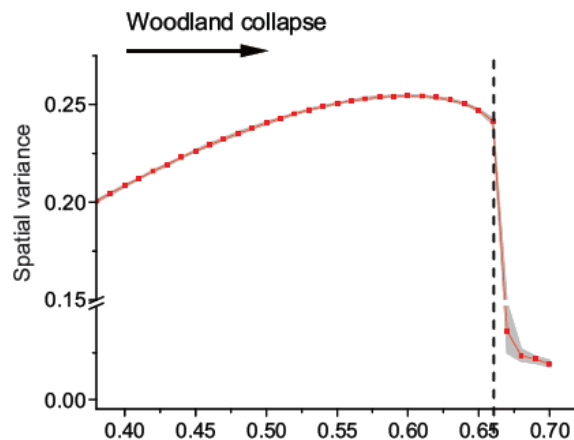
Ili Delta (N. Tesch 2018)

Tarim Becken (P. Gärtner 2014)

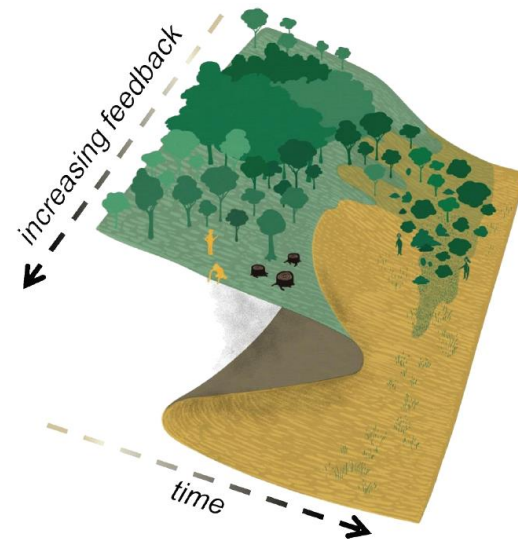
Global 200 Terrestrial Ecoregions (Olson et al. 2001)

„Critical slowing down‘ Theory

„... many complex systems have **critical thresholds**—so-called tipping points—at which the **system shifts abruptly** from one state to another.“ (Scheffer et al. 2009)



Xu et al. 2015



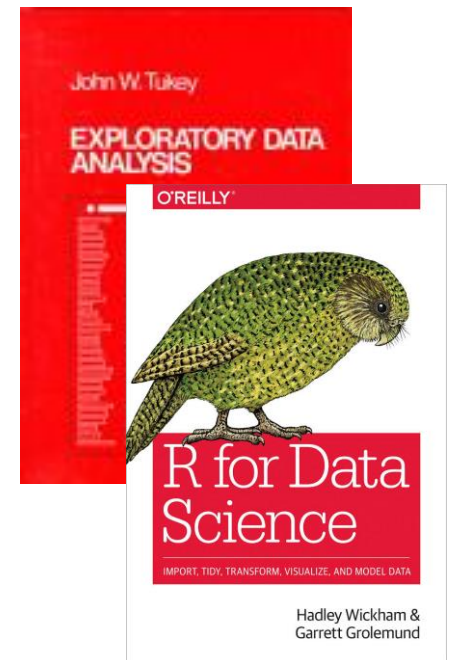
Bathiany et al. 2016

1. Anwendung der Tipping Point Theorie in der Landschafts- und Ökosystemforschung?
2. Fernerkundliche Zeitreihen geeignet für die Detektion von vergangenen & zukünftigen Kipppunkten?

Explorative Datenanalyse (Tukey 1972)

Explorative Datenanalyse dient der **Erkundung von Daten**, der **Bildung von Hypothesen** und der **Auswahl von statistischen Werkzeugen**.

- Univariate Ansätze: Trends, Brüche, Kipppunkte
- Bivariate Ansätze: Zusammenhangsmaße, Korrelation
- Multivariate Ansätze: MVTs plots
- Grafische Ansätze: Darstellungen, Diagramme, Karten





Packages for Time Series Analysis

Raw Data

Raster Data Processing

```
library(raster)
library(sp)
library(maps)
library(mapdata)
library(maptools)
library(mapproj)
library(ggplot2)
library(gpclib)
```

...



Spatial Time Series Data

Time Series Analysis

```
library(bfast)
library(bfastSpatial)
library(xts)
library(zoo)
library(forecast)
library(strucchange)
library(greenbrown)
library(changepoint)
library(prophet)
library(mvtsplot)
library(outbreak)
library(ecp)
library(phenex)
```

...



Output

Breakpoints

Changepoints

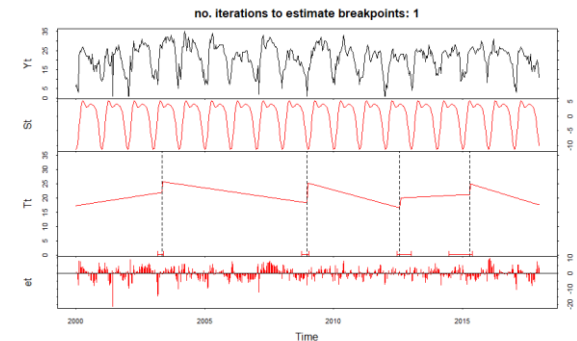
Tipping Points

Spatial Correlation and
Covariance

Land Cover Change

Phenological Change

...

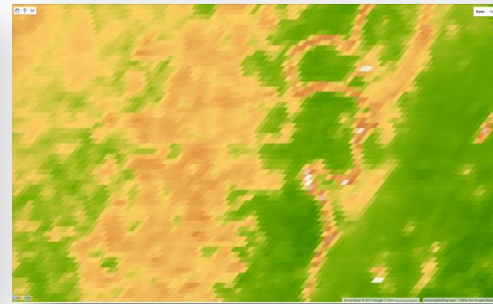
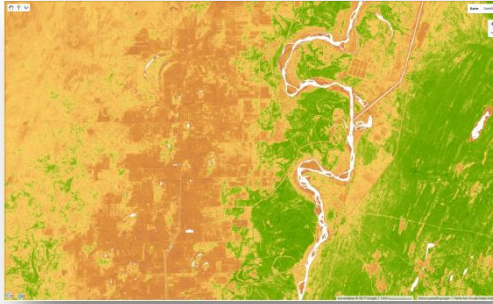


Landsat 30m

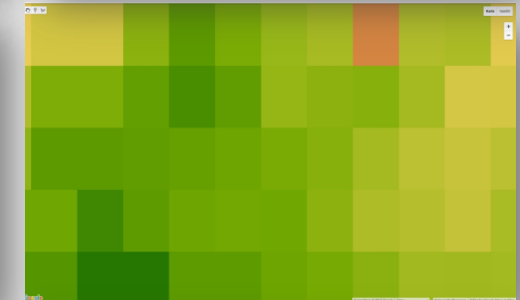
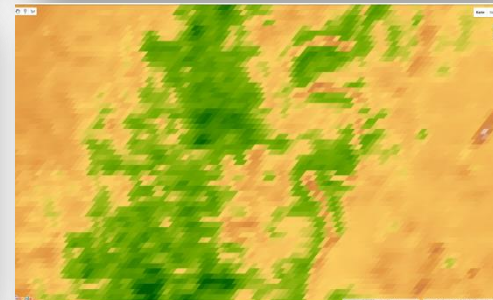
MODIS 250m

AVHRR 0,5°

10.02.2016



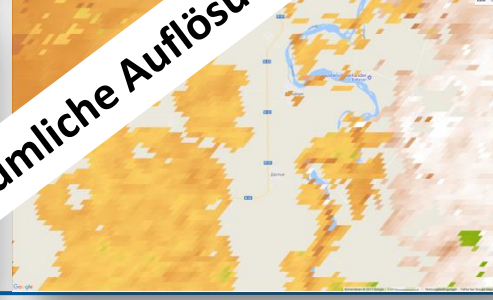
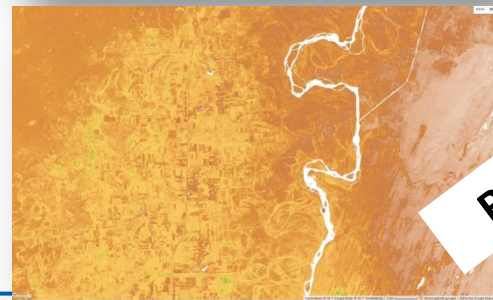
16.05.2016



20.08.2016



24.11.2016



Räumliche Auflösung



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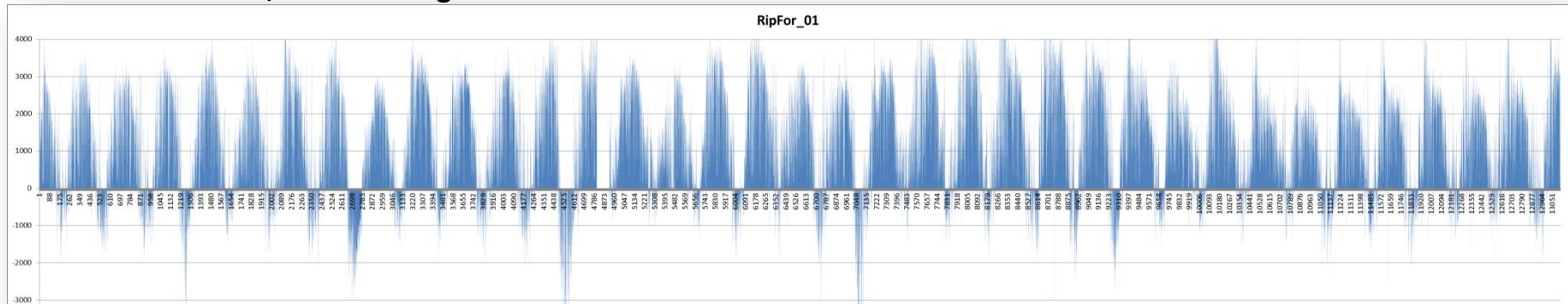
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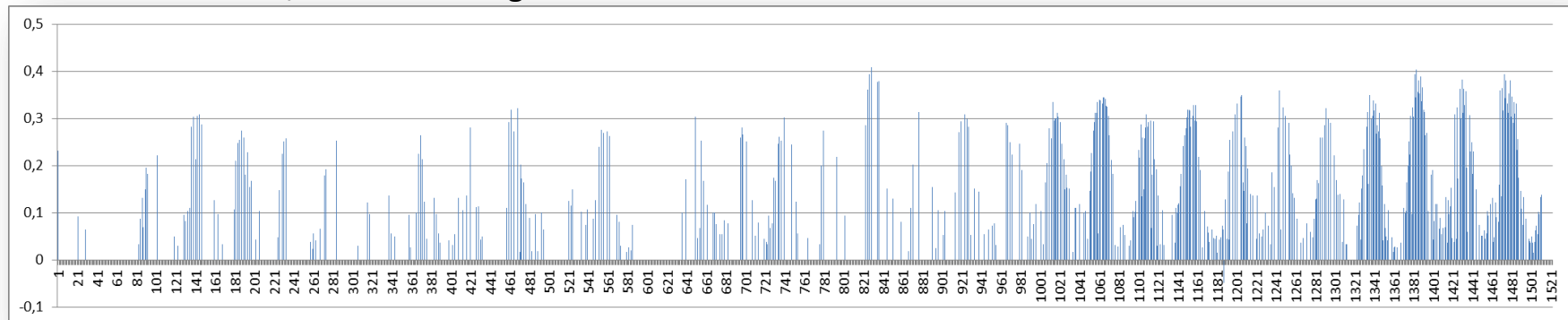


Google Earth Engine 2017

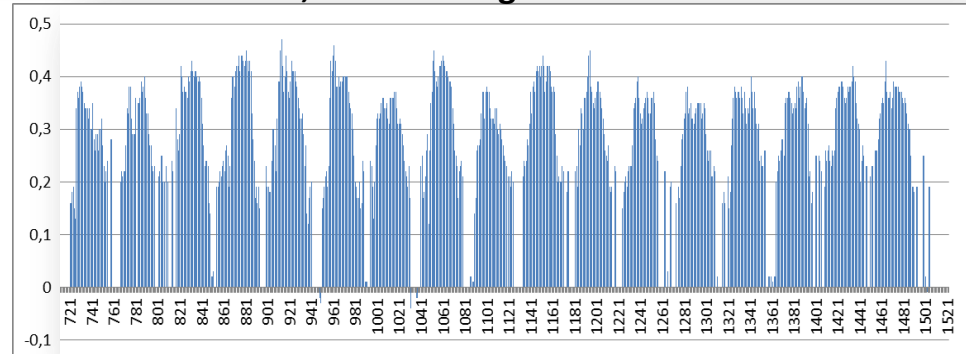
AVHRR 1981-2017, 95% coverage



Landsat 1984-2017; 29-50% coverage

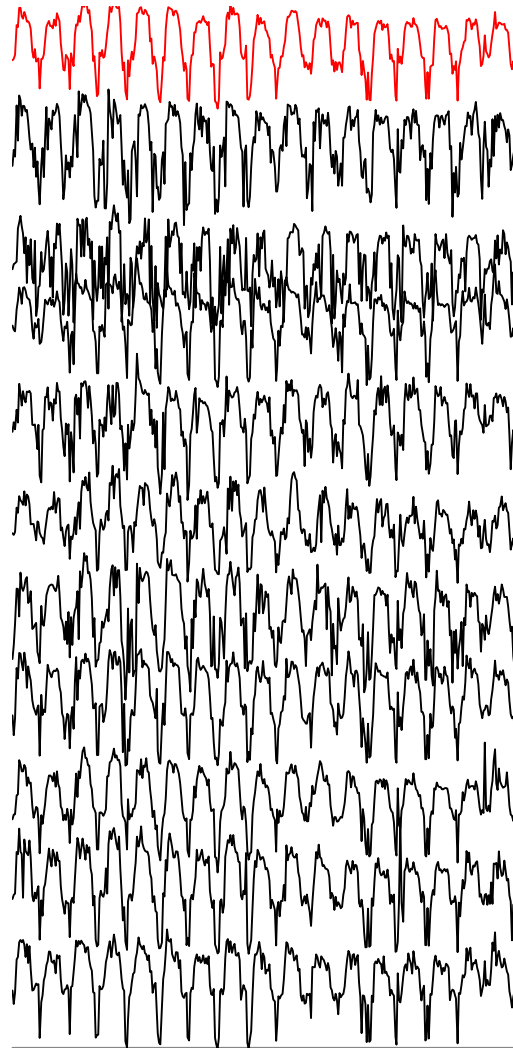


MODIS 2000-2017; 87% coverage

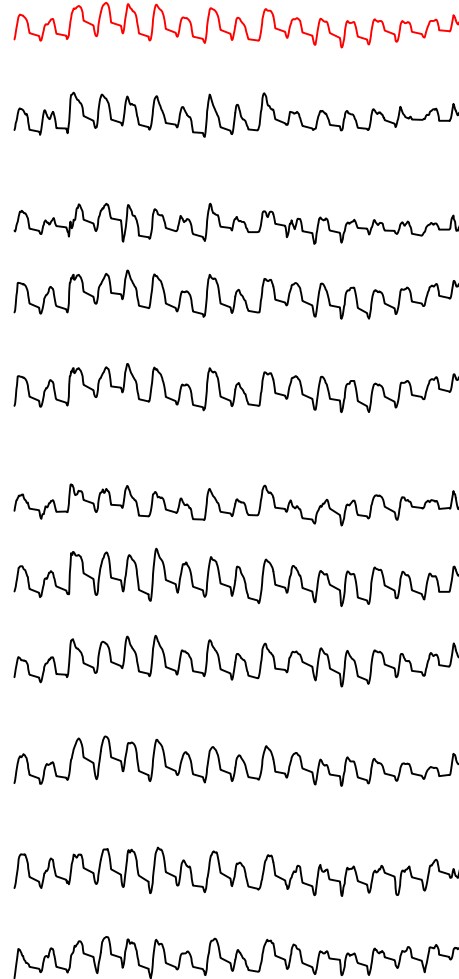


Zeitliche Auflösung

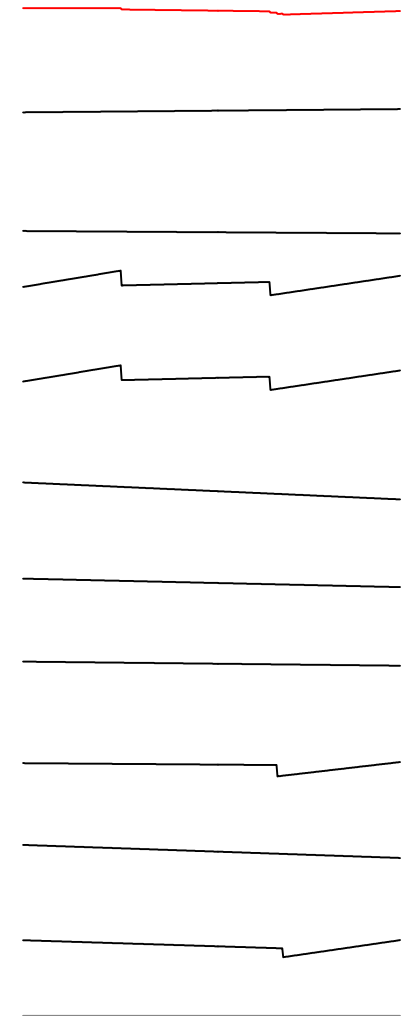




2/18/2000
2/18/2002
2/18/2004
2/18/2006
2/18/2008
2/18/2010
2/18/2012
2/18/2014
2/18/2016

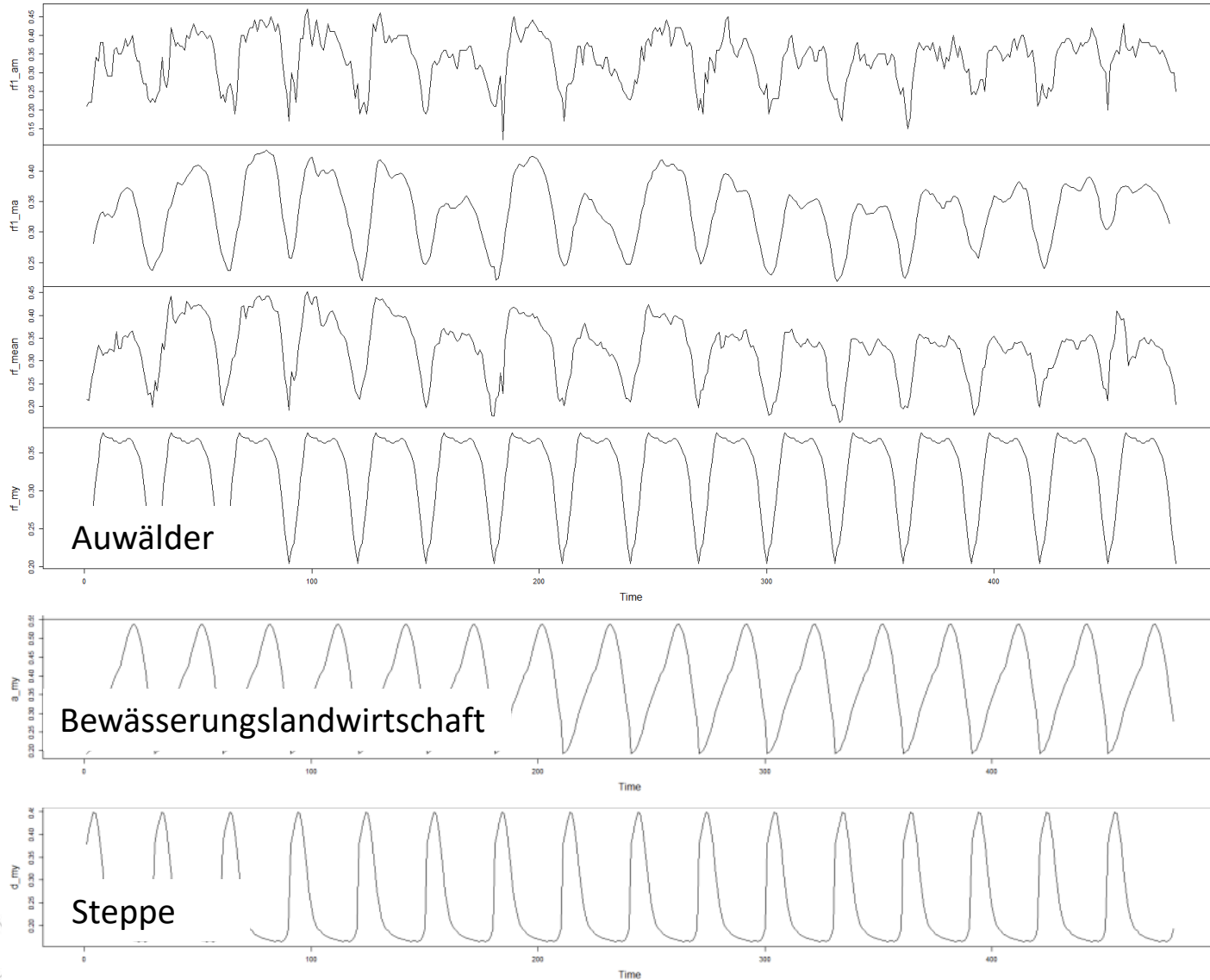


2/18/2000
2/18/2002
2/18/2004
2/18/2006
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2/18/2016



2/18/2000
2/18/2002
2/18/2004
2/18/2006
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2/18/2010
2/18/2012
2/18/2014
2/18/2016

Entwicklung von temporalen Profilen (Verger et al. 2013)

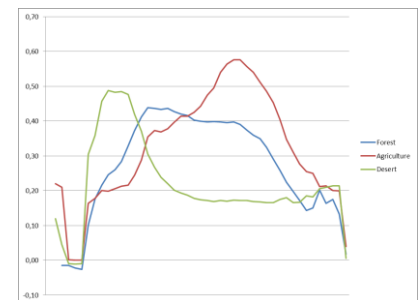


single plot time series

single plot time series, moving average filter

mean time series of 10 plots

mean time series
„Stable Regime“ Profile



Wie ähnlich sind sich die Signale? → **Korrelationsmaße**



TS for POI (e.g. „ripFor01“)

TS1_vp

observed



TS „healthy“ stable regime

TS_sr1

simulated

0.6

0.4

0.2

0

0.00

0.20

0.40

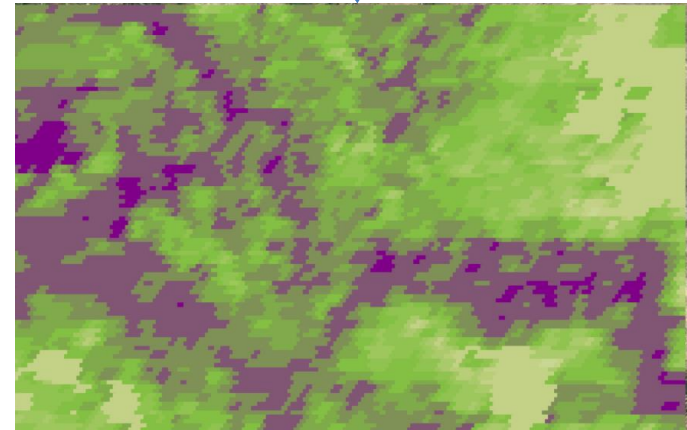
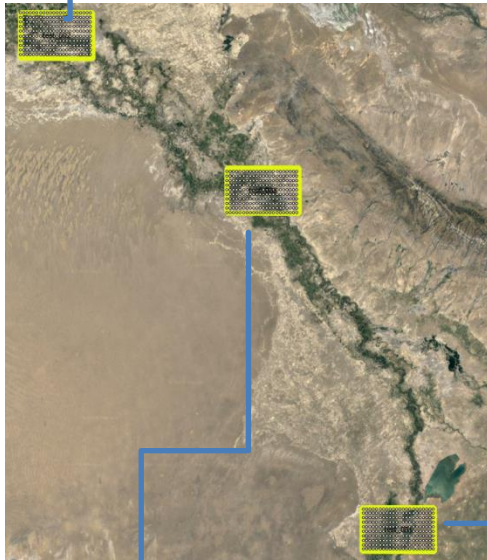
0.60

Pearson's
 $r = 0.75$



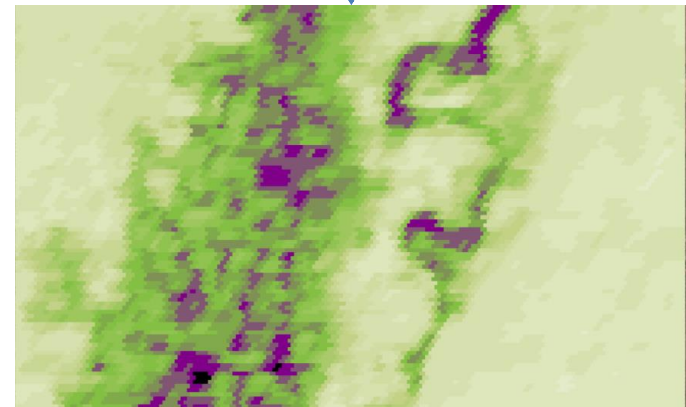
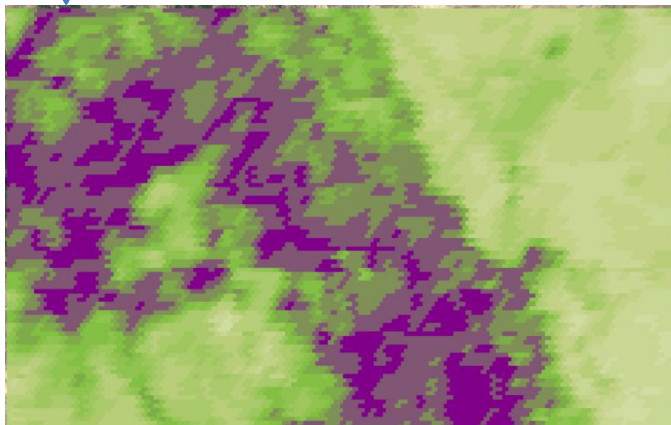
Pearson's r (MODIS)

218x99 grid
(~ 250 m resolution)

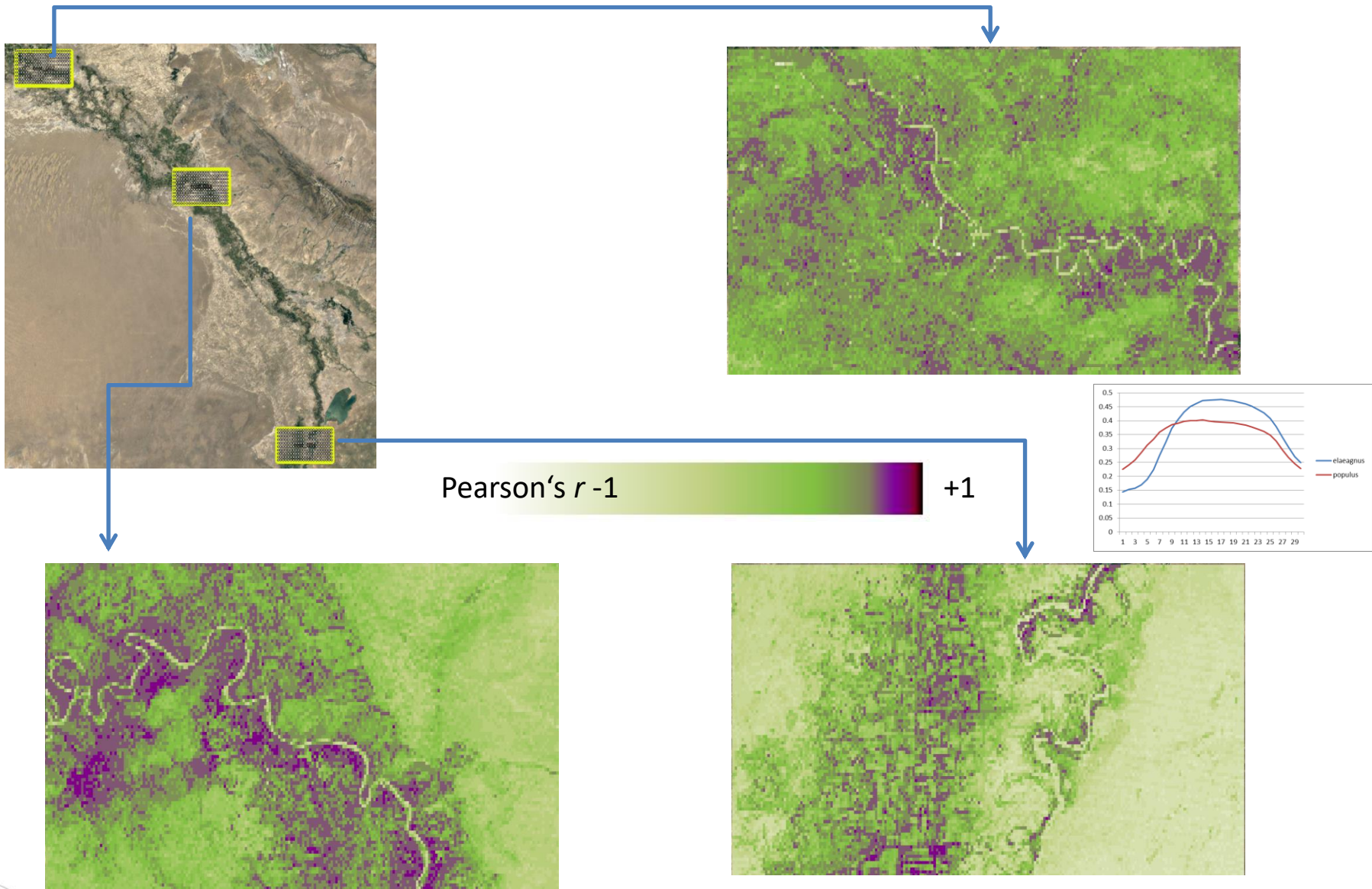


Pearson's r -1

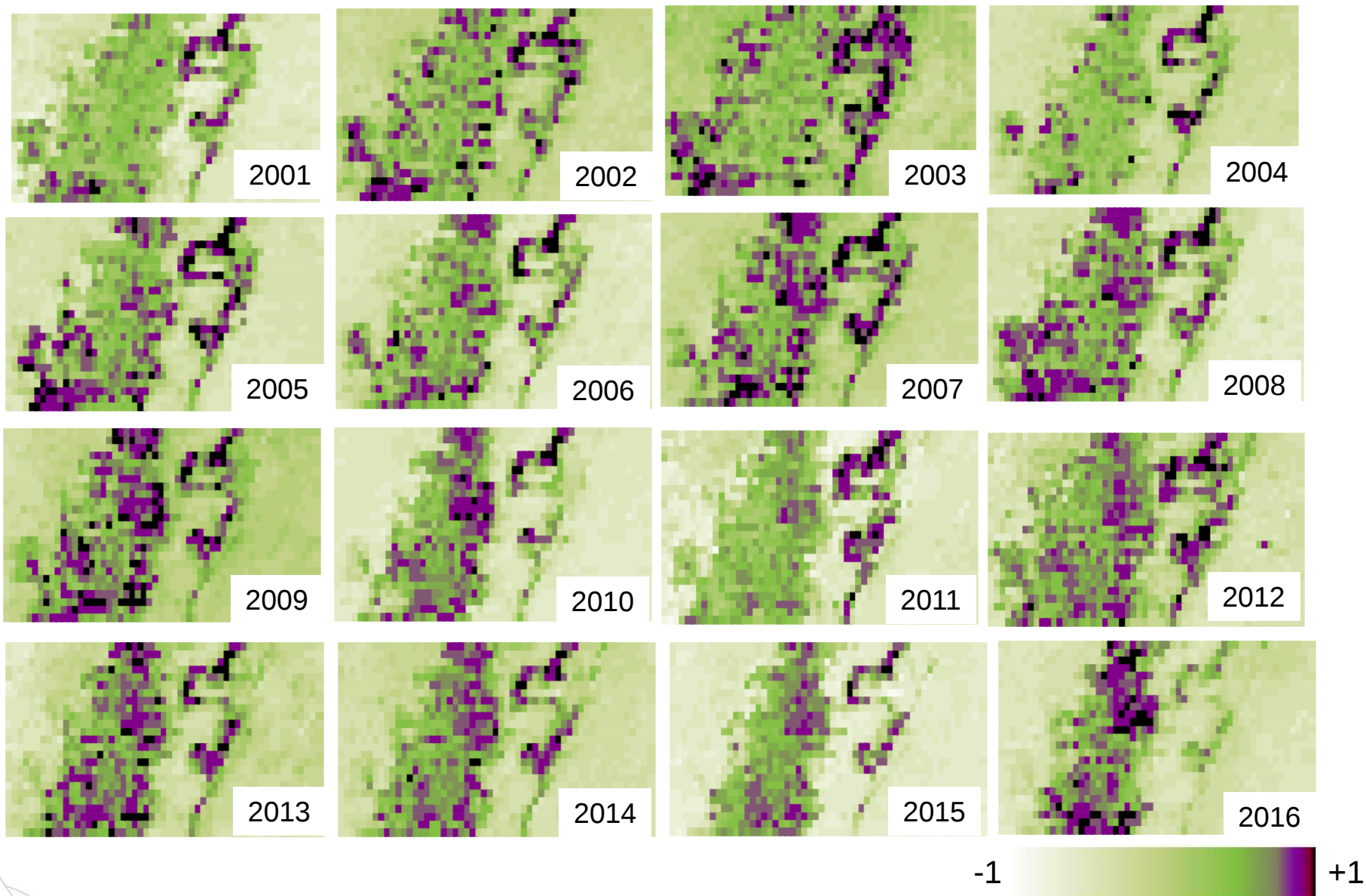
+1

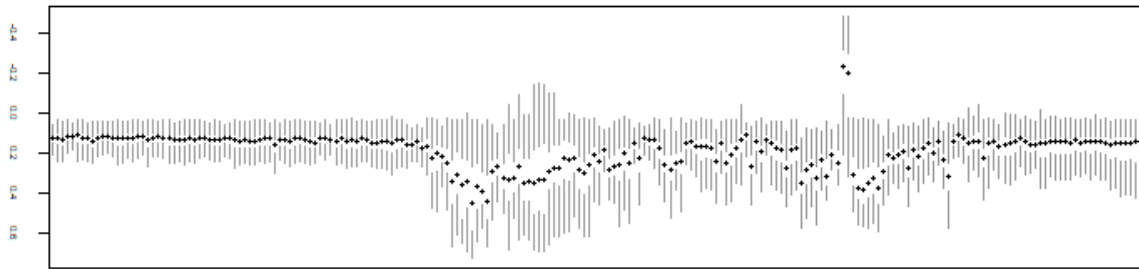


Pearson's r (Landsat 7)

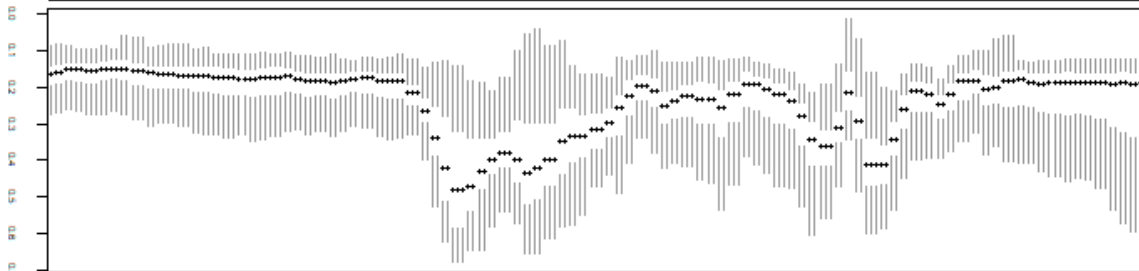


Pearson's r for multiple years (MODIS)





Landsat 7



MODIS



Steppe



Agriculture



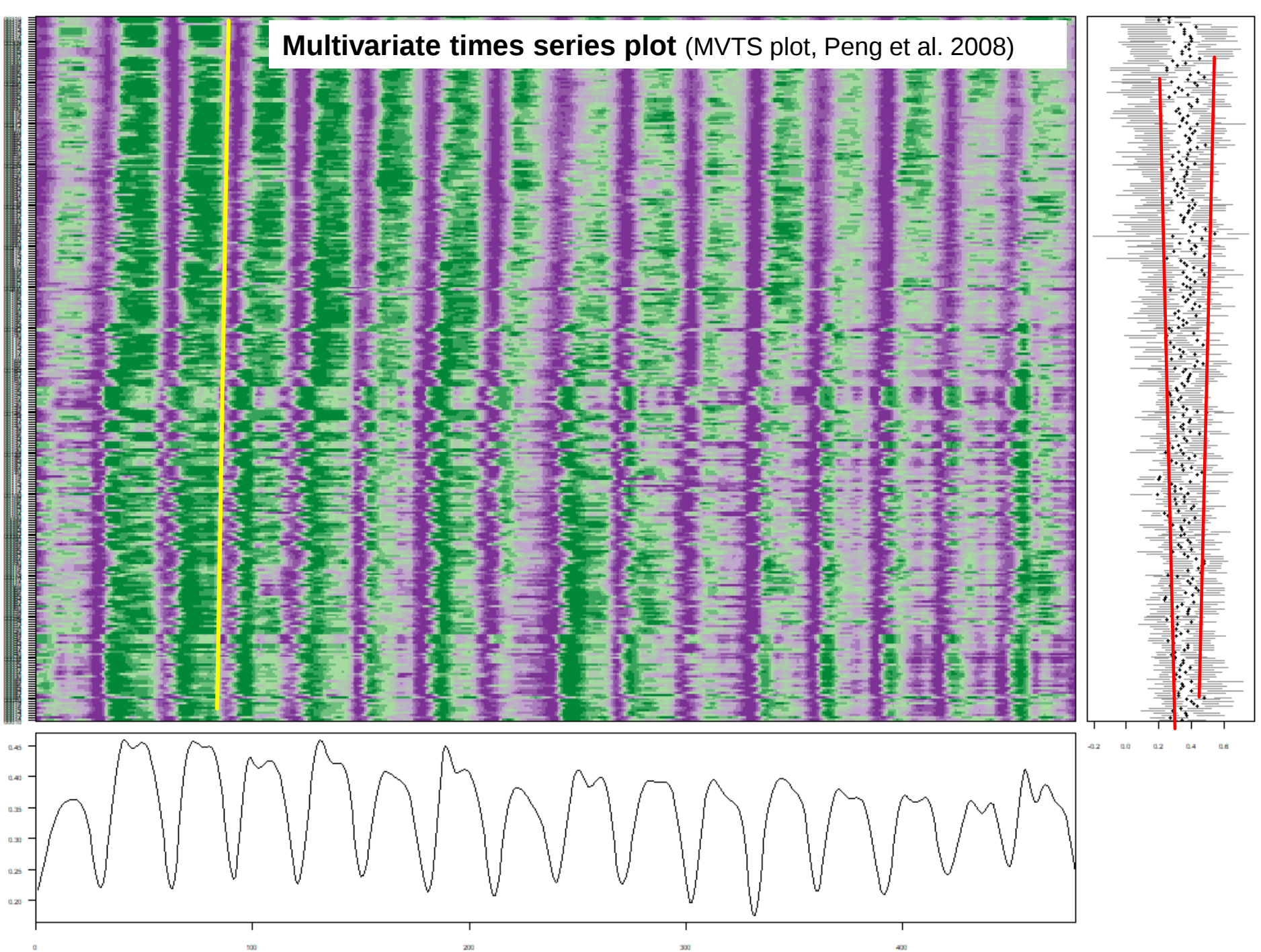
Water

W



E

Multivariate times series plot (MVTs plot, Peng et al. 2008)



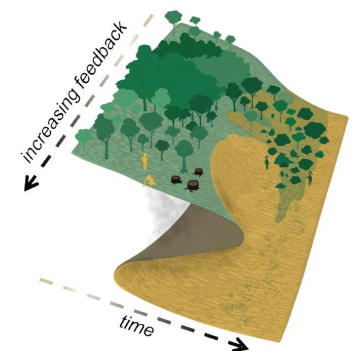
Resümee

1. Anwendung der Tipping Point Theorie in der Landschafts- und Ökosystemforschung?

- ✓ weiterer Forschungsbedarf für geeignete Skalen und Resilienzindikatoren
- ✓ ‚Critical Slowing Down‘ Theorie und ‚System shift‘ in Fallstudien präzisieren und Anwendbarkeit auf weitere terrestrische Ökosysteme überprüfen

2. Sind fernerkundliche Zeitreihen geeignet, um Kipppunkte präzise zu messen und zukünftige Veränderungen frühzeitig vorherzusagen?

- ✓ Zeitreihenanalysen verbessern ein genaues Ökosystemverständnis (Pattern-Process-Relationships)
- ✓ Kipppunktanalysen anhand von historischen Zeitreihen aus Satellitendaten bedingt anwendbar (zeitl. Auflösung, räuml. Auflösung, Umgang mit Datenlücken)



Bathiany et al. 2016



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Herzlichen Dank. Thank you.

