TOWARDS THE LARGE-SCALE ASSESSMENT OF VEGETATION BIOMASS STABILITY

De Keersmaecker W., Lhermitte S., Tits L., Honnay O., Coppin P., Somers B.
KU Leuven, Belgium

Wanda.DeKeersmaecker@biw.kuleuven.be
Multitemp- July 2015

KU LEUVEN

Ecosystem services

Polination

Disease regulation

Provision of goods

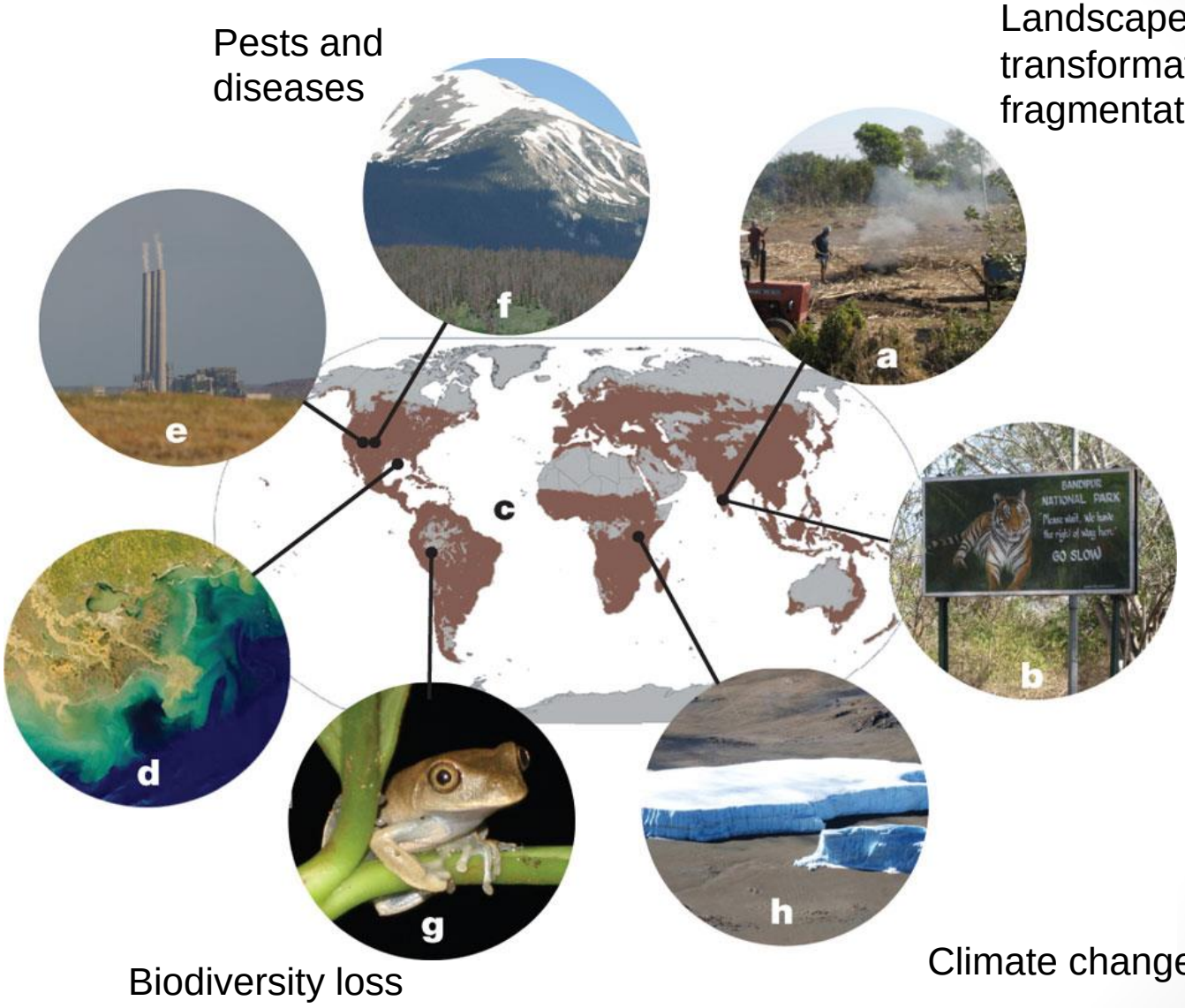
Ecosystem services

Water purification

Air quality

Carbon sequestration

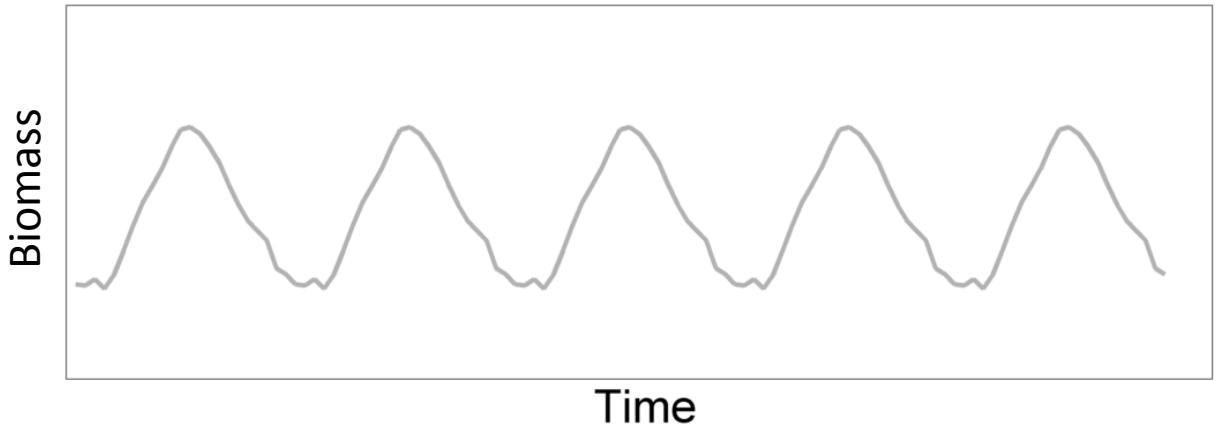
Climate regulation



Barnosky *et al*. (2012). Nature, 486

Vegetation stability

- Vegetation resistance, resilience and variance



De Keersmaecker *et al.* (2014). Global Change Biology

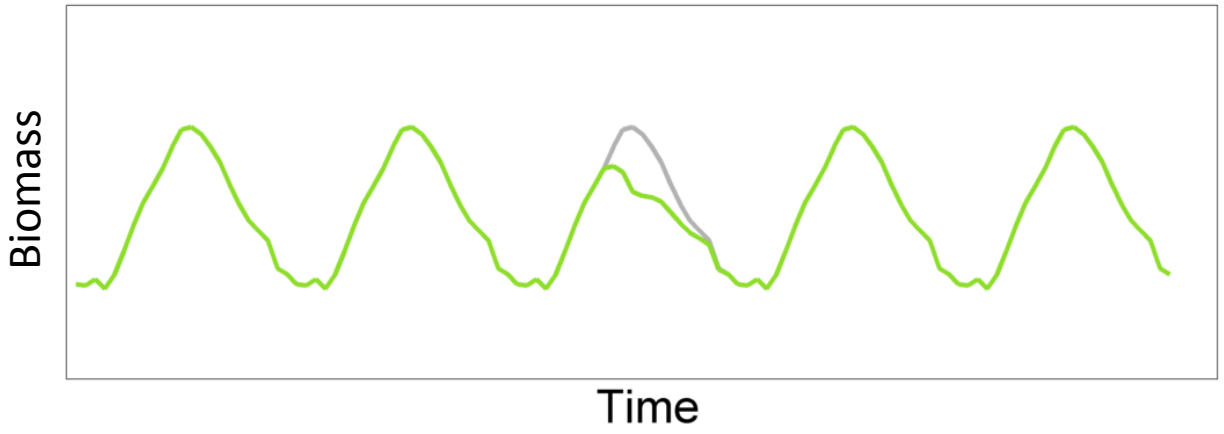
Vegetation stability

- Vegetation resistance, resilience and variance

De Keersmaecker *et al.* (2014). Global Change Biology

Vegetation stability

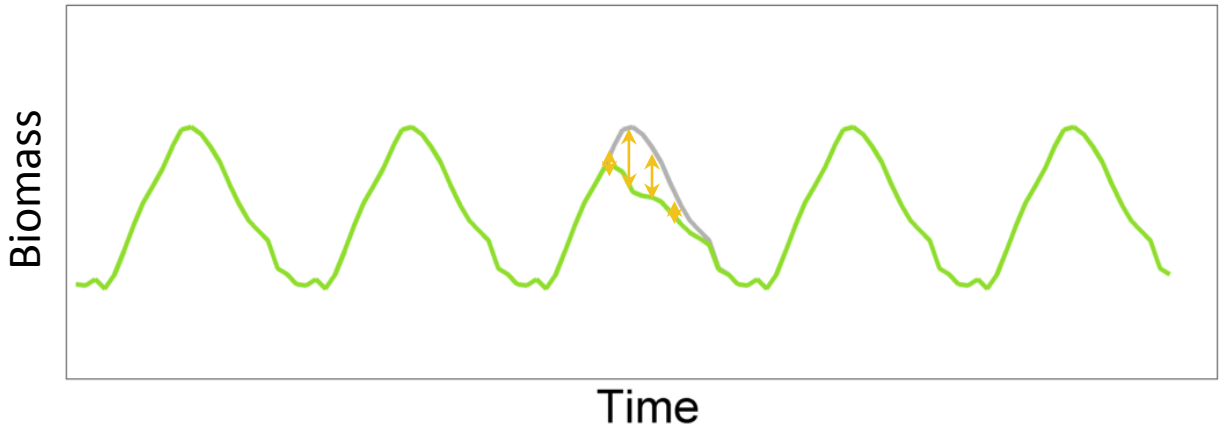
- Vegetation resistance, resilience and variance



De Keersmaecker *et al.* (2014). Global Change Biology

Vegetation stability

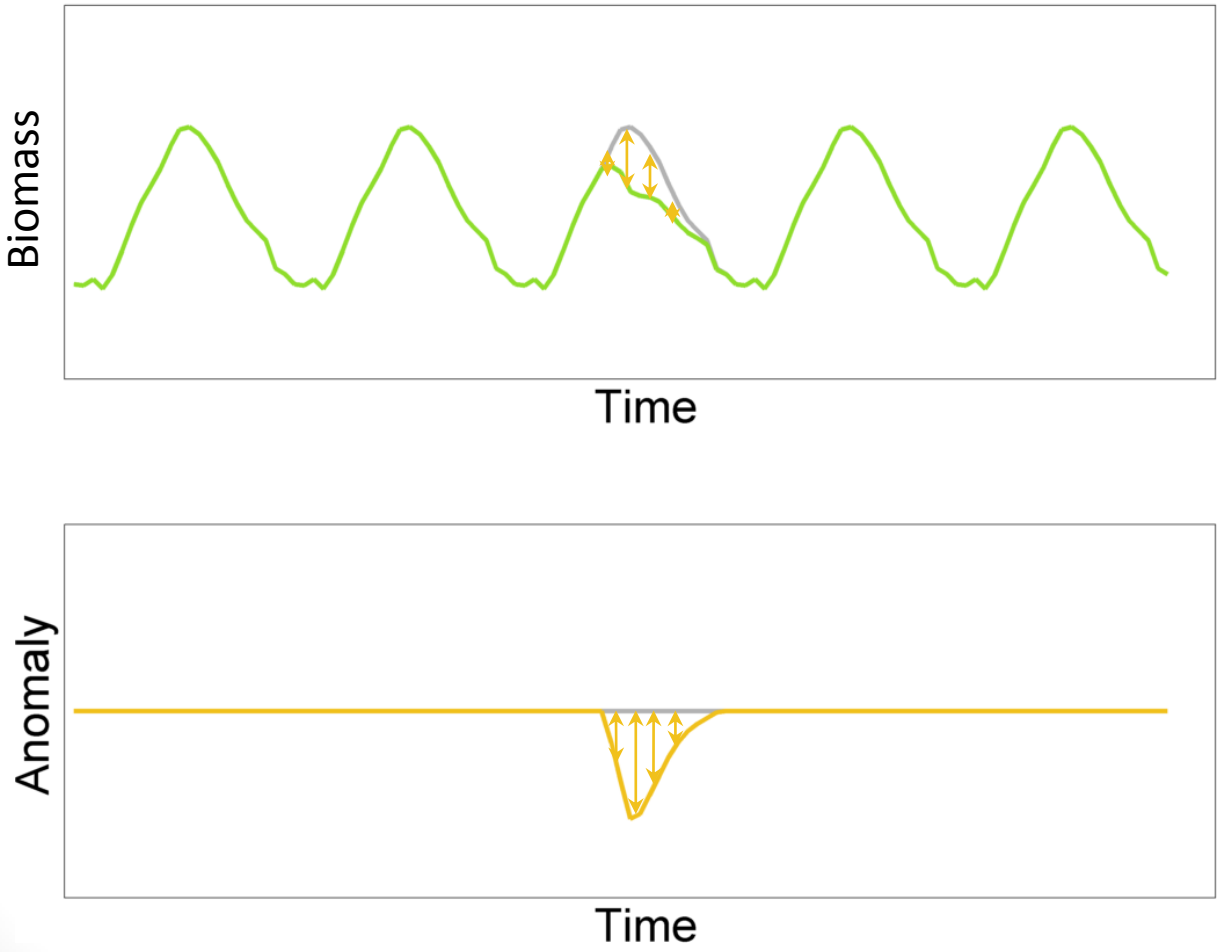
- Vegetation resistance, resilience and variance



De Keersmaecker *et al.* (2014). Global Change Biology

Vegetation stability

- Vegetation resistance, resilience and variance



De Keersmaecker *et al.* (2014). Global Change Biology

Vegetation stability

- Vegetation resistance, resilience and variance

De Keersmaecker *et al.* (2014). Global Change Biology

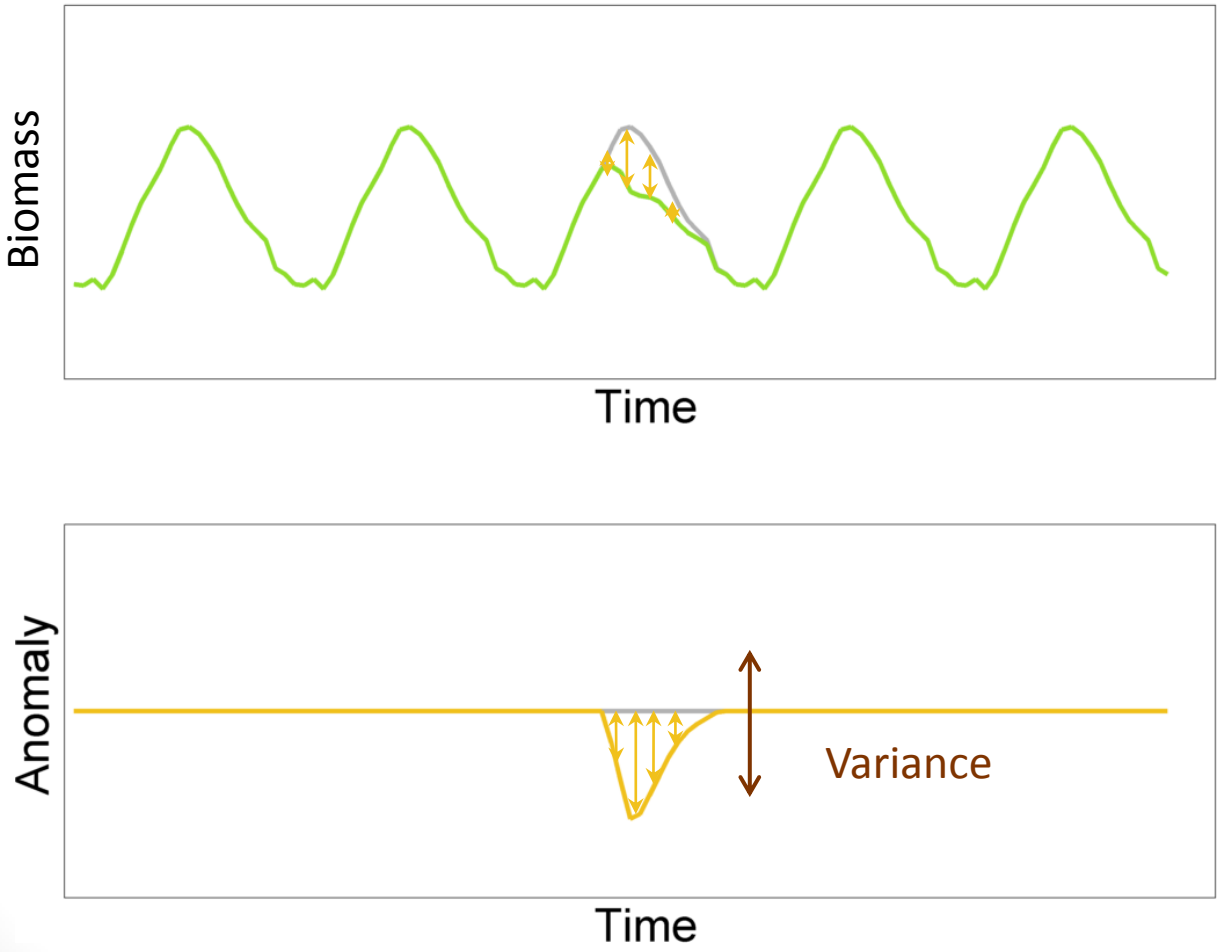
Vegetation stability

- Vegetation resistance, resilience and variance

De Keersmaecker *et al.* (2014). Global Change Biology

Vegetation stability

- Vegetation resistance, resilience and variance



De Keersmaecker *et al.* (2014). Global Change Biology

Vegetation stability

- Relatively small scale field experiments

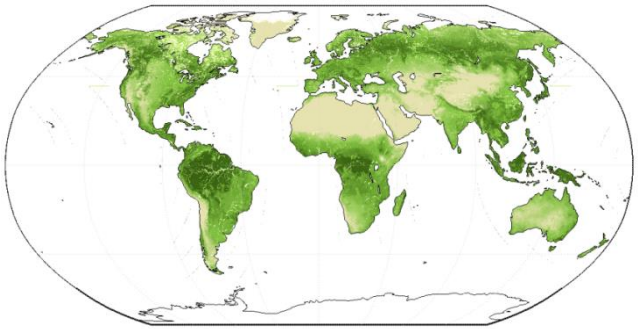
- Hector (1999), Science
- Tilman *et al.* (2006), Nature
- Van Ruijven and Berendse (2010), JoE
- Vogel *et al.* (2012) PloS ONE

Vegetation stability

- Relatively small scale field experiments

- Hector (1999), Science
- Tilman *et al.* (2006), Nature
- Van Ruijven and Berendse (2010), JoE
- Vogel *et al.* (2012) PloS ONE

Scaling up



Challenges

- 1. Noise and data characteristics

Challenges

- 1. Noise and data characteristics
- 2. Spatial heterogeneity of the climate anomalies

Challenges

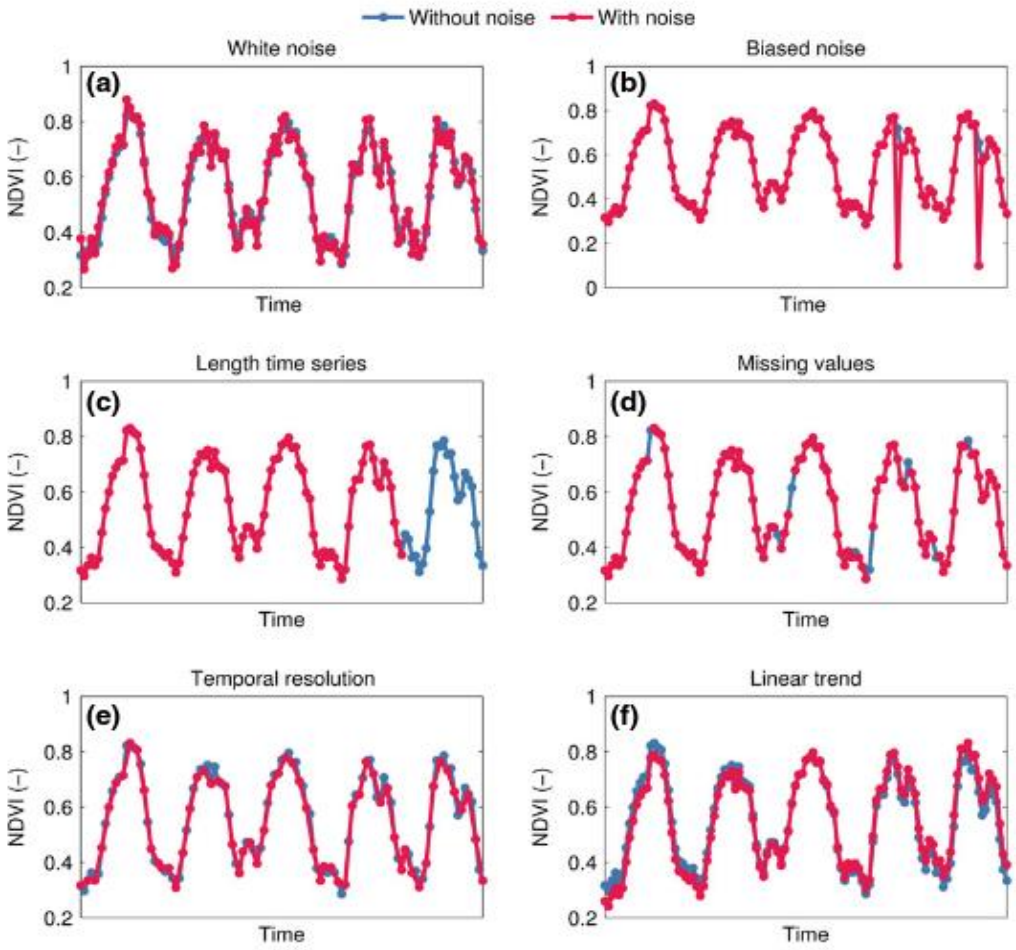
- 1. Noise and data characteristics
- 2. Spatial heterogeneity of the climate anomalies
- 3. Non-stationarity of the vegetation response to climate anomalies

NOISE AND DATA CHARACTERISTICS

Quantify:

- impact of noise
- reliability of time series

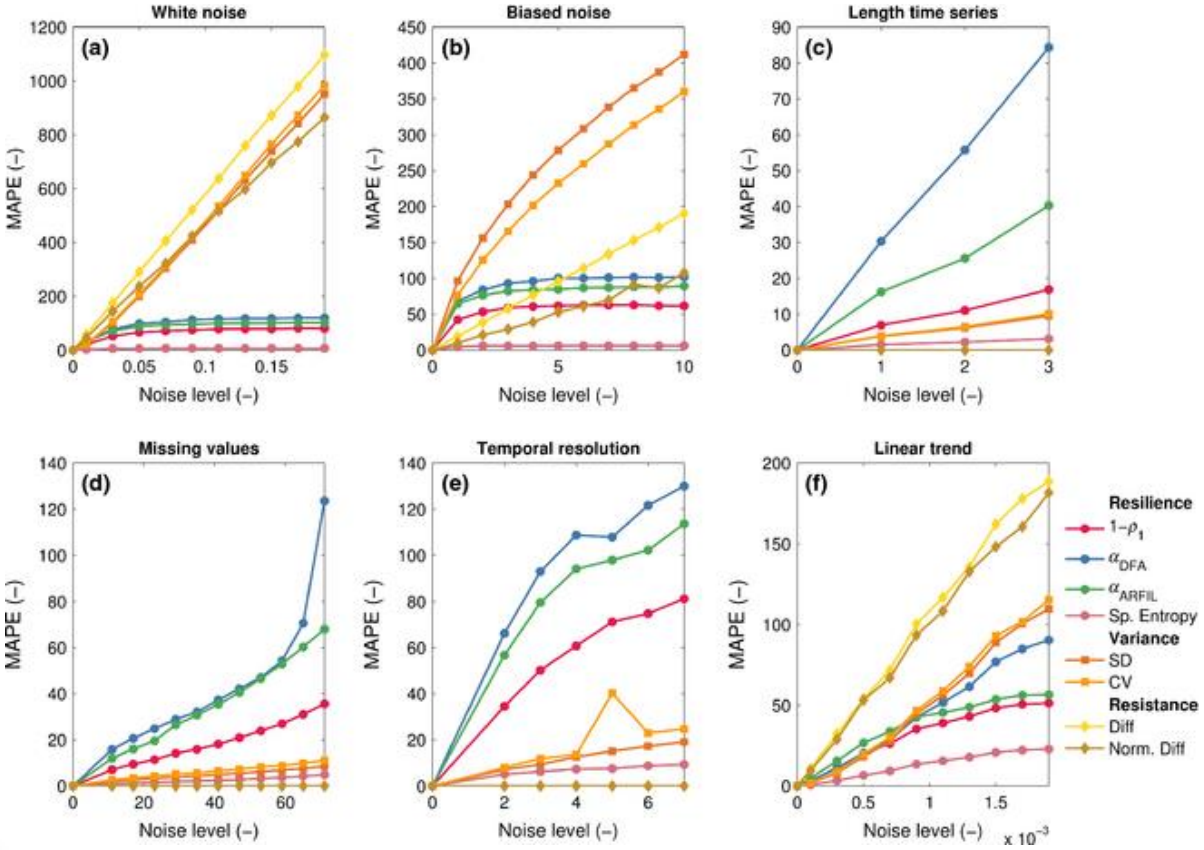
Interfering factors



De Keersmaecker *et al*. (2014). Global Change Biology

Framework

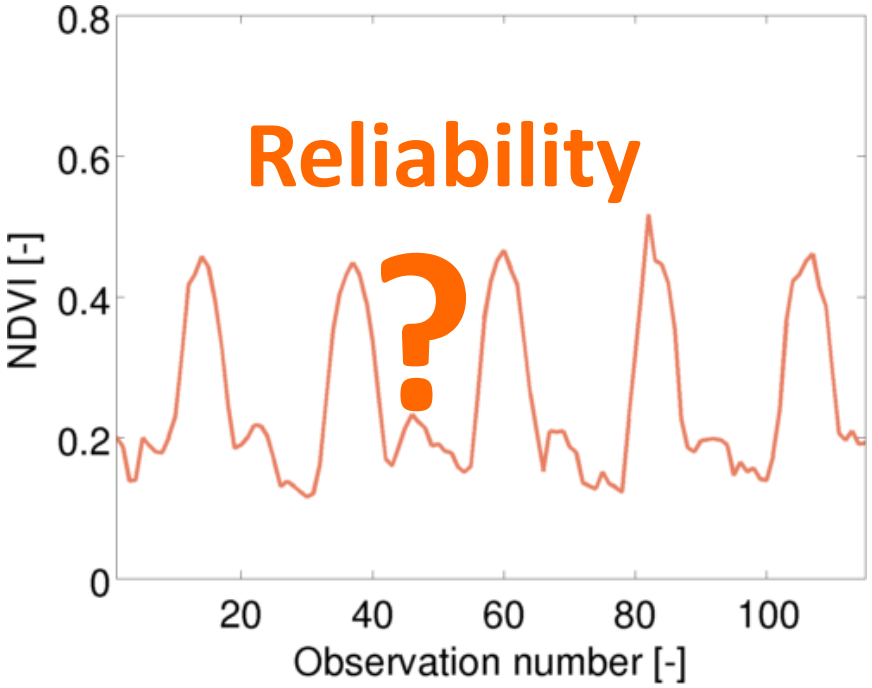
- 1. Sensitivity of metric to noise/data characteristics



De Keersmaecker *et al*. (2014). Global Change Biology

Framework

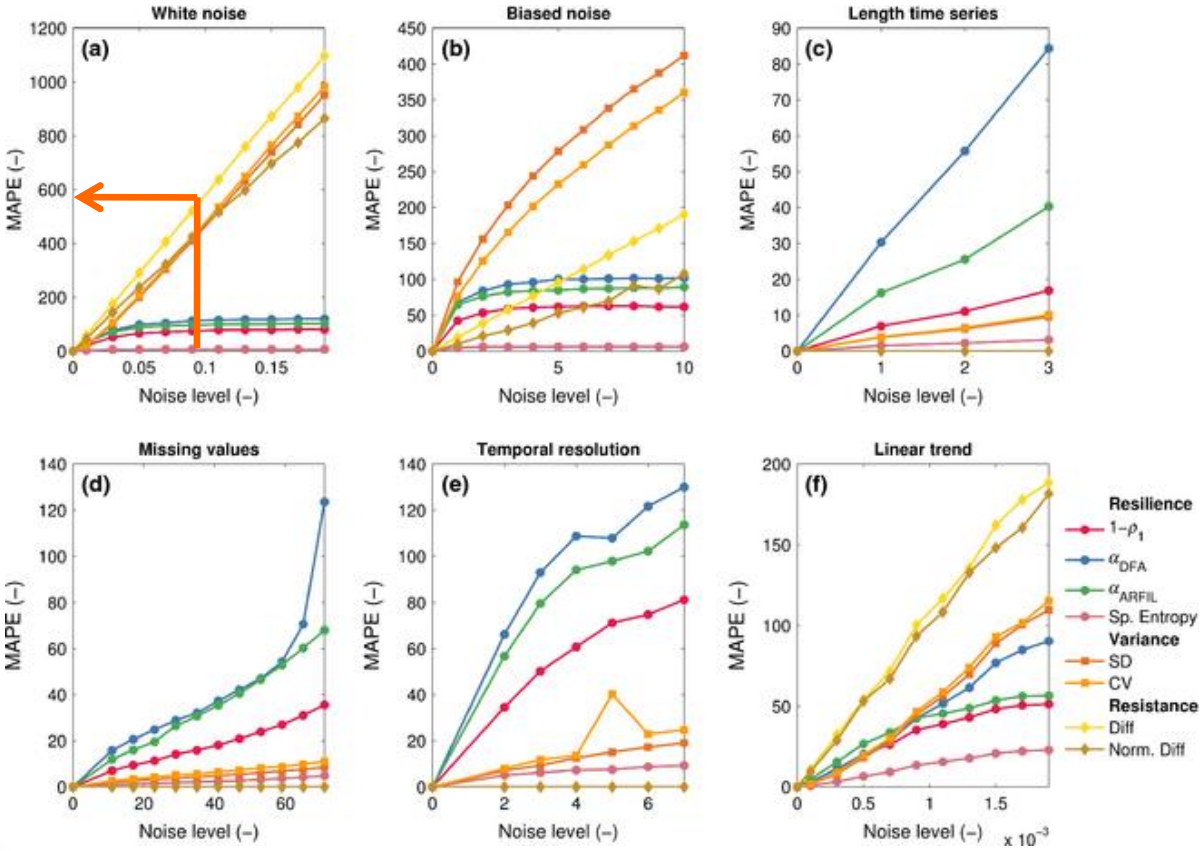
- 2. Reliability of time series



De Keersmaecker *et al*. (2014). Global Change Biology

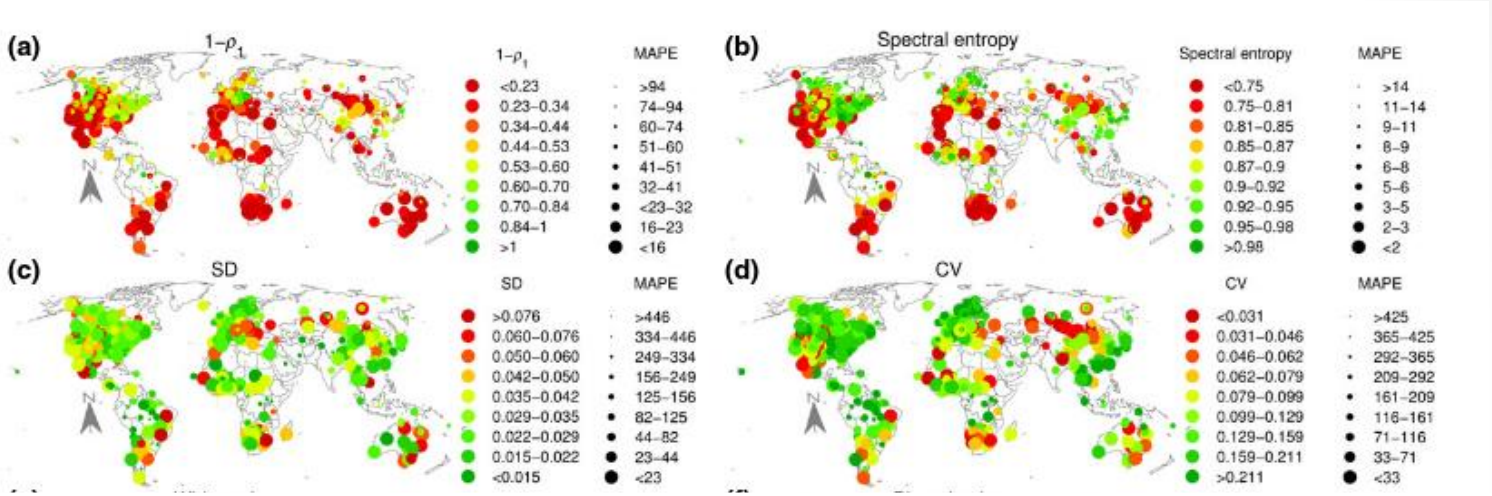
Framework

- 2. Reliability of time series



De Keersmaecker *et al*. (2014). Global Change Biology

Interfering factors

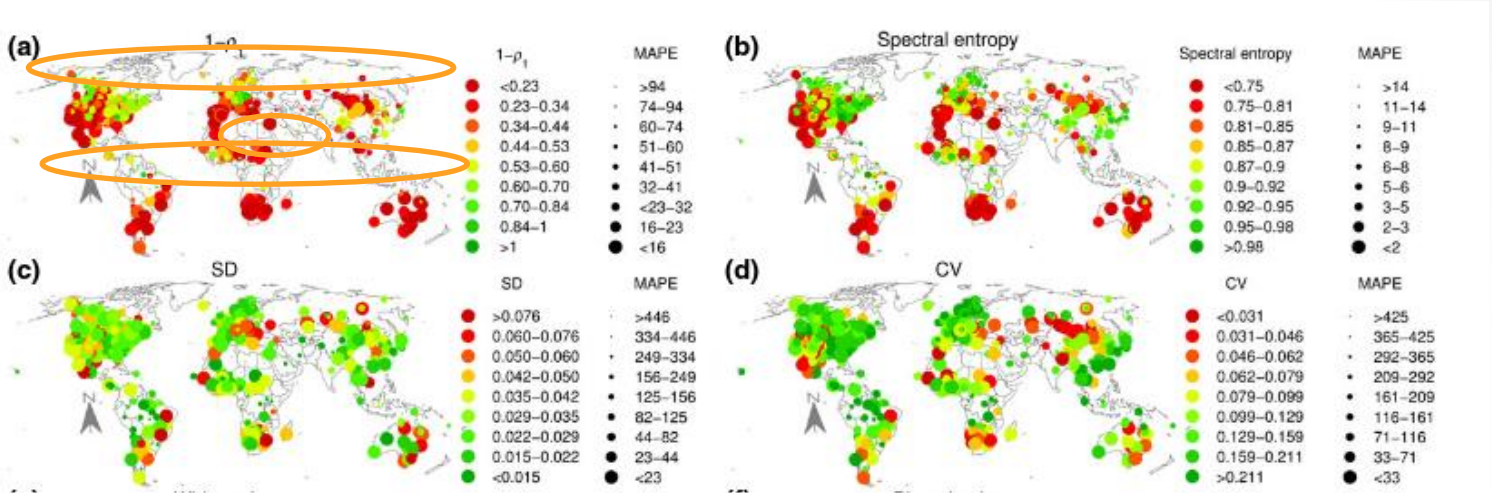


Data:

- MODIS NDVI (MOD13Q1 product) from 2001-2006 around 1079 flux towers or field sites

De Keersmaecker *et al*. (2014). Global Change Biology

Interfering factors

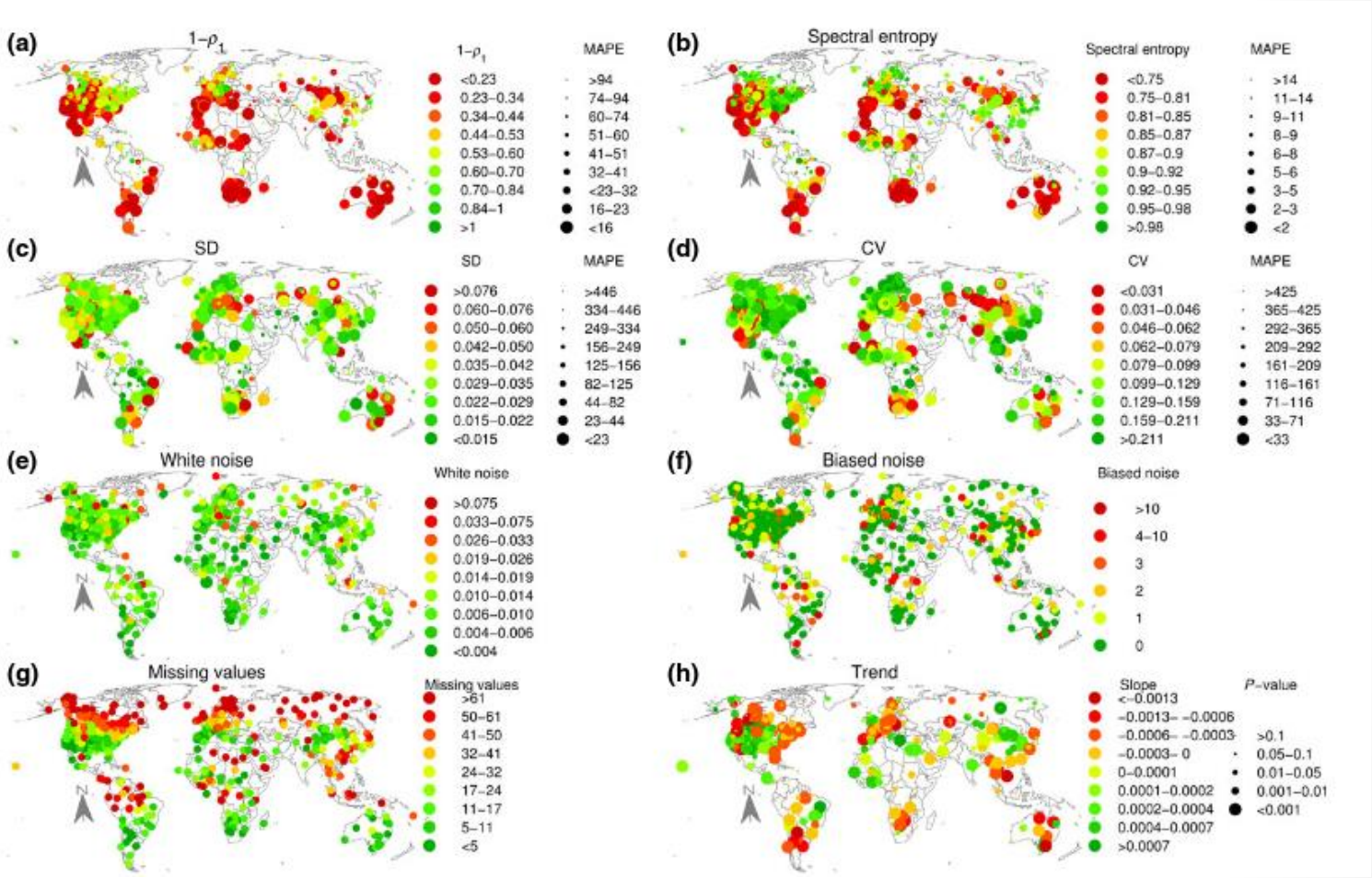


Data:

- MODIS NDVI (MOD13Q1 product) from 2001-2006 around 1079 flux towers or field sites

De Keersmaecker *et al*. (2014). Global Change Biology

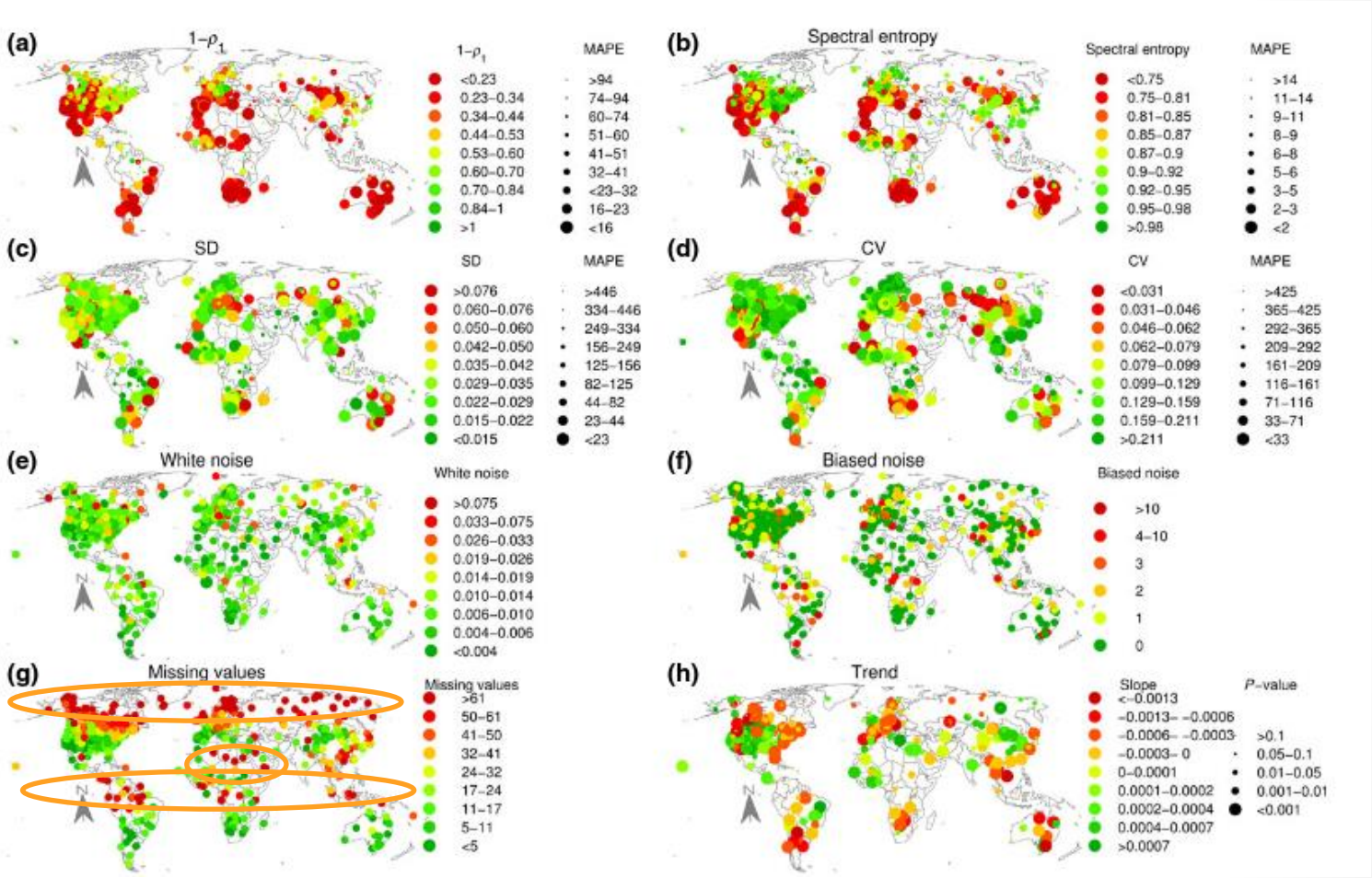
Interfering factors



Conclusion : "*Noise and data characteristics are a major interfering factor of remotely sensed stability metrics.*"

De Keersmaecker *et al*. (2014). Global Change Biology

Interfering factors

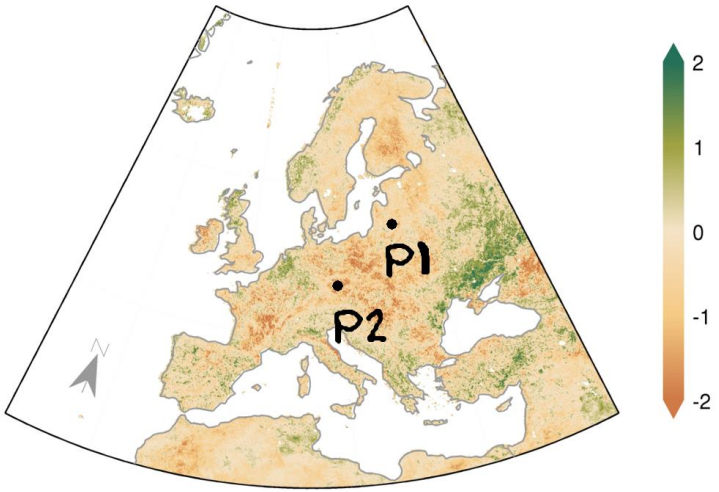


Conclusion : "*Noise and data characteristics are a major interfering factor of remotely sensed stability metrics.*"

SPATIAL HETEROGENEITY OF CLIMATE ANOMALIES

Problem statement

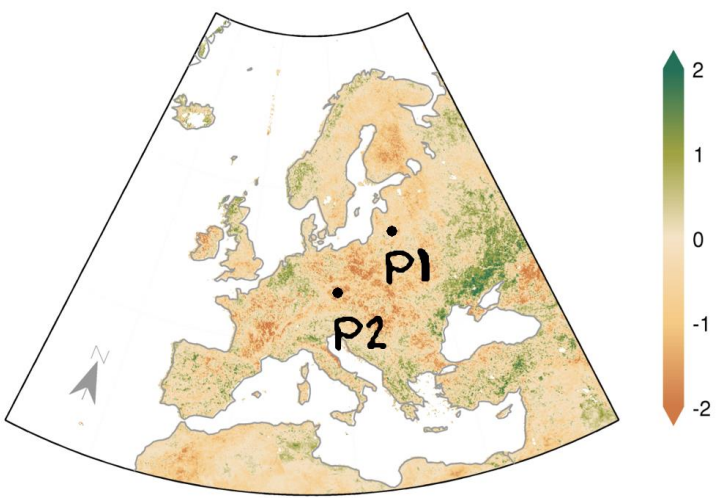
Biomass anomaly



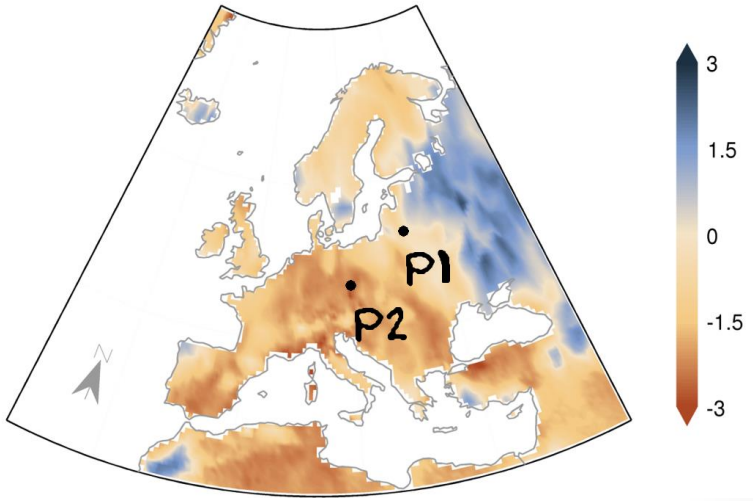
De Keersmaecker *et al*. (2014). Global Ecology and Biogeography

Problem statement

Biomass anomaly



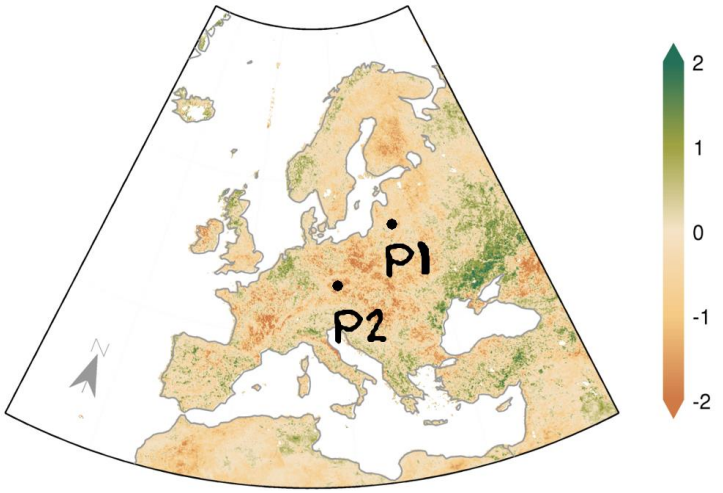
Climate anomaly



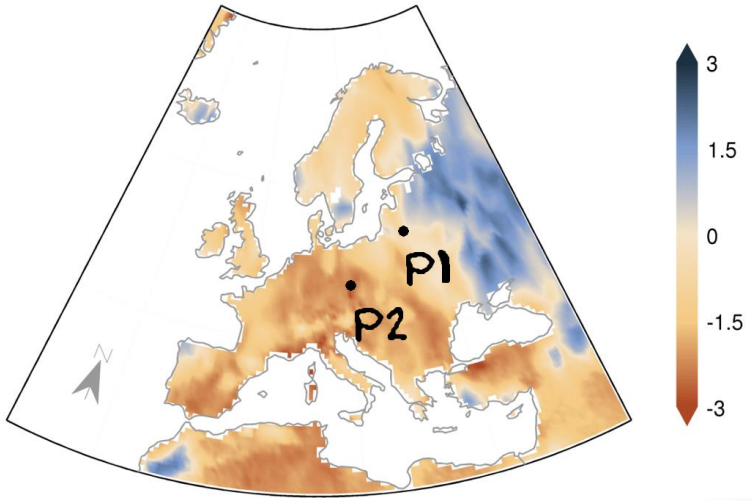
De Keersmaecker *et al*. (2014). Global Ecology and Biogeography

Problem statement

Biomass anomaly



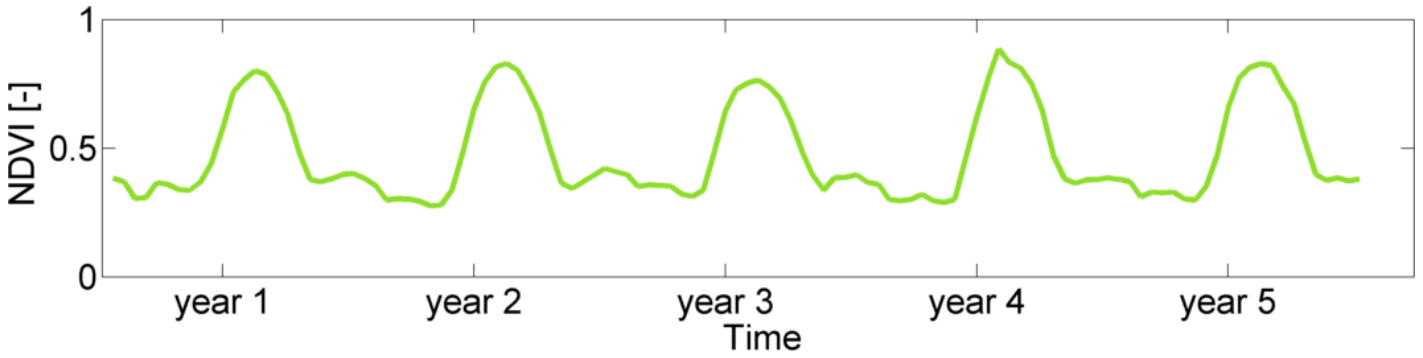
Climate anomaly



- Aim:
  - Standardised stability metrics for climate impact
    - Resistance to drought
    - Resistance to temperature anomalies
    - Resilience

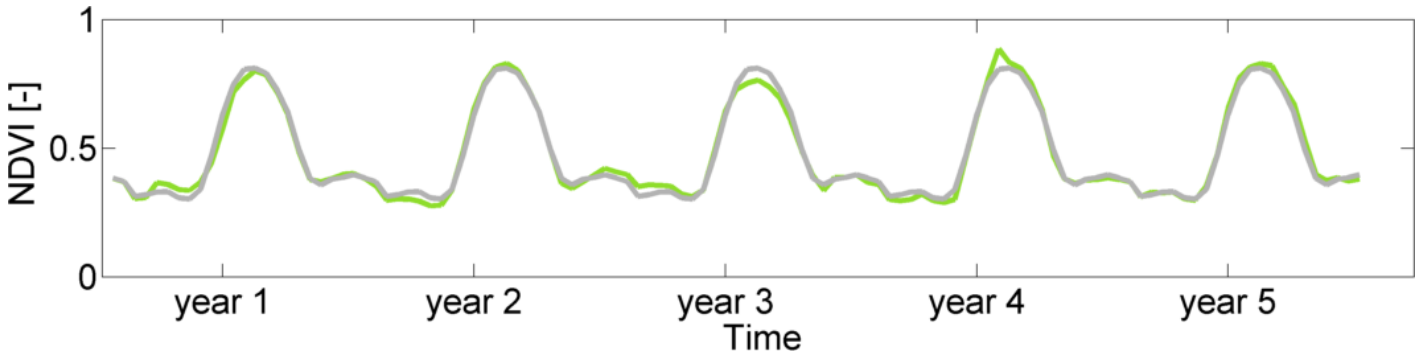
De Keersmaecker *et al*. (2014). Global Ecology and Biogeography

Vegetation stability: ARx model



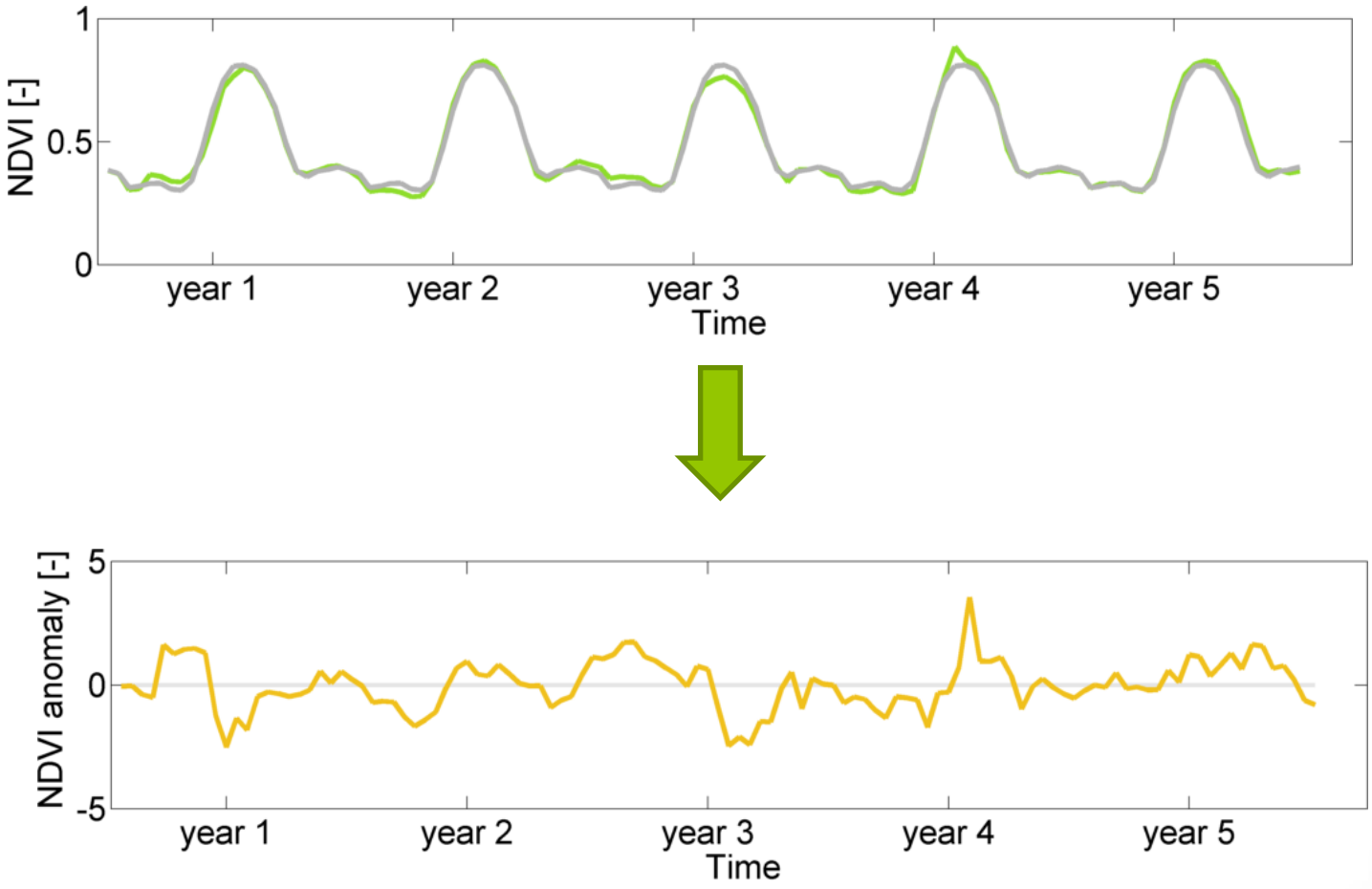
De Keersmaecker *et al*. (2014). Global Ecology and Biogeography

Vegetation stability: ARx model



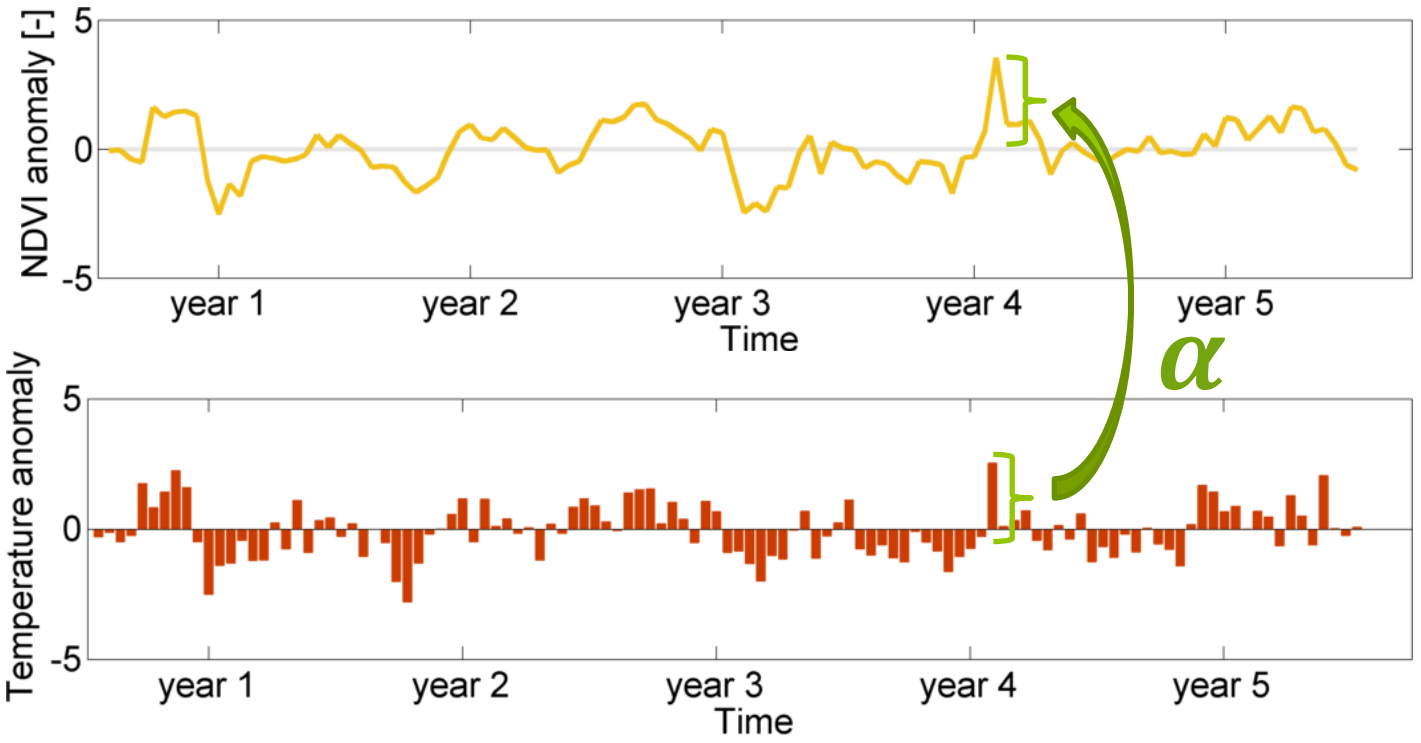
De Keersmaecker *et al*. (2014). Global Ecology and Biogeography

Vegetation stability: ARx model



De Keersmaecker *et al*. (2014). Global Ecology and Biogeography

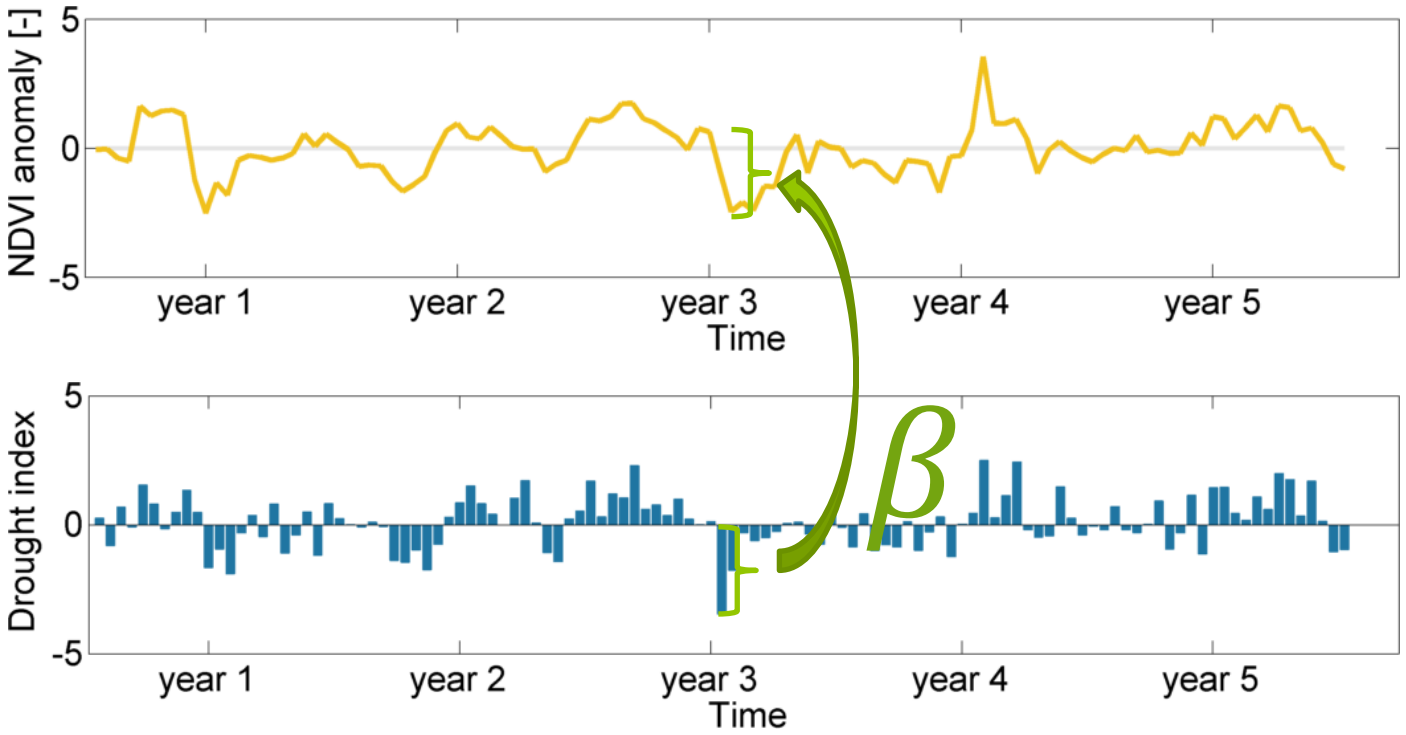
Vegetation stability: ARx model



- $NDVIanom_t = c + \alpha\, Tanom_t$

Resistance to temperature anomalies

Vegetation stability: ARx model

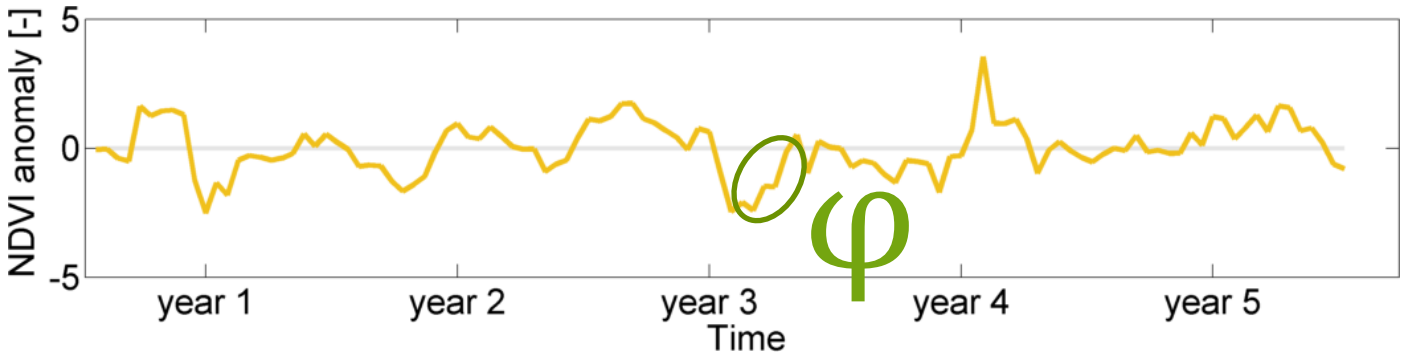


- $NDVIanom_t = c + \alpha\, Tanom_t + \beta\, SPEI_t$

Resistance to temperature anomalies

Resistance to droughts

Vegetation stability: ARx model



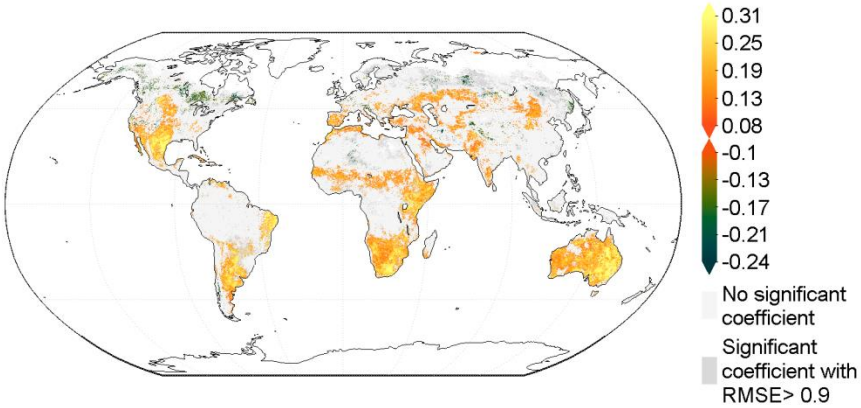
- $NDVIanom_t = c + \alpha\, Tanom_t + \beta\, SPEI_t + \varphi\, NDVIanom_{t-1} + \epsilon_t$

Resistance to temperature anomalies

Resistance to droughts

Resilience

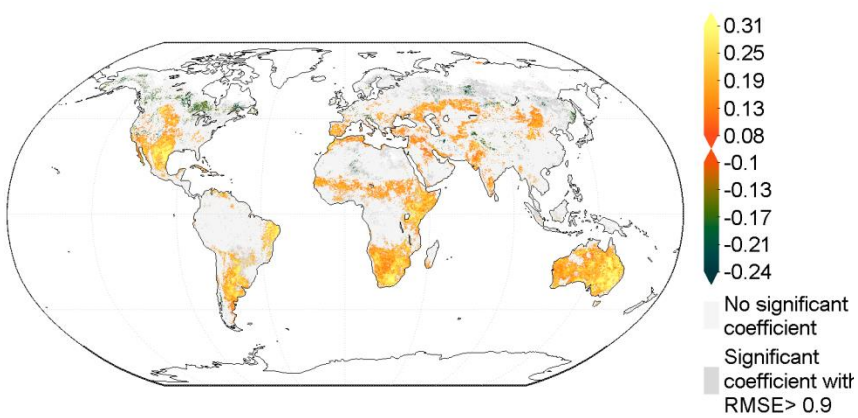
Application



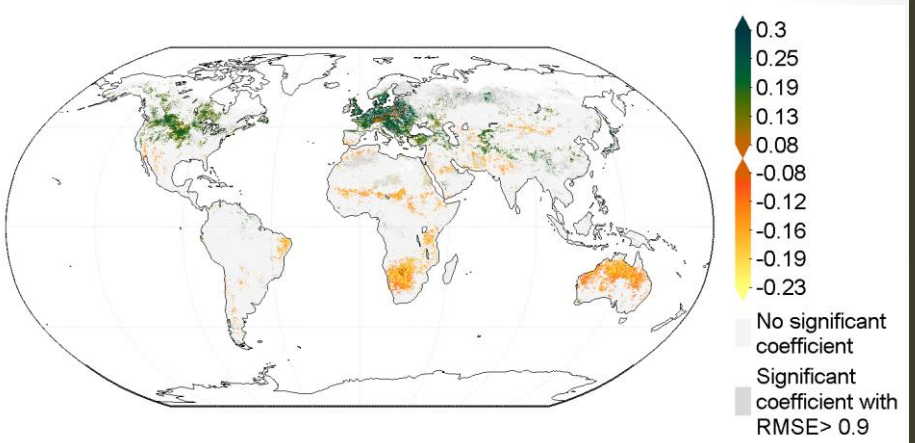
Resistance to drought (β)

- ARx model on:
  - GIMMS NDVI time series (1981 – 2006; 0.072°)
  - Temperature anomaly (GISS, 1200 km smoothing radius; 0.5°)
  - SPEI time series, (Vicente-Serrano; 3 months time scale; 0.5°)

Application

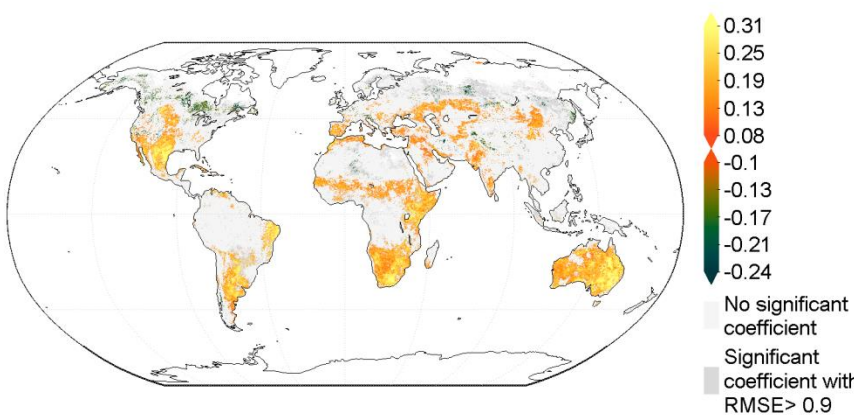


Resistance to drought (β)

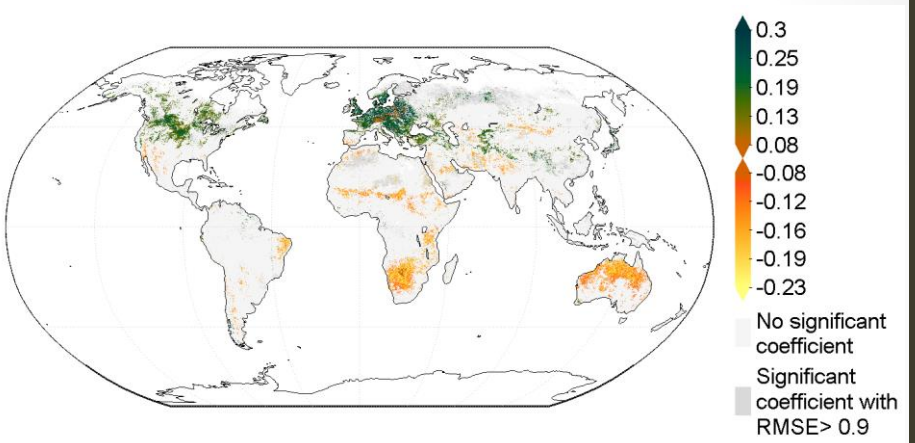


Resistance to temperature anomalies (α)

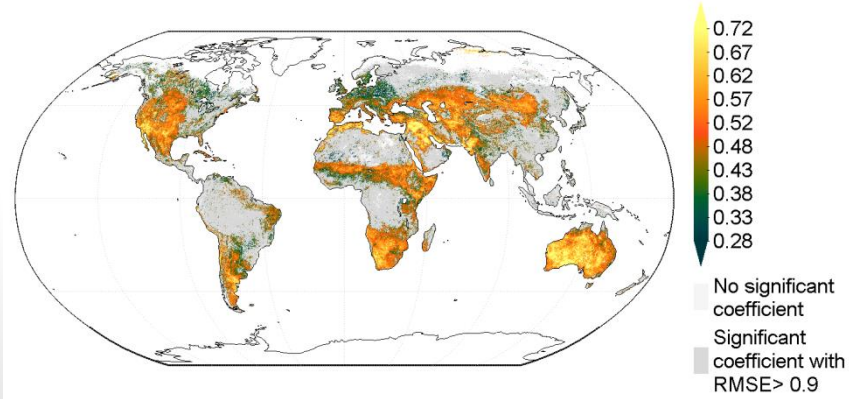
Application



Resistance to drought (β)

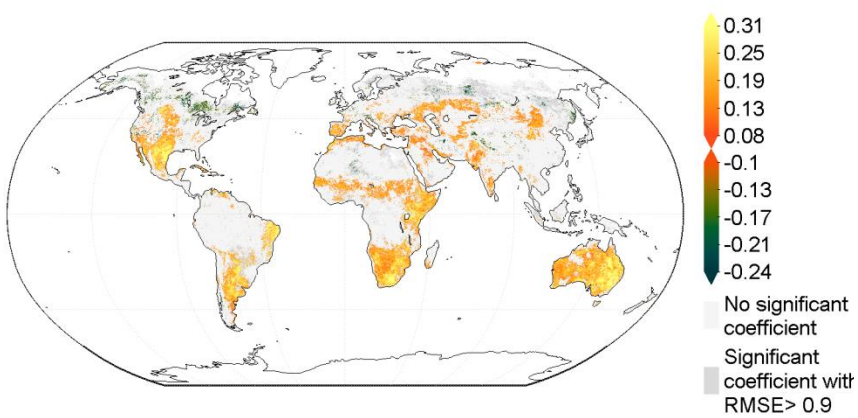


Resistance to temperature anomalies (α)

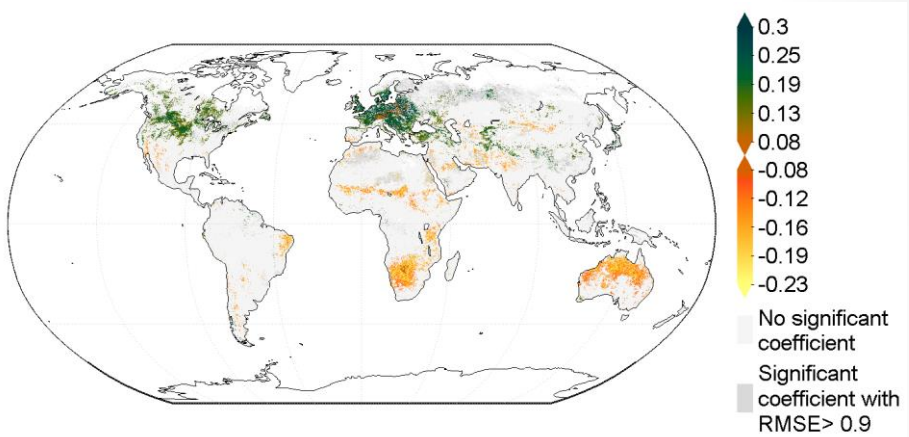


Resilience (φ)

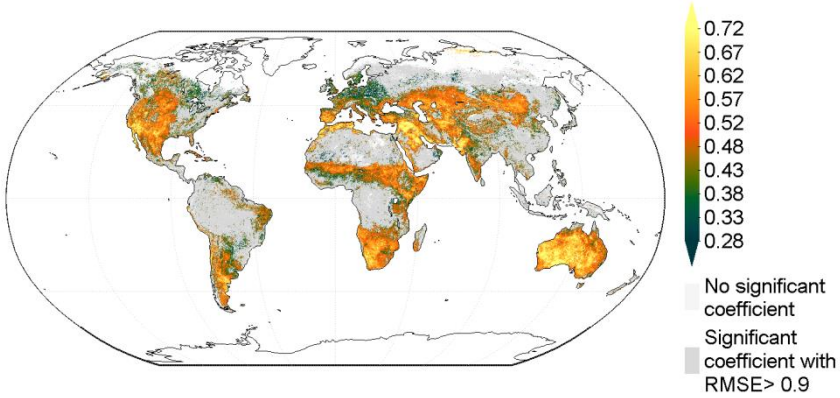
Application



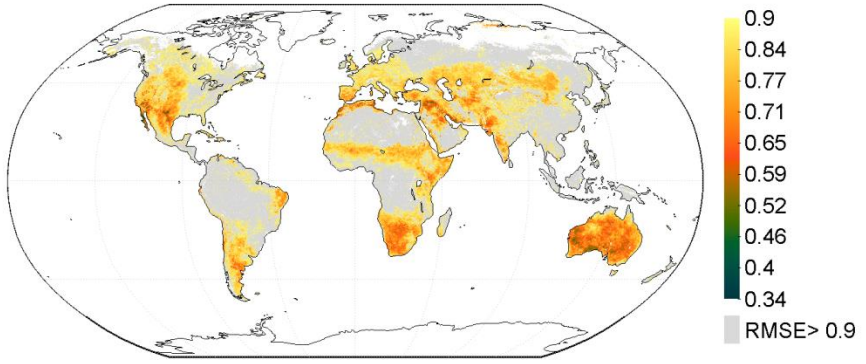
Resistance to drought (β)



Resistance to temperature anomalies (α)

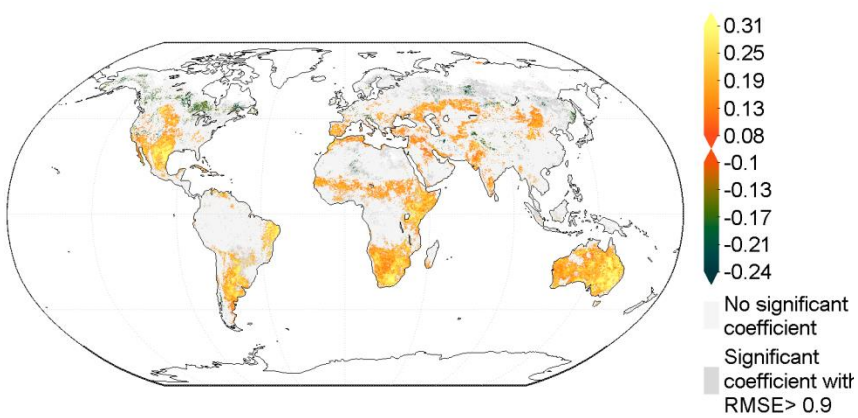


Resilience (φ)

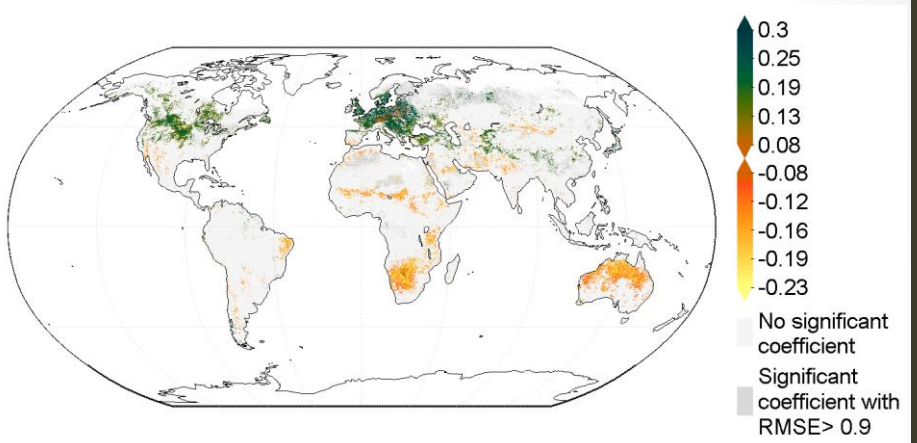


RMSE of ARx fit

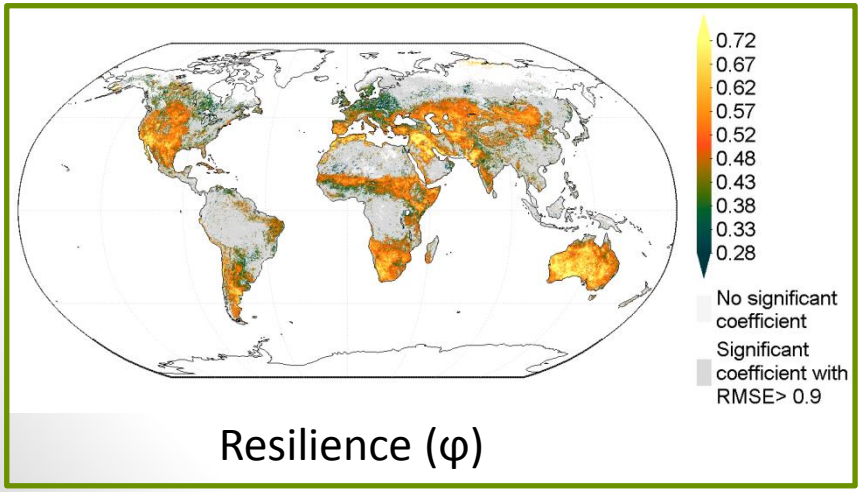
Application



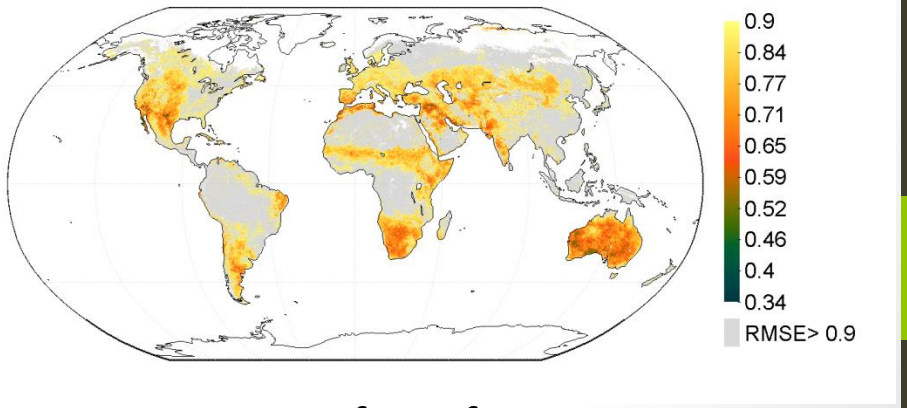
Resistance to drought (β)



Resistance to temperature anomalies (α)

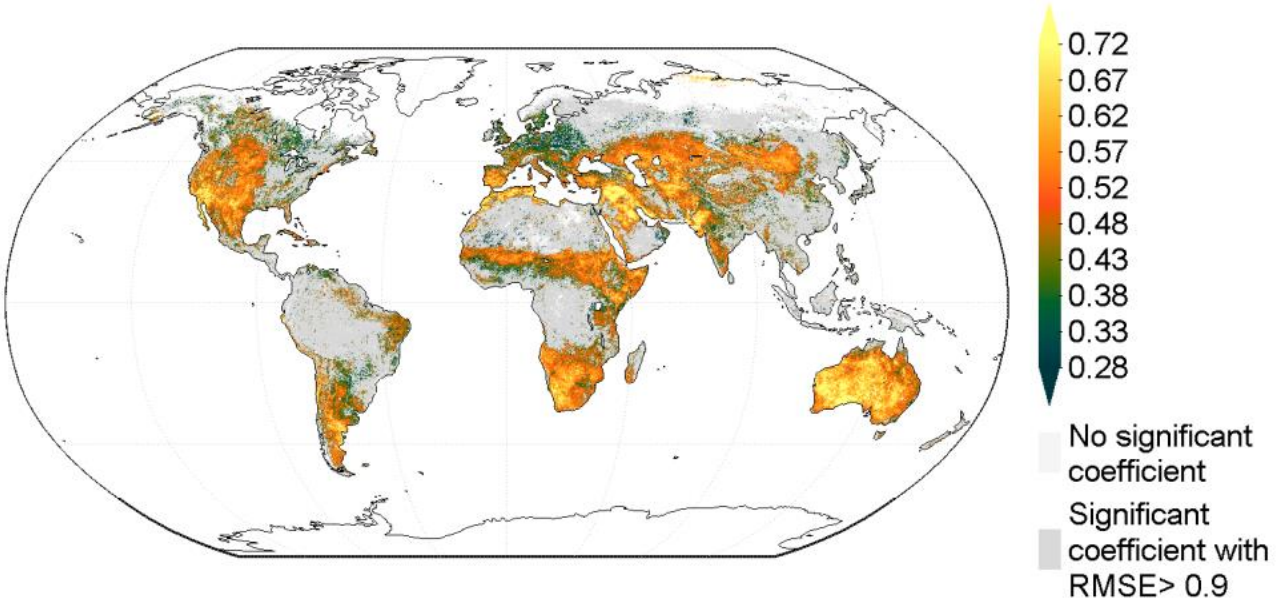


Resilience (φ)

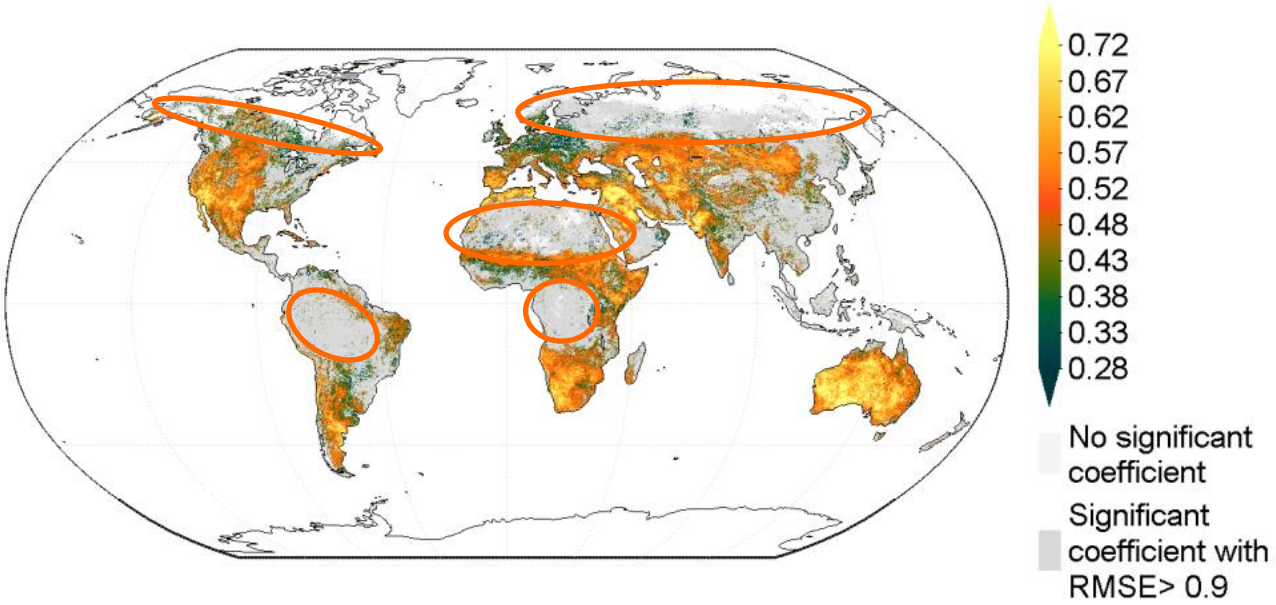


RMSE of ARx fit

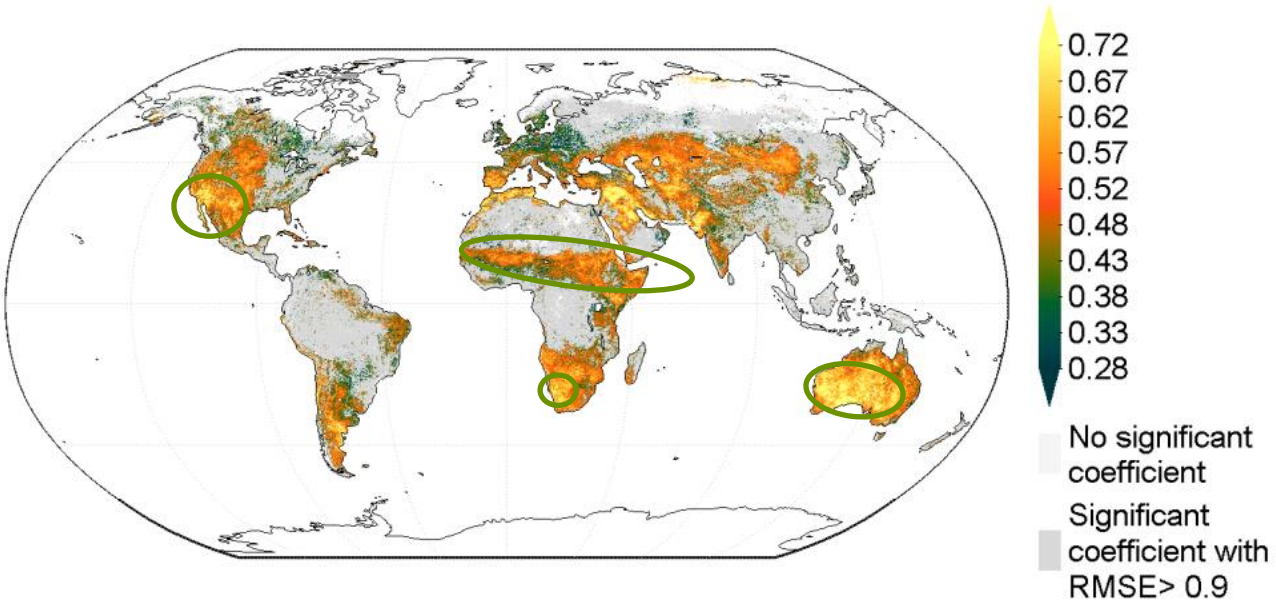
Application



Application



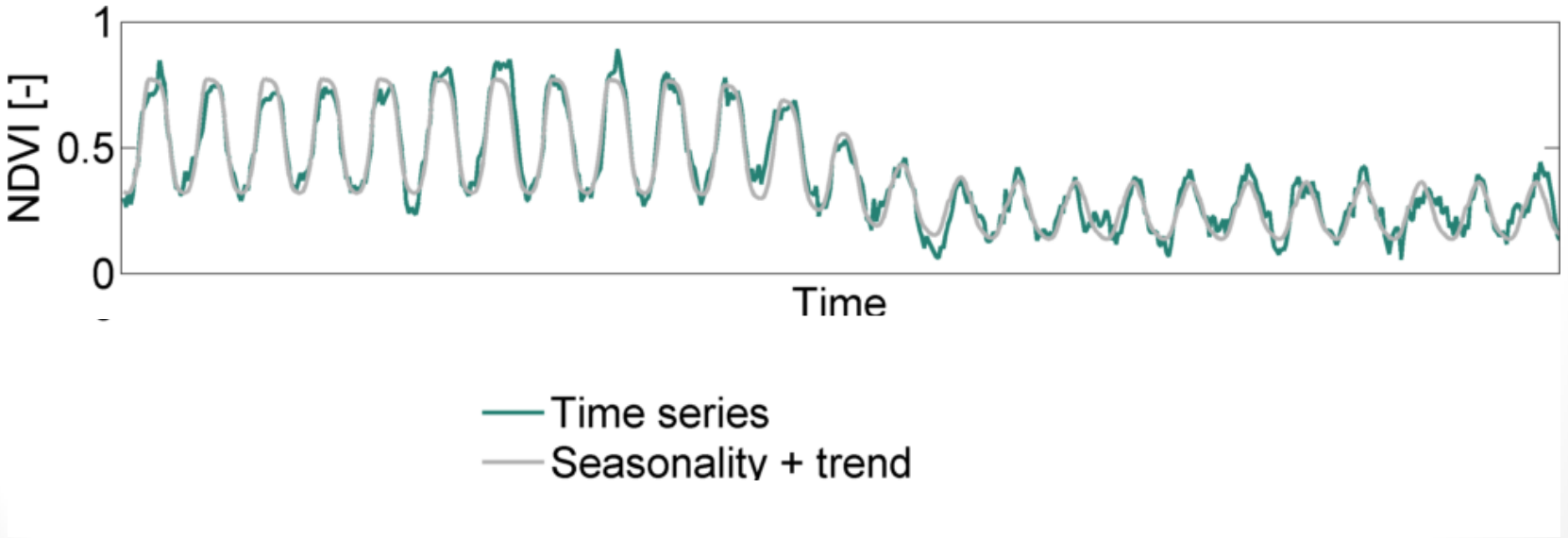
Application



NON-STATIONARY VEGETATION RESPONSE

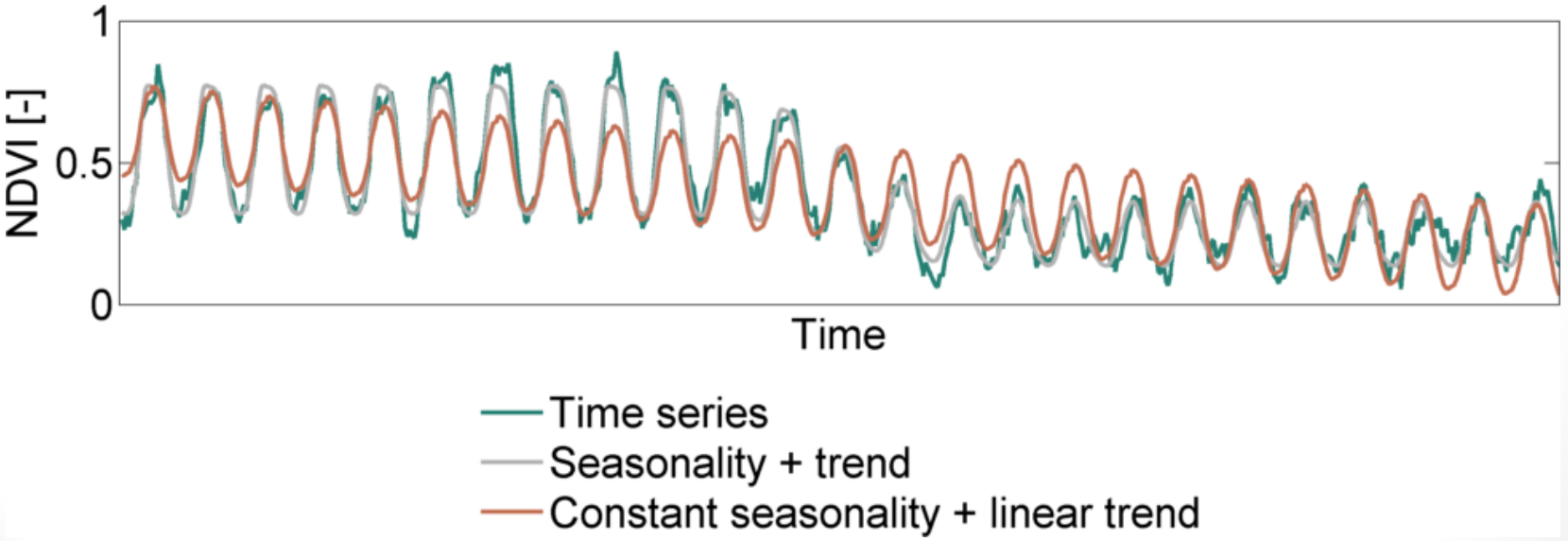
Non-stationarity

- Seasonality/climatology
- Trends



Non-stationarity

- Seasonality/climatology
- Trends



Non-stationarity

- Seasonality/climatology
- Trends

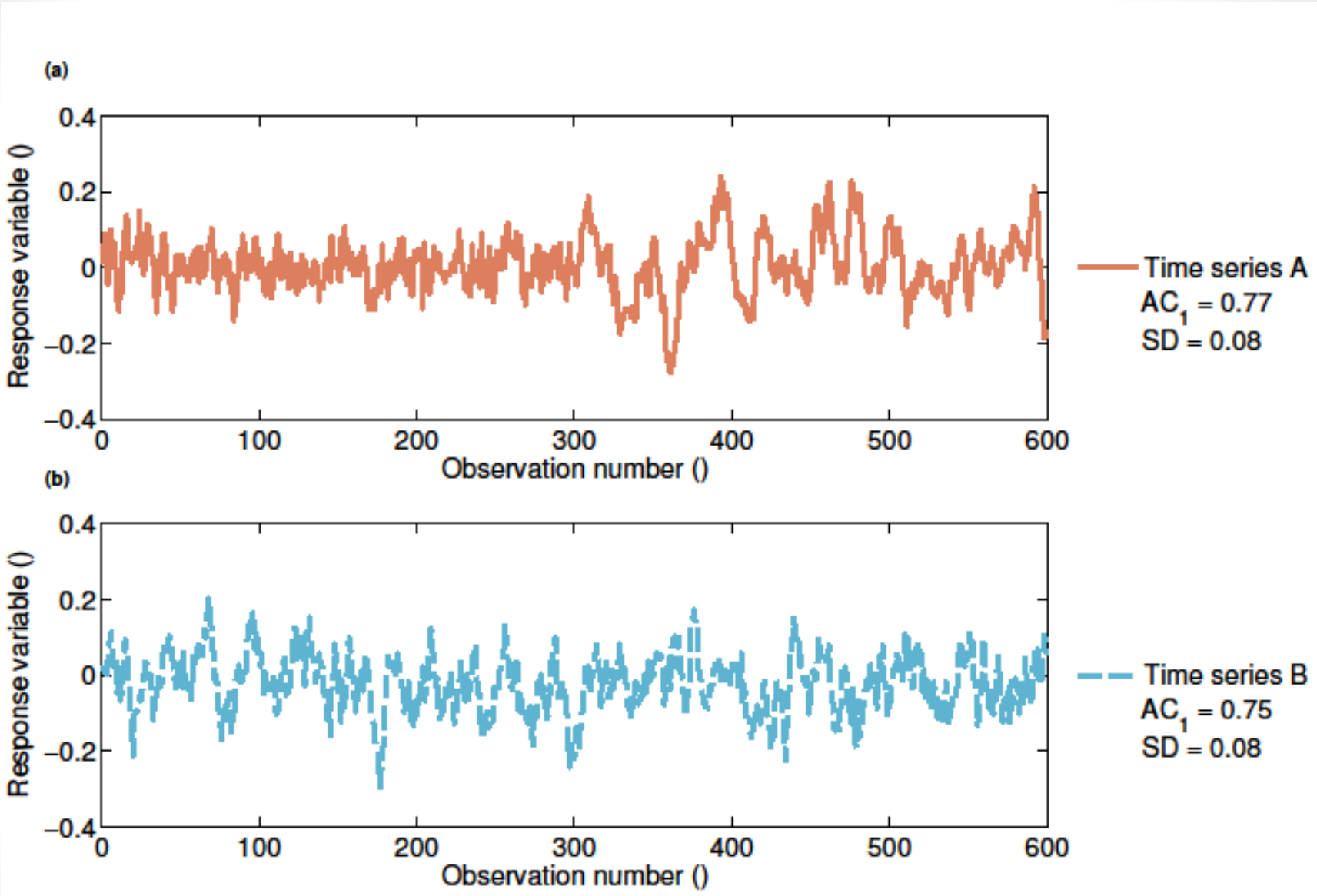
Breaks for Additive Season and Trend (BFAST) algorithm

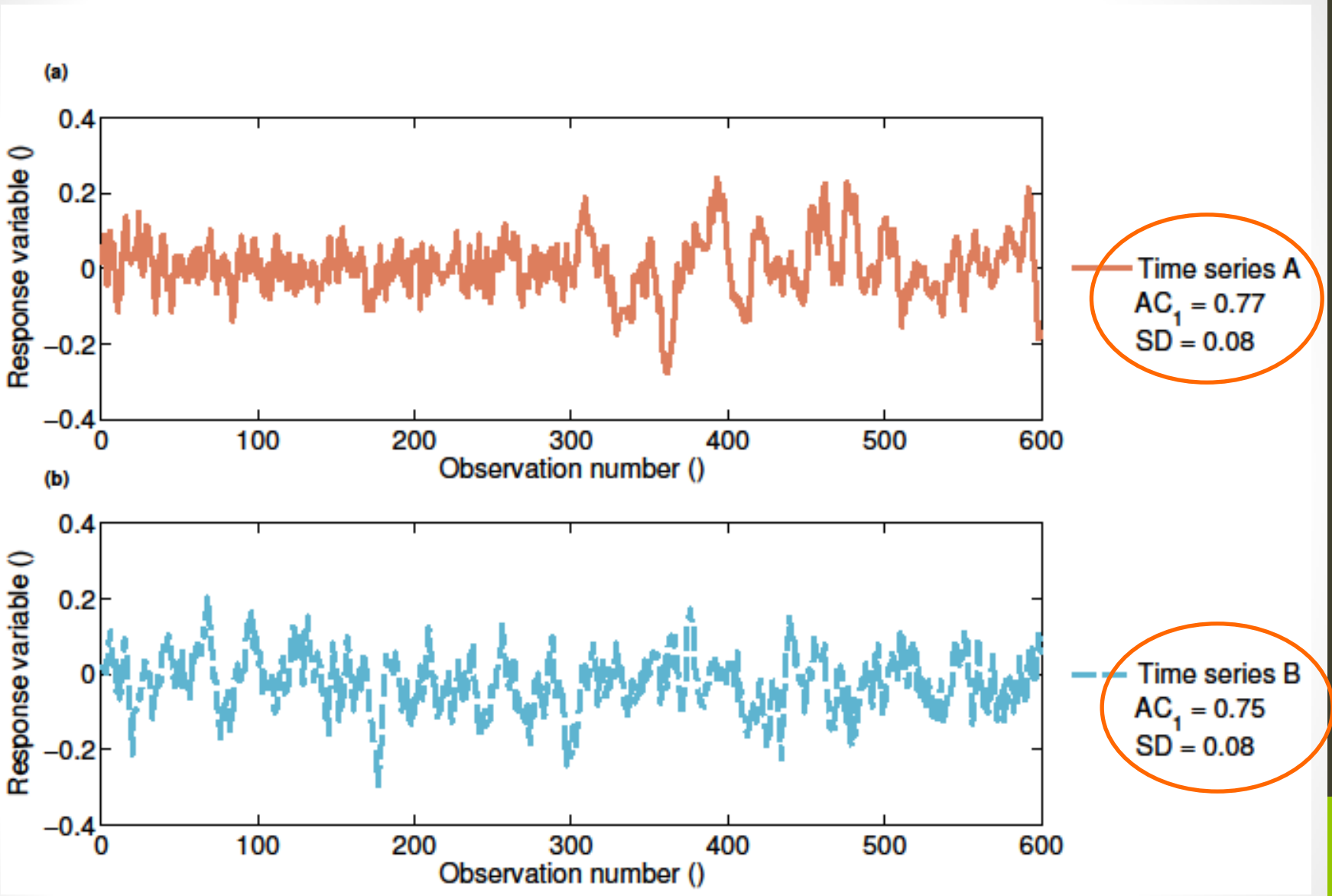
Verbesselt J. *et al.* (2010). Remote Sensing of Environment

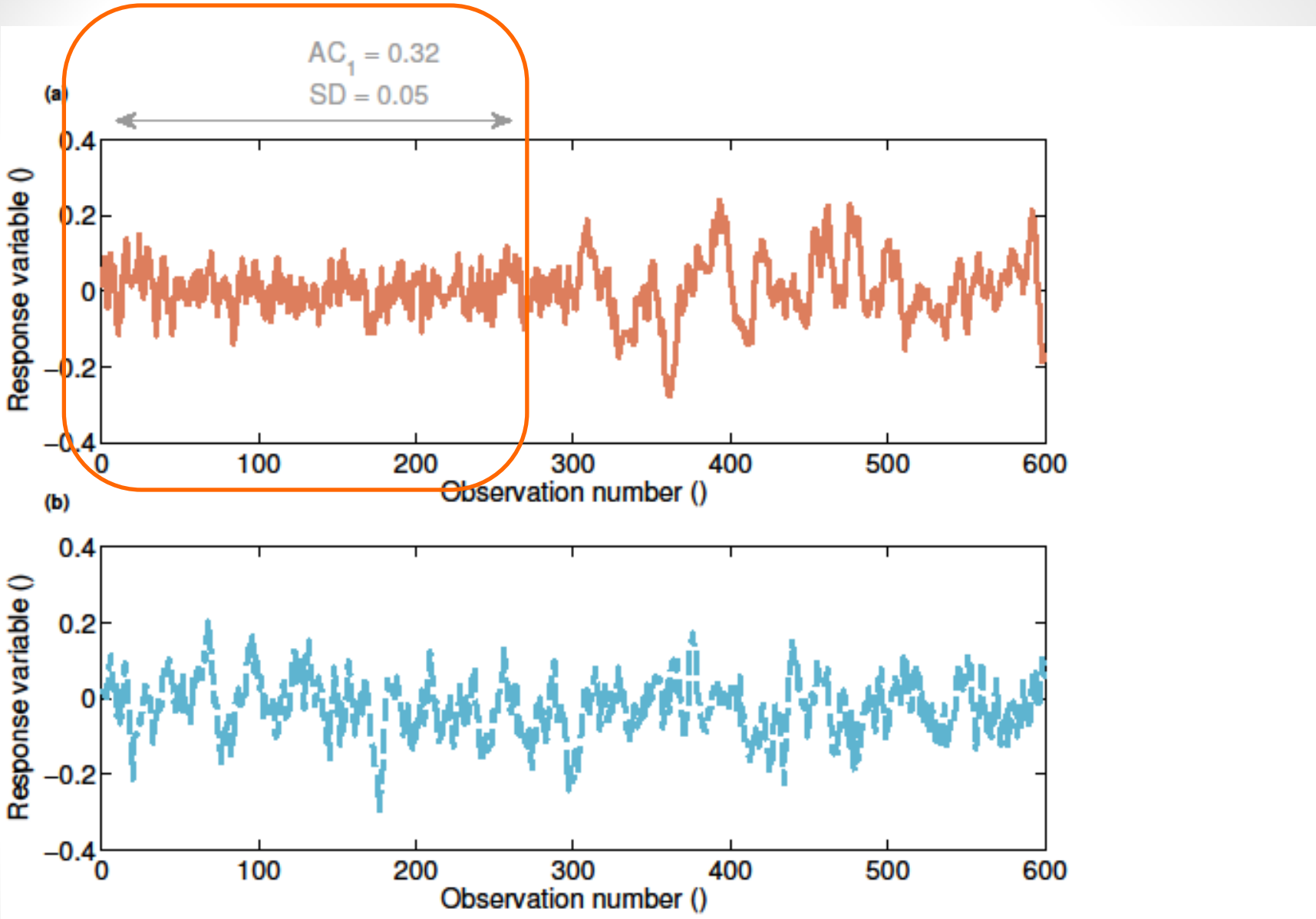
Non-stationarity

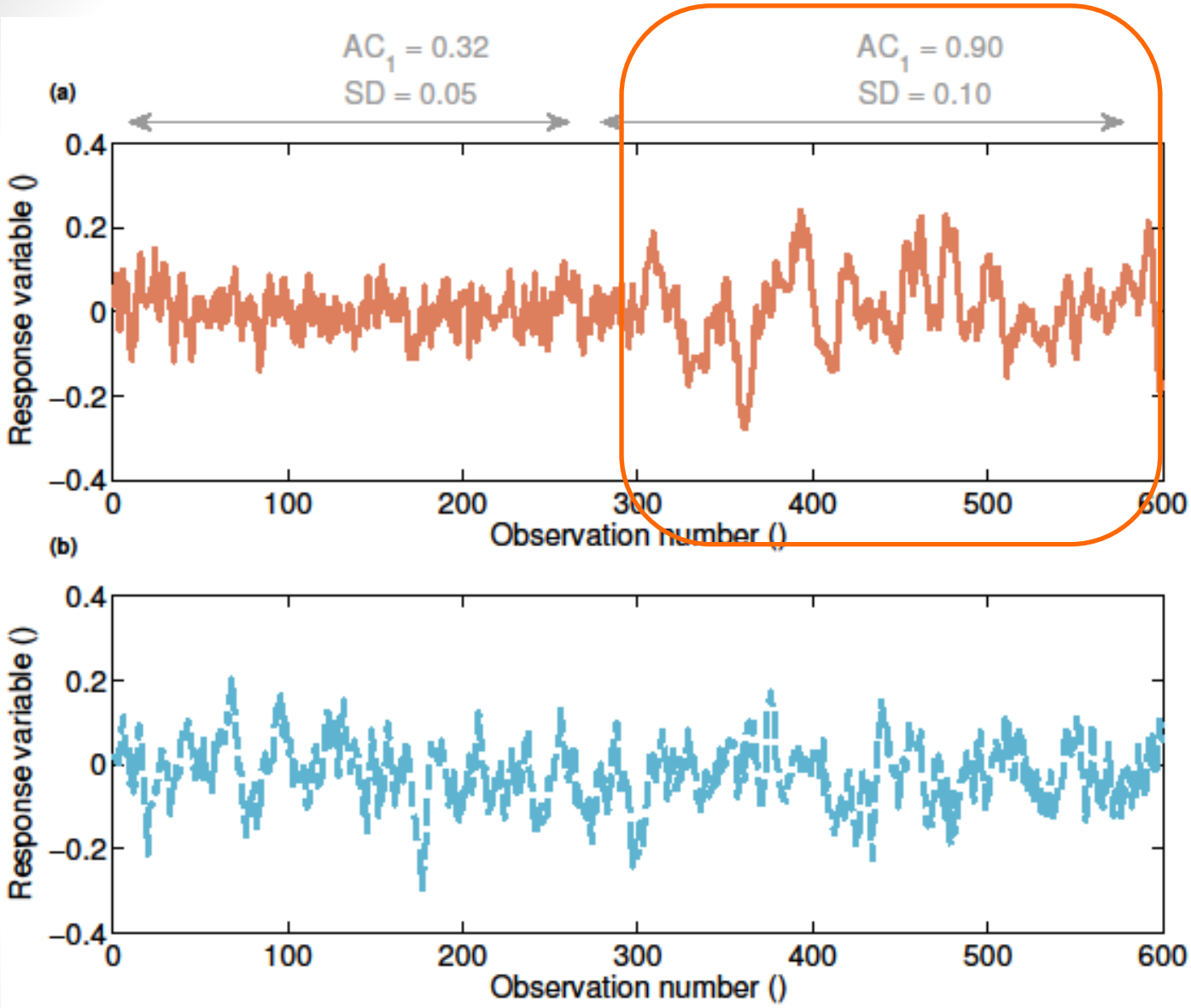
- Seasonality/climatology
- Trends
- Anomaly

Breaks for Additive Season and Trend (BFAST) algorithm

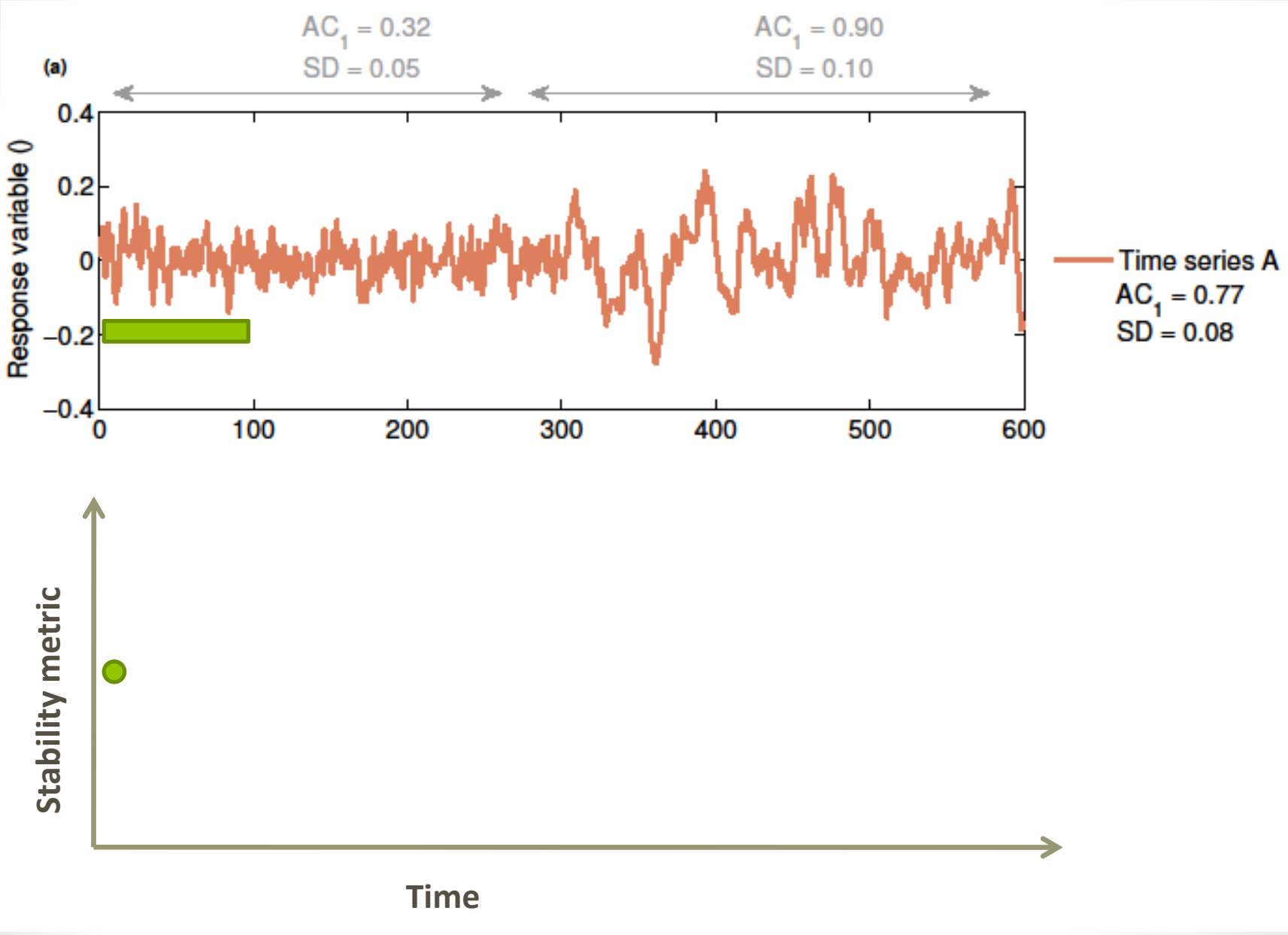

(a)
0.4
0.2
0
−0.2
−0.4
Response variable ()
0
100
200
300
400
500
600
Observation number ()
Time series A
AC1 = 0.77
SD = 0.08
(b)
0.4
0.2
0
−0.2
−0.4
Response variable ()
0
100
200
300
400
500
600
Observation number ()
Time series B
AC1 = 0.75
SD = 0.08

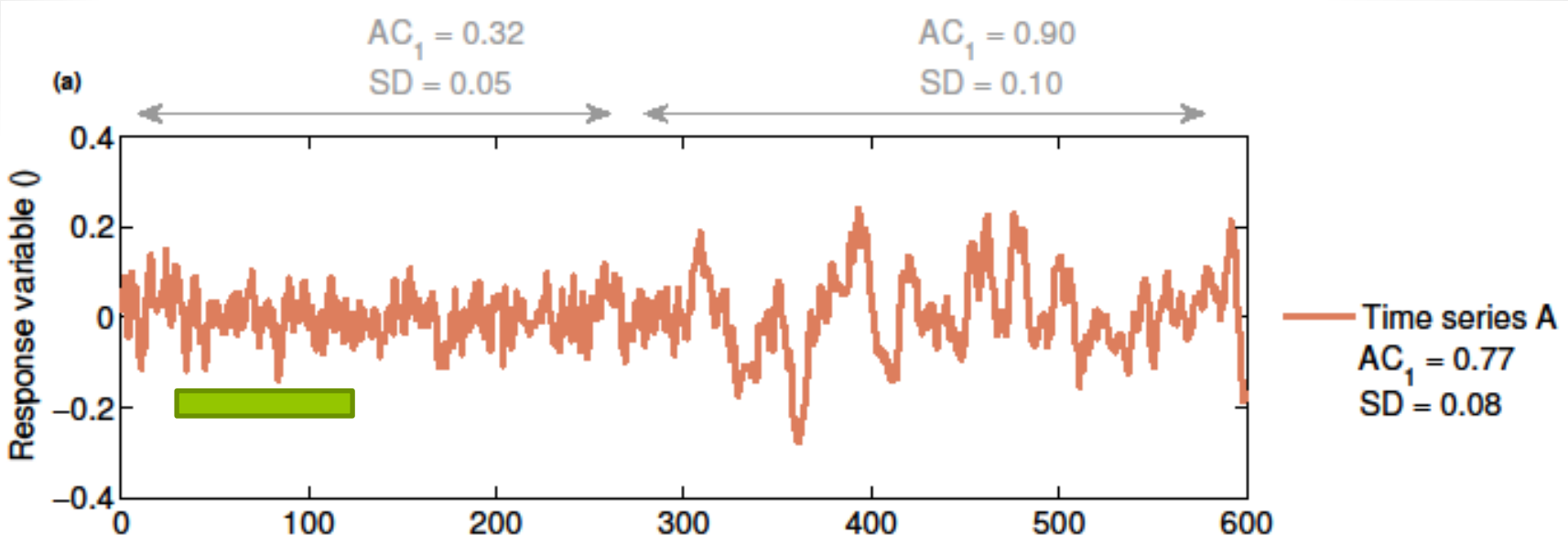

(a)
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Observation number ()
Time series A
AC1 = 0.77
SD = 0.08
(b)
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Observation number ()
Time series B
AC1 = 0.75
SD = 0.08


(a)
AC1 = 0.32
SD = 0.05
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Observation number ()
(b)
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Observation number ()

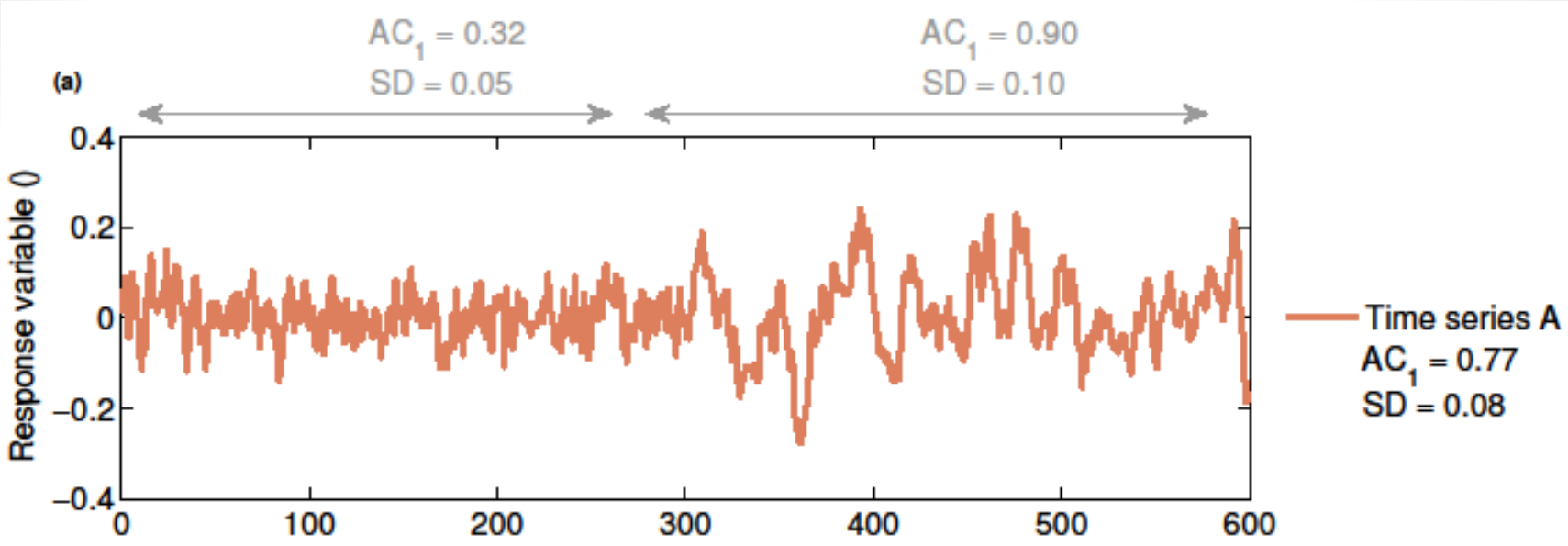

(a)
AC1 = 0.32
SD = 0.05
AC1 = 0.90
SD = 0.10
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Observation number ()
(b)
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Observation number ()

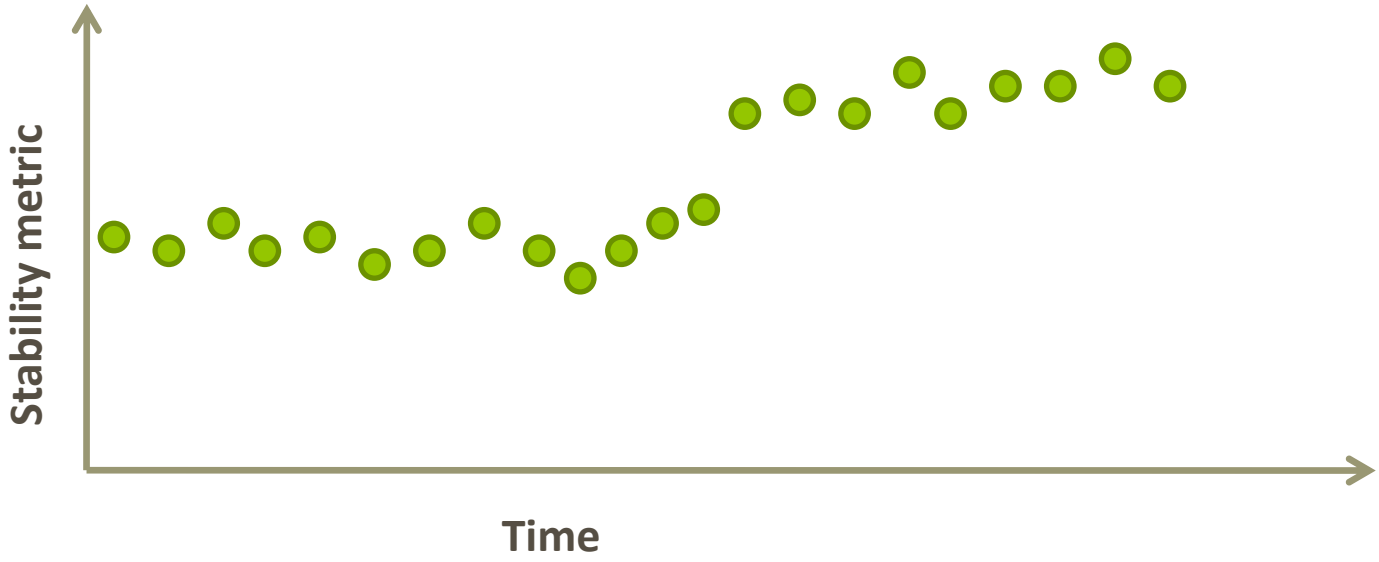
1. Is vegetation response becoming more/less stable?
2. Are the stability changes large?

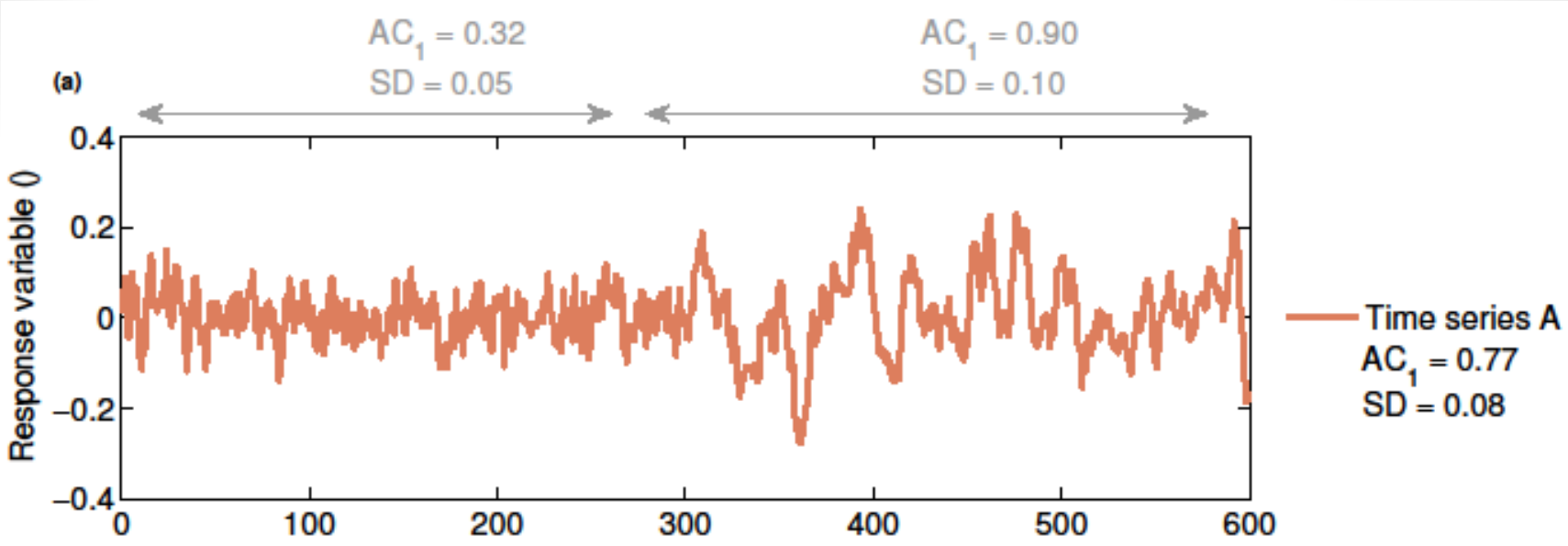

(a)
AC1 = 0.32
SD = 0.05
AC1 = 0.90
SD = 0.10
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Time series A
AC1 = 0.77
SD = 0.08
Stability metric
Time

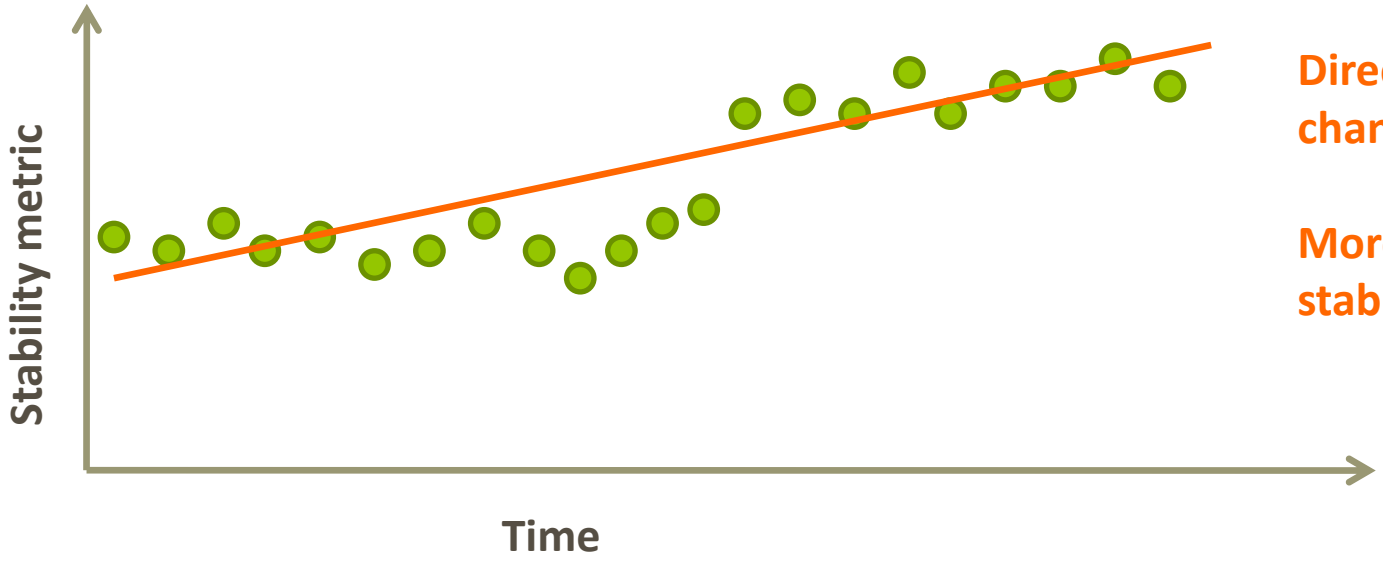

(a)
AC1 = 0.32
SD = 0.05
AC1 = 0.90
SD = 0.10
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Time series A
AC1 = 0.77
SD = 0.08


Stability metric
Time


(a)
AC1 = 0.32
SD = 0.05
AC1 = 0.90
SD = 0.10
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Time series A
AC1 = 0.77
SD = 0.08

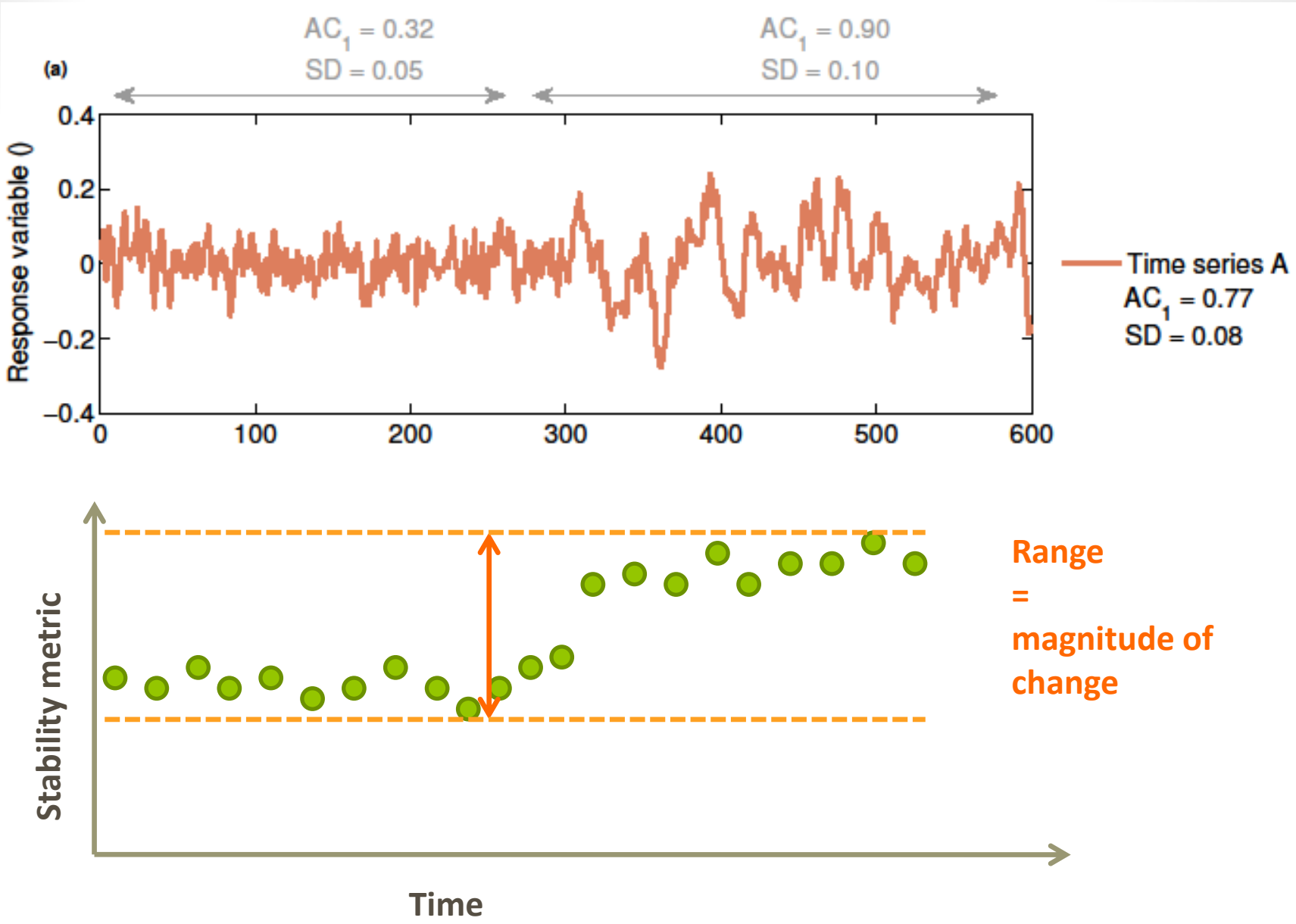

Stability metric
Time



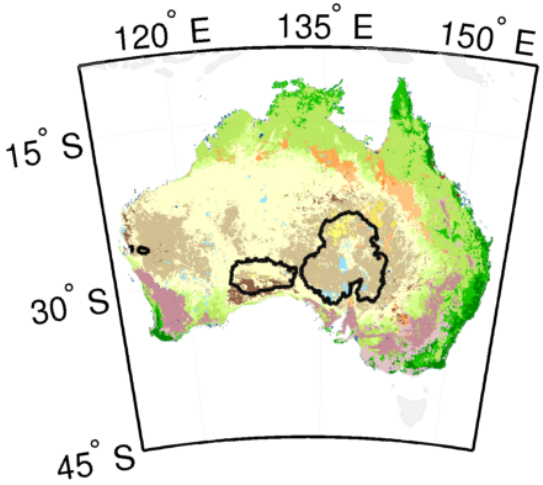


Direction of change:

More/less stable?


(a)
AC1 = 0.32
SD = 0.05
AC1 = 0.90
SD = 0.10
Response variable ()
0.4
0.2
0
−0.2
−0.4
0
100
200
300
400
500
600
Time series A
AC1 = 0.77
SD = 0.08
Stability metric
Time
Range
=
magnitude of
change

Case study



Inland Waterbodies
Salt Lakes
Irrigated Pasture
Irrigated Sugar
Rainfed Cropping
Rainfed Pasture
Wetlands
Tussock Grasses - Closed
Alpine Grasses - Open
Hummock Grasses - Open
Sedges - Open
Tussock Grasses - Open
Grassland - Scattered

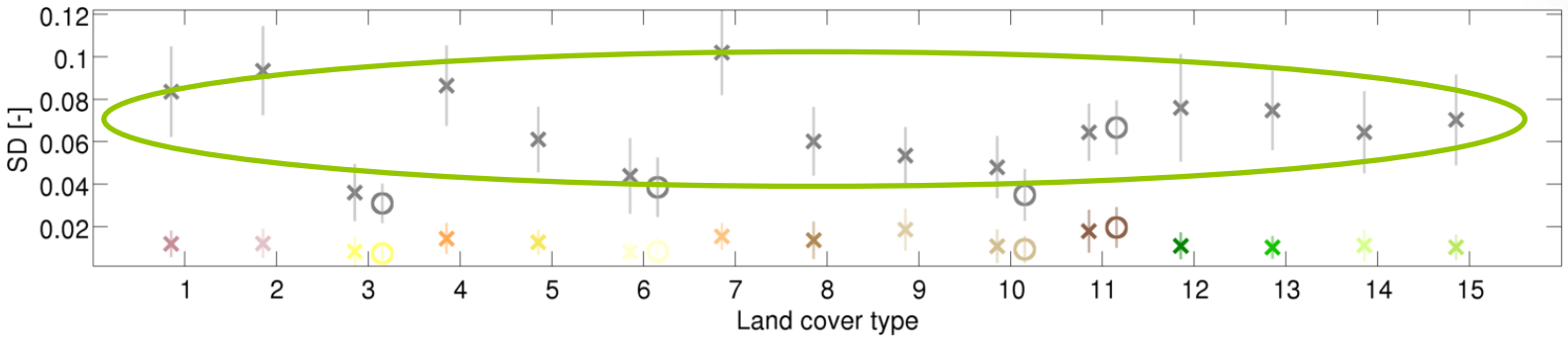
Hummock Grasses - Sparse
Tussock Grasses - Sparse
Shrubs - Closed
Shrubs - Open
Chenopod Shrubs - Open
Shrubs - Scattered
Chenopod Shrubs - Scattered
Shrubs - Sparse
Chenopod Shrubs - Sparse
Trees - Closed
Trees - Open
Trees - Scattered
Trees - Sparse

Data:

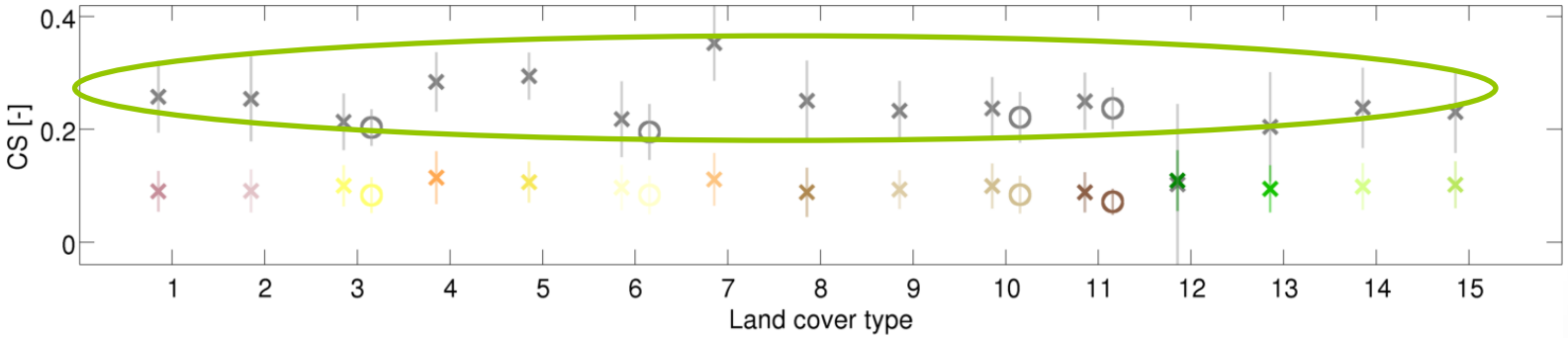
- 0.07° GIMMS NDVI time series from 1982-2006
- 0.5° SPEI time series from 1982-2006 (Vicente-Serrano *et al.* 2010)
- Dynamic Land Cover Dataset (Lymburger *et al.* 2011)

Case study

Stability (entire period)



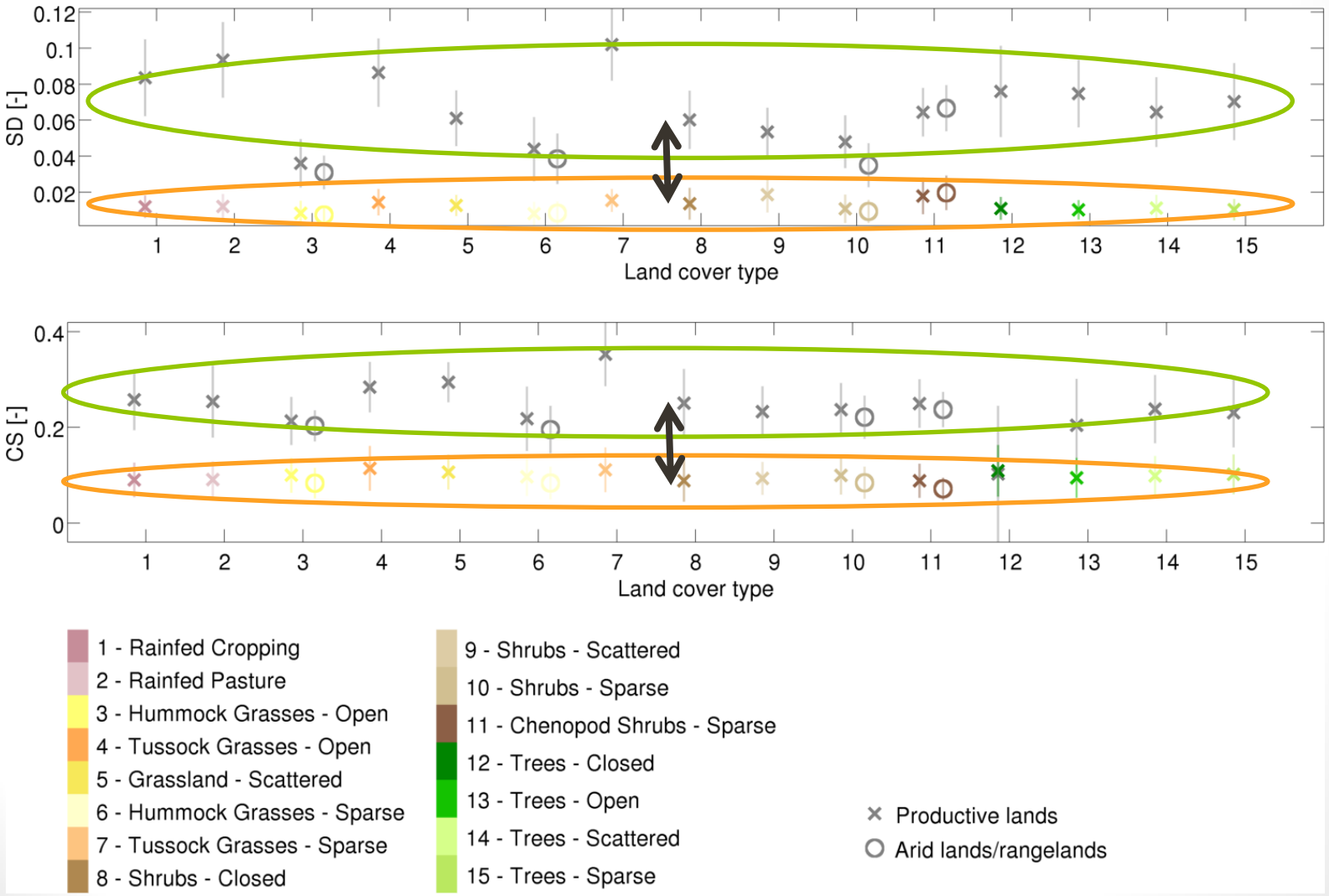
Stability (entire period)



1 - Rainfed Cropping
2 - Rainfed Pasture
3 - Hummock Grasses - Open
4 - Tussock Grasses - Open
5 - Grassland - Scattered
6 - Hummock Grasses - Sparse
7 - Tussock Grasses - Sparse
8 - Shrubs - Closed
9 - Shrubs - Scattered
10 - Shrubs - Sparse
11 - Chenopod Shrubs - Sparse
12 - Trees - Closed
13 - Trees - Open
14 - Trees - Scattered
15 - Trees - Sparse

× Productive lands
○ Arid lands/rangelands

Case study


Stability (entire period)
Range
SD [-]
0.12
0.1
0.08
0.06
0.04
0.02
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Land cover type
Stability (entire period)
Range
CS [-]
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Land cover type
1 - Rainfed Cropping
2 - Rainfed Pasture
3 - Hummock Grasses - Open
4 - Tussock Grasses - Open
5 - Grassland - Scattered
6 - Hummock Grasses - Sparse
7 - Tussock Grasses - Sparse
8 - Shrubs - Closed
9 - Shrubs - Scattered
10 - Shrubs - Sparse
11 - Chenopod Shrubs - Sparse
12 - Trees - Closed
13 - Trees - Open
14 - Trees - Scattered
15 - Trees - Sparse
Productive lands
Arid lands/rangelands

Conclusions

- Three important challenges of remotely sensed stability metrics were illustrated:
  - Noise and data characteristics
  - Spatial heterogeneity climate anomalies
  - Non-stationary vegetation response

Conclusions

- Three important challenges of remotely sensed stability metrics were illustrated:
  - Noise and data characteristics
  - Spatial heterogeneity climate anomalies
  - Non-stationary vegetation response

- Future challenges include:
  - Method integration
  - Seasonally variable, non-linear, lagged, multi-dimensional response
  - Non-climatic disturbances
  - SNR (e.g. through VOD)
  - Validation

Thank you for your attention

Contact information:
Wanda.DeKeersmaecker@biw.kuleuven.be

References:

Barnosky *et al.* (2012). Nature, 486, 52-58
De Keersmaecker *et al.* (2014). Global Change Biology, 20, 2149-2161
De Keersmaecker *et al.* (2015). Global Ecology and Biogeography, 24, 539-548
Hector (1999), Science, 286, 1123-1127
Tilman et al. (2006), Nature, 441, 629-632
Van Ruijven and Berendse (2010), Journal of Ecology, 98 (1), 81-86
Verbesselt J *et al.* (2010). Remote Sensing of Environment , 114 (1), 106–115.
Verbesselt J *et al.*(2010). Remote Sensing of Environment ,114(12), 2970–2980
Vogel *et al.* (2012) PloS ONE, DOI: 10.1371