Tipping points

How can Earth Observation help?

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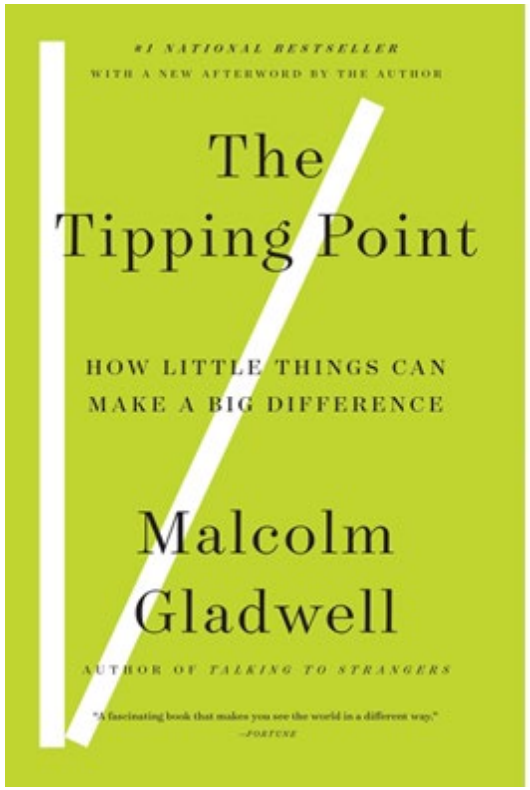
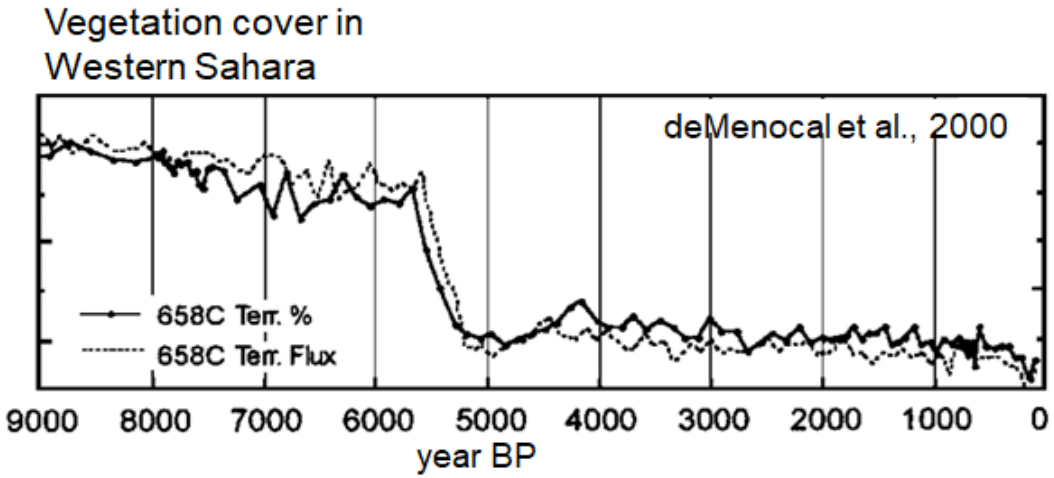
Abrupt shifts are all around us



Abrupt shifts happen in the Earth System

Recon-
struction



Climate
model

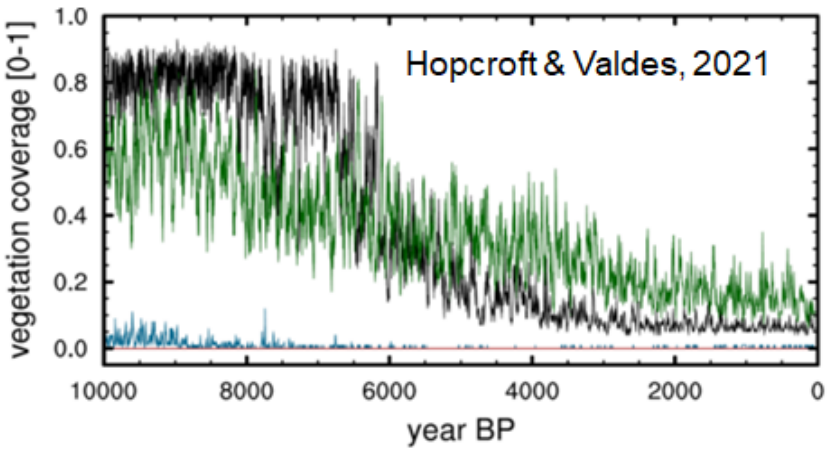
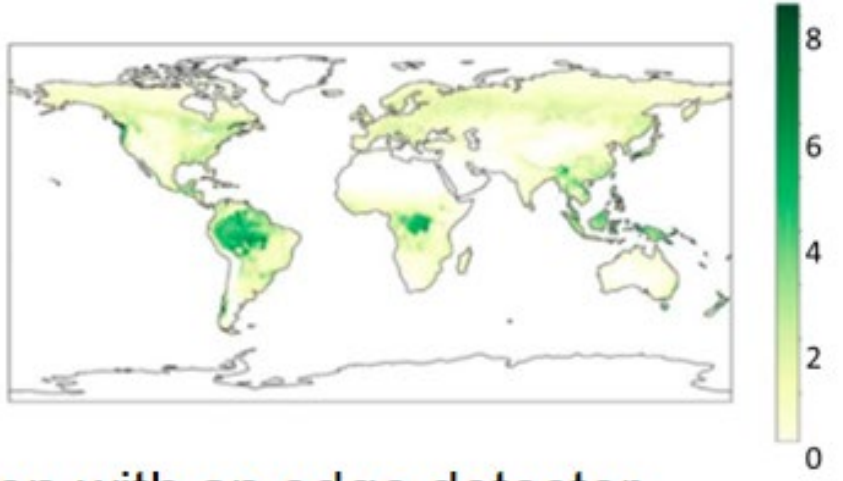


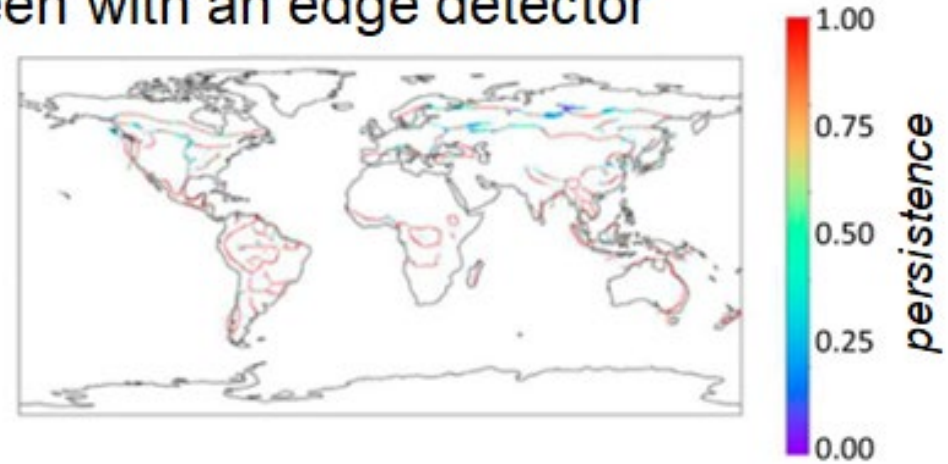
Photo: Philipp Hoelzmann

Edges in space can lead to abrupt shifts

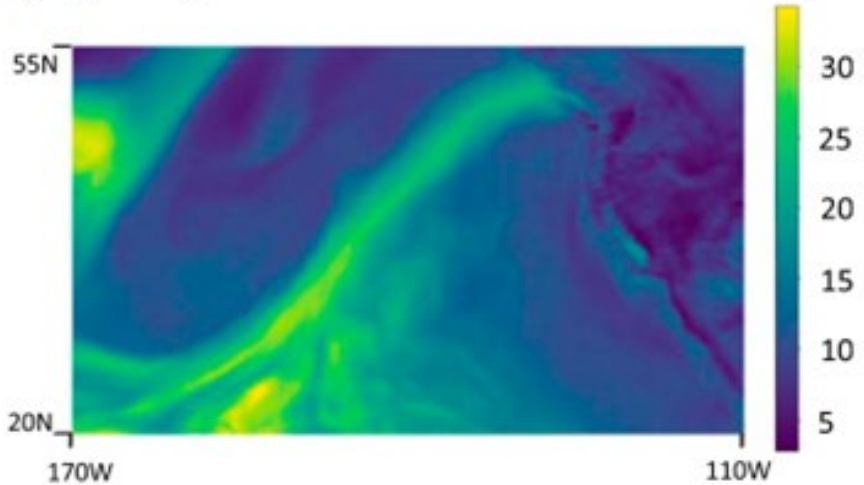
Leaf-area index,
AVHRR / MODIS

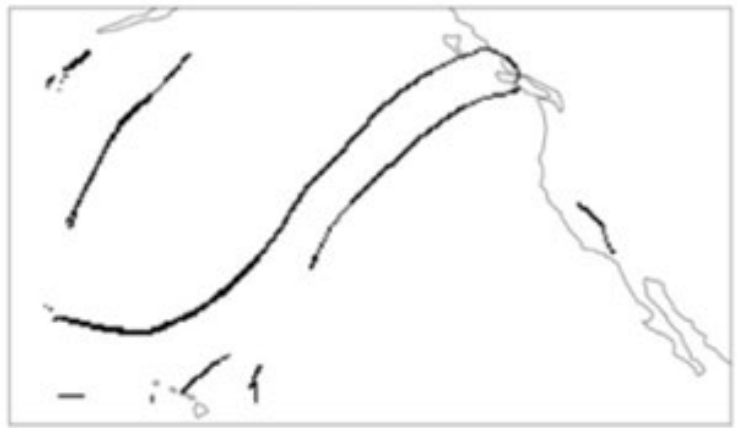


…seen with an edge detector



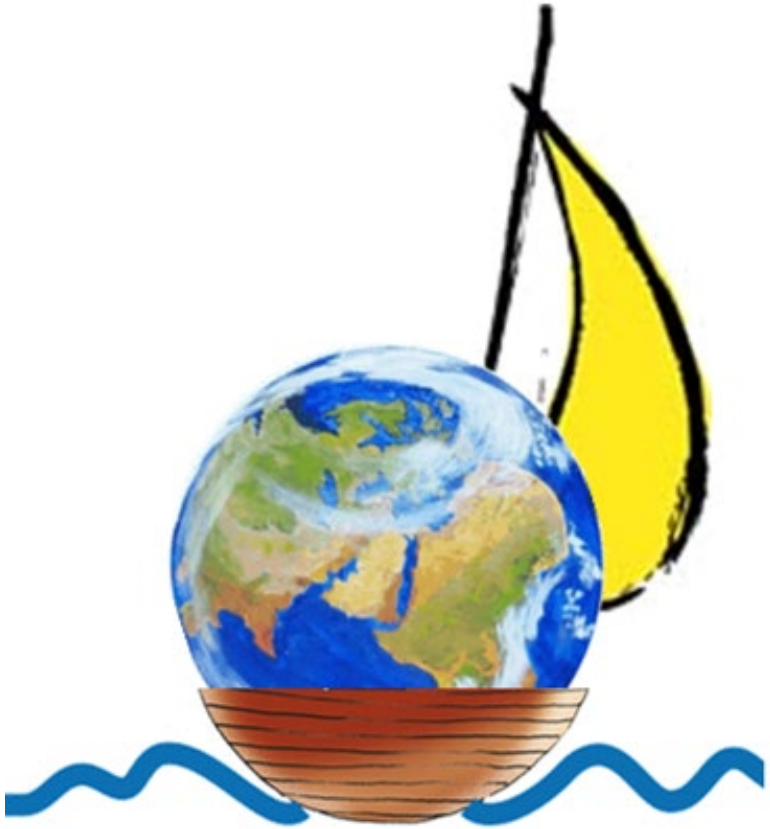
Vertically integrated water vapour
(kg/m^2), *ERA5*

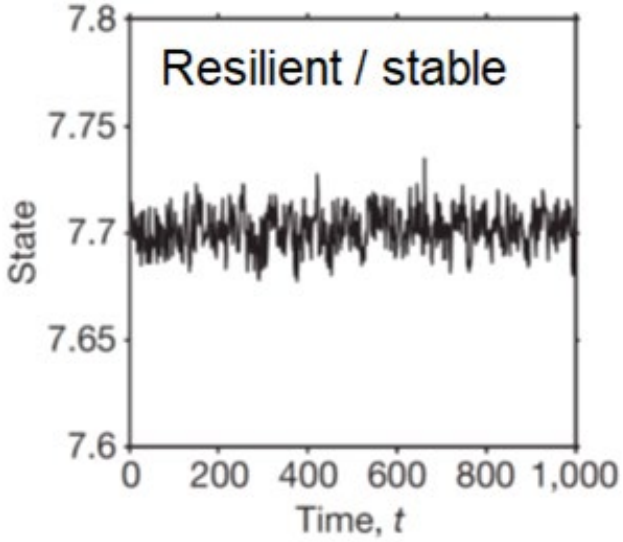


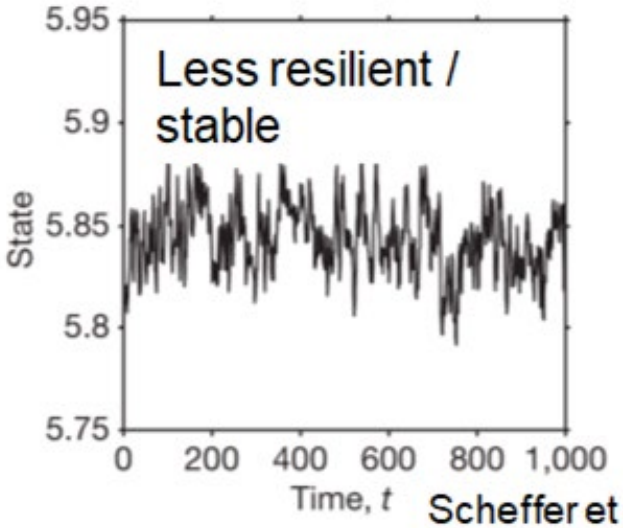


Bathiany et al., 2020

Loss of resilience can lead to abrupt shifts ("tipping points")

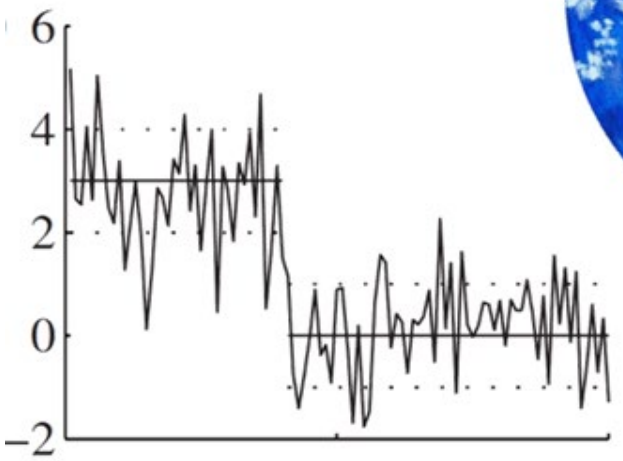




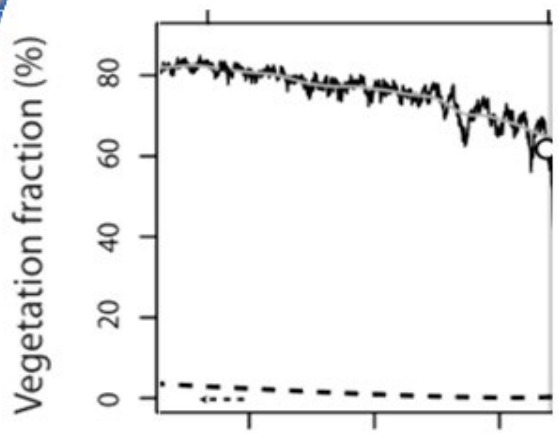


Scheffer et al., 2009

Probing EO for abrupt shifts and resilience indicators



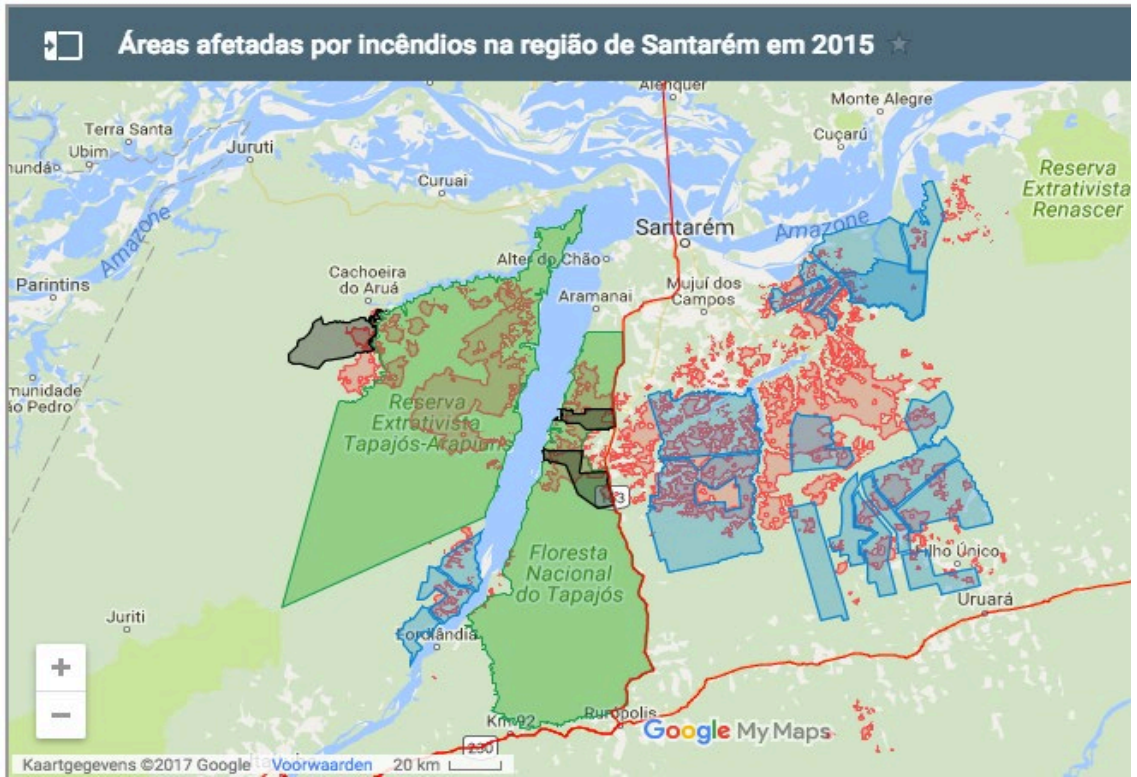
Beaulieu et al., 2012



Dakos et al., 2008

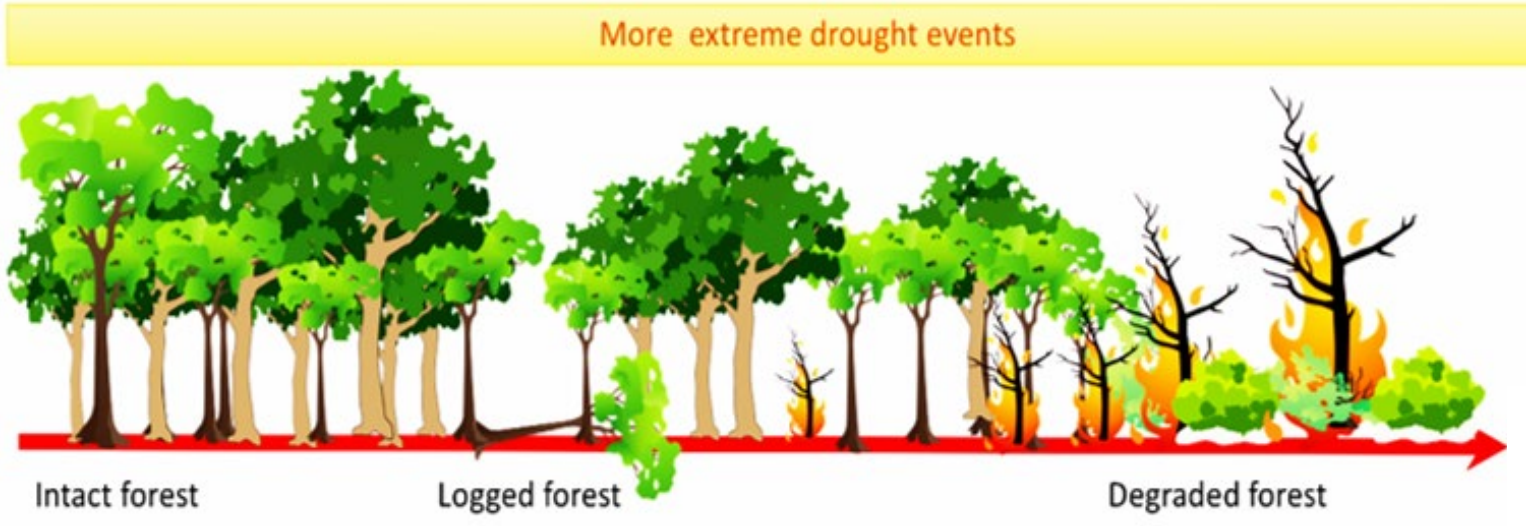
Extreme events – tipping points?

- Record breaking high temperatures and severe drought during e.g. El Niño



Tipping point

- Negative feedback loop



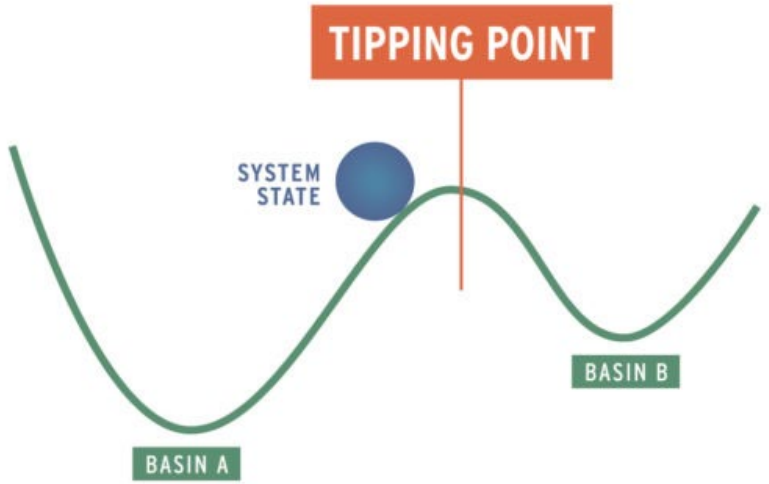
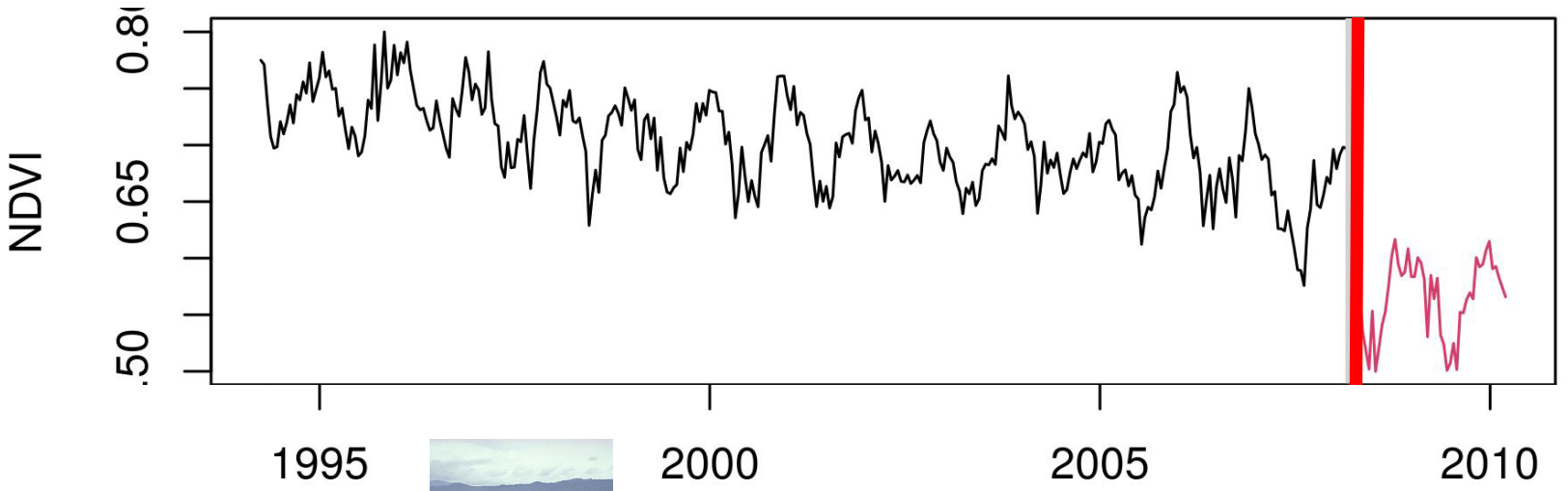


Illustration by Andrew Bernier, adapted from Walker, B. & Salt, D. (2006) Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Island Press: Washington, DC.

Measure resilience of tropical forests?

Long satellite image time series

- VOD: Passive microwave satellite retrievals from e.g. AMSR-E (Liu et al. 2011)
- NDVI: Optical satellite-based retrievals from MODIS, AVHRR (Pinzon et al. 2013)



Resilience

- Recovery rate from ‘small’ perturbations (e.g., droughts)

van Belzen, J. *et al.* (2017).

nature climate change

LETTERS

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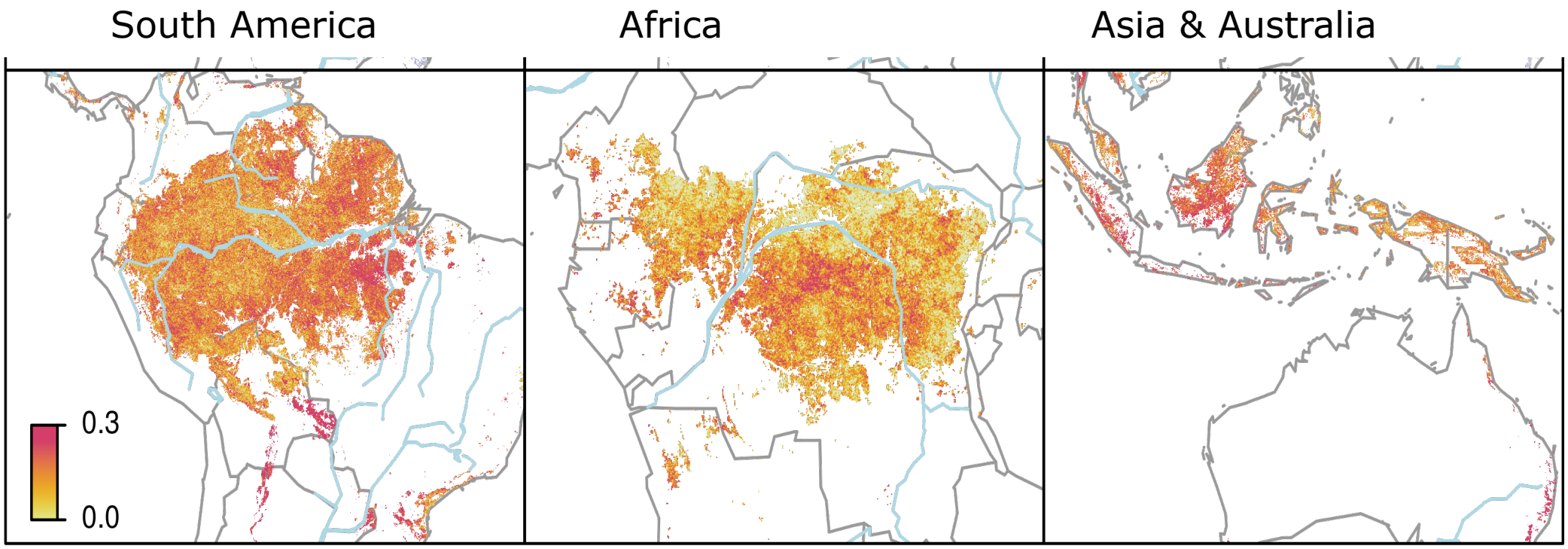
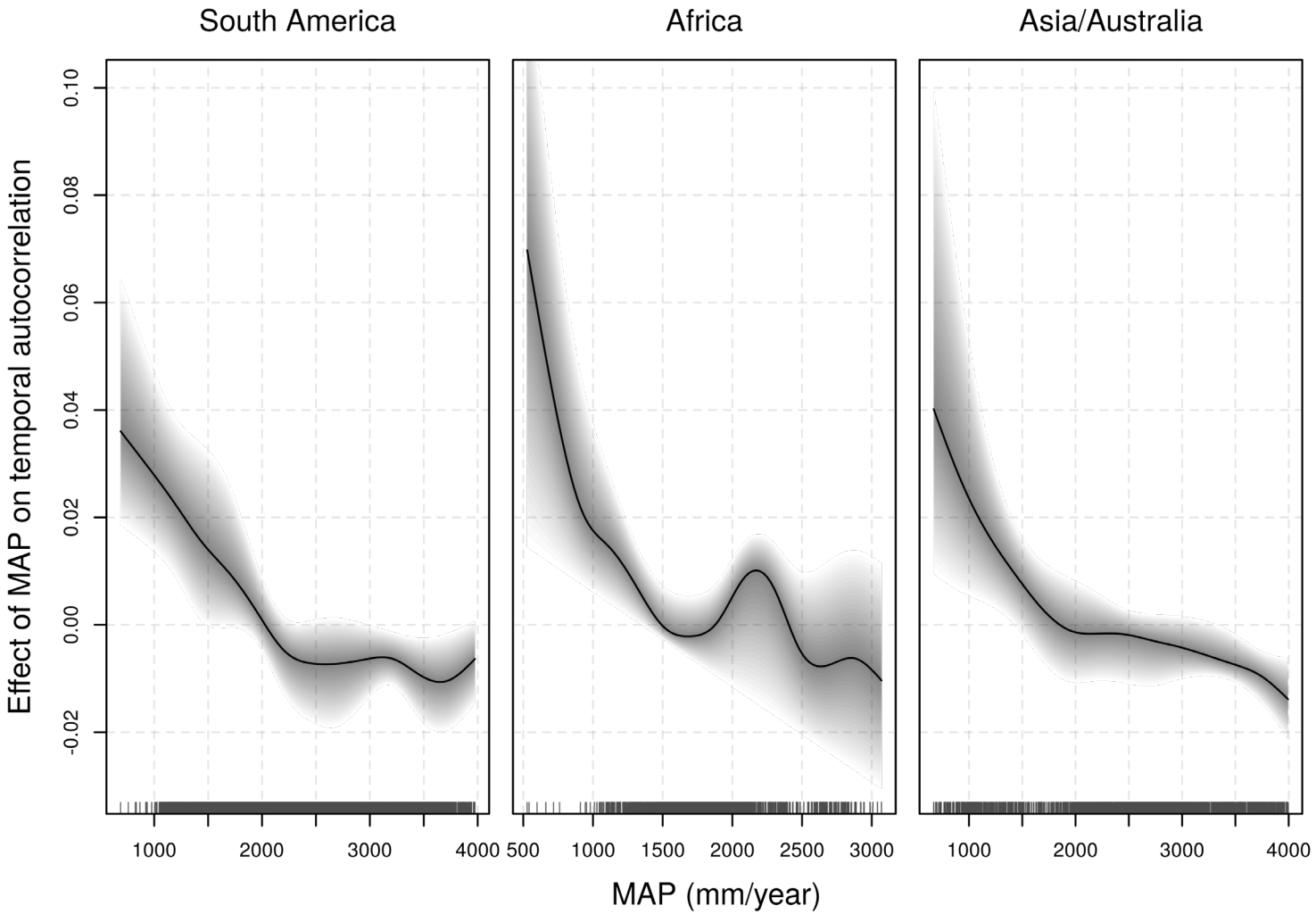
Remotely sensed resilience of tropical forests

Jan Verbesselt[1]*, Nikolaus Umlauf[2], Marina Hirota[3,4,5], Milena Holmgren[6], Egbert H. Van Nes[3], Martin Herold[1], Achim Zeileis[2] and Marten Scheffer[3]*

- **The capacity to recover from disturbances**



Slowing down upon low rainfall amounts



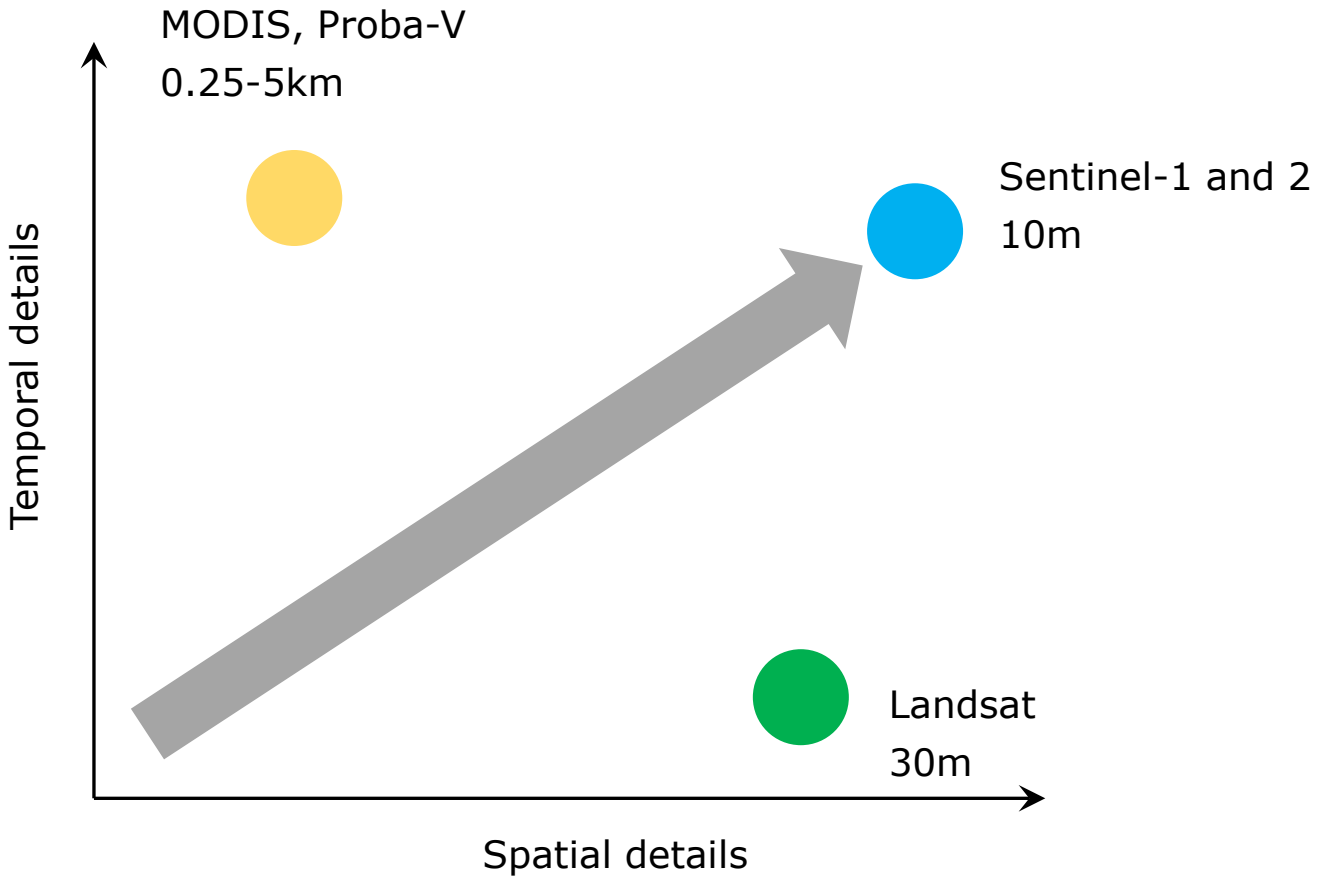
Verbesselt, J. *et al.* Remotely sensed resilience of tropical forests. *Nat. Clim. Chang.* (2016).

Effect of small-scale disturbances?

- Deforestation, shifting cultivation, fires, etc.

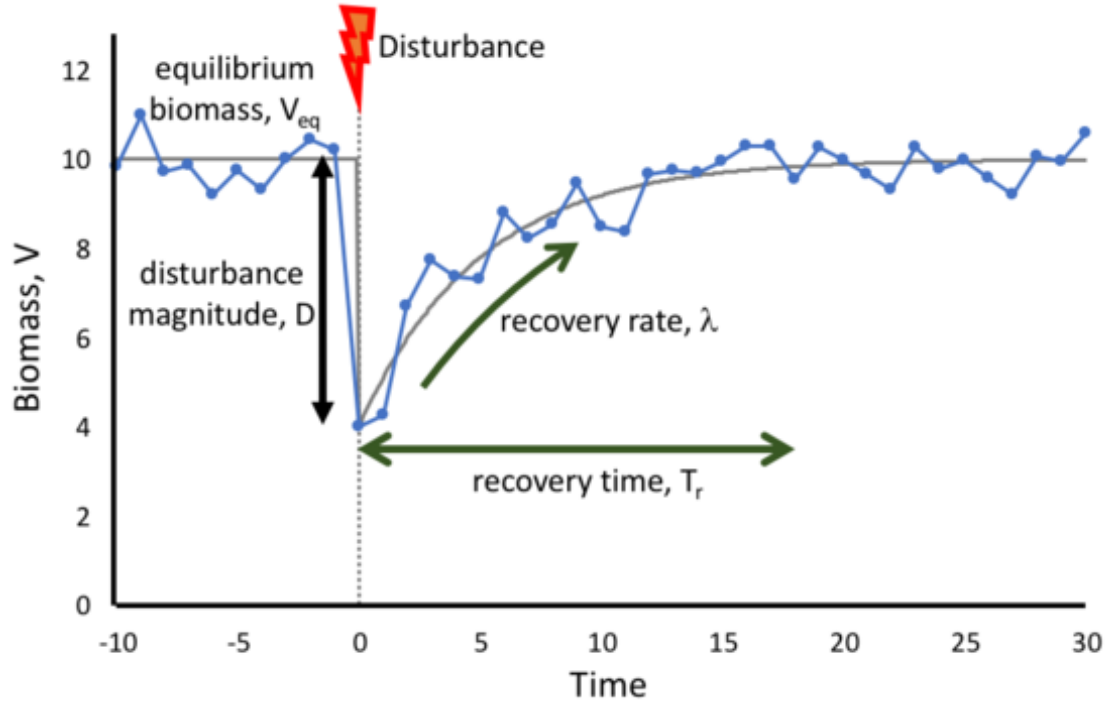
- Difficult to study with e.g., AVHRR, MODIS, AMSR-E
  - Coarse spatial resolution

New satellite sensors



ESA Biomass mission for 2023
P-band RADAR

Measure forest resilience



Evolution of the open-source BFAST functions for characterizing land change using satellite image time series (Sentinel, and Landsat) Speaker

Date: 26.05.2022 , Time: 13:45 | Topic: Enable the Earth Observation Digital Transformation

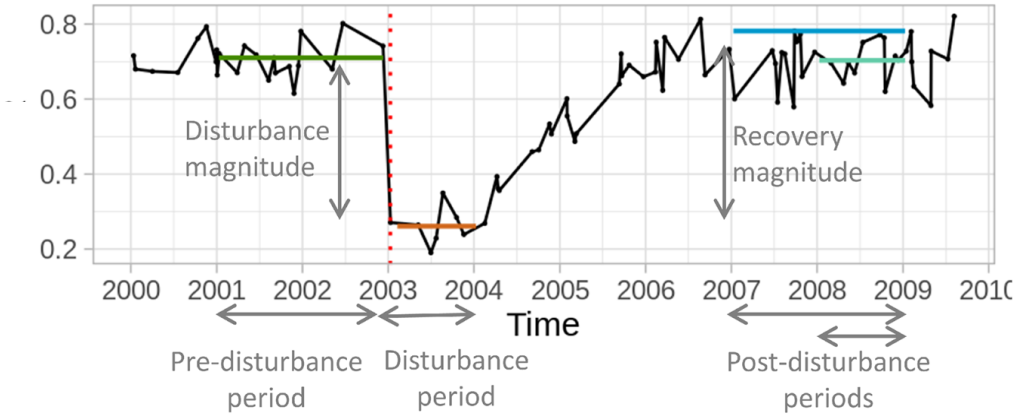
https://bfast2.github.io/

Monitoring tropical forest recovery capacity using:

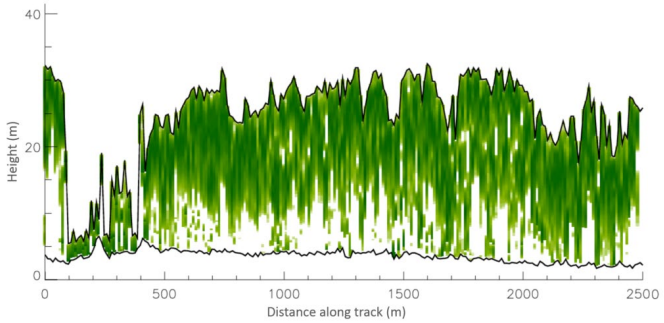
- De Keersmaecker, W. et al. **Evaluating recovery metrics derived from optical time series over tropical forest ecosystems**. RSE (2022)

- Milenković, M. et al. **Assessing Amazon rainforest regrowth with GEDI and ICESat-2 data**. Science of RS (2022)

EO index



Recovery indicator	Equation	Explanation
Relative Recovery Index	$RRI = \frac{\lvert \max(f(t_{post})) - \bar{f}(t_{dist}) \rvert}{\lvert \bar{f}(t_{pre}) - \bar{f}(t_{dist}) \rvert}$	Recovery magnitude relative to disturbance magnitude
Ratio of Eighty Percent	$R80p = \frac{\max(f(t_{post}))}{0.8\,\bar{f}(t_{pre})}$	Post-disturbance state relative to 80% of pre-disturbance state
Year on Year Average	$YrYr = \frac{\bar{f}(t_{\Delta}) - \bar{f}(t_{dist})}{\bar{t_{\Delta}} - \bar{t_{dist}}}$	Related to post-disturbance slope



GEDI & ICESAT-2

Airborne LiDAR

Towards early warning using EO data

Can detailed recovery measures be a proxy for tipping points?

Smith, T., et al. Empirical evidence for recent global shifts in vegetation resilience. *NCC* (2022)