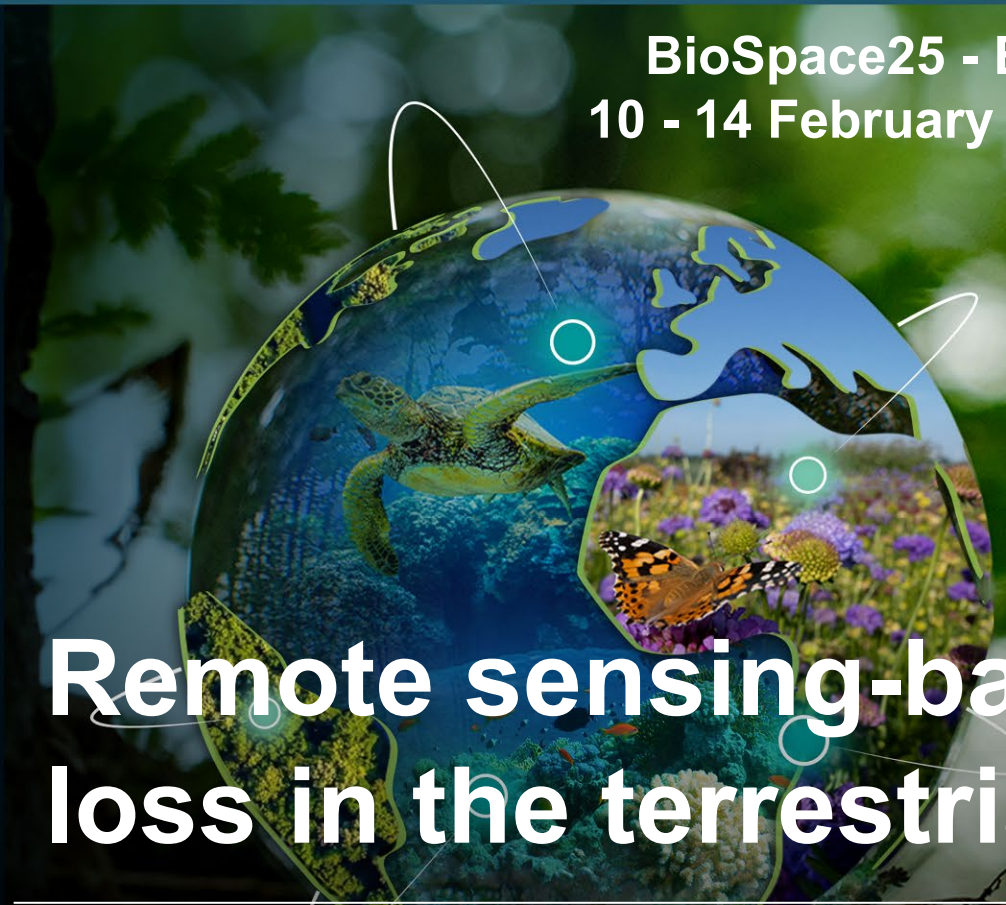
BioSpace25 - Biodiversity insight from Space
10 - 14 February 2025 | ESA-ESRIN | Frascati - Italy



Remote sensing-based detection of resilience loss in the terrestrial water cycle

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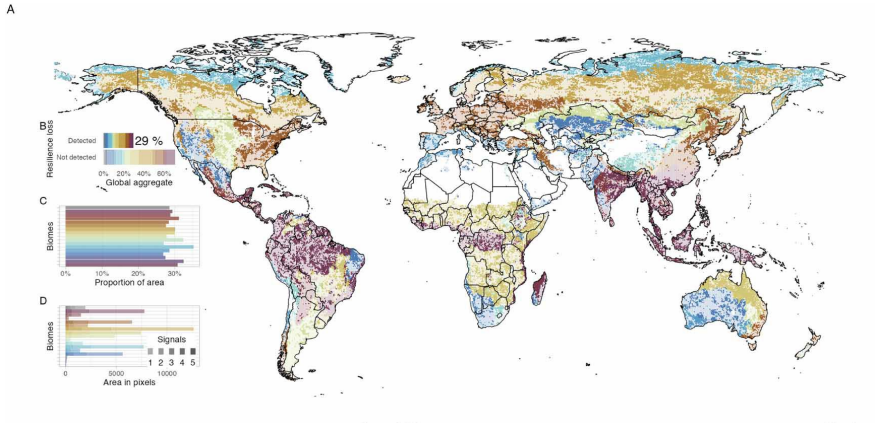
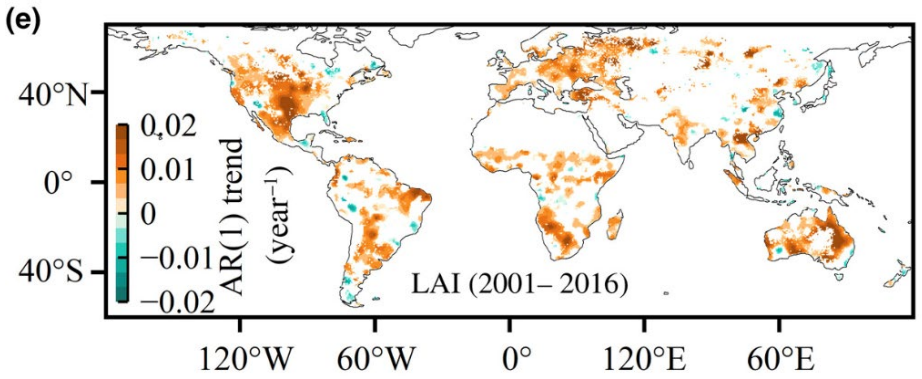
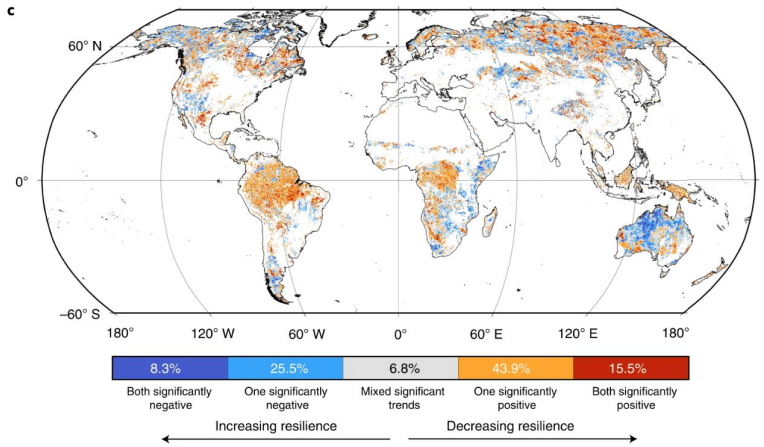
- Globally, ecosystems have evolved within specific hydro-ecological niches[1,2]
- Current biodiversity projections indicate the trajectory of climate and related hydrological change is likely to have catastrophic effects on ecosystems[6]
- Human pressures are altering the water cycle at vast spatial and temporal scales (e.g. climatic change, land-use change)[3-5]
- Understanding change to hydrological conditions is important in fully understanding ecological response



GPP
Rocha, 2022

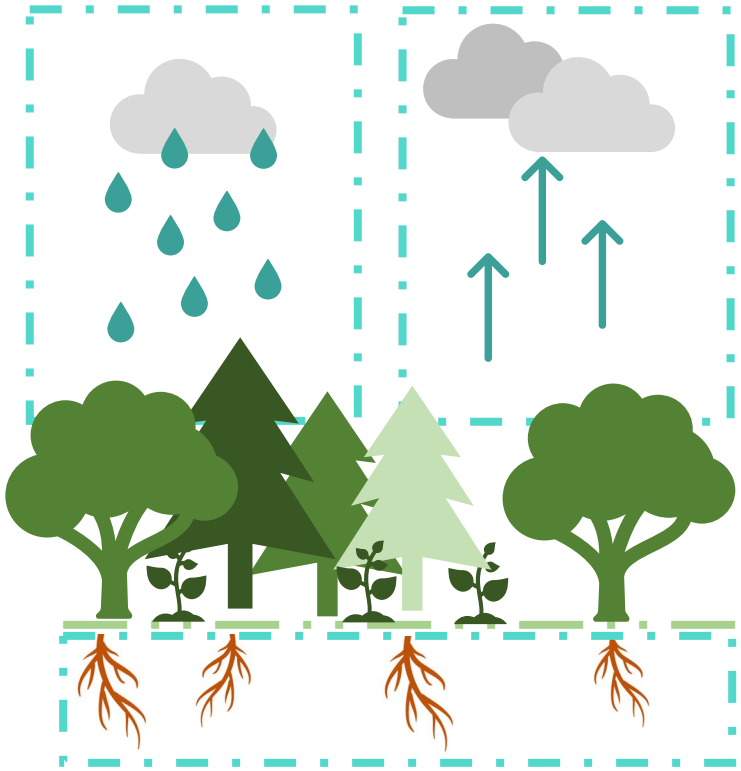


LAI
Yao et al., 2024



VOD
Smith et al., 2022

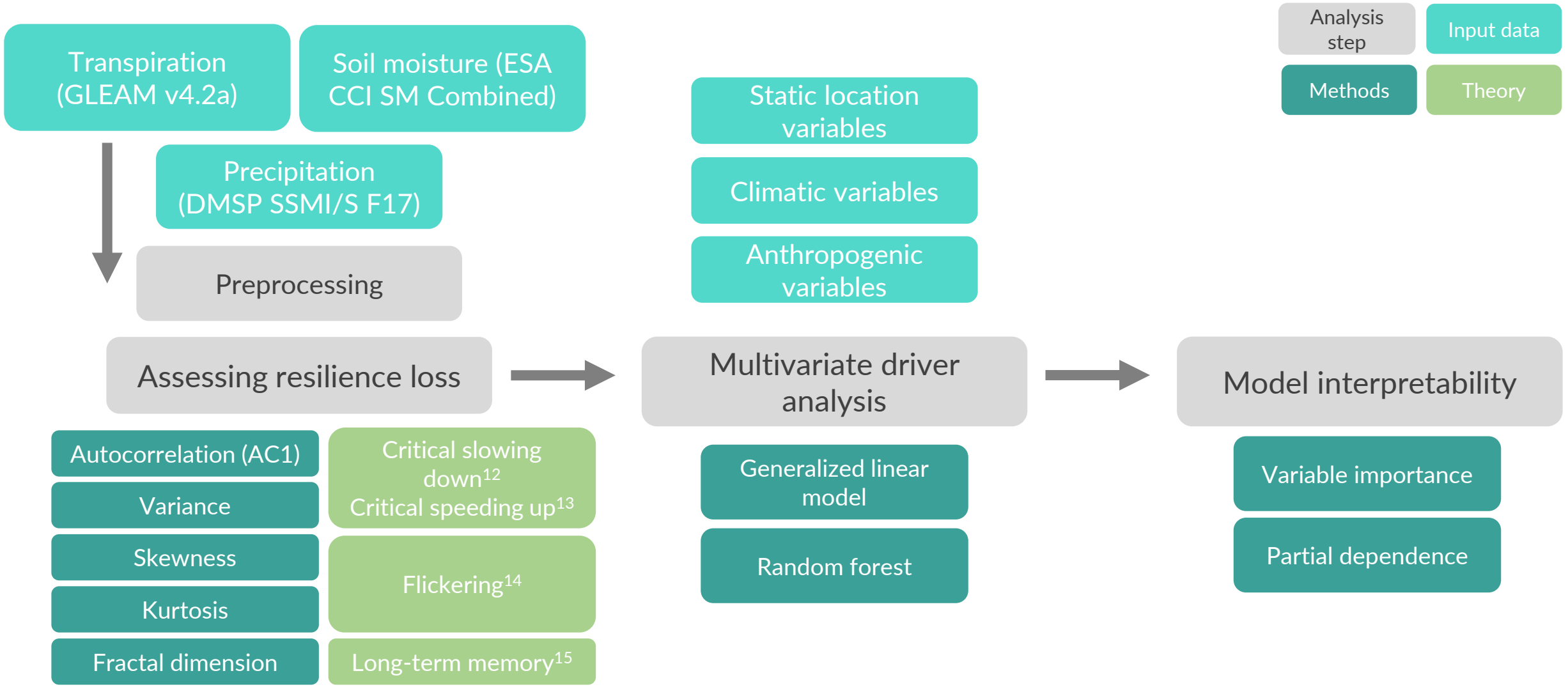
- A resilient system is able to absorb and recover from environmental perturbations and maintain its equilibrium state[7]
- Early Warning Signals (EWS) broadly used to assess resilience loss in terrestrial ecosystems, based on changes to the recover time of a system after a perturbation [8-10]
- Water included as a static driving variable, where some relationships have been identified between resilience and precipitation variability[10,11]
- Water as a driver of resilience loss is equally as dynamic, and contains its own system information, feedbacks, and vulnerabilities



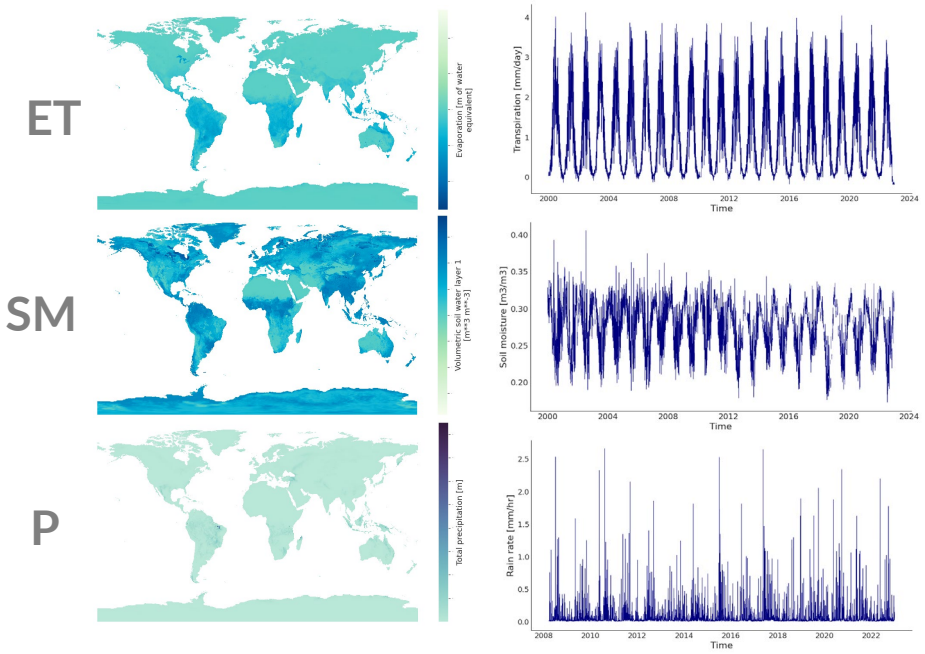
- Green water variables (transpiration, soil moisture, and precipitation).
- Resilience loss is a decrease in the ability of green water variables to remain within their parcels of expected variability

How well do water cycle functions return to their equilibrium state given a perturbation or disturbance?

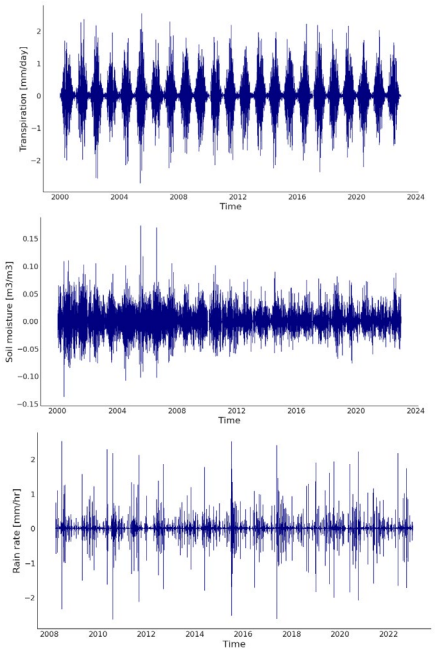
1. What are the spatial patterns of resilience change in transpiration, soil moisture, and precipitation?
2. What environmental conditions explain these patterns of change?



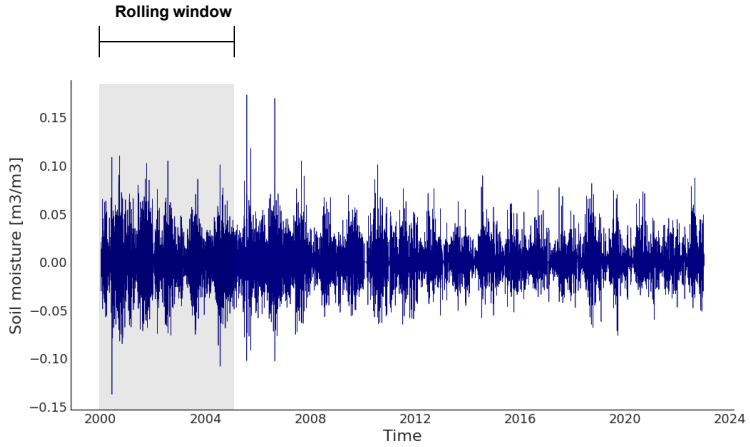
Adapted from Knecht et al. (in prep)



1 Green water variable time series

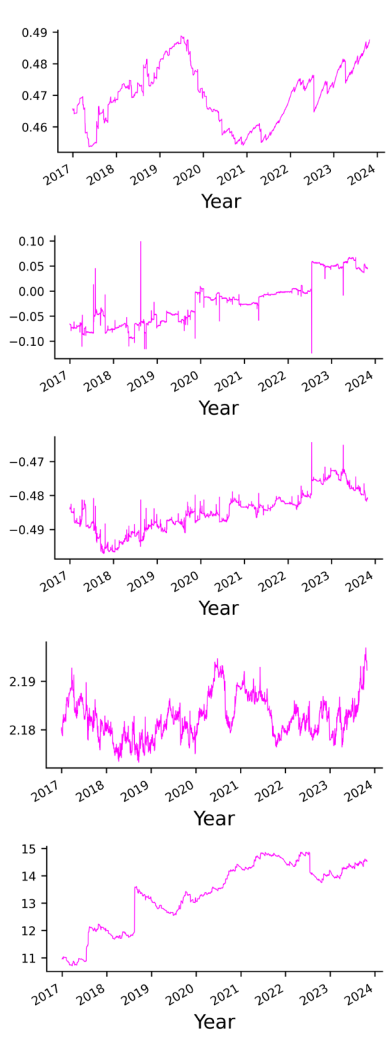


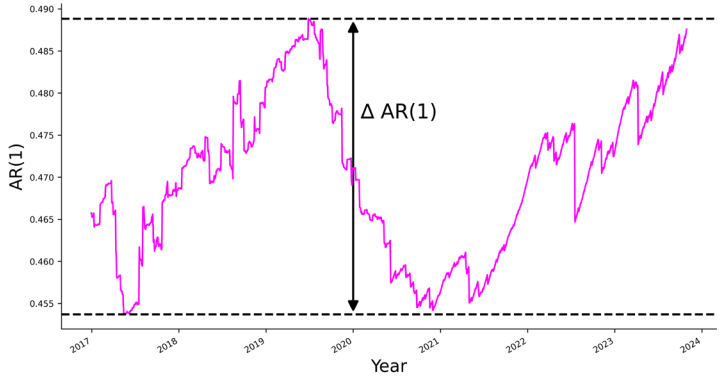
2 Pre-processing

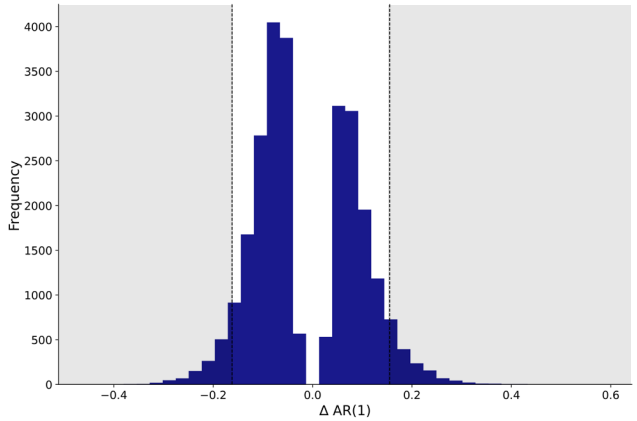


3 Calculate EWS over rolling window

4



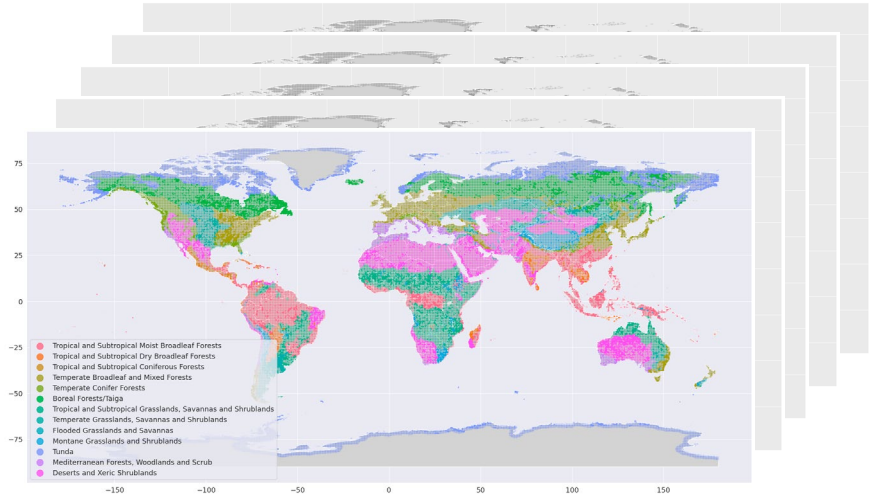




Pixel level change of the change in early warning signal is understood with respect to the biome variable distribution.

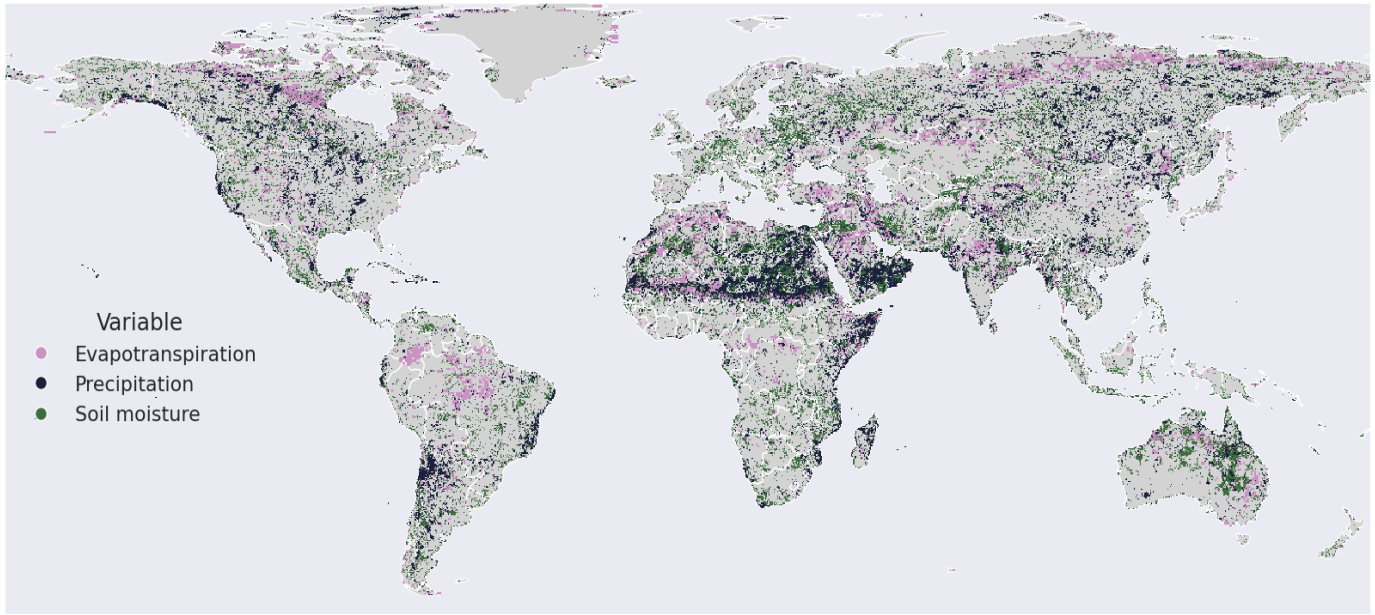
5

Pixels with more than three indicators showing significant changes over the time series are flagged

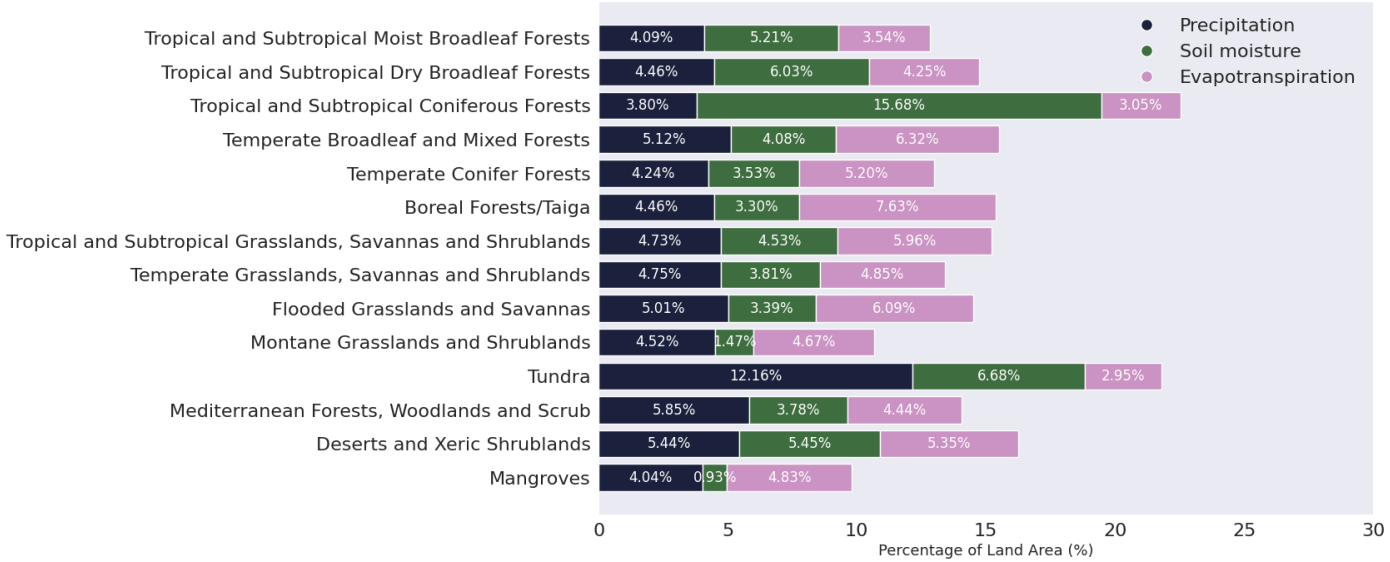


... to provide a global insight into which regions are showing signs of water resilience loss.

A



B



Results suggest that green water variables in the terrestrial **water cycle are showing signs of resilience loss across all biome types.**

When combining these three variables, we see changes to resilience being detected for **10% to 20% of land area per biome** looking at pixels with at least three indicators.

We identify **global climatic variables** as important predictors of resilience loss, rather than local anthropogenic modifications of land use and land cover.

Soil moisture

- Variability, rather than mean climate or hydro-ecological conditions is generally a better predictor

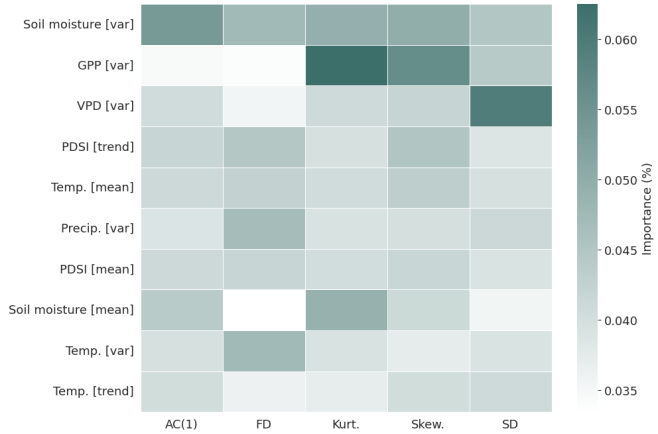
Transpiration

- Biogeographical variables are important predictors of resilience loss (tree cover, GPP)
- More closely related to terrestrial ecosystem state

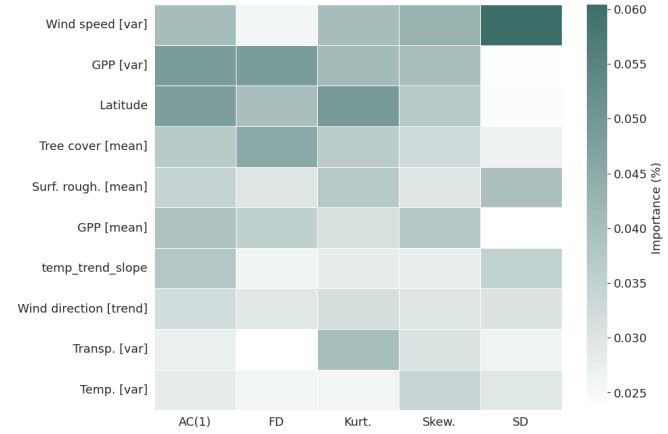
Precipitation

- Climatic variables are important predictors.
- Regions with low mean precipitation and high precipitation variability are more likely to show resilience loss

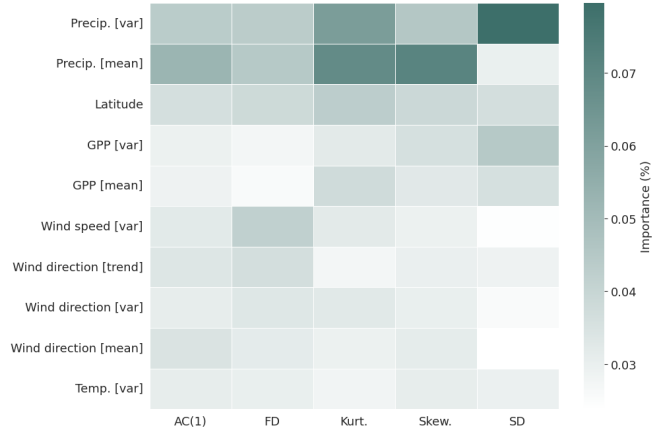
Soil moisture



Transpiration



Precipitation



- We present an **earth observation-based assessment of resilience in the terrestrial water cycle**

- All biomes show signs of changes to water resilience, with **tundra, drylands, tropical coniferous forests, and boreal forests** showing the highest instances.

- We find **climatic variables to be important predictors** of resilience loss in the terrestrial water cycle, with resilience loss in transpiration more closely related to ecosystem state

- Biodiversity conservation efforts in areas showing signs of water resilience loss should **take into account potential unexpected and non-linear changes in the water cycle**.

- Further research needed to understand the **role of local hydrological and global hydro-climatic drivers in contributing to biodiversity loss**

R & D recommendations

- Cross-mission integration for long-term, temporally consistent time series of hydrological variables (e.g. soil moisture, transpiration)

- Multi-instrument time series should **account for sensor change or merging effects on autocorrelation and higher statistical moments** for robust analysis of resilience over time

Thank you!

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waterresilience.earth

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