Dieback events of Scots pines caused by lack of rain in mid and late summer

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1 Motivation

- Pronounced **mortality and needle loss events** occurred in the Swiss Rhône valley since the 1990s
- Previous studies identified drought as a main factor
- However, the **specific drivers causing the observed spatio-temporal dieback patterns are not well understood**

2 Data and methods

- **Crown condition assessments** on four monitored forest plots (**defoliation as indicator of tree health**)
- Parameters and indices derived from **atmospheric variables from 20 meteorological stations**
- Further observational data included (remote sensing, soil moisture, etc.)
- Comprehensive approach combining various analyses such as **trend estimation, sensitivity analysis and multiple regression**

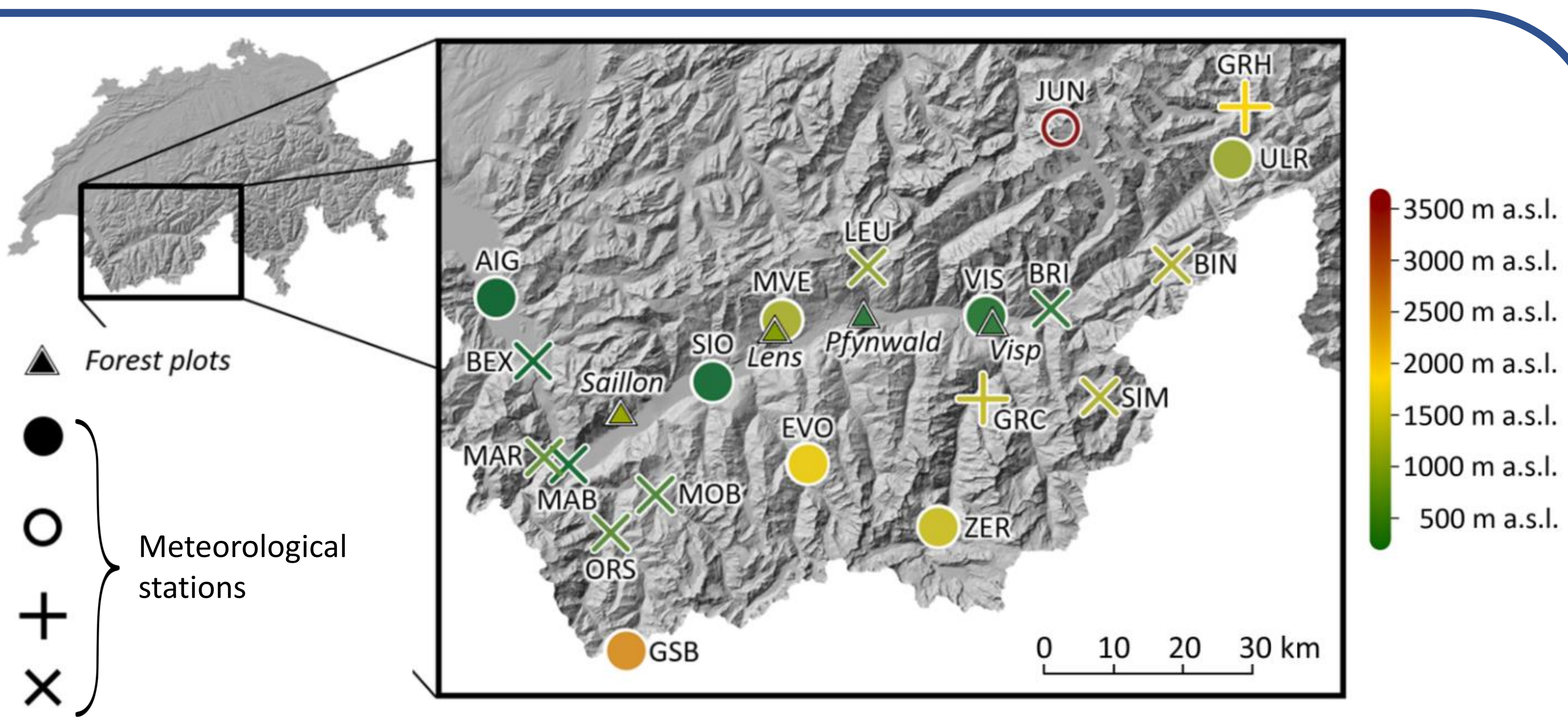


Figure 1. Overview of the study area (abbreviations of the meteorological station names are shown)

3 Mortality events of Scots pines

- **Scots pines have been declining at lower elevations** in Visp (ca. 695 m a.s.l.) and Pfynwald (ca. 615 m a.s.l.), but no clear tendency is found at higher elevations in Lens and Saillon (>1000 m a.s.l.)
- **Defoliation and mortality in Visp** (annual defoliation increase of 5.7% and yearly mortality rate of 7%) **is characterized by four pronounced events, whereas the decline in Pfynwald occurred slower and more gradually** (annual defoliation increase of 1.5% and yearly mortality rate of 1.7%)

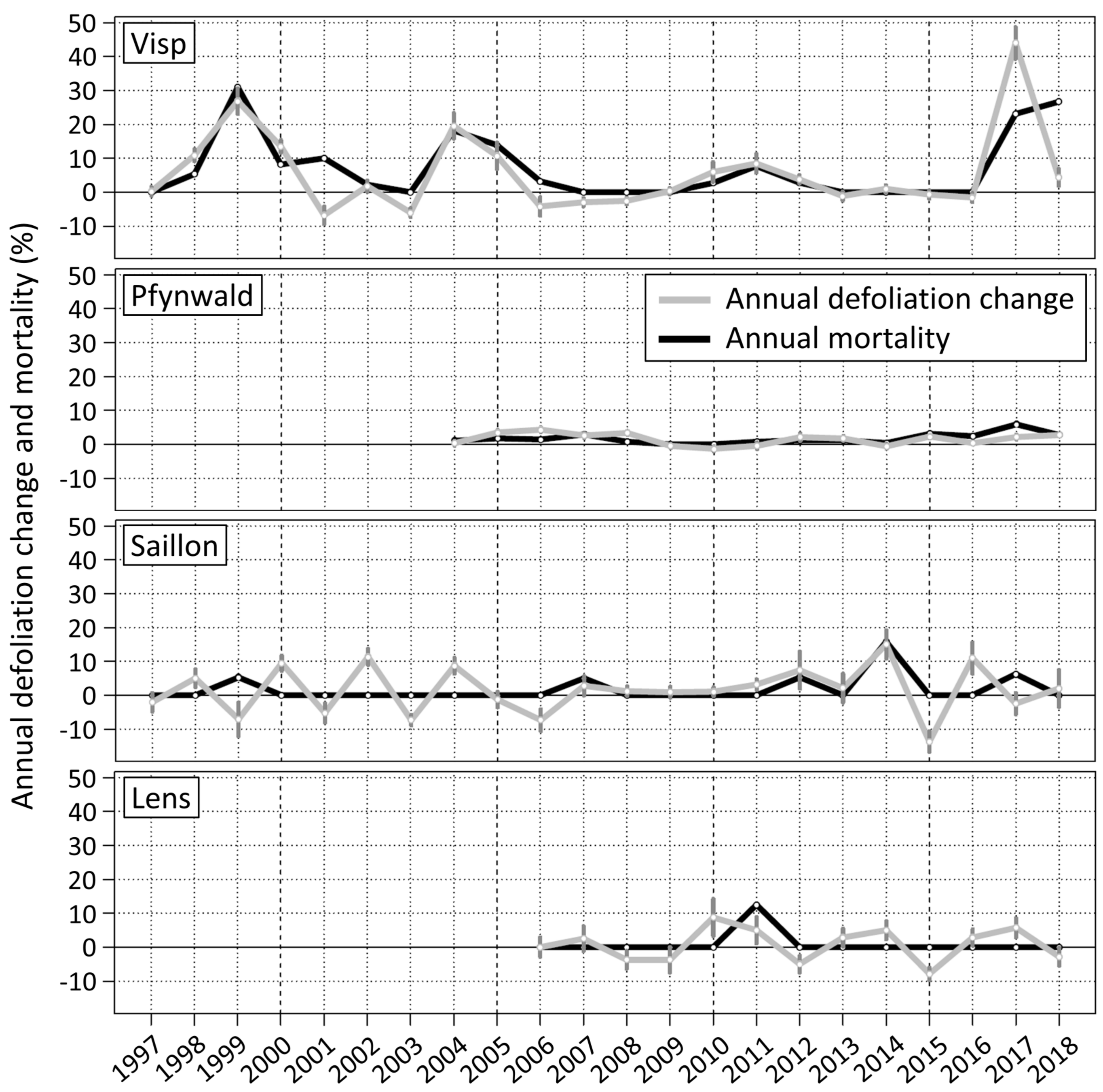


Figure 2. Annual defoliation change and mortality on the monitored forest plots

4 Increasing atmospheric water demand

- **Significant increase of the evapotranspiration** in spring and summer at lower elevations
- **Precipitation is characterized by a strong year-to-year variability**, trends are hardly significant
- Increased evapotranspiration prolonged and intensified the period of **low soil moisture between summer and autumn**

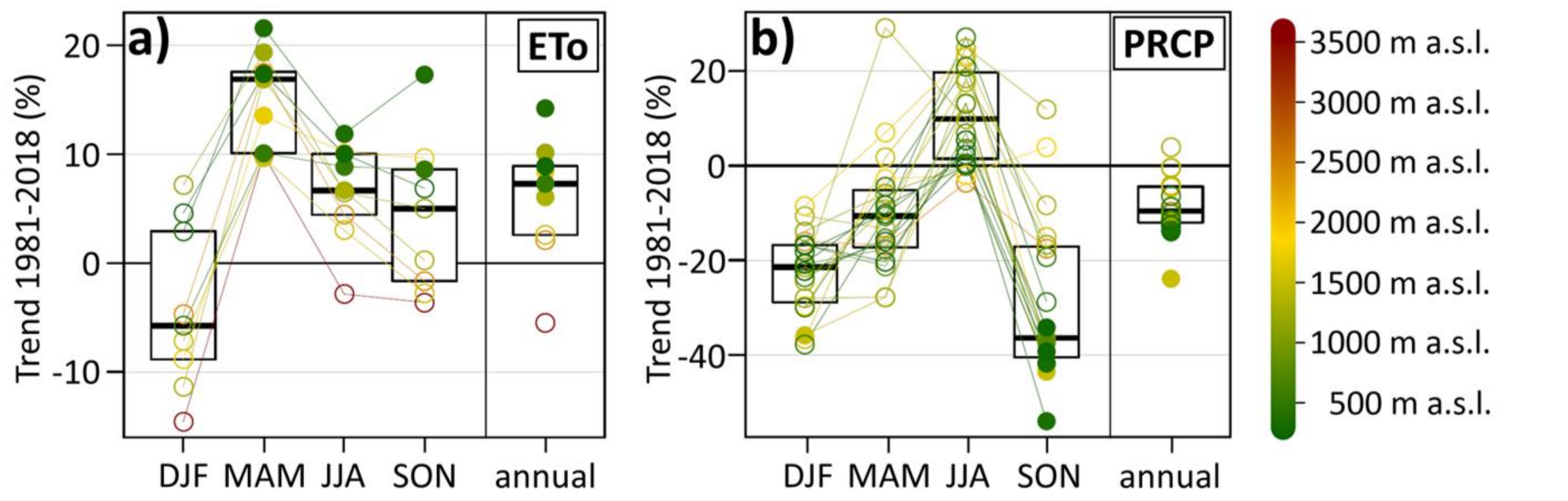


Figure 3. a) Trends of the reference evapotranspiration (ETo) and b) trends of precipitation sums (PRCP) in winter (DJF), spring (MAM), summer (JJA), autumn (SON) and on annual time scale

5 Mid to late summer precipitation anomalies drive mortality events

- Anomalies of **July to September precipitation intensity and frequency explain 62% of the following defoliation change** in Visp
- **Pathogen infestation** (around 1999) and **spring frost** (2017) intensified the severity of dieback events
- A high amount of **severely damaged trees** (≥75% defoliation) results in prolonged mortality after the peak of an event as these trees passed a "point of no return"

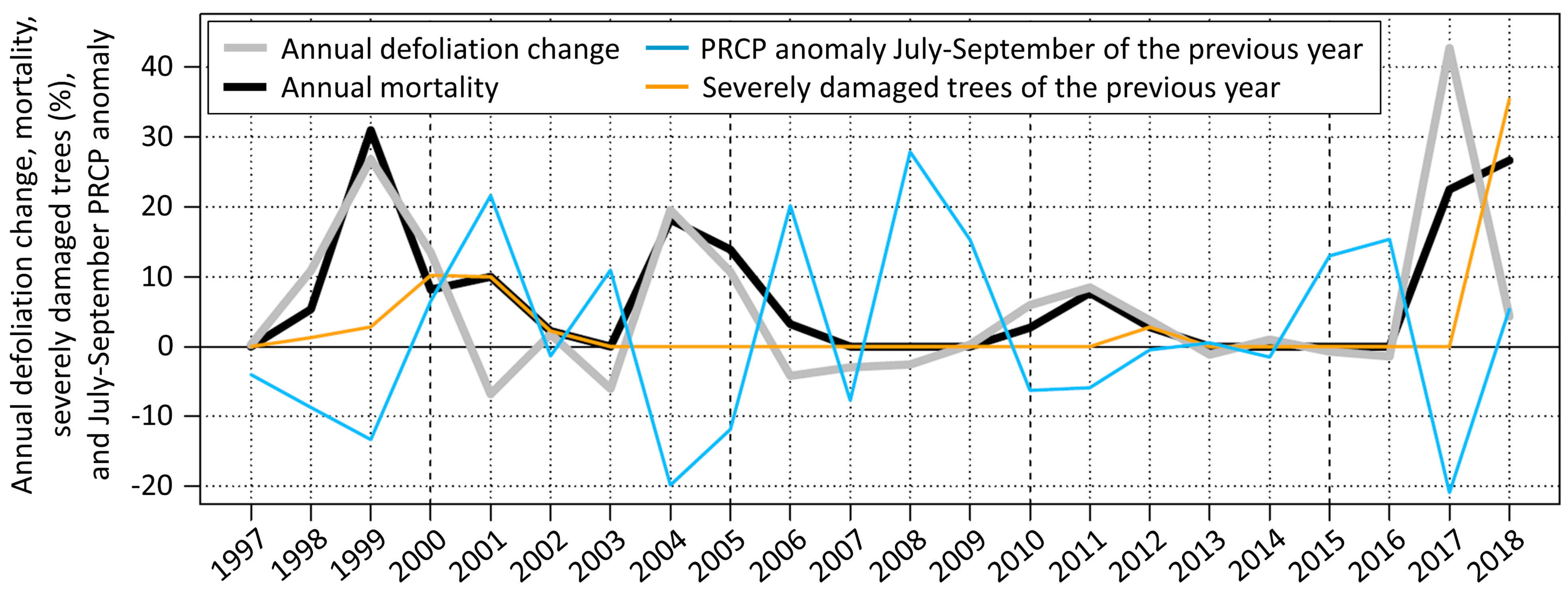


Figure 4. Annual defoliation change, mortality, July to September precipitation sum (PRCP) anomalies and the fraction of severely damaged trees in Visp

6 Local precipitation characteristics explain spatial dieback patterns

- The region with the **lowest 20th percentile of July to September precipitation around Visp matches the area most affected by dieback events**
- Considering climate projections for the next decades, it seems likely that **Scots pine dieback events will occur in larger areas** in the Rhône valley

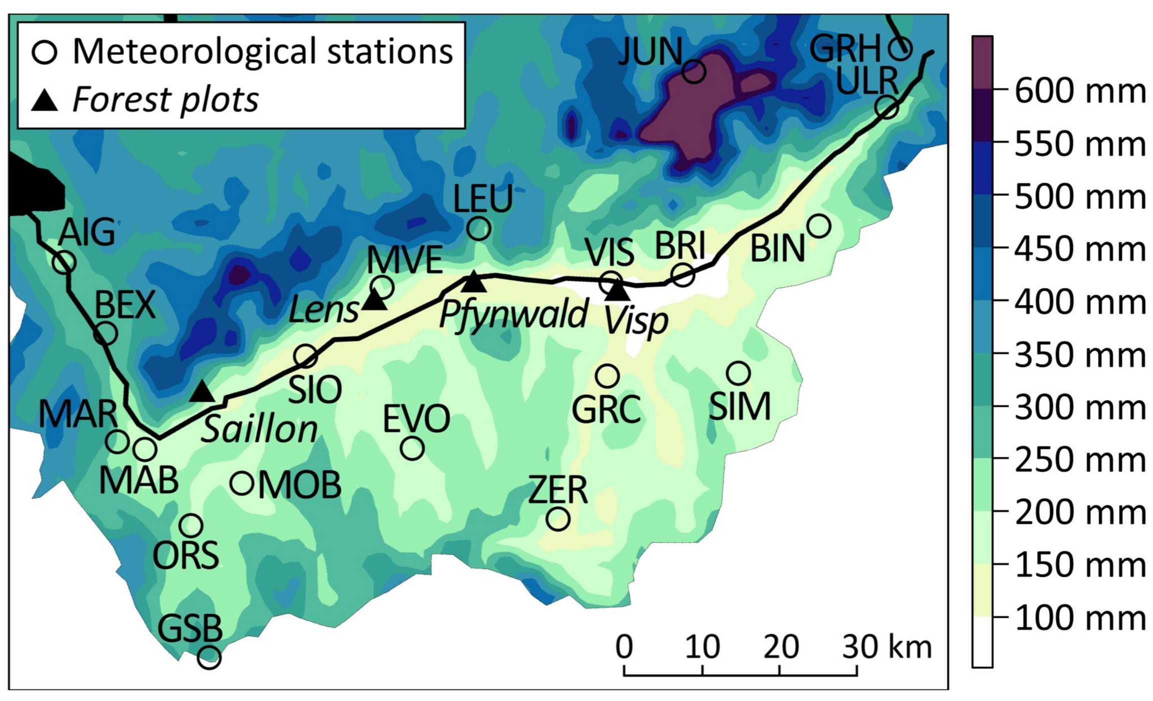


Figure 5. Spatially interpolated 20th percentiles of July to September precipitation sums

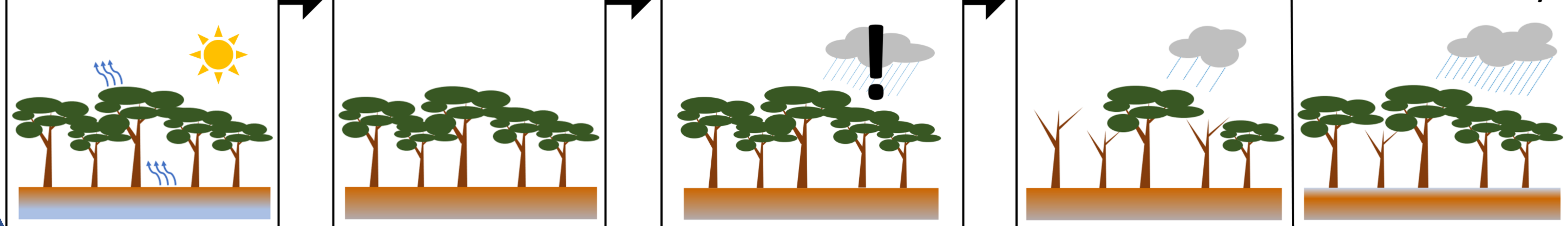
7 Conclusions

Large-scale climate change
Strong spring and summer evapotranspiration increase

Reduction of water availability
Prolongation and intensification of summer to autumn soil moisture minima on dry sites

Crucial precipitation events
The vitality of Scots pines has become dependent on substantial precipitation events between summer and early-autumn

Local climate characteristics cause diverging mortality patterns
Very low summer to early-autumn precipitation minima: **Pronounced dieback events**
Moderately low summer to early-autumn precipitation minima: **More evenly distributed mortality**



References: Hunziker, S.; Begert, M.; Scherrer, S. C.; Rigling, A.; Gessler, A., 2022: Below Average Midsummer to Early Autumn Precipitation Evolved Into the Main Driver of Sudden Scots Pine Vitality Decline in the Swiss Rhône Valley. Frontiers in Forests and Global Change, 5. doi: 10.3389/ffgc.2022.874100