Stress testing: recharge scenarios to quantify streamflow drought sensitivity

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Poster highlights in 1 minute

- Stress testing scenarios are a valuable alternative to conventional climate scenarios.
- "Stress" means recharge reduction before drought, "Test" means a quantification of "Stress"-effect on the drought year (e.g. deficit, recovery, minimum flow).
- Scenarios are embedded in a HBV model framework to compare streamflow series from scenario runs with streamflow from reference runs.
- NAT-VAR stress tests elucidate that drought is catchment- and event-specific, thus improved stress tests should consider more event-specific characteristics (< monthly scale).
- Drought propagation is controlled by short-term and long-term recharge reduction and by recharge timing.
- DRY-UP stress test filters which catchments are more sensitive to progressive drying (dry weather).
- Successful identification of catchments with higher drought sensitivity.

Why stress testing?

Climate change studies often fail to distinguish between inherent climate variability and projected climate change signal. For example, different temporal structures of future climate input can affect low flows, but the sequencing of simulated wet and dry spells is not altered (Vormoor et al., 2017). Climate change scenarios bring huge uncertainties to hydrological assessment of future streamflow droughts and low flow events.

Instead of future climate, we use historical data

- to alter antecedent water deficit conditions while preserving catchment-specific climate variability
- to quantify how sensitive catchments are to such alterations ("Stress"), i.e. under decreased recharge before drought.

Through alteration of antecedent water deficit a new sequencing in drought propagation can be tested.

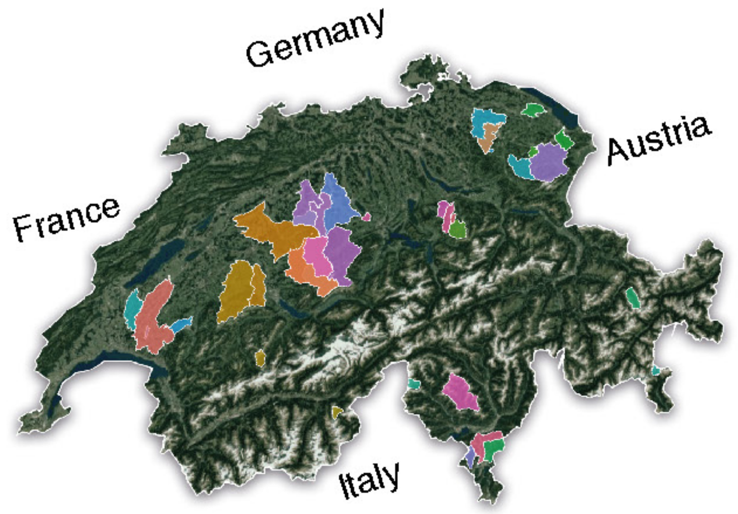
HBV model

- Scenario development is based on GAP-calibrated HBV reference run
- Calibration 1980-2000 with 70% adapted KGE and 30% MARE.
- Model spin-up with 5 average years
- P and T gradients based on input data

Terms & Framework

- "Stress" is defined as systematic decrease of recharge, "Test" is defined as a framework to quantify the streamflow response to this changed main control.
- Stress test scenarios are not about hydrological prediction, but identify catchments' sensitivity to drought.
- All scenarios are compared against the HBV reference run (never against Qobs)! HBV recharge is percolation water from soil box into GW box (incoporates also snow melt)
- All scenarios focus on recharge reduction or decreased recharge rates, but for scenario simulation P and T is changed (HBV input)

Data & Catchments

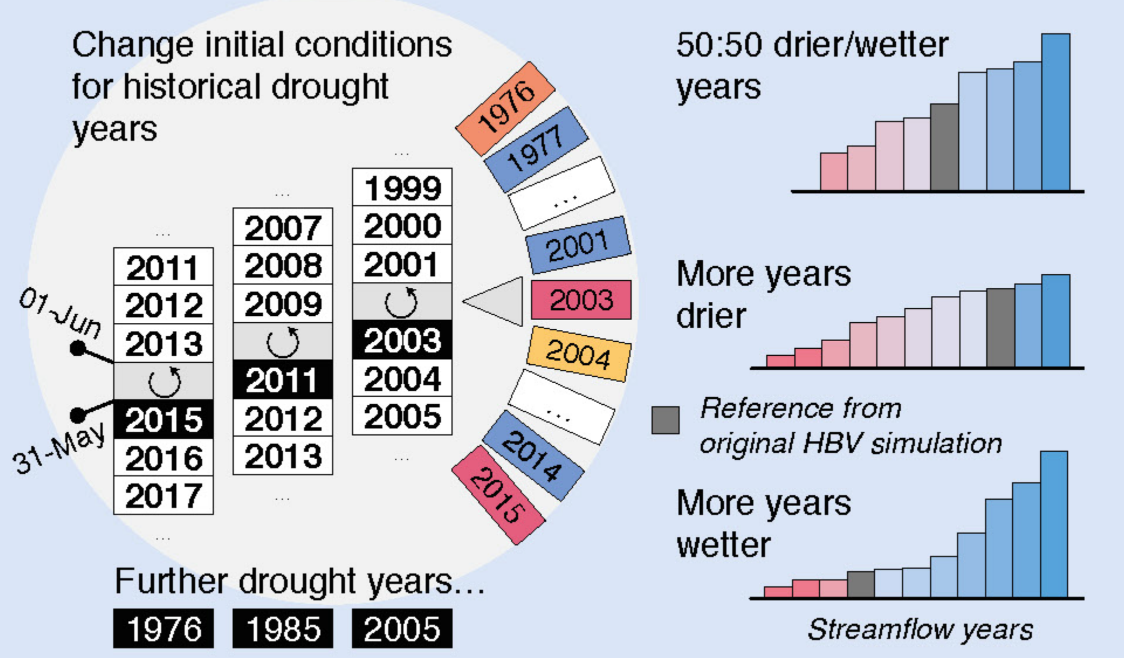


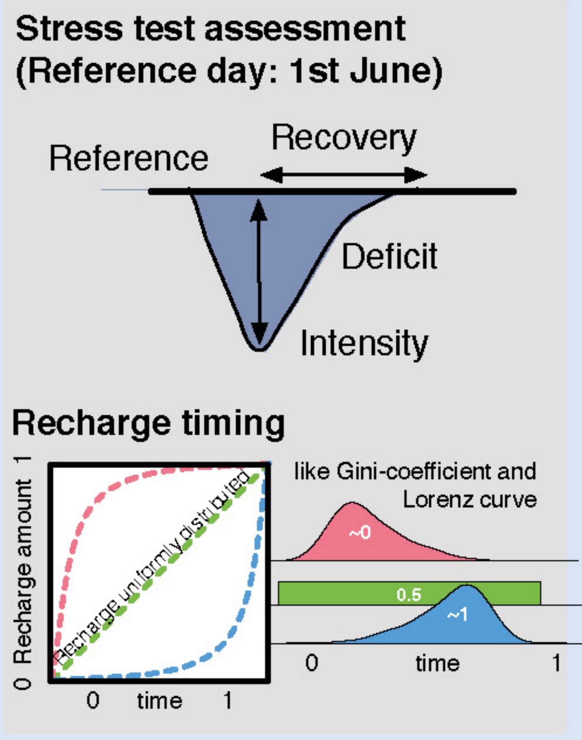
- 40 meso-scale (1-1000km^2) catchments grouped into rainfall-, hybrid- and snowmelt-dominated regimes (<800m, 800-1600m, >1600m).
- Daily data 1971-2015: Precipitation (gridded, Rhires), Temperature (gridded, MeteoSwiss) and observed streamflow (FOEN)

STRESS TEST SCENARIO

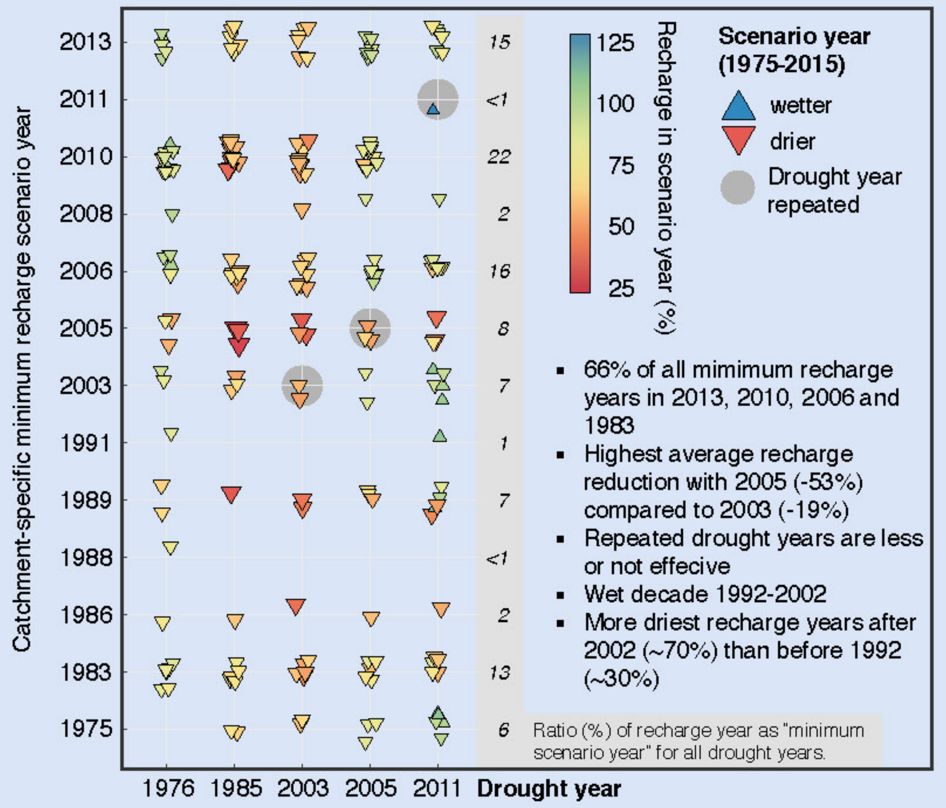
1 NAT-VAR Natural variability

What would have happened in a drought year if the preceding recharge year was changed?



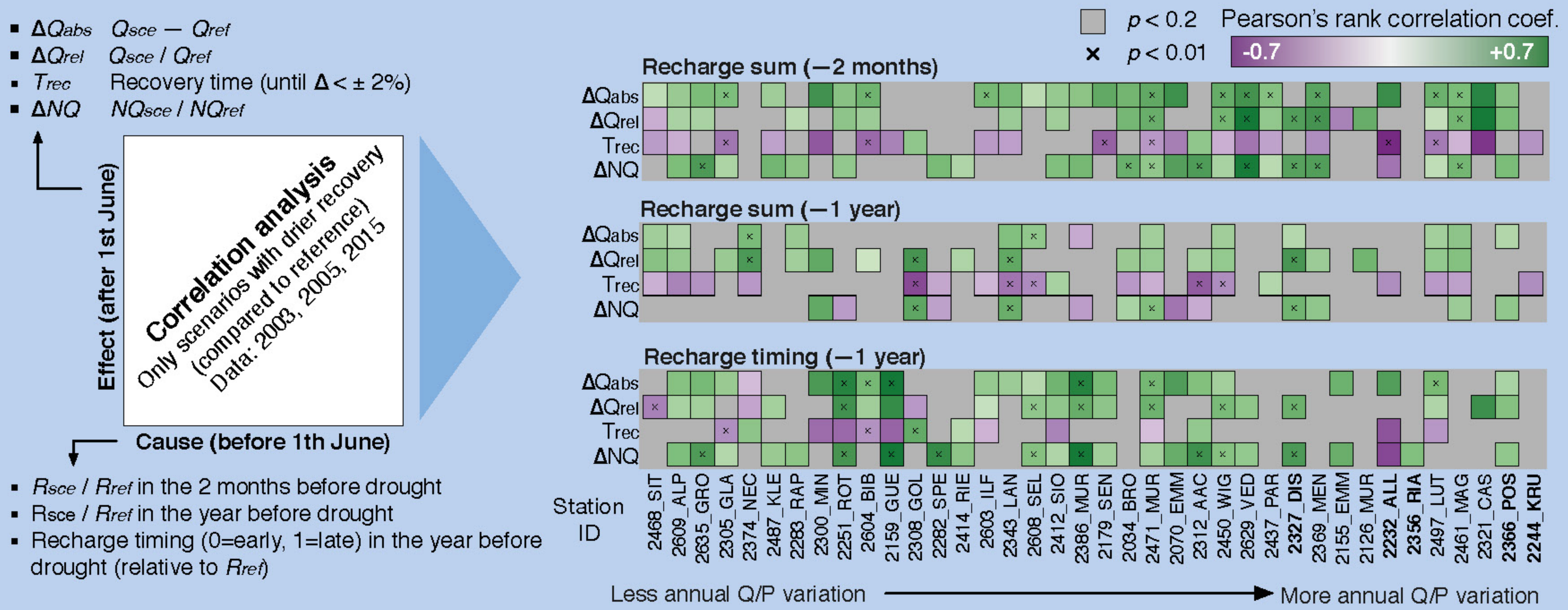


Which recharge years should be used to test the "Stress"-effect on drought years?



RESULTS

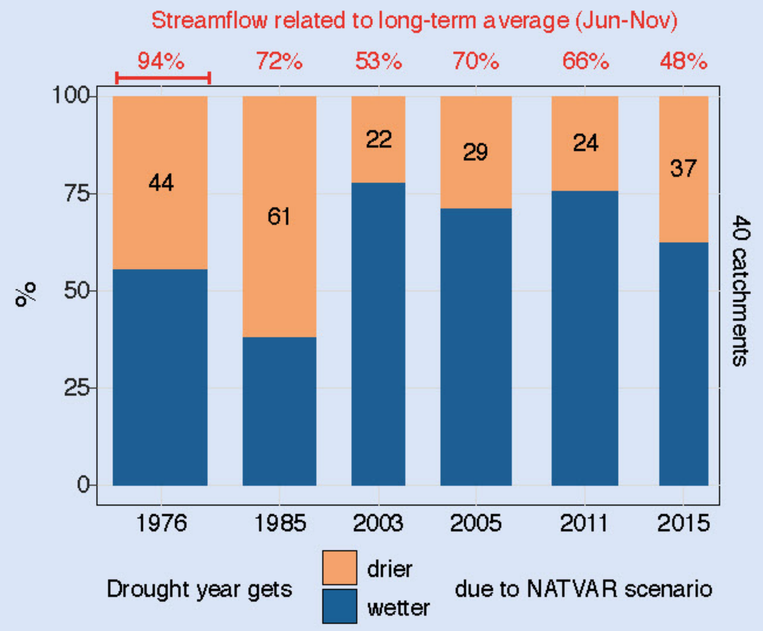
Relationship between antecedent recharge- and following drought-characteristics



- Correlation between short-term recharge and drought characteristics suggest smaller catchment-storage and shorter storage memory.
- Correlation between long-term recharge and drought characteristics suggest larger catchment-storages (e.g. 2343_LAN, 2308_GOL)
- For a faster recovery the recharge amount is more important than the recharge timing.

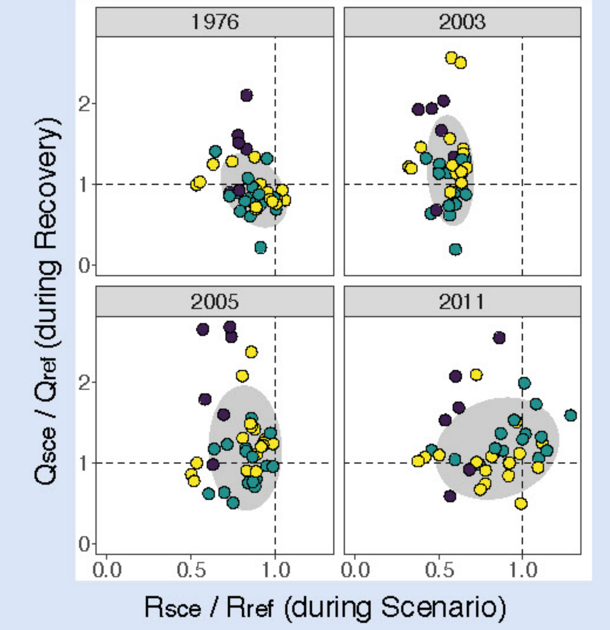
Snow-dominated catchments in bold font type, here snowpack- and snowmelt-effects (before June) must be considered.

Drought intensification / attenuation due to permuted antecedent recharge years



- Severity of summer streamflow droughts is different
- Changing antecedent conditions leads to wetter and drier drought periods
- Thus, a catchment- and event-specific approach is needed

Effect of minimum "worst-case" recharge year before a typical drought year



Effect of driest recharge years (x-axis) on streamflow (y-axis) for 4 drought years:

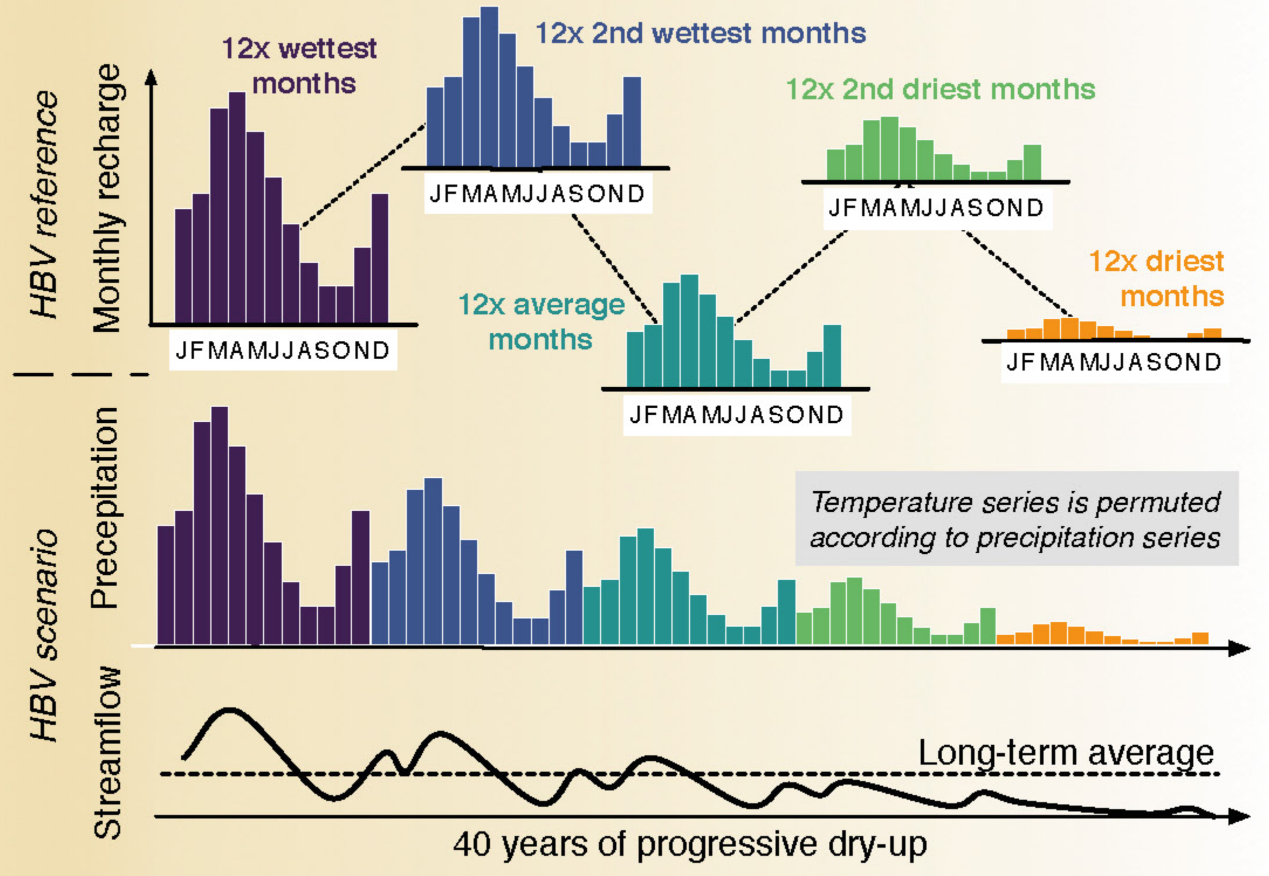
- Antecedent recharge leads to wettest reference in 2003, driest reference in 2011
- Streamflow reduction is smaller for snow-dominated catchments
- Hybrid catchments often more sensitive to reduced recharge (e.g. 1976, 2011)
- Analysis supports the "drought year"- and "catchment"-specific approch

- snow-dominated (> 1600 m asl)
- hybrid
- rain-dominated (< 800 m asl)

STRESS TEST SCENARIO

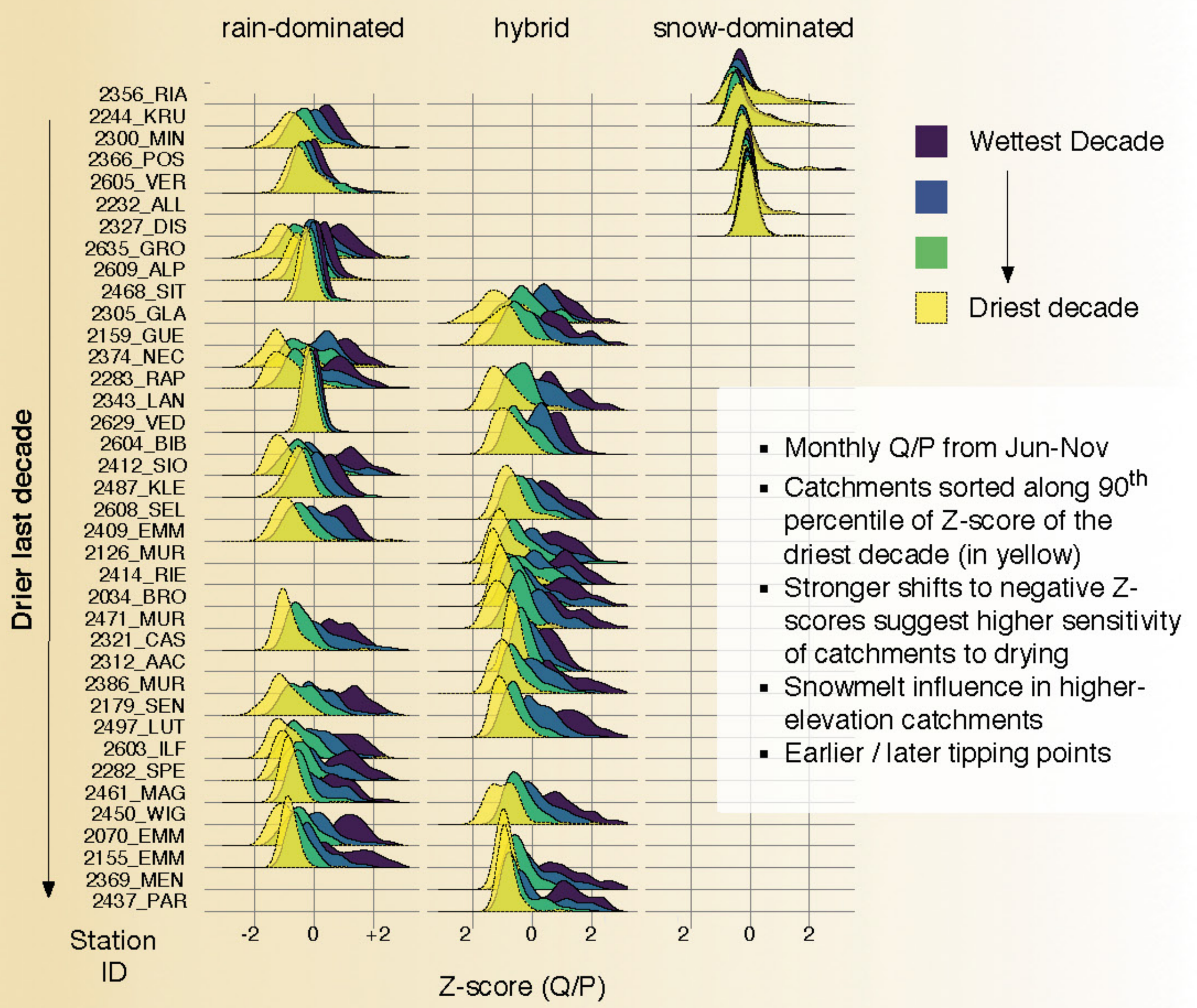
2 DRY-UP From wet to totally dry

Sorting the climate forcing according to decreasing recharge from wet to dry conditions (Staudinger et al., 2015).



RESULTS

Runoff ratio (Q/P) during DRY-UP: Test catchments' sensitivity to progressive drying



- Monthly Q/P from Jun-Nov
- Catchments sorted along 90th percentile of Z-score of driest decade (in yellow)
- Stronger shifts to negative Z-scores suggest higher sensitivity of catchments to drying
- Snowmelt influence in higher-elevation catchments
- Earlier / later tipping points

References Reading list

- Vormoor et al., 2017, *Climatic Change*
- Staudinger et al., 2015, *Hydrology and Earth System Sciences*
- Stoelzle et al., 2014, *Geophysical Research Letters*
- github.com/tidyverse
- github.com/clauswilke/ggridges/

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Data: Bundesamt für Meteorologie und Klimatologie MeteoSchweiz; Bundesamt für Umwelt BAFU

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Poster-Download: researchgate.net/profile/Michael_Stoelzle