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Current and future risk of unprecedented UK droughts

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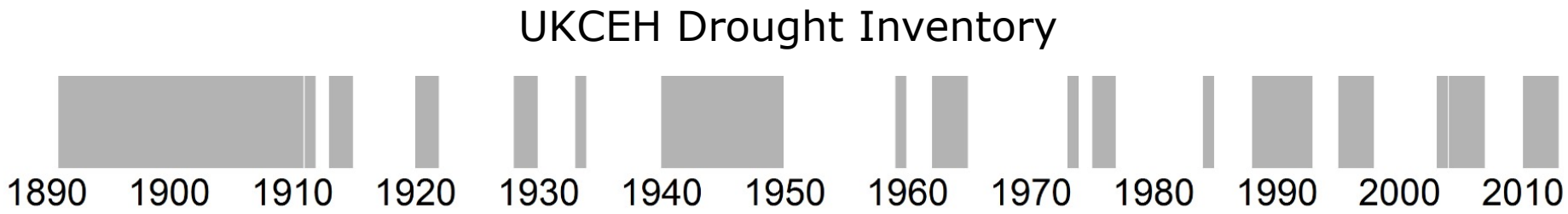
Scenario DOCTORAL TRAINING PARTNERSHIP

UKRI Natural Environment Research Council

UK droughts

The UK is not immune to hydrological droughts with vulnerability to recurring periods of past droughts *(Marsh et al. 2007; Barker et al. 2019)*



- Challenging given natural climate variability, multivariate nature of droughts and short observations. Initialized large ensemble climate simulations following the UNSEEN approach *Thompson et al. (2017)* can help
- EC-Earth SMILE consists of in total 2000 years of climate simulations of present day (representative of 2011-2015), 2°C and 3°C conditions respectively *(van der Wiel et al. 2019)*

Aims and objectives

- Apply the EC-Earth time slice large ensemble (present day, 2°C and 3°C) in GR6J hydrological models of UK river catchments to simulate river flows
- Apply the UNSEEN approach to estimate current and future chance of low rainfall, high temperatures and hydrological droughts
- Construct storylines resembling specific conditions and investigate the plausible impacts of future droughts triggered by the same conditions

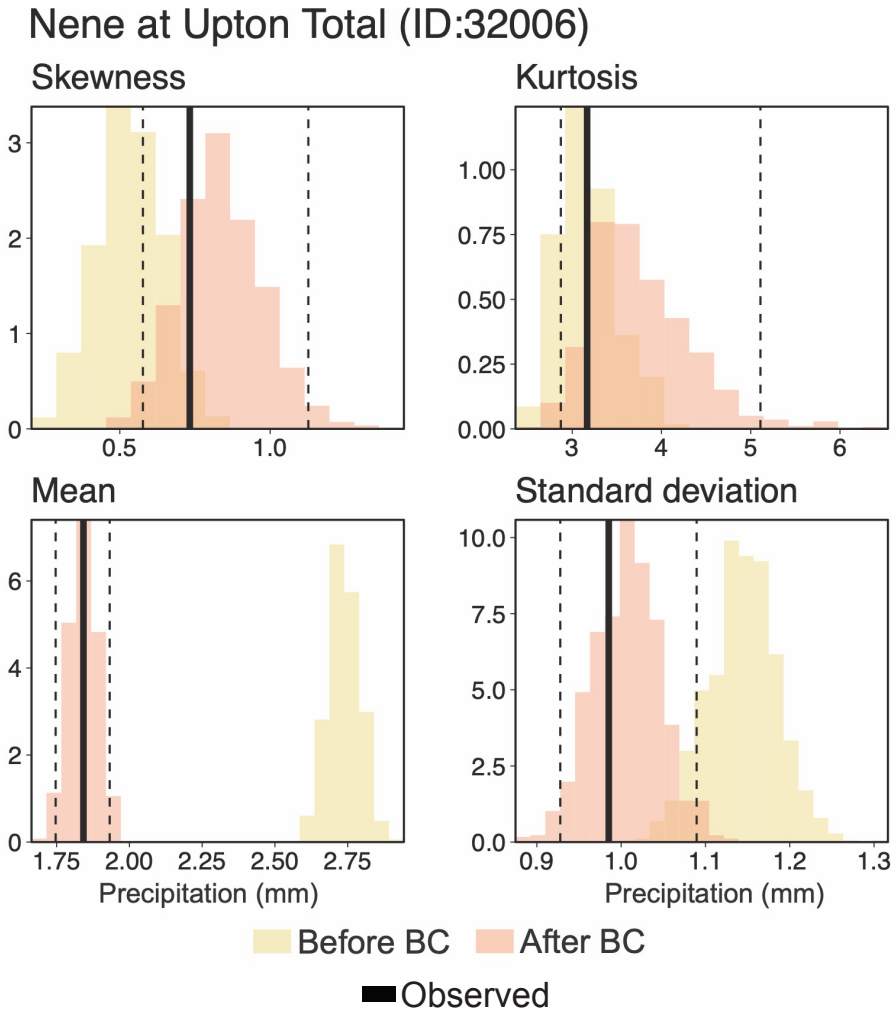
1. Dry summer succeeding dry spring (spring-summers)
   (as seen in the 1975-76 drought)
2. Dry winter succeeding dry autumn (autumn-winters)
   (as seen in the 1920-21 drought)

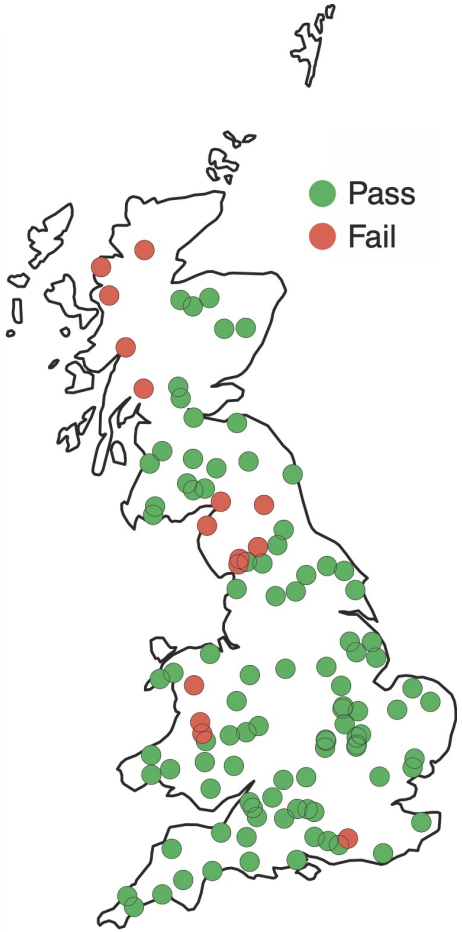
Model fidelity test

Bias corrected P and T to match catchment-averaged observations

- Match monthly observed means and coefficient of variation *(Leander and Buishand 2007)*
- Further investigation could test how UNSEEN estimates may change with more complex bias correction methods (e.g. QM)

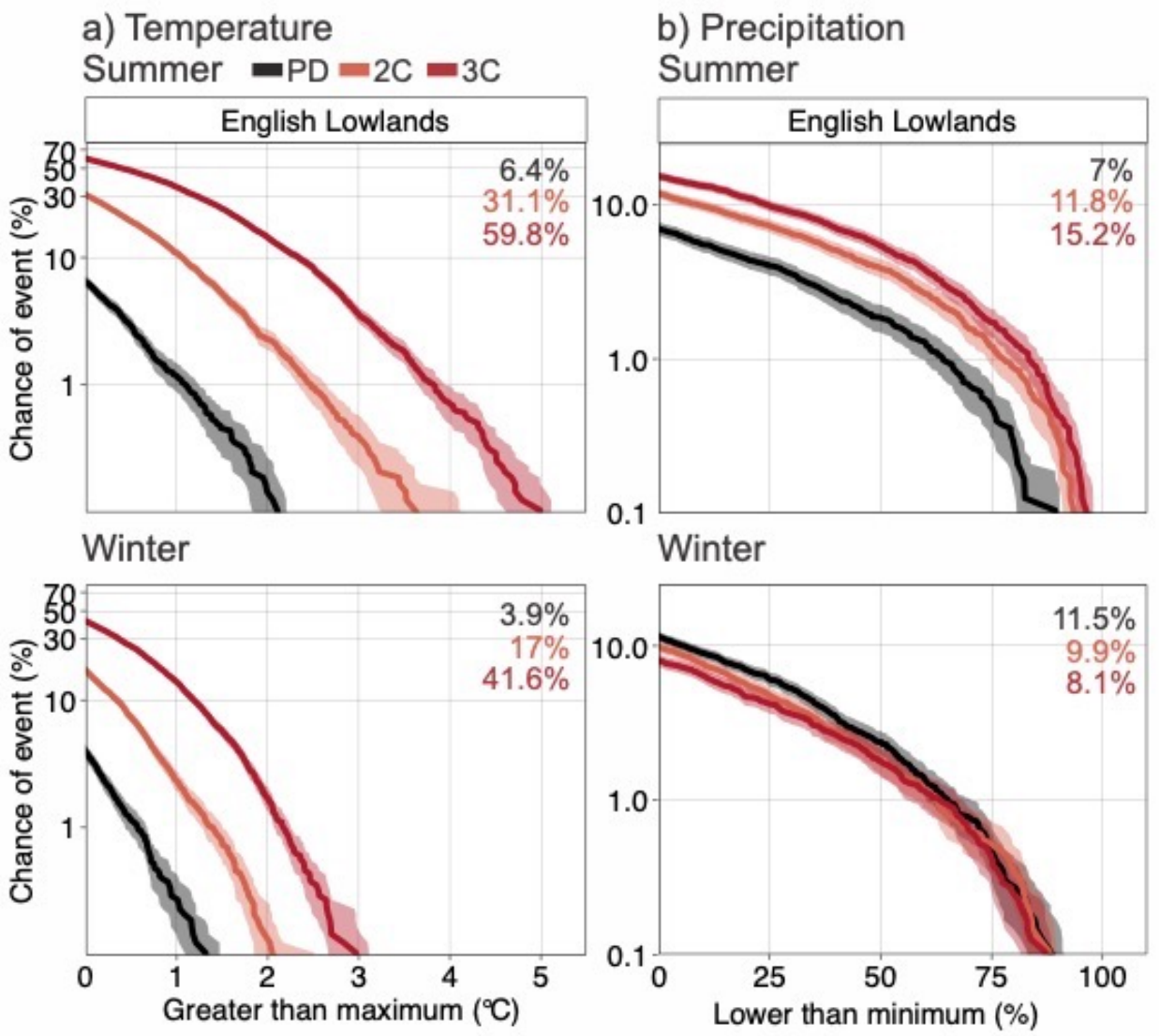
UNSEEN fidelity test to ensure modelled precipitation are statistically comparable to observations (as used in Thompson et al. 2017 and subsequent studies)



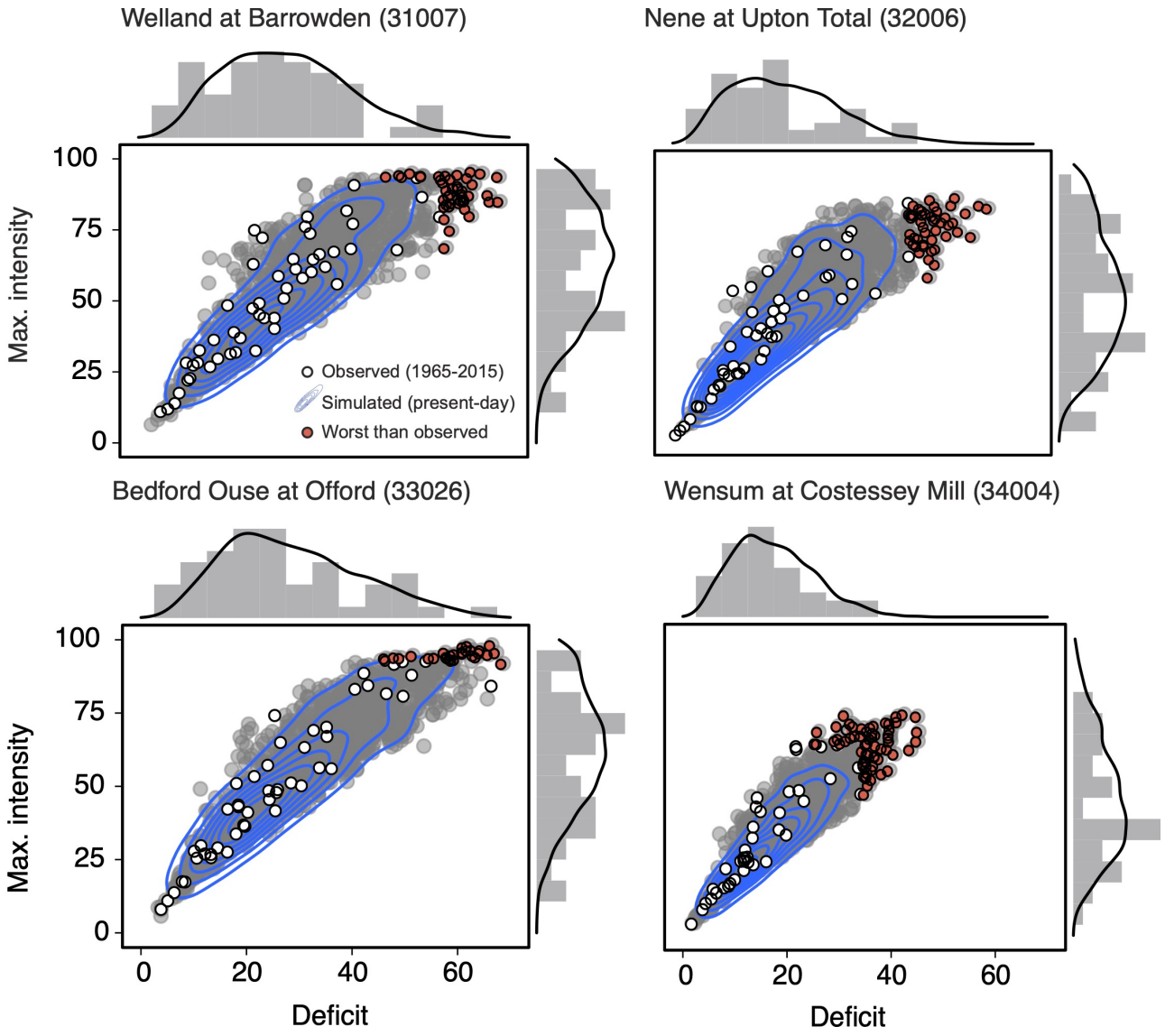


UNSEEN estimates

- Chance of high temperatures (left) and low rainfall (right) in summer and winter
- Beyond observed warmest or driest summer/winter (1965-2015)



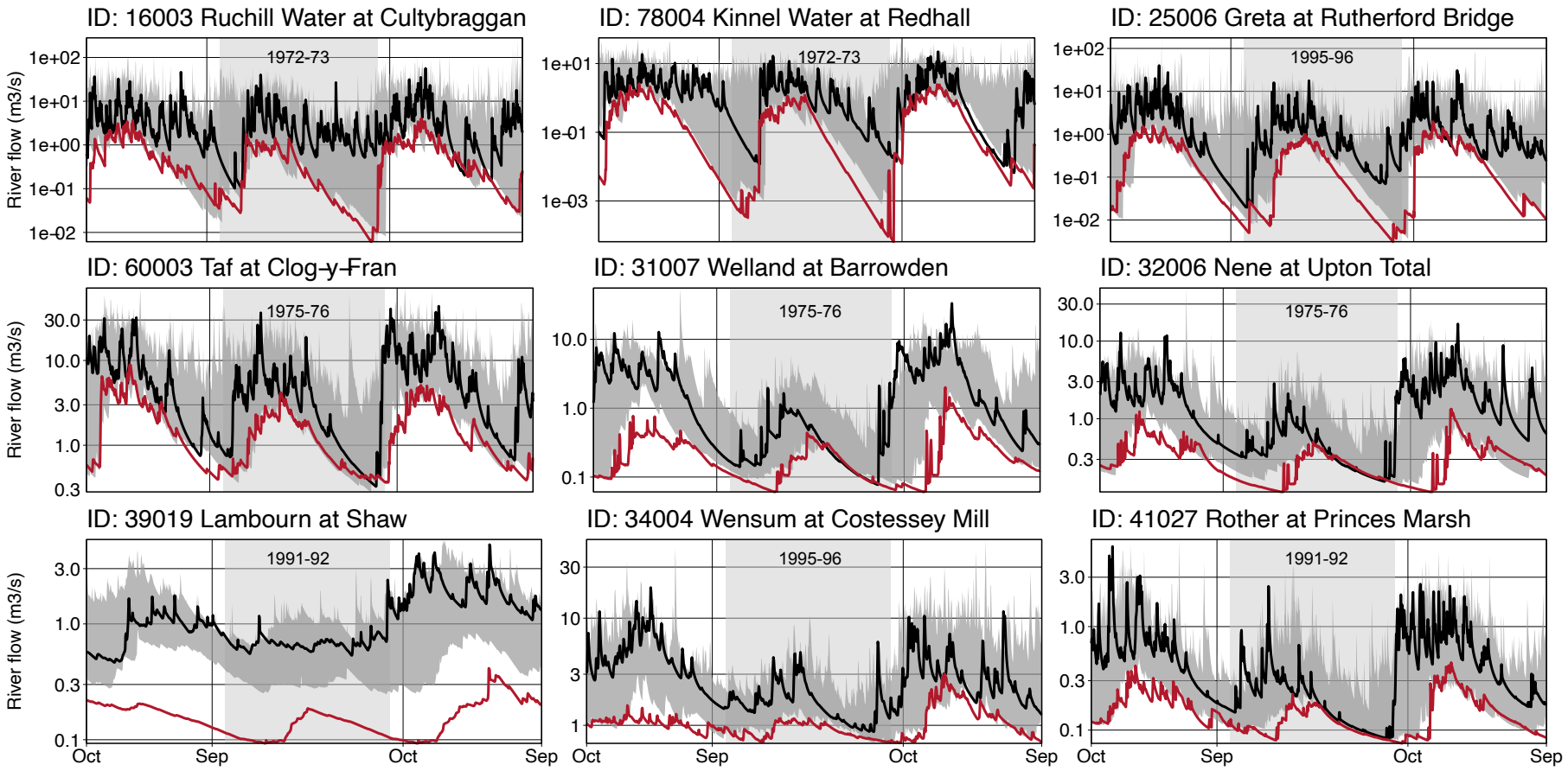
UNSEEN and hydrological modelling



- River flows simulated using GR6J hydrological models of UK catchments
- Droughts extracted via variable threshold method
- Observed droughts (white dots) fall within range of the larger sample of plausible simulated droughts in the LE, increasing confidence in physical credibility of simulated droughts

Physical credibility

- Simulated river flows are also physically credible as seen by comparing the observed driest 12-months period with the top 20 driest periods in the large ensemble and the driest period in the 3°C large ensemble



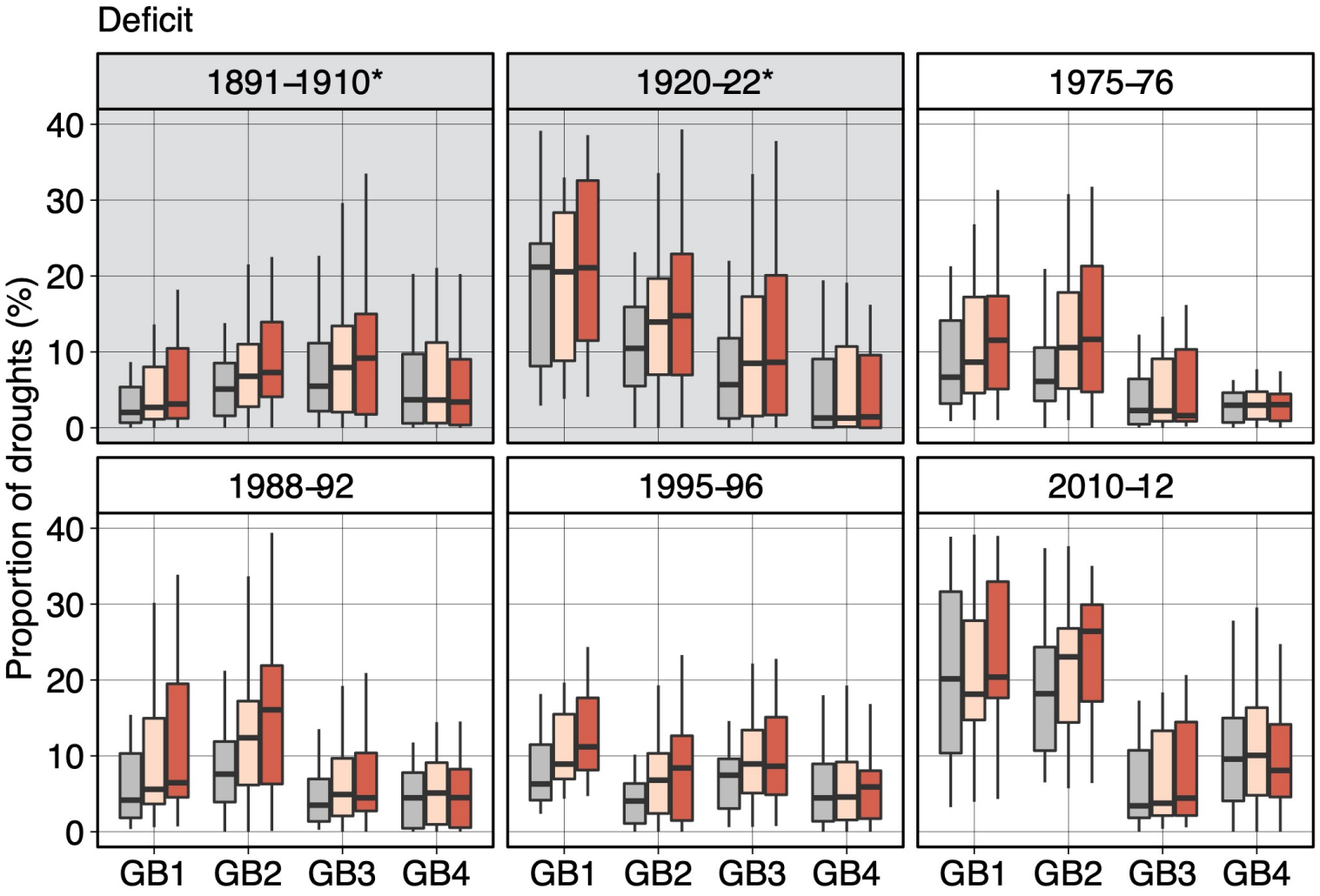
UNSEEN and hydrological modelling

Chance of a given drought with higher deficit than selected observed droughts

Exceedance are different between catchment clusters differentiated by factors including:

- Hydrogeology (Baseflow Index)
- Latitude
- Annual average rainfall

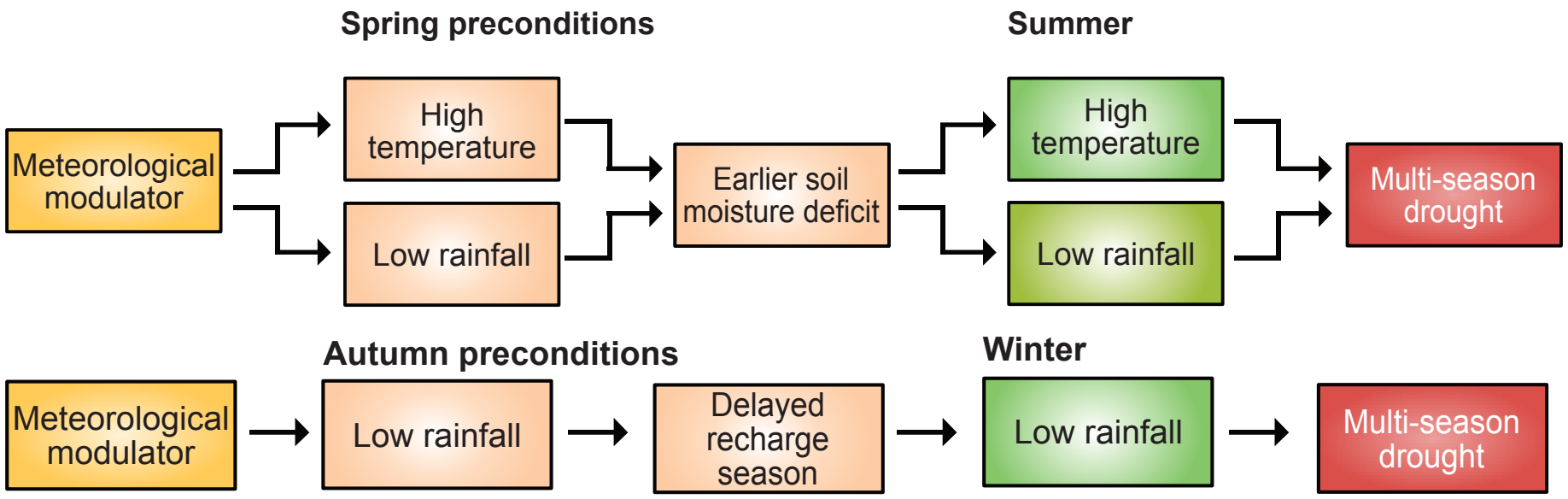
etc…



Bridging UNSEEN and storylines

Storylines here defined as outcomes from large ensemble simulations conditioned on several specific meteorological/hydrological conditions

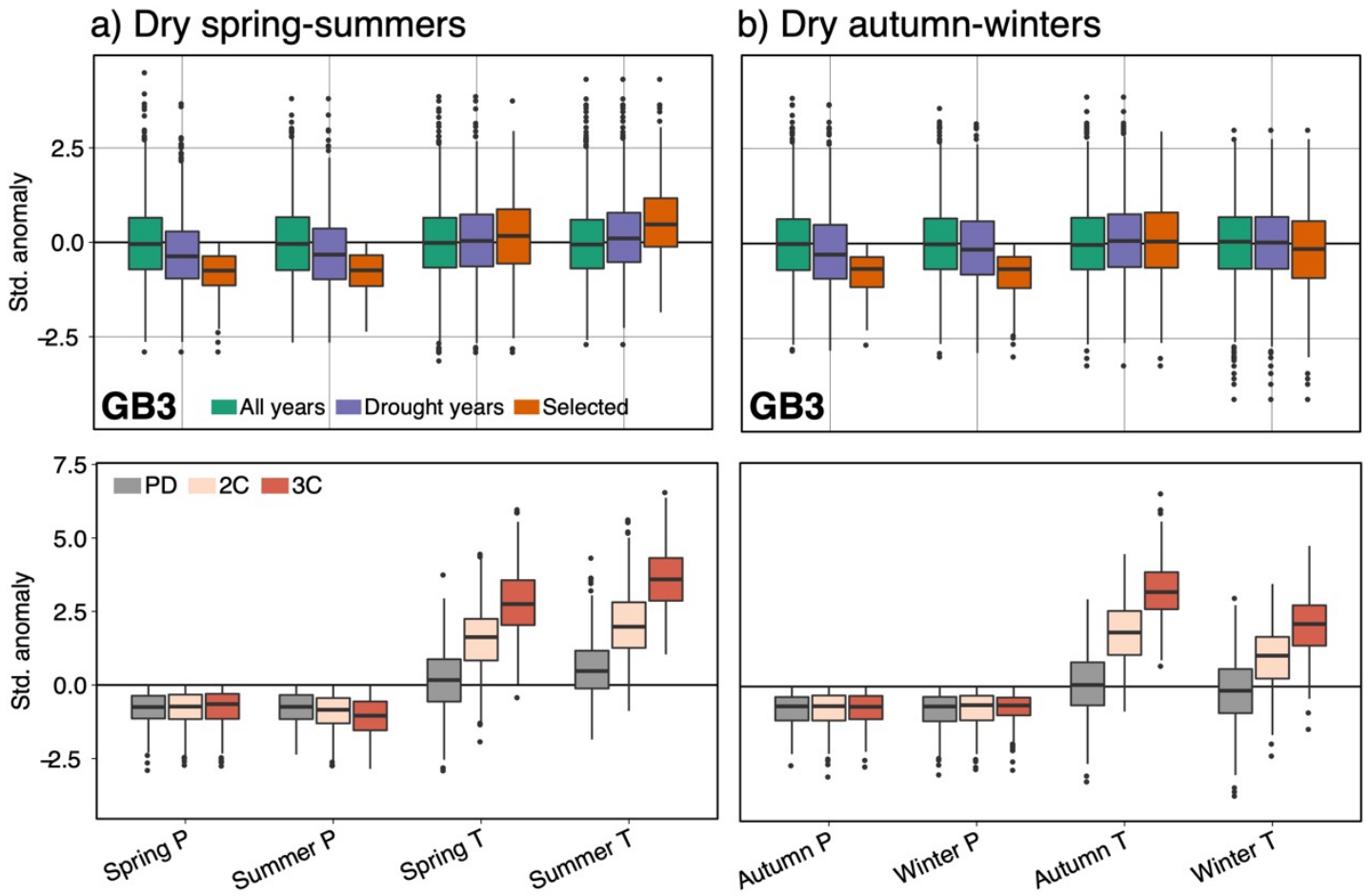
What is relevant?



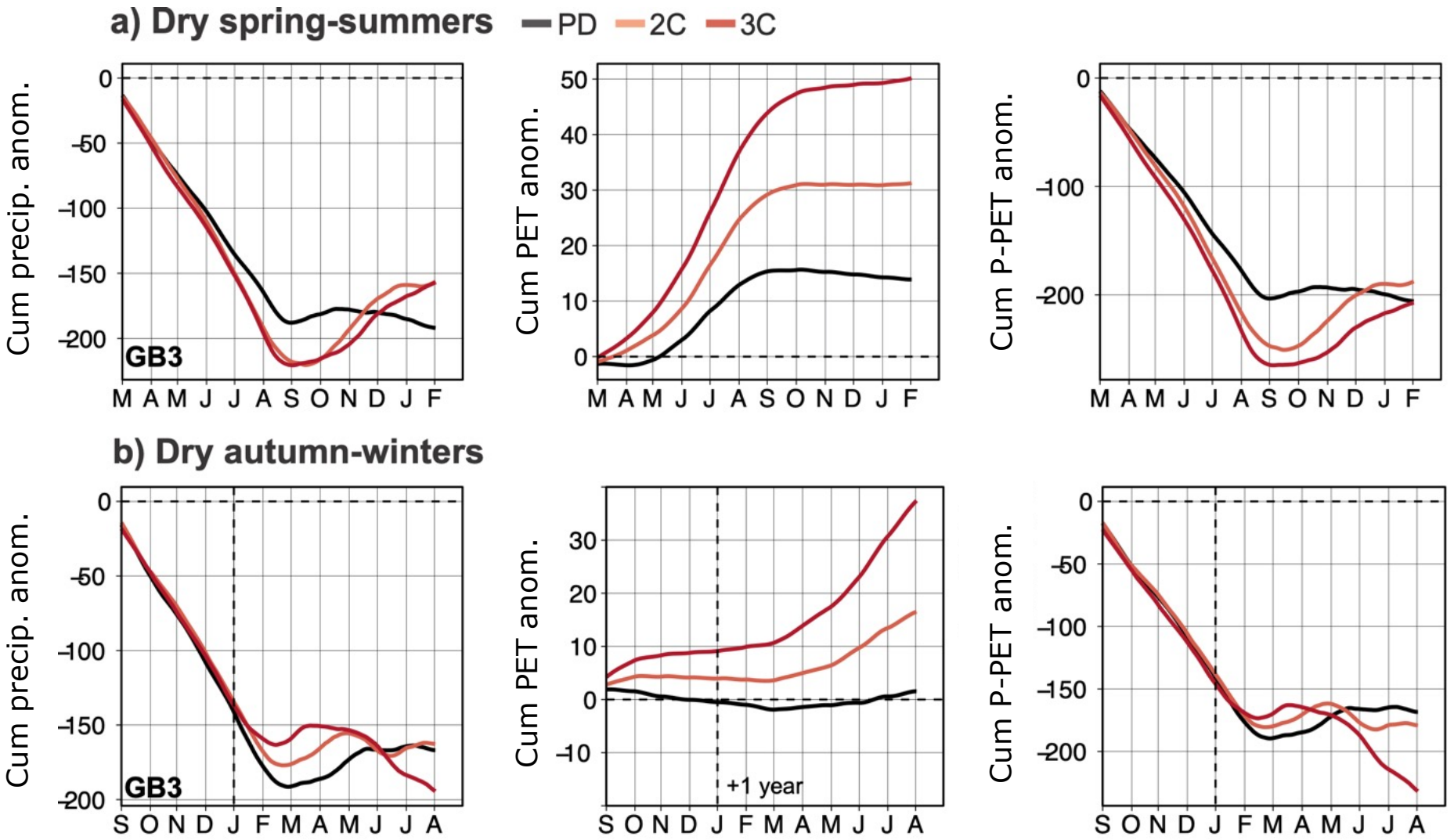
Compound events framework (Zscheischler et al. 2020) and guidelines in search for events within climate model simulations (Bevacqua et al. 2021)

Storylines of specific conditions

- Example of dry spring-summers and dry autumn-winters for slow-responding catchments in English Lowlands showing selected years in the present day (top row) and selected years in the present day, 2°C and 3°C large ensemble



Current and future storylines



Summary

- SMILEs provide UNSEEN estimates of hot-dry conditions and hydrological droughts in present and future
- Increasing chance of extremely warm summers/winters. An increasing chance of extremely dry summers but a more complex picture for winter
- Large sample of plausible simulated droughts to estimate the chance of an unprecedented drought relative to conditions observed in past droughts
- Given atmospheric circulation-related uncertainty across GCMs, storylines created by searching for specific outcomes in the LE can help construct stress-tests for hydrological systems
  - e.g. Construct plausible extreme droughts based on combinations of storylines OR reimagine how past droughts with same conditions could have turned out worse given the magnitude of change in the specific conditions