INTEGRATED MULTISECTOR MULTISCALE MODELING

IM3

Scenario storyline discovery for multi-actor human-natural systems confronting change

...paper currently in revision at Earth's Future

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Motivation

Scenarios are widely used tools in assessing the potential impacts of future uncertain conditions and in informing adaptive management. But, traditional "top-down" scenario approaches rely on reduced numbers of prespecified scenarios that can inadvertently exclude consequential extremes and diverse stakeholder impacts. "Bottom-up" exploratory approaches, on the other hand, use ensembles of large numbers of hypothetical futures to discover the ones most consequential to a system and its stakeholders. **Exploratory modeling methods introduce more rigor into how uncertainty is explored, but struggle with conveying actionable outputs and informing actions.** We therefore introduce the **FRamework for Narrative Storylines and Impact Classification (FRNSIC).**

Case study

We demonstrate FRNSIC on the Upper Colorado River Basin within the state of Colorado. The basin supports thousands of local water diversions, for **multi-sectoral uses**. It is also responsible for making sufficient water deliveries to Lake Powell, to meet Colorado's obligations to downsteam states.

These critical provisions are threatened by the occurrence of **decadal drought events.** This application therefore focuses on the dynamic properties that give rise to these events, as well as the impacts they generate for the basin's stakeholders.

Scenario storylines for impacts and dynamics

Through a high-resolution water resources model, StateMod, we trace how particular **storylines** manifest in terms of impacts at the basin level, and at the sub-basin scale: for **water districts** and **water users**.
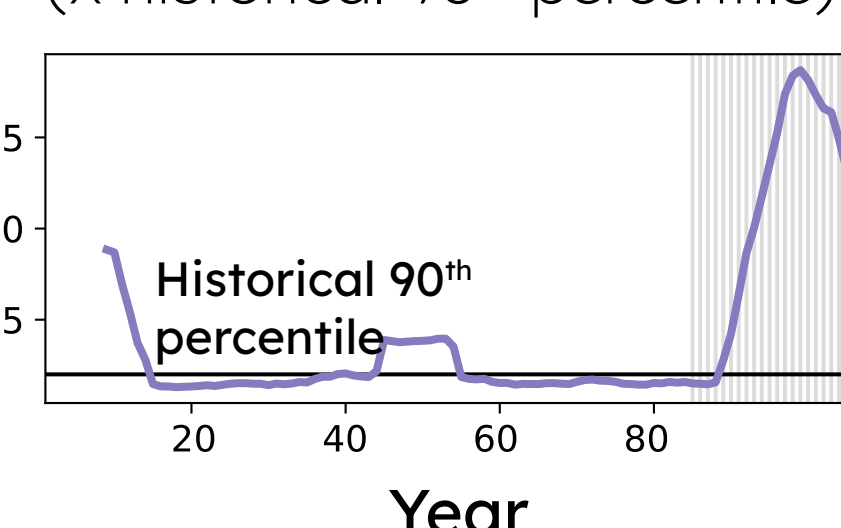
We highlight one particular storyline, that exhibits **significant impacts over a 20-year drought**. At the basin level, we see significant reductions to downstream deliveries and significant increases in shortages within the basin. We see that its effects are quite variable across the basin, for districts and users.

Basin-level impacts of storyline

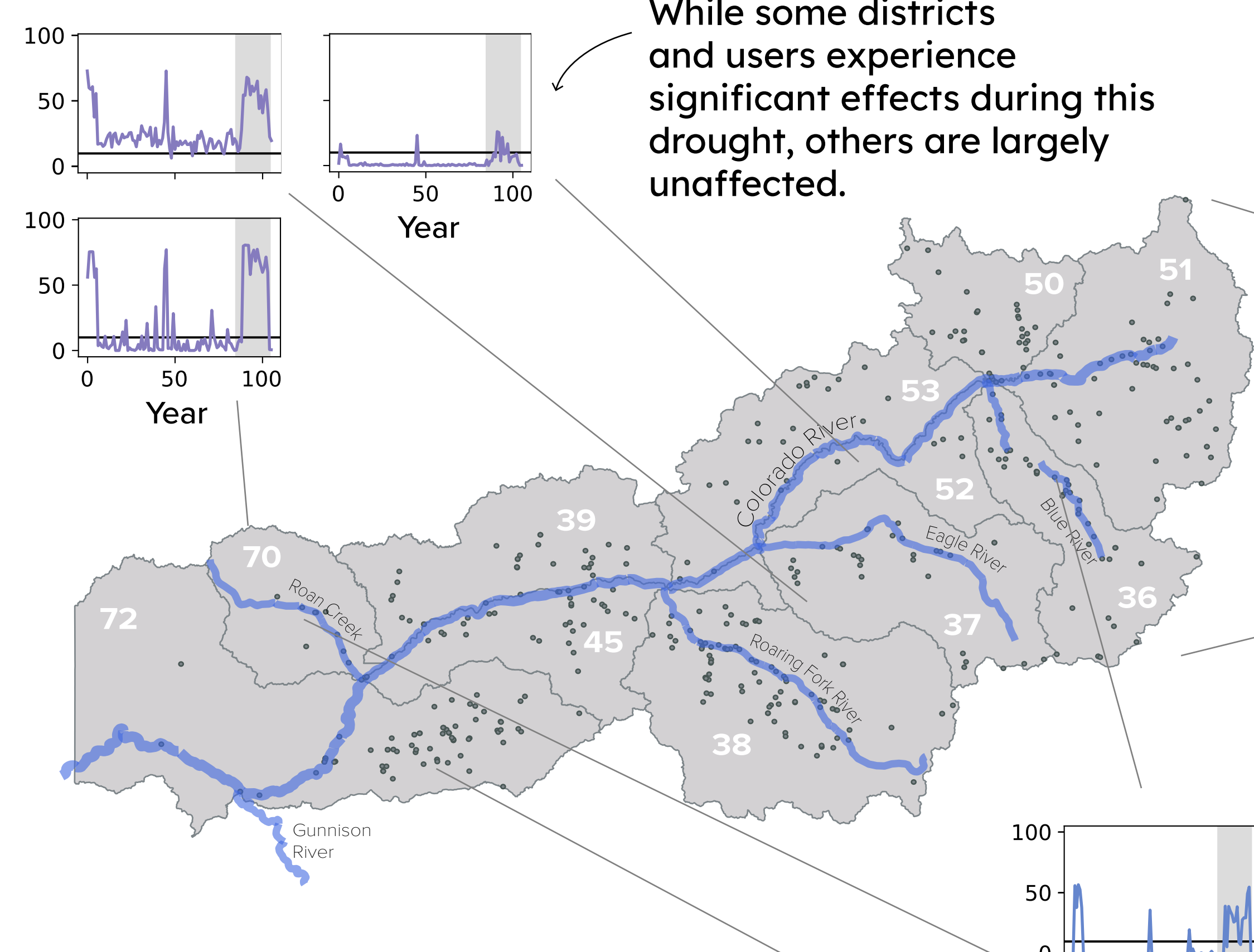Basin deliveries downstream (x historical 10th percentile)
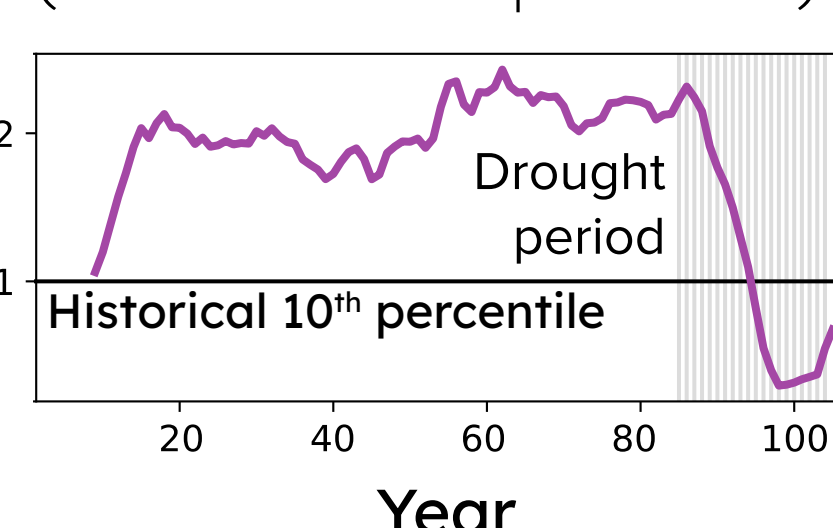
Cumulative basin shortages (x historical 90th percentile)

Exploratory modeling

We use exploratory modeling ensembles that capture extremes beyond regional climate projections. All these **"states of the world"** are treated as deeply uncertain, without prior likelihood assumptions. The states of the world are then evaluated on how consequential they are for stakeholder outcomes.

The exploratory ensemble takes deep uncertainty into account by enveloping all hypotheses of a plausible future

Historical — CMIP5 projections — Paleo reconstruction — Exploratory ensemble

Annual flow (Million m^3)

Diagram: Framework cycle

Problem framing — Evaluation across many states of the world — Update framing — Multi-trait storyline discovery — Multi-trait classification

I, II, III, IV

Hierarchical classification

FRNSIC uses **hierarchical classification** sets to discover **scenario storylines** within the broad exploratory ensemble, that summarize both critical **impacts** and the consequential **system dynamics** that produce them.

Basin deliveries <= P10
Shortage >= 10%
Users >= 50%
No — Yes — Yes — Yes
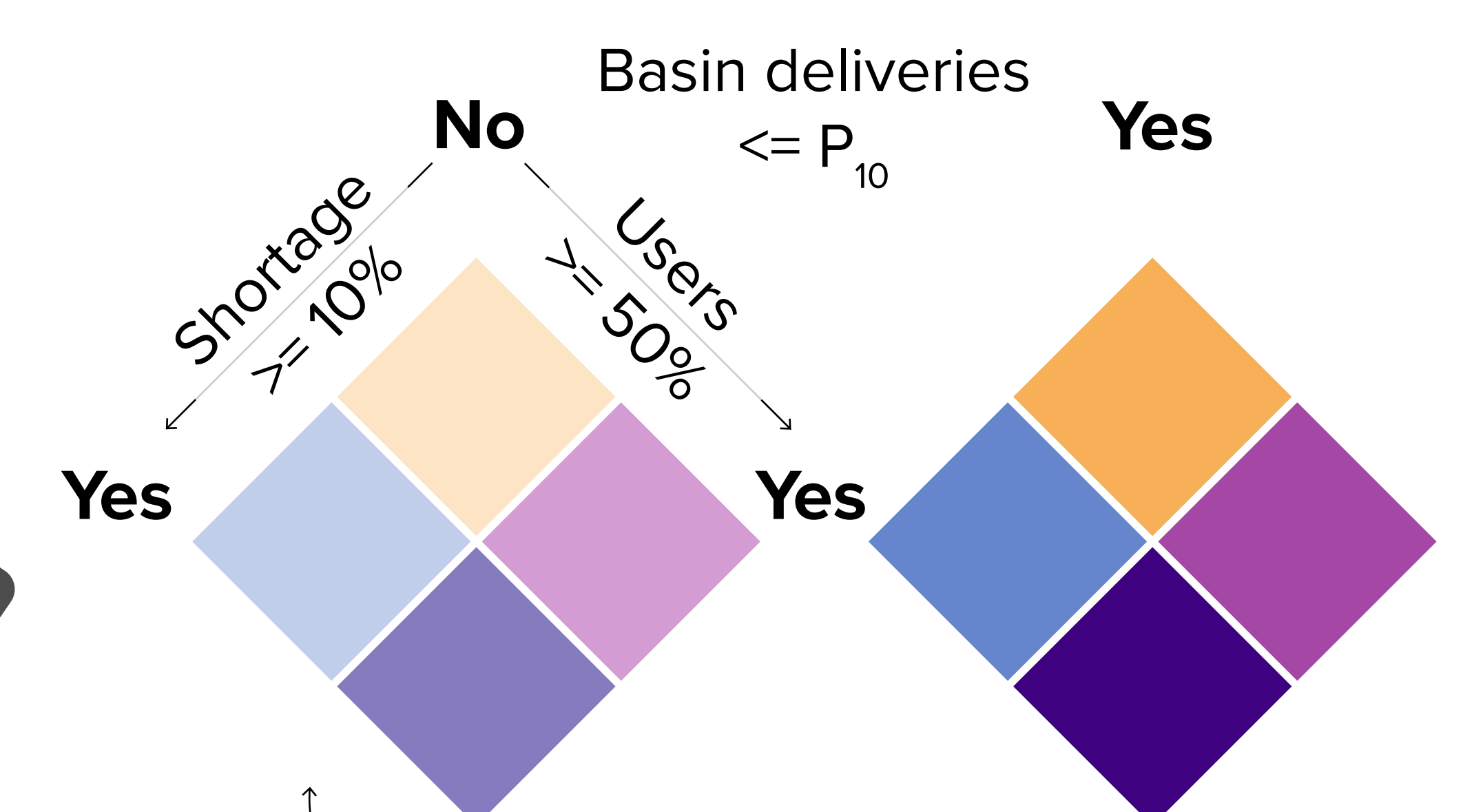
The three-dimensional **impact classification** scheme captures drought impacts, through **shortages** to the basin's water users, the **number of users** affected, and downstream **deliveries to Lake Powell.**
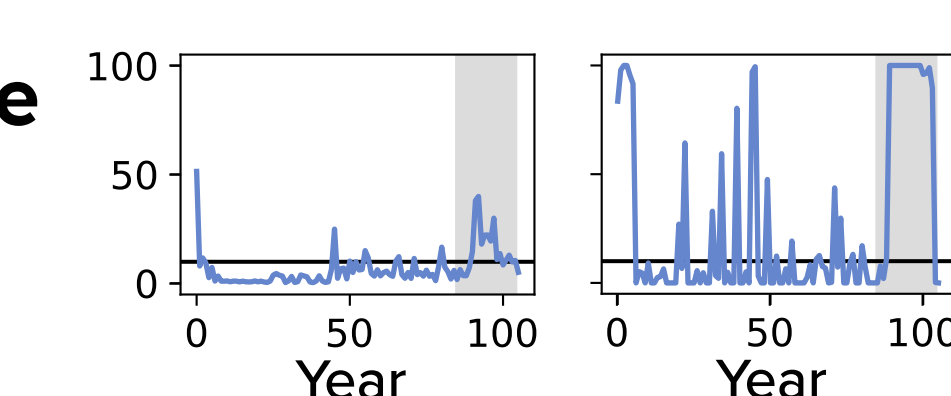
District-level impacts of storyline

District shortage as percentage of demand (%)

While some districts and users experience significant effects during this drought, others are largely unaffected.
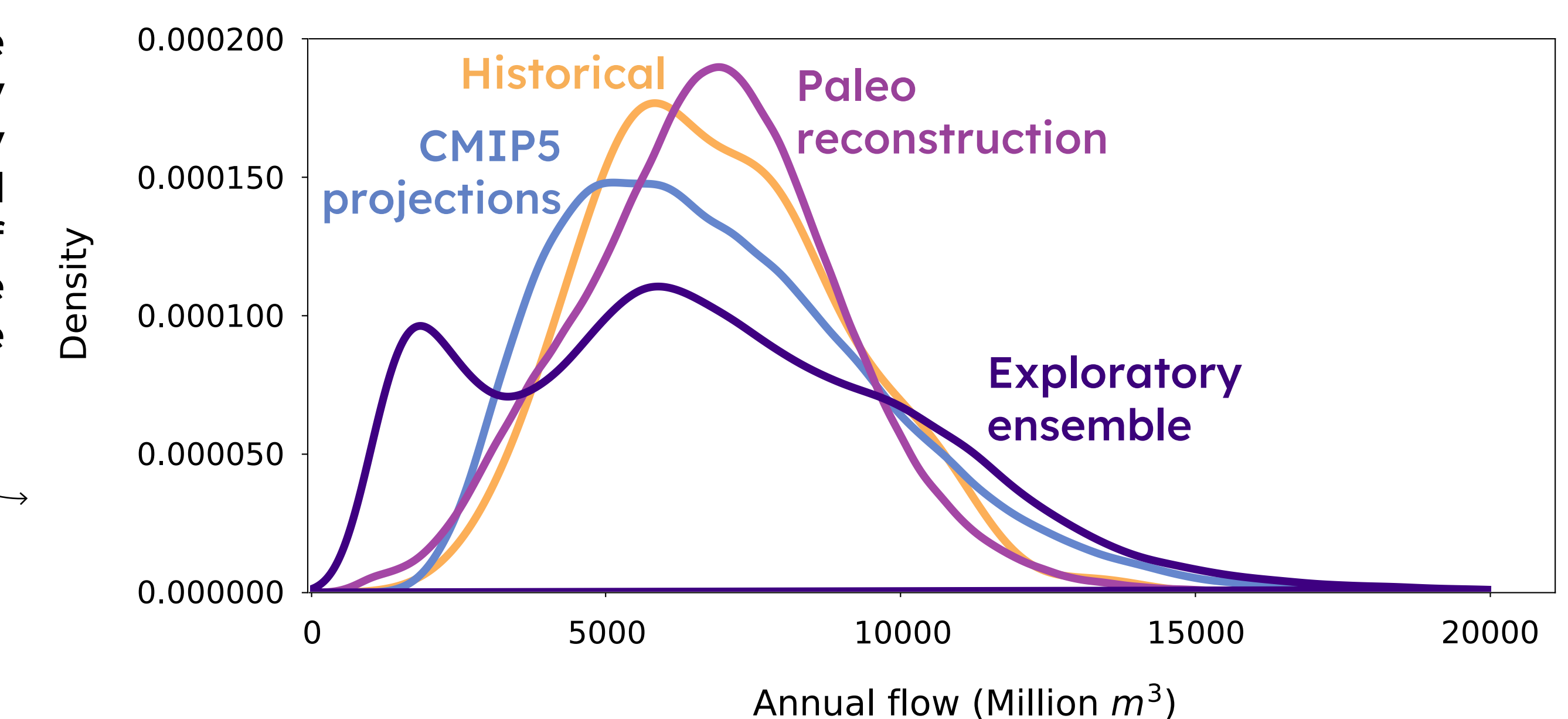
User-level impacts of storyline

User shortage as percentage of demand (%)

Changing average and variability
Changing variability and drought occurrence
Changing average and drought occurrence

570 SOWs* in the ensemble meet these two dynamic conditions
59 SOWs
148 SOWs

Combinations of dynamic conditions are used to visualize how different states of the world behave dynamically, and also how said dynamics relate to different types of impacts. This figure summarizes how 24 combinations of impacts and dynamics emerge across the ensemble.

* SOW: "state of the word"

Potential collaborations

FRNSIC can be applied to a variety of systems with complex dynamics and multi-sectoral users, as well as consider several uncertain drivers in its exploratory ensemble. Potential collaborations include other projects with similar driver-impact questions, such as COMPASS-GLM, BSEC (IFL), and HyperFACETS.