Incorporating Climate Uncertainty into Water Allocations in Kansas

Colton Chapman[1] (coltonchapman@ku.edu), Richard Rockel[2] (Richard.Rockel@kwo.ks.gov) and Joshua K. Roundy[1] (jkroundy@ku.edu)
[1]Department of Civil, Environmental, and Architectural Engineering, University of Kansas, Lawrence, Kansas
[2]Kansas Water Office, Topeka, Kansas

1. Motivation

The current practice at KWO is to use 1950's climate, which was an extreme drought period in the state of Kansas, for determining water allocations. While the 1950's drought was an extreme event for Kansas, it relies on stationarity, the idea that natural systems fluctuate within an envelope of unchanging variability. This lack of robustly accounting for climate uncertainty limits the ability of the state to conduct long-term water supply planning and anticipating the range of future resource conditions for much of its projected population growth area.

2. Methods

KU and KWO will work together to incorporate climate uncertainty into Kansas water allocations.

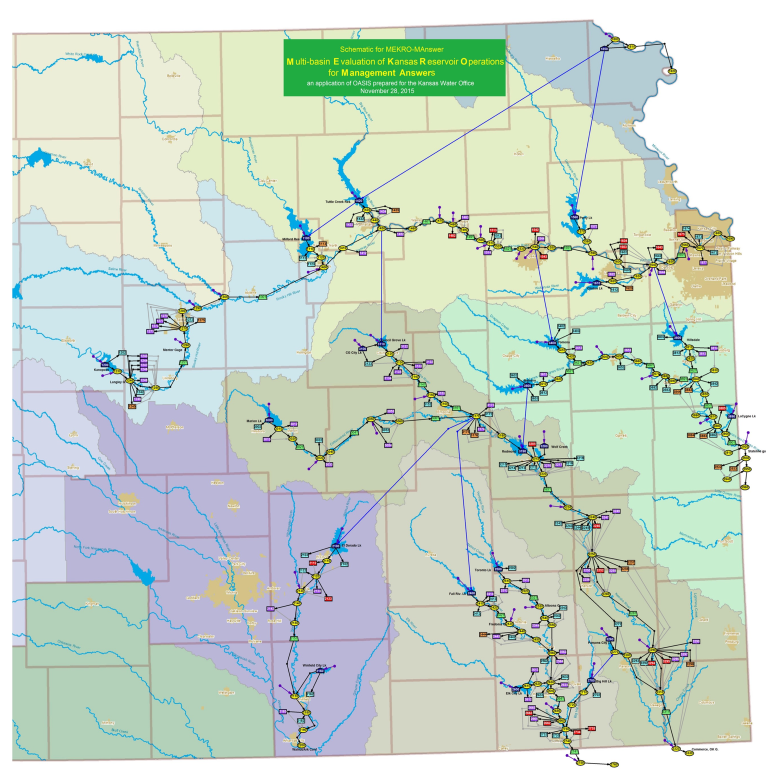

Fig. 1 - A schematic of the KWO model used to allocate water in the state of Kansas. The water balance model incorporates six river basins, 21 reservoirs (16 are federal reservoirs), 51 inflows and 163 sources of consumptive use.

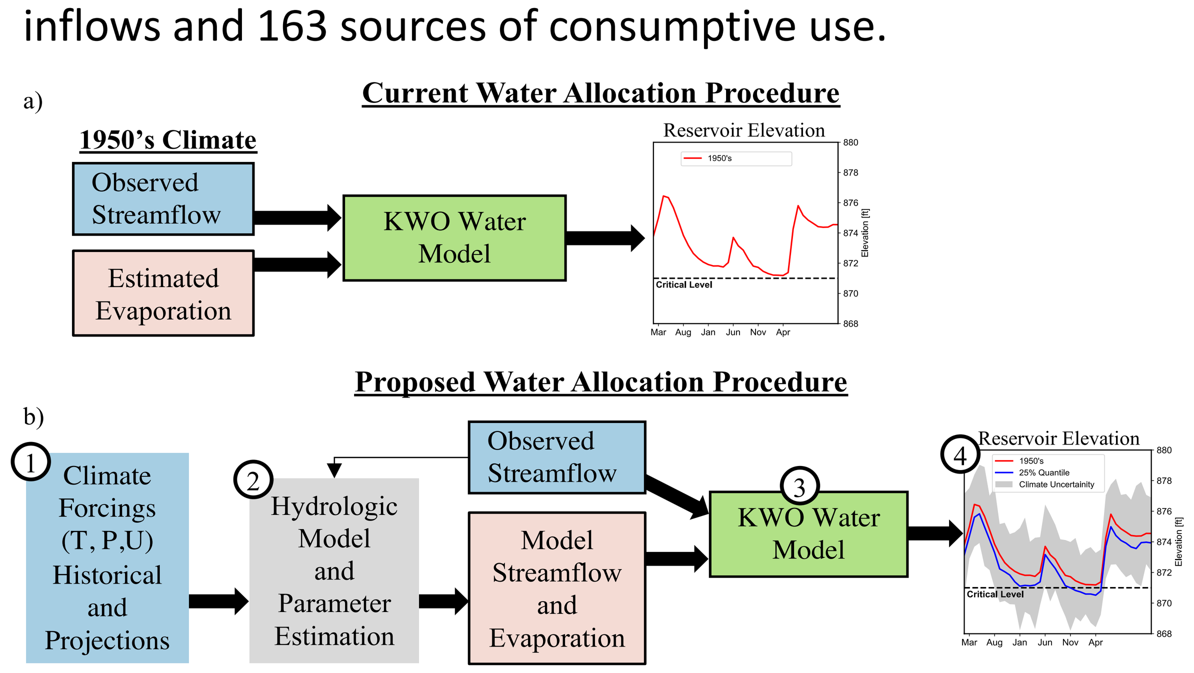

Fig. 2 - **a)** The current practice at KWO is to use the model based on streamflow and evaporation estimated during the 1950's drought.
b) The new water allocation procedure will include climate uncertainty into the water allocation procedure in Kansas by utilizing CMIP5 projections from 32 different models downscaled to 1/16th degree.

3. Future projections

After post processing trends in the data were preserved. Downscaled CMIP5 models use RCP scenarios, RCP4.5 and RCP8.5, which project climate conditions out to the year 2100.

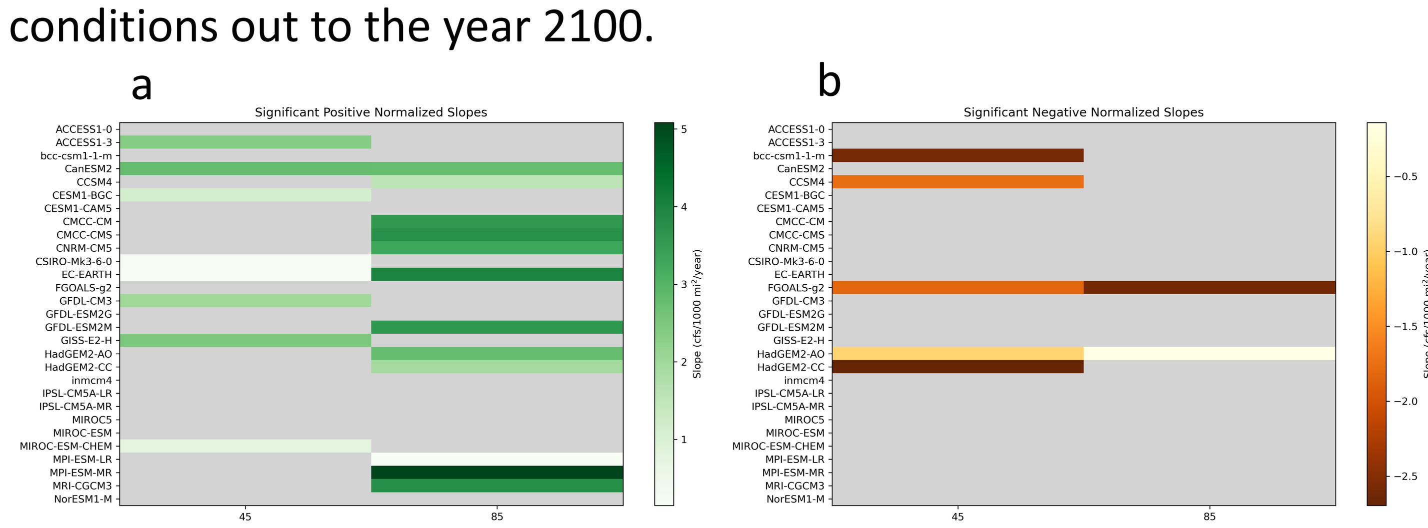

Fig.3 – Slopes of significant annual trends for a) positive trends and b) negative trends

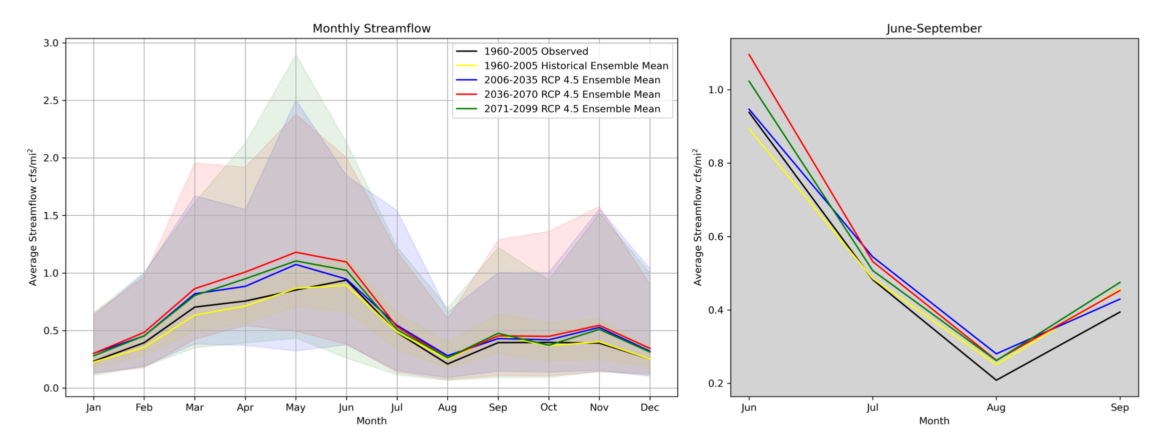

Fig. 4 – Normalized streamflow by month showing the observed, historical ensemble and future ensemble mean and range of ensemble values for RCP4.5

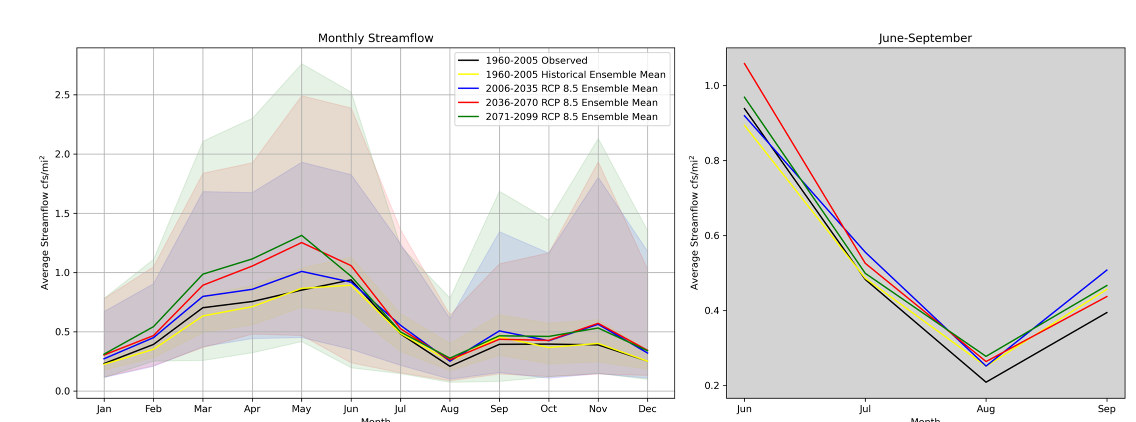

Fig. 5 - Normalized streamflow by month showing the observed, historical ensemble and future ensemble mean and range of ensemble values for RCP8.5

4. Extreme events

With changes in atmospheric composition and increased temperature the water holding ability of the atmosphere increases according to the Clausius-Clapeyron relationship. This can lead to larger precipitation and flood events while also increasing low flow events

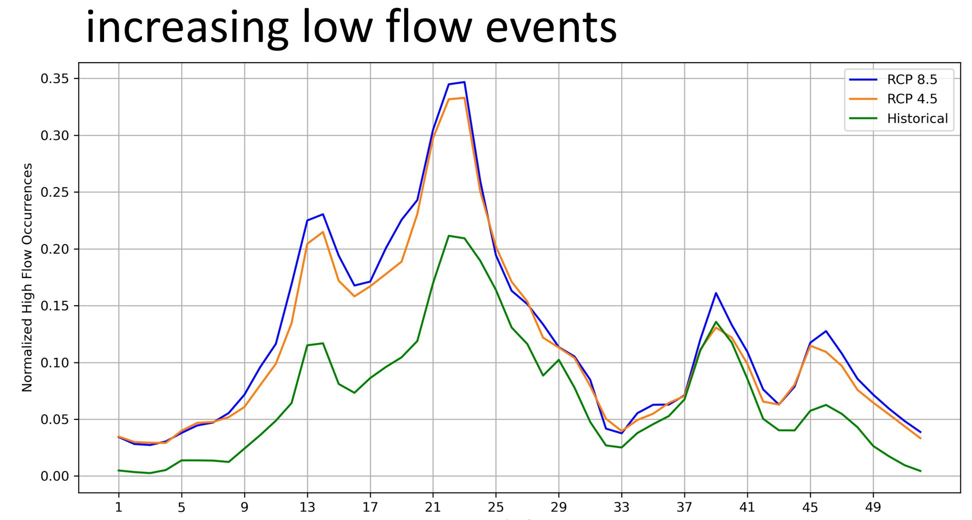

Fig.6 – Seasonal occurrences of flows exceeding the historical 99th percentile under historical, RCP4.5 and RCP8.5

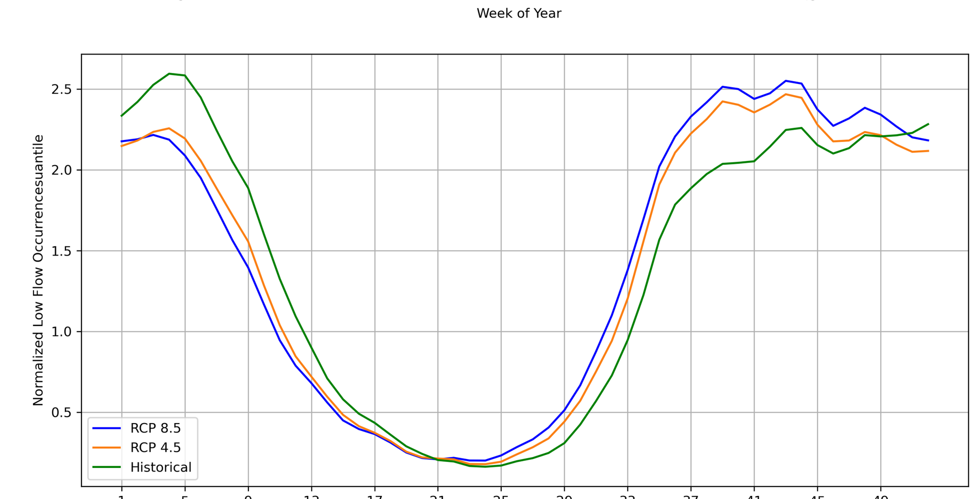

Fig.7 – Seasonal occurrences of flows that fall short of the historical 20th percentile which is considered drought conditions under historical, RCP4.5 and RCP8.5

5. Percent Change

Changes in streamflow are caused by changes in atmospheric conditions. Precipitation and evapotranspiration (ET) are main drivers of determining changes in streamflow. Potential evapotranspiration (PET) changes can indicate the rate of losses in reservoir storage.

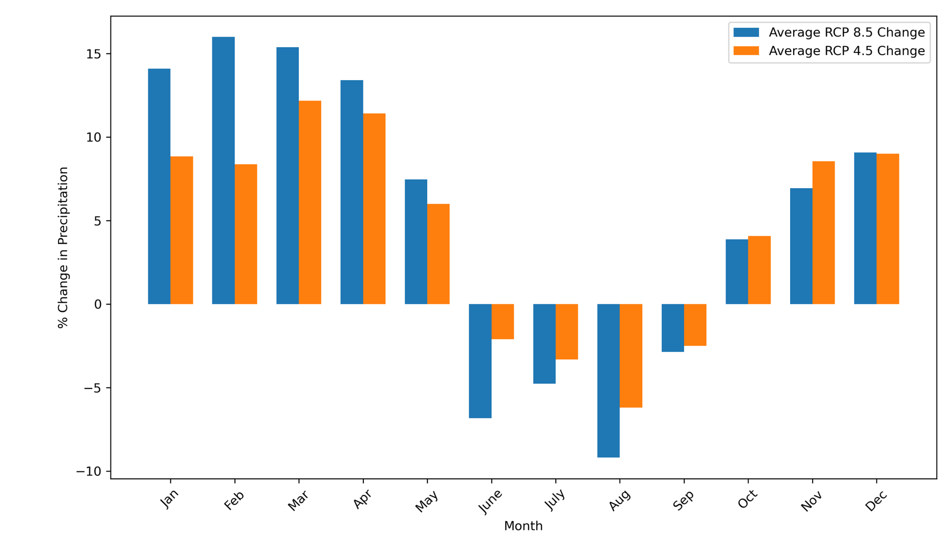

Fig. 8 – Precipitation changes under RCP4.5 and RCP8.5 compared to historical ensemble

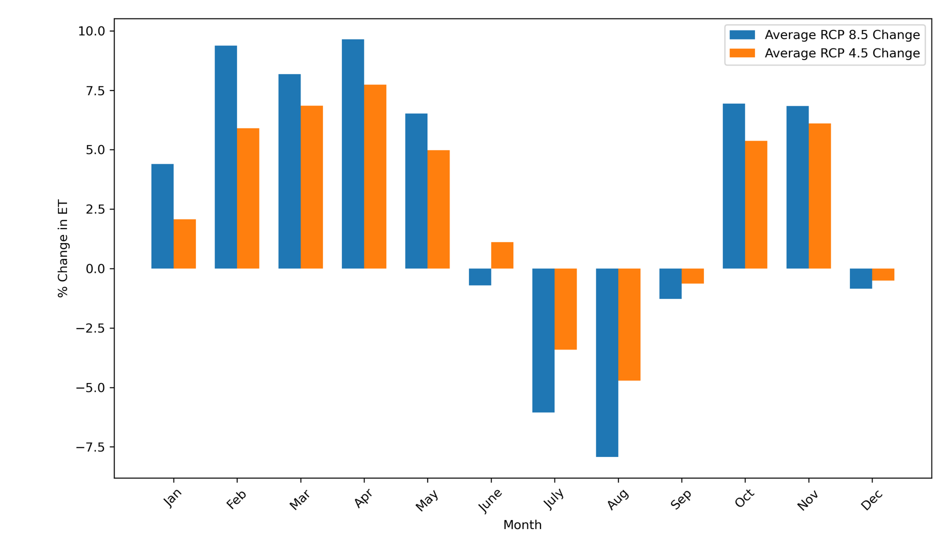

Fig. 10 – ET changes under RCP4.5 and RCP8.5 compared to historical ensemble

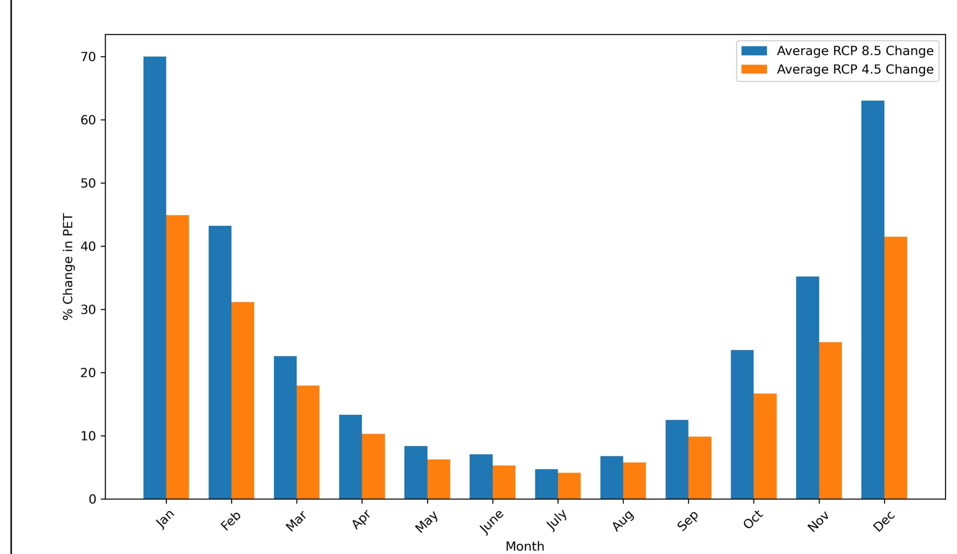

Fig. 9 – PET changes under RCP4.5 and RCP8.5 compared to historical ensemble

6. Results and Future Work

- Future projections for streamflow using the 32 model ensemble from CMIP5 are projected to increase across the eastern part of the state under RCP4.5 and RCP8.5.
- Extreme streamflow events tied to larger precipitation events that also can occur less frequently are projected to cause streamflow's to occur outside the norm. Streamflow that occurs above the historical 99th percentile happens more frequently in the future with little change between RCP4.5 and RCP8.5. Drought conditions are also expected to get worse as streamflow falls under the historical 20th percentile more frequently that in the past when using the historical ensemble.
- PET is expected to increase across all months which will cause greater losses in reservoir storage
- Future work would be to redo the water balance to ensure evaporation is the correct magnitude to match streamflow and precipitation.
- Looking at the CMIP6 data would be helpful in seeing how the newest generation of climate models project changes within the state.
- Creating a routing model that can also tie in with groundwater would be helpful in simulating streamflow in the western part of the state where ground water is more prevalent.

7. References

Schwalm, C., Glendon, S., & Duffy, P. (2020). RCP8.5 tracks cumulative CO_2 emissions. *Proceedings of the National Academy of Sciences - PNAS, 117*(33), 19656-19657.
Zhao, G., Li, Y., Zhou, L., & Gao, H. (2022). Evaporative water loss of 1.42 million global lakes. *Nature Communications, 13*(1), 3686.

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