Incorporating Climate Uncertainty into Water Allocations in Kansas

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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.

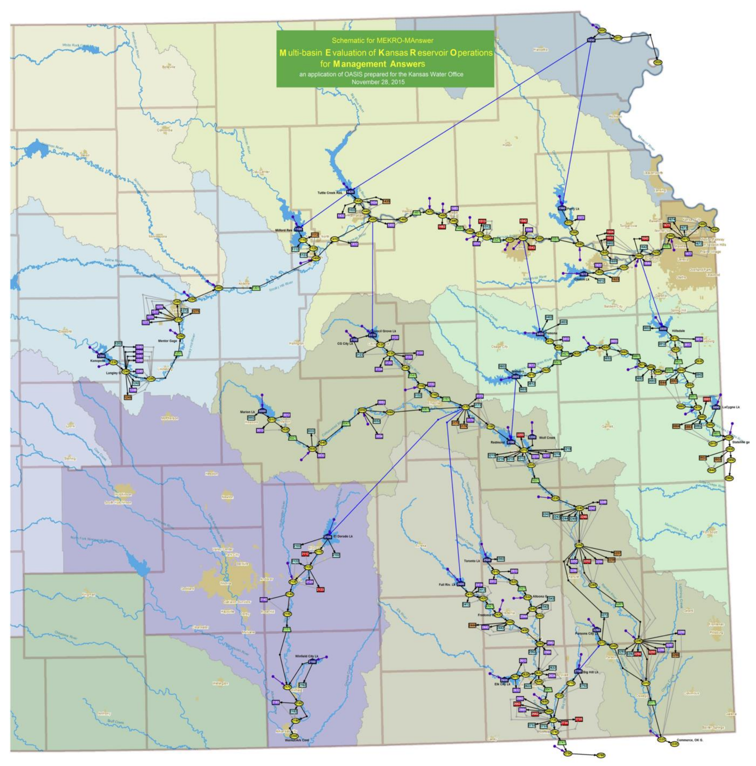

Fig. 1 - A schematic of the KWO model used to allocate water in the state of Kansas. The water balance model incorporates six river basins, 21 reservoirs (16 are federal reservoirs), 51 inflows and 163 sources of consumptive use.

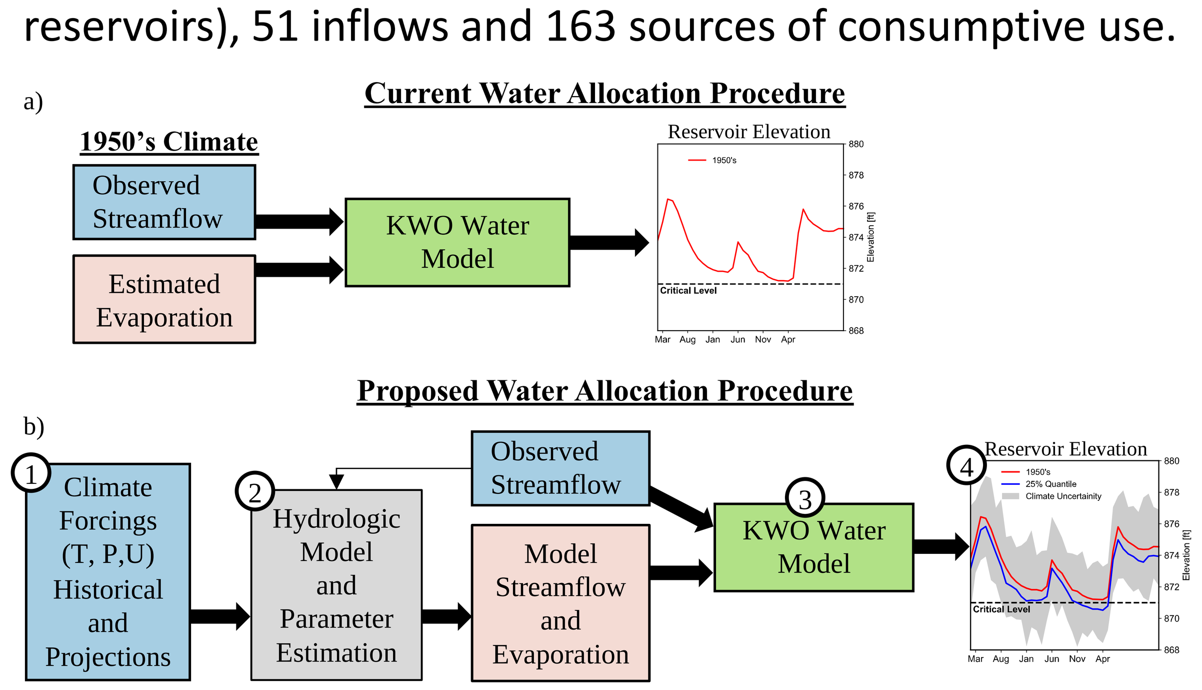

Fig. 2 - **a)** The current practice at KWO is to use the model based on streamflow and evaporation estimated during the 1950's drought.
b) The new water allocation procedure will include climate uncertainty into the water allocation procedure in Kansas by utilizing CMIP5 projections from 34 different models downscaled to 1/16th degree.

3. Historical Model Performance

The historical climate model is evaluated from 1950-2005 at 3 different USGS gauge locations in **Fig. 3-5** that give the magnitude of the average daily streamflow for each month from the USGS stream gage and 5 CMIP5 climate models. **Fig 6** shows the average Kling-Gupta Efficiency (KGE) on a monthly basis across all gages.

Daily Average Per Month 1950-2005

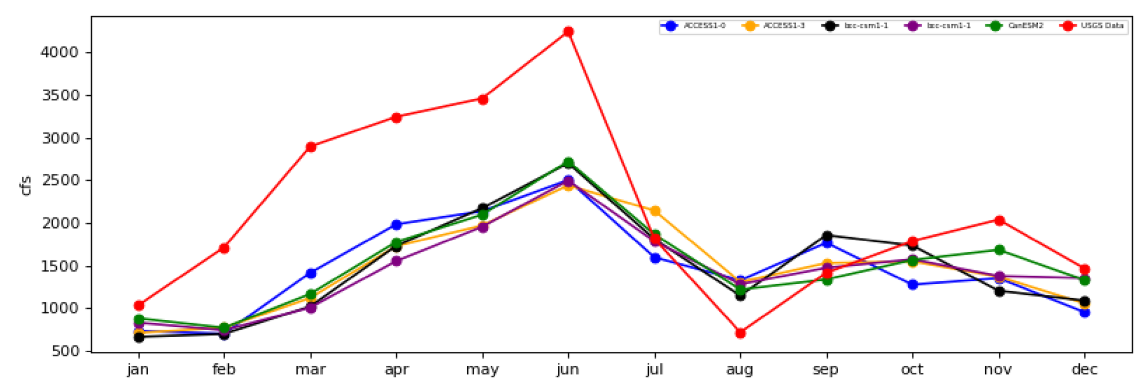

Fig.3 - Streamflow for USGS gage 06916600 for the Marais des Cygnes River in north Linn County, Kansas.

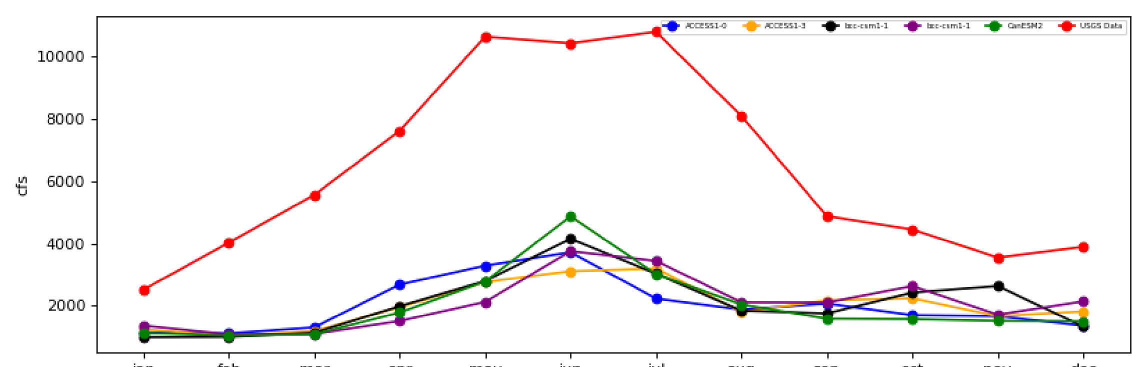

Fig. 4 - Streamflow for USGS gage 06888350 on the Kansas River in Belvue, Kansas.

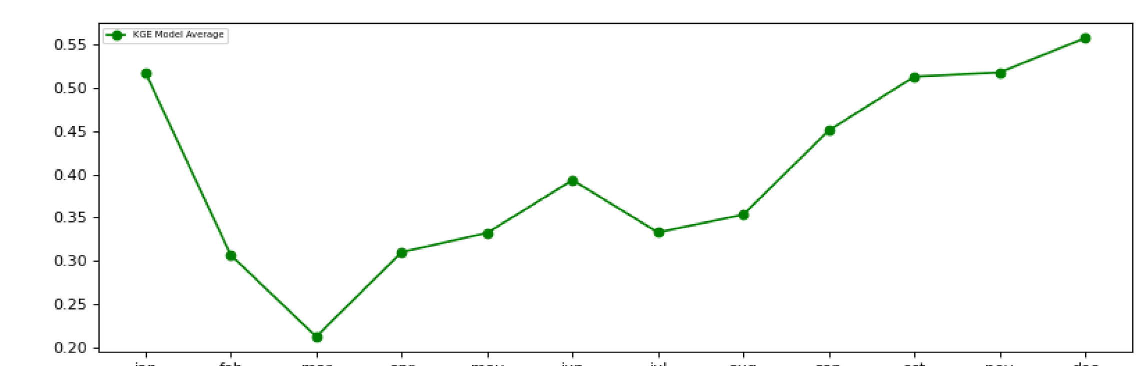

Fig. 5 - The average monthly KGE value for all USGS gages for each month across 5 climate models. A strong KGE value is closest to 1.

4. Projections

Daily Average Per Month 2006-2100

The CMIP5 climate models include two different future climate scenarios categorized under the Representative Concentration Pathway (RCP) named RCP45 and RCP85. These scenarios refer to the concentration of carbon globally by 2100.

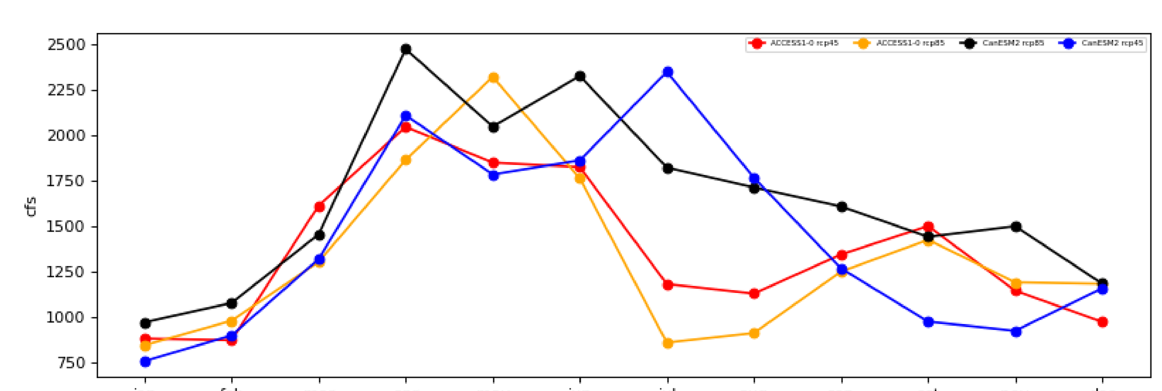

Fig. 6 - Projected average monthly stream flow for USGS gage 06916600 under rcp45 and rcp85 climate scenarios for climate models ACCESS1-0 and CanESM2

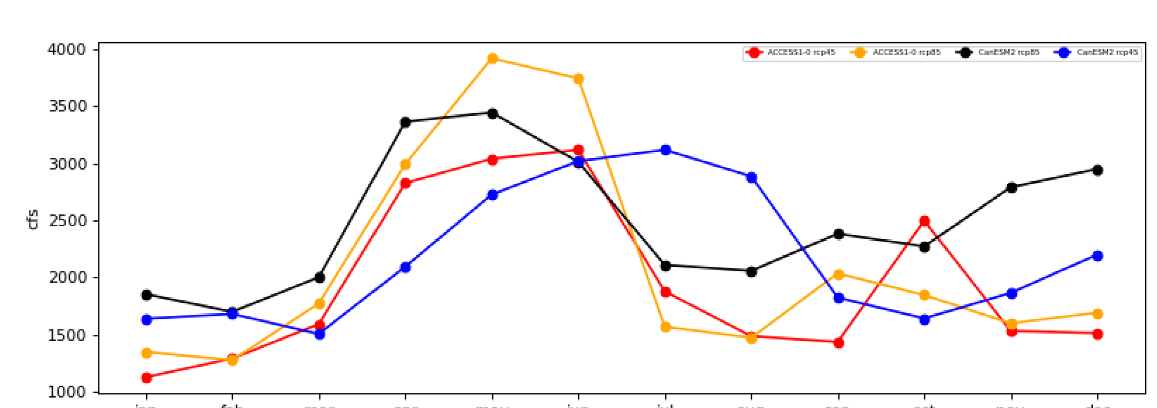

Fig. 7 - Projected average monthly stream flow for USGS gage 06888350 under rcp45 and rcp85 climate scenarios for climate models ACCESS1-0 and CanESM2

5. Evaporation

Daily Average Evapotranspiration Per Month

Evaporation is an important variable to consider especially for reservoirs when modeling for water allocation as loss due to evaporation is substantial. Long-term lake evaporation rate globally has increased to a rate 5.4% per year over the last 30 years (Zhao et. al). Increases in evaporation is shown in some models but not others as seen in **Fig. 8 and 9**. Using several different climate models can give us a better sense of the predicted evaporation values.

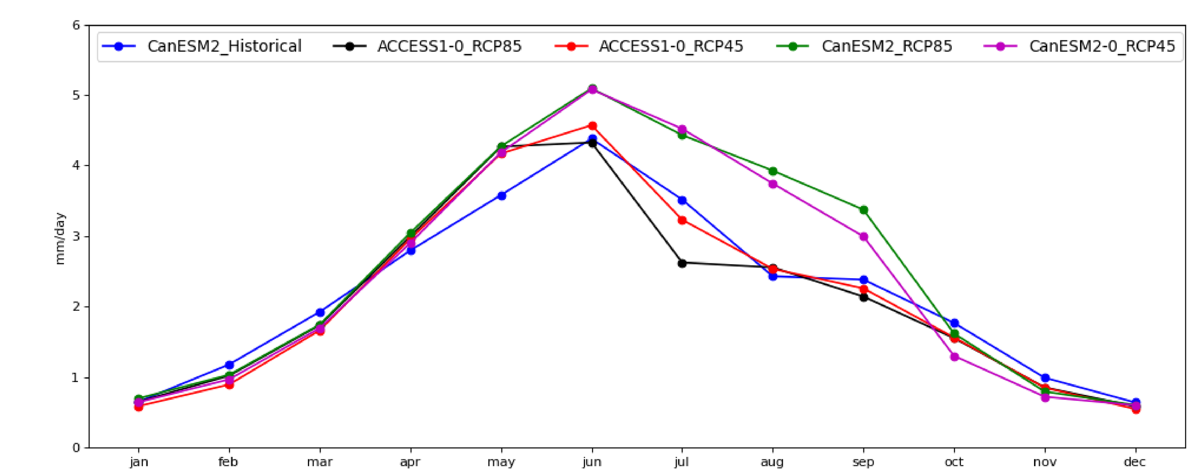

Fig. 8 – Evapotranspiration from the modeled historical period and the RCP45 and RCP85 climate scenarios from the ACCESS1-0 and CanESM2 climate models for USGS gage 06916600.

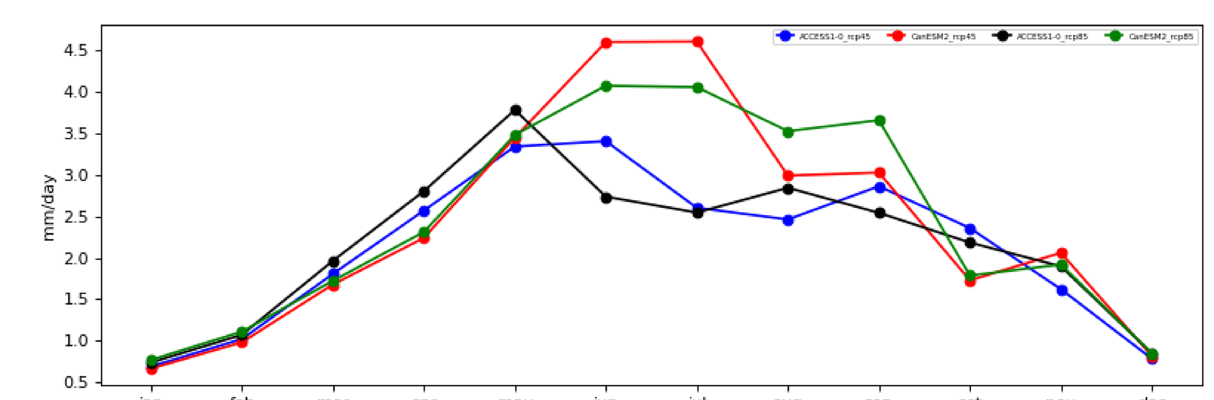

Fig. 9 – Projected precipitation modeled from ACCESS1-0 and CanESM2 under RCP45 and RCP85 scenarios for KWO node 1420 located at Tuttle Lake Kansas

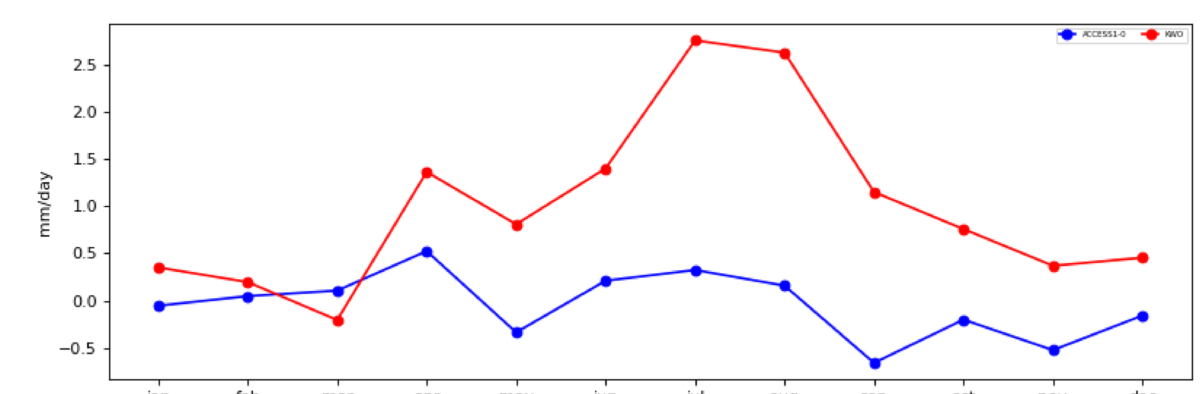

Fig. 10 – Lake evaporation from 1950-2005 from KWO and evapotranspiration from the ACCESS1-0 climate model for KWO node 1420

6. Results and Future Work

- The current models are under predicting streamflow at all USGS and KWO sites with the magnitude of differences becoming greater during the warmer months of the year. The KGE (Kling-Gupta efficiency) which tests the efficiency between the observed data and the model data seen in Fig. 6 shows a lower goodness-of-fit measure during warmer months with a higher fit being seen in the colder months.
- When visually comparing the model's historical evaporation data with the projected, the projected under certain models shows little to no increase while others show roughly a 20% increase at peak from the historical.
- The next steps are to continue to evaluate the remaining climate models against the observed values and to start considering different forcing approaches to allow the model to more accurately represent the observed data and therefore the projected data.

7. References

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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