How soil water storage moderates climate change's effects on transpiration across the Critical Zone Observatories

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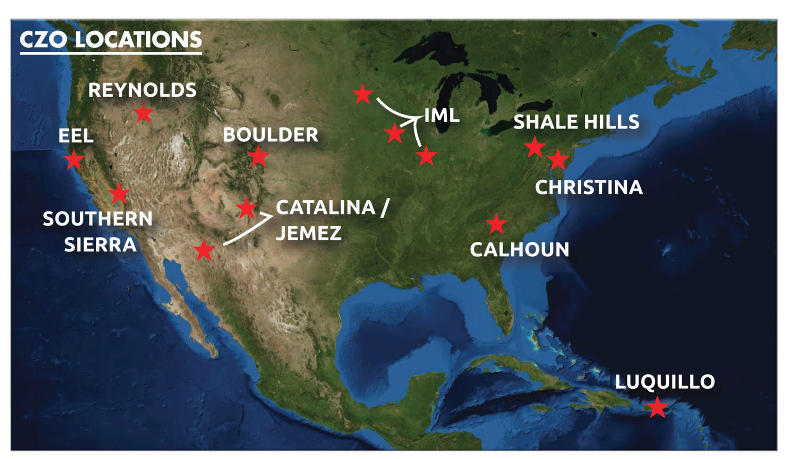
Motivation:

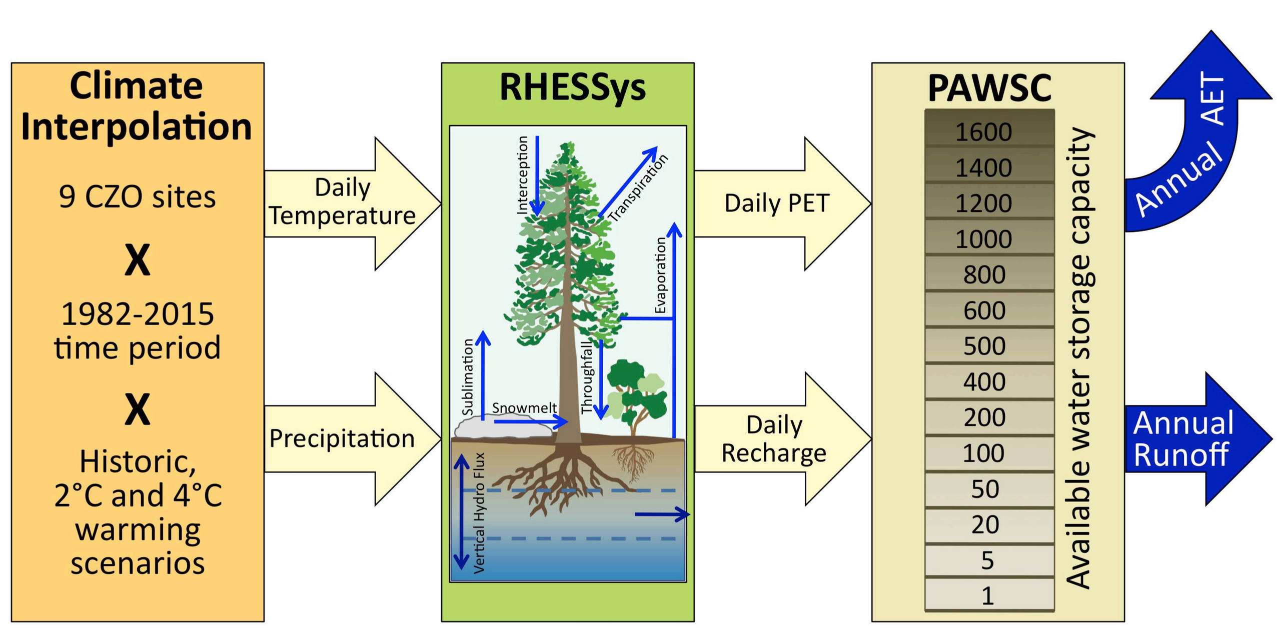
As our climate warms the potential for vegetation to transpire more water increases, however actual increases will depend on how much water is available. Plant accessible water storage capacity (PAWSC), which is defined as the combination of field capacity and rooting depth, plays a primary role in determining not only how much water vegetation sees but also at what times that water is available. Therefore, PAWSC will play a primary role in determining vegetation's response to increased water demands under a warmer climate. Since it is extremely difficult to determine PAWSC, we use a well-tested hydrologic model to estimate the impact of PAWSC, and its uncertainty, on vegetation water use for both historic and projected climate warming.

Methods:



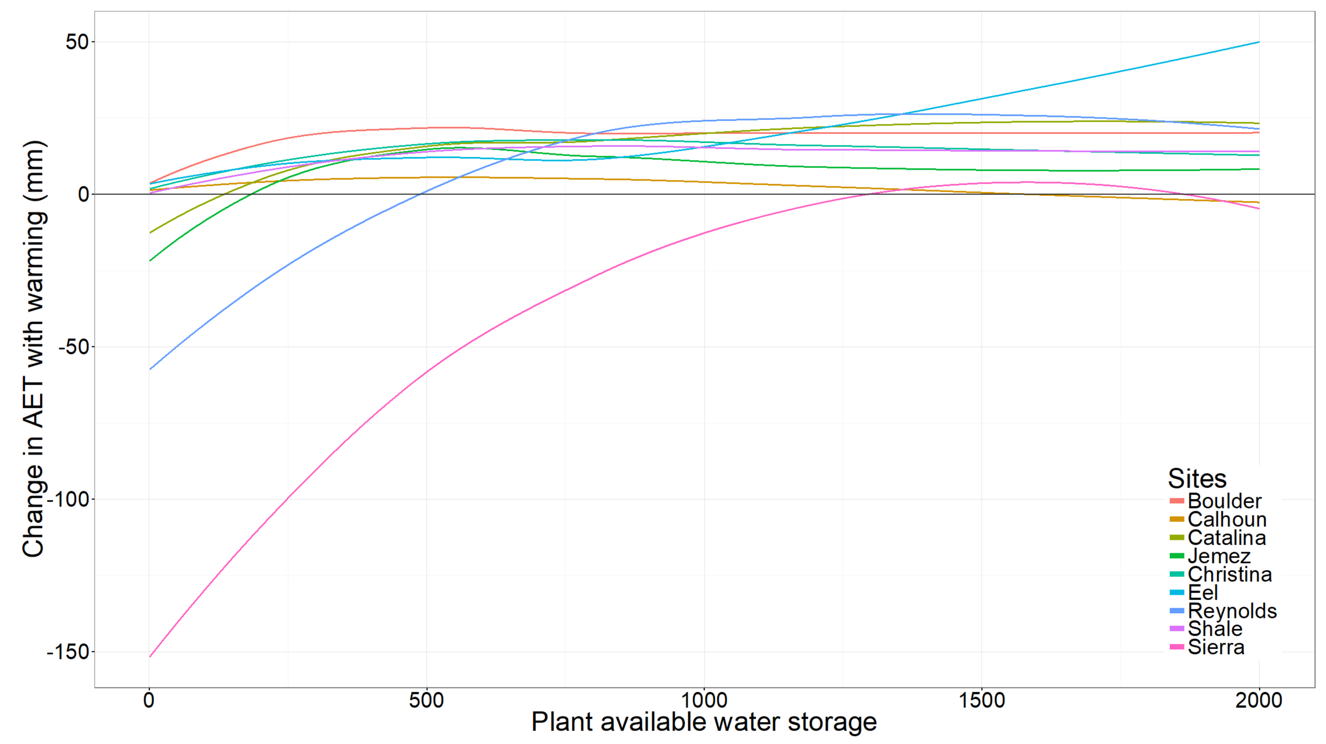
To quantify how PAWSC moderates climate change's effect on transpiration, we combine a spatially explicit climate data product with a mechanistic land surface hydrology model (a modified version of RHESSYs[1]). The inputs into our model are 4km PRISM pixels and the 9 Critical Zone Observatory sites in the continuous United States (pictured right). Each pixel, representing each site, was ran with either deciduous or conifer vegetation and an LAI specific to that site (table right). The hydrology model represents well-understood relationships among AET and energy availability, precipitation and temperature, snow accumulation and melt.

CZO Site	Vegetation	Mean LAI
Boulder	Conifer	3
Calhoun	Deciduous	3.5
Catalina	Conifer	3.43
Jemez	Conifer	3.43
Christina	Deciduous	4.5
Eel	Conifer	10
Reynolds	Deciduous	1.5
Shale Hills	Deciduous	4.5
Sierra	Conifer	5

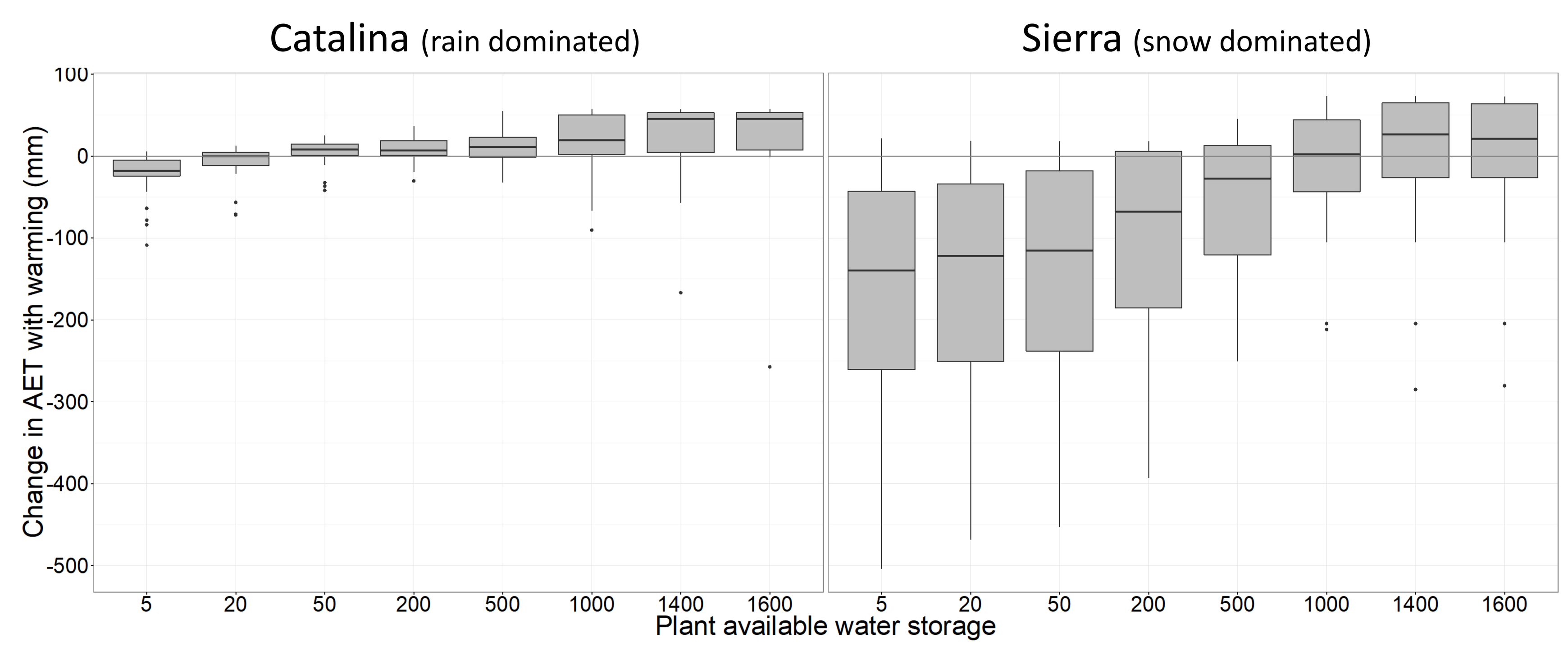


[1] Tague CL, Band LE (2004) RHESSys: regional hydro-ecologic simulation system-an object-oriented approach to spatially distributed modeling of carbon, water, and nutrient cycling. *Earth Interactions* 8(19):1–42.

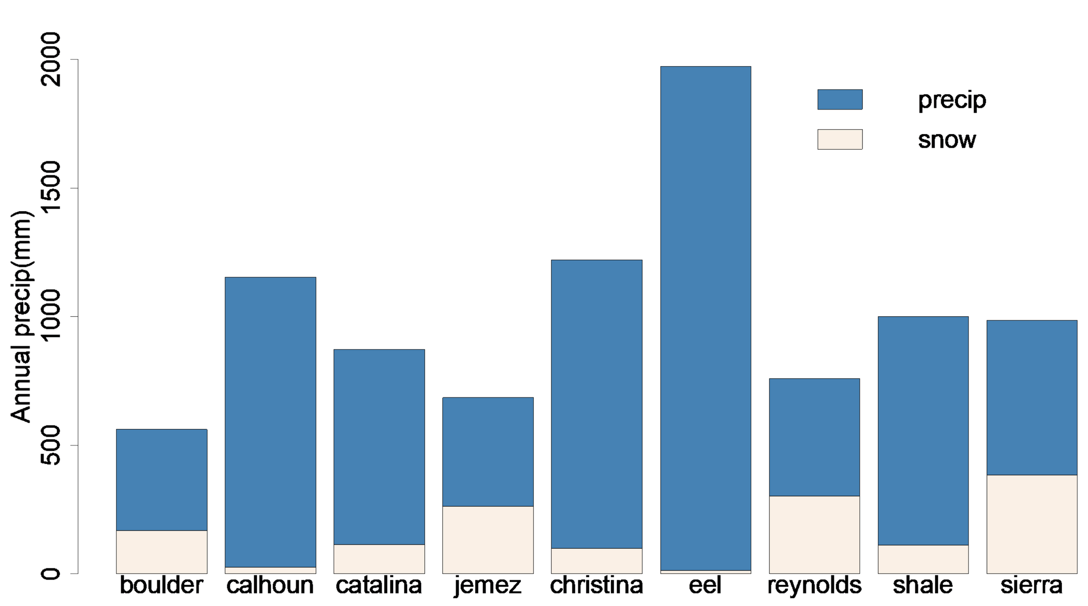
Results: Change in annual AET



The general assumption is that AET will increase with warming and as the graph to the left portrays and on average it generally does. However, the early loss of snowpack can lead to decreases in AET with warming when PAWSC cannot accommodate early melt.



Averages show that while the trend may be an increase in AET, the year to year variation can have both increases and decreases. Decreases happen for two reasons:



1) Snowpack delays water inputs and provides a slow continuous recharge. When snow events switch to rain events, the ability of PAWSC becomes primary in being able to store the water for continued use by vegetation.
2) Higher rates of AET under warming draw down stored water faster than under baseline rates. Should stored water reach 0, it will do so earlier in a warming scenario leading to a longer drought period.

Acknowledgements:

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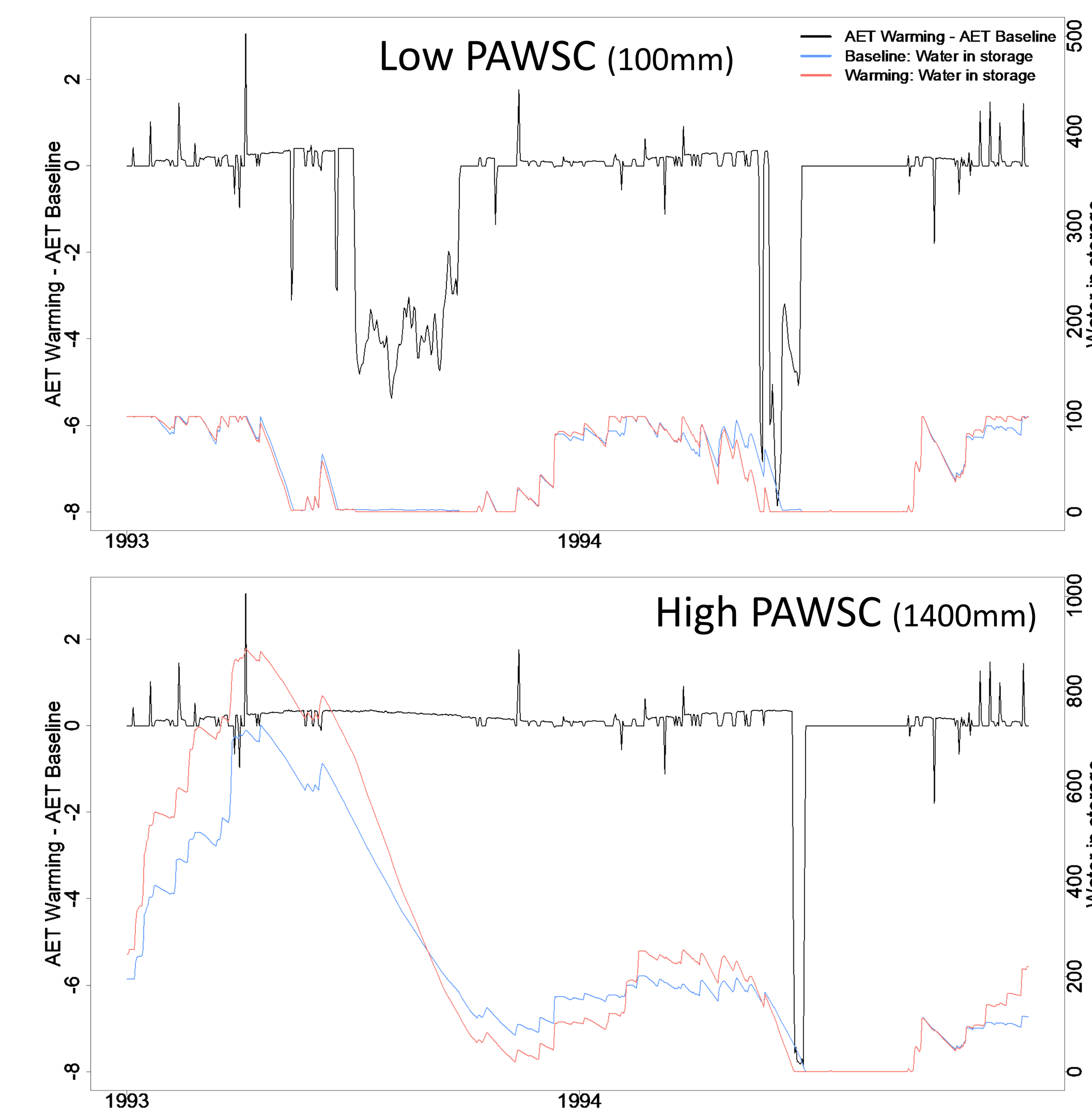
Results: PAWSC matters

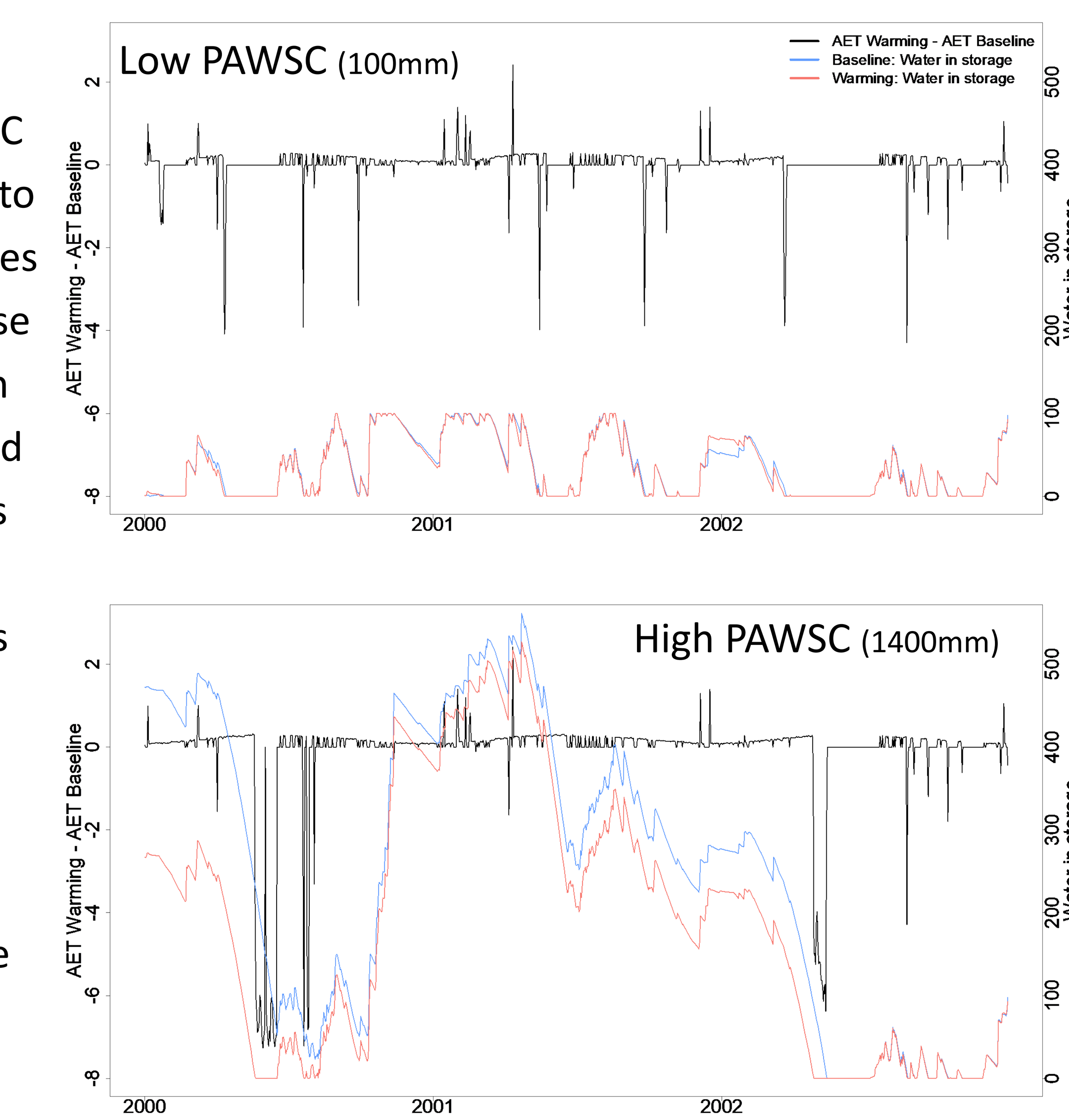


Site: Sierra

In the Sierra CZO, low PAWSC scenarios result in a decrease in AET because the slow, delayed recharge from snowpack supports transpiration for a longer period, as seen by mid-year 1993. In the high PAWSC scenario, PAWSC can hold early melt/quick recharge events from rain storms allowing AET to increase.

Site: Catalina

At Catalina CZO, low PAWSC scenarios are accustomed to drought and small decreases in AET are common because of a lack of PAWSC. In high PAWSC scenarios, increased AET over long time periods comes at the detriment of water in storage. For years where water in storage remains above 0, AET increases, however since increased AET draws this water down at a faster rate there is a higher risk for longer droughts.



Conclusions:

1) Actual evapotranspiration does not always increase with warming
2) Plant available water storage plays a primary role in determining the direction and magnitude of how AET will change with warming
3) Decreases in AET will be more common in sites that are snow dominated
4) High PAWSC scenarios have an increased risk of drought with prolonged increased rates of transpiration