Predicting seasonal precipitation partitioning into discharge and evapotranspiration as a function of climate

Helen M. Kesting, Scott T. Allen
Natural Resources and Environmental Science Dept., University of Nevada, Reno
University of Nevada, Reno

Abstract code: 20817

A Grand Challenge: Conservation planning and water resource management depend on accurate predictions of water availability as the hydrologic cycle evolves with climate change. We can use isotope ratios of precipitation and streamflow to reveal the partitioning of summer and winter precipitation to evapotranspiration (ET) and runoff. Since the timing of water fluxes affects chemical and nutrient export, we can use isotope signatures to improve predictions of water quality and quantity.

Figure 1: Watershed system: colors represent isotope ratios and arrow sizes represent flux sizes

Specific objective:

Predict the relative partitioning of seasonal precipitation into runoff and ET as a function of climate

Approach: The end-member splitting method (Kirchner & Allen, 2020) goes beyond end-member mixing (which addresses the relative fraction of each end-member in a mixture) by also making use of mass-flux data to address how each end-member is partitioned among its different fates.

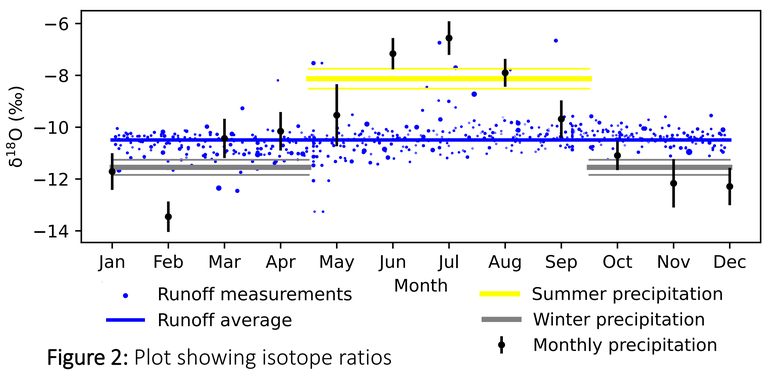


Figure 2: Plot showing isotope ratios measured at a site in Switzerland

- Calculate weighted mean isotope ratios and amounts of summer precipitation (May - October), winter precipitation (November - April), and annual runoff
- Calculate the fraction of ET from summer precipitation

$$f_{ET \leftarrow P_S} = \frac{P_s - Q\frac{\delta_Q - \delta_{P_W}}{\delta_{P_S} - \delta_{P_W}}}{P_S + P_W - Q}$$

- Compare with climate and spatial variables to determine drivers of precipitation sources of ET

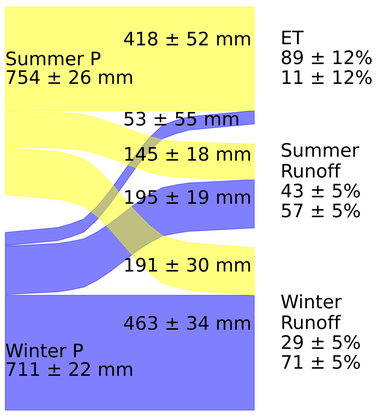
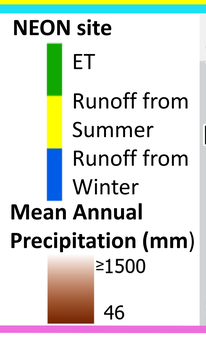


Figure 3: Diagram showing end-member mixing and splitting results for a site in Switzerland

Data:

-Monthly precipitation and annual temperature grids (800m) from PRISM Climate Group

-Watershed area shapefiles and measurements of runoff amounts and isotope values from the National Ecological Observatory Network



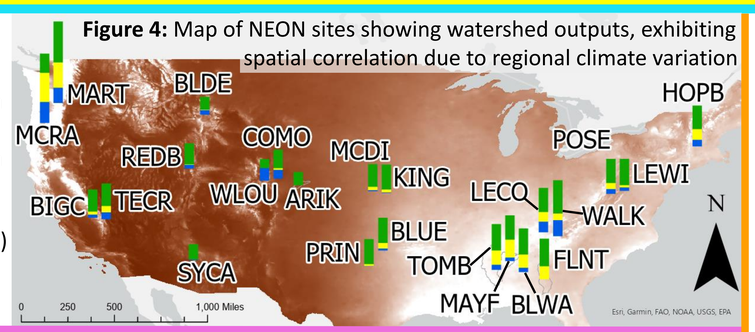
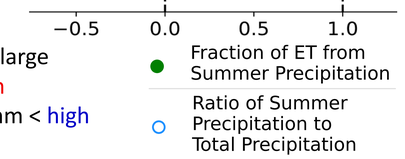


Figure 4: Map of NEON sites showing watershed outputs, exhibiting spatial correlation due to regional climate variation

Results:

Watershed,	State,	Size,	Temp.,	Precip.
MCRA,	OR,	small,	med,	high
MART,	WA,	small,	med,	high
TECR,	CA,	small,	med,	med
BIGC,	CA,	small,	med,	med
BLWA,	AL,	large,	high,	high
FLNT,	GA,	large,	high,	high
MAYF,	AL,	small,	high,	high
TOMB,	AL,	large,	high,	high
SYCA,	AZ,	medium,	high,	low
REDB,	UT,	small,	med,	med
WALK,	TN,	small,	med,	high
HOPB,	MA,	small,	med,	high
COMO,	CO,	small,	low,	med
BLUE,	OK,	medium,	high,	med
POSE,	VA,	small,	med,	med
PRIN,	TX,	medium,	high,	med
LEWI,	VA,	small,	med,	med
BLDE,	WY,	medium,	low,	low
LECO,	TN,	small,	med,	high
MCDI,	KS,	medium,	med,	med
KING,	KS,	small,	med,	med
ARIK,	CO,	large,	med,	low
WLOU,	CO,	small,	low,	low



Size: small < 20 km² < medium < 2000 km² < large
Temperature: low < 3 °C < med < 16 °C < high
Precipitation: low < 700 mm < med < 1200 mm < high

Figure 5: The fraction of ET that is soured from summer precipitation (**green**) and ratios of summer-to-annual precipitation (**blue**) are plotted ± standard errors for each NEON watershed. As fractions, the range of plausible values is 0.0 to 1.0 (delineated by the dashed lines). Although four sites' mean fractions of ET from summer precipitation are outside of that range, end-member splitting is known to be uncertain where precipitation isotope ratios have small inter-seasonal ranges. By comparing fractions of ET from summer precipitation (**green**) and ratios of summer-to-annual precipitation (**blue**), we find that summer precipitation is underrepresented in ET at 8 sites and overrepresented in ET at 4 sites.

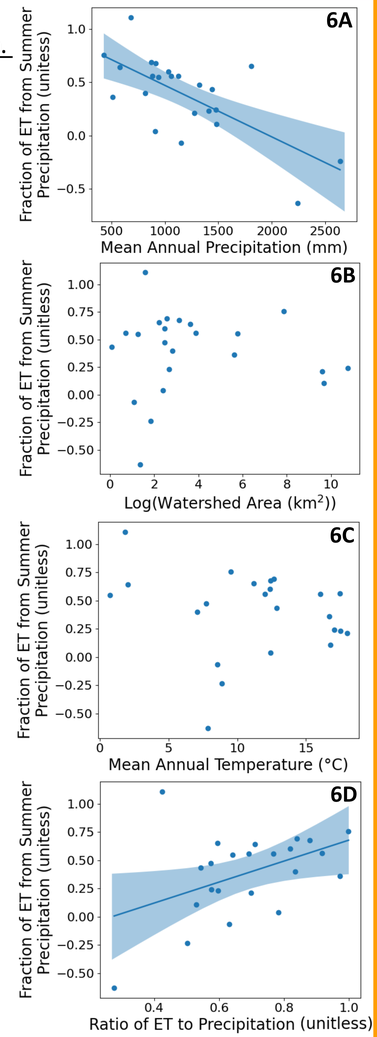


Figure 6: Fractions of ET sourced from summer precipitation plotted against potential predictive variables, showing a negative correlation with mean annual precipitation ($p = 0.0003$, 6A) and a positive correlation with the ratio of annual ET to annual precipitation ($p = 0.0320$, 6D). Watershed area and mean annual temperature are not correlated with the fraction of ET from summer precipitation.

Findings:

- NEON sites across the contiguous U.S. exhibit a range of values for the fraction of ET from summer precipitation
- Summer precipitation is overrepresented in ET at some NEON sites and underrepresented at others
- The fraction of ET from summer precipitation is negatively correlated with mean annual precipitation and positively correlated with the ratio of ET to precipitation

Implications:

- The fraction of ET from summer precipitation varies widely among ecosystems. Hydrological models that assume a constant value are missing this variation.
- Mean annual precipitation and the ratio of ET to precipitation are predictive variables that can likely be used to model precipitation partitioning and evapotranspiration sourcing in watersheds where isotope data are not available.

Next Steps:

- For each NEON watershed, summarize remotely sensed vegetation data such as:
  - ECOSTRESS Land Surface Temperature and Emissivity
  - MODIS Terra Vegetation Indices
  - GEDI Elevation and Height Metrics (canopy height)
- Analyze relationships between vegetation data and partitioning fractions (*e.g.*, the fraction of ET from summer precipitation)
- Develop a model to predict precipitation partitioning fractions using remotely sensed data
- Apply the model to watersheds without isotope data to create a map of precipitation partitioning fractions across the contiguous U.S.

Acknowledgements:
Funding is provided by the Nevada NASA Space Grant Consortium Graduate Research Opportunity Fellowship

References:

Kirchner, J. W., & Allen, S. T. (2020) Seasonal partitioning of precipitation between streamflow and evapotranspiration, inferred from end-member splitting analysis. *Hydrology and Earth System Sciences, 24*(1), 17-39. https://doi.org/10.5194/hess-24-17-2020

NEON (National Ecological Observatory Network). Stable isotopes in surface water (DP1.20206.001), RELEASE-2022. https://doi.org/10.48443/yz7h-f560.

PRISM Climate Group, Oregon State University, https://prism.oregonstate.edu.