# Time-Varying Sensitivity Analysis and its Relationship to Shifting Annual Conditions in California Watersheds

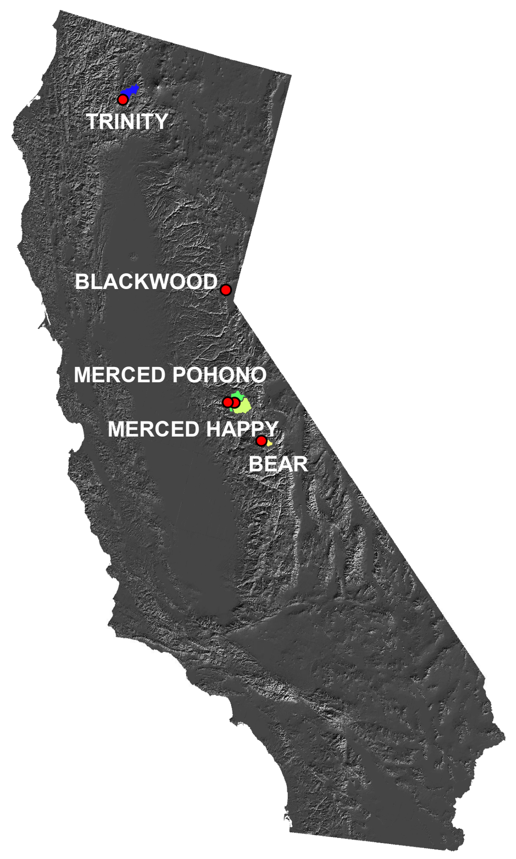
Ruta Basijokaite[1*], Christa Kelleher[1] (1) Department of Earth Sciences, Syracuse University *Corresponding Author: rbasijok@syr.edu

H51L-1454

## Research Objectives

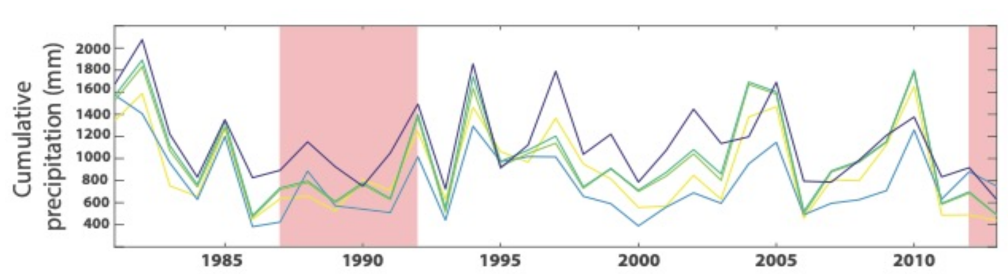
Changing climate affects watershed hydrologic cycles, therefore it is becoming increasingly important to analyze outcomes of this variability on long-term watershed behavior. In particular, we aim to analyze how strong seasonal and annual shifts from wet to dry may be attributed to shifting importance of different model parameters and therefore key watershed processes.

## Study Area - California




We focused on California in particular because of its climate and tendency for extreme weather events, which allows us to better analyze the effects of changing climate on shifts in watershed controls. Time-varying sensitivity analysis can assist in identifying dominant processes in a system and can provide important insight on system responses when observing concurrent changes in parameter sensitivities alongside real-world dominant process variations (Wagener et al., 2001, 2003; Herman et al., 2013).

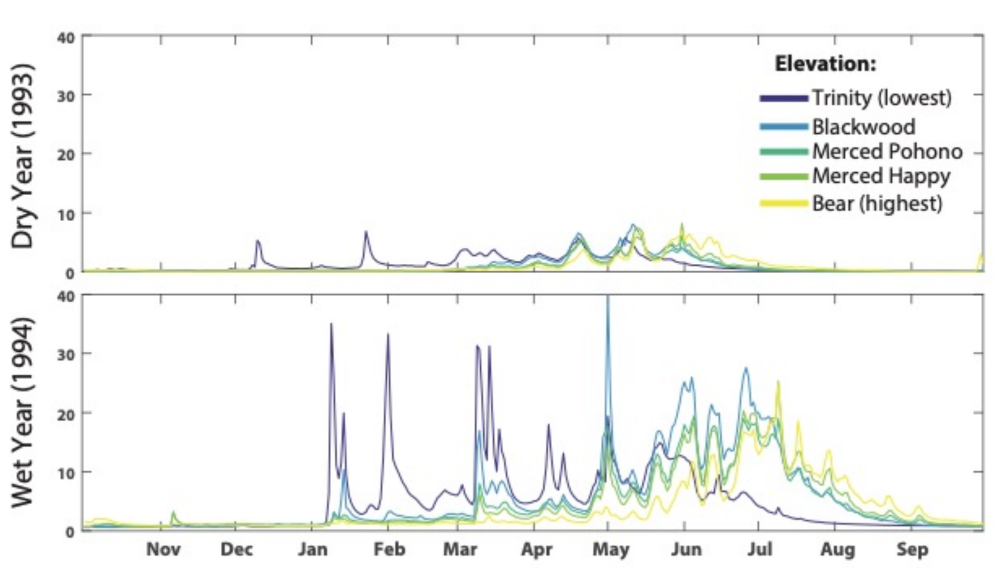
We simulated 33 years of data spanning extreme annual variations in precipitation, from 400 to 2000 mm.




Drought years are highlighted in red.

All sites analyzed in this study are minimally impacted by humans.

| Watershed | Drainage area (km²) | Mean Elevation (m) | Mean annual Precipitation (cm) | Mean annual air temp (°C) | Forest Cover (%) | Urban (%) |
|---|---|---|---|---|---|---|
| Bear Creek | 135.5 | 3244.6 | 115.0 | 0.4 | 26.4 | 0 |
| Blackwood Creek | 29.8 | 2216.4 | 148.6 | 5.8 | 70.2 | 0.9 |
| Merced River (Happy) | 468.0 | 2746.1 | 119.9 | 6.1 | 42.0 | 0 |
| Merced River (Pohono) | 833.1 | 2578.2 | 121.3 | 7.0 | 51.6 | 0.5 |
| Trinity River | 382.9 | 1629.7 | 147.3 | 11.9 | 75.8 | 0.7 |

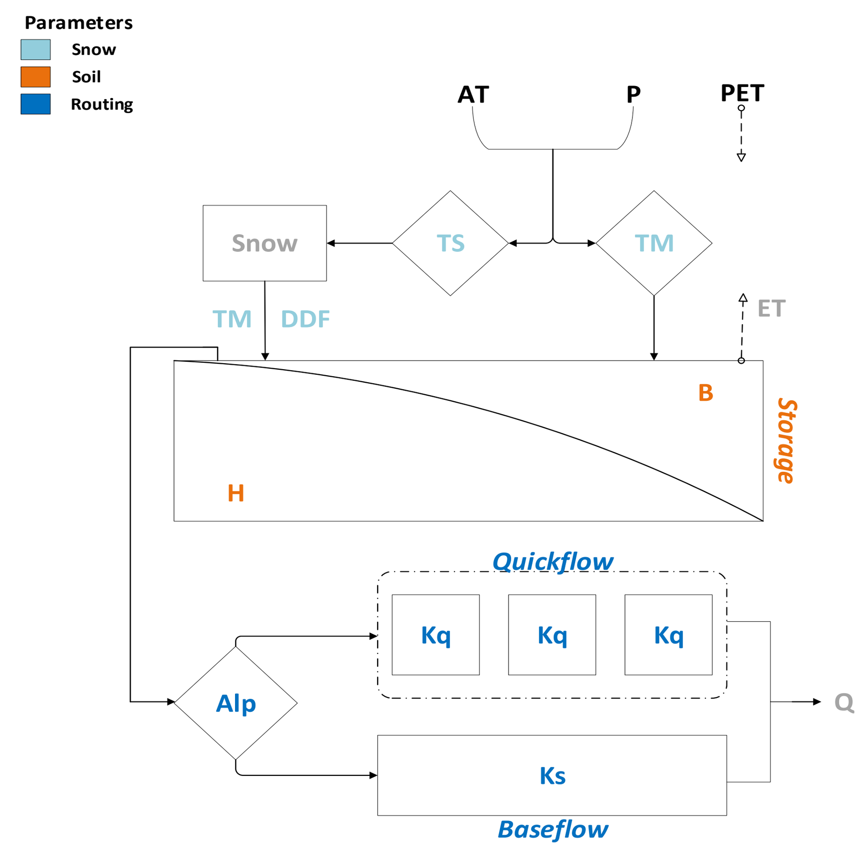



Elevation of the study sites has a great impact on hydrograph timing.

We included watersheds spanning an elevation gradient to explore how model-derived controls may vary with elevation.

## Modeling: Simulating hydrology over a 30+ year period

Conceptual models offer many advantages over complex models while still providing a detailed description of a given system including relevant processes and how they may vary across different sites. We used a simple version of Hymod, a conceptual rainfall runoff model, to simulate streamflow and perform sensitivity analysis across our sites.

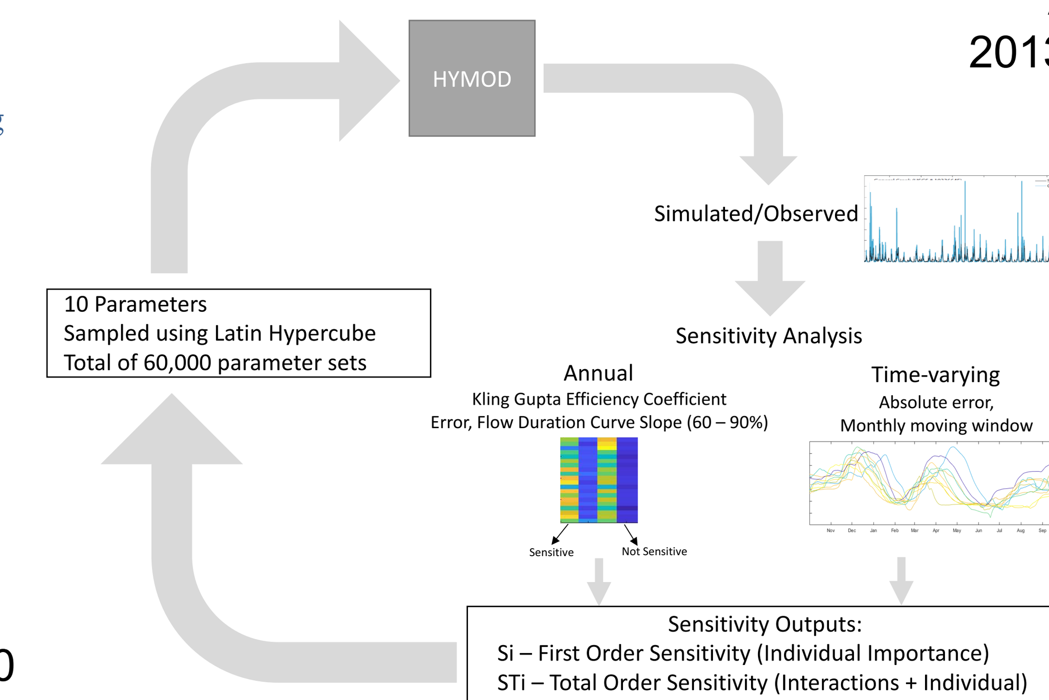



| Parameter | Function |
|---|---|
| Kq | Quick flow reservoir rate constant |
| Ks | Slow flow reservoir rate constant |
| Alp | Division between quick/slow routing |
| Hpar | Maximum soil moisture storage |
| Bpar | Distribution of soil stores function shape |
| DDF | Degree day factor (snow melt rate) |
| TR | Base temperature below which rain occurs |
| TS | Base temperature below which snow occurs |
| TM | Base temperature above which melt occurs |
| SCF | Snow correction factor |

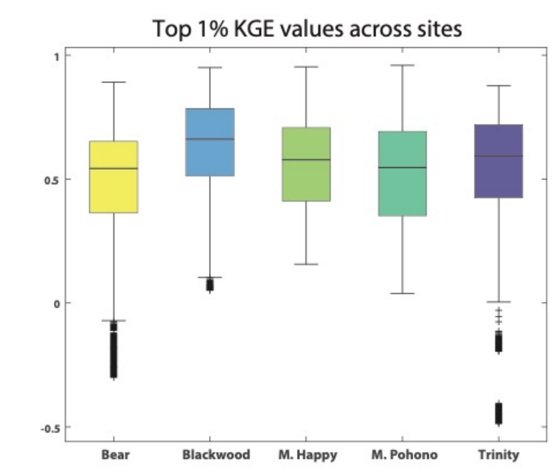
Routing (Kq, Ks, Alp); Soil (Hpar, Bpar); Snow (DDF, TR, TS, TM, SCF)

The parameters above were all sampled 60,000 times to execute variance-based sensitivity analysis.

Sensitivity-based methods have been used to interpret model behavior in the context of the system being simulated. If the model is a good representation of watershed behavior and functioning, these sensitivity results may also be used to understand how the importance of different watershed functions of characteristics, represented by parameters, may change through time, potentially in response to oscillating wet and dry periods.

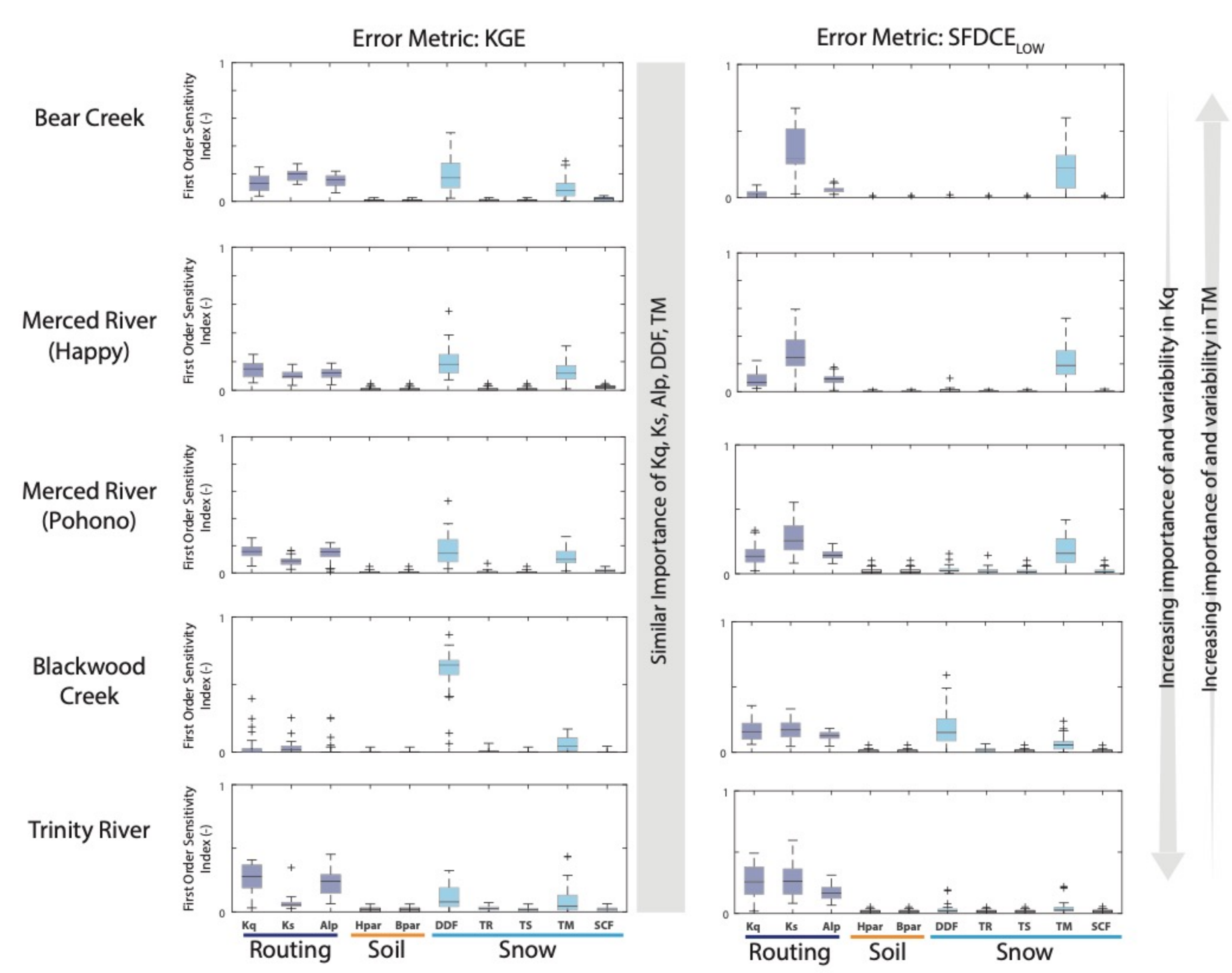



Across the 33 year period (1981 – 2013), the best KGE values exceeded 0.8 in all watersheds.




## Parameter sensitivity across decadal, annual, and seasonal periods

*Are the same parameters sensitive across all watersheds?*

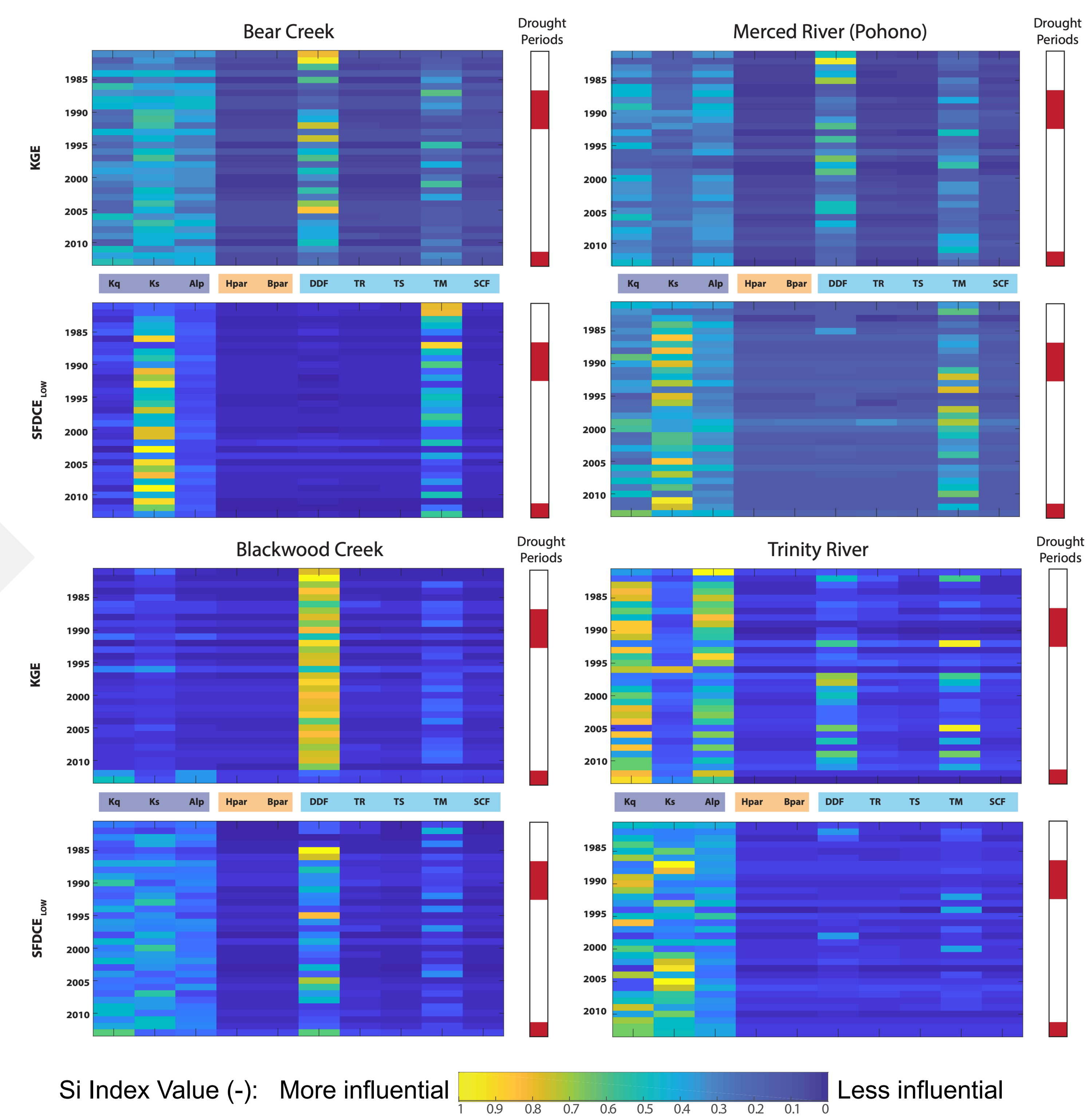



Quickflow and routing parameters were consistently sensitive in four out of five watersheds, meanwhile snow parameters (DDF, TM) were sensitive across all five study sites.

Annual sensitivity index values vary somewhat from year to year. However, we do not see the impact of droughts reflected in these values.

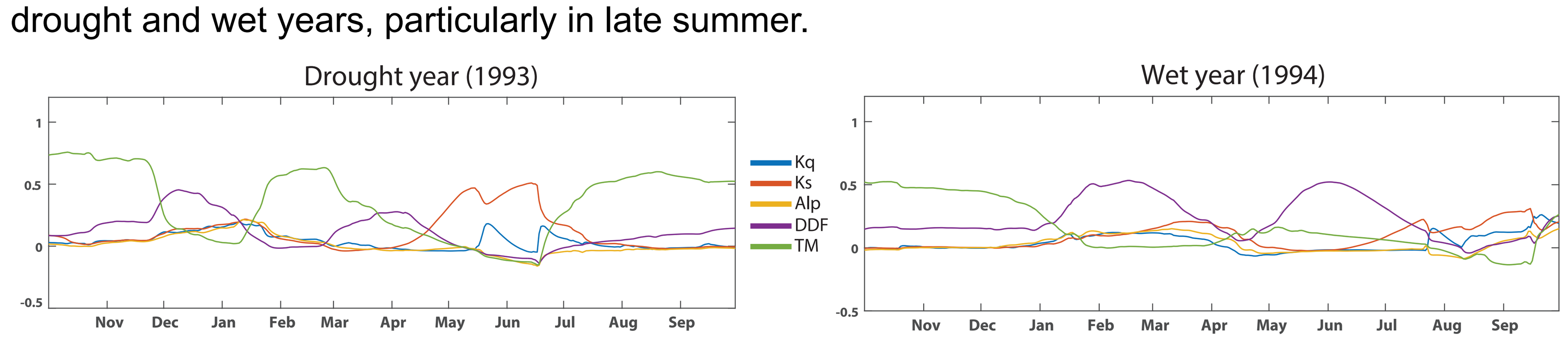
Annual sensitivity indices do vary between metrics assessing high flow (KGE) and low flow (SFDCE).

*How do parameter indices vary from year to year?*




*Are the same parameters sensitive during dry and wet years at sub-annual scales?*

Last, we examined how parameter sensitivity varies within years, for a dry year (1993) and wet year (1994). Examples of first-order parameter index values indicate different watershed controls during drought and wet years, particularly in late summer.




**References:** [1] Herman, J. D., Reed, P. M., Wagener, T. (2013). *Time-varying sensitivity analysis clarifies the effects of watershed model formulation on model behavior*. Water Resources Research, 49: 1400-1414; [2] Wagener, T., Boyle, D. P., Lees, M. J. (2001). *A framework for development and application of hydrological models*. Hydrology and Earth System Sciences, 5(1): 13-26; [3] Wagener, T., McIntyre, N., Lees, M. J. (2003). *Towards reduced uncertainty in conceptual rainfall-runoff modelling: Dynamic identifiability analysis*. Hydrological Processes, 17: 455–476