The Shale Hills Watershed Unit was established in 1961 in the Valley and Ridge province of Central Pennsylvania. The watershed, shown below, is 19 acres in size, with an average relief of 100'. Rose Hill shale underlies the entire study area. Soils on the watershed average 56" in depth, ranging from 18" to 24" on the upper slopes and ridge tops to over 100" in portions of Central Pennsylvania. The watershed, shown below, is 19 acres in size, with an average relief of 100'.

The Shale Hills stable isotope network offers the opportunity to research and use stable isotope signatures covering the entire hydrologic cycle. The goal of the research is to identify flow paths and time scales of water from precipitation input to the watershed through stream flow output. Singular Spectrum Analysis is used to determine dominant “modes” and processes affecting the stable isotope dynamics of the system. Ultimately the stable isotope network, real-time hydrologic network, real-time soil moisture network, and sap flow network will be used to quantitatively estimate the mean age of the water in the watershed.

**Isotopes**

- **Shale Hills local meteoric water line comparable to local meteoric water lines from Northeastern United States**
- **Stream water, groundwater, and soil water are closely related**
- **Samples collected from 03/28/2008 – 10/22/2008**

**Age Model**

An age model is being developed by Duffy (in review) to determine the continuous mean age of the water in the watershed. The premise behind the model is that it is possible to analyze moments of the concentration distribution function, in accordance with Deelersnijder et al (1999). The stable isotope signatures will be used as inputs to the model along with some hydrologic variables. The stable, nonlinear, fully coupled system of equations is:

\[ \frac{dV}{dt} = -Q \frac{dC}{dt} + \Gamma \]

where \( Q \) and \( C \) are inflow and outflow; \( \Gamma \) is the zeroth moment of the concentration distribution function; \( s \) is sources and sinks; \( A \) is the age concentration; and \( Q \) is the mean age.

**Spectral Analysis**

Singular spectrum analysis was carried out on a daily stream water \(^{18}O\) time series, collected from 03/28/2008 – 08/22/2008. A Matlab code written by Eric Breitenberger, and modified by Tongying Shun and Kris Siodema, following the paper by Vautard, Yiou, and Ghil (1993), was used to carry out the analysis.

Singular spectrum analysis embeds a regularly sampled time series, then determines spectral data by diagonalizing the lag-covariance matrix that is Toeplitz in structure. Eigenvalues represent the amount of variance accounted for in the time series by the accompanying eigenvector, which represent an oscillation in the time series. A pair of eigenvalues account for the same amount of variance and are at the same frequency, and the eigenvectors are in phase quadrature, then they represent a significant oscillation in the time series. From the eigenvalue and eigenvectors it is possible to calculate principal components and to reconstruct the time series. The difference between singular spectrum analysis and other spectral techniques is that eigenvectors are data adaptive, instead of being fixed as sines and cosines.

**References**


The Shale Hills Stable Isotope Network samples the entire hydrologic cycle, making it possible to study and visualize otherwise closed-off reservoirs. From the meteoric water line it is obvious that precipitation is somehow filtered before it becomes soil water, groundwater, and stream water. An evaporative signal is recognized in the soil water, groundwater, and stream water, and it is very likely that vegetation is also affecting these reservoirs. Unfortunately no time series is long enough yet to be able to discern any significant oscillations using singular spectrum analysis. It is apparent though that there is variability in the stream \(^{18}O\) time series, and it therefore should be possible to determine oscillations in that series.