The Shale Hills/Susquehanna Zone Critical Observatory:
Earth-System Testbed for Process and Prediction

Advancing interdisciplinary studies of earth surface processes

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Want to Understand Drought? Follow the Water!

Lifecycle of water in the Susquehanna River Basin may reveal answers for drought prone areas

Water is a precious resource many take for granted until there is too little or too much. Scientists and engineers have positioned instruments at the Susquehanna Shale Hills Observatory at Pennsylvania State University to learn much more about the water cycle there. 

Shale Hills Critical Zone Observatory
Stable Isotope Network

George Holmes, MS 2010
Evan Thomas, MS 2012
Instrumentation for Iso.Net
A Transport Model for Age Distribution

Rotenberg 1972, J., of Theoretical Biology, 37, 291-305

\[ \frac{\partial c}{\partial t} + \frac{\partial c}{\partial \tau} = \Gamma_c - L(c) \]

\[ L(c) \rightarrow D \frac{\partial^2 c}{\partial x^2} - u \frac{\partial c}{\partial x} \]

or

\[ L(c) = \frac{Q_i}{V} (c_i - c) \]
Transport Model in Terms of Moments

\[ \frac{\partial c}{\partial t} + \frac{\partial c}{\partial \tau} = \Gamma_c - L(c) \]

Coupling Moment \quad \text{Transport operator}

\[ \frac{\partial \mu_n}{\partial t} = n\mu_{n-1} + \Gamma_{\mu_n} - L(\mu_n) \]

\[ \text{Age} = \frac{1}{0} \]
Predicted Watershed Age at Shale Hills

- Simulated Input
- Observed Record
- Simulated Input
Spatial Mean Watershed Age = 210.9 days

Critical Zone “Age Spots”

yr12-jan-mar
- 7 - 58  [208 - 231]
- 59 - 120 [232 - 260]
- 121 - 157 [261 - 300]
- 158 - 184 [301 - 376]
- 185 - 207 [377 - 510]
- 210 - 510 [511 - 670]
Spatial Mean Watershed Age = 188.7 days
JUL - SEP

Spatial Mean Watershed Age = 161.6 days
OCT – DEC

Spatial Mean Watershed Age = 180.1 days
Spatial Mean Watershed Age = 210.9 days
SH-CZO Isotope-Age Team

Chris Duffy- Professor, Civil-Environmental Eng
George Holmes- MS Student, Civil-Environmental
Gopal Bhatt- PhD Student, Civil-Environmental Eng
Evan Thomas- MS Student, Civil-Environmental
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Ken Davis- Professor, Atmospheric Sciences
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Katie Gaines - PhD Student, Ecology
Dave Eissenstat, professor, Ecology
Where do trees get their water at Shale Hills?

Are some trees different?

How are these relationship measured & modeled?
CZO Hi-Res Data Products

NCALM Lidar -> model grid
Lin and NRCS -> GPR bedrock
Eissenstat -> tree survey
Sap flux (black bars) and soil water potential at 15 cm (red lines) for:
Chestnut oak (*Quercus prinus*), ring porous
Sugar maple (*Acer saccharum*), diffuse porous
Virginia pine (*Pinus virginiana*)

1. Several dry spells over growing season where soil water potentials became low
2. Note drought-tolerant species *Q. prinus* has appreciable sap flux even during low surface soil water potential.
3. Note by Sept., rehydration of soil only marginally increased sap flux in *A. saccharum* and *P. virginiana*. In contrast, *Q. prinus* fully recovered ability to transpire.
Spatial Dynamics of Leaf Area Index at Shale Hills during 2010

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Seasonal Changes in Spatial Distribution of Leaf Area Index and Associated Uncertainty

April 25, 2010
Seasonal Changes in Spatial Distribution of Leaf Area Index and Associated Uncertainty

May 10, 2010
Seasonal Changes in Spatial Distribution of Leaf Area Index and Associated Uncertainty

June 03, 2010

LAI

SD
Seasonal Changes in Spatial Distribution of Leaf Area Index and Associated Uncertainty

July 19, 2010
Seasonal Changes in Spatial Distribution of Leaf Area Index and Associated Uncertainty

July 29, 2010
Seasonal Changes in Spatial Distribution of Leaf Area Index and Associated Uncertainty

September 06, 2010
Seasonal Changes in Spatial Distribution of Leaf Area Index and Associated Uncertainty

October 31, 2010

LAI

SD
LAI and soil moisture display inverse relationship during growing season.

Soil moisture decreases from leaf onset to leaf maturity and then increases from maturity to leaf senescence.
Soils-Ecology Group Conclusions

Leaf area index and soil moisture show high spatial dependence.

There is a tight coupling between vegetation phenology and hydrology. Soil moisture decreases from leaf onset to leaf maturity and then increases from maturity to leaf senescence.
SH-CZO Ecology-Soils Team

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