Annual Report for Period: 09/2007 - 08/2008
Submitted on: 07/19/2008
Principal Investigator: Bales, Roger C.
Award ID: 0725097
Organization: U of Cal - Merced
Submitted By:
Bales, Roger - Principal Investigator
Title:
CZO: Critical Zone Observatory--Snowline Processes in the Southern Sierra Nevada

Project Participants

Senior Personnel

Name: Bales, Roger
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Kirchner, James
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Boyer, Elizabeth
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Tague, Christina
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Conklin, Martha
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Goulden, Mike
Worked for more than 160 Hours: Yes
Contribution to Project:
Flux tower Co-PI, CZO support.

Name: Johnson, Dale
Worked for more than 160 Hours: Yes
Contribution to Project:
Soil nutrients Co-PI. Soil carbon and nutrient analyses, nutrient fluxes, nutrient cycling.

Name: Molotch, Noah
Worked for more than 160 Hours: Yes
Contribution to Project:
Snow surveys and mapping

Name: Houlton, Ben
Worked for more than 160 Hours: Yes
Contribution to Project:
Nitrogen isotopes in streams

Name: Hopmans, Jan

Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI for soil moisture

Post-doc

Name: Hartsough, Peter
Worked for more than 160 Hours: Yes
Contribution to Project:
Instrument calibration in laboratory

Name: Liu, Fengjing
Worked for more than 160 Hours: No
Contribution to Project:
Geochemical analysis

Graduate Student

Name: Malazian, Armen
Worked for more than 160 Hours: Yes
Contribution to Project:
Instrument calibration in laboratory

Name: Godsey, Sarah
Worked for more than 160 Hours: Yes
Contribution to Project:
geomorphology, the extension and contraction of the stream network at the CZO in response to snowmelt

Name: Palucis, Marisa
Worked for more than 160 Hours: Yes
Contribution to Project:
In preparation for Ph.D. qualifying exam, used stream and suction lysimeter data from the CZO to test a theoretical model for concentration-discharge relationships in porewaters and streams

Name: Alvarez, Otto
Worked for more than 160 Hours: No
Contribution to Project:
Data management

Name: Kelly, Anne
Worked for more than 160 Hours: No
Contribution to Project:
Evapotranspiration and water balance in forest

Name: Musselman, Keith
Worked for more than 160 Hours: Yes
Contribution to Project:
Snow surveys and mapping

Name: Kirchner, Peter
Worked for more than 160 Hours: Yes
Contribution to Project:
Water cycle, soil moisture

Name: Lucas, Ryan
Worked for more than 160 Hours: Yes

Contribution to Project:
water cycle research

Undergraduate Student

Name: Baumgartner, Thomas
Worked for more than 160 Hours: Yes
Contribution to Project:
Assisted with field installations

Name: Melendez, Denise
Worked for more than 160 Hours: Yes
Contribution to Project:
Assisted with field installations and data analysis

Name: Kelly, Dean
Worked for more than 160 Hours: No
Contribution to Project:
Field research and data analysis

Name: Rojas, Adrian
Worked for more than 160 Hours: No
Contribution to Project:
Field research and data analysis

Technician, Programmer

Name: Meadows, Matt
Worked for more than 160 Hours: Yes
Contribution to Project:
Research hydrologist in charge of continuing CZO field program

Name: Winston, Greg
Worked for more than 160 Hours: Yes
Contribution to Project:
Flux tower instrumentation

Other Participant

Research Experience for Undergraduates

Organizational Partners

Pacific SW Research Station, USFS

The CZO is located at the Kings River Experimental watersheds, a set of research catchments operated by the Pacific Southwest Research Station, U.S. Forest Service.

Lawrence Livermore National Laboratory

Jean Moran and Brad Esser have collected samples for isotope analysis as part of the meadow experiment in summer 2008. they plan to analyze the samples and collaborate on papers.

Other Collaborators or Contacts

Decagon Inc. Contact: Colin Campbell
Crossbow
Scott Tyler, UNR; summer 2008 deployed DTS system for meadow water cycle experiment
Craig Clemmens, San Jose State, summer 2008 deployed flux tower for meadow water cycle experiment
Reed Maxwell, LLNL, hydrologic modeling

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)
See attached work plan

Findings: (See PDF version submitted by PI at the end of the report)
See attached

Training and Development:
We are developing instrument clusters for mountain water cycle measurements, which is a great learning experience for all. This sort of integrated measurement network across a catchment has not been done before in the mountains of the Western U.S., at the rain-snow transition. Students, postdocs and research scientists are learning strategies that will need to be replicated much more widely in the future.

Outreach Activities:
We have provided press releases, done newspaper interviews and did a radio interview with the California Report, and a PBS TV interview. We are sharing technology with colleagues in research and operational agencies. Educational outreach with the Yosemite Institute will begin this coming school year.

Journal Publications

Johnson, D.W., W.W. Miller, R.B. Susfalk, R.A. Dahlgren, and D.W. Glass, "Biogeochemical Cycling in Forest Soils of the Eastern Sierra Nevada Mountains", Forest Ecology and Management, p. , vol. , (2008). Submitted,

Books or Other One-time Publications

Johnson, D.W., W.W. Miller, R.B. Susfalk, R.A. Dahlgren, N. Matsuyama and D.W. Glass, "How will a warmer climate affect nutrient cycling in forests of the eastern Sierra Nevada Mountains?", (2008). Conference poster paper, Published
Collection: Fourth Biennial Tahoe Basin Science Conference
Science as a Tool in Lake Tahoe Basin Management: Making Sense of Complexity
Bibliography: Incline Village, Nevada March 17-18, 2008.

Johnson, D.W., W.W. Miller, R.B. Susfalk, R.A. Dahlgren, N. Matsuyama and D.W. Glass, "Biogeochemical Cycling in Forest Soils of the Eastern Sierra Nevada Mountains, USA", (2008). Conference poster presentation, Published
Collection: North American Forest Soils Conference
Bibliography: Blacksburg, VA June 22-26 2008

Tague, C, "Spatial modeling of coupled hydrologic-biogeochemical processes for the Southern Sierra Critical Zone Observatory", (2007). Conference presentationa nd abstract, Published
Collection: Eos Trans. AGU
Bibliography: 88(52), Fall Meet. Suppl., Abstract H53A-0957

Bales, R; Boyer, B; Conklin, M;
Goulden, M; Hopmans, J;
Hunsaker, C; Johnson, D; Kirchner, J; Tague, C, "Southern Sierra Critical Zone Observatory: integrating water cycle and biogeochemical

processes across the rain-snow transition", (2007). Conference presentation and abstract, Published
Collection: Eos Trans. AGU
Bibliography: 88(52), Fall Meet. Suppl., Abstract H13A-0962

Bales, R; Hunsaker, C; Conklin, M; Kirchner, J; Boyer, B; Kirchner, P, " Southern Sierra Critical Zone Observatory (CZO): hydrochemical characteristics, science and measurement strategy", (2007). Conference presentationa nd abstract, Published
Collection: Eos Trans. AGU
Bibliography: 88(52), Fall Meet. Suppl., Abstract H51K-02

Web/Internet Site

URL(s):

https://snri.ucmerced.edu/CZO
https://eng.ucmerced.edu/snsjho

Description:

The first is our main CZO url.
the second is the url for our digital library.

Other Specific Products

Contributions

Contributions within Discipline:

The CZO provides a multi-disciplinary platform for research. Many of the CZO data are available to the community, and other data to CZO cooperators who agree to data-sharing protocols.

Contributions to Other Disciplines:

The CZO fosters multi-disciplinary research. the site is also a candidate for a NEON investment, which could significantly enhance some of our CZO activities.

Contributions to Human Resource Development:

Several graduate students, undergraduates and recent Ph.D. graduates are involved with the CZO, and are preparing themselves for independent measurement and data analysis work in field hydrology, and modeling.

Contributions to Resources for Research and Education:

The CZO is a research platform, i.e. infrastructure for multidisciplinary research.

Contributions Beyond Science and Engineering:

The high profile of our CZO helps communicate water and other critical zone issues to the public, and helps educate agencies about the need to modernize measurement and decision-making infrastructure.

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Product

Findings

The following gives the status of various activities in the work plan. Refer to the section in the work plan of the same title for a description of activities.

Core CZO measurements, data management and integration. The 50-m flux tower is up and solar arrays in place (funding through MRE grant). It is being instrumented in July-September, 2008. About half of the ground-based part of the water-balance instrument cluster at KREW was put in place in summer-fall 2007, with the remainder being installed summer-fall 2008 (Figure 1). The part in place is producing consistent data, with QA/QC in progress (Figure 2). The Wolverton instrument cluster is producing quality data (Figure 3). A part-time data manager started July 1, 2008 (Otto Alvarez); prior to that Matt Meadows has been handling data management, with assistance from Ryan Lucas and Peter Kirchner. The digital library is functioning and is populated with data. A full-time data manager is expected to join the team by mid-August. The education and communication position is expected to be filled by early September.

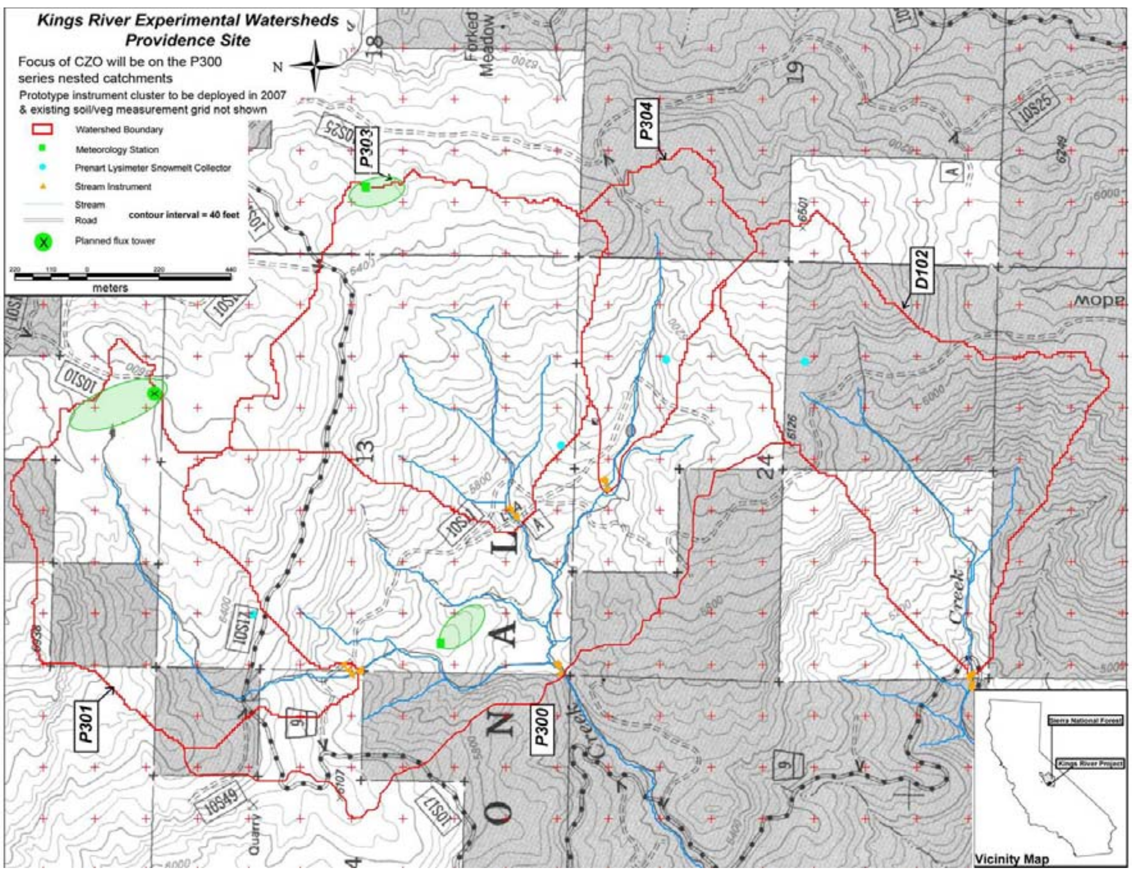

Figure 1. Instrument cluster design at KREW CZO site. Shaded green areas illustrate primary instrument node locations, strategically placed to capture variability in elevation, aspect ad vegetation properties.

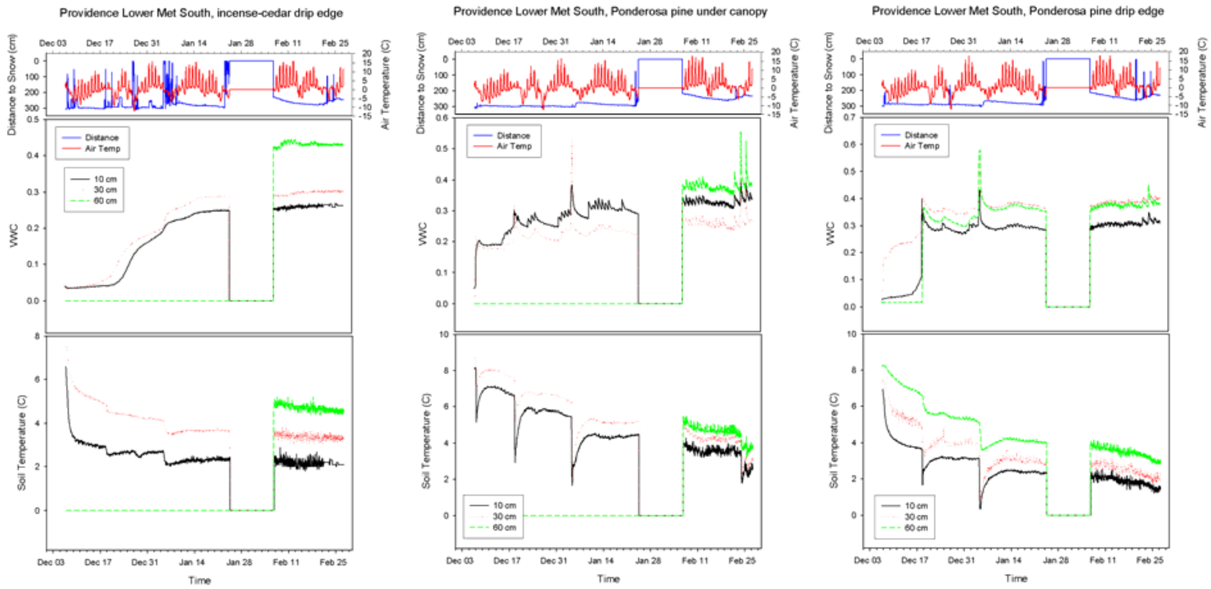

Figure 2. Example of CZO snow-depth, soil moisture and temperature data from portion of instrument cluster located at lower meteorological station. Note that these are raw data without QA/QC, which is in progress. Typical of over 20 soil moistures in place at KREW. Note that the period illustrated had over 2 m snow depth, with soil temperature remaining above freezing.

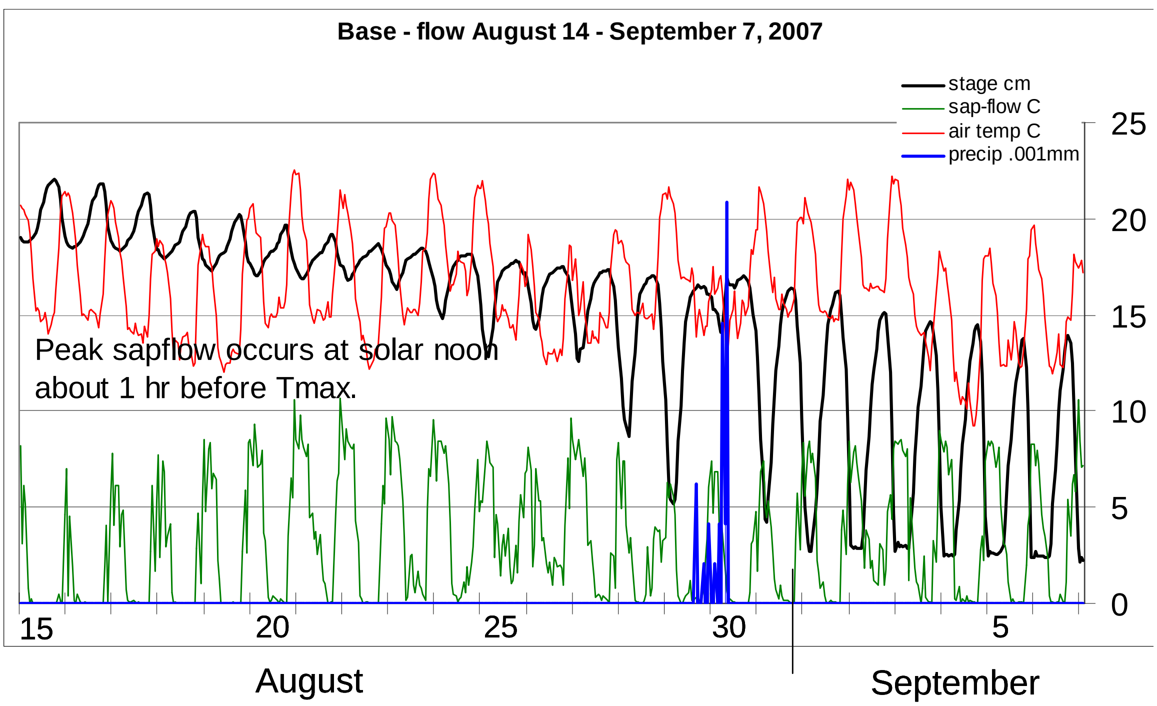

Figure 3. Wolverton Creek stage, precipitation, air temperature and sap flow data for a baseflow period, 2007, illustrating the value of high-frequency, coincident data. Note tracking of air temperature and sap flow, and diel stream stage response to evapotranspiration. After precipitation event, the increase in evapotranspiration is thought to be due to understory and riparian vegetation, as trees showed no response.

Core KREW measurements and data management. Analysis of streamflow (Figure 4) meteorological (Figure 5), turbidity and sediment data is in progress. A series of papers involving USFS and CZO personnel is in preparation. R. Bales is assisting C. Hunsaker with the water-balance analysis and F. Liu has started analysis of geochemical data. See Figure 6 for typical stream control section in CZO/KREW catchments.

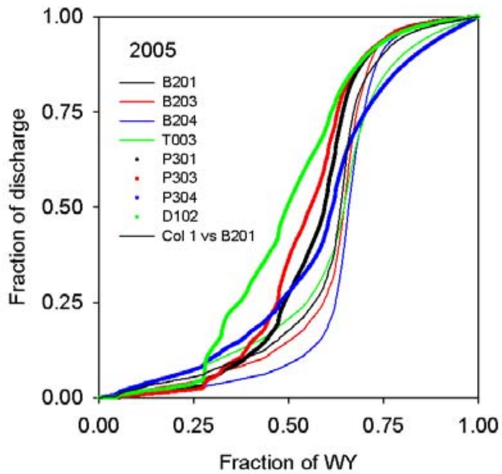

Figure 4. Cumulative streamflow for 8 KREW catchments, illustrating the transition from rain(D102) to snowmelt (B204) dominance.

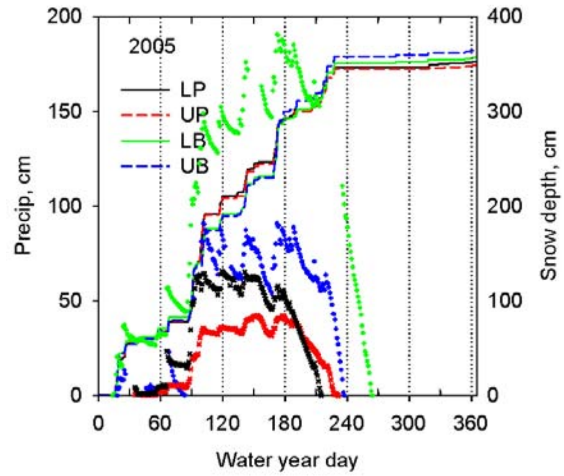

Figure 5. Snow depth shown with cumulative precipitation for 2005, illustrating the differing lags between the two across the higher (UB) versus lower (LP) sites. Note coincidence of precipitation versus lags in snowmelt between the sites.

Figure 6. KREW stream gage. Each stream has 2-stage flumes, for both high and low flows.

Modeling of water and nutrient cycles. Spatial-temporal datasets required for RHESSys (Regional hydro-ecologic simulation system) were obtained and used to set up initial hydrologic simulations for the CZO watersheds. We plan to use these baseline simulations as a starting point for model parameterization, refinements to model representation of the critical zone and linkages with field-based analysis. For these initial simulations, we made the following simplifying assumptions

- spatially uniform soil type
- uniform vegetation, with an LAI (leaf area index) based on literature values for the dominant forest species
- uniform precipitation (note that amount of rain versus snow varies spatially as a function of air temperature but total amount of uniform precipitation was spatially constant)

For these initial simulations, two years of overlapping streamflow and meteorologic data (water year 2004-2005) were available and used for model inputs.
Preliminary Hydro-ecologic simulations have been carried out with RHESSys. A Monte Carlo based approach was used to randomly select values for RHESSys hydrologic

parameters based on typically ranges for Western mountain watersheds (based on existing RHESSys parameters libraries). Figure 7 shows uncertainty bounds around streamflow predictions for one of the CZO sub-watersheds based on these Monte-Carlo simulations. Note that for most parameter values, RHESSys tends to over-predict streamflow, although timing is reasonable. In particular timing of spring snow melt is well captured by the model. Figure 8

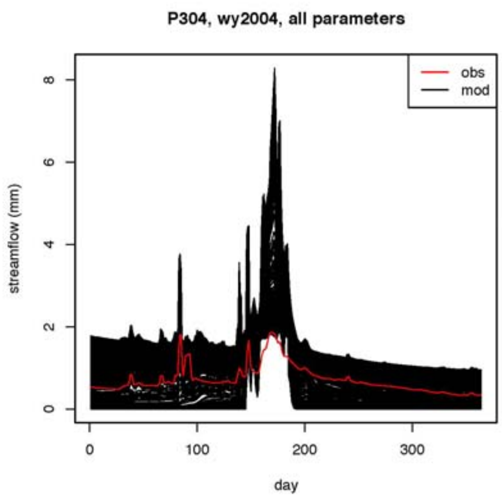

Figure 7. Streamflow predictions using RHESSys, illustrating uncertainty bounds.

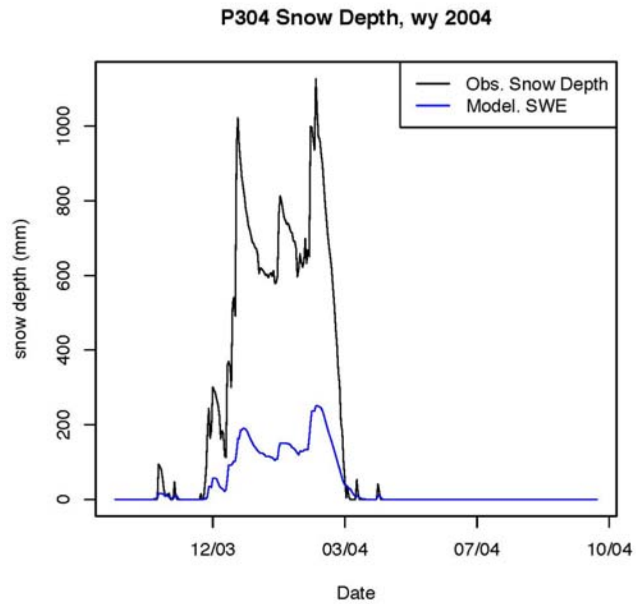

Figure 8. Preliminary RHESSys simulation of snow water equivalent.

shows RHESSys estimates of snow water equivalent depth and a comparison with observed snow depth (not SWE) measurements for a site within the P304 watershed. Next steps will be to assess source of error (water by-passing gage as deeper groundwater, RHESSys under-estimation of ET due to vegetation parameterization, error in rainfall inputs, etc.).

Initial RHESSys estimation of evapotranspiration were also examined. Here the timing of summer water stress reductions in ET was estimated and ultimately will be compared against flux-tower and sap-flow measurements as this data become available through CZO monitoring program. Figure 9 shows spatial patterns of evapotranspiration for late May and mid June. Note the significant spatial differences in predicted ET for the later date which is mid-point during the

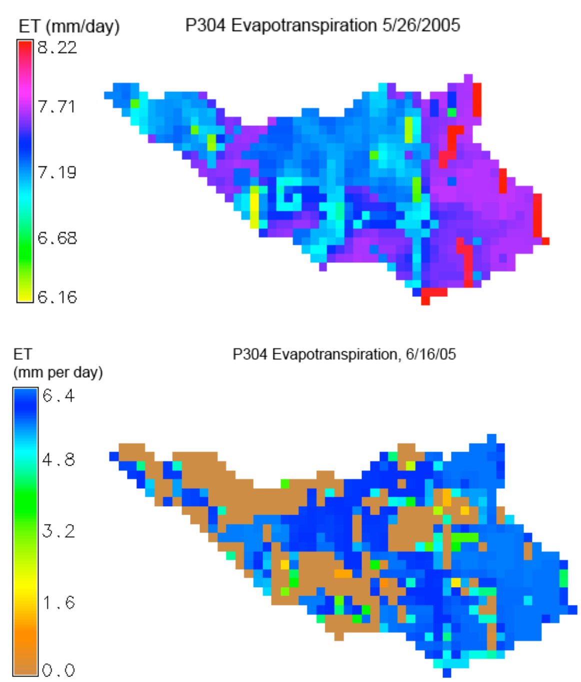

Figure 9. RHESSys simulation of ET for 2 periods.

summer dry-down season. Evapotranspiration earlier in the season depicts a much more uniform spatial patterns of modeled ET. As part of the CZO project, sap-flow and soil moisture instrumentation will be used to explore the whether these modeled spatial patterns are reasonable, and further explore the implications of within watershed spatial patterns of ecosystem drought stress sensitivity

Near-surface soil-water processes. The soil moisture arrays at Wolverton are operational, providing data for 1-2 years. A Crossbow wireless network provides for telemetry of data to enable real-time access (Figure 10). Analysis of data is in progress. A soil moisture network for the KREW site, as part of the larger instrument cluster, was developed (Figures 11-12). In addition, five trees in the P301 watershesd were selected for future intensive soil moisture monitoring. A set of 10 MPS soil water potential sensors was tested and calibrated in the laboratory, using pressure plate apparatus, for a range of pressures to near 4 bar. Based on this successful evaluation, it was decided to use these new Decagon sensors throughout the instrument cluster. Testing and calibration procedure has been implemented for about 150 MPS sensors and 100 EchoTE soil moisture sensors, to be deployed in summer 2008. Using calibration data, a simple calibration procedure was developed that requires a single calibration point (1 bar) for each MPS sensor. No temperature correction was needed. A manuscript is in preparation regarding MPS testing and calibration.

Figure 10. Crossbow prototype atop 10-m pole at Wolverton, for telemetering soil matric potential data.

Figure 11. Soil moisture installation under canopy and at drip edge, KREW-CZO flat site.

Physical controls on water and carbon exchange and plant production. Instrumentation of the flux tower is in progress, summer 2008. Site selection work and landscape characterization were carried out prior to site selection and construction. Sap flow instruments are planned for installation in fall 2008, pending completion of testing of wireless pods and integrated low-power system. Systems previously installed at Wolverton continue to operate (see example data on Figure 3).

Figure 12. Placement of Decagon soil moisture probes at 10-, 30-, 60- and 90-cm depths.

Surface-groundwater interactions. The planned intensive meadow water-balance experiment was carried out in summer 2008, at Long Meadow, Wolverton (Figures 13-14). Data are still being compiled and loaded into the digital library.

Figure 13. Eddy correlation in Long Meadow, looking upstream in meadow.

Figure 14. Calibration of DTS cable with ice, Long Meadow.

Snowpack and snowmelt controls on nitrogen cycling in soil . Soils from the KREW watersheds have been analyzed for total C, total N, NH_4^+ and NO_3^- and the data are being summarized at this time for spatial analysis and calculations of contents (kg ha^{-1}) with previously-determined soil bulk density and rock content data. The other nutrient analyses will be done with next year's budget.

Nitrogen fluxes from soil. Nothing to report.

Baseline hydrologic, sediment and geochemical characterization. See Figures 4-5 for annual-scale analysis.

Water and geochemical cycles. We are currently examining the rain-snow transition period across the elevation gradient. High-frequency data that illustrate the transition form diel cycles dominated by snowmelt to cycles dominated by ET are being analyzed (Figure 15). We are also analyzing data from the snow-soil moisture-sap flow arrays (Figures 16-18)

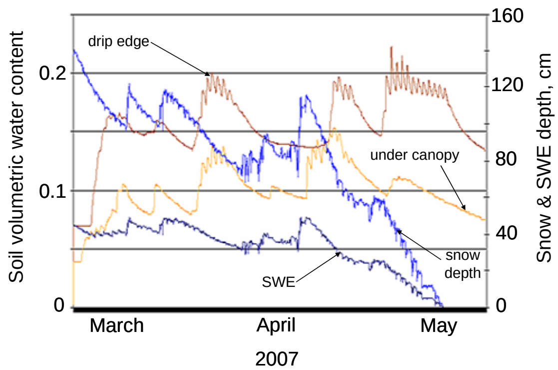

Figure 16. Soil moisture and snowpack data from instrument cluster illustrating how rain-snow transition zone undergoes rapid seasonal changes, going from snowcover to wet soil to dry soil over 1-2 months. Note diel fluctuations in soil moisture during snowmelt and also wetter soil at canopy dip edge versus under canopy.

Figure 17.Wolverton sap flow sensor.

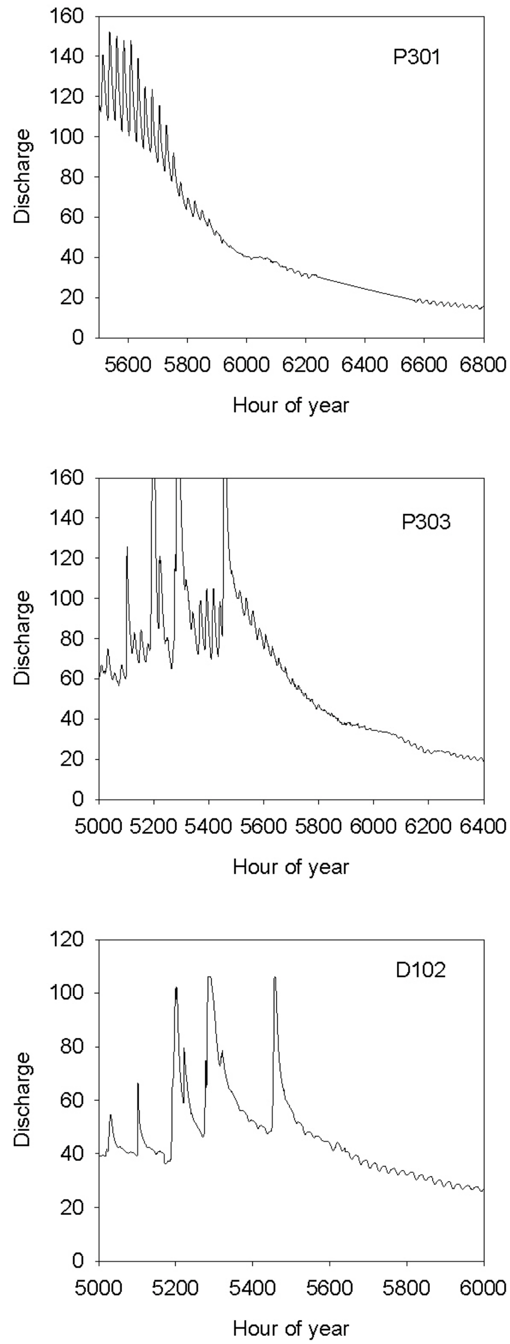

Figure 15. Transition from diel cycles dominated by snowmelt (left half of P301 and P303 panels) to ET domainted (right half of all 3 panels). Note that in lower-elevation D102, rainfall rather than snowmelt dominates, versus both snowmelt and rain in P303.

Figure 18. Acoustic snow-depth sensors under canopy, drip edge and in the open, Wolverton site 3, high elevation, south facing. A set of soil moisture sensors are located beneath each snow sensor. Additional snow sensors that are part of the instrument node are deployed within 50 m.

Photo credits. Figures 10, 13-14, 17-18: Margot Wholey (http://margotwholey.com/). Figures 6, 11-12: Roger Bales.