An Outdoor Hydro-Climatic Laboratory for the 21st Century: 45 Years of Research and Data Collection at the Reynolds Creek Experimental Watershed

Danny Marks, ARS
Coming to you from Boise, ID
October 6th, 2006
To begin at 3:05 ET
Welcome to the 7th Semester of CUAHSI Education and Outreach Cyberseminars

Host: Jon Duncan
CUAHSI Project Manager

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An Outdoor Hydro-Climatic Laboratory for the 21st Century: 45 Years of Research and Data Collection at the Reynolds Creek Experimental Watershed

Danny MARKS, Research Hydrologist

Northwest Watershed Research Center
USDA-Agricultural Research Service
Boise, Idaho
USA
NWRC USDA-ARS Team:

Scientists:
- Mark Seyfried, Soil Scientist
- Danny Marks, Snow Hydrologist
- Gerald Flerchinger, Hydraulic Engineer
- Stuart Hardegree, Plant Physiologist
- Fred Pierson, Surface Water Hydrologist
- Pat Clark, Range Scientist

Current Graduate students:
- Adam Winstral, NWRC staff, University of Reading, UK (Snow distribution and scaling)
- Michele Reba, University of Idaho (Vegetation effects on turbulent fluxes over snow)
- Anurag Nayak, Utah State University (Longterm hydro-climatic trends in the western US)
Collaborators:

Universities:
University of Idaho, Boise State University, Utah State University, University of Utah, Oregon State University, Pennsylvania State University, Stanford University, University of Maryland, Colorado State University, University of Colorado, University of California (Merced, Santa Barbara, Irvine), University of Montana, University of Washington, Kansas State University

University of Saskatchewan (Canada), University of Reading (UK), University of Wales, Aberystwyth (UK), IRD L’Institute de recherche pour le developpement (Grenoble, France), Chinese Academy of Sciences (China)

Federal Agencies:
NRCS, USACE-CRREL, BLM, USGS, USFS, NASA, NOAA, EPA
Active Research

- **Snow & cold season hydrology**
  - Surface, snow & canopy energy balance
  - Mountain hydro-climatology
  - Snow re-distribution
  - Snow-vegetation interaction
  - Winter surface heat & water flux (EC)
  - Mountain precipitation measurement
  - Canopy & terrain radiation climatology
- **Soil micro-climate**
  - Frozen soil erosion
  - Instrument design, testing & development
  - Geophysical subsurface characterization
- **Fire hydrology**
  - Grazing patterns and impacts
  - Noxious plants (Juniper hydrology)
  - Infiltration and erosion
- **RS in complex terrain**
  - Scaling 1-250m
  - Terrain and Canopy analysis (DEM, LiDAR)
Some Research Gaps

- Growing season heat and water flux (EC analysis)
- Carbon flux (EC analysis)
- Ecology: Native plants, critters, riparian zone
- Ecosystem processes, nutrient flux, productivity
- Water quality, chemistry, temperature
- Geochemistry, weathering, pedogenesis
- Sedimentation: Suspended & bed-load
- Runoff routing, channel hydraulics
- Ground water: Storage, pathways & residence times - subsurface and deep GW
- Scaling: 100m - 10km
- Meso-scale atmosphere-hydrology coupling
- Precipitation Radar (winter or cold season)
- LU/LC: Impact of human activities
RCEW: Land Ownership

Federal: 75%

State: 8%

Private: 17%

ARS partnership with:
- Private land owners (ranchers)
- State agencies
- Federal agencies
RCEW (239 km²):

- 27 climate stations
- 36 precipitation stations
- 5 EC systems
- 11 weirs (nested)
- 6 soil microclimate stations
- 2 hill-slope hydrology sites
- 4 instrumented catchments
- 3 instrumented headwater basins:

  **USC** (0.25 km², 186m relief)
  ephemeral, groundwater dominated, annual precipitation 300-500mm

  **RME** (0.38 km², 116m relief)
  perennial, surface water dominated, annual precipitation 750-1200mm

  **Johnston Draw** (1.8 km², 380m relief)
  ephemeral, rain-snow boundary, annual precipitation 400-800mm
Breaks Prescribed Burn

0.67 km², 204m relief

• Infiltration and soil moisture response to fire

Reynolds Creek Experimental Watershed

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1050</td>
<td>Green</td>
</tr>
<tr>
<td>1200</td>
<td>Yellow</td>
</tr>
<tr>
<td>1350</td>
<td>Orange</td>
</tr>
<tr>
<td>1500</td>
<td>Red</td>
</tr>
<tr>
<td>1650</td>
<td>Dark Red</td>
</tr>
<tr>
<td>1800</td>
<td>Brown</td>
</tr>
<tr>
<td>1950</td>
<td>Light Brown</td>
</tr>
<tr>
<td>2100</td>
<td>Gray</td>
</tr>
</tbody>
</table>

Precipitation Gauge
Climate Station
Soil microclimate
Upper Sheep Creek

0.25 km², 186m relief

Fire planned for 2007

Intensive Snow Surveys
  - 1984 – 1994
  - 2004 – 2005

• 10 & 21 year Water Balance
  Reconstruction

• Excellent Basin for Testing
  Distribution Algorithms
  Developed at RME

Reynolds Creek Experimental Watershed

Elevation (m)
- 1050
- 1200
- 1350
- 1500
- 1650
- 1800
- 1950
- 2100

- Well
- Soil Profile: Periodic
- Soil Profile: Continuous
- Weir
- Precipitation Gauge
- Climate Station
- EC Tower
Johnston Draw
1.8 km², 380m relief

- Newly Instrumented
- 380m Elevation Range
- Elevation Effects on Meteorological Forcings
- Evaluation of Rain/Snow Determination
Reynolds Mountain East: 0.38 km², 118m relief

• Primary Snow Research Basin
• HEAVILY! Instrumented
• Intensive Snow Surveys Since 2001
Dobson Creek
14.0 km², 770m relief

1st cut at Scaling:
relief & area
Scaling up to Tollgate

Johnston Draw
1.8 km²

Tollgate
54.6 km²

Upper Sheep Creek
0.25 km²

Dobson Creek
14.0 km²

Reynolds Mountain East
0.38 km²

- Weir
- Precipitation Gauge
- Climate Station
- Met Tripod
- Eddy Covariance
- Snow Course

Scale:
- 0 500 meters
- 0 1 kilometer
- 0 200 meters
- 0 2023
- 1868 1837
- 1474 2244
- 2023 2139

NORTHWEST WATERSHED RESEARCH CENTER
USDA
Monitoring Gradients Across the Landscape

Non-uniform Distributions:

- Wind & Precipitation
- Snow Deposition & Melt
- Soil Moisture & Temperature
- Vegetation & Canopy Structure

Understanding the Range of Canopy & Terrain Affected Conditions
Snow Redistribution and Drifting
Forest Canopy- Snowcover Interaction
Conceptual Diagram of Topographic and Vegetation Effects

- **Ridge Top**
- **Protected Area**

- **Scour**
- **Transport**
- **Deposition**
- **Drift**
- **Snowpack**
- **Soil**
- **Deposition**

- **USDA**

- **NORTHWEST WATERSHED RESEARCH CENTER**

- **USDA (USDA NRCS)**

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- **USDA (USDA NRCS)**
Reynolds Mountain East Study Catchment
(0.38 km², 118 m relief)
The Ridge Site
The Grove Site
The Grove Site
Canopy gradient

- Exposed
  - no cover
  - Low sagebrush
- Exposed
  - Shrubs
  - Big sagebrush
  - Snowberry
- Aspen
  - Vertical gradient
- Conifer
Canopy gradient

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  - no cover
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- Conifer
Eddy Covariance Equipment

- Fast Response
  - Tri-axial anemometer
  - Scalar measurements
    - CO₂, H₂O, aerosols, pollutants
  - Data logger
  - Data table 10 Hz, 9 elements
    - 1 hour = 36,000 lines
    - 1 day = 864,000 lines

- Slow Response
  - Relative humidity & temperature
  - Soil temperature & heat flux
  - Net Radiation
  - Snow depth
  - Data table
Eddy Covariance Equipment

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Vertical scaling
Vertical scaling

Lower air temperature warmer during day & colder at night

Upper air temperature colder during the day & warmer at night
Instrument Calibration and Matching

Critical when you have many instruments in similar locations; We are monitoring gradients over relatively small distances (elevation, space, time)

- Locate failing or unstable instruments
- Reference point - need centered about 0C (not 15C)
- Absolute Accuracy - compare to a reference instrument
- Matching - inter-comparison
Air Temperature Calibration

RME Sensors Prior to Modification
CS107_4

Match: +/- 0.473 C

RME Sensors Post to Modification
CS107_4

Adjusted Match: +/- 0.131 C
Solar Radiation Calibration, Adjusted Match: +/- 6.5 Wm$^{-2}$
Johnston Draw Study Catchment (1.8 km², 380 m relief)
Upper Sheep Creek

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Well

Soil Profile: Periodic

Soil Profile: Continuous

Weir

Precipitation Gauge

Climate Station

EC Tower
Soil moisture response to melt

Soil freeze/thaw dynamics

Aspen site soil water tension by depth
The cyclical, diurnal pulses of melt water are evident to a depth of 90 cm. Peaks at 10 cm are at about 17:30 and peaks at 90 cm are delayed about 5 1/2 hours to 22:00. The water contents displayed have been adjusted with a linear offset so each depth could be distinguished.
USC Landcover & Vegetation Types

Mountain Big Sage

Low Sage

Aspen with drift

USC Panorama
Upper Sheep Creek Experimental Catchment. The white line delineates the extent of snow drifts.
Landsat-derived Soil Adjusted Vegetation Index
Plant-Available Water

Aspen Available Water

High Sagebrush Available Water
Coupling Atmosphere, Surface & Subsurface processes

An integrated measurement strategy:

• Critical for scaling & SVAT modeling

• Improved hydrologic modeling

• Improved streamflow prediction

• Include Geochemical & Ecosystem fluxes
ETRS, Integrated Flux Measurement: Bedrock to Boundary layer

4-D continuous data collection from the ABL through the water table. The subsurface volume is designed on a block-centered grid, representing a discretization of the saturated-unsaturated flow equations including vertical and horizontal components. All fluxes are then estimated coherently from the theoretical equations of the atmosphere-land surface-subsurface system.
Scaling Canopy Effects

- Canopy Structure - ht, shape, closure (gaps)
- LiDAR - Quantify canopy structure at very high resolution (~1m) for scaling
Hydrologic Database

Current status:
- Data telemetry
- Data checking, processing & publication (WRR, 2002)

Issues:
- Data rate
- Data processing backlog

Future work:
- Wireless & Broadband transmission
- Relational database (MySQL)
- Web-based presentation