Using Information from Data Rich Sites to Improve Prediction at Data Limited Sites

A Challenge for Hydrologic Prediction from Mountain Basins:

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The Problem with Hydrologic Prediction in Western North America:

- Nearly all Mountain Hydrology is “ungauged”
- Mountain Hydrology is complicated…
- The Climate is Unstable…
- Statistical Relationships (rainfall/runoff) are unreliable…

We have spent 50 years perfecting the *“technique”* of hydrologic forecasting;

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It is time for us to address hydrology and hydrologic prediction as a science.

- Prediction based on understanding of, and interaction between meteorological, land surface and hydrologic processes

- Re-evaluate our measurement strategy: capture landscape gradients and "end-members"

- Understand and Model distributions of hydro-climatic parameters across complex landscapes

- Re-invest in basic hydrologic and hydro-climatic process research

Outdoor Laboratories:

- High quality, long time-series data record
- Processes and distribution characterized
- Uncertainty analysis (system is "over-measured")

Only a few locations in the world where this can be achieved…

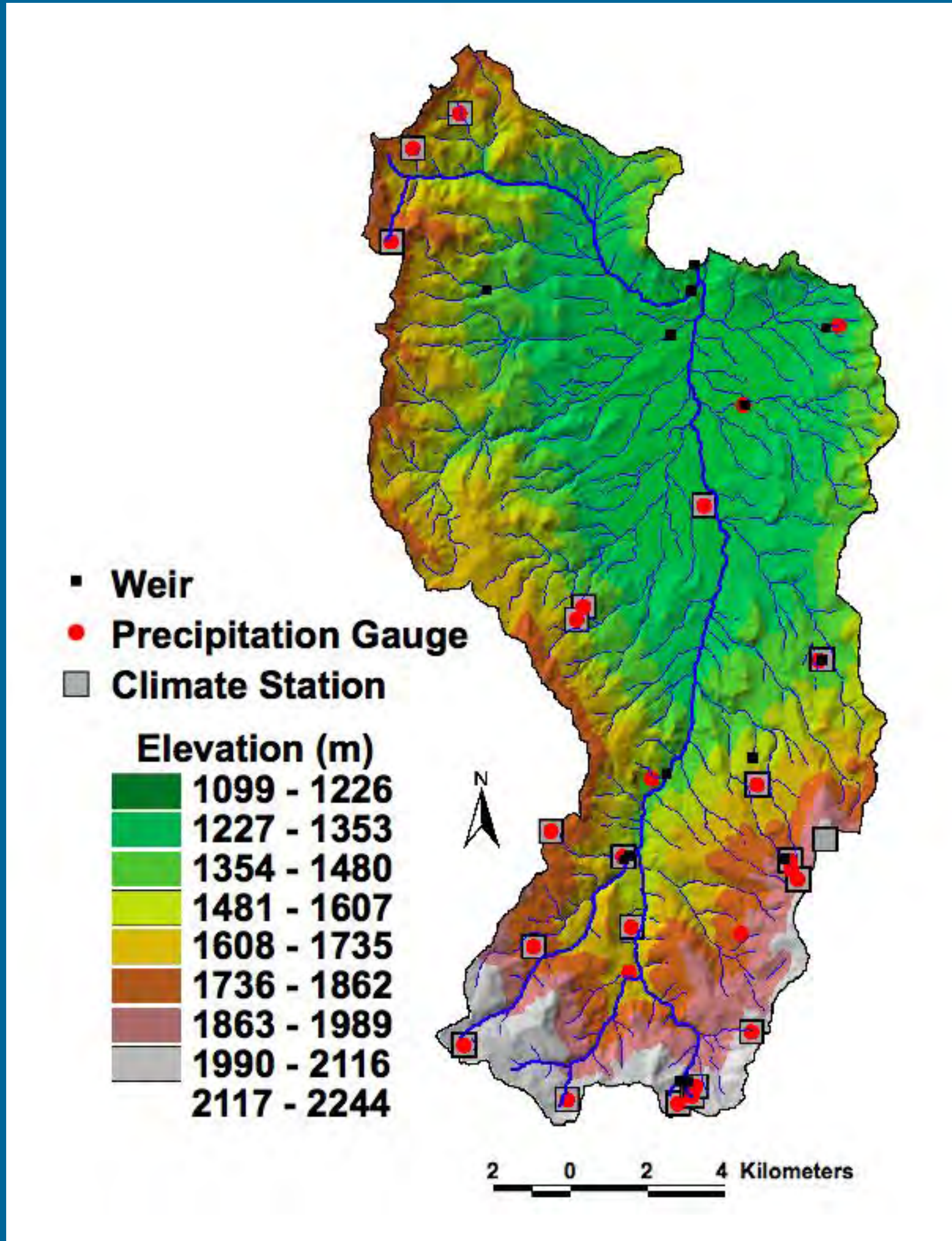
RCEW (239 km^2):

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

<u>USC</u> (0.25 km^2, 186m relief)
ephemeral, groundwater dominated,
annual precipitation 300-500mm

<u>RME</u> (0.38 km^2, 116m relief)
perennial, surface water dominated,
annual precipitation 750-1000mm

<u>Johnston Draw</u> (1.8 km^2, 380m relief)
ephemeral, rain-snow boundary,
annual precipitation 500-600mm



Predicting Hydrologic State & Storage:

- **Snow**
  - **SWE**
  - **Depth**

- **Soil Moisture**

- **Ground Water**

- **Fluxes:**
  - **Evaporation, Transpiration, Sublimation**
  - **Streamflow**

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Critical Forcing Parameters:

- Precipitation
  - Volume
  - Distribution
  - Phase (rain/snow)

- Wind
  - Turbulent transfer
  - Snow redistribution

- Temperature & Humidity
  - Hydrology is sensitive to humidity
  - Snow is VERY sensitive to humidity

- Land Cover Characteristics:
  - Soils & Groundwater
  - Vegetation

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An Unstable Climate:

- Changing Climate – Hydrology Relationship

- Precipitation
  - Volume
  - Phase

- Evaporation – Water Stress

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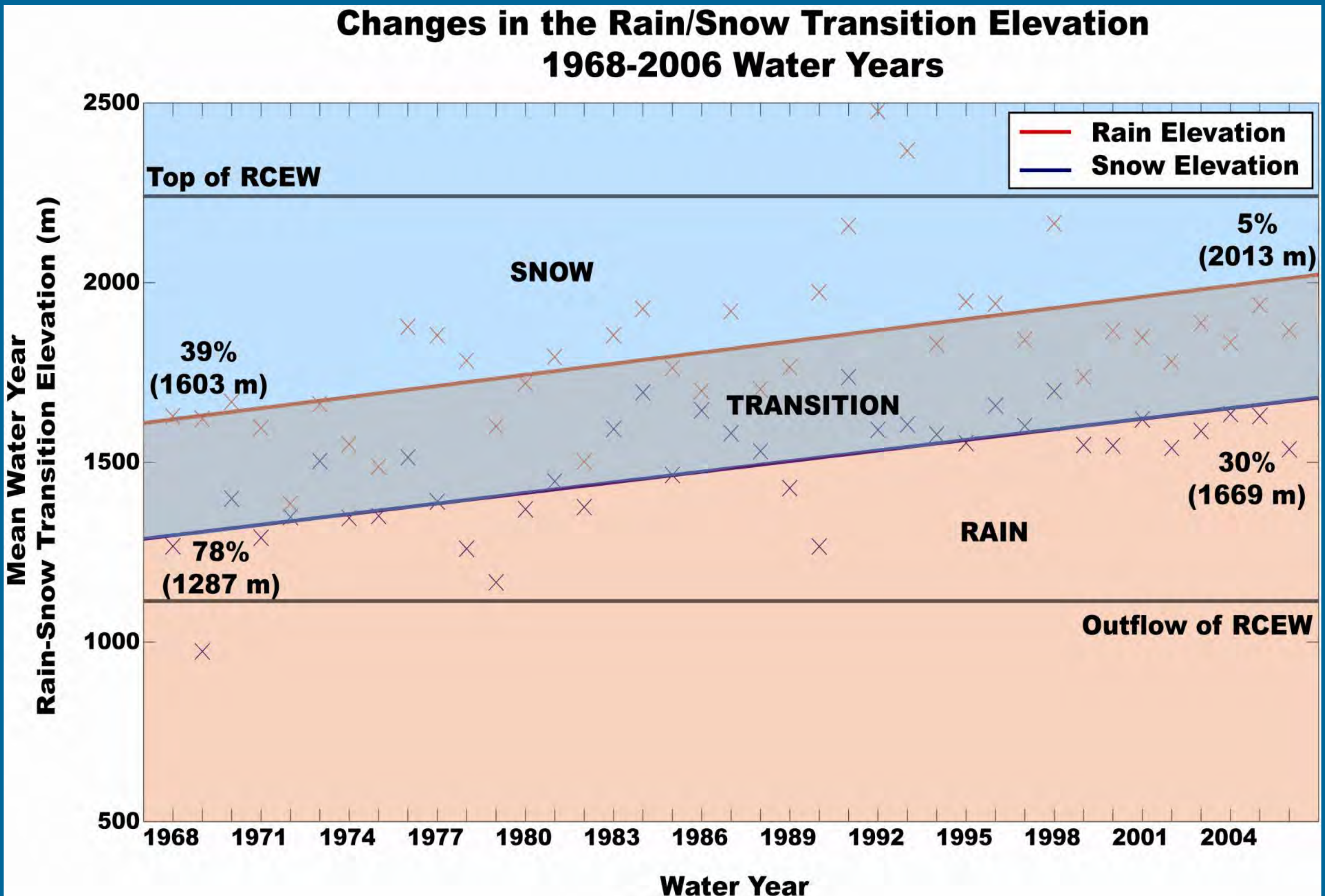

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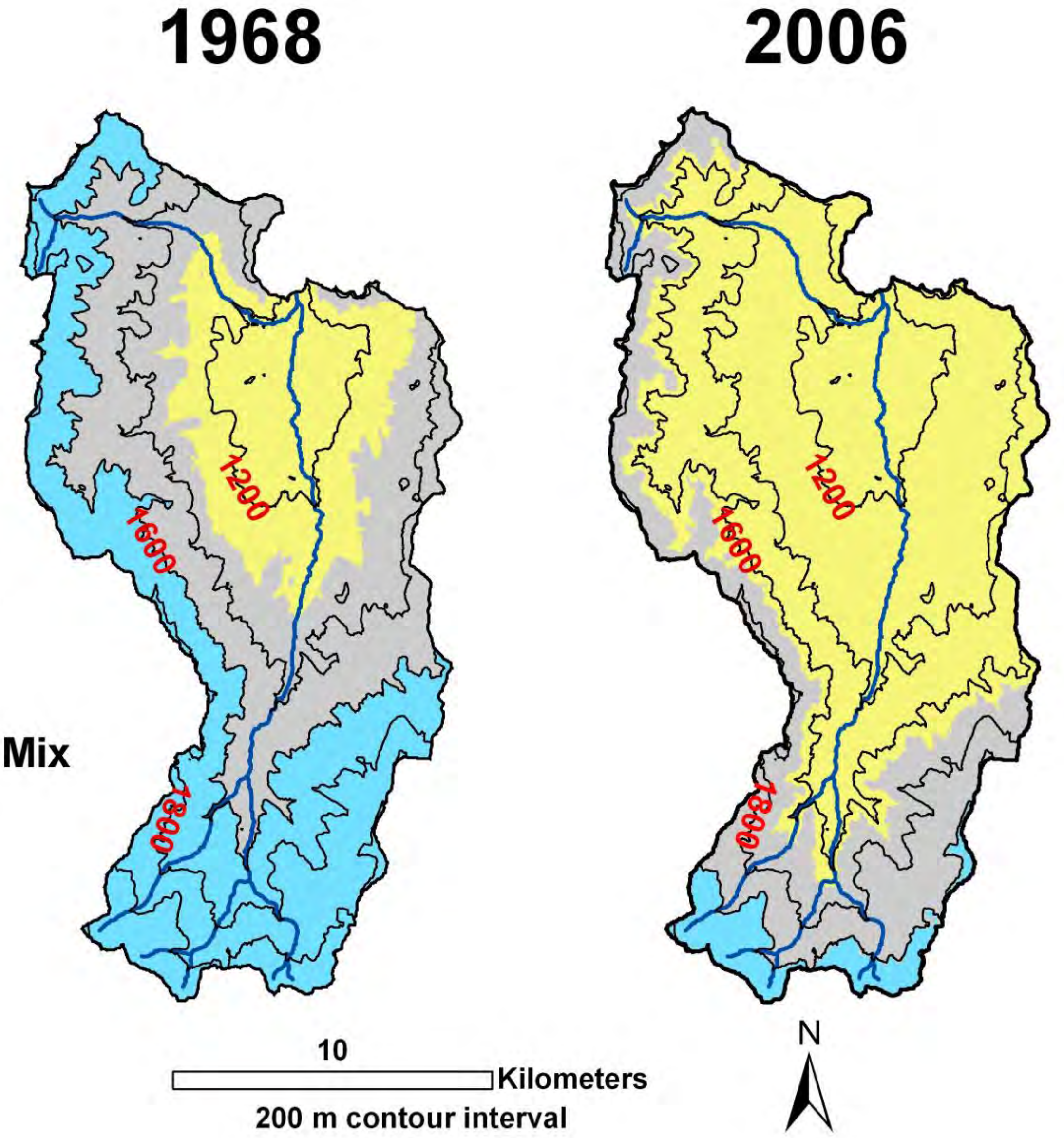
Reynolds Creek Experimental Watershed Idaho, USA



Dominant Precipitation Type

- Snow
- Rain/Snow Mix
- Rain

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Precipitation Distribution:

Persistent Patterns

Snow Distribution:

Wind

Topography

Canopy Structure

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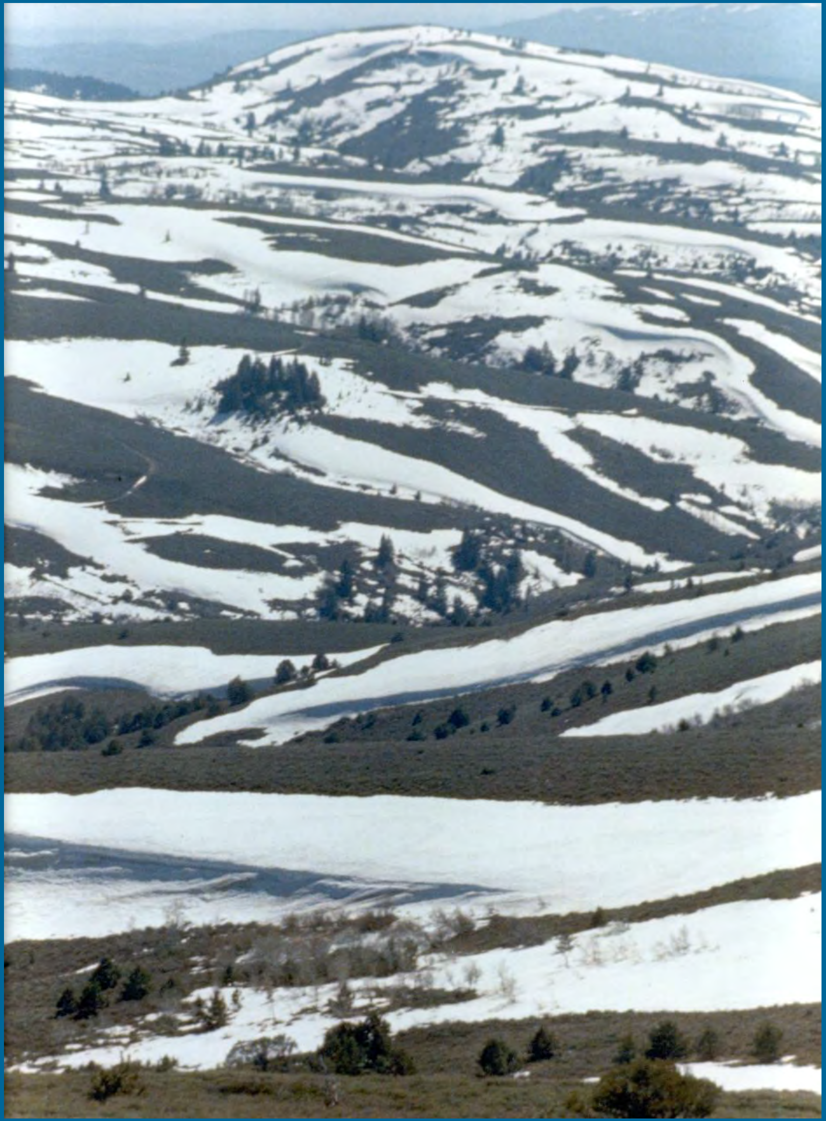

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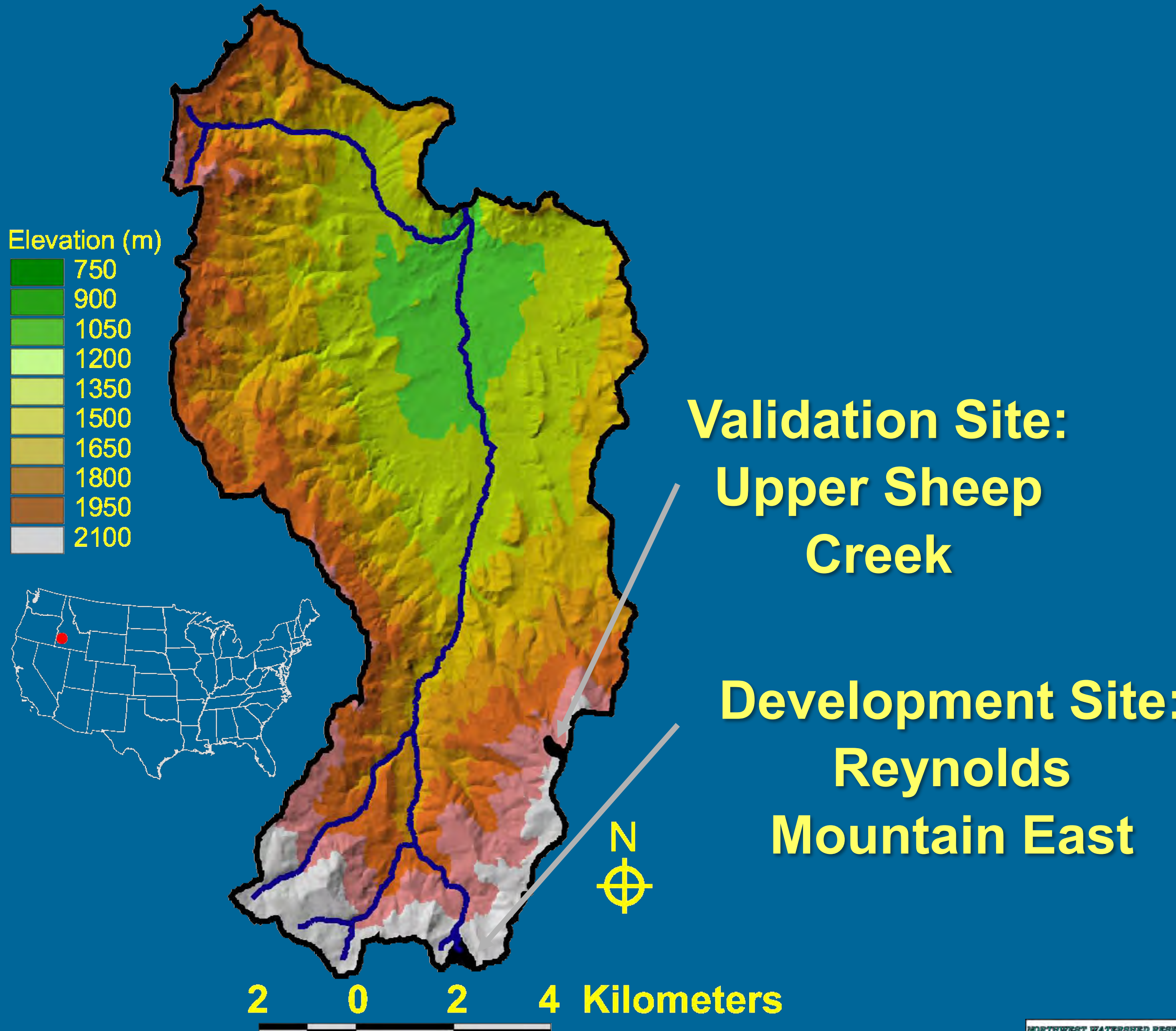
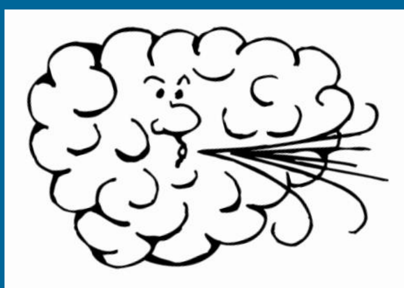
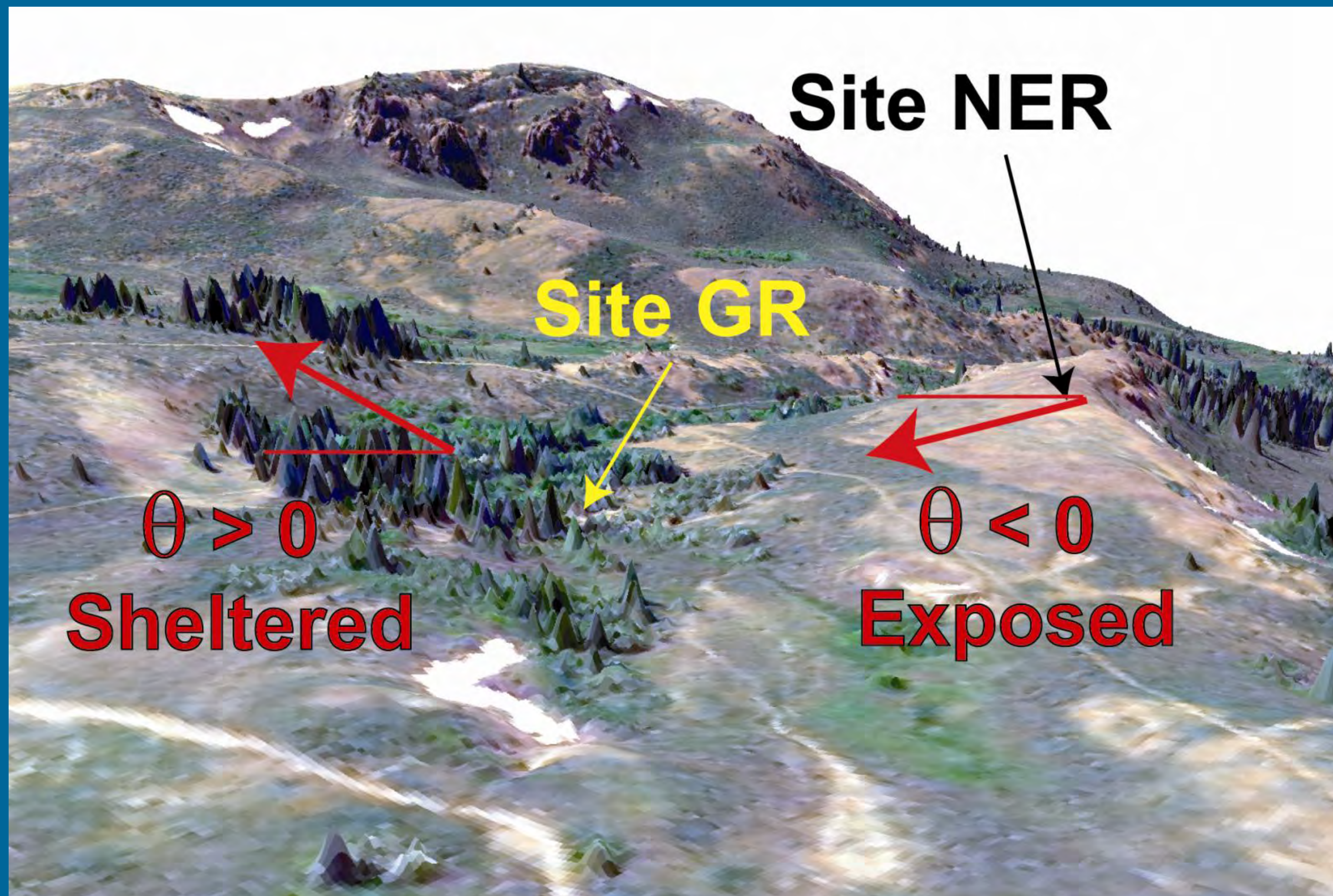

Elevation (m)
750
900
1050
1200
1350
1500
1650
1800
1950
2100
Validation Site:
Upper Sheep
Creek
Development Site:
Reynolds
Mountain East
N
2 0 2 4 Kilometers

LiDAR-Derived Terrain & Canopy

Sx: *a measure of upwind exposure*





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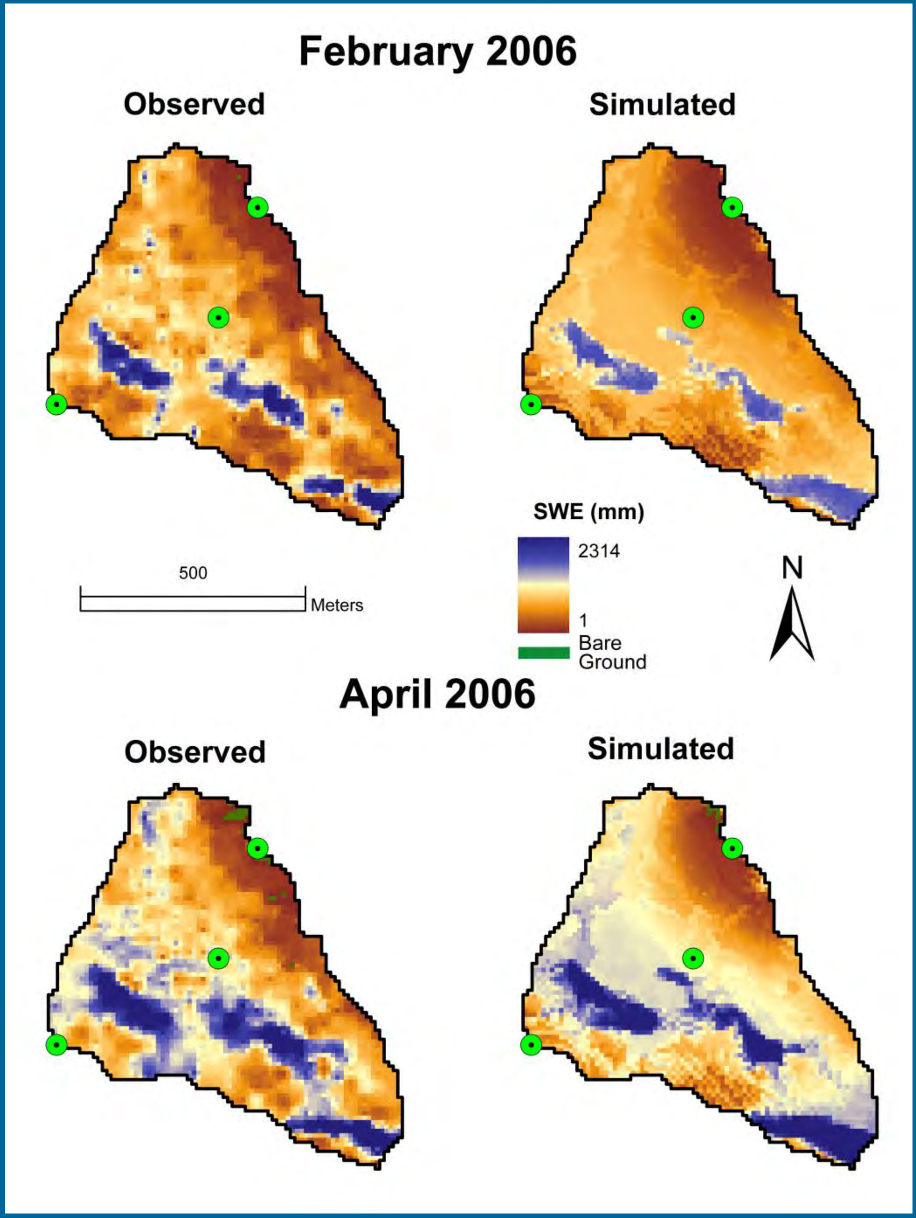
Development Site: Reynolds Mountain East



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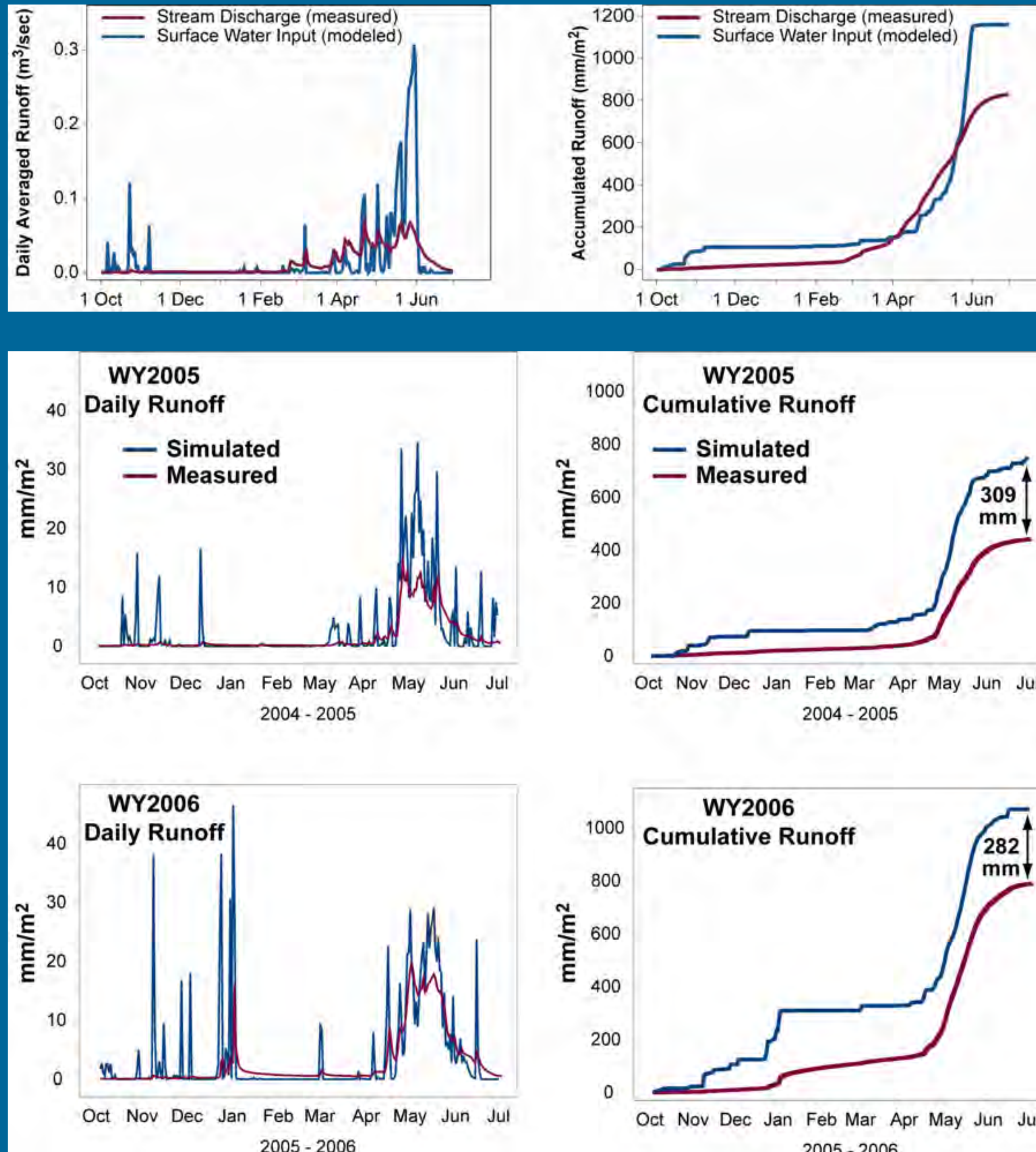

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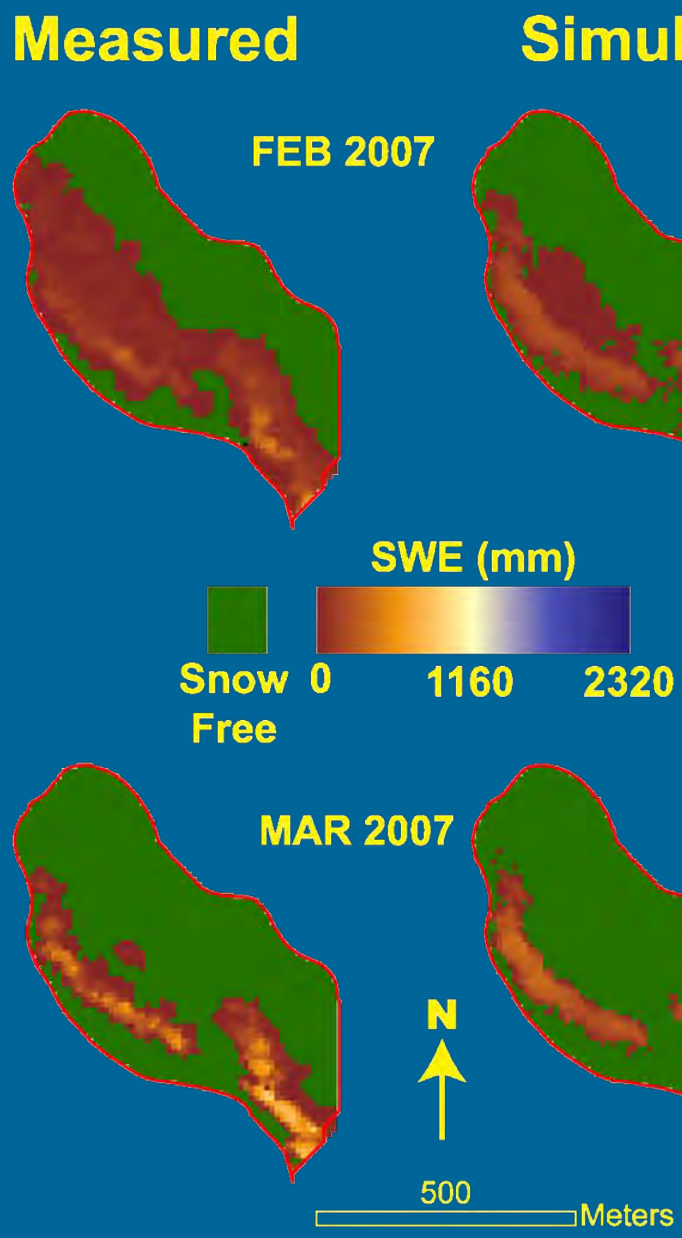
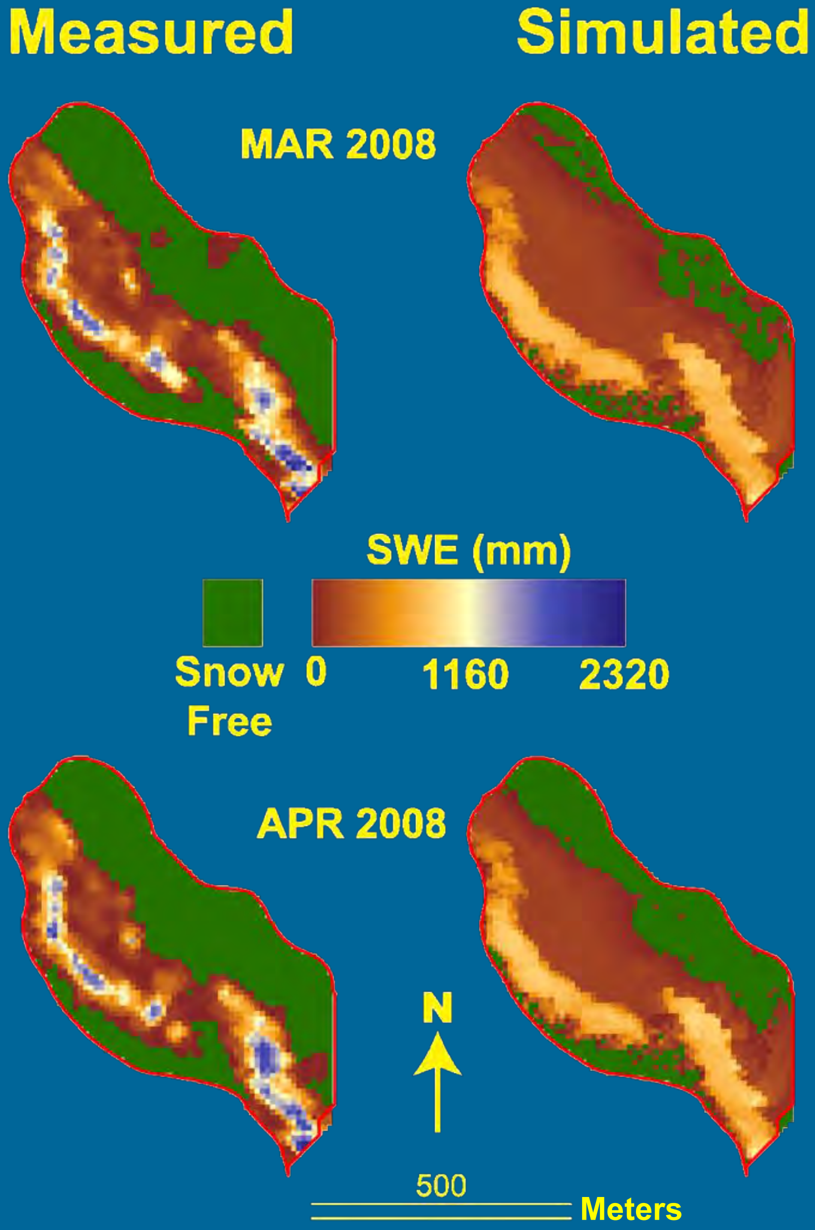
Upper Sheep Creek:

Testing the precipitation distribution model

Upper Sheep Creek:

Measured and Modeled SWE WY2007





Upper Sheep Creek:

Measured and Modeled SWE WY2008

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Can we transfer this to a larger basin?

Marble Fork Kaweah River

152 km^2

Elevation Range: 250 – 3650 m

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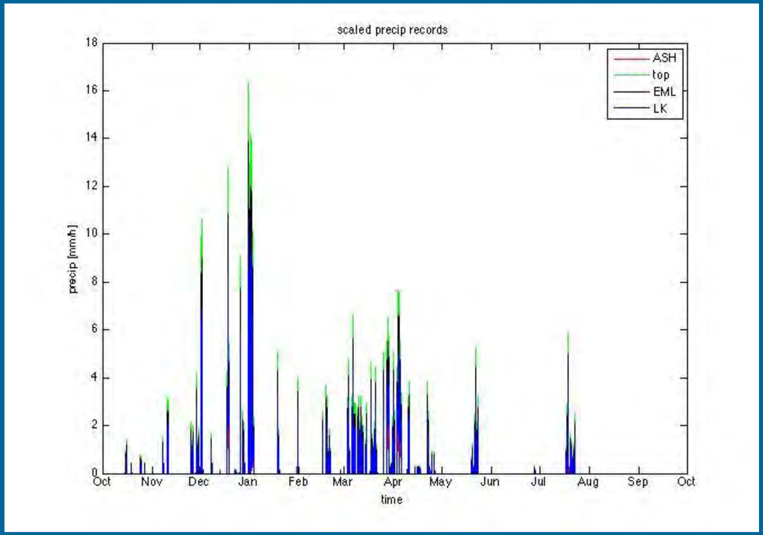
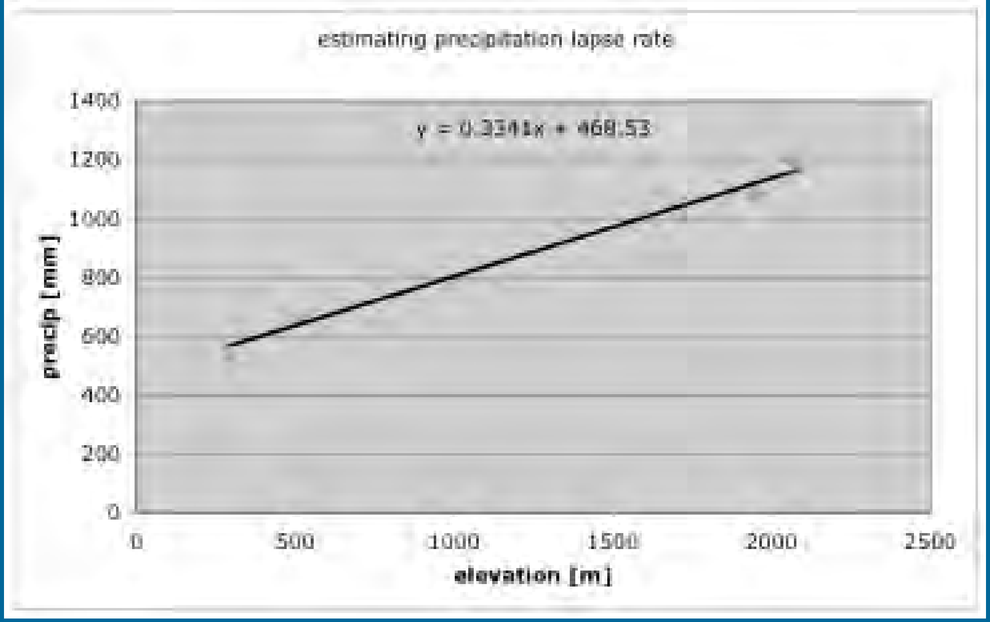
Precipitation Distribution by Lapse Rate:

Marble Fork Kaweah River
152 km^2
Elevation Range: 250 – 3400 m





Annual Lapse Rate:
4 stations
450 – 2200 m
0.34 mm m^{-1}

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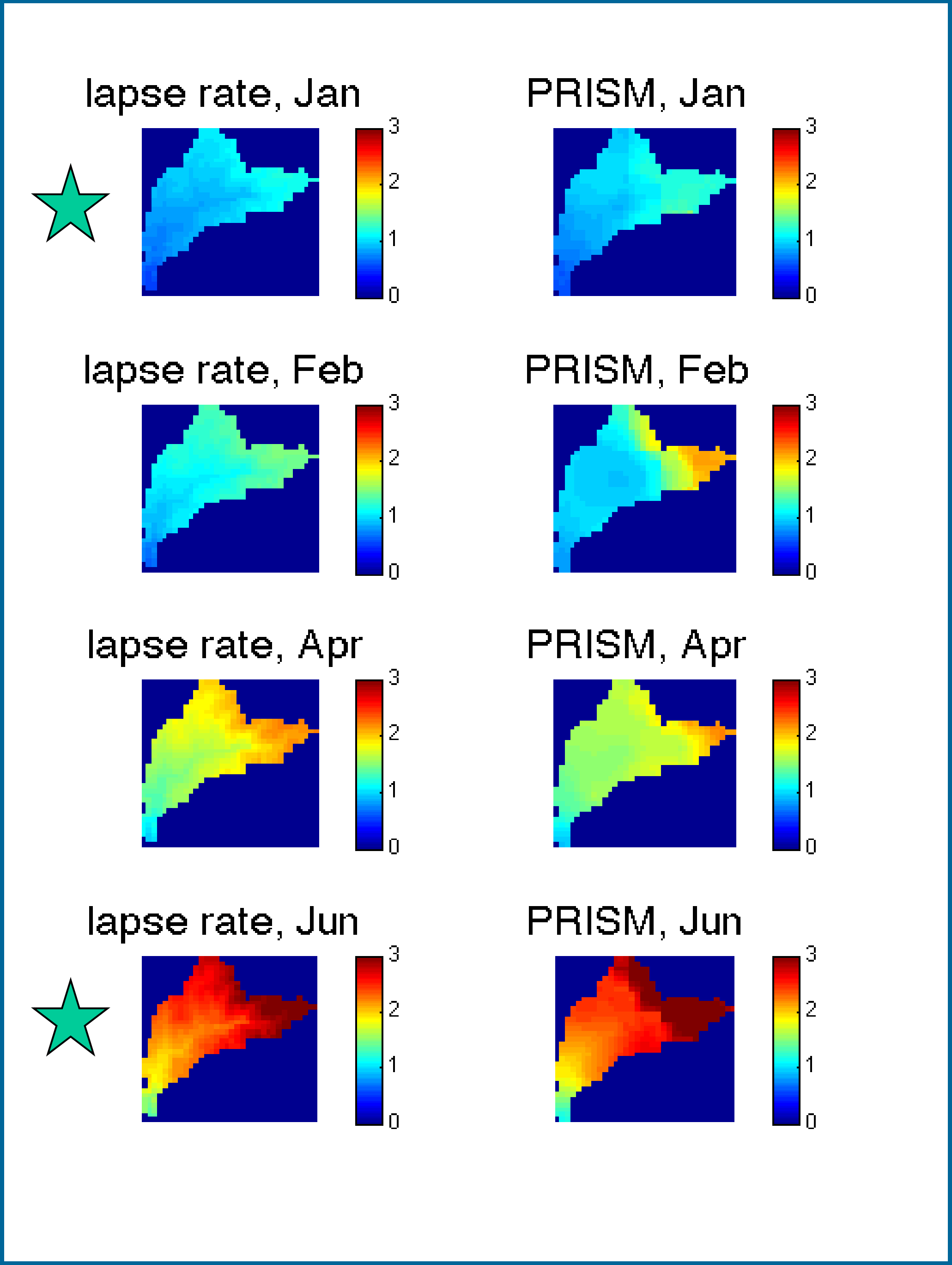
Marble Fork:



Different Distributions:

Sometimes it matters

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Soil Temperature and Moisture:

Spatially and Temporally variable

Limited reference data

RS spatially very coarse resolution

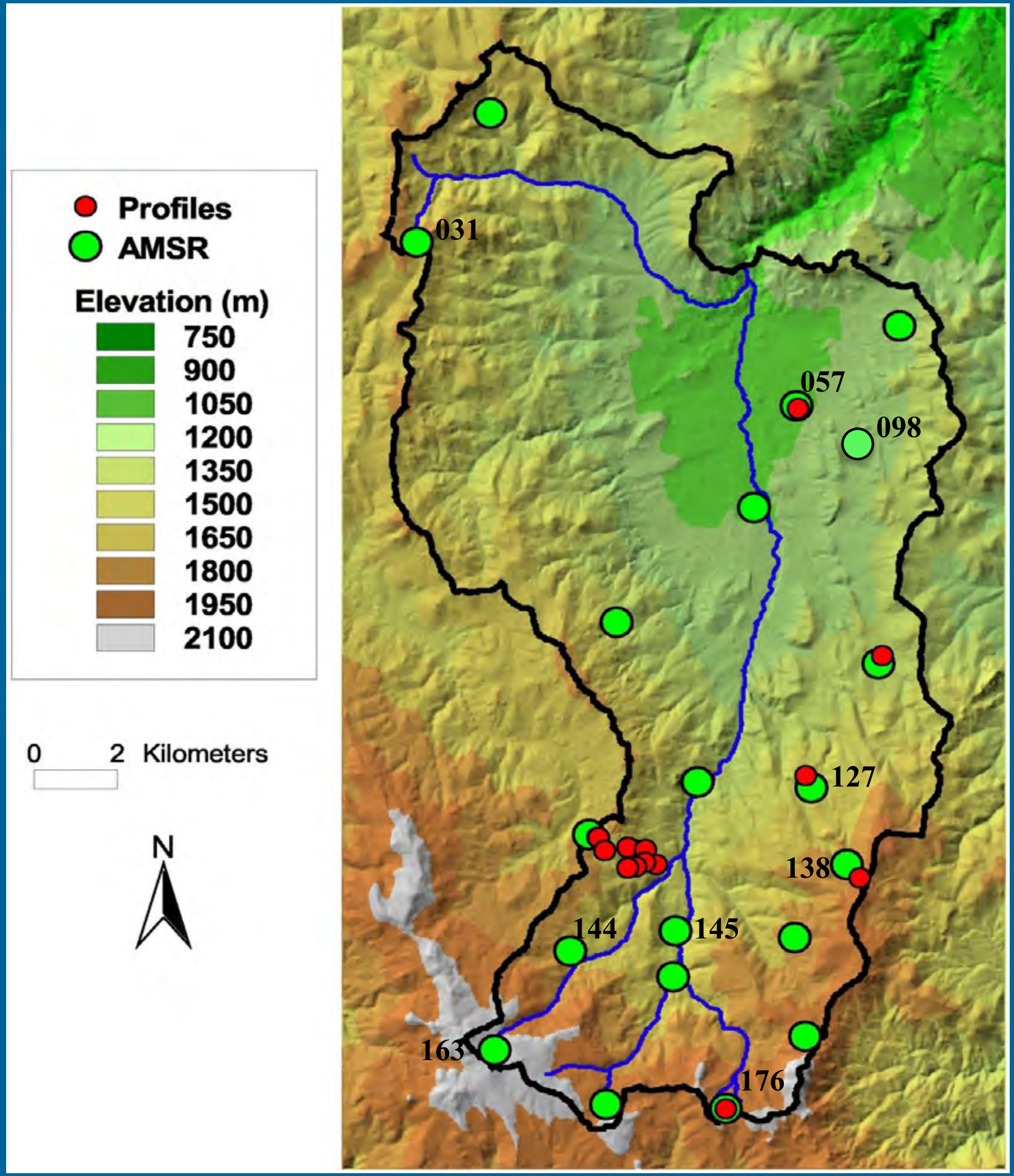
Continuous (hourly) Soil Moisture Measurement Sites, RCEW (2010)

<u>35 sites:</u>

20 Near-Surface (5cm)

15 Profile (5 – 250cm)

22 NP tubes (200cm)



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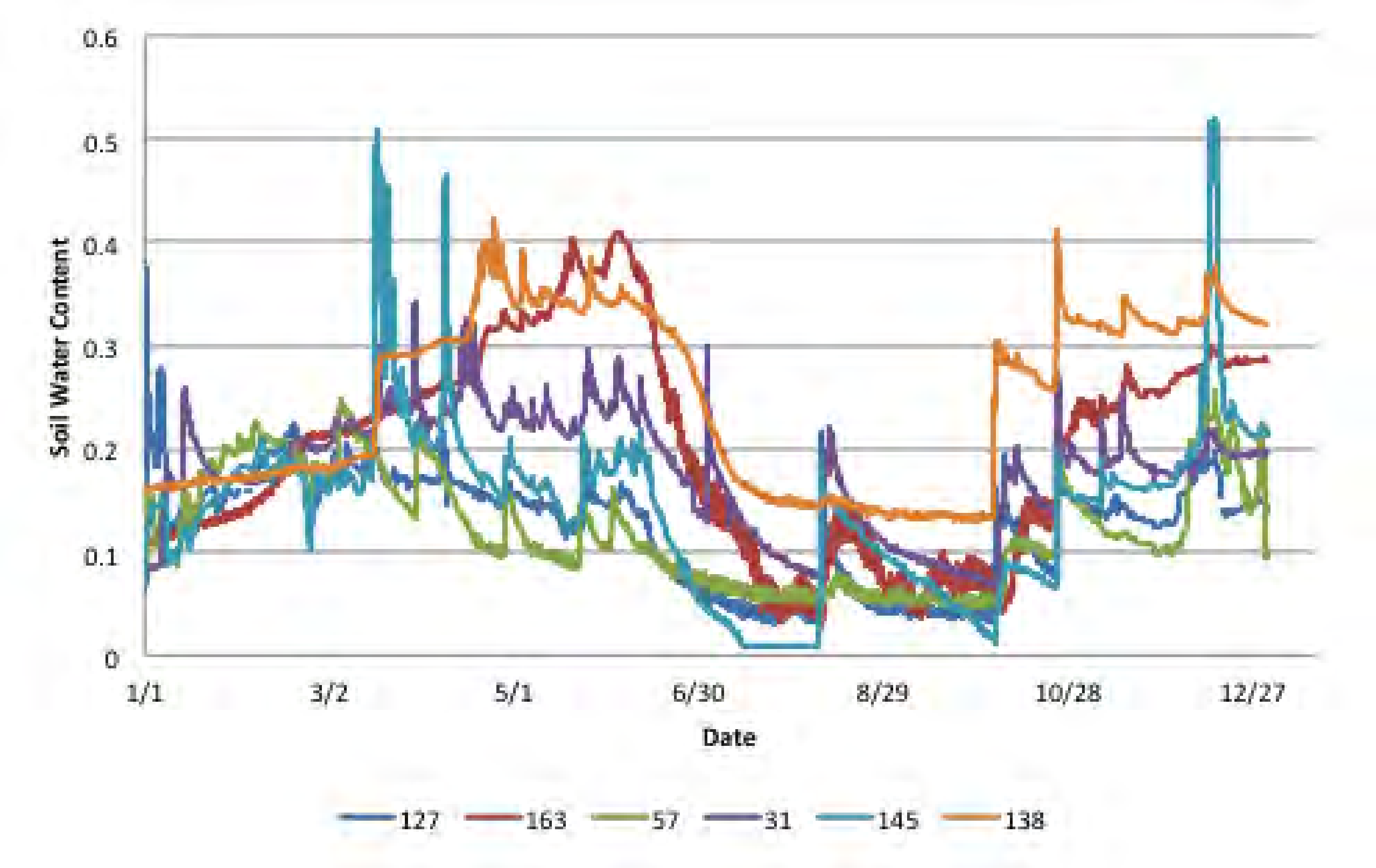
Near Surface Soil Moisture Dynamics Across 1000m of Elevation (CY2010)

Site: Elev:
057: 1188m
145: 1591m
127: 1652m
031: 1794m
144: 1815m
138: 1902m
163: 2170m



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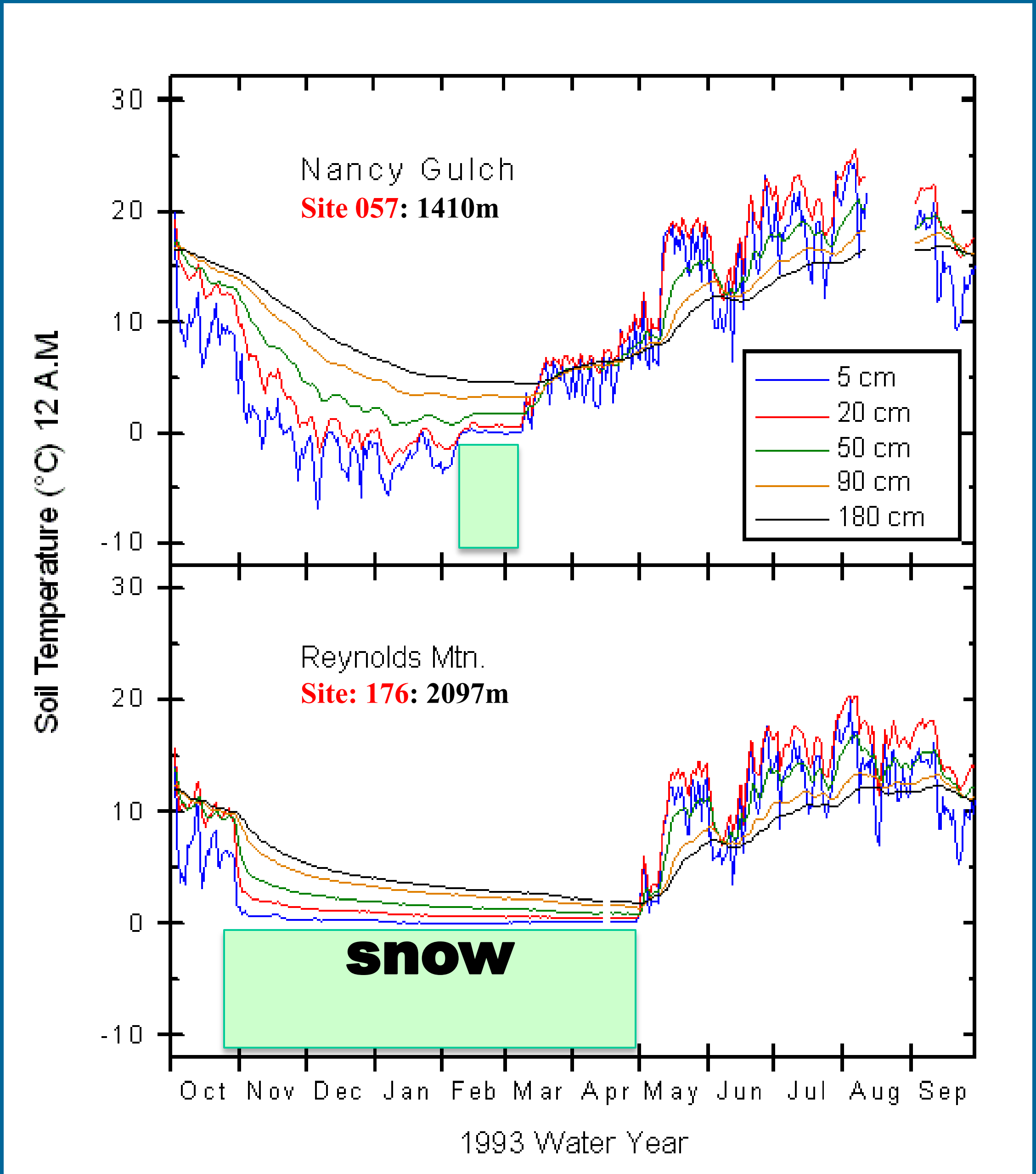
Soil Temperature Dynamics at two sites, WY1993



Comparison of soil temperature dynamics at Nancy Gulch (Site 057, 1410m) and Reynolds Mountain(Site 176, 2097m) during 1993.

Snowcover Duration:

Site 057: 31 days

Site 176: 183 days

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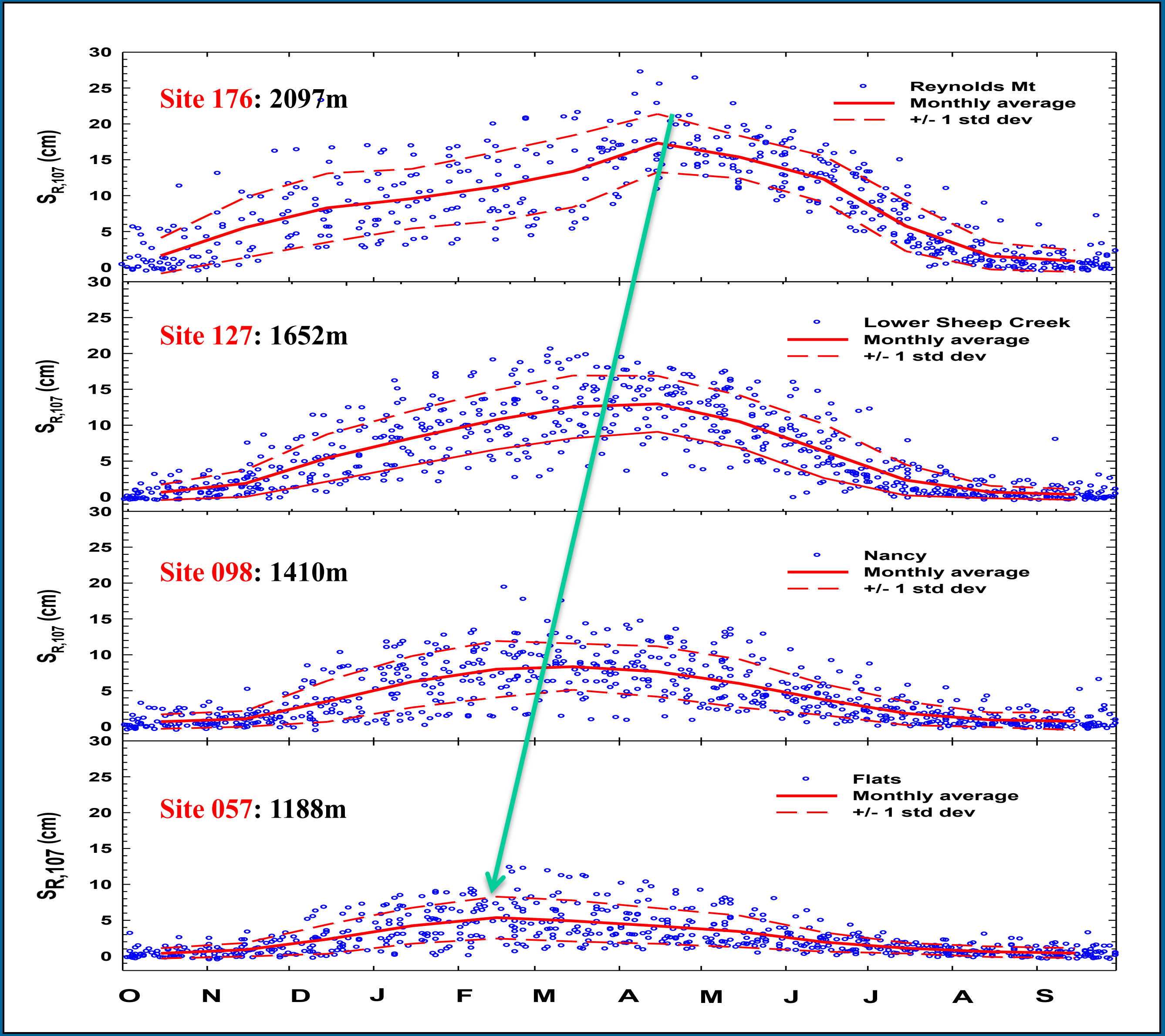
31 years (1978 – 2009) of Monthly NP Soil Moisture Measurements

- Soil H_2O increases with elevation;
- 3 month shift in peak soil H2O;
- Dominated by precipitation (snow vs. rain);



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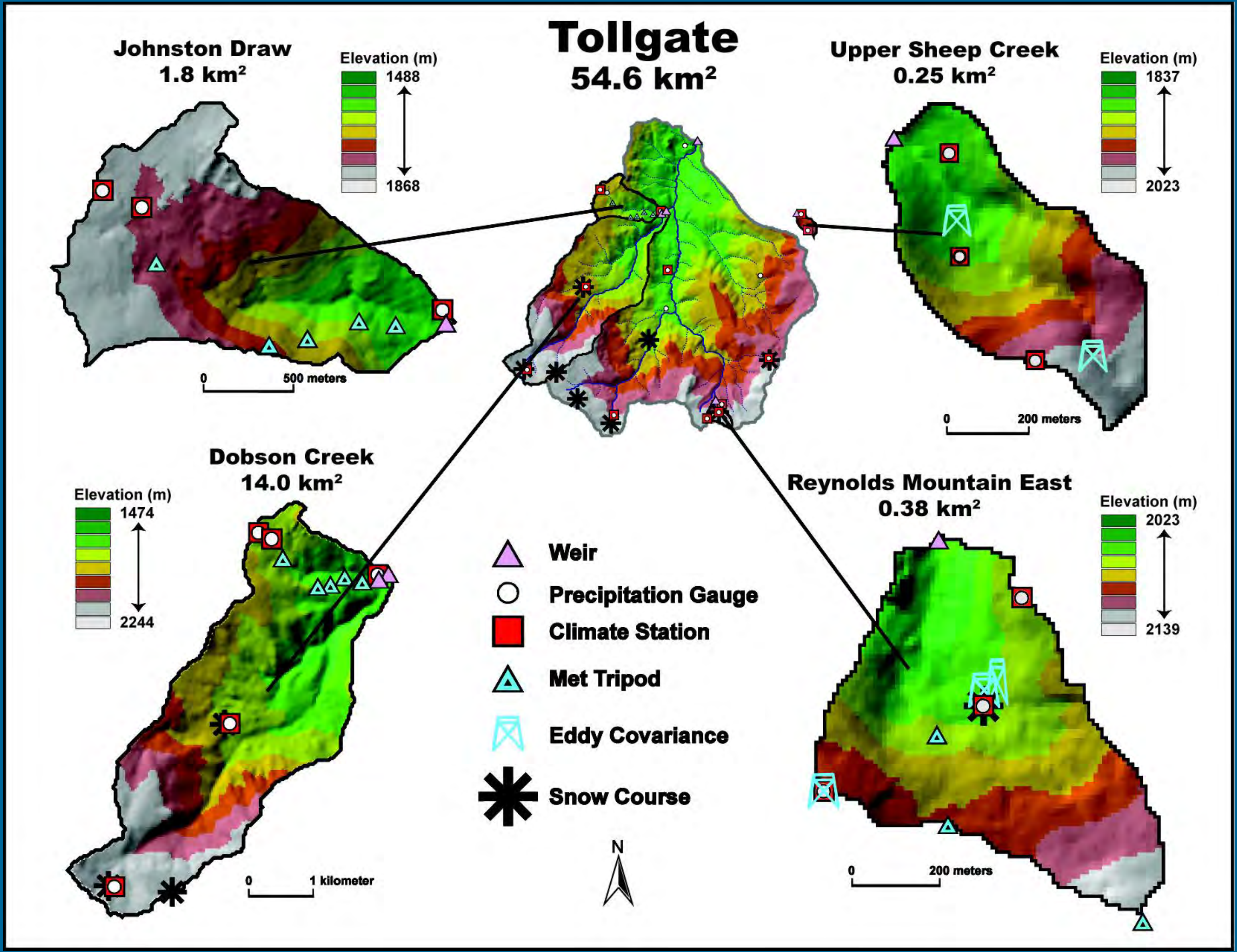
If we can do all this, then this is possible:

Dobson Creek (14 km^2)

889m relief
2 Precipitation - climate sites,
10m DEM, LiDAR veg map

Simulation Area: (67 km^2)

Scaling up to Tollgate



Distributed Snow Accumulation: 2006WY

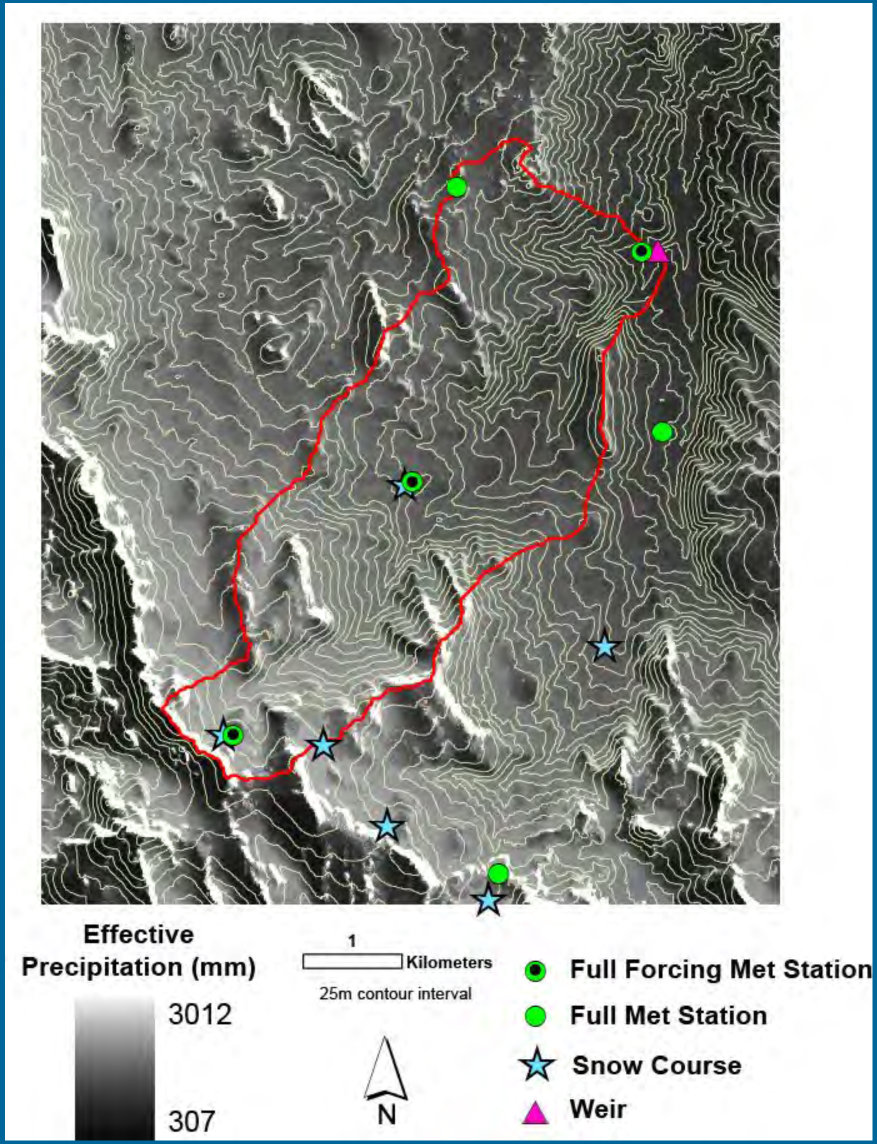
Dobson Creek Watershed

Simulation:

10m² Grid Cells

893 x 747 pixels

(67 km²)



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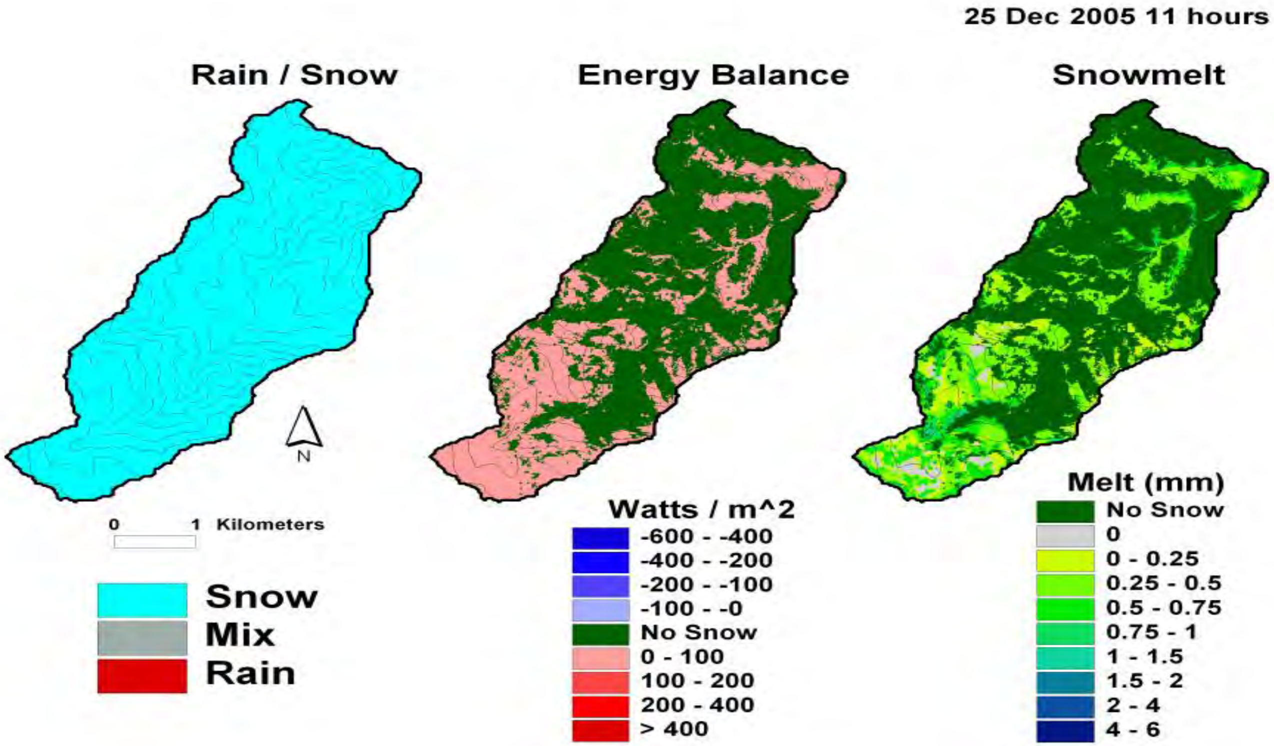

RCEW: Dobson Creek ($14.0\ km^2$)

1474 – 2244m: 770 m relief

7-day Mixed Rain/Snow Event: 12/25 – 31/2005

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Computationally Achievable:

10m DEM, 60 km^2: 600,000 cells

30m DEM, 600 km^2: 670,000 cells

100m DEM, 6,000 km^2: 600,000 cells

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