Hydrologic Research at Reynolds Creek:

The southernmost node of the IP3 network

Dr. Timothy E. Link: University of Idaho
Dr. Danny Marks: Northwest Watershed Research Center
And many others…

University of Idaho

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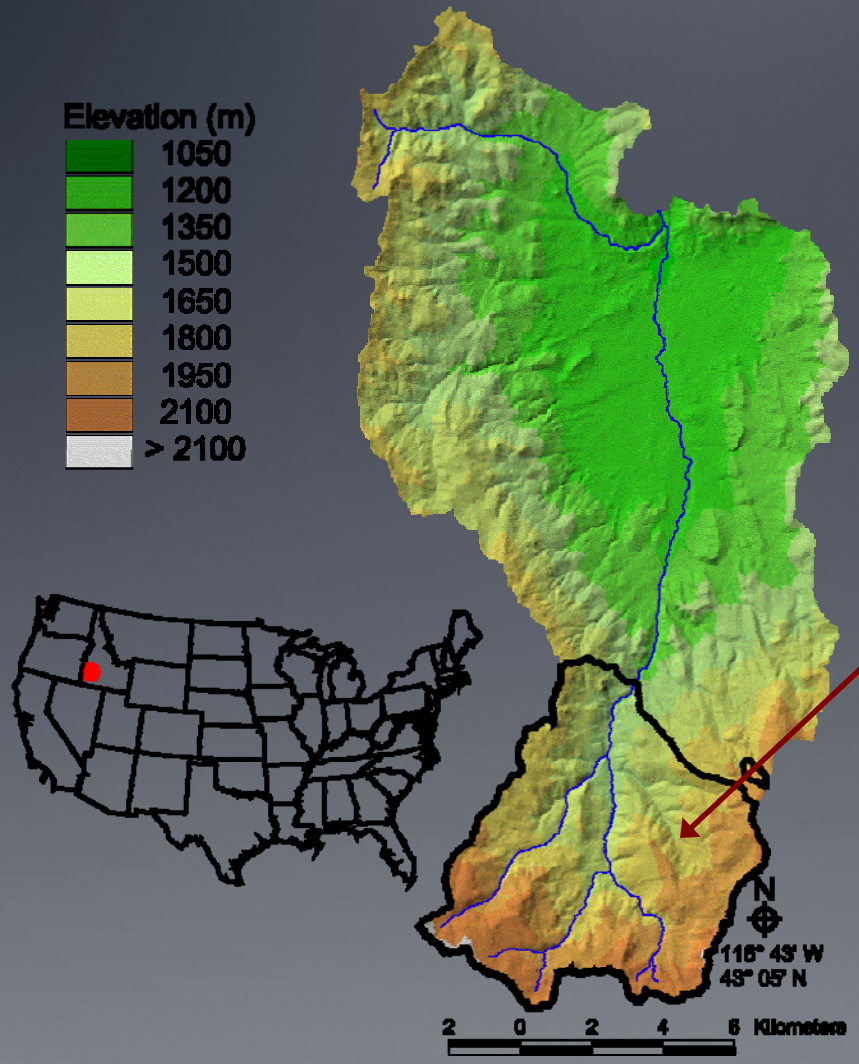
IP3 Scope and Focus:

- Understanding key climate system processes relating to:
  - Land surface, regional climate, cryosphere
- Parameterizing land surface processes relevant to coupled atmospheric-hydrological systems in cold regions
- Validating and improving models for weather and climate systems -
  - Better prediction of climate and weather impacts on water resources in cold climates

Presentation Overview

- Reynolds Creek Infrastructure
- Summary of Active Research
  - Long-term climate and flow trends
  - Long-term water balance
  - Snow distribution
  - Snowcover energetics
    - Turbulent fluxes over snow
    - Vegetation-snowcover interactions
- Future Directions

Reynolds Creek Experimental Watershed



Tollgate Basin
Area: 54.6 km²
Elev: 1410 - 2241 m
831 m relief

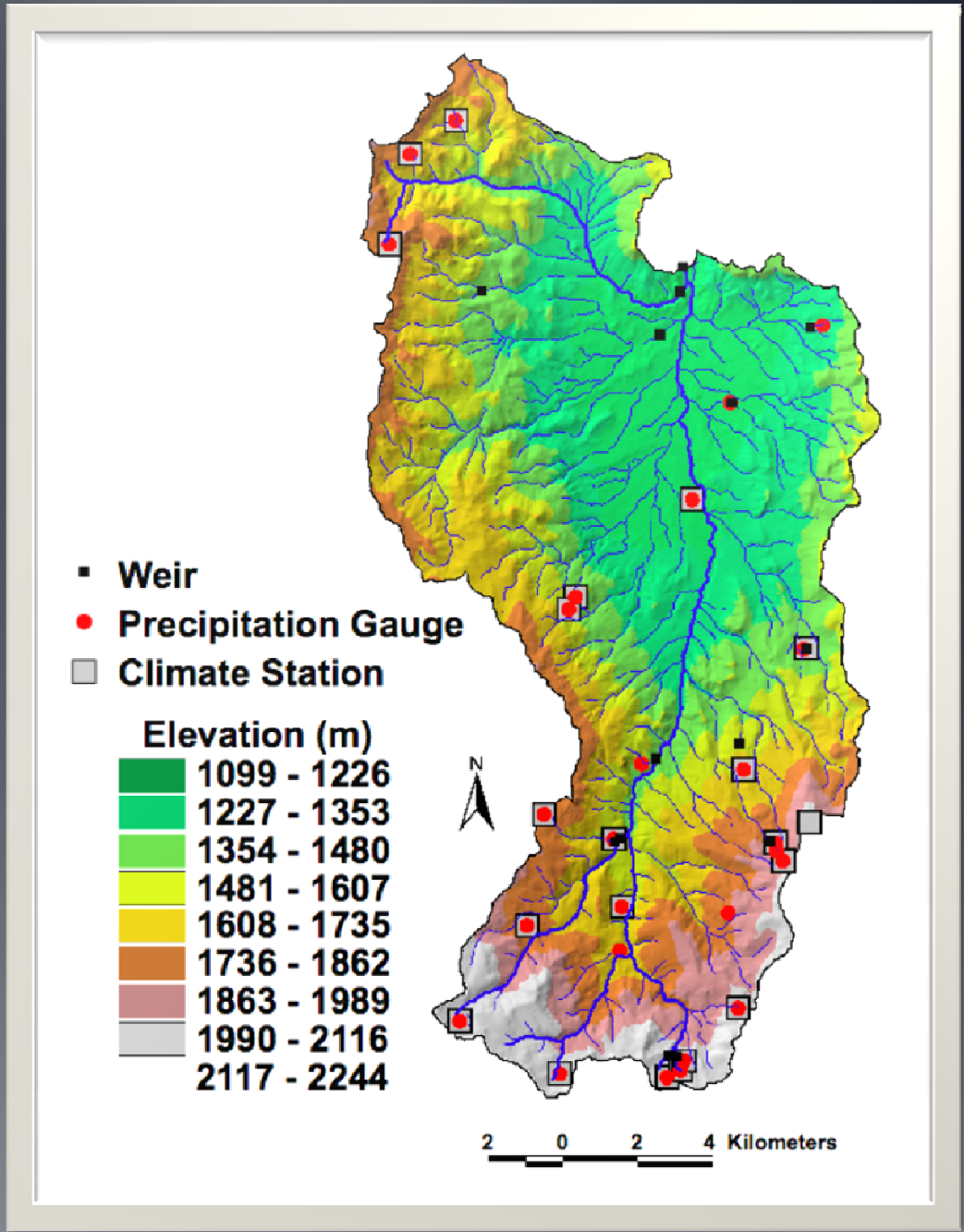
RCEW (239 km²):

- 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:

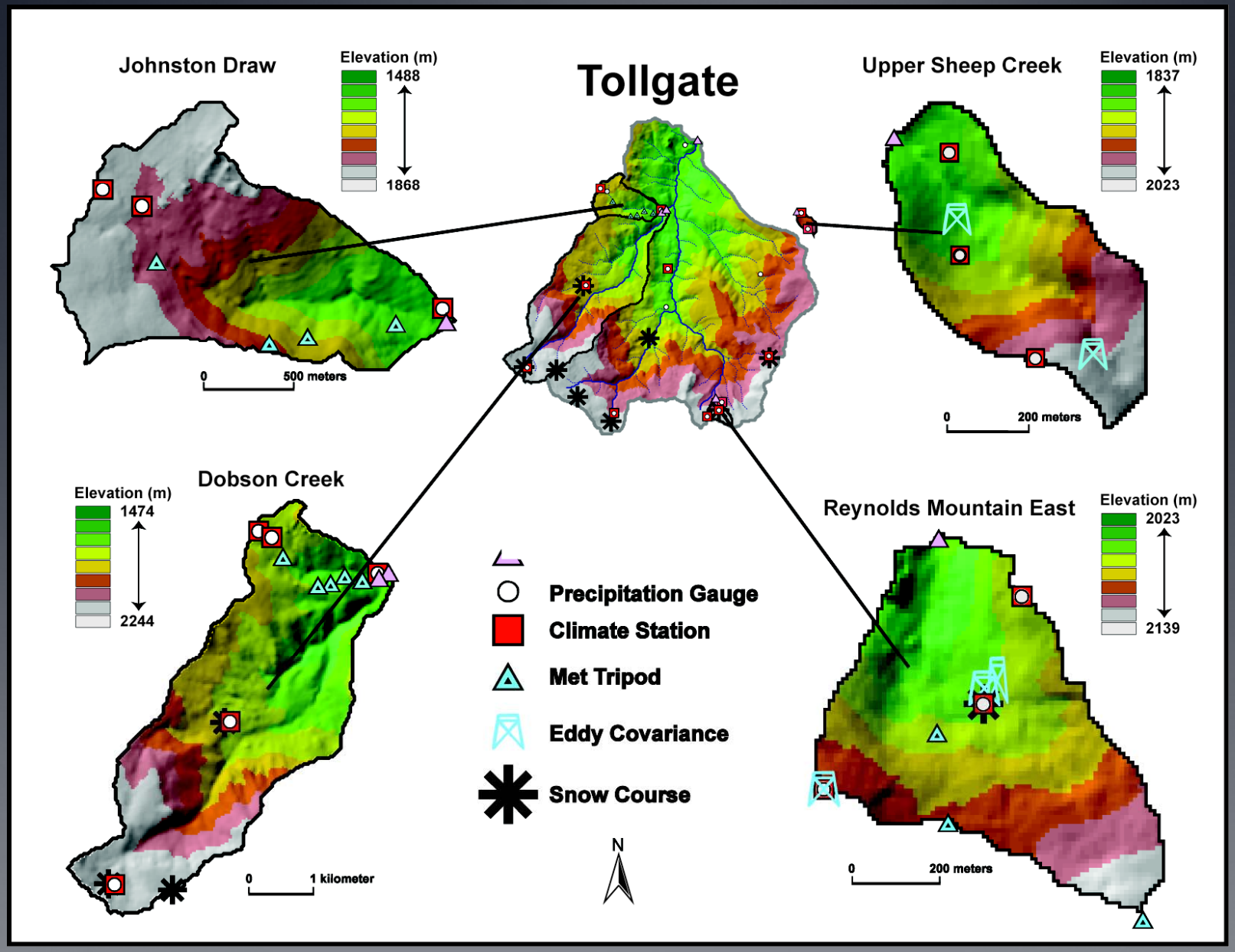
USC (0.25 km², 186m relief) ephemeral, groundwater dominated, annual precipitation 300-500mm

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

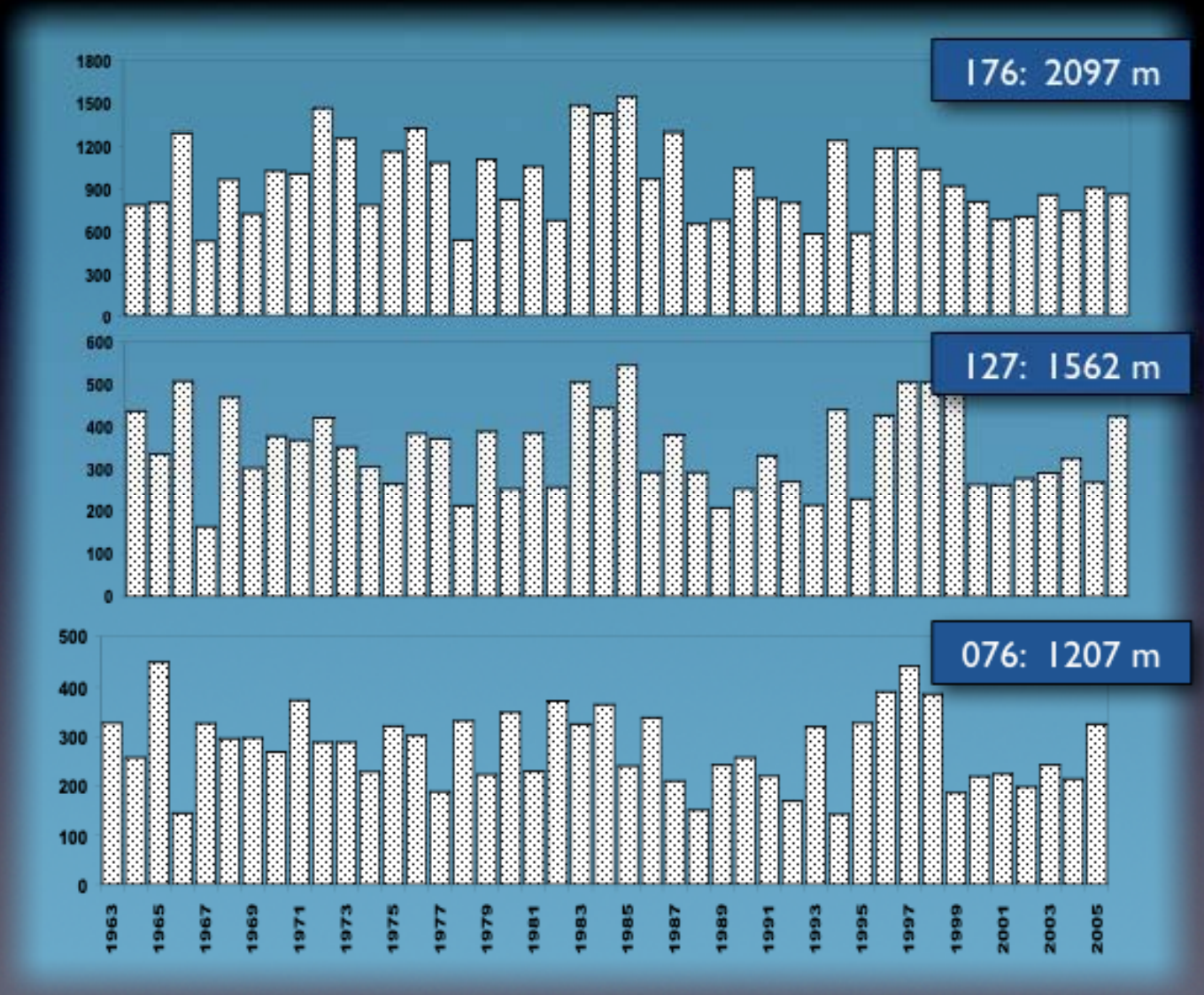
Johnston Draw (1.8 km², 380m relief) ephemeral, rain-snow boundary, annual precipitation 400-800mm



Tollgate Subwatersheds



Annual Precipitation (mm)

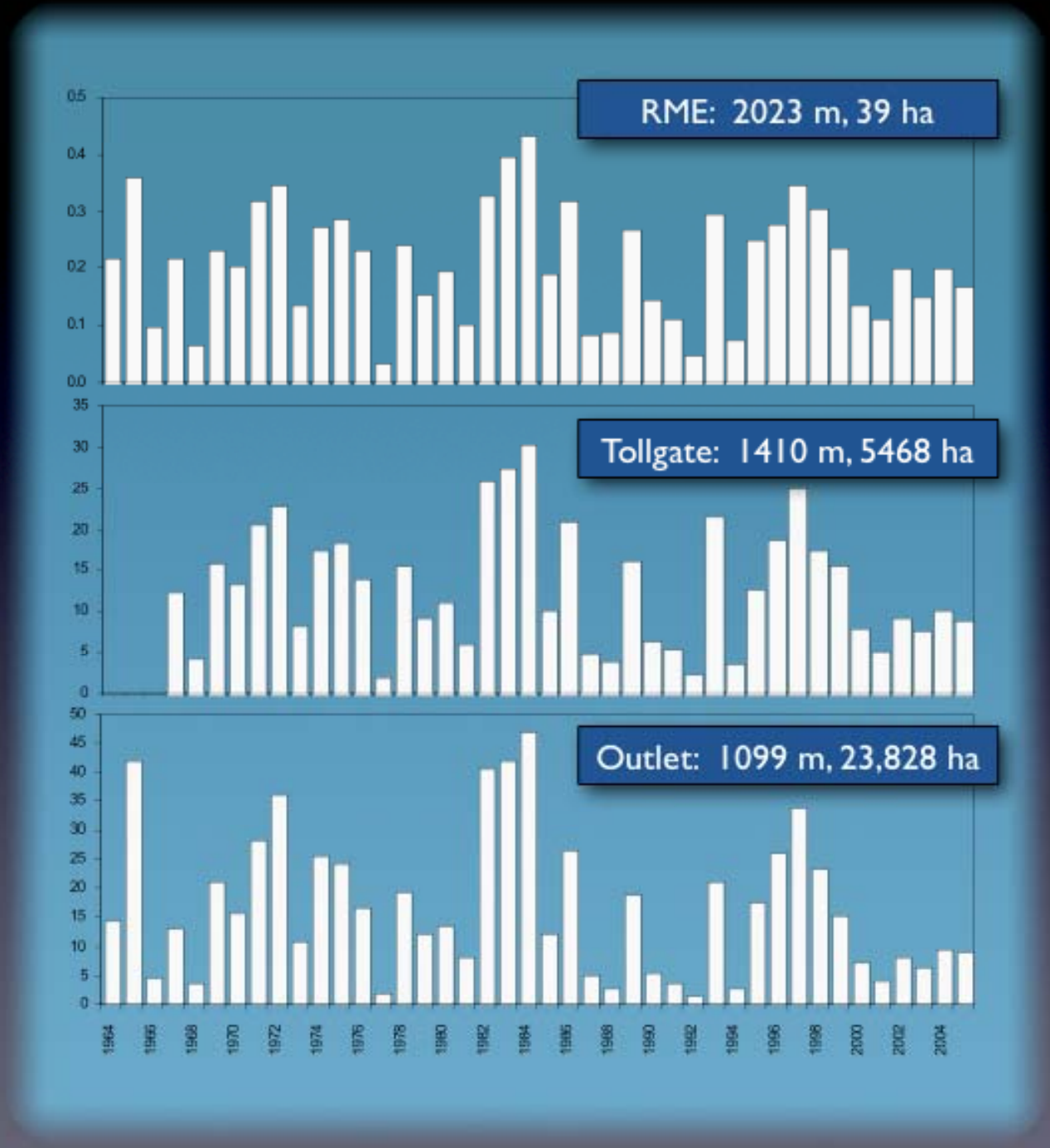


No significant trend

Courtesy of
Dr. Danny Marks (ARS)
& Anurag Nayak (USU)

Annual Stream Discharge (km^3)

No significant trend



Courtesy of
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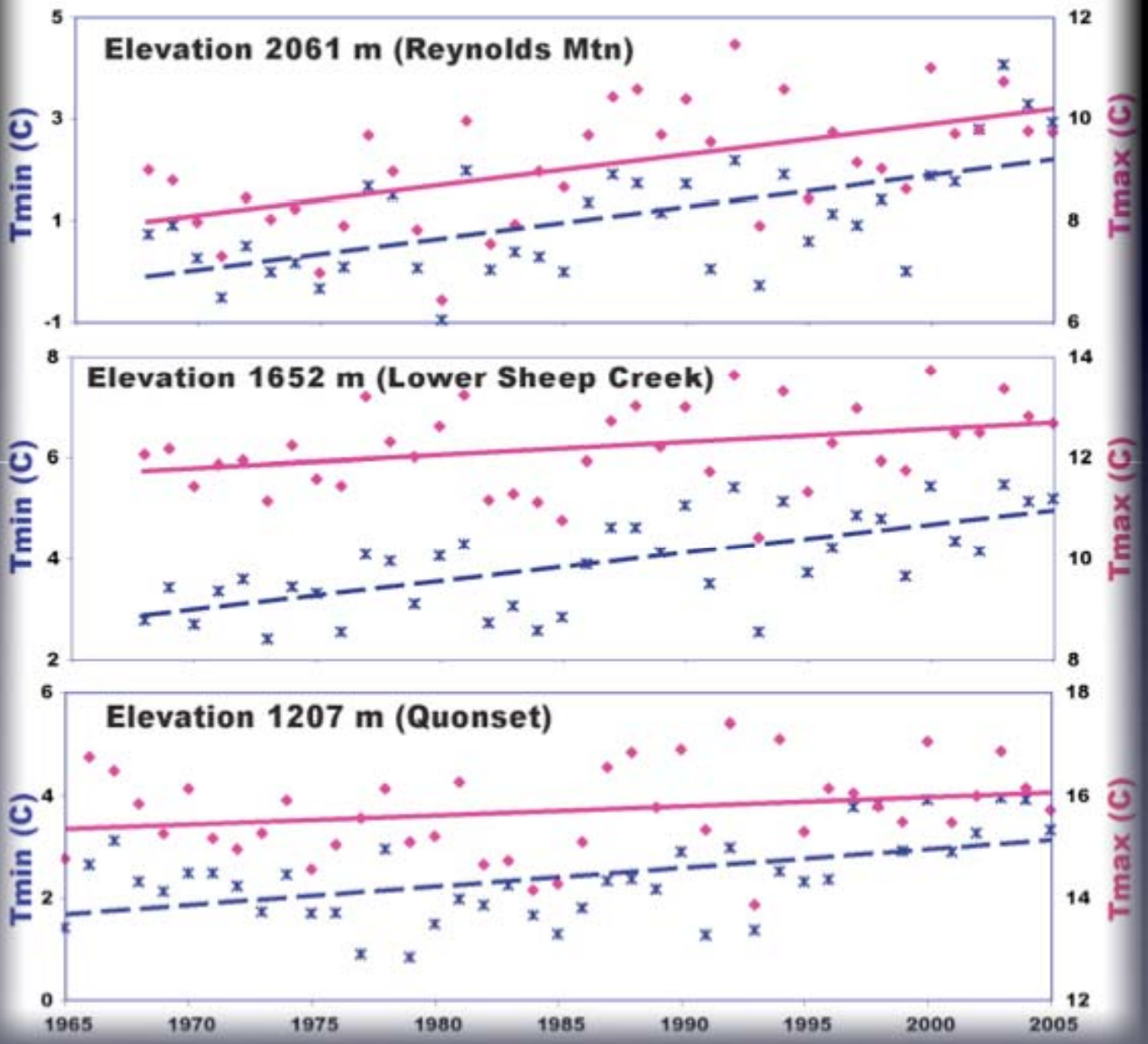
& Anurag Nayak (USU)

Annual Temperature 1965-2005
Reynolds Creek Experimental Watershed



+ 2.4 °C

+ 2.5 °C

+ 0.9 °C

+ 2.7 °C

+ 0.9 °C

+ 1.4 °C

Courtesy of
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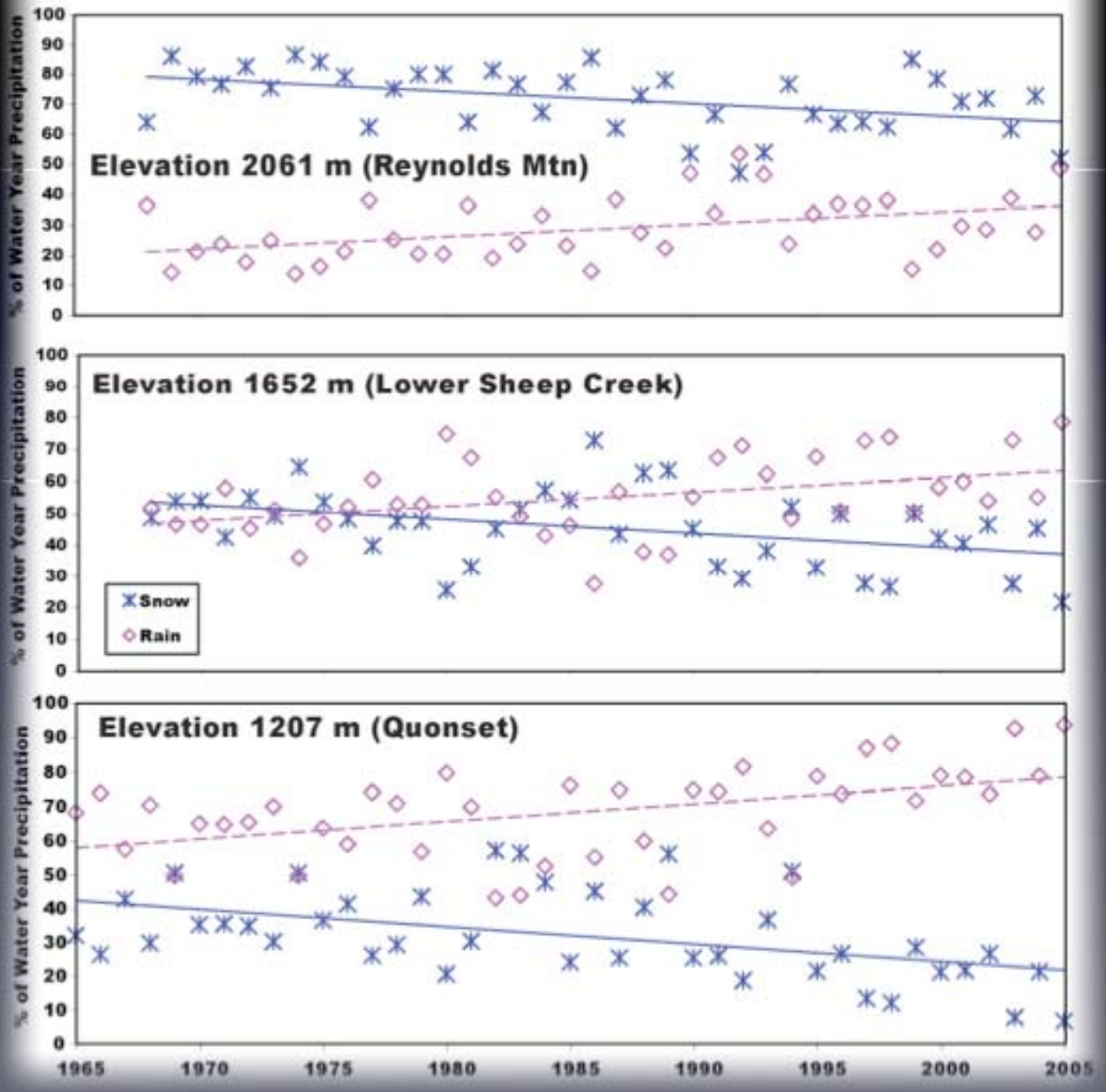
& Anurag Nayak (USU)

Precipitation Type - Rain vs. Snow 1965-2005
Reynolds Creek Experimental Watershed



Still Snow Dominated

Now Rain Dominated

Rarely Snows

Courtesy of
Dr. Danny Marks (ARS)
& Anurag Nayak (USU)

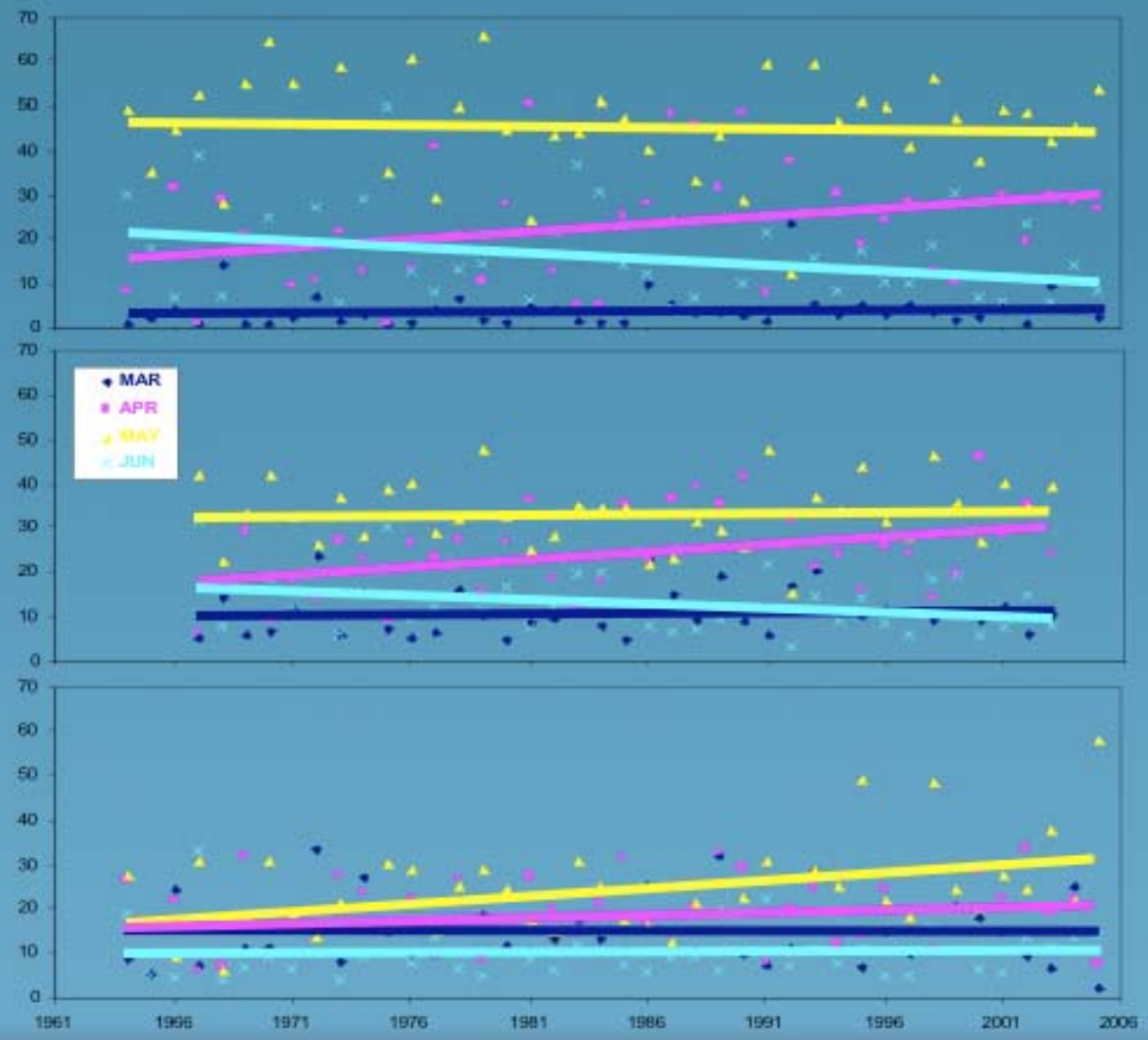
Annual Discharge Fraction by Month

Headwater Catchment:
March +3%
April +14%
May -------
June -13% (95%)

Mid-Elevation Drainage:
March +1%
April +12% (95%)
May +1%
June -8%

Basin Outlet:
March -------
April +4%
May +12% (95%)
June -2%

Courtesy of
Dr. Danny Marks (ARS)
& Anurag Nayak (USU)



Monthly Flow Changes

Reynolds Creek Experimental Watershed (1963-2005)

* denotes statistical significance at the 95% level

How will mountain hydrology and water resources be affected?

- Humidity has increased
- More rain makes the distribution of snow more uniform, causing earlier melt, reduced peak SWE & streamflow
- If snow is limited to higher elevations
  - Reduced area (volume)
  - "flashier", less reliable spring freshet
- less growing season H_2O, increased ecosystem stress

Upper Sheep Creek

0.25 km², 186m relief

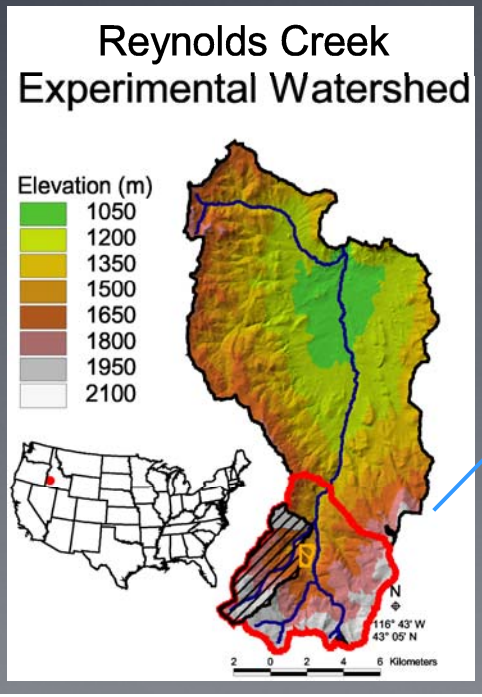
Fire planned for 2008

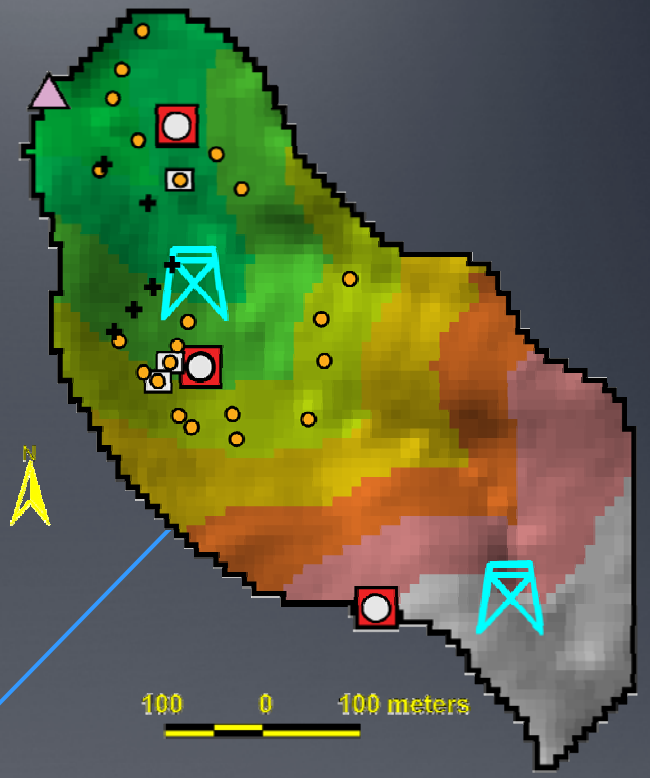
Intensive Snow Surveys

- 1984 – 1994
- 2004 – 2008

- 10 & 23 year Water Balance Reconstruction

- Excellent Basin for Testing Distribution Algorithms Developed at RME





Elevation (m)
1839 - 1857
1858 - 1878
1879 - 1899
1900 - 1919
1920 - 1940
1941 - 1961
1962 - 1981
1982 - 2002
2003 - 2017

Well
Soil Profile: Periodic
Soil Profile: Continuous
Weir
Precipitation Gauge
Climate Station
EC Tower

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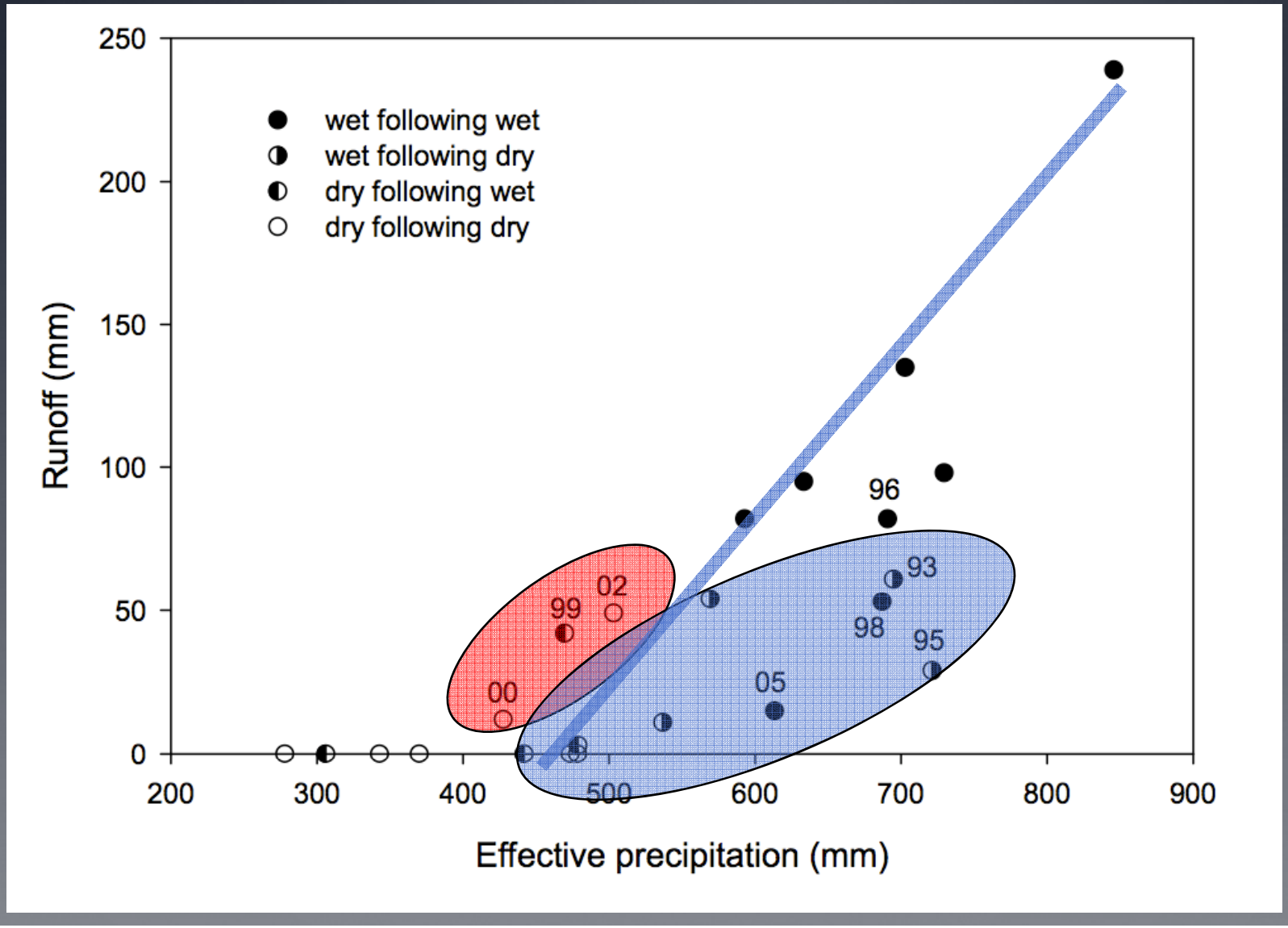
Upper Sheep Creek

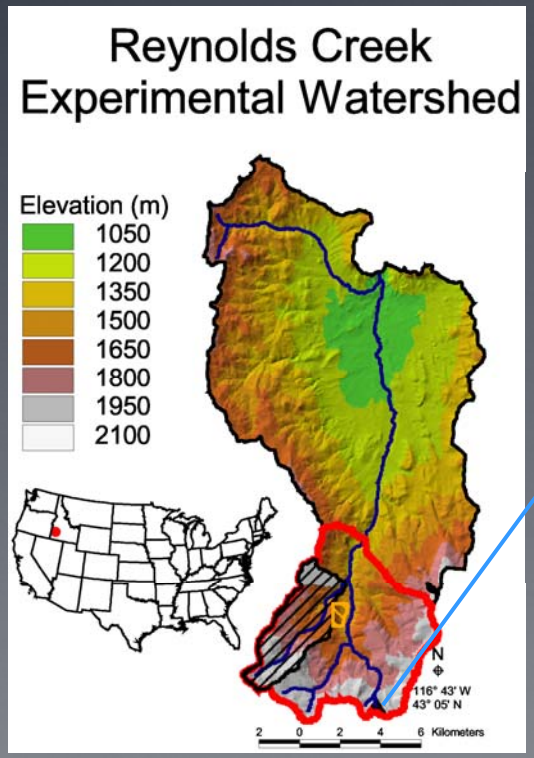
23-Year Water Balance

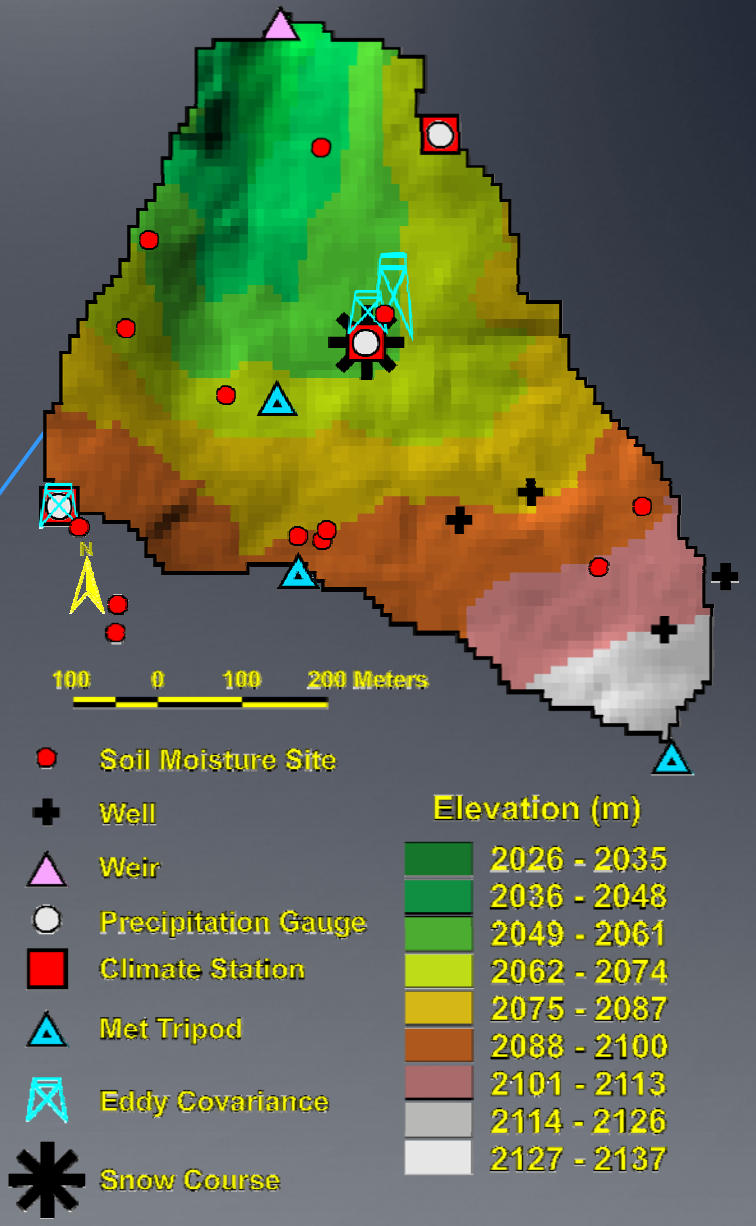


Reynolds Mountain East:

0.38 km², 118m relief

- Primary Snow Research Basin
- HEAVILY! Instrumented
- Intensive Snow Surveys Since 2001





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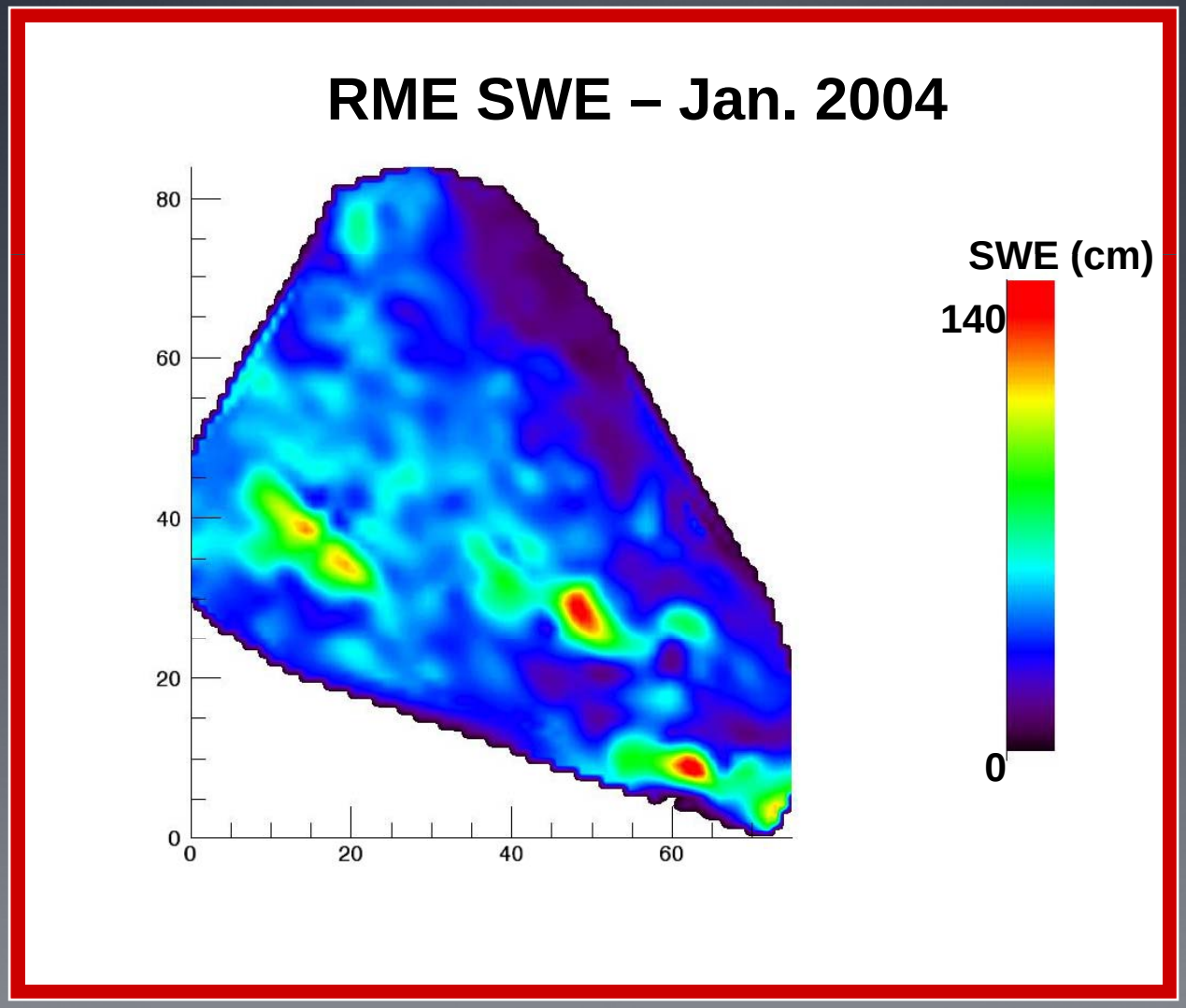
Detailed Snow Surveys

- Since 2003
- 2-3 times annually
- 30 m depth grid + 10 m random offset
- 100 m SWE grid

Measured Snow Distribution

30m + 10m grid



The Ridge Site

The Sheltered Site

Canopy gradient

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

Canopy gradient

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

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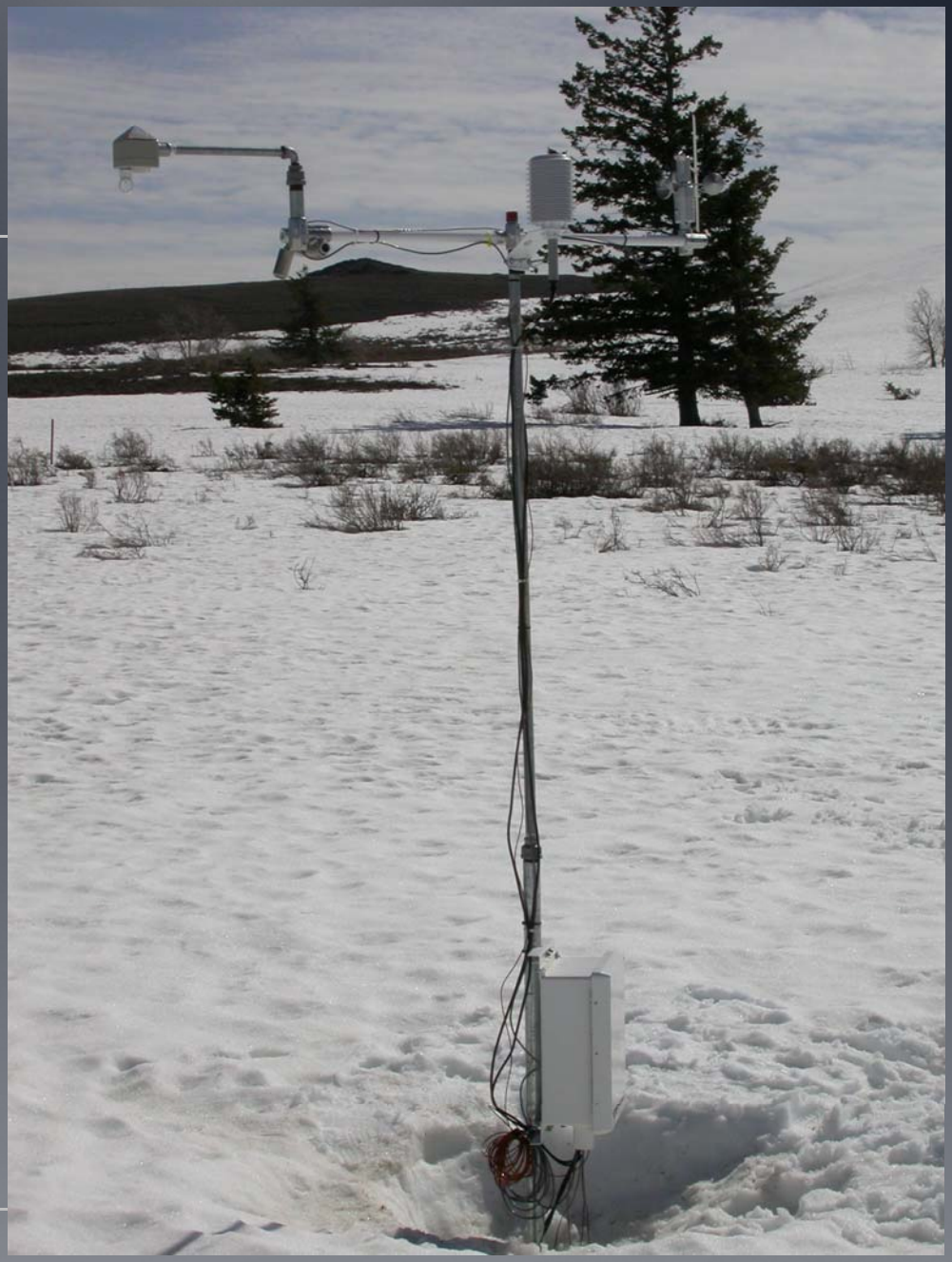
Canopy gradient

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



Canopy gradient

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  - Low sagebrush
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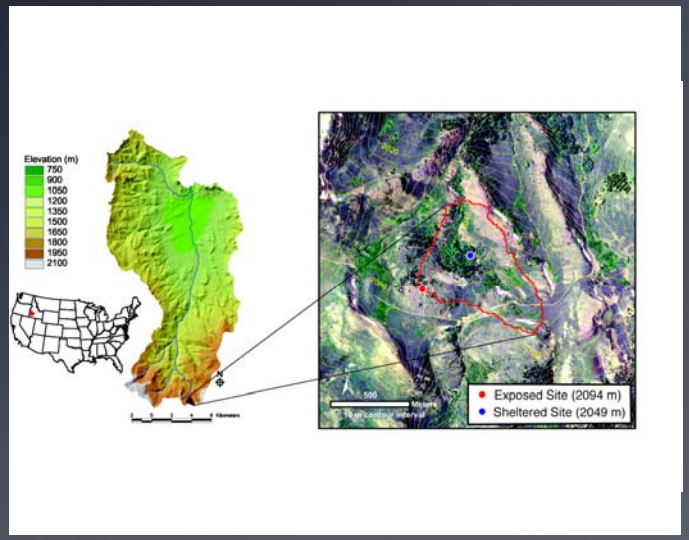
  - Shrubs
  - Big sagebrush
  - Snowberry
- **Aspen**
  - **Vertical gradient**
- Conifer

Canopy gradient

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

Eddy covariance over snow

Reynolds Creek Experimental Watershed

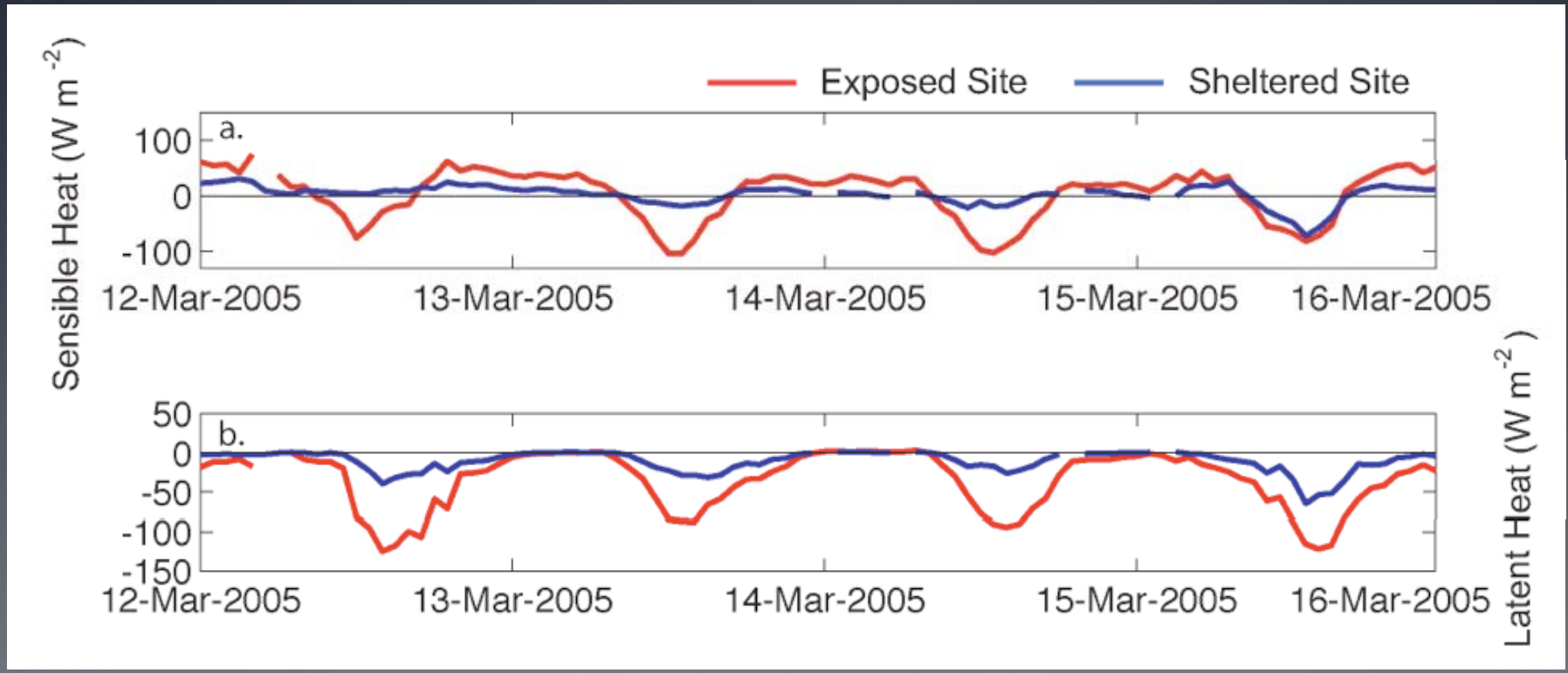


- Difficult & rare to validate turbulent component of snow cover energy balance
- Three snow seasons of 10 Hz EC data
- Two contrasting sites in complex terrain

Mean Air Temperature		Mean Wind Speed	
Exposed	Sheltered	Exposed	Sheltered
-1.9	-1.3	4.9	1.9

EC Results

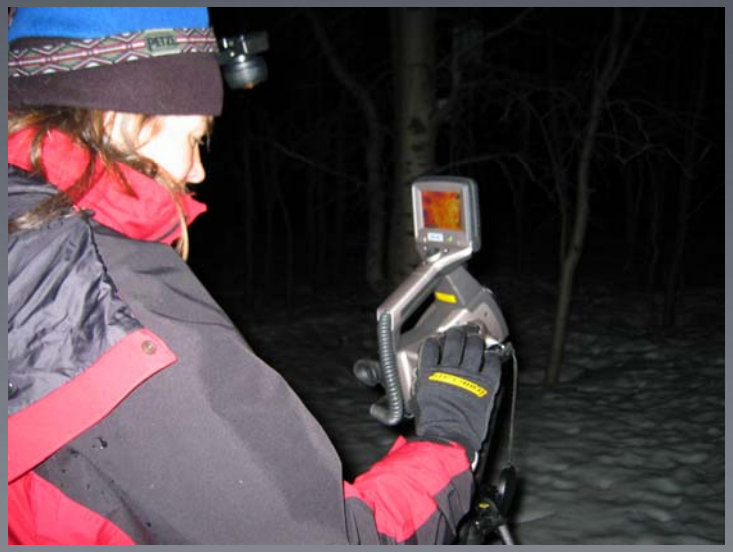
Negative H fluxes ?!



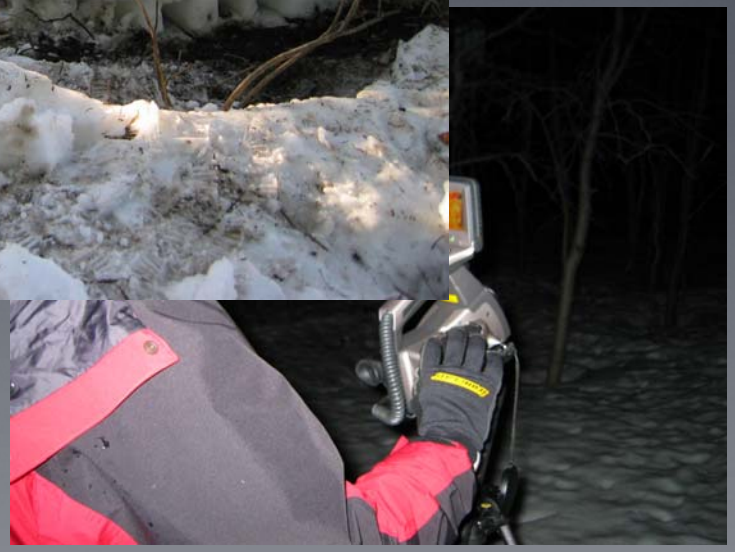
EC over snow findings

- Corrections assessment
  - High Quality data based on stationarity & turbulence
    - 76% of sensible & 95% of latent
- Site differences
  - Sensible: Exposed 2 times magnitude of sheltered
  - Latent: Exposed 5 times magnitude of sheltered
- Simulation parameterization
  - Roughness length: longer at sheltered, variable at exposed
  - Active layer depth
- EC data should be corrected and used with **caution**

Snow-Vegetation Interactions

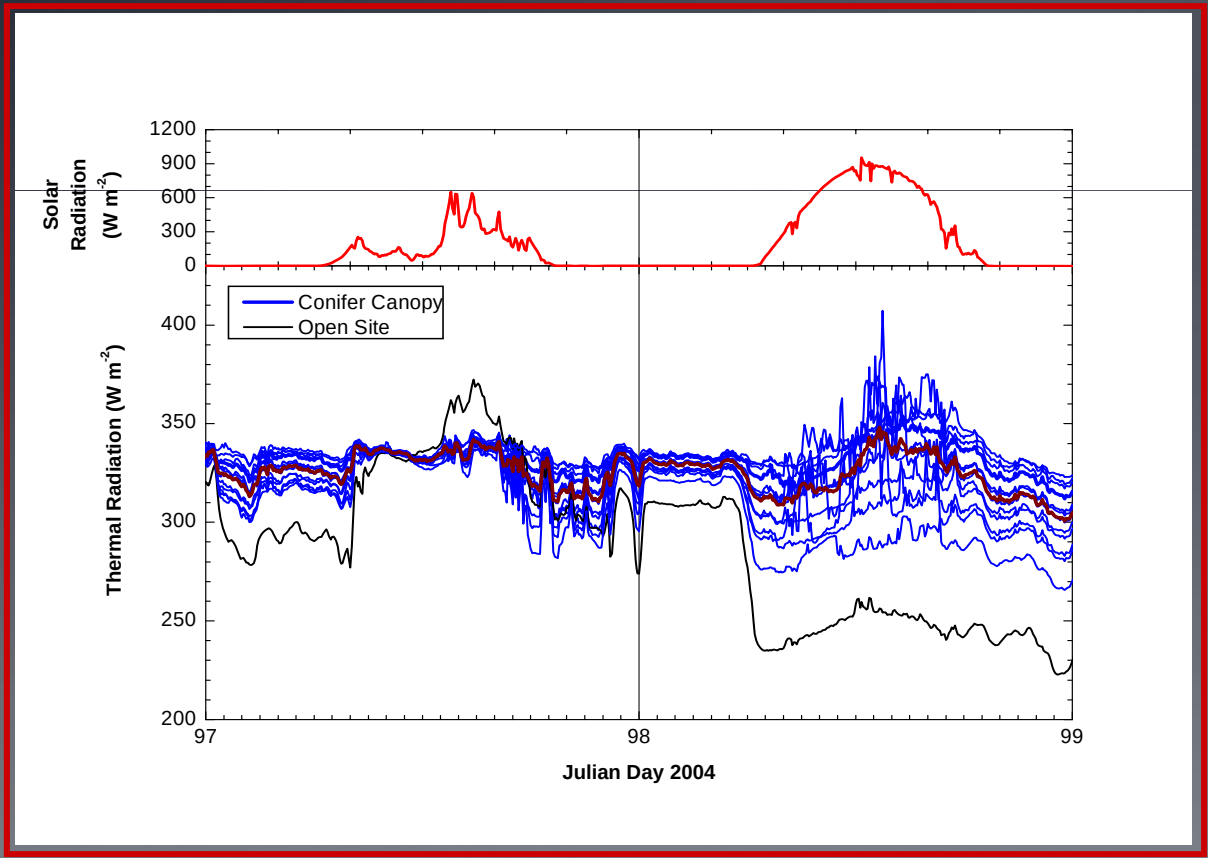


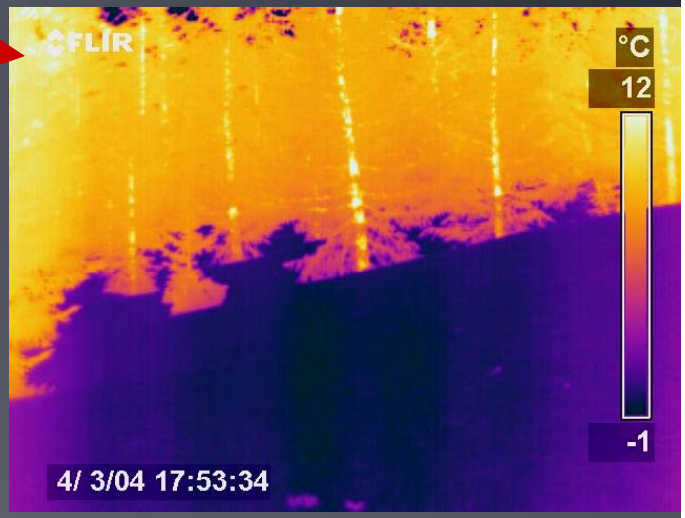
Snow-Vegetation Interactions

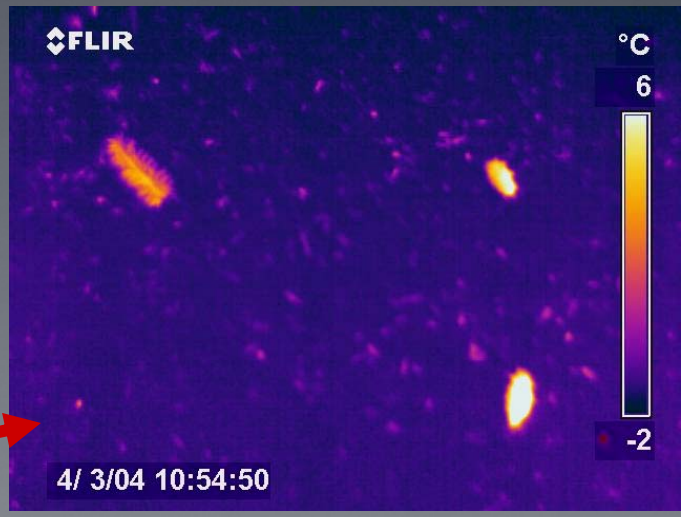


Canopy Radiative Regime

Canopy IR image



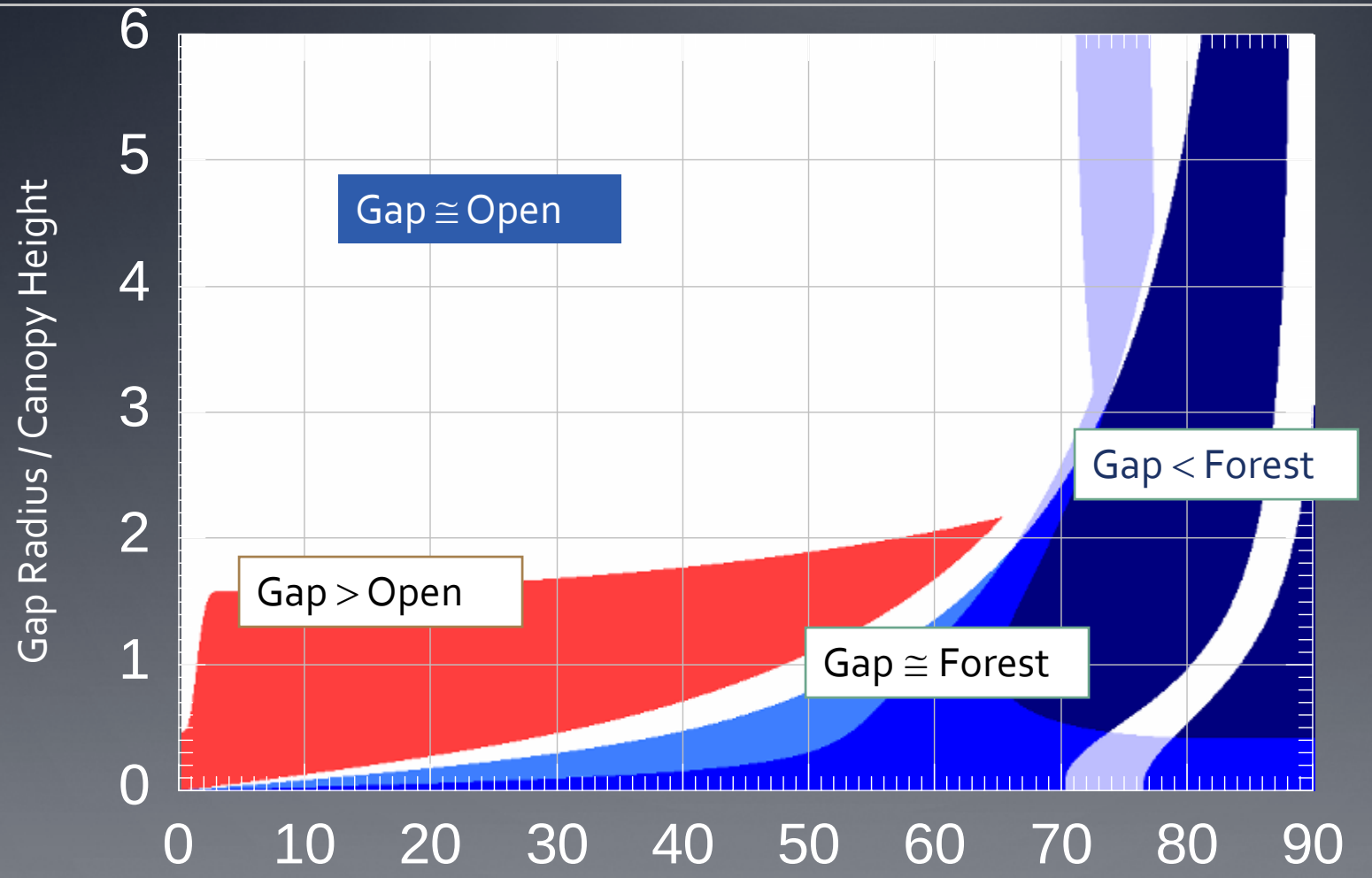


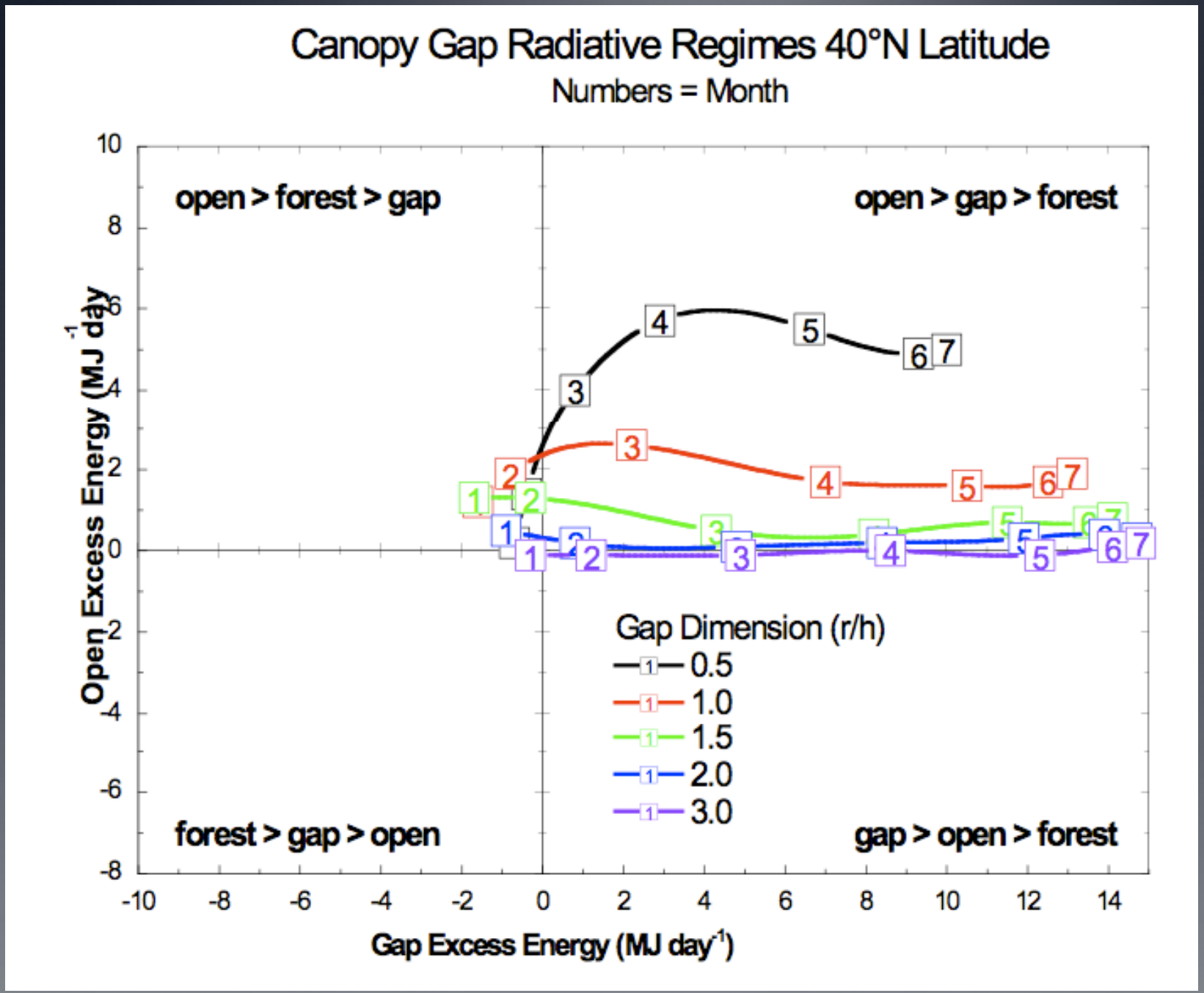


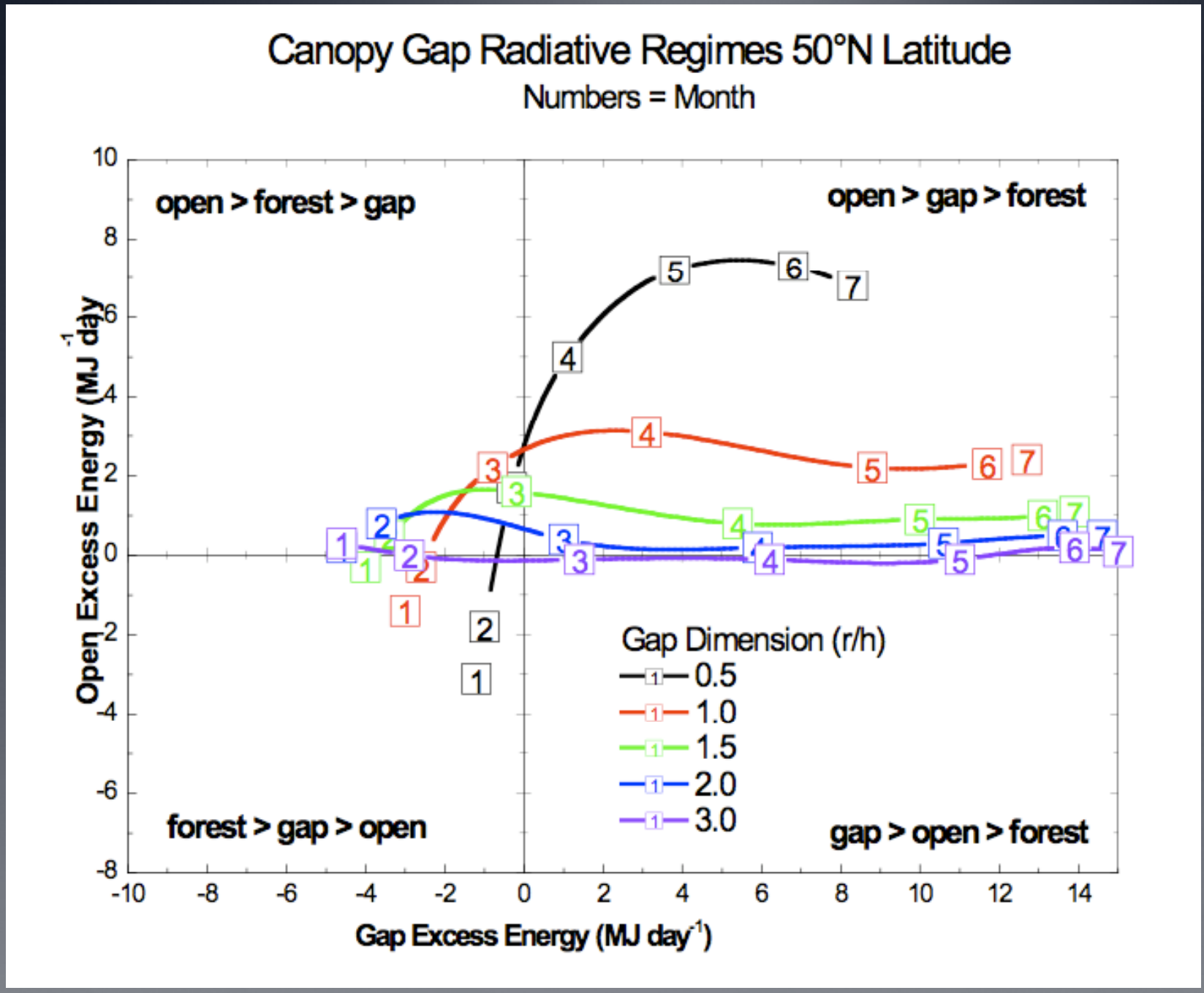
Snow surface debris

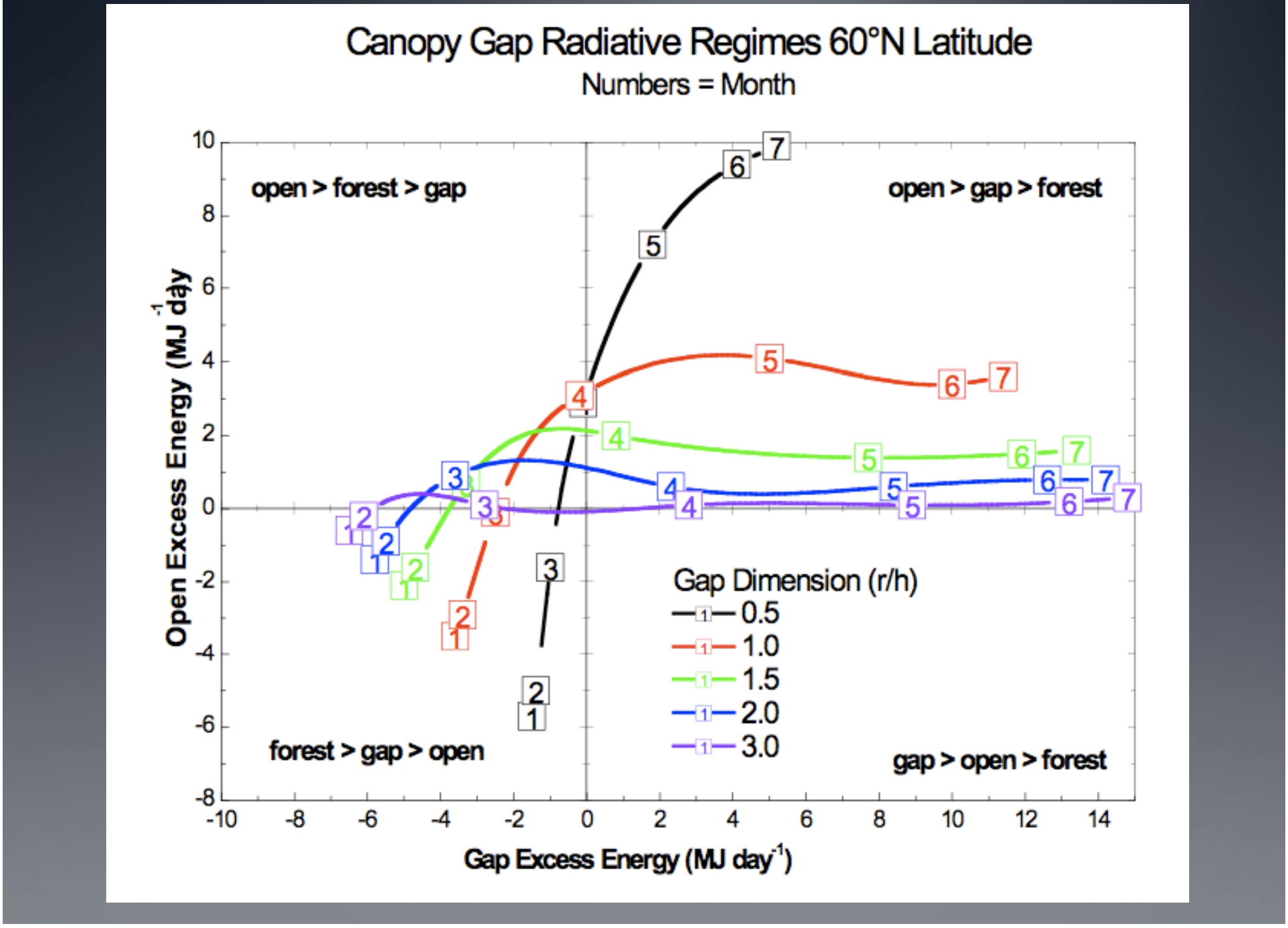
Canopy Gap Radiative Regimes

All-wave Daily Incoming Radiation




Canopy Gap Radiative Regimes 40°N Latitude
Numbers = Month
open > forest > gap
open > gap > forest
forest > gap > open
gap > open > forest
Gap Dimension (r/h)
0.5
1.0
1.5
2.0
3.0
Open Excess Energy (MJ day-1)
Gap Excess Energy (MJ day-1)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14


Canopy Gap Radiative Regimes 50°N Latitude
Numbers = Month
open > forest > gap
open > gap > forest
forest > gap > open
gap > open > forest
Gap Dimension (r/h)
0.5
1.0
1.5
2.0
3.0
Open Excess Energy (MJ day-1)
Gap Excess Energy (MJ day-1)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14


Canopy Gap Radiative Regimes 60°N Latitude
Numbers = Month
open > forest > gap
open > gap > forest
forest > gap > open
gap > open > forest
Gap Dimension (r/h)
0.5
1.0
1.5
2.0
3.0
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10
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6
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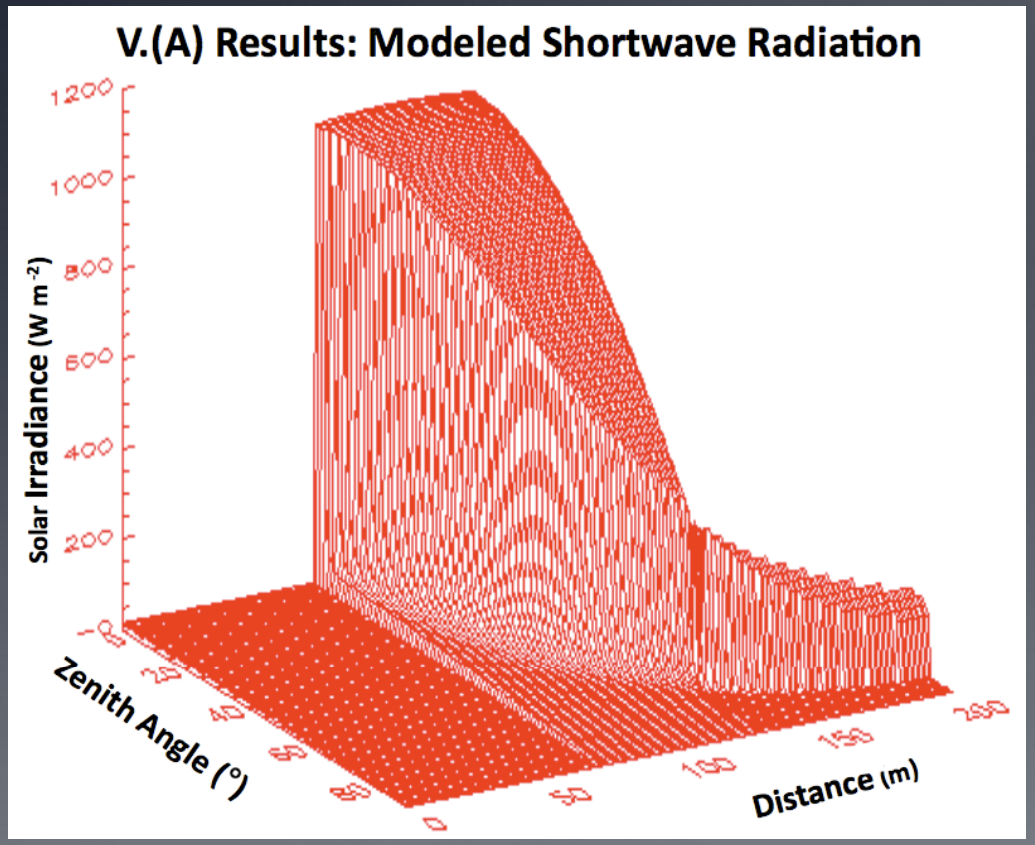
0
-2
-4
-6
-8
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14

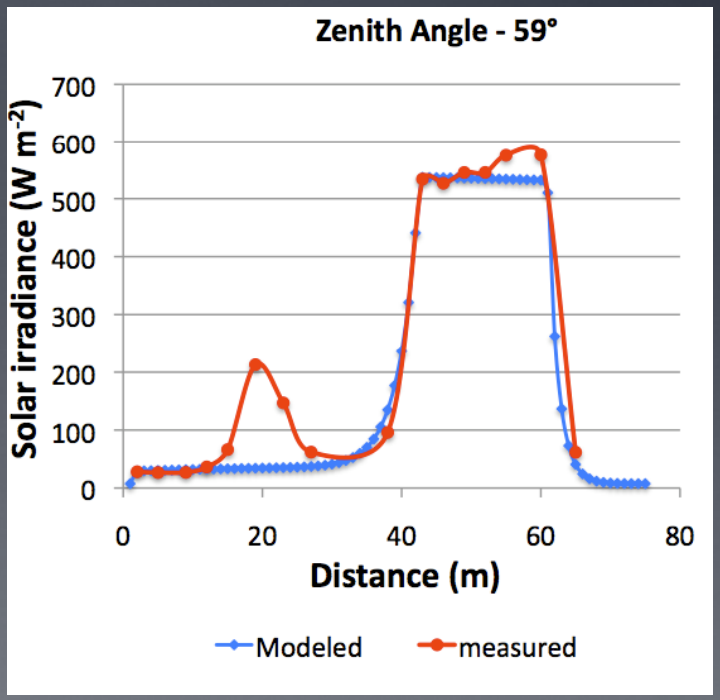
Validation Data

Marmot Cr.

UI Exp. For.

Scaling Up Across Canopy Heterogeneities…

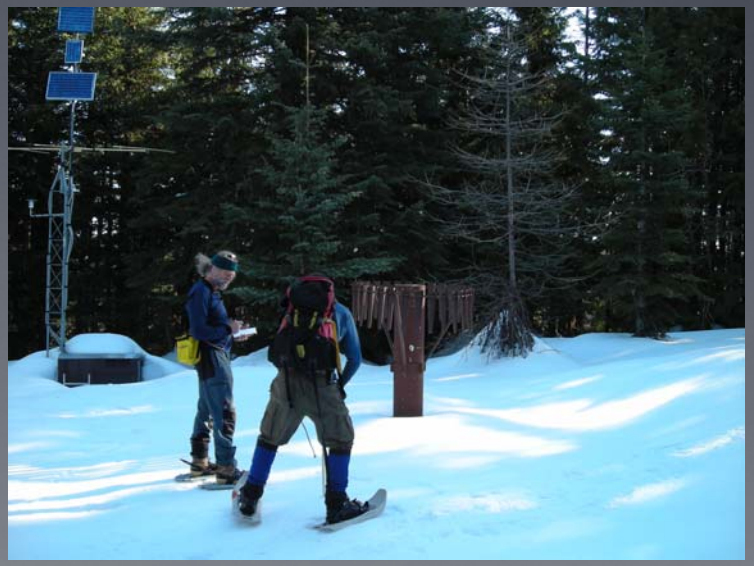




Discontinuous Forest Radiation

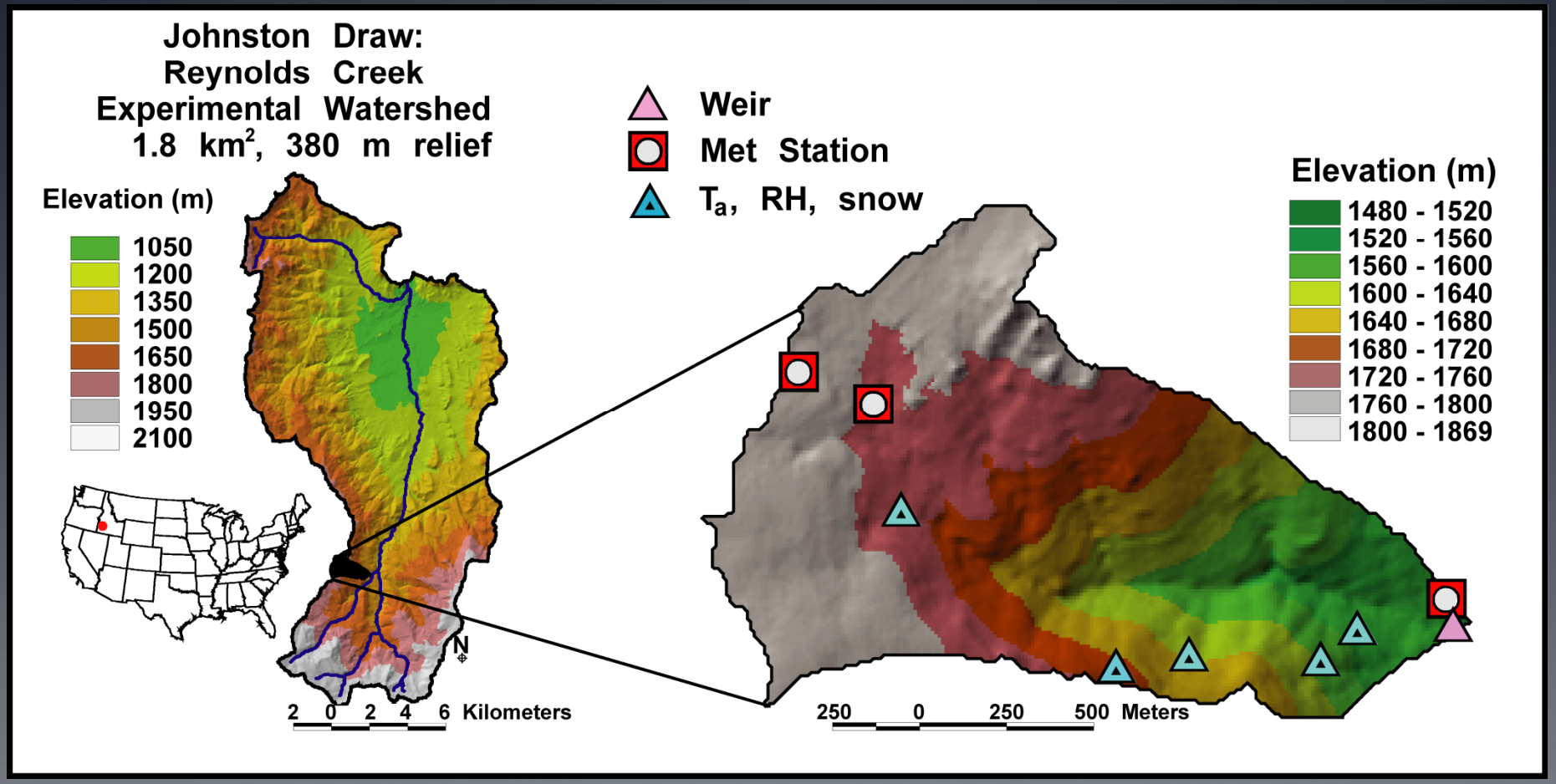
Applications

- Improved snowmelt predictions in tricky forests
  - Semi-arid forests are very discontinuous
- SNOTEL representativeness
  - Most SNOTEL sites are in small gaps
- Precision forest management
  - Flow maintenance
  - Fire hazard risk reduction
  - Fiber production



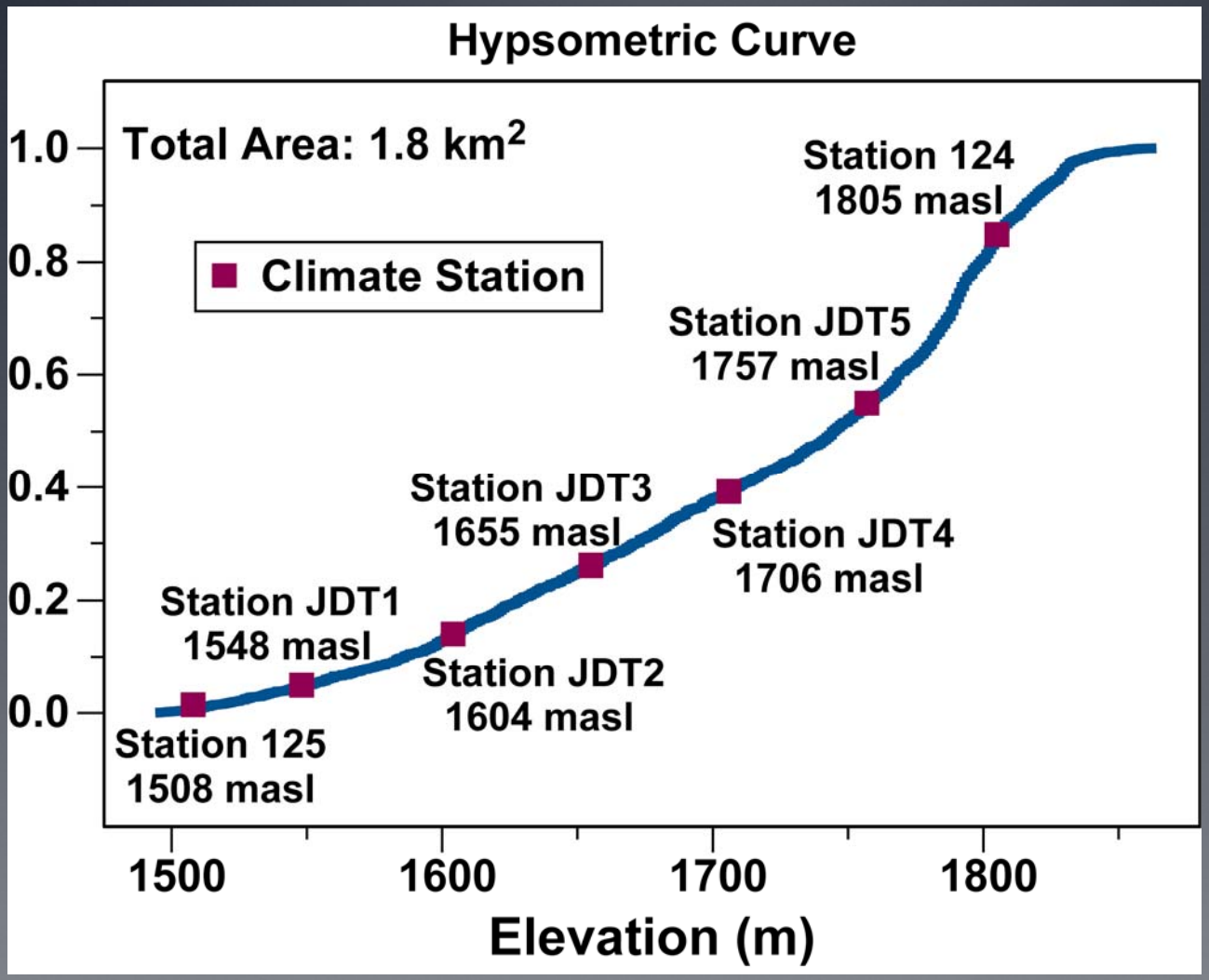
Johnston Draw Study Catchment

(1.8 km² , 380 m relief)

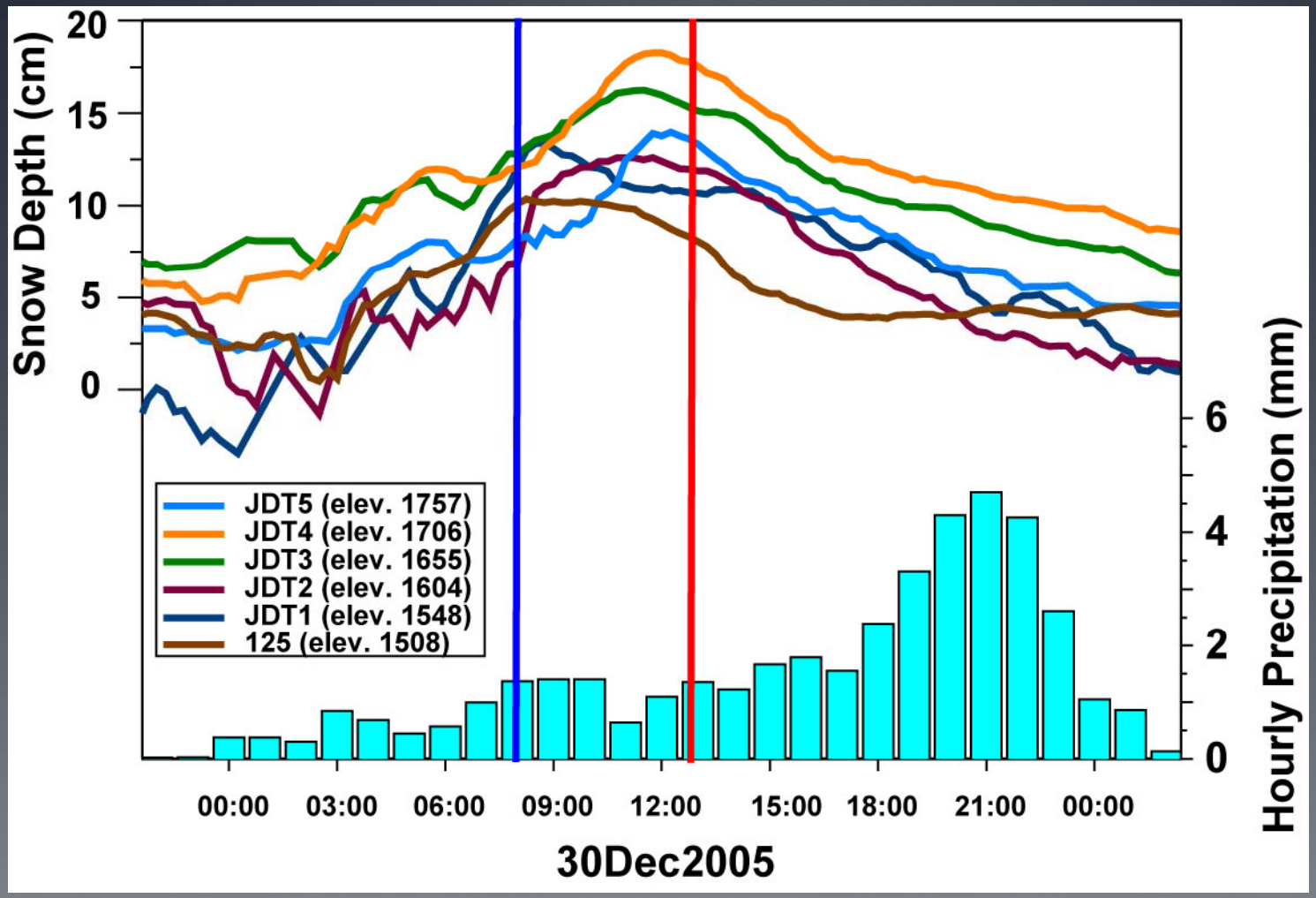


Ideal laboratory for rain/snow transition dynamics

Johnston Draw Study Catchment



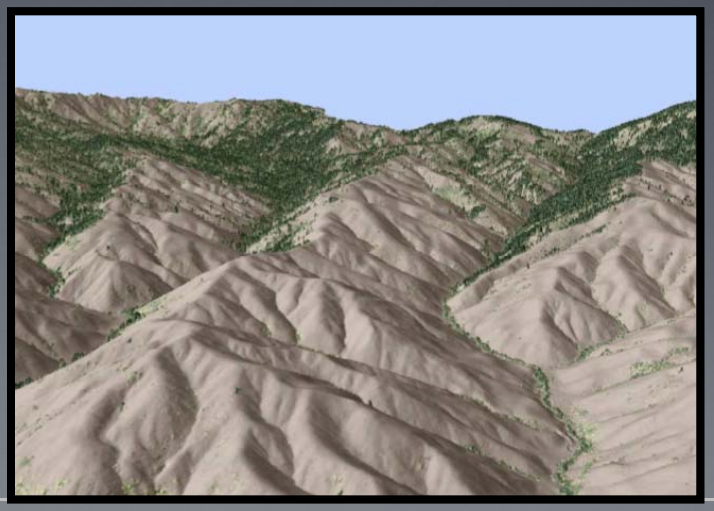
Johnston Draw: Rain/Snow Transition



Applications: Flood-generating processes

Future Directions

- Advanced analysis of snow + soil freezing patterns and dynamics
  - Snow on/snow-off LiDAR (2009)
  - Distributed Temperature Sensing (DTS)
    - Johnston Draw (2 km)
    - Snow presence/absence
    - Soil freeze-thaw dynamics
- Fire effects studies (ongoing)
- Water Resources in a Changing Climate
- Lots of interest in observatory status….



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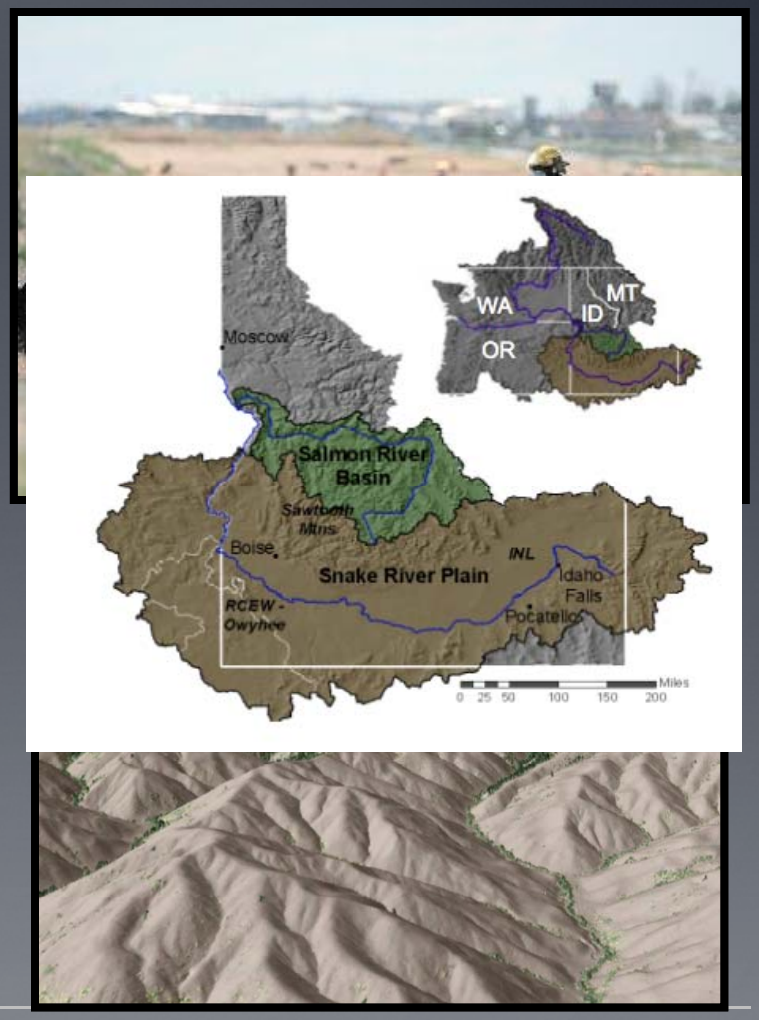

Thank You

Focus on the Science

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