A Sensitivity Study of Radiant Energy During Snowmelt in Small Canopy Gaps:

The quest for the radiative minima and more...

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John Pomeroy - University of Saskatchewan
Robert Lawler - U.S. Forest Service
Chad Ellis - Silvatech Consulting Ltd.
Danny Marks – USDA ARS
Richard Essery - University of Edinburgh

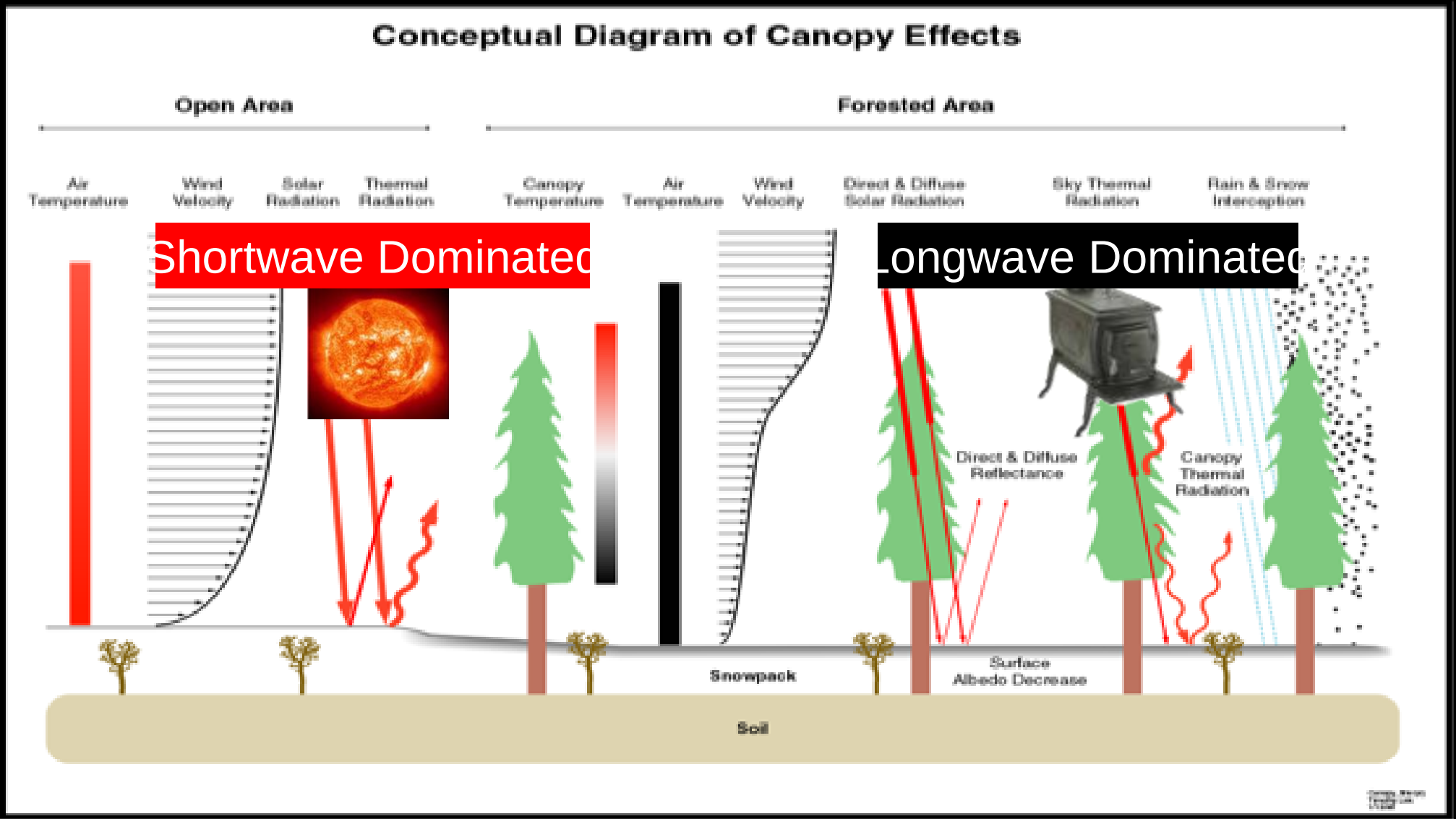
Outline

- Motivation & background
- Radiation in forest gaps
  - Measurements
  - Modeling
- Scaling up...
- Future directions and challenges

Motivation

- Snow is a major water source
  - 50% - 90% in western U. S. watersheds
  - Declining in many areas
- Improve melt prediction in complex terrain
- Can forest management conserve snow?
  - Gap thinning
  - Homogeneous thinning

Snow in Forests



Canopy Effects Summary

In forests, relative to open areas...

- ↓ SWE
- **↓ Shortwave Radiation**
- **↑ Longwave Radiation**
- ↓ Wind Speed

...and hence:
Loss of forest canopy *should*:
1. Increase snow !!
2. Accelerate melt !!!
Not always so!!!

Canopy Gaps…

a.k.a “cold holes”

(Berry & Rothwell, 1992)

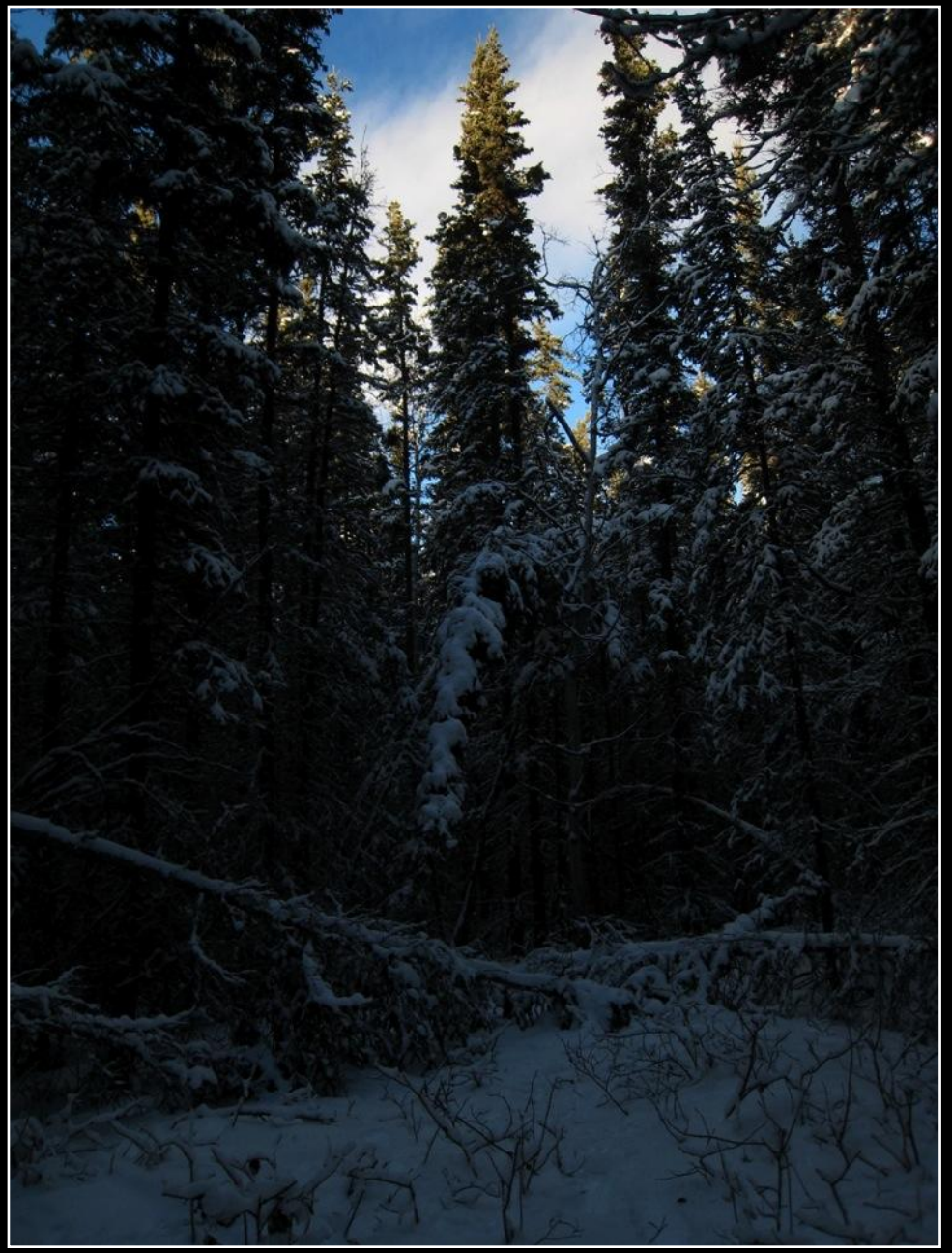
are “open”, and so...

- Accumulate more snow

but...

- Are dark and cold

High Noon in November



Wolf Creek Experimental Basin, Yukon Territory

Some history...

THE
GEOGRAPHICAL REVIEW

VOL. XXIII OCTOBER, 1933 No. 4

SNOW SURVEYING: ITS PRINCIPLES AND POSSIBILITIES*

J. E. Church
Nevada Agricultural Experiment Station

The ideal conservation forest is one honeycombed with glades whose extent is so related to the height of the trees that the sun cannot reach the surface of the snow. Such a forest will permit far more snow to reach the ground than will a forest of great and uniform density and yet will amply protect the snow from the effect of sun and wind.

Church. 1933. Geog. Rev.

More history...

Snow accumulation and melt in small forest openings in Alberta

D. L. GOLDING AND R. H. SWANSON

Northern Forest Research Centre, Canadian Forestry Service, Fisheries and Environment Canada, Edmonton, Alta., Canada T6H 3S5

Received March 6, 1978[1]
Accepted July 10, 1978

ing ablation. The 1/4 H is small enough that the energy regime is essentially that of the uncut forest. The lowest ablation rates are in those openings, 3/4 H and 1 H, that are large enough that little long-wave radiation from adjacent trees but little or no direct solar radiation reaches the snowpack.

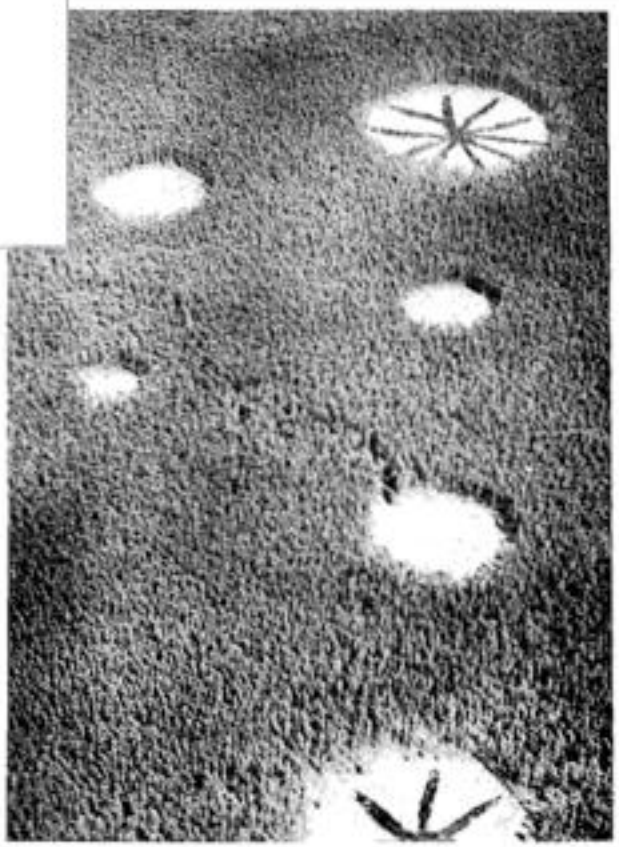


FIG. 1. Openings cut in lodgepole pine at James River study area.

Golding & Swanson. 1978. Can. J. For. Res.

More history...

Snow Distribution Patterns in Clearings and Adjacent Forest

DOUGLAS L. GOLDING

Faculty of Forestry, University of British Columbia, Vancouver

ROBERT H. SWANSON

Northern Forest Research Centre, Canadian Forestry Service, Edmonton, Alberta

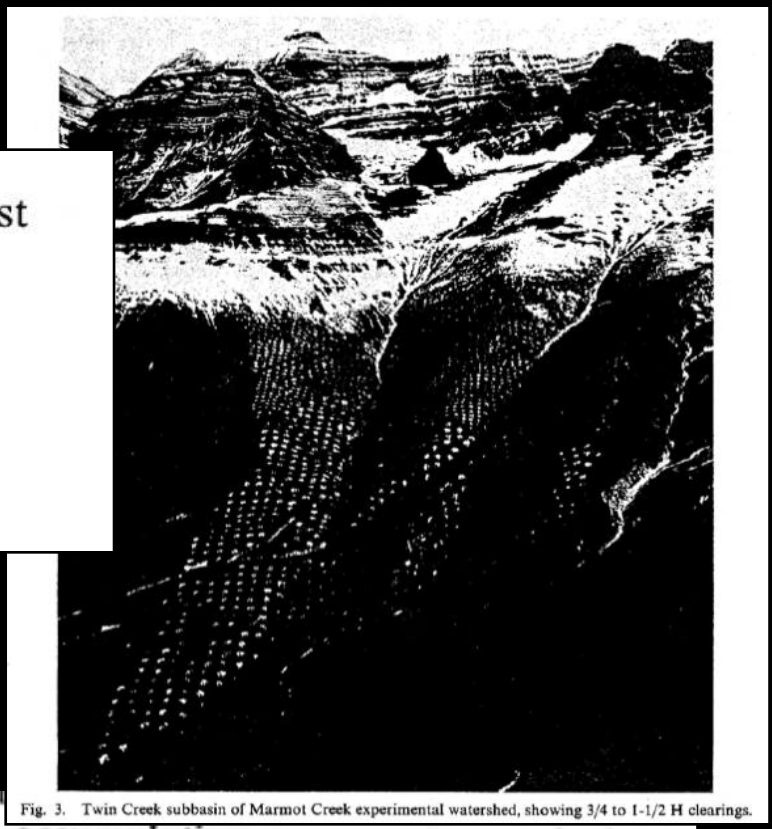


Fig. 3. Twin Creek subbasin of Marmot Creek experimental watershed, showing 3/4 to 1-1/2 H clearings.

experimental watershed and James River, Alberta. At maximum accumulation snow water equivalent (SWE) was greater in clearings than in forest whether clearings were large, as in 8- to 13-ha blocks where SWE averaged 20% more than in the forest, or small as in the 1/4 to 6-H (height) diameter circular clearings where SWE was 13–45% greater than in the forest. SWE was 42 to 52% less in north than in south sectors of 2–6 H clearings. These differences increased with clearing size and time since beginning of accumulation period and are caused by snow ablation (melt and

Golding & Swanson. 1986. Wat. Resour. Res.

More history...

Snow ablation in small forest openings in southwest Alberta

G.J. Berry[1] and R.L. Rothwell

Department of Forest Science, University of Alberta, Edmonton, Alta., Canada T6G 2H1

Received August 1, 1991

Accepted March 6, 1992

Summary and conclusions

The size of canopy opening and direction of exposure significantly affected snow ablation rates. Snowmelt rates were slower in the 1 *H* opening and faster in the uncut forest (0) and 3, and 5 *H* openings. Low ablation rates in the 1 *H* opening

7 times greater than in the 1 and 0 *H* openings. The rate of snowmelt on north and south exposures in 1 *H* opening was up to 26 times lower than in the uncut forest, and up to 103 times lower than in the 3 and 5 *H* openings. South expo-

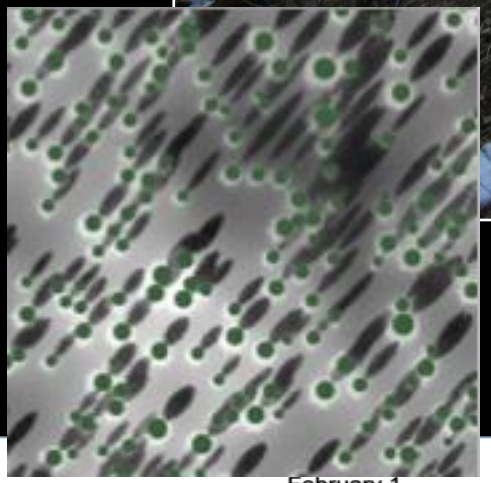
Berry & Rothwell. 1992. Can. J. For. Res

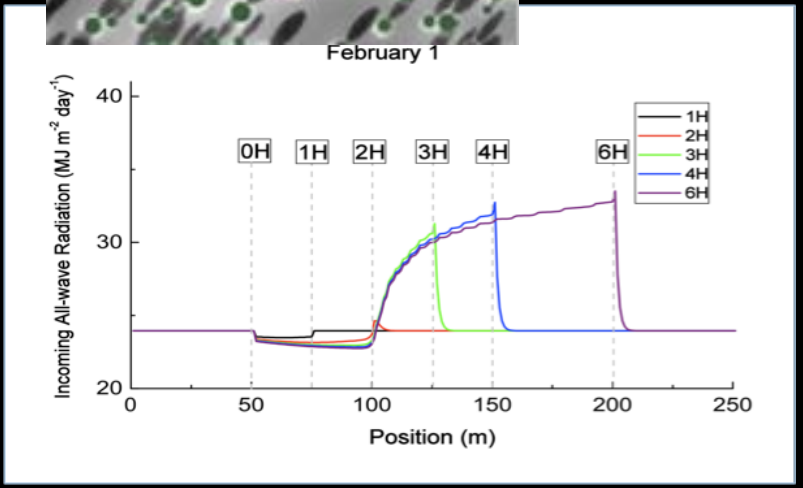
and so the question is…

- How does radiation vary as function of position, gap size, season, and latitude ?
- Optimal density and pattern to minimize radiation to snow?

Methods

- Radiation measurements
- Physically-based models
- Sensitivity experiments





Radiation Measurements

~1H

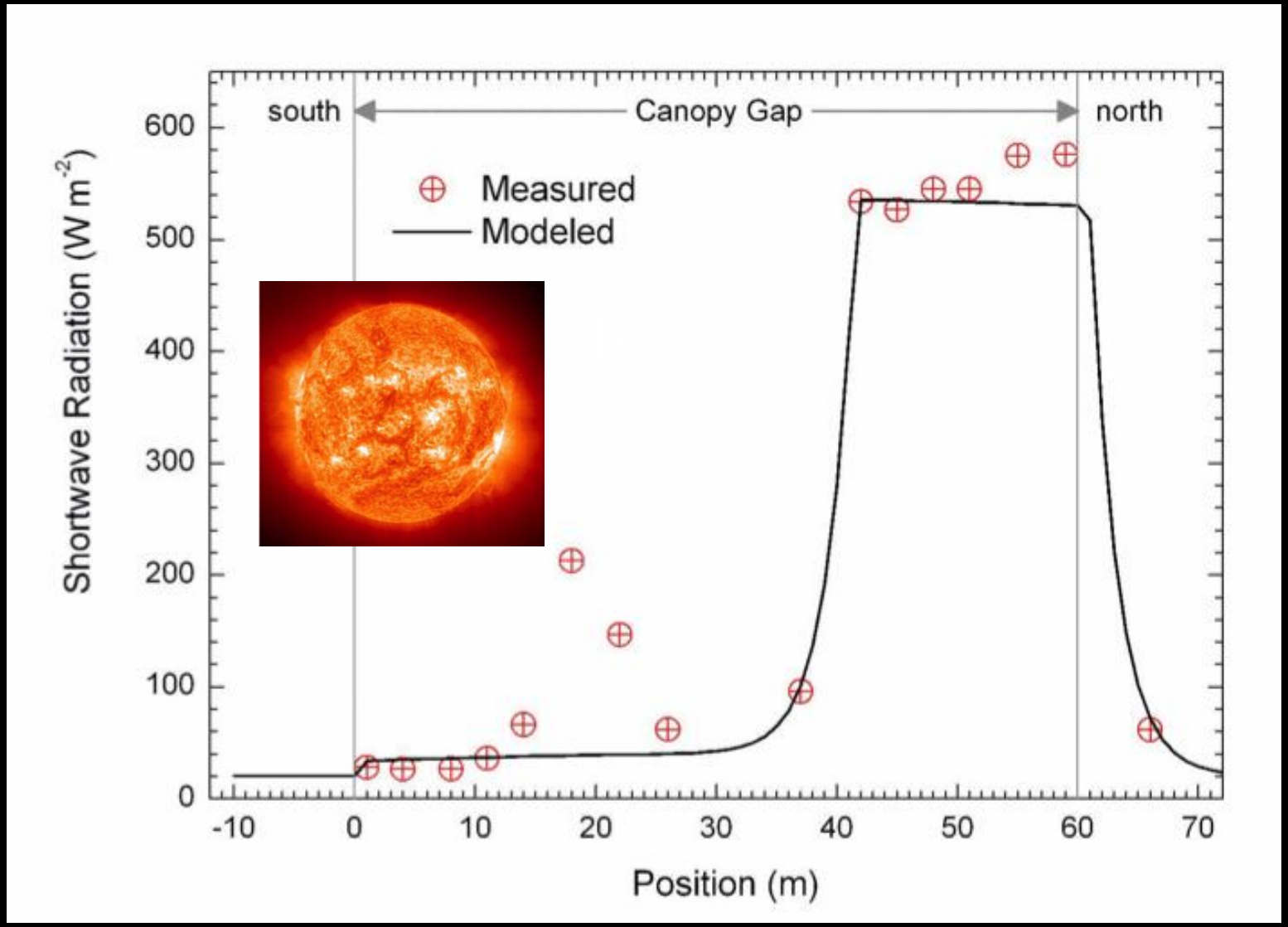
~1.8H

~2.2H

measuring sunshine in a campground in winter...

Simple Model Performance

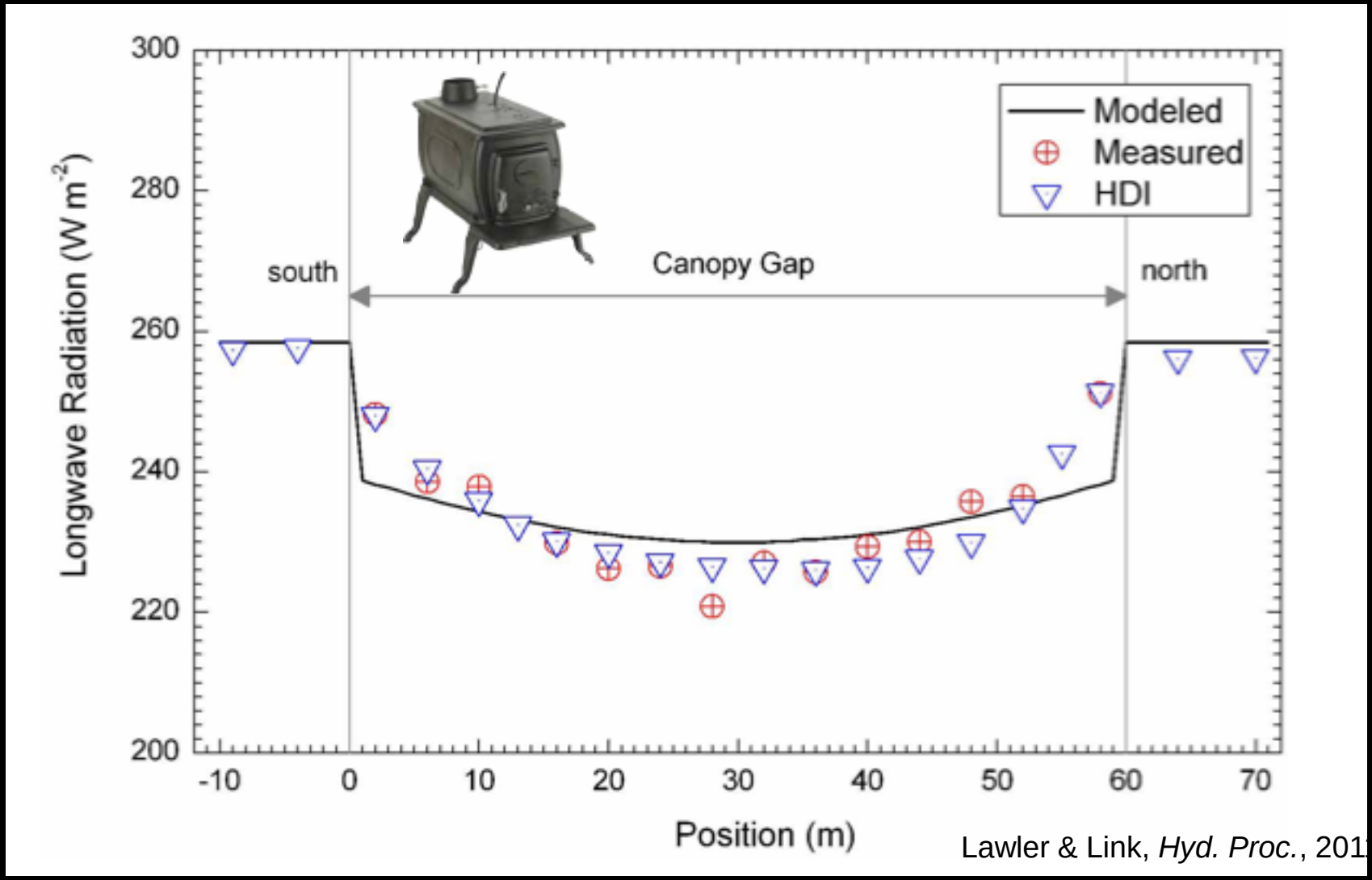
Shortwave Radiation



Lawler & Link, *Hyd. Proc*., 2011

Model Performance:

Longwave Radiation



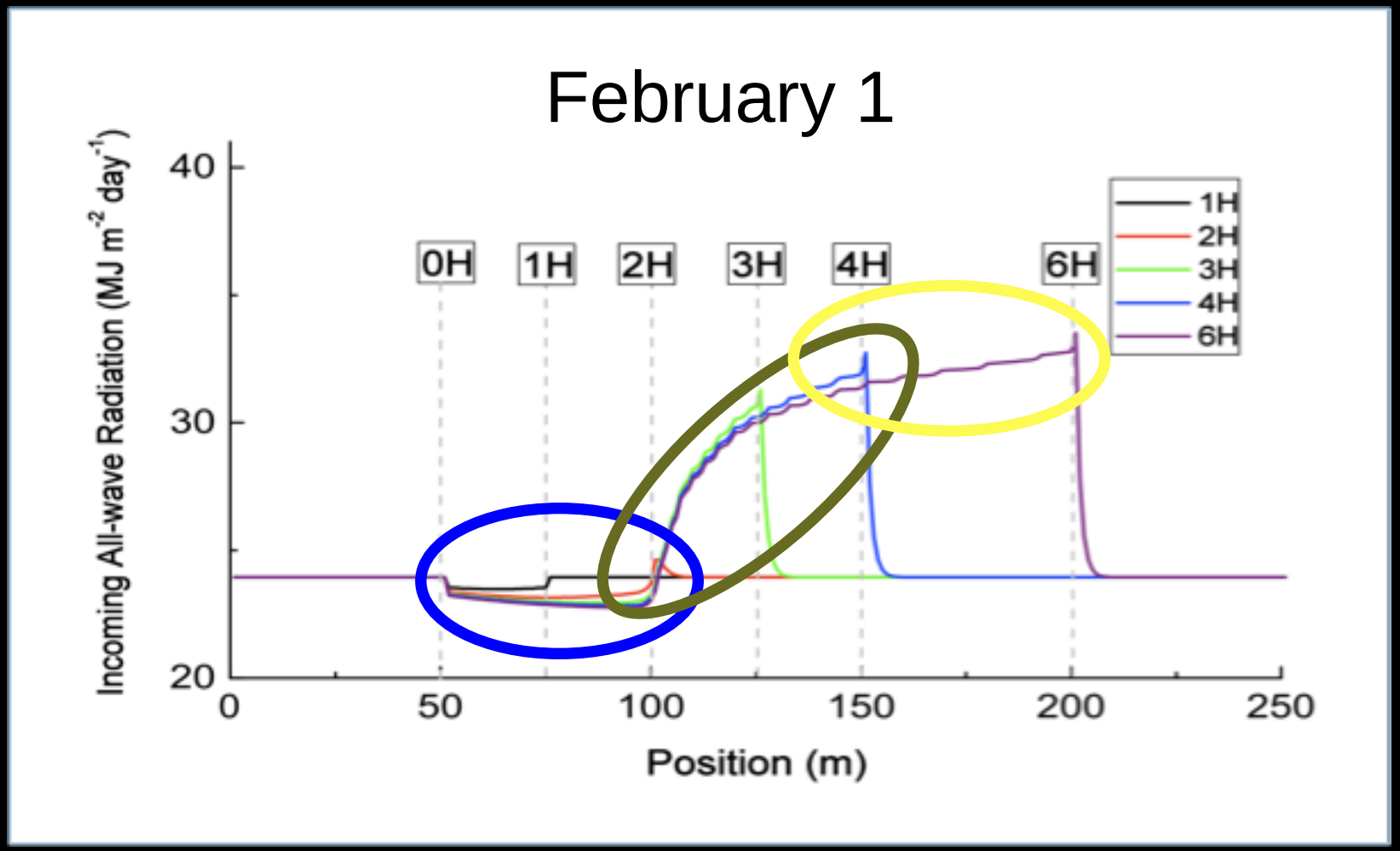
Lawler & Link, *Hyd. Proc.*, 201

Simulated Radiation Regimes

GAP POSITION, SIZE, AND SEASON

Gap Radiation Regimes

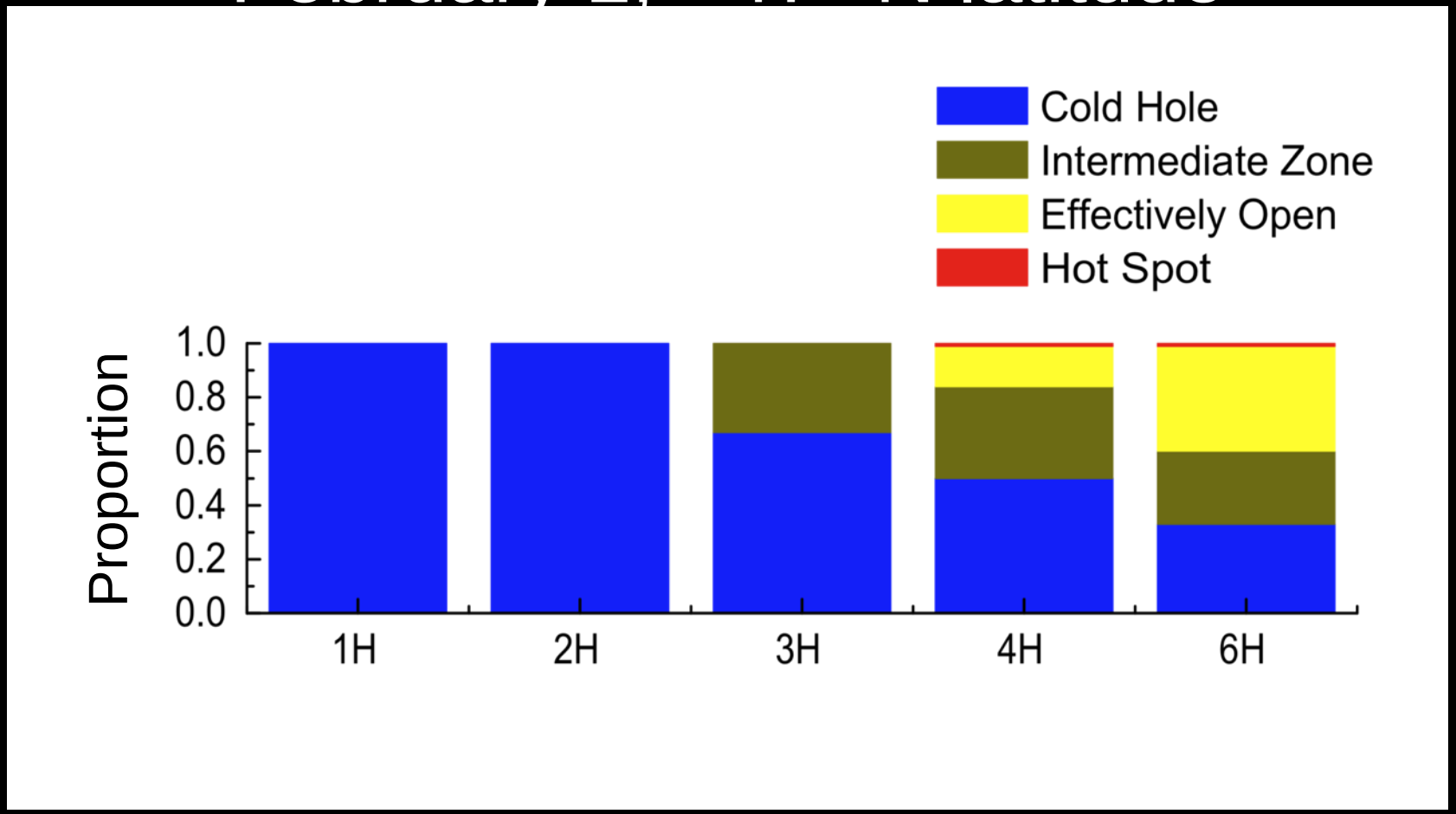
~42° N latitude



Lawler & Link, *Hyd. Proc.*, 2011

Gap Radiation Regimes

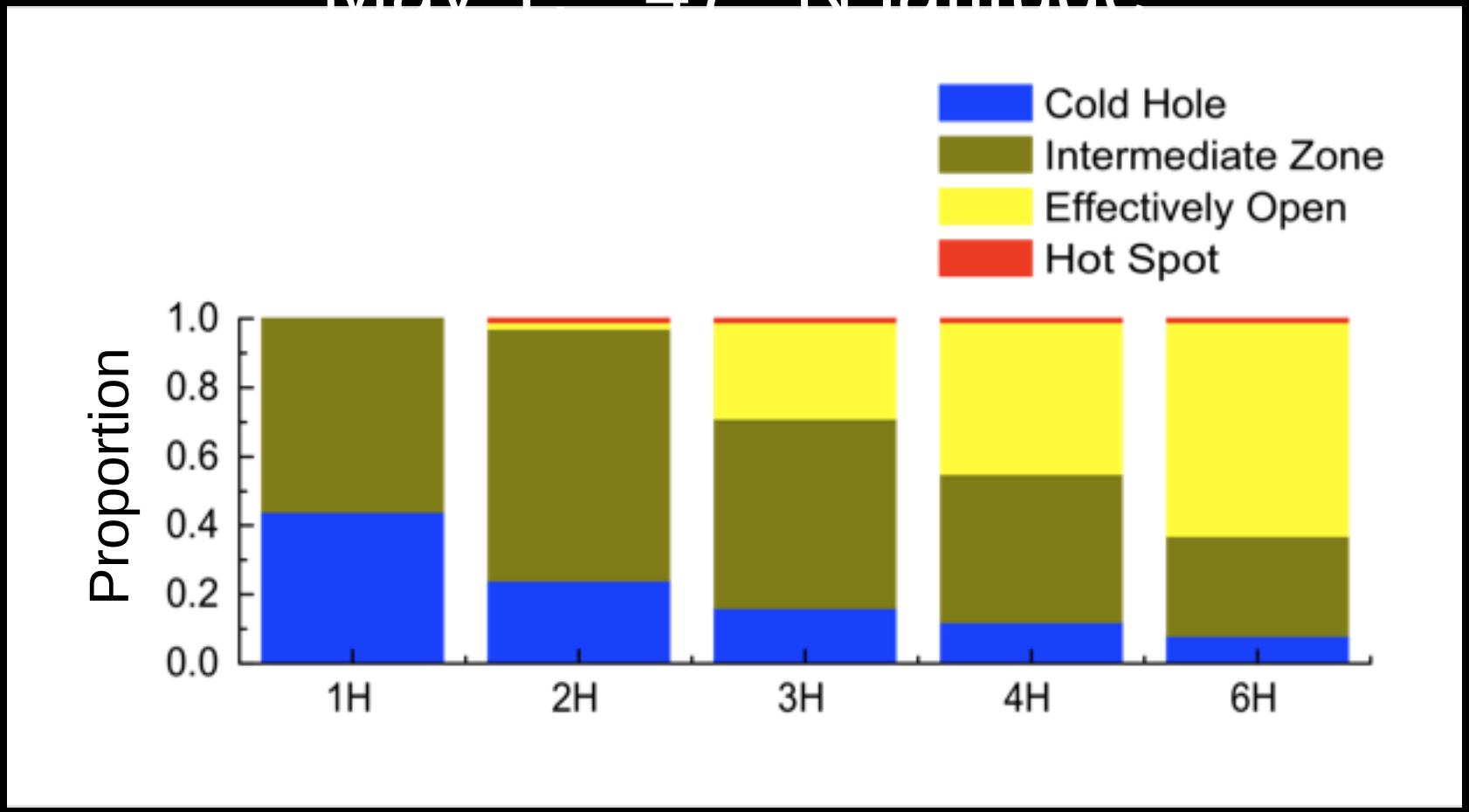
February 1, ~47° N latitude



Lawler & Link, *Hyd. Proc.*, 2011

Gap Radiation Regimes

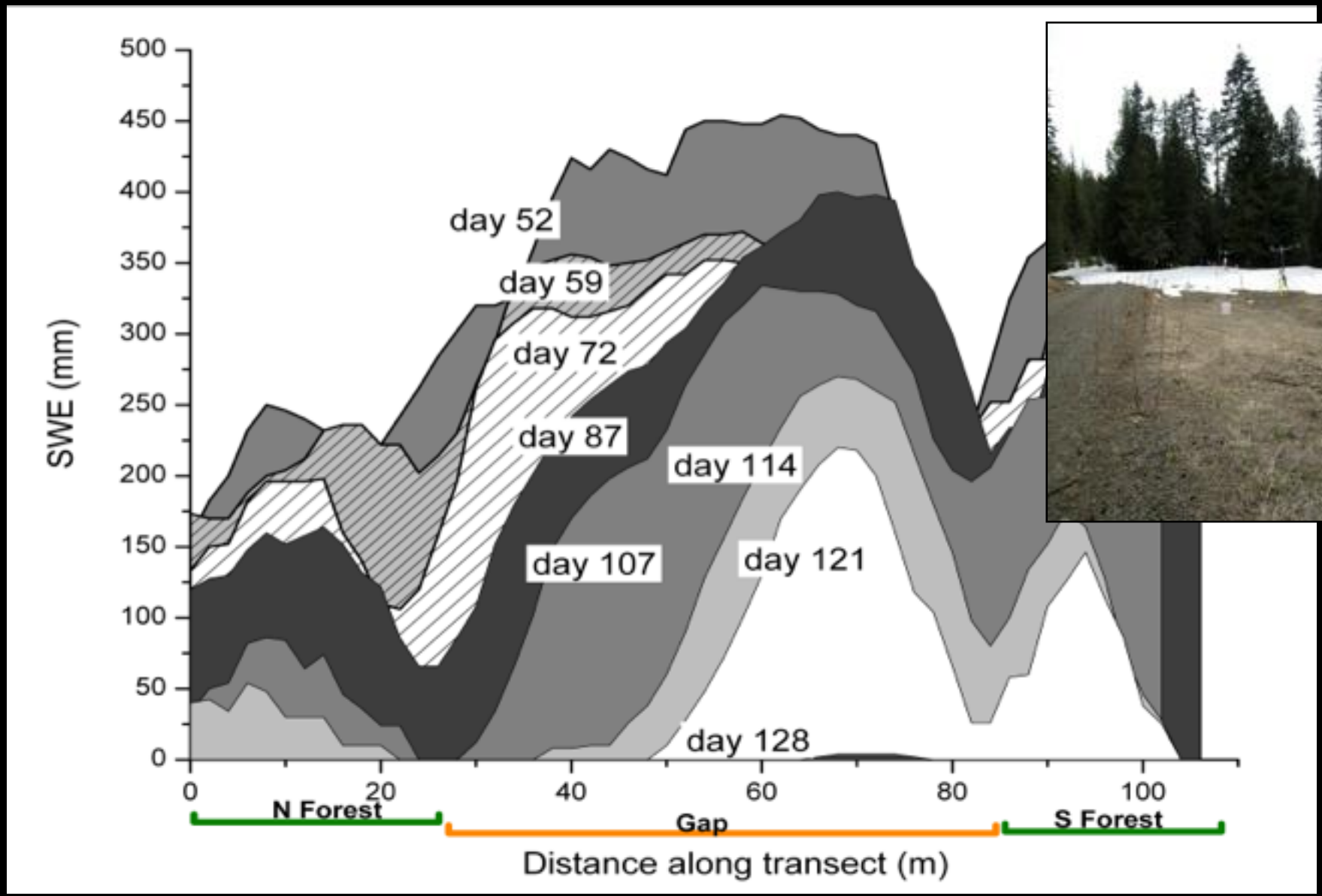
May 1, ~47° N latitude



Lawler & Link, *Hyd. Proc.*, 2011

Snow Depth Trends

~47° N latitude

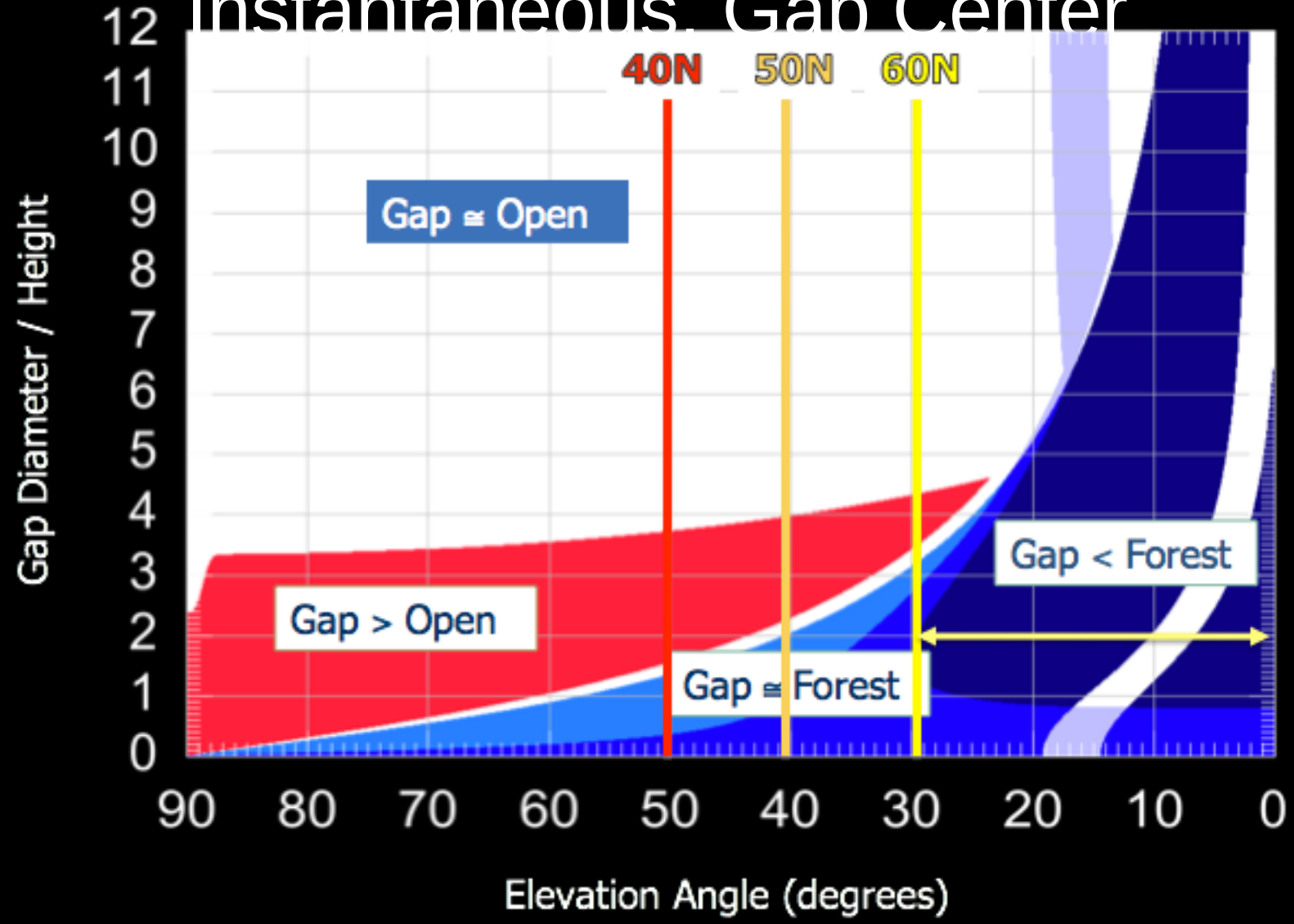


Simulated Radiation Regimes: Another View…

GAP SIZE, SEASON, AND LATITUDE

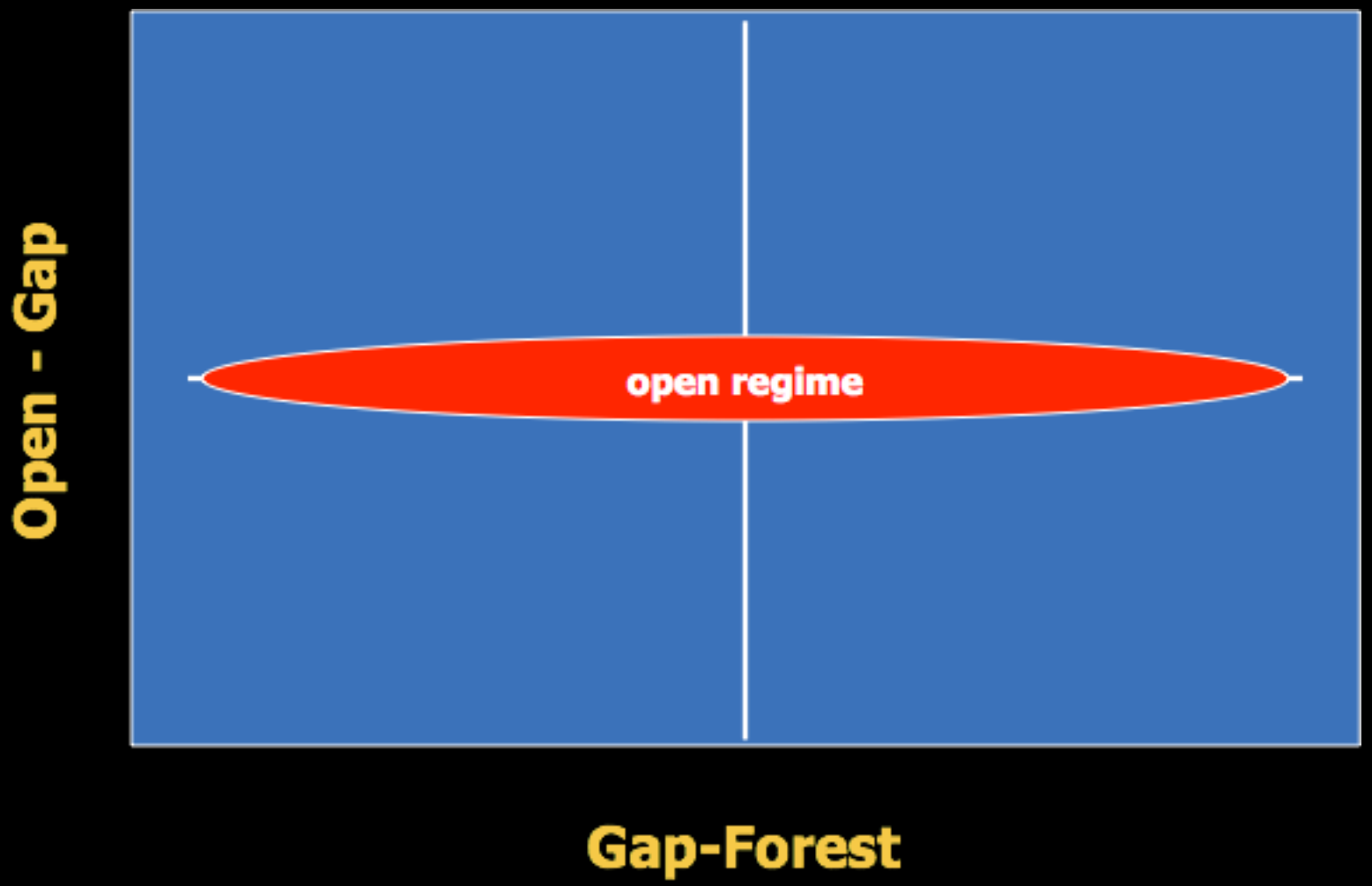
Gap Radiative Regimes

Instantaneous, Gap Center



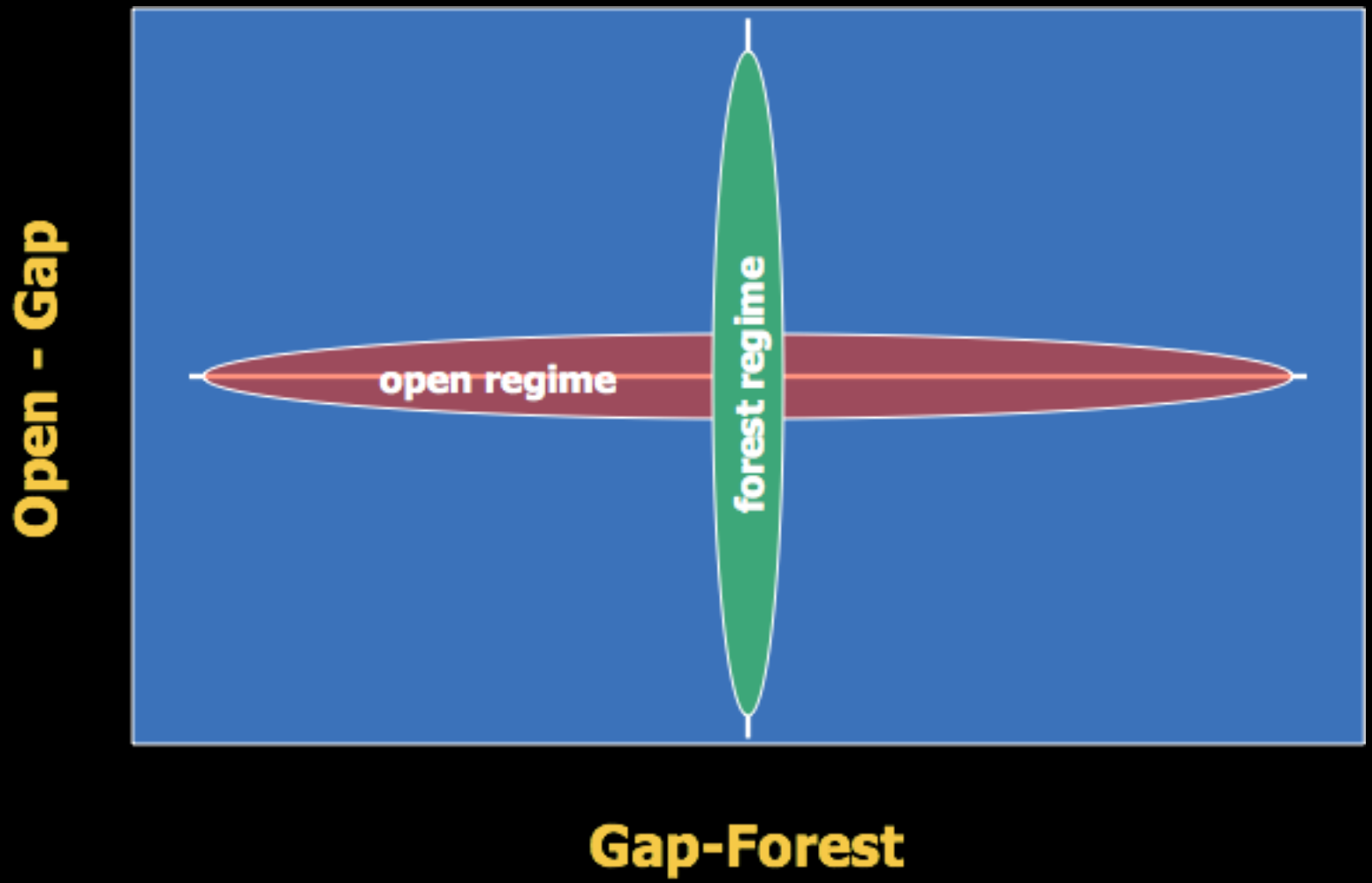
Data Analysis

Daily Incoming Radiation



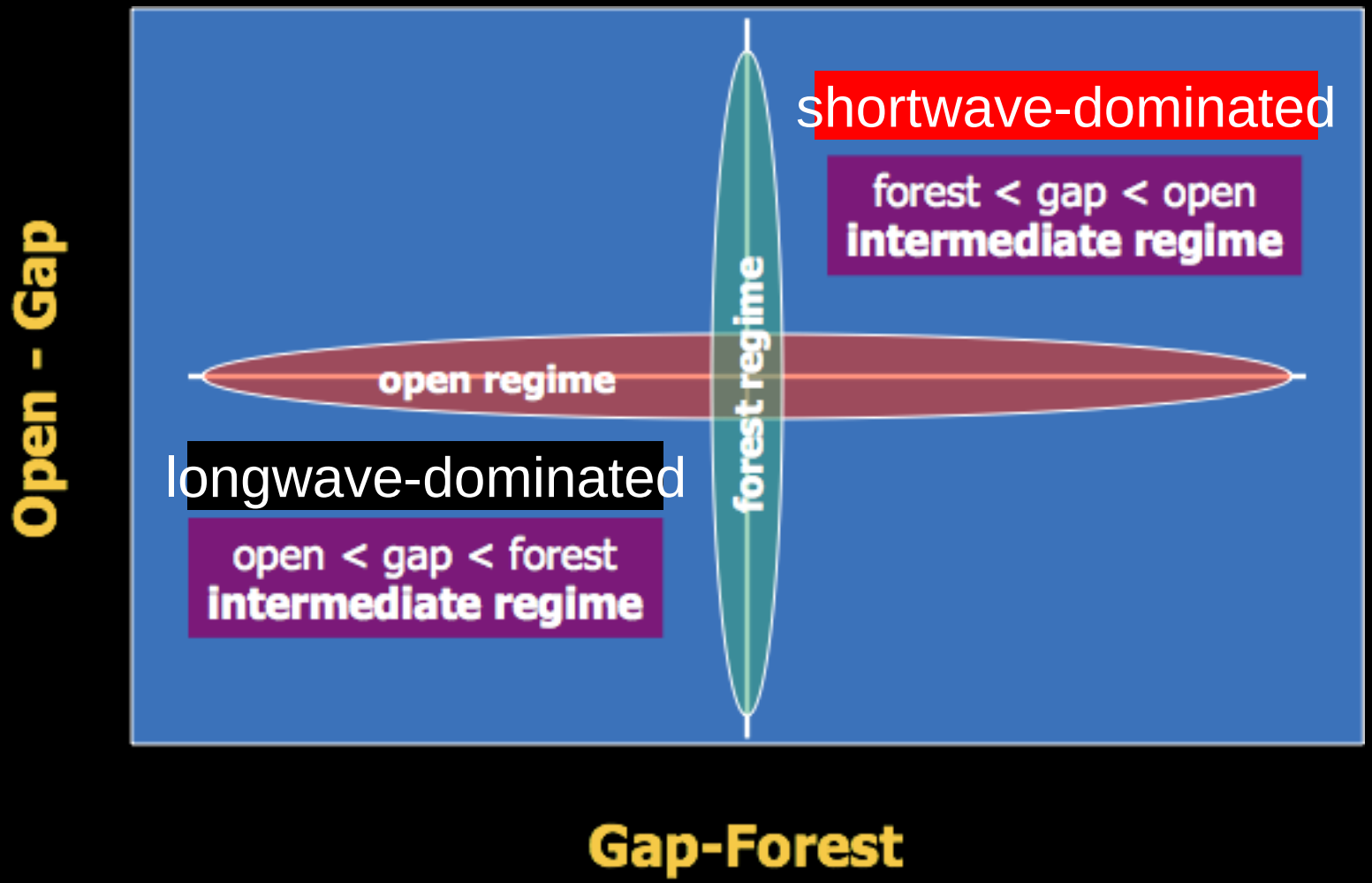
Data Analysis

Daily Incoming Radiation



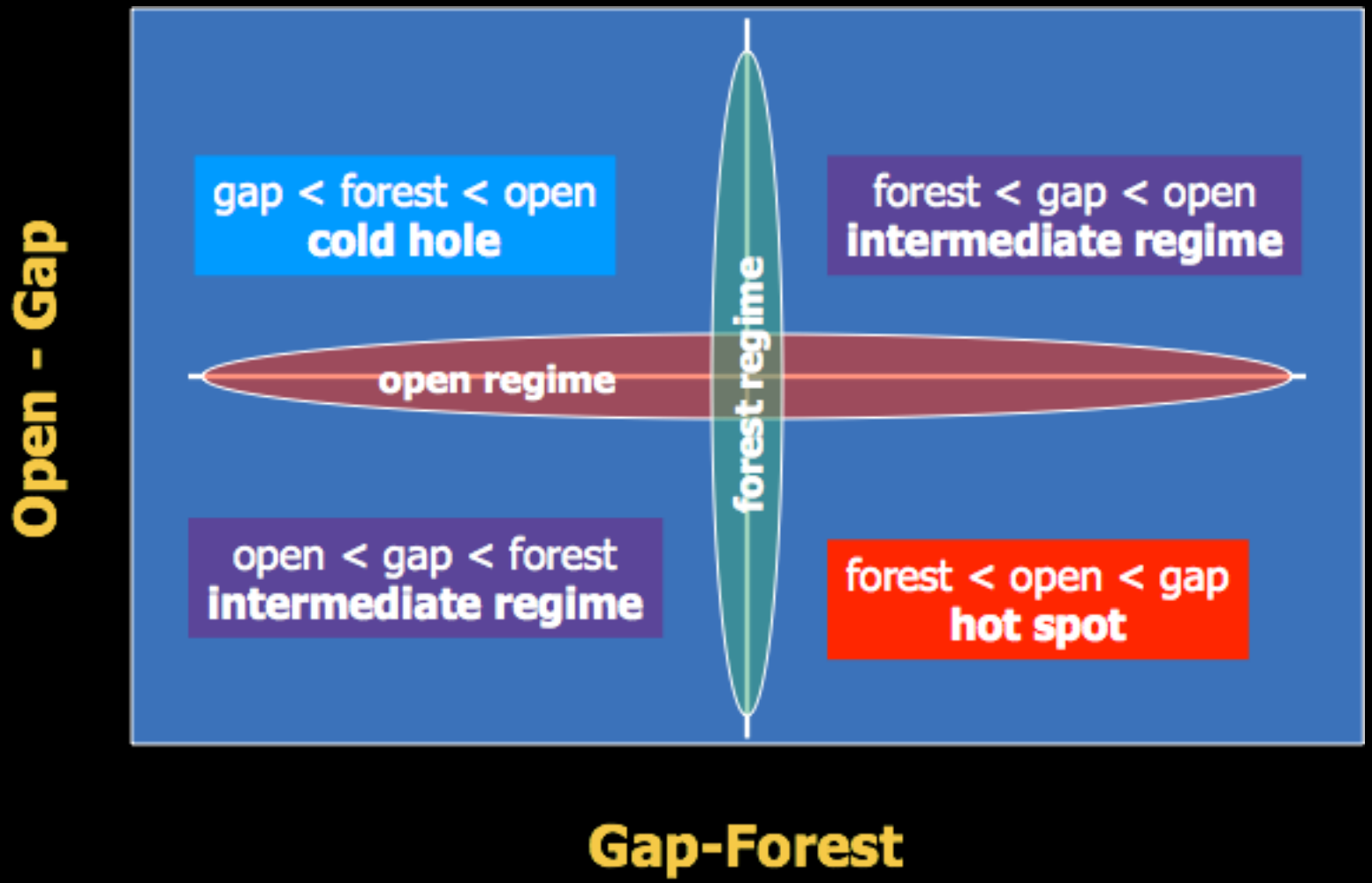
Data Analysis

Daily Incoming Radiation

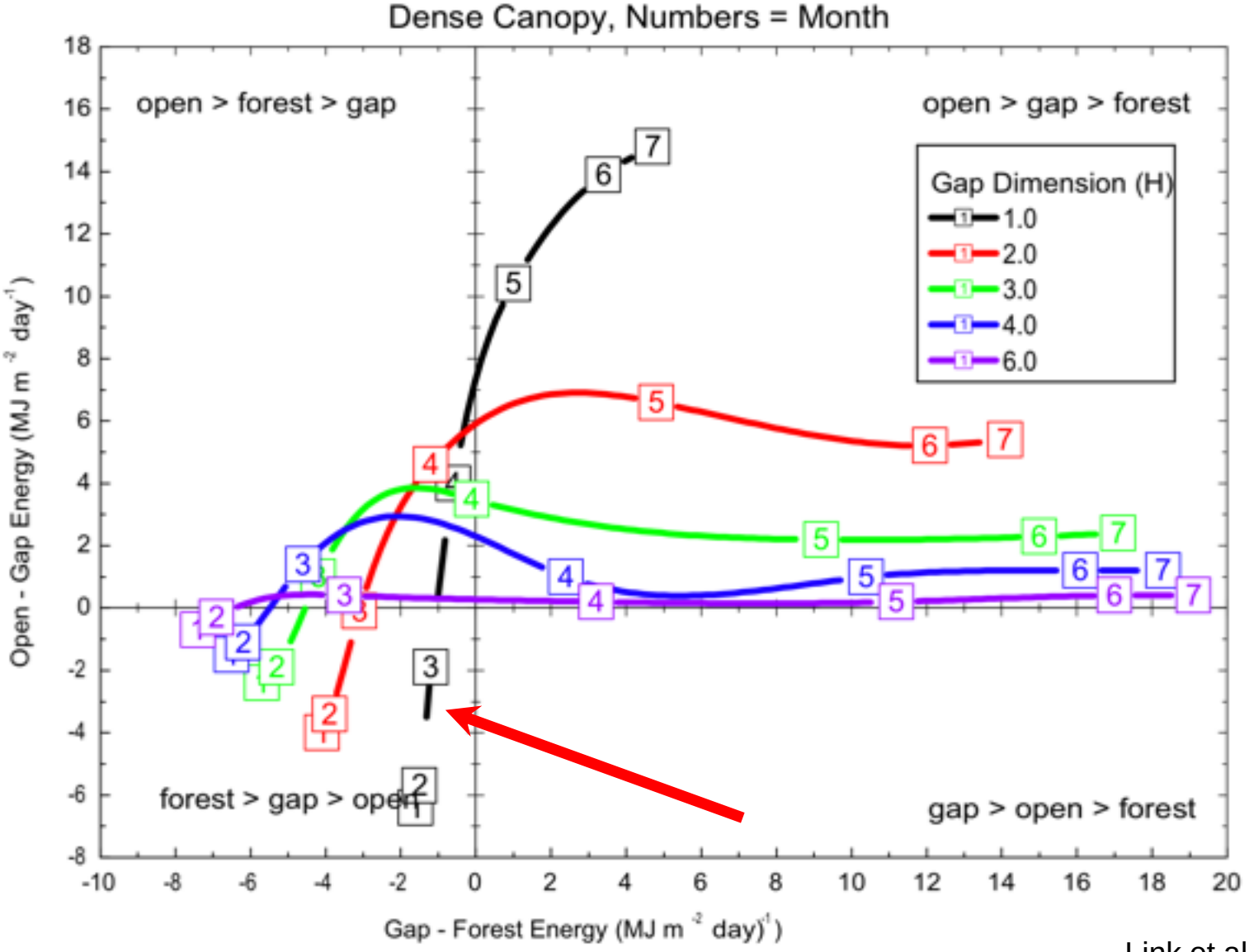


Data Analysis

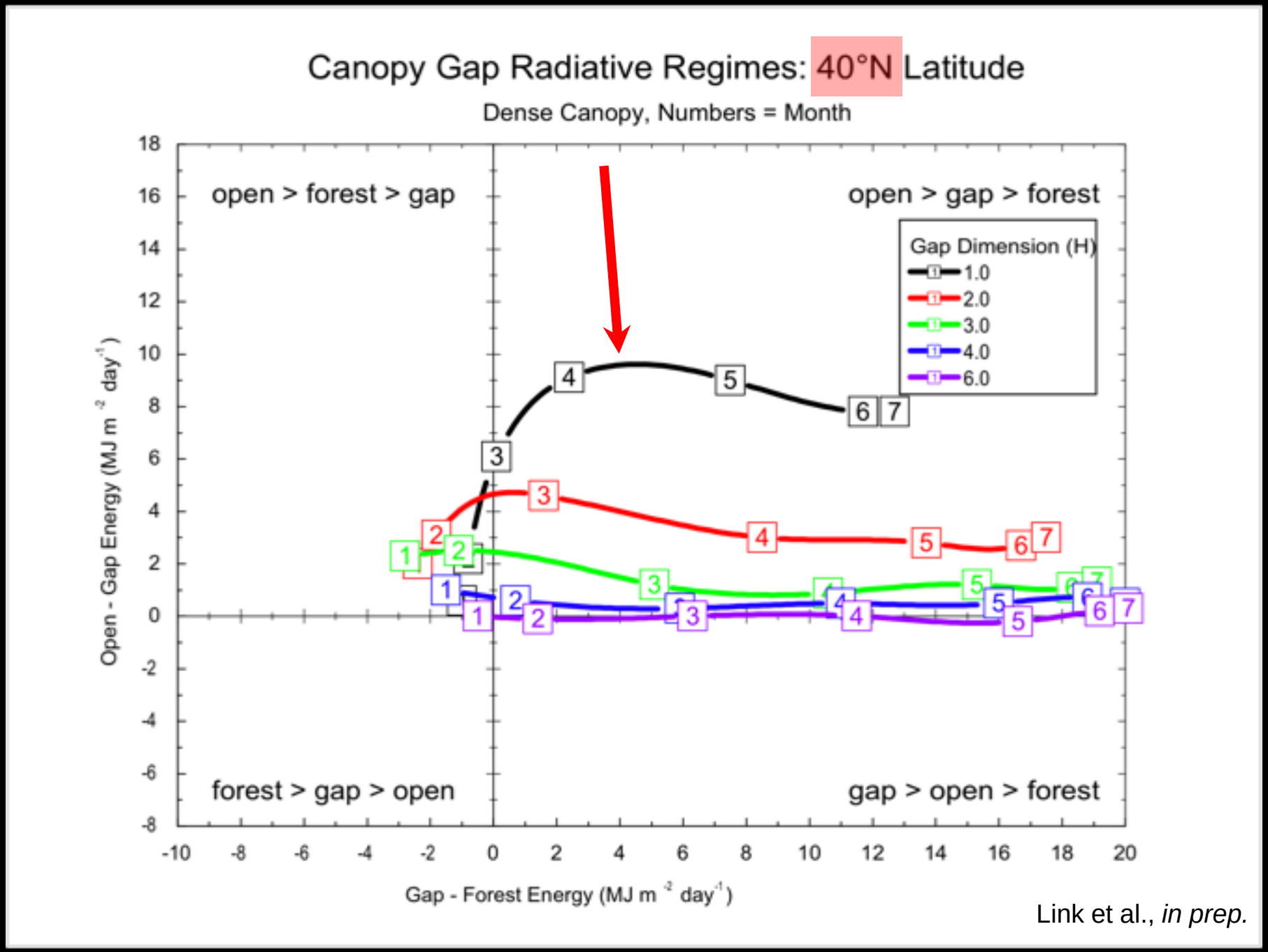
Daily Incoming Radiation



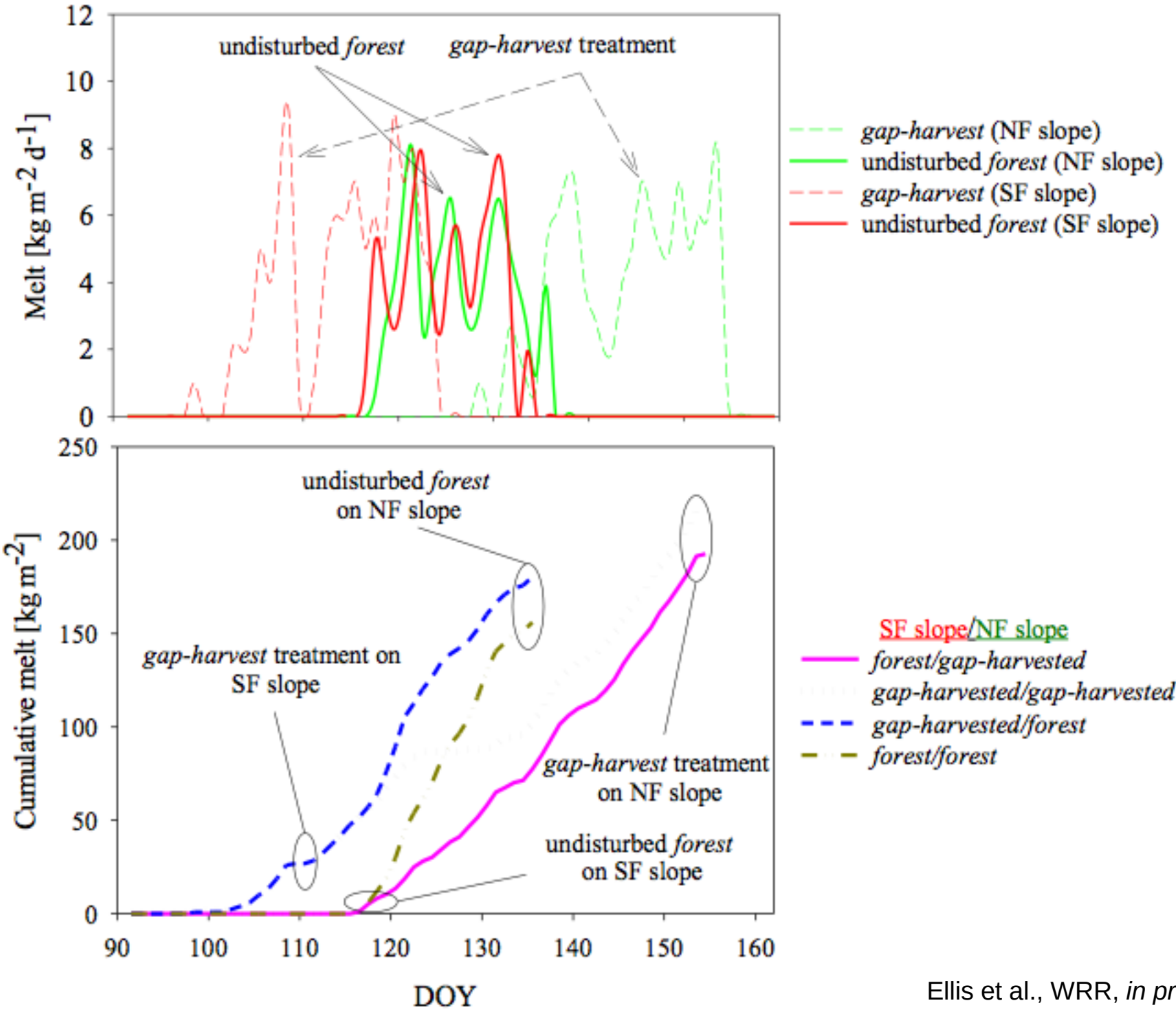
Canopy Gap Radiative Regimes: 60°N Latitude



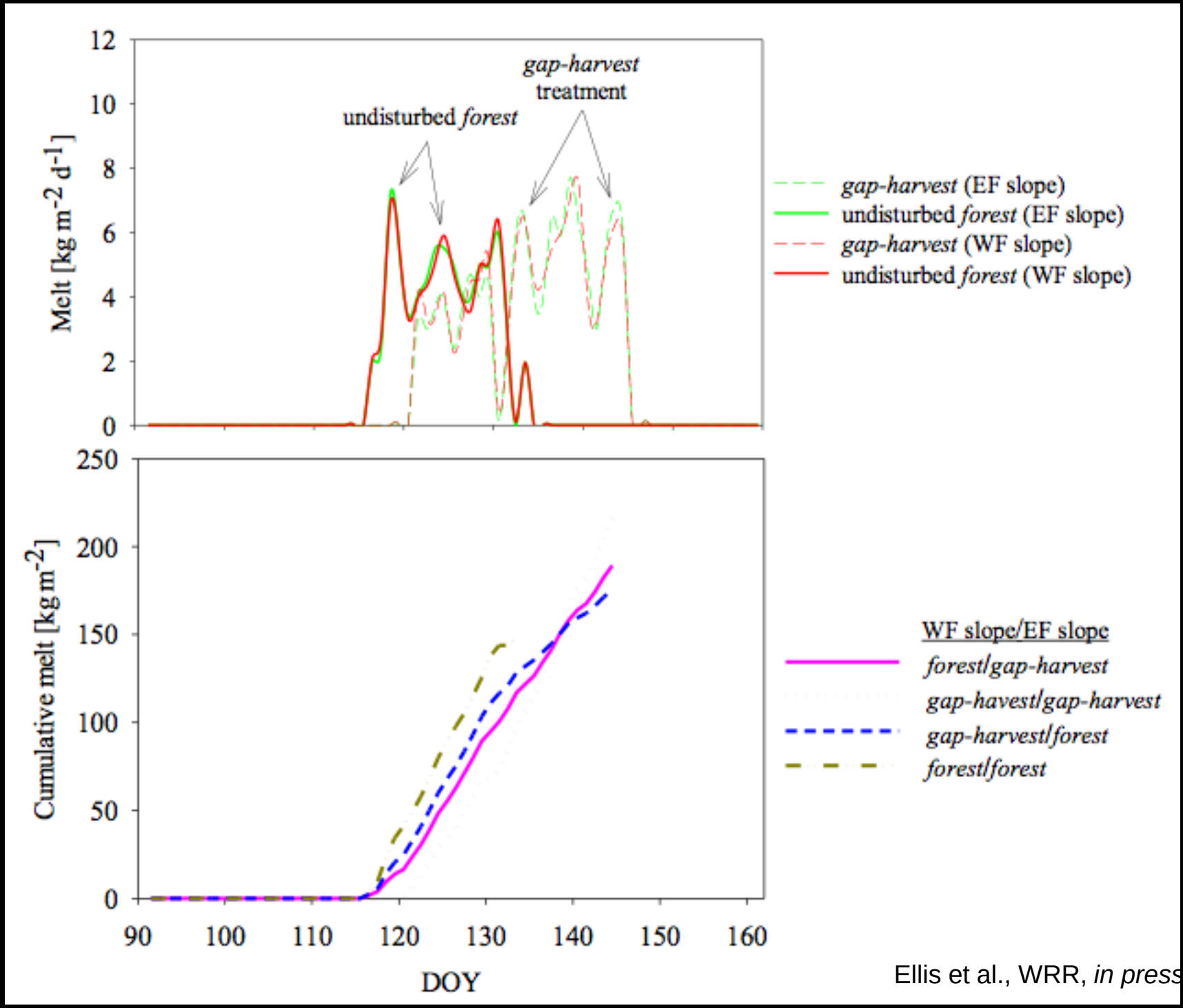
Link et al., *in prep.*



Link et al., *in prep.*



Ellis et al., WRR, *in press*



Ellis et al., WRR, *in press*

Conclusions

(so far!)

Radiative minima occur in gaps

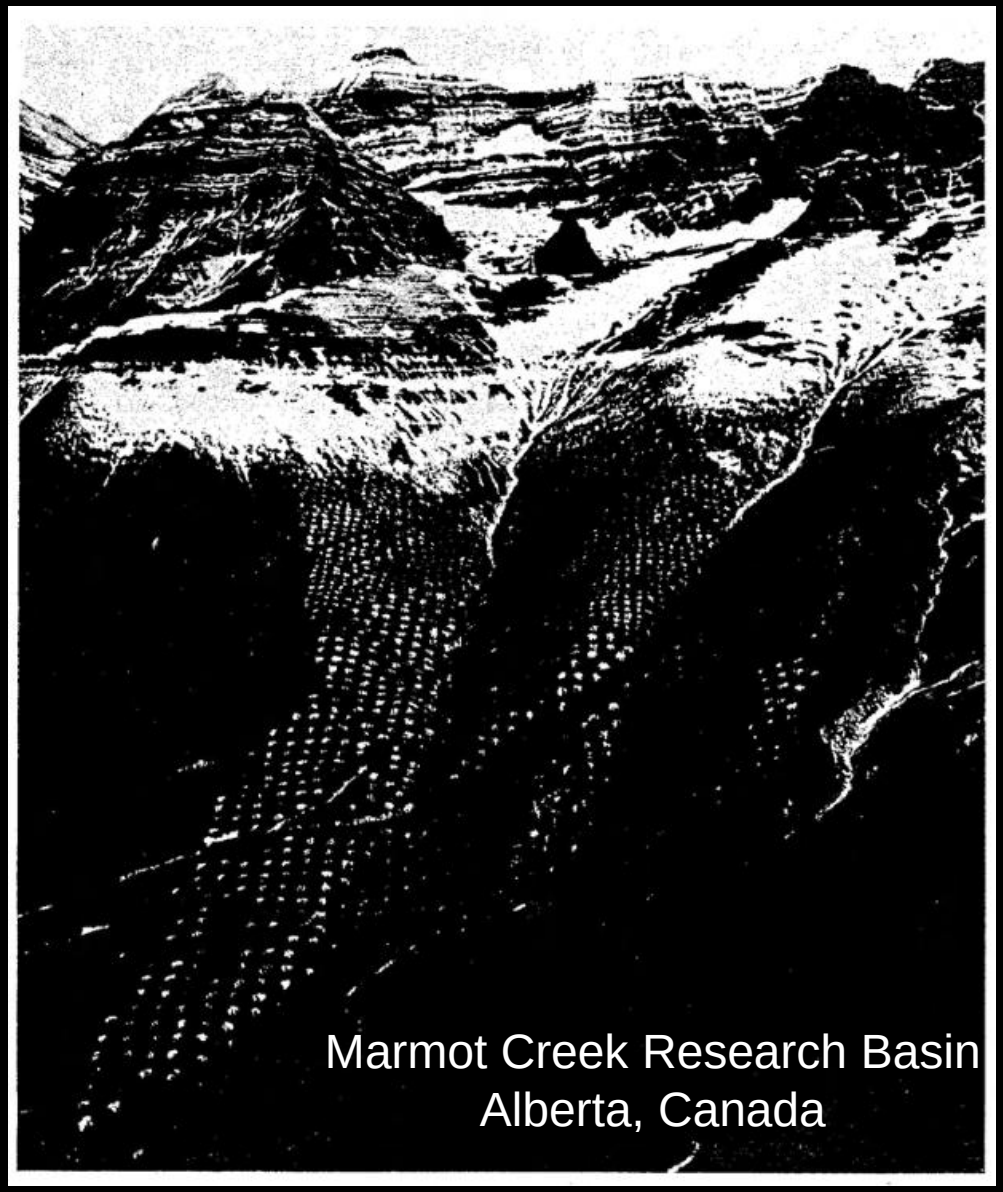
- Optimal size: 1-2 H at ~45° latitude

- Snow can be retained on the landscape
  - Melt can be desynchronized on slopes
- Canopy gap microclimates are distinct

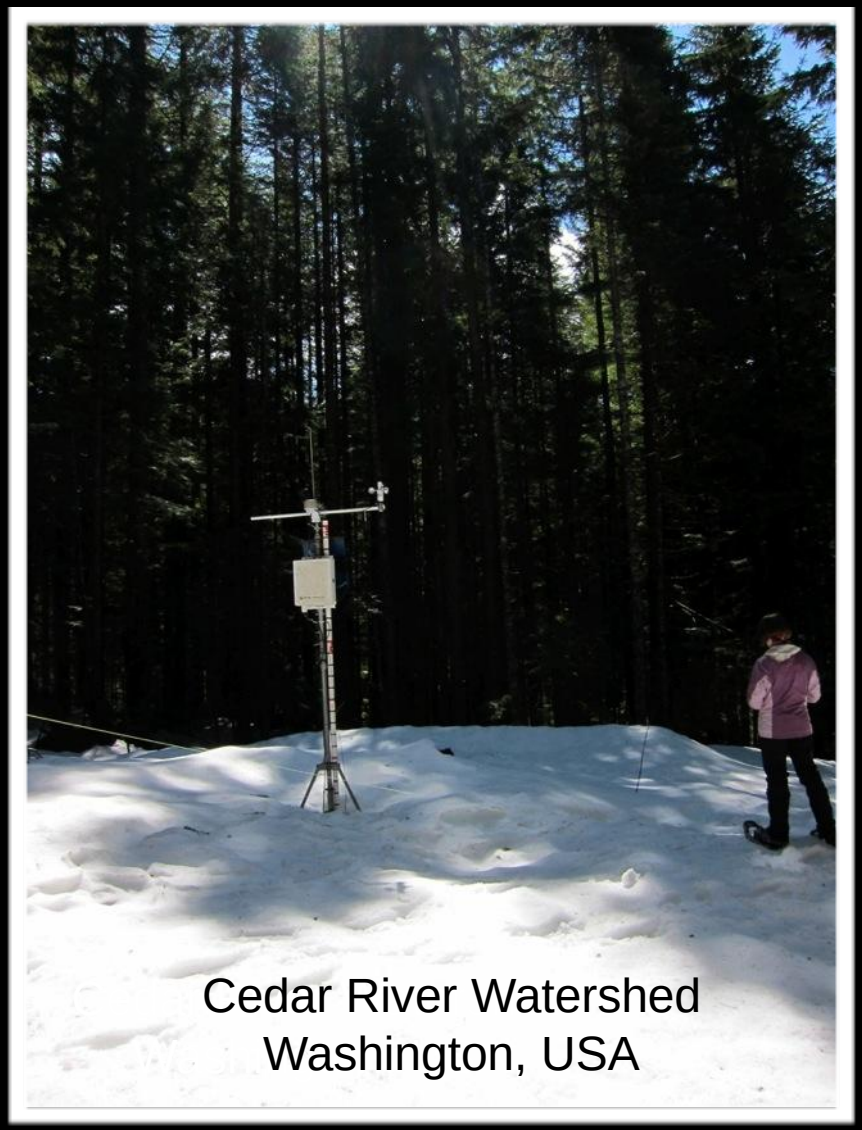
Implications:

- Water resource prediction & enhancement
- Climate change adaptation
- Monitoring site assessment
- Fire hazard risk reduction
- Avalanche initiation
- Vegetation

The Marmot Creek Legacy



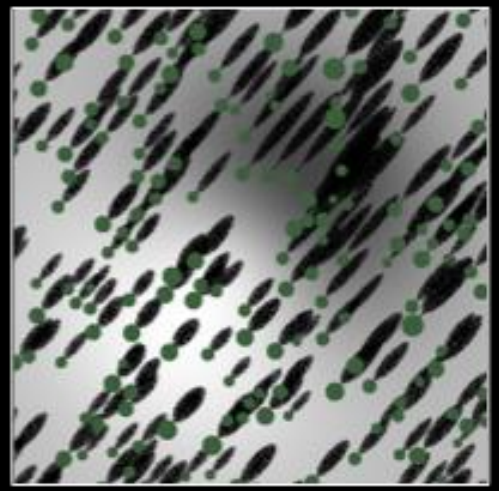
Marmot Creek Research Basin
Alberta, Canada



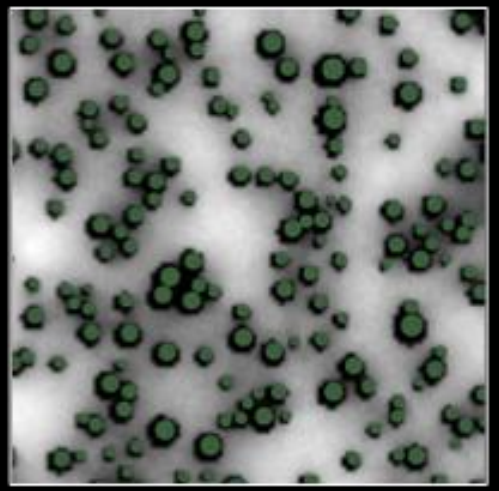
Cedar River Watershed
Washington, USA

Future Directions:
Discrete Tree Model

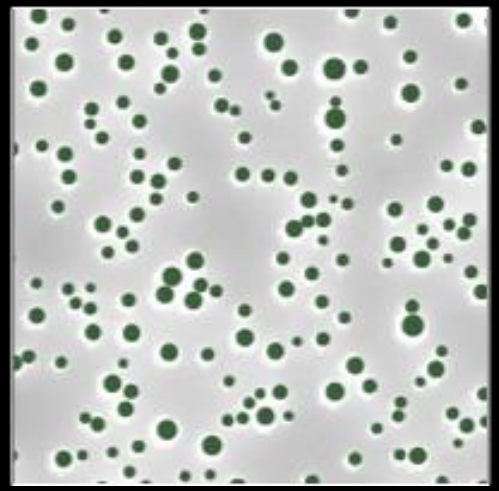
Direct-beam solar radiation



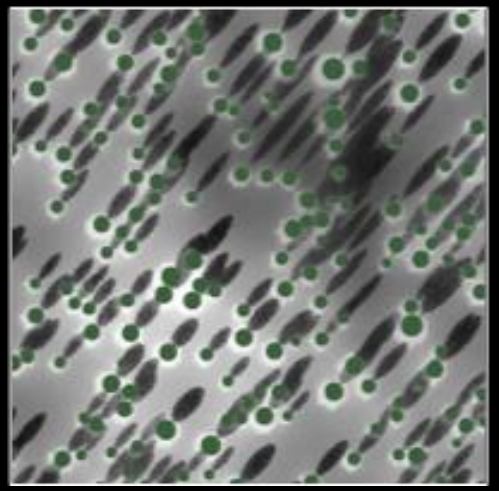
Diffuse solar radiation



Longwave radiation

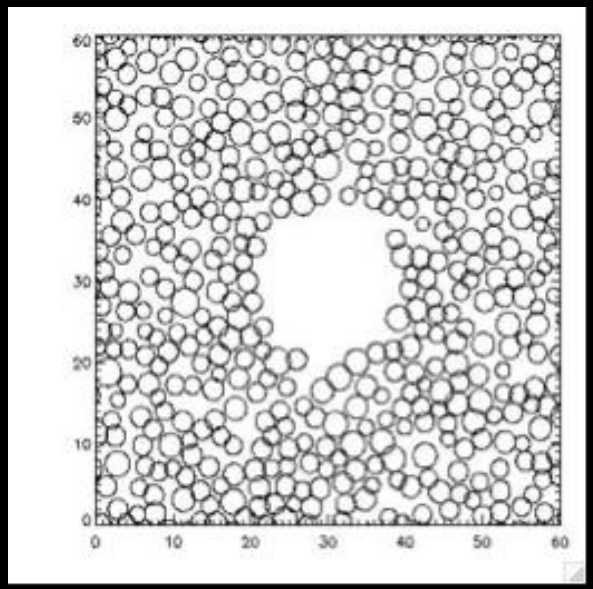


Net radiation



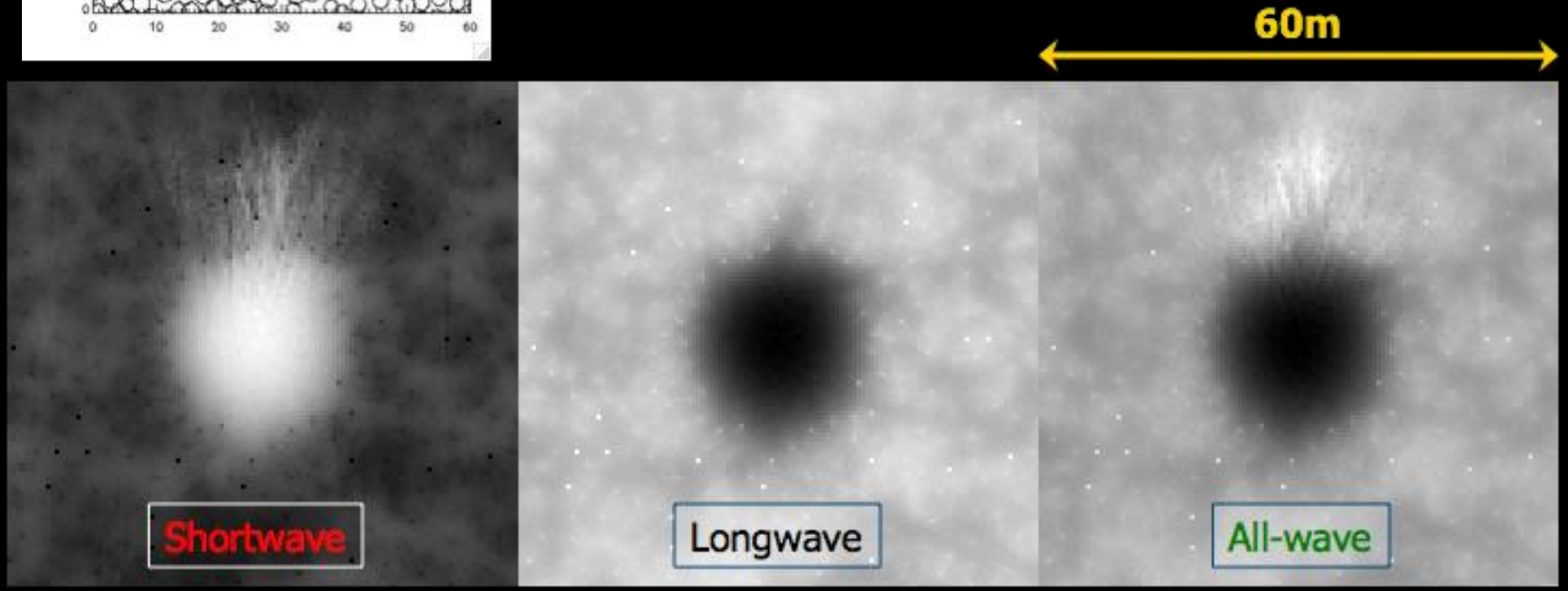
Images courtesy of Dr. Richard Essery

Future Directions



- How does radiation vary as function of canopy density, pattern, slope, and ...

- Optimal density and pattern to minimize radiation to snow?



The Quest for More…

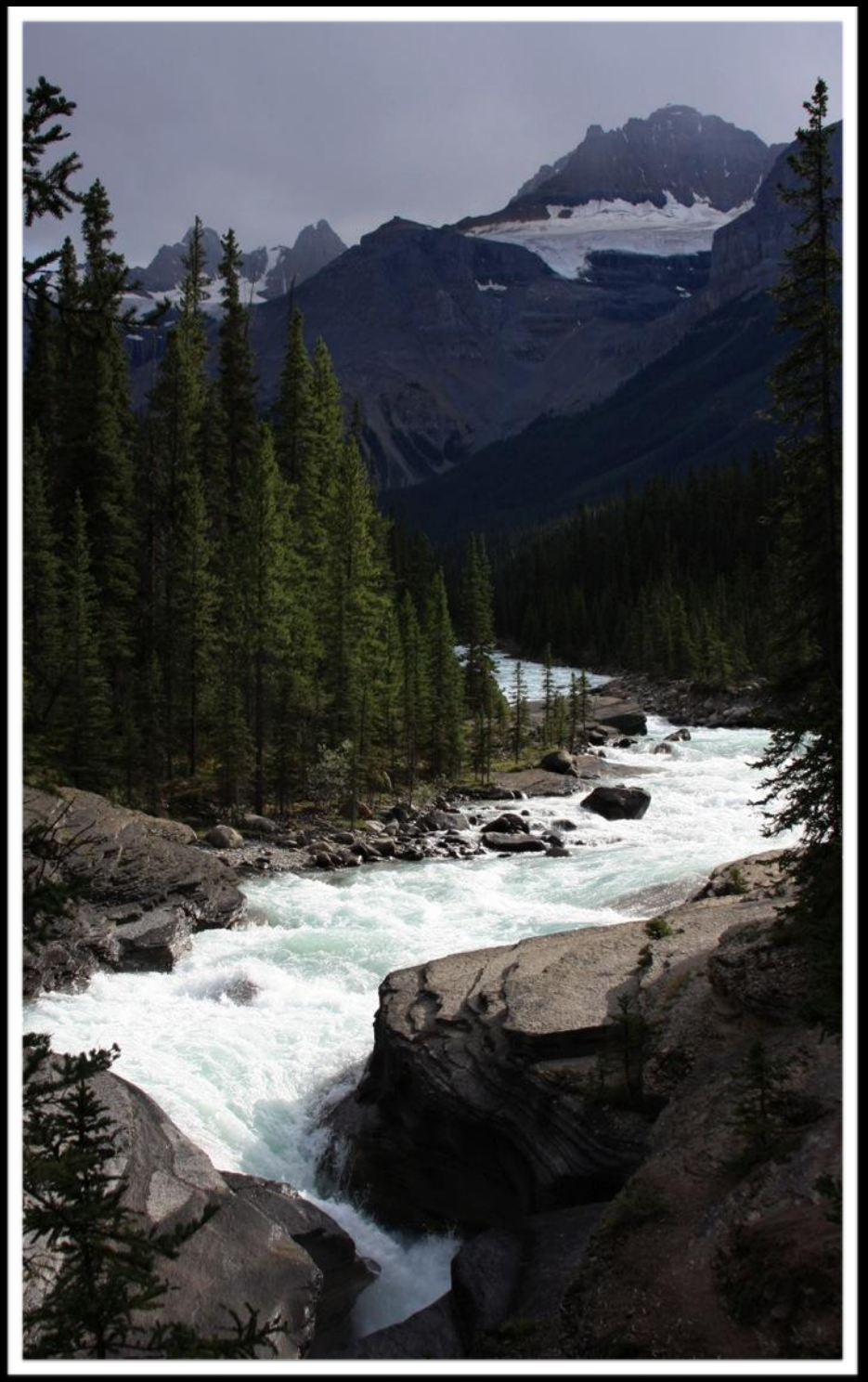
- Seasonal effects ?
  - Productive melt conditions
- Comprehensive snow energetics ?
- Climatological variability ?
  - Spatial
  - Temporal (Intra and inter-annual)
- Depositional effects ?
  - Sublimation vs. meltwater drip
  - Deportment of infiltrated water?

~1H gap

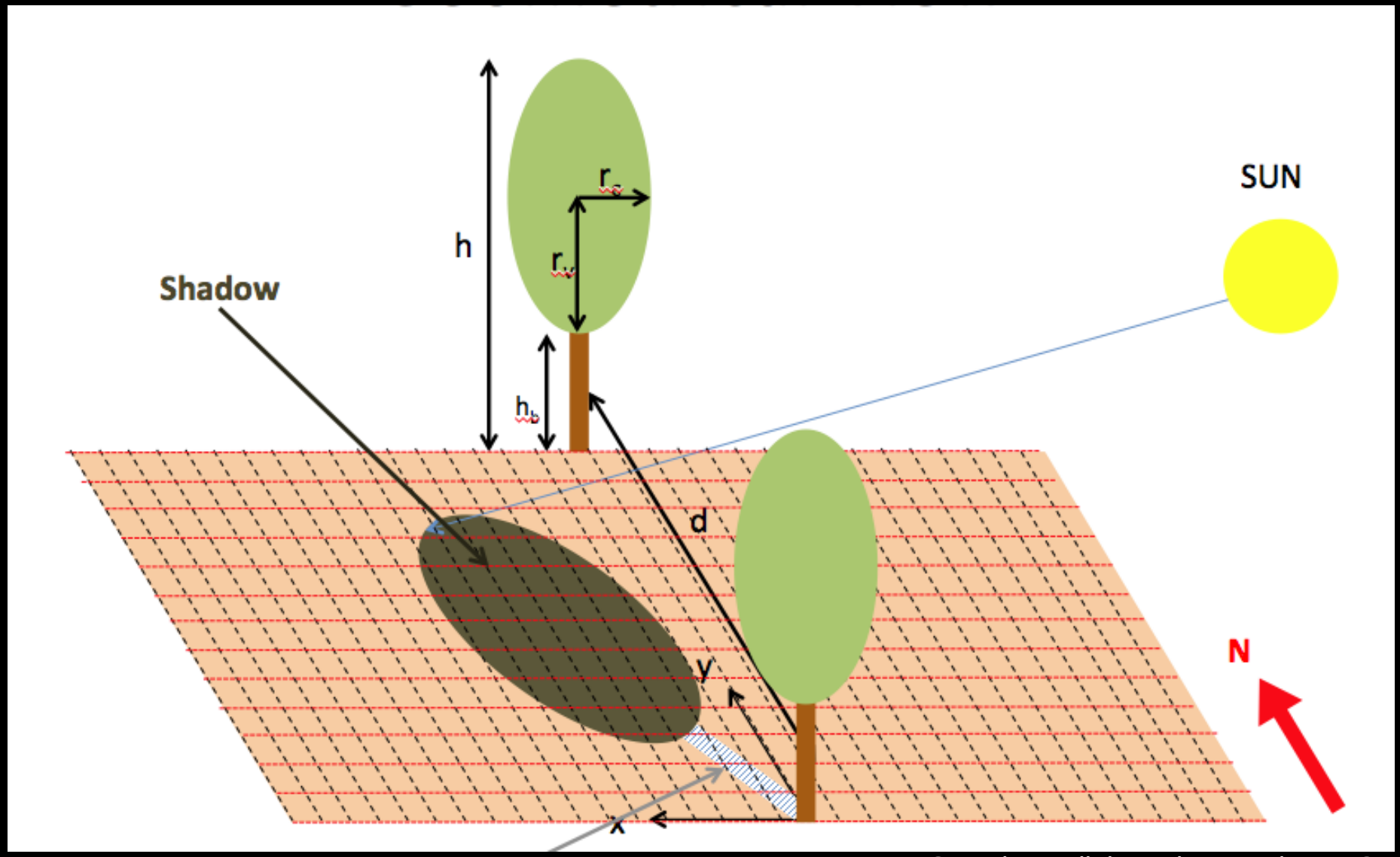
~4H gap

Thank You !

Questions ?

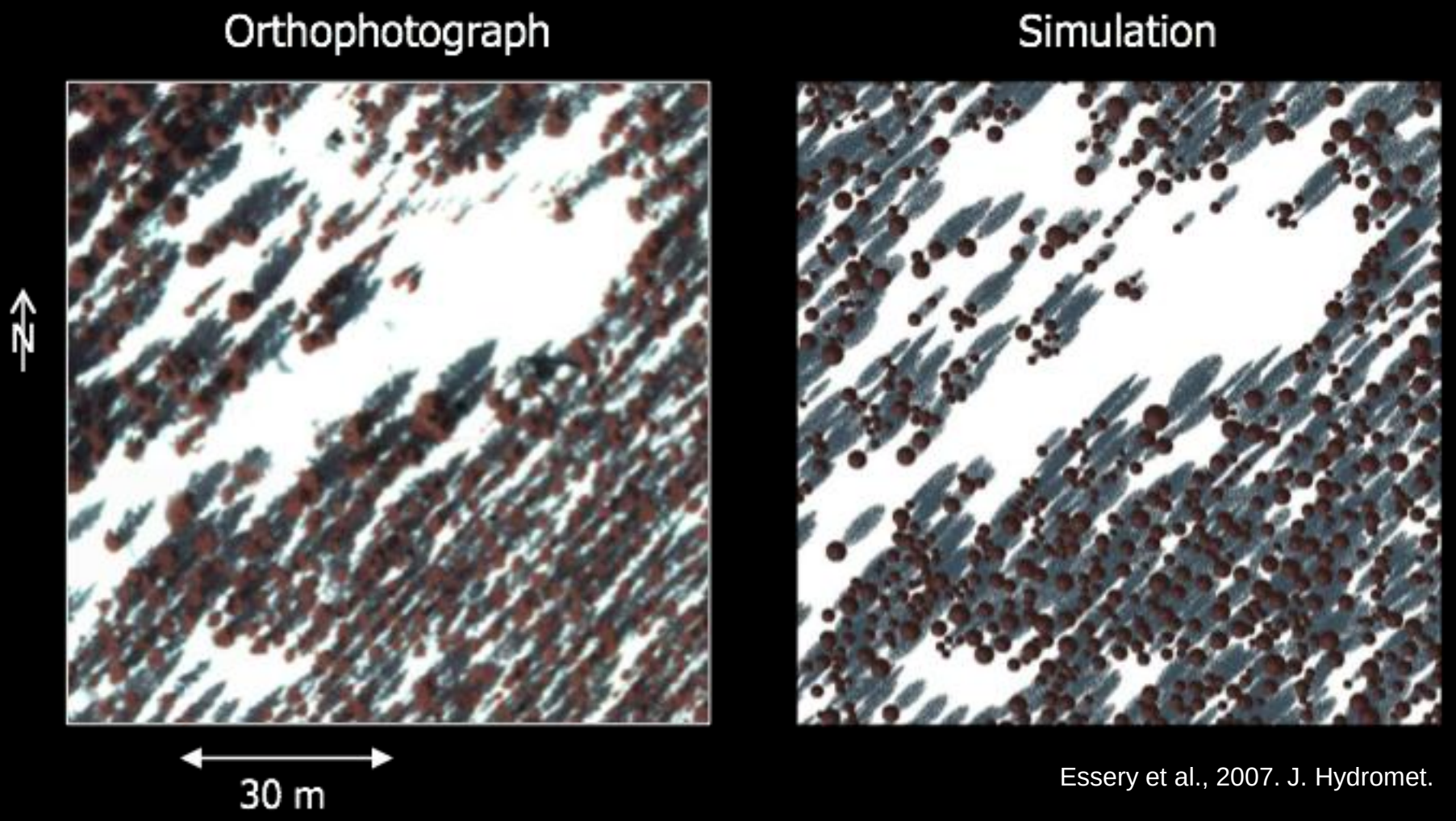


Approach: Modeling



Seyednasrollah et al., *In review*. JGR - Atmospheres.

Example Results: Discrete Tree Model



Essery et al., 2007. J. Hydromet.

In Summary...

- Forests can have higher radiation than open
  - High latitudes, mid-winter, north slopes
- Gaps can have lowest radiation amounts
  - During melt !!
  - Distinct at high latitudes
- North slopes are like high latitudes