Spatial & temporal patterns & processes controlling duff moisture content

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Duff & forest fires

- Duff consumed by smoldering combustion
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  - Distinct patterns often remain
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  - Duff moisture content primary control on consumption
Duff consumed by smoldering combustion
- Distinct patterns often remain
- Duff moisture content primary control on consumption
- Seedlings do poorly where duff remains
Duff consumption & regeneration patterns
Objectives

- Establish & model the processes controlling the duff water budget
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  - In time (dry vs. transient periods) and
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  - In time (dry vs. transient periods) and
  - space (hillslopes)
- Using both field experimentation and modeling

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Duff moisture content variation in space & time
Marmot Basin - Kananaskis, Alberta $\approx 9.6 \text{km}^2$
Transient & Dry Periods

- Two periods evident

![Graph showing moisture content variation](image.png)
Transient & Dry Periods

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  - Rapid drying within 24 hours of precipitation (Transient Periods)

![Graph showing moisture content variation](image)

Dave Keith & E.A. Johnson (keithdm@dal.ca)  Duff moisture content variation in space & time
Transient & Dry Periods

- Two periods evident
  - Rapid drying within 24 hours of precipitation (Transient Periods)
  - Diurnal drying pattern (Dry Periods)

![Graph showing moisture content variation over time](image)
Diurnal Cycles

- Diurnal cycles slow drying in the F layer (top) of the duff
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- Diurnal cycles influenced by:
  - Evaporative fluxes
  - H layer redistribution
  - Not the mineral soil disconnected from duff
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Diurnal cycles slow drying in the F layer (top) of the duff. Diurnal cycles are influenced by:

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Duff moisture content variation in space & time
Diurnal cycles slow drying in the F layer (top) of the duff

Diurnal cycles influenced by

1. Evaporative fluxes
2. H layer redistribution
3. But not the mineral soil

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Duff moisture content variation in space & time
**Diurnal Cycles**

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  2. H layer redistribution
  3. But not the mineral soil
- Disconnected from duff
Modeling Diurnal Cycles

- Used a coupled heat and mass transfer model (TOUGH2 - Pruess 1999)
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- Overall mass balance
  \[
  \frac{d}{dt} \int_{V_n} M dV_n = \int_{\Gamma_n} m \cdot n d\Gamma_n + \int_{V_n} \nu dV_n \quad (1)
  \]
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$$\frac{d}{dt} \int_{V_n} M dV_n = \int_{\Gamma_n} m \cdot n d\Gamma_n + \int_{V_n} \nu dV_n \quad (1)$$

- Overall energy balance

$$\frac{d}{dt} \int_{V_n} Q dV_n = \int_{\Gamma_n} q \cdot n d\Gamma_n + \int_{V_n} \omega dV_n \quad (2)$$
Diurnal Model Results

- The 1-D model captured the dynamics
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- Closely simulates actual conditions
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  - Reproduces the cycles well both in size and timing

[Diagrams showing model results]

Dave Keith & E.A. Johnson (keithdm@dal.ca)  Duff moisture content variation in space & time
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![Diurnal Model Results Graphs]

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Duff moisture content variation in space & time
Diurnal Model Results

- The 1-D model captured the dynamics
  - Closely simulates actual conditions
  - Reproduces the cycles well both in size and timing
  - Cycles and drying driven by evaporative forcing
  - Due to coupled transport of liquid and vapor between F and H layer

![Graph showing model results](image)
Rapid Redistibution

- Rapid movement during and immediately following rainfall

![Graph showing rainfall and moisture content over time.](image)
Rapid Redistribution

- Rapid movement during and immediately following rainfall
- Results in spatial patterns across some hillslopes

![Graph showing moisture content variation over time](image-url)
Hillslopes

- Two experimental hillslopes

Two experimental hillslopes:

- One spruce, one pine
- Twenty transects sampled
- ≈ weekly from June-September

Detailed spatial and temporal moisture content

F layer

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Duff moisture content variation in space & time
Hillslope Processes

- Processes appear to differ between hillslopes
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  - Hillslope "shape" (convergent versus divergent)

![Graph of Duff moisture content variation in space & time](image.png)
Hillslope Processes

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- Spruce hillslope
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- Pine hillslope
Hillslope Processes

- Processes appear to differ between hillslopes
  - Spruce hillslope
    - Hillslope “shape” (convergent versus divergent)
  - Pine hillslope
    - Solar Radiation best correlate
Canopy Influence

- Interception major impact spatially
Canopy Influence

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- Patterns hold throughout the season

![Graph showing moisture content variation over time with open and under canopy conditions.](image)
Canopy Influence

- Interception major impact spatially
- Patterns hold throughout the season
- Pattern similar between hillslopes

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Duff moisture content variation in space & time
Hillslope Model

- Simple model hillslope

![3D model of hillslope](image)
Hillslope Model

- Simple model hillslope
- Convergent and divergent regions
Hillslope Model

- Simple model hillslope
- Convergent and divergent regions
- Regularly spaced canopy

Duff moisture content variation in space & time
Hillslope Model Results

- Results consistent with field
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- Hillslope shape matters

![Graph showing moisture content variation over time](image-url)
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A tale of 2 seasons

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  - Shows rapid redistribution able to recreate pattern
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Short rapid redistribution results in hillslope patterns
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Canopy is the a major influence on duff moisture content

Simple model hillslope
- Shows rapid redistribution able to recreate pattern
- Shows canopy cover also has a large affect
Thank You, Merci

- Family, friends, foes, and field flunkies who’ve helped with this research
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