Linking Hydrology and Vegetation Dynamics in the Southern Boreal Forest

Omer Yetemen\textsuperscript{1}, Andrew Ireson\textsuperscript{1}, Jill Johnstone\textsuperscript{1,2} and Alan G. Barr\textsuperscript{3}

\textsuperscript{1}. Global Institute for Water Security, University of Saskatchewan
\textsuperscript{2}. Department of Biology, University of Saskatchewan
\textsuperscript{3}. Environment Canada
Outline:

- Research questions
- Observations from the southern boreal forest
  - Stand-level
  - Hillslope-scale
  - Ecozone-level
- CLASS-CTEM modeling framework
Research Questions:

- How will climate change (changes in temperature and moisture) alter the vegetation dynamics of the southern boreal forest?
- What will be the role of hydrology in mediating change?
- What will be the controlling ecohydrologic processes at stand, hillslope-landscape, and ecozone scales?
Observations from the southern boreal forest:

- What are the ecohydrologic characteristics of the southern boreal forest? *Does scale matter?*
  - Stand-level
  - Hillslope-scale
  - Ecozone-level
Stand-level: Interannual Variability

Flux towers shows:

- Wet year fosters growth indicates **water limitation**
- Vegetation *responds* to drought or wet years *differently*.

*Zha et al., 2013*
Local topography and geology:
- Defines soil texture and drainage.
- Constrains the vegetation mosaic.

Hillslope-scale: Vegetation Pattern

Glacial till deposits

- High ET
- Moderate ET
- High ET

Lowland
- Coniferous canopy
- Precipitation feeds wetlands
- Shallow soil drainage to deep water table
- Wetlands feed local GW

Upland
- Deciduous canopy
- Clay rich soil with preferential flow paths
- Shallow water table

Fen/bog

Potential transmissive zone with episodic lateral flow
Shallow GW with negligible flow

Glaciofluvial deposits

- Low ET
- Moderate ET
- High ET

Lowland
- Coniferous canopy
- GW feeds wetlands
- Wetlands may drain to stream network

Upland
- Coniferous canopy
- Shallow soil over sand
- High soil drainage to fen

Deep, fast, sustained GW flow

Ireson et al., in preparation
Ecozone-level: Vegetation Distribution

The ecotone in western Canada is:

- Coincident with the P-PET isolines (CMI)
- Makes it sensitive to climate change.

\[ CMI = P - PET \]

**Climate Moisture Index (cm)**

**Precipitation**

**Pot. Evapotranspiration**

*Hogg, 1994*
Addressing Research Questions:

- How will climate change (changes in temperature and moisture) alter the vegetation dynamics of the southern boreal forest?
- What will be the role of hydrology in mediating change?
- What will be the controlling ecohydrologic processes at stand, hillslope-landscape, and ecozone scales?
CLASS – CTEM Modelling Framework: Carbon, water and energy cycles

**Carbon, energy, water balances**

- Albedo and transmittivity calculations
- Photosynthesis, leaf respiration, and canopy conductance
- Surface energy and water balance
- Soil heat and moisture dynamics

**Canopy conductance**

\[ \Delta t = 30 \text{ minutes} \]

**CLASS**

- Autotrophic respiration
- Heterotrophic respiration
- Phenology
- Turnover, Mortality
- Allocation
- Fire
- Conversion of biomass to structural attributes
- Competition between PFTs
- Land use change

\[ \Delta t = 1 \text{ day} \]

**CTEM**

**Arora, 2002**

Carbon, energy, and water balance in CTEM
- Seasonal phenology
- Interannual variations
- Species-specific stress effects

Verseghy and Arora, Environment Canada

www.usask.ca/water
## Competition Among Plant Functional Types

200-yr run for a boreal forest in Siberia:

<table>
<thead>
<tr>
<th>PFT</th>
<th>Observation (%)</th>
<th>CTEM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle leaf Evergreen</td>
<td>9.1</td>
<td>5.05</td>
</tr>
<tr>
<td>Needle leaf Deciduous</td>
<td>64.5</td>
<td>53.7</td>
</tr>
<tr>
<td>Broadleaf Deciduous Cold</td>
<td>5.0</td>
<td>4.3</td>
</tr>
<tr>
<td>C3 Grass</td>
<td>10.95</td>
<td>28.2</td>
</tr>
<tr>
<td>Bare</td>
<td>9.75</td>
<td>8.7</td>
</tr>
</tbody>
</table>

*Arora and Boer, 2006*
References


Water means the WORLD to Us...

University of Saskatchewan
Global Institute for Water Security
www.usask.ca/water