Breakage of branches from experimental freezing rain

A new toolkit for understanding freezing rain effects on forests

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Chaire CRSNG/Hydro-Québec sur le contrôle de la croissance des arbres

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WIND
VEND


SNOW
NEIGE

ICE VERGLAS

- Strongly influence community dynamics in eastern North American forests

- Cause catastrophic damage to important human infrastructure

Context: NSCERC-Hydro-Québec Chaire research goals

- Reduce conflicts between trees and infrastructure

- Increase knowledge of tree biomechanics (stress, strain) and methods of pruning (reduce probability of failure)

Le problème avec les approches a ce jour: event driven research

- The problem of rare and influential events (e.g. ice storms, severe droughts)
- “natural experiments” or “event-based” research--ranks of species susceptibility (% canopy removed)
- No study has reported *In situ* measurements of the driver – ice thickness
- Post-storm, cannot know ice thickness~branch break.
- E.g. 5 cm freezing rain (reported), species *A* suffers damage at 4 cm, species *B* at 2 cm. Ice rapidly melts.
- In the field? Return times for moderate to severe events are generally long (e.g. 4 cm, 1 in 20 years, Greene et al 2007).
- Thus, experimental approach

Questions de Recherche

- How can we measure ice on branches in tall canopies?
- How does ice thickness (load) vary along the length of the branches or position in canopy?
- Can we use voxels to relate canopy structure to ice thickness (load)?
- How can we model the stress of ice on branches?

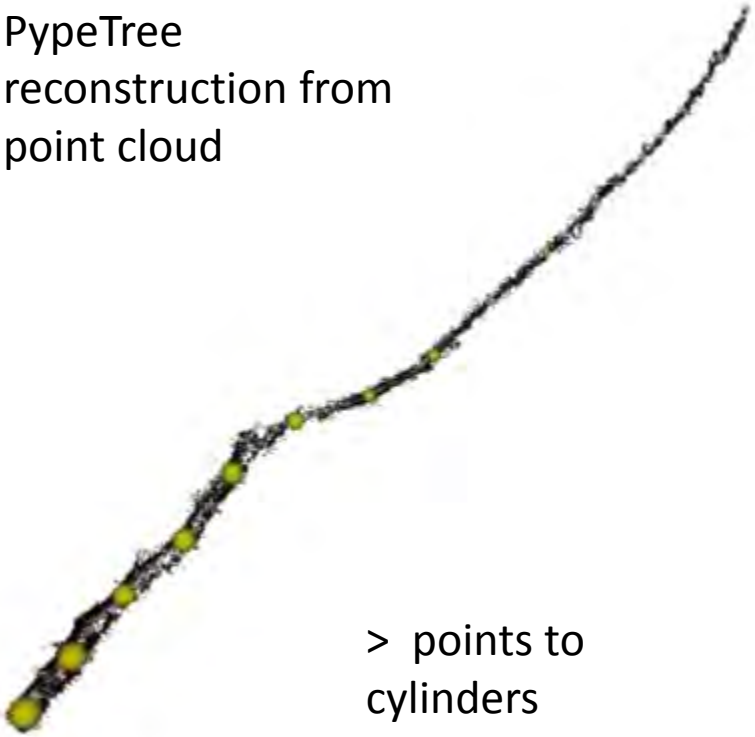
Méthod

How can we measure ice on branches in tall canopies?

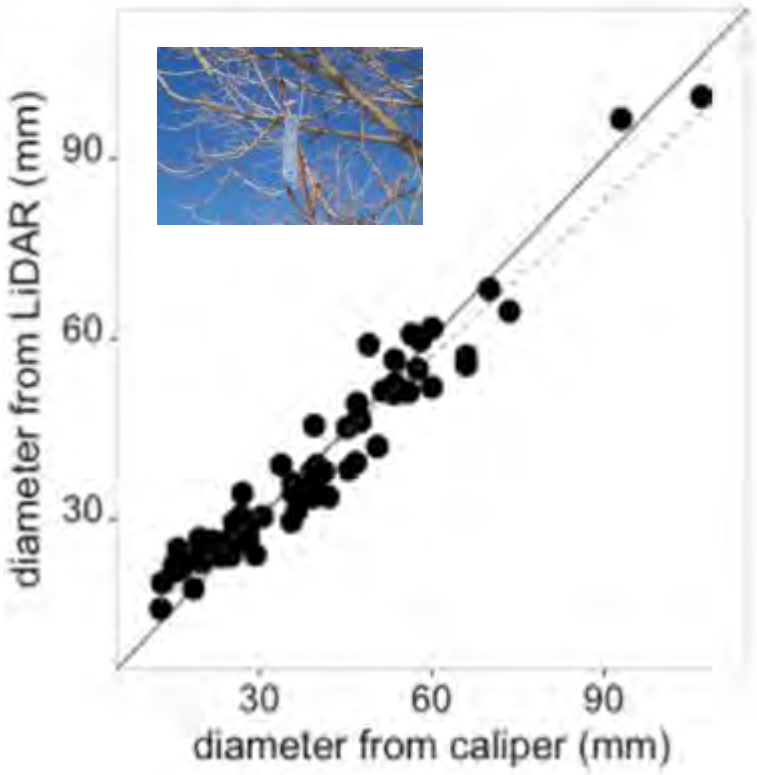
Résultats – *lidar et verglas*

How can we measure ice on branches in tall canopies?

PypeTree reconstruction from point cloud



> points to cylinders

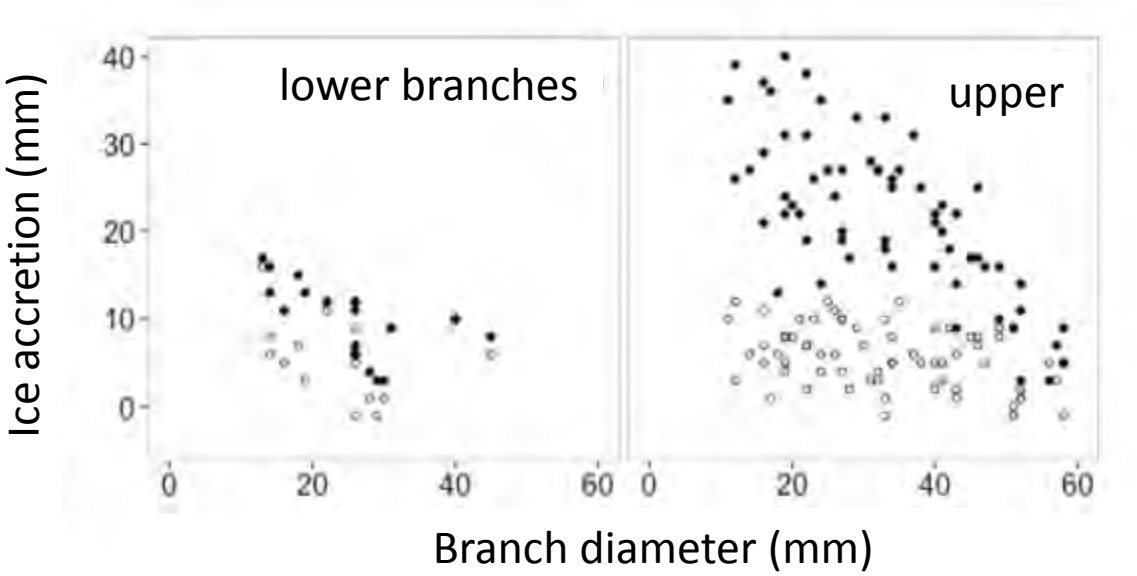


Nock et al. 2013. Plos One, In press

Résultats – *distribution de verglas*

How does ice thickness (load) vary along the length of branches or with position in canopy?

Strong variation: top to bottom and inside to out

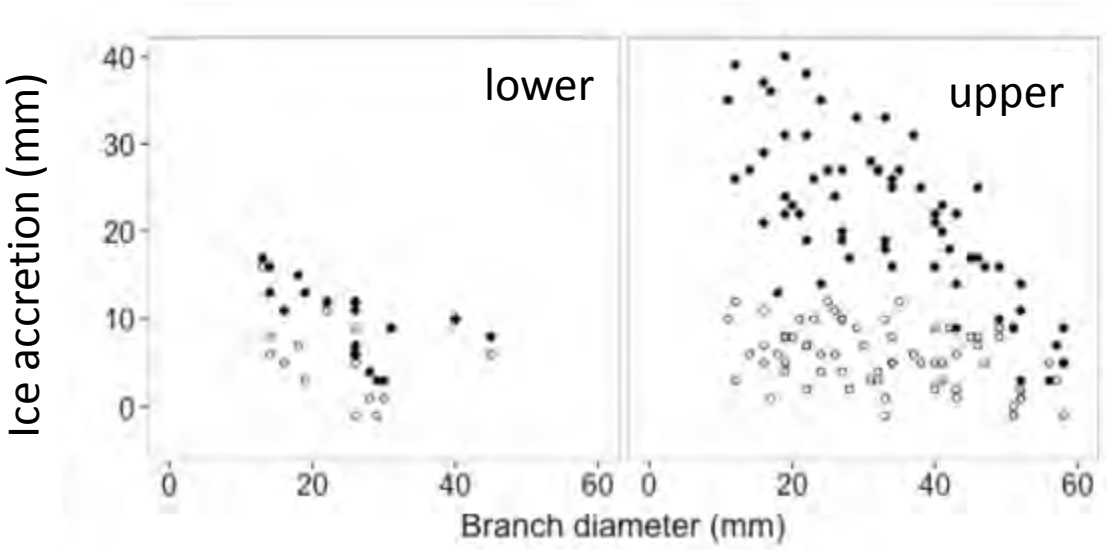


Hollow = after 2.5 hr
Solid = after 6.5 hr

Résultats – *distribution de glas*

Can we use voxels to relate canopy structure to ice thickness (load)?

- linking crown structure to ice accretion – voxels (3D pixel)



B. Lecigne (R-code)

Résultats – *distribution de verglas*

Pre-verglas

Voxels as a proxy of branch area index

Angle = 10°

Angle = 20°

Angle = 60°

Méthods - 2

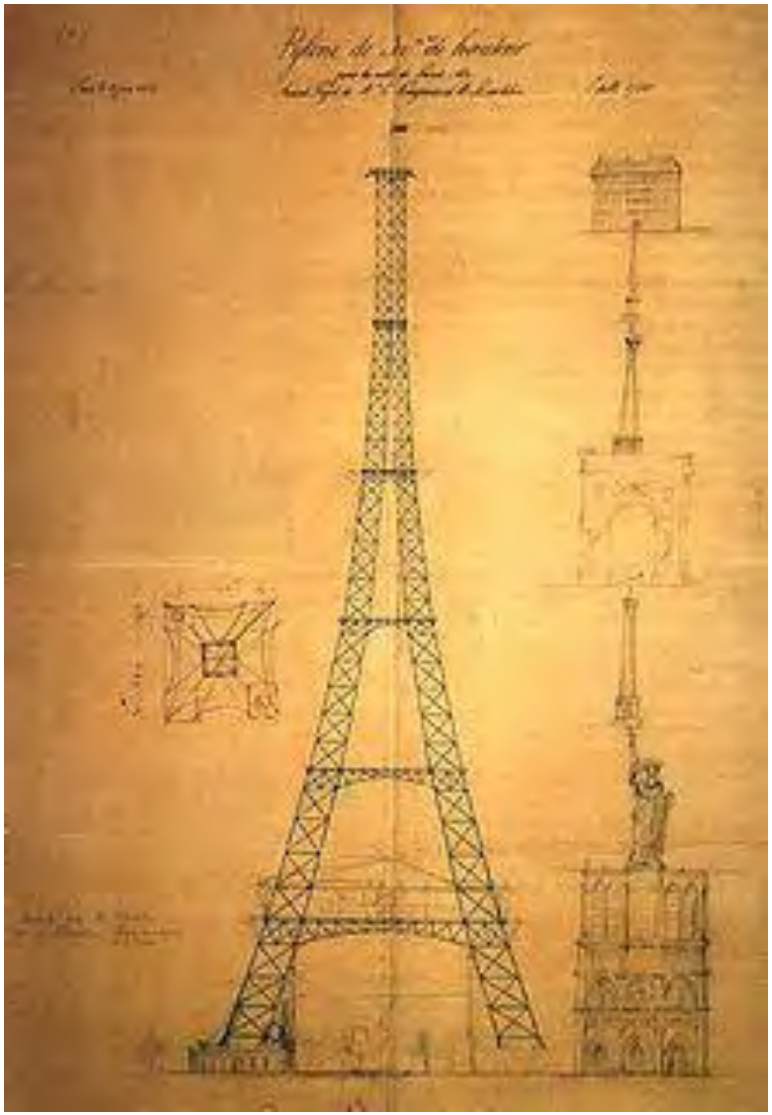
How can we model the stress of ice on branches?

Structural Analysis

Structure: something designed and built to carry loads and resist forces

Analysis of structures: determination of *internal stresses* and *displacements*

- Geometry (segments, angles, coordinates)
- Loads, reactions and stresses
- Material properties (e.g. MOE)



Euler–Bernoulli beam theory (c. 1900)

Methods - 2

Structural Analysis

Analysis of structures: determination of *internal stresses* and *displacements*

- Loads, reactions and stresses (point, distributed)
- Matrix transfer method for large displacements (big problem = many little problems)

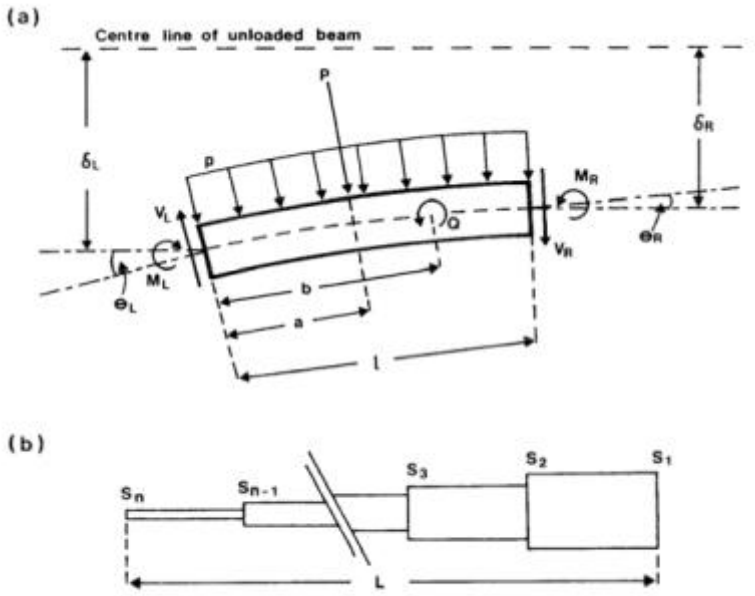


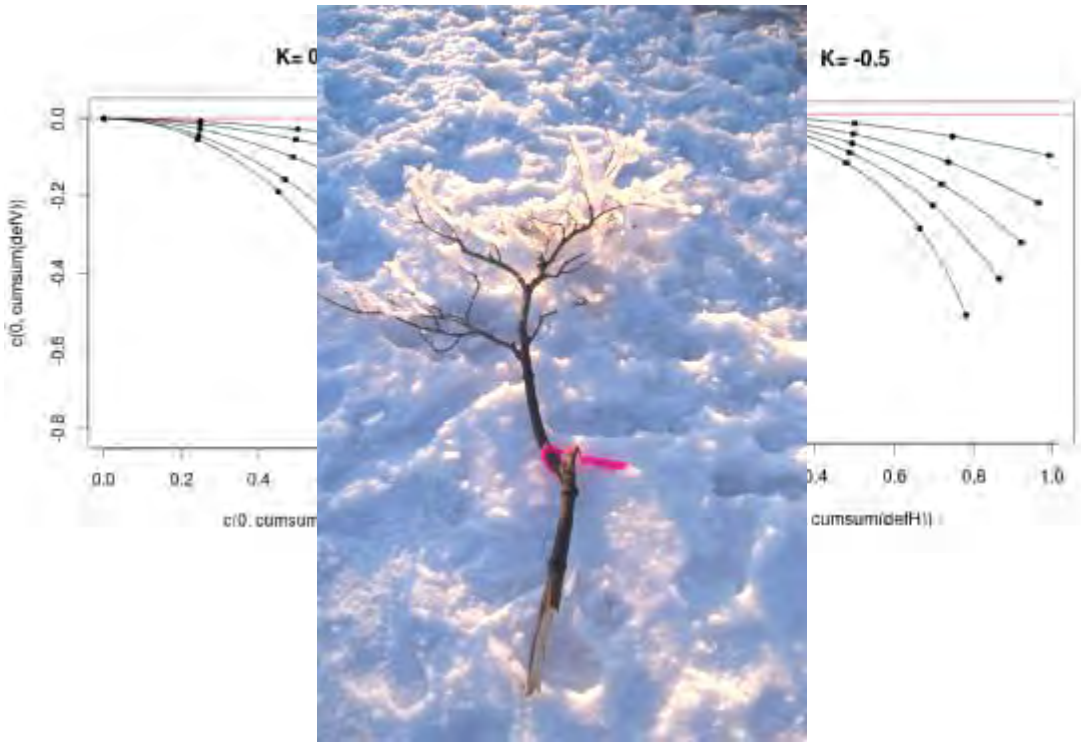
Figure 1. (a) A segment of a beam, shown in relation to the position of a segment of an unloaded beam. (b) A series of segments, approximating a tapered beam. See definitions in Table 1.

$$\begin{bmatrix} 1 \\ V_L \\ M_L \\ -\theta_L \\ -\delta_L \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ F_1 & 1 & 0 & 0 & 0 \\ F_2 & -l & 1 & 0 & 0 \\ F_3 & l^2/2EI & -l/EI & 1 & 0 \\ F_4 & -l^3/6EI & l^2/2EI & -l & 1 \end{bmatrix} \begin{bmatrix} 1 \\ V_R \\ M_R \\ -\theta_R \\ -\delta_R \end{bmatrix}$$

Jan. J. Tuma 1969
Cannel and Morgan 1987

Résultats – *modeling branch stresses*

A model for large deflections with taper, lateral branches, self-loading and an ice load with varying thickness



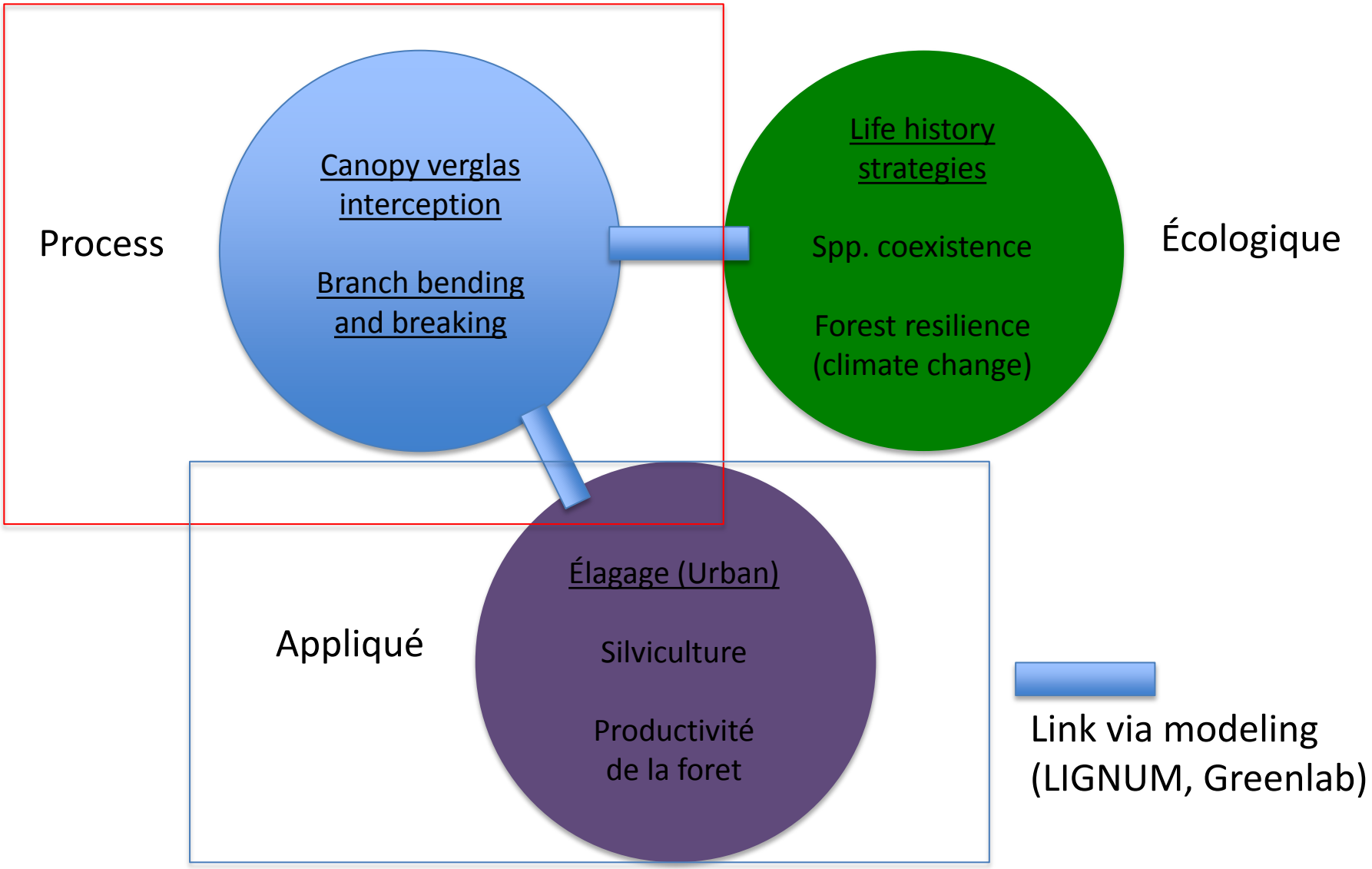
O. Taugourdeau: R-code

Original model: Cannel and Morgan 1987

Conclusions

- Terrestrial LiDAR: accurate estimate of branch diameter and of ice coating.
- Ice accretion: variation in thickness as a function of branch diameter (position in crown) > cannot simply extrapolate reported ice thickness to tree crowns
- Matrix method provides suitable model (laterals, varying ice load)
- Next steps: estimate load for broken branches (model vs. empirical), play with branch properties to explore effect on stress

Verglas - *perspectives*



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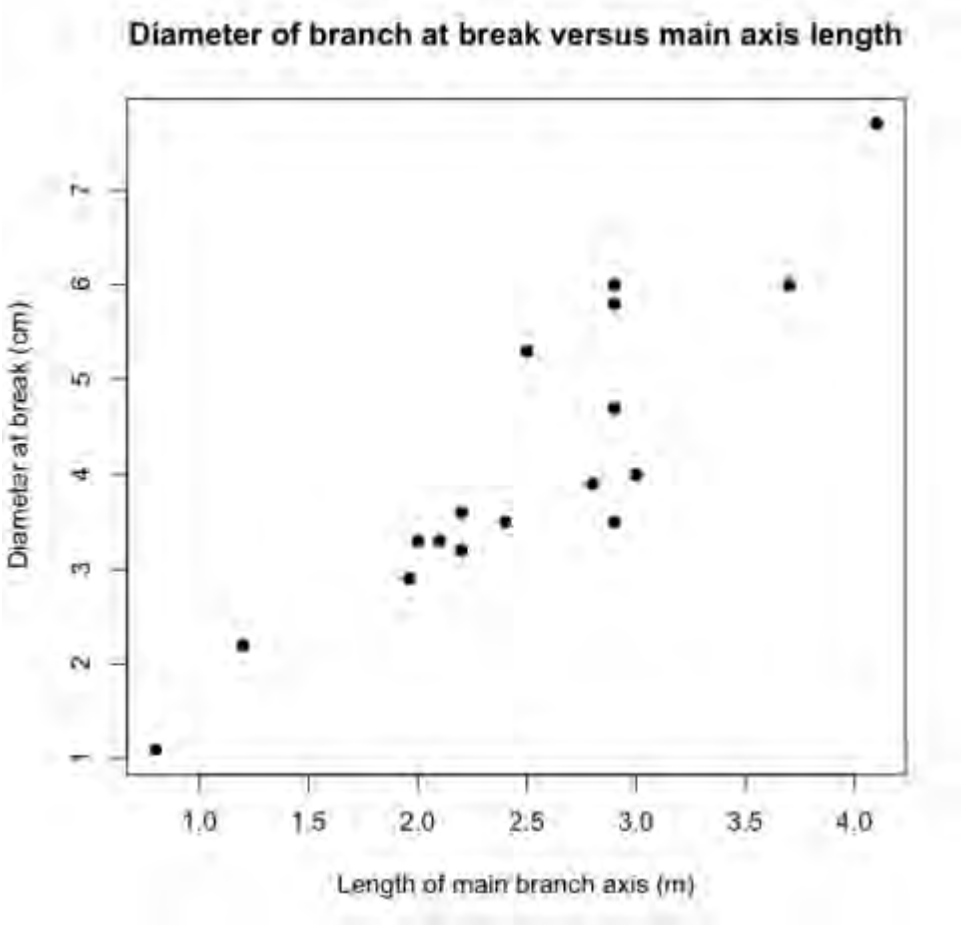
Questions?

Resultats



Branches that did not break need to be added,

Ice storms

t-shirt sold in the Ottawa area c. 1998

- Urban areas
- Example 1998: 3 - 5 cm thick of ice
- Health and well-being & $$ natural disaster in Canada. Branches + power lines
- Central theme of NSERC-Hydro Quebec Chaire: reduce conflicts btw. trees and infrastructure
- To do do: better understand how trees respond to ice loading (ice accretion and biomechanics)