Soil effects on plant distributions and potential migration in Eastern North America

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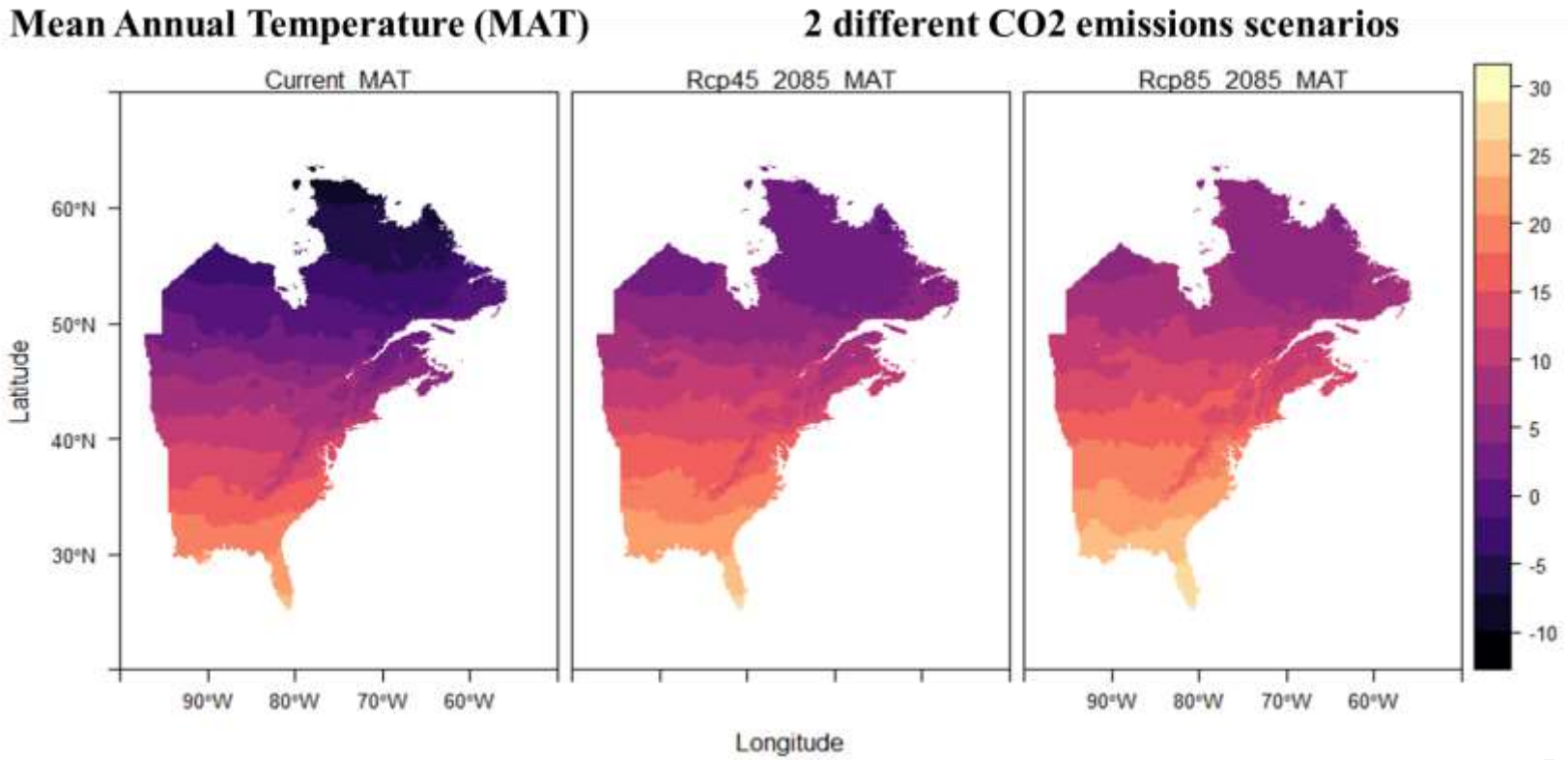
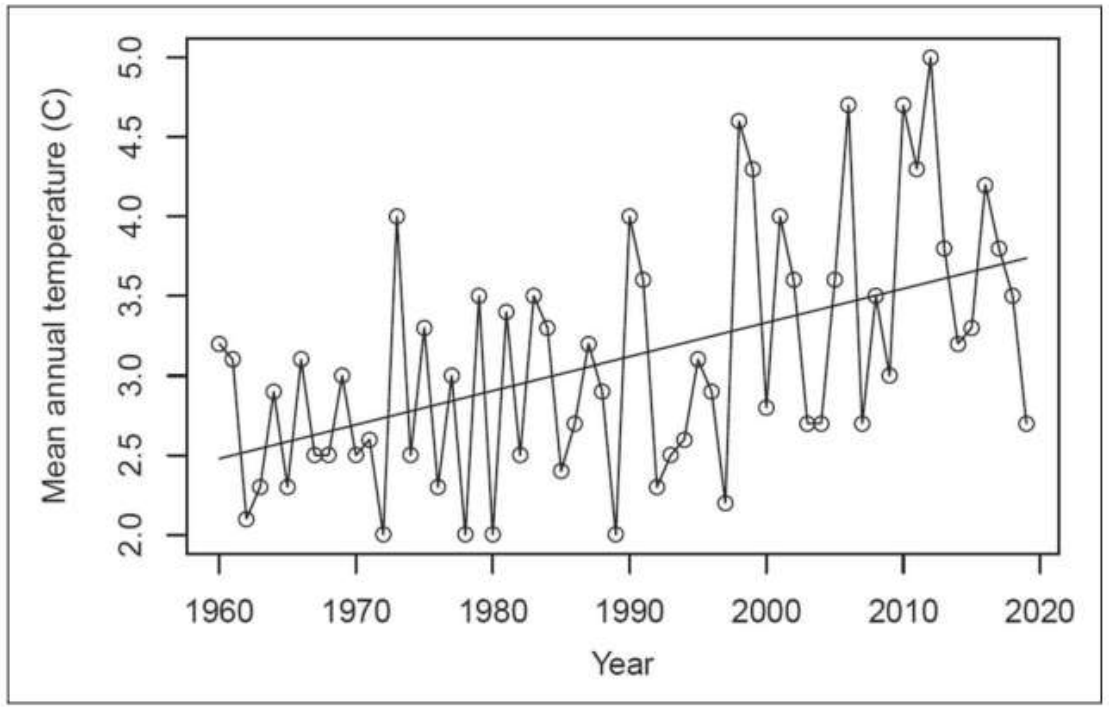
Background - climate warming



Data from *AdaptWest Project* (2015)

In Eastern North America, temperature is projected to increase between **4 and 8 °C** by the end of 21st century.

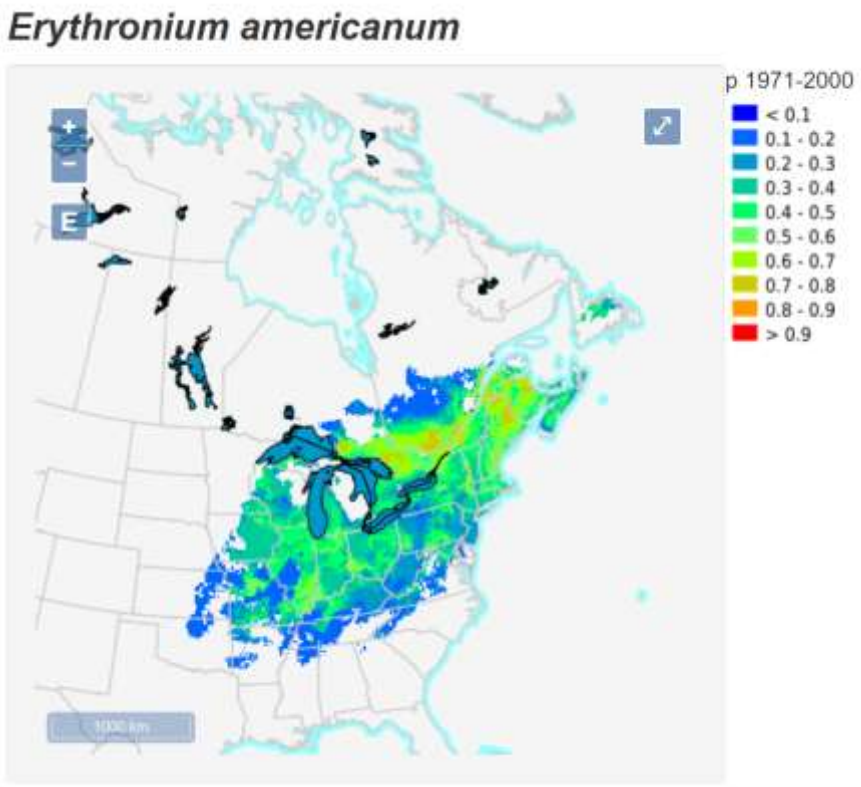
Background - climate warming



Change in mean annual temperature in
Parc national du Mont Mégantic, Québec

Projecting distributions

Current suitable habitat



Future suitable habitat under climate change

Use **Species Distribution Models** (SDMs) to project current and future suitable habitats: Climate-only Models are mostly used!

Map from *Natural Resources Canada*

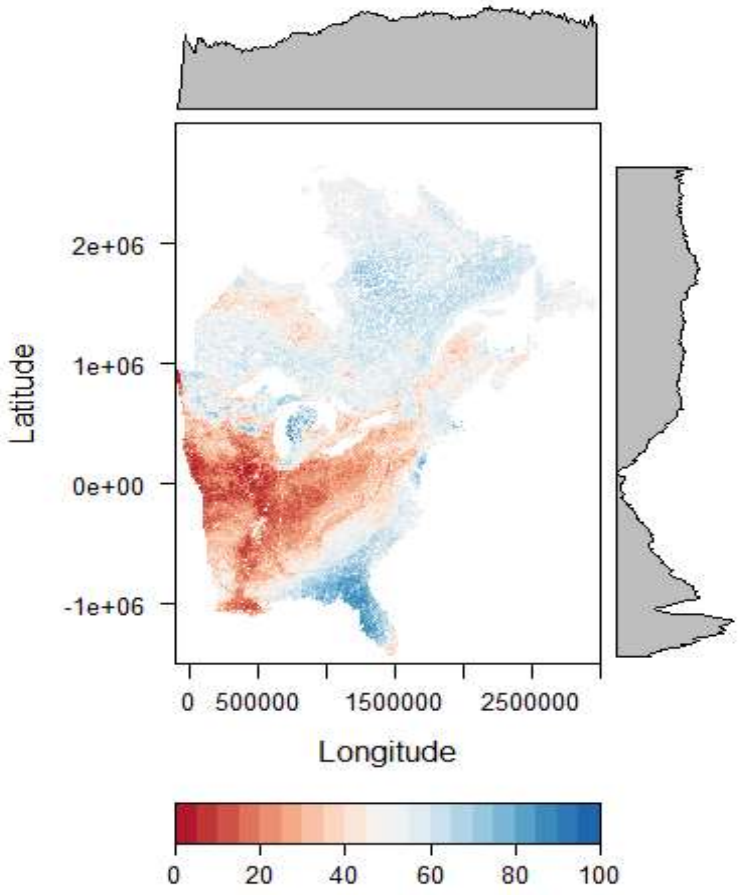
Projecting distributions

But can Trout Lily inhabit in Conifer forest and Tundra?

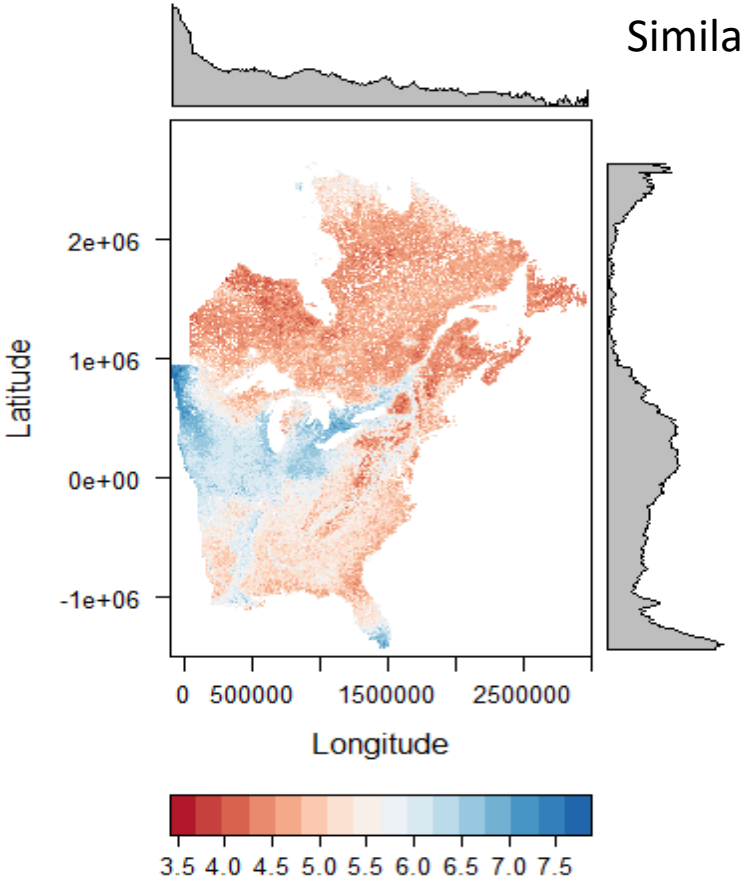
Figure from *OneEarth* and *Wikipedia*

Latitudinal changes in soil properties

Similar pattern in Moutain



Saturated water content (%)



Soil pH

Data from Soilgrid2

Questions

1. How do soil properties influence plant current distributions at climate gradients (latitudes/elevation) ?

2. How do soil properties influence the future ranges of plant suitable habitats under climate change?

Latitudinal gradient – Species distribution models

Species data:

- **1870 species** from Botanical Information and Ecology Network (BIEN)
- Growth form
- Habitat type

Environmental data (250m×250m):

Climate (interpolated form **ClimateNA**):

- Mean annual temperature
- Mean annual relative humidity
- Summer heat moisture index

Soil (from **Soilgrid**):

- Soil pH
- Coarse fragment content
- Absolute soil depth
- Soil depth to R horizon
- Cumulative Histosol content
- Saturated water content
- Sodic grade
- Soil order

BIEN

Centre for Forest Conservation Genetics •CFCG•

ClimateNA_MAP

-- An Interactive Platform for Visualization and Data Access

ISRIC World Soil Information

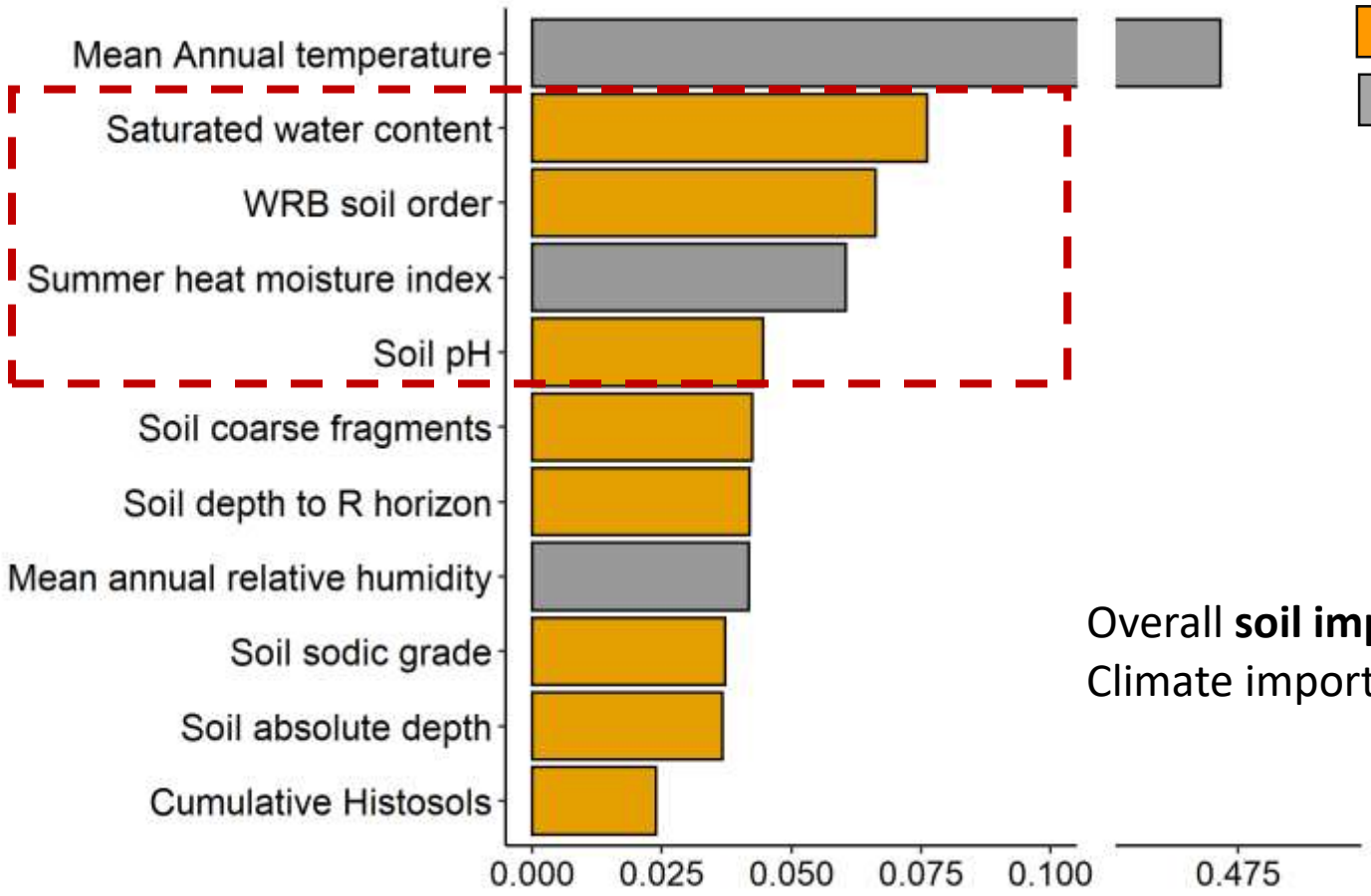
Latitudinal gradient – Species distribution models

1. Climate-only model: $SDM_{climate}$ Probability (presence) ~ Three Climate Variables

2. Climate+soil model: SDM_{sc} Probability (presence) ~ Three Climate Variables + Eight soil variables

Projection: **Current climate**; **Future climate** (end of 21th century) – RCP 4.5, 8.5

Results and discussion – soil effects

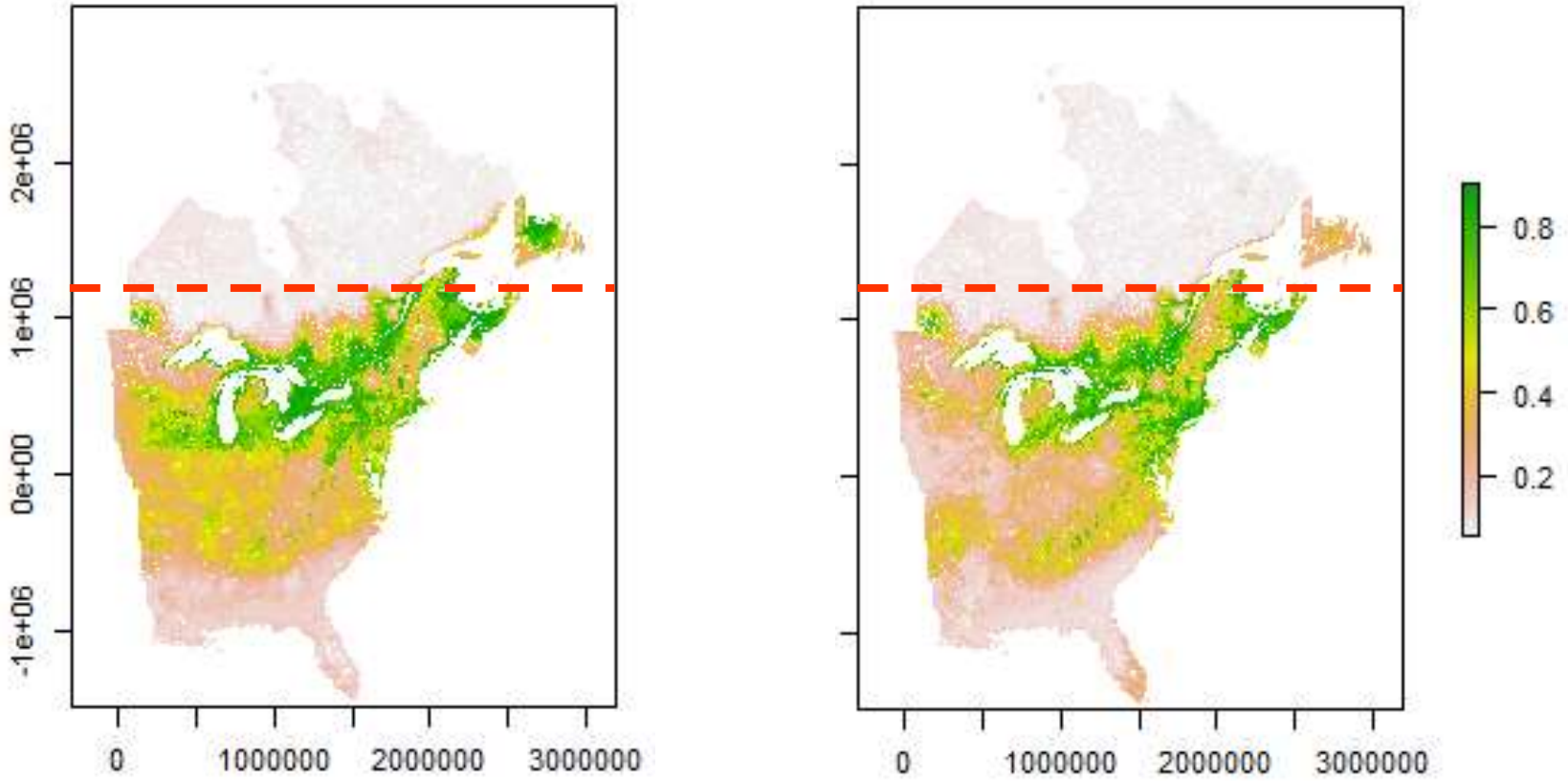


Overall **soil importance** = 0.369
Climate importance = 0.573

Variable relative importance in Climate + Soil model

Model projection - *Erythronium americanum*

Current climate



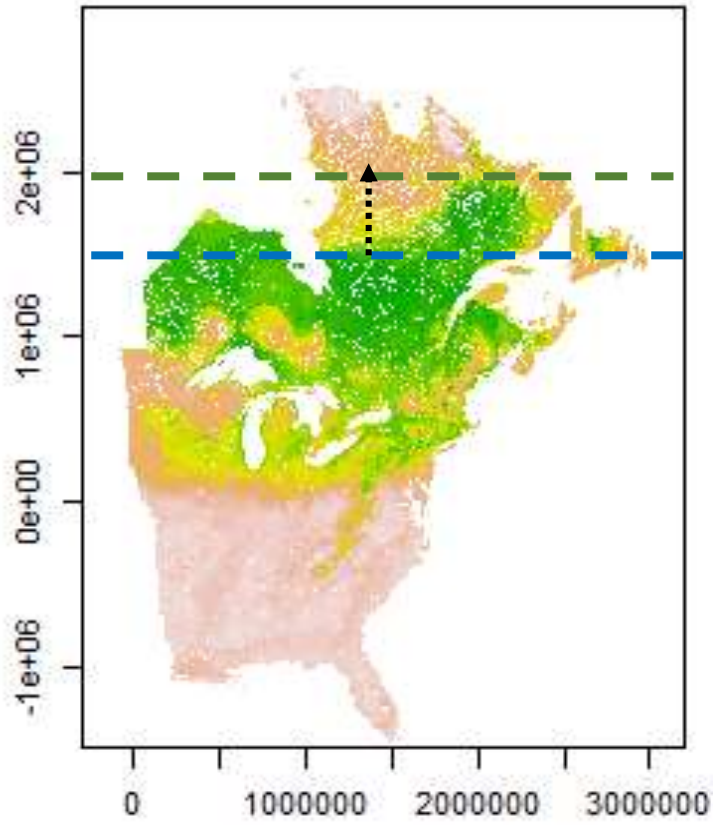
Climate-only model

Climate + Soil model

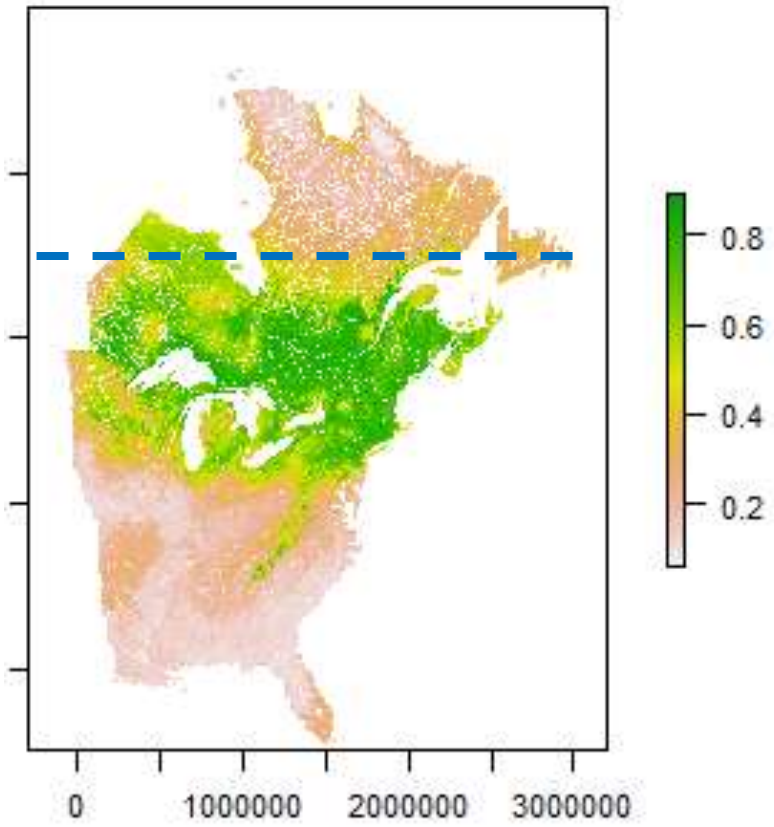
Projected northern range limit

Model projection - *Erythronium americanum*

Future climate RCP 8.5

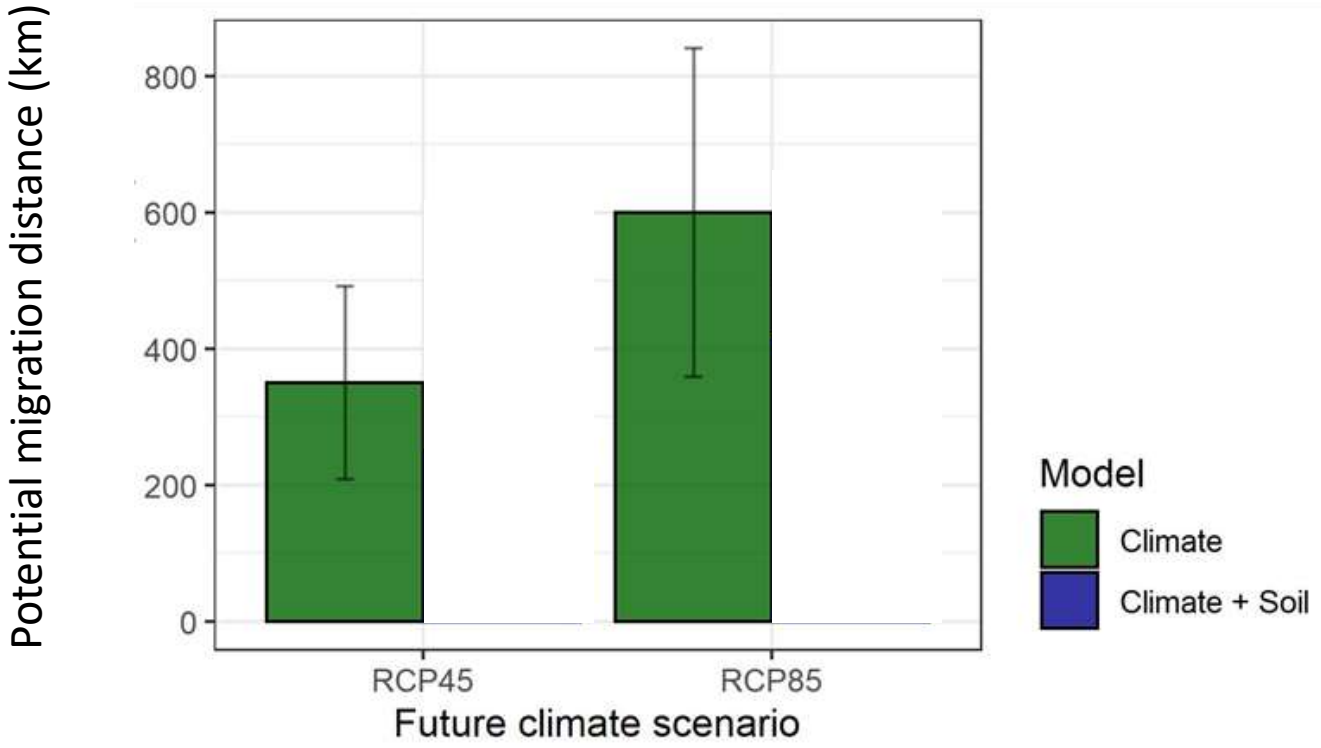


Climate-only model



Climate + Soil model

Potential migration in northern range limit



Potential migration distance:

future northern range limit – current northern range limit

Elevational gradient - background

Some drawbacks in the **latitudinal study**:

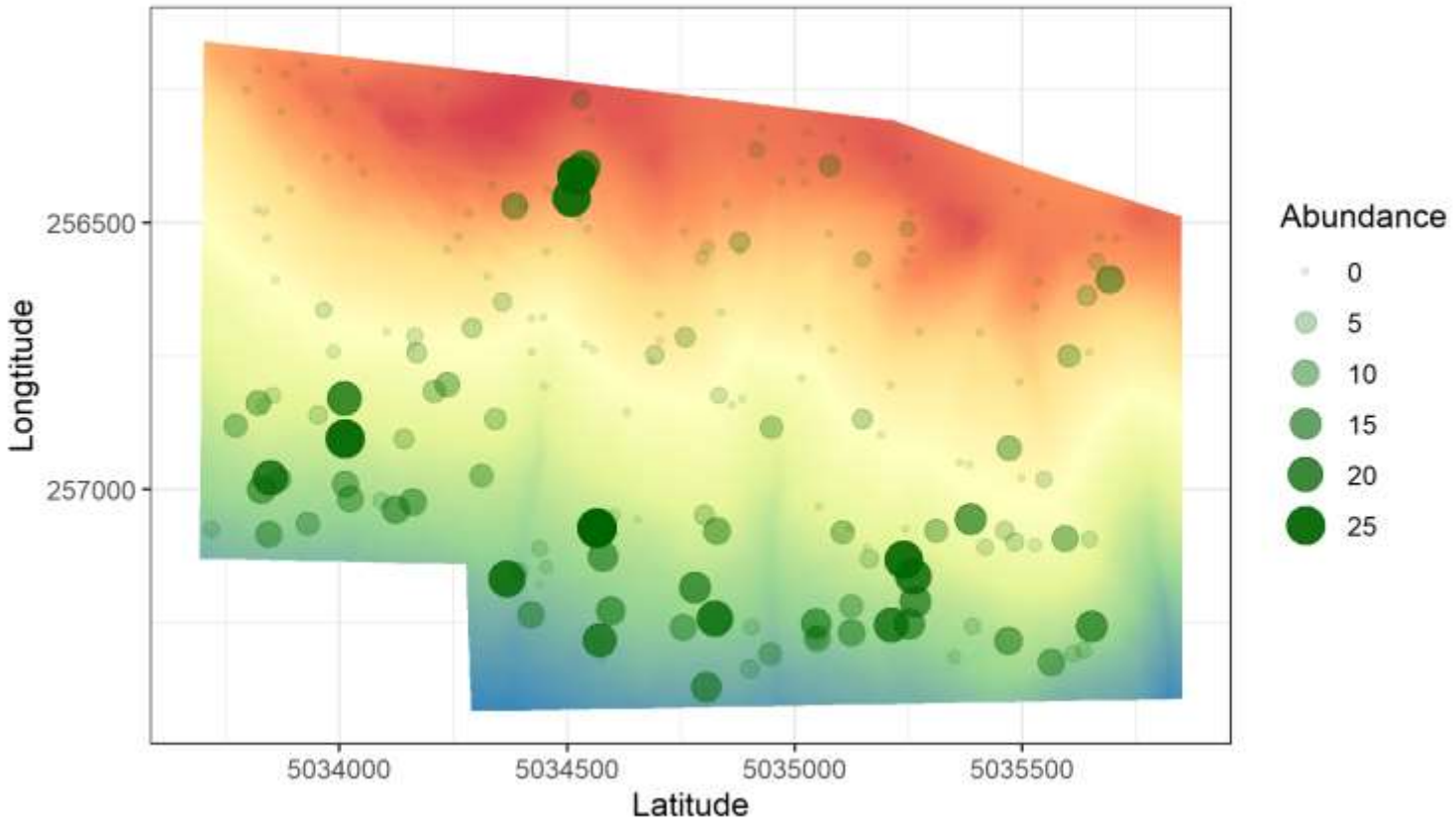
- Coarse resolution of soil data (resolution: 250m*250m);
- Species data: Only-presence, no absence or abundance information;

Mont Saint-Joseph in
Parc national du Mont Mégantic, Québec

Elevational gradient: **an intensive sampling** (about 180 plots) of four early spring understory herbs, and **soil properties – pH, nutrient, depth, moisture** etc.

Elevational distributions of spring ephemerals

Trillium erectrum



Hurdle Model

$$\begin{cases} Y_i \sim \textbf{Binomial}\ (1, \boldsymbol{p_i}) & Y_i = 0/1 \quad \textbf{Occurrence} \\ Y_i \sim \textbf{TruncatedNB}\ (\boldsymbol{\mu_i}, k) & Y_i > 0 \quad \textbf{Abundance} \end{cases}$$

$$\text{logit}\ (p_i) = \mathbf{X_i\beta}$$

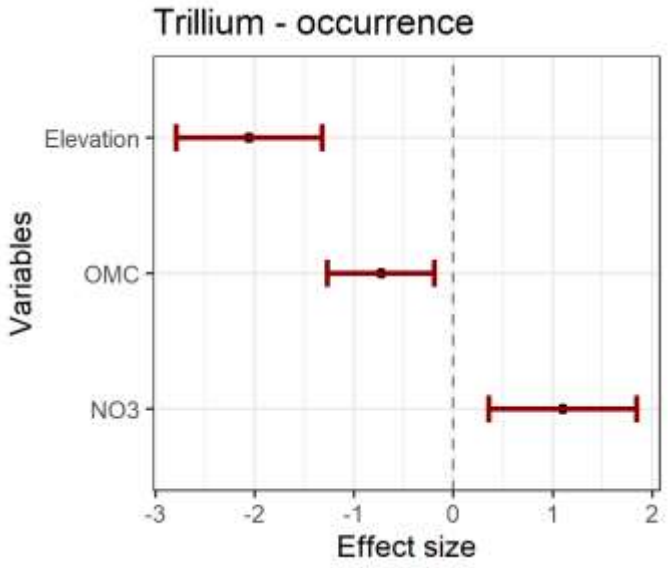
$$\log(\mu_i) = \mathbf{X_i\beta}$$

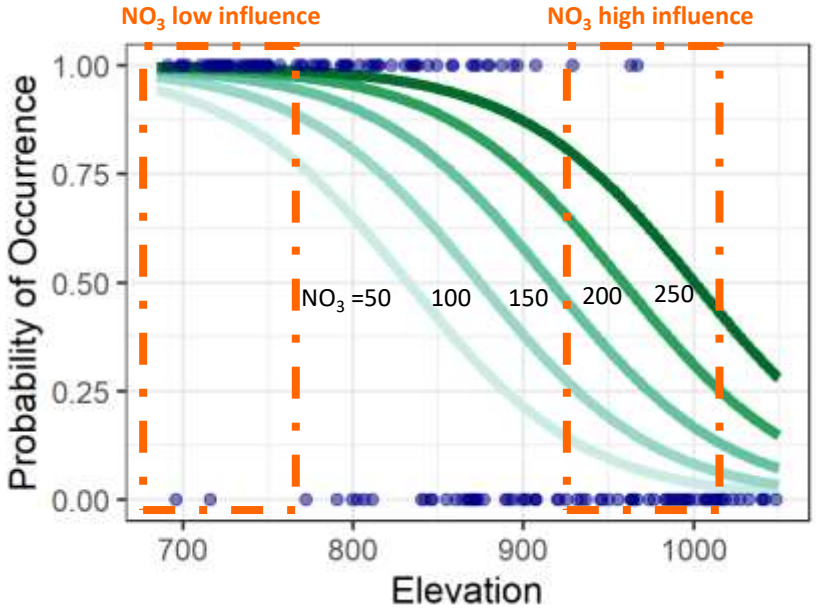
X_i : **ele** + **ele** × **soil** + **soil** + light + slope

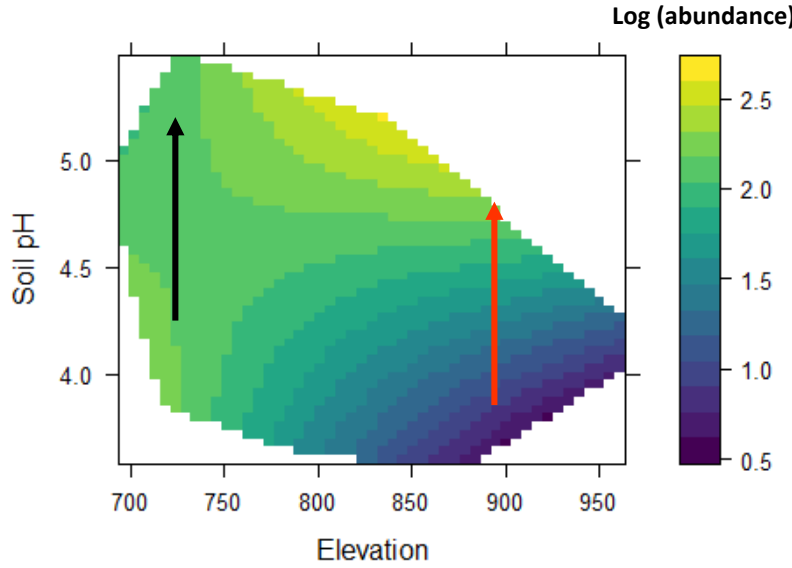
↓

Model selection based on AIC

Results – *Trillium erectrum*



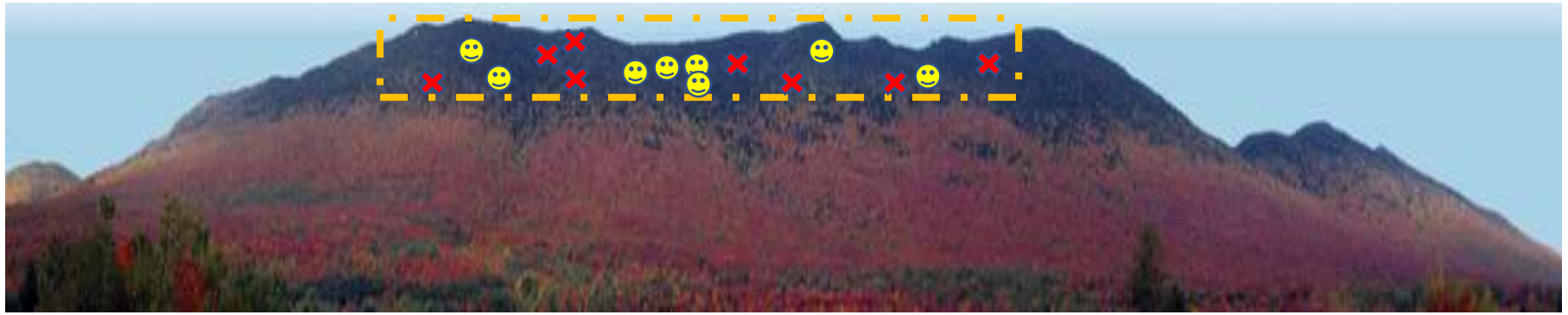


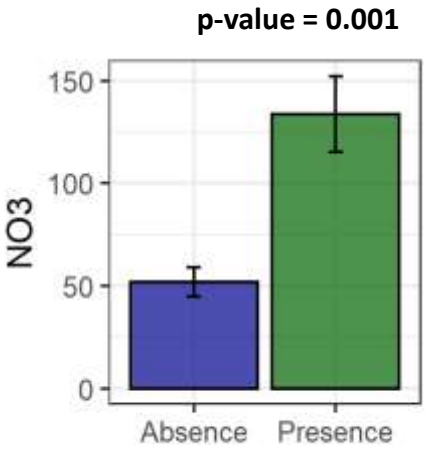


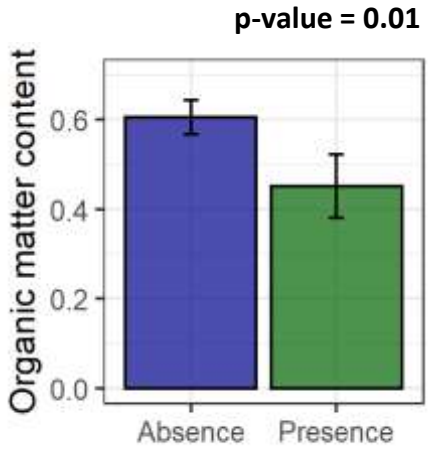
Trillium abundance

Results – *Trillium erectrum* non-random sampling

Trillium can occur in high elevations – what kind of habitats?





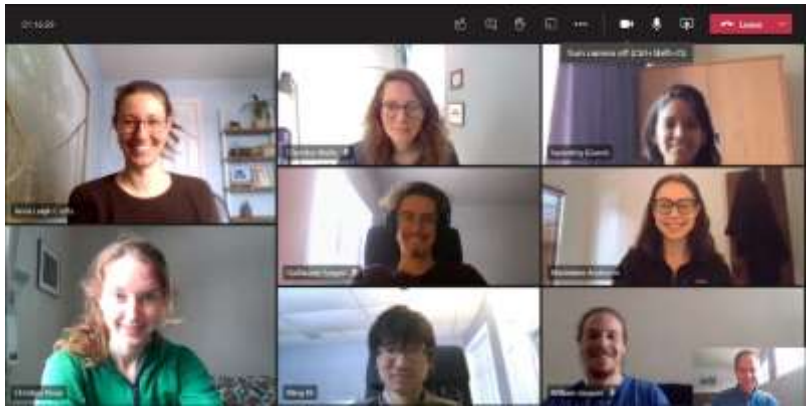


Agree with the occurrence model!

Summary and thanks!

Soil properties explain substantial variation in species current distributions along climatic gradients; **Soil could have major impact on species range limits;**

Higher-latitude/elevation soils can be unsuitable for many species potentially migrating from lower latitudes/elevation



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Results – Model performance