The early bud gets the cold: spring phenology drives exposure to late frost

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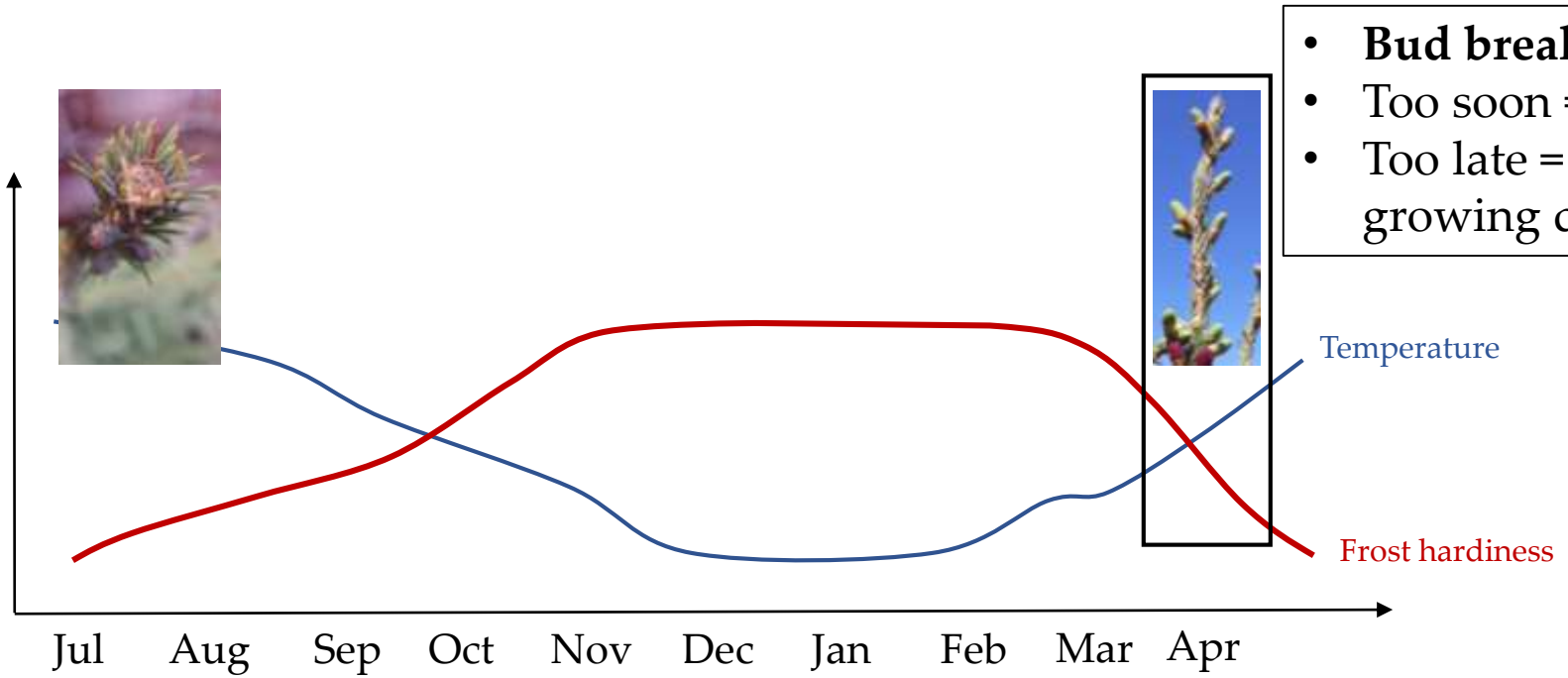
Surviving the cold

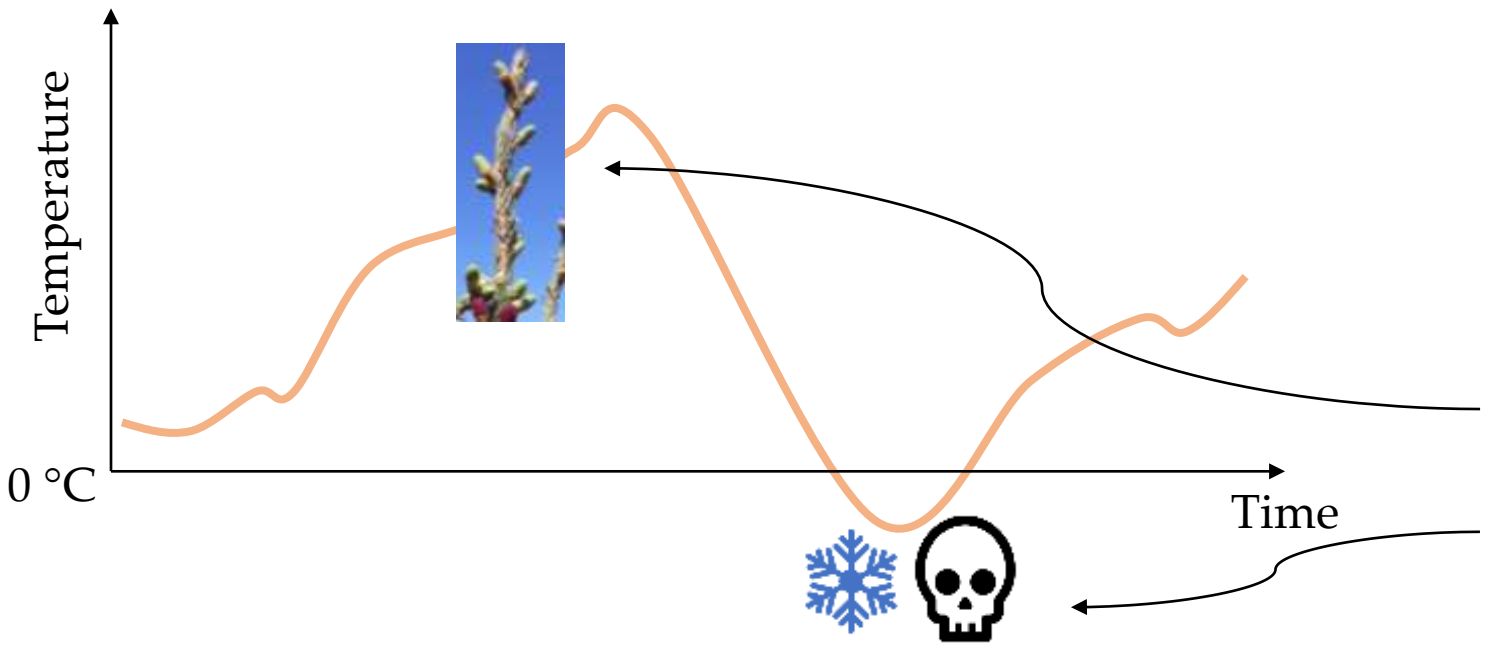
- **Two concurring strategies**

1. **Frost Avoidance**: protect the growing tissues by entering a dormant state
2. **Frost Tolerance**: Increase frost hardiness in overwintering organs



- **Bud break**
- Too soon = frost
- Too late = waste growing days

False spring and late frost



- **Failure in frost avoidance:** Importance of synchronization between tree phenology and actual temperatures

- Climate change may disrupt balance

1. Increase temperatures = advance bud break
2. Increase in extreme events = more likely late frost

Intra-specific differences in phenology → Different vulnerability to frost?

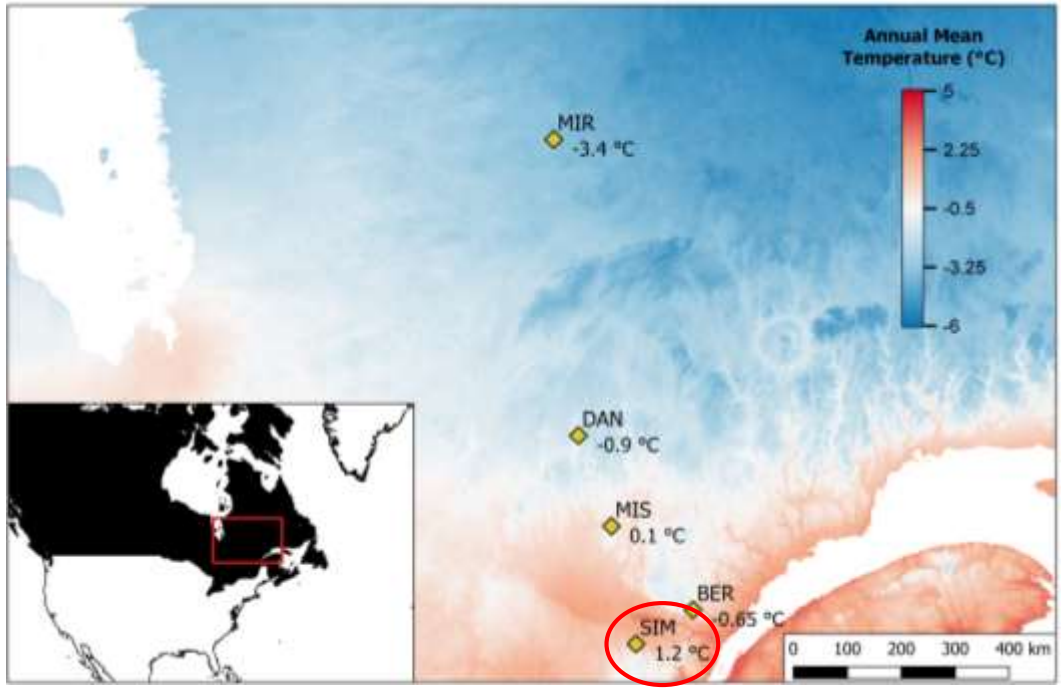
Case study and hypothesis

- Context: natural late frost event in a black spruce (*P. mariana*) common garden, spring 2021
- Five provenances: different phenology? Different frost damage?
- Hypothesis: colder provenances were more damaged by the frost because of an earlier bud break

The common garden

- Plant together trees from different areas, compare their performance

- Black spruce (*Picea mariana* Mill. B.S.P.)
- 5 provenances from a temperature gradient
- Est. in 2014, 371 trees



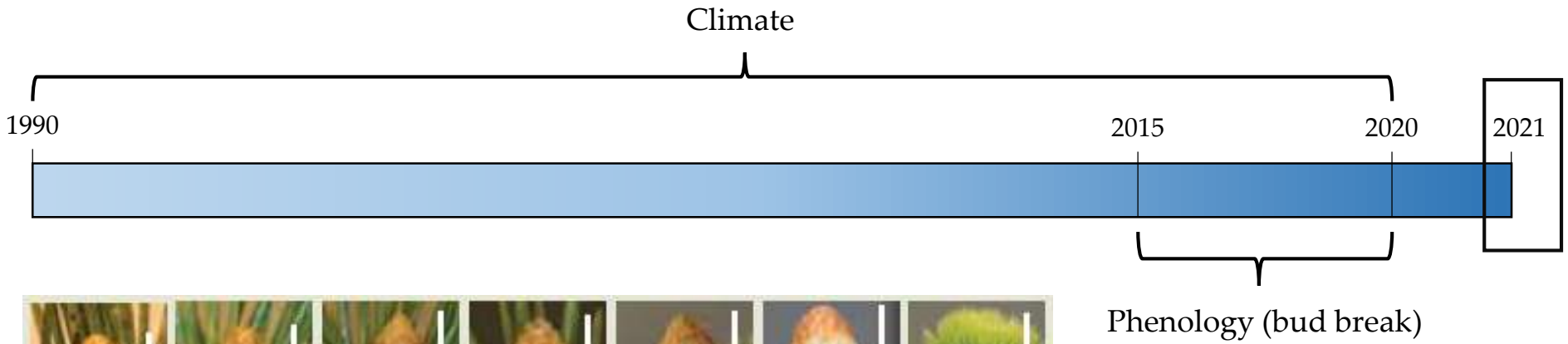
Measurements

1) Previous data available

- Historical climate: T (°C) and snow cover (1990-2020)
- Phenology: bud break from 2015 to 2020 (excl. 2016)

2) Data for 2021

- T (°C) measured on site
- Bud break at time of frost
- Frost damage



Dhont, C., Canada, & Natural Resources Canada. (2010). *Field guide for identifying apical bud break and bud formation stages in white spruce*. Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre.

0 = no damaged buds

1 (low) < 5% of buds

2 (medium) = 5-15%

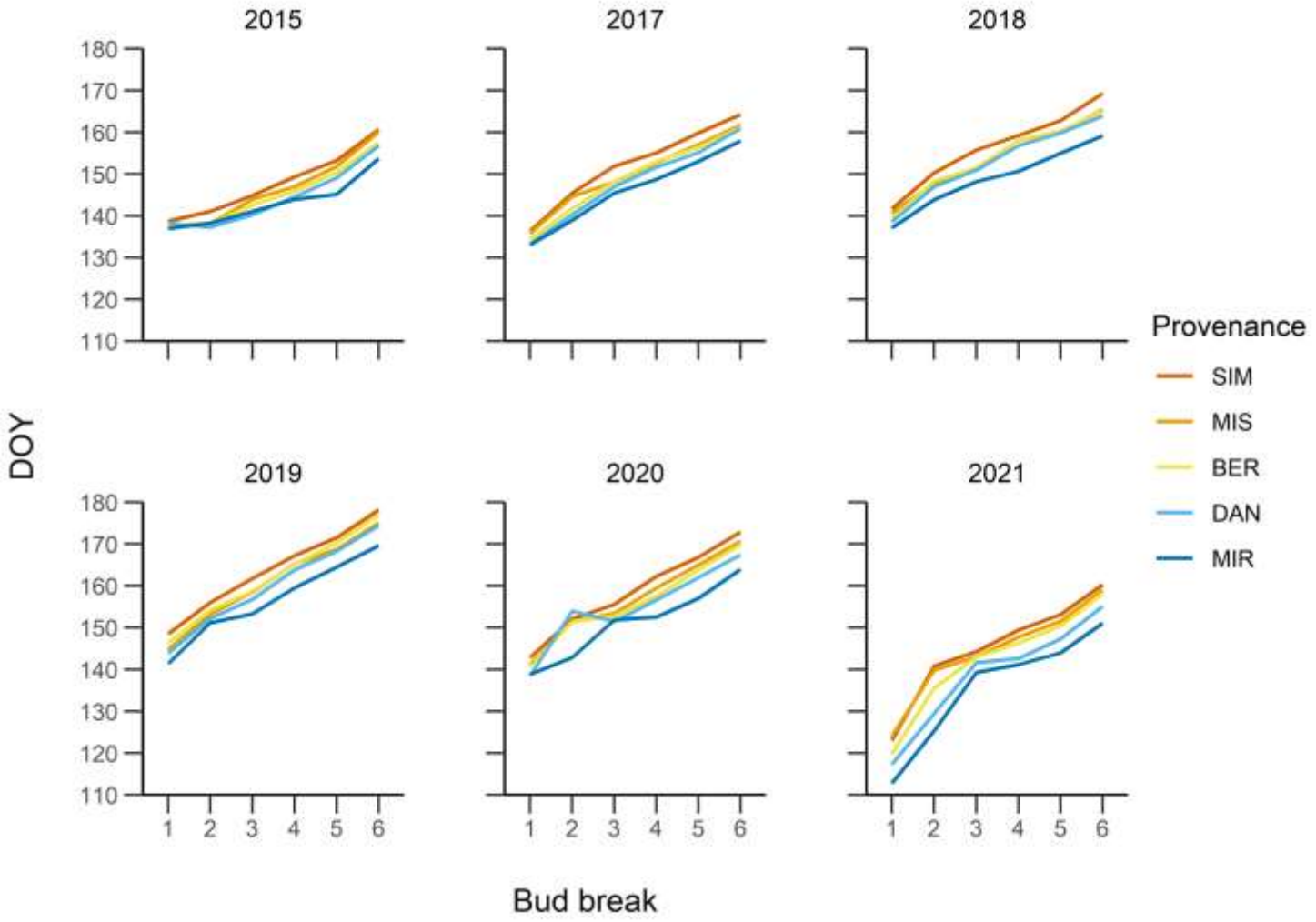
3 (high) = 15-30%

Trends in phenology

- Colder provenances perform earlier bud break

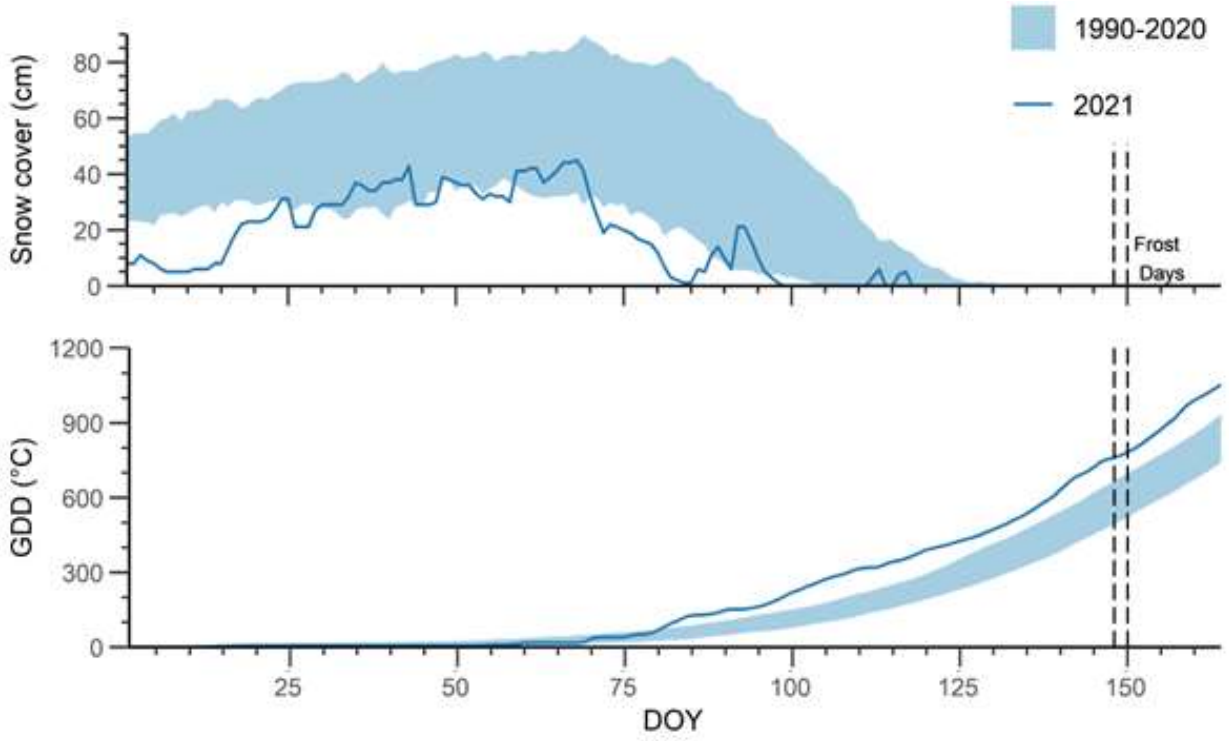
- Consistent with previous studies

1. Guo, X., Klisz, M., Puchałka, R., Silvestro, R., Faubert, P., Belien, E., Huang, J., & Rossi, S. (2021). Common-garden experiment reveals clinal trends of bud phenology in black spruce populations from a latitudinal gradient in the boreal forest. Journal of Ecology, 1365-2745.13582. https://doi.org/10.1111/1365-2745.13582
2. Silvestro, R., Brasseur, S., Klisz, M., Mencuccini, M., & Rossi, S. (2020). Bioclimatic distance and performance of apical shoot extension : Disentangling the role of growth rate and duration in ecotypic differentiation. *Forest Ecology and Management*, *477*, 118483. https://doi.org/10.1016/j.foreco.2020.118483
3. Silvestro, R., Rossi, S., Zhang, S., Froment, I., Huang, J. G., & Saracino, A. (2019). From phenology to forest management : Ecotypes selection can avoid early or late frosts, but not both. *Forest Ecology and Management*, *436*, 21-26. https://doi.org/10.1016/j.foreco.2019.01.005
4. Usmani, A., Silvestro, R., Zhang, S., Huang, J.-G., Saracino, A., & Rossi, S. (2020). Ecotypic differentiation of black spruce populations : Temperature triggers bud burst but not bud set. *Trees*, *34*(5), 1313-1321. https://doi.org/10.1007/s00468-020-01999-4



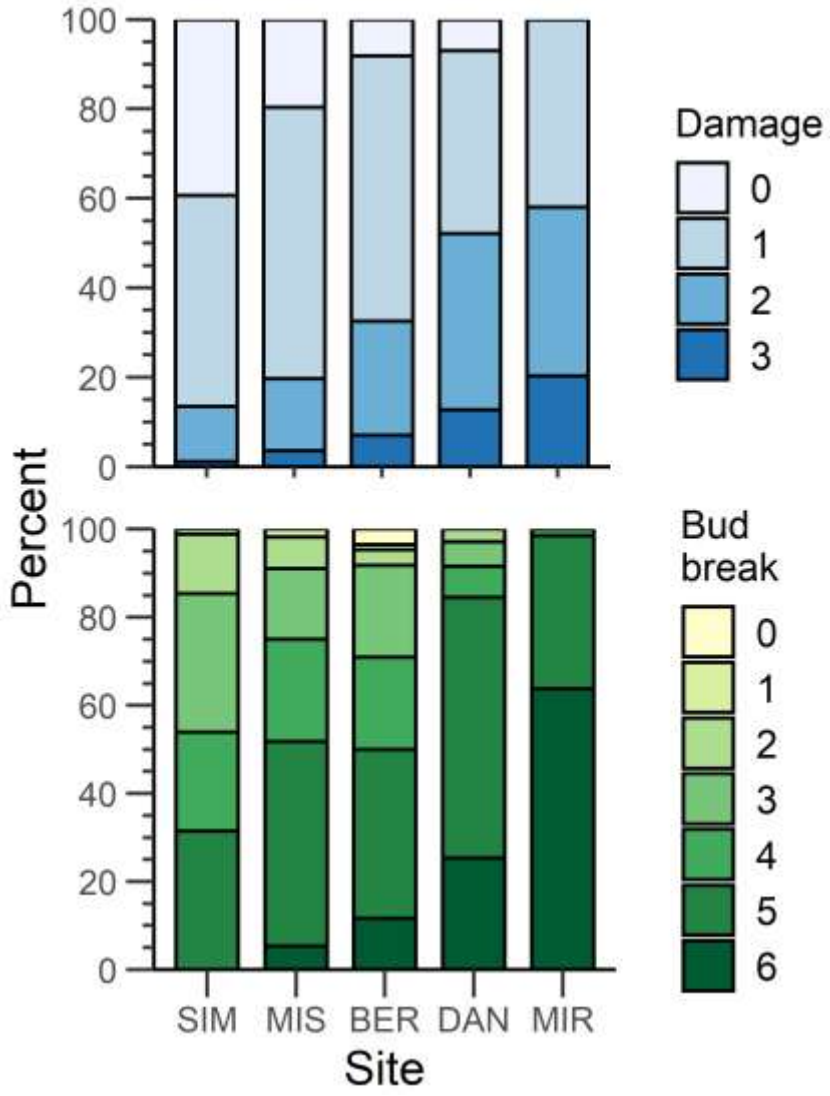
Environmental conditions

- Less snow, disappearing earlier
- Warmer spring conditions



Frost damages

- Frost occurrence differed between provenances
  ($\chi^2 = 58.98$, $p < 0.0001$)
- More advanced bud break = higher damages
- Confirmed by ordinal regression: higher probability to observe damages on more advanced budbreak phases



Conclusions

- Desynchronization = damages even on black spruce at (relatively) mild temperatures!

- Provenances from colder sites react earlier to warm spring temperatures

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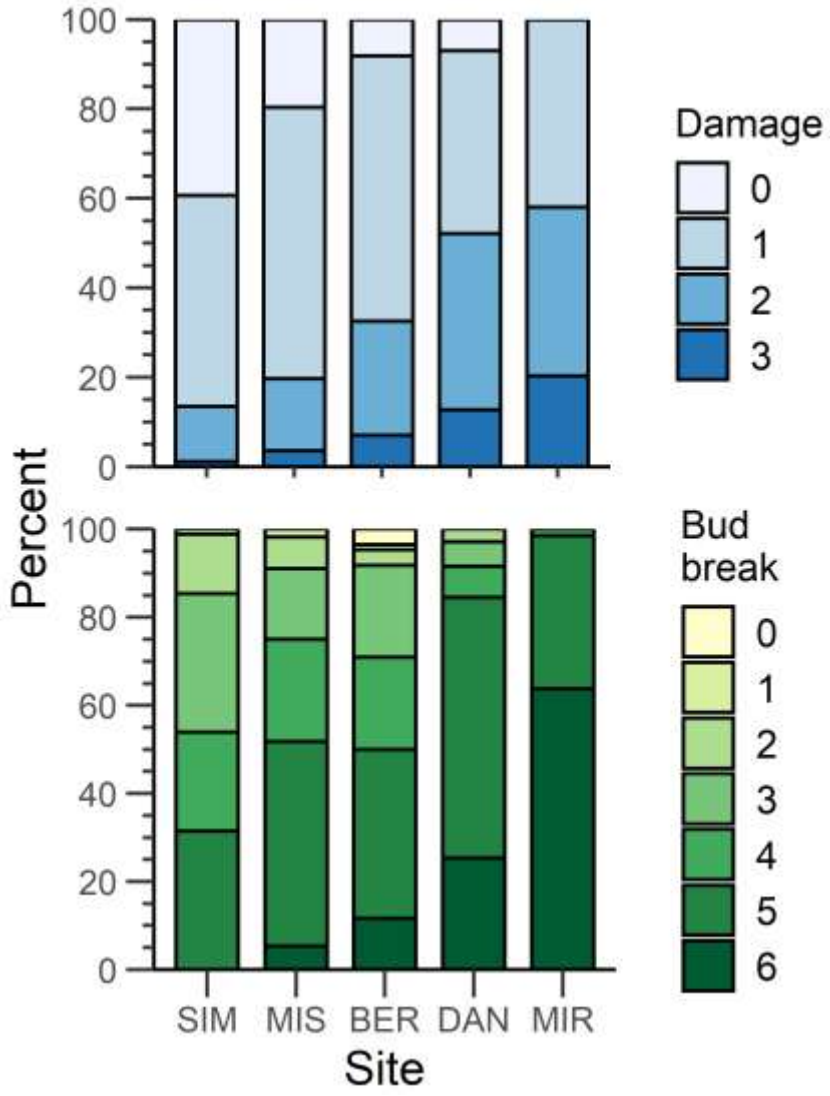
- Higher risk of late frost damages in the spring

Importance → provenance selection

assisted migration




Thank you for your attention!