Modelling budburst response to global warming across Canada

Lorena Balducci, Rémi Saint-Amant, Fabrizio Cartenì, Jacques Régnière, Valérie Néron, Stefano Mazzoleni, and Annie Deslauriers

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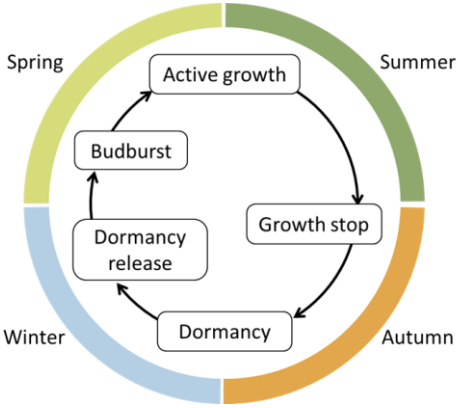
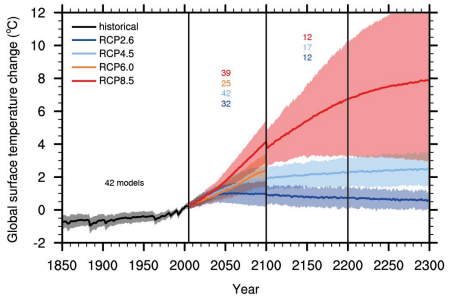
Introduction

Phenology = timing of seasonal life cycles





IPCC, 2022

Climate change: how do we know?

- Phenological change in timing (advanced onset in spring) (Piao et al., 2015; Menzel et al., 2020)
- Shift species range distribution to higher latitudes or elevation (Menzel et al., 2010; Vitasse et al., 2018)

At higher-latitudes, warming has also modified the interactions between plants and insects (frequency and intensity of epidemics), altered phenology potentially causing increasing insect-tree mismatches (Kharouba et al., 2018; Portalier et al., 2022; Pureswaran et al., 2015)

Introduction

- Bud phenology = food resource for insect defoliators
- Forest protection programs against eastern spruce budworm in Canada (pre-treatment and post-spray evaluations)

Bacillus thuringiensis var. kurstaki treatment eligibility → Biological criteria:

Decision tree: yes/no

Source: http://sopfim.qc.ca/fr/les-arrosages/

- Which **species** do we want to protect?
- **When and how** take action – find the best window for aerial **pulverization**

Defining the timing of insect-host phenology

Aims

The aims of this study were to apply PhenoCaB model (Cartenì et al., *in preparation*) on bud/shoot development to:

1. predict bud opening in Canada at wide scale

2. asses the effect of temperature increases on budburst according to global warming scenarios for the main indigenous conifers of Canadian boreal forests:
   - balsam fir (*Abies balsamea)*
   - black spruce (*Picea mariana)*
   - white spruce (*Picea glauca*)

Materials and methods

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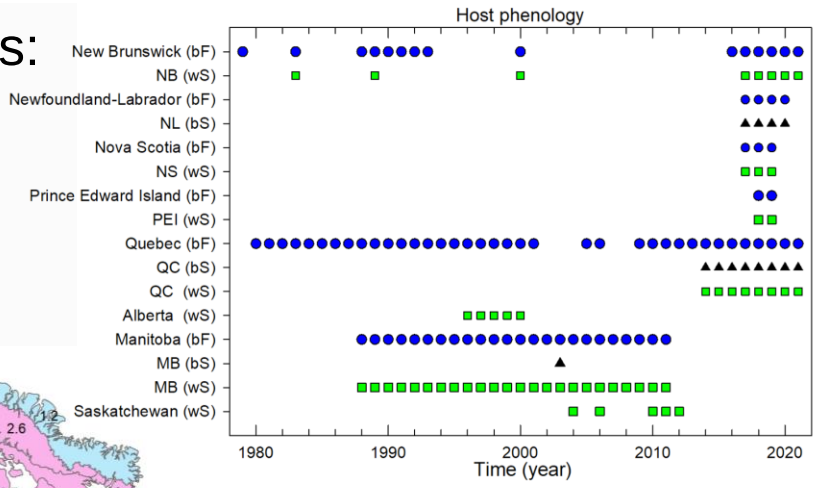
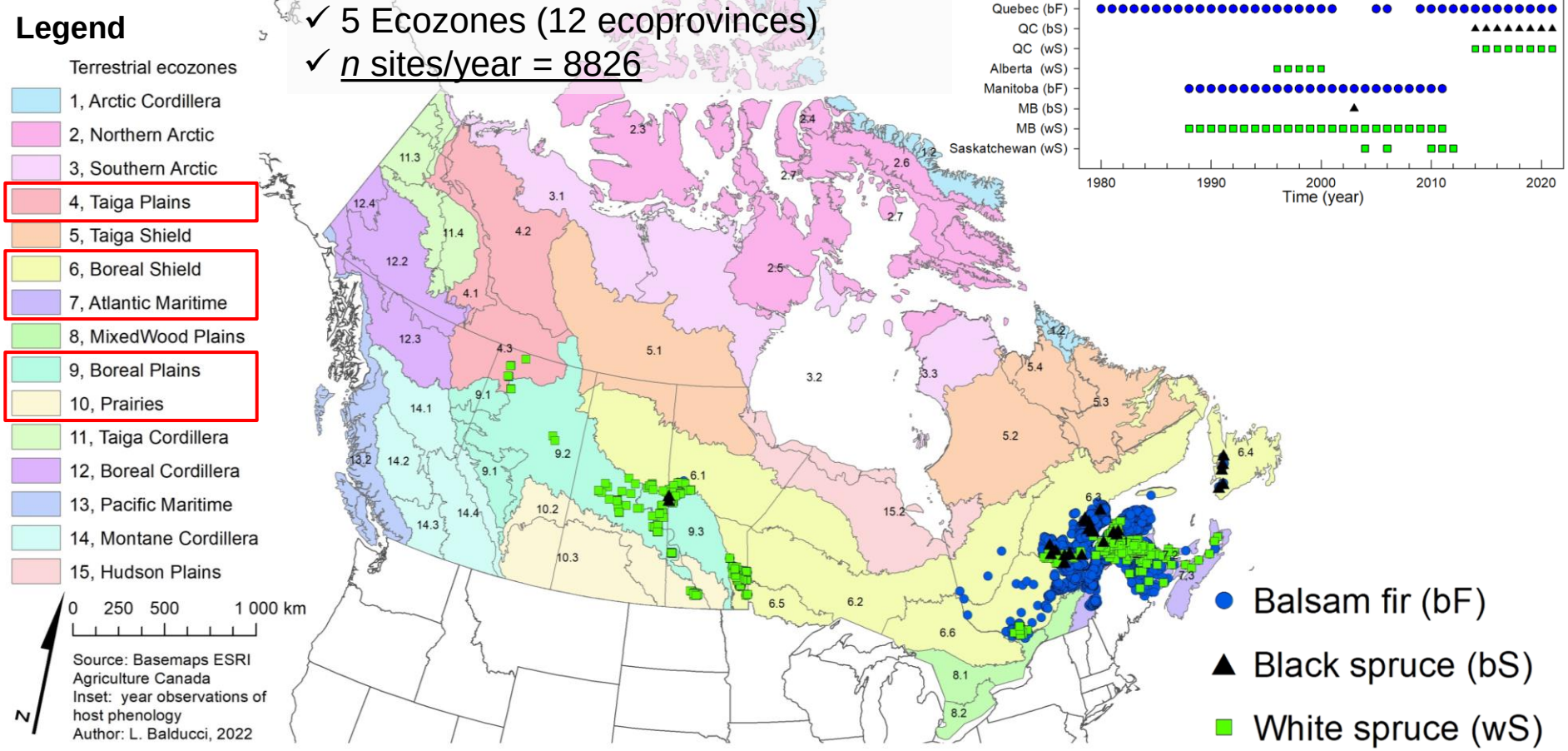
Bud phenological observations:

- ✓ from 1979 to 2021
- ✓ 3 species
- ✓ 8 Canadian provinces
- ✓ 5 Ecozones (12 ecoprovinces)
- ✓ *n* sites/year = 8826





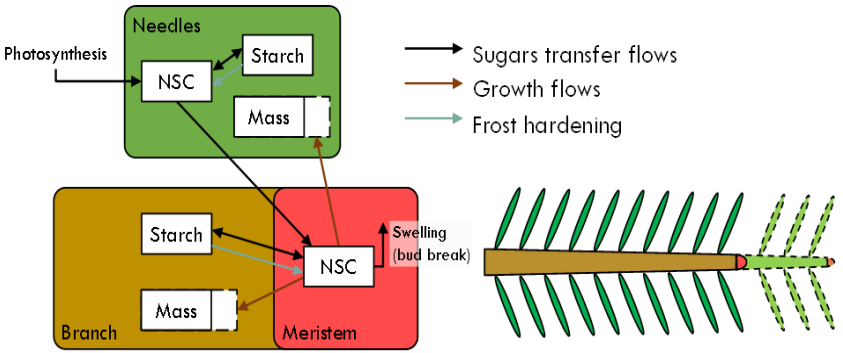
Materials and methods

- ✓ PhenoCaB was coded in BioSIM
- ✓ Collection of climate from BioSIM (interpolation of the four closest weather stations) (Régnière, J., 1996; Régnière, J. et al. 2017)

Hourly air temperature (°C)

PAR ($\mu mol \cdot m^2 \cdot s^{-1}$)

PhenoCaB



Budburst predictions

BioSIM Project: https://cfs.nrcan.gc.ca/projects/133

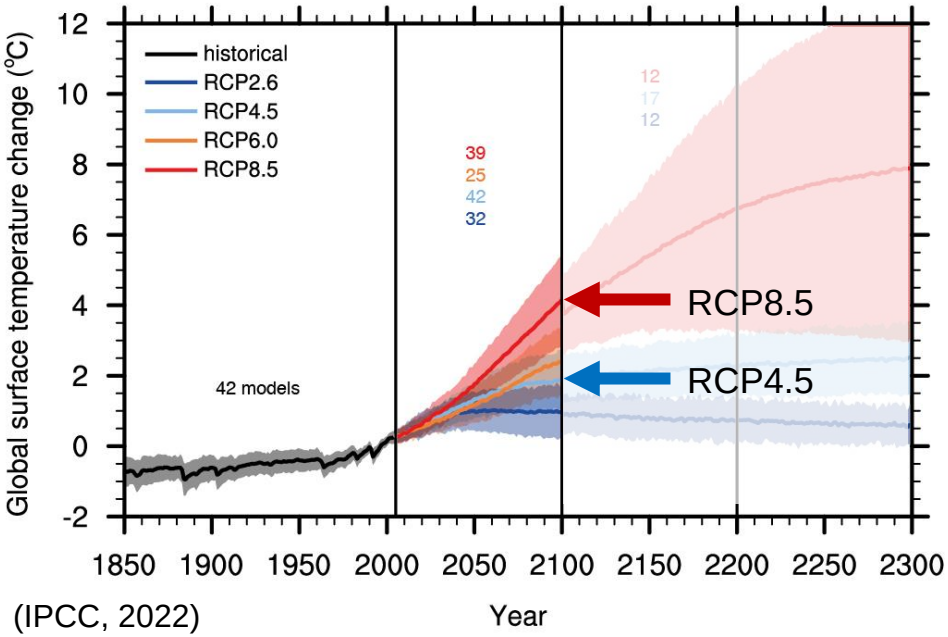
Materials and methods

Simulations setup

1. Observations sites → Recorded climate (1979-2021)

2. Observations sites → Climatic Normals (1981-2010)
   - RPC4.5 (2021-2050 and 2071-2100)
   - RPC8.5 (2021-2050 and 2071-2100)

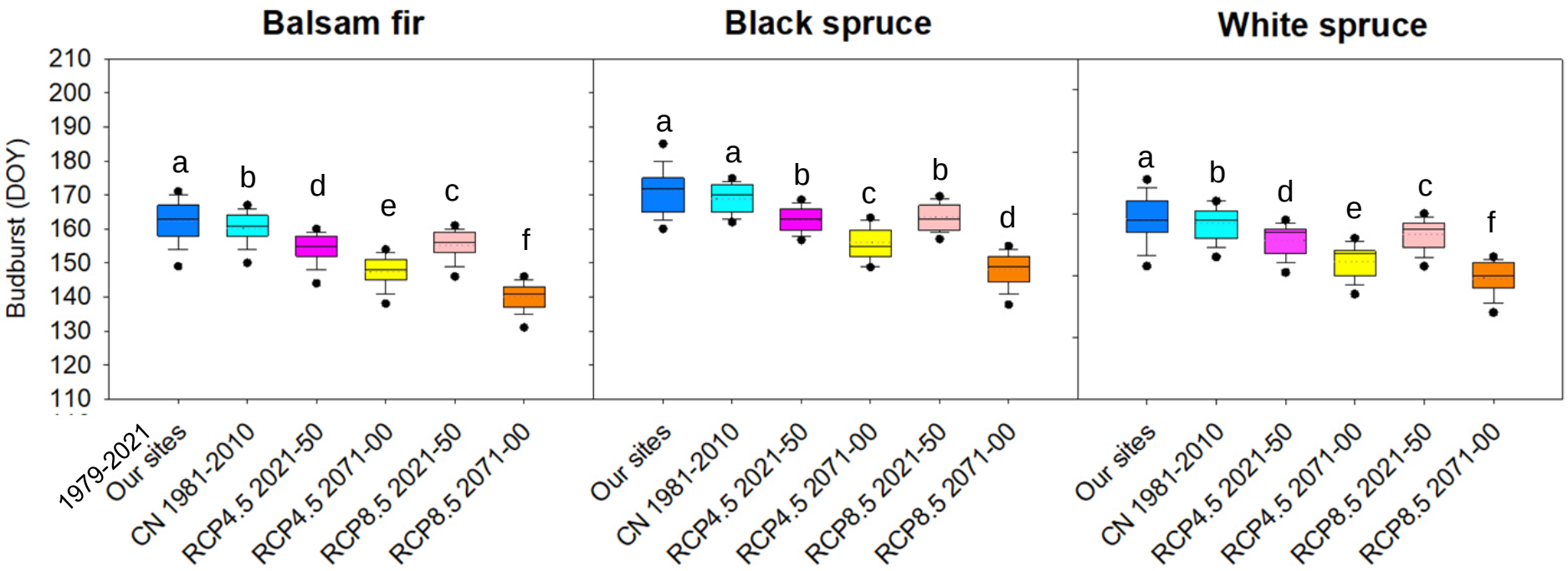
3. Whole distribution area of each species
   (7500 equally spaced points)



(IPCC, 2022)

Results and discussion

- Results at observation sites



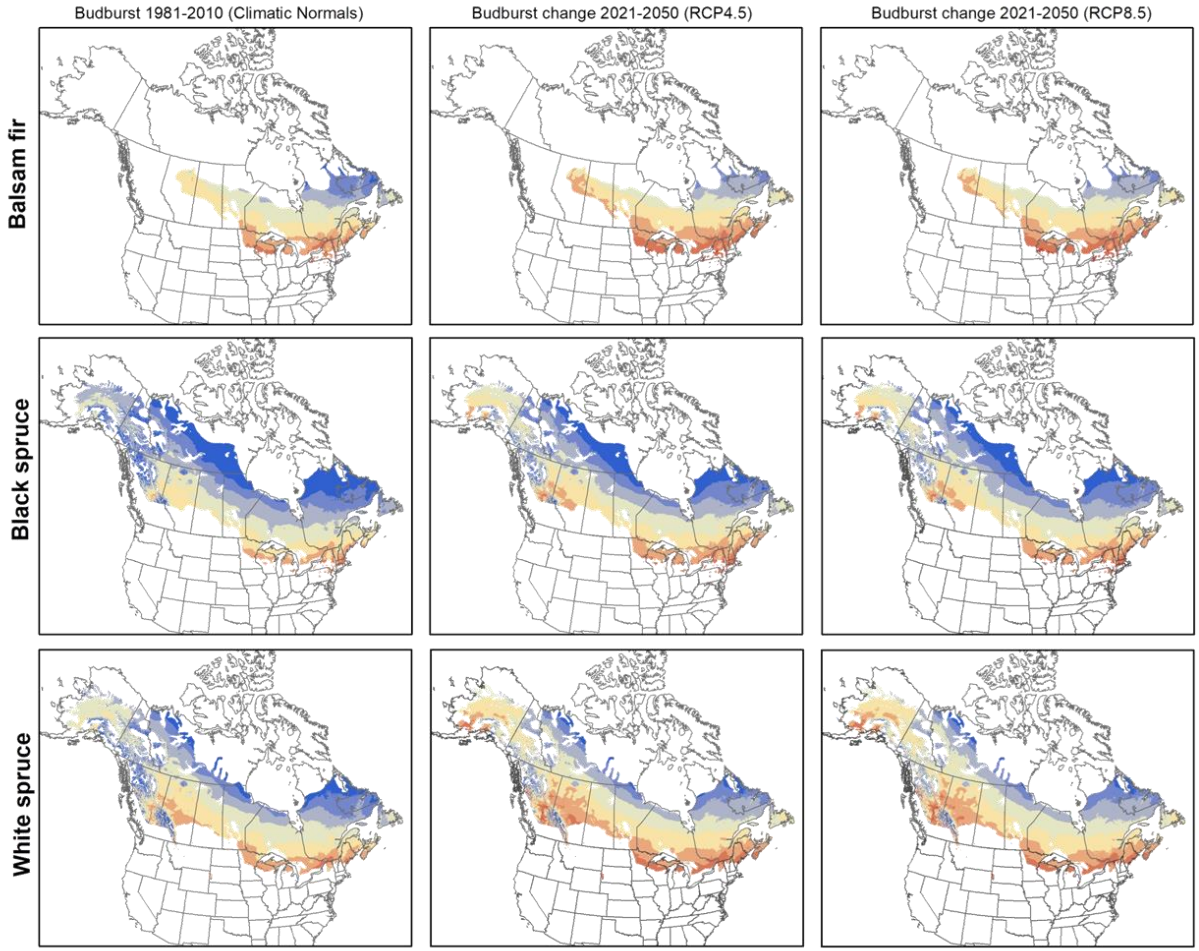
- Small differences between observed climate and Climatic Normals (1-2 days, 0 in black spruce)
- 4-5 days advance in the period 2021-2050 (both RCP4.5 and RCP8.5)
- Between 12 and 19 days advance in the period 2071-2100 (RCP4.5 and RCP8.5 respectively)

Results and discussion

- Maps - near future scenarios

Scenario: Climatic Normals | Intermediate (RCP4.5) | Extreme (RCP8.5)

Period: 1981-2010 | 2021-2050 | 2021-2050



- No difference between scenarios (4.5 vs 8.5)
- Budburst was projected to advance by 6-7 days
- Black spruce budburst occurred later compared to other species

Legend

Budburst (DOY)

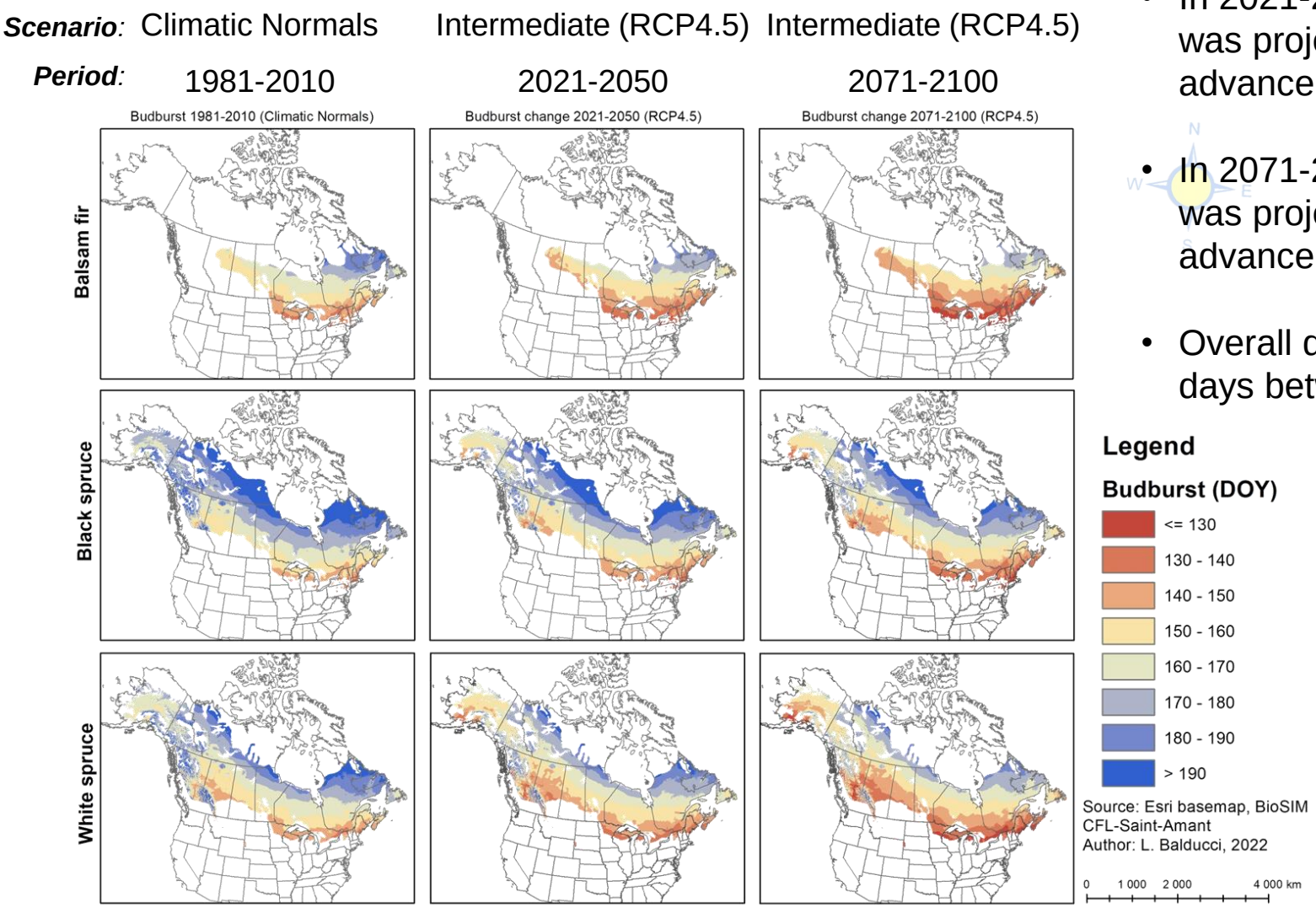
- <=130
- 130 - 140
- 140- 150
- 150 - 160
- 160 - 170
- 170 - 180
- 180 - 190
- > 190

Source: Esri basemap, BioSIM
CFL-Saint-Amant
Author: L. Balducci, 2022

0 1 000 2 000 4 000 km

Results and discussion

- Maps - RCP4.5 scenario

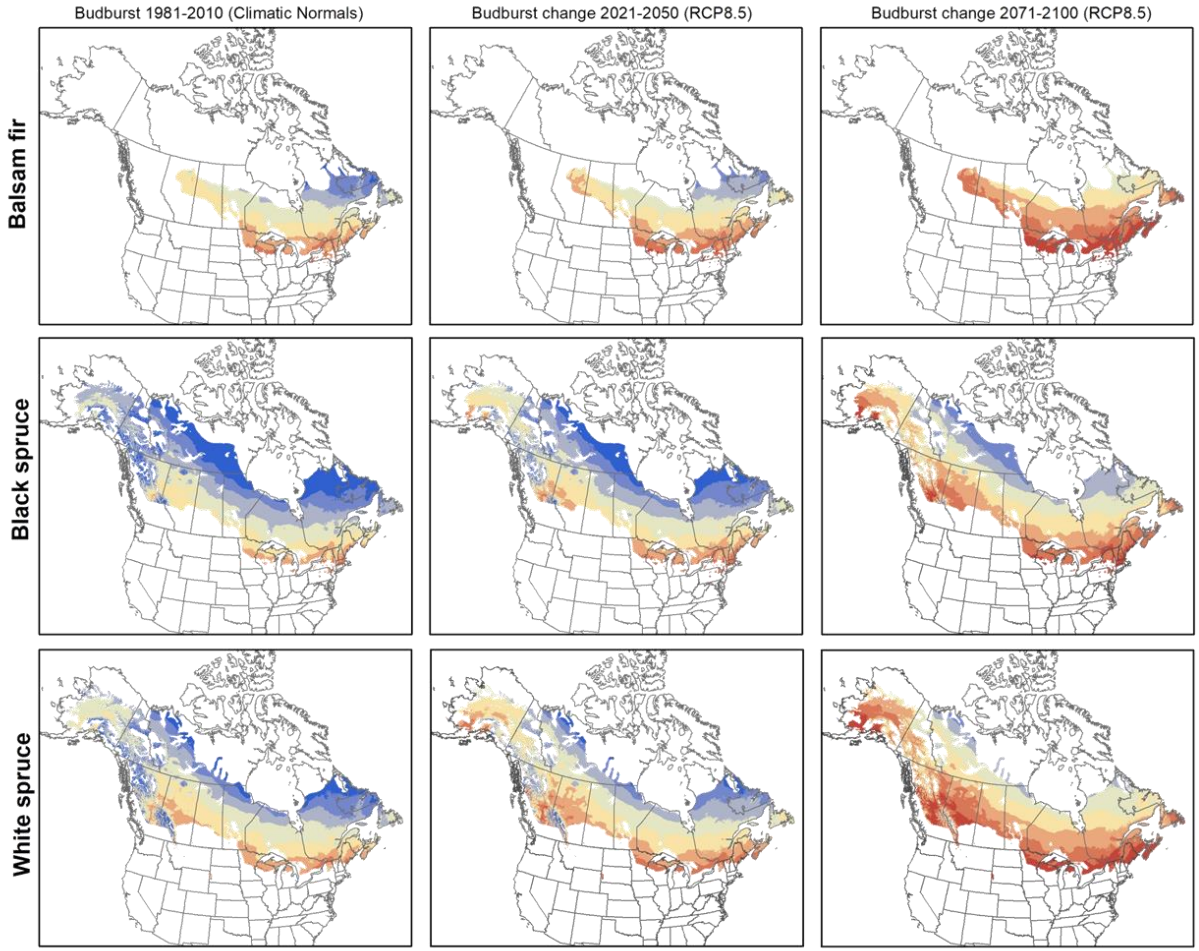


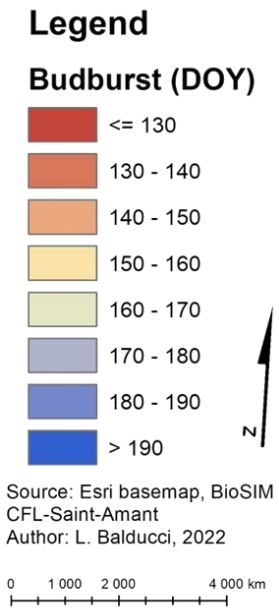
- In 2021-2050 budburst was projected to advance by 6-7 days
- In 2071-2100 budburst was projected to advance by 12-14 days
- Overall difference of ~5 days between periods

Results and discussion

- Maps - RCP8.5 scenario

Scenario:	Climatic Normals	Extreme (RCP8.5)	Extreme (RCP8.5)
Period:	1981-2010	2021-2050	2071-2100





- In 2021-2050 budburst was projected to advance by 6-7 days
- In 2071-2100 budburst was projected to advance by ~20 days
- Overall difference of ~13 days between periods

Conclusions

- Here we showed how PhenoCaB, coupled with spatially distributed climatic inputs and forecasts, could provide accurate phenological predictions at regional scale in global warming scenarios.

- This could become a useful tool also for developing forest management strategies over large areas to increase forest productivity and tree survival and optimizing forest protection programs against pest attacks.

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