Long-term assessment of climate influence on cambial phenology on *Picea mariana* through dendroanatomical techniques

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INTRODUCTION

Tree-ring and xylogenesis studies have shown that the main environmental driver of wood formation in boreal forests is temperature. Quantitative wood anatomy is a new approach to investigate environmental drivers on tree growth at intra-annual scale. The aim of this research is to explore the possibility of detecting cambial phenology information from time series of wood anatomical traits and compare them with previous findings.

METHODS

We selected two sites in the boreal black spruce (*Picea mariana*) forest of Quebec, Canada (50°41' and 53°47' N, Fig 1), where previous xilogenetic monitoring was carried out. Micro-slides of wood cross-sections samples were processed with the image-analysis software ROXAS (Fig 2). We built long chronologies of Tree Ring Width (TRW), Cell Area (CA), and Cell Wall Thickness (CWT), and correlated them to daily temperature, Vapour Pressure Deficit (VPD) and precipitation records from 1936 to 2011 (Fig 3).

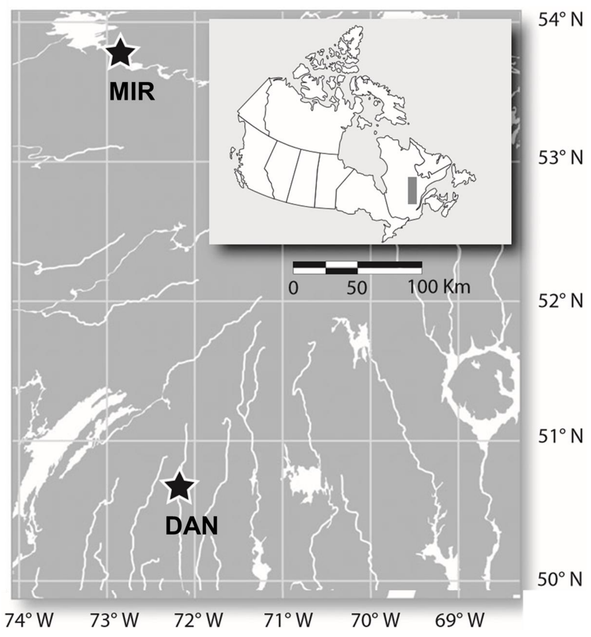

Fig. 1. Study sites location in the boreal forest of Quebec, Canada. (Modified from Rossi et al. 2014)

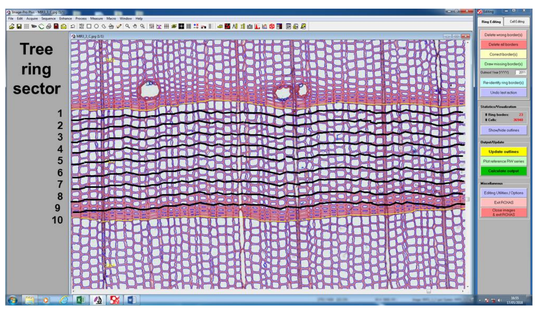

Fig 2. Cross-section image of *Picea mariana* analyzed by ROXAS (von Arx & Carrer, 2014). The software measured tree ring with (yellow line), cell lumen area, cell wall thickness and cell relative position in the ring. The black lines are the grafical representation of TRW partitioning using 10 sectors.

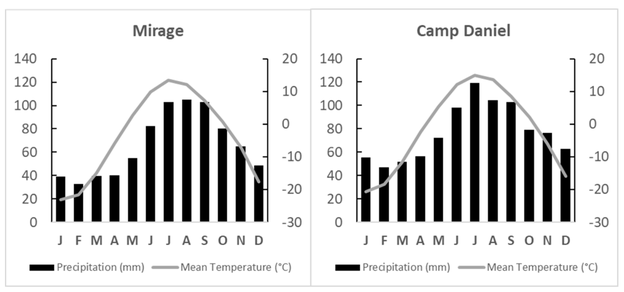

Fig 3. Monthly mean temperature and precipitation for Mirage (MIR) and Camp Daniel (Dan) from 1936 to 2011.

RESULTS

In both sites, the CA was negatively correlated with temperature and VPD during late May to late September. High summer temperatures have a constrain effect on cell enlargement. Meanwhile, precipitation has a positive correlation with CA (Fig 4a).
CWT presents positive correlations with temperature and VPD, indicating a positive effect of spring temperature on cell development.
The last sector (latewood) in cell wall lignification coincide with the ending of xylem differentiation. In both sites, the precipitation do not influence the CWT (Fig 4b).

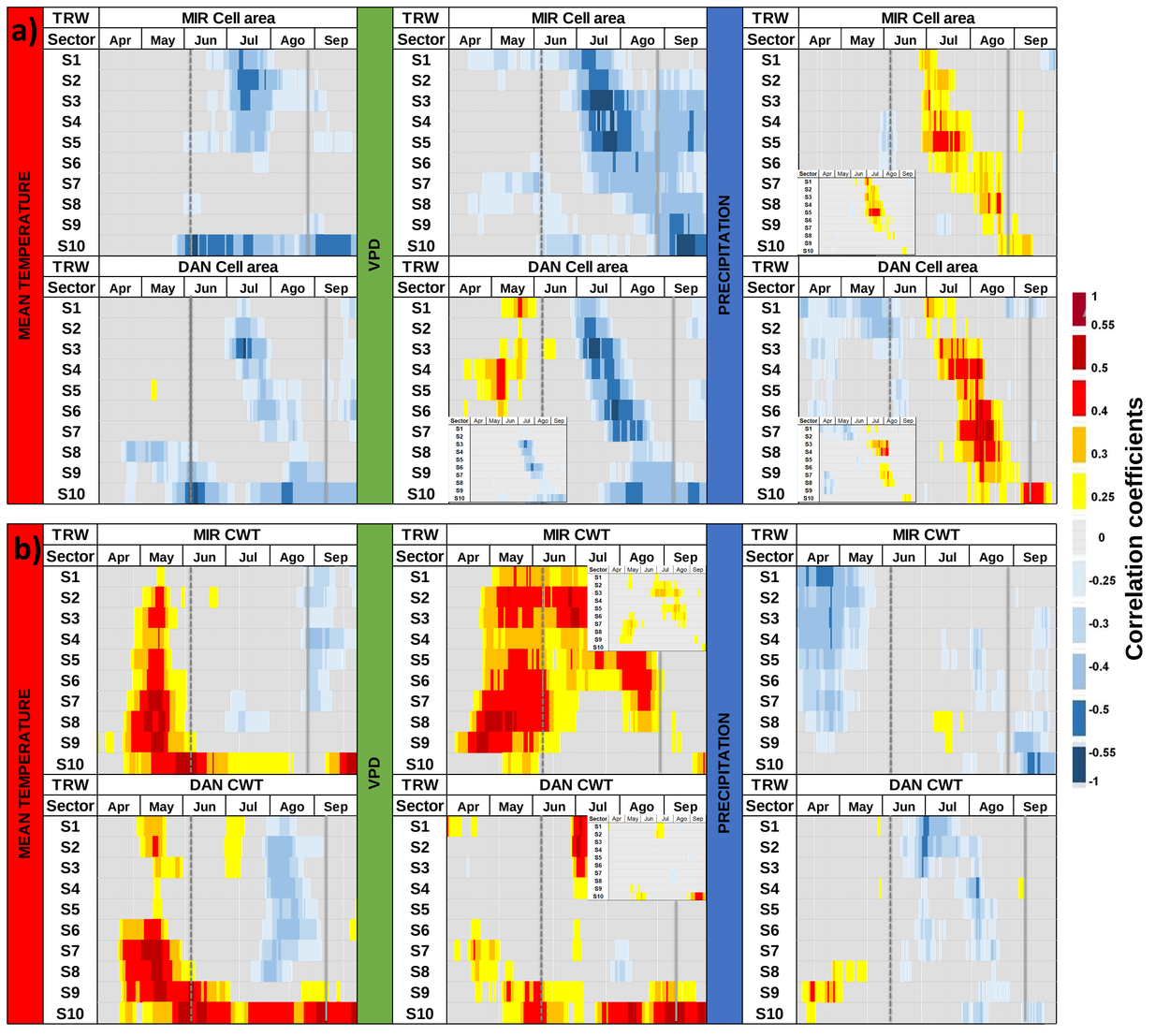

Fig 4. Running correlations between CA (a) and CWT (b) divided in 10 ring sectors along the growth direction (S1→S10, y axes), and 30-day mean temperature, VPD and precipitation, from April to September of the current year (x axes). Correlations were calculated, for MIR and DAN, for the period 1936-1996 and for the period 1936-2011 (inset graphs). The dashed lines indicate xylogenesis onset, the gray lines the ending of xylem differerentiation (xylogenesis information from Boulouf Lugo & Morin 2010; Rossi et al. 2011; Rossi et al. 2014).

DISCUSSION

Both sites present a drastic increase in temperatures during the last years (Fig 5). We hypothesized that the increment of temperature in the last decades, has hampered the trees to show a clear signal (inset graphs Fig 4), indeed, eliminating the last 15 and warmest years from the analysis, the climate-growth relations of CA and CWT were clearer in both the sites.

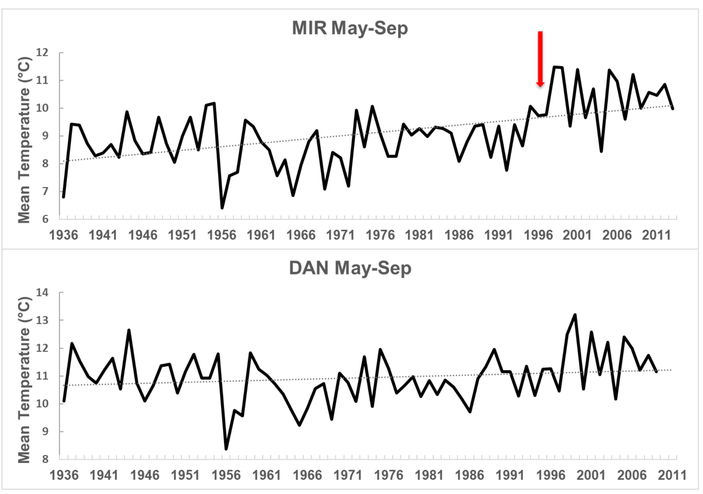

Fig. 5. May-September average temperature records from 1936-2011 in MIR and DAN. The red arrow shows the abrupt increase of temperature in 1996.

This is coherent with Rossi et al. 2014 which indicates a disproportionate increases in xylem cell production rather than a lengthening of the period of cell division as the result of the rise of temperature.

CONCLUSIONS

This study confirms the potential of tree-ring anatomy analysis to better understand the relationship between wood formation and climate variability at both intra-annual scale but also fairly long time scales. Extending this investigation on more sites and species can contribute to elucidate which are the main variables that influence tree growth in boreal forest ecosystem, and how trees will respond to the rapid increase in temperature.

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