Are current climate models able to simulate frost droughts?

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Background

Photosynthesis is most efficient at 25°C, yet despite the rapid warming of the Arctic, vegetation productivity indices are decreasing since 2011. The causes are many, but the damage induced by frost droughts is one of the major ones *(Phoenix and Bjerke, 2016)*. Damaged vegetation has a reduced productivity and lower carbon uptake *(Parmentier et al., 2018),* thus affecting greenhouse gas exchange and ultimately biodiversity. Yet, land surface models fail to accurately simulate the consequences of such events. It is therefore uncertain how arctic and boreal ecosystems will respond to further climate change (*McGuire et al. 2018*).

Objectives

- Assess how different models (CLM5, FATES) perform to represent frost droughts
- Compare the different responses for evergreen and deciduous trees

Damaged evergreen trees next to fit deciduous trees in summer 2018 (Norway)

- Demonstrate how rapidly warming arctic winters affect ecosystems and disturb carbon exchange

What is embolism?

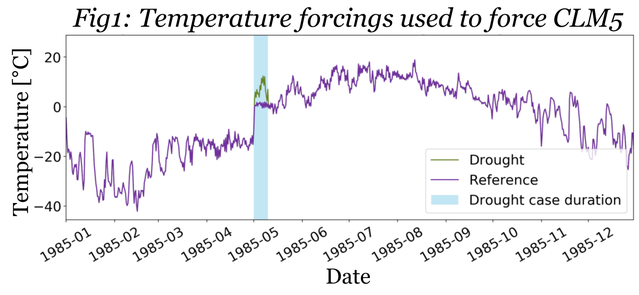
Interruption of the root-leaf water tension due to gas bubbles entering the xylem conduits of the plant.

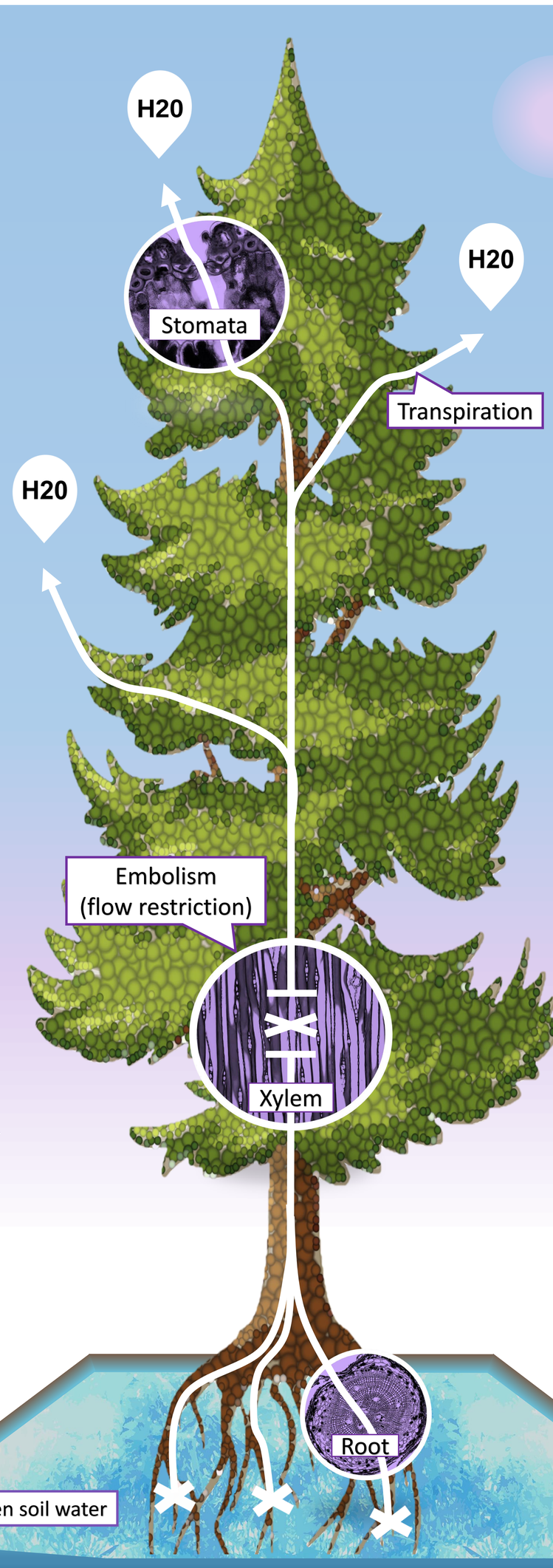
This phenomenon occurs when frozen soil water prevents plants to replace transpiration losses. If desiccation lasts and reaches a certain threshold, it leads to tissue damage.

Case study: Abisko (northern Sweden)

A frost drought (green) and a reference (purple) temperature dataset have been created and used to run CLM5 (Fig1).

Fig1: Temperature forcings used to force CLM5





Model results

Higher plant biomass after a drought?

CLM5 simulates a stronger water stress for the drought scenario (green), but the stress disappears too fast after the event (Fig2). The high temperatures during the frost drought melts the soil water, which becomes available to the plants. This explains why vegetation biomass is simulated higher than expected after the drought (Fig3).

Fig2: Water stress factor (Fw)

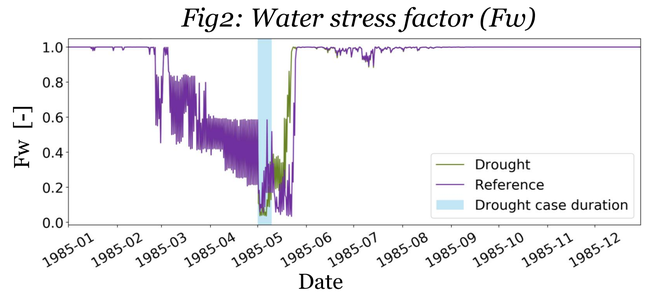
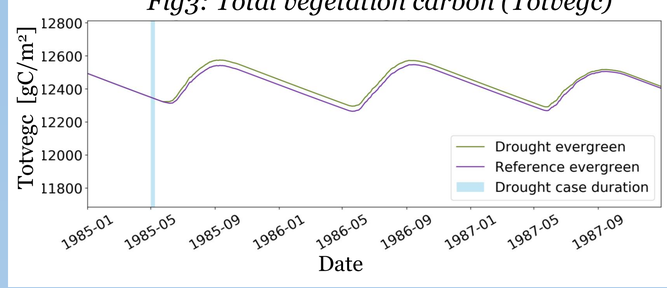


Fig3: Total vegetation carbon (Totvegc)



Outlook

- Represent frost droughts by running single cell simulations with CLM & FATES
- Evaluate the results of FATES by comparing to CLM outputs and to empirical datasets of frost drought mortality

References

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