Multi-physics modelling of freeze-thaw cycles effects on tree branches

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Abstract

Frost hardiness is the main factor affecting plant species distribution at high latitudes and altitudes. The main effects of freeze-thaw cycles on trees are damages to living cells, as well as the formation of gas embolism in xylem vessels. Frost effect on trees is also quantified through changes in branch diameter.

In order to resorb embolism, some species (walnut, maple, birch, etc.) exhibit an increase in xylem sap pressure during successive freeze-thaw cycles. The modelling of such phenomenon is very challenging due to its multi-physics and multi-scale nature. In this work, we present a numerical model coupling heat transfer, phase change, water and osmotic fluxes, taking into consideration different cell types within walnut branch tissues. We show how diameter and pressure variations are inter-related, and we validate the model against experimental results from the literature. We eventually show how this work can be adapted in order to explore inter-species differences.