Can phenological models predict tree phenology accurately under climate change conditions?

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The onset of the growing season of trees has been globally earlier by 2.3 days/decade during the last 50 years because of global warming and this trend is predicted to continue according to climate forecast. The effect of temperature on plant phenology is however not linear because temperature has a dual effect on bud development. On one hand, low temperatures are necessary to break bud dormancy, and on the other hand higher temperatures are necessary to promote bud cells growth afterwards. Increasing phenological changes in temperate woody species have strong impacts on forest trees distribution and productivity, as well as crops cultivation areas. Accurate predictions of trees phenology are therefore a prerequisite to understand and foresee the impacts of climate change on forests and agrosystems.

Different process-based models have been developed in the last two decades to predict the date of budburst or flowering of woody species. They are two main families: (1) one-phase models which consider only the ecodormancy phase and make the assumption that endodormancy is always broken before adequate climatic conditions for cell growth occur; and (2) two-phase models which consider both the endodormancy and ecodormancy phases and predict a date of dormancy break which varies from year to year. So far, one-phase models have been able to predict accurately tree bud break and flowering under historical climate. However, because they do not consider what happens prior to ecodormancy, and especially the possible negative effect of winter temperature warming on dormancy break, it seems unlikely that they can provide accurate predictions in future climate conditions. It is indeed well known that a lack of low temperature results in abnormal pattern of bud break and development in temperate fruit trees. An accurate modelling of the dormancy break date has thus become a major issue in phenology modelling.

Two-phases phenological models predict that global warming should delay or compromise dormancy break at the species equatorward range limits leading to a delay or even impossibility to flower or set new leaves. These models are classically parameterized with flowering or budburst dates only, with no information on the dormancy break date because this information is very scarce. We evaluated the efficiency of a set of process-based phenological models to accurately predict the dormancy break dates of four fruit trees. Our results show that models calibrated solely with flowering or budburst dates do not accurately predict the dormancy break date. Providing dormancy break date for the model parameterization results in much more accurate simulation of this latter, with however a higher error than that on flowering or bud break dates. But most importantly, we show also that models not calibrated with dormancy break dates can generate significant differences in forecasted flowering or bud break dates when using climate scenarios. Our results claim for the urgent need of massive measurements of dormancy break dates in forest and fruit trees to yield more robust projections of phenological changes in a near future.