Modelling climate change induced phenological trends and frost risks in Belgian fruit orchards

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November 22, 2022

Abstract

Apples and pears represent an important share of Belgium's horticultural production but the sector has been subjected to a range of challenging meteorological conditions over the past decade. The most disastrous event was the extraordinarily severe frost night happening during peak flowering of commercially grown apple cultivars, in April 2017. This research aims at investigating how meteorological hazards in Belgium will evolve in space and time with changing climate and at challenging the claim of the insurance sector that the hazards are spatially invariant. It features the assessment of the probability and severity of frosts during the flowering period throughout the 21st century, using a set of regional climate model realizations from the CORDEX ensemble. To this end, the apple and pear tree phenology is modelled using the strong relation between air temperature during winter/early spring and dormancy break and consequently flowering. Local observations since 1950 of the phenology of major cultivars indeed confirm a shift in phenological stages in relation to warmer winters as an effect of climate change. Preliminary results from sequential phenological models, running on future daily mean temperatures, suggest that both the onset of flowering and the last frost event in spring are likely to occur earlier in the year, so that the challenge is to determine which trend is dominant and how the return periods of severe frost nights (< -2*C) during sensitive stages evolve. Thereby, differences between cultivars and between orchard locations within Belgium are taken into consideration. Furthermore, the potential impact of shifting temperature regimes on the pollinator activity during the blossom period is taken into account, knowing that the most commonly commercially employed bee species are sensitive to colder and more variable temperatures. The distinct resulting hazard maps can be used to support decision making regarding adaptation and prevention measures at the field, farm and regional scales. Further downscaling will be possible by considering local pedologic and topographic conditions, while for validation, data about damage compensation claims will be used.

Flemish Fruits Fear Frost

(MODELLING CLIMATE CHANGE INDUCED PHENOLOGICAL TRENDS AND FROST RISKS IN BELGIAN FRUIT ORCHARDS)

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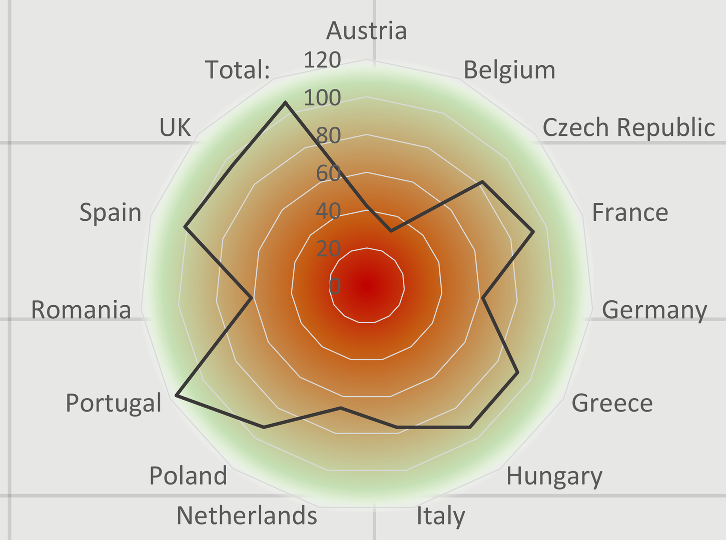
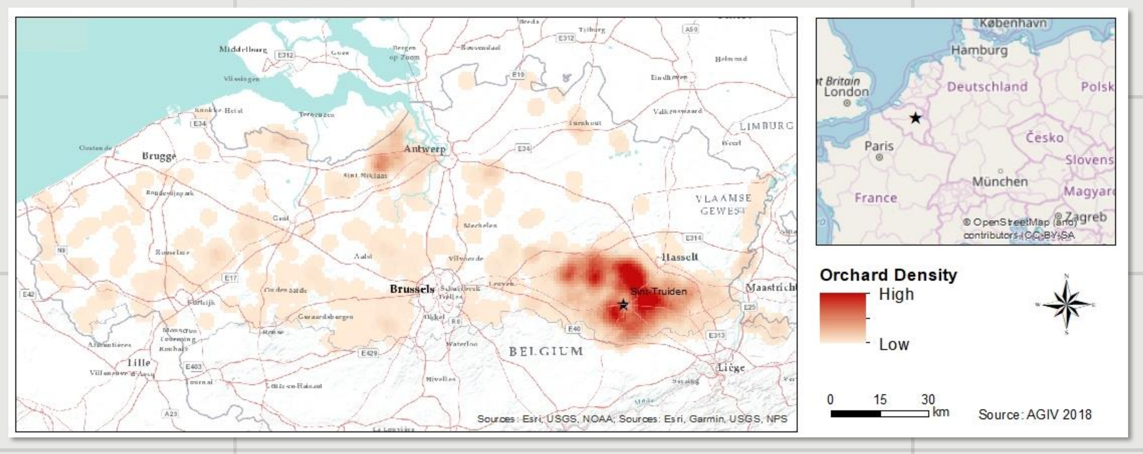
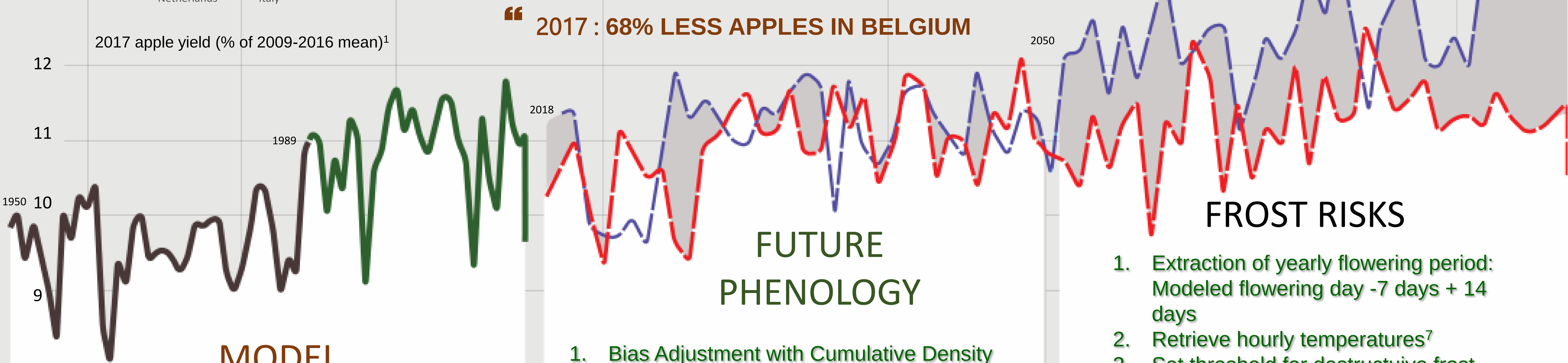


2017 apple yield (% of 2009-2016 mean)[1]

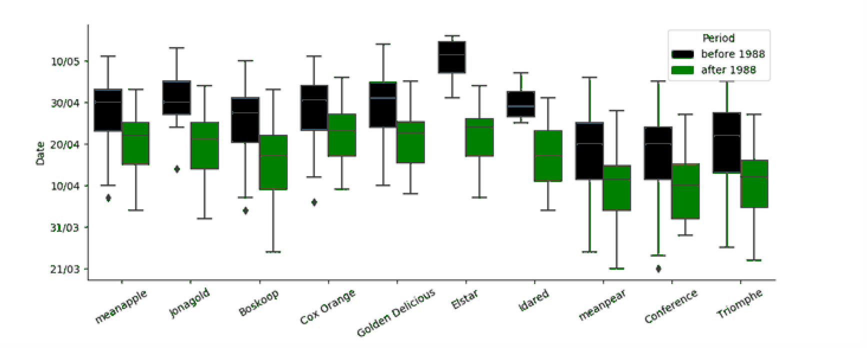


2017 : 68% LESS APPLES IN BELGIUM

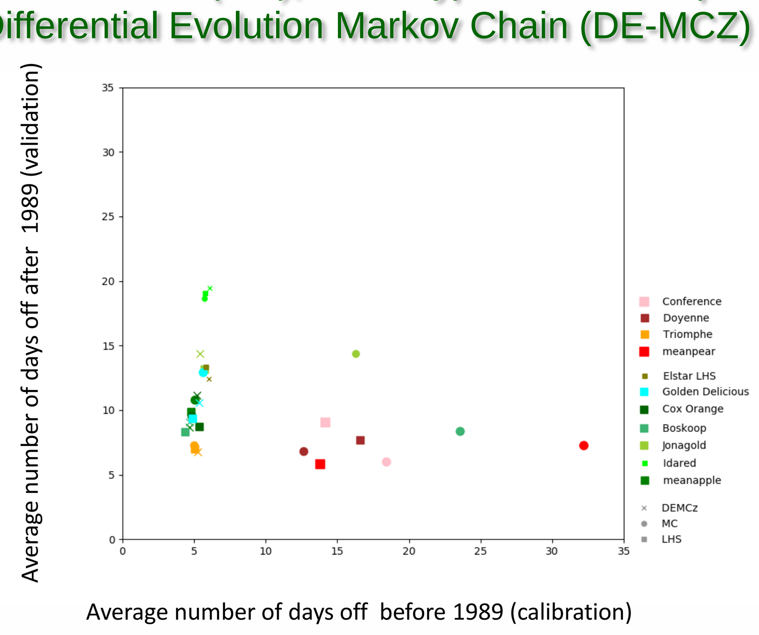


MODEL PARAMETRISATION[2]

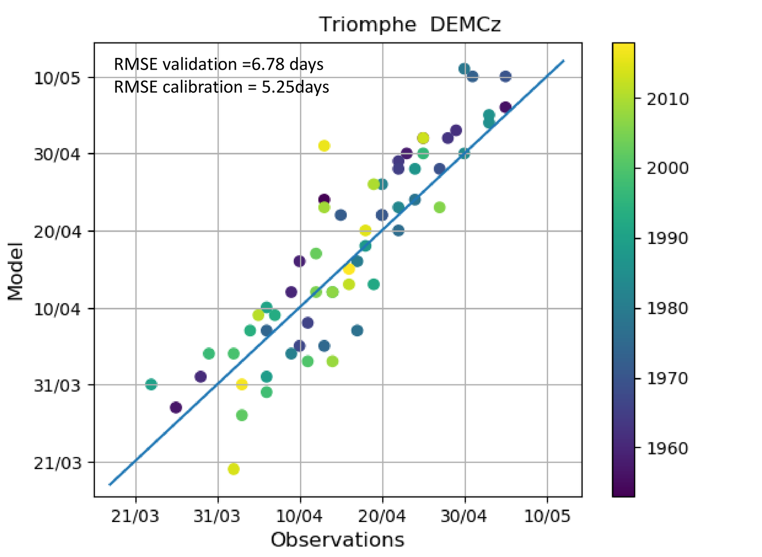
1. Split dataset[3] in 1989[4] for calibration and validation of the sequential model

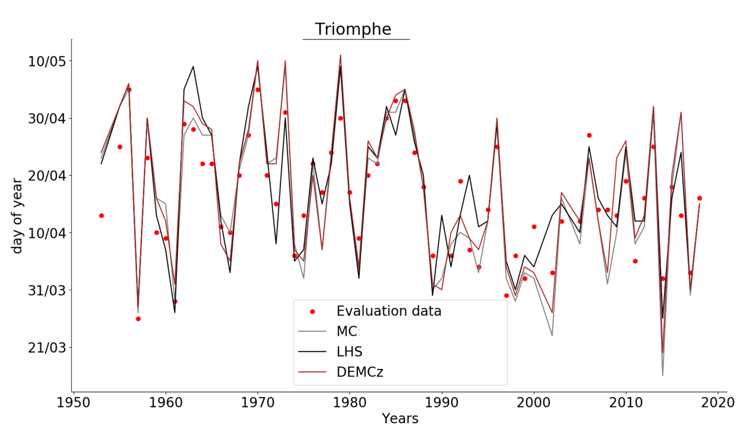


2. Optimisation approaches using SPOTPY [5]
   (Monte Carlo (MC), Latin Hyper Cube Sampler (LHS) Differential Evolution Markov Chain (DE-MCZ)



Model accuracy depends on cultivar and optimisation algorithm



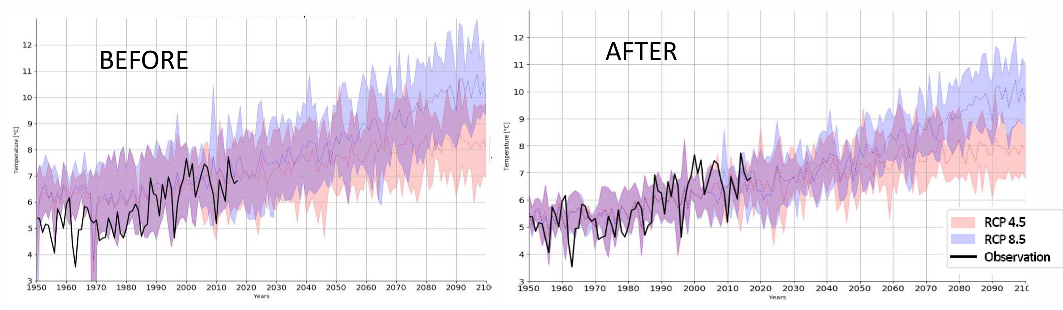


Ex. Triomphe : model performs equally well under a warmer regime

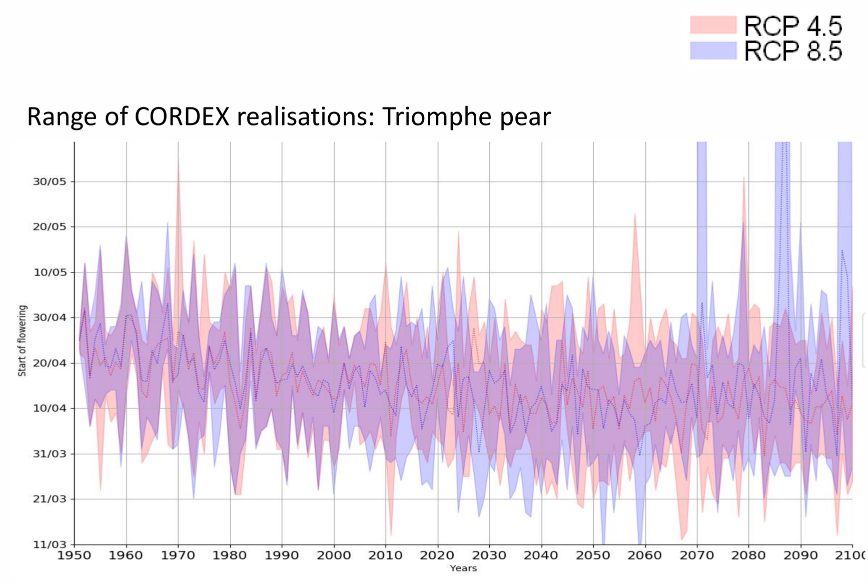
Suitability for Climate change modeling not excluded

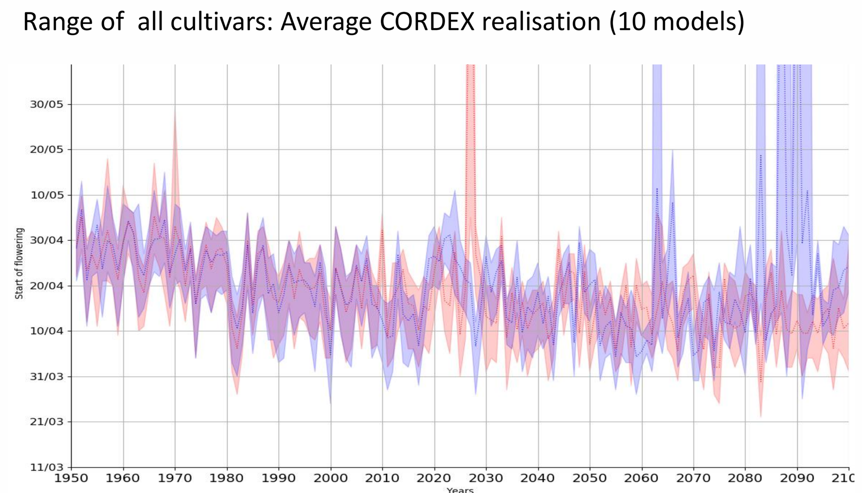
FUTURE PHENOLOGY

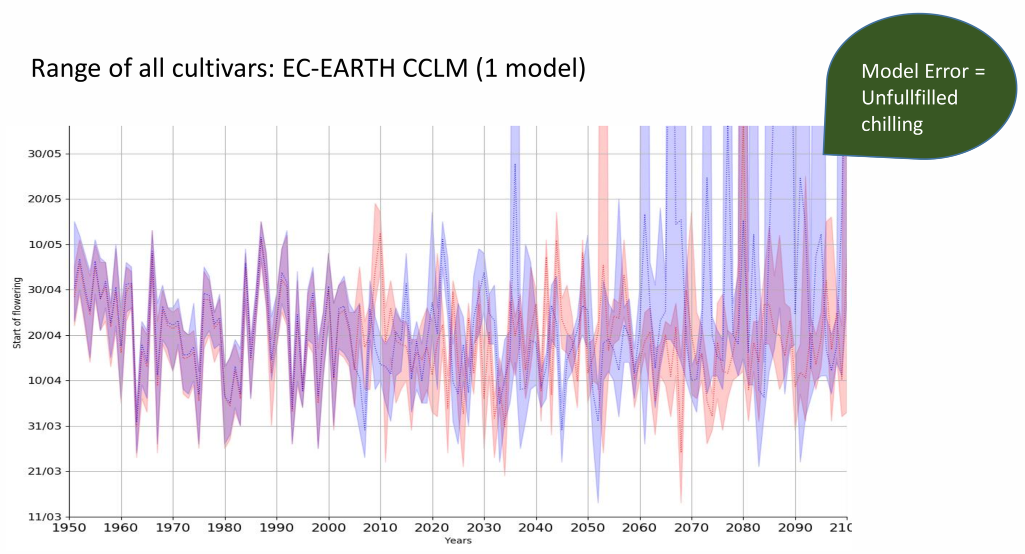
1. Bias Adjustment with Cumulative Density Function transfer (CDFt) [6]



2. Estimate the start of flowering for different CORDEX time series using the best fit sequential model







Persisting trend of earlier bloom

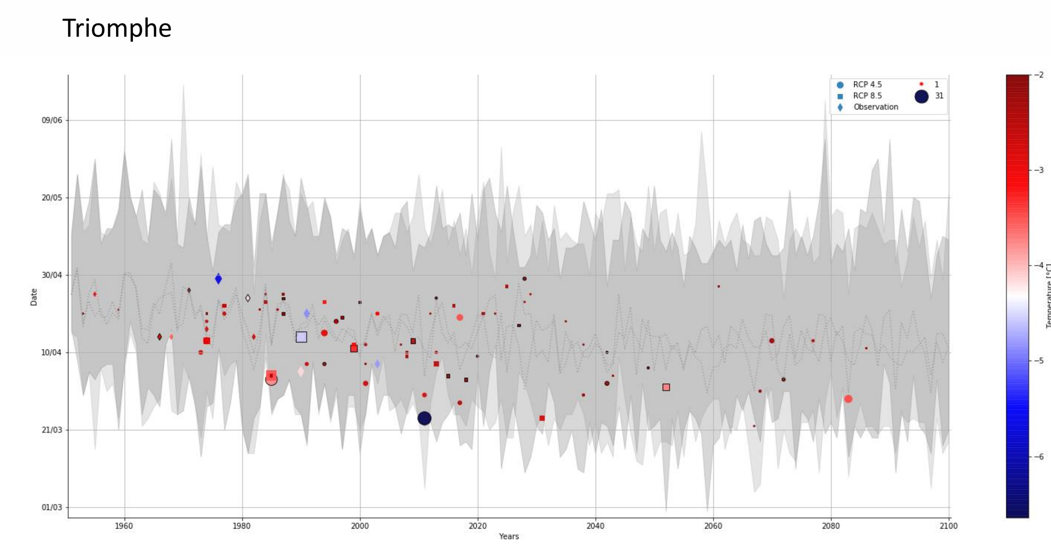
More frequent unfulfilled chilling requirements occuring under

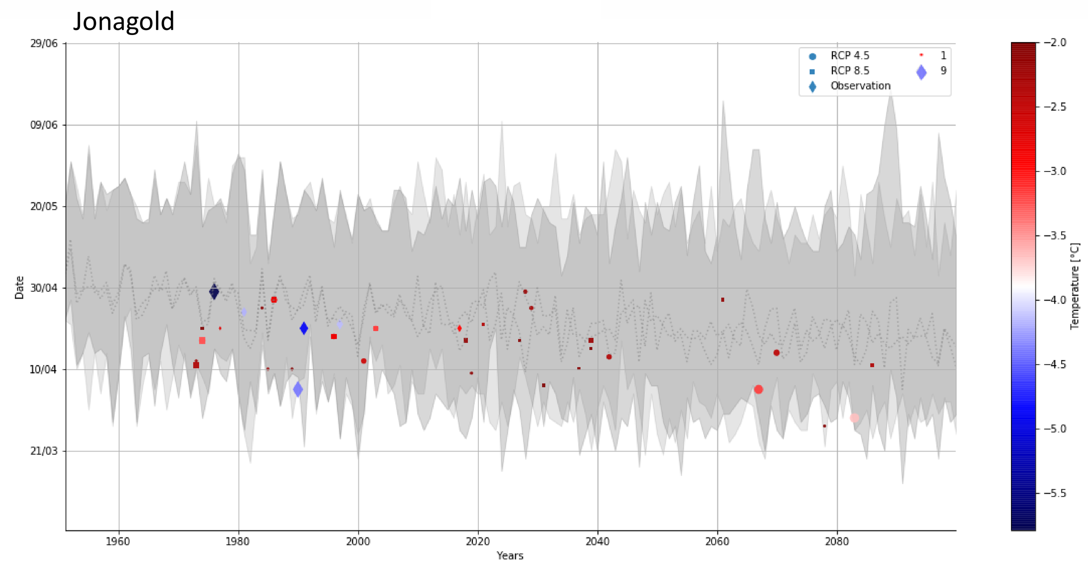
Uncertainty of climate change realisation is greater than the difference between cultivars

Single realisations are not representative for the ensemble

FROST RISKS

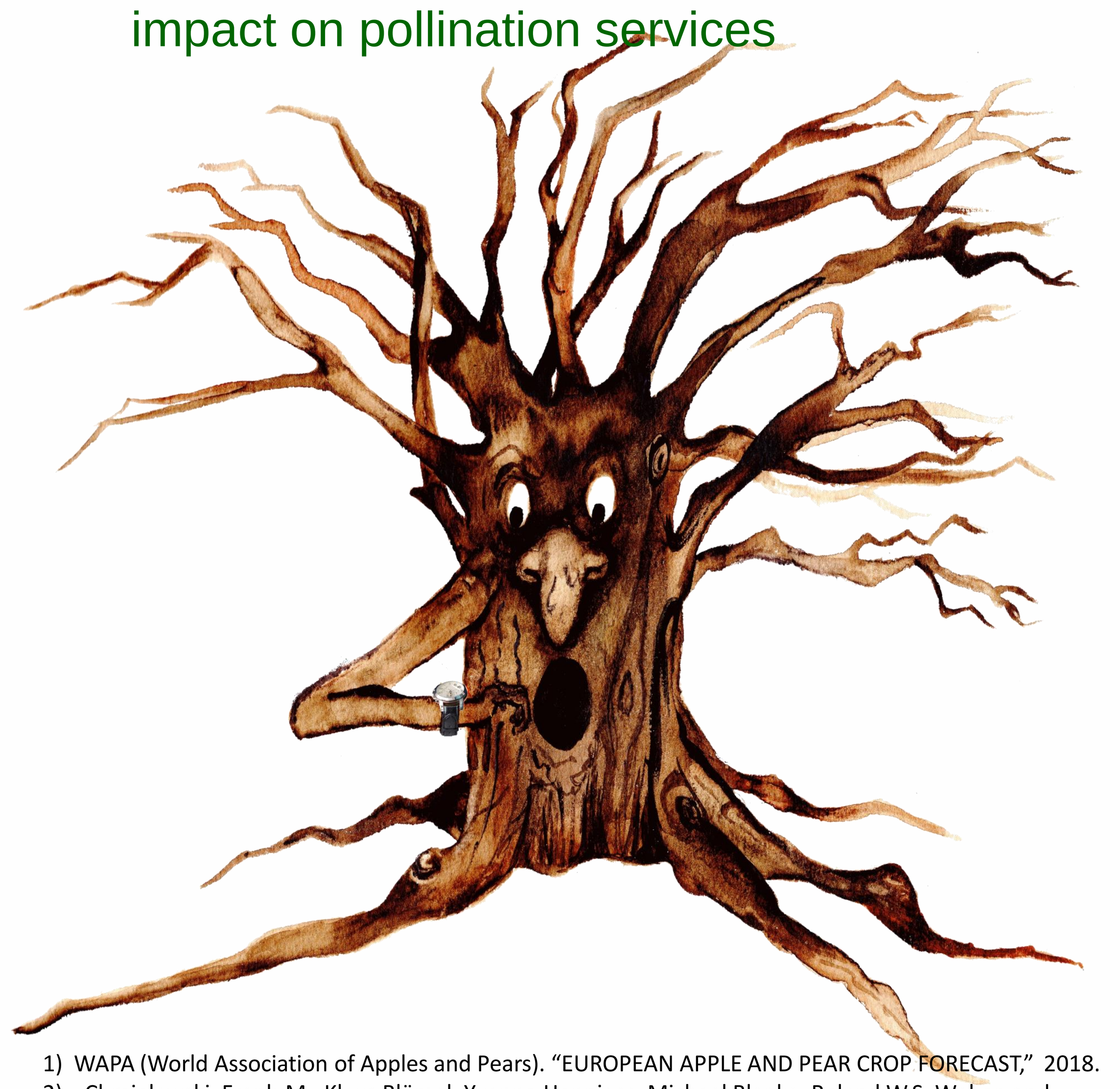
1. Extraction of yearly flowering period: Modeled flowering day -7 days + 14 days
2. Retrieve hourly temperatures[7]
3. Set threshold for destructuive frost as -2°C





Frost risk is decreasing but only towards the end of the century

Further research:
Risk of insufficient chilling;
diversification as risk reduction;
spatial variability
impact on pollination services



1) WAPA (World Association of Apples and Pears). "EUROPEAN APPLE AND PEAR CROP FORECAST," 2018.
2) Chmielewski, Frank-M., Klaus Blümel, Yvonne Henniges, Mark Blanke, Roland W.S. Weber, and Michael Zoth. "Phenological Models for the Beginning of Apple Blossom in Germany." *Meteorologische Zeitschrift* 20, no. 5 (October 1, 2011): 487–96.
3) Phenological timeseries provided by pcfruit research centre (https://www.pcfruit.be)
4) Gobin, A. "Weather Related Risks in Belgian Arable Agriculture." *Agricultural Systems* 159 (January 1, 2018): 225–36.
5) Houska, Tobias, Philipp Kraft, Alejandro Chamorro-Chavez, and Lutz Breuer. "SPOTting Model Parameters Using a Ready-Made Python Package." Edited by Dafeng Hui. *PLOS ONE* 10, no. 12 (December 17, 2015): e0145180.
6) Michelangeli, P.-A., M. Vrac, and H. Loukos. "Probabilistic Downscaling Approaches: Application to Wind Cumulative Distribution Functions." *Geophysical Research Letters* 36, no. 11 (June 11, 2009).
7) Luedeling, Eike. "Statistical Methods for Phenology Analysis in Temperate Fruit Trees (Package ChillR)," February 15, 2019.