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Assessing the reliability of four air temperature interpolation functions in estimating chill accumulation for deciduous fruit trees

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Abstract. Chill models, which are essential for estimating the chill accumulation necessary for the dormancy of various fruit trees, require continuous hourly temperature. To date, there has been no comprehensive study establishing the best method for filling gaps in hourly temperature records for Greek weather stations. Firstly, this study compares the performance of four temperature interpolation functions (the akima, cosine, hourly, and linear) against hourly air temperature observations from the Aristotle University of Thessaloniki weather station, for the dormancy period (October to March), during 1951-2023. Next, it tests these methods as input to two chill accumulation models (the Dynamic and the North Carolina Model. The hourly model was the most robust interpolation method during the day, even though at midday it was outperformed by the others. The hourly and linear interpolation methods exhibited the lower daily MAE values during the dormancy period. The hourly model was also the most accurate method for estimating chill accumulation with both chill models. the Dynamic and North Carolina model.

Keywords: Air temperature interpolation functions; Chill accumulation; The Dynamic chill model; The North Carolina chill model; Greece

1. Introduction, data and methods

The winter chill requirements of deciduous fruit trees are critical for determining the regions where specific varieties can thrive, as they directly influence tree productivity. Chill models (like the North Carolina and the Dynamic model), which are essential for estimating chill during the dormancy of various fruit trees, require hourly temperature data over a long period, conditions that very few meteorological stations meet. Methods that have been used to estimate temperature during the day vary in both their approach and complexity, and include among others trigonometric functions, and more recently, artificial intelligence. This study aims to address this issue by comparing the performance of four temperature interpolation functions (the akima, cosine, hourly, and linear) against hourly air temperature observations from the Aristotle University of Thessaloniki weather station, for the dormancy period (October to March), during 1951-2023. Consequently, these methods are tested as inputs to two chill accumulation models: the Dynamic Model and the North Carolina Model. The interpolation functions, chill models and appropriate references are described in detail by Tolidis (2024).

2. Results and conclusions

MAE is calculated for every hour and day of the dormancy period (Oct. – Apr.) and the findings for every interpolation function are illustrated for Thessaloniki in Fig 1a &b. The absolute minimum MAE in Thessaloniki is observed around 14:00 hour (Fig 1a); the hour of the day when the temperature variable is set to reach its peak value under clear sky conditions. At that time akima, cosine and linear methods reach a minimum of 0.5°C for MAE, whereas for the hourly model the respective value is about 0.8 °C. In contrast to the other methods, the MAE of the hourly model has the smallest range (0.8 -1.6 °C). Overall, the hourly model seems to be the most robust, even though at midday it is outperformed by the others. The hourly and linear interpolation methods exhibit the lower daily MAE values during the dormancy period whereas, cosine and akima the larger (1.1 vs 1.3 (°C)) (Fig. 1b). In winter (Dec-Feb), linear interpolation method presents the lowest MAE, while hourly interpolation is better for the remaining period.

Fig. 1 also compares mean chill accumulation, monthly, during the dormancy period, for every interpolation function and the hourly observations from Thessaloniki, for the Dynamic (Fig. 1d) and North Carolina model (Fig. 1c). The hourly model is the most precise method in estimating chill accumulation with the dynamic model since it presents the lower deviations from these estimated using temperature observations (Fig. 1d) It is followed by the linear, cosine and akima methods. The weather station of Thessaloniki accumulates 108 chill portions (CP) vs. 101 CPs for the hourly model, 95 for the linear model, 89 for the cosine model and 83 for the linear model. The hourly model is also the most accurate for estimating chill accumulation with the North Carolina Model (Fig. 1c), displaying the least deviations from using observations. The hourly, cosine, linear, and akima approximations followed. Thessaloniki's weather station accumulates approximately 1480 chill units as opposed to 1250 units for the hourly model, 1100 for the linear, 1120 for the cosine, and 850 for the akima model.

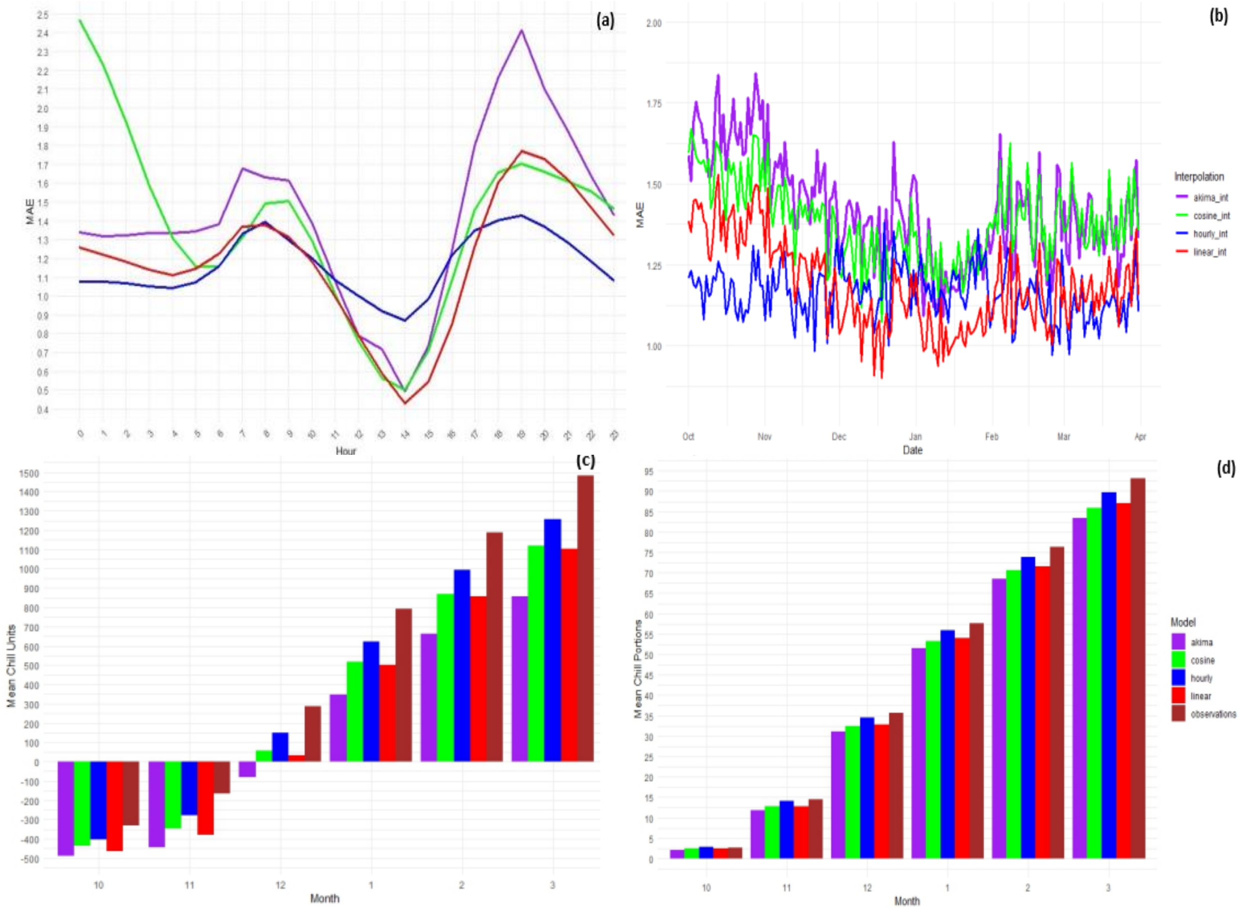

Figure 1. Comparison of (a) mean absolute error (MAE) (°C) on hourly (a), daily (b), cumulative Chill Units (North Carolina model) (c) and cumulative Chill Portions (the Dynamic model) (d) for each of the interpolation methods (hourly, linear, cosine and akima), for the period Oct-Apr in Thessaloniki, during 1951-2023.

Overall, the hourly model seems to be the most robust interpolation method during the day, even though at midday it is outperformed by the others. The hourly and linear interpolation methods exhibited the lower daily MAE values during the dormancy period. The hourly model was the most accurate method for estimating chill accumulation with the Dynamic and North Carolina model.

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