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## Probabilistic prediction of the time to hard freeze using seasonal weather forecasts and survival time methods

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In the agricultural sector there is a high interest for forecasts that predict relevant agroclimatic indicators related to heat accumulation and frost characteristics. The forecasts can simplify agricultural decisions related to planting and harvest timing. Motivated by this, we propose a probabilistic forecasting framework for predicting the end of the freeze-free season, or the time to a mean daily near-surface air temperature below 0 °C (here referred to as hard freeze). The forecasts are constructed based on a multi-model seasonal temperature forecast ensemble provided by the Copernicus Climate Data Store. The raw temperature forecast is statistically post-processed through a mean and variance correction. The resulting ensemble is next used as input to a survival analysis model. Survival analysis is a broad statistical field that is commonly used in the field of biostatistics, but rarely used in meteorology.

The forecasting framework is evaluated by predicting the time to hard freeze from October 1 for 1993-2020 for a region in Fennoscandia that covers Norway and parts of Sweden, Finland and Russia. We find that the proposed forecast outperforms a climatology forecast from an observation-based data product at locations where the average predicted time to hard freeze is less than 40 days after the initialization date.

Our work also forms an entry point showing how survival models can be used in general to construct seasonal forecasts for other meteorological events, e.g. the onset of the rainy season or the time to the next drought.