

Frost-free period, frost dates

The agricultural season is primarily determined by the period of suitable temperatures for growing crops. Temperatures above zero are a necessary condition for crop growth. Frost has a devastating effect on crops. In light frost (between 0°C and -1/-2°C) the tender plants are killed. Moderate freeze (between -2°C and -4°C) is widely destructive to most vegetation and lower frost is already causing severe damage to most plants.[1][2] This is a general simplification, the effects also vary for different growth stages (see picture X) and different crops. Therefore, it is important for farmers to know frost-free period in their agricultural areas. Especially the last spring frost date for starting agricultural work and first fall frost date for the cessation of agricultural activities. The likelihood of frost and frost trends over the years will help effective planning.

Growth Stage	Danger Temperature	Symptoms of Damage	Effect on Yield
Tillering	-11 C	Loss of leaf colour, burnt leaf tips, blue cast to crop	Slight to Moderate
Jointing	-4 C	Death of growing points, leaf yellowing, burnt leaves, splitting and bending of lower stems	Moderate to Severe
Boot	-2 C	Leaf discolouration, floret sterility, spike trapped in boot, damage to lower stem	Moderate to Severe
Heading	-1 C	Leaf discolouration, floret sterility, damage to lower stem, white awns or spikes	Severe
Flowering	-1 C	Leaf discolouration, floret sterility, damage to lower stem, white awns or spikes	Severe
Milk	-2 C	Leaf discolouration, damage to lower stem, white awns or spikes, shrunken, rough or discoloured kernels	Moderate to Severe
Dough	-2 C	Shrivelled, discoloured kernels, poor germination	Slight to Moderate

Picture X: How Frost Damage Affects Crops [3]

The last spring frost date, the first fall frost date

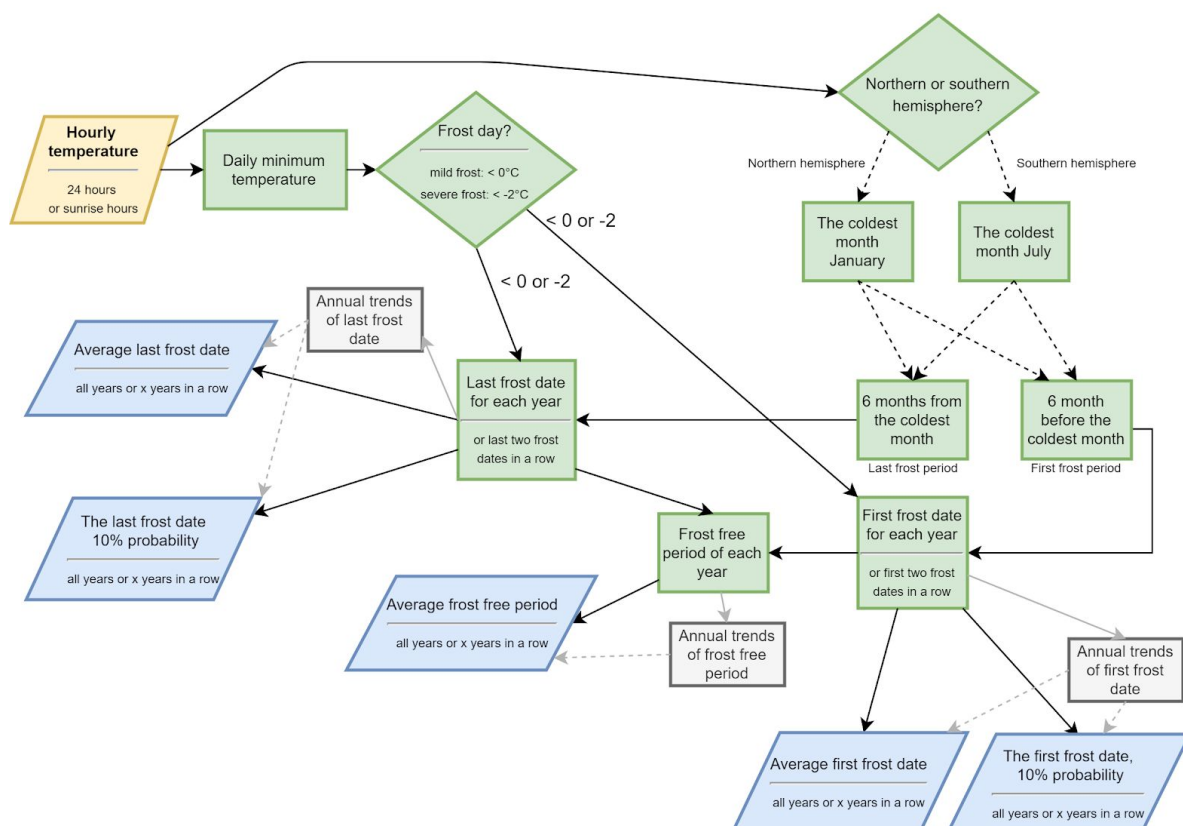
The last spring date is usually called the last day during spring (more correctly from winter to summer), when the minimum daytime temperature is less than 0 degrees of Celsius. The first fall date as the first day in the second half of the year (during autumn), when the minimum temperature is below zero. Usually this date is given with a 50% or 10% probability (statistically from several years) that it will freeze later (spring date) or sooner (autumnal date). For farmers, the most important are days with a low probability of frost, hence the last/first frost dates with a low probability. Sometimes frost dates are also given for other freezing temperatures eg - 2°C.[4]

Frost-free period

The frost free period is a period from the last spring frost to the first fall frost. It includes a period suitable for growing crops.

The minimum daily temperatures are a necessary variable for determining frost dates. The daily minimum is determined to be the lowest value of the day's hourly temperatures. (It is also possible reduce the calculation to the time around sunrise, as usually the lowest daytime temperatures are just after sunrise [5]). We are interested in the days when the minimum is below 0. Subsequently, the last day of each year is determined for the spring period and the first day for the autumn period. The spring period is set as a six-month period from the coldest month, the autumn period as 6 months before the coldest month. For the sake of simplicity, the coldest month is designated as January for the northern hemisphere and July for the southern hemisphere, it corresponds to the middle of the meteorologist winter season.[6][7] The resulting last spring frost date and first autumn frost date are calculated from the annual frost dates with a corresponding probability. The frost free period is calculated as the period between the last and the first frost date. Similarly, it is possible calculate the dates for -2.

Agroclimatic factors: temperature - freeze



Picture Y: Diagram of frost dates and frost-free period calculation

Data

Copernicus ERA5-Land hourly data from 2001 to present, variable 2m temperature

Horizontal coverage: Global

Horizontal resolution: $0.1^{\circ} \times 0.1^{\circ}$, Native resolution is 9 km.

Temporal coverage: January 2001 to present

Temporal resolution: Hourly

[8]

Copernicus ERA5 hourly data on single levels from 1979 to present, variable 2m temperature

Horizontal coverage: Global

Horizontal resolution: Reanalysis: $0.25^{\circ} \times 0.25^{\circ}$ (atmosphere), $0.5^{\circ} \times 0.5^{\circ}$ (ocean waves) Mean, spread and members: $0.5^{\circ} \times 0.5^{\circ}$ (atmosphere), $1^{\circ} \times 1^{\circ}$ (ocean waves)

Temporal coverage: 1979 to present

Temporal resolution: Hourly

Use for a time period that does not cover ERA5-Land.

[9]

Sources

[1] <https://www.almanac.com/gardening/frostdates>

[2] WMO. 1963. Protection Against Frost Damage

https://library.wmo.int/index.php?lvl=notice_display&id=5363#.XZQ_Wkb7SUK

[3] Feed Central, <https://www.feedcentral.com.au/frost-damage-affects-crops/>

[4] Agroclimatic atlas of Canada, 1976

<http://sis.agr.gc.ca/cansis/publications/manuals/1976-acac/index.html>

[5] C. Donald Ahrens, Meteorology Today, 2006

<https://books.google.no/books?id=SpGfKb23Y9QC&lpg=PP1&dq=Meteorology%20Today%20By%20C.%20Donald%20Ahrens&pg=PA117#v=onepage&q=Meteorology%20Today%20By%20C.%20Donald%20Ahrens&f=false>

[6] Jeff Haby, theweatherprediction.com

<https://www.theweatherprediction.com/habyhints3/980/>

[7] Meteorological Versus Astronomical Seasons

<https://www.ncei.noaa.gov/news/meteorological-versus-astronomical-seasons>

[8] Copernicus. ERA5-Land hourly data from 2001 to present

<https://confluence.ecmwf.int/display/CKB/ERA5-Land+data+documentation>

[9] Copernicus. ERA5 hourly data on single levels from 1979 to present

<https://confluence.ecmwf.int/display/CKB/ERA5+data+documentation>