Putting frost on the map

Frost, like other aspects of weather, is a difficult phenomenon to pin down. While the weather bureau can issue frost warnings for a region whenever overnight temperatures are likely to fall near zero, when frost strikes it is likely to be very selective in its targets. A paddock here can be smitten crisp and white; another up the hill can escape with only a chilling.

Yet the difference is vital for many crops. The temperature difference between the two sites may only be 2 or 3 degrees, but crossing the threshold of freezing means inevitable death to frost-sensitive plants.

The problem in trying to say when and where frost will strike is that the phenomenon depends on many factors: terrain aspects combined with meteorological factors such as wind, cloud, humidity, and the like.

Dr Jetse Kalma of the CSIRO Division of Water and Land Resources and Mr Greg Laughlin of the School of Geography of the University of New South Wales are working together to see whether they can improve our ability to predict where frost will strike.

During the winters of 1980, 1981, and 1982 they conducted experiments near Goulburn, N.S.W., to try to disentangle the influences of the various predisposing factors — particularly to separate meteorological influences from those of terrain.

If they could, then the task of dealing with the risk of frost would become easier. It would make it possible to specify which areas in a region are at highest risk — a boon to the farmer.

To understand the factors that make for a frost, the experimenters set out dozens of recording instruments over 90 sq. km of grazing country. Thermometers that registered the minimum air temperature — the most common instruments — were supplemented by continuously recording thermometers (air and ground temperatures), recorders of net radiation loss, and loggers of wind speed and direction. Some balloon soundings were also made.

Why does frost strike one spot but not another?

Braving more than 100 long cold nights during each of the three winters, the researchers obtained enough data to identify the essential ingredients for a frost.

Of the meteorological factors, cloud cover was, as you might expect, the most important. Without an insulating blanket of cloud, radiation quickly carried off the earth's heat to space.

Wind was the next most important. On calm nights cold air ran down into valleys and created intense cold spots. Conversely, a steady breeze dispersed such cold zones and, through vertical mixing, tended to keep the temperature of the ground from falling much below that of the surrounding air.

The third dominant factor was, simply, elevation. The higher the land, the warmer it tended to be.

Although the three variables affect each other, the researchers found that they could combine them in an equation that gives a good prediction of the minimum ground temperature expected at any site on a particular night. Mr Laughlin and Dr Kalma have improved the accuracy further by creating a mathematical model of the experimental area's terrain that takes into account whether a spot is on top of a hill, on a slope, or in a hollow.

The terrain model allows the researchers to produce maps of relative frost-hazard ratings. Given data on the incidence of frost at one location, they can use the model to transform a contour map into a map of relative frost hazard. This ability is potentially useful to farmers in managing their crops, particularly when new plantings are being considered.

The accuracy of the predictive technique was checked on two evenings when researchers from the CSIRO Division of Mineral Physics flew their infra-red scanner over the test area.

This instrument can give readings of the temperature at the surface by measuring the amount of infra-red radiation it picks up. From 1000 m above the ground the airborne scanner can quickly map the surface temperature over many square kilometres with a resolution of 1·5 m.

Its results matched very well with the minimum air temperature recorded on the ground. The scanner also revealed interesting warm spots. Sites covered with trees, roads, and water consistently showed up a couple of degrees warmer than their surroundings.

The researchers believe that aerial scanning can play an important role in assessing the frost risk at one site relative to a neighbouring one. They have tried using satellite data, but the result is presently too coarse for local frost mapping. In the future, though, satellites may become an important aid in predicting where and when frost will settle.

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