Recent trends in frost in New Zealand

Summary of the report: Recent Frost Trends for New Zealand (contract reference WLG2009-16)

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Authors: A Clark and J Sturman

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Requests for further copies should be directed to:
Trecia Smith
Natural Resources Group
Ministry of Agriculture and Forestry
P O Box 2526
Wellington 6140

Telephone: 0800 008 333
Facsimile: +64 4 894 0300

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Key findings

- MAF commissioned NIWA to undertake a trend detection study examining frost occurrence in New Zealand in response to feedback from the kiwifruit and viticulture industries that frost management is a key tool to adapting to climate change. The analysis used data from the early 1970s onwards (1972–2008), when temperature monitoring across the country had become more widespread. This enabled NIWA to examine regional variation in frost trends.
- Understanding trends in frost frequency is complex as there are a number of different factors that influence the occurrence of frost. Two interesting findings came from NIWA's latest research on frosts:
  - Across New Zealand as a whole, the study found strong evidence that frosts have been decreasing in the period 1972–2008. **This is consistent with global level warming over this time.**
  - The study also found significant regional variation within New Zealand, and some agricultural regions have experienced increases in frosts from 1972–2008. **This is consistent with New Zealand's maritime climate, topography and the expected effects of natural variability in climate.**
- That some regions have experienced increased number of frosts since 1972 does not mean that climate change is not happening. It means that over the last 30 years, other factors have been more influential in these regions in creating the right conditions for frost than the global warming signal.
- The study highlights the need for regional and local level analyses to ensure that decision-makers get the best guidance on climate change impacts specific to the area in question. When developing adaptation responses to climate change, like altering frost risk management, we cannot assume that a single global or national trend will apply in every region.

Frosts, climate change and primary production

Frosts occur when the surfaces of plants are cooled to below the dew point of the surrounding air, and then ice crystals form. There are two main types of frost:

- "Radiation" frosts. Most frosts in New Zealand are "radiation" frosts. Heat is lost from the ground to the atmosphere on clear still evenings, creating inversion layers. This is when cold air flows from higher to lower altitudes and the plant canopy becomes cooler than the earth below and air above.
- "Advection" or wind frosts. These occur when a very cold air mass moves across the plant canopy as part of a broader weather system, and are relatively rare in New Zealand.

Frost can reduce production and quality in crops, pastures and forests. The negative physical impacts of frost include: the blistering or bursting of fruit in orchards and vineyards; yield loss when frost damages flowers in broadacre or horticulture crops; the abrupt cessation of growth in some pasture species; and scalding of soft stems, new growth or juvenile plants. On the other hand, some plants have a vernalisation requirement, and need a frost event to proceed to the next development stage.

Frost risk is the combination of both the climatic frequency of these events, or how often frosts happen, and their impact on the farm business. Management actions are implemented by producers to avoid or reduce physical damage from frost. This might include site and species selection, frost insurance, production diversity, timing of planting and or harvesting to avoid the frost window, and physical actions that disturb inversion layers, such as wind machines or helicopters. Frost risk management can be expensive and it makes sense to get value for money by knowing the frost characteristics in a given area and matching management techniques accordingly.

Global climate change brings the prospect of reduced frost risk because of the process of warming that has been observed over the last century. National level studies have confirmed the warming trend for New Zealand as a whole, but other locally focussed studies and anecdotal reports suggest that frosts may be increasing not decreasing, at least in some locations. Given the physical impacts and costs involved in managing frost, the agricultural sector is interested in detecting regional frost trends.

This study examined the climate frequency component of frost risk by detecting trends in "screen frosts". This is a "proxy" for frost, used extensively in weather and climate science. We assume that a frost occurs when the minimum temperature falls below 0°C in a standard measurement screen 1.2 metres above the ground. This assumption holds true regardless of how the frost occurs (that is, it covers both radiation and advection frosts). Box 1 briefly describes methods used to detect frost trends in this study, as well the three main steps used by scientists to examine climate trends.

BOX 1: EXAMINING CLIMATE TRENDS

Climate data: considerable effort is needed in sourcing and quality control of data to ensure that any trend detection is real and not a result of a station change, urban heat island effects, or any other measurement problem. Suspect data can be "homogenised" to correct problems. The frost analysis in this study is based on three sets of data: 112 quality controlled minimum temperature records from around New Zealand (1972–2008); interpolated minimum temperature data from NIWA's virtual climate station network (1972–2008); and New Zealand's national composite temperature record (built from a small number of sites 1884–2008).

Trend detection: Climate scientists use a variety of methods to detect trends depending upon the problem. These might be linear when a trend is known to be the same direction over time, or non-linear when changes in the direction and or rate of a trend occur. More sophisticated methods are also used to discern the contribution of different global, regional and local processes to a trend. Statistical tests can be used to determine if the trends are significant (that is, what is the chance that the trend detected is a result of random fluctuations?). Generally methods suitable for detecting global climate changes are more spatially and temporally aggregated than those that are sensitive to other processes like El Niño Southern Oscillation and the weather. Trend detection in this study is carried out using a standard linear method, ordinary least squares regression, and the metrics of frost are aggregated in time and across the country and regions (Figures 1 to 3).

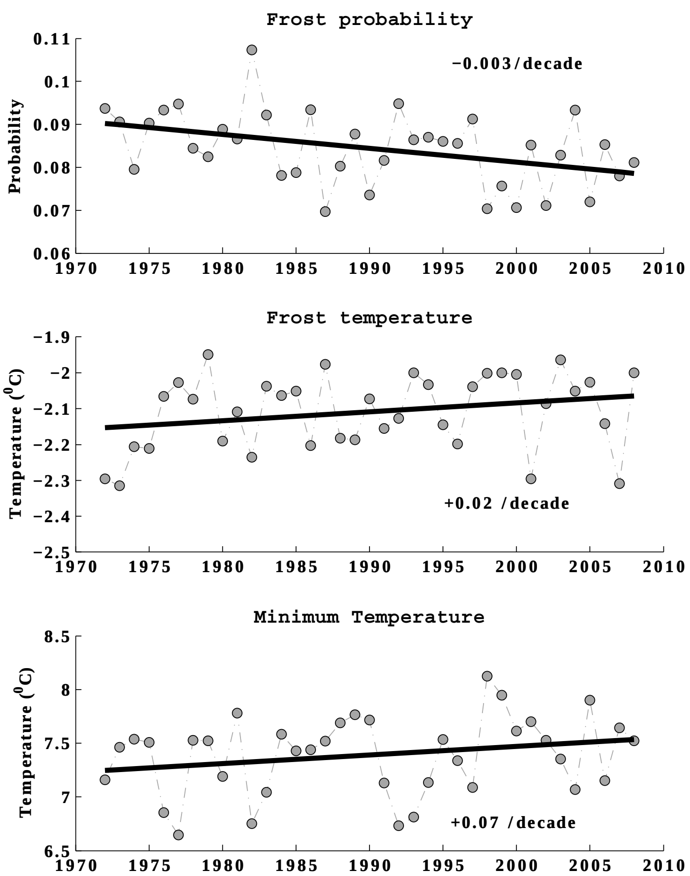
Climate attribution: Further steps would be needed to discern what processes are driving trends. This typically involves correlating trends with measures of climate processes usually in association with physical climate modelling experiments. A formal attribution analysis was not undertaken in this study, but some interpretations are made based on previous studies.

Recent frost trends

NATIONAL WARMING

A significant warming trend was detected when the temperature data were examined nationally. This is evident as reduced frost days, and increasing minimum and frost temperatures (Figure 1).

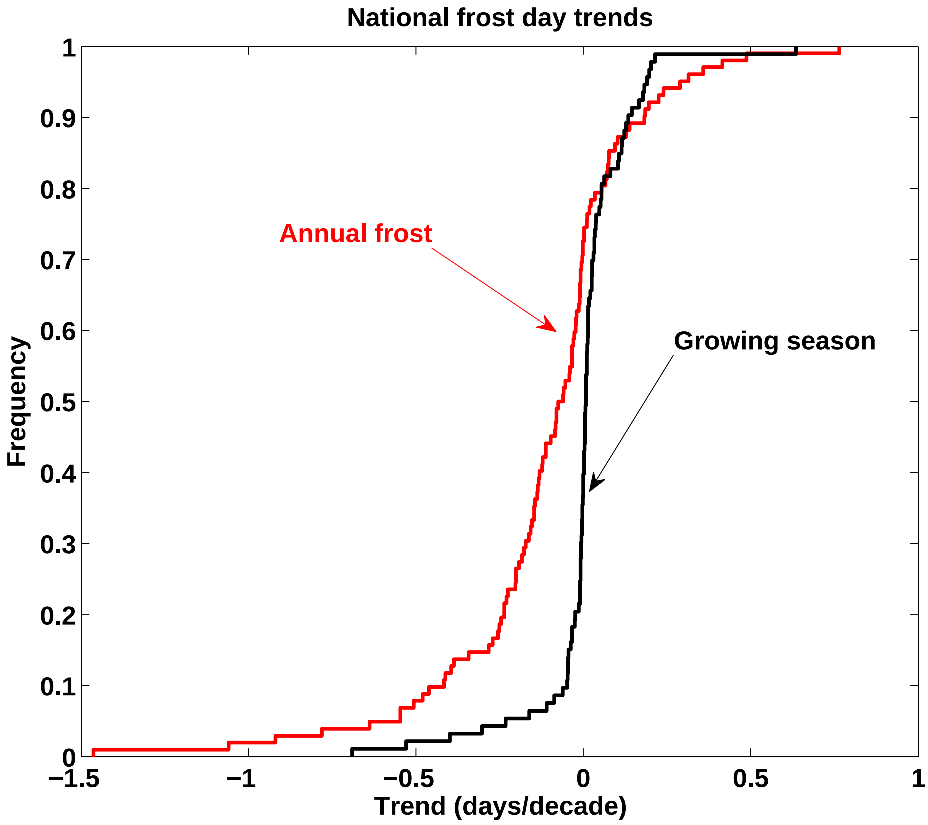
Figure 1: National composite trends in frost frequency, frost temperature and minimum air temperature (based on homogenised data from 112 climate stations)



REGIONAL WARMING AND COOLING

Examining individual climate stations, approximately 70 percent of the 112 analysed had reduced frost days (a “warming”), while 30 percent had increased frost days indicating a “cooling” (Figure 2). The trend is weaker when the growing season is examined (Figure 2) with far fewer sites exhibiting reduced frost days (“warming”).

Figure 2: Cumulative distribution showing the number of stations (frequency) with positive or negative trends



The study detected a distinct regional pattern in the trends, with two regions having increased frost frequency: parts of the Wairarapa, and the lower Canterbury plain south to below Dunedin (Figure 3a). The strongest warming occurs in higher altitude regions of both Islands. The trends in these regions were statistically significant (Figure 3b).

The coastal and low lying zones of the country generally exhibited no change – showing no trend, or slight increases or decreases in frost occurrence that were not statistically significant.

Figure 3a: Maps of frost frequency trends (a) and significance test (b). Analysis based in NIWA's Virtual Climate Station Network.

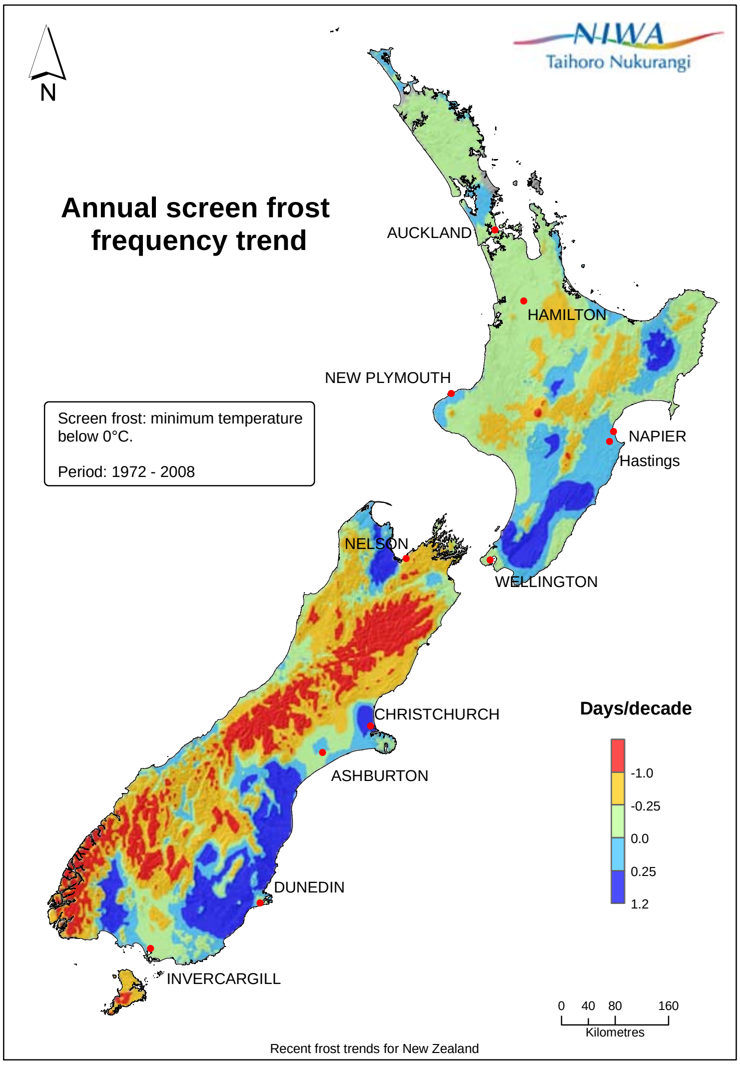
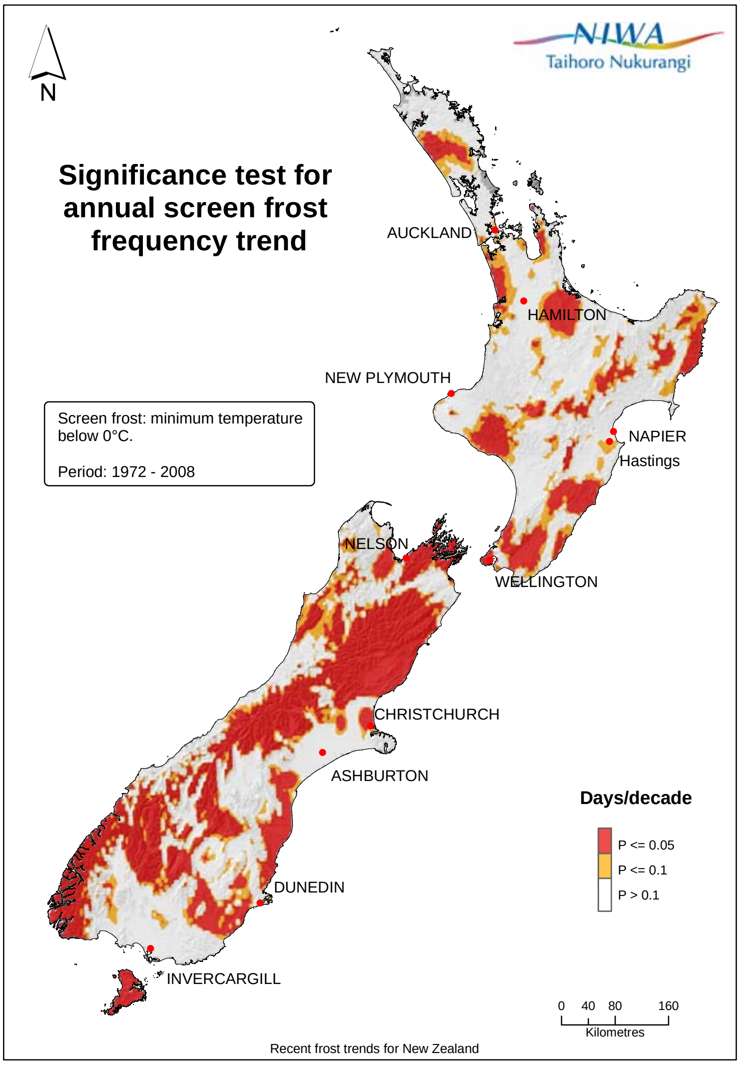


Figure 3b: Maps of frost frequency trends (a) and significance test (b). Analysis based in NIWA's Virtual Climate Station Network.



WILL THE REGIONAL TRENDS CONTINUE?

This study addressed detection of recent trends and, because of the short time series available for regional level analyses, it did not assess how trends and regional patterns might change in the future under the combined influences of projected anthropogenic global warming and decadal natural variability in regional climate. Good quality, widespread temperature data is not yet available for a long enough period in New Zealand to discern the relative contribution of global warming and decadal variability to the regional pattern found in this study. For New Zealand's national aggregate temperatures, however, the record can be extended back to 1884, and we can detect a long-term warming trend. This long-term warming interacts with decadal variability: both affect the climate which producers face.

Implications for climate change adaptation

At first glance, it might seem reasonable to assume that frost risk will decline as global climate change occurs in the coming decades. This prospect is attractive for New Zealand growers and agriculture because of potential reductions in physical impacts and costs of managing frost risk.

But this study illustrates that directly applying national and global trends to a local and regional level, may not be good practice. In some regions of New Zealand local factors appear to have had a stronger influence on frost risk over recent decades than the increasing global temperatures detected in this timeframe.

Importantly, the study shows that New Zealand's climate is changing and overall there is a decrease in frosts, despite the increased occurrence of frost in some areas over the 1972–2008 period.

Adapting to a changing climate by modifying frost risk management will need to be carefully targeted to address the understood drivers and effects of frost in a particular area, as well as the future frequency of frosts. New Zealand growers and agriculture have been managing frost risk for some time, and management techniques in some regions will need to change into the future to reflect the specific challenges of a site.

Further reading

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