Fire Research Report

Climate and Severe Fire Seasons: Part III

Forest Research

March 2003

This report aims to identify characteristic weather patterns that cause extreme regional fire risk in Northland and Canterbury on daily (DSR) scale. The top decile (90th percentile) of long-term MSR months were identified for Dargaville (Northland) and Christchurch (Canterbury). In these extreme high severity months, the DSR were examined for Northland and Canterbury for the same months. Northland and Canterbury were chosen for closer investigation here because these districts have significant areas of forestry.

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Climate and Severe Fire Seasons – Part III Climate Patterns and High Fire Severity in Northland and Canterbury

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Climate and Severe Fire Seasons – Part III Climate Patterns and High Fire Severity in Northland and Canterbury

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Executive Summary

Severe fire seasons experienced in New Zealand have been attributed to the influence of climatic patterns in a number of studies. The National Rural Fire Authority has for a number of years been working towards an improved fire risk forecasting regime, with the aim of better preparedness and resource deployment. The present National Institute of Water and Atmospheric Research (NIWA) report forms part of a multi-year investigation of climatic and weather factors that give rise to high daily, monthly and seasonal severity fire risk.

NIWA have previously investigated linkages between climate predictors and fire severity rating (Salinger et al 1998; Heydenrych et al 2001, 2002) at the seasonal (SSR) and the monthly (MSR) scale. This report aims to identify characteristic weather patterns that cause extreme regional fire risk in Northland and Canterbury on daily (DSR) scale. The top decile (90th percentile) of long-term MSR months were identified for Dargaville (Northland) and Christchurch (Canterbury). In these extreme high severity months, the DSR were examined for Northland and Canterbury for the same months. Northland and Canterbury were chosen for closer investigation here because these districts have significant areas of forestry.

In Dargaville, westerly or southwesterly wind flow increases the fire risk during November. Persistence of weather types that produce dry westerly, southwesterly or anticyclonic easterly wind flow tends to enhance the fire risk during December. January fire risk tends to be due to persistence of anticyclonic wind flows from either the west or the east. February again has extreme fire risk under persistence of anticyclonic easterly or westerly wind flow, while March fire risk is under persistence of weather types that have a westerly wind component.

In Canterbury, westerly or southwesterly wind flow increases the fire risk during November. Persistence of weather types that have westerly quarter (NW, W, or SW) wind flow tends to enhance the fire risk during December. January fire risk again tends to be due to persistence of westerly quarter wind flow, or anticyclonic conditions. February and March both have extreme fire risk under persistence of dry westerly quarter winds.

These results from DSR assessment concurs reasonably well with the long-term MSR findings of Heydenrych (2001). However, greater temporal resolution allows for a more sophisticated assessment. A key finding of the present study shows the high DSR values are linked to a persistence of a specific synoptic weather type over a three to five day period. It is recommended that this approach be used for the other fire climate regions. This study shows that the persistence of dry winds and airflows over a number of days for a region are the primary promoters of extreme fire risk. When such conditions for a fire climate region are forecast, preparedness can be increased by public education campaign and allocation of equipment and resources.

Introduction and Background

Severe fire seasons experienced in New Zealand have been attributed to various climatic circulation features, such as the influence of El Niño and La Niña events. The possible prediction of seasonal severity based on expected seasonal climate variations is important because detection of discernible trends coupled with seasonal climate prediction would allow some anticipation of potential higher regional fire risks. The National Rural Fire Authority (NRFA) has reported variable success in their endeavours to uncover specific factors that cause high seasonal fire risk (Pearce et al., 1995). In an initial study, the National Institute of Water and Atmospheric Research (NIWA) investigated linkages between climate predictors and severe fire seasons for 10 stations in New Zealand up to year 1995 (Salinger, 1998).

Heydenrych et al (2001) extended work presented by Salinger (1998) through detailed analysis of the relationships between global (such as El Niño and La Niña) and regional circulation indices and monthly severity ratings (MSR) and seasonal severity ratings (SSR) for 21 stations throughout New Zealand.

The second part of the 3-year programme focused on inter-regional associations of the different fire regions throughout New Zealand. Heydenrych et al (2002) identified 15 fire regions in New Zealand based on analysis of daily severity ratings (DSR) from 128 stations. The analysis also provided key fire risk indicators for each of the 15 fire regions based on long-term climate and circulations indices.

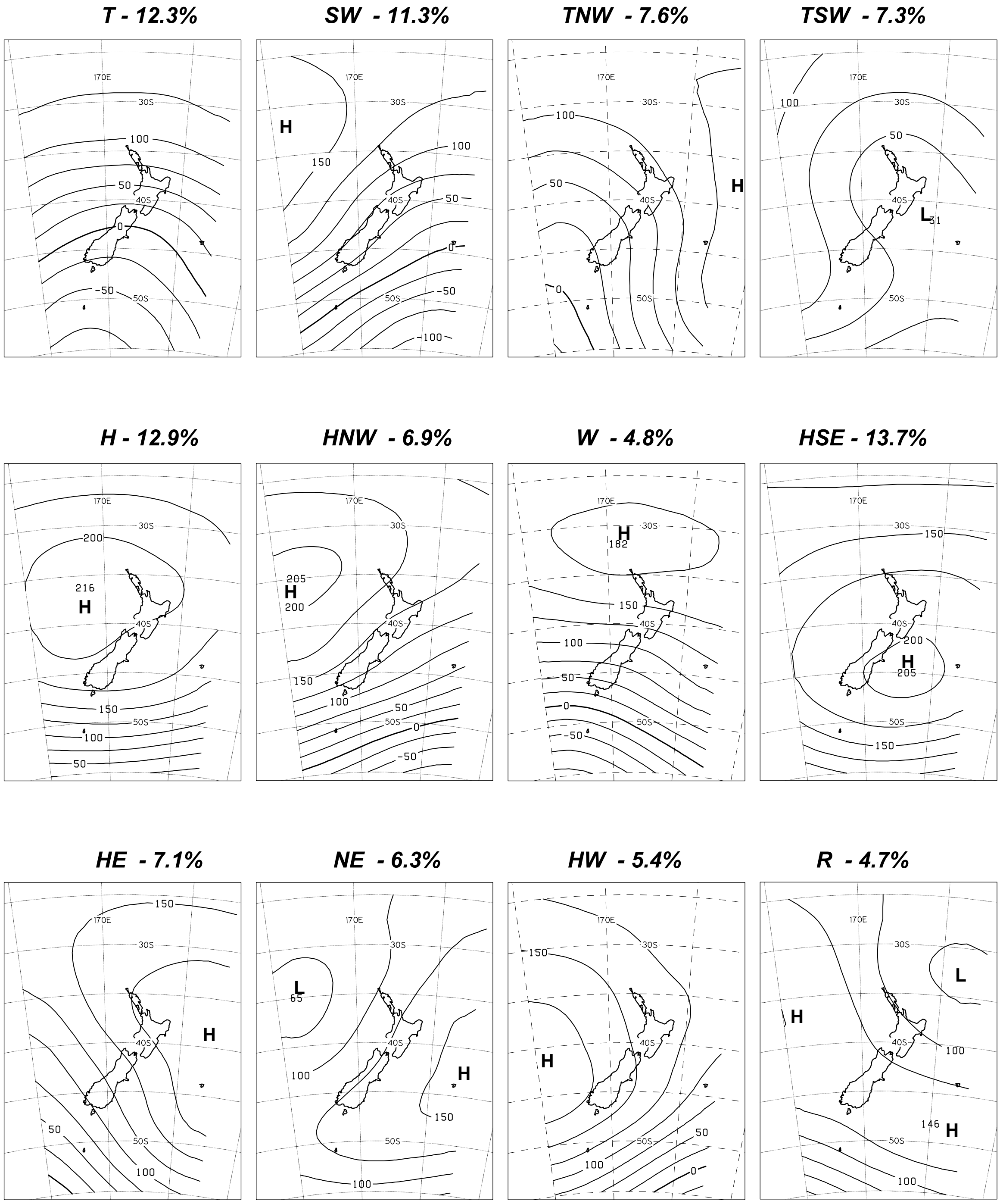
Scope of Part III of the Study

The goal of the third part of the programme is to identify characteristic climatic patterns that cause high regional fire severity in Northland and Canterbury. These two regions, Northland and Canterbury, were selected, as these regions are considered to be key locations to explore more detailed linkages between DSR and climate variability because of large areas of forestry. The present study deals with only the highest MSR months from the long-term monthly data (Heydenrych et al 2001, 2002) for the two regions. The top decile (90^{th} percentile) months from the long-term MSR data and the DSR of these months were compared to the daily synoptic weather types identified by Kidson (2000). See Table 1 and Figure 1 overleaf for Kidson (2000) definitions.

Table 1 Indices of Circulation in New Zealand Region

Index	Pressure difference/Synoptic Type*	Type
Z1	Auckland-Christchurch	Zonal westerlies
Z2	Christchurch-Campbell Island	Zonal westerlies
Z3	Auckland-Invercargill	Zonal westerlies
Z4	Raoul Island- Chatham Island	Zonal westerlies
M1	Hobart-Chatham Islands	Meridional southerlies
M2	Hokitika-Chatham Island	Meridional southerlies
M3	Hobart-Hokitika	Meridional southerlies
MZ1	Gisborne-Hokitika	North-westerly flows
MZ2	Gisborne-Invercargill	North-westerly flows
MZ3	New Plymouth-Chatham Island	South-westerly flows
TSW	* Trough/southwesterly	Trough in southwest flow crossing New Zealand
T	* Trough	Trough in westerly flow crossing New Zealand
SW	* Southwesterly	Southwesterly flows
NE	* Northeasterly	Northeasterly flows
R	* Ridge	Ridge – light winds over the south, easterlies over the north
HW	* High to southwest	High to west of the South Island with light south – southwesterly flows
HE	* High to east	High to the east with developing northwesterly flow
W	* Westerly	Westerly flow
HNW	* High to northwest	High west of the North Island with southwesterly flow
TNW	* Trough in northwest	Trough to the west preceded by northwesterly flow
HSE	* High to southeast	High east of the South Island with easterly flow for the North Island and light winds elsewhere
H	* High	Light winds – North Island Westerly flow – far south

Fig 1 **Mean surface atmospheric circulation flow patterns used to categorise daily weather types (Kidson 2000). Percentage values represent the frequency of each type each year over the period studied. Winds flow along the contours shown, with speed inversely proportional to the contour spacing.**



Methodology

Data

Daily severity ratings (DSR) for Northland and Canterbury were obtained from the NRFA for the years October 1991 to April 2002. NIWA has previously calculated the MSR and SSR values for 21 stations used in Heydenrych et al (2001, 2002). Data availability for MSR and DSR are shown in Table 2 and Table 3 respectively.

Table 2 MSR Data

Site	Month of Commencement	Month to Date
Christchurch	January 1961	April 2001
Kaitaia	January 1963	December 1995
Dargaville	January 1979	April 2001

Table 3 DSR Data

Site	Year of Commencement	Year To Date
Christchurch	January 1994	June 2002
Kaitaia	January 1991	October 1996
Dargaville	January 1995	June 2002

The long-term MSR record was used to identify months with extreme fire risk, namely, the top decile (90^{th} percentile). Figures 2, 3 and 4 show the MSR values for each of the three sites. It should be noted that the 90^{th} percentile MSR value for Christchurch (about 13.5) is much higher than those for Dargaville (2.8) and Kaitaia (4.8) because Canterbury has a much more severe fire climate.

A total of 24, 18 and 20 extreme MSR months (90^{th} percentile) were identified for Christchurch, Dargaville and Kataia, respectively. However, only 8 months for Christchurch, 1 month for Kaitaia and 7 months for Dargaville could be analysed due to limited length of DSR data. Dargaville was thus used to represent Northland due to limited data availability for Kaitaia. The DSR values for the extreme months (8 for Christchurch and 7 for Dargaville) were then analysed with respect to the synoptic weather types described by Kidson (2000).

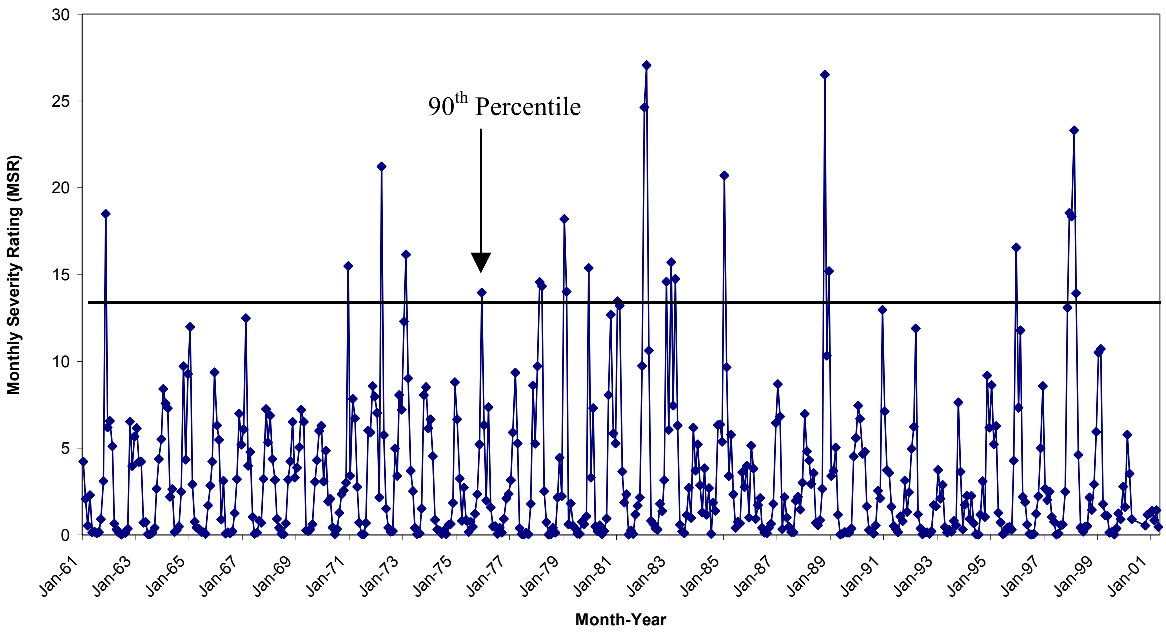


Figure 2 Monthly Severity Rating for Christchurch from 1961 till 2001

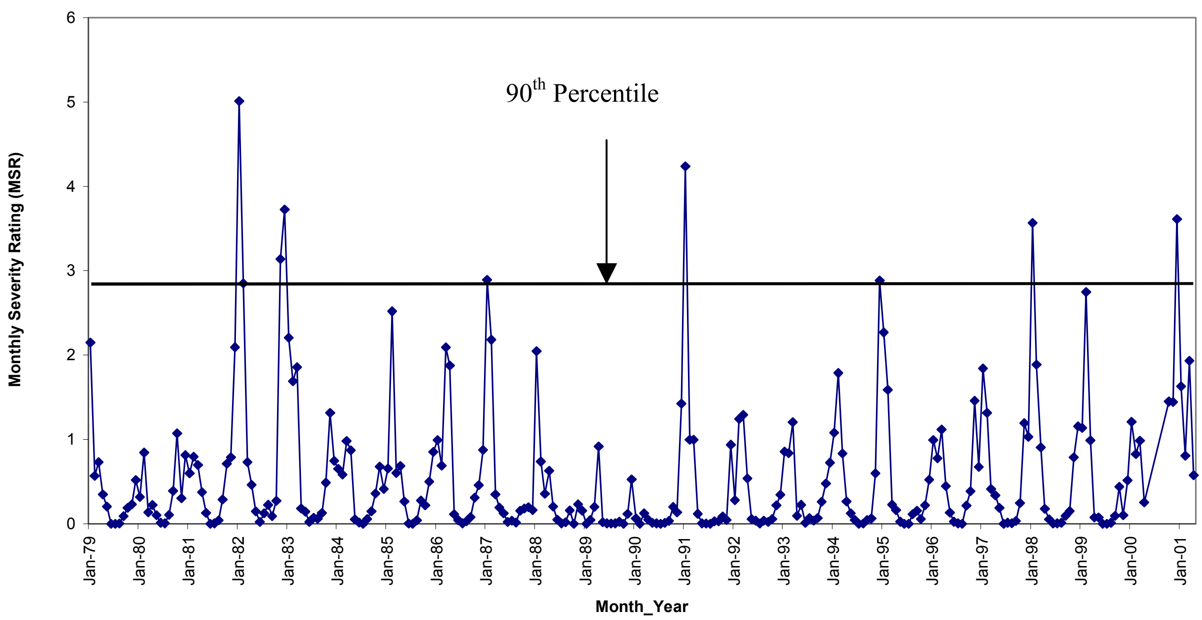


Fig 3 Monthly Severity rating for Dargaville from 1979 till 2001

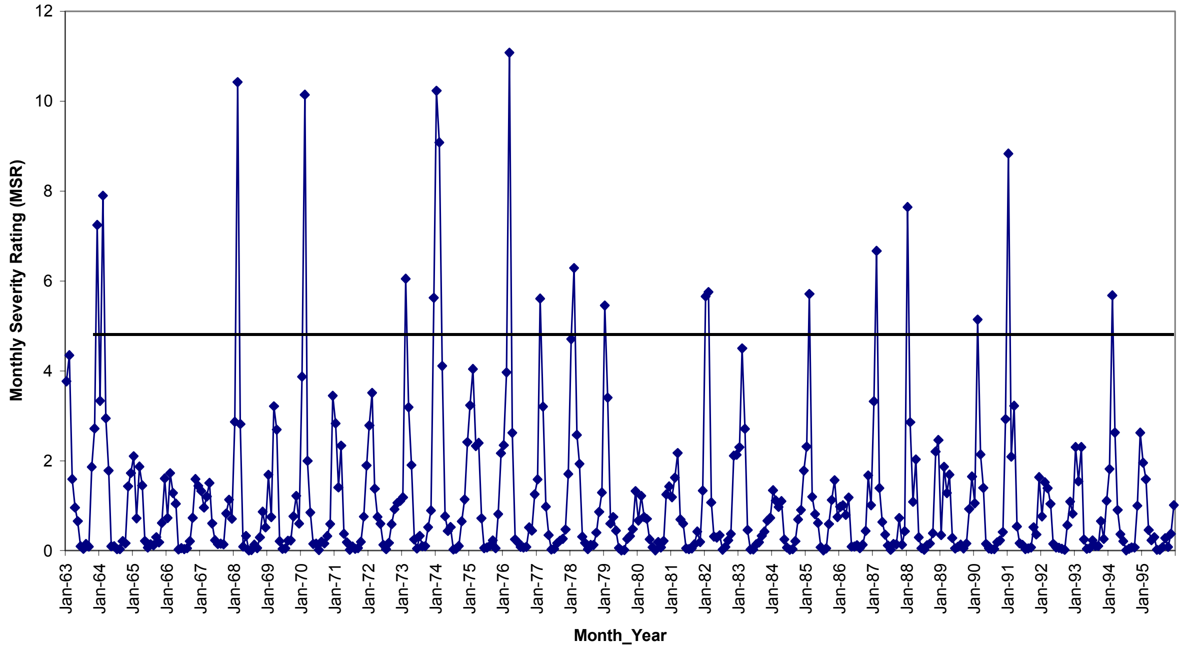


Fig 4 Monthly Severity Rating for Kataia from 1963 till 1995

Twelve daily synoptic weather types described by Kidson (2000) were used to define winds flows for New Zealand (see Table 1 and Figure 1 for descriptions of the synoptic weather type and associated wind flow). Similar patterns of local weather or climate can sometimes be associated with a number of different synoptic weather types For example, a northwesterly flow in Canterbury can result from a TNW, W, HW, R or HE synoptic situation. Hence, dry westerly quarter flow is the guide to high fire risk. The synoptic weather types cannot be statistically correlated with the DSR due to the different data type. DSR is continuous while weather types are categorical definitions, which are not numerically continuous. Hence, it does not make sense to carry out analyses such as correlations between DSR with weather type number, but classification approaches can yield useful information, as shown below. The long-term DSR record (i.e. all available data) was classified with the 5-group classification system used by the NRFA. The classification is summarised below in Table 4.

Table 4 Fire Classifications

Fire Classification	Long-Term DSR Percentiles
Extreme	80th – 100th
Very High	60th – 80th
High	40th – 60th
Moderate	20th – 40th
Low	0 – 20th

Therefore, an increase above the 80th percentile value was assumed to be an extreme fire risk scenario for that location. Northland and Canterbury had different values for the 80th percentile, as the severity ratings for the two regions are different (see Table 5).

Table 5 80th and 100th Percentile of the DSR for Northland and Canterbury

Site	80th Percentile	100th Percentile
Christchurch	7.7	114.4
Dargaville	2.3	24.5

The DSR values that exceeded the 80th percentile were compared with the synoptic weather types for the same days. If the DSR values exceeded the 80th percentile over 3-5 days (as this showed persistence of high fire risk), this was deemed to be extreme fire risk. The extreme fire risk days were then compared with the daily weather types for the same period to determine if the persistence of a wind flow associated with a sequence or persistence of a weather type or types were responsible for the extreme fire risks.

The seasonal and monthly results from Heydenrych et al (2001) were compared with results from the daily analysis to compare and contrast the results with those from the different temporal resolution.

Results and Discussion

The analysis of the extreme DSR months is shown in Table 1 and 2 in Appendix 1 for Dargaville and Christchurch, respectively. DSR values, which have exceeded the 80th percentile, are shown in bold while the corresponding synoptic weather type has been italicised, and an arrow shows the persistence over a period.

The traditional fire season is from the months October until April. Extremes of fire risk tend to occur over the warmest months of November to March, as confirmed in this study.

The daily synoptic weather types during the extreme MSR months in the two regions compared to Heydenrych et al (2001) are summarised in the Appendix 1. Further, the extreme MSR months are defined as months that have extreme DSR values during the month. The results discussed below are not for typical fire season but for situations of extreme fire risks.

Dargaville

In Dargaville, the analysis of the extreme fire risk months show that a predominance of westerly or southwesterly wind flows leads to extreme fire risk during November, whilst in December extreme fire risk is attributed to southerly and westerly wind flow. Extreme fire risk during January is due to easterly and southwesterly wind components and extreme fire risk during February is under the domination of easterly or westerly winds. Easterly wind flow again leads to extreme fire risk during March.

In broad terms, these results for Dargaville are in agreement with those from Heydenrych et al, 2001 (Fig 5). Monthly results (Heydenrych et al, 2001) show a number of weather patterns, which influence the fire risk. The patterns identified using DSR values have wind flows over Northland region that are consistent with the monthly and seasonal results shown in Table 6.

Fig 5 Highest correlations for Dargaville SSR/MSR and climate predictors (from Heydenrych et al, 2001)

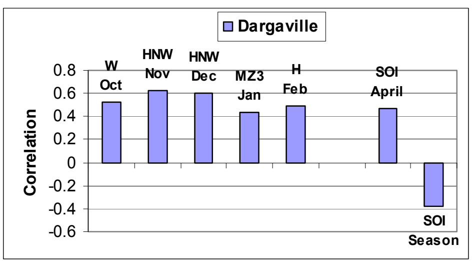


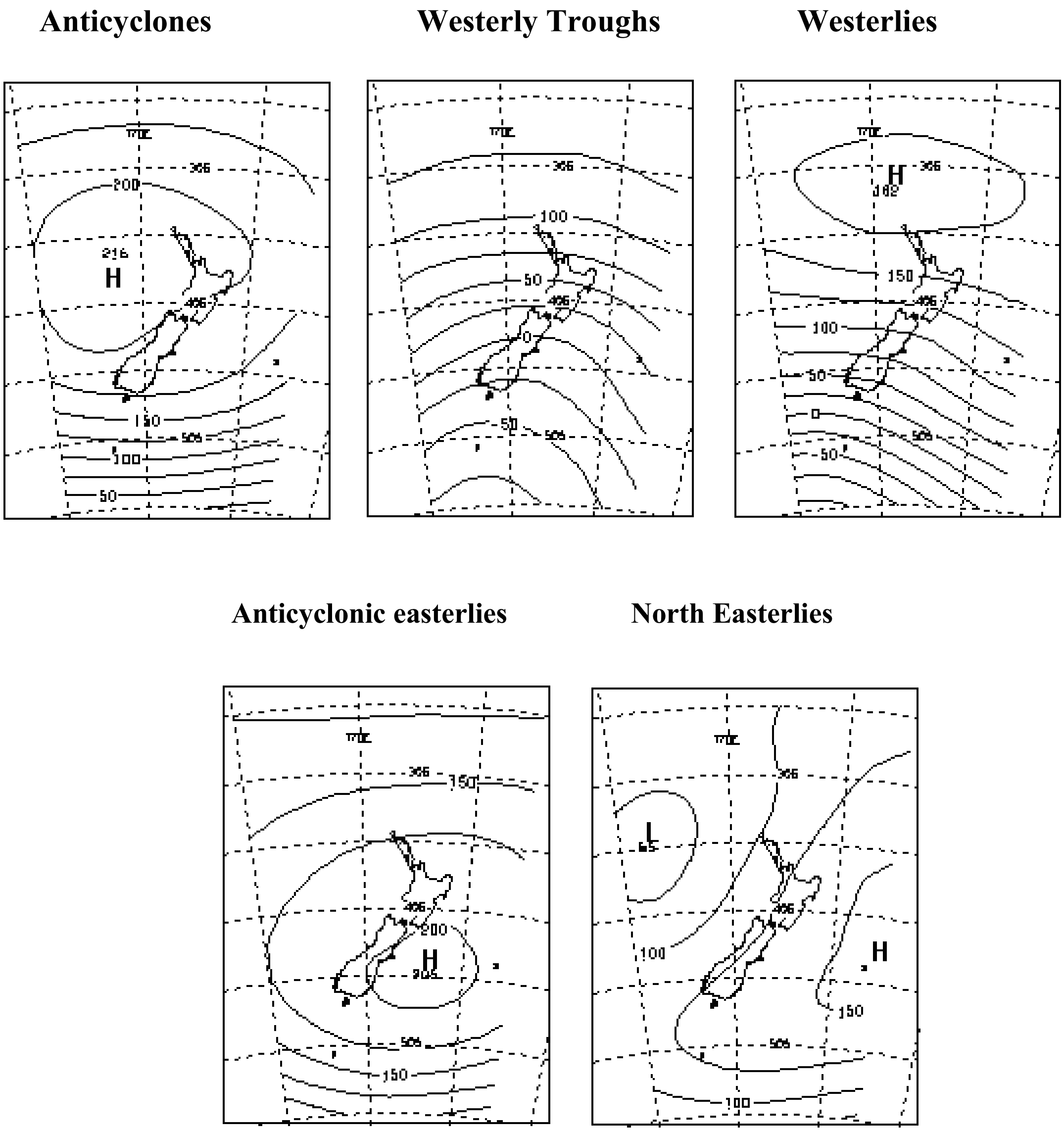
Table 6 Comparison of wind flow affecting Dargaville between current study and Heydenrych et al, 2001

High Fire Risk Months	Daily Wind Flow for Extreme Fire Risk	Long-term correlation between MSR and Wind Flow
November 1996	Westerly or Southwesterly	Westerly (Southwesterly or Northeasterly)
December 2000	Westerly or southwesterly	Westerly (Southwesterly, Southerly or Northeasterly)
January 1997	Easterly	Southwesterly (Easterly)
January 2001	Easterly or Westerly	Southwesterly (Easterly)
February 1995	Easterly or Southwesterly	Northerly (Westerly or Northeasterly)
February 1999	Easterly, Westerly or Southwesterly	Northerly (Westerly or northeasterly)
March 2001	Easterly	

Wind flows shown in brackets in Table 6, although not significantly correlated at the 0.05 level, but are still positively correlated to high MSR values.

Therefore, on the daily time scale, continuous fire risk over a period of days is usually associated with persistence of a specific synoptic weather type over the same period. In Dargaville, the dominant synoptic weather types are H, HSE, T, W and NE. These weather types bring westerly or southwesterly, easterly or northeasterly wind flow to the Northland region (Table 6 and Figure 6) under generally anticyclonic conditions. The key factor appears to be the anticyclonic nature of the flow over Northland, as the direction can be from either the west or the east. These winds types are catalysts to high fire risks on a daily scale for Northland. However, there are more defined wind flow patterns on the daily scale compared to the monthly scale (Figure 5) where winds are averaged over a month, therefore the DSR analysis adds more specific detail to MSR analysis.

Fig 6. The key weather types that cause extreme fire risk at Dargaville.



Christchurch

In Canterbury, the extreme fire risk during November is when southwesterly wind flows persist for the month. December extreme fire risk tends to be due to enhanced westerly and northwesterly wind flows. Enhanced westerly flow during January increased the chance of extreme fire risk in Canterbury. Extreme risk during February tends to be under northwesterly or westerly wind flow. A period of southwesterlies,

westerlies or northwesterlies during March enhances the extreme fire risks in Canterbury.

Fig 7 Highest significant correlation for Christchurch SSR/MSR and climate predictors (adopted from Heydenrych et al, 2001)

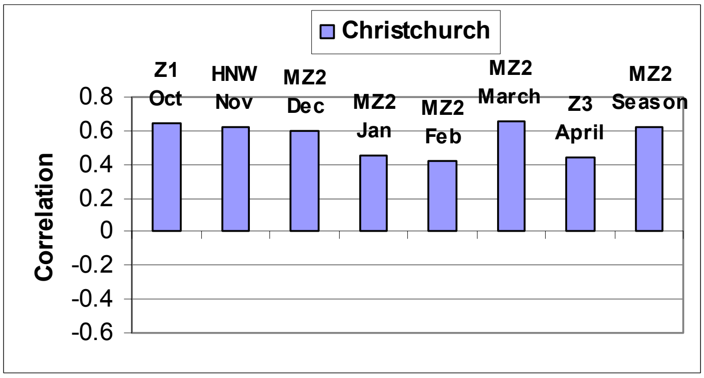
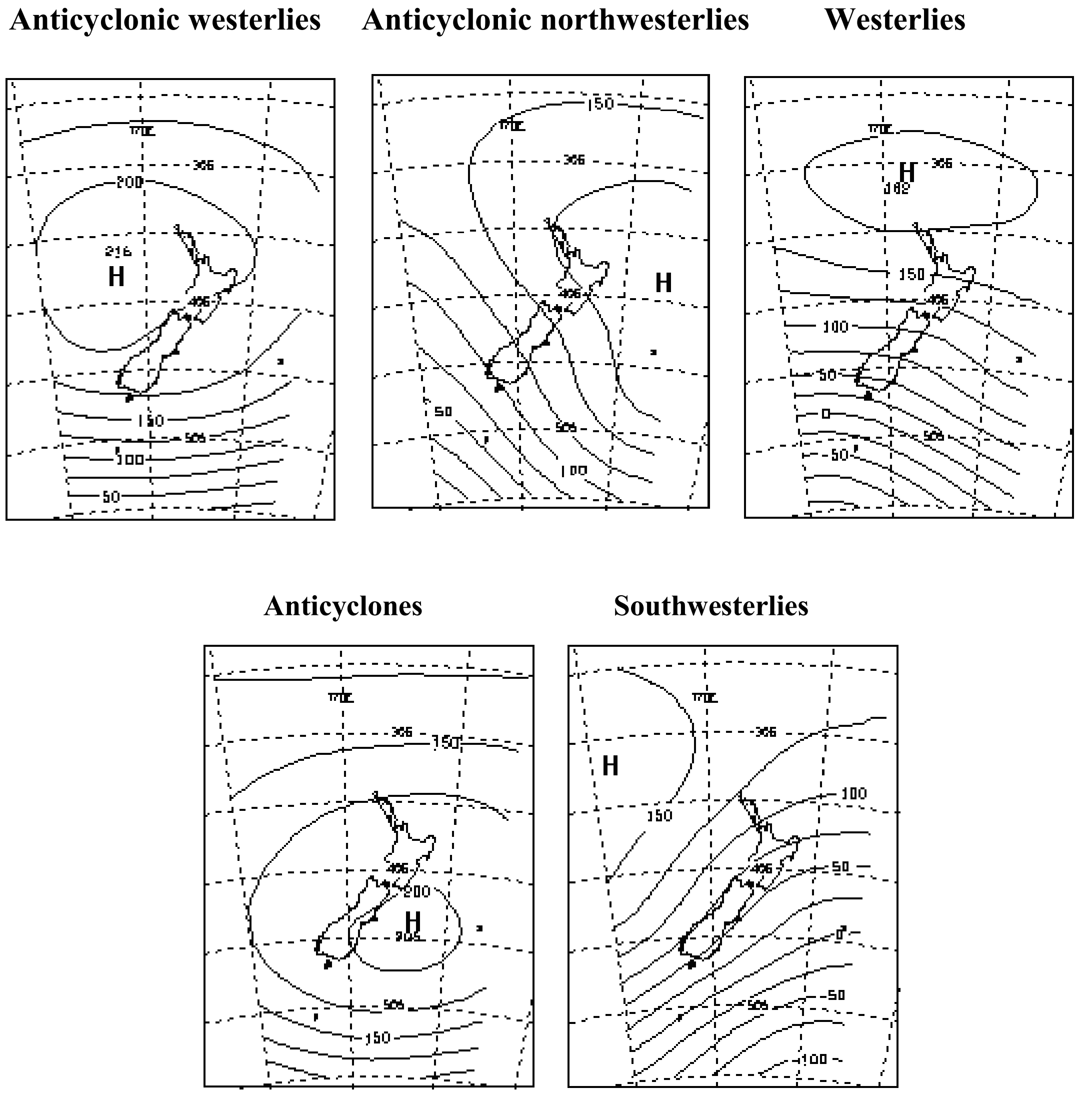


Table 7 Comparison of wind flow affecting Christchurch between current study and Heydenrych et al, 2001

High Fire Risk Months	Daily Wind Flow for Extreme Fire Risk	Long-term correlation between MSR and Wind Flow
November 1997	Westerly or Southwesterly	Southwesterly
December 1995	Southeasterly, Northeasterly, Northwesterly or Westerly	Northwesterly or westerly
December 1997	Westerly or Southwesterly	Northwesterly or Westerly
January 1995	Westerly or Northwesterly	Westerly or Northwesterly
January 1998	Anticyclones, Westerly or Southwesterly	Westerly or Northwesterly
February 1996	Westerly or Northwesterly	Westerly or Northwesterly
February 1998	Anticyclones, Westerly or Northwesterly	Westerly or Northwesterly
March 1998	Westerly, Southwesterly or Northwesterly	Westerly or Northwesterly

Fig 8. The key weather types that cause extreme fire risk at Christchurch.



Therefore, on the daily time scale, continuous fire risk over a period of days is usually associated with persistence of a synoptic weather type over the same period. In Christchurch, the dominant synoptic weather types are SW, HE, HSE, W and H. These weather types bring general very dry westerly quarter (northwesterly, westerly or southwesterly) wind flow to the Canterbury region (Table 7 and Figure 8) or anticyclonic conditions. These winds types promote high fire risk on a daily scale for Canterbury.

Generally, extreme fire risk (November, December, January and March) in Canterbury is usually associated with dry westerly or southwesterly wind flow, except in February, when northwesterly wind flow tends to increase fire risk most strongly.

The DSR and MSR analysis shows very similar trends, however the daily data give more specific detail for the Canterbury region.

Conclusions

The present report completes the work of a three-year program on Integrated Climate and Fire Season Severity Forecasting. Relationships between extreme daily severity rating (DSR) and synoptic weather types have been established for two regions: Northland and Canterbury.

The results from this study indicate that the wind flow patterns influence the fire severity risk on a daily scale. The general wind flow patterns associated with the synoptic weather patterns can be associated with a number of different weather types. A particular wind flow can be associated with a number of synoptic weather types, so even though there a number different weather types affecting New Zealand, the wind flow affecting an area promoting high fire risk is consistent.

Daily fire severity for Northland and Canterbury increases under persistence of a specific wind flow over a number of days, usually greater than 2 or 3 days. The fire severity generally increases until there is a shift or change in wind flow (generally directional change), which can have associated frontal rain resulting in reduced fire risk.

Northland experiences high daily fire severity under dry westerly or southwesterly, and anticyclonic easterly or northeasterly wind regimes. The severity tends to increase with persistence of synoptic weather types associated with each of these wind regimes over a period of few days.

In Canterbury, high daily fire severity risks are associated with northwesterly, westerly or southwesterly wind flow patterns and anticyclones. Persistence also plays a key role, where continuous fire severity over a number of days is associated with similar wind flows over the same period.

Although the synoptic weather type might change, the wind flow associated with these synoptic weather types and its influence on the region of interest remains the same.

The monthly wind flow analysis from Heydenrych et al (2001) is consistent to some extent with this daily analysis. However, Heydenrych et al (2001) focussed on all months in fire season, while the current study analysed only months with extreme fire risk, as a result there is some directional difference in wind flow due to severity and temporal resolution.

For the Northland region, more than Canterbury, assessment of DSR values with synoptic weather types uncovered further relationships between weather types and increased fire risk.

The results from this study show that the fire severity forecasting at daily scale can be enhanced through use of daily synoptic weather types. This initiative should be extended to the other 13 fire regions (Heydenrych and Salinger, 2002) to improve daily fire severity forecasting. The relationships uncovered in this study will also be incorporated into the seasonal and monthly forecasting techniques utilised by NIWA in the seasonal fire danger outlooks.

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