On the likelihood of false alarms and the missing of rainfall events at remote locations in New Zealand by "scaling methods" .

Richard Turner*[*] and Andrew Tait

National Institute of Water and Atmospheric Research, Kilbirnie, Wellington, New Zealand.

Abstract

For remote regions of New Zealand where limited rainfall observations exist most methods for estimating daily rainfall rely to some extent on the scaling/interpolation of "nearby" rainfall observations. Many of these methods do account for orographic enhancement of precipitation, but they all suffer from missed rainfall events (i.e., occasions where heavy rain has fallen at the remote location, but very little or no rainfall will have fallen at any of the "nearby" observing sites. The scaling methods also produce "false alarms", (i.e., where little rain falls at the remote location, but heavy rain has fallen at all or most of the nearby sites). In this note, a contingency table technique is used to quantify the frequency at which "false alarms" and "misses" are likely to occur in various parts of New Zealand. The results are presented for four different climate regions. Results are encouraging in that for three regions, the number of false alarms per year is less than 4 days, however for the most mountainous region the number climbs to 22 days per year. The frequency of missed events was less than 3 days per year for the two drier climates (northern Southland and the eastern Wairarapa) but was more than 10 days per year for the two wetter regions (Northland and the Lewis Pass area).

Keywords: daily rainfall, scaling/interpolation, missing events, false alarms, New Zealand

1. Introduction.

For remote locations of New Zealand where limited, if any, rainfall observations exist most methods for estimating daily rainfall rely to

[*] *Corresponding author:* Dr Richard Turner, National Institute of Water and Atmospheric Research, Private Bag 14-901, Kilbirnie, Wellington, New Zealand.
E-mail: r.turner@niwa.co.nz.

some extent on the scaling/interpolation of "close" rainfall observations. Many of these methods do account for orographic enhancement of precipitation (e.g. Tait & Turner, 2005), but they all suffer from the fact that there will be "missed" rainfall events on occasions where significant or heavy rain has fallen at the remote location, but very little or no rainfall will have fallen at any of the "close" observing sites. For the purposes of this paper, a significant event is defined as a 24 hour rainfall amount exceeding 10 mm, and a 'heavy' event is one exceeding 25 mm. The scaling methods will likely suffer due to

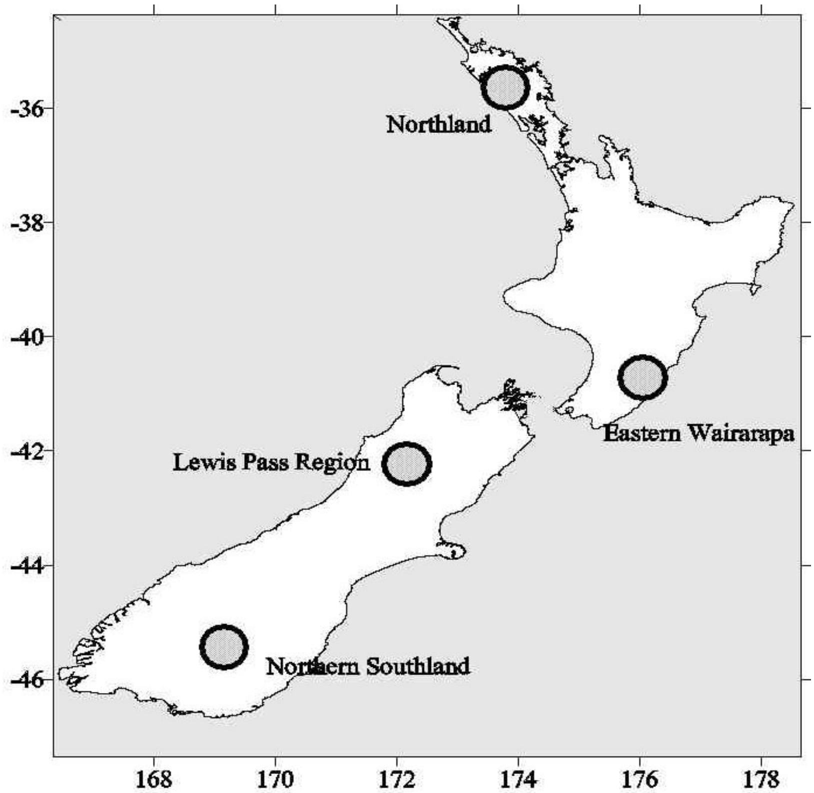

Figure 1: Map of New Zealand showing the location of the four regions of this study.

there being "false alarms" on the days where llittle rain falls at the remote location, but significant or heavy rain has fallen at all or most of the "nearby" sites. In this note, a contingency table technique is used to gauge the frequency at which "false alarms" and "misses" occurred in the period 1985-2000 at four remote stations in different climate regions of New Zealand.

Information about the frequency of misses and false alarms could be useful for users of New Zealand long-term daily rainfall datasets that have been produced using scaling/interpolation techniques such as in Tait and Turner (2005). This information is useful because it gives an easily understood indicationn idea of some of the most extreme likely errors introduced when estimating rainfall at sites where rainfall observations do not exist.

2. Method.

In attempting to simply quantify the frequency of misses and false alarms for remote sites where no observations exist we applied the method described below in each of the following four regions of New Zealand; northern Southland, the Lewis Pass region of Northern Westland, eastern Wairarapa, and Northland. Figure 1 shows the locations of these regions within New Zealand. A "central" observing location was selected for which there were four "surrounding" (i.e., roughly one in each quadrant) observing sites between 15 and 50 km distance. Figures 2 - 5 show for each of the regions the spatial configuration of the selected rainfall observing sites. Table 1 gives further details about each of the stations. The reason for picking stations in such a configuration is that the central observing site can then be thought of as a "remote" site, and if no observations actually existed at that site, then the four surrounding stations would be the ones most relied upon by any scaling technique to estimate rainfall at that location. We can then compare observed rainfall at the

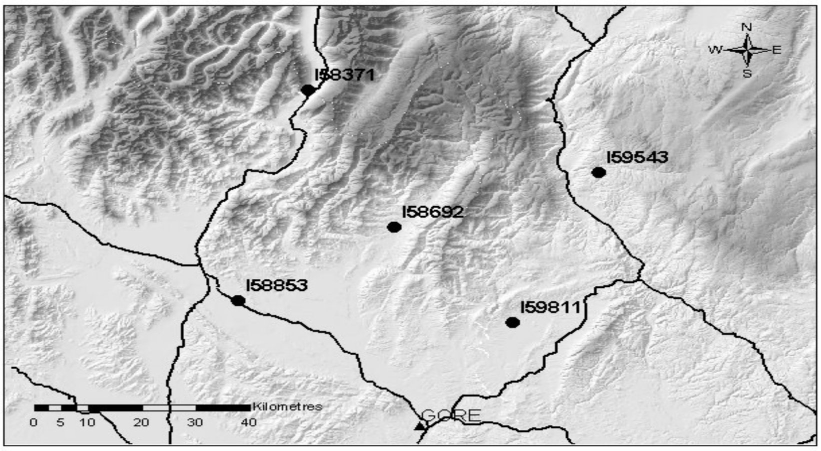

Figure 2: Shaded relief map showing locations of the five northern Southland stations used in this study.

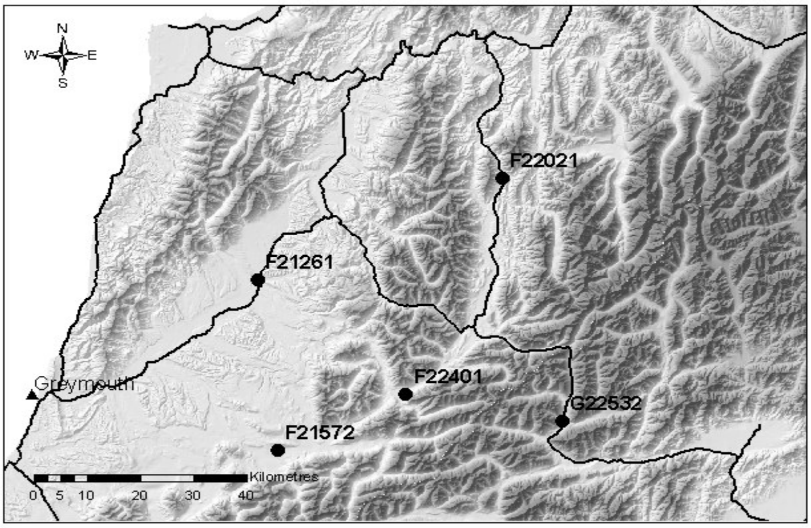

Figure 3: Shaded relief map showing locations of the five Lewis Pass region stations used in this study.

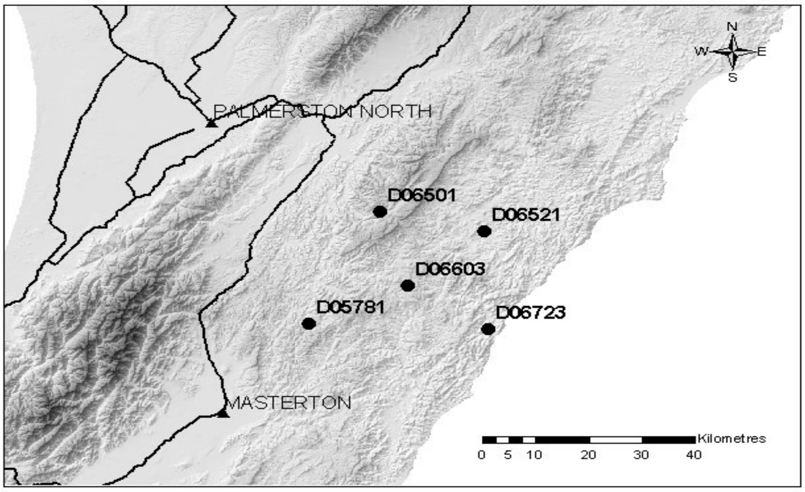

Figure 4: Shaded relief map showing locations of the five eastern Wairarapa stations used in this study.

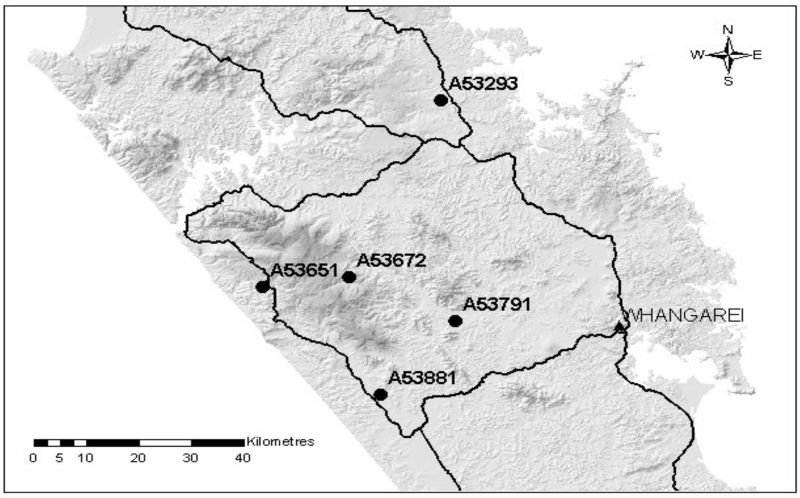

Figure 5: Shaded relief map showing locations of the five Northland stations used in this study.

Region	Station ID	Elevation (m)	Distance from X (km)
N. Southland	I58692 X	190	0
N. Southland	I58853 O	177	34
N. Southland	I58371 O	313	38
N. Southland	I59543 O	518	40
N. Southland	I59811 O	183	32
Lewis Pass	F22401 X	366	0
Lewis Pass	F21572 O	175	27
Lewis Pass	F21261 O	120	49
Lewis Pass	F22021 O	347	37
Lewis Pass	G22532 O	600	30
E. Wairarapa	D06603 X	183	0
E. Wairarapa	D05781 O	262	21
E. Wairarapa	D06501 O	274	18
E. Wairarapa	D06521 O	107	19
E. Wairarapa	D06723 O	20	18
Northland	A53672 X	213	0
Northland	A53881 O	49	27
Northland	A53651 O	88	16
Northland	A53293 O	150	44
Northland	A53791 O	55	22

Table 1: List of stations used in this study, showing region, station ID's, names, elevation, and distance from the central location. The X or O in the station ID denotes whether the station was either a "central" or a "surrounding" one respectively.

”remote" site with estimated rainfall derived from what the scaling technique would produce if we relied solely on the surrounding observations.

For this analysis daily rainfalls at each station for the period 1985-2000 were obtained from NIWA' s Climate Database. These were then sorted by rainfall amamount, first at the central location and then by the average of the surrounding stations. A 6x6 contingency table was created where the amounts were then binned into one of six classes (0 mm, 0.1-0.9 mm, 1.0 - 4.9 mm, 5.0 - 9.9 mm, 10.0 - 24.9 mm, and > 25 mm). Counts were then made of the number of days for which each combination of classes occurred and these were then normalized on an annual basis. For exam-

Rainfall at surrounding nearby stations.	Rainfall at central location (mm)					
	0	0.1-0.9	1.0-4.9	5.0-9.9	10.0-24.9	25+
0	174.7	5.6	3.8	0.3	0.3	0.0
0.1-0.9	46.3	11.0	11.4	1.0	0.1	0.0
1.0-4.9	23.5	6.7	26.6	12.6	1.5	0.1
5.0-9.9	2.6	0.4	5.8	6.7	6.4	0.1
10.0-24.9	0.5	0.1	0.8	2.9	9.3	2.0
25+	0.0	0.0	0.0	0.1	0.1	1.8

Table 2: The distribution of the number of days for station I58692 in northern Southland (normalized to an annual average) when the daily rainfall of a certain range is classed according to the average of the daily rainfalls (binned into the same ranges) at surrounding "nearby" stations. Grey shaded areas in the upper right correspond to 'misses' of significant or heavy rainfall events at the central location, while the grey shaded areas in the lower left correspond to 'false alarms'.

ple, for northern Southland, there were 187 days (out of 2908) when the rainfall at the central station was zero and the average of the rainfall at the surrounding stations was between 1.0-4.9 mm (this equates to about 23.5 days per year). This was done for all 36 possible combinations and the results are presented in Tables 2-5. Days on which any of the stations had missing observations were discarded. Note the sample size varied from 28% to 77% of possible days and this reflects a large amount of either missing or substandard data. It is assumed that the data problems were independent of the recorded daily rainfall.

3. Results and discussion

An examination of Tables 2-5 will give an indication as to the number of days per year when a scaling technique would likely result in a missed heavy rainfall event or a false alarm. The upper right-hand regions (shaded grey) of the tables correspond to likely "missed" events, while the lower left

Rainfall at surrounding nearby stations.	Rainfall at central location (mm)					
	0	0.1-0.9	1.0-4.9	5.0-9.9	10.0-24.9	25+
0	131.8	2.9	5.5	2.6	3.1	1.8
0.1-0.9	44.6	5.3	7.5	2.2	1.1	2.4
1.0-4.9	33.0	4.4	12.3	9.0	5.7	2.2
5.0-9.9	12.5	1.5	4.6	4.0	5.9	1.3
10.0-24.9	12.3	0.7	2.4	3.1	10.8	9.9
25+	4.4	0.0	1.3	0.9	2.2	9.9

Table 3: The distribution of the number of days for station F22401 in the Lewis Pass region (normalized to an annual average) where the daily rainfall of a certain range is classed according to the average of the daily rainfalls (binned into the same ranges) at surrounding "nearby" stations. Grey shaded areas in the upper right correspond to ' misses' of significant or heavy rainfall events at the central location, while the grey shaded areas in the lower left correspond to ' false alarms' .

Rainfall at surrounding nearby stations.	Rainfall at central location (mm)					
	0	0.1-0.9	1.0-4.9	5.0-9.9	10.0-24.9	25+
0	134.3	13.7	4.1	0.4	0.2	0.0
0.1-0.9	36.7	7.0	10.7	0.6	0.5	0.0
1.0-4.9	27.9	14.1	37.3	8.7	1.9	0.0
5.0-9.9	3.3	1.3	9.0	12.4	7.1	0.2
10.0-24.9	0.9	0.0	1.8	5.7	15.5	2.4
25+	0.0	0.0	0.1	0.0	0.9	6.2

Table 4: The distribution of the number of days for station D06603 in eastern Wairarapa (normalized to an annual average) when the daily rainfall of a certain range is classed according to the average of the daily rainfalls (binned into the same ranges) at surrounding "nearby" stations. Grey shaded areas in the upper right correspond to ' misses' of significant or heavy rainfall events at the central location, while the grey shaded areas in the lower left correspond to ' false alarms' .

Rainfall at surrounding nearby stations.	Rainfall at central location (mm)					
	0	0.1-0.9	1.0-4.9	5.0-9.9	10.0-24.9	25+
0	113.5	4.9	4.0	0.6	0.0	0.0
0.1-0.9	46.9	11.9	14.7	1.8	1.0	0.1
1.0-4.9	22.3	9.1	36.2	17.5	6.1	0.8
5.0-9.9	3.0	0.9	5.3	10.3	12.6	2.2
10.0-24.9	0.9	0.3	1.8	3.0	13.8	7.5
25+	0.4	0.0	0.1	0.3	1.4	9.8

Table 5: The distribution of the number of days for station A53672 in Northland (normalized to an annual average) when the daily rainfall of a certain range is classed according to the average of the daily rainfalls (binned into the same ranges) at surrounding "nearby" stations. Grey shaded areas in the upper right correspond to ' misses' of significant or heavy rainfall events at the central location, while the grey shaded areas in the lower left correspond to ' false alarms' .

regions (shaded grey) correspond to likely "false alarms". In this note our "”scaling" technique is one where the rain at the central location is simply the average of the four surrounding stations. While this might not bbe the best scaling technique to employ, the results would be similar to any weighted averaging scheme reliant on the surrounding observations. Note, it is possible a situation could occur in which heavy rain fell at two of the surrounding stations, but not at the other two surrounding stations or central station. In this case, the occurrence of a false alarm could be sensitive to the choice of scaling method and a surface fitting method could produce different and better results.

Table 6 summarizes, for each of the four central sites, the number of days per year that likely misses and false alarms occurred. The most apparent result is that the worst results occur for the Lewis Pass region:

Station – Region	Miss	False Alarm	Sample size	No of rain days	Annual (mm)
I58692 – N. Southland	2.1 (2.2%)	1.5 (0.4%)	2908 (49.7%)	94	900
F22401 – Lewis Pass	17.4 (15.6%)	22.0 (6.2%)	1661 (28.4%)	111	2800
D06603 – E. Wairarapa	2.8 (2.2%)	2.8 (0.8%)	4521 (77.4%)	126	1300
A53672 – Northland	10.2 (6.8%)	3.8 (1.2%)	3861 (66.1%)	150	2050

Table 6: Summary of likely misses and false alarms, expressed in days per year, that would result from the use of a scaling method for the central stations in each of the four New Zealand regions in this study. The percentage of misses per rain days and false alarms per non-rain days is given in brackets. The 4th column shows the number of days (i.e. the sample size) in the period 1985-2000 for which observations were available at all the central and surrounding locations; the percentage coverage (out of a possible 5844 days) is given in brackets. The 5th column shows the annual average number of rain days (> 1 mm) at the central station. The 6th column shows the approximate annual average rainfall for the five stations used in each region.

here there were about 17 misses and 22 false alarms per year. This is the most mountainous region of the four in the study and it had the most distant neighbouring station (49 km) which is on the other side of the divide. Having a surrounding station at a higher altitude could also contribute to the greater false alarm rate due to higher rainfall at that station. It was also the region in which the most number of days had to be discarded because of missing data. Compensating for this is that it is has the highest annual average rainfall of any of the four sites, so missing a 25 mm event is perhaps not as significant as missing a heavy rain event in a drier climate. The results were most encouraging for the other 3 regions in that the numbers of likely false alarms per year were between 1 and 4 days. The number of missed events for the two drier climates (eastern Wairarapa and northern Southland) was similar to the rate for false alarms; however the rate of misses in Northland was much higher at about 10 days per year. Having all the surrounding stations at lower altitudes could have contributed to the greater rate of misses in Northland. However, the high miss rate is probably reflective of the more convective and sporadic nature of rainfall events in Northland as the false alarm rate was higher (albeit slightly) there also. Note the sample size varied from 28% to 77% of possible days and this reflects a large amount of either missing or substandard data. It is assumed that the data problems were independent of the recorded daily rainfall.

The seasonal distribution of the misses and false alarms is given in Table 7. Points of interest here are the fact that were no false alarms for the station in northern Southland in Autumn, and that the frequency of misses for the Northland station was noticeably higher in the winter and spring, the wettest time of the year. Analysing the results from the perspective of synoptic typing also revealed some interesting points. Here we classed all the days from 1985 to 2002 into 3 synoptic types after Kidson (2000). These

Station – Region	Error	DJF	MAM	JJA	SON
I58692 – N. Southland	Miss	0.38	0.88	0.25	0.63
I58692 – N. Southland	False Alarm	0.13	0.00	0.38	1.00
F22401 – Lewis Pass	Miss	3.96	4.83	4.39	4.39
F22401 – Lewis Pass	False Alarm	6.59	3.96	6.37	5.05
D06603 – E. Wairarapa	Miss	1.05	0.57	0.97	0.24
D06603 – E. Wairarapa	False Alarm	0.57	0.73	1.05	0.40
A53672 – Northland	Miss	1.32	1.61	3.69	3.59
A53672 – Northland	False Alarm	1.13	0.28	1.61	0.66

Table 7: Seasonal contribution to per annum days of misses and false alarms for the central station s in each of the four regions. The sum of the rows equals the corresponding total given in Table 6.

types were: Trough, Zonal, or Blocking and are the major sub-groupings of the 12 Kidson synoptic types. From Table 8 we see that for most regions the greatest frequency of false alarms and misses occurred for the group of Trough synoptic types. One other interesting point is that for Northland the

Region	Error	Trough	Zonal	Block
I58692 N. Southland	Miss	1.05	0.60	0.45
I58692 N. Southland	False Alarm	0.63	0.63	0.25
F22401Lewis Pass	Miss	6.31	5.66	5.44
F22401Lewis Pass	False Alarm	12.54	5.06	4.40
D06603 E. Wairarapa	Miss	1.21	0.56	1.03
D06603 E. Wairarapa	False Alarm	1.03	0.47	1.31
A53672 Northland	Miss	5.81	1.53	2.86
A53672 Northland	False Alarm	2.44	0.19	1.17
	Expected Days per year	136	103	126

Table 8: Contribution by synoptic type to the per annum days of misses and false alarms for the central stations in each of the four regions. The bottom row gives the number of expected days per year that the synoptic type will occur over New Zealand. The sum of the rows equals the corresponding total in Table 6.

false alarm rate during Zonal flow situations was quite low at 0.19, i.e. we would expect 1 day in 5 years that a false alarm would occur on 'Zonal' flow days.

While a large degree of spatial variability exists at a daily time step, the seasonal and annual characteristics of rainfall within each region (such as presented in Thompson, 1985) exhibit less variability. Conversely, rainfall at hourly time scales is likely to exhibit much greater spatial variability, and we would expect the rate of misses and false alarms to be greater. Therefore much more thought and care would have to be taken, before one attempted, to apply a scaling technique for estimating hourly rainfall at remote locations. IIt would even perhaps be preferable to use some model of precipitation for sub-density scales such as a hidden semi-Markov model (Sansom, 2002) but conditioned on the Kidson daily series of synoptic types.

Acknowledgements

We would like to thank Kevin McGill of NIWA for assistance in this research and to Craig Thompson also of NIWA for providing comments. We would also like to thank the two anonynmous reviewers of the article. The authors would also like to thank New Zealand's Foundation for Research Science and Technology for supporting this work under contract C01X0010.

References

Kidson, J.W., 2000: An analysis of New Zealand synoptic types and their use in defining weather regimes. *Int. J. Climatology*, **20**:, 299-316.

Sansom J., and C. S. Thompson, 2003: Mesoscale spatial variation of rainfall through a hidden semi-Markov model of breakpoint data, *J. Geophys. Res.,* **108 (D8), CIP 4**, 1-17.

Tait, A, and R. W. Turner, 2005: Generating Multi-year Gridded Daily Rainfall over New Zealand *In press Journal of Applied Meteorology,* **44**, 1315-1323.

Thompson, C. S. 1985: Maps of rainfall parameters for New Zealand. *N.Z. Met. S. Misc.Pub 187.* 58 pp.

Submitted to Weather and Climate July 2003, revised August 2005