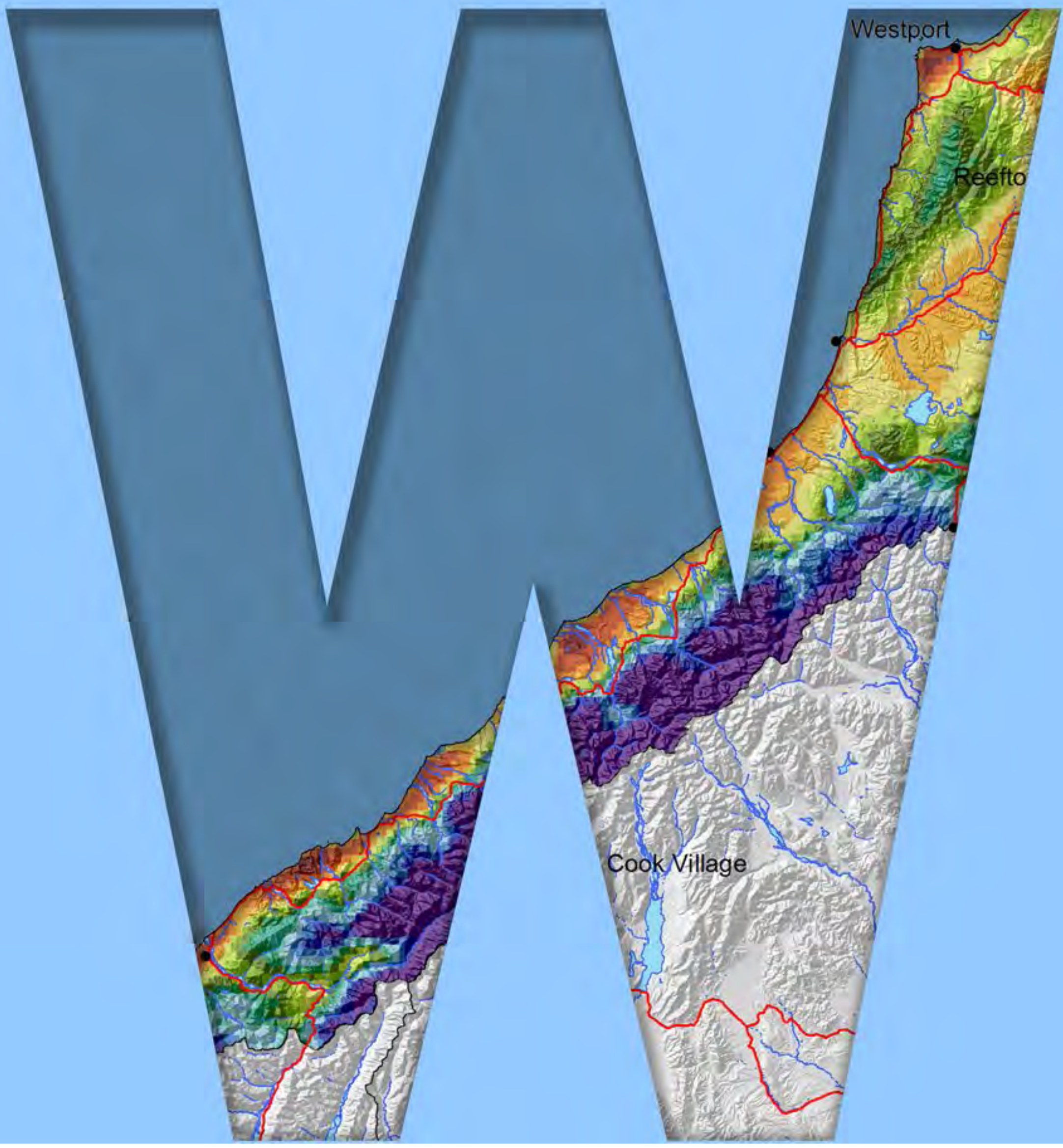
NIWA
Taihoro Nukurangi

THE CLIMATE AND WEATHER OF
WEST COAST

2nd edition

G. R. Macara



NIWA SCIENCE AND TECHNOLOGY SERIES
NUMBER 72

ISSN 1173-0382

Note to Second Edition

This publication replaces the first edition of New Zealand Meteorological Service Miscellaneous Publication 115 (10), written in 1982 by J. W. D. Hessell. It was considered necessary to update the first edition, incorporating more recent data and updated methods of climatological variable calculation.

THE CLIMATE AND WEATHER OF WEST COAST

2nd edition

G. R. Macara

SUMMARY

West Coast is New Zealand's wettest region, and this may be attributed to its exposure to the predominant westerly airflow over the country, combined with the orographic effect of the Southern Alps. Annual rainfall totals at relatively high elevations regularly exceed 10,000 mm, with low elevation coastal locations typically recording between 2,000 and 3,000 mm of rainfall annually. Temperatures in lowland areas remain mild throughout the year, with temperatures less than 0°C and greater than 25°C occurring infrequently compared to most other regions of New Zealand. West Coast is not especially windy, and local wind regimes are strongly influenced by the southwest to northeast orientation of the Southern Alps.

Photo: ©mychillybin.co.nz/Jingyi Tan

CONTENTS

Photo: ©mychillybin.co.nz/Haught Net Images

INTRODUCTION

New Zealand spans latitudes 34 to 47 degrees south, and so lies within the Southern Hemisphere temperate zone. In this zone, westerly winds at all levels of the atmosphere move weather systems, which may also be either decaying or developing, eastwards over New Zealand giving great variability to its weather. The Southern Alps act as a barrier to the prevailing westerly airstream which is both deflected by them and forced to ascend; this causes rain which is often heavy and prolonged in West Coast. These prevailing westerlies sometimes abate, and air from either tropical or polar regions may reach New Zealand with heavy rainfalls or cold showery conditions respectively. The effect of the oceans on air of tropical origin is to cool the lower layers, creating extensive sheets of stratiform cloud capable of producing large amounts of rain in West Coast, especially when entrained into cyclonic (low pressure) systems and subjected to orographic processes. Conversely, air originating from the far south typically reaches New Zealand as a southerly airstream, and the Southern Alps protect West Coast from the instability showers formed when cold air is heated from below by a relatively warm sea surface. Under these circumstances, West Coast experiences fine weather and sunny skies with exceptionally good visibility.

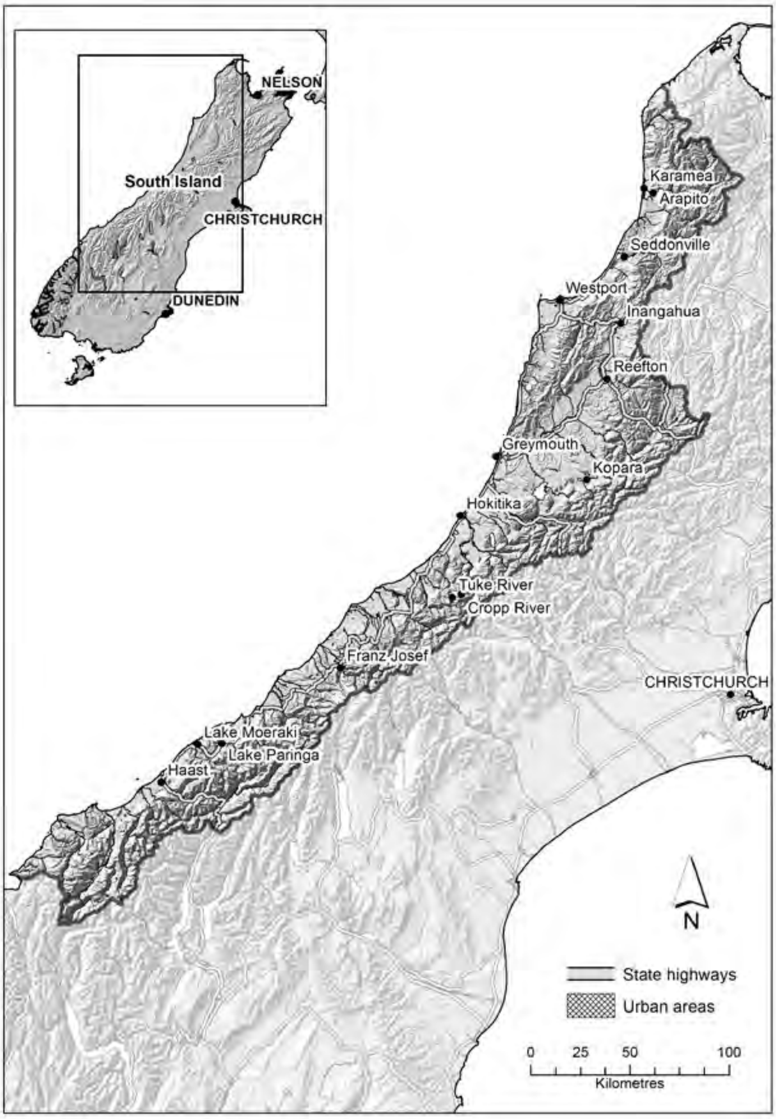


Figure 1. Map of the West Coast region, showing the places mentioned in this publication.

The West Coast region (Figure 1) is bounded in the west by the coast, and in the east by the main divide of the Southern Alps which reaches 3,724 m at the summit of Mount Cook. The region drains westwards to the coast, and the river systems are subject to remarkable fluctuations in flow in response to rainfall events. The river catchments extend into high alpine regions, where a proportion of the considerable annual precipitation falls as snow, enabling the formation of numerous glaciers. The Fox Glacier and Franz Josef Glacier are particularly renowned and contribute to the ongoing tourism of the region. These glaciers reach comparatively low altitudes for middle latitudes and their rates of flow are relatively fast due to the steep topography of the western face of the Southern Alps down which they descend. These glaciers respond relatively quickly to climatic forcings; their dynamic nature make these glaciers useful indicators of climate variability and change.

Note that all numbers given in the following tables are calculated from the 1981–2010 normal period (a normal is an average or estimated average over a standard 30-year period), unless otherwise stated.


Photo: ©mychillybin.co.nz/Mark Meredith

TYPICAL WEATHER SITUATIONS IN WEST COAST

Surface winds on the West Coast tend to be light and variable, and are influenced both by the synoptic-scale circulation and by large frictional effects caused by the mountain barrier to the east. Nevertheless the weather is strongly typified by the wind flow in the free atmosphere above the friction layer, and the following sections refer to the direction of this wind rather than to local surface wind directions.

Disturbed westerly flows

Disturbed westerly flows over New Zealand are associated with depressions to the south of the country which usually move rapidly eastward (Figure 2). The flow may be intensified by development and southward movement of the belt of subtropical anticyclones which in turn are associated with changes in the principal upper-air hemispheric jet stream. The seasonal changes in the general circulation of the Southern Hemisphere as described above result in a maximum frequency of disturbed westerly situations in spring (Reid, 1980). The "disturbances" in the westerlies may have varied dynamics; most are usually depicted on synoptic charts as cold fronts.

Winds just above the surface friction layer ahead of each front tend to be north of west and are almost perpendicular to the Alpine divide. The fronts are preceded by rain in West Coast which is often heavy due to orographic uplift. The change in wind direction to the southwest behind the fronts usually brings an initial dramatic clearance in the weather, though showers soon re-develop with the gradual change of winds back towards the west in the generally rather unstable conditions.

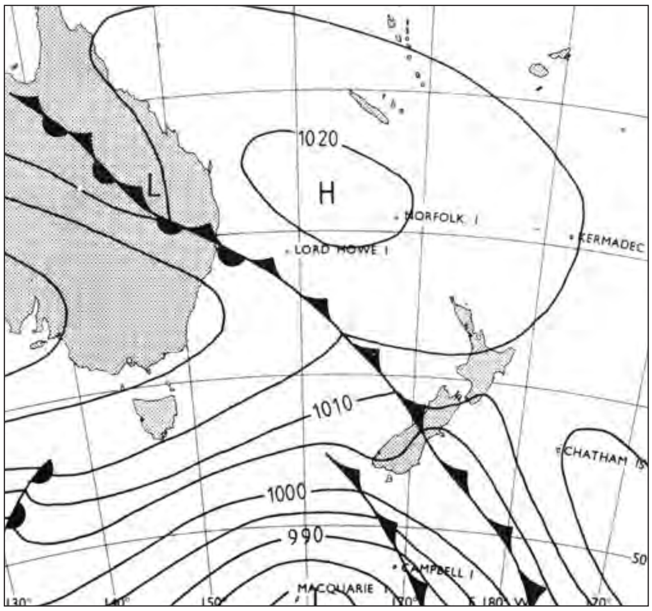


Figure 2. Mean sea level pressure analysis for 0000 hours NZDT on 16 October 1977.

Northerly flows

Extensive northerly airflows (Figure 3) between an anticyclone (high pressure system) and a depression (low pressure system) are usually accompanied by prolonged rainfall which can reach torrential intensities in the Southern Alps. The skies over the West Coast typically remain overcast throughout these periods. The majority of West Coast's rain occurs in winds having a northerly component, and the temperature during these rainfall events is relatively mild. The occurrence of thunder during the rain often

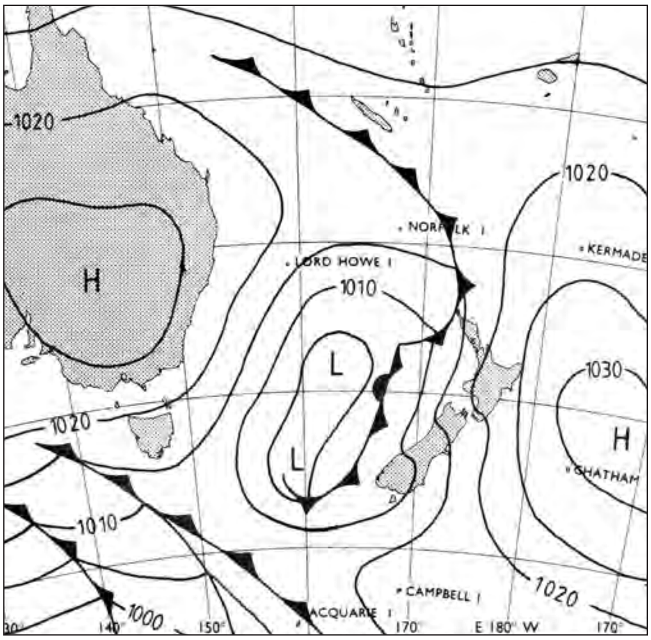


Figure 3. Mean sea level pressure analysis for 0000 hrs NZST on 15 August 1977.

heralds the arrival of the front, which brings a change to south-westerly winds and clearing skies.

Southeasterly flows

Southeast winds are often accompanied by clear skies in West Coast as the air has lost moisture during uplift on the eastern side of the Southern Alps. Southeast airstreams over the South Island are usually caused by depressions (lows) over the North Island and anticyclones (highs) to the south of the country (Figure 4). The foehn effect occurs in West Coast under strong southeast gradients, just as they do in eastern parts of the South Island under strong northwest gradients. The highest temperatures recorded in West Coast occur during southeast airflows in summer, and southeast winds usually result in higher than average temperatures at all times of the year.

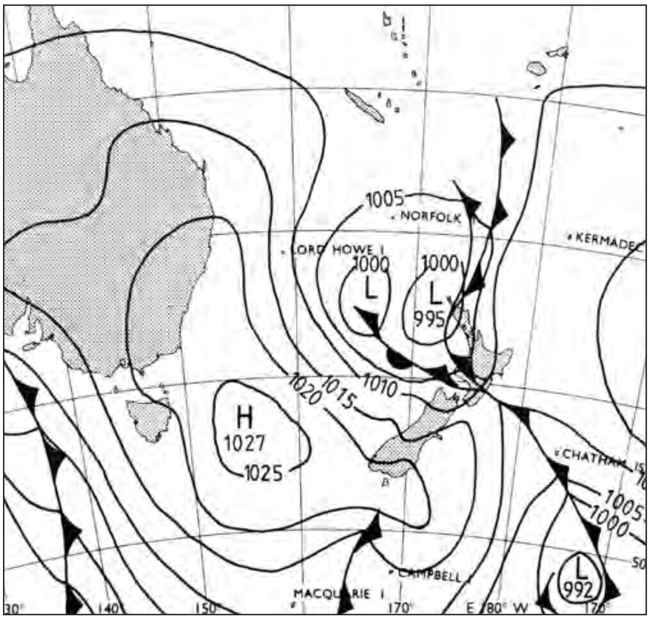


Figure 4. Mean sea level pressure analysis for 0000 hours NZST on 12 April 1981.

Fine weather spells

Fine weather spells are usually associated with an anticyclone moving slowly eastwards over the South Island, or the area just south of it. If a depression develops to the north or north-east of the North Island a ridge of high pressure may still extend over the South Island when the anticyclone is centred far to the east or south-east. Prolonged dry spells are relatively infrequent in West Coast, and usually occur when an anticyclone becomes stationary over or very near New Zealand. Figure 5 shows a situation in which the air pressure over New Zealand is very high, with two intense anticyclones separated by a trough of relatively low pressure. The anticyclone east of New Zealand is forming a "block" to the progression of the trough which has become stationary, and the weather over the whole country including West Coast is fine and settled. In this case, no rain occurred at Hokitika between 5 July and 25 July 1971, and the anticyclone east of New Zealand intensified to 1040 hPa at times.

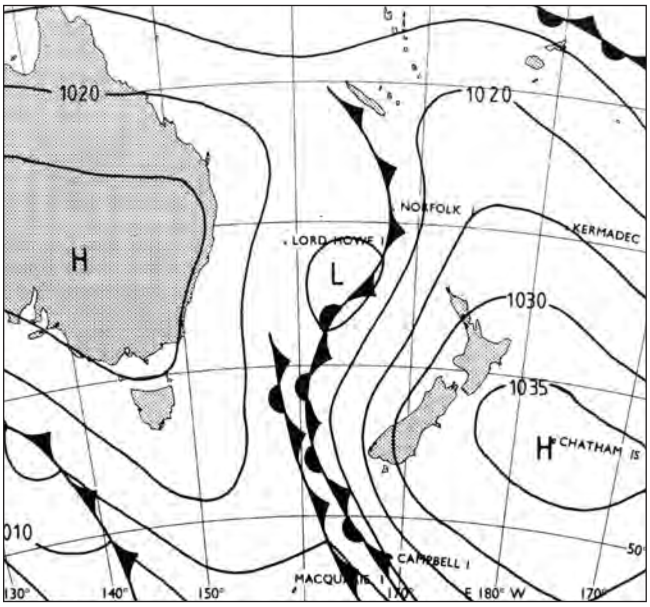


Figure 5. Mean sea level pressure analysis for 0000 hours NZST on 20 July 1971.

Photo: ©mychillybin.co.nz/jeremy town

CLIMATIC ELEMENTS

Wind

Wind direction over New Zealand in the zone directly above the Earth's surface may be interpreted from a mean sea level pressure (MSLP) map, following the general principle that air flows in a clockwise direction around a depression (a 'low'), and in an anticlockwise direction around an anticyclone (a 'high'). As such, MSLP maps can be used to indicate the general wind direction at the Earth's surface. However, actual wind direction at a particular locality is modified by the influence of friction and topography. Furthermore, wind speeds are also subject to topographical influence. Northwest winds are relatively uncommon in West Coast, as they are typically deflected to the northeast or southwest by the Southern Alps. As such, northeasterlies and southwesterlies are the predominant wind directions in West Coast, especially for stronger winds, but there are local variants to this general rule.

The direction of a steady sea breeze flow on most coastal areas is southwest, and sea breezes are common near the coasts in summer. Occasionally these penetrate considerable distances up some valleys, adding to the frequency of moderate strength southwesterlies in these areas. Katabatic winds, which are gravity winds caused by comparatively cold dense air flowing down the river valleys, are most noticeable on winter nights. Such winds are usually of moderate strength but may become stronger under favourable synoptic conditions. Their formation is also enhanced by snow-covered high ground due to the radiative properties of a snow surface which becomes substantially colder at night than the free air at a similar level. Figure 6 shows mean annual wind frequencies of surface wind based on hourly observations from selected West Coast stations.

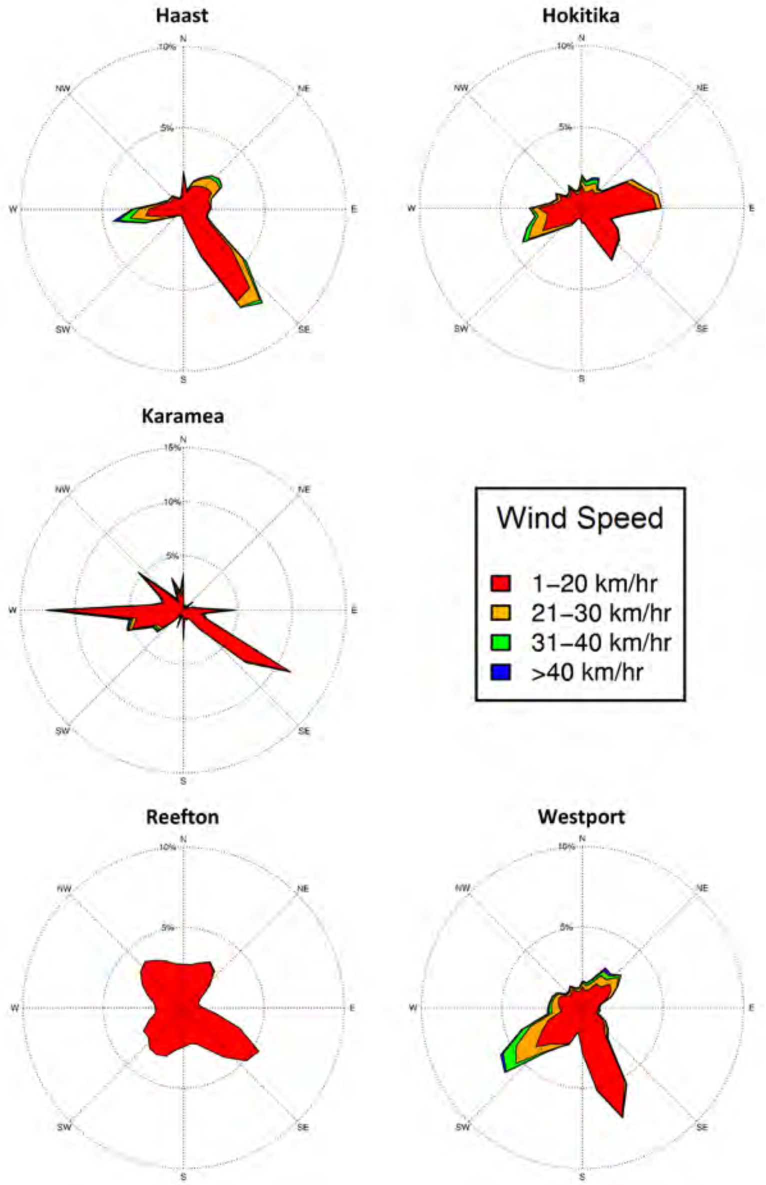


Figure 6. Mean annual wind frequencies (%) of surface wind directions from hourly observations at selected West Coast stations. The plot shows the directions from which the wind blows, e.g. the dominant wind direction at Haast is from the south-east.

Mean wind speed data (average wind speeds are taken over the 10 minute period preceding each hour) are available for a number of sites in West Coast, and these illustrate the several different wind regimes of the region (Table 1). Mean wind speeds are highest at coastal locations such as Greymouth and Westport, and lowest at the sheltered inland location of Reefton. There is notable variability in mean monthly wind speeds over the course of a year in West Coast, with the highest wind speeds typically observed in spring. The exception is Greymouth, where highest wind speeds are observed in winter. This may be attributed in part to the katabatic wind, which locally is reputed to be cold enough to 'shave the hair off one's head', and has consequently earned the nickname "barber".

Table 1. Mean monthly and annual wind speed (km/hr) for selected West Coast locations, from all available data.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Westport	13.8	12.8	12.4	12.2	12.5	13.2	12.9	12.9	14.9	16.0	15.6	14.7	13.7
Greymouth	13.5	11.1	12.0	13.4	13.6	14.5	14.7	12.7	14.0	14.5	13.7	12.7	13.4
Hokitika	11.7	10.5	10.3	9.8	9.9	10.1	9.6	10.2	11.7	13.2	12.9	12.2	11.0
Haast	9.2	8.4	8.9	9.5	10.7	11.1	11.6	10.7	11.0	11.8	11.2	10.1	10.3
Franz Josef	8.5	7.8	7.4	7.4	7.2	7.3	7.2	7.3	8.3	8.5	8.4	8.4	7.8
Reefton	6.6	5.8	5.4	4.8	4.4	4.1	3.9	5.0	6.0	6.5	6.6	6.5	5.4

Table 2 gives the seasonal distribution and frequency of occurrence of strong winds (defined as having a daily mean wind speed of greater than 30 km/hr). For example, of all strong winds recorded at Greymouth, 30% occur in winter. In addition, during a Greymouth winter an average of nine days have a daily mean wind speed of greater than 30 km/hr. As a further example, Greymouth and Reefton have a similar distribution of strong winds in autumn, with 26% and 24% of their respective annual strong winds being recorded in that season. However, Greymouth has an average of eight strong wind days in autumn, compared to just two in Reefton. This highlights that although a similar seasonal distribution of strong winds may be observed between different locations in West Coast, the actual number of strong wind days per season at those locations may be considerably different.

Table 2. Seasonal distribution and frequency (mean number of days) of strong winds (daily mean wind speed > 30 km/hr) recorded at selected West Coast locations, from all available data.

Location	Summer		Autumn		Winter		Spring		Annual Frequency
	Distribution	Frequency	Distribution	Frequency	Distribution	Frequency	Distribution	Frequency	
Greymouth	18%	5	26%	8	30%	9	26%	8	31
Haast	16%	4	27%	7	29%	8	28%	7	26
Westport	19%	4	21%	4	27%	5	33%	6	19
Hokitika	24%	2	21%	2	20%	2	34%	4	10
Reefton	32%	3	24%	2	11%	1	32%	3	8
Franz Josef	22%	1	23%	1	34%	1	21%	1	3

Diurnal variation in wind speed is well-marked, with highest wind speeds occurring mid-afternoon before decreasing overnight. This is because heating of the land surface is most intense during the day, and stronger winds aloft are brought down to ground level by turbulent mixing. Cooling at night generally restores a lighter wind regime. Table 3 gives average wind speeds at three-hourly intervals for selected locations, whilst Figure 7 visually highlights the typical diurnal variation of wind speed observed throughout West Coast.

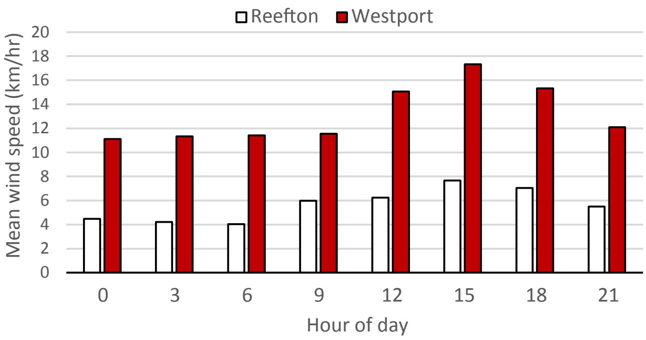


Figure 7. Mean wind speed at selected hours of the day for Reefton and Westport.

Table 3. Mean wind speed (km/hr) at three-hourly intervals of the day.

Location	0000	0300	0600	0900	1200	1500	1800	2100
Franz Josef	6.2	6.5	6.5	6.6	8.4	11.9	9.6	6.7
Greymouth	12.6	12.5	12.6	13.0	14.2	14.5	14.2	13.1
Haast	8.7	9.4	9.8	10.1	12.3	14.5	12.6	9.5
Hokitika	8.8	8.7	8.8	9.4	13.0	14.9	12.7	9.9
Reefton	4.5	4.2	4.0	6.0	6.2	7.7	7.0	5.5
Westport	11.1	11.3	11.4	11.5	15.1	17.3	15.3	12.1

Gusty winds are relatively infrequent throughout most lowland West Coast locations, occurring more frequently in the mountain ranges and exposed coastal locations. Greymouth experiences an average of 46 days per year with wind gusts exceeding 61 km/hr, considerably more than Reefton where on average less than one such day per year is recorded (Table 4). Maximum gusts recorded at different West Coast locations are listed in Table 5. The highest gust recorded in the region was 140.8 km/hr, occurring at Greymouth on 17 April 2014.

Table 4. Mean number of days per year with gusts exceeding 61 km/hr and 94 km/hr for selected locations.

Location	Days with gusts >61 km/hr	Days with gusts >94 km/hr
Franz Josef	17	0.7
Greymouth	46	0.9
Hokitika	29	0.7
Reefton	0.4	0
Westport	41	2

Table 5. Highest recorded wind gusts at selected West Coast locations, from all available data.

Location	Gust (km/hr)	Direction	Date
Franz Josef	109.3	WNW	10/07/2011
Greymouth	140.8	E	17/04/2014
Hokitika	133.4	W	14/05/1979
Reefton	66.7	NE	01/03/2009
Westport	135.3	SE	16/07/1976

Photo: ©mychillybin.co.nz/ Vibeke Friis

Rainfall

Rainfall distribution

The spatial distribution of West Coast's median annual rainfall is shown in Figure 8, which clearly illustrates both its dependence on elevation and exposure to the main rain bearing airflows from the west. Rainfall is highest among the main divide which has both high elevation and western exposure. Such high rainfall is primarily a result of the orographic effect. Specifically, moisture-laden air masses passing over the Tasman Sea and are forced to rise over the Southern Alps. As these air masses rise, they cool rapidly, causing the stored water vapour to condense, resulting in rainfall. Inland low elevation locations around Reefton are located in the rain-shadow of the Paparoa Range, and receive considerably less rainfall than many other West Coast locations. In coastal locations, the general trend is for annual rainfall to increase towards the southern-most parts of the region. West Coast is New Zealand's wettest region, and wet periods, however defined, are relatively common compared with the remainder of the country.

Table 6 lists monthly rainfall normals and the percentage of annual total for selected locations. The seasonal distribution of rainfall is fairly even throughout West Coast. Most locations observe a rainfall minimum in February, however this is generally offset by relatively high rainfalls in December, which balances out the summer rainfall totals received. The distribution of monthly rainfall is shown in Figure 9. The 10th percentile, 90th percentile, and mean rainfall values for each month are shown along with maximum and minimum recorded values for several stations.

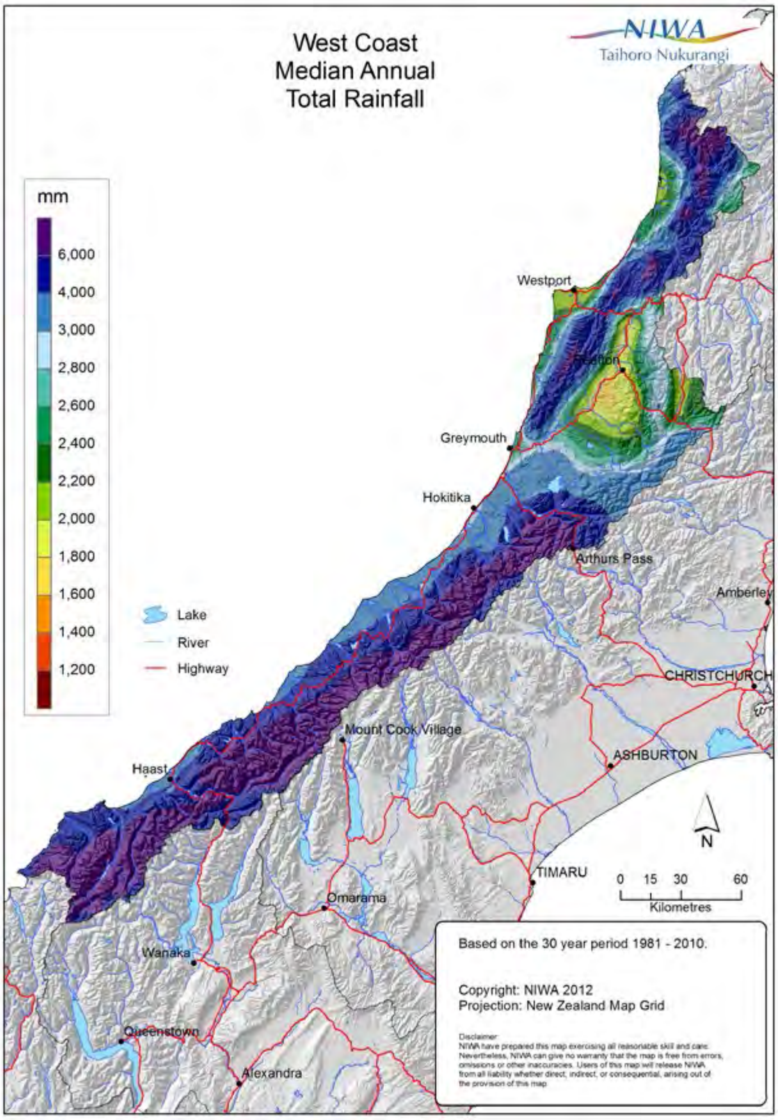


Figure 8. West Coast median annual total rainfall, 1981–2010.

Table 6. Monthly and annual rainfall normal (a; mm), and monthly distribution of annual rainfall (b; %) at selected West Coast locations, for the period 1981–2010.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cropp River	a	1117	696	872	866	917	897	680	846	967	1240	1007	1288	11400
	b	10	6	8	8	8	8	6	7	8	11	9	11	
Franz Josef	a	567	387	473	407	446	451	352	422	505	595	487	659	5751
	b	10	7	8	7	8	8	6	7	9	10	8	11	
Greymouth	a	209	161	177	195	197	238	198	192	209	225	197	252	2452
	b	9	7	7	8	8	10	8	8	9	9	8	10	
Hokitika	a	211	204	184	203	246	267	183	243	221	273	197	301	2732
	b	8	7	7	7	9	10	7	9	8	10	7	11	
Inangahua	a	190	132	180	178	206	193	260	211	201	239	191	253	2433
	b	8	5	7	7	8	8	11	9	8	10	8	10	
Karamea	a	146	91	132	168	192	159	158	129	186	166	152	190	1868
	b	8	5	7	9	10	9	8	7	10	9	8	10	
Kopara	a	246	173	187	240	201	253	256	319	232	332	297	259	2995
	b	8	6	6	8	7	8	9	11	8	11	10	9	
Lake Moeraki	a	392	328	365	309	344	387	272	313	356	428	391	415	4301
	b	9	8	8	7	8	9	6	7	8	10	9	10	
Lake Paringa	a	526	366	527	376	440	486	381	381	502	550	482	573	5588
	b	9	7	9	7	8	9	7	7	9	10	9	10	
Reefton	a	146	106	117	143	167	200	169	173	177	196	162	189	1943
	b	8	5	6	7	9	10	9	9	9	10	8	10	
Seddonville	a	239	175	210	208	227	226	246	191	250	260	282	301	2813
	b	9	6	7	7	8	8	9	7	9	9	10	11	
Tuke River	a	1029	643	835	789	808	804	576	739	971	1177	946	1241	10558
	b	10	6	8	7	8	7	6	7	9	11	9	11	
Westport	a	158	128	136	142	171	230	139	192	184	209	168	190	2046
	b	8	6	7	7	8	11	7	9	9	10	8	9	

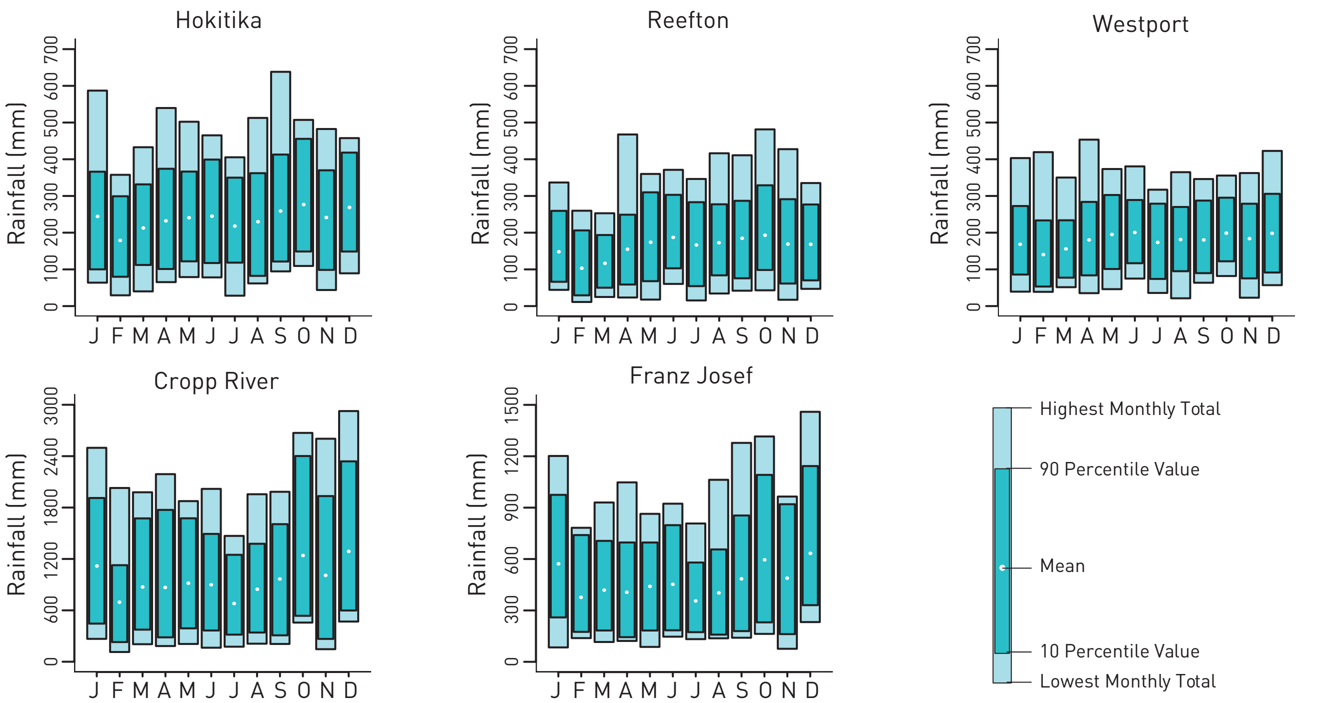


Figure 9. Monthly variation of rainfall for selected West Coast locations from all available data.

Rainfall variability is further indicated by rainfall deciles, as given in Tables 7, 8 and 9. The 10th percentile values show the accumulated rainfalls that will normally be exceeded in nine out of ten years, while the 90th percentile values indicate the accumulated falls that will normally be exceeded in only one year in ten. The tables include periods from one month to twelve months (annual), with each time period that is longer than one month beginning with the month stated. For example, using the table for Greymouth (Table 8), it can be seen that in the three month period beginning in January, 404 mm or more of rainfall can be expected in nine years in ten, while a total of 766 mm or more should occur in only one year in ten.

Table 7. Rainfall means and deciles at monthly, 3-monthly, 6-monthly, 9-monthly and annual intervals for Cropp River from all available data.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cropp River												
1 month												
90th	1912	1127	1674	1773	1675	1492	1248	1377	1606	2401	1934	2339
Mean	1118	696	873	867	918	898	680	846	967	1241	1008	1288
10th	445	230	375	285	390	365	316	341	308	536	266	598
3 months												
90th	3779	3510	3872	3608	3504	3506	3399	4134	4423	4727	4966	4830
Mean	2650	2424	2623	2633	2474	2432	2437	3015	3217	3525	3415	3130
10th	1882	1473	1550	1807	1476	1711	1330	1632	1930	2400	2068	2060
6 months												
90th	6750	5690	6501	6531	6972	7322	7117	7612	7770	7635	7571	7922
Mean	5263	4843	4998	5122	5501	5632	6025	6498	6287	6132	5816	5760
10th	3813	3609	3601	3614	3757	3703	4567	5210	4972	4698	4164	4101
9 months												
90th	9773	9434	10370	10275	10414	10451	10546	10105	10406	10488	10228	9810
Mean	7870	7898	8214	8687	8827	8680	8673	8871	8873	8667	8157	8135
10th	6181	6389	6168	6601	6902	7007	7149	7149	6979	6325	6099	5853
Annual												
90th	13473											
Mean	11357											
10th	9354											

Table 8. Rainfall means and deciles at monthly, 3-monthly, 6-monthly, 9-monthly and annual intervals for Greymouth from all available data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Greymouth												
1 month												
90th	300	264	312	355	338	334	314	307	331	367	330	370
Mean	202	165	190	211	218	213	195	195	199	225	211	227
10th	96	70	99	77	115	97	83	98	92	134	94	106
3 months												
90th	766	775	833	780	780	775	832	879	845	873	892	842
Mean	557	566	619	641	624	603	589	619	635	662	641	592
10th	404	371	474	490	493	459	387	414	470	483	442	387
6 months												
90th	1498	1498	1480	1509	1522	1488	1541	1484	1512	1480	1520	1475
Mean	1198	1190	1220	1228	1242	1237	1251	1258	1228	1221	1206	1211
10th	983	929	961	1014	998	983	960	994	969	925	874	968
9 months												
90th	2121	2173	2256	2261	2198	2172	2172	2188	2193	2267	2191	2134
Mean	1785	1807	1855	1893	1887	1832	1808	1823	1847	1862	1831	1812
10th	1484	1477	1498	1521	1574	1495	1454	1460	1489	1525	1465	1469
Annual												
90th	2853											
Mean	2450											
10th	2032											

Table 9. Rainfall means and deciles at monthly, 3-monthly, 6-monthly, 9-monthly and annual intervals for Reefton from all available data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Reefton												
1 month												
90th	259	206	194	249	310	303	283	277	287	329	291	277
Mean	148	103	117	155	174	187	167	173	185	193	169	168
10th	66	29	50	59	68	103	54	84	76	98	61	70
3 months												
90th	515	547	651	665	712	679	767	760	710	670	677	559
Mean	367	374	448	517	529	528	525	551	541	525	482	419
10th	236	225	284	372	363	400	335	351	404	354	327	261
6 months												
90th	1089	1166	1209	1311	1366	1349	1331	1264	1186	1135	1152	1120
Mean	888	907	978	1046	1084	1069	1052	1034	964	891	856	868
10th	681	690	717	831	822	846	803	823	759	690	613	611
9 months												
90th	1792	1839	1866	1891	1889	1784	1772	1726	1645	1737	1730	1699
Mean	1416	1456	1520	1577	1571	1499	1425	1408	1412	1413	1392	1398
10th	1163	1209	1243	1339	1319	1229	1134	1124	1113	1113	1126	1160
Annual												
90th	2329											
Mean	1947											
10th	1644											

Rainfall frequency and intensity

Table 10 lists the average number of days per month with at least 0.1 mm (a 'rain day') and at least 1 mm (a 'wet day') of rain for selected locations. The average number of days each year on which 0.1 mm or more of rain is recorded varies from 140 days at Inangahua to 206 days at Franz Josef and Hokitika. Inangahua and Lake Paringa exhibit the lowest number of wet days in the region, with 136 and 147 wet days recorded on average respectively, compared with 185 wet days at Franz Josef. The number of rain and wet days recorded at a given station tends to be higher nearer the coast, and lower at locations farther inland. A seasonal variation of rain days and wet days is present in most West Coast locations, with a maximum occurring in spring. This may be attributed to the seasonal changes in the general circulation of the Southern Hemisphere described previously, which result in a maximum frequency of disturbed westerly situations in spring.

Heaviest short period rainfalls in West Coast are recorded at relatively high elevations, which often occur when persistent west/northwesterly airflows are established as a trough approaches the South Island. These moisture-laden airflows bring considerable rainfall totals throughout the region, even at relatively low elevations along the coast. In Table 11, maximum short period rainfalls for periods of 10 minutes to 72 hours with calculated return periods are given for Greymouth and Reefton. Also listed in this table are the maximum rainfalls expected in 2, 5, 10, 20, and 50 years. Depth-duration frequency tables for West Coast locations are available from NIWA's High Intensity Rainfall Design System (HIRDS). HIRDS uses the index-frequency method to calculate rainfall return periods. For more information on methods and to use the tool, see http://hirds.niwa.co.nz/.

Table 10. Average monthly rain days (a; days where at least 0.1 mm rainfall is measured) and wet days (b; days where at least 1 mm rainfall is measured) at selected West Coast locations.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Franz Josef	a	16	15	15	16	16	16	14	18	20	21	18	20	206
	b	14	14	13	14	15	15	13	16	18	19	16	18	185
Greymouth	a	15	13	15	16	17	16	16	18	19	20	18	18	201
	b	13	11	13	14	15	14	14	15	16	17	15	15	173
Hokitika	a	16	13	15	16	18	17	16	18	20	21	19	18	206
	b	12	10	13	13	15	14	13	15	17	17	15	16	170
Inangahua	a	10	9	10	11	13	12	12	12	13	14	13	12	140
	b	9	8	10	11	12	11	11	11	12	14	13	12	136
Karamea	a	12	11	12	13	14	15	14	14	15	17	16	13	167
	b	11	10	11	12	13	14	12	13	14	15	15	12	151
Kopara	a	15	12	13	11	16	15	13	18	17	22	18	18	187
	b	13	10	11	10	15	13	12	17	15	19	16	16	167
Lake Moeraki	a	12	11	12	12	15	15	13	15	15	17	13	15	166
	b	12	10	12	11	15	15	13	14	15	16	13	15	160
Lake Paringa	a	12	10	12	11	13	12	11	11	13	14	14	13	149
	b	12	10	12	11	13	12	11	11	13	14	14	13	147
Reefton	a	13	11	13	14	16	16	16	17	19	19	17	16	187
	b	11	9	10	11	14	13	13	13	16	16	14	14	153
Seddonville	a	14	11	14	12	15	14	15	16	18	19	16	16	179
	b	12	10	12	10	14	13	14	15	17	17	15	15	164
Westport	a	14	12	15	16	18	18	17	18	19	20	18	17	200
	b	12	10	12	13	15	15	14	15	16	17	15	15	171

Table 11. Maximum recorded short period rainfalls and calculated return periods from HIRDS.

Location		10min	20min	30min	1hr	2hrs	6hrs	12hrs	24hrs	48hrs	72hrs
Greymouth	a	24.0	47.0	55.3	70.0	84.4	121.4	169.5	196.6	251.5	303.7
	b	Apr 1968	Apr 1968	Apr 1968	Apr 1968	Apr 1968	Jan 2000	Jan 2000	Jan 2000	Apr 1978	Apr 1957
	c	100+	100+	100+	100+	100+	77	100+	52	59	81
	d	9.3	13.8	17.4	25.8	35.2	57.4	78.1	106.3	133.3	152.3
	e	11.9	17.6	22.2	32.9	44.3	71.1	95.8	129.1	162	185
	f	13.9	20.6	26	38.5	51.6	81.9	109.7	146.8	184.2	210.4
	g	16.2	24	30.3	44.9	59.7	93.9	124.9	166.1	208.4	238
	h	19.8	29.3	36.9	54.7	72.2	112	147.7	194.9	244.6	279.3
Reefton	a	16.0	23.3	24.1	27.3	40.9	72.2	117.0	176.3	242.6	271.0
	b	Dec 2009	Dec 2009	Dec 2009	Jan 2004	Dec 1979	Apr 1975	Apr 1975	Jul 1983	Aug 1970	Aug 1970
	c	100+	100+	67	25	29	27	50	66	100+	83
	d	6.6	9.2	11.1	15.3	22.8	42.7	63.4	94.3	120.7	139.5
	e	8.3	11.5	14	19.3	28.4	52.4	77.2	113.6	145.4	168.1
	f	9.7	13.4	16.3	22.5	32.9	60.1	87.9	128.5	164.5	190.2
	g	11.2	15.6	18.8	26.1	37.9	68.5	99.5	144.6	185.2	214.1
	h	13.6	18.8	22.8	31.5	45.4	81.1	117	168.6	215.9	249.5

a: highest fall recorded (mm)
b: month and year of occurrence
c: calculated return period of a (years)
d: max fall calculated with ARI 2 years (mm)
e: max fall calculated with ARI 5 years (mm)
f: max fall calculated with ARI 10 years (mm)
g: max fall calculated with ARI 20 years (mm)
h: max fall calculated with ARI 50 years (mm)

Recent extreme events in West Coast

West Coast has experienced numerous extreme weather events, with significant damage and disruption caused by heavy rain and flooding. The events listed below are some of the most severe rainfall and flooding events to have affected the West Coast region between 1988 and 2015.

23–25 November 2008: As an anticyclone (high pressure system) moved slowly to the east of New Zealand, a large depression (low pressure system) gradually moved across the Taman Sea. A strong, humid northerly flow contained between the two systems covered New Zealand on 23 November, carrying air down from the subtropics. On the night of 24 November, the low crossed the South Island and the flow tended westerly. Several fronts passed over the South Island, bringing enhanced bouts of heavy rainfall to West Coast. Widespread surface flooding occurred in the region with numerous road closures, including the closure of State Highway 6 between Whataroa and Haast where flooding was particularly severe. Approximately 70% of the Fox Glacier access road was washed away when the Fox River burst its banks on 25 November, leaving four cars stranded in the carpark. A rainfall gauge located at Cropp River recorded 991 mm of rain in three days from 23 to 25 November, and Greymouth recorded 122.5 mm of rain over the same period of time.

1–3 April 1991: A Civil Defence emergency was declared in Franz Josef after prolonged heavy rain caused considerable flooding. The rainfall resulted from a warm, moist northwest airflow over the region due to a low pressure system centred southwest of the South Island and a high pressure system centred east of the South Island. A total of 75 people were evacuated from riverside homes, motels and the motor camp. The Waiho River rose dramatically, and carried gravel and ice amongst other debris. At around 11 p.m. on 2 April, a wall of slush swept down the valley, and dumped up to one tonne of ice on the Waiho River bridge surface. Franz Josef recorded 246 mm of rain in the 48 hours to 9 a.m. on 3 April 1991.

13–14 September 1988: Heavy rain associated with a northwest airflow combined with snow-melt to cause extensive flooding in West Coast, particularly in the Greymouth area. A Civil Defence Emergency was declared for the Inangahua County, Runanga Borough, Greymouth Borough and Grey County due to flooding, with 356 people evacuated from 183 houses. Stopbanks along the lengths of the Grey and Ahaura rivers were severely damaged, and many farm fences were destroyed. Significant numbers of stock were killed by the floodwaters, and substantial damage was caused by silting of farmland near the lower reaches of the Grey River, and in the Buller Gorge, Rotomaunu and Te Kinga areas. At Dobson, the Grey River peaked at 5,768 cumecs and was 5.8 metres above its normal level. In Greymouth, floodwaters were over 2 metres deep in some lower parts of the town, and over a metre deep on the aerodrome. Thick silt was deposited throughout the city, much of it contaminated with sewage and oil. Greymouth recorded 107.4 mm of rain in the 24 hours to 9 a.m. on 13 September 1988. Total flood damage costs totalled approximately $16 million (1994 New Zealand dollars).

Periods of low rainfall

Periods of fifteen days or longer with less than 1 mm of rain on any day are referred to as 'dry spells'. Dry spells are quite uncommon in most areas of West Coast, but can occur throughout the region when a persistent (blocking) anticyclone becomes established over the South Island. Additionally, the Southern Alps provide a great deal of sheltering for the region during easterly airstreams, such that dry spell conditions can occur in West Coast when considerable rain may be falling east of the main divide. Table 12 outlines the dry spell frequency and duration for Greymouth and Reefton. On average, a dry spell occurs once every 11 months in Reefton, and once every 19 months in Greymouth. The longest dry spell was 40 days, recorded in Reefton from 6 February to 17 March 2013. Table 13 shows the seasonal distribution of dry spells at Greymouth and Reefton. Dry spell occurrence is notably infrequent during spring at both locations, reflecting the high frequency of westerly airflows in that season.

Table 12. Dry spell (at least 15 consecutive days with less than 1 mm rainfall per day) frequency and duration for selected West Coast locations, from all available data.

Location	Frequency	Mean duration (days)	Max duration (days)	Max duration date
Greymouth	One every 19 months	17	39	6/2/2013 to 16/3/2013
Reefton	One every 11 months	18	40	6/2/2013 to 17/3/2013

Table 13. Seasonal distribution (%) of dry spells at selected West Coast locations, from all available data.

Location	Summer	Autumn	Winter	Spring
Greymouth	25%	30%	35%	10%
Reefton	22%	36%	31%	11%

Temperature

Sea surface temperature

Monthly mean sea surface temperatures off the coast of West Coast are compared with mean air temperature for Greymouth and Reefton in Figure 10. There is a lag in the increase of sea surface temperatures when compared to air temperatures from July to September. This is the result of the greater heat capacity of the sea compared to land, which results in the sea surface temperatures taking longer to increase and decrease in response to changing seasons compared to land-based areas. Greymouth records considerably higher mean air temperatures in winter compared with the inland location of Reefton, whereas Reefton observes higher mean temperatures than Greymouth in summer. This is attributed to the moderating influence of the sea on winter minimum temperatures and summer maximum temperatures near the coast. Figure 11 shows the mean sea surface temperatures for the New Zealand region for February and August, which are the warmest and coolest months with respect to sea surface temperatures.

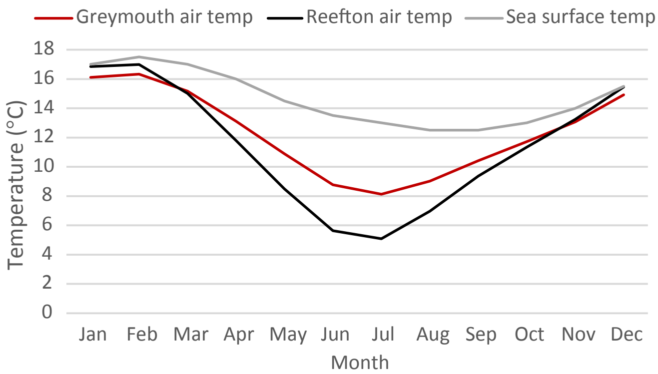


Figure 10. Mean monthly air temperature (Greymouth and Reefton) and estimated sea surface temperatures (off the coast of West Coast).

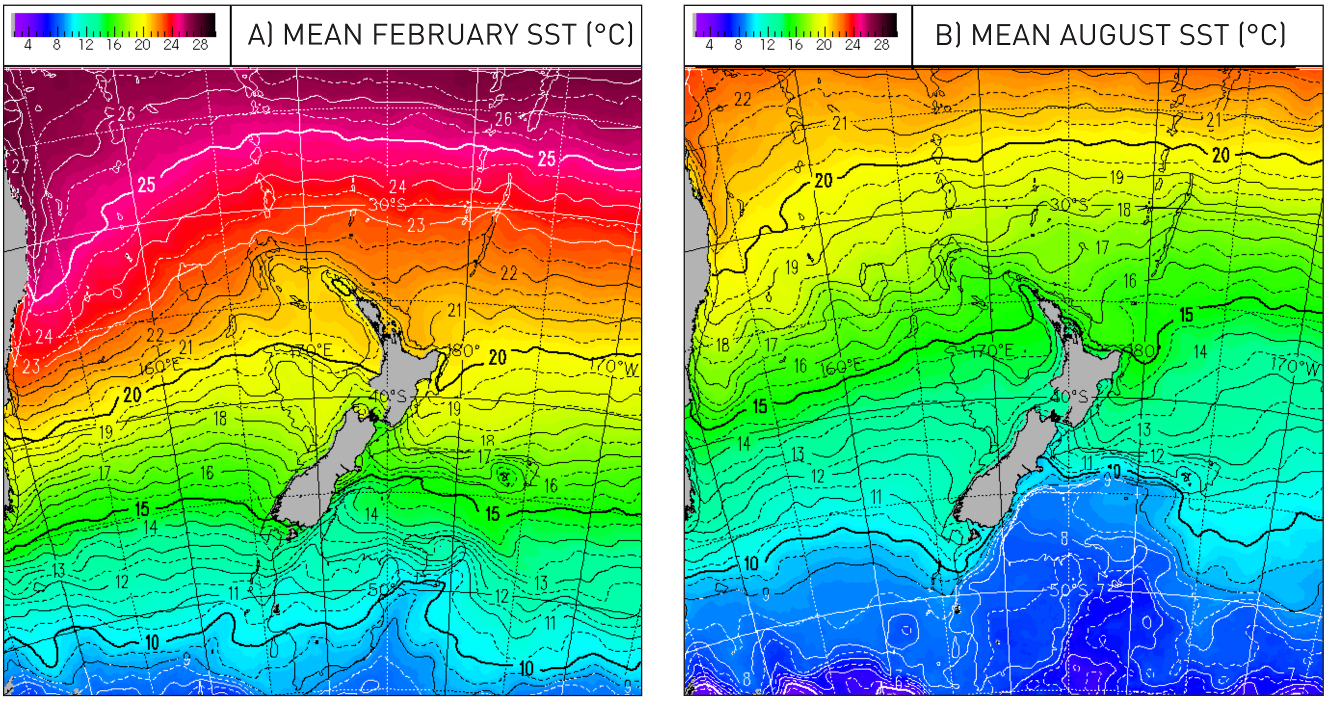


Figure 11. Monthly mean sea surface temperatures (°C) for: a) February; b) August. Source: NIWA SST Archive, Uddstrom and Oien (1999).

Air temperature

West Coast typically observes afternoon temperatures reaching between 18°C and 22°C in summer, and overnight temperatures falling to between 1°C and 6°C in winter (Figure 12). Similar daily maximum temperatures are recorded throughout West Coast in summer, with the notable exception of high elevation areas where temperatures become increasingly lower as elevation increases, and inland low elevation locations where temperatures are higher. In winter, daily minimum temperatures become lower as distance from the coast and elevation increases. Figure 13 shows the median annual average temperature in the West Coast region, and clearly demonstrates that lower temperatures are recorded at higher elevation locations. Low elevation locations have a median annual temperature of between 11°C and 13°C. Median annual temperatures of below 2°C occur along the main divide especially around Mt Cook, which contributes to the perennial snow and glaciers at high elevations in those areas. Figure 14 gives the monthly temperature regime (highest recorded, mean monthly maximum, mean daily maximum, mean, mean daily minimum, mean monthly minimum, and lowest recorded) for selected West Coast locations.

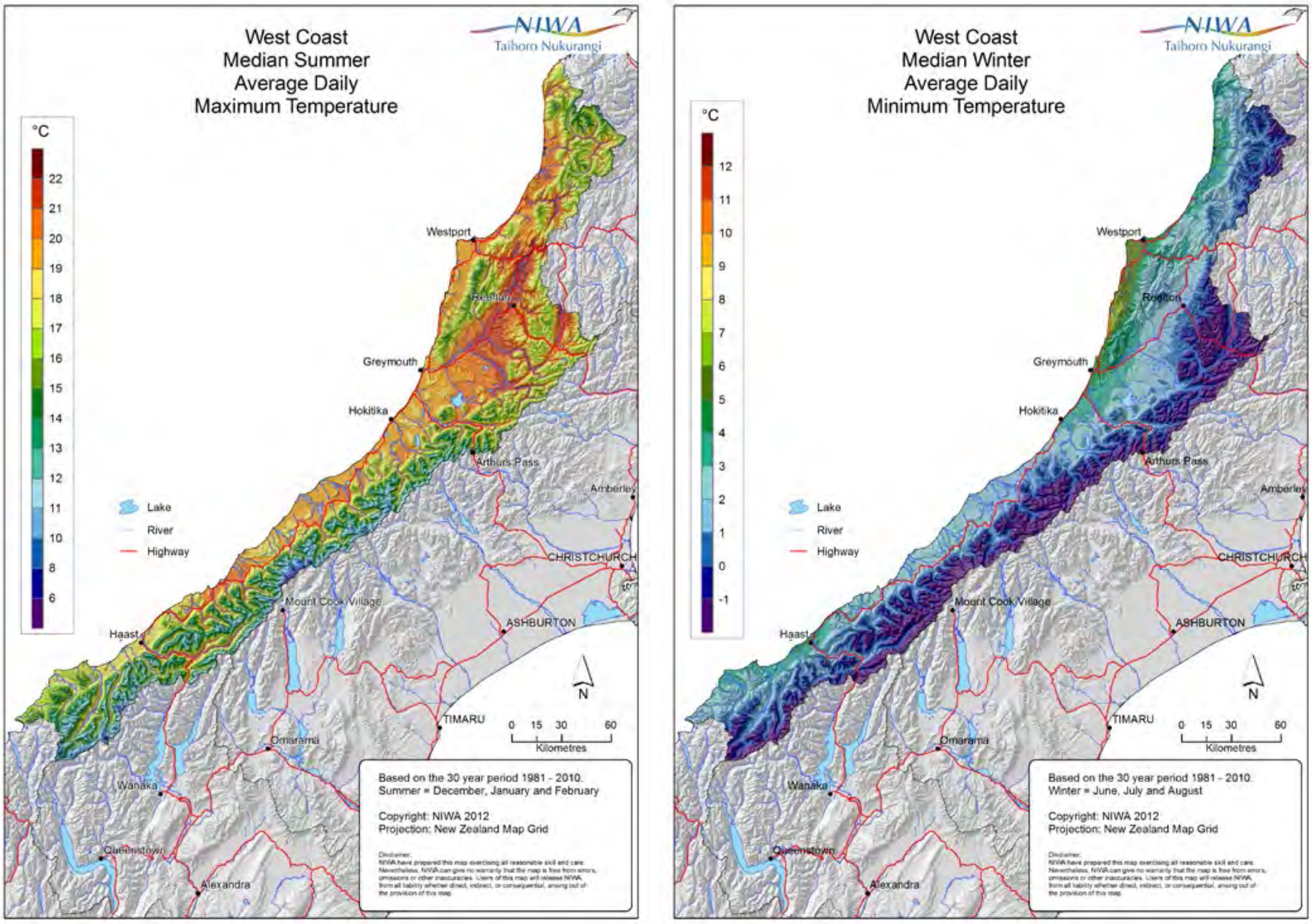


Figure 12. Left: West Coast median summer (December, January and February) average daily maximum temperature; Right: West Coast median winter (June, July and August) average daily minimum temperature.

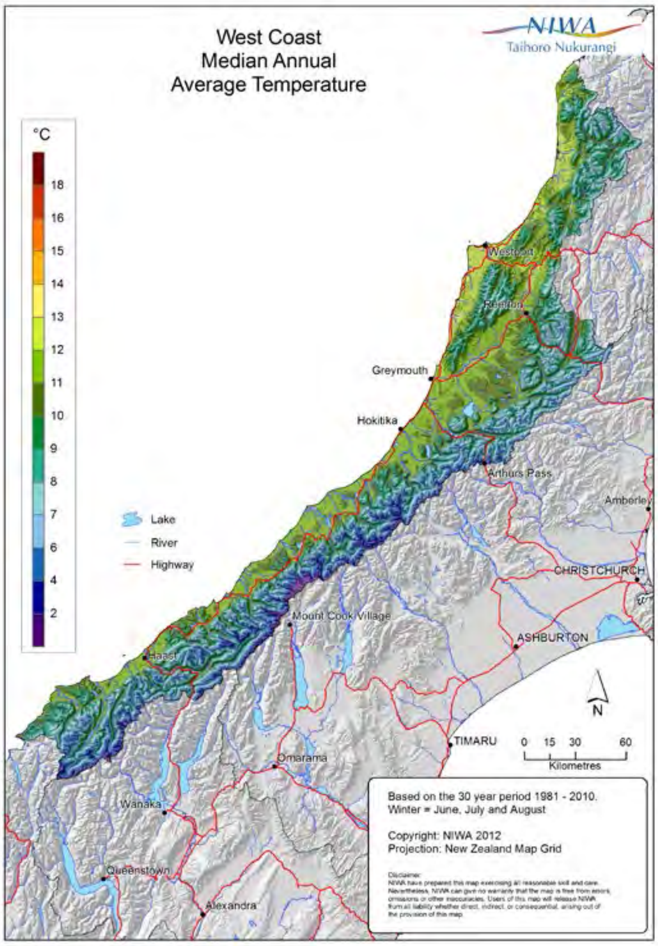


Figure 13. West Coast median annual average temperature, 1981–2010.

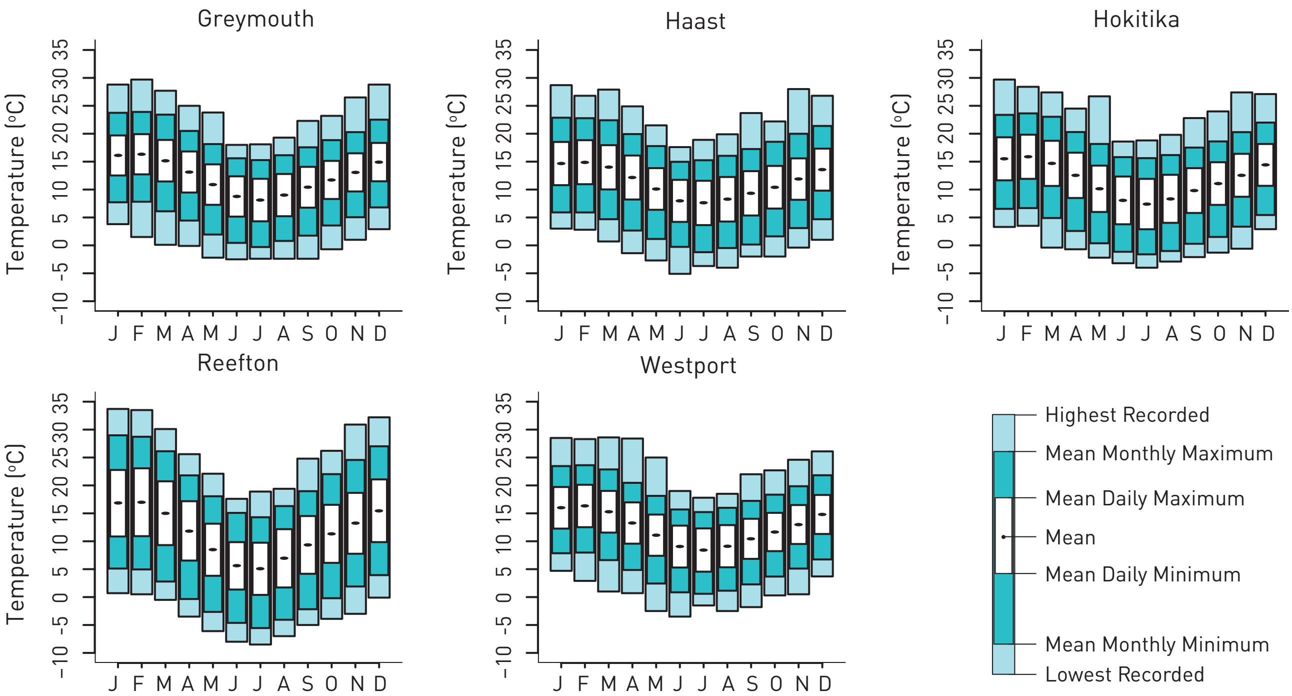


Figure 14. Monthly variation in air temperatures for selected West Coast locations from all available data.

Table 14 shows that the average daily temperature range, i.e. the difference between the daily maximum and minimum temperature, is much smaller at coastal locations than in inland areas (e.g. Reefton). This is the case for most of the year, however the difference is least prominent in June and July. Average daily temperature ranges are similar throughout the year at each coastal location, but are higher in Reefton during summer compared with winter.

Table 14. Average daily temperature range (Tmax – Tmin, °C) for selected West Coast locations.

Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ann**
Greymouth	7.2	7.2	7.4	7.4	7.3	7.2	7.6	7.6	7.3	6.8	6.8	6.9	7.2
Haast	7.7	7.9	7.9	7.9	7.5	7.5	7.9	8.0	7.9	7.6	7.4	7.5	7.7
Hokitika	7.7	7.9	8.1	8.1	8.3	8.6	9.0	8.6	8.0	7.6	7.7	7.5	8.1
Reefton	11.9	12.2	11.4	10.6	9.3	8.5	9.3	10.4	10.3	10.4	10.9	11.2	10.6
Westport	7.5	7.6	7.5	7.4	7.4	7.5	7.8	7.6	7.2	6.9	7.0	7.0	7.3

Table 15 and Figure 15 further highlight the diurnal temperature range, showing the median hourly mean air temperature for January and July at Greymouth and Reefton. Air temperatures at Reefton remain lower than Greymouth at all hours of the day in July. In January, the moderating influence of the sea on air temperatures at Greymouth are clearly demonstrated, as daily minimum temperatures are higher and daily maximum temperatures are considerably lower than Reefton. Note that hourly mean air temperature at a given time is calculated as the mean of the maximum and minimum air temperature recorded over the previous hour. As such, daily temperature ranges for January and July for Greymouth and Reefton calculated from Table 15 are lower than those in Table 14, which are based on the extreme daily maximum and minimum temperatures.

Table 15. Median hourly mean air temperatures for January and July at Greymouth and Reefton.

		00	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
Greymouth	**January**	14.7	14.5	14.3	14.1	13.9	13.6	13.4	13.4	13.8	14.8	15.8	16.4
	July	7.2	7.1	7.0	7.1	6.7	6.6	6.4	6.3	6.2	6.4	7.4	8.4
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
	January	16.9	17.4	17.7	18.0	18.1	18.0	17.8	17.4	17.0	16.4	15.8	15.3
	July	9.5	10.3	11.0	11.2	11.2	10.6	9.1	8.3	7.8	7.7	7.5	7.4
Reefton		**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
	January	14.9	14.0	13.5	13.3	13.0	12.6	12.3	12.0	12.5	13.9	15.5	17.0
	July	3.7	3.7	3.5	3.1	2.9	2.7	2.7	2.5	2.4	2.5	3.1	4.5
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
	January	18.6	19.9	20.9	21.4	22.1	21.8	21.7	20.9	19.7	18.2	16.9	15.7
	July	6.2	7.4	9.0	9.6	9.6	8.9	7.0	5.9	5.0	4.8	4.5	4.2

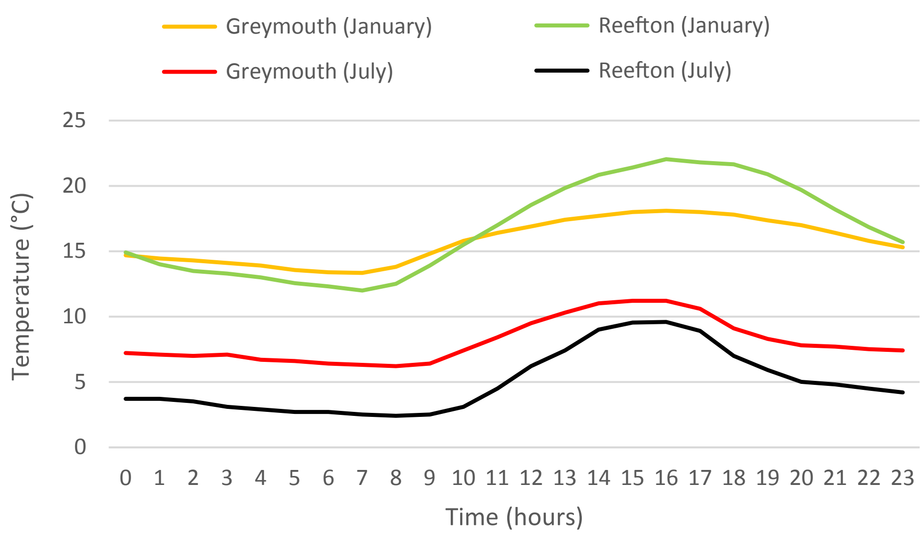


Figure 15. Median hourly mean air temperatures at Greymouth and Reefton in January and July.

Maximum air temperatures in excess of 25°C are a rare occurrence for coastal areas of West Coast. However, they do occur more frequently for inland locations, particularly in Reefton, where an annual average of 24 such days occur (Table 16). Inland parts of West Coast record considerably more days with a minimum temperature below 0°C compared to locations closer to the coast. The highest air temperature recorded in West Coast to date is 33.7°C at Reefton on 4 January 1975. This temperature occurred on the first day of a very hot spell in Reefton from 4 January to 13 January 1975. During these 10 days, the average daily maximum temperature was 30.0°C, with the temperature reaching at least 30.3°C on five out of the ten days. Reefton also recorded the lowest air temperature in West Coast; -8.5°C on 8 July 1972.

Table 16. Highest and lowest recorded air temperatures, average number of days per year where maximum air temperature exceeds 25°C, and average number of days per year where the minimum air temperature falls below 0°C, for selected West Coast locations from all available data.

Location	Highest recorded (°C)	Annual days max temp > 25°C	Lowest recorded (°C)	Annual days min temp < 0°C
Greymouth	29.7	1	-2.5	2
Haast	29.0	0.8	-5.1	9
Hokitika	30.6	0.9	-6.6	14
Reefton	33.7	24	-8.5	46
Westport	28.5	1	-3.5	1

Earth temperatures

Earth (soil) temperatures are measured once daily at 9 a.m. at several West Coast locations. Earth temperatures are measured at varying depths and are important for determining the growth and development of plants. Different plants have different rooting depths and as such, earth temperatures are routinely monitored at 10, 20, 30, 50, and 100 cm depths. Table 17 lists mean monthly earth temperatures for a number of standard depths. At the coastal Greymouth location, higher winter earth temperatures are observed when compared with the inland location of Reefton.

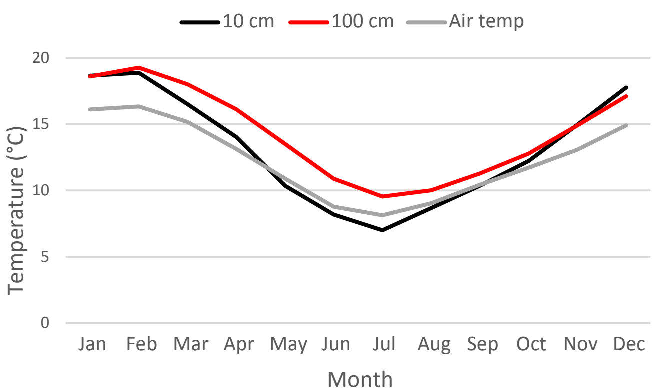


Figure 16. Monthly mean 9 a.m. earth temperature at different depths from the ground surface, and monthly mean air temperature, from all available data at Greymouth.

Figure 16 shows how earth temperatures change throughout the year at Greymouth compared with mean air temperature. The 10 cm earth temperatures are lower than the mean air temperature from May to September, but higher for remaining months of the year. The annual earth temperature cycle at 100 cm depth is more damped and lagged than at shallower depths. As a result, earth temperatures at 100 cm remain above mean air temperature at all times of the year. Diurnal variation of earth temperatures (not shown) decreases with increasing depth, such that earth temperatures may show little-to-no diurnal variation at 100 cm depth.

Table 17. Monthly and annual mean 9 a.m. earth temperatures (°C) at varying depths from the ground surface for selected West Coast locations.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Greymouth													
10 cm	18.6	18.9	16.5	14.0	10.4	8.2	7.0	8.7	10.4	12.2	15.0	17.8	13.1
20 cm	19.9	20.3	17.8	15.1	11.4	9.0	7.8	9.3	11.2	13.2	16.0	18.7	14.1
50 cm	19.7	20.3	18.2	15.8	12.5	9.8	8.6	9.7	11.4	13.2	15.8	18.4	14.4
100 cm	18.6	19.3	18.0	16.1	13.5	10.9	9.5	10.0	11.3	12.8	14.9	17.1	14.3
Hokitika													
10 cm	17.1	17.0	14.9	12.0	8.8	6.2	5.0	6.3	8.8	11.2	13.7	16.1	11.4
20 cm	18.1	18.2	16.2	13.1	9.9	7.2	5.9	7.2	9.5	11.8	14.4	16.8	12.4
30 cm	18.8	19.0	17.0	14.0	10.8	8.1	6.7	8.0	10.2	12.5	15.0	17.4	13.1
100cm	17.6	18.4	17.7	15.8	13.4	10.8	8.9	8.9	10.0	11.8	13.9	15.9	13.6
Reefton													
10 cm	16.6	16.2	14.2	11.1	7.9	5.2	4.0	5.5	8.3	10.9	13.5	15.8	10.8
20 cm	17.8	17.9	15.9	12.8	9.5	6.5	5.2	6.7	9.2	11.8	14.3	16.6	12.0
30 cm	18.4	18.5	16.6	13.5	10.0	7.1	5.9	7.3	9.8	12.4	14.8	17.0	12.6
50 cm	19.1	19.4	17.8	15.2	12.2	9.2	7.4	8.5	10.6	12.9	15.5	17.9	13.8
100 cm	17.4	17.9	17.2	15.4	12.8	10.3	8.6	8.8	10.3	12.1	14.2	16.0	13.4

Frosts

Frost is a local phenomenon and both its frequency of occurrence and intensity can vary widely over small areas. Frosts occur most frequently in winter during periods of anticyclonic conditions, primarily for two reasons. Firstly, clear skies associated with anticyclones enhance the rate of radiative cooling during the night. Secondly, anticyclones are associated with light winds, which reduces the amount of turbulent mixing of air. Cold air is relatively dense, so when there is a lack of turbulent mixing it tends to sink towards the Earth's surface. Therefore, areas most likely to experience frost are flat areas, where relatively cold air is not able to drain away on calm nights, and in valleys and basins, where relatively cold air pools after descending from higher elevation areas nearby. Under such conditions, temperature inversions (where the air temperature increases with elevation) are common.

There are two types of frost recorded. Air frosts occur when air temperature measured in a screen by a thermometer 1.3 m above the ground falls below 0°C. Ground frosts are recorded when the air temperature 2.5 cm above a closely cut grass surface falls to -1.0°C or lower. Both types of frost are relatively uncommon in West Coast compared with other South Island regions. Table 18 lists for selected locations the mean daily grass minimum and extreme grass minimum temperatures, and the average number of days each month with ground and air frosts. Ground frosts occur more frequently than air frosts, and air frosts occur most frequently at the inland location of Reefton.

Photo: ©mychillybin.co.nz/Mark Meredith

Table 18. Frost occurrence and grass minimum temperatures at selected West Coast locations from all available data.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Greymouth	a	10.9	11.0	9.5	7.3	5.1	2.9	2.0	2.9	4.6	6.5	8.0	9.9
	b	0.1	-3.4	-3.2	-3.8	-6.7	-7.2	-8.6	-7.3	-6.0	-5.7	-2.3	-0.4
	c	0	0.03	0.09	0.3	2	4	6	4	2	0.3	0.04	0
	d	0	0	0	0.02	0.2	0.6	1	0.3	0.05	0.01	0	0
Hokitika	a	10.1	10.2	8.5	6.0	3.4	1.1	0.1	1.5	3.6	5.4	7.0	9.2
	b	1.0	0.6	-2.8	-5.6	-6.8	-8.1	-11.6	-7.7	-7.0	-4.6	-4.0	-1.2
	c	0	0	0.08	1	5	11	15	10	4	2	0.4	0.04
	d	0	0	0.02	0.08	1	4	5	3	0.7	0.1	0.02	0
Reefton	a	9.1	9.0	7.5	4.9	2.3	-0.1	-1.2	0.1	2.4	4.3	6.0	8.2
	b	-3.3	-5.0	-4.2	-5.4	-9.4	-11.5	-12.5	-11.0	-9.0	-6.7	-5.0	-2.2
	c	0.04	0.06	0.4	2	7	13	17	12	6	3	0.7	0.2
	d	0	0	0.04	1	5	11	15	9	4	1	0.1	0.02

a: Mean daily grass minimum (°C)
b: Lowest grass minimum recorded (°C)
c: Mean number of ground frosts per month
d: Mean number of air frosts per month

Sunshine and solar radiation

Sunshine

Sunshine hours are generally highest along the coastal margins of West Coast, which typically receive between 1,900 and 2,050 hours of sunshine annually (Figure 17). The remainder of the West Coast region receives relatively low annual sunshine hours compared to the rest of New Zealand, particularly the high elevation mountainous areas where increased cloudiness reduces the annual sunshine totals experienced. Figure 18 shows the monthly mean, maximum, and minimum recorded bright sunshine hours for selected locations in West Coast. Note that the lower sunshine hours recorded in the winter months tends to reflect the northerly declination of the sun, as opposed to signalling an increase in cloudiness during those times.

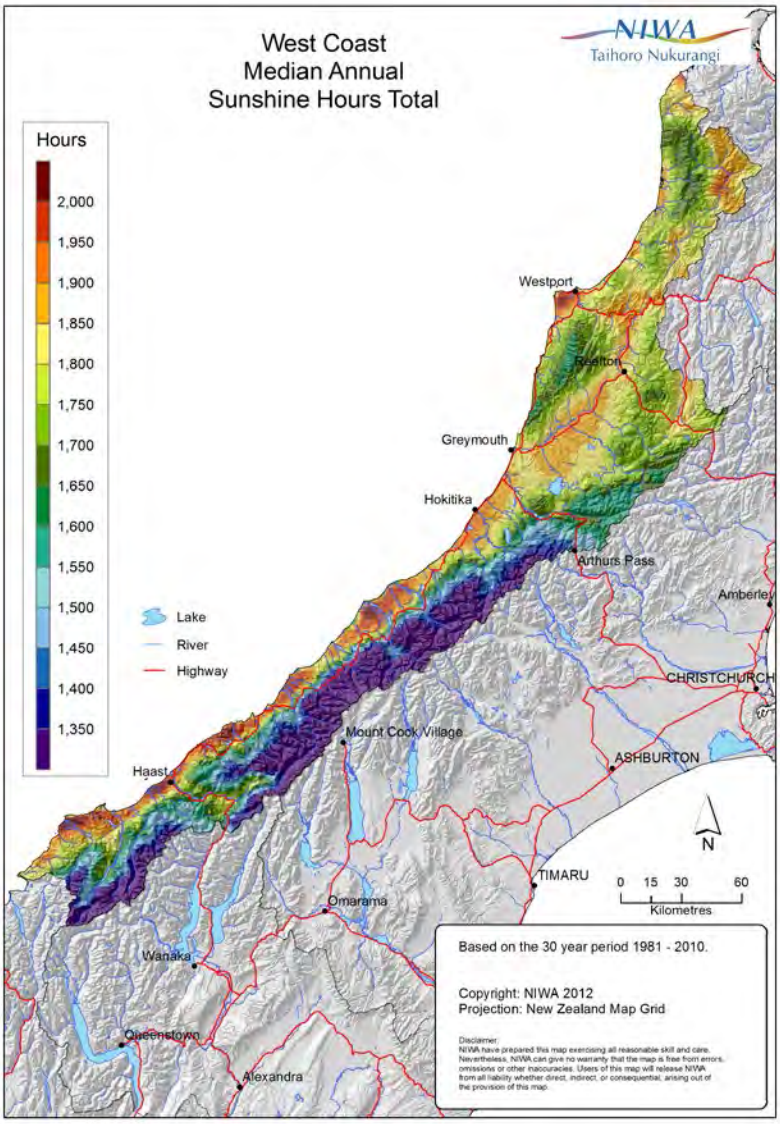


Figure 17. Median annual sunshine hours for the West Coast, 1981–2010.

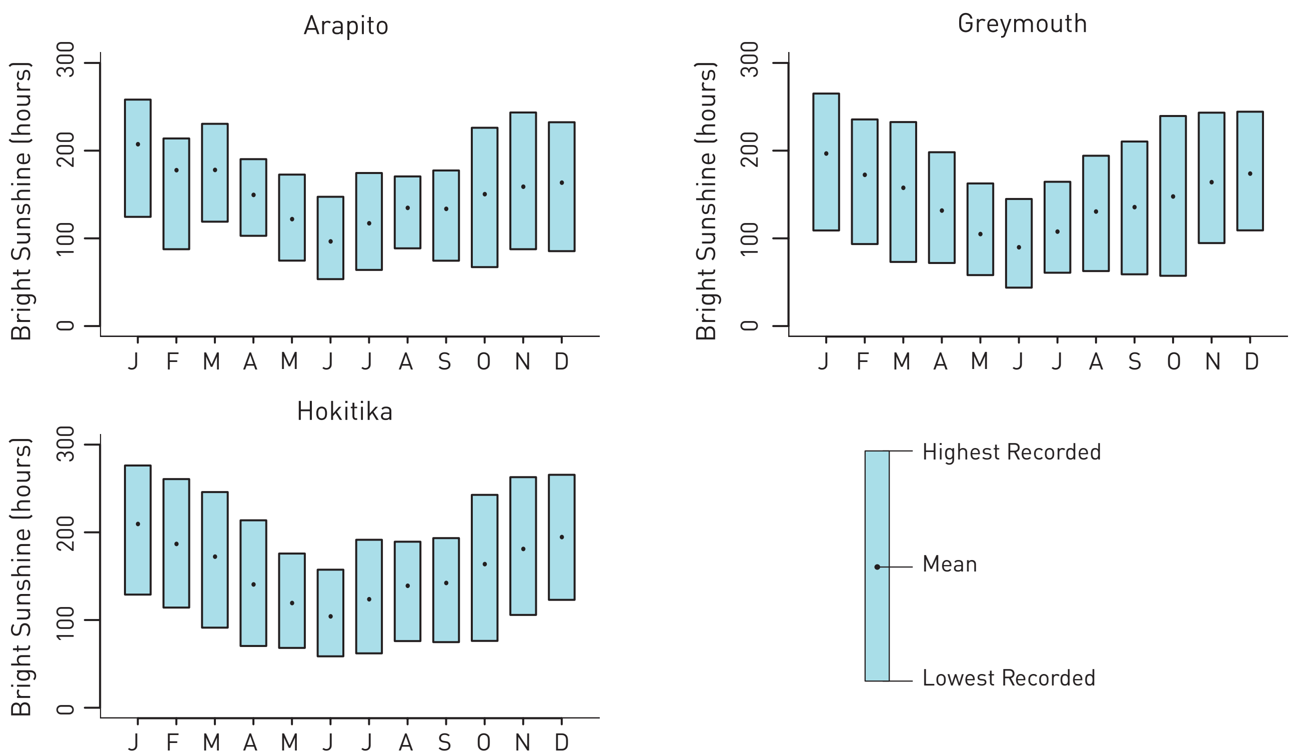


Figure 18. Mean, highest and lowest recorded monthly bright sunshine hours for selected West Coast locations from all available data (Arapito is located inland from Karamea, see Figure 1).

Solar radiation

Solar radiation records of greater than 10 years are available for only a few sites in West Coast. Table 19 presents the mean daily global solar radiation (i.e. direct and diffuse) for Greymouth, Hokitika and Reefton. Insolation is highest in January and lowest in June at all locations.

Table 19. Mean daily global solar radiation (MJ/m^2/day) for selected West Coast locations from all available data.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Greymouth	21.9	19.3	15.1	9.4	6.6	4.7	5.8	8.2	11.7	15.5	19.4	20.9	13.2
Hokitika	21.9	19.0	14.6	9.4	6.1	4.6	5.6	8.1	11.5	15.3	19.7	21.0	13.1
Reefton	21.7	19.0	14.7	9.1	5.6	4.1	5.4	7.5	10.9	14.8	19.1	20.3	12.7

UV (ultra-violet) radiation

Figure 19 shows an example of a UV forecast for Greymouth, indicating the UV levels and times of the day where sun protection is required. UV levels in Greymouth are higher than New Zealand's southern-most locations, but lower than those experienced in northern-most areas. All West Coast locations observe significantly higher UV levels in summer than in winter.

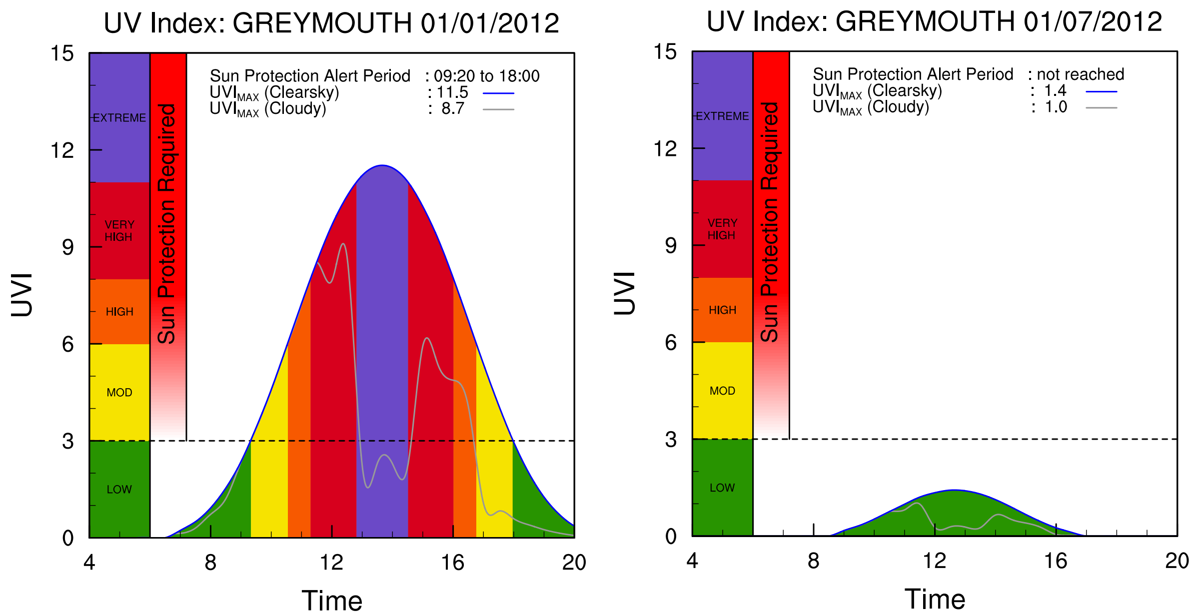


Figure 19. UV Index forecast for Greymouth, January and July. Source: https://www.niwa.co.nz/our-services/online-services/uv-ozone

Other elements

Thunderstorms and hail

Thunder occurs relatively frequently in parts of West Coast compared to other regions of New Zealand, with 21 days of occurrence per year Hokitika (Table 20). Due to the localised nature of thunderstorm occurrence, it is possible that not all thunderstorms are detected at each station. Thunderstorms in West Coast are associated with bouts of high intensity rainfall, lightning, hail, and wind squalls which sometimes cause localised flooding. Table 20 gives the average number of days per year on which hail is reported at selected locations. Hail occurs most often at Hokitika compared with the other locations shown. As with thunder, hail can be a localised event, meaning some falls may escape detection at some stations. Severe hailstorms, which may be classified as those which cause damage and/or have hailstones of at least 0.5 cm in diameter, are a rare occurrence for the West Coast region.

Table 20. Average number of days each year with thunder, hail, fog and snow recorded at selected West Coast locations, from all available data. The elevation of each station above mean sea level is also shown.

Location	Snow	Thunder	Hail	Fog
Hokitika Airport (39 m)	21	12	16	0.5
Reefton (198 m)	3	0.9	62	1
Westport Airport (2 m)	10	4	7	0.5

Fog

The most common type of fog for inland West Coast locations is radiation fog, formed when the air cools to its dew-point on clear nights, allowing the water vapour in the air to condense. Near the coast, advection fog can occur, where sea fog spreads onto the land as evening cooling proceeds. The average number of days per year with fog for selected West Coast locations is listed in Table 20. The frequency of fog varies widely over the West Coast region, ranging from an average of seven days with fog per year at Westport to an average of 62 days per year at Reefton. Of the annual average of 62 days with fog at Reefton, 42 days (67%) are recorded between May and August. In contrast, of the annual average of 16 days with fog at Hokitika, eight days (50%) are recorded between December and March.

Snow

Snowfalls at sea level are very rare in West Coast. However, the extensive mountainous terrain of the region sees seasonal snowfields typically begin to accumulate in late autumn, and persist through to early summer. Large snowfalls occur along the Southern Alps which contributes to the perennial snow and glaciers at high elevations in those areas. A single winter storm cycle can deposit 2 – 3 m of snow in the Fiordland mountains farther south (Conway et al., 2000), and it is likely that similar totals would be recorded along and near the main divide in West Coast. Glaciers (and therefore snow) have an important role to play for the economy of the West Coast region, as the glaciers attract thousands of visitors to the region each year.

Photo: ©mychillybin.co.nz/

DERIVED CLIMATOLOGICAL PARAMETERS

Apart from elements such as temperature and rainfall which can be measured directly, it has been found that parameters calculated from several elements have some important uses, especially in industry. Parameters which define the overall suitability of the climate for agriculture, horticulture, architectural and structural designs, and contracting, etc., are vapour pressure, relative humidity, evapotranspiration (leading to soil water balance), degree-days (thermal time), and rainfall extremes. Some of these and their uses are discussed in the following paragraphs. Note that short-term high intensity rainfalls have already been addressed in this publication.

Vapour pressure and relative humidity

Vapour pressure and relative humidity are the two parameters most frequently used to indicate moisture levels in the atmosphere. Both are calculated from simultaneous dry and wet bulb thermometer readings, although a hygrograph may be used to obtain continuous humidity readings.

Vapour pressure is the part of the total atmospheric pressure that results from the presence of water vapour in the atmosphere. It varies greatly with air masses from different sources, being greatest in warm air masses that have tropical origins and lowest in cold, polar-derived air masses. Vapour pressure can be important in determining the physiological response of organisms to the environment (very dry air, especially if there is a pre-existing soil moisture deficit, can cause or increase wilting in plants). Mean monthly 9 a.m. vapour pressures for several locations are given in Table 21, which shows that vapour pressures are lowest in the winter months.

Relative humidity relates the amount of water present in the atmosphere to the amount of water necessary to saturate the atmosphere. Unlike vapour pressure, relative humidity is dependent on the air temperature. This is because as air temperature increases, the capacity of the atmosphere to hold water also increases. Therefore, relative humidity often displays large diurnal variation. Table 22 highlights this diurnal variation, showing 9 a.m. relative humidity is higher than that recorded at 3 p.m. at corresponding times of year.

Table 21. Mean monthly and annual 9 a.m. vapour pressure (hPa) at selected West Coast locations from all available data.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Greymouth	15.1	15.4	14.1	12.3	10.5	9.0	8.3	8.9	10.3	11.4	12.4	14.0	11.8
Haast	14.6	14.9	13.4	11.6	9.9	8.4	7.7	8.4	9.8	10.6	11.8	13.6	11.2
Hokitika	14.8	15.2	14.0	12.2	10.2	8.6	7.9	8.8	10.1	11.0	12.0	13.8	11.6
Reefton	13.9	14.1	13.0	11.2	9.4	7.9	7.4	8.0	9.4	10.5	11.4	13.1	10.8
Westport	15.7	16.2	14.5	13.2	11.4	9.7	8.7	9.7	11.1	11.8	12.5	14.6	12.4

Table 22. Mean monthly and annual 9 a.m. (a) and 3 p.m. (b) relative humidity (%) at selected West Coast locations.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Greymouth	a	82	84	84	85	86	84	84	82	82	82	81	82	83
	b	74	74	72	73	70	73	70	73	74	75	74	76	73
Haast	a	85	88	85	82	84	82	79	79	81	81	81	84	83
	b	81	81	80	78	75	70	72	76	77	78	79	81	77
Hokitika	a	83	86	85	86	88	87	85	84	82	82	81	82	84
	b	75	76	74	75	75	73	70	72	74	75	74	76	74
Reefton	a	82	86	88	92	94	95	95	93	88	85	82	81	88
	b	52	53	57	65	73	81	75	68	63	60	55	56	63
Westport	a	83	86	86	86	87	87	84	85	83	84	81	83	85
	b	71	72	71	74	75	75	69	72	74	73	71	76	73

Evapotranspiration and soil water balance

Evapotranspiration is the process where water held in the soil is gradually released to the atmosphere through a combination of direct evaporation and transpiration from plants. A water balance can be calculated by using daily rainfalls and by assuming that the soil can hold a fixed amount of water with actual evapotranspiration continuing at the potential rate until total moisture depletion of the soil occurs. The calculation of water balance begins after a long dry spell when it is known that all available soil moisture is depleted or after a period of very heavy rainfall when the soil is at field capacity. Daily calculations are then made of moisture lost through evapotranspiration or replaced through precipitation. If the available soil water becomes insufficient to maintain evapotranspiration then a soil moisture deficit occurs and irrigation becomes necessary to maintain plant growth. Runoff occurs when the rainfall exceeds the field capacity (assumed to be 150 mm for most New Zealand soils).

Mean monthly and annual water balance values for a number of West Coast locations are given in Table 23. Very little soil moisture deficit occurs in West Coast due to the abundance of year-round rainfall in the region. Runoff is very high throughout West Coast, and generally peaks in the winter months. Compared to the remainder of New Zealand, mean soil moisture deficit observed throughout the year is very low. Figure 20 shows region-wide variability in days of soil moisture deficit per year, which further illustrates the lack of soil moisture deficit that occurs throughout West Coast.

Table 23. Mean monthly and annual water balance summary for a soil moisture capacity of 150 mm at selected West Coast locations.

Location		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ann**
Greymouth	DE	4	3	1	0	0	0	0	0	0	0	1	1	9
	ND	1	1	0	0	0	0	0	0	0	0	0	0	3
	RO	92	65	101	163	194	198	173	159	147	151	118	111	1671
	NR	5	4	7	11	14	14	13	13	12	12	8	7	119
Haast	DE	5	1	2	0	0	0	0	0	0	0	0	0	7
	ND	1	0	1	0	0	0	0	0	0	0	0	0	2
	RO	154	93	168	180	236	245	208	211	235	219	159	199	2307
	NR	6	5	9	10	14	13	13	14	13	13	9	10	129
Hokitika	DE	2	2	1	0	0	0	0	0	0	0	0	0	4
	ND	0	1	0	0	0	0	0	0	0	0	0	0	1
	RO	135	84	133	190	218	230	199	200	211	204	154	157	2116
	NR	7	5	8	11	14	13	13	13	14	13	9	9	127
Reefton	DE	10	16	7	1	0	0	0	0	0	0	3	6	44
	ND	2	4	3	1	0	0	0	0	0	0	1	1	12
	RO	37	16	21	87	142	172	149	141	131	121	76	57	1149
	NR	3	1	2	6	12	13	12	11	11	9	6	4	90
Westport	DE	7	7	4	0	0	0	0	0	0	0	2	2	22
	ND	2	2	1	0	0	0	0	0	0	0	0	0	6
	RO	58	38	59	124	165	182	152	147	128	121	92	83	1349
	NR	4	3	5	9	13	15	14	13	12	11	8	6	111

DE: average amount of soil moisture deficit (mm)
ND: average number of days on which a soil moisture deficit occurs
RO: average amount of runoff (mm)
NR: average number of days on which runoff occurs

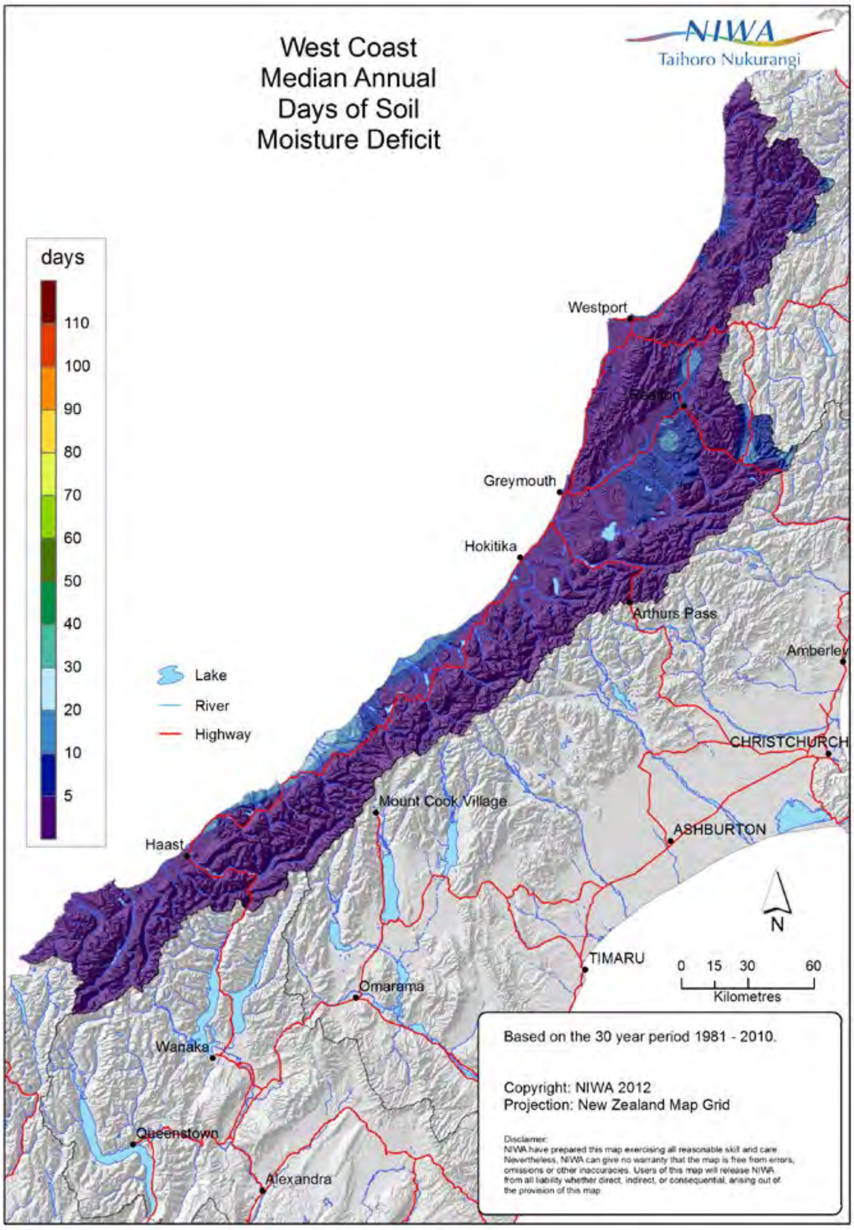


Figure 20. Median annual days of wilting point deficit for West Coast, 1981–2010.

Potential evapotranspiration (PET) has been calculated for Hokitika, Reefton and Westport using the Penman method (Penman, 1948). The monthly mean, minimum, and maximum PET values for these locations are listed in Table 24.

Table 24. Penman calculated maximum, mean, and minimum monthly potential evapotranspiration (mm), and mean annual total potential evapotranspiration, for selected West Coast locations.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hokitika	Max	140	111	83	49	26	20	22	34	55	84	120	134	
	Mean	120	93	72	38	21	14	18	28	46	73	97	112	732
	Min	107	80	59	30	17	8	14	24	33	57	72	92	
Reefton	Max	160	132	90	41	21	10	13	30	53	86	125	136	
	Mean	130	101	76	37	17	7	11	25	45	71	98	119	736
	Min	109	77	67	34	13	4	8	21	32	55	73	97	
Westport	Max	152	120	96	59	34	27	39	45	65	93	127	128	
	Mean	125	99	79	44	27	20	26	34	51	78	103	115	800
	Min	99	83	65	29	14	11	18	25	34	61	78	88	

Degree-day totals

The departure of mean daily temperature above a base temperature which has been found to be critical to the growth or development of a particular plant is a measure of the plant's development on that day. The sum of these departures then relates to the maturity or harvestable state of the crop. Thus, as the plant grows, updated estimates of harvest time can be made. These estimates have been found to be very valuable for a variety of crops with different base temperatures. Degree-day totals indicate the overall effects of temperature for a specified period, and can be applied to agricultural and horticultural production. Growing degree-days express the sum of daily temperatures above a selected base temperature that represent a threshold of plant growth. Table 25 lists the monthly totals of growing degree-day totals above base temperatures of 5°C and 10°C for locations in West Coast.

Cooling and heating degree days are measurements that reflect the amount of energy that is required to cool or heat buildings to a comfortable base temperature, which in this case is 18°C. Table 26 shows that the number of cooling degree days reach a peak in mid-late summer in West Coast, when energy required to cool building interiors to 18°C is highest. Conversely, heating degree days reach a peak in winter, where the energy required to heat buildings to 18°C is highest. Figure 21 shows region-wide variability in the number of heating degree days per year. The number of heating degree days tends to be lower in low elevation coastal areas towards the north, compared with areas further inland, farther south and at higher elevations.

Table 25. Average growing degree-day totals above base 5°C and 10°C for selected West Coast locations.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Greymouth	5°C	343	321	313	246	182	115	100	125	164	205	241	305	2658
	10°C	188	180	158	97	42	12	6	11	29	56	92	150	1021
Haast	5°C	300	280	279	217	164	92	84	104	130	168	208	265	2291
	10°C	145	139	125	72	32	6	4	7	14	34	62	111	750
Hokitika	5°C	326	307	300	226	159	93	77	104	144	188	227	293	2445
	10°C	171	166	146	81	30	8	3	7	20	44	80	138	893
Reefton	5°C	368	342	314	211	120	56	40	74	135	197	253	326	2435
	10°C	213	201	160	70	19	3	1	3	19	54	106	172	1021
Westport	5°C	348	328	325	254	193	128	113	134	170	209	244	311	2757
	10°C	193	186	170	105	48	16	8	14	32	58	95	156	1084

Table 26. Average cooling (CDD) and heating (HDD) degree-day totals with base 18°C for selected West Coast locations.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Greymouth	CDD	6	6	2	0	0	0	0	0	0	0	0	2	17
	HDD	66	53	93	145	221	276	304	279	226	198	149	100	2109
Haast	CDD	2	2	1	0	0	0	0	0	0	0	0	1	6
	HDD	105	89	125	173	240	300	321	301	260	235	183	139	2470
Hokitika	CDD	4	4	1	0	0	0	0	0	0	0	0	1	11
	HDD	81	65	104	164	244	298	329	300	246	215	163	111	2319
Reefton	CDD	18	18	4	0	0	0	0	0	0	0	1	8	48
	HDD	53	43	93	180	288	362	394	336	255	206	138	84	2432
Westport	CDD	7	8	3	0	0	0	0	0	0	0	0	2	20
	HDD	61	48	81	136	210	263	291	269	220	194	146	93	2012

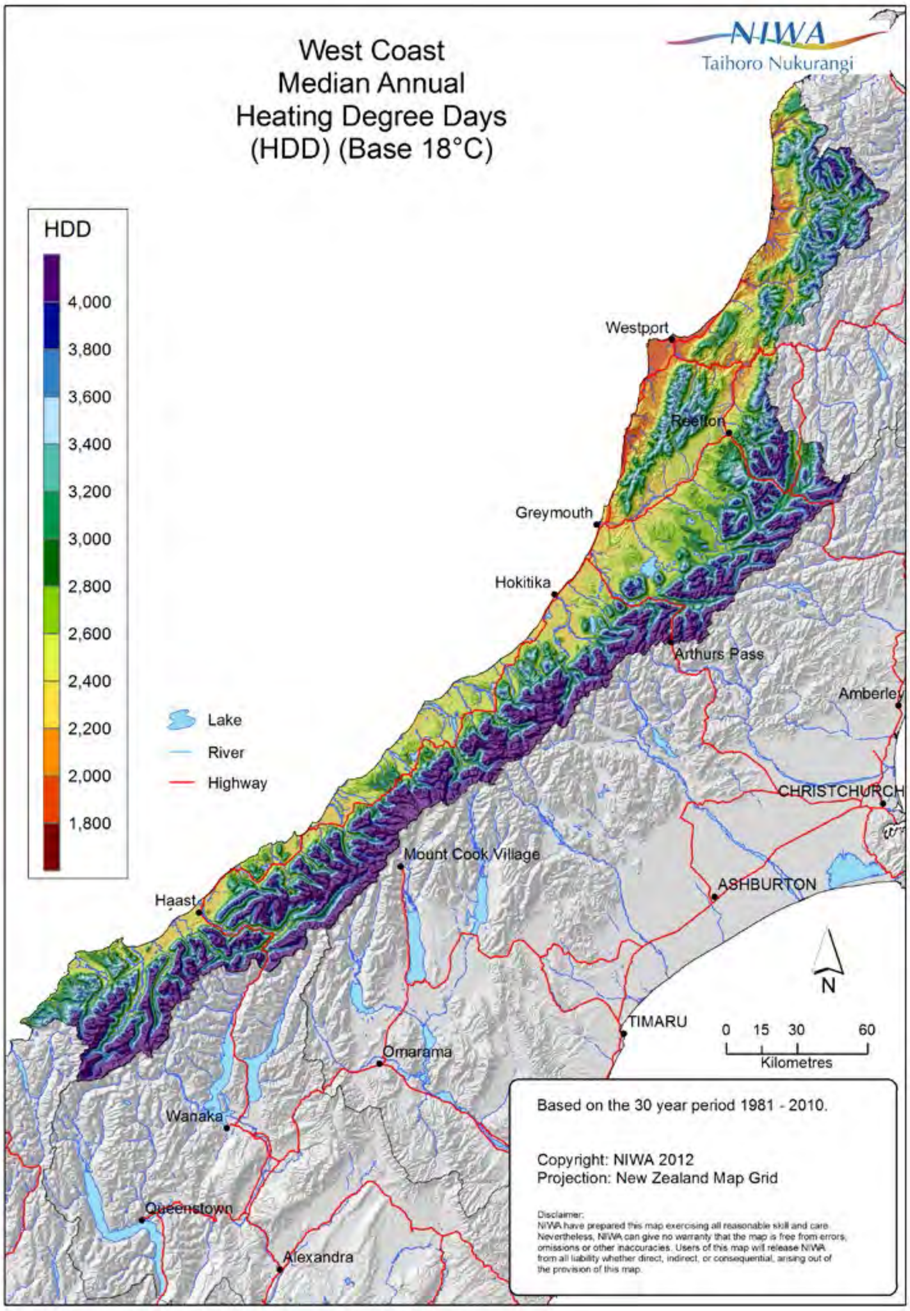


Figure 21. Median annual heating degree days for West Coast, 1981–2010.

ACKNOWLEDGEMENTS

The following people from NIWA are acknowledged for their contribution to the preparation of this publication: Dr Andrew Tait, Petra Chappell, Erika Mackay, Dr Elizabeth Somervell and Dr Michael Uddstrom.

Photo credits:

Page 11, Peter Marriott, NIWA.

REFERENCES

NIWA databases used:

The National Climate Database cliflo.niwa.co.nz

HIRDS (High Intensity Rainfall Design System) hirds.niwa.co.nz

New Zealand Historic Weather Events Catalogue hwe.niwa.co.nz

NIWA Sea Surface Temperature Database

References:

CONWAY, H., CARRAN, W. & CARRAN, A. 2000. The timing, size and impact of avalanches on the Milford Highway, New Zealand. *Proceedings of the International Snow Science Workshop, Big Sky, Montana USA*, 167–172.

PENMAN, H. L. 1948. Natural evaporation from open water, bare soil, and grass. *Proceedings of the Royal Society of London A*, 193, 120–145.

REID, S. J. 1980. Frequencies of Low Level Free Atmospheric Wind Flows in Northern and Southern New Zealand. *New Zealand Meteorological Service Technical Note 240*.

UDDSTROM, M. J. & OIEN, N. A. 1999. On the use of high resolution satellite data to describe the spatial and temporal variability of sea surface temperatures in the New Zealand Region. J*ournal of Geophysical Research (Oceans)*, 104, 20729–20751.