The lee wave systems of New Zealand

By G.A. Hookings, University of Auckland, New Zealand
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Introduction

Since New Zealand is a predominantly mountainous country with mean latitude in the 'Roaring Forties', it is not surprising that lee wave systems are fairly plentiful throughout the length of the two main islands. Of recent years some of the New Zealand wave systems have been investigated fairly extensively by glider pilots, one of whom, S.H. Georgeson of Christchurch, has succeeded in breaking the world gain of height record and the world goal and return record (on two occasions) by exploiting the waves.

Corby (Ref. 1) pointed out that the South Island of New Zealand 'has much to recommend it as a site for field investigations, because the mountain range is quite isolated, with an ocean to the north-west and flat ground and further ocean to the south-east'. Many of the mountain ranges of the North Island also possess this characteristic of virtual freedom from obstruction upwind. In the description of the wave systems to follow, the mountain ranges will be treated in order moving from North to South, which is also the order of increasing mean altitude of the mountain ranges.

The Kaimai Range

The most northerly mountain range whose wave system has regularly been investigated by soaring pilots is the Kaimai Range. This is a comparatively low range averaging only about 2,000 ft. above MSL. Nevertheless it has been found to give strong wave systems in both south-westerly and north-easterly airstreams. The range runs in a mean direction of about 15° west of true north and is illustrated in Figure 1. The location of the Kaimai Range and of all other geographical features mentioned later are shown in the map of Figure 2.

The Kaimai Westerly Wave System

It is remarkable that in spite of the low average height of the Kaimai Range, some climbs in excess of 30,000 ft. have been achieved under westerly wind conditions. Generally the rate of climb in these conditions has been only slow to moderate, two hours or so being necessary to climb to 30,000 ft. However a useful feature from the point of view of the soaring pilot is that it is possible to commence the flight by hill-soaring on the windward side of the range and then, when sufficient height has been gained, to cross the range and enter the primary lee wave for the continuation of the climb. Although this method of entering the wave system from the windward side of the range has succeeded on several occasions, there have also been times when such attempts have failed. Fortunately there are sufficient suitable landing fields on the eastern side of the range to make the possibility of failure to contact the wave an acceptable risk. There are two airfields within striking distance of the range, the nearest, Matamata airport being 7 n.m. to the west of the ridge, the other, Tauranga, being 15 n.m. to the east. There are gliding clubs based on both these airfields, although, of course, the Piako club at Matamata is in the better position to reach the range.

No-one has had the incentive to turn down-wind on any of the occasions when heights in excess of 30,000 ft. have been reached. It would seem certain that the eastern-most point of the North Island, East Cape, could be reached with little trouble from such an altitude especially since a strong tail wind would assist in such a flight. On 24 February 1965, during the Auckland gliding championships, G.A. Hookings set off from the top of a weak westerly wave at only 7,800 ft. and reached the vicinity of Whakatane, nearly halfway between Matamata and East Cape.

At the beginning of April 1963 that year's New Zealand

champion, J. Cooper, was waiting for suitable conditions for the Kaimai westerly wave. Such a day was 2nd April and Cooper alerted several pilots, all of whom exceeded 20,000 ft. Cooper and N. Murray exceeded 30,000 ft., but J. Roake who planned to convert his great height into distance reported that the lift was restricted to a length of about 15 miles of the range. The meteorological conditions on 2nd April 1963 are summarized in the appropriate entry in Table 1, which lists the variation with height of the wind direction and strength in knots, and the Scorer parameter for lee waves, l^{-1}.

The Kaimai Easterly Wave System

Under easterly wind conditions a much stronger though more shallow wave is set up. The increased strength is probably due to the more sudden descent from the ridge to the valley floor when traversing the range from east to west. The comparative shallowness is undoubtedly due to change of wind direction with altitude. Rarely does the easterly wave extend higher than 8,000 ft. Often easterly winds are due to the approach of bad weather and a complete overcast above the valley floor on the western side of the range is broken only by a long patch of sunlight indicating the trough of the primary wave.

The flow in the vicinity of the rotor can be extremely turbulent and as the rotor is at low altitude, entry into the wave from the downwind side can be quite rough. On one occasion J.R.Court had his tow-rope break at 500 ft. but was able to get into the wave lift and climb to 5,000 ft. On another occasion, 3rd January 1956, his barograph recorded a steady climb of 1800 ft./min. from 2,000 ft. to 6,000 ft.

The Kaimai easterly wave obtained notoriety when on 3rd July 1963 a DC3 airliner was caught in the downdraught and crashed into a face of rock on the range with the loss of life of all 20 passengers and crew of three. The meteorological situation on this date and for several days before was of the north-easterly type; i.e., there was an anticyclone east of New Zealand and an extreme low-pressure system north of New Zealand and over the north Tasman Sea, so that the airflow over the North Island was from the north-east. The flight route was from Auckland to Tauranga and rain was falling over most of the route—continuous and moderate-to-heavy in and near the ranges, but intermittent and mainly light near Auckland and Tauranga. The surface wind was from east to south-east about 15 to 20 knots except in a few places where the evidence showed that this flow was considerably distorted by local topography. The flight level chosen for the flight was 5500 ft. and the forecast winds: at 5,000 ft. 070° 40 knots; at 7,000 ft. 060° 40 knots. The 5,000 ft. wind in the immediate vicinity of Auckland airport was certainly less than 40 knots and was probably 070° 30 knots. However the 5,000 ft. wind over the latter half of the flight increased to about 75 knots or possibly more.

The crew might have expected decreasing winds over the second half of the flight since the forecast wind velocity south of Tauranga at 5,000 ft. was given as 060° 25 knots. In any case the aircraft followed a track along the western side of the Kaimai Range in or above almost complete overcast. Using dead reckoning and interpreting the radio compass to show Tauranga well to port, but unaware of the displacement of the aircraft to the west, the crew requested and received permission to descend from cruise altitude of 5,500 ft. to 4,100 ft. Shortly thereafter the aircraft must have encountered a severe downcurrent which caused a rapid and unavoidable descent terminating in the crash. (See Ref. 2.)

The Wairarapa—Hawkes Bay Lee Wave System

Another region particularly favoured by frequent lee waves is the southern half of the North Island. A main mountain backbone with many peaks over 5,000 ft. traverses this region from Cook Strait to East Cape. The ranges of this chain run in directions between 30° and 45° east of true north, and are generally unobstructed to the west with a reasonably flat valley to the east.

The Wairarapa lee wave system was first investigated fairly intensively in the (Southern hemisphere) spring of 1957. (Ref. 3.) On 26th October 1957 J.R.Court made an Out and Return flight of 200 miles from Masterton reaching a maximum altitude of 25,000 ft. The meteorological conditions during this flight are summarized in Table 1.

On 10th November 1957 G.A.Hookings made a climb to 21,000 ft. and it will be seen from Table 1 that a change of wind direction of 40° between 500 and 400 millibars makes it seem likely that this was about the maximum height that could have been achieved on that occasion.

The first soaring flight over British Commonwealth terrain to exceed 500 km was that by G.A.Hookings on 13th December 1957 using the Wairarapa Hawkes Bay wave system. Conditions were ideal, with the winds constant in direction and increasing steadily with altitude up to 300 mb. (Table 1.) The Scorer parameter l^{-1} likewise increased steadily up to 300 mb. On this occasion Hookings was able to contact a thermal at 800 ft. near Masterton, climb to 3,500 ft. and

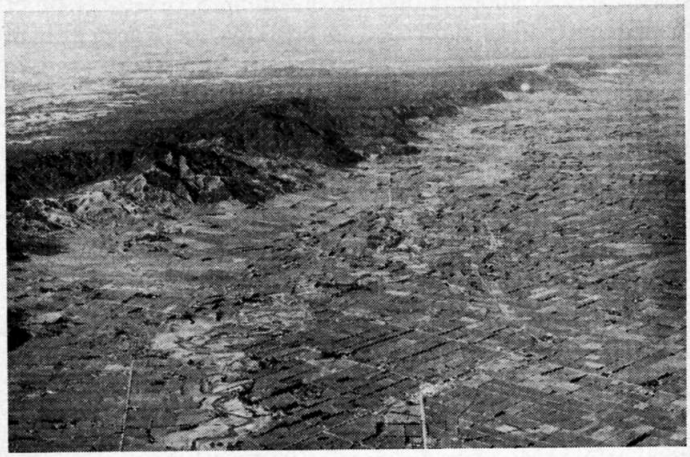


Fig. 1 – Aerial View of the Kamai Range from the North-West

then move upwind into the primary wave which was of unusually long wavelength, as is apparent from the large absolute values of l^{-1}. In the wave Hookings climbed to 18,000 ft. before setting course north-eastwards. He continued this route for about 100 miles and in the lee of the Ruahine range regained sufficient height for a second leg to the southwest. A third leg from Lake Wairarapa to the north-east completed the flight although it should be added that on each crossing of the gap between the Tararuas and the Ruahines so much height was lost that the termination of

the flight appeared to be imminent. On 12th November 1963 J. Cooper made a very similar flight when an anticyclone from the north Tasman Sea extended on to northern New Zealand as a deep low passed eastwards well to the south-west of the South Island. A westerly airstream flowed over the South Island and most of the North Island.

On 27th November 1964, during the second New Zealand National gliding championships, a powerful wave system was forecast. It was expected that the surface wind would increase, possibly to dangerous strengths, so that there was an eagerness to launch all the contestants before conditions on the ground became impossible. The rotor was not at all well marked by cloud, but one of the first aircraft to be launched was towed beneath it into the fantastically strong primary wave. The pilot, R. Reid, found that an airspeed of 90 knots was insufficient to maintain station ahead of the rotor. The sailplane drifted back and was turned on its back so Reid decided to return to base immediately. Meanwhile G. Hookings had released in the secondary wave and after climbing to 10,000 ft. elected to try to move forward into the primary. But he proved to be insufficiently high to clear the rotor and entered the turbulent region from the rear. The severity of the turbulence dictated an immediate retreat, but not before the accelerometer had recorded maximum readings of +4 g and −3 g. What it did not indicate, of course, was how closely these accelerations followed one another. Another pilot, A. Fowke, had watched with interest Hookings' attempt to move forward and realised that additional height was necessary before the transfer to the primary would be possible. However in a later attempt he still had insufficient altitude and became entangled with the rotor. He was thrown into the inverted position and needed 2,000 ft. of height to recover. He was so overcome by the experience that he started to hyperventilate and also one of his legs was seized with cramp, the foot being behind the rudder bar! On learning of these experiences the task-setter stopped further launches, cancelled the task and recalled all the sailplanes fitted with radio. This day emphasized the tricky nature of the problem of transferring from the secondary to the primary wave over the top of the rotor. High speed is necessary to progress against the wind and to maintain position in front of the rotor if successful in making the transition, but should one become entangled with the rotor, high speed is undesirable due to the turbulence. The only solution is to make absolutely certain of a large reserve of height before trying to cross above the rotor.

The Southern Alps Wave Systems

Without doubt the Southern Alps provide the best lee wave conditions in New Zealand. The mountains of the South Island are made of old, hard, sedimentary rocks, in contrast to the highest mountains of the North Island which are volcanic. Numerous active faults cut through the South Island, the longest being the great Alpine Fault which can be traced for some 300 miles from Milford Sound to Marlborough. The Southern Alps rise as a great white wall along this fault and contain 17 peaks higher than 10,000 ft., the highest being Mt. Cook of 12,349 ft. Great distances as well as great heights are possible by soaring the waves from this mountain system. The New Zealand altitude records have been progressively increased through use of the waves from the Southern Alps.

Philip Wills was the first to exceed 30,000 ft. in New Zealand and at the same time to show that these high waves may exist in absolutely clear air. At 16.15 hours on 29th December 1954, dressed for a ground temperature of 100° F, not for sub-zero temperatures, he took a winch launch to 550 ft. After ridge soaring to the top of Simon's Hill he caught a thermal to 6,500 ft. Thence he moved upwind in a northwesterly direction into a 5 ft./sec. wave—it was actually the sixth wave downwind of the mountains. Careful flying was necessary to stay in the wave, and he crabbed northwards until the wave seemed to peter out. Then he turned and flew directly upwind through the downdraught until he reached the fifth lee wave, which proved to be slightly stronger than the previous one. By repeating this tactic he slowly dog-legged northwards until at 14,000 ft. he was at the mouth of the gorge leading to the mountain he was stalking, Mt. Cook itself. There was a waterfall-like cap of cloud over the Southern Alps and over most of Mt. Cook. The primary gave 20 ft./sec. and Wills climbed in it in spite of the freezing temperatures until at 30,000 ft. with 'a sharp bang' a 3 inch crack suddenly appeared in the perspex of the canopy just in front of his nose. Acting on this signal for home he turned down-wind and into the downdraught, taking the British absolute altitude and gain of height records with him. (Ref. 4.)

First Crossing of Cook Strait

On 31st October 1957 K. Wakeman made a spectacular flight in the course of which he made the first crossing of Cook Strait by a sailplane in free flight. He took off from Christchurch airport at 10 a.m. in a Skylark 2 and was towed into a series of waves formed by a south-westerly at altitude, although the surface wind was almost north-westerly. The Auster tug took an hour to place him in the third wave at 11,000 ft. over Lees Valley. At 11.30 a.m., having reached 13,000 ft., he decided to head northwards and see how far he could fly. He found the lift restricted to a narrow band in front of the lenticulars, and was down to 10,000 ft. at Hanmer. Thereafter his altitude improved to 13,000 ft. over Molesworth and finally reached a maximum for the flight of 18,000 ft. He passed Blenheim at 15,000 ft. and Picton at 14,000 ft., and lost only 3,000 ft. in actually crossing the Strait. He considers he ran into further wave lift generated by South Island mountains while flying up the west coast of the North Island. He finally landed at 2.20 p.m. at Palmerston North, only 2 hours 50 minutes after setting course 270 miles away.

World Gain of Height Record

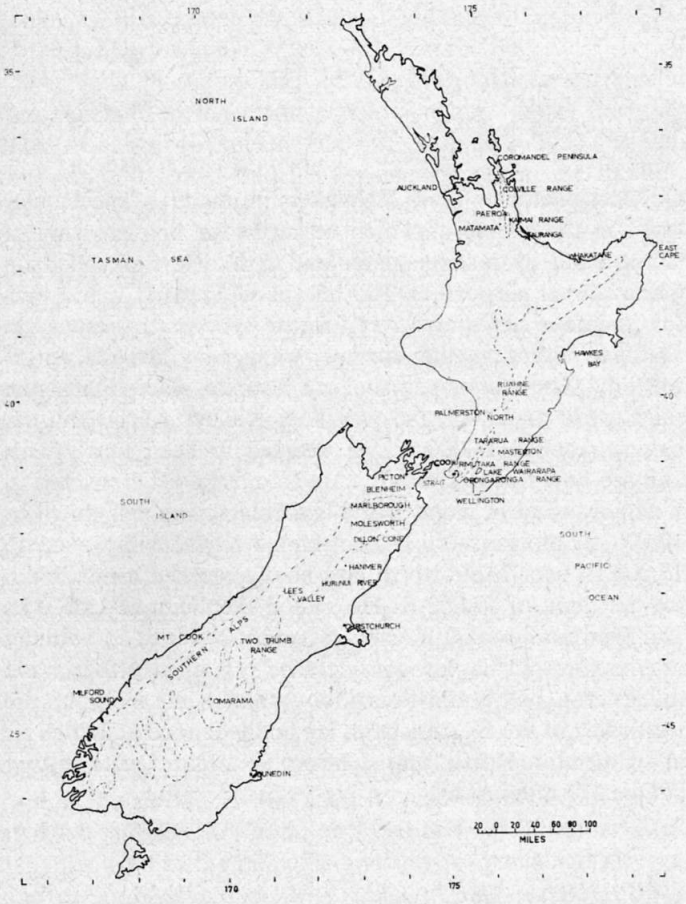
On 16th December 1960 S.H. Georgeson broke the world gain of height record with a gain of 34,300 ft. The previous evening he had received a forecast that a westerly wind would last for two days. The first launch at 8.30 a.m. from Dunsandel near Christchurch provided a flight of 1½ hours but no great altitude. At 2 p.m. however he towed off again and after an hour's struggle at low altitude he went into weak smooth wave lift at 5,000 ft.

In this wave he climbed to 25,000 ft. and then flew upwind at 100 m.p.h. through a downcurrent that took him down to 9,500 ft. where another wave lifted him to 16,000 ft. Forward again without success, but eventually he contacted the main wave which took him to 35,700 ft. (Ref. 5.)

World Goal and Return Records

On 4th January 1962 Georgeson declared Hanmer and return as his task for the day. He was towed off from Omarama at 11.05 and released 5 miles away at 3,000 ft. He had an hour's struggle to get up through the weak mixed thermal and wave lift to the critical altitude above which the wave is properly established. Eventually at 6,500 ft. he struck the wave proper and climbed to 14,000 ft. before setting off northwards. He climbed to 20,000 ft. en route, but over the inhospitable country of the Two Thumb Range he turned downwind towards the first of a series of lenticular clouds that had been reported to him as stretching the length of the Canterbury province. At 18,000 ft. he ran into smooth wave lift again and eventually reached the Hurunui River at

Fig. 2



25,000 ft. Ahead he could see the end of the lenticular cloud but fortunately lift continued to his turning point, 200 miles from the start. This was reached 2½ hours after setting course, a high average speed, thanks to a favourable wind component and the increased ground speed due to the great altitudes at which he had been cruising. The return journey was much harder, the wind now having an adverse component. A speed of between 80 and 100 m.p.h. had to be maintained to make any headway. The down-currents were of the order of 3,000 ft./min. He was able to follow the wave for 100 miles but then had to move upwind to find the next wave, regain height and repeat the procedure. At 18.00 hours he was 60 miles from home at 13,700 ft.—insufficient altitude to be certain of completing the journey with such severe downdraughts in the locality. However he was able to find sufficient lift to complete the task soon after 19.30 hours. (Ref. 6.)

The Goal and Return record did not remain in Georgeson's name more than a couple of years, so on 6th January 1965 he again declared Goal and Return, this time nominating Dillon Cone as his turning point, just 27 miles further from Omarama than Hanmer. The flight was similar to the 1962 one, but the average speed from crossing the starting line to landing was 4 m.p.h. faster (54 compared with 50 m.p.h.). Total flight time was 10 hours 2 minutes compared with 8 hours 45 minutes for the first flight. In 1962 Georgeson used a Skylark 3 F; in 1965 a Dart 15.

Conclusions

From a study of Table 1 it will be seen that on most of the occasions of the flights described above the wind was reasonably steady in direction at the wave levels and the wind speed increased with altitude. Likewise the Scorer parameter in general showed a steady increase with height. A study of the surface synoptic charts shows that the most favoured condition for the formation of strong waves is the existence of a deep depression well to the south of New Zealand.

To summarize it may be claimed that the mountain ranges of New Zealand have proved to be ideal sites for field investigations of lee waves.

Acknowledgements

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References:

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(2) Report of a public inquiry into the circumstances of a civil aircraft accident involving ZK-AYZ in the Kaimai Range on 3rd July 1963. New Zealand Government Printer, Wellington, 1963. 23 pp.
(3) *J.R.Court and G.A.Hookings*, Sailplane and Gliding, April 1958, pp. 82–88.
(4) *P.A.Wills*, Gliding, Vol. 6, No. 2, 1955, p. 71.
(5) *P.A.Wills*, Sailplane and Gliding, April 1961, p. 76.
(6) *P.A.Wills*, Sailplane and Gliding, June 1962, p. 158.

TABLE 1 – Summary of meteorological conditions on the occasions of the flights described in the text

Level	*Wind direction and speed in knots*								
(mb.)	*29/12/54*	*26/10/57*	*31/10/57*	*10/11/57*	*13/12/57*	*16/12/60*	*4/1/62*	*2/4/63*	*6/1/65*
200	270/51	250/36		350/60	290/68	260/70	270/32		
300	280/63	340/48	260/66	360/81	300/94	270/46	280/40	270/65	290/49
400	290/52	340/42	260/59	010/66	300/81	280/36	290/38	260/50	290/46
500	290/40	330/34	260/61	330/55	300/73	240/24	280/40	270/54	310/42
600	290/30	320/23	250/58	350/46	300/65	260/29	280/33	260/38	
700	300/31	310/17	270/50	340/50	290/57	280/12	270/22	260/40	300/31
850	340/18	280/17	280/51	320/29	300/37	300/17	290/18	230/30	330/14
1000	120/14	290/10	300/38	280/19	290/16	040/07	030/66	220/28	070/03
				Scorer's parameter l-[1]					
200						1.10			
300	1.14	1.34			1.82	.82	.90	1.07	1.13
400	.83	.92	1.20	1.42	1.68	.63	.92	1.35	.97
500	.68	.62	1.20	1.38	1.53	.56	.83	1.29	1.21
600	.50	.40	1.46	1.50	1.37	.42	.47	.72	.85
700	.30	.34	1.45	1.00	.85	.23	.38	.75	.57
850	.22	.23	.80	.67	.38	.23	.38	.55	.38

Zusammenfassung

Die langgestreckten Bergketten Neuseelands bilden ein ideales Gelände für die Untersuchung von Leewellen. Das Gebirge stellt ein isoliertes Hindernis dar mit der See im Nordwesten und mit Flachland und Meer im Südosten. Im folgenden werden – von Norden nach Süden gehend – zwei Wellensysteme des Nordlandes (Kamai und Wairapara – Hawkes Bay) und eines im Südland (Südliche Alpen) beschrieben, siehe Fig. 2.

Kamai-Gebirge

Dieser 600 m hohe Gebirgszug streckt sich von Nord-Nordwest nach Süd-Südost und hat einen scharfen Abfall nach Westen (Photo, Fig. 1). Er bildet Wellen bei West- und Ostwind. Trotz seiner geringen Höhe erlaubt er Segelflüge über 9000 m in Westwindlagen und bis zu 2500 m in Ostwindlagen.

Eine seltene (und angenehme) Eigenart dieses Gebirgszuges ist es, dass man bei Westwind am Luvhang segeln und von dort leewärts direkt in die erste Welle fliegen kann. Zwei Flugplätze auf der Luv- und Leeseite erleichtern solche Versuche. Höhen- und Streckenflüge werden beschrieben. Höhenwinde und «Scorer Parameter» sind in Tabelle 1 für den 2. April 1963 wiedergegeben, an dem 9000 m erreicht wurden.

Bei östlichen Winden, die gewöhnlich nur bis zu mässiger Höhe reichen, werden sehr hohe Aufwinde (9 m/sec) und starke Rotorturbulenz berichtet. Der Verlust eines DC-3-Verkehrsflugzeuges unter diesen Bedingungen deutet auf gefährliche Abwinde hin und wird genauer beschrieben.

Wairapara – Hawkes-Bay-Gebiet

Weiter südlich hat das Nordland zwei Gebirgsketten, die etwa von Südwest nach Nordost verlaufen und durch eine Lücke zwischen den Tararua- und Ruahine-Bergen getrennt sind. Diese Gebirge reichen bis zu 1500 m Höhe. Flüge bis zu 7500 m Höhe, Zielflüge mit Rückkehr bis zu 320 km und Auf- und Abflüge bis zu 500 km totaler Länge werden beschrieben. Höhenwinde und Scorer-Parameter für 3 Tage im Jahre 1957 sind in Tabelle 1 enthalten. Am 27. November 1964 machten mehrere Piloten üble Erfahrungen, als sie vergebens versuchten, von der zweiten Welle über den Rotor in die erste Welle gegen sehr starke Westwinde vorzudringen. Obgleich kaum eine Rotorwolke sichtbar war, wurden zwei Segelflugzeuge im Fluge auf den Rücken gedreht.

Die Südlichen Alpen

Diese über 500 km lange Gebirgskette des Südlandes gipfelt in dem 3700 m hohen Mt. Cook, an dem Philip Wills zum ersten Male 9000 m am 29. Dezember 1954 erreichte, indem er sich durch sechs Wellen vorarbeitete (siehe Tab. 1 für die aerologischen Verhältnisse).

Die erste Überfliegung der Cook Street zwischen Süd- und Nordland erfolgte am 31. Oktober 1957 (Tab. 1) durch Wakeman in einem dreistündigen Wellenflug von 5500 m Gipfelhöhe und 400 km Entfernung. Die Weltrekorde von Georgeson (Höhengewinn von 10 300 m am 16. Dezember 1960, Tab. 1; Zielflüge mit Rückkehr von 640 km am 4. Januar 1962 und von 725 km am 6. Januar 1965) werden beschrieben. Die letzten Flüge erforderten Flugzeiten von 8¾ und 10 Stunden und zeigten deutlich, wie sehr eine leichte Rückenwindkomponente hilft (Hinflug = 2½ Stunden) und wie schwer eine leichte Gegenwindkomponente zu überkommen ist (Rückflug in 6¼ Stunden).

Schlussfolgerungen

Tabelle 1 zeigt, dass bei guten Wellenlagen die Windrichtung sich mit der Höhe wenig ändert, während die Windstärke und der Scorer-Parameter (wie erwartet) mit der Höhe zunehmen. Die beste Wetterlage für starke Wellen ist mit einer tiefen Depression südlich Neuseelands verbunden. In jeder Hinsicht bietet dieses Inselland ein ideales Wellensegelfluggelände.

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