COASTAL WIND PATTERNS REVEALED BY HOURLY REPORTS FROM A SHIP AT SEA

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ABSTRACT

Hourly wind reports from an automatic weather station onboard a research vessel have shown interesting structure in the wind field around New Zealand, and in particular, the existence of areas of strong winds tens of kilometres wide and hundreds of kilometres long formed by the interaction of a stable airstream and the orography of New Zealand.

INTRODUCTION

The equipping of the fisheries research vessel Tangaroa with an automatic weather station provides an unprecedented opportunity to measure spatial and temporal variations in the wind field over the ocean, where data traditionally is very sparse.

Occasional anecdotes from fishers and other seafarers over the years have indicated much stronger winds than forecasters expected in a number of places around the New Zealand coastline.

Reports of extreme winds southwest of Taranaki were confirmed with the commencement of synops ever three hours from the Maui gas production platform. These showed, on occasion, 60-80 knots mean speed, when 30-40 knots might have been expected.

A study by Neale and Thompson (1978) of reports from fishing vessels off the West Coast of the South Island found large differences between the wind over land and sea. Another study by Stainer (1983) showed dramatic small scale effects in the lee of high ground, with enhanced wind speeds being associated with small pressure falls.

During the period of this study the Tangaroa visited a number of different locations around the New Zealand coast in a variety of different synoptic situations.

The anemometer on the Tangaroa is positioned on top of a mast 25m above sea level, and reports are received almost every hour when the ship is at sea. An onboard computer automatically allows for the ship's speed and direction in calculating the wind speed and direction.

The reports from the Tangaroa show the wind at sea is almost always stronger than the wind reported from adjacent land stations. This is thought to be due to a number of causes including friction, damming, position of the lee trough, and channelling around topography.

METHOD

Some ten months of Tangaroa wind reports were examined to find cases when the ship was near the coastline of New Zealand's main islands. The ship's wind was then compared with nearby land stations and the synoptic situation was examined.

RESULTS

Case 1 (figure 1)

At 17 UTC 24 March 1992 the Tangaroa was 70km northeast of East Cape with a westnorthwest wind of 40 knots. Winds of 30-40 knots were experienced for about 12 hours, during which time Tangaroa covered an area of about 100km long and 10km wide. Prior to this, the wind was 20 to 25 knots and the ship was positioned further south as can be seen from the diagram. From 23 UTC onwards, a different regime applies as the wind turns

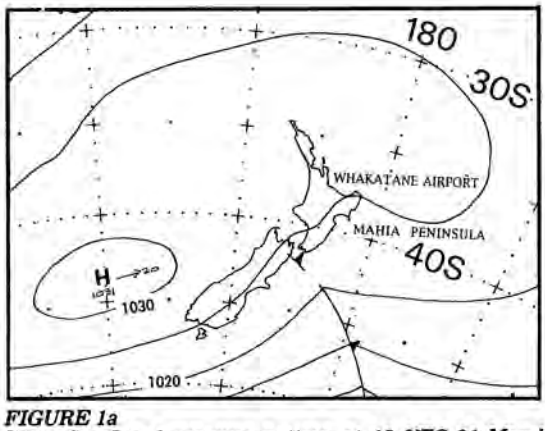

FIGURE 1a
Mean Sea Level pressure pattern at 18 UTC 24 March 1992 with 5hPa spacing.

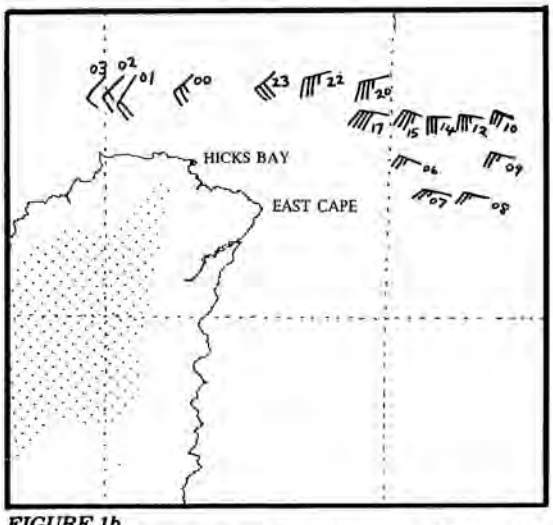

FIGURE 1b
Hourly wind reports from Tangaroa on 24 March 1994. Wind speed in knots, time in UTC.

southwest when the lee trough moves offshore ahead of the weak front approaching from the south.

Comparison with adjacent land stations shows they had much lighter winds than the Tangaroa. Hicks Bay automatic had a few reports around 20 knots but were often in the range 10-15 knots. Whakatane Airport and Mahia Peninsula automatics were never more than 15 knots and mostly less than 10 knots during the period Tangaroa had 30-40 knots.

Inspection of the tephigram shows that the air was stable with a marked inversion near

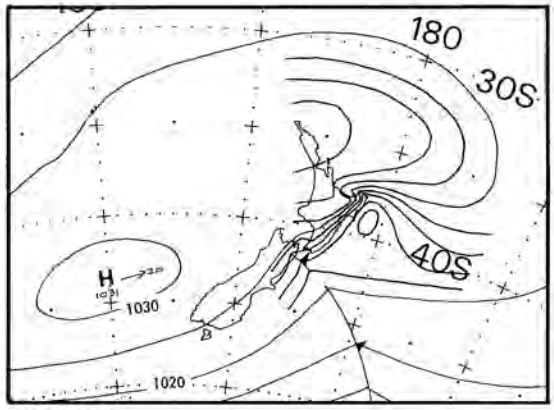

FIGURE 1c
Same as fig 1a but 1hPa spacing east of New Zealand.

1500m, which is the height of the peaks of the Tararua and Ruahine ranges in the south of the North Island, and considerably below the volcanoes in the centre of the North Island.

The inversion would have made it difficult for air to rise over the mountains. Instead the air would have been channelled around the end of the ranges, forming the belt of gales that affected the Tangaroa.

This area of gales seems to have been tens of kilometres wide and hundreds of kilometres long and has led the author to coin the phrase a "river of wind." It is certainly an area of stronger winds way beyond that catered for by the notion of "near exposed headlands".

The synoptic analysis with isobars every 5hPa has no indication of the westerly gales Tangaroa reported. However, it is possible on an analysis with isobars every 1hPa, to indicate a long narrow area of enhanced gradient on the northern side of the low pressure area in the lee trough.

Case 2 (figure 2)

On 1 August 1992 the Tangaroa left Nelson and proceeded westward around Farewell Spit then down the West Coast. As it moved southwestwards from Farewell Spit it crossed a river of strong southwest wind with one report of 31 knots and one of 37 knots, before dropping down to 22 knots and eventually 17 knots. At this time the Maui production platform, some 140 kilometres downstream, also had strong southwest winds, twice reporting 30 knots and once 32 knots.

This river of wind is thought to be due to a lee trough caused by the Tasman Mountains

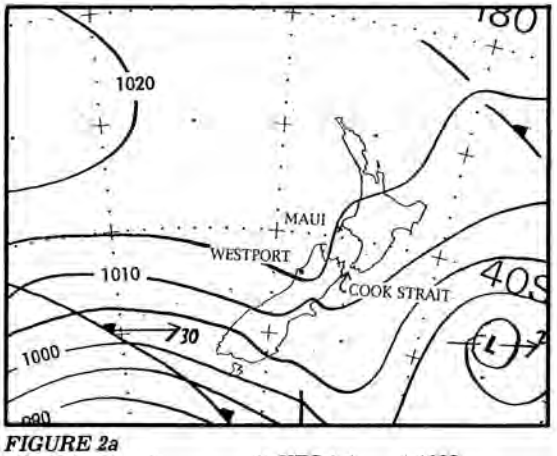

FIGURE 2a
Mean Sea Level pressure 18 UTC 1 August 1992.

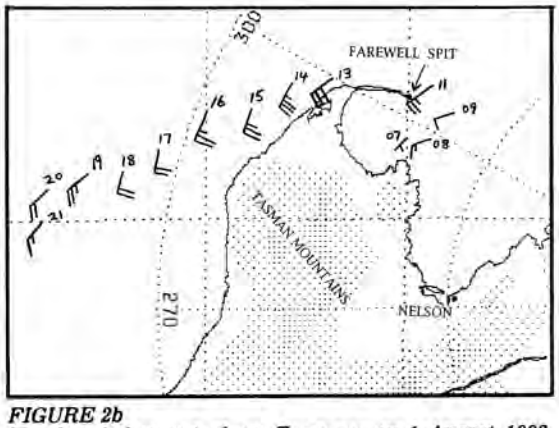

FIGURE 2b
Hourly wind reports from Tangaroa on 1 August 1992. Wind speed in knots, time in UTC.

that lie to the west of Nelson and rise to heights of over 1500m, and are oriented perpendicular to a southwest flow.

Other reporting stations had considerably less wind. Farewell Spit automatic reported 10-15 knots throughout the period and Westport Airport automatic had 5 knots or less.

Again the 5hPa analysis gave no indication of a belt of 30-35 knot winds but analysis at 2.5hPa or finer resolution did.

Case 3 (figure 3)

On 6 March 1992 the Tangaroa was moving southwards from Wellington to Lyttleton. As it was offshore of the Kaikoura coast it reported northnortheast winds of around 25 knots, similar to Brothers Island in Cook

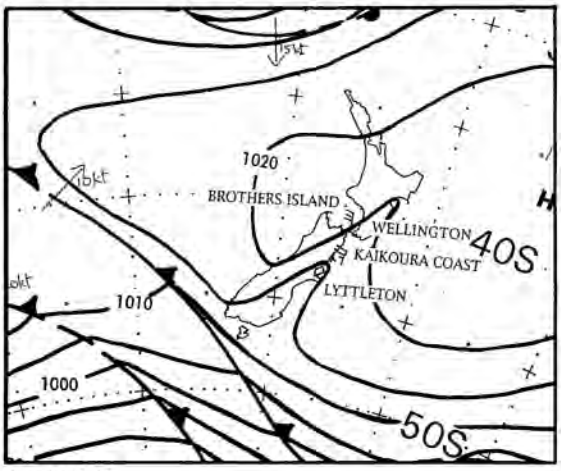

FIGURE 3
Mean Sea Level pressure at 00 UTC 6 March 1992. Tangaroa just east of Kaikoura.

Strait, while Kaikoura, Le Bons Bay, and Christchurch Airport all reported considerably less. Kaikoura was mostly less than 10 knots and often southwest in direction. Christchurch Airport was northeast about 10 knots or less and Le Bons Bay northerly or northeast 10-15 knots.

The MSL analysis of the pressure field shows a ridge lying east to west across the North Island with northwest isobars approaching the South Island and a pronounced lee trough near the east coasts of New Zealand. It appears that the Tangaroa was in an area of strong pressure gradient just beyond the lee trough on the seaward side but the other reporting stations were in less gradient closer to the trough axis. Kaikoura with light southwesterlies would appear to be to the west of the trough axis.

So again on this occasion the strength of the wind reported at the land stations is a poor indication of the wind strength at sea.

As a weak front in the westerlies over the Tasman Sea approached the South Island, the lee trough moved offshore and all stations changed to the southwest. Tangaroa briefly reached 30 knots in the southwesterly but the maximum speed reported from Le Bons Bay was 8 knots and Christchurch Airport was around 18 knots.

Case 4 (figure 4)

On 19 April Tangaroa was moving south off the coast of Fiordland with 5-15 knot winds

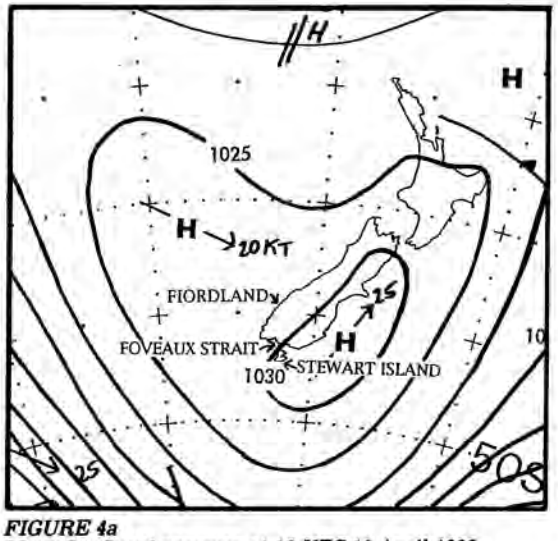

FIGURE 4a
Mean Sea Level pressure at 12 UTC 19 April 1992.

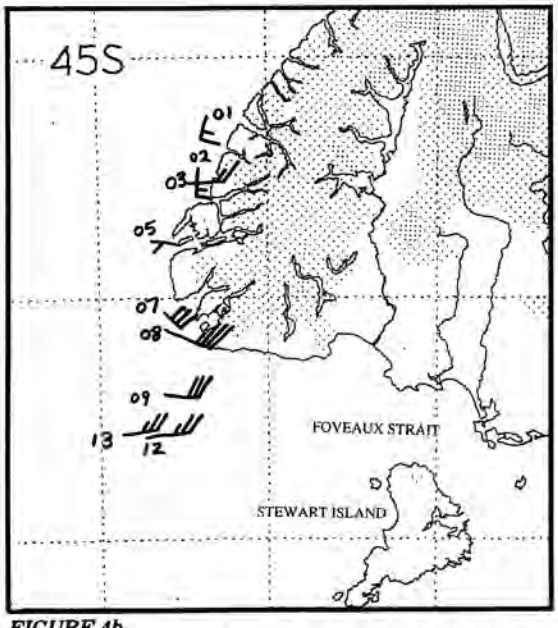

FIGURE 4b
Hourly wind reports from Tangaroa on 19 April 1992. Wind speed in knots, time in UTC.

from a variety of directions. However, as it came abreast of Puysegur Point, the wind speed jumped to 35 knots from the eastsoutheast. The MSL analysis showed a large anticyclone centred just east of Otago. With 5hPa spacing the analysis suggests only light winds over the area but at 2.5hPa it can be seen that there is a modest lee trough with enough easterly gradient across Foveaux Strait to produce strong easterly winds.

Puysegur Point was about 5 knots when Tangaroa had its maximum wind. A few hours before Puysegur had been up to 20 knots. This is a good example of how a land station may experience a sudden drop in wind speed, which is not evidence that a river of wind has ceased to exist, but only that it may have changed orientation slightly so as to no longer affect the land station.

Southwest Cape was 10 knots or less throughout the time Tangaroa had strong winds, which suggests this river of wind was only blowing through Foveaux Strait and downwind of it but not affecting the southern side of Stewart Island.

Case 5 (figure 5)

On 18 and 19 April Tangaroa was moving southwards off the coast of Fiordland. A weak cold front moved northwards over the South Island. Behind the front the wind went southeast at Tangaroa and speeds dropped to 10 knots or less. However, at 22 UTC on the 18th as the ship passed the mouth of George Sound the speed jumped to 25 knots, then dropped again once the ship had moved on.

The tephigram for Invercargill one hour later shows a strong inversion at about 1300 metres. The pass at the head of George Sound is about 1000 metres although the mountains

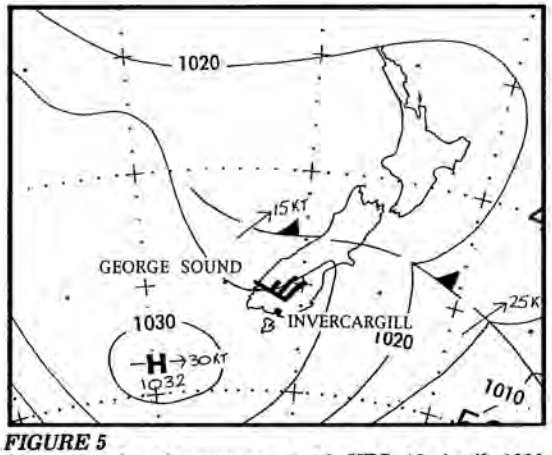

FIGURE 5
Mean Sea Level pressure at 18 UTC 18 April 1992. Tangaroa moving south off the coast of Fiordland, has seven hours of 10 knots or less until off the mouth of George Sound when wind rises to 25 knots.

either side are higher, with peaks above 1500 metres.

It would seem there was a strong wind blowing down George Sound because the air was able to move from high to low pressure, beneath the inversion and above the land. Further north or south of this mountain pass, the land was significantly higher than the inversion and so the air could not move freely from east to west and consequently the Tangaroa had only light easterlies.

Case 6 (figure 6)

On 11 September 1992 the Tangaroa was 100 kilometres southwest of Puysegur point reporting a southwest wind of 25 knots while Puysegur was reporting only 10 knots southwest. By contrast Southwest Cape, on the upwind corner of Stewart Island, and Nugget Point, on the Otago coast, both had wind speeds similar to the Tangaroa.

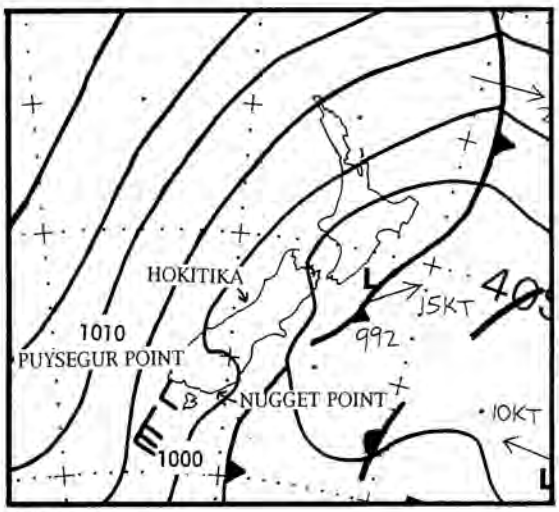

FIGURE 6
Mean Sea Level pressure 06 UTC 21 August 1992. Tangaroa (30 knots) 100 kilometres upwind of Puysegur Point (10 knots).

A similar situation also occurred on 21 August with Tangaroa in about the same location in a southwest flow. Puysegur reported 15-20 knots less wind than Tangaroa or Southwest Cape.

The explanation is thought to be this: the greater friction the air experiences over land causes it to slow down, and over time this results in air piling up or "damming" against the land. This is most pronounced where the land rises steeply from the sea and is perpendicular to the wind flow, as it is near Puysegur Point.

By contrast the automatic weather station at Southwest Cape on Stewart Island is situated on a narrow neck of land oriented so that it protrudes into the southwest flow and is therefore unlikely to experience this effect in a southwesterly. Nugget Point lies on a narrow point where the large scale land-sea boundary is oriented parallel to the southwest flow, so damming is also unlikely there in these conditions.

A third example of damming occurred on 2 August 1992 when the Tangaroa was about 110km westnorthwest of Westport in a westnorthwest flow. The ship reported northwest 30 knots while both Westport and Hokitika airports automatics reported northwest 15 knots.

Case 7 (figure 7)

On 11 March 1992 Tangaroa was returning to Wellington from east of the Wairarapa. After Tangaroa turned the corner near Cape Palliser it reported northerly winds between 35 and 45 knots 5 hours out of 6 but on the other hour had 56 knots. At this stage it was about 25 kilometres south of the southern end of the Rimutaka Ranges. It is thought that the ship passed through an area of locally enhanced wind downstream from high ground similar to that documented by Stainer (1983)

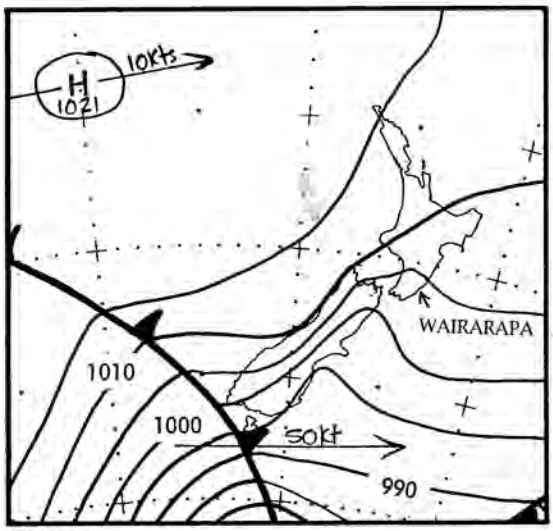

FIGURE 7a
Mean Sea Level pressure 12 UTC 11 March 1992.

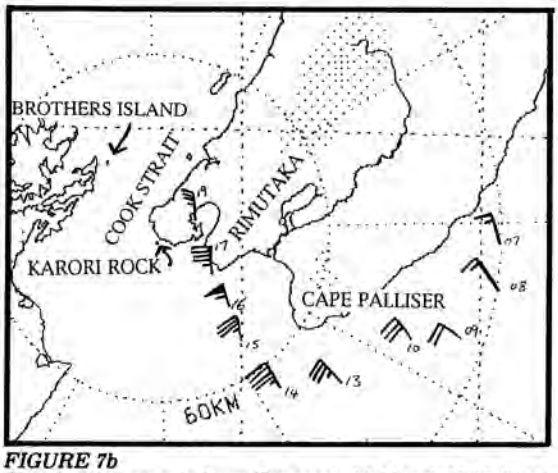

FIGURE 7b
Hourly wind reports from Tangaroa 11 March 1992. Wind speed in knots, time in UTC.

near Karori Rock. This also ties in with occasional reports from fishermen of extreme northerly winds in Palliser Bay that pick up stones from the land and hurl them against fishing boats many kilometres out to sea "with the force of rifle shots".

As the Tangaroa entered the area of enhanced wind it also reported a sudden pressure fall of 0.7hPa in one hour against a rising trend. Stainer also reported a small pressure fall in association with the enhanced winds near Karori rock.

Case 8 (figure 8)

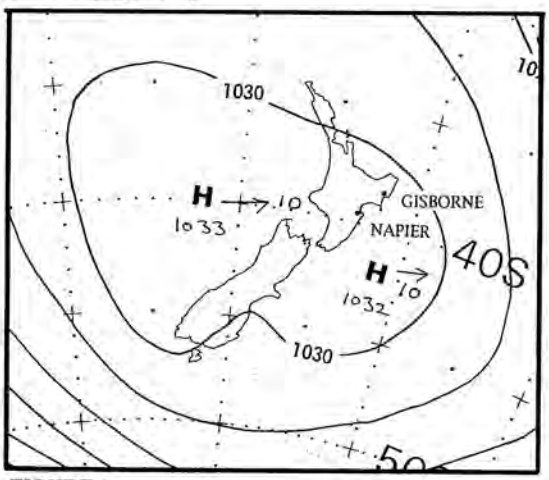

FIGURE 8a
Mean Sea Level Pressure 00 UTC 15 April 1992.

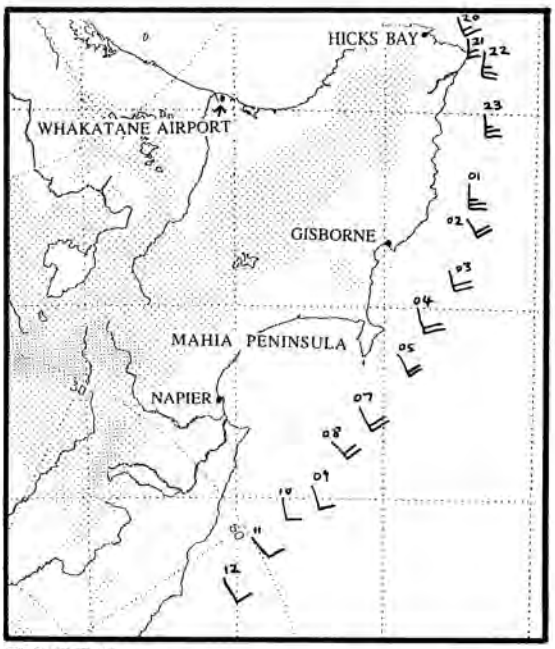

FIGURE 8b
Hourly wind reports from Tangaroa 15 April 1992. Wind speed in knots, time in UTC.

On 15 April 1992 Tangaroa was moving southwards just east of Gisborne, reporting a southerly wind of 25 knots easing to 20 knots as it came south. The synoptic situation showed a large high across New Zealand with one centre 500km west of the North Island and another centre 300km east of Cook Strait. A weak southeast flow was indicated over the Gisborne area.

Winds reported from adjacent land stations such as Mahia Peninsula, Gisborne and Napier airports were mostly less than 10 knots.

The stronger winds at the ship are thought to be caused by the stable conditions under the anticyclone. Air is unable to rise over the North Island ranges and instead is deflected to blow around the northern end of the hills.

Case 9 (figure 9)

On 27 and 28 August 1992 the Tangaroa was near 47 south 166 east — about 100km westnorthwest of the automatic weather station on the southwest corner of Stewart Island. The area was covered by a broad strong to gale force southeast flow between a complex trough over central New Zealand and a ridge of high pressure over the southwest Tasman Sea.

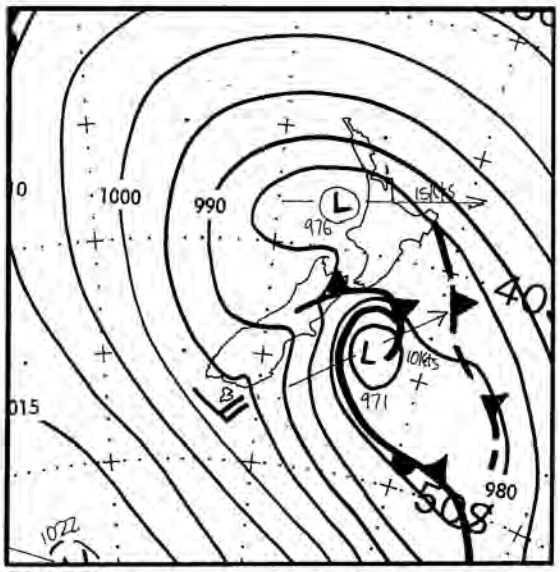

FIGURE 9a
Mean Sea Level pressure at 12 UTC 27 August 1992.

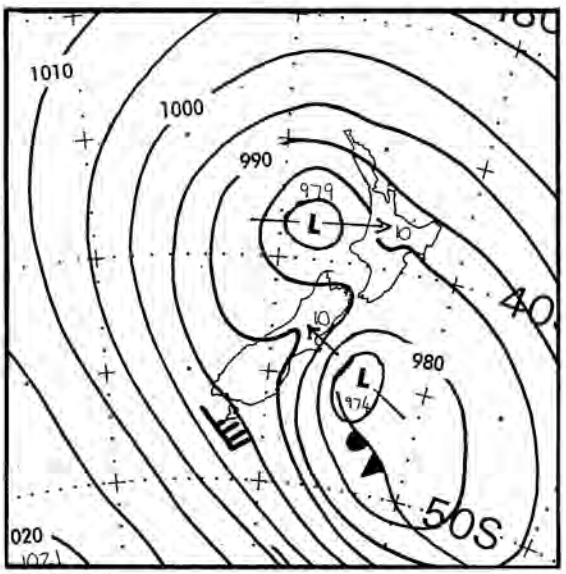

FIGURE 9b
Mean Sea Level pressure at 18 UTC 27 August 1992.

During a period when Tangaroa was mostly around 33 knots it dropped briefly to 22 knots (19 UTC) and 26 knots (20 UTC) before rising to 33 knots again.

At the same time Southwest Cape also registered a minimum of 14 knots for one hour when mostly it was blowing at 25-30 knots.

The synoptic analysis at 5hPa spacing showed a smooth featureless southeast flow over the area, so the explanation for this simultaneous drop in wind affecting two points 100 kilometres apart must lie in the sub-synoptic or meso-scale scale, possibly with gravity waves.

Since the Tangaroa did not lie directly downstream of Stewart Island but to the westnorthwest it seems possible that the explanation may not lie in the orographic consequences of Stewart Island but rather something intrinsic to a strong stable flow over open ocean.

This phenomenon creates an analysis problem when a ship reports only once or twice a day and may experience an atypical light wind at reporting time.

Other Cases

Among the other examples, too numerous to be shown here, several common threads emerge. When Tangaroa moves across the boundary between a river of wind and its surroundings, the change in wind strength is often dramatic. For example, on 5 August 1992, Tangaroa was about 50km west of Hokitika in a southwest airstream. As the ship moved closer inshore its wind speed dropped from 29 knots to 7 knots in one hour, then when it moved back out to sea a little later the wind speed rose from 14 knots to 33 knots in one hour.

On 1 June 1992 with a large high over the North Island the Tangaroa reported a drop from northerly 30 knots to 10 knots in one hour as it moved away from Cook Strait towards Cape Palliser, while Brothers Island automatic in Cook Strait continued to blow between 30 and 35 knots from the north.

Whenever an anticyclone was over or near New Zealand, and Tangaroa was near the end of a mountain range the ship reported strong or gale force winds despite the fact that the MSL pressure analysis at 5hPa spacing indicated no strong winds.

This requires a modification of the popular notion that anticyclones only have light or moderate winds. When the flow around an anticyclone is blocked by high ground, the wind then blows from high to low pressure parallel to the ranges and becomes strong or gale force around the end of the orographic obstacle, in conjunction with a lee trough in the pressure field.

CONCLUSION

The hourly wind observations from RV Tangaroa show interesting structure in the wind field around New Zealand. In particular, in stable atmospheric conditions when the air tends to flow around the land rather than over it, they show areas of strong or gale force wind that are typically tens of kilometres wide and hundreds of kilometres long. These so-called rivers of wind form in association with lee troughs that create strong pressure gradients that show up clearly in a 1hPa analysis, but not when isobars are drawn every 5hPa. Wind speeds at land stations rarely give an indication of the presence of these strong winds at sea.

It is intended in future work to further investigate the relationship between rivers of wind and stability, and also see to what extent satellite-derived wind fields show these features. It is important to have an independent way of measuring the extent and intensity of rivers of wind in order to verify any mesoscale models of wind flow around New Zealand that may appear in the future.

This material was originally presented at the Meteorological Society conference at Lincoln University in August 1992. A series of workshops for marine forecasters on rivers of wind was held soon afterwards.

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Neale, A.A. and G.H. Thompson, 1978: Surface Winds in Coastal Waters Off Westland. *N.Z. Met. Service*, Tech Note No. 234.

Stainer, B.A., 1983: The Distribution of Wind and Pressure in Cook Strait in strong Northerlies. *The Marine Observer*, 280, 77-84.