to any that I have seen before in the colony: it well deserves further exploration. Specimens of the rock formations which I have seen are placed in the Museum.

I have, &c.,

JOSEPH MILLIGAN.

The Hon.
The Colonial Secretary.

XII. *On the Law of Storms in the Pacific and High Southern Latitudes. By* THOMAS DOBSON, *Esq., B.A., Head Master, High School, Hobart Town.* [*Read 12th November*, 1851.]

THE importance of a practical knowledge of the Law of Great Storms has induced me to draw up a brief exposition of their most striking phenomena. In bringing this subject under the notice of the Royal Society of Van Diemen's Land, I am not without a hope of securing the co-operation of its members in the desirable attempt to develop the Law of the Progressive Motion of the Storms of the Pacific Ocean, and of those of High Southern Latitudes.

Information on these points of the theory may reasonably be looked for by the scientific world from a Society placed in the very field of observation, in a comparatively high southern latitude, and comprising the scientific representatives of a community largely interested in maritime pursuits.

The laws of the great hurricanes which traverse the low and middle latitudes of the North Atlantic and Indian

Oceans have now been satisfactorily established by the labours of Redfield, Reid, and Piddington.

Whether the same laws apply to the frequent and severe storms of the Pacific Ocean, and to those of high latitudes, are questions still undetermined.

Both these questions have been invested with increased interest by events of recent occurrence, which have tended to make the localities referred to much more frequented by ships than heretofore.

Gold has been found in profusion on both shores of the Pacific.

Our whaling grounds have been extended from the high latitudes of the Southern to those of the Northern Hemisphere.

Merchant and emigrant vessels from England hither have successfully adopted the principle of great circle sailing, which necessarily takes them into a much higher latitude than formerly: the great circle route to these Colonies will also most probably be followed by steam ships, as it is more practicable for them than for sailing vessels.

The determination of these questions requires a process of careful induction. A considerable number of distinctly-marked and well-observed instances of great storms in the several localities must be collocated and compared.

Such a *special* investigation will be properly introduced by a *general* summary of what may now be considered the classical phenomena of a hurricane.

An atmospheric storm *(fig.* 1*)* is a vast whirlwind in the air, like to a whirlpool, vortex, or eddy in water. The wind blows in horizontal circles around the vertical axis of the storm.

In all circular motion there exists a centrifugal force, tending to throw the moving body outwards from the axis.

This force creates a cone-shaped depression on the outer surface of the atmosphere, rarefies the air in the neighbourhood of the axis, and by accumulation condenses that towards the circumference of the storm. The atmospheric pressure on the surface of the sea around the centre of the storm is less, and at the circumference is greater than the mean pressure ; therefore at the centre the sea is raised above, and at its circumference is depressed below, the mean level, about a foot for each inch of range of mercury in the barometer.

For the same reason the mercury in the barometer will rise above the mean height at the circumference, and fall below it at the centre ; so that when such a storm approaches a ship, the mercury rises: as it passes over her the mercury falls, at first gradually, but afterwards rapidly until the centre reaches her, when the mercury reaches its minimum height.

During the passage of the second half of the storm, the mercury rises rapidly, afterwards more gradually, and finally sinks to its mean height. It is probable, however, that the fluctuations of level in an ordinary barometer occur some three or four hours *after* the atmospheric changes by which they are caused; for, at page 207, vol. 2, of Daniell's Meteorology, it is stated that the water barometer of the Royal Society preceded by one hour the mercurial barometer of $\frac{1}{2}$ inch bore ; and the latter, the mountain barometer of ·15 inch bore, by the same interval in their indications.

The knowledge that barometric fluctuations are not simultaneous with, but often considerably later than, the corresponding atmospheric changes, may remove the apparent anomalies which often arise from the sluggish indications of an instrument of narrow bore, and perhaps otherwise imperfect.

Each wind of definite direction raises a swell parallel to that radius of the circle which is perpendicular to the wind.

One swell therefore precedes, and an opposite swell succeeds, a hurricane: these swells will be greater than any other. The swells of oblique directions intersect and form a "heavy cross sea." As they all necessarily intersect at the centre, their super-position raises there confused pyramidal seas, having extreme vertical, but little lateral, motion.

This coincidence of swells at the centre I conceive to be the true cause of the strange seas always met with there, although all writers agree in ascribing them to the diminished atmospheric pressure, which will only produce a general elevation of the surface of about two feet, and will not account for the great vertical oscillations of the central waves. The dense air near the circumference of the storm has a retarded circular motion; and from the tendency of each revolving particle of air to obey the dynamical law of the conservation of areas, the wind blows stronger and stronger as we approach the axis: but in the immediate neighbourhood of the centre there exists a perfect calm, the sky overhead is clear, forming what is called the "eye" of the storm; while a dense bank of clouds rests all around the horizon.

In the Southern Hemisphere the circular motion of the wind is the same in direction as that of the hands of a watch; and in the opposite direction in the Northern Hemisphere.

The whole storm moves bodily across the ocean; but the rotatory motion is much more violent than the progressive, and constitutes the "gale" of seamen.

Tropical storms begin near the equator, move from it to the westward, recurve, and pass to the eastward into middle latitudes.

The circumstances of the formation and final extinction of whirlwind storms are unknown; but many reasons lead me to

believe that they originate in the centres of great volcanic action.

I shall now examine some storms met with in high southern latitudes, in 1840, by the respective exploring expeditions of America and Great Britain.

The United States Squadron, consisting of the *Vincennes*, a first-class sloop of 780 tons, the two brigs *Peacock* and *Porpoise*, and the schooner *Flying Fish*, left Sydney for the Antarctic Ocean on December 26, 1839. A few days before the hurricane all the vessels were near the latitude 66° S., and longitude 150° E., or about 1300 miles to the southward of Van Diemen's Land. The *Peacock* was standing northwards for Sydney to repair injuries received among the ice: the others making to the southward and westward along the icy barrier, and the supposed Antarctic Continent. In the annexed diagram *(fig. 2)*, the vessels are denoted by their respective initials, and the successive positions of each indicated by the subscript numerals.

The dotted line represents that part of the storm which passed over the *Vincennes* as she sailed from V_1 to V_2. A full report is given of the proceedings of each ship during the storm in the second volume of the "Narrative of the United States Exploring Expedition," by Lieut. Wilkes, the Commander of the Expedition. I shall extract the parts necessary to determine the characteristic features of the storm.

It will be seen that Lieut. Wilkes speaks of several simultaneous gales, and thinks it "remarkable that, while the *Peacock* had a strong gale from the N.W., the *Vincennes*, 450 miles to the S.W. of her, should have met with *another* gale from the S.E.," without recognizing the obvious truth that these subordinate gales were consistent parts of the same great progressive whirlwind storm.

The proceedings on board the *Vincennes* are recorded thus:—

January 27th, 1840.—142° 40′ E., 66° 54′ 21″ S. (V_1), *Porpoise* in sight; surrounded by tabular icebergs. Midnight, wind shifted to S.E.

28th, 11 A.M.—Land in view; more than 100 icebergs, some 3 miles long; weather thickens; breeze freshens; Noon, hove to, so thick that every thing was hidden. 2 P.M. Barometer began to fall, and weather to change for the worse. 5 P.M. A gale coming on, in three reefs of topsails. 8 P.M. Blew very hard; a violent snow-storm; barometer still falling. Midnight, gale was awful; all hands called.

29th, 1 A.M.—Gale terrific; sea so heavy that sail was further reduced. 4 A.M. Hove to, all hands still on deck. 7 A.M. Appearances of weather moderating. This gale was from the S.E., from which quarter it blew during the whole of its strength: when it began to moderate the wind veered to the *southward;* by noon the gale was over, and *it cleared off* towards 4 o'clock; 140° E., 63° 30′ S. (V_2). 6 P.M. Wind now hauled to the S.W., and we again made sail to the S. to pass over the very route we had just traversed.

30th, Morning.—A brisk breeze from eastward; sea quite smooth; all sail crowded. A brisk gale ensued; ran at 9 or 10 miles an hour; one reef topsails; stood directly for the most southerly part of Piner's Bay, 140° 2′ 30″ E. 66° 45′ S. (V_3). Noon; wind has increased to a gale. 1 P.M. Reduced to storm topsails; topgallant yards on deck. Barometer had again declined rapidly, wind S.E. This, like the former gale, was an old-fashioned snow-storm. All the canvas we could show to it at one time were a close-reefed mainsail and fore storm-staysail. It blew tremendously:

the sea was a short disagreeable one, but nothing compared to that which accompanied the first gale.

31st.—No moderation of weather; gale unabated. Noon. Gale continued; lowest reading of barometer 28·59. 6 P.M. After lasting 30 hours the gale moderated a little.

The circumstances under which the *Porpoise* had the storm are thus given:—

JANUARY 27th.—142° 31′ E. 65° 41′ S. (P_1) making for 105° E.

28th, Noon.—Strong winds from eastward, close-reefed topsails. 3 P.M. Hove to, 65° 16′ S. 8 P.M. Blowing very heavy, with snow—have seldom experienced a heavier blow: towards end, squalls were severe and frequent.

29th, 3 A.M.—A heavy sea; thick snow; barometer 28·2 lowest reading. 8 A.M. Gale abated, 64° 46′ S. 137° 16′ E. (P_2).

30th, 4 A.M.—Stood to S.W.; wind increased; shortened sail; during day blowing a heavy gale of wind, and a very heavy sea running. Noon; hove to under storm-staysails; wind south-easterly.

31st, 7 A.M.—Gale moderated; made sail to westward.

In latitude 48° S. the *Flying Fish* was lost sight of, and not seen again until their return to Sydney. Her position was—

On JANUARY 23rd.—65° 58′ S. 157° 49′ E. (F_1).

29th.—Thick snow. Wind N.E. 9 P.M. A heavy gale. Lay to.

30th, Morning.—Gale abated. 65° 15′ S. 150° 16′ E. (F_2).

31st.—Thick snow; heavy sea; wind N.

The *Vincennes* found the *Peacock* at Sydney on 12th March. On the 22nd January she lost sight of the *Porpoise*, in 66° 41′ S. 151° 24′ E. (P_1').

29th.—Had a strong gale from the N.W., increased until midnight, and then moderated. Ship during this storm was in 61° 30′ S. 154° 9′ E. *(P_2^1).*

This is the best example I have met with of a well-observed revolving storm in a high latitude. It appears to have moved slowly to the westward. At *(V_2)* the *Vincennes* had entered the comparatively calm centre, with clear sky, the "eye" of the storm: she then re-entered the storm, passing to V_3 into the most dangerous quadrant; and, together with the *Porpoise*, sailed in this quadrant along with the storm to the westward for some days. During the same period the *Flying Fish* had sailed into and along with the S.E. quarter of the storm. The *Peacock* passed out of it. The barometrical fluctuations on board the *Vincennes* from January 28th to February 2nd inclusive are given for intervals of an hour, with a few exceptions.

I have expressed these in a curve *(fig. 3)*, which forms a graphic and instructive record of the various phases of the hurricane.

In July the same year, the English discovery ships *Erebus* and *Terror* were lying in Christmas Harbour, 48° 41′ S., 69° 3′ 35″ E. Sir James Ross remarks, that the westerly winds prevail there almost as steadily as do the trade winds in the equatorial regions.

During the passage from Christmas Harbour to Hobart Town, between the parallels of 47° and 48° S., they met with a gale, which is thus recorded:—

July 24th, 1840.—Wind more moderate, still from westward. 7 P.M. Strong south-westerly gale and snow showers. The rise of the barometer to 30 inches, remarkably high for these latitudes, was followed, at 8 P.M. on the 25th, by a gale from the N.W. of twelve hours' duration.

26th.—At night the north wind again freshened to a gale.

27th, Noon.—The increasing gale reduced our sails to close-reefed maintopsail and foresail, which were necessary to keep the ship before the *high following* sea. The gale continued all night, with a *heavy cross sea;* much lightning to the *eastward;* meteors in great numbers darting about in all directions. The whole aspect of the sky proclaimed a convulsion or disturbance of the atmosphere of an unusual character. Barometer descended rapidly, and at 4 A.M. (28th) stood at 28·88.

29th, Day-break.—Sea more regular. Hove-to all day to enable the *Terror* to rejoin, supposing that she had broached-to during the night, or had found it impossible or imprudent to scud before the gale. The barometer continued to fall until 3 P.M.: when at its lowest, 28·29, there was nothing in the sky to indicate more than an ordinary storm—indeed, the gale had *abated* considerably (eye of storm); but so great was our reliance on the barometer that we kept the ship under snug sail, and every way prepared, and soon the dense accumulating clouds gave notice of the tempest. We kept the vessel directly before the wind, although the seas broke over both quarters, flooding the decks to a depth of more than 2 feet, and obliging us to knock out the ports to let the water run off, and relieve the ship of its weight. The mountainous sea before which we had been scudding was quelled for the time by the force of wind, whilst the tops of the waves were driven completely over us in sheets of water; but the violence of the hurricane was such as soon to expend itself. Beginning at the N.N.W., in an hour and three-quarters the storm had abated to the strength of a common gale from the west; and in that short space of time the barometer rose nearly half an inch.

July 30th.—During the night the wind and sea subsided.

If, with Sir J. Ross, we consider this hurricane as beginning at N.N.W. and veering to the westward, it would have a south-easterly progression, and was one of the well-known Mauritius hurricanes; but I am disposed to regard the westerly winds that preceded and followed the storm as parts of the general prevailing current,—the hurricane would then begin at S.W. and end at N.W., indicating a westerly progressive motion. The ship, sailing eastward, was in the northern half of the circle, and had a high *following* sea; the lightning in the east shows that to have been the quarter from which the storm proceeded. The hurricane described begins with all the marks pertaining to the second half of a whirlwind storm; a comparative lull, clear weather, barometer rising rapidly from a minimum, wind suddenly violent, and not increasing in force gradually, as when entering the first part of the storm. It is much to be regretted that the information respecting this hurricane is not more full and definite. Lieutenant-Colonel Reid does not attempt to determine its progressive motion.

At page 281, vol. 2, Sir J. Ross says, "during our passage from the Falkland Islands to Cape Horn we encountered very severe weather, the gales usually commencing in the S.W., veering to W., and generally, as in the North Atlantic Ocean, ending in the N.W." On this Colonel Reid remarks—"I have not been able to obtain a sight of any of the log-books of either the *Erebus* or the *Terror* for 1842; Sir James Ross may have met gales moving from E. to W. It is the barometer which enables us to separate one gale from another: the barometrical observations made on board these two ships are therefore necessary before these *exceptional cases* can be fully established." I consider the hurricane of the *Vincennes* a well-determined instance of westerly progression, and shall not be surprised to find that westerly

movement in high southern latitudes forms the rule, and not the exception.

Speaking of the Fejee Group, Lieut. Wilkes says,—"from April to November the winds prevail from the E.N.E. to S.E. quarter, at times blowing a fresh trade wind. From November to April northerly winds are often experienced, and in February and March heavy gales are frequent. They usually begin at the N.E., pass round to the N. and N.W., from which quarters they blow with most violence; then hauling to the westward they moderate.

A very heavy gale was experienced from the 22nd to the 25th February, 1840. The only data I could get, to be at all depended upon, were from Capt. Engleston, whose ship was lying under Toba Peak, on the north shore of Vitileva. The gale began from the N.E., with heavy rain on the morning of the 22nd. During the night and morning of the 23rd it was more to the N., increasing with violent gusts. They let go a third anchor, and sent down the topmasts and lower yards. On the 24th the gale was the same, with much rain and wind, hauling to the westward at midnight of the 25th. It became N.W. in the morning, when it began to moderate, the wind hauling gradually to the southward, when it cleared off. The Missionaries could give no further information than that the gale had lasted four days. This gale was not felt at Tonga, although they had strong winds there at the time.

At Rewa, on the eastern point of Vitileva, Capt. Hudson visited the Missionaries, and found them most miserably accommodated, their dwelling-house having been blown down in the tremendous storm on the 25th February."

This hurricane appears to have travelled to the southward, at the rate of about 200 miles a day. Captain Morgan, of the *John Williams*, has favoured me with a perusal of his journal, and of the log of the Missionary brig *Camden*, then

under his command, on a passage from Sydney to Tutuilah, from which I have made the following extracts:—

27th FEBRUARY, 1840.—Wind shifted suddenly from N. to S.W., and then to S.E., lat. 31° 45′ S., long. 171° 52′ E.

28th, Friday.—Increasing breeze from eastward, barometer falling gradually. Midnight: under double-reefed topsail and foresail—31° S., 174° 7′ E.

29th, Saturday.—Wind increased from S.E. till 10 A.M., when it blew a perfect gale,—yea, a hurricane. Barometer 28·40; took in all sail, and lay on our side; kept the pumps sucking; the water came up the *skin* into the cabins, between decks. The sea stoved the whaleboat, triced up in the rigging, and we were forced to cut her away. At noon it began to abate a little; at 2 P.M. the gale had subsided: sent down topgallant yards with foretopgallant mast. At 7 P.M. wore round, the wind at S.W.; set maintopsail and foresail, steering N.E. Next day a light S.E. wind.

I have known it to blow as hard, but never harder—we could not look to windward for a second at a time.

In a work entitled "Missionary Life in Samoa, 1849," I find a letter by Mr. G. A. Lundie, a passenger by the *Camden*, in which this hurricane is described thus:—"A few days since we met a fearful and long-continued hurricane. Friday (28th February) was a day of rough and restless calm; barometer fell gradually. In the evening a fresh breeze set in, increasing gradually till 4 A.M. (29th). Lay-to under a small sail, to keep the vessel from rolling. 8 A.M., without a stitch of canvas, at the mercy of the fierce wind and infuriated waves. The lee bulwarks and nearly half the deck under the boiling waters. The day-time, darkness rendered more dismal by the burning of a solitary lamp. Boat, bulwarks, &c., carried away. At 11¾ A.M. mercury began to rise. At 1 P.M. the rain had ceased, but the wind had not per-

ceptibly abated. Sun shone out at 4 P.M., wind subsiding, and continued to abate till Sunday morning."

Since the western half of the storm passed over the *Camden* in two days, and its centre moved to the south at the rate of 200 miles daily, the diameter of the hurricane must have been 500 miles at least.

From p. 381, vol. 2, of Lieut. Wilkes's narrative, we learn that, on the 29th February, there was a violent gale at the Bay of Islands, said by the Missionaries to have been the severest they had experienced, with perhaps the exception of one which took place shortly after their arrival. Many vessels suffered great damage. The *Thom*, of Sag Harbour, which sailed a few days before, bound home, was obliged to put back in consequence of the damage received, and was condemned as unseaworthy; as was also the *Tuscan*, an English whaler. The barque *Nimrod* arrived, having lost her topmast. Several coasters were missing, supposed to have been lost. Most of the vessels lying off Kororarika dragged their anchors. The *Harriet* was driven ashore at Tipoona; she parted her cables during the night, and next morning was found a complete wreck: the crew barely escaped with their lives. On land, fences were carried away, houses and grounds deluged, wharves injured, and the extensive embankment of the Missionary establishment at Pahia nearly demolished. The tide rose six feet during the night of Saturday beyond its usual mark. This gale was experienced at the Thames, on board H.M.'s ship *Herald*, 140 miles to the south; also by the *Flying Fish*, off Cook's Strait on the east; and by the barque *Achilles* to the north. Mr. Hale was a passenger in the *Achilles*, and took barometrical observations and notes, from which it appears that the change took place at the two northern and two southern positions, in opposite directions, proving that the gale was a rotatory one, and that its centre

must have passed between the Bay of Islands and the River Thames. The greatest force of the gale was between 1 and 3 o'clock A.M. on 1st March. At the Bay of Islands a *calm* was observed by Mr. Dana and others, which lasted fifteen minutes, after which the wind rapidly hauled round to the *westward,* and blew with increased violence. On board the *Herald* the barometer fell to 28·75; and as the gale was experienced first to the northward and eastward, it is certain that it came from that quarter, and passed over New Zealand in a S.W. direction. The width of its track was about 500 miles.

On the 29th February the *Flying Fish* was in 40° S. and 178° 30′ E. At noon the wind hauled to the southward and eastward, and by midnight blew a most violent gale, hauling to the eastward, until about 8 P.M. (March 1), when its violence moderated.

About this time the *Vincennes* was in 50° S. and 135° E., and escaped the hurricane, which probably passed to the southward of her.

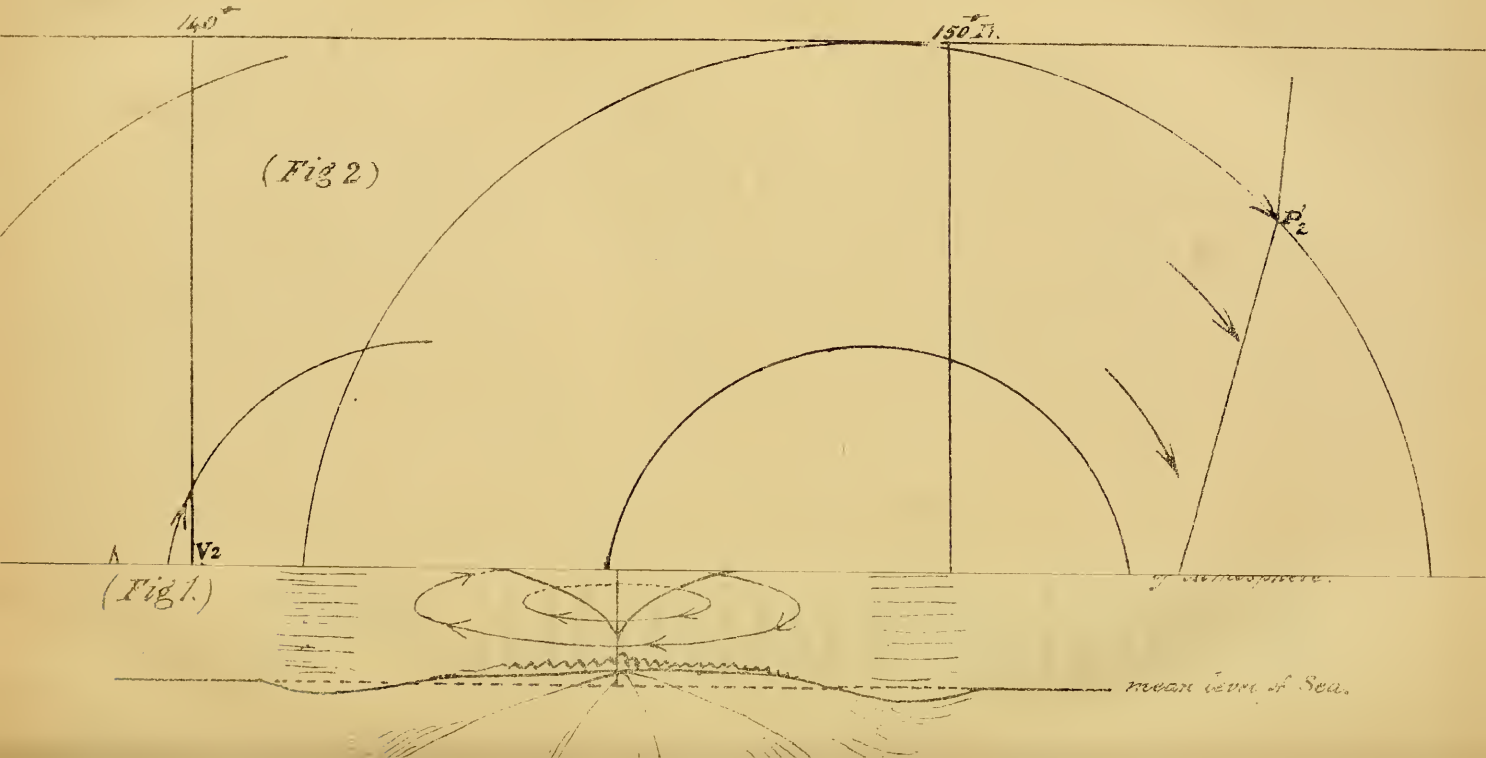
The author of "Rovings in the Pacific from 1837 to 1849," 2 vols., 1851, a merchant long resident at Tahiti, states at p. 64, that he met with a most violent gale from the northward, on the 29th February, when off the Three Kings, at the northern extremity of New Zealand. The gale increasing they lay-to, when the vessel was thrown on her beam-ends. Next day the wind moderated, and gradually veered round to the S.E. The vessel had drifted to the southward of the Bay of Islands—hundreds of red bream were seen floating about killed by the gale.

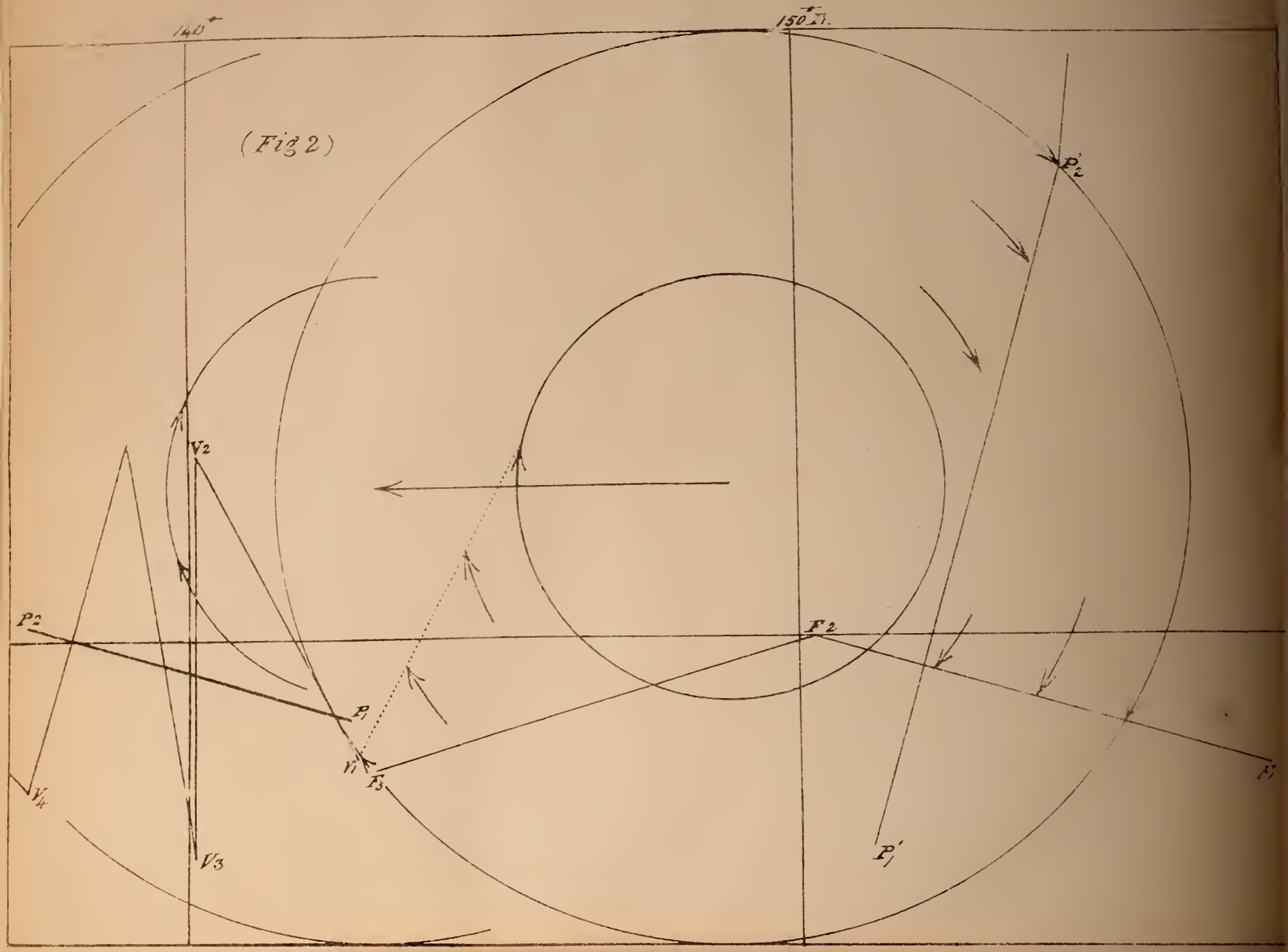
The *Flying Fish,* and the *Rover* just mentioned, offer two instructive instances of the modification that circular storms undergo by the interposition of land.

The *Rover* was about 500 miles to the N.W. of the *Flying*

Fish: the island stretching in the same direction, and nearly to the same extent, was crossed between them by the centre of the storm. The *Rover* was sheltered from the force of the S.E. quarter of the storm, but suffered from the last, or N.W quarter; while the *Flying Fish* experienced the former, but was protected by the land from the latter. *The off-shore wind* was modified in both cases. The curvature of the track of this storm is well defined. That the centre was to the west of Vitileva is shown by the order of veering there, and by the storm not extending to Tonga. The centre was to the east of the *Camden*, in 31° S. 175° E., and afterwards passed between the Bay of Islands and the Thames. Its path was therefore convex to the eastward, and, in obedience to the law of continuity, the centre must have passed down the west coast of New Zealand, and moved more and more in a westerly direction, until between the parallels of 60° and 70° S. it would pass the meridian of Van Diemen's Land, travelling slowly to the westward, like the hurricane met with by the *Vincennes* in the preceding month.*

* I find that at page 48 of Piddington's "Sailors' Storm Book," speaking of New Zealand storms, the author alludes to that of the 29th February, 1840, as a true tropical hurricane, its course being to the south-westward; and adds the following note:—"Its track to the south-westward, or perhaps S.S.W. after crossing the island, I am enabled perhaps to corroborate from a log in my possession of the ship *Adelaide*, which vessel, between the 1st and 2nd of March, about 3½ degrees due west of Cape Egmont, experienced a smart gale, commencing at about E. by S. or E.S.E. and veering to S. by E., reducing her to close reefs with a heavy cross sea. This, roughly calculated, gives 340 miles for 36 hours, or about 10 miles per hour."


140
150 M.
(Fig 2)
P2
V2
A
(Fig 1.)
mean level of Sea.


140°
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P'2
V2
P2
F2
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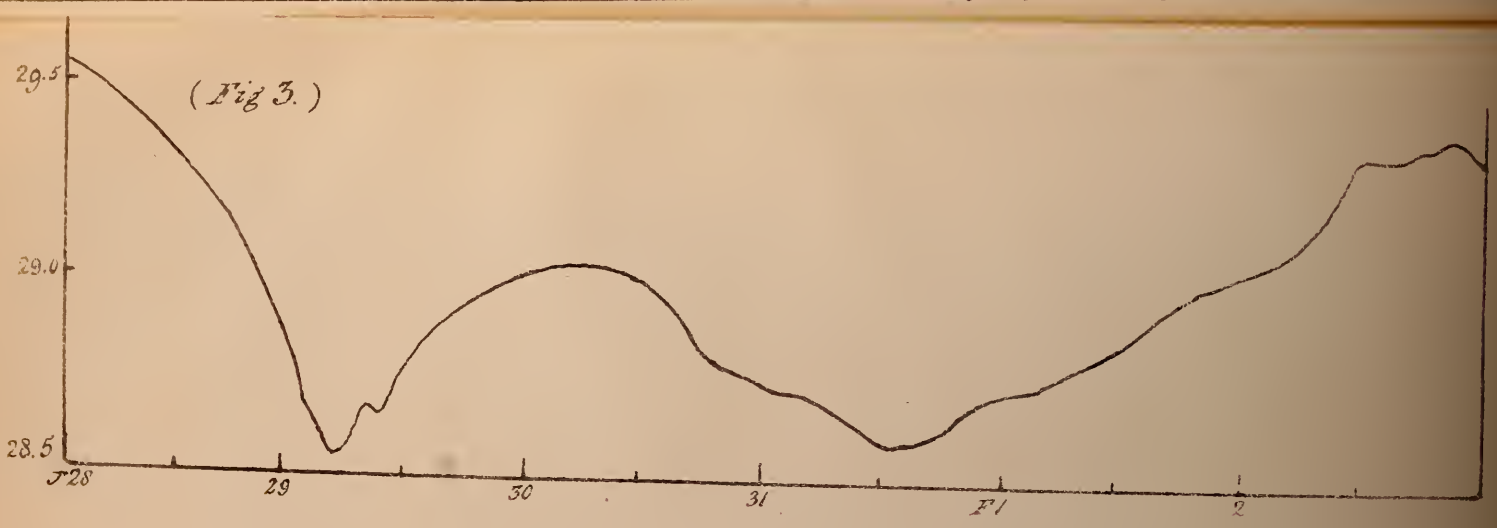
V1
F3
F1
V4
V3
P'1


29.5
(Fig 3.)
29.0
28.5
28
29
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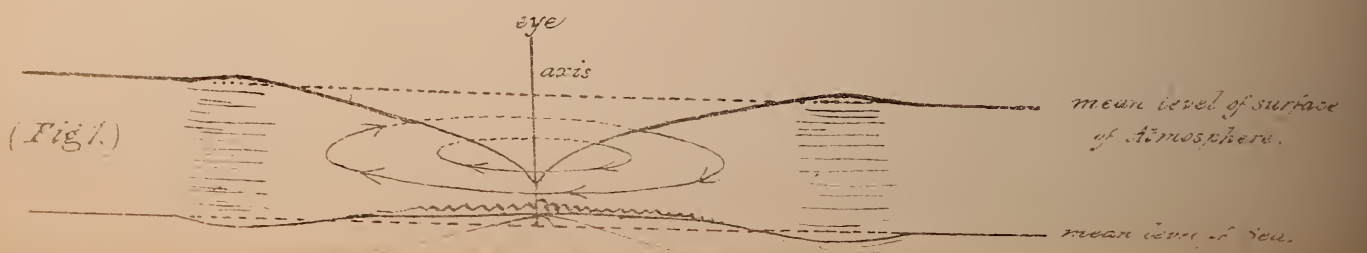
31
F1
2


eye
axis
(Fig 1.)
mean level of surface of Atmosphere.
mean level of Sea.