A half-yearly variation of the circumpolar surface drift in the Southern Hemisphere

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ABSTRACT

The annual march of the zonal geostrophic wind at sea level in middle and high southern latitudes includes a marked half-yearly wave whose phase reverses near 50 S. South of this latitude the maxima are in the transitional seasons and north of it in the extreme seasons. Surface-current velocitites at middle latitudes in the western Indian Ocean suggest that the circumpolar current may vary semiannually in the same sense as the wind.

1. Introduction

There is a large, often dominant, half-yearly wave (second harmonic) in the surface air pressure south of the subtropical ridge in the Southern Hemisphere; see for example Reuter (1936), Wahl (1942), Schwerdtfeger & Prohaska (1956), and van Loon (1967 and 1971). The amplitude of the second harmonic reaches a peak in the latitudes near 50 S (Fig. 1), goes toward nought at 60 S, and rises to another peak over Antarctica. The phase of the harmonic reverses at 60 S: from maxima in the transitional seasons to the north to maxima in the extreme seasons to the south. Fig. 2. shows the annual curves of the zonally averaged surface pressure at 50 and 65 S whose shape the harmonic almost solely determines. Evidently, the annual march in the zonally averaged pressure *difference* between the two latitudes must have a large half-yearly oscillation with maxima in spring and fall. And since the amplitude of the second harmonic in the pressure is highest near 50 S and its two maxima *there* are in spring and autumn, north of 50 S there must be a half-yearly variation in the latitudinal pressure *gradients* with maxima in summer and winter.

The zonal component of the geostrophic wind at sea level varies seasonally as the latitudinal pressure gradients, and the zonally averaged geostrophic zonal winds in Fig. 3 accordingly show the opposition on either side of 50 S of the double maxima in the annual curves. The size and phase of the second harmonic in the winds of Fig. 3 are given in Table 1, which also indicates that the harmonic controls the annual march of the zonally averaged wind over a wide span of latitudes.[2]

Considering the close connection between the wind and the currents of the ocean's surface layers, one would expect the half-yearly wave in the zonal wind to be reflected in the velocities

Table 1. *The half-yearly wave (second harmonic) in the zonally averaged, geostrophic zonal wind*

The amplitude is in m sec^{-1}; phase is given as the months when the maxima are reached (1.5 = 15 January); and the percentage is the harmonic's share of the total variance

	Amplitude	Phase	Percentage	Annual mean wind speed
40 S	0.8	6.4/12.4	32	5.9
45 S	0.6	6.5/12.5	94	8.5
50 S	0.05	3.3/ 9.3	1	10.1
55 S	1.1	3.7/ 9.7	94	9.7
60 S	2.0	3.8/ 9.8	94	6.2
65 S	1.7	3.9/ 9.9	79	0.3

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[2] This is not representative of single longitudes: Because the phase of the first harmonic changes with longitude its contribution is reduced in the zonal average. The second harmonic's share of the total variance changes, for example, between 10 and 90 % along 40 S and between 30 and 98 % along 60 S, but its phase is stable with longitude.

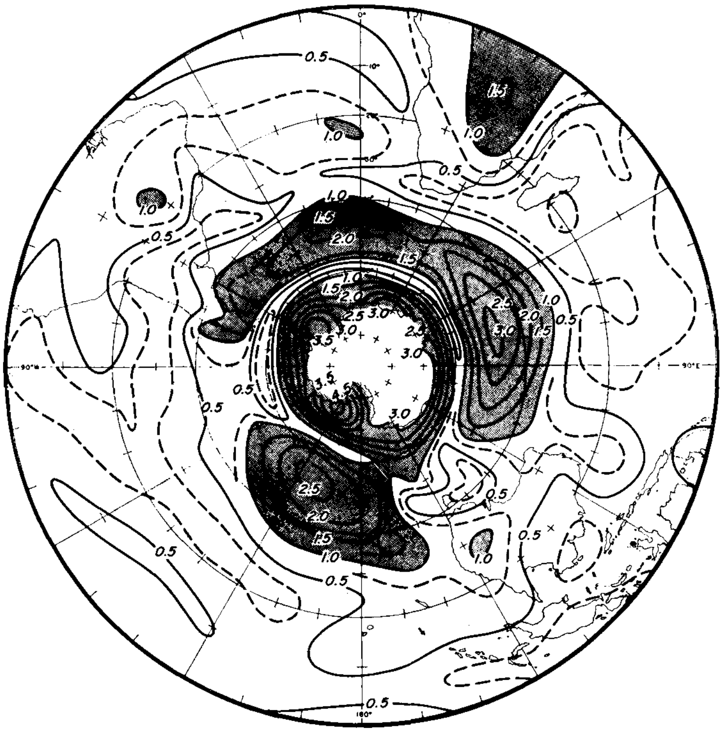

Fig. 1. Amplitude (mb) of the second harmonic (half-yearly wave) in the pressure at sea level. From van Loon (1971) where also the harmonic's phase and its part of the total variance are shown.

of the currents. That is, south of about 50 S the annual march of the current velocity should contain a second harmonic with maxima in spring and autumn, and between 50 S and the subtropical ridge there should be a second harmonic with maxima during the extreme seasons. Such a link between semiannual variations in pressure, wind, and currents in the ocean's surface layers is known from the North Atlantic Ocean where the pressure variation in the subtropical high is predominantly semiannual with maxima in winter and summer —see, e.g., Wahl (1942)—and where the annual march of the geostrophic wind (Chase, 1954) and of the surface currents (Fuglister, 1951) around the high generally includes a not insubstantial half-yearly component.

2. A half-yearly wave in the surface current

Fixed measurements are rare where one wants to examine current speeds in the Southern Hemisphere for half-yearly oscillations, and one must therefore turn to the current data which are derived from the differences between ships' positions determined astronomically and by dead reckoning. Although such data are inadequate as to absolute values, their change from month to month may be a fair approximation of the seasonal change in the surface currents.

The Dutch atlas of the Indian Ocean (Koninklijk Nederl. Meteor. Inst., 1952) shows the direction and speed of monthly mean resultant currents for areal units of two degrees latitude by two degrees longitude. The coverage is complete north of 45 S, but the data are naturally densest in the most frequented shipping lanes. One such lane lies between 40 and 44 S from Cape of Good Hope to 70 E where it turns northeastwards. The interval between 30 and 60 E in this lane, where the current is fairly uniformly from westerly directions, was chosen for the investigation. The current speeds

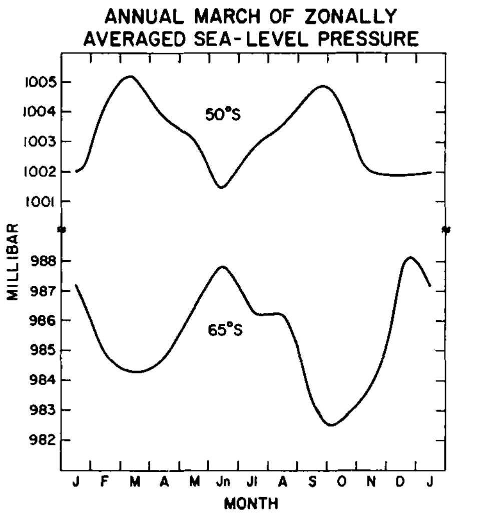

Fig. 2. Annual march of the zonally averaged sea-level pressure (mb) at 50 and 65 S.

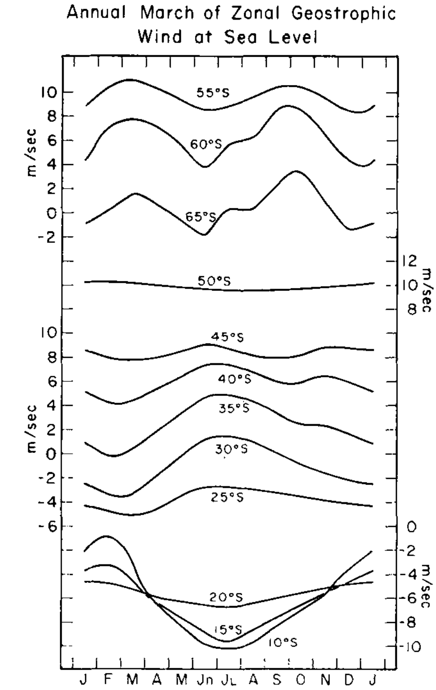

Fig. 3. Annual march of the zonally averaged, geostrophic zonal wind (m sec^{-1}) at sea level. From van Loon (1971).

in the lane vary much from one unit to the next, despite the higher number of observations there than over the surrounding latitudes, and some smoothing was obviously needed.

Fig. 4, which also shows how uneven the velocities are in the atlas, illustrates the smoothing: all resultant velocities between 36 and 48 S, 20 and 70 E, were plotted for each month; isotachs were drawn with more attention to the general pattern than to the individual point; and the values according to the isotachs were averaged for each month along 41, 42, and 43 S between 30 and 60 E. The annual march of the surface current velocities so obtained is seen in Fig. 5. A half-yearly oscillation is plain at all three parallels, the second harmonic in the three annual curves (see Table 2) reaches its maxima early in January and July (that is, it lags the second harmonic in the geostrophic zonal wind by about 3 weeks), and it explains a considerable part of the total variance in the curves (as a significant part of the total variance evidently is owing to random uncertainties, the real contribution of the second harmonic may be larger). The amplitudes

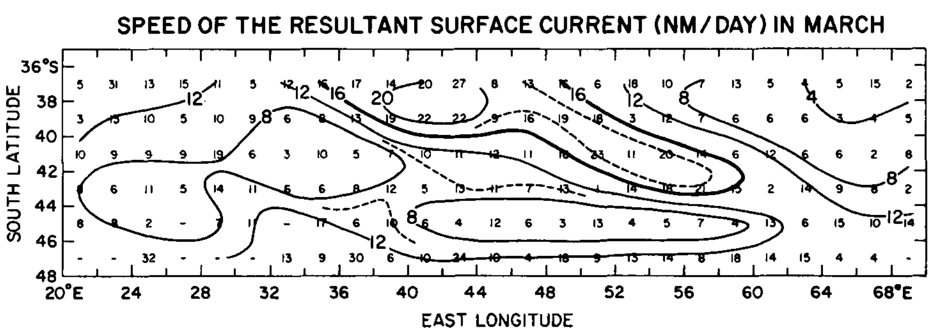

Fig. 4. Resultant velocities of the surface current (naut mi day^{-1}) in March for a sector in the south-western Indian Ocean.

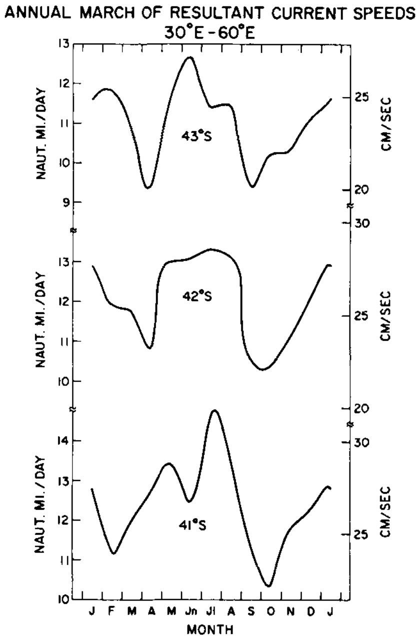

Fig. 5. Annual march of the surface-current velocities (naut mi day^{-1}) at 41, 42 and 43 S, averaged between 30 and 60 E.

of the second harmonic in the current and in the wind of the same sector (Table 3) amount to nearly the same portion of the annual mean, i.e. about one tenth.

The demonstrated similarity in the seasonal change of wind and current in the Indian Ocean, however suggestive, naturally does not prove that the current oscillates in the same sense everywhere along the three parallels. And it is only speculation to suggest that south of 50 S where the wind varies semiannually with maxima in spring and fall the current will vary likewise.

Table 2. *The half-yearly wave (second harmonic) in the resultant surface current averaged between 30 and 60 E*

The amplitude is in nautical miles per 24 hours; the phase is shown as the months when the maxima are reached (1.5 = 15 January); and the percentage is the harmonic's share of the total variance

	Amplitude	Phase	Percentage	Annual mean current speed
43 S	1.0	1.2	58	11.0
42 S	1.2	1.3	64	12.0
41 S	0.8	1.2	29	12.4

Table 3. *The half-yearly wave (second harmonic) in the zonal geostrophic wind at 42.5 S, averaged between 30 and 60 E*

The amplitude is in m sec^{-1}; the phase is given as the dates when the maxima occur; and the percentage is the harmonic's share of the total variance

Amplitude	Phase	Percentage	Annual mean wind speed
1.1	6.4/12.4	27	9.4

Appendix

The arrangement of the current velocity in Fig. 4—in a maximum orientated NW–SE

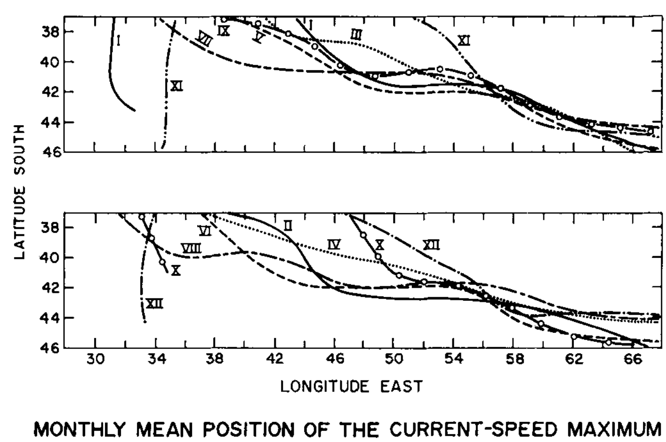

Fig. 6. The monthly mean positions of the current-speed maximum (cf. Fig. 4).

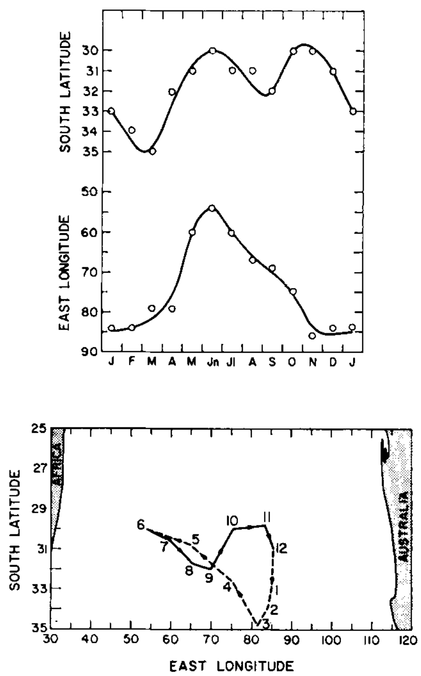

Fig. 7. The monthly mean positions of the center of the subtropical high in the Indian Ocean. Top: the south and east coordinates. Bottom: the total movement according to the smooth lines in the upper part of the diagram; movements with an eastward component are shown by a solid line, and with a westward component by a broken line.

and bounded by two minima—is the same in all months. The monthly positions of the axis of the maximum is shown in Fig. 6, which for the sake of convenience is divided into one part with the odd and another with the even months. South of about 42 S the axis moves little from one month to another, but to the north one observes a regular movement over 20 degrees of longitude such that the speed maximum is farther east between October and March than during the rest of the year. In the months when it is farthest east, October–January, a second maximum appears in the western part of the region.

This might seem spurious and be attributed to deficient data were it not that the monthly mean subtropical high in the Indian Ocean moves in the same sense (Vowinckel, 1955). The upper part of Fig. 7 shows the coordinates of the center of the high determined from the monthly mean maps in Taljaard et al. (1969), with a smooth line drawn to outline the W–E and the S–N movement. The latter has a strong half-yearly oscillation whereas the former's variation is mainly annual. The lower part of Fig. 7. shows the total month-to-month progression using the smoothed positions in the upper part.

The large W–E movement of the high, and thus, presumably, of the highest current velocity, may be the reason why the second harmonic accounts for substantially more of the total variance in the current than in the wind (cf. Tables 2 and 3). The zonal movement would cause the maximum of the annual wave in the current speed to be reached at different times of the year in different parts of the sector and thus reduce the first harmonic's share in the sector mean.

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ПОЛУГОДОВЫЕ ИЗМЕНЕНИЯ ЦИРКУМПОЛЯРНОГО ПОВЕРХНОСТНОГО ДРЕЙФА В ЮЖНОМ ПОЛУШАРИИ

Годовой ход зонального геострофического ветра на уровне моря в средних и высоких южных широтах включает в себя заметную полугодовую волну, фаза которой меняет знак вблизи 50° ю. ш. Южнее от этой широты максимумы находятся в переходные сезоны, а севернее — в экстремальные сезоны. Скорости поверхностных течений в средних широтах в западной части Индийского океана наводят на мысль, что циркумполярное течение может меняться с полугодовым периодом аналогично ветру.