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The semi-annual oscillation and Antarctic climate. Part 1: influence on near surface temperatures (1957–79)

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Abstract: We studied the influence of the semi-annual oscillation (SAO) on near-surface temperatures in Antarctica, using observations of 27 stations that were operational during (part of) the period 1957–79. For the annual cycle of surface pressure, the second harmonic explains 17–36% of the total variance on the Antarctic Plateau, 36–68% along the East Antarctic coast and almost 80% on the west coast of the Peninsula, and decreases further to the north. As a result of the amplification of the wave-3 structure of the circulation around Antarctica, a significant modification of the seasonal cooling is observed at many stations. The magnitude of this modification is largely determined by the strength of the temperature inversion at the surface: the percentage of the variance explained by the second harmonic of the annual temperature cycle is then largest on the Antarctic Plateau (11–18%), followed by the large ice shelves and coastal East Antarctica (6–12%) and stations at or close to the Peninsula (0–5%). A significant coupling between the half-yearly wave in surface pressure and that in surface temperature is found for coastal East Antarctica, which can be directly explained by the changes in meridional circulation brought about by the SAO. We show that the coupling of Antarctic temperatures to the meridional circulation is not only valid on the seasonal time scale of the SAO, but probably also on daily and interannual time scales. This has important implications for the interpretation of time series of Antarctic temperatures, a problem that will be addressed in part 2 of this paper.

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Introduction

The semi-annual oscillation (SAO) in the middle and high latitudes is an important and well known component of the Southern Hemisphere climate. An overview of the early literature on the SAO is given by van Loon (1967), and a re-examination of the phenomenon and its causes is presented by Meehl (1991). The SAO consists of the twice-yearly contraction and expansion of the pressure trough around Antarctica, in response to differences in heat storage between Antarctica and the surrounding oceans. As a result of the SAO, the surface pressure in middle and high latitudes shows a clear half-yearly wave. Van Loon (1972) showed that the amplitude of this wave peaks at 45–50°S in each of the 3 oceans (with values of 2–3 hPa), has a minimum at 60°S (0.5 hPa) and peaks again over coastal Antarctica (4–5 hPa). The phase reverses at approximately 60°S from equinoctial pressure maxima (March/September) north of this location to solstitial maxima (January/July) south of it, which was first demonstrated by Schwerdtfeger & Prohaska (1956). Because the phase of the first harmonic shows large interannual variations, which tend to cancel out in the long term means (van Loon & Rogers 1984a), the second harmonic dominates the annual cycle of surface pressure in high southern latitudes, explaining up to 80% of the total variance. In response to the variation in the meridional pressure gradient, the zonal westerlies show equinoctial maxima which are 20–30% stronger than those in summer and winter.

In conjunction with pressure rises over the three mid-latitude continents, the expansion of the pressure belt in autumn causes an amplification of the wave-3 structure of the circulation around Antarctica. This increases the transport of air from lower latitudes towards continental Antarctica, a process that directly links the SAO to Antarctic surface temperatures. In this paper we explore this link further by studying the annual cycles of pressure and temperature at 27 Antarctic stations. First we give some information on the dataset that was used, followed by a discussion of the yearly and half-yearly pressure and temperature waves in various sectors of Antarctica. Finally we discuss the implications of the SAO for interpretation of temperature time series in the Antarctic, making the link to part 2 of this paper.

Data

Smith & Stearns (1993) compiled a dataset of monthly mean temperature and pressure at 24 long-term stations in the Antarctic, based on data that were originally collected by Jones & Limbert (1987). These data form the basis of this study. Because several authors have reported on a marked weakening in the SAO since the late 1970s (van Loon *et al.*

1993, Hurrell & van Loon 1994), we only use data from the period 1957–79. The influence of the recent changes in the SAO on Antarctic temperatures will be discussed in part 2 of this paper. For the calculation of the mean annual cycle of temperature and pressure we used all available monthly data, not only the years that were complete. The resulting annual cycle formed the basis for harmonic analysis and the calculation of annual mean temperatures which are given in Table I. To improve coverage over the continent, we also included some stations with short data records (Plateau station, Pioneerskaya, Hallett, Little America, Eights, Matienzo). Most of these data were taken from Schwerdtfeger (1970). We grouped the stations in five regions, according to their location, elevation, mean temperature and the shape of the annual cycle. Figure 1 shows the location of all the stations that were used in this study. Table I summarizes some of the station characteristics as well as the length of the data records that were used for harmonic analysis.

Yearly and half-yearly cycle of surface pressure

Figure 2a–c show the observed annual cycle of pressure together with the first and second harmonic at three Antarctic stations, Dumont d'Urville, Vostok and Faraday. These stations are fairly typical for the region they are situated in, i.e. coastal East Antarctica, the East Antarctic plateau and the Antarctic Peninsula. The total variance of the annual cycle in surface pressure can be almost entirely (96–99%) explained by the first two harmonics, $H_1(P)$ and $H_2(P)$. The patterns are very similar for the two coastal stations, with a dominant half-yearly wave that explains the largest part of the total variance, 67% at Dumont d'Urville and 77% at Faraday. The half-yearly wave has maxima in the extreme seasons January and July, which represents the months in which the circumpolar trough is situated furthest away from the continent. The amplitude of $H_2(P)$ is around 3 hPa for both coastal stations, which is in agreement with the analysis of van Loon (1972). At Faraday, the amplitude of $H_2(P)$ is somewhat smaller and

Table I. Location, elevation, annual mean temperature, number of years with observations and data source of 27 stations that were used for harmonic analysis.

Station	Location	Elevation (m a.s.l.)	Temp (°C)	# yrs (57–79)		Source
				T	P	
I. East Antarctic plateau						
South Pole	90.0°S	2835	-49.3	23	23	S. & S. '93
Plateau	79.3°S, 40.5°E	3625	-56.4	3	3	Schw. '70
Vostok	78.5°S, 106.9°E	3488	-55.5	21	21	S. & S. '93
II. Katabatic East-Antarctica						
Mizuho	70.7°S, 44.3°E	2230	-32.1	4	-	CRC/AAD
Pionerskaya	69.7°S, 95.5°E	2740	-38.0	3	3	Schw. '70
III. Coastal East Antarctica						
Halley	75.5°S, 26.7°W	32	-18.6	23	23	BAS
Sanae	70.3°S, 2.4°W	52	-17.1	22	23	S. & S. '93
Novolazarevskaya	70.8°S, 11.8°E	99	-10.7	19	18	S. & S. '93
Syowa	69.0°S, 39.6°E	21	-10.8	18	19	S. & S. '93
Molodezhnaya	67.7°S, 45.9°E	40	-10.9	17	17	S. & S. '93
Mawson	67.6°S, 62.9°E	16	-11.2	23	23	S. & S. '93
Davis	68.6°S, 78.0°E	13	-10.3	19	19	S. & S. '93
Mirny	66.6°S, 93.0°E	30	-11.4	23	23	S. & S. '93
Casey	66.3°S, 110.5°E	15	-9.5	23	23	S. & S. '93
Dumont d'Urville	66.7°S, 140.0°E	43	-10.9	23	23	S. & S. '93
Hallett	72.3°S, 170.3°E	5	-15.3	8	8	Schw. '70
IV. Large Ice Shelves						
Belgrano	78.0°S, 38.8°W	32	-22.3	23	17	S. & S. '93
Scott	77.9°S, 166.8°E	16	-20.3	23	23	S. & S. '93
Little America	78.6°S, 179.0°W	40	-23.6	6	6	Rusin '62
V. West Antarctica						
Byrd	80.0°S, 119.5°W	1515	-27.9	15	15	S. & S. '93
Eights	75.5°S, 77.2°W	420	-26.0	3	3	Schw. '70
VI. Antarctic Peninsula						
Rothera	67.8°S, 68.1°W	15	-5.6	20	20	BAS
Faraday	65.3°S, 64.3°W	9	-4.5	23	23	BAS
Esperanza	63.4°S, 57.0°W	8	-5.8	23	23	S. & S. '93
Signy	60.7°S, 45.6°W	7	-3.6	23	23	BAS
Orcadas	60.7°S, 44.7°W	6	-3.8	22	23	S. & S. '93
Matienzo	65.0°S, 60.1°W	32	-12.3	12	12	CRC/AAD

Abbreviations: S. & S. '93: Smith & Stearns (1993); Schw. '70: Schwerdtfeger (1970); CRC/AAD: Antarctic Cooperative Research Centre/Australian Antarctic Division internet page; BAS: British Antarctic Survey internet page.

Fig. 1. Location of stations used in this study. *RIS* = Ross Ice Shelf, *FRIS* = Filchner-Ronne Ice Shelf.

the phase shifted slightly compared to Dumont d'Urville. The amplitude of $H_2(P)$ is largest at Vostok, but in spite of this the first harmonic or yearly cycle dominates, explaining 63% of the total variance (Fig. 2b). In contrast to the middle and lower latitudes, the yearly pressure wave on the Antarctic plateau has a very constant phase from year to year and a large amplitude (at Vostok: 5.7 hPa), and therefore clearly shows up in the climatology of this station.

No satisfactory explanation has yet been found for the dominant annual cycle in surface pressure on the Antarctic plateau. Papers that deal with the annual cycle of sea level pressure in the Southern Hemisphere often do not include the Antarctic plateau, because of the uncertainty that exists in the reduction to sea level pressure. Meinardus (1909) and Radok *et al.* (1996) related the strong pressure rise in spring to the 'flooding' of the plateau by warmed subantarctic air that was previously blocked by the steep coastal topography. This air then gradually cools and drains from the plateau in the form of katabatic winds during the rest of the year. However, the spring warming of subantarctic air masses does not start before September, which is in disagreement with the phase of the first harmonic. It is therefore unlikely that this is the only reason for the strong yearly wave. Another candidate is the yearly cycle of the katabatic circulation. Forced by radiational cooling at the surface, katabatic winds are strongest and have the largest downslope component in midwinter, thereby

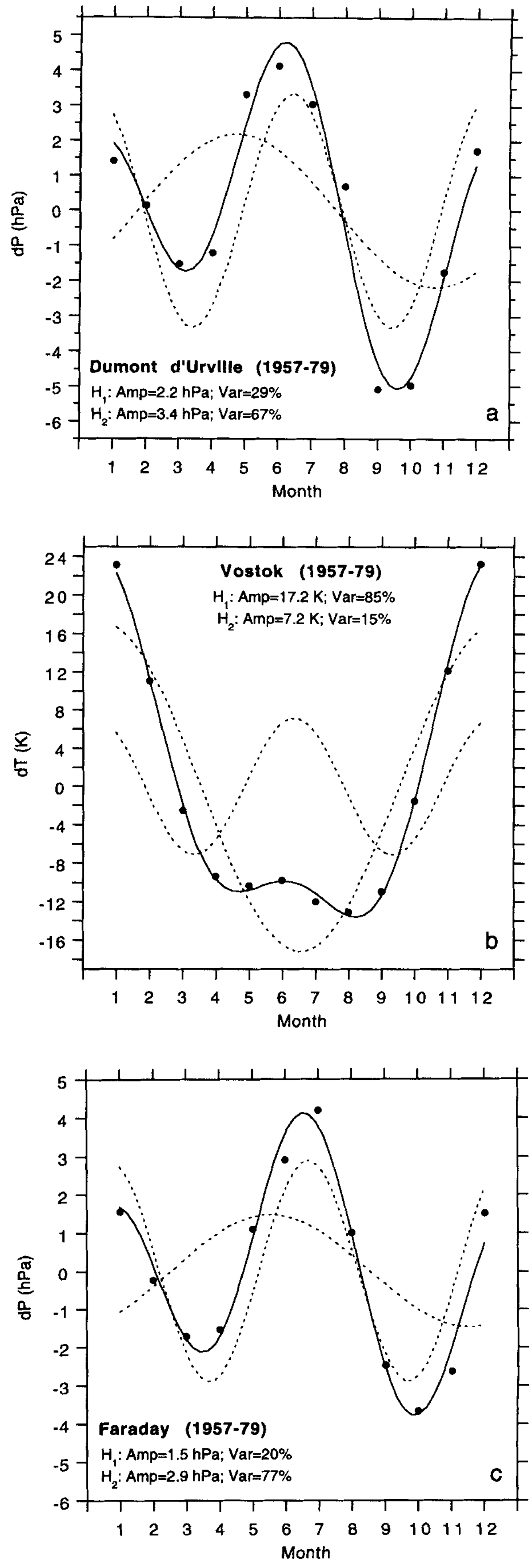

Fig. 2. First and second harmonics of mean annual pressure cycle $H_1(P)$, $H_2(P)$ (dotted lines) and sum $H_1(P)$ and $H_2(P)$ (solid line) for the period 1957–79 at **a.** Dumont d'Urville, **b.** Vostock and **c.** Faraday. Observations are represented by black dots.

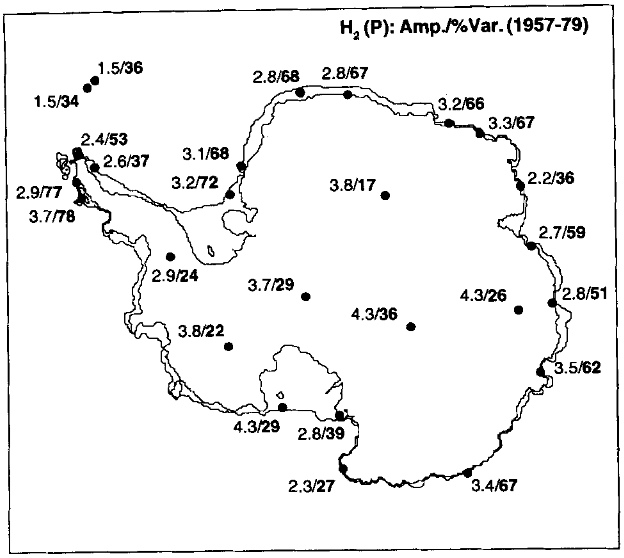

Fig. 3. Amplitude of (Amp.) and percentage of the total variance explained by (%Var.) the second harmonic $H_2(P)$ of annual pressure cycle at 26 Antarctic stations.

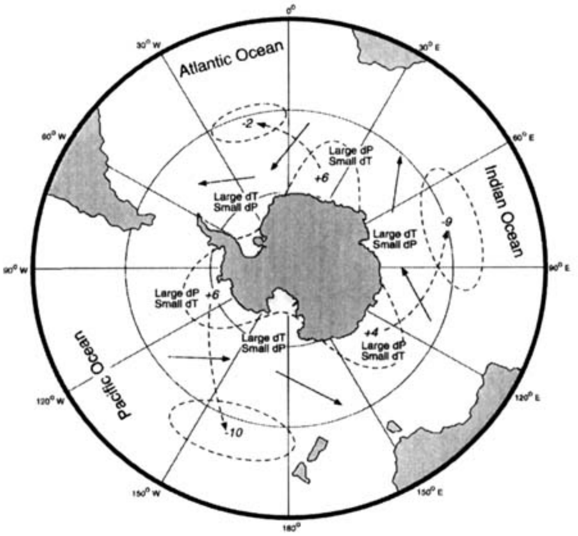

Fig. 4. Schematic outline of pressure and circulation changes from March to June. Dashed arrows connect locations of largest pressure changes (the approximate movement of climatological low pressure areas), solid arrows indicate associated mean circulation changes. Numbers indicate pressure change from March to June (hPa, 12 years of observations, van Loon & Rogers 1984b).

effectively removing air from the Antarctic plateau in the winter months (van den Broeke *et al.* 1997).

Figure 3 shows the amplitude of the second harmonic $H_2(P)$ and the percentage of the total variance explained at all stations. In agreement with van Loon's (1972) analysis, the amplitude of $H_2(P)$ along the entire Antarctic coast is close to 3 hPa, with local minima in the sectors around 10°W, 75°E and a maximum over 4 hPa in the eastern corner of the Ross Ice Shelf. The second harmonic explains 17–36% of the total variance on the interior of west Antarctica and the Antarctic Plateau, 36–68% along the East Antarctic coast and almost 80% on the west coast of the Peninsula. Further to the north, at the subantarctic islands, both amplitude and explained variance decrease towards the minimum at 60°S (van Loon 1972, van Loon & Rogers 1984b). On all plateau stations (Byrd, South Pole, Vostok and Plateau), the first harmonic dominates in spite of the large amplitude of $H_2(P)$.

Yearly and half-yearly cycle of near-surface temperature

Van Loon (1967) discussed the coreless winter in Antarctica (i.e. the absence of an outstanding minimum in the annual temperature cycle) in relation to circulation changes brought about by the half-yearly pressure wave. He showed that, in combination with pressure rises over Australia, Africa and South America, the north-westward movement of the low-pressure belt from March to June causes an amplification of the wavenumber 3 structure around Antarctica. Figure 4 shows in a qualitative way the changes that occur from March to June: the dotted arrows connect the locations of largest pressure changes, and the numbers indicate the magnitude of the monthly mean pressure changes (June minus May, based on 12 years of data, van Loon & Rogers 1984b). The solid arrows denote the associated circulation changes, clearly showing the increased meridional component of the circulation.

Van Loon (1967) showed that the increased poleward transport of air in the Pacific sector of Antarctica strongly decreases or even reverses the seasonal cooling from May to June. The most marked effect was observed at the station Little America, situated on the northern edge of the Ross Ice

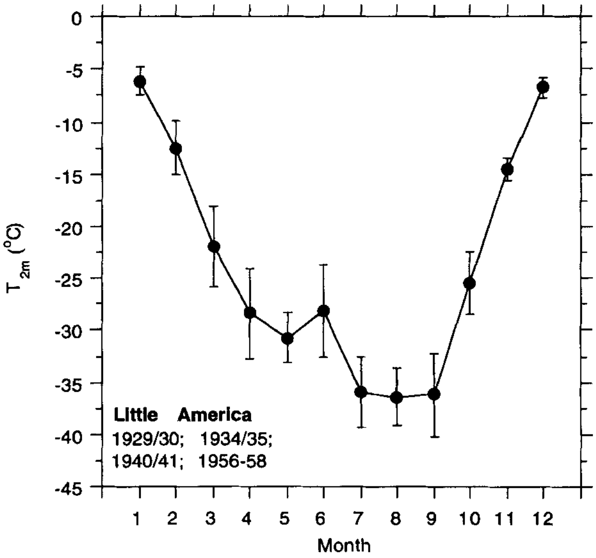

Fig. 5. Mean annual temperature cycle and standard deviations at Little America, 6 years of observations.

Shelf (Fig. 1). Figure 5 shows the annual cycle of temperature at Little America, together with the standard deviation, based on six years of measurements. On average, June was 2.7 K warmer than May, but owing to the brevity of the record and the large variability this difference is not statistically significant. The strong reduction of the cooling rate in autumn is clear, though.

Figure 6a–c presents the annual cycle of near-surface temperature together with the first two harmonics $H_1(T)$ and $H_2(T)$ at Dumont d'Urville, Vostok and Faraday. As with pressure, the first two harmonics explain next to all of the total variance in temperature. Although the annual cycle is dominated by the first harmonic, the second harmonic at Dumont d'Urville and Vostok is significant, explaining 8% and 15% of the total variance, respectively. Comparing these results with Figs 2a & b we find that $H_2(T)$ at Vostok is almost in phase with $H_2(P)$, while at Dumont d'Urville it lags the pressure wave by about 10 days. At Faraday, $H_2(T)$ does not contribute significantly to the total variance.

Figure 7 shows amplitude of and variance explained by $H_2(T)$ for the period 1957–79. In the region of the Antarctic Peninsula, $H_2(T)$ has a small amplitude (0.1–0.8 K), which explains <0.5–2% of the total variance. The half-yearly wave peaks in May/November at Rothera and Faraday and in January/June at Matienzo. Somewhat further to the north at Signy and Orcadas, the amplitude (0.5 K) and variance explained (5%) are more significant, with maxima in April/October. At all other stations, the half-yearly temperature wave is in phase with the pressure wave. This suggests that the mechanism that van Loon (1967) proposed for the Pacific sector of Antarctica, probably holds for a much larger area. The largest amplitudes of $H_2(T)$ are again found on the plateau (3.5–7.2 K), explaining 9–18% of the total variance. Along the coast of East Antarctica, the amplitude of $H_2(T)$ ranges from 1.9 to 2.9 K, explaining 4–11% of the total variance. Larger values of the amplitude are found on the large ice shelves (3.5–5.3 K), where $H_2(T)$ explains from 6% (Belgrano) to 12% (Little America) of the total variance.

The large ice shelves play a particular role in the detection of warm air advection: their flatness prohibits the development of katabatic winds, so that strong temperature inversions can develop at the surface. Moreover, the relative proximity to the ocean and absence of a significant topographic barrier makes that warm air can easily penetrate inland. This is especially valid for the Ross Ice Shelf; the Filchner-Ronne Ice Shelf is separated from open ocean by a semi-permanent belt of sea ice in the Weddell Sea, which cools maritime air from below before it reaches the shelf. Moreover, the Antarctic Peninsula blocks depressions that approach from the west. Nevertheless, the amplitude of $H_2(T)$ at Belgrano is substantially larger than that of neighboring stations.

These results show that the amplitude of $H_2(T)$ is sensitive to the magnitude of the surface temperature inversion that develops during the winter. The inversion strength in winter is determined by the longwave radiation loss at the surface

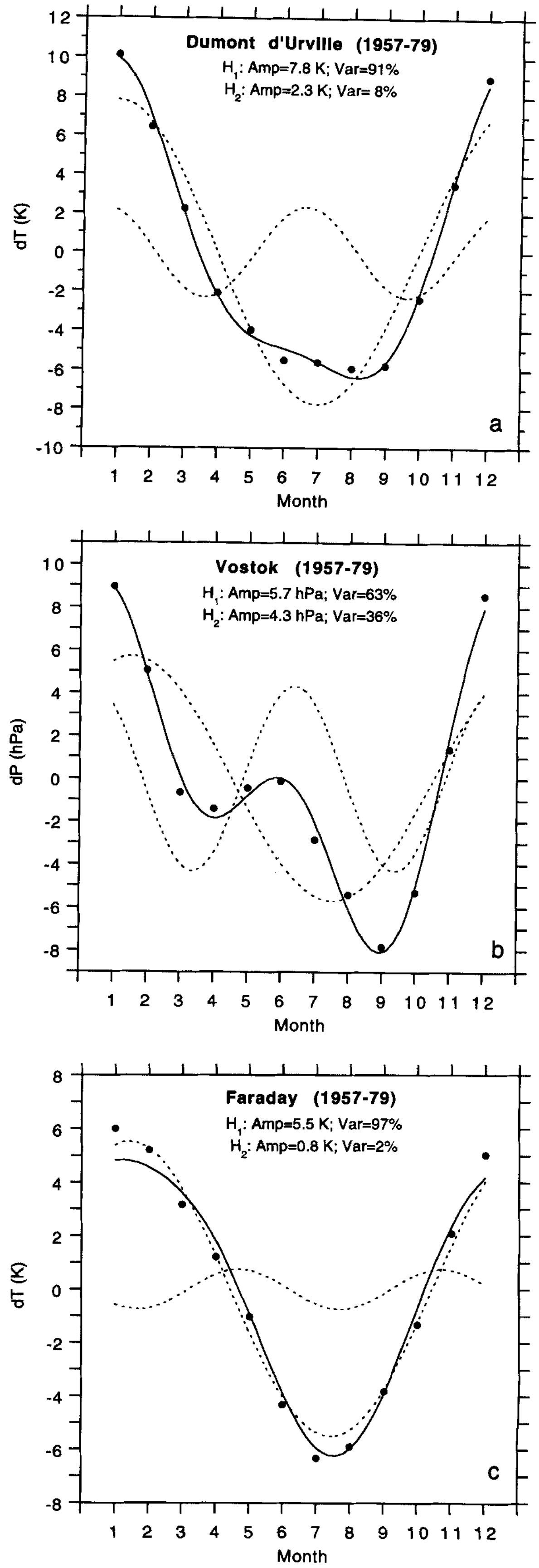

Fig. 6. As Fig. 2, but for temperature.

and the wind speed in the lower troposphere. Low atmospheric moisture content and low wind speeds are favorable for the formation of strong surface inversions. The surface inversion during winter at Vostok typically equals 20–25 K, that at South Pole 20 K and at Byrd 10 K (Schwerdtfeger 1970, Phillpot & Zillman 1970). Processes that disturb the strongly negative longwave radiation budget at the surface, such as advection of warm and moist air in the middle and upper troposphere, will therefore have large effects on surface temperatures, in spite of the relatively large distance of these stations to the coast.

King & Turner (1997) report on a winter temperature inversion of approximately 10 K at Halley, which is situated on the Brunt Ice Shelf, 40 km away from the foot of the ice cap. At Mawson, the surface inversion in winter is about 2 K (Streten 1990), which is probably typical for stations situated at the coast of East Antarctica at the foot of the ice cap. On the western coast of the Antarctic Peninsula and on the subantarctic islands, locations that are very exposed to the zonal westerly circulation, the average inversion strength is probably insignificant. Moreover, peninsula temperatures are strongly influenced by sea-ice extent (King 1994), which makes that $H_2(T)$ is likely to include processes other than the SAO.

Sea ice extent modifies the influence of the SAO on Antarctic temperatures by cooling the maritime air that is advected over it, but does not seem to influence the latitudinal position of the trough: both months with extreme sea ice extent, September and February, fall close to the time when the low pressure belt is situated nearest to Antarctica. When the sea ice has reached its maximum northward expansion in the late winter, the influence of warm air advection is reduced. With the southward movement of the pressure trough from June onwards, and the northwards extending sea ice, it becomes more likely that air transported towards Antarctica originates from within the sea ice belt. These conditions are reflected in the negative contribution of $H_2(T)$ to the temperature signal in August and September, causing the late-winter minimum temperature at most of the Antarctic stations.

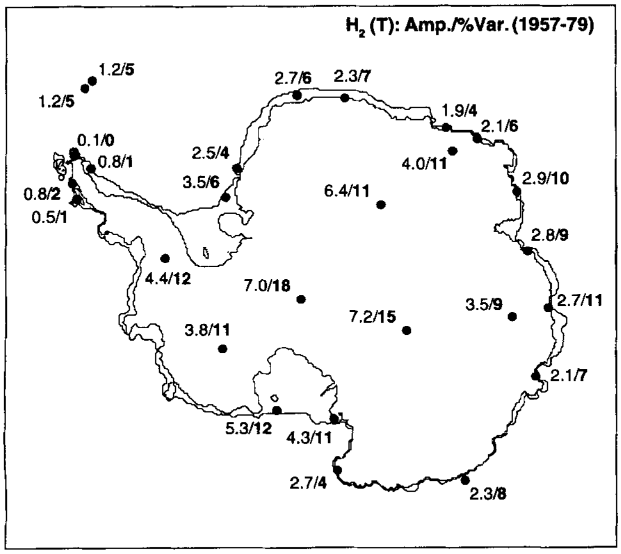

Fig. 7. As Fig. 3, but for temperature at 27 stations.

Coupling of pressure and temperatures in coastal East Antarctica

To study relations between the half-yearly waves of temperature and pressure we selected 11 stations along the coast of East Antarctica that are expected to show a similar response to warm air advection on near-surface temperatures. Figure 8 shows the relation between the amplitudes of $H_2(T)$ and $H_2(P)$ for these stations. The negative correlation (r=0.81) is significant at the 99% confidence level. If we only use stations with a complete data record of 23 years for both temperature and pressure (Halley, Mawson, Mirny, Casey and Dumont d'Urville, denoted by the open circles in Fig. 8) we find an even higher correlation of 0.98.

This strong spatial coherency between $H_2(T)$ and $H_2(P)$ is a direct result of the latitudinal and longitudinal displacement of the circumpolar trough during different phases of the SAO. During the expanding phase from March to June, as illustrated in Fig. 4, the three areas in Antarctica that experience the largest pressure rises are situated in the ridges of the wave-3 structure. In these regions the circulation change has a southerly component, reducing the warming effect (large dP, small dT). In the troughs the pressure changes are smaller, but it is in these regions that the large scale circulation gains the most significant northerly component, resulting in relatively strong reduction of seasonal cooling (small dP, large dT). The

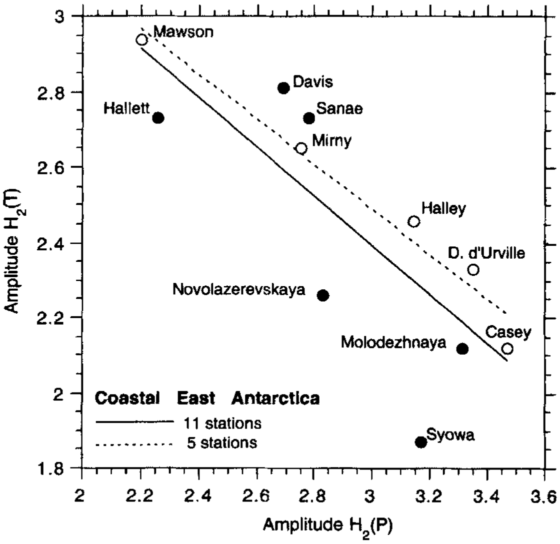

Fig. 8. Amplitudes of $H_2(P)$ vs. $H_2(T)$ for 11 East Antarctic coastal stations (linear fit denoted by solid line, r = 0.81). Open circles indicate stations with complete data records (linear fit denoted by broken line, r = 0.98).

strong correlation proves that the amplification of the wave-3 structure also influences the temperatures in the Indian and Atlantic sectors of Antarctica. Owing to the weaker surface inversions at these stations, the effect is not as evident as for the stations presented by van Loon (1967).

The analysis presented above shows that the so called 'depression graveyards', the preferred locations along the Antarctic coastline for disturbances to end their southward journey, cause the longitudinal asymmetry in temperature response to the SAO. These climatological pressure minima are often associated with embayments in the Antarctic topography (Baines & Fraedrich 1989), but a satisfactory explanation has not yet been given. From the maps presented by van Loon (1972) it appears that the position and strength of maxima in the subtropical ridge principally determine the preferred tracks of depressions. This is especially true for the expansion phase towards midwinter, when strong high pressure areas build up over the three southern continents, forcing depressions towards the centres of the ocean basins (Fig. 4).

Another yet unexplained phenomenon is the asymmetry of the expansion phase. Van Loon (1972) and van Loon & Rogers (1984b) showed that the amplification of the wave pattern in autumn is especially pronounced in the Indian and the South Pacific Ocean, but considerably less in the Atlantic sector (Fig. 4). This is possibly related to the shielding effect of the South American continent and the Antarctic Peninsula for depressions to cross to the Weddell Sea. From Fig. 7 we see that this does not negatively influence the amplitude of $H_2(T)$ at, for instance, Halley in relation to other East Antarctic coastal stations. However, the variance explained by $H_2(T)$ is small owing to the much larger annual cycle, reflecting the relatively small importance of the half-yearly temperature wave in this sector.

Time and length scales of the coupling between temperature and pressure

It should be realized that the circumpolar trough and the half-yearly waves of surface pressure and temperature are merely climatological features. Only because the phase of the SAO is so stable (in contrast to that of the yearly cycle) does it clearly show up in the long-year climatologies of pressure and temperature. In reality, the circumpolar trough consists of numerous disturbances that travel south-eastward from middle latitudes towards Antarctica, or that develop in the vicinity of the continent (Jones & Simmonds 1993, King & Turner 1997). A conceptual picture of the SAO could be as follows: in times of maximum meridional temperature gradients between middle and high southern latitudes (the equinoctial months), both the strength of the westerlies and baroclinicity is greatest. This causes disturbances on average to be deeper and travel faster and further south-east towards the continent before they decay. This causes the apparent contraction of the trough that shows up in the climatologies. In the winter and summer months, the atmosphere is less baroclinic and the westerlies are weaker. On average, disturbances therefore do not reach so far southwards and eastward, resulting in an apparent north-westward displacement of the trough.

We showed that the contraction of the trough is associated with rapid cooling rates at Antarctic stations while expansion tends to decrease or even reverse the cooling in autumn. In this section we discuss whether this result also applies on shorter time and length scales, i.e. whether it is valid for each individual event of a depression that passes the Antarctic coast. Wendler & Kodama (1993) presented numerous 3-hourly winter (April–September) observations of pressure vs. temperature for an array of five automatic weather stations (AWS) in Adélie Land, East Antarctica (the location of these stations can be found in Fig. 1). All five stations showed a clear positive correlation between temperature and pressure; correlation coefficients for the linear regressions ranged between 0.22 and 0.25, but were all statistically significant at the 99% confidence level owing to the large amount of data. The linear regressions and the typical range of the data are qualitatively reproduced in Fig. 9. It shows that the coastal station D10 (240 m a.s.l., 5 km from the coast) experiences the largest range of pressure values and the smallest range of temperatures, while the opposite is true for the station on the plateau (Dome C, 3280 m a.s.l., 860 km from the coast). This reflects the presence of a strong surface inversion at the inland stations. All these stations show an unambiguous trend for

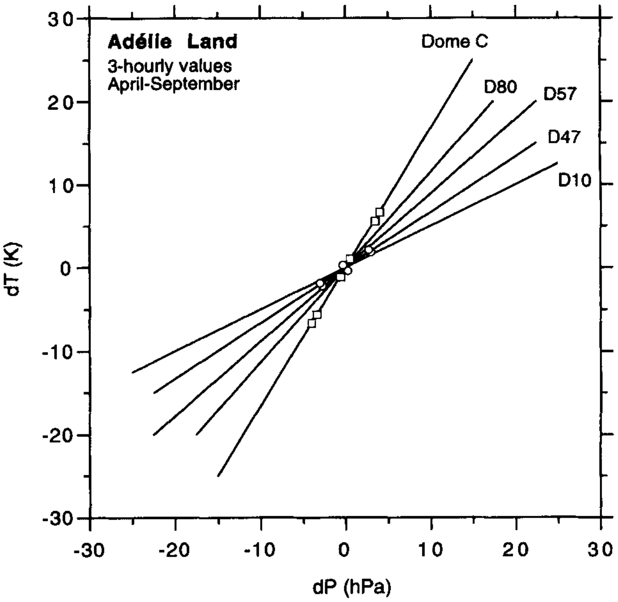

Fig. 9. Qualitative fit to 3-hourly observations of temperature and pressure at 5 AWS in Adélie Land, performed during the period April–September, presented as deviations from the mean (Wendler & Kodama 1993; solid lines). Points represent monthly mean values of $H_2(P)$ vs. $H_2(T)$ at Dumont d'Urville (circles) and Vostok (squares) for the months April–September.

warmer temperatures when the pressure is high, i.e. when the disturbance is likely to be further from the coast. We also included monthly mean values (April–September) of $H_2(P)$ vs. $H_2(T)$ for Dumont d'Urville (white circles) and Vostok (white squares). The high degree of correlation found between the lines (based on the 3-hourly values) and the monthly means suggests that the climatological relation between pressure and temperature that was found in the second harmonic of the long-term means is also robustly present on the (very) short time scales of several hours to days. This intuitively unexpected result means that temperatures on the continent tend to rise more strongly when a low pressure area passes the Antarctic coast at some distance (typical for the summer and winter) compared to the passage of disturbances that 'hug' the coastline (typical for equinoctial months).

Cyclones that move close to the coast are more likely to cause precipitation, as is illustrated by the larger number of precipitation events that occur in the equinoctial months (King & Turner 1997). In combination with the results presented above this indicates that precipitation events in East Antarctica will be biased towards lower-than-average temperatures, at least during winter.

On much longer time and length scales, Rogers & van Loon (1982) showed that the circumpolar westerlies, beside their seasonal oscillation, also vary in a longitudinally coherent way on an interannual time scale. They found that yearly averaged near-surface temperatures at South Pole station were lower in years with strong circumpolar westerlies south of 40°S. This result was later confirmed and generalized for mean Antarctic temperatures by Raper *et al.* (1984). The results that we presented in this paper confirm that changes in the circulation that are associated with the SAO (which is strongly linked to the strength of the circumpolar westerlies) cause temperature changes in Antarctica. However, as was demonstrated in the earlier section "Coupling of pressure and temperatures in coastal East Antarctica", these changes are likely to be a function of longitude. The relation between changes in the SAO and Antarctic temperatures will be discussed in part 2 of this paper.

Summary and conclusions

We discussed the half-yearly waves in pressure and temperature at 27 Antarctic stations, as derived from climatological data (spanning the period 1957–79). The circulation changes brought about by the semi-annual oscillation (SAO) in the Southern Hemisphere modifies the annual temperature cycle at both inland and coastal Antarctic stations. Van Loon (1967) proposed that the amplification of the wave-3 structure in late autumn caused the modification of seasonal cooling in the Pacific sector of Antarctica. We showed that this mechanism is also valid for the Indian and Atlantic sector and on much shorter time scales of hours to days. The strong coupling of temperature and circulation patterns (as derived from the annual pressure cycle) probably has important implications for the interpretation of time series of Antarctic temperatures. This will be the subject of part 2 of this paper.

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