Surface winds in West Antarctica

D.H. BROMWICH

Institute of Polar Studies
Ohio State University
Columbus, Ohio 43210

Knowledge of the surface windfield over the sloping ice fields of Antarctica is understandably limited because of the vast size of the continent, the small number of observing points, and the complexity of the governing physical processes. Recent advances in understanding have come through numerical simulations (Parish 1982, 1984) and analyses of data collected by automatic weather stations (Wendler and Kodama 1985; Allison 1985) and specially constructed towers (Ohata et al. 1985). Recently Parish and Bromwich (1986) have modeled the surface wind regime of the west antarctic ice sheet. Here new observations are reported which support their description of surface winds over that part of Marie Byrd Land facing the Ross Ice Shelf.

Parish and Bromwich (1986) derived the time-averaged pattern of surface air motion over West Antarctica. Input data consisted of terrain slopes determined from the ice-sheet elevation synthesis of Drewry (1983) and plausible estimates of the temperature structure of the lower atmosphere. The steady-state, horizontal equations of motion were solved over a square network of grid points separated by 38 kilometers. At each grid point, the solution provides an estimate of the near-surface wind direction and wind speed. Because the solution is not required to conserve atmospheric mass, the wind-speed estimates are viewed as unreliable; incorporation of mass conservation would vastly increase the complexity of the simulation and is not needed for the first-order description of the wind regime. However, streamlines derived from the field of wind direction estimates are known to describe accurately the pattern of time-averaged near-surface air motions. Furthermore, regions of substantial streamline convergence are known, from comparison with three-dimensional, time-dependent numerical model simulations over limited areas, to contain faster moving and much deeper airstreams. Such inland features are thought to be responsible for coastal regions of anomalously intense katabatic (that is, downslope) winds, such as those found at Cape Denison by Douglas Mawson (Mawson 1915).

The figure presents the derived west antarctic airflow pattern for the summer half-year. Surface air converges into several zones around the ice-sheet periphery; the most prominent of these occurs upslope from the Siple Coast. This strong horizontal lack of homogeneity is now believed to characterize the wind regime over the entire continent and has previously escaped detection because of the sparse observational network.

Parish and Bromwich (1986) analyzed wind observations collected at north, Upstream B and south camps (the figure and table 1) during the 1984–1985 austral summer as part of the Siple Coast glaciology project. Similar observations were obtained at the same locations during the 1985–1986 summer. The hand-held anemometers (wind-speed meters) used at north and south camps in 1985–1986 and at north camp in 1984–1985 were calibrated before and after each field season. All other observations were taken with anemometers provided by the U.S. Navy; unfortunately, it was not possible to calibrate these instruments. However, the very similar results obtained at Upstream B camp during three consecutive summers suggest that this deficiency does not invalidate the results.

Table 1 summarizes all wind observations taken at the temporary camps. Following Parish and Bromwich (1986), resultant wind vectors for the Byrd automatic weather station during each temporary camp occupation have been calculated to gauge the impact of varying observation intervals. It appears from the Byrd data that the 1985–1986 wind conditions during the occupation of south camp were somewhat lighter than during the north camp observation period and significantly lighter than during Upstream B occupation. This leads to a small directional constancy contrast between Upstream B and south camps. Overall, both the 1984–1985 and 1985–1986 data sets show that the directional constancy systematically increases from north to south camps and that the average wind speed at south camp is twice as strong as that at Upstream B.

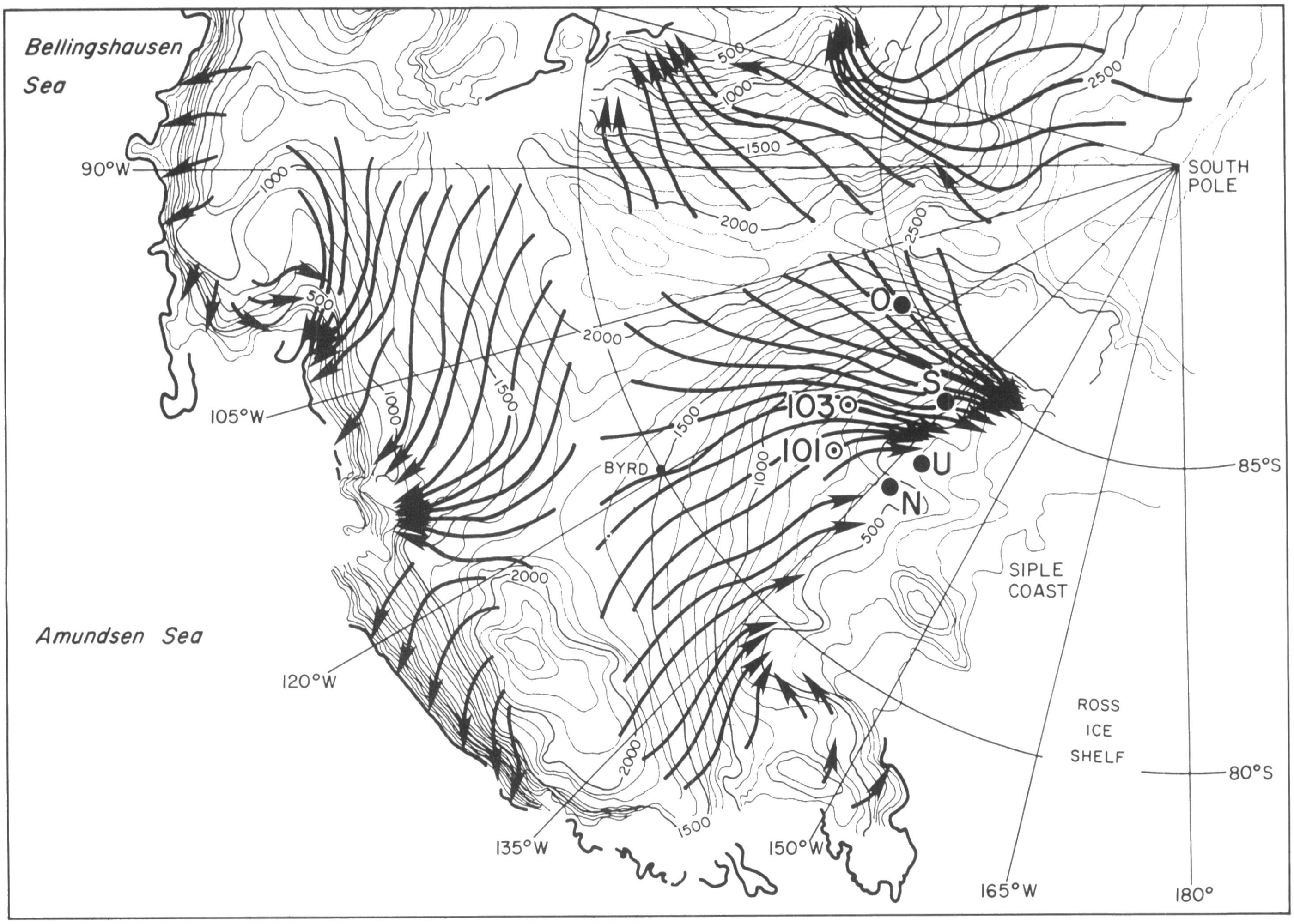
To investigate the spatial structure of the windfield further, resultant winds were also derived for the two periods for which simultaneous observations were collected at all three sites. In table 2 both the 1984–1985 and 1985–1986 data show very clearly that the directional constancy steadily increases from north to south and that speeds at south camp are much higher than those at Upstream B camp. The relative speed difference and directional variability contrast between Upstream B and south camps are more marked for 1985–1986 than 1984–1985; this situation probably arises because of the much lighter winds during the former period.

It is known from observations in East Antarctica that katabatic confluence zones are characterized by enhanced wind speeds and high directional constancies. Taken together, tables 1 and 2 indicate that south camp resides in such a region, and that on average, the katabatic confluence zones's northern edge is located somewhere between south camp and Upstream B. The higher constancy at Upstream B than at north camp probably arises because Upstream B sometimes is embedded within the confluence zone. These findings strongly support the summer windfield simulation of Parish and Bromwich (1986) (see the figure). In winter, the airflow pattern should be similar, but much higher wind speeds are expected.

Circumstantial evidence is available to locate the northern edge of the confluence zone upslope from the temporary camps. Numerous geoceiver stations were briefly occupied in the 1985–1986 summer between Siple Coast and the ice divide near 100°W longitude. At 10 sites between and including north camp and station 101 (figure) deep, soft snow was observed. This zone of minimal surface wind disturbance may arise because most of the surface airflow is deflected around the ridge linking the two locations as suggested by the figure. Station 103, south camp, and all 24 sites to the south and southeast have a compacted and wind-swept surface. All of the above observations indicate that the northern boundary of the confluence zone is adjacent to, but south of, a line joining station 101 to Upstream B camp; again this is consistent with the simulation in the figure. Few stations were occupied to the east and north of 101. As a result the northern boundary cannot be extrapolated farther upslope on the basis of observational evidence.

Finally, it should be mentioned that summer parties occupying temporary camps in and around the Ohio Range since the early 1960s (including 1985–1986) have reported that surface wind speeds are substantially stronger than at Byrd station; however, reliable measurements to substantiate these impressions are not available.

In summary, I can state that all available summer observations [including sastrugi orientations which were analyzed by Parish



Summer surface airflow over the west antarctic ice sheet, after Parish and Bromwich (1986). Heavy lines are derived streamlines which show the time-averaged pattern of surface winds. Thin lines are terrain contours in meters above sea level. The filled circles identify temporary camps occupied during the 1985–1986 austral summer: "N" denotes north camp, "U" indicates Upstream B camp, "S" labels south camp; and "O" locates the Ohio Range camp. The open circles show geoceiver stations.

Table 1. Summer surface wind data from the vicinity of the Siple Coast confluence zone

	Temporary station		Byrd automatic weather station for same interval as temporary station		Speed ration
Period of record at temporary location	Resultant wind (in meters per second)	Directional constancy	Resultant wind (in meters per second)	Directional constancy	(temporary station divided by Byrd)
North camp					
10 Dec 84 to 8 Jan 85	81° 1.7	0.55	20° 4.6	0.82	0.54
18 Dec 85 to 19 Jan 86	47° 0.8	0.45	10° 3.7	0.80	0.38
Upstream B					
10 Nov 83 to 25 Jan 84	69° 2.3	0.77	15° 4.1	0.73	0.53
1 Dec 84 to 18 Jan 85	95° 2.5	0.78	13° 4.1	0.77	0.61
15 Nov 85 to 19 Jan 86	82° 2.4	0.88	17° 4.5	0.84	0.52
South camp					
21 Dec 84 to 7 Jan 85	87° 6.4	0.97	8° 4.5	0.86	1.25
20 Dec 85 to 11 Jan 86	99° 3.9	0.90	0° 3.3	0.81	1.07

Note: Directional constancy equals the vector average wind speed divided by the speed averaged without regard to direction; values near zero usually mean that winds show no directional preference and values near 1 indicate that the direction hardly changes. Because of a coding mistake, the 1983-1984 and 1985-1984 resultant wind directions given by Parish and Bromwich (1986) for the Byrd automatic weather station are in error.

Table 2. Simultaneous surface wind statistics for Siple Coast stations

Temporary location	21 Dec 84 to 7 Jan 85 Resultant wind (in meters per second)	Directional constancy	Mean speed (in meters per second	20 Dec 85 to 11 Jan 86 Resultant wind (in meters per second	Directional constancy	Mean speed (in meters per second)
North camp	66° 1.3	0.41	3.2	13° 0.4	0.25	1.6
Upstream B	92° 2.6	0.74	3.5	87° 1.0	0.59	1.7
South camp	87° 6.4	0.97	6.6	99° 3.9	0.90	4.3

and Bromwich (1986) but not discussed here] show that the simulated Siple Coast confluence zone is correctly located and is a region of enhanced surface wind speeds.

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Boundary layer meteorology of the western Ross Sea

D.H. BROMWICH

Institute of Polar Studies
Ohio State University
Columbus, Ohio 43210

Franklin Island is situated in the western Ross Sea about 150 kilometers to the east of the nearest part of the Transantarctic Mountains (figure 1). An automatic weather station (AWS) on top of the island (274 meters above sea level) has operated continuously since 23 January 1982. Wind readings show that the direction is rather variable (Savage and Stearns 1985). One might conclude that this arises because the atmospheric pressure gradients, which usually determine the surface wind direction over the ocean, have no preferred orientation in this area. However, pressure contours on climatic maps (Taljaard et al. 1969) and on individual weather charts (Kurtz and Bromwich 1983) support predominantly southerly surface airflow in the western Ross Sea.

When the surface wind direction at Franklin Island is divided into eight classes (northeast, east, southeast etc.), it is found that on average, winds come from the west plus northwest and from the southeast plus south about 70 percent of the time. If wind directions were completely random, these four classes should account for about 50 percent of the observations. In addition, when the frequency of west plus northwest winds is lower for a particular month, the frequency of southwest plus south winds is generally higher and vice versa. It is this predominant bimodal directional distribution which accounts for the very low directional constancies (about 0.1) calculated by Savage and Stearns (1985). Directional constancy is the ratio of the vector-average wind speed to the scalar-average speed; it measures directional variability and ranges from zero for randomly oriented winds to one for unidirectional airflow.

Bromwich and Kurtz (1982) and Bromwich (1985) have shown that very strong katabatic (i.e., downslope) winds from the Victoria Land plateau are invariably present along the western shore of Terra Nova Bay. This area lies about 190 kilometers to the northwest of Franklin Island. That these katabatic winds usually blow for at least 34 kilometers across flat terrain is a notable anomaly (Bromwich and Kurtz 1984); such airstreams are usually observed to dissipate completely within 10–20 kilometers of the east antarctic coastal slopes (e.g., Weller 1969). Here, it is proposed that the Terra Nova Bay katabatic airflow often continues for at least 190 kilometers offshore and gener-