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Complexity of the climatic regime over the Lambert Glacier basin of the East Antarctic ice sheet: firn-core evidences

Deep ice-core records from Antarctica and Greenland indicate rather similar climate histories over long time-scales (Bender and others, 1994; Jouzel, 1994; Kreutz and others, 1997), but over decadal to centennial scales the records from different regions of the Antarctic ice sheet show large differences. For instance, although increasing accumulation rates have been reported for many sites (Pourchet and others, 1983; Peel and Mulvaney, 1988; Morgan and others, 1991; Mosley-Thompson and others, 1995), several sites show decreasing trends (Graf and others, 1990; Kameda and others, 1990; Bindschadler and others, 1993; Isaksson and Karlén, 1994; Ren and others, 1999). A similar situation is apparent in isotope temperature records (Isaksson and others, 1996; Ren and others, 1999). Here, we discuss firn-core records of accumulation and isotopic trends since 1940 deduced from the top sections of four cores drilled on the west and east sides of the Lambert Glacier basin (LGB; Fig. 1).

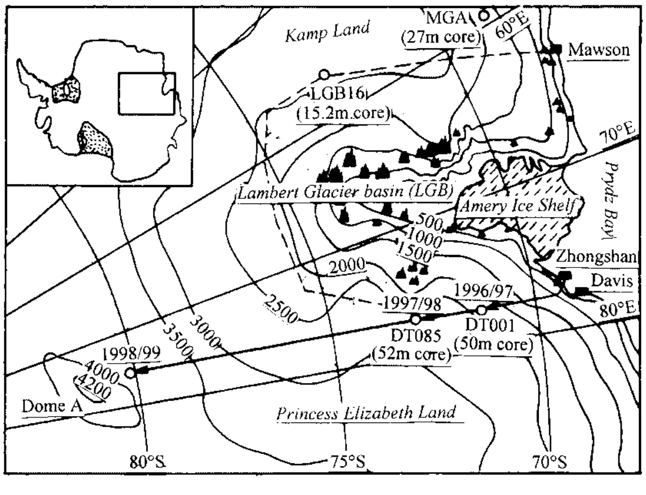

Fig. 1. Location map of the firn cores (empty circles) drilled over the LGB. The solid line is the traverse route of the Chinese National Antarctic Research Expedition (CHINARE), and the dashed line is the route of the Australian National Antarctic Research Expedition (ANARE).

During the 1992 joint Australian–Chinese over-snow traverse on the west side of the LGB, we drilled two firn cores, MGA (68°39′ S, 60°15′ E; 1830 m a.s.l.) and LGB16 (72°49′ S, 57°20′ E; 2689 m a.s.l.), 27 and 15 m long, respectively. These cores were dated stratigraphically using isotopic profiles, electrical conductivity measurements, stratigraphy and known accumulation rates. A series of firn cores were drilled adjacent to each of the two sites to check the precision of the dating (Ren and others, 1999). Between 1996 and 1998, a second pair of firn cores were extracted, DT001 (71°51′ S, 77°55′ E; 2325 m a.s.l.) and DT085 (73°22′ S, 77°01′ E; 2577 m a.s.l.), 50 and 52 m long, respectively. $\delta^{18}O$ and chemical series (Cl^-, Na^+ and NO_3^-) were used to cross-date these with a precision believed to be ±2 years for the upper 20 m (Qin and others, 2000). Only top sections of these latter two cores were used in order to match roughly

Table 1. Comparison of decadal accumulation and $\delta^{18}O$ values in the firn cores at MGA, LGB16, DT001 and DT085; the rates of change in accumulation and $\delta^{18}O$ since 1940 are also listed

Firn core and time period	*Mean accumulation rate*		*Mean $\delta^{18}O$*	
		Deviation from average		*Deviation from average*
	kg m^{-2} a^{-1}	%	‰, V-SMOW*	‰
MGA				
1940–49	345.8	+24.5	−35.73	+0.13
1950–59	296.1	+6.6	−35.93	−0.07
1960–69	275.6	−0.7	−36.87	−1.01
1970–79	249.8	−10.0	−35.02	+0.84
1980–89	246.5	−11.2	−35.76	+0.10
1990–92	238.7		−35.16	
1940–92	277.7	−2.4 kg m^{-2} a^{-1} (rate of change)	−35.86	+0.015‰ a^{-1} (rate of change)
LGB16				
1940–49	148.7	+20.9	−43.80	+0.53
1950–59	112.6	−8.5	−44.51	−0.18
1960–69	136.4	+10.9	−43.94	+0.39
1970–79	106.0	−13.7	−45.55	−1.22
1980–89	106.1	−13.7	−44.83	−0.50
1990–92	140.3		−42.85	
1940–92	123.0	−0.7 kg m^{-2} a^{-1} (rate of change)	−44.33	−0.011‰ a^{-1} (rate of change)
DT001				
1940–49	135.2	+2.8	−38.89	−0.76
1950–59	131.0	−0.3	−37.73	+0.43
1960–69	92.5	−70.0	−38.67	−0.54
1970–79	142.3	+8.0	−38.44	−0.31
1980–89	154.6	+17.6	−37.35	+0.78
1990–96	133.7	+1.7	−37.57	+0.56
1940–96	131.4	+0.3 kg m^{-2} a^{-1} (rate of change)	−38.13	+0.025‰ a^{-1} (rate of change)
DT085				
1940–49	151.6	−1.1	−41.15	−0.13
1950–59	155.8	+1.6	−42.09	−1.07
1960–69	93.8	−38.8	−39.98	+1.04
1970–79	149.0	−2.8	−41.43	−0.41
1980–89	178.8	+16.6	−40.60	+0.42
1990–97	160.0	+4.4	−40.62	+0.40
1940–97	153.3	+1.2 kg m^{-2} a^{-1} (rate of change)	−41.02	+0.017‰ a^{-1} (rate of change)

* Vienna Standard Mean Ocean Water.

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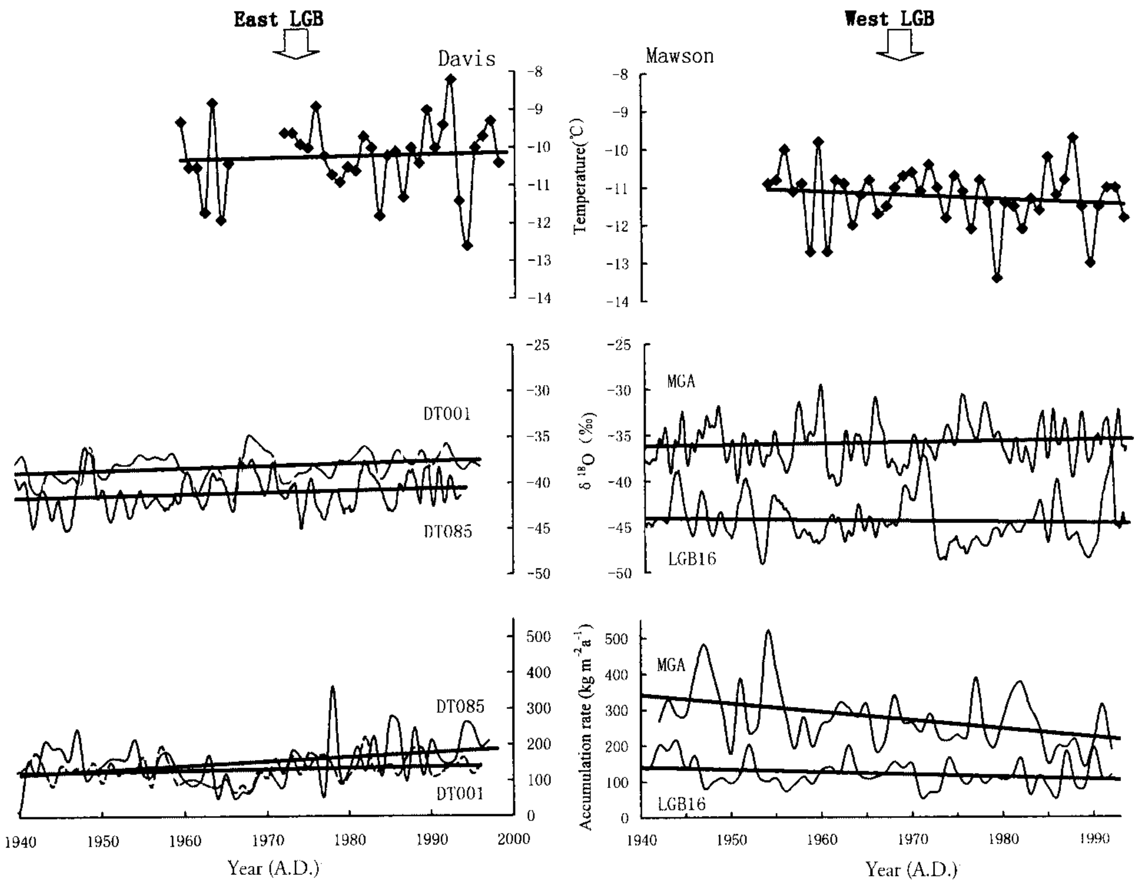

Fig. 2. Variations of the seven-point smoothed $\delta^{18}O$ and the annual accumulation rates at DT001, DT085, MGA and LGB16 during the period 1940–1990s. Instrumental surface air temperature at Davis and Mawson is also shown. The regression lines are all significant at $p = 0.05$ confidence level, with coefficient values for DT001, DT085, MGA and LGB16, respectively, of $r = 0.28, 0.14, 0.11, 0.10$ for $\delta^{18}O$ trends, and $r = 0.20, 0.36, 0.43$ and 0.30 for accumulation rates.

the time period corresponding with that of the MGA and LGB16 cores. The four cores were all re-sampled every 3 cm in the laboratory.

The annual variations of accumulation and the seven-point smoothed $\delta^{18}O$ profiles for the four cores are shown in Figure 2. The most remarkable feature is that both the isotopic temperature and the accumulation rate on the east side of the LGB have increased since 1940, while on the west side they have not. The accumulation rates at MGA and LGB16 display decreasing trends, with the rates of change respectively −2.4 and −0.7 kg m^{-2} a^{-1}, but with no obvious change in $\delta^{18}O$.

We suggest that the reason for the differences between the two sides of the LGB is that on the east side large amounts of moisture are advected inland, but on the west side the trajectory of the air mass is not directly inland from the coast, which reduces the link between temperature and accumulation rate (Qin and others, 2000). We note that there is a similar pattern of fluctuation of accumulation rates and $\delta^{18}O$ between DT001 and DT085, but not between MGA and LGB16. Again, different circulation patterns between the two sides of the catchment may be responsible, or alternatively there may be post-depositional modification of the records on the west side. We have noticed the different spatial distribution of accumulation rates between the two sides of the basin (Qin and others, 2000), and previous studies pointing out this difference have attributed it to the "rain-shadow" effect of the prevailing upper-level winds (Allison, 1979; Higham and others, 1997).

The decadal changes of accumulation rates and $\delta^{18}O$ in the four cores are presented in Table 1. An obvious decrease of accumulation rate and $\delta^{18}O$ occurred during the 1960s in the two cores from the east side, which was not observed on the west side. Accumulation at DT001 and DT085 has clearly increased since 1970 (0–17%), whereas for MGA and LGB16 it has decreased rapidly (10–14%). An increase of $\delta^{18}O$ in the range 0–0.8‰ has occurred since 1970 at DT001 and DT085, while the fluctuations are much more complicated at MGA and LGB16.

Instrumental records at Davis and Mawson meteorological stations display the same difference in air temperature between the east and west sides of the LGB. Mawson is one of the few stations showing a temperature decrease in the past half-century (Jones, 1995). Jacka and Budd (1998), summarizing the temperature and sea-ice-extent changes in Antarctica and the Southern Ocean, found that the coastal regions of the two sides have converse trends of temperature and sea-ice extent. Our study therefore supports the earlier suggestion that cooling over the west side of the LGB may be affected by increased airflow from the cold interior (Jones and Wigley, 1988; Jacka and Budd, 1991).

The LGB system occupies almost 10^6 km^2 and drains around one-eighth of the East Antarctic ice sheet (Higham and others, 1997). This study shows that the drainage basin breaks the smooth topography of the East Antarctic ice sheet into two different climatic regimes, though the two sides (DT001 and DT085 vs MGA and LGB16) are only 500–700 km apart. We believe that the records from the east side reflect climatic variations related to the south Indian Ocean, whereas those from the west side are probably much more complicated and caution should be exercised when relating them to regional and global climate change.

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Laboratory of Ice Core and Cold Regions Environment Research Institute, Chinese Academy of Sciences, Lanzhou, Gansu 730000, China

XIAO CUNDE
REN JIAWEN
QIN DAHE
LI ZHONGQIN
SUN WEIZHEN

Antarctic CRC and Australia Antarctic Division, Box 252-80, Hobart, Tasmania 7001, Australia

IAN ALLISON

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