

VI:A;1 Micro-and Meso Climate Studies of Antarctica's Iceshield

Subsections:

- 1.1 How the 'Natick Program' was Initiated
- 1.2 First Phase of Antarctic Studies.
- 1.3 Entr'acte: A Natick Program of Tropical Boundary-Layer Research.
- 1.4 Resuming Climate Studies in Antarctica.
- 1.5 Departmental Activity and Research Results at Plateau Station
- 1.6 Departmental Research on Polar Climates in a New Era.
- 1.7 Epilog
- 1.8 Classified Bibliography
- 1.9 Samples of Graphs illustrating significant Results

1.1 How the 'Natick Program' was Initiated. In late 1958, just when I began to feel at home in my office at Science Hall, a telephone call by the Chief Scientist of the U.S. Weather Bureau, Dr. Harry Wexler, initiated more than two decades of researching the micro and mesoclimate of polar iceshields. It turned out to be quite influential for staff and students at the UW Dept of Meteorology.

At the end of 1958 the IGY, the *International Geophysical Year*, was terminated. IUGG, the 'International Union of Geophysic and Geodesy' had organized the IGY as a period of world-wide intensified observations. Precedents were the *International Polar Years* of 1882/83 and 1932/33; a third had been planned for 1982/83. In the early 1950s an IUGG committee decided that progress in observing techniques called for a *global* international effort and 25, not 50 yrs after the last Polar Year. Thus, the IGY had begun in July 1956. As research assistant at the U. of Leipzig, I had used the intensified data from both Polar Years for evaluating macro-diffusivity of north-hemispheric circulations as factor of heat transfer from low to high latitudes [Sec.1.8A, 1935 and 1939]. Dr. Wexler had been interested in that study. Moreover he was familiar with my work in micrometeorology culminating with the the documentation of the low-level jetstream as result my boundary-layer experiment in Nebraska's prairie country . In 1960 Dr. Wexler inaugurated a US Weather Bureau Project with an east-to-west array of 12 rawin stations, from Little Rock Arkansas to Amarillo, Texas. The zonal array of 'Wexler's Low-Level Jetstream Experiment' established a counter part to Gregg's meridional array of aerological stations from Texas via Nebraska to North

Dakota. Results of both help to interpret data discussed in Section 1. 5; [Sec. 1.8 D : Gregg, 1922, Hoecker, 1965; Sec. 1.8A, 1976 and 1990].

Wexler's call in 1958 was on behalf of Paul Dalrymple of the Polar and Mountain Laboratories, U.S Army Quartermaster Laboratories, Natick, Mass. Paul was in Wexler's office with a set of micrometeorological data that he had obtained during both IGY winters in Antarctica. Paul, a pioneer of wind chill studies, had gotten his Ph.D. in geography and had been competent to make the measurements. But for data evaluation he had come to the Weather Bureau to ask for meteorological assistance. Wexler wanted to know if I would be willing to cooperate. I replied that I would like to see Dr. Dalrymple in Madison.

A few days later he appeared in Science Hall. Paul had labored 12 months at *Little America V* [78 S] and without break the following 12 months at *Amundsen-Scott Station* [90 S]. He brought with him graphs and strip charts representing simultaneous profiles of temperature and windspeed along two masts with sensors at the customary logarithmic spacing, i.e., 8, 4, 2, 1 and 0.5 m. I was impressed by the quality as well as the quantity of data and agreed to cooperate. Paul declined to stay in Madison. He said he needed 'firstly to renew acquaintances with his Massachusetts based family' and that there were already 'too many IGY-penguins' at Madison referring to Prof. Woollard's geophysicists. The Natick Laboratories offered adequate office space, assistance by technical personel, and funds for my travel between Madison and Natick.

1.2 First Phase of Antarctic Studies. It happened that since the mid 1950s my family and I used to spend summer vacations at an old farm in Newfane, Vermont. The house had been bought as summer retreat by my wife's friend Ilse Wolfsberg-Hochwald; the two had been together at grammar and highschool in Plauen, Saxony; later they shared university years at Munich and Leipzig. From 1959 to 1963 our summer vacations got a new twist. I spent weekends with my family in Vermont, and midweek to work in Massachusetts with Paul and Miss Wollaston of the Natick technical staff.

Results from *Little America V* and *Amundsen-Scott* were published in 1963 as Natick Technical Report and in final form by the American Geophysical Union [Sec. 1.8A, 1966]. Highlights are representative monthly values for the surface energy budget at antarctic snow surfaces, extension of surface-layer profile structure theory to cases of extreme thermal stratification and an explanation of 'sudden

warmings' during the winter night. We supplemented the conventional theory of low-level wind and temperature profile structure to include strong inversion cases [Sec.1.8 A, 1979]. We documented that the gentle terrain slope between 90 S and the highlands NE to ENE of the pole has two different effects on wind structure in the boundary layer. Dominating at about 600 m above the surface are NW to NNW winds. This suggested that the prevailing direction is due to the thermal wind parallel to the contour lines; [see Sec. 1.9, p.1] Dominating in the lowest 10 m were down-slope or katabatic air motion; Paul's recordings established the wind and temperature profile structure of these gentle breezes; [Sec.1.8A, 1966 and 1979].

Near the antarctic circle the sun's elevation varies harmonically between zero at the June solstice and the angle of ecliptic at the December solstice; this produces temperature variation with a well-rounded maximum as well as a well-rounded minimum six months later. At 90 S the insolation varies as the positive arc of a sine-curve from September to March and is 'flatly' zero from March to September. The temperature has a maximum in December but a very low value is reached in March about only 3.5 months later and fails to drop lower during the following 8.5 months. Such 'flatness' of winter temperature variation was discovered at high polar latitudes during the 1882/83 Polar Year; Hann named it "kernloser Winter" ['coreless winter'; Sec.1.8 D , 1911]. The IGY-data from 90 S document the extreme of 'coreless winters'. We made this feature comprehensible by referring to the annual balance of snow heating. Conduction downward during 4 months must be upward during 8 months. This requires that the difference of T between the depth of vanishing day-to-day variation [$z' \approx 0.5$ m] and the depth of vanishing annual variation [$Z' \approx 8$ m] is large-positive during 4 months and small-negative during 8 months. Thus, the shape and bundeling of tautochrones of monthly snow temperature T between z' and Z' and the duration of sunless periods at the South Pole and at Maudheim serve to explain the extreme of coreless winters at 90 S; see Sec. 1.9 , page 2.

The 'Natick Program' began to show impacts at UW's Meteorology Dept. Prof. Schwerdtfeger joined me in a general study of winds in Antarctica; [Sec.1.8A, 1967; Sec. 1.8 C : 1984]. Among my graduate students Walter Dabberdt was the first to use data from the Natick Program for his Ph.D. thesis; [Sec.1.8B]

1.3 Entr'acte : A Natick Program of Tropical Boundary-Layer Research. Paul Dalrymple contacted me again in 1961. On behalf of the Quartermaster Laboratories

he asked me to assist in the planning of a micrometeorological program in a vastly different environment, the tropical dry evergreen forest of Southeast Asia; I agreed and I inspected a prospective site on the northeast edge of the Khorat Plateau in Thailand. I suggested instrument towers that were at least 8 m above the average canopy level. Paul wanted assistance by one of my graduate students. Jo Zabransky volunteered and worked with the Natick team one year at the station. In 1963 the program had matured, and following Paul's invitation I revisited the site. Temperature, windspeed and direction were recorded on magnetic tape with sensors on two 40 m towers, one in the forest and one in an artificial clearing. I enjoyed the memorable view of the forest from the 40 m-level. Zabransky became the second of my graduate students to use data from a Natick Program for his Ph.D. thesis [Sec. 1.8B]

1.4 Resuming Climate Studies in Antarctica. In 1963 Dr.A.P. Crary, Chief Scientist, Office of Antarctic Programs of the National Science Foundation announced a plan to locate a wintering station from Dec. 1965 to Feb. 1968 in the most remote highlands of East Antarctica, at about 80 S and 25 E and 12,000 feet elevation. On behalf of the Natick Laboratories Dr. Dalrymple offered for evaluation of microclimatic conditions at Plateau Station one tower and the recording system used in Thailand. Crary accepted.

Once more Paul asked for my advice. I knew that the tower had landings every four meters. I expected that the lower atmosphere at the site will be relatively stagnant which means extreme density stratification causing terrestrial refraction visible as extraordinary distorting of distant objects. Hence I proposed two particular aspects for the Natick Program. Firstly, installation of sensors for air temperature, wind speed and direction at 0.5, 1, 2 m and all landings [i.e., 4; 8; 12; 16; 20; 24; 28; 32 m] instead of logarithmic spacing. Secondly, tele-photographic documentation of terrestrial refraction distortings using 'slanting targets' at 3 distances. This particular method was part of my micro-meteorology program at the UW Meteorology Department. It used telephoto-lens photography across ice-covered Lake Mendota by my graduate student J. Sparkman.

1.5 Departmental Activity at Plateau Station. The selected site was at 79.2 S, 3,624 m elevation, about 800 m above and 1,700 km NE of *Amundsen-Scott*. U.S.Navy 'Seabees' built in Dec.1965 the shelters and erected a 32-m tower using 8

sections from the Thailand Project. The accommodations were for eight wintering personnel at Plateau Station. Three were scientists: one for the Natick Program and the other for geomagnetics and weather studies. In Feb. 1966 Dr. Strohschein from the Natick Laboratories instrumented the tower and installed the recording equipment. Dr. Dalrymple had arranged that volunteers for the Natick Program should be briefed by me for use of the 'slanting target' method and that I was given priority for the evaluation of telephoto documentation of optical refraction. For the Natick Program Paul wished to give preference to volunteers from the UW Meteorology Department.

Selected for the Natick Program during the 1966 austral winter was Marty Sponholz. In 1964 Marty was a M.S. student of Prof. Deland; after Prof. Deland's move to NYU, I continued as Marty's advisor for his thesis work on wind structure 50 to 150 m above an urban area. Marty got the MS degree in June '65. For Plateau Station he designed a snow-accumulation project using a network of bamboo stakes. According to my briefing Marty erected 'slanting targets' by three 10-ft bamboo poles inclined by 45° at distances of 1000, 2000, and 3000 ft from the shelter. On return to Madison Marty submitted a series of photographs. However, all were made during the sunlit-period and showed optical distortings similar to what we knew from Sparkman's photos across Lake Mendota in winter time.

Selected for the Natick Program during the 1967 austral winter was Dr. Michael Kuhn, research assistant of Prof. Hoinkes, U. of Innsbruck, Austria. Mike was well prepared to take care of the tower instruments and the automatic recordings. At the briefing in Madison I showed him Marty's photos and proposed to install X-Mas outdoor lights on the slanted bamboo poles and concentrate on photographing during the sunless period.

Mike returned home via Madison and left for my evaluation his photos of the three 'lighted slanted targets' showing really phantastic optical distortings. Two extremes were previously not discussed in textbooks of Meteorological Optics. I named them 'inverted' and 'upright' ghosts. They are at the ends of the classical scale that ranges from superior mirage via stooping and looming to neutral, then via sinking and towering to inferior mirage. The 'classical phenoma' require uniform temperature profiles ranging from monotonically height-decreasing inversion via isothermy to monotonically height-decreasing lapse; [see page 3 of Section 1.9] The 'ghosts' are due to non-uniform temperature profiles. Specifically

at Plateau Station, when a temperature extreme occurred at mid-elevation of the targets $z=1.5$ m. The 'upright ghost' is *towering above stooping* & the 'inverted ghost' is *stooping above towering* due to an 'elevated' T-minimum & maximum; [see page 3 of Sec. 1.9]. For his own evaluation Mike Kuhn had fascinating color photos of astronomical refraction during the sun's apparent 'meandering' above and below the horizon while circling around it at begin as well as end of the polar night.

Selected for the Natick Program during the 1968 austral winter was one of Schwerdtfeger's MS-students, Tom Frostman. Plateau Station began to be plagued with difficulties. In October, the electrically heated insulation at the fuel-line junction caught fire; that situation was quickly brought under control. However, damages at the equipment could not be repaired which caused a premature end to micrometeorology recordings.

The three-year scientific program at Plateau was terminated and the station de-activated on Jan. 29, 1969. The tower was left standing. Snow fall data suggest accumulation of the order of 0.1 m per year. Thus, the tower might be buried about 320 years after the station was abandoned. Presently, in 2004, seven sections could be standing. During the three years of occupation at Plateau Station the lowest air temperature was $-86.4^{\circ}\text{C} = -124.5^{\circ}\text{F}$ on 20 July 1968.

1.5 Results of Plateau Station Micrometeorology. The American Geophysical Union devoted Vol. 25 of *Antarctic Res. Series* to the documentaton of Plateau Station data. Temperature, wind speed and direction profiles of the 'Natick Program' were analysed in cooperation with Mike Kuhn and A. Riordan, one of my graduate students. We began by evaluating hourly averages during the 'dark season' [Sec.1.8 A, 1977]. *Inversion strength*, defined by $\Delta T = T(32\text{ m})$ minus $T(0.5\text{ m})$, ranged from 3.5°C for *Class 1*, to 21°C for *Class 8*. Direction change ΔD and speed increase Δv from $z = 0.5$ to $z = 32$ m was controlled by inversion strength. Wind turning was always *contra-solem*. Our statistics yielded for *Class 1*: $\Delta D = 5$ deg, $\Delta v = 9$ m/s and for *Class 8*.: $\Delta D = 50$ deg, $\Delta v = 3$ m/s; such turning and a speed maximum near 16 m produced a nearly complete Ekman spiral. *Richardson Number* effects previously established at *Little America V* and *Amundsen-Scott* were confirmed. Profiles of *Deacon Number* for strong inversion show that the level of inflection occurred most frequently around 6 m. This is significantly higher than the 2.5 m at the South Pole; [see Sec.1.9, page 4]

During the sunlit months the structure of the 32 m layer is controlled by the surface energy budget. There are significant diurnal variations. Most interestingly, the 'wind spiral shape' changed regularly from *small ΔD and Δv* near noon to *wide ΔD and large Δv* near midnight. This corresponds to diurnal control of Ekman spiral structure found at the *Great Plains Turbulence Field Program*, as well as at the *Wexler Experiment* [Sec. 1.8A : 1990; or, 1.8D : Hoecker]. Thus, the nocturnal wind extreme at 16 m at Plateau station represents a *miniature low-level jet* in a boundary layer of less than 50 m thickness while above the Great Plains the jet layer of more than 500 m occurs below the highest and lowest elevation of the terrain slope just as Plateau Station is lower than Antarctica's highest elevation. The miniature low-level jet is furthered by the fact that the diurnal temperature amplitude is zero at the pole but 10 deg C at Plateau Station; [see Sec. 1.9, page 5].

In 1970 Dr. L. Quam of the American Association for the Advancement of Science invited a contribution to a special volume on *Research in the Antarctic*. I choose a title that expressed my growing conviction that the climate of Antarctica is regulated by the uniform curvature of this gigantic snow mound; [Sec. 1.8 A ;; 1972]. I highlighted our study of optical refraction anomalies at Plateau Station and the explanation of the coreless winters by tautochrones of monthly snow temperatures. This provided a final closure of Dr. Siple's puzzlement [Sec. 1.8 D]. Siple had arrived at the Pole in December 1956 when the air emperature was around -22 C. By digging into the snow he measured -53 C at 6 m depth. Based on his experience during wintering at the series of Byrd stations near the antarctic circle, he assumed crrectly that -53 C was close to the annual mean and expected that the annual minimum should reach an extreme of $-53 - (53 - 22) = -84$ C. Actually, the minmum did not sink below -60 C, an unexpected blessing of the 'coreless winter'.

A counterpart is the 'coreless summer' of the ice-covered Arctic Ocean. It was documented by Nansen [Sec.1.8 D, 1897] on the 'Fram' ice-locked at 75 N, 130 E, then drifting to 86 N and released to the Atlantic near 78 N, 10 E. The winter minimum is pronounced but moderated to -10 to -15 C because the pack is about 6 m thick and its bottom remains at the freezing point of sea water. In Spring the surface temperature rises but remains capped at the melting point until Fall. This is thru for pieces of the shelf on Ellesmere Island floating on the West Arctic Ocean. However on the 50 m thick ice the winter temperature is 10 to 15 C lower than on the pack which exaggerates the 'coreless summer'. This was documented 1952/53 on an 'Ice Island T3' near 86 N and 85 W; [Sec. 1.8 A ;; 1958].

1.6 Departmental Research on Polar Climates in a New Era. The International Polar Years of 1882/83 and 1932/33 and the International Geophysical Year of 1956/58 are climaxing three eras of polar research. Clearly distinctive was the mode of travel. Researchers went by sailing vessel, steamship and dog, pony, or hand sled during the first era; by airship, monoplane, flying boat and motor sled propelled by airscrews during the second era; by atom-powered submarine and icebreaker, jet propelled aircraft for passengers and heavy load, and snow mobile during the third era. Common was the establishment of man-occupied year-round stations in normally not habitable regions.

A new era began around 1980 with the development and field testing of Automatic Weather Stations [AWS] in polar regions. Measured at the basic AWS unit are air temperature, wind speed and direction at a nominal height of 3 m above the ground. To establish an AWS or a network of AWS 's requires transportation, usually by small aircraft, helicopter, or snowmobile from a base station. The most significant improvement is the use of the Data Collection System on board of polar-orbiting satellites maintained by the National Oceanic and Atmospheric Administration. Year-round the recordings are nearly instantaneously available at the home of the institution that monitors an AWS program.

At the UW Department of Meteorology, Charles Stearns became the leader of academic studies using AWS-networks in Antarctica and Greenland sponsored by the National Science Foundation's Office of Polar Programs. [Sect. 1.8 C, Stearns et al, 1993; Stearns et al, 1997; Schwerdtfeger, 1984]

1.7 Epilog. On my retirement at UW in 1980 I received a letter by Paul Dalrymple from which I may extract the following :

At the National Academy of Sciences 100th Anniversary Symposium at UCLA in Aug.1963, the late Dr.Herfried Hoinkes, U. of Innsbruck, Austria, referred to our analyses as the most remarkable contribution to glacial micrometeorology during the IGY.

The 'Natick Program' began on a personal basis. Its effect on the UW Department of Meteorology had grown with time. There were effects in foreign countries.

Melbourne, Australia, requested advice concerning evaluation of data obtained at one of their wintering stations. New Zealand wanted one of my graduate students for wintering in the 'Dry Valley Region'. Allen Riordan volunteered. The title of his Ph.D. dissertation [Sec. 1.8 B, 1977] is self explanatory.

At the new era in full swing I want to remember the men who endured the hardship of wintering in Antarctica such as Paul Dalrymple, Marty Sponholz, Michael Kuhn and their helpers. Marty was not afraid to let us know how life was as team mate of a group isolated from civilisation during the long polar night. He likens their isolation to that of *magi*, the members of the Zoroastrian priestly caste of the ancient Persians with their eternal struggle between good and evil; [Sec. 1.8 C Sponholz, 1980]

1.8 Classified Bibliography

- A. Biobibliography [by years] including papers co-authored by H.L
 - B. UW Ph.D. theses generated by this program
 - C. Departmental Publications related to this program
 - D. List of referenced titles in general literature
 - A. Biobibliography [by years] including papers co-authored by H.L
- 1935: Luftmassen and Energie Austausch zwischen nied. und hoh. Breiten d. Nordhalbkugel..Polarjahr 1932/33;Beitr. Physik Atmosph. Vol. 23, 45-75
- 1939: Chapter 12 in *Atmosphaerische Turbulenz*, , Akad.Verl.Ges.,Leipzig, 288 pp
- 1958: Chapter 2, Section 1, 'Temperature' in *Handbook of Geophysics* ;AF Cambridge Res. Center; Reprinted 1960 by Macmillan New York; (with D.A. Haugen)
- 1966: A case study of katabatic flow on the south polar plateau
Antarctic Res.Series AGU, 9, 1-11
- 1966: South Pole micrometeorology program (with P. Dalrymple & S. Wollaston).
Antarctic Res.Series AGU, 9, 13 - 57
- 1967: Dynamics of the surface-wind regime over the interior of Antarctica(with W. Schwerdtfeger), *Antarctic J.United States*, 12, 155-158
- 1972: Antarctic atmosphere as a test tube for meteorological theories
Amer.Associ. for the Advancement of Science Publ. No. 93, 443 - 475.
- 1976: Small to Large-Scale Features of Boundary Layer Structure over Mountain Slopes. *Symp.osium Proced.Fort Collins Colorado State U.*, Paper 122, 3-74
- 1977: Climatonomical modeling of temperature response to dust contamination of Antarctic snow surfaces, *Boundary Layer Meteorol.* 12, 213-29
- 1977: Thermal Response to Albedo Reduction on Antarctic Snowsurfaces
Antarctic J. of the US, 12, #4, 134 - 136
- 1977: Air temperature and two-dimensional wind profiles in the lowest 32 m as function of bulk stability at Plateau Station; and: Stability related wind-

spiraling in the lowest 32 m above Plateau Station (with M. Kuhn and A. Riordan), *Antarctic Res.Series AGU* , 25 , 77 -111

1979: Wind and temperature profile prediction for diabatic surface layers including strong inversion cases, *Boundary Layer Meteorol.* 17, 443-464, -

1990: The O'Neill experiment of 1953, *Boundary Layer Meteorol.* 50,,1-9

B. UW Ph.D. theses generated by this program

Dabberdt, Walter F., Aug, 1969, 'Wind and turbulence structure in the boundary layer over the Antarctic Plateau'

Zabransky, Joseph Jr., May 1967, 'Wind in and above a dry-evergreen forest and the boundary-layer characteristics of both monsoons in Thailand'

Riordan, Allen J., Aug. 1977, 'Climatonic modeling of the Dry Valleys of Victoria Land, Antarctica, with comparison to snow-covered regions'

C. Selected List of Departmental Studies on Polar Climates

Schwerdtfeger, W., 1972: The vertical variation of the wind through the friction-layer over the Greenland ice cap *Tellus* XXIV, 13 - 16

Schwerdtfeger, W., 1984: Weather and Climate of the Antarctic, *Developments in Atmo.Sciences*; 15; Elsevier Science, New York, 261 pp

Sponholz, M., 1980: *Among the magi ; research tracks in the desert snow*
<BASE HREF>"http://205.174.118.254/nspt/magi/magiol.htm"

Stearns, C. & D.Bromwich [editors], 1993: *Antarctic Meteorology and Climate Studies based on automatic Weather Stations* [10 papers by a variety of authors]

Amer. Geophys.Union, Antarctic Research Series Vol. 61, 209 pp

Stearns, C., G.Weidner, & L.Keller, 1997: Atmospheric circulation around the Greenland Crest *J. Geophys. Res.*, 102, No.D12, 13,801 - 13, 812

D. List of referenced titles in general literature

Hann, J., 1911: *Handbuch der Klimatologie*,
Vol III, 635 pp Engelhorn, Stuttgart

Gregg, W.R., 1922: An aerological Survey of the United States
Monthly Weather Rev., . 20, 78 pp

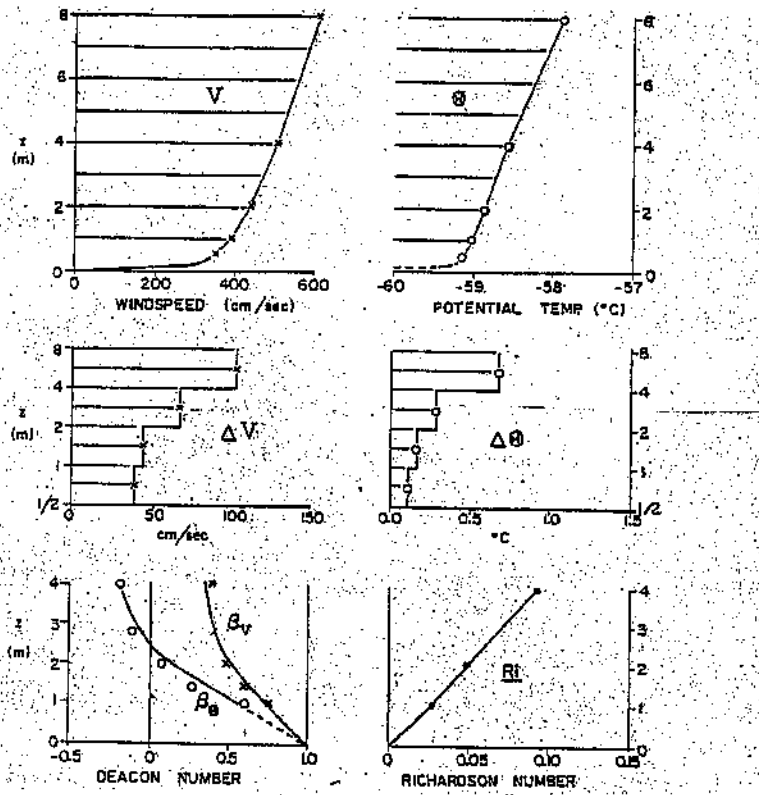
Hoecker, W.H. 1965: Three southerly Low-Level Jet systems delineated by the W.B.special Pibal Network of 1961 *Monthly Weather Rev.* 91, 537 - 582

Nansen, F., 1897: *In Nacht und Eis -- Die Norwegische Polarexpedition 1893-1896*
2 Volumes. Brockhaus Publ., Leipzig, Germany 507 pp,

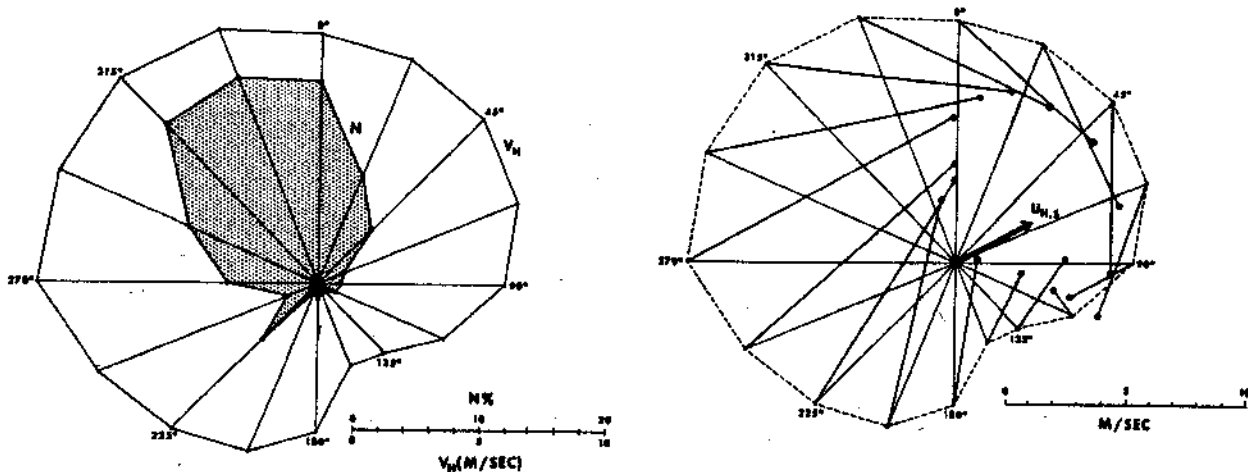
Siple, P., 1959: *90 Degrees South; The Story of the American South Pole Conquest*
Putnam's Son, New York, NY, 222 pp

1.9 Samples of Graphs illustrating significant Results.

1.9;1. South Pole Micrometeorology

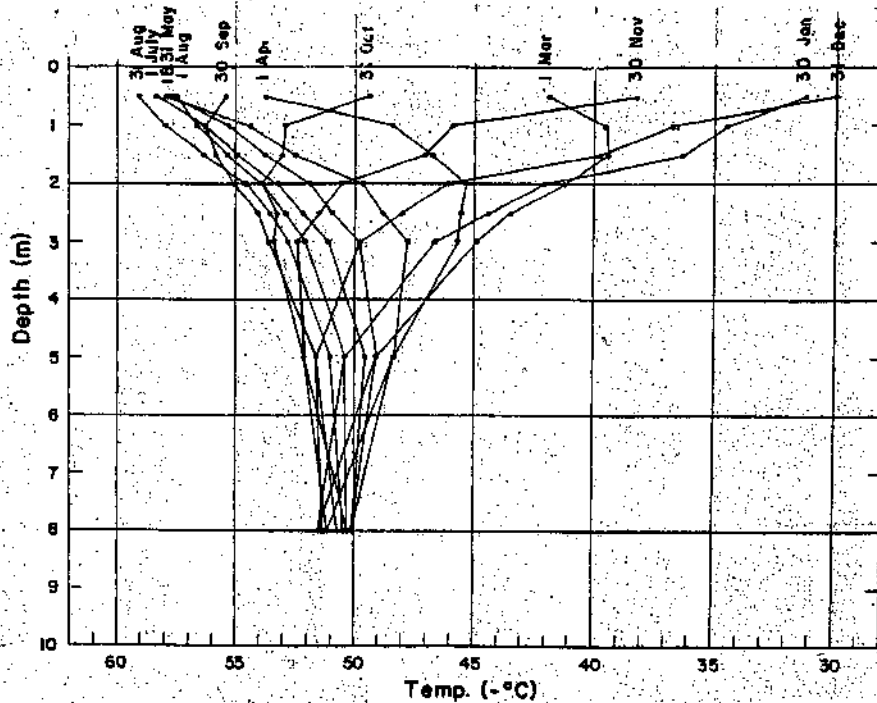


Reference: 1.8 A, 1979, Fig.1. Profile structure of wind speed and air temperature and their vertical differences; means for 30 hours during which the Richardson number [the conventional measure of stability] at 1 m was $0.023 \leq Ri \leq 0.025$. Ri increases linearly with z . Deacon numbers measure profile curvature. Note the inflection point at $z \approx 2.5$ m of the temp. profile.

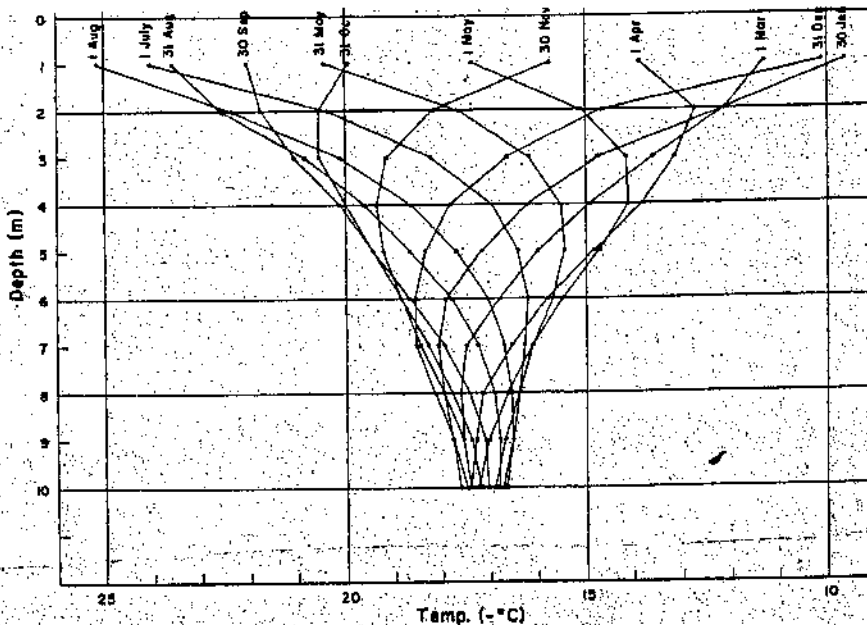


Reference: 1.8 A, 1966; Figs 11 and 12: The azimuth dependency of frequency N of wind vectors V at $H =$ top of the inversion, Mar. to Sep. 1958. Most frequent are NW to N winds, i.e., a direction parallel to the contour lines of interior Antarctica. Our analysis of vector differences between V and surface wind vector v yields a resultant perpendicular to the contour lines.

1.9 A. Data of the South Pole micrometeorology program [continued]. Tautochrones of snow temperature are used to explain the 'coreless winter' at high polar latitudes
 Reference: VI 1.8A, 1966, Figs. 21 and 22



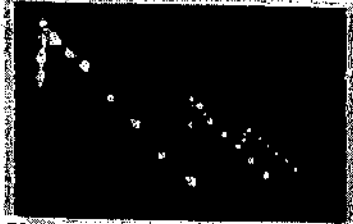
At 90 S the annual mean temperature is -51 C ; snow temperature T is within $\pm 1\text{ C}$ of the annual mean at a depth of 8 m. At 0.5 m depth, $T(\text{max})$ of -30 C occurs on 31 Dec., $T(\text{min})$ of -59 C on 03 Aug. The absolute values of the departure from the mean are 19 versus 8 C. This asymmetry corresponds to heat flux *into the snow* during 4 and *out of the snow* during 8 months.



At 71 S [Maudheim] the annual mean temperature is -17 C ; snow temperature T is within $\pm 1\text{ C}$ of the annual mean at a depth of 10 m. At 1 m depth, $T(\text{max})$ of -9.5 C occurs on 30 Jan., $T(\text{min})$ of -25 C on 01 Aug. The absolute values of departure from the mean are 7.5 versus 8 C. This near symmetry corresponds to heat flux *into the snow* during 6 and *out of the snow* during 6 months.

1.9 ;2 Plateau Station Micrometeorology

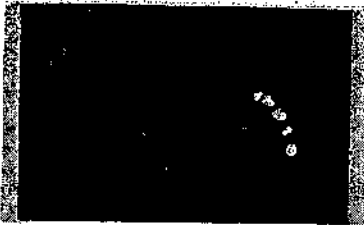
Sample of M.Kuhn's telelens-camera photos in the winternight of 1967 of the illuminated slantline targets at 1000, 2000, and 3000 feet from the shelter at Plateau Station, supplemented by H. Lettau's schematic interpretation of optical distortion due to dependency of the refractive index on air temperature.--Reference: H. Lettau, 1971: Antarctic atmosphere as a test tube for meteorological theories, in *Research in the Antarctic*, [Dr.Quom,ed.] *Americ. Assoc. for the Advancement of Science*, Publication No.93, pp 443 - 447



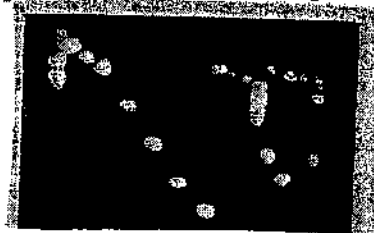
UNDISTORTED Targets, indicating neutral or isothermal surface layer [Photo No. 54]



STOOPING & LOOMING, indicating moderately height-decreasing strong inversion [Photo No. 224]

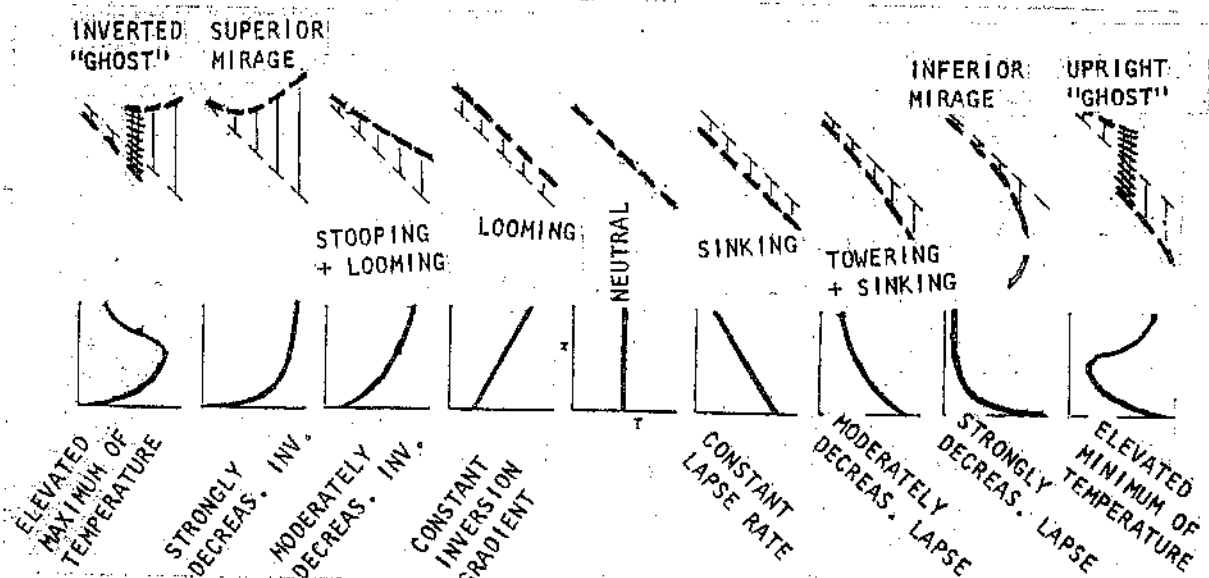


STOOPING & LOOMING for upper part, TOWERING & SINKING for lower part, indicating temperature inversion over lapse [Photo No. 162]



UPRIGHT "GHOST", indicating pronounced case of 'elevated minimum of temperature' [PHOTO No.34]

Selected photos of the illuminated slantline targets, three of which show optical distortions due to anomalous vertical gradients of air temperature on the Antarctic Plateau.

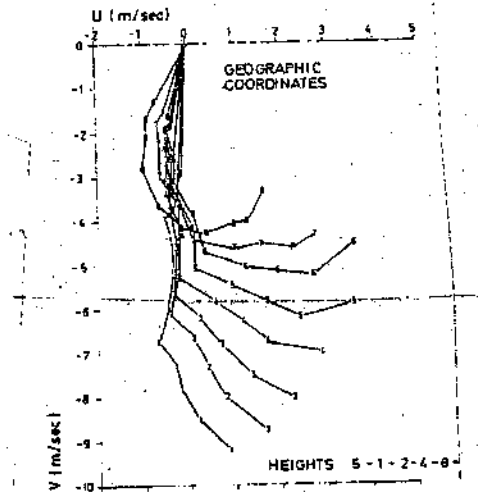
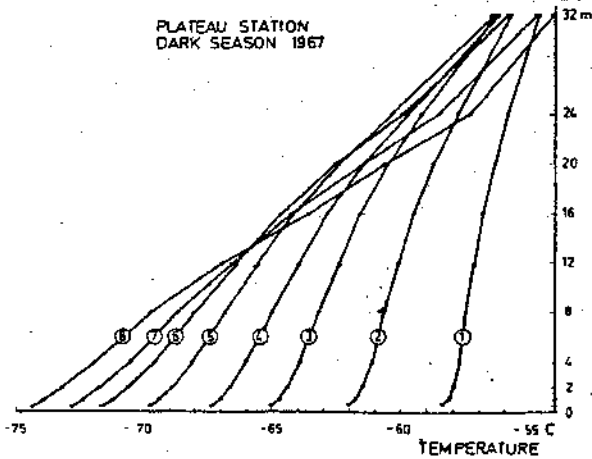


Heavy dashes illustrate how a slantline target [thin dashes] is optically distorted by atmospheric refraction if vertical profiles of air temperature [surface to 4 m] are as indicated in the lower part. Conventional notation of optical phenomena is supplemented by two extremes ['super mirages'] suggested to be called inverted and upright "ghosts".

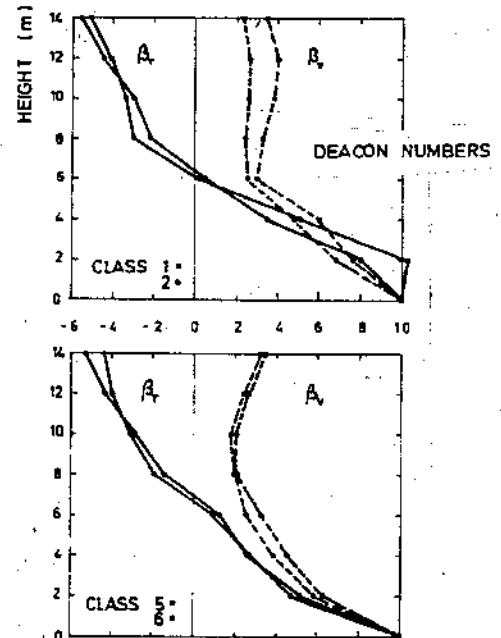
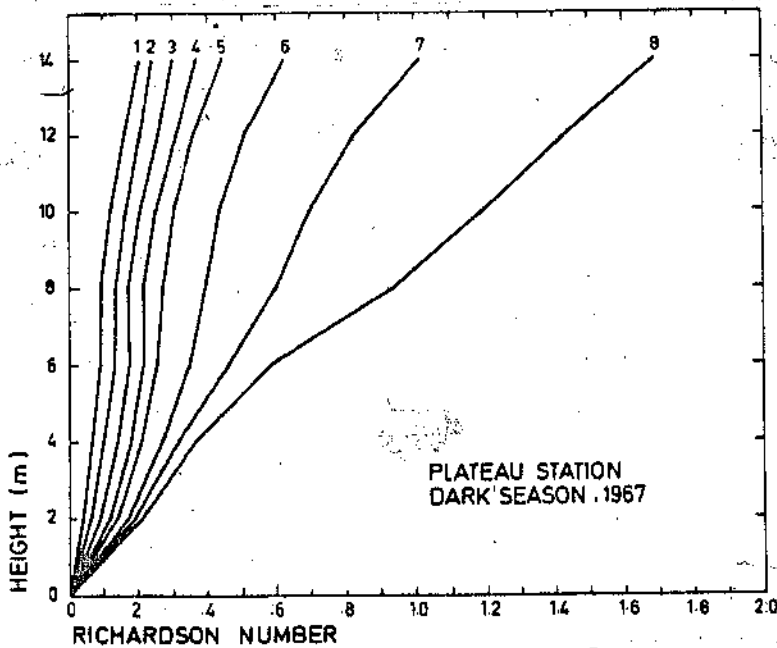
1.9; 2 Plateau Station Micrometeorology - continued

Evaluations of air temperature, windspeed and direction at the 32m-tower at Plateau Station [79.2 deg S, elevation 3624 m] for the sunless period document an extraordinarily large variability of boundary-layer structure controlled by inversion strength.

Reference: H.Lettau, A.Riordan, and M.Kuhn, 1977: Air temperature and two-dimensional wind profiles as function of bulk stability -- Meteorological studies at Plateau Station. *Antarctic Research Series*, AGU, Vol. 25, # 6, pp 77-91



Inversion strength is used to generate classes 1 through 8 for evaluation of hourly averages ; note the systematic increase of counter-clockwise wind-spiraling from class 1 to class 8.

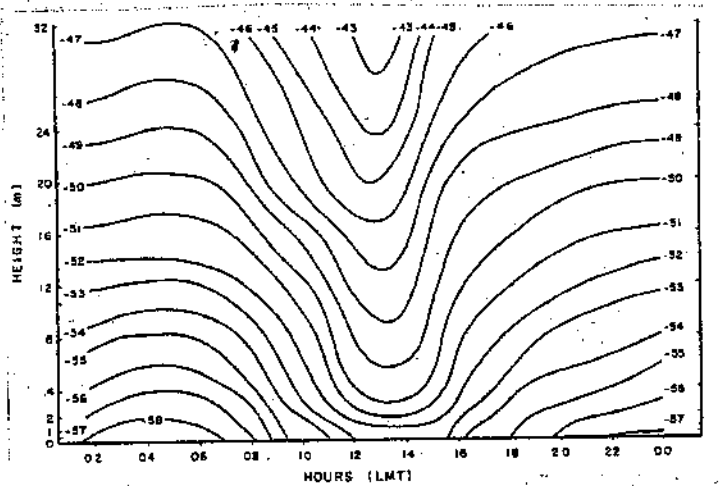


Vertical profiles of Richardson Numbers [a conventional dimensionless measure of thermodynamic stability] between the surface and 14 m is essentially controlled by inversion strength [class 1 through 8]. Vertical profiles of Deacon Numbers [Lettau's dimensionless measure of profile curvature] for temperature [full curves] as well as for windspeed profile [dashed curves] for class 1 & 2 are essentially the same as for class 5 & 6. Note that the βT -profile inflection point occurs near 6 m while near 2 m at 90 deg S.

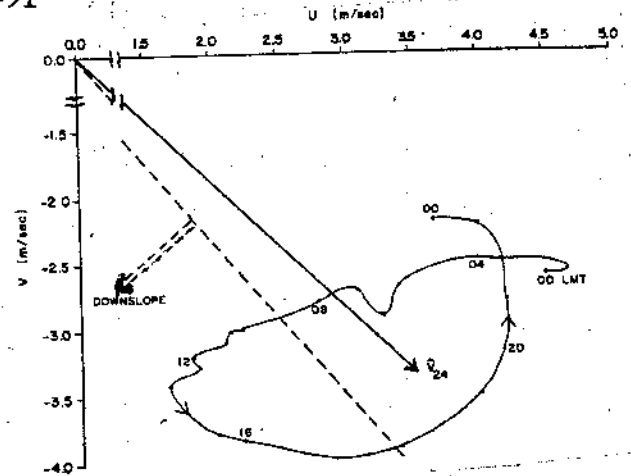
1.9; 2 Plateau Station Micrometeorology - continued

Air temperature, windspeed and direction recordings at the 32m-tower at Plateau Station [79.2 deg S, elevation 3624 m]. Sample of evaluations for February and March [sunlit period] showing pronounced 24-hourly variations.

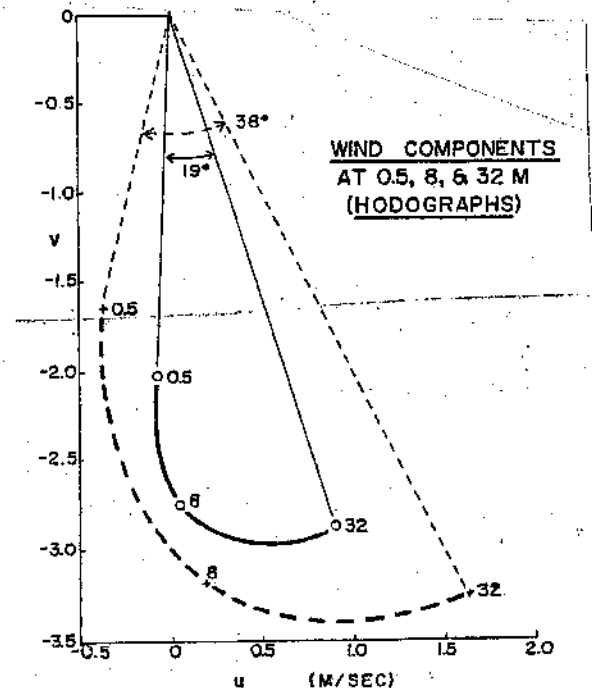
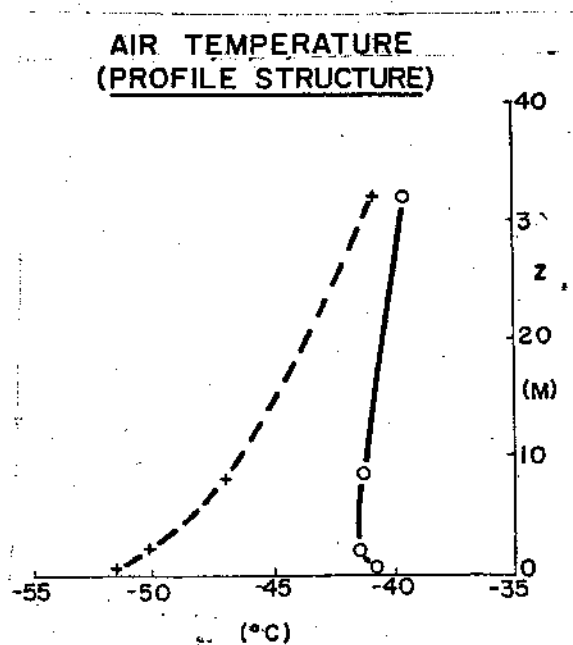
Reference: H.Lettau, A.Riordan, and M.Kuhn, 1977: Air temperature and two-dimensional wind profiles as function of bulk stability – Meteorological studies at Plateau Station. *Antarctic Research Series*, AGU, Vol. 25, # 6, pp 77-91



Mean daily isotherms [Celsius], March 1967



Hodograph of hourly positions of the wind vector at the 24 m level, averages for February, 1967, showing effect of the topographical gradient.



Temperature and wind component averages for February 1967 and local-mean-hours of 11 [circles] and 23 [crosses] show nearly perfect spiral structure with Ekman Angles of 19 degrees for nearly isothermal stratification and 38 degrees for strong inversion.