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MIDWINTER DISTURBANCES IN THE MIDDLE ATMOSPHERE

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The "Middle Atmosphere" is coupled to the troposphere during winter because planetary scale waves can propagate upwards if the prevailing winds are from the west. It is during this time of the year that the well-known "midwinter disturbances" are observed which ultimately affect the whole of the Middle Atmosphere. The mechanism of these disturbances is not completely understood and it will be one key problem to be studied within the MAP (Middle Atmosphere Program).

The large-scale circulation features up to the upper mesosphere will be shown in this paper to demonstrate the synoptic-scale behaviour of the midwinter disturbances. Ground-based and satellite observations will be combined.

The interannual variability of the disturbances will be discussed briefly and it will be shown that the QBO (Quasi Biennial Oscillation) of the equatorial stratosphere appears to modulate the planetary waves during the northern winters, in the troposphere as well as in the Middle Atmosphere.

Figure 1 shows the course of the stratospheric temperatures or radiances over the North Pole during the last winter, 1982/83, and three warming pulses can be clearly distinguished. These warming pulses are also well documented by the rocketsondes launched from Heiss Island/USSR, Figure 2. While the data given in Figure 1 cover only the stratosphere, the rocketsonde data also show the temperature changes in the upper stratosphere, if one considers the situation at the same location and at the same time.

The midwinter disturbances are caused by the amplification of the large planetary-scale waves which propagate upwards from the troposphere through the stratosphere into the upper mesosphere. The horizontal patterns of these waves are shown in Figures 3-6 for a few selected days between 13 and 27 February, 1983, covering the last warming pulse, cf. Figure 1.

While the 30-mbar height fields are based on radiosondes, the upper levels are constructed using thicknesses derived from the SAMS experiment (Stratospheric and Mesospheric Sounder, onboard Nimbus 7). The 1-mbar height fields are based on the SSU experiment (Stratospheric Sounding Unit, onboard the NOAA satellites).

On February 13, 1983, Figure 3, the circulation was relatively undisturbed in the stratosphere and lower mesosphere, i.e., up to the 0.1-mbar level. But a minor warming was present over Eastern Europe, as indicated by the high radiance values of Ch. 27 of the SSU. And consequently, an anticyclone developed, cf. the 0.01-mbar chart in Figure 3, which accounts for a period with winds from the east in the 90-100 km region over Central Europe, as indicated by the low frequency ion drift measurements of the Collm Observatory, cf. Figure 7. When comparing the Collm-data with the 0.01-mbar charts, one has to keep in mind that the planetary-scale waves usually are sloping westwards with height and that the Collm-data belong to a region about 15 km above the 0.01-mbar level.

At the same time the winds were from the west in the whole layer between 58-84 km over Canada, as reported by the partial reflection radar of Saskatchewan, cf. Figure 7.

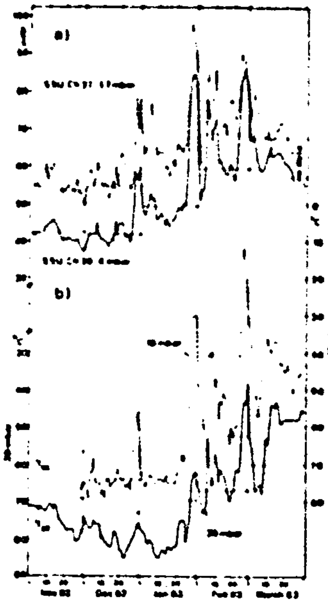

Figure 1. March of radiances and temperatures over the North Pole (horizontal lines are long-term monthly means). a) Radiances (mW/m²sr cm^{-1}) of channel 27 and 26 of the SSU, maximum weight around 1.7 and 4 mbar (courtesy Meteorological Office, Bracknell, UK); b) Temperatures (°C) at 10 and 30 mbar (data FU Berlin) (from NAUJOKAT et al., 1983).

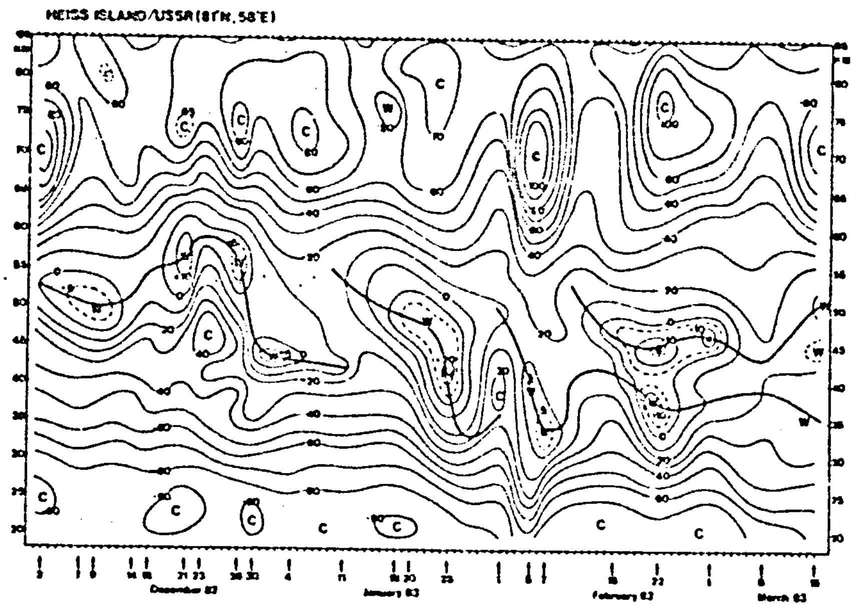

Figure 2. Time height section of rocketsonde temperatures (°C) from 2 December 1982 to 15 March 1983 (from NAUJOKAT et al., 1983).

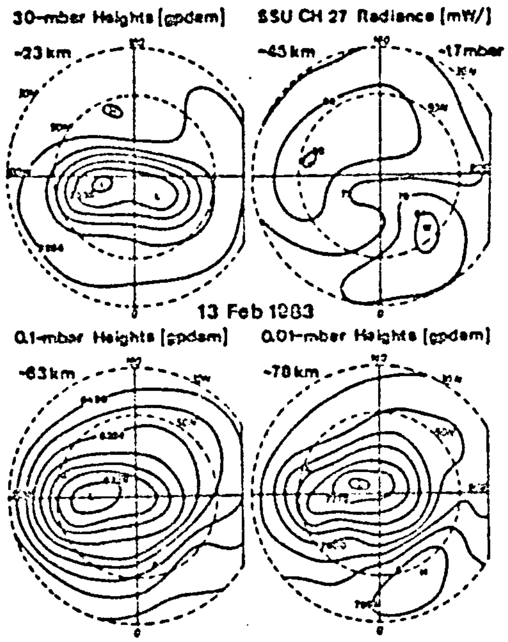

Figure 3.

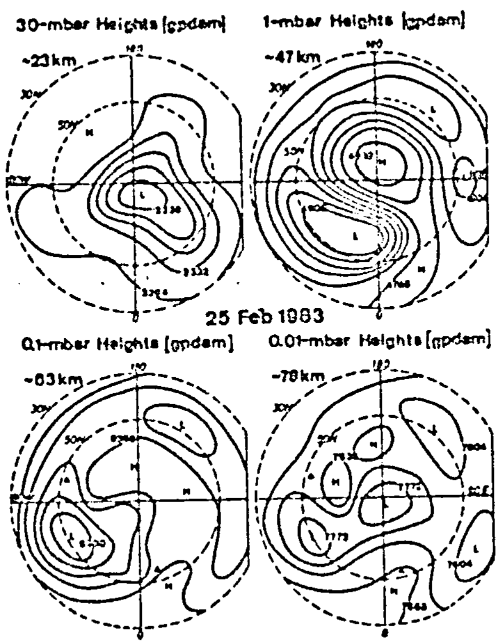

Figure 4.

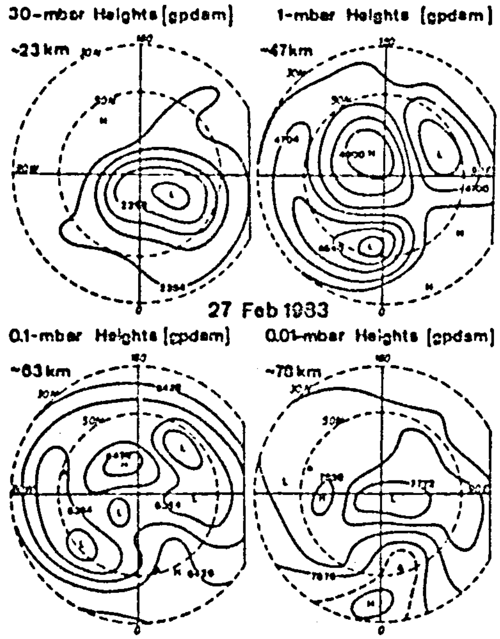

Figure 5.

On 25 February, Figure 4, the third warming pulse of the winter developed, cf. Figures 1 and 2, and its influence is clearly noticeable in the mesosphere. Winds from the east were observed again over Central Europe at about 95 km, and also over Canada at about 60 and 70 km, cf. Figure 7. Here the wind speed had decreased considerably since 13 February, well in agreement with the movement and weakening of the polar vortex.

On 27 February the stratospheric warming reached its peak, Figure 6, with the reversal of the temperature gradient in the stratosphere, concurrently with a cooling in the mesosphere. The resulting height fields, Figure 5, also display a reversal of the circulation in the upper stratosphere over the polar region. The circulation over Central Europe was dominated by a separate anticyclone and the very strong winds from the north reported by the Collm Observatory (not shown) agree with the slope of the anticyclone, Figure 5. The varying winds over Canada (cf. Figure 7) agree with the rather complex circulation systems, Figure 5.

Attempts have been made to show that the large-scale circulation in the mesosphere is similar to the well-known circulation in the stratosphere and that it is possible to study these changes synoptically. For such studies ground-based observations of winds and temperatures can give an important input to the analyses, in addition to the satellite data. However, for the synoptic analyses which concentrate on the large-scale circulation, it is necessary that the prevailing winds (or temperatures) are made available, after the tides have been removed.

The interannual variability of the midwinter disturbances is very large, Figure 8, particularly in the capability of the disturbances to develop into so-called "Major warmings" (* in Figure 9), i.e., to penetrate into the middle

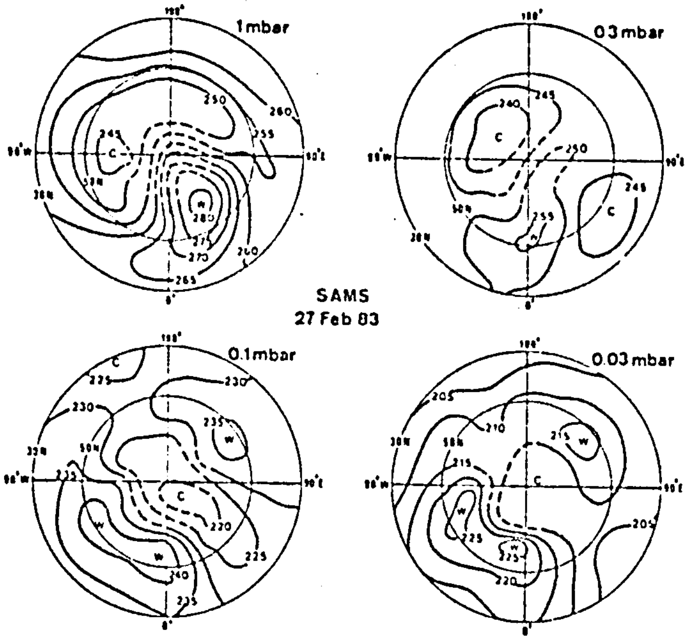

Figure 6. Charts of temperatures (K) retrieved from measurements of the SAMS aboard NIMBUS 7 (courtesy Clarendon Laboratory, University of Oxford, UK) (from NAUJOKAT et al, 1983).

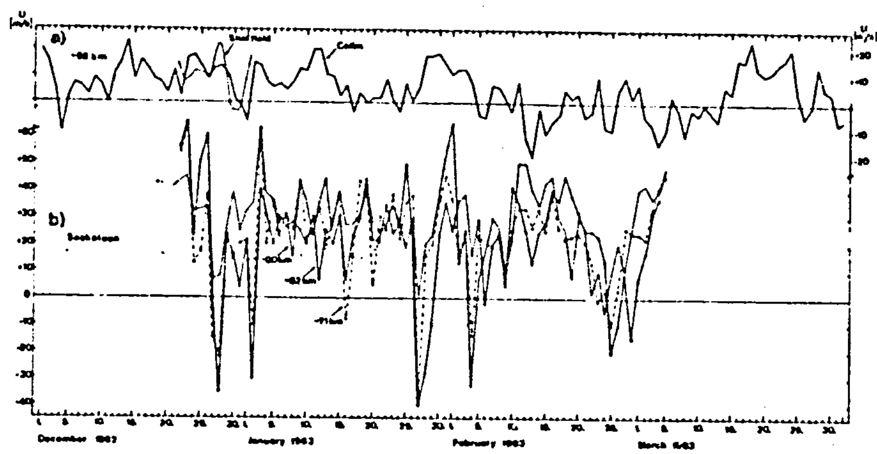

Figure 7. a) Prevailing zonal winds (m s^{-1}) around 95 km over middle (51N,13E) and western (53N,2W) Europe measured by low frequency ion drift (courtesy Geophysical Observatory Collm, GDR) and by meteor radar (courtesy Physical Dept., Univ. of Sheffield, UK), respectively; b) Zonal winds (m s^{-1}) over Canada (52N, 107W) at three layers (58-66 km layer daily means, 76-84 km layer tidally corrected) measured by partial reflection radar (courtesy University of Saskatchewan, Saskatoon, Canada) (from NAUJOKAT et al., 1983).

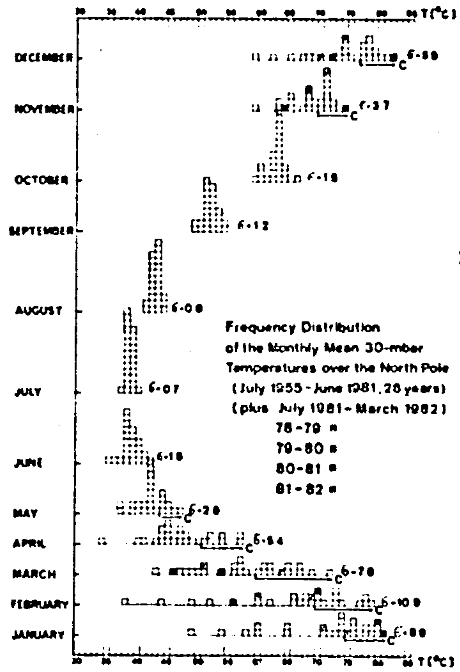

Figure 8. (from LABITZKE, 1983.)

WESTERLY CATEGORY

R_j	YEAR	NOV	DEC	JAN	FEB	MAR	APR	MAY	F.W.
27	1952/53	CW							early
0	1953/54					NFW			early
74	1955/56		C	C	C	C		C	late
203	1957/58	C	C		✱	[C]	[C]	[C]	[late]
146	1959/60	C	CW		C	C			early
39	1961/62		C	C		C	C		late
16	1963/64	C	C	C	C	NFW			early
18	1964/65	C CW	C	C	C	C			late
111	1966/67		CW	C	C	C			late
122	1967/68	C CW		✱		[C]	[C]		[late]
112	1969/70	C		✱		[C]			[late]
62	1971/72	C	C	C	C				early
28	1973/74	C	C CW	C	C	NFW			early
8	1975/76	C	C	C	C	C	NFW		early
167	1978/79	C	CW	C	NFW				early
114	1980/81	CW	C	C	✱		[C]	[C]	[late]
	ΣC	10	8	10	8	9	4	3	
	Σ✱			2	2				
	ΣNFW				1	3	1		
	1982/83	C	C CW	C					late

$\sum^{n=17}$ ✱ = 4 = 24%

EASTERLY CATEGORY

R_j	YEAR	NOV	DEC	JAN	FEB	MAR	APR	MAY	F.W.
41	[illegible]	CW			✱				[late]
23	1954/55		CW	✱					[late]
106	1956/57				✱		[C]	[C]	[late]
217	1958/59	CW	CW		C	NFW			early
58	1960/61		CW		C	NFW		[C]	early
20	1962/63	CW			✱	[C]	[C]	[C]	[late]
28	1965/66		CW	C	✱				[late]
104	[illegible]	CW			C				late
81	1970/71	C	C	✱			[C]	[C]	[late]
43	1972/73	CW	C		✱		[C]	[C]	[late]
19	1974/75	CW				NFW			early
16	1976/77	CW	C	✱		[C]			early
162	1979/80	CW		C	C	NFW			early
	ΣC	1	3	2	4	2	4	8	
	Σ✱			3	6				
	ΣNFW					4			
111	1981/82	C	CW						early

$\sum^{n=14}$ ✱ = 8 = 57%

Figure 9. Winters of Figure 8 are grouped according to the case of the zonal winds at the 50-mbar level over the equator (update, LABITZKE, 1982).

stratosphere and to lead to a breakdown of the polar vortex. It is not understood why the winters do develop so differently. One possible explanation appears to be connected with the QBO of the stratospheric winds over the tropics. If one groups the winters according to the equatorial 50-mbar winds in November/December, one can find "Major warmings" (*) during 57% of the winters belonging to the easterly category, but only during 24% of the winters belonging to the westerly category, Figure 9. And these 24% are winters very close to the solar maximum. (Of course, not enough cases are yet available to put any significance to this result.) But the whole phenomenon is very interesting as it suggests that the stratospheric QBO over the tropics modulates the polar winters, probably through a modulation of the planetary-scale waves of the whole middle atmosphere. This will surely be one important subject to be studied within the MAP.

ACKNOWLEDGEMENTS

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