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7.3 MIDDLE ATMOSPHERE THERMAL STRUCTURE DURING MAP/WINE

D. Offermann

Physics Department, University of Wuppertal
5600 Wuppertal 1
Federal Republic of Germany

Middle atmosphere temperatures were measured during the MAP/WINE campaign by various ground-based techniques, by rocket instruments, and by satellites. Respective data have been analyzed for atmospheric thermal mean state as well as for long and short period variations. A brief survey of the results is given. Monthly mean temperatures agree well with the new CIRA model. Long period (planetary) waves frequently exhibit peculiar vertical amplitude and phase structures, resembling those of standing waves. Short period oscillations tend to begin breaking well below the stratosphere.

Temperature Measurements during MAP/WINE

Technique	Place/Institution
1. Ground-based	
Lidar	Observatoire de Haute Provence/CNRS
Lidar	Andoya/Bonn University
Near infrared	Andoya/Wuppertal University
OH spectrometers	ESRANGE/Utah State University
OH spectrometers	Lista, Oslo/Wuppertal University; NDRE
OH spectrometer	Zvenigorod/IPA
2. Rockets	
Met. rockets	Heiss Island/CAO
Datasondes	Andoya/Bonn University
Falling spheres (passive)	Andoya/Bonn University; NASA GSFC
Falling spheres (active)	Andoya/AFGL
IR radiometers	Andoya/Wuppertal University
Mass spectrometers	Andoya/Bonn University
IR spectrometer	ESRANGE/Wuppertal University
Datasondes	Lista/NASA GSFC; NDRE
Met. rockets	Volgograd/CAO
3. Satellites	
Stratospheric Sounding Unit SSU	NOAA

Figure 1. Techniques used for middle atmosphere temperature measurements during MAP/WINE. For details see the following papers in *J. Atmos. Terr. Phys., 49*, 1987: v. Zahn, p. 607; Petzold et al., p. 621; Hauchecorne et al., p. 649; Offermann et al, p. 655; v. Zahn, p. 863. Also, Schmidlin, *ESA SP 270 (Sunne)*, 133, 1987; Gerndt, Ph. D., University of Wuppertal, 1986; Brückelmann, Ph.D. University of Wuppertal, 1988; Meyer et al., *ESA SP 229 (Loen)*, 41, 1985; Lübken et al., *ESA SP 229* (Loen) 259, 1985.

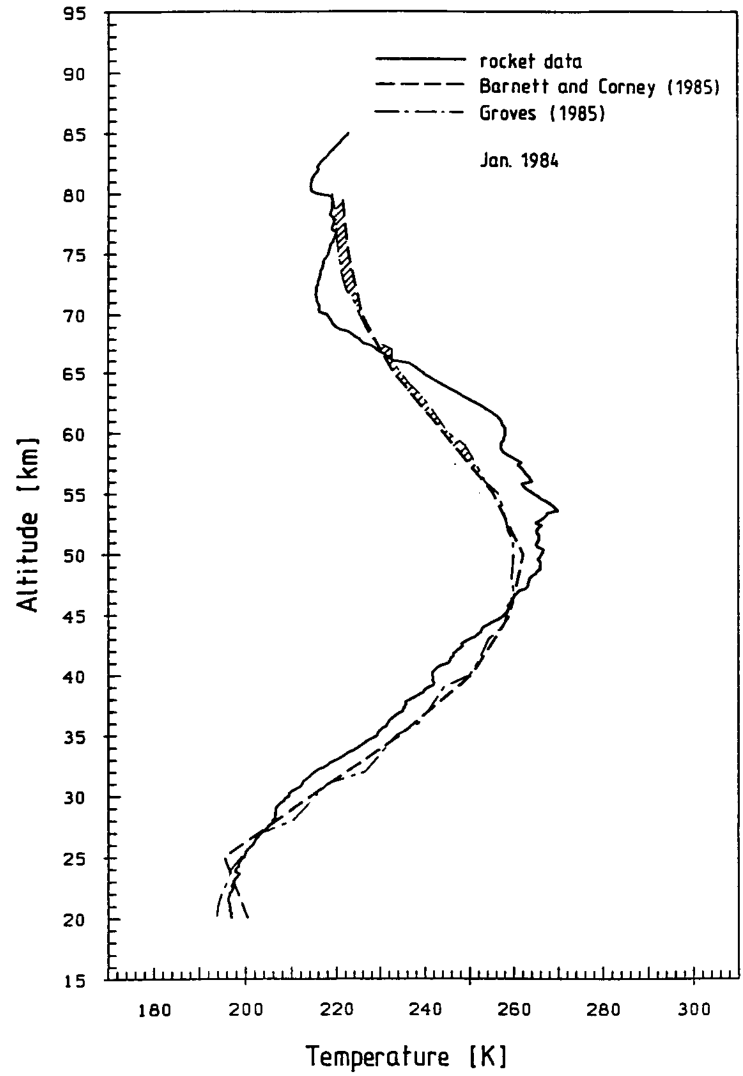

Figure 2. Mean temperature profile calculated from the rocket measurements above Andoya in January 1984. The model profiles of Barnett and Corney (*Handbook for MAP 16*, 47, 1985) and Groves (AFGL-TR-85-0129) are given for comparison. Differences between measured and model profiles in the mesosphere appear to show a precursor structure related to the major stratospheric warming, which occurred by end of February 1984. (For details see Offermann et al., *J. Atmos. Terr. Phys.*, *49*, 655, 1987.)

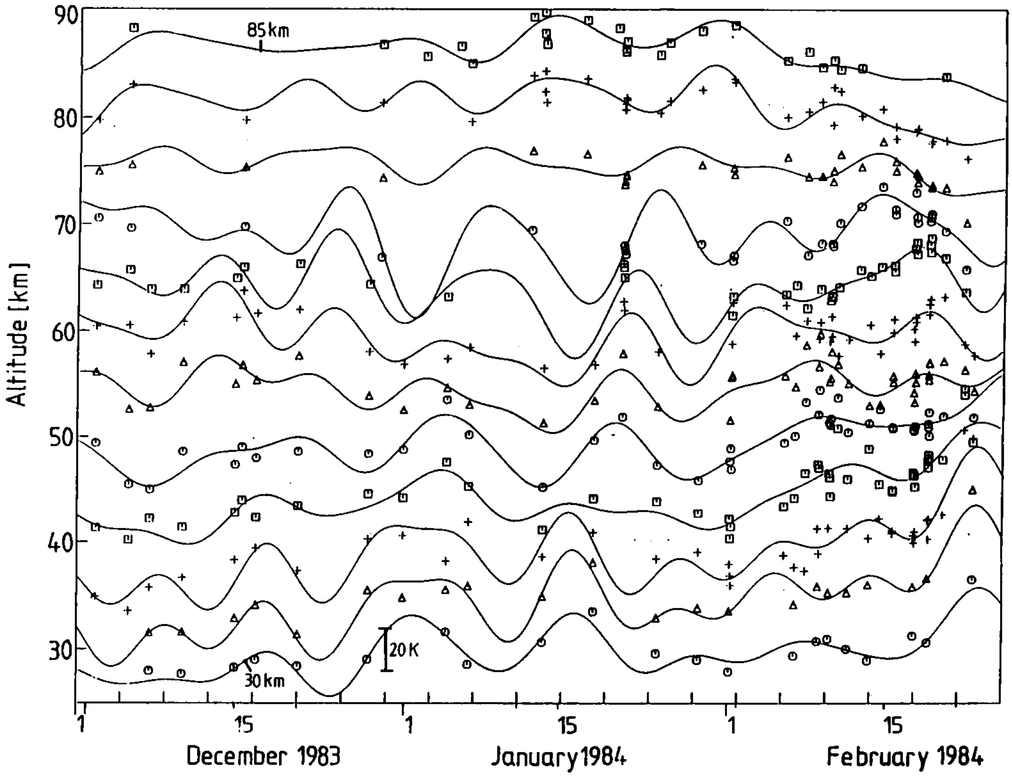

Figure 3. Harmonic least square fit to temperatures measured at given altitudes during the MAP/WINE campaign above Andoya. Analysis is performed at 1 km altitude steps, only part of which is shown here. Five oscillations are superimposed. The periods are 9.6 days, 13.3 days, 17.4 days, 54 days and 144 days. The shorter ones are believed to represent planetary waves (Details of this and the following pictures are given by Offermann et al., *J. Atmos. Terr. Phys., 49*, 655, 1987.)

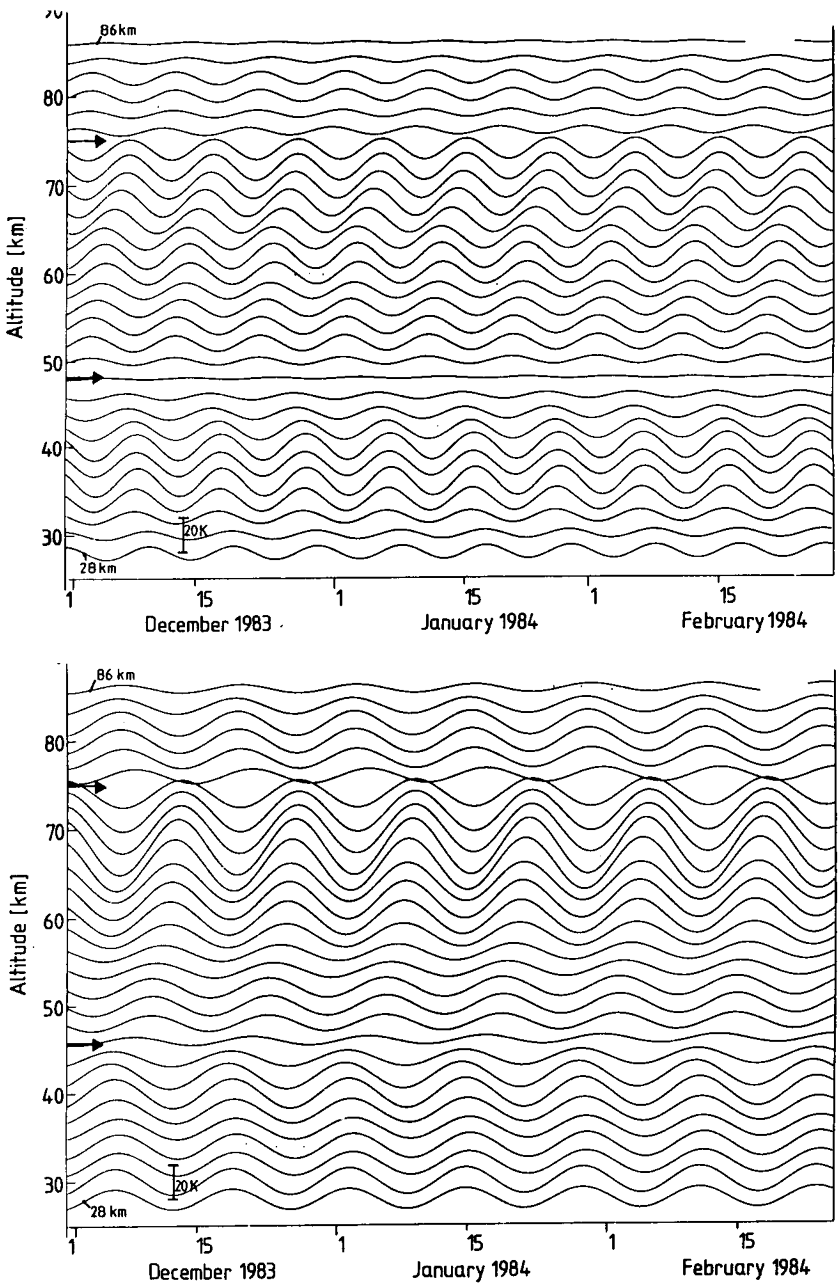

Figure 4. Two components of the harmonic analysis shown in Figure 3 (Andoya): a) period is 9.6 days, b) period is 13.3 days.

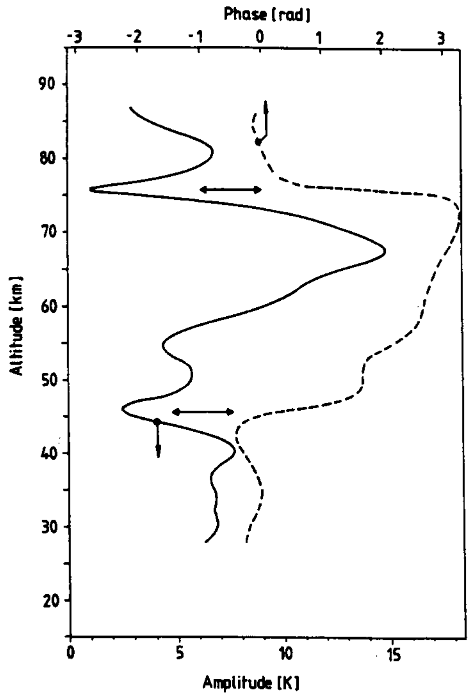

Figure 5. Vertical amplitude and phase structure of the wave with 13.3 days period. Oscillation nodes with amplitude minima and phase jumps (of about 180°) are seen at altitudes of 46 km and 76 km. They are indicative of a standing wave. Similar structures are seen in most of the other oscillations analyzed. They were also found in other winter campaigns in Western Europe.

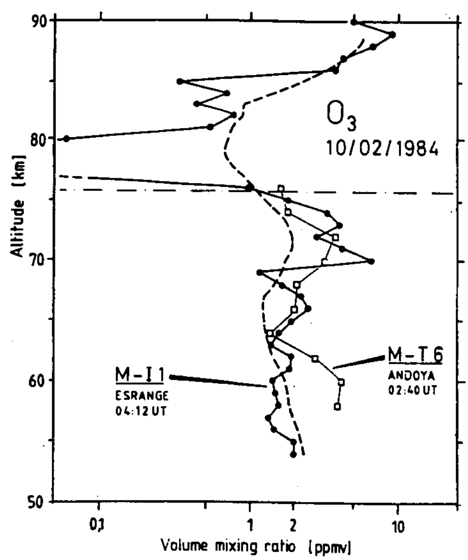

Figure 6. Ozone mixing ratios as measured by infrared rocket experiments (at night). Dashed line is a very approximate mean curve including several other measurements. With respect to this curve, ozone is found to be depleted above 76 km, and enhanced below this level. The level coincides with one of the nodes of the 13.3 d oscillation (Figure 5). Only a small fraction of the ozone deviations can be explained by photochemistry. (For details see Grossmann et al., *J. Atmos. Terr. Phys., 49,* 827, 1987.)

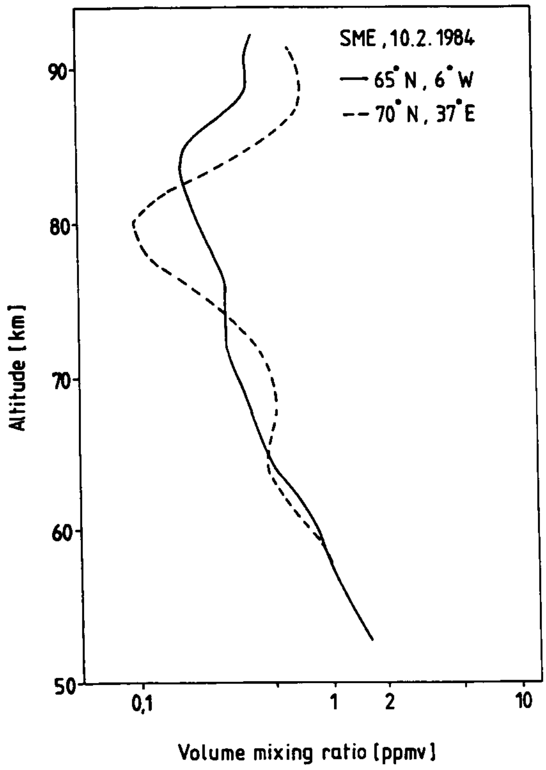

Figure 7. Ozone mixing ratios as measured by the SME satellite at two different longitudes. Measurements are during daytime. Dashed curve is at 378 east and resembles qualitatively the solid curve in Figure 6. Hence the wave structure extended to this longitude at least. The profile at 68 west resembles an undisturbed profile, i.e., a wave with zero phase. If it is assumed that the dashed curve approximately shows the maximum of the wave disturbance, and the solid curve shows zero disturbance, a longitudinal wavelength of 428 results. Hence the disturbance seen is compatible with a planetary wave 2. A similar result was obtained before by Hauchecorne et al. [1987] (see Figure 8).

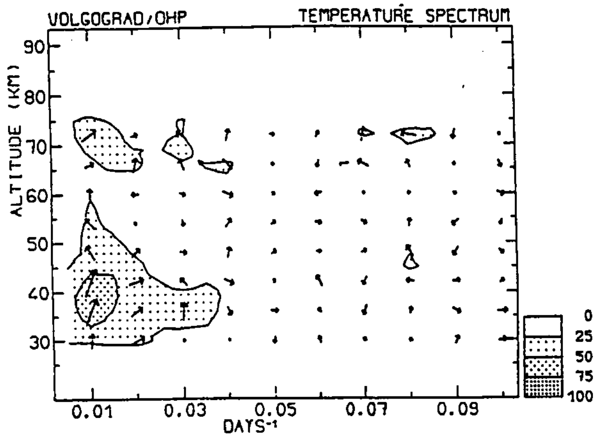

Figure 8. Fourier analysis of temperature measured by lidar and rockets at the Observatoire de Haute Provence (OHP) and at Volgograd, respectively (Hauchecorne et al., *J. Atmos. Terr. Phys.*, *49*, 649, 1987). Direction of the arrows gives the phase difference between the two stations. An arrow directed toward right indicates that the maximum occurs sooner at OHP than at Volgograd. The wave at 12.5 days period (45 km, 70 km) shows westward propagation and is interpreted as a planetary wave 2 (second symmetric mode).

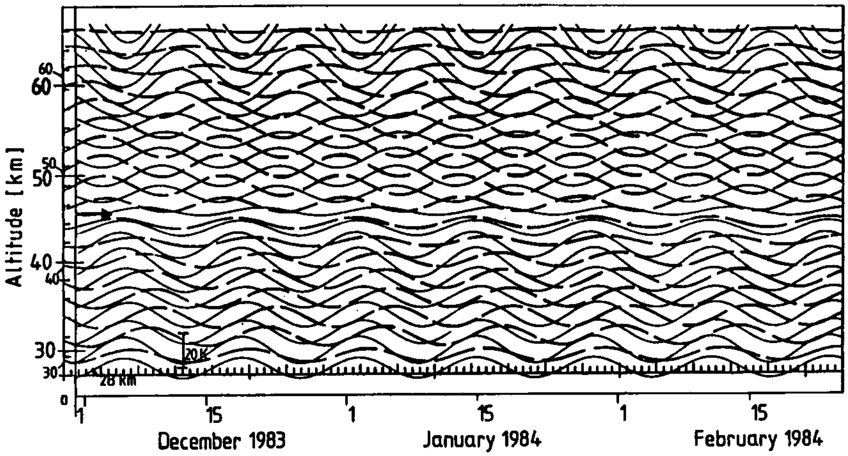

Figure 9. Comparison of an oscillation with 13.3 days period at Andoya (solid lines) and OHP (dashed lines). The lidar data of OHP were analyzed by the same technique as sketched for Andoya above (Figures 3 - 5). An oscillation period of 12.5 days was obtained which is exactly the same as the one of the Fourier analysis of Hauchecorne et al. [1987]. When a period of 13.3 days is prescribed to the OHP data (this picture), an anticorrelation between Andoya and OHP is obtained above the node at 46 km, and a phase shift greater than 908 in most part below it.

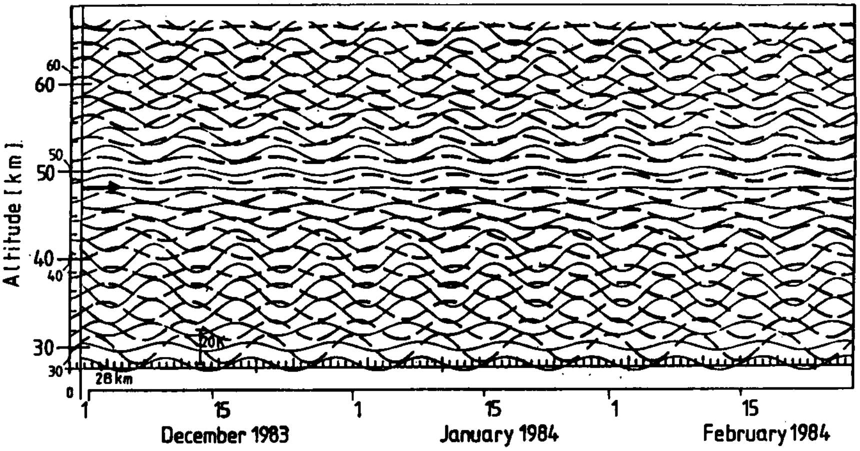

Figure 10. Comparison of an oscillation with 9.6 days period at Andoya (solid lines) and OHP (dashed lines). the 9.6 day value is prescribed to the OHP data. An anticorrelation between the two stations is obtained in most part of the altitude regime, except around the node at 48 km (arrow) and the very lowest altitudes. Please note that a phase reversal occurs at the node (Andoya) similar to and even larger than the one shown in Figure 5 at 46 km.

Wave Summary		
Periods observed:	12.5 d - 13.3 d	9.6 d
Vertical structure:		
$\lambda_z/2$:	≈ 30 km	≈ 30 km
Nodes at:	46 km, 76 km	48 km, 76 km
Zonal structure:		
λ_x	180° (wave 2)	?
Meridional structure:		
Nodes at	50° - 60° (?)	50° - 60° (?)

Figure 11. Results obtained from rocket data at Andoya and lidar data at OHP for the two shortest oscillation periods. Meridional structure results are preliminary. Respective analysis is still in progress.

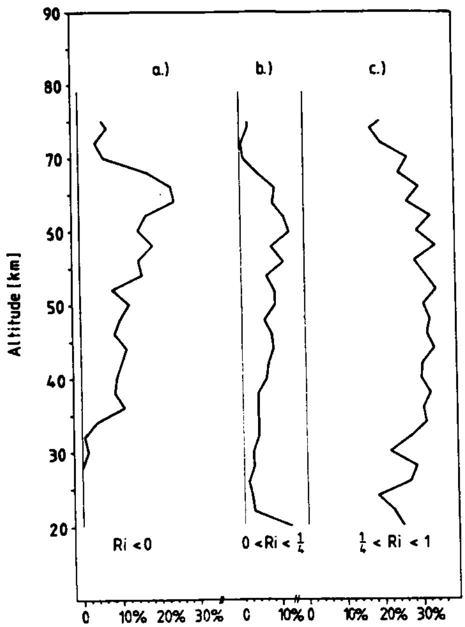

Figure 12. Occurrence frequency of Richardson numbers R_i at Andoya as determined from more than 60 rocket flights during three months. Atmospheric instability sets in as low as 35 km. Above this altitude the atmosphere is unstable ($R_i < 1$) for more than 50% of the time.