united nations educational, scientific and cultural organization

international atomic energy agency

the
abdus salam
international centre for theoretical physics

H4. SMR/1247
Lecture Note: 07

WORKSHOP ON PHYSICS OF MESOSPHERE-STRATOSPHERE-TROPOSPHERE INTERACTIONS WITH SPECIAL EMPHASIS ON MST RADAR TECHNIQUES

(13 - 24 November 2000)

SYPNOTIC AND MESO-SCALE DISTURBANCES OBSERVED IN THE ARCTIC TROPOSPHERE AND LOWER STRATOSPHERE WITH THE SOUSY SVALBARD RADAR

Prof. Jurgen ROTTGER

Max-Planck-Institut fur Aeronomie
Katlenburg-Lindau
GERMANY

Synoptic and meso-scale disturbances observed in the Arctic troposphere and lower stratosphere with the SOUSY Svalbard Radar

Jürgen Röttger and Jörg Trautner
Max-Planck-Institut für Aeronomie
D-37191 Katlenburg-Lindau, Germany
<roettger@linmpi.mpg.de>

Observations of the structure and dynamics of the Arctic troposphere and stratosphere are of particular interest to obtain information on the climatology of atmospheric layering, waves and turbulence in the high latitudes. Investigations of the variability of the polar vortex and the propagation of synoptic scale disturbances into high latitudes are also essential phenomena of polar meteorology, which require continuous observations. Röttger and Tsuda (1995) have presented particular suggestions for radar studies of the Arctic middle and lower atmosphere.

The SOUSY Svalbard Radar (SSR) was originally specified for investigations of Polar Mesosphere Summer Echoes (PMSE). Its technical specifications are found in Czechowsky et al. (1998) and the initial PMSE observations are described by Röttger et al. (2000) and Rüster et al. (2000), and Röttger (2000a) presented some of the very initial troposphere and lower stratosphere observations with the SSR.

The SSR was constructed in summer 1998 near Longyearbyen (78°N, 16°E) on the island Spitzbergen, which is part of the Svalbard archipelago. The SSR is an MST VHF radar and operates on 53.5 MHz with 70 kW peak power and 4 % duty cycle, applying a hybrid modulation of single and complementary pulse coding for ST applications, and a phased antenna array of 356 Yagis (see Fig. 2 of Röttger et al., 2000). The antenna has a beam width of 4 degrees and is steerable into the zenith direction, and at 5 degrees zenith angle in four azimuths NE, SE, SW and NW. The antenna array has been modified in the year 2000 such that four receiving sub-arrays, consisting each of 9 x 4 Yagis, can be utilized for spaced antenna and interferometer measurements. For this purpose 36 passive transmit-receive switches had been constructed, which are included in the feed lines of the individual 4-Yagi antenna sub-modules. These allow the total antenna array of 356 Yagis to be used for transmission, and four groups of 9 x 4 Yagis (nine sub-modules are combined) are utilized during the receiving phase. The signals of the four groups of 36 Yagis are multiplexed into one receiver and thereafter processed in the standard way.

In the initial troposphere and lower stratosphere observations in August and November 1999, which are briefly described here, only one sub-module of 4 Yagis was used for reception to allow recording of signals from lower tropospheric heights down to about 1 km. Since the beam width of the receiving modules (with vertical pointing direction) is wider than the steering angle of the full array antenna, the vertical pointing receiving beams need not to be steered. These data were taken in the Doppler-Beam-Swing method. We will present here just some examples of these initial observations of the Arctic troposphere and lower stratosphere with the very reduced receiving antenna system. It is noticeable that reasonable signals could be detected up to altitudes above the tropopause, although signal gaps are then and now occuring also in the troposphere. The newly implemented application of 36 Yagis per group instead of the 4 Yagis used here results in an additional gain of close to 10 dB.

To appear in:
Proceedings of the Ninth Workshop on Technical and Scientific Aspects of MST Radar,

L01

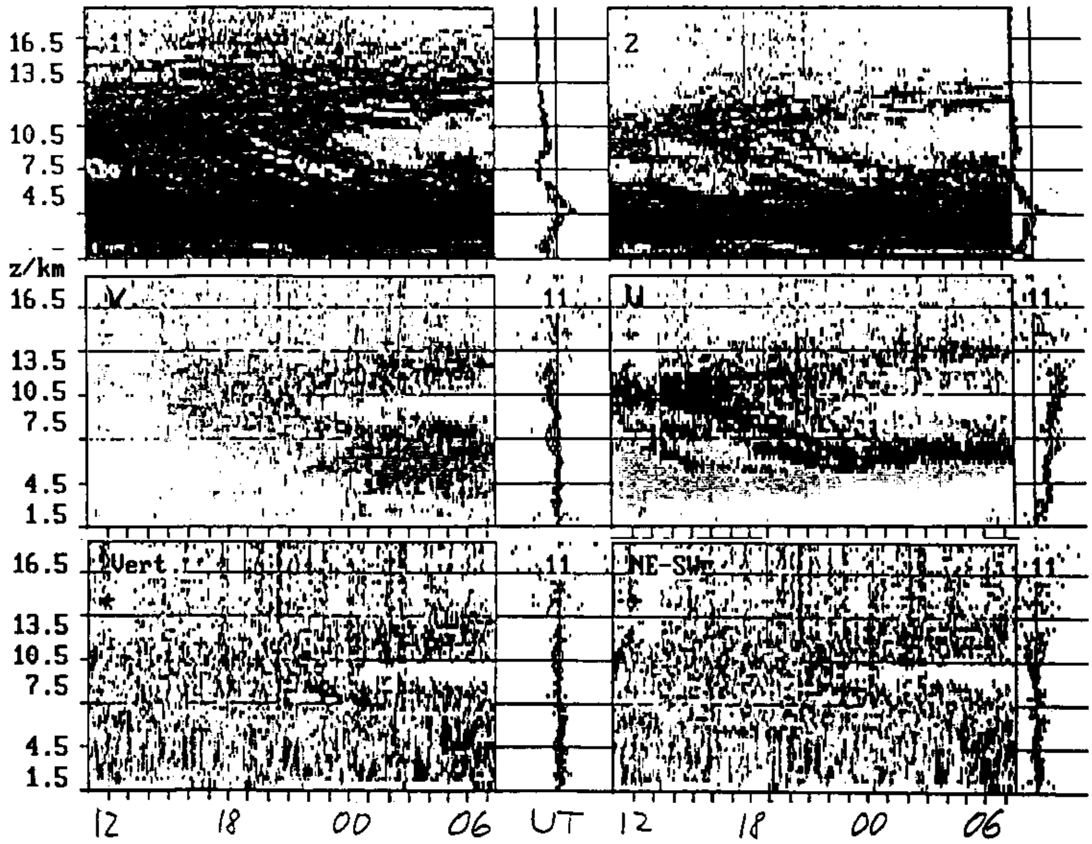

Fig. 1 SOUSY Svalbard Radar observations between 13 November, 11:04 UT, and 14 November 1999, 07:28 UT, showing height-time intensity plots of signal power (upper panels), estimates of horizontal velocity (center panels) and radial velocity in vertical direction during a warm-front passage (see text for further explanation).

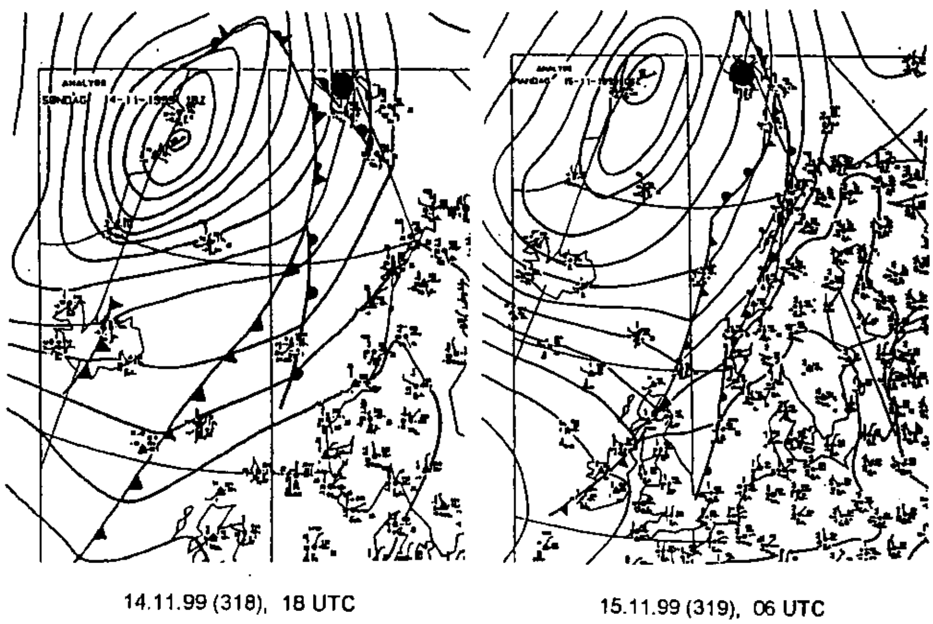

Fig. 2 Surface weather charts of the warmfront passage on 14 November 1999. Courtesy airport of Longyearbyen. Svalbard is marked by •.

The panels in Fig. 1 show height-time-intensity plots of signal power in the vertical (upper left-hand) and off-vertical toward NE (upper right-hand) antenna beam. The maximum signal (black) is in the order of 15 dB above the noise level. The aspect sensitivity is obvious, as known from many other VHF radar observations. At 12 UT on 13 November the tropopause signal was quite extended in altitude. Thereafter several streaks of signal power detached from the tropopause and moved downward, which is a clear sign of a warmfront passage (Larsen and Röttger, 1985). Notable is that there is no real signature of a tropopause fold and that there were at least four streaks, which moved downward and were separated by about 1-3 hours. Following this multiply laminated warmfront passage the tropopause lifted by about 1-2 km. The surface weather maps in Fig. 2 show that the warm front had passed Svalbard in the late afternoon of 14 November, which occurred several hours later as compared to the extrapolation from the SSR observations.

In the center panels of Fig.1 the meridional (left-hand) and zonal (right-hand) velocities are shown. Their peak velocity was in the order of 45 m s^{-1} (black). The jet stream followed the warmfront; in the jet core the signal disappeared, which confirms earlier observations. The lower panels show the radial velocity in the vertical beam (left-hand) and the 'vertical' velocity deduced from the combination of the radial velocities measured with the coplanar NE and SW antenna beams (right-hand). Both these velocity estimates (maximum amplitude of about 1 m s^{-1}) compare satisfyingly, and we note some short-period gravity wave oscillations in the cold sector preceding the warmfront.

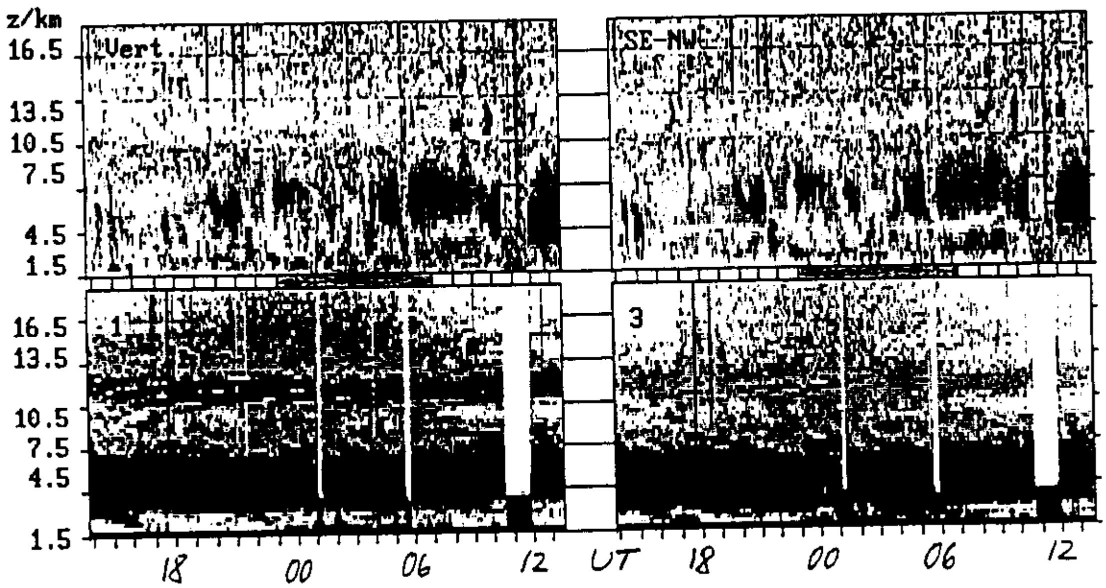

Fig. 3 Observations with the SSR 29 – 30 August 1999. Upper panels: Radial velocity in the vertical beam (left-hand) and 'vertical' velocity estimate resulting from the combination of the SE and NW antenna beams (right-hand). Lower panels: Signal power (max. 15 dB) in the vertical beam (left-hand) and the SE beam (right-hand); the maximum velocity amplitude is 2.5 m s^{-1}.

Fig. 3 shows that large quasi-vertical velocity amplitudes in the order of 2 m s^{-1} can occur and persist over several hours. These are signatures of mountain or lee waves (Röttger, 2000b), which are observed quite frequently with the SOUSY Svalbard Radar. Since the radar reflectivity layers in such wave events are inclined, the measured velocity is truly not the vertical velocity and great care has to be taken when analyzing such data to obtain the 3-dimensional wind vector.

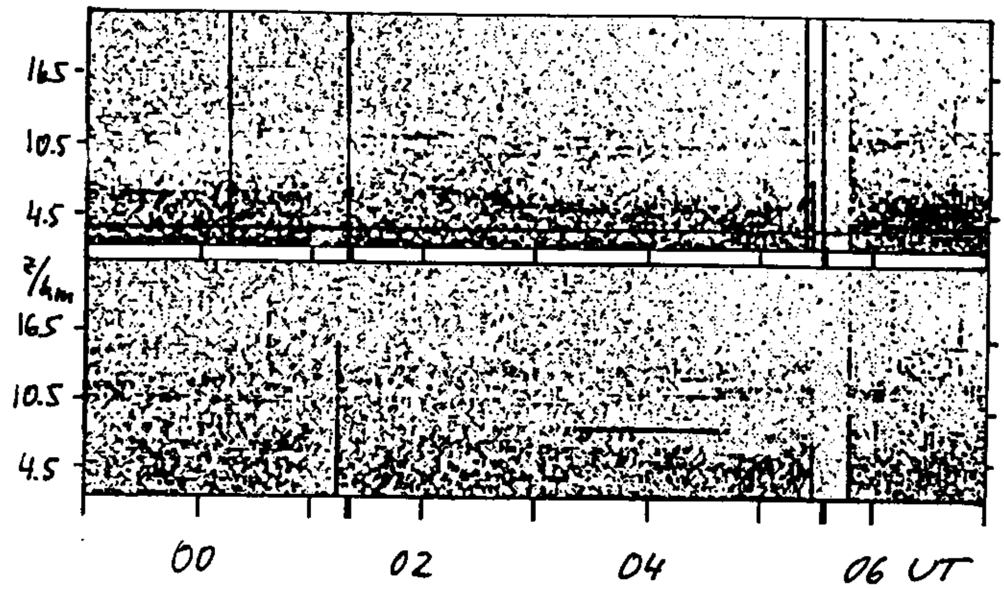

Fig. 4 Modulus of the difference of signal powers measured in the SE-NW beams (upper panel) and in the SW-NE beams (lower panel) between 23:30 UT on 29 August and 06:30 UT on 30 August 1999. The maximum difference is 5 dB.

This effect due to lee wave events can be seen in Fig. 4. The grey-scale plot cannot show the sign of the difference, but it is obvious from the original data that the sign changes according to the lee wave activity as seen in Fig. 3. There is also an unisometry of the difference, which results from the fact that lee waves have a particular fairly constant horizontal phase structure over certain periods. Noticeable is also in the original data that the sign of the radial velocity (Fig. 3) can change rapidly as function of time. Intriguing is further a small but significant unisometry below the tropopause level (Fig. 4). All these new observations, done particularly with the SOUSY Svalbard Radar, need many further detailed studies. For this purpose it is essential to have the modified antenna array of the SSR, which can be used in the spaced antenna and spatial interferometer mode.

Acknowledgement: We thank Klaus Meyer for carefully designing the prototype of the passive transmit-receive switch as well as Klaus-Dieter Preschel and staff of the MPAe workshop and laboratory for producing the hardware.

References:

Czechowsky, P., J. Klostermeyer, J. Röttger. R. Rüster and G. Schmidt, The SOUSY Svalbard Radar for middle and lower atmosphere research in the polar region, *Proc. 8th Works. Techn. Scie. Aspects MST Radar*, SCOSTEP, 318-321, 1998.

Larsen, M.F. (1985) and J. Röttger: Observations of frontal zone and tropopause structures with VHF Doppler radar and radiosondes, *Radio Sci., 20*, 1223-1232, 1985.

Röttger, J. and Tsuda, T., Studies of the polar middle and lower atmosphere by an MST radar on Svalbard, *J. Geomagn. Geoelectr., 43*, 1173-1195, 1994.

Röttger, J., Radar investigations of the mesosphere, stratosphere and troposphere in Svalbard, *Adv. Polar Upper Atmosph. Res., 14*, 202-220, 2000a

Röttger, J.: ST radar observations of atmospheric waves over mountainous areas: A review, *Ann. Geophys., 18*, 750-765, 2000b.

Röttger, J., G. Schmidt, R. Rüster, P. Czechowsky, J. Klostermeyer, J. Trautner, K. Meyer, K.D. Preschel and H. Becker, An update on the SOUSY Svalbard Radar: Observations of Polar Mesosphere Summer Echoes, *Proc. Ninth Workshop on Techn. Scient. Aspects MST Radar*, SCOSTEP, this issue, 2000.

Rüster, R., J. Röttger, G. Schmidt, P. Czechowsky and J. Klostermeyer, Observations of mesospheric summer echoes at VHF in the polar cap region, submitted to *Geophys. Res. Lett.*, 2000.