Mesospheric Summer Echoes as Observed by VHF Radar at Kühlungsborn (54°N)

Ralph Latteck and Werner Singer

Leibniz-Institute of Atmospheric Physics, Schloss-Str. 6, D-18225 Kühlungsborn, Germany

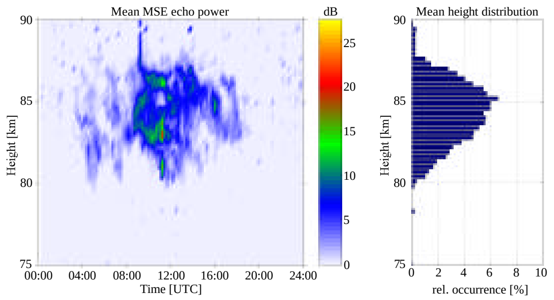
LEIBNIZ-INSTITUT FÜR ATMOSPHÄREN PHYSIK IAP

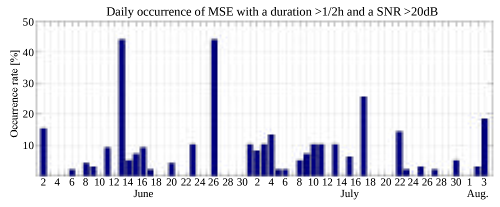
A first mesospheric observation campaign with the new 53.5 Mhz radar system at Kühlungsborn (54.1°N, 11.8°E) was conducted from May 19 until August 31, 1998 to study Mesospheric Summer Echoes (MSE), the equivalent of Polar Mesosphere Summer Echoes (PMSE) at midlatitudes.

The Doppler-beam-swinging (DBS) technique and the spaced antenna (SA) method have been applied using 16 bit complementary code with 300 m range resolution and a Doppler velocity resolution of 0.26 m/s. DBS obseravations with five beam directions (two minutes) and SA observations (one minute) are performed alternatingly.

MSE events have been observed on 33 days during day-time at solar zenith angles less than 90° for a total of 100 hours with the first MSE occurrence on June 2 and the last on August 3, 1998. The duration varies normally between 0.5 and about 6 hours. Two long lasting events (8 - 12 hours) on June 13 and 26 were connected with the occurrence of NLC layers at night-time detected by co-located Ca/Ca+ and RMR lidar observations.

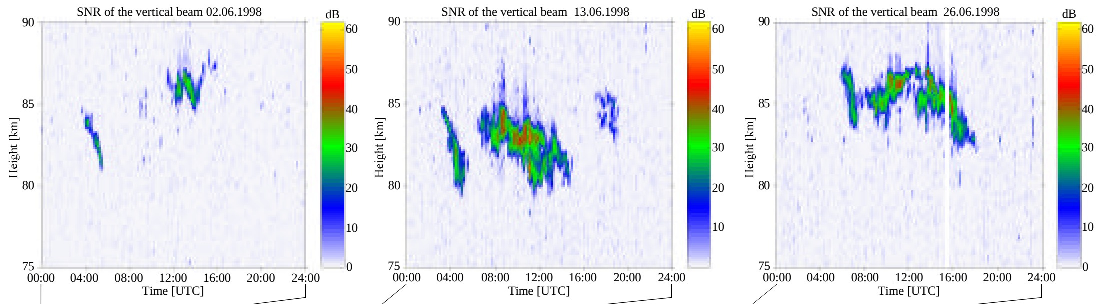
MSE layers occur in an altitude range between 80.4 km and and 90 km with a maximum occurrence around 85 km comparable to the PMSE heights at polar latitudes. MSE echoes below 82 km are dominating in June whereas echoes above 87 km occurring preferred in July.





Left figures: Time variation of echo power (expressed as S/N-ratio) and mean height distribution of MSE's with durations greater 30 minutes and S/N-ratios greater 20 dB. Data are derived as mean of the MSE events observed in the period 2 June to 3 August 1998.

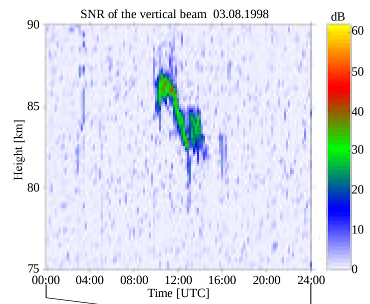
MSE observation at Kühlungsborn (54°)	
MSE campaign	19 May - 31 August 1998 75 days
Radar operation	71 days
Efficiency	95%
Days with MSE	33
First MSE	02 June
Last MSE	03 August
Percentage of MSE days	52%
Daily occurrence rate	2 - 50%

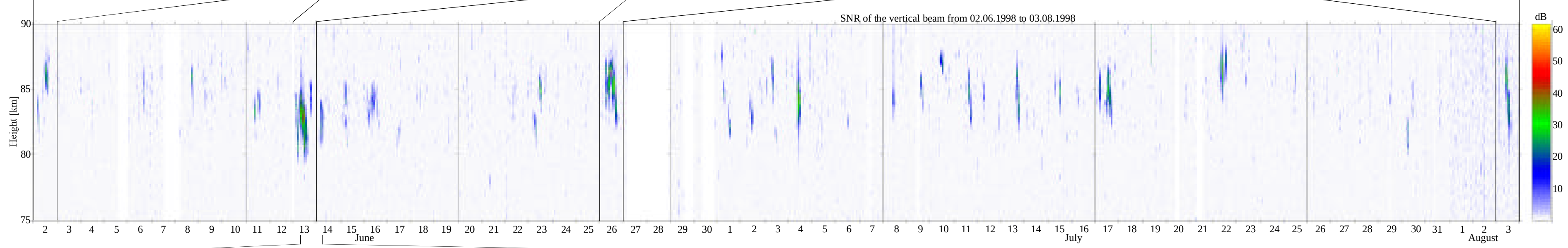


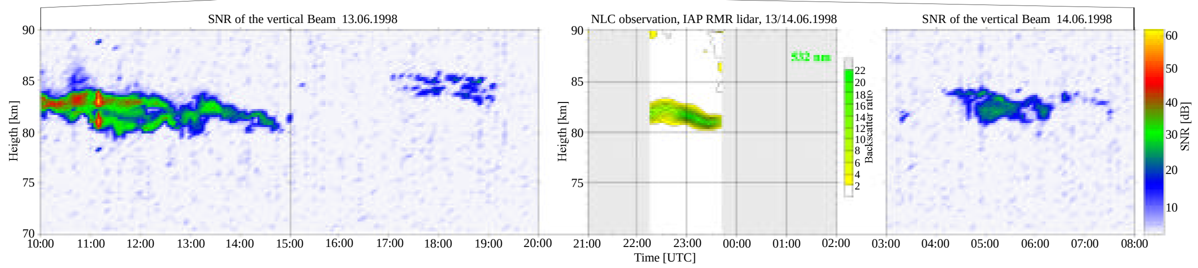
Overview on the MSE season 1998

A compressed time sequence of the mesospheric echoes observed between June 2, 1998 and August 3, 1998 is presented.

The first and last day of MSE occurrence (June 2 and August 3) as well as the two days with long lasting MSE events (June 13 and 26) are shown in detail.







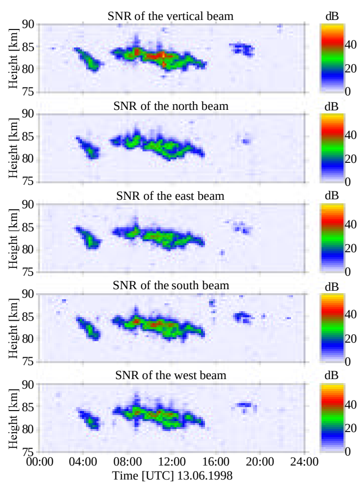
MSE/NLC events on June 13/14, 1998

The first strong long lasting MSE event occurred on June 13 between 0315 and 1430 UT with maximum echo power around 83 km and is follwed by a weaker two-hourly event in the morning hours on the next day.

A NLC layer with a maximum backscatter altitude between 81 and 82.2 km and maximum backscatter ratios of 7 to 30 has been detected in the night of June 13/14 between 2130 and 2345 UT by co-located lidar observations 300 m apart from the radar. The NLC has been observed on five wavelength 355, 393, 423, 532, and 770 nm (M. Alpers, private communication). The time dependence of MSE echo power and NLC backscatter ratio at 532 nm is shown in the Figure left.

The occurrence of long lasting MSE events in combination with NLC hints at the existence of low mesospheric temperatures during these events.

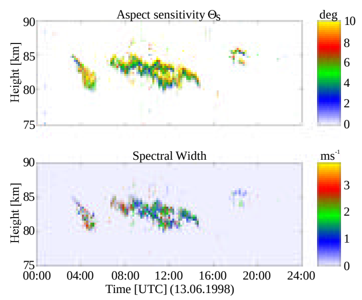
The MSE layer observed on June 13, 1998



Winds (Figures on the right)

During the main phase of the second MSE event westward directed winds with velocities up to 50 m/s are dominating. The meridional winds are changing at the onset of enhanced echo power from southward to northward directed winds (up to 40 m/s). MF radar winds obtained simultaneously at Juliusruh 115 km apart from the VHF site show the same transition of the meridional wind.

The vertical winds obtained with the VHF radar are upward directed in the upper part of the layer.

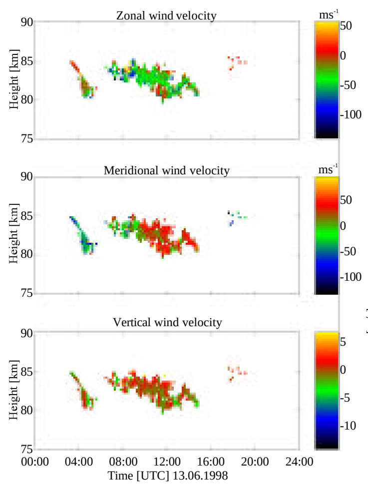


Echo power and Aspect sensitivity (Figures on the left)

Two descending MSE layers are observed between 03:15-05:20 UT and 06:30-14:30 UT. During the second and 8 hours lasting event, maximum echo power occurs around 83 km. The layer splits into a double layer at 11:00 UT. The lower layer at 81 km lasts until 1430 UT whereas the upper layer vanishes at 12:30 UT.

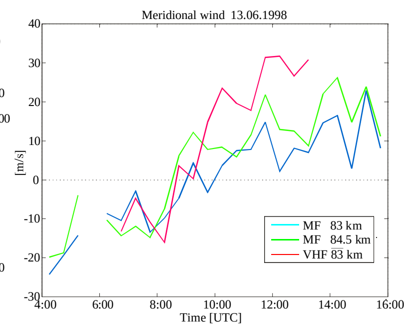
The five beam DBS observations provide information on the aspect sensitivity of the scatters. The northward and eastward directed beams show a higher aspect sensitivity than the two other oblique beams a possible indication of a layer tilting.

The single layer as well as the double layer, show enhanced aspect sensitivity, parameterized by the quantity Θ_s, at their lower ledges indicating the existence of specular scatters (enhanced stratification of the layer). The narrow total spectral width (less than 3 m/s) indicates that non-turbulent echos dominate the whole MSE event.



Comparison of half-hourly winds obtained with the VHF radar (Kühlungsborn 54.1°N, 11.8°E); 300m height resolution) and the 3.18MHz MF radar (Juliusruh 54.6°N, 13.4°E; 1.5km height resolution) on June 13, 1998.

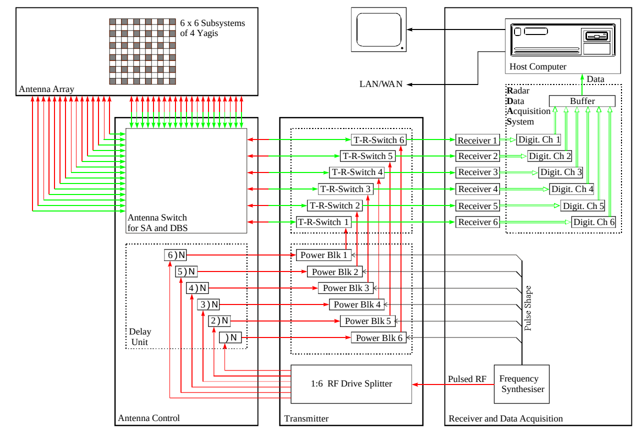
The transition from southward to northward directed winds is well reproduced by both experiments. The higher wind speeds in the vicinity of the MSE layer, as seen in the VHF winds, are not reproduced by the MF winds. The much greater height resolution causes a smoothing of the fine structure.



View through the antenna array at the radar lab

Frequency	53,5 MHz
Peak power	36 kW
Average power	1,8 kW (max. 5% Duty Cycle)
Pulse length	1 ... 50 µs
Pulse repetition rate	< 50 kHz
Height range	(0,4) 1 ... 18 km (65 ... 95 km)
Height resolution	150m, 300m, 600m, 1000m
Time resolution	~ 1 minute
Transmitted Waveforms	Single pulse, Complementary code
Pulse shapes	Rectangle, Gauss
Antenna: Number of elements	144 Yagi
Antenna: Beam width	6.5°
Antenna: Beam directions	5 (V, N, S, E, W)
Antenna: Off-zenith angles	7°, 14°, 21°
Receiving channels	6

Basic parameters of the VHF radar Kühlungsborn



Simplified block diagram of the VHF radar Kühlungsborn

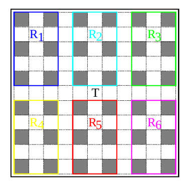
The Kühlungsborn (54.1°N; 11.8°E) VHF radar for investigation of the dynamics and structure of the lower and middle atmosphere was put into operation in September 1997. The radar system is designed for unattended, continuous operation and is capable to operate either in the Spaced Antenna (SA) or in the Doppler Beam Swinging (DBS) mode.

The radar consists of a 36 kW solid state transmitter consisting of six transmitter modules with six low-power passive transmit-receive switches and of six receiving channels. The antenna array consists of 144 Yagi antennas arranged in squared subsystems of four Yagis, so 36 basic units exist in the whole array.

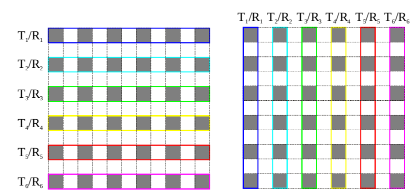
In SA mode, six groups of 24 Yagis are available for transmission and reception. For DBS mode, six North-South rows or six East-West columns are used to form beams which can be steered off-zenith in the North-South or East-West directions on transmission. During reception in DBS mode, the effective beam is formed in software.

The Radar Data Acquisition System (RDAS) is a highly versatile radar controller and data recording system used to sample and buffer the coherent signals produced by the six receiver channels. It can be rapidly and easily configured under software control to a wide varity of research experiments and routine observations. The acquisition, configuration and maintenance software allows both local and remote users access to the radar system.

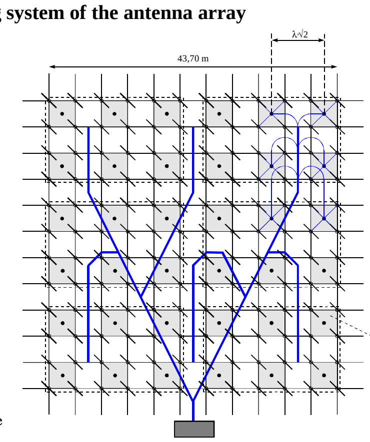
Feeding system of the antenna array

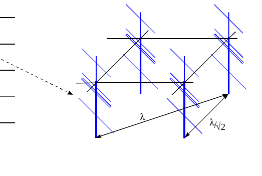


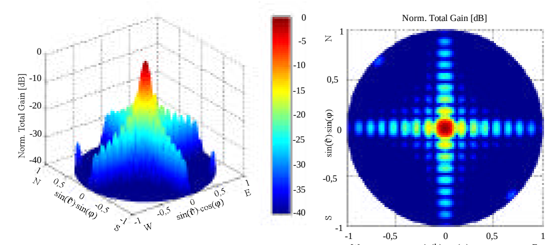
In SA mode the whole antenna array is used for transmission and six groups of six subsystems are available for reception (left figure).



In DBS mode each row (column) consisting of six subsystems must be fed coherently with a variable phase offset Äφ corresponding to the Off-zenith angle for steering the beam in North-South (East-West) direction.







3D-plot and contour plot of the antenna radiation pattern for the vertical beam in DBS mode (144 Yagis)