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10 years of radar observations of the quasi two-day wave over Collm (51°N, 13°E)

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Summary: From a VHF meteor radar at Collm (51°N, 13°E), the quasi two-day wave (QTDW) has been observed. The data set covers 10 years of measurements (09/2004-08/2014) which allows to obtain a picture about the wave properties:

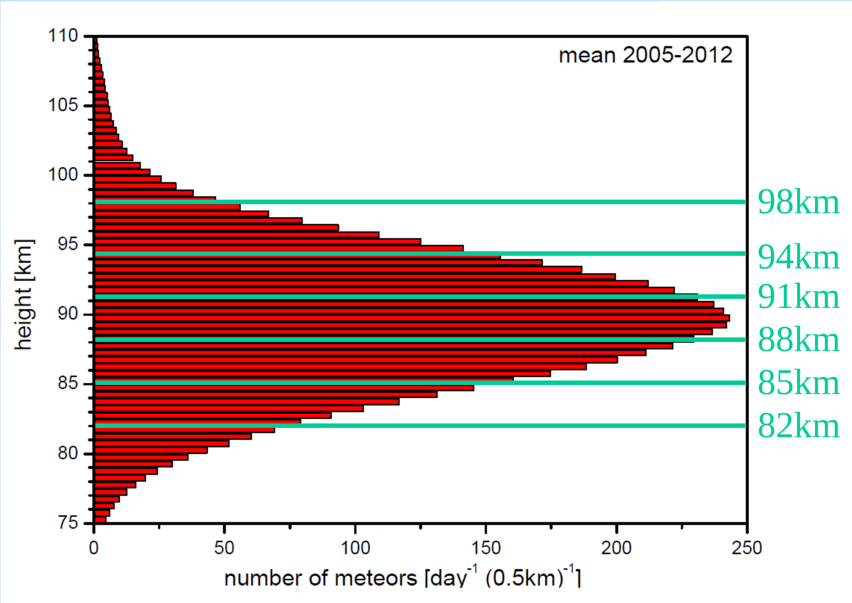
- clear summer maximum and weaker winter maxima
- stronger meridional than zonal amplitudes
- an approximately circularly polarized wave
- vertical wavelengths smaller than 200km
- connection between QTDW and background shear indicating baroclinic instability to be a possible forcing mechanism

Meteor Radar Collm and Analysis Method

At Collm Observatory (51°N, 13°E) a VHF SKiYMET meteor radar is operated since July 2004. The five receiving antennas are 2-element Yagis, the transmitting antenna is a 3-element Yagi.

power	6 kW
transmitter frequency	36.2 MHz
pulse repetition frequency	2144 Hz
coherent integrations	4-point
effective pulse repetition frequency	536 Hz
sampling resolution	1.87 ms
angular resolution	2°
height range	70-110 km
height resolution	2 km
pulse width	13 μs
receiver bandwidth	50 kHz

Above: Overview on the characteristics of the meteor radar at Collm.



Above: Meteor reflection heights as a histogram for all detected meteors 2005-2012 (red) and the centers of the six height gates (green).

From Signal to horizontal winds:

→ Obtain Doppler shift from phase change with time

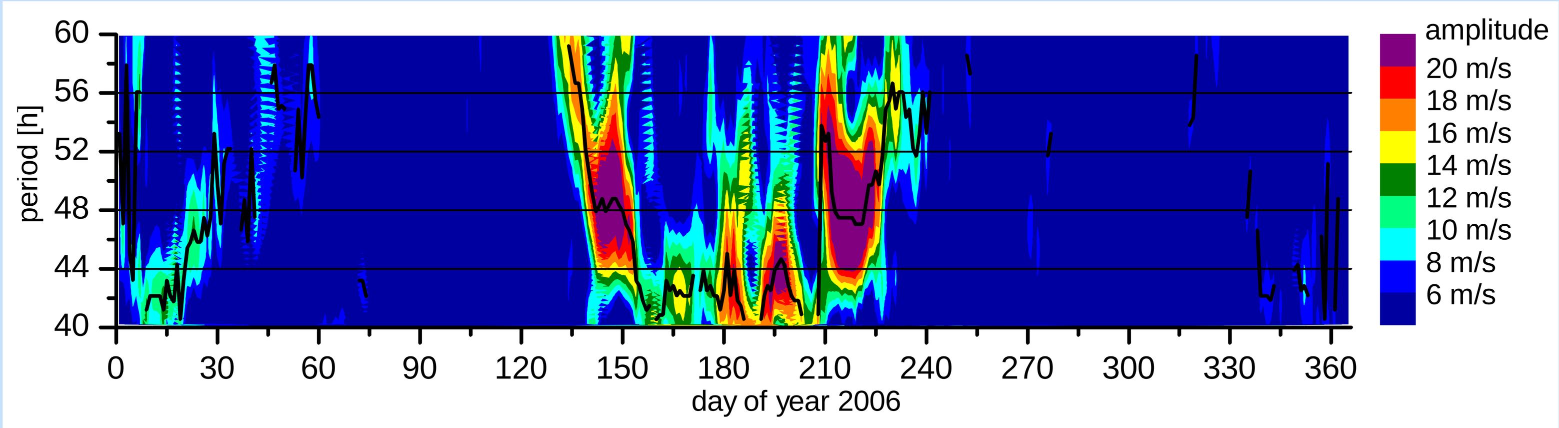
→ Radial velocity along the line of sight

→ Least-squares fit of horizontal wind components to radial wind (vertical winds assumed to be small)

→ Half-hourly averages

An 11-day Lomb-Scargle periodogram analysis has been applied on the meridional wind component. Then, the period of maximum amplitude (between 40-60h) was defined as the QTDW period.

Below: Time series of a Lomb-Scargle Periodogram of the meridional wind for the year 2006. Amplitudes are given as contour plot, the black line indicates the period of maximum amplitude at each day of the year if the amplitude is larger than 6m/s.



To obtain amplitudes and phases of the QTDW, a least squares fit was performed based on the prevailing wind, tidal oscillations of 8, 12 and 24h and the period of the QTDW as obtained from the periodogram:

$$u(t) = u_0 + \sum \left(A_i \sin(\omega_i t) + B_i \cos(\omega_i t)\right)$$

This procedure was applied for zonal and meridional wind and for each height gate seperately.

Related Papers:

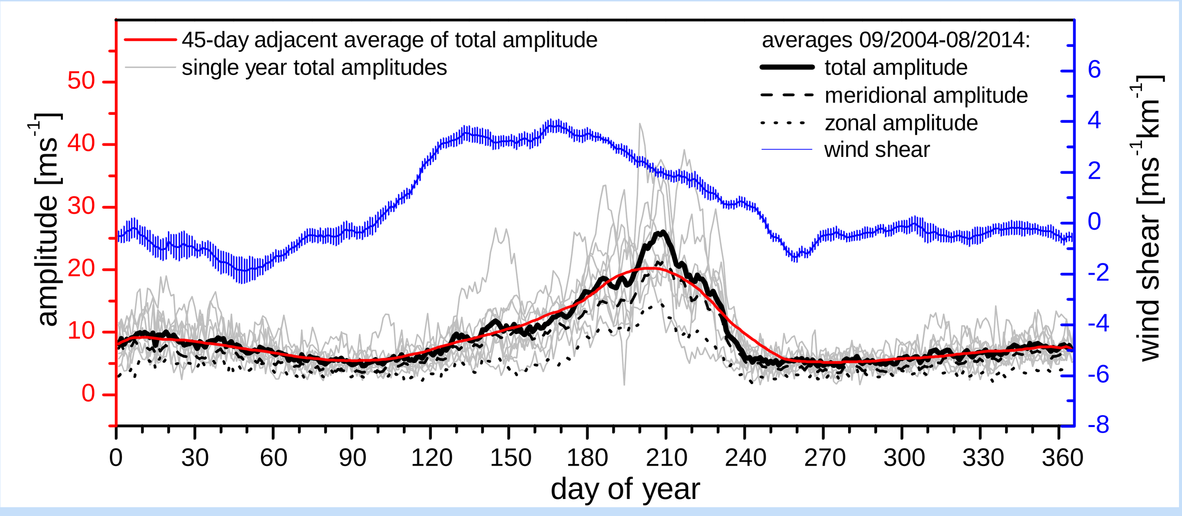
Lilienthal, F. and Jacobi, Ch.: Seasonal and inter-annual variability of the quasi 2 day wave over Collm (51.3°N, 13°E) as obtained from VHF meteor radar measurements, Adv. Radio Sci., 12, 205-210, doi:10.5194/ars-12-205-2014, 2014a.

Lilienthal, F. and Jacobi, Ch.: Comparison of quasi-2-day wave amplitudes and phases over Collm (51.3°N, 13.0°E) based on two different analyses, Rep. Inst. Meteorol. Univ. Leipzig, 52, 25 – 34, 2014b.

Lilienthal, F. and Jacobi, Ch.: Meteor radar quasi two-day wave observations over 10 years at Collm (51.3°N, 13.0°E), Atmos. Chem. Phys. Discuss., 15, 9631-9659, doi:10.5194/acpd-15-9631-2015, 2015.

Wave Properties

Right: Annual QTDW amplitudes for each year 2004-2014 (grey), their average (black) and a smoothed annual cycle (red). Vertical shear of the zonal wind in blue with standard error. Summer and winter maxima are visible, wind shear amplifies some days earlier than the QTDW.

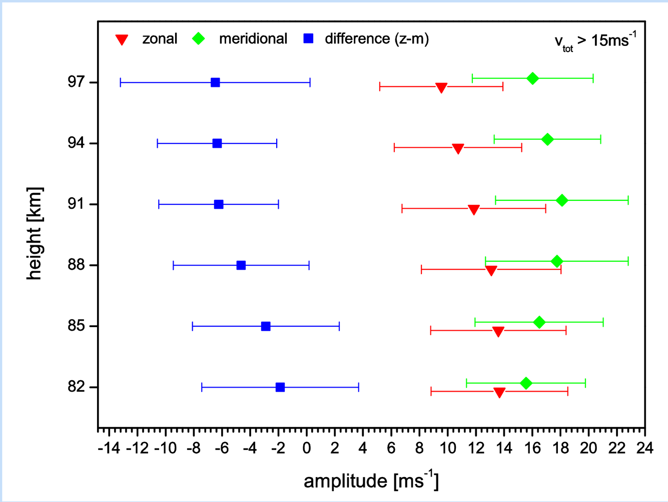


Annual cycle:

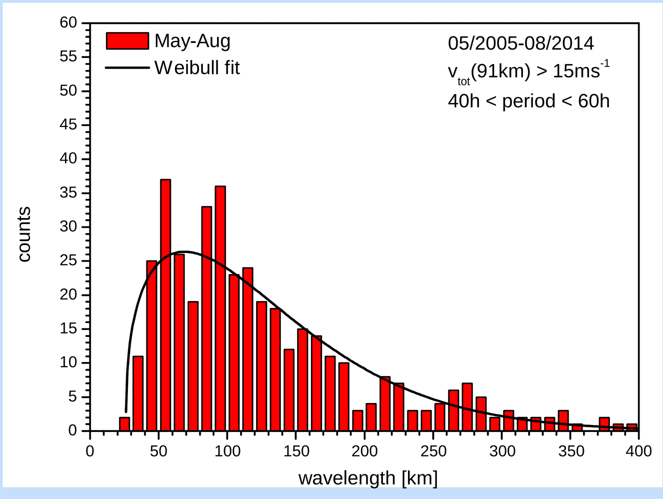
- clear summer maximum (May-August): 20m/s on an average
- smaller winter maxima reaching 10m/s
- strong year-to-year variability
- summer: Amplitude of QTDW related to vertical shear of zonal wind

Larger meridional than zonal amplitudes:

Right: Zonal (red) and meridional (green) mean amplitudes 2004-2014 with standard deviation. Amplitude difference with standard deviation in blue. Only days with total amplitude >15m/s are used.



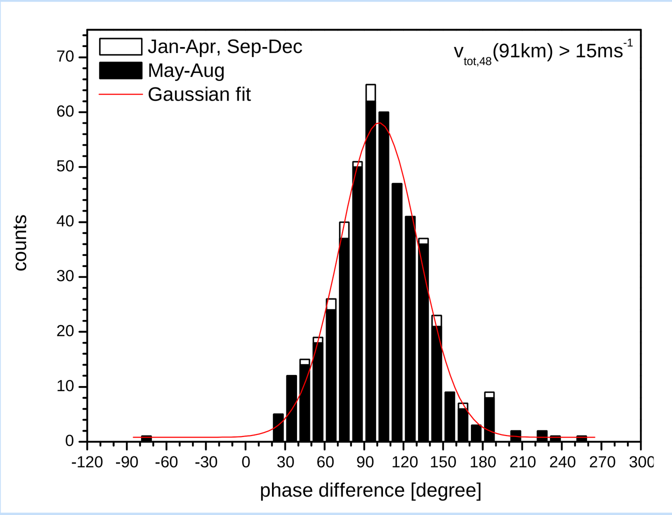
Vertical wavelength <200km:



Above: Histogram of daily QTDW vertical wavelengths during summer (May-Aug) 2005-2014 at 91km altitude and only for amplitudes >15m/s. Wavelengths >400km are not shown (refers to 56 out of 460 days). A Weibull fit is added.

Almost circularly polarized wave (phase differences close to 90°):

Below: Histogram of 91km phase differences for amplitudes >15m/s. Black bars: May-Aug. White bars: Jan-Apr and Sep-Dec. A Gaussian fit is added in red.



Connection with background wind shear

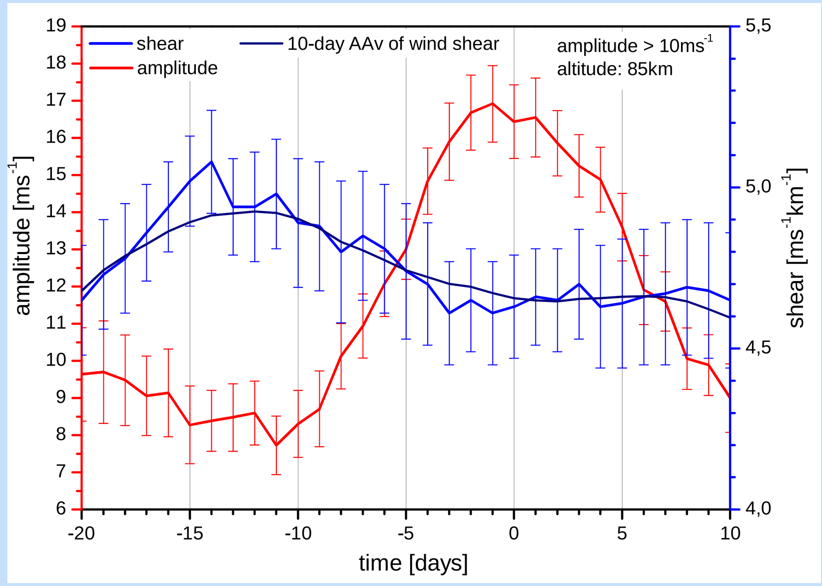
The Charney and Stern theorem states that baroclinic instability may appear when the meridional gradient of quasi geostrophic potential vorticity changes sign. It can be written as follows:

$$\frac{\partial \overline{q_g}}{\partial y} = \beta - \frac{\partial^2 \overline{u}}{\partial y^2} - \frac{1}{\rho_0}\left(\frac{\partial}{\partial z}\left[\rho_0 \epsilon \left(\frac{\partial \overline{u}}{\partial z}\right)\right]\right)$$

Thus, a necessary condition is a minimum of zonal wind which is represented in the summer mesospheric easterlies. Vertical wind shear of the zonal wind may be used as a proxy for that minimum.

Epoch analysis of QTDW amplitude maxima:

Right: Epoch analysis of summer QTDW amplitude maxima >10m/s and corresponding vertical shear of the zonal wind at 85km altitude. Windows of 20 days before the event until 10 days after the event are chosen. Between May 2005 and August 2014, 25 key events are considered.



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