On the winter anomaly of the night-to-day ratio of ozone in the middle to upper mesosphere in

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Over seven years of ozone measurements by means of the microwave technique in middle latitudes at Lindau, Germany (51.660 N, 10.130 E) brought evidence that the night-to-day ratio (NDR) is clearly enhanced in the middle mesosphere during the winter season compared with summer. The increase is most pronounced between about 60 and 75 km. The domain of increase includes the region of the occurrence of the so-called tertiary ozone maximum. This ratio is more than twice as large as in the summer season. The measurements show an annual asymmetry with largest values before winter solstice. The NDR is modulated by variations of planetary time scale. Its appearance resembles that of the well-known winter anomaly of the plasma parameter of the D-region. Model calculations on the basis of our new 3D-model LIMA (Leibniz-Institute Middle Atmosphere model) agree, in essence, with the observations although differences occur in some details. The strong superimposed variations of planetary time scale indicate that dynamical processes are responsible for these modulations. Particularly, the planetary wave activity and the occurrence of sudden stratospheric warmings changing the temperature and the transport of water vapor are reasons for these variations. An essential influence on the anomaly also has the photochemical Doppler effect introduced by Sonnemann in 2001. According to this effect, the night-time values of ozone noticeably increase while the daytime values slightly decrease in the region of the enhanced NDRs in winter, under the condition of a prevailing zonal west wind system if compared with the behavior with the case of zero or even a zonal east wind. The cause of this effect is given by the fact that the photochemical system represents an enforced nonlinear chemical oscillator driven by the diurnally periodic solar insolation. The period of the insolation changes when an air parcel moves with or against the rotation of the Earth and consequently, the diurnal variations of the chemically active species also alter in a specific way. Particularly, the relations during sunset influences the nighttime ozone level. We present both observations and model calculations and discuss them in terms of chemistry and dynamics.