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Interaction between gravity waves and thermal tides in the middle atmosphere

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Gravity waves (GWs) and thermal tides are important phenomena in middle-atmosphere dynamics. Breaking GWs have a major impact on the mean flow by driving the residual circulation in the mesosphere / lower thermosphere. Moreover, a major part of mesospheric variability is made up by these types of wave motion. In former investigations of the GW-mean flow interaction GW parameterizations (e.g. Lindzen 1981) have been used which assume stationarity of the background fields. In these single-column approximations the impact of horizontal gradients in the background atmosphere on the GW propagation is neglected as well. However, highly transient tidal perturbations are always present and dominate diurnal variations in the middle atmosphere through which the GWs propagate. Even in studies of the interaction between GWs and these thermal tides, a possibly important aspect of tidal dynamics, a columnar parametrization of GWs is applied which does not account for the time dependence of thermal tides.

To close the corresponding gap we use a ray tracing technique to solve the time-dependent dynamical equations of GWs in WKB approximation. Both the horizontal gradients of the background (including the tides) and its time dependence are properly taken into account. It is shown that tidal transience leads to a strong modulation of the frequency or, equivalently, of the horizontal phase speed of slow GWs. This horizontal phase speed changes in a way that follows the shape of the tidal wind field. In contrast to the results with a stationary background, filtering at tidal critical layers is suppressed. In comparison with the conventional columnar approach reduced mean flow accelerations are obtained. This results in a weaker attenuation of thermal tides. Last, we identify and discuss effects of horizontal refraction of the wave vector, and thus wave momentum, mainly due to meridional wind shears.