The interaction between Gravity Waves and Solar Tides: results from 4D Ray Tracing coupled to a Linear Tidal Model

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abstract

Gravity waves (GWs) and solar tides (STs) are major components of the mesosphere-lower-thermosphere (MLT) dynamics. Global scale and thermally driven, STs modulate all dynamical fields in the middle atmosphere. Short scale free GWs shape the middle atmosphere mean circulation by transporting energy and momentum from high to low density region. Mostly exited in the lower atmosphere and propagating upward, GWs and STs form the main constituents of the dynamical coupling between troposphere and MLT.

GWs and STs incorporate a huge range of scale, from small to global. But conventional GWs parameterizations used to describe this interaction (e.g. [1]) neglect time-dependence and horizontal gradients of the background flow, with potentially fatal effects (e.g. [2]). We here consider a step-by-step approach to study the interplay between GWs and diurnal STs.

GWs propagate in a time-dependent background flow, composed by a climatological mean and diurnal tidal fields extracted initially from a general circulation model (HAMMONIA, see [3]). The deposition of momentum and buoyancy from the GWs propagation is calculated. The evaluated Rayleigh-friction and temperature-relaxation coefficients impose in turn a GW forcing on the propagation of diurnal STs in a climatological mean background flow. The extracted STs are then used for a new computation of the GW fluxes. This is iterated a few times to obtain a converged result on GW fluxes and STs.

The propagation of GWs is modeled by a new WKB GW model (ray tracer). The crossing of rays (caustic problem) is prevented by implementing a new wave-action phase-space-density conservation scheme [4, 5]. The scheme attaches to each ray a finite volume in the location & wavenumber phase-space. The location-wavenumber volume is conserved during the propagation, responding in shape to the local stretching and squeezing in wave-number space. The propagation of STs is described in a linear version of a general circulation model (KMCm), see [6], allowing for planetary waves in the background state. STs are projected onto their migrating and non-migrating components \(D_{S0}, D_{E[1,2,3]}\) and \(D_{W[1,2,3]}\). In both wave propagation, the climatological mean include stationary planetary waves.

A simplified GWs ensemble is considered, homogenously launched in all directions, at a single launch level. The temporal dependence of the background flow leads to a modulation of the GWs momentum deposition. Due to constructive and destructive interferences, planeraty waves play an active role in the modulation of the GW fluxes but they also influence the \(D_{S0}\) and \(D_{W[1,2]}\) amplitudes. Because transient critical layers disappear, the horizontal and temporal dependence of the background flow reduce the amplitude of GW momentum and entropy. In consequence, the amplitude of the STs is also reduced. The seasonal variability of the GWs-STs interaction is studied as well.

Key words: Middle-Atmosphere dynamics, Solar Tides, Gravity Waves

References:


