Impact of Middle-Atmosphere Solar Tides on Gravity Waves

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Objectives

Gravity Waves (GWs) and Solar Tides (STs) are main constituents of dynamical coupling between troposphere and the middle atm.

- Diurnal heating forcing ($O_{h}$: water vapor, convection, condensation . . .)
- STs are large-scale forced waves, that modulate all dynamical fields in mesosphere.
- GWs are small-scale free waves, that shape mesosphere mean circulation.

GWs and STs interaction

Introduction | Methodology

- GWs - STs interaction: step-by-step approach. Extension of studies [1, 2]
- GWs propagate in a climatology + STs time-changing background flow. Fig. 1. Cautusics problem is solved (intrinsically all Ray tracer model).
- STs are solved using a linearised GCM with climatology + GWs forcing. Fig. 3

Ray tracers model

- Model do not resolve GWs lead to parametrisation of GWs, based on WKB:

$$\mathbf{(X, T)} = e^{\mathbf{x, \omega}} \quad A(X, T) = e^{\mathbf{X, \omega}} \quad \mathbf{\omega}(X, T) = -\mathbf{\partial}_{\mathbf{\omega}} \phi \quad \mathbf{k}(X, T) = \mathbf{\partial}_{\mathbf{\omega}} \phi$$

$$=\text{leads to numerical Ray tracers.}$$
- GWs propagate in time-changing background flow; on rays parallel to $c_{g}$
- “Wave-Action phase-space density Ray tracer”$^{*}$ is implemented, using [1, 3, 4], in order to solve the impossibility of Rays to cross each other.
- Each ray attached to a finite volume conserved during the propagation (Fig. 2) in the 6D location-wavenumber phase-space.
- Propagation of a small spectrum of GWs, launched at 25km (all direction, see Fig. 2) with a constant emission source:

NEW RAY only emitted when OLD one has left

Figure 2: Schematic illustration of the location-wavenumber conservation (from Muraschko et al.). Right: Initial phase velocity $c_{g}$ [nondim.]

The Ray tracer model evaluate:

$$\begin{align*}
F_{GW} &= \frac{1}{2} \mathbf{\partial}_{\mathbf{x}} \mathbf{(\rho \mathbf{u}^{'2})} + \mathbf{\partial}_{\mathbf{y}} \mathbf{(\rho \mathbf{u}^{'} \mathbf{v}')} + \mathbf{\partial}_{\mathbf{z}} (\rho \mathbf{w}^{'} \mathbf{w}') + \text{“curvature terms”} \\
\alpha_{B} &= \frac{< F_{GW} \times \mathbf{U}_{\text{tide}} >}{< \mathbf{U}_{\text{tide}}^{2} >} \\
\alpha_{I} &= \frac{< F_{GW} \times \partial \mathbf{U}_{\text{tide}} >}{< \partial \mathbf{U}_{\text{tide}}^{2} >}
\end{align*}$$

Figure 3: Left: deposition of momentum $< \rho \mathbf{u}^{'} \mathbf{w}'>$ [kg/m/s/day]. Middle: $F_{GW}$ [m/s/day]. Right: $\alpha_{B}$ [day$^{-1}$].

Important Result

GWs and STs strongly interact together.

- STs influence the propagation of GWs, but also their deposition of momentum and buoyancy (Fig. 3).
- Rayleigh friction and Newtonian cooling coefficients ($\alpha_B, \alpha_I$) quantify the strength of the STs - GWs interaction.
- GWs influence phase and amplitude of STs (Fig. 4), via momentum deposition.

STs model

In order to obtain STs (Fig. 4), study [2] is used, where:

- Linearisation of $K M C M$ - GCM around the climatology (Background flow, Fig. 1) is considered.
- and GWs forcing ($\alpha_B, \alpha_I$) from our Ray tracer is introduced (Fig. 3).

Figure 4: Diurnal tides $V_{\text{tide}}$ [m/s] with GWs forcing.

Summary & Perspectives

- Through $\alpha_B, \alpha_I$, the study quantify the STs - GWs interaction and show how one (STs, GWs) influence the other (GWs, STs).
- 1st perspective: Direct coupling of STs and GWs.

References


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