Effects of Background Wind on Secondary waves Generated by Breaking of Mesospheric Gravity Waves

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Motivation

Airglow imaging in the mesosphere reveals that quasi-monochromatic, small-scale gravity waves (GWs) frequently propagate through the mesosphere and lower thermosphere. Snively and Pasko [2003] studied these small-scale mesospheric GWs using a simple numerical model, showing that secondary waves generated by breaking of primary gravity waves can be ducted and observed in the airglow layer. The results also reveal that horizontal wavenumber and frequency of the secondary waves are twice them of the primary waves in their quiescent simulation.

Here, extending their study, the effects of background wind on secondary waves generated by breaking of gravity waves in the mesosphere are investigated.

Experiments

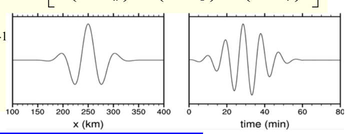
2-D non-hydrostatic model (ARPS; Advanced Regional Prediction System)

- 1000 X 141 km, Δx = 1 km, Δz = 300 m, Δt = 1 s
- Upper B. C. : sponge layer
  Lateral B. C. : radiation condition, sponge layer

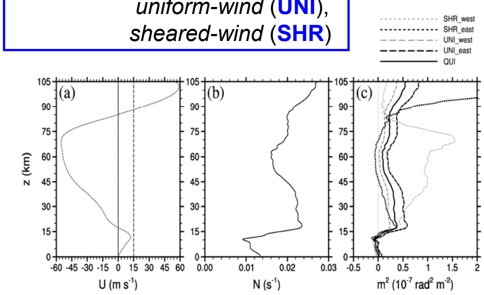
Tropospheric forcing on vertical momentum

$$F = A\cos k_1 x\cdot\cos\omega_1 t\cdot\exp\left[-\left(\frac{x-x_0}{\sqrt{2}\sigma_x}\right)^2-\left(\frac{z-z_0}{\sqrt{2}\sigma_z}\right)^2-\left(\frac{t-t_0}{\sqrt{2}\sigma_t}\right)^2\right]$$

$k_1 = 0.00011$ rad m^{-1}
$\omega_1 = 0.011$ rad s^{-1}
$A = 0.0072$ m s^{-2}

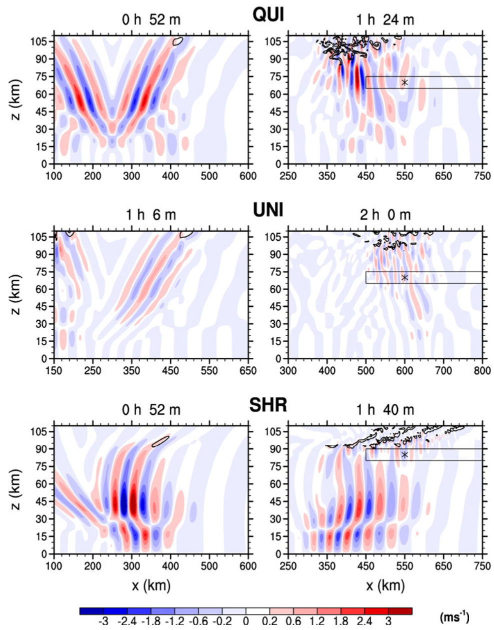


Experiments : *quiescent* (**QUI**), *uniform-wind* (**UNI**), *sheared-wind* (**SHR**)

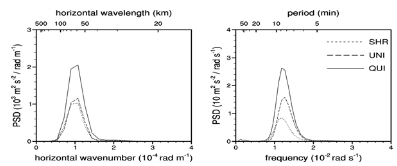


(a) Basic-state wind and (b) stability, and (c) profiles of m^2 for the primary waves in three experiments

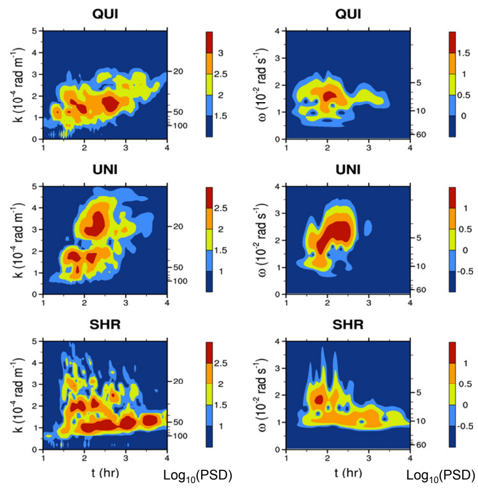
Simulated Secondary Waves



Normalized vertical velocity fields and Richardson number of 1/3 at beginning (left) and vigorous stages (right) of wave breaking

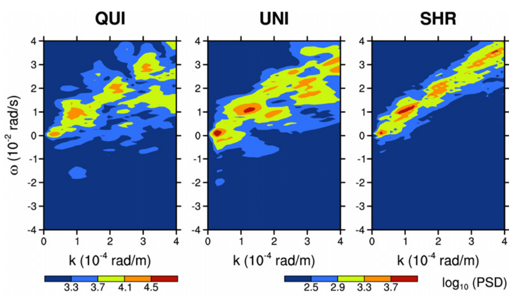


PSDs of the primary gravity waves



PSD of the normalized vertical velocity fields with respect to the horizontal wavenumber (left) and frequency (right) after wave breaking

Sources and Propagation Condition

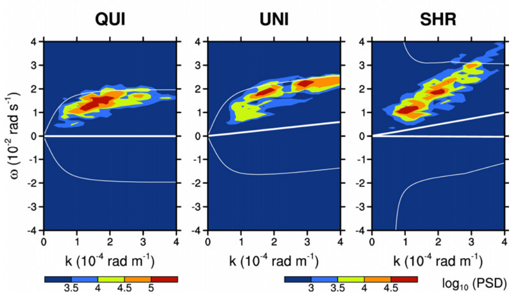


Spectra of the sources of secondary waves

(2-D PSDs of the normalized vertical forcing, F_w, as functions of k and ω)

$$F_w = -\frac{1}{\bar{\rho}}\frac{\partial}{\partial x}(\bar{\rho}u'w') - \frac{1}{\bar{\rho}}\frac{\partial}{\partial z}(\bar{\rho}w'^2) + D_w$$

→ Similar spectral shapes (i.e., peak at c_p ~ 100 m s^{-1} that is equal to the phase speed of primary wave, and existence of very high-frequency components)



The propagation condition

superimposed on the 2-D PSDs of the normalized vertical velocity as functions of k and ω.

Thick lines denote the phase velocity equal to the basic-state wind in the interval of wave propagation and thin lines indicate effective regions to vertically propagate with noticeable amplitudes.

→ Spectral characteristics of the secondary waves differ significantly for each experiment, although spectral shapes of nonlinear forcing due to breaking of the primary waves are similar. The difference is due mainly to the propagation conditions of the secondary waves.

Reference

Snively, J. B. and V. P. Pasko, 2003: Breaking of thunderstorm-generated gravity waves as a source of short-period ducted waves at mesopause altitudes. *Geophys. Res. Lett.*, **30**(24), 2254.