Gravity Wave Penetration into the Thermosphere and Responses to Solar Variability

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Motivation

GW forcing of the MLT occurs primarily by GWs with large scales and high frequencies.

These GWs can arise:
- from discrete sources in the lower atmos.
- from strong local forcing in the MLT
- from refraction in strong shears
Approach

• Formulate general viscous dispersion relation to understand implications for penetration

• Use Fourier and ray-tracing methods to assess GW spectra and thermospheric penetration

• Initial focus on method development, applications to real temperatures, winds, and MLT effects thereafter
Fourier representation of GWs arising from mesoscale convection

responses at 90 km

$w', T'$

responses above 90 km

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Fourier description of response to local dissipation

- contribution to “mean” body forcing
- radiation of high-freq. GWs to higher and lower altitudes
MCC GW momentum flux spectrum

smaller $\lambda_z$ portion interacts with MLT winds near the mesopause

large $\lambda_z$ portion penetrates quickly to high altitudes near the mesopause

$\omega/N$, $\lambda_z$ (km)
Time-height plot of thermospheric body force due to GWs excited by MCCs
- forcing extends to high altitudes, will exhibit **strong** solar-cycle dependence

![Diagram showing time-height plot with arrows indicating GWs and a color contour map representing force distribution.]

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Penetration of GWs excited by MCCs in a viscous thermosphere

Altitude penetration of GWs varies as
(from viscous dispersion relation)

\[ Z_{\text{diss}} - Z_0 \sim H \ln \left( \frac{\omega_r H}{4 m_0 \nu_0} \right) \sim T \ln T \]

=>

penetr. to \( \sim250 \text{ km}, \) solar min (\( T \sim 500 \text{ K} \))

penetr. to \( \sim300-400 \text{ km}, \) solar max (\( T \sim 1000 \text{ K} \))
Penetration of GWs excited by MCCs in a viscous thermosphere

\[ T(z) \]

\[ \ln(\rho/\rho_0) \]

\[ N^2(z) \]

\[ H(z) \]
Penetration of GWs excited by MCCs in a viscous thermosphere

\(T_{th} = 250 \, \text{K} \) (ref. only)

\(T_{th} = 500 \, \text{K}

\(T_{th} = 1000 \, \text{K}

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