Numerical simulation of high-frequency normal atmospheric modes in the non-isothermal atmosphere with Newtonian cooling

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Content:

- Linearized theory of global-scale atmospheric waves:
  - **basic equations;**
  - **the vertical structure equation.**
- Simulation results (numerical solution of the vertical stucture problem):
  - **Amplitude disrtibution (the atmospheric resonance);**
  - **Phase profile;**
  - **The vertical profile of energy flux.**

N=1 Kelvin normal mode:

Period – about 33-hours

Horizontal phase speed – close to the speed of sound

Largely unfectectet by mean wind

Linearized wave theory:

$$q = q_0 + q'$$

mean

small perturbation

$$q'(\lambda, \varphi, z, t) = \mathrm{Re} \sum_{m,\omega} \underline{\underline{q'_{m,\omega}(\varphi, z)}} \exp\left[i\left(m\lambda - \omega t\right)\right]$$

Complex amplitude

Basic equations for complex amplitudes (without subscripts m,ω):

$$-i\omega u' - f v' = -imp'/(\rho_0 a\cos\varphi),$$

$$-i\omega v' + fu' = -p'_\varphi/(\rho_0 a),$$

$$p'_z = -\rho' g,$$

$$-i\omega\rho'/\rho_0 + imu'/(a\cos\varphi) + (\cos\varphi\, v')_\varphi/(a\cos\varphi) + (\rho_0 w')_z/\rho_0 = 0,$$

$$-i\omega p' + (p_0)_z w' = c_s^2(-i\omega\rho' + (p_0)_z w') + (\gamma - 1)\rho_0(J' - a_N T'),$$

$$\frac{p'}{p_0} = \frac{\rho'}{\rho_0} + \frac{T'}{T_0}.$$

Heating

Newtonian cooling

Separation

$$\phi' = \sum_n \Theta_n(\varphi) G_n(z)$$

$$F' = \sum_n \Theta_n(\varphi) F_n(z)$$

Hough function Θ_n transform

$$L_\varphi[\phi'] = L_z[\phi'] - F'$$

Latitudanal structure equation

(Laplace's tidal equation)

h_n

Separation parameter
(equivalent deph)

Vertical structure equation

Vertical structure equation (log-isobaric coordinates)

$$\frac{d^2 G_n}{d x^2} + M\left[N^2; a_N\right]\frac{d\ G_n}{d\ x} + \frac{H^2 N^2}{g h_n} G_n = F_n'$$

$$x = -\ln(P/P_0)$$

$$H = \frac{R\overline{T}}{g}$$

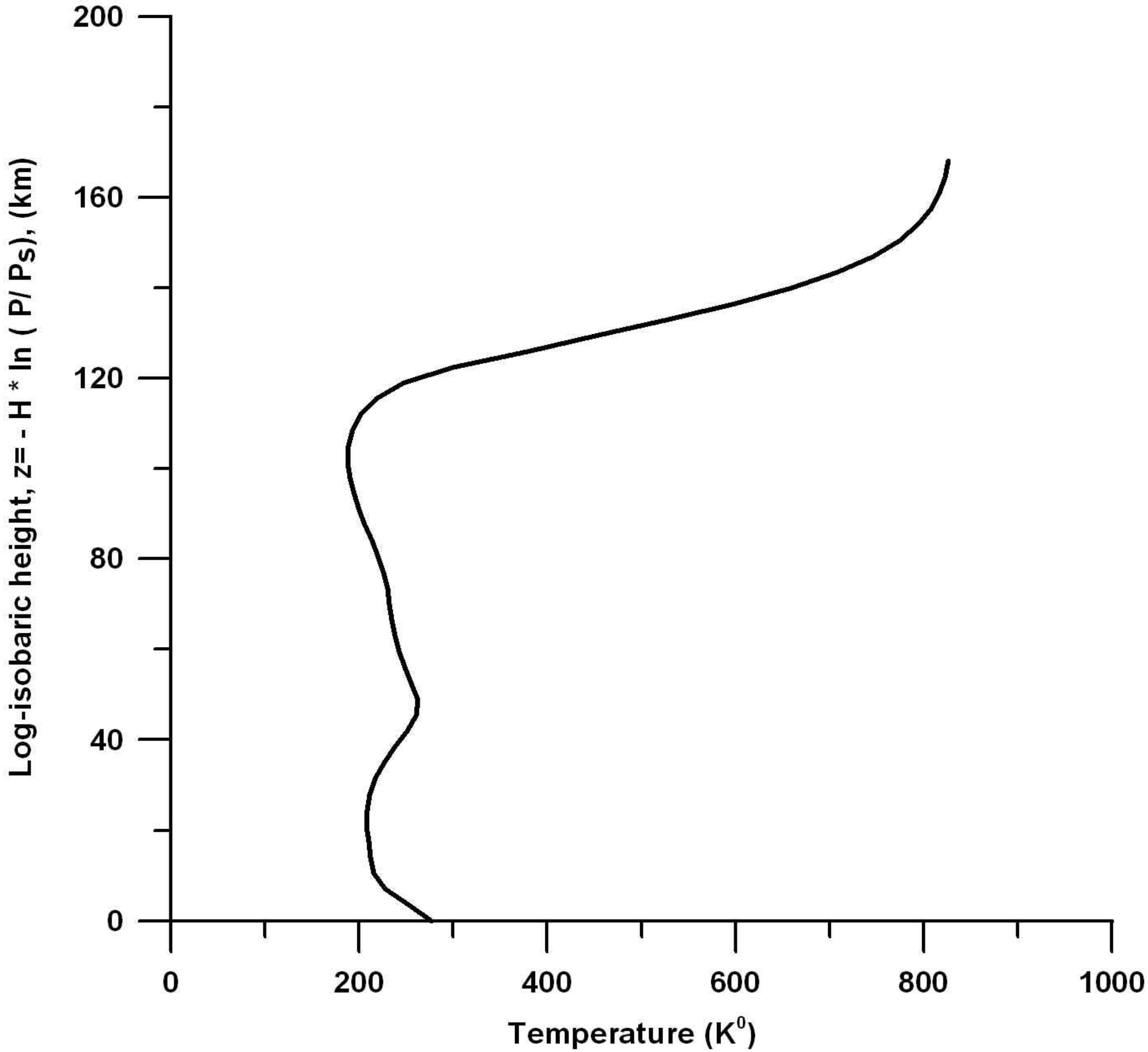
$$N^2 = \frac{R}{H}\left(\frac{dT_0}{dx} + \kappa\frac{T_0}{H}\right)$$

Boundary conditions:

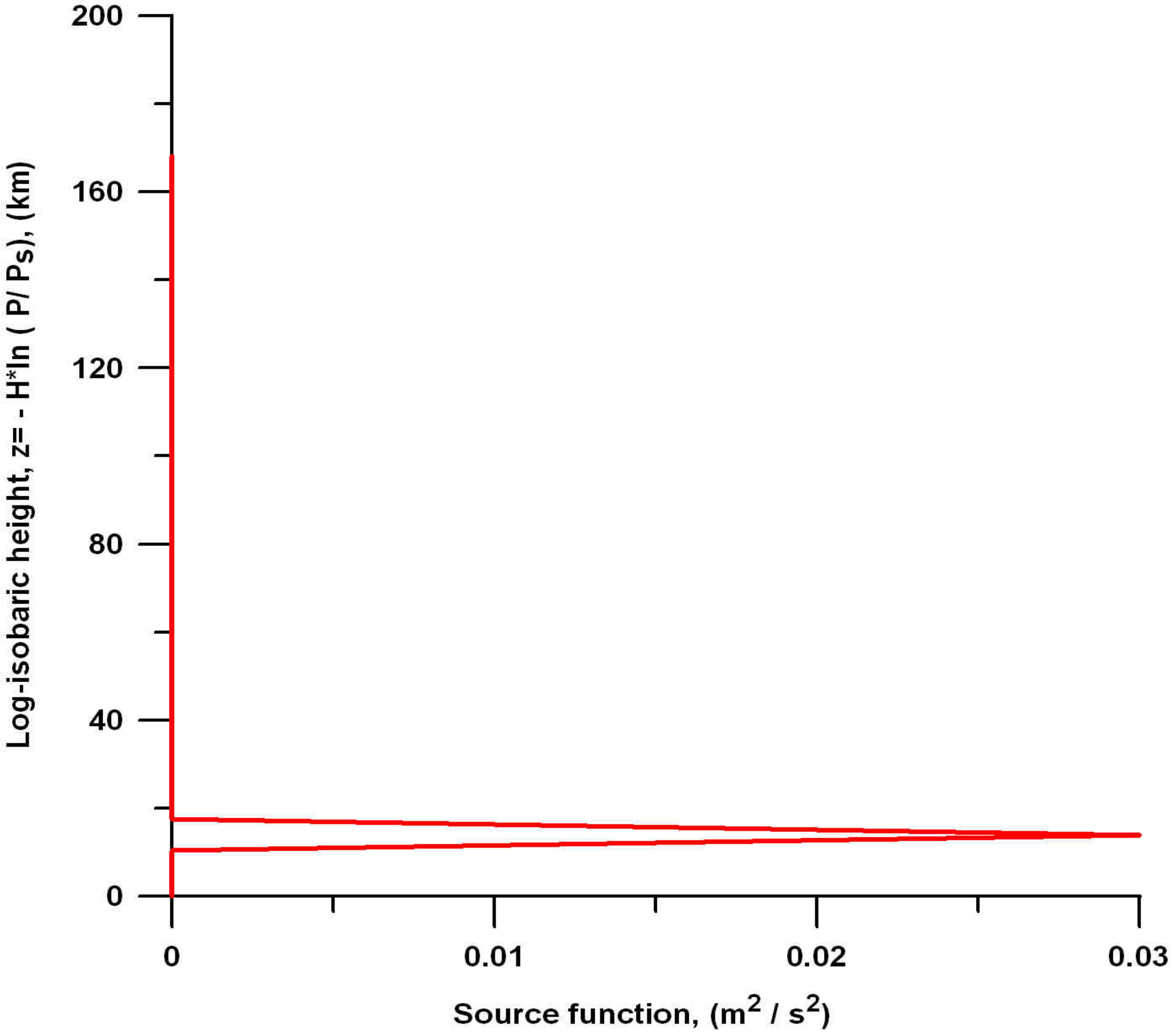
Upper - Radiation\finite energy condition

Lover - No vertical velocity disturbance condition

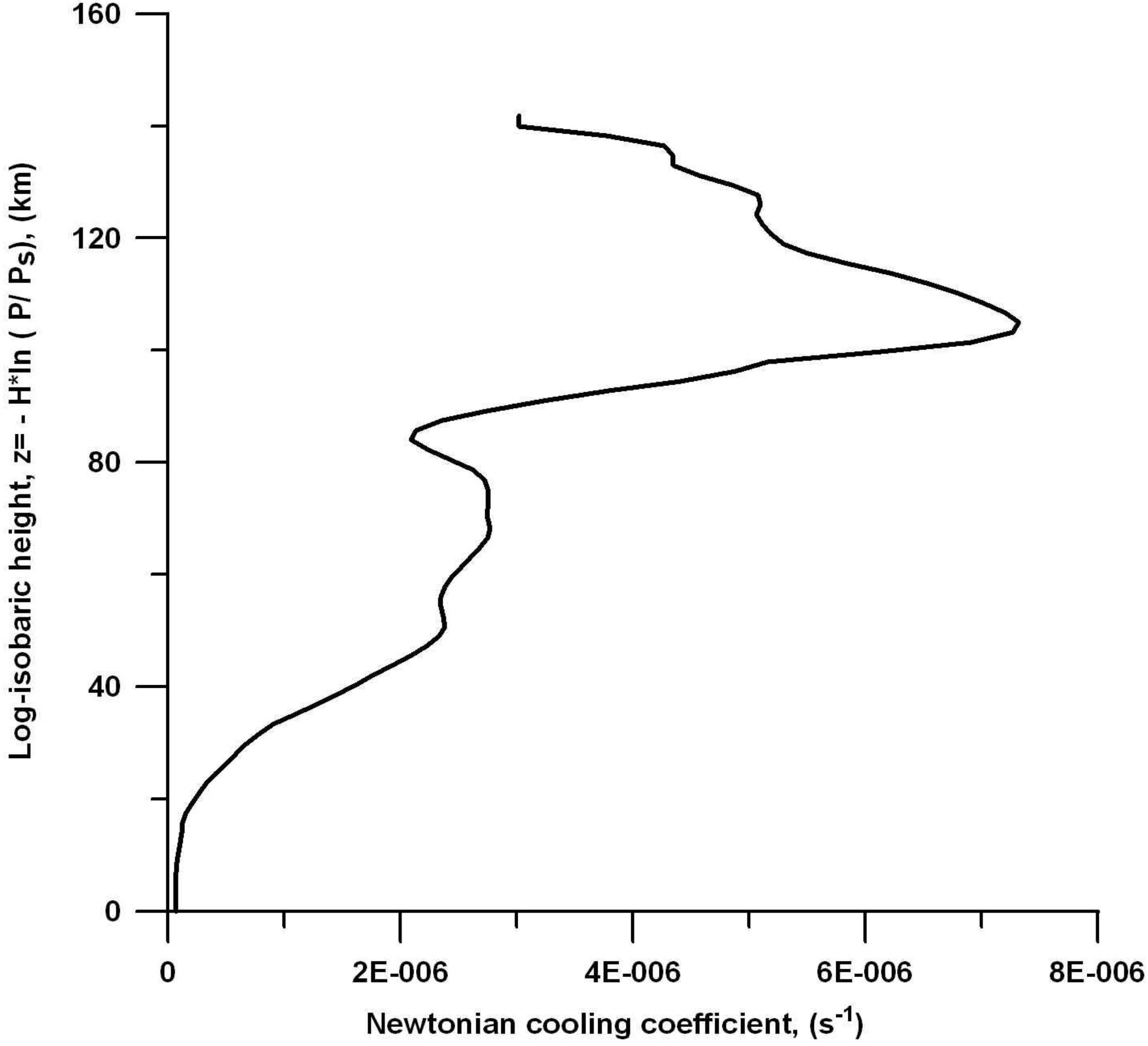
Mean disribution of temperature used in calculation



Source function:

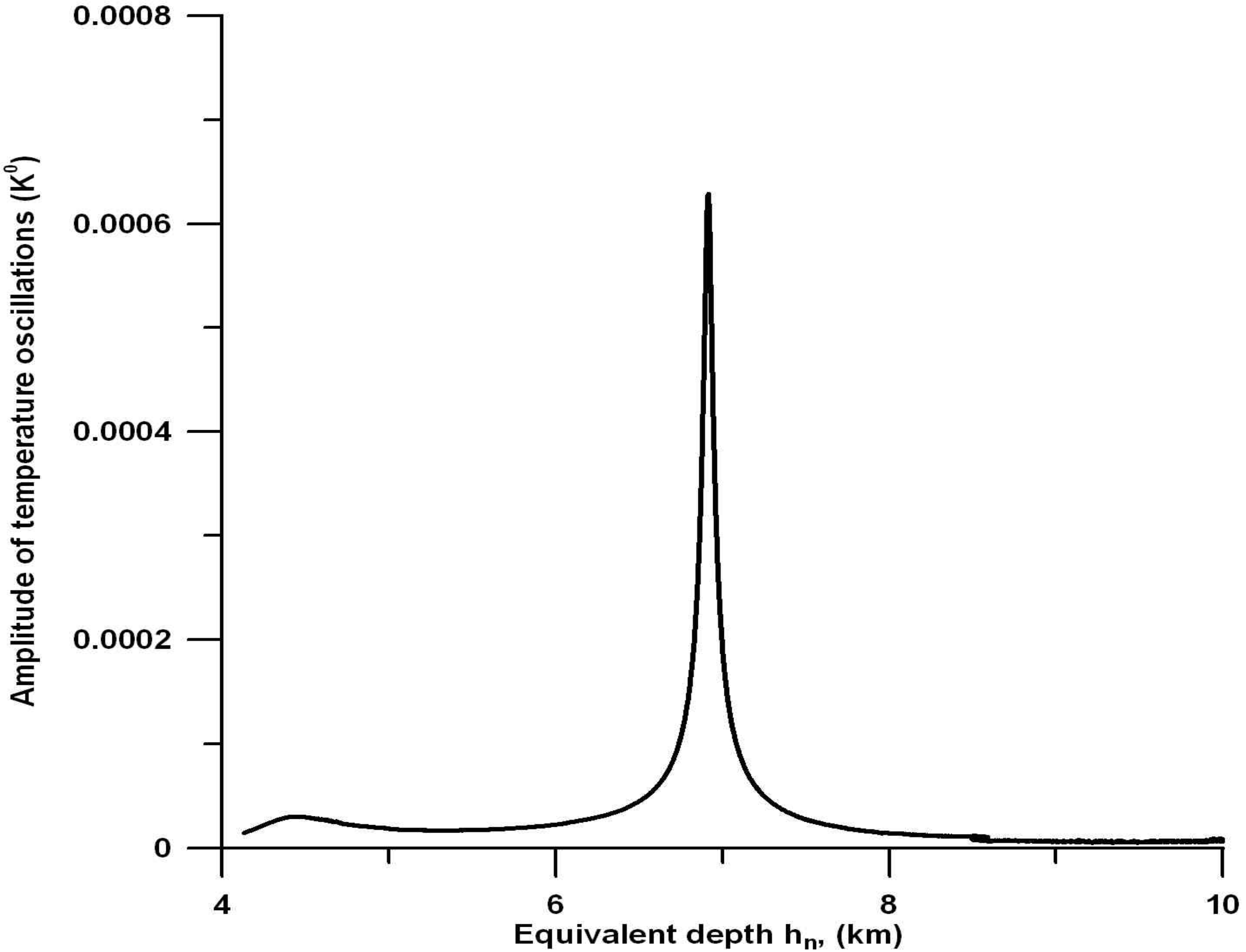


Newtonian cooling coefficient (a_N)

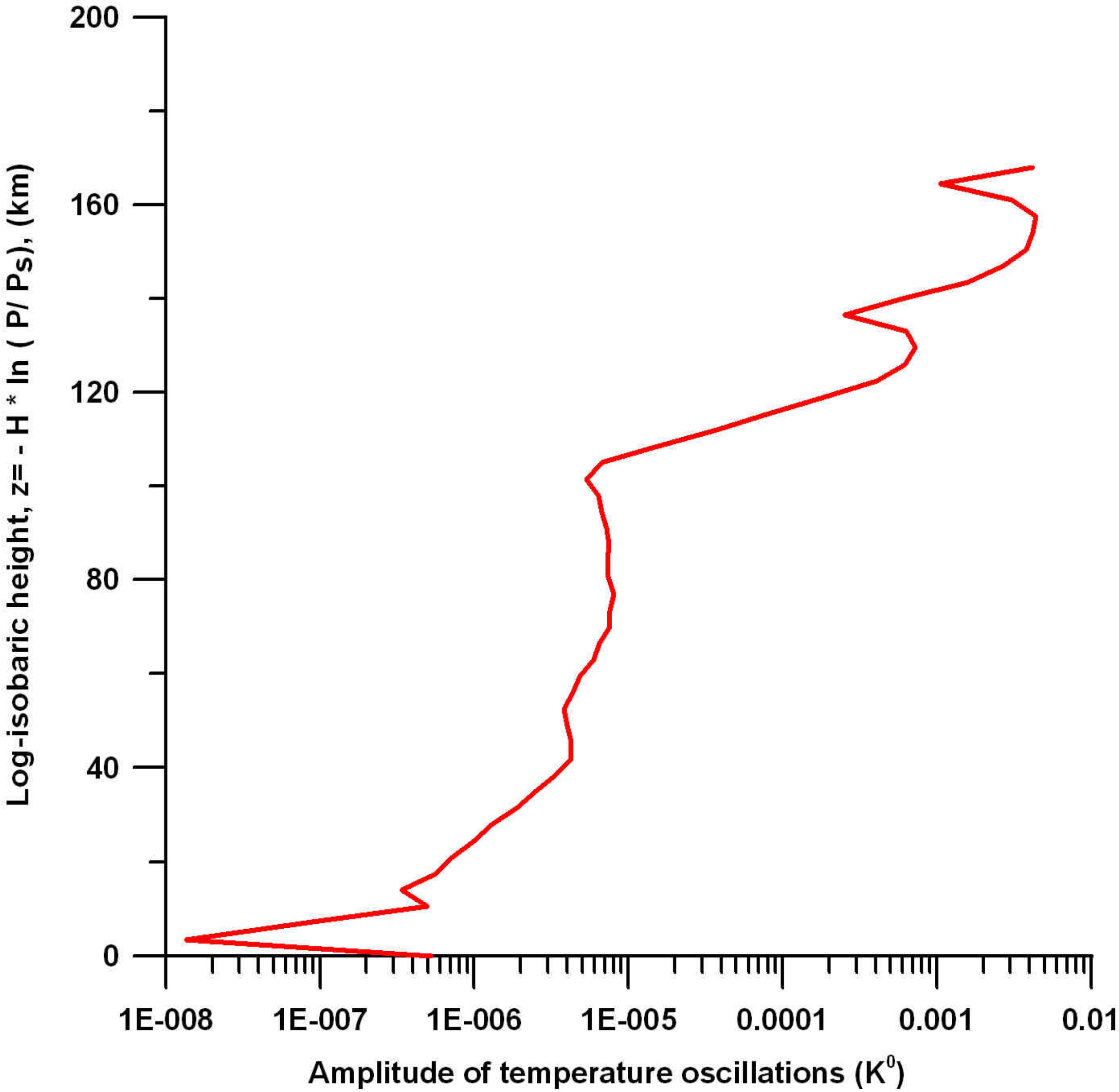


Simulation results

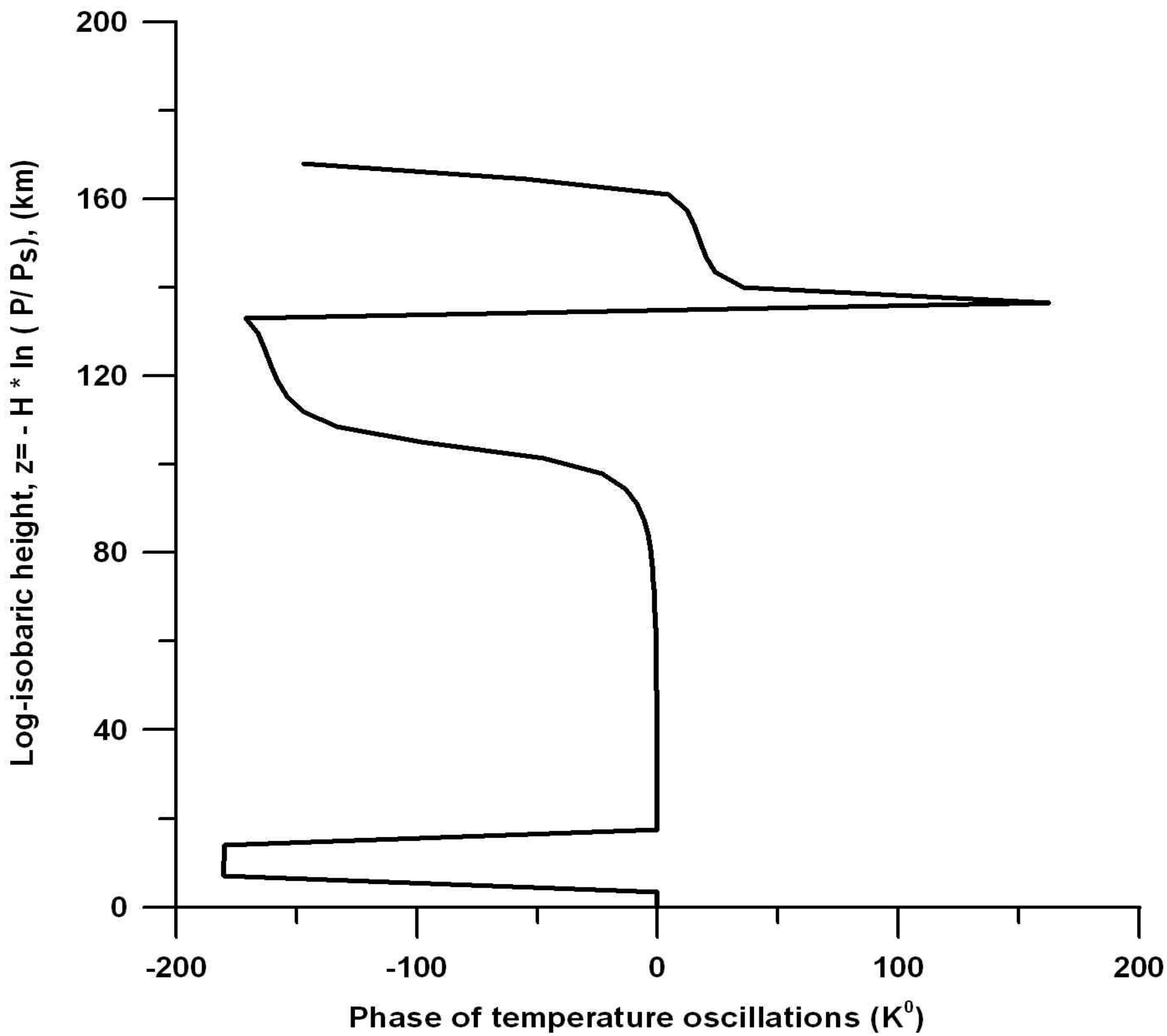
Atmospheric response (LI-height z=80km)



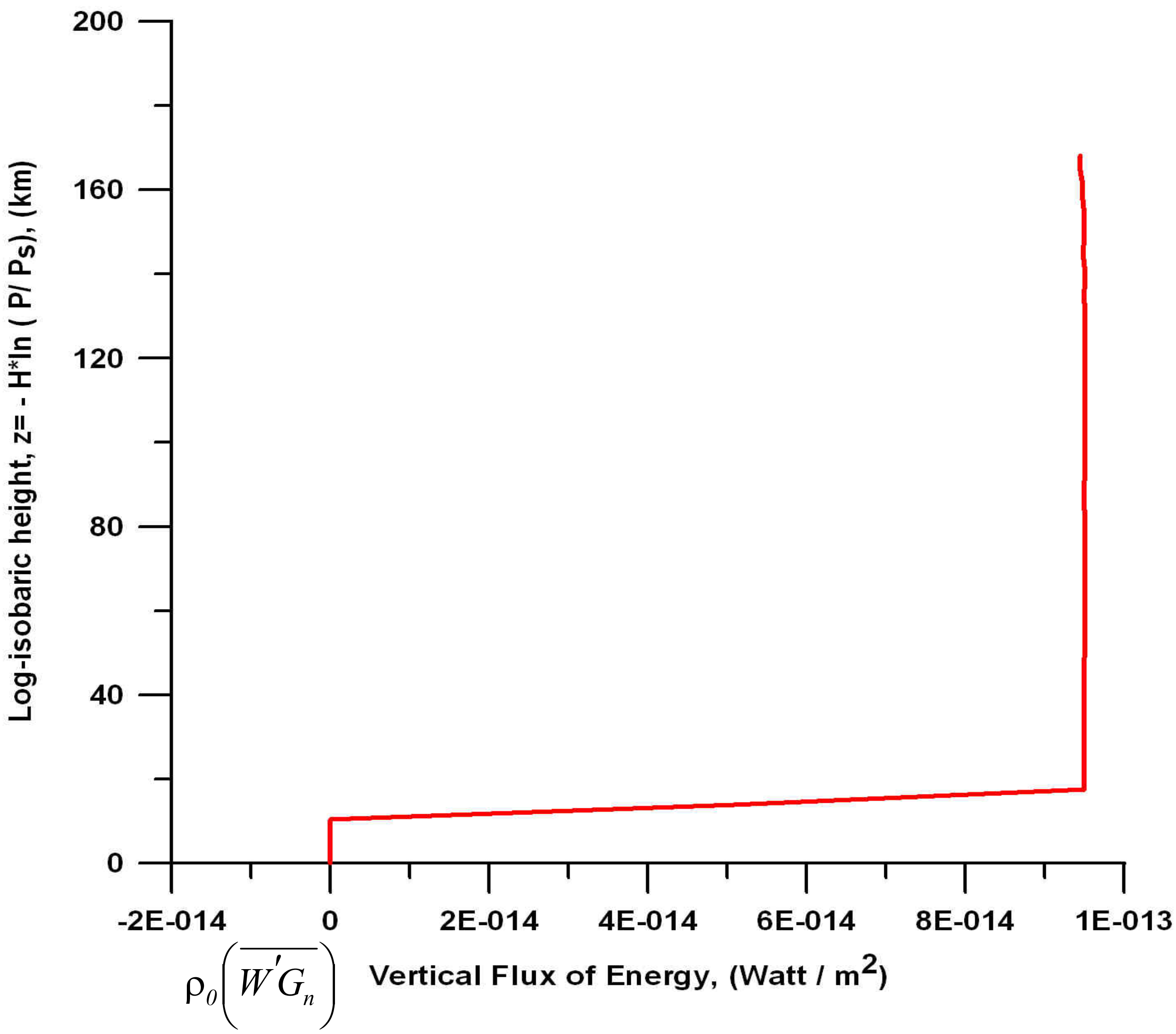
Amplitude as a function of height (NM)



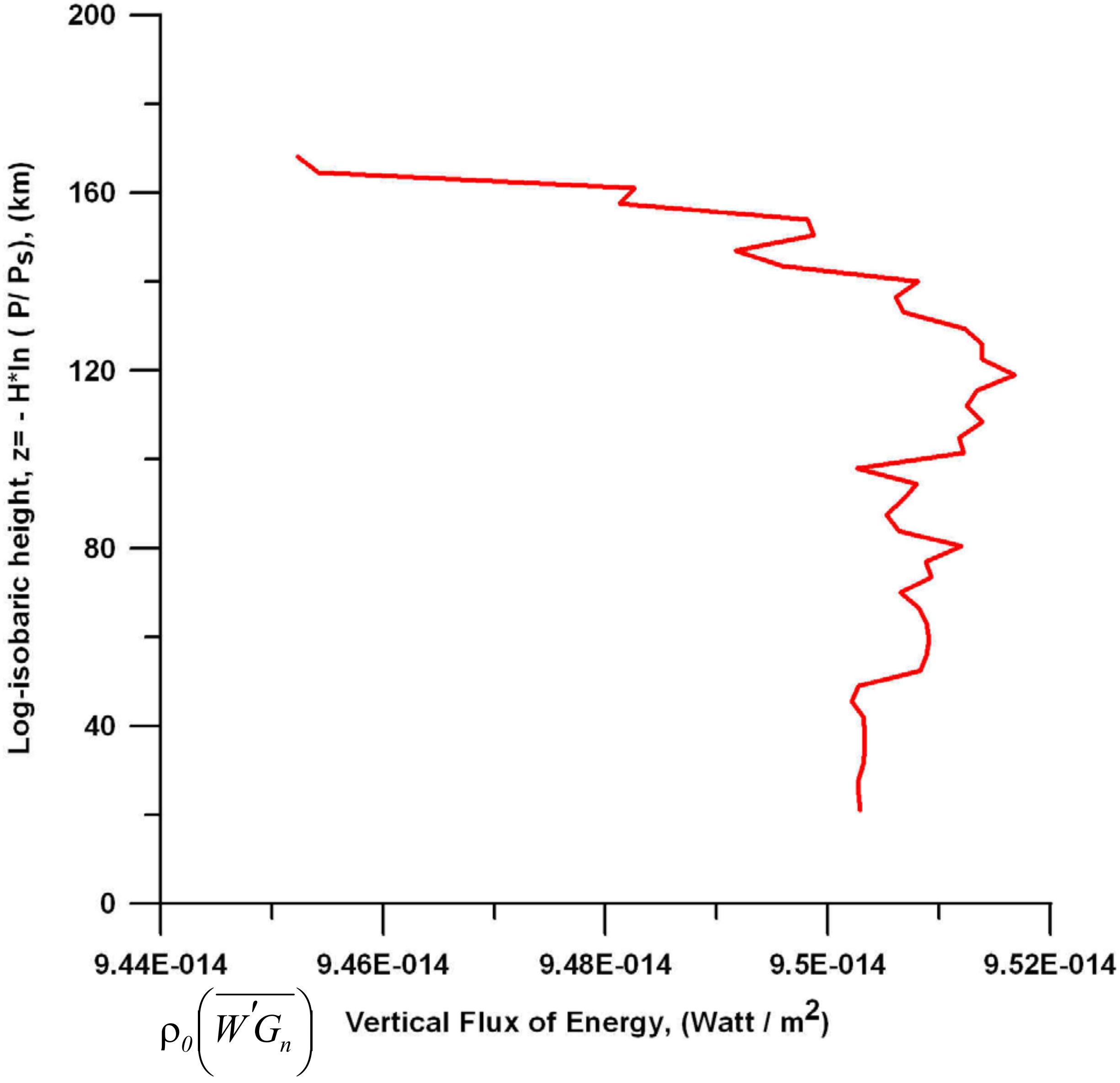
Phase as a function of height (NM)



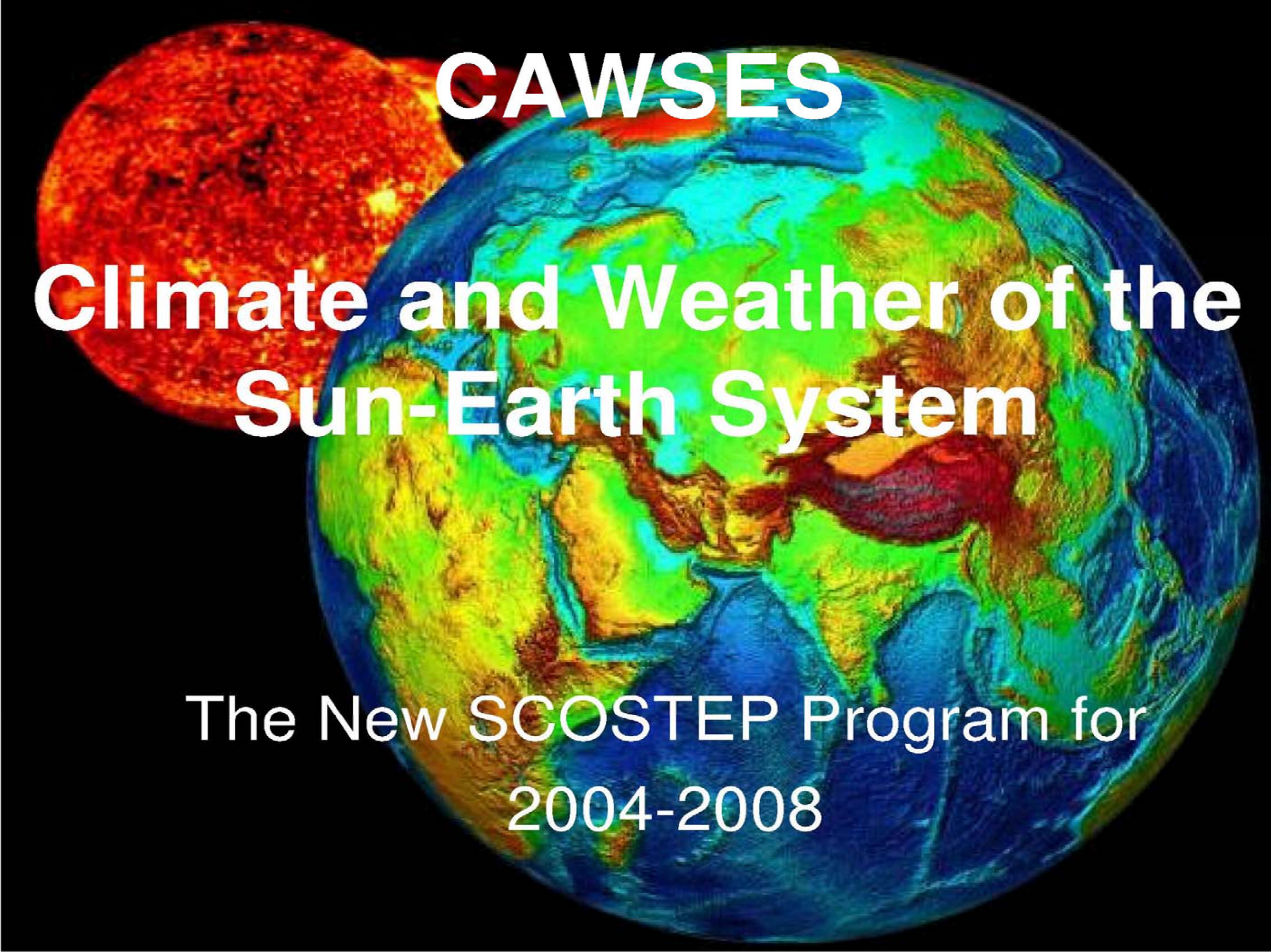
Vertical flux of energy



Vertical flux of energy (upper part of previos figure)



Thank You!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Sea level pressure spectrum

(obtained by K. Hamilton and R.Garcia)