Troposphere/Stratosphere Interaction

A Simple Model

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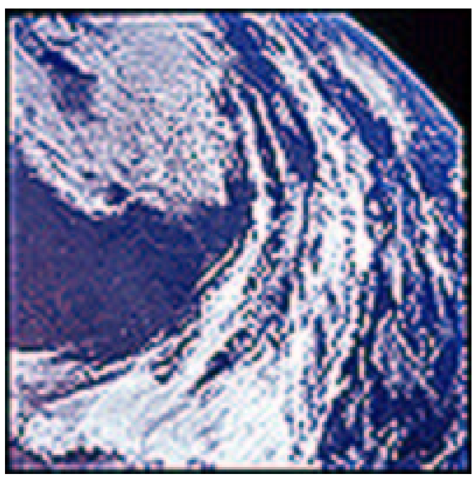

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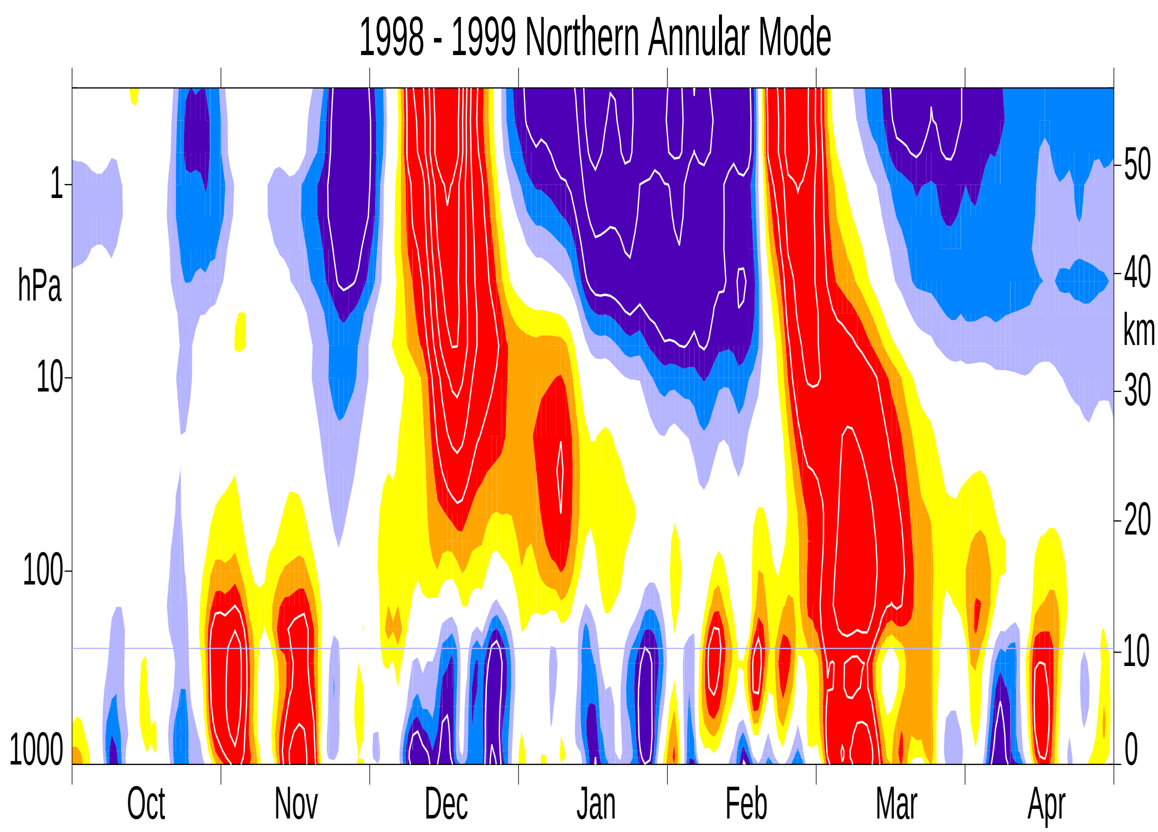
Overview

- Observations of zonal deceleration in the Stratosphere and the Wave Response in the Troposphere

- Explanation of the Simple Model

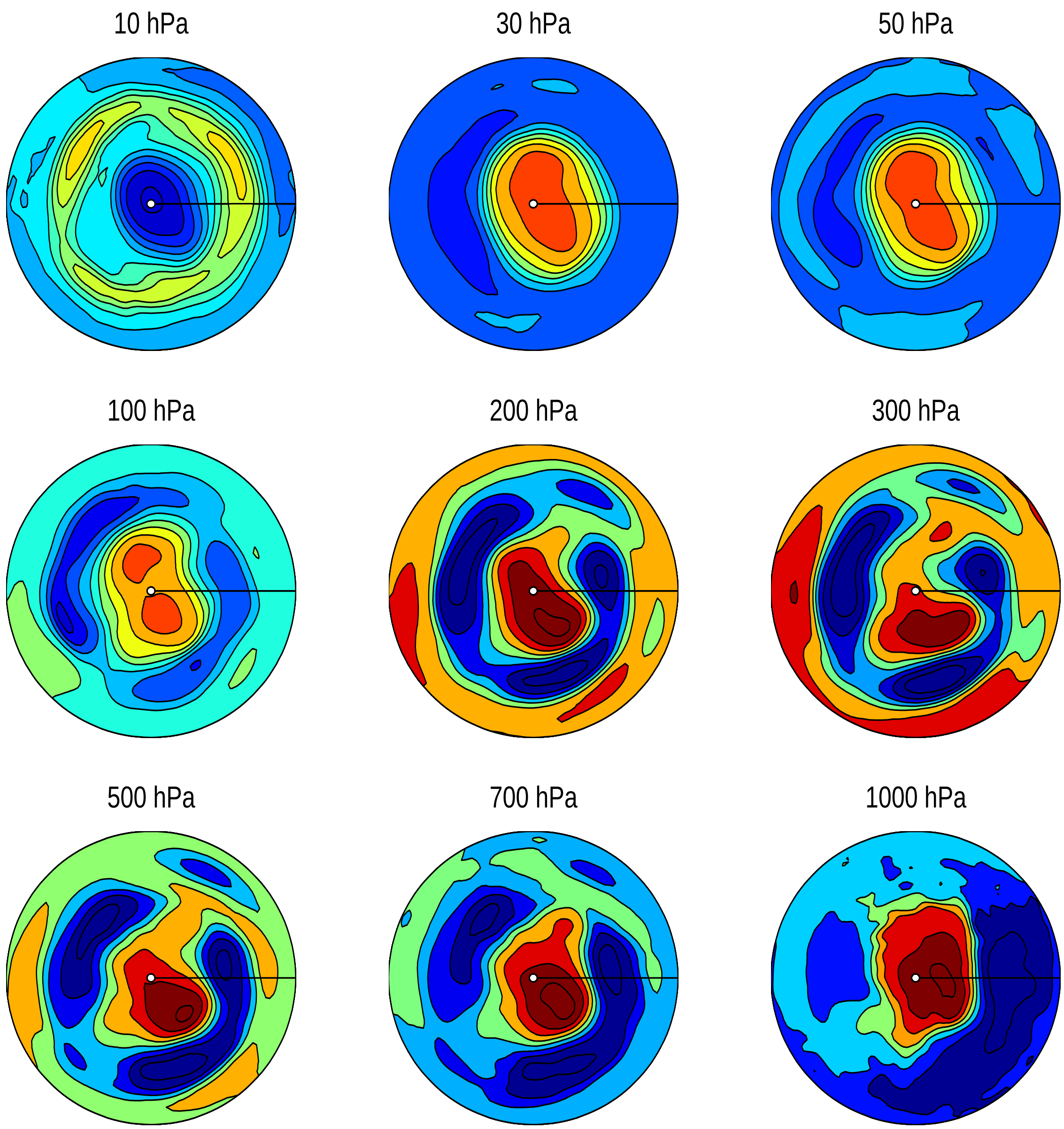
- Analytical Solutions show Tropospheric response to descending Stratospheric deceleration.

Descent of Stratospheric Deceleration



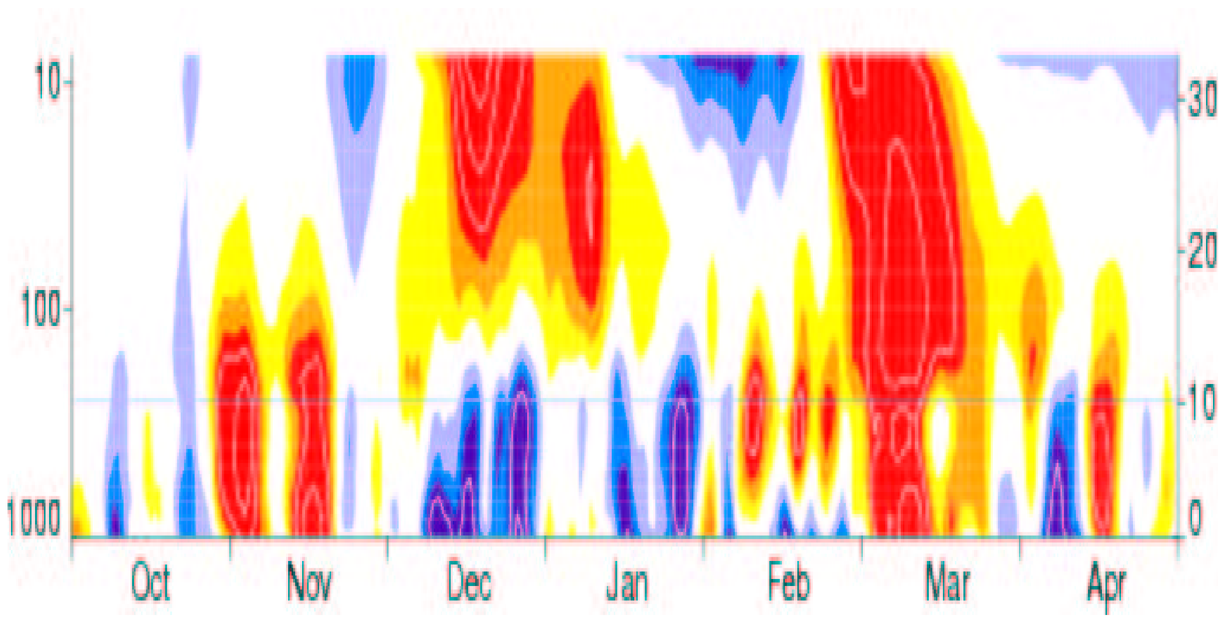
Baldwin, M.P., and T.J. Dunkerton, 2001: Stratospheric harbingers of anomalous weather regimes. *Science*, 294, 581-584.

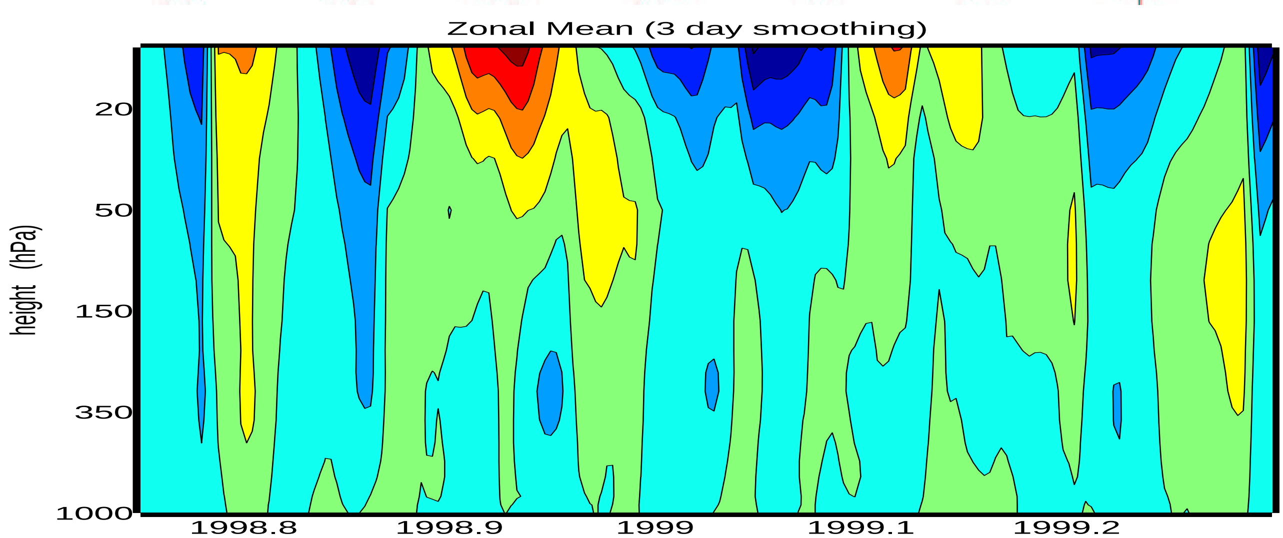
The Vertical Structures of the EOFs



Winter EOFs from NOAA-CIRES Climate Diagnostic Center, Boulder CO.

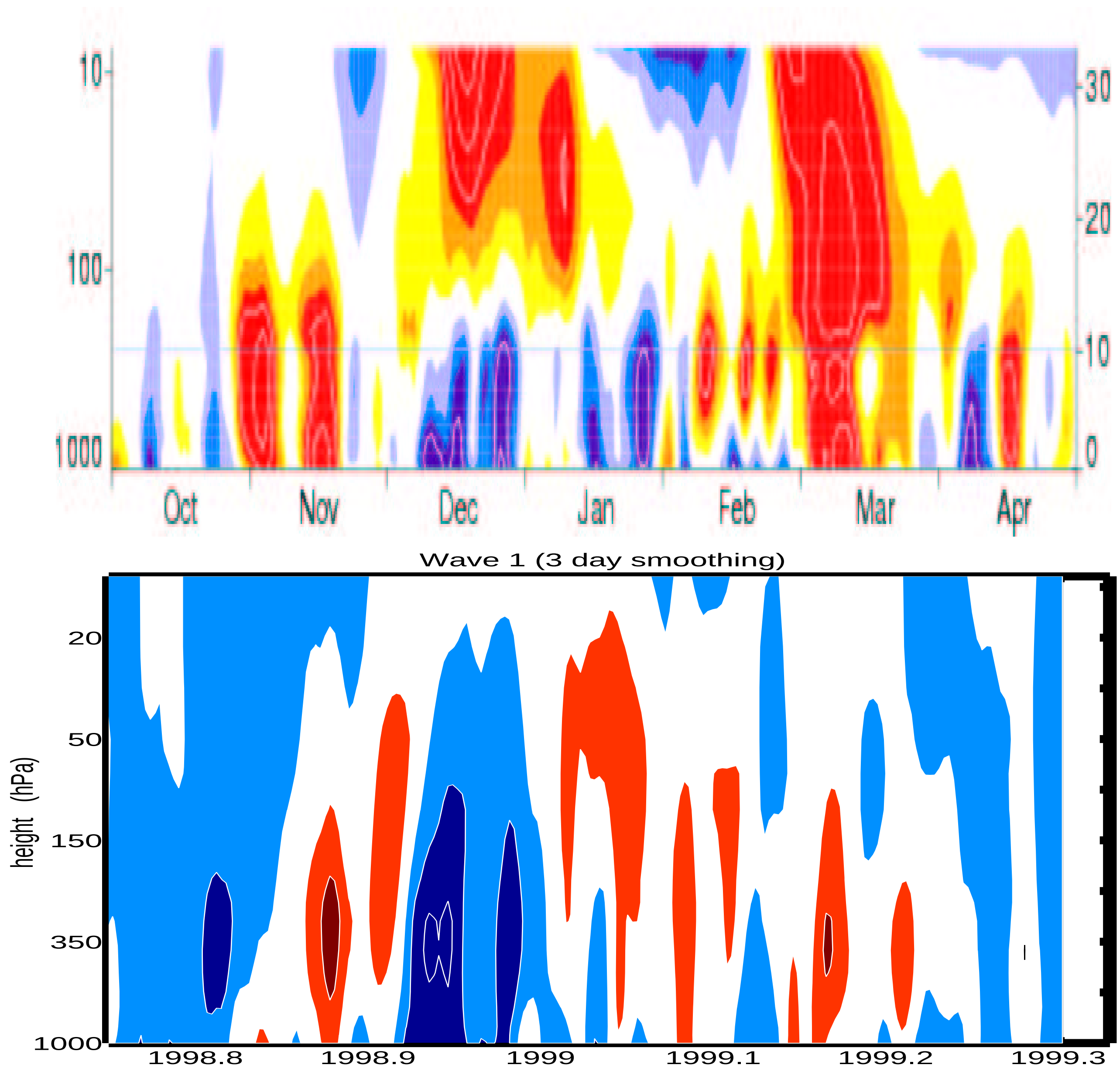
Zonal Mean is seen in the Stratosphere





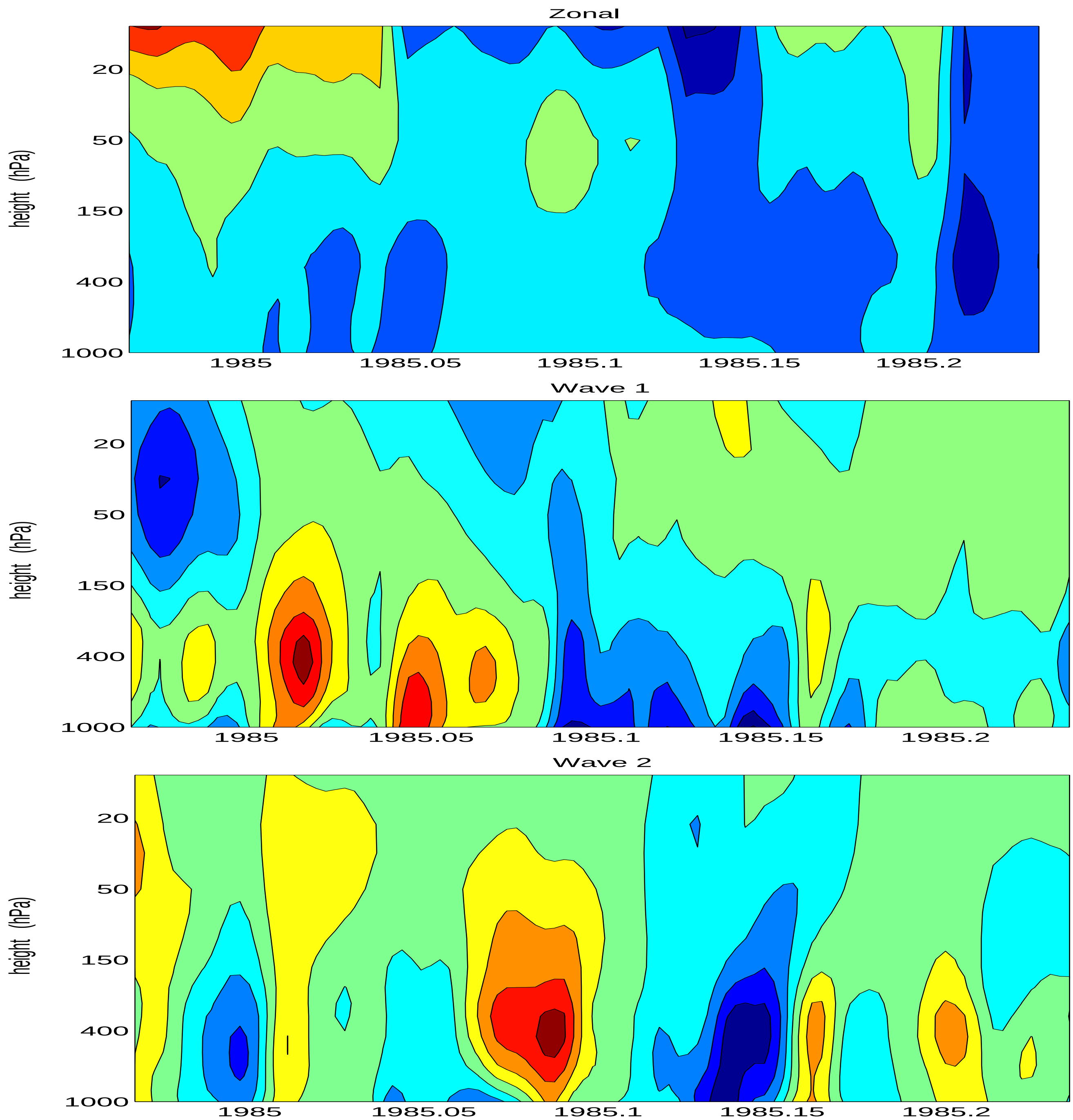
$60^{\circ} N$

Wave Reaction is seen in the Troposphere



$60^{\circ}N$

1985



$60^{\circ}N$

The Quasi-Geostrophic Equations

Linearized Potential Vorticity

$$\epsilon(u_0 - c)(\Psi_{zz} - \Psi_z) + (u_0 - c)\Psi yy$$
$$+\Psi[-k^2(u_0 - c) - \epsilon(u_{0zz} - u_{0z}) + \beta] = 0$$

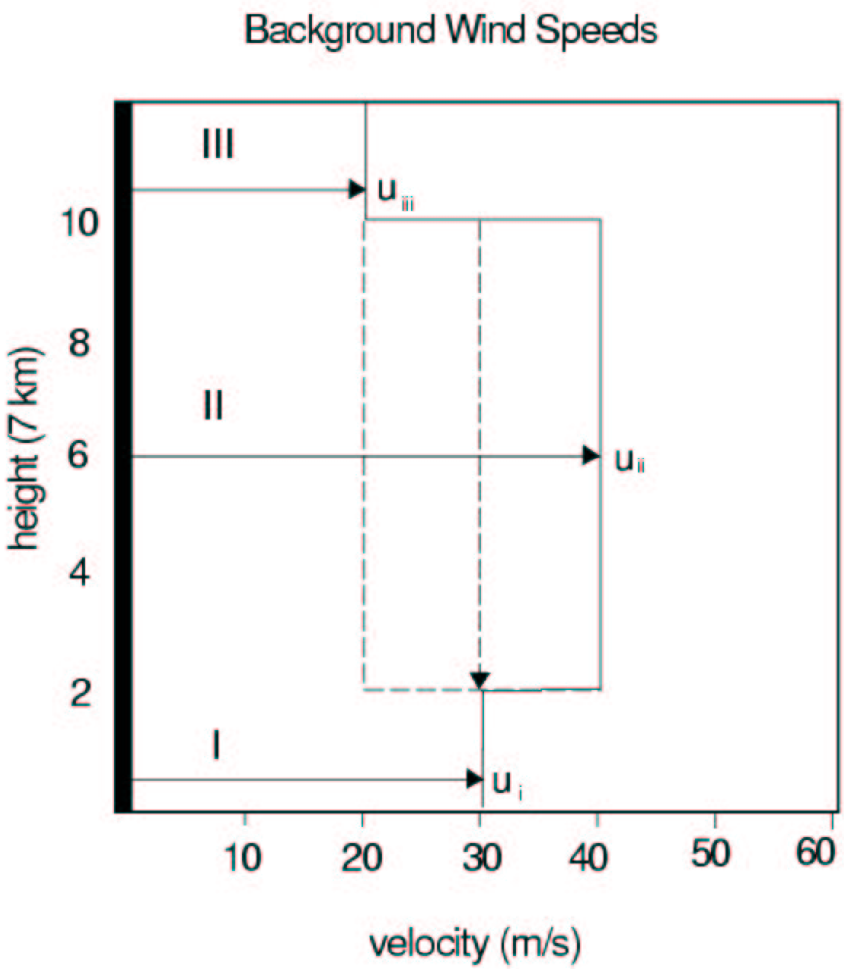
Linearized Thermodynamics

$$\frac{-wN^2H}{ikf} + (c - u_0)\Psi_z + u_0\Psi = 0$$

$$\Psi(y,z) = \phi(y,z)e^{\frac{z}{2}}$$
$$\phi(y,z) = Y(y)Z(z)$$
$$F_* = -\frac{u_{0zz} - u_{0z}}{u_0 - c} + \frac{\beta}{\epsilon(u_0 - c)} - \frac{k^2 + l^2}{\epsilon} - \frac{1}{4}$$

$$Y_{yy} + l^2 Y = 0$$
$$Z_{zz} + F_* Z = 0$$

Assume $c = 0$ and $u_0(z)$.



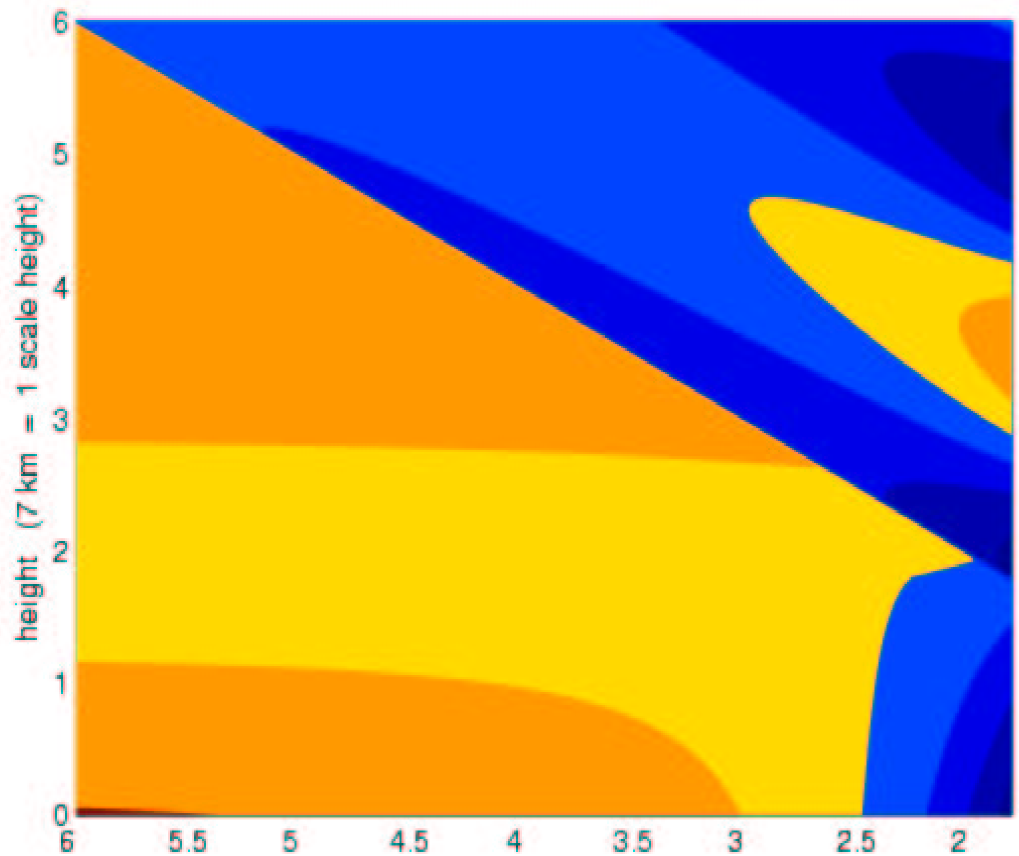
Boundary Conditions

at the surface, $z = 0$, $w = u\frac{db}{dx}$
assume a Gaussian mountain $\rightarrow b = e^{ikx}e^{-c^2(y-\frac{\pi a}{4})^2}$

We require bounded solutions as our upper condition.
$\rightarrow$ vertical group velocity is positive.

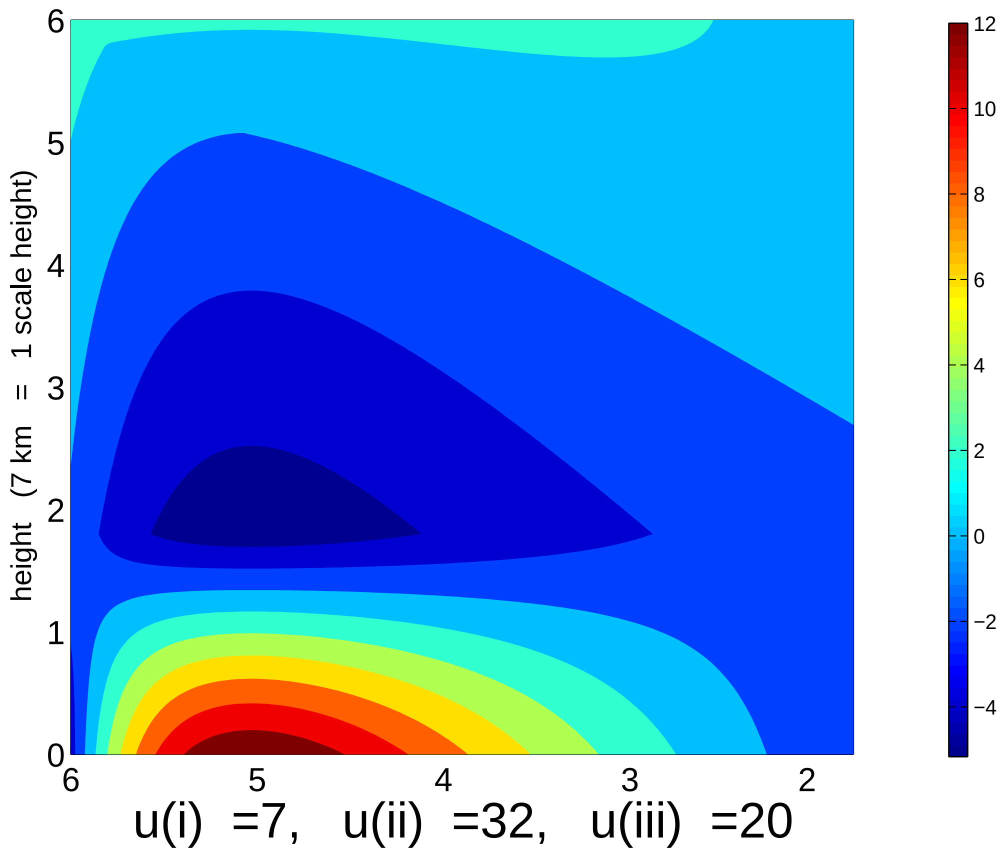
The vertical wave number is $m = \pm\sqrt{-F_{top}}$ and the group velocity is $c_g = \frac{d\omega}{dm}$.

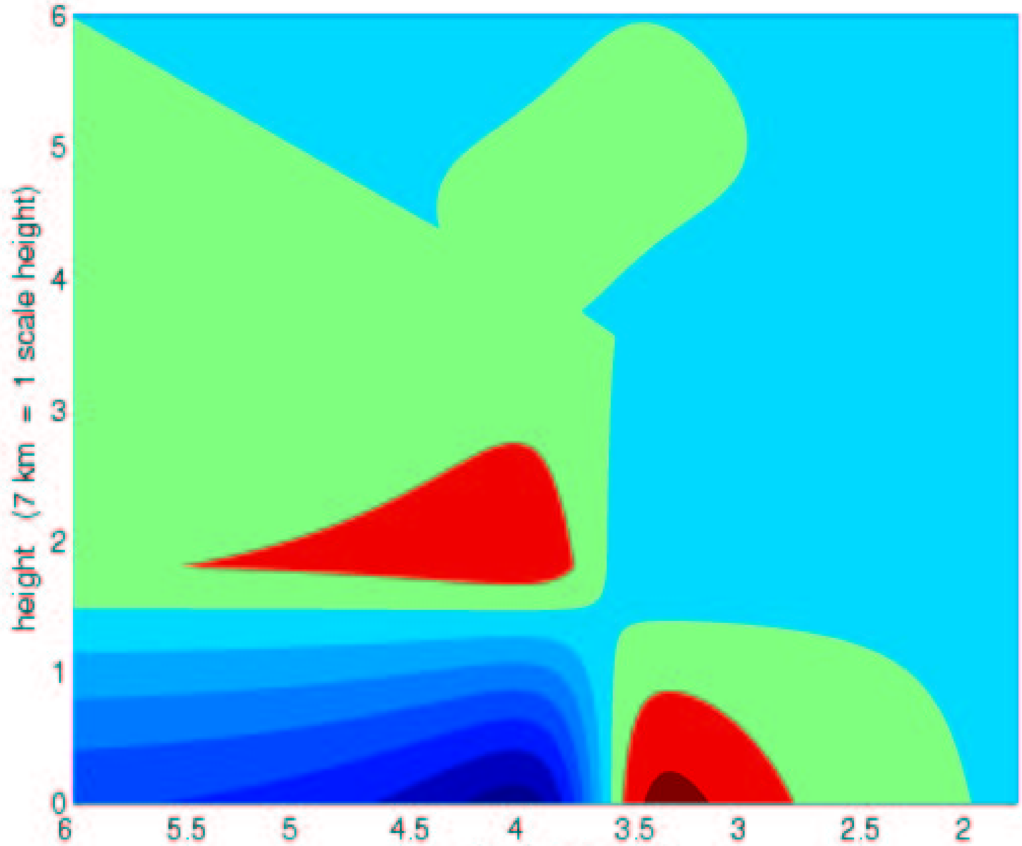
Tropospheric Wave Reaction to Descending Decelleration



scale height of dissipation region

$u_i = 17$ m/s, $u_{ii} = 50$ m/s, $u_{iii} = 4$ m/s


height (7 km = 1 scale height)
u(i) =7, u(ii) =32, u(iii) =20
6
5
4
3
2
1
0
12
10
8
6
4
2
0
−2
−4



scale height of dissipation region

$u_i = 7$ m/s, $u_{ii} = 60$ m/s, $u_{iii} = 9$ m/s

Conclusions

Tropospheric Waves respond to Stratospheric changes in zonal wind speed (i.e. stratospheric changes in the index of refraction).