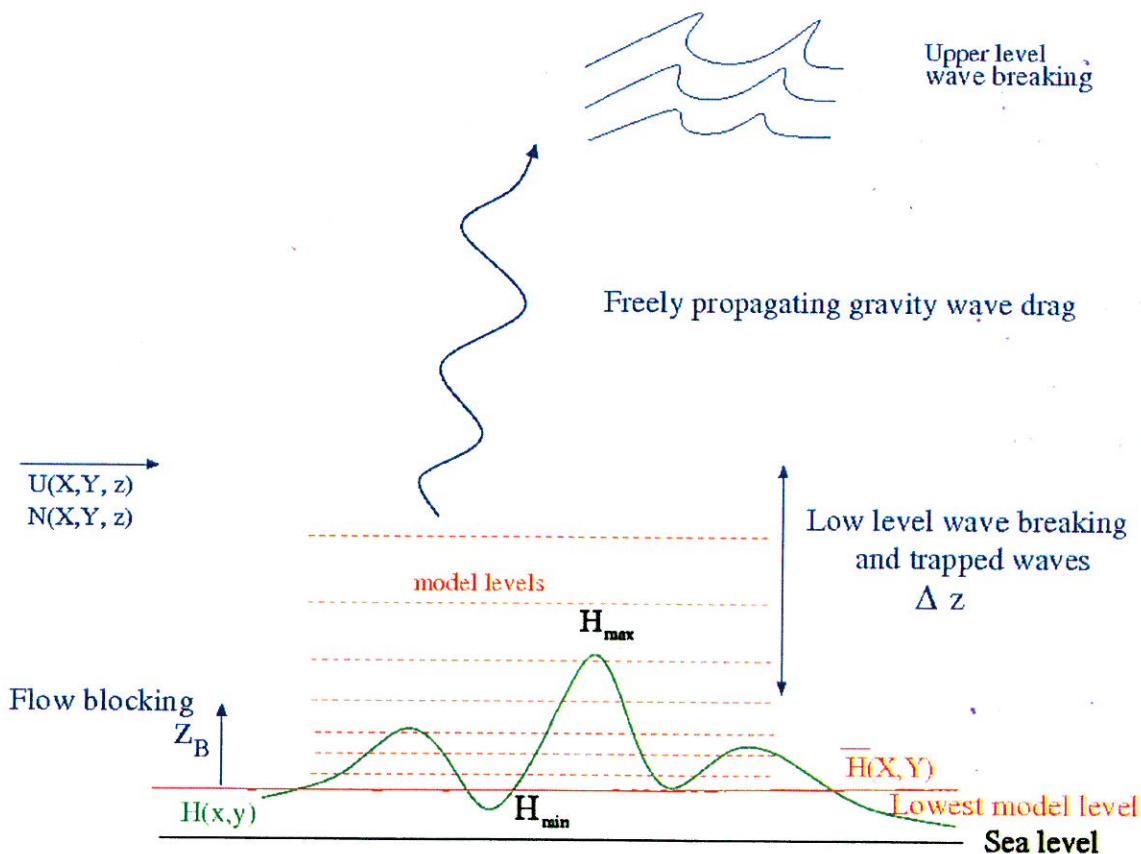


drag_noro

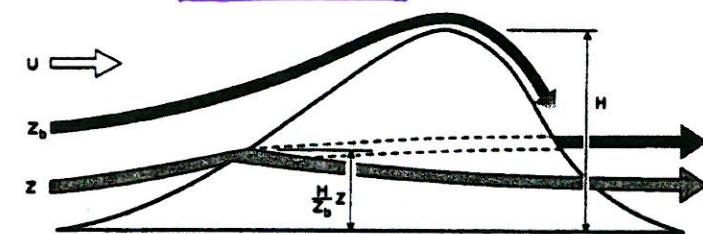
Effects of subgrid-scale orography (SSO):

- drag and lifting effects on the obstacle,
 - generation and propagation of gravity waves.
- τ : surface stress due to waves.



H_n : Non-dimensional height of the mountain.

$$H_n = \frac{N H_{\max}}{U}$$



- At small H_n , the flow goes over the mountain, gravity waves are forced by the vertical motion of the fluid.

$$\tau = \rho C_g N U H_{\max}^2$$

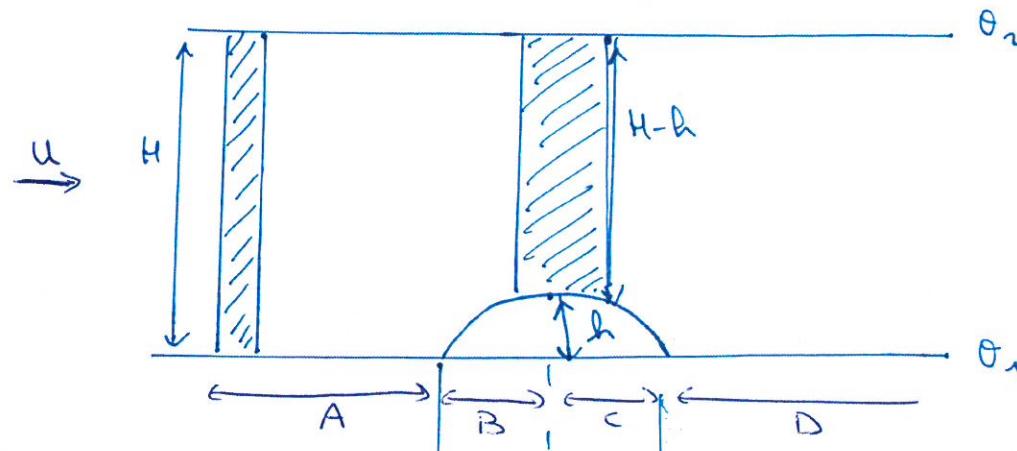
- At large H_n , part of the low-level flow goes around the mountain $z < z_b$:

$$\tau = \rho C_d U^2 H_{\max}$$

lift_noro

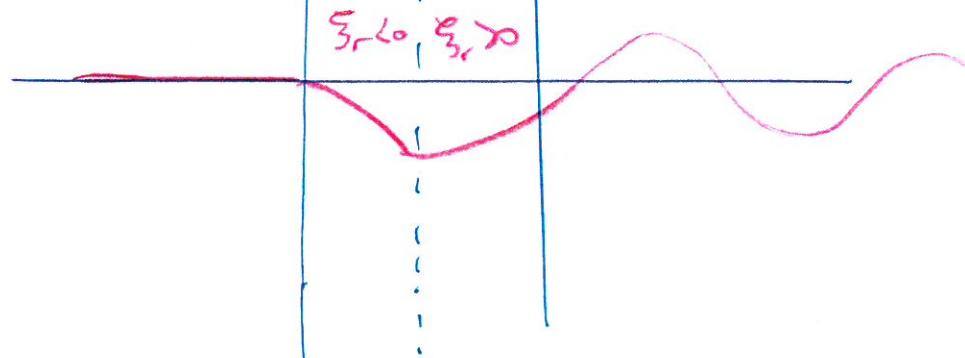
Au cours d'un mouvement adiabatique
on conserve la vorticité potentielle :

$$PV = \frac{1}{\rho} \xi_a \frac{\partial \theta}{\partial z} \quad \text{avec } \xi_a = f + \xi_r$$



Vue de haut.

$$\psi = \psi_0$$



- En A = $\frac{PV}{\rho} = \frac{f_0}{\rho} \frac{(\theta_2 - \theta_1)}{H}$ $\xi_r = 0$
 $\xi_a = f_0$

- En B = $\frac{\partial \theta}{\partial z} \rightarrow$ donc $\xi_a \downarrow$
 $\Rightarrow \xi_r < 0$

Déviation vers le Sud ($v < 0$)

- En C = $\frac{\partial \theta}{\partial z} \downarrow$ donc $\xi_a \nearrow \xi_r \gg$

Déviation vers le Nord

- En D = $\frac{\partial \theta}{\partial z}$ retrouve sa valeur initiale
 $\frac{\partial \theta}{\partial z} = \frac{\theta_2 - \theta_1}{H}$ $\xi_a = f_0$

Mais quand la colonne atteint la latitude ψ_0 elle vient du Sud \Rightarrow trajectoire oblique.

La colonne traverse la parallèle.
Au Nord $f = f_0 + \beta \psi$ $\xi_r = -\beta \psi$
 \Rightarrow on retourne vers le Sud.

Etc.

- The lift is the component of the force that modifies the direction of the flow.
- The lift is essentially related to the mountain volume: often assumed that this force is correctly represented by the mean orography.
- But between the narrow ridges of a mountain air can be blocked and separated from the large-scale flow.

⇒ A region of complex terrain acts as if it has a height larger than actual height.

⇒ In lift-wors the mean orography is kept and the missing forces are applied.

⇒ Another solution can be to higher up the mountain elevation.

hines_gwd

⇒ Parametrization of the momentum flux deposition due to a broad band spectrum of gravity waves.

Sources d'ondes de gravité: Convective, fronts, relief.

Wave mean flow interaction equations:

$$\frac{\partial \bar{u}_g}{\partial t} - f_0 \bar{v} = -\frac{1}{\rho_0} \frac{\partial}{\partial y} \left(\rho_0 \bar{u}' g \bar{v}' \right)$$

$$\frac{\partial \bar{T}}{\partial t} + N^2 \frac{H}{R} \bar{w} = -\frac{1}{\rho_0} \frac{\partial}{\partial y} \left(\rho_0 \bar{v}' g \bar{T}' \right) + \frac{\bar{J}}{c_p}$$

Transformed Eulerian mean equations:

$$\frac{\partial \bar{u}_g}{\partial t} - f_0 \bar{v}^* = \frac{1}{\rho_0} \nabla \cdot \bar{F} + \bar{X}$$

$$\frac{\partial \bar{T}}{\partial t} + N^2 \frac{H}{R} \bar{w}^* = \frac{\bar{J}}{c_p}$$

Avec (\bar{v}^*, \bar{w}^*) : "residual mean circulation"

$$\bar{v}^* = \bar{v} - \frac{1}{\rho_0} \frac{R}{H} \frac{\partial}{\partial z} \left(\rho_0 \frac{\bar{v}' g \bar{T}'}{N^2} \right)$$

$$\bar{w}^* = \bar{w} + \frac{1}{\rho_0} \frac{R}{H} \frac{\partial}{\partial y} \left(\rho_0 \frac{\bar{v}' g \bar{T}'}{N^2} \right)$$

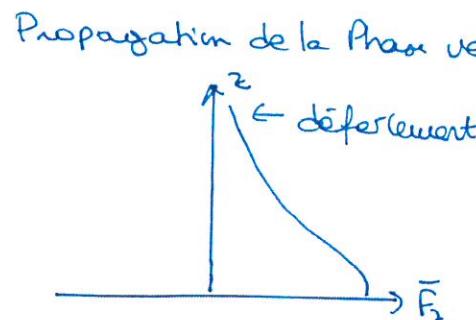
\bar{F} flux d'Eliassen-Palm

$$\bar{F} = \bar{c}_q \cdot \bar{A}$$

Pour Ondes de gravité:

- Niveau critique de déferlement: $|\hat{\omega}| = |\omega - k u| \rightarrow 0$
 $\hat{\omega}$ fréquence intrinsèque
- Signe $(\bar{F}_2) = -\text{sign}(\hat{\omega})$

$$\begin{cases} \hat{\omega} < 0 \\ k > 0 \end{cases} \quad \begin{cases} \hat{c}_q < 0 \\ \bar{F}_2 > 0 \end{cases}$$

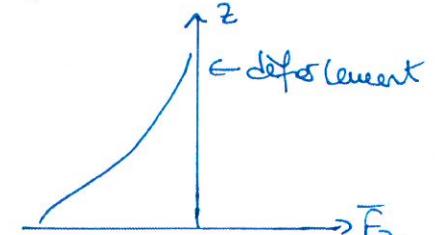


$$\frac{d\bar{F}_2}{dz} < 0 \Rightarrow \frac{\partial \bar{u}}{\partial t} < 0$$

Freine le vent moyen

$$\begin{cases} \hat{\omega} > 0 \\ k > 0 \end{cases} \quad \begin{cases} \hat{c}_q > 0 \\ \bar{F}_2 < 0 \end{cases}$$

Propagation de la Phase vers l'Ouest Propagation de la Phase vers l'Est



$$\frac{d\bar{F}_2}{dz} > 0 \Rightarrow \frac{\partial \bar{u}}{\partial t} > 0$$

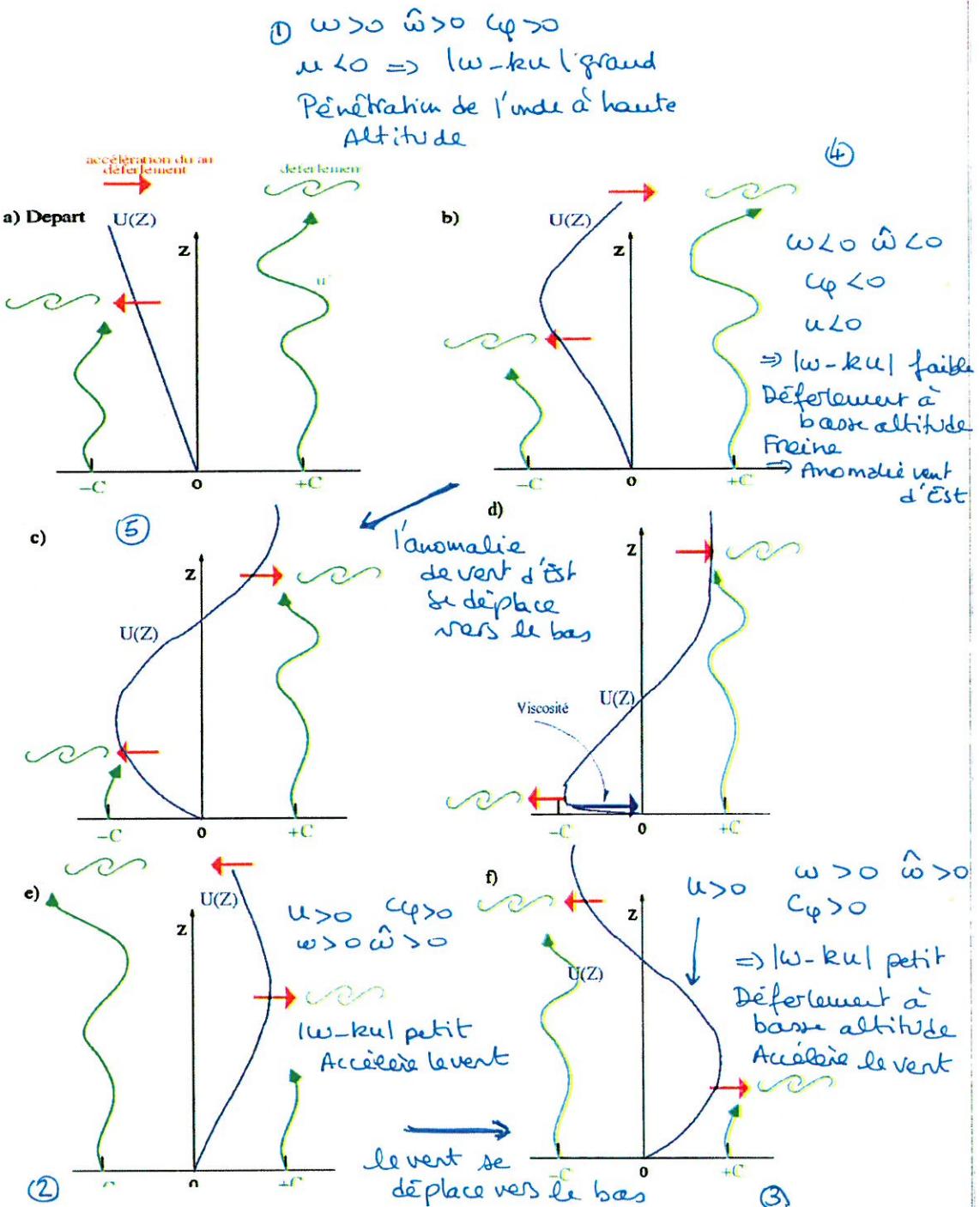
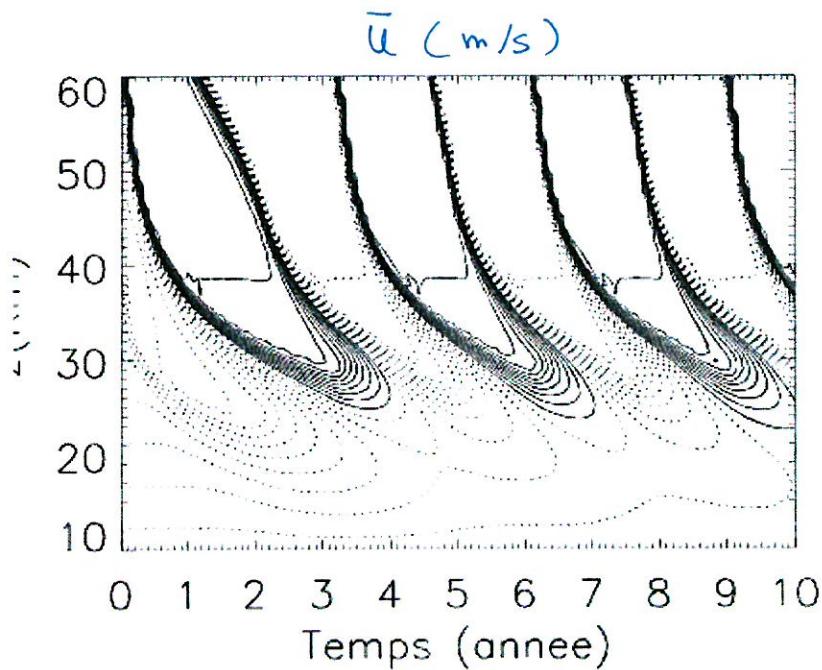
Accélère le vent moyen

=> Quasi-Biennial Oscillation

Altitude de déferlement des ondes de gravité =

$$z = 2H \ln \left(\frac{|\omega - ku|}{|m| \omega_0} \right)$$

- $\hat{\omega} > 0$ Accélère le vent moyen
- $\hat{\omega} < 0$ Freine le vent moyen

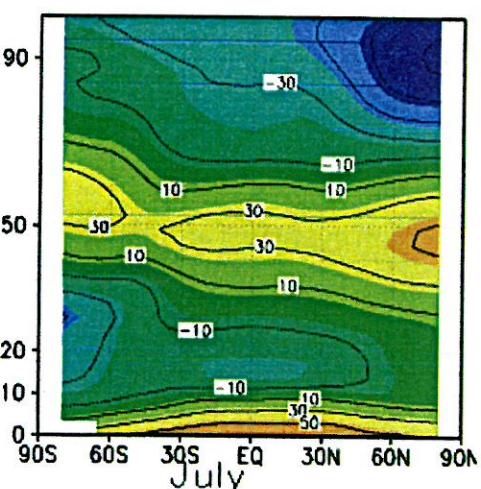
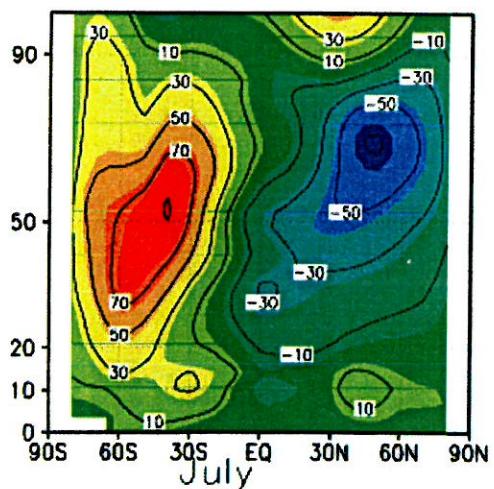
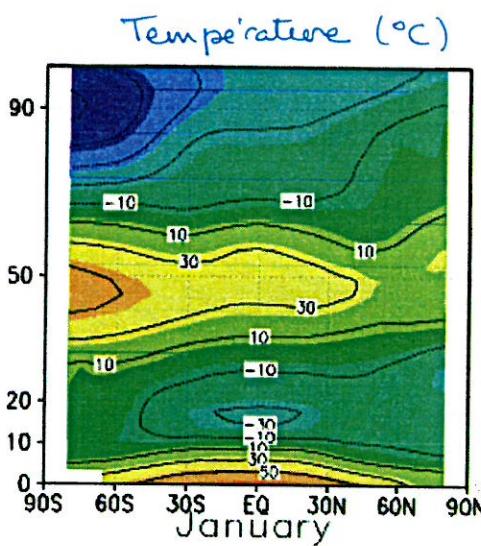
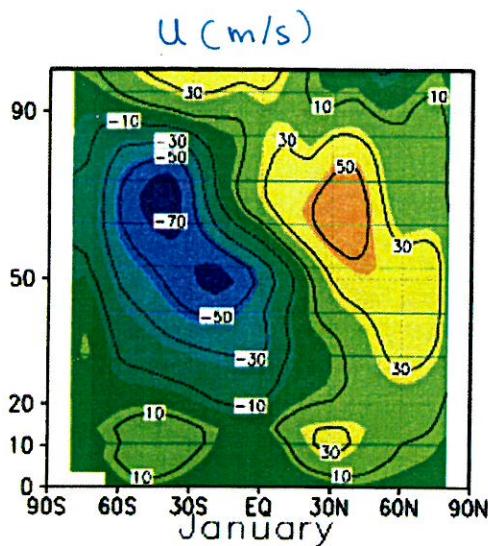


⇒ Importance des ondes de Rossby stationnaires créées par le relief pour la circulation stratosphérique.

- A 50 km max de Température au Pôle d'Été

- En Janvier $u > 0$ du l'Hem Nord
 $u < 0$ du l'Hem Sud

- Le gradient de Température n'est pas aussi fort que s'il était déterminé radiativement uniquement.



Relation de dispersion des ondes de Rossby :

$$c - u_0 = \frac{-\beta}{k^2 + l^2 + \frac{f_0^2}{N^2} \left(m^2 + \frac{1}{4h^2} \right)}$$

Ondes stationnaires: $c = 0 \Rightarrow u_0 > 0$

$$m^2 = \frac{N^2}{f_0^2} \left[\frac{\beta}{u_0} - (k^2 + l^2) \right] - \frac{1}{4h^2}$$

Propagation verticale des ondes de Rossby pour $m^2 > 0$

$$\Rightarrow 0 < u_0 < u_c$$

$$\begin{aligned} z & \\ u = u_c & \quad \vec{F} = 0 \\ 0 < u < u_c & \quad \uparrow \vec{F} = \vec{g} A \quad \left. \begin{array}{l} \frac{\partial F_z}{\partial z} < 0 \end{array} \right\} \end{aligned}$$

En Janvier ds tN

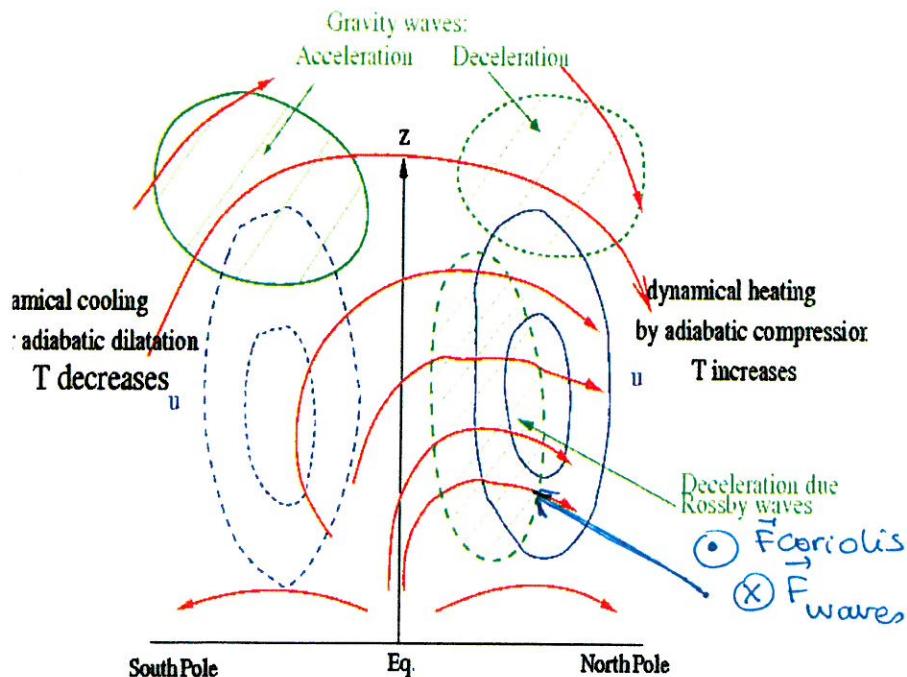
$u > 0 \Rightarrow$ propagation verticale
jusqu'à $z = t_p$ $u = u_c$

$$TEH \text{ équation: } \frac{\partial \bar{u}}{\partial t} - f_0 \bar{v}^* = \frac{1}{\rho_0} \nabla \cdot \vec{F}$$

$\frac{\partial F_z}{\partial z} < 0 \Rightarrow$ freinage

$$\text{stationnaire: } -f_0 \bar{v}^* = \frac{1}{\rho_0} \nabla \cdot \vec{F}$$

En Janvier :



\Rightarrow Diminution du gradient horizontal de Température obtenu par les termes radiatif.