The parameterization of subgrid scale orography in LMDZ

Mountains influence the dynamics of the atmosphere at different length scales:

- They force **gravity waves** that take angular momentum from the earth and transport it through the atmosphere over long distances

- **At large-scales** mountains contribute to the steady planetary wave, to the storm tracks, to the low-frequency variability

- F is the force exerted by an obstacle on a fluid

- **The drag** is the component of the force F that decelerates the fluid because it is opposite to the wind

- **The lift** is the component of the force that modifies the direction of the flow but does not decelerate it.

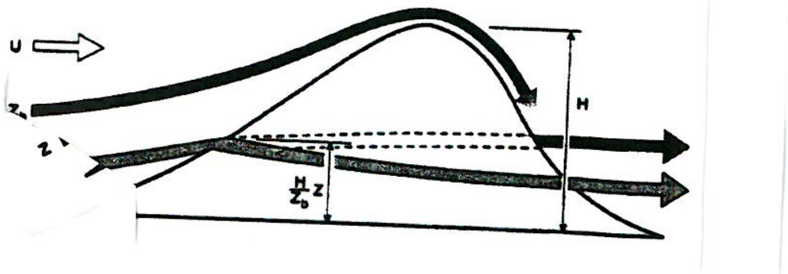
Outline

- Drag controlled by gravity waves
- Lift and forcing of the steady planetary waves

- Why are gravity waves important for stratospheric circulation?
- Why are planetary waves important for stratospheric circulation?

1. drag_noro : drag controlled by gravity waves

The Lott and Miller (1997) scheme treats the Subgrid Scale Dynamics controlled by the Gravity Waves



Non-dimensional height of the mountain: $H_n = NH/U$
H is the maximum height of the obstacle

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

Tau the surface stress due to the gravity wave :

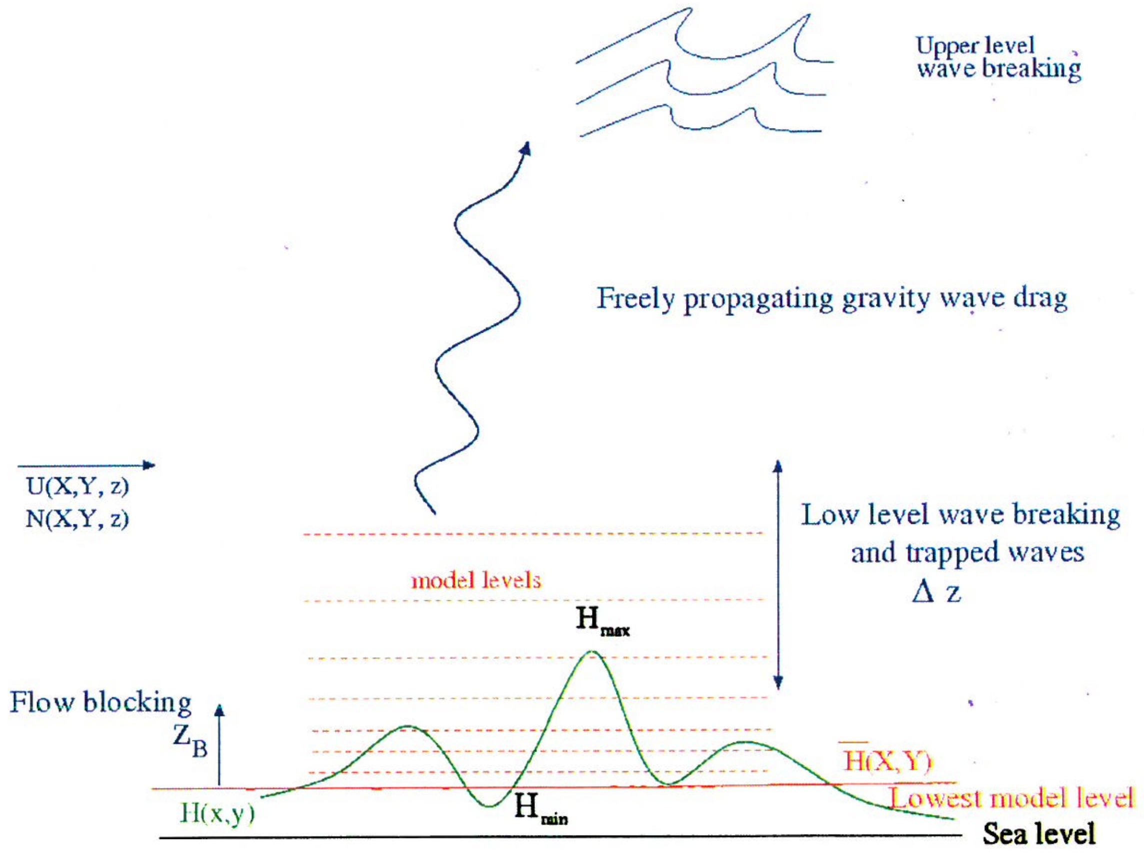
$$\tau = \rho b G B(\gamma) N U H^2$$

- At large H_n the vertical motion of the fluid is limited and part of the low-level flow goes around the mountain for $z<z_b$.
The surface stress is then : $\tau = \rho C_d z_b b U^2$

drag_noro

The scheme depends on 4 parameters C_{d}, G, R_{ic} and z_{b}.

- C_{d} and G control the amplitude of the blocked-flow drag and of the gravity-wave drag.
- R_{ic} and z_{b} control the vertical distribution of these drags.

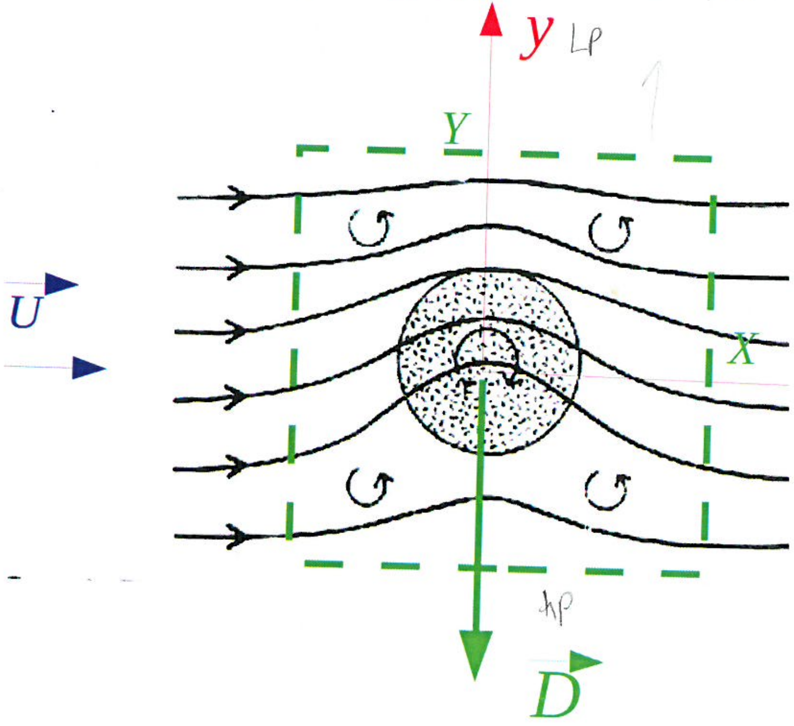


2. lift_noro: The component of the force that modifies the direction of the flow

Pressure force acting on the mountain to the left due to the background pressure gradient associated with the mean flow:

$F = MV\rho\, U f$; MV is the mountain volume

The lifting of the air over the mountain is balanced by the force acting on the mountain and then results in a push to the right (*Smith 1979*).



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 the actual height.

A solution could be to increase the sizes of the mountains

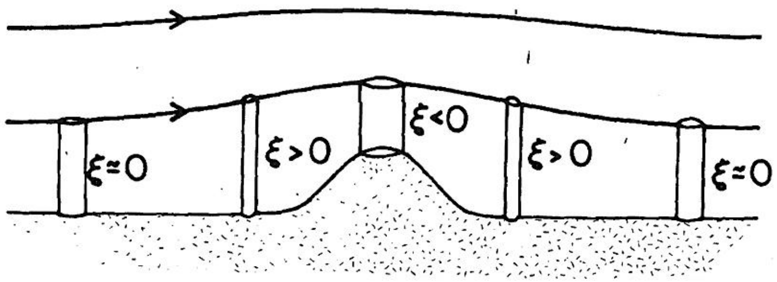
In lift-noro the mean orography is kept and the missing forces are applied.

Conservation of potential vorticity for an adiabatic motion:

$$PV = \frac{1}{\rho}(f + \xi_r)\frac{d\theta}{dz}$$

If the motion to the South or North is large enough, one can't consider that *f* is constant.

The mountain triggers a steady Rossby wave.



3. Why are gravity waves important for the middle atmosphere circulation?

The sources of gravity waves are orography, but also convective and frontal systems.

Gravity waves can propagate vertically and break.

The moment flux deposition due to gravity wave breaking is parameterized (for example in hines_gwd).

This breaking affects the mean circulation in the stratosphere (Quasi-Biennal Oscillation) and the mesosphere (changes in the zonal wind).

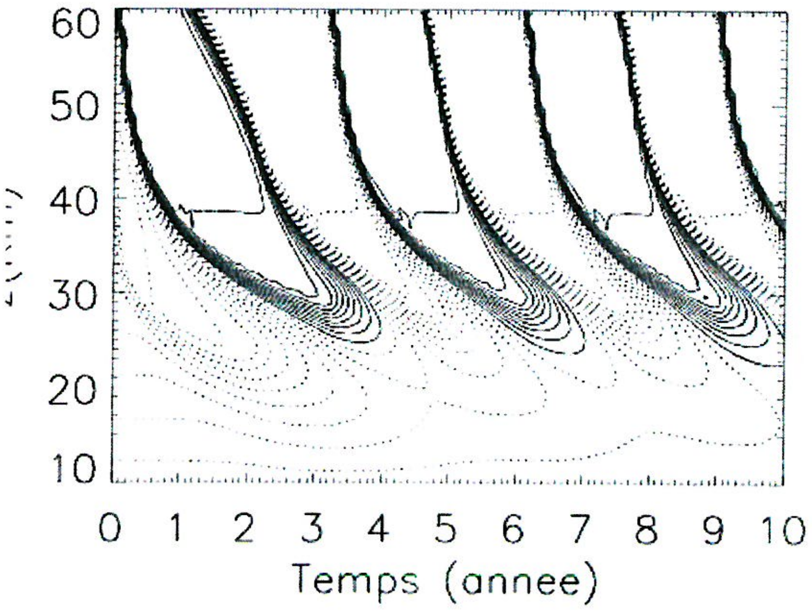
⇒ Quasi-Biennal Oscillation

Altitude de déferlement des ondes de gravité :

$$z = 2H \ln\left(\frac{|\omega - ku|}{|m|\, w_0}\right)$$

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

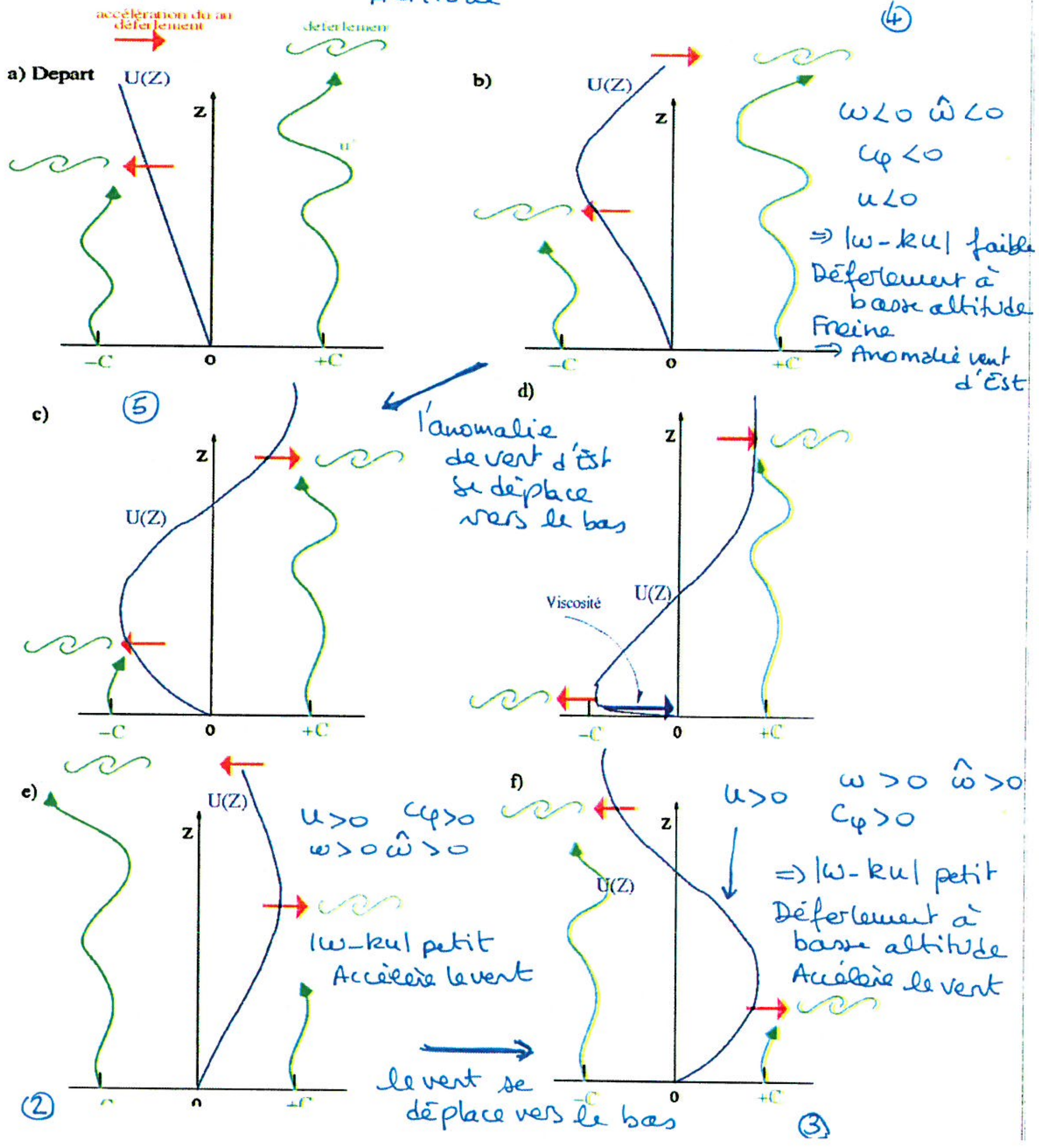
$\bar{u}$ (m/s)



① $\omega > 0$ $\hat{\omega} > 0$ $c_\varphi > 0$

$u < 0 \Rightarrow |\omega - ku|$ grand

Pénétration de l'onde à haute Altitude



④

$\omega < 0$ $\hat{\omega} < 0$

$c_\varphi < 0$

$u < 0$

$\Rightarrow |\omega - ku|$ faible

Déferlement à basse altitude

Freine

⇒ Anomalie vent d'Est

⑤

l'anomalie de vent d'Est se déplace vers le bas

$u > 0$ $c_\varphi > 0$

$\omega > 0$ $\hat{\omega} > 0$

$|\omega - ku|$ petit

Accélère le vent

②

le vent se déplace vers le bas

$u > 0$

$\omega > 0$ $\hat{\omega} > 0$

$c_\varphi > 0$

$\Rightarrow |\omega - ku|$ petit

Déferlement à basse altitude

Accélère le vent

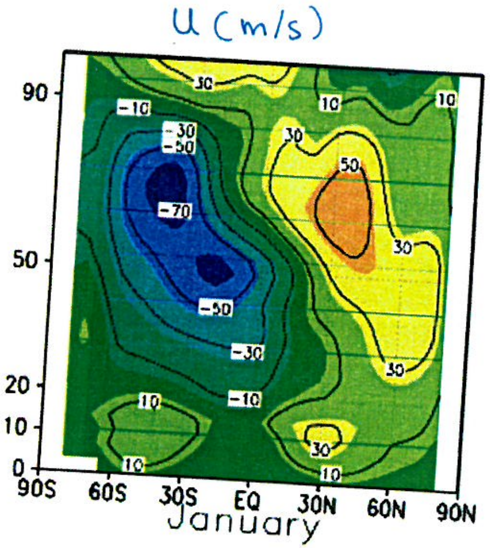
③

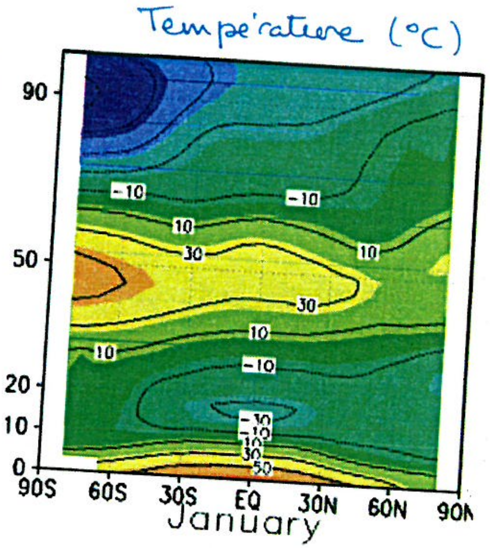
In the mesosphere

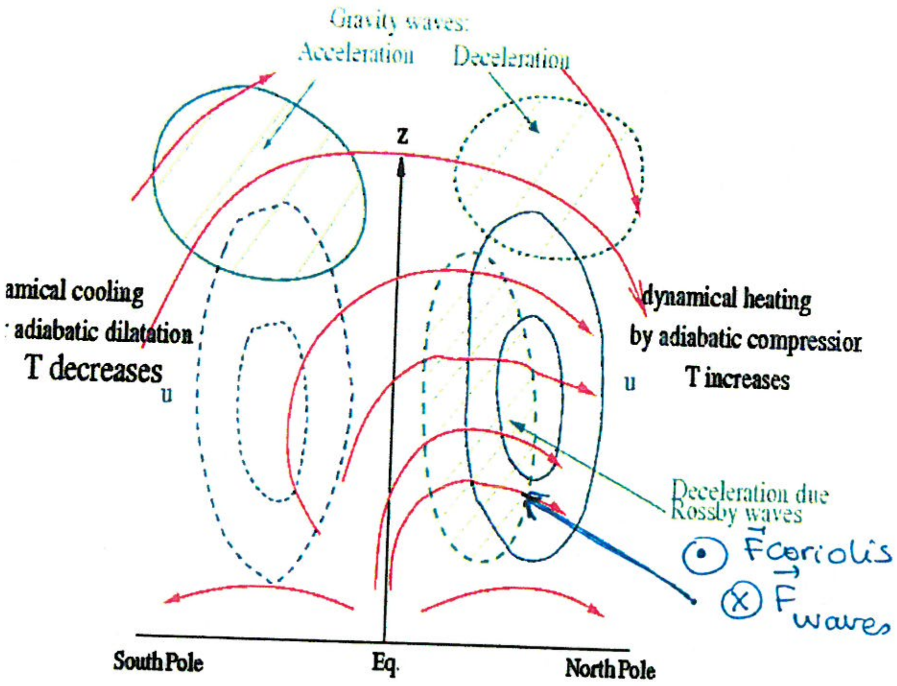
-At 50 km in the stratosphere, there is a maximum of Temperature at the summer pole

- Thermal wind: In January, u>0 in the Northern Hemisphere u<0 in the Southern Hemisphere

- But not in the mesosphere, because of gravity wave breaking!







4. Why are planetary waves important for stratospheric circulation?

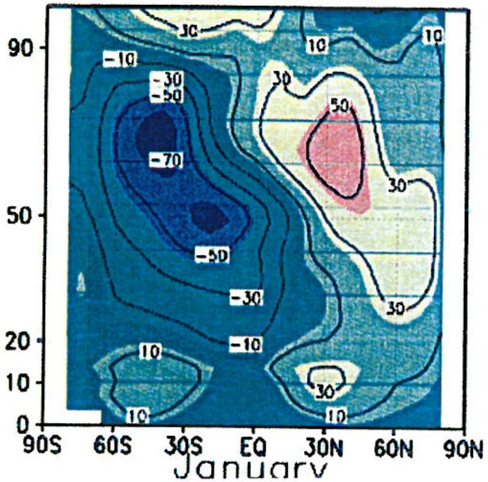
-At 50 km in the stratosphere, there is a maximum of Temperature at the summer pole

- Thermal wind: In January, u>0 in the Northern Hemisphere u<0 in the Southern Hemisphere

-But the meridional gradient of temperature is less strong than what is expected by radiative considerations.

- This is because of the Brewer-Dobson circulation, linked to Rossby-wave breaking.

U (m/s)



Température (°C)