دانشگاه رازی

Dynamic Meteorology 2

Lecture 6

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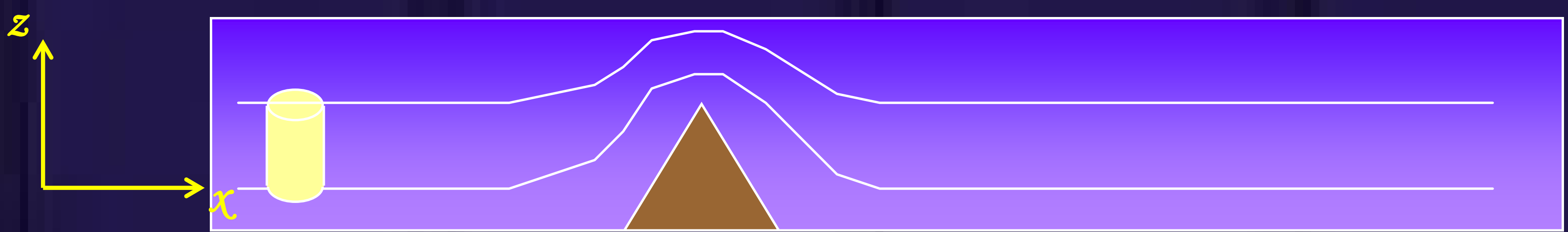
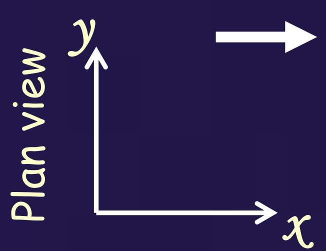
Mountain lee waves

Assume air with no vorticity moving west to east towards a mountain range

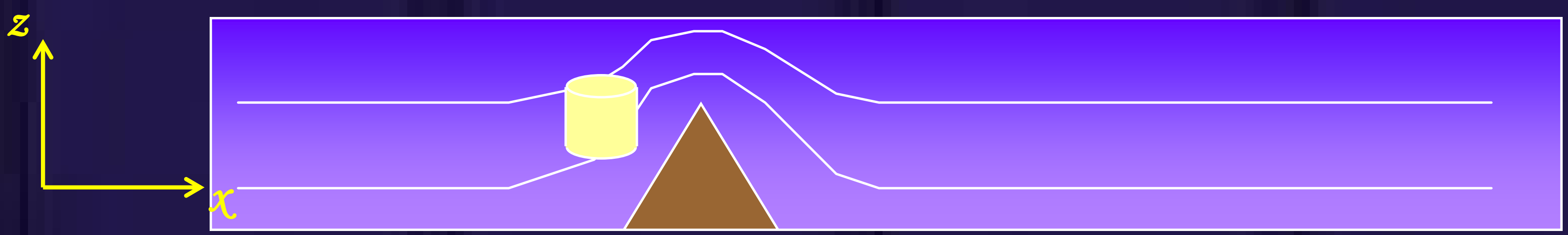


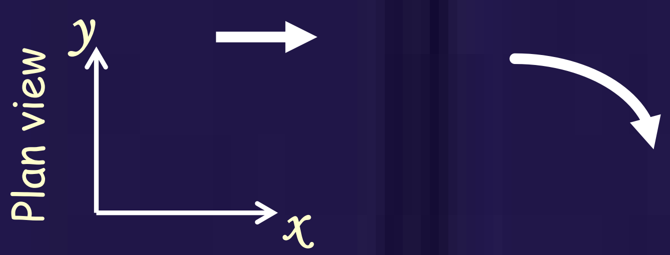


$$\frac{\zeta}{h} = const$$

Vortex shrinks, h reduced

ζ becomes -ve, anticyclonic spin

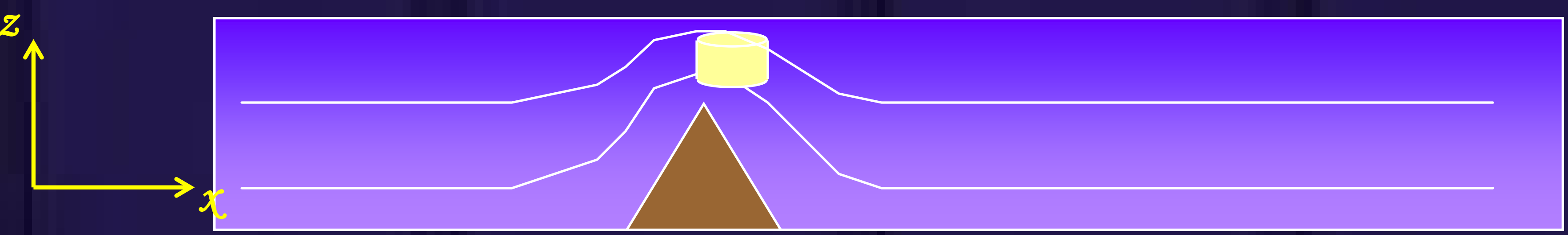




$$\frac{\zeta}{h} = const$$

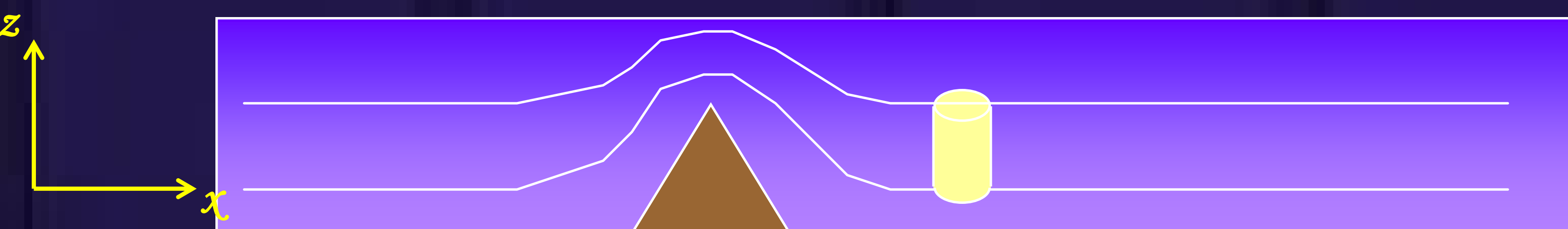
Vortex starts to stretch, h increases

ζ becomes +ve, cyclonic spin



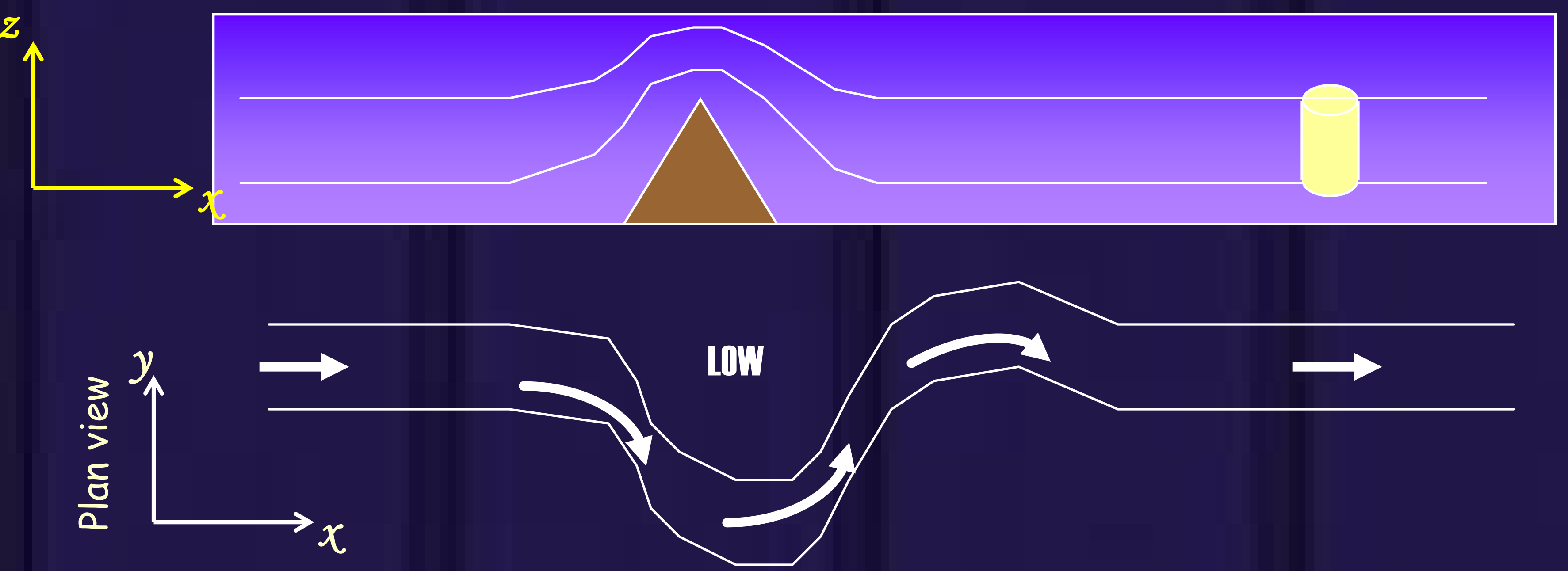
$$\frac{\zeta}{h} = const$$

Back to original trajectory



Mountain lee waves

Trough of low pressure in the lee of the mountain range



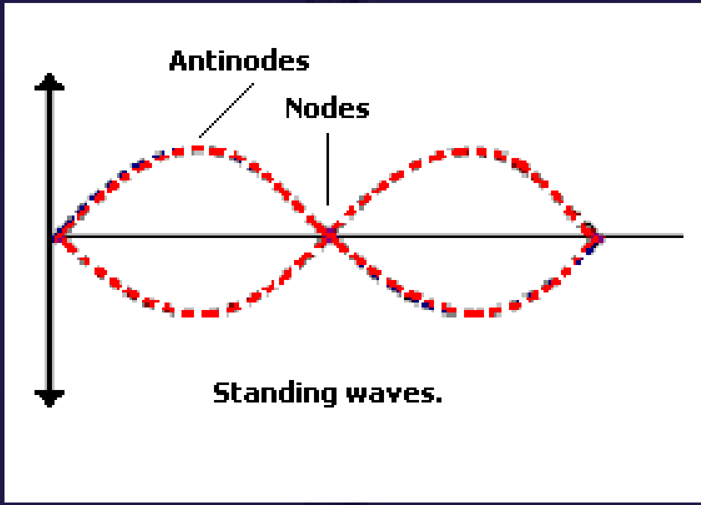
Lee wave: a standing wave generated on the sheltered side of a mountain by an air current passing over or around it, and often made visible by the formation of clouds. (The lee side is the side that is downstream from the wind.)

Lee waves cause updrafts and downdrafts

The wave appears stationary because its nodes and anti-nodes do not move.

What is actually happening though is that there is a wave called an incident wave created by the vibrations, which reaches the end of the medium and bounces back as a reflected wave.

The two waves occur at the same time with continued vibration and combine to form the pattern you can see.

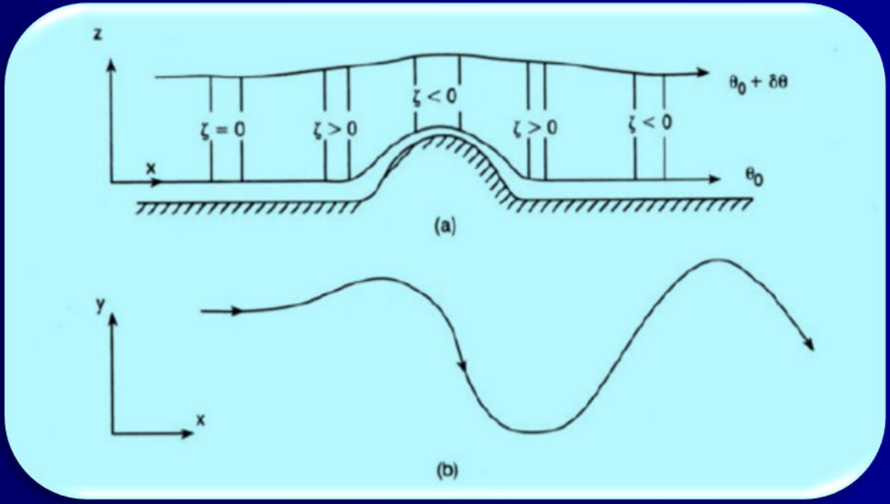


Conservation of potential vorticity

Westerly Flow Over a Barrier

Consider a westerly flow of air encountering a north-south mountain barrier. Upstream of the barrier, assume the flow is zonal and uniform, thus $\zeta = 0$.

When the depth of the vortex changes following motion, its absolute vorticity must change to maintain conservation of potential vorticity

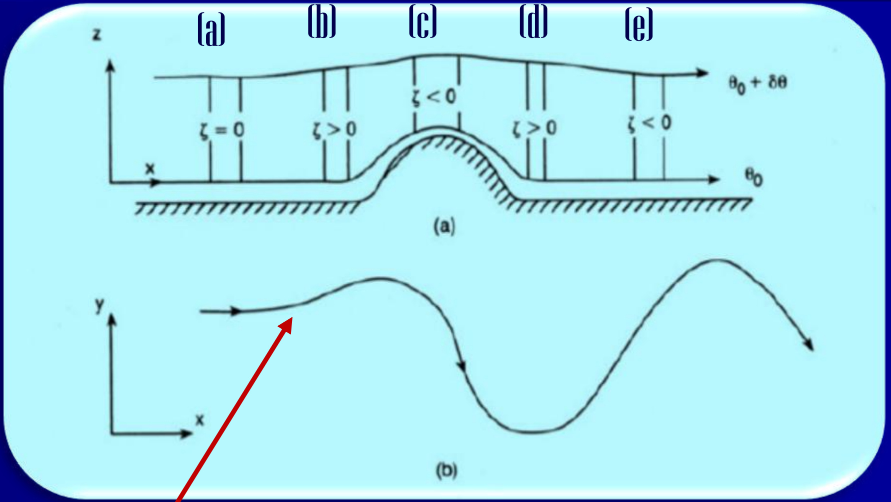


Conservation of potential vorticity

For westerly flow impinging on an *infinitely long* mountain range…

(a) upstream, zonal flow is uniform

$$(\delta u / \delta y = 0, \quad v = 0), \quad \zeta = 0$$



(Holton 2004, p. 98)

(b) deflection of upper θ surface upstream of barrier

→ *increases h*

→ absolute vorticity must increase

→ air column turns cyclonically

$$-\frac{\partial \theta}{\partial p} \quad decreases$$

Conservation of potential vorticity

For westerly flow impinging on an infinitely long mountain range…

poleward drift in (b) also causes increase in *f*

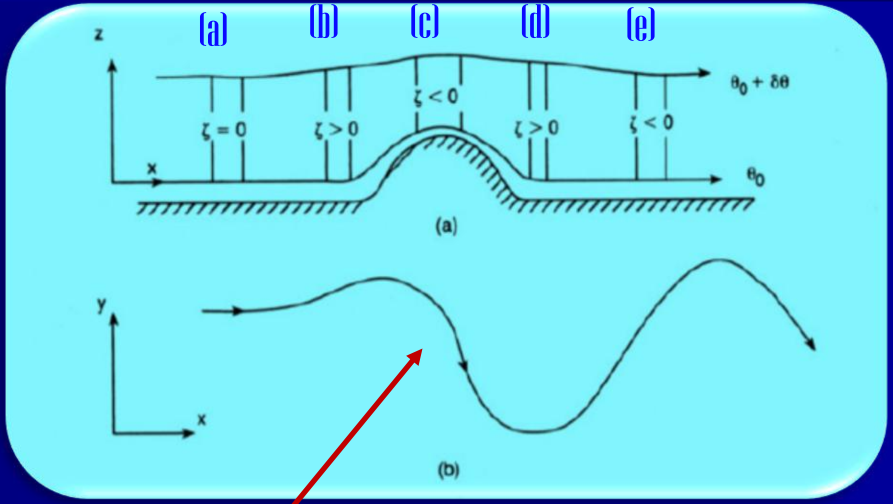
(c) as column crosses mountain,

h decreases

→absolute vorticity must decrease

→ ζ becomes negative

→air column drifts equatorward



Conservation of potential vorticity

equatorward drift in (c) also causes decrease in f

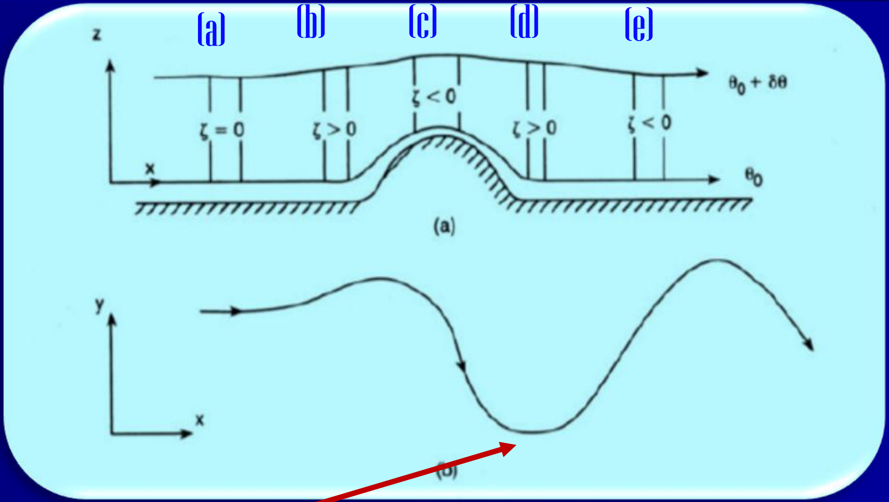
(d) as column crosses mountain,

h increases

→ absolute vorticity must increase

→ ζ becomes positive

→ air column drifts poleward



When the air column has passed over the barrier and returned to its original depth, it will be south of its original latitude so that f will be smaller and the relative vorticity must be positive.

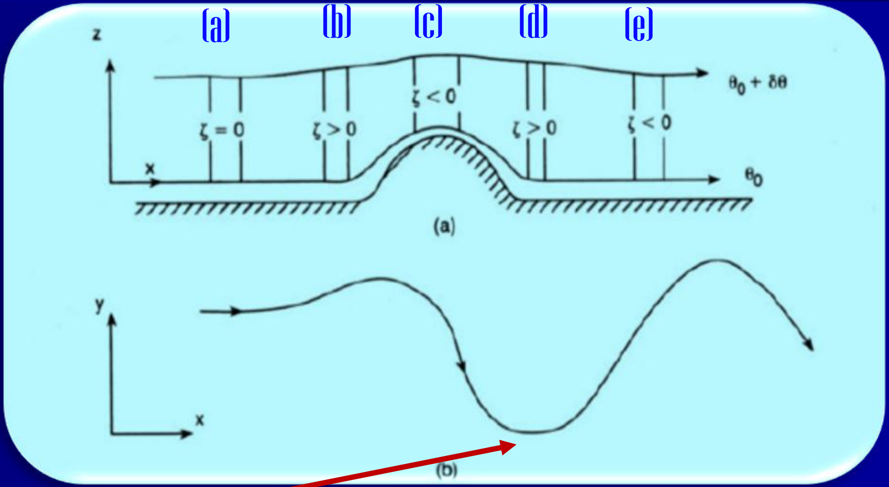
Thus, the trajectory must have cyclonic curvature and the column will be deflected poleward. When the parcel returns again to its original latitude, it will still have a poleward velocity component and will continue poleward gradually, acquiring anticyclonic curvature until its direction is again reversed.

The parcel will then move downstream, conserving potential vorticity by following a wave-like trajectory in the horizontal plane.

Therefore, steady westerly flow over a large-scale ridge will result in an anticyclonic flow over the mountain, a cyclonic flow pattern to the east of the barrier, followed by wave train downstream.

Conservation of potential vorticity

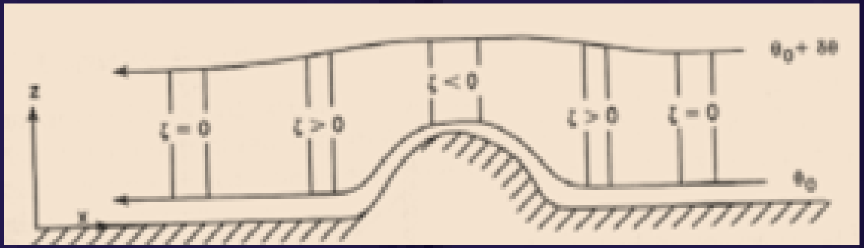
(e) alternating series of ridges and troughs downstream of mountain range

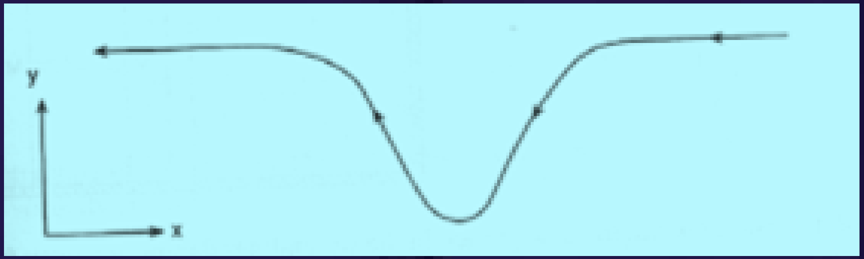


cyclonic flow pattern immediately to the east of the mountains (*lee side trough*)

The cyclonic flow downstream of a mountain barrier is known as a lee-side mountain trough, or lee trough.

Easterly Flow Over a Barrier





Thus, the dependence of the Coriolis parameter on latitude creates a dramatic difference between westerly and easterly flow over large-scale topographic barriers.

In the case of a westerly wind, the barrier generates a wave-like disturbance in the streamlines that extends far downstream. However, in the case of an easterly wind, the disturbance in the streamlines damps out away from the barrier.

For a constant absolute vorticity value, as f decreases moving equatorward, cyclonic relative vorticity increases (large positive values)

For a constant absolute vorticity value, as f increases moving poleward, cyclonic relative vorticity decreases (small positive values)