Hydraulic Jump Phenomenon

The Froude number expresses a ratio between the kinetic energy (wind speed) and the potential energy (stability times mountain height).

$$Fr = \frac{V}{N\left(z_{stablelayer} - z_{mtn}\right)}$$

where N is the Brunt-Väisala Frequency (static stability parameter) and V is the wind determined from the synoptic scale pressure gradient. For a significant hydraulic jump to occur, though, synoptic scale wind already need to be significant, say 15 m/s or greater.

- If the Froude number is equal to or slightly greater than 1, then there is the likelihood of mountain wave activity
- If the Froude number is less than one, then the airflow is insufficient to carry the flow over the mountain and the flow is blocked
- If Froude number is much more than 1, airflow proceeds right over the mountain and down the other side, with no significant oscillations

Fr at 1 or slightly greater than 1 occurs when the stable layer depth is near the top of the blocking mountains, but not at the top. Thus the term in parentheses in the denominator is positive but very small.

When this occurs horizontal pressure gradient accelerations are greatly augmented between the top of the mountain and the top of the stable layer. Downwind of the mountain crest, negative vertical pressure gradient accelerations far exceed horizontal pressure gradient accelerations leading to acceleration downslope resulting in horizontal speeds two to three times the strength of the synoptic scale wind speeds. Ground speeds in excess of 60 m/s have occurred down wind of the Rockies in some very marked hydraulic jumps.

At some distance from the mountain crest, the upward portion of the oscillation creates upward directed vertical pressure gradient accelerations that far exceed the horizontal pressure gradient accelerations leading to a jump in the vertical velocities called the hydraulic jump phenomenon (ground based mountain wave) but small horizontal wind speeds.