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Synoptic responses to mountain gravity waves encountering directional critical levels

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A heuristic model is used to study the synoptic response to mountain Gravity Waves (GWs) breaking at directional critical levels. The model is a Semi-Geostrophic (SG) version of the Eady model for baroclinic instability adapted by Smith (1986) to study lee cyclogenesis. In it, the GWs affect the large-scale flow when they encounter directional critical levels (Shutts 1995). In our model, this effect is represented by a force which produces Potential Vorticity (PV) anomalies in the mid-troposphere.

First, we consider the case of an idealized mountain massif where the small-scales and the large-scales of the height are well separated, and in the absence of tropopause. In this case, the PV produced by the GWs force has a surface impact that is significant when compared to the surface response to the large-scales. For a cold front, the GWs force produces a trough over the massif and a larger amplitude ridge immediately downstream. It opposes somehow to the response due to the large-scales of the massif, which is anticyclonic aloft and cyclonic downstream. For a warm front, the GWs force produces a ridge over the massif and a trough downstream, hence reinforcing the response due to the large-scales.

Second, we verify that the above results are rather systematic by a series of sensitivity studies where we change the small and large scales specification of the mountain massif, the intensity of the low level flow, or include baroclinic instabilities. We also repeat some experiments in the Quasi-Geostrophic approximation and consider the case of a small-scale orographic spectrum representative of the Alps.

The significance of our results is discussed in the context of the parameterization of GWs in General Circulation Models. They may also help to interpret the complex PV structures occurring when mountain gravity waves break in a baroclinic environment.