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Which Flow Regime favors Banner Cloud Formation?

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Banner clouds are clouds which are attached to the immediate lee of steep mountains or sharp ridges. They have dynamical rather than convective character. Banner cloud formation has previously been investigated using large eddy simulations with a fixed model configuration including an idealized pyramid-shaped orography. It was found that the key mechanism involves a fundamental windward-leeward asymmetry of the flow in the neighborhood of the orography, which in turn is associated with boundary layer separation at the salient edges of the pyramid. This leads to a pronounced windward-leeward asymmetry in the Lagrangian uplift with large values in the immediate lee of the pyramid, thus explaining the occurrence of a banner cloud.

In the present work we go a significant step further in asking the following question: under what conditions can one expect banner cloud to form most readily? In other words: under what conditions does the flow separate right at the top of the mountain, leading to flow reversal and upwelling on the leeward side of the mountain?

To elucidate this question, we carried through a series of numerical simulations using a cosine-shaped mountain and varying both the aspect ratio (steepness) of the mountain as well as the Froude number (stratification) of the oncoming flow. This is motivated by earlier studies of flow over two-dimensional orography that identified essentially three different regimes: lee side separation, no separation and post wave separation. However, banner clouds imply fully three-dimensional orography by necessity, and the questions remains as to what extent these two-dimensional results carry over. Our simulations show that even in the case of three-dimensional orography they are essentially the same three regimes as for two-dimensional orography. It turns out that banner clouds prefer steep mountains (large aspect ratio) in combination with week stratification (low Froude number), corresponding to the regime of lee-side separation.