A Z-Coordinate Version of the Non-Hydrostatic Model LM in Three Space Dimensions

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Meso γ scale models in terrain following coordinates generate strong erroneous forces near mountains, which lead to artificial circulations even with a horizontally stratified atmosphere. An obvious remedy of this problem is the use of a Z-coordinate, with the effect that the orography cuts into the lower model levels. With such an approach it is necessary to be careful in formulating the lower boundary condition. It is necessary to allow for a sufficiently smooth representation of the orography (see Kröner,1997). Step function representations of the lower boundary can have problems in representing the orography smoothly and therefore can produce problems in representing the flow around hills (Gallus and Klemp, 2000).

The approach presented here is based on the finite volume approach using shaved cells. These are obtained by cutting a regular rectangular grid with an orographic function which is represented as a continuous bilinear spline. A number of further approximations are applied in order to make the scheme practical for operational use.

Continuing our work on two dimensions, the scheme is implemented now in three space dimensions. A number of improvements were introduced as compared to the two dimensional version. Most important, the boundary values for the computation of the advection terms are computed by interpolating into the mountain using planes determined by three points which are outside the mountain.

A numerical experiment was performed using a circular mountain of height 400m and half width 10 km with 36 levels changing in thickness from 100m to 200m near the surface. The thickness of upper layers is 1200m. The horizontal grid length was 2 km. According to Gallus and Klemp (2000) the generation of a hydrostatic gravitational wave generated by a smooth bell shaped mountain is a crucial test for Z-coordinate models. Boundary treatments of the step mountain type often create solutions which are not very smooth and can even be entirely wrong.

Fig. 1a shows the u-velocity of the solution after 2.5 hrs, corresponding to a cross section through the centre of the mountain. It corresponds well to the terrain following solution of this problem, shown in fig. 1b.

Reference:

Gallus, W. and J. Klemp, 2000: Behaviour of flow over Steep Orography. *Mon. Wea. Rev.* **128**, 1153-1164.

Kröner,D., 1997: Numerical Schemes for Conservation Laws, Wiley, N. Y., pp507.

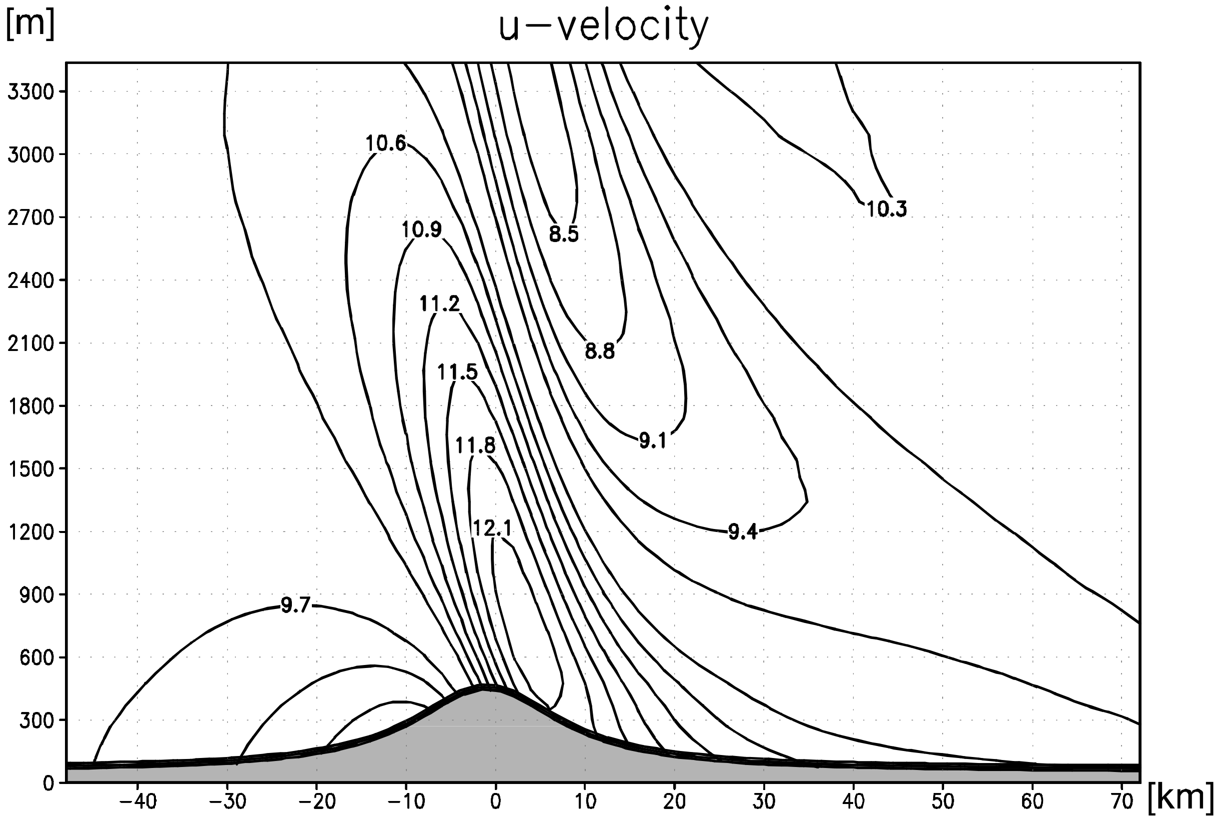

Fig. 1a: The u-velocity of the 2.5 hr forecast with the z-coordinate LM

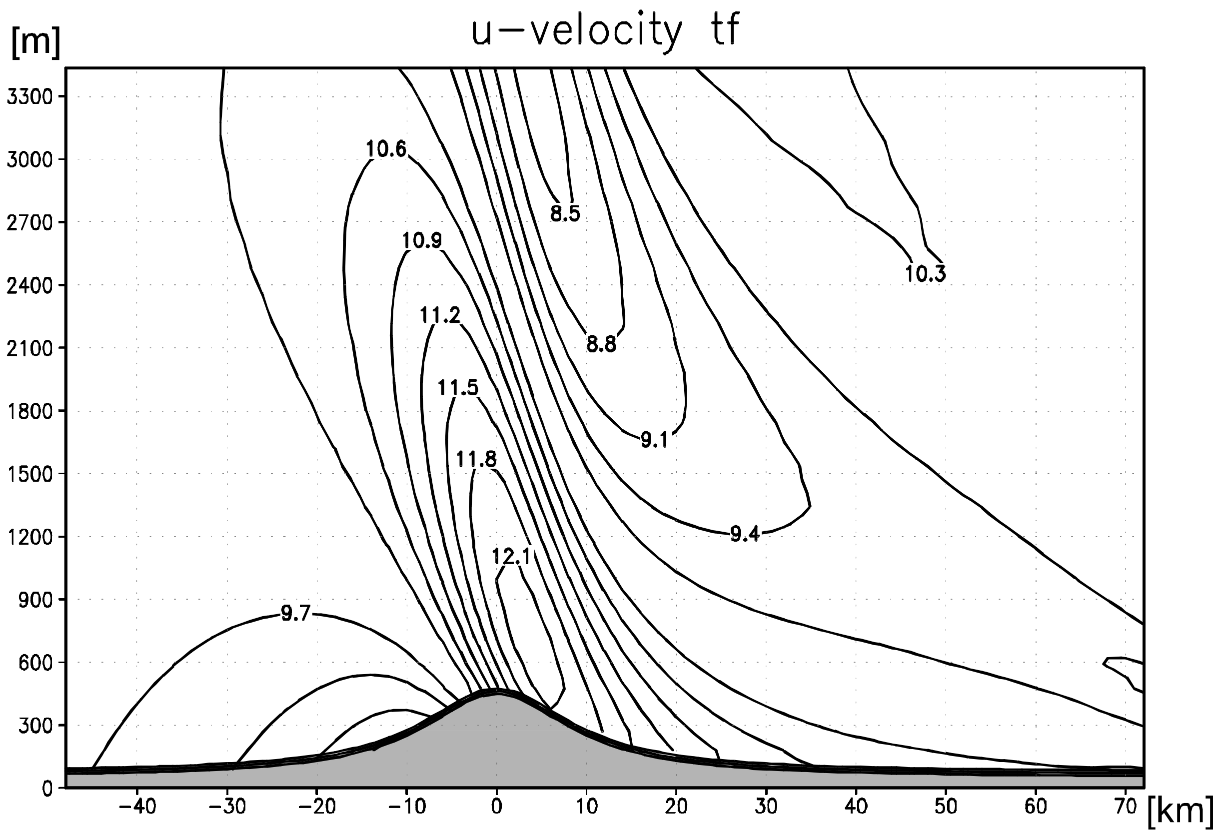

Fig. 1b: As fig 1a, for terrain following coordinate.