Incorporation of the topography effects in Vector Vorticity Model (VVM)

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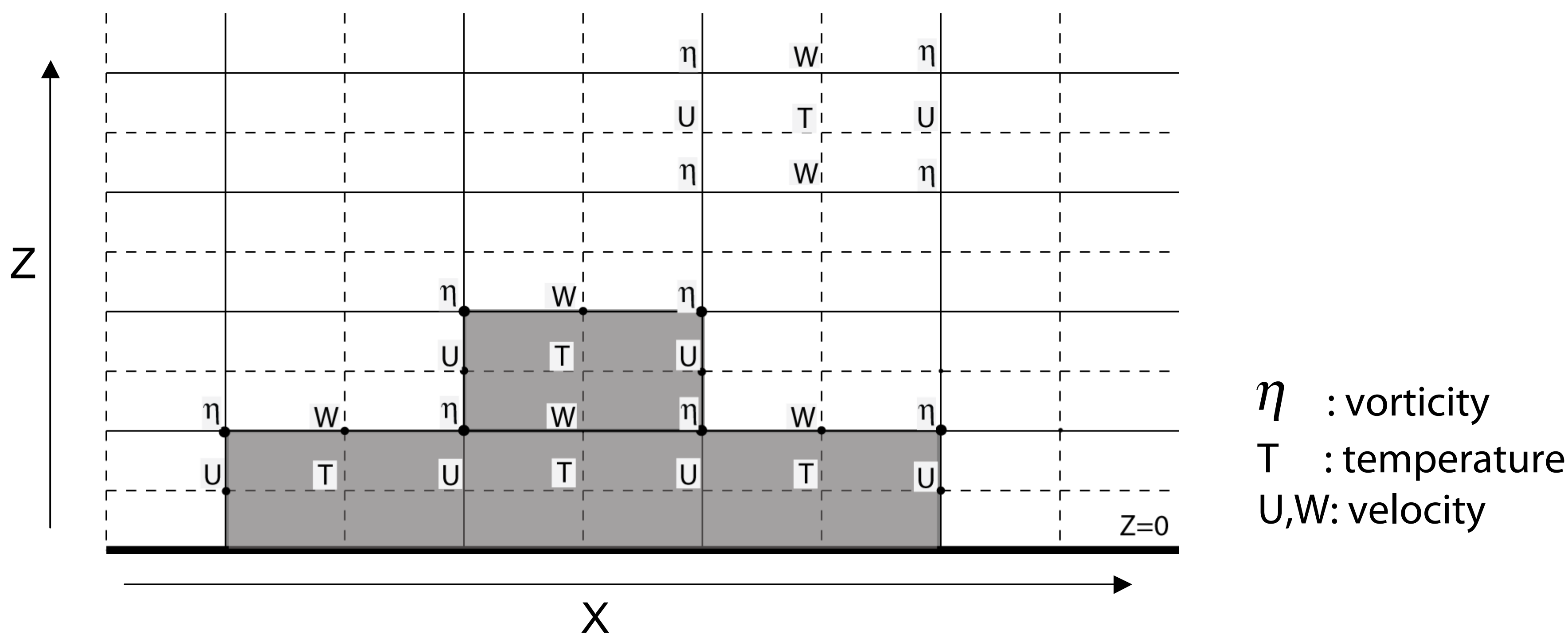
The block mountain

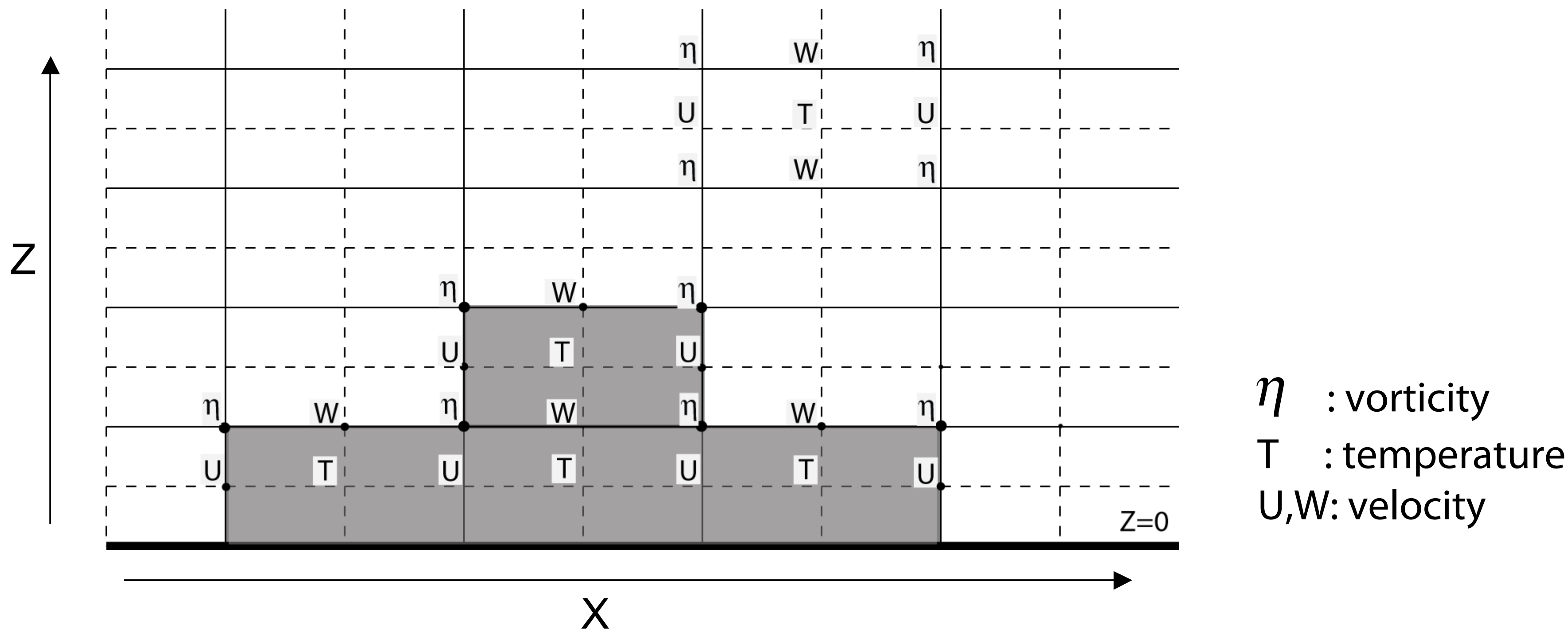
- Rectangular blocks with mountain surface fixed at coordinate surface.
- W is zero at the horizontal boundaries and U is zero at the vertical boundaries.



The block mountain in Vector Vorticity Model

Problem: The predicted vorticity field recognizes W=0 at the horizontal boundaries through the lower boundary condition for the w-equation. But, if the voricity at the boundary is arbitrarily specified (e.g., as zero), the diagnosed U field generally does not satisfy U=0 at the vertical boundary.

• Enforcing the velocity boundary condition requires an appropriate computational boundary condition for vorticity.

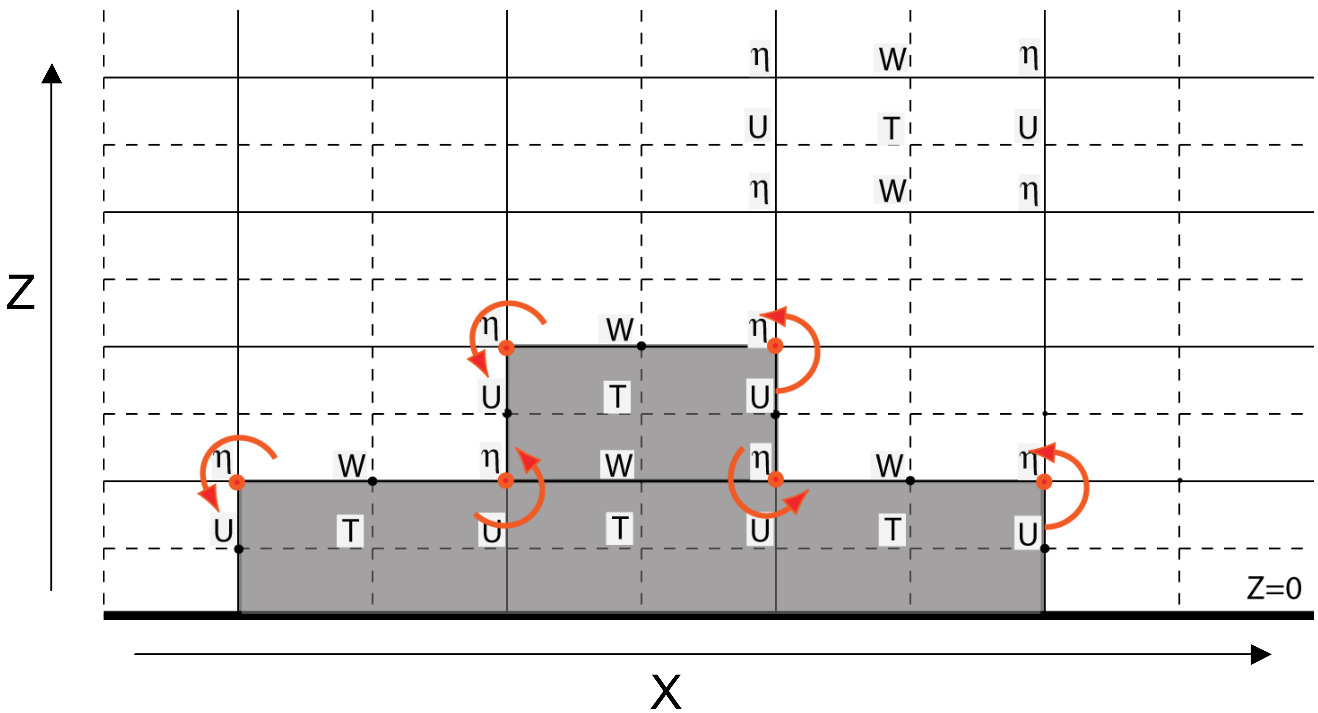


The block mountain in Vector Vorticity Model

Solution: Incorporate the barrier influence into the flow with the addition of point vortices at the corners.

•*The effect of the vorticity added to boundary points is superposed to satisfy the boundary condition without perturbing the interior dynamics.*

--Roache(1972), Kim and Arakawa(1995).

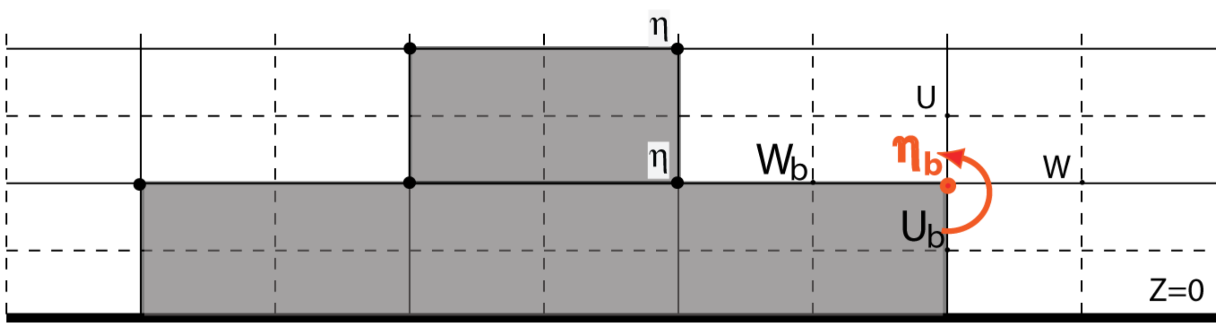


η : vorticity
T : temperature
U,W: velocity

Determination of the strength of the point vortices

- The strength of the point vorticity is determined through vorticity definition.

$$\eta_b = \frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} \qquad u_b = w_b = 0$$



Update velocity fields with:

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right) w + \frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\left(\frac{\partial}{\partial z}\rho_0 w\right)\right] = -\frac{\partial(\eta + \delta\eta_b)}{\partial x}$$

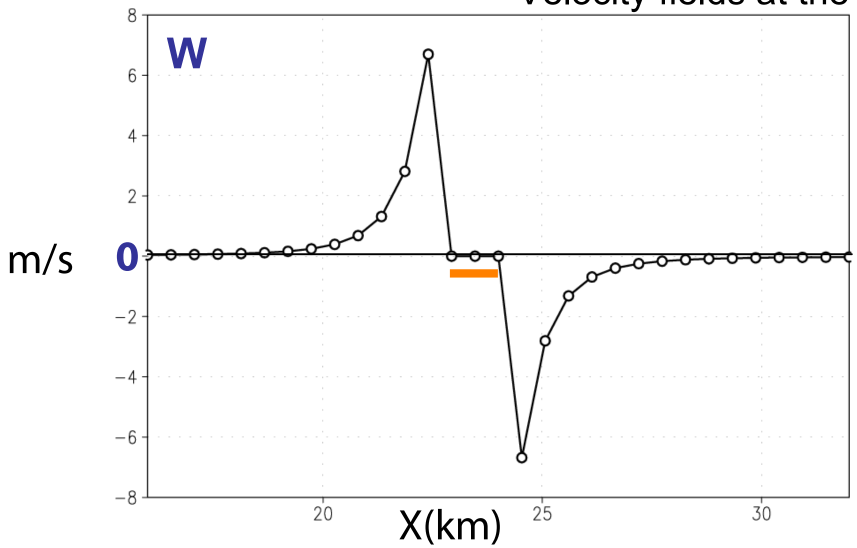
$$u = \int_{z_t}^{z} \left(\frac{\partial w}{\partial x} + \rho_0(\eta + \delta\eta_b)\right) dz + u_t(x,y,t)$$

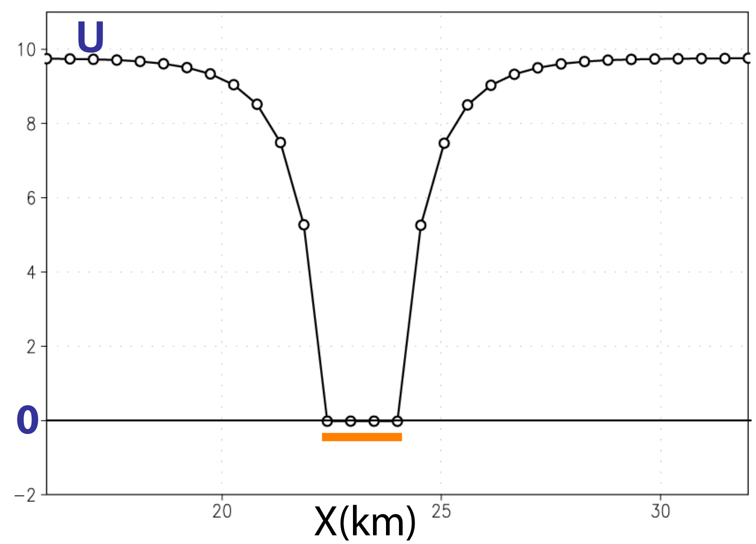
$$\left\{\begin{array}{l} \delta = 1 \text{ at the boundary corners} \\ \delta = 0 \text{ at all other points} \end{array}\right\}$$

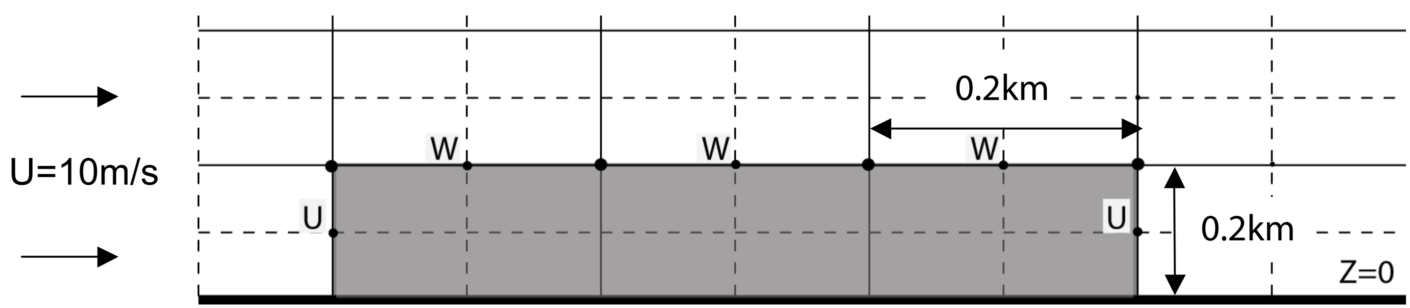
VVM 2D experiment

- Topography is introduced with the block mountain approach.
- The velocity fields satisfy the desired boundary conditions.

Velocity fields at the surface of the topography

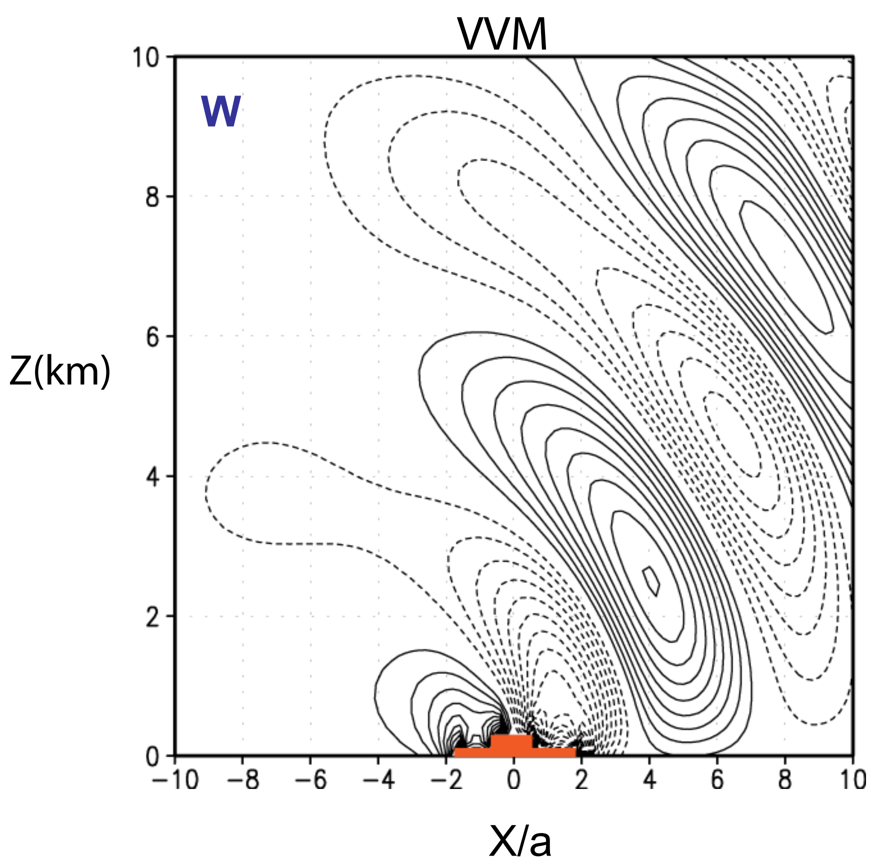


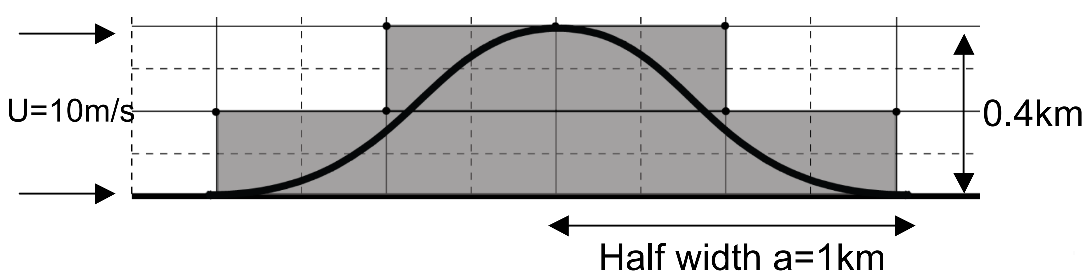


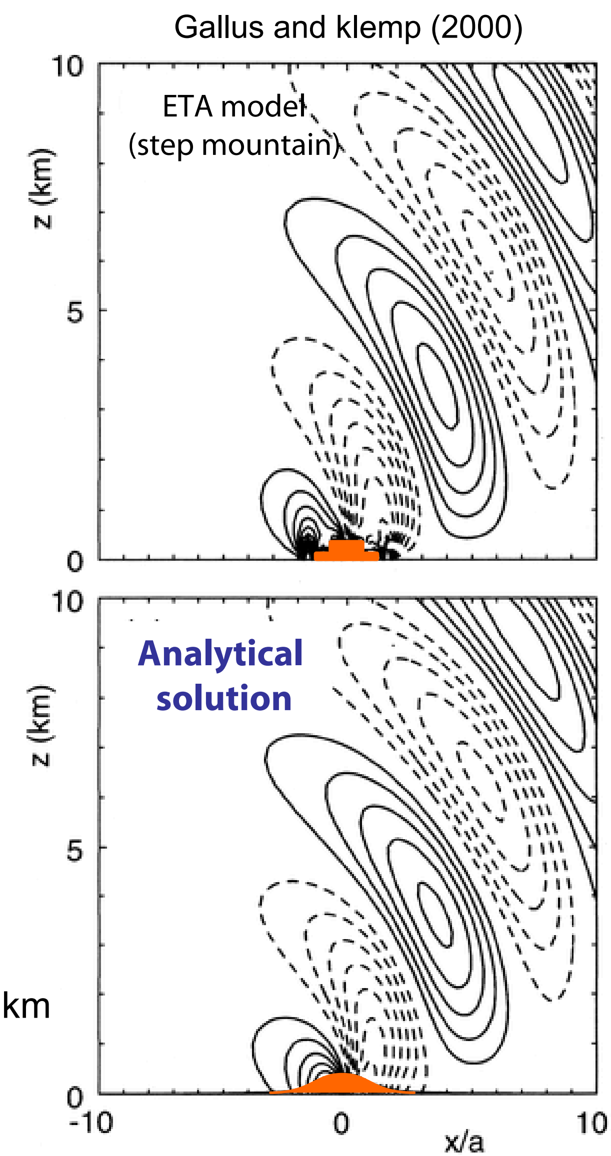


VVM 2D experiment

- A block representation of bell-shaped mountain (Na/U=1) is introduced.
- The mountain wave associated with the topography is reasonable.



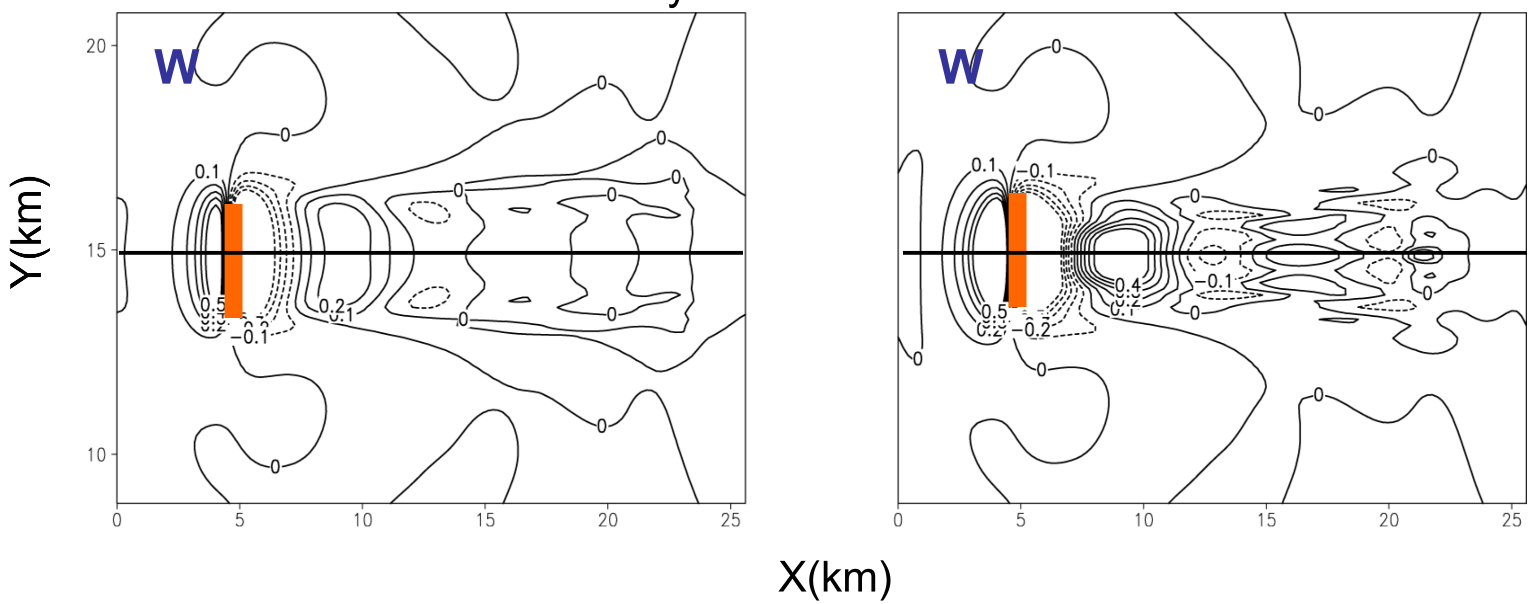


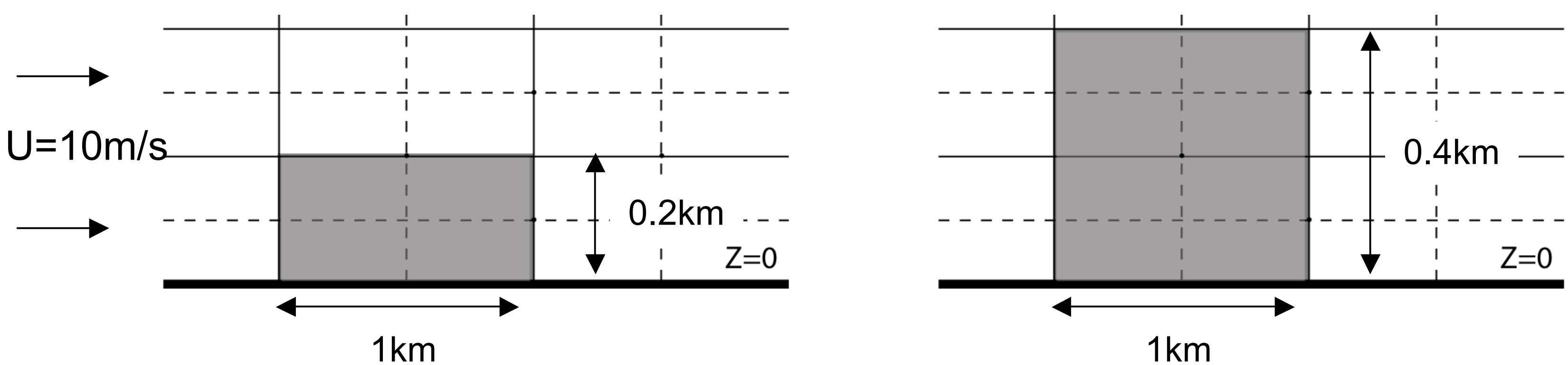


VVM 3D experiment

- Block mountain 4km x 1km with mountain height h=0.2km and h=0.4km.

Vertical velocity X-Y cross section at 1km





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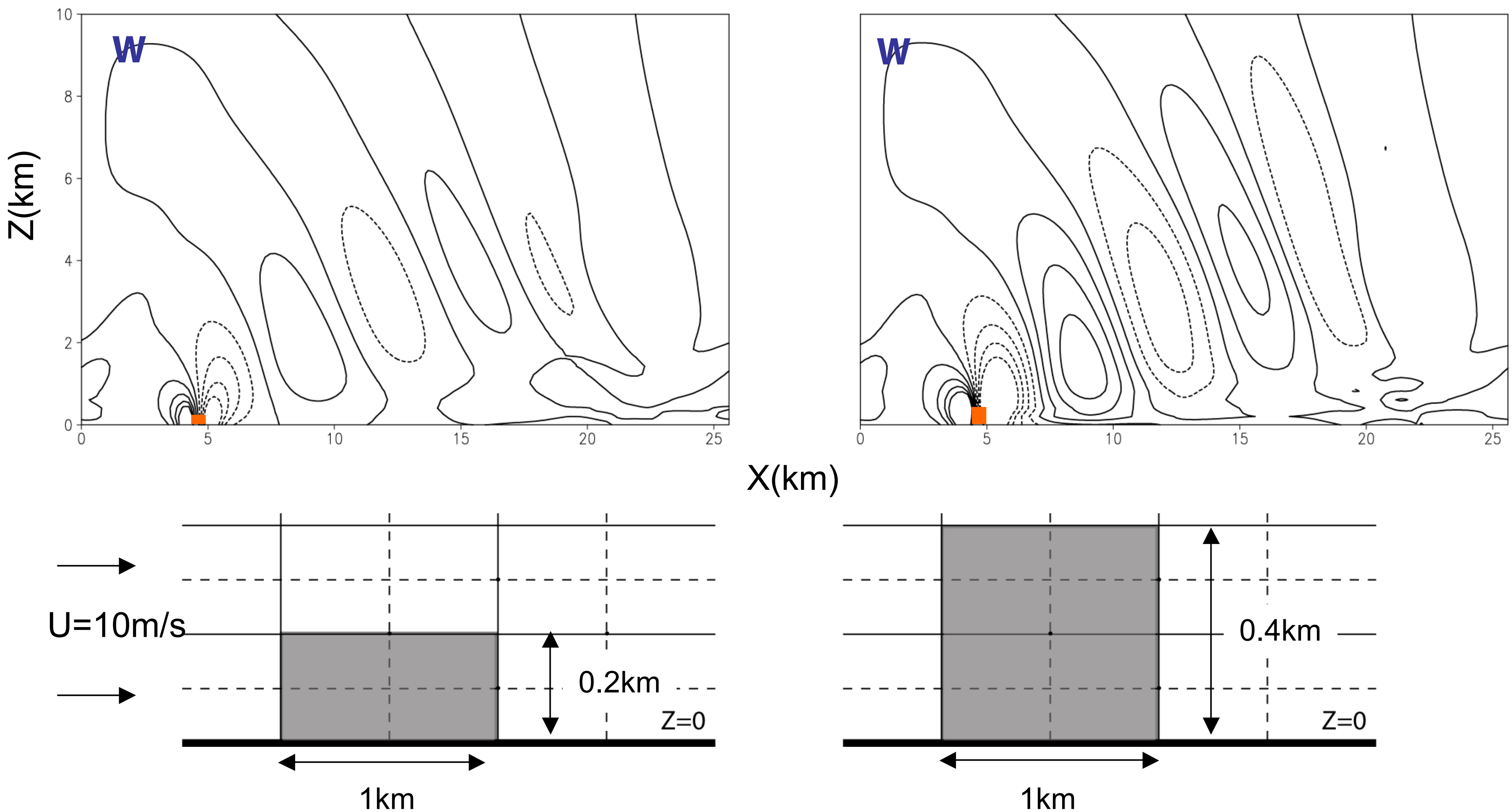

Future direction

- Test various setup of topography in 3D VVM.
- Incorporate realistic complex topography.