Progress Report

Research Objective:

Development of a Q3D MMF

Inclusion of Surface Topography: Preliminary Tests

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How does the topography affect weather and climate?

- Influences the large scale flow through low-level flow blocking.
  (Resolved by the GCM through enhanced orography)
- Generates vertically propagating internal gravity waves that influence the large scale flow through wave-breaking aloft.
  (Subgrid parameterization of orographic gravity wave drag)
- Initiates atmospheric convection through forced lifting and surface heating by diurnal solar radiation on mountain slopes.
  (Subgrid parameterization of orographic precipitation)

Topographic effect depends on various factors: airflow velocity and direction, thermodynamic conditions, and the shape and dimensions of the mountains

Explicit Representation of Subgrid-scale Topography in the Q3D MMF

In the Q3D MMF, the subgrid-scale inhomogeneity in topography can be explicitly represented by the CRM channels, at least along the channel direction.

How well the (basically) 2-D representations of topography by the two perpendicular channels can mimic the 3-D topography?

Idealized Test of Orographic Precipitation

Objective of the test is to find how well the statistics of orographic precipitation due to 3-D topography can be simulated with a 2-D representation of topography

Idealized 3D MMF (one-cell GCM + 3-D CRM)

vs.

Idealized 2D MMF (one-cell GCM + 2-D CRM)

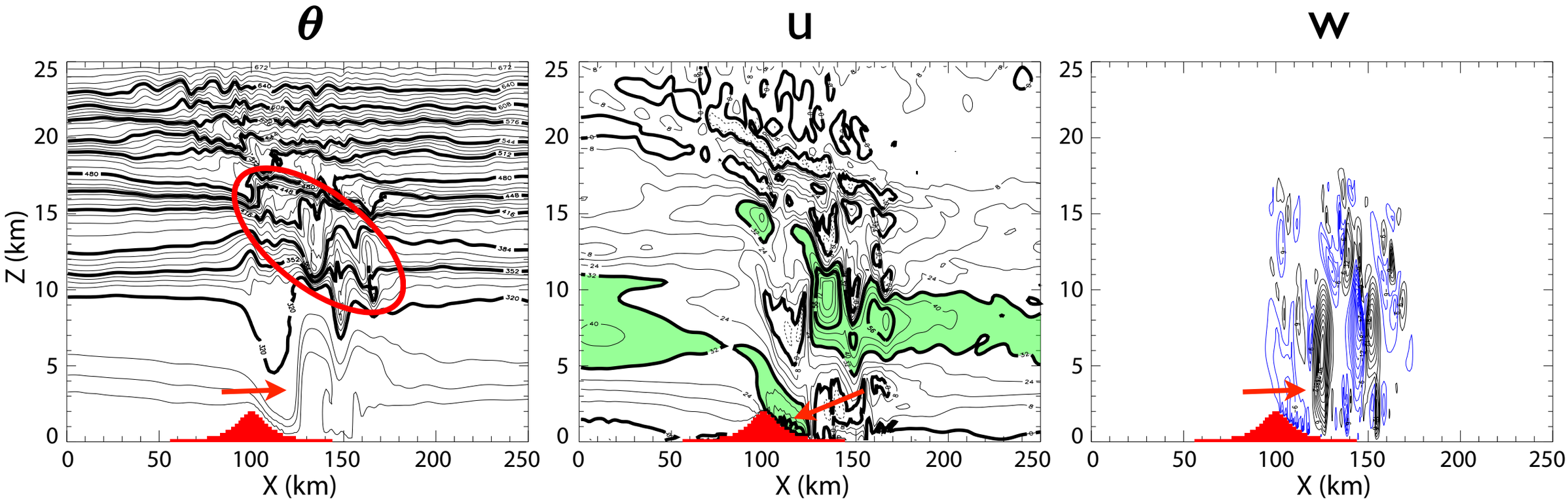
Base Model:
Vector **V**orticity **M**odel (Jung and Arakawa 2008)

Inclusion of Surface Topography to VVM

Following the block-mountain method of Wu and Arakawa (2011), surface topography has been implemented to the parallelized VVM.

VVM Results: Boulder Windstorm Case (2-D)

Experiment setup follows Doyle et al. (2000)

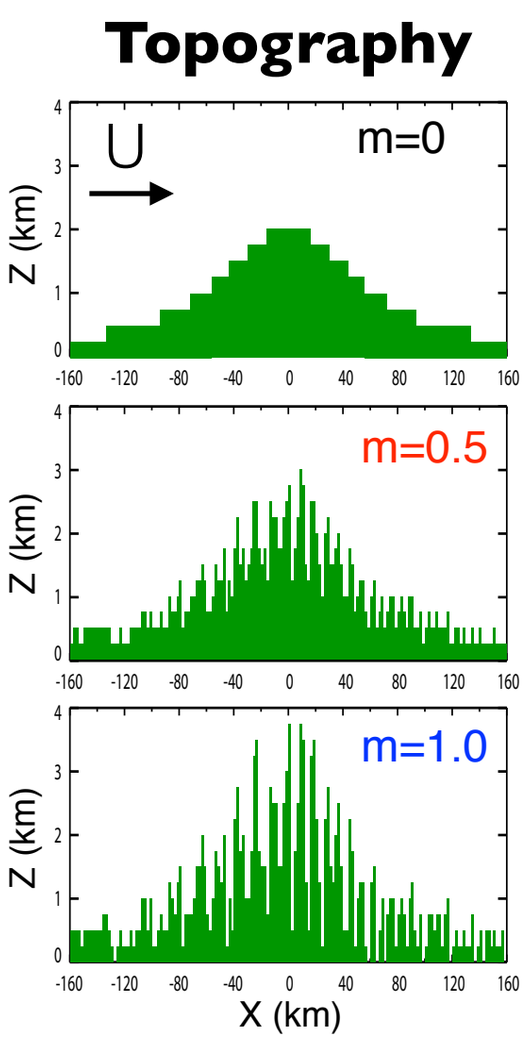


Upper level wave breaking and hydraulic jump at downstream region

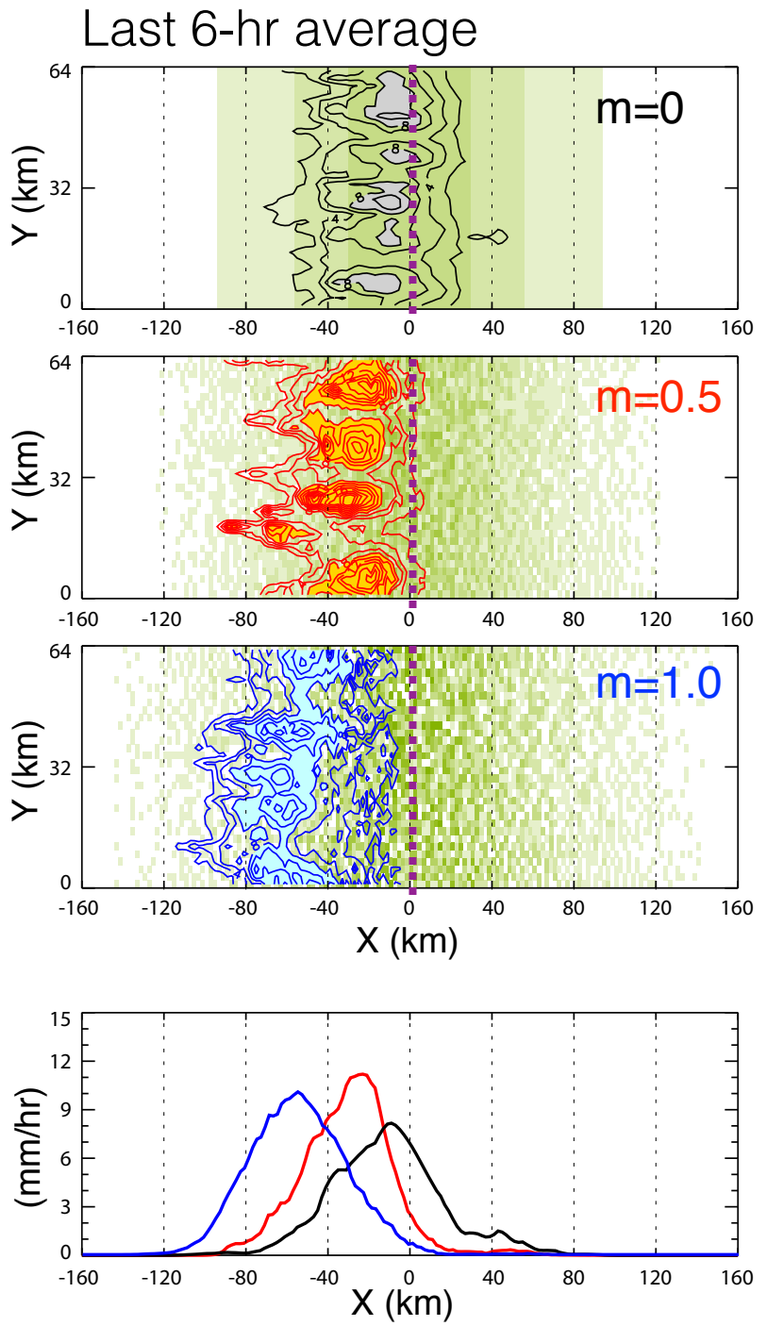
Downslope horizontal wind exceeds 64 m/s

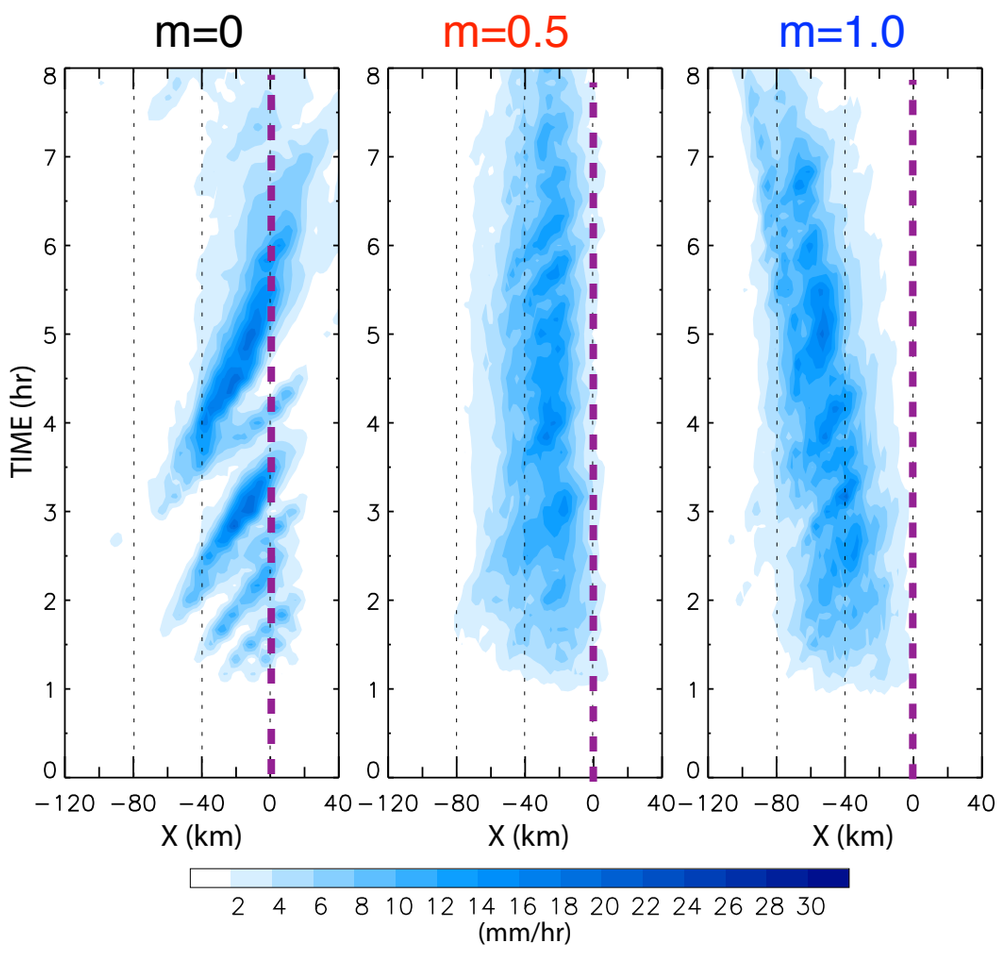
Strong vertical velocity in the jump region

Inclusion of Surface Topography to VVM
(Continued)
VVM Results: Orographic Precipitation over a Ridge (3-D)



m: measure of irregularity





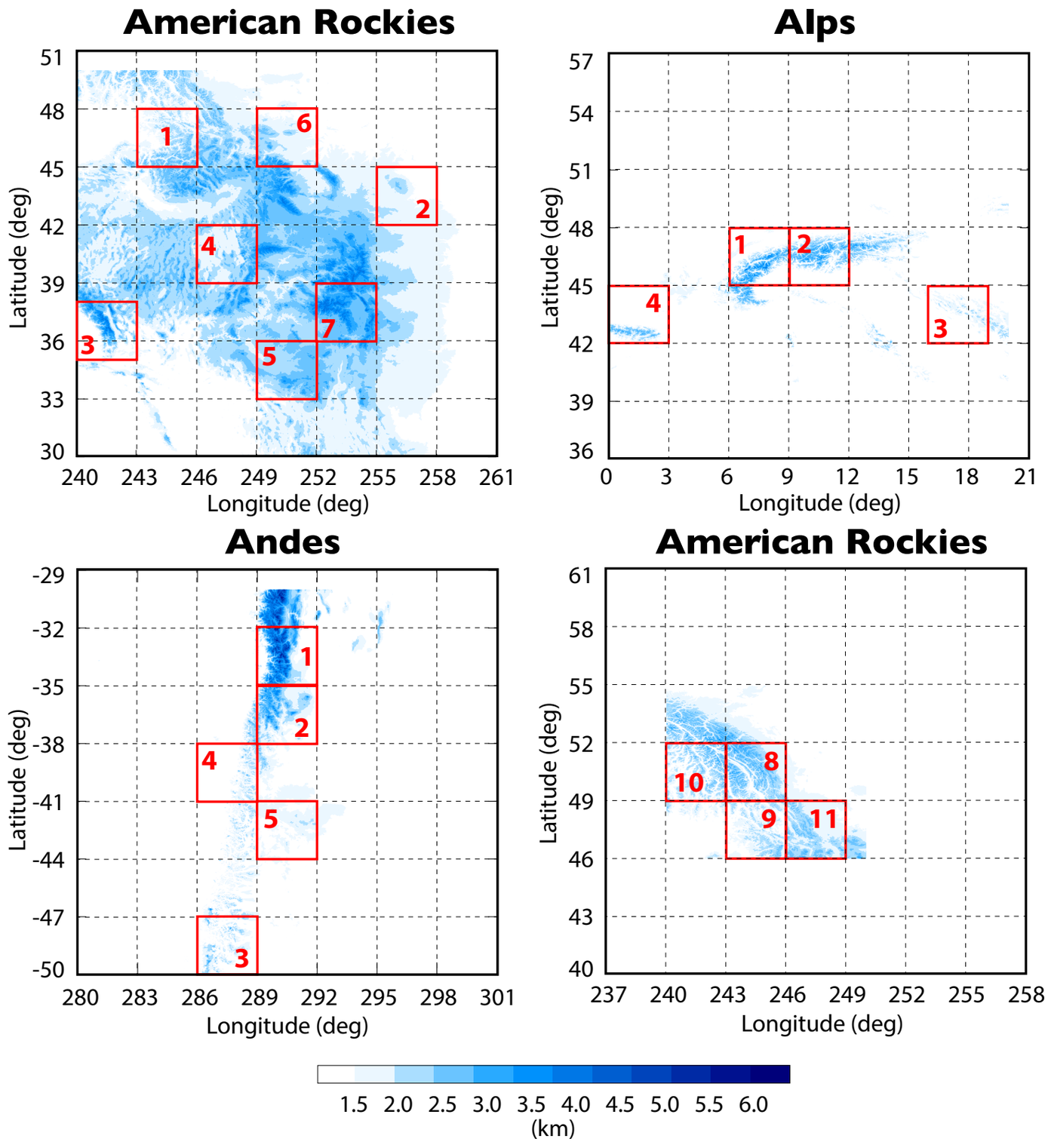
- Overall precipitation falls over the windward slope.
- The upstream convection develops sooner as m increases.
- The precipitation tends to be locked geographically as m increases.

Idealized 3D MMF Simulation: (One-cell GCM + 3-D CRM)

- **GCM cell size:** 300 km x 300 km (horizontal domain size of the CRM)
- **Vertical domain** of the GCM and CRM: 30 km
- **One-way coupling:** nudging of the domain averages of CRM to GCM values that are constant with time
- **Initial Conditions:**
  - Mean profiles of potential temp. and water vapor mixing ratio are given (following Weisman and Klemp 1982). All other water species are initially set to zero.
  - Uniform wind speed: U=10 m/s
  - The uniform initial conditions are regarded as the GCM state
- **In the CRM**
  - Horizontal grid: 3 km, Vertical grid: 0.1 ~ 1.7 km (stretched grid)
  - No radiation, No Coriolis force, No surface fluxes of sensible heat and moisture
  - Random perturbation of potential temp. in the lowest layer to initiate convection
  - Double Periodic boundary condition

Sampling of Surface Elevation Data

From 1-minute grid data (Smith, W.H.F., and D.T. Sandwell 1997)



It is difficult to parametrically represent a variety of complex terrain data.

Modification of Surface Elevation Data

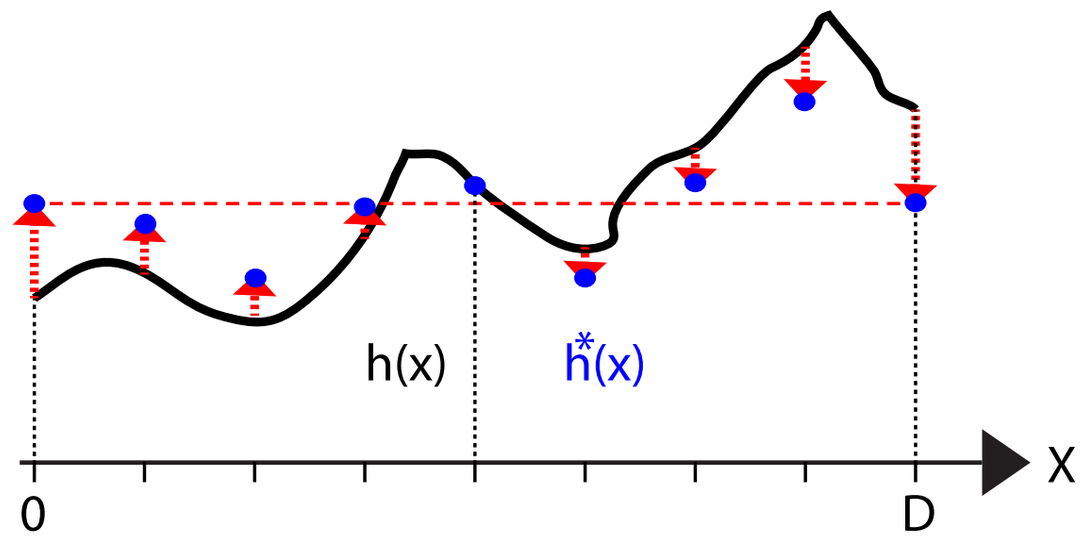
To apply the cyclic boundary condition, the data is modified as follows:

$$h^*(x) = \max\left\{0., \left[h(x) + C(x)\right]\right\}$$

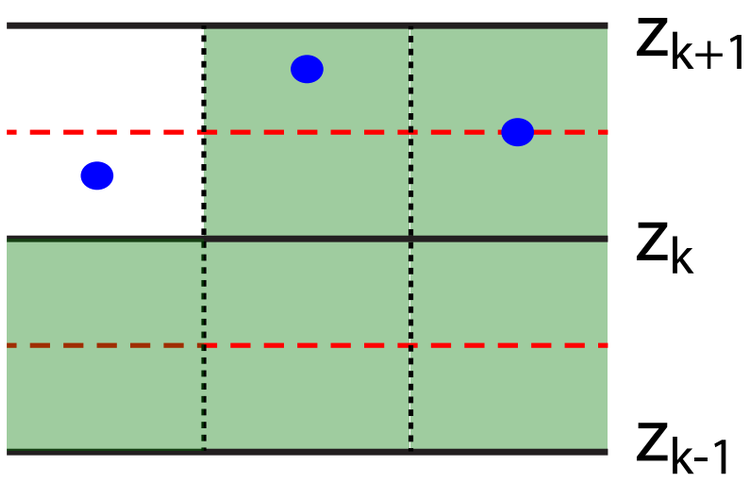
Here C is a correction term given by

$$C(x) \equiv C(0)\cos(\pi x / D)$$

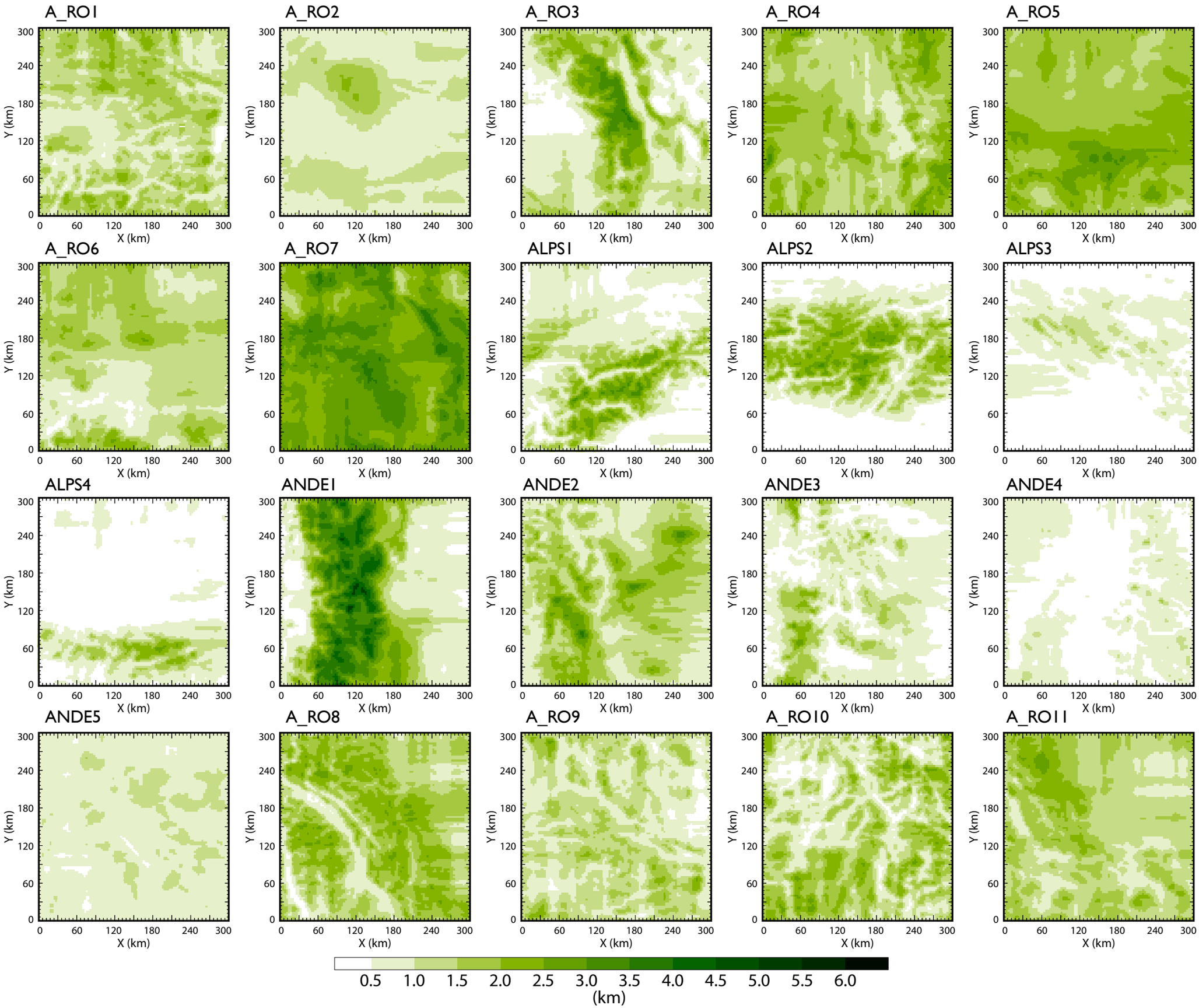
$$C(0) = \left[h(0) + h(D)\right]/2 - h(0).$$



The block mountain data is prepared with the vertical grids of the model (i.e., round h to the nearest model level z).

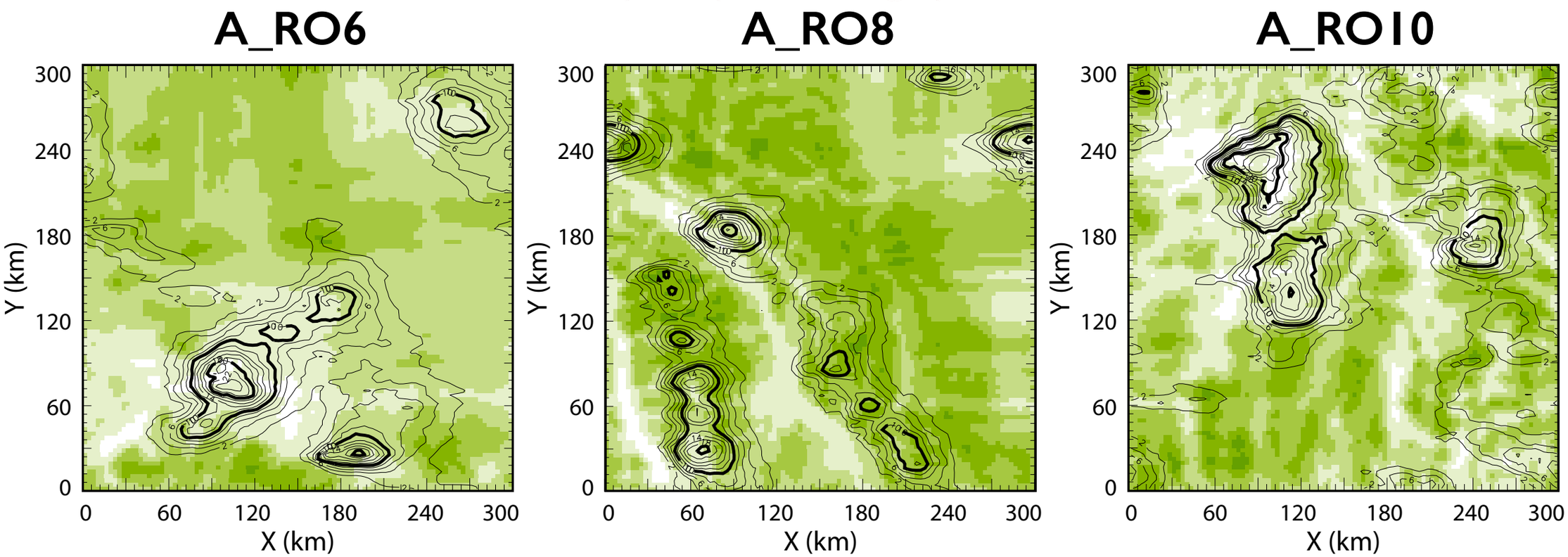


Surface Elevation Used in the Simulation

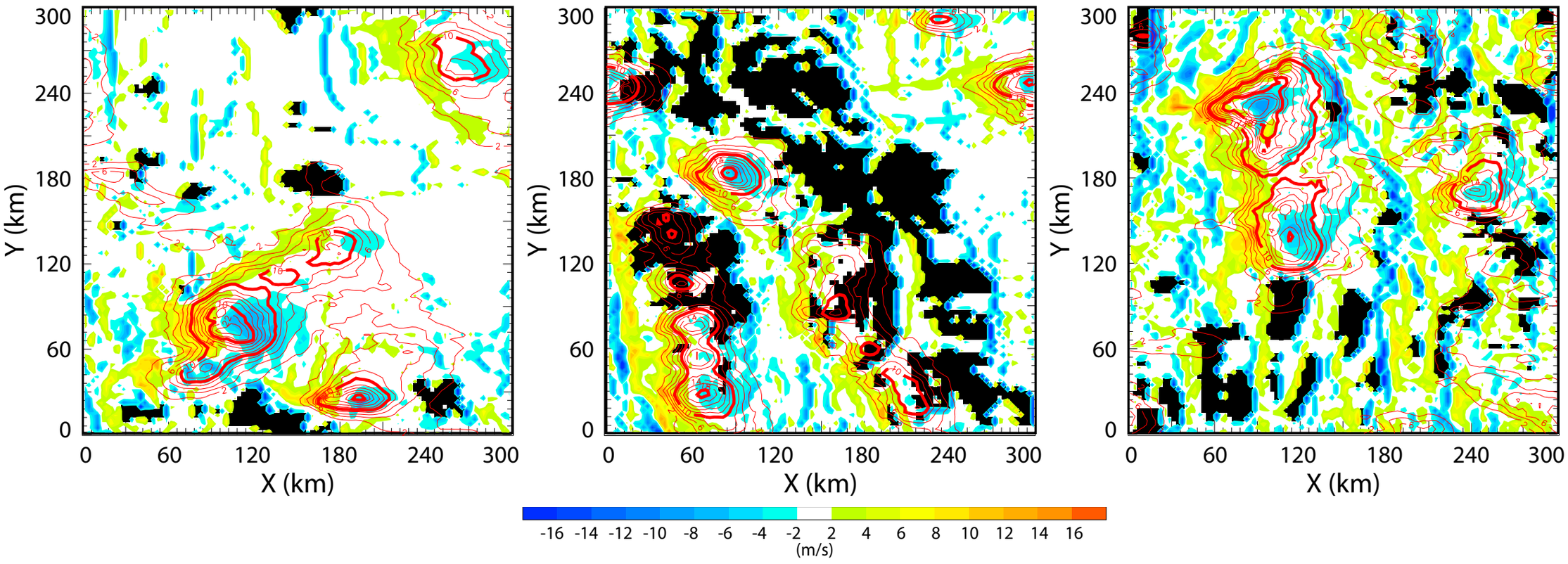


Examples of Simulated Precipitation Rate

(2day average)

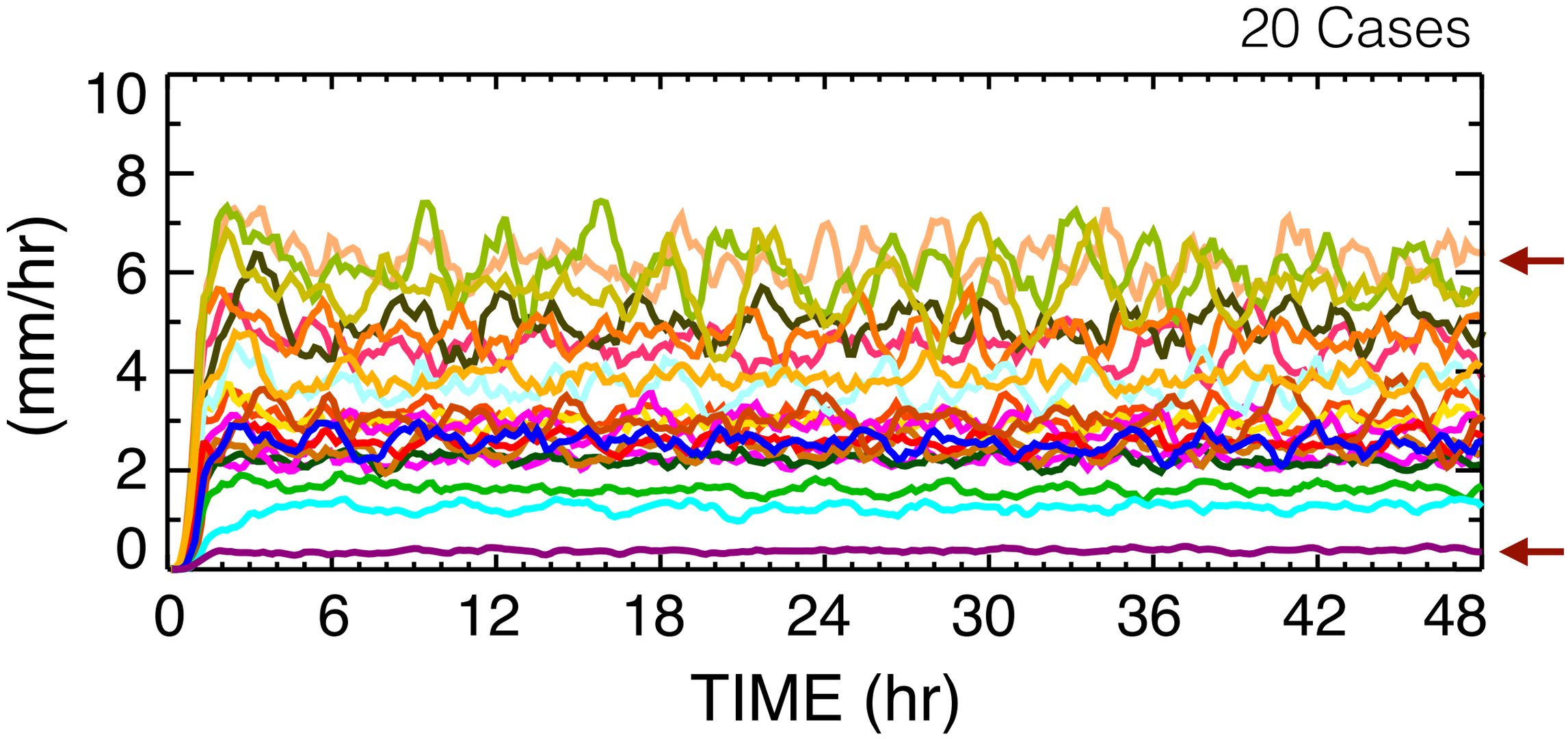


Vertical Velocity (z ~ 2 km)



Simulated Precipitation Rate

(Domain average)



The (GCM-cell averaged) precipitation rate varies considerably among the cases.

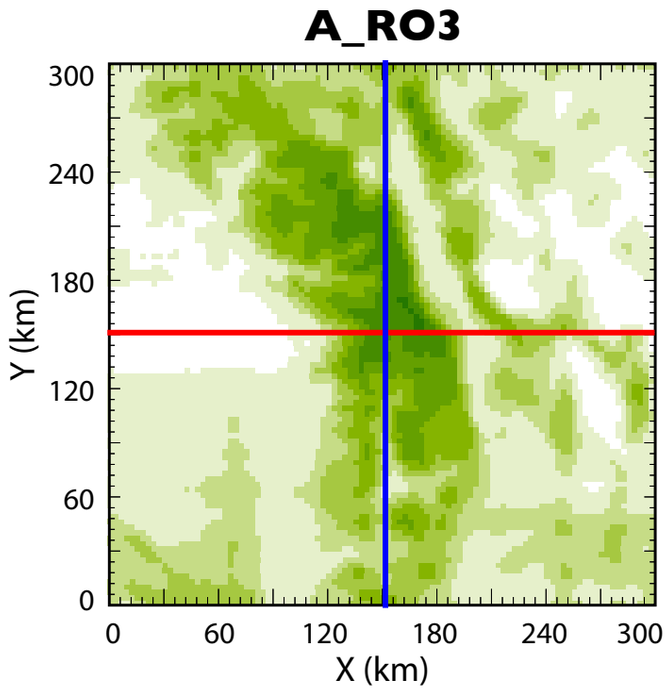
Idealized 2D MMF Simulation: (One-cell GCM + 2-D CRM)

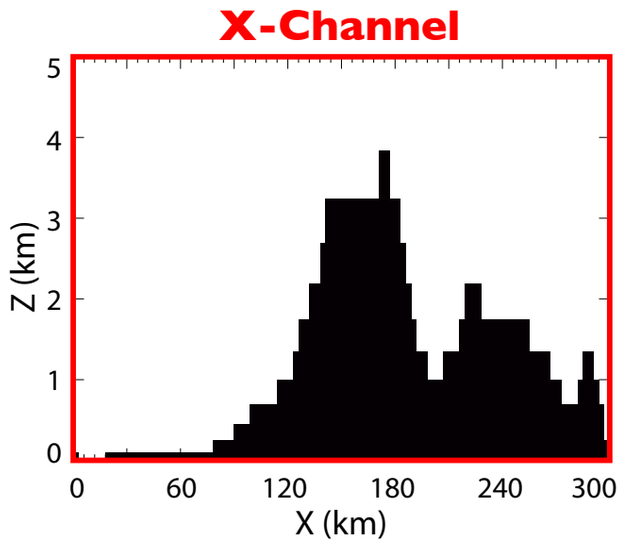
Two runs of each test case:

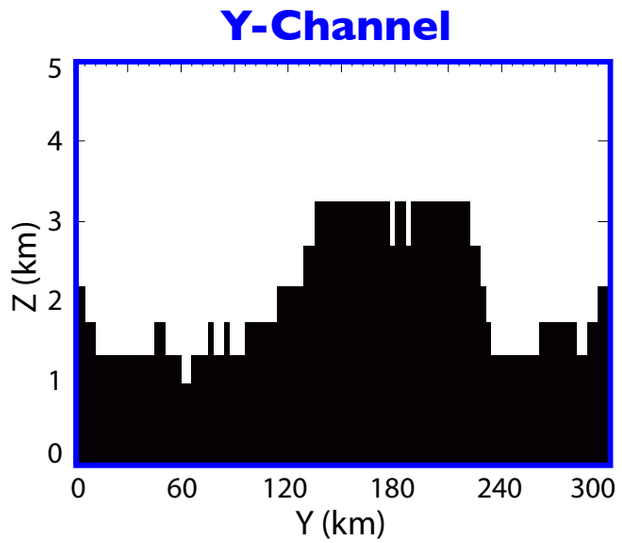
X-channel run

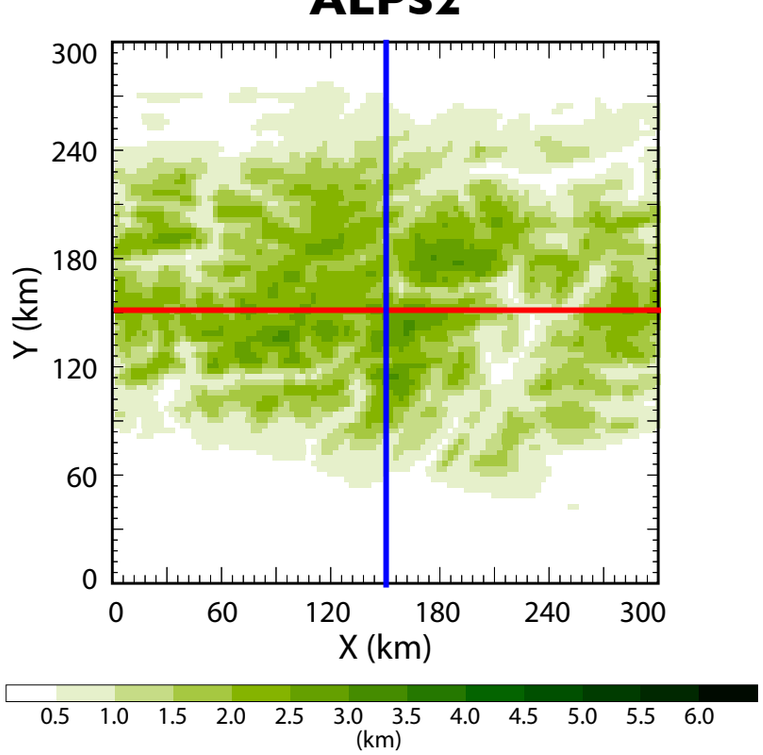
Y-channel run

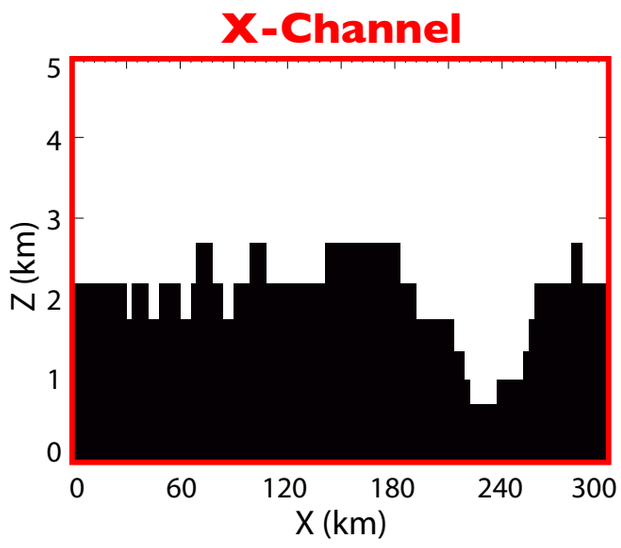
Examples of Surface Elevation Used in the Simulation of 2D MMF

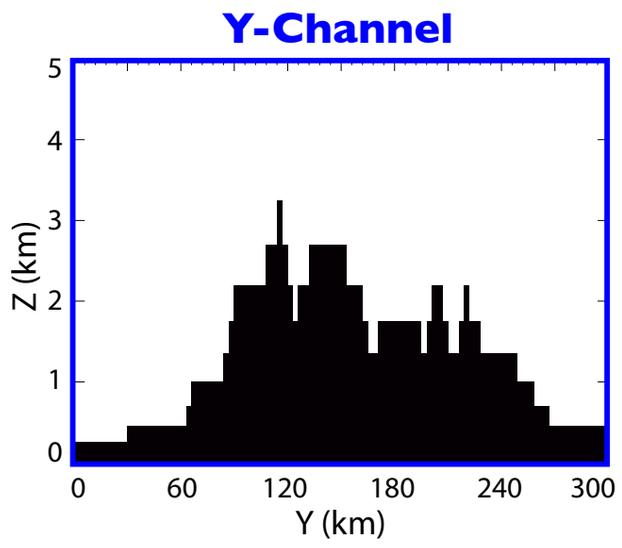






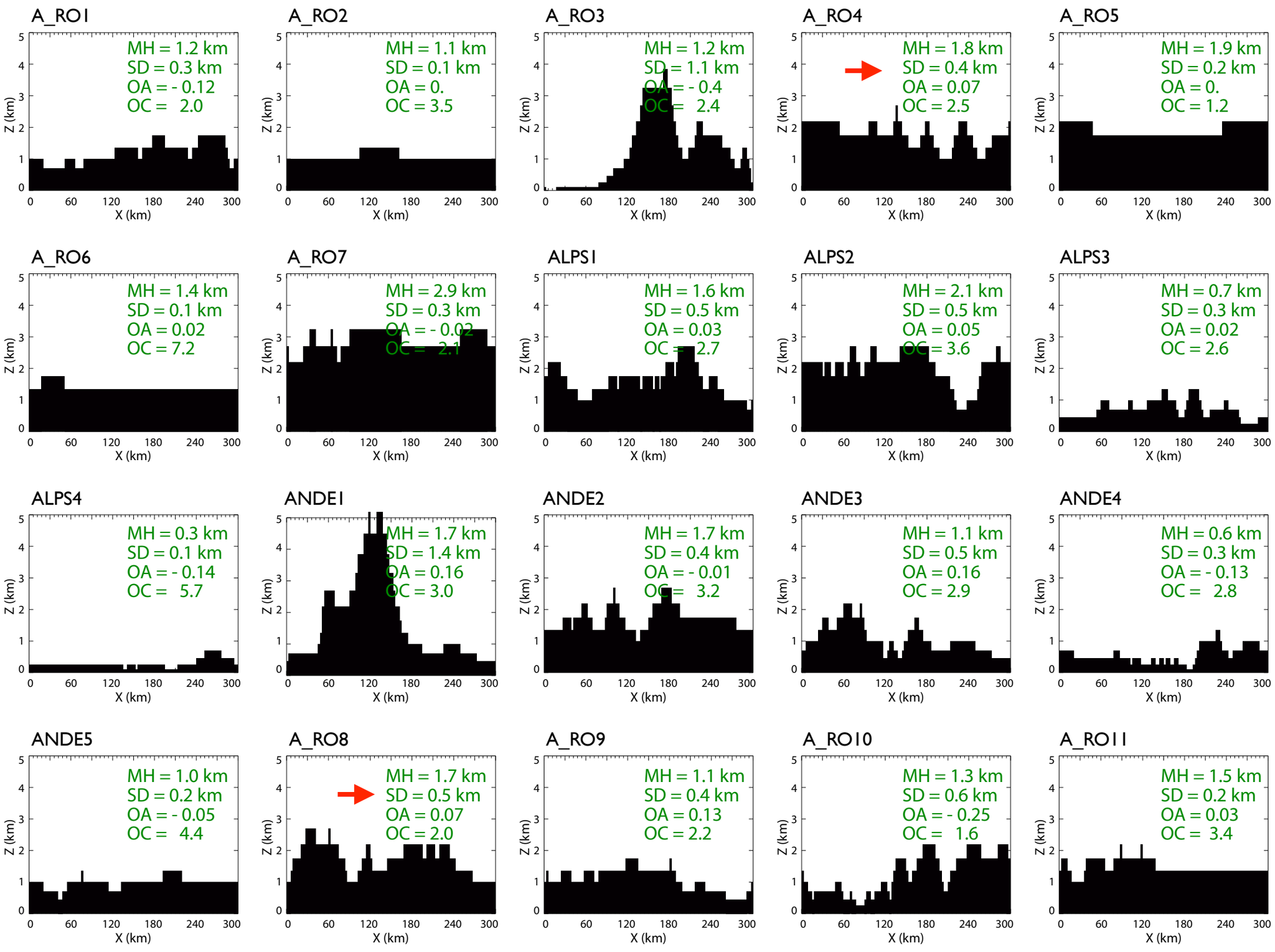






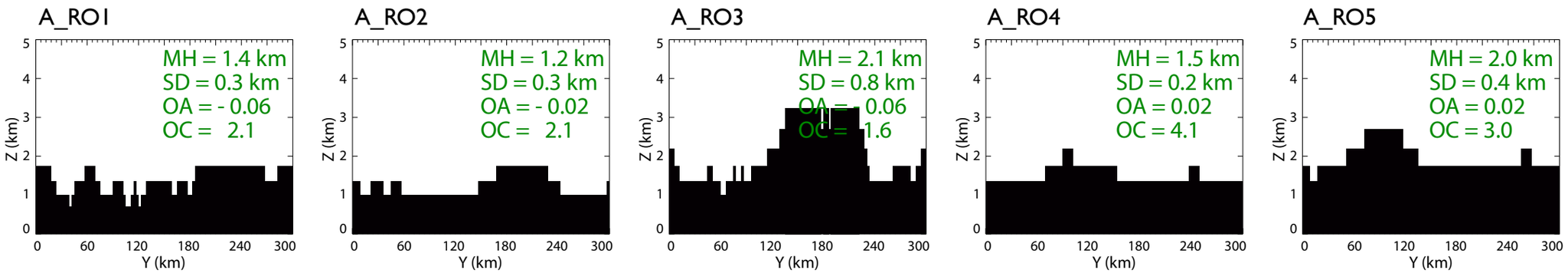
Surface Elevation Used in the Simulation of 2D MMF

X-Channel Run

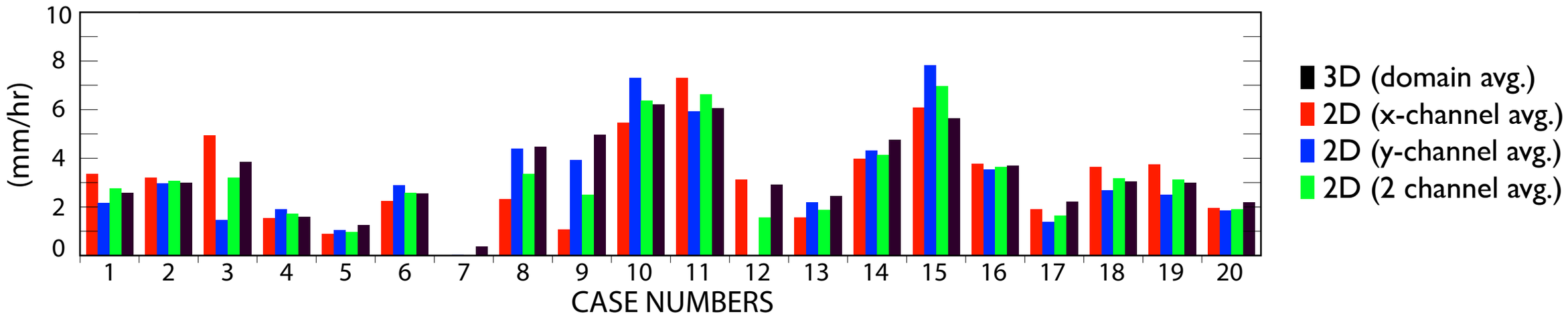


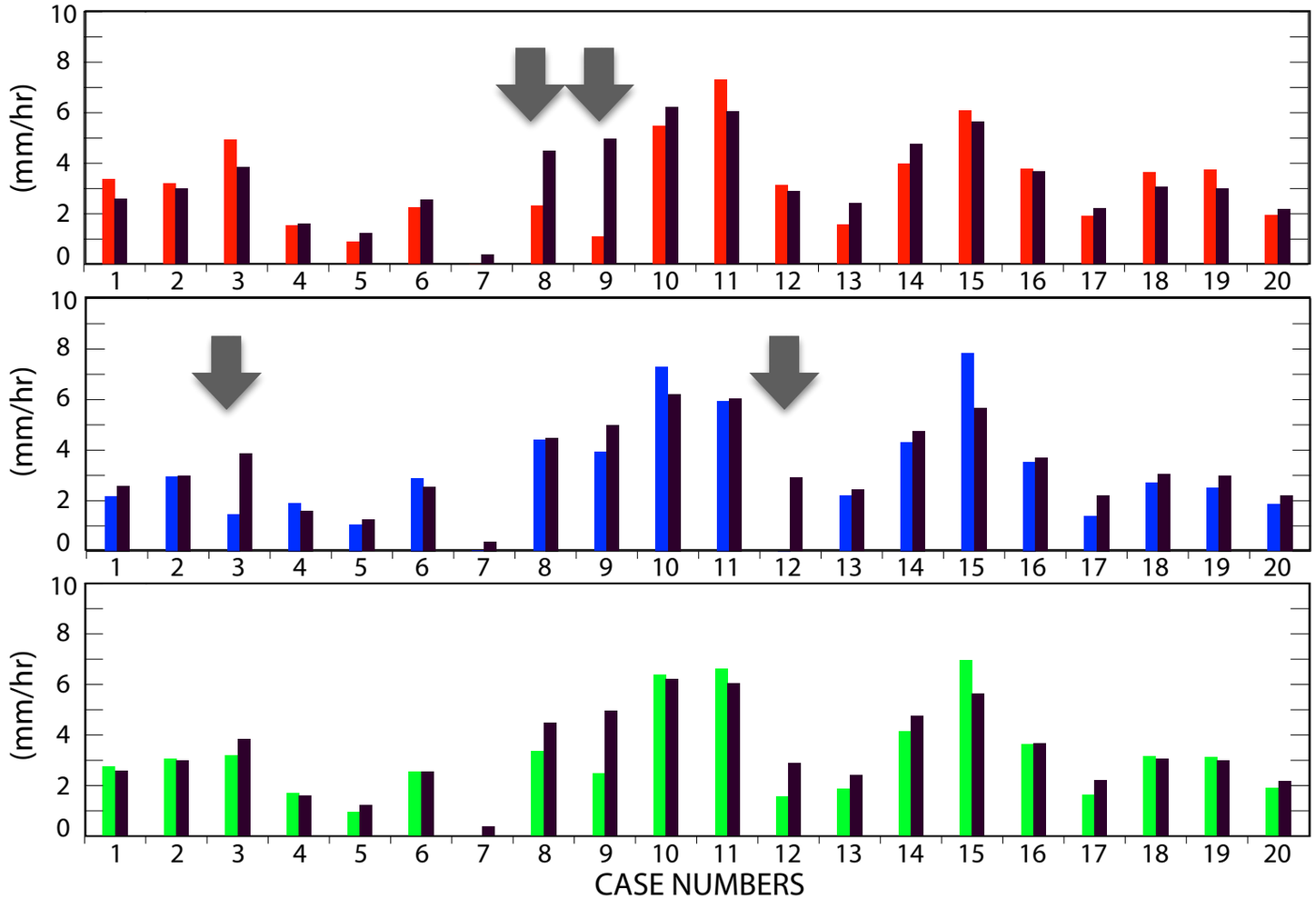
Surface Elevation Used in the Simulation of 2D MMF

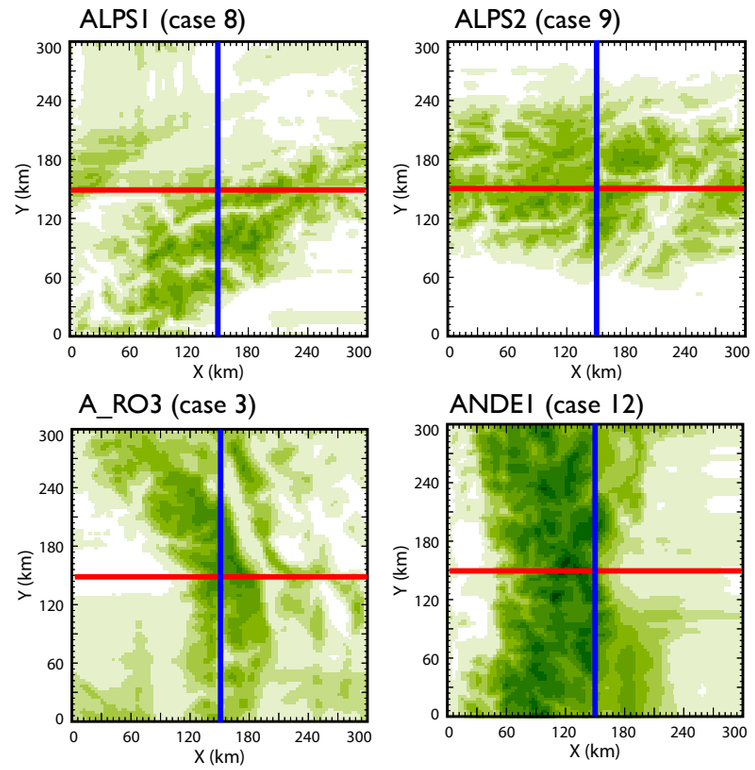
Y-Channel Run



Domain- and Time-averaged Surface Precipitation Rate







"Objective of the test is to find how well the statistics of orographic precipitation due to 3-D topography can be simulated with a 2-D representation of topography"

- The mean precipitation due to 3-D topography is fairly well simulated with a selected 2-D representation of topography in most test cases.
- The error due to the selection of a specific 2-D representation of topography can be reduced by the use of two perpendicular channels.

Next step is
to finalize the Q3D algorithm and code with topography.