Progress Report

Research Objective:
Development of a Q3D MMF

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Completed Task

The main algorithm of the Q3D MMF has been developed and successfully tested in a limited-area modeling framework.

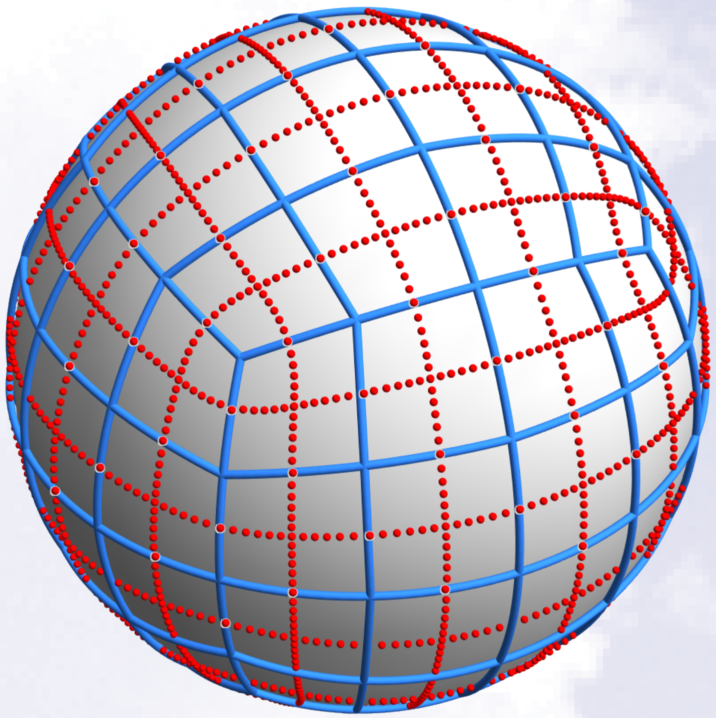
Jung, J.-H. and A. Arakawa, 2014: Modeling the moist-convective atmosphere with a Quasi-3-D Multiscale Modeling Framework (Q3D MMF). *J. Adv. Model. Earth Syst.* 6, 185-205, DOI: 10.1002/2013MS000295.

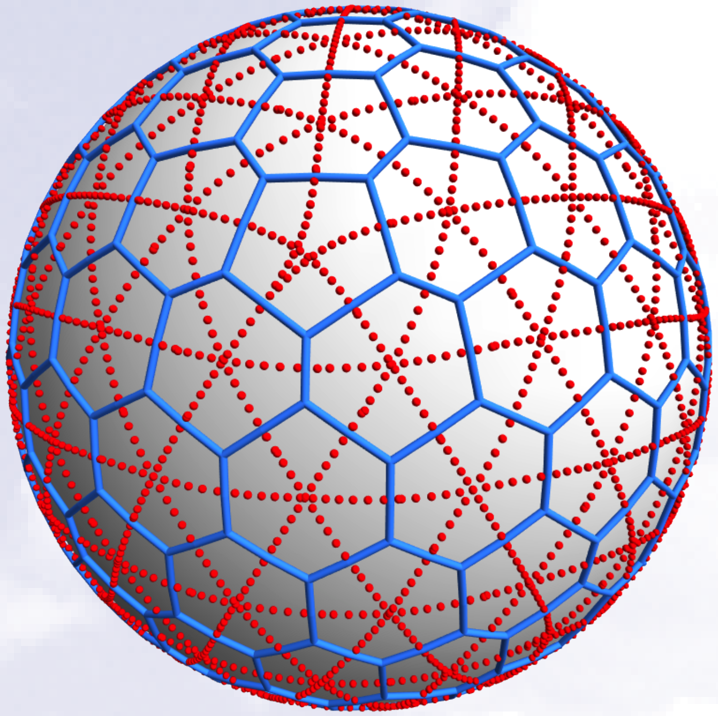
- The Q3D MMF can simulate the cooperative interaction between the synoptic and cloud scales very well as demonstrated by the successful simulation of the tropical cyclogenesis.

- The Q3D MMF can simulate the statistical properties such as time-averaged precipitation, surface fluxes, and (co)variances (e.g., the eddy transports) well.

Future Task

Construct and evaluate the global version of the Q3D MMF.





- Quadrilateral grid cells are similar to the configuration of the limited-area model.
- CRM channels can seamlessly circumvent the globe.
- CRM channels will be more isotropically distributed than on the cubed-sphere grid.

Ongoing Work

- **Test of the limited-area Q3D MMF with different model configuration**

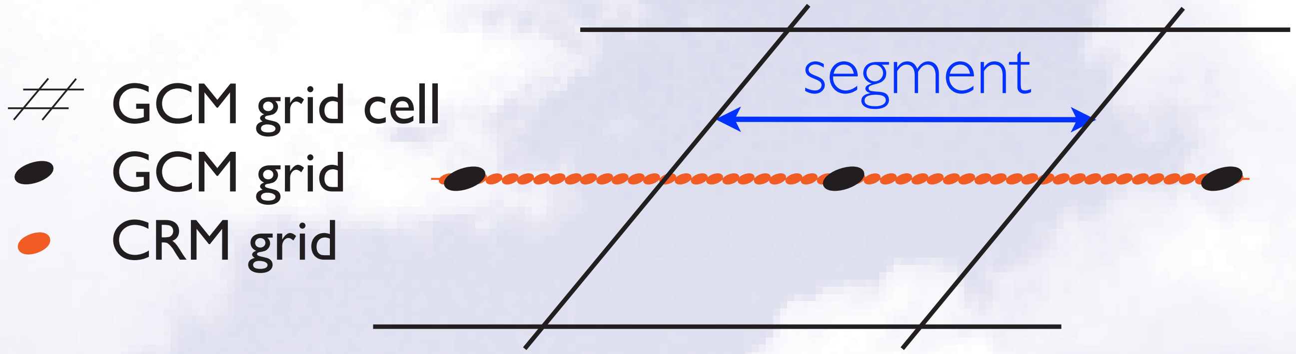
  Sensitivity to the choice of relaxation time scale

  Sensitivity to the GCM resolution change

- **Inclusion of surface topography**

Sensitivity to Relaxation Time scale

To guarantee the compatibility between the large-scale solutions of the GCM and CRM, the segment average of CRM value is relaxed to the GCM value.



The relaxation time scale can be determined by the time associated with horizontal advection that plays an important role in the development of the mesoscale organization.

$$\text{Horizontal advection timescale } (\tau) \sim \frac{d}{V}$$

d : GCM grid size

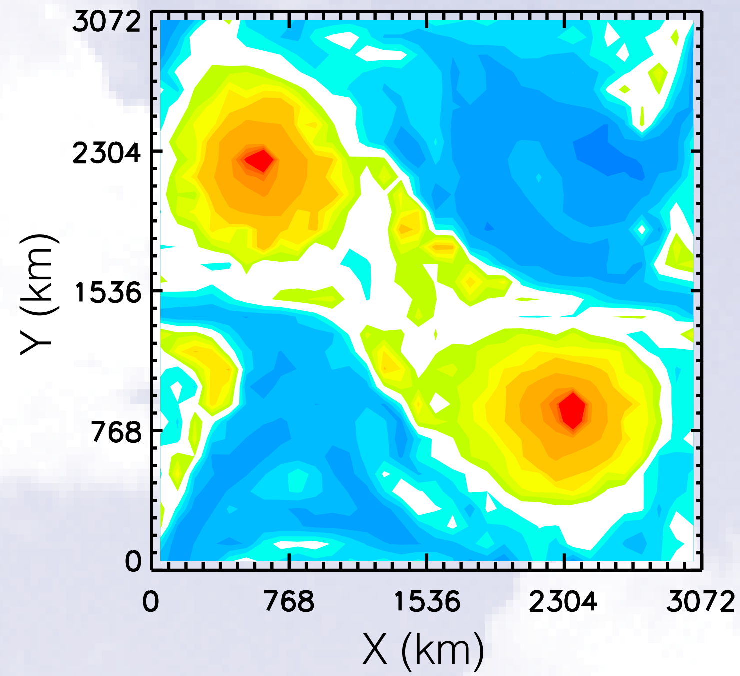
V : characteristic wind speed

Sensitivity to Relaxation Time scale (Continued)

SIMULATED VERTICAL COMPONENT OF VORTICITY

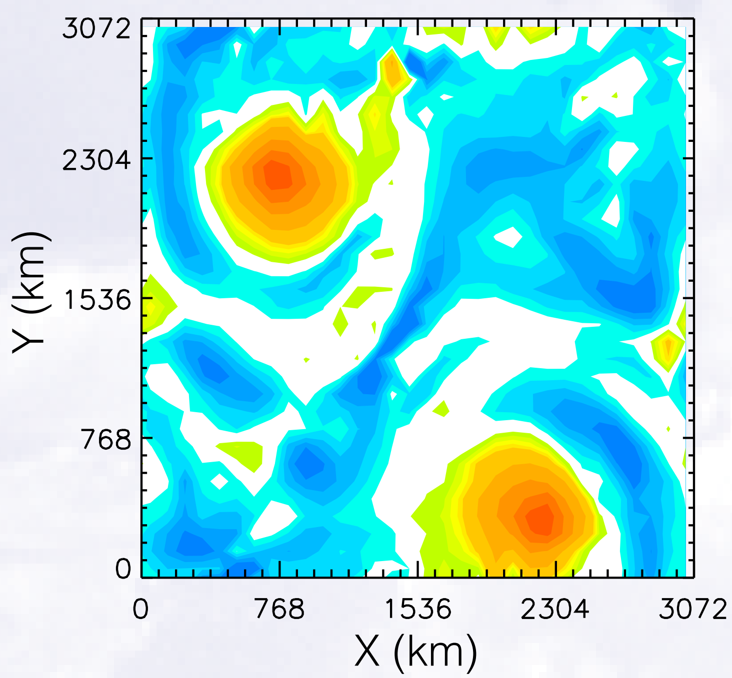
DAY 14
HEIGHT~3km
dx_{GCM} = 96km
dx_{CRM} = 3km

BM (3-D)

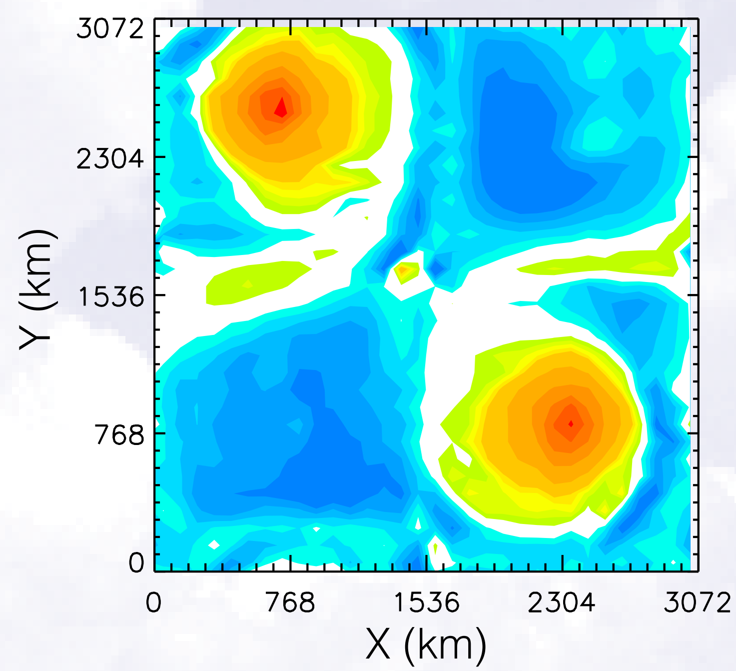


Q3D MMF

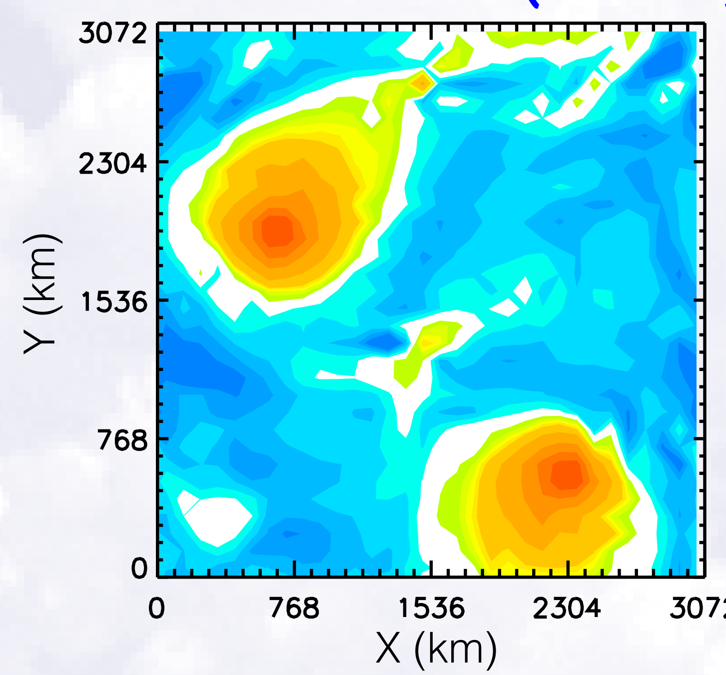
timescale=2hr

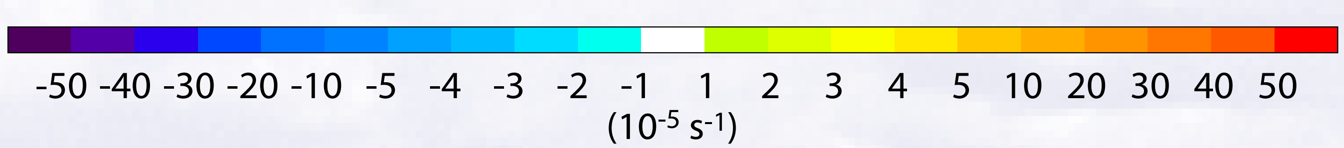


timescale= $\tau(t)$



timescale= $\tau(x,y,z,t)$

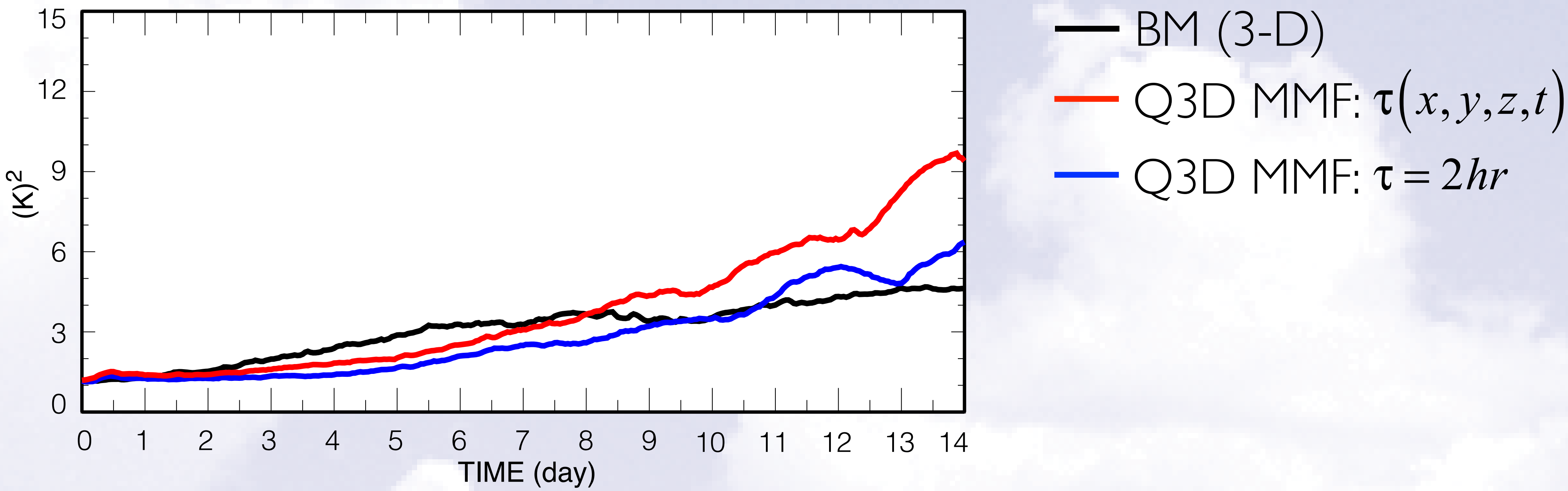




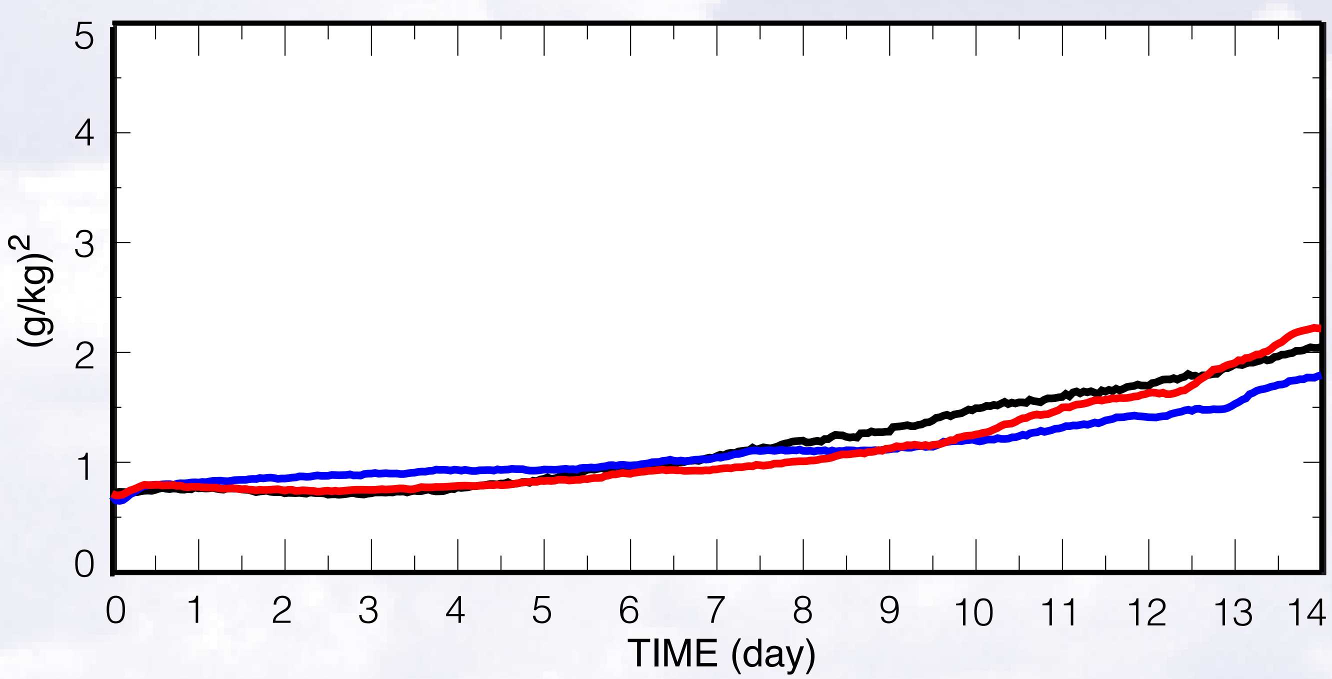
Sensitivity to Relaxation Time scale (Continued)

VARIANCES

Vertically Averaged Variance of θ



Vertically Averaged Variance of q_v



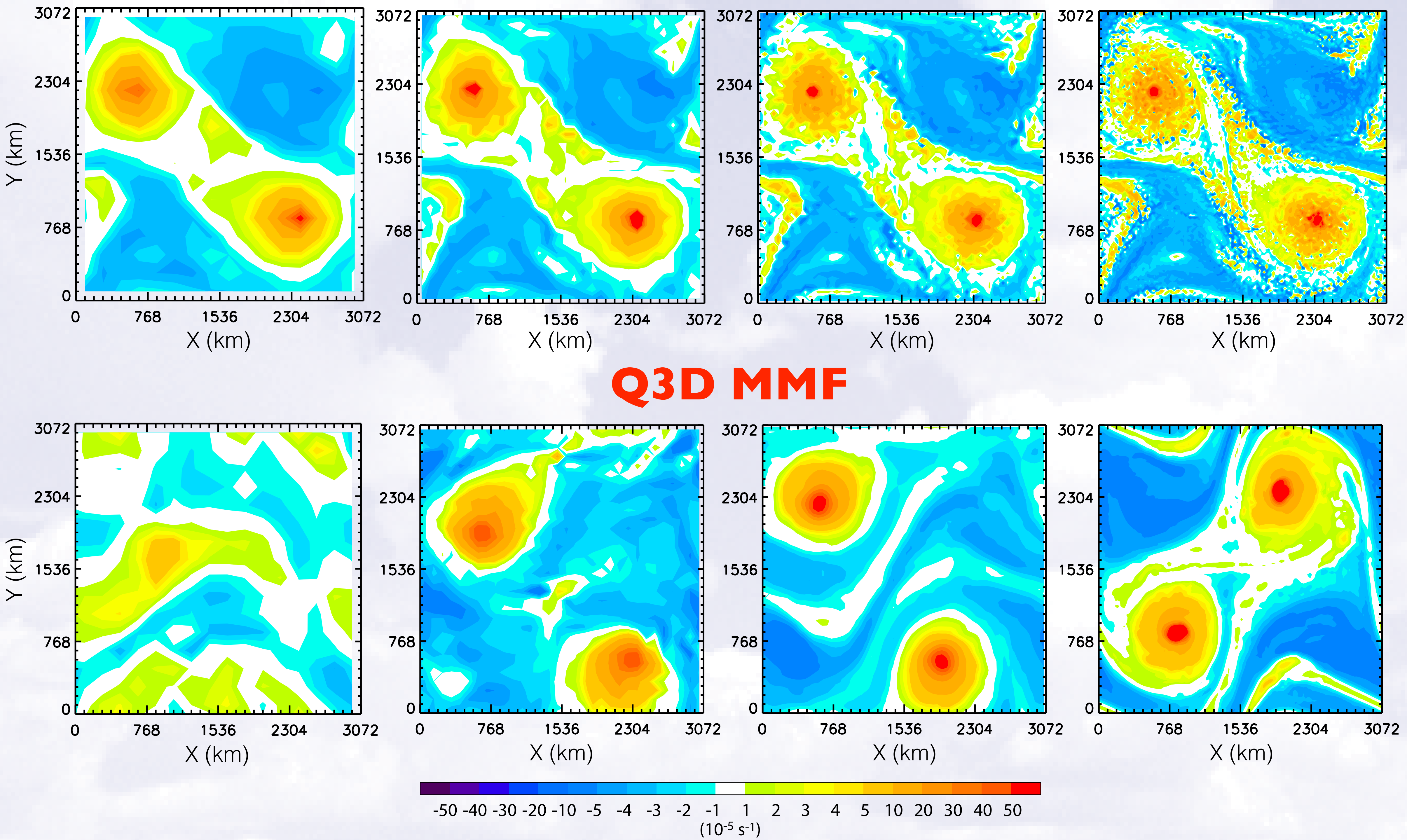
Simulations with Different Resolutions (Continued)

SIMULATED VERTICAL COMPONENT OF VORTICITY

(DAY 14, HEIGHT~3km)

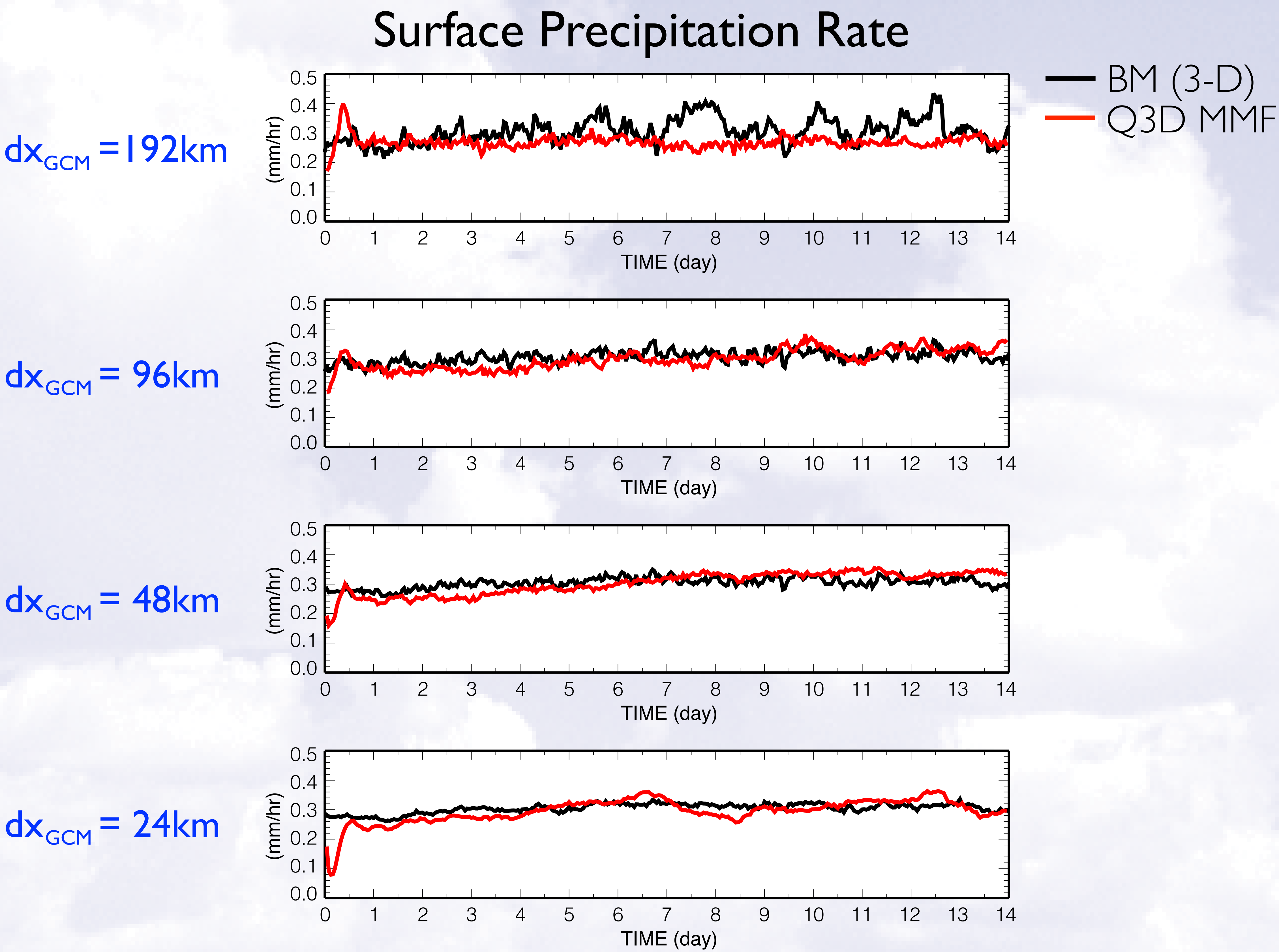
dx_{GCM} =192km dx_{GCM} = 96km dx_{GCM} = 48km dx_{GCM} = 24km

BM (3-D)



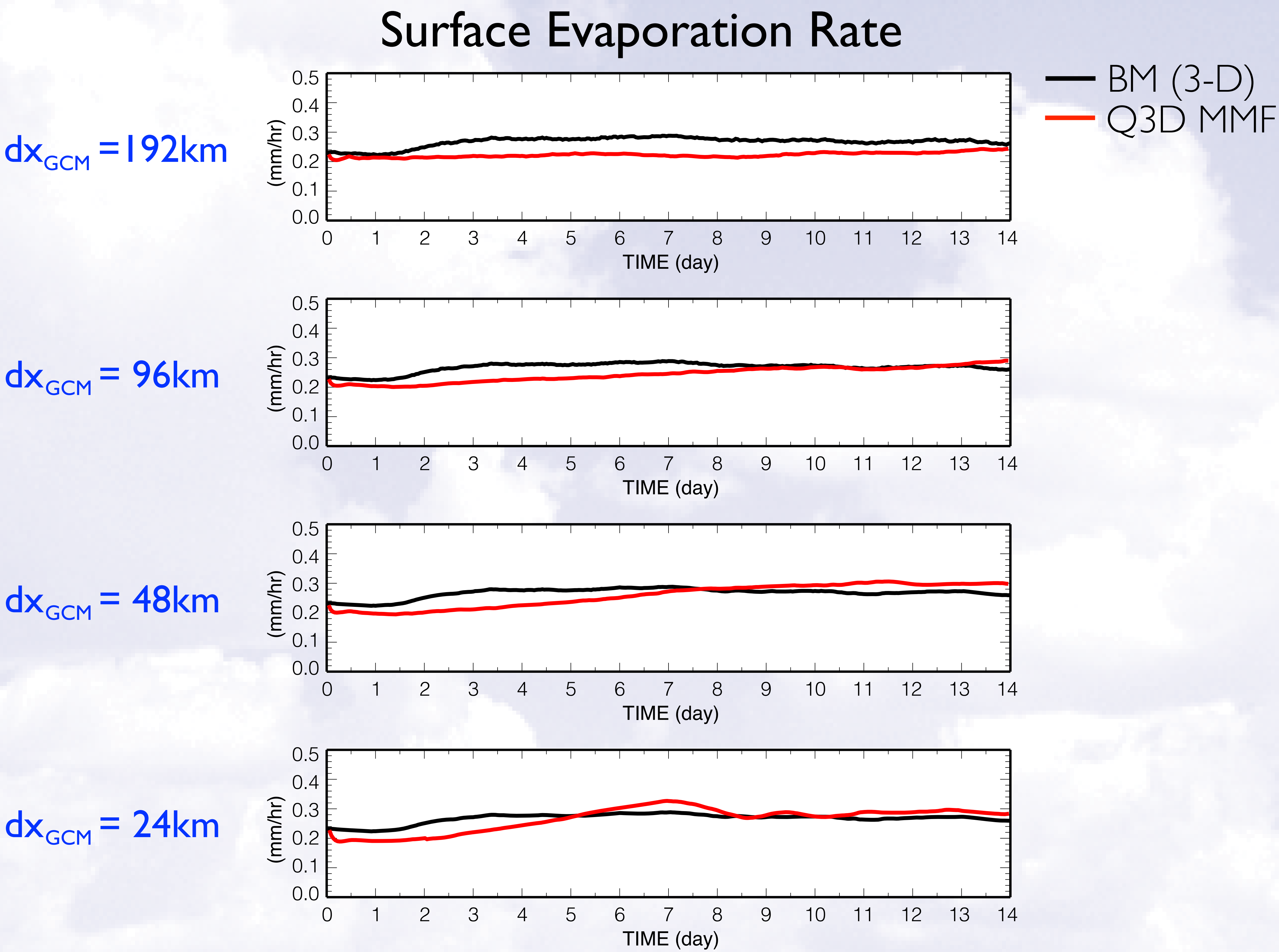
Simulations with Different Resolutions (Continued)

DOMAIN AVERAGES



Simulations with Different Resolutions (Continued)

DOMAIN AVERAGES



Simulations with Different Resolutions (Continued)

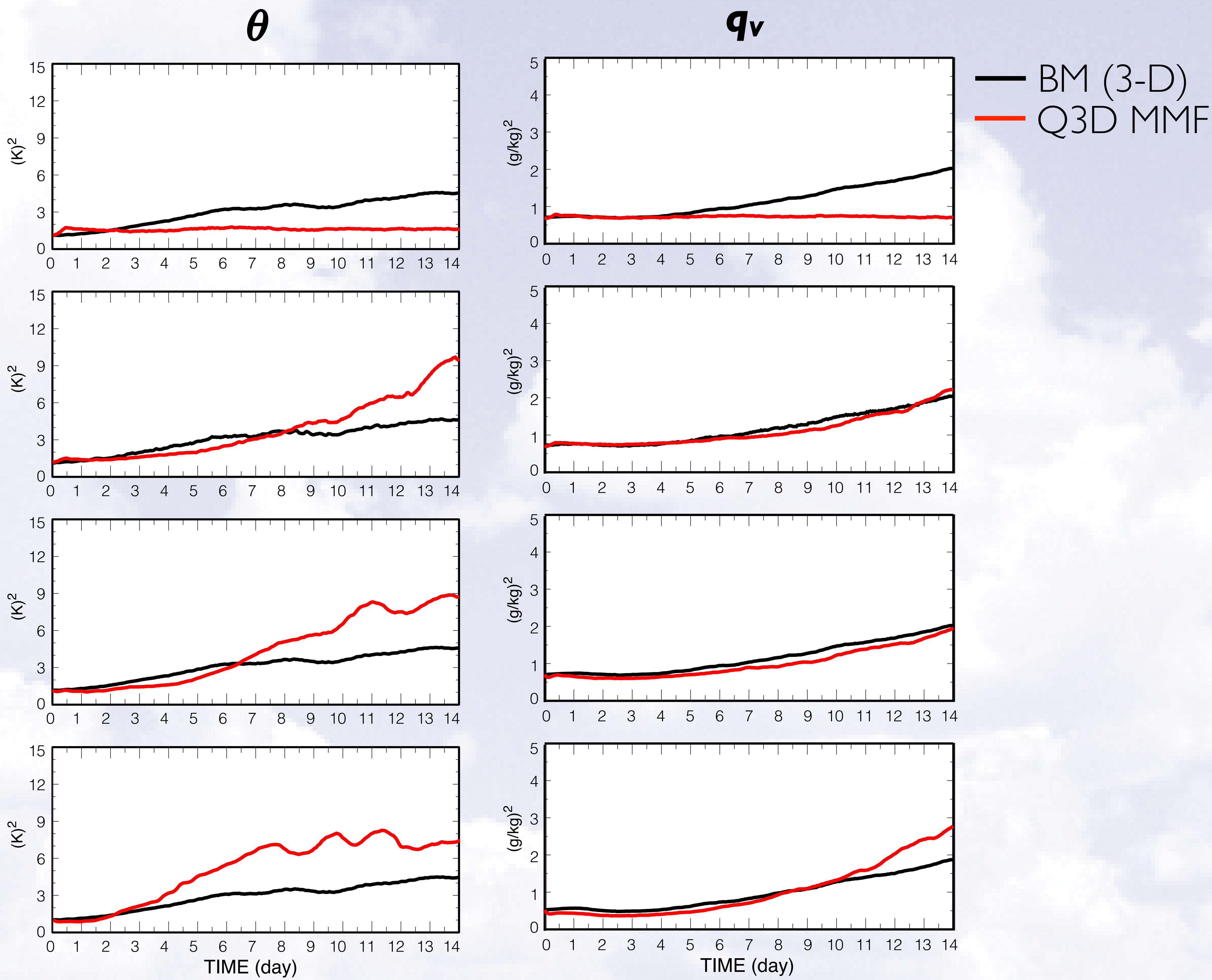
VARIANCES

dx_{GCM} =192km

dx_{GCM} = 96km

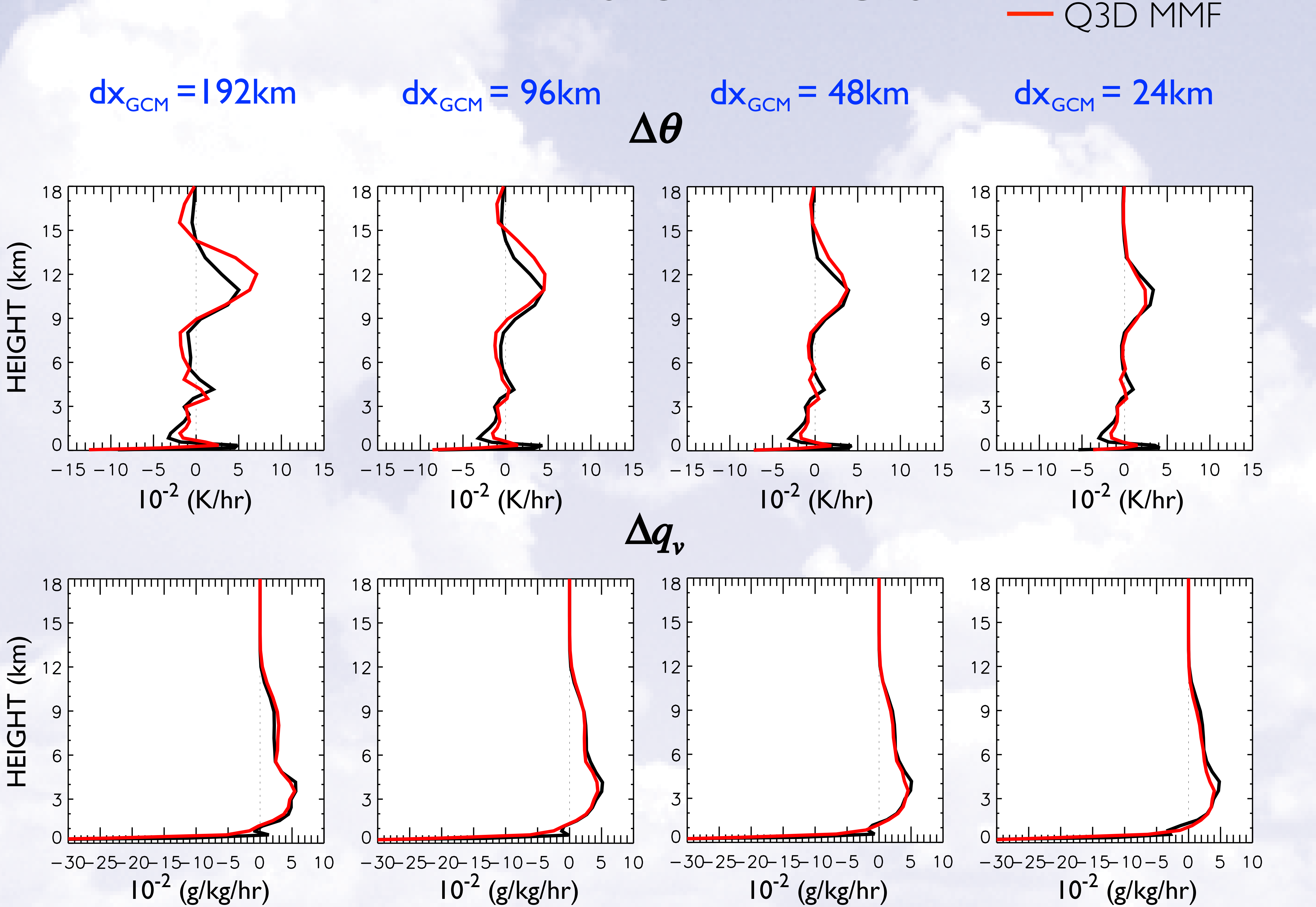
dx_{GCM} = 48km

dx_{GCM} = 24km



Simulations with Different Resolutions (Continued)

EDDY TRANSPORT EFFECTS



Inclusion of Surface Topography

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

VVM Results: Idealized 2-D Mountain Wave

Block representation of a bell-shaped mountain, Na/U=1

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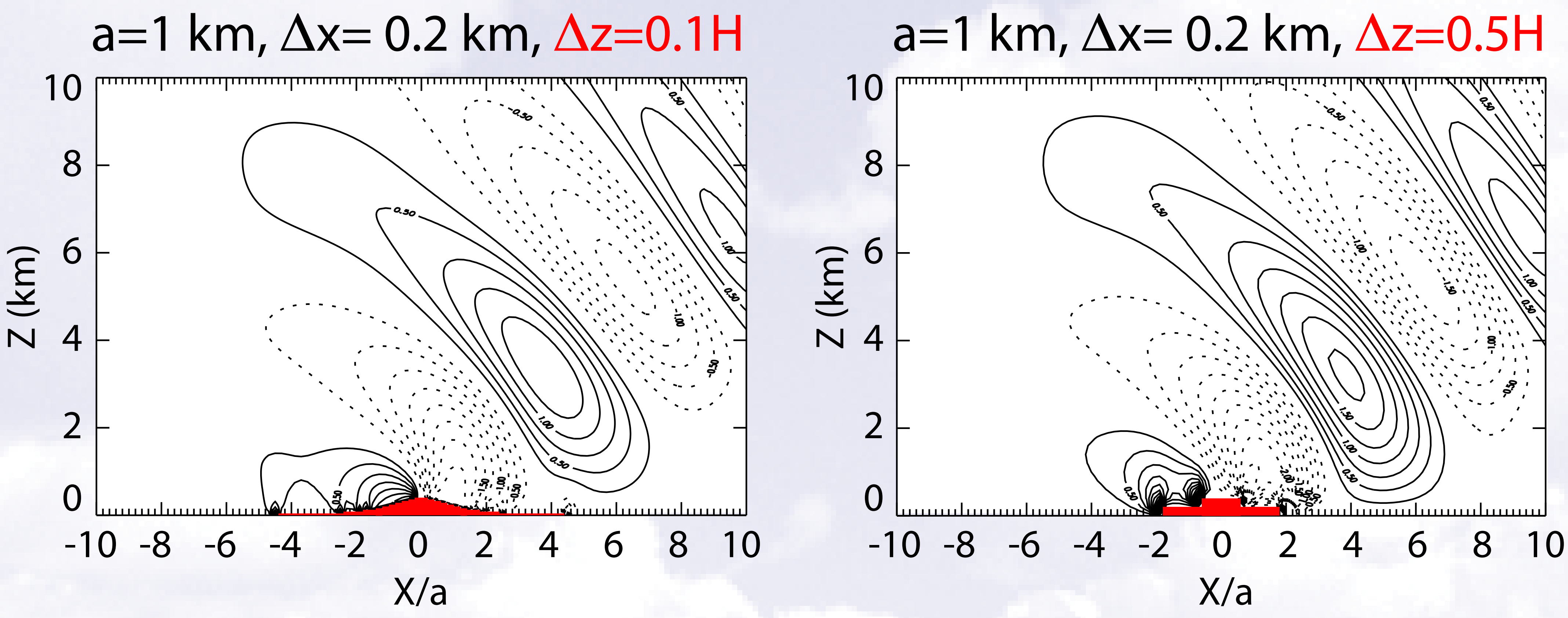
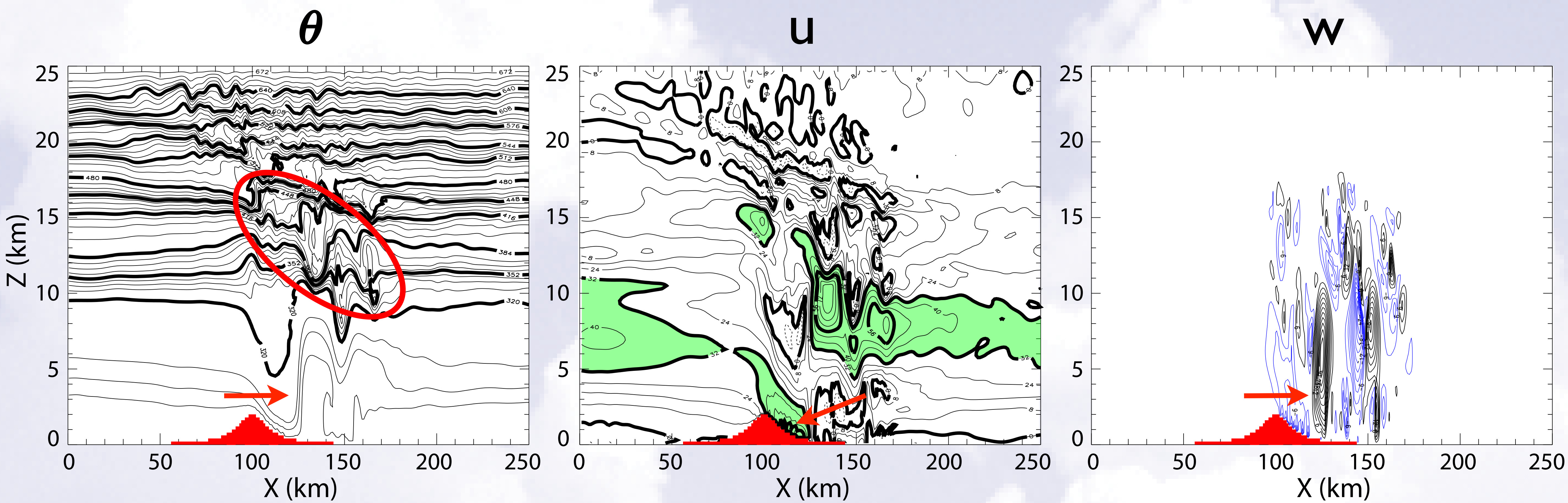


Nonhydrostatic gravity mountain waves are well simulated.

Inclusion of Surface Topography (Continued)

VVM Results: Boulder Windstorm Case (2-D)

Experiment setup follows Doyle et al. (2000)



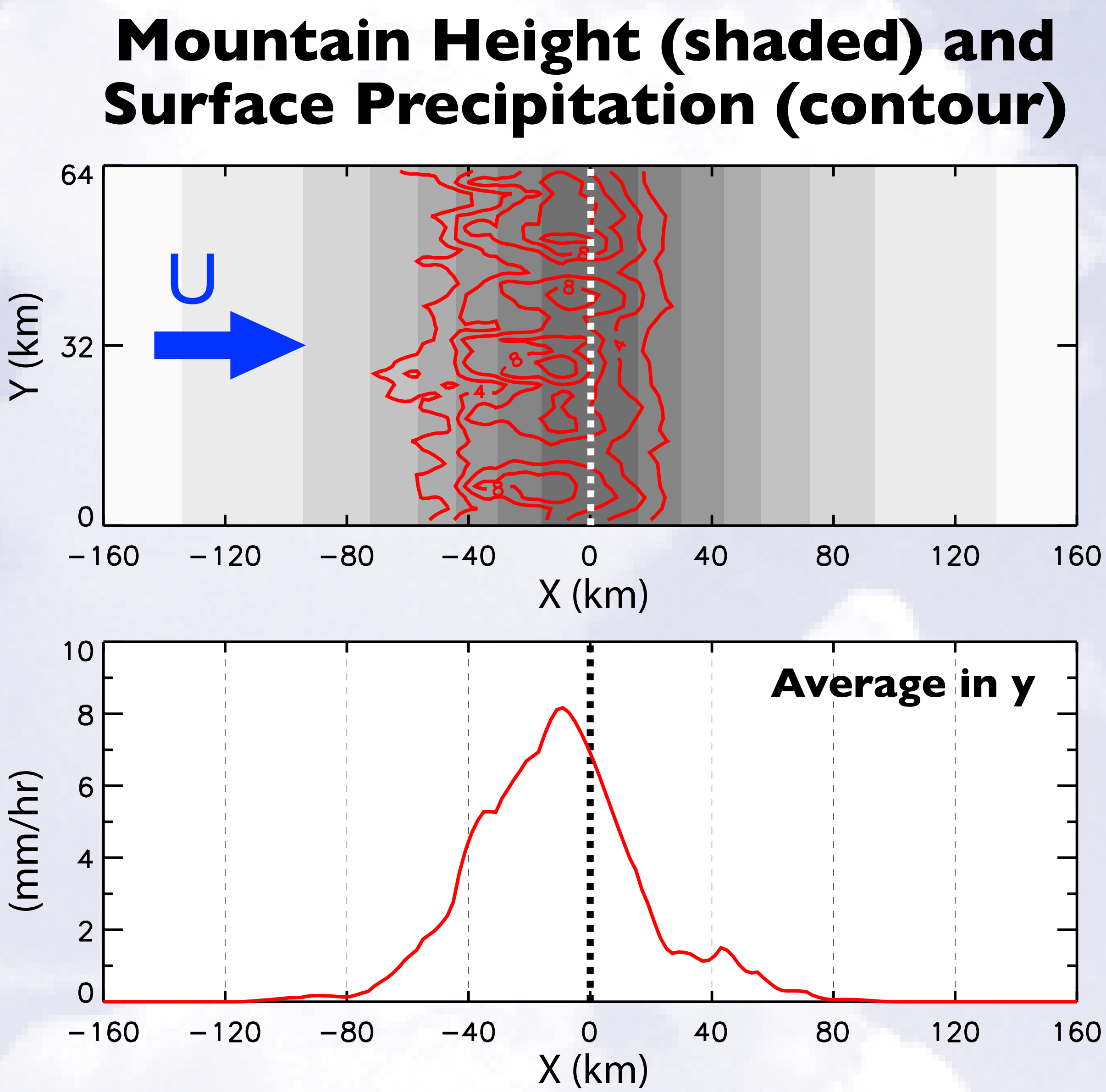
Upper level wave breaking and hydraulic jump at downstream region

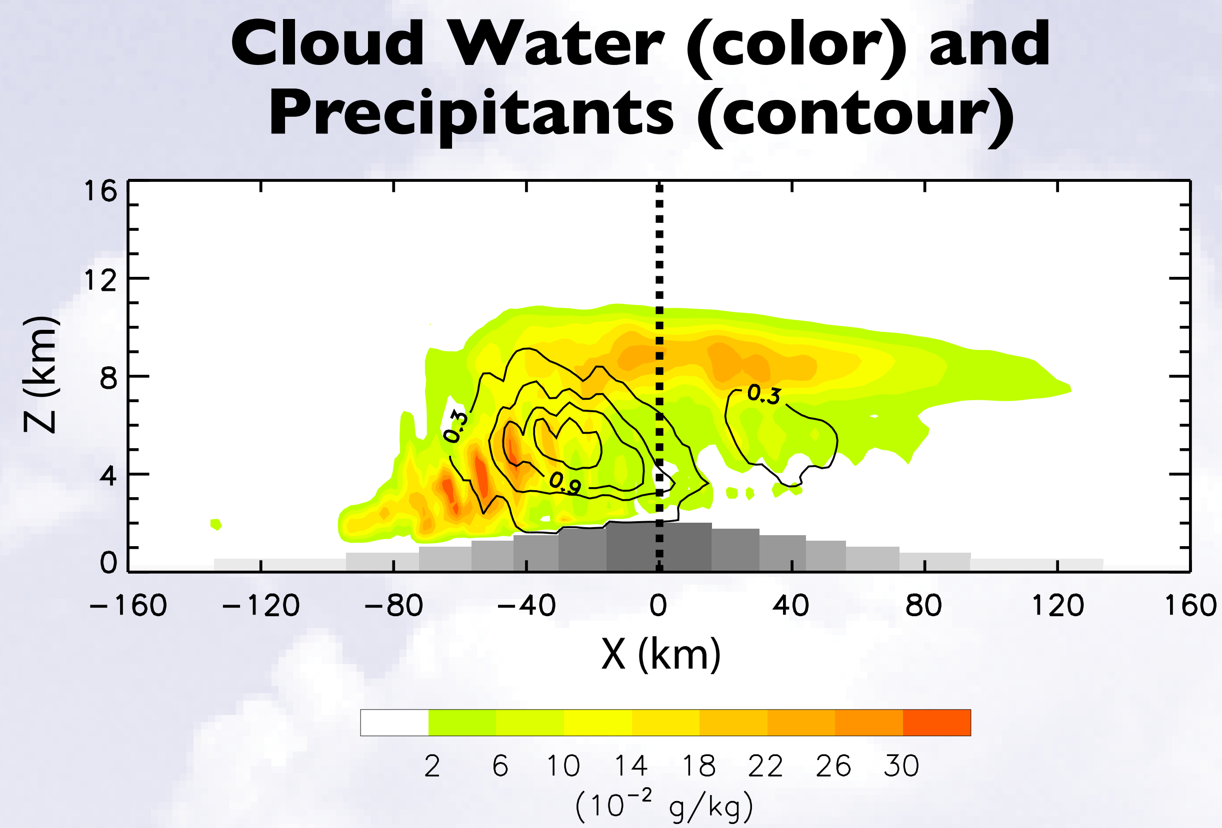
Downslope horizontal wind exceeds 64 m/s

Strong vertical velocity in the jump region

Inclusion of Surface Topography (Continued)

VVM Results: Orographic Precipitation over a Ridge (3-D)





Overall precipitation falls over the windward slope and the mountain crest.

Inclusion of Surface Topography to the Q3D MMF

- We expect that the simulation of orographic precipitation will be improved with the Q3D MMF because the subgrid-scale inhomogeneity in topography and the corresponding lifting can be explicitly resolved at least along the CRM channels.

Question:

How well can the use of two perpendicular channel domains simulate the statistics of orographic precipitation due to 3-D topography?