Super-parameterization in a mesoscale model

(and its potential links to troposphere-stratosphere coupling)

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Cloud-Resolving Convection Parameterization (CRCP)

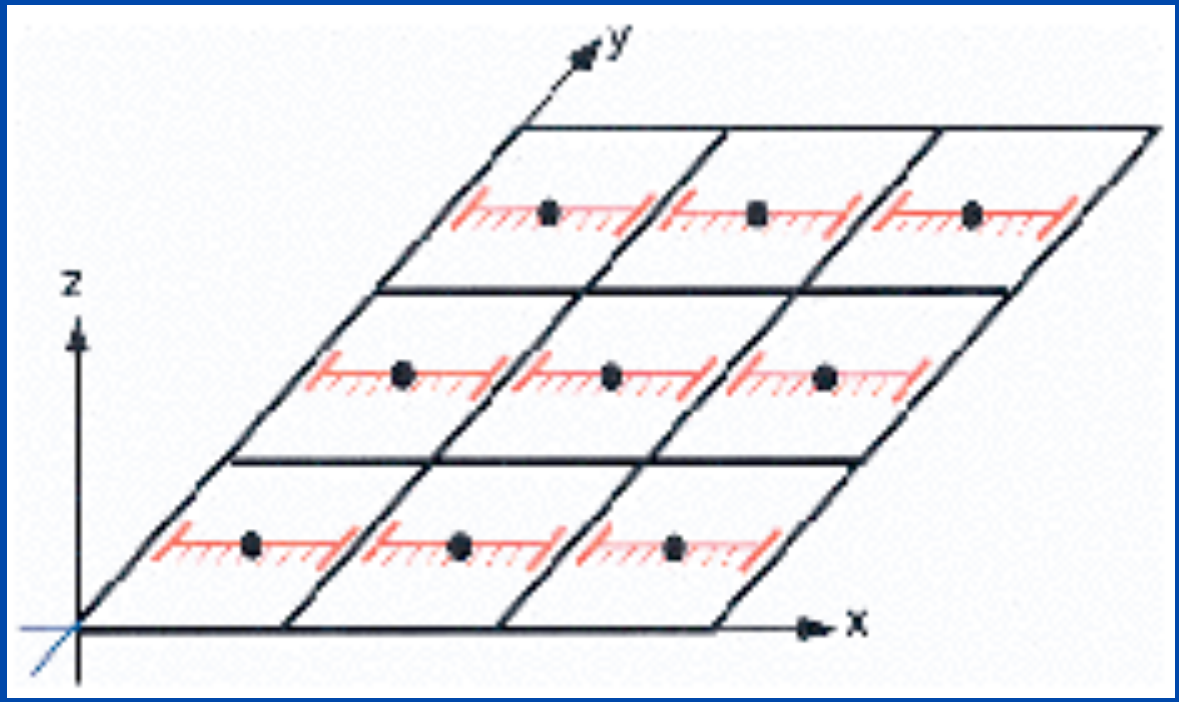
Super-parameterization (SP)

Multi-scale modeling framework (MMF)

Grabowski and Smolarkiewicz, Physica D 1999
Grabowski, JAS 2001
Khairoutdinov and Randall, JGR 2001

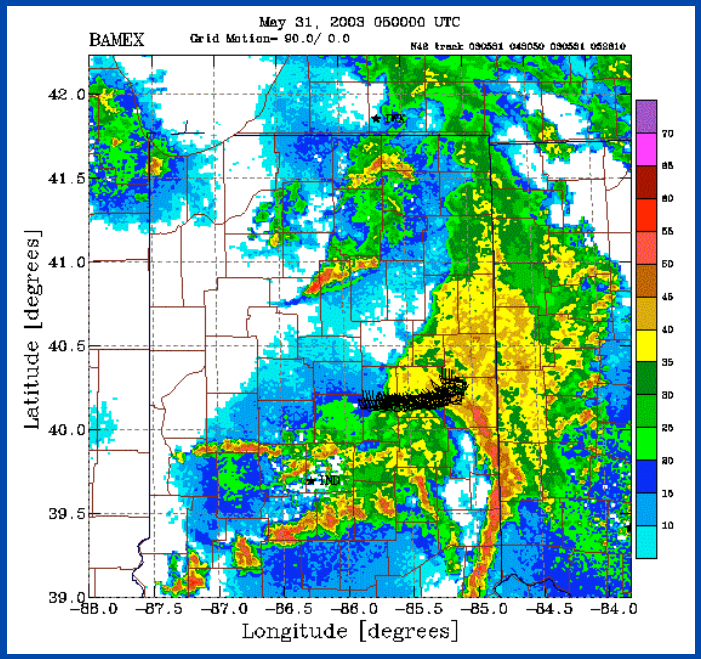
The idea is to represent subgrid scales of the 3D large-scale model (horizontal resolution of 100s km) by embedding periodic-domain 2D cloud-resolving model (CRM; horizontal resolution around 1 km) in each column of the large-scale model

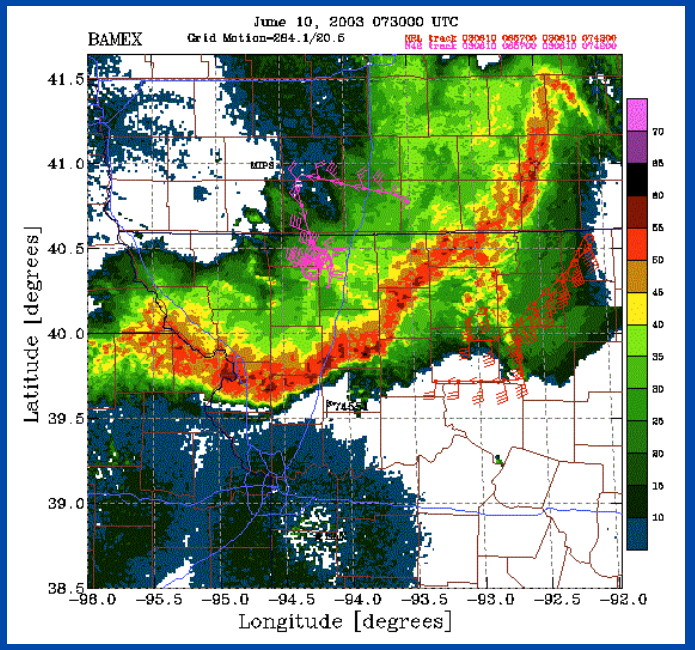
Original CRCP proposal

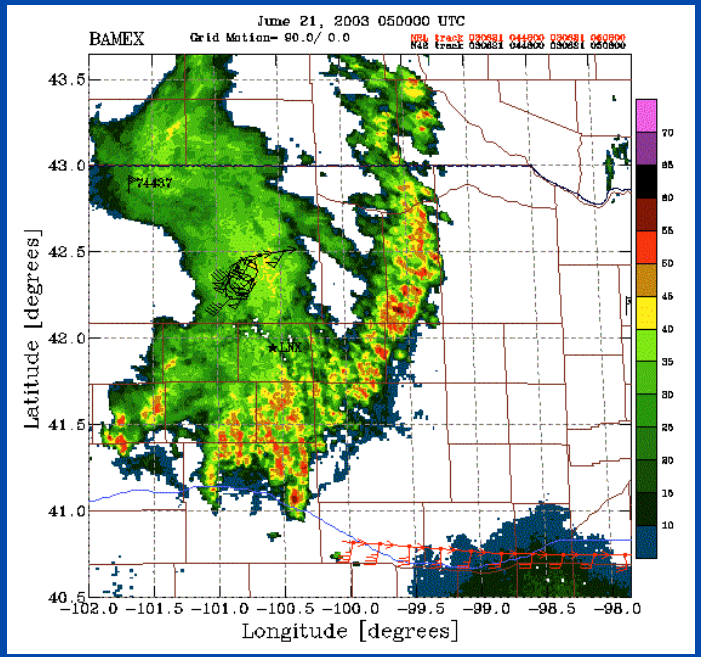


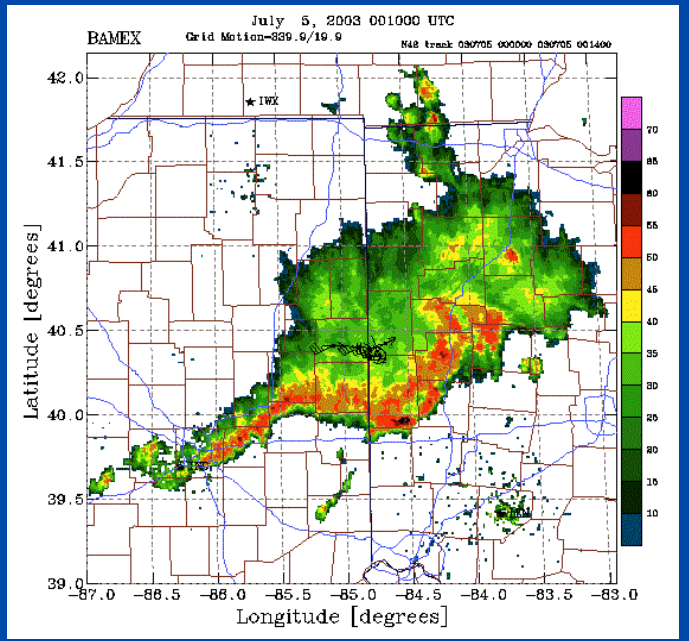
Can the super-parameterization approach be used in mesoscale models (i.e., model with horizontal grid spacings in the range of 10-50 km) to improve representation of organized convection?

Mesoscale Convective Systems – examples from BAMEX (Central US, May-July 2003)







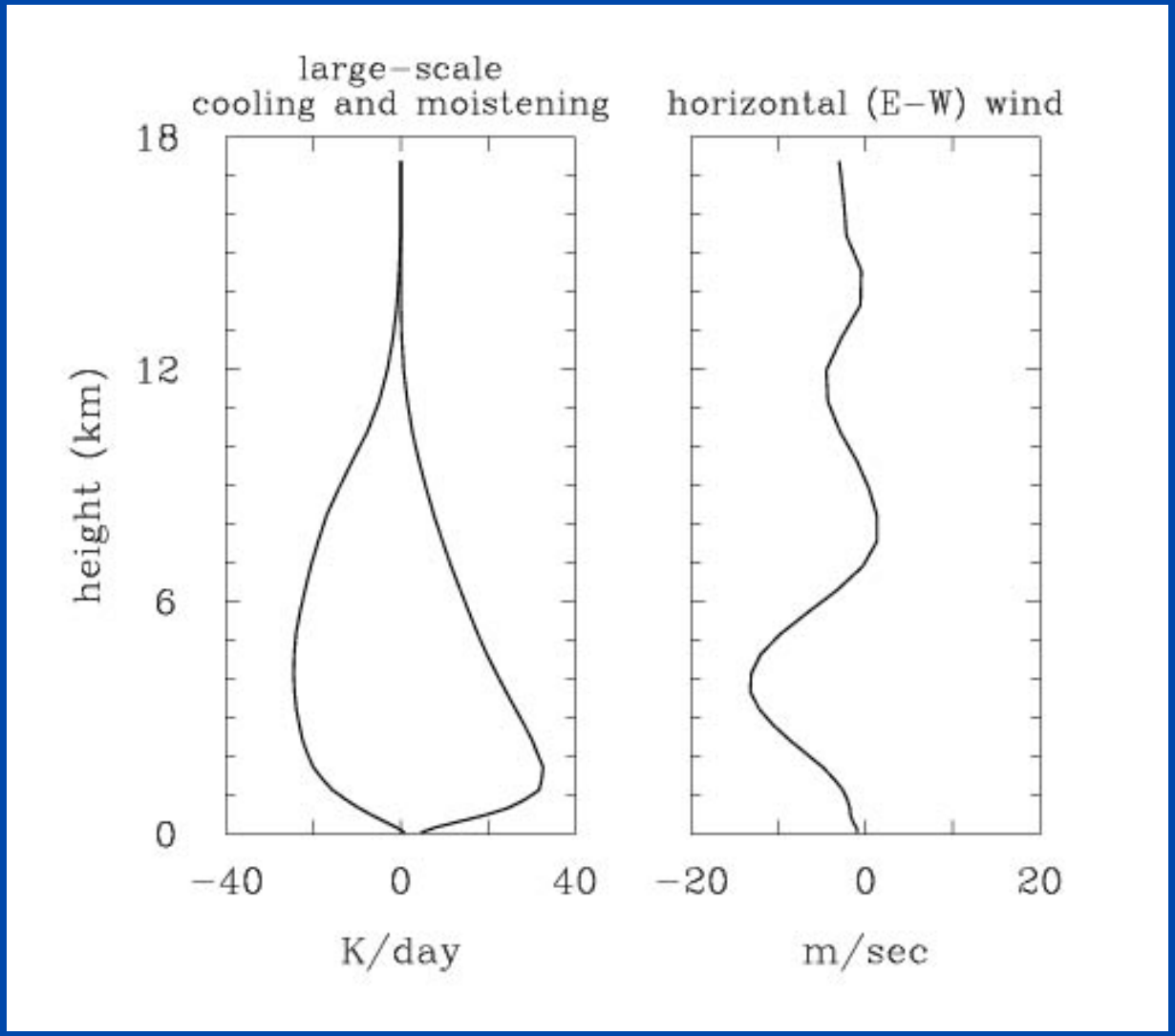


Can the super-parameterization approach be used in a mesoscale model (i.e., model with horizontal grid spacing in the range of 10-50 km; e.g., in a regional climate model)?

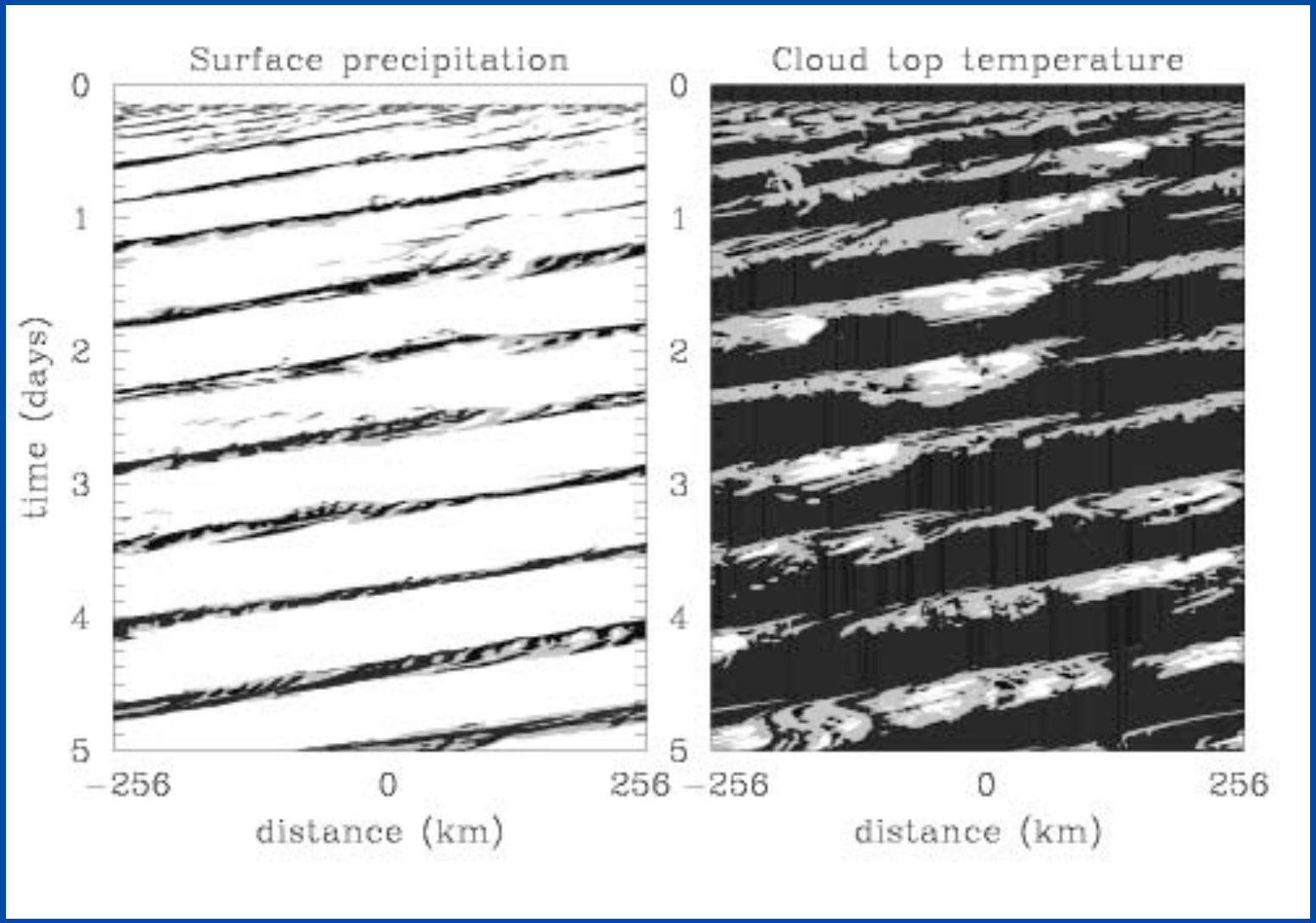
Compare idealized simulations using cloud-resolving model (CRM) and super-parameterization (SP)

Some results are in Grabowski MWR 2006 (in press; comment to Jung and Arakawa MWR 2005)

Simulations of organized convection (a squall line) in the mean GATE environment (Jung and Arakawa MWR 2005)



2D cloud-resolving simulation (benchmark): Δx=2km



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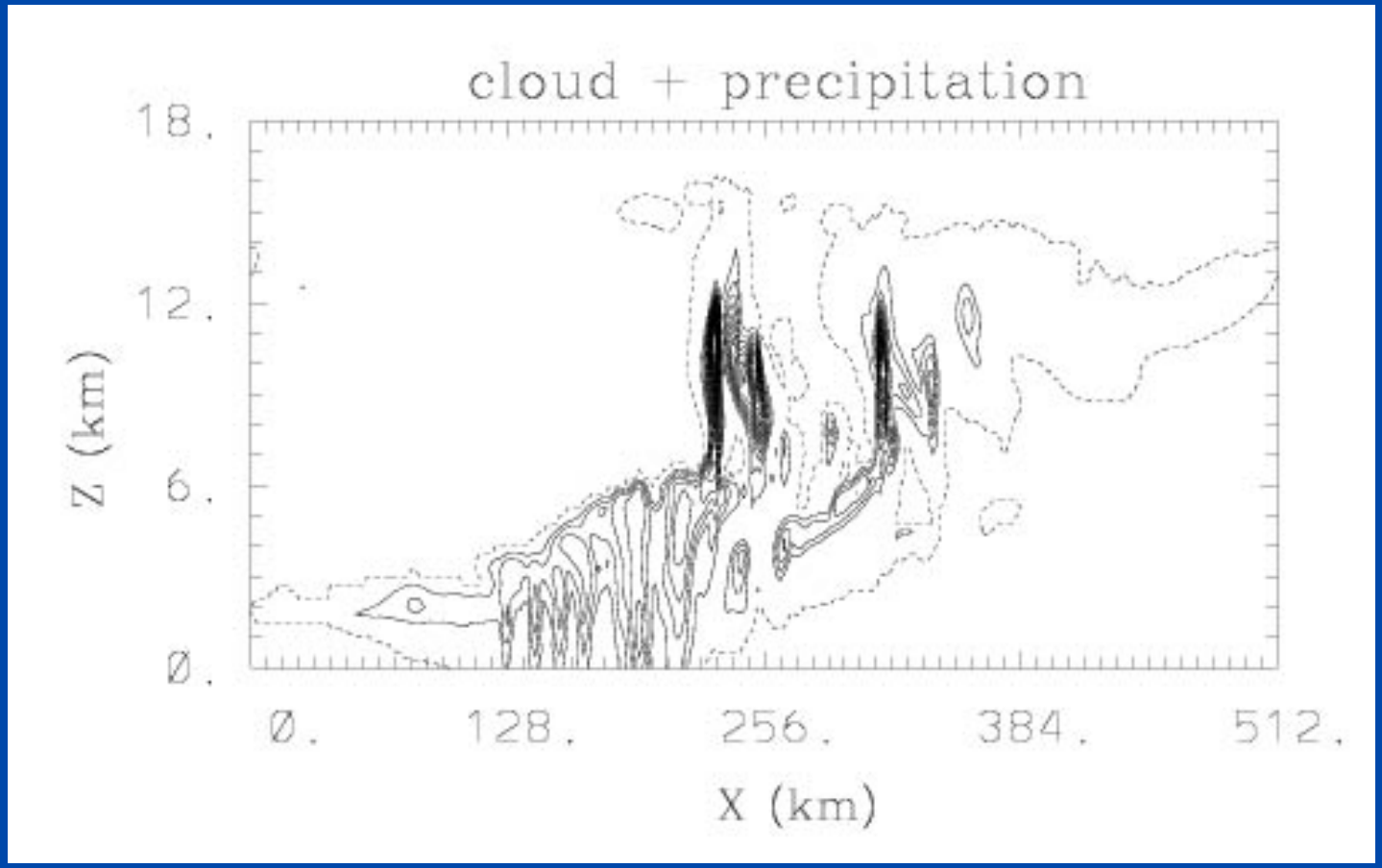
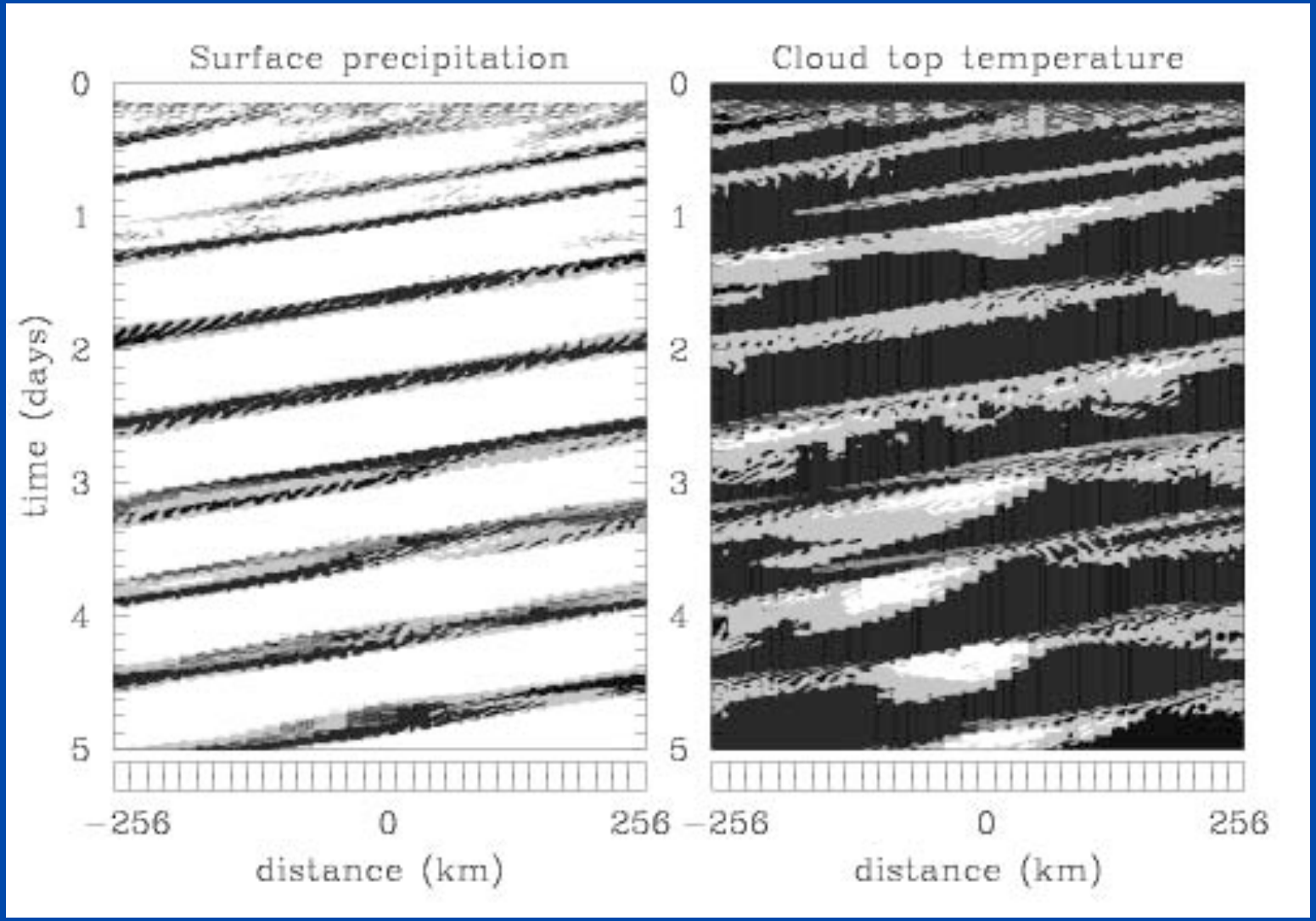


SP simulation: 32 columns with 16-km periodic small-scale models



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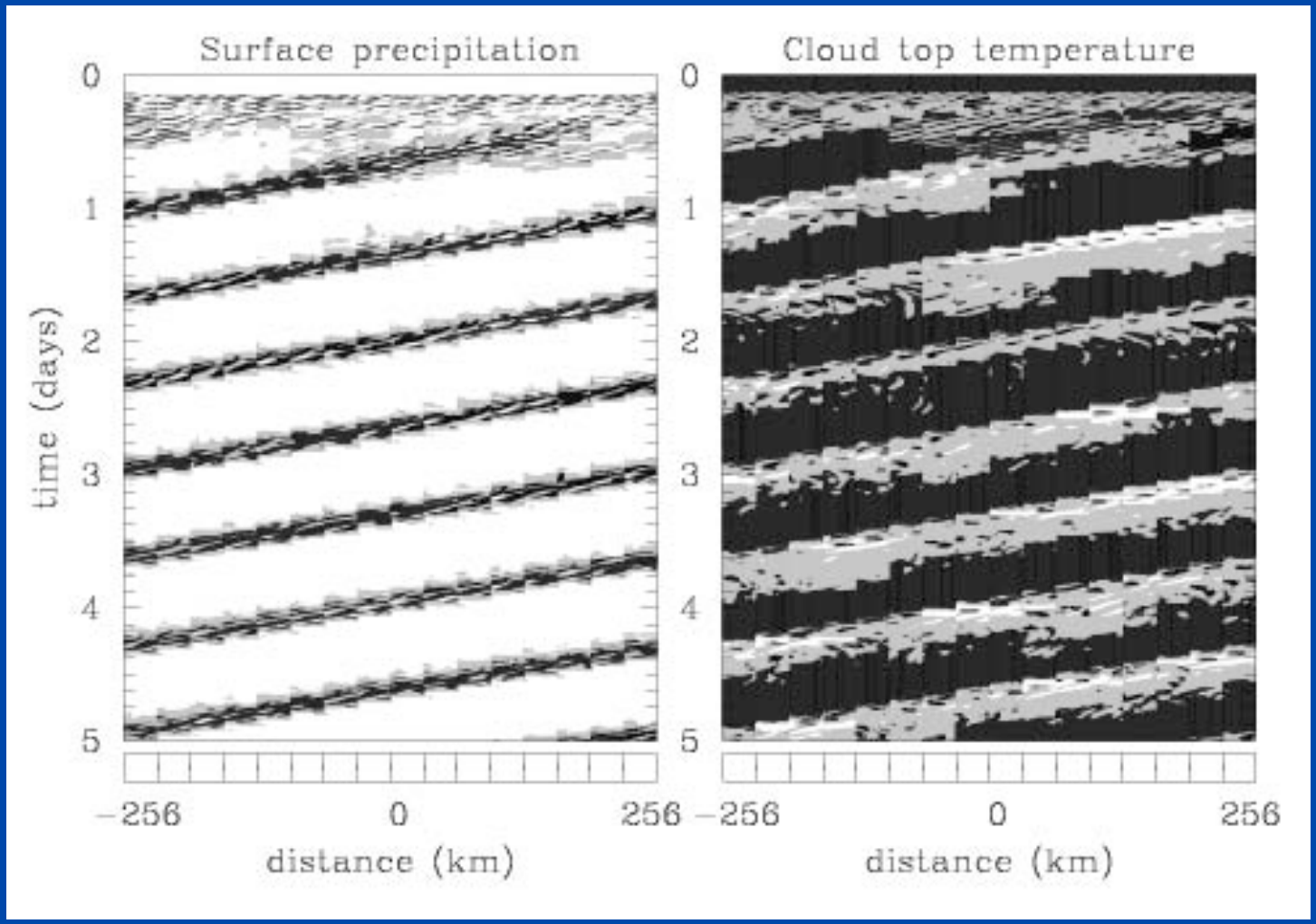
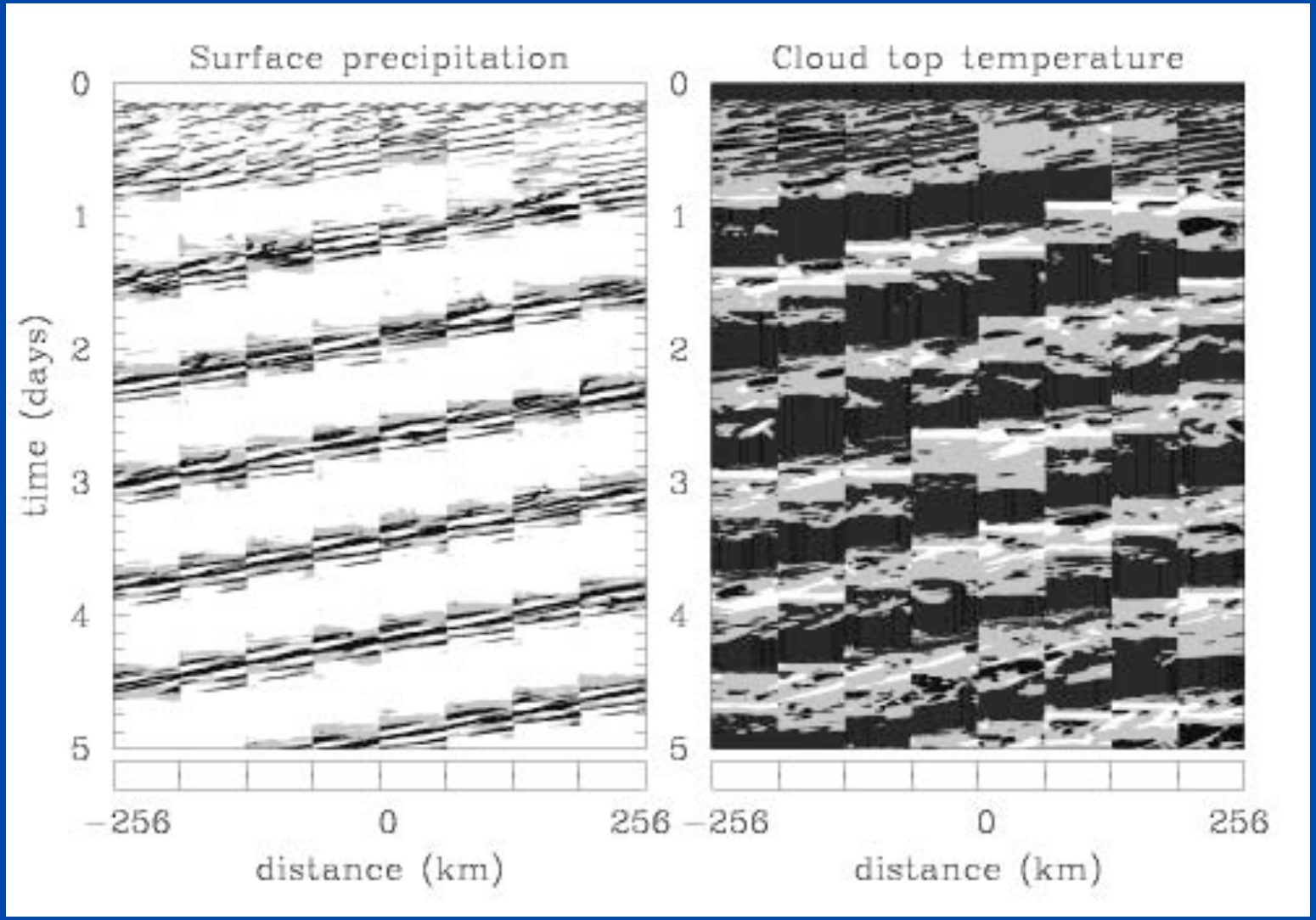


SP simulation: 8 columns with 64-km periodic small-scale models



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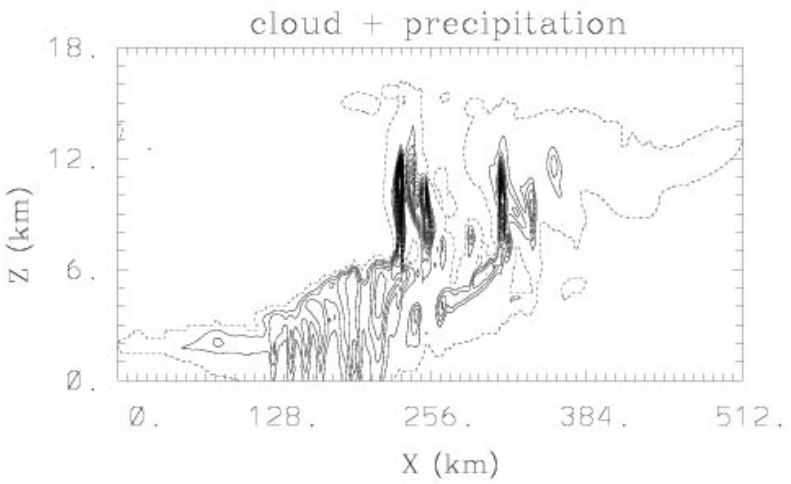
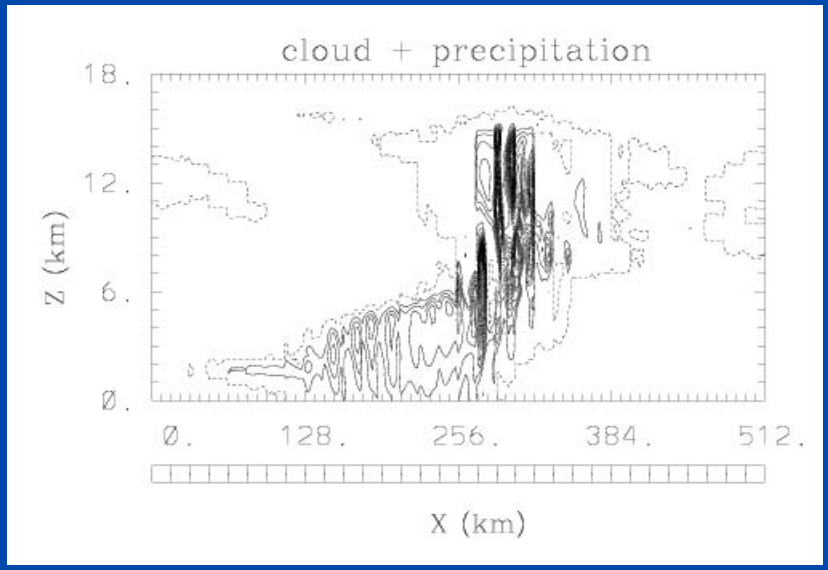
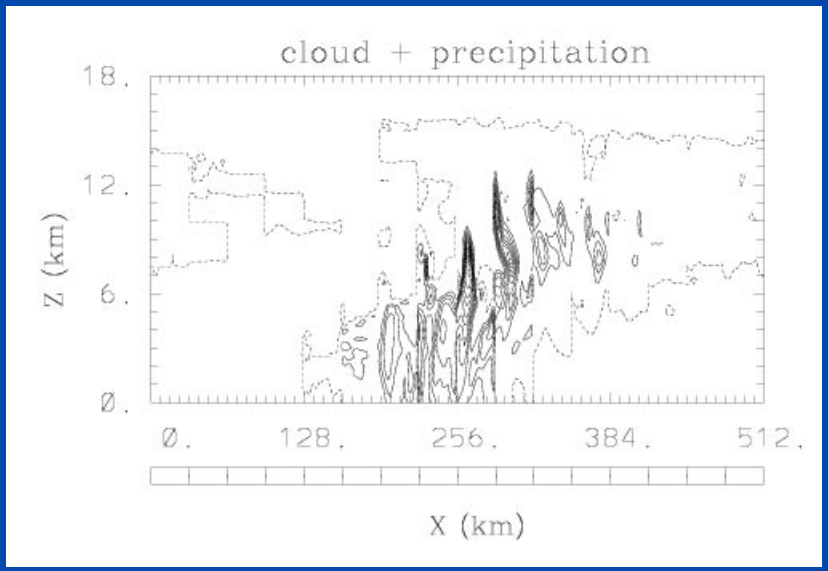


32 columns with 16-km periodic small-scale models



16 columns with 32-km periodic small-scale models



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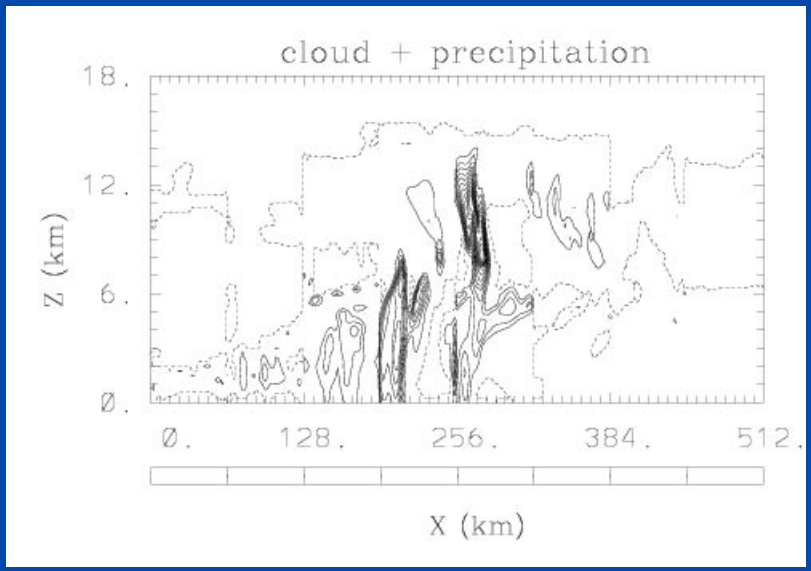
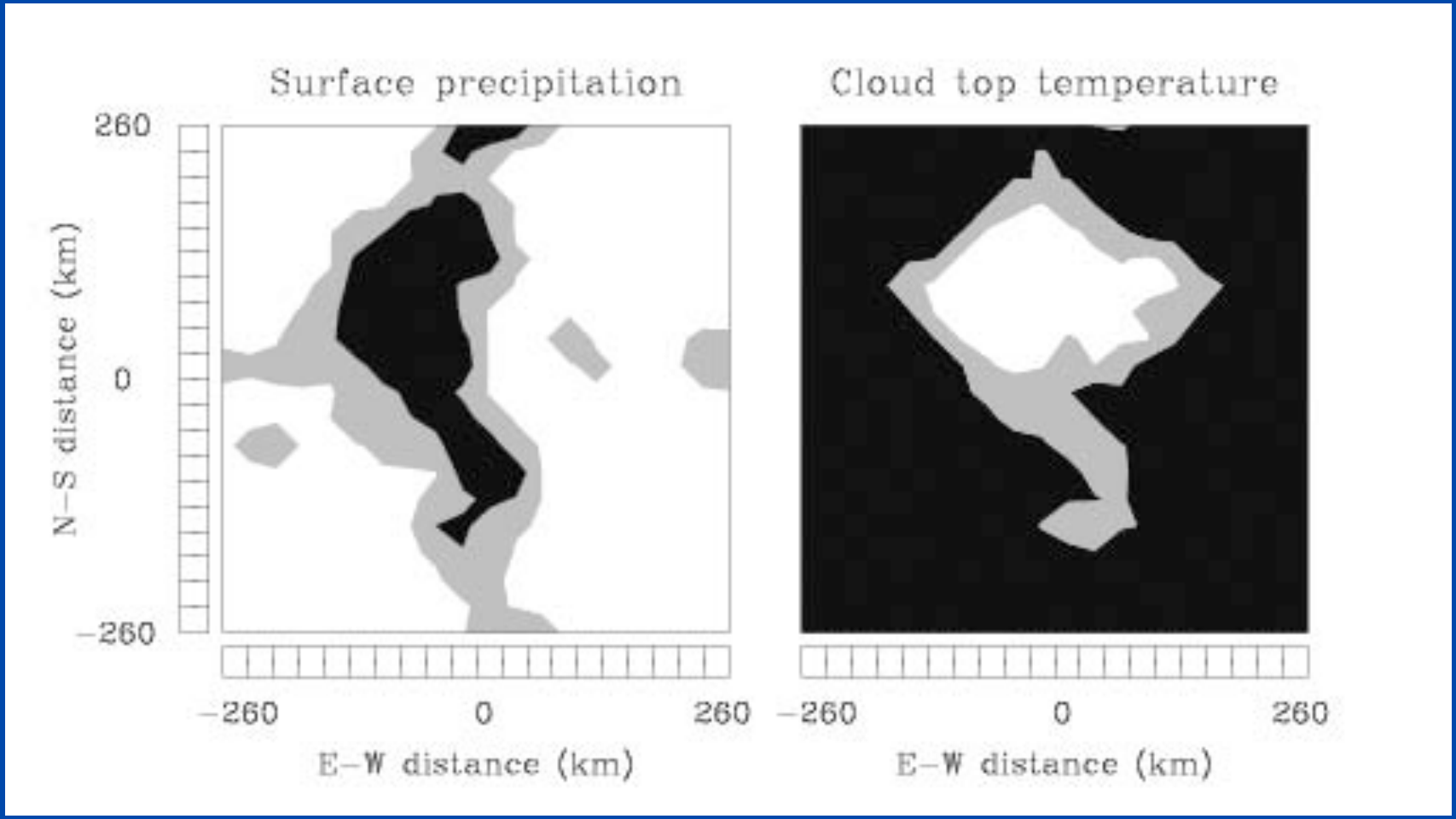


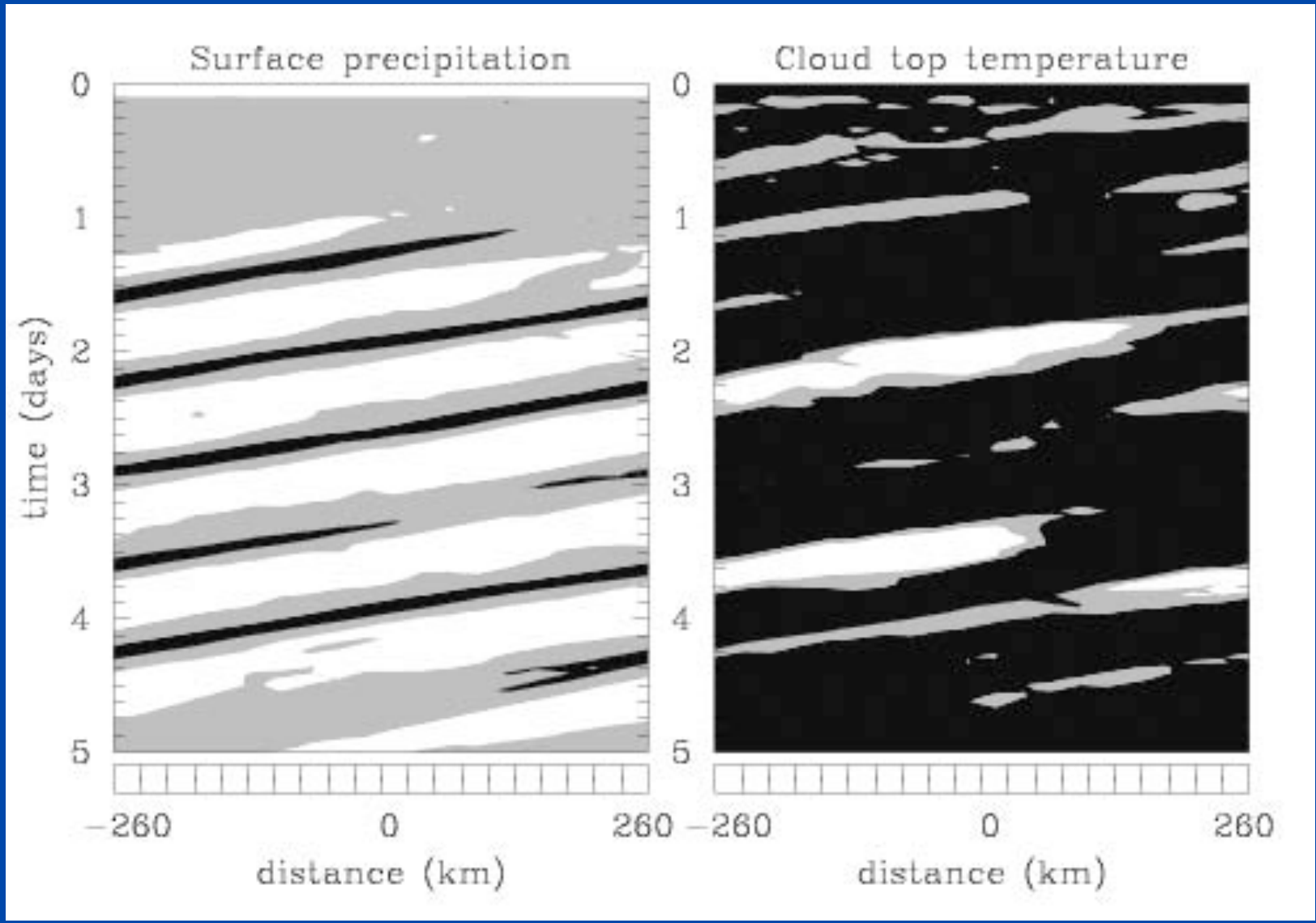
This approach extends naturally into 3D mesoscale model:

2D convective dynamics plus 3D mesoscale dynamics

Snapshots from a 3D simulation in the same setup as before, 520-km mesoscale domain, 26-km grid; 26-km SP domains aligned E-W

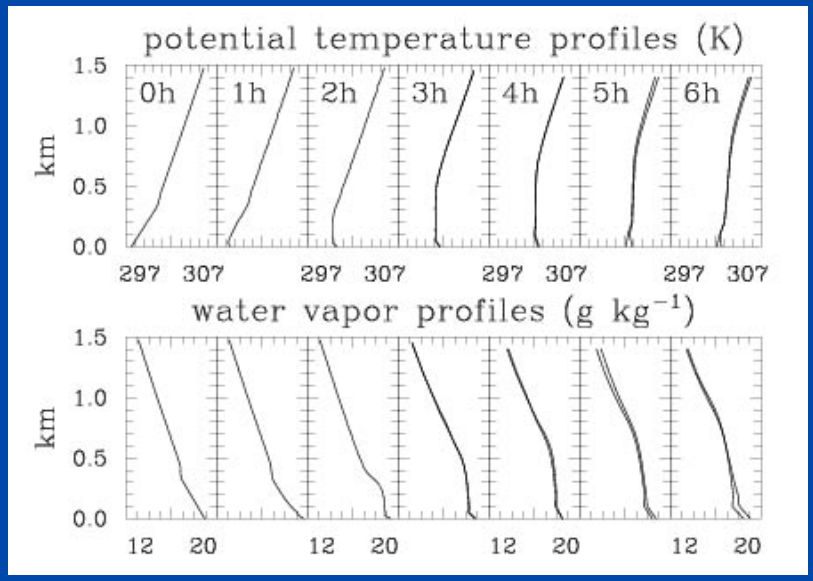


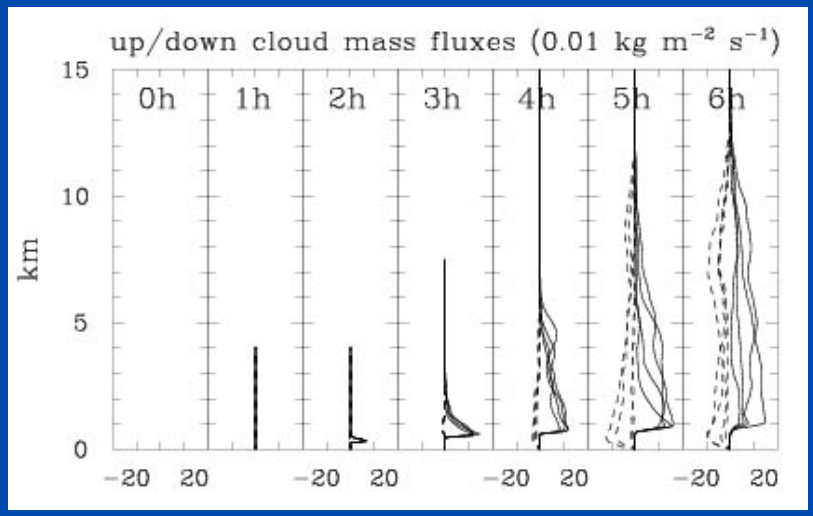
Hovmoeller diagrams of N-S averaged surface precipitation and cloud-top temperature from the 3D simulation



Over land, development of organized convection is closely tied to the diurnal cycle of solar insolation:

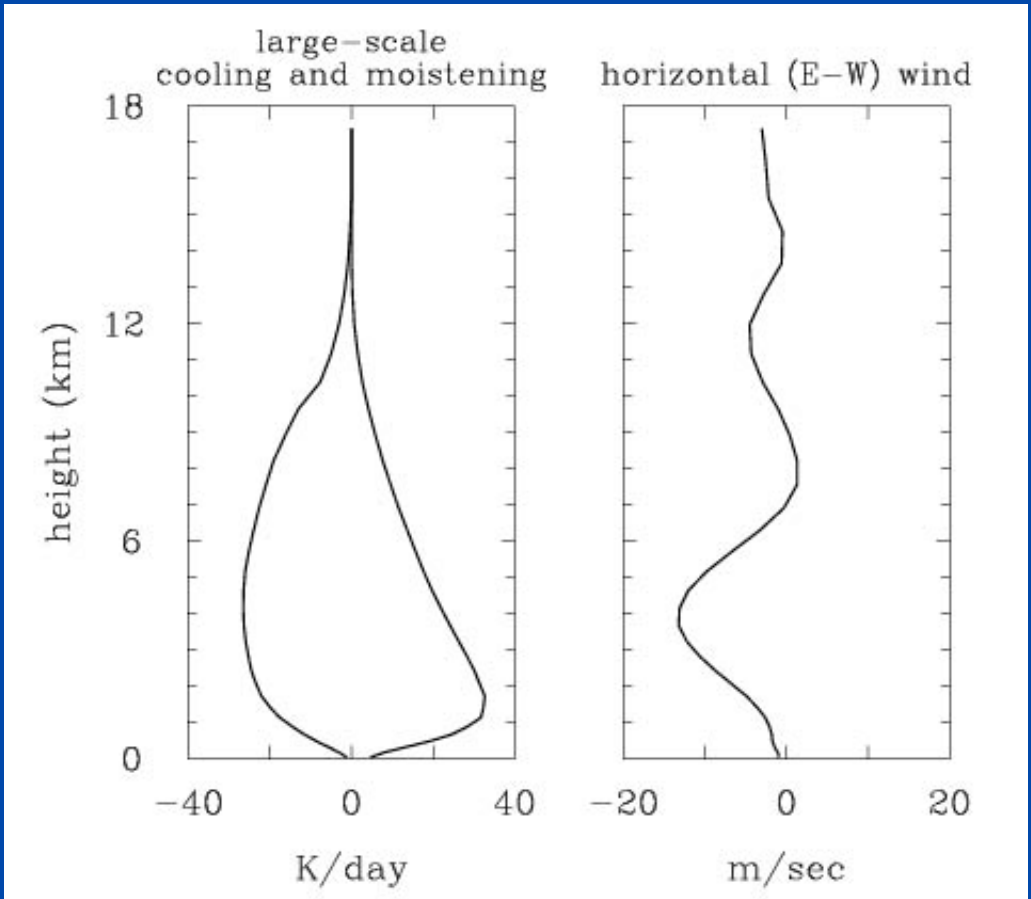
- ♣ Boundary layer processes
- ♣ Transition from shallow to deep convection
- ♣ Mesoscale organization (from individual convective clouds to a mesoscale convective system)





Grabowski et al. QJRMS 2006

Development of an idealized diurnal cycle case using GATE winds and forcing…

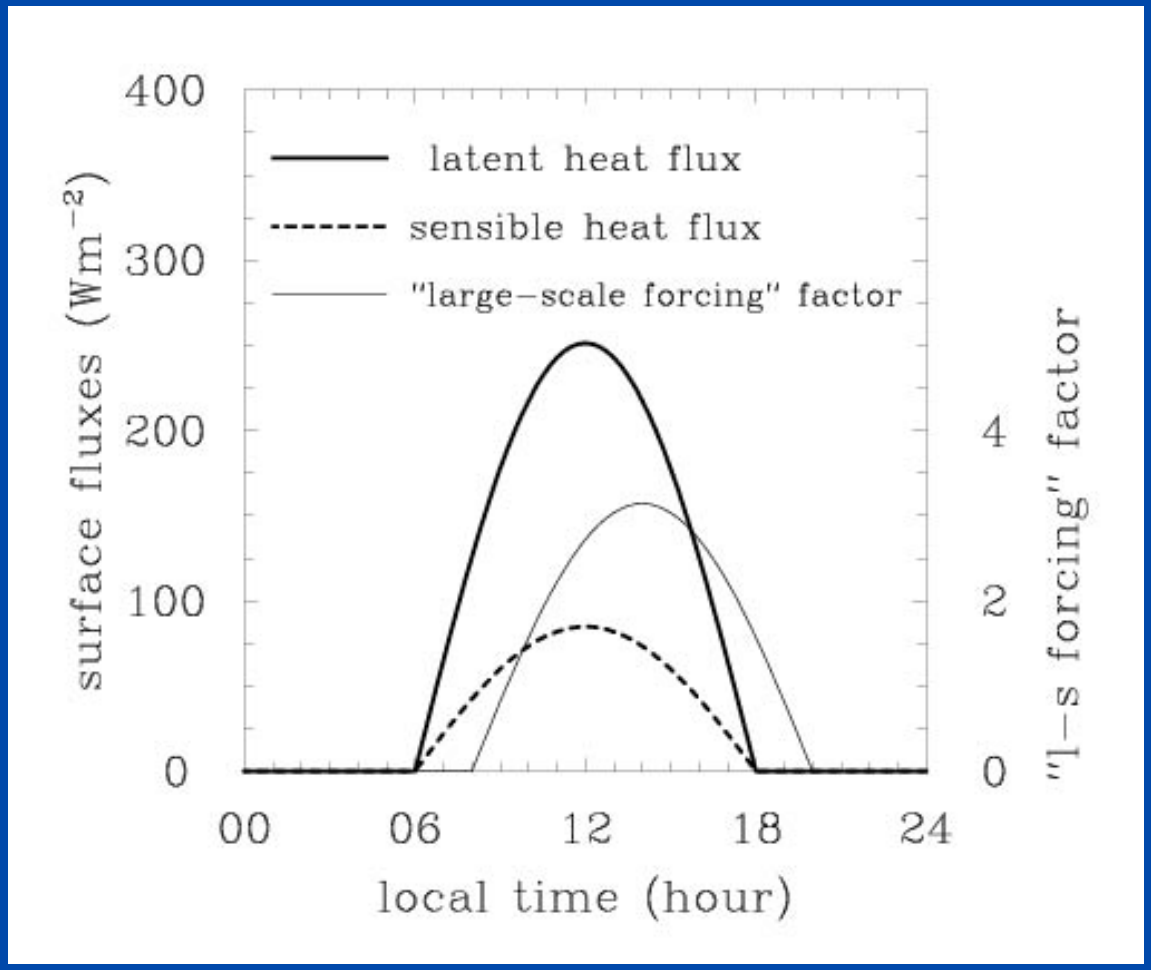


Diurnally-averaged forcing (2 K/day radiative cooling added below 10 km):

-Cooling: -1834 Wm^{-2}

-Moistening 1727 Wm^{-2}

-Required surface flux: 107 Wm^{-2} (80 latent, 27 sensible)



Idealized diurnal cycle case using mean GATE forcing…

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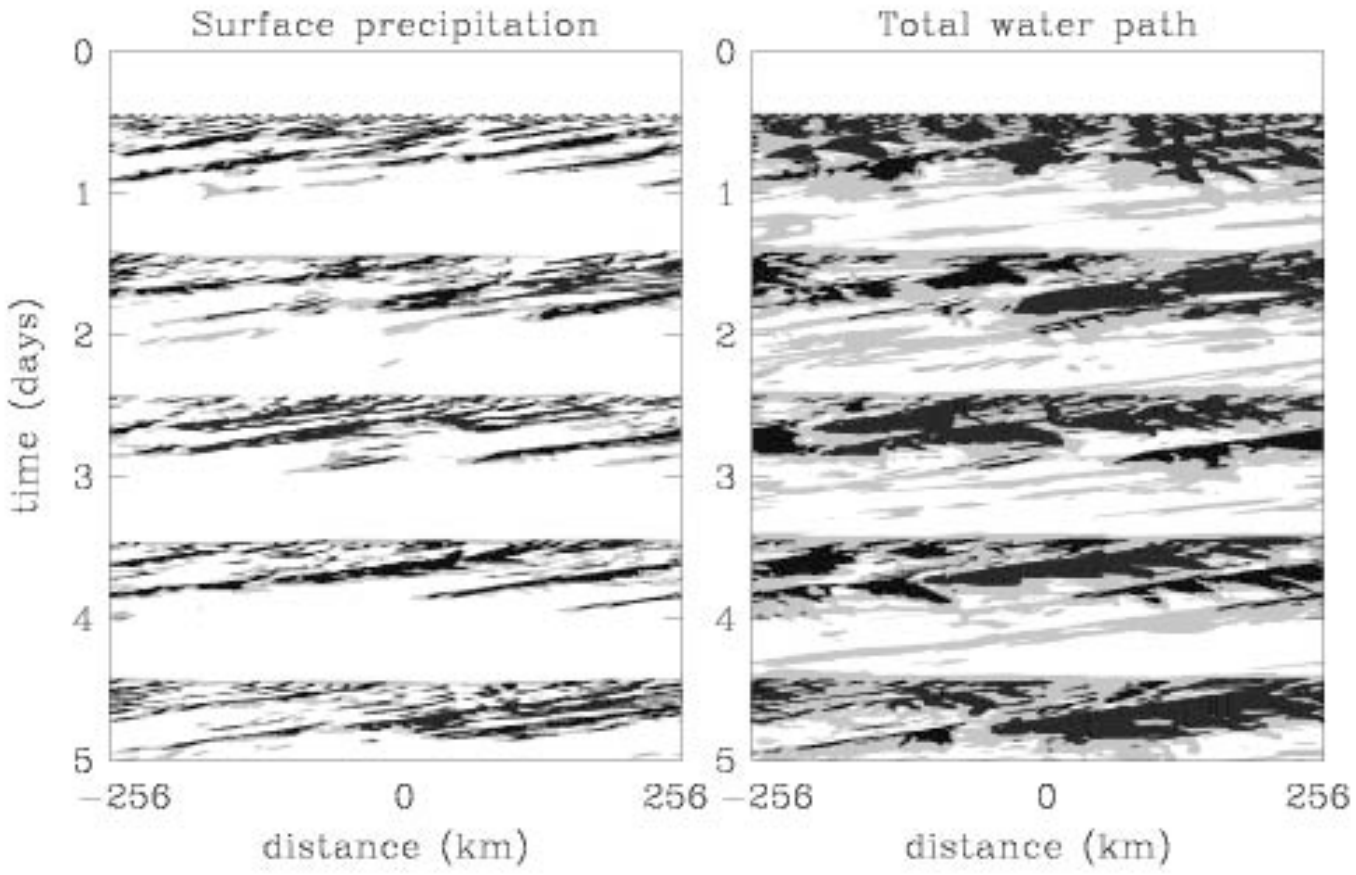

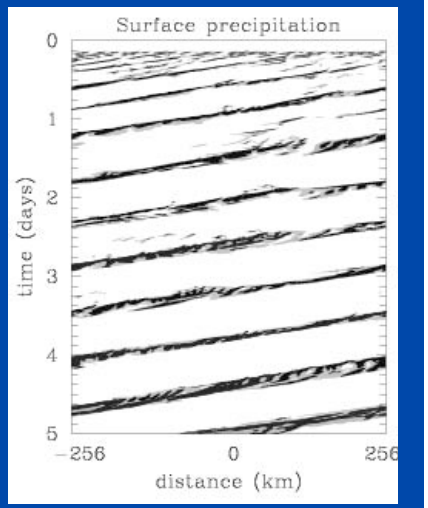

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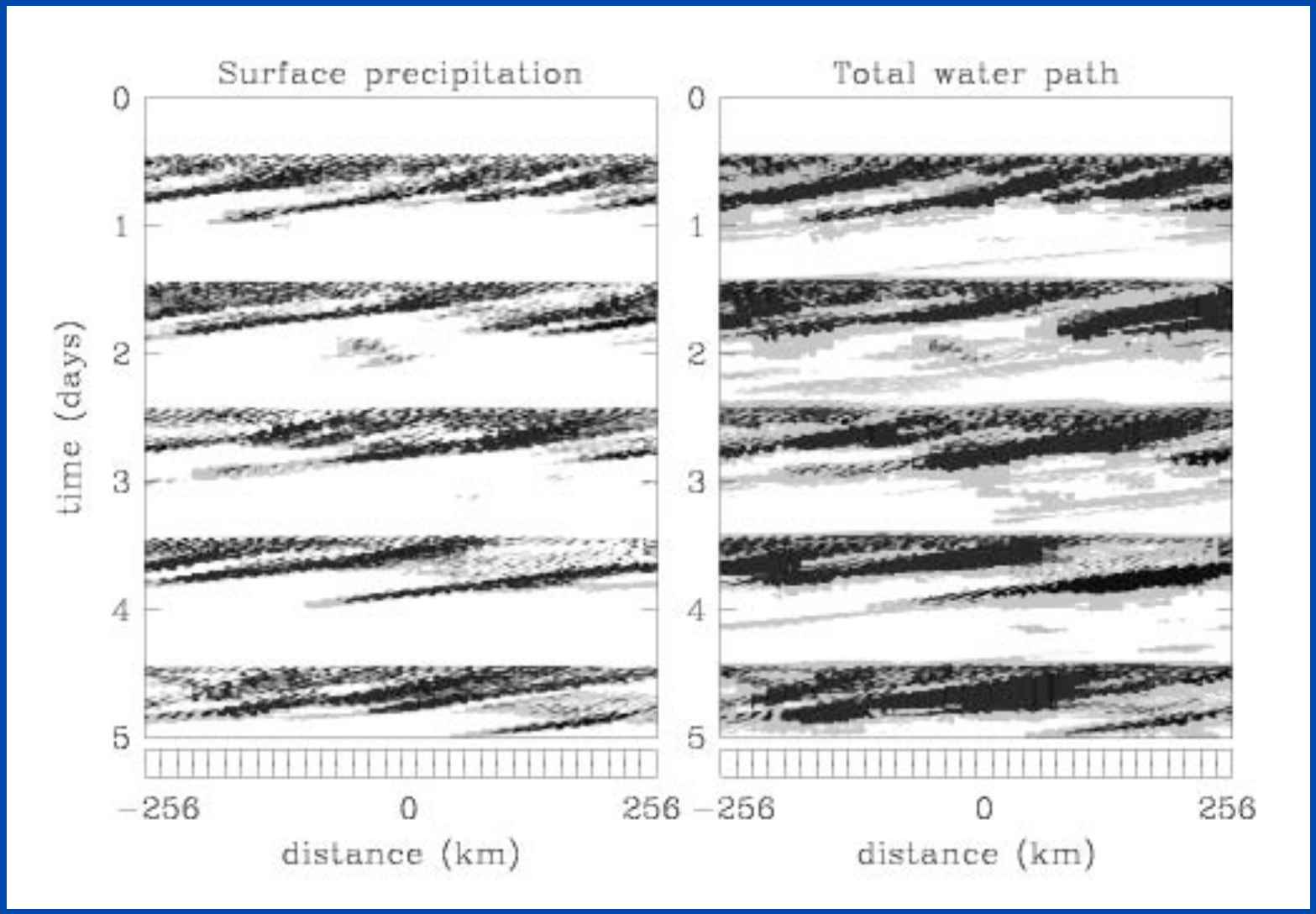

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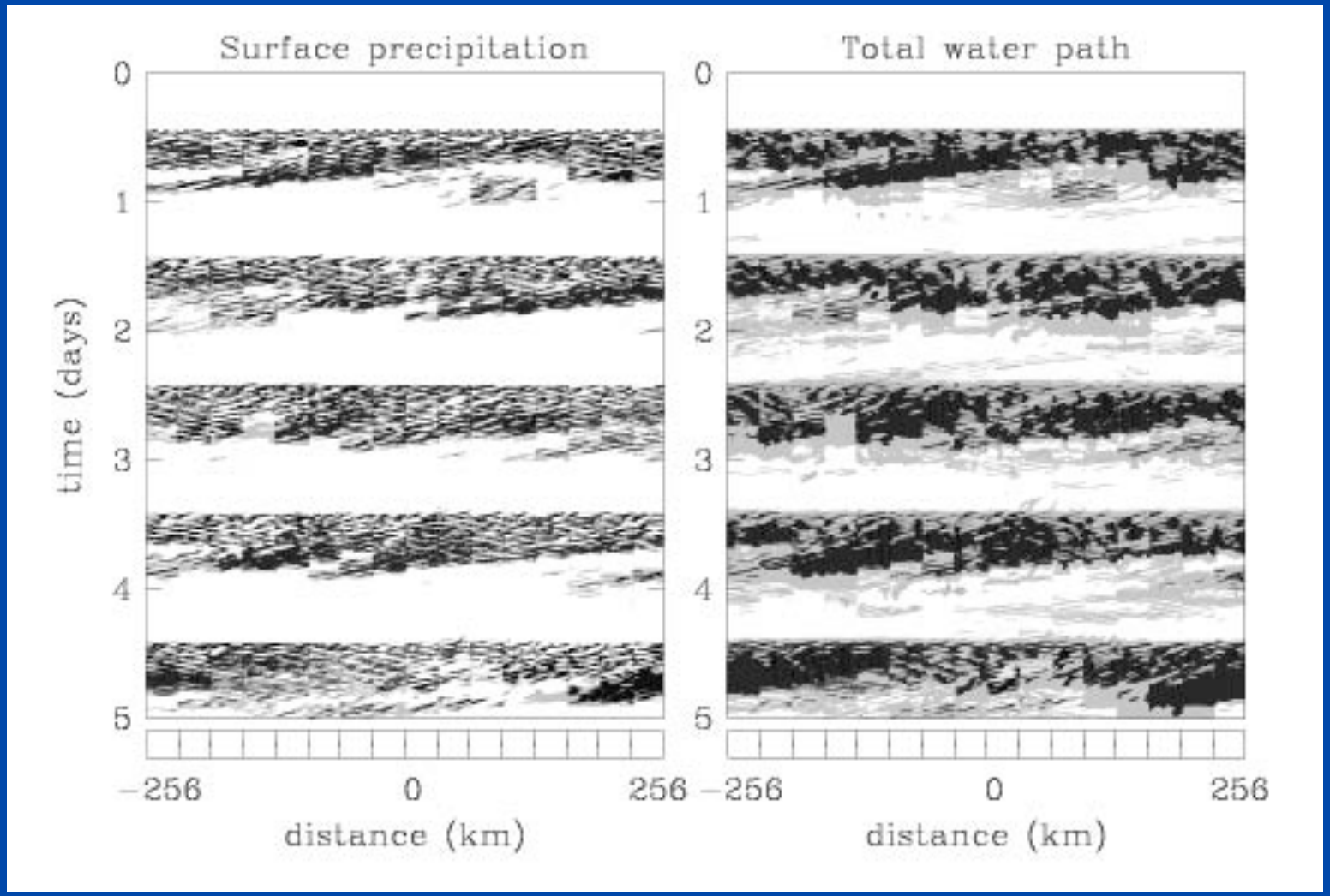

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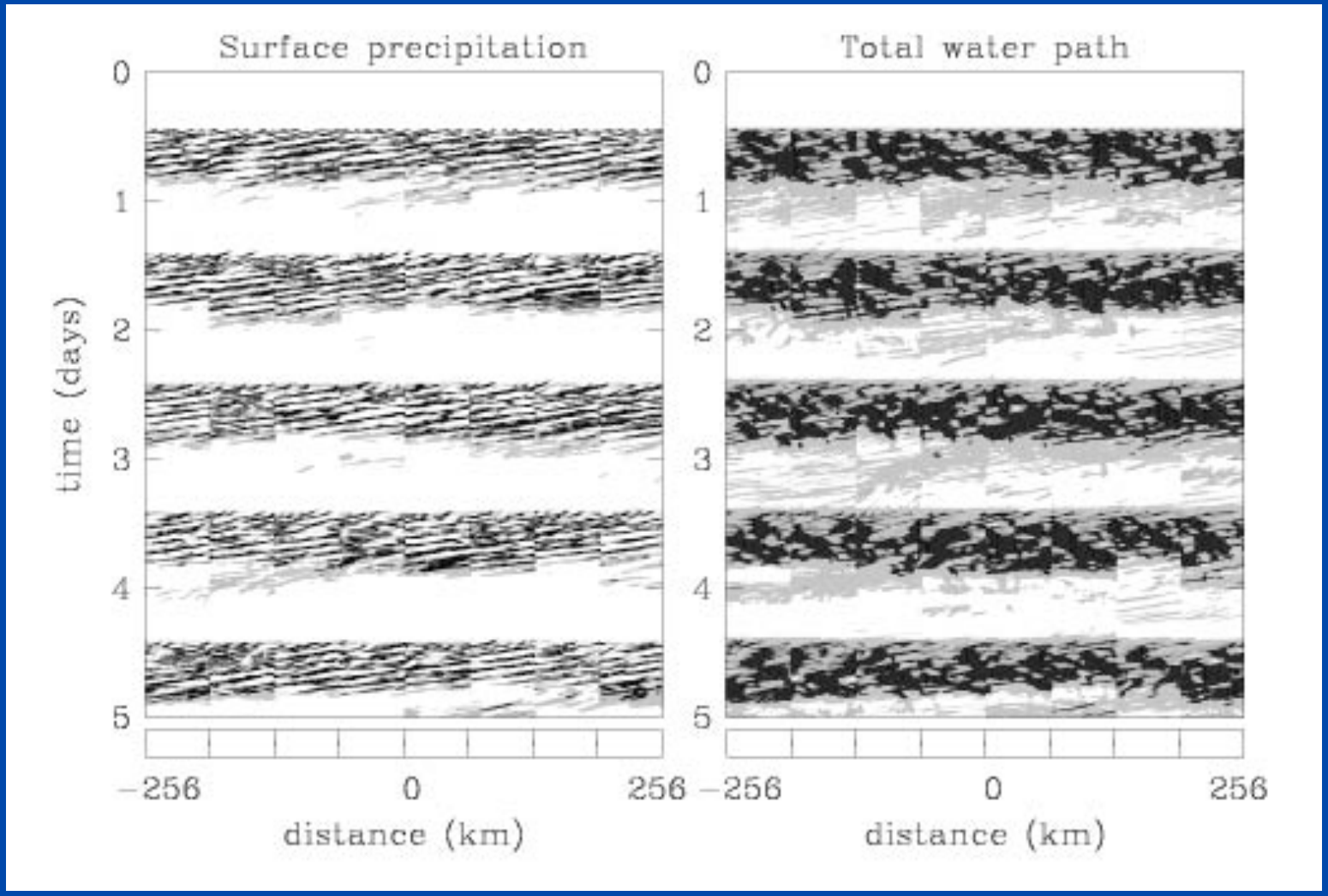

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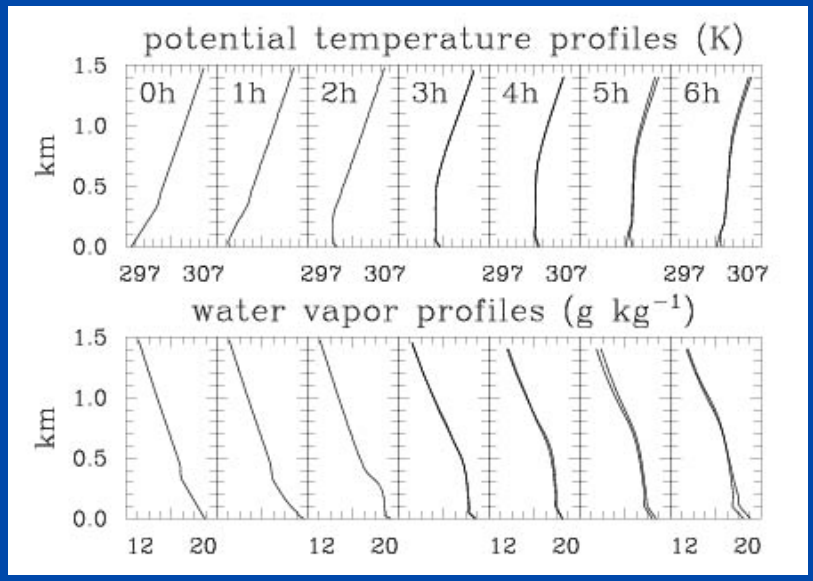
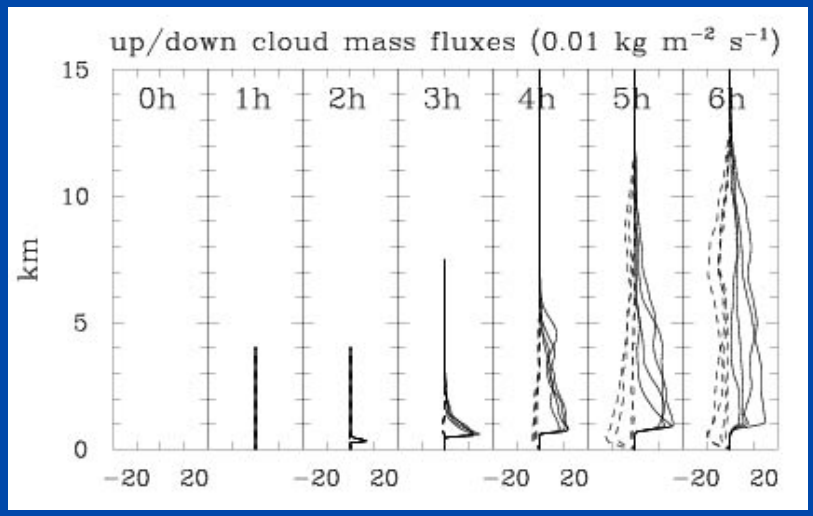
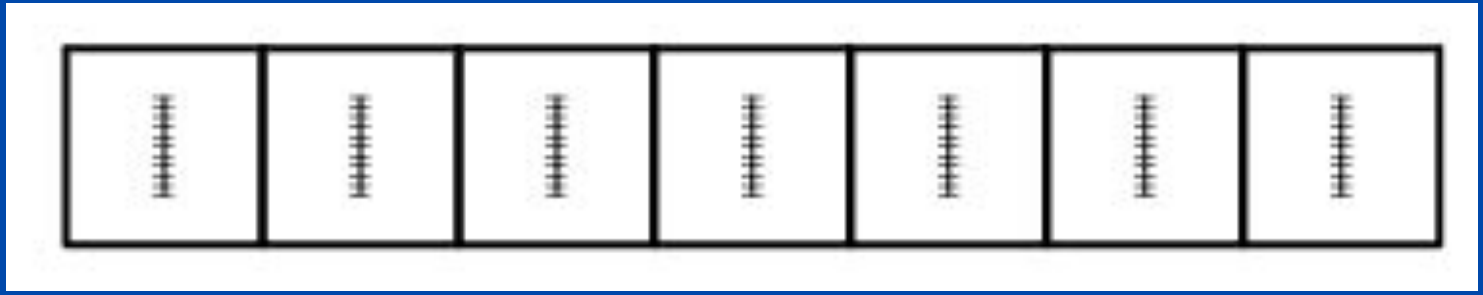


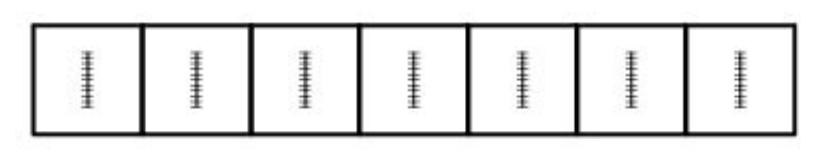


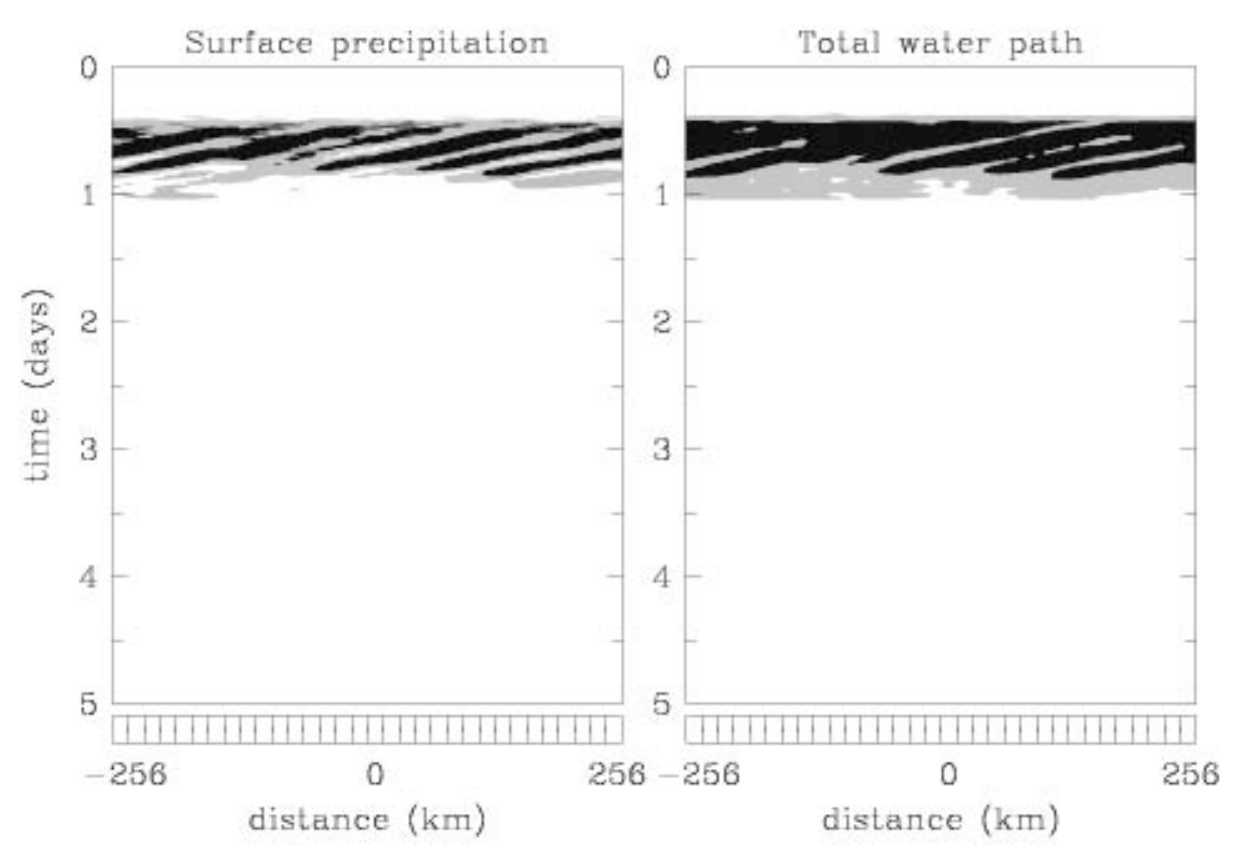
Grabowski et al. QJRMS 2006

When the mesoscale model gridlength is around 10 km, SP can be run at high resolution (say, around 100 m) to improve representation of boundary-layer processes and shallow convection. SP models have to be aligned perpendicular to the boundary layer shear (Moeng et al. JAS 2004). For the 2D case considered here:



SP BL simulation: 32 columns with 16-km gridboxes; 12-km BL models with 200 m gridlength





(simulation in progress…)

Conclusions:

Super-parameterization (SP) is an attractive approach for mesoscale models with horizontal grid spacings in the 10-30 km range (e.g., regional climate models). Such an approach allows representing 3D organized convection. SP can be run at high resolution (say, around 100 m; e.g., Moeng et al. JAS 2004) to improve representation of boundary-layer processes and shallow convection.

Troposphere-stratosphere coupling?