DEVELOPMENT OF QUASI-3D (Q3D) MMF

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GCM, 3D CRM AND Q3D MMF

DEEP CUMULUS CONVECTION

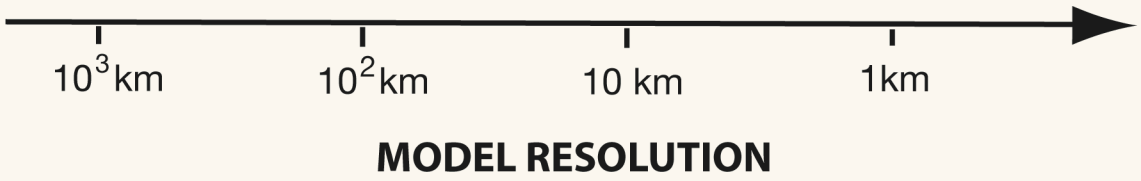
Explicitly Simulated

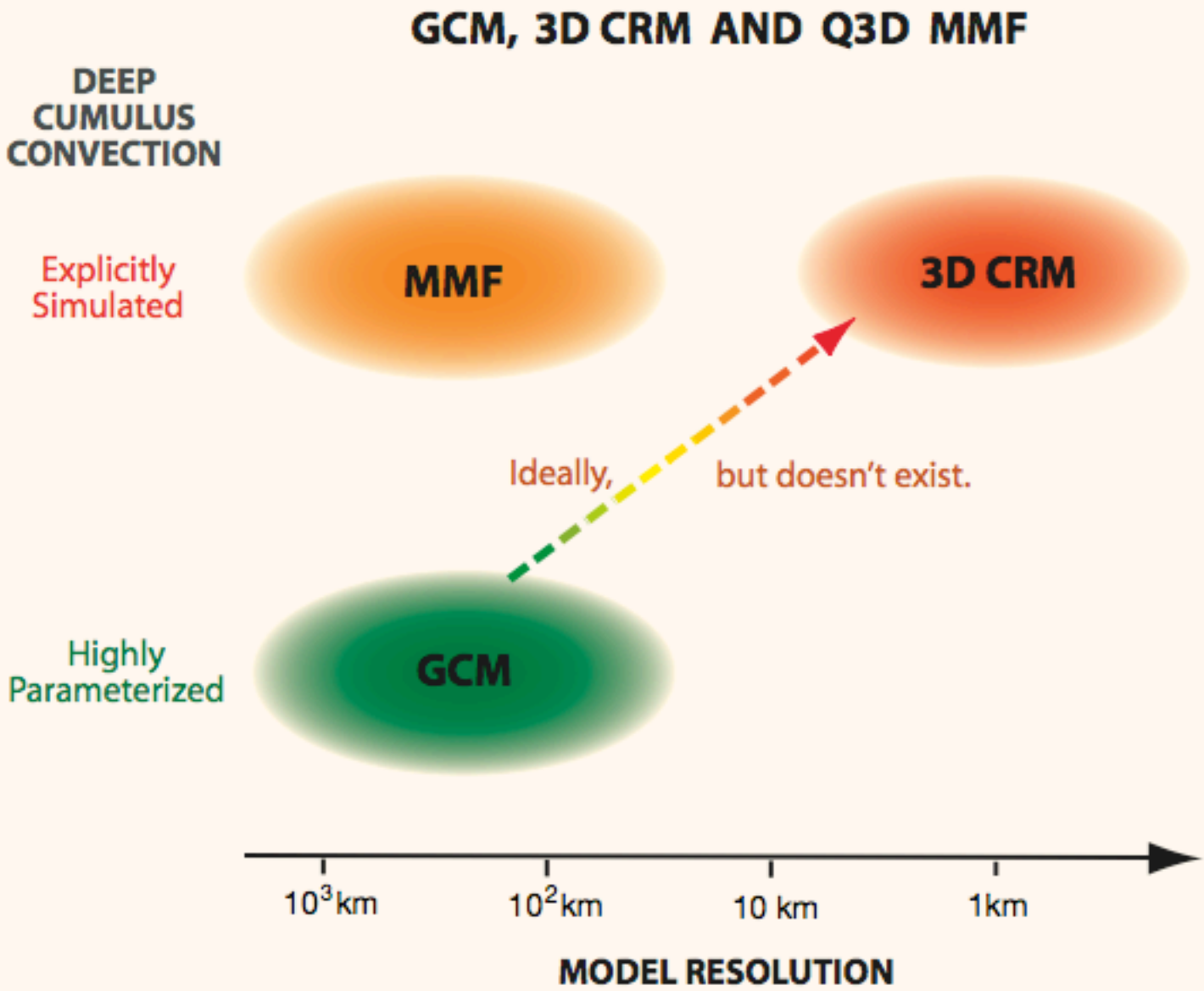
3D CRM

These two families of models have distinctly different model physics.

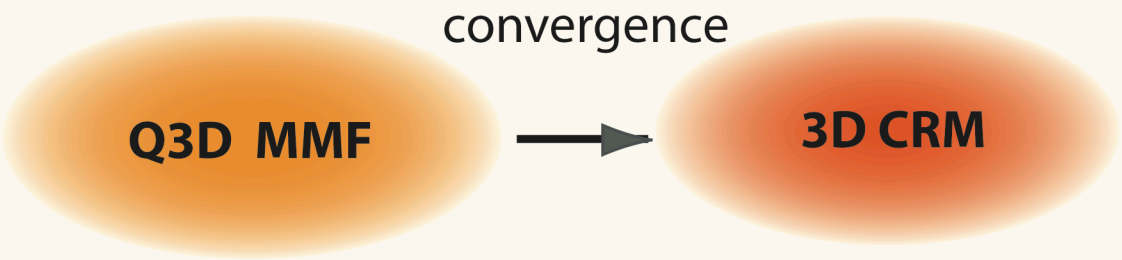
Highly Parameterized

GCM



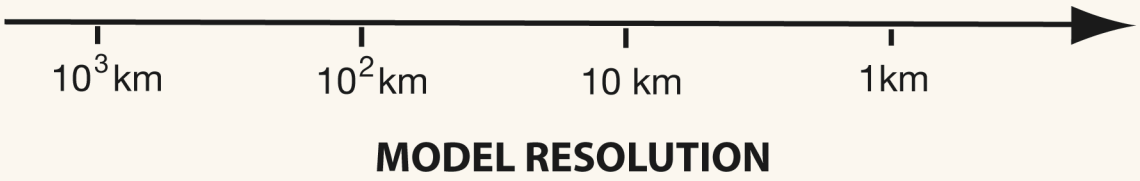

GCM, 3D CRM AND Q3D MMF
DEEP CUMULUS CONVECTION
Explicitly Simulated
MMF
3D CRM
Ideally,
but doesn't exist.
Highly Parameterized
GCM
10^3km
10^2km
10 km
1km
MODEL RESOLUTION

GCM, 3D CRM AND Q3D MMF



ISSUES

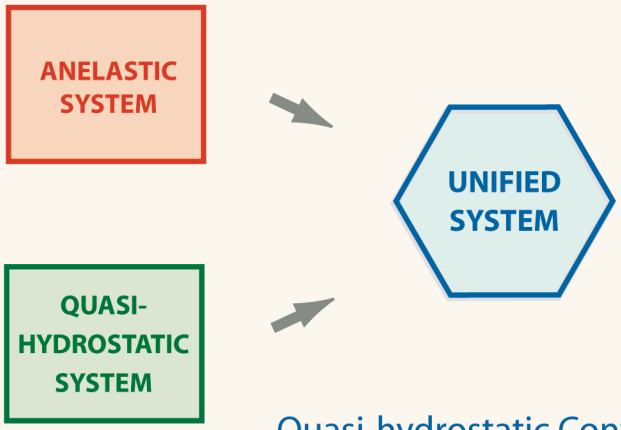
- Dynamics needs to be unified between GCM and CRM
- 2D and 3D grids need to be linked (Q3D).
- GCM and CRM need to be coupled interactively.



UNIFICATION OF DYNAMICS BETWEEN GCM AND CRM

We have developed a system of equations
that can cover a wide range of atmospheric motions
from turbulence to planetary waves
while filtering vertically-propagating sound waves of all scales.

(Arakawa and Konor 2008)

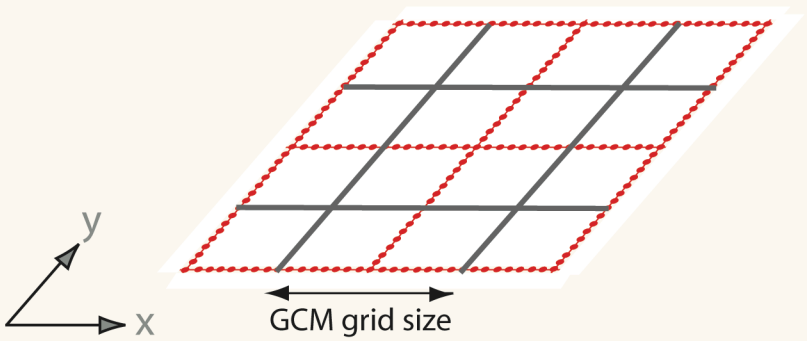


Importance of the system

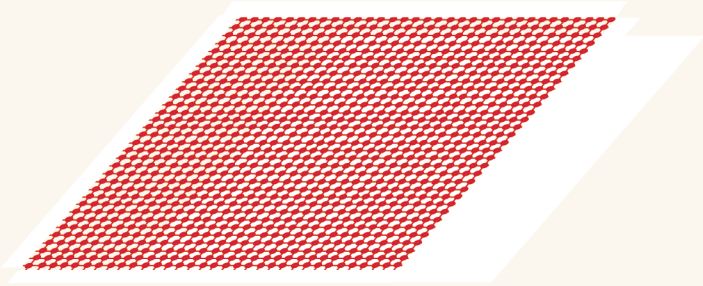
- Vertically-propagating sound waves are filtered without distorting motions of our interest.
- A single system that maintains close ties with both the anelastic models for small scales and the "primitive equation" models for large scales, for each of which we have generations of valuable experience.

Horizontal Grids of Q3D MMF and 3D CRM

Q3D MMF



3D CRM (benchmark)



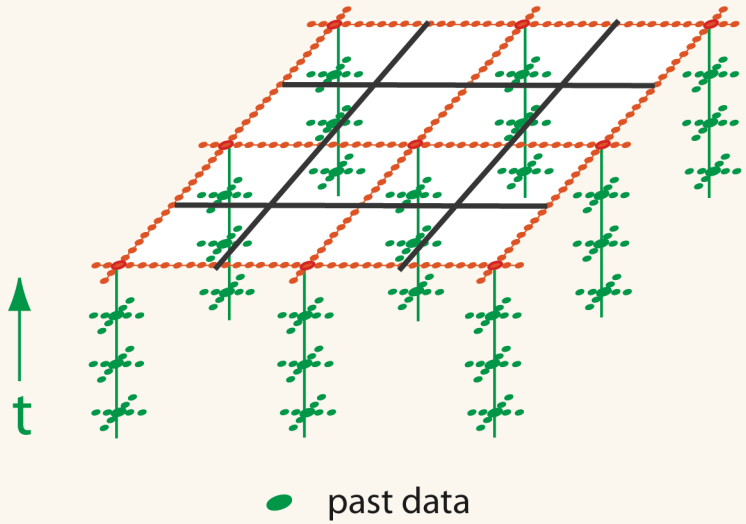
Three-dimensionality

For the GCM scale :

Controlled by the GCM.

For the CRM scale :

Normal gradients are estimated based on the statistics of the cloud regime identified by past data at the intersections.

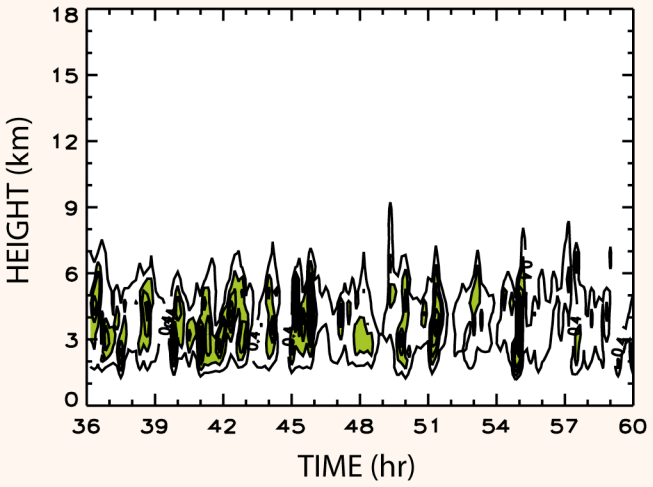


TEST OF Q3D ADVECTION OF WATER SPECIES

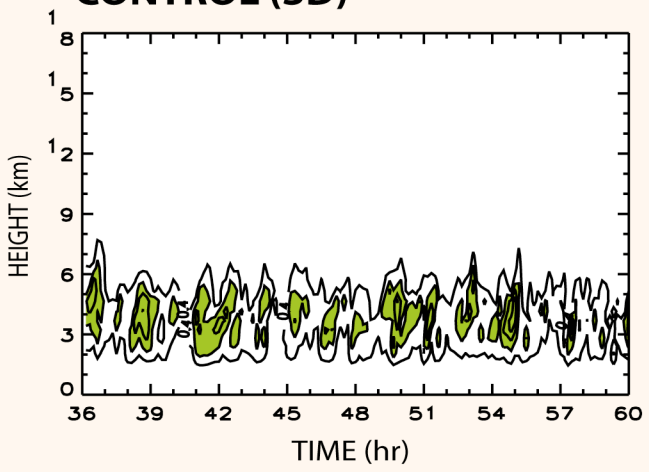
With θ and velocity components prescribed at all Q3D grid points

Variance of liquid water mixing ratio

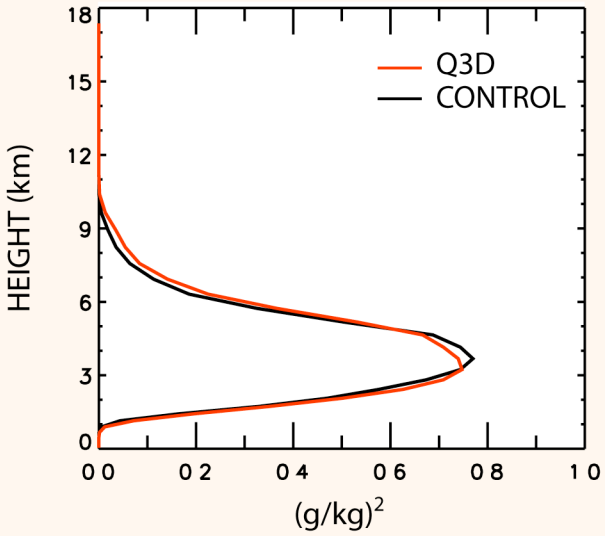
Q3D



CONTROL (3D)



Time Average

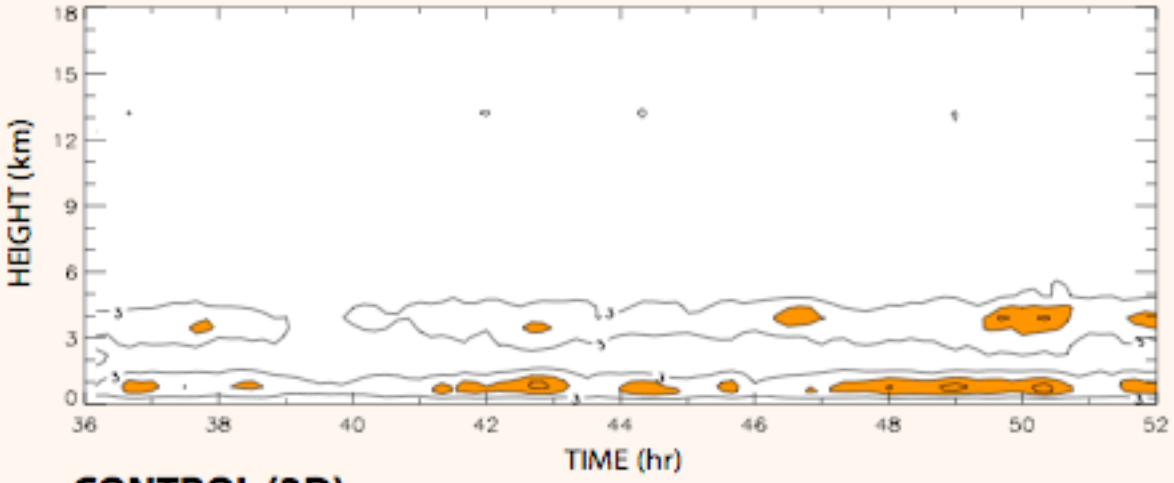


TEST OF Q3D DYNAMICS (FULLY-PROGNOSTIC)

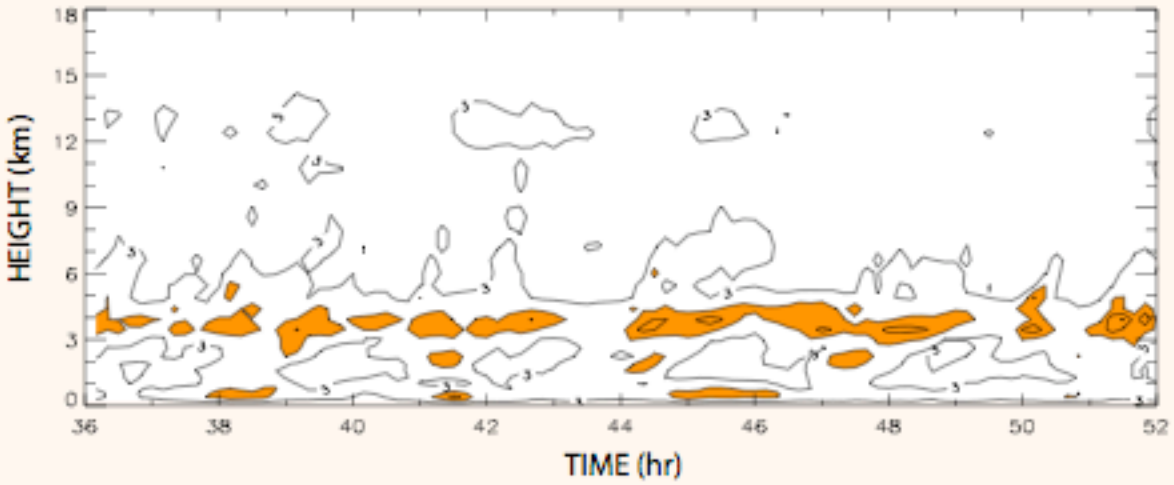
(Still without coupling with the GCM)

X-Array Variance of the y-component of vorticity

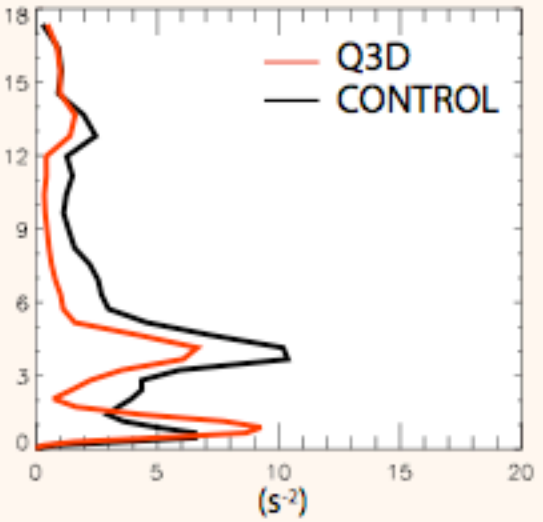
Q3D



CONTROL (3D)



Time Average

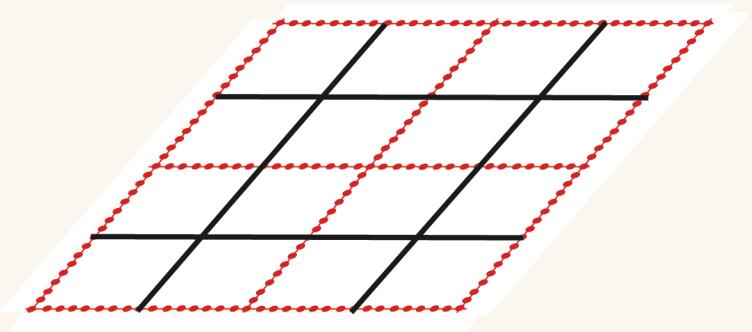


However,
prediction of horizontal wind
was unsuccessful.

Q3D and 3D MMF

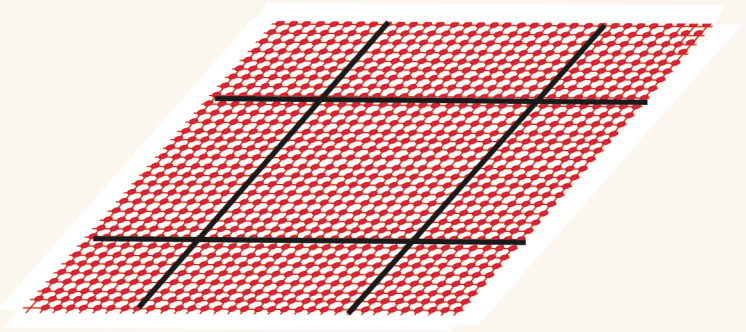
Q3D MMF

our goal



3D MMF

Useful as an intermediate tool



Two basic approaches for coupling GCM and CRM :

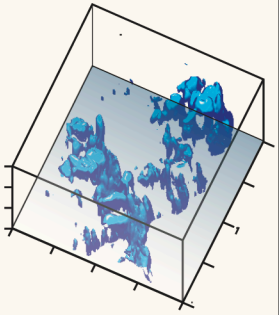
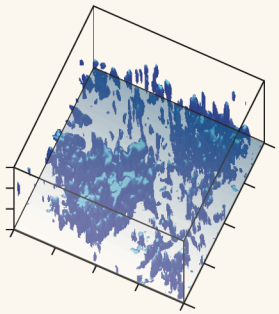
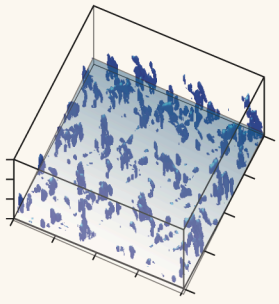
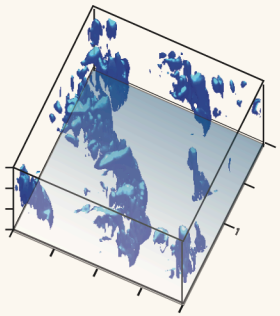
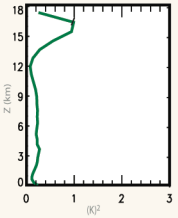
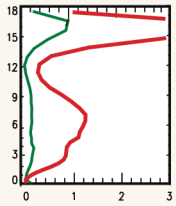
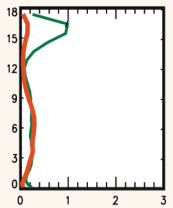
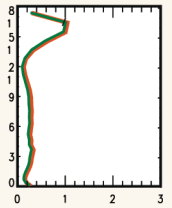
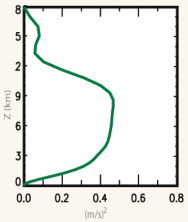
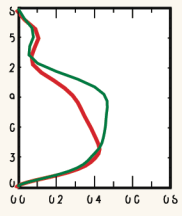
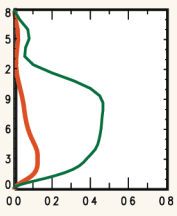
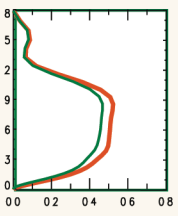
I. Coupling through processes

(Parallel to the traditional cumulus parameterization)

II. Mutual relaxation of prognostic variables

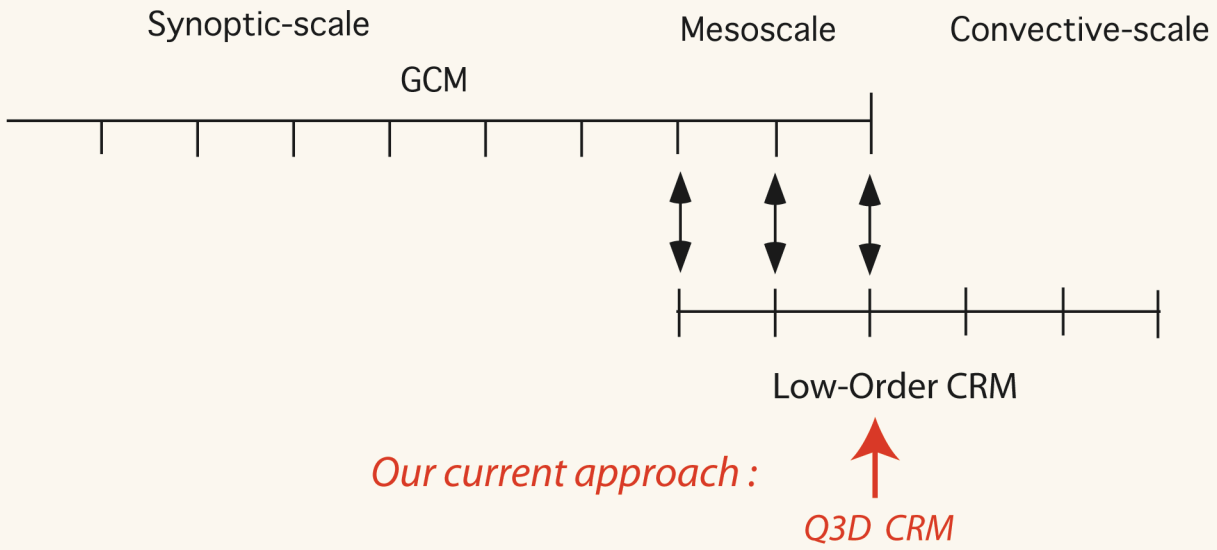
Also, we can think of a variety of hybrid approaches.

EXPERIMENTS USING A SMALL-DOMAIN GCM WITH DIFFERENT COUPLING METHODS

BACKGROUN FORCING	BENCHMARK	PRESCRIBED		
LOCAL FORCING		PROCESS		RELAXATION
VORTICITY FEEDBACK		PROCESS	RELAXATION	
THERMAL FEEDBACK		PROCESS		PROCESS
				
Variance of θ				
Variance of w				

Local process forcing can degrade the performance of CRM
due to the poor single-column parameterizability of the mesoscale.

Multi-scale coupling proposal by Palmer (1996) and Arakawa (2004) :



Relaxation coupling or horizontally-smoothed process coupling
may effectively do the same job.

FUTURE PLAN

- Test of the coupling methods using the Q3D CRM, still with the idealized GCM (in progress)
- Test of the coupling methods using the Q3D CRM with a larger GCM domain (a real test of multi-scale coupling)
- Investigating the stochastic nature of the parameterization and multi-scale modeling problems