Dynamical Core Breakout

- **Akio Arakawa -- Unified Parameterization**
- **Joon-Hee Jung -- Q3D MMF**
- **Celal Konor -- Grid optimization**
- **Ross Heikes -- Computational performance of GCRM**

UNIFIED PARAMETRIZATION

– MORE DIAGNOSTICS AND INTERPRETATIONS –

A. Arakawa[1] **and C.-M. Wu**[2]

[1] *University of California, Los Angeles*

[2] *National Taiwan University*

January 2012 CMMAP Team Meeting

UNIFIED PARAMETERIZATION

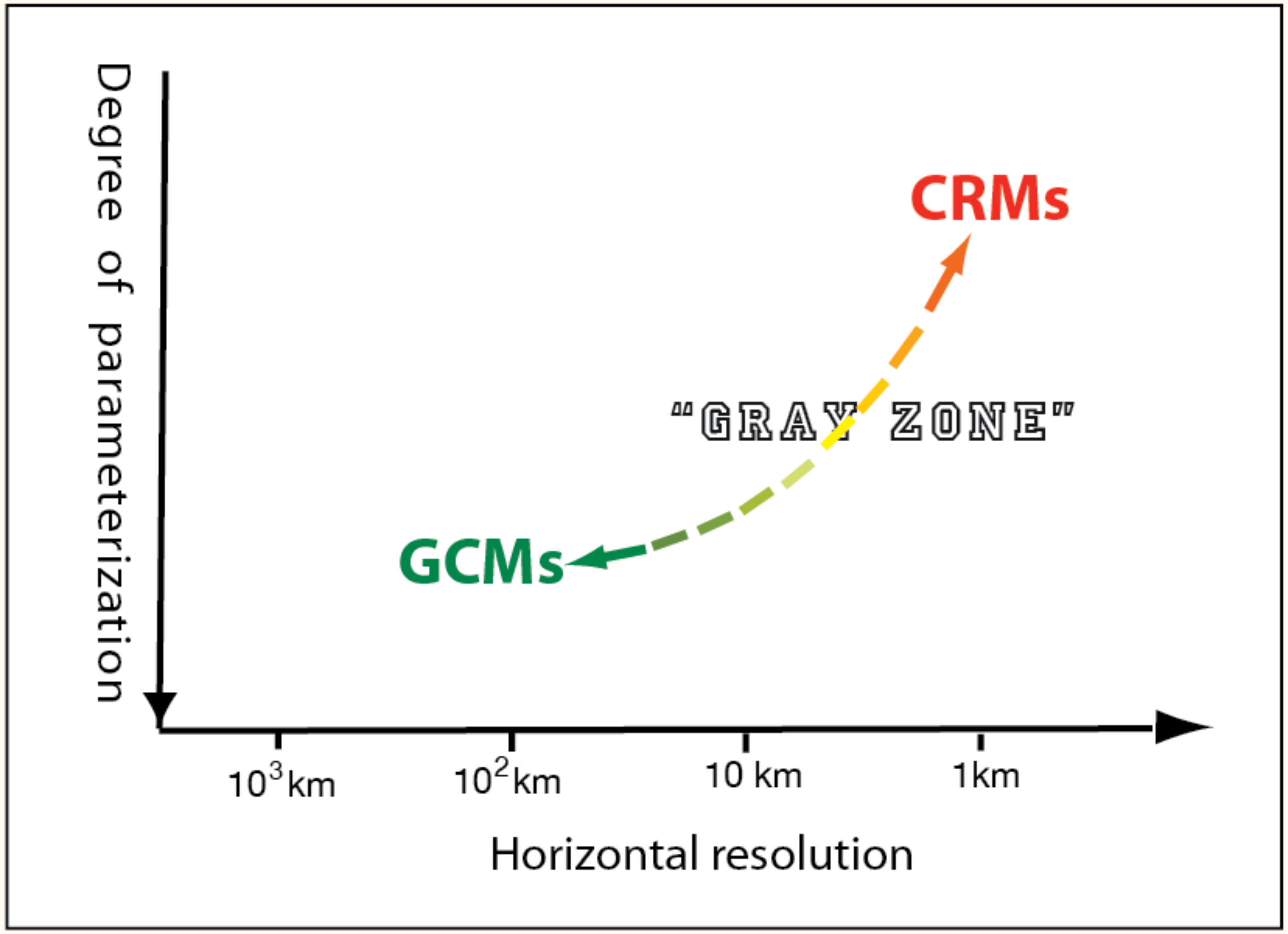
– An attempt to break through the "GRAY ZONE" –

Deep convection

explicitly simulated

Deep convection

highly parameterized



SPECTRAL REPRESENTATION OF CLOUDS

Suppose that we use w at cloud base to classify cloud types (as in Chikira 2010).

We can drive

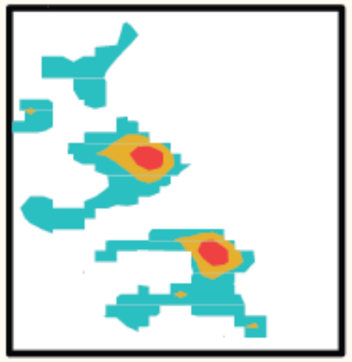
$$\overline{w'\psi'} = \sum_i \left(\Delta w_i \Delta\psi_i\right) \sigma_i - \sum_i \Delta w_i \sigma_i \sum_i \Delta\psi_i \sigma_i$$

A generalization of $\overline{w'\psi'} = \sigma(1-\sigma)\Delta w \, \Delta\psi$

Δ : cloud-env. difference

i : cloud type

We have to consider possible overlap of clouds.



internal structure

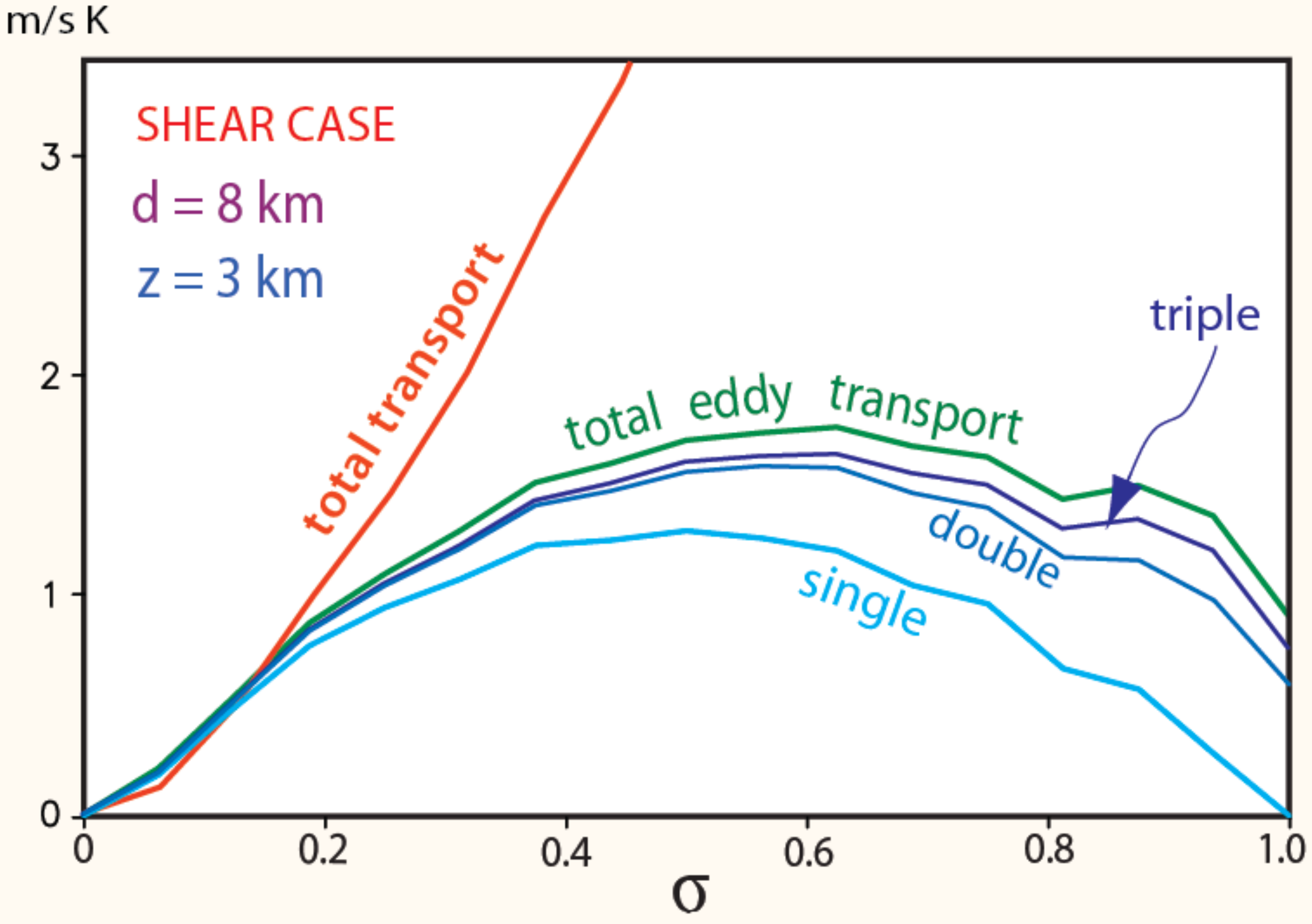
is more likely than

different cloud types

→ **The problem of cloud organization**

A challenge !

THE EFFECT OF MULTIPLE CLOUD-STRUCTURE / CLOUD-TYPE



single

0.5 m/s < w

double

0.5 m/s < w < 2 m/s

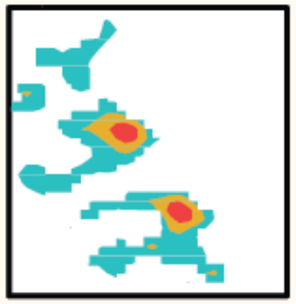
2 m/s < w

triple

0.5 m/s < w < 2 m/s

2 m/s < w < 4 m/s

4 m/s < w



SUMMARY AND CONCLUSIONS

The unified parameterization (UP) *generalizes* conventional parameterization including the transition to explicit simulation of cloud processes.

UP eliminates the assumption of $\sigma << 1$, distinguishing the cloud environment from the grid-cell mean.

Eddy transport in UP decreases as $\sigma \rightarrow 1$ and, therefore, the adjustment to a neutral state is relaxed for large σ.

UP determines σ for each realization.

Outstanding problems in conventional parameterization (e.g., determination of cloud properties, cloud spectrum, cloud organization, . . .) remain important in UP.

Progress Report

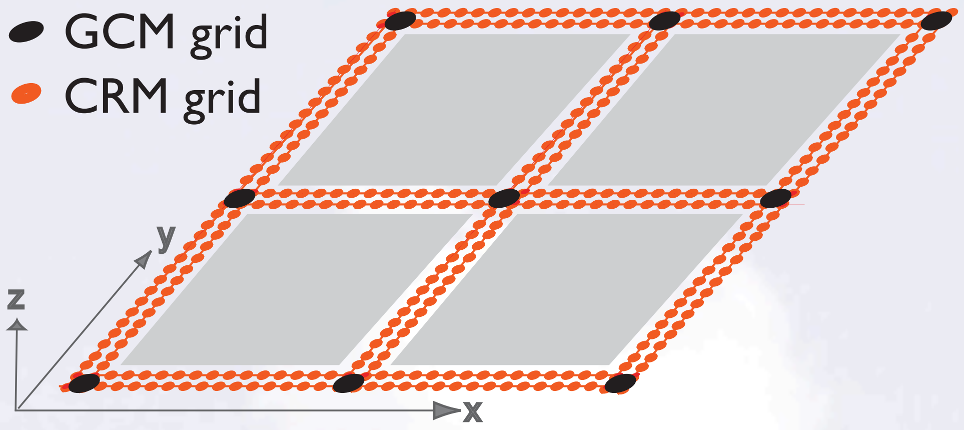
Research Objective 1:
Development of a Q3D MMF

Joon-Hee Jung and Akio Arakawa

January 2012 CMMAP Team Meeting

Test of Q3D Algorithm with a non-trivial GCM

The Q3D MMF introduces two perpendicular sets of channel domains, each of which contains a locally 3D array of grid points.



Shaded areas: gaps of the grid network

The lateral boundary condition for the channel domains consists of the sum of two parts: *one taken from smoothed background fields* interpolated from the gross features of GCM and *the other from cyclic conditions for deviations*.

In the earlier algorithm, the lateral boundary condition for solving the 2D elliptic equations (used in the determination of horizontal velocity at the uppermost layer) **was not consistent with the above. It has been modified in a consistent way.**

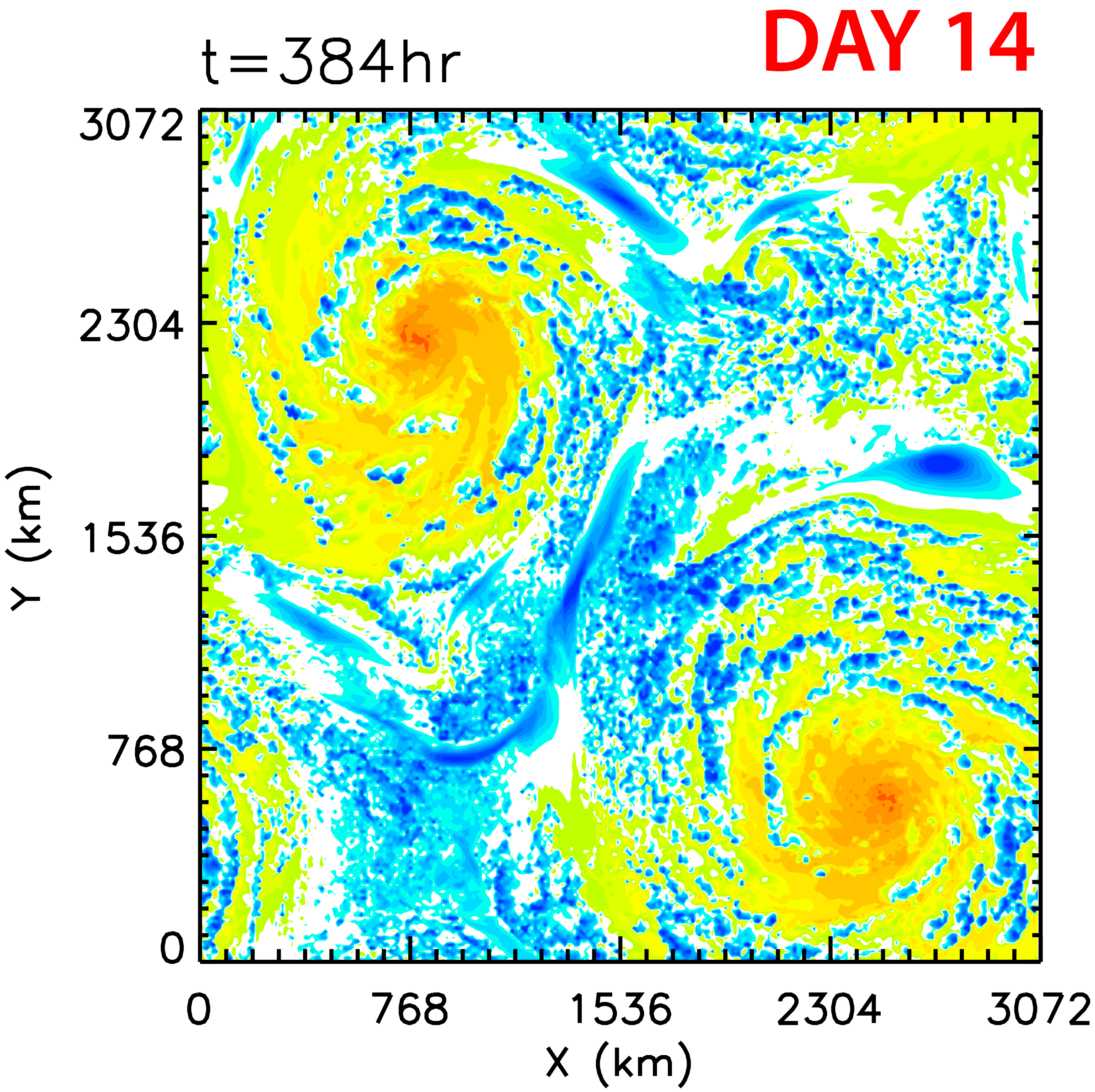
Smoothing of the background fields seems crucial to stable integration of the Q3D CRM. At present, a simple weighted average is used and it will be refined later.

From *“August 2011 CMMAP Team Meeting”*

Ongoing work:

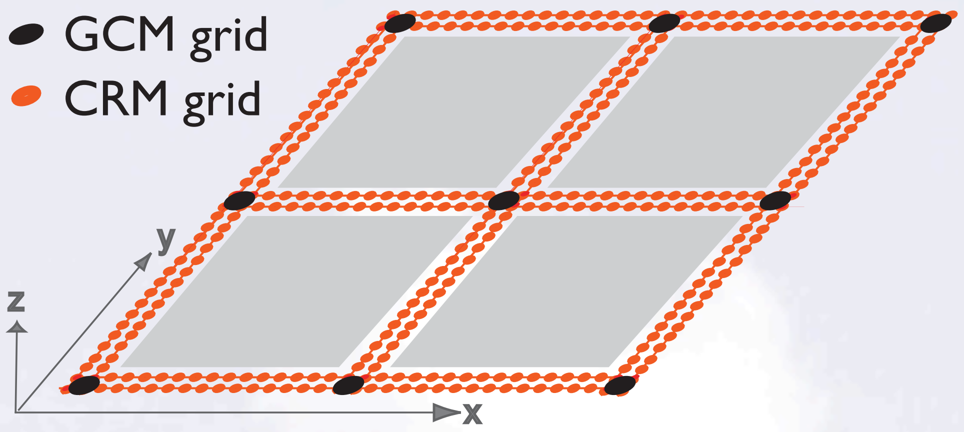
- Prepare a new benchmark simulation with a large domain
- Test the new Q3D MMF code using a non-trivial GCM
  (Still using an idealized setting with a domain size of a few thousands km.)
  - Investigate the coupling strategy between GCM and CRM
  - Finalize the Q3D algorithm

Water vapor in Benchmark



Test of Q3D Algorithm with a non-trivial GCM

The Q3D MMF introduces two perpendicular sets of channel domains, each of which contains a locally 3D array of grid points.



Shaded areas: gaps of the grid network

The lateral boundary condition for the channel domains consists of the sum of two parts: *one taken from smoothed background fields* interpolated from the gross features of GCM and *the other from cyclic conditions for deviations*.

In the earlier algorithm, the lateral boundary condition for solving the 2D elliptic equations (used in the determination of horizontal velocity at the uppermost layer) **was not consistent with the above. It has been modified in a consistent way.**

Smoothing of the background fields seems crucial to stable integration of the Q3D CRM. At present, a simple weighted average is used and it will be refined later.

Coupling Strategy

GCM effect on the CRM

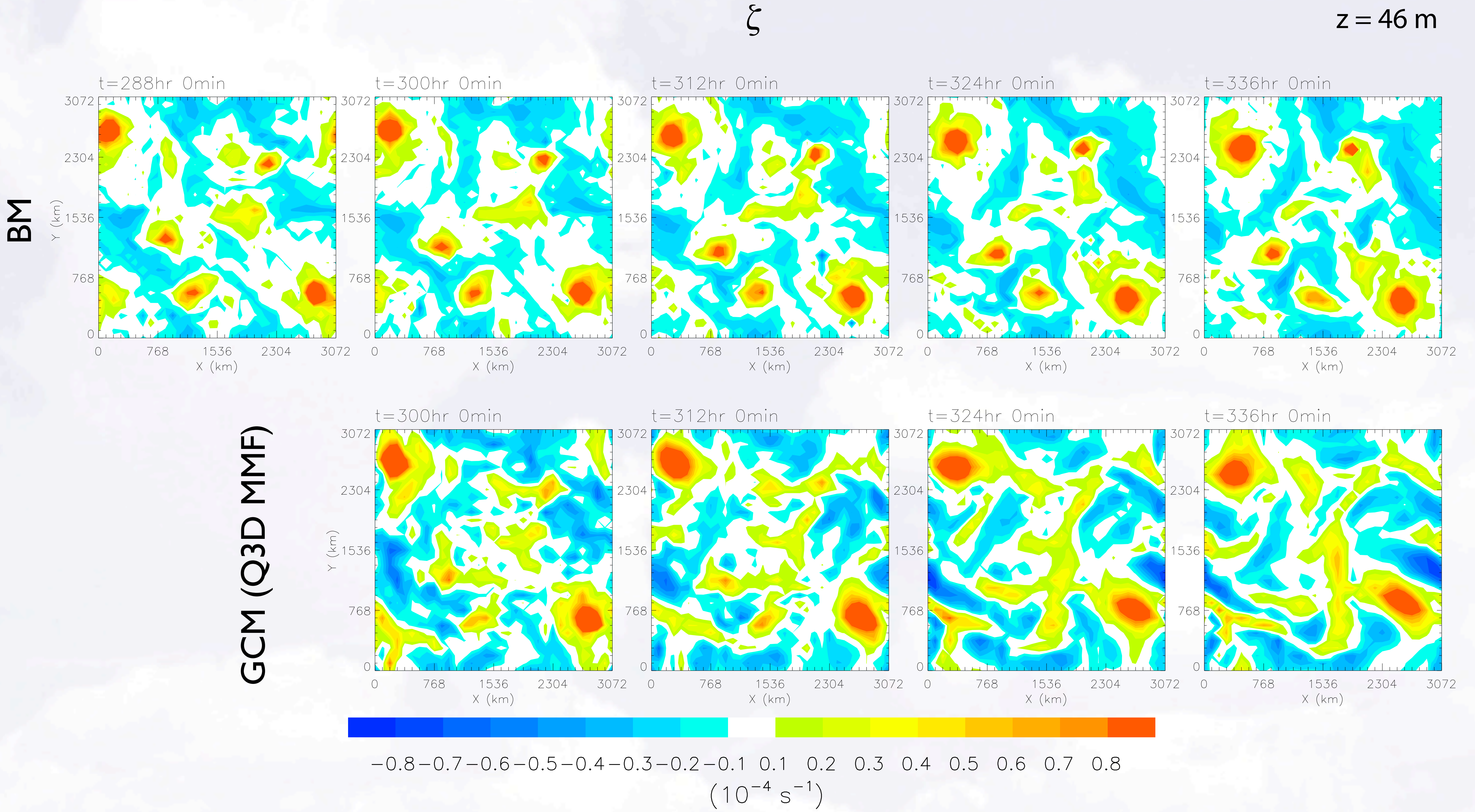
The GCM effect on the CRM is simply through the boundary condition on the background field of CRM. This is parallel to the typical limited area modeling in which the large-scale model provides the boundary condition for the embedded small-scale model.

CRM effect on the GCM

As in the subgrid parameterization problems, the role of the CRM is to estimate the effects of eddies not resolved by the GCM. Thus, the CRM effect must be limited to the eddy effects by subtracting the non-eddy effects.

Test of Q3D Algorithm with a non-trivial GCM

“Two way coupling”



How Can I Choose A Horizontal Grid For My Model?

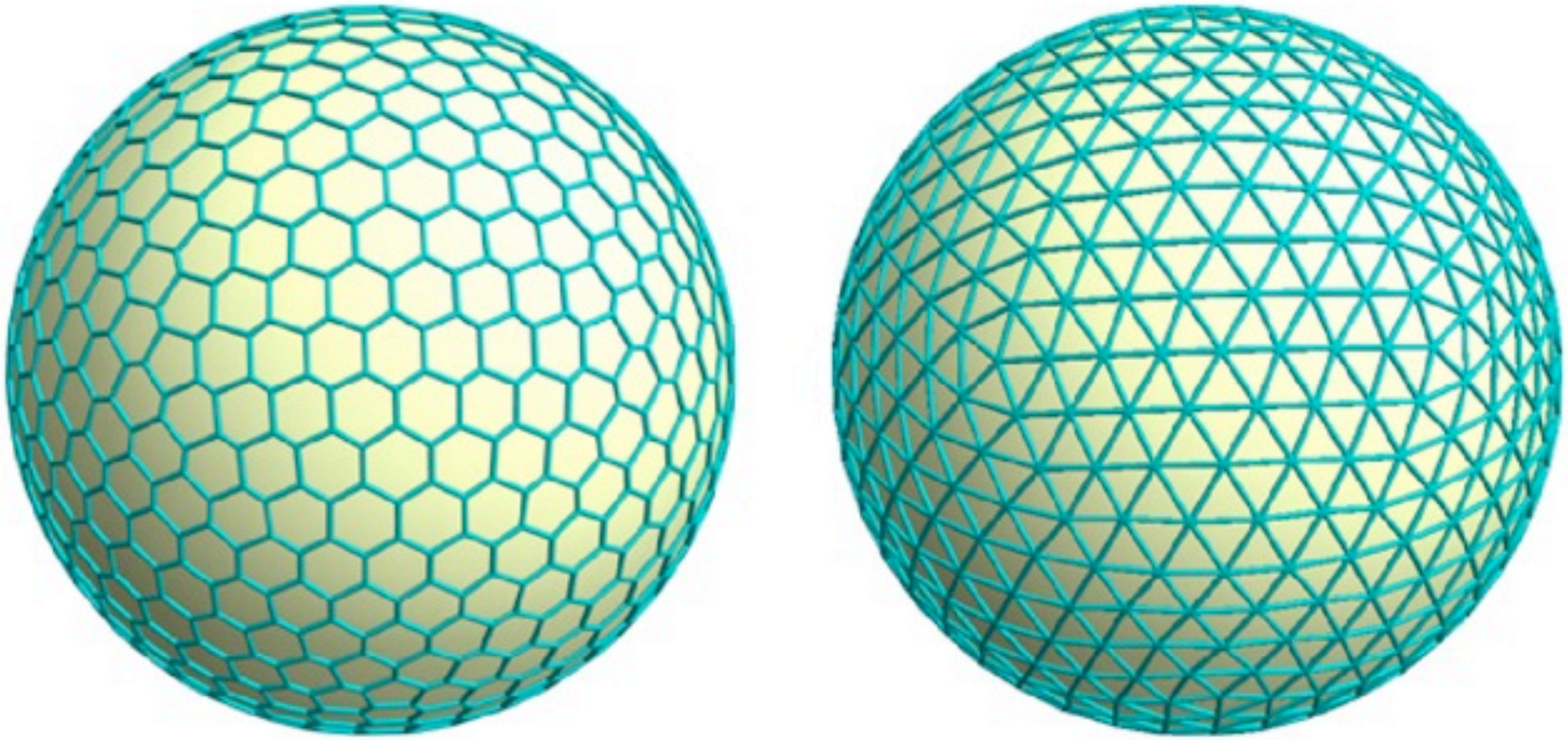
Celal S Konor, Ross P Heikes and David A Randall

Department of Atmospheric Science
Colorado State University

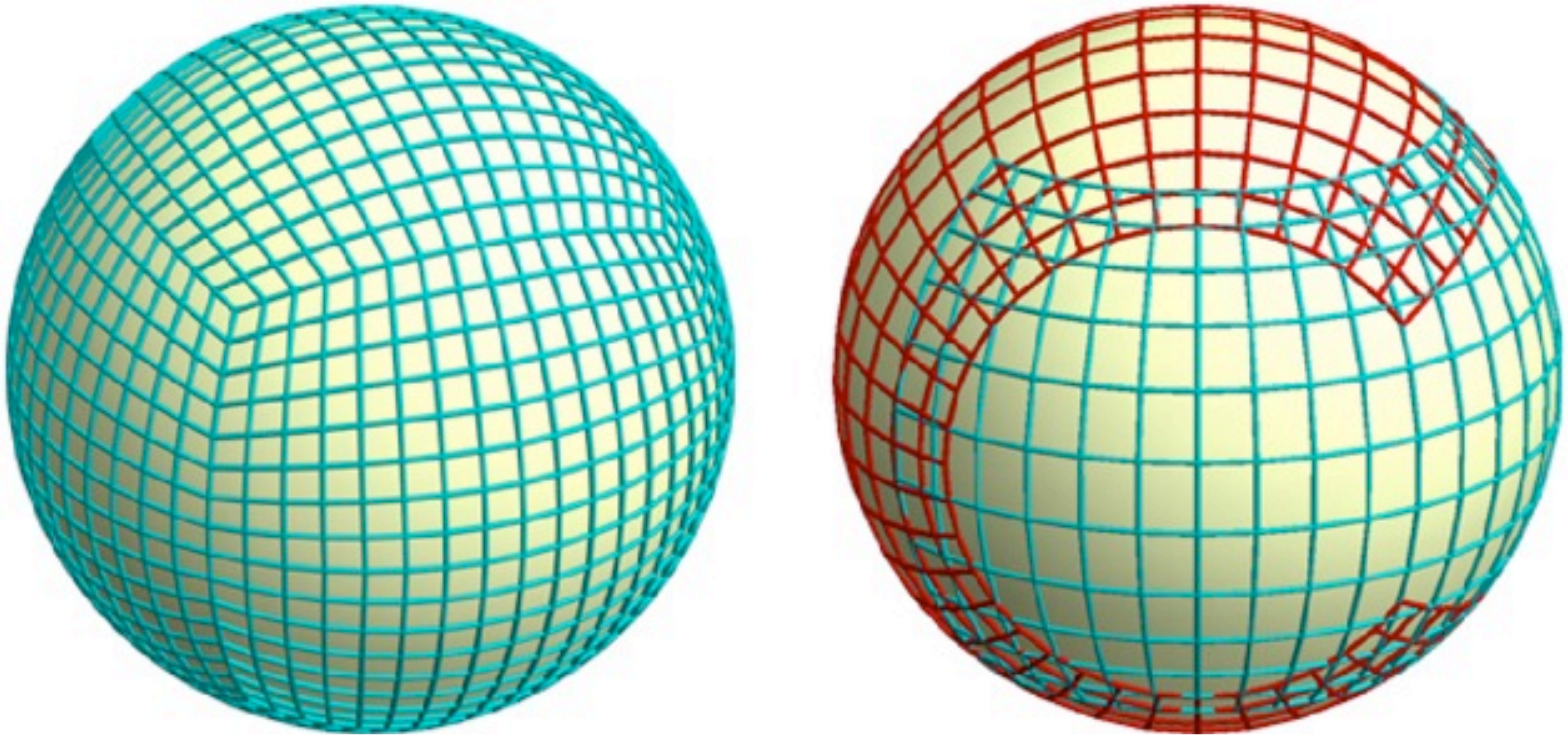
Twelfth CMMAP Team Meeting, 10-12 January 2012, Fort Lauderdale, FL
Dynamical Framework Working Group

Popular Global Grids (Nowadays)

(a) **Icosahedral hex/pent grid** (b) **Icosahedral triangular grid**



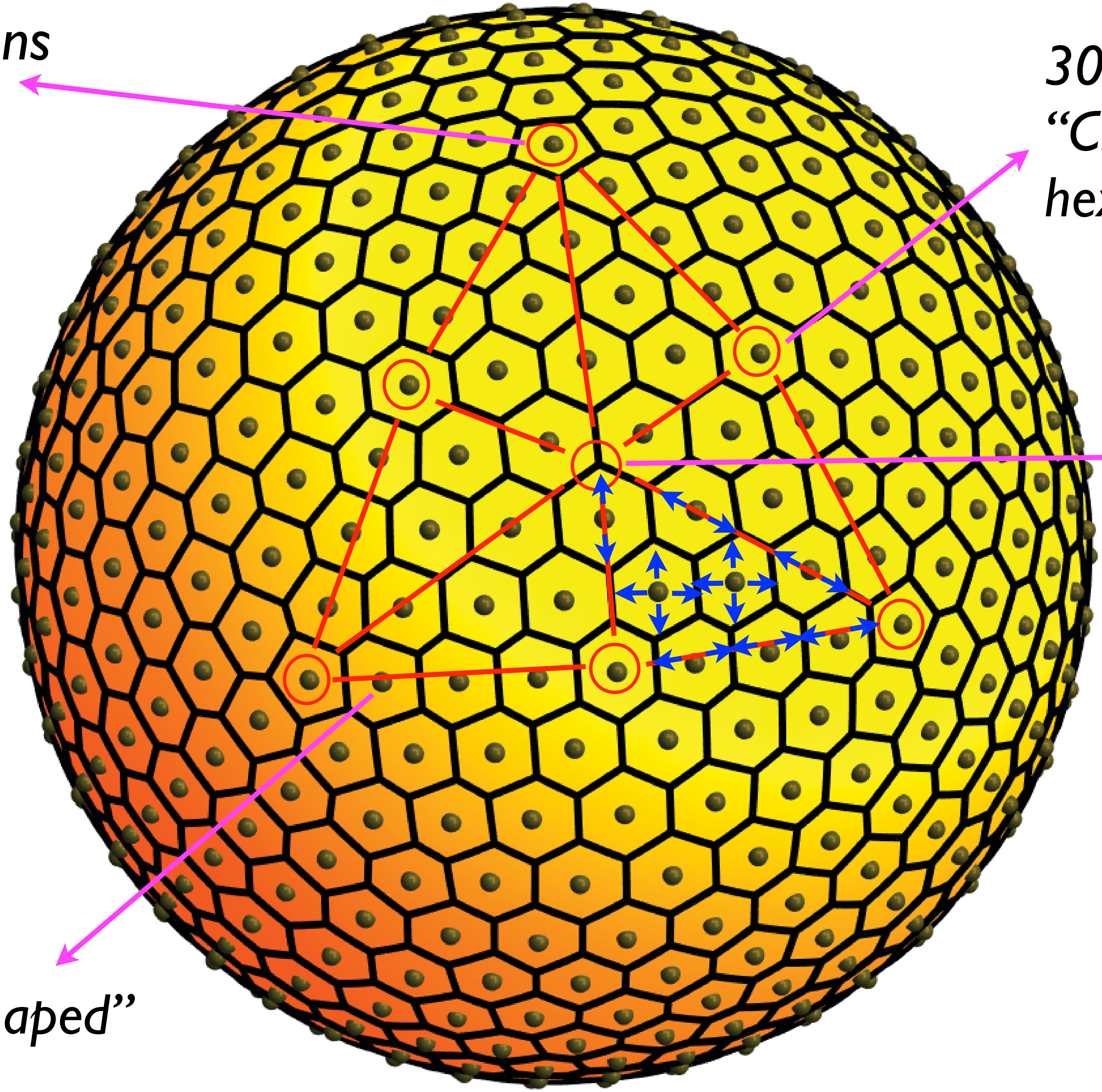
(c) **Cubed-Sphere grid** (d) **Overlapping yin-yang grid**



Criteria to choose a grid

Uniformity (in area, shape etc.)	(Weighting factor: 7/28)
Isotropy	(Weighting factor: 6/28)
Avoiding computational modes	(Weighting factor: 5/28)
Allowing "consistency"	(Weighting factor: 4/28)
Allowing conservation	(Weighting factor: 3/28)
Allowing computational efficiency	(Weighting factor: 2/28)
Allowing smooth resolution change	(Weighting factor: 1/28)

Some features of the icosahedral pen/hex grid



12 Pentagons

30 Elongated “Crystal-shaped” hexagons

“Center” corner

“Coffin-shaped” hexagons

G3 642 cells (~1000 km)

Update

Ross Heikes, C.S. Konor and D. Randall

Dept. of Atmospheric Science
Colorado State University

Grid Optimization Saga

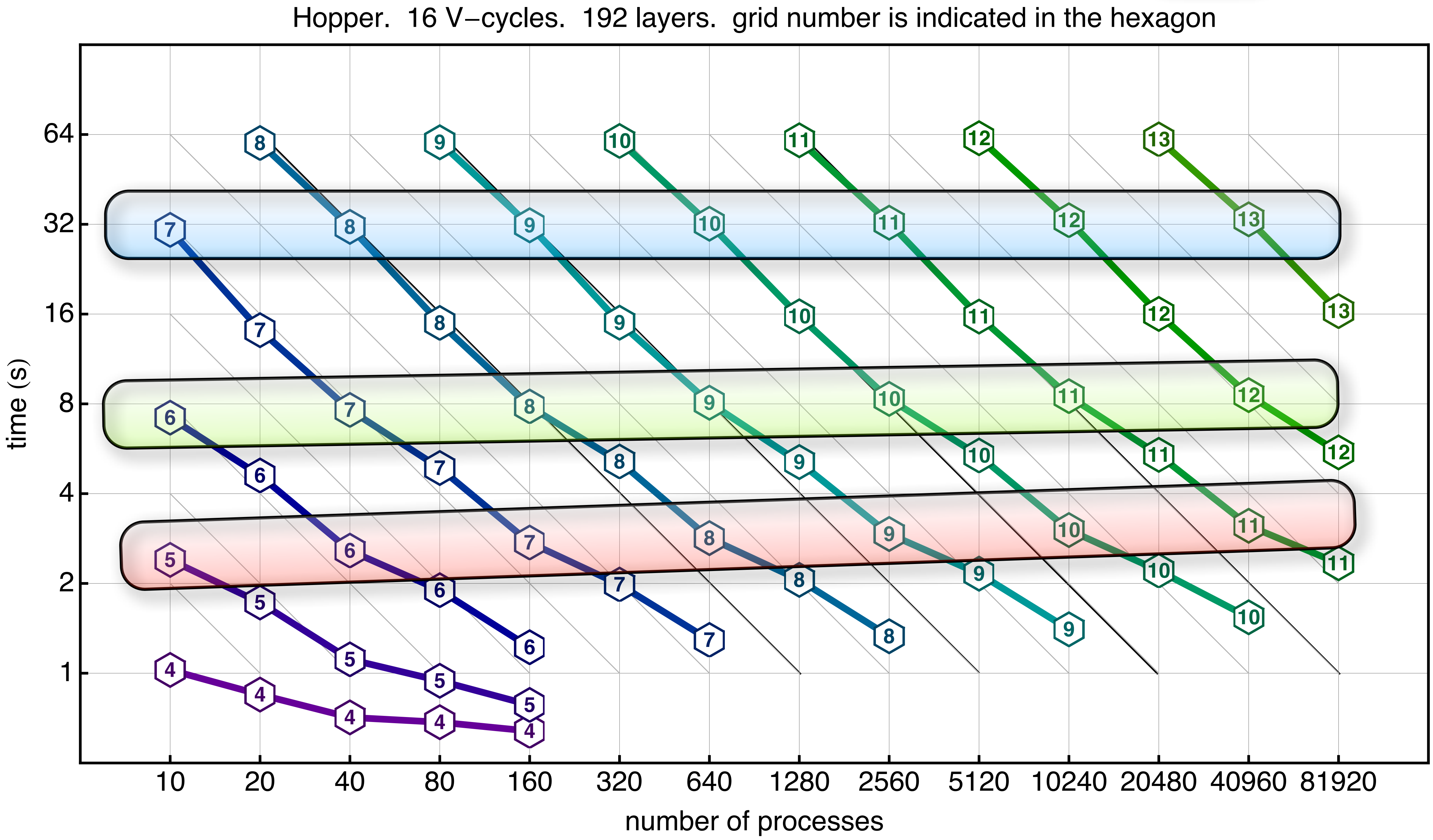
- The **grid optimization algorithm** positions the grid point to improve the convergence rate of the finite-difference operators.
- Number of independent variables is shown in the table.
- Since the last meeting we have tried to extend the optimization to grid 13.
- Grid 13 has proven itself difficult to fit onto any normal computer.

grid resolution	number of independent variables
(9) 2,621,442 (15.64km)	32,768
(10) 10,485,762 (7.819km)	131,072
(11) 41,943,042 (3.909km)	524,288
(12) 167,772,162 (1.955km)	2,097,152
(13) 671,088,642 (0.997km)	8,388,608

Parallel Scaling

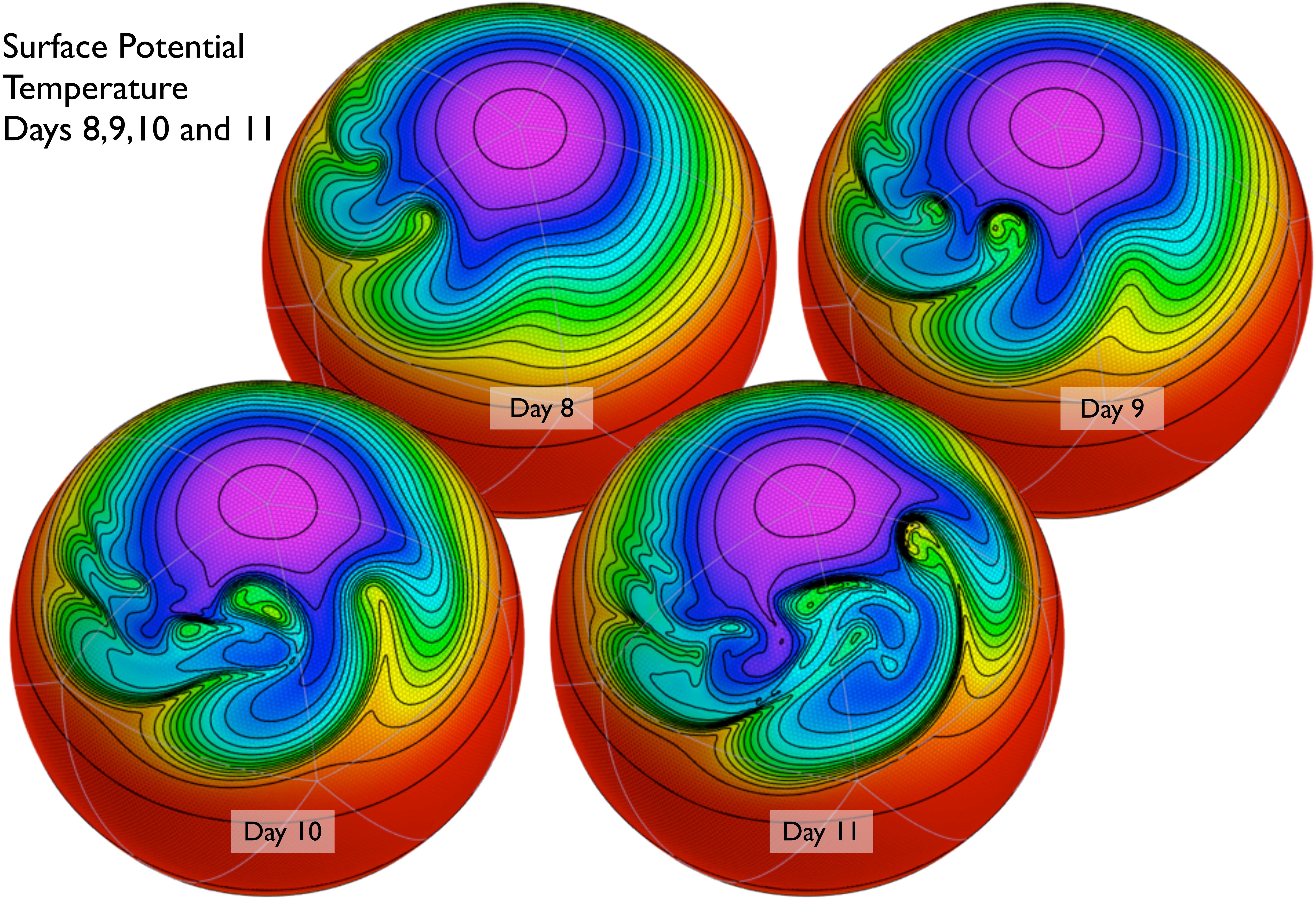
- What is the relation between parallel efficiency and parallel scalability?

🟦 pe=32
🟩 pe=16
🟥 pe=8


Hopper. 16 V−cycles. 192 layers. grid number is indicated in the hexagon

Extratropical cyclone

- Surface Potential Temperature
- Days 8,9,10 and 11



A parallel tridiagonal solver using OpenMP

- Let’s look at four experiments:

The **old** algorithm

Gaussian elimination and back substitution

time = 7.4×10^{-3}s

The **new** algorithm

1 OpenMp thread

time = 1.8×10^{-2}s
(2.5 time slower)

The **new** algorithm

4 OpenMp thread

time = 7.8×10^{-3}s
(1.06 time slower)

The **new** algorithm

6 OpenMp thread

time = 6.9×10^{-3}s
(0.93 time slower)

- Again, somewhat disappointing results

Action Items

- **Continue diagnostic exploration of the Unified Parameterization, and think about implementation**
- **Continue refining the coupling strategy for the Q3D MMF, and test using benchmark**
- **Finish and submit papers on grid optimization and multigrid solver**
- **Run and analyze Held-Suarez and Aquaplanet tests of GCRM**
- **Continue optimization of multigrid solver**
- **Explore strategies for adding topography to GCRM**
- **Continue parallel development of VV GCRM**