Dynamical Frameworks Working Group Report

- **Q3D MMF -- AA & JHJ**
- **Hex VVM & GCRM -- CK & RH**
- **ZC VMM -- HM**

DEVELOPMENT OF A NEW QUASI-3D ALGORITHM

Akio Arakawa and Joon-Hee Jung

I. Introduction

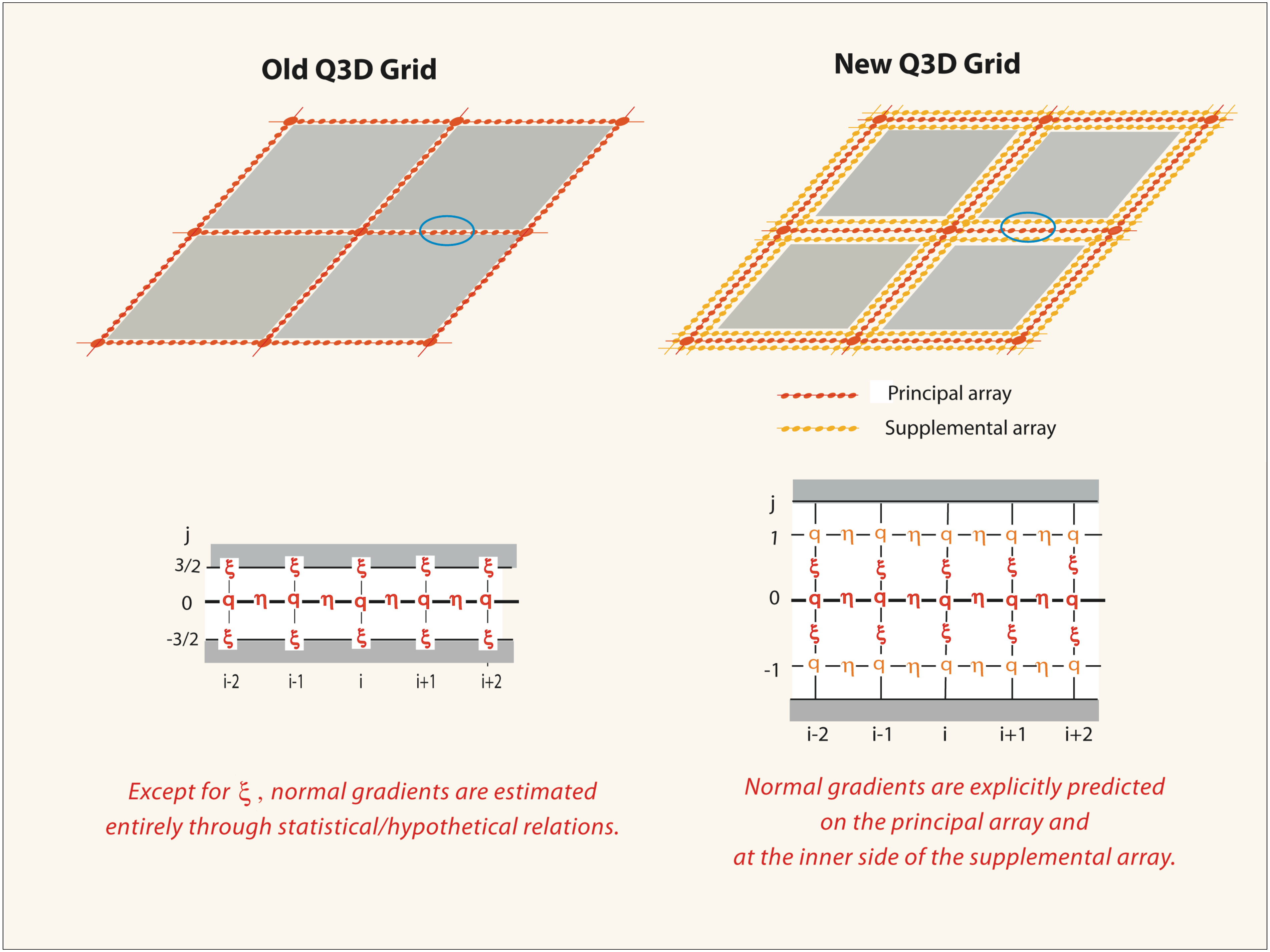
III. Old and new Q3D grids

III. Outline of the new Q3D algorithm

IV. Sample results

V. Summary and future plan

January 2009 CMMAP Team Meeting



Old Q3D Grid
New Q3D Grid
Principal array
Supplemental array
j
3/2
0
-3/2
i-2
i-1
i
i+1
i+2
j
1
0
-1
i-2
i-1
i
i+1
i+2
Except for ξ , normal gradients are estimated entirely through statistical/hypothetical relations.
Normal gradients are explicitly predicted on the principal array and at the inner side of the supplemental array.

SAMPLE RESULTS

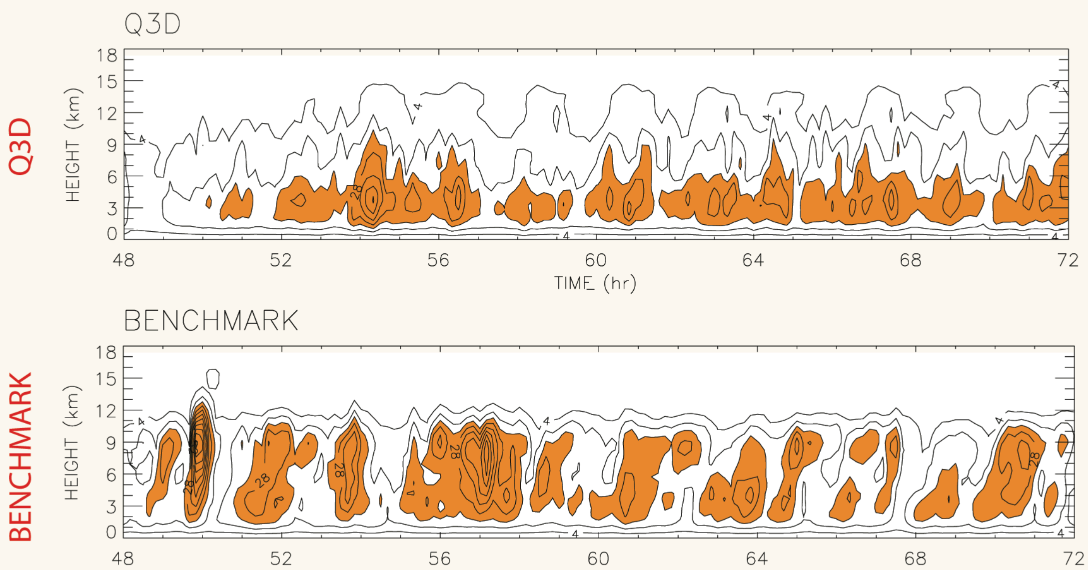
CRM grid size: 3 km GCM grid size : 96 km

Domain size : 384 km

Several problems have already been identified

Tests with full model

Time sequences of horizontal variance of w



Convective activity is not sufficiently deep.

SAMPLE RESULTS

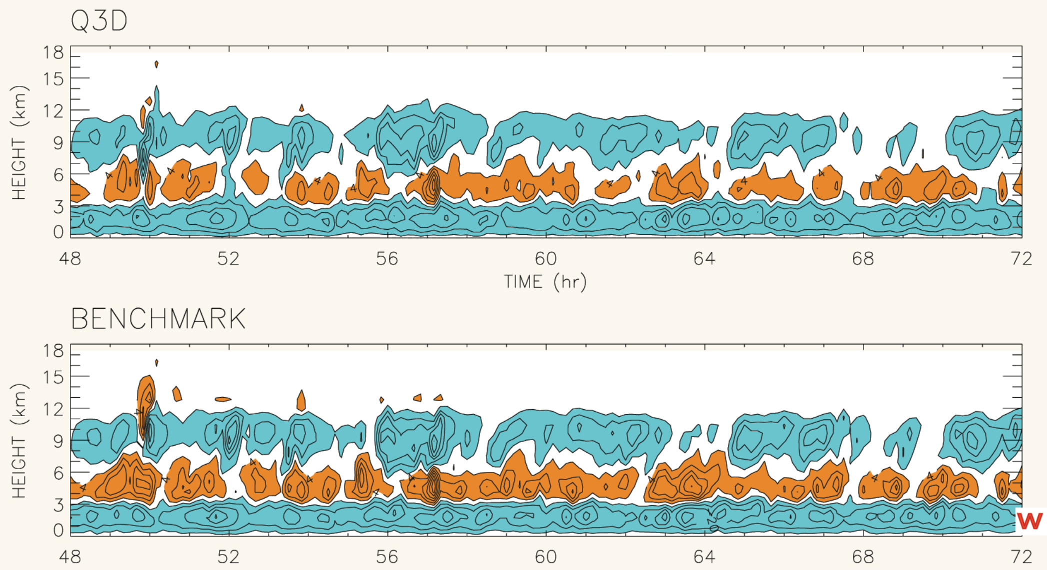
CRM grid size: 3 km GCM grid size : 96 km

Domain size : 384 km

Several problems have been identified

Tests with prescribed ξ, η and θ (Not trivial because the w-equation must be solved)

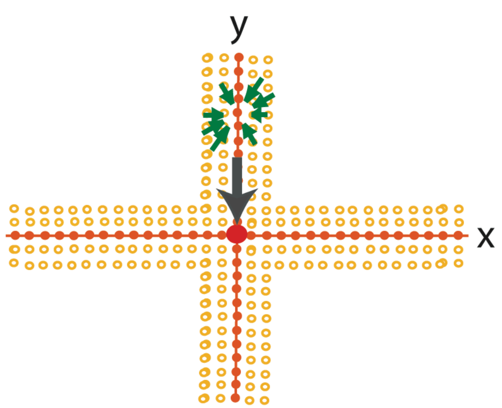
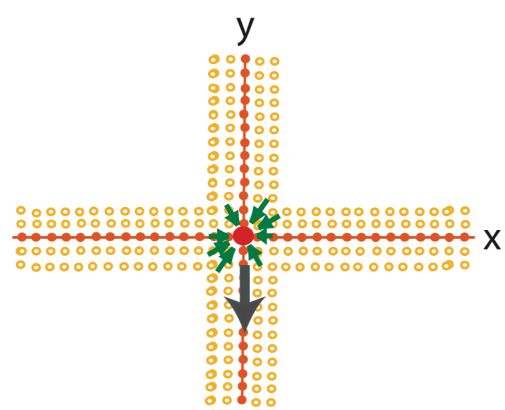
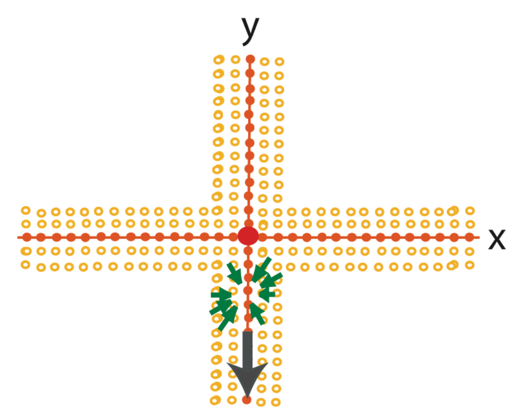
Time sequences of horizontal co-variance of u and w



This is encouraging .

There is another reason why convective activity is underpredicted.

Passage of a strong convective system over an intersection point produces large-scale circulation on the other axis.

		
The structure of the system in x is constrained.	The structure of the system in x becomes free, suppressing convective atvity on the x-axis by induced subsidence.	The structure of the system in x is again constrained, but the lare-scale circulation on the x-axis remains.

Control of netsize-scale circulation is the most serious problem we now have.

Summary

- We have developed a new Q3D algorithm that has a minimum degree of freedom for the 3D convective-scale dynamics.
- The 3D effect due to vorticity twisting seems to be well handled.
- The 3D effect due to advection also seems to be well handled although there is a room to improve inflow/outflow conditions.
- The convective-scale vertical velocity tends to be under-predicted. One of the cause for this seems to be the fixed (Dirichlet type) boundary condition for w at the boundary.
- The netsize-scale circulation also tends to suppress vertical velocity through subsidence..

Future Plan

- We will try to stabilize the model so that it does not have to depend on diffusion/damping for computational purpose.
- We need, however, to filter or damp the netsize-scale structure like

Construction of a Global Geodesic Cloud Resolving Model Based on the Vector Vorticity Dynamical Core

Hexagonal Vector-Vorticity Model (Hex-VVM)

Report on VVM Activities

Celal S Konor, Ross Heikes, Joon-Hee Jung, MingXuan Chen, Thomas Cram and David A Randall

Colorado State University

and

Akio Arakawa

University of California, Los Angeles

Report on VVM Activities

1 - Code development of VVM (with parallelized code) is completed

2 - Simulations with GATE Phase III forcing are underway

3 - CAM radiation is implemented as an option

4 - Work on the implementation of RRTMG radiation code is still continuing

Vector-Vorticity Model (VVM)

Jung and Arakawa (2008)

①- Derives and solves an elliptic equation for vertical velocity (w)

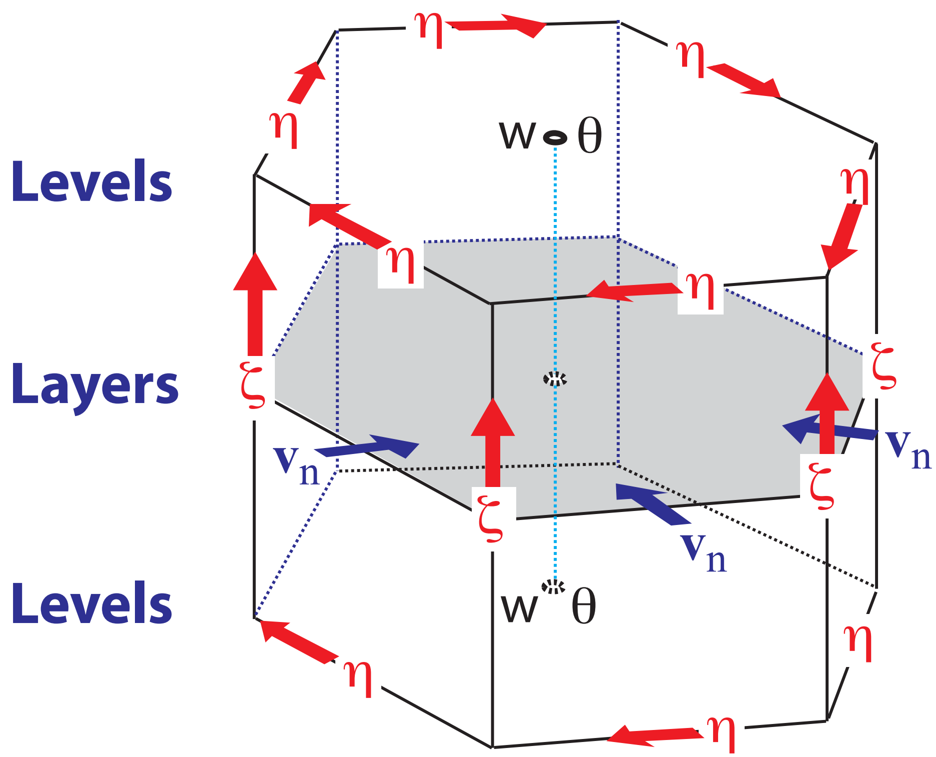
②- Obtains horizontal velocity (**v**) by vertically integrating η and using w (by using a proper boundary condition for **v**)

③- Obtains ζ by vertically integrating the divergence of 3D vorticity (after predicting ζ at a particular height)

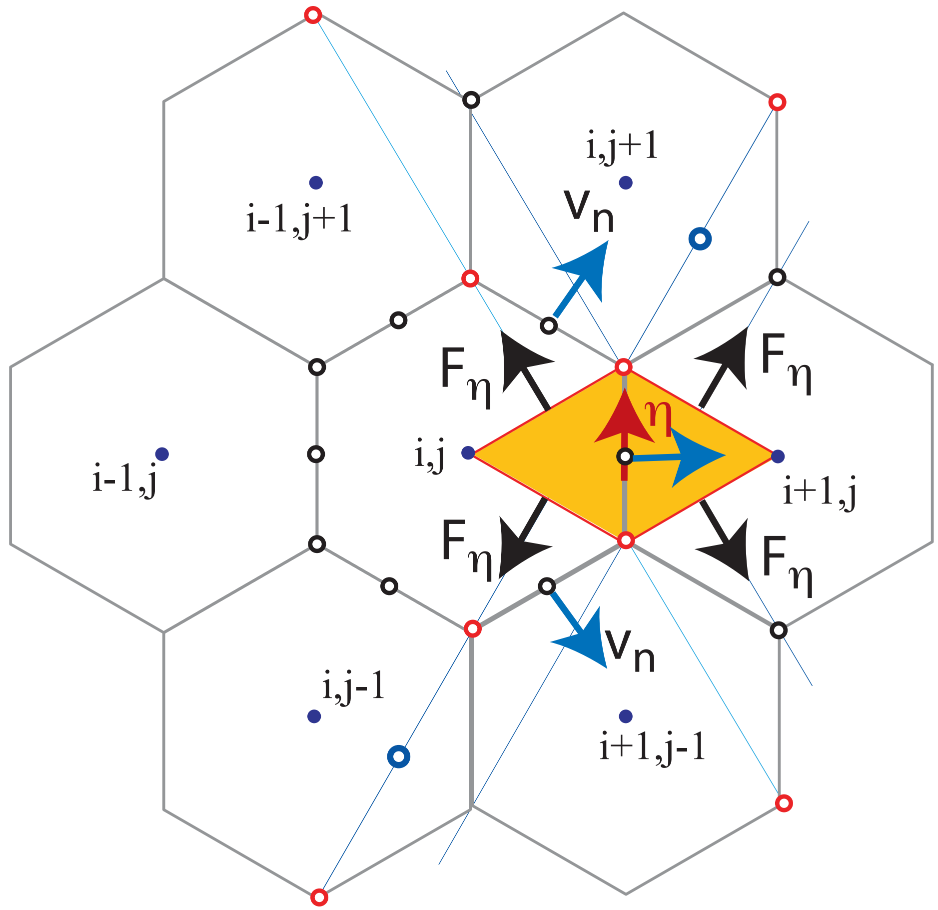
4- These calculations are made on Cartesian coordinates

Hexagonal Vector-Vorticity Model (Hex-VVM)

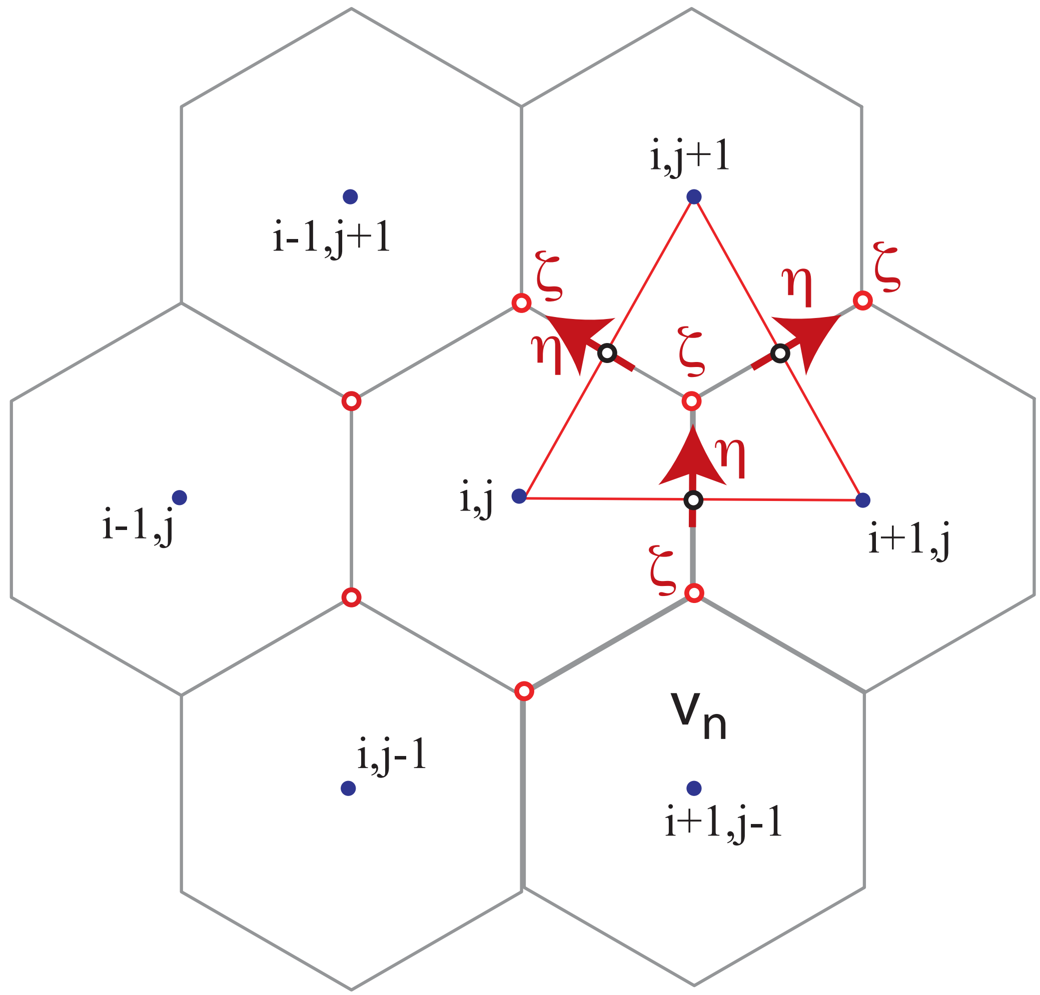
3-D view of the interior grid



Horizontal η Fluxes



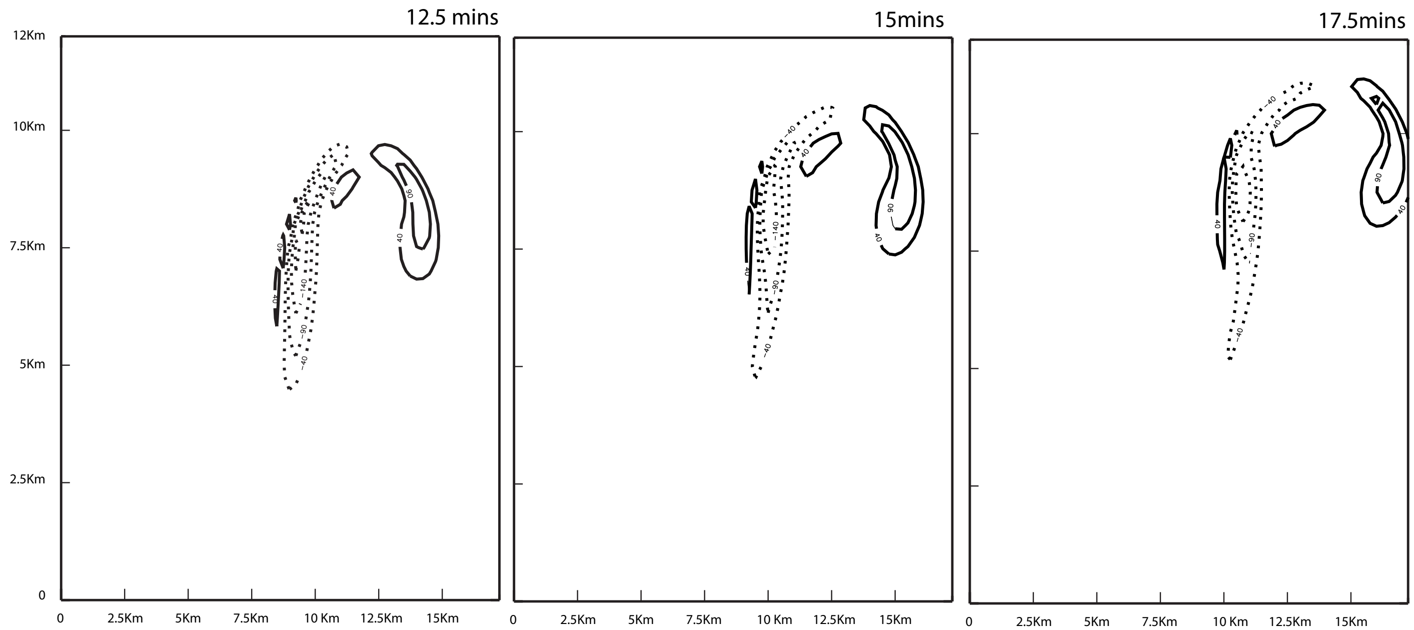
Distribution of η and ζ



Buoyant Bubble Experiment with Hex-VVM

Under Constant Westerly Shear (8.3×10^{-4} sec^{-1})

(Horizontal Component of Vorticity, η', 10^{-4} sec^{-1})



Exp75.7.1nn

Franklin (2D multigrid, 20 V-cycles, 20 layers)

The **NERSC Cray XT4** system, named **Franklin**, is a massively parallel processing (MPP) system with **9,660 compute nodes**. Each node has quad processor cores, and the entire system has a total of **38,640 processor cores**.

Each compute nodes consists of a **2.3 GHz** single socket **quad-core AMD Opteron processor (Budapest)** with a theoretical peak performance of 9.2 GFlop/sec per core (4 flops/cycle if using SSE128 instructions). **Each compute node has 8 GB of memory (2 GB of memory per core)**, and each service node (e.g. login node) has 8 GB of memory. Each compute node is connected to a dedicated **SeaStar2** router through Hypertransport with a 3D torus topology.

Time (s)		Number of cores					
		640	1280	2560	5120	10240	20480
Grid resolution	2,621,442 **(9)** (15.64km)	0.563	0.368	0.276	0.220		
	10,485,762 **(10)** (7.819km)	2.306	0.953	0.545	0.386	0.265	
	41,943,042 **(11)** (3.909km)	9.434	4.447	2.281	0.968	0.595	0.411
	167,088,642 **(12)** (1.955km)	insufficient memory per core	18.163	9.427	4.420	2.359	1.005
	671,088,642 **(13)** (0.977km)	insufficient memory per core	insufficient memory per core	insufficient memory per core	18.235	9.405	4.427

Progress in the development of a zonal channel version of the vector vorticity model

Hiroaki Miura (CSU)

Thanks to David Randall, Akio Arakawa, Celal Konor, Joon-Hee Jung, and Ross Heikes

- Motivation
- A parallel Poisson solver
- Current configuration of the model
- Test results
  - Cold bubble experiment
  - Held-Suarez-like test
- Summary

Motivation

regional ↓ global

Jung and Arakawa (2008)

- A new CRM using the vorticity equation (VVM)
- Cyclic conditions in X and Y
- Not parallelized

Celal and MingXuan's model

- Upgrading the original model
- Cyclic conditions in X and Y
- Parallelized (FFT)

My work

- Zonal channel (Cyclic in X, walls in Y)
- Parallelized (Multigrid)

VVM on the spherical geodesic grid (future)

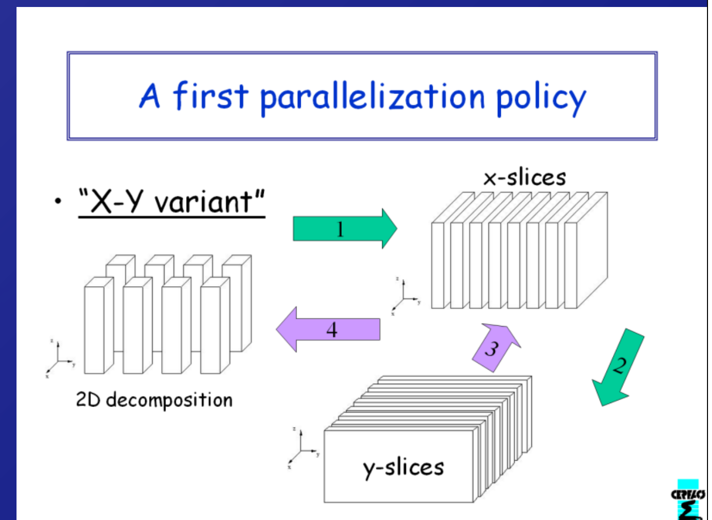
- Celal is working on a hexagonal VVM
- Ross is working on the Multigrid method

Why multigrid?

FFT can be faster even on parallel computers.

• Celal and MingXuan's model is testing a FFT solver.

• Other examples using FFT: SAM, meso-NH



From a presentation of Dr. L. Giraud
http://www.cerfacs.fr/~giraud/Talks/parCfd.pps

Merits of the multigrid method

• It is easier to code.

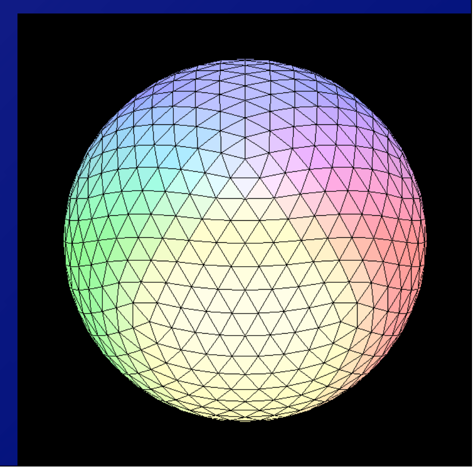
• Its computation is local.

  • We can code it using MPI_(I)SEND and MPI_(I)RECV only.

  • This may be desirable for large number of processors.

• We can use the same method on the spherical geodesic grid.

  • Heikes and Randall (1995)



Held-Suarez(-like) test

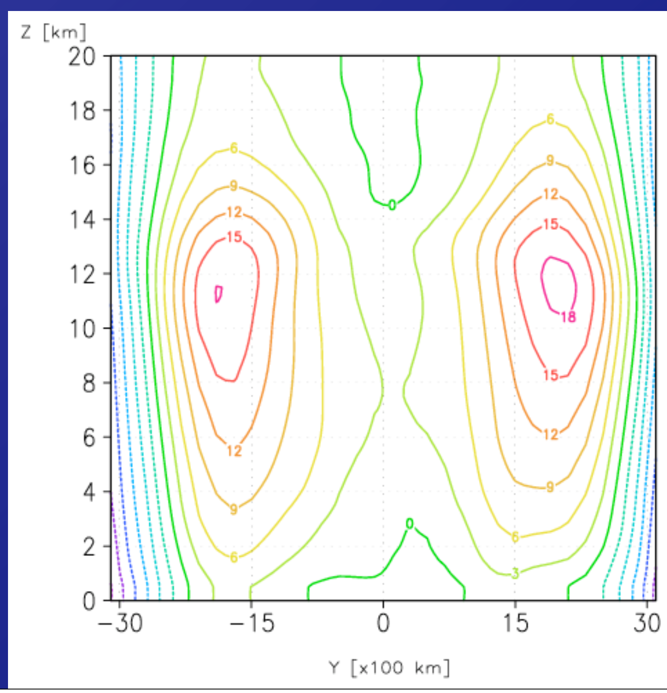
Following Held and Suarez (1994), but the forcing terms are modified to be a function of z because pressure is not diagnosed in my model currently.

Equatorial beta plane was assumed.

dx=dy= 200 km
dz= 500 m
dt = 600 s
nx= 16 x 2 (processes)
ny= 16 x 2 (processes)
nz = 60
np = 4

Day 30

Zonal mean zonal wind



Potential temperature and winds