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
Except for $\xi$, 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 $\xi$, $\eta$ and $\theta$ (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 activity on the x-axis by induced subsidence.

The structure of the system in x is again constrained, but the large-scale circulation on the x-axis remains.

Control of large-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 \(h\) and using \(w\) (by using a proper boundary condition for \(v\))

③- Obtains \(g\) by vertically integrating the divergence of 3D vorticity (after predicting \(g\) 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

Levels

Layers

Levels
Horizontal $\eta$ Fluxes
Distribution of $\eta$ and $\zeta$
Buoyant Bubble Experiment with Hex-VVM
Under Constant Westerly Shear (8.3 × 10^{-4} \text{ sec}^{-1})

(Horizontal Component of Vorticity, $\eta^\prime$, 10^{-4} \text{ sec}^{-1})
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 node 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.

<table>
<thead>
<tr>
<th>Grid resolution</th>
<th>Time (s)</th>
<th>Number of cores</th>
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<tbody>
<tr>
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<tr>
<td>(11) (3.909km)</td>
<td>(11) (3.909km)</td>
<td>9.434</td>
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<tr>
<td>(12) (1.955km)</td>
<td>(12) (1.955km)</td>
<td>insufficient memory per core</td>
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<tr>
<td>671,088,642</td>
<td>671,088,642</td>
<td>671,088,642</td>
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<tr>
<td>(13) (0.977km)</td>
<td>(13) (0.977km)</td>
<td>insufficient memory per core</td>
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</tbody>
</table>
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

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

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.

d$x$=dy= 200 km

d$z$= 500 m

d$t$ = 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