Progress Report:

1) **Cloud Resolving Global Model**
   - a) ***Planar Hexagonal*** **Anelastic Model**
   - b) ***Global Geodesic*** **Anelastic Model**

2) **Parallel Vector-Vorticity Model**

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Planar Hexagonal Anelastic Model
(Completed Tasks)

- ☑ A paper presenting a unification of the anelastic and quasi-hydrostatic systems of equations is submitted.
- ☑ Coding: Horizontal advections of variables for cell centers, corners and walls are completed (parallelized and optimized).
- ☑ Several solution methods for the 3D elliptic w-equation are tested.
- ☑ Coding: The 3D elliptic solver is coded (parallelized and optimized).

3D Elliptic w-Equation

$$\nabla_H^2 w + \frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 w\right)\right] = \underbrace{-\boldsymbol{k}\cdot\nabla_H \times \boldsymbol{\eta}}_{RHS}$$

I) Elliptic Form (Iterative Method)

(a)

$$\left\{\underbrace{\nabla_H^2 w + \frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 w\right)\right]}\right\} = RHS$$

Centered in space

Backward in “time” for the center point

Forward in “time” for the surrounding points

“time” describes iteration order

(b)

$$\left\{\underbrace{\nabla_H^2 w} + \underbrace{\frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 w\right)\right]}\right\} = RHS$$

Centered in space

Backward in time for the center point

Forward in time for the surrounding points

Centered in space

Backward in time

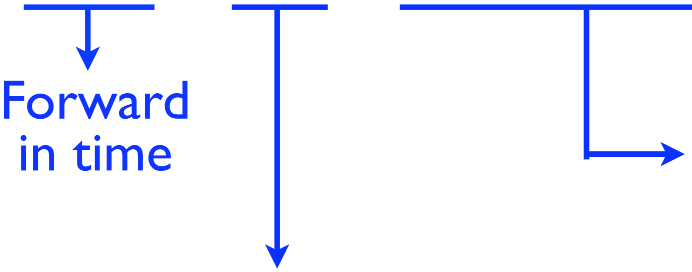
(*Implicit in vertical*)

3D Elliptic w-Equation

$$\left\{\nabla_H^2 w + \frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}(\rho_0 w)\right]\right\} = RHS$$

II) Parabolic Form (Relaxed Method)

$$\mu\frac{\partial w}{\partial t} = \left\{\nabla_H^2 w + \frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}(\rho_0 w)\right]\right\} - RHS$$



Forward
in time

Centered in space

Backward in time

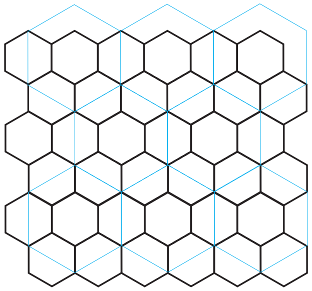
Centered in space

Backward in time for
the center point

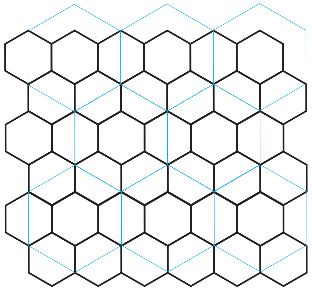
Forward in time for
the surrounding points

For m=0, Relaxed method becomes identical to the iterative method (Ib)

Solution Procedure for I and II



$$\mu \frac{\partial w}{\partial t} = \left\{ \nabla_H^2 w + \frac{\partial}{\partial z}\left[\frac{1}{\rho_0} \frac{\partial}{\partial z}\left(\rho_0 w\right)\right]\right\} - RHS$$



Start from a good guess for w

Discrete form with Ia

$$w_{i,j,k+1/2}^{(\kappa+1)} = F\left(w^{(\kappa)}_{i+i',j+j',k+1/2},\ w^{(\kappa)}_{i,j,k-1/2},\ w^{(\kappa)}_{i,j,k+3/2},\ RHS_{i,j,k+1/2} \right)$$

Discrete form with Ib and II

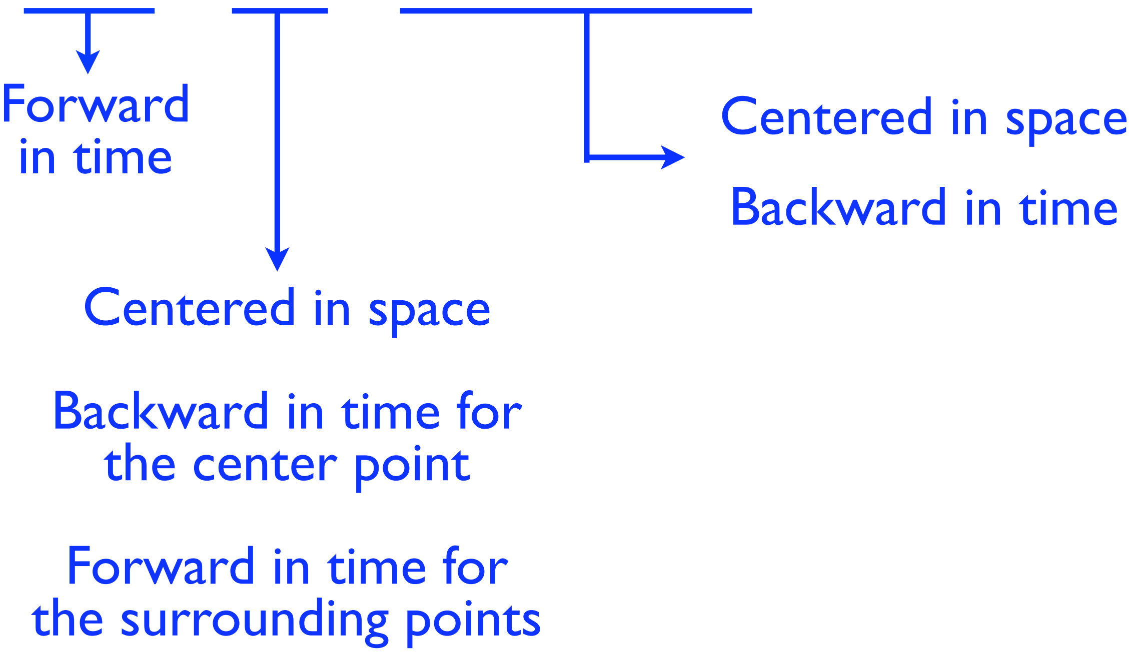
$$A_{k+1/2} w^{(\kappa+1)}_{i,j,k-1/2} + B_{k+1/2} w^{(\kappa+1)}_{i,j,k+1/2} + C_{k+1/2} w^{(\kappa+1)}_{i,j,k+3/2} = D\left(w^{(\kappa)}_{i+i',j+j',k+1/2},\ RHS_{i,j,k+1/2} \right)$$

3D Elliptic w-Equation

$$\left\{\nabla_H^2 w + \frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 w\right)\right]\right\} = RHS$$

III) Relaxed Method with Multigrid Solver

$$\mu\frac{\partial w}{\partial t} = \left\{\nabla_H^2 w + \frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 w\right)\right]\right\} - RHS$$



Forward
in time

Centered in space

Backward in time

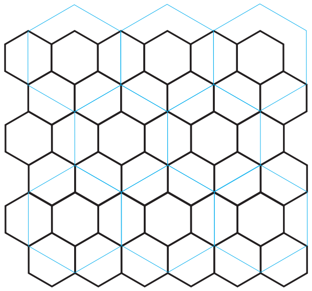
Centered in space

Backward in time for
the center point

Forward in time for
the surrounding points

Solution Procedure for III

①

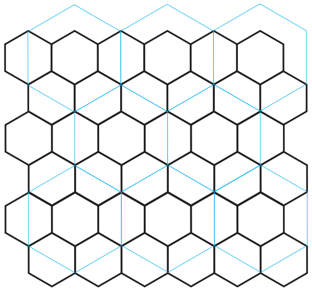


Start from a good guess for w

Native Resolution

$$\mu\frac{\partial w}{\partial t}=\left\{\nabla_H^2 w+\frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 w\right)\right]\right\}-RHS$$

③



Start from $w+w'$

$$R=\nabla_H^2 w+\frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 w\right)\right]-RHS$$

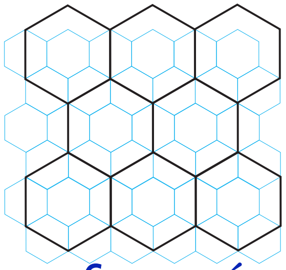
Residual

One Level Lower Resolution

②

Restricting

$R \Rightarrow R_{LR}$



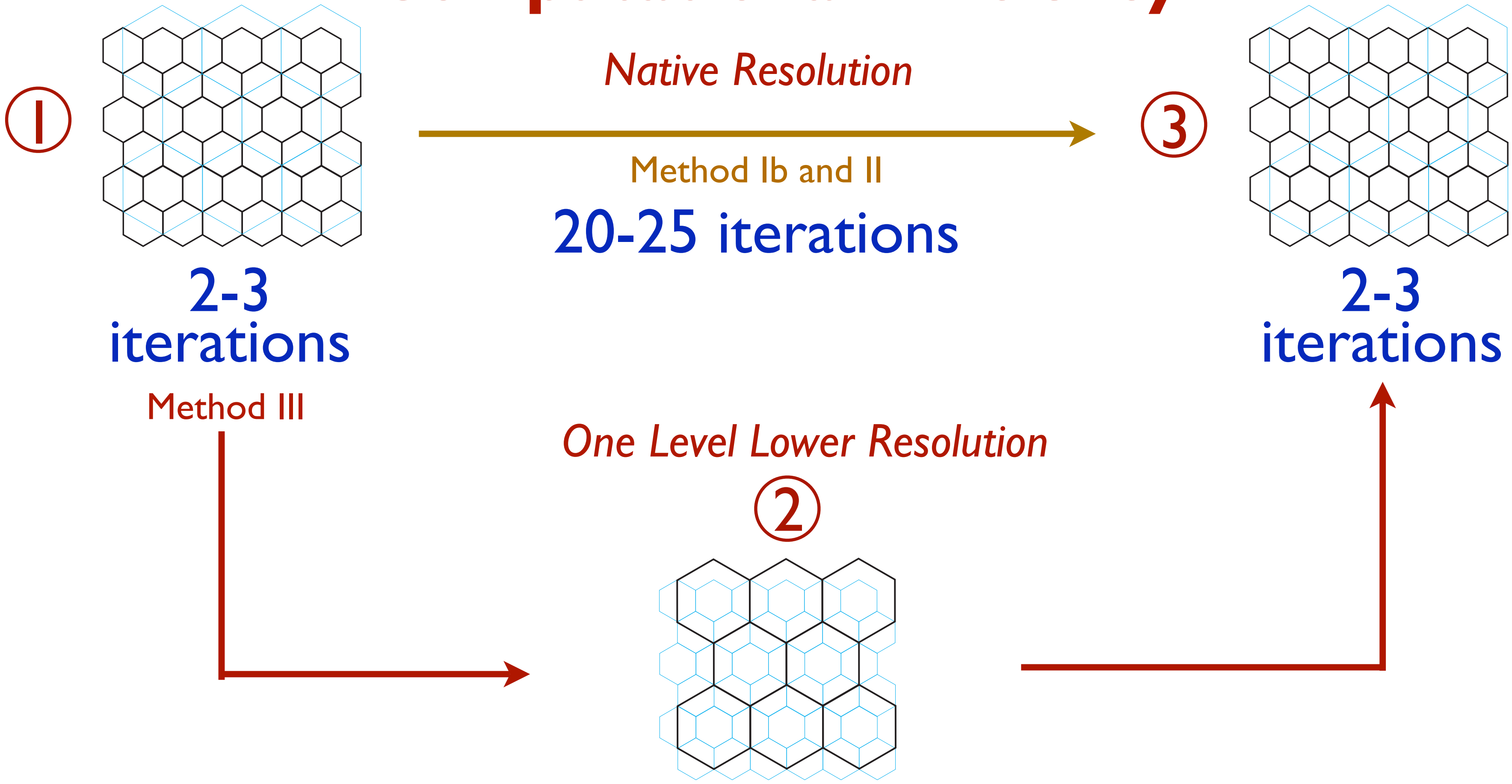
Prolonging

$w'_{LR} \Rightarrow w'$

Start from $w'_{LR}=0$

$$\mu\frac{\partial w'_{LR}}{\partial t}=\left\{\nabla_H^2 w'_{LR}+\frac{\partial}{\partial z}\left[\frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 w'_{LR}\right)\right]\right\}+R_{LR}$$

Computational Efficiency



①

Native Resolution

Method Ib and II

20-25 iterations

③

2-3
iterations

2-3
iterations

Method III

One Level Lower Resolution

②

10-12
iterations
(equivalent to 3
iterations in native resolution)

Projections

Planar Hexagonal Anelastic Model

Feb 2008: Non buoyant bubble experiment

Mar 2008: Buoyant bubble experiment and simulations with physics

July 2008: Tests with the *unified system of equations*

Global Geodesic Anelastic Model

Mar 2008: Non buoyant bubble experiment

May 2008: Buoyant bubble experiment and simulations with physics

Parallel Vector-Vorticity Model

Currently: The code is not integrable.

Mar 2008: Complete and verify the code by comparing to the sequential version.

May 2008: Test various radiation schemes in the sequential and parallel versions of the Vector-Vorticity Cloud Model.