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2) Conference on **Current Efforts Toward Advancing the Skill of Regional Weather Prediction. Challenges and Outlook,** *April 20 - 22*

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Medium Range Weather Forecasting using a Variable Resolution Version of the Global Eta Model

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Medium Range Weather Forecasting Using a Variable Resolution Version of a Global Eta Model

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- Introduction
- Global Eta Model Framework (GEF)
- Experiments
- Conclusions and future work

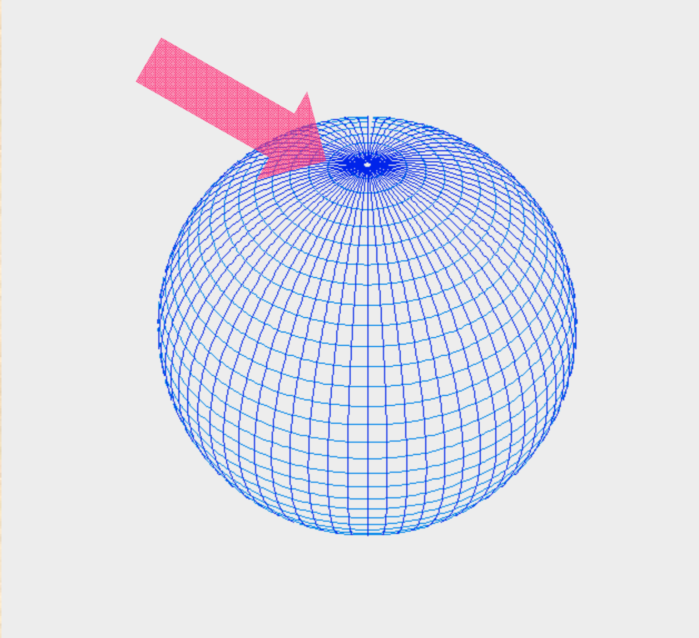
Introduction

- With an extension of weather forecasting time (for example to about 10 days), the adverse effect of boundary forcing in a limited area model is expected to aggravate
- This is a simple consequence of disproportion that exists between the high- and the low-resolution solutions that can only become worse with increase of time
- For example, the phase lag between the two solutions increase with time

- One way to cope with this problem is to replace a classical paradigm with two separate models, global and regional, running one after another with a single global model operating at variable resolution
- Such a variable resolution model approach was successfully applied in the regional climate studies (e.g. Fox-Rabinovitz 2000)
- We here propose application of a similar approach in the medium (up to about 10 days) weather forecasting
- Recently developed variable resolution version of a global Eta model 'framework' (GEF) is used and this study

Global Eta Model Framework (GEF)

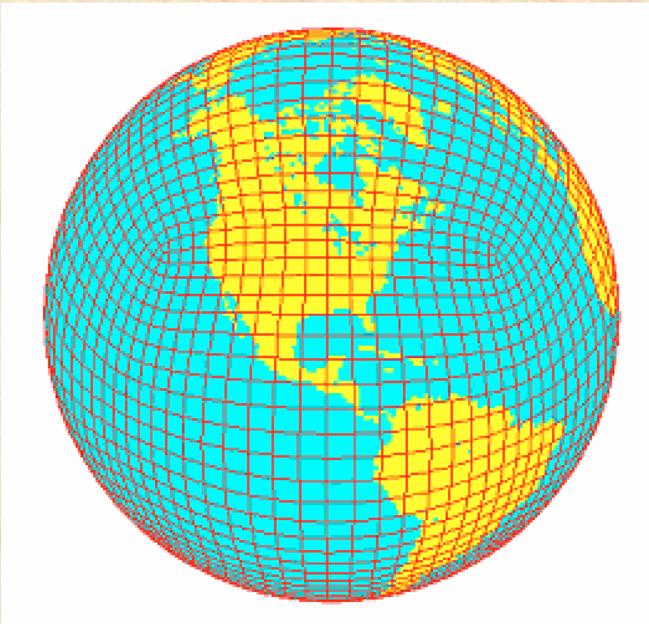
- Standard longitude-latitude grid has many problems in global modeling
- The basic questions related to treatment of poles are
  - How to maintain conservation of important integral constraints?
  - How to apply polar filtering?



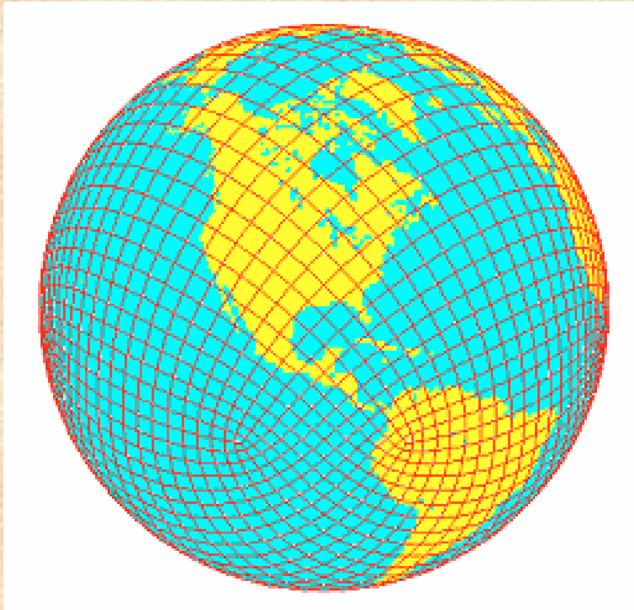
- Rancic and Nickovic (1988) suggested a solution to the first problem which was implemented by Wyman (1996) in a GFDL version of the Eta model
- Yet, the feeling that the poles represent a major nuisance, came once again in the focus of attention with appearance of distributed memory computers

- Polar filtering is a "typical example of an excessive spatial resolution which does not effectively use computing resources" (c.f., Randal et al. 1997)
  - First, the areas around poles are "over-resolved" – wasting memory
  - Then, the effect of this over-resolution is thrown away – wasting computing time
- Additionally, there is a problem of load balancing – meaning that in principle the rest of the processors is idle while the processors assigned to deal with areas around poles are computing polar filtering
- And finally, application of polar filtering generally requires global operators – which assume a lot of communications

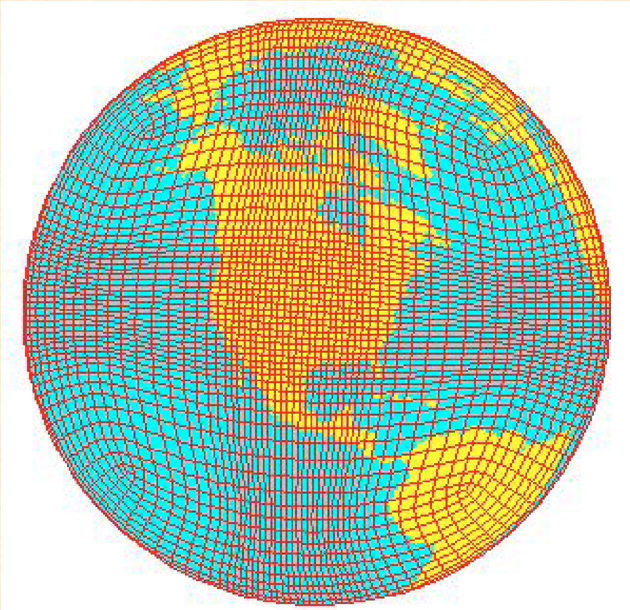
- Global Eta model framework consists of a global version of NCEP's Eta model derived using quasi-uniform spherical grids for horizontal discretization:
  - cubic (Rancic et al. 1996)
  - octagonal (Purser and Rancic 1997), and
  - their derivatives designed in formulation of the variable resolution
- This approach evades the polar problem by casting a fairly uniform mesh of grid points over the sphere



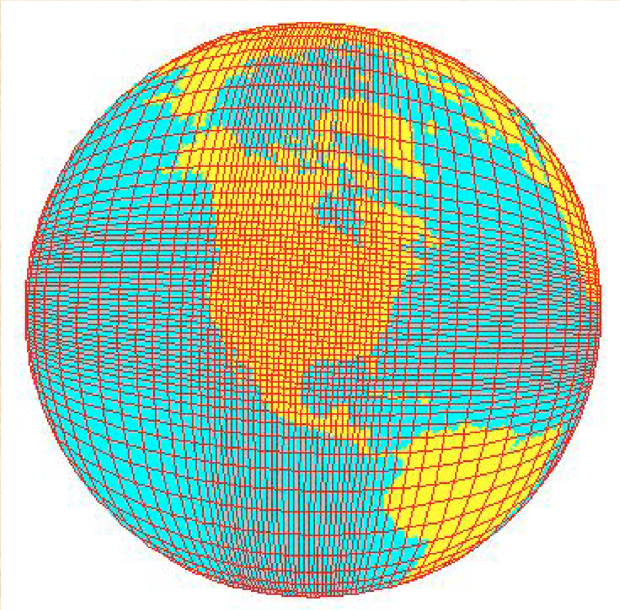
Cubic grid



Octagonal Grid



Cubic grid with variable resolution



Octagonal grid with variable resolution

- Eta model dynamics is converted in a general curvilinear system using the concept of covariant and contravariant winds

$$\frac{\partial u}{\partial t} = (\zeta + f)G\tilde{v} - \frac{\partial}{\partial x}\left(\frac{u\tilde{u} + v\tilde{v}}{2}\right) - \dot{\eta}\frac{\partial u}{\partial \eta} - \frac{\partial \Phi}{\partial x} - \frac{RT}{p}\frac{\partial p}{\partial x}$$

$$\frac{\partial v}{\partial t} = -(\zeta + f)G\tilde{u} - \frac{\partial}{\partial y}\left(\frac{u\tilde{u} + v\tilde{v}}{2}\right) - \dot{\eta}\frac{\partial v}{\partial \eta} - \frac{\partial \Phi}{\partial y} - \frac{RT}{p}\frac{\partial p}{\partial y}$$

$$\frac{\partial T}{\partial t} = -\left(\tilde{u}\frac{\partial T}{\partial x} + \tilde{v}\frac{\partial T}{\partial y}\right) - \dot{\eta}\frac{\partial T}{\partial \eta} - \frac{1}{c_p}\frac{RT}{p}\omega$$

$$\frac{\partial m}{\partial t} = -\frac{1}{G}\left(\frac{\partial m\tilde{u}G}{\partial x} + \frac{\partial m\tilde{u}G}{\partial y}\right) - \frac{\partial m\dot{\eta}}{\partial \eta}$$

$$\frac{\partial \Phi}{\partial \eta} = -\frac{RT}{p}m$$

- Here:

(u,v) - covariant wind components

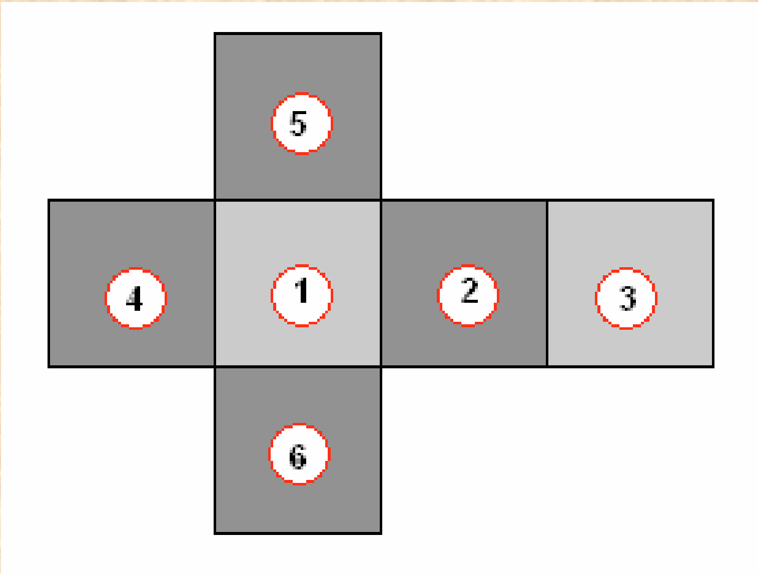
$(\tilde{u},\tilde{v})$ - contravariant wind components

G - Jacobian of transformation

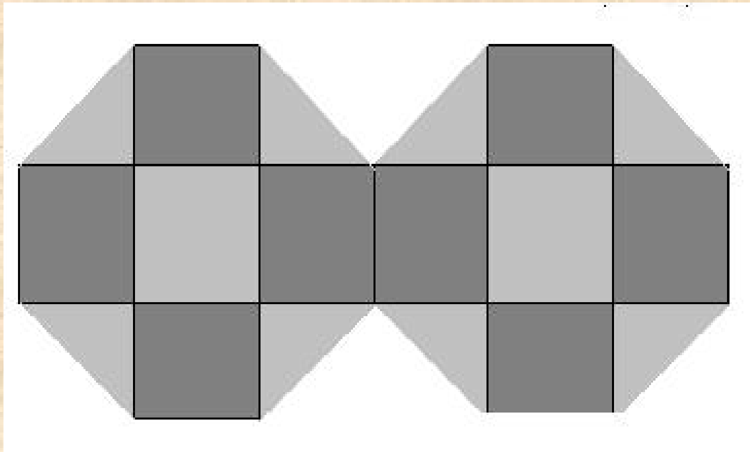
$$m = \frac{\partial p}{\partial \eta} = \frac{1}{\eta_s}(p_s - p_T)$$

- Model physics is generally defined in columns and does not strictly depend on underlying geometry

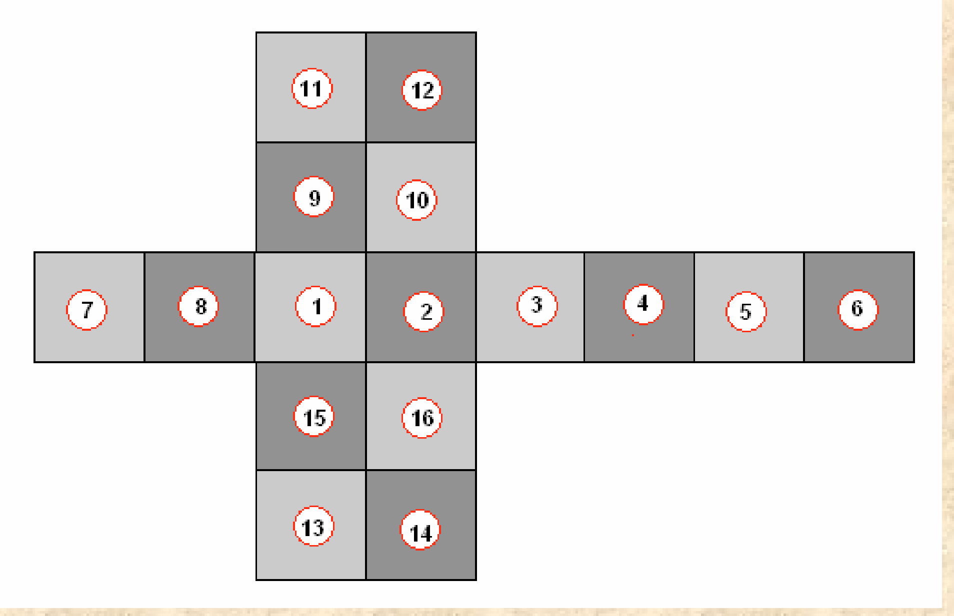
- One advantage of this approach is that the same code can be run on each of the grids of the framework, with only difference in definition of communications among processors



Topology of basic cubic grid

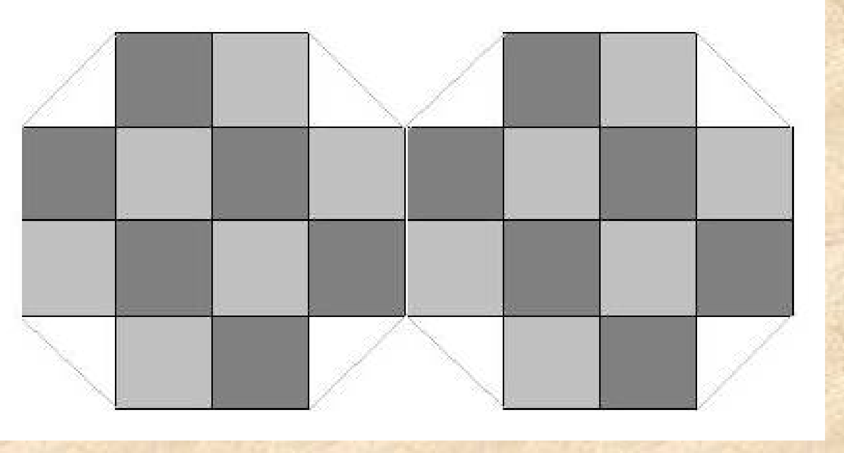


Topology of basic octagonal grid



Topology of the first derived cubic grid

Topology of the first derived octagonal grid



Groups that use conformal cubic grid

- Climate model at MIT (John Marshal)
- An oceanic model at NCEP (Dmitry Chalikov)
- Atmospheric model of Australian Weather Bureau (John McGregor)
- An oceanic model at Japanese Earth Simulator (Motohiko Tsugawa)
- An atmospheric model associated with Japanese Earth Simulator (Sung-Dea Kang)
- …

Potential Applications

- Study and simulation of tropical phenomena (hurricanes, El Niño, etc.) because a cubic version of this model has some 15% higher resolution around equator then long-latitude grid models with the same number of grid-points
- Study and simulations of polar circulation and phenomena (ozone, stratospheric sudden warming, interaction with ice, etc.) because neither cubic nor octagonal version has a singular polar problem and both provide a uniform resolution in polar regions
- Regional medium range weather forecasting

Experiments

- At this moment, we were able to run four series of 5 days forecasts (starting from 0000 UTC Feb 1,2005) using:

  (1) Variable resolution cubic grid.

  Face 1 to 4 have 181x61 grid points.

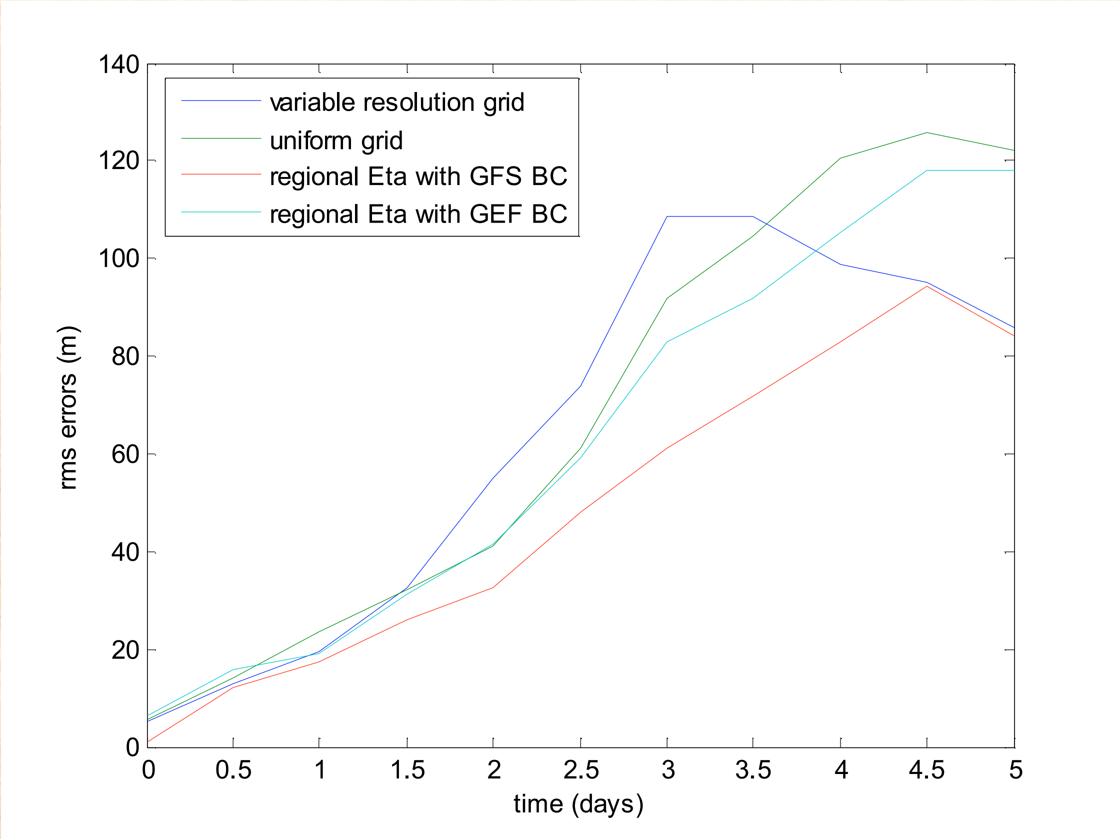
  Face 5 and 6 have 181x181 grid points. The region with high resolution is located over the United States area. The low resolution area has a grid distance of 166 km and the high resolution area has a grid distance of about 40 km. The global stretch factor is 4.2. The time step is set to 80 s.

(2) Uniform cubic grid with low resolution (GEF). The mesh is set to 61x61x6 grid points with a grid distance of about 166 km. The time step is set to 180 s.

(3)The regional Eta model. The grid distance is set to 40 km. Boundary values are acquired every three hours from NCEP GFS global model run, which has resolution of T126 (about 110km). The integration area covers the United States. The time step is set to 80 s.

(4)The regional Eta model. Same as (3)with boundary conditions derived from GEF

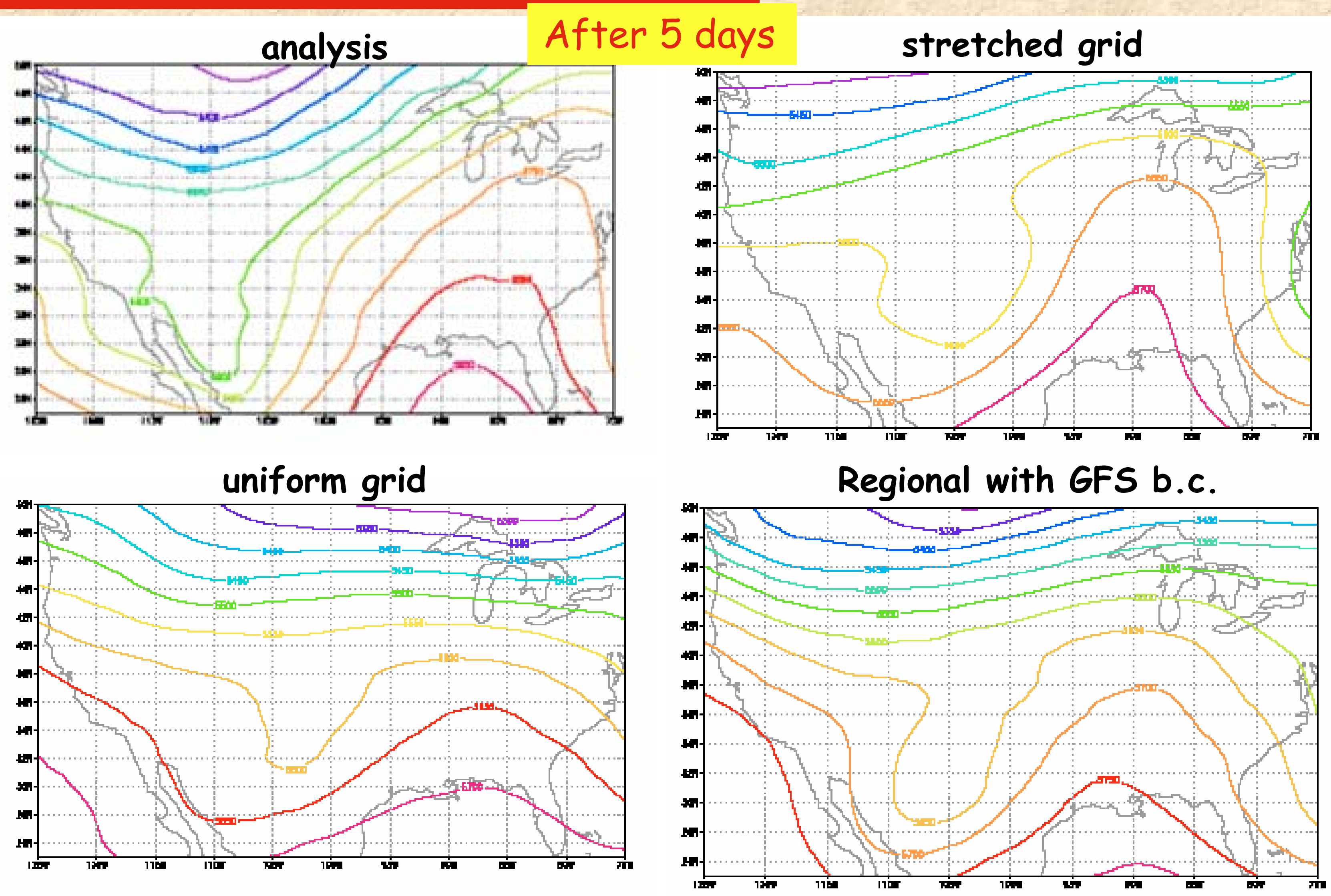
- Geopotential heights of 500 mb surface derived in the experiments are compared against the analysis data. The figure show evolution rms errors over US region



- The regional Eta model with GFS boundary condition has the best performance. This is expected since GFS has higher resolution than the low resolution portion of the variable resolution global Eta model.
- After day 3, the rms error of the variable resolution grid drops, and it performs fairly similar to regional Eta
- We speculate that during first 3 days model physics sufficiently spins up in order to enable better performance of the model

Global Eta Model :
Variable Resolution

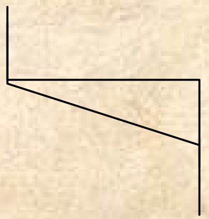
M. Rancic



Conclusions and future work

- The stretched grid model was able to perform at the end of a 5 day integration almost as well as the regional model – in spite of being forced by a substantially lower resolution
- Dropping back of rms error after 3 days of the worst performance, is an interesting behavior of the stretched grid model that yet has to be explained
- We begin experiments with 10-day forecast for both cubic and octagonal variable resolution grids
- We also begin to build an emulation of a multimodel ensemble forecasting systems using different grid structures

- Including a strong conservative formalism and Janjic (1984) nonlinear advection scheme (as well as Rancic 1988) in the Global Eta Framework is the next important step **[There is a new solution!]**
- For high-resolution integrations – close and below 10 km – propagation properties of the pure gravity waves in the Eta model has to be fixed **[There is a new solution!]**
- Increased resolution of the elevated PBL
  - Molod (2004) at MIT solved the problem of eta coordinate in representing elevated PBL
- Sloped terrain



A version of the regional Eta where a slope is included has been recently finished and is now in the stage of testing

Acknowledgements

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- The work is done on a Beowulf cluster computer ('Kali') located at the Mathematics Department of UMBC