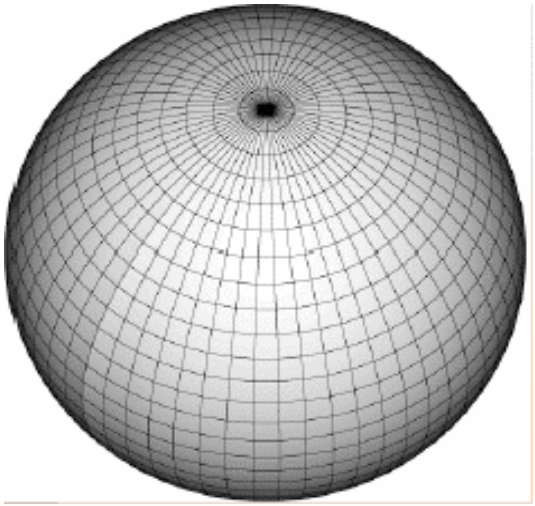
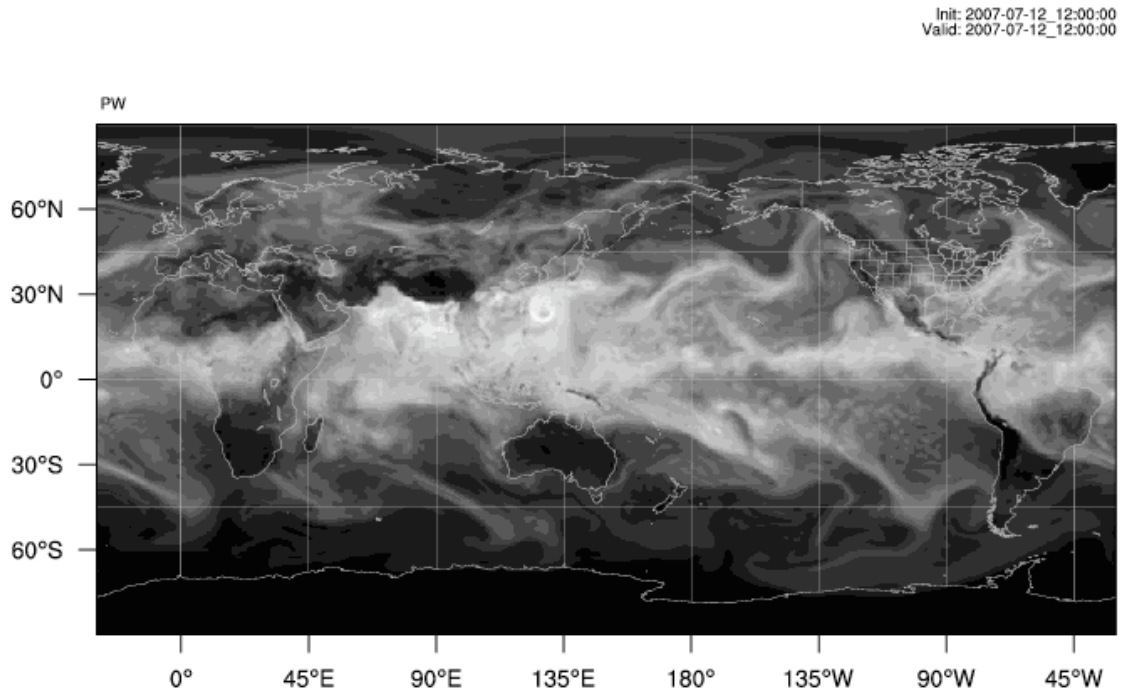
Global WRF Development

Bill Skamarock NCAR/MMM

WRF Version 3, released 4 April 2008

Precipitable water, 10 day forecast 2007-07-12 to 2007-07-22, 50 km grid



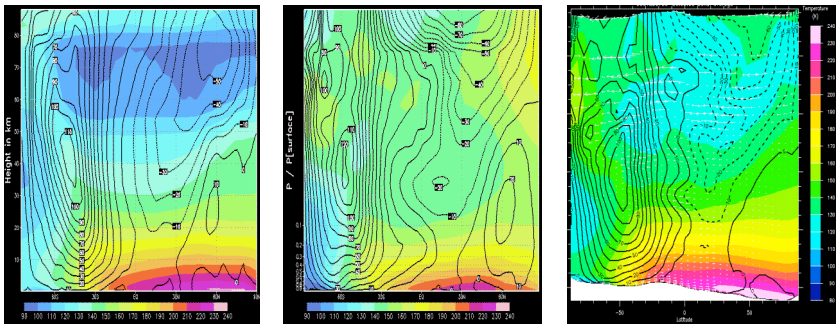


WRF Global Model

Global WRF on a lat-long grid

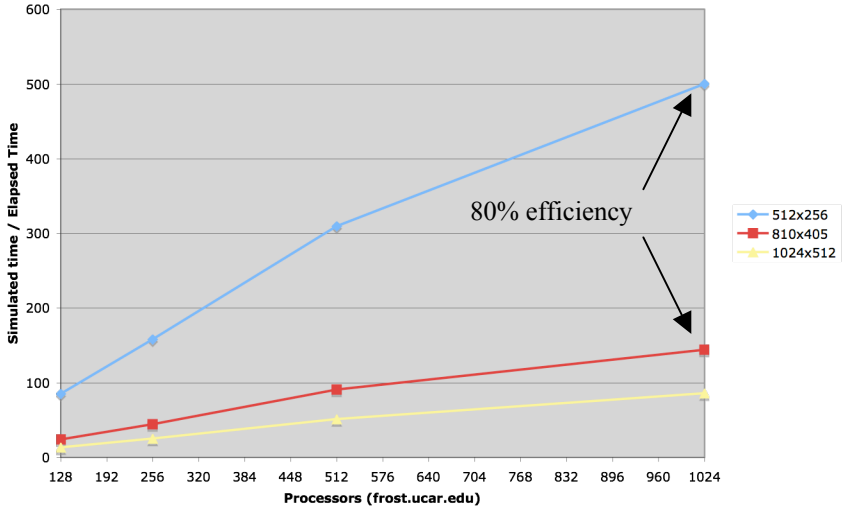
- Adapted from community development at Cal Tech for planetary atmospheres
- Functional system for nested nonhydrostatic global simulations
- Baseline for future nonhydrostatic global model development

Mars at northern summer solstice (temperature and zonal wind)



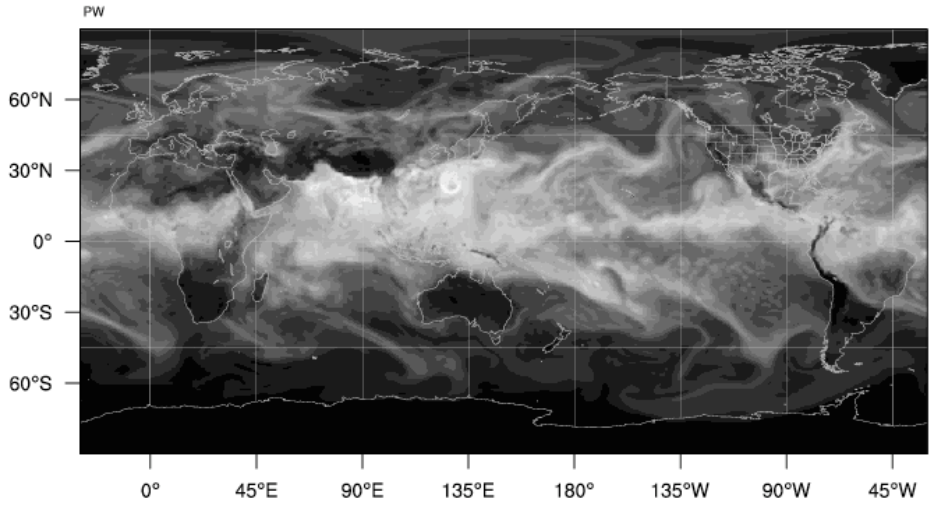
GFDL MARS GCM | Oxford Mars GCM | Global WRF

Simulation speed [1]



10 day precipitable water forecast, initialized 7-11-2007 12Z

810 x 405 x 41 (x,y,z), ~50 km grid at the equator, 200 second timestep



Latitude-Longitude Grid
WRF Version 3 Release

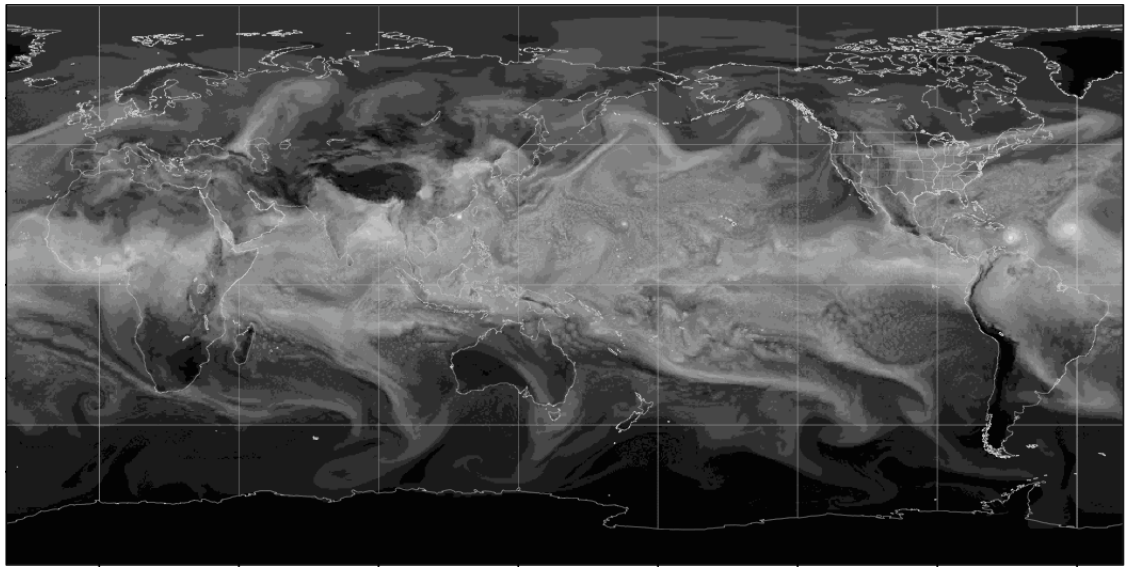
Additions to WRF Version 2

- Map factors are generalized - m_x and m_y
  - Computational grid poles need not be geographic poles.
  - Limited area and nesting capable.
- Upper gravity-wave absorbing layer
- Polar boundary conditions
- Polar filtering

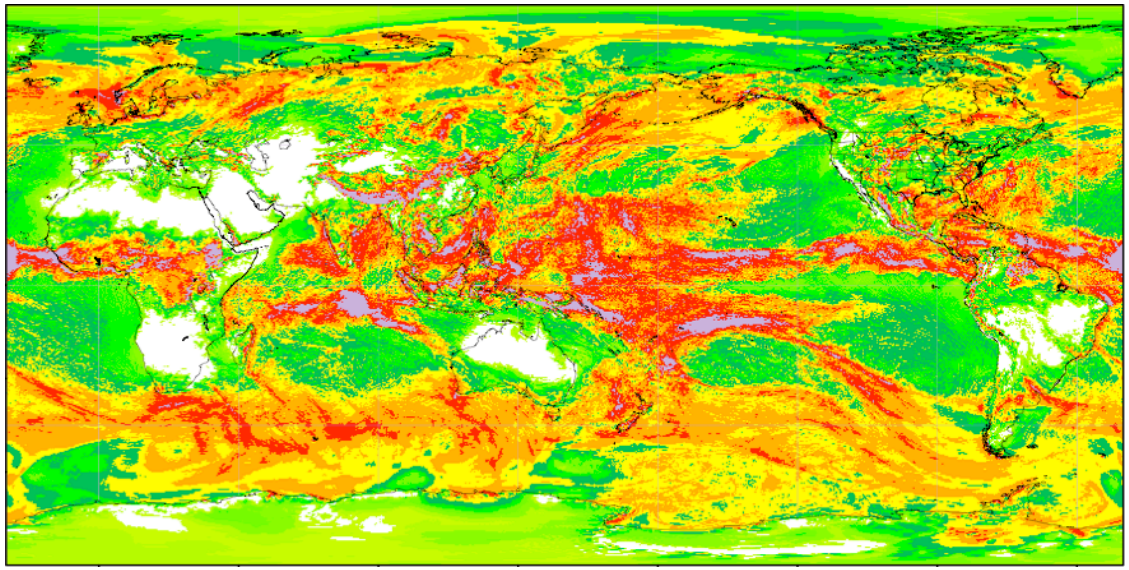
Global WRF

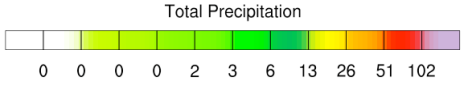
20 km, 5 day forecast, valid 00 UTC 8 August 2007

Precipitable water

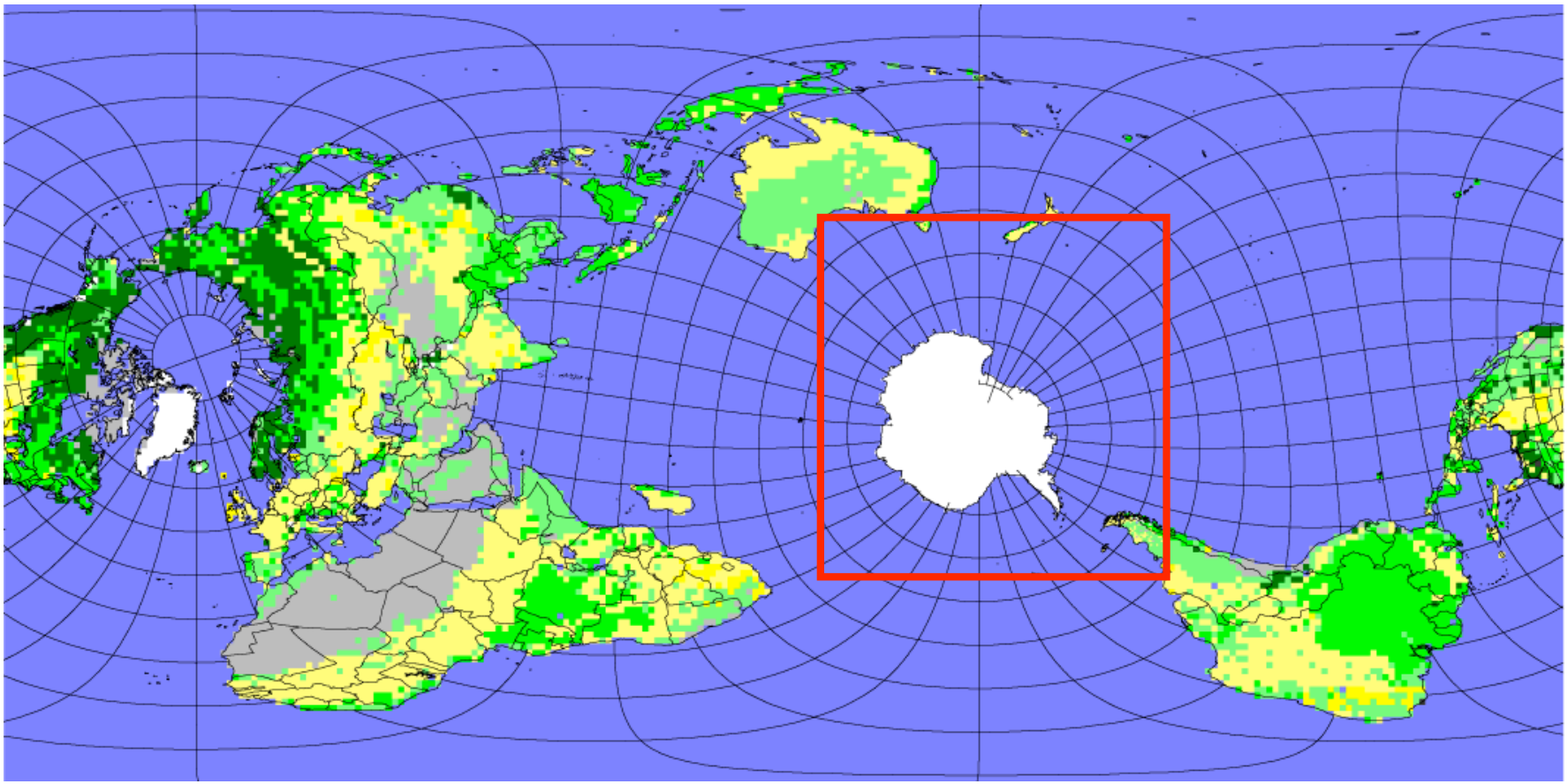


Accumulated precipitation



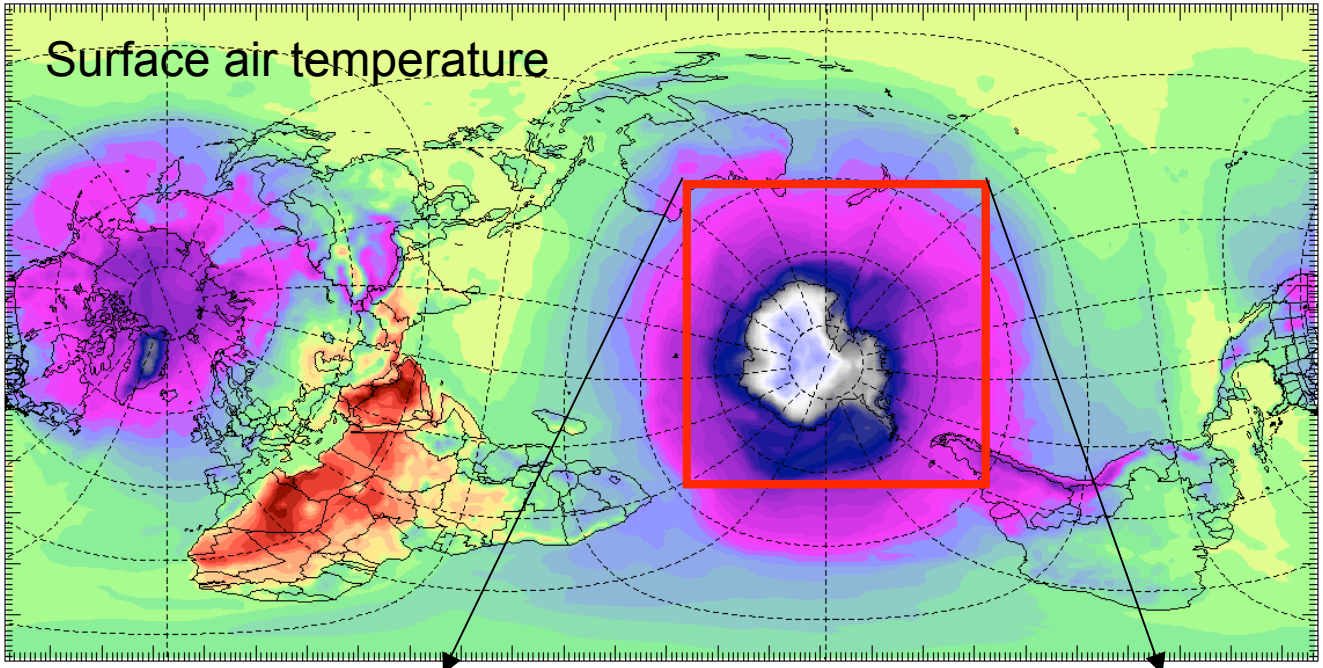


Latitude-Longitude Grid

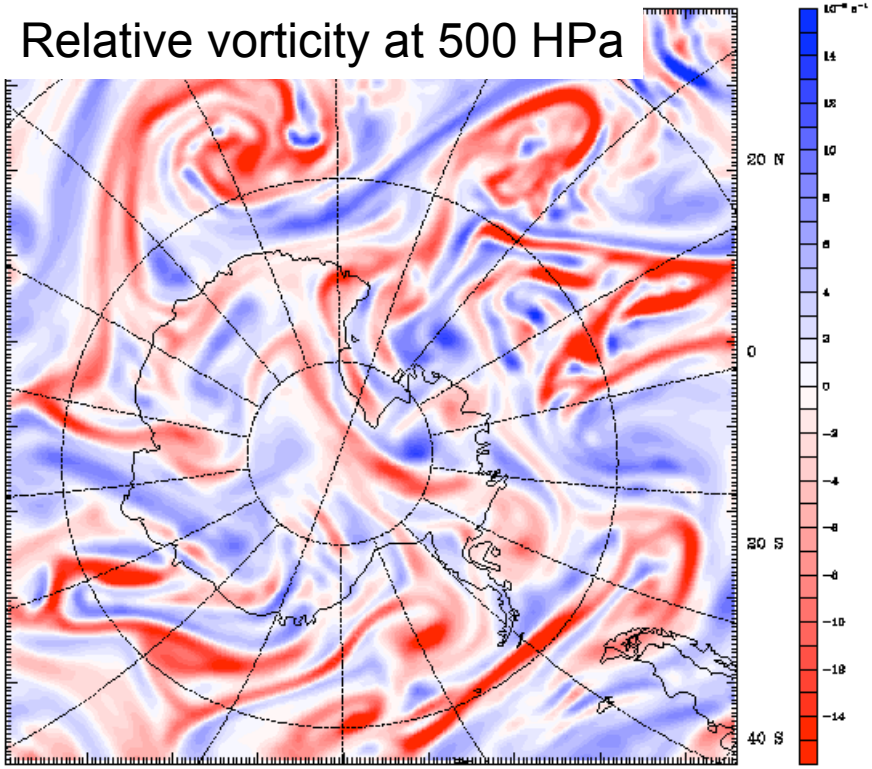


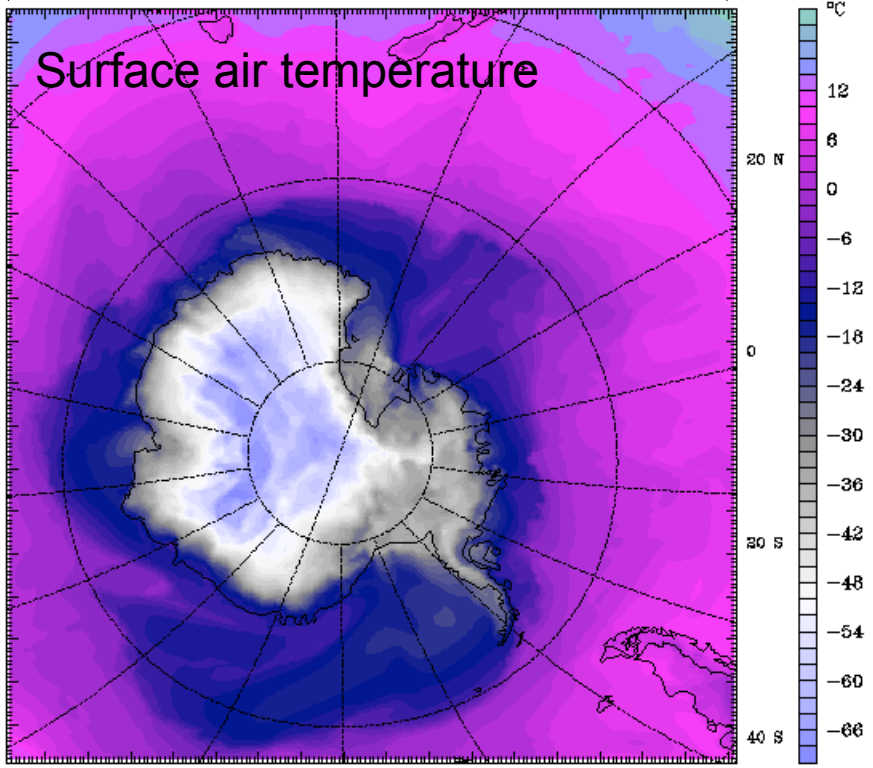
Computational poles placed close to the equator.
Nest positioned over Antarctica. Land use category (color).

1 day global +
2-way nest
forecast,
valid 12 UTC
17 August 2006
(Michael Duda)



Relative vorticity at 500 HPa



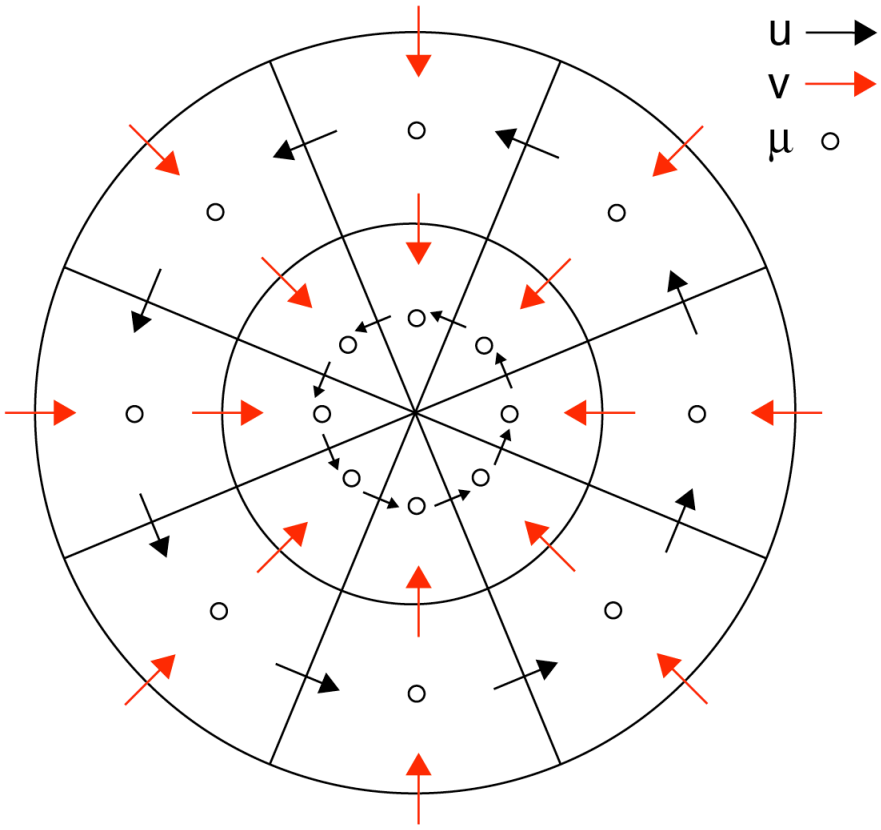


Lat-Long Grid Global WRF

Lat-Long WRFV3

Polar boundary condition (pole point).

Meridional velocity (v) is undefined at the poles.



Lat-Long Grid Global WRF

Lat-Long WRFV3

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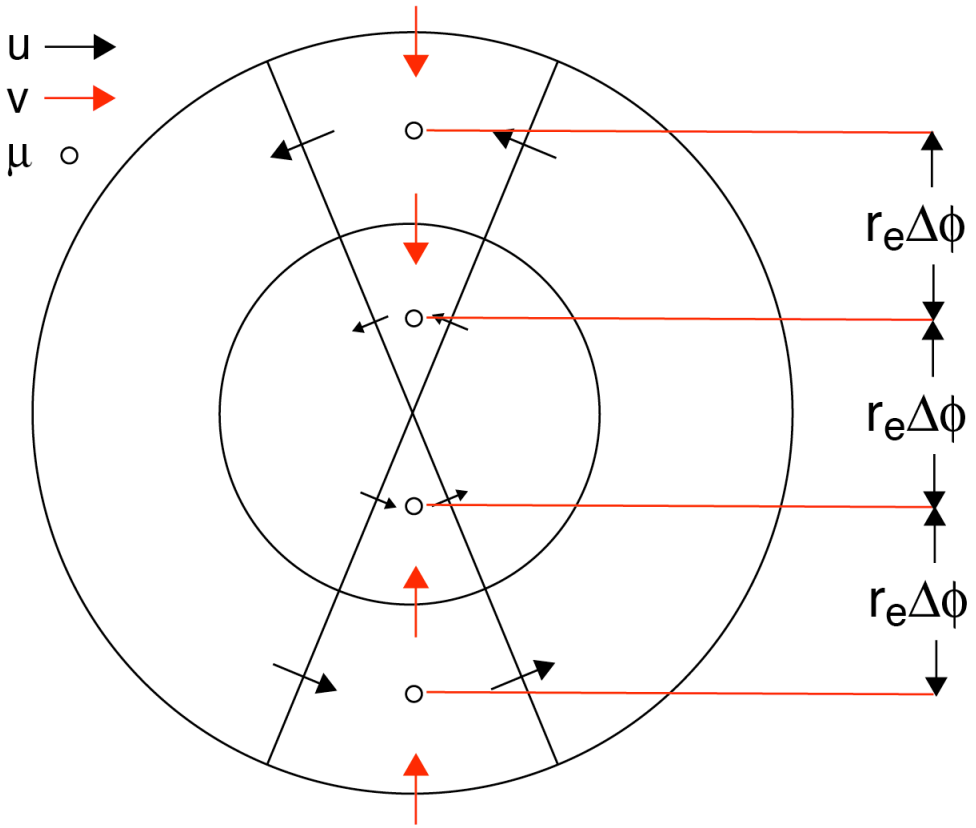
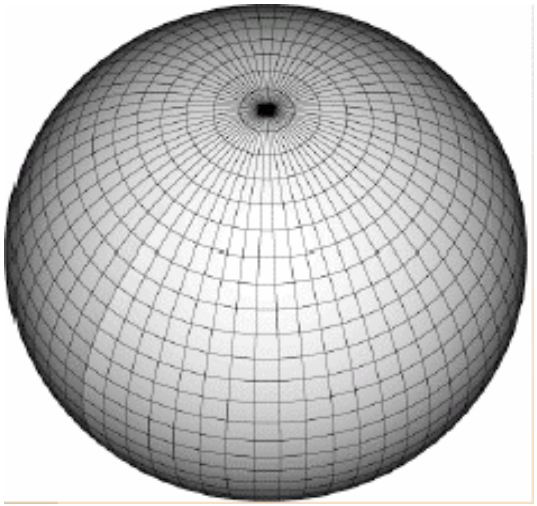


Zero meriodional flux at the poles (cell-face area is zero).

v(poles) only needed for meridional derivative of v near the poles (some approximation needed).

All other meriodional derivatives are well-defined near/at poles.

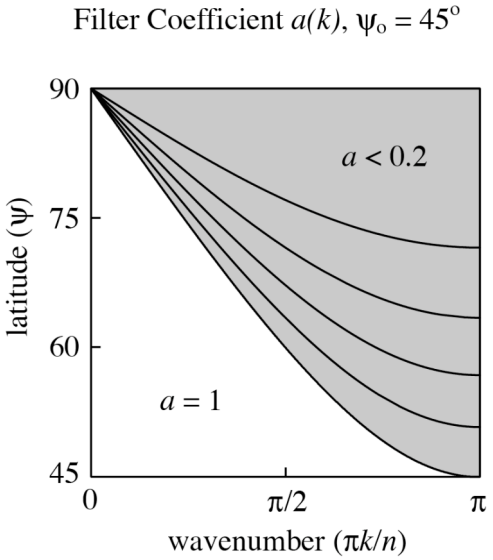
ARW Filters: Polar Filter



Converging gridlines severely limit timestep.
The polar filter removes this limitation.

Filter procedure - Along a grid latitude circle:

1. Fourier transform variable.
2. Filter Fourier coefficients.
3. Transform back to physical space.



$$\hat{\phi}(k)_{filtered} = a(k)\,\hat{\phi}(k), \quad \text{for all } k$$

$$a(k) = \min\left[1., \max\left(0., \left(\frac{\cos\psi}{\cos\psi_o}\right)^2 \frac{1}{\sin^2(\pi k/n)}\right)\right]$$

$k =$ dimensionless wavenumber
$\hat{\phi}(k) =$ Fourier coefficients from forward transform
$a(k) =$ filter coefficients
$\psi =$ latitude $\psi_o =$ polar filter latitude, filter when $|\psi| > \psi_o$

Time Integration in ARW

3rd Order Runge-Kutta time integration

advance $\phi^t \rightarrow \phi^{t+\Delta t}$

$$\phi^* = \phi^t + \frac{\Delta t}{3} R\left(\phi^t\right)$$

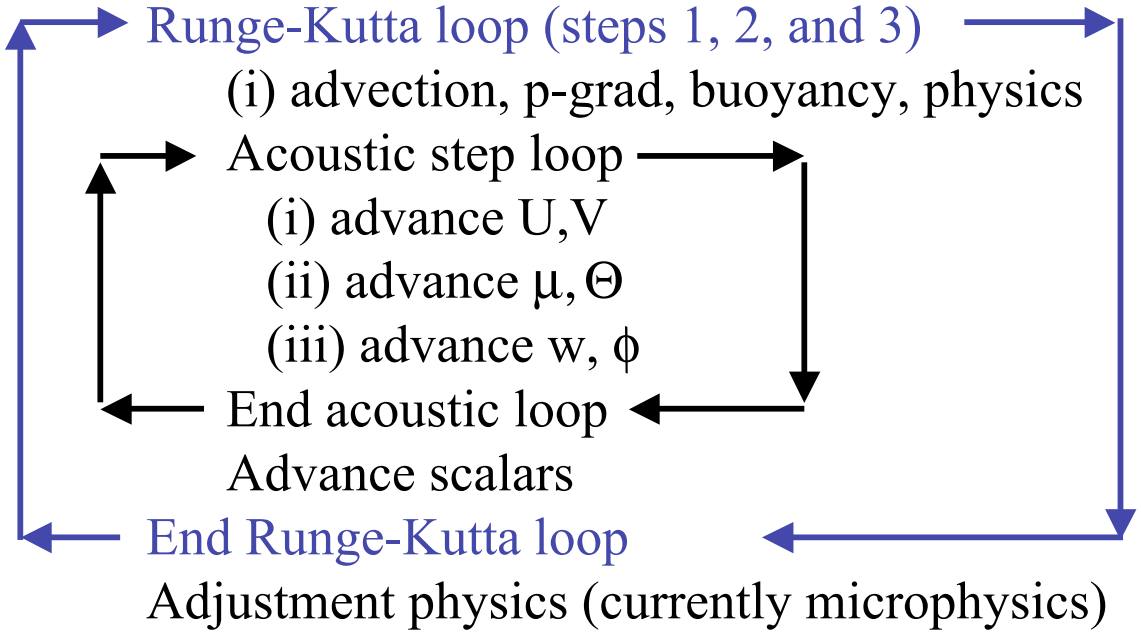
$$\phi^{**} = \phi^t + \frac{\Delta t}{2} R\left(\phi^*\right)$$

$$\phi^{t+\Delta t} = \phi^t + \Delta t\, R\left(\phi^{**}\right)$$

Amplification factor $\phi_t = i\,k\phi;\quad \phi^{n+1} = A\phi^n;\quad \left|A\right| = 1 - \frac{\left(k\Delta t\right)^4}{24}$

WRF ARW Model Integration Procedure

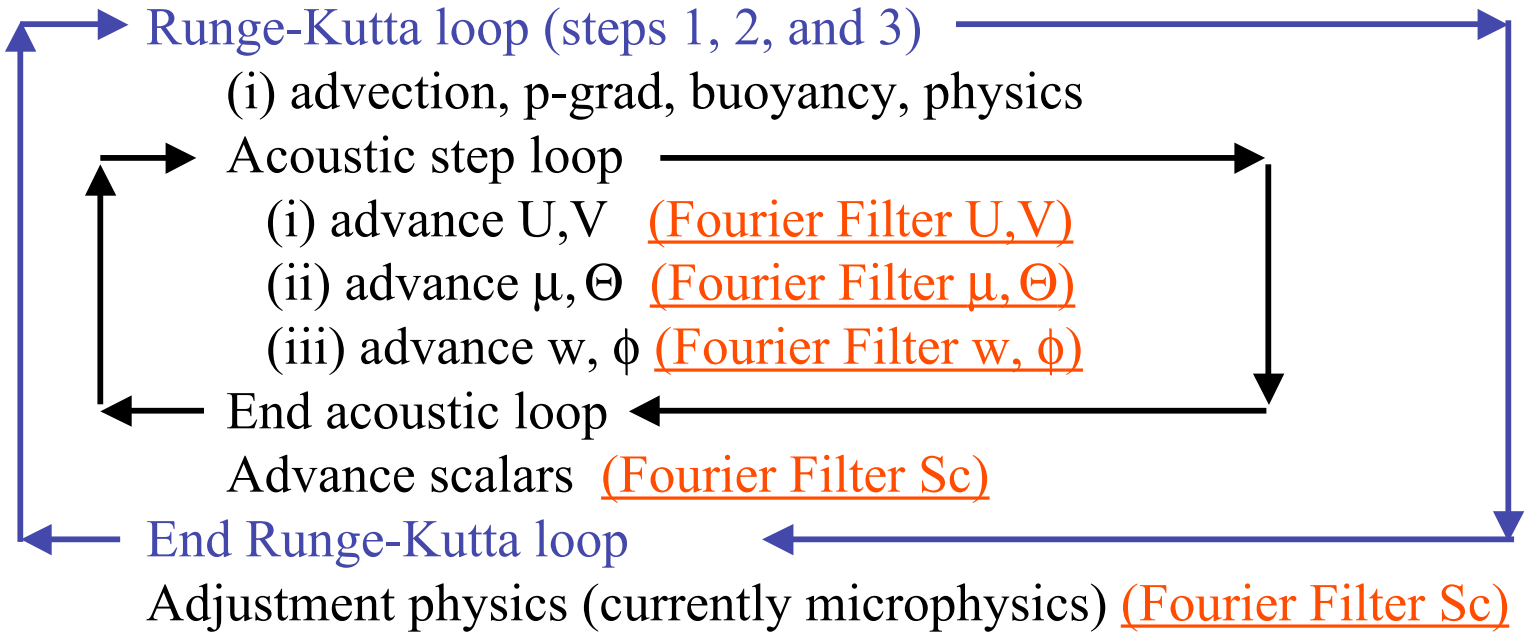
Begin time step



End time step

WRF ARW Model Integration Procedure

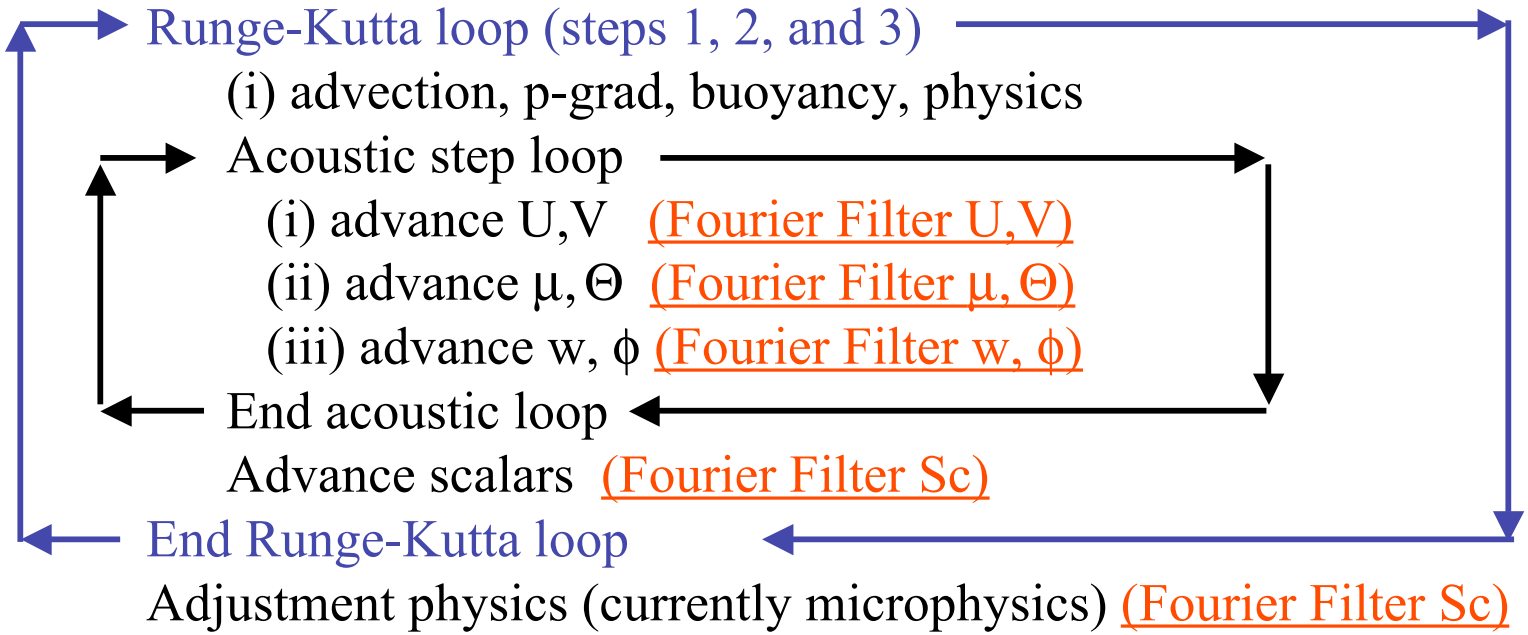
Begin time step



End time step

WRF ARW Model Integration Procedure

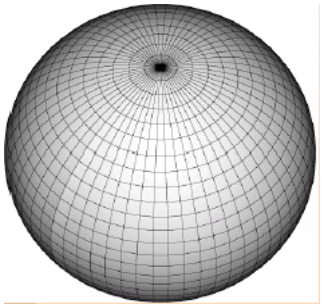
Begin time step



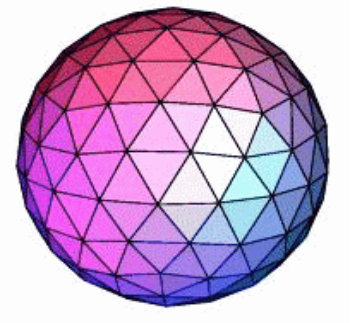
End time step

Timestep limited by minimum Δx outside of polar-filter region.

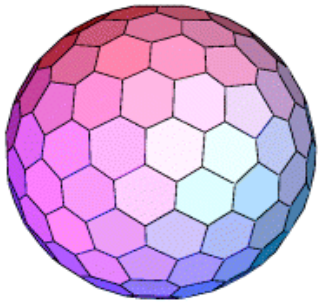
Possible Grids for a New Global Solver



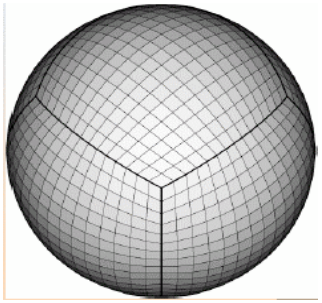
lat-long grid



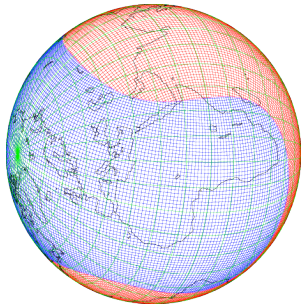
icosahedral grid (triangles)



icosahedral grid (hexagons)



cubed sphere



Yin-Yang grid

All spatial discretizations of the sphere have potential problems.

- Rectangular grids: special points, boundaries, region, solution/grid isotropy
- Other grids: accuracy and efficiency? special coding.

There is no clear obvious choice - significant development, analysis and evaluation is needed to identify a future nonhydrostatic, locally refining dynamical core.

Summary

WRF Version 3 global latitude-longitude grid

- Adapted from community development at Cal Tech.
- Functional system for nested nonhydrostatic global simulations.
- Baseline for future nonhydrostatic global model development.

Early testing has revealed some
significant biases and deficiencies.

- Evaluation, tuning, physics augmentation needed for weather and climate applications.

Development and Evaluation of new global solvers is underway to remove pole-problem and to get good performance and scaling on massively parallel computers.