Modeling Thermal Convection Flow

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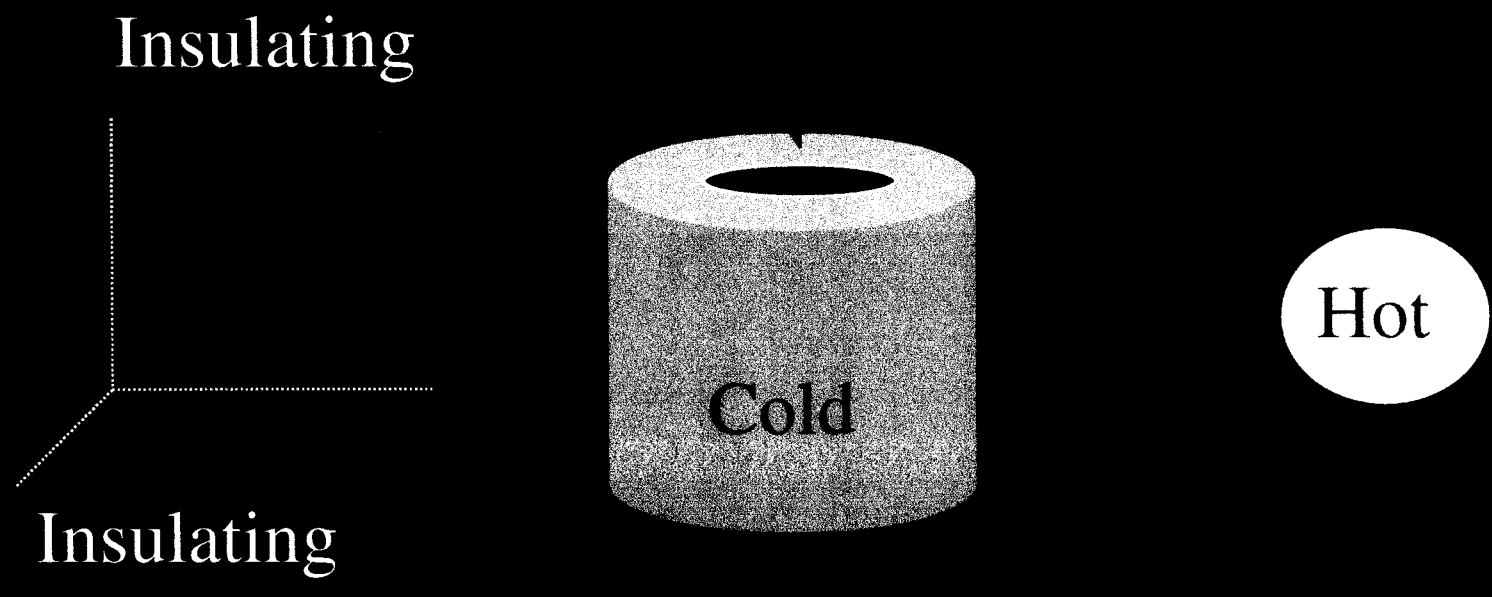
Research Objectives

- Design a powerful 3D parallel software package for thermal convection simulation
- Apply the software for Earth and Planetary science applications
- Some other applications in engineering and industry

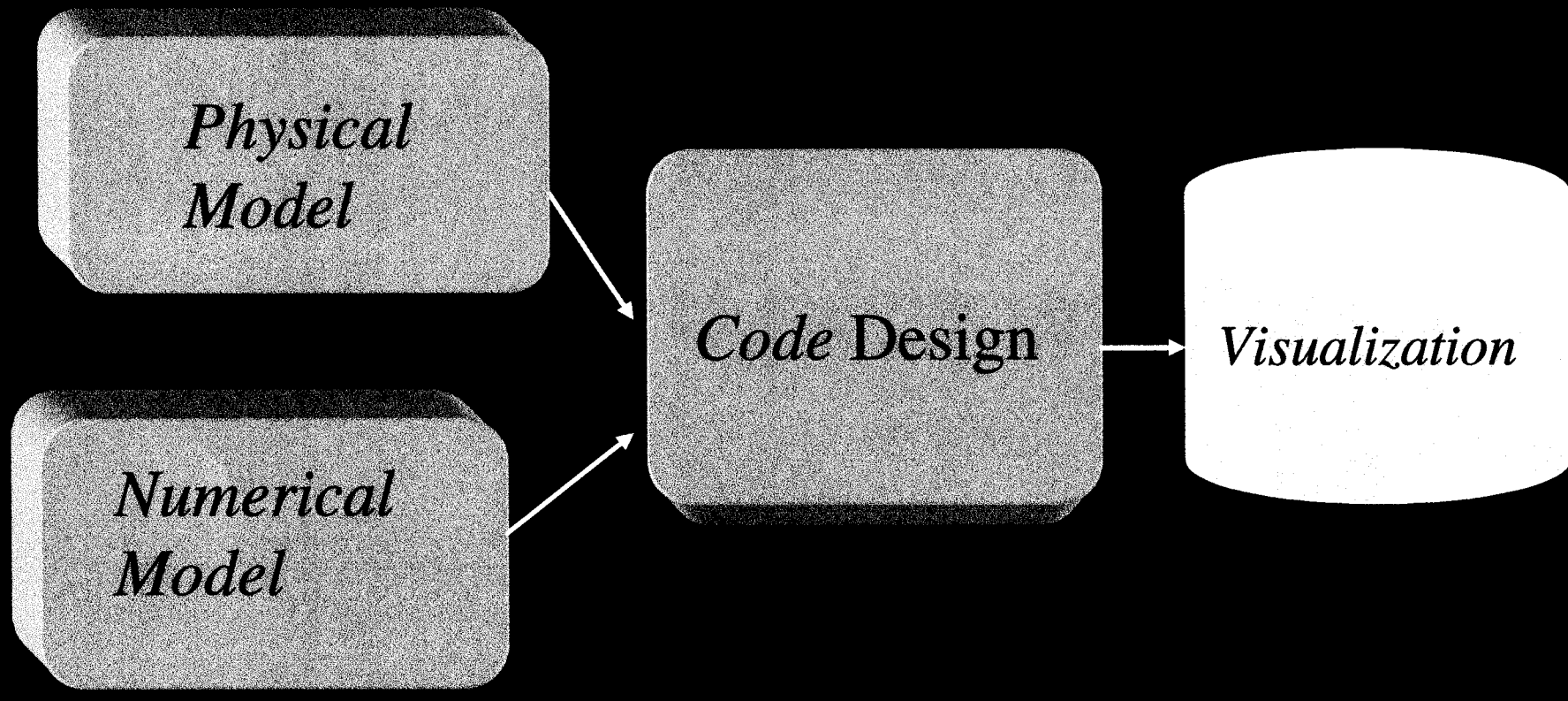
Problems



Technical Approach

- Use a better physical model
- Apply advanced numerical methods
- Apply modern software design techniques
- Use advanced parallel and supercomputing systems

Project Elements



Physical Model

- Navier- Stokes Equations
- Energy equation
- Boussinesq or anelastic approximation
- Boundary conditions (insulating, conducting, or periodical)

Numerical Model

- Finite volume with Multigrid for solving discretized equations
- V-cycle with flexible number of grid levels
- SOR as the smoother
- Injection and linear interpolation operators

Code Design

- Domain decomposition(1D partition, 2D partition, or 3D partition)
- MPI for communication
- Optimization
- Portability
- Reusability

Visualization

- Visualization for large data sets
- 2D and 3D features
- Spherical or rectilinear geometry
- Velocity, temperature, and pressure
- Animations
- Parvox

Resources

- Origin 2000 (128 PEs in JPL)
- Cray T3E (1024 PEs in GFSC)
- HP SPP 2000 (256 PEs in JPL/Caltech)
- Beowulf (32 PEs in JPL)
- Other parallel systems

Code Performance

Grid /System	32^3	64^3	128^3	256^3
Paragon	60	181		
Beowulf	41	100	177	
Cray T3D	18	58	117	
IBM SP2	12	38	95	280
Cray T3E	4	14	32	155

Wallclock times (seconds) on different systems with 16 nodes

Numerical Results

High Rayleigh number, side-heating problem:

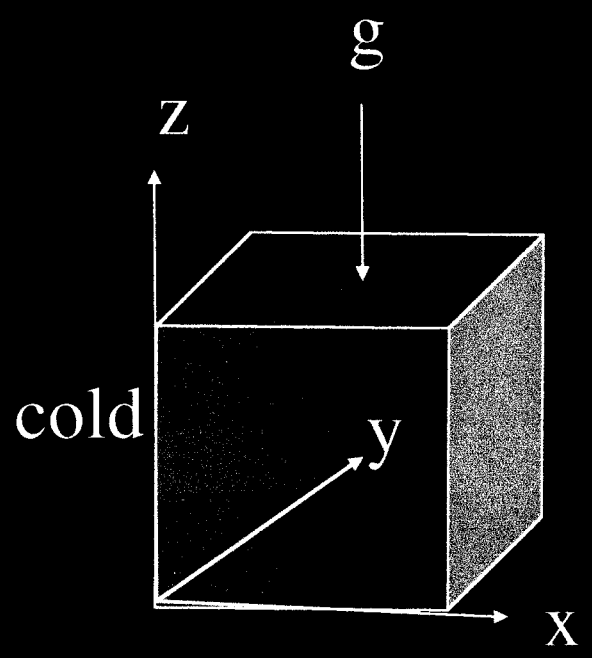
Rayleigh=5x10^7

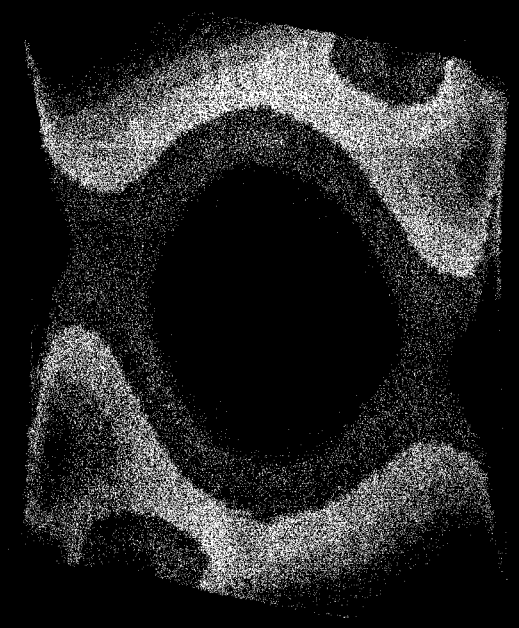
Pr=0.733

Grid=128x128x128

Partition: 3D (4x4x2)

Velocity field by Parvox system





Conclusions

- The package is scalable, portable, and reliable, and the numerical method is efficient and robust
- The package is ready to study various convection problems
- Beowulf cluster system is suitable for small to medium size scientific applications (price/performance)