NSF Site Visit to the Computational Infrastructure for Geodynamics

Geodynamo and Magma Migration

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Computational Infrastructure for Geodynamics

National Science Foundation
WHERE DISCOVERIES BEGIN

Outline

- Both Geodynamo and Magma Migration are emerging areas within CIG
- Current Status
- Near-term Plans and Challenges

Geodynamo

- Existing codes expected to be available to CIG
  - MAG – evolution of original Glatzmaier code
    - single processor
    - well benchmarked
  - MAGIC – Christensen, Wicht, Glatzmaier
    - parallized
    - also benchmarked
  - Kuang and Bloxham

- Near-term directions for CIG
  - Community workshop: from latest ***CIG News:***

    "July 9-14. Studies of Earth's Deep Interior (SEDI). An informal discussion of community geodynamo codes under the CIG umbrella is planned. Prague, Czech Republic. Please contact: Peter Olson".

  - CIG actively seeking high quality software engineer who would devote significant fraction of effort working with geodynamo codes.

Current Dynamo Code Attributes

- Pseudo-spectral (regular 3D grid + spectral representation)
  - Spherical harmonics in (θ,ϕ), Chebychef polynomials in r
  - Magnetic field boundary condition is local in harmonic space
  - Time stepping 3 equations (Alfven & inertia wave-limited)
- Slow - harmonic transforms with dense polar grid
- Resolution determined by spherical harmonic degree truncations:

$n < 48$ -	workstation
$48 < n < 256$ -	cluster
$n > 256$ -	Simulator, Terra Grid...

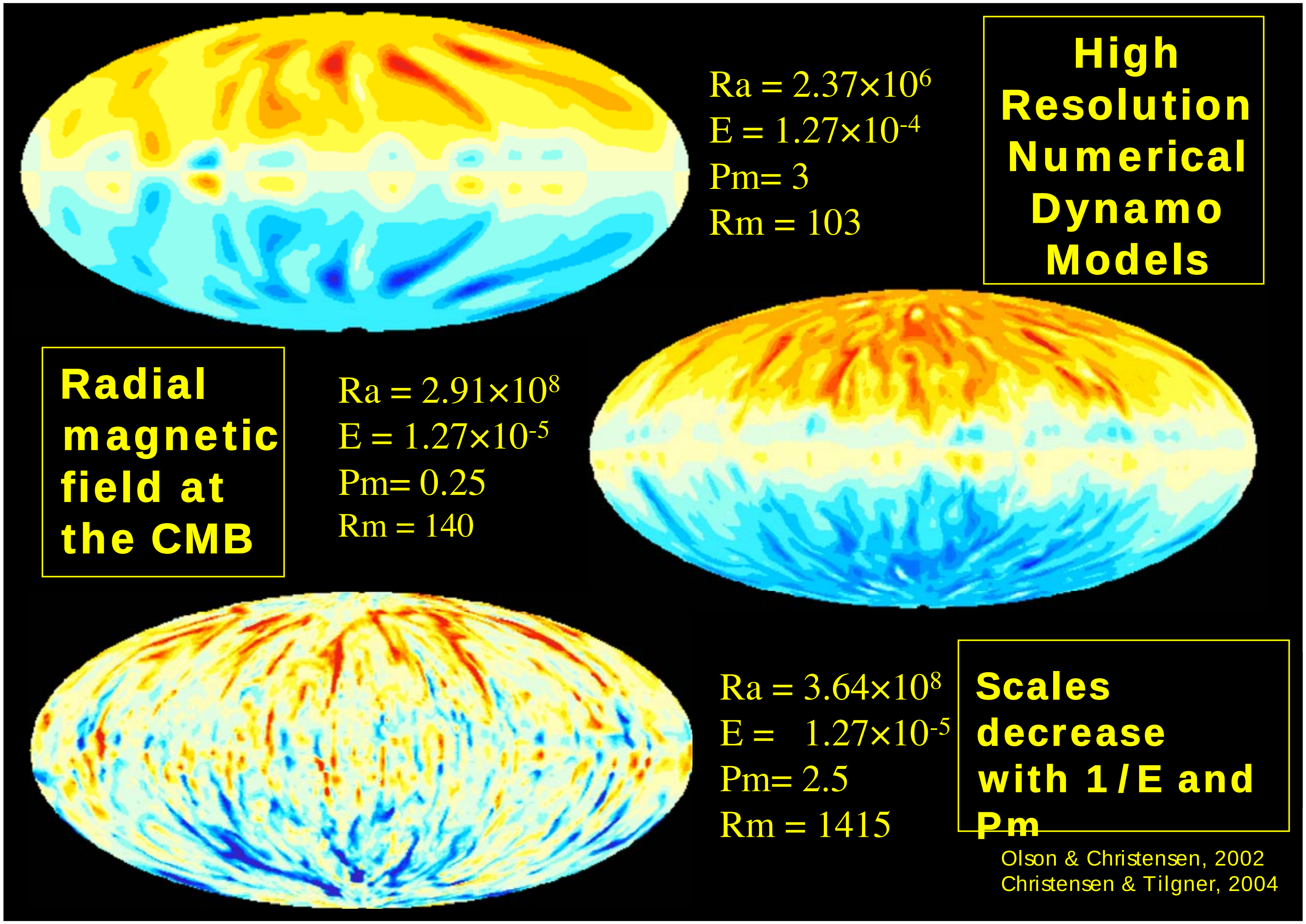
- Several partially-to-well-documented Fortran & C-codes are available now (e.g. MAGIC) with good, existing benchmarks.

Model Parameters

Parameter	Turbulent Core	Dynamo Models
$Pr = \frac{\nu}{\kappa}$	≈ 1	≈ 1
$Pm = \frac{\nu}{\lambda}$	≈ 1	≈ 1
$E = \frac{\nu}{\Omega D^2}$	$\approx 10^{-9}$	$10^{-4} - 10^{-5}$
$Ra = \frac{\alpha g \Delta T D^3}{\kappa \nu}$	$\approx 10^{15}$	$10^{6} - 10^{9}$
$Rm = \frac{UD}{\lambda}$	$\approx 10^{3}$	$10^{2} - 10^{3}$

Increased “resolution” by

- **Finer spatial descretization in full numerical simulation**
- **Large eddy simulation (LES) – introduce subgrid model**



High Resolution Numerical Dynamo Models
Radial magnetic field at the CMB
Ra = 2.37×10^6
E = 1.27×10^-4
Pm= 3
Rm = 103
Ra = 2.91×10^8
E = 1.27×10^-5
Pm= 0.25
Rm = 140
Ra = 3.64×10^8
E = 1.27×10^-5
Pm= 2.5
Rm = 1415
Scales decrease with 1/E and Pm
Olson & Christensen, 2002
Christensen & Tilgner, 2004

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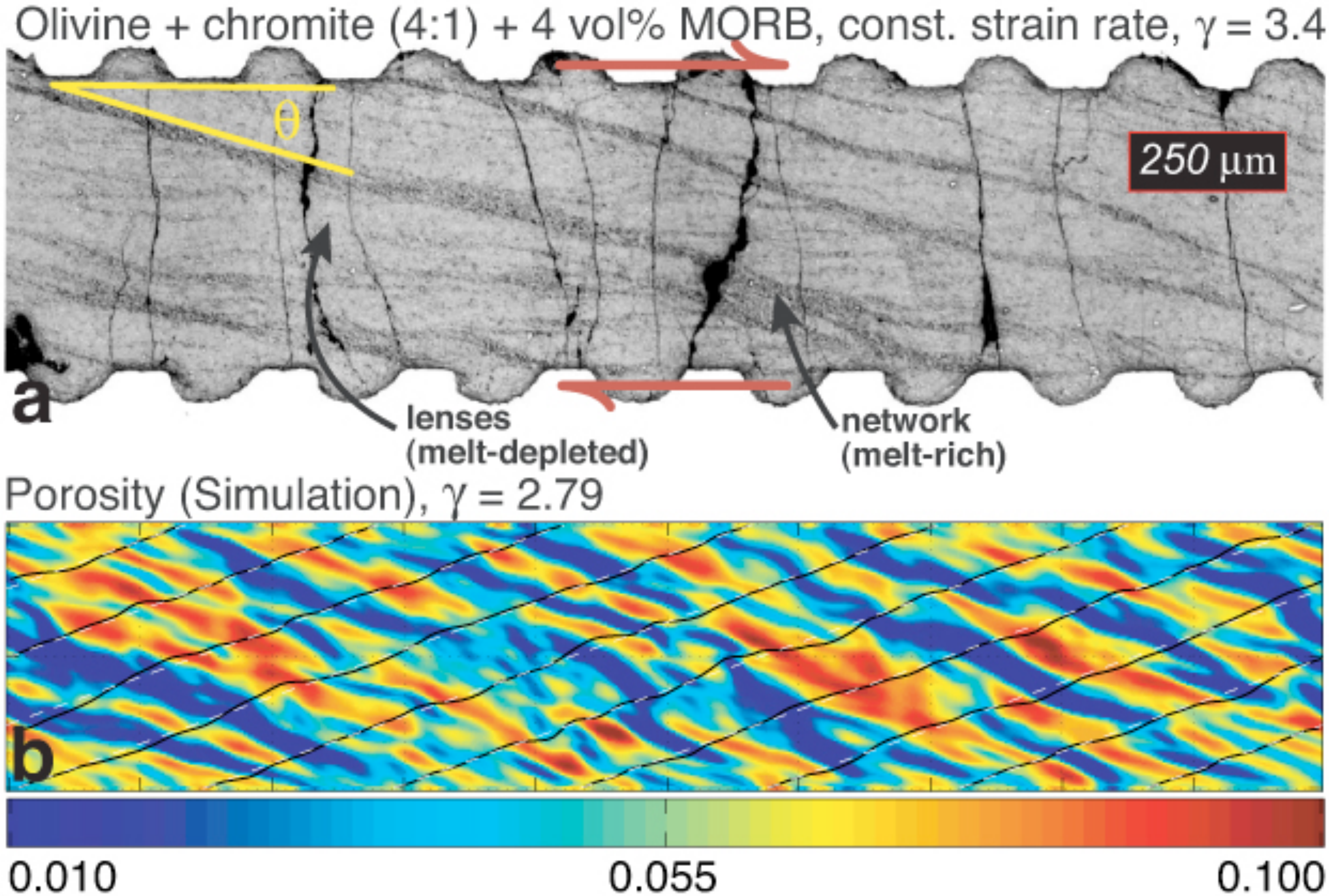
Magma Migration

- Numerical challenges
  - treatment of multiscale processes
  - strongly and locally varying physical properties

- Code "development"
  - Modular - existing codes (e.g. PETSc solvers) within a framework
  - Synergies with other CIG areas – for example
    - Compressible mantle convection
    - Crustal/lithospheric scale fluid transport

- Near-term directions:

  Community workshop Summer 2006 – being organized by Laurent Montesi and Marc Speigelman



Katz, Spiegelman, and Holtzman, in prep.

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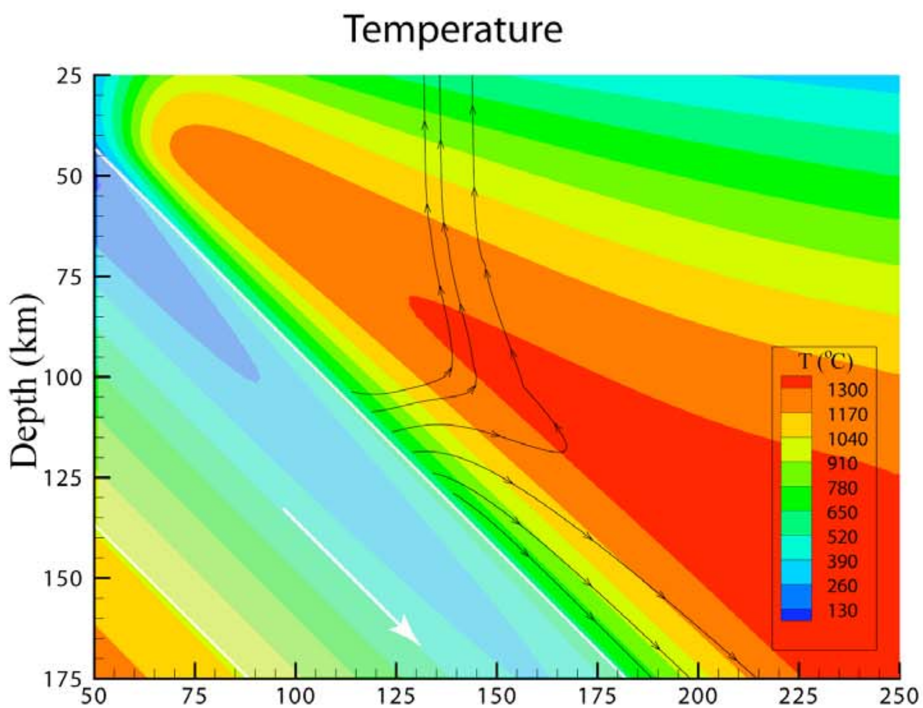

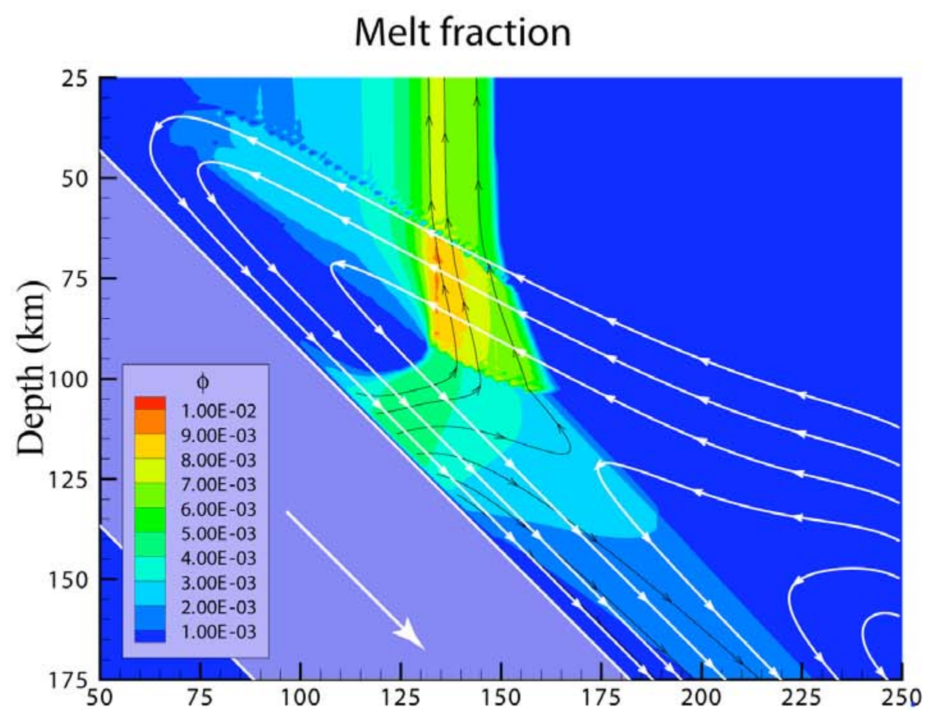

convergence rate = 60 km/Myr

Cagnioncle, et al, submitted to JGR

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