effects of the seafloor bathymetry and the nearby resistive coastline have to be considered.

URL: http://mahi.ucsd.edu/Steve/APPLE/

GP52A-09 1600h INVITED

Enhanced Mantle Conductivity from Sulfides beneath the Sierra Nevada?

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A region of enhanced mantle conductivity (0.03-0.1 S/m) beneath the southern Sierra Nevada, where elevations of over 4000 m are found, has been attributed previously to 3-5% basaltic melt (Park et al., 1996) and to a mix of basaltic and sulfide melt (Ducea and Park, 2000). Because the sulfide melt is assumed to have similar conductivities to its solid counterpart (10,000 S/m), very small amounts (< 0.1%) of sulfide are needed in order to reduce the bulk conductivity from matrix values of about 0.003 S/m or even that of the matrix-basalt melt mix to the values observed. Basaltic melt percentages of less than 1% are needed in the presence of 0.1% sulfide melt in order to match the observed mantle values. Xenoliths from the Holocene basalts in the Big Pine Volcanic Field contain 0.06-0.4% sulfide, so the estimated values are reasonable. Given the lack of evidence for volumetrically extensive, young (< 10 Ma) basaltic volcanism, calculated residence times of approximately 100 Ka for 3-5% partial melt, the short (about 300 Ka) times needed to develop connected pathways for the basalt, and the young extension of the adjacent Basin and Range province, a mixed melt with both basalt and sulfides seems more reasonable.

This conclusion presupposes that the sulfide melt is somehow interconnected in the mantle. Models in which the matrix, the basaltic melt, and the sulfide melt each form interconnected, interlaced networks leads to much higher predictions of mantle conductivity; the sulfide melt fraction must be discontinuous in order to lower bulk conductivity. Petrological studies of sulfide-silicate systems confirm this conclusion; sulfide melts form isolated blebs on the surfaces of olivine within interconnected basaltic melt channels (Holzheid et al., 2000). Simple series-parallel models of 1% continuous basaltic melt and 0.01% discontinuous sulfide melt provide bulk conductivities comparable to the observed mantle values. More complicated equivalent media and Hashin-Shtrikman models provide similar estimates.

The idea that a discontinous, volumetrically small component can alter substantially the bulk conductivity of a rock is counterintuitive. If this hypothesis is true, then the interconnected basaltic melt forms the bridge between the patches of sulfide melt. Laboratory studies are needed to confirm this hypothesis, however. Measurements of sulfide melt at elevated pressures and temperatures are needed, as are measurements of mixed basalt-matrix-sulfide systems.

Ducea, M.N., and S.K. Park, 2000. Enhanced mantle conductivity from sulfide minerals, southern Sierra Nevada, California, Geophys. Res. Lett., 27, 2405-2408.

Holzheid, A., Schmitz, M.D., and T.L. Grove, Textural equilibria of iron sulfide liquids in partially molten silicate aggregates and their relevance to core formation scenarios, J. Geophys. Res., 105, 13555-13567, 2000.

Park, S.K., B. Hirasuna, G.R. Jiracek, and C.L. Kinn, Magnetotelluric evidence of lithospheric mantle thinning beneath the southern Sierra Nevada, J. Geophys. Res., 101, 16241-16255, 1996.

GP52A-10 1615h

Electrical Conductivity of Mantle Minerals: A Laboratory View

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Since the work of Lahiri and Price (1939) geophysicists have attempted to interpret electrical conductivity profiles of Earth's mantle. As we now know, the basic materials are olivines, pyroxenes, spinels, garnets, and their high-pressure, high-temperature polymorphs. However, beginning in the late 1940s researchers plunged in by measuring conductivities in ultramafic rocks. As inconsistencies appeared over the next couple of decades, it was necessary to define minerals in terms of condensed matter physics—an approach needed for extrapolation to extremes of mantle conditions not then available in the laboratory. By these standards mantle minerals are insulators, and for insulators electrical transport properties are difficult to measure reliably.

Achieving chemical buffering (principally of oxygen fugacity by Duba and colleagues) in the early 1970s had two big effects: (1) it threw into doubt most of the previous quarter-century of work, and (2) it introduced nearly unprecedented reproducibility. Improved laboratory measurements permitted the role of iron in charge transfer to be defined and interpreted in terms of oxygen-sensitive defect populations. For mantle olivine (~10% fayalite content) there was actually general agreement among several groups for measurements at mantle temperatures. [In both field and laboratory conductivity measurements half an order of magnitude appears to be the level at which disagreements become academic.] Other advances, measurements of mineral conductivity in multi-anvil devices and diamond anvil cells have become possible at mantle pressures and/or temperatures, and the role of crystallographic phase transitions was elucidated. Attention to chemical buffering has led to other advances. For instance, "water" in its various chemical species appears to enhance conductivity, at least in the uppermost mantle. Elemental carbon could also play a role. Finally, an unusual agreement with geophysical observations has been achieved. However, current successes may be less interesting than some discrepancies that suggest further work.

GP52A-11 1630h

Concentration and Mobility of Electrically-Conducting Defects in Olivine

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We have collected measurements of electrical conductivity and thermopower as a function of temperature and oxygen fugacity (f_{O_2}) on a sample of San Quintin dunite (95% olivine), and measurements of electrical conductivity equilibration after changes in f_{O_2} on Mt.Porndon lherzolite (65% olivine). Both data sets have been analysed using nonlinear parameter inversion of mathematical models relating conductivity, thermopower, and diffusion kinetics to temperature, f_{O_2}, time, and defect concentration and mobility.

From the dunite thermopower/conductivity data we are able to estimate the concentration and mobilities of electrically conducting defects. Our model allows electrons, small polarons (Fe^{+++} on Fe^{++} sites), and magnesium vacancies (V''_{Mg}) to contribute to conduction, but only polarons and V''_{Mg} are required by our data. Polarons dominate conduction below 1300° C; at this temperature conduction, is equal for the two defects at all f_{O_2} tested. Thermopower measurements allow us to estimate defect concentration independently from mobility, and so we can back out polaron mobility as $12.2 \times 10^{-6}\exp(-1.05$ eV/kT) $m^2V^{-1}s^{-1}$ and magnesium vacancy mobility as $2.72 \times 10^{-6}\exp(-1.09$ eV/kT) $m^2V^{-1}s^{-1}$.

Electrical conductivity of the lherzolite, measured as a function of time after changes in the oxygen fugacity of the surrounding CO_2/CO atmosphere, is used to infer the diffusivity of the point defects associated with the oxidation reactions. An observed f_{O_2} dependence in the time constants associated with equilibration implies two species of fixed diffusivity, each with f_{O_2}-dependent concentrations. Although the rate-limiting step may not necessarily be associated with conducting defects, when time constants are converted to mobilities, the magnitudes and activation energies agree extremely well with the model presented above for the dunite, after one free parameter (effective grain size) is fit at a plausible 1.6 mm diameter. Not only does this study represent one of the few direct measurements of polaron mobility, but the very good agreement between two independent measurement techniques (thermopower versus equilibration kinetics) and two independent samples (dunite versus lherzolite) provides some level of confidence in the results. We are currently extending these modeling techniques to study olivine defect mobility anisotropy.

URL: http://mahi.ucsd.edu/Steve/olivine.html

GP52A-12 1645h

Heterogeneity of the Transition Zone

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Research on the composition of the transition zone has particulary benefited from collaborations between laboratory and field geophysicists. In laboratory studies, the composition of the samples has been varied until a laboratory based mantle conductivity-depth profile matches the electromagnetic field data. Before 2000, these consisted of tensor magnetotelluric (MT) data at periods below 20.000s and scalar geomagnetic transfer functions (GDS) at longer periods. The overlap period corresponded to 350 - 400 km penetration depth and heterogeneities below that could not be resolved from the scalar GDS data. Recent long period measurements in the Simpson desert, Australia, provided high quality tensor MT data in the 20.000s - 80.000s period range, corresponding to 350 - 600 km penetration depth with indications for strong heterogeneities in this depth range.

GP61A MCC: Hall C Saturday 0830h

Numerical Modeling in Geomagnetism/Paleomagnetism Posters *(joint with NG, P)*

Presiding: **L Tauxe,** Scripps Institution of Oceanography**; J Bloxham,** Harvard University

GP61A-1001 0830h POSTER

Micromagnetic Modeling of First-Order Reversal Curves (FORC) Diagrams for Single-Domain and Pseudo-Single-Domain Magnetite

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A micromagnetic model based on a conjugate gradient algorithm was used to calculate FORC diagrams for isolated grains of magnetite as well as for arrays of grains. In the case of individual elongated grains, we found that the FORC diagram consists of a single peak centered on the coercive force if the grain is single-domain. For a pseudo-single domain grain, we observe multiple peaks on the FORC diagram.

The modelling of arrays of elongated single-domain particles reveals two distinct types of patterns on the FORC diagram depending on the spacing between particles. In a 2×2×2 array a secondary branch on the reversal curves appears if the spacing is less than two times the particle width. This feature translates into the appearance of one negative and two positive peaks on the FORC diagram. In the case of a 3×3×3 array we also observe several secondary branches when the spacing between grains is less than 2.5 times the particle width, leading to the appearance of several peaks on the FORC diagram. Arrays of cubic single-domain grains having random magnetocrystalline anisotropy axes show the same features, the only difference being a lower coercive force. Therefore the presence of symmetrical peaks on a FORC diagram can be an indicator of the presence of magnetic interactions in an ensemble of grains.

GP61A-1002 0830h POSTER

Inverting Magnetic Data Using Parallel Processing

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We have collaborated to develop an innovative method for inverting magnetic data from high-resolution geomagnetic maps. Our method uses parallel computations and asynchronous communication among multiple nodes of a Beowulf cluster to produce geologically constrained 3-D models of magnetic anomalies. This modeling effort comes in response to the current revolution in gathering geophysical data. Interfacing

kinematic differential GPS to magnetometers has presented geo-scientists with the daunting task of interpreting very high-resolution geomagnetic maps. Traditional methods of data interpretation, such as forward modeling, are sorely taxed. Our method manipulates a set of geologically constrained parameters to eventually build a geometric model that accurately represents the magnetic anomaly. Iterations of the code execute in parallel on multiple networked nodes via MPI, a message passing interface. Each node computes a magnetic solution at different geographical field locations based on a modeled set of geological parameters, using various forward calculations. The parameter sets are continually adjusted by the downhill simplex method. Calculated values are continually compared to the observed data using a goodness-of-fit test until all parameter sets generate the same result within a specified tolerance. A set of parameters producing an anomaly mimicking the observed anomaly is the result. By changing bounds on input parameters it is practical to quickly identify equivalent solutions. These techniques are applied to a high resolution geomagnetic data set consisting of 30,000 data points and four discrete magnetic anomalies. Data were smoothed and inverted using the parallel code. The subsurface was discretized and the depth to each unit, magnetization, and depth to the base of the entire structure were allowed to vary as independent parameters. Inversion clearly highlights volcanic features of the source rocks, including the truncated cone, crater, lava flows, and reasonable remanent magnetization (reverse polarity, 1.2 amp/m). These same methods should be applicable to a wide range of geomagnetic data and geologic structures.

GP61A-1003 0830h POSTER

Dynamo Action and its Temporal Variation Inside the Tangent Cylinder in MHD Dynamo Simulations.

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We have been performing numerical simulations of MHD dynamos. In this paper, we present the results of our parameter survey for this problem. We consider a spherical shell rotating about its rotation axis (z-axis) and it is filled with electrically conducting Boussinesq fluid. The solid inner core has the same electrical conductivity as that of the fluid outer core, and it can freely rotate about the same axis as that of the reference frame.

At present we have obtained 8 successful dynamos among about 20 trials. At highly supercritical Ra more than 10 times the critical value, convection inside the tangent cylinder appears. Irregular upward and downward plumes inside the tangent cylinder are observed alternatingly in both time and space. They stretch the toroidal field into north-south direction and generate a new poloidal field, which could have both polarities. Reversed toroidal field can easily be generated by the ω-effect just above the inner-core boundary (ICB) inside the tangent cylinder. The direction of differential rotation just above the ICB at high latitudes alternates temporally, which generates a new toroidal field with opposite polarity to the original toroidal field. Such reversed toroidal field propagates outward and makes the toroidal field quadrupolar inside the tangent cylinder when such a phenomenon happens only in one hemisphere. Quadrupolar toroidal field persists until a new toroidal field with the original polarity undergoes the same process. We here emphasize the effect of meridional circulation. We have observed that the dipolar toroidal field recovers after strong and intermittent fluctuation of equatorially anti-symmetric meridional circulation inside the tangent cylinder appears. Such a phenomenon suggests a stabilizing role of meridional circulation, although Sarson and Jones (1999) proposed a counter role of meridional circulation. Nevertheless, these results clearly show that more attention should be paid to the tangent cylinder.

GP61A-1004 0830h POSTER

Numerical Dynamo Modelling and the Magnetic Fields of Uranus and Neptune

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In an effort to model the Earth's magnetic field, current numerical dynamo models have produced fields dominated by an axial dipole. In these models, the dynamo is usually generated by convection in a thick, electrically conducting fluid shell surrounding a solid conducting inner core.

The Voyager II observations of Uranus (1986) and Neptune (1989) revealed that these planets have non-dipolar, non-axisymmetric magnetic fields, in sharp contrast to the axially dipolar fields of Earth, Jupiter and Saturn.

Here we present results of a numerical dynamo model for Uranus and Neptune where the magnetic field is generated in a convecting fluid shell surrounding a stably stratified, electrically conducting fluid interior. This configuration is consistent with current interior models for these planets and has been proposed in the past to help explain their differences in internal heat flows. We find that we can produce magnetic fields with significant higher degree structure and little axial symmetry, similar to those of Uranus and Neptune.

GP61A-1005 0830h POSTER

Subgrid-scale Methods for Simulations of Turbulent Magneto-convection

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No computer model of the geodynamo has been able to afford the spatial resolution needed to simulate the turbulence spectrum in the Earth's liquid core, which spans at least seven orders of magnitude in length scale. All geodynamo models have employed greatly enhanced eddy diffusivities, which are both homogeneous and isotropic, to stabilize the low resolution numerical solutions and crudely account for the transport and mixing by the unresolved (subgrid-scale) turbulence. Alternative approaches rely on better approximations for the nonlinear cascade of energy to and from the subgrid-scales, so that much smaller eddy diffusivities can be used in the numerical simulations. We present preliminary results from two of these methods: the similarity model and the alpha model. They use the time dependent structure of the large resolved scales to estimate the structure and effects of the unresolved scales. Predictions for the effects of the unresolved turbulence on the resolved flow and field are inhomogeneous, anisotropic and time dependent. 3D results with periodic boundaries in all directions and 2D results with impermeable top and bottom boundaries are presented.

GP61A-1006 0830h INVITED POSTER

The Role of Micromagnetic Modelling in Rock Magnetism

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Numerical micromagnetic models (NMM) provide the most rigorous approach towards extending the physical theory of rock magnetism into the realm of inhomogeneously magnetized remanence carriers, often denoted as pseudo single-domain (PSD) particles. Here a number of applications of NMM will be presented and a critical review of their respective strengths and problems is given.

1) NMM of PSD particle magnetization structures allow to trace the transition from single-domain (SD) to multi-domain (MD) states in great detail. The results for magnetite are in very good agreement with experimental data. Depending on material constants, either magnetization swirls or domain walls are formed when grain size increases beyond the SD limit. The upper limit of particle sizes which can reasonably be modelled depends on characteristic length scales obtained from the material constants.

2) Thermoremanent magnetization (TRM) processes can be modelled by appropriately changing the material constants in function of the model temperature. The fundamental aim of TRM modeling is to obtain estimates of TRM stability at different temperatures. This requires to calculate the energy barriers between different possible magnetization states. Here estimates from 3D NMM are necessary, because intermediate magnetization states can show intricate three-dimensional patterns, which hardly can be resolved by lower-dimensional models.

3) Calculating hysteresis loops is straightforward if dynamical effects and thermal activation are disregarded. By averaging the loops of suitably chosen field directions, an isotropic particle ensemble can be modelled. More complicated isothermal magnetization processes (like IRM acquisition curves, backfield curves or FORC diagrams) can be modelled analogously.

Further topics of current research are influences of stress, irregular grain shape, magnetostatic interaction and dynamic effects during magnetization change.

GP61A-1007 0830h POSTER

Low Ekman Number Dynamos in Cartesian Geometry

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Fully self consistent 3d dynamo simulations in spherical geometry have become an important part of geomagnetic research during the last years. The parameter range accesible for these models is quite limited and far away from the values estimated for the Earth's core. Especially viscous effects are overestimated by many orders of magnitude in all models published today. In view of these difficulties, we use a plane layer dynamo model which is computationally less demanding to study dynamo processes in the regime of low viscosity. The calculations we present employ Ekman numbers in the range $E = 10^{-4} - 5 \times 10^{-6}$ without using parameterizations such as hyperdiffusion. Full inertia with $Pr = 1$ is included where Pr denotes the Prandtl number. We find subcritical dynamos which remain stable for two magnetic decay times and an example of an initially stable subcritical dynamo which starts to decay after more than one magnetic diffusion time. For both supercritical and subcritical cases, the force balances are analyzed in detail. We show that at low Ekman number the leading order force balance in our calculations is between Coriolis, buoyancy, pressure and Lorentz forces while both inertial and viscous forces are small in the bulk of the layer. The resulting flow is strongly influenced by the Taylor-Proudman effect and dominated by small scale structures. In the range of investigated Ekman numbers, the dominating length scales decrease with decreasing E. Although Taylor's constraint is not satisfied in the entire domain we find that the spatial mean value of the normalized Taylor integrals decreases with decreasing Ekman number.

GP61A-1008 0830h POSTER

Location of Magnetic Dipoles with Arbitrary Directions of Magnetization in Chongcho Lake, Republic of Korea

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The SOAPFI-MD (shape-of-anomaly potential field inversion for magnetic dipoles) program determines locations, strengths, and orientations of buried magnetic dipoles from surface measurements of the magnetic field. It minimizes an objective function that measures the difference between the shape of observed fields and modeled dipole fields using an L2-norm. An application is presented for fields measured by a towed magnetometer in Chongcho Lake, Sokcho, Korea. Previously, many dipoles in Chongcho Lake were modeled using SOAPFI-MD with magnetic dipoles magnetized along the direction of the earths field. For this study, an iterative procedure varied both location and dipole orientation. The effects of remanent magnetization and self-demagnetization of elongated bodies were approximated for depths exceeding the greatest dimensions of causative bodies such as the archeological artifacts and military debris on the lake bottom. The SOAPFI program allows automatic inversion of gravity and magnetic fields of extended bodies by growth from a small seed (initial model) that may produce a field dissimilar to the observed field; the model grows by automatically filling prisms on the periphery of the growing model. The analogous procedure in SOAPFI-MD is to increase the number of dipoles. For given locations and orientations of multiple dipoles with overlapping fields, a system of linear equations determines the relative strengths of the dipoles to minimize the objective function. "Profile-adaptive" filters to pass highwavenumber signals were applied to the observed signal in intersecting and overlapping profiles and to the modeled dipole fields before evaluation of the objective function.

GP61A-1009 0830h INVITED POSTER

Numerical Modeling of the Low-temperature Magnetism of SSD Magnetite

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We present a numerical model developed in order to simulate the low-temperature magnetism of assemblages of stable single domain magnetite particles. Given an energy surface as a function of magnetization direction for a given particle-defined by shape anisotropy, grain interactions, and crystalline anisotropy-and an initial magnetization direction the model settles the magnetization to a minimum energy orientation by rotating iteratively down the steepest energy gradient. The main advantage of this technique is the large number of particles which can be modeled. We present simulation results for zero field cooled (ZFC) and field cooled (FC) low temperature demagnetization curves for "inorganic" randomly oriented non-interacting particles as well as randomly oriented biogenic chains of magnetosome particles. Specifically we concentrate on the amount of remanence lost (δ_{fc} and δ_{zfc}) on warming through the Verwey transition. The model predicts that delta ratios (δ_{fc} / δ_{zfc}) for the inorganic material should range from 1 to 1.6 depending on particle shape, and that the magnetosome chains have delta ratios of at least 2. Simulations of magnetosome chains aligned with the applied field are also presented and compared to experimental results for aligned chains. Room temperature saturation isothermal remanence cycled to low temperature and back to room temperature was also simulated for both non-interacting grains and magnetosome chains. Although the model results are in general agreement with the experimental observations, the two diverge in some curious ways. For example, the modeling yields FC remanence ratios at 20 K as high as 0.83 while the experimental data typically yield ratios around 0.65. The modeling also predicts a large offset in the FC and ZFC remanence above the Verwey transition–the FC being elevated above the ZFC. Finally the steep drop in FC remanence below the Verwey transition observed in experiments on magnetosome chains is not seen in the modeling. Possible explanations for these discrepancies are discussed.

GP61A-1010 0830h POSTER

Thermal Evolution of the Earth's Core and the Geodynamo

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The thermal evolution of the Earth's core and the growth history of the inner core can be modeled using the equation for global energy conservation for a convective core. However, this requires the knowledge of the heat flow at the core mantle boundary (CMB) as a function of time, a parameter that results from the dynamics and evolution of the mantle. Another limitation to that approach is that it cannot provide any information about the magnetic field that can be produced, since the dissipation is internally equilibrated by the work of buoyancy forces. On the other hand, the entropy equation can be used to relate the Joule dissipation to the energy sources available to drive the dynamo. In the present time, all these sources, except the radioactive heating, can be parameterized by the inner core radius and growth rate that can then be derived for any given dissipation in the core. Before the existence of the inner core, the only energy sources maintaining the dynamo are the secular cooling and possibly some radioactive heating.

The present dissipation in the core is poorly known but taking its contribution to the entropy equation between 350 and 700$MW\ K^{-1}$ gives a present heat flow across the CMB between 6 and 10 TW. To construct a thermal history of the core, the value of the Joule dissipation at all time is needed, and the published and some recently additional paleo-intensity data are used to constrain the Joule dissipation for the period before the inner core crystallization. The record is very scarce and displays variation of the largest amplitude on very short time scales that cannot be attributed to the change of buoyancy sources available but rather to exchange of energy between the dipole field and the smaller scales of the magnetic field, a process that can take place without change of the overall Joule dissipation. On the other hand, the virtual dipole moment (VDM) averaged for the ancient period (more than 1 Ga old) is about twice lower than the value averaged for the recent period. Consequently, computing the heat flow at the CMB that is necessary to maintain a total dissipation that is 4 times lower than the present estimates before the inner core, we get a value between 7 and 9 TW. Considering the large scatter of the record on short time-scales, one can consider that the dissipation is essentially constant during the whole time. In that hypothesis, the heat flow at the CMB has be-tween 14 and 24 TW before the crystallization of the inner core. The largest figure, when extrapolated backward, gives a temperature at the CMB of 10000 K at $t = -4.5\ Ga$ and should be excluded. Another possibility that is explored is the presence of ^{40}K in the core. The radioactive heating is the less efficient of all energy sources but it may extend the time during which the inner core and the associated energy sources have been present.

GP61A-1011 0830h POSTER

Kinematic dynamo properties of a quasigeostrophic flow in a rotating sphere.

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The problem of convection in rapidly rotating spherical shells is central to the study of planetary core dynamics. In the limit of large rotation this problem is mainly two-dimensional and can be simplified by the use of a quasigeostrophic approximation, without loss of the essential features in the flow. This allows the simulation to reach regimes of small Ekman and large Reynolds number, which are appropriate for planetary cores. A magnetohydrodynamic study of this parameter regime is crucial for the understanding of planetary dynamos, especially weak-field dynamos which are expected to operate on a quasigeostrophic flow state.

We present a first study of the kinematic dynamo properties of quasigeostrophic flows. They contains vertical helicity and dissymmetry between cyclones and anticyclones, two factors favouring a strong alpha effect to convert toroidal magnetic field into poloidal field. Previous studies of slightly ageostrophic convection at more moderate parameter values have shown that the second dynamo effect, which converts back poloidal field into toroidal field is mainly another alpha. We show that in the quasigeostrophic limit, this second effect cannot be an alpha and has therefore to be an omega effect. Quasigeostrophic flows contain strong zonal winds created by potential vorticity mixing, and can naturally produce this omega effect. The efficiency of both dynamo effects is studied versus flow parameters. We then anticipate where in the parameter space dynamo action should be easier to create and present preliminary results of kinematic dynamo calculations, done in the case of a thermally forced flow and in the case of the flow produced by a differentially rotating inner core.

GP61A-1012 0830h POSTER

Experiments on Turbulent Viscosity in Earths Core

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One of the main criticisms of the present generation of numerical geodynamo simulations is that they are carried out using non-dimensional parameter values far from those of the Earth. In particular, simulations use values of the fluid viscosity many orders of magnitude greater than molecular viscosity estimates for core fluid, such that the Ekman number, Ek, and the magnetic Prandtl number, Pm, have values of $\geq 10^{-5}$ and ~ 1, respectively. Using molecular viscosity estimates, these parameters take on values of $\sim 10^{-15}$ and $\sim 10^{-6}$, respectively. Here, we present experimental measurements of turbulent viscosity, made in a rotating spherical shell of water, relevant to the dynamical conditions within planetary cores. In these "spin-up" experiments we increase the shells rotation rate and measure the time for the fluid to re-equilibrate to the new rate. These measurements provide a value for the *effective viscosity*, which averages in the effects of small-scale turbulence on the large-scale fluid behaviour. Our results verify the theoretical prediction that the spin-up time is proportional to the inverse square-root of the fluids molecular viscosity in the laminar regime. Beyond this, with turbulent convection, the effective viscosity increases by as much as 50% over molecular values. From these measurements, we have derived a phenomenological law that predicts that the effective viscosity of core fluid may be $\sim 10^6$ times greater than molecular viscosity estimates. Using this effective viscosity estimate yields values of $Ek \sim 10^{-9}$ and $Pm \sim 1$ in the Earths core. Thus, our experimental results suggest that the numerical dynamo simulations may be dynamically far more similar to the Earths core than previously thought. This, in turn, may explain the gross agreement between magnetic fields generated in the numerical simulations and observations of the geomagnetic field.

GP61A-1013 0830h POSTER

A new Method for Determining the Fluid Flow Below the Core-Mantle Boundary From Global Models of the Geomagnetic Field

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We use geomagnetic field models from the Magsat (1980) and Oersted (2000) satellites to determine the fluid flow just below the core-mantle boundary (CMB). Mapping core flow places constraints on geodynamo models, changes in the length of the day, and the thermal structure of the core. We assume the flow obeys the quasi-geostrophic constraint, in which the radial upwelling is correlated with the horizontal vorticity. In the context of the quasi-geostrophic constraint we examine various physical assumptions, including frozen magnetic flux, tangential magnetic diffusion, columnar flow, toroidal flow, Ekman boundary layer flow, and tangential geostrophy. The sign of quasi-geostrophic circulation is dictated by the change in magnetic energy density on the CMB. The circulation is clockwise where the magnetic energy density is decreasing and is counterclockwise where the magnetic energy density is increasing. Our solutions contain some features found in previous core flow models, such as high velocities in the Atlantic hemisphere relative to the Pacific hemisphere, and a general absence of zonal velocity except in the polar regions. However, our solutions differ from previous ones in the nonzonal velocity field. For example, our solutions contain a significant amount of field-aligned flow, and include intense vortices and jets.

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Main Magnetic Field Determination and Sq-Model Tuning From Local Geomagnetic Variations

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A study of geomagnetic variations at several ground observatories approximately aligned along the same meridian ($\sim 295^{\circ}$) has been performed.

First, the monthly frequency distribution (histogram) of the measured magnetic field is investigated, and its seasonal and yearly variations are examined. At Godhavn (Greenland), the distribution is found sharply peaked for winter months, allowing for a new determination of the background geomagnetic field of internal origin and of its secular variation. The method has the advantage of taking into account any local anomaly. However, it requires high quality data, and cannot be applied to San Juan and Fredericksburg observatories. Their data present too much dispersion, and a digital filter (bandpass) must be used to determine the background field, although it might remove some physics.

In a second analysis, we take the 5 quietest days of each month, and then separate observations according to the polarity of the y-component of the Interplanetary Magnetic Field. Using 20 years of data to cover two consecutive solar cycles allows us to cancel out the Svalgaard-Mansurov effect at high latitudes, and to isolate a typical Sq daily pattern at any station for each month. This Sq characterization from local measurements is found very useful in tuning Sq models, which provide daily field-variations that are not always in phase with observations, particularly at high-latitudes.

For example, the NOAA/Sq1 model and observations at Godhavn present a phase-shift of about 3 hours.

Both the tuning of Sq-model and the determination of the background field have implications for daily field-variation removal in local crustal magnetic surveys, for the establishment of reference levels in disturbed field analysis, and for the improvement of the Earth's main field determination.

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Torsional Oscillations and Geomagnetic Variation

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Fluctuations in the length of day at decadal periods are commonly associated with torsional oscillations in the fluid outer core. The frequency and spatial structure of the torsional oscillations depend on physical properties of the core-mantle system, most importantly the cylindrically averaged radial component of the magnetic field within the fluid. The fluid motion of these oscillations will also produce periodic variations in the geomagnetic field. We have developed a numerical model that describes the torsional oscillations of the fluid core together with the associated rigid-body rotations of the mantle and inner core. The model includes the effects of mechanisms such as gravitational coupling between the inner core and mantle and electromagnetic coupling between the outer core and the inner core and mantle. Our model allows us to determine the natural modes of axial rotational oscillation of the core-mantle system. We have derived the orthogonality condition which enables us to formally decompose an arbitrary fluid motion, and its associated geomagnetic variation, into a sum of these modes. This result establishes a framework whereby physical properties of the core and the excitation of torsional oscillations can be recovered from observed geomagnetic variations using a method analagous to normal mode seismology.

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Symmetry in Micromagnetics

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Hysteresis occurs in a ferromagnet because the magnetization can become unstable and jump to a different state. One of the challenges for micromagnetics is finding all the solution curves for a given variable such as the magnetic field. In this talk I show that the symmetries of magnetic states can be used to analyze existing solutions and obtain new ones.

A given particle has a magnetic and a nonmagnetic symmetry group. The nonmagnetic group is determined by the crystallographic point group and the shape of the particle. In response to a given operation in this group, the magnetization and magnetic field transform as pseudovectors. In zero field, every symmetry that leaves the body invariant also maps one equilibrium state onto itself or another state of the same energy. Thus, symmetry operations can quickly generate new solutions. Comparisons between equivalent solutions provide a good estimate of their precision.

Magnetic symmetry groups are a combination of spatial operations and time reversal (which changes the sign of the magnetization). They leaves the magnetic field and moment invariant, so the highest symmetry the magnetization can have is determined by the physical symmetry of the particle and the field direction. The single-domain (SD) or "flower" state has the highest symmetry. Other states can be traced back to the SD state through bifurcations. The most important such bifurcation, a generalization of curling-mode nucleation, breaks inversion symmetry. The result is that the SD state splits into two states, each of which can be obtained from the other by inversion. For many materials (including magnetite), this bifurcation can occur even when the magnetic field is in an arbitrary direction.

An important feature of bifurcations is that the prebifurcation state continues as an unstable state. Numerical micromagnetic algorithms can easily be fooled into following the unstable state. Several modelers have obtained a remanent state called the double vortex state. This is the result of a second bifurcation off the unstable state, and is itself unstable. The incorrect choice of continuation at a bifurcation is a major source of error in micromagnetic models, and it is difficult to spot without some understanding of the symmetry.

URL: http://www.geol.ucsb.edu/∼newell/FallAGU2002.html

GP61A-1017 0830h POSTER

Ocean Tidal Dynamo Identified in CHAMP Satellite Magnetic Data

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Sea water is an electrical conductor. As it is moved by ocean flow through the Earth's magnetic field, electrical currents are induced. These currents generate secondary magnetic fields which have now been identified for the first time in CHAMP satellite magnetic data.

From the first 2 years of CHAMP total field magnetic measurements we select magnetically quiet periods by using only the night time data (22:00 to 6:00 local time) and discarding periods with a magnetic activity index $K_p > 2$. The analysis is restricted to track segments of -60° to 60° geomagnetic latitude. After subtracting a main field model 05m-02 *[Olsen, 2002]* and a lithospheric field model MF1 *[Maus et al., 2002]*, we remove long wavelength magnetospheric and ionospheric contributions by subtracting best-fitting external and internal spherical harmonic degree-1 fields, separately for each track. In the future, this filtering can possibly be substituted by a joint inversion of multiple satellite and ground observatory data.

For a first demonstration of this effect we focus on tidal ocean flow because periodic signals are readily separable from steady contributions to the magnetic field, the lithospheric magnetization in particular. For the strong lunar M_2 tidal constituency, we find an ocean magnetic signal with a filtered amplitude in the range of ±1 nT at CHAMP altitude (380-470 km). A global map of the signal agrees remarkably well with fully independently derived model predictions.

The identification of this ocean dynamo signal has important implications: In broader terms, it encourages future studies to assess the feasibility of monitoring ocean flow from space using magnetic field satellites. A more immediate consequence, however, is that oceanic signals must be incorporated into geomagnetic field models. Indeed, with recent advances in internal/external field separation the ocean flow signal is now the strongest remaining signal in the low latitude magnetic residuals which has not yet been modeled. Correcting magnetic readings for predictable ocean flow signals could significantly raise the detectability of small scale crustal magnetization.

References

Olsen, N., *Geophys. J. Int.*, **149**, 454-462, 2002.

Maus et al., *Geophys. Res. Lett.*, **29**, 14, 10.1029/2001GL013685, 2002.

URL: http://www.gfz-potsdam.de/pb2/pb23/SatMag/ocean_tides.html

GP61A-1018 0830h POSTER

Forecasting the geomagnetic field secular variation

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Despite of the great amount of studies on the processes that generate the geomagnetic field, some of its main aspects are not completely known yet. One of the consequences is the difficulty to predict, even for short time intervals, say of a few years, its apparently erratic temporal behavior. Some recent studies suggest the possibility of a chaotic regime for the fluid core motions originating the field; if this were true, for short-time predictions a nonlinear forecasting approach would produce better results than any linear method. To test this statement, a nonlinear forecasting method is compared with other four linear forecasting techniques when applied to some geomagnetic field observations. The linear techniques range from a simple linear regression to more sophisticated procedures such as singular value decomposition and maximum entropy approaches. The observational data were composed of the Y-component yearly means first differences from five Observatories running for the last 130 years. Results show with a good statistical confidence that the nonlinear method is definitely the best way to predict the geomagnetic field 1-year ahead, supporting the initial idea of an underlying chaotic dynamics.

GP61A-1019 0830h POSTER

Verification of a MHD dynamo simulation Code Using the Finite Element Method by the Dynamo Benchmark Test

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We have developed a simulation code for MHD dynamo in a rotating spherical shell using the GeoFEM platform, which serves simulation platforms using the finite-element method (FEM). An advantage of FEM is that FEM is suitable for parallel computation because FEM consists of local operation while a spectral harmonics expansion requires a significant number of global computation. However, one difficulty exists in the treatment of boundary condition for the magnetic field between a conductive fluid and the electrical insulator under the FEM platform. To solve the problem, we consider a finite element mesh from the center to $r_m = 14.8L = 5.1R_e$, where L and R_e are width of the fluid shell and the Earth's radius. Furthermore, the vector potential of the magnetic field with the Coulomb gauge is treated to solve the magnetic field.We performed the dynamo benchmark test by Christensen et al. (2001) for verification of the present simulation code. In the present study, we performed the non-magnetic case and a simple MHD case of the benchmark test. We performed the MHD simulation using a rotating hemispherical shell considering symmetries with respect to the equatorial plane. The simulation performed with 3 different horizontal resolution from 7.8×10^4 elements to 3.3×10^5 elements. The results show that the compared parameters have approximately 5% of differences from the suggersted solution by Christensen. Amplitude of these errors depends on parameters; that is, the magnetic energy has only 1.5% error while the kinetic energy has 5 % of difference from the solution because the convection is strongly influenced by the Lorentz force.

GP61A-1020 0830h POSTER

Geomagnetic Polarity Reversals as a Stochastic Resonance Phenomenon

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A special class of noise-induced co-operative phenomena is represented by Stochastic Resonance (SR). In detail, stochastic resonance refers to a nonlinear process in which a very small periodic modulating signal, generally undetectable, is strongly enhanced by intrinsic random fluctuations or noise. Its essential ingredients are a bistable system with two inputs of different source: an external coherent periodic driving signal and an intrinsic noise source. In the last decade, stochastic resonance has been observed to occur in a wide variety of physical and biological systems: from bistable ring lasers to mechanoreceptor cells of crayfishes.

Here, we show that geomagnetic polarity reversal phenomenon might be read as a stochastic resonance process. In detail, analysing the distribution function of polarity residence-time (chron) as observed from magnetostratigraphic measurements, we find the evidence of a stochastic synchronisation process, i.e. a series of peaks at $T_n = (2n+1)T_\Omega/2$ with $n = 0, 1, ., j$ and $T_\Omega \sim 100$ kyr. This result is discussed in the framework of dynamo theory and in connection with variation of the Earths orbit parameters.

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