

Earth's Magnetic Field Modelled with a Variable Speed Inner Core

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Abstract

Recent data on the paleomagnetic and seismic record show that the solid inner core rotates faster than the mantle and is consistent with an elongated volume and 10 degree tilt in the north south axis. Using this data it is argued that the liquid core circulates around the earth's equatorial plane and has a speed differential across its radius. And that it is this which drives the dynamo mechanism powering the earth's magnetic field. It is also argued that the polarity reversals and drift observed in the data record are consistent with precession of and various changes in the shape, rotational speeds and angle of the north south axis of the solid inner core relative to the mantle.

Keywords: magnetic field reversal, paleomagnetic record, geomagnetic phenomena, geodynamo theory, solid inner core

Introduction

The Earth's magnetic field is attributed to a dynamo effect of circulating electric currents generated by flowing liquid iron in Earth's liquid core. As magnetic fields surround electric currents, we can surmise that circulating electric currents in the Earth's molten metallic core are the origin of the magnetic field. Although little is known of the flows within the liquid core, in this paper it is proposed that rather than the currently assumed chaotic heat driven convection heat driven flow a more uniform directional flow is operating in the liquid core. And, that this flow direction is circulating strongest in the equatorial east-west plane. Data supporting this proposed directional flow of the liquid core can be found in studies of the seismic record made by Song and Richards in 2005. (3) From their research they concluded that the earth's solid inner core is rotating west to east relative to the mantle. Their conclusion is based on data which indicates that seismic waves travel fastest along a north-south axis that is skewed slightly from an exact north-south alignment. And that this anisotropy has shifted in the last 100 years from an axis centred over Siberia to one that is centred over Alaska. This implies that the earth's solid inner core is rotating west to east at approximately 1 degree longitude a year faster than the mantle, and that the centre of rotational axis of the solid core is similarly off axis and changing with time. Based on this assumption, one can conclude that the inner part of the liquid core must be rotating in an easterly direction relative to the mantle. The important point proposed here is that the liquid inner core must be rotating in a relatively uniform easterly direction around the earth's equatorial axis. Rather than the theoretical chaotic non-rotational convection flow currently assumed. And that the inner liquid core must flow faster in this easterly direction than the outer liquid core (and mantle). It is also assumed here that this core spinning is accompanied by precession, which in shorter time frames could also appear to be similar in the data measurements to topological deformities (5).

The Liquid Dynamo

It is this difference in rotational speeds across the radius of the liquid core that drives the geodynamo and in turn gives rise to the electrical currents flowing in the earth's liquid core. Since the equatorial region of the liquid core has the greatest speed differential across its radius it is this equatorial flow in the liquid core that defines the strength and direction of the magnetic field that it induces. And that the axis of this induced field is perpendicular, or north south, to the direction of the equatorial plane of rotation. This is observed in the Earth's magnetic field. As observed in any dynamo mechanism one can assume that the direction of the motion of rotation of the constituent `parts` of the dynamo must dictate the direction of the induced electrical currents and in turn the direction or polarity of the induced magnetic field. This directional rotational flow in the liquid core generates either an opposing equatorial electric current or possibly one that travels perpendicular to the flow, i.e. from core to mantle or vice versa. In either case a reversal of this directional flow in the liquid core must therefore induce a reversal in the induced electromagnetic field. Hence if the solid core were to slow its rotation so that it rotated slower, rather than faster than the mantle, the direction of rotation of the circulating flow in the liquid inner core will also be reversed. The result would be a reversal of polarity of the induced electromagnetic field. This is observed in the paleomagnetic record.

It is worth pointing out here that in recent experiments a freely rotating liquid metal can generate a self-sustaining magnetic field without a necessary seed magnetic field to kick-start the dynamo effect as previously thought (2). Currently there is no data from this or similar experiments which rules out the possibility that the liquid flows in the experimental setup are rotational rather than chaotic or convective. In addition to this the model proposed here also predicts that if the equatorial rotation of the liquid sodium in these experiments were to be reversed a reversal in the observed induced magnetic fields should be observed.

A Variable Speed Core

The next step in this model is to explain how the observed data on the solid cores rotations and alignments of axis can be made consistent with and explain how the equatorial circulation of the liquid core can reverse in direction. The seismic record shows that sound waves travel fastest along earths N-S axis. This observation is consistent with this model's proposal that the solid inner core is being slightly elongated in the earths N-S axis. That is; sound waves travel through a larger proportion of the distance travelled in solid core material than liquid core in the north south axis. As sound waves travel fastest in a denser medium. Following from this assumption I propose that the `solid` inner core has elastic properties. Observations support this possibility (1,5) And that its shape could then be said to oscillate over very large timescales between that of elongated in the N-S axis to stretched along the equatorial plane. Obviously, this implies that the solid inner cores rotational speeds would vary relative to the mantle. Slower when it is wider along its equatorial axis and faster when it is stretched along its north-south axis. The historical record of Earths pole reversals and changing field strength can thus be well modelled by this variable core speed model. In that if one assumes from the data that the `solid core` is currently stretched in the north south axis then its rotational velocity must be faster than the mantle. And when the cores volume

changes shape to that of more stretched in the equatorial axis, the solid inner core will then be forced to rotate slower than the mantle .(i.e. the core will then rotate in a westerly direction relative to the mantle than the present day easterly direction as deduced by Song and Richards in their research.)

This would reverse the relative motion between the inner and outer parts of the liquid core (as described above) and in turn reverse the induced electromagnetic field from N-S to S-N. This is observed in the historical seismic record.

The current weakening of Earth's magnetic field is consistent with the assumption that the solid cores` rotational speed is slowing relative to the mantle. In other words, if it is assumed that currently the core is observed to be travelling faster than the mantle in an easterly direction at 0.1 longitude per year than this rate would have been faster in the past and will be slower in the future. This can only be explained if it is assumed that the `solid` core itself is becoming less stretched in the N-S axis and tending towards becoming stretched in the equatorial axis. That is, the solid inner core is slowing down its rate of rotation from the currently observed 0.1 longitude /year to that of one closer to 0 longitude /year. It is also possible but difficult to currently verify, that precession of the inner core and thus a change its tilt relative to the earth's rotation axis is driving this recent weakening of the overall geomagnetic field strength.

Off axis Magnetic field

The next step in this model is to explain the observed off axis magnetic North pole and its northward drift. One can again refer to the seismic record, which shows that the axis of anisotropy, corresponding to the fastest direction for seismic waves, tilts about 10 degrees from the Earth's N-S axis of rotation, towards Siberia. From this data one can interpret that the inner core is not only `stretched` in the N-S axis but is also physically tilted 10 degrees off axis towards Siberia as it rotates within the earth's core. So, in addition to rotating faster than the mantle, its axis of mass is also tilted off centre by 10 degrees and stretched slightly in the N-S axis. This should in turn effect the angle of rotation within the liquid inner core, which acts as a fluid boundary layer between the different rotational speeds of the mantle and the solid inner core. Modelling the flows within the liquid core flow will always be speculative for any model, but it is not unreasonable to assume that a 10 degree off axis solid core centred over Siberia could create an equatorial flow in the inner part of the liquid core that would be tilted to an equal but opposite 10 degrees centred over the north of Canada. Resulting in an equal and opposite tilt in the induced magnetic North pole of 10 degrees towards the Arctic. This predicted tilt in the magnetic pole towards the arctic is consistent with observation. As the axis of the solid core is indeed observed to be tilted towards Siberia.

Magnetic Pole drift

The final part of this model is to explain the northerly drift of the magnetic North pole. There is insufficient seismic data to confirm or refute predictions made by the variable speed core model proposed here. However, in this paper it is proposed that the northerly drift of the magnetic north pole is due to a northerly drift of the solid inner core's rotational axis from its

current 10 degrees off axis tilt towards one that is 0 degrees. In other words, the north south axis of the solid inner core currently observed at 10 degrees off axis over Siberia should in time be observed to align itself to one that is 0 degrees in the north south axis. And furthermore, in the past this motion can be extrapolated backwards to an oscillation in the north south axis of the solid inner core's rotation around the north pole from anywhere between 0 degrees north south to the current 10 degrees or more. In fact, the geomagnetic record indicates that this is indeed what has occurred. Research by Joseph Stoner (4) and his colleagues shows that the North Magnetic Pole has indeed moved in a similar pattern over the last few thousand years. In general, it moves back and forth between northern Canada and Siberia. But it also can veer sideways. The observed oscillation in the magnetic pole around the geographic true north in the geomagnetic record is consistent with predictions of an oscillating precession of the rotational axis of the solid inner core proposed in this paper.

Summary and Conclusions

In conclusion, a model is proposed here where the inner core is said to oscillate between stretched in the north south axis to stretched in the equatorial axis as it rotates. And that this oscillation forces the solid inner core to alternately rotate slower and then faster than the mantle. Forcing a similar reversal in the flow direction of the liquid core. It is this alternating equatorial flow direction in the liquid core which generates the observed north-south reversals in the earth's magnetic field.

In addition, this model proposes that superimposed on this flow reversal pattern is an oscillation or precession in the solid inner core's vertical rotational axis around the Earth's geographic north-south axis. Which in turn forces an equal and opposite oscillation in the equatorial rotation plane of the liquid core, and an oscillation in the north south axis of the induced electromagnetic field. This is consistent with the observed oscillation in the direction of the magnetic north pole around the earth's true geographic North Pole.

References

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