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2006 Ocean Sciences Meeting Travel Grant Opportunities

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Travel support for students participating in the 2006 Ocean Sciences Meeting (20–24 February, Honolulu, Hawaii) is being offered through two programs. The 2006 Ocean Sciences Meeting is jointly sponsored by AGU, the American Society of Limnology and Oceanography (ASLO), and The Oceanography Society (TOS).

Student Travel Grant Program: Students presenting first-author papers at the Ocean Sciences Meeting are eligible to apply for partial travel support through the Student Travel Grant program. Support for this program has been made available by a grant from the U.S. National Oceanographic Partnership Program (www.nopp.org), with additional contributions from AGU and ASLO.

Grant recipients will be selected using several criteria, including degree level, availability of additional travel support, evidence of need, and advisor/supervisor comments. Disciplinary breadth and the variety of geographic/institutional locations of the recipients will be taken into consideration. Grants will range between $400 and $750. The final award will be determined on the basis of geographic proximity to the meeting.

Applications are due by 20 October 2005. Applicants must be a student member of AGU, ASLO or TOS. Previous recipients of AGU Student Travel Grants are not eligible to apply. Complete eligibility requirements and the online application form are available at www.agu.org/meetings/os06/.

ASLO Minorities Program: Underrepresented minority students (undergraduate and graduate) who are interested in the marine and aquatic sciences are eligible to apply for full travel support (transportation, housing, food, and registration) to attend the Ocean Sciences Meeting. The ASLO Minorities Program also includes several special activities for participating students: a one-day pre-conference workshop (19 February), field trips, a dedicated student research symposium, partnering with meeting mentors, and a keynote address from a leading aquatic scientist. Students will also receive a free membership in ASLO, including a subscription to the journal *Limnology and Oceanography*.

The ASLO Minorities Program is a collaboration between Hampton University, Virginia, and ASLO, with sponsorship from the U.S. National Science Foundation. Over 520 students have participated in this program since 1990. Applications for the 2006 Ocean Sciences Meeting program are due 3 October 2005. Complete information and application forms are available at: http://www.hamptonu.edu/science/ASLO.htm.

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FORUM

COMMENT & REPLY

Comment on "Could the $M_w = 9.3$ Sumatra Earthquake Trigger a Geomagnetic Jerk?"

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In a recent issue of *Eos*, *Florindo et al.* [2005] suggest that large seismic events, such as the magnitude 9.3 Sumatra earthquake of 26 December 2004, may cause changes in topography at the core-mantle boundary (CMB), thereby affecting flow in the core. They hypothesize that this effect may trigger a geomagnetic jerk, which would be observed at Earth's surface after a time delay to allow for the signal to propagate through the weakly conducting mantle. However, they do not provide any estimates of the amplitude or form of the CMB topography changes that are required, or of the actual CMB deformation that may have occurred as a result of the Sumatra event.

Here, I argue that it is unlikely that large earthquakes can lead to geomagnetic jerks.

Geomagnetic jerks are rapid (~1 year) changes in the slope of the first time derivative of the geomagnetic field recorded at the surface. They are of internal origin [*Malin and Hodder,* 1982] and are observed on a global scale [*Alexandrescu et al.,* 1996]. They also correlate with times at which inflections in the time derivative of the length of day (LOD) are observed [*Holme and De Viron,* 2005]. Thus, if geomagnetic jerks originate in the core, they must be related to a global change in flow near the surface of the core, and this global flow must participate in the angular momentum balance between the core and the mantle.

Torsional oscillations, which are oscillations of rigid coaxial cylindrical surfaces inside the core, meet both of these criteria. Moreover, they have been shown to be consistent with geomagnetic jerks [*Bloxham et al.,* 2002], with variations in flow amplitude of the order of 1 km/yr. We note that global flows other than torsional oscillations could conceivably produce geomagnetic jerks, but the required CMB topography change should be of the same order as the value given below and so the general result presented here remains valid.

In order to instigate a change in torsional oscillations, the deformation of the CMB must be axisymmetric and symmetric about the equator. The amplitude of the required deformation is modest: Inside the core, a torsional oscillation flow of 1 km/yr results from a distortion of the elliptical surfaces of constant density of 0.2 mm [*Dumberry and Bloxham*, 2004]. Hence, if large earthquakes can generate such a change in CMB ellipticity, they can induce significant changes in core flow and produce a geomagnetic jerk.

Considering the relatively large displacements that took place in the Sumatra earthquake (as high as 20 m in some places), this hypothesis seems plausible. However, the north-south orientation of the fault plane implies that the largest gradients in vertical deformations were east-west, incompatible with the axisymmetric CMB deformations required for torsional oscillations. In addition, despite the huge fault rupture zone of 1200 km, most of this deformation occurred locally.

To give an idea of the much smaller global CMB topography change that has occurred, consider the change in ellipticity. The displacement in an earthquake produces a change in the moment of inertia of the whole Earth. From this, we can calculate the adjustment in global ellipticity required to produce the equivalent change, as if one were to redistribute the local mass displacement over the entire Earth.

Interestingly, for the Sumatra event this amounts to an adjustment in CMB ellipticity of a fraction of a millimeter, roughly the value required to generate a 1-km/yr torsional oscillation flow. But since the actual mass displacement was mostly local, we can only conclude that the actual change in CMB ellipticity must have been orders of magnitude smaller.

Another mechanism by which earthquakes can produce global changes in CMB topography is a shift in the direction of the rotation axis, which results from the change in the equatorial moment of inertia induced by seismic deformation. This process is equivalent to tilting the oblate CMB with respect to a fixed core. In order to produce a CMB topography change of 0.1 mm, a tilt of ~0.004° is required, which amounts to an arc displacement of the rotation axis of ~400 m at the surface of the Earth. This is a huge displacement, four orders of magnitude larger than the ~2.5-cm shift calculated to have occurred for the Sumatra earthquake [*Chao and Gross*, 2005].

A complementary approach is to consider the impact that the requisite change in core flows would have on the changes in LOD. A change in torsional oscillation flow of 1 km/yr should produce a signature in LOD of about 0.5 milliseconds. This is in addition to the direct change in LOD due to changes in the axial moment of inertia of the mantle, which for the Sumatra event was calculated to be 2.68 microseconds [*Chao and Gross,* 2005]. The response of the core to a change in CMB topography is not instantaneous, but the resulting flow should be established within a few periods of inertial waves in the core, i.e., a few days. However, no abrupt change in LOD has been observed in the wake of the 26 December earthquake (Richard Gross, personal communication, 2005).

Because a coincident change in LOD has not occurred, and because the CMB topography changes were too small, the Sumatra earthquake should not have triggered a geomagnetic jerk. Indeed, one can be convinced of this by considering previous large earthquakes. Following the 1960 Chilean earthquake and the 1964 Alaskan earthquake, the next jerk to be recorded was not until 1969, a full five years after the Alaskan earthquake and a delay too long to be accounted for by mantle conductivity. Similarly, there is no evidence that these two large earthquakes were followed by abrupt variations in LOD. We must then conclude that large earthquakes do not lead to geomagnetic jerks.

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Reply to Comment by M. Dumberry

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We thank M. Dumberry for providing the opportunity to discuss further the article [*Florindo et al.*, 2005] in which we suggested that the Sumatra earthquake could have triggered a geomagnetic jerk. Dumberry is against our hypothesis for different reasons: (1) The displacement pattern produced by this earthquake is incompatible with the core-mantle boundary (CMB) deformations required for a torsional oscillation; (2) most of the deformations occurred locally, producing an actual mass displacement that has not involved the entire Earth; and (3) no abrupt change in the length of day (LOD) has been observed after this event.

Although we agree with some of the considerations proposed by Dumberry, we think that these do not rule out the possibility that a jerk has been triggered by the Sumatra earthquake or that in the future, other earthquakes could induce a change in the flow pattern near the CMB leading to a geomagnetic jerk. On the contrary, we retain that this hypothesis is plausible, although it is more correct to talk about the existence of a possible link between geomagnetic jerks and earthquakes where the earthquake magnitude is not the only discriminating parameter.

About the specific possibility that a geomagnetic jerk has been triggered by the Sumatra earthquake, we think that the considerations provided by Dumberry on the deformation effects produced by this earthquake, specifically on the local nature of the deformation field and on the negligibility of the effects on the CMB topography, cannot be accepted as conclusive.

Indeed, there are neither observational nor modeling data on the effects on the CMB, while both GPS data and synthetic modeling of surface displacements indicate that the deformation pattern is far from being local. In particular, there is evidence of surface displacements exceeding 1 mm at distances ranging from 2000 to 5000 km from the epicenter [*Banerjee et al.*, 2005; eformations triggered by the Sumatra earthquake, submitted to *Science,* available at http://arXiv.org/physics/0506003].

Finally, Dumberry suggests that a change in the torsional oscillation flow able to trigger a geomagnetic jerk should produce a signature in the LOD. On this basis all geomagnetic jerks should be characterized by a change in the LOD. Since this was not observed after the Sumatra earthquake, the possibility of a geomagnetic jerk occurrence should be excluded. Nevertheless, the existence of a correspondence between the jerk and the LOD variation is not so clear. It has been proposed both that jerks are markers that anticipate the changes in the Earth's rotation rate of a few years [*Le Mouël et al.,* 1992; *Mandea et al.*, 2000] and that there exists a direct and rapid connection between the timing of jerks and certain features in LOD changes [*Holme and de Viron,* 2005].

However, in this last work the authors underline that their interpretation is clearly nonunique, and moreover, the acceptance of this correlation is based on the assumption that the 1969 and 1978 geomagnetic jerks are, according to the authors, four separate events: in 1969, 1972, 1978, and 1982. On the contrary, the 1991 jerk, which is characterized by the same bimodal distribution of the time occurrence of the 1969 and 1978 jerks [*De Michelis and Tozz*i, 2005], should remain a single event as well as should the 1999 event.

We find this connection still worthy of further investigation, and we think it is probably too early to conclude that geomagnetic jerks are always coupled to fluctuations in the LOD.

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