EVIDENCE FOR A GEOMAGNETIC JERK AFTER 2003 IN LOD

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ABSTRACT

Geomagnetic jerks are well-known, but arguably still poorly understood, features of the temporal behaviour of the geomagnetic field. They consist of sharp changes in the secular acceleration of the field, in some cases seen globally, while in other cases only at some locations at the Earth's surface. We have recently [1] provided evidence for a correlated feature in the rotation of the Earth. Here we extend analysis of the rotation signal to the start of 2006. We find evidence of a jerk-like feature centred approximately in 2003, suggesting that a geomagnetic jerk may be visible in the time following this. Our study was motivated by suggestions [2] that such a jerk can be detected in satellite observations of the geomagnetic field. Thus, our results provide support for the existence of a geomagnetic jerk in 2004, and also for the detection of such jerks in satellite magnetic data.

1. REMOVING AAM FROM LOD

Applying the same techniques as in [1], we subtract a direct calculation of atmospheric angular momentum (AAM) from the observed length-of-day (LOD) variation. After doing this, much power remains at annual, biannual and terannual periods, related to errors in the AAM modelling and to many other less important processes that contribute to LOD variation. We eliminate such variations by taking a simple 365 day running average. Oceanic angular momentum has not been removed, as this increases rather than decreases the residual signal on annual time scales (although the long-term trend may be more robust (R. Gross, *pers. comm.)).*

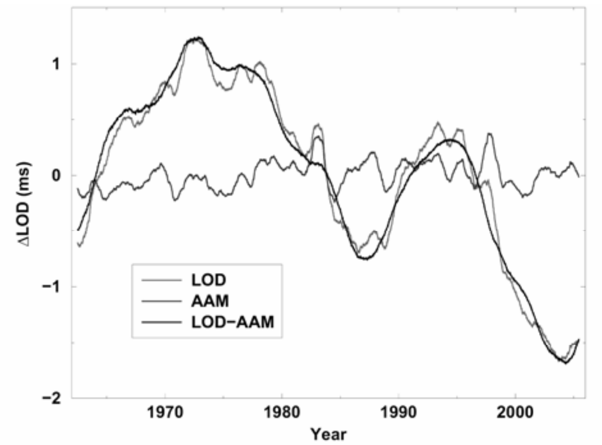

Figure 1. 365-day running averages of LOD, AAM and their difference

The result of this procedure, extended from [1] to the beginning of 2006, is shown in Fig. 1. The LOD signal after removal of the calculated AAM is clearly much cleaner than could be achieved by a purely numerical filter. We recommend this smoothed time series for use in studies of decadal LOD variation, particularly for studies relating to the Earth's core.

2. TIME DERIVATIVE OF THE SMOOTHED LOD SIGNAL

Even after taking the yearly running average, some short period noise remains in the data, which can be eliminated simply by fitting penalised least-squares to the time series [3]. This method has the further advantage that it enables direct calculation of the time derivative of the time series, of particular interest in studies of the torques giving rise to LOD variation. The form of this derivative depends on the "taughtness" of the splines: the choice of Lagrange multiplier which controls the trade-off between the fit to the data and the smoothness of the spline curve. In Fig. 2, we compare the derivatives of a "rough" curve (providing a very close fit to the data) with that of a "smoother", less well-fitting, curve. This comparison highlights small features in the rougher curve (seen as "wiggles" departing from the smoother curve), which in [1] we argued were associated with, or preceded, times at which a geomagnetic jerk is observed.

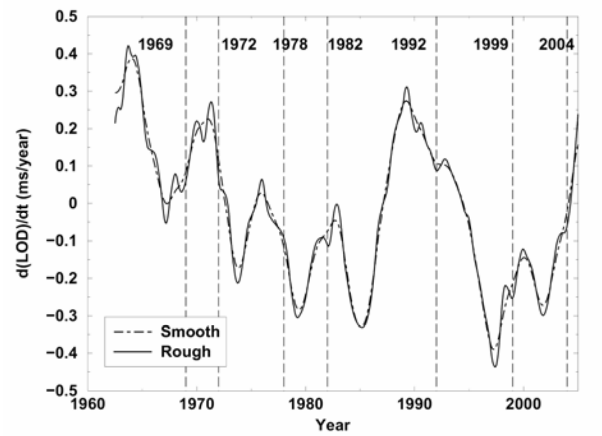

Figure 2. Time derivatives of a rough and a smooth spline fit to the 365-day running average of LOD- AAM. Vertical dashed lines mark approximate jerk epochs.

LOD features immediately correlated with geomagnetic jerks had been predicted previously [4], but are only visible with the cleaner time series available from direct modelling of AAM. A link between LOD and geomagnetic jerks is particularly to be expected if the jerks arise from large-scale core flows called torsional oscillations [5], which carry the rotational angular momentum changes in the core.

Recently, CHAMP satellite data have been used to suggest a geomagnetic jerk around the start of 2004 [2]. The extended LOD series presented here shows a feature in its derivative just prior to this time, although this feature is at first sight less clear than similar features corresponding to earlier jerks. The signal is more difficult to identify because of the steep gradient of the curve at this time: in Fig. 3 we focus on the two jerk features at the end of the interval, and subtract in each case a local linear regression from the rough curve.

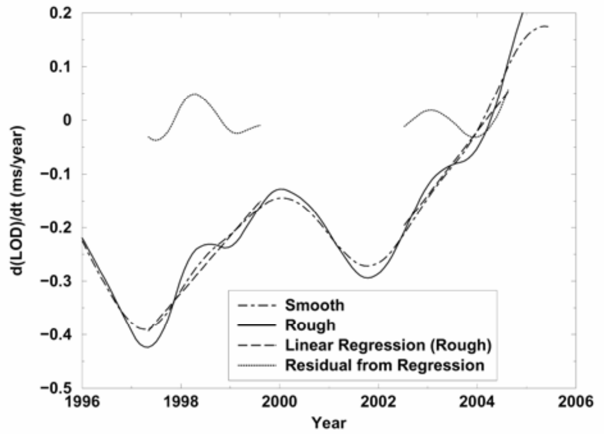

Figure 3. Departure of rough curve from a local linear fit. The residual signals are of similar magnitude for both jerk fetures (prior to 1999 and 2004).

The residuals to these linear fits demonstrate that the rotational effects seen in 1999 and 2003-4 are of similar magnitude. Overall, analysis of LOD provides evidence supporting the suggestion of a geomagnetic jerk close to 2004 [2]. Conversely, the appearance of a new feature in LOD near an identified jerk provides further support for a link between geomagnetic jerks and Earth rotation.

3. SYNTHETIC ELIMINATION OF THE JERK SIGNAL

Direct analysis of the features in the LOD time derivative curve is difficult because of the extent of the filtering which has been applied to the original time series (both a 365-day running average, and a smooth spline fit). Instead, we proceed by forward modelling. We add a chosen signal to the raw data, process the modified time series in the same way as described above, and look for any changes in the signals associated with geomagnetic jerks. Here, we choose a starting point close to the time of the jerk, and add an additional signal of 0.16ms / year – in other words, creating a discontinuity in the gradient of LOD. Physically, assuming that decadal LOD variation is dominated by changes in rotation in the fluid core, this is equivalent to a sudden jump in the torque on the core. The results of this procedure starting in 1998.8 and 2003.5 are shown in Fig. 4.

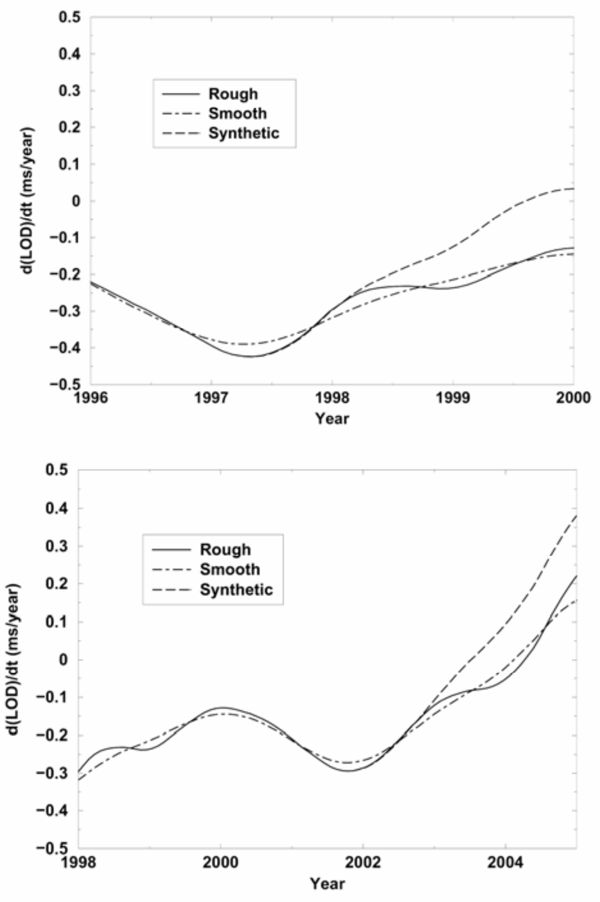

Figure 4. Synthetic signals added to the LOD curve at 1998.8 and 2003.5. The resulting curves are then processed as before (365-day running average, spline fit, and calculation of first derivative).

By adding such synthetic changes in LOD time derivative, we are able to eliminate both jerk signals. This implies that these signals could be generated by a discontinuity in the LOD derivative of equal and opposite magnitude to the signal we have added, although this interpretation is naturally severely non-unique. Interestingly, the features at the two times are of the same sign. In the earlier study [1] we were able to explain close jerk features (e.g., 1969 and 1979) by an equal and opposite change in gradient (in other words, a top-hat function in torque). This appears not to be possible for 1999 and 2004.

4. SOME OPEN QUESTIONS

The identification of an additional feature in LOD corresponding to a geomagnetic jerk encourages us to consider again some open questions concerning the nature of geomagnetic jerks.

1. Why is the geomagnetic signal of some jerks (e.g., 1969) well-explained by simple torsional oscillations [5], while others (e.g., 1972) are less well explained, despite the link supported here between the jerk and changes in Earth rotation?
2. Can the lag between the Earth rotation feature and the geomagnetic signal be used to constrain mantle conductivity? Can the LOD feature be located sufficiently accurately to permit this?
3. The closely spaced jerks in, e.g., 1969 and 1972 have been used for evidence of laterally varying mantle conductivity, assuming that the two signals are from the same event, but take longer to propagate through the mantle in the southern hemisphere, where the 1972 jerk is seen clearly, than in the northern hemisphere, where the 1969 jerk is particularly clear. However, the appearance of two separate events in the LOD curve suggests that these two jerks are separate events, and so such interpretation is not appropriate.
4. Smaller features can just be seen in the rough curve in Fig. 2 which are not associated with known geomagnetic jerks; allowing a closer fit to data (an even "rougher" curve) displays such features more clearly. Could the observed jerks be merely the largest of a continuum of features?

5. REFERENCES

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