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Signature of geomagnetic superstorm in Earth's rotation speed

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Abstract. A connection between solar activity and decadal Length of day variations is investigated. Statistical comparison of Length of day with various geomagnetic and Solar activity indices has been done for the last 140 years. A jump in Length of day (LOD) is found at the moment of the geomagnetic storm, the largest one for the last few decades, that happened in late October 2003, the so called Halloween storm. This change in rotational velocity of the Earth can not be explained by any known atmospheric or oceanic influences. Moreover, such jump in LOD is an unique one for the few recent years. It is supposed that this jump can be caused by transfer of angular momentum between Solar wind and the solid Earth. A possible mechanism of such a transfer is proposed.

1. Introduction

There are long-period variations of LOD (length of day), manifested in the characteristic periods of the order of 10 – 60 years and reaching 5 ms per year. These variations have been known for over 100 years, but their causes are still unclear.

Currently, there are two sets of hypotheses that attempt to explain the cause of these oscillations of Earth's rotation. The first group of hypotheses [1][2] suggests that the source of energy, exciting these variations is the liquid core of the Earth. The second group of hypotheses suggests that the excitation source is of Solar origin. Currently, the first group of hypotheses is preferred, but it still lacks an adequate theory. At the same time, there are numerous studies that address statistical associations between indices of solar activity and variations of LOD [3].

One possible mechanism of LOD variations can be electromagnetic effects of solar wind during magnetic storms. This mechanism is similar to the mechanism proposed in [1][2]. Rapid changes in the geomagnetic field during magnetic storms induce currents in the weakly conducting mantle, so the mantle is a circuit with a current, which is affected by Lorentz force. In this case, the observed variations of LOD can be due to accumulated disturbances from magnetic storms over a long period of time.

We try to find in the series of LOD features that could be interpreted as the results of the direct effect of geomagnetic storms on the Earth's rotation. Due to the fact that the effect of the identity of the storm should be small, traces can be left by a very large storm.



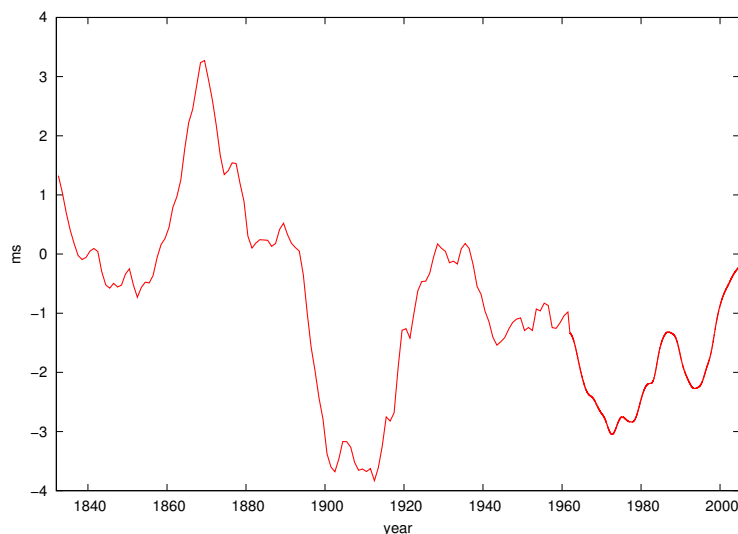


Figure 1. LOD from 1832 to 2010 (from 1832 to 1962 – Jet Propulsion Laboratory, from 1962 to the present – IERS – International Earth Rotation Service).

2. Geomagnetic storm

“Halloween storm” is one of the three most powerful geomagnetic storms in the history of geomagnetic observations:

- Geomagnetic storm on 1-2 September 1859. Refusal of telegraph in Europe and North America. Auroras in the tropics. Estimated value of Dst-index – 1760 nT.
- Geomagnetic storm on 13-14 March 1989. Faults in the power system of North America (blackout in Quebec), aurora over Mexico and Crimea, Dst-index – 589 nT. Radio failure.
- Geomagnetic storm late October – early November 2003. Radio failure, the failure of the spacecraft, Dst-index – 401 nT (29 October 2003). Average daily solar wind speed exceeded 1000 km/s.

In the course of the storm there were over 80 coronal mass ejections (CME) towards Earth. CME average speed during the storm was 878 km/s (average for the entire set of observations – 480 km/s). The share of CME speeds of over 900 km/s – 36% (7% on average). Ultra-fast CME (speed of more than 2000 km/s) – 9% (average 0.3%). The average kinetic energy of 1 CME – $4.4 \times 10^{23} J$ (average for the sample of observations – $5.4 \times 10^{22} J$). 13 CME had a kinetic energy of more than $10^{25} J$. In Figure 2 presented series of the velocity of the solar wind according ACE satellite data.

3. Earth rotation

At short time scales, non-tidal variations of the Earth’s rotation are well described by the influence of the atmosphere and ocean. In our work, we used the atmospheric angular momentum functions calculated according to the atmospheric model from NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research) and the oceanic angular momentum functions calculated according to the oceanic model from ECCO (Estimating the Circulation and Climate of the Ocean consortium of the Jet Propulsion Laboratory). Tidal variations was calculated according IERS Conventions 2000.

Therefore, we construct the difference between the observed LOD (geodetic excitation) and geophysical excitation (total impact of the tidal variations, of the atmosphere and the ocean). The difference between the geodetic and geophysical excitation is presented in Figure 3. From

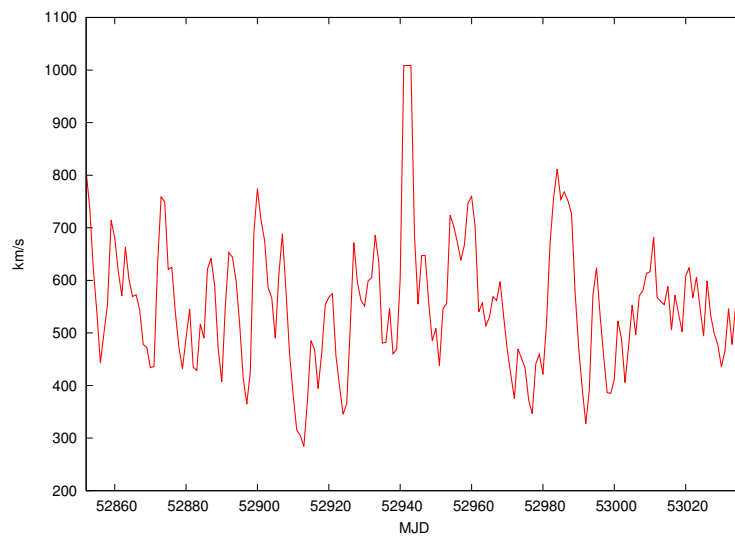


Figure 2. Velocity of the solar wind from August 2003 to January 2004.

the number of geodetic excitation the tidal variations and the influence of the atmosphere and ocean has been removed. From the resulting series was deleted long-period component obtained by filtering with the moving average with $n = 31$.

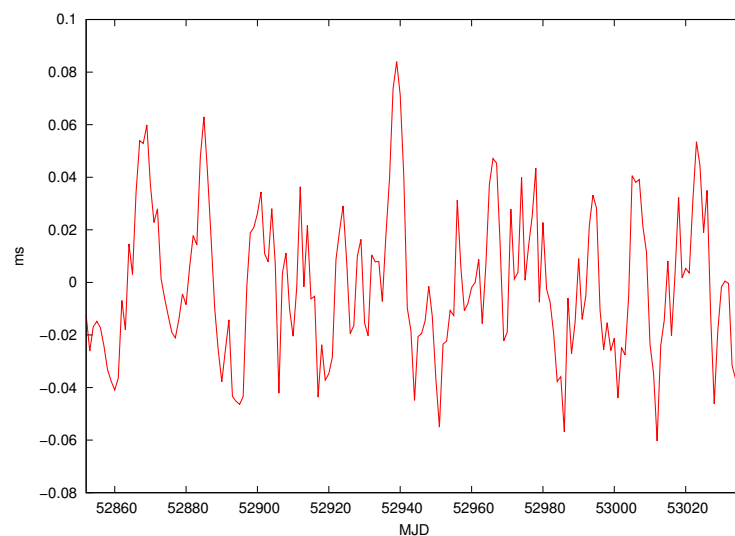


Figure 3. Behavior of the difference of geodetic and geophysical disturbances on the long time interval (from August 2003 to January 2004). Have been removed long-period components.

It is clearly seen that the jump in the November 1 2003 (MJD – Modified Julian Date 52944) stands out.

Figure 4 shows that the storm occurs simultaneously with a major change in the difference of geophysical and geodetic disturbance. At the beginning of the storm, on October 26 (MJD 52938), this difference is about 0.1 ms, by the end of the storm, in 5 days, it monotonically decreases to -0.05 ms. For similar regime change rotational motion requires energy of the order

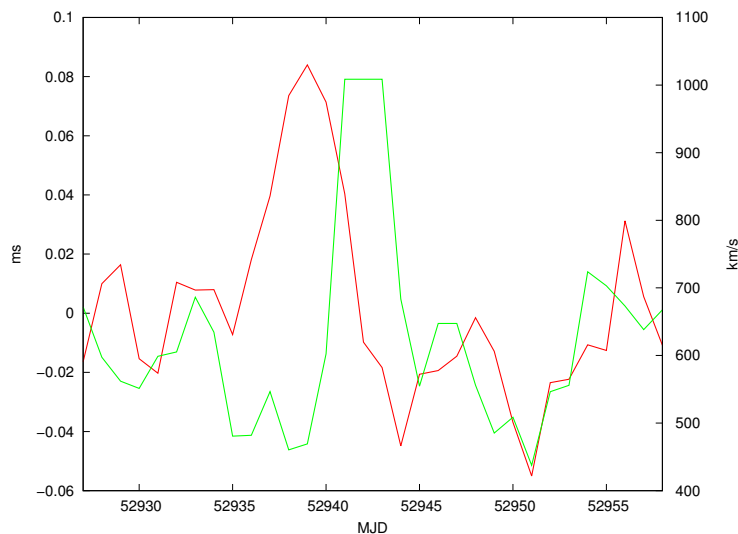


Figure 4. The LOD with geophysical excitation removed (red line) and the solar wind speed (green line).

$-7 \times 10^{20} J$. Capacity of this energy source $-1.35 \times 10^{15} W$ and torque $-5 \times 10^{19} Nm$. As already mentioned above the average kinetic energy of 1 CME in the storm $-4.4 \times 10^{23} J$. Thus the average energy of a CME to three orders of magnitude the energy necessary for the observed changes in the Earth's rotation.

4. Conclusions

We found a local rapid change in the Earth's rotation speed around November 1, 2003, inexplicable by the influence of the atmosphere and the ocean. This change coincides in time with the most powerful in recent time geomagnetic storm. Thus, with a high probability we found a trace from a geomagnetic storm in the EOP series. One of the possible mechanisms of the effect of solar wind on the rotation of the solid Earth can be the electromagnetic interaction between the solar plasma and weakly conducting mantle.

References

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