# Time variation of shock activity due to moderate and severe CMEs from 1966 to 1998

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**Abstract**

The occurrence of shock activity is evaluated from 1966 to 1998 in terms of one day's shock, two days' shock and three days' shock according to their geoeffectiveness time duration. For the period involved it can be found 168 one day's shock, 105 two days' shock and 50 three days' shock. Each type of shock has 11-year period. The occurrence of the whole shock increases with solar cycle. Only during solar cycle 22, shock occurrence peaks match those of solar cycle. Three days' shock represents 52% of all shock days for the considering period.

**Keywords:** CMEs, Shock activity, Occurrence, Sunspot number, Pixel diagram

## 1. Introduction

Geomagnetic activity has been divided into four classes of activity by Legand and Simon (1989) and Simon and Legrand (1989) (quiet, shock, recurrent and fluctuating activities) and by Richardson et al. (2000) and Richardson and Cane (2002) (quiet, shock, co-rotating or recurrent and non-clear activities). The present paper aim is to analyze occurrence and time variation of moderate and severe shock activity. Therefore, we follow Legand and Simon ( 1989) and Simon and Legrand (1989) method by using pixel diagrams carried out by means of geomagnetic aa index (computed by Mayaud (1971, 1973) daily index (Aa) and Sudden Storm Commencement (SCC) dates. This work follows that of Ouattara et al. (2015) which highlighted the global cycle occurrence of CMEs (coronal mass ejections) shock from 11-23 cycles. Here, we interest to yearly occurrence through solar cycle and that for only the four solar cycles (20, 21, 22 i.e. from 1966 to 1998) in order to analyze in a further work this occurrence impact in F2 layer critical frequency (foF2) at Ouagadougou station Ouagadougou (12.4°N, 358.5°E; dip: +1.45)which operates from 1966 to 1998. For the present work, the 1966-1998 pixel diagrams are used and comparison is made between CMEs shock activity occurrence and sunspot number (Rz) time variation. Here, we not globally study their occurrence. We separate CMEs shock into three types according to their geoeffectiveness time duration expressed in day and after compare each time occurrence with Rz time variation. Therefore, firstly, we firstly present our materials and methods, secondly, our results and end the paper by discussions and conclusion.

## 2. Materials and Methods

The data concerns four solar cycles' Aa values and sunspot Rz number. For the determination of shock activity we used 44 yearly pixel diagrams (e.g. figure 1) corresponding to the 44 years of the four solar cycles involved.

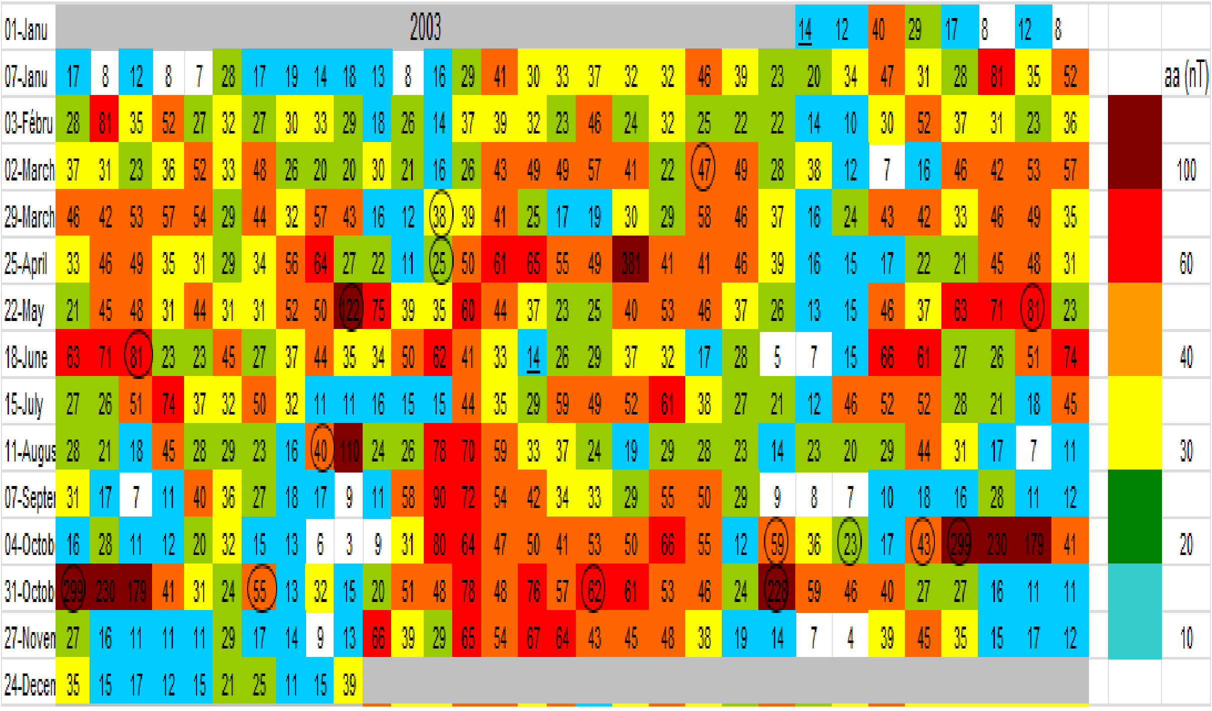



**Figure 1: An example of Pixel diagram: Diagram of year 2003**

For the determination of geomagnetic class of activity we use Mayaud (1971, 1973) aa index and SSC (Sudden Storm Commencement) (see Ouattara, 2009a; Ouattara and Amory Mazaudier, 2009). The shock activity studied in this paper concerns moderate and severe activity SSC storm called CME's storm (Legrand and Simon, 1989; Ouattara et al., 2015). Shock are divided into three types: one day's shock (shock that does not exceed the SSC day), two days' shock (shock that has two days duration including the SSC day) three days' shock has three days duration including the SSC day) (Ouattara et al. 2015). In that study, the number of shock involved is 323. That is divided into 168 one day shock, 105 two days' shock and 50 three day's shock. An example of each type of CME's shock can be seen in figure 2 taken from Ouattara et al. (20015).

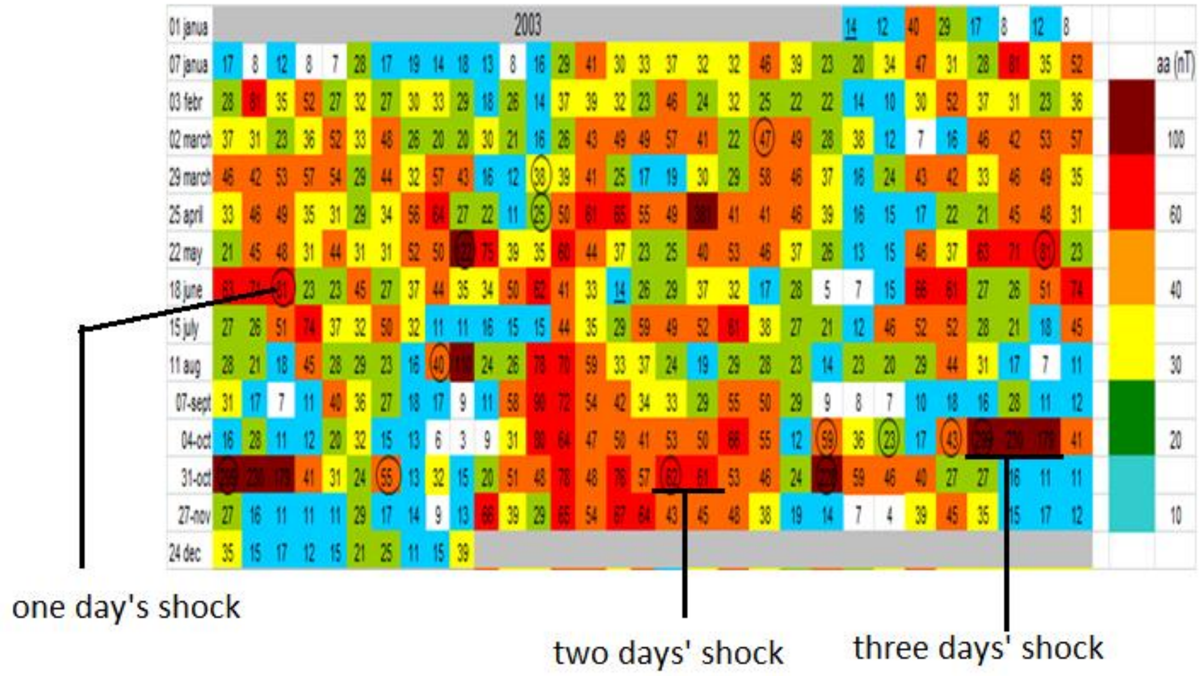



**Figure 2: An example of each type of CME's shock (taken from Ouattara et al., 2015)**

## 2. Results

For better analyzing shocks' occurrence a monthly number of each type of shock and a monthly sunspot number are plotting together. Figure 3 shows Rz and shock activity time variation. Panel a concerns one day's shock, panel b two days' shock and panel c three days' shock. Figure 4 concerns the whole shock time variation (panel a) and different shock percentages during the three solar cycles involved (panel b).

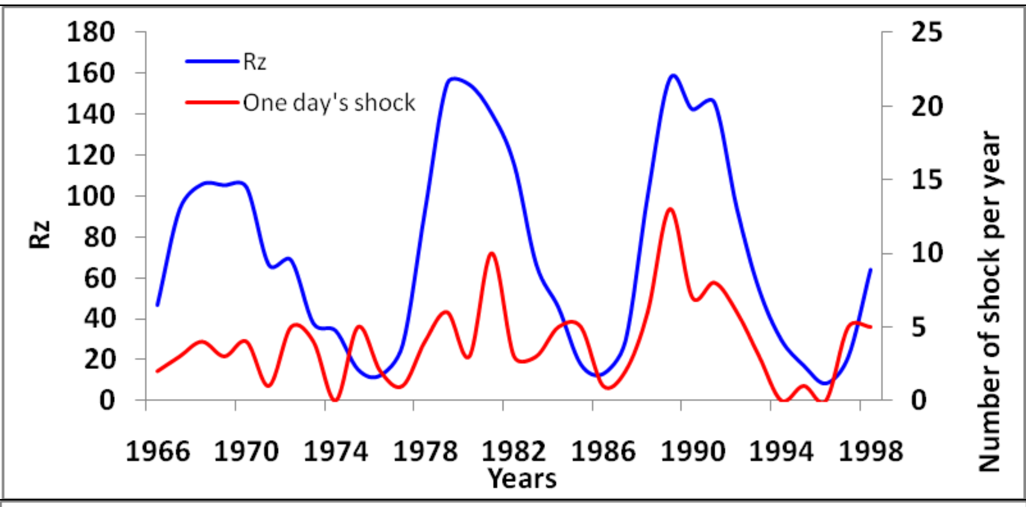
In figure 3a, it can be seen that one day's shock follows solar cycle. The occurrence of one day's shock increases from cycle 20 to cycle 22 and exhibits always three peaks. These maximum occurrence peaks are seen during (1) the end of descending phase of cycle 20, (2) the beginning of the declining phase of cycle 21 and (3) the maximum phase of cycle 22. During solar cycle minimum occurs one day's shock activity. Only during the last solar cycle, shock activity presents the same variability as solar cycle.

Figure 3b highlights that two days' shock also follows solar cycle. This kind of shock shows different behavior (panel b of figure 3). In fact, it can be observed from cycle 20 to cycle 22, four occurrence peaks for cycle 20 and three occurrence peaks for the two others. The maximum occurrence peak happens during (1) the ascending phase of cycle 20, (2) the declining phase of cycle 21 and (3) the maximum phase of cycle 22. Only, during solar cycle 22, major shock occurrence peaks match more solar cycle peak.

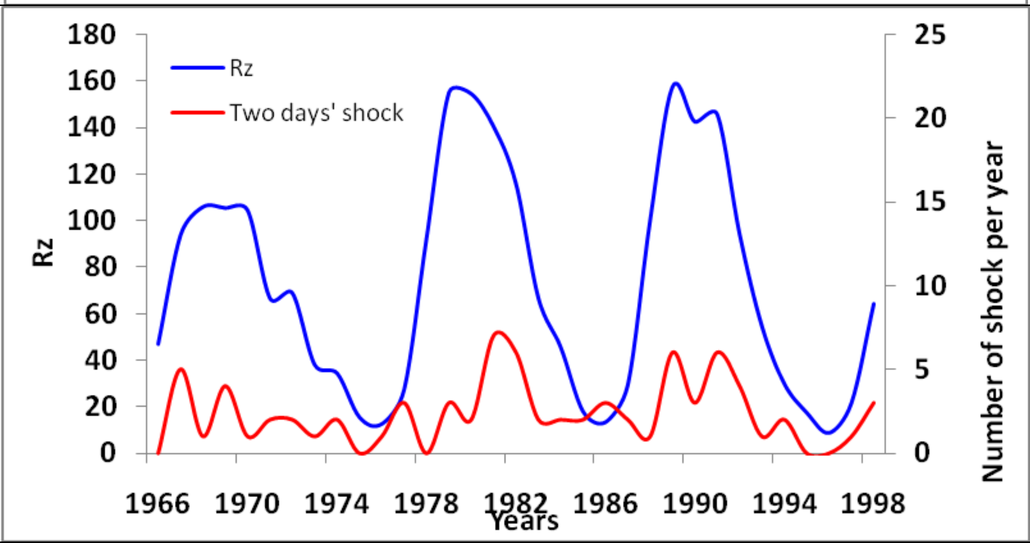
Figure 3 c shows three shock occurrence peaks during cycle 20, two occurrence peaks during cycle 21 and three occurrence peaks for cycle 22. The maximum occurrence is shown during

(1) the maximum phase of cycle 20, (2) the declining phase of cycle 21 and (3) the second maximum of cycle 22. Here also it can be noted that only during cycle 22, there is shock occurrence peaks that match solar cycle peak. It also emerges from this panel that three days' shock follows solar cycle.

a




b




c

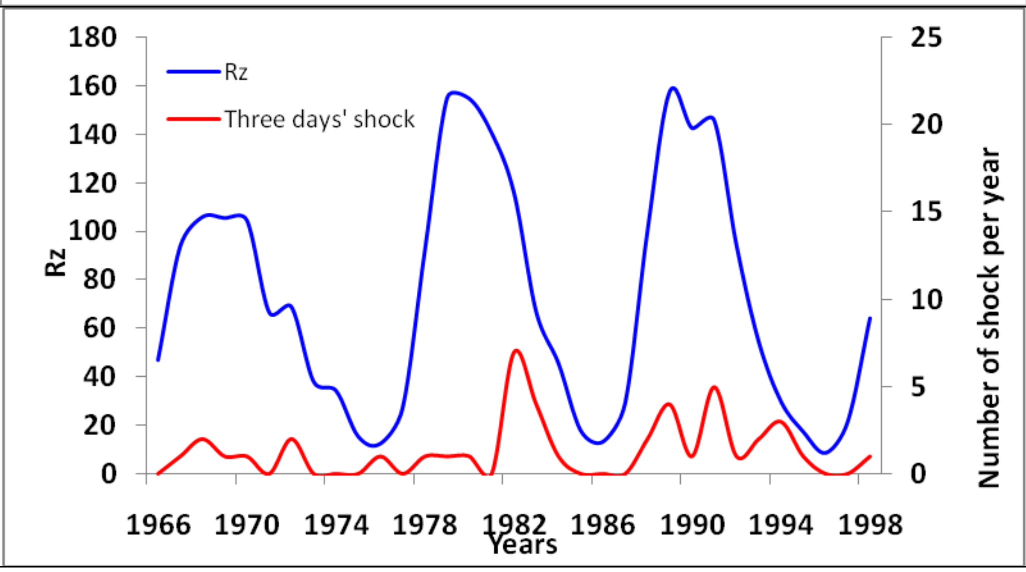


**Figure 3: Sunspot and different types of shock time variation for solar cycles 20-22**

Figure 4a shows that shock activity follows solar cycle. Shock occurrence peaks match solar cycle peaks. Only, during solar cycle 22, it can be noted the excellent correlation between shock occurrence and sunspot. The occurrence of shock activity increases with solar cycle. In panel b, one can see that the most important shock activity is that of one day's shock.

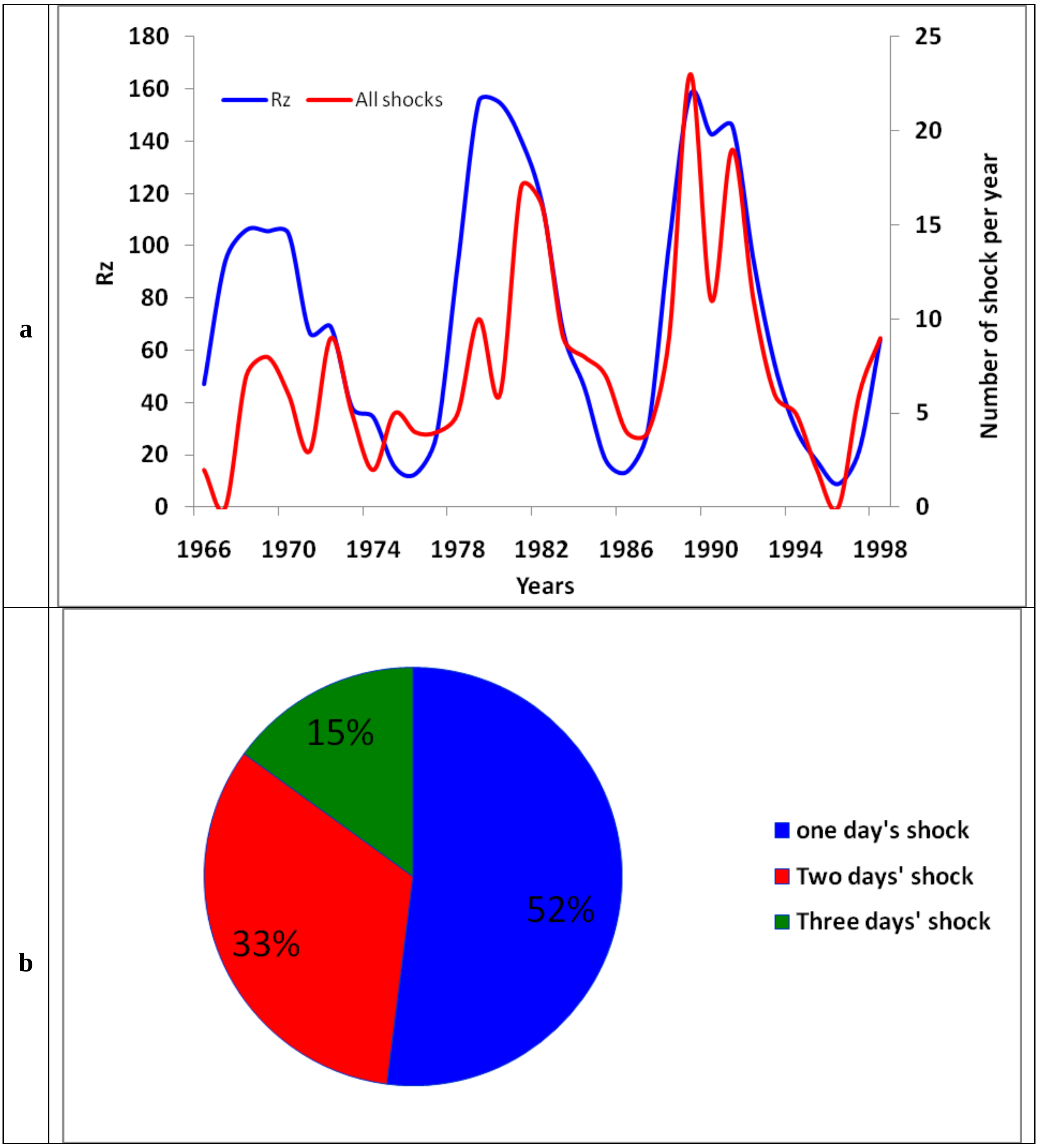



**Figure 4: Sunspot and all shock time variation for solar cycles 20-22 (panel a) and different shock percentages during the three solar cycles.**

## 3. Discussions and Conclusion

It is shown here that the trend of the whole shock occurrence and that of the one day's shock are the same and the former trend is specifically due to that of the latter. It can be concluded that the behavior of the one day's shock could explain that of the whole shock. The above conclusion maybe also explained by the important percentage of one day's shock (52%).

The work pointed out that all shock activities follow solar cycle and present 11-years periodicity. This result confirms that CMEs and sunspot have the same solar source (Ouattara, 2009b; Luhmann et al., 2002).

The increase of the whole shock occurrence exhibits the increase of geomagnetic activity and principally the change in solar activity as shown by Ouattara (2009c). This change may be also explained by (1) the decreasing of the number of quiet days (Ouattara et al., 2009), (2) the change in the dipole magnetic field (Rouillard et al., 2007) and the increase of solar wind (Svalgaard and Cliver, 2007).

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