DRIFT AND FORBUSH DECREASES

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ABSTRACT

Evidence is presented that the drift effect on the modulation of galactic cosmic rays can be seen on Forbush decreases observed by the Deep River and Hermanus neutron monitors.

1. Introduction

Since the description of drift effects on the modulation of galactic cosmic rays (Jokipii, Levy, and Hubbard, 1977) its significance has been controversial. Lee and Fisk (1981) argued that the topology of, and fluctuations in the Interplanetary Magnetic Field (IMF) might render drift effects quite ineffective. Jones (1983) remarked that observable drift effects seem hard to find. Current drift models (e.g. those of Jokipii and Thomas; 1981, and Potgieter and Moraal; 1985) however are now in agreement that there should be a small effect on near-Earth observations. In addition, Potgieter and Moraal also showed that despite small observable effects, the dynamics of the modulation in consecutive solar cycles (IMF directions reversed), may be drastically different. These authors also summarised a score of independent observations reflecting drift effects.

Figure 1 shows that after a blast wave has passed Earth, the drift velocity field in the 1970 to 1980 IMF configuration should cause a Forbush decrease to reset faster than during the 1959 to 1969 configuration. In this paper we investigate this hypothesis with data from the Deep River and Hermanus neutron monitors.

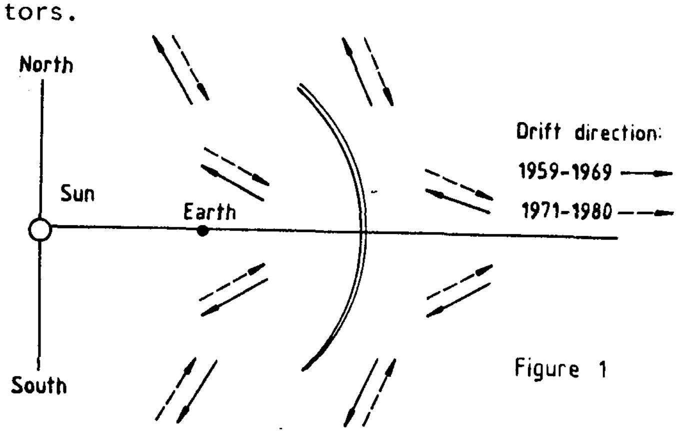


Figure 1

2. Data Analysis and Results

The Table lists the Forbush decreases selected from the Deep River (cutoff rigidity P_c = 1,0 GV) and Hermanus (P_c = 4,7 GV) neutron monitors. The time of onset is given as a two digit number for the year, a three digit num= ber for the day, and a two digit number for the hour. The selection criteria for the 109 Hermanus decreases were rather loose. This means that about 15% of them are contaminated by other decreases in the onset phase, reset phase, or both. For Deep Rivier even more decreases were included for a total of 131, but the 85 marked with an asterisk are clear, uncontaminated decreases that reach a clear minimum within 12 hours of onset time.

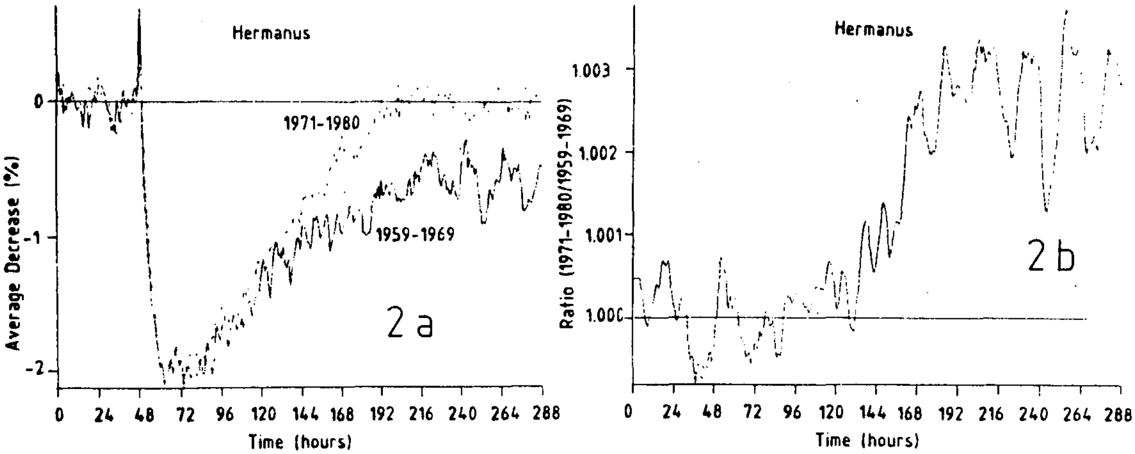
Figure 2a shows the averages of these decreases for Hermanus. The solid curve is for the period 1959 to 1969 and the dashed one for the period 1971 to 1980. The drift effect predicted from figure 1 is clearly visible. Note that the sharp peaks at onset time (hour 48) and diurnal variations are due to subjectivity of selection of the hour of onset: One is inclined to select a high counting rate at onset time, and this automatically favours the peak of the diurnal variation. The drift effect is even more clearly visible on Figure 2b, which shows the five hour running average of the ratio of 1971-1980 decreases relative to 1959-1969 decreases. Figures 3a and 3b repeat this analysis for all 131 Deep River decreases, while Figures 4a and 4b are for the 85 uncontaminated Deep River decreases only.

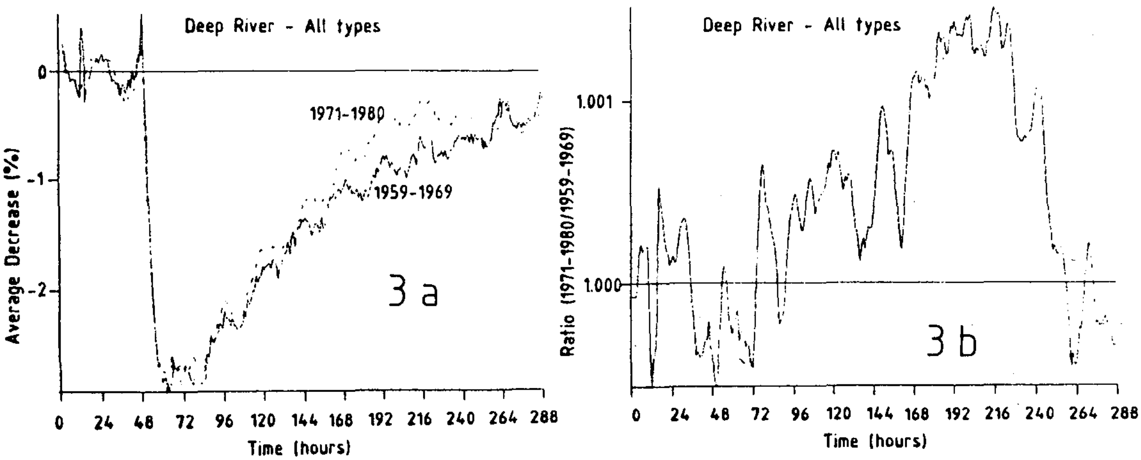
Hermanus

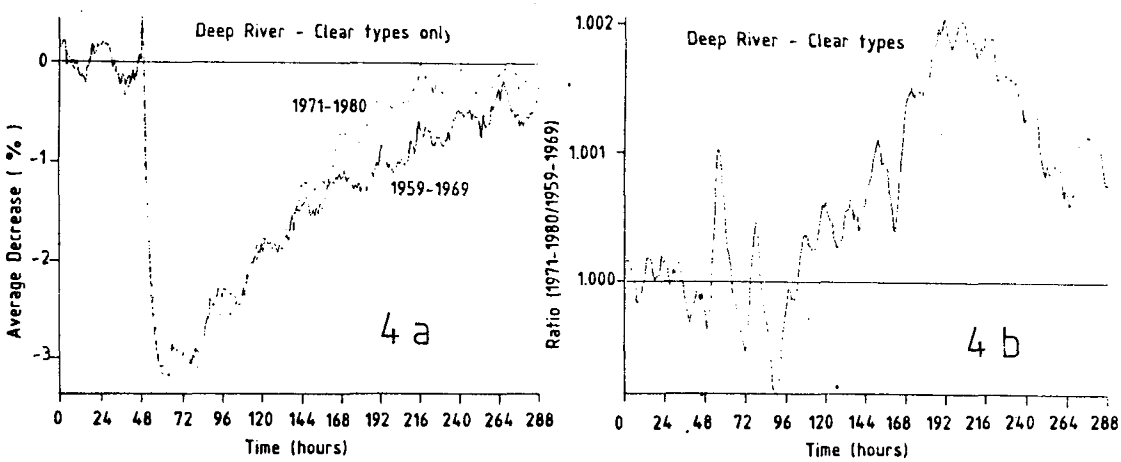
5900916	6.6	6905907	6.5
5902618	6.5	6908312	8.7
5904516	7.4	6910212	5.3
5909918	5.1	6911710	9.0
5911320	5.2	7127823	4.8
5913122	12.2	7135118	7.0
5916212	7.0	7204906	5.5
5923124	9.0	7215113	5.8
5929214	6.0	7217114	3.7
5933706	5.7	7230516	8.3
6009110	7.8	7312714	4.5
6010614	5.6	7313415	5.4
6012116	10.4	7318917	3.5
6014314	7.0	7321213	4.3
6019620	10.6	7402516	2.7
6022712	6.1	7406424	3.5
6028009	5.9	7501513	3.7
6110614	4.7	7508515	3.0
6114122	5.5	7511012	3.9
6120712	5.9	7513916	4.1
6127320	4.5	7518909	3.0
6201018	4.1	7522516	2.9
6203604	5.6	7529118	2.5
6214714	4.7	7530817	3.7
6223316	3.8	7532609	3.6
6227304	6.5	7605121	2.0
6228106	6.1	7611802	2.5
6306916	4.1	7612411	3.2
6310820	5.8	7623619	2.4
6318514	4.1	7633904	2.3
6323312	3.8	7702911	3.0
6326506	7.2	7709712	3.3
6330212	6.6	7800318	5.3
6425414	3.5	7802914	4.8
6502102	4.6	7806816	7.0
6510911	3.8	7810012	7.4
6516621	3.8	7812105	16.4
6519924	4.7	7815312	7.5
6522721	3.3	7819409	5.7
6527919	3.7	7831601	4.6
6626608	6.5	7835512	5.1
6625810	8.9	7900613	5.0
6629913	4.5	7903412	3.8
6701305	6.5	7906304	3.5
6703822	5.5	7908712	8.2
6714515	7.4	7909501	7.4
6730218	4.7	7911506	7.1
6802620	5.4	7915719	6.2
6807016	5.0	7918711	7.7
6816218	6.1	7921309	4.4
6816823	4.4	7927916	5.4
6819205	5.8	7931505	5.5
6832108	7.7	8003701	6.0
6834012	6.2	8007912	4.8
6902613	5.1		

Deep River

5900919	6.5	*	6608212	6.5	*	7720918	3.7	*
5902621	9.1		6615122	4.3		7726420	10.4	*
5904510	9.1		6618918	5.1	*	7734704	4.0	*
5909917	5.4	*	6624208	8.4		7800320	6.4	
5911320	6.4	*	6626619	6.1	*	7810017	9.2	
5913121	16.0	*	6628818	5.0	*	7812106	16.5	*
5916208	6.6		6629905	3.9	*	7815311	8.4	*
5919813	21.4		6632117	4.1	*	7823021	5.3	*
5923203	9.6	*	6634716	5.3		7831604	5.0	*
5924621	8.4	*	6701312	5.8	*	7834802	6.7	
5926123	9.5		6704623	5.2	*	7804520	20.2	*
5933704	9.2		6712119	6.2		7908712	7.9	
6009110	12.7	*	6714519	9.0	*	7909503	7.4	
6010722	4.8	*	6730218	5.6		7915718	7.6	*
6012124	14.3		6732602	3.8	*	7918722	8.5	*
6014321	7.2		6802623	4.7		7924106	10.1	*
6014924	6.6		6809622	4.8		7927918	5.6	*
6017923	9.6	*	6811702	3.3	*	7904206	9.6	
6019619	7.9	*	6814202	2.9		8003703	6.3	*
6022714	6.6	*	6830221	12.6		8006606	2.5	*
6028005	8.8	*	6901419	3.6	*	8007916	5.7	*
6104624	5.1		6904119	3.7	*			
6110407	6.6	*	6908219	13.6	*			
6114103	4.8	*	6910301	5.0	*			
6120719	9.9	*	7110419	4.4	*			
6127319	8.4	*	7113716	5.2	*			
6130115	5.5		7127823	4.6	*			
6133517	7.6	*	7135116	7.2	*			
6201004	4.5	*	7206619	4.4				
6203520	6.6		7211401	5.0	*			
6207922	3.9	*	7213619	5.8	*			
6208924	5.3	*	7215119	5.7	*			
6211104	6.3	*	7216909	5.9	*			
6227303	5.5		7221721	22.8	*			
6306917	4.0	*	7230518	10.3	*			
6308123	3.5		7235718	3.5	*			
6310903	2.5		7225714	4.9	*			
6312222	5.7		7229219	4.5				
6314720	4.1		7301921	4.1	*			
6325918	10.3	*	7321213	4.5	*			
6326517	9.2	*	7406418	3.1				
6330214	7.8		7412705	6.1	*			
6332020	3.4	*	7428718	5.8	*			
6402820	3.2	*	7501522	3.4				
6425020	2.5	*	7511012	4.0				
6426520	3.0	*	7518909	2.6	*			
6432023	2.4		7506514	5.2				
6502016	3.0		7508520	3.9	*			
6510918	3.2		7522517	2.7	*			
6516619	3.9	*	7612322	5.2	*			
6519317	2.8		7604720	3.1	*			
6520002	2.3	*	7702919	3.9	*			
6522719	2.5	*	7709716	3.4				
6530812	2.9	*	7717017	3.9				
6602815	2.8	*	7717903	3.4				







In all cases the effect builds up at approximately the same rate towards maximum at hour 192 (6 days after onset), but on Deep River (Figure 3b) it starts to disappear at about hour 240 (8 days after onset). The Deep River effect is also about a factor two smaller than on Hermanus. Figure 4b shows however that when the contaminated decreases are omitted the effect on Deep River increases somewhat in magnitude and becomes more persistent.

3. Interpretation and Significance

If $\langle \underline{v}_d \rangle$ denotes the omnidirectional drift velocity and U the differential cosmic ray density, then the divergence of the drift flux is

$$\underline{\nabla}.(\langle \underline{v}_d \rangle U) = \langle \underline{v}_d \rangle . \underline{\nabla} U,$$

because $\underline{\nabla}.\langle \underline{v}_d \rangle = 0$. Now $\langle \underline{v}_d \rangle \propto P$ (rigidity) and Potgieter (1984) has shown from his numerical drift model calculations that $\langle \underline{v}_d \rangle . \underline{\nabla} U$ is a rapidly increasing function of P. This qualitatively explains why the Hermanus effect may be larger than the one on Deep River. Quantitative comparison with observations requires that the calculations of Potgieter must be weighted over the response functions of the respective neutron monitors. Such steady state drift calculations can however not explain why the Hermanus effect is more persistent than the Deep River one.

To test the significance of these results, the following tests were performed:

(a) The three largest decreases (5919813, 722172, 7804520 for Deep River and 5913122, 7812105 for Hermanus) were omitted to see whether these had an un= desirable weighting effect. This caused no change in the results.
(b) The Hermanus calculations were repeated separately for decreases greater and smaller than the median. Both sets showed the effect, but it was much more significant on the large decreases.
(c) The chronological order of the Hermanus decreases was scrambled randomnly. In this case the effect completely disappeared.

From these tests we think that the drift effect is real and significant. We are presently extending the analysis to additional low, mid, and high lati= tude neutron monitors to confirm this and to establish a rigidity depence of the effect.

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