Characteristics of the brief but bright discharges that often occur along the trails of upward positive leaders

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ABSTRACT: Characteristics of nearly 200 brief discharges in 14 upward positive leaders have been studied. Majority of the brief discharges did not exhibit electrical current at the lightning channel bottom. As a comparison, the brief discharges have been compared with those which occurred in a downward positive CG flash. The brief discharges can be grouped into five types according to their 2D shapes. Some of the brief discharges are identified progressing at two sides and some only at one side. Typical progression speed of the brief discharges is similar to that of a negative dart-stepped leader. We suggested that the brief discharges should not be simply classified as recoil leaders.

INTRODUCTION

As shown by Saba et al. (2008) and Warner et al. (2012), many positive leaders occurred with some brief but bright discharges along their trails. Those authors classified these discharges as recoil leaders. As described by Mazur (2002), recoil leaders are negative leaders that developed on weakly luminous positive leader branches that became cutoff from the main positive leader channel, and then retrace the channel previously ionized by the positive leader. In contrast, many of the brief discharges reported by Warner et al. (2012), exhibit fine structures like check marks among others, and thus it seems to us that most of these brief discharges can't be simply classified into recoil leaders. We have also recorded many of such brief discharges exhibiting fine structures during upward positive leaders that are initiated from a windmill and its lightning protection tower. Therefore in this study, using the simultaneously recorded high speed video, channel bottom current and electric field change, we have performed a detailed statistics on the structure, the current and the electric field change of nearly 200 brief discharges in 14 upward

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positive leaders. As a comparison, we have also studied the structure of the brief discharges occurred in a downward positive leader with only high speed video pictures.

OBSERVATION

The high speed video camera we used is MEMRECAM GX-8. Our observation target is the lightning to a windmill and its lightning protection tower and a bridge girder which locate at Uchinada town in the northern coast area of Japan. The detailed description can be found in our companion paper in this conference [Takamatsu et al., 2014].

RESULTS

Our high speed video camera has been set up from 2011 November. So far we have recorded 14 upward lightning which exhibited apparent brief and bright discharges along the trails of upward positive leaders as shown in Table.1. For 3 of the lightning, we have simultaneously recorded their electric currents and E-field changes with brief discharge as shown in Table.2.

date	time (JST)	struck point	E-field anttena	current		high speed video camera	brief discharge
				windmill	tower		
2011/12/22	0:12:49	other point	○	–	–	○	○
	1:08:26	tower	○	–	–	○	○
	13:55:49	tower	–	–	–	○	○
2011/12/24	14:51:50	tower windmill	○	○	○	○	○
2012/1/4	1:19:50	tower	○	○	○	○	○
	1:23:43	tower windmill	–	○	–	○	○
2012/11/1	6:18:28	tower windmill	–	–	–	○	○
2012/11/13	19:52:14	cloud to cloud	–	–	–	○	○
	0:56:05	tower	○	–	–	○	○
	9:39:38	tower	○	–	–	○	○
	9:50:12	other point	–	–	–	○	○
	22:50:44	bridghe	–	–	–	○	○
2012/11/15	6:27:16	tower	○	–	–	○	○
2013/1/25	0:25:02	tower	○	–	○	○	○

Table.1 A list of recorded lightning exhibited apparent brief and bright discharges

2011/12/24 14:51:00 tower and windmill 1(F)=25(μs)

ganereted time (+F)	shape	duration time (F)	variation direction	speed(10^6m/s)	length(m)
0	I	2	–	–	97
98	レ	2	one side	2.96	104
161	I	1	–	–	–
271	I	1	–	–	–
286	I	2	one side	0.17	44
334	レ	4	one side	1.92	–
363	I	1	–	–	–
365	I	1	–	–	–
372	レ	1	–	–	–
378	I	1	–	–	–
440	レ	3	one side	3.52	209
481	I	2	–	–	–
498	レ	3	one side	0.72	–
512	レ	2	–	–	–
593	I	1	–	–	–
691	I	2	–	–	–
1684	I	3	one side	1.84	114

2012/1/4 1:19:00 tower 1(F)=25(μs)

ganereted time (+F)	shape	duration time (F)	variation direction	speed(10^6m/s)	length(m)
0	・	1	–	–	4
6	I	2	–	–	207
95	レ	2	one side	–	145
160	I	2	one side	–	–
769	I	1	–	–	44
1169	レ	3	one side	–	116
2222	I	6	–	–	–

2013/1/25 0:25:02 tower 1(F)=25(μs)

ganereted time (+F)	shape	duration time (F)	variation direction	speed(10^6m/s)	length(m)
279	・	1	–	–	11
324	・	1	–	–	11
546	I	1	–	–	–
856	Y	5	–	–	–
919	I	3	one side	0.96	–
998	レ	30	one side	–	–
1062	レ	19	one side	–	131
1702	I	4	one side	0.44	–

Table.2 A list of recorded lightning simultaneously recorded their electric currents and E-field changes with brief discharge

As an example, Fig.1 shows the time-integrated image of 14 brief discharges in an upward lightning occurred at 14:51:00 on 12/24/2011. The lightning was an other-triggered upward lightning simultaneously hitting the windmill and the tower as shown in Fig.2. For this lightning, we have recorded its electric current and electric field changes as shown in Fig.3. For most of the brief discharges their bright channels appeared floating in the sky and no electric currents were detected for these brief discharges as an example shown in Fig. 4. A few discharges appeared connecting to either the tower or the windmill through a low-luminosity channel. For these types of brief discharges, their current can usually be detected as shown in an example in Fig.5.

As a comparison, Fig.6 shows the brief discharges occurred in a downward positive cloud-to-ground lightning discharge with the colors from blue to red indicating the time sequences of the brief discharges.

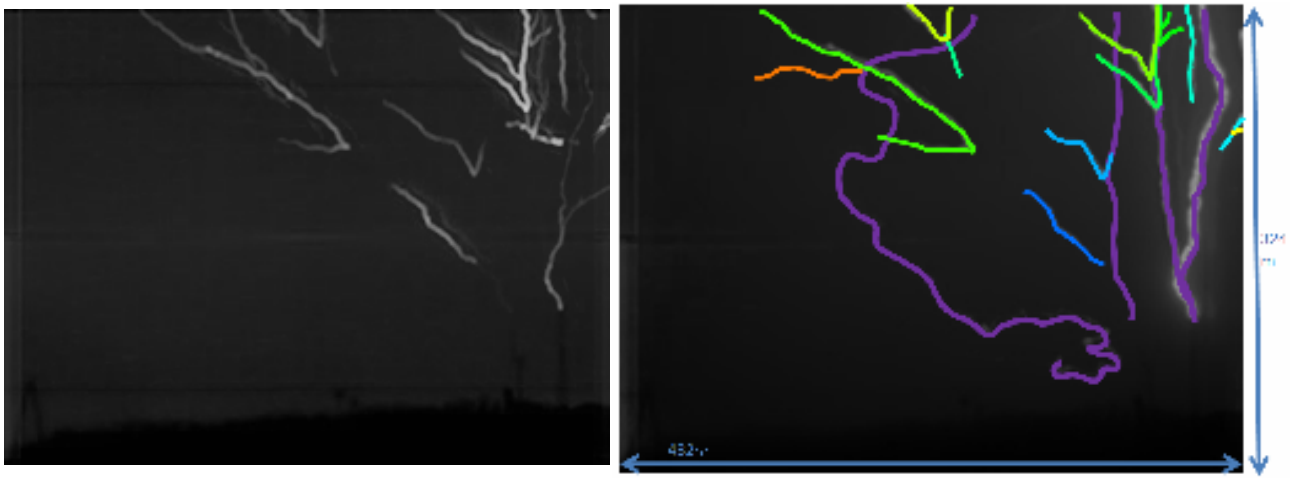

Fig.1 Time-integrated picture of 14 brief discharges occurred in an upward lightning discharge.

Fig.2 Time integrated image of 2011/12/24 lightning

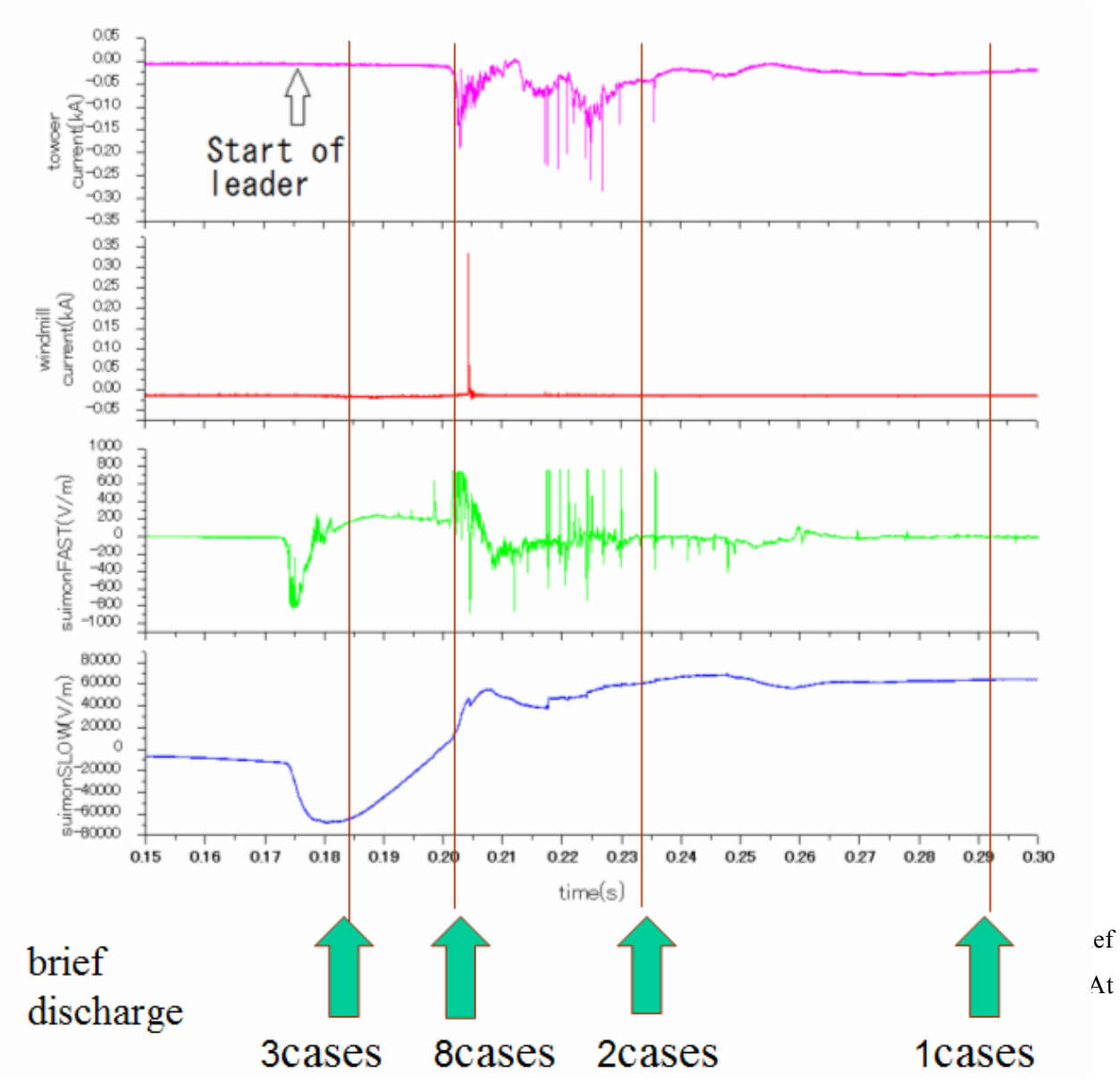

Fig.3 Electric current, E-field waveforms of lightning 2012/12/24 which contained brief discharges with their approximate occurrence times shown in vertical lines.

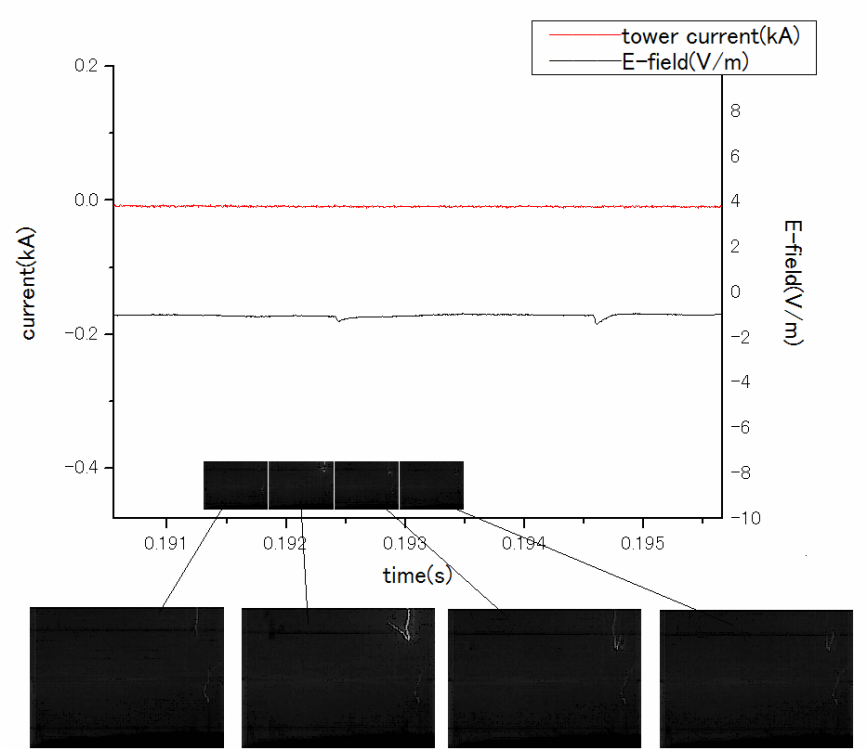

Fig.4 E-field and current of an example brief discharge that didn't exhibited detected current.

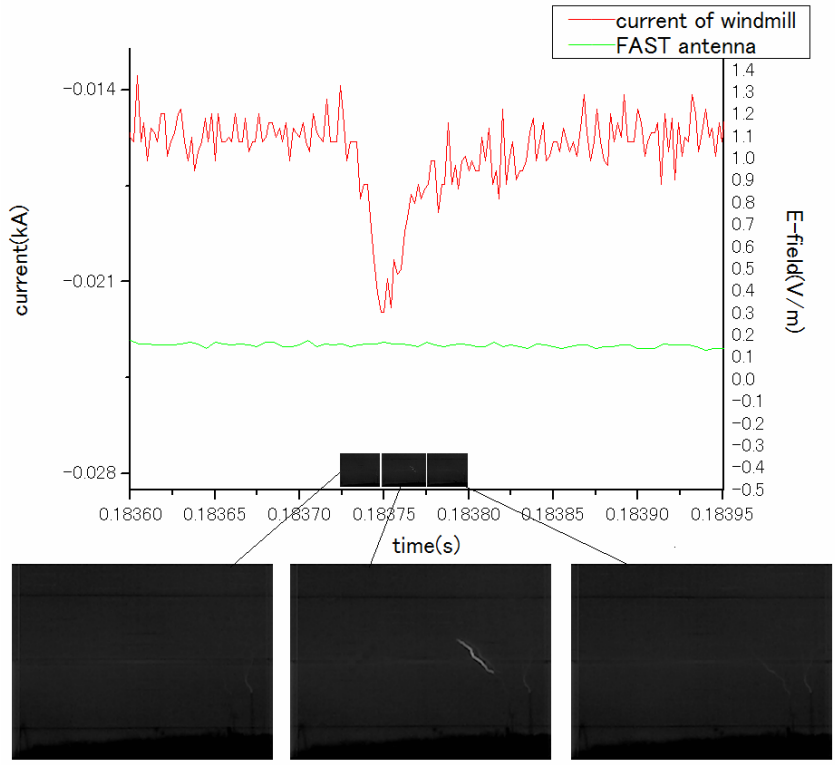

Fig.5 E-field and current of an example brief discharge that exhibited detected current.

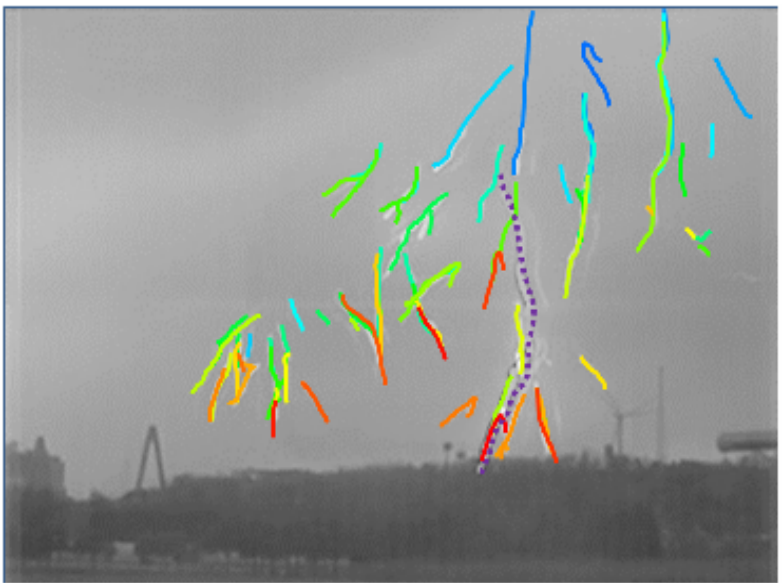

Fig.6 Brief discharges in a downward positive lighting. The colors from blue to red indicates the occurrence sequences of the brief discharges.

As shown in Fig.7, the brief discharges can be grouped into five types according to their 2D shapes. In this paper, the types are represented as S, I, Y, ・, ✔, respectively. Fig.8 shows how frequent the shapes are. Apparently, majority of the shapes are I. There are more ✔ shapes of the brief discharges in upward lightning than in downward lightning. The brief discharges have various durations from less than 50 us to more than 400 us as shown in Fig.9.

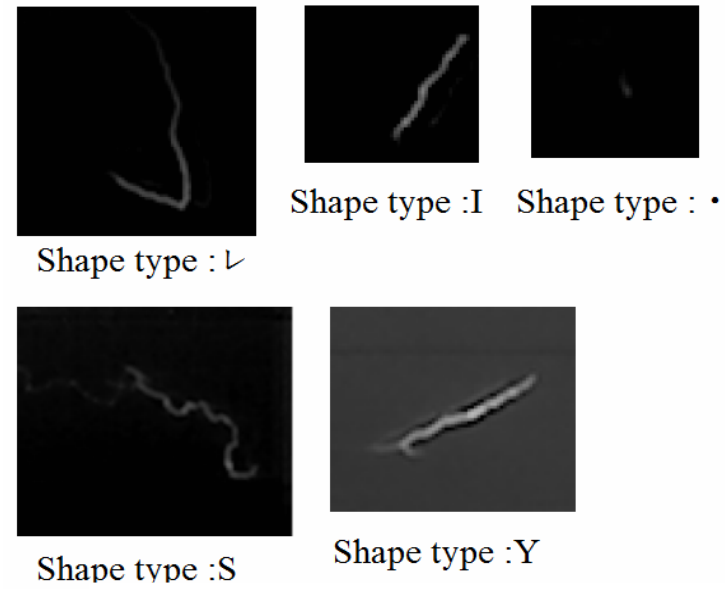

Fig.7 classify of shape of brief discharge

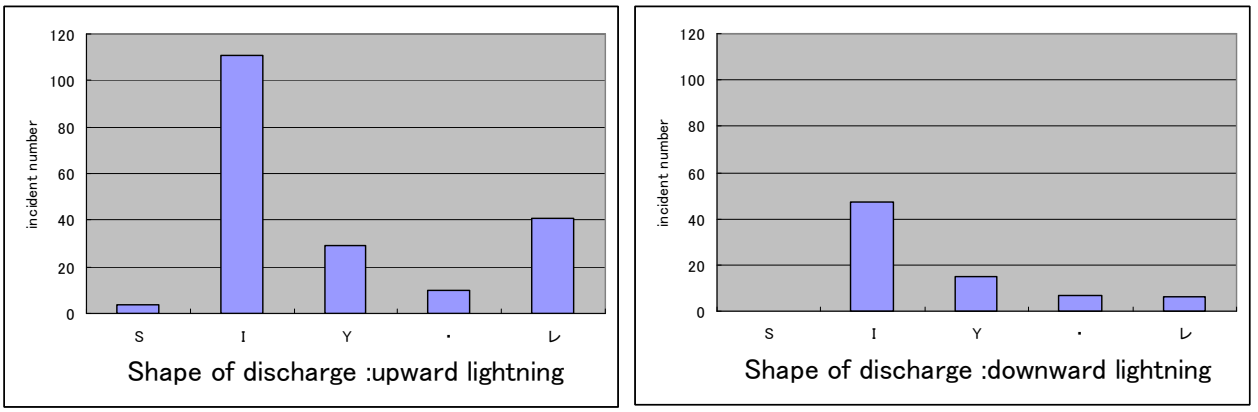

Fig.8 Statistics shapes of brief discharge

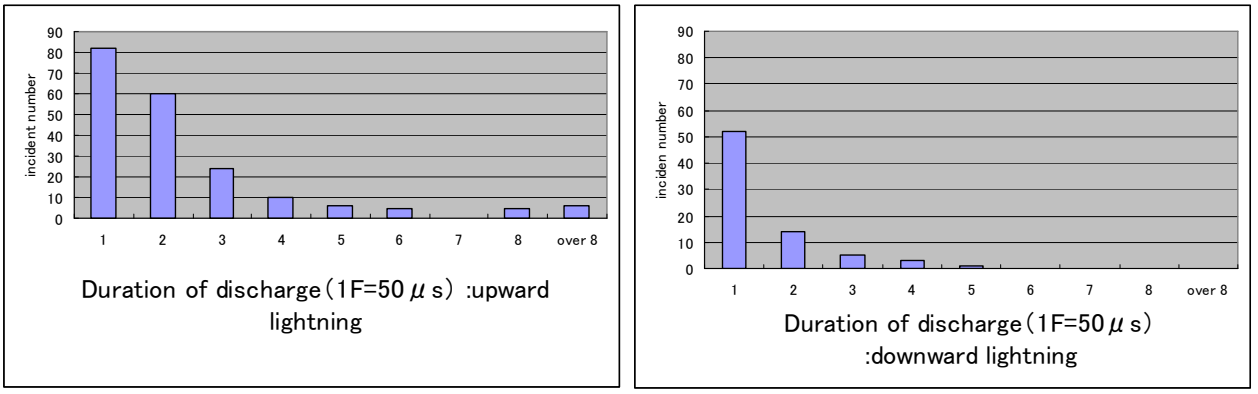

Fig.9 Duration of brief discharges.

Fig.10 gives the statistics of 2D lengths of the brief discharge. Most of the brief discharges have a length of less than 100 m. With the time resolution of our high speed camera, we are able to identify some brief discharges progressing at two sides and some only in one side as shown in Fig.11. Their propagation speeds are shown in Fig.12. Most of the brief discharges propagated at a speed similar to that of negative dart-stepped leaders.

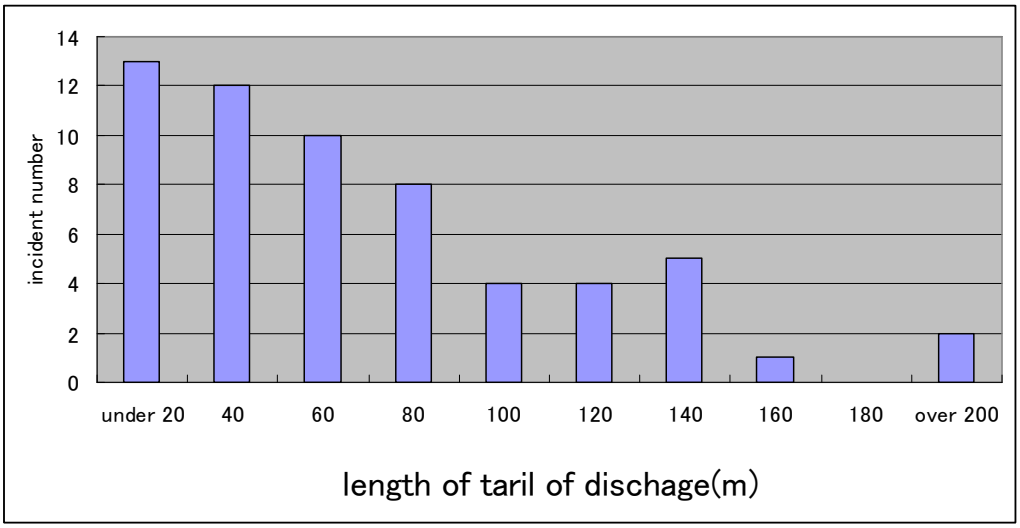

Fig.10 2D length of brief discharges

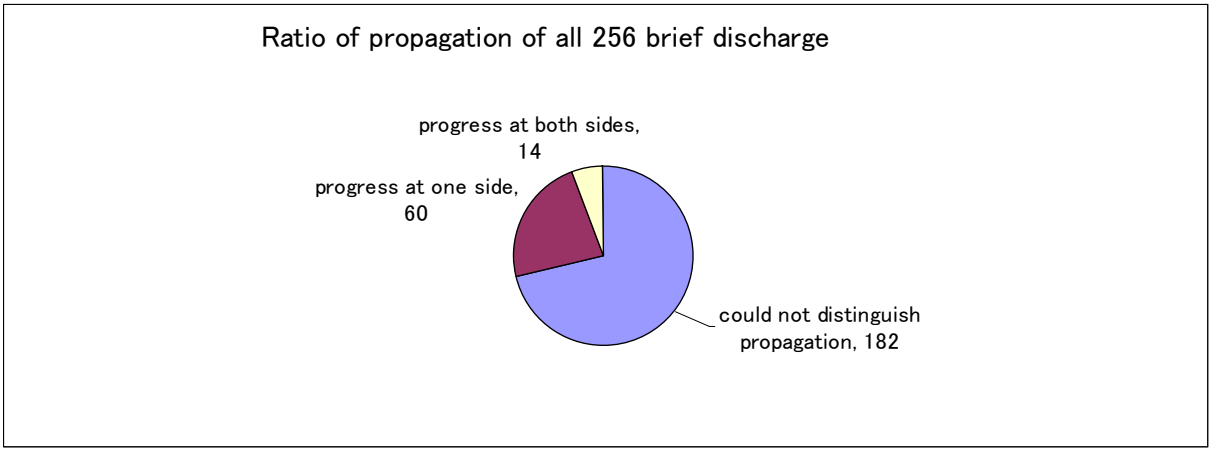

Fig.11 Statistics of Progression patterns of brief discharges

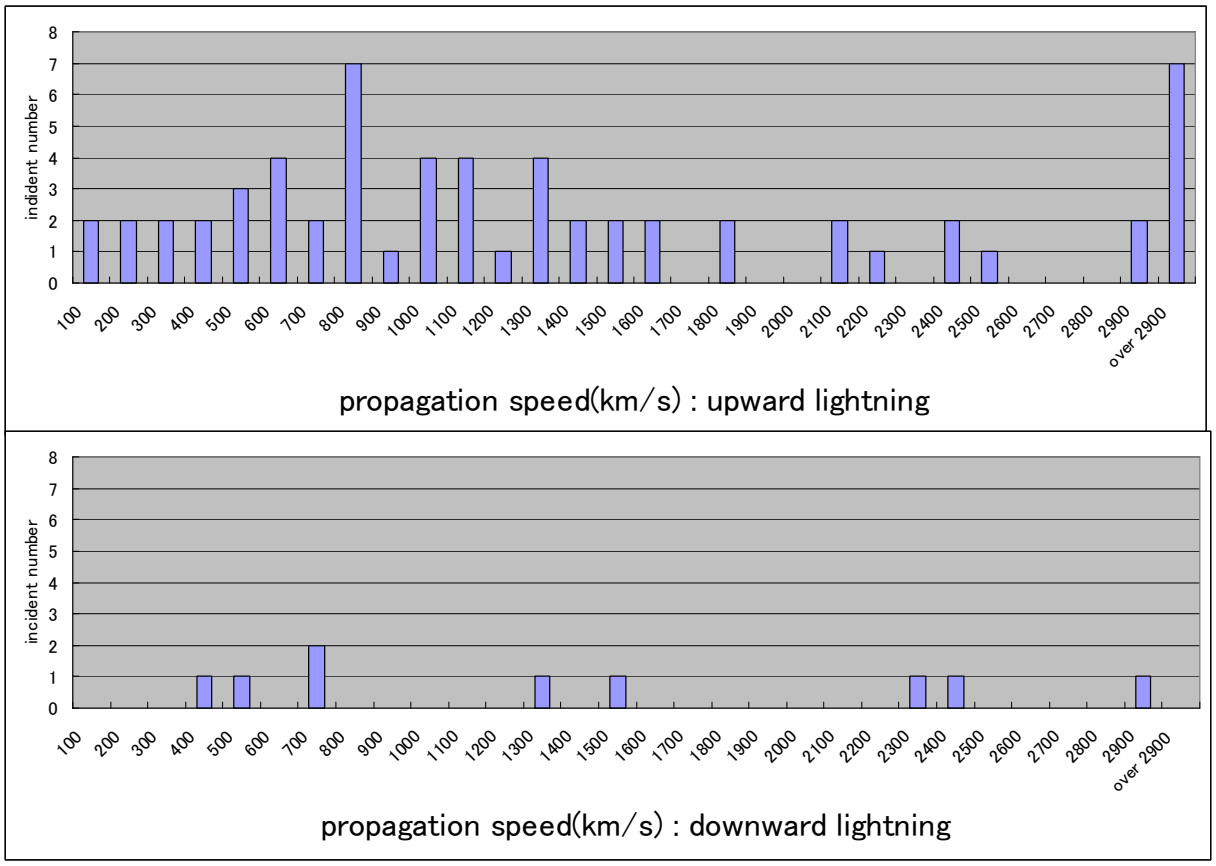

Fig.12 Statistics variation speed of brief discharge

CONCLUDING REMARKS

Characteristics of nearly 200 brief discharges in 14 upward positive leaders have been studied. Majority of the brief discharges did not exhibit detected current at the lightning channel bottom. Moreover, since many brief discharges exhibited fine structures, we suggested that the brief discharges should not be simply classified as recoil leaders.

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