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*Supplement of*

## **Relationships between snowfall density and solid hydrometeors, based on measured size and fall speed, for snowpack modeling applications**

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Table S1 Data on the distance between each CMF of the graupel group event and the lump-graupel curve.

Event	Density (kg m <sup>-3</sup> )	Distance* (arbitrary unit)
G1	77.6	1.04
G2	95.1	0.68
G3	135.1	0.35
G4	143.1	0.14
G5	139.7	0.26
G6	48.7	1.35
G7	100.8	0.48
G8	99.4	0.46
G9	92.6	0.63

\* The distance is defined as the length of the line drawn from each CMF perpendicularly to the lump-graupel curve in the size–fall speed coordinates. The curve is expressed as following equation,

$$v = 1.3d^{0.66},$$

where  $v$  is fall speed (m s<sup>-1</sup>) and  $d$  is size (mm).

Table S2 Characteristics of the 11 snowfall events illustrated in Fig. 12.

Period (Japan standard time)	Density (kg m <sup>-3</sup> )	Sampling snow depth (mm)	Sampling snow weight (g)
20 Feb 2013, 8:30–9:25	32.9	68.5	17.7
20 Feb 2013, 9:33–10:35	50.6	9.8	3.9
20 Feb 2013, 10:38–11:16	70.1	18.2	10
20 Feb 2013, 11:20–12:17	30.8	4.4	1.1
20 Feb 2013, 13:08–13:28	135.1	19.1	20.2
20 Feb 2013, 13:35–14:10	62.9	21.1	10.4
20 Feb 2013, 15:13–16:05	32.2	18.4	4.7
20 Feb 2013, 16:10–16:56	29.9	21.8	5.1
20 Feb 2013, 16:57–17:57	33.3	38.1	10
20 Feb 2013, 18:00–18:50	44.1	39.1	13.6
20 Feb 2013, 19:00–19:50	36.3	12.6	3.6

Table S3 5 min CMFs and estimated densities illustrated in Fig. 12.

Date	Time	CMF		CMF density (kg m <sup>-3</sup> )	Estimated density (kg m <sup>-3</sup> )	Date	Time	CMF		CMF density (kg m <sup>-3</sup> )	Estimated density (kg m <sup>-3</sup> )
		Size (mm)	Fall speed (m s <sup>-1</sup> )					Size (mm)	Fall speed (m s <sup>-1</sup> )		
20 Feb 2013	8:00	5.0	0.9	20.8	47.5	20 Feb 2013	14:35	0.4	0.3	29.0	46.4
	8:05	6.0	0.9	16.0	36.7		14:40	1.2	1.0	76.4	84.0
	8:10	5.5	0.9	17.6	40.4		14:45	1.2	0.9	71.3	78.4
	8:15	5.5	0.9	18.6	42.5		14:50	1.0	0.6	31.9	51.1
	8:20	4.3	0.9	23.2	52.7		14:55	7.1	0.7	12.0	27.9
	8:25	8.7	0.9	10.9	25.4		15:00	5.3	0.9	18.6	42.5
	8:30	11.2	0.9	8.2	19.2		15:05	3.7	0.9	29.4	47.0
	8:35	9.5	1.0	10.4	24.1		15:10	2.8	1.0	41.1	65.8
	8:40	8.1	1.0	12.1	28.0		15:15	3.0	1.0	37.2	59.5
	8:45	6.3	0.9	15.7	36.2		15:20	5.5	1.0	18.7	42.8
	8:50	6.0	0.9	17.0	39.1		15:25	6.0	1.0	16.9	38.9
	8:55	7.6	0.9	12.2	28.2		15:30	5.1	1.2	22.0	50.0
	9:00	6.4	0.8	14.7	33.9		15:35	4.9	1.1	23.1	52.5
	9:05	7.2	0.9	13.6	31.5		15:40	7.2	0.9	13.8	32.0
	9:10	4.9	1.0	21.5	49.0		15:45	4.0	1.1	27.5	62.2
	9:15	5.1	0.9	20.3	46.3		15:50	7.6	0.9	12.8	29.6
	9:20	6.5	0.9	15.5	35.7		15:55	7.3	0.9	13.8	32.0
	9:25	5.1	1.0	20.5	46.9		16:00	6.9	0.9	14.4	33.3
	9:30	3.8	1.0	28.5	45.6		16:05	6.6	1.0	15.4	35.6
	9:35	5.0	1.1	22.6	51.4		16:10	5.0	1.3	27.7	62.8
	9:40	3.0	1.0	41.6	66.6		16:15	5.7	1.0	18.4	42.2
	9:45	2.8	1.6	62.9	87.4		16:20	7.3	0.9	13.3	30.7
	9:50	1.2	0.9	71.3	78.4		16:25	6.2	0.9	16.2	37.3
	9:55	1.3	1.0	54.9	60.4		16:30	7.6	1.0	13.3	30.7
	10:00	1.7	0.9	41.4	66.2		16:35	7.6	0.9	12.4	28.7
	10:05	1.3	0.6	20.9	33.5		16:40	4.3	0.9	24.0	54.5
	10:10	1.4	0.4	8.4	13.4		16:45	5.3	0.9	18.6	42.5
	10:15	1.8	1.2	60.3	66.3		16:50	5.6	0.9	17.3	39.7
	10:20	2.9	1.6	61.5	84.9		16:55	4.2	0.9	25.7	58.3
	10:25	2.3	1.6	73.0	106.8		17:00	6.0	1.1	17.3	39.7
	10:30	2.4	1.9	90.2	141.7		17:05	7.4	0.9	13.3	30.7
	10:35	2.5	1.4	70.3	77.4		17:10	6.3	0.9	15.2	35.1
	10:40	2.3	1.4	70.2	101.2		17:15	6.9	0.9	14.2	32.8
	10:45	2.6	1.5	64.9	91.1		17:20	6.0	0.9	16.5	37.8
	10:50	2.4	1.3	71.2	78.3		17:25	6.1	0.9	15.7	36.1
	10:55	2.5	1.3	72.0	79.2		17:30	6.3	0.9	15.7	36.2
	11:00	3.0	1.6	62.2	86.1		17:35	4.2	0.9	26.1	59.1
	11:05	2.7	1.2	57.4	63.1		17:40	6.1	0.9	16.0	36.7
	11:10	4.3	1.0	24.7	56.1		17:45	5.8	1.0	17.5	40.2
	11:15	7.6	0.9	12.4	28.7		17:50	5.3	1.0	19.7	45.0
	11:20	8.1	0.9	11.9	27.6		17:55	6.7	1.0	15.3	35.1
	11:25	5.3	0.8	17.5	40.2		18:00	5.4	1.0	19.9	45.5
	11:30	5.8	0.9	16.5	37.8		18:05	4.5	0.9	22.8	52.0
	11:35	5.8	0.9	16.5	37.8		18:10	6.5	1.0	15.0	34.7
	11:40	2.5	1.6	72.2	105.2		18:15	6.4	1.0	15.9	36.7
	11:45	1.8	1.2	65.5	72.0		18:20	3.6	1.1	32.3	51.7
	11:50	none	none	0.0	0.0		18:25	3.5	1.1	32.7	52.3
	11:55	none	none	0.0	0.0		18:30	5.2	0.9	20.3	46.3
	12:00	none	none	0.0	0.0		18:35	5.4	1.1	20.4	46.5
	12:05	1.0	0.7	57.8	92.5		18:40	5.1	1.0	20.8	47.5
	12:10	4.2	1.0	27.2	61.5		18:45	3.8	1.1	30.2	48.3
	12:15	3.4	0.8	29.4	47.0		18:50	3.8	1.1	29.6	47.3
	12:20	5.9	0.9	16.7	38.5		18:55	5.2	1.0	20.5	46.9
	12:25	7.7	0.9	12.6	29.2		19:00	7.2	0.9	13.4	31.0
	12:30	6.7	0.8	14.0	32.4		19:05	4.7	1.0	23.5	53.3
	12:35	4.9	1.1	22.8	52.0		19:10	4.5	1.0	23.2	52.7
	12:40	3.5	1.2	40.2	44.2		19:15	6.7	1.0	15.4	35.6
	12:45	4.3	0.9	24.0	54.5		19:20	3.7	0.7	26.3	42.1
	12:50	4.1	1.0	26.1	59.1		19:25	5.4	0.7	16.7	38.3
	12:55	3.4	1.1	35.2	56.3		19:30	3.9	1.2	34.8	55.7
	13:00	3.8	2.7	92.3	146.1		19:35	4.4	0.9	24.0	54.5
	13:05	3.3	2.5	93.8	149.5		19:40	3.6	1.4	45.7	50.3
	13:10	2.7	2.0	88.6	138.3		19:45	5.3	1.0	19.4	44.4
	13:15	2.9	2.2	87.5	136.2		19:50	7.0	0.8	12.6	29.3
	13:20	2.9	1.8	69.5	100.0		19:55	5.4	0.8	17.5	40.2
	13:25	4.1	1.2	28.6	64.7		20:00	3.4	1.6	55.1	73.3
	13:30	5.9	1.1	18.5	42.5		20:05	3.0	1.3	55.3	60.8
	13:35	7.0	1.2	15.1	34.8		20:10	1.2	1.1	99.0	108.9
	13:40	5.6	1.1	19.5	44.6		20:15	3.4	1.5	52.1	57.3
	13:45	4.6	1.2	24.8	56.2		20:20	2.3	1.2	66.2	72.8
	13:50	7.2	1.1	14.5	33.5		20:25	1.6	0.9	41.4	66.2
	13:55	3.8	1.0	28.9	46.2		20:30	2.3	0.9	48.5	77.6
	14:00	3.4	1.2	40.2	64.3		20:35	1.6	1.0	49.2	54.1
	14:05	5.6	1.1	18.9	43.3		20:40	0.5	0.3	14.5	23.2
	14:10	4.9	1.2	24.0	54.5		20:45	9.2	0.8	9.5	22.2
	14:15	3.5	1.2	38.2	42.0		20:50	0.3	0.3	29.0	46.4
	14:20	4.9	0.9	21.1	48.2		20:55	1.6	0.8	31.9	51.1
	14:25	2.3	1.0	51.0	81.5		21:00	3.3	0.9	31.4	50.2
	14:30	1.0	1.0	81.8	90.0						

(Japan standard time)