

1 Table S1: Mass fraction and density of each size class used in model simulations, before aggregating fine ash. Mass fractions and phi sizes for  
2 Mount St. Helens were taken from supplement 2008jb005756-tx03.txt in Durant et al. [2009] for samples integrated out to 671 km distance.  
3 Densities were estimated based on component analysis of Carey and Sigurdsson [1982], assuming a density of 2900 kg/m<sup>3</sup> for lithics, 490 kg/m<sup>3</sup>  
4 for pumice at  $\phi \leq 1$  [Klug and Cashman, 1994], and 2300 kg/m<sup>3</sup> for glass fragments at  $\phi \geq 4.5$ . TGSDs for Spurr, Ruapehu, and Redoubt were  
5 obtained respectively from Durant and Rose [2009], Bonadonna and Houghton [2005], and Mastin et al. [2013]. For Ruapehu, we give both the  
6 TGSD derived using Technique C of Bonadonna and Houghton [2005], used throughout this paper, and that using Technique B, whose result is  
7 illustrated in Supplementary Figure 173. Clast densities were not always given by these sources. For Spurr clasts we assume  $\rho = 1700$  kg m<sup>-3</sup> at  
8  $\phi \leq -2$  [Gardner et al., 1998],  $\rho = 2500$  kg m<sup>-3</sup> at  $\phi \geq 7$ , and a linear variation with  $\phi$  in between. For Ruapehu we assume  $\rho = 1100$  kg m<sup>-3</sup> at  $\phi \leq -1$   
9 [Gardner et al., 1998],  $\rho = 2650$  kg m<sup>-3</sup> at  $\phi \geq 6$ , and a linear variation in between [Bonadonna and Phillips, 2003; Bonadonna et al., 2005]. For  
10 Redoubt we use the same values as in Mastin et al. [2013]. Sources give the TGSD for Spurr, Ruapehu and Redoubt only in 1-phi intervals. For  
11 modeling, for particles coarser than 5 $\phi$ , we interpolate to half-phi intervals to avoid deposit artifacts. Phi values in bold are not included in  
12 aggregation.

		Mount St. Helens		Spurr		Ruapehu			Redoubt	
						C	B			
$\phi$	mm	m <sub>m</sub>	$\rho$ , kg/m <sup>3</sup>	m <sub>m</sub>	$\rho$ , kg/m <sup>3</sup>	m <sub>m</sub>	m <sub>m</sub>	$\rho$ , kg/m <sup>3</sup>	m <sub>m</sub>	$\rho$ , kg/m <sup>3</sup>
<b><math>\leq -4.0</math></b>	16.0000		490	0.024	1700	0.0647	0.0384	1100	0.0059	800
<b>-3.5</b>	11.3137	0.0007	490	0.0185	1700	0.0404	0.0194	1100	0.0087	800
<b>-3.0</b>	8.0000	0.0019	490	0.013	1700	0.0495	0.0227	1100	0.0134	800
<b>-2.5</b>	5.6569	0.0021	490	0.0115	1700	0.0620	0.0262	1100	0.0143	800
<b>-2.0</b>	4.0000	0.0047	665	0.0100	1700	0.0744	0.0297	1100	0.0153	800
<b>-1.5</b>	2.8284	0.0058	1292	0.0125	1744	0.0705	0.0291	1100	0.0140	800
<b>-1.0</b>	2.0000	0.0056	2003	0.015	1789	0.0666	0.0285	1100	0.0128	800
<b>-0.5</b>	1.4142	0.0084	2350	0.021	1833	0.0717	0.0353	1211	0.0334	800
<b>0.0</b>	1.0000	0.0141	2005	0.027	1878	0.0767	0.0420	1321	0.0541	800
<b>0.5</b>	1.4142	0.0214	2248	0.0195	1922	0.0754	0.0567	1432	0.0620	900
<b>1.0</b>	0.5000	0.0459	2624	0.012	1967	0.0740	0.0714	1543	0.0698	1000
<b>1.5</b>	0.3536	0.0723	2644	0.011	2011	0.0650	0.0798	1654	0.0629	1050
<b>2.0</b>	0.2500	0.0532	2639	0.010	2056	0.0560	0.0881	1764	0.0560	1083
2.5	0.1768	0.0292	2706	0.044	2100	0.0439	0.0864	1875	0.0687	1400
3.0	0.1250	0.0330	2691	0.079	2144	0.0318	0.0847	1986	0.0813	1790
3.5	0.0884	0.0460	2730	0.118	2189	0.0235	0.0750	2096	0.0791	2200
4.0	0.0625	0.0602	2698	0.118	2233	0.0152	0.0652	2207	0.0577	2250
4.5	0.0442	0.0700	2640	0.095	2278	0.0119	0.0457	2317	0.0624	2275

5.0	0.0313	0.0799	2581	0.112	2322	0.0086	0.0262	2429	0.0672	2300
5.5	0.0221	0.0829	2570							
6.0	0.0156	0.0790	2670	0.101	2411	0.0074	0.0206	2650	0.0767	2500
6.5	0.0110	0.07174	2670							
7.0	0.0078	0.0575	2670	0.066	2500	0.0045	0.0115	2650	0.0401	2500
7.5	0.0055	0.0429	2670							
8.0	0.0039	0.0327	2670	0.038	2500	0.0029	0.0081	2650	0.0193	2500
8.5	0.0028	0.0261	2670							
9.0	0.0020	0.0207	2670	0.024	2500	0.0018	0.0054	2650	0.0115	2500
9.5	0.0014	0.0138	2670							
10.0	0.0010	0.0094	2670	0.003	2500	0.0011	0.0037	2650	0.0223	2500
10.5	0.0007	0.0063	2670							
≥11.0	0.0005	0.0029	2670	0.001	2500	0.0005	0.0000	2650		

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16 Table S2: Grain-size distributions used to simulate the deposits in Figures 11-14. Numbers in italics in the last five rows are aggregates.

		Mount St. Helens		Crater Peak		Ruapehu		Redoubt	
$\phi$	mm	$m_m$	$\rho$ , kg/m <sup>3</sup>	$m_m$	$\rho$ , kg/m <sup>3</sup>	$m_m$	$\rho$ , kg/m <sup>3</sup>	$m_m$	$\rho$ , kg/m <sup>3</sup>
$\leq -4.0$	16.0000	0.0000	490	0.024	1700	0.0647	1100	0.0059	800
-3.5	11.3137	0.0007	490	0.0185	1700	0.0404	1100	0.0087	800
-3.0	8.0000	0.0019	490	0.013	1700	0.0495	1100	0.0134	800
-2.5	5.6569	0.0021	490	0.0115	1700	0.0620	1100	0.0143	800
-2.0	4.0000	0.0047	665	0.0100	1700	0.0744	1100	0.0153	800
-1.5	2.8284	0.0058	1292	0.0125	1744	0.0705	1100	0.0140	800
-1.0	2.0000	0.0056	2003	0.0150	1789	0.0666	1100	0.0128	800
-0.5	1.4142	0.0084	2350	0.0210	1833	0.0717	1211	0.0334	800
0.0	1.0000	0.0141	2005	0.0270	1878	0.0767	1321	0.0541	800
0.5	1.4142	0.0214	2248	0.0195	1922	0.0754	1432	0.0620	900
1.0	0.5000	0.0459	2624	0.0120	1967	0.0740	1543	0.0698	1000
1.5	0.3536	0.0723	2644	0.0110	2011	0.0650	1654	0.0629	1050
2.0	0.2500	0.0532	2639	0.0100	2056	0.0560	1764	0.0560	1083
2.5	0.1768	0.0219	2706	0.0334	2100	0.0439	1875	0.0515	1400
3.0	0.1250	0.0165	2691	0.0395	2144	0.0239	1986	0.0407	1790
3.5	0.0884	0.0115	2730	0.0295	2189	0.0130	2096	0.0198	2200
2.2	0.2176	0.0428	600	0.0416	600	0.0043	600	0.0279	600
2.3	0.2031	0.1714	600	0.1663	600	0.0174	600	0.1117	600
2.4	0.1895	0.2856	600	0.2772	600	0.0289	600	0.1862	600
2.5	0.1768	0.1714	600	0.1663	600	0.0174	600	0.1117	600
2.5	0.1649	0.0428	600	0.0416	600	0.0043	600	0.0279	600

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19 Table S3: Values of  $\Delta^2$ ,  $\Delta_{downwind}^2$ , and  $\Delta_{area}^2$  for the Mount St. Helens simulations. Minimum values are indicated in bold. The last row gives  
 20 values of these parameters for the simulation that used the raw particle-size distribution (Table S1) with no aggregation.

	$\Delta^2$				$\Delta_{downwind}^2$				$\Delta_{area}^2$			
	$\sigma_{agg}=0$	0.1	0.2	0.3	$\sigma_{agg}=0$	0.1	0.2	0.3	$\sigma_{agg}=0$	0.1	0.2	0.3
$\mu_{agg}=1.9$	0.9167	1.3374	0.8970	0.6892	1.4376	1.3080	1.1695	0.9785	0.5482	0.4886	0.4476	0.3923
<b>2.0</b>	1.1617	1.3041	0.8245	0.6190	1.4065	1.2346	1.0179	0.7987	0.5301	0.4638	0.3989	0.3336
<b>2.1</b>	1.7211	0.9212	0.6469	0.5245	1.3565	1.1278	0.8244	0.6250	0.5073	0.4283	0.3435	0.2738
<b>2.2</b>	1.6604	0.4743	0.4294	0.4210	1.2967	0.9478	0.6260	0.4708	0.4848	0.3783	0.2862	0.2337
<b>2.3</b>	1.1409	0.2002	0.2646	0.3372	1.2163	0.7092	0.4415	0.3567	0.4556	0.3248	0.2310	0.2058
<b>2.4</b>	0.5118	<b>0.1385</b>	0.2104	0.2990	1.0980	0.4910	0.3083	0.3033	0.4167	0.2510	0.1962	0.1886
<b>2.5</b>	0.2008	0.2669	0.2718	0.3187	0.9040	0.3624	<b>0.2923</b>	0.3097	0.3713	0.1903	0.1782	0.1737
<b>2.6</b>	0.1412	0.5083	0.4103	0.3914	0.6655	0.4213	0.3703	0.3596	0.3136	0.1748	0.1696	0.1695
<b>2.7</b>	0.2713	0.6968	0.5682	0.4978	0.4842	0.5376	0.4731	0.4323	0.2544	0.1696	<b>0.1689</b>	0.1695
<b>2.8</b>	0.6333	0.7910	0.7021	0.6137	0.4926	0.6183	0.5698	0.5139	0.1946	0.1893	0.1764	0.1769
<b>2.9</b>	0.7680	0.8479	0.7972	0.7197	0.5736	0.6949	0.6514	0.6006	0.1791	0.1985	0.1925	0.1843
<b>3.0</b>	0.7917	0.8893	0.8581	0.8037	0.6306	0.7777	0.7374	0.6864	0.2061	0.2171	0.2045	0.1987
<b>3.1</b>	0.8613	0.9145	0.8953	0.8619	0.7117	0.8702	0.8304	0.7756	0.2038	0.2645	0.2359	0.2163
<b>no aggregation</b>	0.954				1.262				0.660			

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23 Table S4: values of  $\Delta^2$ ,  $\Delta_{downwind}^2$ , and  $\Delta_{area}^2$  for the Crater Peak (Mount Spurr) simulations. Minimum values are indicated in bold. The last row  
 24 gives values of these parameters for the simulation that used the raw particle-size distribution (Table S1) with no aggregation.

	$\Delta^2$				$\Delta_{downwind}^2$				$\Delta_{area}^2$			
	$\sigma_{agg}=0$	0.1	0.2	0.3	$\sigma_{agg}=0$	0.1	0.2	0.3	$\sigma_{agg}=0$	0.1	0.2	0.3
$\mu_{agg}=1.9$	1.2213	0.7550	0.7281	0.7083	1.0503	0.8745	0.7356	0.6593	0.0416	0.0112	0.0082	0.0271
<b>2.0</b>	0.9293	0.6309	0.5859	0.5758	0.9932	0.7505	0.6160	0.5715	0.0278	<b>0.0066</b>	0.0237	0.0632
<b>2.1</b>	0.7619	0.5192	0.4875	0.4905	0.9269	0.5981	0.5358	0.5162	0.0161	0.0143	0.0616	0.1539
<b>2.2</b>	0.6656	0.4245	0.4274	0.4483	0.8226	0.4982	0.4837	0.4946	0.0073	0.0516	0.1490	0.3132
<b>2.3</b>	0.5493	0.3711	0.4047	0.4405	0.6766	0.4525	0.4679	0.4915	0.0077	0.1311	0.3132	0.6266
<b>2.4</b>	0.4305	0.3724	0.4179	0.4586	0.5274	0.4807	0.4977	0.5183	0.0254	0.2989	0.6467	1.0519
<b>2.5</b>	0.3656	0.4322	0.4635	0.4960	<b>0.4474</b>	0.5551	0.5611	0.5685	0.0786	0.6522	1.1981	1.5187
<b>2.6</b>	<b>0.3548</b>	0.5358	0.5349	0.5475	0.4734	0.6562	0.6447	0.6373	0.1910	1.2708	1.7507	1.8623
<b>2.7</b>	0.4229	0.6577	0.6219	0.6083	0.5535	0.7703	0.7435	0.7197	0.4402	1.8933	2.2288	2.2387
<b>2.8</b>	0.5443	0.7668	0.7098	0.6735	0.6611	0.8963	0.8546	0.8103	0.9439	2.4292	2.6285	2.5848
<b>2.9</b>	0.6823	0.8392	0.7839	0.7368	0.7806	1.0212	0.9665	0.9088	1.6937	2.7673	2.8290	2.7361
<b>3.0</b>	0.7961	0.8735	0.8359	0.7918	0.9156	1.1187	1.0745	1.0081	2.3168	2.9186	2.9897	2.8702
<b>3.1</b>	0.8614	0.8851	0.8660	0.8340	1.0451	1.1897	1.1558	1.0973	2.6996	2.7018	2.8795	2.8253
<b>no aggregation</b>	0.934				1.182				0.641			

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27 Table S5: values of  $\Delta^2$ ,  $\Delta_{downwind}^2$ , and  $\Delta_{area}^2$  for the Ruapehu simulations. Minimum values are indicated in bold. The last row gives values of  
 28 these parameters for the simulation that used the raw particle-size distribution (Table S1) with no aggregation.

	$\Delta^2$				$\Delta_{downwind}^2$				$\Delta_{area}^2$			
	$\sigma_{agg}=0$	0.1	0.2	0.3	$\sigma_{agg}=0$	0.1	0.2	0.3	$\sigma_{agg}=0$	0.1	0.2	0.3
$\mu_{agg}=1.9$	0.6472	0.5980	0.5924	0.5886	0.5032	0.3450	0.2801	0.2581	0.2691	0.2313	0.2068	0.1925
<b>2.0</b>	0.6295	0.5774	0.5783	0.5785	0.4693	0.2556	0.2162	0.2173	0.2597	0.2057	0.1846	0.1750
<b>2.1</b>	0.6009	0.5669	0.5687	0.5707	0.3957	0.1866	0.1633	0.1847	0.2430	0.1783	0.1633	0.1570
<b>2.2</b>	0.5766	0.5641	0.5641	0.5658	0.2624	0.0991	0.1287	0.1624	0.2198	0.1516	0.1418	0.1407
<b>2.3</b>	0.5667	0.5636	<b>0.5627</b>	0.5635	0.1494	0.0898	0.1182	0.1546	0.1918	0.1340	0.1265	0.1284
<b>2.4</b>	0.5650	0.5636	0.5629	0.5632	0.0940	0.1342	0.1443	0.1673	0.1623	0.1222	<b>0.1209</b>	0.1216
<b>2.5</b>	0.5643	0.5644	0.5641	0.5643	<b>0.0870</b>	0.2075	0.1975	0.1993	0.1407	0.1253	0.1221	0.1229
<b>2.6</b>	0.5641	0.5663	0.5662	0.5662	0.1341	0.2903	0.2635	0.2458	0.1283	0.1361	0.1262	0.1247
<b>2.7</b>	0.5646	0.5695	0.5691	0.5688	0.2145	0.3803	0.3333	0.2981	0.1291	0.1594	0.1432	0.1384
<b>2.8</b>	0.5665	0.5733	0.5725	0.5718	0.3011	0.4638	0.4081	0.3614	0.1420	0.1738	0.1691	0.1596
<b>2.9</b>	0.5696	0.5771	0.5760	0.5750	0.4033	0.5006	0.4659	0.4200	0.1655	0.1680	0.1677	0.1697
<b>3.0</b>	0.5736	0.5803	0.5792	0.5781	0.4877	0.4971	0.4863	0.4554	0.1751	0.1644	0.1673	0.1712
<b>3.1</b>	0.5775	0.5828	0.5819	0.5808	0.5030	0.5030	0.5006	0.4874	0.1681	0.1632	0.1670	0.1758
<b>no aggregation</b>	0.699				0.320				0.439			

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31 Table S6: values of  $\Delta^2$ ,  $\Delta_{downwind}^2$ , and  $\Delta_{area}^2$  for the Redoubt simulations. Minimum values are indicated in bold. The last row gives values of  
 32 these parameters for the simulation that used the raw particle-size distribution (Table S1) with no aggregation.

	$\Delta^2$				$\Delta_{downwind}^2$				$\Delta_{area}^2$			
	$\sigma_{agg}=0$	0.1	0.2	0.3	$\sigma_{agg}=0$	0.1	0.2	0.3	$\sigma_{agg}=0$	0.1	0.2	0.3
$\mu_{agg}=1.9$	0.9911	0.9896	0.9890	0.9888	0.4375	0.4399	0.4238	0.4132	<b>0.3027</b>	0.4536	0.5615	0.7179
<b>2.0</b>	0.9908	0.9880	0.9880	0.9881	0.4338	0.4359	0.4175	0.3985	0.3337	0.5746	0.7438	0.9578
<b>2.1</b>	0.9899	0.9863	0.9869	0.9875	0.4341	0.4342	0.4081	0.3935	0.4255	0.7366	0.9536	1.3610
<b>2.2</b>	0.9881	0.9852	0.9863	0.9870	0.4454	0.4312	0.4038	0.3855	0.5236	0.9979	1.3955	1.9363
<b>2.3</b>	0.9861	0.9850	0.9860	0.9866	0.4487	0.4256	0.4010	<b>0.3815</b>	0.6688	1.4186	2.1302	2.5339
<b>2.4</b>	<b>0.9846</b>	0.9857	0.9863	0.9864	0.4457	0.4180	0.3956	0.3904	0.8866	2.1719	2.8538	3.0590
<b>2.5</b>	<b>0.9846</b>	0.9872	0.9866	0.9864	0.4374	0.4197	0.4194	0.4107	1.2329	3.2620	3.4237	3.5218
<b>2.6</b>	0.9859	0.9887	0.9869	0.9865	0.4256	0.5050	0.4535	0.4336	1.7518	3.5144	3.8499	3.8835
<b>2.7</b>	0.9861	0.9878	0.9869	0.9867	0.4233	0.5251	0.4775	0.4537	2.2629	3.7178	4.0838	4.0723
<b>2.8</b>	0.9908	0.9863	0.9869	0.9870	0.5772	0.4836	0.4777	0.4658	2.3218	4.0193	4.1475	4.1992
<b>2.9</b>	0.9908	0.9864	0.9870	0.9874	0.5782	0.4821	0.4799	0.4687	2.2774	3.9286	4.1132	4.2023
<b>3.0</b>	0.9859	0.9872	0.9875	0.9878	0.4590	0.5046	0.4943	0.4809	3.6379	3.8054	3.9603	3.9889
<b>3.1</b>	0.9865	0.9887	0.9882	0.9883	0.4833	0.5202	0.5029	0.4890	3.7961	3.5489	3.6194	3.7292
<b>no aggregation</b>	0.998				0.649				1.091			

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