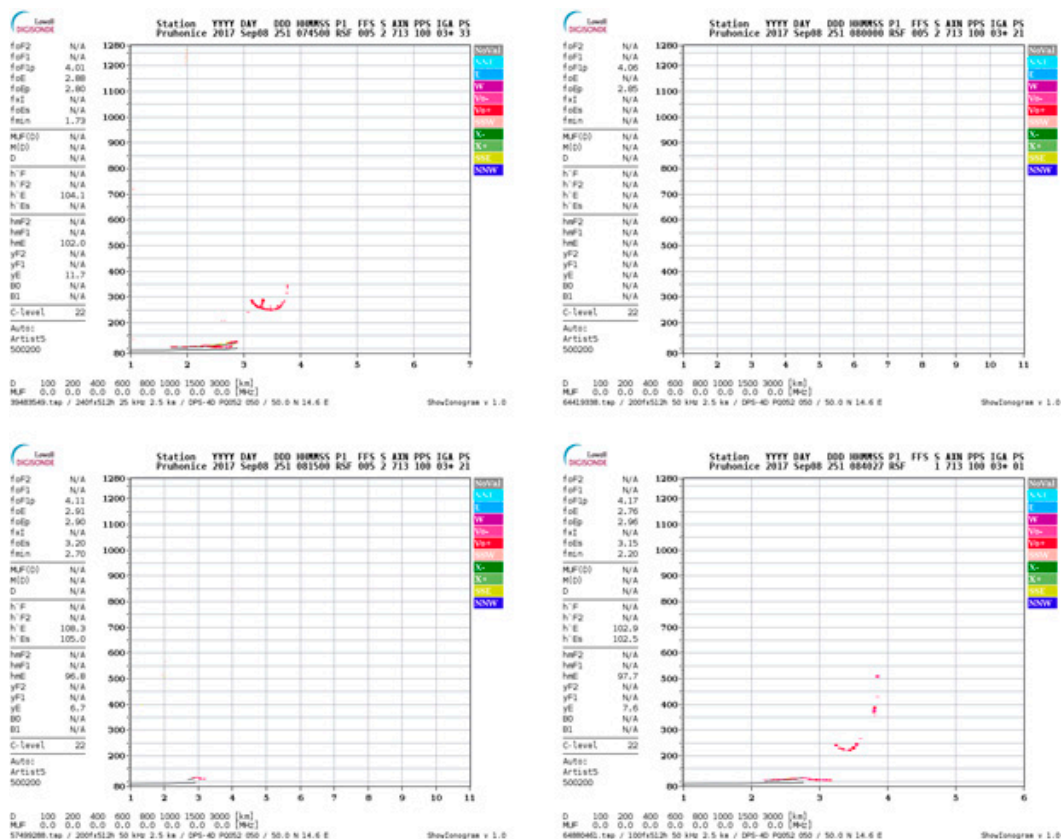
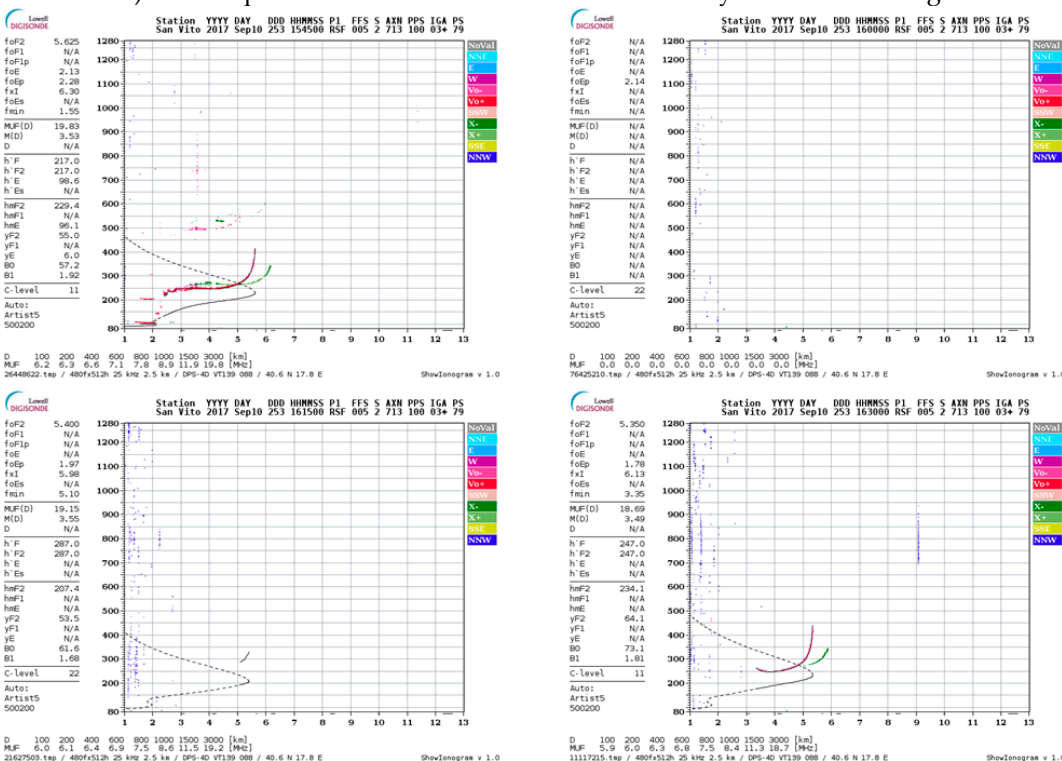


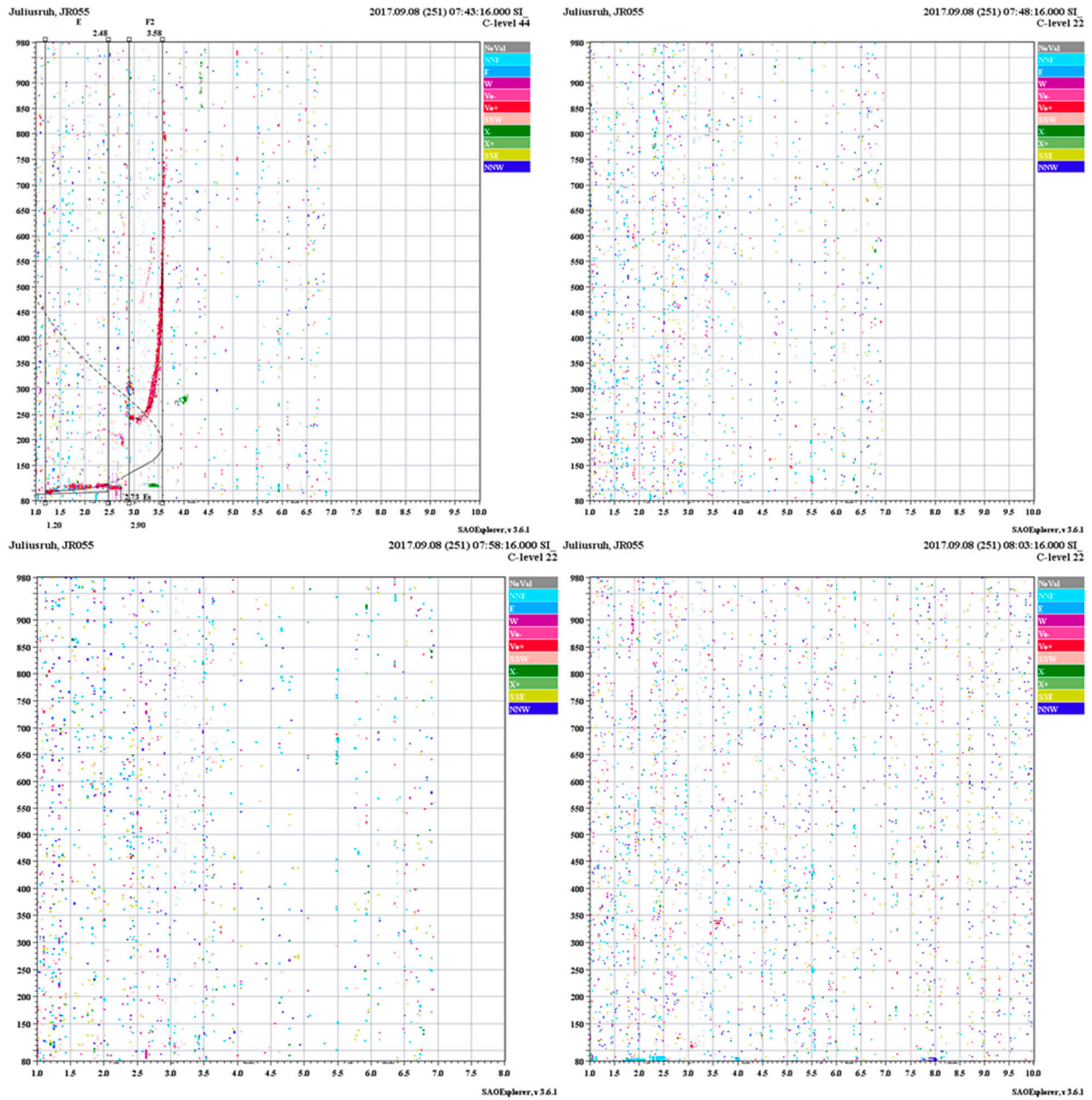
Supplementary material



Supplementary Figure S1. Consecutive ionograms recorded at Pruhonice ionosonde station during and after an M8.1 class flare (between 07:45–08:40) on 08 September. The total radio fade-out is clearly seen on the ionograms.



Supplementary Figure S2. Consecutive ionograms recorded at San Vito ionosonde station during and after an X8.2 class flare (between 15:45–16:30) on 10 September. The total radio fade-out is clearly seen on the ionograms.



Supplementary Figure S3. Consecutive ionograms recorded at Juliusruh ionosonde station during and after an M8.1 class flare (between 07:45–08:40) on 08 September. The total radio fade-out, thus the disappearance of the traces from the Ionograms can be seen, despite that the Ionograms are very noisy.

Supplementary Table S1. Detailed data of the investigated flare and energetic particle events. Date, maximum X-ray or proton flux (measured at different channels) and the exact time of the maximum. In the case of the flare events, the class is also indicated in the upper row. The time period from which the maximum was selected is also shown in the last row.

Flare/proton event	C8.3	M1.5	M3.2	M3.8	X2.2	X9.3	proton	M1.4	M7.3	X1.3	M8.1	M2.9	M3.7	X8.2	proton
	Observed peak time	2017. 9. 4. 15:30	2017. 9. 5. 4:53	2017. 9. 5. 6:40	2017. 9. 6. 9:10	2017. 9. 6. 12:02	2017. 9. 6. 0:00	2017. 9. 7. 9:54	2017. 9. 7. 10:15	2017. 9. 7. 14:36	2017. 9. 8. 7:49	2017. 9. 8. 15:47	2017. 9. 9. 11:04	2017. 9. 10. 16:06	2017. 9. 10. 0:00
xray	Max value	Time of the maximum	Max value	Time of the maximum	Max value	Time of the maximum	Max value	Time of the maximum	Max value	Time of the maximum	Max value	Time of the maximum	Max value	Time of the maximum	Max value
proton 10MeV	0.29	12:25	1.5259e-05	15:30	1.3177e-05	4:35	3.9515e-05	6:40	3.00022658	9:10	0.0010368	12:02	3.00020037	12:45	3.00089805
proton 30MeV	0.13	12:20	0.34	15:35	71.47	5:20	78.030	7:05	23.120	8:40	17.43	12:05	19.48	13:05	1.0018642
proton 60MeV	0.09	12:20	0.13	15:30 - 15:35	1.020	4:20	1.110	6:50	0.34	9:10	0.32	11:55	3.44	13:05	3.00018642
Used time interval		11:50 - 12:34	15:25 - 16:00	4:20 - 5:24	8:40 - 9:40	11:30 - 12:30	12:30 - 13:20	9:30 - 10:04	10:05 - 10:45	14:05 - 15:10	7:30 - 8:20	15:00 - 16:20	10:50 - 11:35	15:35 - 16:25	16:55 - 17:30

Measured values at the peak time of the flares								
Date	Type	Peak time	Juliusruh		Průhonice		San Vito	
			2.5 MHz	4 MHz	2.5 MHz	4 MHz	2.5 MHz	4 MHz
9.4.2017	C8.3	12:22	17.120	13.318	23.828	14.8475	21.122	FD
9.4.2017	M1.5	15:30	8.127	6.2356	20.256	9.294	12.7977	9.0804
9.5.2017	M3.2	4:53	3.99734	3.90642	6.773	2.891	8.239	5.627
9.5.2017	M3.8	6:40	13.6911	9.8525	18.288	8.4478	16.611	6.2419
9.6.2017	X2.2	9:10	18.0267	20.377	FD	FD	FD	FD
9.6.2017	X9.3	12:02	19.8132	20.154	FD	FD	FD	FD
9.7.2017	M1.4	9:54	17.8374	15.3312	FD	13.41712	FD	14.81684
9.7.2017	M7.3	10:15	18.4586	15.2559	FD	FD	FD	FD
9.7.2017	X1.3	14:36	19.568	17.4016	FD	FD	FD	FD
9.8.2017	M8.1	7:49	20.3543	24.785512	FD	FD	FD	FD
9.8.2017	M2.9	15:47	17.4162	22.1528	23.627	FD	18.15	7.705
9.9.2017	M3.7	11:04	17.41	20.1795	FD	FD	FD	FD
9.10.2017	X8.2	16:06	19.0022	23.7532	FD	FD	FD	FD
D-RAP values at the peak time of the flares								
Date	Type	Peak time	Juliusruh		Průhonice		San Vito	
			2.5 MHz	4 MHz	2.5 MHz	4 MHz	2.5 MHz	4 MHz
9.4.2017	C8.3	12:22	15.140043857268052	7.48078475997004	17.576	8.684405024237412	19.158854245491817	9.466502621084516
9.4.2017	M1.5	15:30	7.88030050188443	3.8937028488316887	8.854532850467042	4.375076785040463	7.88030050188443	3.8937028488316887
9.5.2017	M3.2	4:53	2.1002247498779747	1.0377334074799747	1.6565023392678924	0.8184875533567997	2.9998186611860396	1.4822280526288796
9.5.2017	M3.8	6:40	11.994908253088058	5.926754750704637	13.537002326955546	6.688712506902954	16.801797999023798	8.301867259839797
9.6.2017	X2.2	9:10	nan	nan	nan	nan	nan	nan
9.6.2017	X9.3	12:02	62.327371579427286	30.79632105666194	70.3403274373954	34.75556969753194	77.64385358803362	38.36428494544112
9.7.2017	M1.4	9:54	16.801797999023798	8.301867259839797	19.158854245491817	9.466502621084516	22.45792367962808	11.096592241539744
9.7.2017	M7.3	10:15	12.828351102148709	6.338563766737699	15.140043857268052	7.48078475997004	16.801797999023798	8.301867259839797
9.7.2017	X1.3	14:36	25.572876881571226	12.635708948254543	28.819854267501082	14.24005958116047	28.819854267501082	14.24005958116047
9.8.2017	M8.1	7:49	23.998549289488317	11.857824421031037	27.180199852098223	13.429896686125328	32.768000000000001	16.190861620062105
9.8.2017	M2.9	15:47	9.609651814712127	4.74818550869698	10.3850939331332	5.131336022421451	9.609651814712127	4.74818550869698
9.9.2017	M3.7	11:04	28.819854267501082	14.24005958116047	32.00300785863729	15.81287450149403	36.88159042123862	18.223410853212968
9.10.2017	X8.2	16:06	16.801797999023798	8.301867259839797	18.3617410939159	9.07264432235718	15.140043857268052	7.48078475997004

Supplementary Table S2. The values [dB] measured by the Digisondes (upper table) and determined by D-RAP (lower table) at 2.5 and at 4 MHz at the peak time of the investigated flares. If at the peak time there was a fade-out at the analyzed frequency range (2.5 or 4 MHz) it is indicated by FD in the upper table. Missing values in D-RAP are indicated by nan.

Solar Zenith Angle at the Digisonde stations (2.5 MHz measurements)						
Date	Class	Time (UT) of peak or of first record after Fadeout	X-ray flux at that time [Wm ⁻²]	JR	PQ	VT
2017-9-4	C8.3	12:22	7.6508E-06	50.032°	46.201°	39.633°
2017-9-4	M1.5	15:30	1.5259E-05	70.629°	70.162°	70.730°
2017-9-5	M3.2	4:53	5.0111E-05	86.070°	85.853°	84.426°
2017-9-5	M3.8	6:40	3.9515E-05	70.899°	68.963°	64.392°
2017-9-6	X2.2	15:15	2.1828E-05	69.270°	68.518°	68.533°
2017-9-6	X9.3	15:15	2.1828E-05	69.270°	68.518°	68.533°
2017-9-7	M1.4	10:30	1.5815E-06	49.195°	44.495°	34.881°
2017-9-7	M7.3	10:30	1.5815E-06	49.195°	44.495°	34.881°
2017-9-7	X1.3	15:15	2.7468E-05	69.630°	68.863°	68.845°
2017-9-8	M8.1	8:45	3.8351E-06	56.456°	52.584°	44.325°
2017-9-8	M2.9	15:47	3.1061E-05	74.429°	74.199°	75.155°
2017-9-9	M3.7	12:15	6.3839E-06	51.534°	47.602°	40.690°
2017-9-10	X8.2	16:45	2.5411E-04	83.410°	84.095°	86.630°

Supplementary Table S3. The solar zenith angle (SZA) calculated at the peak time of the flare or, in the case of a fade-out, at the time of the first measurement after the fade-out (2.5 MHz measurements), and at the location of the Digisonde stations. The X-ray flux values are from the 0.1–0.8 nm wavelength band measured by the GOES spacecrafts.

Solar Zenith Angle at the Digisonde stations (4 MHz measurements)						
Date	Class	Time (UT) of peak or of first record after Fadeout	X-ray flux at that time [Wm ⁻²]	JR	PQ	VT
2017-9-4	C8.3	12:45	4.4809E-06	51.633°	48.183°	42.571°
2017-9-4	M1.5	15:30	1.5259E-05	70.629°	70.162°	70.730°
2017-9-5	M3.2	4:53	5.0111E-05	86.070°	85.853°	84.426°
2017-9-5	M3.8	6:40	3.9515E-05	70.899°	68.963°	64.392°
2017-9-6	X2.2	10:15	2.0114E-05	49.353°	44.689°	35.044°
2017-9-6	X9.3	14:15	4.4764E-05	61.502°	59.671°	57.612°
2017-9-7	M1.4	09:54	1.5658E-05	50.718°	46.157°	36.625°
2017-9-7	M7.3	10:30	1.5815E-06	49.195°	44.495°	34.881°
2017-9-7	X1.3	15:15	2.7468E-05	69.630°	68.863°	68.845°
2017-9-8	M8.1	8:30	8.9745E-06	57.985°	54.313°	46.443°
2017-9-8	M2.9	15:57	2.2704E-05	75.843°	75.781°	77.040°
2017-9-9	M3.7	12:00	1.0895E-05	50.768°	46.634°	39.148°
2017-9-10	X8.2	16:30	4.3431E-04	81.266°	81.717°	83.862°

Supplementary Table S4. The solar zenith angle (SZA) calculated at the peak time of the flare or, in the case of a fade-out, at the time of the first measurement after the fade-out (4 MHz measurements), and at the location of the Digisonde stations. The X-ray flux values are from the 0.1–0.8 nm wavelength band measured by the GOES spacecrafts.

Solar Zenith Angle at the riometer stations									
Date	Class	Peak Time (UT)	X-ray flux at that time [Wm ⁻²]	ABI	IVA	SOD	ROV	OUL	JYV
2017-9-4	C8.3	12:22	7.6508E-06	63.526°	65.282°	64.175°	63.554°	62.169°	59.863°
2017-9-4	M1.5	15:30	1.5259E-05	76.793°	79.820°	79.355°	79.100°	78.863°	78.254°
2017-9-5	M3.2	4:53	5.0111E-05	82.703°	79.679°	79.868°	79.970°	79.812°	79.842°
2017-9-5	M3.8	6:40	3.9515E-05	73.252°	70.655°	70.322°	70.132°	69.262°	68.157°
2017-9-6	X2.2	9:10	2.2658E-04	63.882°	62.941°	61.954°	61.400°	59.786°	57.357°
2017-9-6	X9.3	12:02	1.0368E-03	63.507°	65.097°	63.880°	63.240°	61.767°	59.342°
2017-9-6	Proton	13:05	1.5930E-04	66.468°	68.685°	67.678°	67.115°	65.950°	63.956°
2017-9-7	M1.4	9:54	1.5658E-05	62.973°	62.650°	61.551°	60.932°	59.244°	56.633°
2017-9-7	M7.3	10:15	8.0138E-05	62.624°	62.614°	61.479°	60.839°	59.140°	56.483°
2017-9-7	X1.3	14:36	1.5126E-04	73.305°	76.167°	75.470°	75.084°	74.480°	73.313°
2017-9-8	M8.1	7:49	8.6106E-05	69.030°	67.068°	66.397°	66.020°	64.733°	62.920°
2017-9-8	M2.9	15:47	3.1061E-05	79.820°	82.854°	82.461°	82.247°	82.117°	81.668°
2017-9-9	M3.7	11:04	3.9615E-05	63.332°	64.058°	62.882°	62.220°	60.570°	57.928°
2017-9-10	X8.2	16:06	8.9805E-04	82.295°	85.313°	85.007°	84.840°	84.833°	84.574°
2017-9-10	Proton	17:25	1.0252E-04	89.231°	92.576°	92.634°	92.673°	93.192°	93.750°

Supplementary Table S5. The solar zenith angle (SZA) calculated at the peak time of the flare and at the location of the riometer stations.