Debye-like shielding effect on low-cloud electricity by the radioactive aerosol after Fukushima nuclear accident

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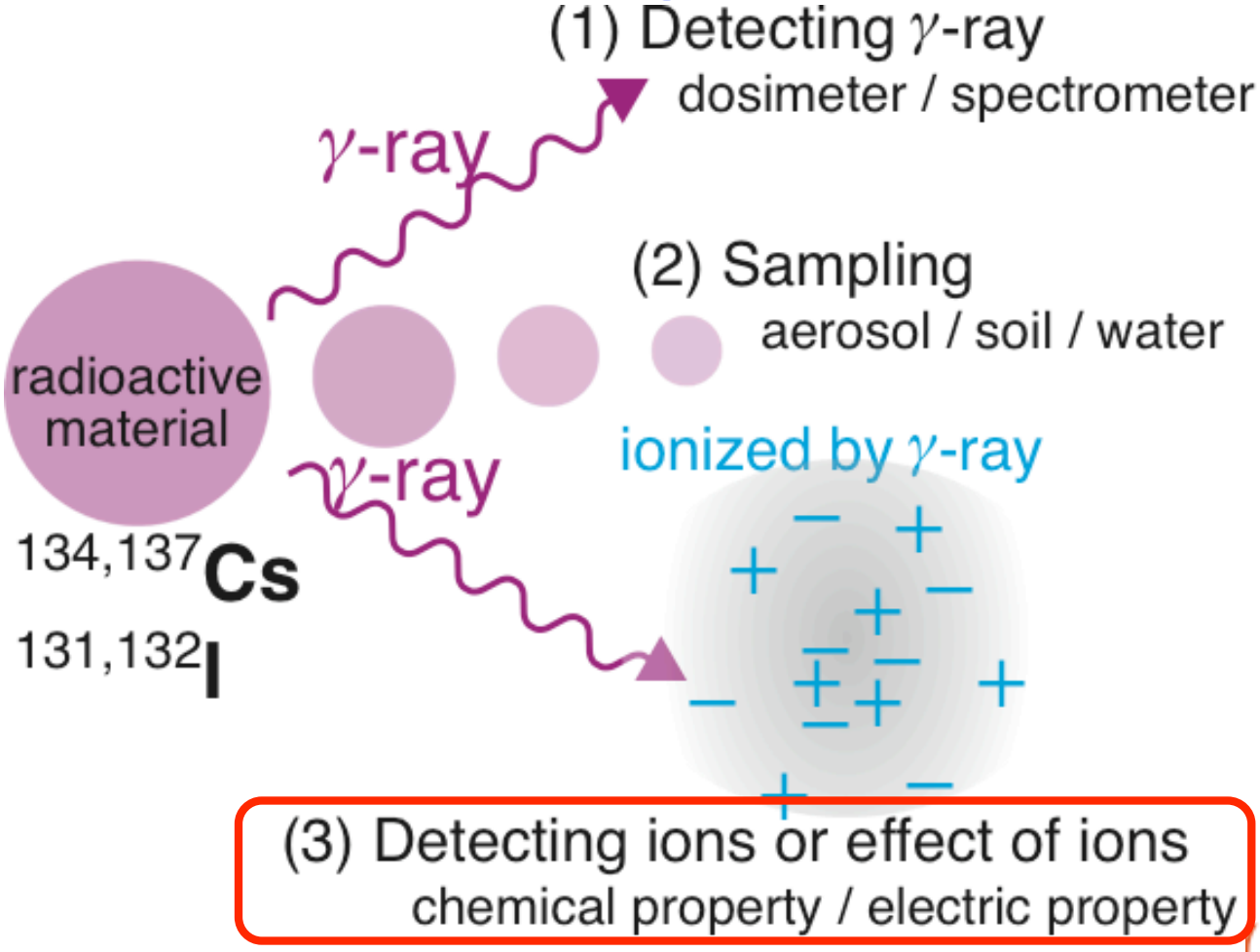
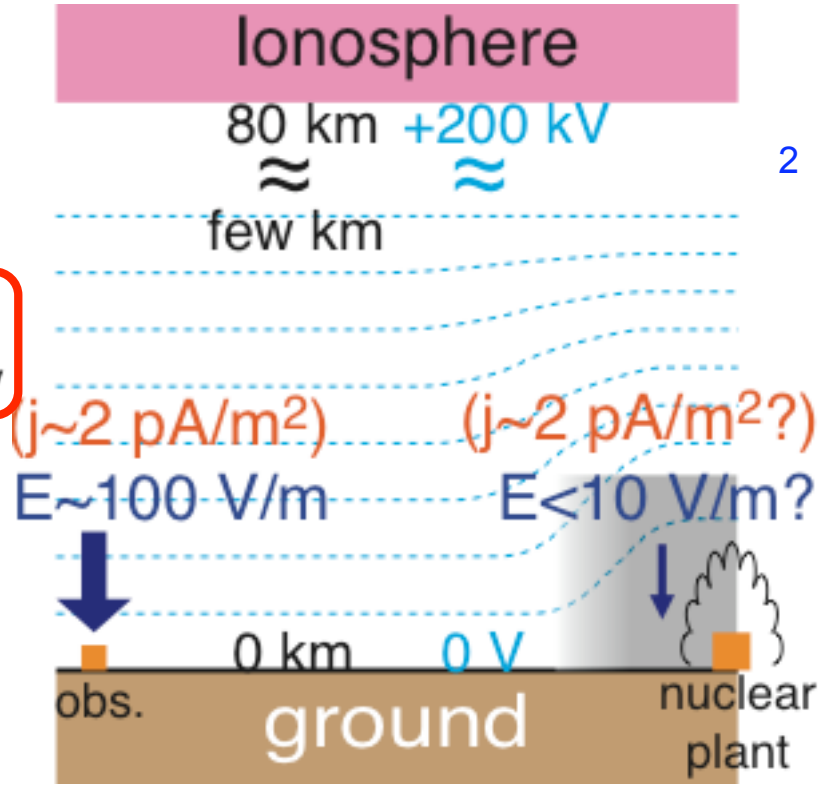
Effect of ionizing radiation



Instrument to measure E-field



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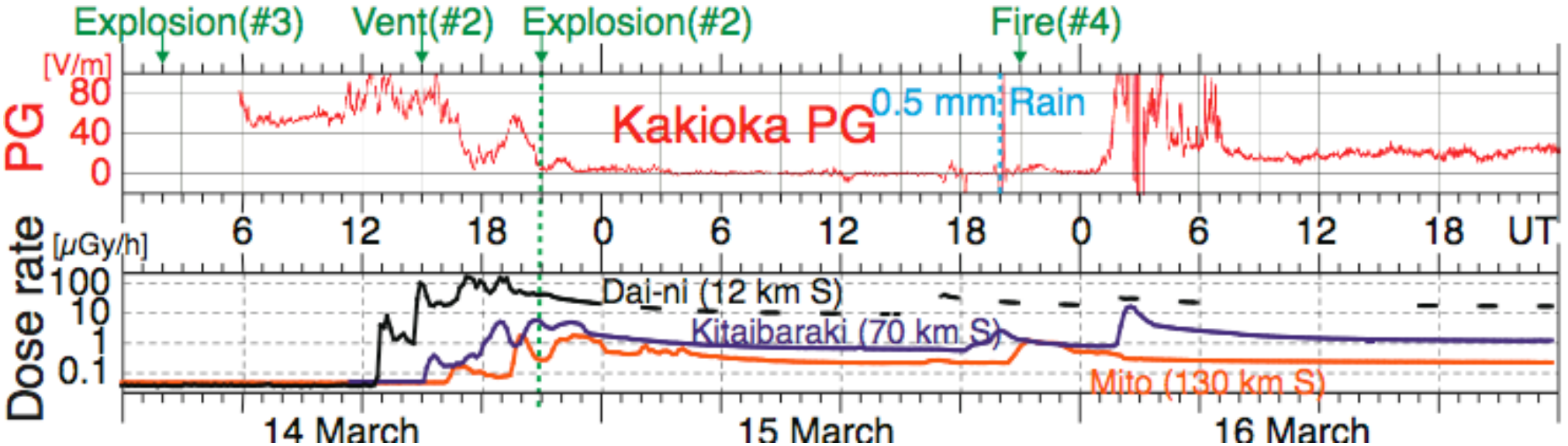
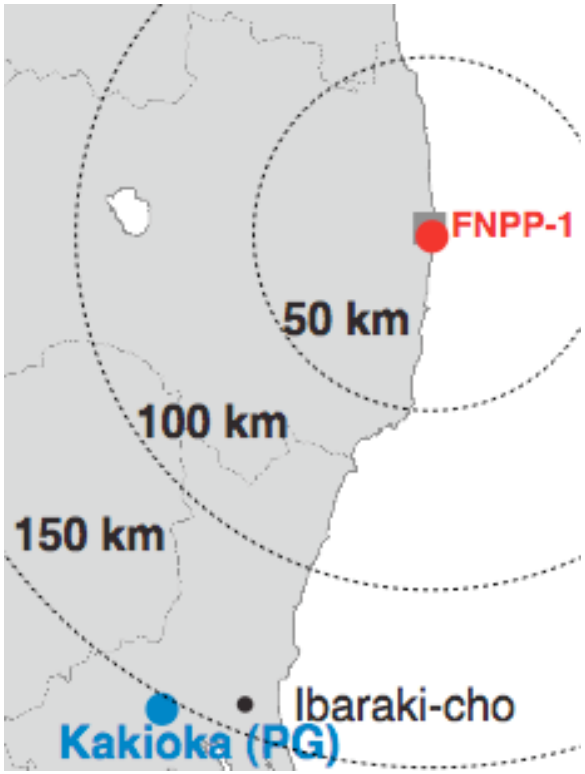
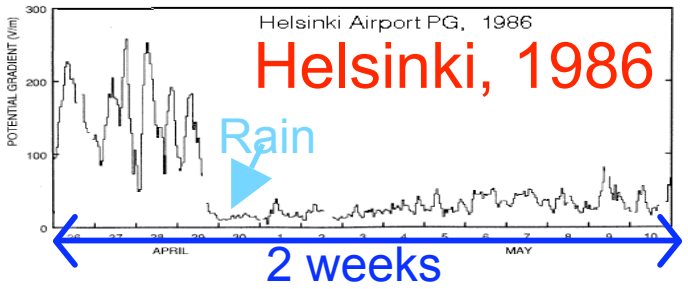
Extra ionization decreases the atmospheric E-field (PG) →

(Kakioka PG sampling is 1 Hz. Data is calibrated and compared with backup measurement)

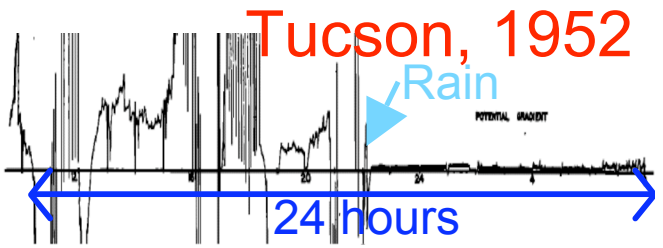




observed PG drop

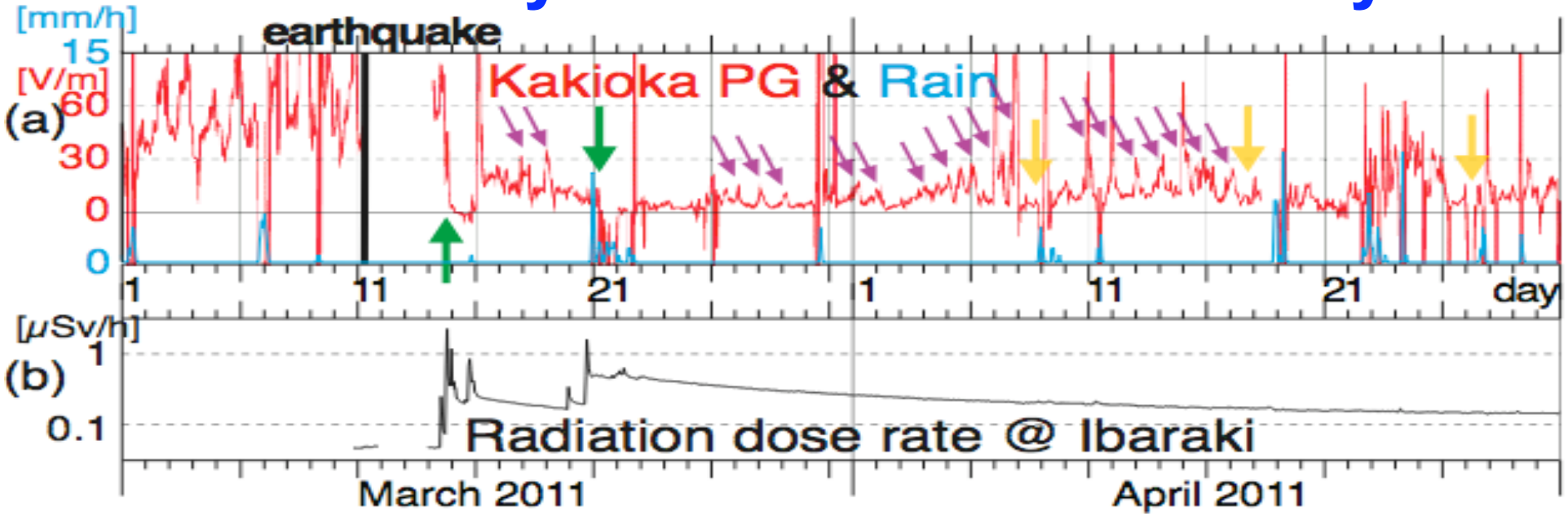


PG drops after Chernobyl Accident (*Tuomi, 1988*)



PG drops after nuclear test (*Harris, 1955*)

Past analyses = PG under clear sky



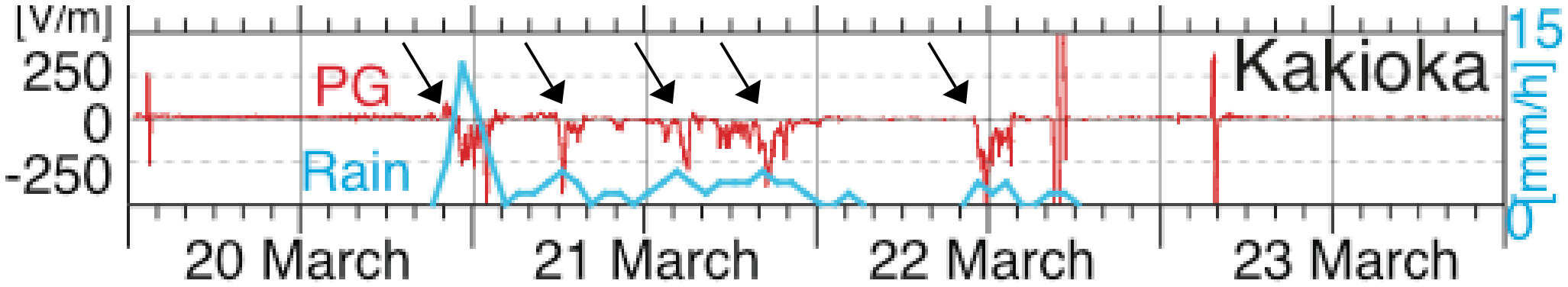
(A) 14-20 March = floating radionuclide

- 14 March: Dry deposition on 14 March at Kakioka, 150 km.
- 16-20 March: Strong re-suspension by wind.

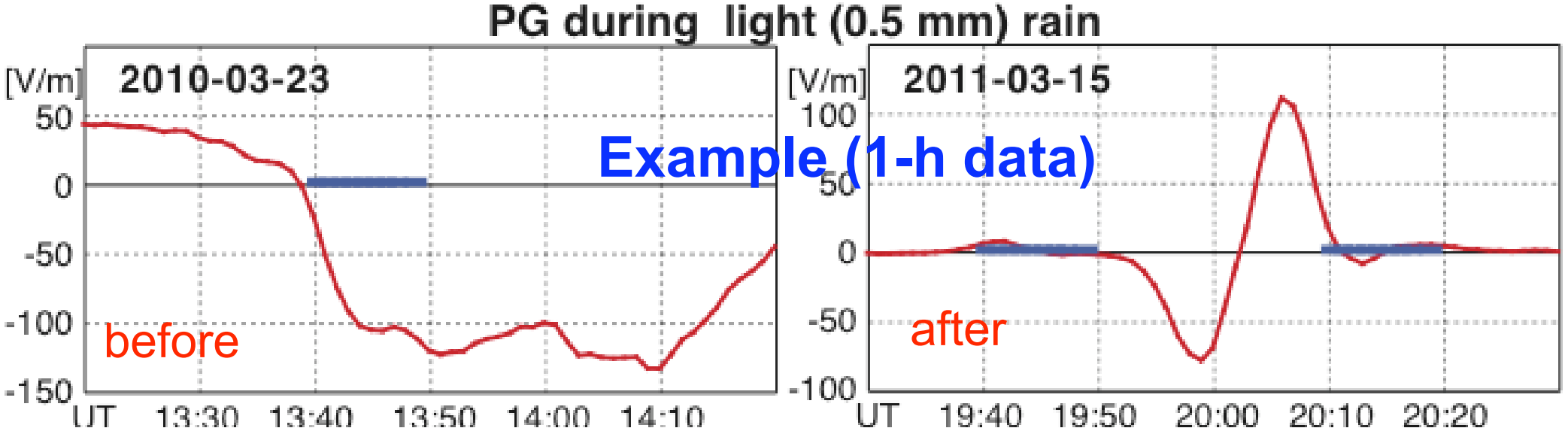
(B) - 20 April = some re-suspension & occasional plumes from FNPP-1

- 20-21 March: Wet deposition at Kakioka by the first substantial rain.
- until around 20 April : Transport from highly-contaminated to moderately-contaminated areas by daily wind.

(C) afterward = minor plumes until summer from FNPP-1



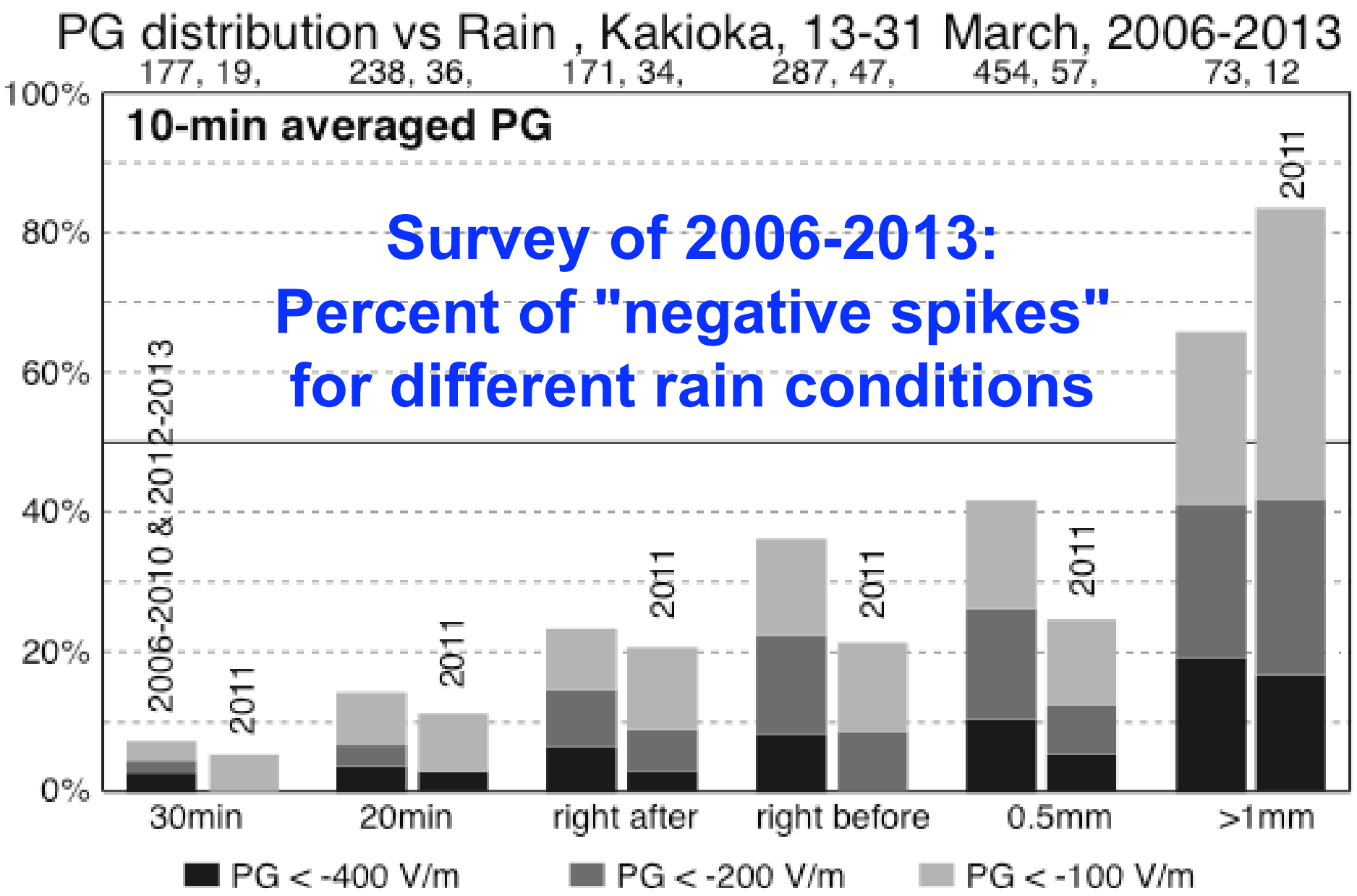
What about rain-time PG?



Difficulty (reason why no work for Chernobyl and nuclear tests):

- PG under rain-cloud is highly variable and dynamic
- Reliability of observation is not well established

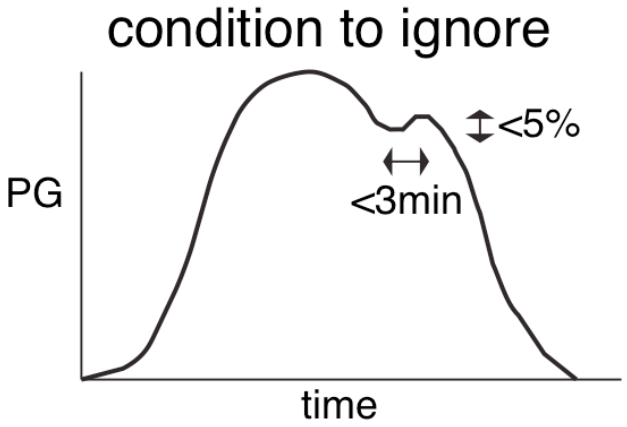
⇒ yet worth examining **whether there is statistical difference**

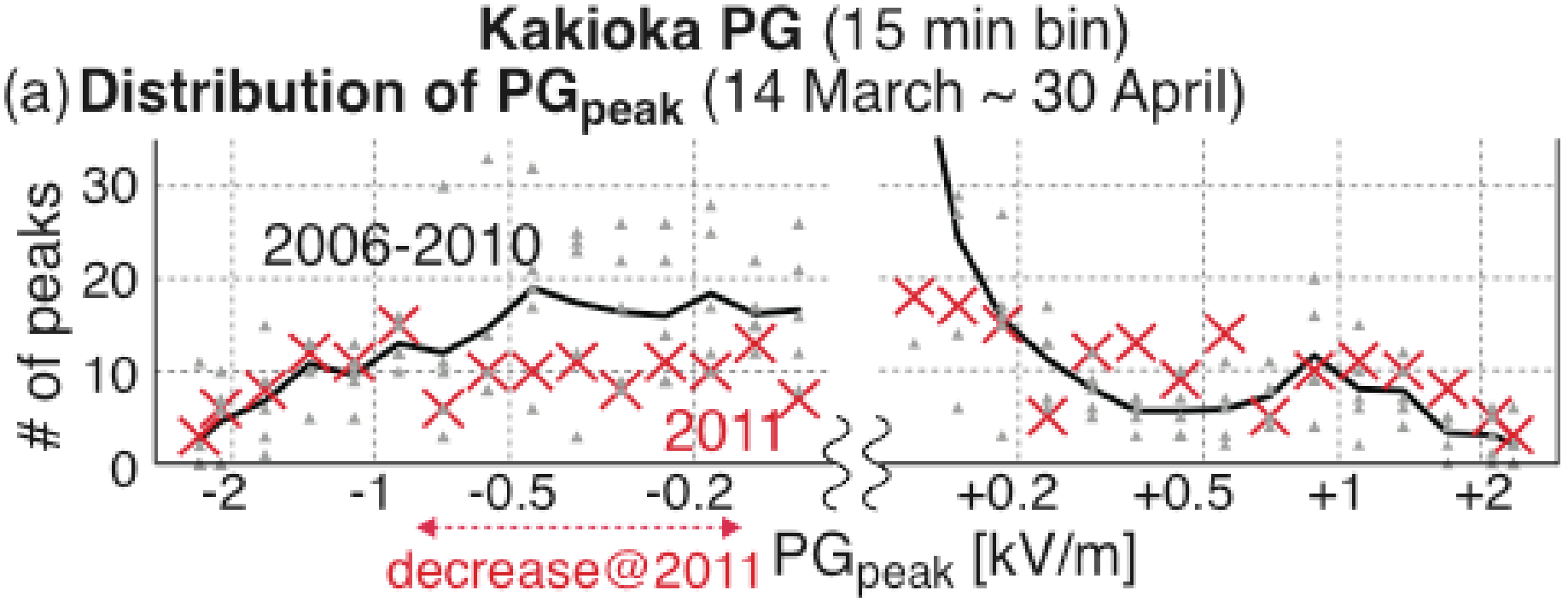


Largest difference in PG value between 2011 and the other years are during weak rain or right before/after the rain

Our Statistics

- Use 1-min value data (binned every 15 min)
- Examine all positive and negative peaks (no comparison to rain data to increase statistics)
- Remove even minor peaks (see illustration)

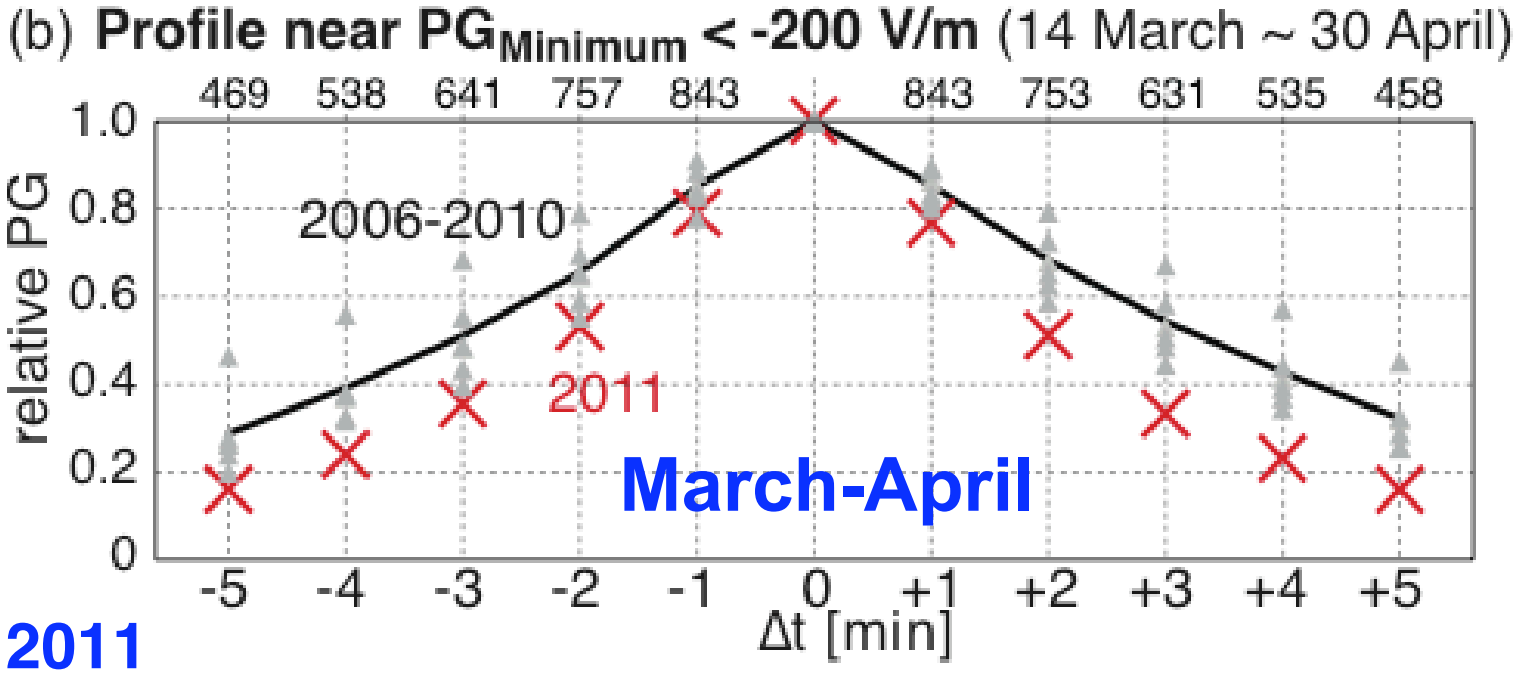


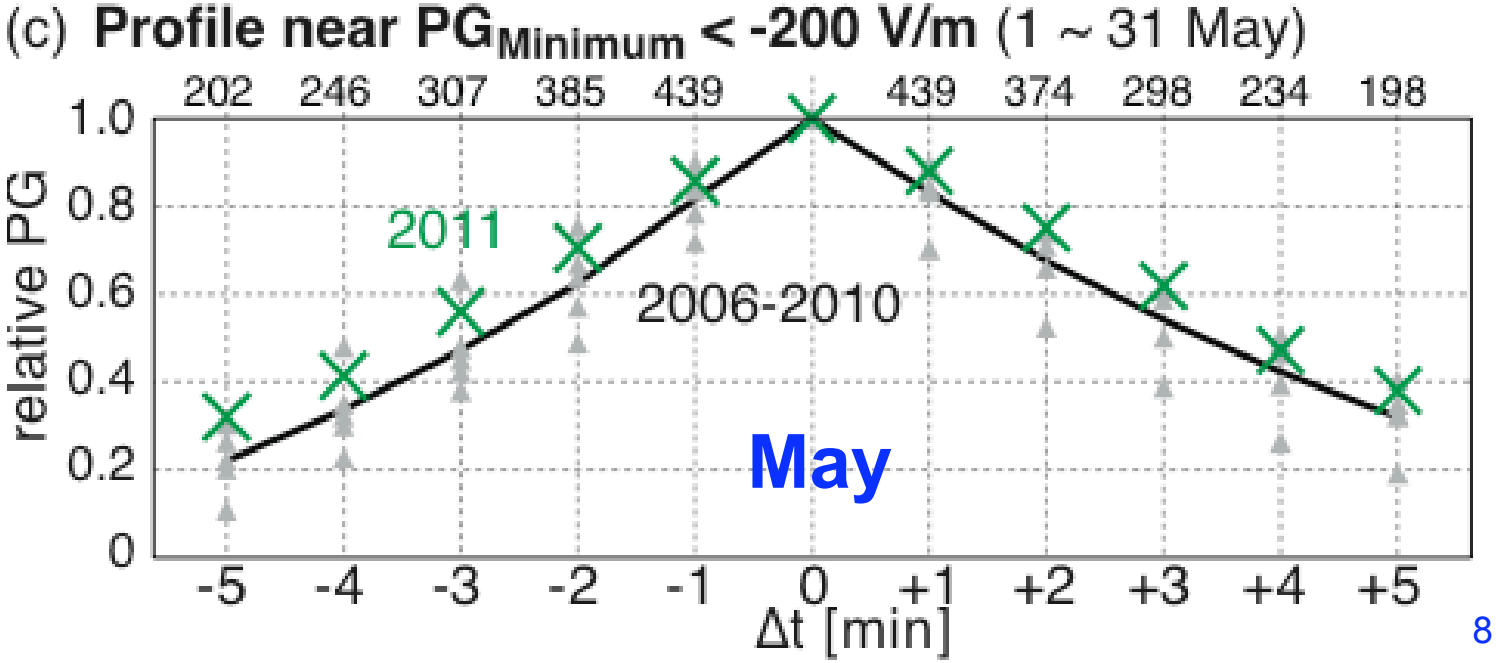


Less occurrence of -100 ~ -800 V/m (most likely minor rain) in 2011

time scale (overview)

- **Quick decay & development for 2011**
- **Effect ended by May**

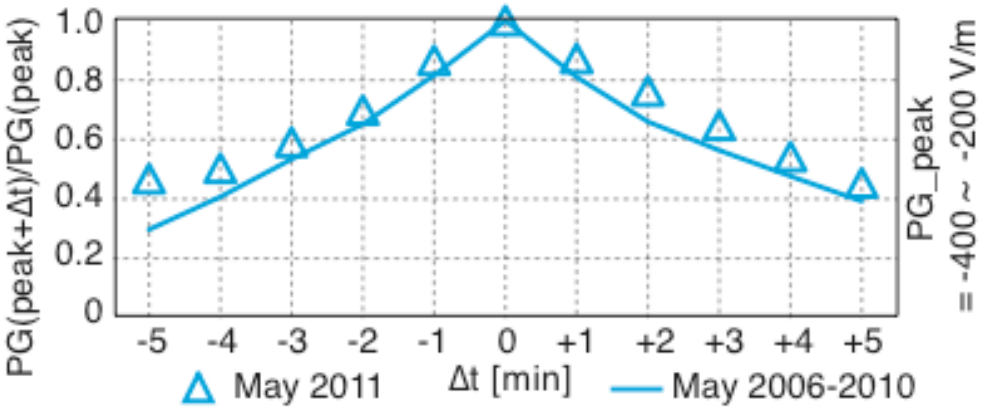


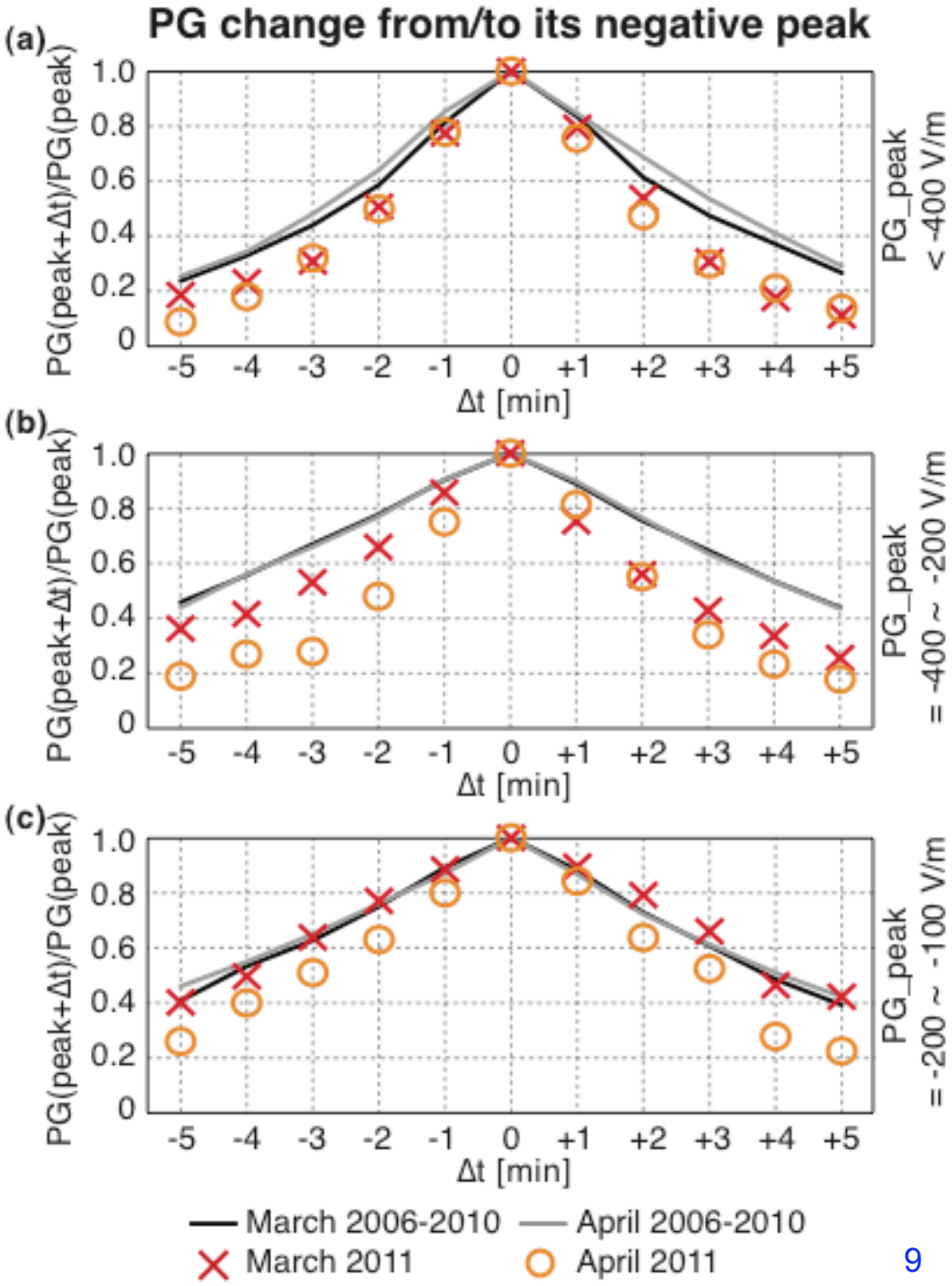


Relative PG values compared to the peak during 5 min before and 5 min after.

time scale (detail)

- The difference is most clear for peak values of -200 ~ -400 V/m
- May (⇓) is already back to normal (consistent with the end of re-suspension).

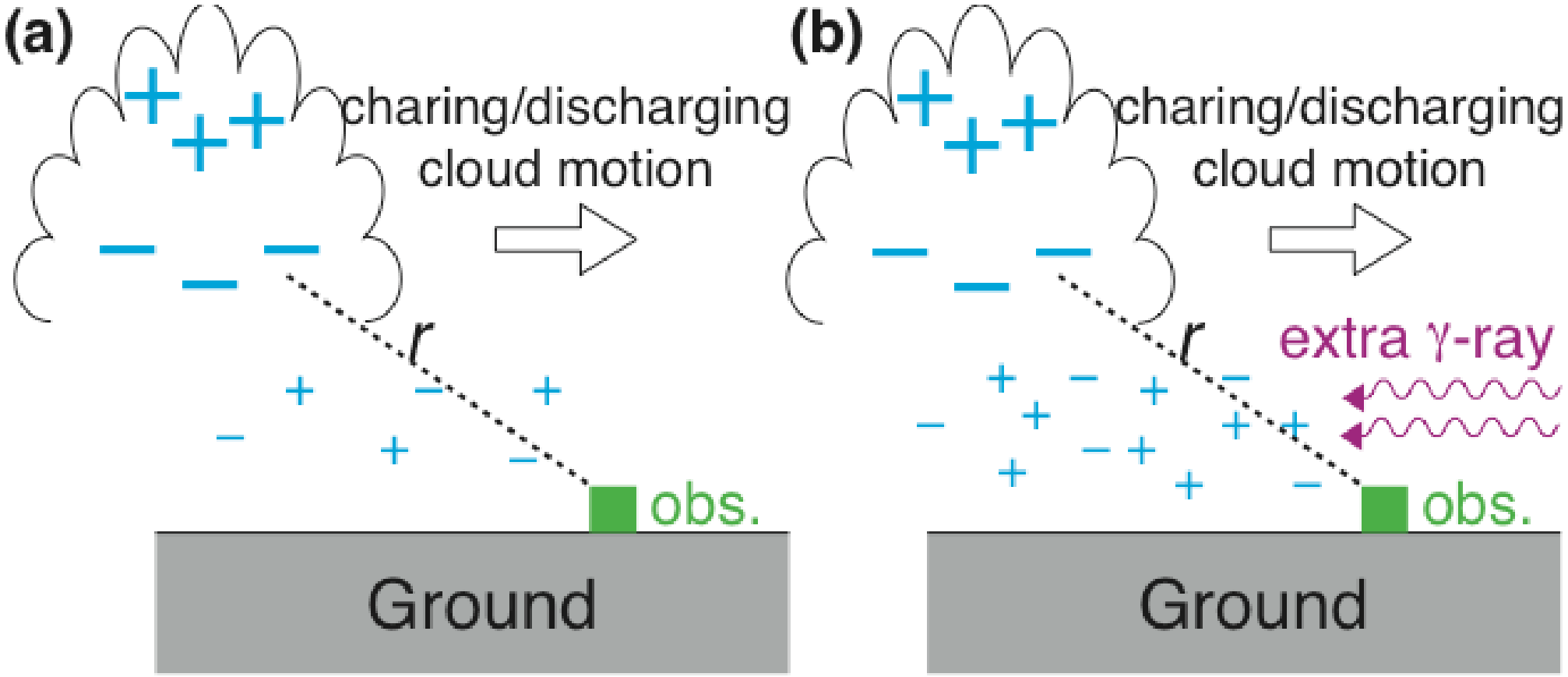




Interpretation

Extra ionization of aerosols in the lower atmosphere by the ionizing radiation except during heavy rain that washes out these aerosols. ⇒

Quicker response to the change in the cloud-origin electric field

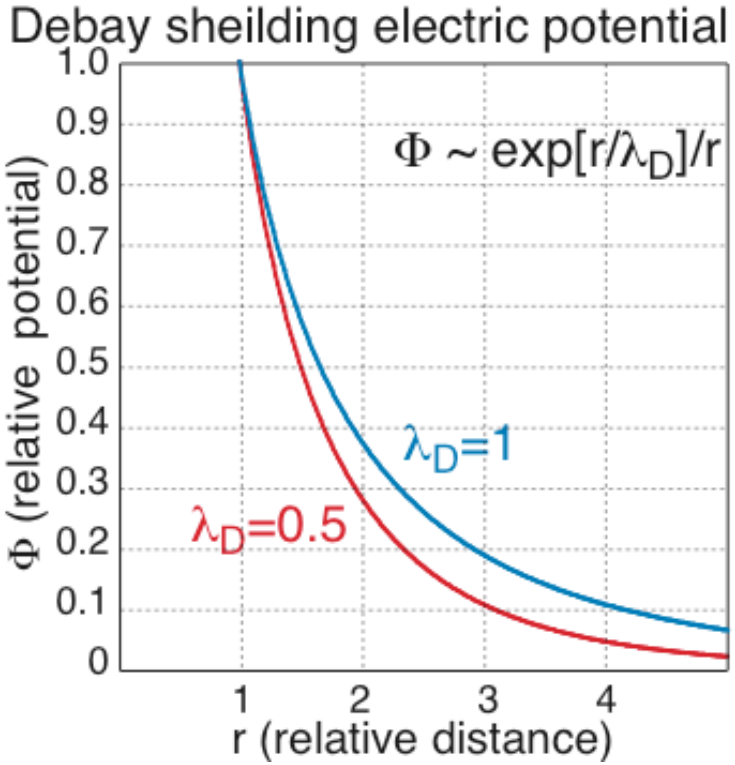


Increase of electric conductivity σ~x10 near ground and x 1.5~3 at higher

consequence of high σ

There are two way of describing the response of ionized aerosols to E:

- Shorter "re-distribution" time of ionized aerosols to respond changes in the cloud electricity (by internal convection + cloud motion).
- Shorter "shielding distance" of quasi-neutral atmosphere. This extra effect to (1) keeps aerosols more dielectric rather than conductive



- Increase of ions results more shielding (i.e., decrease of shielding distance λ_D).
- λ_D for time scale < 5 min depends on ion density & how quickly ions moves
  $\Rightarrow \lambda_D \propto \sqrt{\sigma}$ when σ (conductivity) is very low
- Just doubling λ_D (σ~1/4) makes substantial difference
- $\lambda_D \sim \sigma/\sigma_{ionosphere} * (\lambda_D)_{ionosphere} \sim$ 1~10 km
  $\Rightarrow$ **agrees with observation**

Summary

- 10-min averaged PG during weak rain or just before/after the rain is not as large right after the Fukushima accident as the same season of the other years
- This difference is due to the shorter time scale toward/from the peak during the time that ionizing radiation increased.
- The behavior is consistent with extra shielding of the could charges by the increased ions.
- May is already back to normal (consistent with the end of re-suspension).

PG measurement at **Kakioka**

Latitude	Longitude
36°13'56"N	140°11'11" E

		Main	Sub
Electrometer		Electrostatic sensor type	Field mill type
Collector	Type	Water-dropper	Mechanical
	Height	2.55 m	1.00m
	Separation from the wall	1.17 m	
Sampling		1 sec	1sec

Overview of radioactive deposition