

Cosmic rays and earth science

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and
Toshio Terasawa (Tokyo Tech)

contents

General Introduction (5min)

... T. Terasawa

Cosmic rays and weather (20min)

... K. Kusano

Historical view

- Cosmic ray physics started as a part of earth science
... measurements of altitude variation of atmospheric conductivity (V. F. Hess)



Recent topics

- Possible link between cosmic rays and weather

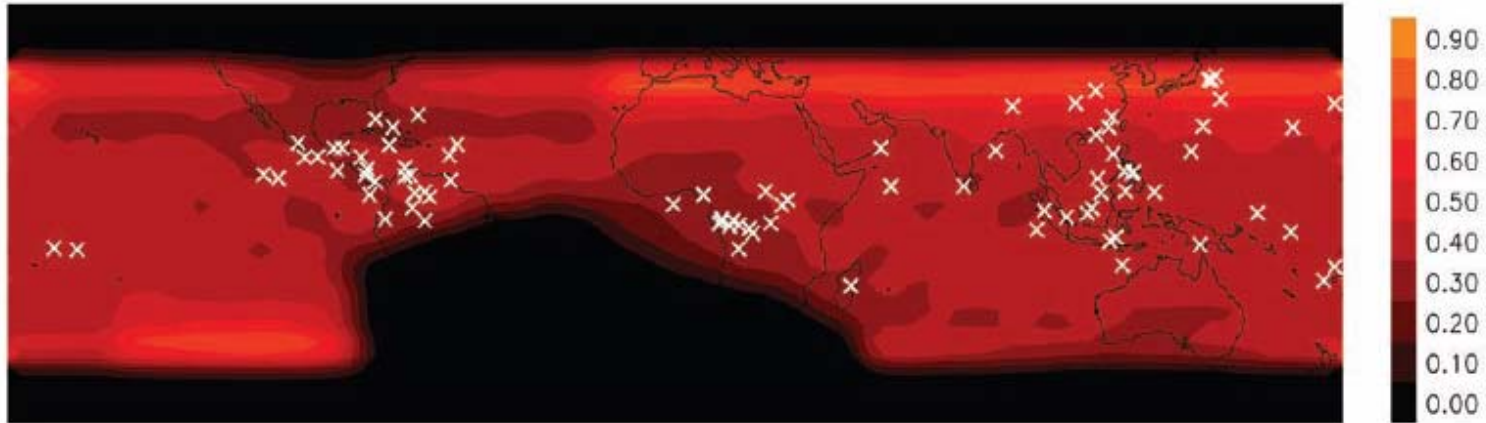
(to be discussed in detail by Kusano san)

- Cosmic rays and thunderstorms

Cosmic rays and thunderstorms

Earth as a gamma ray emitter

Terrestrial
gamma ray
flashes
(monitored by
the RHESSI solar
gamma ray
monitor)



Long-term
lightning
frequency
distribution
(radio map)

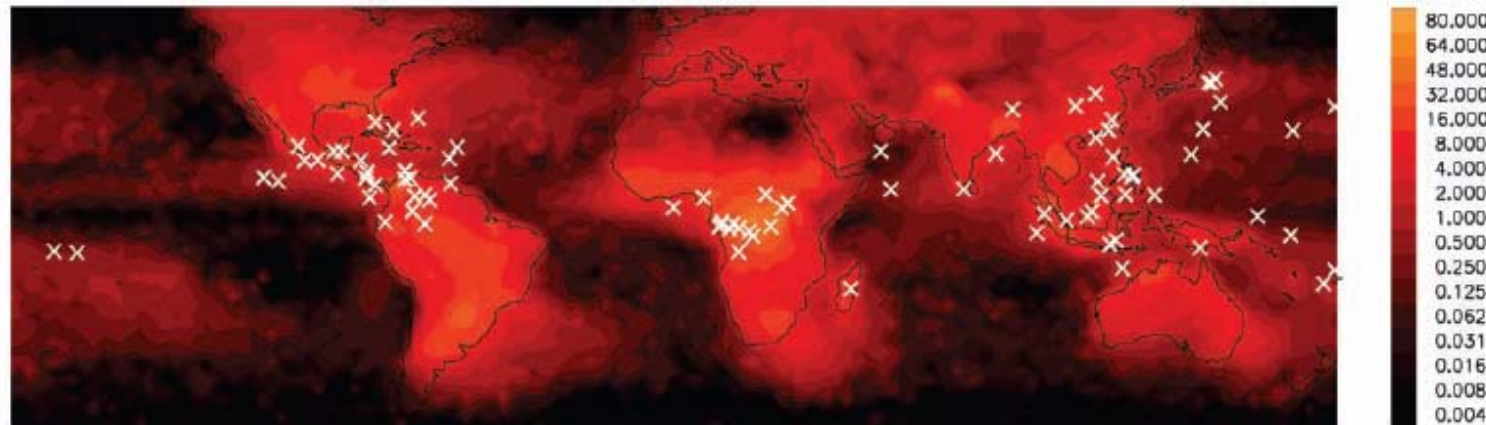


Fig. 1. RHESSI position during each recorded TGF, plotted over (i) the expected distribution of observed TGFs if the population were evenly distributed over the globe, with the scale in fraction of maximum exposure (top); and (ii) long-term lightning frequency data (29), with the scale in flashes square kilometer per year (bottom).

Cosmic rays and thunderstorms

Earth as a gamma ray emitter

30TH INTERNATIONAL COSMIC RAY CONFERENCE



Detection of gamma-rays from winter thunderclouds along the coast of Japan Sea

T. ENOTO¹, H. TSUCHIYA², S. YAMADA¹, T. YUASA¹, M. KAWAHARADA², T. KITAGUCHI¹, M. KOKUBUN³, H. KATO², M. OKANO², S. NAKAMURA⁴, AND K. MAKISHIMA^{1,2}

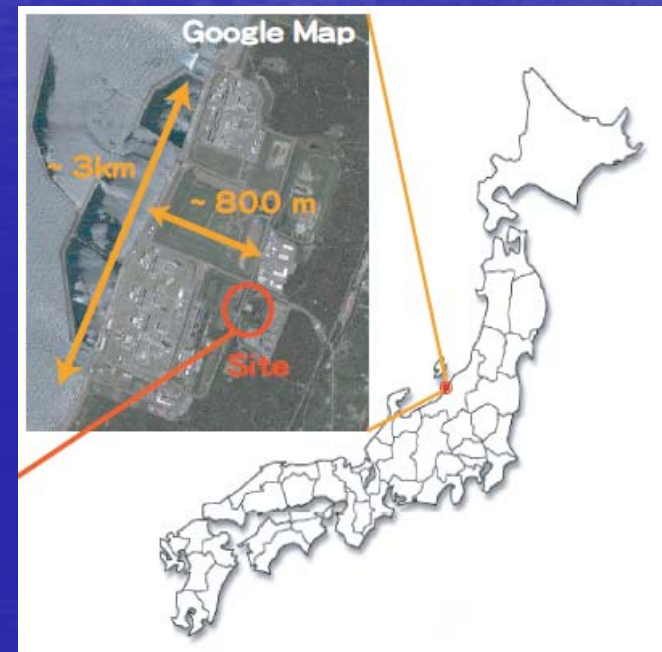
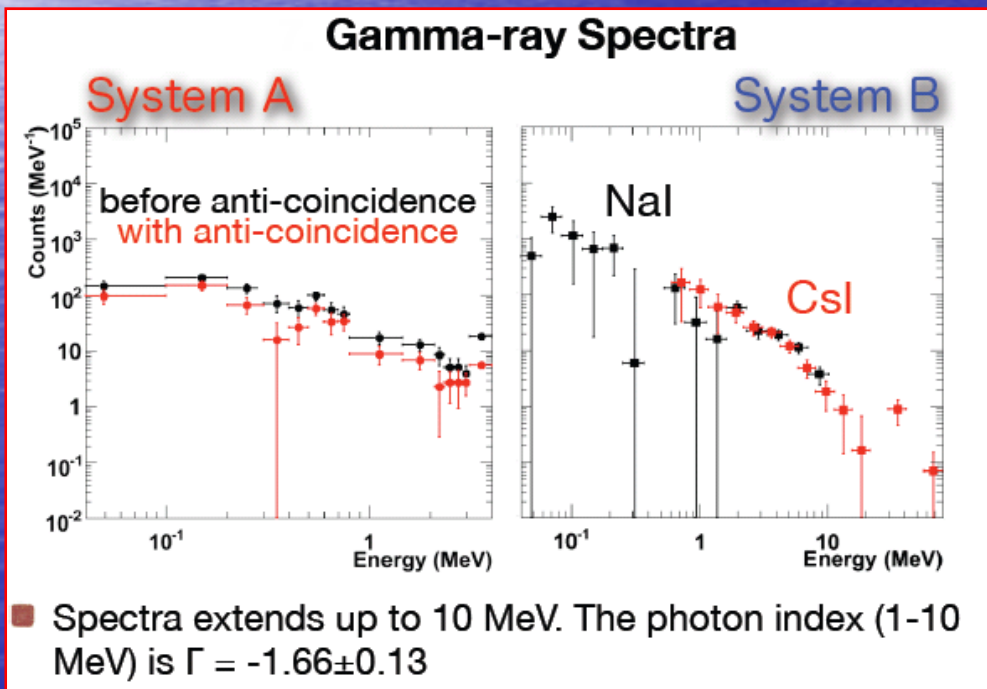


Figure courtesy of T. Enoto

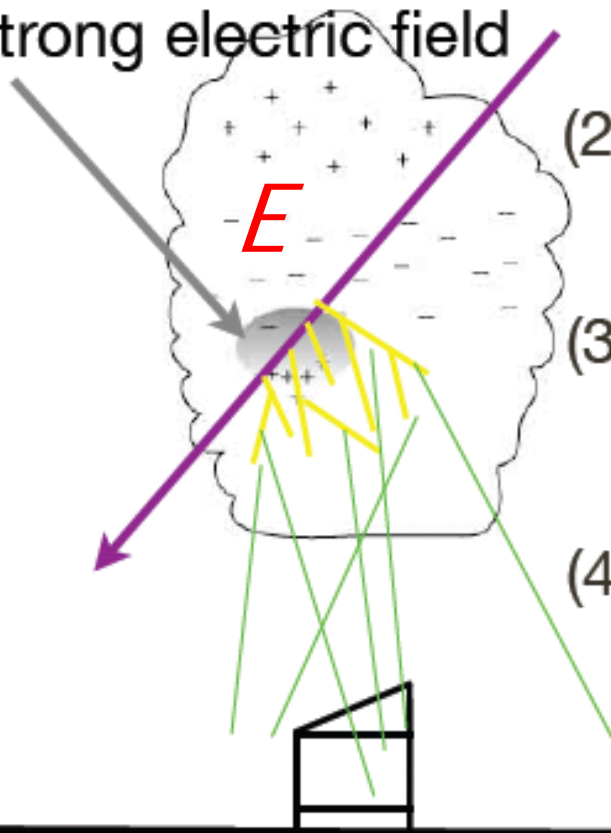
Cosmic rays and thunderstorms

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(1) Strong electric field



(2) cosmic ray

Extensive air shower

(3) relativistic electron

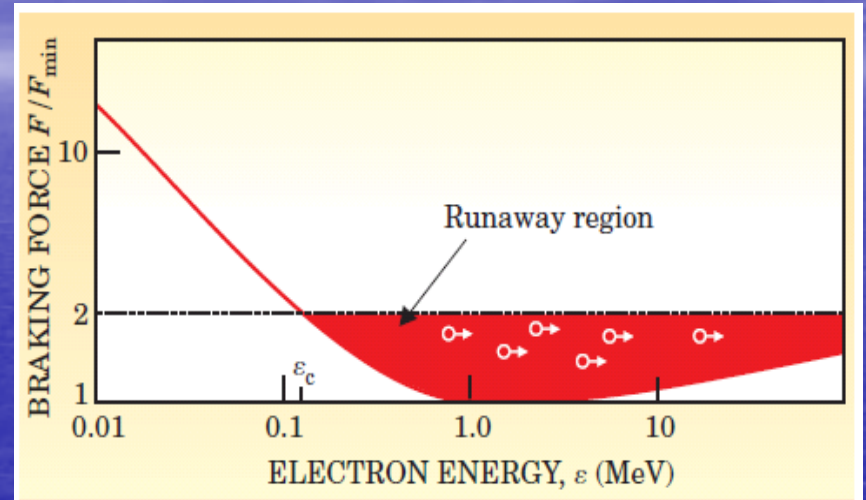
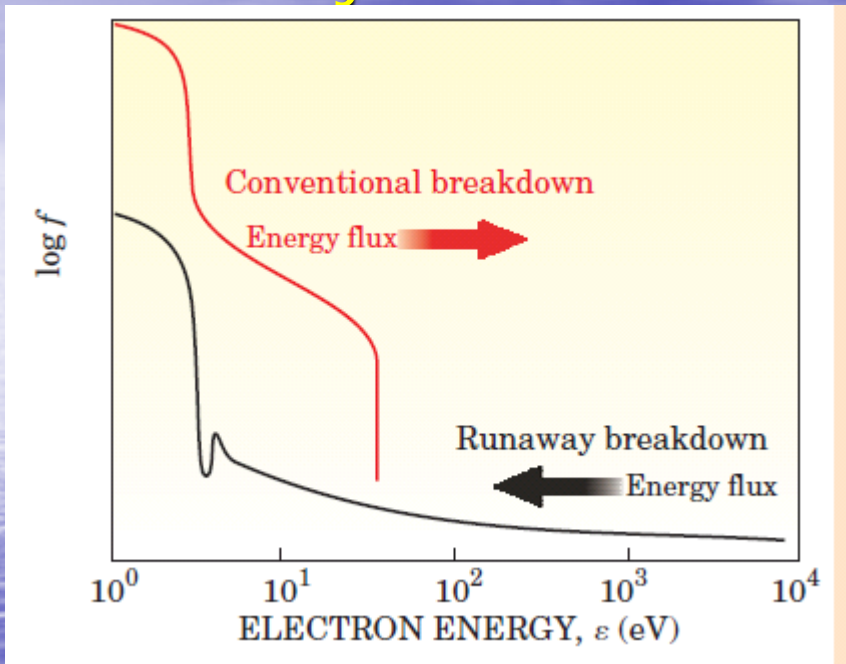
Further accelerated by E
(runaway avalanche)

(4) bremsstrahlung gamma-rays

$> \sim 10\text{MeV}$

Cosmic rays and thunderstorms

necessity of relativistic electrons



Grevich and Zybin, *Physics Today*, 2005

Derived Energies and Currents

Observation	Energy of primary cosmic-ray particle, ϵ_p	Maximum electron current, J_m
Radio-extensive atmospheric shower	10^{14} – 10^{15} eV	1–10 A
Lightning initiation	10^{16} – 10^{17} eV	0.1–1 kA
Narrow bipolar pulses	10^{17} – 10^{19} eV	10–100 kA

Grevich and Zybin, *Physics Today*, 2005

Cosmic rays and thunderstorms

Earth as a gamma ray emitter

We could expect that cosmic rays contribute to the global weather/climate system through their interaction with thunderclouds.

T You might think that this is not your own business.
F However, ...

Department of Meteorology, The University of Reading

PHYSICAL REVIEW D 70, 121303(R) (2004)

Effects of atmospheric electric fields on detection of ultrahigh-energy cosmic rays

Alexander Kusenko¹ and Dmitry Semikoz^{1,2}

Overestimation of air shower energy as much as ~20%(!?)

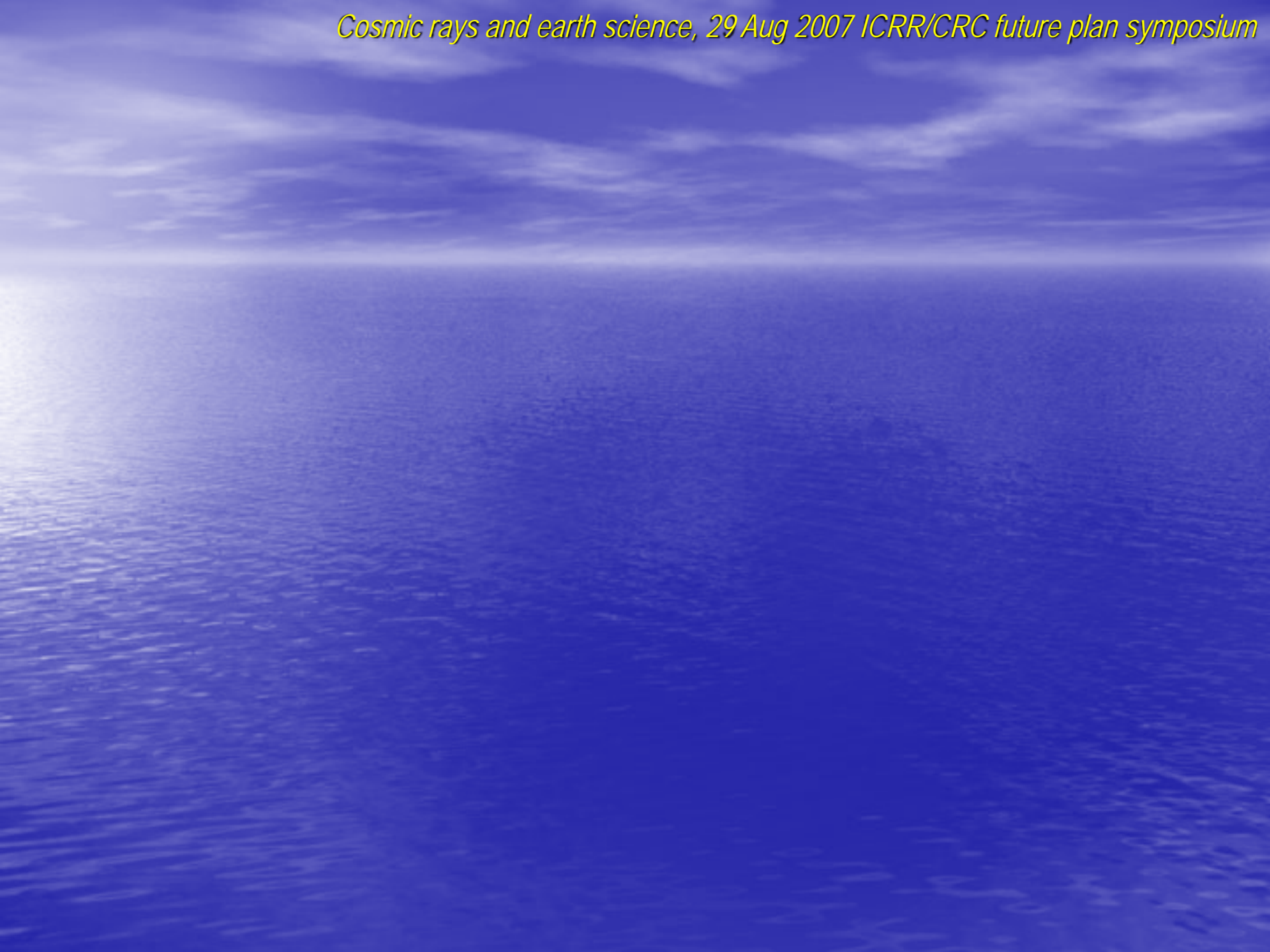
in the fair weather part of the global circuit. Through the (inverse) solar modulation of

Cosmic rays and thunderstorms

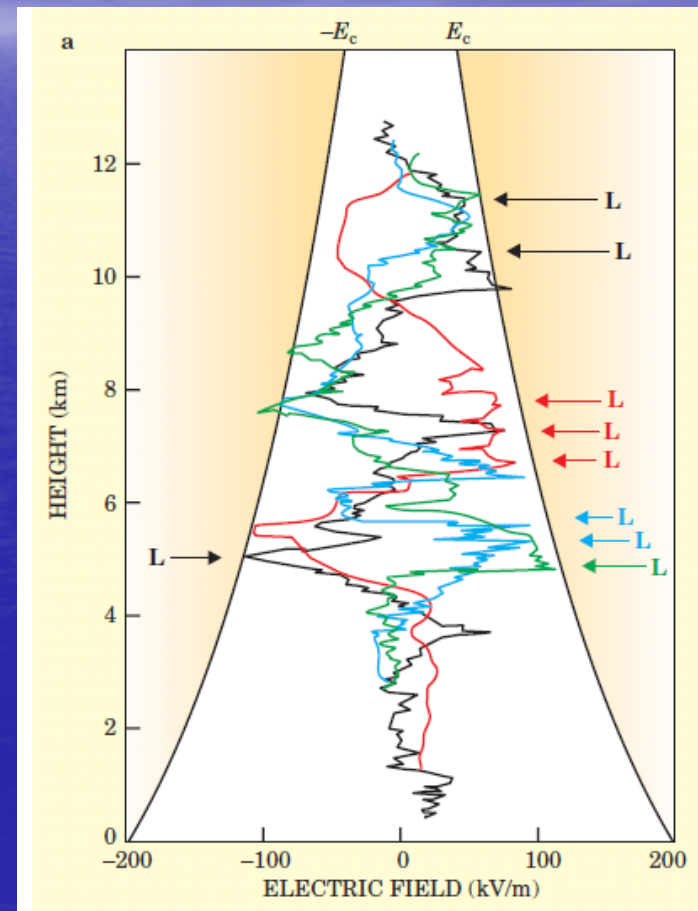
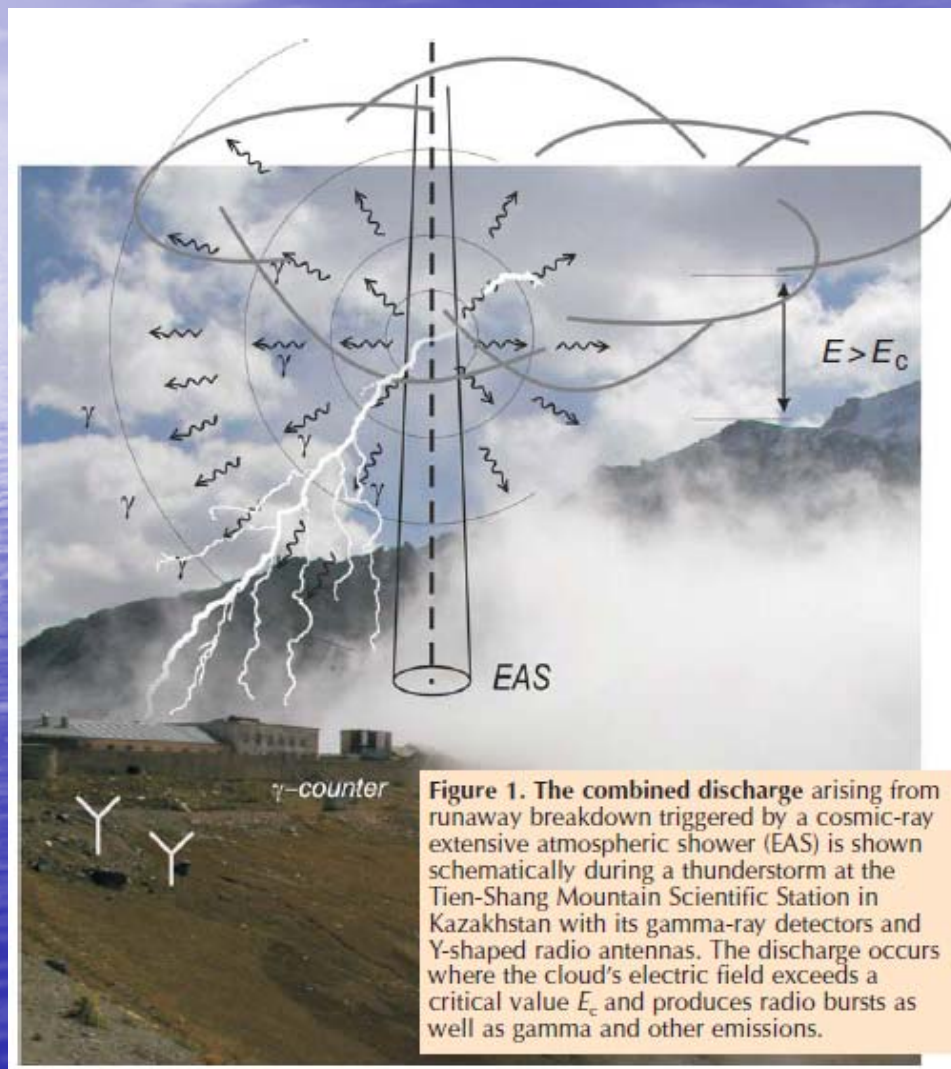
Earth as a gamma ray emitter

Now, Kusano san starts talking about another way of cosmic-ray-weather relationship.

Cosmic rays and earth science, 29 Aug 2007 ICRR/CRC future plan symposium



Cosmic rays and thunderstorms role of extensive air showers by CRs



Cosmic rays and thunderstorms

Earth as a gamma ray emitter

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System A	System B
<ul style="list-style-type: none">■ NaI+BGO(shield)■ Coarse collimation■ 40 keV-3.3 MeV■ single photon detection■ Plastic scintillator■ Optical & sound sensor	<ul style="list-style-type: none">■ NaI,CsI,Plastic scintillator■ Omni direction■ 40 keV-100 MeV■ Pulse heights (6 s) & rates (1 s)■ Electric field sensor & barometer

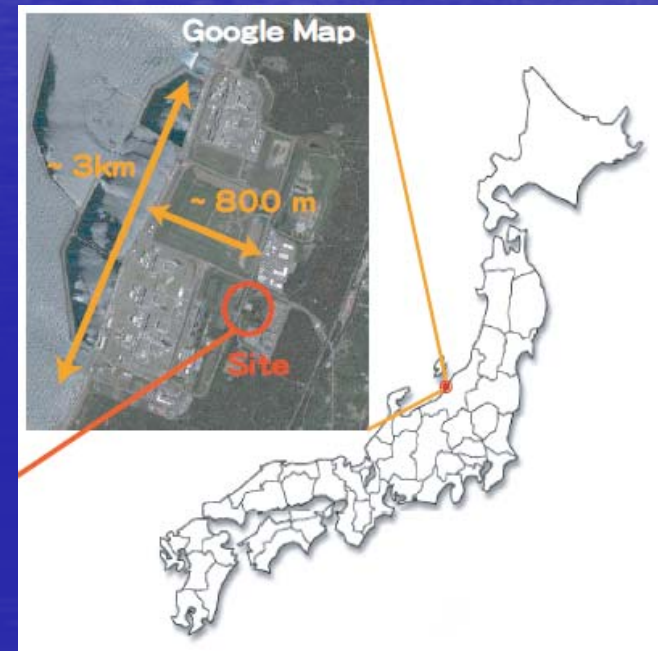
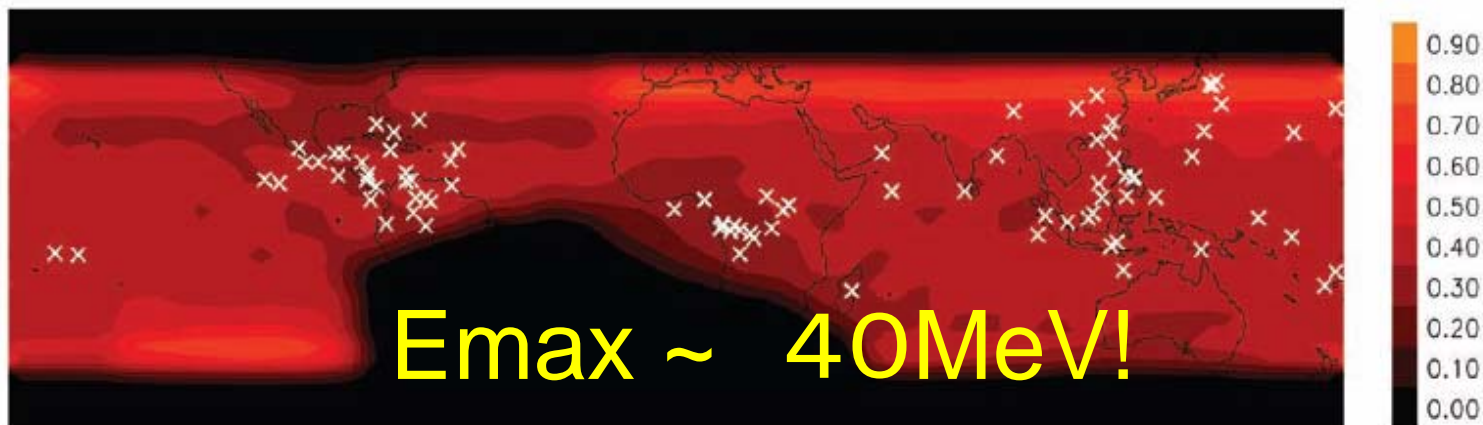


Figure courtesy of T. Enoto

Cosmic rays and thunderstorms

Earth as a gamma ray emitter

Terrestrial
gamma ray
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(monitored
by RHESSI
solar gamma
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Long-term
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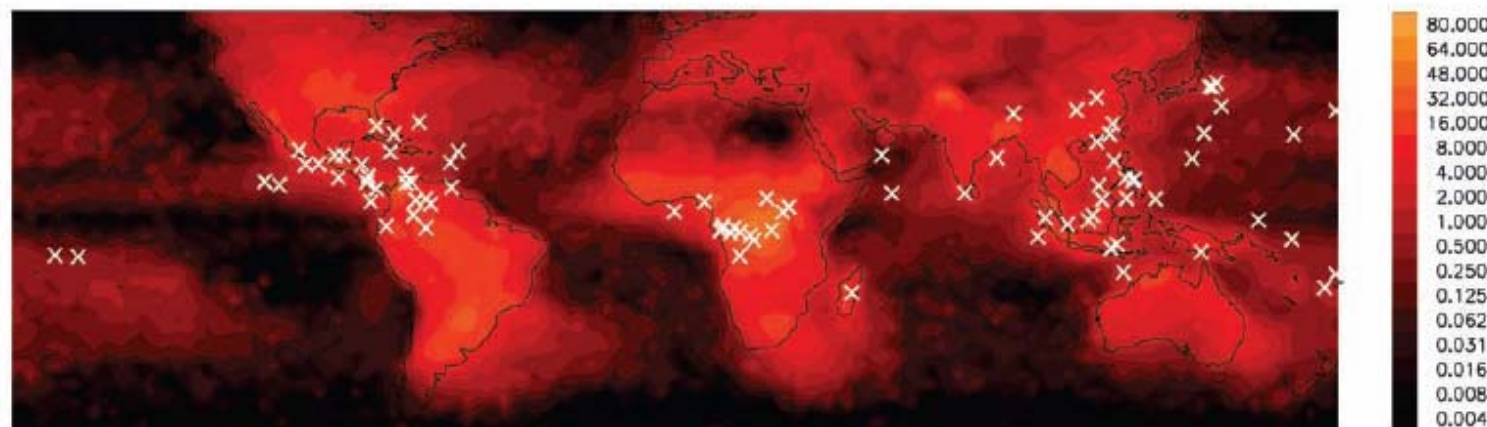


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Cosmic rays and thunderstorms

Earth as a gamma ray emitter

The global atmospheric electrical circuit and climate

R.G. Harrison

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Abstract

Evidence is emerging for physical links among clouds, global temperatures, the global atmospheric electrical circuit and cosmic ray ionisation. The global circuit extends throughout the atmosphere from the planetary surface to the lower layers of the ionosphere. Cosmic rays are the principal source of atmospheric ions away from the continental boundary layer: the ions formed permit a vertical conduction current to flow in the fair weather part of the global circuit. Through the (inverse) solar modulation of cosmic rays, the resulting columnar ionisation changes may allow the global circuit to convey a solar influence to meteorological phenomena of the lower atmosphere. Electrical effects on non-thunderstorm clouds have been proposed to occur via the ion-assisted formation of ultrafine aerosol, which can grow to sizes able to act as cloud condensation nuclei, or through the increased ice nucleation capability of charged aerosols. Even small atmospheric electrical modulations on the aerosol size distribution

Recent topics

Cosmic rays and thunderstorms

1. Earth as a gamma ray emitter (RHESSI discovery)
2. necessity of runaway relativistic electrons
3. role of extensive air showers by CRs

